Science and Training Workshop on Climate Change over the HMA, Pune, 9 – 12 October 2018

High resolution global climate modelling for the Himalayan region

Sabin TP

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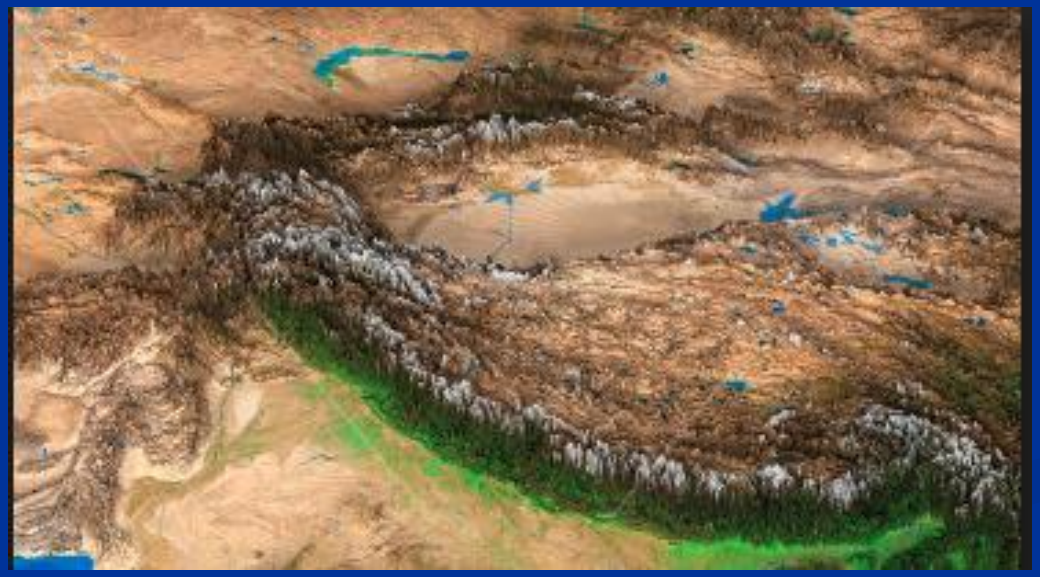
This talk will try to cover….

- Inference from CMIP5 models over Himalaya
- Why we need a high resolution simulation
- Two high resolution approach
  1) LMDZ (35 km over south Asia)
  2) IITM-GFS (27 km global)
- Summary

The Great Himalayas….

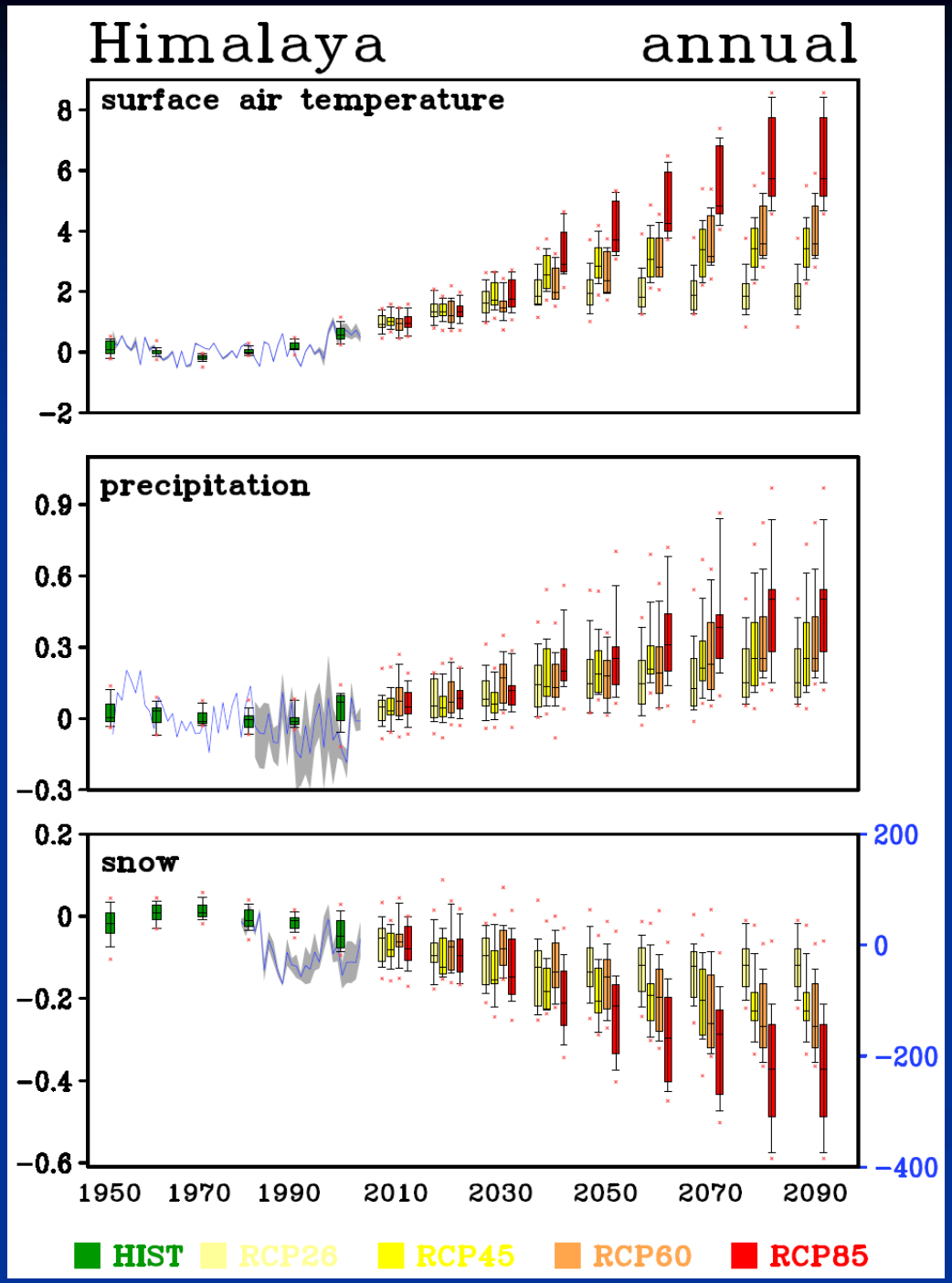
The Himalayas stretch around 3 km between eight countries across Asia, is the world's tallest mountain range. In addition to Mount Everest, the range also features several other mountain peaks over 8 km.

This region is the source of the 10 major river systems that provide irrigation, power and drinking water for over 1.5 billion people in Asia – nearly 20% of the world's population.



Observational and model results suggest that Himalayan mountains produce a strong monsoon by insulating warm, moist air over continental India from the cold and dry extra-tropics.

Due to its complex terrain features and wide thermal and dynamical role proper representation of the Himalayan mountain range is having profound importance in simulating the regional weather of entire South Asia.



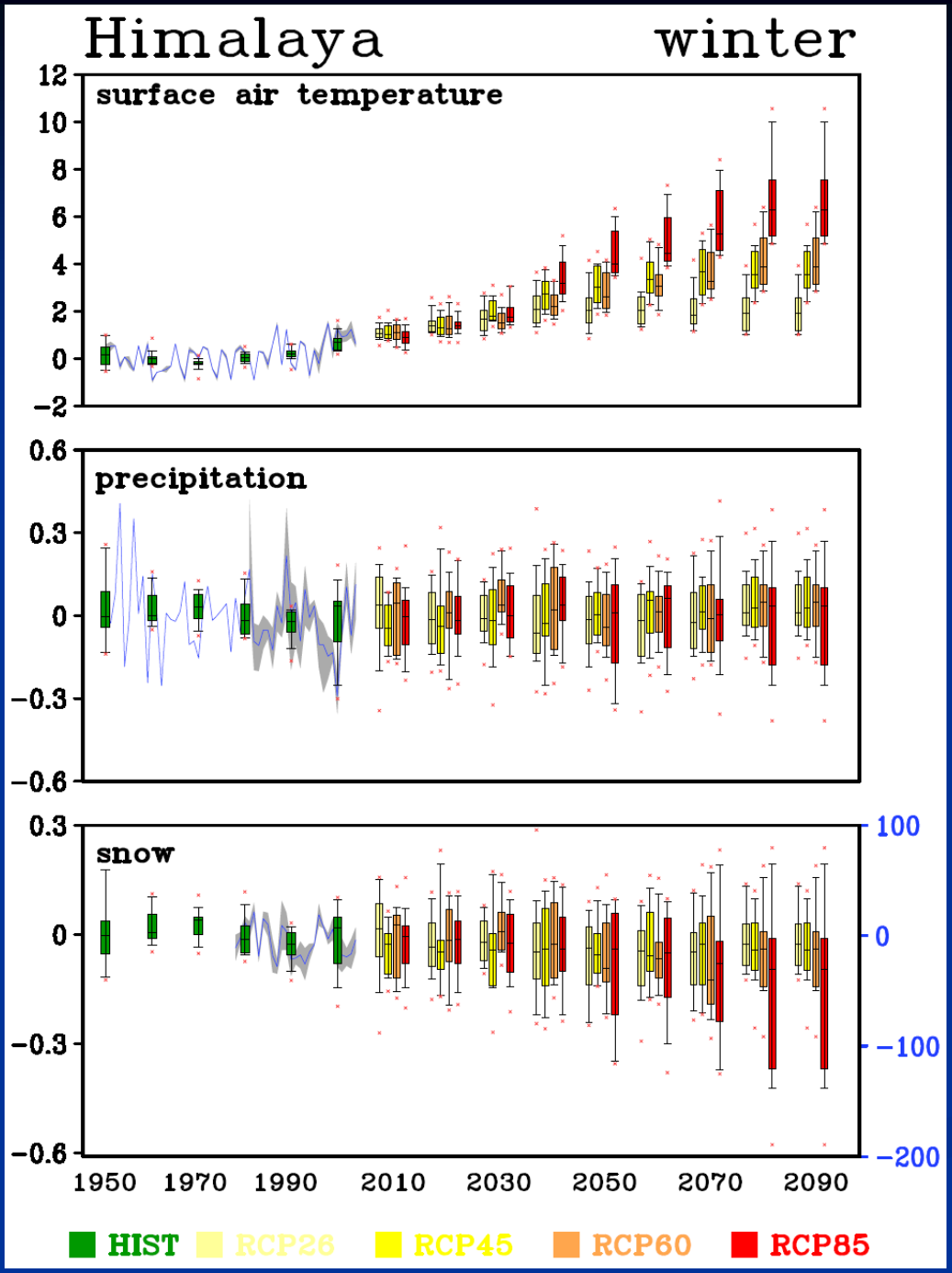
CMIP5 Perspective …

The annual average temperature changes with respect to present day mean, clearly shows a consistent increase in surface temperature over the Himalaya from present day and 4 future scenarios.

