Dynamic Downscaling of Climate over the Himalayas

S. C. Kar

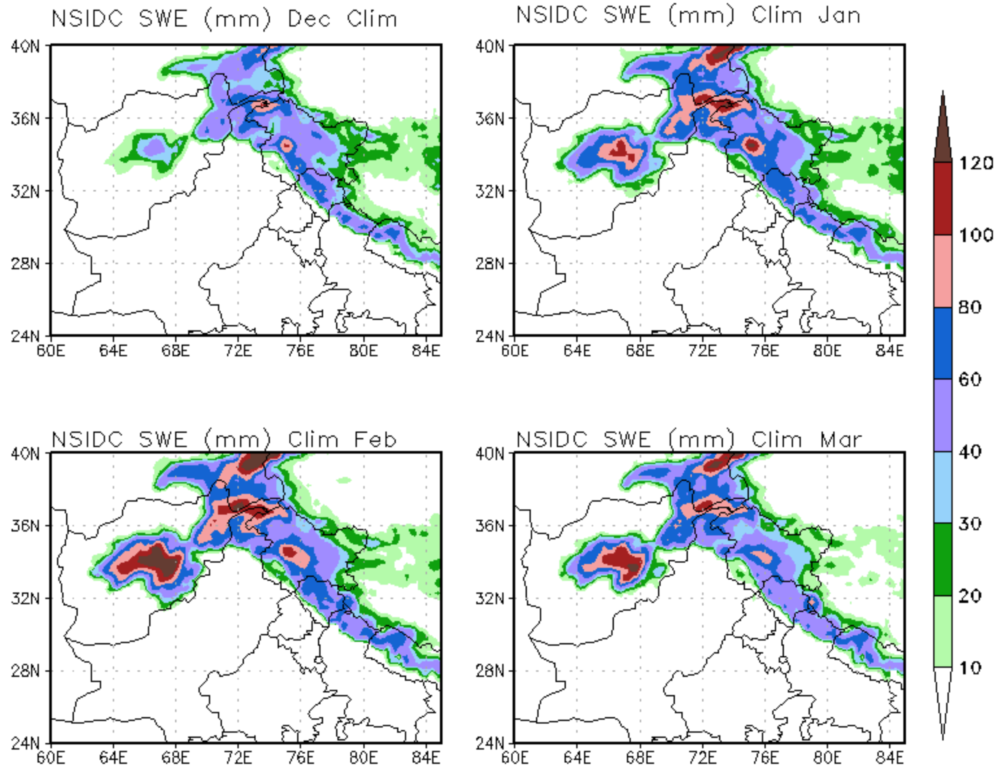
National Centre for Medium Range Weather Forecasting, Noida

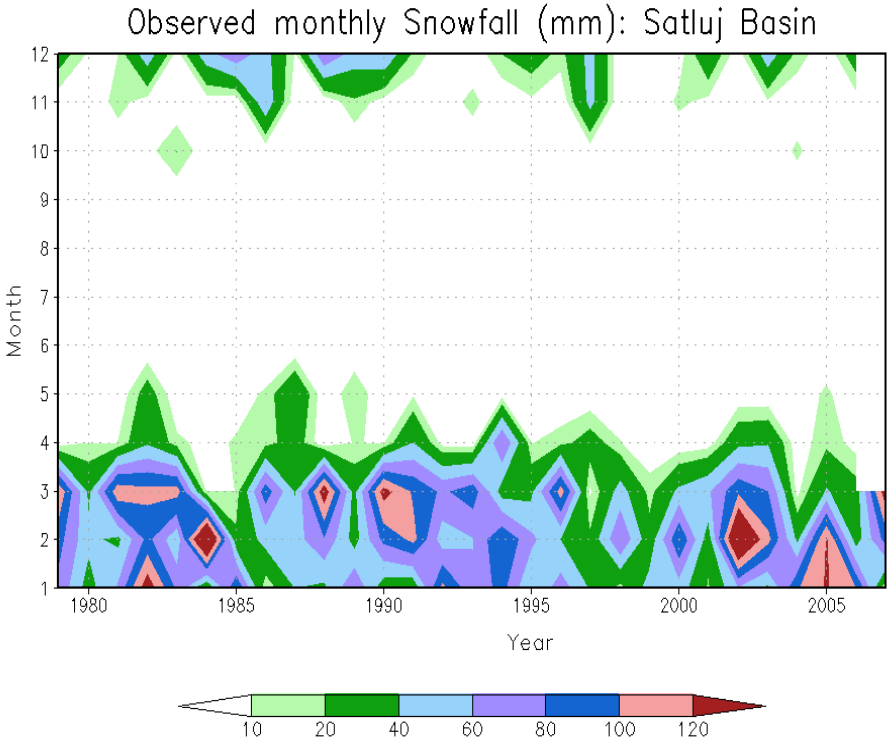
(Email: sckar@ncmrwf.gov.in)

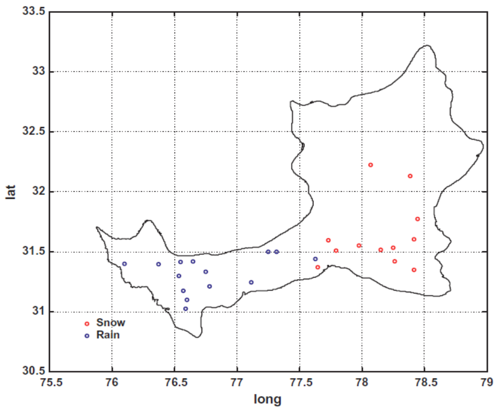
Changing Water Cycle in the Himalayas

Snow Accumulation Variability over Himalayas

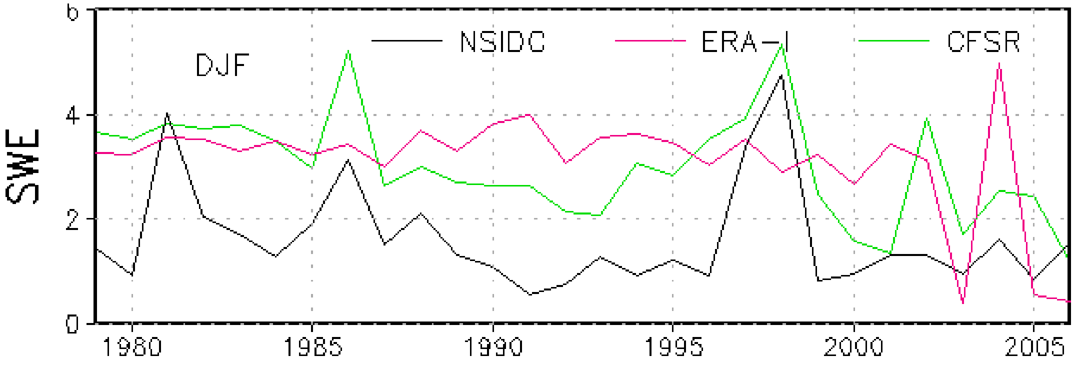
Climatology of Snow in Dec, Jan, Feb and Mar







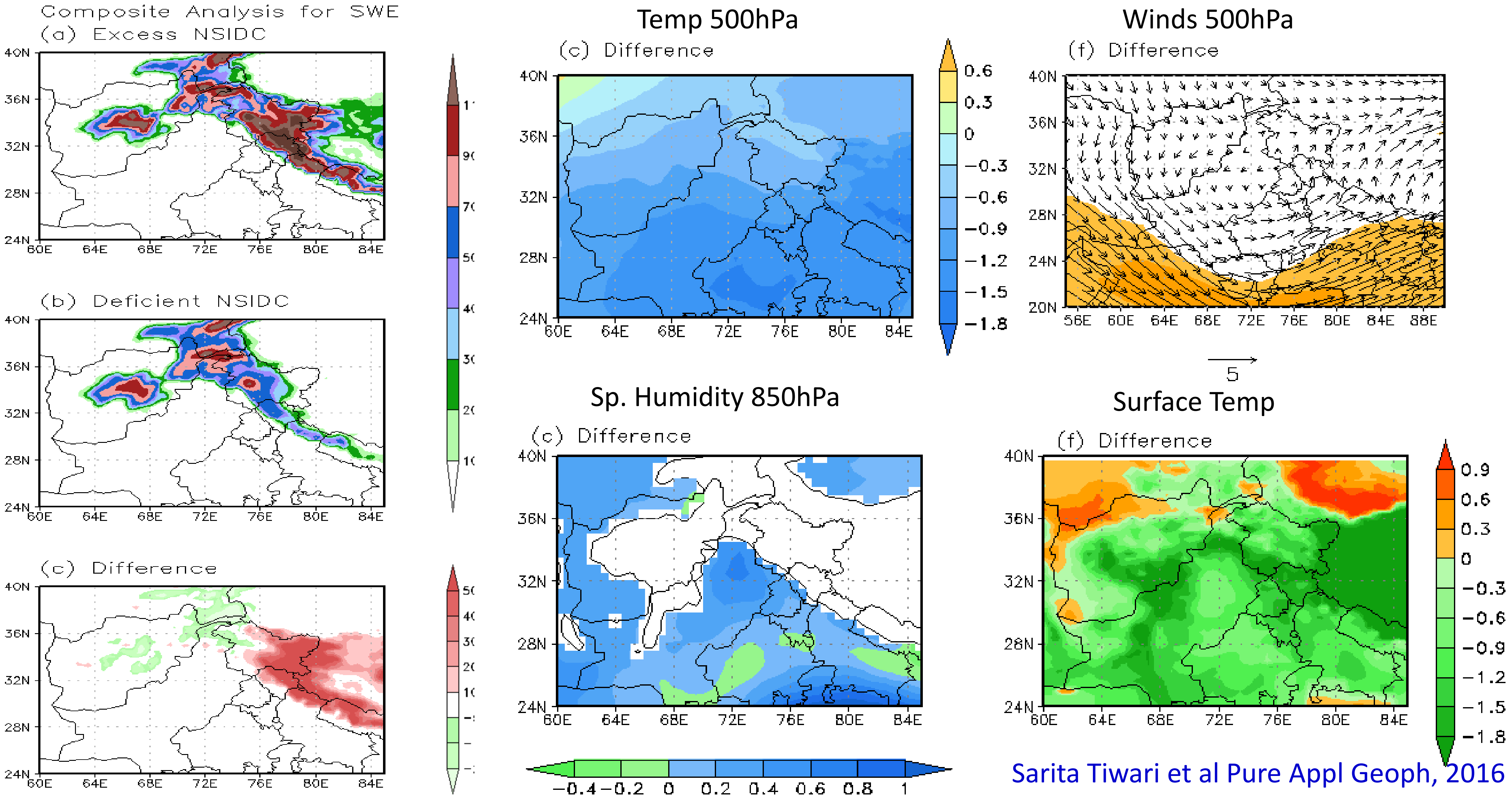
Observed Snowfall at BBMB stations in Satluj Basin



Yearly Variation of Snow from NSIDC, CFSR and ERA-I

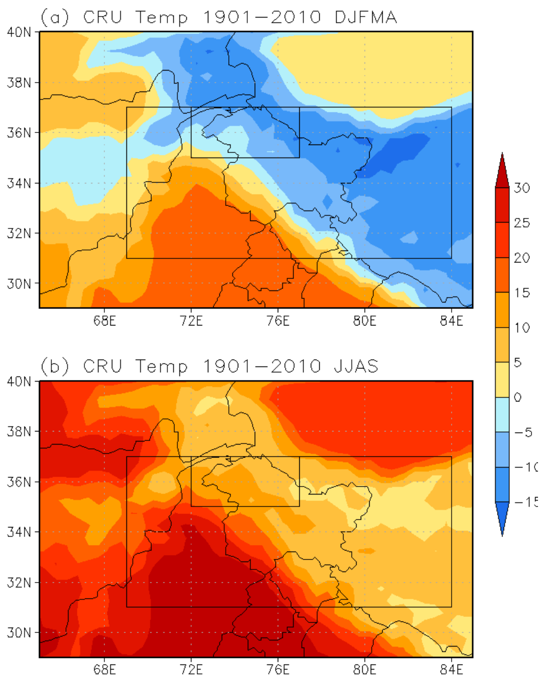
Remote Sensing data of snow accumulation and ablation (from National Snow and Ice Data Centre, NOAA) suggest large interannual variability over Himalayas. Mechanism of such variability has been examined using CFSR reanalysis upper-air data.

