ICIMOD

Regional climate change projections: Climate change analysis using CORDEX regional climate models over South Asia

Climate change scenarios for Nepal

Experience from National Adaptation Plan process

Saurav Pradhananga

Santosh Nepal

13 October 2020

Government of Nepal
Ministry of Population and Environment
Department of Hydrology and Meteorology

Observed Climate Trend Analysis of Nepal (1971-2014)

June 2017

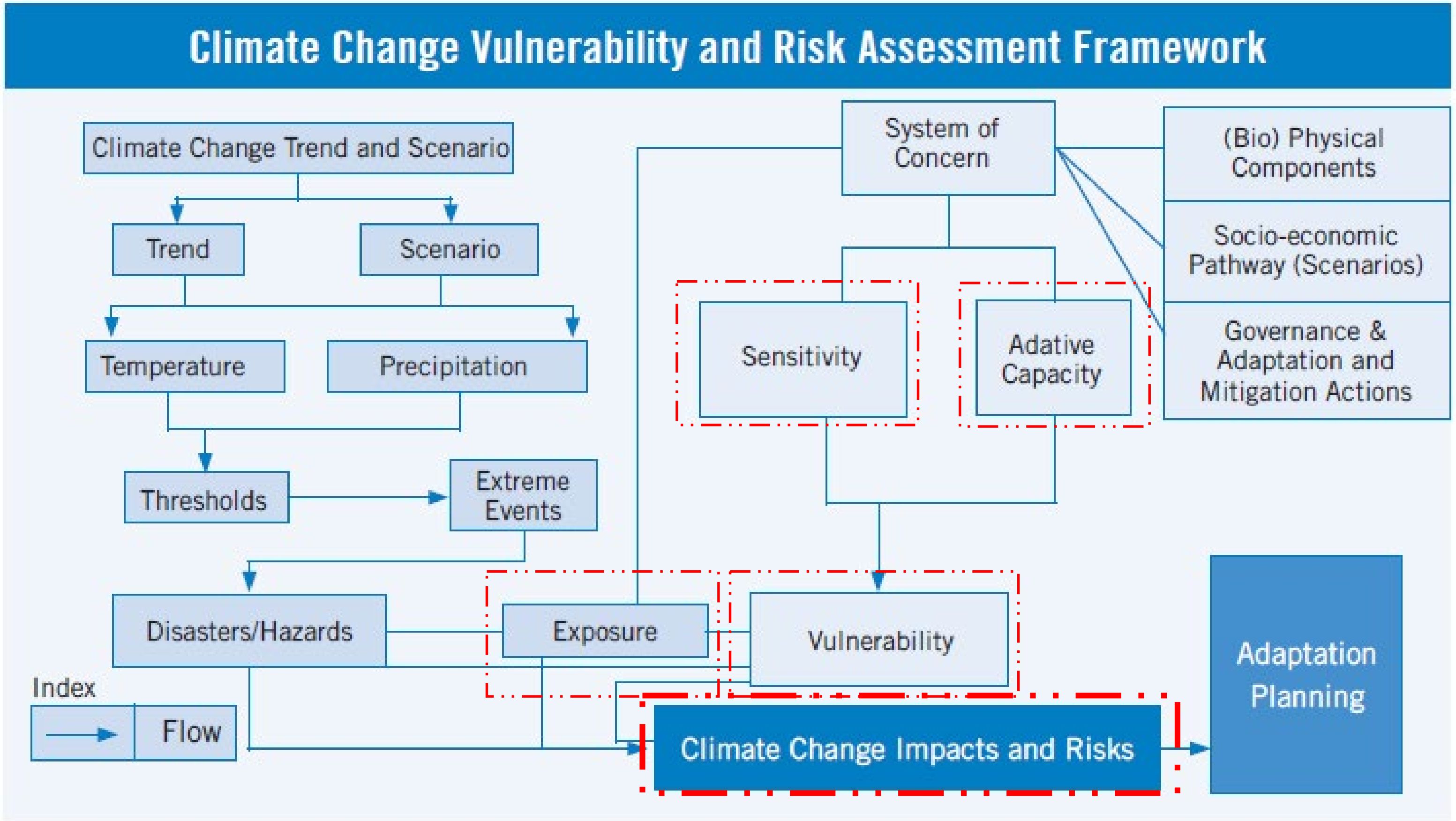
Government of Nepal
Ministry of Population and Environment
Department of Hydrology and Meteorology

Climate Change Scenarios for Nepal

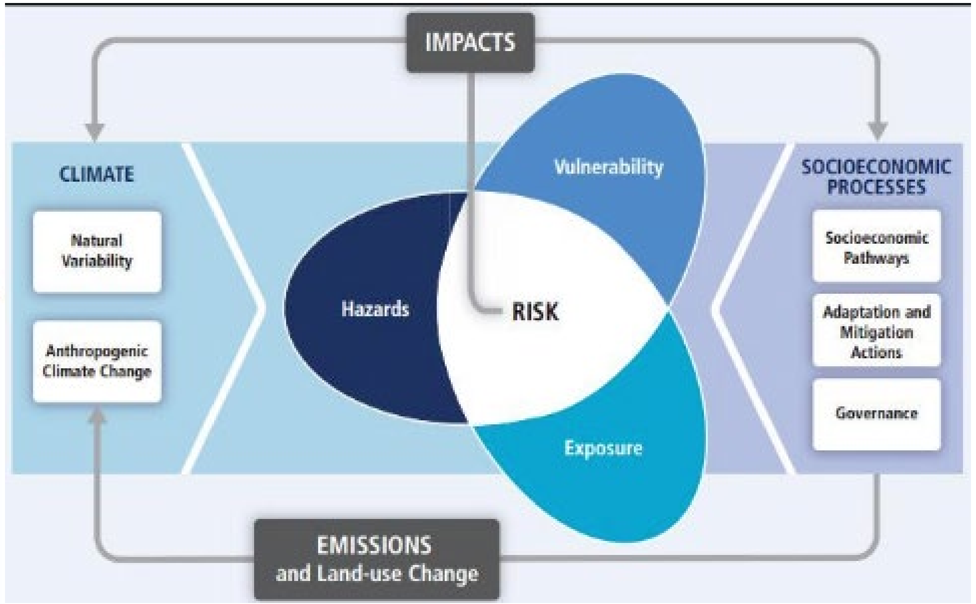
National Adaptation Plan Formulation Process

May 2018

Risk assessment

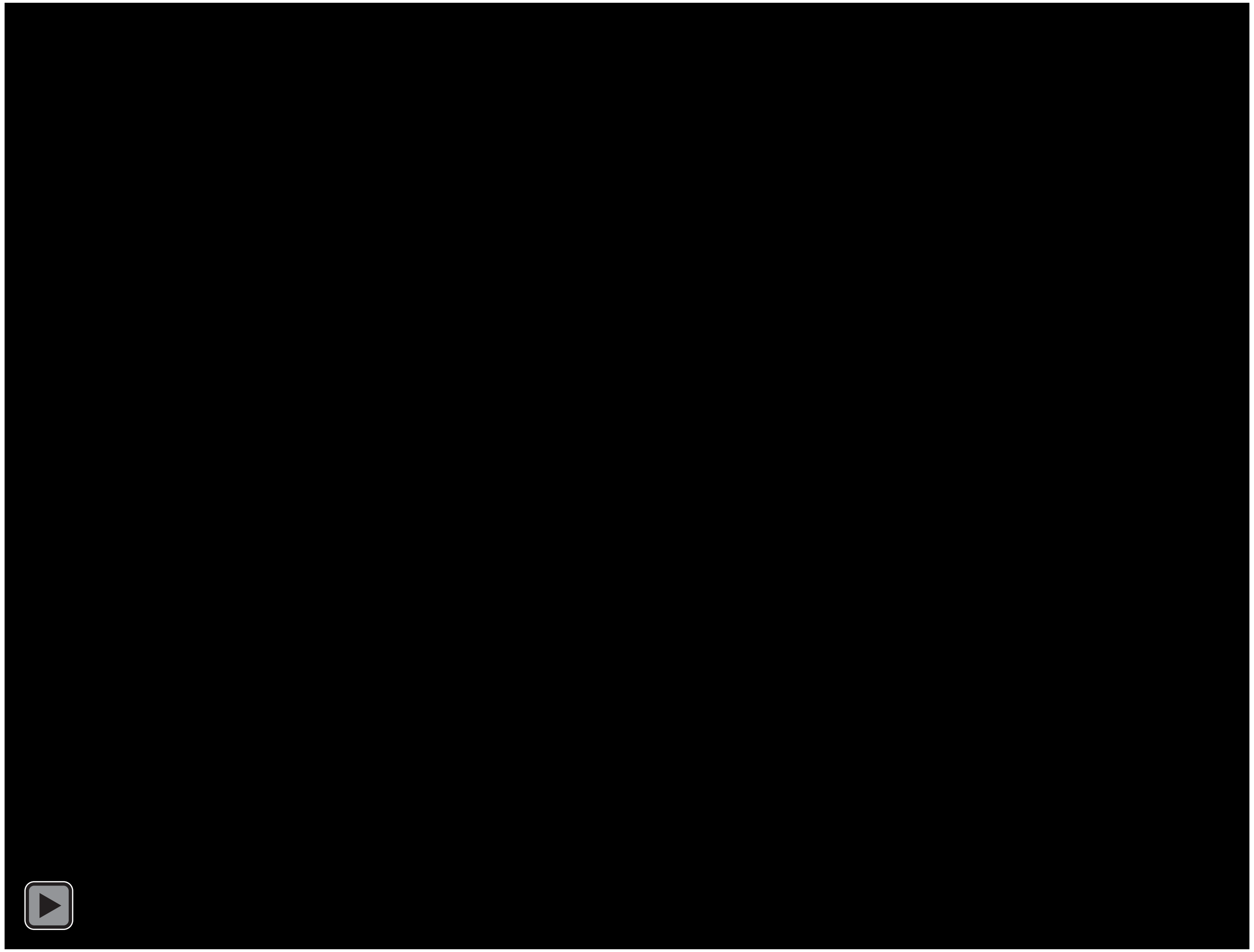


MOFE, 2017



IPCC, 2013

Temperature Change for each country



Source: Antti Lipponen/ClimateCentral.org
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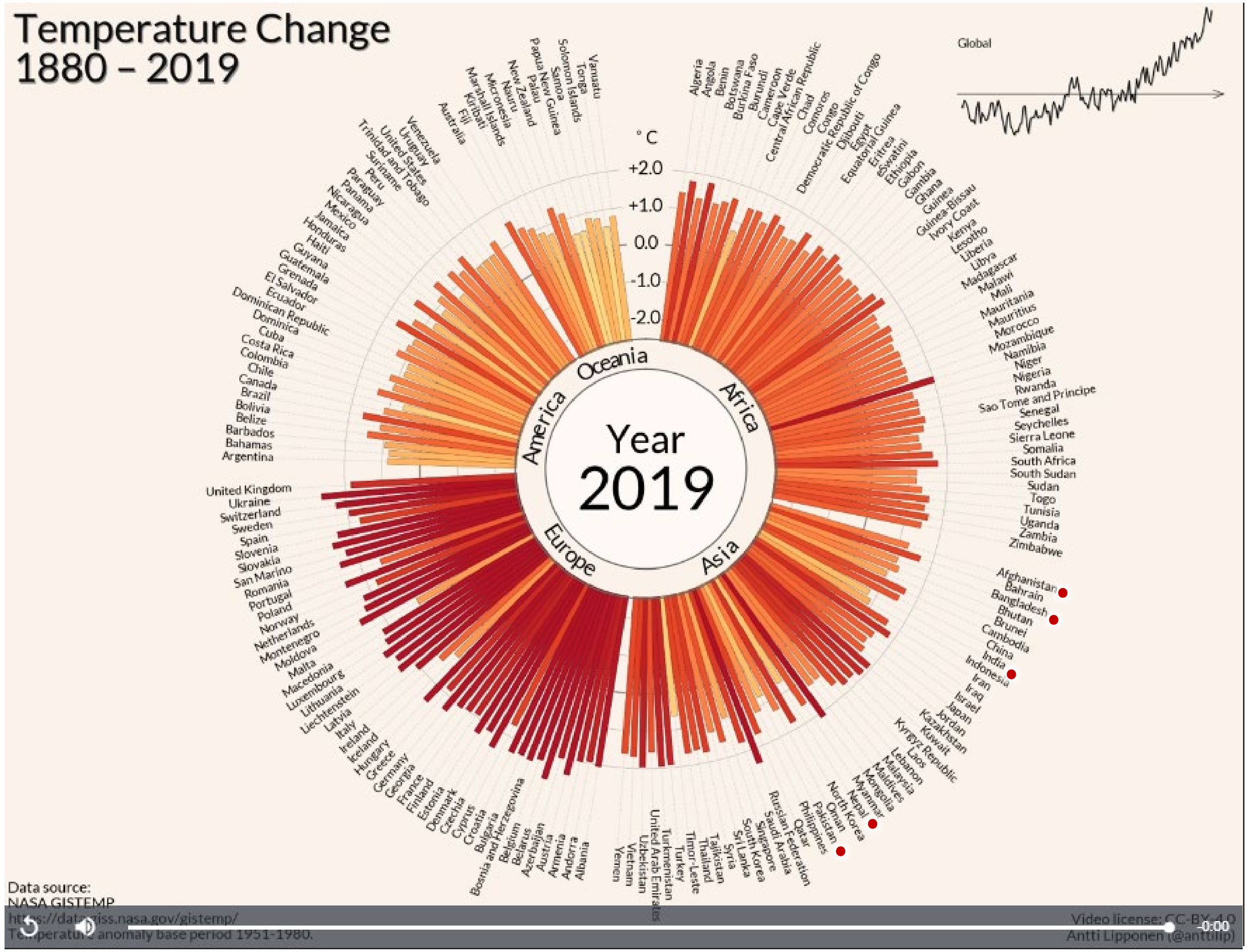
Temperature Change for each country