Overall, there is an increase in annual precipitation if we consider the entire Himalayan region, which is consistent among RCP2.6 RCP4.5 RCP6.0 and RCP8.5

The snow observation is based on the area cover from NSIDC data

The snowfall is projected to be decreasing throughout the 21st century, in which RCP4.5, RCP6.0 and RCP8.5 shows a significant decline.



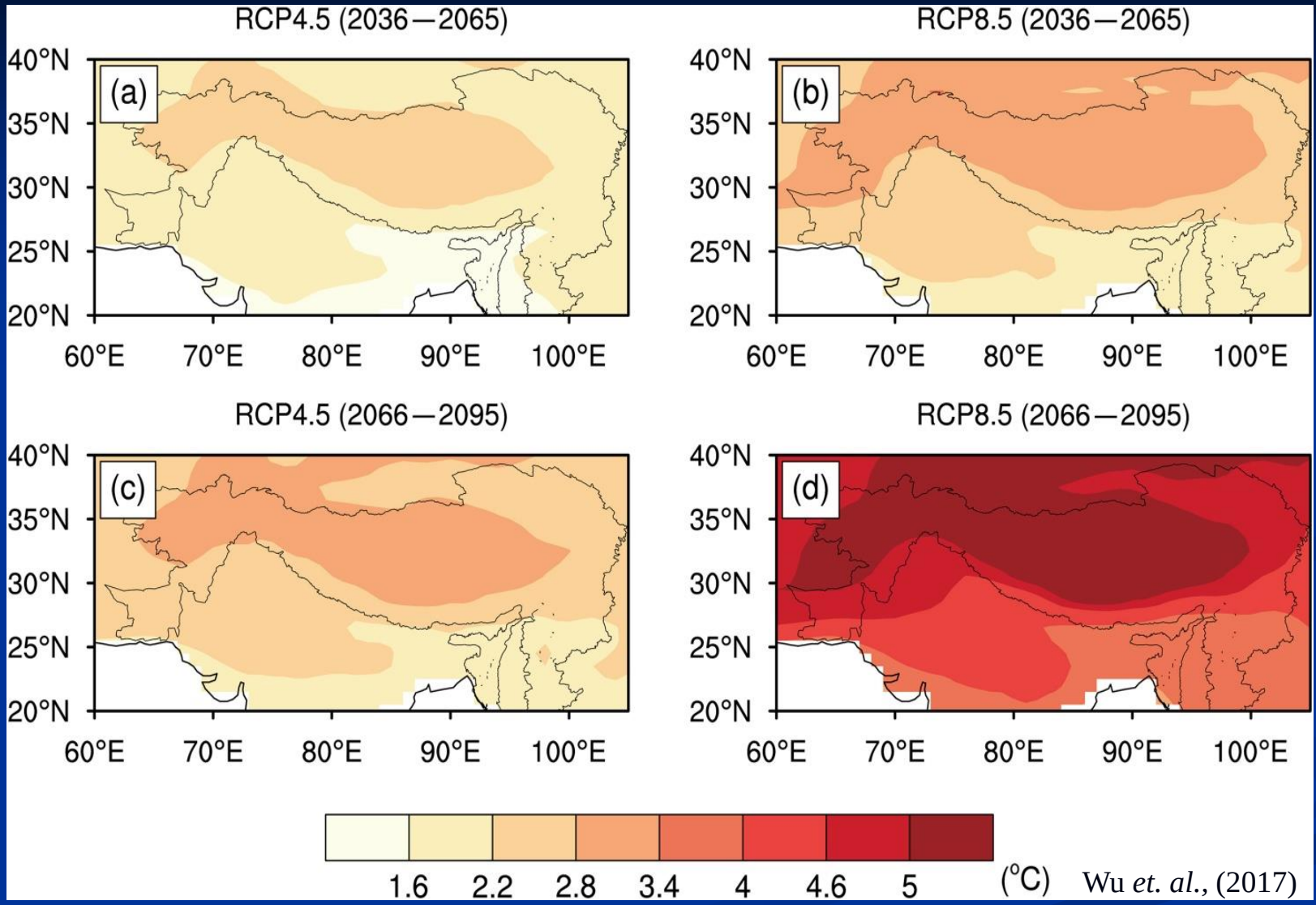
CMIP5 Perspective …

During the northern hemisphere winter as well the mean temperature rise is very clear and consistent in different scenarios.

But the CMIP5 models shows not much change in observed precipitation pattern during the winter for the entire Himalayan range.

Relatively less decrease is noted in RCP2.6, 4.5 and 6.0 while the extreme scenario (RCP8.5) project a decline in wintertime snowfall by the end of the 21st century.

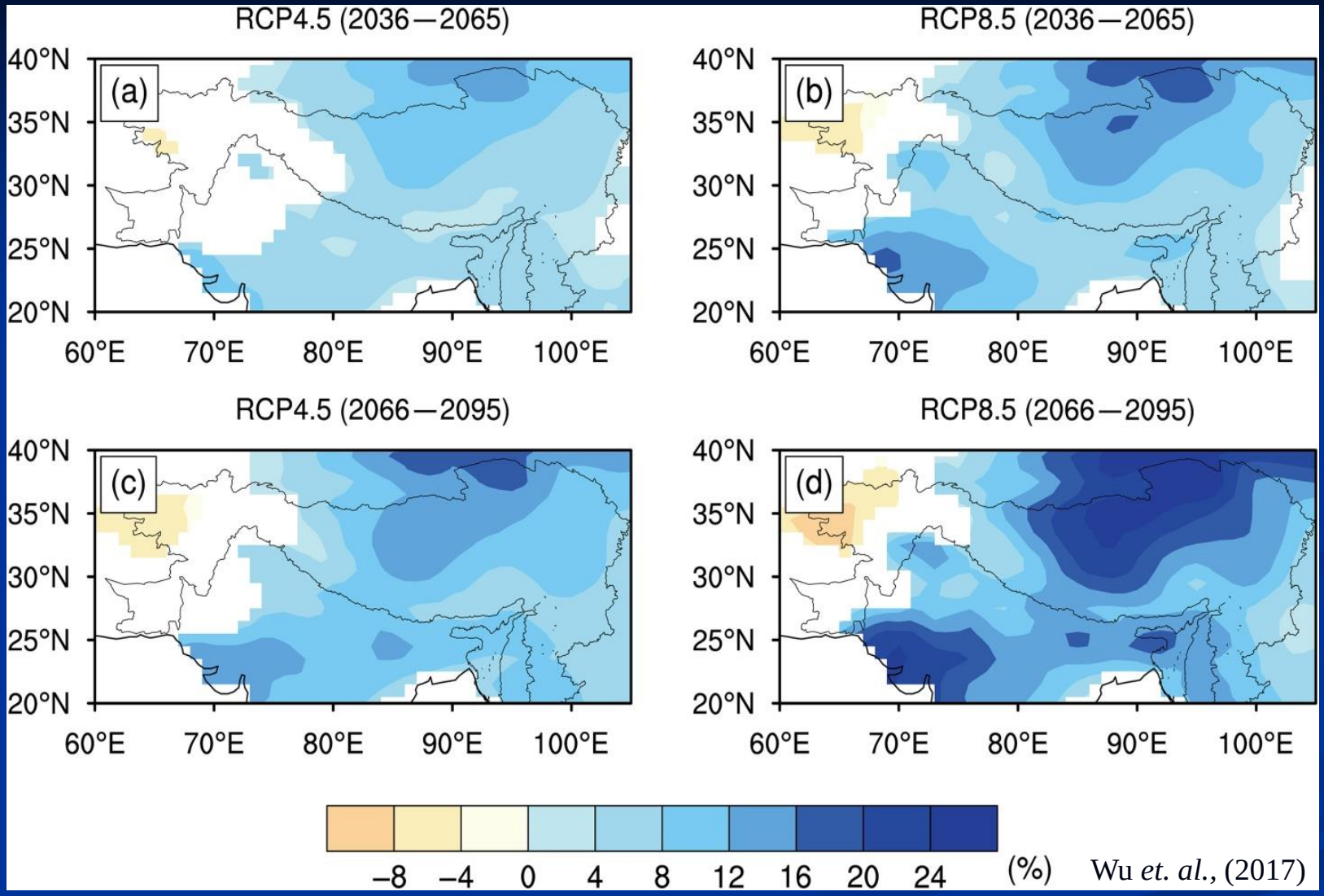
Change in surface temperature (CMIP5)…



Wu *et. al.*, (2017)

The projected multimodal ensemble mean changes in surface air temperature for near and far future under RCP4.5 (a, c) and RCP8.5 (b, d), relative to 1976–2005.

Change in precipitation (CMIP5) …



Wu *et. al.*, (2017)

The projected multimodal ensemble mean percentage changes in precipitation for near and far future under RCP4.5 (a, c) and RCP8.5 (b, d), relative to 1976–2005.

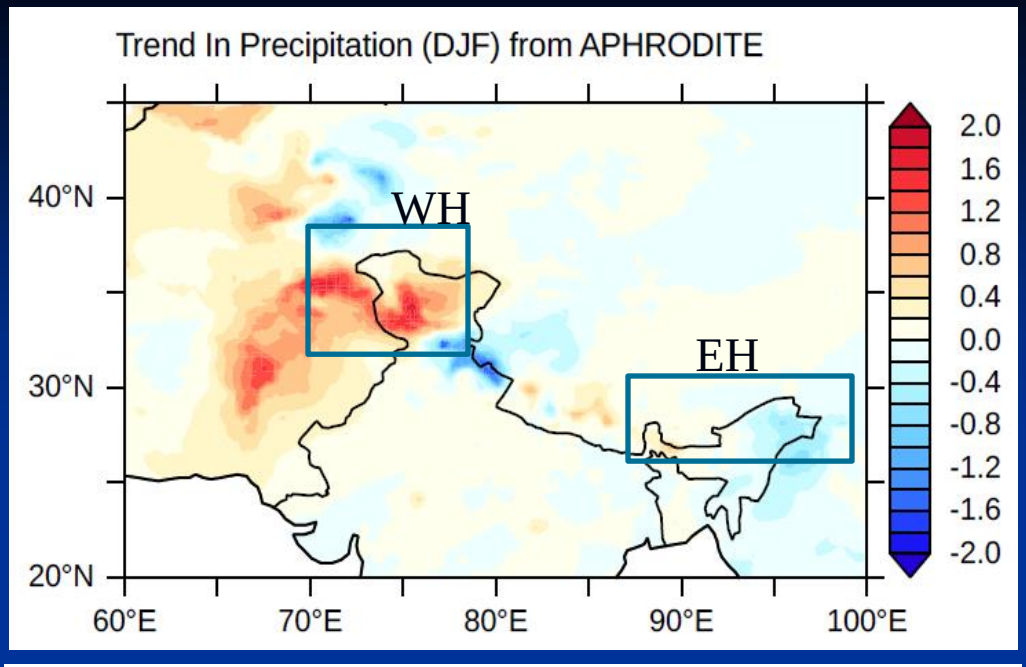
Why we need high resolution simulation…

- Overall CMIP5 models are able to provide a generalized pattern in major changes happened over the Himalaya

