2 Climate Trends and Projections

Introduction

Due to the complexity of the topography and the orographic features, it is more difficult to understand climatic characteristics in the mountains than in the plains. Existing knowledge of the climatic characteristics of the EH is limited by both paucity of observations and the limited theoretical attention paid to the complex interaction of spatial scales in weather and climate phenomena in mountains. In order to determine the degree and rate of climatic trends, there is a need for long-term data sets, which are currently lacking for most of the EH. Research has tended to focus on the influence of barriers on air flow and on orographic effects on weather systems, rather than on conditions within the mountain environment. As much as climate shapes the mountain environment and determines its constituent characteristics, so do the mountains in turn influence the climate and related environmental features through altitude, continentality, latitude, and topography, each of which affects several important climate variables. The roles of these factors are summarised schematically in Table 3. The mountain ecosystems not only significantly influence atmospheric circulation, they also exhibit a great deal of variation in local climatic patterns. These climatic differences are expressed in vegetation type and cover, and geomorphic and hydrological features.

The Fourth Assessment Report (AR4) of the IPCC concludes that changes in the atmosphere, the oceans, and glaciers and ice caps show unequivocally that the world is warming. It further concludes that major advances in climate modelling and the collection and analysis of data now give scientists "very high confidence" (higher than what could be achieved in the Third Assessment Report) in their understanding of how human activities are contributing to global warming. This was the strongest conclusion to date, making it virtually impossible to blame natural forces for global warming. The average temperature increase across the globe during the 20th Century has been around 0.74°C. These changes have been accompanied by changes in precipitation, including an increase in precipitation at higher latitudes and a decline at lower latitudes, and an increase in the frequency and intensity of extreme precipitation events. Floods and droughts have also been observed to be increasing in frequency and intensity, and this trend is likely to continue.

Projections of temperature increases in the 21st Century have been made on the basis of established and plausible scenarios of the future. A warming of about 0.2°C is projected for each of the next two decades and the best estimate of temperature increase by the end of the 21st Century is placed at 1.8°C to 4°C. These projections are based on the assumption that no specific action is taken to mitigate GHG emissions. Hot extremes, heat waves, and heavy precipitation events will become more frequent, future tropical cyclones (typhoons and hurricanes) are likely to become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases in tropical sea-surface temperatures. Increases in the amount of precipitation are very likely at high-latitudes, while decreases are likely in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100) (IPCC 2007a).

Table 3: **Climatic effects of mountain factors**

Factors	Primary effects	Secondary effects
Altitude	Reduced air density, vapour pressure; increased solar radiation receipts; lower temperatures	Increased wind velocity (mid-latitude); increased precipitation (mid-latitude); reduced evaporation; physiological stress
Continentality	Increased annual/diurnal temperature range; modified cloud/ precipitation regimes	Snowline altitude rises
Latitude	Seasonal variation in day length and solar radiation totals	Snowfall proportion increases; annual temperatures decrease
Topography	Spatial contrasts in solar radiation/ temperature regimes and precipitation as a result of slope and aspect	Diurnal wind regimes; snow cover related to topography

A growing number of studies on past climate and model-based projections have been reported in recent times at different spatio-temporal scales, some of which cover the EH in part or as a whole. There are several constraints and issues that need to be resolved at the policy, institutional, and field levels to improve the observational and prediction basis for accurate and conclusive statements on climate variability and change. There is a need to probe deeper into the dynamics of mountain climate systems in search of signs of climate change. There has been limited coordination in such efforts across the EH region, and the different countries in the region have interpreted the existing observational and prediction results within their respective political boundaries only, despite the fact that climate systems are large-scale processes.

For this vulnerability assessment, it was necessary to reflect on climate trends and projections determined at the country level from a large compilation of national reports. In this synthesis, climate variability refers to day-to-day, year-to-year, and decade-to-decade patterns of weather and climate; climate change refers to longer trends, usually measured by temperature and precipitation. Historical climatic conditions provide the context for potential future changes.

Past information was consolidated and the latest updates incorporated, and a synthesis review made with a reassessment of climate trends and change projections to the end of this century . The findings confirm earlier studies that temperatures will continue to rise and rainfall patterns will be more variable, with both localised increases and decreases. The figures for the EH are not a drastic deviation from the IPCC outcomes for the South Asian region. Nonetheless, they reinforce the scientific basis for the contention that the EH is undergoing a warming trend.