Source: Antti Lipponen/ClimateCentral.org
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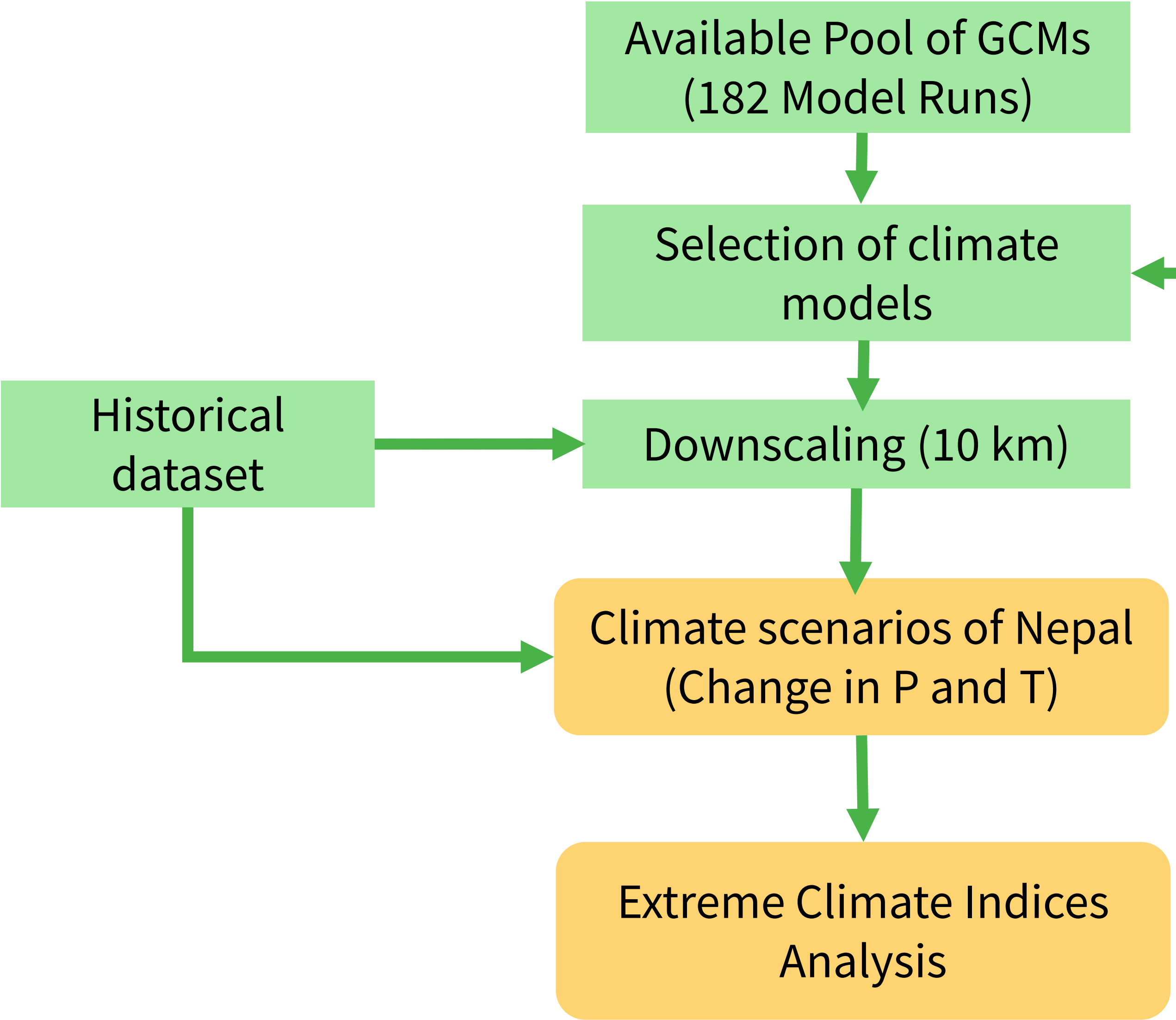
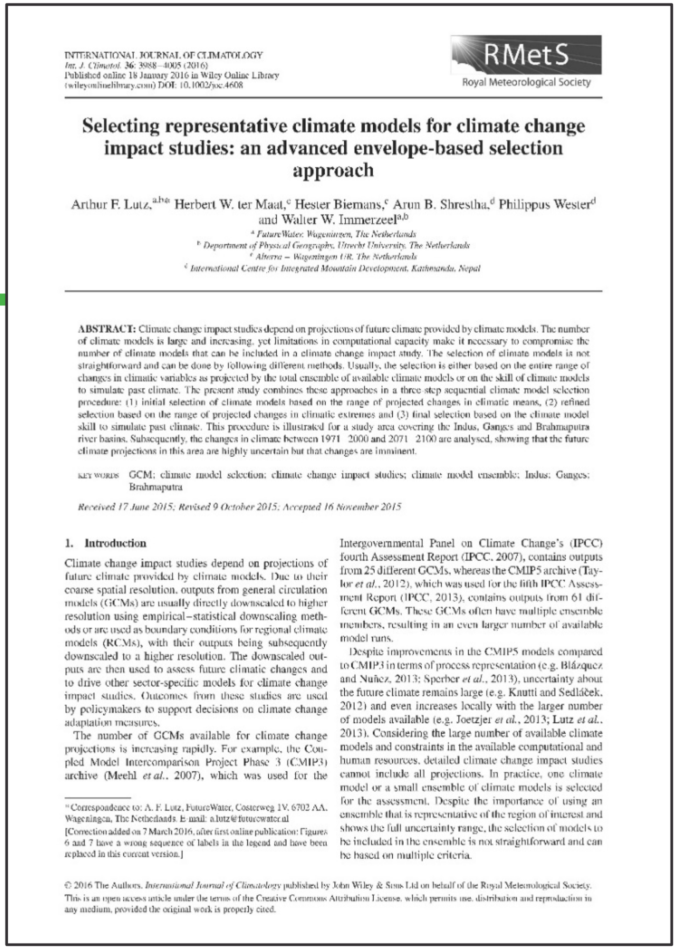
Methodological Approach for climate scenarios for NAP





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Selecting representative climate models for climate change impact studies: an advanced envelope-based selection approach

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ABSTRACT: Climate change impact studies depend on projections of future climate provided by climate models. The number of climate models is large and increasing, yet limitations in computational capacity make it necessary to compromise the number of climate models that can be included in a climate change impact study. The selection of climate models is not straightforward and can be done by following different methods. Usually, the selection is either based on the entire range of changes in climatic variables as projected by the total ensemble of available climate models or on the skill of climate models to simulate past climate. The present study combines these approaches in a three-step sequential climate model selection procedure: (1) initial selection of climate models based on the range of projected changes in climatic means, (2) refined selection based on the range of projected changes in climatic extremes and (3) final selection based on the climate model skill to simulate past climate. This procedure is illustrated for a study area covering the Indus, Ganges and Brahmaputra river basins. Subsequently, the changes in climate between 1971–2000 and 2071–2100 are analysed, showing that the future climate projections in this area are highly uncertain but that changes are imminent.

KEY WORDS GCM; climate model selection; climate change impact studies; climate model ensemble; Indus; Ganges; Brahmaputra

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1. Introduction

Climate change impact studies depend on projections of future climate provided by climate models. Due to their coarse spatial resolution, outputs from general circulation models (GCMs) are usually directly downscaled to higher resolution using empirical–statistical downscaling methods or are used as boundary conditions for regional climate models (RCMs), with their outputs being subsequently downscaled to a higher resolution. The downscaled outputs are then used to assess future climatic changes and to drive other sector-specific models for climate change impact studies. Outcomes from these studies are used by policymakers to support decisions on climate change adaptation measures.

The number of GCMs available for climate change projections is increasing rapidly. For example, the Coupled Model Intercomparison Project Phase 3 (CMIP3) archive (Meehl *et al.*, 2007), which was used for the Intergovernmental Panel on Climate Change's (IPCC) fourth Assessment Report (IPCC, 2007), contains outputs from 25 different GCMs, whereas the CMIP5 archive (Taylor *et al.*, 2012), which was used for the fifth IPCC Assessment Report (IPCC, 2013), contains outputs from 61 different GCMs. These GCMs often have multiple ensemble members, resulting in an even larger number of available model runs.

Despite improvements in the CMIP5 models compared to CMIP3 in terms of process representation (e.g. Blázquez and Nuñez, 2013; Sperber *et al.*, 2013), uncertainty about the future climate remains large (e.g. Knutti and Sedláček, 2012) and even increases locally with the larger number of models available (e.g. Joetzjer *et al.*, 2013; Lutz *et al.*, 2013). Considering the large number of available climate models and constraints in the available computational and human resources, detailed climate change impact studies cannot include all projections. In practice, one climate model or a small ensemble of climate models is selected for the assessment. Despite the importance of using an ensemble that is representative of the region of interest and shows the full uncertainty range, the selection of models to be included in the ensemble is not straightforward and can be based on multiple criteria.

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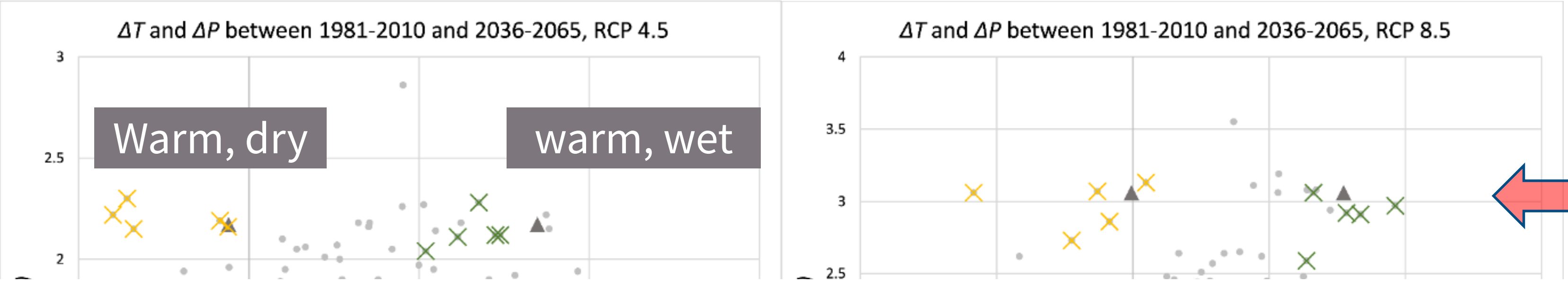
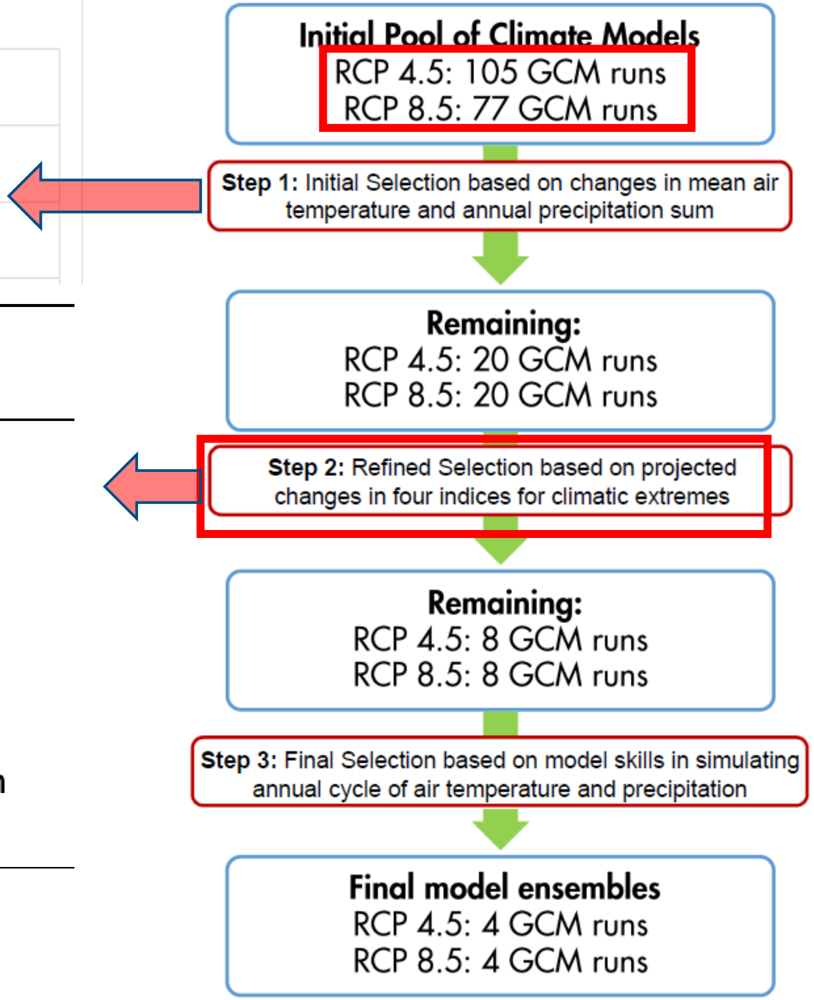
[Correction added on 7 March 2016, after first online publication: Figures 6 and 7 have a wrong sequence of labels in the legend and have been replaced in this current version.]

