Application of Statistical Downscaling for the Himalayan region

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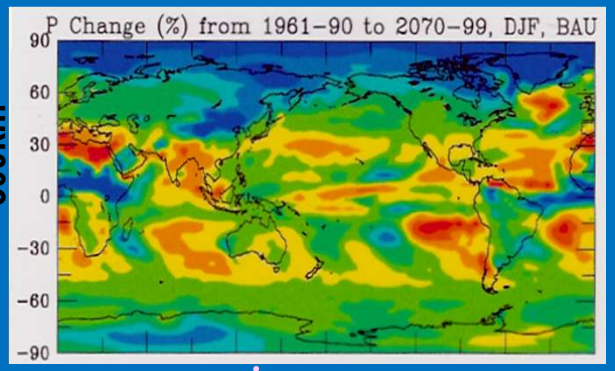
Why regionalisation and downscaling?

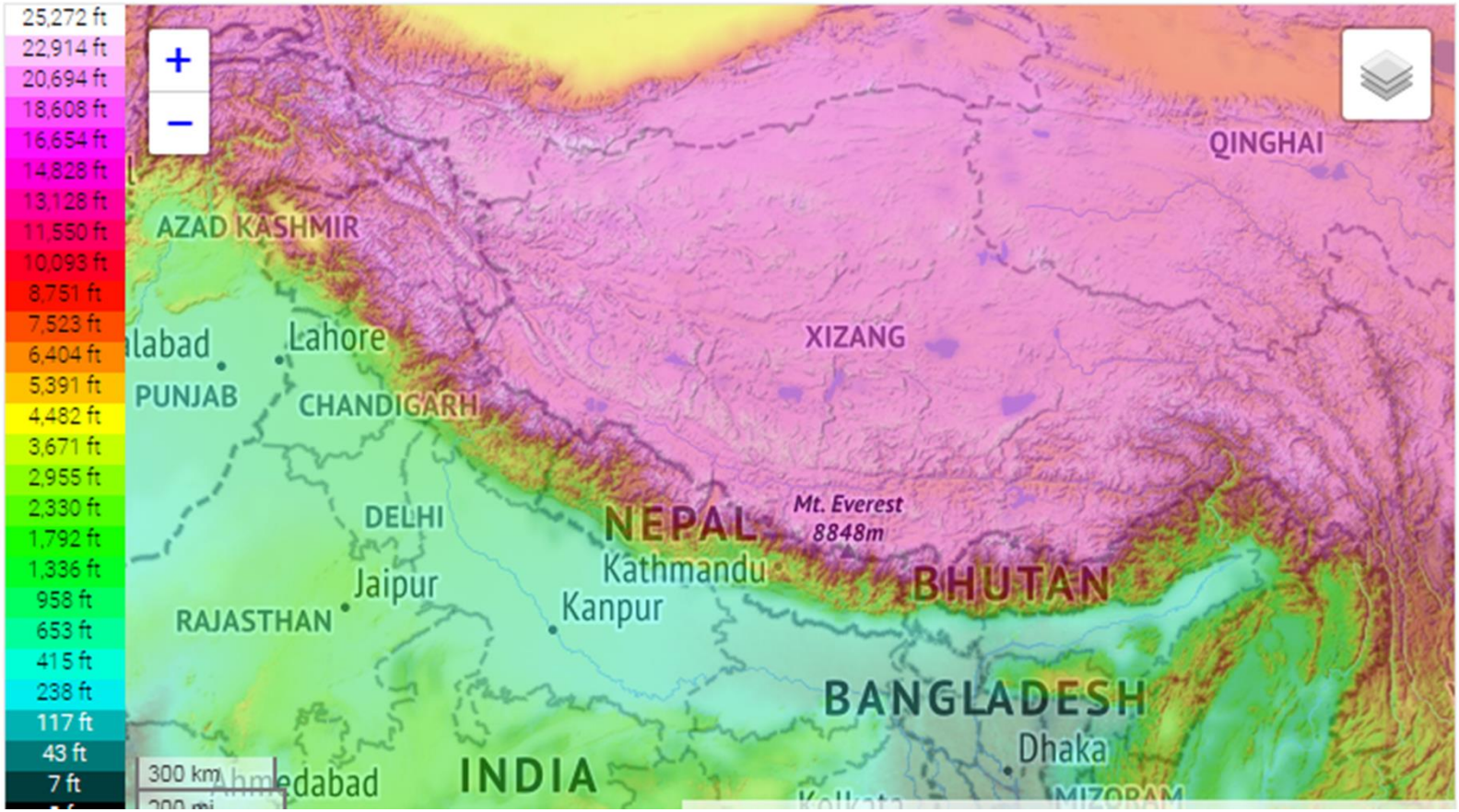


Impact models require …

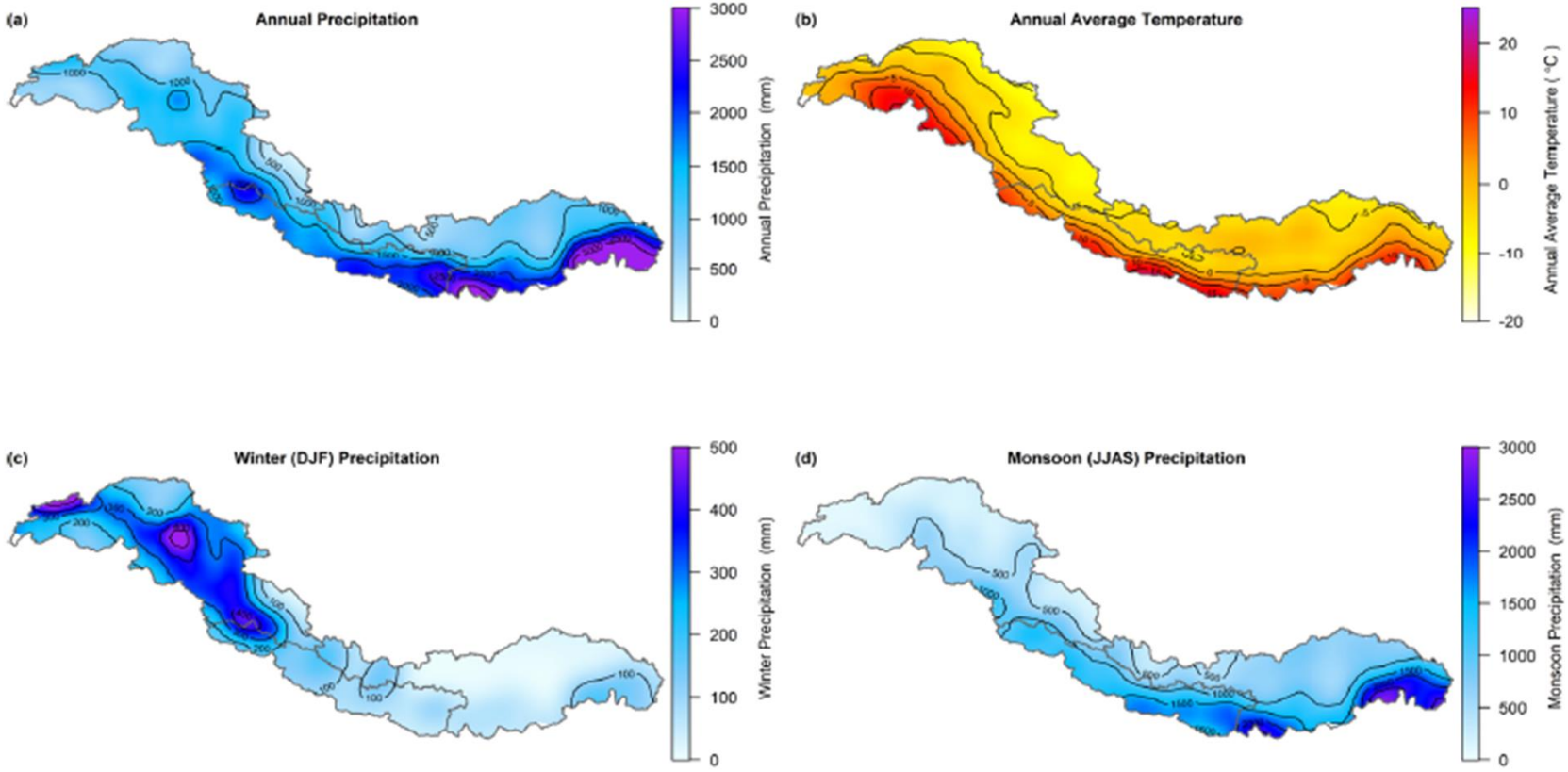
General Circulation Models supply…

mismatch of scales between what climate models can supply and environmental impact models require.....STATISTICAL DOWNSCALING

Topography of Himalaya



Mean Climate



From Rene et al

Temperature

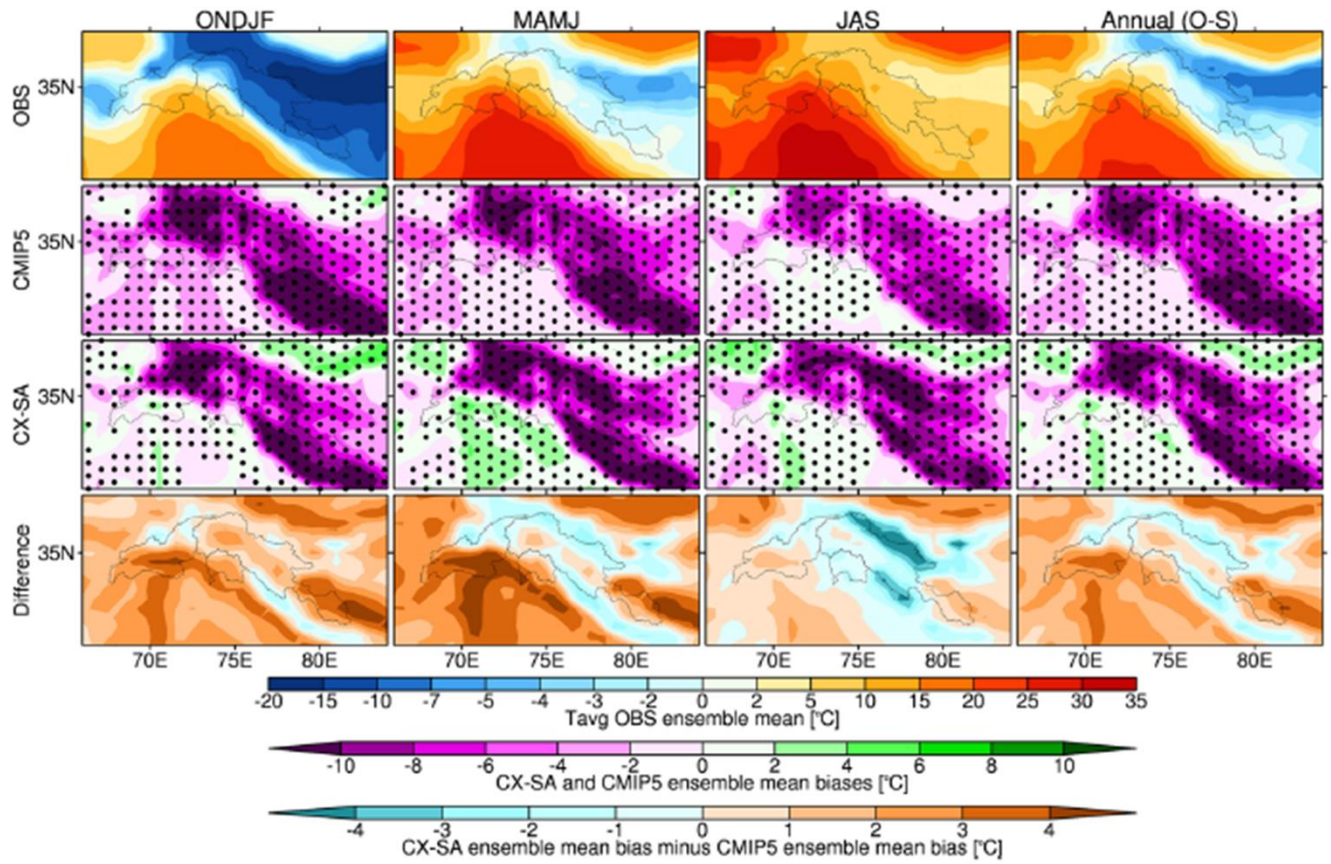
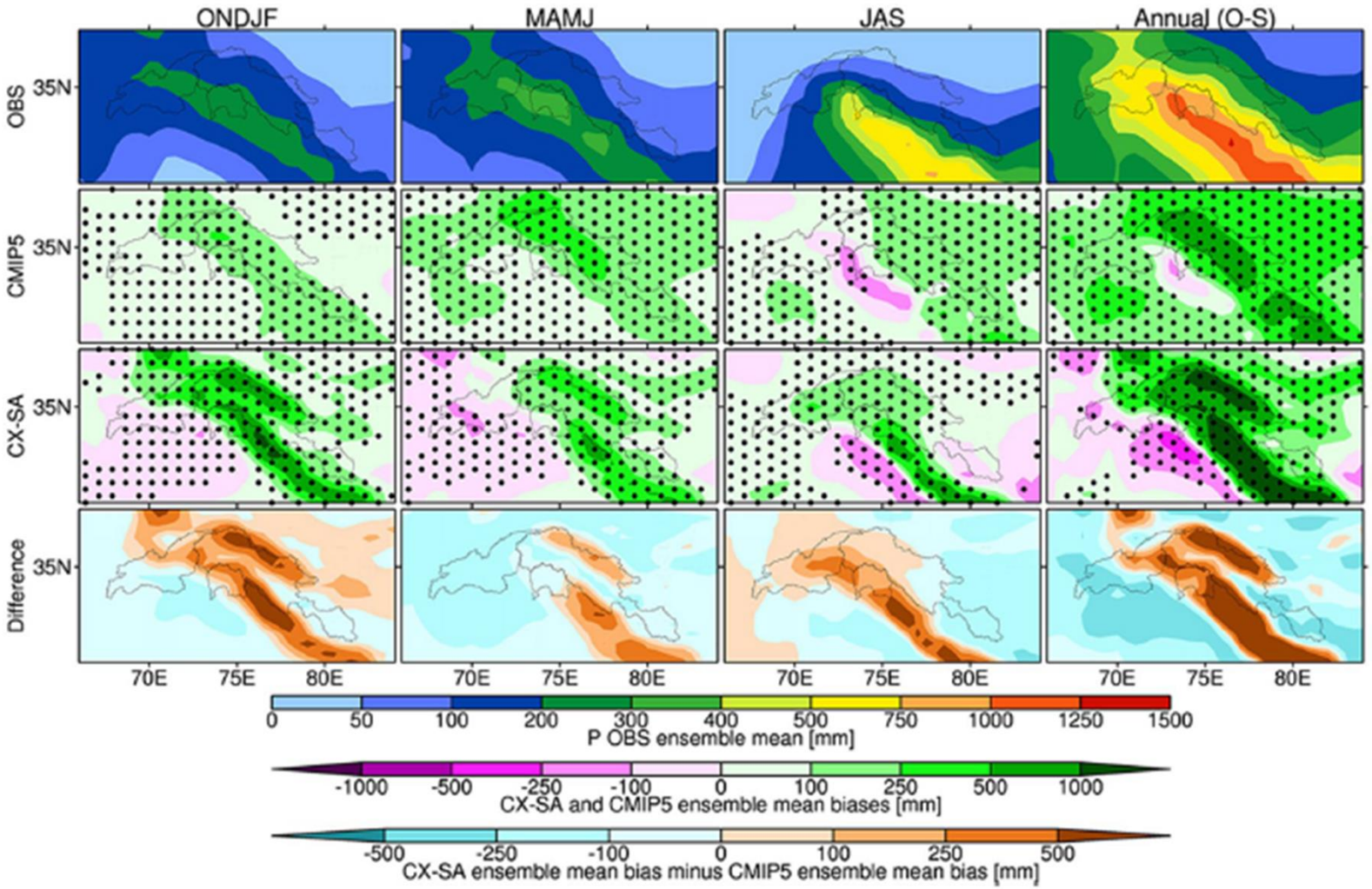


Fig. 2 Ensemble means of the mean temperature climatology (1971–2005) from the observational datasets (OBS), offsets (or biases) of the CMIP5 and CORDEX ensemble means from the OBS ensemble mean. The last row presents relative differences, where a negative (positive) scale refers to the under- (over-) estimation of CX-SA relative to CMIP5 datasets. Note: stippling indicates where the magnitude of bias is higher than the OBS uncertainty

From Hasson et al , 2018

Precipitation



Hasson et al, 2018

STATISTICAL DOWNSCALING (SDS)

Essentially the idea of the statistical downscaling consists in using the observed relationships between the large-scale circulation and the local climates to set up statistical models that could translate anomalies of the large-scale flow into anomalies of some local climate variable (von Storch 1995).

Assumptions in SDS methods

- Regional climate is conditioned by two factors : the large scale climate state and regional/local physiographic features
- GCMS are able to simulate large scale circulation patterns realistically
- There is strong and physically meaningful relationship between predictor(large scale climate variable) and predictand (regional/local variables)
- Consistent relationship exists between circulation patterns and surface climate variables.
- The relationships remain unchanged in future climate also

- Typical predictand is single site daily precipitation/temperature

- Typical predictors are derived from sea level pressure, surface pressure, geopotential heights, wind fields, absolute/relative humidity and temperatures

Spatial downscaling

- Spatial downscaling refers to the techniques used to derive finer resolution climate information from coarser resolution GCM output.

- assumes that it will be possible to determine significant relationships between local and large-scale climate (thus allowing meaningful site-scale information to be determined from large-scale information alone)

Temporal Downscaling

- Temporal downscaling refers to the derivation of fine-scale temporal data from coarser-scale temporal information, e.g., daily data from monthly or seasonal information.

- The simplest method for obtaining daily data for a particular climate change scenario is to apply the monthly or seasonal changes to an historical daily weather record for a particular station.

Typical steps in Statistical Downscaling

- Identify the large scale parameter G which controls the local parameter L
- If the intent is to calculate L for climate experiments , G should be well simulated by climate models
- Find statistical relationship between L and G
- Validate the relationship with independent data
- If the relationship is confirmed, G can be derived from GCM s to estimate L.

Statistical Downscaling

- Three categories of techniques
  - Transfer Function
  - Weather Typing
  - Weather Generators

Methods for SD

- Analogues
- Weather Classification Schemes
- Regression Models
- Multiple regression, Cannonical Correlations and Singular Value Decomposition
- Stochastic Weather Generators

Most Recent techniques

- Bias Corrected Spatial Disaggrgation Wood et al 2002, 2004
- Bias Corrected Constructed Analogues Hidalgo et al 2008; Maurer-Hidalgo 2010
- Localised Constructed Analogues Pierce et al 2014
- Hidden Markov Models Robertson et al 2004
- Pattern Projection Downscaling Kang et al 2009
- Asynchronous Regression Stoner
- Multivariate Multi-site Downscaling Jeong et al 2012
- Quantile based downscaling using genetic programming Hassazadeh et al 2014

Softwares/Portals

- SDSM
  http ://co-public/lboro.ac.uk/cocwd/SDSM

- Clim.pact
  http://cran.r-project.org

- ENSEMBLE
  http://www.meteo.unican.es/ensembles/

- CHAC
  http://sourceforge.net/projects/chac

- LARS-WG
  http://www.iacr.bbsrc.ac.uk/mas-models/larswg.html

  http://www.cru.uea.ac.uk/projects/ensembles/ScenariosPortal/Downscaling2.htm

- ESD : R Package

NEX-GDDP

(NASA Earth Exchange – Global Daily Downscaled Projections)

- This NASA dataset is provided to assist the science community in conducting studies of climate change impacts at local to regional scales, and to enhance public understanding of possible future climate patterns at the spatial scale of individual towns, cities, and watersheds.

- Dataset URL: https://nex.nasa.gov/nex/projects/1356/

- Data access URL: https://cds.nccs.nasa.gov/nex-gddp/

- Daily Near surface Minimum, Maximum Temperature (^{o} K)and Precipitation (kg/m^2s^1)
- 0.25^{o} x 0.25^{o} long/lat
- 1950-2005 historical ; 2006-2100 RCP4.5 and RCP8.5
- 90^{o} S – 90^{o} N ; 180^{o} W – 180^{o} E
- 21 CMIP5 Models
- Bias Correction Spatial Disaggregation Method of Statistical Downscaling (Wood et al, 2002,2004 ; Maurer et al 2008 ; Thrasher et al 2012)

Observed data used is

Global Meteorological Forcing Data set (GMFD)

This dataset provides near-surface meteorological data

Constructed by combining a suite of global observation-based datasets with the NCEP/NCAR reanalysis and disaggregates in time and space.