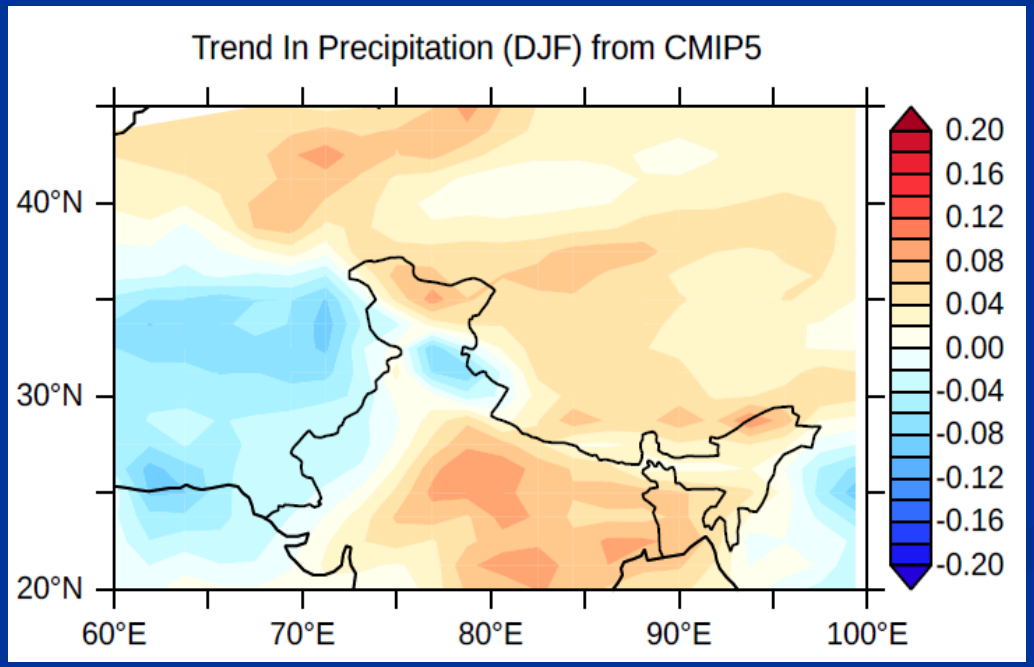
- Temperature related indices are relatively better represented since its spatial variability's are relatively less

- But the precipitation pattern seems to be different while looking more closely. The weather features over this elevated mountain terrain is also to be better represented. Course resolution climate models, partly fail in these two aspects.

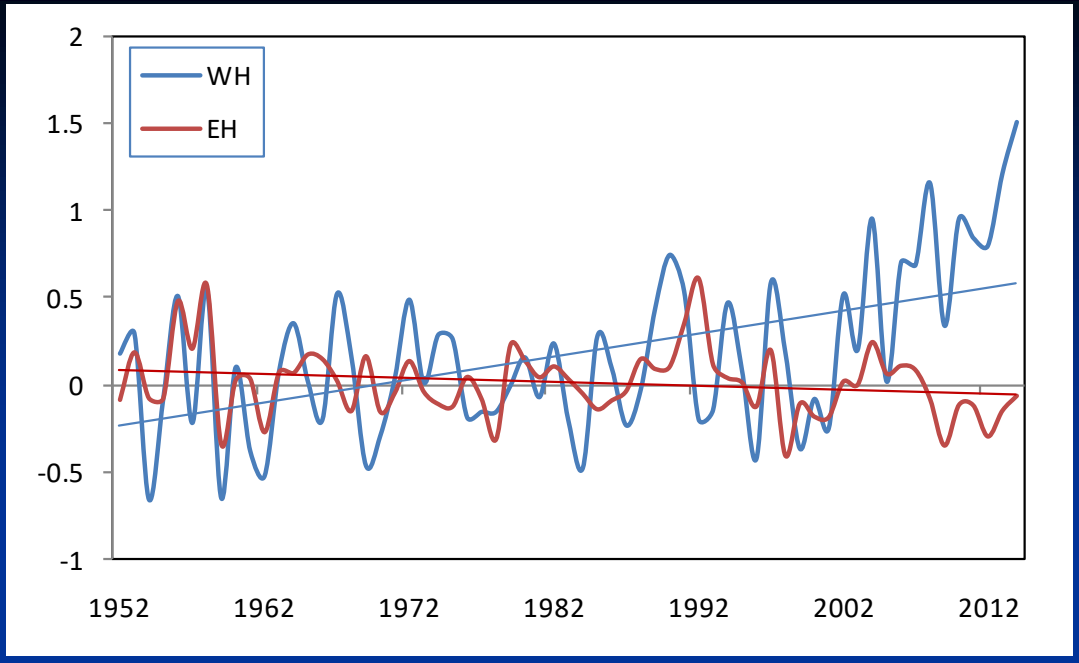
- If we intrigue towards the distinct sectors, such as Karakoram Himalaya, Central Himalaya or Eastern Himalaya, the CMIP5 projections may not be sufficient to provide a satisfactory inference



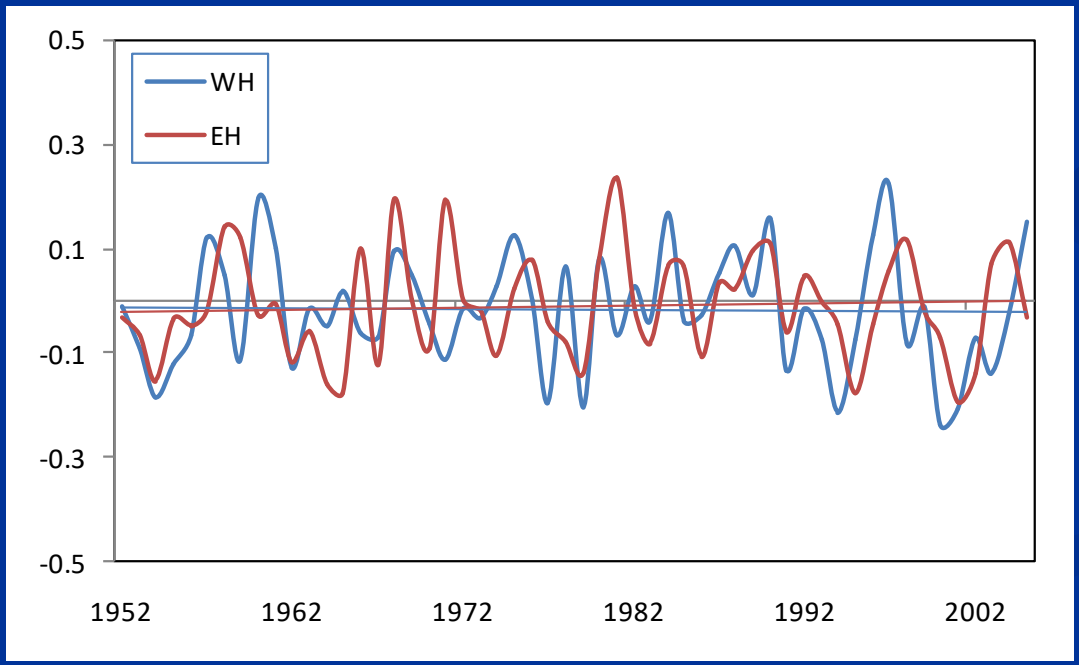
Observed Trend in winter precipitation (1951-2015)



Trend in simulated winter precipitation (CMIP5:Historical)

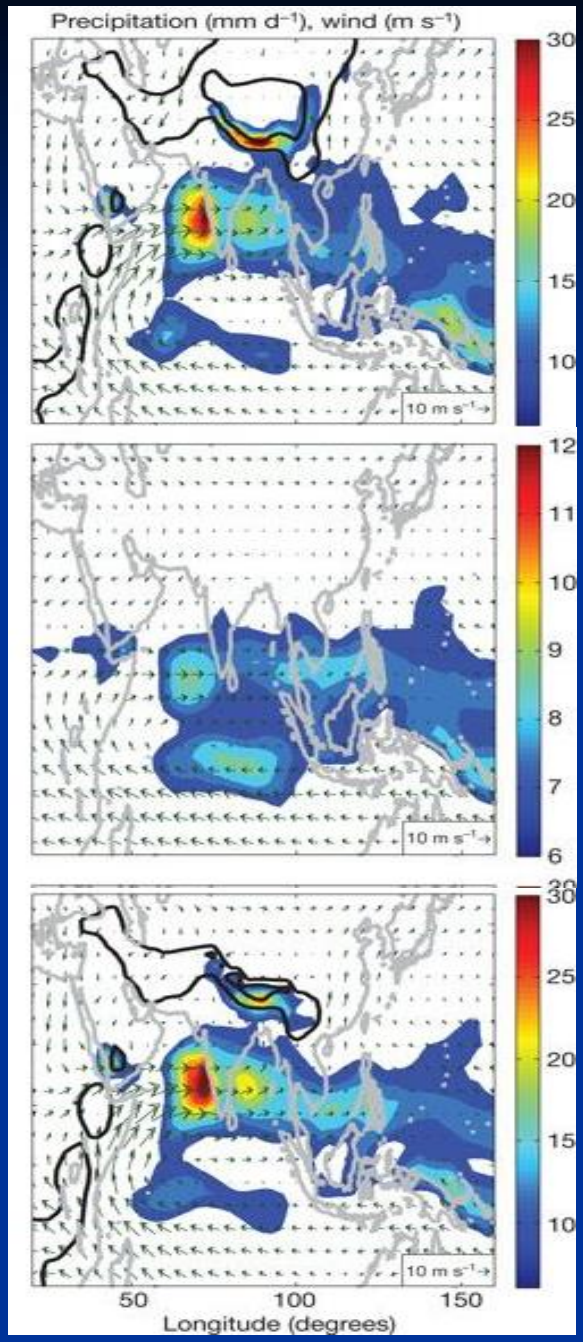


Time series of Observed (APHRODITE) precipitation during winter (1951-2015)



Time series of precipitation from CMIP5 ensemble mean during winter (Historical)

Role of Himalaya in Monsoon



Boos and Kuang (2010)

The importance of Himalaya is not only for the local climate, but it has a strong influence on defining the regional climate, especially the monsoon