Approach introduced by Lutz et al., IJoC, 2016

Selection of representative climate models



Meteorological variable	ETCCDI index	Index description
Precipitation	R95pTOT	precipitation due to very wet days (> 95th percentile)
Precipitation	CDD	consecutive dry days: maximum length of a dry spell (P < 1 mm)
Air temperature	WSDI	warm spell duration index: count of days in a span of at least six days where TX > 90th percentile (TX_{ij} is the daily Tmax on day i in period j)
Air temperature	CSDI	Cold spell duration index: count of days in a span of at least six days where TN < 10th percentile (TNij is the daily Tmin on day i in period j



Expert Team (ET) on Climate Change Detection and Indices (**ETCCDI**)

Lutz, et al. 2016. *International Journal of Climatology*.

Final Selected models

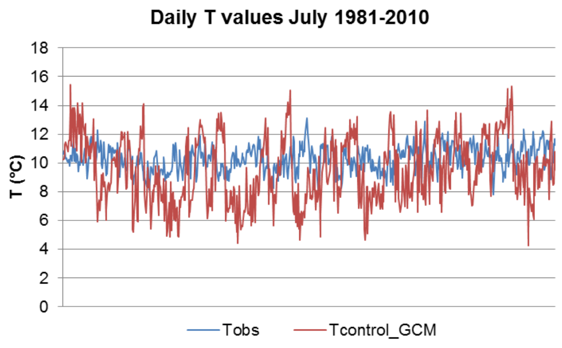
RCPs	General Circulation Model	Model characteristics
RCP4.5	BCC-CSM1-1_r1i1p1	Cold, Wet
	GFDL-ESM2M_r1i1p1	Cold, Dry
	MIROC-ESM-CHEM_r1i1p1	Warm, Dry
	CanESM2_r2i1p1	Warm, Wet
RCP8.5	BCC-CSM1-1_r1i1p1	Cold, Wet
	GFDL-ESM2M_r1i1p1	Cold, Dry
	MIROC-ESM-CHEM_r1i1p1	Warm, Dry
	CanESM2_r5i1p1	Warm, Wet

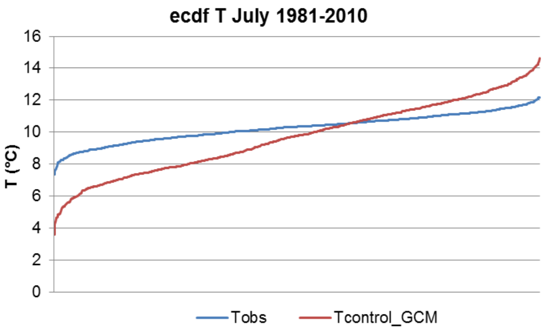
Historic dataset 1981-2010

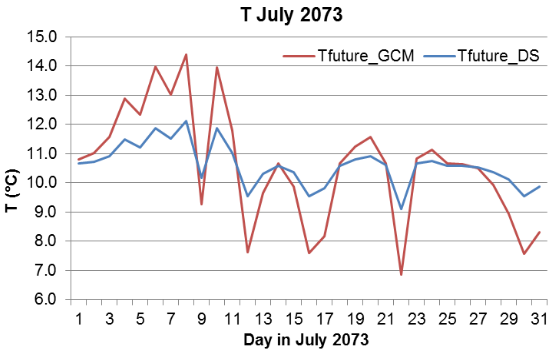
- Watch Forcing Data ERA-Interim (WFDEI) dataset
- Precipitation is corrected using the Global Precipitation Climatology Centre (GPCC) monthly dataset
- Additional bias correction with glacier mass balance
- Temp is bias corrected with observed stations data
    - Interpolated using lapse rate (monthly for upstream, annual for IGB)
- Upstream domain (5 km) and IGB basins (10 km)

One of the high resolution dataset available for the longer period of time with different level of bias corrections

Downscaling: Quantile mapping







1

Steps

1. All daily observations and GCM control run values for days for July during control period (1981-2010).

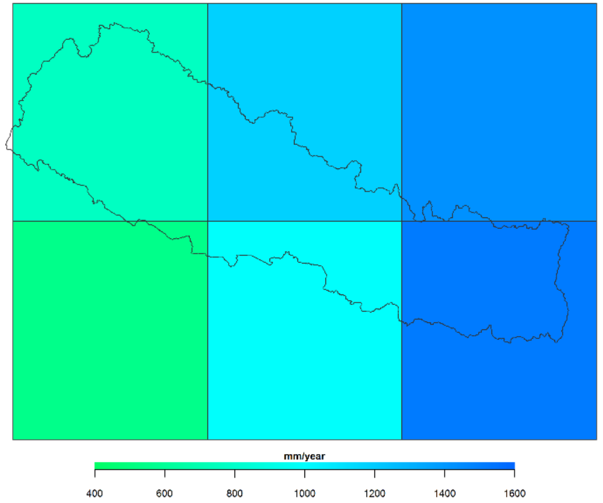
2

2. Empirical distribution functions (ECDF) constructed for observations and GCM control run values for July 1981-2010.

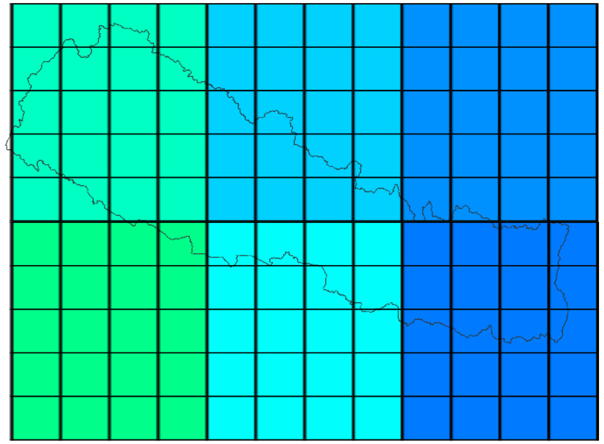
3

3. Future daily temperature for 2073 July in the future as from raw GCM input and corresponding downscaled values.

GCM (~250 km)



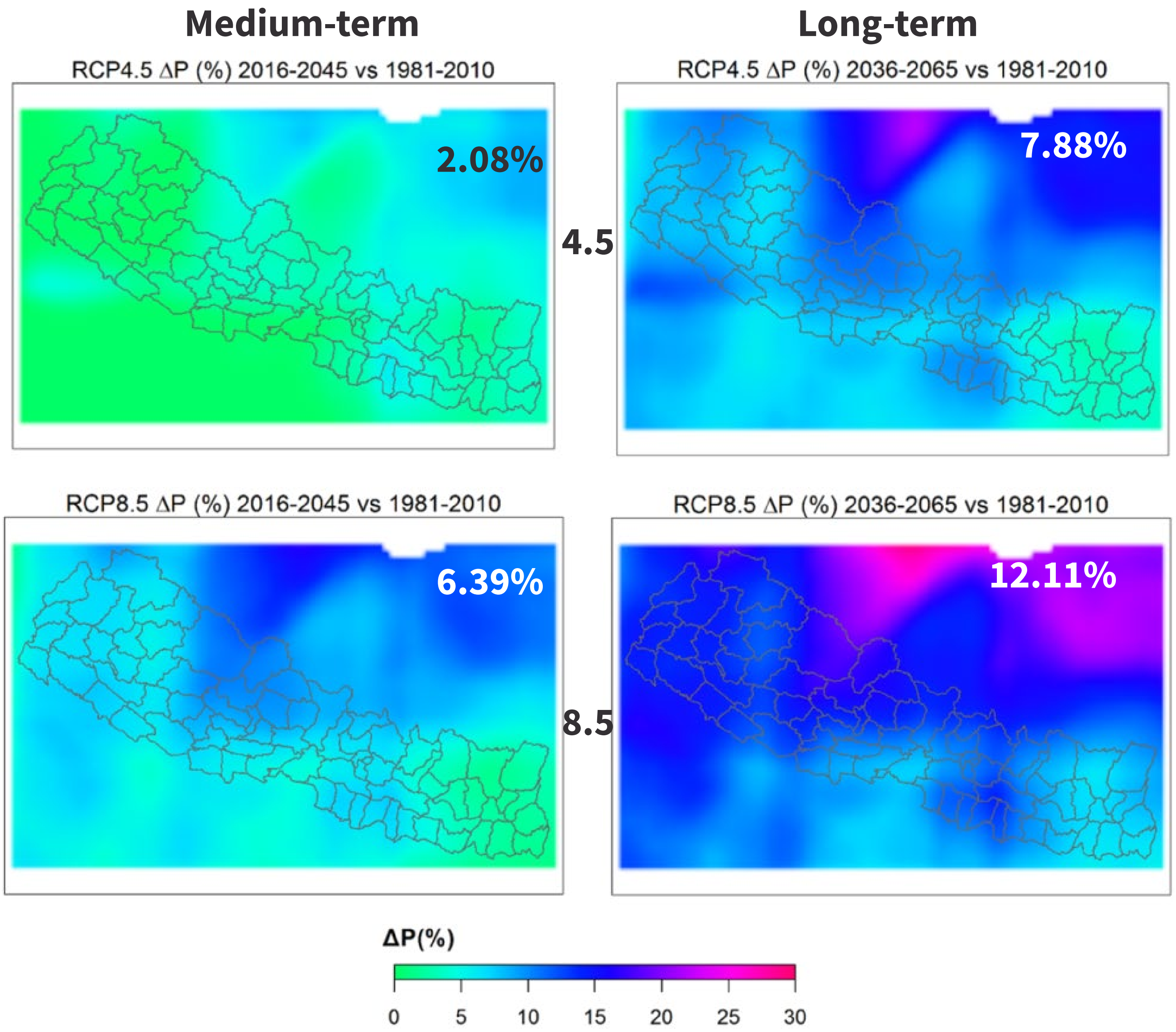
downscaled (~10 km)



Quantile mapping approach preserves extreme dynamics of data

Results and Findings

Change in Precipitation (%)



Highlights

Change in precipitation by 8-12 % in the long-term period

Precipitation increase in higher in western region

Medium-term: 2016-2045

Long-term: 2036-2065

As defined by NAP

Change in Temperature (°C)