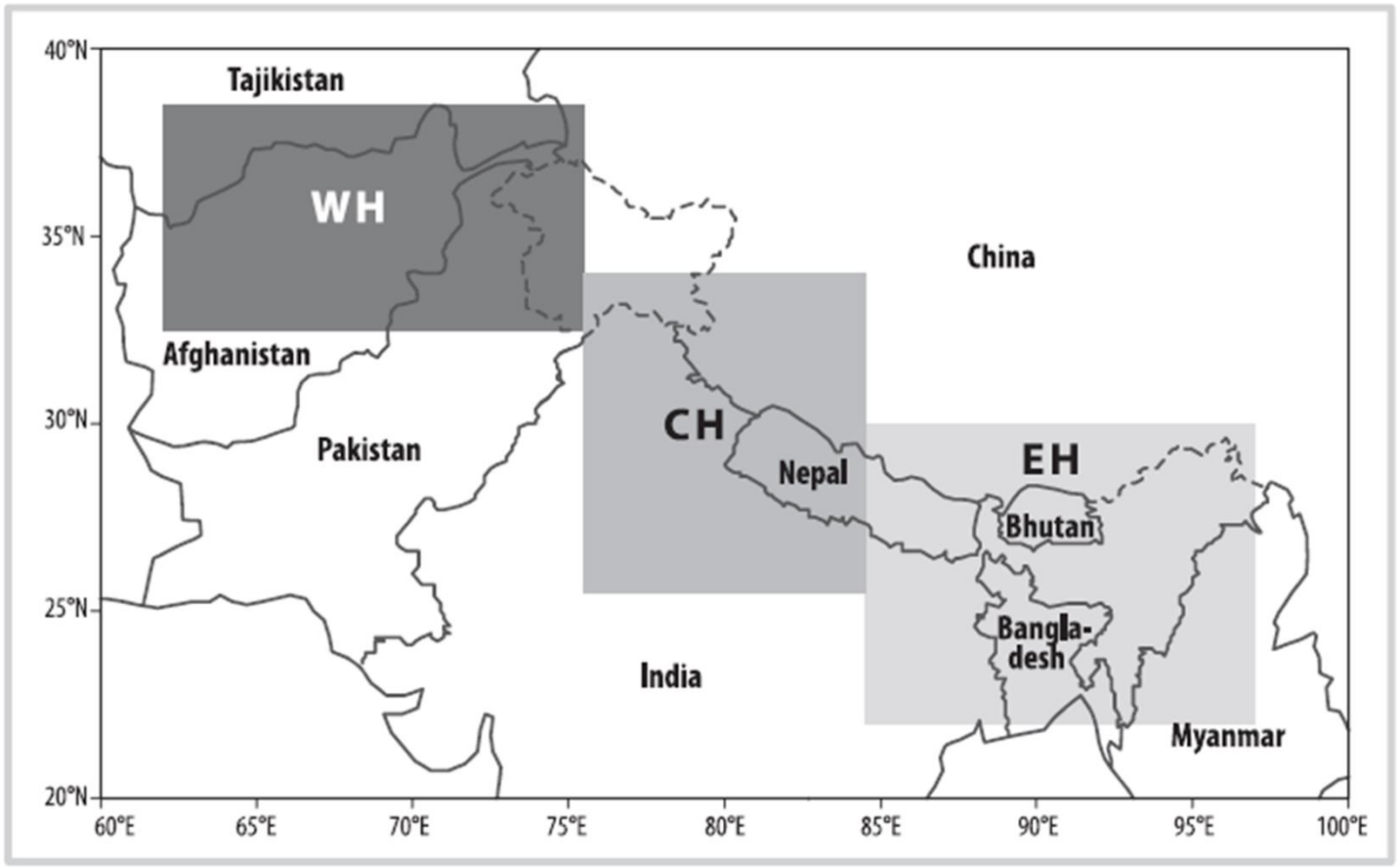
Currently available at 1.0 degree (plus 0.5 and 0.25 degree), 3-hourly (plus daily and monthly) resolution globally for 1948-2008.

Models used in NEX-GDDP

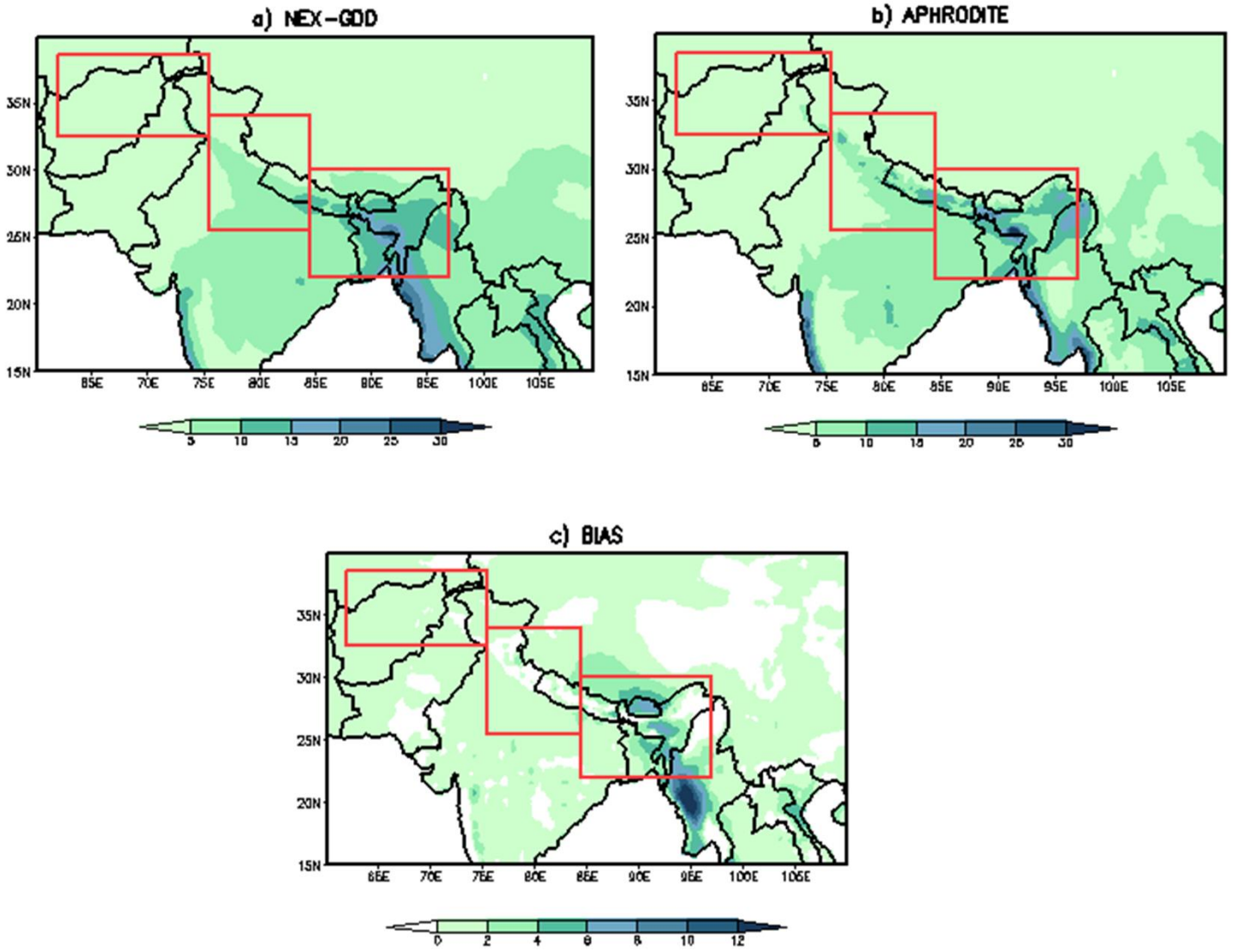
ACCESS1-0
BCC-CSM1-1
BNU-ESM
CanESM2
CCSM4
CESM1-BGC
CNRM-CM5
CSIRO-MK3-6-0
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
MIROC-ESM
MIROC-ESM-CHEM
MIROC5
MPI-ESM-LR
MPI-ESM-MR
MRI-CGCM3
NorESM1-M

Hindukush Himalayan Region

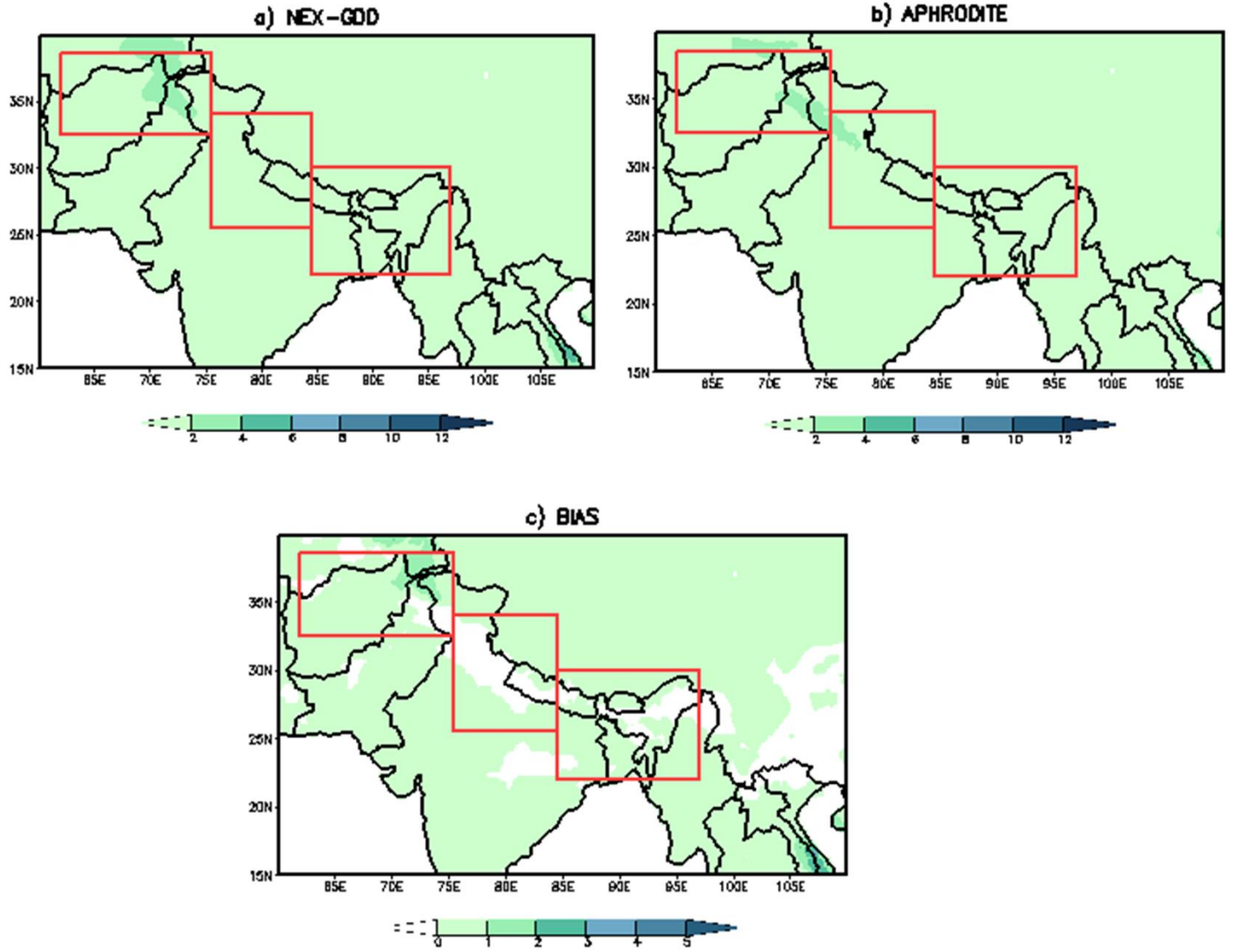
Western Himalaya	62-75.5 E	32.5-38.5 N
Central Himalaya	75.5-84.5 E	25.5-34 N
Eastern Himalaya	84.5-97 E	22-30 N



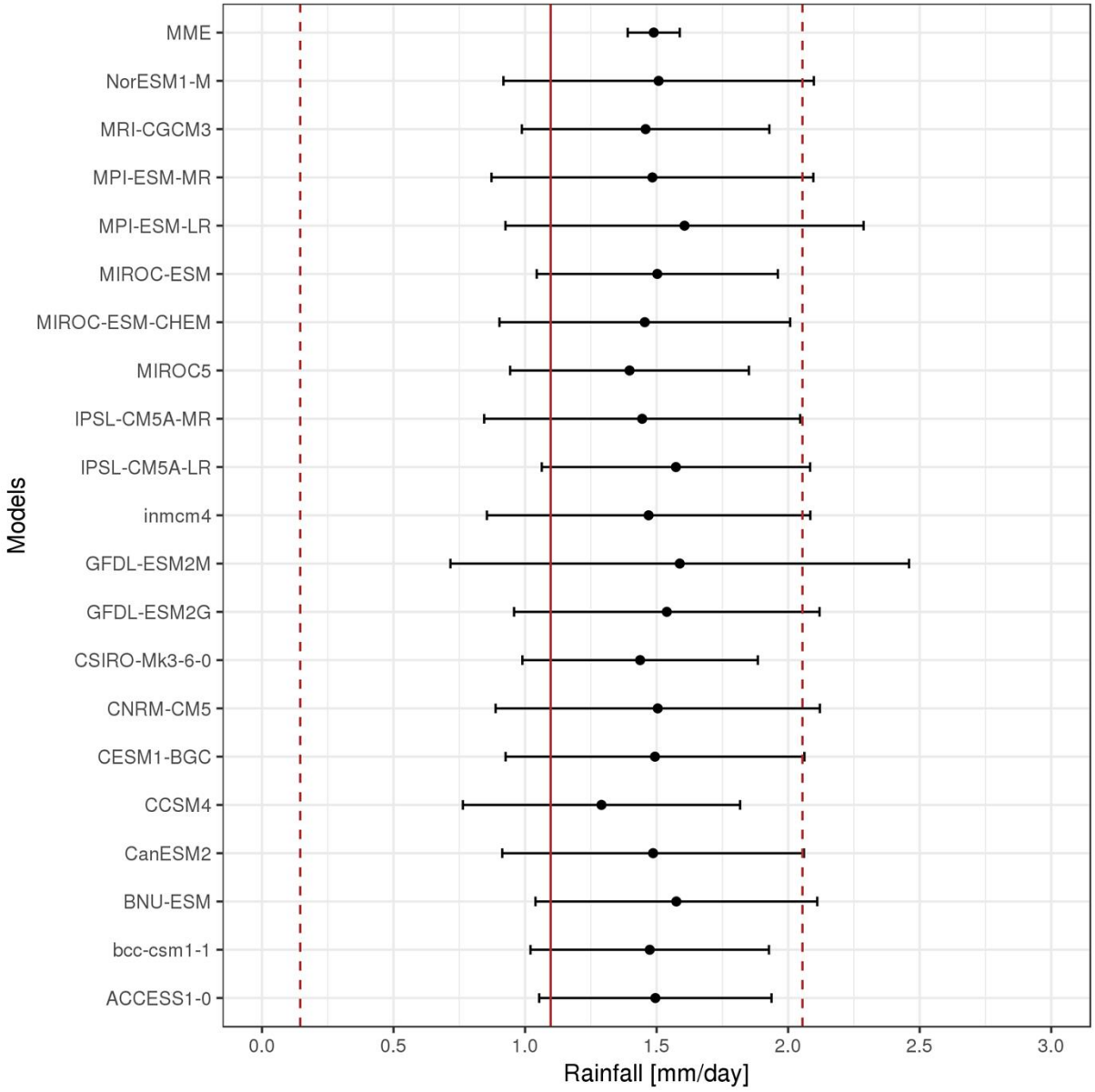
Summer Monsoon simulation (JJAS) : 1976-2005



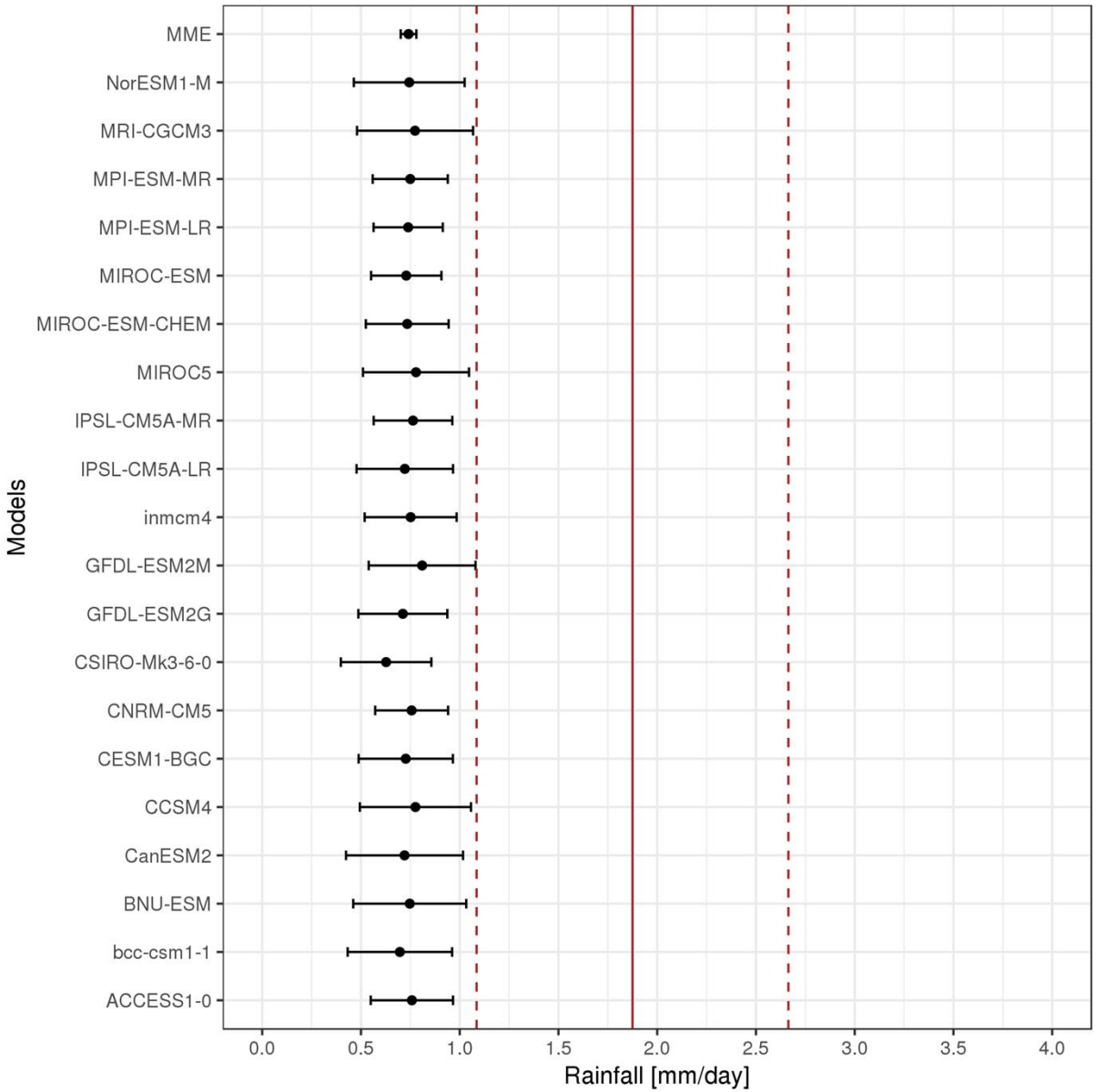
Winter Monsoon Simulation(DJF) : 1976-2005