Trends

Few studies provide an exclusive and comprehensive analysis of the EH. There is a need for a concerted effort to formally document the magnitude and direction of climate trends that have taken place. Dash et al. (2007) observed that during the last century the maximum temperature increased over North East India by 1°C during winter and 1.1°C during the post-monsoon months. There have been small increases in rainfall during winter, pre- and post-monsoon seasons. They also noted a decreasing trend in high-intensity depressions and cyclonic storms, but increases in the number of low pressure areas during the monsoon. Conversely, another study reported a slightly negative trend of -0.008 to -0.06°C in the annual mean temperature in North East India from 1960 to 1990 (APN 2003).

There have been investigations into climate trends and characteristics in the Himalayan regions of southwest and northwest China using time series data of varying lengths (Yunling and Yiping 2005; Yin 2006). In the southwest region covering the counties of Deqin and Weixi of the Hengduan mountain range, over the observation period of 41 years, the mean annual air temperature increased at the rate of 0.01°C/yr to 0.04°C/yr. The changes in precipitation, however, are very different and complex. At some locations, mean annual precipitation decreased by 2.9 to 5.3 mm/yr, and at others by 5.8 to 7.4 mm/yr. Trends in air temperature were more significant in the dry season than in the rainy season, with precipitation showing the opposite behaviour. Climate trends differed from climate element to climate element, region to region, and season to season.

Significant warming has been observed on the Tibetan Plateau (Liu and Chen 2000), with warming more pronounced at higher altitude stations, than lower ones. The unexpected observed decreases in potential evapotranspiration (PET) in Tibet AR has been linked to reduced wind speed under the decreasing strength of the Asian monsoon (Chen et al. 2006).

An increasing rate of warming with elevation was also observed in a similar study encompassing the whole physiographic region of Nepal using climatological data from 1977 to 2000 (updated from Shrestha et al. 1999). The altitudinal dependency was less clear during the post-monsoon period, with the middle mountain region recording the highest positive trend (Table 4). The results suggest that the seasonal temperature variability is increasing and the altitudinal lapse rate of temperature is decreasing. Unlike temperature, precipitation does not show any consistent spatial trends. Annual precipitation changes are quite variable, decreasing at one site and increasing at a site nearby.

In Bhutan, the analysis of available observations on surface air temperatures has shown a warming trend of about 0.5°C from 1985 to 2002, mainly during the non-monsoon seasons. Temperatures in the summer monsoon season do not show a significant trend in any major part of the country. Rainfall fluctuations are largely random with no systematic change detectable on either an annual or monthly scale (Tse-ring 2003).

Table 4: **Regional mean temperature trends in Nepal 1977–2000 (°C/year)**

	Seasonal				Annual
Regions	**Winter**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Jan-Dec**
	Dec-Feb	**Mar-May**	**Jun-Sep**	**Oct-Nov**	
Trans-Himalaya	0.12	0.01	0.11	0.10	0.09
Himalaya	0.09	0.05	0.06	0.08	0.06
Middle Mountains	0.06	0.05	0.06	0.09	0.08
Siwalik	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0.00	0.01	0.07	0.04

Source: updated from Shrestha et al. (1999) and Xu et al. (2007)

Table 5: **Changes in primary climate change drivers and climate system responses in the Eastern Himalayas from 1977-2000**

Climate change drivers	**Biophysical responses to climate change**
• Average annual temperature increased by 0.01°C in the foothills, 0.02°C in the middle mountains, and 0.04°C in the higher Himalayas • Night-time temperatures increased across most of the EH in spring and summer • Annual precipitation changes are quite variable, decreasing at one site and increasing at a site nearby	• Duration of snow cover reduced and snow disappears earlier • Less snowfall • Flow in river basins reduced/increased • Glacier retreat 20-30 m/year • Net primary production (NPP) increased • Wetlands contract • Early spring and late autumn flowering

The technical papers written for this assessment capture much of the detail on how the climate of the EH changed during the 20th Century using a set of indicators including primary climate change drivers (e.g., temperature, precipitation), climate system responses (e.g., receding glaciers, hydrological systems, water-related hazards), and ecosystem responses (e.g., ecotone shifts, phenological changes, ecosystem structure, function, type and distribution, decoupled trophic levels). Some of the changes detected in the primary climate change drivers and climate system responses are summarised in Table 5.