Highlights

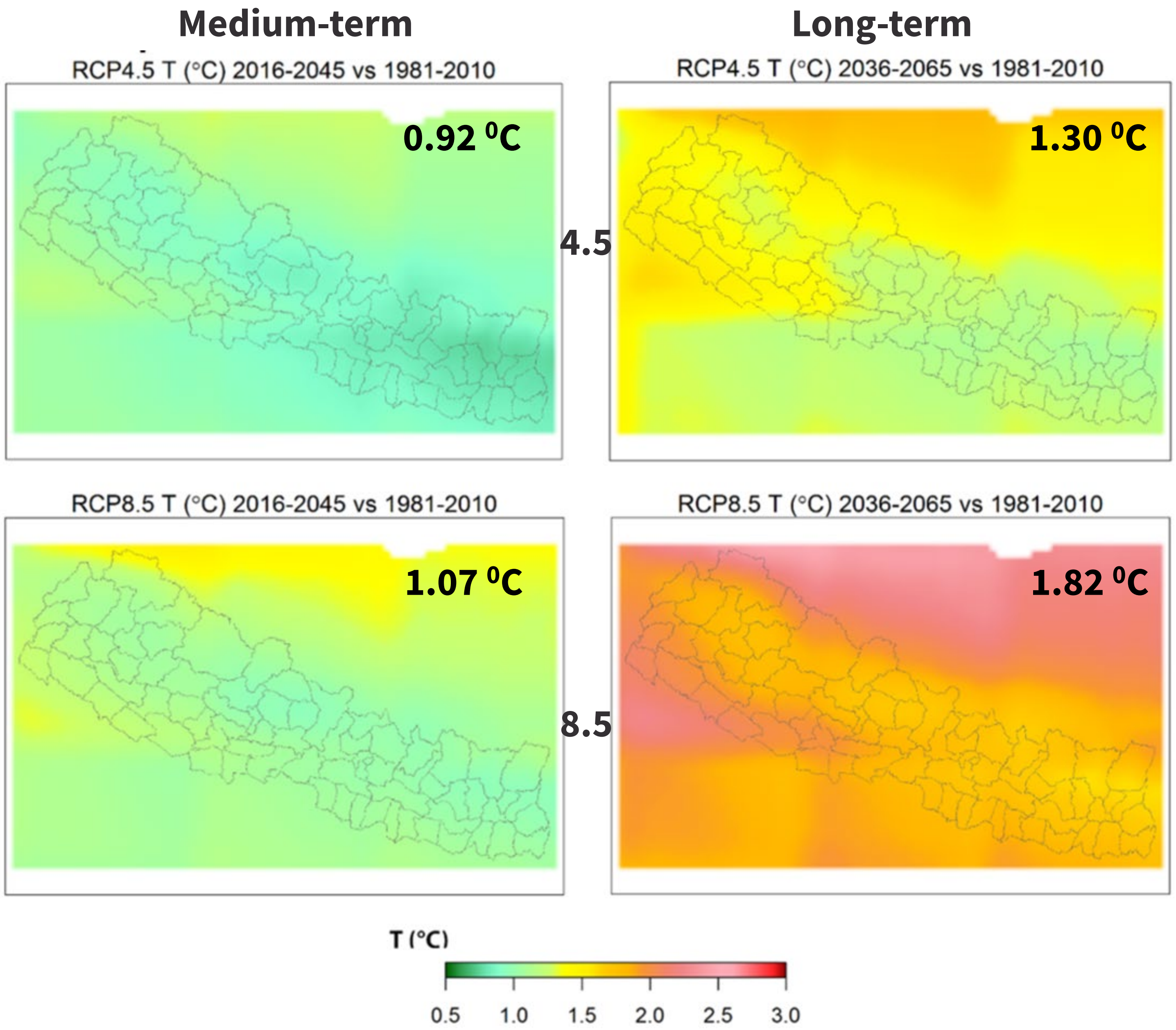
Increase in temperature throughout the country

Temperature increase by 1.3 to 1.82 °C in the long-term period (up to 2.5 °C in some places)

Medium-term: 2016-2045

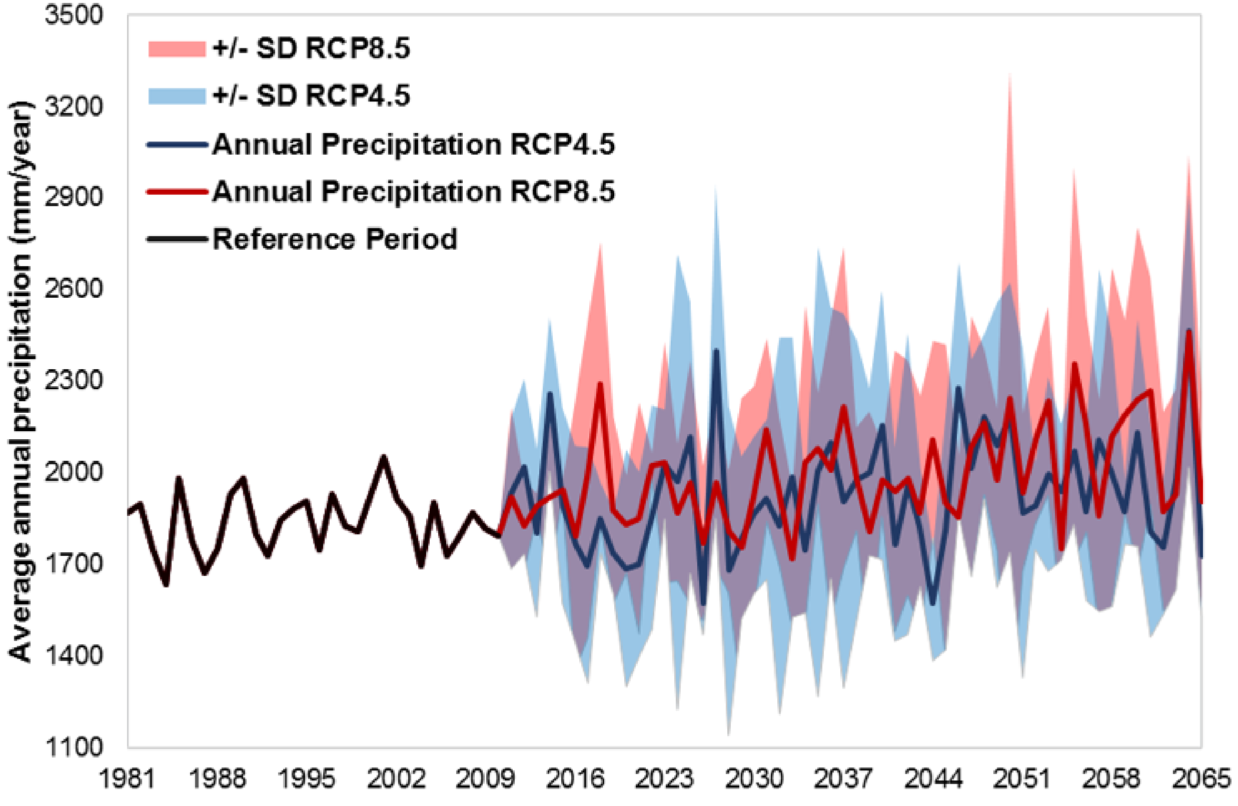
Long-term: 2036-2065

As defined by NAP

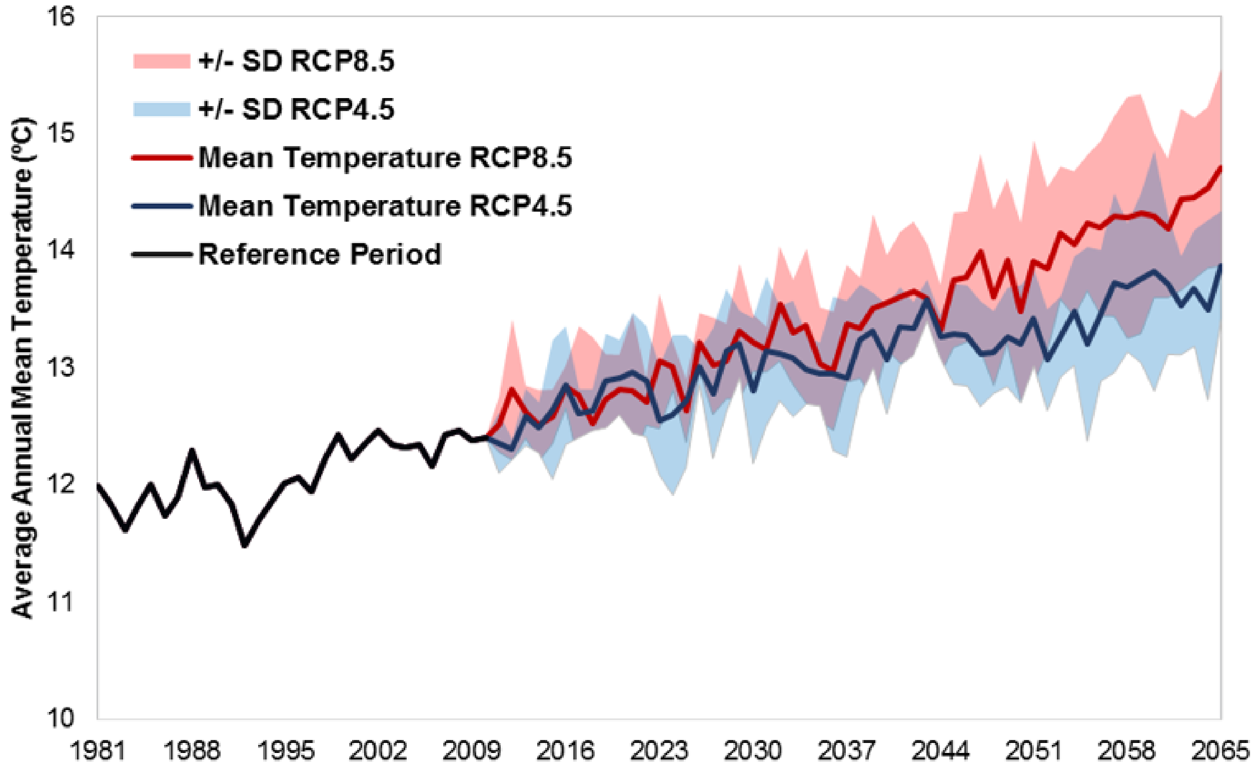


Precipitation and Temperature for Nepal

Annual Precipitation from 1981-2065



Annual Mean Temperature from 1981-2065



Change

2.1 – 6.4% (2016-2045)
7.9 – 12.1% (2036-2065)

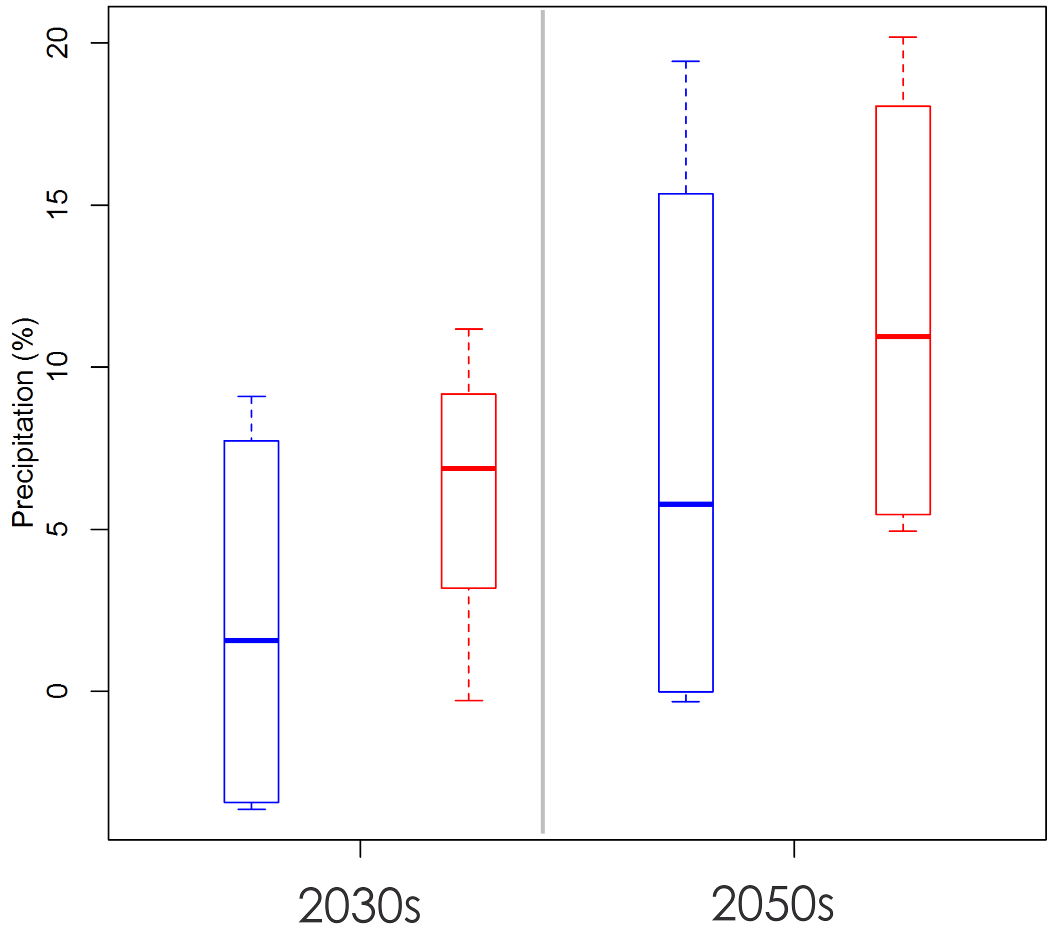
0.9 – 1.1 °C (2016-2045)
1.3 – 1.8 °C (2036-2065)