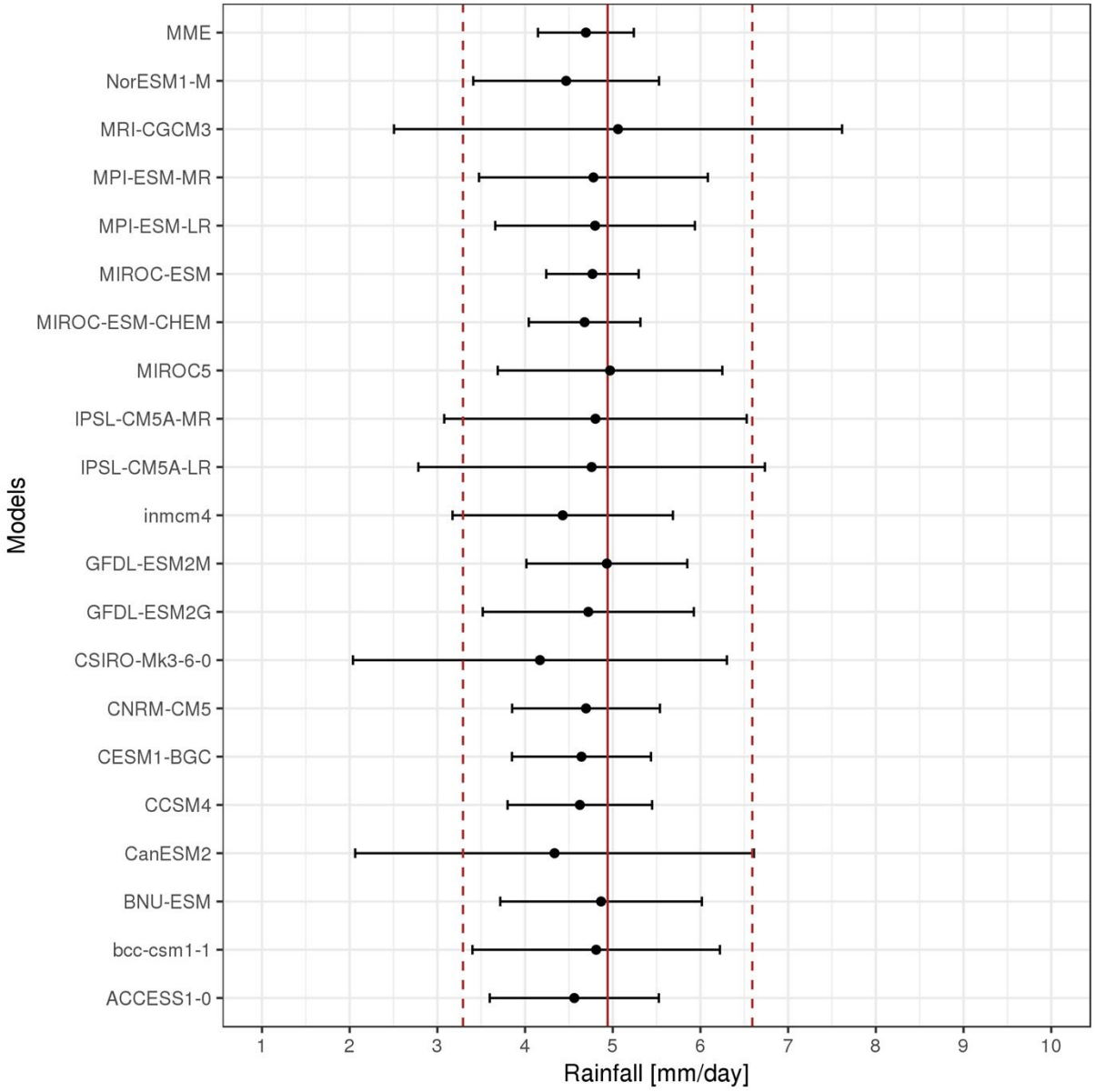
Western Himalaya - DJF



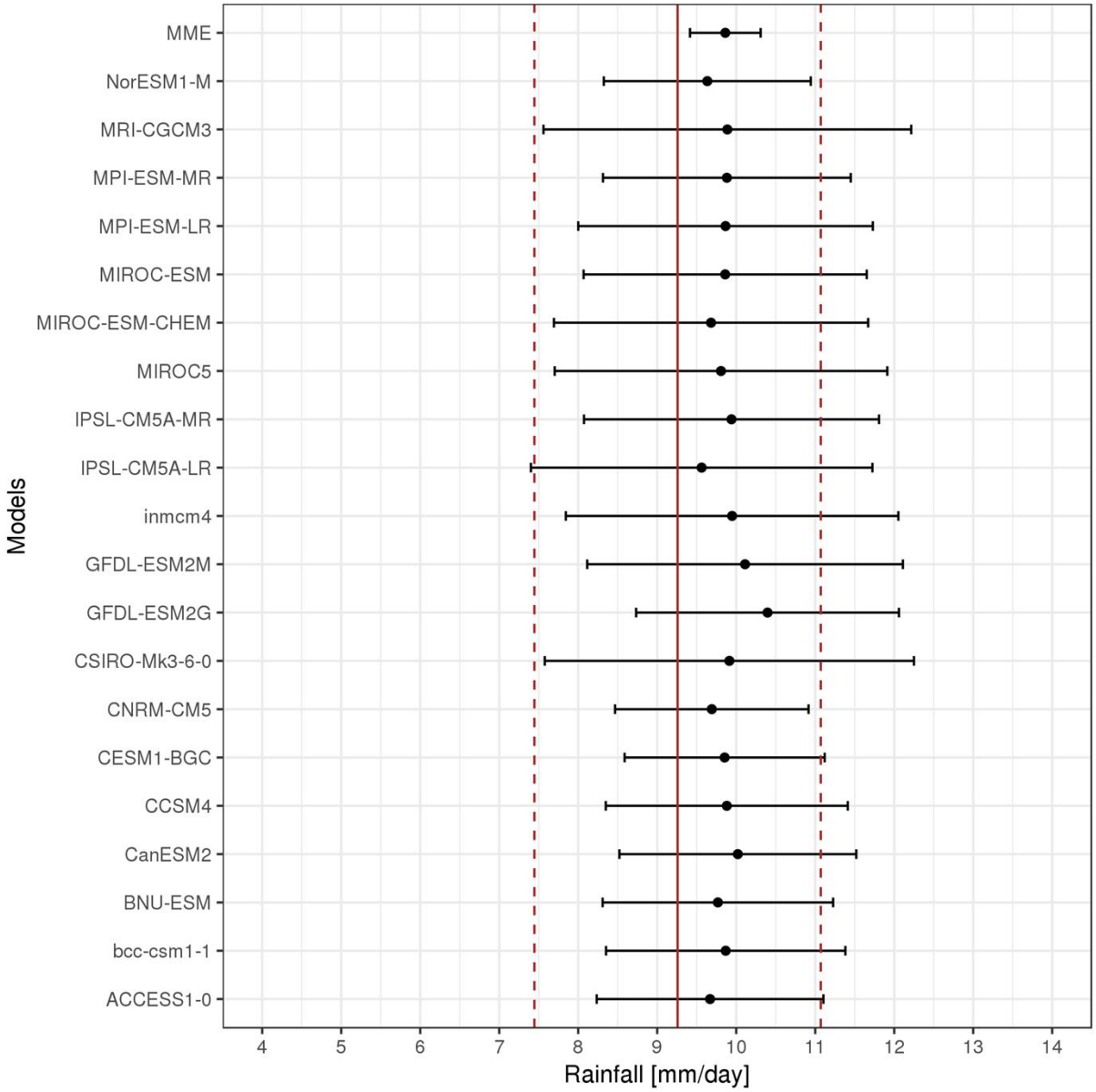
Western Himalaya - JJAS



Central Himalaya - JJAS

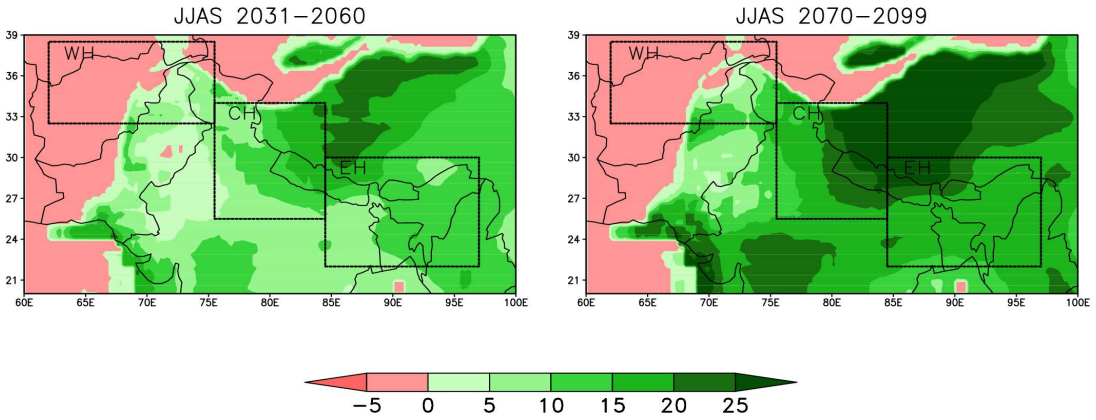


Eastern Himalaya - JJAS

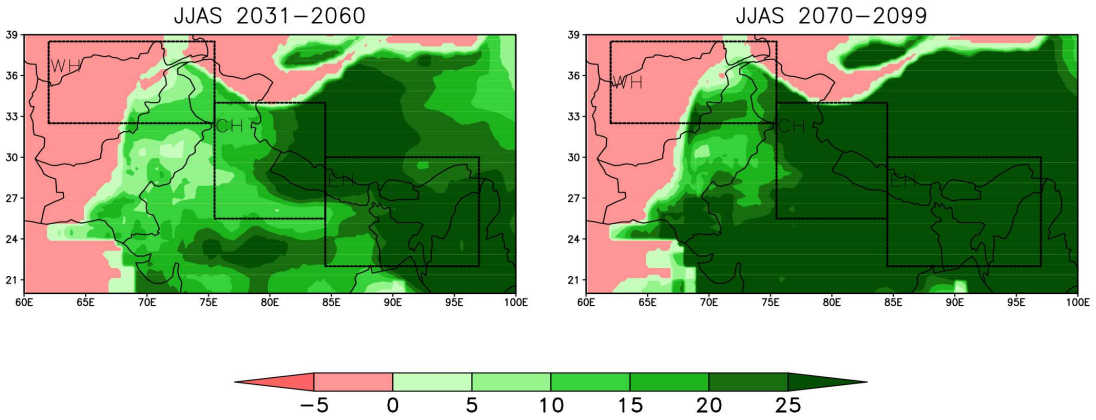


Projected Change Summer Monsoon Rainfall : JJAS

RCP4.5 : Projected Change w.r.t Hist (%)

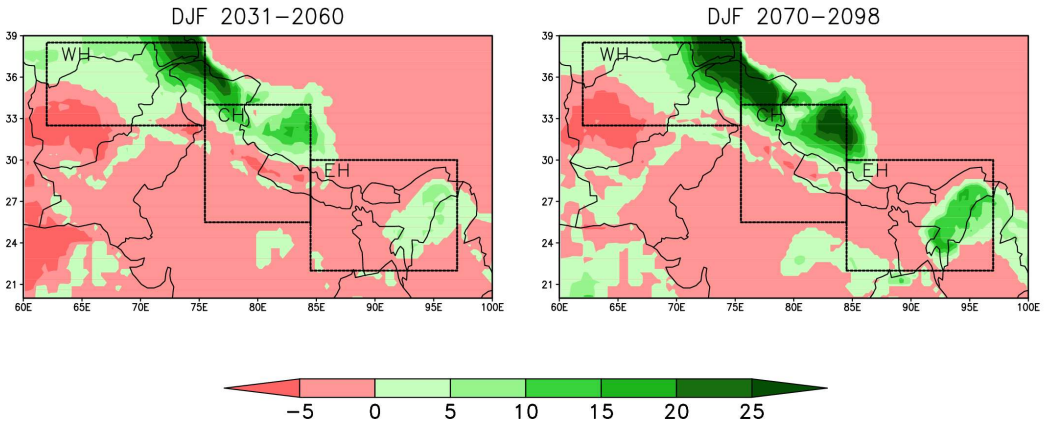


RCP8.5 : Projected Change w.r.t Hist (%)

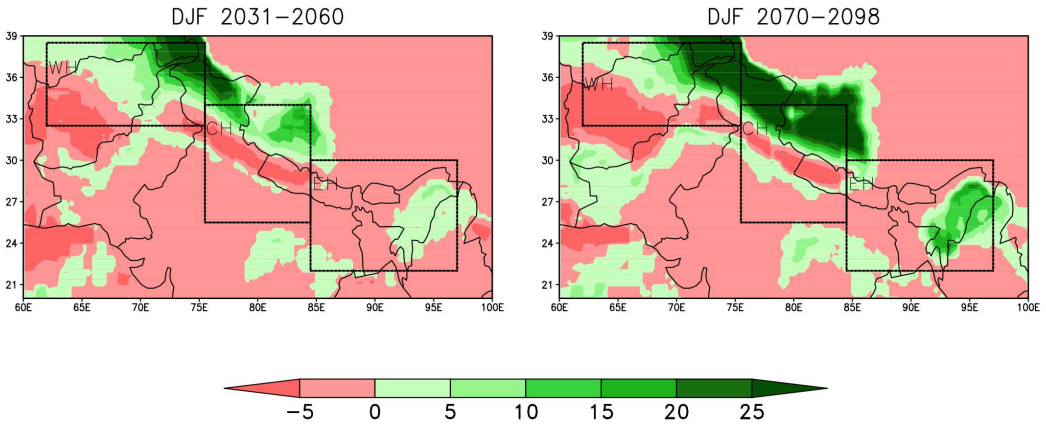


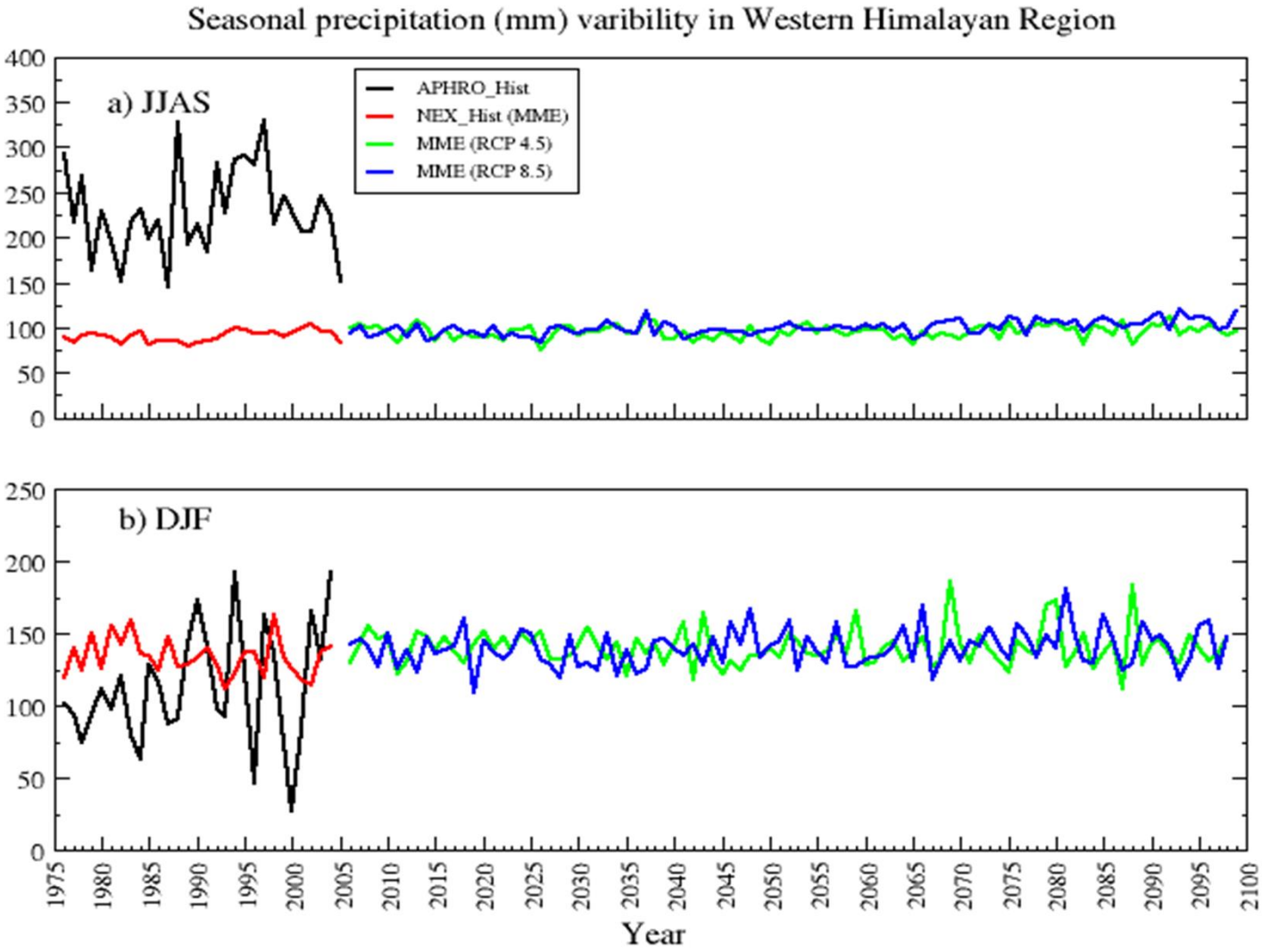
Winter Monsoon : DJF

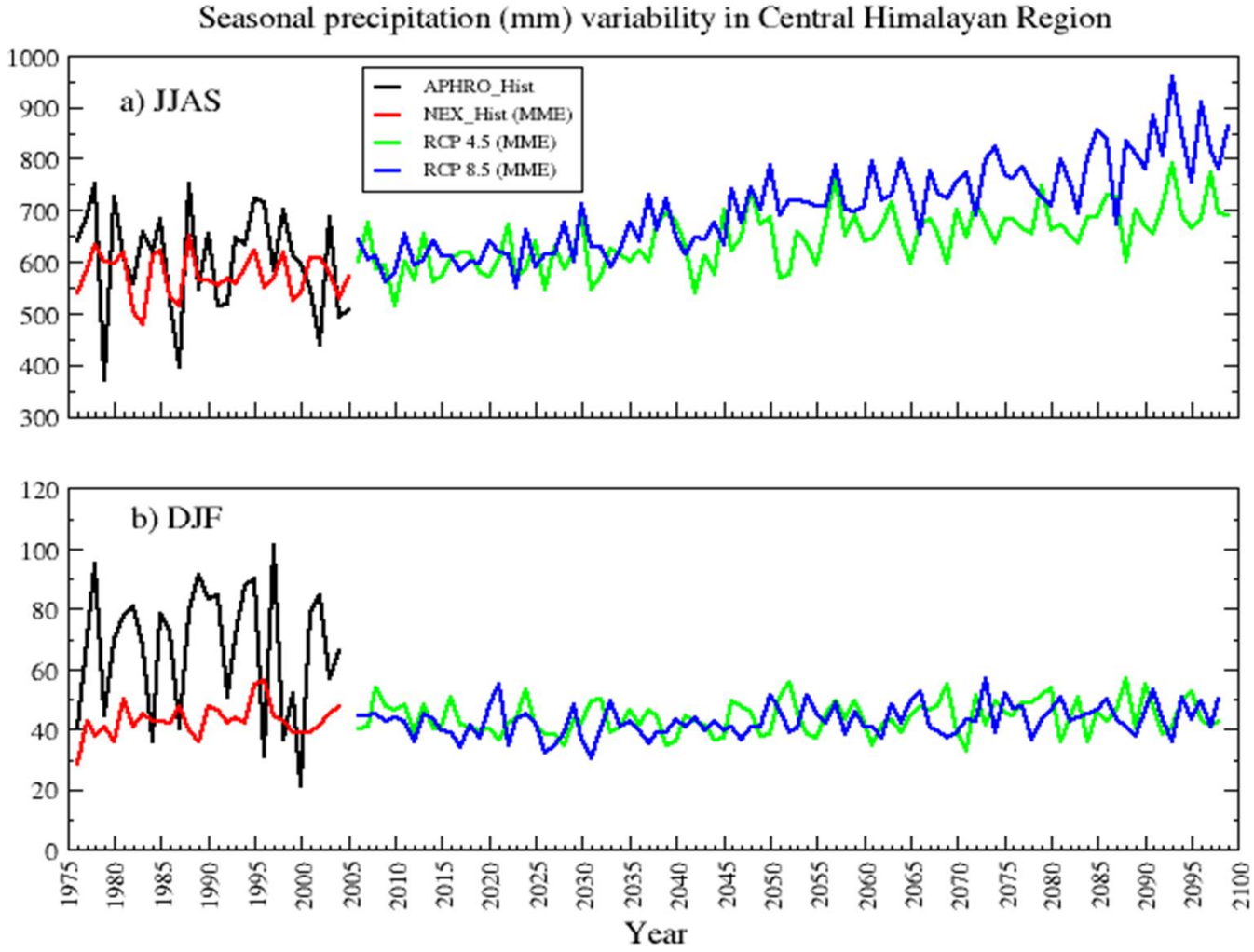
RCP4.5 : Projected Change w.r.t Hist (%)