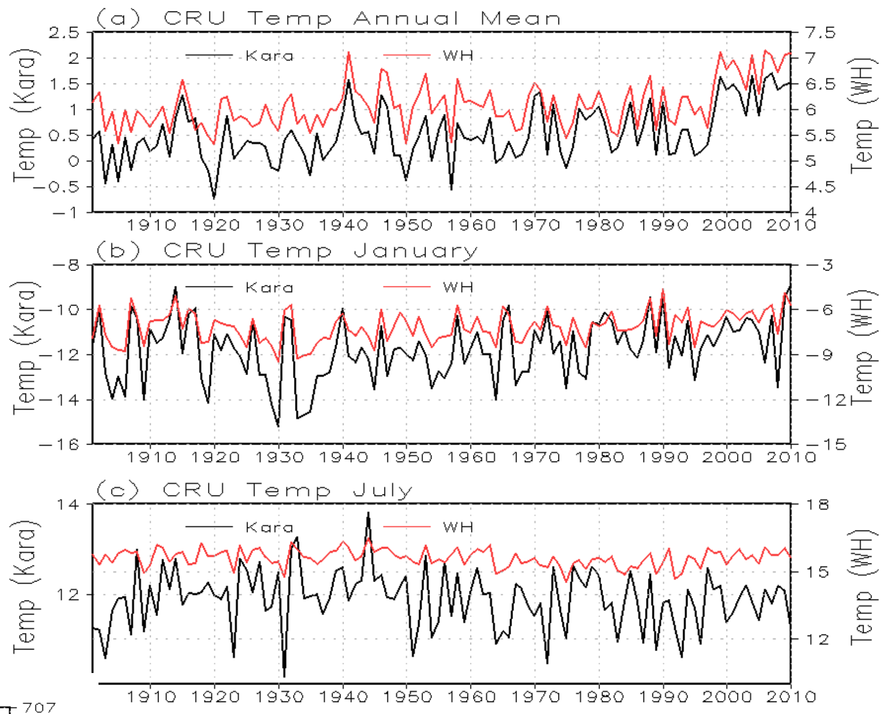
Composite Analysis and Difference in Snow, T500, Winds500, SpHum850 and Tsur

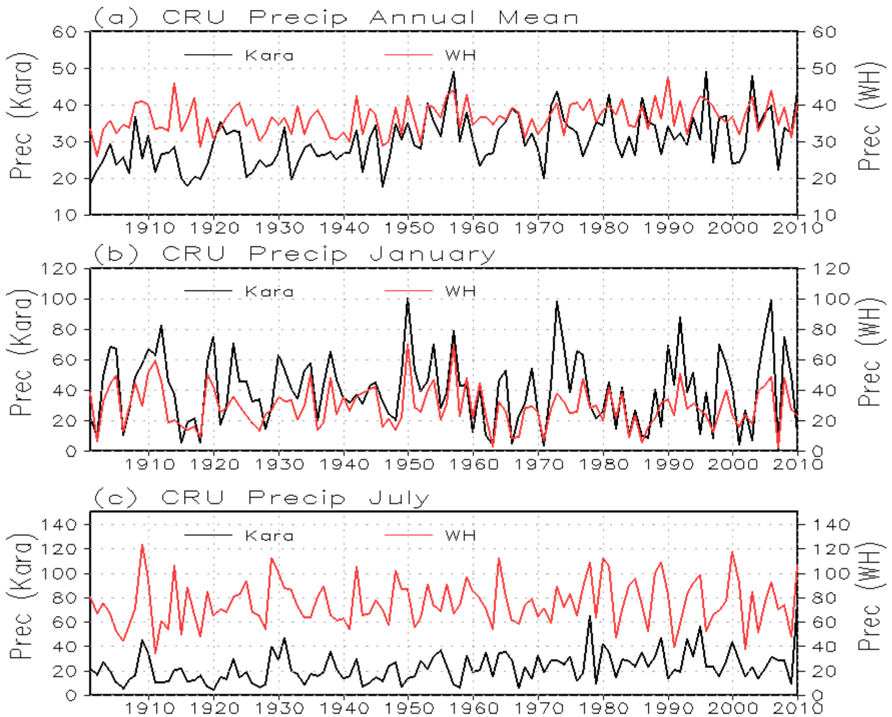


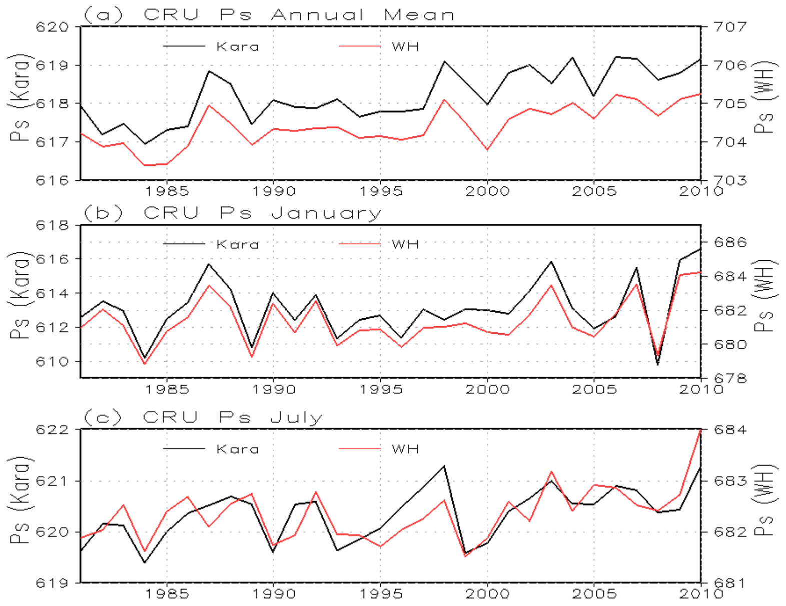
Sarita Tiwari et al Pure Appl Geoph, 2016

Karakorum and Western Himalayas





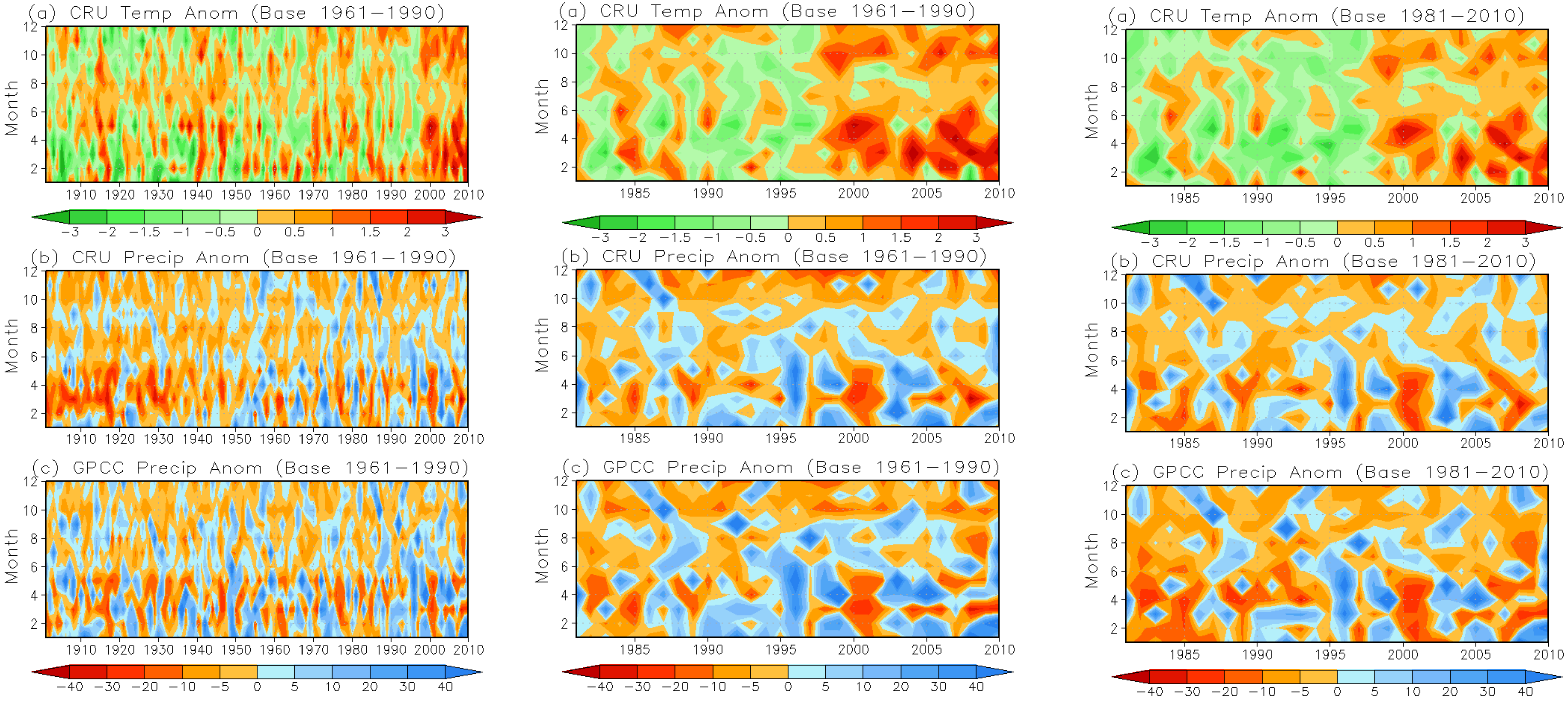




An increasing trend is seen in surface temperature over Karakorum and WH in annual mean and winter temp.
An increasing trend is seen in precipitation over Karakorum and WH in annual mean. Increasing trend in July over Karakorum.

Surface Pressure is increasing over Karakorum and WH consistent with increase in surface temperature

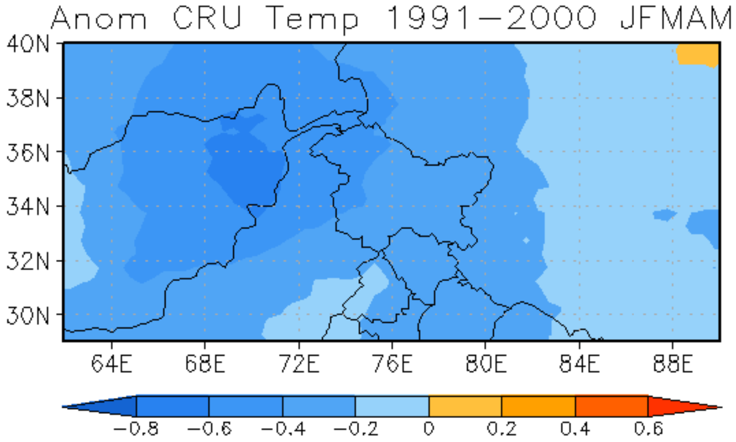
Temperature and Precipitation Variability over Karakorum

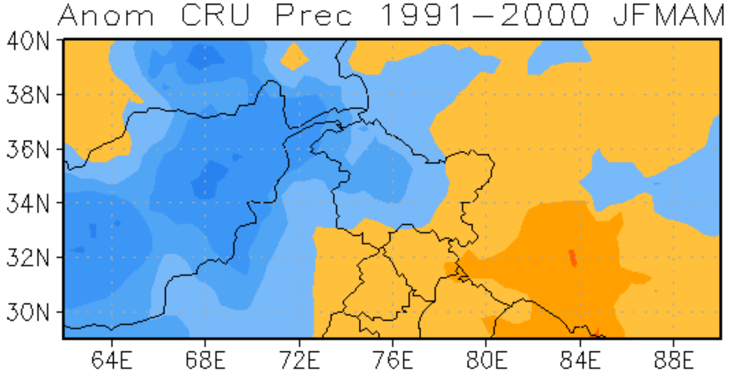


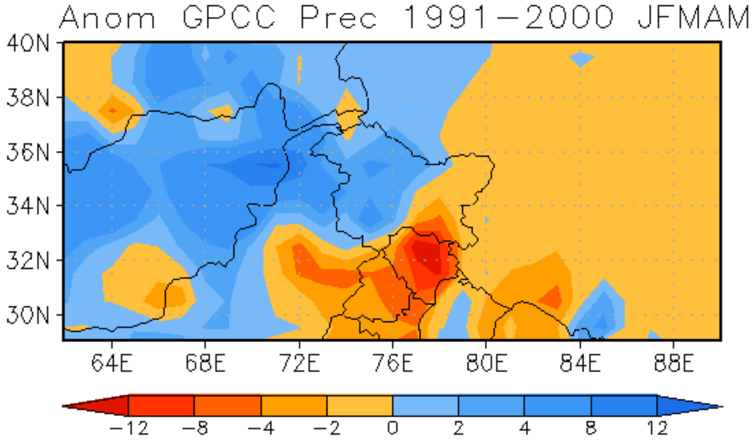
During the decade of 1991-2000, Karakorum experienced colder temperature anomaly as compared to base climate of both 1961-1990 and 1981-2010.

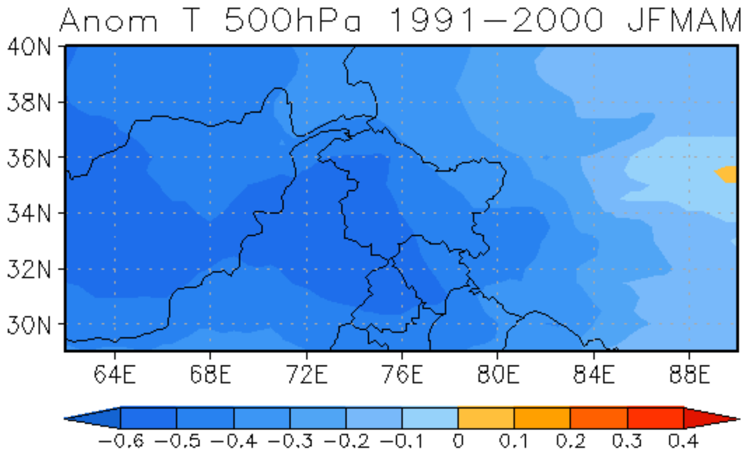
More precipitation occurred over the region during the same decade.

