Climate projections for local adaptation in the Hindu-Kush Himalayas

ICIMOD

G·R·i·D
ARENDAL
A Centre Collaborating with UNEP

°CICERO
Senter for klimaforskning

CICERO Report 2014:01

Climate projections for local adaptation in the Hindu-Kush Himalayas

Presentation of an easy and applicable method to downscale climate information, and graphical presentations to support local climate services anywhere

Bob van Oort, November 2014

Tittel: xx	**Title:** Climate projections for local adaptation in the Hindu-Kush Himalayas
Forfatter(e): xx	**Author(s):** Bob van Oort
CICERO Report 2014:01	CICERO Report 2014:01 165 pages
Finansieringskilde: xx	**Financed by:** the Norwegian Ministry of Foreign Affairs
Prosjekt: xx	**Project:** HICAP
Prosjektleder: xx	**Project manager**: Bob van Oort
Kvalitetsansvarlig: xx	**Quality manager**: Jana Sillmann
Nøkkelord: xx	**Keywords:** Downscaling; Scenarios; Himalayas; Projections; Climate; Relevance; Climate services; Decision-makers; Local adaptation
Sammendrag: xx	**Abstract:** This report is an output of the Himalayan Climate Change Adaptation Programme (HICAP). The aim of this report is to present downscaled climate scenarios in a relevant, understandable and illustrative manner for a diverse group of end-users and stakeholders, including other HICAP research components decision-makers at different levels. This report is based on dynamically downscaled temperature and precipitation projections for 8 different domains in the Hindu-Kush Himalayas. It uses the HICAP model (the WRF model, driven by the NorESM GCM model) for the RCP4.5 and RCP8.5 scenarios. Comparing model results with local observations for a reference period (1996-2005, the output was corrected for various under- and overestimations. For each domain, projections for periods 1996-2005, 2010-2030, 2030-2050 and 2050-2080 are presented a) in figures relevant for local users and decision makers, b) in a simplified text summing up the projections, and briefly discussing them in relation to potential impacts. This report provides highly relevant, locally specific results for the HICAP region, and relates these to geographical variations within each domain across the Himalayas. No other models and projections have been used in this report, and the HICAP model results should be compared with other sources of information for a final assessment of local climate change and impacts. The usability of the report extends beyond the HICAP project: the model-adjustment method, aimed at showing how to make projections realistic and relevant at the local level, the ease of the calculations and the guided interpretations of the figures and projections can serve as a guide to model use and presentations anywhere, provided the availability of a minimal amount of observations to compare and adjust larger scale model outputs to local climate observations for a certain reference period.
Språk: xx	Language of report: English

Contents

1 Project background

The Hindu Kush Himalayas (HKH) is a region with many socioeconomic and environmental drivers of change at play, including climate change. The increased incidence of extreme weather events and magnitude of associated natural disasters, believed to be related to climate change, are exacting high economic and social costs. The Himalayan region and the downstream areas that depend on its water supply and ecosystem services are particularly vulnerable to these changes.
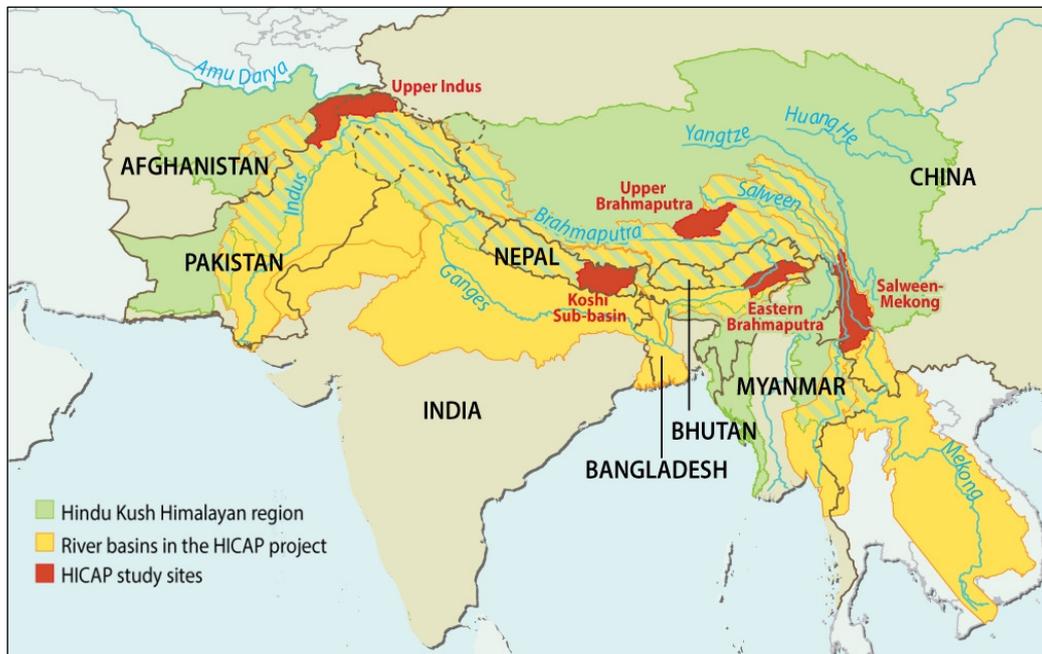
Figure 1. HICAP project region and study sites, showing the river basins and sub-basins, country borders and the Hindu-Kush Himalaya regions. (Figure from http://www.icimod.org/hicap/?q=4779).

The Himalayan Climate Change Adaptation Programme (HICAP, 2011-2016) is a collaboration project between CICERO, ICIMOD, and UNEP GRID-Arendal, financed by the Norwegian Ministry of Foreign Affairs and the Swedish International Development Agency. The project and its components are described in detail on http://www.icimod.org/?q=7277. In short, the project aims to enhance resilience of mountain communities through improved understanding of vulnerabilities, opportunities, and potentials for adaptation. HICAP aims to reach this goal through the generation of knowledge of climate change, its impacts on natural resources, ecosystem services, and the communities depending on them, and to contribute to policy and practice for enhanced adaptation.

The programme is focused on the region's large river basins (see figure 1) and organized around seven interlinked components: 1) Climate change scenarios, 2) Water availability and demand scenarios, 3) Ecosystem services, 4) Food security, 5) Vulnerability and adaptation, 6) Women in adaptation and 7) Communications and outreach.

The project has three objectives,

1) To reduce uncertainty through the development of scenarios for climate and for water availability and demand, customized and downscaled for parts of the Brahmaputra, Ganges, and Indus river basins.

2) To develop knowledge on the environmental and socioeconomic impacts of and responses to climate change at local, national, and regional levels, and to enhance capacities to assess, monitor, and communicate them

3) To make concrete and actionable proposals for strategies and policies for adaptation, considering vulnerabilities, opportunities, and potentials, with particular reference to strengthening the role of women and local communities

1.1 Report Aim

As stated in the HICAP project website (http://www.icimod.org/?q=7227), at present, global climate scenarios for the HKH region have a coarse resolution, and poorly capture major features such as monsoons and westerly regimes. A large uncertainty is also due to limited model outputs and lack of multi-model ensemble results. Impact assessments need better quantitative information on future climate to enable and improve informed planning of adaptation and risk mitigation measures. To this extent, component 1 of the HICAP project aims to downscale and customize climate scenarios to the region, for selected basins and relevant sub-basins.

This report is an output of component 1 in line with its strategic orientation to dynamically downscale climate scenarios to the basins and statistically/stochastically downscale these at strategic locations in the sub-basins for impact studies. It is based on the modeling efforts by the project partner at the Bjerkness Centre, Bergen, Norway, and the results from his Regional Climate Model model, in the text further referred to as the HICAP model. This report is specifically dedicated to adjust these downscaling efforts to locally more realistic levels, to extract relevant information from the model and to translate that information in different ways to make it better understandable and more usable for different groups of users. This report addresses several of the proposed activities in the component, which are listed as follows:

Collection of data and information, historical trend analysis, dynamic downscaling at basin and sub-basin levels, statistical/stochastic downscaling at strategic points relevant for impact studies, validation for the baseline period, scenario development and assessment. The component will draw from existing peer-reviewed and established international models on climate change and scenarios. This is important for supporting other components with required material for linking regional and local changes to adaptation strategies and methods. The component will ensure that models and scenarios used also have solid international foundations.

In line with the proposed deliverables, the report presents the downscaled scenarios of climate change in the different river basins, and presents this in a number of figures related to precipitation, temperature, monsoon and growing season derived from the dynamically downscaled model outputs of daily precipitation, daily maximum temperature and daily minimum temperature. It also provides an interpretation of these figures with a view of the projected impacts on agriculture, forestry, flooding danger, and other social or ecosystem impacts. To allow for its widest possible use, we have made an effort to make figures and text accessible and understandable to different user groups, ranging from climate scientists (modelers as well as scientists less versed in model reading and interpretation) for publications and HICAP component support, managers and politicians, and local users. There are several levels of uncertainty and simplification introduced in this process. Regional Climate Models are compared with Global Climate Models while these are of different scale and give different outputs. The methodology used to adjust model results to locally realistic levels is based on very few reference stations. The method of transposing the model's projections of change by simply placing the change over time on top of local observations simplifies and ignores potential differences between the local scale and at the model's regional scale over time. However, we consider that the disadvantage of these simplifications and newly introduced uncertainties is far outweighed by the advantage of 1) having results that are more realistic and of greater practical use at the local level, and 2) having a simple method of model adjustment which is comparable to statistical downscaling, which due to its simplicity easily can be replicated elsewhere with only a limited amount of data, time or modelling knowledge available.

The aim of this report is to i) support the different HICAP research components with relevant climate projections, and ii) facilitate decision-making with regard to land-use (agriculture, forestry, ecosystem service use) and (flood) risk management. To deliver a climate service for such a large and geographically varied region and for such diverse groups of end-users means that the report has to balance between the different needs and level of understanding of these groups. Its message and method may be too much simplified at the scientific and modeling level, while parts of it may be too complicated for local decision-makers. However, the main aim of the report is to help local decision makers make sense of the local implications of climate change, to provide climate data for local, practical use, and to give a simplified but scientifically supported indication of local impacts. It does <u>not</u> aim to compare models with each other or highlight uncertainties that may lead to inaction and further waiting for "even better and more downscaled" model results to become available. The generalizations of the complexity and uncertainties of models are thus justified by the need for an easy message that supports action.

The aim and usability of this report extends beyond the HICAP project: the method, aimed at showing how to make projections relevant at the local level, the ease of the calculations and the guided interpretations of the figures and projections are applicable to any area in the world, as long as there are some observations at least on a monthly level to compare model outputs with local weather for a certain reference period. To really be an effective tool in adaptation and decision making processes, climate projections and their uncertainties need to be combined with e.g., communication approaches, institutional strengthening, assessment mechanisms, and stakeholder engagement.

2 Model background, comparisons and adjustment

2.1 Models used

The dynamic downscaling work has been performed by and should be accredited to Bhuwan Bhatt at the Bjerknes Centre for Climate Research (see also Bhatt et al., 2014). Basis for the dynamic downscaling are two models; 1) the internationally well-used and tested Weather Research and Forecasting Model (WRF downscaling model; http://www.wrf-model.org/) which has over 20,000 users in over 130 countries, combined with 2) the Norwegian Earth System Model (NorESM), a global, coupled model system for the physical climate system (see http://folk.uib.no/ngfhd/EarthClim/index.htm#no and links therein for further documentation and publications related to the model).
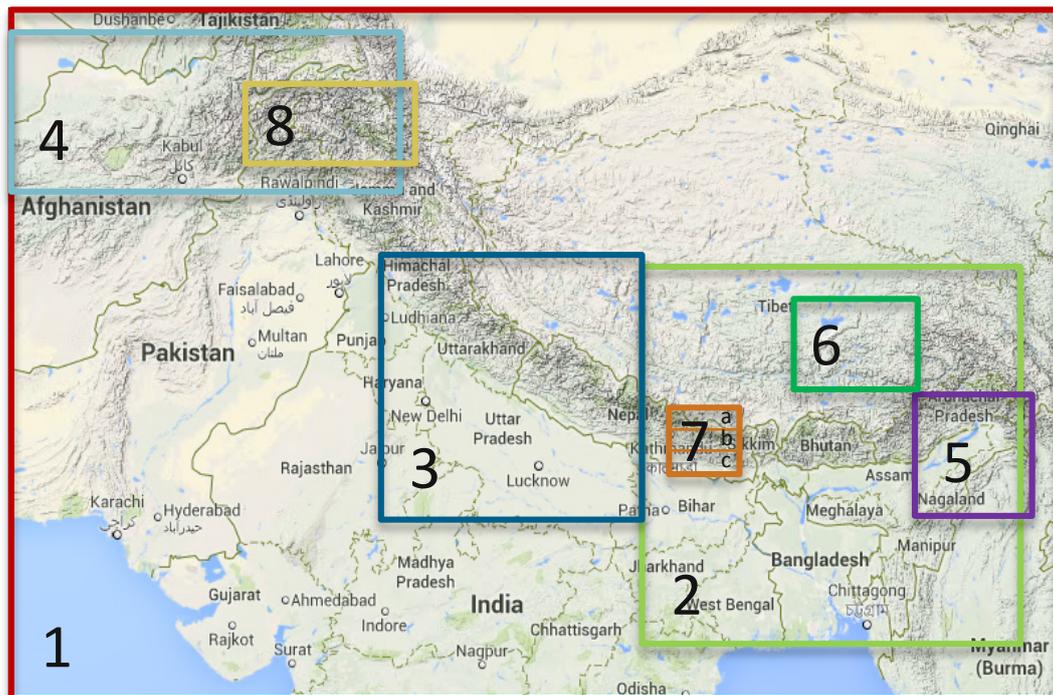
Figure 2. HICAP WRF/NorESM model dynamic downscaling domains. All are located within the largest domain limited by 20.00-39.00 degrees North and 63.35-98.00 degrees East. Domains 5-8 coincide with specific river basins and case study sites. Note that domain 7 is split into 3 sub-domains a (high mountains), b (middle hills) and c (terai). The figure also shows how most domains, even the smallest ones, cover a geographically very heterogeneous area with often many thousands of meters difference in elevation between a domain's highest and lowest point.

The WRF model, driven by the NorESM GCM model and using the RCP4.5 and RCP8.5 scenarios, dynamically downscaled temperature and precipitation projections to 8 different domains (figure 2) including the larger HICAP region and the various basins and sub-basins,. The WRF model has a 12km x 12km grid and uses local topography for each grid taking into account the variations in elevation.

It is important to realize that the downscaled model data do not use local weather station data as an input. The WRF model instead is forced by historical and scenario emissions and driven by the NorESm GCM which includes many components such as Greenhouse Gasses, Circulation models, etc. Thus, precipitation and temperature are outputs, and not inputs to the model. Specifically, outputs of the model are 1) daily temperature (Tmin and Tmax) at 2 meter above the ground, equivalent with near surface temperature, and 2) daily precipitation at ground level, equivalent with surface precipitation.

Modelling challenges

To place the modelling work in context, it is important to understand that running a model takes a lot of computer capacity and time. Adjustments to a model to make its results more realistic may result in model crashes, which in turn makes the process take even more time. The downscaling effort has suffered from such setbacks, which in practise means that instead of running a scenario for the full projection period from 2010 to 2050-(2080), the NorESM driven WRF downscaling model (hereafter referred to in short as the "HICAP model") was cut into shorter time-sections to avoid crashes or allow for quick adjustments and re-runs. An overall set-back in time however meant that multiple runs of the same scenario for internal model-result comparison weren't possible, and that each RCP and projection period has only been run once. This also has implications for our ability to express how certain these projections are, as a single model run means that intra-model variations cannot be assessed. However, a comparison with alternative models and observations for the region allows for a general assessment of how well the model performs and if its results can be used for its purpose of supporting local adaptation and decision making.

2.2 Model results for past and present

The HICAP model was compared for the baseline period 1996-2005 with 1996-2005 temperature data for domain 1-4 from Princeton University (a freely available Global Meteorological Forcing Dataset for land surface modelling; see http://hydrology.princeton.edu/data.pgf.php for background and documentation), and with monthly averaged precipitation data for 1996-2005, region 1-8, from Aphrodite (daily precipitation datasets with high-resolution grids for Asia, created primarily with data obtained from a rain-gauge-observation network; see http://www.chikyu.ac.jp/precip/index.html for background and documentation) and for 1998-2005 with TRMM satellite data (TRMM-based precipitation estimates; see http://trmm.gsfc.nasa.gov/data_dir/data.html for background and documentation). Projection periods cover the periods 2010-2030, 2031-2050 and 2050-2080.
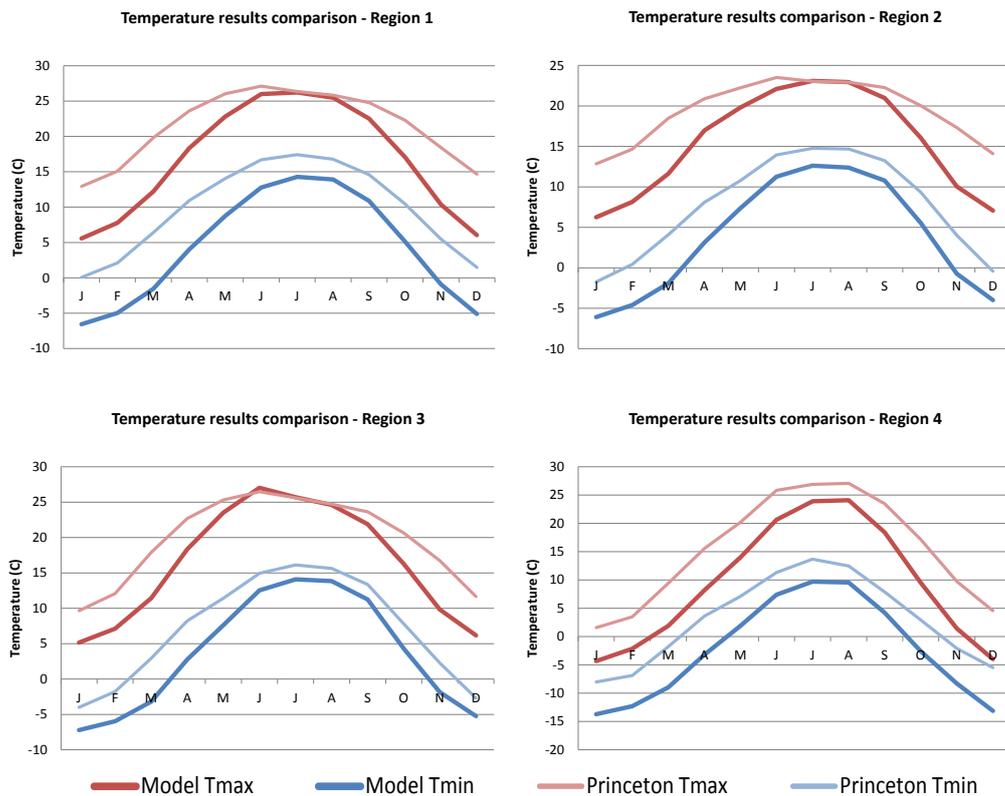
Figure 3. Comparison of HICAP (RCP8.5) model (dark red and blue) baseline period for monthly average temperature (Tmin and Tmax) with Princeton temperature data (light red and blue) for domain 1-4.

Comparison of HICAP model temperature projections for the baseline period with Princeton temperature data for domain 1-4 (figure 3) shows that in all cases the HICAP model underestimates temperature. The underestimation is larger in winter than in summer. Regions 1-4 are very large, and a comparison for the other domains as well as with local weather stations was necessary to estimate how well the model performs for any location within a domain, and how applicable its description of the baseline period and per extension its projections are for local adaptation.

For precipitation, the model did not perform optimal either, albeit it did better than for temperature. Figure 4 shows how the initial comparison of the HICAP model results for the baseline compares to the Aphrodite and TRMM satellite data. In all above cases the HICAP model overestimates precipitation, while the general shape (timing) compares reasonably well (see also Bhatt et al., 2014).

This initial comparison of the model data with other available data for the domains suggests that the model did not perform well for most of the domains: it overestimates precipitation, underestimates temperature grossly, and no comparison with local observation was available so that there is no information as to its capacity to support local climate change information and adaptation planning. A more thorough comparison with other models and with a different

set of local observations within the domains was necessary to get a better idea of the models projection efficiency and test the realism of its absolute values.
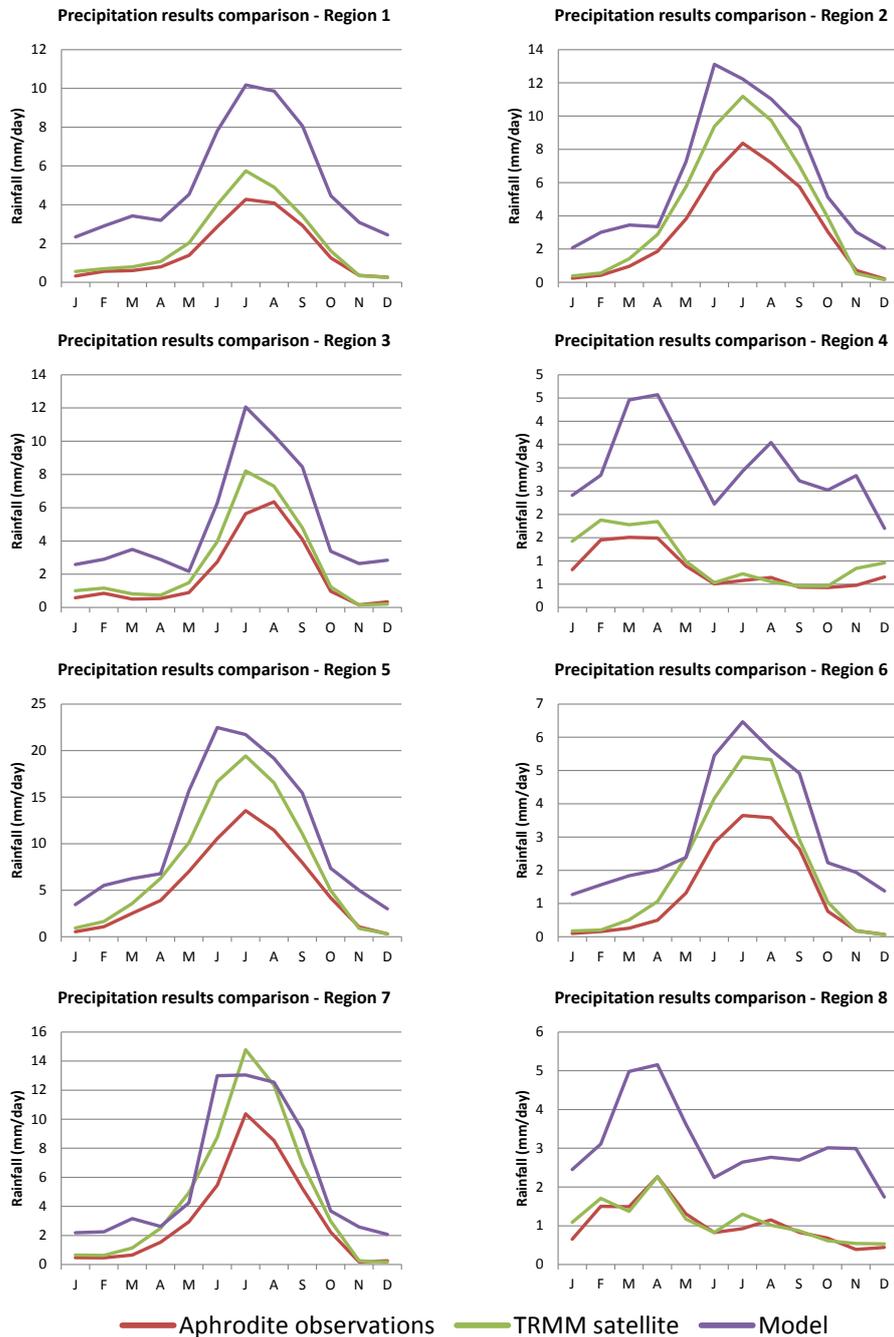
Figure 4. Comparison of HICAP (RCP8.5) model (purple) baseline period results for monthly average precipitation with Aphrodite (red) and TRMM (green) satellite data for domain 1-8.

A second round of comparisons was done with available monthly average precipitation and temperature data from observations and models available from the Nepalese Department of Hydrology and Meteorology (http://www.dhm.gov.np/dpc). Models did not always cover the

exact same period as baseline (1996-2005) but as close as possible periods were selected for each. In the comparison of the HICAP RCP scenario projections with available models for the region we also needed to compare with older IPCC AR4 SRES scenarios. There was a limited availability of SRES scenarios for the regions, and we compare RCPs not with the best matching SRES, but with the best available matching SRES. As a result, RCP8.5 (best match with SRES A1F) was compared with SRES A2, which projects a smaller change than RCP8.5. RCP4.5 (best match with SRES B1) was compared with SRES A1B which has reasonable overlap with RCP 4.5 (SRES A1B projecting a slightly large change than RCP4.5).

We selected domain 7, the smallest but yet very heterogeneous domain, and compared a subset of model results (further downscaled to project temperature and precipitation specifically for the middle hills, region 7B) also with actual observations for field stations all in the same subdomain, but at 3 different elevations (2003m, 1210-1295m and 410-444m) in that same region and period. The average altitude for the model results for sub-region 7B is 4000m, (compared to 1200m for the Terai and 4950m for the High Mountains). This comparison (figures 5-7) shows that:

1) The HICAP model has a significantly better fit with all three field station observations than any of the other models available considering its shape and timing. However, it consistently overestimates precipitation outside the monsoon period for all stations, and for the two stations with lowest elevation during the monsoon. The HICAP model underestimates precipitation for the highest elevation during monsoon. The figures thus shows that model results for the whole (sub)-domain baseline period do not reliably reflect precipitation in any one location in this domain, because observations at different elevations/locations give very different results for precipitation.
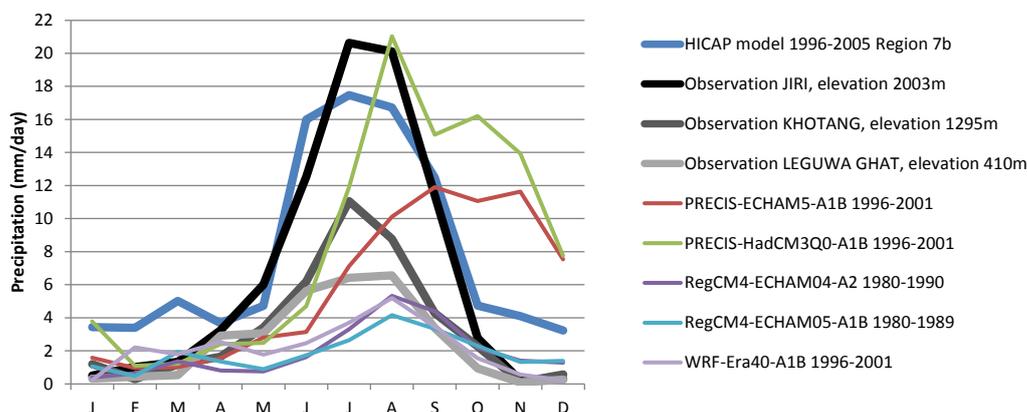
Figure 5. HICAP (RCP8.5) model precipitation projections for the baseline period (1996-2005) compared with observations from 3 stations at different location and elevation in the same sub-domain (7) and model results for the region of Jiri station – monthly average precipitation data obtained from *www.dhm.gov.np/dpc*.

2) Temperature (both maximum and minimum) is significantly underestimated by the HICAP model, more so when compared with lower elevations. Similar to precipitation above, the

model again performs better in shape and timing than the alternative models. However, again it is clear that observations at different elevations/locations even within the (sub)-domain give different results, and that the model does not reliably reproduce the observations for any one location for the baseline period.
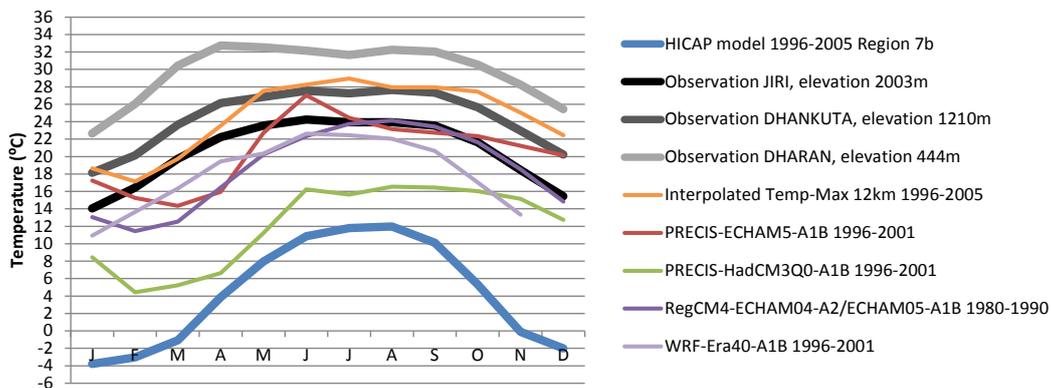

Figure 6. HICAP (RCP8.5) model maximum temperature projections for the baseline period (1996-2005) compared with observations from 3 stations at different location and elevation in the same sub-domain (7) and model results for the region of Jiri station – monthly average maximum temperature data obtained from *www.dhm.gov.np/dpc*.
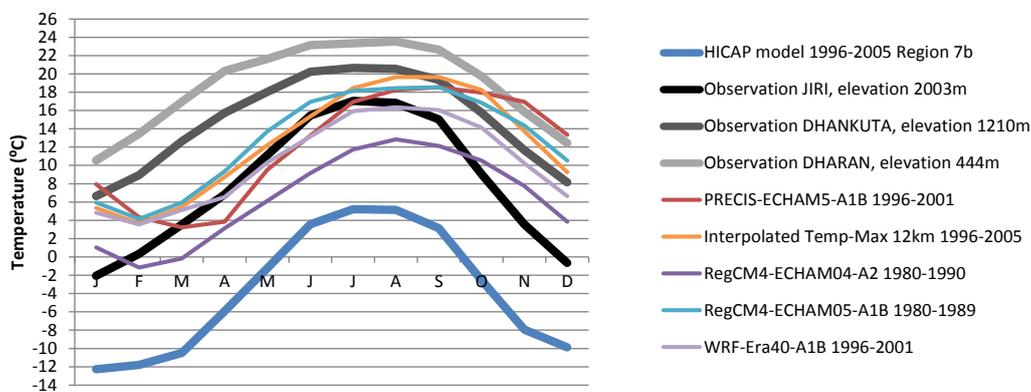
Figure 7. HICAP (RCP8.5) model minimum temperature projections for the baseline period (1996-2005) compared with observations from 3 stations at different location and elevation in the same sub-domain (7) and model results for the region of Jiri station – monthly average minimum temperature data obtained from *www.dhm.gov.np/dpc.*

A model based on a larger domain of course is not expected to reliably reproduce any specific location's climate. However, this is the intended ultimate purpose and use of the model results. Thus, in order for the model (and its results) to be relevant, realistic and useful in providing climate change information at the different levels of management and decision-making, the results have to be adjusted to fit local observations. Within the scope of this

project, this could not be done through modifications of the model itself, but considering the model shape generally being better than any of the alternatives, the HICAP model is still the best model available for projections for the domains.

2.3 Model results for future projections

Above comparisons indicate that the HICAP model can be used at least for the baseline period. The model projections for 2010-2030-2050-2080 however also need to be compared to other models for the same region and period in order to judge whether the model projections are plausible and of similar scale. Comparable datasets were found on basin level (most HICAP river basins) and downscaled level (via the website of the Department of Hydrology and Meteorology, Nepal), but limited to 2060 at the most. Thus, comparison of the projections was limited to the 2010-2030-2050 periods and does not include the 2050-2080 period.

Thus, HICAP model projected precipitation and average temperature changes (from 1996-2006 to 2031-2050) are compared with alternative RCP models projected changes (from 1961-1990 to 2021-2050) on a basin level (figure 8; compared with data from Immerzeel & Lutz, 2012).
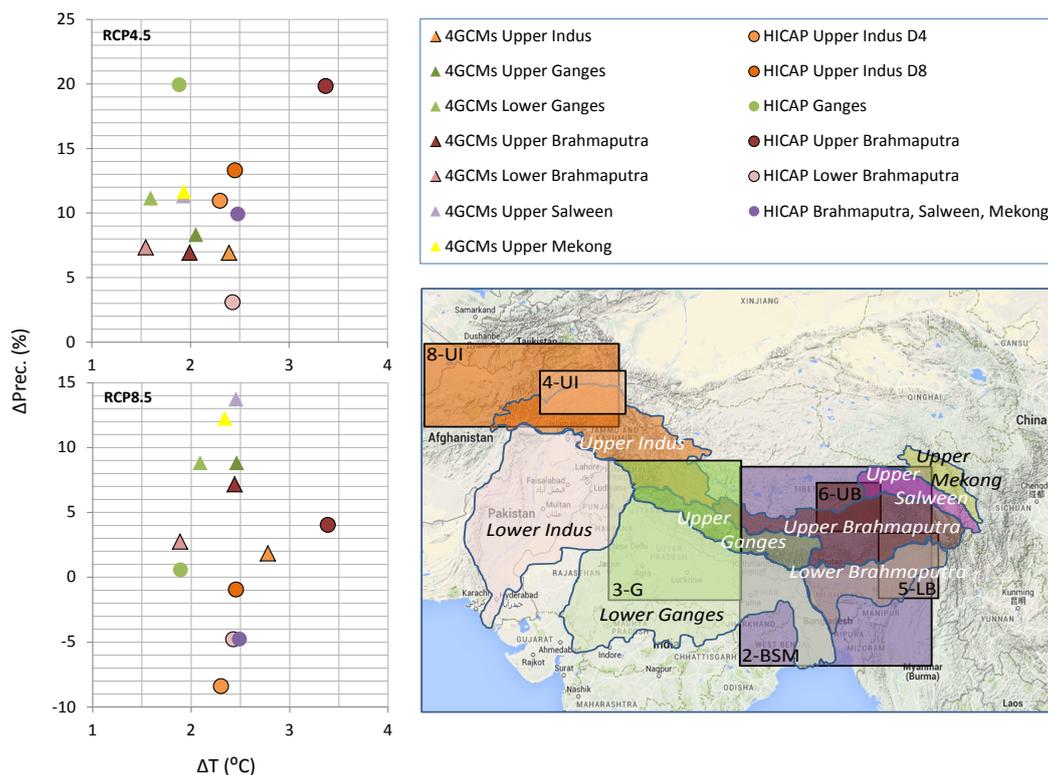
**Figure 8.** HICAP RCP4.5 and RCP8.5 model projections of change for annual average precipitation and temperature compared with the average projected change of 4 GCMs (Immerzeel and Lutz, 2012) for the same domains/river basins. The map indicates the domains used for HICAP model (squares, domain number and basin initials), and for the 4GCM model (shapes+basin name) with approximate colours corresponding to the graphs.

13

Figure 8 indicates that the HICAP model RCP4.5 simulations project a higher temperature change in comparison with the alternative RCPs, while results for precipitation are mixed for the different basins. The HICAP RCP8.5 simulations for temperature change compare fairly well with the alternative GCMs, but the HICAP RCP8.5 simulations show less precipitation change in this comparison. Both the 4GCMs and the HICAP model show an equal or lower precipitation for the RCP8.5 simulations compared to the RCP4.5 simulations. Lower precipitation projections for the RCP8.4 vs the RCP4.5 scenarios were also found by other authors, see e.g. (Chong-hai & Ying, 2012).
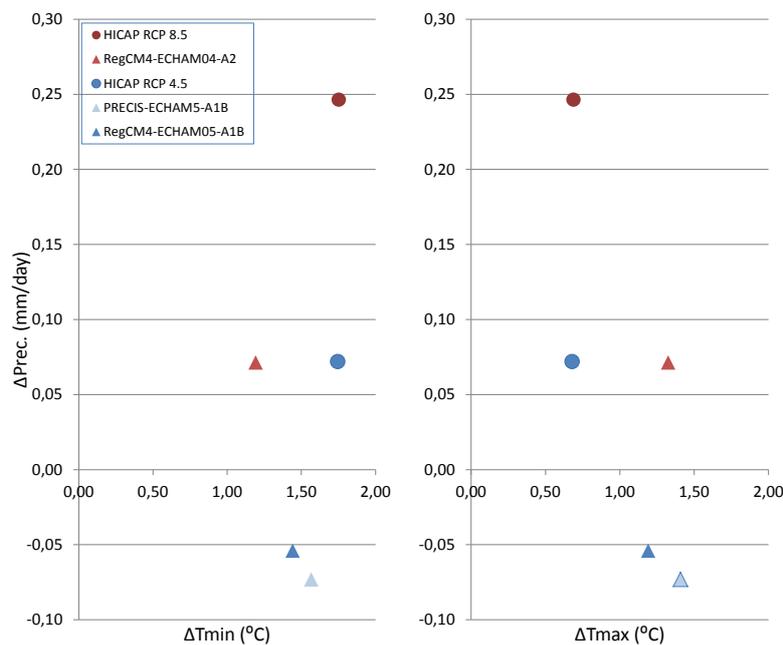

Figure 9. HICAP model projections of change for annual average precipitation, maximum and minimum temperature compared with the projected change by available models using SRES A2 and A1B scenarios for the same sub-domain 7b. SRES scenario data obtained from *www.dhm.gov.np/dpc*.

Figure 9 presents a comparison of the HICAP model RCPs on a more downscaled, local level with available alternative models using the older SRES scenarios for sub-domain 7b. In this comparison, the RCP8.5 scenario was compared to the A2 scenario, and the RCP4.5 was compared to the A1B scenarios. This comparison shows that HICAP model temperature projections are a bit higher for minimum temperature changes, and a bit lower for maximum temperature changes compared to the alternative models running SRES scenarios. Another difference with the comparisons above (figure 8) is that for this particular domain (Koshi basin) both the HICAP model RCPs and the alternative models SRESs project a larger precipitation change when using the RCP8.5/A2 scenario compared to the RCP4.5/A1B.

In summary, these comparisons show that different models and scenarios give reasonably similar results with regard to the amount of temperature change, with in fact not much

difference between scenarios at the basin level. However, the comparisons show very different results with regard to the amount of change in precipitation for the different domains, but in general lower for RCP8.5 compared to RCP4.5 scenarios, and higher for the new RCPs compared to the old SRES scenarios. Given the greater variations in precipitation projections across comparisons, which moreover don't seem to be systematic for the Eastern or Western Himalayas, the results of precipitation change in this report need to be taken with a caution and a greater amount of uncertainty than the projections for temperature change.

2.4   Adjustments of model results

The Himalayas are geographically a very heterogeneous region, where altitude differs greatly from one location to the other even within a small area. The region is also very large with different precipitation patterns depending on the location in the Himalayas. While generalizations can be made for larger areas, it is exactly these local and altitudinal differences which make that different locations face different challenges, and thus demand accurate information tailored for their specific locations and needs for adaptation.
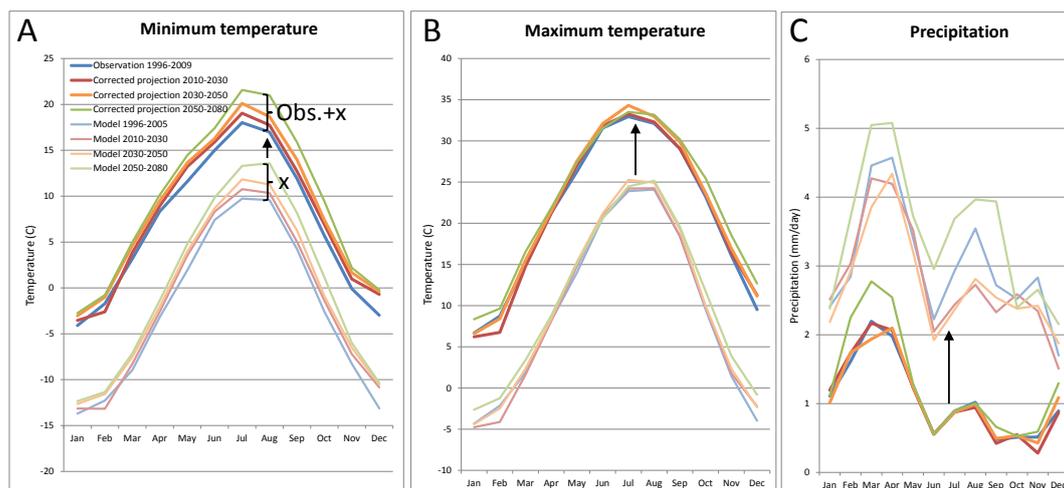
Figure 10. To obtain locally relevant projections, corrections for minimum temperature (A), maximum temperature (B) and precipitation (C) are required. Corrections for projection periods for any specific location are made by calculating the projected change over time (i.e. the difference between the baseline period 1996-2005 and the projection period, e.g. 2050-2080, indicated by "x"). This change over time "x" is then added to local observations for the baseline period (indicated by "Obs.+x"), resulting in a locally more realistic projection for that particular projection period (2050-2080). The same method of correction is done in s similar way for each projection period and for each climate variable, and the change from model to local projections is indicated in each graph by an arrow.

HICAP model results are in general several degrees off with realistic levels for the domain, nor do they of course agree with every location within a domain as a projection gives the average for many locations within a domain. Thus, to obtain locally relevant projections,

corrections of model results for temperature and precipitation to locally relevant levels are required. Corrections for projection periods for any specific location are made by first selecting the original model results for the smallest domain possible. The following steps are indicated in figure 10, and consist of first calculating the projected change over time (i.e. the difference between the baseline period 1996-2005 and the projection period, e.g. 2050-2080, indicated in the figure by "x"). Then, this change over time "x" is added to local observations for the baseline period (indicated by "Obs.+x"), resulting in a locally more realistic projection for that particular projection period (2050-2080). Thus, differences over time between baseline and projection periods remain the same for those calculated originally by the model and those used for any given locality, but the absolute level is adjusted to match locally more realistic levels. The same method of correction is done for each climate variable. Throughout this report, this correction is performed for all periods and selected RCP scenarios.

The HICAP model is an improvement with regard the seasonal representation of the model compared to other models, important for timing issues in temperature and precipitation. The projections of change compare reasonably well with alternative projections (figure 8-9) for similar period and area. Thus, the projected amount of change by the HICAP model is expected to be realistic, and due to its better timing properties the model overall is the preferred model to use for local adaptation input. However, its absolute levels are quite off when compared to regional and local observations. Thus, it is necessary to adjust the final model results to locally realistic levels.

Due to the crash-proneness of the model as well as time constraints, the model itself has not been adjusted to make final results more realistic. Instead, an alternative and very simple method was used to correct model results for any specific location. The correction consists of 1) the assumption that the location will follow the projected pattern as described by the projections for the smallest available domain, followed by 2) transposing the change over time by this projection on top of local climate observations at the desired location within that domain (see figure 10). Given available data (monthly average values for Tmin, Tmax and precipitation), the model can thus be adjusted to any location and projections will be more realistic than larger scale, e.g. regional projections including that exact location.

2.5 Extrapolation to different elevations and specific locations

As the correction is based on observational data from nearby weather stations for the baseline period, the model is adjusted for the location and elevation of this weather station. Naturally, not all locations in that same area are on the same altitude as that weather station. Another issue is that projected changes of temperature or precipitation are based on an average for that domain, and most domains have a very large geographical variation which is reflected in both large local differences in temperature and precipitation. This is demonstrated by figure 11 which shows spatial differences in annual variation in temperature (e.g. higher in low-lying areas and further south) and precipitation (wetter in the eastern HKH than west, and wetter in low lying areas close to the mountain range, but not on higher elevations).

Average annual temperature	Average annual precipitation
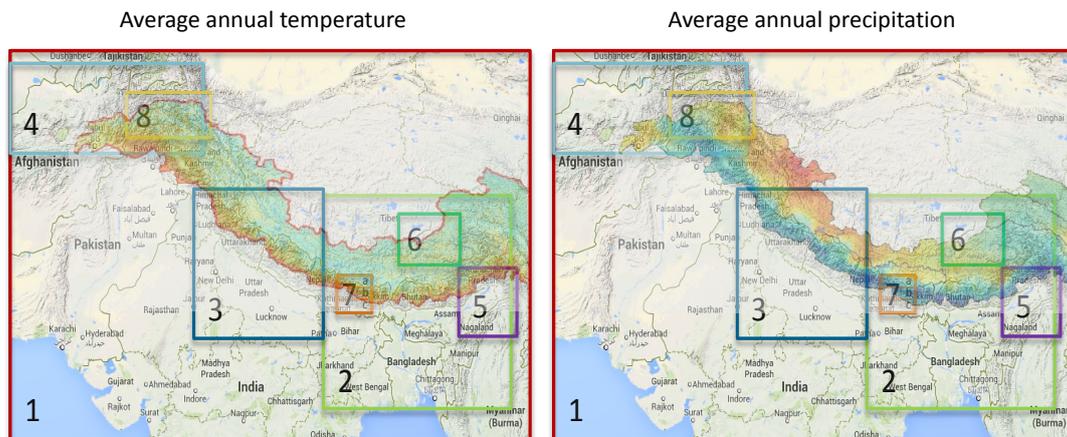
Figure 11. Spatial and geography related variation in average annual temperature and precipitation (1997-2007) for parts of the analysis domains. Precipitation and temperature maps adapted from Lutz and Immerzeel, 2013, with colour gradients indicating high (red) and low (green) temperatures and likewise high (blue) and low (red) precipitation.

The average change for the domain and the geographical specifics (figure 11) cannot tell us whether projected temperature or precipitation changes for a location will be greater or smaller than the domain average. If, for example, the projection indicates increased precipitation and more rainy days, it may be that all of these will occur in the low lying areas of a domain, and none in the higher lying areas. The average moreover would then underestimate the change for the low-lying areas, and over-estimate the change for the higher lying areas. Thus, using the method's approach of adding the change in temperature or precipitation for a domain and plot that on top of any local climate observations must be approached with care and, where such data and information is available, this must be placed in the spatial and even temporal context. This should especially be taken into account when using the interpretations of projected change per domains below for any specific location within those domains.

On a methodological level, temperature can be corrected and incorporated for any given location, as it has a clear linear relationship with elevation (figure 12). Thus, if the only data available for a location at e.g. 2000m altitude are weather station data from 3000m altitude, Tmin can be corrected for with (Tmin2000 – Tmin3000 =) 5,37^{0}C and Tmax can be corrected with (Tmax2000 – Tmax3000 =) 6,30^{0}C.

Precipitation is less easy to correct, as this depends on more factors than elevation, including monsoonal circulation patterns, rainshadow/rainside of a valley, etc. In the absence of any clear relationship of precipitation for specific locations within the smallest domain 7 with elevation (R^2=0,07), latitude (R^2=0,04) or longitude (R^2=0,01) we did not further alter the precipitation projections beyond the adjustment of the model to current levels and projected change for that (smallest) domain.
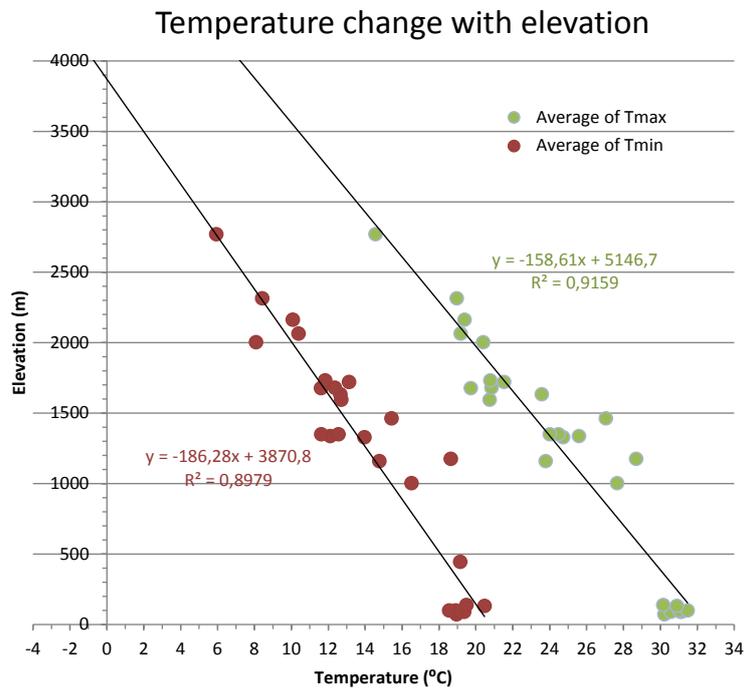
Figure 12. Correlation of minimum and maximum temperature with elevation based on available weather station data (elevation and annual mean for Tmin and Tmax) in domain 7, for the period 1980-2010.

Uncertainty

The current modelling effort has a number of inherent uncertainties resulting from different sources. At the modelling level, a main source of uncertainty is the limited amount of runs for each scenario: each scenario was only run once for the whole period (1996-2005, 2010-2030-2050), so no inherent model uncertainty could be calculated. Secondly, the choice of scenario (RCP4.5 or 8.5) results in a level of uncertainty of which projections to use for adaptation. In this respect, at least on the short term, this does not present any major problem, as the two scenarios do not differ greatly in their projections until 2050. A next layer of uncertainty was introduced by adapting the model results for each domain to local observations. This correction makes the model fit with current local observations, but as the correction is standardized over the whole projection period it does not take into account future changes in temperature and precipitation patterns. Such a potential change is part of the uncorrected downscaled model itself, and we consider that the bias-correction removes a substantial error in the model (gross underestimation of temperature and under- or overestimations of precipitation), which far outweighs the introduced error. To limit uncertainty in the adaptation of results to the specific localities, we use the model results and projections for the smallest domain possible. For instance, if a case study village is located in domain 5 as well as domain 2 and 1, we adapt domain 5 projections to the local observations.

Another source of uncertainty is in the presentation of results the figures. To reveal patterns of change, we use in many instances monthly averages. These might give the impression of

18

certain trends that do not really exist, as the variation around these averages may be very large, making apparent changes insignificant. We have tried to indicate the variation in several figures by using the extreme values to indicate upper and lower limits of temperature or precipitation.

The downscaling effort and consecutive adaptation of domain-scale changes to specific local changes (e.g. for a community living at a 2000m altitude in contrast to the domain projection for changes at 3000m) was done specifically to make results locally relevant. Details are important, as is local accuracy of current and projected climate variables. However, uncertainty or variation in the projections and the precipitation- or temperature- extremes are just as important. While we did not calculate the level of confidence and degrees of uncertainty, we do make an effort to underline whether a certain change and the degree of change is likely to happen or not.

As documented in the previous sections, the projections for temperature and precipitation compare well both in shape/timing with observations. After the adjustments for underestimation of temperature and over/under estimation of precipitation, the model describes current temperature and precipitation well. Also, the projected change of temperature is reasonably in line with alternative models for the region. Thus, given the uncertainties stemming from a lack of model runs, the relative good fit of the model 1) with current local observations of seasonal changes and 2) projected temperature change gives us a reasonable level of confidence that the *projections for temperature* are correct, realistic and useful at the local level. However, HICAP model projections of precipitation change differ unpredictably with other models (sometimes higher, sometimes lower than comparable models, differing per river basin and RCP scenario). Thus, projections for precipitation are highly uncertain and should not be taken at absolute levels.

3 Climate projections and potential consequences per domain

3.1 Background for interpretation and selection of figures

Changes in temperature and precipitation are important for many people and many reasons. People living in flood prone areas must know if precipitation will increase and if so, when. They need information not just on how much more rain will fall in a year, but also on a seasonal, monthly or daily basis, if the rain will come in large amounts during a concentrated period of time, or if it will be spread out in time, if the number of consecutive rainfall days increases or not, etc. Clearly, not all figures are applicable or needed for each user group, agriculture needs different info and figures than flood risk or urban planning, but any of the figures might provide useful information for at least some user groups. Changes in rainfall may affect drinking water availability, flood risk, but also agriculture (especially in rain-fed areas but also irrigated areas) and forest production. Similarly, temperature and variations in number of hot and cold days, changes in onset and end of the growing season, monsoon and shifting temperature gradients, which may allow for alternative crops but also may bring new pests and diseases, may be of importance. In short: climate change has to be placed in a local perspective, and related to what people indicate as important for their livelihoods, infrastructure/housing situation, health and general well-being.

3.2 Indicators

A set of indicators was selected based on indices recommended by the Commission for Climatology (CCl), World Climate Research programme (WCRP) of Climate Variability and Predictability component (CLIVAR) project and the Expert Team for Climate Change Detection and Indices (ETCCDI). These indices were partly confirmed and partly adapted using insights and feedback from researchers and local users/population in field studies. The original ETCCDI list was also complemented with additional indices of local relevance, such as monsoon onset and end, growing season onset and end, wet days, frost-free nights, and temperature and precipitation variability, and the daily extreme temperatures. Table 1 shows the selected climate indices and a description for their calculation. All indices are based on 3 model outputs: daily maximum temperature (1), daily minimum temperature (2) and daily precipitation (3). Detailed results in form of figures and a short list of bullet point explanations for the domains at river basin level (domain 2-8) are presented in the appendix (section 7). A summary of these changes is presented for each domain in the subsections below and in the comparison across domains in section 3.5. We refer to the website http://www.cccma.ec.gc.ca/data/climdex/ for a detailed description and source of the indices adapted here, and to Sillmann et al. (2013a; 2013b) for work on the validation of these indices and an analysis of their simulated future changes.

Table 1. Selected climate indices and their description.

ID	Indicator name	Definitions	UNITS
FD0	Frost days	Annual count of days when daily minimum temperature < 0°C	Days
SU25	Summer days	Annual count days when daily maximum temperature > 25°C	Days
ID0	Ice days	Annual count of days when daily maximum temperature < 0°C	Days
TR20	Tropical nights	Annual count of days when daily minimum temperature > 20°C	Days
GSL	Growing season Length	Annual count between first span of at least 6 days with daily average temperature > 5°C and first span after July 1 of 6 days with daily average temperature < 5°C, combined with at least 6 consecutive wet days (days with precipitation ≥ 1mm)	Days
Gsoe	Growing season onset/end	Annual dates of growing season onset and end as defined by GSL	Date
TXx	Max Tmax	Monthly maximum value of daily maximum temperature	°C
TNx	Max Tmin	Monthly maximum value of daily minimum temperature	°C
TXn	Min Tmax	Monthly minimum value of daily maximum temperature	°C
TNn	Min Tmin	Monthly minimum value of daily minimum temperature	°C
Tavg	Average T	Monthly average temperature	°C
TN10p	Cool nights	Annual count of days when daily minimum temperature < 10th percentile	Days
TX10p	Cool days	Annual count of days when daily maximum temperature < 10th percentile	Days
TN90p	Warm nights	Annual count of days when daily minimum temperature > 90th percentile	Days
TX90p	Warm days	Annual count of days when daily maximum temperature > 90th percentile	Days
TN>0	Frostfree nights	Annual/Monthly count of nights with daily minimum temperature > 0°C	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when daily minimum temperature < 10th	Days
DTR	Diurnal temperature range	Monthly mean difference between daily maximum temperature and daily minimum temperature	°C
Ravg	Average precipitation	Monthly average precipitation	mm/day
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as precipitation ≥ 1mm) in the year	mm/day
R10	Number of heavy precipitation days	Annual count of days when precipitation ≥ 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when precipitation ≥ 20mm	Days
CDD	Consecutive dry days	Maximum number of consecutive days with precipitation < 1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with precipitation ≥ 1mm	Days
R95p	Wet days	Monthy average and extreme (min/max) number or days with precipitation > 90th percentile	Days
R95p	Very wet days	Monthy average and extreme (min/max) number or days with precipitation > 95th percentile	Days
R99p	Extremely wet days	Monthy average and extreme (min/max) number or days with precipitation > 99th percentile	Days
PRCPTOT	Annual total wet-day precipitation	Annual total precipitation in wet days (precipitation ≥ 1mm)	mm
Tvar	Temperature variability	Daily extremes for daily minimum and maximum temperature	°C
Rvar	Precipitation variability	Daily standard deviation from the daily average precipitation	mm/day
TXxd	Daily Tmax	Daily temperature maximum	°C
TNnd	Daily Tmin	Daily temperature minimum	°C
Ravgd	Daily average precipitation+extremes	Daily rainfall and daily extremes	mm/day
Monsoon	Monsoon onset/end	Days from April through October with continuous precipitation above the 45 percentile of the 7 day average baseline precipitation	Date

3.3 Monsoon and growing season

Monsoon

Monsoon is one of the defining climatic features in the earth's climate. Apart from its essential role in atmospheric circulation and the hydrology cycle, monsoonal precipitation is crucial for life, providing drinking water and water for agriculture and vegetation in general. As such, it co-determines the length of the growing season. The monsoon is typified by a seasonal change in prevailing winds between winter and summer (e.g. Chang et al., 2011). The actual definition of monsoon varies significantly per region and who is asked: scientists and meteorologists use various different definitions, and these again are different from what e.g. local farmers define as monsoon (Stiller-Reeve et al., 2014).

To make numerical predictions of the onset and end of monsoon, various definitions have been proposed. For example, the onset of the Indian summer monsoon (ISM) over the southern tip of the Indian peninsula (also known as monsoon onset over Kerala] has been considered the beginning of India's rainy season, and the Indian Meteorological Department makes an official prediction of ISM onset every year using a subjective method. These predictions are based a.o. on 5-day rainfall events for many stations, and though produced over 60 years ago these "normals" are still in use today (Wang et al., 2009). In general, it is based on subjective measures of persistent, widespread rainfall, include wind direction parameters and have higher than a given threshold air humidity. More objective methods are based on the rapid increase of daily precipitation rate, large temperature increase over the

Tibetan plateau, or other defining indicators (see Wang et al., 2009 for a more comprehensive listing).

Often, monsoon is used as an equivalent to the "rainy season". Existing definitions using precipitation include 1) If the local summer minus winter precipitation rate exceeds 2,5 mm/day and the local summer (MJJA) precipitation exceeds 55% of the annual total (Chang et al., 2011); 2) If, after the 10th of May, 60% of [14 selected stations] report rainfall of 2.5 mm or more for two consecutive days, the onset over Kerala be declared on the 2nd day, provided [criteria for wind- and radiation] are also in concurrence (Indian Meteorological Department (IMD); www.imd.gov.in). However, standard meteorological definitions of monsoon in the pan Indian context often don't work for the NE-region often (personal communication from local HICAP partner Partha Jyoti Das, Aaranyak, regarding monsoon in Assam), let alone for the larger HICAP region. In that specific region they define two rainfall seasons: "one covering April to October where April and May experience large pre-monsoon rainfall. October comes in because of late withdrawal of monsoon. Sometimes monsoon sets in as early as the last week of May here. Sometimes the rains in May and June are so continuous that it is difficult to say when the pre-monsoon rains ended and the monsoon rains started."

Clearly, one main problem is the absence of a universal definition of monsoon or for the rainy season. Available definitions do not fit all HICAP regions, and even the latest and most robust models are not able to confidently project how climate change will affect monsoon (Chang et al., 2011). With only temperature and precipitation at hand, we thus have very limited tools to objectively and correctly calculate monsoon onset and end in all end-users' eyes and for a geographically and precipitation-wise diverse area. However, we assume that the main interest in monsoon predictions relate to rainfall, and any projected changes relative to todays' onset, end, and seasonal distribution and amount, including any increase or decrease in variability. Therefore, by using a relative measure for changes in precipitation rather than an absolute measure, we attempt to provide some locally useful and sufficient insight in "monsoonal" changes – acknowledging different perceptions and large uncertainties.

After testing different definitions, a method that proved useful to project (changes in) onset and end of monsoon for areas with different timing of monsoon onset and monsoon patterns (Assam and Nepal) was a simplification and adjustment of the above IMD monsoon calculation using summer (MJJA) precipitation minus Winter (NDJF) precipitation, and summer precipitation exceeds 55% of the annual total. In a twist on this definition, a cut-off was created for days from April through October where precipitation is above the annual 45 percentile (55%) of the 7-day average of the baseline period (1996-2005) precipitation. Onset and end of monsoon were defined by the period when precipitation (> 1mm/day) is uninterrupted above this threshold. This method may still not be exact in date, but it corresponds reasonably well with local descriptions of monsoon for the domains, clearly shows pre-monsoon and post-monsoon periods, and it allows for an objective calculation of monsoon/rainy period change useful for most practical purposes.

Growing season

Growing season varies per plant species, and is dependent on many factors, including precipitation and temperature thresholds, but also threshold conditions for day length (time between sunrise and sunset) after winter short day length dormant periods and before the

onset of the next winter dormancy. In the areas closer to the equator, and in the HICAP region, day length (at the Northern limit 39N at its shortest 9h25m) is not considered to be a limiting factor for crop growth, and farmers in fact are able to grow crops on their land year-round. This leaves temperature and precipitation as the limiting factors. Originally defined only by temperature indices as the first span of at least 6 days with daily average temperature > 5 ^{0}C and the first span after July 1 of 6 days with TG<5ºC (see table 1), the precipitation index was added to this to account for differences in growing season between irrigated land and rain-fed land. Growing season length was thus defined as follows for irrigated areas: the annual count of at least 6 consecutive days when daily average temperature is above 5 ^{0}C, combined (for rain-fed only agricultural areas) with the additional criterion of each of those 6 consecutive days having a precipitation of at least 1 mm/day.

3.4 Summary of changes per river basin/domain

The following sub-sections give a summary of the more detailed figures and descriptions in the appendix (section 7) for each domain and river basin. As the description on model background, adaptation of results and comparison of projections with other models for the region show, temperature projections are fairly certain, but precipitation projections must be interpreted and used cautiously as these results are very uncertain.

Due to the large and heterogeneous character of the HKH Himalayas, especially domain 1, only the downscaled domains 2-8 will be analysed in the sections below (3.4), while more detailed figures supporting these sections can be found in the appendix (section 7). These smaller, downscaled domains too can be very heterogeneous, but since they are limited to specific river basins they lend themselves to a more realistic and meaningful short summary of projected climate change and potential impacts. The aim of this report is first and foremost to present a methodological approach of how to downscale date to locally relevant and more realistic level. This facilitates the second aim, to support informed local decision making with detailed climate information. The aim of this report is not to give a detailed analysis of local impacts for each domain, as such an analysis stretches far beyond climate drivers alone. The below impact analysis does not include comparisons with other projections nor is it a literature analysis, and therefore only serves as a guideline of how to use these type of results. However, to facilitate the use of the presented climate date to all stakeholders, we do attempt to give indications of which potential effects climate change may have for agriculture, infrastructure and flood risk. It should be noted that these are indicative only, and impacts depend also on local adaptation measures.

3.4.1 Overall changes and comparison across domains

Projection results for the two RCPs for the different domains

Temperature and precipitation change for the different RCP scenarios are presented in detail in tables for each (sub-)domain in this section 3.4. Table 2 summarizes the annual average changes to facilitate a comparison across domains. For all domains, temperature changes are increasingly larger towards 2050-2080, regardless of the scenario used. Minimum (night-time) temperature increases more than maximum (day-time) temperature, and especially the Tibetan plateau and the Middle Hill region in Nepal will see a large increase in temperature. It is important to remember that the values given in table 2 represent an average annual change for each period, and when viewed in detail on a month-to-month and year-to-year basis temperature may increase for some months and decrease for others, while in general annual variation tends to increase. With regard to the different scenarios, RCP8.5 generally shows higher minimum temperature but initially lower maximum temperatures for compared with RCP4.5. On the long term (2030-2050) there is no large difference in projections between the two scenarios neither for maximum nor for minimum temperatures.

The results for precipitation are less clear cut; depending on the scenario, precipitation increases (RCP4.5) already from 2010 for all domains, or initially decreases (RCP8.5) until 2050, after which it increases on an annual basis, but not for all domains. The Tibetan plateau and the Middle Hills in Nepal especially appear to become drier, but this stresses the

importance of looking at the results in detail on a month-to-month basis, which indicate that some months become much drier, others will see an increase in precipitation.

Table 2. Annual average change in temperature and precipitation for the three projection periods and 2 RCP scenarios for each (sub-)domain. Colour schemes indicate direction and size of differences compared across domains with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.
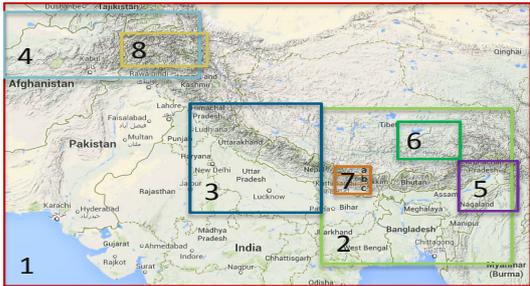
ΔPrec.	RCP4.5			RCP8.5		
Domain	2010-2030	2030-2050	2050-2080	2010-2030	2030-2050	2050-2080
1	0,2	0,6	0,8	-0,3	-0,3	0,7
2	0,2	0,4	0,8	-0,1	-0,2	0,3
3	0,3	0,6	0,9	-0,2	-0,2	0,7
4	0,1	0,3	0,7	-0,2	-0,3	0,5
5	0,4	0,5	1,8	0,3	0,0	0,6
6	0,2	0,4	-0,5	0,1	0,1	-0,5
7	0,1	0,3	0,5	-0,1	0,0	0,0
7HH	0,1	0,1	-0,1	-0,1	-0,1	-0,1
7MH	0,0	0,1	0,2	-0,3	-0,2	-0,9
7LH	0,2	0,6	1,1	0,1	0,3	1,0
8	0,1	0,4	0,7	-0,1	0,0	0,6

ΔTmin	RCP4.5			RCP8.5		
Domain	2010-2030	2030-2050	2050-2080	2010-2030	2030-2050	2050-2080
1	0,5	1,5	2,1	0,8	1,5	2,8
2	0,6	1,7	2,3	0,9	1,7	2,7
3	0,4	1,4	2,0	0,7	1,4	2,8
4	0,6	1,6	2,3	0,9	1,6	2,6
5	0,6	1,6	1,8	0,8	1,6	2,2
6	0,9	2,3	3,3	1,2	2,3	3,3
7	0,7	1,7	2,1	0,9	1,7	2,7
7HH	0,8	1,9	2,3	1,0	1,9	2,5
7MH	0,7	1,7	2,2	0,9	1,8	3,2
7LH	0,5	1,3	1,7	0,7	1,3	2,2
8	0,7	1,7	2,7	0,9	1,7	2,0

ΔTmax	RCP4.5			RCP8.5		
Domain	2010-2030	2030-2050	2050-2080	2010-2030	2030-2050	2050-2080
1	0,2	0,5	0,8	0,0	0,5	0,9
2	0,4	0,8	1,3	0,2	0,8	1,3
3	0,1	0,4	0,6	-0,1	0,4	0,5
4	0,3	0,7	1,1	0,1	0,7	1,3
5	0,5	0,9	0,8	0,2	0,9	1,6
6	0,5	1,1	2,5	0,3	1,1	2,1
7	0,3	0,7	0,8	0,1	0,7	1,4
7HH	0,4	1,0	0,9	0,2	1,0	1,1
7MH	0,3	0,7	1,0	0,1	0,7	1,9
7LH	0,2	0,4	0,6	-0,1	0,4	1,1
8	0,4	0,8	1,3	0,2	0,8	1,1

Overall, the <u>eastern</u> Himalayas (domains 2 and 5) will see increased precipitation, especially during the monsoon period from June-August and October, while the monsoon shoulder seasons become dryer, especially towards 2050. On the <u>northern</u> Himalayas, the Tibetan plateau will see an initial increase in rainfall but become much drier after 2050. On the <u>western</u> side (domains 4 and 8), February-May and September will see an increase in precipitation already from 2010 (RCP4.5) or after 2050 (RCP8.5), especially for the currently wet months (February-May), while November may become a bit drier (RCP8.5). For the <u>southern/middle</u> Himalayas (domains 7 and 3), precipitation is projected to increase slightly over time (RCP4.5) or remain the same as today (RCP8.5), with higher elevations becoming drier and lower regions seeing more rain over time. On a month-to-month basis these regions will see an increase in precipitation in the winter months (January-February) and October, but a decrease in summer (June-September). After 2050, the Nepalese Terai and the north-Indian region will see some increase in precipitation in the monsoon shoulder seasons June and September-October, but also a general decrease during monsoon itself.