Boos and Kuang (2010) suggest that even without a Tibetan plateau they could able to retain a strong monsoon only with a narrow Hindukush and Himalayan mountain, by insulating warm, moist air over continental India from the cold and dry extra tropics

The small mountain ranges over Hindukush Himalaya can act as a barrier by insulating the dry desert air intrusion from the nearby deserts to the moist monsoon trough region, which can decrease the precipitation over the monsoon trough (Krishnan et al 2009; Sabin et al 2013)

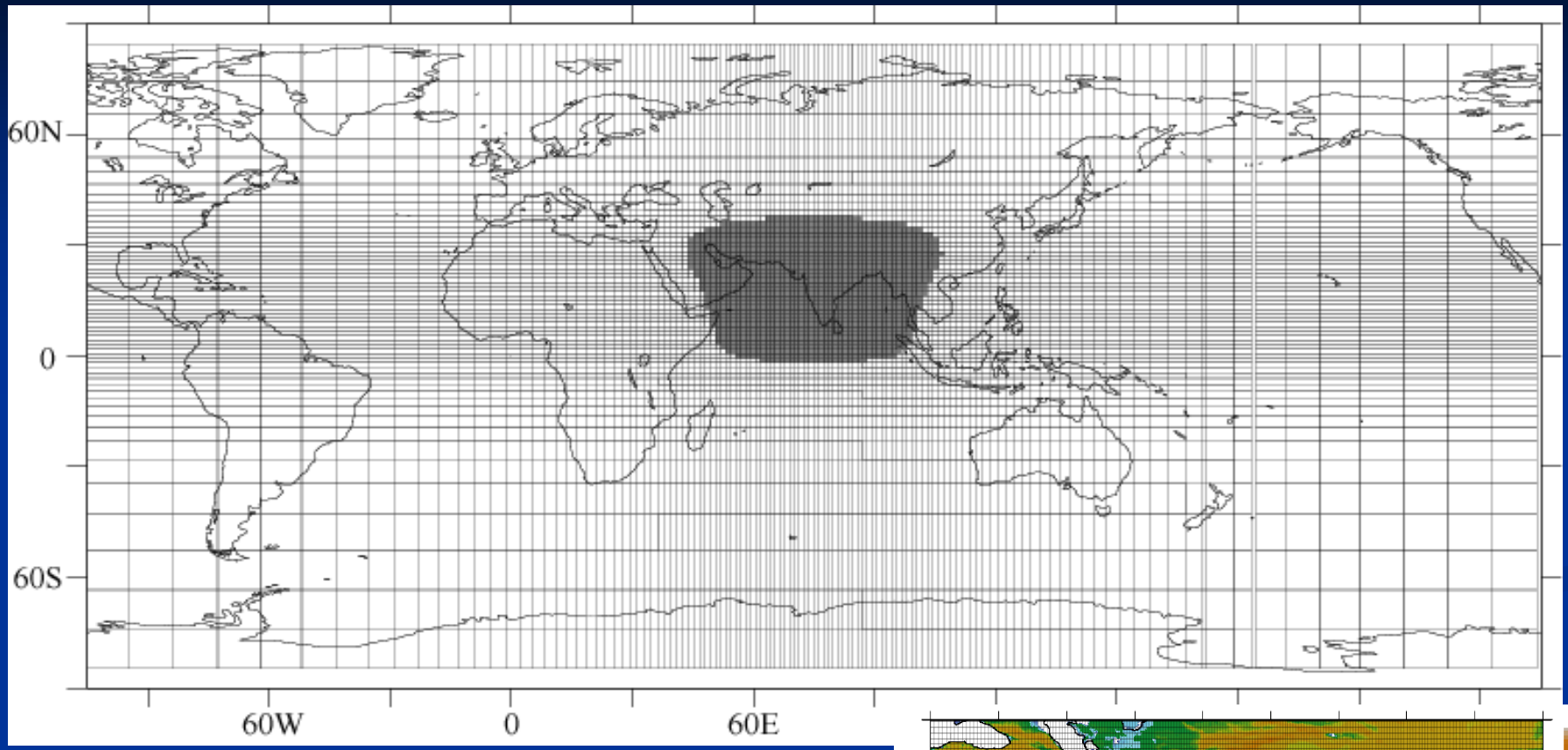
Hence representing the very narrow mountain ranges is also having profound importance in simulating the south-Asian climate, hence high resolution is inevitable

We have two High resolution Global climate modelling approach in CCCR to addressing the science of climate change in addition to our regional climate modelling as part of CORDEX-SA and Earth System Model as part of CMIP6

1) **A variable resolution Global Climate model (LMDZ)- 35km over south Asia**

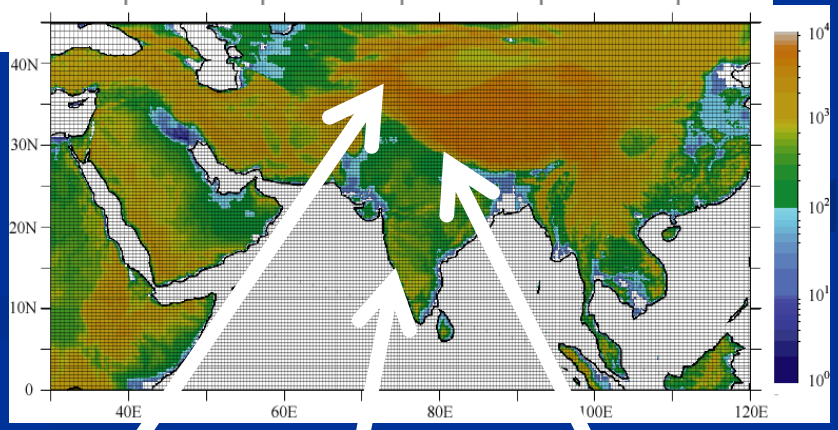
2) **IITM –GFS T574 :- 27 km global**

LMDZ grid setup for South Asia (shaded region has grid-size < 35 km)



LMDZ global atmospheric model: Variable resolution with zooming capability

The resolution becomes gradually coarser outside the zoom domain.



Understanding regional climate change over South Asia

High resolution (~ 35 km) dynamical downscaling at CCCR, IITM

Historical (1886-2005):

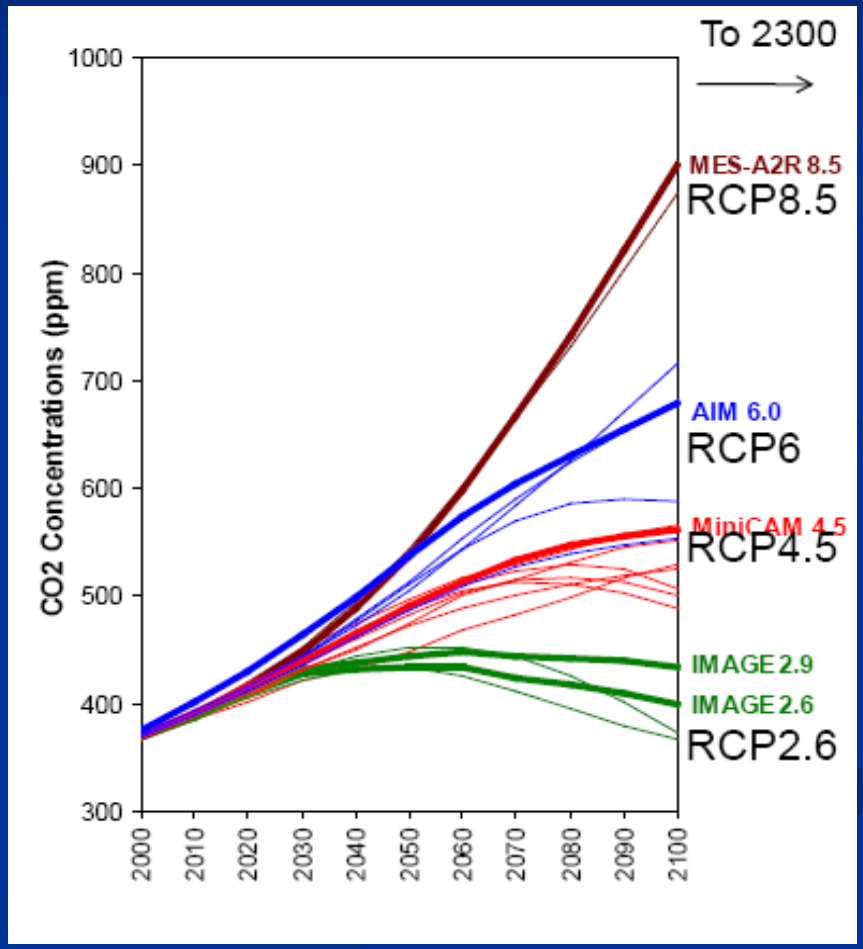
Includes natural and anthropogenic (GHG, aerosols, land cover etc) climate forcing during the historical period (1886 – 2005) ~ 120 years

Historical Natural (1886 – 2005):