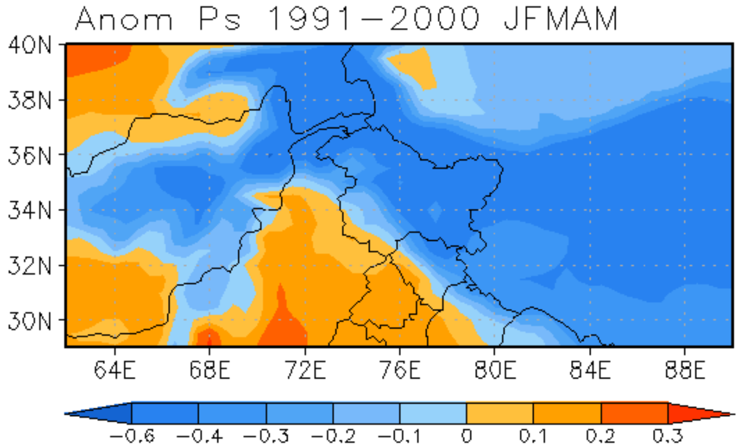
The decade of 1991 to 2000

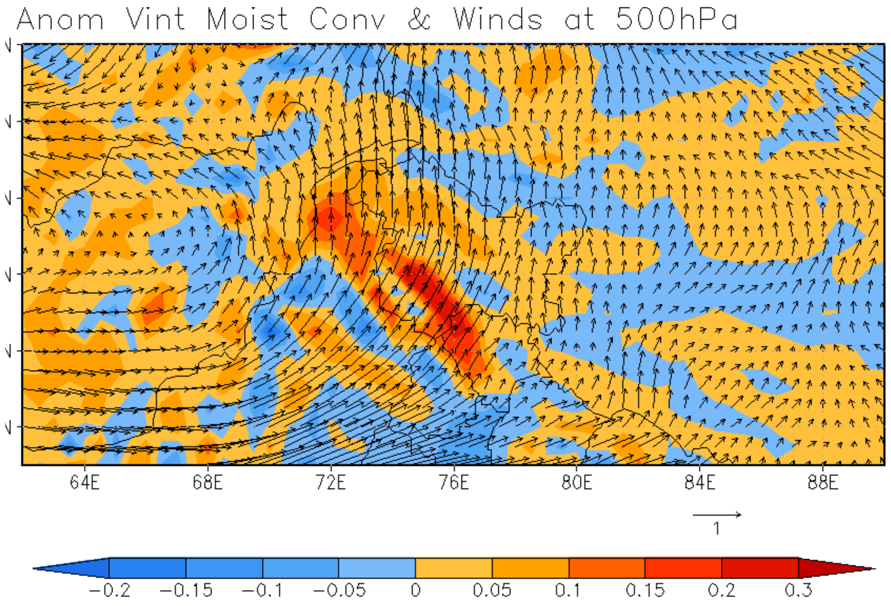












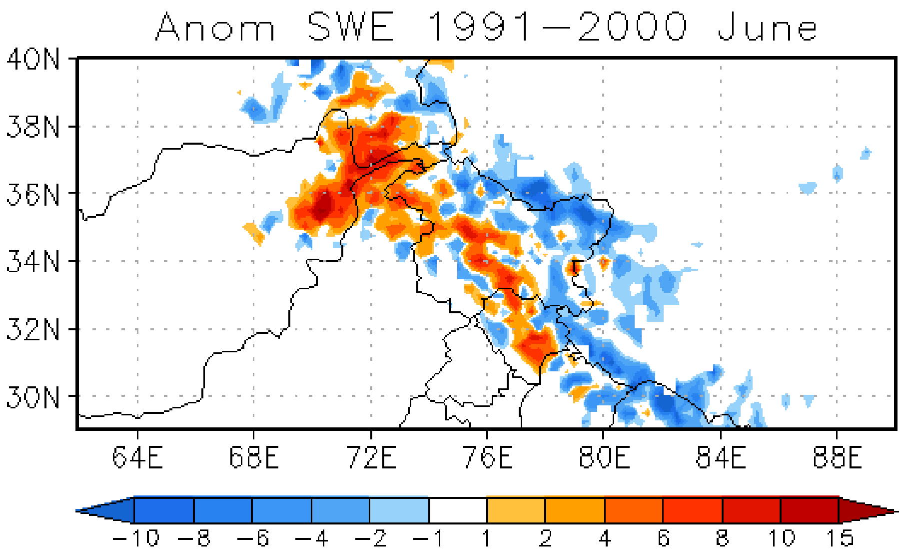
The Winter & Spring climate of Karakorum and adjoining WH in the decade of 1991-2000 is characterized by

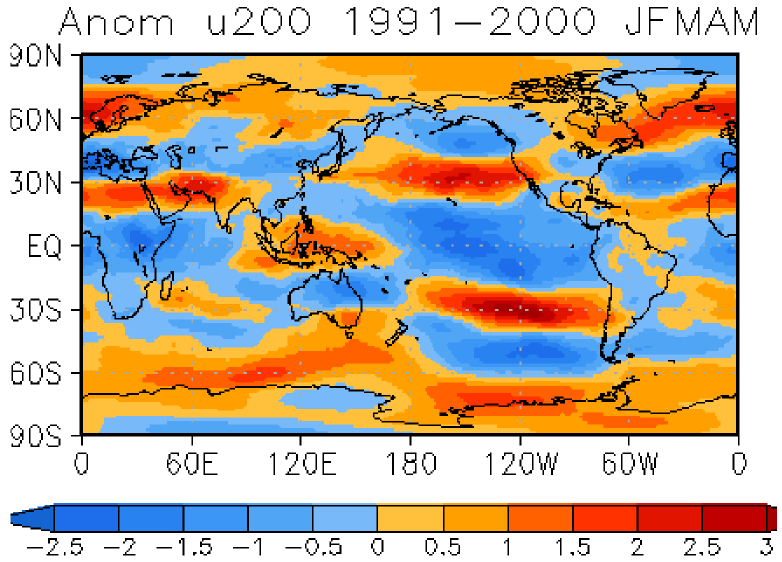
(i) Colder surface temperature anomalies

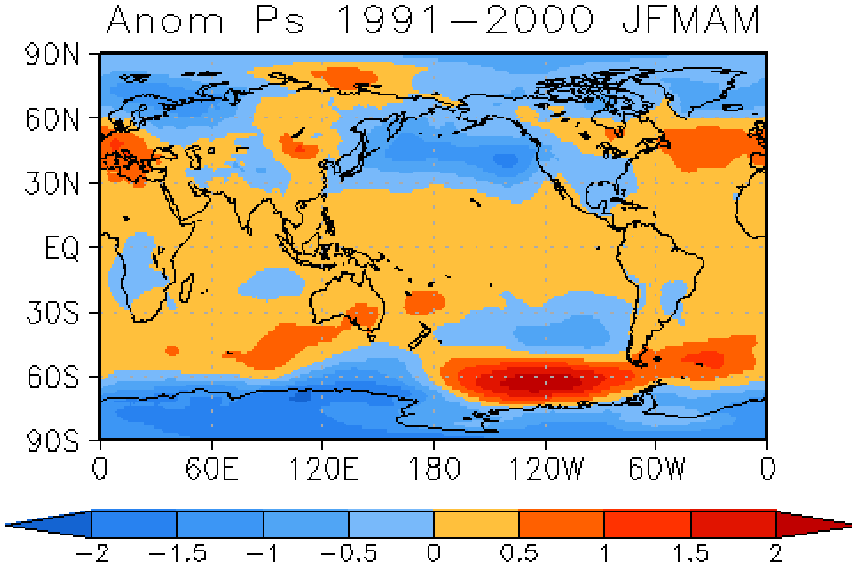
(ii) Colder upper air temperature anomalies

(iii) More amount of precipitation due to presence of a cyclonic anomaly

(iv) and more moisture convergence



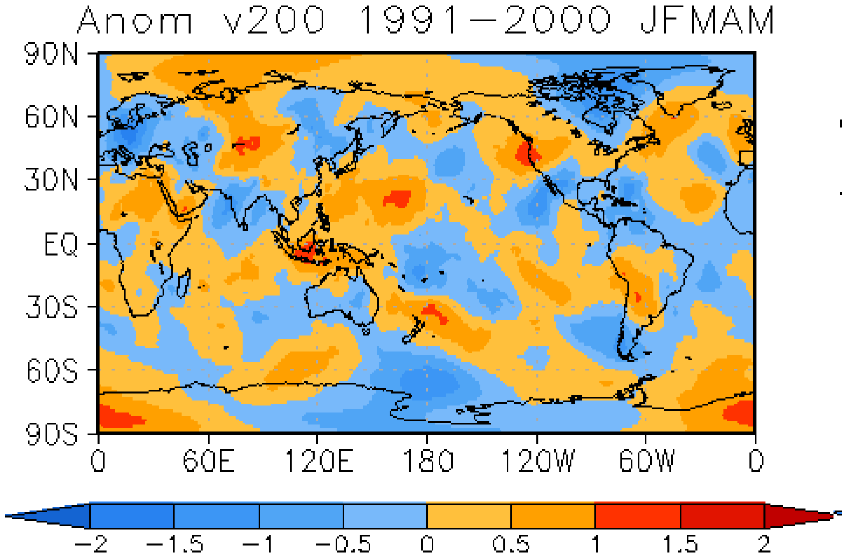


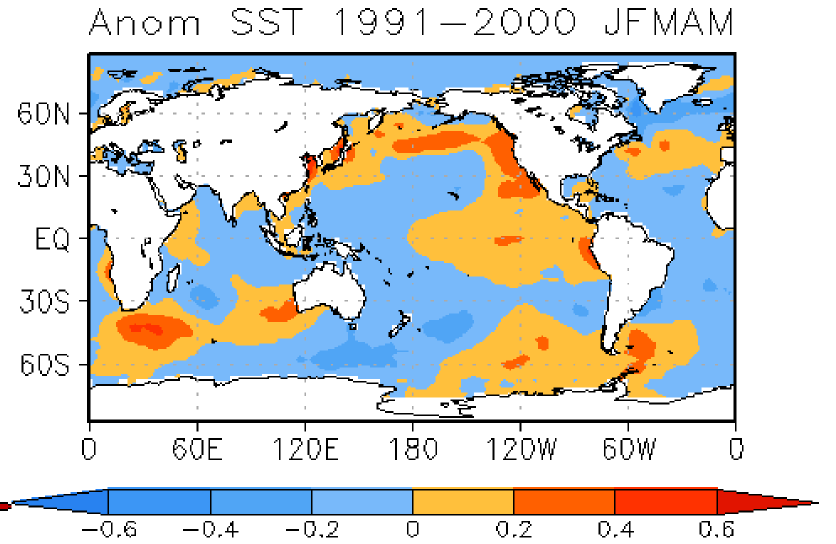


More snow was accumulating in the region by end of May or early June in the decade of 1991-2000

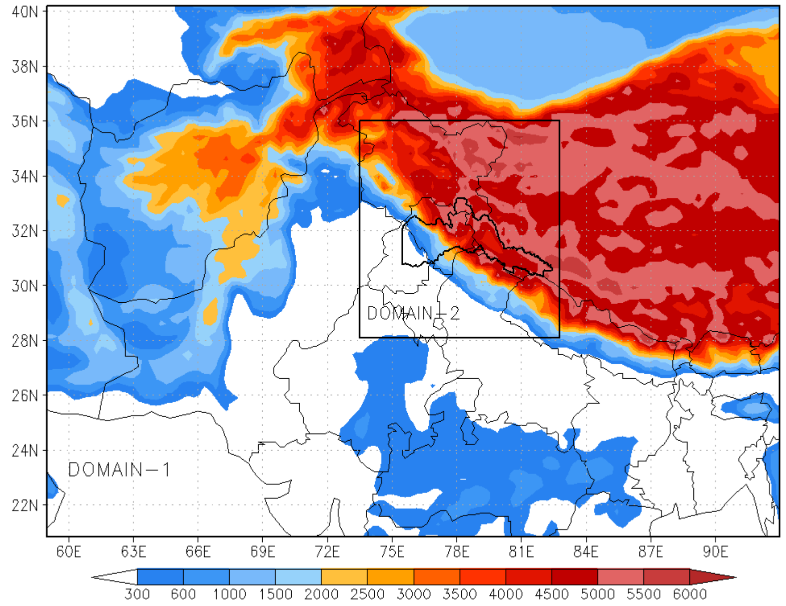
The global climate of the decade 1991-2000 was dominated by the strongest El Nino of 1997-98. Other than that the notable features are

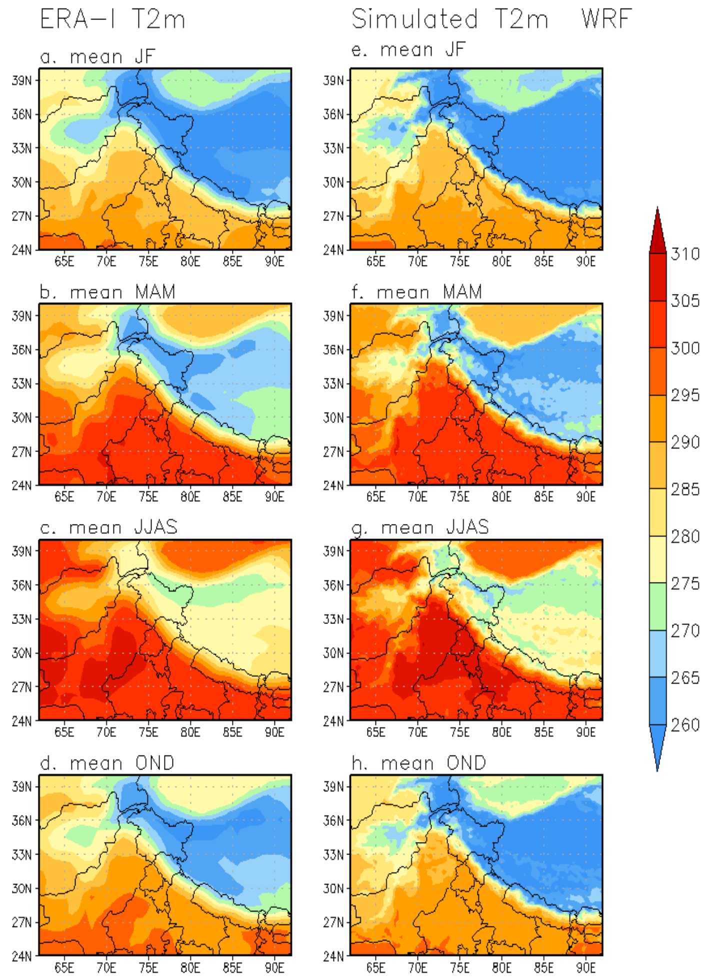
(i) Colder SST anomaly (except Nino region) and
(ii) Higher surface pressure over the Tropics