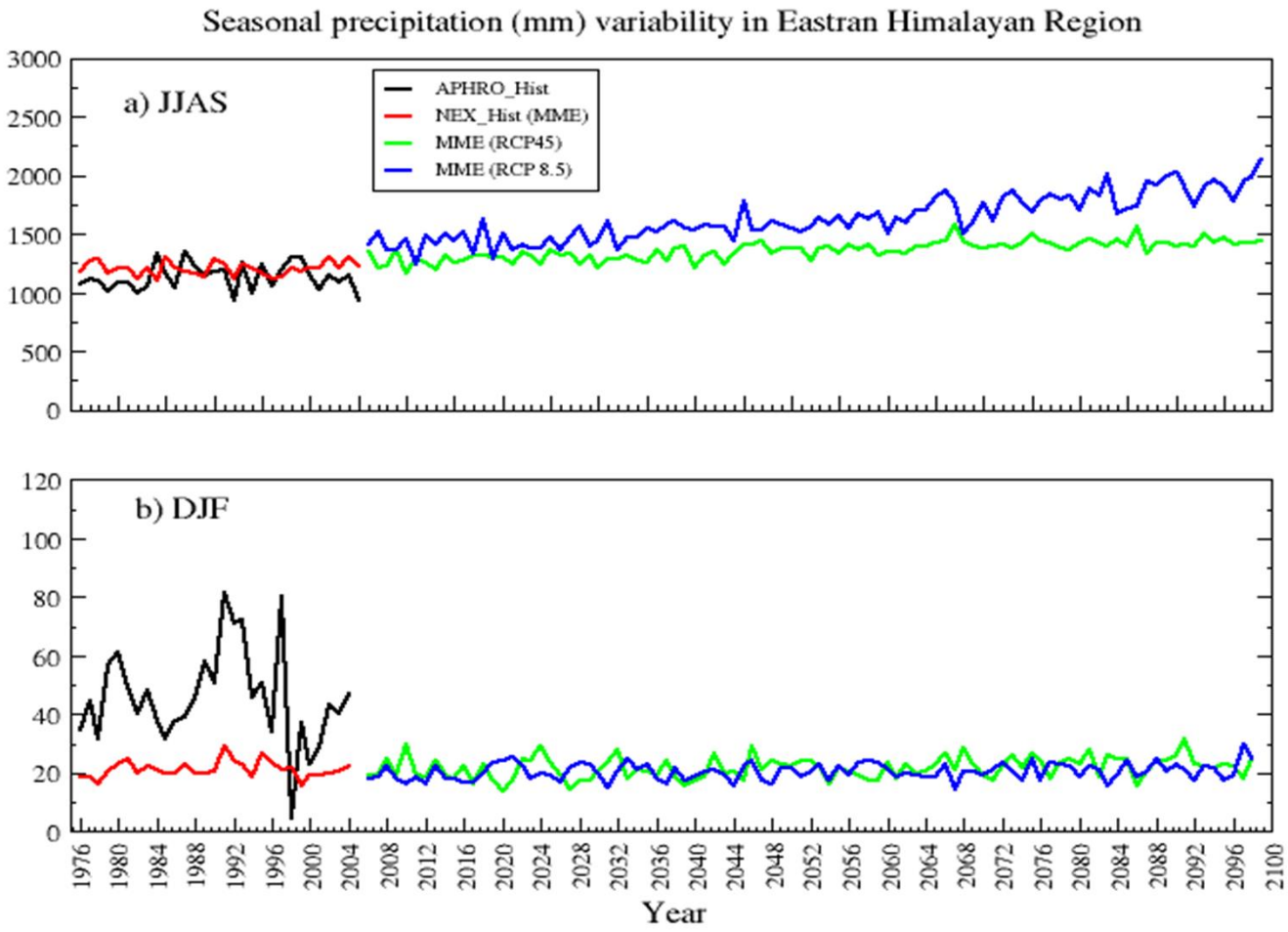


RCP8.5 : Projected Change w.r.t Hist (%)



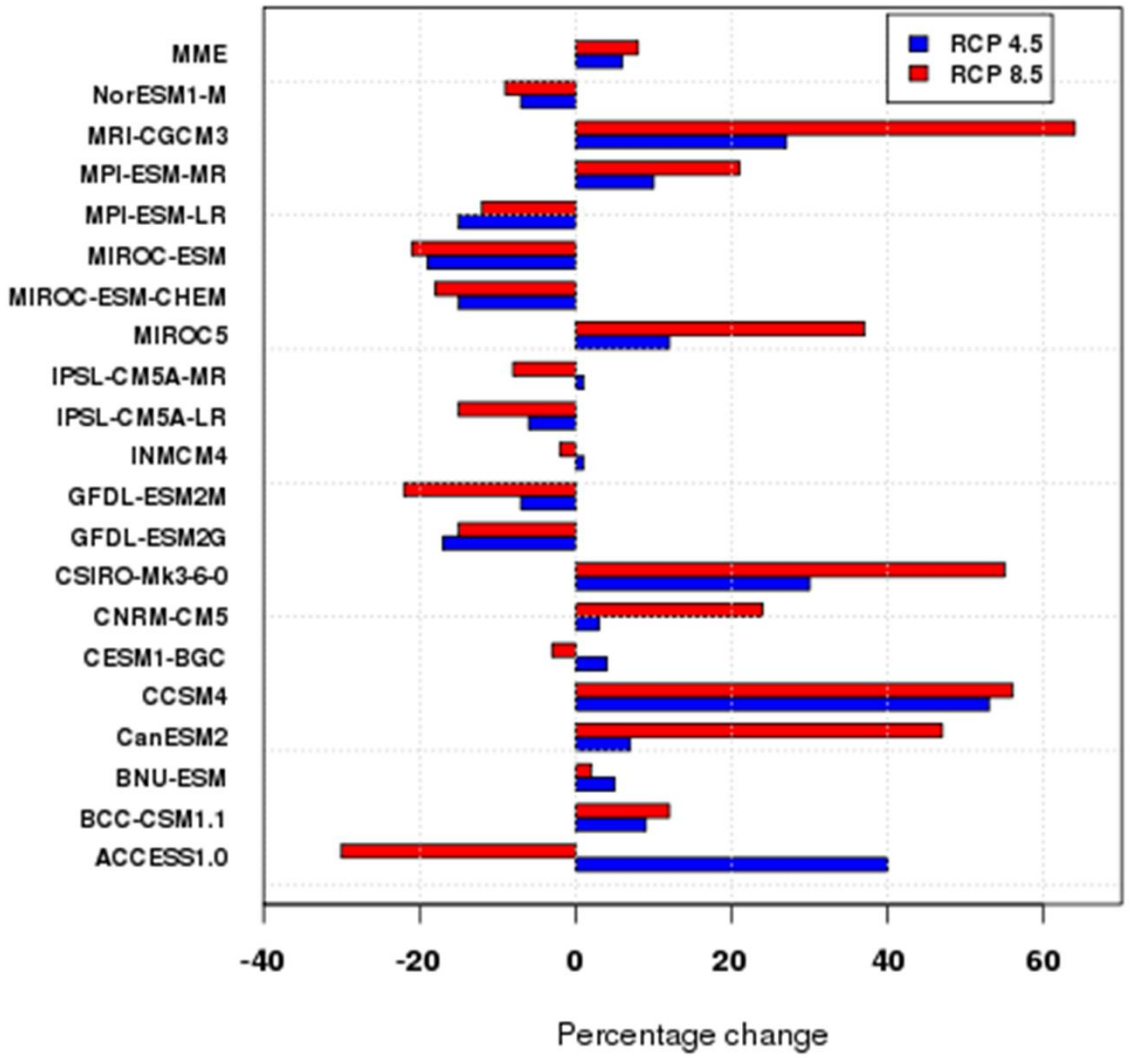

Seasonal precipitation (mm) varibility in Western Himalayan Region
a) JJAS
b) DJF
APHRO_Hist
NEX_Hist (MME)
MME (RCP 4.5)
MME (RCP 8.5)
Year


Seasonal precipitation (mm) variability in Central Himalayan Region
a) JJAS
APHRO_Hist
NEX_Hist (MME)
RCP 4.5 (MME)
RCP 8.5 (MME)
b) DJF
Year


Seasonal precipitation (mm) variability in Eastran Himalayan Region
a) JJAS
APHRO_Hist
NEX_Hist (MME)
MME (RCP45)
MME (RCP 8.5)
b) DJF
Year

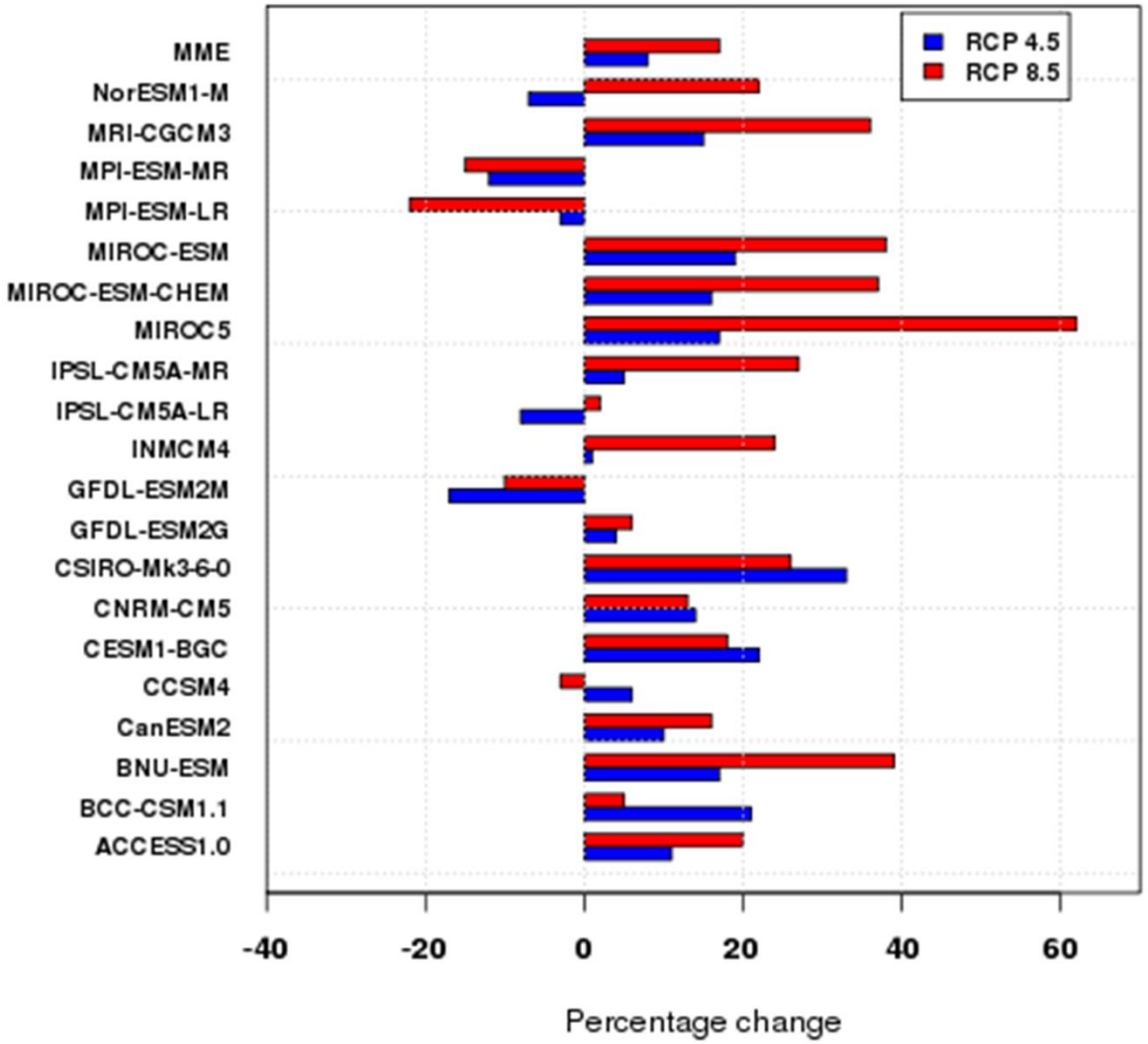
Projected changes in Precipitation for 2070-2099 w.r.t 1976-2005

WETSRN HIMALAYA : DJF



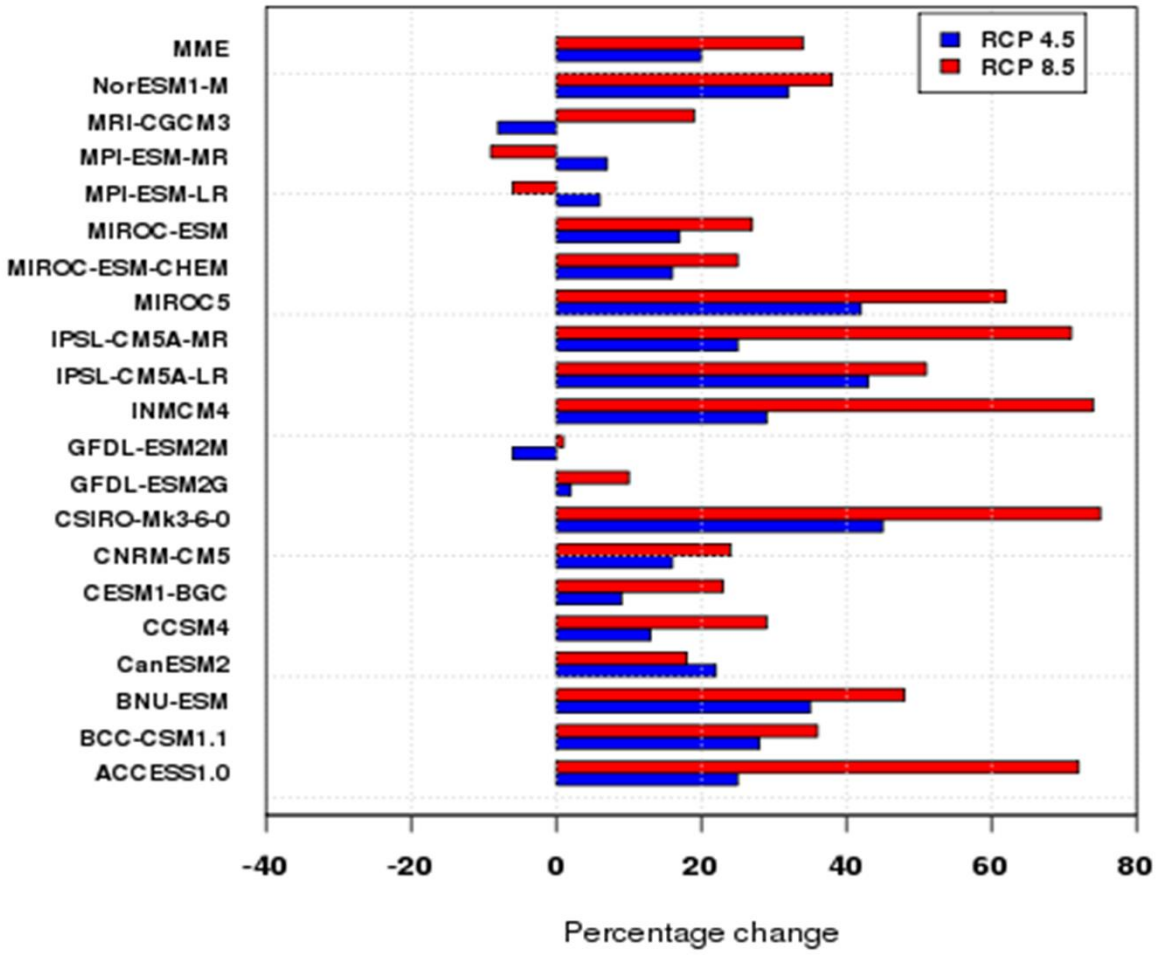
Projected changes in Precipitation for 2070-2099 w.r.t 1976-2005

WESTERN HIMALAYA : JJAS



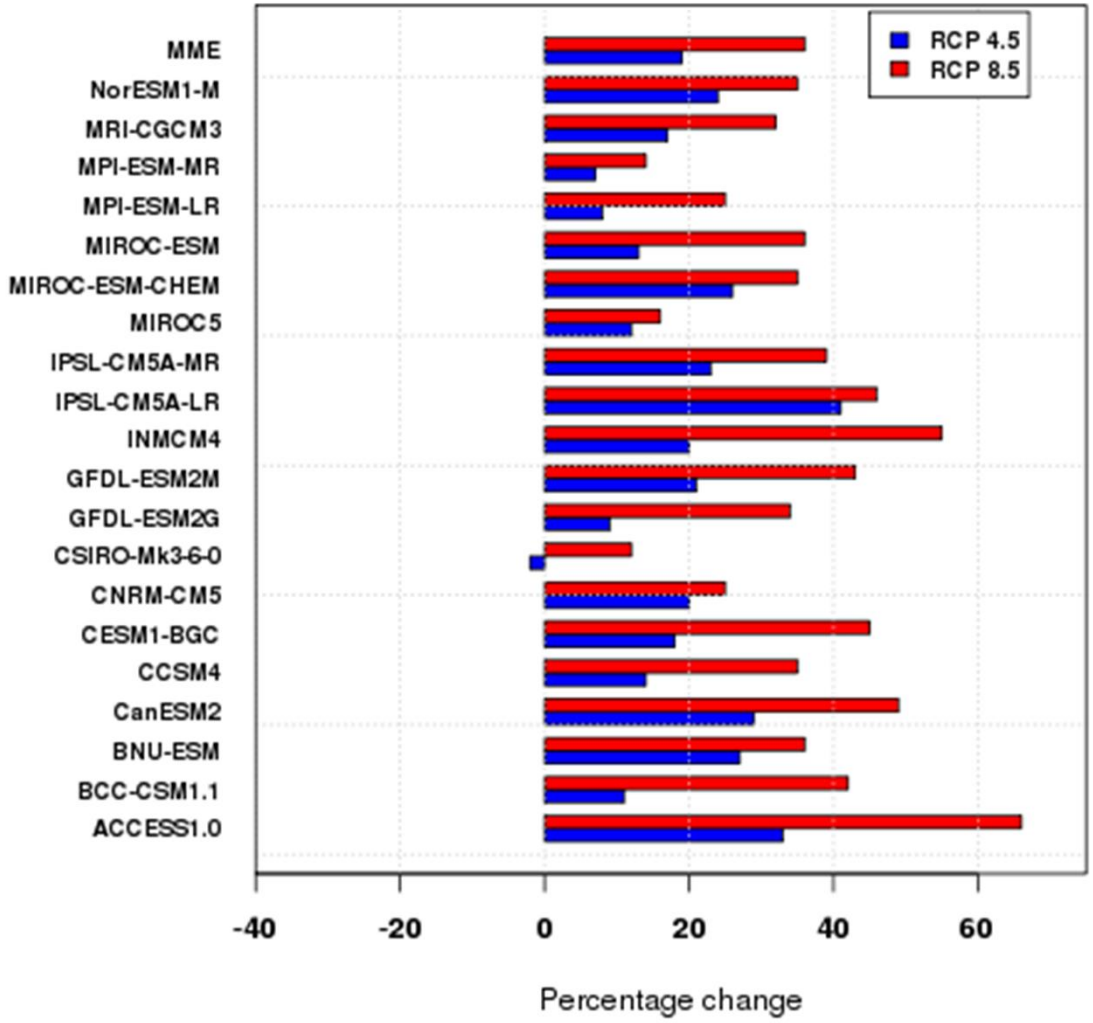
Projected changes in Precipitation for 2070-2099 w.r.t 1976-2005