Uncertainty in projected changes in P and T

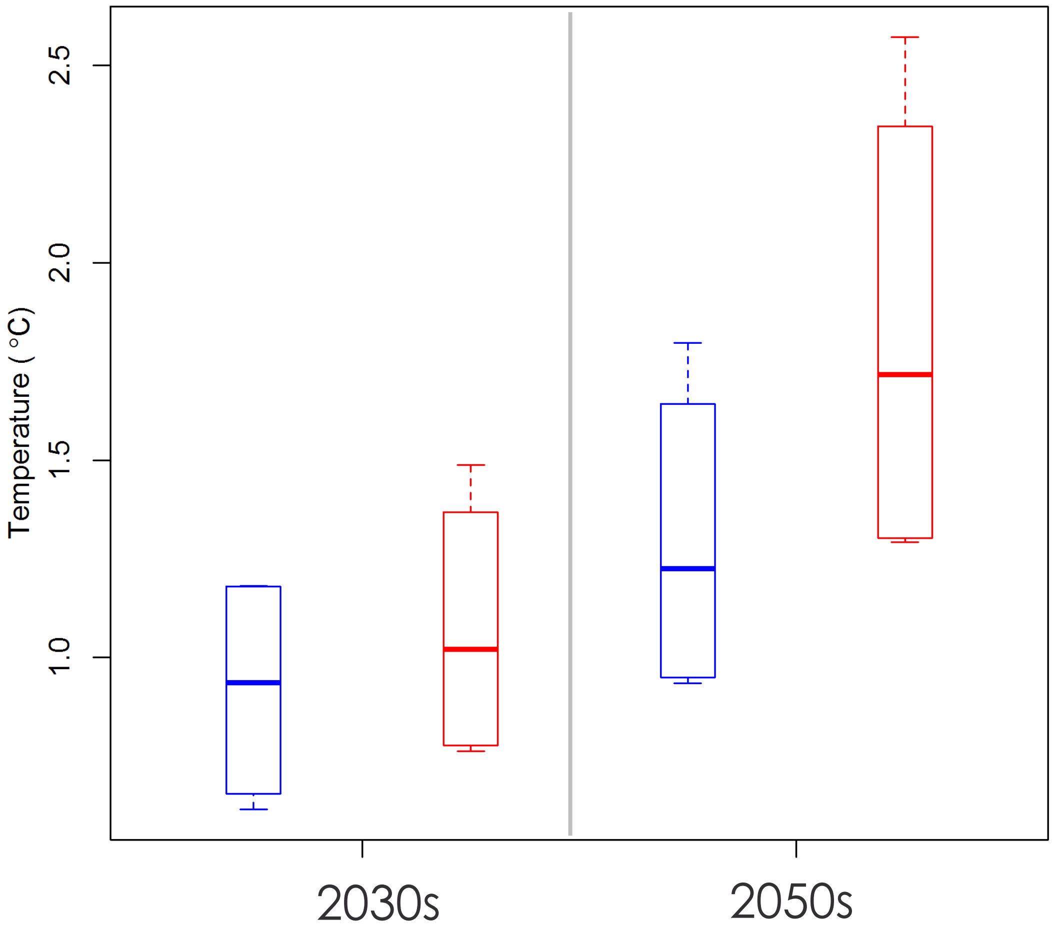
RCP 4.5

RCP 8.5

Precipitation



Temperature



Uncertainty in i) Variables ii) RCPs and iii) Time period

Confidence in model agreement

For temperature, **all GCMs indicate an increase** for both RCPs and time periods.

For precipitation, **5 out of 8** models show increase for medium-term and **7 out of 8** models show increase for long-term period.

RCPs	Models	Change in Precipitation (%)		Change in temperature (ºC)	
		Medium-term	Long-term	Medium-term	Long-term
RCP4.5	bcc-csm1-1_rcp45_r1i1p1	6.3	19.4	0.69	0.96
	CanESM2_rcp45_r2i1p1	9.1	11.3	1.18	1.49
	GFDL-ESM2M_rcp45_r1i1p1	-3.2	-0.3	0.62	0.93
	MIROC-ESM-CHEM_rcp45_r1i1p1	-3.6	0.3	1.18	1.80
RCP8.5	bcc-csm1-1_rcp85_r1i1p1	6.6	20.2	0.76	1.29
	CanESM2_rcp85_r5i1p1	11.2	15.9	1.25	2.12
	GFDL-ESM2M_rcp85_r1i1p1	7.1	6.0	0.79	1.31
	MIROC-ESM-CHEM_rcp85_r1i1p1	-0.3	4.9	1.49	2.57
Average		4.2	9.7	1.0	1.6
Standard Deviation		5.7	8.2	0.3	0.6
Co-efficient of Variation		137%	84%	32%	37%

Higher confidence in projection of change for temperature than precipitation

Change in P and T in physiographic region

Highlights

Increase in temperature higher in mountain region than whole Nepal average

	RCP 4.5			RCP 8.5		
	2016-2045	2036-2065	2071-2100	2016-2045	2036-2065	2071-2100
Change in precipitation (%)						
High Mountain	2.57	9.46	12.55	7.96	14.36	25.1
Middle Mountain	1.66	7.59	10.3	6.29	12.42	21.66
Hill	2.14	7.18	9.86	5.81	11.16	22.55
Siwalik	1.56	7.44	9.85	5.84	11.08	21.86
Terai	2.11	7.25	10.16	5.44	10.56	22.71
Whole Nepal	**2.1**	**7.9**	**10.7**	**6.4**	**12.1**	**23**
Change in temperature (°C)						
	RCP 4.5			RCP 8.5		
High Mountain	0.95	1.36	1.79	1.09	1.86	3.61
Middle Mountain	0.89	1.27	1.66	1.04	1.76	3.44
Hill	0.9	1.26	1.69	1.06	1.8	3.56
Siwalik	0.94	1.29	1.72	1.1	1.87	3.66
Terai	0.93	1.29	1.73	1.11	1.87	3.69
Whole Nepal	**0.92**	**1.3**	**1.72**	**1.07**	**1.82**	**3.58**

Seasonal changes in P and T

Highlights

Increase in precipitation in most of the seasons while decrease during pre-monsoon

Increase in temperature higher in the winter and post-monsoon seasons

	RCP 4.5			RCP 8.5		
	2016-2045	2036-2065	2071-2100	2016-2045	2036-2065	2071-2100
Change in precipitation (%)						
Winter	-5.8	13.6	24.4	7.2	5.0	20.9
Pre-monsoon	-5.0	-7.4	-7.8	-4.0	4.2	-3.1
Monsoon	2.7	9.4	12.4	7.8	13.6	27.1
Post-monsoon	18.6	20.3	16.5	6.0	19.0	22.9
Change in temperature (°C)						
		RCP 4.5			**RCP 8.5**	
Winter	1.0	1.5	2.1	1.2	2.0	4.0
Pre-monsoon	0.7	1.0	1.2	1.0	1.6	3.4
Monsoon	0.8	1.1	1.4	0.8	1.5	3.0
Post-monsoon	1.3	1.8	2.5	1.4	2.4	4.5

Summary results of extreme indices

- Extreme events are increasing
- Temperature events are more pronounced than precipitation

Indices	No. of mean annual days in the reference period	RCP4.5				RCP8.5			
		Medium-term		Long-term		Medium-term		Long-term	
		%	Days	%	Days	%	Days	%	Days
P95 days	18.1	1.5	0.3	12	2.2	12.1	2.2	18.6	3.4
P99 days	3.5	26.3	0.9	41.3	1.4	28	1.0	59.8	2.1
Rainy days	166.4	-1.8	-3	-1	-1.7	-0.9	-1.6	-0.5	-0.8
CDD	45.3	6	2.7	2.4	1.1	-1.6	-0.7	-2.9	-1.3
CWD	78.1	-4.2	-3.3	-1.3	-1	3.1	2.5	2.2	1.7
Warm days	36.5	64.5	23.9	87.3	32.3	71.4	26.4	124.7	46.1
Warm nights	36.5	81.4	30.5	115.7	43.3	101.0	37.8	159.2	59.6
Cold days	36.5	-42	-15.4	-52.6	-19.3	-55.8	-20.5	-75	-27.5
Cold nights	36.5	-40.7	-15	-53.5	-19.7	-54.1	-19.9	-74	-27.3
Warm spell Duration Index	17.6	110	19.3	149	26.2	157.4	27.6	244.8	43
Cold Spell Duration Index	20.3	-51.8	-10.5	-63.9	-12.9	-55.1	-11.2	-73.3	-14.8