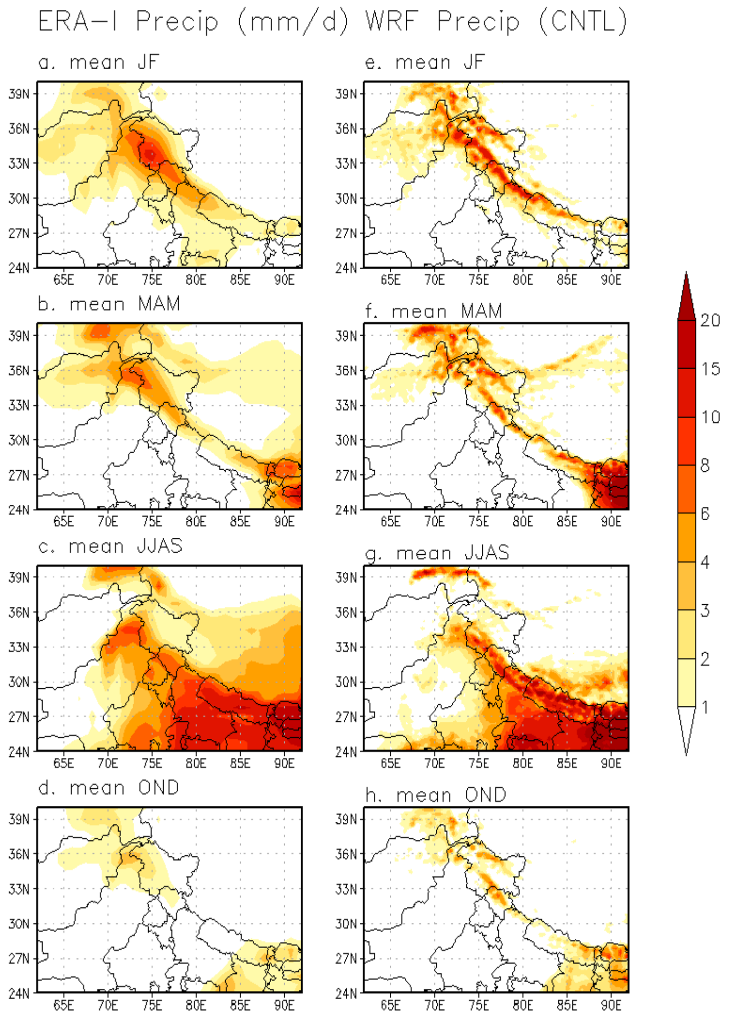




Dynamic Downscaling using WRF Model







The WRF model was configured for Western Himalayas and simulation runs were carried out following various strategies.

Sensitivity Experiments were carried out using various convection and cloud microphysics parameterization schemes

Simulated climate is reasonably good and agrees with reanalysis data (ERA-Interim)

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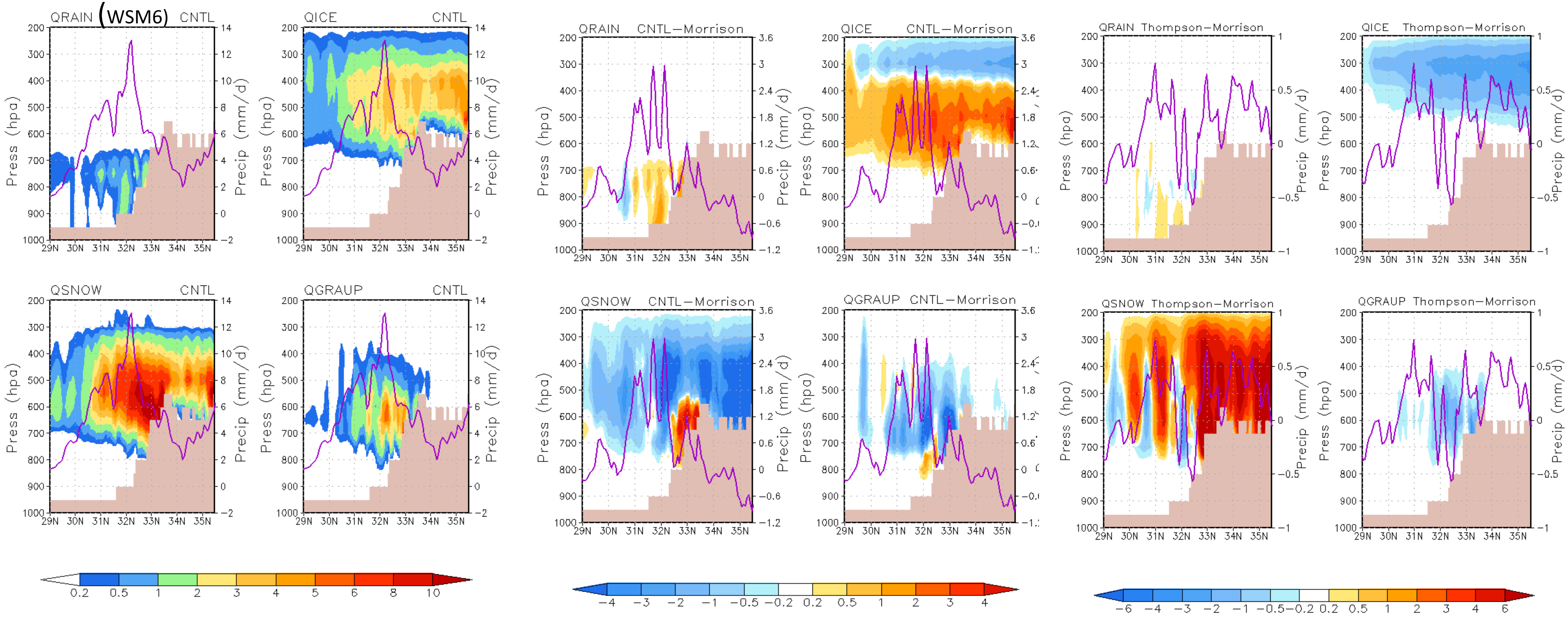
Sensitivity Modeling with Cloud Microphysics Schemes



Mixing Ratio of hydrometeors (Rain, Snow, Ice or Graupel) in the atmosphere over high mountain region of the Himalayas

Model simulations of amount and location of Snowfall or Rainfall depends on the Cloud Microphysics scheme

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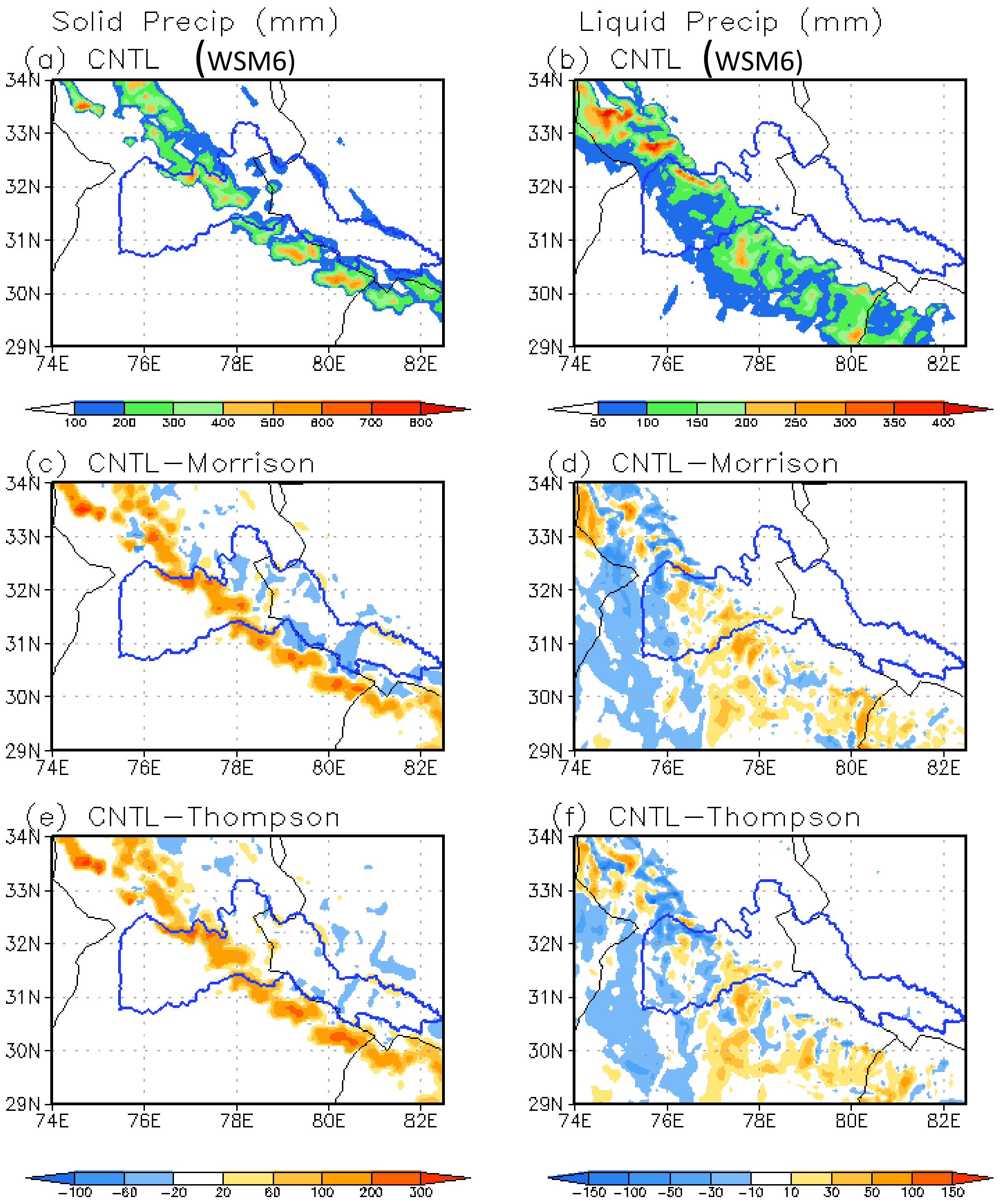

Specification of cloud microphysics scheme decides if snow and rain occur on the lower/middle altitude regions of high mountains or even at higher altitudes

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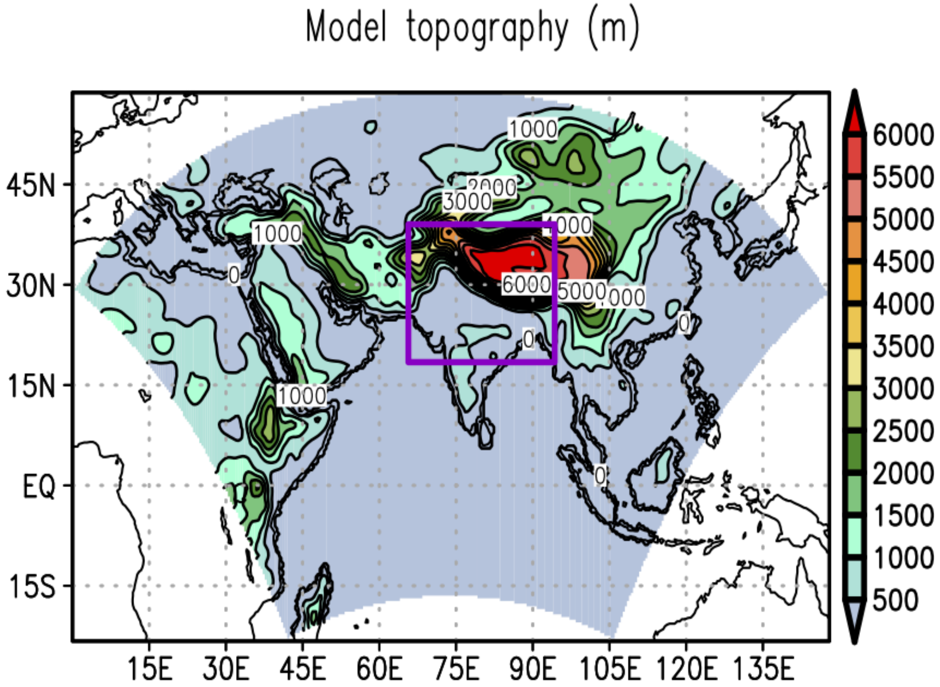
Dynamic Downscaling using Regional Climate Model (RegCM)



The RegCM (version 4.1.1) was configured for the Himalayas and simulations carried out for winter seasons of 28 years using reanalysis as well as global model simulations as initial and boundary conditions.