CENTRAL HIMALAYA : JJAS

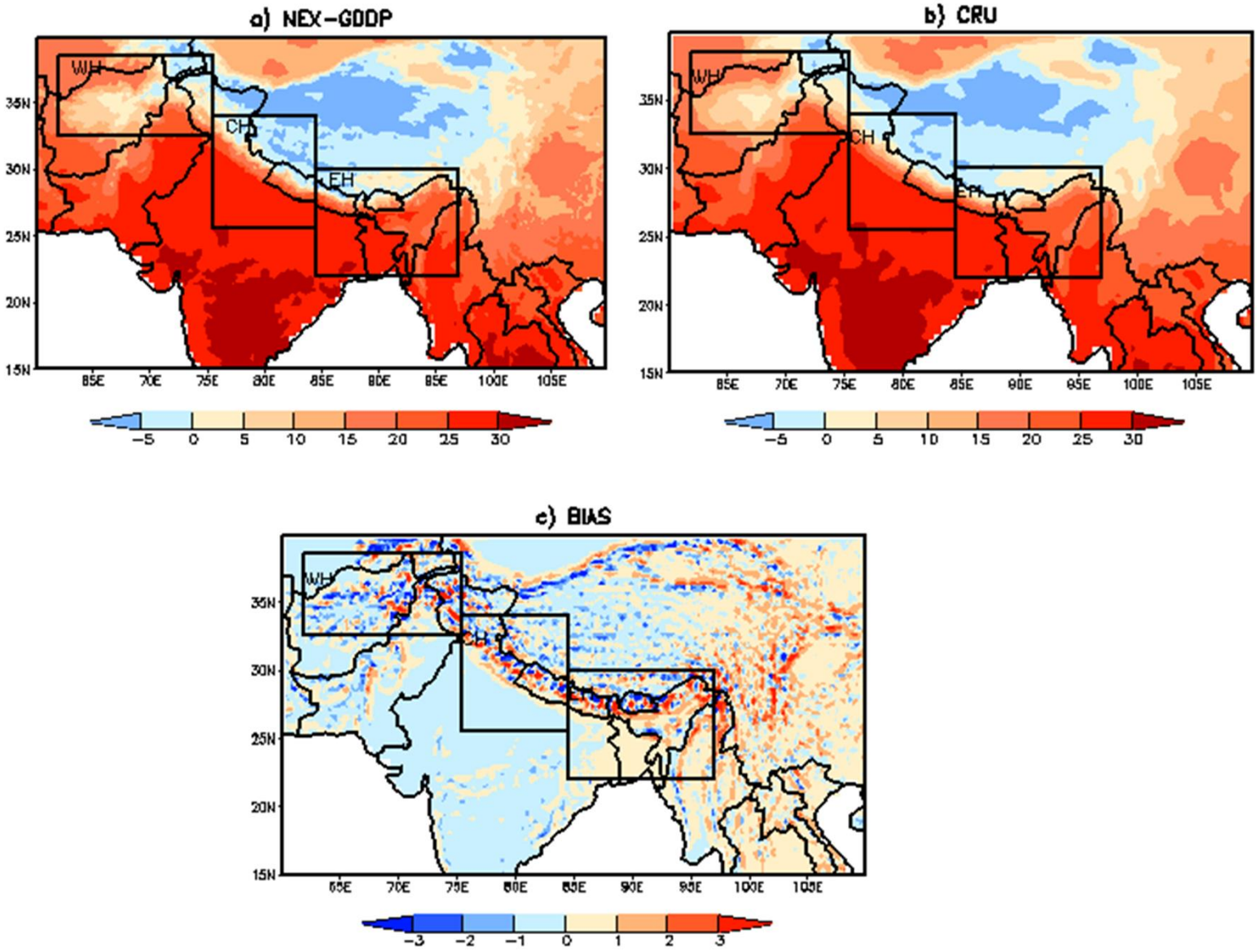


Projected changes in Precipitation for 2070-2099 w.r.t 1976-2005

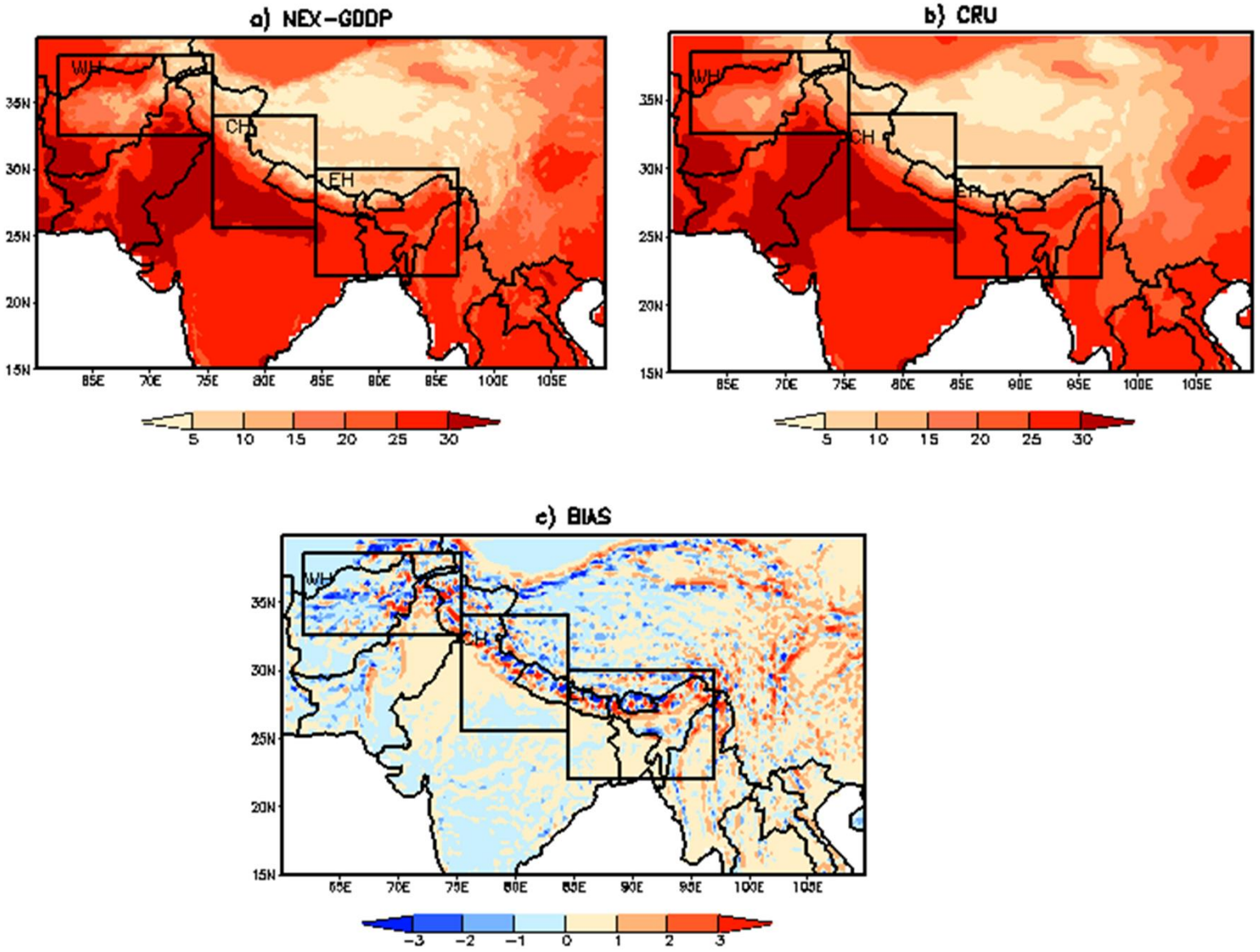
EASTERN HIMALAYA : JJAS



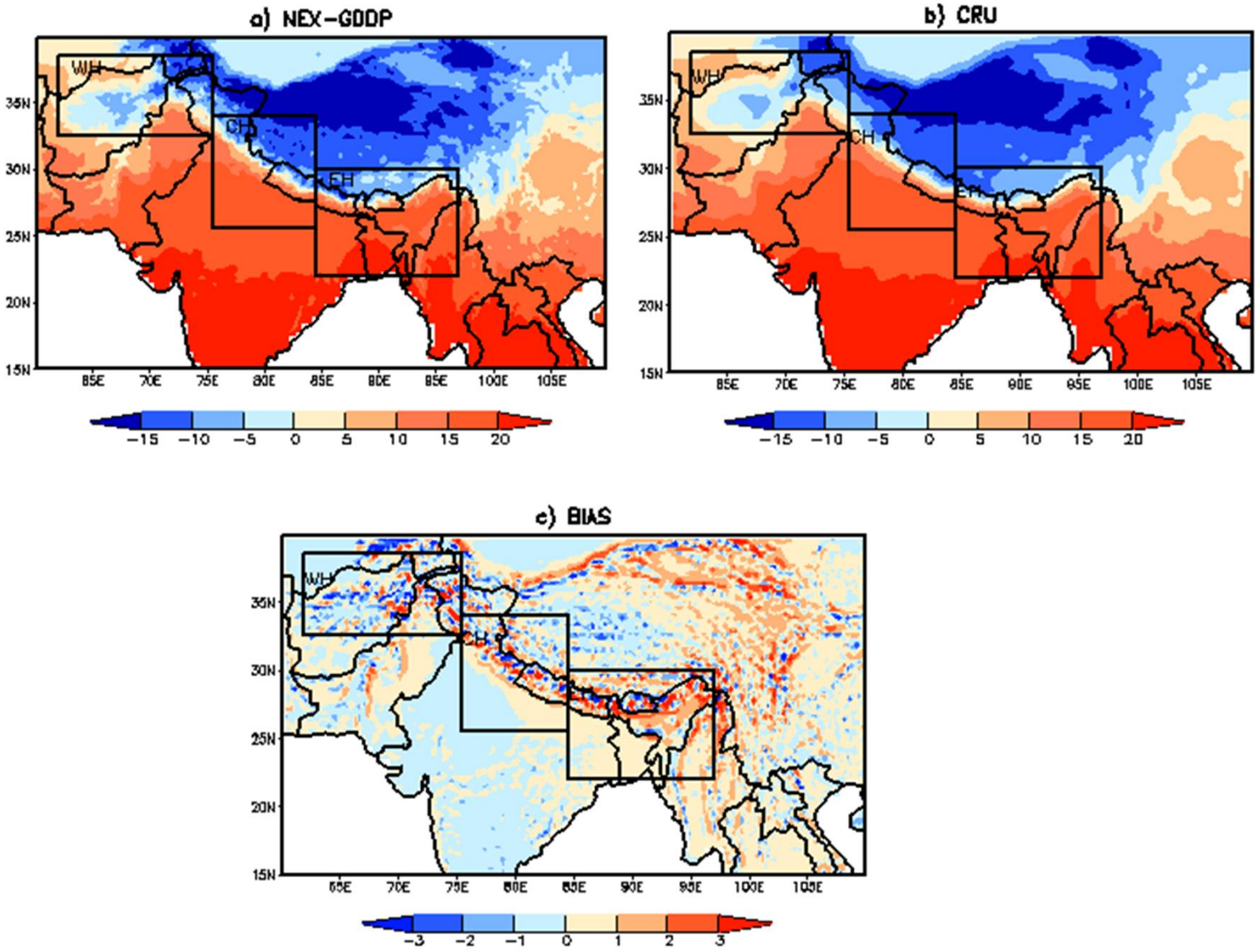
MAM mean temperature (°C) 1976-2005



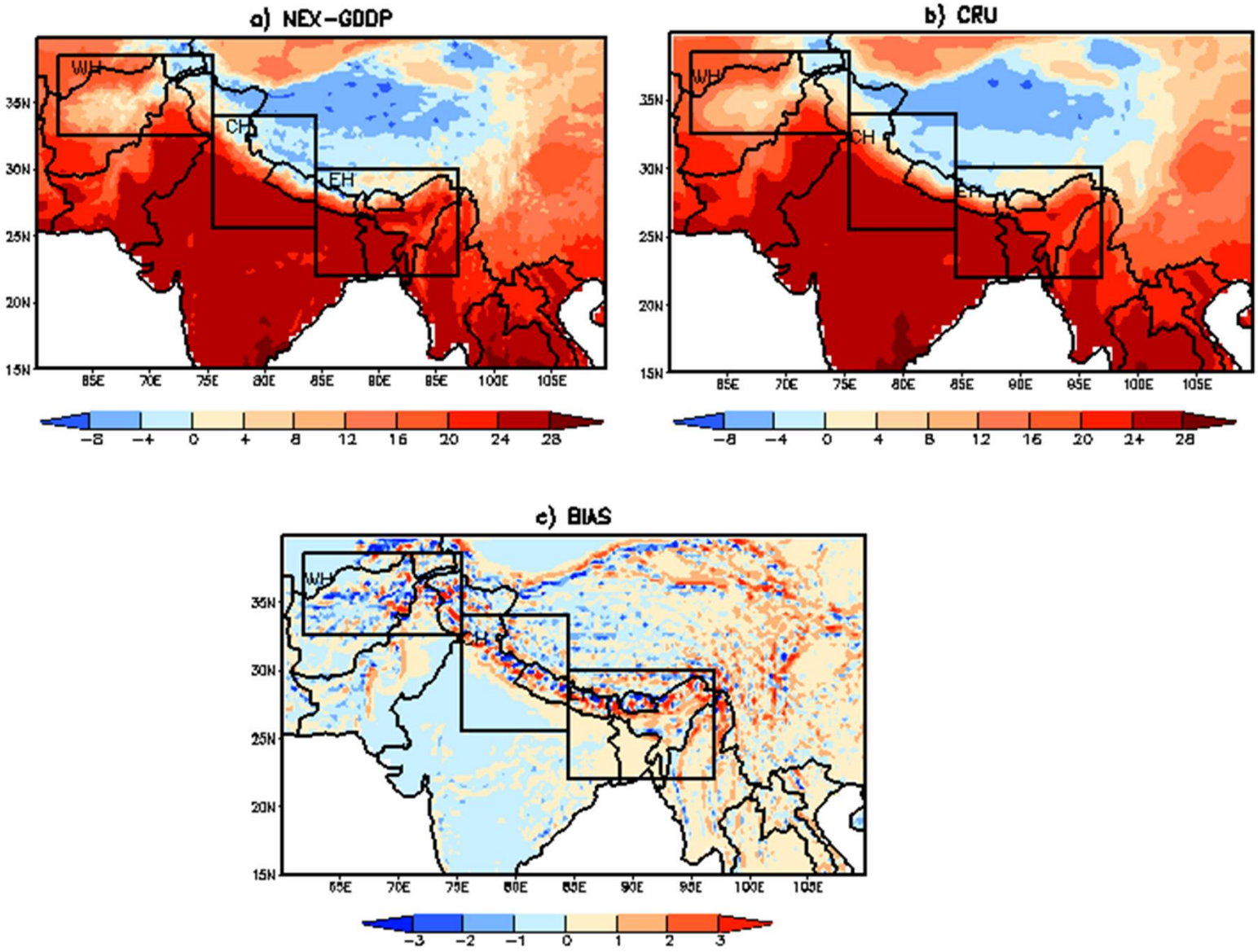
JJAS mean temperature (°C) 1976-2005



DJF mean temperature (°C) 1976-2004

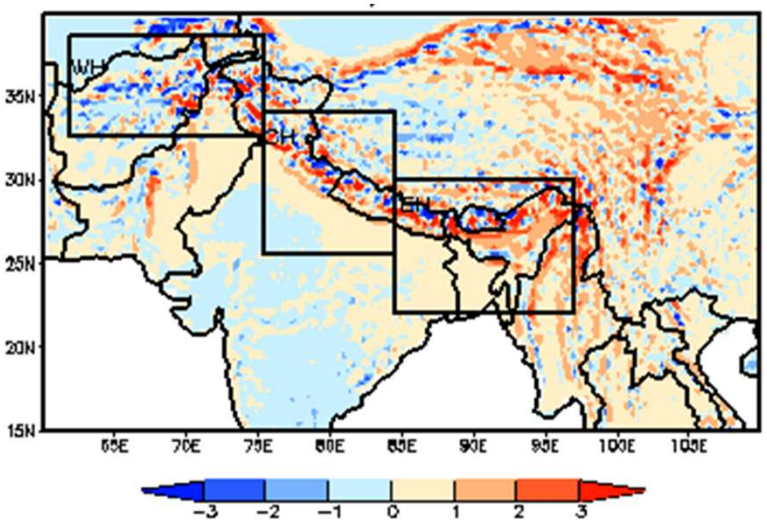


Annual mean temperature (°C) 1976-2004

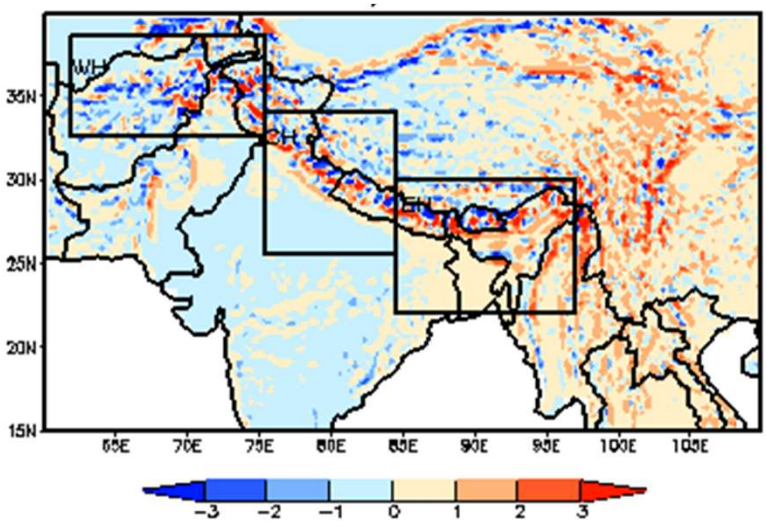


Bias in maximum temperature (°C) 1976-2005

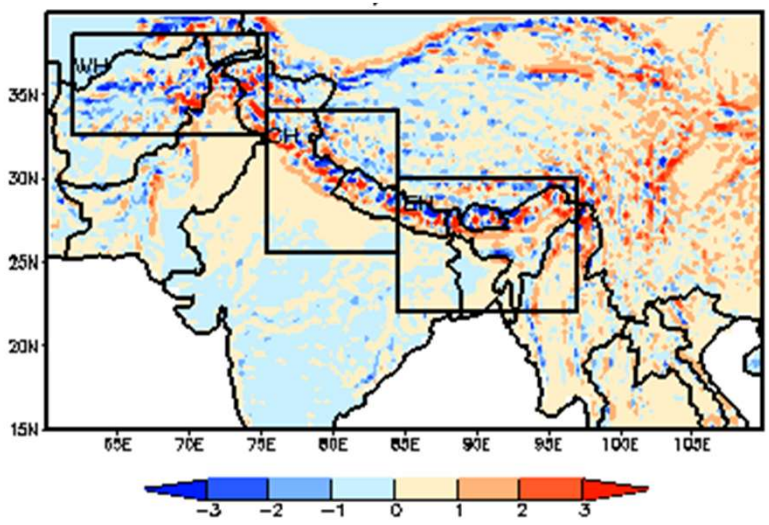
DJF



MAM



JJAS



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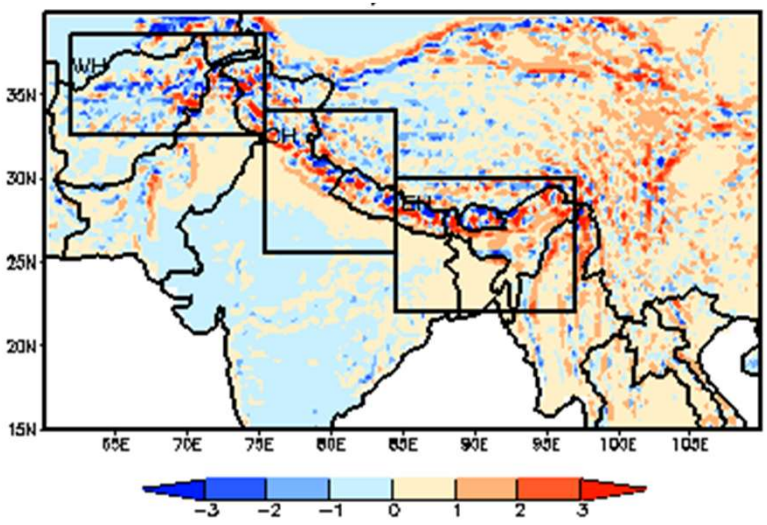
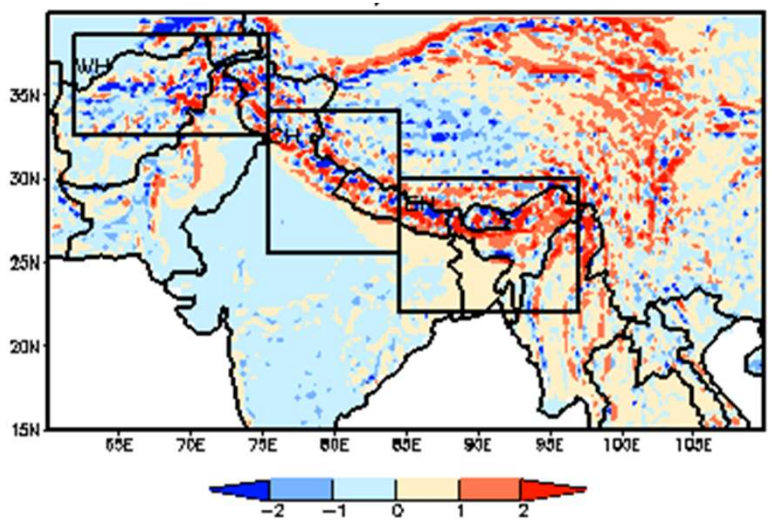
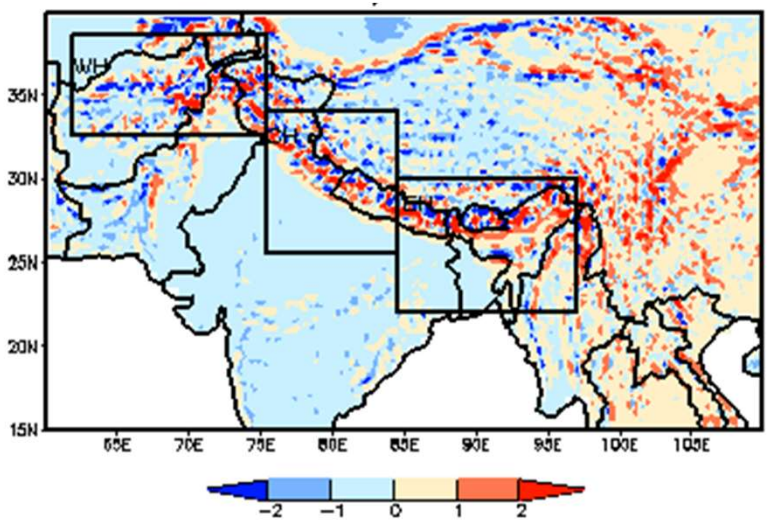