The two RCP scenarios are very different in their assumptions and projected global temperature increase in the long term (Rogelj, Meinshausen, & Knutti, 2012). Considering the timeline of projected temperature increase (figure 13), we see that the two scenarios only really begin to diverge and give different results after 2050. This change for average temperature is consistent with earlier studies indicating the same for minimum and maximum temperatures (see references in Knutti & Sedláček, 2012). Thus, differences between the RCP scenarios and

the absolute temperature increase in the HICAP region are expected to reflect this global picture, with larger differences and increases taking place after 2050. A comparison of recent trends in carbon dioxide emissions from fossil-fuel combustion, cement production and gas flaring with the primary emission scenarios used in the more recent IPCC reports follow the RCP8.5 scenario (Peters et al., 2012), making this currently the most likely scenario of change.
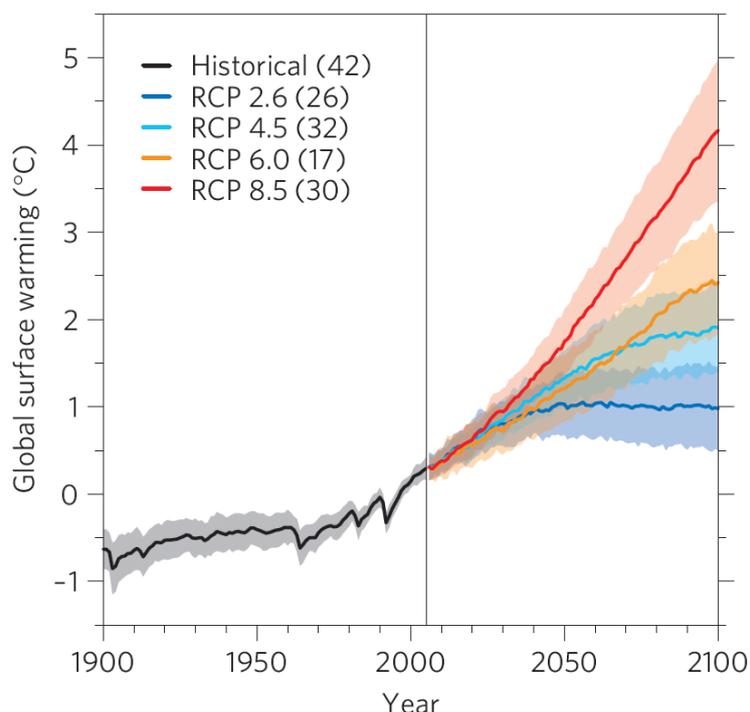

Figure 13. Global temperature change (mean and one standard deviation as shading) relative to 1986–2005 for the RCP scenarios run by CMIP5. The number of models is given in brackets (Adapted and reprinted from (Knutti & Sedláček, 2012) with permission from Macmillan Publishers Ltd.).

The analysis of precipitation and temperature change and their potential impacts for each of the domains is based only on the locally downscaled projections. Clearly, many impacts upstream, especially to glaciers and precipitation, will eventually affect flow, water availability and also flood-risks in downstream areas. These can be the valleys and lower elevations within the same domain, but also go across domains from higher to lower elevations (e.g. from domain 4 to domain 8, or from domain 6 to domain 5 and from 6 and 7a to domain 7b, 7c and 2). It is also important to realize that much of the agriculture in the hills and higher elevations is dependent on rainfall, and thus will be relatively unaffected by changes in river flow (Lutz et al., 2014). Change in growing season and local impacts in general must thus be viewed with both local precipitation and temperature in mind, but also with these upstream-downstream interconnections across domains and elevations.

Climate change will occur simultaneously with other, socio-ecological, socio-economic, political or infrastructural changes. As not only change, but also vulnerability, adaptive

capacity and resilience to change are different in different regions, across different levels in society and also have a gender component, the impacts especially on the long term are near to impossible to assess, especially as many adaptations already exist (e.g. Aase et al, 2010; Eriksson et al., 2009; Moors et al., 2011; Nelleman et al., 2014). In this report we only refer to impacts assuming climate change without adaptation, and with a focus on agriculture, forestry, and flood risk (see also Xu et al., 2009), leaving out many important issues such as impacts on e.g. health effects and biodiversity. To best adapt to future change, it is crucial for any assessment of change and impacts to take an inclusive approach, taking into account both local knowledge and perspectives, regional and national economic and political setting, and potential global linkages (Tschakert et al., 2013). Included in such an approach, addressing and including differences in social and geographical scale is of utmost importance, as impacts may differ widely.

3.4.2 Domain 2: Eastern HKH – Salween-Mekong-Brahmaputra

Left: Detailed map domain 2
Also covers domains 5, 6, 7

Domain delimitations:

32.28N, 84.50E	32.28N, 97.33E
21.99N, 84.50E	21.99N, 97.33E
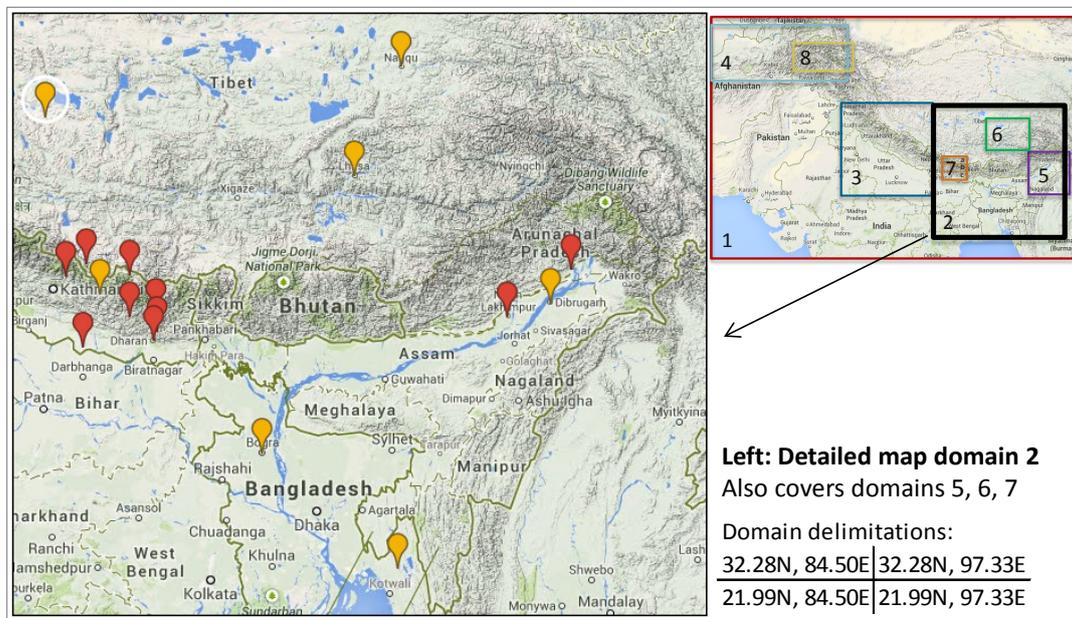
Figure 14 Domain map with reference stations (orange markers) used for analysis of climate change in this report. Reference stations for domain 2 are spread across its very diverse geographic area, with station's elevations ranging from 23 m.a.s.l. (meters above sea level) to 5200 m.a.s.l. The following analyses are based on their average elevation of 2206 m.a.s.l.

Climate change: Table 3 shows that minimum (night-time) temperature change is projected to be about twice the size of the projected maximum (day-time) temperature change. Most warming takes place in pre- (March-May) and post- (September-November) monsoon months. There is no large difference on the short- (2010-2030) and mid-term (2030-2050) between scenarios RCP4.5 and RCP8.5, though on the long term (2050-2080), RCP8.5 projects a bit more warming. Precipitation is projected to change especially for June and October (wetter) and May and September (drier).

Table 3. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

| | ΔTmin | | | | | | ΔTmax | | | | | | ΔPrec. | | | | | |
| | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | |
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,6	1,6	2,3	0,9	1,6	2,0	-0,1	0,4	1,1	-0,2	0,4	1,5	0,8	0,6	1,6	0,5	0,0	0,2
F	0,3	1,7	1,8	0,6	1,7	1,6	0,1	0,9	1,0	0,0	0,9	1,2	0,0	0,6	1,0	-0,3	-0,1	-0,1
M	1,4	2,3	2,8	1,7	2,3	2,6	1,7	1,6	1,8	1,5	1,7	2,3	-0,2	0,3	0,7	-0,6	-0,3	-0,4
A	0,6	1,8	2,7	0,9	1,8	3,1	0,5	0,9	1,6	0,2	0,9	1,6	0,3	0,4	0,7	0,0	-0,2	-0,1
M	0,9	1,9	2,6	1,2	1,9	3,2	0,5	1,0	2,0	0,3	1,0	1,8	0,3	-0,6	-0,4	-0,3	-1,2	-0,3
J	1,0	2,0	2,2	1,2	2,0	3,0	0,6	0,8	1,7	0,4	0,8	1,2	0,1	0,5	0,3	-0,4	-0,2	1,4
J	0,5	1,4	1,8	0,7	1,4	2,7	0,2	0,2	0,6	-0,1	0,2	0,1	1,1	1,7	0,8	0,9	1,2	1,9
A	0,4	1,4	1,6	0,6	1,4	2,8	0,1	0,3	0,1	-0,2	0,3	0,1	0,2	0,7	0,3	0,0	0,2	0,6
S	0,6	1,5	2,0	0,7	1,5	3,0	0,5	0,9	1,0	0,2	0,9	0,9	-0,3	-0,6	0,6	-0,6	-1,2	-0,1
O	0,7	1,7	2,6	0,9	1,7	4,2	0,3	0,6	1,1	0,0	0,6	1,6	0,3	1,0	1,4	-0,2	0,2	1,8
N	1,1	1,8	2,6	1,2	1,8	3,0	1,0	1,2	1,7	0,8	1,2	2,0	0,0	0,2	1,1	-0,3	-0,4	-0,3
D	-0,4	1,0	2,2	-0,1	1,0	1,4	-0,2	0,7	1,6	-0,4	0,7	1,6	0,2	0,3	1,3	0,0	-0,3	-0,4
AVG	0,6	1,7	2,3	0,9	1,7	2,7	0,4	0,8	1,3	0,2	0,8	1,3	0,2	0,4	0,8	-0,1	-0,2	0,3

The more detailed figures in the appendix (section 7.1.2) for this domain indicate that the average daily minimum temperature is projected to increase gradually towards 2080, with up to about 3-4 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially from 2050-2080, but mostly between September and May, outside the monsoon period. The lowest daily minimum temperatures (coldest nights) will remain the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080, mostly outside the monsoon season. Variation in extreme temperatures will not increase much beyond today's variation. The annual number of days above 25^{0}C is projected to increase from on average 105 (1996-2005) to 155 (2050-2080), though the annual variation increases as well and is larger than the projected change between periods. The annual number of warm days will increase especially towards 2050-2080, with a tripling of today's number of warm days. The number of warm nights will also increase drastically. Substantial year-to-year differences will persist and increase towards 2080. Already in 2030-2050 the number of warms days will increase with over 20 more compared to today. However, annual variations will also persist and even increase. The number of cool days on an annual basis is projected to decrease. The number of cool nights will also decrease significantly on an annual basis. The number of frost nights remains approximately the same, and gradually decrease after 2030. The number of warm spells per year will increase, especially towards 2050-2080. The number of cold spell periods per year will decrease.

The annual total amount of precipitation is projected to remain approximately constant. The annual number of heavy precipitation days is not set to change much from the current situation. Monthly total rainfall will not change much for the dry period, but June and October (on the longer term), and July (already from 2010) are projected to see an increase. This suggests that there will be more rainfall during the monsoon and in time during the post-monsoon. Inter-annual variations however are large, and also larger than the change between periods. Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution: May and July (already from 2010) and June and October (for 2030-2050) are expected to see the largest changes. Monsoon onsets will remain variable,

with a tendency to later onsets over time. During the monsoon, daily mount of precipitation will increase, and the end of monsoon remains the same on the short term but may extend to the end of October towards 2050-2080. The dry period will become drier in the long term (especially February-March). It must be kept in mind that projections for precipitation are more uncertain than for temperature. The number of heavy precipitation days will remain as today's level, with the exception of a gradual increase in July from 2010, as well as in June from 2050. The maximum number of consecutive wet days, a measure for monsoon duration, is projected to remain the same. The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase.

The precipitation independent growing season remains year-round as it is today, while the precipitation dependent growing season shows great annual variations but onset and end remain on average the same.

For RCP8.5, the HICAP model projects about the same temperature change for the Salween-Mekong-Brahmaputra compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 7-20% for the Salween-Mekong-Brahmaputra region compared to the alternative GCM models.

Conclusions: The domain will see an increased precipitation during monsoon, with May and July (from 2010) and June and October (for 2030-2050) seeing the largest precipitation increase. Monsoon duration and variation stays about the same initially, but may extend to the end of October on the long term. Precipitation may be underestimated by the HICAP model, and thus may be more than the figures in the appendix (section 7.1.2) indicate. The number of warm days and nights will increase drastically especially towards 2050-2080, mainly by extending into pre- and post-monsoon seasons. The growing season will not be much affected, as temperatures are already well suited for growth, while precipitation will be more intense during monsoon and the dry season will become drier. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon and growing season (at this level of analysis) will not significantly change, the increased temperatures and decreased frost days/nights may open up for alternative crops in agriculture. On the long term, extension of the monsoon into October may benefit "monsoon crops", while increased drought during the dry period will limit agriculture during that part of the year. Increased precipitation in the long term especially during July may impact flood risk in some areas, especially if combined with increased glacial melt. It may also impact on soil-washout, erosion, and nutrient levels and thus impact forest and agriculture. Long term projections of increased precipitation during monsoon and less precipitation outside monsoon also affect water availability, and sustainable management and water tanks/reservoirs are a necessity to secure year-round water availability.

3.4.3 Domain 3: Central HKH – Koshi sub-basin

Left: Detailed map domain 3

Domain delimitations:

32.60N, 76.20E	32.60N, 84.50E
25.49N, 76.20E	25.49N, 84.50E
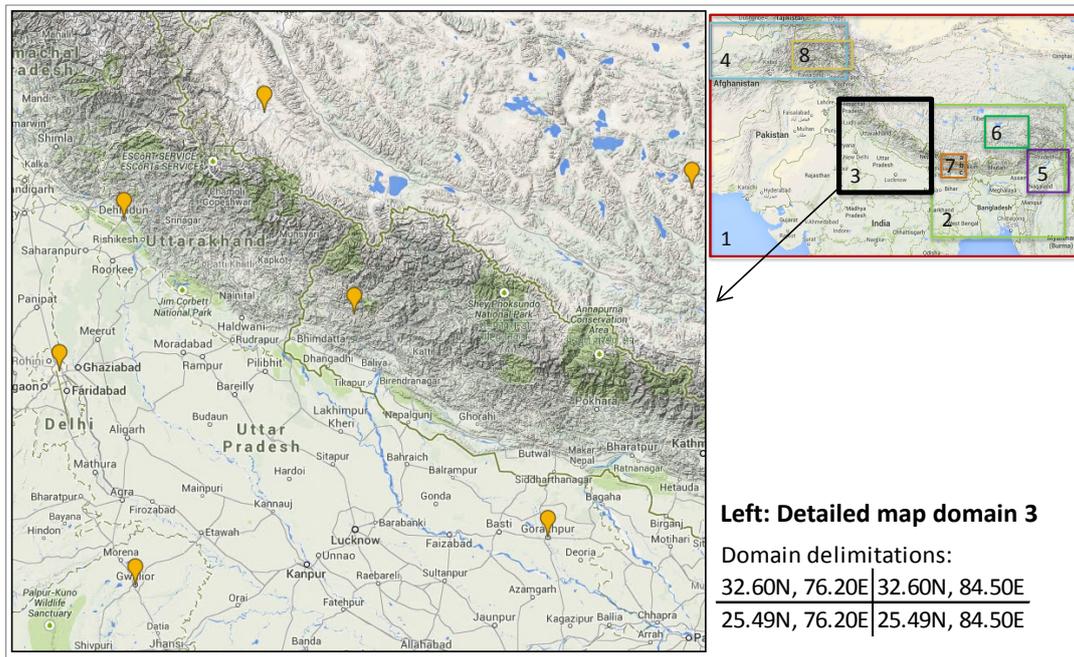
Figure 15 Domain map with reference stations (orange markers) used for analysis of climate change in this report. Reference stations are spread across its very diverse geographic area, with station's elevations ranging from 82 to 5200 m.a.s.l. The following analyses are based on their average elevation of 1501 m.a.s.l.

Climate change: Table 4 shows that minimum (night-time) temperature change is projected to be 3-4 times higher than projected maximum (day-time) temperature change. Most warming takes place during the night, during October and through the winter months, and on the long term. RCP8.5 scenarios projects higher minimum temperatures (warmer nights) but lower maximum temperatures (colder days) than RCP4.5 on the short term (2010-2030). There is no difference for the mid-term (2030-2050) between the two scenarios, both projecting increased warming, and RCP8.5 projects more warming than RCP4.5 for the long term (2050-2080), with minimum temperatures reaching up to on average 4,9°C increase in October, and an increase of day-time temperatures with 0,5°C. Precipitation is projected to change especially for October (wetter) and July-September and December (drier).

The more detailed figures in the appendix (section 7.1.3) for this domain indicate that the average minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 2-3 degrees. The average daily maximum is projected to increase only a little, especially outside the monsoon period. The daily minimum (night-time) temperature range is projected to increase compared to today's variation, especially from February-August already from 2010. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during monsoon, indicating more and warmer night-time temperatures that time of year. Frost nights and cool nights will remain about the same as today. The annual number of summer days and warm days will increase especially after 2050, with a doubling of today's number of warm days.

However, annual variations will persist and increase, and are larger than the projected change between periods. The number of warm nights will also increase drastically, while the number of cool nights and cool days on an annual basis is projected to decrease. The number of warm spells per year will increase slowly, but especially towards 2050-2080. Correspondingly, the number of cold spell periods per year will decrease.

Table 4. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

| | ΔTmin | | | | | | ΔTmax | | | | | | ΔPrec. | | | | | |
| | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | |
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,2	1,0	2,1	0,5	1,0	2,6	-0,4	-0,2	0,3	-0,5	-0,2	1,0	0,6	0,4	0,9	0,4	-0,1	1,0
F	-0,5	1,3	1,7	-0,2	1,3	1,6	-0,9	0,4	0,2	-1,0	0,4	0,1	0,7	0,8	0,6	0,4	0,1	0,6
M	1,0	1,9	2,0	1,4	1,9	2,2	0,9	0,9	0,3	0,8	0,9	0,8	0,5	0,8	0,9	0,1	0,1	0,5
A	0,0	1,2	1,8	0,4	1,2	2,4	-0,1	0,4	0,3	-0,3	0,4	-0,2	0,4	0,8	0,5	0,1	0,1	0,3
M	0,7	1,5	2,0	0,9	1,5	2,7	0,2	0,4	0,3	0,1	0,4	-0,4	0,3	0,6	1,0	0,0	0,0	0,2
J	0,5	1,2	1,5	0,7	1,2	2,2	0,1	0,1	0,1	-0,1	0,1	-1,0	0,1	0,9	1,6	-0,8	-0,4	0,8
J	0,4	1,2	1,7	0,7	1,2	2,5	0,1	0,2	0,5	-0,2	0,2	-0,2	-0,6	0,2	0,3	-1,3	-1,1	-0,1
A	0,2	1,2	1,5	0,4	1,2	2,9	0,0	0,3	0,3	-0,3	0,3	0,5	0,2	0,5	1,1	-0,6	-0,7	-0,5
S	0,5	1,5	2,2	0,7	1,6	3,6	0,2	0,8	1,0	-0,1	0,8	1,0	0,4	-0,5	0,9	-0,3	-1,5	1,1
O	0,7	1,7	2,8	0,9	1,7	4,9	-0,1	0,1	0,9	-0,3	0,1	1,3	0,9	2,2	1,6	0,3	1,3	3,6
N	1,1	2,1	2,8	1,3	2,1	3,2	0,7	1,3	1,4	0,5	1,3	1,6	0,3	0,6	1,1	0,0	0,1	0,5
D	0,2	1,5	2,5	0,4	1,5	2,3	0,2	0,6	1,3	0,0	0,6	1,3	-0,8	0,4	0,7	-1,0	-0,1	0,3
AVG	0,4	1,4	2,0	0,7	1,4	2,8	0,1	0,4	0,6	-0,1	0,4	0,5	0,3	0,6	0,9	-0,2	-0,2	0,7

The annual total amount of precipitation is projected to remain approximately constant, and the number of heavy precipitation days will not change much, with the exception of an increase in September-October on the long term. Also the number of wet days per month will see a gradual increase in September-October, but otherwise remain roughly the same to today's occurrence. Monthly total (and average) rainfall may increase a bit for the dry period, while October will see a gradual increase and July a decrease already from 2010. Inter-annual variations however are larger than the change between periods. Smoothened data, with large day-to-day variations taken out, also suggest a slight increased precipitation for the dry period, while July and September (drier on short term) and October (wetter) will see the largest changes. Precipitation during the dry period however becomes more variable both in the short and long term. There will be a continued variation in monsoon onset and the end of monsoon remains the same on the short term but may be extended to the end of October towards 2050-2080. It must be kept in mind that projections for precipitation are more uncertain than for temperature. The maximum number of consecutive wet days is projected to decrease already from 2010, suggesting a shortening of the monsoon, while the maximum number of consecutive dry days is projected to remain about the same. The amount of precipitation on wet days is projected to increase slightly for 2050-2080. At the same time, the number of wet days is set to remain about the same, confirming projections of a decreased daily precipitation for the monsoon period, spread over a slightly longer period towards 2050.

The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations in onsets and ends, and remains approximately the same as today until 2050, after which the season increases. The average

duration of the precipitation dependent growing season increases from 2050 onward, while its duration varies a lot especially from 2030 onward.

For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,5°C for the upper Ganges compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 8% for upper Ganges region compared to the alternative GCM models in figure 8.

Conclusions: Monsoon duration and variation stays about the same initially. However, the domain will see decreased precipitation during monsoon already from 2010, and a slight extension of the monsoon with less precipitation in July and more in October on the longer term. The winter months will also see a slight increase in precipitation on the longer term, but remain the same on the short term. These changes must be seen in light of a potential underestimation of precipitation by the model, and thus result in unchanged precipitation during monsoon and a stronger increase in precipitation in the winter months and October in the long run. The number of warm nights will increase drastically already from 2010 but especially after 2050, mainly due to increased night-time temperatures in March and September-November. The growing season will not be much affected, as temperatures are already well suited for growth, but may after 2050 extend further into October. Temperature changes may be underestimated by the model and be larger than described in the figures. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon and growing season (at this level of analysis) will not significantly change in the short term, the increased night-time temperatures may open up for alternative crops in agriculture. On the long term, extension of the monsoon into October may benefit "monsoon crops", while a slight increase in precipitation during the dry period will allow for more possibilities for agriculture during that part of the year. It may also impact on soil-washout, erosion, and nutrient levels and thus forestry and agriculture. Together, these changes may contribute to increases year-round water availability, if combined with sustainable agricultural management. Decreased precipitation during July may decrease flood risk in some areas, although the number of heavy precipitation days will not change much.

3.4.4 Domain 4: Western HKH – Indus

Detailed map domain 4 Also covers domain 8	Domain delimitations: 38.49N, 64.35E 38.49N, 76.20E 34.04N, 64.35E 34.04N, 76.20E
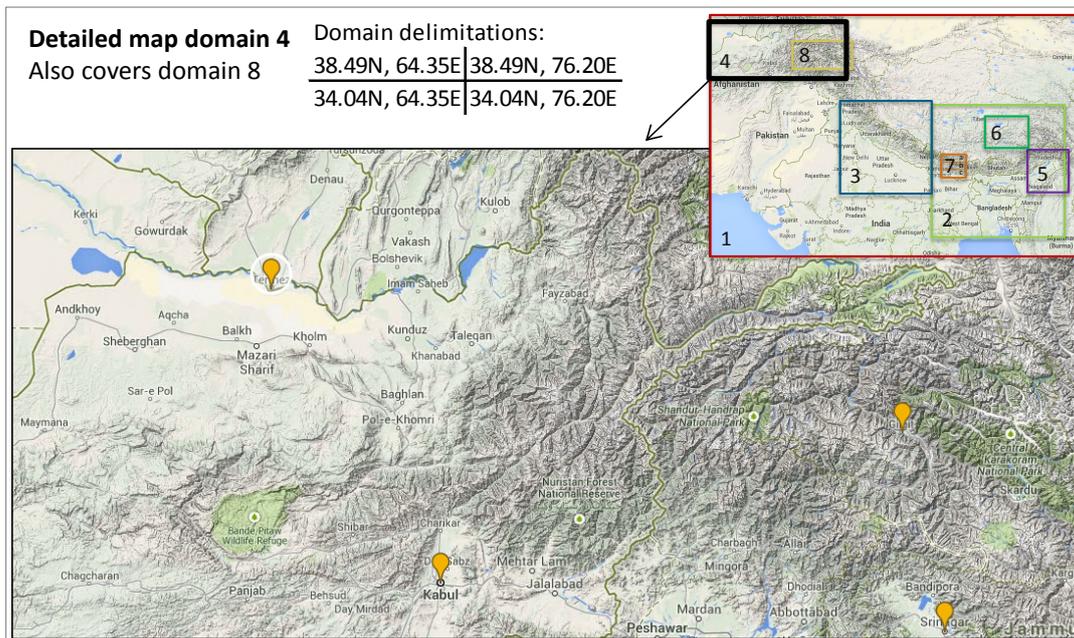
Figure 16 Domain map with reference stations (orange markers) used for analysis of climate change in this report. The geographic area is diverse also for this domain. Reference stations for domain 4 are few, mostly at high altitudes, and range from 313 to 1791 m.a.s.l. The following analyses are based on their average elevation of 1386 m.a.s.l.

Climate change: Table 5 shows that minimum (night-time) temperature change is projected to be about twice as much as the projected maximum (day-time) temperature change. Most warming takes place during the night, during December, May and from March through December on the mid- and long term.

Table 5. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

	ΔTmin						ΔTmax						ΔPrec.					
	RCP4.5			RCP8.5			RCP4.5			RCP8.5			RCP4.5			RCP8.5		
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,3	1,1	2,1	0,6	1,1	1,4	-0,2	-0,1	1,0	-0,5	-0,1	1,7	0,3	0,2	0,3	0,1	-0,2	0,0
F	-1,2	0,7	2,3	-0,9	0,7	0,8	-1,8	-0,3	1,2	-2,0	-0,3	0,8	0,5	0,6	1,1	0,2	0,1	0,8
M	0,4	1,4	1,7	0,7	1,4	1,8	-0,1	0,5	0,5	-0,3	0,5	1,5	0,2	0,0	0,5	-0,2	-0,6	0,6
A	0,2	1,1	2,1	0,6	1,1	1,8	0,1	0,2	0,9	0,0	0,2	0,6	0,0	0,5	0,7	-0,4	-0,2	0,6
M	1,3	2,0	2,5	1,6	2,0	2,8	0,9	1,3	1,4	0,8	1,3	1,0	0,4	0,4	0,5	0,1	-0,2	0,3
J	0,6	1,3	1,5	0,9	1,3	2,3	0,4	0,5	0,2	0,3	0,5	0,0	0,1	0,2	0,7	-0,2	-0,3	0,7
J	0,7	2,1	2,4	1,0	2,1	3,5	0,5	1,4	1,0	0,3	1,4	0,4	-0,1	0,0	0,9	-0,5	-0,6	0,7
A	0,4	1,7	2,2	0,8	1,7	3,9	0,4	0,8	0,7	0,2	0,8	0,9	-0,5	-0,1	0,7	-0,8	-0,7	0,4
S	0,5	2,0	2,7	0,8	2,0	3,8	0,3	0,8	1,0	0,0	0,8	1,0	-0,1	0,5	1,0	-0,4	-0,2	1,2
O	1,0	1,7	2,6	1,2	1,7	3,8	0,7	0,4	1,5	0,3	0,4	2,3	0,3	0,3	0,5	0,1	-0,1	-0,1
N	0,9	1,7	2,2	1,1	1,7	2,3	0,7	0,9	1,4	0,3	0,9	2,5	-0,2	0,1	0,5	-0,5	-0,4	-0,2
D	2,1	2,6	3,0	2,3	2,6	2,7	2,0	1,6	2,1	1,8	1,6	3,1	0,0	0,6	0,7	-0,2	0,2	0,5
AVG	0,6	1,6	2,3	0,9	1,6	2,6	0,3	0,7	1,1	0,1	0,7	1,3	0,1	0,3	0,7	-0,2	-0,3	0,5

Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods (safe for a higher night-time increase in RCP8.5 after 2050, with 3,5-4°C increase between July-October), but differ in precipitation projections: RCP8.5 projects an decrease in precipitation year-round until 2050, while RCP4.5 only projects a drier July-November until 2030, after which precipitation increases for all months onward.

The more detailed figures in the appendix (section 7.1.4) for this domain indicate that the average daily minimum (night-time) temperature is projected to increase gradually already from 2010 throughout the year towards 2080, especially during the summer months, with up to 3-4 degrees. The average daily maximum temperature is not projected to increase. The lowest daily minimum temperatures (coldest nights) will remain about the same for all periods, while extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080, and mostly outside (after) the summer months. Temperature change will lead to an increase in number of warm days, notably in May-June and September, as well as for the long term (2050-2080) and an increase in cool days (bar below line) from January-March from 2010 onward. Variations in daily minimum and maximum temperature will increase compared to today's variation. Especially towards 2050-2080 and April-November will see large variations with both high and low night-time temperatures occurring. The occurrence of frost- and cool nights will decrease already from 2010 on an annual basis, mostly because of a decrease in December though January-March may actually see an increase. The annual number of warm days will increase gradually, especially towards 2050-2080, approximating a doubling of today's number of warm days. Already in 2030-2050 the number of warms days will increase by 20 compared to today, although annual variations will persist and perhaps even increase. Similarly, the number of tropical and warm nights will increase, especially towards 2050-2080. The number of warm spells per year will increase only slightly, and the number of cold spell periods per year will decrease, but both remain few per year.

The total annual amount of precipitation is projected to remain approximately constant until 2050, after which it may increase. Also the number of heavy and very heavy precipitation days may increase after 2050. This increase on the longer term is distributed over all months of the year. Inter-annual variations however are large, and also larger than any change between projection periods. Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. It also indicates that rainfall will increase for most months on the longer term, but for the near term remain largely unchanged. There is a tendency to later onsets of rainfall in July. It must be kept in mind that projections for precipitation are more uncertain than for temperature. Daily variation in precipitation remains about the same as today's variation at any time of year, with large variations occurring especially during September. The number of very heavy precipitation days is not expected to change much between periods until 2050, when it may increase a bit in September. The number of wet days and extremely wet days per month will see some increase on the long term for February-April and July-September, but otherwise remain roughly the same to today's occurrence. The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same. The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase between 2010 and 2050, but to decrease after 2050. The amount of precipitation on wet days is projected to increase slightly for 2050-2080. Since the number of

wet days is also set to increase a bit, this indicates that on the long term there will be more rainy days with more precipitation per day during a year.

The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations, and on average initially decreases, but goes back to today's duration after 2050. The decrease between 2010 and 2050 is caused mainly by an increase in number of sudden short seasons (less or interrupted rainfall on days with favourable temperatures) rather than generally shorter seasons.

For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,5°C for the upper Indus compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 10% for upper Indus region compared to the alternative GCM models in figure 8.

Conclusions: The domain will see an increase of especially night-time temperatures already from 2010, but especially between May-December after 2030. Day-time temperatures will also increase but less than night-time temperatures. Underestimation of temperature by the model makes that increase of minimum and maximum temperatures may be larger than projected in the figures. Precipitation changes are small on the short term, but on the long term, after 2050, more rainy days and more rain per day may occur especially during July-September. The monsoon variation and rainfall remains as is today, but may become a bit wetter and extend a bit after 2050, while on the short term especially the dry period may see less rainfall. Precipitation may be larger than projected here due to underestimations by the model. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon and growing season (at this level of analysis) will not significantly change in the short term, increased night-time temperatures may allow for alternative crops in agriculture. More rainy days later in September and increased rainfall in February may benefit agriculture on the long term, but no large changes are expected until 2050. Agriculture may be affected somewhat during the dry period, which may become drier. Year-round water availability remains the same (given the same level of water use as today), and with the same amount of very heavy precipitation days as today, and a small increase after 2050, flood risk remains the same and may increase slightly after 2050.

3.4.5 Domain 5: North-East India – Salween-Mekong-Eastern Brahmaputra

Left: Detailed map domain 5

Domain delimitations:

28.79N, 93.40E	28.79N, 97.58E
25.80N, 93.40E	25.80N, 97.58E
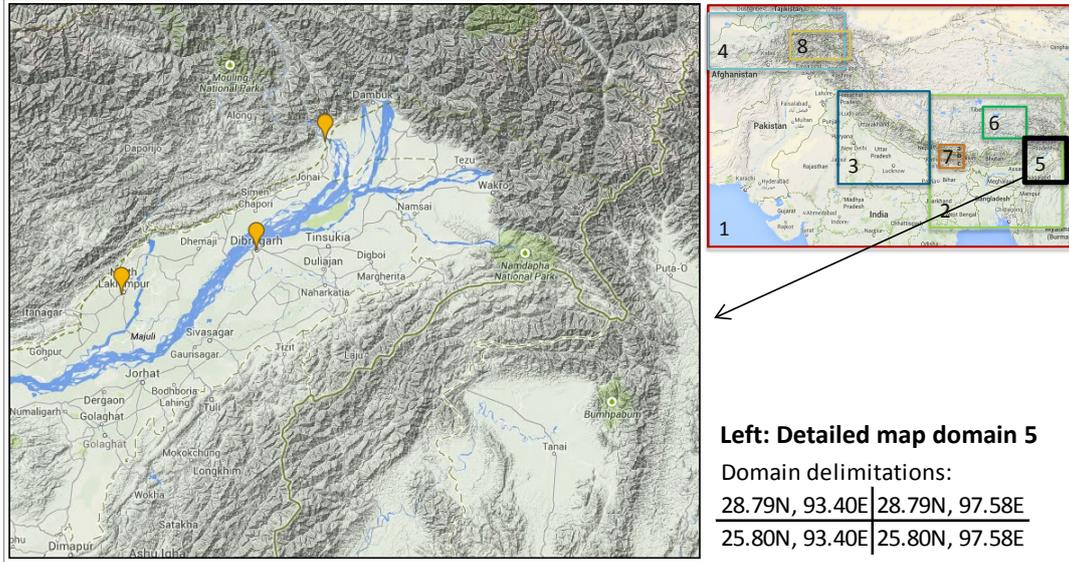
Figure 17 Domain map with reference stations (orange markers) used for analysis of climate change in this report. The analysis for this domain is based on available observational input from 3 stations (markers in above figure) at 109, 154 and 95 m.a.s.l.. The following analyses are based on an average elevation of 119 m.a.s.l. The stations were selected based on data availability and the areas' population densities.

Climate change: Table 6 shows that minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, especially on the short term. Most warming takes place during the night throughout the year already from 2010, with largest changes in March and October, but especially from 2030 onward throughout the year, mostly between March-May and September-October.

Table 6. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

	ΔTmin						ΔTmax						ΔPrec.					
	RCP4.5			RCP8.5			RCP4.5			RCP8.5			RCP4.5			RCP8.5		
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,4	1,4	1,9	0,6	1,4	1,5	-0,2	0,5	0,8	-0,4	0,5	1,8	0,4	0,2	2,3	0,2	-0,3	-0,5
F	0,4	1,5	1,6	0,6	1,5	1,6	0,5	1,1	0,9	0,4	1,1	2,1	-0,9	-0,2	1,6	-1,1	-0,7	-1,1
M	1,4	2,2	2,3	1,6	2,2	2,5	1,6	1,8	1,5	1,5	1,8	3,0	-0,7	-0,4	1,5	-0,8	-1,1	-1,5
A	0,7	1,8	2,0	0,9	1,8	2,6	0,8	1,3	1,0	0,4	1,3	2,1	-0,3	-0,2	2,5	-0,5	-0,7	-0,5
M	0,9	2,0	2,1	1,1	2,0	2,6	0,7	1,4	1,3	0,4	1,4	1,8	0,8	-1,4	-0,4	0,4	-1,8	0,5
J	0,8	1,7	1,7	1,0	1,7	2,4	0,5	0,6	0,3	0,1	0,6	0,9	2,0	2,1	3,1	1,9	1,7	5,0
J	0,5	1,2	1,3	0,7	1,2	2,0	0,4	0,1	0,0	0,0	0,1	0,3	2,3	3,2	1,3	2,7	2,8	2,6
A	0,4	1,3	1,3	0,6	1,3	2,1	0,2	0,3	-0,2	-0,2	0,3	0,4	1,0	1,6	0,4	1,2	0,9	-0,1
S	0,8	1,6	1,9	0,9	1,6	2,6	0,7	1,0	0,6	0,3	1,0	1,3	-0,5	-0,7	1,5	-0,7	-1,3	0,0
O	0,6	1,4	2,0	0,6	1,4	2,9	0,1	0,3	0,5	-0,2	0,3	1,3	1,4	2,1	2,6	1,0	1,5	4,0
N	1,0	1,4	2,0	1,0	1,4	2,3	1,0	1,0	1,2	0,7	1,0	2,3	-0,7	-0,6	1,8	-0,9	-1,1	-0,7
D	0,0	1,2	2,1	0,1	1,2	1,5	0,1	1,0	1,4	-0,1	1,0	2,4	0,4	0,2	2,9	0,3	-0,3	-0,8
AVG	0,6	1,6	1,8	0,8	1,6	2,2	0,5	0,9	0,8	0,2	0,9	1,6	0,4	0,5	1,8	0,3	0,0	0,6

Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods but differ in precipitation projections after 2050: from this period, RCP8.5 continues to project a decrease in precipitation for most of the year except between June-October, while RCP4.5 projects an increase in precipitation year-round from then-on.

The more detailed figures in the appendix (section 7.1.5) for this domain indicate no great difference between scenarios RCP4.5 and RCP8.5 except for a drier long-term future predicted by RCP8.5. The average daily minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 2-3 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially between September and May, outside the monsoon period. The extreme lowest night-time temperatures will remain the same as today, while the highest day-time temperatures will increase slightly, but especially towards 2050-2080, mostly outside the monsoon season. Variations in daily maximum temperatures will also remain the same as today, but will increase after 2050, when there will be more cool days and more warm days per month compared to today. Warm days will already increase slightly on the shorter term, especially during May-July and October. Variations in daily minimum (night-time) temperatures is projected to increase compared to today's variation, especially during February-August already from 2010, and to shift towards and increased number of warmer nights except in November-December from 2030. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 throughout the year except for November-December, indicating more and warmer night-time temperatures most of the year. Frost- and cool nights will remain the same or decrease gradually in January. While the annual number of days above 25°C is projected to remain about the same, the number of warm days will increase especially towards 2050-2080, with almost a tripling of today's number of warm days. Already in 2030-2050 the number of warms days will increase by on average 20 days compared to today. The number of tropical nights will also increase drastically already from 2010, although substantial year-to-year differences will persist and even increase towards 2080. The number of warm nights will also increase drastically, and already double from 40 to 80 in 2010-2030. The number of cool days and nights on an annual basis is projected to decrease. The number of warm spells will increase slightly from 2030 onward, and the number of cold spells will decrease from 2030 onward, although annual variations in both will persist.

The annual total amount of precipitation is projected to remain approximately constant, as is the number of heavy and very heavy precipitation days. Monthly total and average rainfall will not change much for the dry period, but June, July and October are projected to see an increase already from 2010. This suggests that there will be more rainfall during the monsoon and the post-monsoon. Variations are large and precipitation will vary from year to year, especially for the wet months. Smoothened data, with large day-to-day variations taken out, indicate that rainfall will not change much for the dry period, but June, July and October are projected to see an increase already from 2010. There will be a continued variation in monsoon onset, with a small tendency to later onsets over time. During the monsoon, there will be an increased rainfall per day, and the end of monsoon remains the same on the short term but may be extended to the end of October towards 2050-2080. The dry period will also become drier in the long term (especially February-March). It must be kept in mind that projections for precipitation are more uncertain than for temperature. June and July may see a small increase in number of wet days and (very) heavy precipitation days, though with great

variations from year to year. The maximum number of consecutive wet days (corresponding to monsoon duration) is projected to remain about the same, while the maximum number of consecutive dry days will increase slightly, already from 2010.

The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations, but is expected to shift slightly towards later onsets from 2010 and may increase after 2050 both through an earlier onset and a later end.

For RCP8.5, the HICAP model may have a tendency to overestimate temperature change with about 1°C for the upper Brahmaputra and 0,5°C for the lower Brahmaputra compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 7-8% for the lower Brahmaputra and 2-3% for the upper Brahmaputra region compared to the alternative GCM models in figure 8.

Conclusions: The domain will see an increase of temperature, and especially night-time temperatures will increase already from 2010, but particularly between May-December after 2030. Day-time temperatures will also increase but less than night-time temperatures. The number of (very) warm days and nights will increase significantly, and there will be less cold days and nights. Overestimation of temperature by the model makes that increase of minimum and maximum temperatures may be less large than projected in the figures, and in fact remain similar to today until 2030. There will be a significant increase of rainfall during monsoon and post-monsoon already from 2010, while the dry period will become drier. Precipitation may be larger than projected here due to underestimations by the model. The growing season will not be much affected, as temperatures are already well suited for growth, while precipitation will be more intense during monsoon and the dry season will become drier. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon and growing season will not significantly change, the increased temperatures may open up for alternative crops in agriculture. Increased rainfall during monsoon may pose risks for crops and soil-washout, erosion, and nutrient levels and thus impact forest and agriculture. Increased drought during the dry period may limit agriculture during that part of the year. Increased intense precipitation especially during June-July may impact flood risk in some areas, especially if combined with increased glacial melt. Projections of increased precipitation during monsoon and less precipitation outside monsoon also affect water availability, and needs increased sustainable management and water tanks/reservoirs to secure year-round water availability.

3.4.6 Domain 6: East Tibet – Upper Brahmaputra

Left: Detailed map domain 6

Domain delimitations:

31.59N, 89.56E	31.59N, 93.69E
28.79N, 89.56E	28.79N, 93.69E
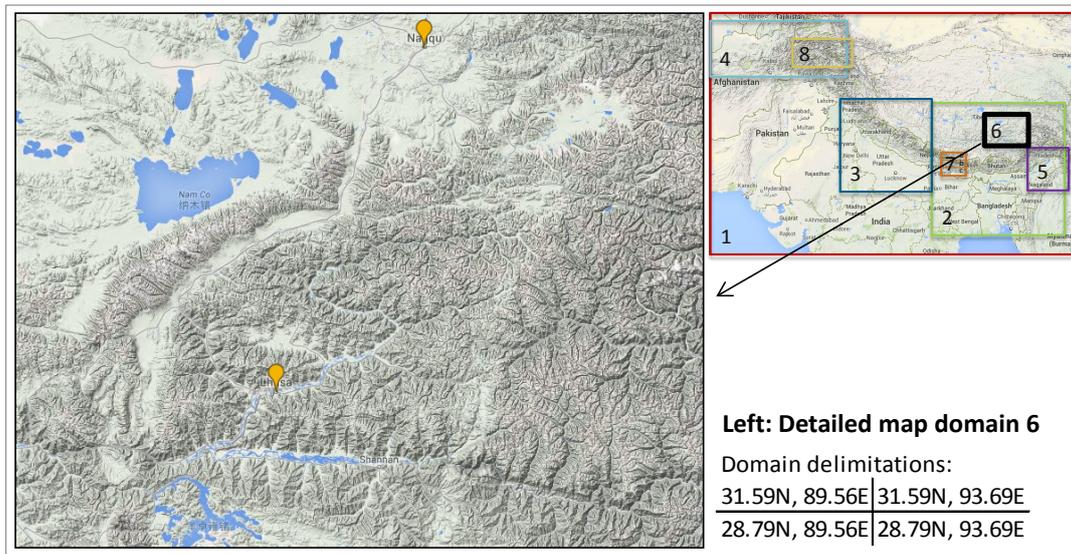
Figure 18 Domain map with reference stations (orange markers) used for analysis of climate change in this report. Geographic variation in this domain is less large than in some of the other domains. Reference stations in this domain are few, their elevations are at 3650 and 4436 m.a.s.l. The following analyses are based on their average elevation of 4043 m.a.s.l.

Climate change: Table 7 shows that minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, especially on the short term. Most warming takes place during the night throughout the year already from 2010, with largest changes in March-June and October-November, and with large changes especially in April-June and October after 2050.

Table 7. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

	ΔTmin						ΔTmax						ΔPrec.					
	RCP4.5			RCP8.5			RCP4.5			RCP8.5			RCP4.5			RCP8.5		
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,9	2,1	3,0	1,3	2,1	1,7	0,2	0,7	2,3	0,1	0,7	2,1	0,3	0,5	-0,7	0,1	0,1	-0,8
F	0,8	2,7	2,6	1,3	2,7	1,1	0,3	1,3	2,3	0,2	1,3	1,6	0,2	0,4	-0,8	0,0	0,0	-0,8
M	2,2	3,3	4,2	2,6	3,3	2,8	1,7	1,8	3,7	1,6	1,8	3,2	0,2	0,6	-0,6	0,0	0,2	-0,8
A	0,8	2,4	4,7	1,2	2,4	4,3	0,4	1,0	3,9	0,2	1,0	3,2	0,3	0,5	-0,5	0,2	0,2	-0,7
M	1,4	2,6	4,9	1,8	2,6	5,0	0,9	1,3	5,3	0,7	1,3	4,8	-0,1	0,1	-0,3	-0,3	-0,2	-0,3
J	1,7	3,2	3,9	2,1	3,2	4,5	1,5	2,1	4,4	1,3	2,1	3,4	0,3	0,9	0,3	0,0	0,7	1,1
J	0,6	2,1	2,6	1,0	2,1	3,6	0,3	0,6	0,9	-0,1	0,6	0,2	0,3	0,7	-0,4	0,3	0,5	-0,6
A	0,5	1,9	2,1	0,8	1,9	3,4	0,0	0,5	0,1	-0,3	0,5	-0,1	0,5	0,5	-0,2	0,5	0,4	-0,8
S	0,6	1,6	2,4	0,8	1,7	3,4	0,6	1,1	1,4	0,3	1,1	1,2	-0,2	-0,2	-0,4	-0,2	-0,4	-1,1
O	0,9	2,2	3,4	1,1	2,2	5,5	0,3	1,0	1,8	0,0	1,0	2,8	0,5	0,6	0,0	0,3	0,3	0,2
N	1,3	2,6	3,6	1,6	2,6	3,6	0,9	1,5	2,6	0,7	1,5	2,6	-0,1	0,3	-1,0	-0,3	-0,2	-1,1
D	-1,0	1,0	2,3	-0,6	1,0	0,2	-1,2	0,0	1,9	-1,3	0,0	0,7	0,1	0,5	-0,8	-0,1	0,1	-1,0
AVG	0,9	2,3	3,3	1,2	2,3	3,3	0,5	1,1	2,5	0,3	1,1	2,1	0,2	0,4	-0,5	0,1	0,1	-0,5

Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods, while RCP4.5 projects more precipitation until 2050 than RCP8.5, and both project drier months throughout the year (except for June) after 2050.

The more detailed figures in the appendix (section 7.1.6) for this domain indicate no great difference between scenarios RCP4.5 and RCP8.5 except for a slightly drier short- and mid-term future predicted by RCP8.5. The average daily minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 4-5 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially during 2050-2080, but mostly from September and June, outside the monsoon period. The lowest daily minimum temperatures (coldest nights) will remain the same for all periods. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, mostly outside the monsoon season, but especially towards 2050-2080. Variation in extreme temperatures will not increase much beyond today's variation, but with increasing daily maxima for most of the year, and especially from 2050-2080. Extreme warm days will increase notably in April-July and October, as well as for the long term (2050-2080), cool day temperatures will remain roughly the same until 2050, after which their temperature decreases from November-May for 2050-2080. Daily minima will increase in variation already from 2010, and see especially large changes in warmer extremes after 2050, and there will be more and warmer night-time temperatures throughout the year, shown in the figures by a drastic increase (almost doubling) of warm nights already from 2010. Day-time temperatures will also increase, demonstrated by an increase in summer days (temperature above 25°C) which will start occurring after 2050, an increase in warm days from 2030 onward, and a decrease in cool days, cool nights and frost nights especially after 2030. In spite of the general warming, the number of cold spell periods per year will remain around the same as today.

The annual total and average amount of precipitation is projected initially to remain approximately constant, and to decrease towards the end of the century. Likewise, the annual number of heavy precipitation days will not change notably from today's occurrence. On a monthly basis there will be differences. June-August and October are projected to see an increased precipitation already from 2010, although annual variation for these months remains large and may be increasing especially for the wet months (monsoon). Smoothened data, with large day-to-day variations taken out, confirm that June-August and October are projected to see an increase already from 2010. Monsoon will have a tendency to later onsets especially towards 2050. During the monsoon, there will be an increased rainfall per day, and the end of monsoon may be extended to mid-/end- of October already from 2010. The dry period may also become drier in the long term (November-May). It must be kept in mind that projections for precipitation are more uncertain than for temperature. The number of wet and very wet days per month will see a gradual increase in June-July-August, and a small decrease in September, while extremely wet days will see a gradual decrease in July and remain otherwise unchanged to today's situation. The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain about the same, while the maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase from 2050. The amount of precipitation on wet days is projected to remain the same. At the same time, the number of wet days is set to decrease from 2050, corresponding to increased rainfall during monsoon and decreased precipitation during the dry period.

The precipitation independent growing season (considering temperature only) is larger than the precipitation dependent one (considering both temperature and precipitation), and increases gradually already from 2010, while the latter remains approximately constant and perhaps decreases slightly after 2050. Both type of growing seasons show great annual variations, but the precipitation dependent one especially in its onsets after 2050. This suggests that temperature is the main variable of change.

For RCP8.5, the HICAP model may have a tendency to overestimate temperature change with about 1°C for the upper Brahmaputra compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 4% for the upper Brahmaputra region compared to the alternative GCM models in figure 8.

Conclusions: _The domain will see an increase of temperature, and especially night-time temperatures will increase already from 2010, particularly between March-June and October-November. Day-time temperatures will also increase but less than night-time temperatures. The number of (very) warm days and nights will increase significantly, and there will be less cold days and nights, although overestimation of temperature by the model makes that increase of minimum and maximum temperatures may be less drastic than projected in the figures. There will be a significant increase of rainfall during monsoon and post-monsoon already from 2010, while the dry period will become drier in the long term. Monsoon will have a tendency to later onsets especially towards 2050, while the end of monsoon may be extended to mid-/end- of October already from 2010. Overall, the projections indicate increased rainfall during monsoon and decreased precipitation during the dry period. Precipitation may be slightly larger than projected here due to underestimations by the model. The growing season will increase due to increased temperatures, but rain dependent growth remains constricted to today's period, and show great variations especially in its onset after 2050. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level._

Potential impacts/consequences:

Although monsoon may see an extension already from 2010, changes in growing season are mostly related to temperature changes, and may open up for alternative crops in agriculture or agriculture at higher elevations. Increased rainfall during monsoon may pose risks for crops and soil-washout, erosion, and nutrient levels and thus impact forest and agriculture. Long term projections of increased drought during the dry period may limit agriculture during that part of the year. Increased intense precipitation especially during March-June may impact flood risk in some areas, especially if combined with increased flow from glacial melt in higher elevations. Projections of increased precipitation during monsoon and less precipitation outside monsoon also affect water availability, and needs increased sustainable management and water tanks/reservoirs to secure year-round water availability.

3.4.7 Domain 7: East Nepal – Koshi basin

Left: Detailed map domain 7

Domain delimitations: 7a

28.50N, 85.62E	28.50N, 87.55E
27.87N, 85.62E	27.87N, 87.55E

Domain delimitations: 7b

27.87N, 85.62E	27.87N, 87.55E
27.24N, 85.62E	27.24N, 87.55E

Domain delimitations: 7c

27.24N, 85.62E	27.24N, 87.55E
26.60N, 85.62E	26.60N, 87.55E
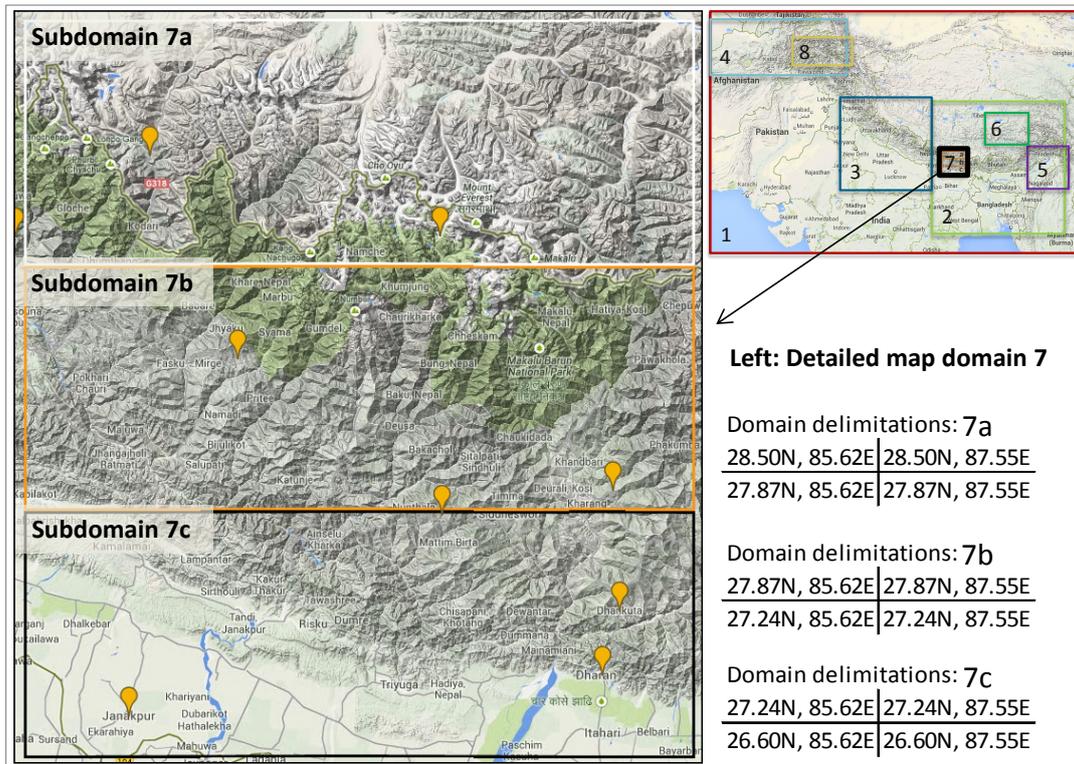
Figure 19 Domain (and subdomain) map with reference stations (orange markers) used for analysis of climate change in this report. We used observational input from 3 stations in each subdomain, lying at 2625, 3750 and 5000 m.a.s.l. for the high mountains (7a), 2003, 1295 and 1329 m.a.s.l. for the middle hills (7b) and 1210, 444 and 90 m.a.s.l. for the Terai (7c). The following analyses are based on their average elevations of 3792, 1542 and 581 m.a.s.l. for subdomains 7a, b and c respectively.

Climate change: Table 8 shows an increase in temperature for the whole domain already from 2010. The minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, already on the short term but with an increasingly large difference towards 2080. March-June and October-November will see the largest warming, and with large changes especially in April-June and October after 2050. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods. For precipitation, RCP8.5 indicates no great change from today on an annual basis, while RCP4.5 indicates an increase in precipitation especially after 2030 and onward. The distribution however changes compared to today, with January-February becoming wetter, and June-September drier than today especially in RCP8.5 after 2050.

Further analysis, conclusions and brief impact analysis for this domain has been done on the subdomain level only, and detailed figures for all subdomains are presented in the appendix (section 7.1.7) figures in 7.1.7a-c. For all subdomains we focus on scenario RCP8.5. For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,5°C for the Ganges compared to other models for these regions (figure 8). Projections

Table 8. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

	ΔTmin						ΔTmax						ΔPrec.					
	RCP4.5			RCP8.5			RCP4.5			RCP8.5			RCP4.5			RCP8.5		
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,5	1,2	1,9	0,7	1,2	2,0	0,0	0,2	0,6	-0,2	0,2	1,7	0,8	0,0	1,1	0,7	-0,2	1,2
F	0,0	1,5	1,5	0,2	1,5	1,2	-0,5	0,6	0,3	-0,7	0,6	0,8	1,2	0,9	0,8	1,0	0,4	1,3
M	1,6	2,4	2,5	1,8	2,4	2,3	1,4	1,5	0,9	1,2	1,5	1,7	-0,3	0,2	0,5	-0,5	-0,3	0,0
A	0,3	1,6	1,9	0,5	1,6	2,4	0,0	0,8	0,5	-0,2	0,8	0,8	0,6	0,6	0,2	0,4	0,1	0,0
M	0,9	1,9	2,0	1,1	1,9	2,7	0,3	0,7	0,7	0,0	0,8	0,9	0,5	0,3	0,6	0,1	-0,1	0,1
J	1,0	2,0	1,9	1,2	2,0	2,6	0,3	0,5	0,9	0,1	0,6	0,9	-0,8	0,3	-0,2	-1,5	-0,1	-1,9
J	0,5	1,5	1,7	0,8	1,5	2,7	0,2	0,3	0,6	-0,1	0,3	0,8	0,3	1,1	0,8	0,2	1,0	-0,3
A	0,4	1,4	1,5	0,6	1,4	2,9	0,1	0,4	0,3	-0,2	0,4	1,0	-0,3	-0,5	-0,4	-0,7	-0,7	-2,0
S	0,7	1,6	2,1	0,8	1,6	3,4	0,5	0,8	1,2	0,2	0,9	1,7	-0,3	-0,3	0,5	-0,7	-0,8	-0,9
O	0,9	1,8	2,8	1,0	1,8	4,8	0,3	0,6	1,2	0,1	0,6	2,3	0,5	0,9	1,5	0,2	0,3	2,5
N	1,5	2,3	3,0	1,6	2,3	3,6	1,3	1,6	1,8	1,0	1,6	2,7	0,1	0,2	0,5	-0,1	-0,1	0,0
D	-0,1	1,2	2,2	0,1	1,2	1,6	0,0	0,6	1,2	-0,3	0,6	1,7	-0,5	0,4	0,7	-0,4	0,1	0,1
AVG	0,7	1,7	2,1	0,9	1,7	2,7	0,3	0,7	0,8	0,1	0,7	1,4	0,1	0,3	0,5	-0,1	0,0	0,0

of precipitation are more uncertain, but underestimated by the HICAP model by around 8% for the Ganges region compared to the alternative GCM models in figure 8.

Subdomain 7a: High Mountains

Climate change: Table 9 shows an increase in temperature for the high mountain subdomain already from 2010, but increasingly so towards 2080. The minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, already on the short term but with an increasingly large difference towards 2080. March-June and October-November will see the largest warming, and with large changes especially in April-June and October after 2050. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods. For precipitation neither scenario RCP4.5 nor RCP8.5 indicates any great changes from today on an annual basis. Both however indicate that the monthly distribution changes compared to today, with January-February and October becoming slightly wetter, and June-September drier than today, especially after 2050.

The more detailed figures in the appendix (section 7.1.7a) for this domain indicate no great difference between scenarios RCP4.5 and RCP8.5. The average daily minimum temperature is projected to increase gradually throughout the year towards and especially in 2050-2080, with up to about 4-5 degrees. The average daily maximum temperature is projected to increase only a little from 2050-2080 right after the monsoon. The lowest daily minimum temperatures (coldest nights) will remain about the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080. Variation in extreme temperatures will not increase much beyond today's variation until after 2050, when variation range becomes much larger throughout the year, and lead to more warm days as well as more cool days. Minimum (night-time) temperature range is also projected to remain fairly the same as today's variation, except for an increase in variation from April-May and July-September already from 2010.

Table 9. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

| | ΔTmin | | | | | | ΔTmax | | | | | | ΔPrec. | | | | | |
| | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | |
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,9	1,4	2,1	1,0	1,4	1,3	0,4	0,5	0,5	0,2	0,4	1,4	0,6	0,0	0,7	0,5	-0,1	0,6
F	0,0	1,7	1,5	0,2	1,7	0,1	-0,7	0,7	0,1	-0,9	0,7	-0,1	0,8	0,7	0,5	0,7	0,4	0,7
M	1,6	2,7	2,7	1,8	2,7	1,5	1,1	1,4	0,8	1,0	1,5	1,0	0,1	0,2	0,4	-0,1	-0,1	-0,2
A	0,3	1,7	1,8	0,5	1,7	1,7	-0,1	0,8	0,4	-0,2	0,8	0,1	0,3	0,3	0,0	0,1	0,0	-0,3
M	1,1	2,2	2,1	1,4	2,2	2,3	0,6	1,1	0,6	0,4	1,1	0,6	0,1	0,0	-0,1	-0,1	-0,2	-0,6
J	1,2	2,5	2,3	1,5	2,5	2,7	0,6	1,0	1,2	0,4	1,0	0,8	-0,2	-0,3	-2,0	-0,7	-0,2	-1,3
J	0,5	1,7	2,0	0,8	1,7	3,1	0,1	0,5	0,6	-0,1	0,5	0,5	-0,1	0,0	-0,8	-0,5	0,1	-0,9
A	0,4	1,6	1,9	0,6	1,6	3,5	0,1	0,5	0,3	-0,2	0,6	0,8	-0,2	-0,2	-0,8	-0,2	-0,2	-0,5
S	0,6	1,6	2,4	0,8	1,6	3,7	0,5	1,1	1,5	0,4	1,1	1,8	-0,4	0,0	-0,4	-0,7	-0,3	-0,1
O	1,2	2,2	3,6	1,3	2,2	5,9	0,5	0,9	1,5	0,3	0,9	2,6	0,4	0,5	0,5	0,1	0,2	1,2
N	1,7	2,8	3,5	1,8	2,8	3,7	1,7	2,3	2,2	1,5	2,3	2,6	0,1	-0,1	0,1	-0,1	-0,3	-0,2
D	-0,2	1,1	2,2	0,0	1,1	0,3	0,2	0,7	0,9	0,0	0,7	0,8	-0,5	0,2	0,3	-0,5	0,0	-0,3
AVG	0,8	1,9	2,3	1,0	1,9	2,5	0,4	1,0	0,9	0,2	1,0	1,1	0,1	0,1	-0,1	-0,1	-0,1	-0,1

Temperature range and variation increases drastically towards 2050-2080, and lead to an increased number of warmer nights and higher night-time temperatures and a small increase in cool nights. In agreement with the increase in variation, the number of ice-days will increase after 2050, as will the number of warm days (up from around 40 annually to around 70 after 2030 and to 115 after 2050), tropical nights. Warm nights will increases already from 2010 onward while cool nights will decrease between 2010-2050 but increase again slightly thereafter. Warm spell duration will increase especially towards 2050-2080, while the number of cold spell periods per year will remain about the same.

The annual total and average amount of precipitation is projected to remain approximately constant, with no great change in annual number of (very) heavy precipitation days from today's situation. The monthly rainfall pattern and amount will not change much either throughout the year, suggesting that rainfall during dry period, monsoon and post monsoon will remain the same, although annual variation will increase a bit after 2050, especially in February, June and October, indicating larger variations in rainfall for these months, and thus greater variation in onset and end of Monsoon than nowadays. Except for a greater variation, the average monsoon onset and end will remain about the same as today. The number of (very) heavy precipitation days and (very) wet days is not expected to change much, and the number of consecutive wet days and dry days will likewise remain the same.

The precipitation independent growing season is larger than the precipitation dependent one, and gradually increases after 2010 due to increasing temperatures but with great annual variations in onset and end. Because precipitation amounts and pattern remain largely the same as today, the precipitation dependent growing season remains constant in duration and remarkably constant in its onsets and ends.

For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,5°C for the Ganges compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 8% for the Ganges region compared to the alternative GCM models in figure 8.