Examination of observational records from different sites distributed across the region, and an analysis of the Climate Research Unit, University of East Anglia, United Kingdom, dataset on global historical time series (Mitchell et al. 2004) show that the global climate has already changed significantly. In the EH, the annual mean temperature is increasing at a rate of 0.01°C/yr (0.01-0.04°C yr-1) or higher. The warming trend has been greatest during the post-monsoon season and at higher elevations. Increases in temperature during the period (1977-2000) have been spatially variable indicating the biophysical influence of the land surface on the surrounding atmospheric conditions. In general, there is a diagonal zone with a south-west to north-east trend of relatively less or no annual and seasonal warming. This zone encompasses the Yunnan province of China, part of the Kachin State of Myanmar, and the North Eastern states of India. Eastern Nepal and eastern Tibet record relatively higher warming trends. Warming in the winter (DJF) is much higher and more widespread. In addition, a significant positive trend with altitude has been observed throughout the region. High altitude areas have been exposed to comparatively greater warming effects than those in the lowlands and adjacent plains.

The temperature trends in the three elevation zones are given in Table 6. The analysis suggests the following major points:

1. The Eastern Himalayan region is experiencing widespread warming. The warming is generally higher than 0.01°C/yr.

Table 6: **Temperature trends by elevation zone for the period 1977–2000 (°C/year)**

Elevation zone	**Annual**	**DJF**	**MAM**	**JJA**	**SON**
Level 1: (<1000 m)	0.01	0.03	0.00	- 0.01	0.02
Level 2: (1000-4000 m)	0.02	0.03	0.02	- 0.01	0.02
Level 3: (> 4000 m)	0.04	0.06	0.04	0.02	0.03

Source: Shrestha and Devkota (2010)

2. The highest rates of warming are occurring in winter (DJF) and lowest or even cooling trends are observed in summer (JJA).
3. There is progressively more warming with elevation, with the areas >4000 m experiencing the highest warming rates.

The results from the stakeholder workshops and the questionnaire survey on people's perceptions of climate change in the region are presented in the technical report on biodiversity (Chettri et al 2010). Some of the perceived changes in primary climate change drivers and climate system responses are summarised in Table 7.

Projections

A considerable amount of work has been done to predict future climates by downscaling General Circulation Model (GCM) outputs using statistical or dynamic methods. In most cases, the results are not comparable due to differences in the choice of GCMs, spatial and temporal resolutions, emission scenarios associated with diverse socioeconomic assumptions, and the formats in which the results are published, although all of them describe plausible models of future climate meaningful to the research context. For this assessment, climate scenarios were reconstructed specifically for the EH domain using data generated by recent model runs at regional and global levels. The climate scenarios developed are summarised first to put the remaining results into perspective.

Regional projections

The current spatial resolution of general circulation models (GCMs) is generally too crude to adequately represent the orographic detail of most mountain regions and inadequate for assessing future projections in the regional climate. Since the mid-1990s, the scaling problem related to complex orography has been addressed through regional modelling techniques, pioneered by Giorgi and Mearns (1991), and through statistical-dynamic downscaling techniques (e.g., Zorita and von Storch 1999). The following discussion of potential ecological responses to changes in climate and climate variability primarily uses the Indian Institute of Tropical Meteorology (IITM) regional climate scenarios, which are based on a transient HadCM3 model downscaled using HadRM2 and PRECIS (Providing Regional Climates for Impacts Studies; Hadley Centre) regional climate models (RCMs) run under two future GHG emission scenarios (A2 and B2 of the SRES [Special Report on Emissions Scenarios]). This approach, which applies general methods in accordance with the IPCC Data Distribution Center guidelines on the use of scenario data for impacts and adaptation assessments (IPCC-TGCIA 1999), allows us to identify both potential trends and the range of uncertainty around them. The discussion is rather general and presumes no major surprises due to uncertainties regarding the rate, magnitude, spatial distribution, and seasonality of temperature and precipitation changes.