Very Wet days

Highlights

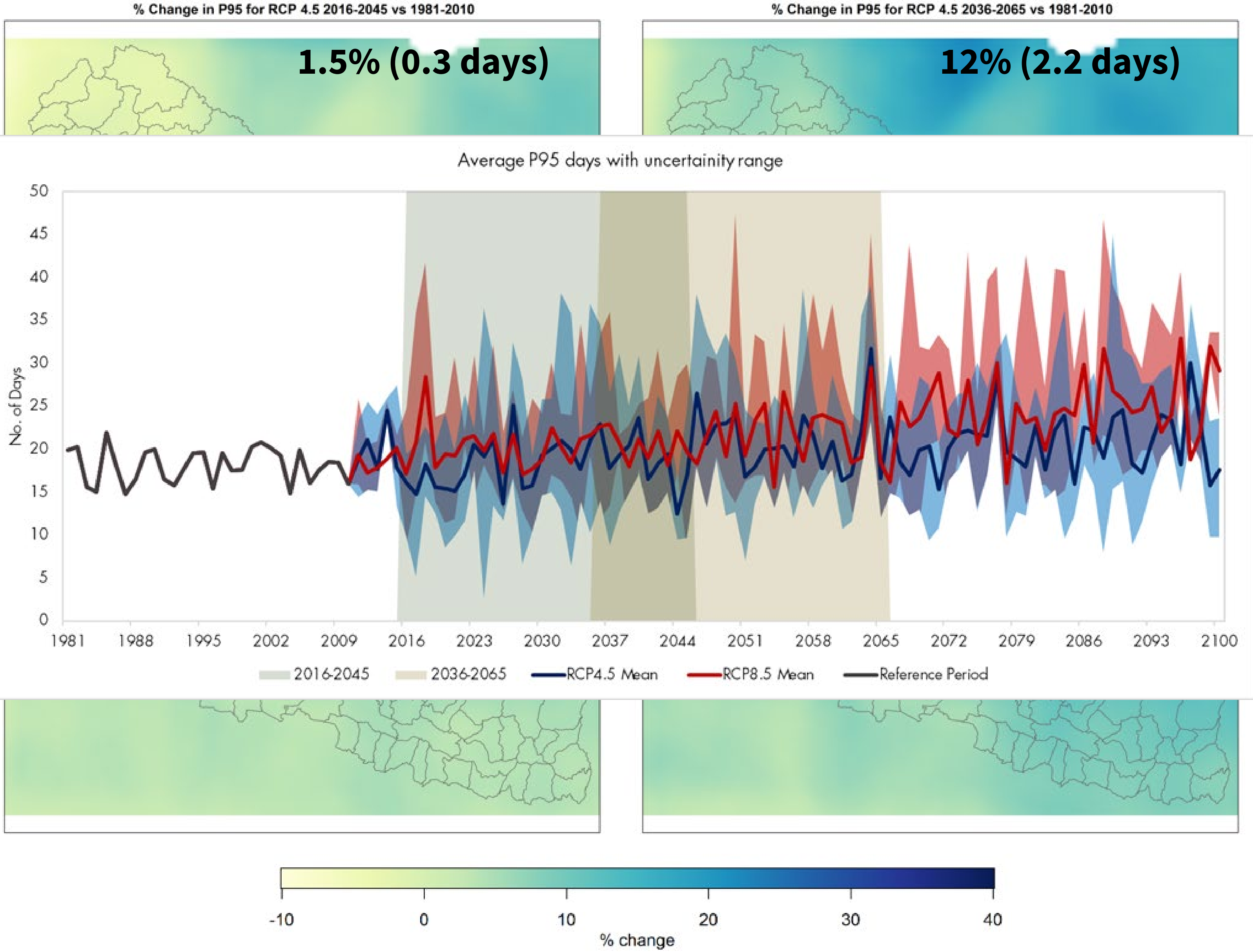
Increase in very wet days

Slightly higher increase in western region than eastern

Large uncertainty range

Medium-term

Long-term

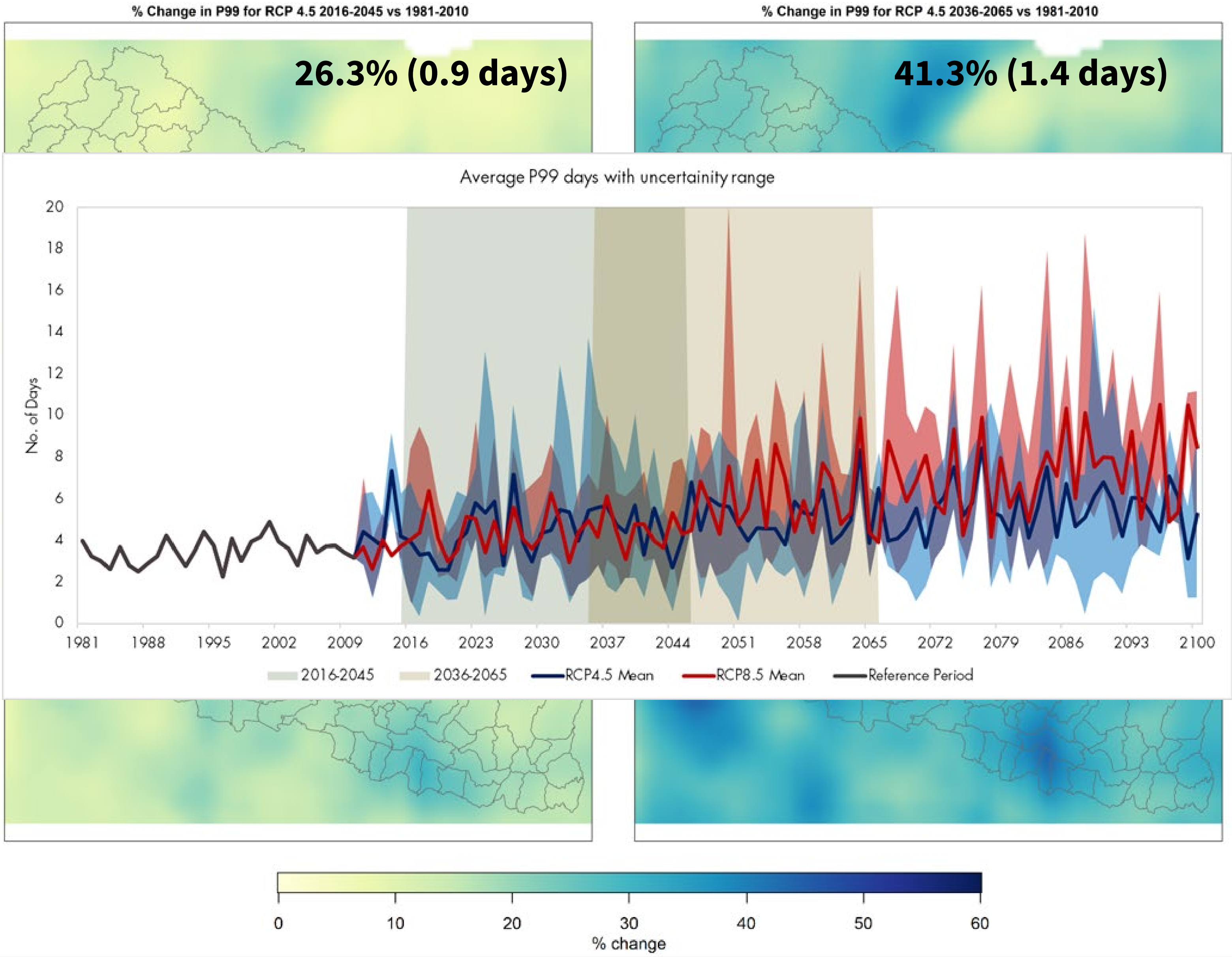


Extreme Wet days

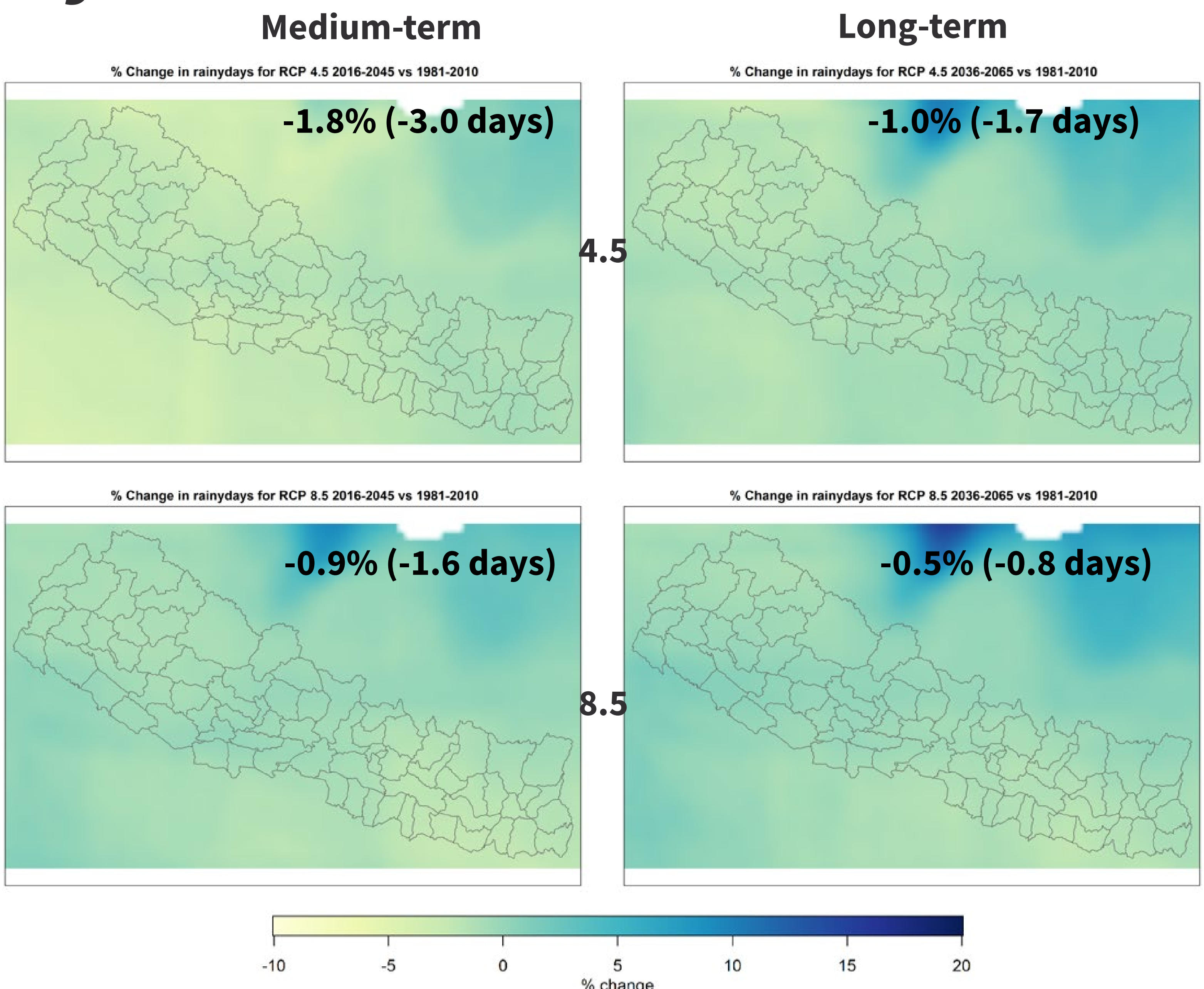
Highlights

Increase in extreme wet days (up to 2.1 days) throughout Nepal

Medium-term **Long-term**



Number of rainy days



Highlights

Overall, decrease in number of rainy days

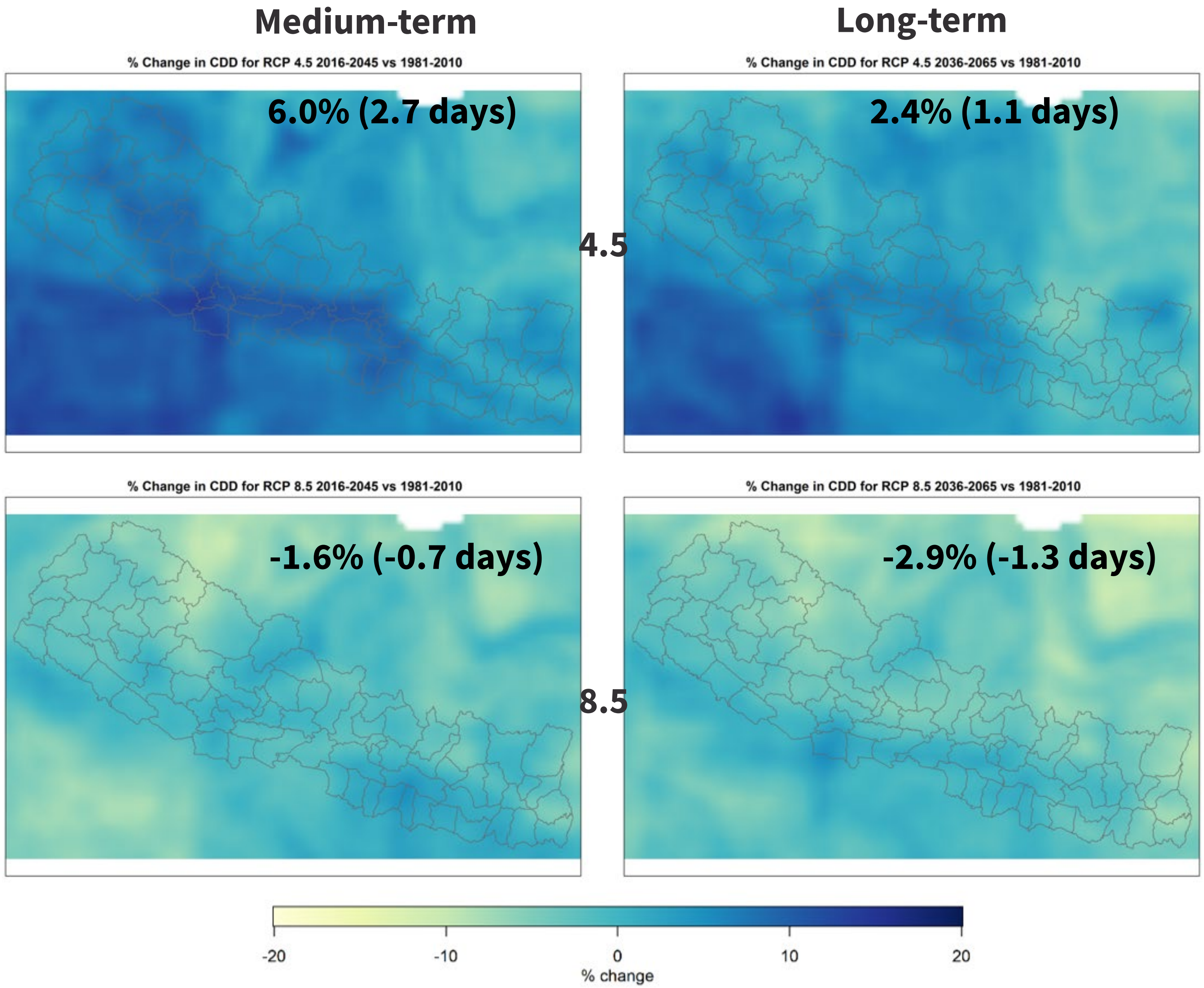
Slightly increasing trend towards the long-term period

Consecutive dry days (CDD)

Highlights

CDD increasing in RCP4.5 scenarios and decreasing during RCP8.5

Mainly due to higher volume of precipitation in RCP8.5 than 4.5

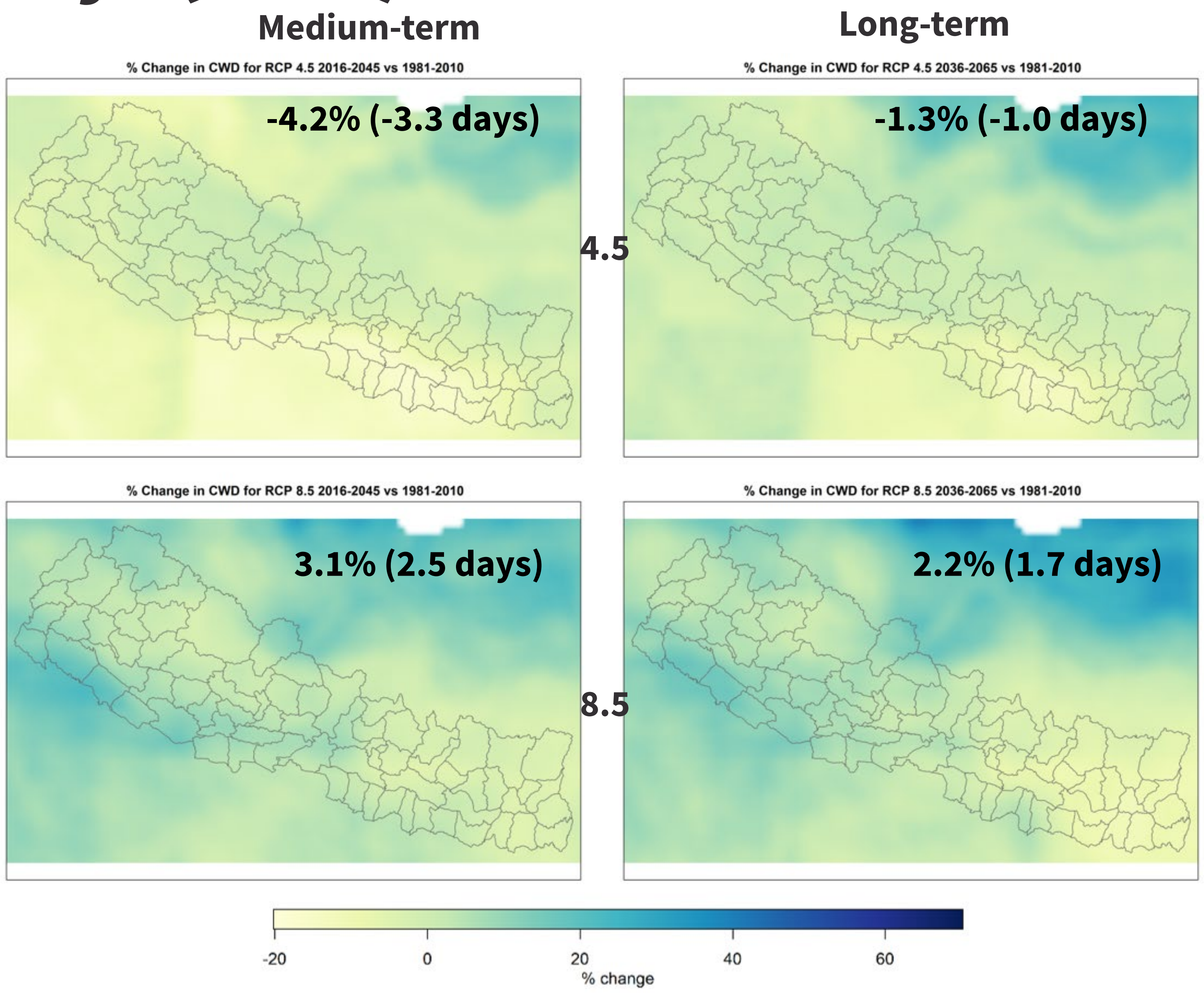


Consecutive wet days (CWD)