Conclusions: The high mountain subdomain will see a gradual increase of temperature, especially of night-time temperatures, and particularly between March-June and October-November. Day-time temperatures will also increase but less than night-time temperatures. Variation in temperature will increase especially after 2050 with more warm days and nights but also more cool days than today. Due to underestimation of temperature change by the model, changes are likely to be larger than here projected. Precipitation remains remarkably similar to today's amount and timing, albeit with somewhat greater variation in monsoon onset and end after 2050. Precipitation is underestimated somewhat by the model and may be larger than projected. Growing season will increase with temperature, but not with precipitation. Changes will not be the same everywhere even on the subdomain level, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Most of the changes relate to increasing temperature and increasing variation in temperature, while precipitation remains roughly the same as today. The increasing temperatures may open up for greater agricultural possibilities and different crops, but the being mostly precipitation dependent, the season is unlikely to increase. Warming on the other hand may have consequences for glacier melt on these high elevations, providing melting water both earlier and later in the year, with potentially more water available for irrigation and drinking water purposes. Flood risk in the valleys may increase, not in the shoulder seasons, but especially during the warmest months.

Subdomain 7b: Middle Hills

Climate change: Table 10 shows an increase in temperature for the middle hill subdomain already from 2010, and especially after 2050. The minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, already on the short term but with an increasingly large difference towards 2080. March and September-November will see the largest warming. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods. For precipitation, scenario RCP4.5 does not indicate any great changes on an annual or monthly basis, while RCP8.5 projects increasingly less precipitation towards 2080. On a monthly basis, both scenarios indicate a drier monsoon (June-September), an extension of monsoon into October, and wetter winter months (January-February) than today – already from 2010 but especially after 2050.

The more detailed figures in the appendix (section 7.1.7b) for this domain indicate no great difference between scenarios RCP4.5 and RCP8.5 except for a drier mid- and long-term future predicted by RCP8.5. The average daily minimum temperature is projected to increase gradually especially towards 2080, with up to about 4-5 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially from 2050-2080, and mostly after the monsoon. Especially October nights will become a bit warmer after 2050, while daily maximum temperatures (warmest days) are projected to increase slightly, mostly during the monsoon season and its shoulder months, and especially towards 2050-2080. Variation in temperature extremes remains similar to today, but is expected to increase after 2050, leading to more extreme cold days (November-March) and warm days (March-July and September), while cool night temperatures remain the same as today. The number of summer days will gradually increase, but the number of warm days will increase more drastically especially after 2030 (double of today's number) and 2050, although annual variations are

large. Especially night-time will get warmer, with the number of tropical nights and warm night increasing drastically from around 20 to 140 per year after 2050, and already increasing noticeably after 2010. Likewise, cool days and nights will decrease in number, and frost days will disappear. After 2030, warm spell occurrence will increase and cold spells will decrease.

Table 10. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

| | ΔTmin | | | | | | ΔTmax | | | | | | ΔPrec. | | | | | |
| | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | |
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,6	1,2	2,0	0,7	1,2	2,9	0,0	0,1	0,7	-0,3	0,1	2,2	1,1	-0,3	1,4	0,9	-0,5	1,9
F	0,0	1,6	1,7	0,2	1,6	2,2	-0,4	0,6	0,6	-0,6	0,6	1,5	1,8	1,0	1,1	1,6	0,5	2,1
M	1,7	2,4	2,5	1,8	2,4	3,2	1,5	1,5	1,2	1,3	1,5	2,4	-0,9	-0,3	0,4	-1,0	-0,6	-0,3
A	0,4	1,6	1,9	0,6	1,7	3,0	0,1	0,7	0,7	-0,2	0,7	1,3	0,9	0,7	0,0	0,7	0,1	-0,2
M	0,9	1,9	2,0	1,1	1,9	3,2	0,3	0,6	0,6	0,0	0,6	1,4	0,6	0,0	0,5	0,2	-0,2	-1,3
J	0,9	2,0	2,0	1,2	2,0	3,0	0,3	0,5	0,7	0,0	0,5	1,3	-1,0	-0,2	-1,5	-1,6	-0,4	-4,0
J	0,6	1,6	1,8	0,8	1,6	2,9	0,2	0,4	0,7	-0,1	0,4	1,5	-0,4	0,3	-0,2	-0,8	0,3	-3,5
A	0,4	1,5	1,6	0,6	1,5	3,1	0,1	0,5	0,5	-0,2	0,5	1,5	-0,7	-1,2	-1,1	-1,1	-1,3	-4,4
S	0,7	1,7	2,3	0,9	1,7	3,8	0,4	0,8	1,2	0,1	0,8	2,1	-0,8	-0,8	-0,6	-1,3	-1,2	-3,0
O	0,9	1,7	2,8	1,0	1,7	5,2	0,4	0,5	1,2	0,1	0,5	2,8	0,7	1,2	1,8	0,5	0,5	2,6
N	1,6	2,4	3,0	1,7	2,4	4,1	1,3	1,6	1,9	1,0	1,6	3,1	0,0	0,0	0,3	-0,3	-0,3	-0,3
D	0,0	1,3	2,4	0,1	1,3	2,5	-0,1	0,5	1,4	-0,4	0,5	2,0	-0,7	0,5	0,7	-0,9	0,2	-0,2
AVG	0,7	1,7	2,2	0,9	1,8	3,2	0,3	0,7	1,0	0,1	0,7	1,9	0,0	0,1	0,2	-0,3	-0,2	-0,9

The annual total amount of precipitation is projected initially to remain approximately constant, and to decrease towards the end of the century, and the number of (very) heavy precipitation days will gradually decrease towards 2050-2080. Monthly total and average rainfall will increase slightly for the dry period, while June-September already from 2010 but especially on the longer term are projected to see a decrease in precipitation. Annual variations are large and increase over time. Smoothened data, with large day-to-day variations taken out, indicate that rainfall will increase slightly for the dry period (January-February), while June-September especially on the longer term are projected to see a decrease in precipitation. There will be a continued variation in monsoon onset, with a tendency to earlier onsets on the short term. During the monsoon, there will be a decreased rainfall per day, and the end of monsoon may be extended slightly already from 2010 but especially after 2050. Daily variation analysis shows that especially the period December-February the precipitation/monsoon extension in October will be highly variable. The number of (very) heavy precipitation days and (very and extremely) wet days is not expected to change much on the short term, with the exception of a small decrease in September from 2010, with only small and gradual decreases during monsoon, and slightly larger decreases throughout monsoon for the long term. The number of consecutive wet days is projected to decrease from 2050 onward, suggesting a shortening of the monsoon, while the dry period duration is projected to remain roughly the same as todays'. The amount of precipitation on wet days is projected to decrease slightly after 2050. The number of wet days is projected to remain roughly stable, confirming decreased rainfall during monsoon, while monsoon duration or at least the number of wet days per year remains the same.

The precipitation independent growing season remains year-round. The precipitation dependent growing season also remains constant on average over time, albeit with great annual variations. Together, this indicates that the main factor of variance for growth season is precipitation.

For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,5°C for the Ganges compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 8% for the Ganges region compared to the alternative GCM models in figure 8.

Conclusions: The domain will see an increase of temperature, and especially night-time temperatures will increase already from 2010, particularly during March and September-November and increasingly more after 2030. Day-time temperatures will also increase but less than night-time temperatures. The number of (very) warm days and nights will increase significantly from 2030 onward, and there will be less cold days and nights. The number of warm spells will also increase. Variation in extreme temperature will increase after 2050. Underestimation of temperature by the model makes that increase of minimum and maximum temperatures may be larger than projected here. Rainfall will increase during January-February and in October, while the monsoon months will become drier already from 2010. Monsoon timing will remain roughly the same (and equally varied), but see less rainfall. There are no large changes expected in heavy rainfall episodes. Precipitation may be larger than projected here due to underestimations by the model. The growing season will not be much affected, as temperatures are already well suited for growth, while precipitation will decrease during monsoon and the dry season will become wetter, though the total growing season does not seem to be affected. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon duration will not be affected, the decreased rainfall this time of year may negatively affect water demanding crops. At the same time, increased rainfall during the winter months and October paired with increased temperatures may open up for alternative crops in agriculture, and increased options at higher elevations and off-season. Decreased rainfall during monsoon combined with continued high intensity agriculture may threaten sustainability due to soil degradation and further decrease of ground water level. This may also affect forest condition and products, and general drinking water availability and quality. This stresses the need for increased sustainable management and water tanks/reservoirs to secure year-round water availability. There is no particular increased flood risk due to local climatic reasons, though climate change at higher elevations and upstream may affect glacial melt and downstream locations.

Subdomain 7c: Terai

Climate change: Table 11 shows an increase in minimum temperatures for the Terai region subdomain already from 2010, and increasingly higher temperatures towards 2050-2080. The minimum (night-time) temperature change is projected to be larger than the maximum (day-time) temperature change, already from 2010 but with increasingly higher temperatures for both towards 2080. March and November will see the largest warming initially both during day and night time, extended to March-May and September-December towards 2050. Between 2010-2030, maximum temperatures will drop somewhat during the winter months compared to today. Compared to RCP4.5, scenario RCP8.5 projects lower maximum

temperatures on the short term, but greater warming than RCP4.5 after 2050. For precipitation, scenarios RCP4.5 and RCP8.5 do not differ much, but both indicate generally increased precipitation year-round, but particularly during July already from 2010 and in October on the long term, but also some drier months (June, August) already from 2010 and onward.

Table 11. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

| | ΔTmin | | | | | | ΔTmax | | | | | | ΔPrec. | | | | | |
| | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | |
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,1	0,9	1,7	0,3	0,9	1,9	-0,5	0,0	0,5	-0,7	-0,1	1,5	0,8	0,1	1,0	0,7	0,0	1,2
F	0,0	1,1	1,4	0,2	1,1	1,5	-0,4	0,5	0,2	-0,6	0,5	0,9	0,9	0,5	0,8	0,9	0,3	1,1
M	1,5	2,0	2,1	1,6	2,0	2,3	1,5	1,4	0,8	1,4	1,4	1,7	-0,4	0,2	0,6	-0,4	0,1	0,4
A	0,3	1,3	1,8	0,4	1,3	2,5	0,1	0,8	0,5	-0,2	0,8	1,0	0,4	0,5	0,0	0,3	0,3	0,3
M	0,6	1,6	1,8	0,8	1,6	2,3	0,0	0,4	0,7	-0,4	0,4	0,5	0,5	0,3	0,3	0,3	0,0	1,0
J	0,7	1,4	1,4	0,9	1,4	2,1	0,1	0,0	0,4	-0,1	0,0	0,4	-1,4	0,8	1,4	-2,1	0,4	-0,6
J	0,5	1,1	1,2	0,7	1,1	1,9	0,2	0,1	0,4	-0,1	0,1	0,4	1,3	3,3	3,4	1,9	3,0	3,8
A	0,4	1,1	1,0	0,5	1,1	2,0	0,1	0,2	0,2	-0,2	0,2	0,6	-0,1	0,1	0,5	-0,5	-0,6	-1,1
S	0,8	1,5	1,5	0,8	1,5	2,4	0,4	0,6	0,7	0,1	0,6	1,0	0,2	-0,3	2,5	0,0	-0,7	0,6
O	0,6	1,2	1,9	0,6	1,2	3,0	0,1	0,2	0,7	-0,2	0,2	1,3	0,4	1,0	1,8	0,3	0,4	3,9
N	1,1	1,6	2,2	1,2	1,6	2,7	0,8	0,7	1,3	0,5	0,7	2,2	0,0	0,4	0,8	0,0	0,3	0,5
D	-0,1	1,1	2,0	0,0	1,1	2,2	-0,2	0,4	1,3	-0,5	0,4	2,2	0,4	0,3	0,7	0,1	0,3	0,6
AVG	0,5	1,3	1,7	0,7	1,3	2,2	0,2	0,4	0,6	-0,1	0,4	1,1	0,2	0,6	1,1	0,1	0,3	1,0

The more detailed figures in the appendix (section 7.1.7c) for this domain indicate no great difference between scenarios RCP4.5 and RCP8.5 in precipitation but with slightly higher temperatures in RCP8.5 on the long term. The average daily minimum temperature is projected to increase gradually throughout the year towards 2080, with up to about 2-3 degrees. The average daily maximum temperature is projected to increase too, especially from 2050-2080, but much less dramatic and mostly between September and May, outside the monsoon period. The lowest daily minimum temperatures (coldest nights) will remain the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase with several degrees, but especially towards 2050-2080. Daily maximum temperature range remains fairly similar until 2050, with some increase in June, but is projected to increase year round for 2050-2080. This increase is reflected in an increasingly warmer "warm days" notably in June-July, as well as for the long term (2050-2080), but also increased variation including increasingly cold "cool days" especially after 2050. The daily minimum (night-time) temperature range is projected to remain fairly the same as today's variation, except for an increase in variation from April-August already from 2010, and a shift in September-October from 2030. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during February-August, indicating more and warmer night-time temperatures that time of year. The number of warm days is projected to increase especially towards 2050-2080, with between a doubling and tripling of today's number of warm days. By 2030-2050 the number of warms days will increase with over 10 more compared to today. The number of warm and tropical nights will also increase

substantially, although this figure also shows that substantial year-to-year differences will persist and increase towards 2080. Likewise, the number of cool days and night will decrease from 2030 onward. The number of warm spells will be about the same as today, though the analysis does not indicate exactly how long each of these spells will be. The number of cold spells will decrease even further.

The annual total amount of precipitation and number of (very) heavy precipitation days is projected to remain approximately constant, perhaps slightly increase towards the end of the century. Monthly total and average rainfall will not change much for the dry period, but July (already from 2010) and October (on the longer term) are projected to see an increase. This suggests that the monsoon will be shorter and see more rainfall during a shorter timeframe, and in time the post-monsoon will see an increase as well. Inter-annual variations however are very large, and larger than the change between periods, indicating that making monsoon timing (onset and end) and precipitation will remain very variable. Smoothened data, with large day-to-day variations taken out, confirm above trends, and indicate that rainfall will not change much for the dry period, but July (already from 2010) and October (on the longer term) are projected to see an increase, while June will see a decrease. There will be a continued variation in monsoon onset, with a tendency to earlier onsets over time but a disappearance of the pre-monsoon. During the monsoon, there will be an increased rainfall per day, and the end of monsoon may be extended towards the end of October already from 2010 but especially towards 2050-2080, while the post-monsoon disappears. The current variations in June and end of July will become smaller, while end of monsoon in October will become more variable from year to year. The number of (very) heavy precipitation and (very and extremely) wet days is not expected to change much, with the exception of July (and October), which are expected to see a gradual increase from 2010. The maximum number of consecutive wet days initially suggests a lengthening of the monsoon or at least the annual number of wet days in 2010-2050, but this decreases again after 2050. The number of consecutive dry days is likewise projected to increase between 2030-2050, and decrease back to todays' level after that.

The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows increasingly large annual variations and a small shift towards later onsets and earlier ends after 2050.

For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,5°C for the Ganges compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 8% for the Ganges region compared to the alternative GCM models in figure 8.

Conclusions: The domain will see an increase of temperature, and especially night-time temperatures will increase already from 2010, particularly during March and (September-)November and increasingly more after 2030. Day-time temperatures will also increase, with some increases during June and year-round after 2050, but less than night-time temperatures. The number of (very) warm days and nights will increase substantially from 2030 onward, and there will be less cold days and nights, although year-to-year differences will persist and increase towards 2080. Variation in extreme temperature will increase after 2050. Underestimation of temperature by the model makes that increase of minimum and maximum temperatures may be larger than projected here. There will be an increase of rainfall during July and in October, and the monsoon is projected to merge with the post-monsoon in October, but delay its onset in June. Monsoon will in general see more and more intense rainfall during a shorter timeframe, and in time the post-monsoon will see an increase as well.

Inter-annual variations however are very large, and larger than the change between periods, indicating that making monsoon timing (onset and end) and precipitation will remain very variable. Increased rainfall in July comes with increased heavy rainfall episodes. Precipitation may be larger even than projected here due to underestimations by the model. The growing season will not be much affected, as temperatures are already well suited for growth, while the precipitation dependent growing season will shift gradually to later onsets and ends. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon duration will not be much affected, the much increased rainfall during July may negatively affect agriculture through soil erosion, water logging and damage, as well as nutrient wash-out. Generally increased temperatures may open up for alternative crops in agriculture, but elevation differences are relatively small in this sub-domain and much land is already dedicated to agriculture. Intensified rainfall not only during monsoon but also year-round may replenish ground-water levels, but the risks in terms of damage to crops and flood-risks are increased. This stresses the need for increased infrastructure diverting increased precipitation while simultaneously securing year-round water availability. Climate change at higher elevations supstream affecting glacial melt may add to the flood risk in downstream locations.

3.4.8   Domain 8: Karakoram-North Pakistan – Upper Indus
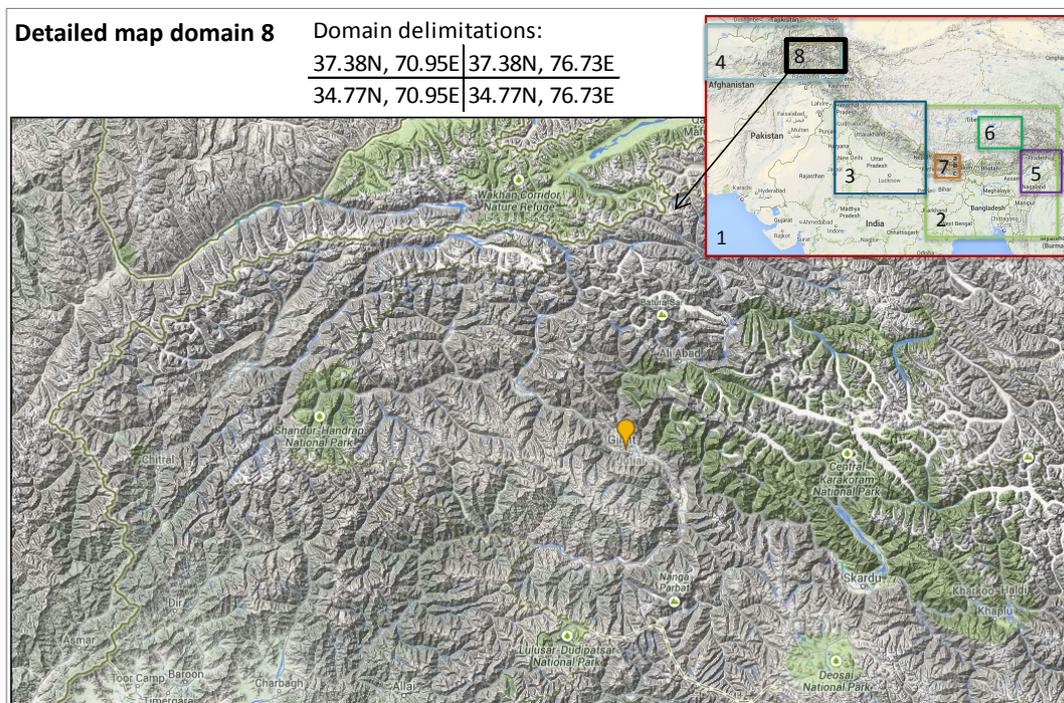
Figure 20 Domain map with reference station (orange markers) used for analysis of climate change in this report. Geographic variation in this domain is less large than in most other domains. Reference stations in this domain are few, and the one used has an elevation at 1459 m.a.s.l., this also being the elevation used for the following analyses.

Climate change: Table 12 shows that minimum (night-time) temperature change is projected to be about twice as much as the projected maximum (day-time) temperature change. Most warming takes place during the night, during October-December and May from 2010, and from May through December on the mid- and long term. Scenario RCP4.5 projects a bit more warming than RCP8.5 on the long term, but otherwise the scenarios are comparable. They do however differ in their projection of precipitation, with RCP8.5 projecting a decrease in precipitation year-round until 2050, while RCP4.5 only projects a drier August-December until 2030, after which precipitation increases year-round.

Table 12. Monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios. Colour schemes indicate direction and size of differences compared to reference period 1996-2005 with red (warmer) and blue (colder) colours for temperature and blue (wetter) and yellow (drier) colours for precipitation.

| | ΔTmin | | | | | | ΔTmax | | | | | | ΔPrec. | | | | | |
| | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | | RCP4.5 | | | RCP8.5 | | |
Month	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80	'10-'30	'30-'50	'50-'80
J	0,3	1,1	2,6	0,6	1,1	1,1	-0,2	0,2	1,3	-0,4	0,2	1,7	0,4	0,2	0,6	0,2	-0,1	0,3
F	-0,7	1,3	2,8	-0,4	1,3	0,6	-1,1	0,5	1,6	-1,2	0,5	0,8	0,4	0,7	1,4	0,3	0,3	1,3
M	0,9	1,7	2,3	1,2	1,7	1,6	0,3	0,6	0,7	0,2	0,5	1,4	0,6	0,2	0,9	0,4	-0,2	1,2
A	0,1	1,0	2,1	0,4	1,0	1,0	-0,2	0,0	0,7	-0,3	0,0	0,0	0,2	0,8	1,0	0,0	0,4	0,9
M	1,6	1,9	2,7	1,8	1,9	1,8	1,1	0,8	1,2	0,9	0,8	0,2	0,1	0,6	0,3	-0,1	0,1	0,1
J	0,6	1,2	1,8	0,8	1,2	1,2	0,4	0,4	0,5	0,3	0,4	-0,6	0,1	0,3	0,5	-0,1	-0,2	0,3
J	0,8	1,8	2,7	1,1	1,8	2,3	0,6	1,1	1,2	0,4	1,1	-0,2	0,0	-0,1	0,5	-0,3	-0,5	0,4
A	-0,1	1,2	2,0	0,2	1,2	2,3	0,0	0,6	0,7	-0,2	0,6	0,3	-0,4	0,1	0,4	-0,6	-0,3	0,2
S	0,2	1,9	2,9	0,4	1,9	3,0	0,3	1,0	1,3	0,0	1,0	1,0	-0,2	0,4	0,7	-0,4	-0,1	1,0
O	1,3	1,9	3,2	1,5	1,9	3,9	1,1	0,9	1,8	0,7	0,9	2,8	0,4	0,3	0,5	0,3	0,0	-0,2
N	1,3	2,2	3,1	1,5	2,2	2,5	1,1	1,4	1,9	0,9	1,4	2,8	0,0	0,5	1,1	-0,2	0,1	0,3
D	1,8	2,8	3,8	2,0	2,8	2,5	1,7	2,0	2,6	1,6	2,0	2,8	-0,1	0,7	0,9	-0,2	0,3	0,8
AVG	0,7	1,7	2,7	0,9	1,7	2,0	0,4	0,8	1,3	0,2	0,8	1,1	0,1	0,4	0,7	-0,1	0,0	0,6

The more detailed figures in the appendix (section 7.1.8) for this domain indicate that the average daily minimum (night-time) temperature is projected to increase gradually already from 2010 throughout the year towards 2080, especially during the summer months, with up to 2-3 degrees. The average daily maximum temperature is not projected to increase. The lowest daily minimum temperatures (coldest nights) will remain about the same for all periods, while extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080, between July-November. Temperature change will lead to an increase in number of warm days, notably in July-September, as well as for the long term (2050-2080) and an increase in cool days (bar below line) from November-February from 2010 onward. Variations in daily minimum and maximum temperature will increase compared to today's variation. Especially January-March and June-October already from 2010, and all months outside winter towards 2050-2080 will see large variations with especially increasingly warmer nights. The annual number of warm days will increase gradually towards 2050-2080, adding about 20 warm days to today's annual average, although annual variations will persist and increase. Similarly, the number of tropical and warm nights will increase, especially towards 2050-2080, and the number of cool days and nights and frost days will similarly decrease. The number of warm spells per year will remain constant, while the number of cold spell periods per year will decrease.

The total annual amount of precipitation is projected to remain approximately constant until 2050, after which it may increase. Also the number of heavy and very heavy precipitation days may increase somewhat after 2050. This increase on the longer term is distributed over all months of the year. Inter-annual variations however are large, and also larger than any change between projection periods. Smoothened data, with large day-to-day variations taken out, indicate that rainfall will increase for most months on the longer term. On the short term, February will see earlier onsets of rain, while June-August will be drier on the short, but wetter on the long term. It must be kept in mind that projections for precipitation are more uncertain than for temperature. Daily variation in precipitation remains about the same as today's variation at any time of year, with larger variations occurring especially during the wetter months February-April and September. The number of (very) heavy precipitation and (very and extremely) wet days is expected to increase slightly between February and April from 2010. The maximum number of consecutive wet days and maximum number of consecutive dry days are projected to remain approximately the same to today. The amount of precipitation on wet days is projected to increase slightly for 2050-2080. Since the number of wet days is also set to increase a bit, this indicates that on the long term there will be more rainy days with more precipitation per day during a year.

The precipitation independent growing season remains almost year-round as today, while the precipitation dependent growing season shows great annual variations and shifts of onsets and ends, but on average increases. The analysis indicates that precipitation is the factor affecting growing season duration and timing.

For RCP8.5, the HICAP model may have a tendency to underestimate temperature change with about 0,3°C for the upper Indus compared to other models for these regions (figure 8). Projections of precipitation are more uncertain, but underestimated by the HICAP model by around 2-3% for the upper Indus region compared to the alternative GCM models in figure 8.

Conclusions: The domain will see an increase of especially night-time temperatures already from 2010, but especially between May-December after 2030. Day-time temperatures will also increase but less than night-time temperatures. The coldest extremes will remain about the same as today, while the warmest extremes will increase, resulting in (more) warmer nights especially in July-September in the long term, but also more annual variation already from 2010 onward. Underestimation of temperature by the model makes that increase of minimum and maximum temperatures may be larger than projected in the figures. Precipitation changes are small on the short term, but indicate somewhat drier years with some drier months (June-August) but also some wetter months (February). On the long term, the whole year will be wetter than today, especially during February-April and September-December, with a slight increase in wet days for those months. Monsoon variation and rainfall remains as is today, but may become a bit wetter and extend a bit after 2050. Precipitation may be larger than projected here due to underestimations by the model. Changes will not be the same everywhere in the domain, and very much depend on geography, and current rainfall and temperature as compared to elsewhere in the domain. We therefore refer as well to figures 11 and 12 before making assumptions about impacts on the local level.

Potential impacts/consequences: Although the monsoon and growing season (at this level of analysis) will not significantly change in the short term, increased night-time temperatures may allow for alternative crops in agriculture, especially at higher elevations. More rainy days later in September and increased rainfall in February may benefit agriculture on the long term, but no large changes are expected until 2050. Agriculture may be affected somewhat during the

dry period, which may become drier. Year-round water availability remains the same (given the same level of water use as today) until 2050, but water reservoirs may improve water availability during the drier summer months. With higher warming during the late summer months and at higher elevations (upstream), flood risk may increase after 2050.

4 Conclusion

The Hindu Kush Himalaya region is a geographically very diverse area, with great differences in temperature, not only on a north-south gradient, but also related to elevation. Precipitation likewise differs greatly from the wetter eastern Himalayas to the drier western Himalayas, and from the wetter lowlands in the south to the drier highlands of the Tibetan plateau. Precipitation moreover is characterised by regional differences in the timing of monsoonal rains, pre-monsoon and post-monsoon periods, as well as local differences due to geographical characteristics. The region is also characterized by a great dependence on forest use, agriculture, and rain-, ground- and melting-water providing for drinking and irrigation. Such temporal and spatial variability combined with the reliance on natural resources demonstrates the need for precise and downscaled climate information. Such downscaled information however is not readily available for the region, and recent efforts have provided regional and river basin scale models, but these still cover large and varied terrain where even over small distances climate may vary a lot.

The HICAP model provides downscaled information on a basin level for 8 different domains across the Himalayas. A comparison of the model to 1) other available models for comparable domains and 2) local observations shows that the projections of change in temperature and precipitation are in line with comparable models, and that the annual timing of increases and decreases in temperature and precipitation compares better than most other models results with local observations. However, the model often under- or over-estimates temperature and/or precipitation, showing different mismatches with observations depending on the domain. This report presents a simple method to correct for these mismatches, and how to make the model results more realistic for single locations. The method is based on using the smallest, most downscaled domain and projected changes therein, combined with monthly climate information for a reference period for (a) specific location(s) and their elevation. The method is applicable to any other location beyond the Himalayas as well, provided availability of regional downscaled projections, and at least monthly climate data of a nearby station. The use and need of the method for adaptation of large scale models to local observations depends partly on the local geography: the method is most useful in locations with great altitudinal variations.

The report also presents data in different formats, ranging from detailed figures on temperature and precipitation changes, including analyses of extreme events such as number of heavy precipitation days, heatwaves and frost events, and monsoon and growing season changes. The figures are briefly explained in simple text, and summarized per domain with brief, simple conclusions and a potential impact analysis. The various forms of presentation are developed to provide different stakeholders, sectors, decision makers and scientists with relevant and understandable information.

The report is aimed at presenting a method and figures for relevant and realistic climate information. It does *not* aim to provide a comprehensive impact analysis for the HICAP region, and it must be stressed that the results for the domains must be compared with other

models for the region. A thorough analysis of changes and impacts places multiple model results under different scenarios into context of geographical and temporal scale, social-, economic-, political- and ecological status and change. It considers current and future vulnerability and adaptive capacity at multiple scales in society. Relevant climate information is a prerequisite for adaptation to climate change. Impacts may differ greatly over social and geographical and temporal scales, making adaptation a local issue which further underlines the importance of downscaling. However, no matter how detailed projections may be, they remain projections, and are not predictions of the future. Uncertainty about change and impacts will remain, and while projections help inform about trends in local climate change, and expected changes in extreme events, adaptation may first and foremost need to focus on adaptation to uncertainty.

5 Acknowledgements

6 References

Aase, T. H., Chaudhary, R. P., & Vetaas, O. R. (2010). Farming flexibility and food security under climatic uncertainty: Manang, Nepal Himalaya. *Area*, *42*(2), 228–238. doi:10.1111/j.1475-4762.2009.00911.x

Bhatt, B., Sobolowski, S., & King, M. P. (2014). Assessment of downscaled current and future projections of diurnal rainfall patterns for the Himalaya. *Journal of Geophysical Research: Atmospheres*, n/a. doi:10.1002/2014JD022134

Chang, C.-P., Ding, Y., Lau, N.-C., Johnson, R. H., Wang, B., and Yasunari, T. (2011, April). The Global Monsoon Systems. World Scientific. doi:10.1142/8109

Chong-hai, X., and Ying, X. (2012). The Projection of Temperature and Precipitation over China under RCP Scenarios using a CMIP5 Multi-Model Ensemble. *Atmospheric and Oceanic Science Letters*, *5*(6), 527–533.

Eriksson, M., Jianchu, X., Shrestha, A. B., Vaidya, R., Nepal, S., and Sandstrom, K. (2009). *The Changing Himalayas: impact of climate change on water resources and livelihoods in the greater Himalayas.* (Vol. 114, pp. 1–28). ICIMOD. doi:10.1144/SP312.3

Immerzeel, W. W., and Lutz, A. F. (2012). *Regional knowledge sharing on climate change scenario downscaling* (pp. 1–51).

Knutti, R., and Sedláček, J. (2012). Robustness and uncertainties in the new CMIP5 climate model projections. *Nature Climate Change*, *3*(4), 369–373. doi:10.1038/nclimate1716

Lutz, A. F., and Immerzeel, W. W. (2013). *Water Availability Analysis for the Upper Indus , Ganges , Brahmaputra , Salween and Mekong River Basins. Future Water report 127,* 85pp.

Lutz, A. F., Immerzeel, W. W., Shrestha, A. B., and Bierkens, M. F. P. (2014). Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. *Nature Climate Change*, (June), 1–6. doi:10.1038/NCLIMATE2237

Moors, E., Biemans, H., Siderius, C., & Collins, D. (2011). Adaptation to changing water resources in the Ganges basin, northern India. *Environmental Science Policy*, *14*(7), 758–769

Nellemann, C., Verma, R., & Hislop, L. (2011). Women at the frontline of climate change: Gender risks and hopes. A Rapid Response Assessment. (C. Nellemann, R. Verma, & L. Hislop, Eds.) (p. 68). United Nations Environment Programme, GRID-Arendal.

Peters, G. P., Andrew, R. M., Boden, T., Canadell, J. G., Ciais, P., Le Quéré, C., … Wilson, C. (2012). The challenge to keep global warming below 2 °C. *Nature Climate Change*, *3*(1), 4–6. doi:10.1038/nclimate1783

Rogelj, J., Meinshausen, M., and Knutti, R. (2012). Global warming under old and new scenarios using IPCC climate sensitivity range estimates. *Nature Climate Change*, *2*(4), 248–253. doi:10.1038/nclimate1385

Sillmann, J., Kharin, V. V., Zhang, X., Zwiers, F. W., and Bronaugh, D. (2013). Climate extremes indices in the CMIP5 multimodel ensemble: Part 1. Model evaluation in the present climate. *Journal of Geophysical Research: Atmospheres*, *118*(4), 1716–1733. doi:10.1002/jgrd.50203

Sillmann, J., Kharin, V. V., Zwiers, F. W., Zhang, X., and Bronaugh, D. (2013). Climate extremes indices in the CMIP5 multimodel ensemble: Part 2. Future climate projections. *Journal of Geophysical Research: Atmospheres*, *118*(6), 2473–2493. doi:10.1002/jgrd.50188

Stiller-Reeve, M. A., Syed, M. A., Spengler, T., Spinney, J. A., and Hossain, R. (2014). Complementing scientific monsoon definitions with social perception in Bangladesh. *American Meteorological Society*.

Tschakert, P., van Oort, B., St. Clair, A. L., and LaMadrid, A. (2013). Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change. Climate and Development, 5(4), 340–350. doi:10.1080/17565529.2013.828583

Wang, B., Ding, Q., and Joseph, P. V. (2009). Objective Definition of the Indian Summer Monsoon Onset*. *Journal of Climate*, *22*(12), 3303–3316. doi:10.1175/2008JCLI2675.1

Xu, J., Grumbine, R. E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y., and Wilkes, A. (2009). The Melting Himalayas: Cascading Effects of Climate Change on Water, Biodiversity, and Livelihoods. *Conservation Biology*, *23*(3), 520–530. doi:10.1111/j.1523-1739.2009.01237.x

7 Appendix

7.1 Interpretation of figures per domain

7.1.1 General figure text

The figure text below is valid for all figures in the appendix. The text next to the figures themselves explains in short how to interpret the figures. Throughout the figures below we use the same colour coding for the periods, i.e. **blue for the baseline period 1996-2005**, **red for 2010-2030**, **orange for 2031-2050** and **green for 2051-2080**, unless otherwise indicated.

Model adjustment

Figure 7.1.X.0: Results 1) of the HICAP model and 2) after adjustment using RCP8.5 and a selection of field observations (see appendix 7.2 for stations and average for each domain). The adjusted results have been used as basis for the figures and analysis for this domain.

RCPs

Figure 7.1.X.1 A comparison between RCP4.5 and RCP8.5 for annual average minimum temperature, maximum temperature and precipitation. This comparison helps to identify if the two scenarios give very different pathways or if their climate projections are in the same order of magnitude and direction. This also helps in selecting a "worst case scenario" to help optimize adaptation and policy information.

Temperature

Figure 7.1.X.2a Average daily maximum and minimum temperature, daily averages for each projection period. This figure shows the average minimum and maximum daily values between which daily temperatures will vary for each period.

Figure 7.1.X.2b Graphical visualization of monthly change in temperature and precipitation for the three projection periods and 2 RCP scenarios.

Figure 7.1.X.3 Extreme daily maximum and minimum temperature, maximum (for maximum temperature) and minimum (for minimum temperature) daily values for each projection period. This figure shows the extreme values between which daily temperatures will vary for each period.

Figure 7.1.X.4 Daily maximum temperature extremes. This figure indicates the variation in maximum daily temperature values on a monthly basis for each period (i.e. the *minimum* maximum temperature and the *maximum* maximum temperature). It also shows the temperature level for the baseline period above which occur "summer days", "warm days" and below which occur "cool days" and "ice days". These thresholds visualize the monthly increase or decrease in these type of days (see definitions further down in detailed figures regarding these days) during projection periods.

Figure 7.1.X.5 Daily minimum temperature extremes. This figure indicates the variation in minimum daily temperature values on a monthly basis for each period (i.e. the *minimum* minimum temperature and the *maximum* minimum temperature). It also shows the temperature level for the baseline period above which occur "tropical nights", "warm nights" and below which occur "cool nights" and "frost nights". These thresholds visualize the monthly increase or decrease in these type of days (see definitions further down in detailed figures regarding these days) during projection periods.

Figure 7.1.X.6 Summer days. Annual count of days for each period with a daily maximum temperature above 25^0C.

Figure 7.1.X.7 Warm days. Annual count of days for each period with a daily maximum temperature in the upper 10% of the baseline period. The figure indicates the annual increase or decrease of days with a daily maximum temperature above the threshold set for "warm days". The absolute value of this threshold is indicated in Figure 7.1.X.4 in ^{0}C.

Figure 7.1.X.8 Tropical nights. Annual count of days for each period with a daily minimum temperature above 20^0C.

Figure 7.1.X.9 Warm nights. Annual count of days for each period with a daily minimum temperature in the upper 10% of the baseline period. The figure indicates the annual increase or decrease of days with a daily minimum temperature above the threshold set for "warm nights". The absolute value of this threshold is indicated in Figure 7.1.X.5 in ^{0}C.

Figure 7.1.X.10 Cool days. Annual count of days for each period with a daily maximum temperature in the lower 10% of the baseline period. The figure indicates the annual increase or decrease of days with a daily maximum temperature below the threshold set for "cool days". The absolute value of this threshold is indicated in Figure 7.1.X.4 in ^{0}C.

Figure 7.1.X.11 Cool nights. Annual count of days for each period with a daily minimum temperature in the lower 10% of the baseline period. The figure indicates the annual increase or decrease of days with a daily minimum temperature below the threshold set for "cool nights". The absolute value of this threshold is indicated in Figure 7.1.X.5 in ^{0}C.

Figure 7.1.X.12 Frost free nights. Annual count of days for each period with a daily minimum temperature above 0^0C.

Figure 7.1.X.13 Warm spell duration. This figure describes the change in warm spells; periods with at least 6 consecutive "warm days" - days of daily maximum temperatures in the upper 10% of the baseline period. The duration is given in "number of periods", identifying separate periods, not consecutive days or exactly how many days, of warm spells in a year.

Figure 7.1.X.14 Cold spell duration. This figure describes the change in cold spells; periods with at least 6 consecutive "cool nights" - days of daily minimum temperatures in the lower 10% of the baseline period. The duration is given in "number of periods", identifying separate periods, not consecutive days or exactly how many days, of cold spells in a year.

Precipitation and Monsoon timing

Figure 7.1.X.15 Annual total precipitation presented with coloured bars, and averages for each projection period with horizontal black lines

Figure 7.1.X.16 Annual number of heavy precipitation days (days with a precipitation larger than 10mm per day). Averages for each projection period presented with horizontal black lines.

Figure 7.1.X.17 Annual number of very heavy precipitation days (days with a precipitation larger than 20mm per day). Averages for each projection period presented with horizontal black lines.

Figure 7.1.X.18 Monthly total precipitation, with coloured bars representing the different projection periods. The error bars present the extreme (minimum and maximum) values measured/projected for each period, and thus the values between which total monthly precipitation is most likely to vary.

Figure 7.1.X.19 Monthly representation of daily average precipitation, with coloured bars representing the different projection periods. The error bars present the extreme (minimum and maximum) daily average values measured/projected for each period, and thus the values between which average daily precipitation is most likely to vary. The graph is essentially the same as 8.1.X.18, but total divided by the number of days per month.

Figure 7.1.X.20 Average and extreme daily precipitation. The graph presents variations in daily precipitation averaged per day over each projection period, and gives the extreme minimum and maximum daily precipitation values for each projection period. As daily precipitation can vary a lot from day-to-day, this figure results in a somewhat chaotic picture typical for daily variations. The next two figures smoothen this picture by presenting weekly averages of daily precipitation and daily variation.

Figure 7.1.X.21 Smoothened daily precipitation and monsoon duration. This figure presents sliding weekly averages of daily precipitation for each projection period, which takes out large day-to-day variations. It further uses a subjective threshold above which we find 55% of the smoothened annual rainfall during the baseline period takes place, and below which is 45% of the smoothened annual rainfall. This threshold separates the periods with high rainfall from those with less rainfall. Typically, but not in all cases, this coincides with the periods of summer/rainy period/monsoon rainfall and the drier rest of the year. The horizontal colourful bars below in the graph indicate the duration, onset and end of precipitation above this threshold. These bars can be used as an estimate for changes in monsoon onset, end and duration. In those cases where the bars and actual monsoon period do not coincide well, shifts in the projections for daily precipitation may proof more useful instead.

Figure 7.1.X.22 Variation of average daily precipitation. This figure gives a measure of how much variation or dispersion from the daily average precipitation for each projection period average exists. It uses the standard deviation which covers 68.2% of the data, and thus about two thirds of the variation falls within the indicated amount of daily precipitation.

Figure 7.1.X.23 Number of heavy precipitation days (days with precipitation>10mm). The error bars present the extreme (minimum and maximum) number of heavy precipitation days and thus annual spread or variation likely to occur for each month and period.

Figure 7.1.X.24 Number of very heavy precipitation days (days with precipitation>20mm). The error bars present the extreme (minimum and maximum) number of very heavy

precipitation days and thus annual spread or variation likely to occur for each month and period.

Figure 7.1.X.25 Number of wet days (number of days with a precipitation amount in the upper 10% of the baseline period). The error bars present the extreme (minimum and maximum) number of wet days for each period and thus annual spread or variation in number of wet days likely to occur for each month and period.

Figure 7.1.X.26 Number of very wet days (number of days with a precipitation amount in the upper 5% of the baseline period). The error bars present the extreme (minimum and maximum) number of very wet days for each period and thus annual spread or variation in number of very wet days likely to occur for each month and period.

Figure 7.1.X.27 Number of extremely wet days (number of days with a precipitation amount in the upper 1% of the baseline period). The error bars present the extreme (minimum and maximum) number of extremely wet days for each period and thus annual spread or variation in number of extremely wet days likely to occur for each month and period.

Figure 7.1.X.28 Annual maximum number of consecutive wet days (at least 2 consecutive days with precipitation over 1mm/day). As most rainy days typically fall during monsoon or rainy season, this maximum number consecutive wet days is a measure of the duration of monsoon. The average maximum number of consecutive wet days for each projection period is indicated by horizontal black lines.

Figure 7.1.X.29 Annual maximum number of consecutive dry days (at least 2 consecutive days with precipitation below 1mm/day). As most dry days typically occur during the winter season, this maximum number of consecutive dry days is a measure of the duration of the dry period in the winter months. The average maximum number of consecutive dry days for each projection period is indicated by horizontal black lines.

Figure 7.1.X.30 Simple Daily Intensity Index. This figure uses two vertical axes: on the left – the columns, indicating the annual average amount of precipitation per wet day (days with precipitation more than 1mm), or in simple terms how much it on average rains on a wet day. On the right – the purple line, the annual number of wet days. This gives an indication if e.g. the precipitation per wet day increases because of a decrease of number of wet days or because of an increase of precipitation. The average precipitation on wet days for each projection period is indicated by horizontal black lines.

Growing season

Figure 7.1.X.31 Growing season onset and end dates as defined by two different definitions : 1) Red markers, GSLt: growing season based on temperature only, with at least 6 consecutive days of daily average temperature above 5^0C defining the onset of the growing season, and likewise when temperature falls below 5^0C again it defines the end of the growing season, and 2) Blue markers, GSLtp: growing season based on temperature and precipitation, using the same temperature definition as above, but adding a criteria of at least 6 consecutive days of more than 1mm/day precipitation. The vertical axis indicates the time of year (in day number and in month), and the horizontal blue lines indicate the average growing season onset and end dates per period for the definition using both temperature and precipitation.

Figure 7.1.X.32 Average growing season duration. The figure shows the growing season duration for each projection period in number of days as defined by temperature alone (red, GSLt) and by both temperature and precipitation (blue, GSLtp). The error bars indicate the maximum and minimum number of days for the growing season duration per projection period.

Figure 7.1.X.33 Annual growing season duration. This figure shows essentially the same as the figure above (8.1.X.32), but instead of using an average, minimum and maximum it shows how the growing season (defined in two different ways, see above) varies from year to year. The average duration in number of days for each projection period is indicated by horizontal black lines.

7.1.2 Domain 2
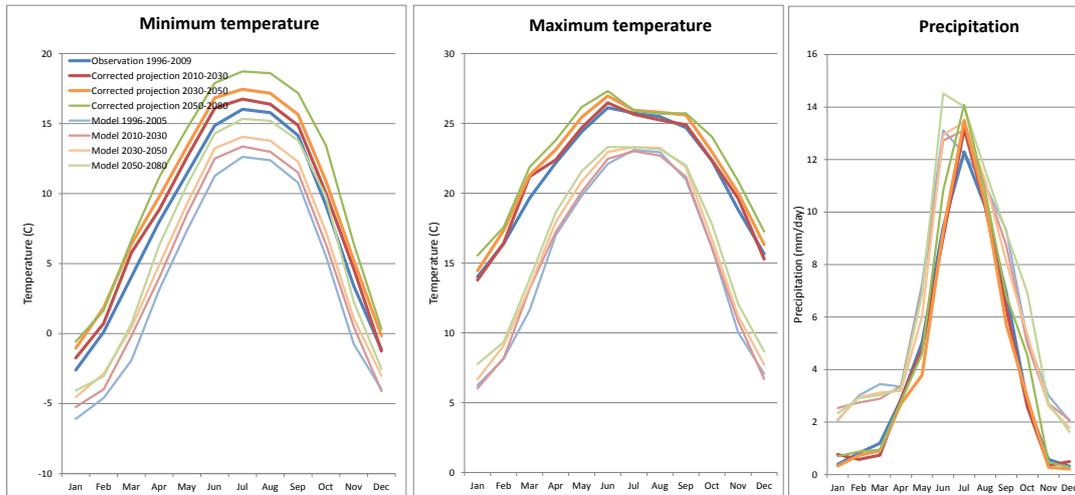
Figure 7.1.2.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, with a greater difference for maximum temperature results. Precipitation is overestimated outside the rainy season, while the model matches observed values quite well during the rainy season.
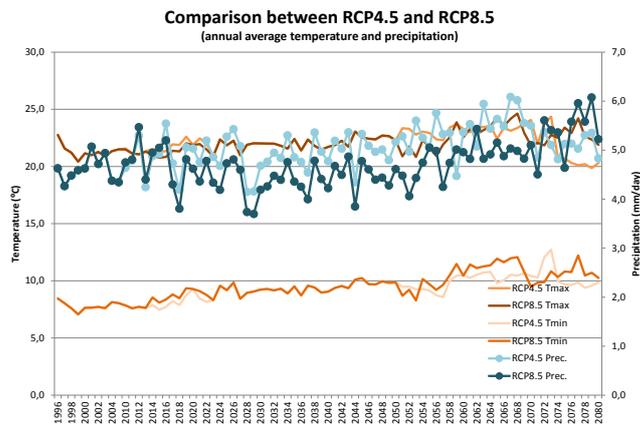
Figure 7.1.2.1a: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a drier mid-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
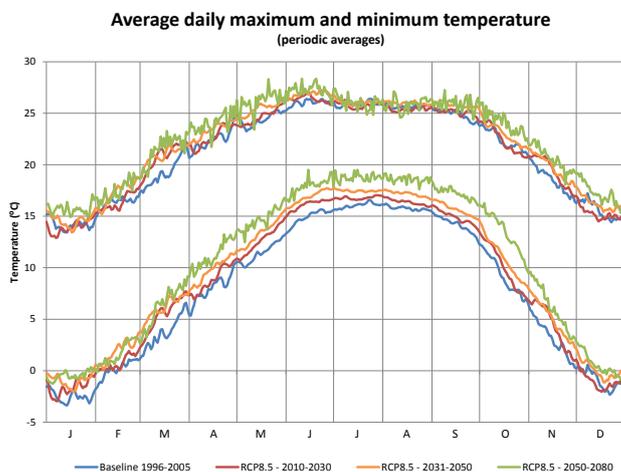
Temperature

Figure 7.1.2.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually throughout the year towards 2080, with up to about 3-4 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially from 2050-2080, but mostly between September and May, outside the monsoon period.
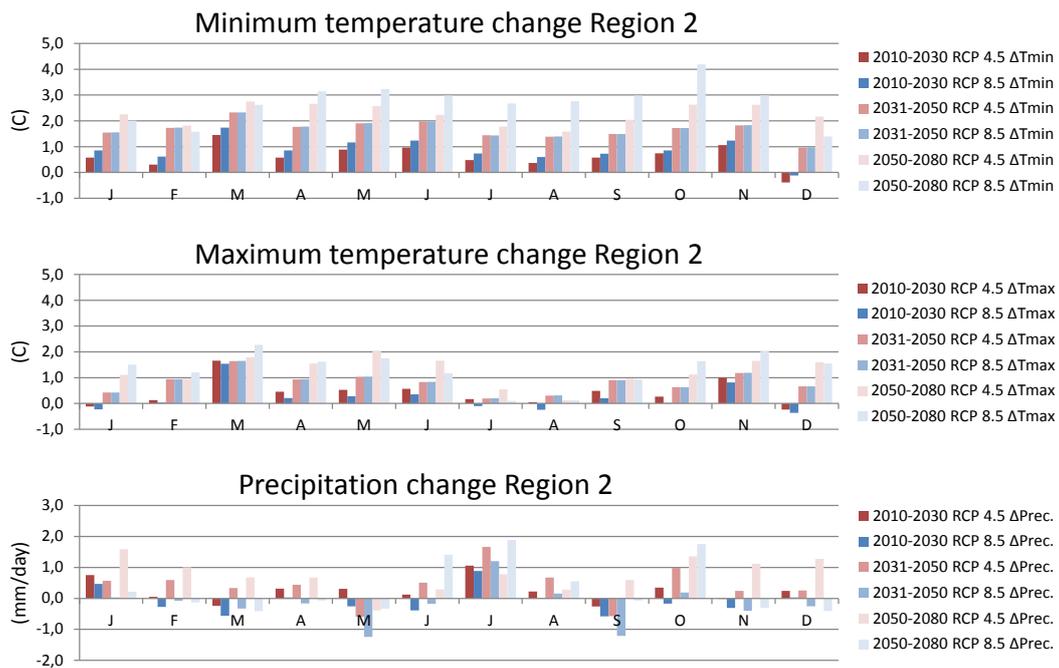
Figure 7.1.2.2b: Minimum (night-time) temperature change is projected to be about twice the size of the projected maximum (day-time) temperature change. Most warming takes place in pre- (March-May) and post- (September-November) monsoon months. There is no large difference on the short- (2010-2030) and mid-term (2030-2050) between scenarios RCP4.5 and RCP8.5, though on the long term (2050-2080), RCP8.5 projects a bit more warming. Precipitation is projected to change especially for June and October (wetter) and May and September (drier).
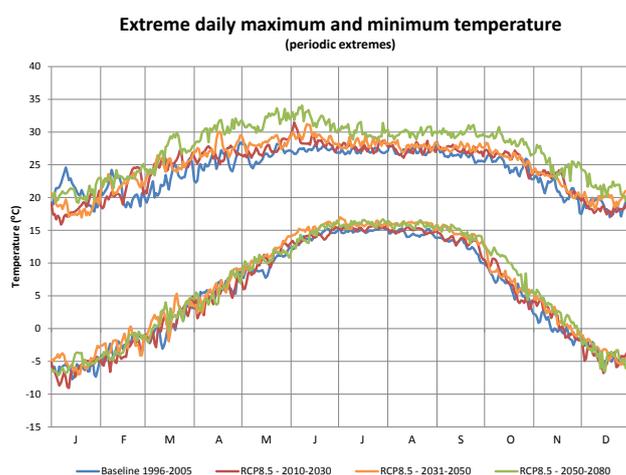
Figure 7.1.2.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080, mostly outside the monsoon season. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)

Figure 7.1.2.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, with some increase in June, but is projected to increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in April-June and October, as well as for the long term (2050-2080) and an increase in cool days (bar below line) from November-May for 2050-2080.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)

Figure 7.1.2.5: The daily minimum (night-time) temperature range is projected to remain fairly the same as today's variation, except for an increase in variation from April-August already from 2010, and a shift in September-October from 2030. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during monsoon, indicating more and warmer night-time temperatures that time of year. Frost nights will remain the same and only decrease gradually after 2030 while cool nights will remain approximately the same.

Summer days
(count of days when Tx>25°C)

Figure 7.1.2.6: The annual number of days above 25°C is projected to increase from on average 105 (1996-2005) to 155 (2050-2080). The annual variation increases and is larger than the projected change between periods.

Warm days
(count of days when Tx>90th percentile of baseline)
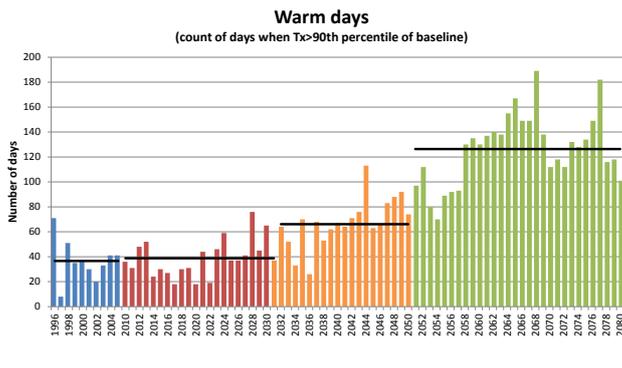
Figure 7.1.2.7: The annual number of warm days will increase especially towards 2050-2080, with a tripling of today's number of warm days. Already in 2030-2050 the number of warms days will increase with over 20 more compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
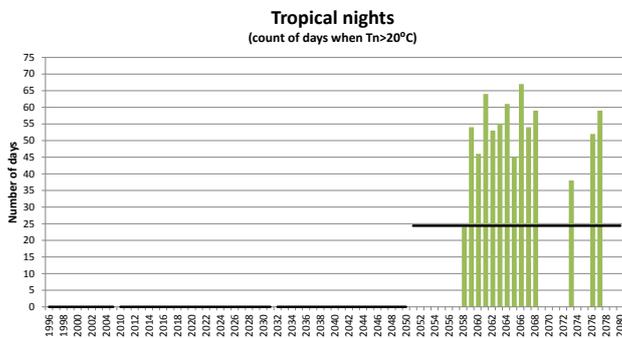
Figure 7.1.2.8: The annual number of tropical nights will increase drastically from not occurring to on average 25 per year during 2050-2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
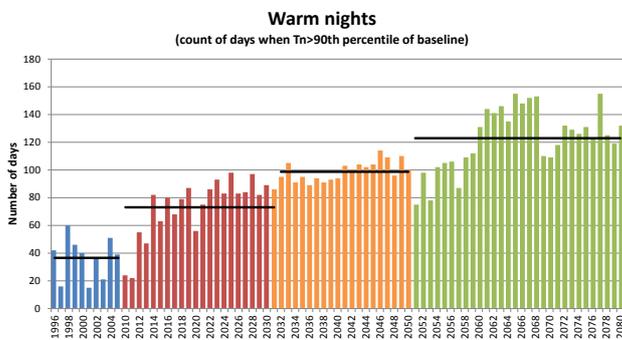
Figure 7.1.2.9: The number of warm nights will also increase drastically. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
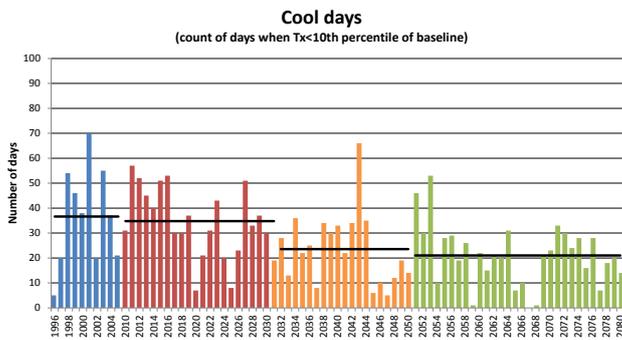
Figure 7.1.2.10: In apparent contrast with figure 7.1.2.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

66

Cool nights
(count of days when Tn<10th percentile) of baseline
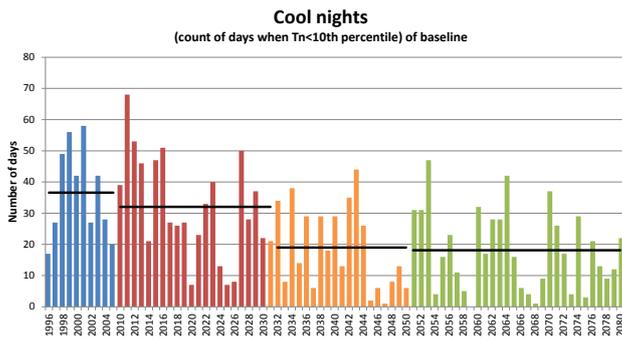
Figure 7.1.2.11: The number of cool nights will also decrease significantly on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.

Frost free nights
(count of days when Tn>0°C)
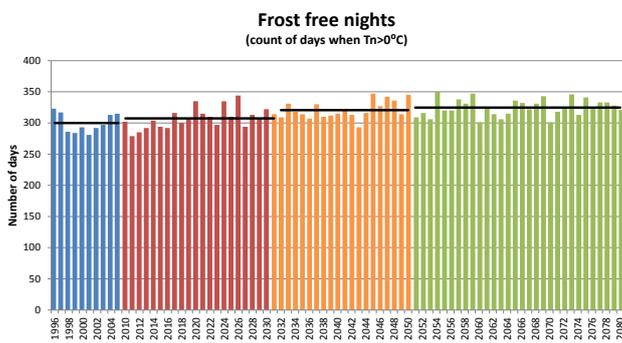
Figure 7.1.2.12: In line with figure 7.1.2.5, the number of frost nights remains approximately the same, and gradually decrease after 2030.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
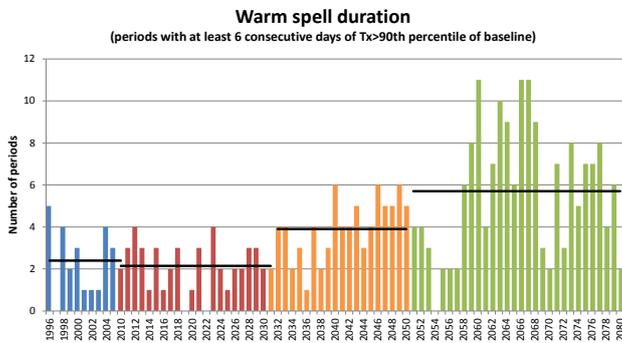
Figure 7.1.2.13: The number of warm spells per year will increase, especially towards 2050-2080. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase significantly.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
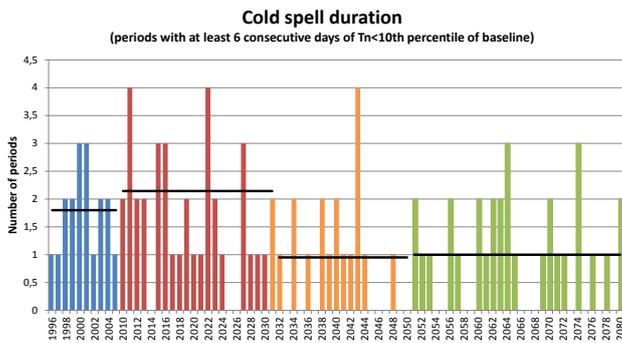
Figure 7.1.2.14: The number of cold spell periods per year will decrease. Although these currently only count around 2, they are set to fall to around 1 spell per year. Still, there will be annual variations.

Precipitation and Monsoon timing
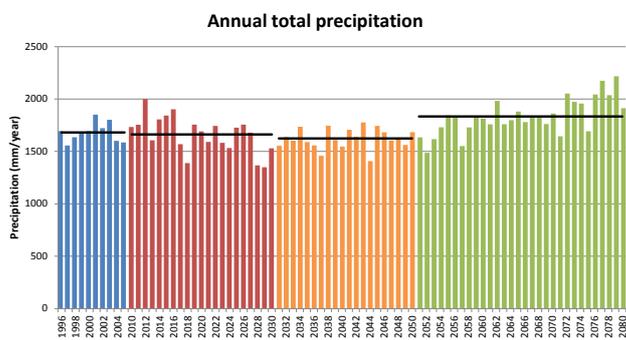
Figure 7.1.2.15: The annual total amount of precipitation is projected to remain approximately constant, perhaps slightly increase towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.2.18-27).
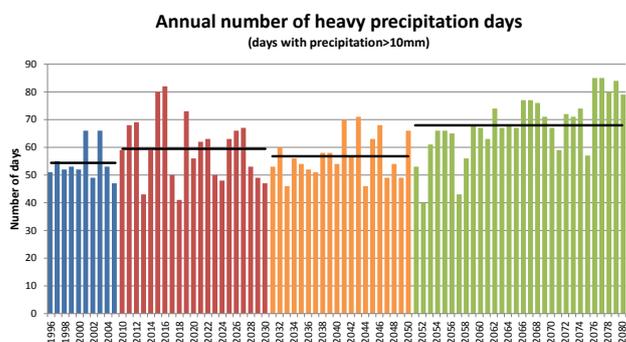
Figure 7.1.2.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.2.18-27).
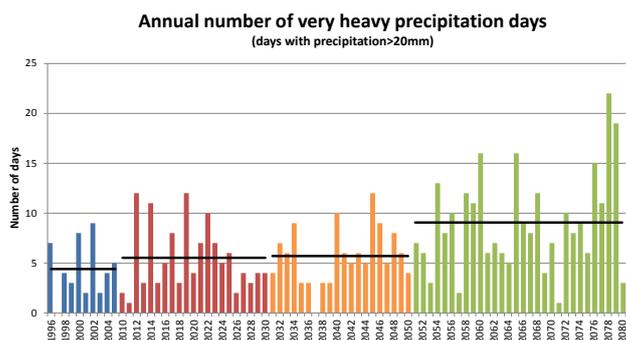
Figure 7.1.2.17: As in the former figure, the annual number of very heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.2.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)
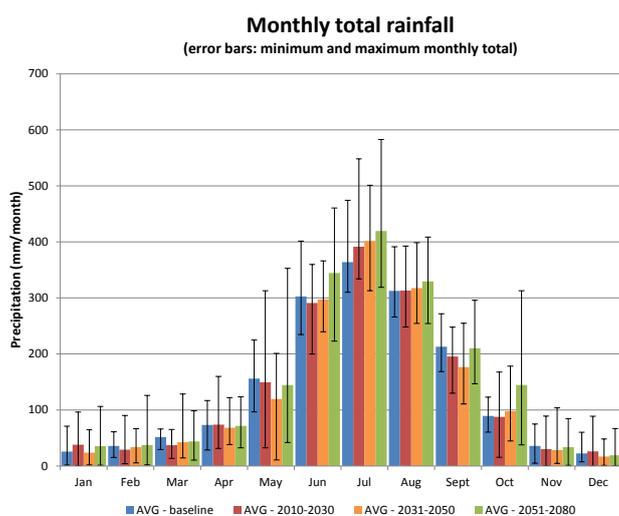
Figure 7.1.2.18: Monthly total rainfall will not change much for the dry period, but June and October (on the longer term), and July (already from 2010) are projected to see an increase. This suggests that there will be more rainfall during the monsoon and in time during the post-monsoon. Error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large, and also larger than the change between periods.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
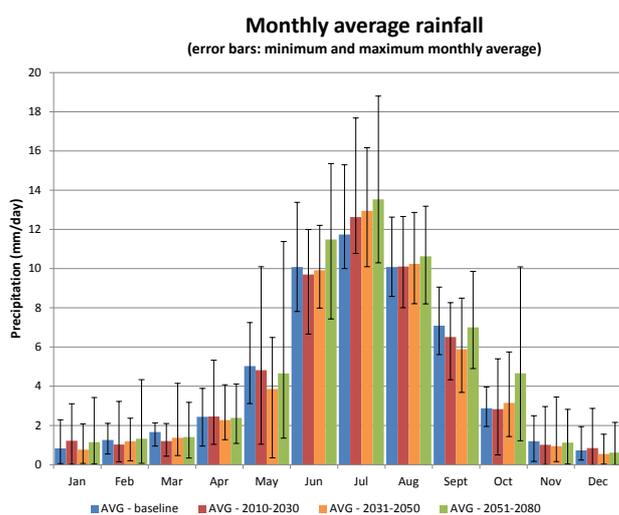
Figure 7.1.2.19: As in the figure above, monthly average rainfall will not change much for the dry period, but again June and October (on the longer term), and July (already from 2010) are projected to see an increase. Again, this suggests that there will be more rainfall during the monsoon and post-monsoon, but with large inter-annual variations especially for the wet months.