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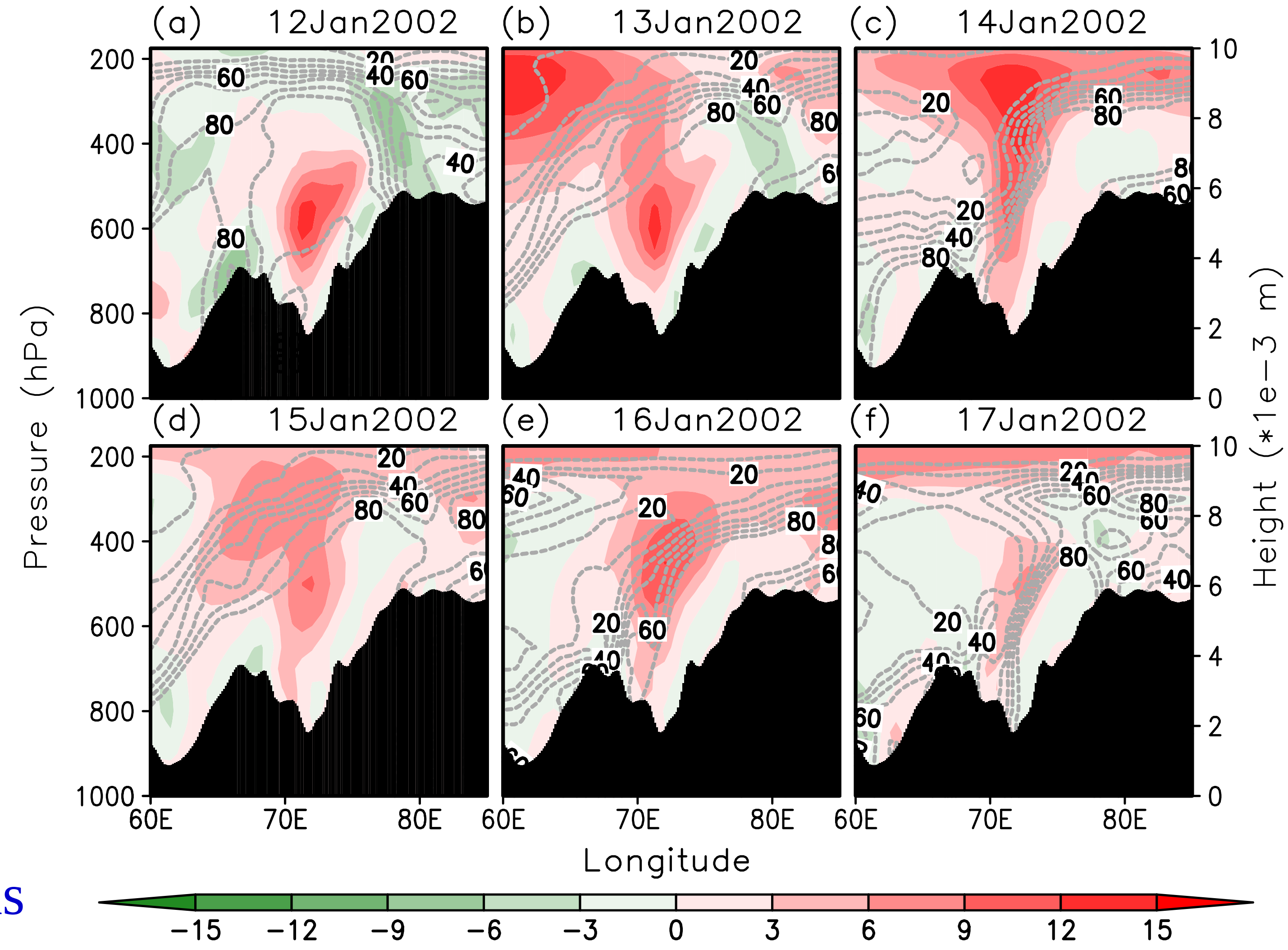
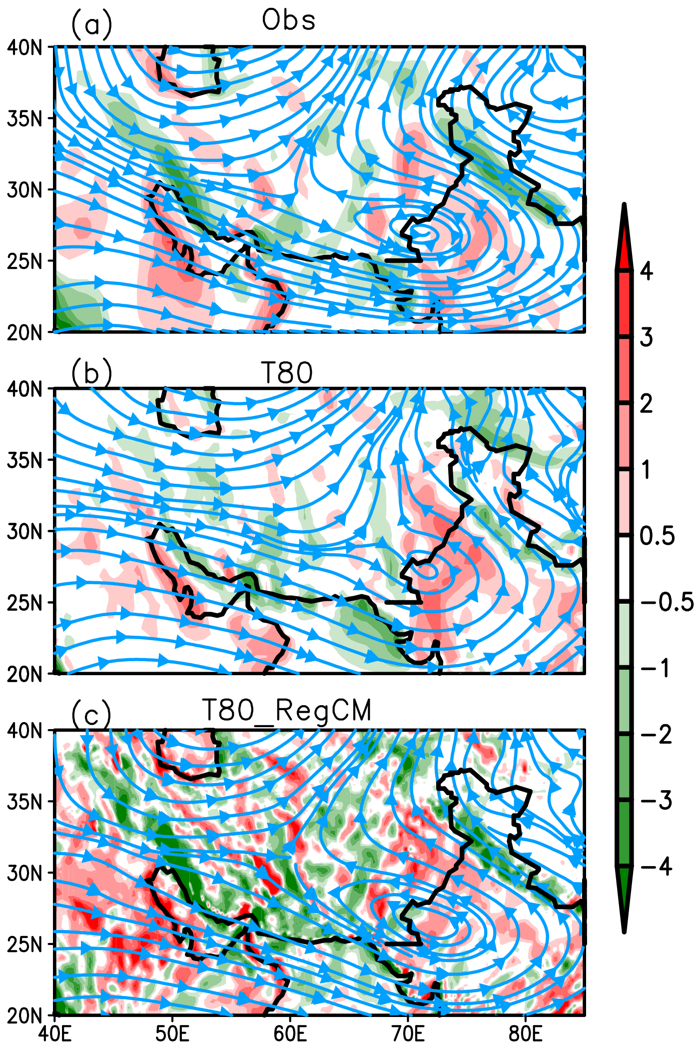
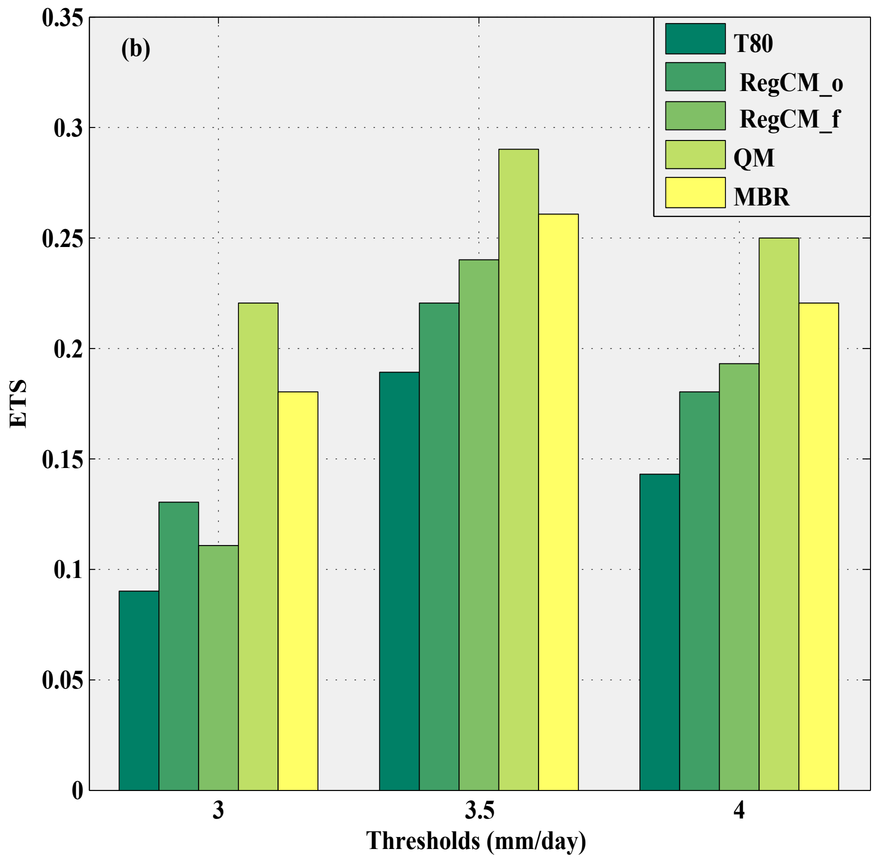


Longitude–height distribution of vorticity (*1e-5/s; shaded), relative humidity (%; broken contour), and topography (*1e-3 m; shaded bar, right-hand vertical axis)



Difference between seasonal mean (DJF) wet- and dry-year composites of vertical integrated moisture flux (shaded) and transport (streamlines) in (a) observation, (b) T80, and (c) T80 and T80_RegCM) simulations



Bias Correction: Quantile mapping technique (QM) & Mean Bias Removal

Equitable threat score (ETS) computed for T80_RegCM and two bias correction methods (QM & MBR) for winter season.

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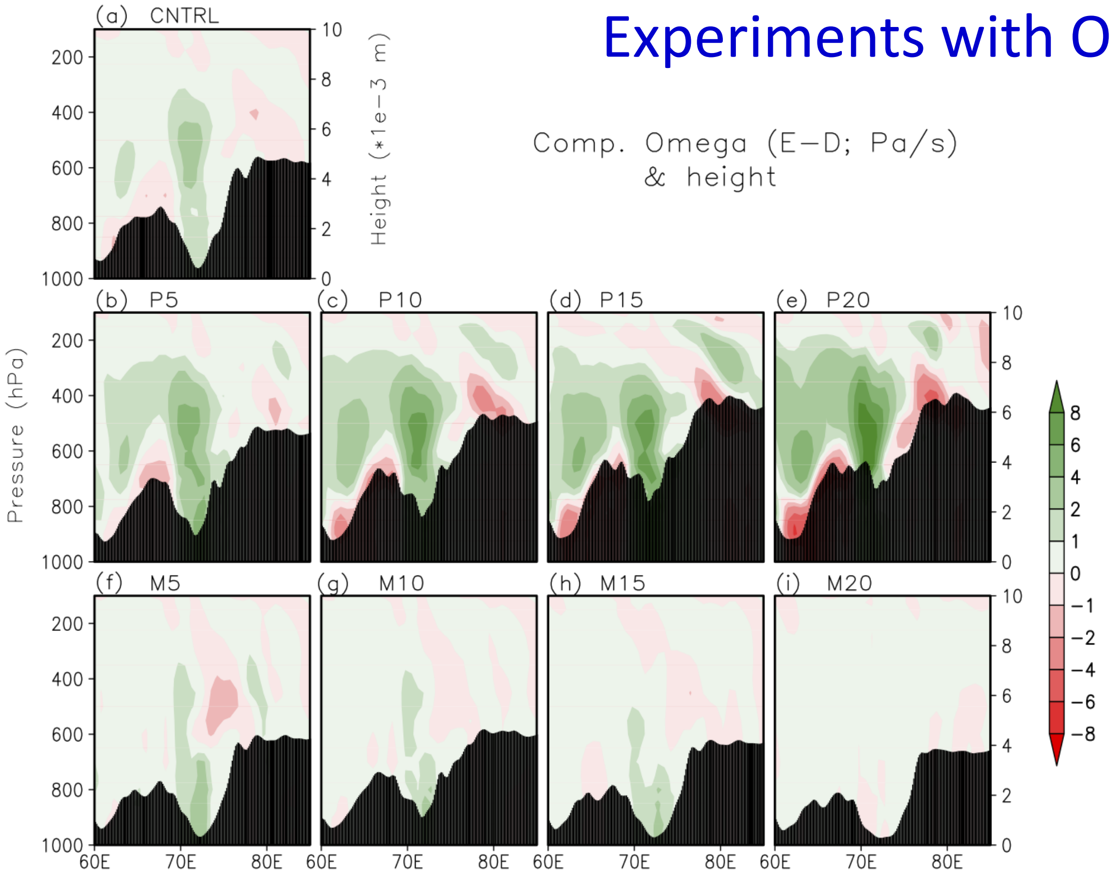
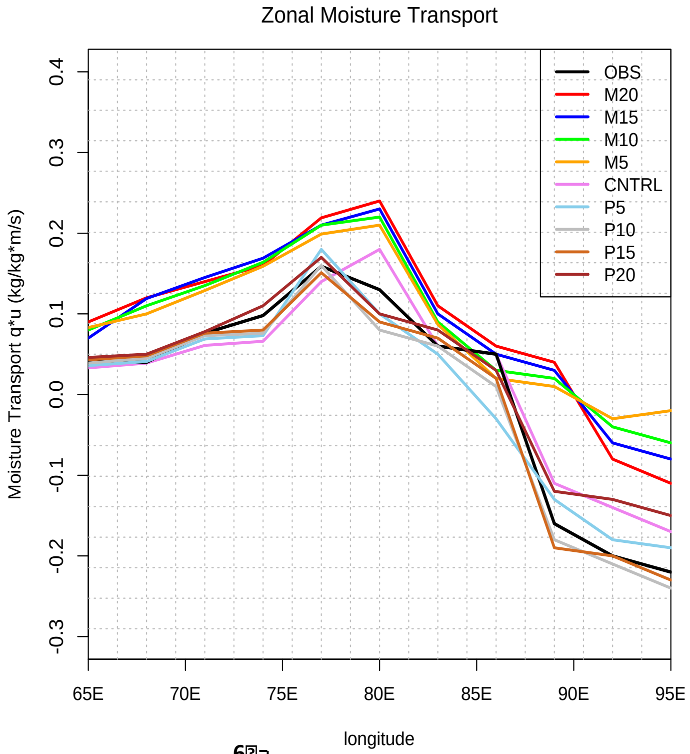
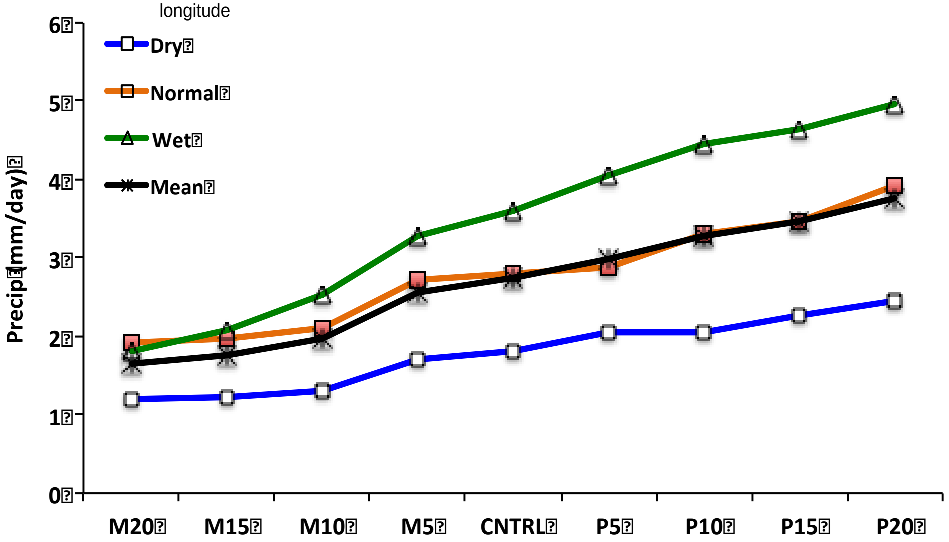
Experiments with Orography height