Bias in minimum temperature (°C) 1976-2004

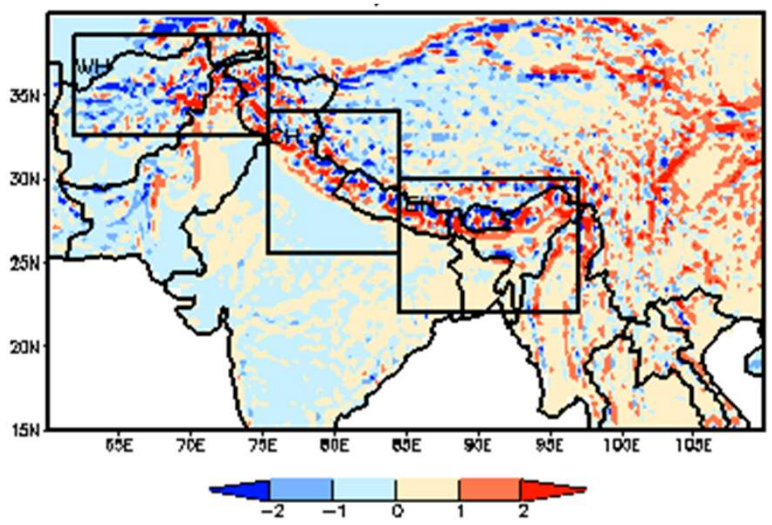
DJF



MAM



JJAS



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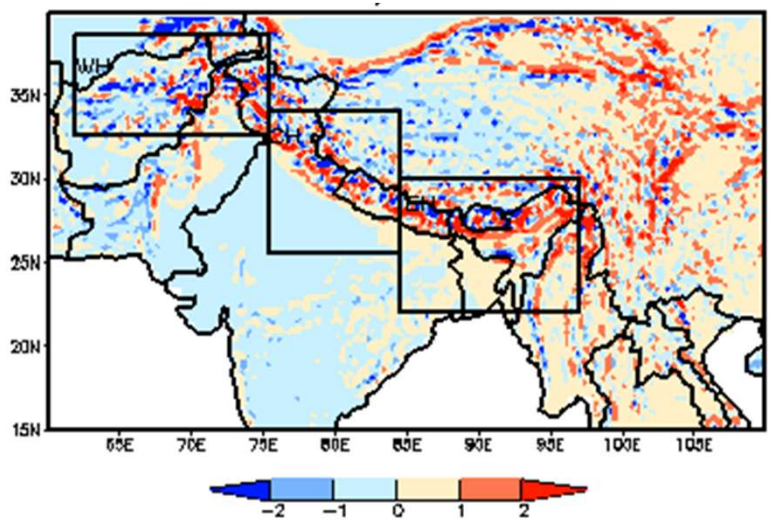
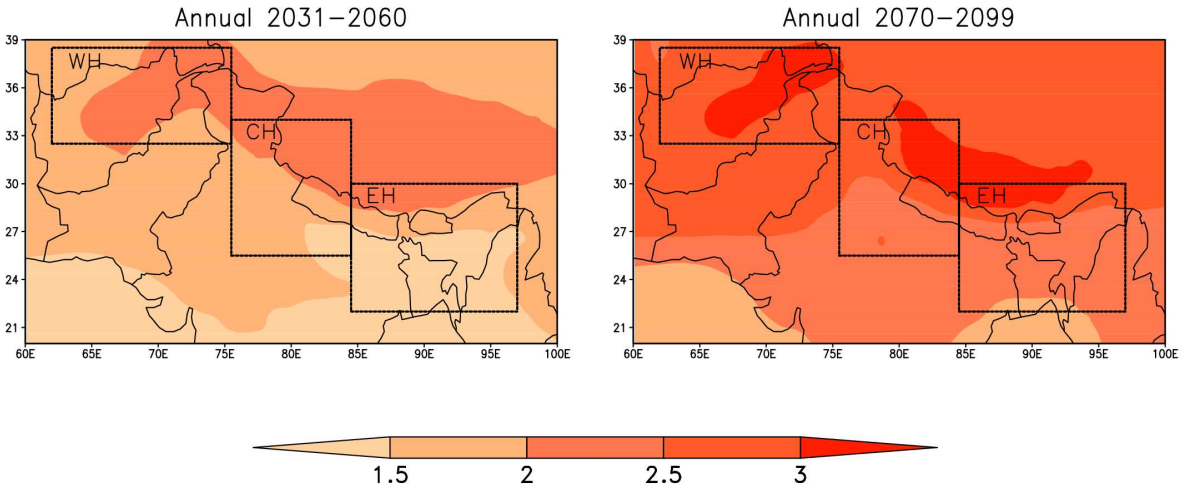
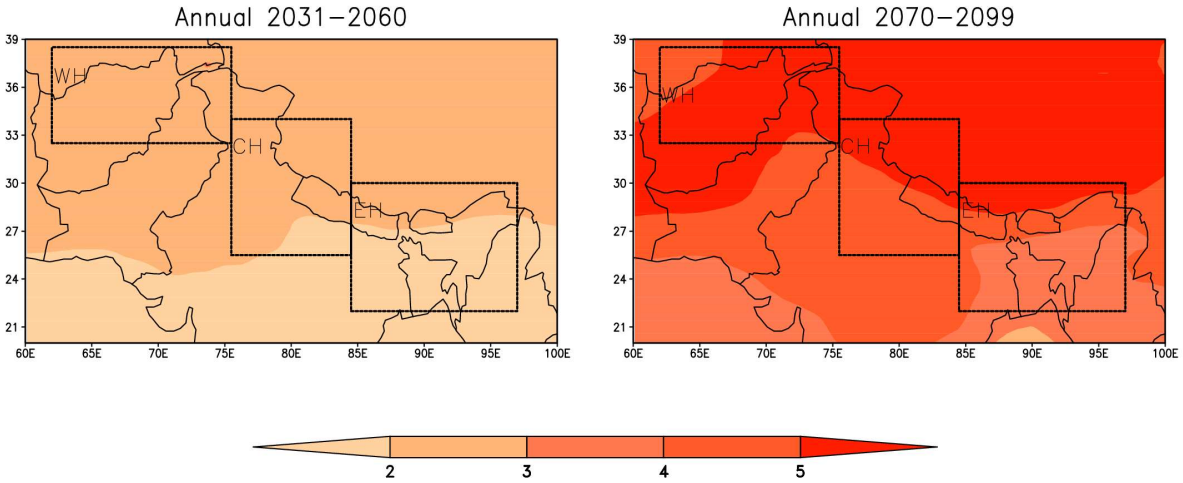
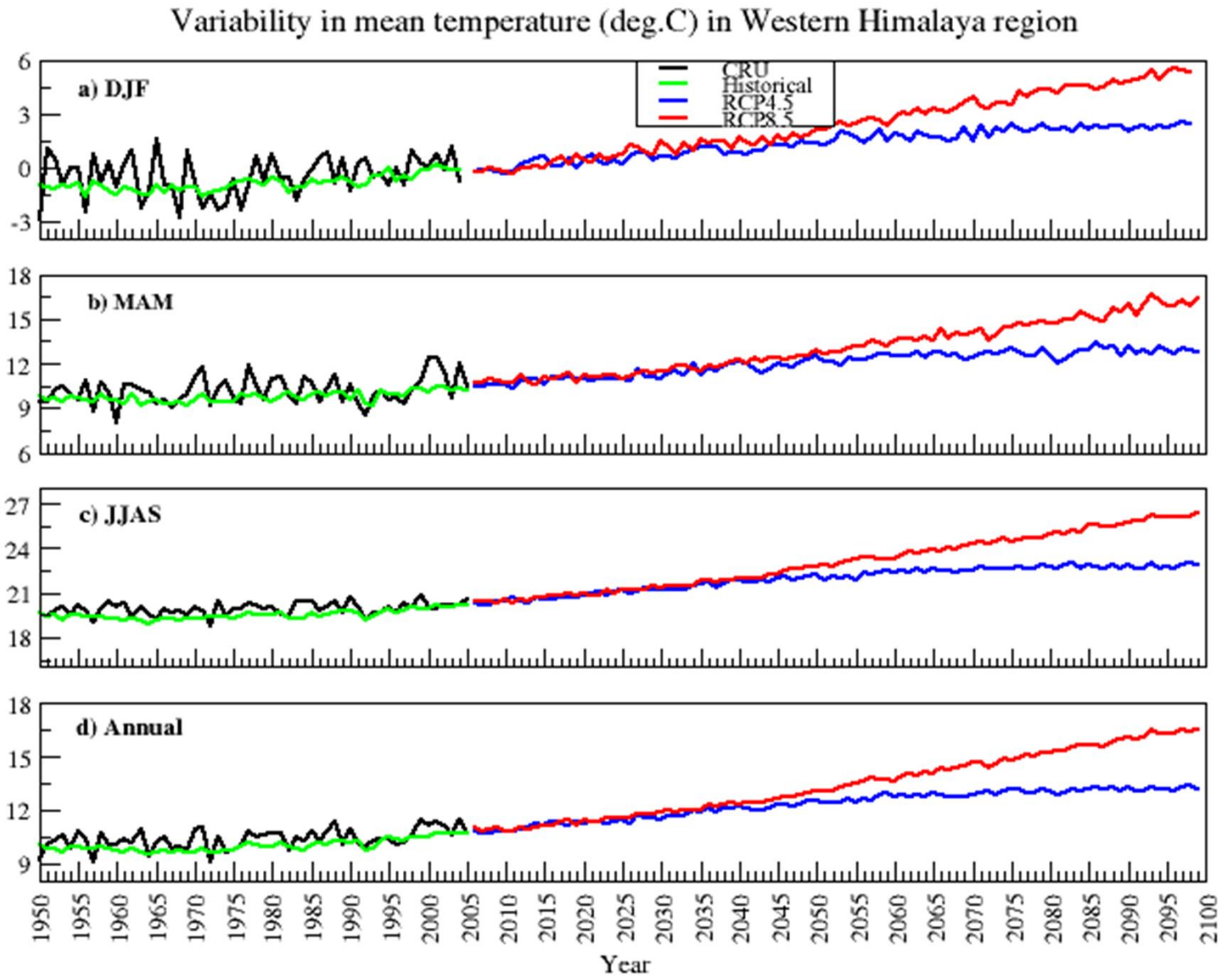


RCP4.5 : Mean Temp.(deg.C) Projected Change w.r.t Hist



RCP8.5 : Mean Temp.(deg.C) Projected Change w.r.t Hist




Variability in mean temperature (deg.C) in Western Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
6
3
0
-3
18
15
12
9
6
27
24
21
18
18
15
12
9
1950
1955
1960
1965
1970
1975
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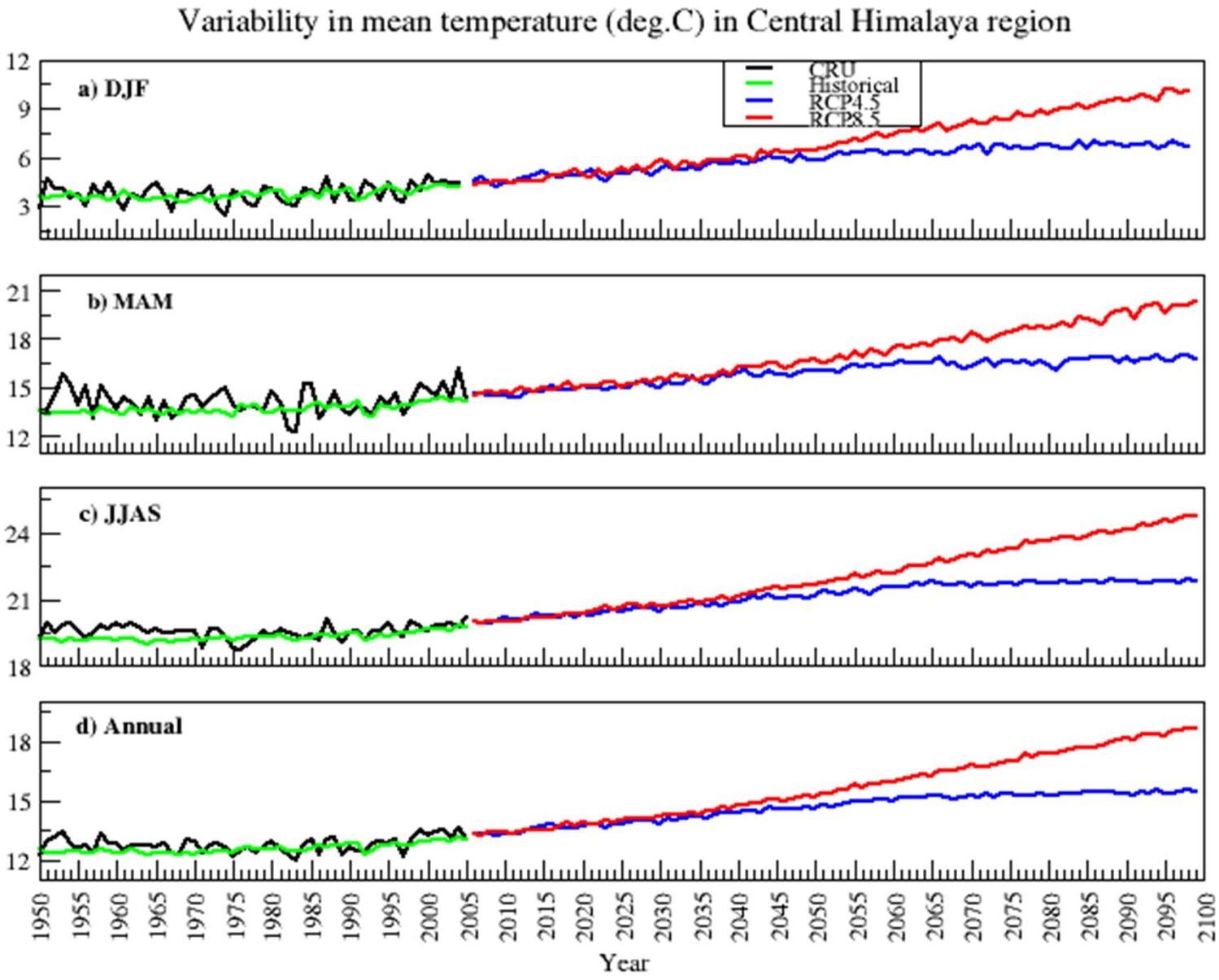
2095
2100
Year


Variability in mean temperature (deg.C) in Central Himalaya region
a) DJF
b) MAM
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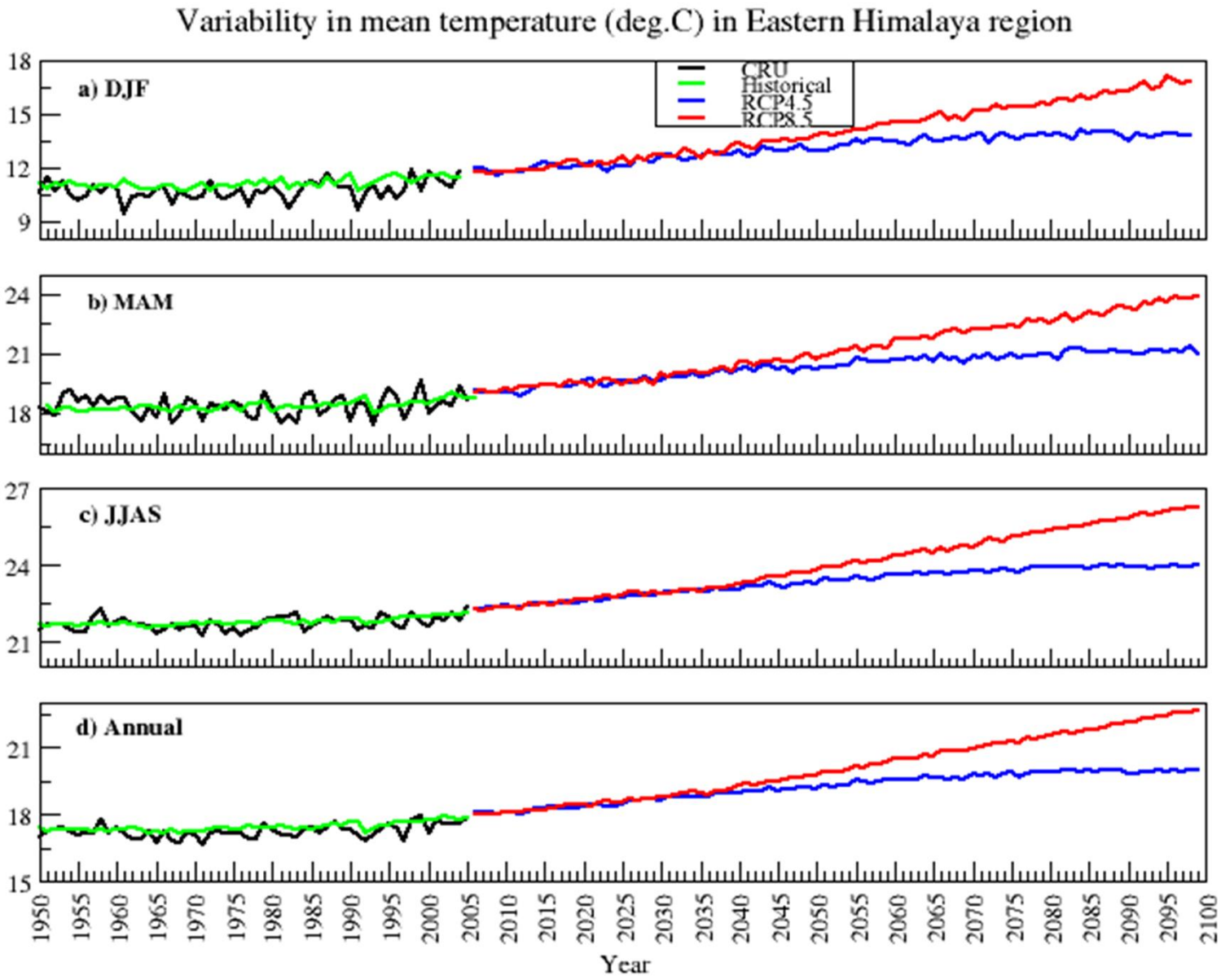
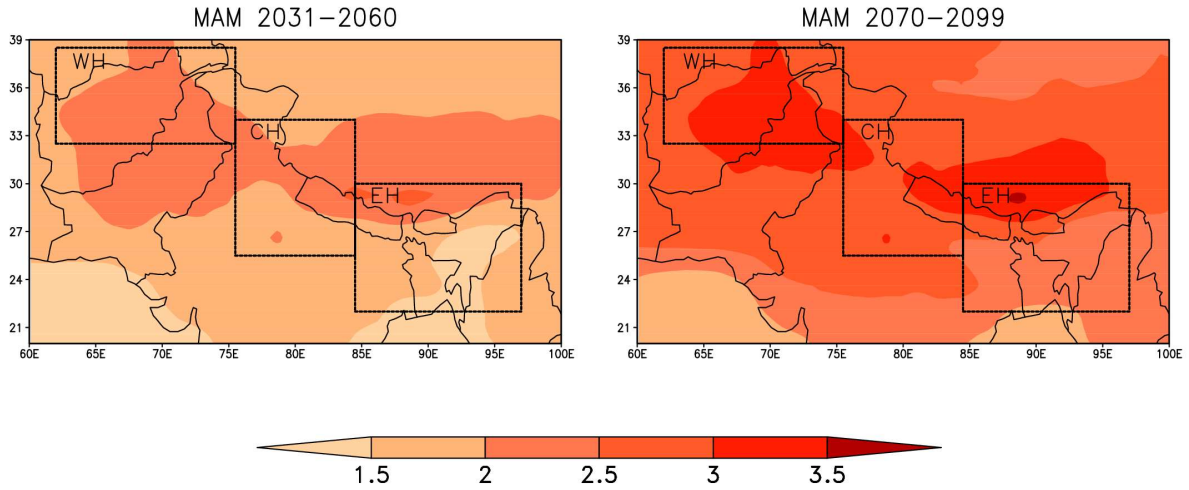
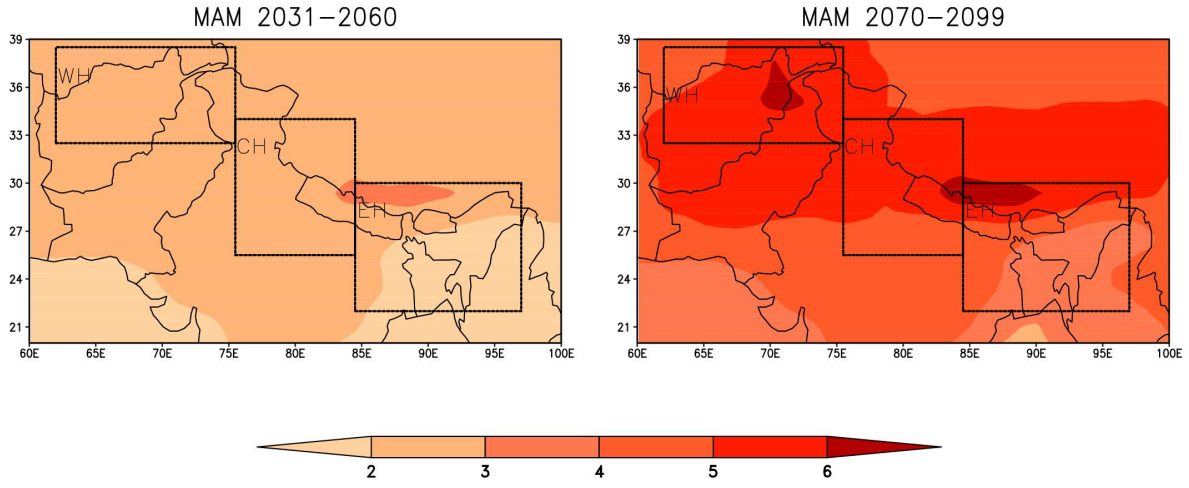
RCP8.5
Year