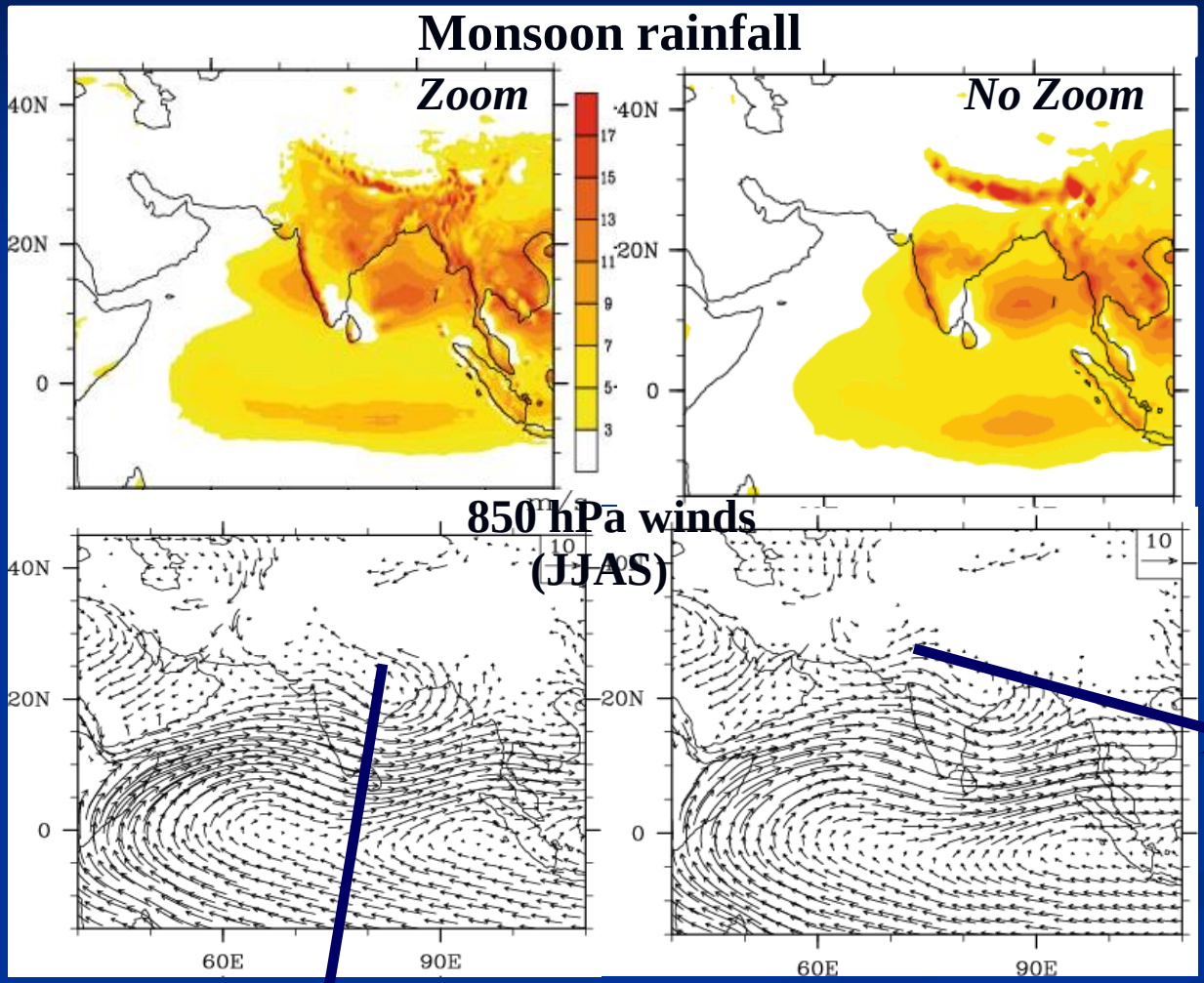
Includes only natural climate forcing during the historical period (1886– 2005) ~ 120 years

RCP 4.5 scenario (2006-2100) ~ 95 years:

Future projection run which includes both natural and anthropogenic forcing based on the IPCC AR5 RCP4.5 climate scenario. The evolution of GHG and anthropogenic aerosols in RCP 4.5 scenario produces a global radiative forcing of + 4.5 W m^{-2} by 2100



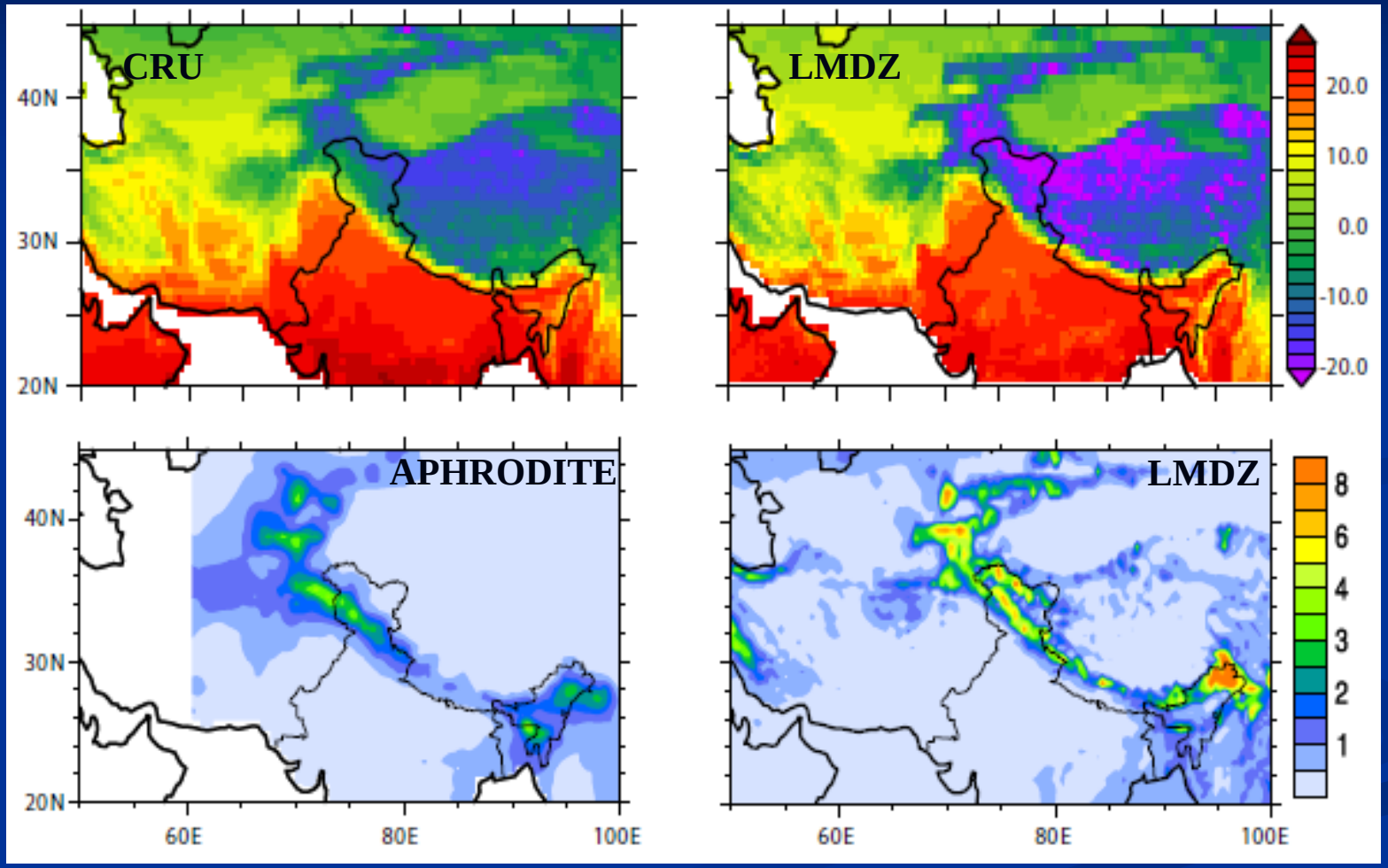
Improvement in monsoon due to high resolution…

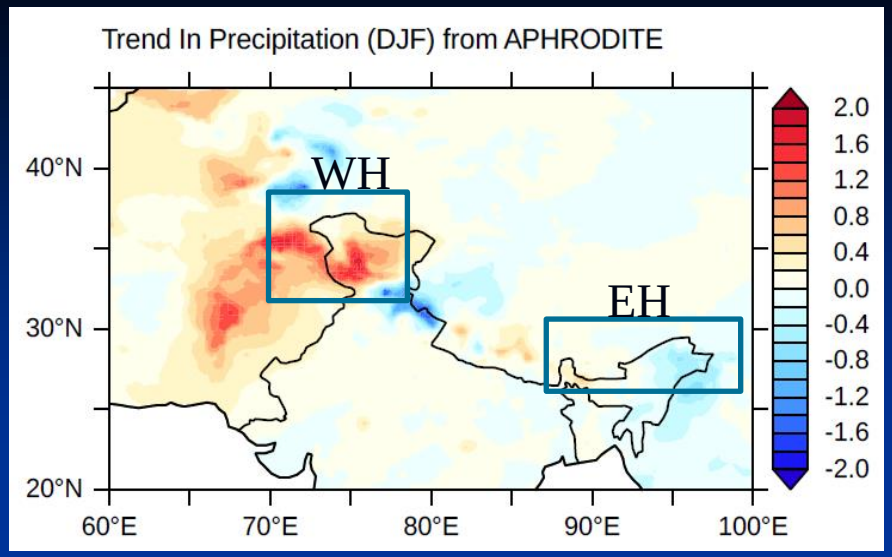


Dry westerly winds from Indo-Pak and adjoining areas

Cyclonic turning of moist winds from Bay of Bengal

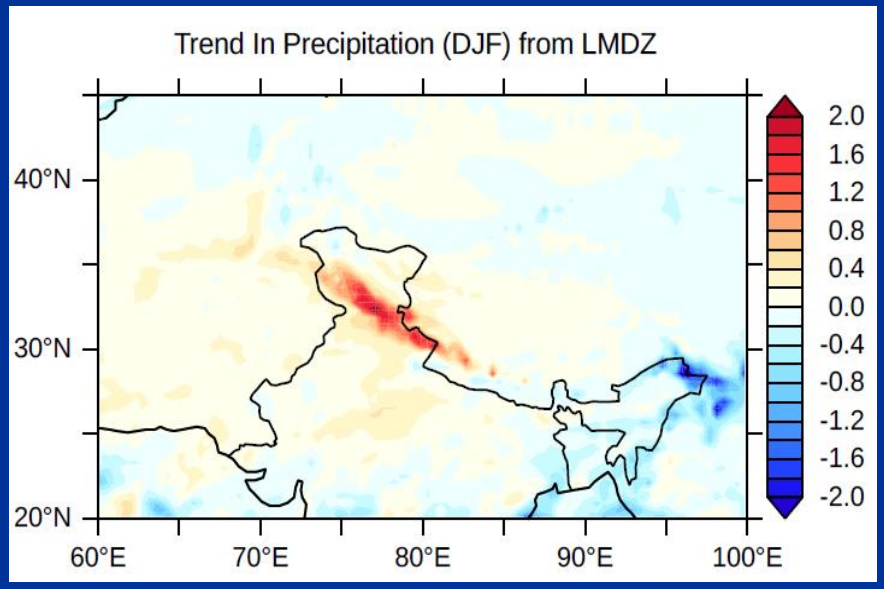
Spatial maps of wintertime climatological surface air temperature (°C) & precipitation (mm day^{-1}) from observations and simulation