Longitude–height distribution of the differences between seasonal mean (DJF) wet- and dry-year composites of vertical velocity (Pa/s; shaded) and topography (*1e-3 m; shaded bar, right-hand vertical axis) in at 35°N latitude



Sectorial (27ºN-38.5ºN) seasonal mean (DJF) differences between wet- and dry-year composites of zonal moisture transport at 500hPa obtained form observation and different Himalayan orography representations



RegCM4 simulated area averaged (72°E-81°E; 29°N-37°N) seasonal (DJF) mean precipitation

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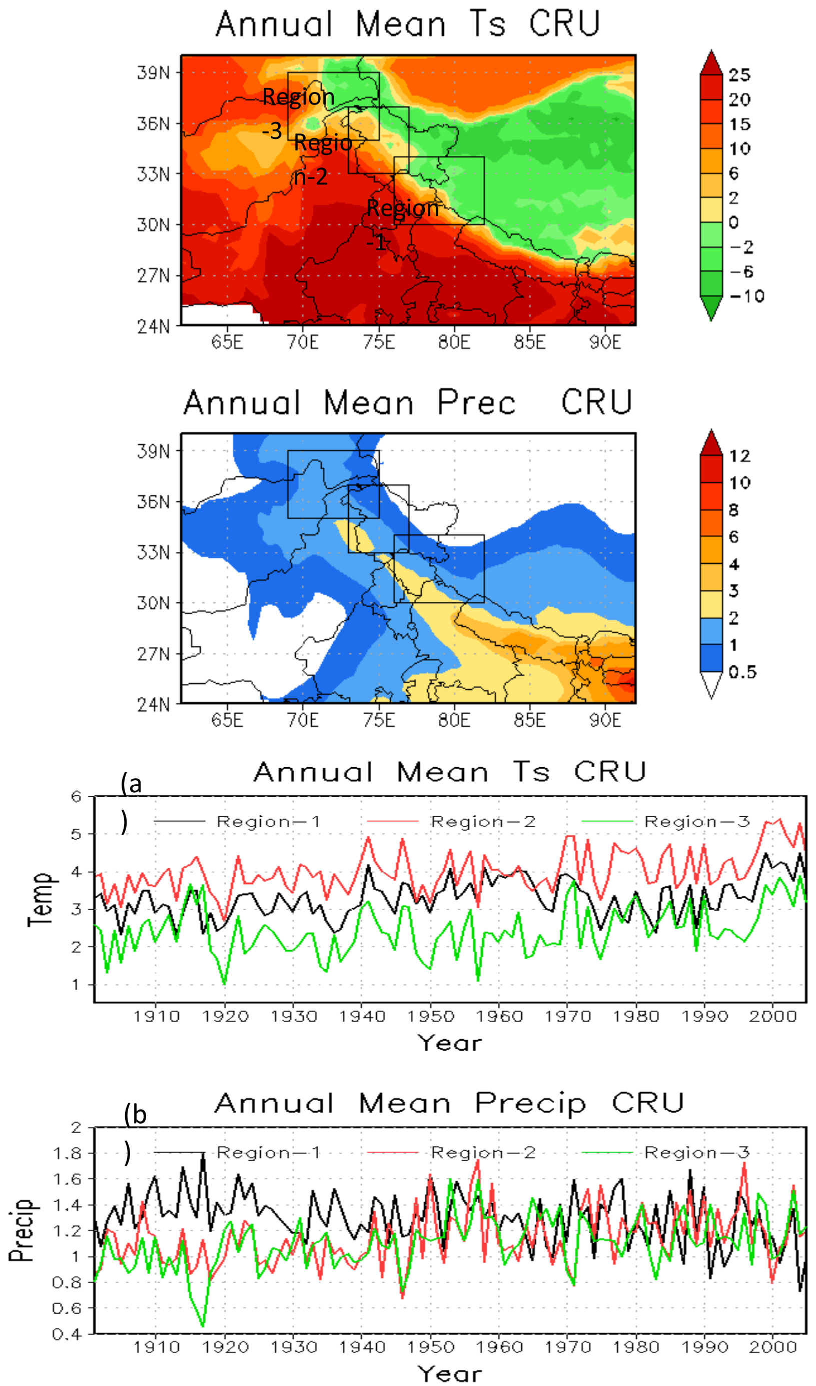
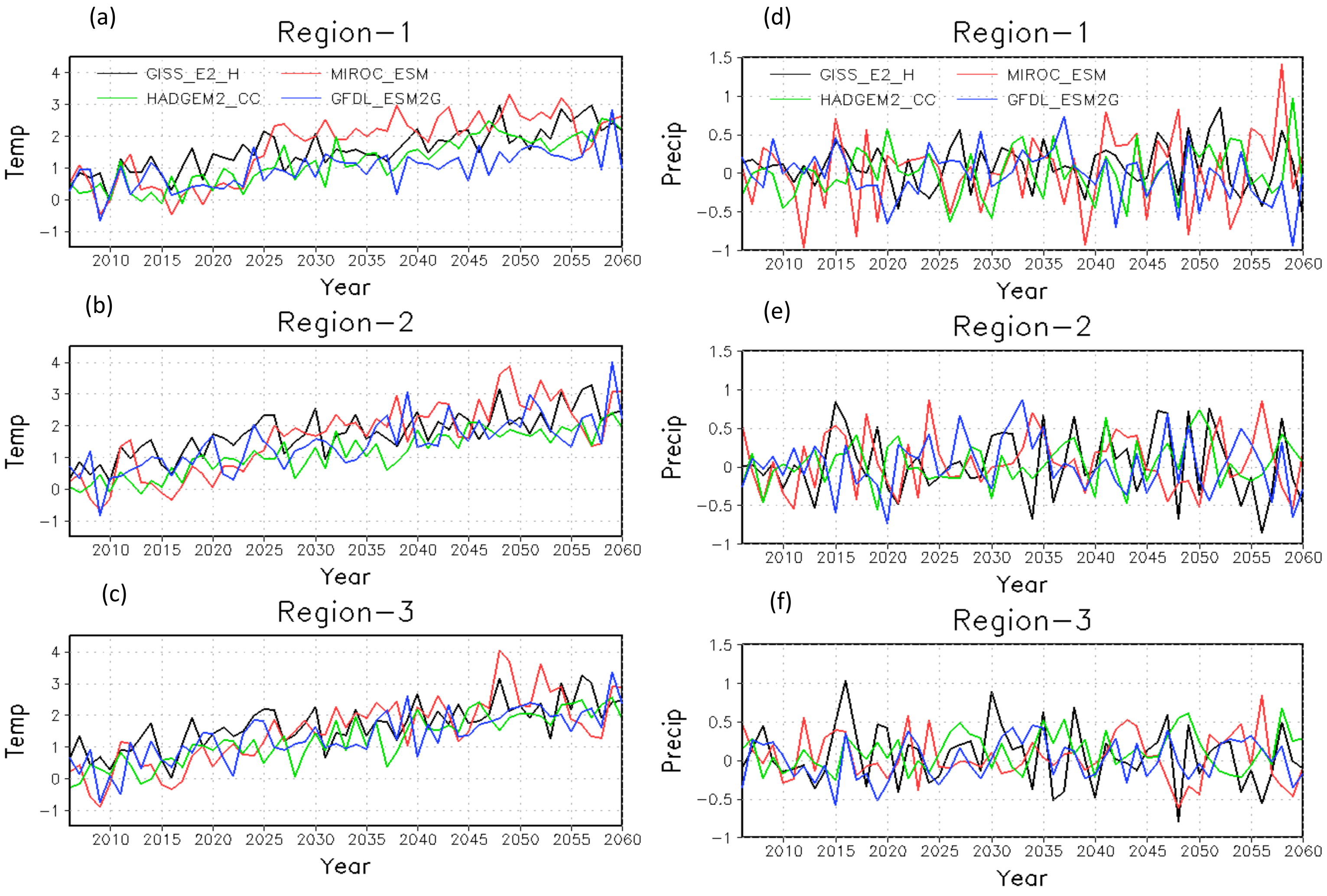
Mid-21st Century Climate Projections over Western Himalayas





Temperature and precipitation trends in various models in RCP4.5 scenario from 2006 to 2060: temperature trend (a) Region-1; (b) Region-2 and (c) Region-3; precipitation trend (d) Region-1; (e) Region-2 and (f) Region-3

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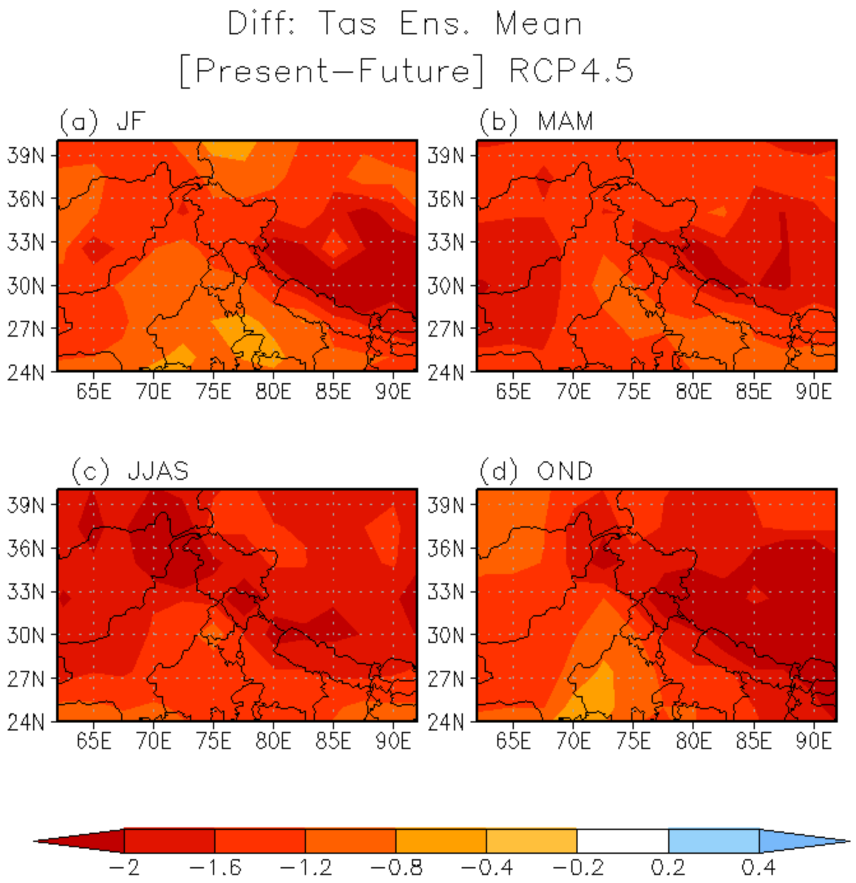

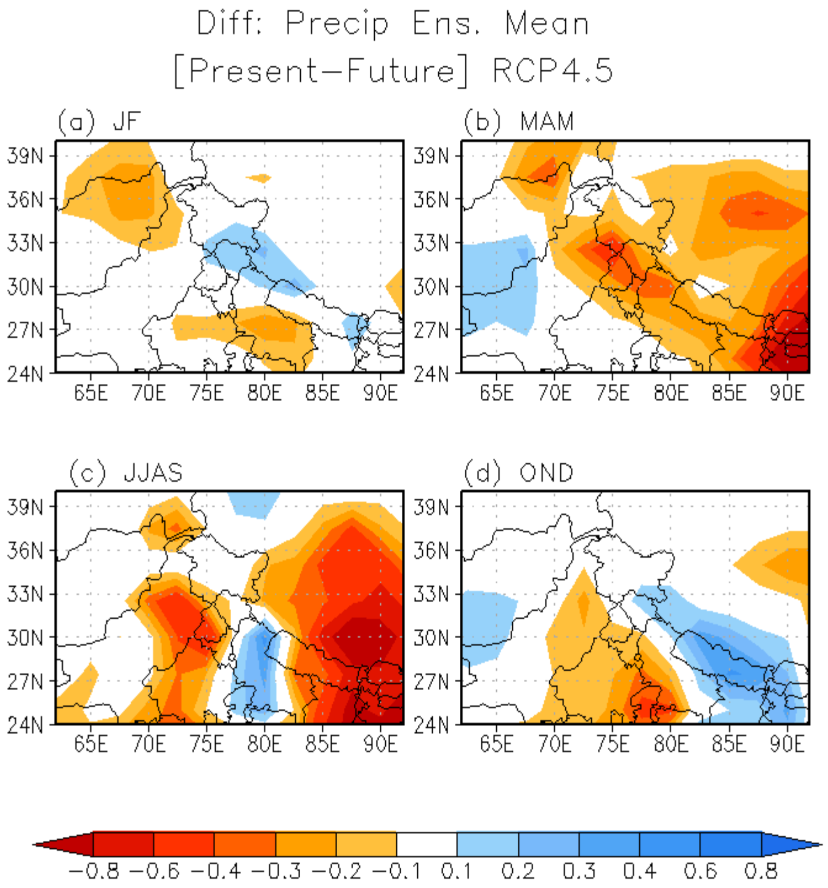

Multi-model ensemble mean difference in surface air temperature (°C) and precipitation between present climate (2001-2005) and mid-21st century projections (2051-2055) in RCP4.5 scenario