Variability in mean temperature (deg.C) in Eastern Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
Year

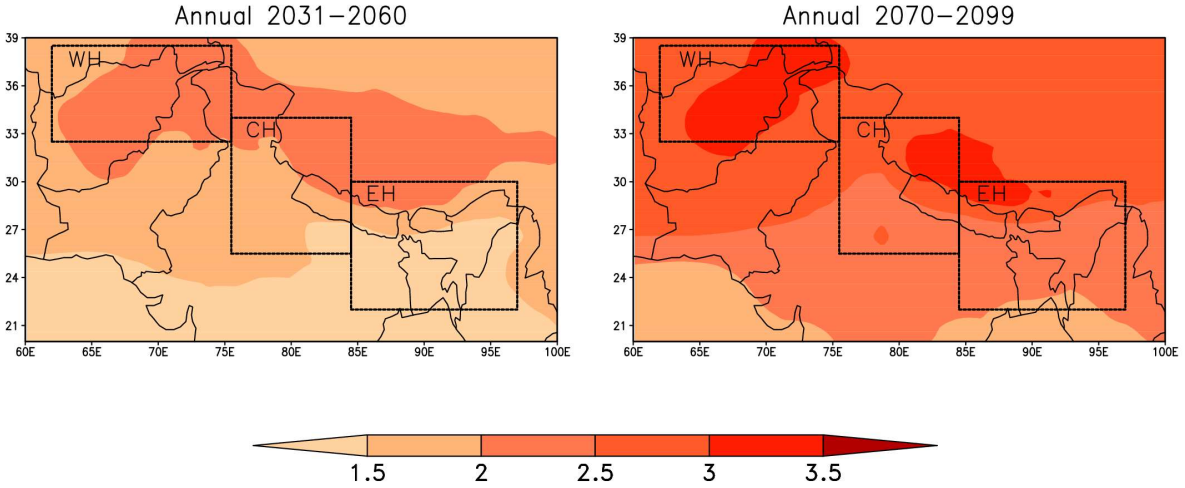
RCP4.5 : Max. Temp.(deg.C) Projected Change w.r.t Hist



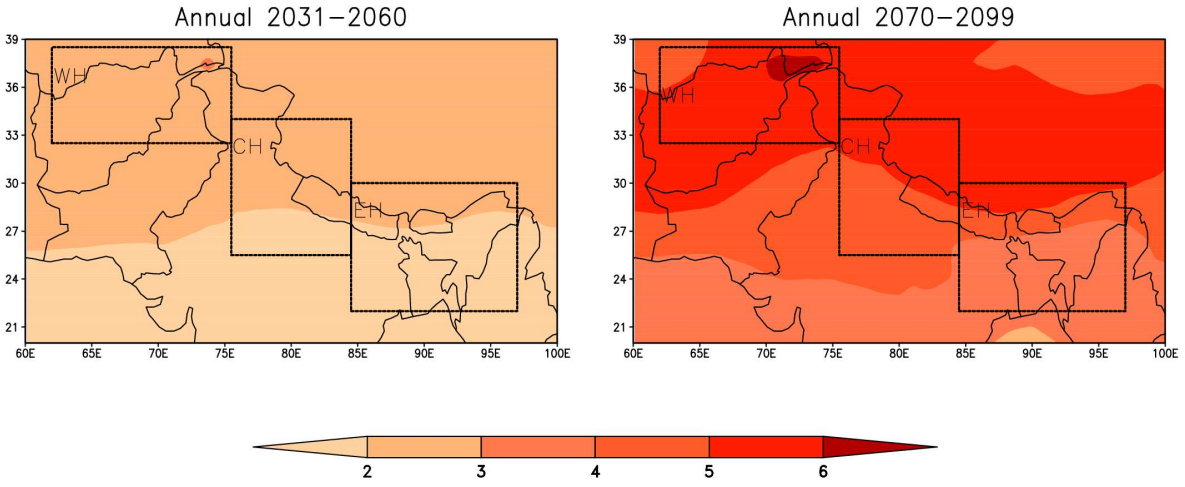
RCP8.5 : Max. Temp.(deg.C) Projected Change w.r.t Hist

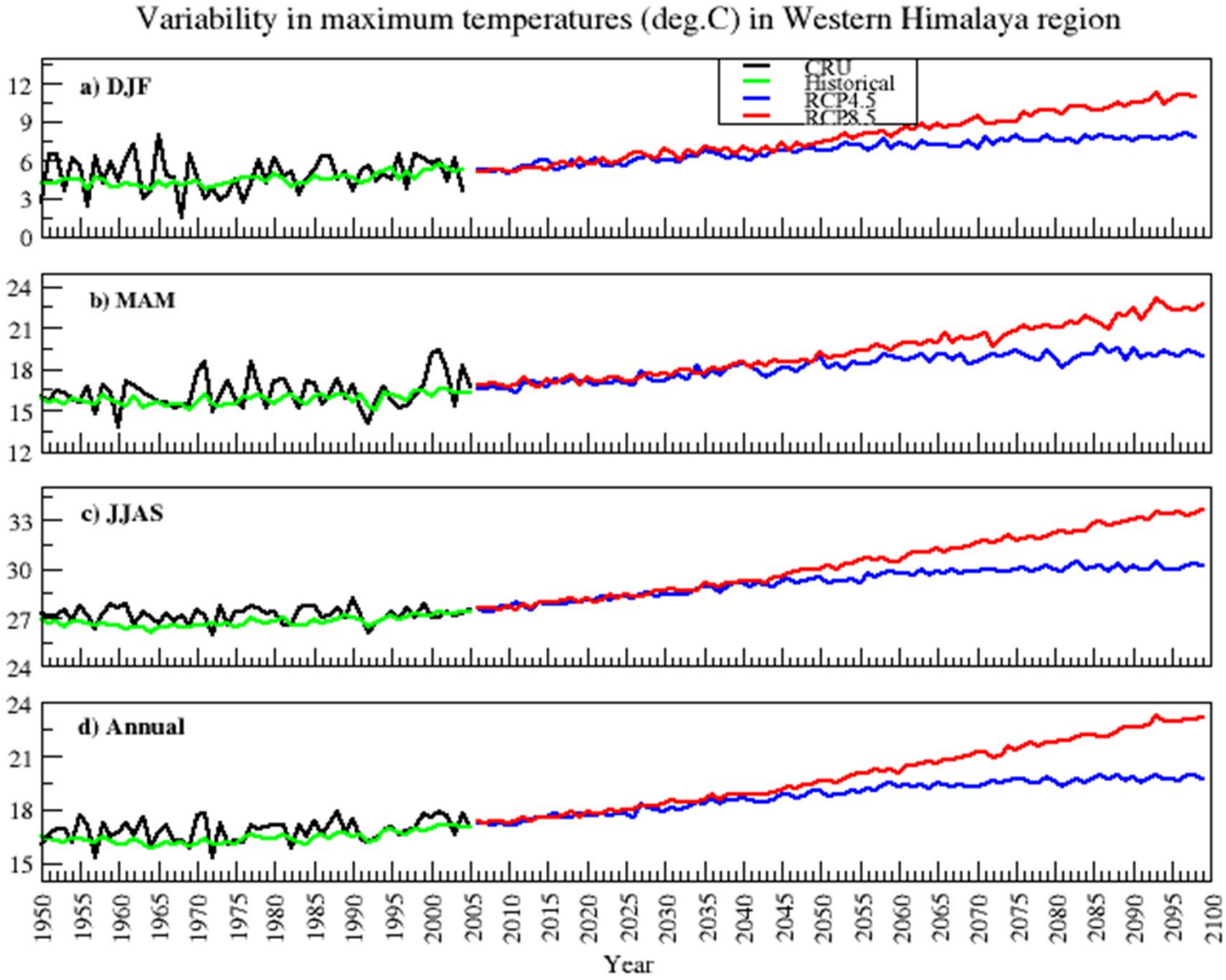


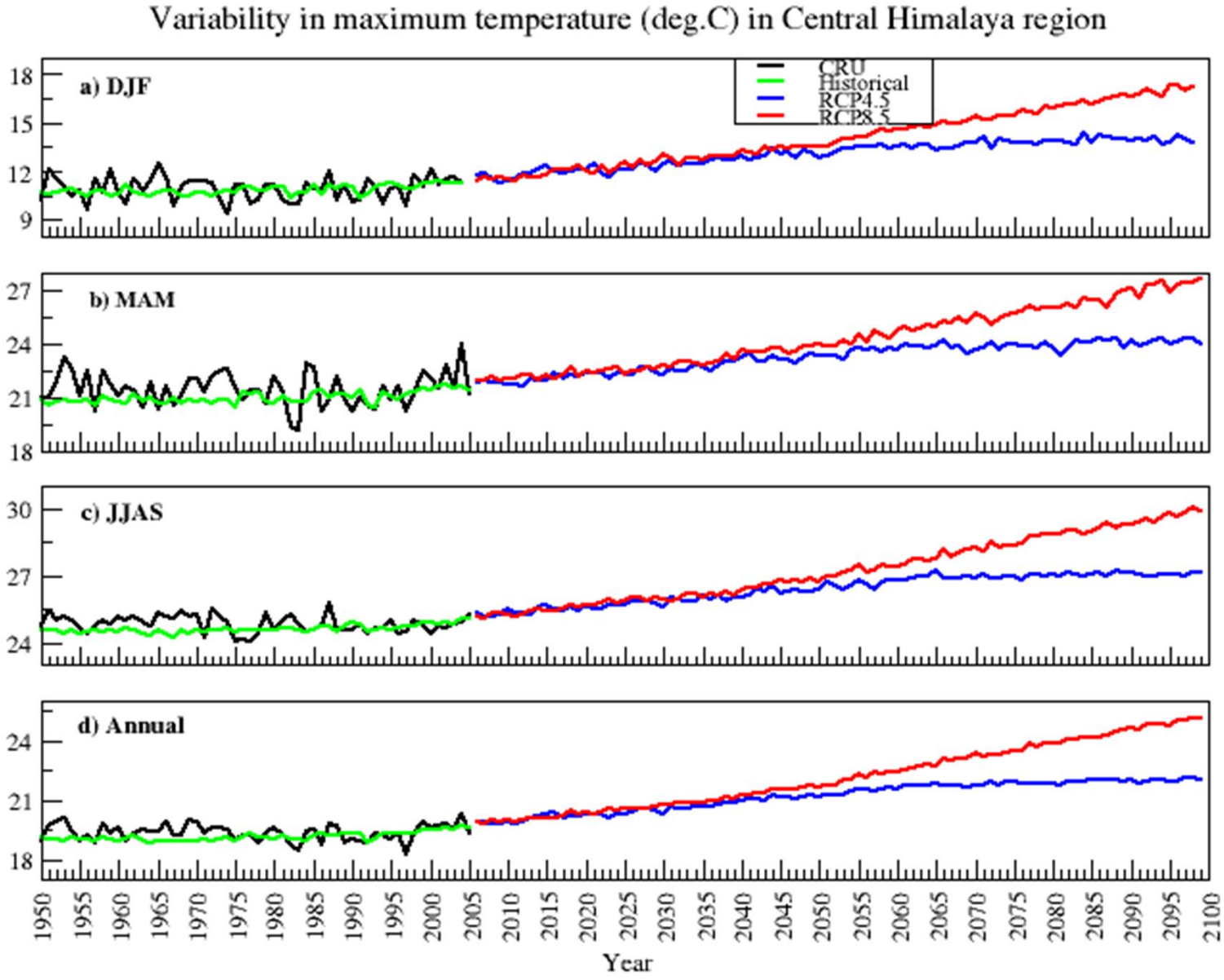
RCP4.5 : Max. Temp.(deg.C) Projected Change w.r.t Hist



RCP8.5 : Max. Temp.(deg.C) Projected Change w.r.t Hist




Variability in maximum temperatures (deg.C) in Western Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
Year


Variability in maximum temperature (deg.C) in Central Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
18
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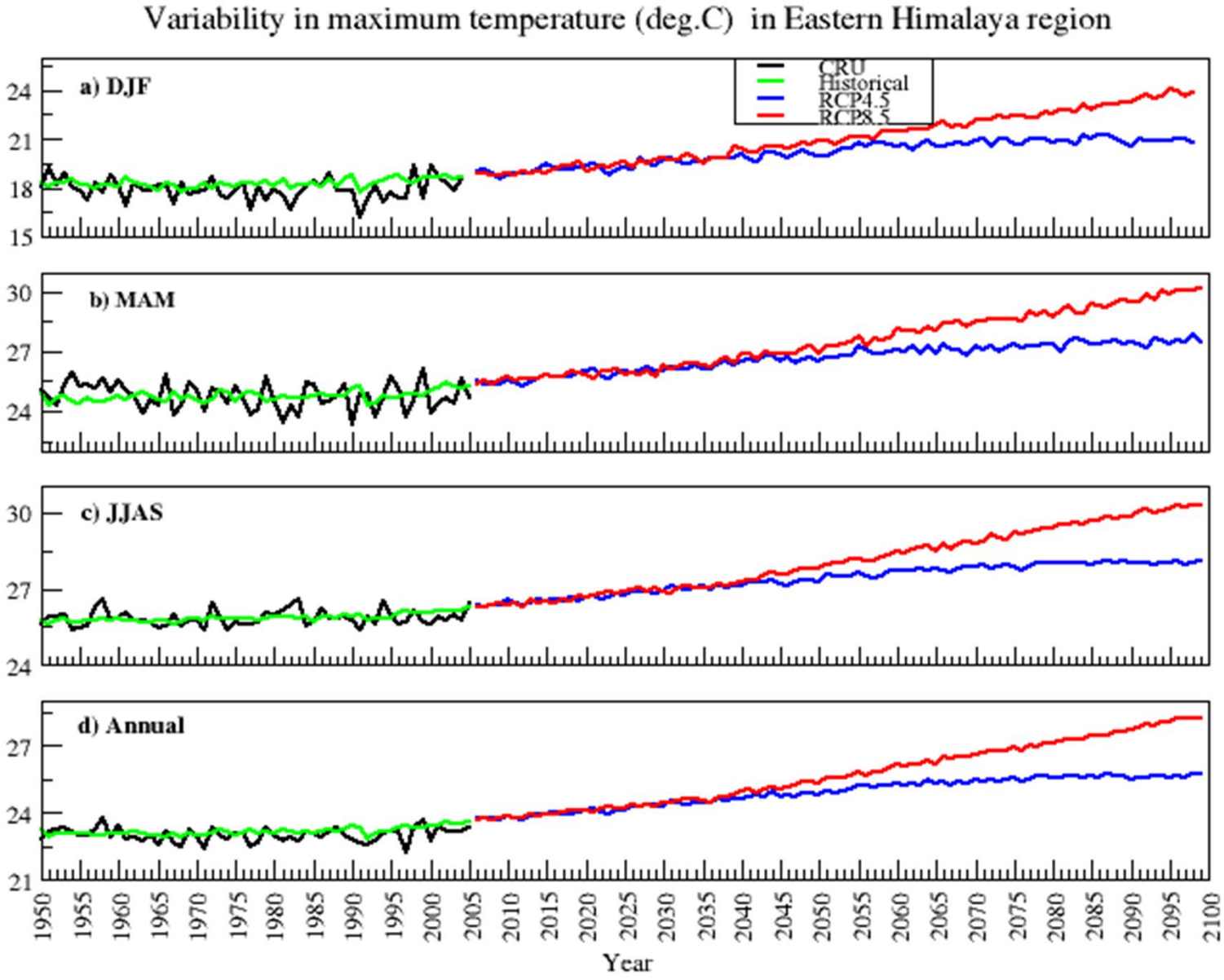
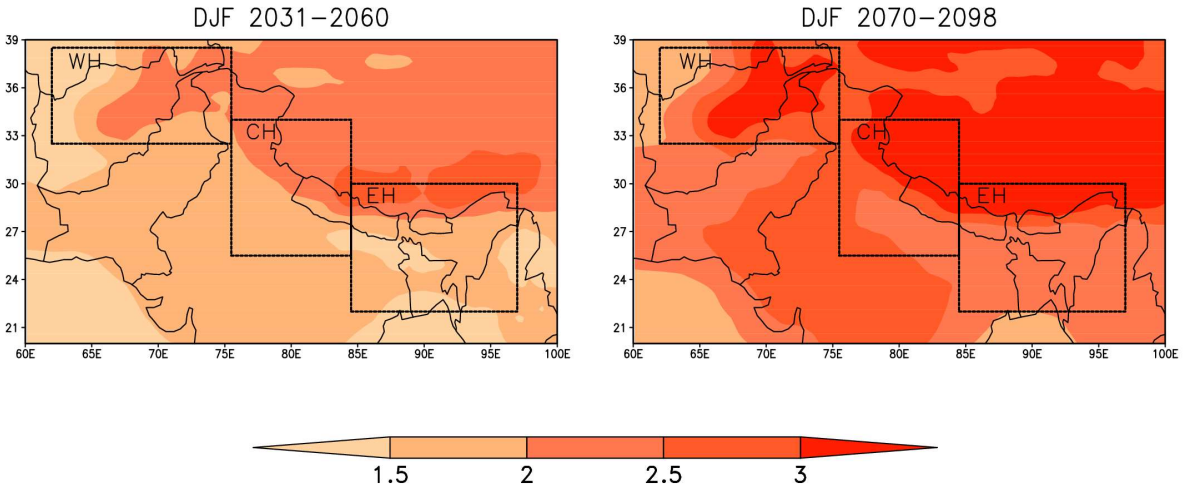
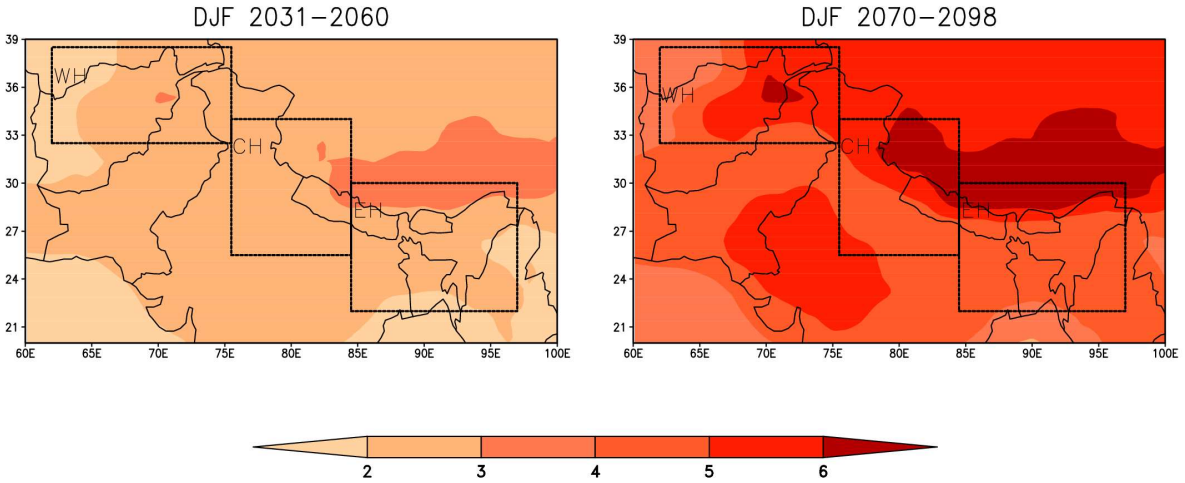
2100
Year