In order to accommodate some level of sensitivity analysis, the RCM simulation runs were supplemented with data from the IPCC's SRES runs performed with three Coupled General Circulation Models (GCMs), the HadCM3, CGCM2, and CSIRO Mk2, interpolated to higher temporal and spatial resolution for the development of WorldClim (www.worldclim.org) (Hijmans et al. 2005). The GCM results are given as 30-year monthly mean changes (i.e., no information is presented about changes in inter-annual or inter-daily variability). All data is extracted as change values, expressed either in absolute or percentage terms using the 1961 to 1990 model-simulated baseline period. Results are, therefore, generally reported as the change between the 1961 to 1990 30-year mean period, and the future 30-year mean periods (2020s, 2050s or 2080s). These time periods represent 30-year mean fields centred on the decade used to name the time period, e.g., the 2020s represent the 30-year mean period 2010–2039, the 2050s represent 2040–2069 and the 2080s represent 2070–2099. For all the models, the response to the middle forcing emission scenarios A2 and B2 was referred to, and future climate change was presented for two 30-year time slices centred on the 2020s and 2050s for WorldClim using HadCM3, and 2050s and 2080s for HadRM2 and PRECIS, each relative to the baseline period 1961–1990. Among the three models, the HadCM3 provided the closest match to observed data.

Table 7: **Perceived changes in primary climate change drivers and climate system responses in the Eastern Himalayas**

Climate change drivers	Biophysical responses to climate change
• Temperatures have been rising across the entire region, with winter and spring temperatures rising more rapidly than those in summer • The daily temperature range has gone down • Total annual precipitation has increased in some areas and decreased in others	• Longer growing season • Reduced snowfall in frequency and amount • Tree line moving to higher elevation • Ice fields contracting • Biomass increase in wetlands

Table 8: **Summary of plausible future climates considered for the assessment of the Eastern Himalayas in terms of character, magnitude and rate**

Time slice	Exposure	Climate model/SRES scenario			
		HadCM3/A2	HadCM3/B2	CGCM2/A2	CSIROMk2/A2
2020s	Δ T (°C)	0.99	0.80	0.49	1.11
	Δ P (%)	5.43	4.55	47.05	12.40
2050s	Δ T (°C)	2.22	2.06	1.43	1.90
	Δ P (%)	14.07	6.23	60.80	18.96
2080s[a]	Δ T (°C)	4.3	2.9		
	Δ P (%)	34	13		

[a] Values from PRECIS RCM runs; Δ T = mean annual temperature change; Δ P = mean annual precipitation change

Table 9: **Climate change projections for the Eastern Himalayas based on RCM outputs**

Temperature change (°C)	HadRM2	PRECIS (B2)	PRECIS (A2)	Precipitation change (%)	HadRM2	PRECIS (B2)	PRECIS (A2)
Winter (DJF)	3.2	3.6	5.3	**Winter (DJF)**	57	23	35
Spring (MAM)	2.0	2.6	3.8	**Pre-monsoon (MAM)**	46	8	46
Summer (JJA)	3.0	2.8	3.8	**Monsoon (JJA)**	7	17	28
Autumn (SON)	3.2	2.5	4.3	**Post-monsoon (ON)**	15	12	18
Annual	2.9	2.9	4.3	**Annual**	18	13	34

Notes: HadRM2 is used for 2050s for 2xCO_2 and PRECIS for 2080s for A2 and B2 SRES scenarios.
Source: Shrestha and Devkota (2010)

Figures 5 and 6 show maps of the spatial variation of mean annual temperature change and mean annual precipitation change, respectively, for each scenario at each future time period based on the interpolated HadCM3 (2020s and 2050s) and PRECIS (2080s) simulation runs. By the 2080s, the mean annual temperature change for all of the EH is shown to be in the range of +2.9 to +4.3°C and the mean annual precipitation change in the range of 13 to 34%. The PRECIS simulation indicated a slightly higher warming in winter than in summer . Changes in monsoon precipitation showed enormous spatial variability predicted to range anywhere between minus 20% to plus 50% of the baseline period.

The mean projected annual temperature and precipitation changes under three GCMs plus PRECIS, three time-slices, and two SRE scenarios are summarised in Table 8, to present a wider range of future climate scenarios. The differences across the scenario results reinforces the need to explicitly recognise and account for the uncertainties that exist in projections of future climate. That said, the results are generally consistent with those reported by the IPCC for the northern hemisphere (IPCC 2001a) although the magnitude of climate change is predicted to be greater for the EH than that projected by the IPCC for the Asia region both for the mid and for the end of the century. Future winters are likely to experience larger temperature increases above the current level. Such increases will be greater under the SRES A2 emission trajectory, which describes the region as geared towards economic development with a regional orientation in strategic approaches. Precipitation changes will be greater in winter and spring, while the monsoon season is not expected to experience significant changes in mean conditions. There are important seasonal differences and trends that are not generally reflected in these annual maps. The seasonally differentiated values are summarised in Table 9. Any specific impact assessment that is sensitive to seasonal climate trends would need to generate maps and data specific to the season of interest.