Average and extreme daily precipitation
(periodic averages and extremes)
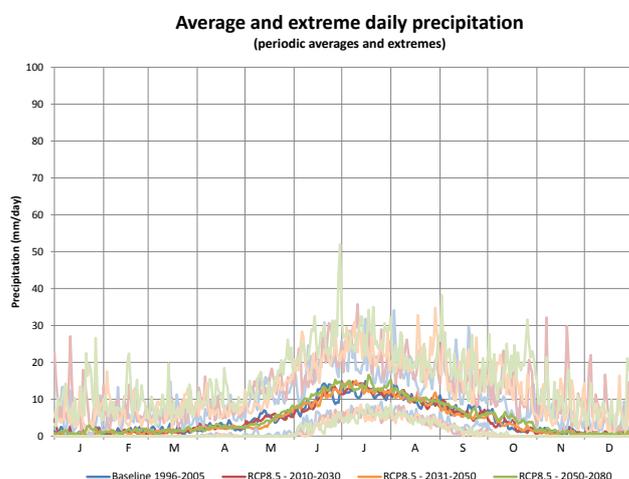
Figure 7.1.2.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations remain as large as they are today, larger than any shift in rainfall between periods.
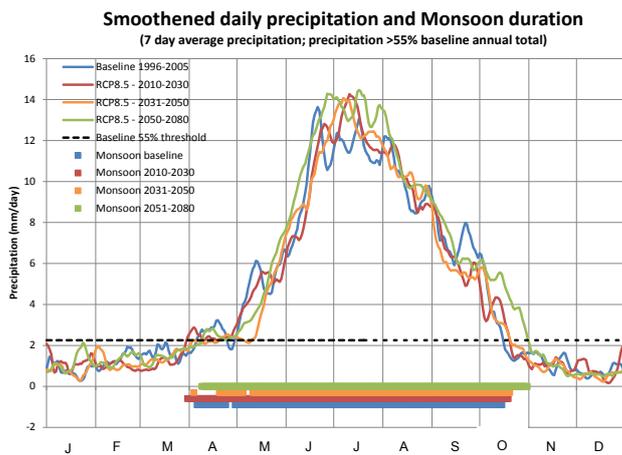
Figure 7.1.2.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.2.18-19, May and July (already from 2010) and June and October (for 2030-2050) are expected to see the largest changes. There will be a continued variation in monsoon onset, with a tendency to later onsets over time. During the monsoon, there will be an increased rainfall per day, and the end of monsoon remains the same on the short term but may be extended to the end of October towards 2050-2080. The dry period will also become drier in the long term (especially February-March). It must be kept in mind that projections for precipitation are more uncertain than for temperature.
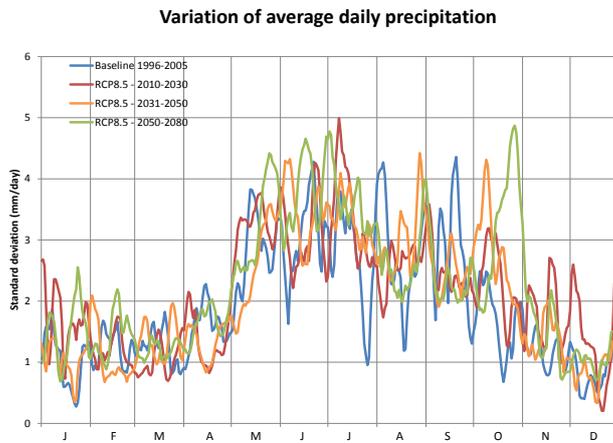
Figure 7.1.2.22: This figure indicates that the daily variation is larger in the wet period than in the dry period of the year, and especially the projected changes in precipitation may vary much from year to year.
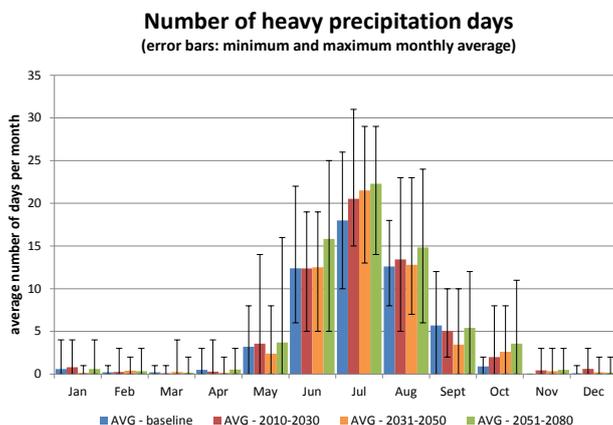
Figure 7.1.2.23: The number of heavy precipitation days is not expected to change much, with the exception of July, which is expected to see a gradual increase from 2010, and June in the long term. Annual and periodic variation in number of heavy precipitation days will remain about the same.

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
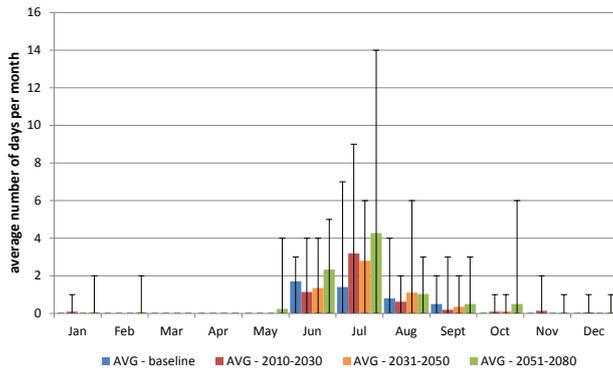
Figure 7.1.2.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, with the exception of an increase in July although variation within projection periods far outweighs the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
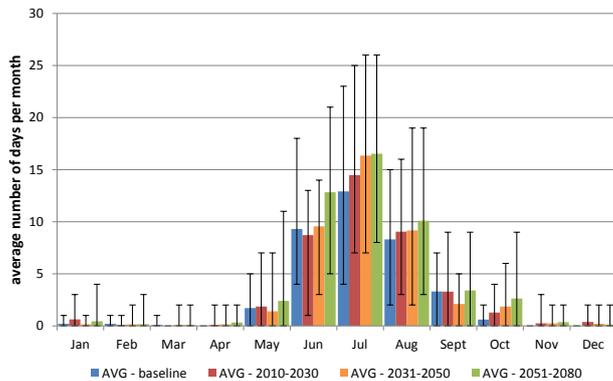
Figure 7.1.2.25: Similar to the previous graphs, the number of wet days per month will see a gradual increase in July, but otherwise remain roughly the same to today's occurrence.

Number of very wet days
(error bars: minimum and maximum values)
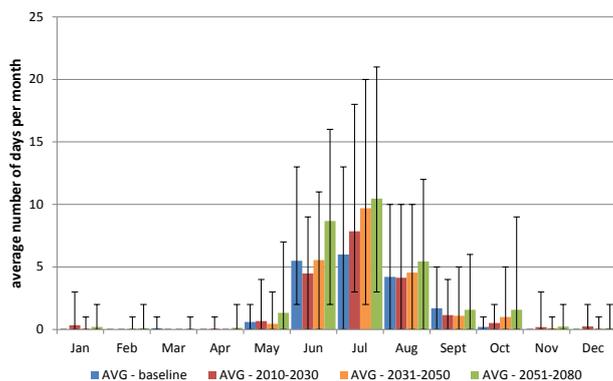
Figure 7.1.2.26: As in the figure above, the number of very wet days per month will see a gradual increase in July although with greater variations within projection periods than between projection periods.

Number of extremely wet days
(error bars: minimum and maximum values)
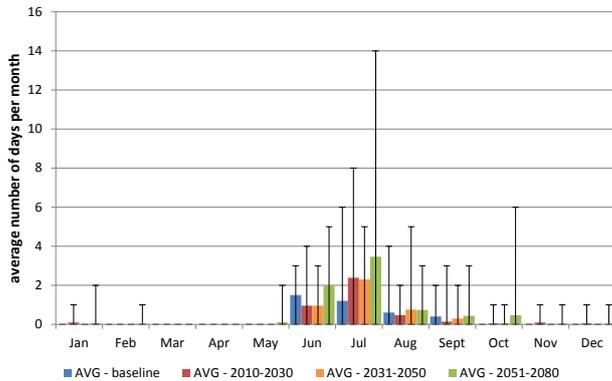
Figure 7.1.2.27: As in the figure above, the number of extremely wet days per month will see a gradual increase in July, although with greater variations within projection periods than between projection periods.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
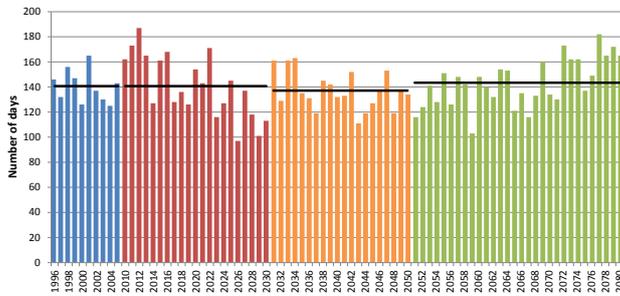
Figure 7.1.2.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
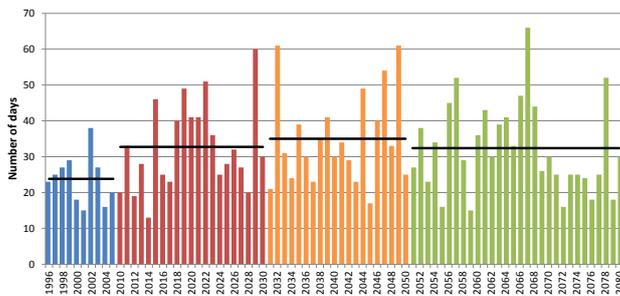
Figure 7.1.2.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase. This corresponds with figure 7.1.2.21, which indicated a slight decrease in precipitation during the dry period.

Simple Daily Intensity Index
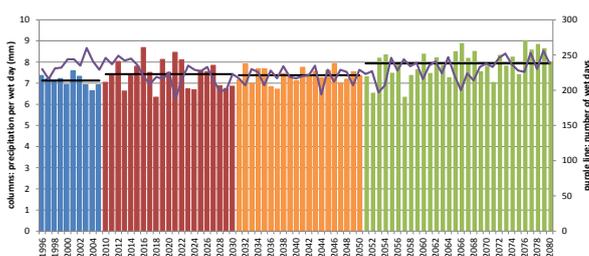
Figure 7.1.2.30: The amount of precipitation on wet days is projected to increase slightly for 2010-2030 and again for 2050-2080. At the same time, the number of wet days is set to remain about the same, confirming above figures showing increased precipitation during the monsoon.

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)
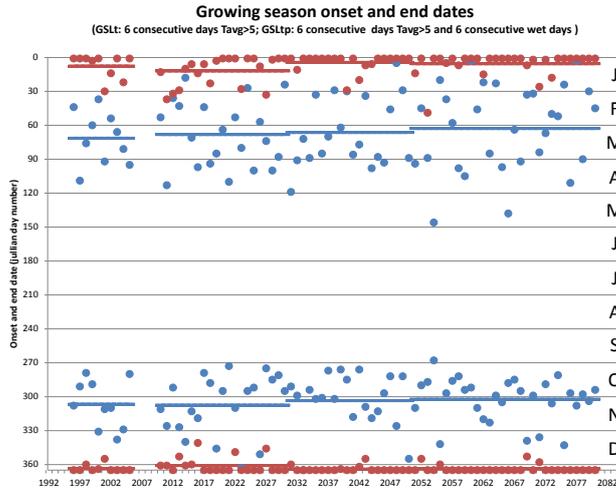
Figure 7.1.2.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations but onset and end remain on average the same.

Average growing season duration
(error bars: minimum and maximum extremes)
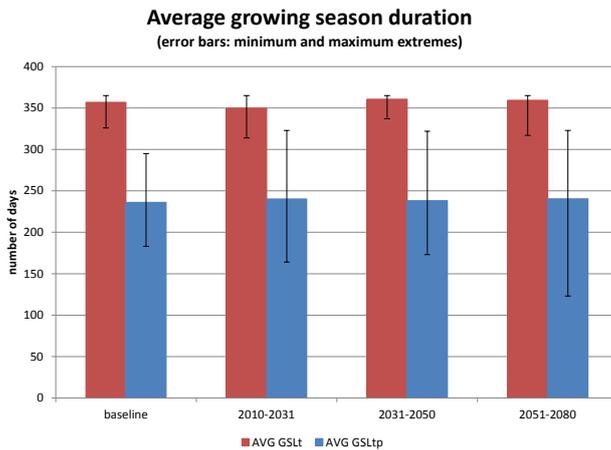
Figure 7.1.2.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms above figure: Variations in onset and end make the precipitation dependent growing season duration vary a lot currently and even more in the future, while the average duration remains the same as today's. The precipitation independent growing season remains constant, year-round.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
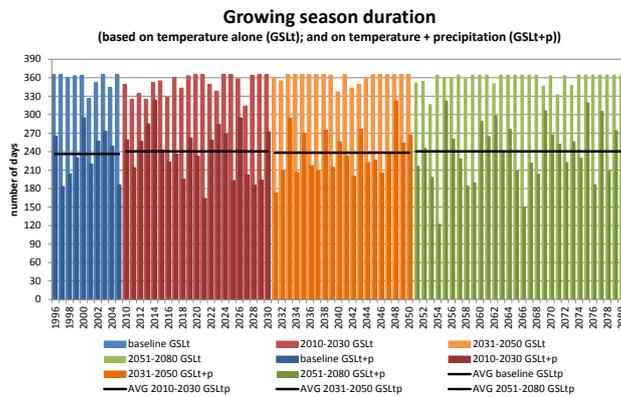
Figure 7.1.2.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the variation in duration of the precipitation dependent growing season especially increases from 2050 onward.

73

7.1.3 Domain 3
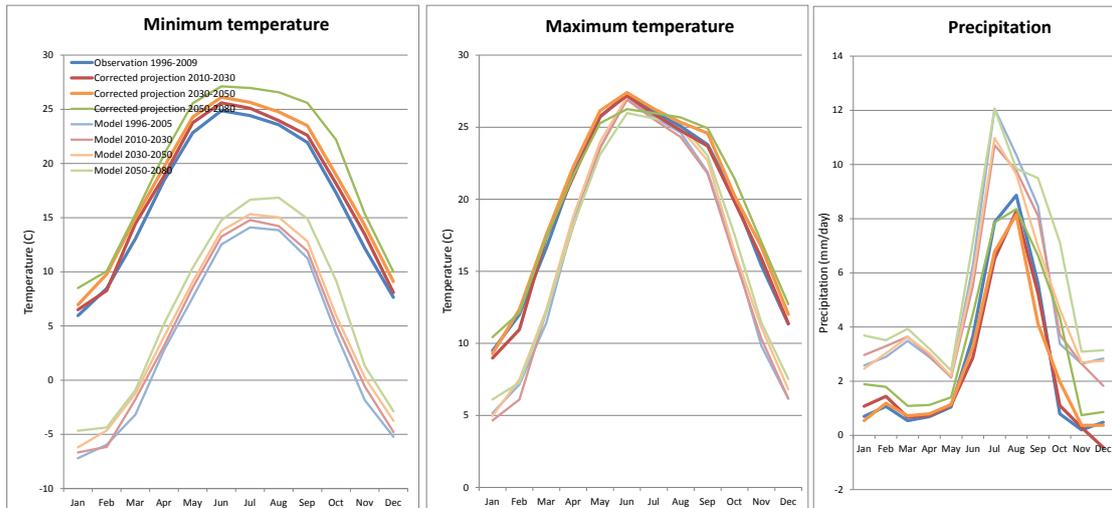
Figure 7.1.3.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, with a greater difference for minimum temperature results. Precipitation is overestimated both outside and during the rainy season.
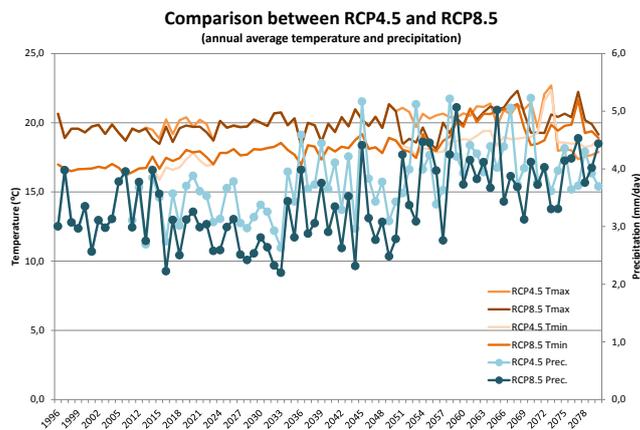
Figure 7.1.3.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a drier short- and mid-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
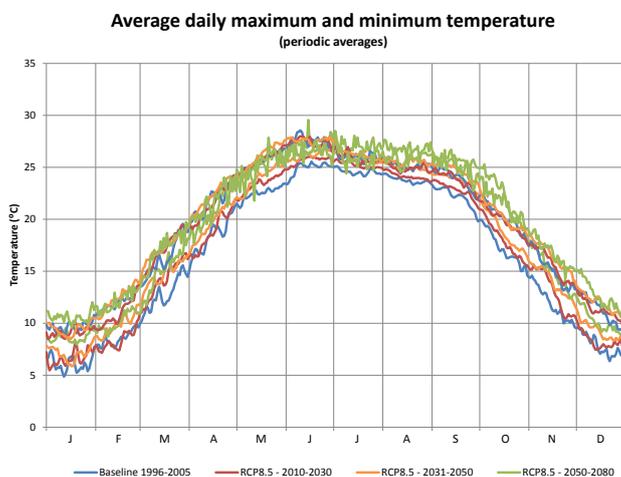
Temperature

Figure 7.1.3.2a: Average daily minimum and maximum temperatures are very similar in this domain. The average minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 2-3 degrees. The average daily maximum is projected to increase only a little, especially outside the monsoon period.
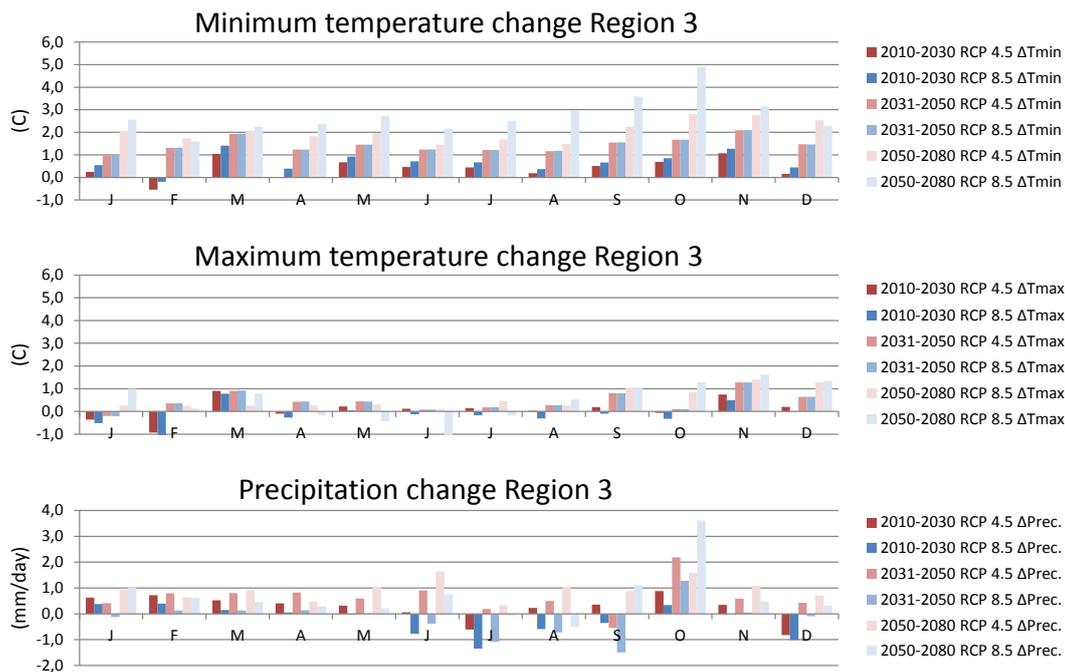
Figure 7.1.3.2b: Minimum (night-time) temperature change is projected to be 3-4 times higher than projected maximum (day-time) temperature change. Most warming takes place during the night, during October and through the winter months, and on the long term. RCP8.5 scenarios projects higher minimum temperatures (warmer nights) but lower maximum temperatures (colder days) than RCP4.5 on the short term (2010-2030). There is no difference for the mid-term (2030-2050) between the two scenarios, both projecting increased warming, and RCP8.5 projects more warming than RCP4.5 for the long term (2050-2080), with minimum temperatures reaching up to on average 4,9**°**C increase in October, and an increase of day-time temperatures with 0,5**°**C. Precipitation is projected to change especially for October (wetter) and July-September and December (drier).

Figure 7.1.3.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080. This figure suggests that variation in extreme temperatures will not increase beyond today's variation.
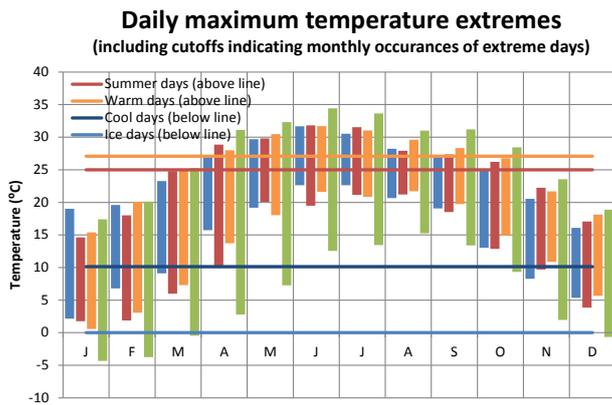
Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)

Figure 7.1.3.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, with some increase in June, but is projected to increase for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate a slight increase (bar above line) of warm days notably in August-September, as well as for the long term (2050-2080) and an increase in cool days (bar below line) especially during February-March and for 2050-2080.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)

Figure 7.1.3.5: The daily minimum (night-time) temperature range is projected to increase compared to today's variation, especially from February-August already from 2010. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during monsoon, indicating more and warmer night-time temperatures that time of year. Frost nights and cool nights will remain about the same as today.

Summer days
(count of days when Tx>25°C)

Figure 7.1.3.6: The annual number of days above 25^{0}C is projected to increase from on average 100 (1996-2005) to 120 (2050-2080). The annual variation increases a bit and is larger than the projected change between periods.

Warm days
(count of days when Tx>90th percentile of baseline)
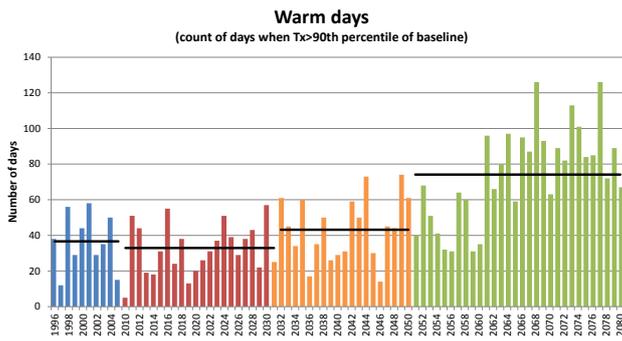
Figure 7.1.3.7: The annual number of warm days will increase especially towards 2050-2080, with a doubling of today's number of warm days. The largest change will take place after 2050. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20ºC)
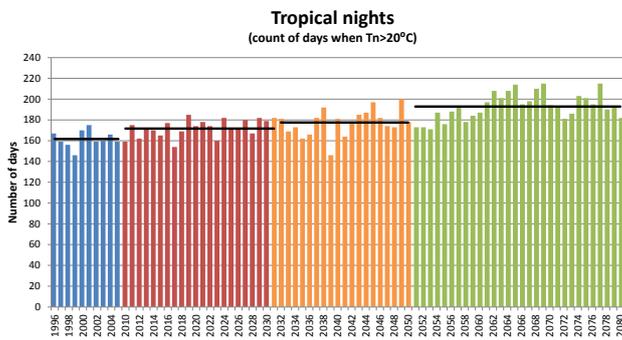
Figure 7.1.3.8: In line with figure 7.1.3.5, the annual number of tropical nights will increase, but this figure however also shows that substantial year-to-year differences will persist towards 2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
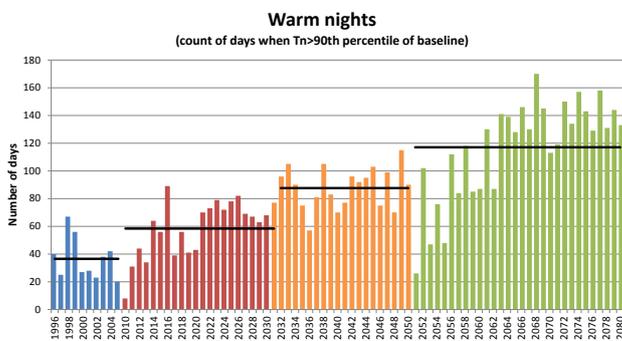
Figure 7.1.3.9: The number of warm nights will also increase drastically. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
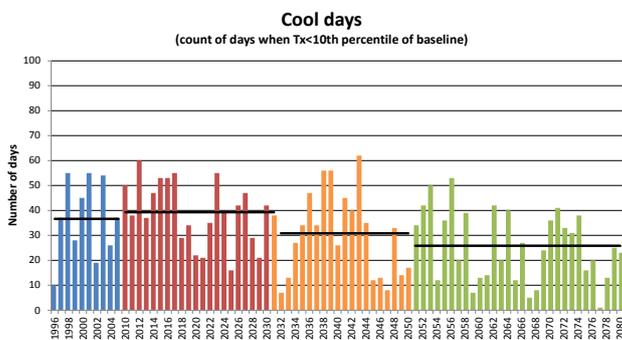
Figure 7.1.3.10: In apparent contrast with figure 7.1.3.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.
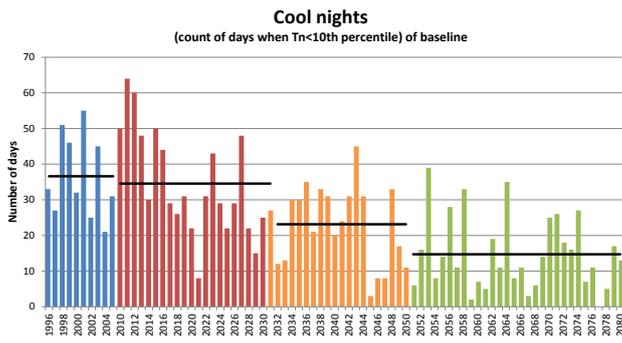
Figure 7.1.3.11: The number of cool nights will also decrease significantly on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.
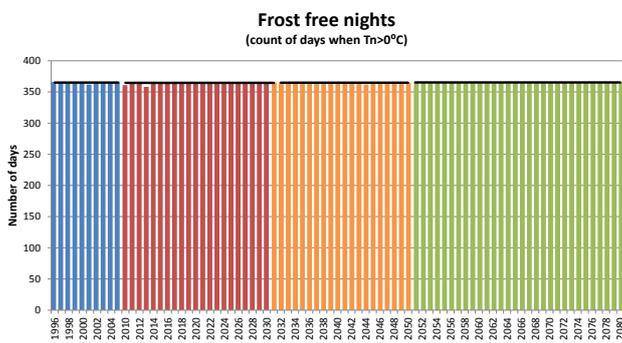
Figure 7.1.3.12: In line with figure 7.1.3.5, the number of frost (free) nights remains approximately the same.
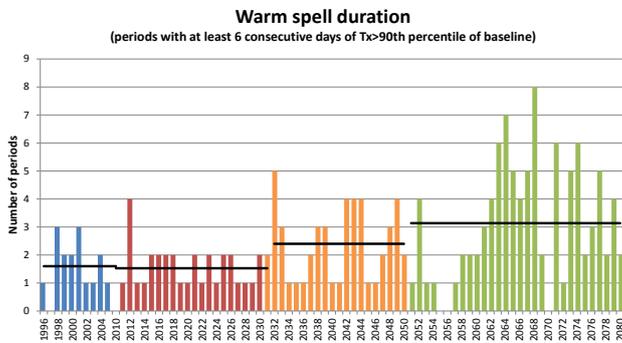
Figure 7.1.3.13: The number of warm spells per year will increase slowly, but especially towards 2050-2080. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase significantly.
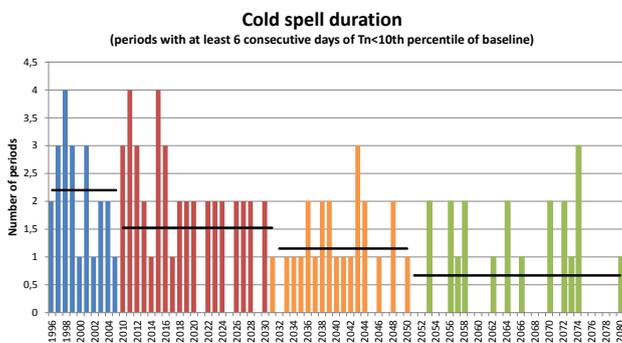
Figure 7.1.3.14: The number of cold spell periods per year will decrease. Although these currently only count just above 2, they are set to fall to below 1 spell per year. Still, there will be annual variations.

78

Precipitation and Monsoon timing

Annual total precipitation
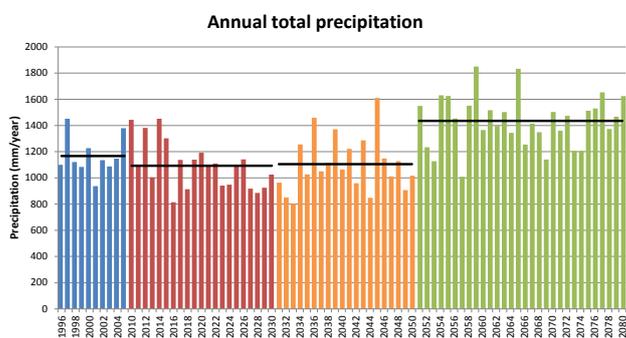
Figure 7.1.3.15: The annual total amount of precipitation is projected to remain approximately constant, perhaps slightly increase towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.3.18-27).

Annual number of heavy precipitation days
(days with precipitation>10mm)
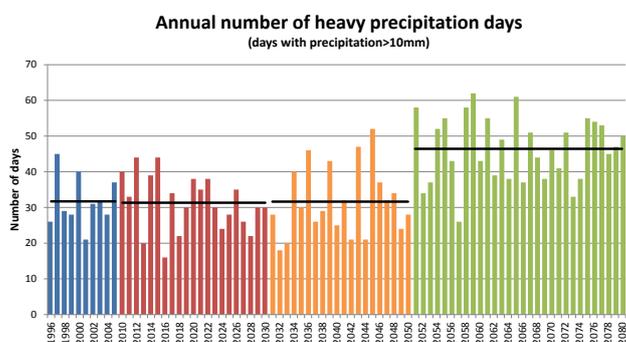
Figure 7.1.3.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.3.18-27).

Annual number of very heavy precipitation days
(days with precipitation>20mm)
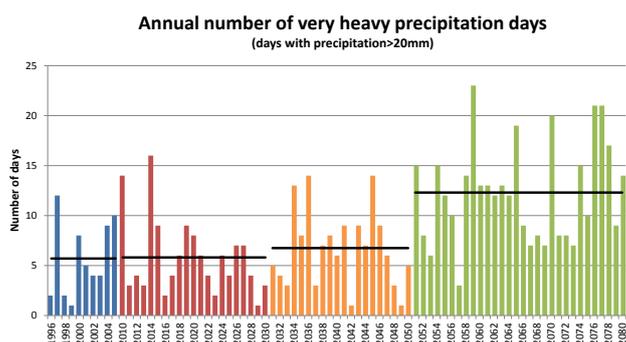
Figure 7.1.3.17: As in the former figure, the annual number of very heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.3.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)
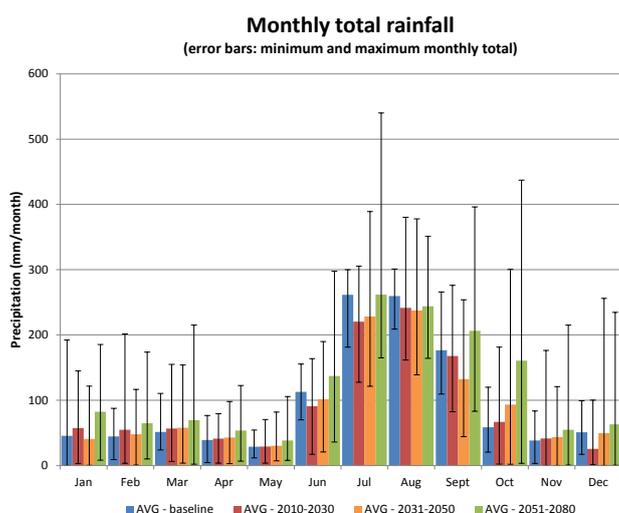
Figure 7.1.3.18: Monthly total rainfall may increase a bit for the dry period, while October will see a gradual increase and July a decrease already from 2010. This suggests that there will be a bit more rainfall during dry period but especially the post-monsoon. Error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large, and also larger than the change between periods.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
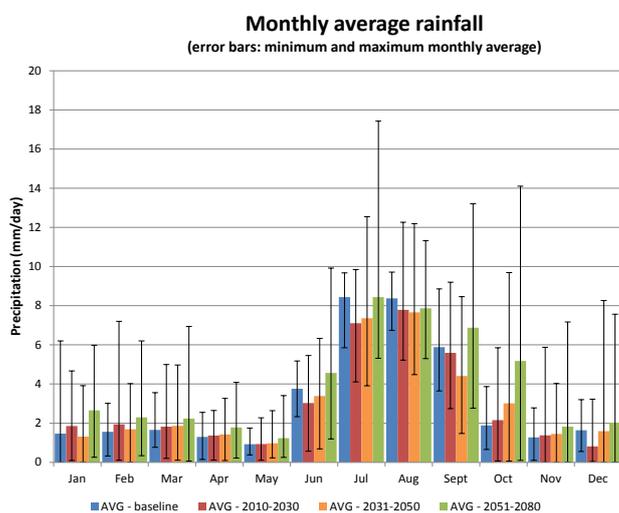
Figure 7.1.3.19: As in the figure above, monthly average rainfall will increase slightly for the dry period, but again especially October is projected to see an increase and July a decrease from 2010. Again, this suggests that there will be more rainfall during the dry period and the post-monsoon, but with large inter-annual variations especially for the wet months.

Average and extreme daily precipitation
(periodic averages and extremes)
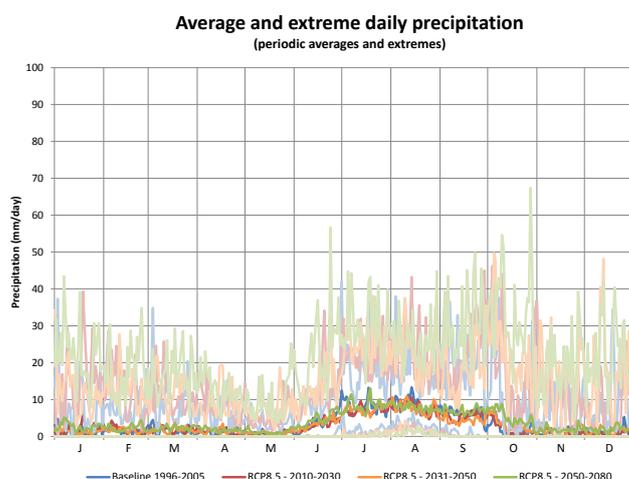
Figure 7.1.3.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations remain as large as they are today, larger than any shift in rainfall between periods.

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
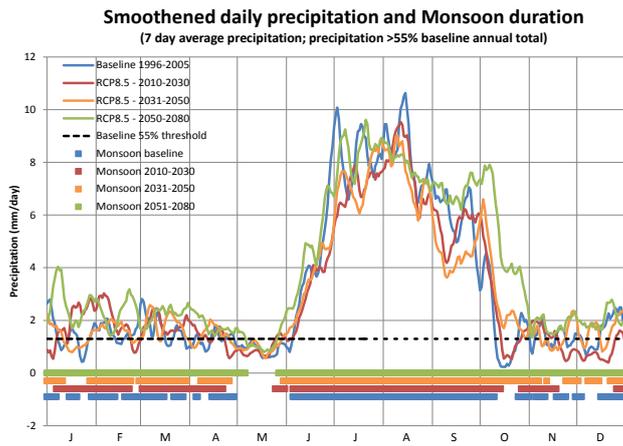
Figure 7.1.3.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.3.18-19, precipitation may increase a bit for the dry period, while July and September (drier on short term) and October (wetter) will see the largest changes. There will be a continued variation in monsoon onset, with a tendency to earlier onsets over time. During the monsoon, there will be a decreased rainfall per day, and the end of monsoon remains the same on the short term but may be extended to the end of October towards 2050-2080. Precipitation during the dry period becomes more variable both in the short and long term. It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation
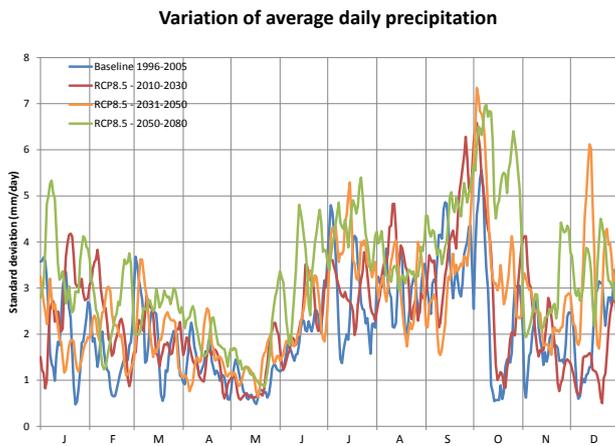
Figure 7.1.3.22: This figure indicates that the daily variation is large both during the wet period and the dry period of the year, and projected changes in precipitation may increase especially during the winter months and during the post-monsoon in October.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
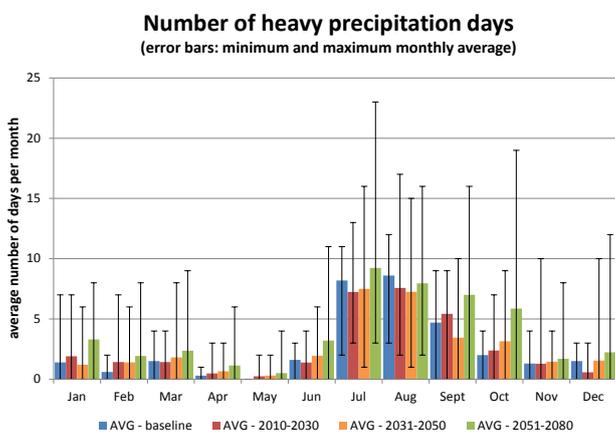
Figure 7.1.3.23: The number of heavy precipitation days is not expected to change much, with the exception of an increase in September-October on the long term. Annual and periodic variation in number heavy precipitation days will remain about the same.

81

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
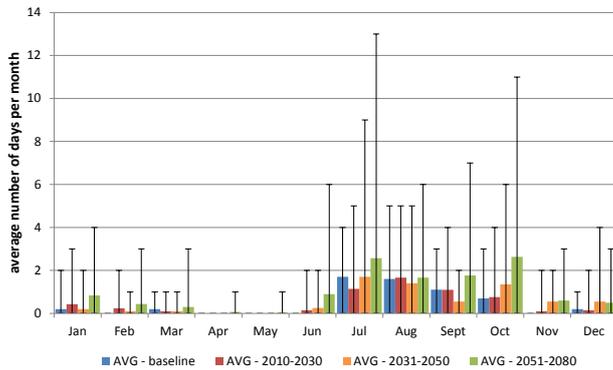
Figure 7.1.3.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, perhaps with the exception of a small increase in September-October, although variation within projection periods far outweigh the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
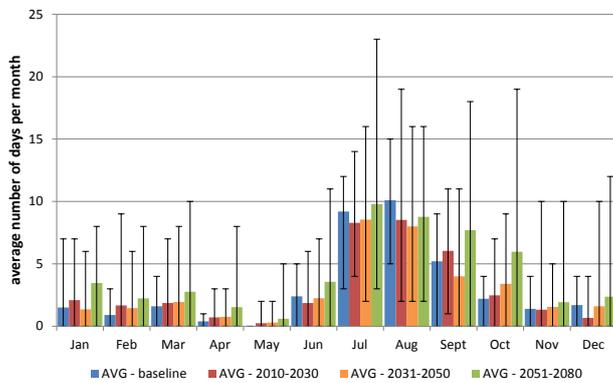
Figure 7.1.3.25: Similar to the previous graphs, the number of wet days per month will see a gradual increase in September-October, but otherwise remain roughly the same to today's occurrence.

Number of very wet days
(error bars: minimum and maximum values)
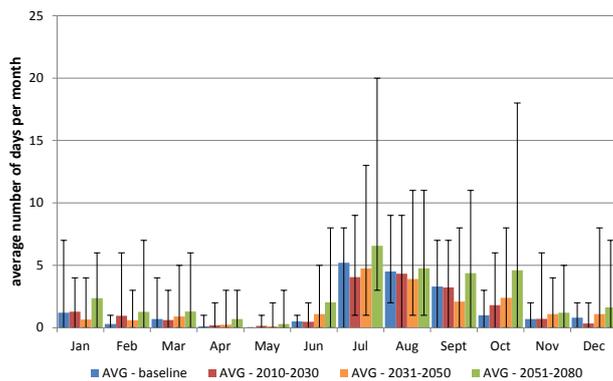
Figure 7.1.3.26: The number of very wet days per month will see a small increase in July, and September-October, although with greater variations within projection periods than between projection periods.

Number of extremely wet days
(error bars: minimum and maximum values)
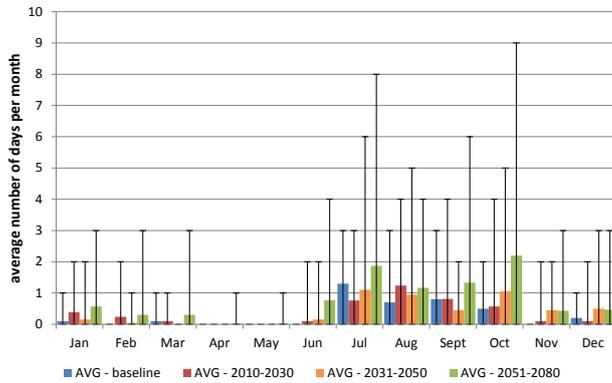
Figure 7.1.3.27: As in the figure above, the number of extremely wet days per month will see a small increase in July, and September-October, although with greater variations within projection periods than between projection periods.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
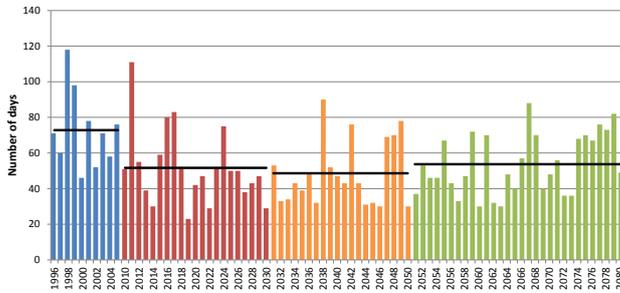
Figure 7.1.3.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to decrease already from 2010, suggesting a shortening of the monsoon.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
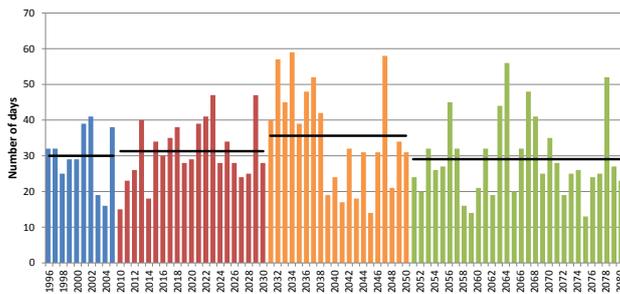
Figure 7.1.3.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to remain about the same.

Simple Daily Intensity Index
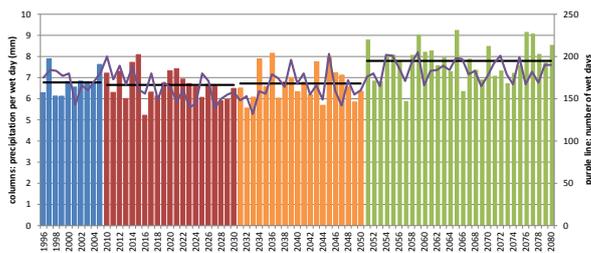
Figure 7.1.3.30: The amount of precipitation on wet days is projected to increase slightly for 2050-2080. At the same time, the number of wet days is set to remain about the same, confirming above figures showing similar total but decreased daily precipitation for the monsoon period, spread over a slightly longer period towards 2050.

Growing season
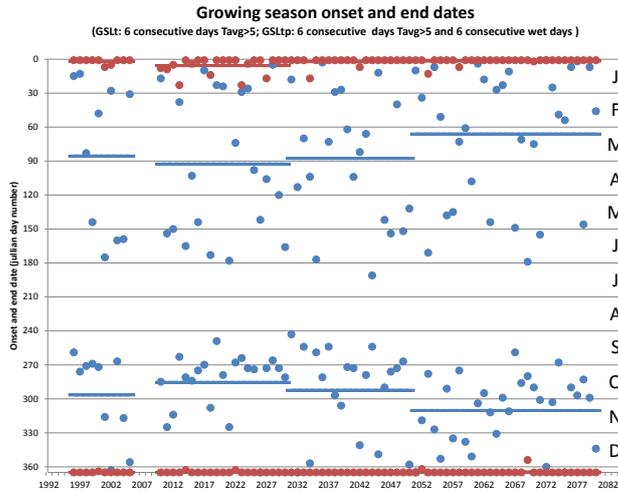
Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)
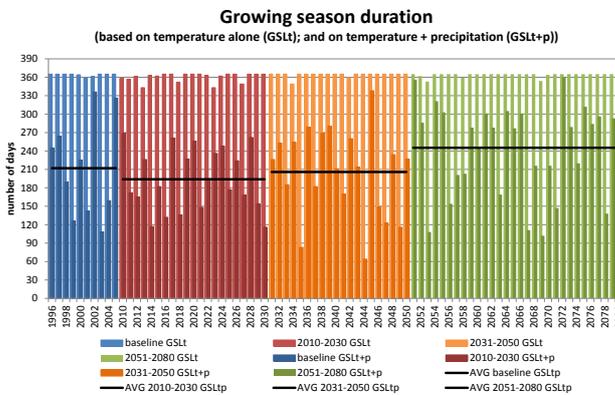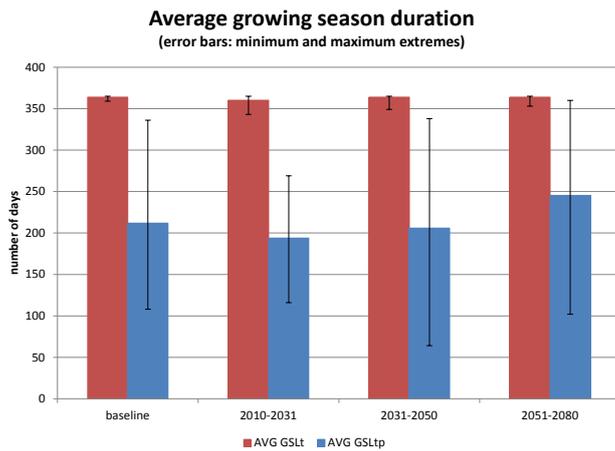
Figure 7.1.3.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations and on average starts (top) and ends (bottom) approximately the same

as today until 2050, after which the season increases.

Average growing season duration
(error bars: minimum and maximum extremes)

Figure 7.1.3.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: The precipitation independent growing season remains constant, year-round. The average duration of the precipitation dependent growing season increases from 2050 onward, while its duration varies a lot especially from 2030 onward.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))

Figure 7.1.3.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the longer duration of the precipitation dependent growing season from 2050 onward is caused by more, longer duration seasons, while annual variations also increase.

84

7.1.4   Domain 4
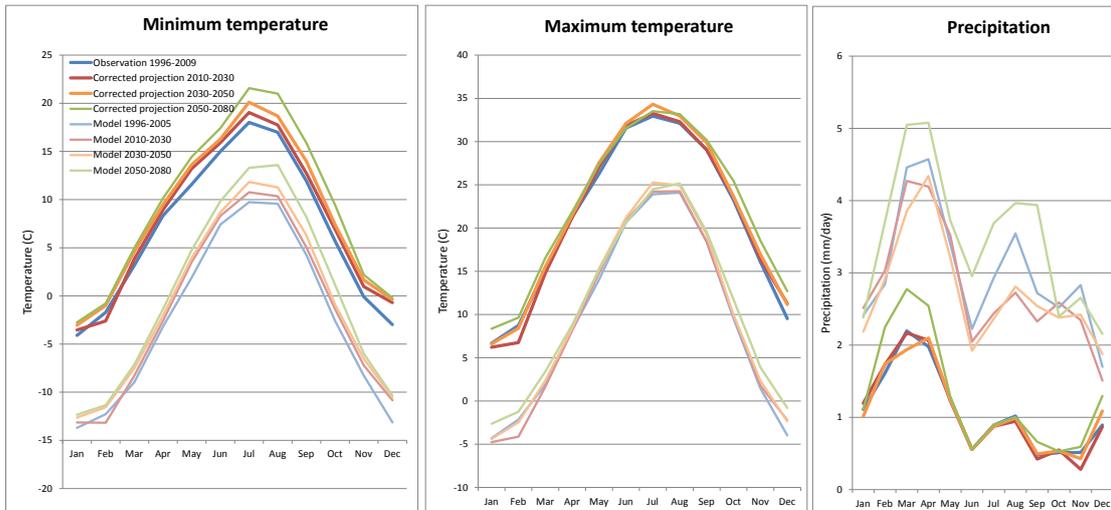
Figure 7.1.4.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature with about ten degrees throughout the year. Precipitation is overestimated at all times, outside as well as during the rainy season.
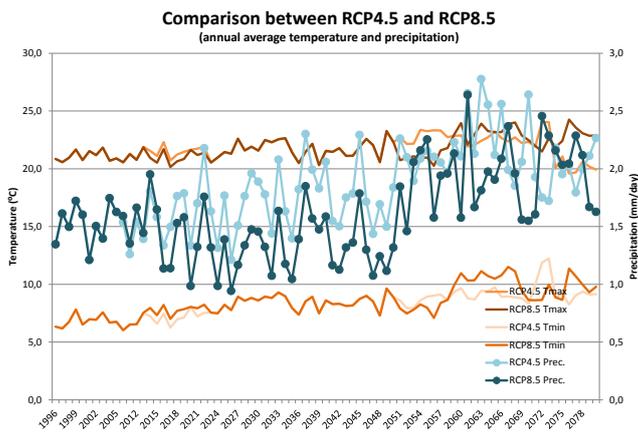
Figure 7.1.4.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a drier short- and mid-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
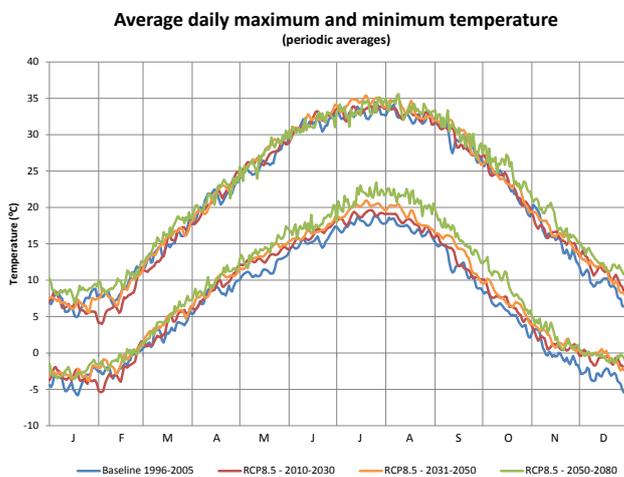
Temperature

Figure 7.1.4.2a: This figure indicates that the temperature increase in this domain is very limited. The average daily minimum temperature is projected to increase gradually throughout the year towards 2080, especially during the summer months, with up to 3-4 degrees. The average daily maximum temperature is not projected to change much except for a slight increase outside the monsoon period.

Minimum temperature change Region 4

Maximum temperature change Region 4

Precipitation change Region 4
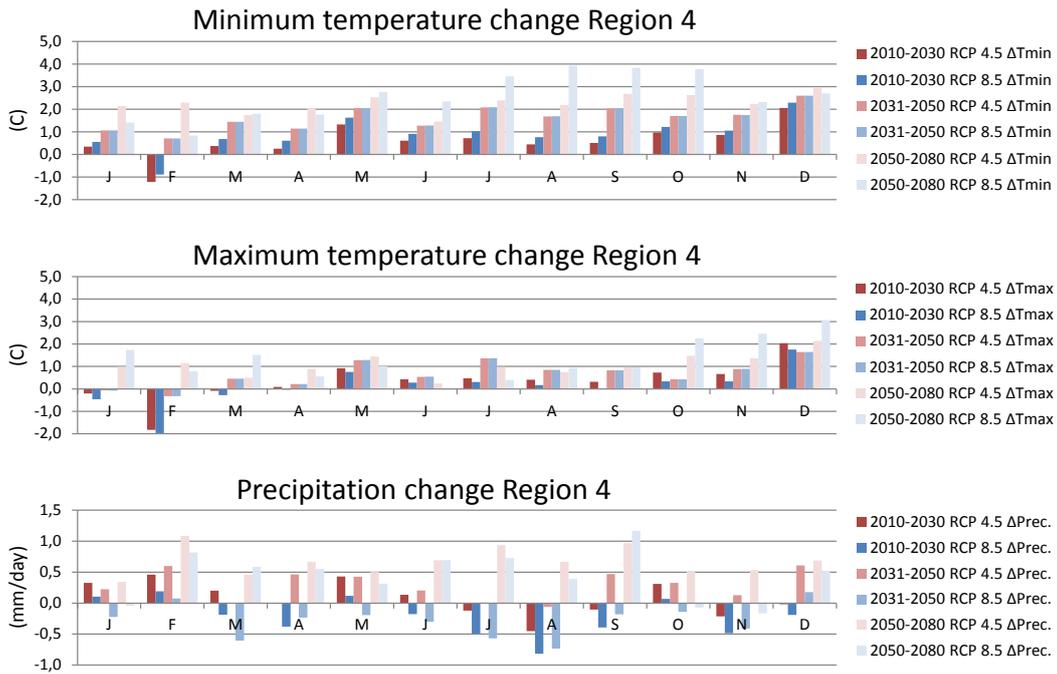
Figure 7.1.4.2b: Minimum (night-time) temperature change is projected to be about twice as much as the projected maximum (day-time) temperature change. Most warming takes place during the night, during December, May and from March through December on the mid- and long term. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods (safe for a higher night-time increase in RCP8.5 after 2050, with 3,5-4°C increase between July-October), but differ in precipitation projections: RCP8.5 projects an decrease in precipitation year-round until 2050, while RCP4.5 only projects a drier July-November until 2030, after which precipitation increases for all months onward.
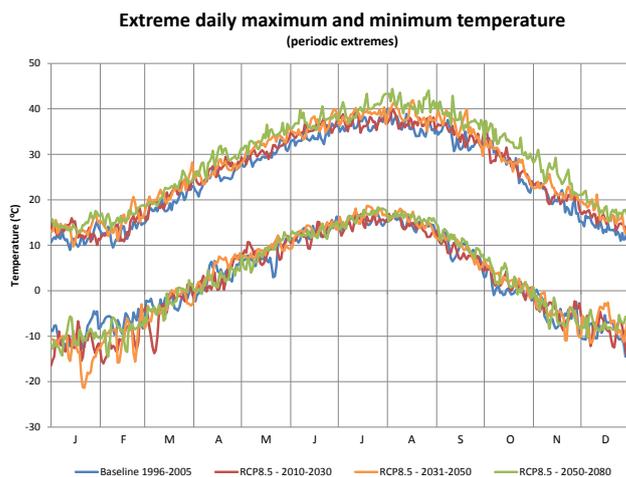
Figure 7.1.4.3: The lowest daily minimum temperatures (coldest nights) will remain about the same for all periods. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080, and mostly outside (after) the summer months. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

86

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
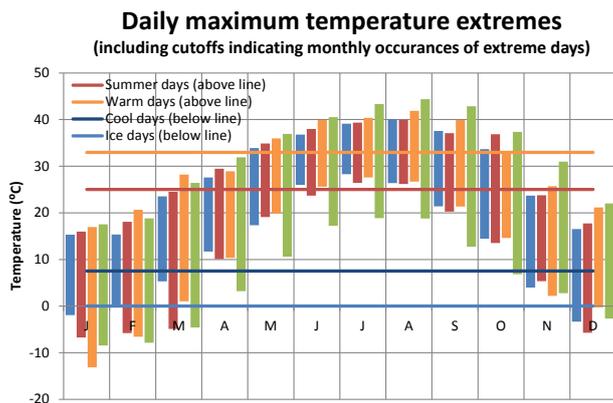
Figure 7.1.4.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, except for an increase in range in January-April, and a projected increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in May-June and September, as well as for the long term (2050-2080) and an increase in cool days (bar below line) from January-March from 2010 onward.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)
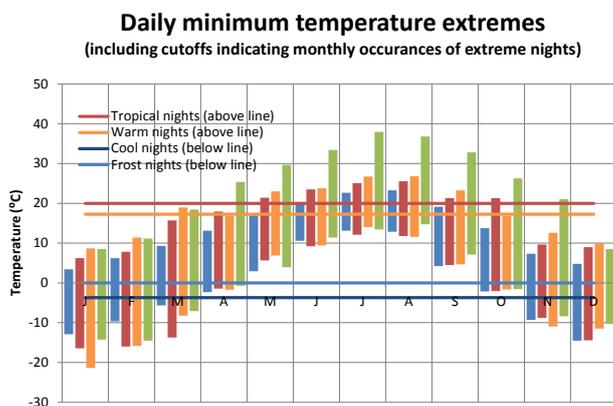
Figure 7.1.4.5: The daily minimum (night-time) temperature range is projected to increase compared to today's variation, already from 2010. Variation towards 2050-2080 increases drastically especially during April-November. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010, indicating more and warmer night-time temperatures at any time of year. Frost-and cool nights will decrease in December but increase between January-March.

Summer days
(count of days when Tx>25⁰C)
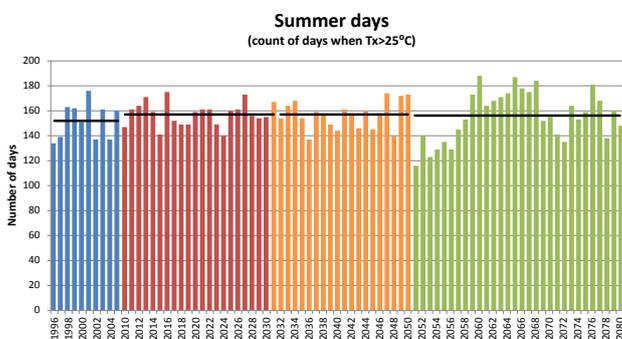
Figure 7.1.4.6: The annual number of days above 25^0C is projected to remain about the same, although the annual variation increases and is clearly larger than the projected change between periods.

Warm days
(count of days when Tx>90th percentile of baseline)
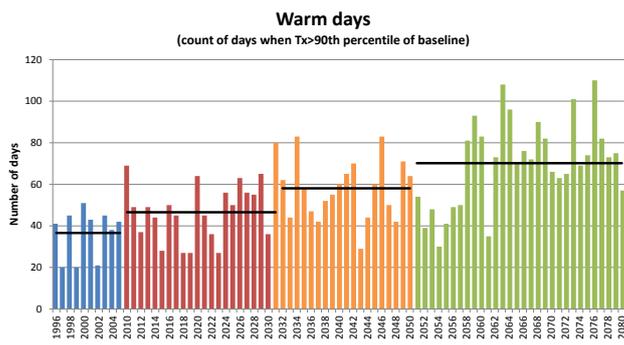
Figure 7.1.4.7: The annual number of warm days will increase gradually, especially towards 2050-2080, approximating a doubling of today's number of warm days. Already in 2030-2050 the number of warms days will increase with 20 more compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
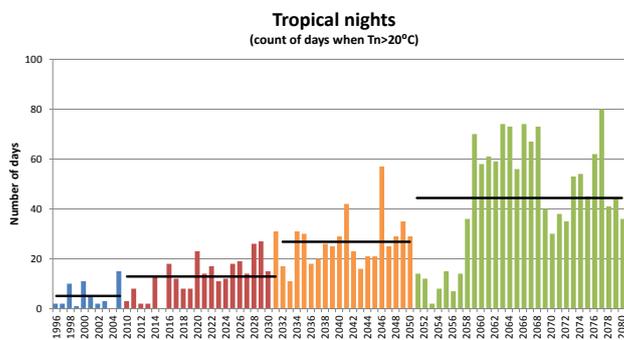
Figure 7.1.4.8: In line with figure 7.1.4.5, the number of tropical nights will increase, especially towards 2050-2080. This figure however also shows that substantial year-to-year differences will persist towards 2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
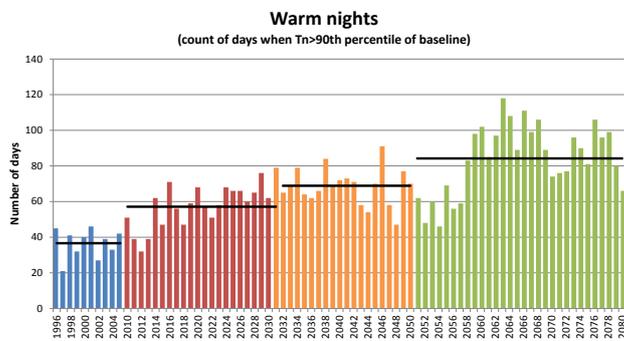
Figure 7.1.4.9: The number of warm nights will also increase drastically. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
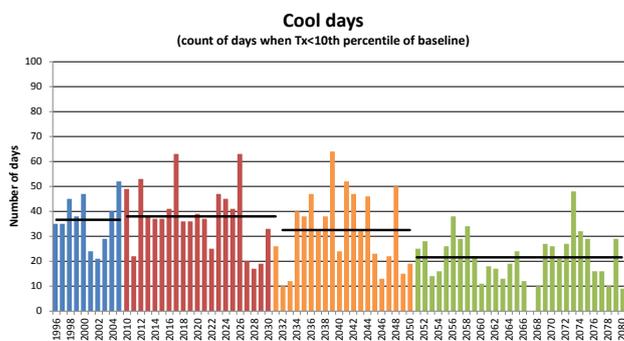
Figure 7.1.4.10: In apparent contrast with figure 7.1.4.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

Cool nights
(count of days when Tn<10th percentile) of baseline
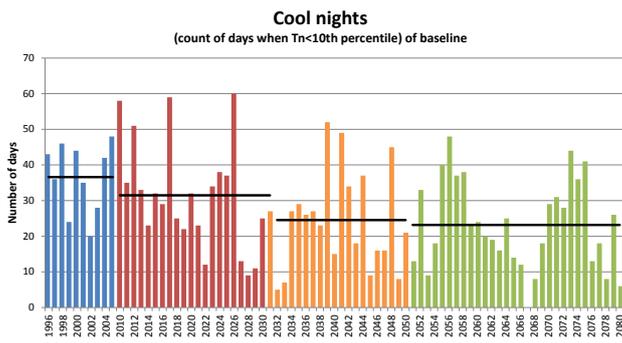
Figure 7.1.4.11: The number of cool nights will also decrease significantly on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.

Frost free nights
(count of days when Tn>0°C)
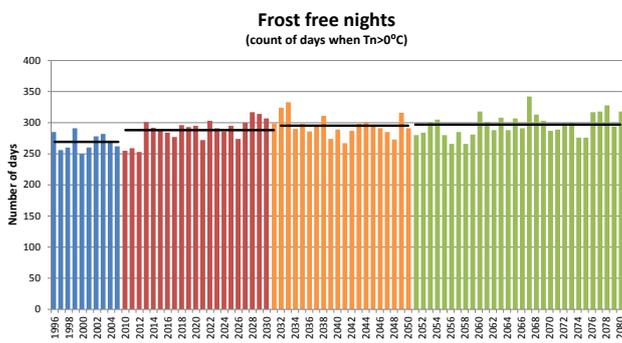
Figure 7.1.4.12: In line with figure 7.1.4.5, the number of frost free nights will increase a bit compared to the baseline period, especially from 2010, after which it remains more constant again.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
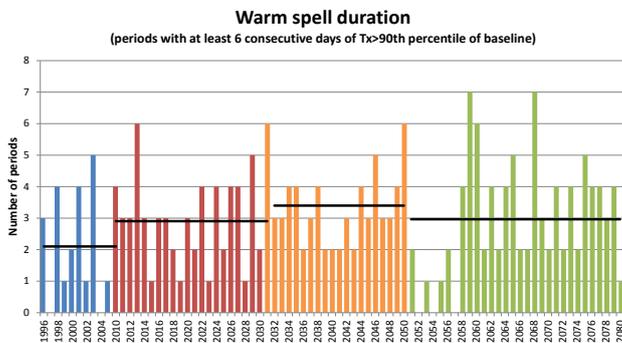
Figure 7.1.4.13: The number of warm spells per year will increase only slightly, and annual variation in number of warm spells is significantly larger than between period averages.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
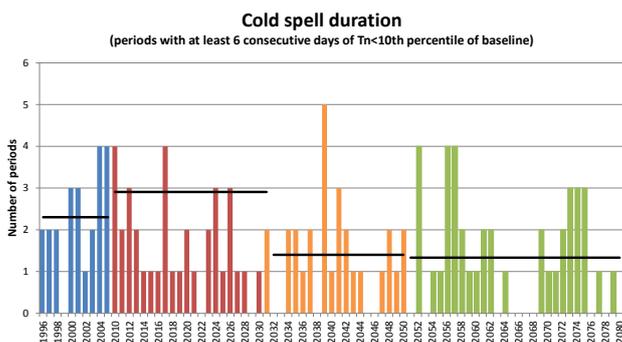
Figure 7.1.4.14: The number of cold spell periods per year will decrease. Although these currently only count just above 2, they are set to fall to around 1 spell per year. Still, there will be annual variations.

89

Precipitation and Monsoon timing

Annual total precipitation
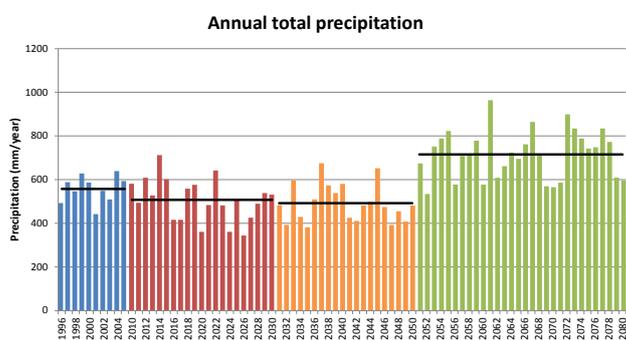
Figure 7.1.4.15: The annual total amount of precipitation is projected to remain approximately constant, perhaps slightly increase towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.4.18-27).

Annual number of heavy precipitation days
(days with precipitation>10mm)
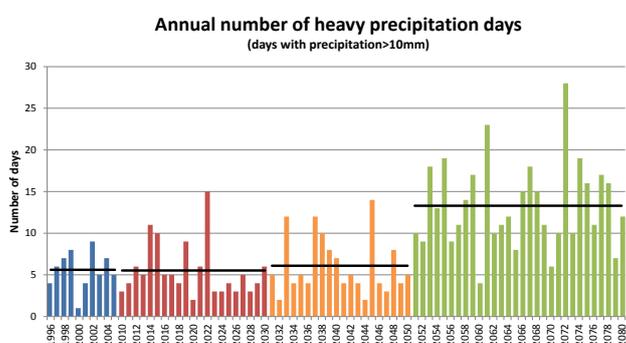
Figure 7.1.4.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation except after 2050. Again, the distribution over the year might change (see figures 7.1.4.18-27).