Variability in maximum temperature (deg.C) in Eastern Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
Year

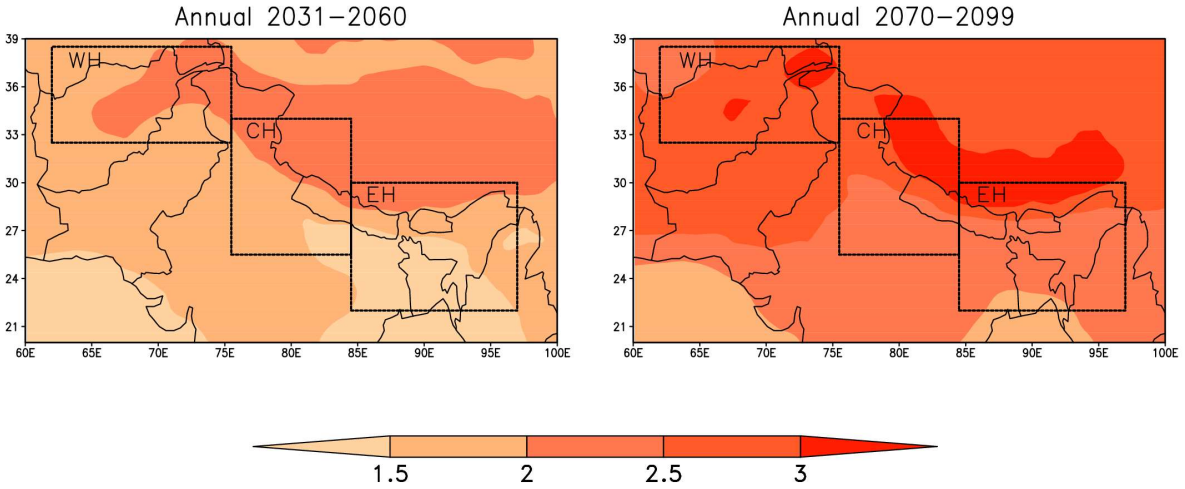
RCP4.5 : Min. Temp. (deg.C) Projected Change w.r.t Hist



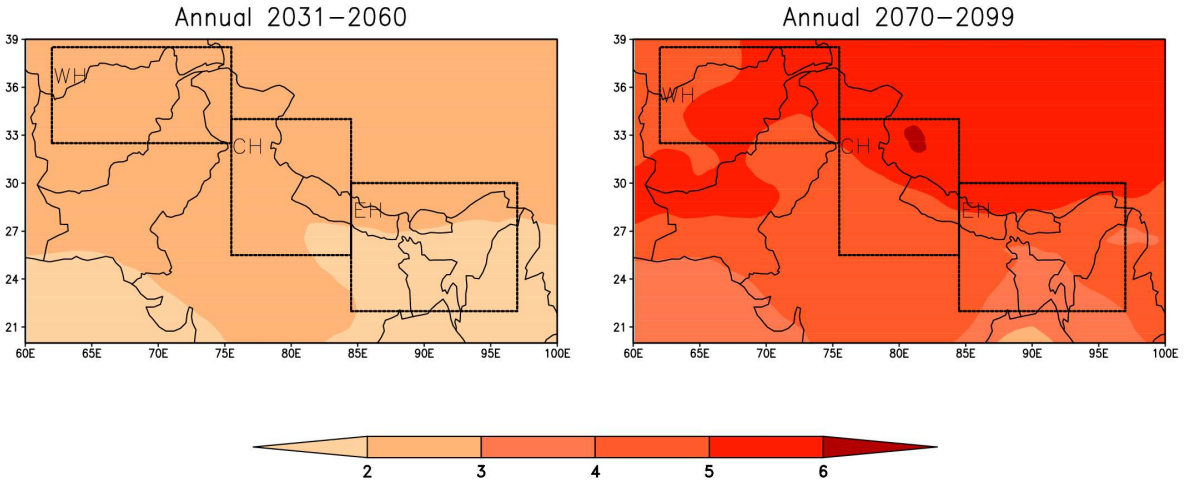
RCP8.5 : Min. Temp. (deg.C) Projected Change w.r.t Hist

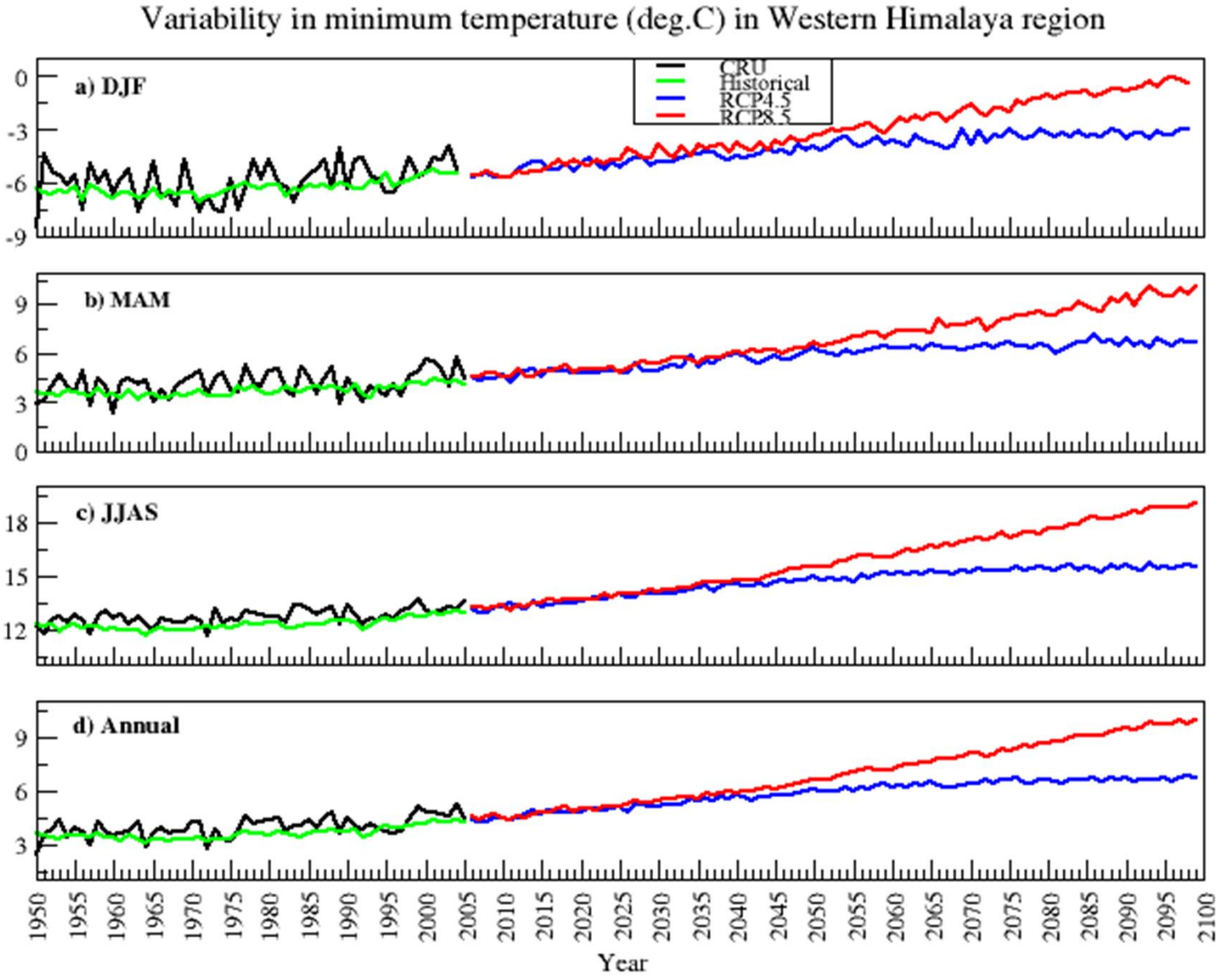


RCP4.5 : Min. Temp. (deg.C) Projected Change w.r.t Hist



RCP8.5 : Min. Temp. (deg.C) Projected Change w.r.t Hist




Variability in minimum temperature (deg.C) in Western Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
0
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-9
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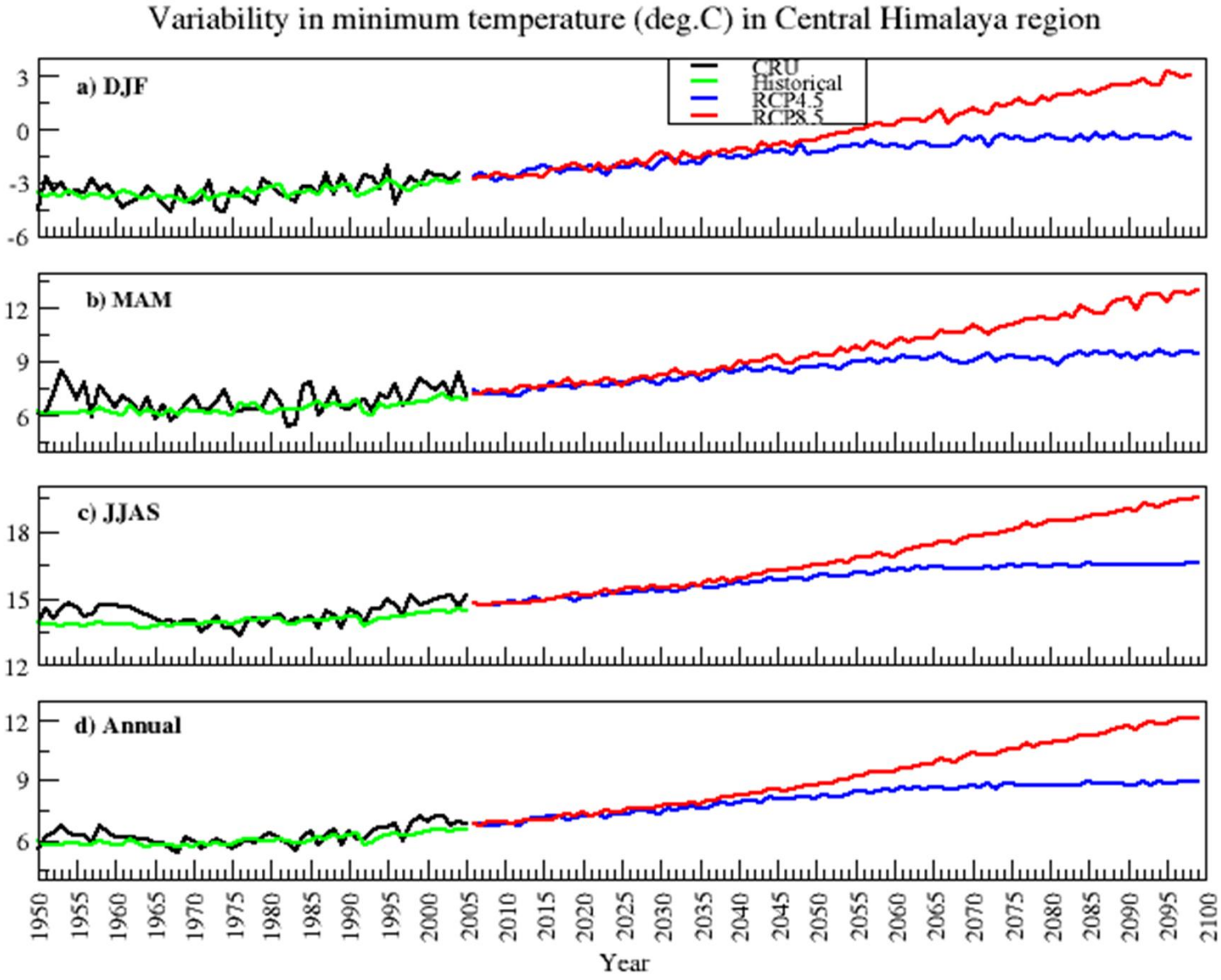
2100
Year


Variability in minimum temperature (deg.C) in Central Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
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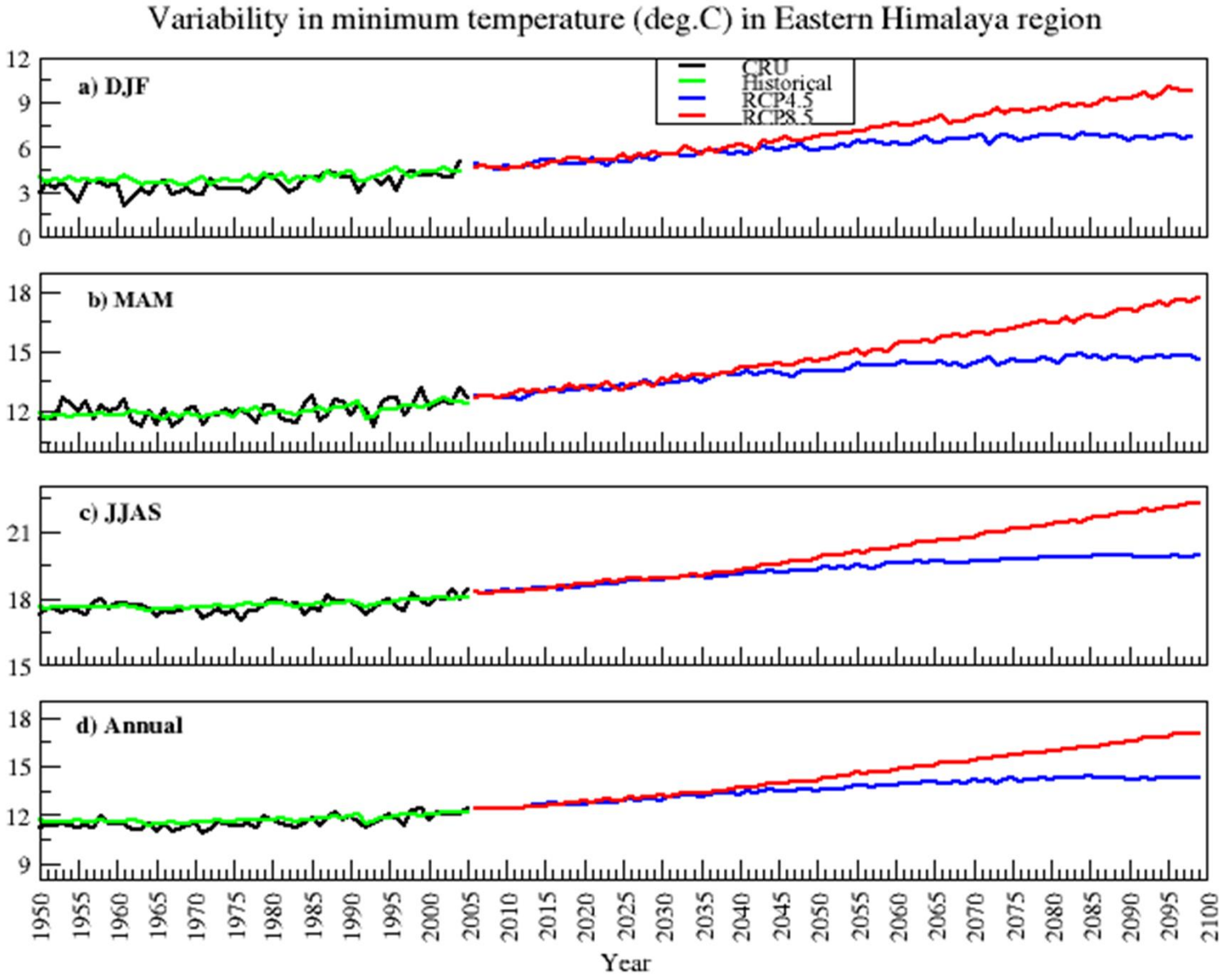
Year


Variability in minimum temperature (deg.C) in Eastern Himalaya region
a) DJF
b) MAM
c) JJAS
d) Annual
CRU
Historical
RCP4.5
RCP8.5
Year

Projected changes in temperature : WH

WH		Change Max Temp				Change Min Temp			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
RCP4.5	2050s	**2.4**	2.53	2.62	2.59	**2.14**	2.23	2.52	2.34
	2080s	**2.32**	2.62	2.86	2.71	2.48	2.66	3.01	2.7
RCP8.5	2050s	3.18	3.33	3.45	3.47	2.89	3.01	3.41	3.18
	2080s	4.84	4.58	4.8	**4.96**	5.0	5.05	**5.7**	5.43

Projected changes in temperature : CH

CH		Change Max Temp				Change Min Temp			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
RCP4.5	2050s	2.18	2.43	**1.98**	2.01	2.3	2.33	**1.99**	2.3
	2080s	2.73	2.61	2.18	2.42	2.79	2.77	2.32	2.6
RCP8.5	2050s	2.94	3.2	2.59	2.75	3.26	3.2	2.69	3.06
	2080s	4.38	**4.76**	3.75	4.01	**5.56**	5.43	4.61	5.26

Projected changes in temperature : EH

EH		Change Max Temp				Change Min Temp			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
RCP4.5	2050s	1.82	2.06	1.58	**1.7**	1.88	2.07	**1.6**	1.76
	2080s	2.44	2.54	1.9	2.07	2.43	2.52	2.52	2.23
RCP8.5	2050s	2.54	2.74	2.17	2.38	2.62	3.78	3.72	4.32
	2080s	**3.71**	3.84	2.88	3.41	3.62	4.43	4.61	**4.76**

Summary

- Statistical downscaling can give projections at local scale where as dynamical downscaling on regional scale
- MME of NEX-GDDP models simulate wet bias in winter monsoon and dry bias in summer monsoon over western Himalaya
- MME simulate dry bias in summer monsoon rainfall over central Himalaya and wet bias over eastern Himalaya.
- Also ensemble simulate warm bias at foothills and bias reduces with height
- Summer monsoon rainfall in western parts of western Himalaya is projected to reduce by about 5% under both the scenarios, while over remaining parts the rainfall may increase
- Towards the end of the century the rise in minimum temperatures may be more than that in maximum temperatures in all seasons.

THANK YOU !!