Highlights

CWD decreasing in RCP4.5 scenarios and increasing during RCP8.5

Mainly due to higher volume of precipitation in RCP8.5 than 4.5



Warm days

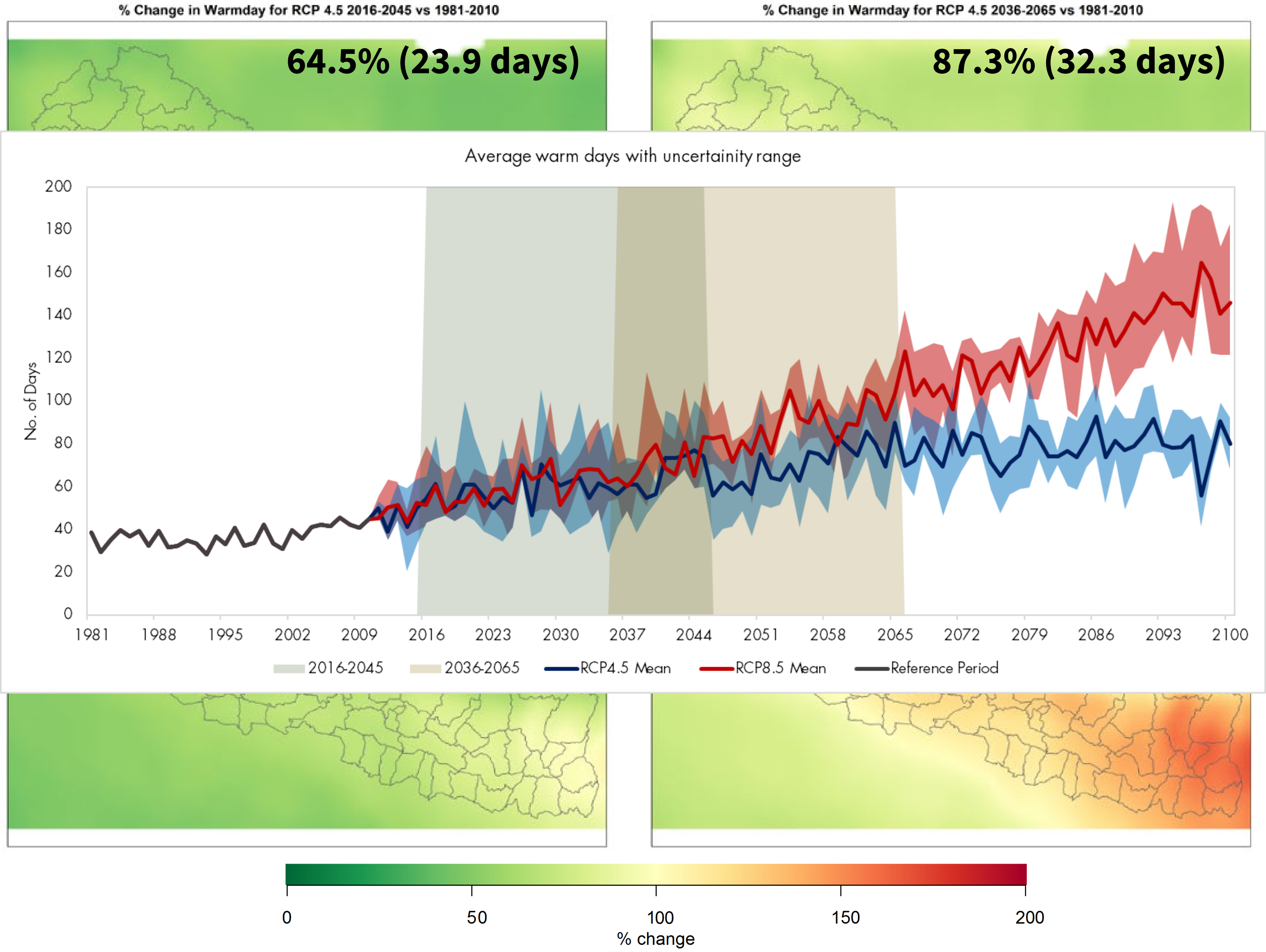
Highlights

Consistent increase in warm days

Increase in average up to 46 days (up to 70 days in some places)