Temperature scenarios vary across space and over time, but show a clear trend towards warming with average projected increases from 0.80 to 0.99°C (2020s) to 2.06 to 2.22°C (2050s) across the A2 and B2 scenarios calculated with HadCM3, and from 0.49 to 1.11°C (2020s), and 1.43 to 1.90°C (2050s) for A2 across GCMs, with the greatest increase in the high altitude area. All the GCMs indicated a higher rate of warming at higher elevations.

The spatial variation of changes in precipitation was considerable with enormous contradictions between the models in the pattern of changes. HadCM3 projected a decrease in precipitation along the northeastern

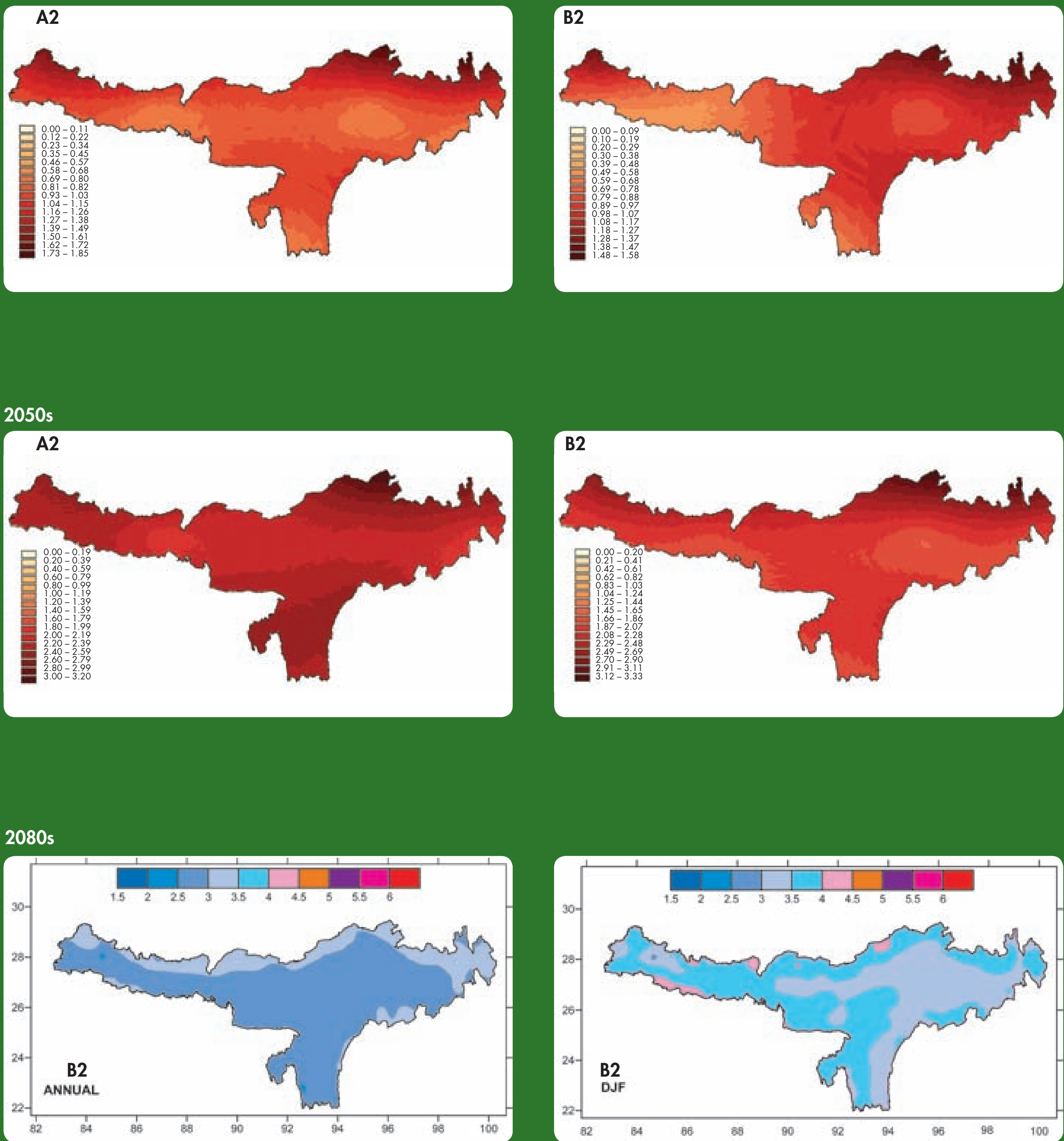
Figure 5: **Spatial variation of mean annual temperature changes (°C) over the EH**