Annual number of very heavy precipitation days
(days with precipitation>20mm)
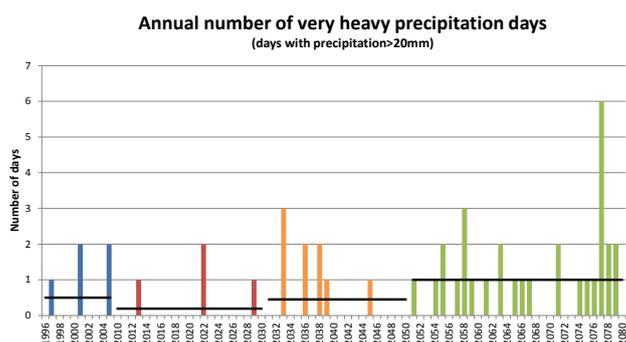
Figure 7.1.4.17: As in the former figure, the annual number of very heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.4.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)
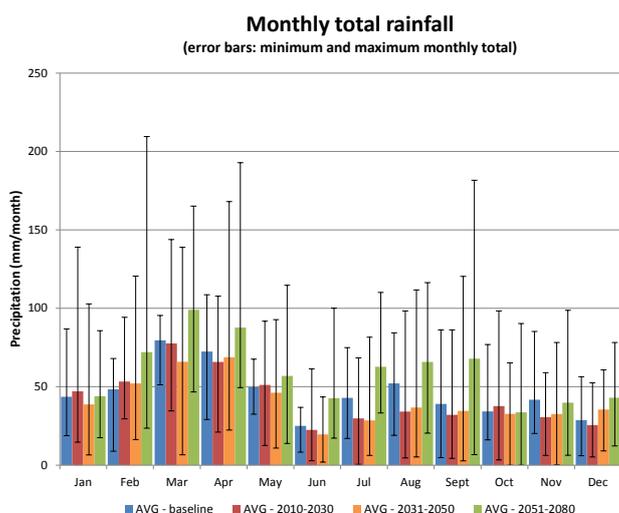
Figure 7.1.4.18: Monthly total rainfall will increase for most months on the longer term), but for the near term remain largely unchanged.

Error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large, and also larger than any change between periods.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
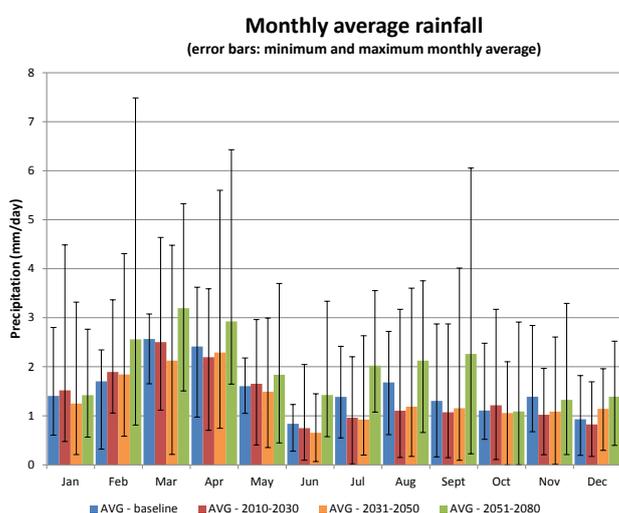
Figure 7.1.4.19: As in the figure above, monthly average will increase for most months on the longer term), but for the near term remain largely unchanged.

Error bars showing minimum and maximum monthly average indicate that inter-annual variations are large and increasing per period, indicating increasing variability from year to year.

Average and extreme daily precipitation
(periodic averages and extremes)
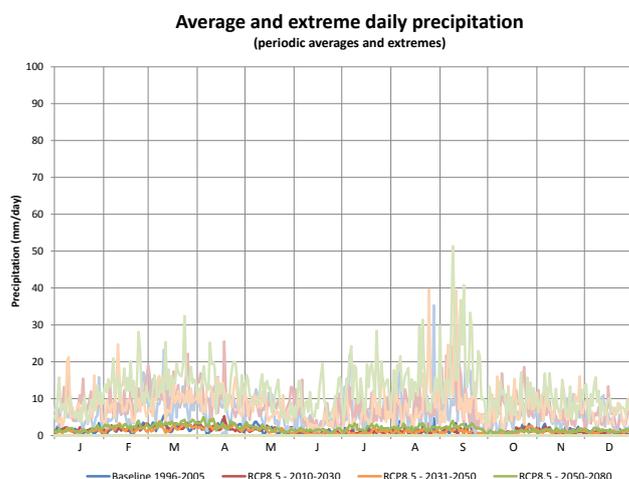
Figure 7.1.4.20: Average daily precipitation between periods shows a lot of overlap. This indicates that there will not be much change from day-to-day between periods. Annual variations on the other hand appear to increase from one period to the other, indicating that inter-annual variation increases in the future.

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
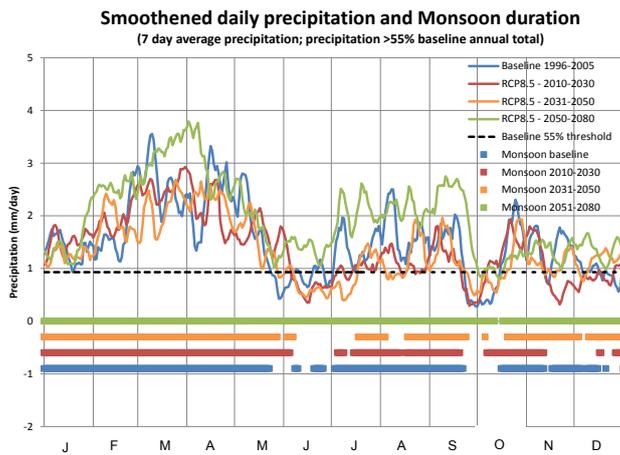
Figure 7.1.4.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly rainfall in figure 7.1.4.18-19, rainfall will increase for most months on the longer term, but for the near term remain largely unchanged. There is a tendency to later onsets of rainfall in July. It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation
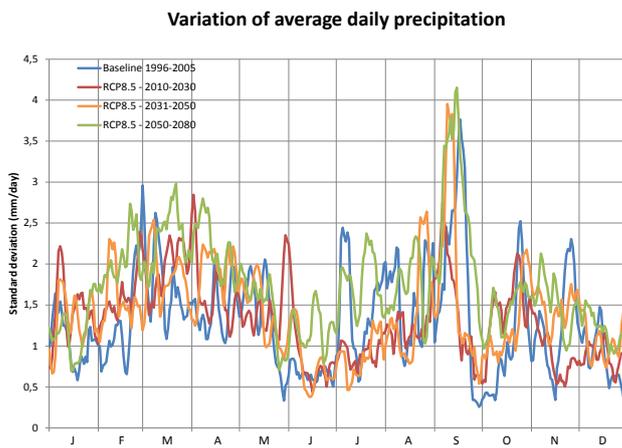
Figure 7.1.4.22: This figure indicates that the daily variation in precipitation remains about the same as today's variation at any time of year, with large variations especially during September.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
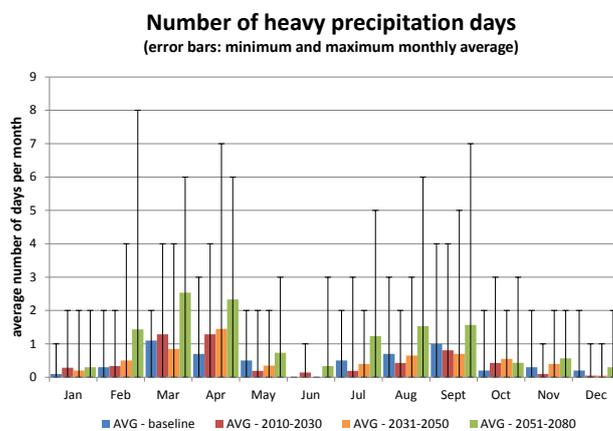
Figure 7.1.4.23: The number of heavy precipitation days is not expected to change much on the short term, but some increase is expected on the long term for February-April and July-September. Annual and periodic variation in number of heavy precipitation days will remain about the same, but increase for the long term predictions.

92

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
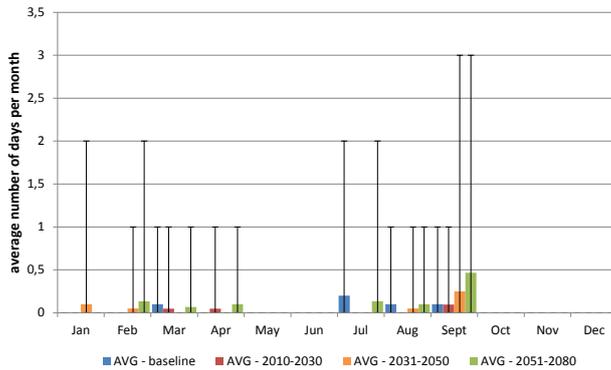
Figure 7.1.4.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, with the exception of a small increase in September for the long term. Variation within projection periods however far outweighs the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
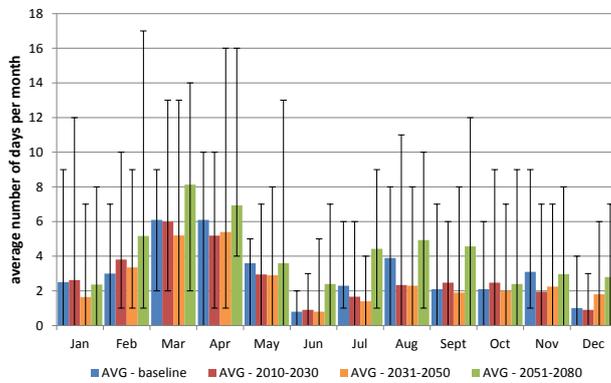
Figure 7.1.4.25: Similar to the previous graphs, the number of wet days per month will see some increase is on the long term for February-April and July-September, but otherwise remain roughly the same to today's occurrence.

Number of very wet days
(error bars: minimum and maximum values)
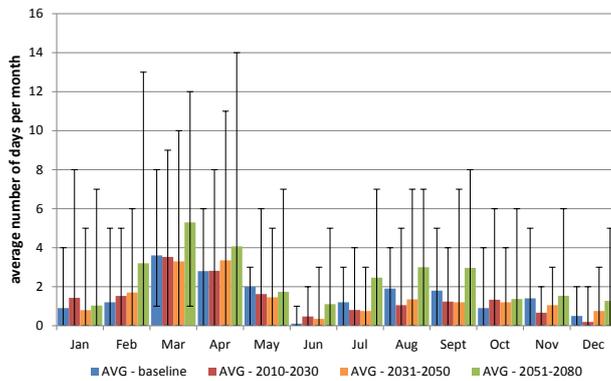
Figure 7.1.4.26: As in the figure above, the number of very wet days per month will see some increase is on the long term for February-April and July-September, although with greater variations within projection periods than between projection periods.

Number of extremely wet days
(error bars: minimum and maximum values)
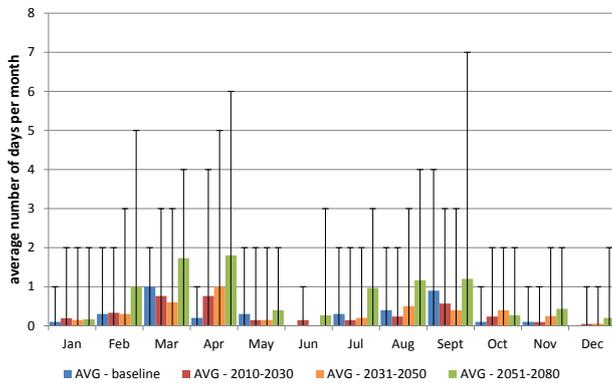
Figure 7.1.4.27: As in the figure above, the number of extremely wet days per month will see a small increase on the long term for February-April and July-September, although with greater variations within projection periods than between projection periods.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
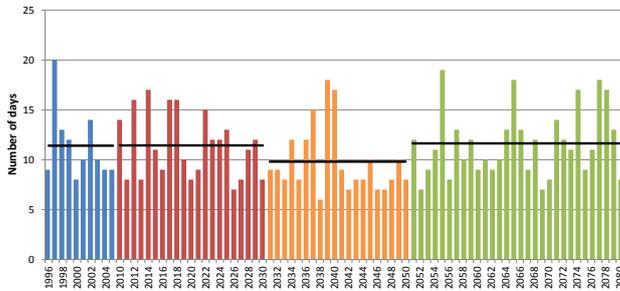
Figure 7.1.4.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
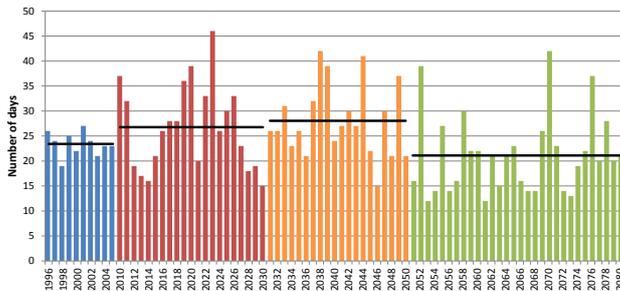
Figure 7.1.4.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase between 2010-2050, but decrease after 2050.

Simple Daily Intensity Index
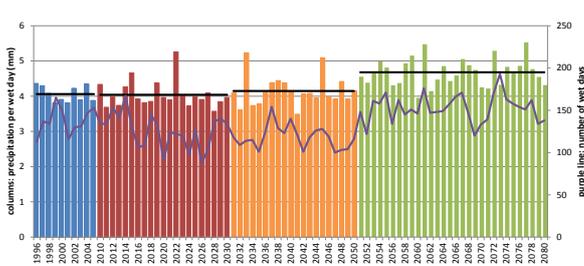
Figure 7.1.4.30: The amount of precipitation on wet days is projected to increase slightly for 2050-2080. At the same time, the number of wet days is set to increase a bit, indicating the same amount of precipitation per day but for more days towards 2050.

94
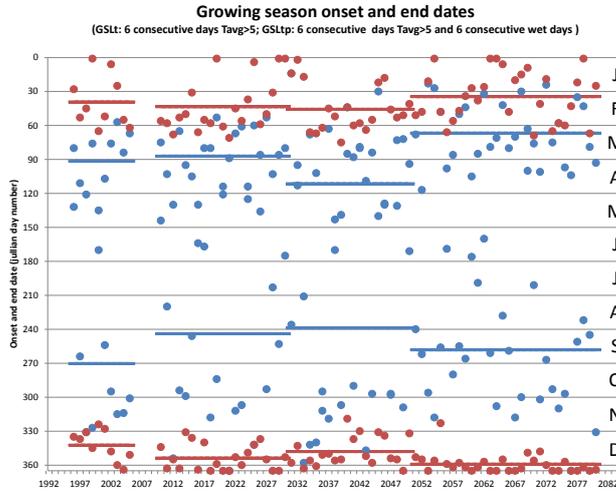
Growing season

Figure 7.1.4.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations, and on average initially decreases, but goes back to today's duration after 2050.
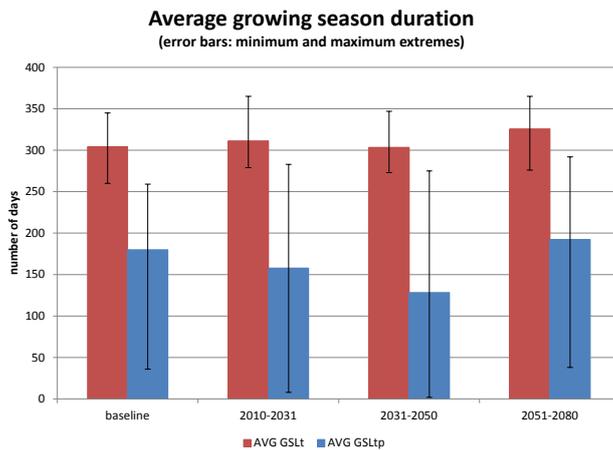
Figure 7.1.4.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: the precipitation dependent growing season shows great annual variations, and on average initially decreases, but goes back to today's duration after 2050, while the precipitation independent growing season remains constant, year-round.
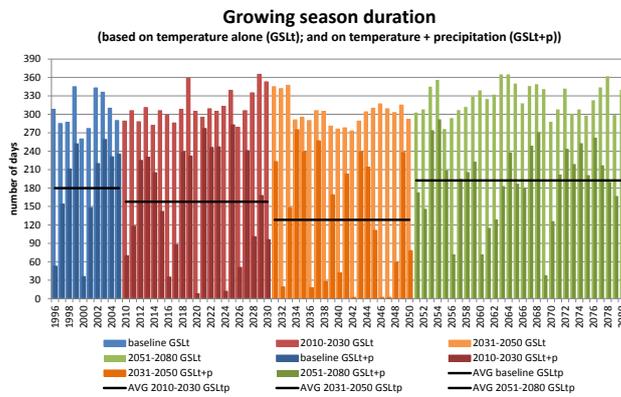
Figure 7.1.4.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the decreased duration of the precipitation dependent growing season between 2010 and 2050 is caused mainly by an increase in number of sudden short seasons rather than generally shorter seasons.

7.1.5 Domain 5
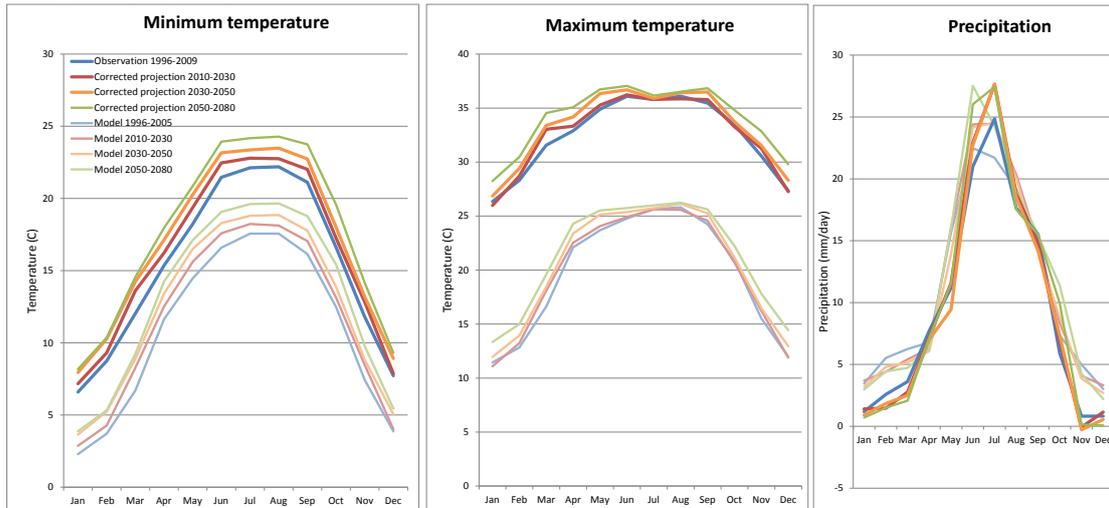
Figure 7.1.5.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, with a greater difference for maximum temperature results. Precipitation is overestimated outside the rainy season, while the model matches observed values quite well during the rainy season.
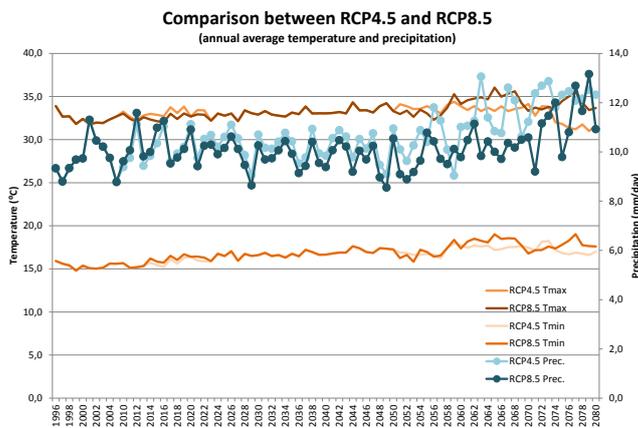
Figure 7.1.5.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a drier long-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
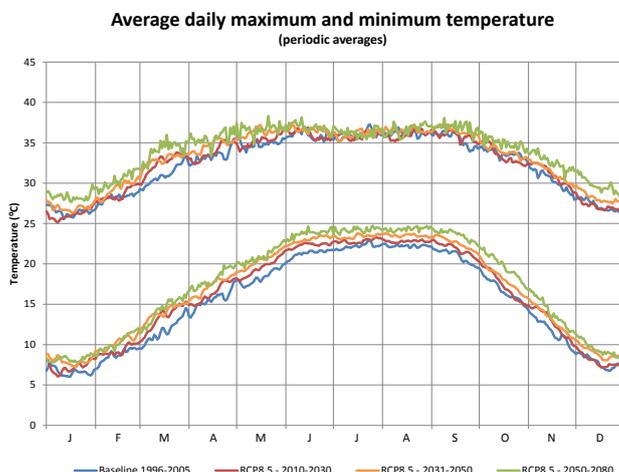
Temperature

Figure 7.1.5.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 2-3 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially between September and May, outside the monsoon period.
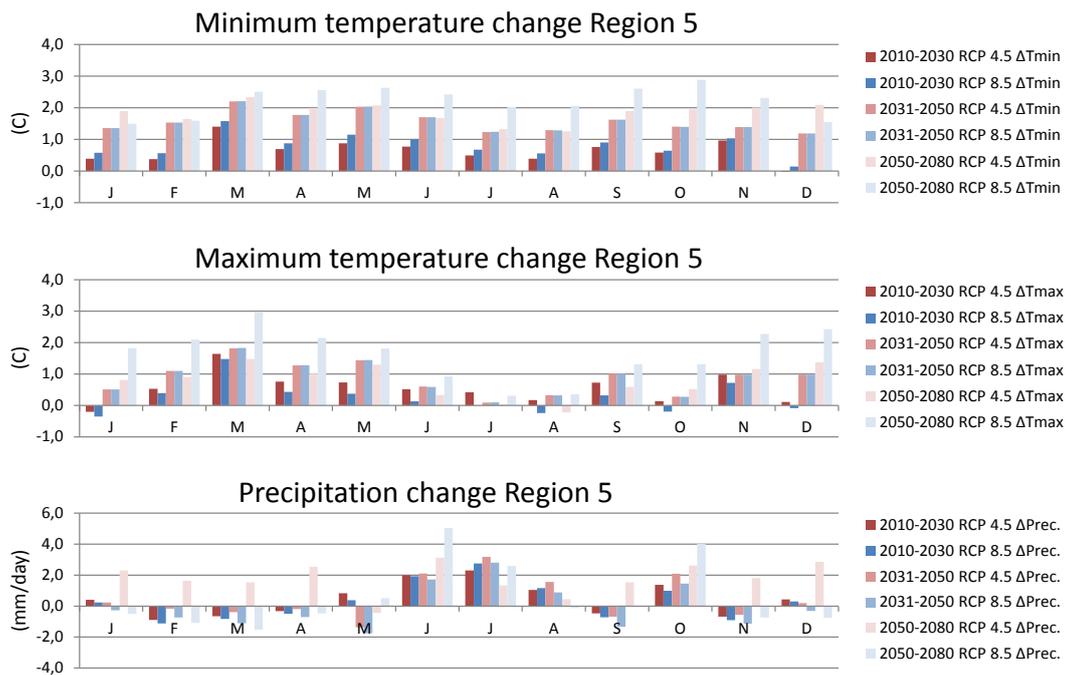
Figure 7.1.5.2b: Minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, especially on the short term. Most warming takes place during the night throughout the year already from 2010, with largest changes in March and October, but especially from 2030 onward throughout the year, mostly between March-May and September-October. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods but differ in precipitation projections after 2050: from this period, RCP8.5 continues to project a decrease in precipitation for most of the year except between June-October, while RCP4.5 projects an increase in precipitation year-round from then-on.
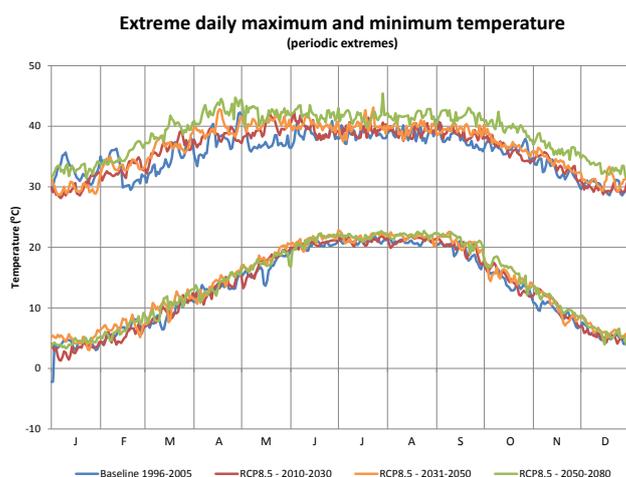
Figure 7.1.5.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080, mostly outside the monsoon season. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
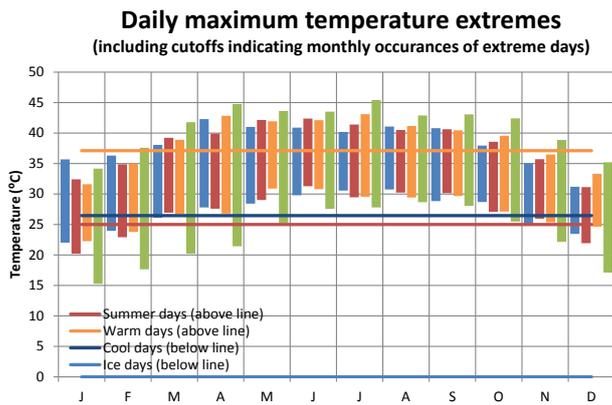
Figure 7.1.5.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, with some small increases or shifts at some times of year, but is projected to increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in May-July and October, as well as for the long term (2050-2080) and an increase in cool days (bar below line) for 2050-2080.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)
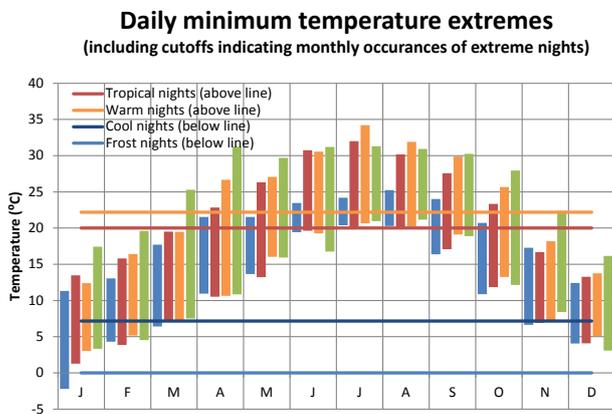
Figure 7.1.5.5: The daily minimum (night-time) temperature range is projected to increase compared to today's variation during February-August already from 2010, and a shift towards more warmer nights except in November-December from 2030. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 at all times except November-December, indicating more and warmer night-time temperatures throughout most of the year. Frost- and cool nights will remain the same or decrease gradually in January.

Summer days
(count of days when Tx>25ºC)
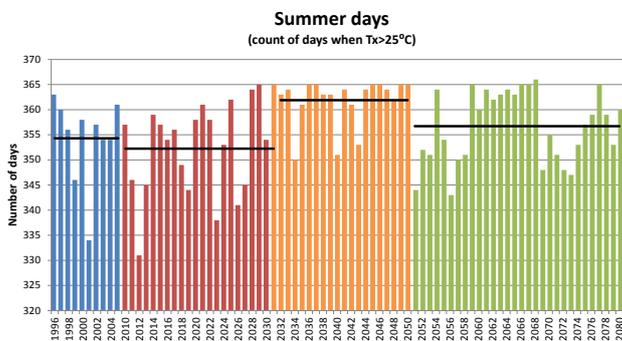
Figure 7.1.5.6: The annual number of days above 25^0C is projected to remain about the same. The annual variation remains large and is clearly larger than any projected change between periods.

Warm days
(count of days when Tx>90th percentile of baseline)
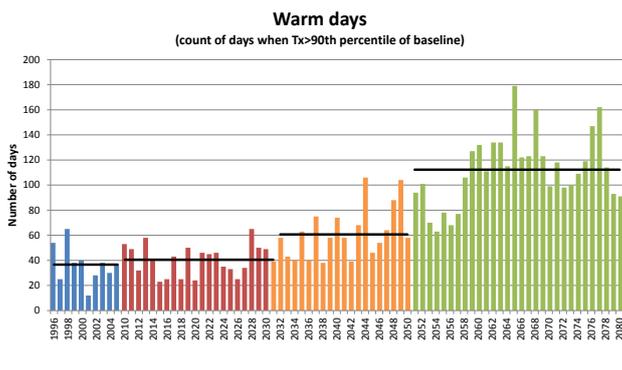
Figure 7.1.5.7: As suggested in figure 7.1.5.4, the annual number of warm days will increase especially towards 2050-2080, with almost a tripling of today's number of warm days. Already in 2030-2050 the number of warms days will increase with on average 20 more compared to today. This figure however also shows annual variations will persist.

Tropical nights
(count of days when Tn>20°C)
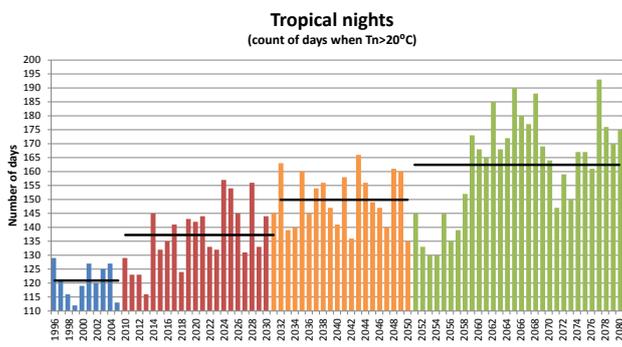
Figure 7.1.5.8: In line with figure 7.1.5.5, the number of tropical nights will also increase drastically already from 2010. This figure however also shows that substantial year-to-year differences will persist and even increase towards 2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
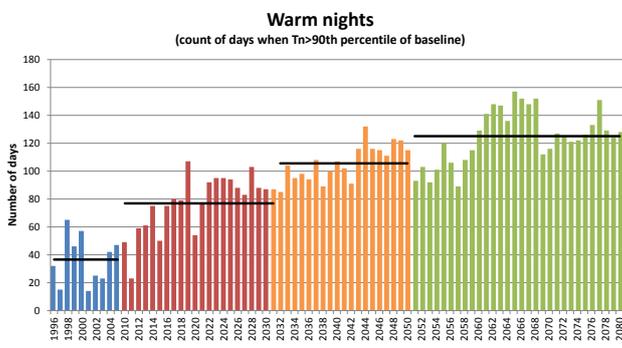
Figure 7.1.5.9: In line with figure 7.1.5.5, the number of warm nights will also increase drastically. This figure too shows that substantial year-to-year differences will persist towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
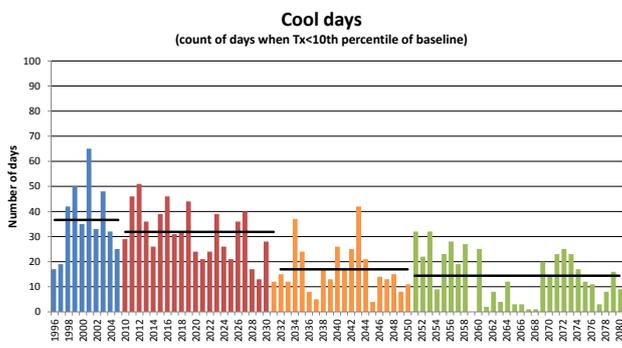
Figure 7.1.5.10: In apparent contrast with figure 7.1.5.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

Cool nights
(count of days when Tn<10th percentile) of baseline
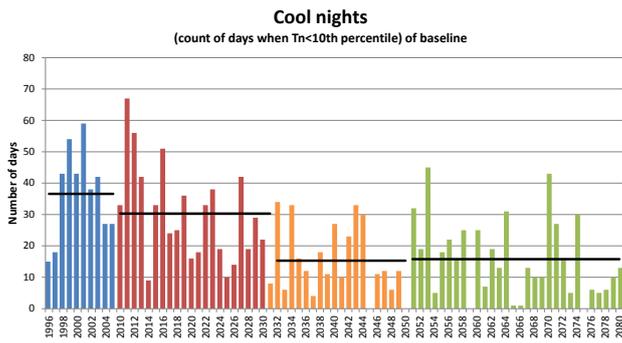
Figure 7.1.5.11: In line with figure 7.1.5.5, the decreased number of cool nights (especially in January) will also decrease significantly on an annual basis**.** This figure however also shows that substantial year-to-year differences will persist towards 2080.

Frost free nights
(count of days when Tn>0°C)
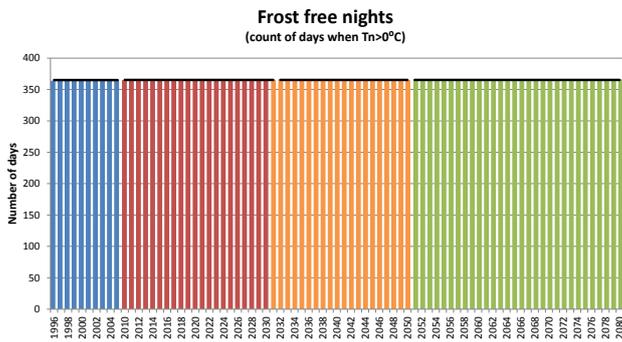
Figure 7.1.5.12: In line with figure 7.1.5.5, there are no frost nights to be expected neither in the near nor in the further future.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
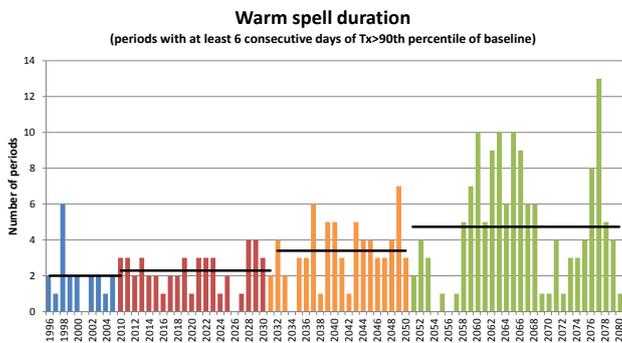
Figure 7.1.5.13: The number of warm spells per year will increase, especially towards 2050-2080. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase significantly.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
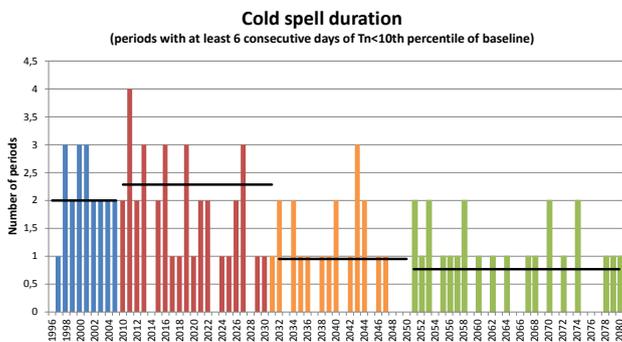
Figure 7.1.5.14: The number of cold spell periods per year will decrease, although these currently only count around 2, and they are set to fall to around 1 spell per year. Still, there will be annual variations.

Precipitation and Monsoon timing
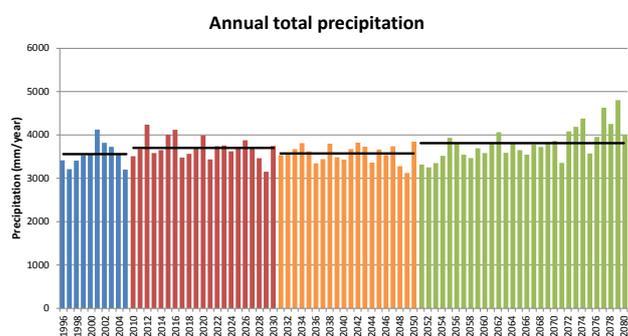
Figure 7.1.5.15: The annual total amount of precipitation is projected to remain approximately constant, perhaps slightly increase towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.5.18-27)
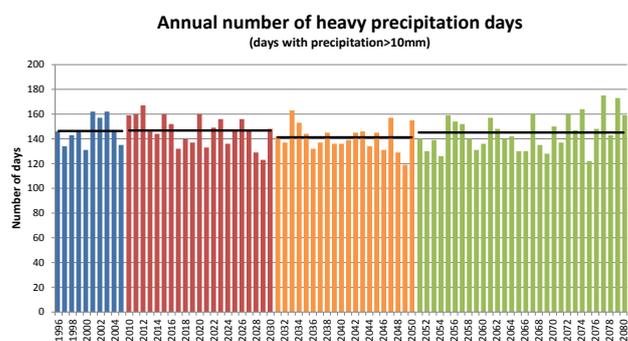
Figure 7.1.5.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.5.18-27).
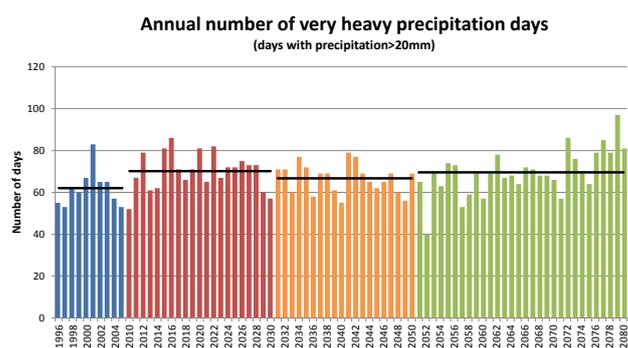
Figure 7.1.5.17: As in the former figure, the annual number of very heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.5.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)
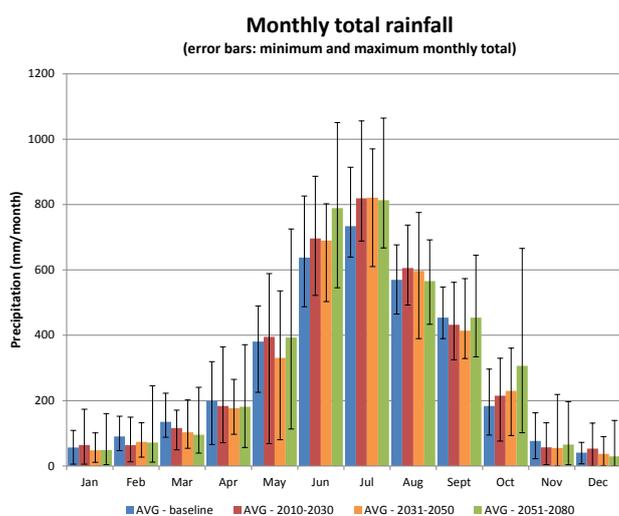
Figure 7.1.5.18: Monthly total rainfall will not change much for the dry period, but June, July and October are projected to see an increase already from 2010. This suggests that there will be more rainfall during the monsoon and the post-monsoon. Error bars showing minimum and maximum monthly totals however indicate that inter-annual variations are large and increasing for those wetter months, making this increase variable from year to year.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
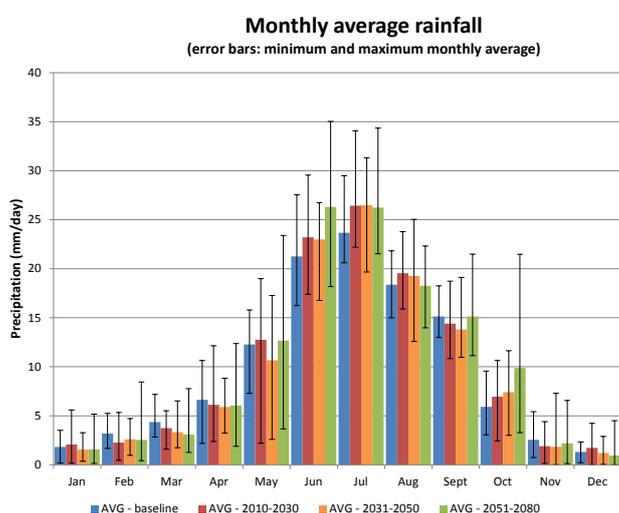
Figure 7.1.5.19: As in the figure above, monthly average rainfall will not change much for the dry period, but again June, July and October are projected to see an increase already from 2010. Again, this suggests that there will be more rainfall during the monsoon and post-monsoon, but with large inter-annual variations especially for the wet months.

Average and extreme daily precipitation
(periodic averages and extremes)
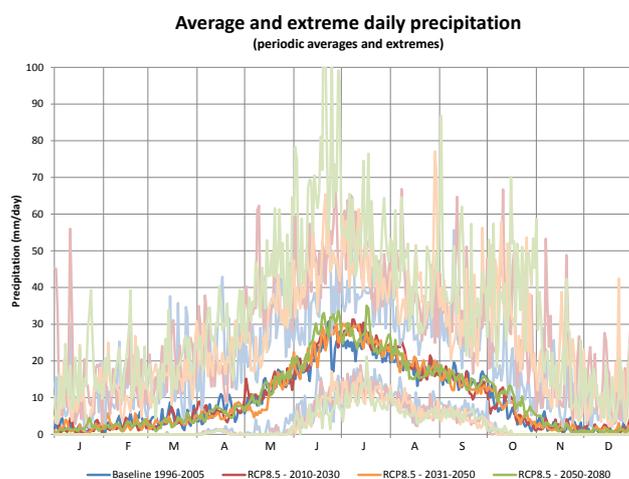
Figure 7.1.5.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations remain as large as they are today, larger than any shift in rainfall between periods. Variation appears to increase for the wet months indicating that projected increased precipitation for those months will differ much from year to year.

102

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
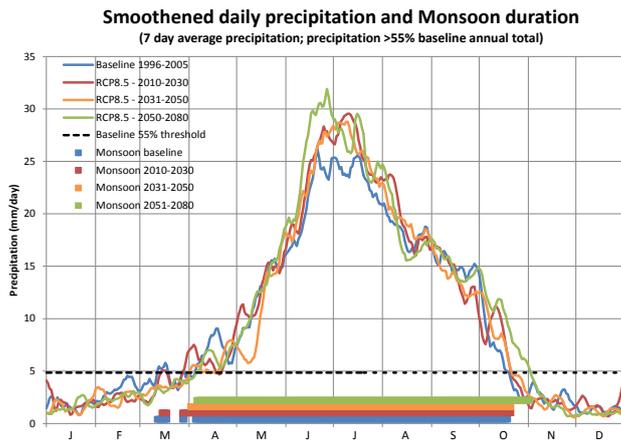
Figure 7.1.5.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.5.18-19, rainfall will not change much for the dry period, but June, July and October are projected to see an increase already from 2010. There will be a continued variation in monsoon onset, with a small tendency to later onsets over time. During the monsoon, there will be an increased rainfall per day, and the end of monsoon remains the same on the short term but may be extended to the end of October towards 2050-2080. The dry period will also become drier in the long term (especially February-March). It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation
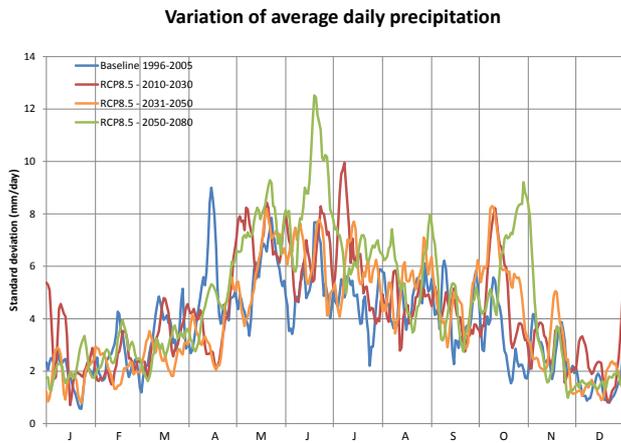
Figure 7.1.5.22: This figure indicates that the daily variation is larger in the wet period than in the dry period of the year, and especially the projected changes in precipitation may vary much from year to year.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
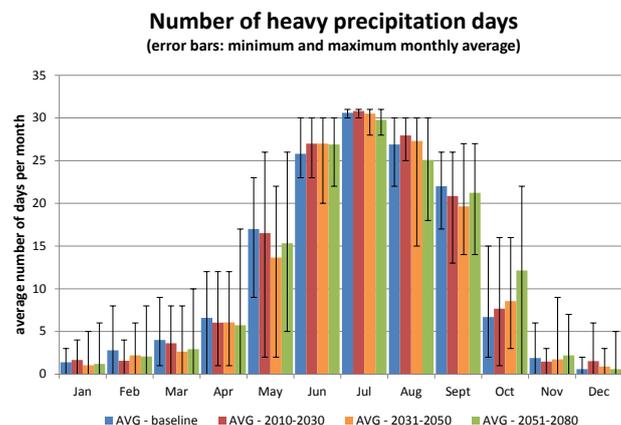
Figure 7.1.5.23: The number of heavy precipitation days is not expected to change much, with the exception of October, which is expected to see a gradual increase from 2010. Annual and periodic variation in number of heavy precipitation days will remain about the same or increase for some months.

103

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
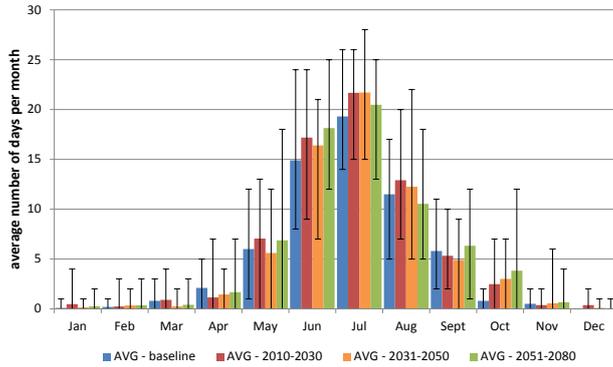
Figure 7.1.5.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, with the exception of a small increase in June-July and October, although variation within projection periods far outweighs the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
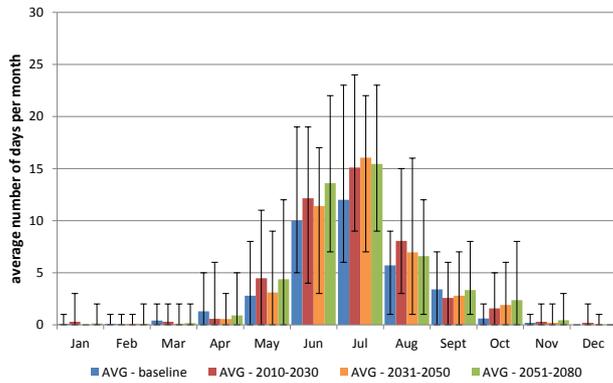
Figure 7.1.5.25: Similar to the previous graphs, the number of wet days per month will see a small increase in July, but otherwise remain roughly the same to today's occurrence.

Number of very wet days
(error bars: minimum and maximum values)
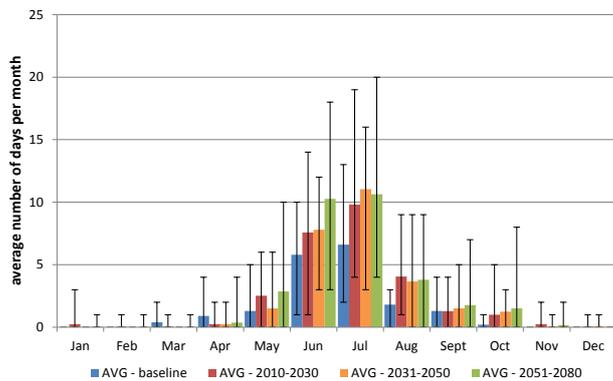
Figure 7.1.5.26: As in the figure above, the number of very wet days per month will see a small increase in June-July although with greater variations within projection periods than between projection periods.

Number of extremely wet days
(error bars: minimum and maximum values)
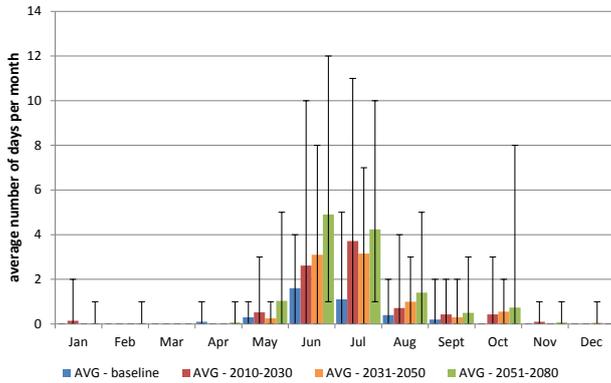
Figure 7.1.5.27: As in the figure above, the number of extremely wet days per month will see a small increase in June-July, although with greater variations within projection periods than between projection periods.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
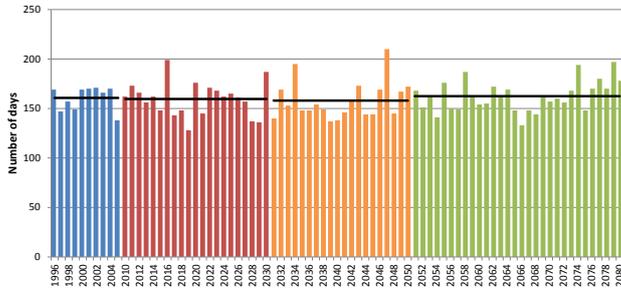
Figure 7.1.5.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
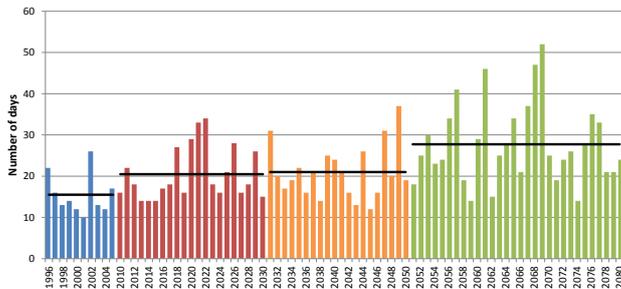
Figure 7.1.5.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase slightly from 2010 and again from 2050. This corresponds with figure 7.1.5.21, which indicated a slight decrease in precipitation during the dry period.

Simple Daily Intensity Index

Figure 7.1.5.30: The amount of precipitation on wet days is projected to increase slightly for 2010-2030 and again for 2050-2080. At the same time, the number of wet days is set to remain about the same, confirming above figures showing increased precipitation during the monsoon.

105

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)
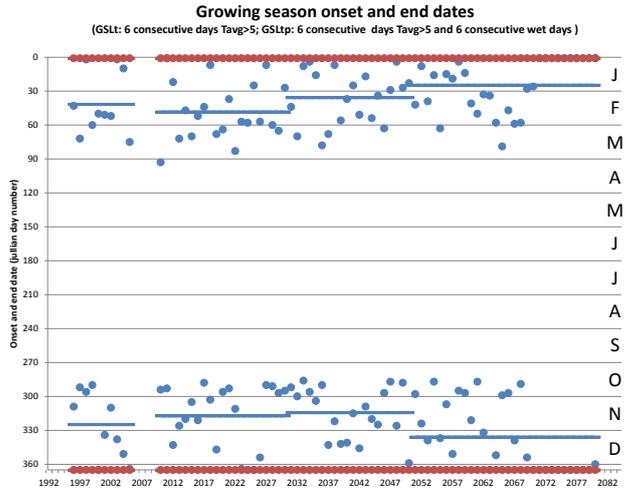
Figure 7.1.5.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations. On average, the latter growing season's start (top) and end (bottom) remain approximately the same until 2050, after which the season increases.

Average growing season duration
(error bars: minimum and maximum extremes)
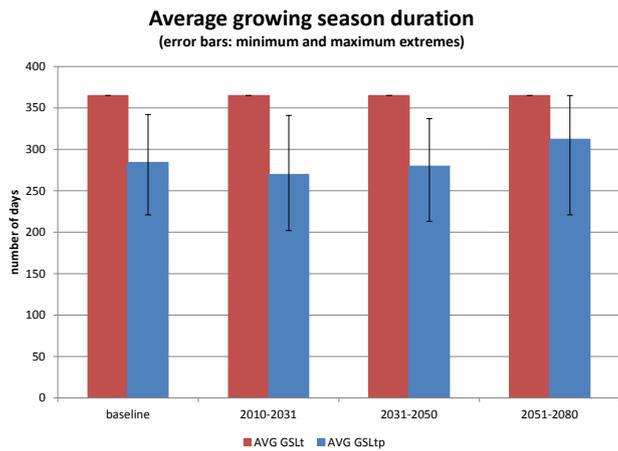
Figure 7.1.5.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: Variations in onset and end make the precipitation dependent growing season duration vary a lot currently and in time ahead, while the average duration increases from 2050 onward. The precipitation independent growing season remains constant, year-round.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
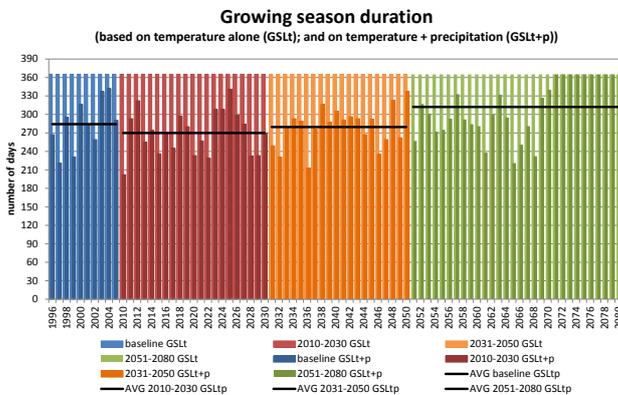
Figure 7.1.5.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the longer duration of the precipitation dependent growing season from 2050 onward is caused mainly by an anomalous long duration from 2072 onward.

7.1.6 Domain 6
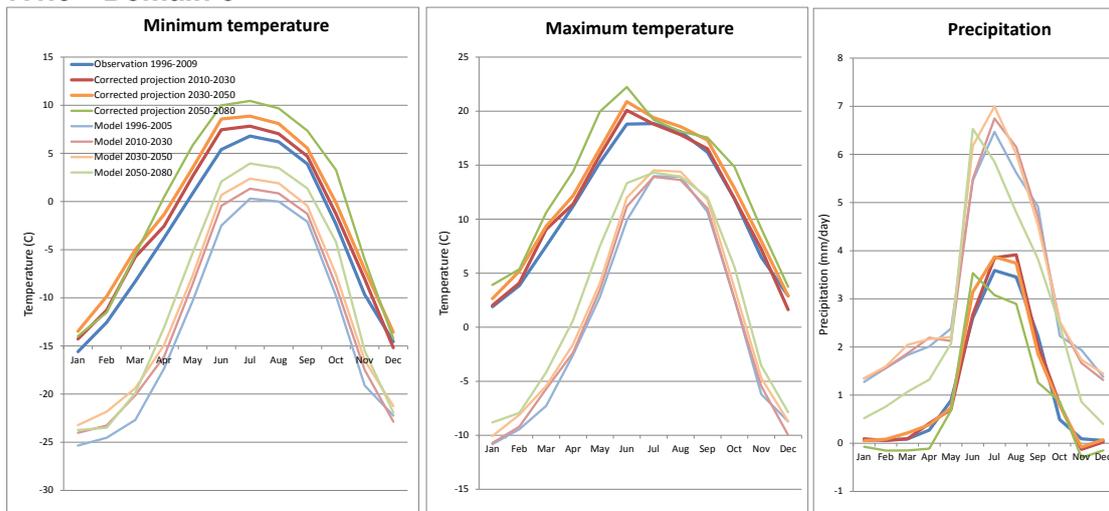
Figure 7.1.6.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, with a greater difference for maximum temperature results. Precipitation is overestimated both outside and during the rainy season, but the timing of the increase/decrease fits reasonably well.
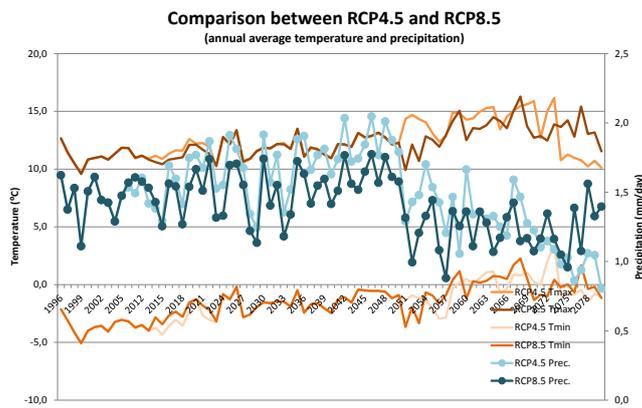
Figure 7.1.6.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a slightly drier short- and mid-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
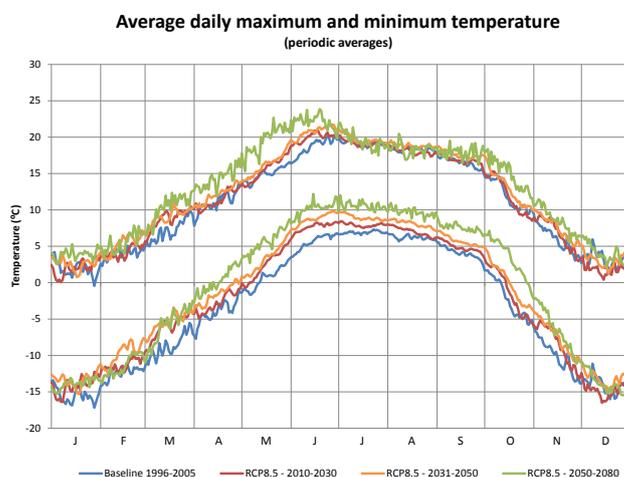
Temperature

Figure 7.1.6.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 4-5 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially during 2050-2080, but mostly from September and June, outside the monsoon period.
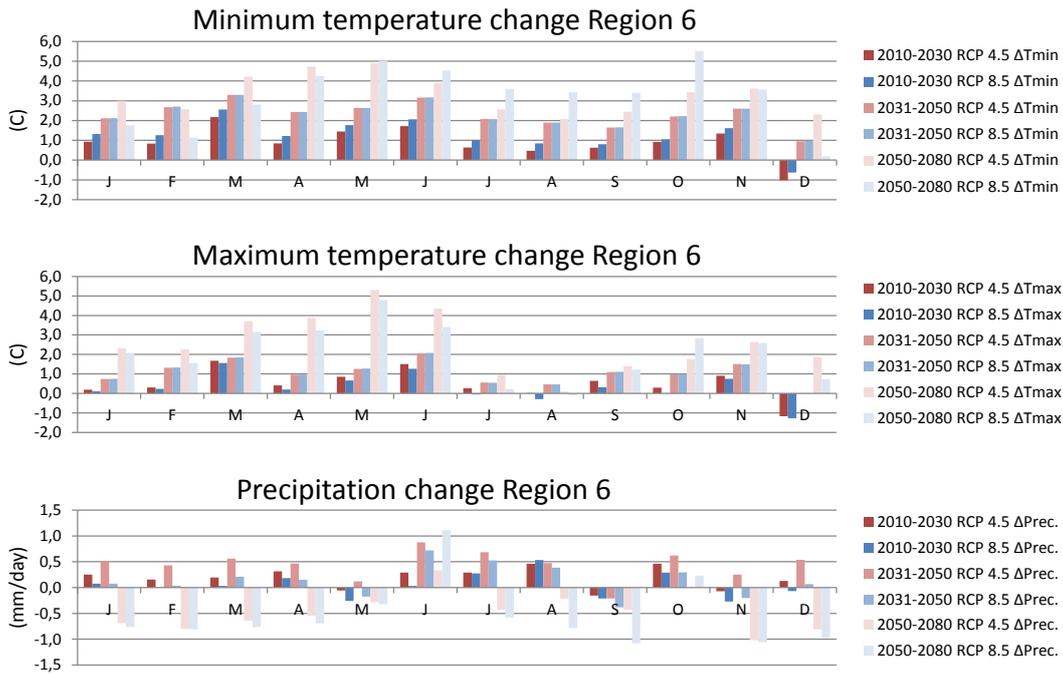
Figure 7.1.6.2b: Minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, especially on the short term. Most warming takes place during the night throughout the year already from 2010, with largest changes in March-June and October-November, and with large changes especially in April-June and October after 2050. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods, while RCP4.5 projects more precipitation until 2050 than RCP8.5, and both project drier months throughout the year (except for June) after 2050.
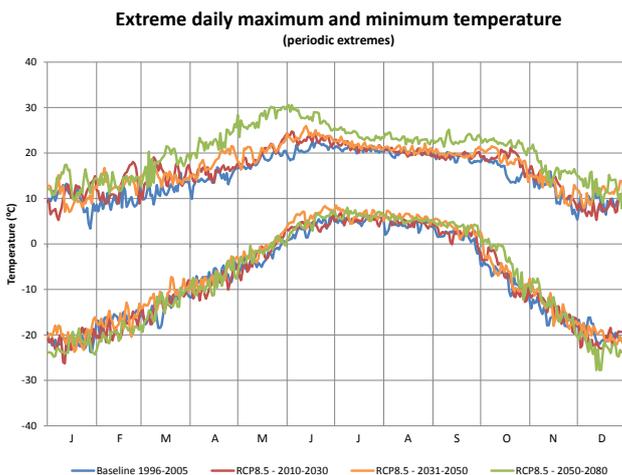
Figure 7.1.6.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, mostly outside the monsoon season, but especially towards 2050-2080. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
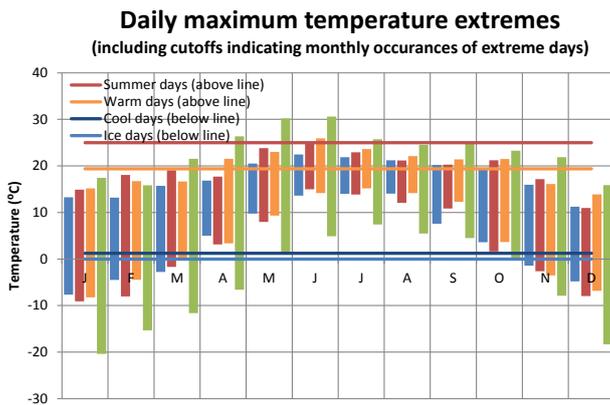
Figure 7.1.6.4: The projected daily maximum temperature range (length of the bar) increases for most of the year, and especially from 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in April-July and October, as well as for the long term (2050-2080) and more or less the same temperatures on cool days throughout the year until 2050 (bar below line), but a temperature decrease from November-May for 2050-2080.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)

Figure 7.1.6.5: The daily minimum (night-time) temperature range is projected to increase in variation for most of the year except November-December, already from 2010. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during monsoon, indicating more and warmer night-time temperatures that time of year. Frost- and cool nights will remain about the same and temperatures only decrease a bit in December in the long term.

Summer days
(count of days when Tx>25ºC)
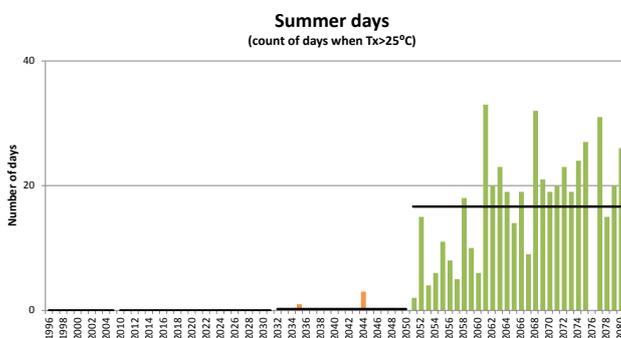
Figure 7.1.6.6: The annual number of days above 25^{0}C is projected to increase from not-occurring to just below 20 in 2050-2080.

Warm days
(count of days when Tx>90th percentile of baseline)
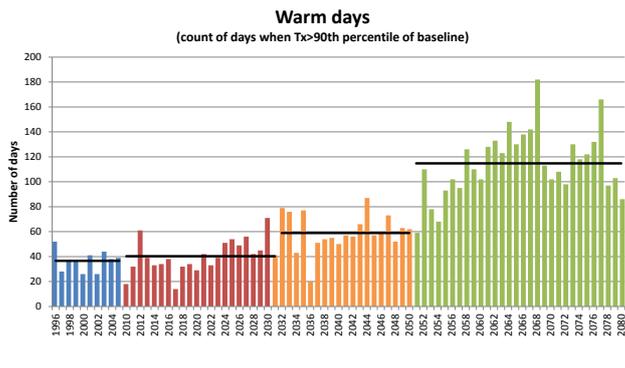
Figure 7.1.6.7: The annual number of warm days will increase especially towards 2050-2080, with a tripling of today's number of warm days. Already in 2030-2050 the number of warms days will increase with over 20 more compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
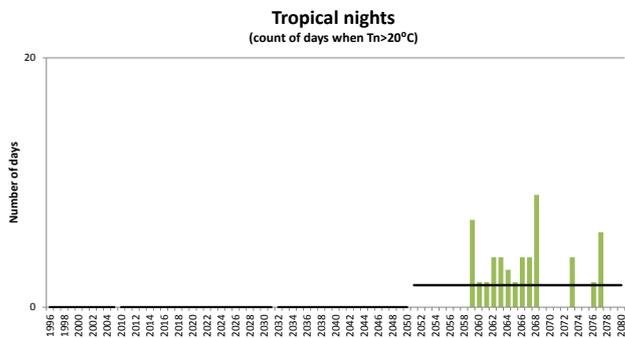
Figure 7.1.6.8: The annual number of tropical nights will increase drastically from not occurring to a few per year during 2050-2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
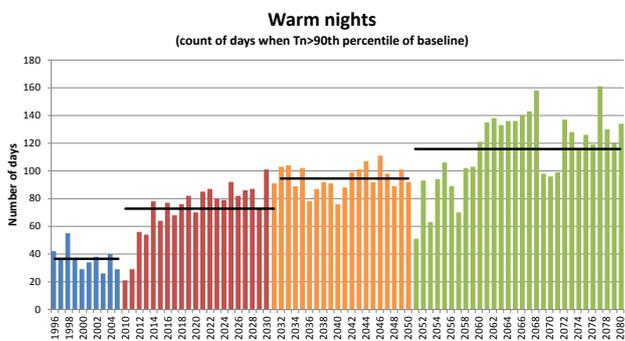
Figure 7.1.6.9: The number of warm nights will also increase drastically, and in fact triple. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
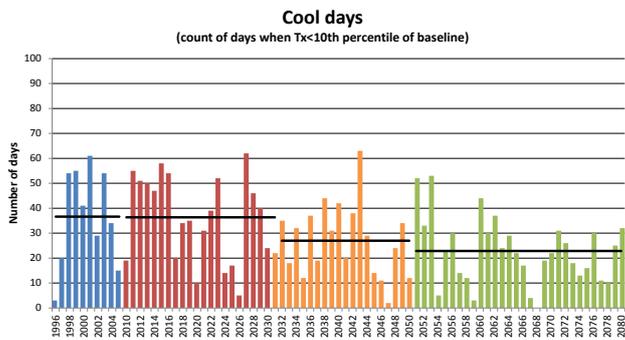
Figure 7.1.6.10: The number of cool days on an annual basis is projected to decrease to about half today's number. The difference between these figures also makes clear an important point, namely that annual and seasonal representations can highlight different details.