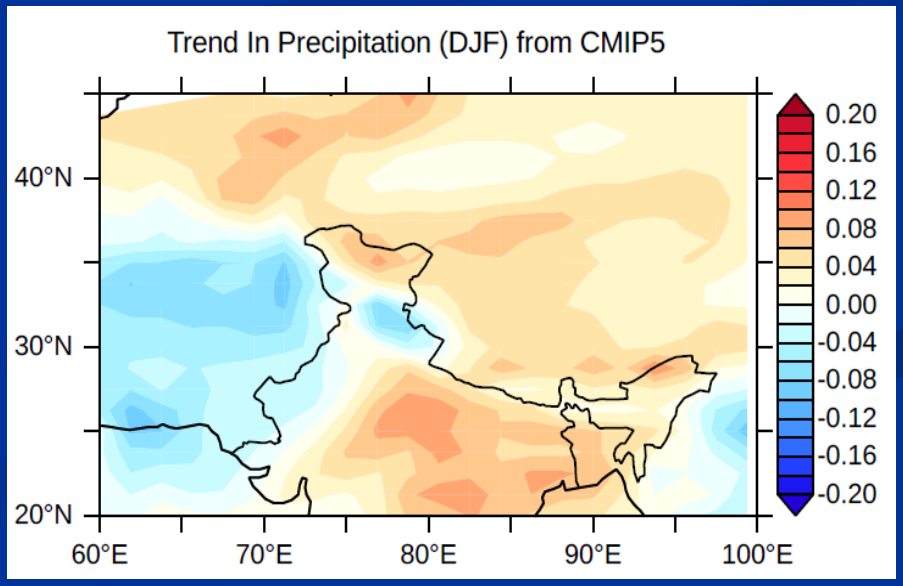


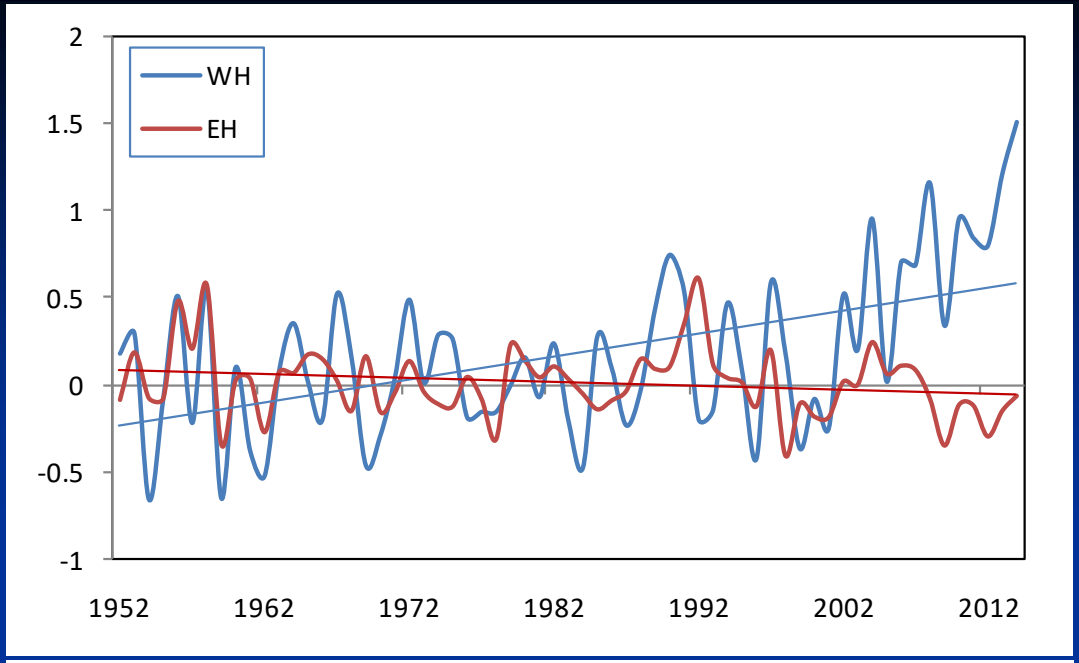
Observed Trend in winter precipitation (1951-2015)

Trend in simulated winter precipitation (LMDZ:Historical)



Trend in simulated winter precipitation (CMIP5:Historical)





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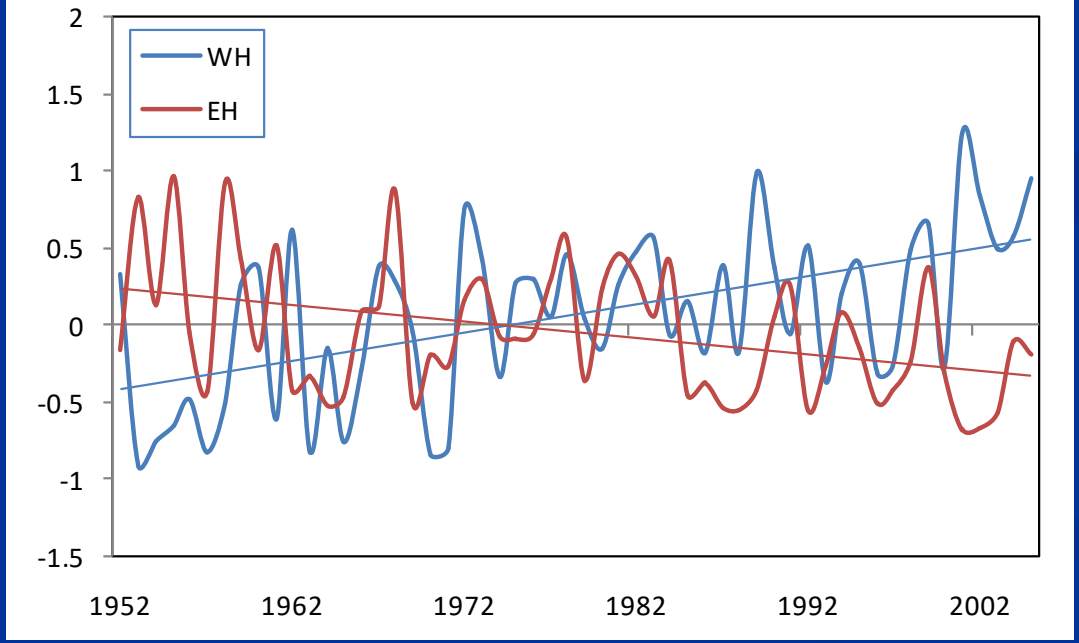
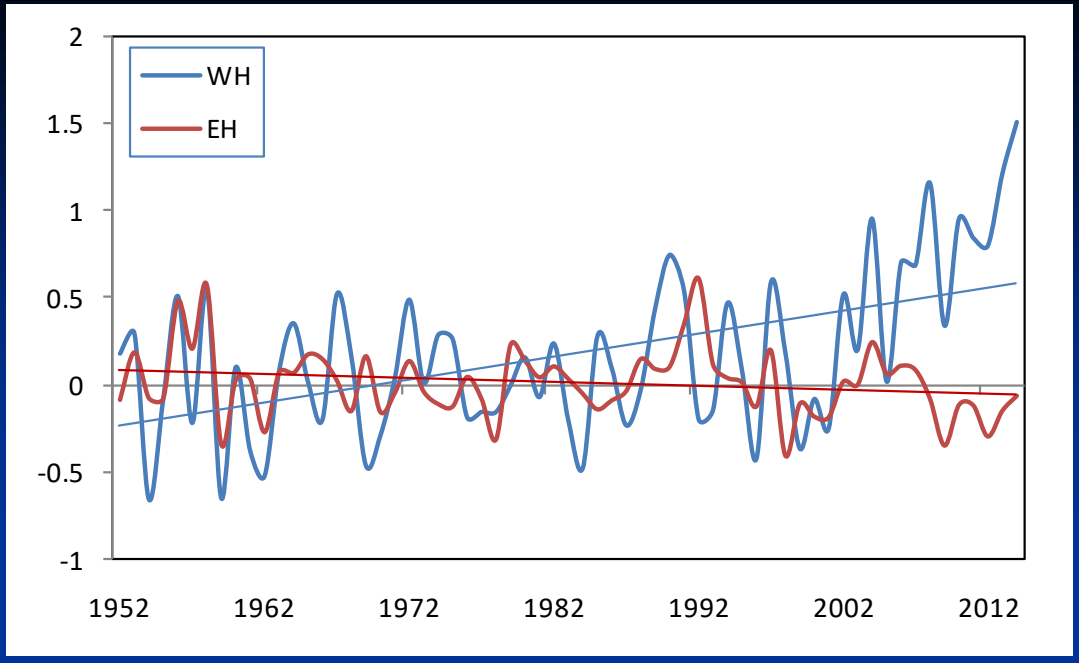


Time series of precipitation from LMDZ Historical simulation during winter



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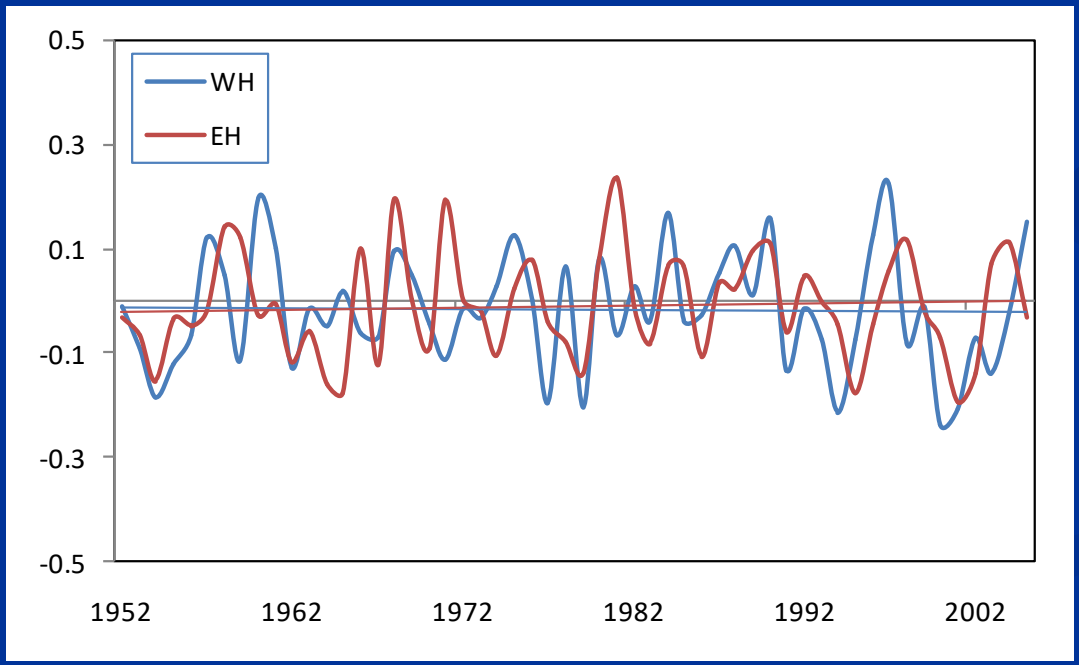
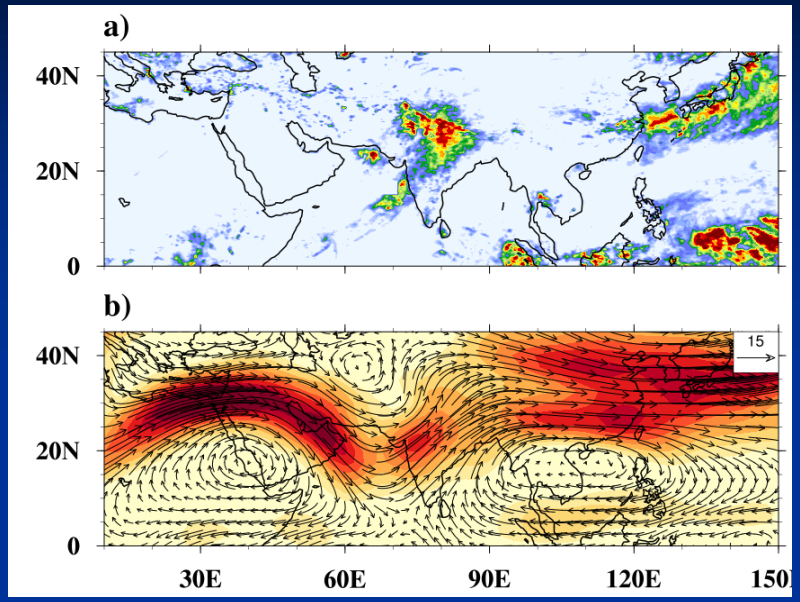