Eastern region has higher increase than western

Medium-term **Long-term**



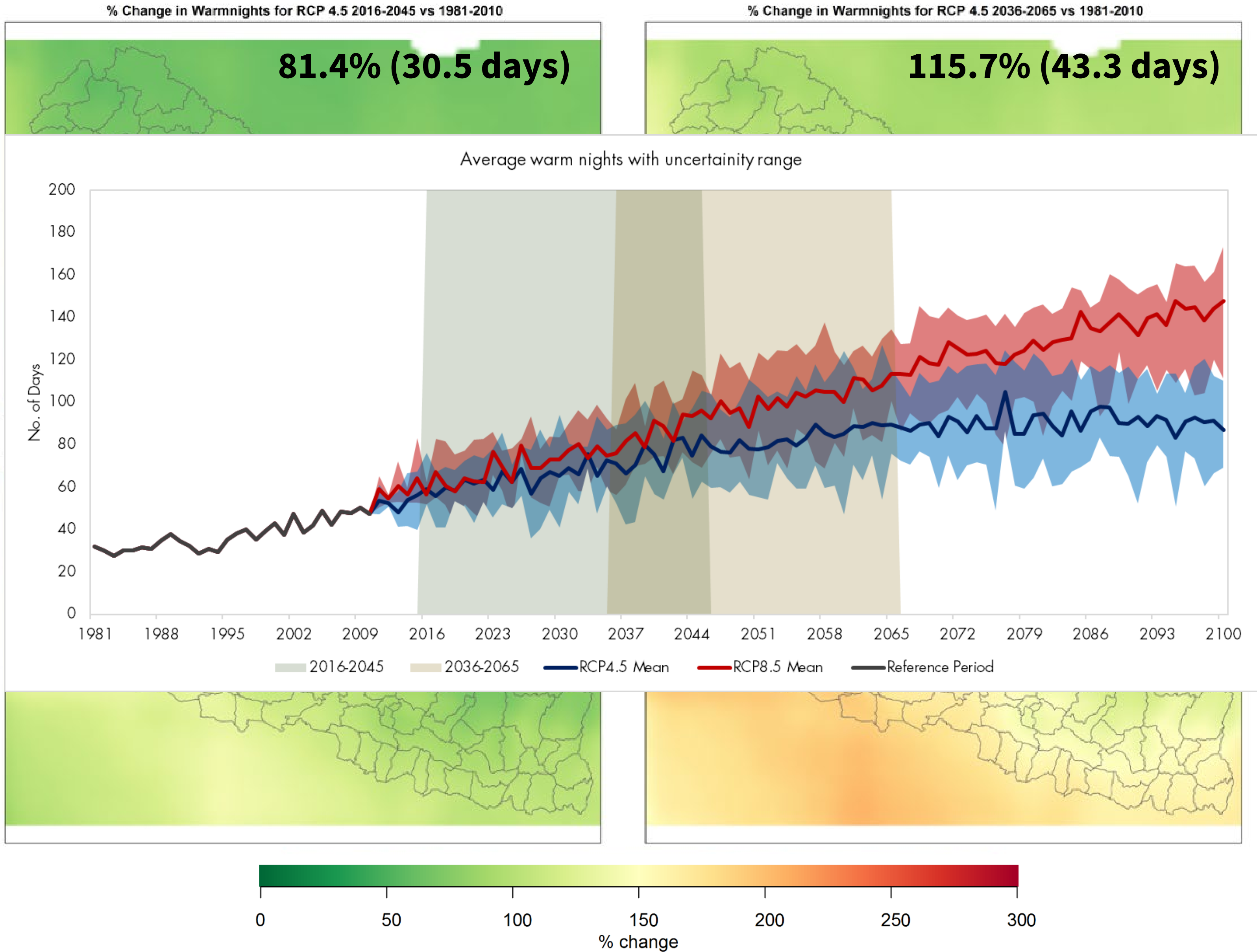
Warm nights

Highlights

Warm nights will increase up to 60 days

Higher increase in Terai region than hilly areas

Medium-term | **Long-term**

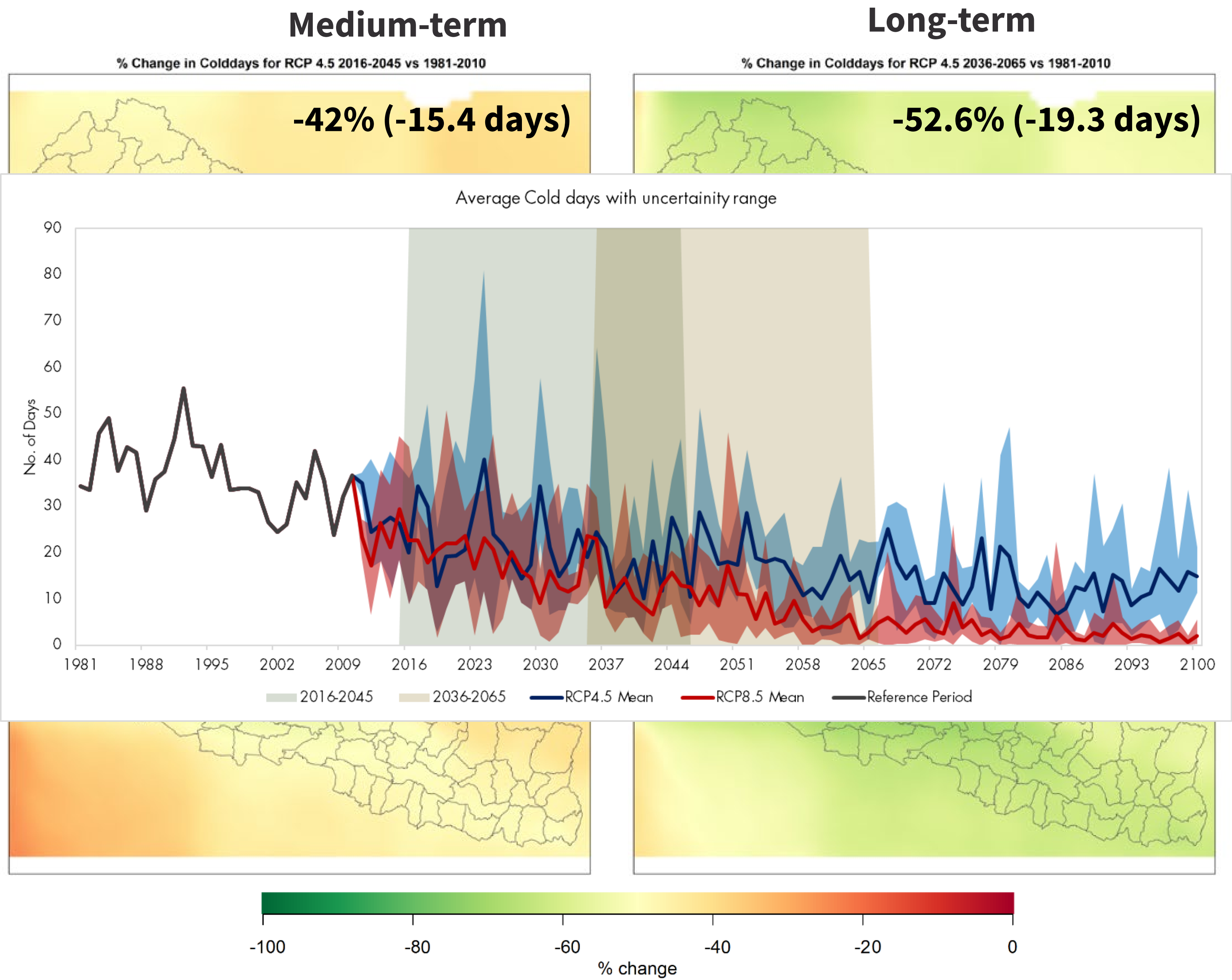


Cold days

Highlights

Continuous decrease in cold days throughout the country

Decrease may up to 27.5 days



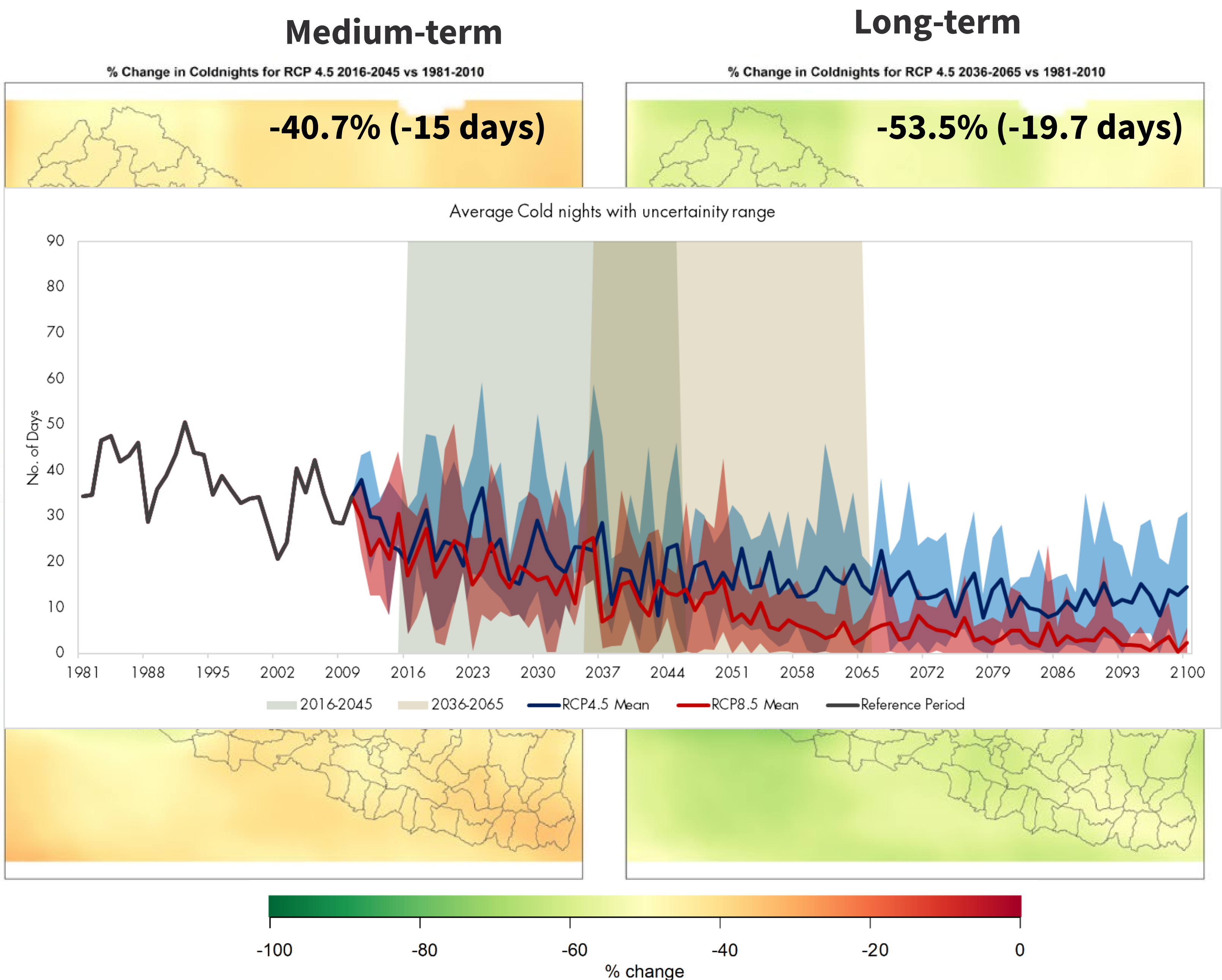
Cold nights

Highlights

Continuous decrease in cold nights throughout the country

Decrease may up to 27.3 days

Higher level of decrease in western areas



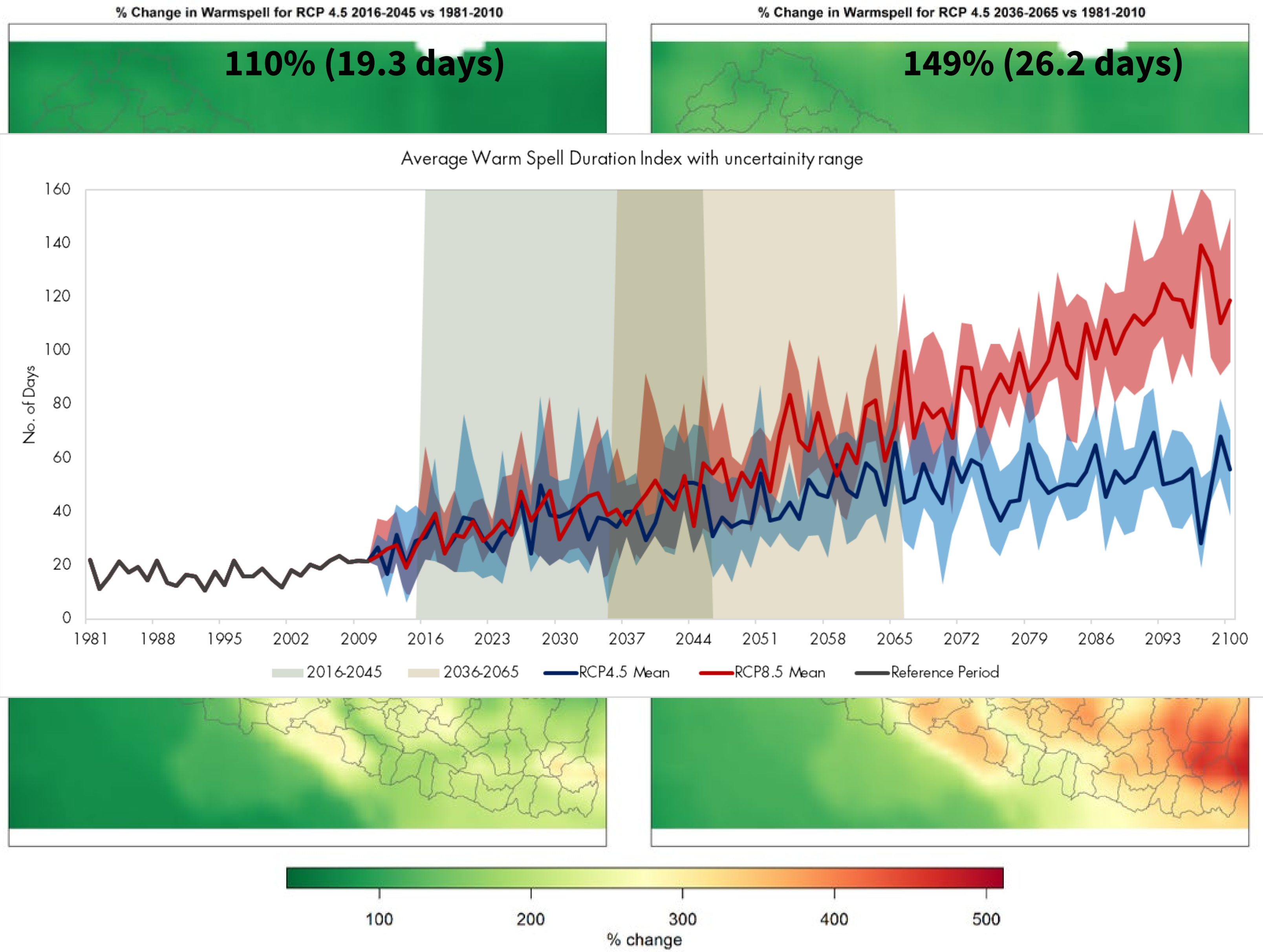
Warm spell duration

Highlights

Continuous increase in warm spell duration throughout the country (increase by 43 days)

Magnitude is higher in eastern and central region than western

Medium-term | **Long-term**



Cold spell duration

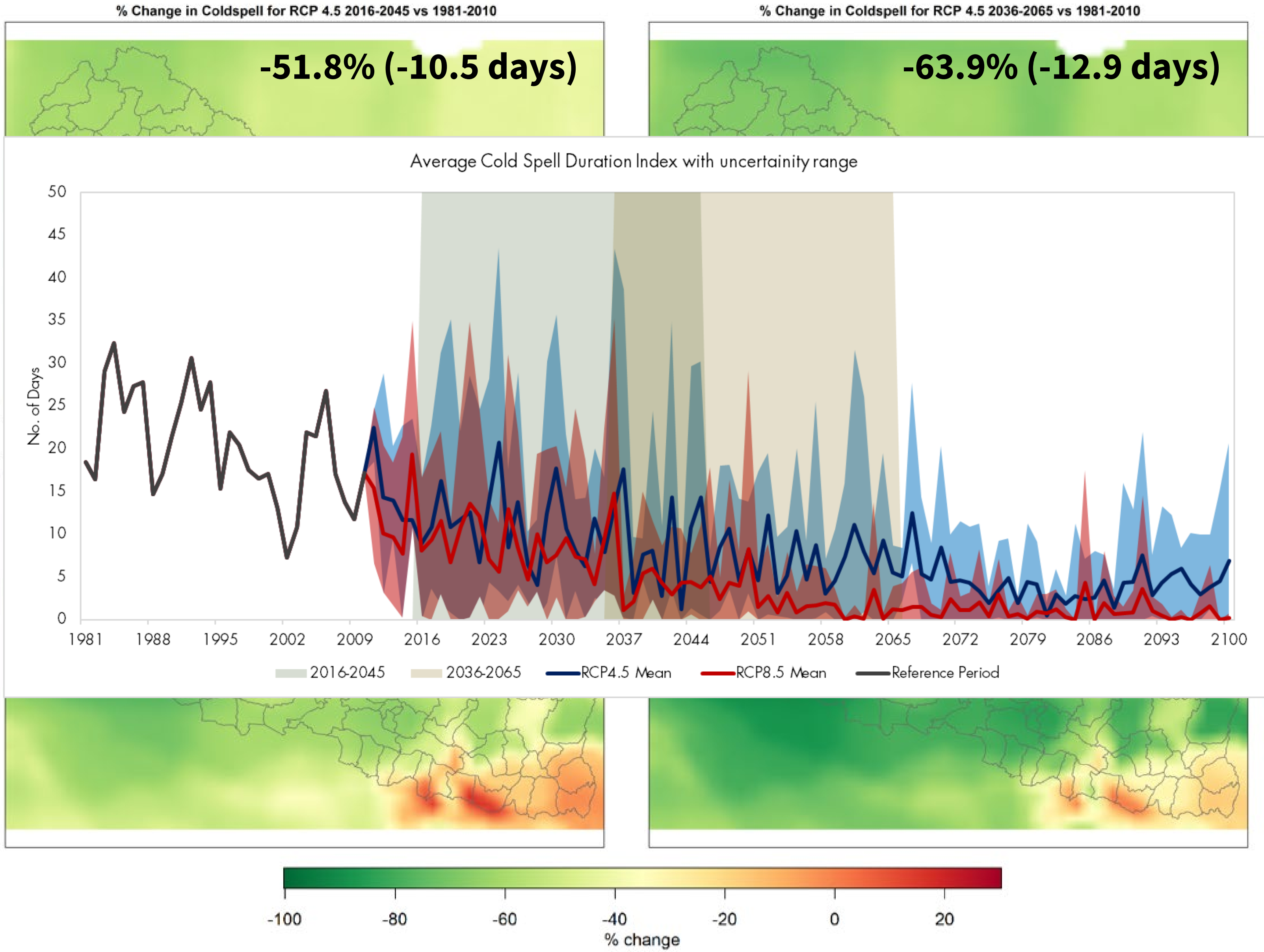
Highlights

Continuous decrease in cold spell duration throughout the country (decrease by 15 days)

Magnitude is higher in eastern region than western

Medium-term

Long-term



Summary

- Increase in precipitation and temperature in both short-term and long-term periods
  - Up to 12 % increase in long term period and 23 % towards the end century
  - Up to 1.82 ^{o}C increase in the long-term period and 3.58 ^{o}C towards the end of the century
- Extreme events are increasing in both medium and long term periods
- Extremes related to temperature have clear signal than precipitation
- The range of uncertainty is large in these projections

The scenarios can be helpful in designing adaptation plans but the plan should be flexible enough to take into account the uncertainties

https://lib.icimod.org/record/34554

Thank you

Protect the pulse.