Period

2020s

2050s

2080s

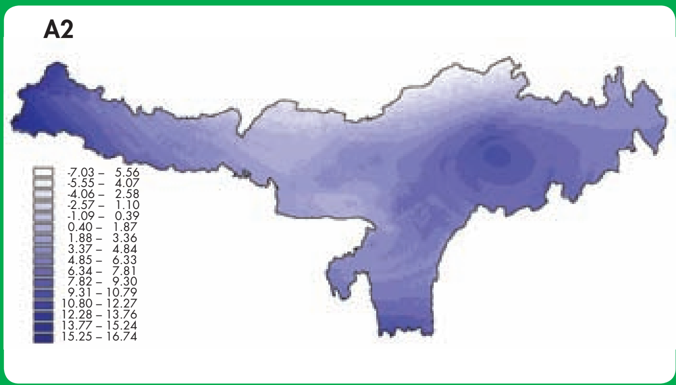


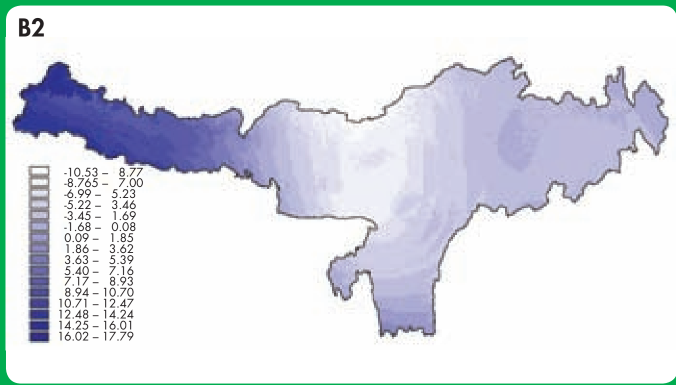
Notes: A2 and B2 scenarios are simulated by HadCM3 (2020 and 2050) and PRECIS (2080).
Changes are relative to the 1961–1990 model-simulated baseline period.
Maps in the 2080s row show mean annual and winter temperature changes under the B2 scenario.

Figure 6: **Spatial variation of mean annual precipitation changes (%) over the EH**