Cool nights
(count of days when Tn<10th percentile) of baseline
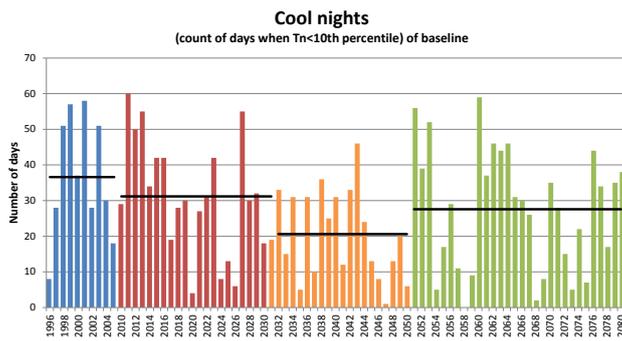
Figure 7.1.6.11: The number of cool nights will also decrease on an annual basis. This figure also shows that year-to-year differences are substantial and larger than between period changes.

Frost free nights
(count of days when Tn>0°C)
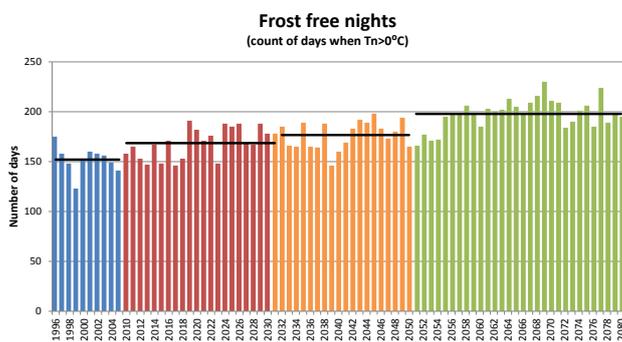
Figure 7.1.6.12: The number of frost free nights increases gradually towards 2050-2080, but annual variations are larger than between period difference.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
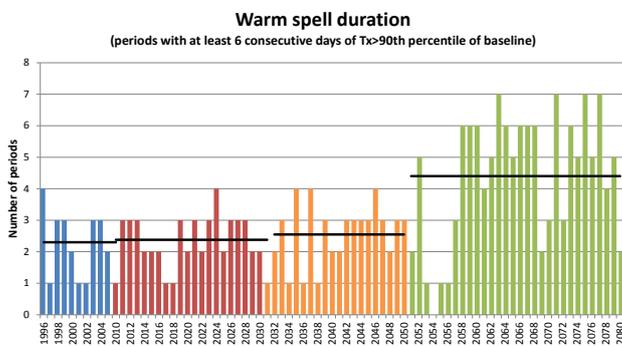
Figure 7.1.6.13: The number of warm spells per year will increase, especially towards 2050-2080. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase significantly.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
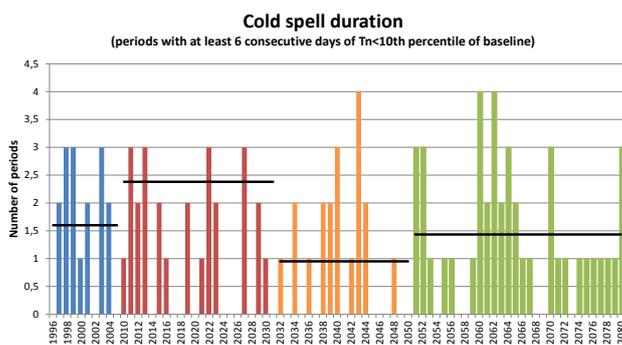
Figure 7.1.6.14: The number of cold spell periods per year will remain around the same, with some small increase in 2010-2030 and a decrease in the following period.

Precipitation and Monsoon timing
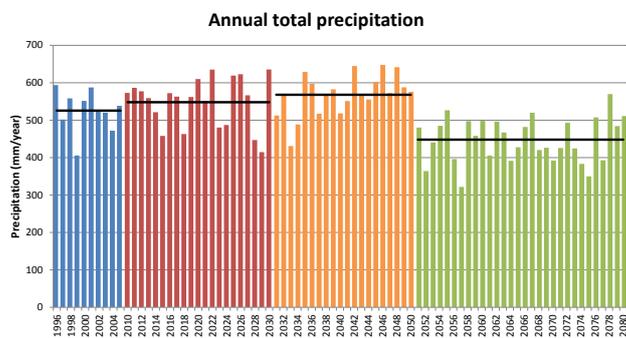
Figure 7.1.6.15: The annual total amount of precipitation is projected initially to remain approximately constant, and to decrease towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.6.18-27).
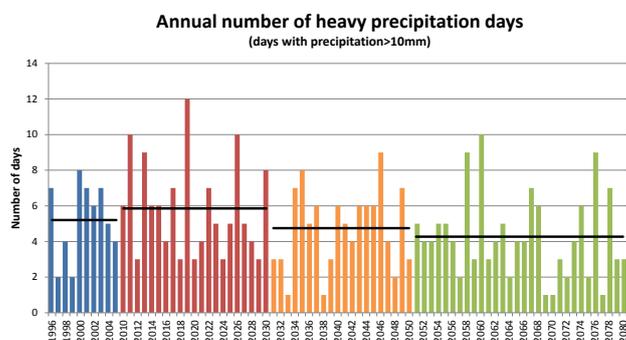
Figure 7.1.6.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.6.18-27).
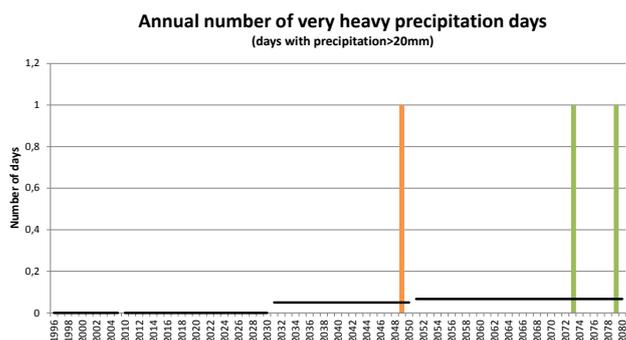
Figure 7.1.6.17: As in the former figure, the annual number of very heavy precipitation days is not set to change much from the current situation, and in fact remain nihil. Again, the distribution over the year might change (see figures 7.1.6.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)

AVG - baseline ■ AVG - 2010-2030 ■ AVG - 2031-2050 ■ AVG - 2051-2080
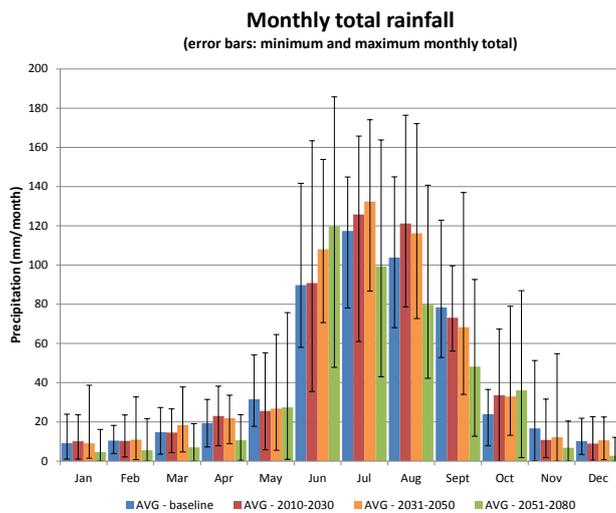
Figure 7.1.6.18: Monthly total rainfall will not change much for the dry period, but June-August and October are projected to see an increase already from 2010. This suggests that there will be more rainfall during the monsoon and the post-monsoon. Error bars showing minimum and maximum monthly totals indicate that annual variations for these months are large, and also larger than the change between periods.

Monthly average rainfall
(error bars: minimum and maximum monthly average)

■ AVG - baseline ■ AVG - 2010-2030 ■ AVG - 2031-2050 ■ AVG - 2051-2080
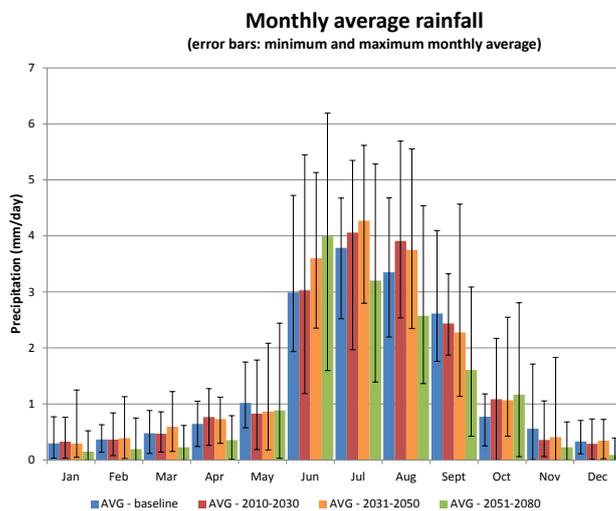
Figure 7.1.6.19: As in the figure above, monthly average rainfall will not change much for the dry period, while June-August and October are projected to see an increase already from 2010. Again, this suggests that there will be more rainfall during the monsoon and post-monsoon, but with large and increasing inter-annual variations especially for the wet months.

Average and extreme daily precipitation
(periodic averages and extremes)

Baseline 1996-2005 — RCP8.5 - 2010-2030 — RCP8.5 - 2031-2050 — RCP8.5 - 2050-2080
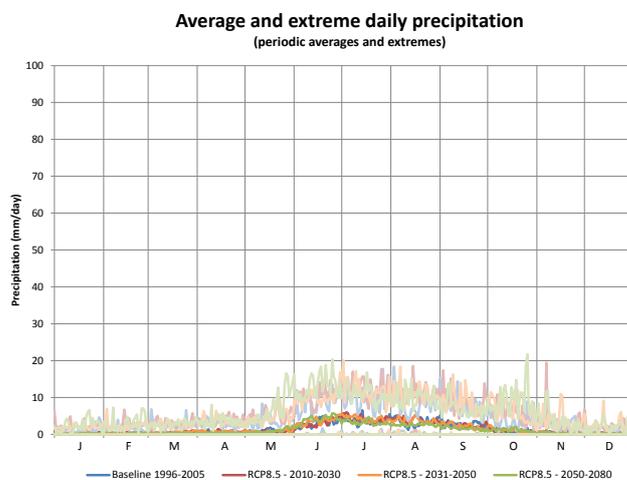
Figure 7.1.6.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations remain as large as they are today, or become even larger during the wet months, larger than any shift in rainfall between periods.

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
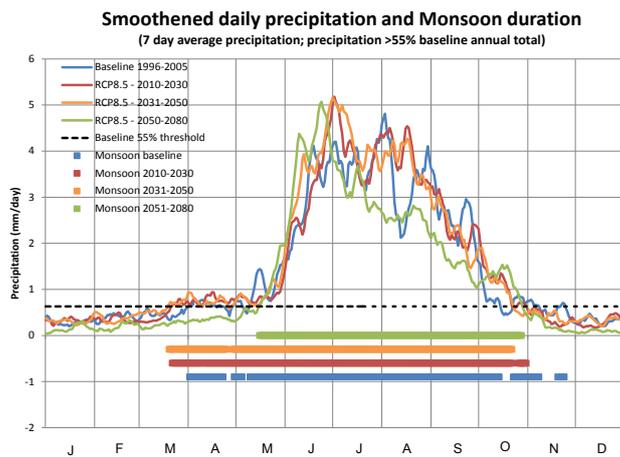
Figure 7.1.6.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.2.18-19, rainfall will not change much for the dry period, but June-August and October are projected to see an increase already from 2010. Monsoon will have a tendency to later onsets especially towards 2050. During the monsoon, there will be an increased rainfall per day,

and the end of monsoon may be extended to mid-/end- of October already from 2010. The dry period may also become drier in the long term (November-May). It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation

Figure 7.1.6.22: This figure indicates that the daily variation is larger in the wet period than in the dry period of the year, and especially the projected changes in monsoon end may vary much from year to year.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
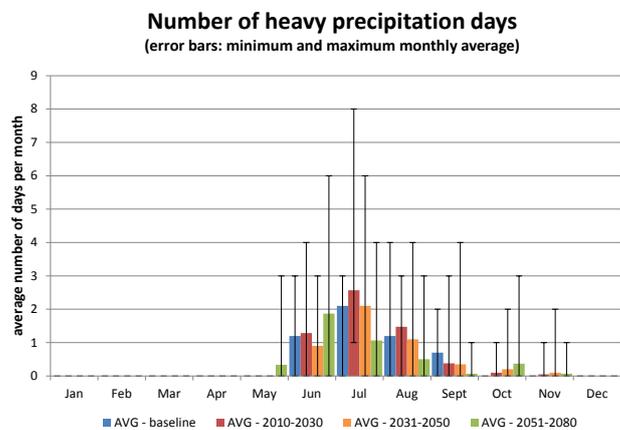
Figure 7.1.6.23: The number of heavy precipitation days is not expected to change much. Annual and periodic variation in number of heavy precipitation days will increase somewhat compared to today.

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
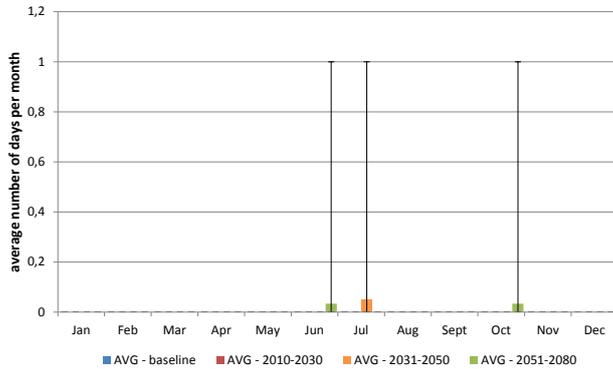
Figure 7.1.6.24: The number of very heavy precipitation days is not expected to change much and remain nihil.

Number of wet days
(error bars: minimum and maximum values)
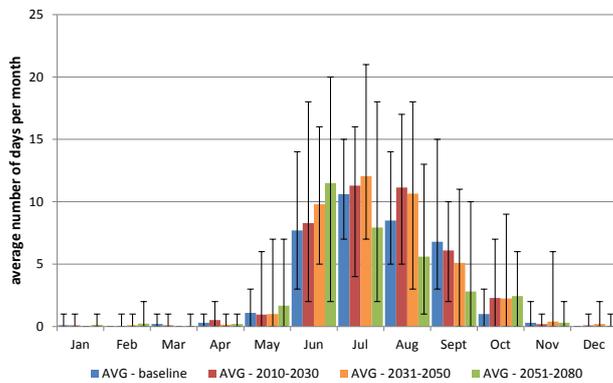
Figure 7.1.6.25: The number of wet days per month will see a gradual increase in June-July-August, and a small decrease in September. Annual variations remain roughly the same to today's, or increase slightly.


Number of very wet days
(error bars: minimum and maximum values)
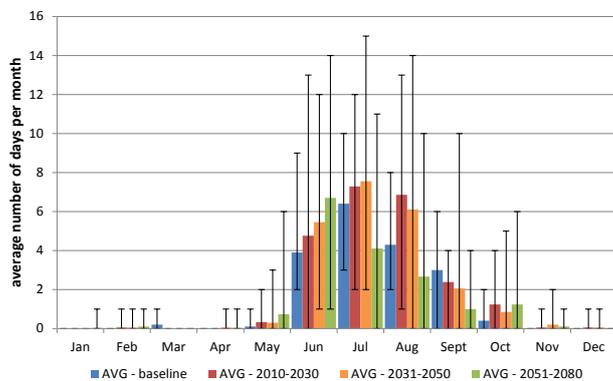
Figure 7.1.6.26: The number of very wet days per month will see a similar gradual increase in June-July-August, and a small decrease in September. Annual variations remain roughly the same to today's, or increase slightly.

Number of extremely wet days
(error bars: minimum and maximum values)
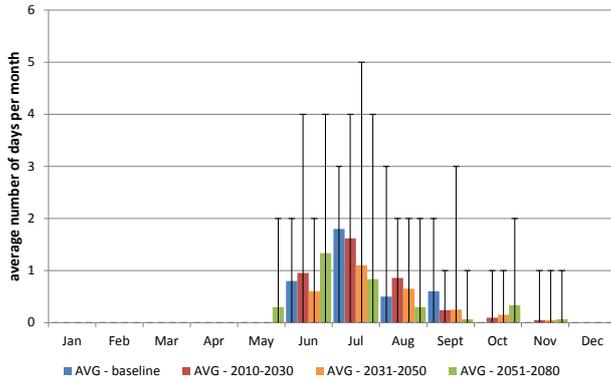
Figure 7.1.6.27: The number of extremely wet days per month will see a gradual decrease in July and remain otherwise unchanged to today's situation. Annual variations remain roughly the same to today's, or increase slightly.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
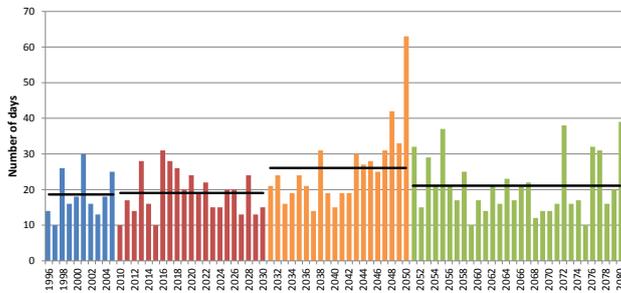
Figure 7.1.6.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain about the same.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
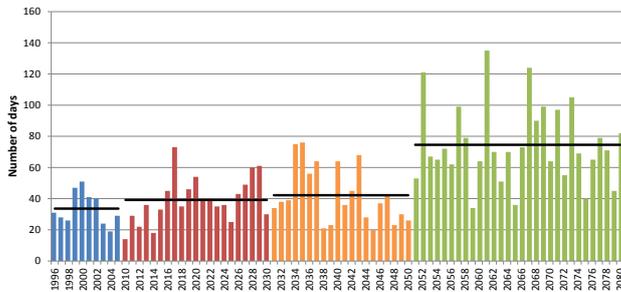
Figure 7.1.6.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to increase from 2050. This corresponds with figure 7.1.2.21, which indicated a slight decrease in precipitation during the dry time of year for that period.

Simple Daily Intensity Index
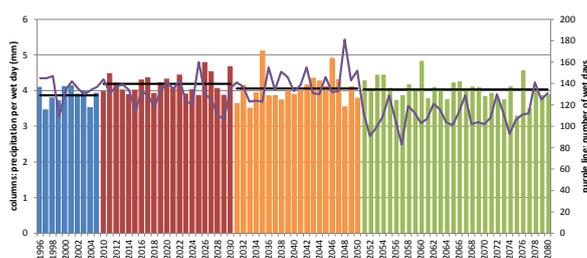
Figure 7.1.6.30: The amount of precipitation on wet days is projected to remain the same. At the same time, the number of wet days is set to decrease from 2050, corresponding to above figures showing increased rainfall during monsoon and decreased precipitation during the dry period.

116

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)
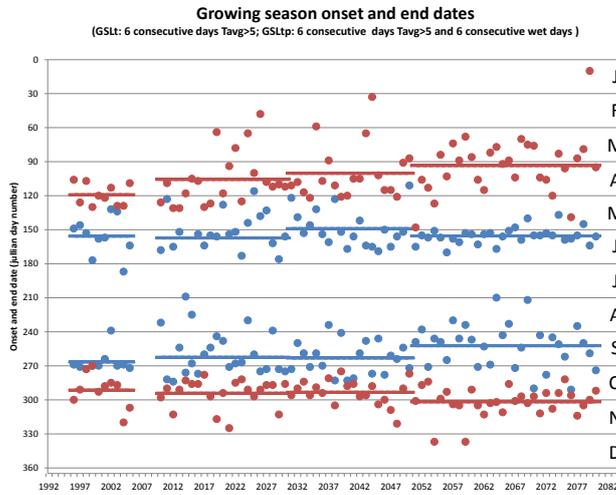
Figure 7.1.6.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season is larger than the precipitation dependent one, and increases gradually already from 2010, while the latter remains approximately constant, perhaps decreases after 2050. Both type of growing seasons show great annual variations, but the precipitation dependent one especially in its onsets after 2050.

Average growing season duration
(error bars: minimum and maximum extremes)
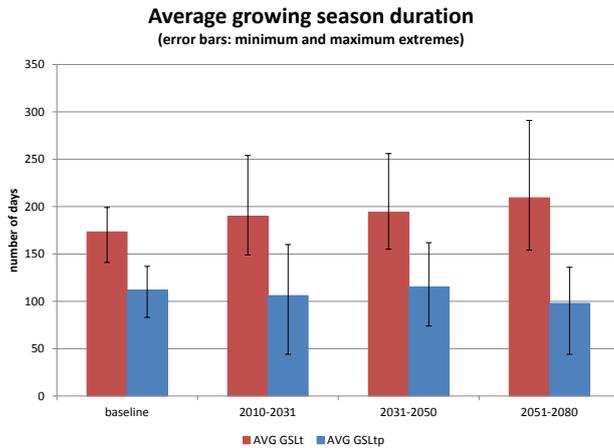
Figure 7.1.6.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: a gradual increase in the first, while the latter remains constant, pointing at temperature as the main variable of change. Variations in duration increase in both for the projected periods.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
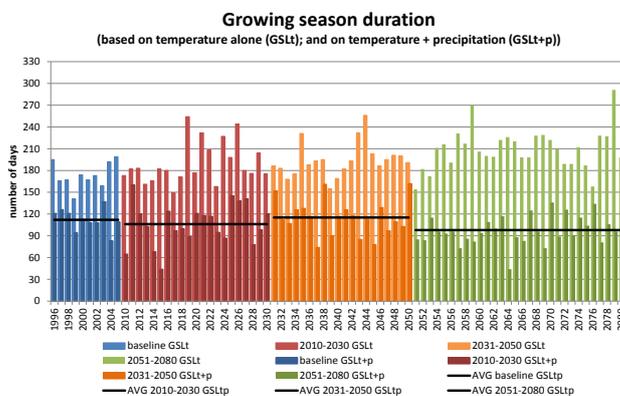
Figure 7.1.6.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the longer duration of the precipitation independent growing season from 2050 onward is caused mainly by more longer-duration seasons.

117

7.1.7 Domain 7

Subdomain 7a: High Mountains
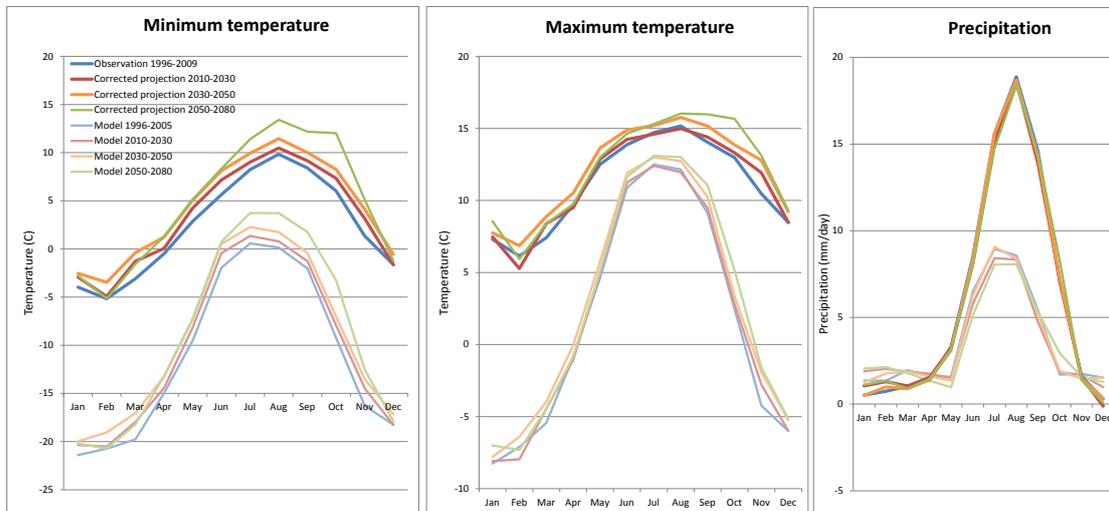
Figure 7.1.7a.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, with a greater difference for maximum temperature results and the period September-May. Precipitation is underestimated especially during the rainy season, while it fits reasonably well with observed values outside the rainy season.
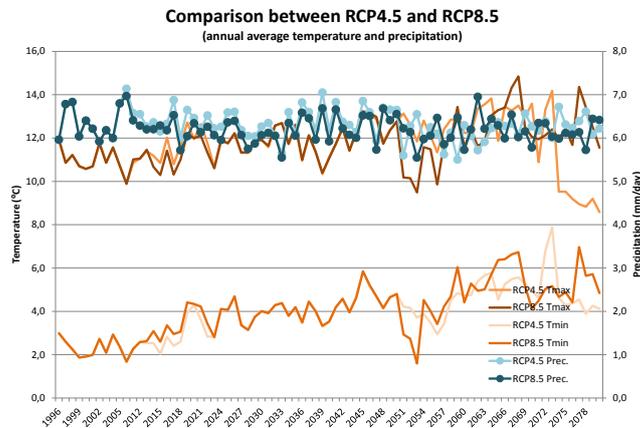

Figure 7.1.7a.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
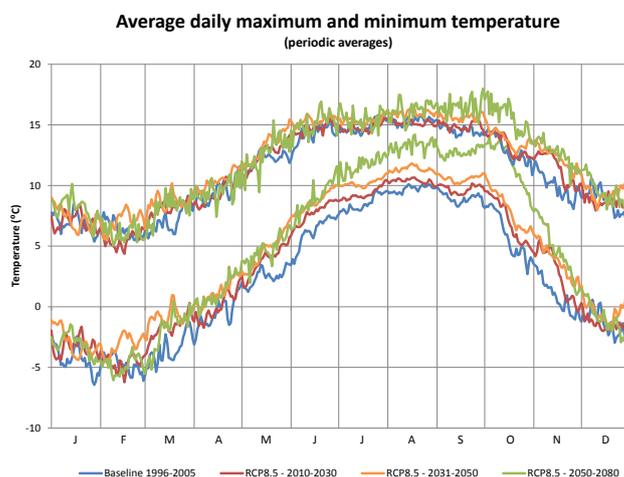
Temperature

Figure 7.1.7a.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually throughout the year towards and especially in 2050-2080, with up to about 4-5 degrees. The average daily maximum temperature is projected to increase only a little from 2050-2080 right after the monsoon.
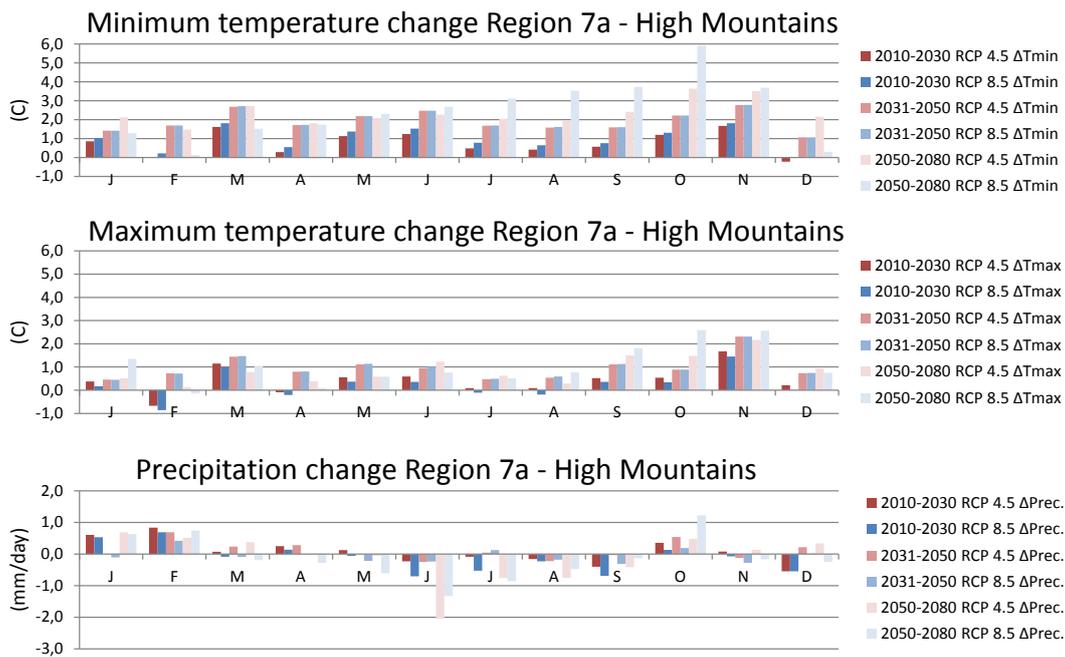
Figure 7.1.7a.2b: Temperature will increase for the high mountain subdomain already from 2010, but increasingly so towards 2080. The minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, already on the short term but with an increasingly large difference towards 2080. March-June and October-November will see the largest warming, and with large changes especially in April-June and October after 2050. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods. For precipitation neither scenario RCP4.5 nor RCP8.5 indicates any great changes from today on an annual basis. Both however indicate that the monthly distribution changes compared to today, with January-February and October becoming slightly wetter, and June-September drier than today, especially after 2050.

Figure 7.1.7a.3: The lowest daily minimum temperatures (coldest nights) will remain about the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, but especially towards 2050-2080. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
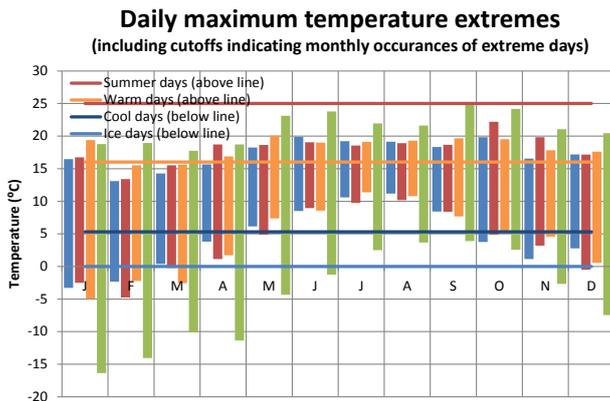
Figure 7.1.7a.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, but is projected to increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days especially for the long term (2050-2080) and an increase in cool days (bar below line) for the same period.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)
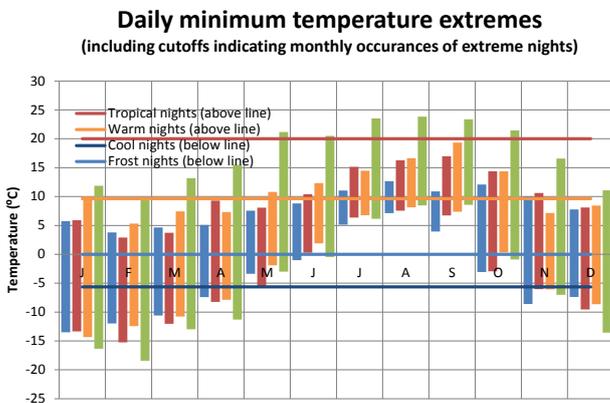
Figure 7.1.7a.5: The daily minimum (night-time) temperature range is projected to remain fairly the same as today's variation, except for an increase in variation from April-May and July-September already from 2010. Temperature range and variation increases drastically towards 2050-2080. Also, especially the upper extreme of daily minimum temperatures is set to increase

especially from 2030 particularly during January-October, indicating more and warmer night-time temperatures that time of year. Frost- and cool nights will remain about the same or increase slightly.

Ice days
(count of days when Tx<0°C)
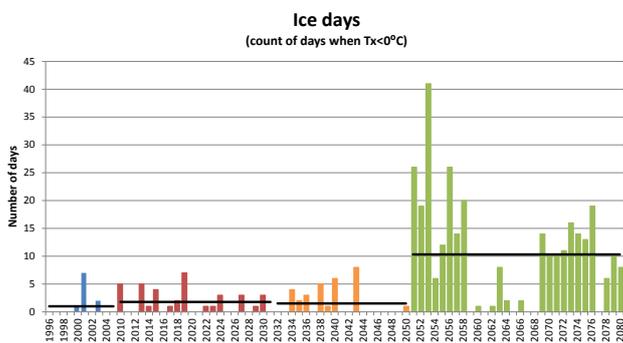
Figure 7.1.7a.6: The annual number of days below 0^0C is projected to increase from about not-occurring to on average 10 (occurring mostly in September) for the period 2050-2080.

Warm days
(count of days when Tx>90th percentile of baseline)
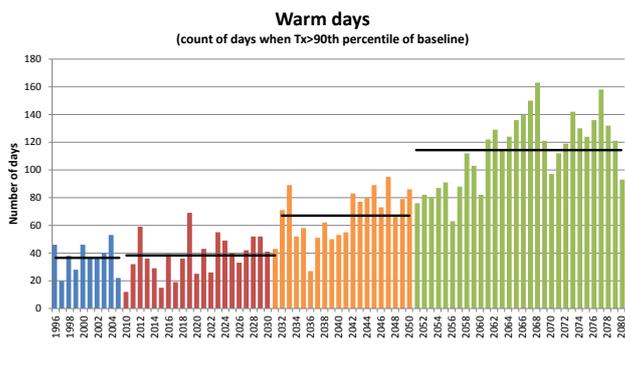
Figure 7.1.7a.7: The annual number of warm days will increase especially towards 2050-2080, with a tripling of today's number of warm days. Already in 2030-2050 the number of warms days will increase with over 20 more compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
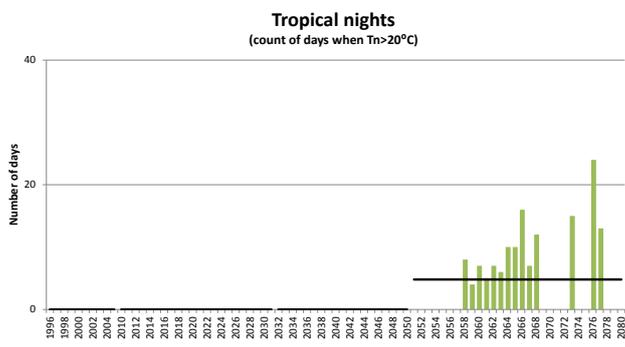
Figure 7.1.7a.8: The annual number of tropical nights will increase drastically from not occurring to a few per year during 2050-2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
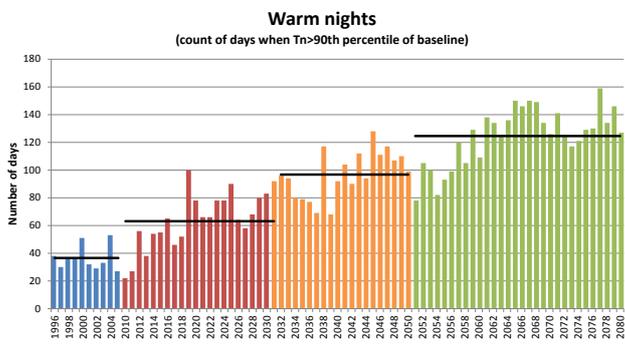
Figure 7.1.7a.9: The number of warm nights will also increase drastically, and in fact triple. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
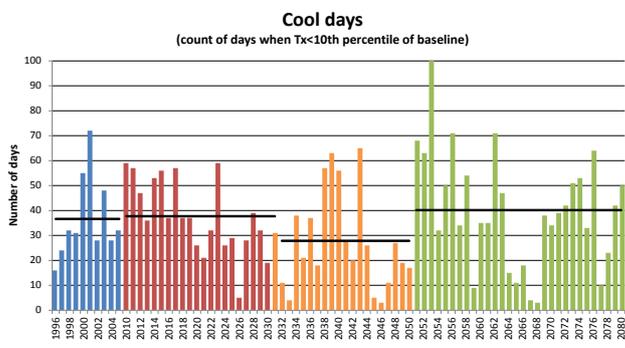
Figure 7.1.7a.10: In apparent contrast with figure 7.1.7a.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to remain about the same. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

121

Cool nights
(count of days when Tn<10th percentile) of baseline
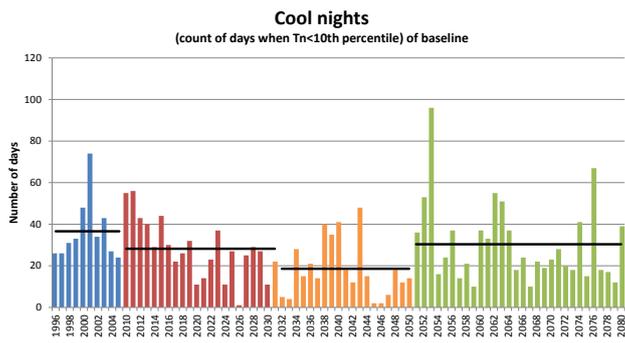
Figure 7.1.7a.11: The number of cool nights will also remain about constant on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.


Frost free nights
(count of days when Tn>0°C)
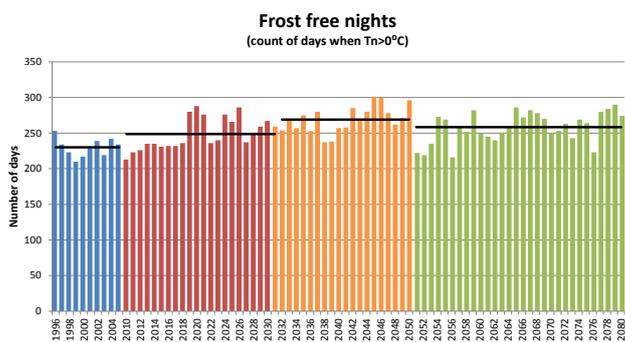
Figure 7.1.7a.12: In line with figure 7.1.7.5, the number of frost nights remains approximately the same.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
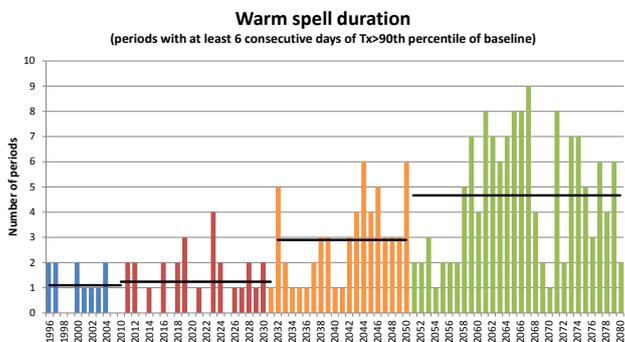
Figure 7.1.7a.13: The number of warm spells per year will increase, especially towards 2050-2080. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase significantly.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
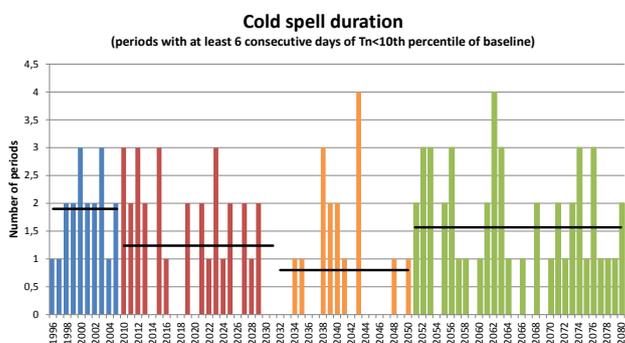
Figure 7.1.7a.14: The number of cold spell periods per year will remain about the same. Although these currently only count around 2, they are set to vary a bit between periods, and also show large annual variations.

122

Precipitation and Monsoon timing

Annual total precipitation
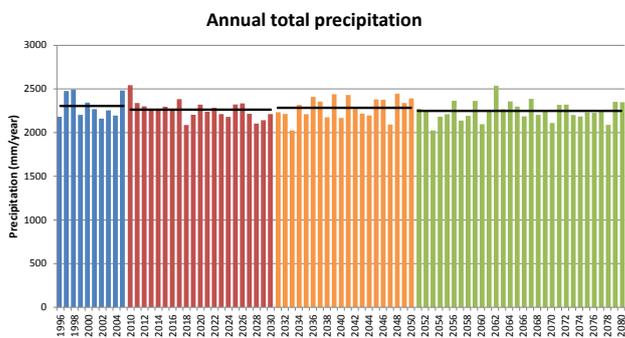
Figure 7.1.7a.15: The annual total amount of precipitation is projected to remain approximately constant. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.7a.18-27).


Annual number of heavy precipitation days (days with precipitation>10mm)
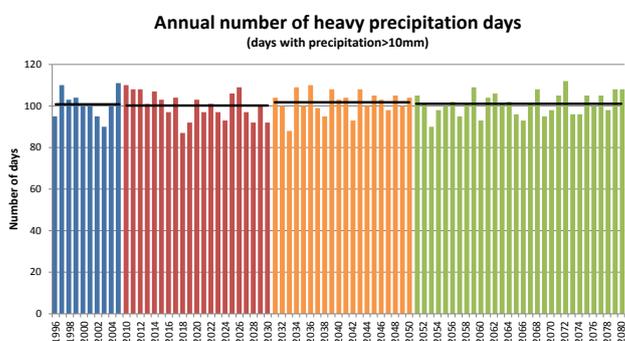
Figure 7.1.7a.16: As in the former figure, the annual number of heavy precipitation days is not set to change from the current situation. Again, the distribution over the year might change (see figures 7.1.7a.18-27).


Annual number of very heavy precipitation days (days with precipitation>20mm)
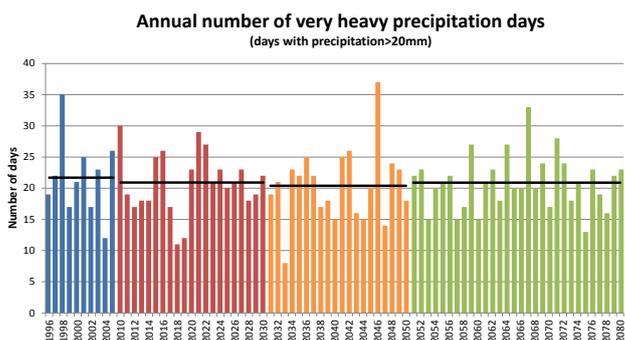
Figure 7.1.7a.17: As in the former figure, the annual number of very heavy precipitation days is not set to change from the current situation. Again, the distribution over the year might change (see figures 7.1.7a.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)
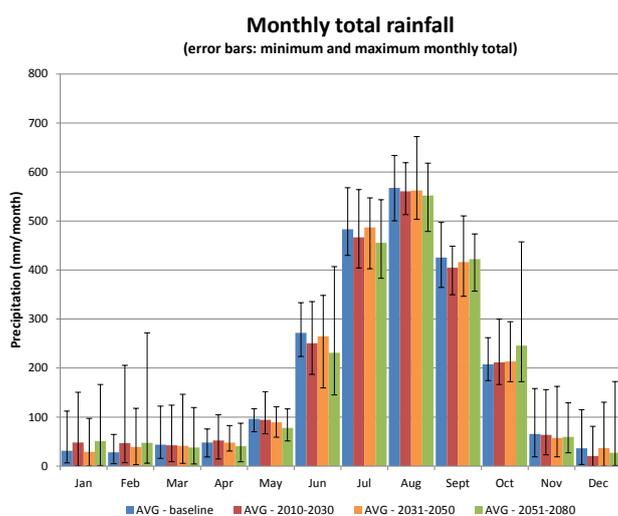
Figure 7.1.7a.18: Monthly total rainfall will not change much throughout the year. This suggests that rainfall during dry period, monsoon and post monsoon will remain the same. Error bars showing minimum and maximum monthly totals indicate that inter-annual variations increase a bit, especially in February, June and October, indicating larger variations in rainfall for these months.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
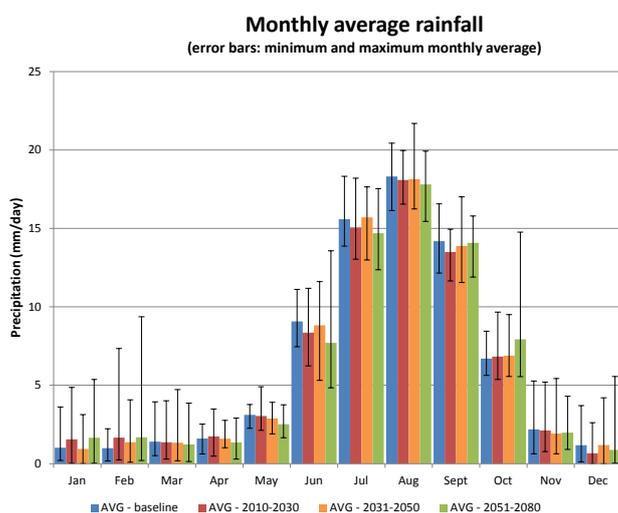
Figure 7.1.7a.19: As in the figure above, monthly average rainfall will not change much. Again, this suggests that there will about the same rainfall during dry period, monsoon and post-monsoon in the future as currently the case. With slightly larger inter-annual variations especially for June and October, means greater variation in onset and end of Monsoon than nowadays.

Average and extreme daily precipitation
(periodic averages and extremes)
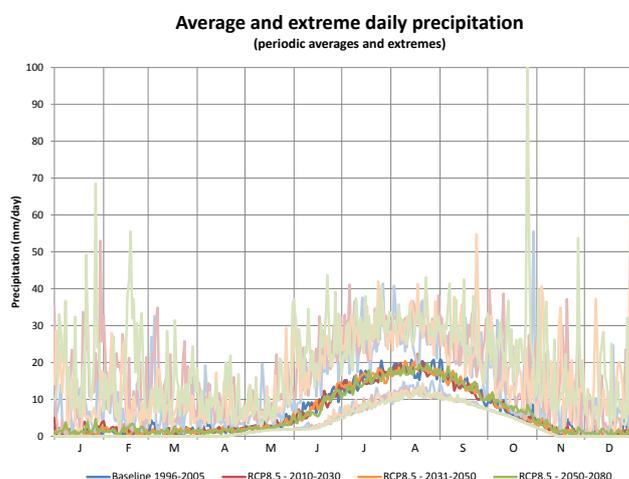
Figure 7.1.7a.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations remain as large as they are today, larger than any shift in rainfall between periods. The spike in October indicates large variations for that period over time.

124

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
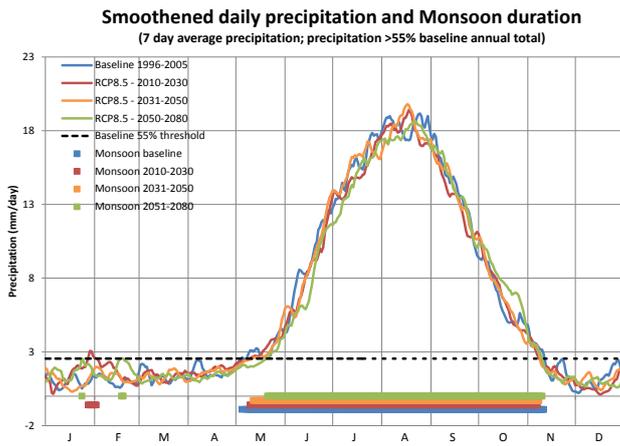
Figure 7.1.7a.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.7a.18-19, rainfall will not change much for throughout the year, except perhaps for a small increase in January-February.

Monsoon onset and end will remain about the same. It must be kept in mind that projections for

precipitation are more uncertain than for temperature.

Variation of average daily precipitation
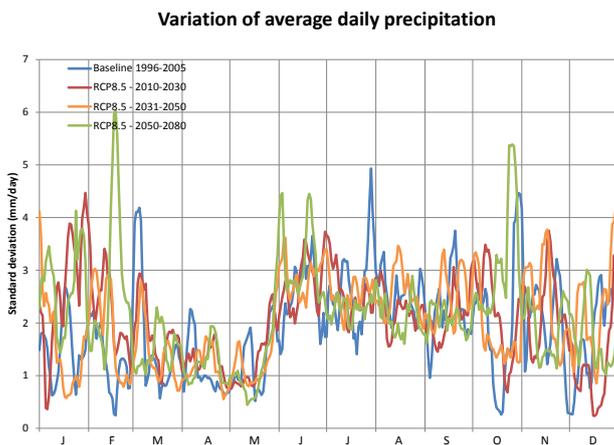
Figure 7.1.7a.22: This figure indicates that the daily variation is large both during monsoon and during the dry period of the year, and the projected small change in precipitation in January-February may vary much from year to year.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
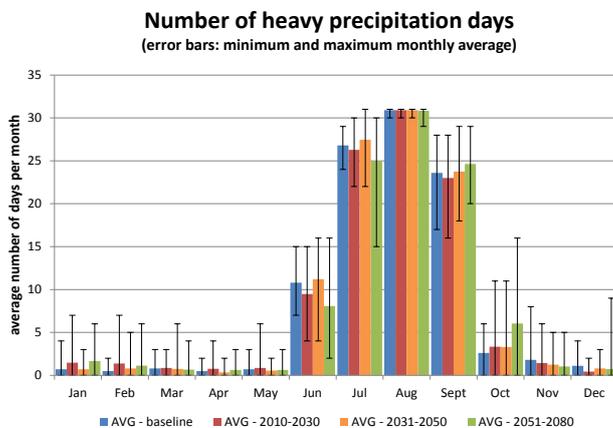
Figure 7.1.7a.23: The number of heavy precipitation days is not expected to change much, and annual and periodic variation in number of heavy precipitation days will remain about the same, and relatively small.

125

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
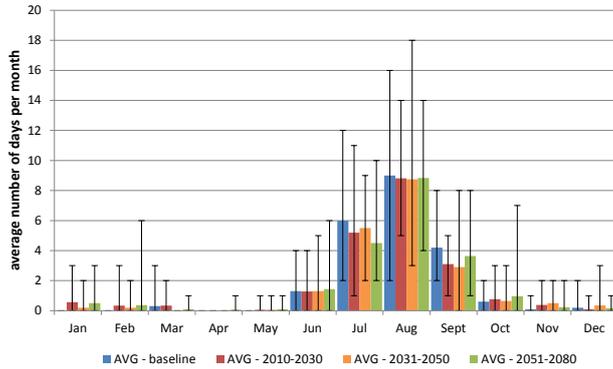
Figure 7.1.7a.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, and variation within projection periods will remain about the same as well.

Number of wet days
(error bars: minimum and maximum values)
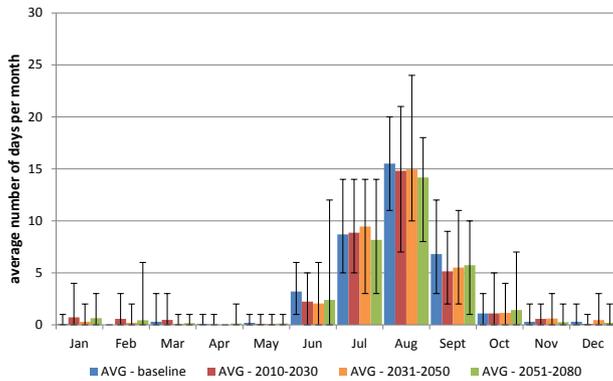
Figure 7.1.7a.25: Similar to the previous graphs, the number of wet days per month will remain roughly the same to today's occurrence.

Number of very wet days
(error bars: minimum and maximum values)
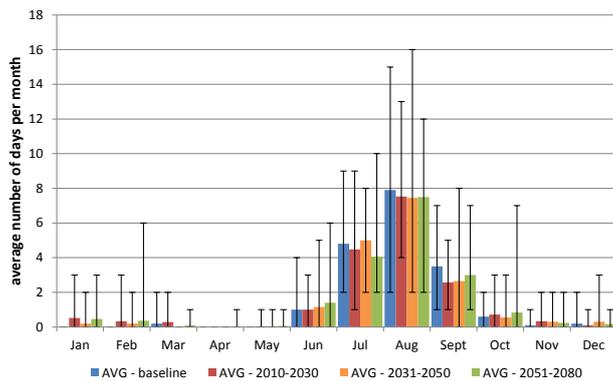
Figure 7.1.7a.26: Similar to the previous graphs, the number of very wet days per month will remain roughly the same to today's occurrence.

Number of extremely wet days
(error bars: minimum and maximum values)
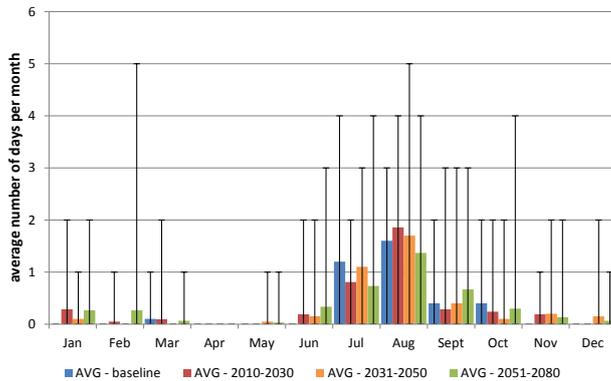
Figure 7.1.7a.27: Similar to the previous graphs, the number of extremely wet days per month will remain roughly the same to today's occurrence, with large annual variations.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
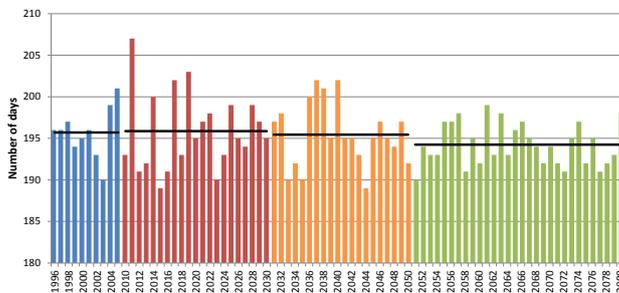
Figure 7.1.7a.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
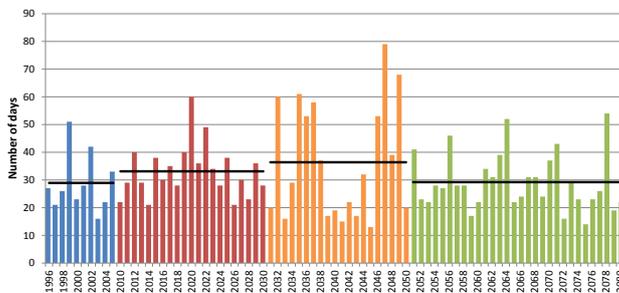
Figure 7.1.7a.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to remain the same. This corresponds with figure 7.1.7a.21, which indicated similar monsoon pattern throughout the projection periods.

Simple Daily Intensity Index
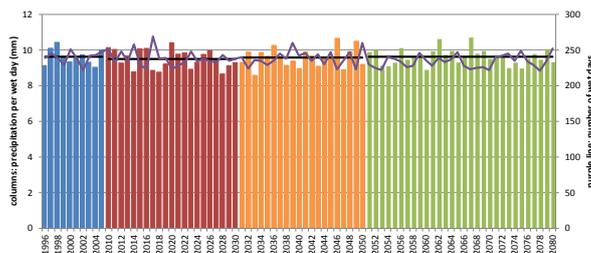
Figure 7.1.7a.30: The amount of precipitation on wet days is projected to remain the same over time. The number of wet days is also set to remain about the same, confirming above figures showing a persisting similar monsoon pattern throughout the projection periods.

127

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)

Figure 7.1.7a.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season is larger than the precipitation dependent one, and gradually increases after 2010, while the latter remains approximately constant. Especially the temperature dependent growing seasons show great annual variations, while the precipitation dependent one is remarkably constant in its onsets and ends.


Average growing season duration
(error bars: minimum and maximum extremes)
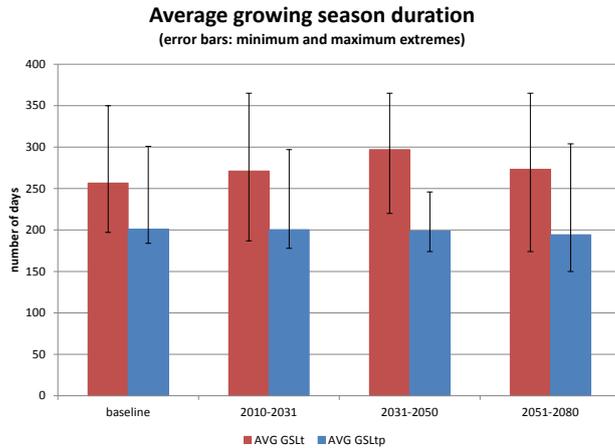
Figure 7.1.7a.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: a gradual increase in the first, while the latter remains constant, pointing at temperature as the main variable of change. Variations in duration remain about the same as today for the projected periods.


Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
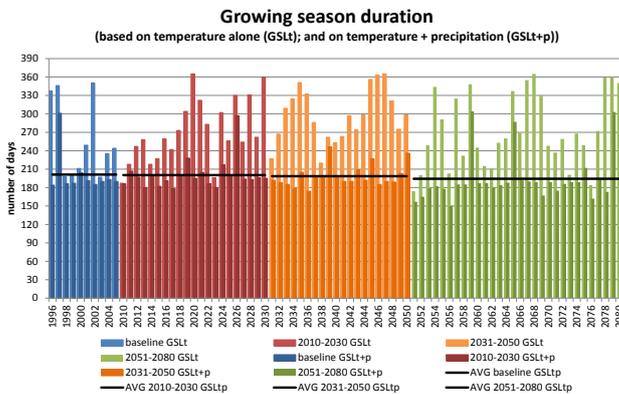
Figure 7.1.7a.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the annual variations in the precipitation independent growing season are much larger than for the precipitation dependent growing season, which in turn is remarkably constant with just a few outliers per period.

128

Subdomain 7b: Middle Hills
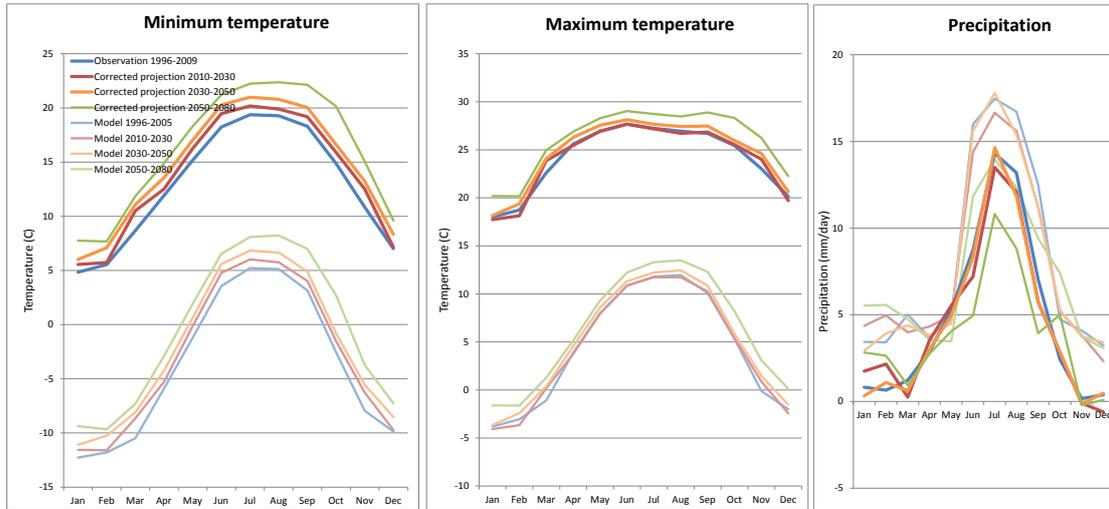
Figure 7.1.7b.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, with a greater difference for maximum temperature results. Precipitation was overestimated especially outside the rainy season, but also to a lesser extent during the rainy season.
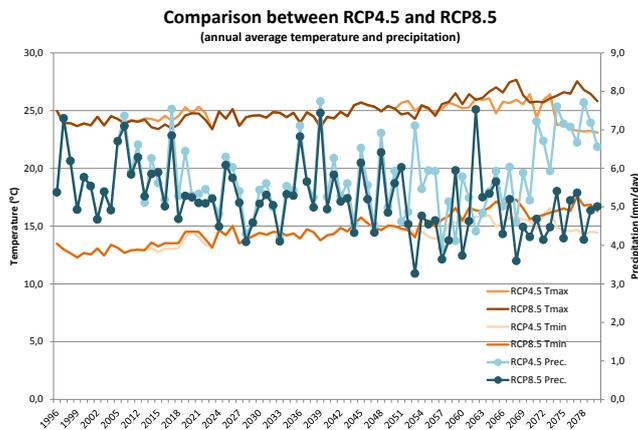
Figure 7.1.7b.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a drier mid- and long-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
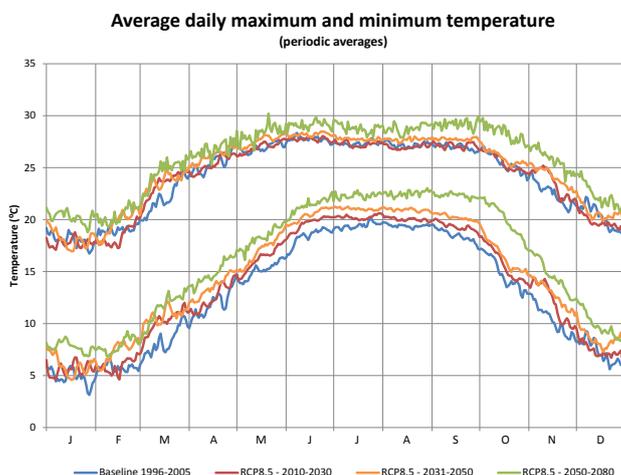
Temperature

Figure 7.1.7b.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually especially towards 2080, with up to about 4-5 degrees. The average daily maximum temperature is projected to increase too, but less dramatic, and especially from 2050-2080, and mostly after the monsoon.
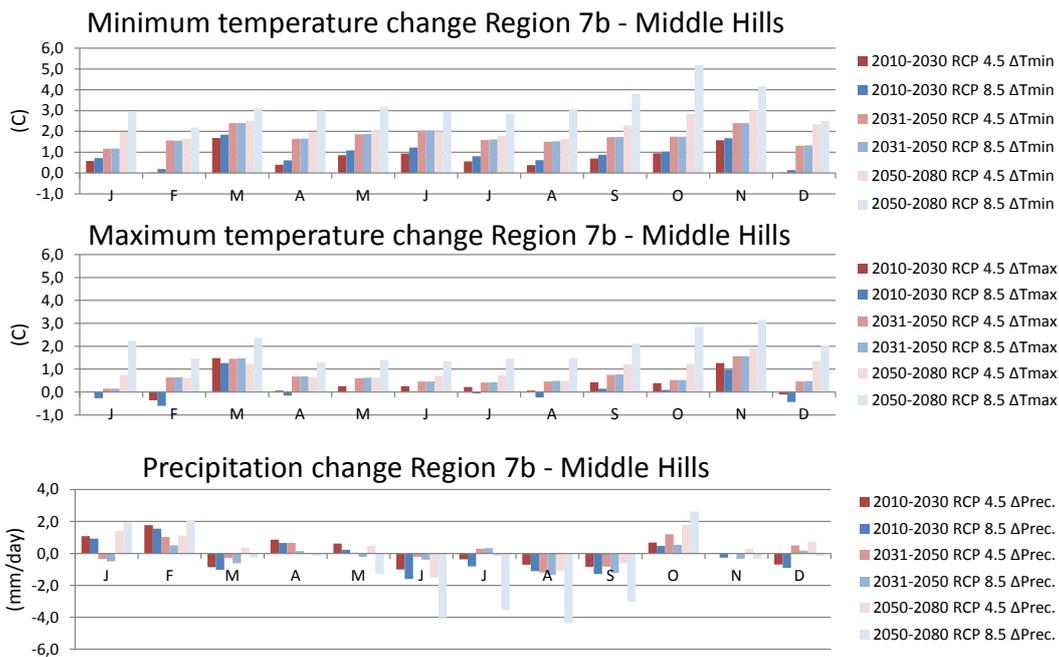
Figure 7.1.7b.2b: Temperature will increase for the middle hill subdomain already from 2010, and especially after 2050. The minimum (night-time) temperature change is projected to be larger than the projected maximum (day-time) temperature change, already on the short term but with an increasingly large difference towards 2080. March and September-November will see the largest warming. Scenarios RCP4.5 and RCP8.5 project a similar rate of warming for all periods. For precipitation, scenario RCP4.5 does not indicate any great changes on an annual or monthly basis, while RCP8.5 projects increasingly less precipitation towards 2080. On a monthly basis, both scenarios indicate a drier monsoon (June-September), an extension of monsoon into October, and wetter winter months (January-February) than today – already from 2010 but especially after 2050.

Figure 7.1.7b.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase slightly, mostly during the monsoon season and its shoulder months, and especially towards 2050-2080. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
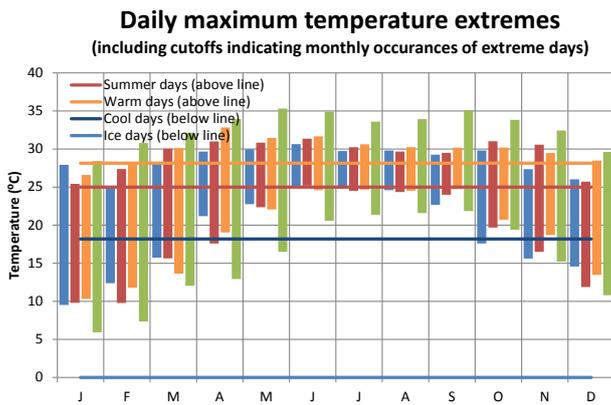
Figure 7.1.7b.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, but is projected to increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in March-July and September and December, as well as for the long term (2050-2080) and an increase in cool days (bar below line) in December and 2050-2080.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)

Figure 7.1.7b.5: The daily minimum (night-time) temperature range is projected to remain fairly the same as today's variation, except for an increase in variation in April and June and a decrease in October-November already from 2010. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2030, indicating more and warmer night-time temperatures at most times of year outside winter. Frost- and cool nights will remain the same.