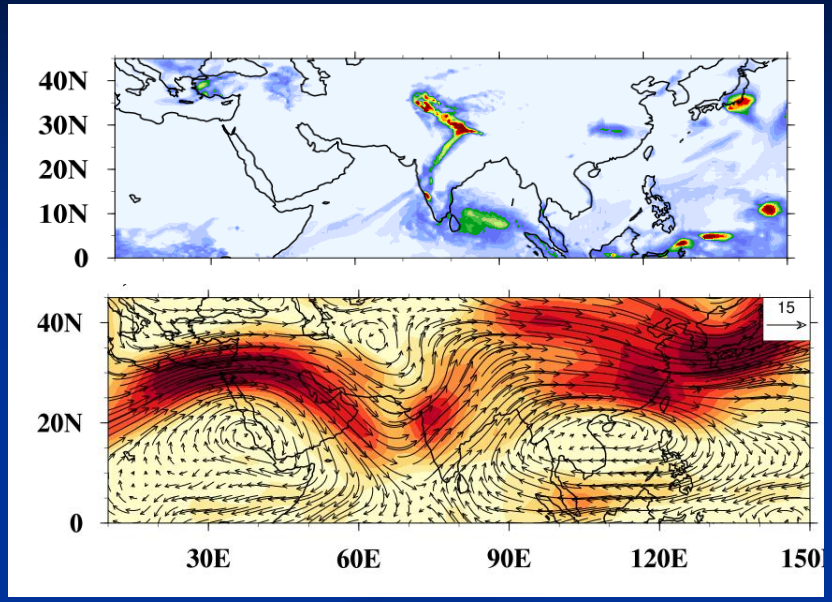
Time series of precipitation from CMIP5 ensemble mean during winter (Historical)

Improvement in simulating wintertime WD's…..

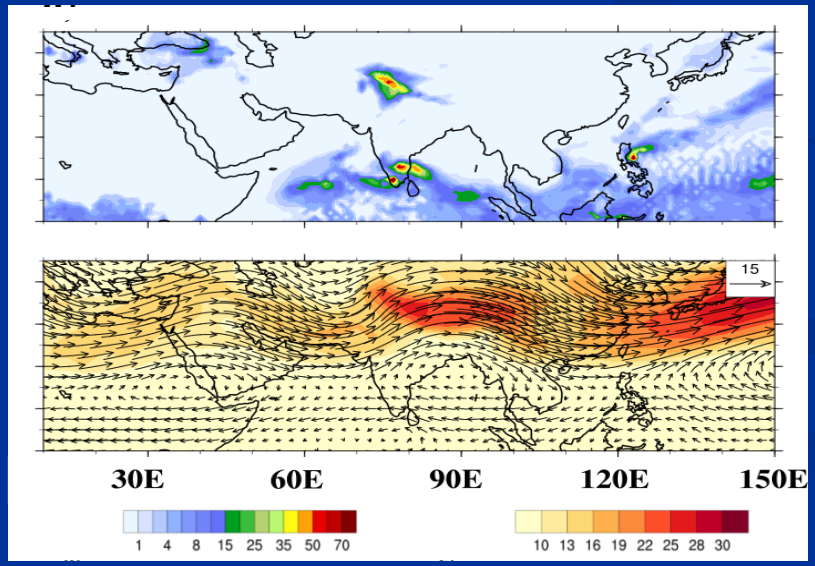
Western Disturbance case from TRMM &NCEP

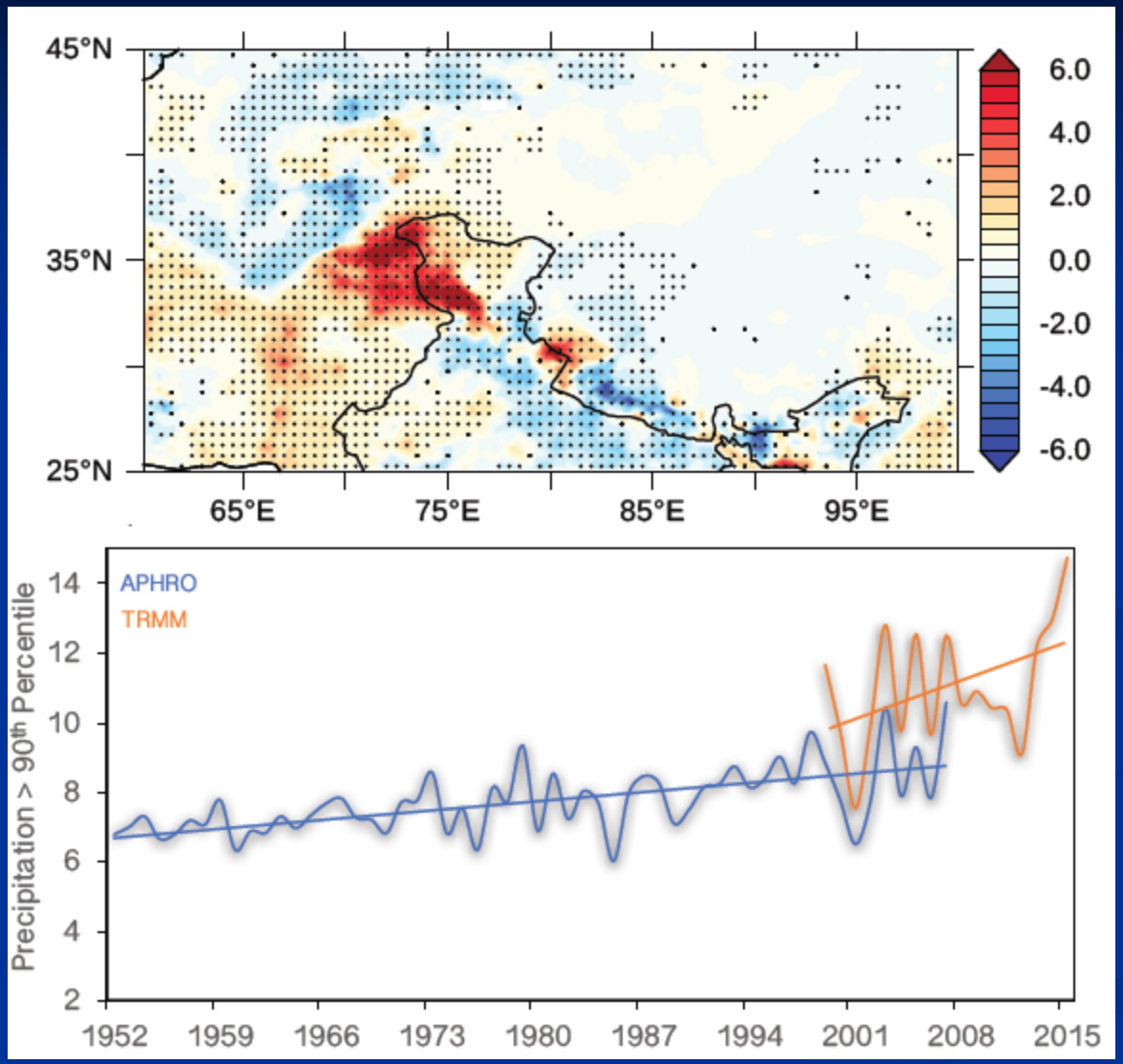


Western Disturbance case from Zoomed version



Western Disturbance case from No Zoom version



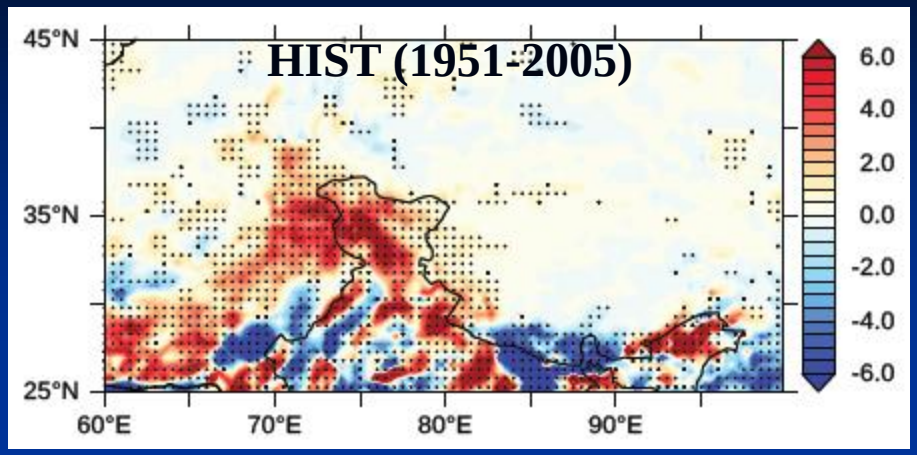


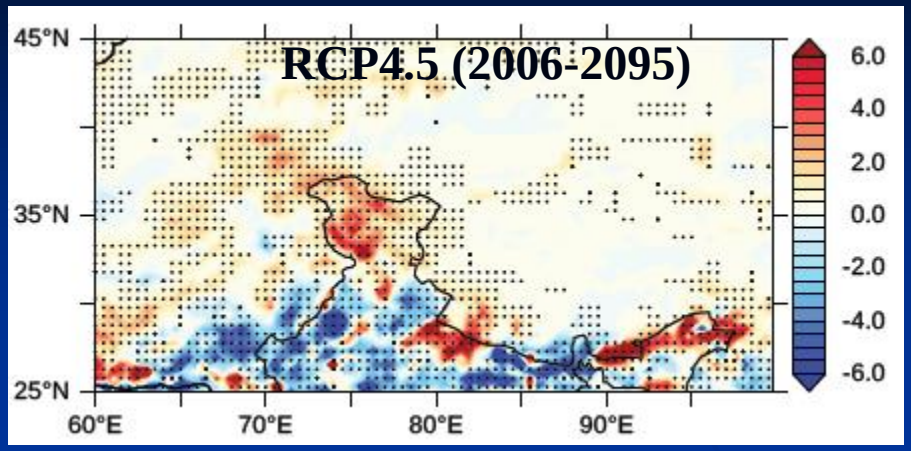
Spatial map of trend in daily precipitation (DJFMA) exceeding the 90th percentile during 1951-2007 (APHRODITE)