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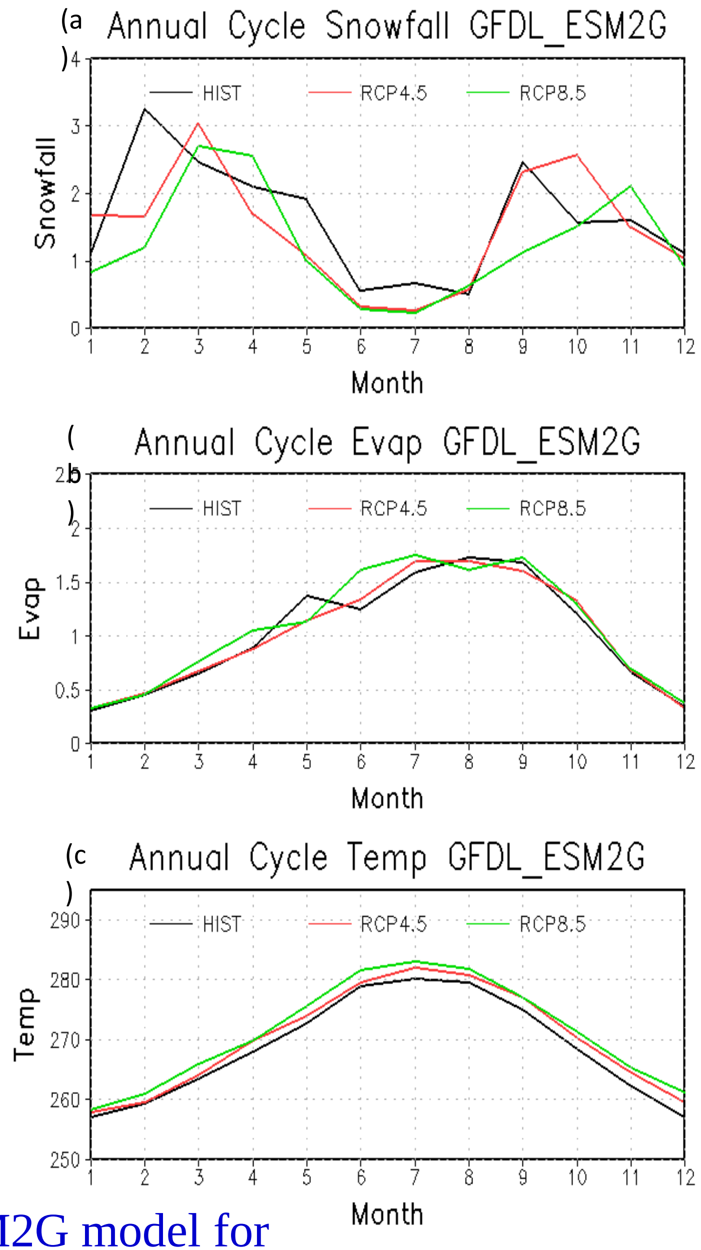
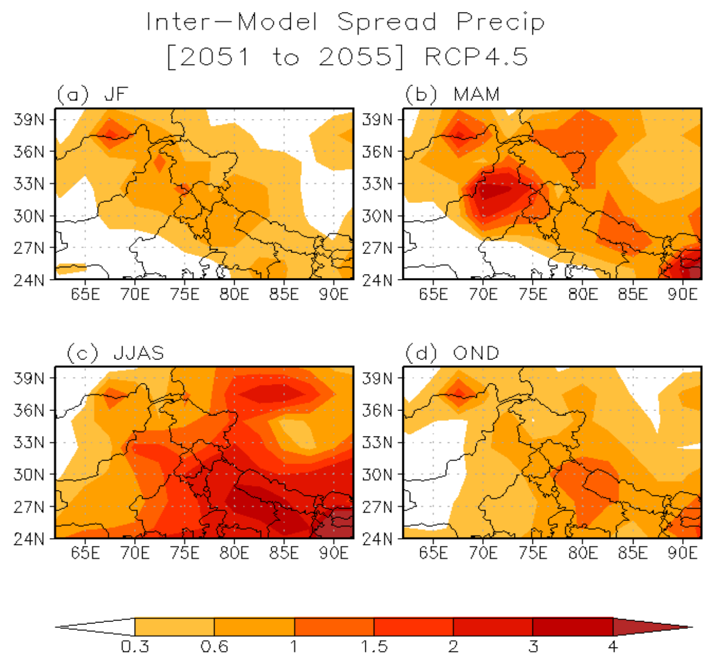
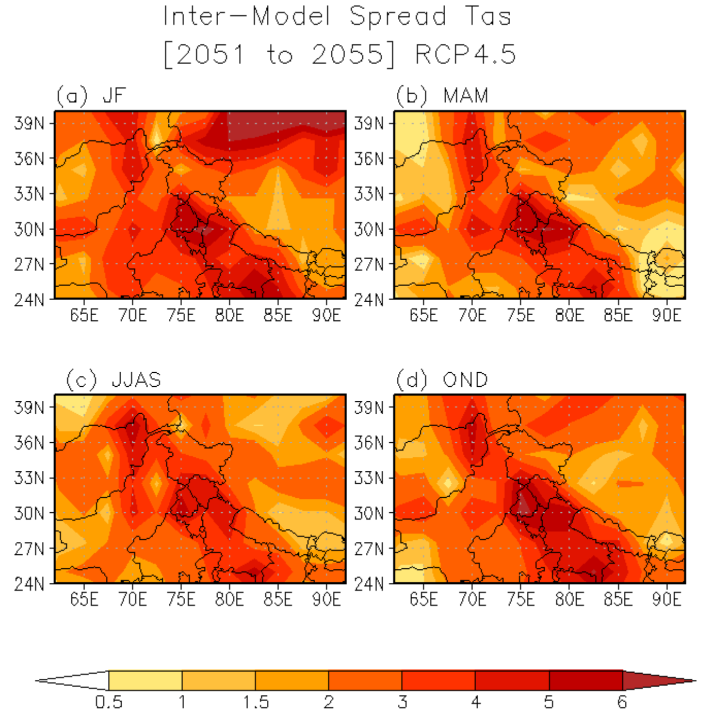


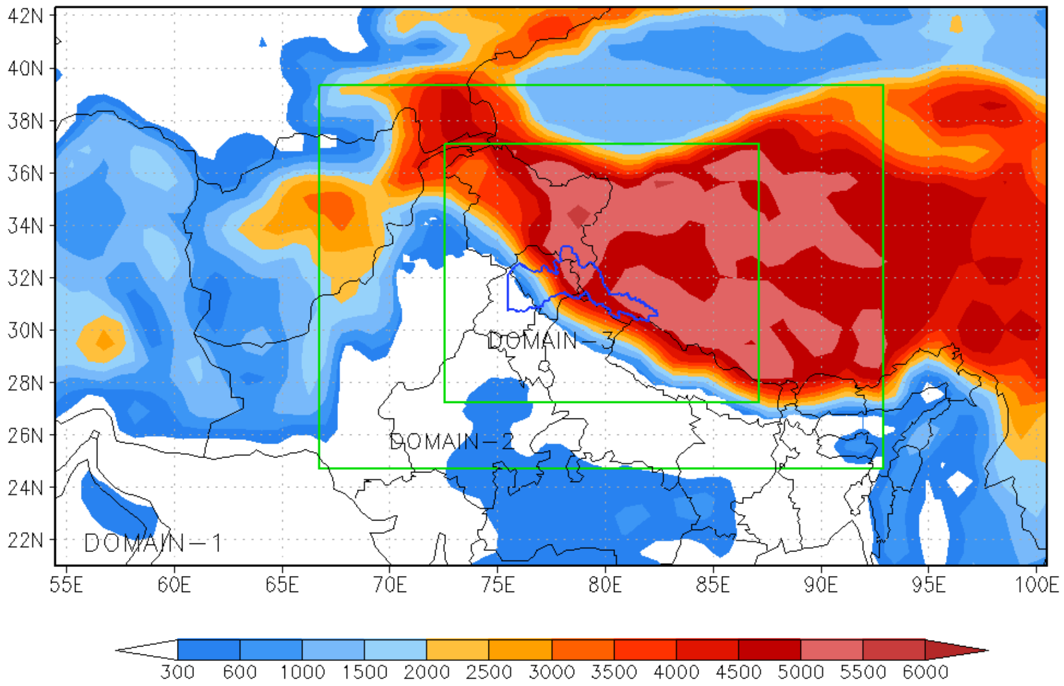
Annual cycle over Region-1 from GFDL_ESM2G model for runs with historical forcing (2001-2005), RCP4.5 and RCP8.5 forcing (2051-2055)



Precip Spread



Temp Spread



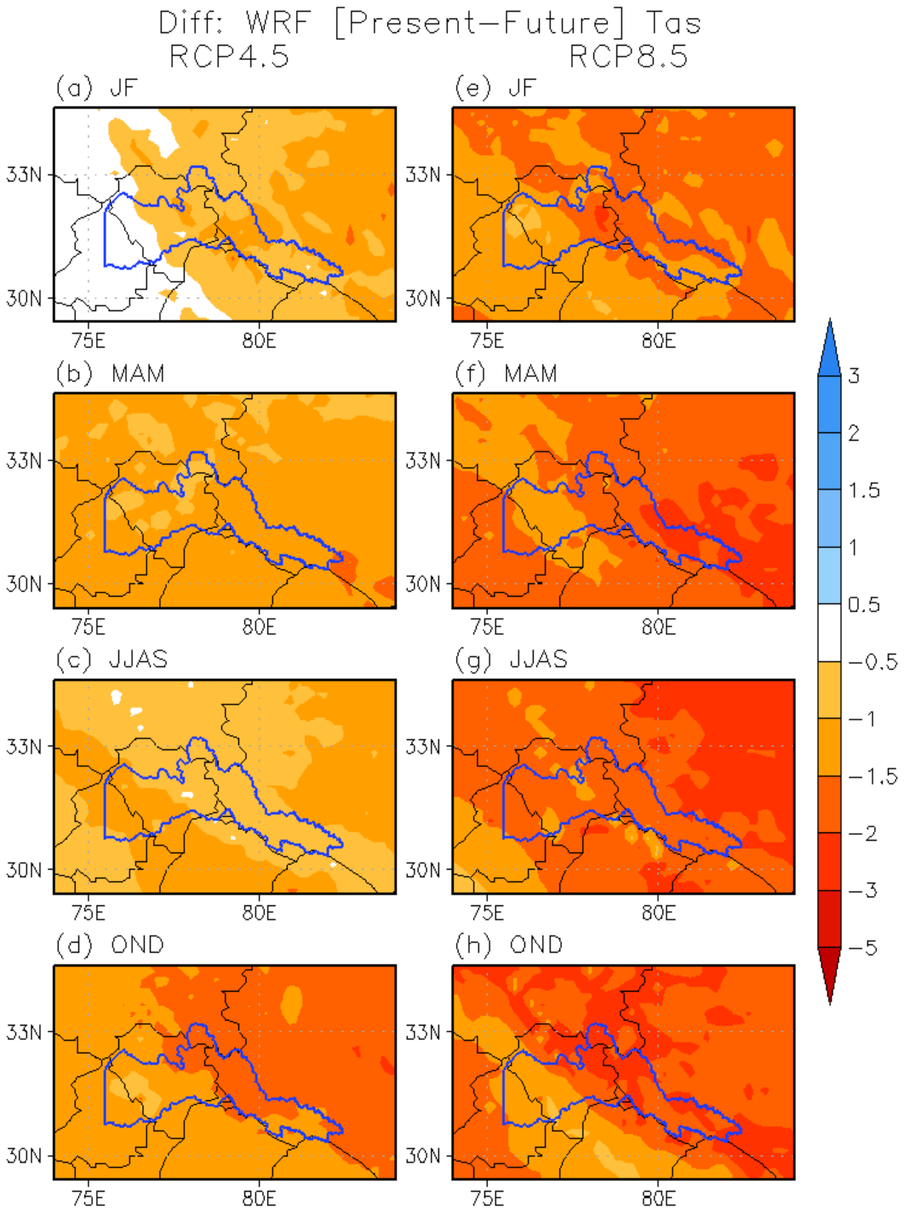
The GFDL ESM2G Model products were downscaled using the WRF model (72km, 24km and 8 km) for

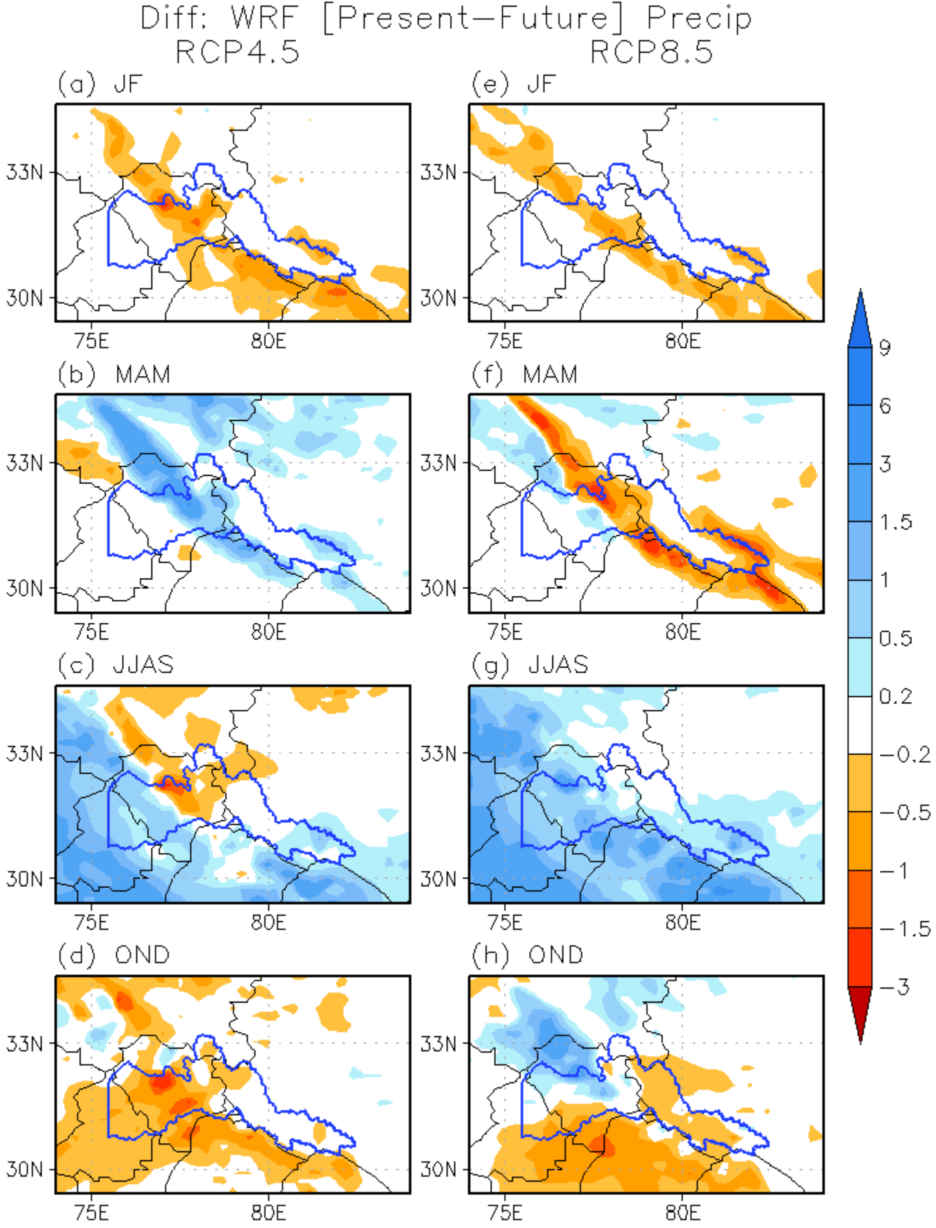
(i) Present Climate 2001-2005

(ii) Future Climate (RCP4.5) 2051-2055

(iii) Future Climate (RCP8.5) 2051-2055

Inter-model ensemble spread for surface air temperature and precipitation in mid-21st century projections (2051-2055) in RCP4.5 scenario