Summer days
(count of days when Tx>25°C)
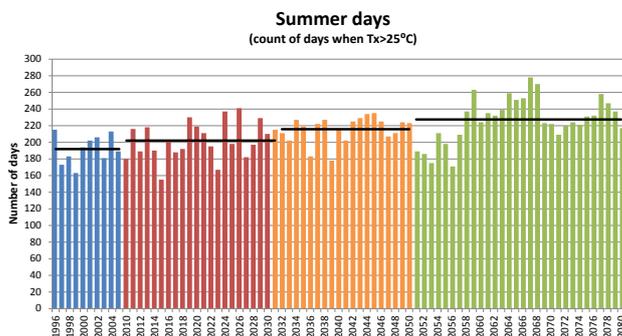
Figure 7.1.7b.6: The annual number of days above 25^{0}C is projected to increase from on average 190 (1996-2005) to 230 (2050-2080). The annual variation increases and is larger than the projected change between periods.

131

Warm days
(count of days when Tx>90th percentile of baseline)
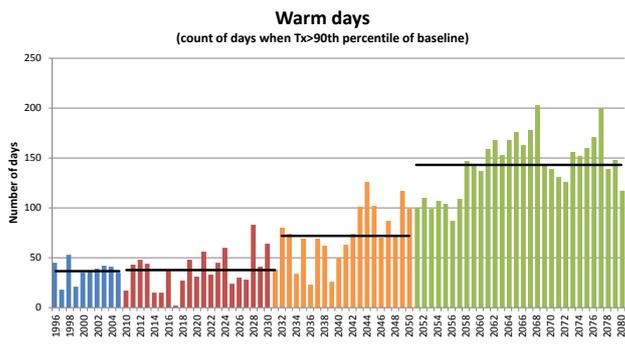
**Figure 7.1.7b.7:** The annual number of warm days will increase especially towards 2050-2080, with a tripling of today's number of warm days. Already in 2030-2050 the number of warms days will almost double compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
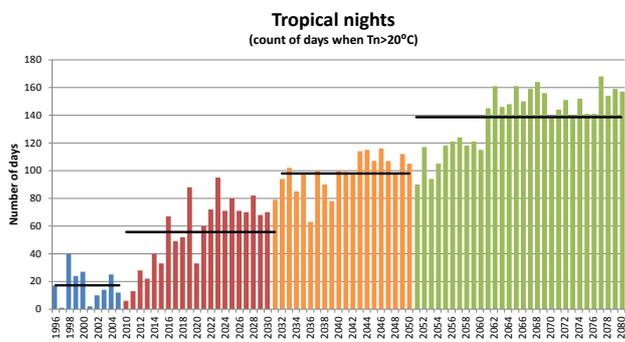
Figure 7.1.7b.8: The number of tropical nights will increase drastically from around 20 to 140 per year, with increases already taking place after 2010. This figure however also shows that substantial year-to-year differences will persist towards 2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
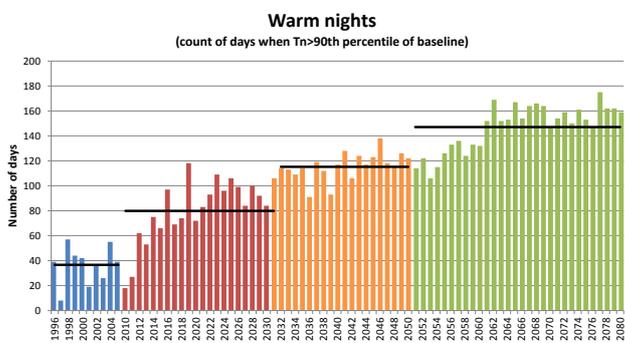
Figure 7.1.7b.9: The number of warm nights will increase drastically to a similar extent. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
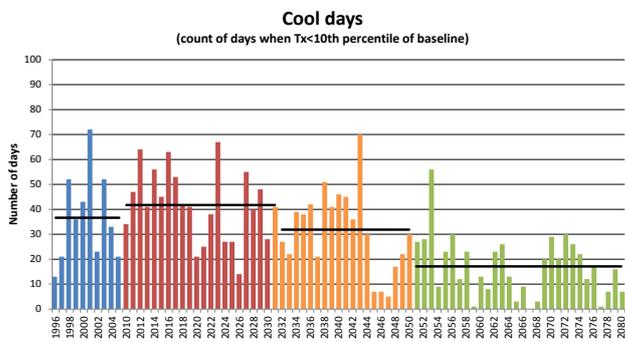
Figure 7.1.7b.10: In apparent contrast with figure 7.1.7b.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

Cool nights
(count of days when Tn<10th percentile) of baseline
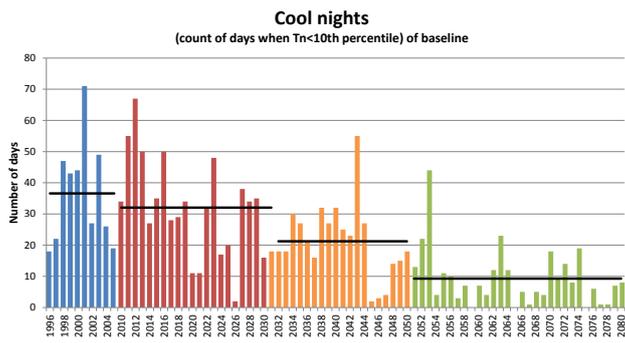
Figure 7.1.7b.11: The number of cool nights will also decrease significantly on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.

Frost days
(count of days when Tn<0°C)
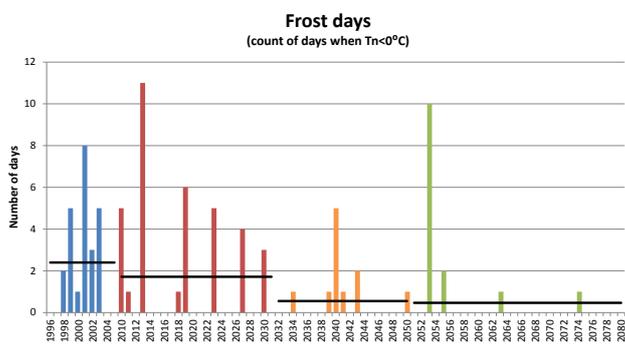
Figure 7.1.7b.12: In line with figure 7.1.7b.5, there are hardly any frost nights to be expected neither in the near nor in the further future.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
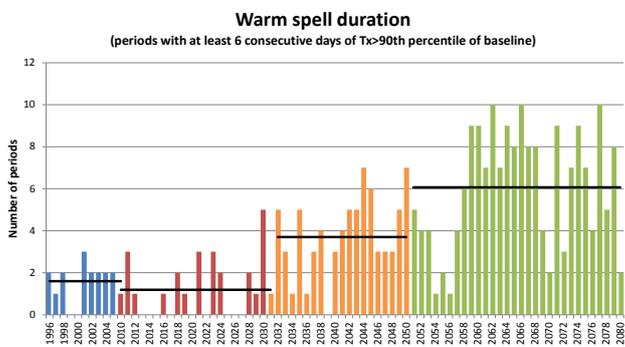
Figure 7.1.7b.13: The number of warm spells per year will increase, especially towards 2050-2080. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase significantly.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
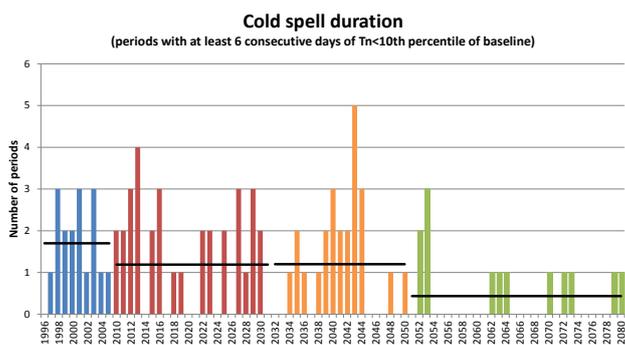
Figure 7.1.7b.14: The number of cold spell periods per year will decrease. Although these currently only count just below 2, they are set to fall below 1 spell per year. Still, there will be annual variations.

133

Precipitation and Monsoon timing

Annual total precipitation
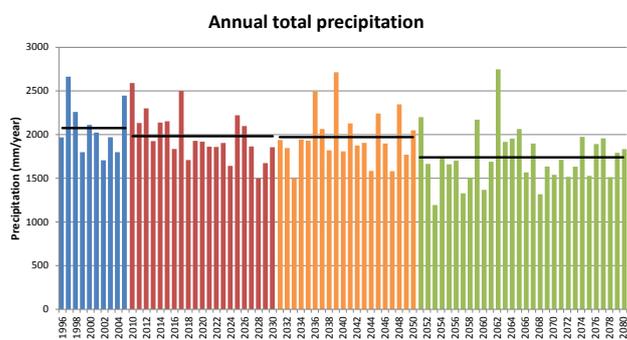
Figure 7.1.7b.15: The annual total amount of precipitation is projected initially to remain approximately constant, and to decrease towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.7b.18-27).

Annual number of heavy precipitation days
(days with precipitation>10mm)
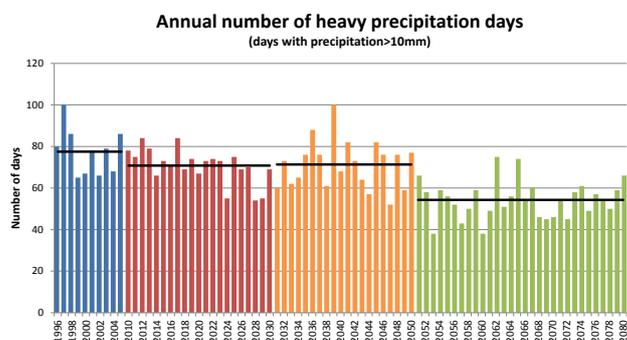
Figure 7.1.7b.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation until after 2050. Again, the distribution over the year might change (see figures 7.1.7b.18-27).

Annual number of very heavy precipitation days
(days with precipitation>20mm)
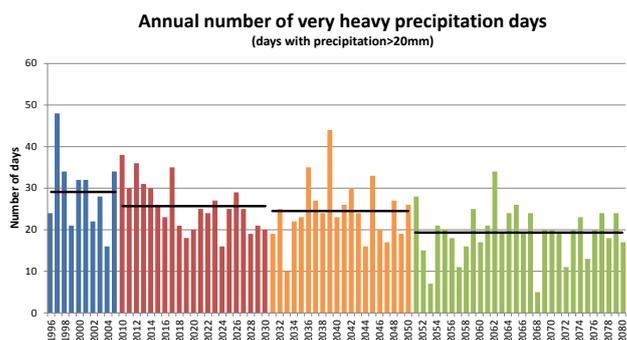
Figure 7.1.7b.17: The annual number of very heavy precipitation days is set to decrease gradually from the current situation. Again, the distribution over the year might change (see figures 7.1.7b.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)

AVG - baseline   AVG - 2010-2030   AVG - 2031-2050   AVG - 2051-2080
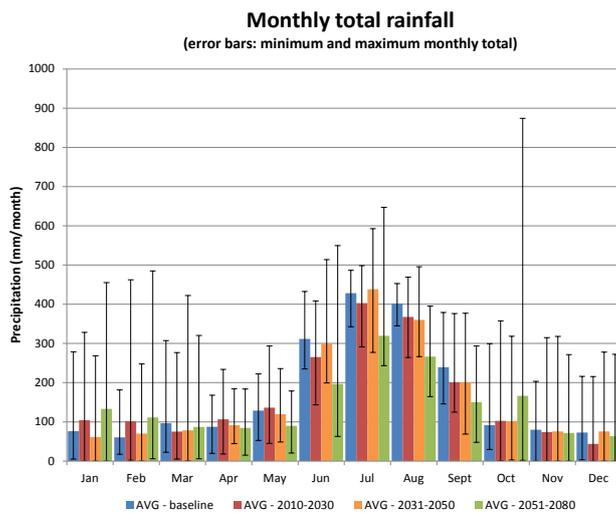
Figure 7.1.7b.18: Monthly total rainfall will increase slightly for the dry period, while June-September especially on the longer term are projected to see a decrease in precipitation. However, error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large and increasing for these drier monsoon months, and at times future rainfall may be larger than today. Also, annual variations are larger than the change between periods.

Monthly average rainfall
(error bars: minimum and maximum monthly average)

AVG - baseline   AVG - 2010-2030   AVG - 2031-2050   AVG - 2051-2080
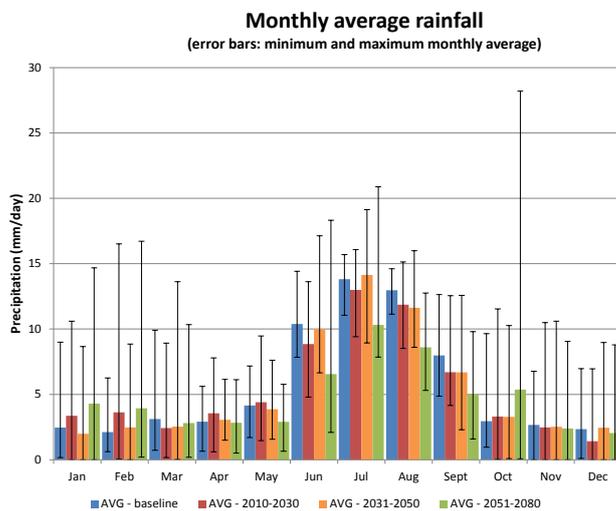
Figure 7.1.7b.19: As in the figure above, monthly average rainfall will increase slightly for the dry period, while June-September especially on the longer term are projected to see a decrease in precipitation and an increase in October. The error bars indicate that inter-annual variations are large and increasing for these drier monsoon months (and October), and at times future rainfall may be larger than today. Also, annual variations are larger than the change between periods

Average and extreme daily precipitation
(periodic averages and extremes)

Baseline 1996-2005   RCP8.5 - 2010-2030   RCP8.5 - 2031-2050   RCP8.5 - 2050-2080
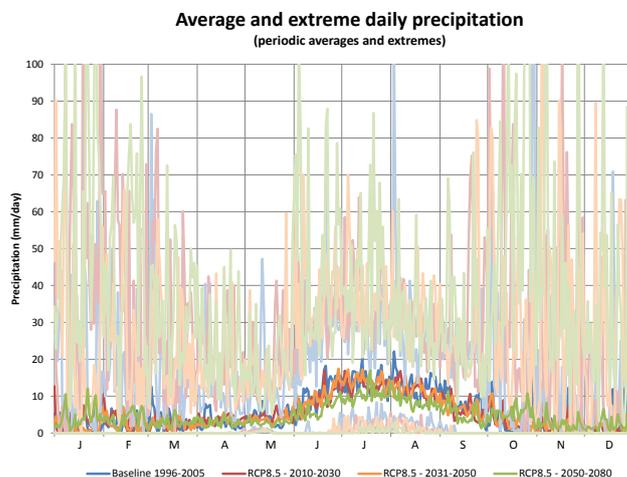
Figure 7.1.7b.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations are very large, and will remain as large as they are today, larger than any shift in rainfall between periods.

135

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
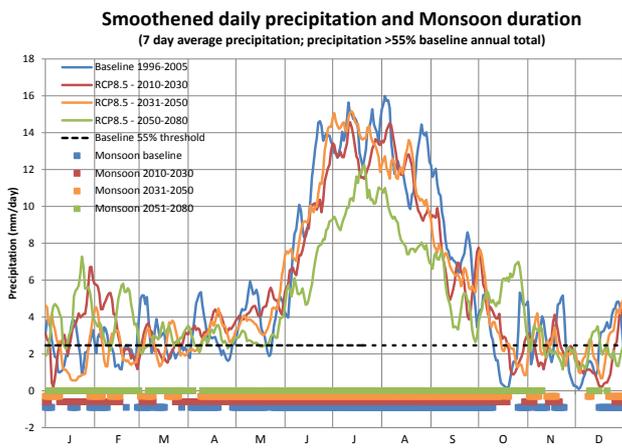
Figure 7.1.7b.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.7b.18-19, rainfall will increase slightly for the dry period (January-February), while June-September especially on the longer term are projected to see a decrease in precipitation. There will be a continued variation in monsoon onset, with a tendency to earlier onsets on the short term. During the monsoon, there will be a decreased rainfall per day, and the end of monsoon may be extended slightly already from 2010 but especially after 2050. It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation
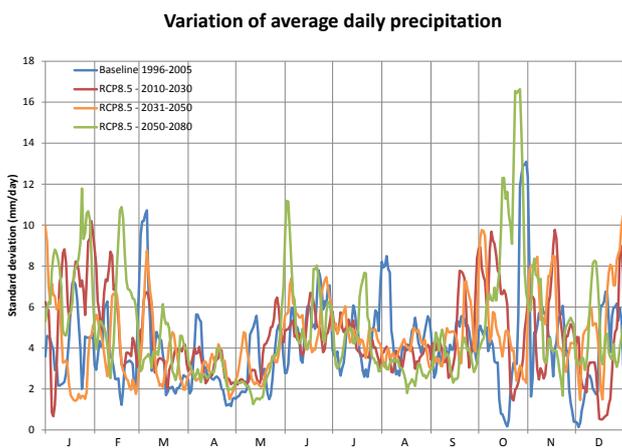
Figure 7.1.7b.22: This figure indicates that the daily variation remains about the same as today's variations, but increases especially during the period December-February and regarding the precipitation/monsoon extension in October.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
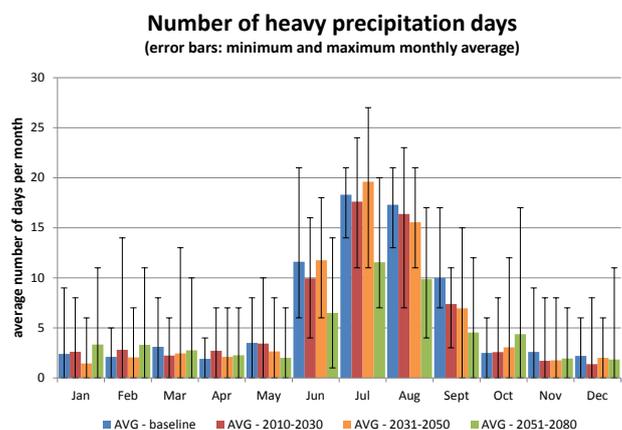
Figure 7.1.7b.23: The number of heavy precipitation days is not expected to change much on the short term, with the exception of a small decrease in September from 2010, and decreases throughout monsoon for the long term. Annual and periodic variation in number of heavy precipitation days will remain about the same.

136

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
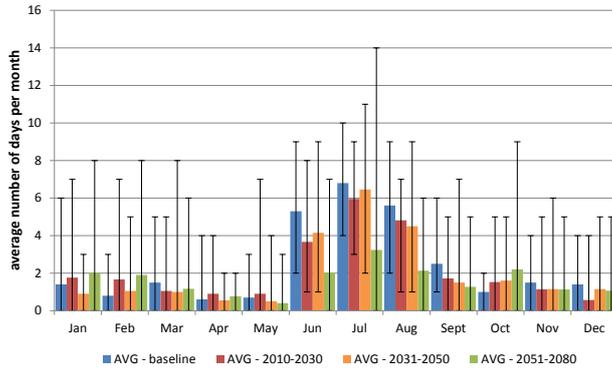
Figure 7.1.7b.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much, and decrease only slowly between periods in the short term and increasingly so on the long term, although variation within projection periods far outweighs the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
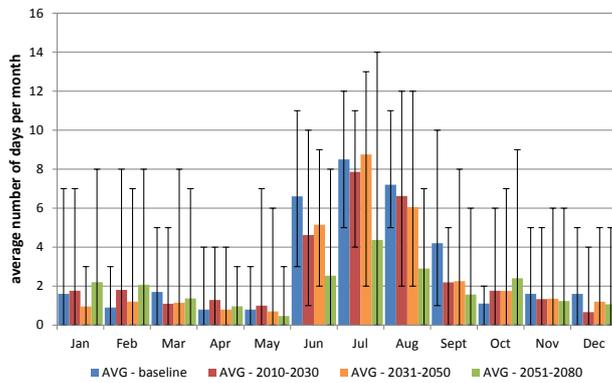
Figure 7.1.7b.25: Similar to the previous graphs, the number of wet days per month will remain about the same for the short term, and decrease on the long term.

Number of very wet days
(error bars: minimum and maximum values)
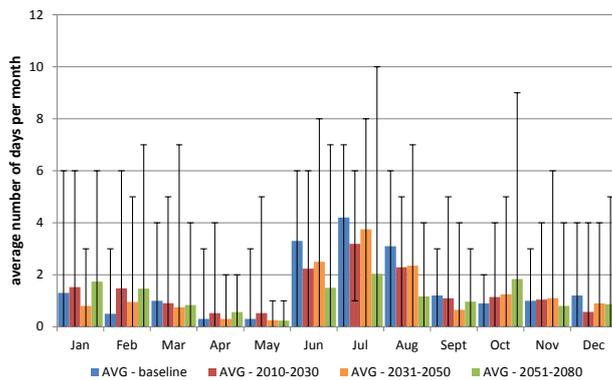
Figure 7.1.7b.26: Similar to the previous graphs, the number of very wet days per month will remain about the same for the short term, and decrease on the long term, with continuing large annual variations.

Number of extremely wet days
(error bars: minimum and maximum values)
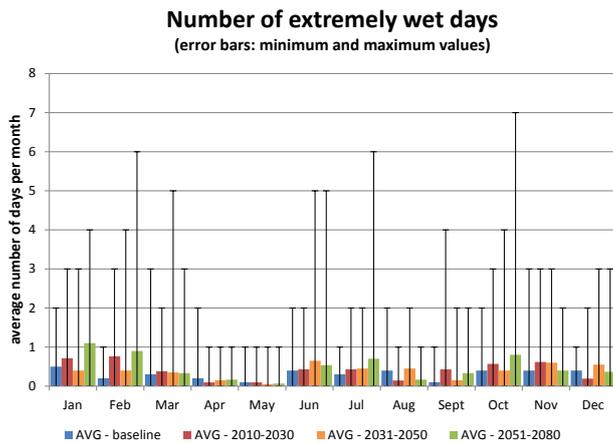
Figure 7.1.7b.27: Similar to the previous graphs, the number of very wet days per month will remain about the same (nihil) as today's situation.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
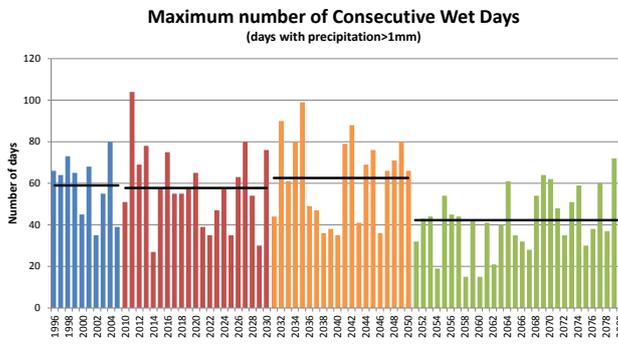
Figure 7.1.7b.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same for the short term but to decrease from 2050 onward, suggesting a shortening of the monsoon.

.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
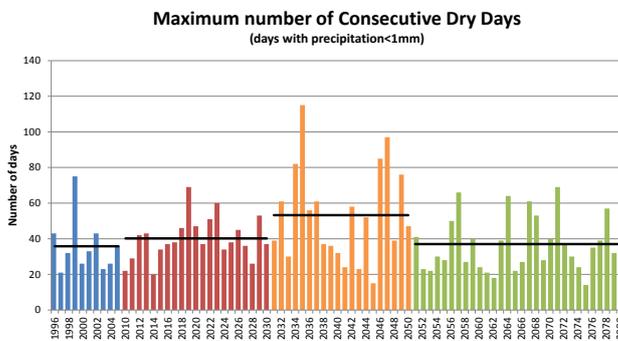
Figure 7.1.7b.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to remain about the same.

Simple Daily Intensity Index
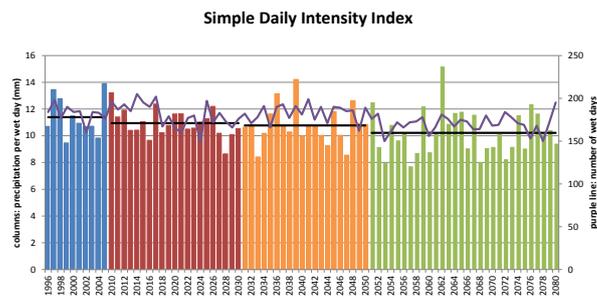
Figure 7.1.7b.30: The amount of precipitation on wet days is projected to remain the same until 2050, for then to decrease slightly. The number of wet days is projected to remain roughly stable, confirming above figures showing decreased precipitation during the monsoon, while monsoon duration

or at least the number of wet days per year remains the same.

138

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)
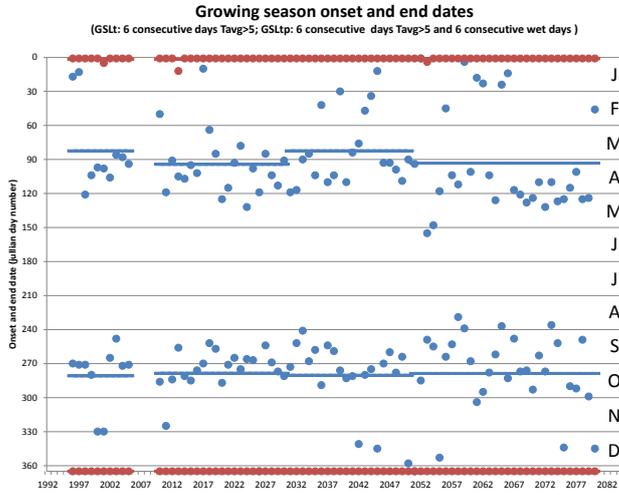
Figure 7.1.7b.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows great annual variations but also remains constant on average over time.

Average growing season duration
(error bars: minimum and maximum extremes)
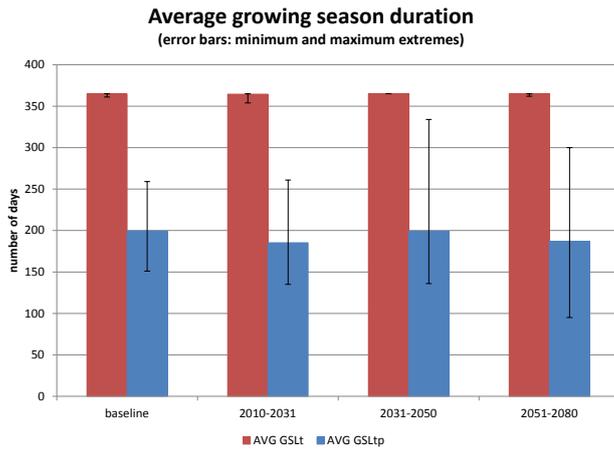
Figure 7.1.7b.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: Both type of growing seasons remain constant in duration, while variation in the precipitation dependent one varies a lot, especially towards the future.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
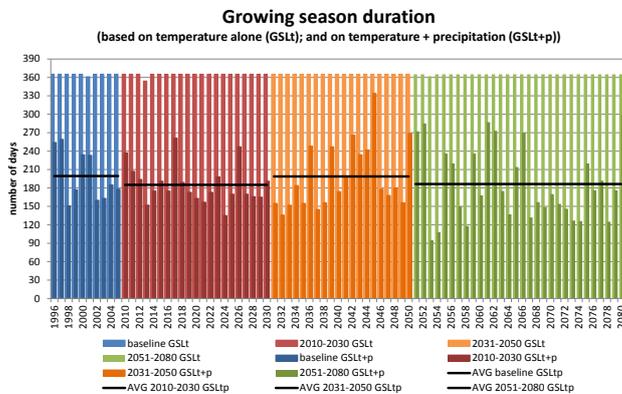
Figure 7.1.7b.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the greater variation in duration of the precipitation dependent growing season towards 2050 onward is caused mainly by both longer and shorter seasons towards 2080.

139

Subdomain 7c: Terai
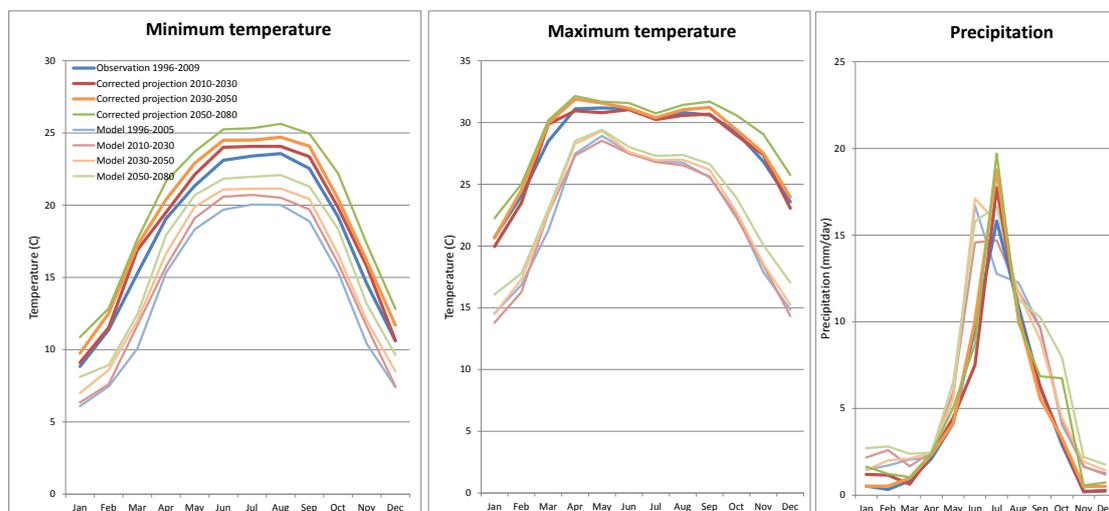
Figure 7.1.7c.0: Adjusted results of the HICAP model show that the model underestimates the minimum and maximum temperature, though less than in the high mountains and middle hills in this domain. Precipitation is slightly overestimated outside the rainy season but fits otherwise quite well with observations, safe for an overestimation of the rain-season duration.
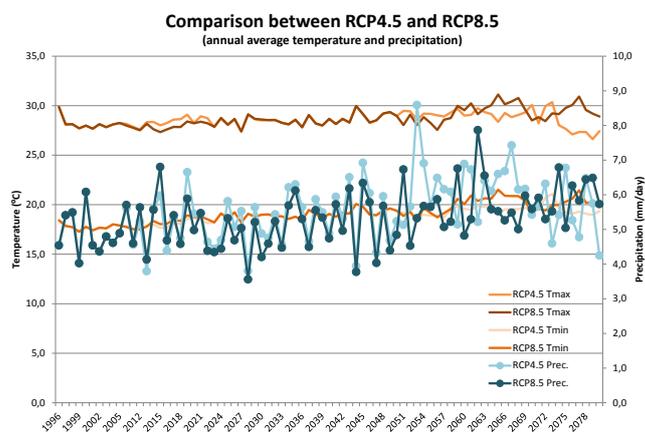
Figure 7.1.7c.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
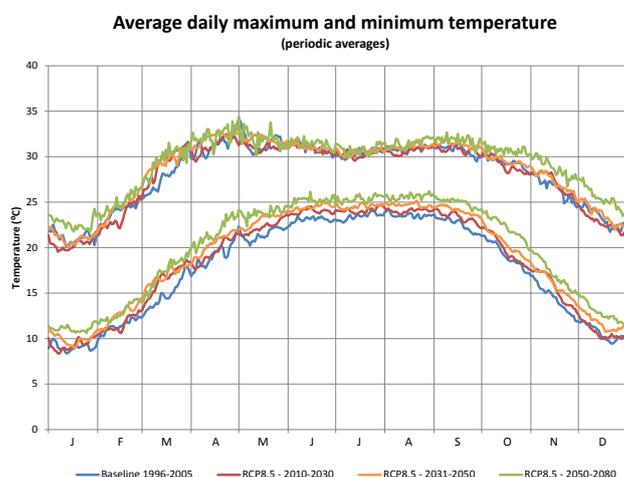
Temperature

Figure 7.1.7c.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually throughout the year towards 2080, with up to about 2-3 degrees. The average daily maximum temperature is projected to increase too, especially from 2050-2080, but much less dramatic and mostly between September and May, outside the monsoon period.

140

Minimum temperature change Region 7c - Terai

Maximum temperature change Region 7c - Terai

Precipitation change Region 7c - Terai
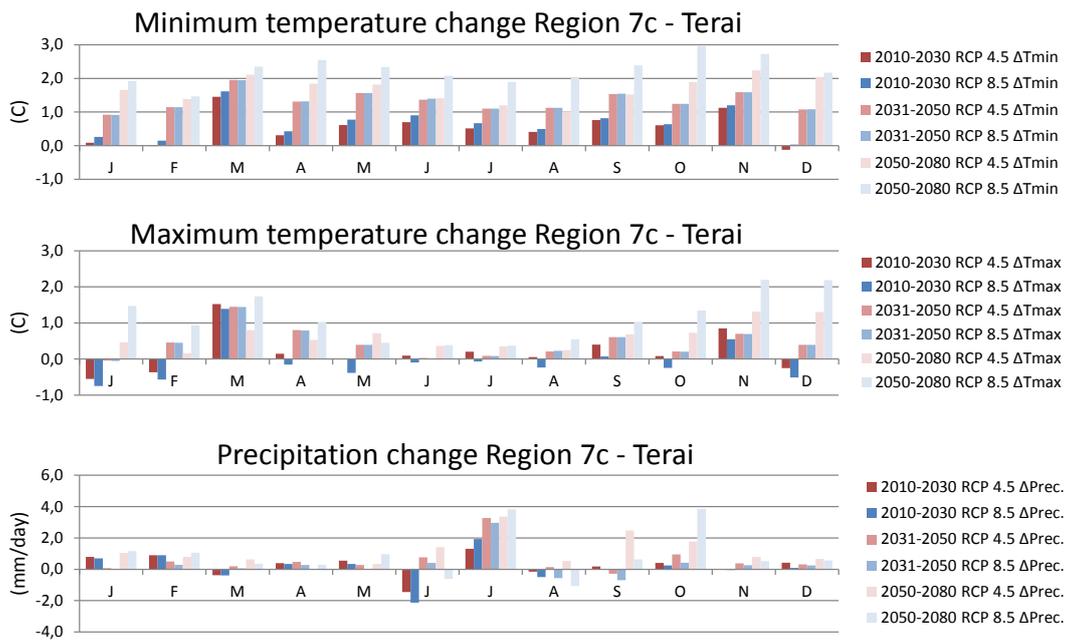
Figure 7.1.7c.2b: Minimum temperatures for the Terai region subdomain will increase already from 2010, and temperatures will grow increasingly higher towards 2050-2080. The minimum (night-time) temperature change is projected to be larger than the maximum (day-time) temperature change, already from 2010 but with increasingly higher temperatures for both towards 2080. March and November will see the largest warming initially both during day and night time, extended to March-May and September-December towards 2050. Between 2010-2030, maximum temperatures will drop somewhat during the winter months compared to today. Compared to RCP4.5, scenario RCP8.5 projects lower maximum temperatures on the short term, but greater warming than RCP4.5 after 2050. For precipitation, scenarios RCP4.5 and RCP8.5 do not differ much, but both indicate generally increased precipitation year-round, but particularly during July already from 2010 and in October on the long term, but also some drier months (June, August) already from 2010 and onward.

Extreme daily maximum and minimum temperature
(periodic extremes)

Figure 7.1.7c.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods except for a small increase in October towards 2050. Extreme daily maximum temperatures (warmest days) are projected to increase with several degrees, but especially towards 2050-2080. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
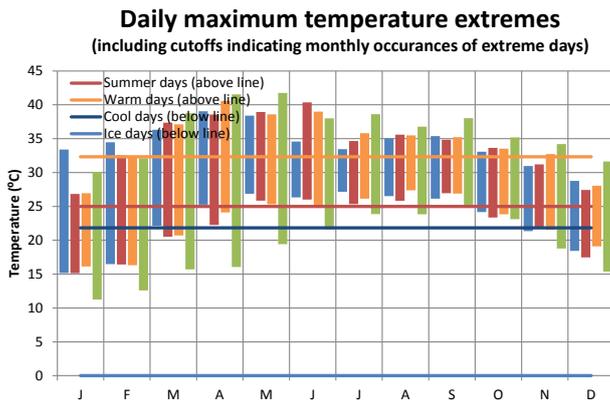
Figure 7.1.7c.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, with some increase in June, but is projected to increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in June-July, as well as for the long term (2050-2080) and an increase in cool days (bar below line) especially for 2050-2080.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)
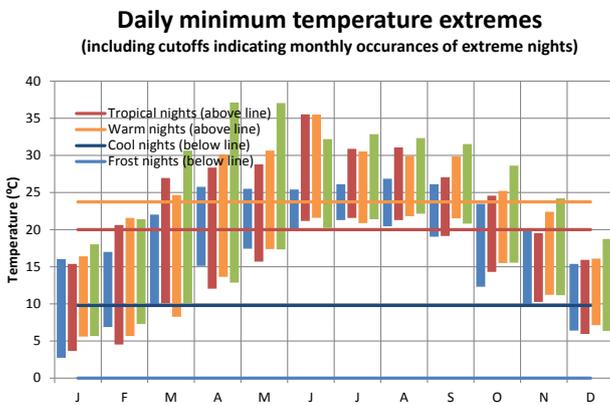
Figure 7.1.7c.5: The daily minimum (night-time) temperature range is projected to remain fairly the same as today's variation, except for an increase in variation from April-August already from 2010, and a shift in September-October from 2030. Variation towards 2050-2080 increases drastically. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during February-August, indicating more and warmer night-time temperatures that time of year. Cool nights will remain about the same.

Summer days
(count of days when Tx>25ºC)
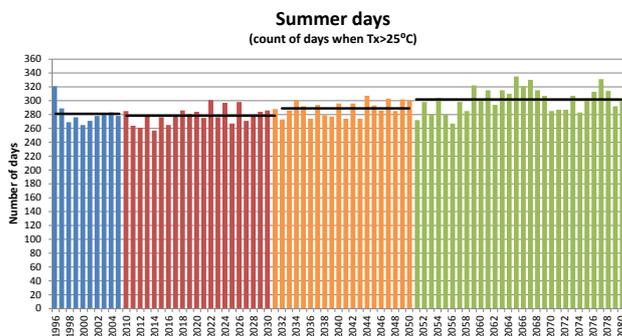
Figure 7.1.7c.6: The annual number of days above 25^{0}C is projected to remain about the same, and annual variations are larger than any projected change between periods.

142

Warm days
(count of days when Tx>90th percentile of baseline)
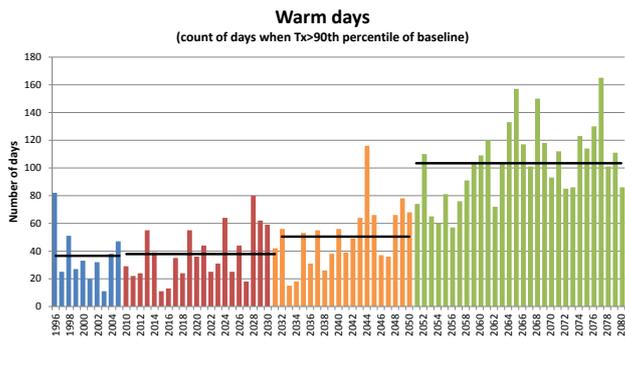
Figure 7.1.7c.7: The annual number of warm days will increase especially towards 2050-2080, with between a doubling and tripling of today's number of warm days. By 2030-2050 the number of warms days will increase with over 10 more compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
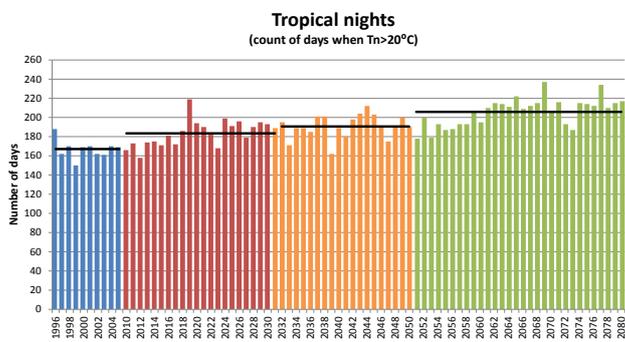
Figure 7.1.7c.8: The number of tropical nights will also increase, although this figure also shows that substantial year-to-year differences will persist towards 2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
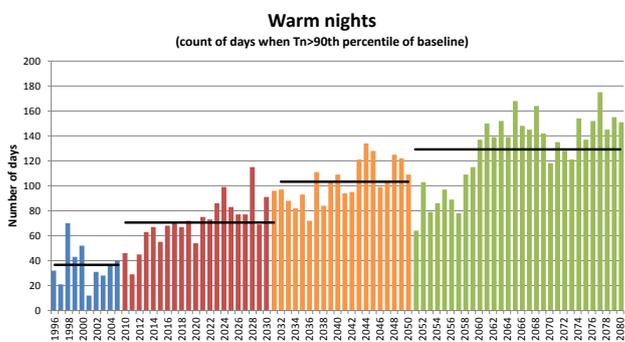
Figure 7.1.7c.9: The number of warm nights will also increase drastically and in fact triple. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
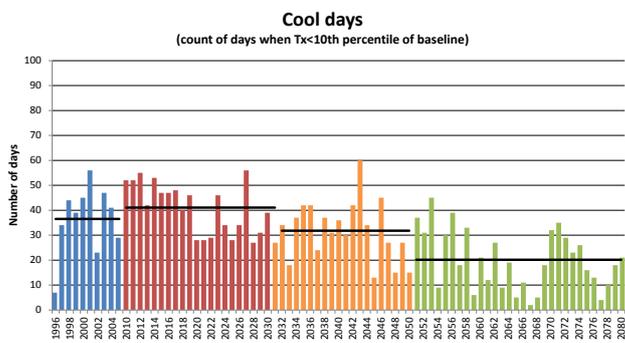
Figure 7.1.7c.10: In apparent contrast with figure 7.1.7c.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

143

Cool nights
(count of days when Tn<10th percentile) of baseline
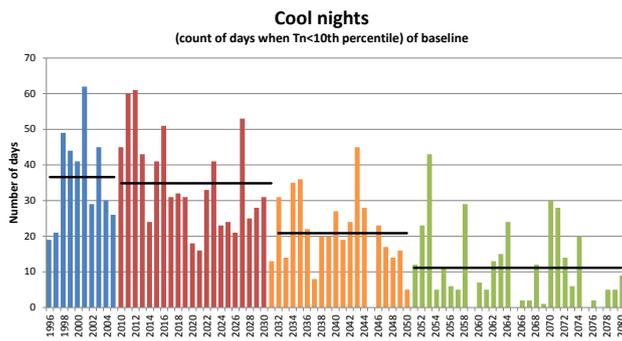
Figure 7.1.7c.11: The number of cool nights will also decrease significantly on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.

Frost free nights
(count of days when Tn>0°C)
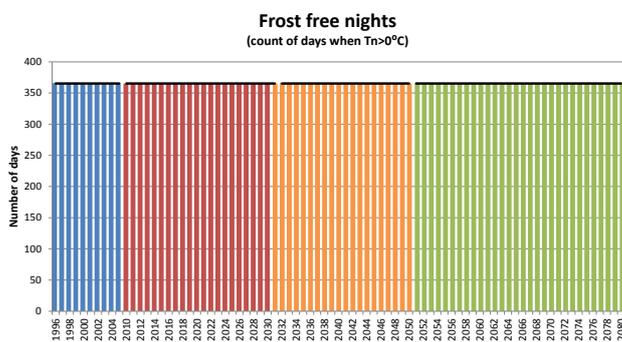
Figure 7.1.7c.12: In line with figure 7.1.7c.5, there are no frost nights to be expected neither in the near nor in the further future.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
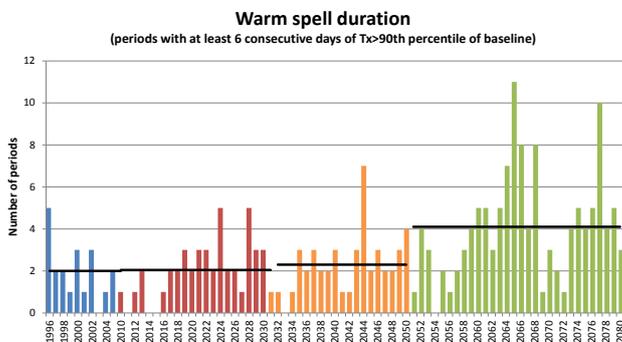
Figure 7.1.7c.13: The number of warm spells per year will increase with a few but note that the figure does not indicate exactly how long each of these spells will be, and that annual variations in number of warm spells are larger than between period changes.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
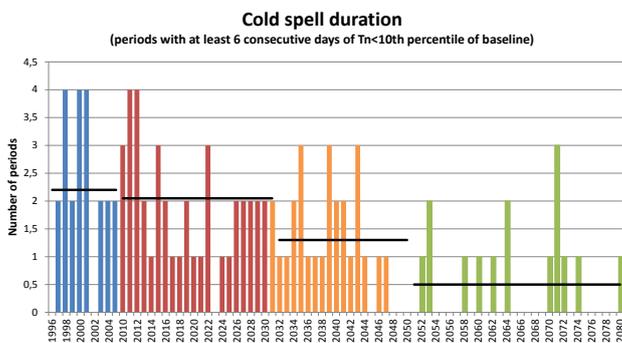
Figure 7.1.7c.14: The number of cold spell periods per year will decrease. Although these currently only count just above 2, they are set to fall to below 1 spell per year. Still, there will be annual variations.

Precipitation and Monsoon timing

Annual total precipitation
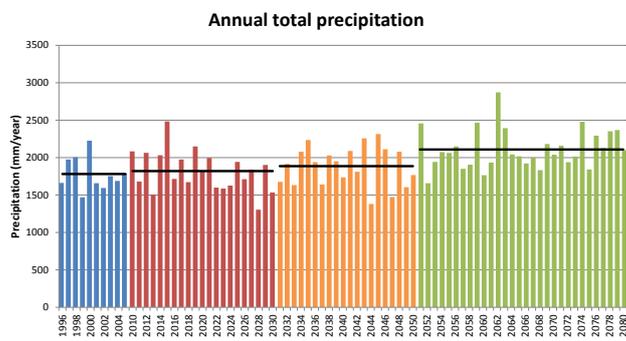
Figure 7.1.7c.15: The annual total amount of precipitation is projected to remain approximately constant, perhaps slightly increase towards the end of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.7c.18-27).

Annual number of heavy precipitation days
(days with precipitation>10mm)
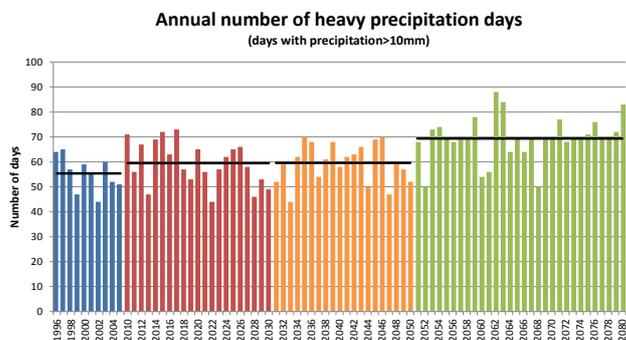
Figure 7.1.7c.16: The annual number of heavy precipitation days is not set to change much, but to increase a bit from the current situation towards 2050-2080. Again, the distribution over the year might change (see figures 7.1.7c.18-27).

Annual number of very heavy precipitation days
(days with precipitation>20mm)
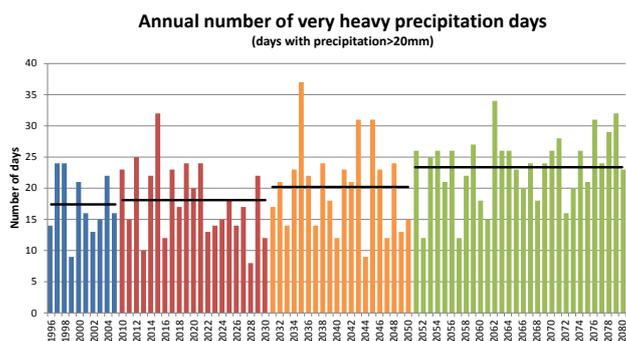
Figure 7.1.7c.17: As in the former figure, the annual number of very heavy precipitation days is not set to change much from the current situation initially and increase a bit towards 2050-2080. Again, the distribution over the year might change (see figures 7.1.7c.18-27).

Monthly total rainfall
(error bars: minimum and maximum monthly total)
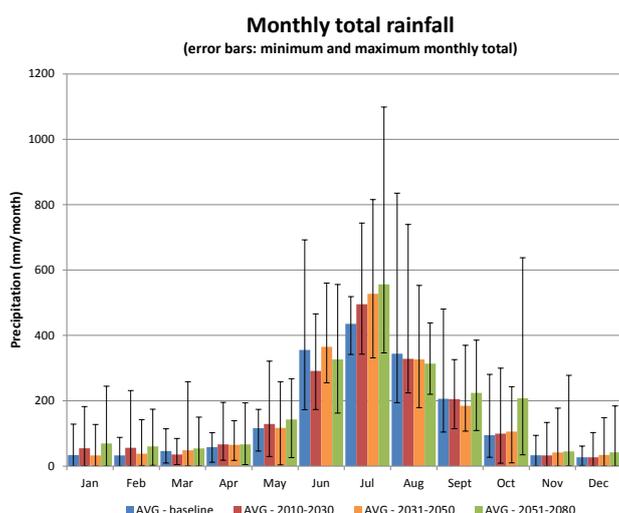
Figure 7.1.7c.18: Monthly total rainfall will not change much for the dry period, but July (already from 2010) and October (on the longer term) are projected to see an increase. This suggests that there will be a bit more rainfall during the monsoon and in time during the post-monsoon. Error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large, larger than the change between periods.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
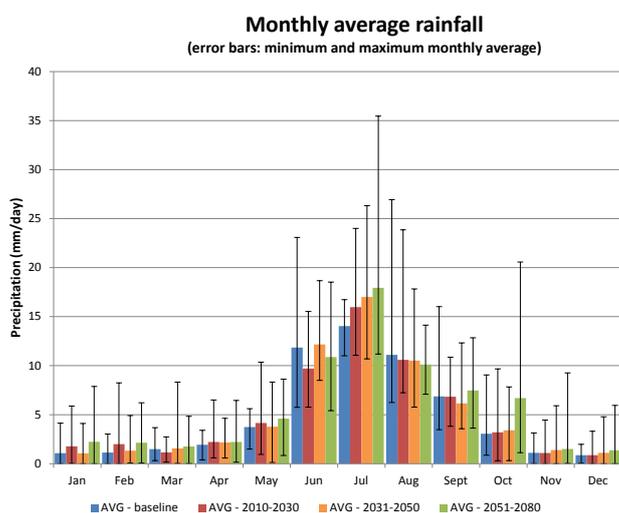
Figure 7.1.7c.19: As in the figure above, monthly average rainfall will not change much for the dry period, but again July (from 2010) and October (on the longer term), are projected to see an increase. Again, this suggests that there will be a bit more rainfall during the monsoon and post-monsoon (in time), but with large (and increasing) inter-annual variations especially for these wet months, as well as for June, the onset of monsoon.

Average and extreme daily precipitation
(periodic averages and extremes)
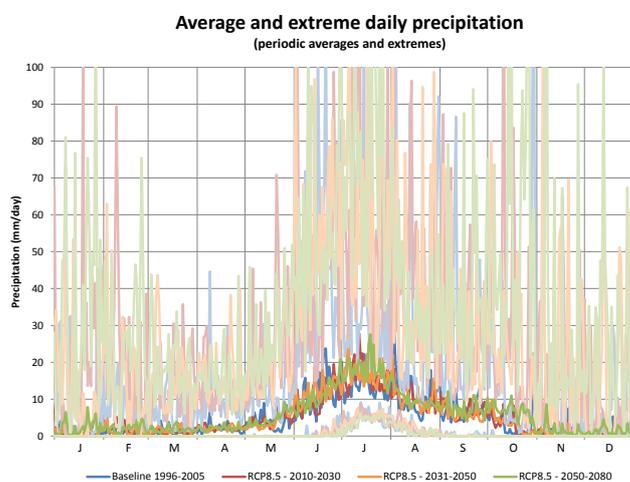
Figure 7.1.7c.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day between periods, and 2) that annual variations are very large, and will remain as large as they are today, larger than any shift in rainfall between periods. This means large variations in monsoon rainfall, onset and end, and in rainfall during winter.

146

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
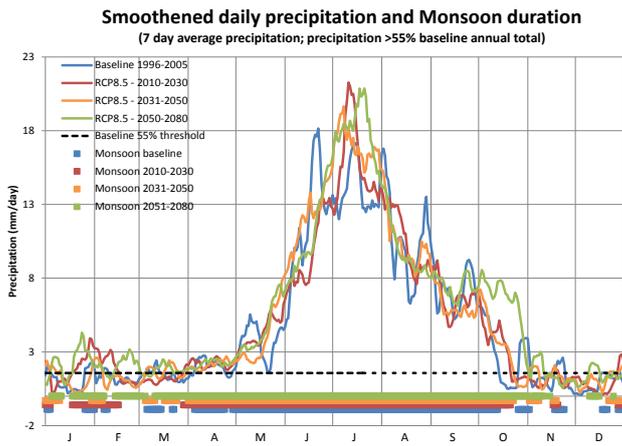
Figure 7.1.7c.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.7c.18-19, rainfall will not change much for the dry period, but July (already from 2010) and October (on the longer term) are projected to see an increase, while June will see a decrease. There will be a continued variation in monsoon onset, with a tendency to earlier onsets over time but a disappearance of the pre-monsoon. During the monsoon, there will be an increased rainfall per day, and the end of monsoon may be extended towards the end of October already from 2010 but especially towards 2050-2080, while the post-monsoon disappears. It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation
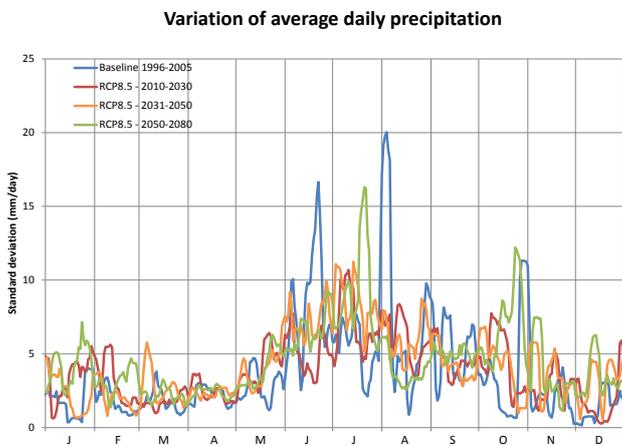
Figure 7.1.7c.22: This figure indicates that the daily variation is a bit larger in the wet period than in the dry period of the year, and that the current variation in June and end of July will become smaller, while end of monsoon in October will become more variable from year to year.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
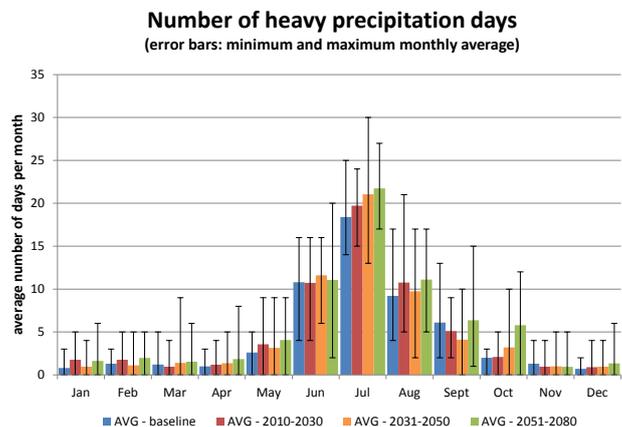
Figure 7.1.7c.23: The number of heavy precipitation days is not expected to change much, with the exception of July and October, which are expected to see a gradual increase from 2010. Annual and periodic variation in number of heavy precipitation days will remain about the same.

147

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
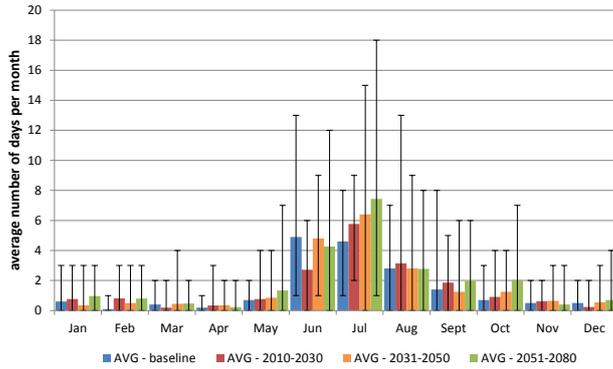
Figure 7.1.7c.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, with the exception of an increase in July although variation within projection periods far outweighs the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
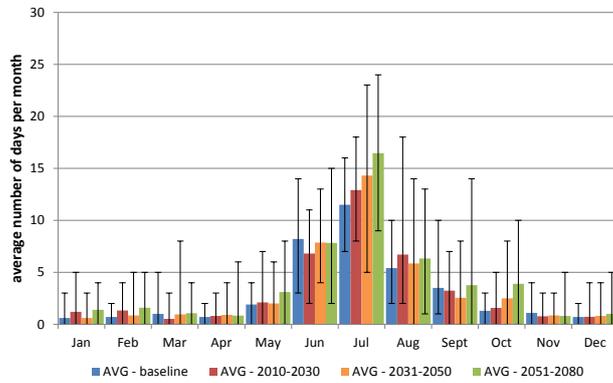
Figure 7.1.7c.25: Similar to the previous graphs, the number of wet days per month will see a gradual increase in July, but otherwise remain roughly the same to today's occurrence.

Number of very wet days
(error bars: minimum and maximum values)
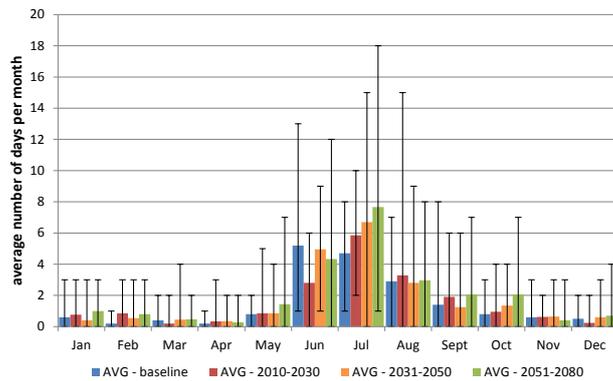
Figure 7.1.7c.26: As in the figure above, the number of very wet days per month will see a gradual increase in July although with greater variations within projection periods than between projection periods.

148

Number of extremely wet days
(error bars: minimum and maximum values)
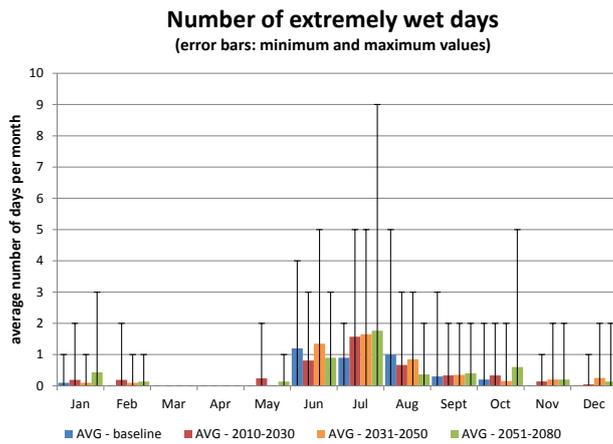
Figure 7.1.7c.27: As in the figure above, the number of extremely wet days per month will increase slightly in July, although with greater variations within projection periods than between projection periods.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
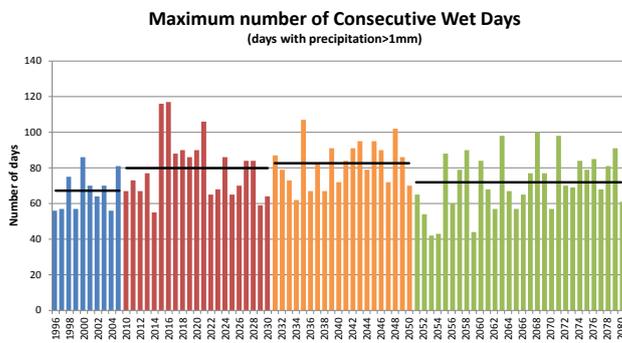
Figure 7.1.7c.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to initially increase from 2010, suggesting a lengthening of the monsoon or increased wet days outside monsoon, followed by a decrease after 2050, back to today's monsoon duration or drier days

outside monsoon.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
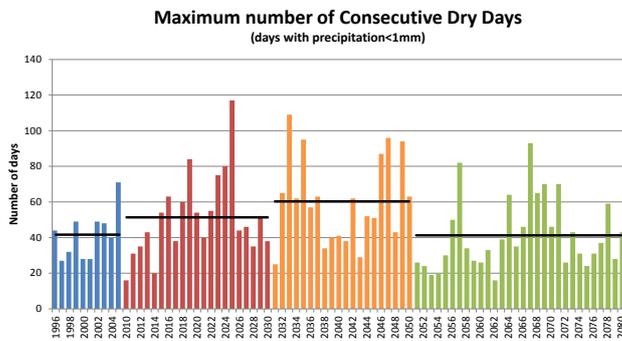
Figure 7.1.7c.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to initially increase slightly from 2010, and then decrease again to today's number of dry days.

Simple Daily Intensity Index
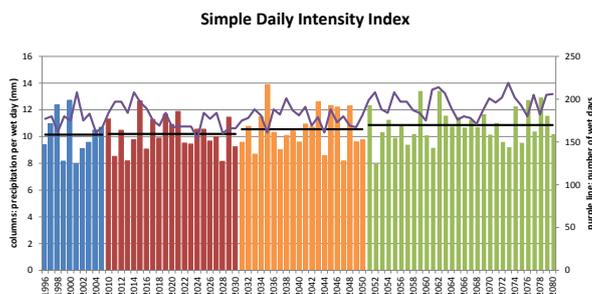
Figure 7.1.7c.30: The amount of precipitation on wet days is projected to remain roughly the same. At the same time, the number of wet days is set to remain about the same, confirming above figures showing no great changes in the duration and precipitation of monsoon or dry periods.

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)
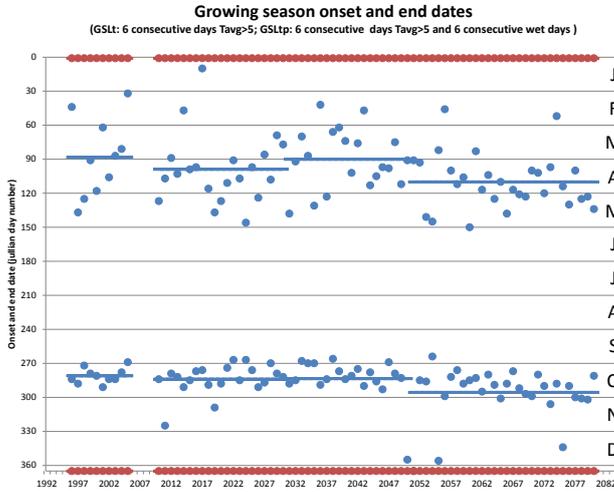
Figure 7.1.7c.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season remains year-round, while the precipitation dependent growing season shows greater annual variations and a small shift towards later onsets and ends after 2050.

Average growing season duration
(error bars: minimum and maximum extremes)
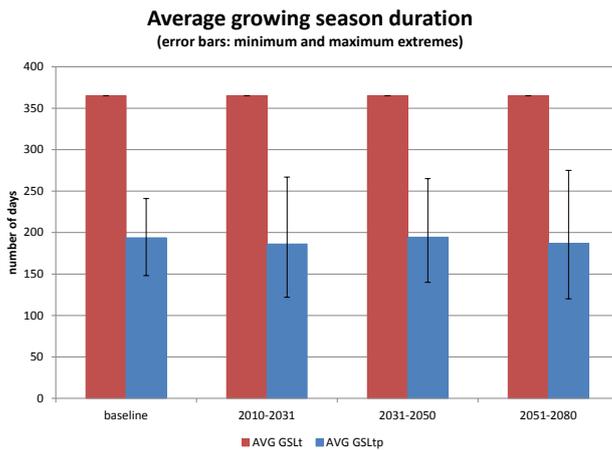
Figure 7.1.7c.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: Variations duration make the precipitation dependent growing season duration vary a lot currently and increasingly from 2010 onward. The average duration remains about the same for both type of growing seasons.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
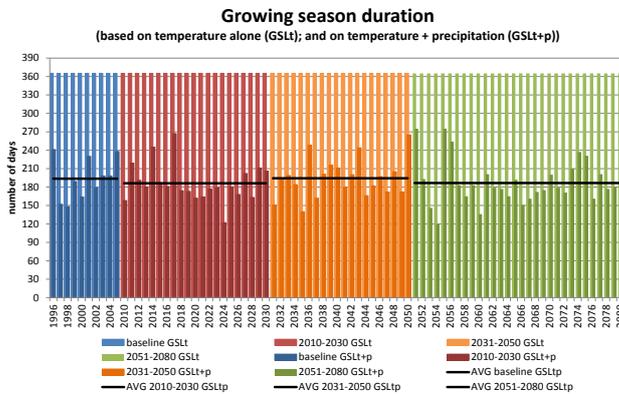
Figure 7.1.7c.33: This figure takes a closer look at the annual variations in growing season duration, and shows that the increased variation in duration of the precipitation dependent growing season especially from 2050 onward is caused mainly by both longer and shorter seasons.