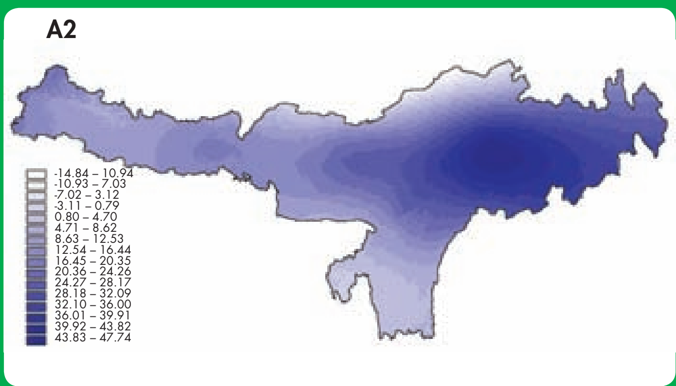
Period

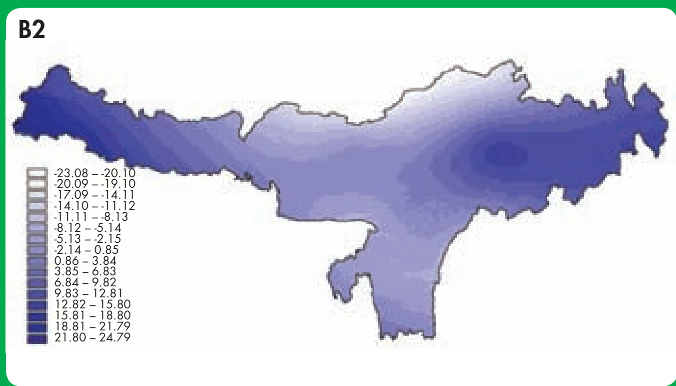
2020s



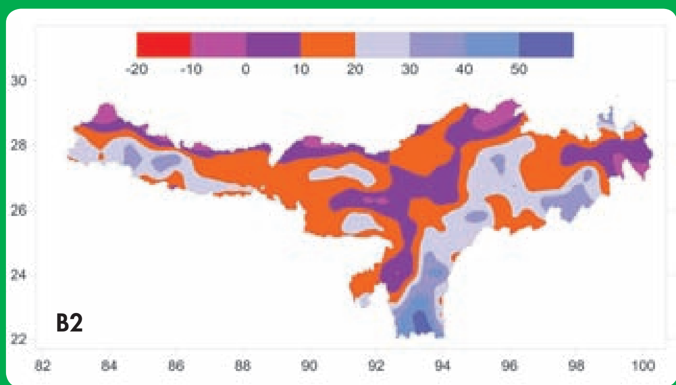


2050s





2080s



Notes: A2 and B2 scenarios are simulated by HadCM3 (2020 and 2050) and PRECIS (2080).
Changes are relative to the 1961-1990 model-simulated baseline period.
Maps in the 2080s row are for monsoon season (JJA).

fringes of the region, while the CSIRO-Mk2 projected a decrease along the southeastern fringes of the region. The lack of spatial concurrence in the model simulations of the magnitude and direction of precipitation changes confirms the inadequacy of GCMs in capturing the mountain influence on the weather and climate of the region, as described by temperature and precipitation characteristics. A slight, sub-regional trend is discernible with decreasing precipitation towards the east and increasing precipitation over much of the western part of the region. Variation in the spatial pattern and magnitude of projected changes is considerable between models for the same A2 SRES scenario, but the relative spatial pattern projected by HadCM3 remains the same for different emission scenarios (A2 and B2), varying only in the size of the anomaly.

The climate models suggest the following:

1. The rate of future winter warming to the 2080s is projected to vary from 3.6 to 5.3°C, while the summer temperature increase is projected to vary from 2.8 to 3.8°C.
2. Winter precipitation averaged across the EH is likely to increase by 23 to 35%, and summer (monsoon) precipitation by 17 to 28%; at the local level some places may experience negative anomalies.
3. In contrast to the small increase in summer rainfall, a much higher increase is expected in evapotranspiration depending on the ecosystem. In general, the modelled scenarios project dry and hot summers and milder winters with generally enhanced precipitation.

Projections of climate change and its impacts beyond about 2050 are strongly scenario- and model-dependent. Options for considering other transient periods and a full range of SRES development pathways are constrained by the availability of usable outputs from other GCMs and limited runs of the RCMs. Although the results do not account for the range of uncertainties, the probability of these scenarios is normally higher, being closer to the central measures in an empirical sense. The RCM results are only as good as the driving GCM within which they are nested (HadCM3 in this case). Even the RCM resolution is too crude to adequately represent the orographic detail of the EH. Further, it is also extremely difficult to model the monsoon with the current limitations in model representation of the underlying physics and the computing power currently available.

Nonetheless, the scientific evidence is unequivocal on the emergence of climate change as an important stress in the EH over the span of this century, despite considerable uncertainty about precise mechanisms and impacts, especially in precipitation.

Climatic variables projected to change in the EH include: carbon dioxide concentrations (increases are certain), temperature (increases are highly likely, but the distribution across space and time is uncertain), precipitation (projections are uncertain, increased frequency and intensity of severe storms and overall increases in precipitation are possible), and fires (predictions remain uncertain) (IPCC 2007a,c). It is increasingly unlikely that greenhouse gas emissions will be reduced quickly enough to fully prevent significant warming.

Country projections

In the assessment of future climates over India (Table 10), there is a broad consensus that both minimum and maximum temperatures will increase by 2 to 4°C leading to a mean surface temperature rise of 3.5 to 5°C by the end of the century. Mean annual precipitation may increase by 7 to 20%. Substantial spatial differences in precipitation changes are also expected (Aggarwal and Lal 2001). A 10 to 15% increase in monsoon precipitation in many regions, a simultaneous decline in precipitation of 5 to 25% in semi-arid and drought-prone central India, and a sharp decline in winter rainfall in northern India is also projected (Ramesh and Yadava 2005). A decrease in the number of rainy days (by 5-15 days on average) is expected over much of India, along with an increase in heavy rainfall days and in the frequency of heavy rainfall events in the monsoon season (Rupa Kumar et al. 2006).