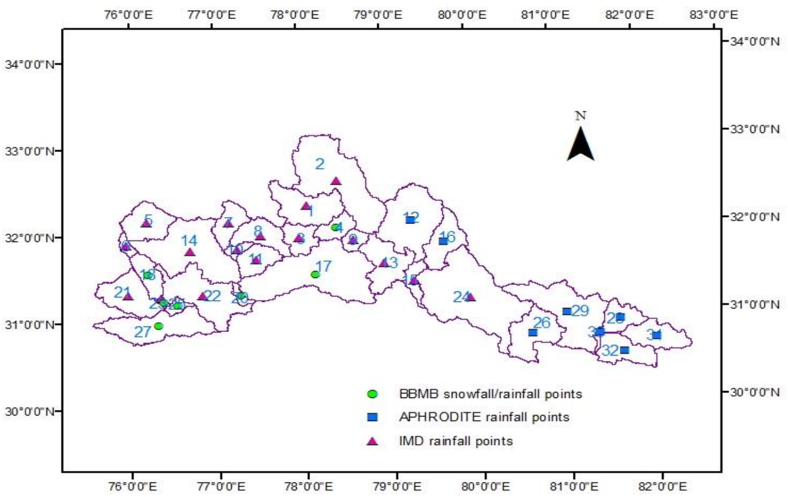


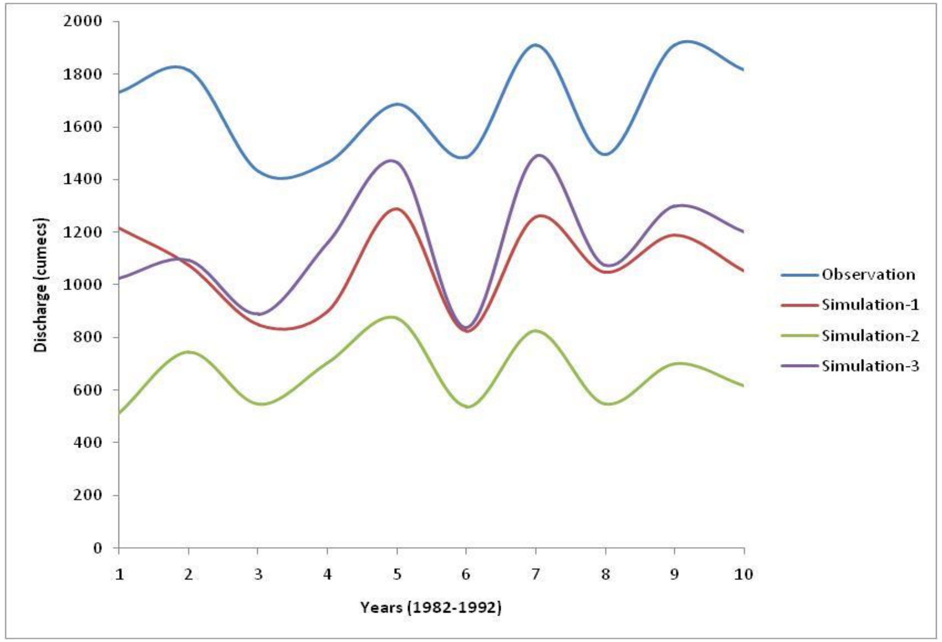


Difference in surface air temperature and precipitation between present climate (2001 to 2005) and mid-21st century projections (2051 to 2055) for the downscaled projection using WRF model

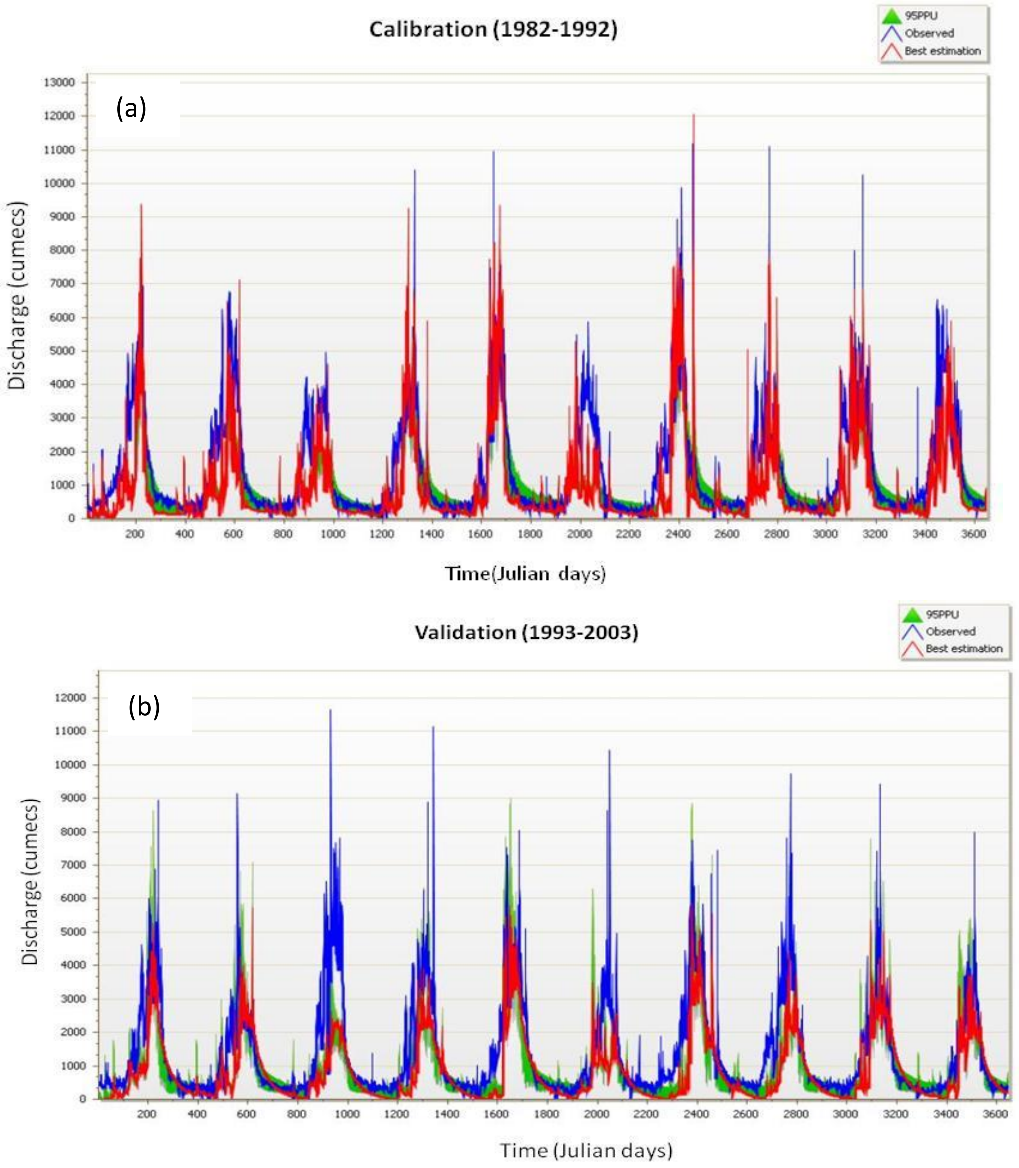
Snowmelt Runoff Modeling in Satluj River Basin

SWAT model was configured for Satluj basin. Experiments carried out using various combinations of observed precip and temp data





Annual mean of observed discharge and model simulated discharge from the three experiments at Bhakra station from 1982 to 1992.



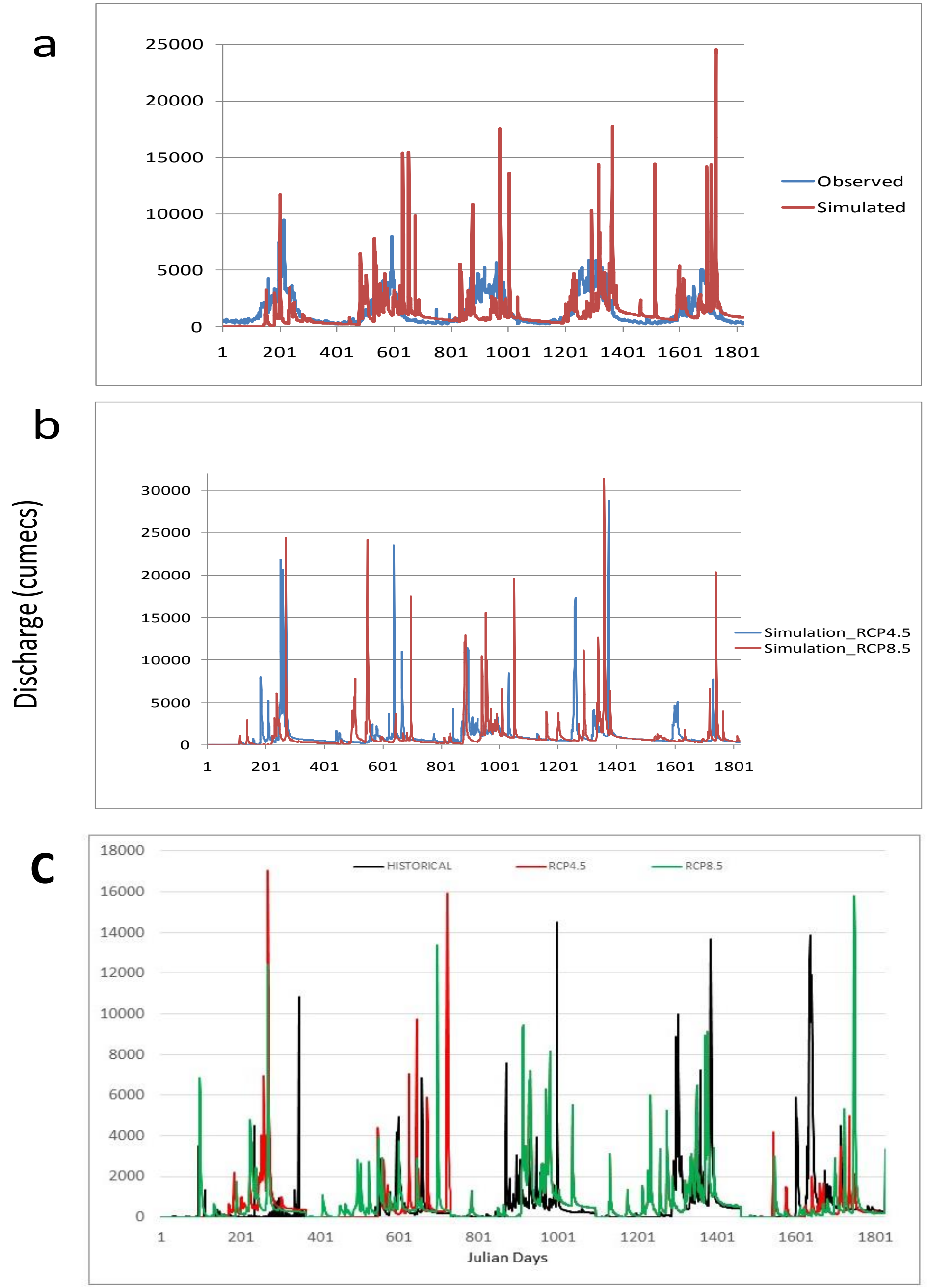
Observed and model simulated discharge at Bhakra station during (a) calibration and (b) validation periods.

Simulated discharge from Satluj River using SWAT model with GFDL_ESM2G meteorological forcing for

(a) Historical (2001-2005) and observed discharge;

(b) RCP4.5 (2051-2055); and

(c) downscaled GFDL_ESM2G (using WRF model) With Historical (2001-2005) and future climate (2051-2055) under RCP4.5 and RCP8.5 scenarios.



Summary

- Downscaling of the climate of Himalayas has been attempted
- Importance of model resolution, physical parameterization as well as orography height has been highlighted
- These results will be useful for a prediction system under WMO GFCS for the Himalayan region.
- Major changes in streamflow in Satluj River are expected by mid-21st century.

Thank You