150

7.1.8　Domain 8
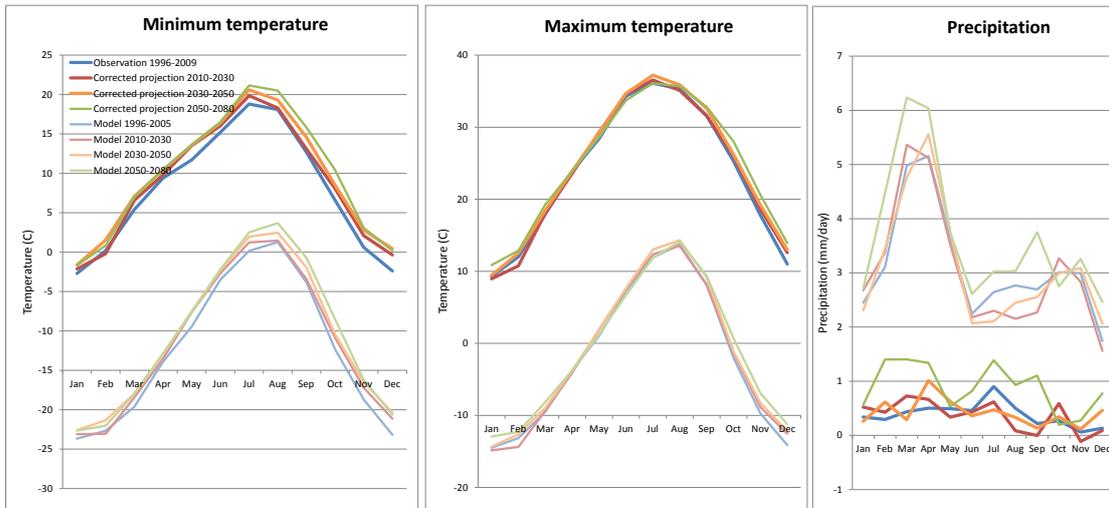
Figure 7.1.8.0: Adjusted results of the HICAP model show that the model very much underestimates the minimum and maximum temperature, with a greater difference for minimum temperature results. Precipitation was overestimated especially during February-May, but also during the remainder of the year.
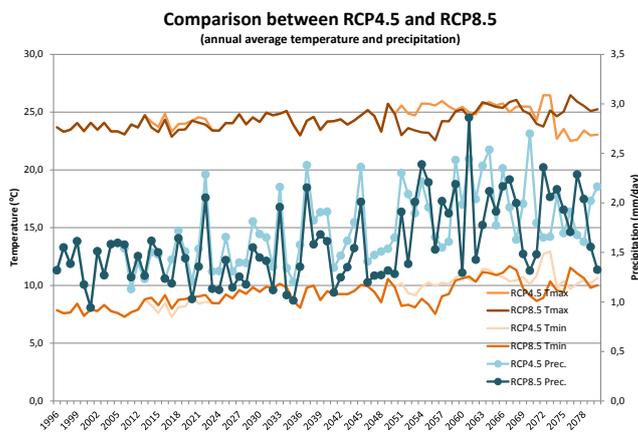
Figure 7.1.8.1: A comparison between temperature (red/orange) and precipitation (blue) projections shows no great difference between scenarios RCP4.5 and RCP8.5 except for a drier mid-term future predicted by RCP8.5. As global emissions currently follow the RCP8.5 track most closely (Peters et al., 2012) we limit the figures presented in this domain to the RCP8.5 scenario.
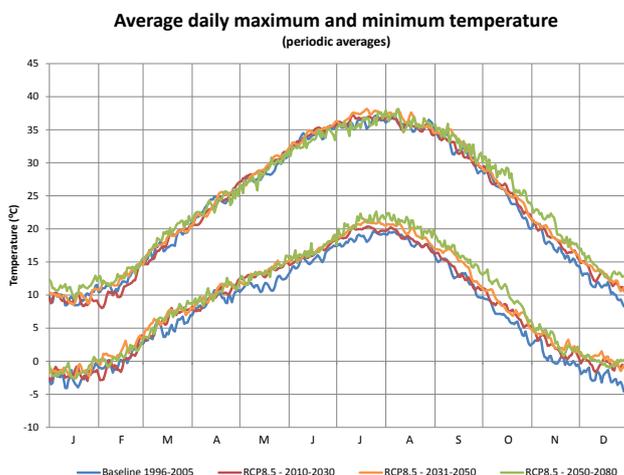
Temperature

Figure 7.1.8.2a: This figure indicates that the average daily minimum temperature is projected to increase gradually throughout the year towards 2080, up to about 2-3 degrees. The average daily maximum temperature is not projected to increase, except for just after the monsoon from 2050-2080.

Minimum temperature change Region 8

Legend:
- 2010-2030 RCP 4.5 ΔTmin
- 2010-2030 RCP 8.5 ΔTmin
- 2031-2050 RCP 4.5 ΔTmin
- 2031-2050 RCP 8.5 ΔTmin
- 2050-2080 RCP 4.5 ΔTmin
- 2050-2080 RCP 8.5 ΔTmin

Maximum temperature change Region 8

Legend:
- 2010-2030 RCP 4.5 ΔTmax
- 2010-2030 RCP 8.5 ΔTmax
- 2031-2050 RCP 4.5 ΔTmax
- 2031-2050 RCP 8.5 ΔTmax
- 2050-2080 RCP 4.5 ΔTmax
- 2050-2080 RCP 8.5 ΔTmax

Precipitation change Region 8

Legend:
- 2010-2030 RCP 4.5 ΔPrec.
- 2010-2030 RCP 8.5 ΔPrec.
- 2031-2050 RCP 4.5 ΔPrec.
- 2031-2050 RCP 8.5 ΔPrec.
- 2050-2080 RCP 4.5 ΔPrec.
- 2050-2080 RCP 8.5 ΔPrec.

Figure 7.1.8.2b: Minimum (night-time) temperature change is projected to be about twice as much as the projected maximum (day-time) temperature change. Most warming takes place during the night, during October-December and May from 2010, and from May through December on the mid- and long term. Scenario RCP4.5 projects a bit more warming than RCP8.5 on the long term, but otherwise the scenarios are comparable. They do however differ in their projection of precipitation, with RCP8.5 projecting a decrease in precipitation year-round until 2050, while RCP4.5 only projects a drier August-December until 2030, after which precipitation increases year-round.

Extreme daily maximum and minimum temperature
(periodic extremes)

Legend: Baseline 1996-2005 — RCP8.5 - 2010-2030 — RCP8.5 - 2031-2050 — RCP8.5 - 2050-2080
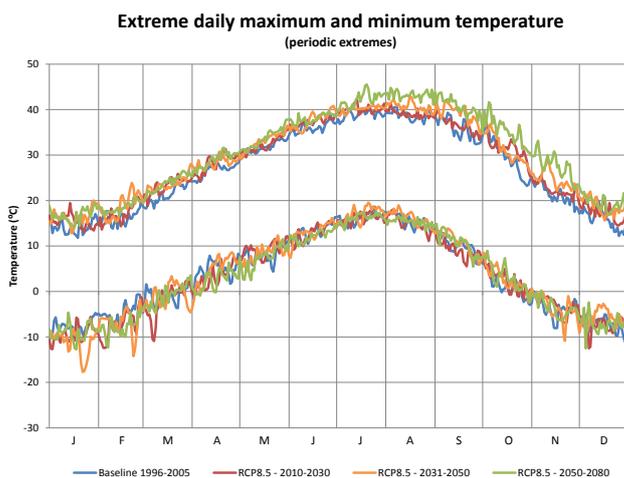
Figure 7.1.8.3: The lowest daily minimum temperatures (coldest nights) will remain the same for all periods while extreme daily maximum temperatures (warmest days) are projected to increase especially towards 2050-2080, from July-November. This figure suggests that variation in extreme temperatures will not increase much beyond today's variation.

Daily maximum temperature extremes
(including cutoffs indicating monthly occurances of extreme days)
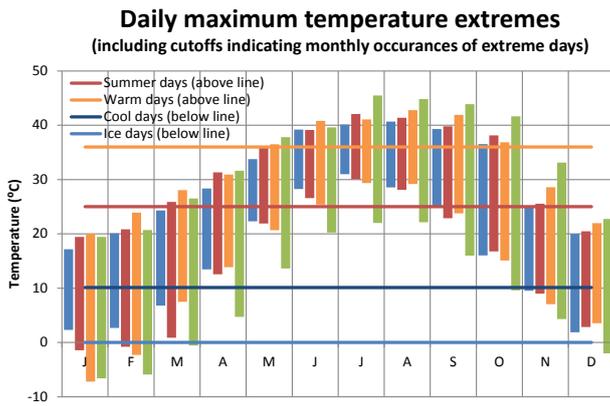
Figure 7.1.8.4: The projected daily maximum temperature range (length of the bar) remains fairly similar until 2050, with some increase in January-March, but is projected to increase year round for 2050-2080. The thresholds (horizontal lines and legend) in the figure indicate an increase (bar above line) of warm days notably in July-September, as well as for the long term (2050-2080) and an increase in cool days (bar below line) from November-February from 2010.

Daily minimum temperature extremes
(including cutoffs indicating monthly occurances of extreme nights)

Figure 7.1.8.5: The daily minimum (night-time) temperature range is projected to remain fairly the same as today's variation, except for an increase in variation from January-March and June-October already from 2010. Variation towards 2050-2080 increases drastically especially outside winter. Also, especially the upper extreme of daily minimum temperatures is set to increase from 2010 particularly during April-October, indicating more and warmer night-time temperatures that time of year. Frost- and cool nights temperatures will remain the same or decrease a bit from 2010.

Summer days
(count of days when Tx>25ºC)
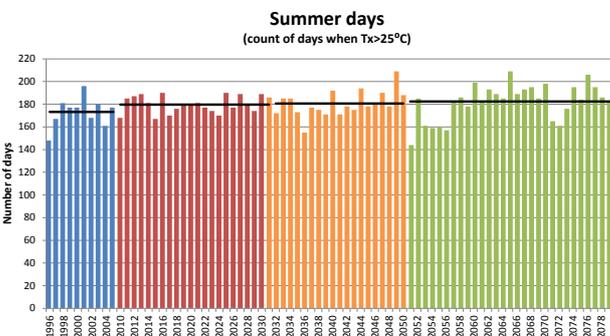
Figure 7.1.8.6: The annual number of days above 25^0C is projected to remain about the same as currently. The annual variation is larger than the projected change between periods.

Warm days
(count of days when Tx>90th percentile of baseline)
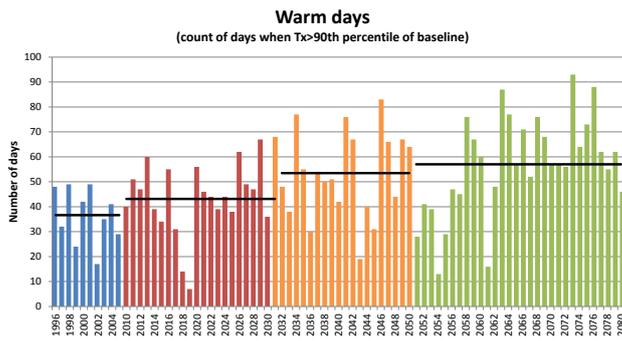
Figure 7.1.8.7: The annual number of warm days will increase especially towards 2050-2080. Already in 2030-2050 the number of warms days will increase with about 20 more compared to today. This figure however also shows annual variations will persist and increase.

Tropical nights
(count of days when Tn>20°C)
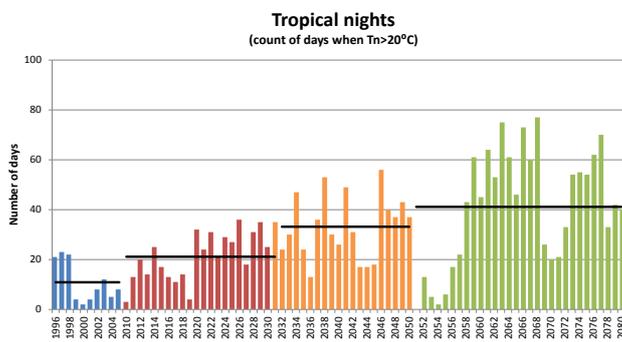
Figure 7.1.8.8: The number of tropical nights will more than double towards 2050-2080. This figure however also shows that substantial year-to-year differences will persist towards 2080.

Warm nights
(count of days when Tn>90th percentile of baseline)
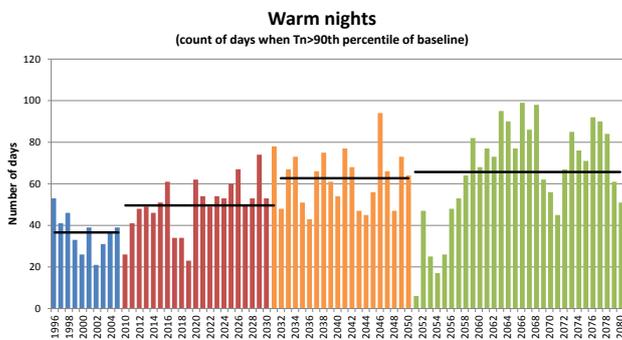
Figure 7.1.8.9: The number of warm nights will also increase, with over 20 more in 2050-2080. This figure however shows that substantial year-to-year differences will persist and increase towards 2080.

Cool days
(count of days when Tx<10th percentile of baseline)
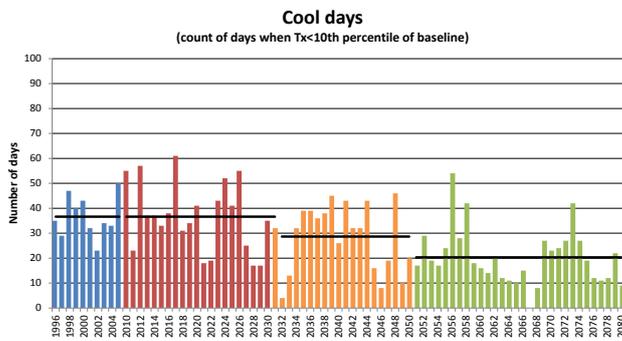
Figure 7.1.8.10: In apparent contrast with figure 7.1.8.4, which suggested an increase in cool days for several months of the year, the number of cool days on an annual basis is projected to decrease. The difference between these figures also highlights the point that annual and seasonal representations can highlight different details.

154

Cool nights
(count of days when Tn<10th percentile) of baseline
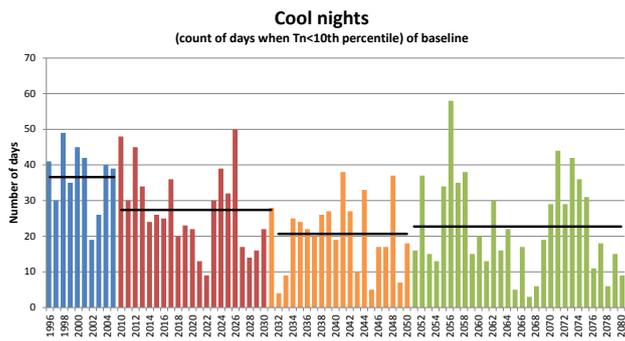
Figure 7.1.8.11: The number of cool nights will also decrease on an annual basis. This figure also shows that substantial year-to-year differences will persist towards 2080.

Frost days
(count of days when Tn<0°C)
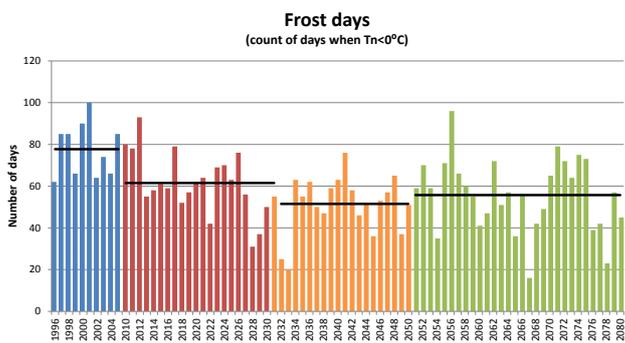
Figure 7.1.8.12: In line with figure 7.1.8.5, the number of frost nights is expected to remain the same or decrease a bit from 2010 onward.

Warm spell duration
(periods with at least 6 consecutive days of Tx>90th percentile of baseline)
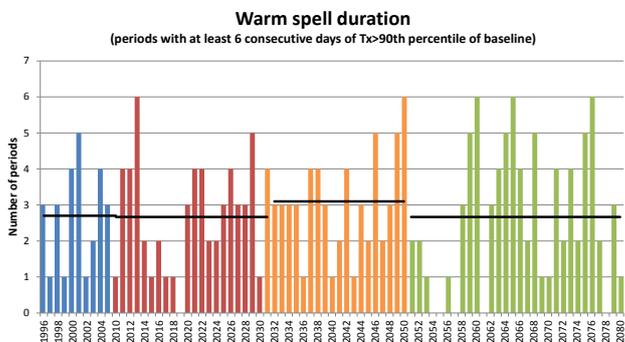
Figure 7.1.8.13: The number of warm spells per year will remain about the same. Note that the figure does not indicate exactly how long each of these spells will be. Annual variations in number of warm spells will increase.

Cold spell duration
(periods with at least 6 consecutive days of Tn<10th percentile of baseline)
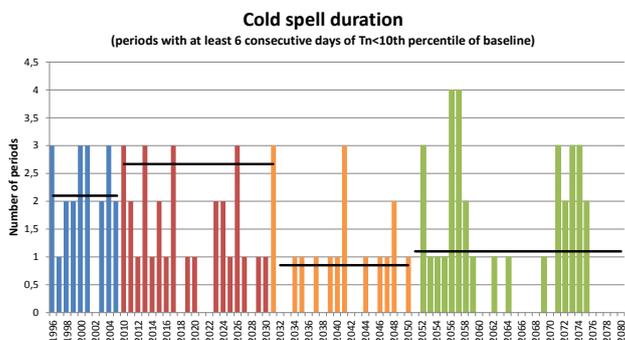
Figure 7.1.8.14: The number of cold spell periods per year will decrease, although they will initially increase a bit. They currently count around 2, and are set to fall to around 1 spell per year. Still, there will be annual variations.

155

Precipitation and Monsoon timing
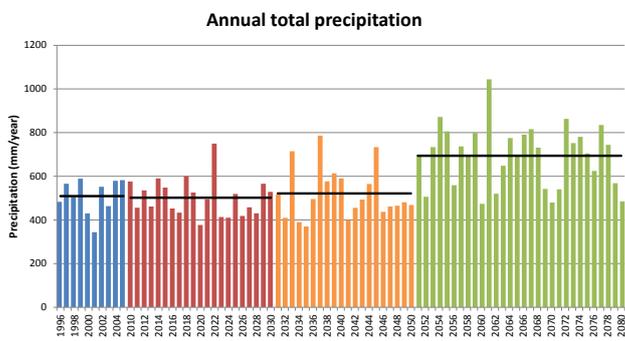
Figure 7.1.8.15: The annual total amount of precipitation is projected to remain approximately constant, and to increase towards the second half of the century. Here, it will be important to look into more detail to understand if and how the seasonal distribution will change (see figures 7.1.8.18-27).
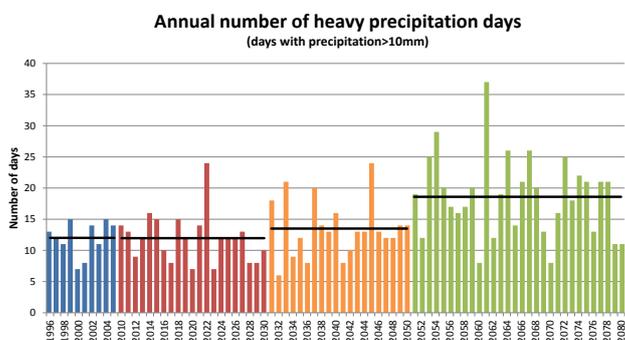
Figure 7.1.8.16: As in the former figure, the annual number of heavy precipitation days is not set to change much from the current situation initially, but to increase somewhat towards 2050-2080. Again, the distribution over the year might change (see figures 7.1.8.18-27).
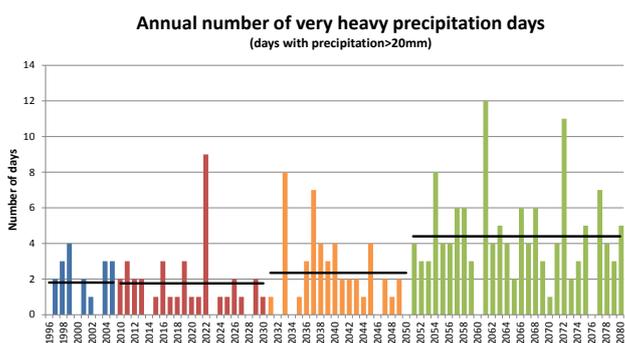
Figure 7.1.8.17: The annual number of very heavy precipitation days is not set to change much from the current situation. Again, the distribution over the year might change (see figures 7.1.8.18-27).

156

Monthly total rainfall
(error bars: minimum and maximum monthly total)
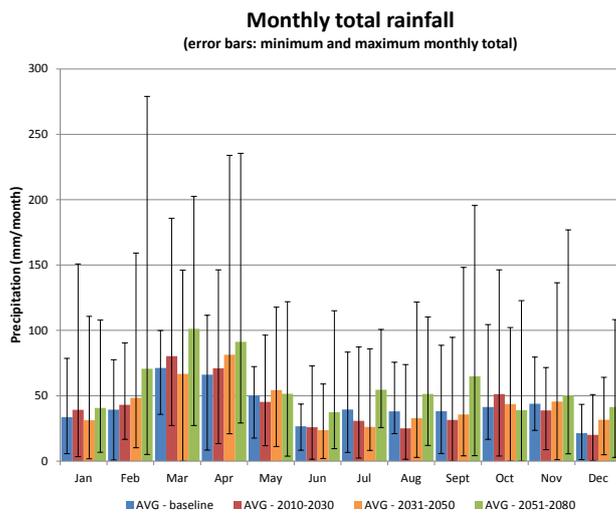
Figure 7.1.8.18: Monthly total rainfall will not change much from today on the short and mid-term (2010-2050), and might increase all over the year on the longer term. Error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large, especially during the wet months, and that variability in precipitation may increase already from 2010 and after.

Monthly average rainfall
(error bars: minimum and maximum monthly average)
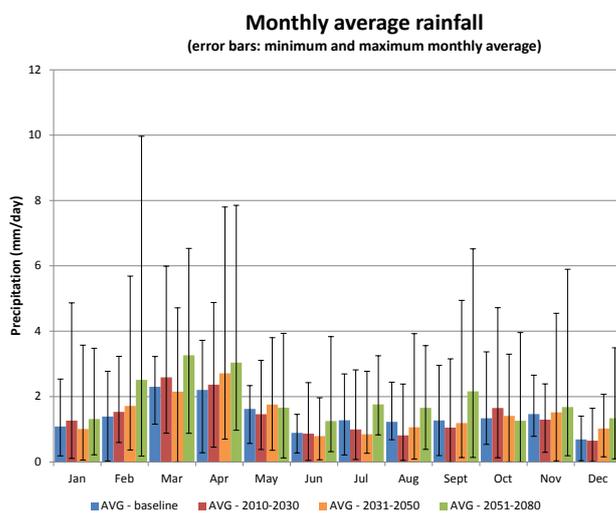
Figure 7.1.8.19: As in the figure above, monthly average rainfall will not change much from today on the short and mid-term (2010-2050), and might increase all over the year on the longer term. Error bars showing minimum and maximum monthly totals indicate that inter-annual variations are large, especially during the wet months, and that variability in precipitation may increase already from 2010 and after.

Average and extreme daily precipitation
(periodic averages and extremes)
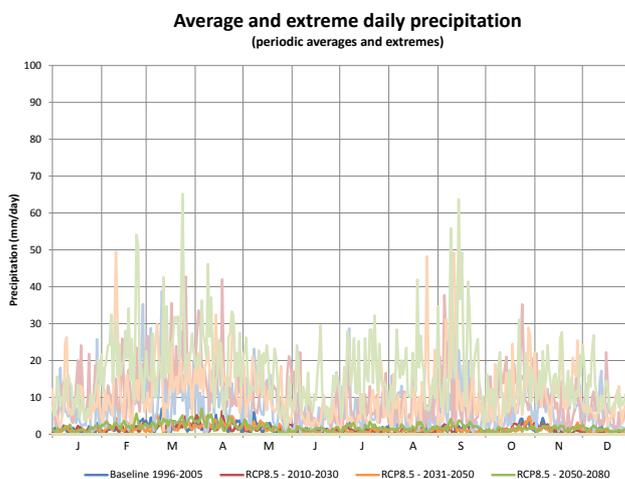
Figure 7.1.8.20: Average daily precipitation and the variations in these between periods show a lot of overlap. This indicates that 1) there will not be much change from day-to-day rainfall between periods, and 2) that annual variations will remain as large or even increase compared to today, especially for the wet months, meaning both more rainfall and more drought for those months.

157

Smoothened daily precipitation and Monsoon duration
(7 day average precipitation; precipitation >55% baseline annual total)
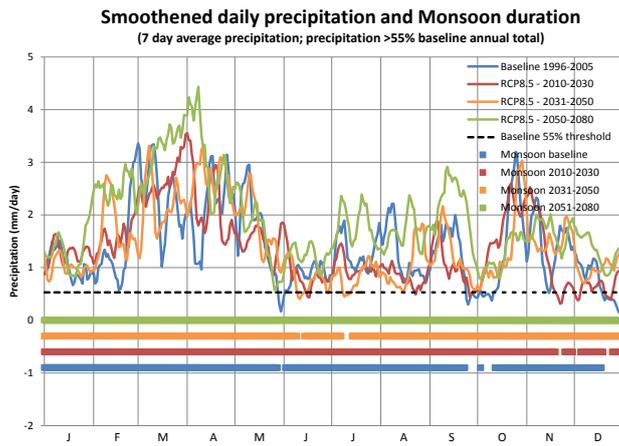
Figure 7.1.8.21: Smoothened data, with large day-to-day variations taken out, present a clearer picture of changes in rainfall distribution. As suggested by the monthly representation in figure 7.1.2.18-19, rainfall will not change much from today on the short and mid-term (2010-2050), and might increase all over the year on the longer term. On the short term, February will see earlier onsets of rain, while June-August will be drier on the short, but wetter on the long term.

It must be kept in mind that projections for precipitation are more uncertain than for temperature.

Variation of average daily precipitation
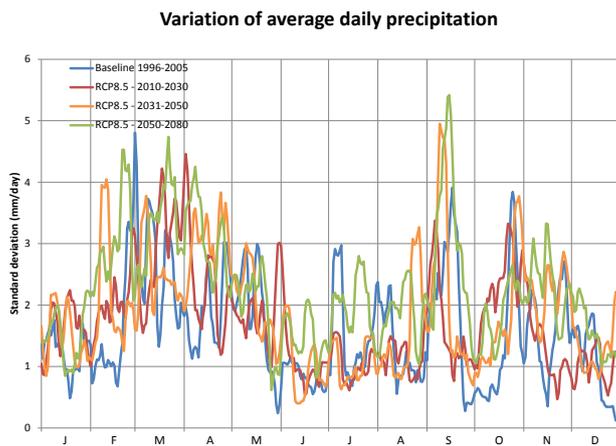
Figure 7.1.8.22: This figure indicates that the daily variation will remain about the same as it is today, with the larger variations taking place during the wetter periods of year, indicating persisting variations in precipitation from year to year.

Number of heavy precipitation days
(error bars: minimum and maximum monthly average)
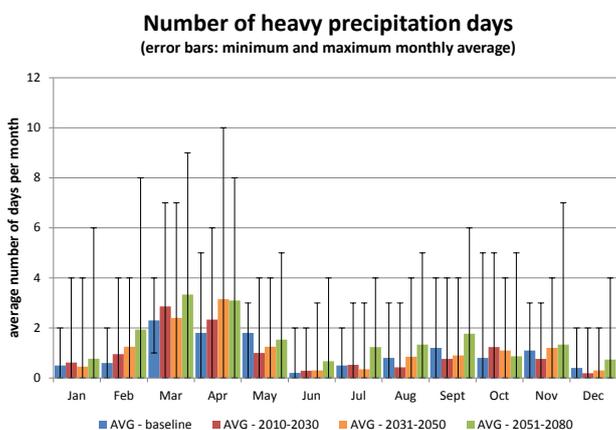
Figure 7.1.8.23: The number of heavy precipitation days is expected to increase slightly between February and April from 2010. Annual and periodic variation in number of heavy precipitation days will remain about the same or increase for the indicated period of increase.

158

Number of very heavy precipitation days
(error bars: minimum and maximum monthly average)
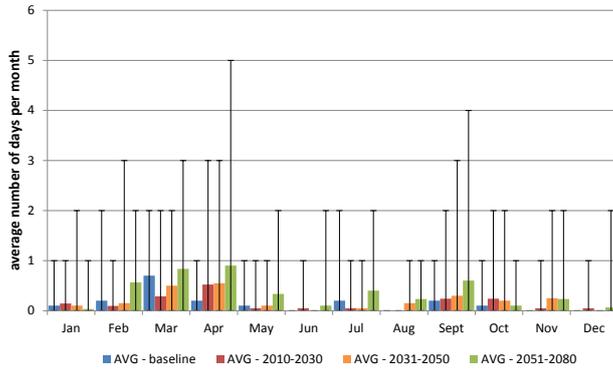
Figure 7.1.8.24: Similar to the previous figure, the number of very heavy precipitation days is not expected to change much between periods, with the exception of a small increase in February-April, although variation within projection periods far outweighs the differences between periods.

Number of wet days
(error bars: minimum and maximum values)
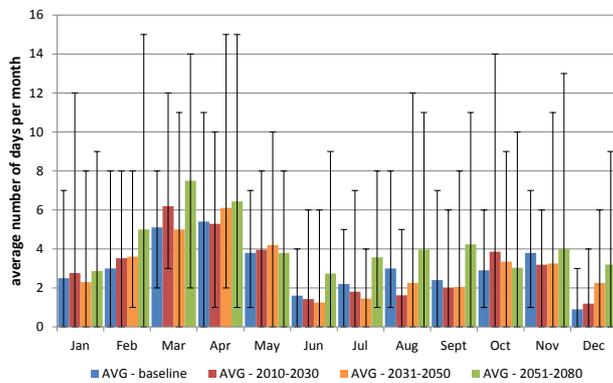
Figure 7.1.8.25: Similar to the previous graphs, the number of wet days per month will see a small increase in February-April, but otherwise remain roughly the same to today's occurrence. Large variations will occur from year to year.

Number of very wet days
(error bars: minimum and maximum values)
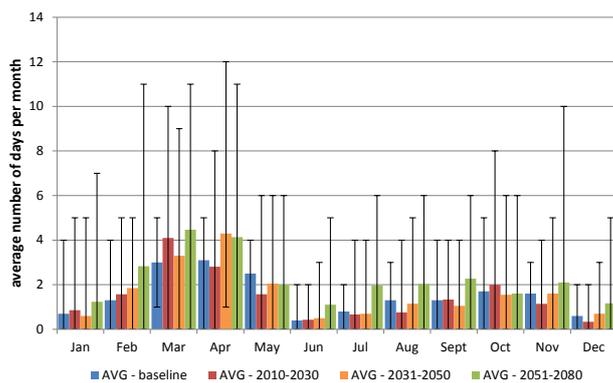
Figure 7.1.8.26: As in the figure above, the number of very wet days per month will see a small increase in February-April, but otherwise remain roughly the same to today's occurrence. Large variations will occur from year to year.

159

Number of extremely wet days
(error bars: minimum and maximum values)
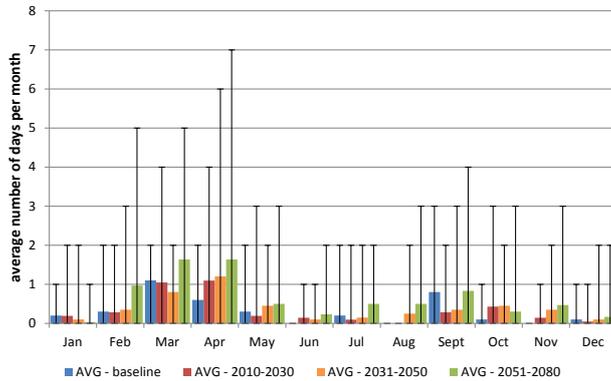
Figure 7.1.8.27: As in the figure above, the number of extremely wet days per month will see a small increase in February-April, although with greater variations within projection periods than between projection periods.

Maximum number of Consecutive Wet Days
(days with precipitation>1mm)
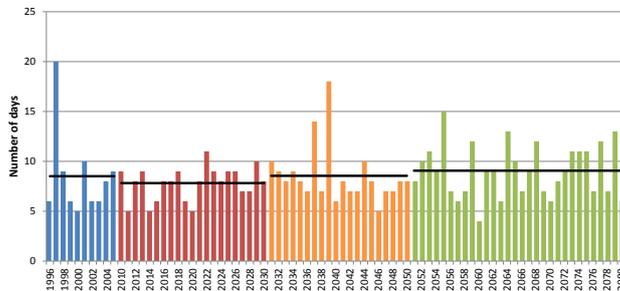
Figure 7.1.8.28: The maximum number of consecutive wet days, a measure for the (maximum) duration of the monsoon period, is projected to remain the same.

Maximum number of Consecutive Dry Days
(days with precipitation<1mm)
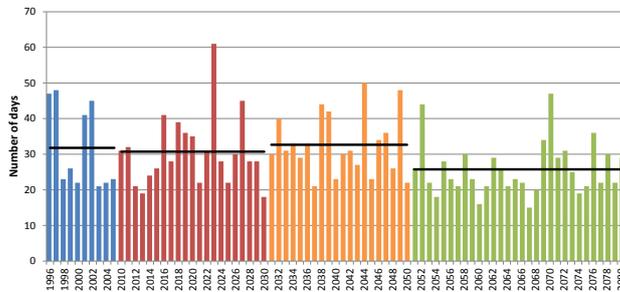
Figure 7.1.8.29: The maximum number of consecutive dry days, a measure for the (maximum) duration of the dry period, is projected to remain the same until 2050, and to decrease slightly thereafter. This corresponds with figure 7.1.8.21, which indicates an increase in precipitation during February-April and June-

September after 2050.

Simple Daily Intensity Index
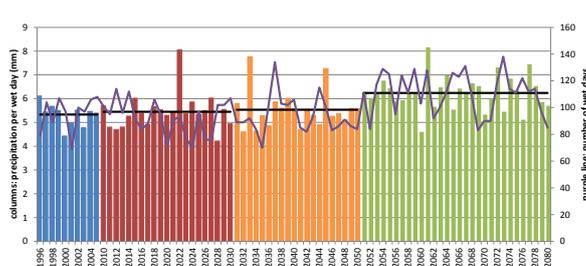
Figure 7.1.8.30: The amount of precipitation on wet days is projected to remain the same until 2050 for then to increase slightly. The number of wet days is set to follow the same pattern, confirming above figures showing both increased precipitation and number of wet days after 2050.

160

Growing season

Growing season onset and end dates
(GSLt: 6 consecutive days Tavg>5; GSLtp: 6 consecutive days Tavg>5 and 6 consecutive wet days)

Figure 7.1.8.31: This figure shows changes in growing season considering both temperature and precipitation (blue, for precipitation dependent fields) and temperature only (red, for irrigated or otherwise precipitation independent fields). The precipitation independent growing season close to year-round, while the precipitation dependent growing season shows great annual variations and shifts strangely between periods in onset and end data mainly due to the large onset and end variations.

Average growing season duration
(error bars: minimum and maximum extremes)

Figure 7.1.8.32: This figure shows the duration of a precipitation independent (red) and dependent (blue) growing season, and confirms the findings of the figure above: Enormous variations in onset and end make the precipitation dependent growing season duration vary a lot currently and in time ahead, while the average duration gradually increases from 2010 onward. The precipitation independent growing season remains constant, year-round, pointing at increased precipitation as the main variable.

Growing season duration
(based on temperature alone (GSLt); and on temperature + precipitation (GSLt+p))
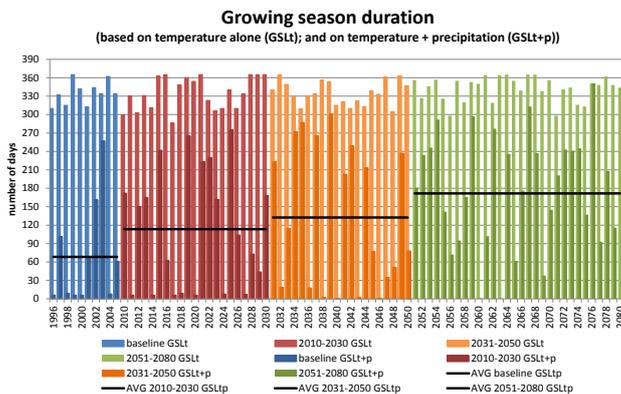
Figure 7.1.8.33: This figure takes a closer look at the annual variations in growing season duration, and highlights especially the anomalously large variations from year to year in the precipitation dependent growing season already from today and towards 2080.

7.2 Observation data used as basis for model result adjustments

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 2	Average	Tmin	-2,60	0,10	4,04	7,99	11,42	14,86	16,02	15,78	14,15	9,18	3,42	-1,13
elevation	2206	Tmax	14,02	16,37	19,65	22,17	24,41	26,12	25,75	25,48	24,70	22,33	18,84	15,65
		Pavg	0,39	0,82	1,19	2,86	5,02	9,42	12,29	10,21	6,92	2,73	0,58	0,32
Station	Chittagong	Tmin	14,05	16,68	20,67	23,88	24,94	25,60	25,44	25,55	25,34	24,31	20,22	16,13
period	1996-2005	Tmax	26,59	29,56	31,40	32,42	32,64	31,95	31,47	31,51	32,18	32,49	30,97	28,31
source	1 and 2	Pavg	0,18	0,87	1,76	4,91	9,63	20,24	23,45	17,12	8,64	5,96	2,25	0,38
elevation	23	Psum	5,60	24,40	54,70	147,40	298,60	607,30	727,00	530,60	259,30	184,80	67,50	11,90
Station	Bogra	Tmin	11,56	14,76	19,30	22,74	24,23	25,93	26,39	26,59	25,82	23,57	18,85	14,13
period	1996-2005	Tmax	23,57	27,57	31,09	32,76	33,18	32,87	32,12	32,53	32,17	31,65	30,19	26,61
source	3 and 4	Pavg	0,28	0,54	0,65	2,68	7,16	11,46	13,10	9,20	10,34	4,09	0,44	0,36
elevation	27	Psum	8,70	15,20	20,10	80,50	222,00	343,80	406,10	285,30	310,10	126,90	13,10	11,30
Station	Dibrugarh	Tmin	5,05	8,01	11,08	15,04	18,04	21,08	22,06	22,08	21,05	16,05	11,00	6,06
period	1971-2000	Tmax	26,03	28,04	31,60	33,00	34,90	36,00	35,40	35,80	35,20	33,50	30,08	27,02
source	5	Pavg	0,97	2,10	3,40	7,68	9,29	14,28	16,95	13,80	11,67	4,62	0,53	0,58
elevation	109	Psum	30,01	58,90	105,50	230,40	287,90	428,50	525,50	427,70	350,10	143,30	16,04	18,06
Station	Lhasa	Tmin	-10,10	-6,80	-3,00	0,90	5,00	9,30	10,10	9,40	7,50	1,30	-4,90	-9,00
period	1984-2014	Tmax	6,90	9,00	12,10	15,60	19,30	22,70	22,10	21,10	19,70	16,30	11,20	7,70
source	6	Pavg	0,02	0,03	0,06	0,17	0,86	2,41	3,85	3,95	1,94	0,33	0,06	0,03
elevation	3650	Psum	0,50	0,70	2,00	5,20	26,60	72,30	119,40	122,60	58,30	10,20	1,70	1,00
Station	Nagqu	Tmin	-21,10	-18,30	-13,60	-8,50	-3,30	1,50	3,50	3,00	0,30	-6,00	-14,40	-20,10
period	1984-2014	Tmax	-3,10	-1,30	2,90	6,80	11,20	14,90	15,60	15,10	12,70	7,50	1,80	-1,90
source	7	Pavg	0,10	0,12	0,12	0,37	0,92	2,79	3,33	2,95	2,51	0,66	0,13	0,08
elevation	4436	Psum	3,20	3,30	3,60	11,20	28,50	83,80	103,10	91,50	75,20	20,40	3,80	2,60
Station	Jiri	Tmin	-2,06	0,34	3,54	6,84	11,14	15,44	17,04	16,84	15,04	9,04	3,54	-0,66
period	1996-2005	Tmax	14,04	16,44	19,74	22,24	23,54	24,24	23,94	23,94	23,54	21,64	18,44	15,44
source	8	Pavg	0,69	0,96	1,37	3,00	6,03	12,21	21,72	20,52	11,62	2,93	0,22	0,30
elevation	2003	Psum	21,33	26,86	42,57	90,05	187,00	366,20	673,30	636,10	348,50	90,85	6,68	9,32
Station	Coqên	Tmin	-15,60	-14,00	-9,70	-5,00	-0,10	5,20	7,60	7,00	4,00	-4,00	-10,40	-14,50
period	1900-2000 (T)	Tmax	4,10	5,30	8,70	12,40	16,10	20,20	19,60	18,40	17,40	13,20	9,20	6,40
	1990-2009 (P)	Pavg	0,49	1,14	0,97	1,17	1,27	2,54	3,64	3,92	1,69	0,51	0,41	0,47
source	9 (T)	Psum	15,32	32,03	30,18	35,17	39,50	76,06	112,87	121,58	50,67	15,67	12,35	14,50
	10 (P)													
elevation	5200													

Left margin label: Domain 2. Elevation varies from 3 to 5399m, average 2364m

1 http://www.bmd.gov.bd/Files/25072013015712pmNormal_Rainfall.pdf

2 http://www.bmd.gov.bd/Files/16012014011427pmMnlyTempWeb.pdf

3 http://www.bmd.gov.bd/Files/25072013015712pmNormal_Rainfall.pdf

4 http://www.bmd.gov.bd/Files/16012014011427pmMnlyTempWeb.pdf

5 http://www.imd.gov.in/section/climate/extreme/dibrugarh2.htm

6 http://worldweather.wmo.int/en/city.html?cityId=236

7 http://worldweather.wmo.int/en/city.html?cityId=1846

8 http://www.dhm.gov.np/dpc

9 http://www.storm247.com/weather/30.64736_85.19348/climate

10 http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Asia&ThisCCode=PAK

Domain 3. Elevation varies from 345 to 5816m, average 2815m

Info	Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 3 / elevation 1501	Tmin	5,96	8,46	13,04	18,43	22,83	24,88	24,42	23,58	21,94	17,29	12,19	7,64
	Tmax	9,49	11,99	16,61	21,81	25,70	27,31	26,08	25,06	23,79	20,16	15,41	11,36
	Pavg	0,70	1,07	0,54	0,69	1,05	3,64	7,87	8,86	5,59	0,80	0,20	0,48
Station Dipayal / period 1996-2005 / source 1 / elevation 720	Tmin	4,44	6,94	10,44	15,24	19,84	23,24	24,54	24,14	22,34	16,74	10,44	5,74
	Tmax	23,14	25,64	30,74	35,14	37,14	36,34	34,44	34,14	31,84	28,34	24,84	
	Pavg	1,59	2,23	0,71	1,39	2,15	5,99	7,69	7,14	5,69	1,05	0,17	0,61
	Psum	49,42	62,41	21,96	41,60	66,51	179,80	238,50	221,30	170,60	32,44	4,97	18,93
Station New Delhi (Palam) / period 1990-2000 / source 2 / elevation 216	Tmin	7,73	10,32	14,95	21,20	26,46	27,98	26,79	26,02	24,77	19,83	14,03	8,98
	Tmax	20,47	23,55	29,33	36,63	40,80	40,08	35,53	33,98	34,16	32,97	28,15	22,72
	Pavg	0,67	0,92	0,22	0,48	0,58	1,67	5,87	7,61	6,58	0,36	0,27	1,03
	Psum	20,87	25,87	6,75	14,46	18,07	50,21	181,88	235,91	197,33	11,15	8,15	32,08
Station Gorakhpur / period 1990-2000 / source 3 / elevation 82	Tmin	22,15	26,20	32,21	37,85	38,69	36,66	32,93	32,45	32,29	33,05	30,31	25,28
	Tmax	9,06	11,55	16,02	21,27	24,95	26,49	26,21	25,96	24,85	21,05	15,33	10,69
	Pavg	0,41	0,50	0,23	0,34	0,99	4,94	8,66	11,08	7,25	1,16	0,22	0,28
	Psum	12,78	14,04	7,00	10,12	30,75	148,26	268,43	343,37	217,44	35,84	6,47	8,75
Station Dehradun / period 1990-2000 / source 4 / elevation 435	Tmin	19,70	21,71	26,20	32,10	35,25	34,19	30,44	29,70	29,77	28,83	25,42	21,49
	Tmax	6,70	8,66	12,35	16,66	21,02	23,25	23,48	23,01	21,37	16,15	11,30	7,54
	Pavg	1,34	2,22	1,42	1,17	1,71	8,13	20,87	24,23	10,76	1,43	0,22	0,78
	Psum	41,59	62,28	44,07	35,13	52,95	244,00	646,89	751,01	322,77	44,18	6,52	24,22
Station Gwalior / period 1990-2000 / source 5 / elevation 196	Tmin	7,30	10,07	15,17	20,65	26,67	28,85	26,64	25,77	24,44	18,57	12,54	7,48
	Tmax	22,93	26,25	32,10	38,54	41,92	40,83	35,33	32,92	33,30	33,90	29,58	25,30
	Pavg	0,32	0,43	0,20	0,21	0,49	1,99	7,64	7,37	6,99	1,01	0,12	0,14
	Psum	9,92	12,06	6,05	6,22	15,26	59,65	236,90	228,45	209,57	31,23	3,62	4,49
Station Zanda / period unknown / source 6 / elevation 3660	Tmin	-4,00	-2,00	2,00	7,00	13,00	18,00	22,00	20,00	16,00	8,00	3,00	-1,00
	Tmax	-20,00	-17,00	-13,00	-8,00	-2,00	4,00	8,00	7,00	2,00	-8,00	-14,00	-18,00
	Pavg	0,07	0,06	0,05	0,07	0,15	0,20	0,74	0,70	0,22	0,09	0,02	0,04
	Psum	2,30	1,60	1,70	2,20	4,50	6,00	22,80	21,70	6,50	2,70	0,50	1,30
Station Coqên / period 1900-2000 (T), 1990-2009 (P) / source 7 (T), 8 (P) / elevation 5200	Tmin	-15,60	-14,00	-9,70	-5,00	-0,10	5,20	7,60	7,00	4,00	-4,00	-10,40	-14,50
	Tmax	4,10	5,30	8,70	12,40	16,10	20,20	19,60	18,40	17,40	13,20	9,20	6,40
	Pavg	0,49	1,14	0,97	1,17	1,27	2,54	3,64	3,92	1,69	0,51	0,41	0,47
	Psum	15,32	32,03	30,18	35,17	39,50	76,06	112,87	121,58	50,67	15,67	12,35	14,50

1 http://www.dhm.gov.np/dpc
2 http://www.imd.gov.in/section/nhac/mean/Delhi%20Palam.htm
3 http://www.imd.gov.in/section/nhac/mean/Gorakhpur.htm
4 http://www.imd.gov.in/section/nhac/mean/Dehradun.htm
5 http://www.imd.gov.in/section/nhac/mean/Gwalior.htm
6 http://www.worldweatheronline.com/Zanda-weather-averages/Xizang/CN.aspx
7 http://www.storm247.com/weather/30.64736_85.19348/climate
8 http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Asia&ThisCCode=PAK

Domain 4. Elevation varies from 265 to 5145m, average 2230m

Info	Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 4 / elevation 1386	Tmin	-4,10	-1,72	3,17	8,33	11,58	15,00	18,02	16,98	11,93	5,70	-0,08	-2,98
	Tmax	6,68	8,73	15,05	21,28	26,28	31,57	32,95	32,12	29,05	23,23	16,10	9,52
	Pavg	1,11	1,61	2,20	1,98	1,25	0,55	0,89	0,48	0,51	0,51	0,89	
Station Gilgit / period last 30 years / source 1 / elevation 1459	Tmin	-2,70	0,20	5,40	9,40	11,70	15,20	18,80	18,10	12,70	6,60	0,60	-2,40
	Tmax	9,30	12,00	17,90	23,90	28,40	34,30	36,10	35,30	31,60	25,30	17,80	11,00
	Pavg	0,13	0,21	0,41	0,77	0,82	0,20	0,50	0,50	0,22	0,27	0,06	0,13
	Psum	4,00	6,00	12,60	23,00	25,30	6,10	15,60	15,50	6,50	8,40	1,80	4,10
Station Srinagar / period 1901-2000 / source 2 / elevation 1585	Tmin	-2,30	-0,80	3,40	7,40	10,90	14,50	18,20	17,70	12,50	5,60	0,30	-2,00
	Tmax	5,00	7,60	13,50	19,30	24,20	28,90	30,30	29,70	27,60	22,10	15,40	8,50
	Pavg	2,01	2,55	3,26	3,02	2,20	1,21	1,75	2,08	1,18	1,00	0,66	1,34
	Psum	62,20	71,40	101,10	90,70	68,20	36,30	54,30	64,60	35,40	30,90	19,70	41,40
Station Srinagar / period 1961-1990 / source 3 / elevation 1585	Tmin	-2,00	-0,70	3,40	7,90	10,80	14,90	18,10	17,50	12,10	5,80	0,90	-1,50
	Tmax	7,00	8,20	14,10	20,50	24,50	29,60	30,10	29,60	27,40	22,40	15,10	8,20
Station Srinagar / period 1901-2000 / source 4 / elevation 1585	Tmin	-9,00	-4,00	0,00	7,00	11,00	14,00	17,00	16,00	12,00	4,00	-5,00	-8,00
	Tmax	5,00	7,00	14,00	19,00	24,00	29,00	30,00	29,00	27,00	22,00	15,00	9,00
	Pavg	1,55	2,43	3,90	2,83	2,19	1,30	2,00	2,45	0,93	1,06	0,93	1,74
	Psum	48,00	68,00	121,00	85,00	68,00	39,00	62,00	76,00	28,00	33,00	28,00	54,00
Station Kabul / period 1956-1983 / source 5 / elevation 1791	Tmin	-7,10	-5,70	0,70	6,00	8,80	12,40	15,30	14,30	9,40	3,90	-1,20	-4,70
	Tmax	4,50	5,50	12,50	19,20	24,40	30,20	32,10	32,00	28,50	22,40	15,00	8,30
	Pavg	1,11	2,15	2,19	2,40	0,75	0,03	0,20	0,05	0,06	0,12	0,62	0,70
	Psum	34,30	60,10	67,90	71,90	23,40	1,00	6,20	1,60	1,70	3,70	18,60	21,60
Station Termez / period last 30 years / source 6 / elevation 313	Tmin	-1,50	0,70	6,10	12,30	16,30	19,00	20,70	18,30	12,90	8,30	3,90	0,70
	Tmax	9,30	12,10	18,30	25,80	32,20	37,40	39,10	37,10	32,20	25,20	18,30	12,10
	Pavg	0,75	0,72	1,22	0,87	0,30	0,03	0,00	0,00	0,00	0,11	0,29	0,56
	Psum	23,40	20,20	37,70	26,20	9,30	0,80	0,10	0,00	0,10	3,30	8,80	17,40

1 http://www.worldweather.org/047/c00897.htm
2 http://www.worldweather.org/047/c00897.htm
3 http://www.yr.no/place/India/Jammu_and_Kashmir/Srinagar/statistics.html
4 http://en.wikipedia.org/wiki/Srinagar#Climate
5 http://www.worldweather.org/en/city.html?cityId=219
6 http://www.worldweather.org/en/city.html?cityId=117

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 5	Average	Tmin	6,58	8,74	12,03	15,35	18,21	21,46	22,12	22,19	21,12	16,62	11,80	7,72
elevation	119	Tmax	26,34	28,31	31,57	32,90	34,90	36,10	35,80	36,10	35,47	33,47	30,56	27,34
		Pavg	1,19	2,58	3,60	7,74	11,19	20,98	24,86	17,63	15,51	5,91	0,81	0,82
Station	Dibrugarh	Tmin	5,05	8,01	11,08	15,04	18,04	21,08	22,06	22,08	21,05	16,05	11,00	6,06
period	1971-2000	Tmax	26,03	28,04	31,60	33,00	34,90	36,00	35,40	35,80	35,20	33,50	30,08	27,02
source	1	Pavg	0,97	2,10	3,40	7,68	9,29	14,28	16,95	13,80	11,67	4,62	0,53	0,58
elevation	109	Psum	30,01	58,90	105,50	230,40	287,90	428,50	525,50	427,70	350,10	143,30	16,04	18,06
Station	Passighat	Tmin	9,30	10,60	13,50	15,70	18,30	21,30	21,70	21,90	20,90	17,30	14,10	10,70
period	1971-2000	Tmax	26,50	28,50	31,70	33,00	35,10	36,60	36,60	36,50	36,00	33,50	31,00	27,50
source	2	Pavg	1,38	3,43	4,66	8,65	11,97	28,26	34,87	21,63	19,46	7,47	0,97	0,98
elevation	154	Psum	42,80	96,10	144,60	259,50	371,00	847,80	1081,10	670,60	583,70	231,70	29,10	30,30
Station	Lakhimpur	Tmin	5,40	7,60	11,50	15,30	18,30	22,00	22,60	22,60	21,40	16,50	10,30	6,40
period	1971-2000	Tmax	26,50	28,40	31,40	32,70	34,70	35,70	35,40	36,00	35,20	33,40	30,60	27,50
source	3	Pavg	1,22	2,20	2,74	6,89	12,31	20,41	22,75	17,47	15,42	5,62	0,93	0,91
elevation	95	Psum	37,70	61,70	85,00	206,80	381,60	612,30	705,40	541,60	462,50	174,30	27,80	28,20

Domain 5. Elevation varies between 95-3462m, average 1121m

1 http://www.imd.gov.in/section/climate/extreme/dibrugarh2.htm

2 http://www.imd.gov.in/section/climate/extreme/passighat2.htm

3 http://www.imd.gov.in/section/climate/lakhimpur2.htm

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 6	Average	Tmin	-15,60	-12,55	-8,30	-3,80	0,85	5,40	6,80	6,20	3,90	-2,35	-9,65	-14,55
elevation	4043	Tmax	1,90	3,85	7,50	11,20	15,25	18,80	18,85	18,10	16,20	11,90	6,50	2,90
		Pavg	0,06	0,07	0,09	0,27	0,89	2,60	3,59	3,45	2,23	0,49	0,09	0,06
Station	Lhasa	Tmin	-10,10	-6,80	-3,00	0,90	5,00	9,30	10,10	9,40	7,50	1,30	-4,90	-9,00
period	1984-2014	Tmax	6,90	9,00	12,10	15,60	19,30	22,70	22,10	21,10	19,70	16,30	11,20	7,70
source	1	Pavg	0,02	0,03	0,06	0,17	0,86	2,41	3,85	3,95	1,94	0,33	0,06	0,03
elevation	3650	Psum	0,50	0,70	2,00	5,20	26,60	72,30	119,40	122,60	58,30	10,20	1,70	1,00
Station	Nagqu	Tmin	-21,10	-18,30	-13,60	-8,50	-3,30	1,50	3,50	3,00	0,30	-6,00	-14,40	-20,10
period	1984-2014	Tmax	-3,10	-1,30	2,90	6,80	11,20	14,90	15,60	15,10	12,70	7,50	1,80	-1,90
source	2	Pavg	0,10	0,12	0,12	0,37	0,92	2,79	3,33	2,95	2,51	0,66	0,13	0,08
elevation	4436	Psum	3,20	3,30	3,60	11,20	28,50	83,80	103,10	91,50	75,20	20,40	3,80	2,60

Domain 6. Elevation varies from 4098 to 5160m, average 4736m

1 http://worldweather.wmo.int/en/city.html?cityId=236

2 http://worldweather.wmo.int/en/city.html?cityId=1846

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 7. Elevation varies from 124 to 5534m, average 3286m		Domain 7 elevation	Average 1972	Tmin	3,24	3,92	6,95	10,16	13,13	15,66	17,01	17,56	16,42	13,37	8,92	5,33
				Tmax	15,34	16,32	19,50	22,14	23,54	24,23	24,08	24,31	23,78	22,54	20,12	17,40
				Pavg	0,62	0,57	1,02	2,13	4,24	8,94	15,24	14,32	9,28	4,14	0,65	0,31
	High Mountains (model elevation: 4950m)	Domain 7a elevation	Average 3792	Tmin	-3,96	-5,16	-3,09	-0,49	2,87	5,64	8,24	9,84	8,41	6,04	1,34	-1,63
				Tmax	7,31	6,14	7,41	9,71	12,51	13,87	14,71	15,17	14,04	12,97	10,47	8,47
				Pavg	0,52	0,74	1,02	1,39	3,29	8,47	15,59	18,88	14,56	7,05	1,58	0,29
		Station period source elevation	Sermatang 1976-1986 1 2625	Tmin	-0,96	0,14	4,44	6,04	8,44	11,54	12,54	12,94	10,74	7,44	2,44	0,14
				Tmax	11,34	11,84	15,44	17,24	18,04	19,24	18,64	19,64	17,84	17,04	13,64	11,84
				Pavg	1,05	0,84	1,51	2,26	6,10	17,58	29,95	28,48	15,74	4,87	0,27	0,30
				Psum	32,60	23,44	46,87	67,94	189,20	527,50	928,40	882,80	472,10	150,90	8,18	9,26
		Station period source elevation	85.83E, 28.23N (N 1996-2005 2 3750	Tmin	-0,76	-3,06	-2,46	0,64	3,84	7,54	10,34	12,54	11,14	9,64	5,25	1,74
				Tmax	9,94	7,54	7,84	10,74	14,24	16,94	18,04	18,34	17,04	16,04	13,64	11,74
				Pavg	0,33	1,00	0,72	1,14	2,32	5,39	11,89	20,12	20,40	11,78	3,43	0,37
				Psum	10,31	28,05	22,25	34,27	71,85	161,60	368,70	623,60	612,10	365,10	102,90	11,51
		Station period source elevation	86.9E, 27.96N 1996-2005 3 5000	Tmin	-10,16	-12,56	-11,26	-8,16	-3,66	-2,16	1,84	4,04	3,34	1,04	-3,66	-6,76
				Tmax	0,64	-0,96	-1,06	1,14	5,24	5,44	7,44	7,54	7,24	5,84	4,14	1,84
				Pavg	0,17	0,38	0,84	0,75	1,46	2,44	4,94	8,04	7,55	4,50	1,05	0,20
				Psum	5,35	10,53	26,07	22,62	45,17	73,32	153,20	249,30	226,40	139,50	31,40	6,28
	Middle Hills (model elevation: 4000m)	Domain 7b elevation	Average 1542	Tmin	4,84	5,54	8,67	11,91	15,17	18,24	19,37	19,27	18,31	14,87	10,84	7,01
				Tmax	18,01	18,74	22,61	25,61	26,94	27,67	27,24	26,94	26,71	25,44	23,04	20,14
				Pavg	0,82	0,65	1,22	2,88	5,28	8,73	14,31	13,20	7,02	2,43	0,16	0,38
		Station period source elevation	Jiri 1996-2005 4 2003	Tmin	-2,06	0,34	3,54	6,84	11,14	15,44	17,04	16,84	15,04	9,04	3,54	-0,66
				Tmax	14,04	16,44	19,74	22,24	23,54	24,24	23,94	23,94	23,54	21,64	18,44	15,44
				Pavg	0,69	0,96	1,37	3,00	6,03	12,21	21,72	20,52	11,62	2,93	0,22	0,30
				Psum	21,33	26,86	42,57	90,05	187,00	366,20	673,30	636,10	348,50	90,85	6,68	9,32
		Station period source elevation	Khotang 1996-2005 5 1295	Tmin	10,14	8,04	10,74	14,44	18,34	21,04	22,34	22,24	22,34	21,24	18,74	14,14
				Tmax	22,04	19,64	23,14	27,34	29,64	30,54	30,54	29,34	29,64	29,34	28,24	25,54
				Pavg	1,19	0,29	1,17	1,65	3,40	6,20	11,05	8,78	4,28	2,27	0,11	0,57
		Station period source elevation	Chainpur 1996-2005 6 1329	Tmin	6,44	8,24	11,74	14,44	16,04	18,24	18,74	18,74	17,54	14,34	10,24	7,54
				Tmax	17,94	20,14	24,94	27,24	27,64	28,24	27,24	27,54	26,94	25,34	22,44	19,44
				Pavg	0,58	0,72	1,11	3,98	6,39	7,77	10,17	10,29	5,15	2,09	0,16	0,27
				Psum	17,99	20,09	34,38	119,30	198,20	233,00	315,20	319,10	154,50	64,94	4,83	8,52
	Terai (model elevation: 1200m)	Domain 7c elevation	Average 581	Tmin	8,84	11,37	15,27	19,07	21,34	23,11	23,41	23,57	22,54	19,21	14,57	10,61
				Tmax	20,71	24,07	28,47	31,11	31,17	31,14	30,31	30,81	30,61	29,21	26,84	23,57
				Pavg	0,52	0,33	0,82	2,11	4,14	9,62	15,81	10,89	6,26	2,93	0,20	0,25
		Station period source elevation	Dhankuta 1996-2005 7 1210	Tmin	6,64	8,94	12,64	15,74	18,04	20,24	20,64	20,54	19,34	15,74	11,64	8,14
				Tmax	18,14	20,14	23,64	26,14	26,84	27,54	27,24	27,64	27,34	25,64	22,94	20,24
				Pavg	0,47	0,38	1,01	1,88	3,40	5,40	9,21	6,35	3,27	1,67	0,20	0,41
				Psum	14,66	10,63	31,43	56,52	105,30	161,90	285,50	196,80	98,02	51,88	6,04	12,76
		Station period source elevation	Dharan 1996-2005 8 444	Tmin	10,54	13,44	16,94	20,34	21,64	23,14	23,34	23,54	22,64	19,74	15,84	12,44
				Tmax	22,64	26,04	30,44	32,74	32,54	32,14	31,64	32,24	32,04	30,54	28,24	25,44
				Pavg	0,62	0,35	1,19	2,36	4,89	11,16	19,49	15,58	10,73	4,36	0,34	0,20
				Psum	19,26	9,78	36,74	70,90	151,50	334,70	604,20	482,90	321,90	135,30	10,26	6,28
		Station period source elevation	Janakpur 1996-2005 9 90	Tmin	9,34	11,74	16,24	21,14	24,34	25,94	26,24	26,64	25,64	22,14	16,24	11,24
				Tmax	21,34	26,04	31,34	34,44	34,14	33,74	32,04	32,24	31,44	29,34	25,04	
				Pavg	0,48	0,25	0,26	2,10	4,13	12,31	18,73	10,75	4,77	2,74	0,04	0,15
				Psum	14,86	7,00	8,15	62,91	128,00	369,20	580,50	333,30	143,10	84,94	1,33	4,50

1 http://www.dhm.gov.np/dpc

2 http://www.dhm.gov.np/dpc - Interpolated data 25km2

3 http://www.dhm.gov.np/dpc - Interpolated data 25km2

4 http://www.dhm.gov.np/dpc

5 http://www.dhm.gov.np/dpc

6 http://www.dhm.gov.np/dpc

7 http://www.dhm.gov.np/dpc

8 http://www.dhm.gov.np/dpc

9 http://www.dhm.gov.np/dpc

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domain 8. Elevation varies from 2871 to 5447m, average 4274m	Domain 8 elevation	Average 1459	Tmin	-2,70	0,20	5,40	9,40	11,70	15,20	18,80	18,10	12,70	6,60	0,60	-2,40
			Tmax	9,30	12,00	17,90	23,90	28,40	34,30	36,10	35,30	31,60	25,30	17,80	11,00
			Pavg	0,49	0,54	0,77	0,83	0,90	0,38	0,44	0,48	0,23	0,22	0,39	0,72
	Station period source elevation period source	Gilgit last 30 years 1 1459 1990-2007 2	Tmin	-2,70	0,20	5,40	9,40	11,70	15,20	18,80	18,10	12,70	6,60	0,60	-2,40
			Tmax	9,30	12,00	17,90	23,90	28,40	34,30	36,10	35,30	31,60	25,30	17,80	11,00
			Pavg	0,13	0,21	0,41	0,77	0,82	0,20	0,50	0,50	0,22	0,27	0,06	0,13
			Psum	4,00	6,00	12,60	23,00	25,30	6,10	15,60	15,50	6,50	8,40	1,80	4,10
			Pavg	0,86	0,86	1,13	0,89	0,98	0,55	0,37	0,47	0,24	0,17	0,71	1,30
			Psum	26,67	24,19	35,15	26,55	30,41	16,43	11,57	14,45	7,10	5,24	21,31	40,29

1 http://www.worldweather.org/047/c00897.htm

2 http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Asia&ThisCCode=PAK#

CICERO (Center for International Climate and Environmental Research - Oslo)
CICERO (Center for International Climate and Environmental Research - Oslo) was
established by the Norwegian government in 1990 as a policy research foundation
associated with the University of Oslo. CICERO's research and information helps to keep
the Norwegian public informed about developments in climate change and climate policy.

The complexity of climate and environment problems requires global solutions and
international cooperation. CICERO's multi-disciplinary research in the areas of the natural
sciences, economics and politics is needed to give policy-makers the best possible
information on which to base decisions affecting the Earth's climate.

The research at CICERO concentrates on:
- Chemical processes in the atmosphere
- Impacts of climate change on human society and the natural
  environment caused by emissions of greenhouse gases
- Domestic and international climate policy instruments
- International negotiations on environmental agreements

CICERO (Center for International Climate and Environmental Research - Oslo)
P.O.Box 1129 Blindern, N-0318 Oslo, Norway
Visiting address: CIENS, Gaustadalléen 21, 0349 Oslo
Telephone: +47 22 85 87 50   Fax: +47 22 85 87 51
E-mail: admin@cicero.uio.no   www.cicero.uio.no

cicero.uio.no