Future climates based on eight Coupled Atmosphere-Ocean GCMs (AOGCMs) over west China project a clear warming in the 21st Century, showing an increase in temperature anomalies for SRES (Special Report on Emissions Scenarios) by 1.0 to 2.5°C by about 2050. A higher rate of warming is indicated than the mean warming for the whole country. The annual mean temperature change around 2050 relative to 1961 to 1990 is expected to be 3.5 to 6.5°C for scenario A2 and 2.5 to 4.5°C for scenario B2. Precipitation over most parts of the region is likely to increase by about 5 to 30% for A2 and 5 to 25% for B2 by about 2050, relative to 1961 to 1990. A future decrease is expected in the diurnal temperature range due to relatively larger increases in minimum temperature than in maximum temperature (Yunling and Yiping 2005).

The values averaged over the whole area of GCM ensemble experiments for Nepal indicate an increase

Table 10: **Climate change projections for India based on an ensemble of four GCM outputs**

Year	Temperature change (°C)			Precipitation change (%)			Sea level rise (cm)
	Annual	Winter	Monsoon	Annual	Winter	Monsoon	
2020s	1.36±0.19	1.61±0.16	1.13±0.43	2.9±3.7	2.7±17.7	2.9±3.7	4 to 8
2050s	2.69±0.41	3.25±0.36	2.19±0.88	6.7±8.9	-2.9±26.3	6.7±8.9	15 to 38
2080s	3.84±0.76	4.52±0.49	3.19±1.42	11.0±12.3	5.3±34.4	11.0±12.3	46 to 59

Source: Aggarwal and Lal 2001

Table 11: **Climate change projections for Nepal for A2 scenario based on 13-GCM ensemble**

Year	Temperature change (°C)			Precipitation change (%)		
	Annual	Winter	Monsoon	Annual	Winter	Monsoon
2020s	1.24 ± 0.20	1.49 ± 0.11	1.05 ± 0.11	-3.60 ± 3.08	-11.74 ± 2.69	-0.76 ± 4.07
2050s	2.47 ± 0.33	2.89 ± 0.14	2.09 ± 0.18	1.81 ± 4.76	-10.93 ± 3.63	5.88 ± 6.67
2080s	4.29 ± 0.47	4.96 ± 0.19	3.67 ± 0.24	6.22 ± 6.56	-17.58 ± 2.53	14.98 ± 9.74

Note: Errors are standard deviations worked out on the basis of spread of the ensemble member values around the mean value.
Source: APN 2005

Table 12: **Climate change projections* for Bhutan under SRE scenarios**

Scenarios		Temperature change (°C)				Rainfall change (mm)			
		A1	A2	B1	B2	A1	A2	B1	B2
2020s	Annual	1.197	1.107	1.039	1.103	61.339	57.559	26.660	28.918
2030s	Annual	1.859	1.785	1.461	1.672	98.908	80.951	40.393	44.924
2040s	Annual	2.642	2.597	2.000	2.448	143.857	110.812	59.153	63.849
2050s	Annual	3.412	3.321	2.561	3.157	183.986	141.903	76.290	82.443

* Based on PRECIS RCM experiments; country level area-averages
Source: Tse-ring (2003)

in annual temperature overall, as well as for summer/ monsoon (JJAS) and winter (DJFM) for all three time horizons across the scenarios evaluated.

The increase in temperature is projected to be higher in the north than in the central or southern parts of the country. A relatively larger temperature increase in winter than in summer is predicted over this century (Table 11). Precipitation is expected to increase in summer and decrease in winter, while on an annual basis it will show no significant change. The projected increase in temperature for the EH is slightly higher than the projected average increase over the South Asian region, but precipitation change is consistent with projected regional changes. The central part of the country will have the lowest temperature increase. Precipitation changes will be higher in the eastern and southern parts of Nepal, than in the northern parts (APN 2005).

The projections for Bhutan (Table 12) indicate that surface air temperature will increase with the greatest change in the west, gradually decreasing towards the east. The projected surface warming will be more pronounced during the pre-monsoon than during the summer monsoon season. Climate change maps show that the spatial pattern of temperature change has a large seasonal dependency. The temperature increase will be higher in the inner valleys than in the northern and southern parts of the country. The model predicts peak warming of about 3.5°C by the 2050s in Bhutan. This pattern of change is consistent for all months and all time slices.

In general, Bhutan is expected to experience a significant overall increase in precipitation, but with an appreciable change in the spatial pattern of winter and summer monsoon precipitation, including a 20 to 30% decrease in winter precipitation, over the north-east and south-west parts of Bhutan for the 2050s.