Time series showing interannual variation of daily precipitation exceeding the 90th percentile over the Karakoram Western Himalayas

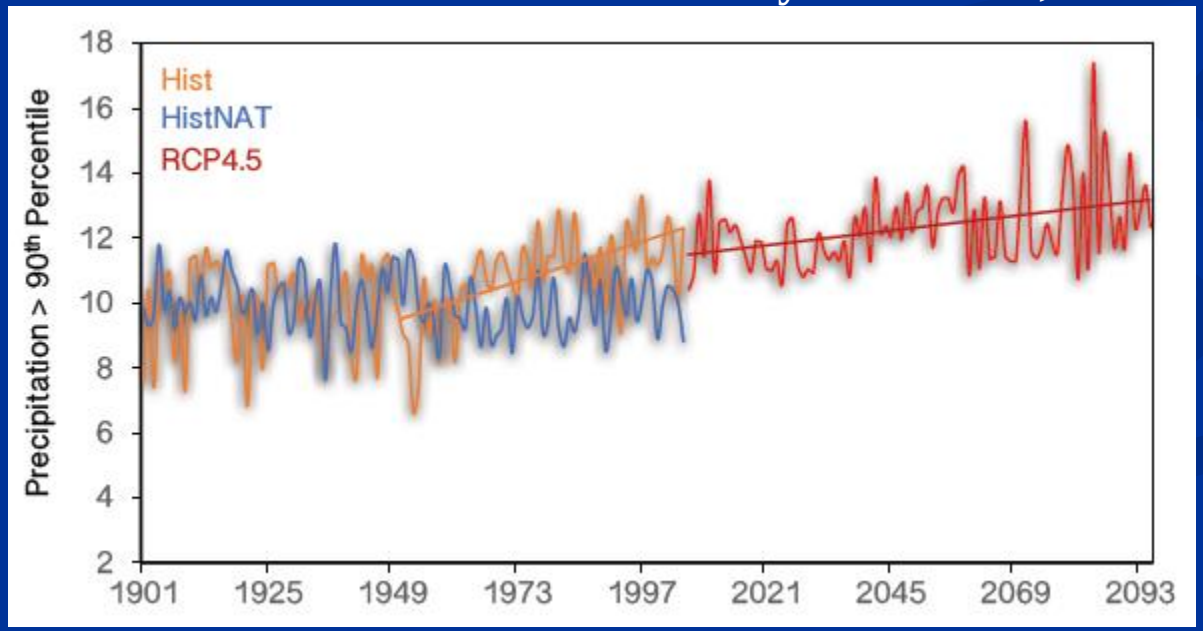
Krishnan et al. (2018)

Spatial map of trend in daily precipitation (DJFMA) exceeding the 90th percentile





Time series showing interannual variation of daily precipitation exceeding the 90th percentile over the Karakoram Western Himalayas for HIST, HISTNAT & RCP4.5



Krishnan et al. (2018)

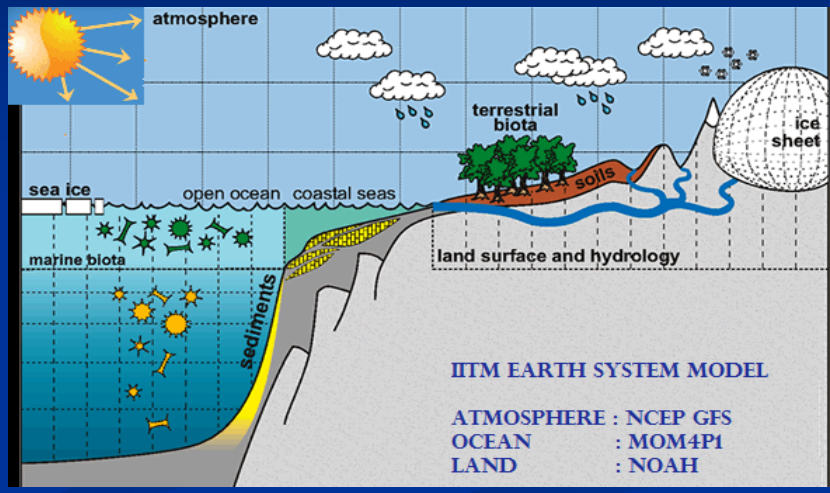
Earth System Modeling Research at CCCR

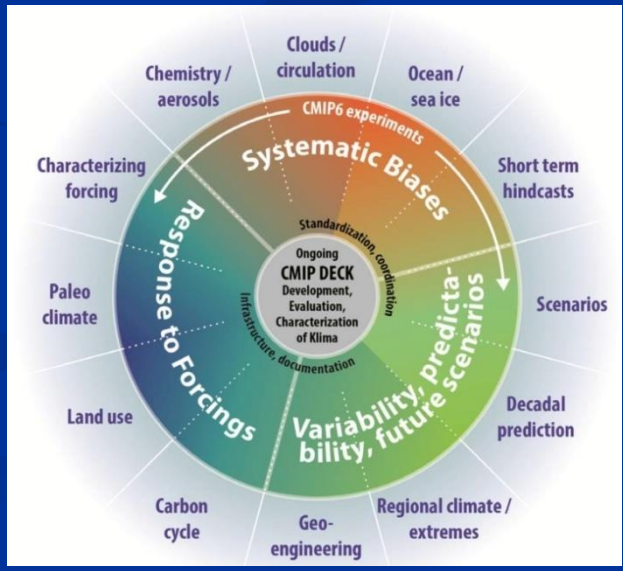
The IITM Earth System Model: Transformation of a seasonal prediction model to a long term climate model

Swapna, P., M. Roxy, A. Krishnamurthy, K. Kulkarni, P. Prajeesh, K. Ashok, R. Krishnan, S. Moorthi, A. Kumar and B.N. Goswami , *Bull. Amer. Meteorol. Soc.*, 2015, DOI: 10.1175/BAMS-D-13-00276-1.

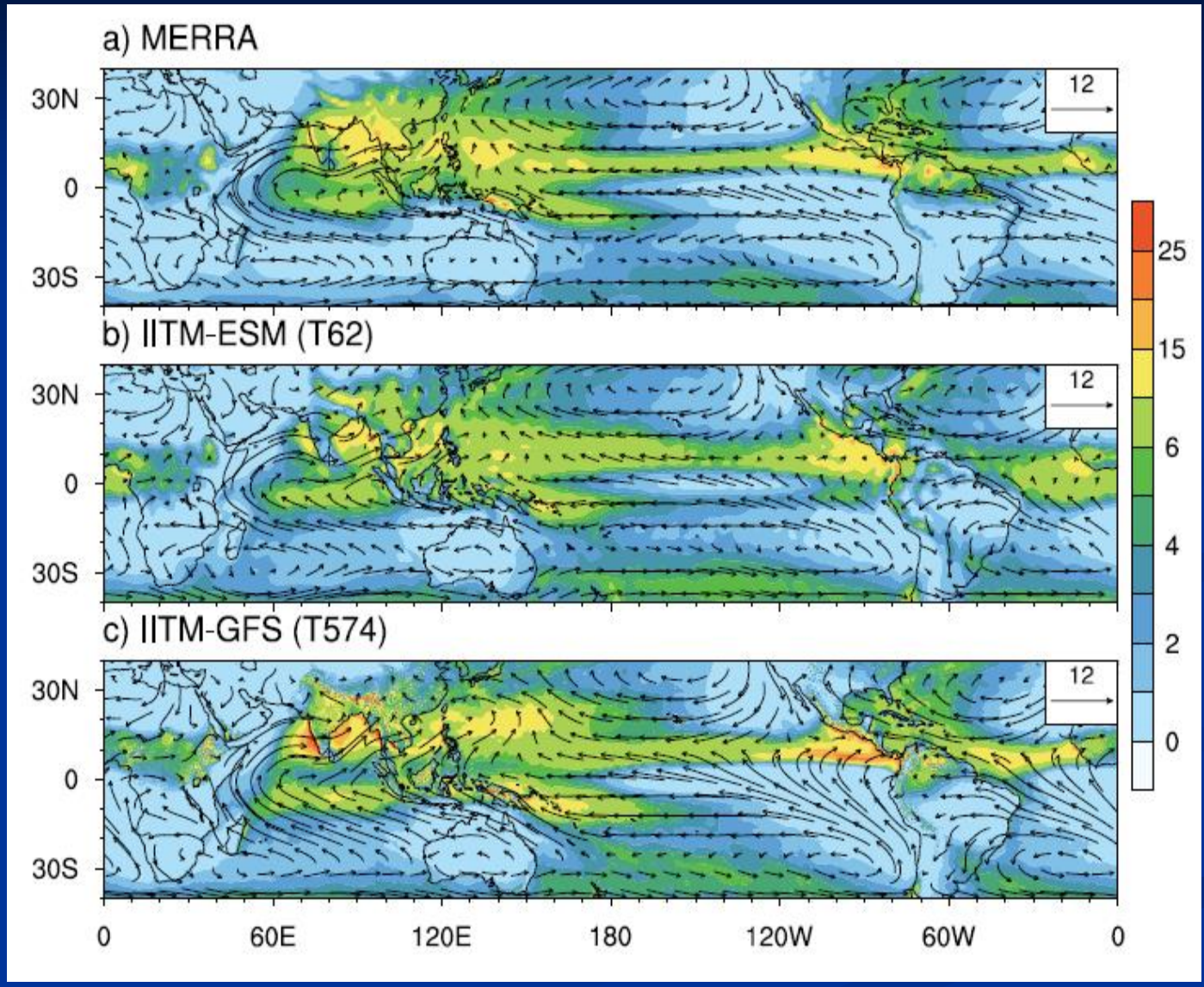
- Developing a state-of-the-art climate model from India suitable for long-term climate studies is a critical requirement in order to generate reliable future projections of the global and regional climate, and particularly the Indian monsoon rainfall.
- The Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology (IITM) has developed an Earth System Model, IITM-ESM by incorporating earth system components in the Climate Forecast System (CFS) from National Center for Environmental Prediction (NCEP, USA), and thereby transforming the CFS seasonal prediction model to a long-term climate model.
- The IITM-ESM is the first climate model from India participating in the Coupled Model Intercomparison Project- Phase 6 (CMIP6) experiments required for the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report.

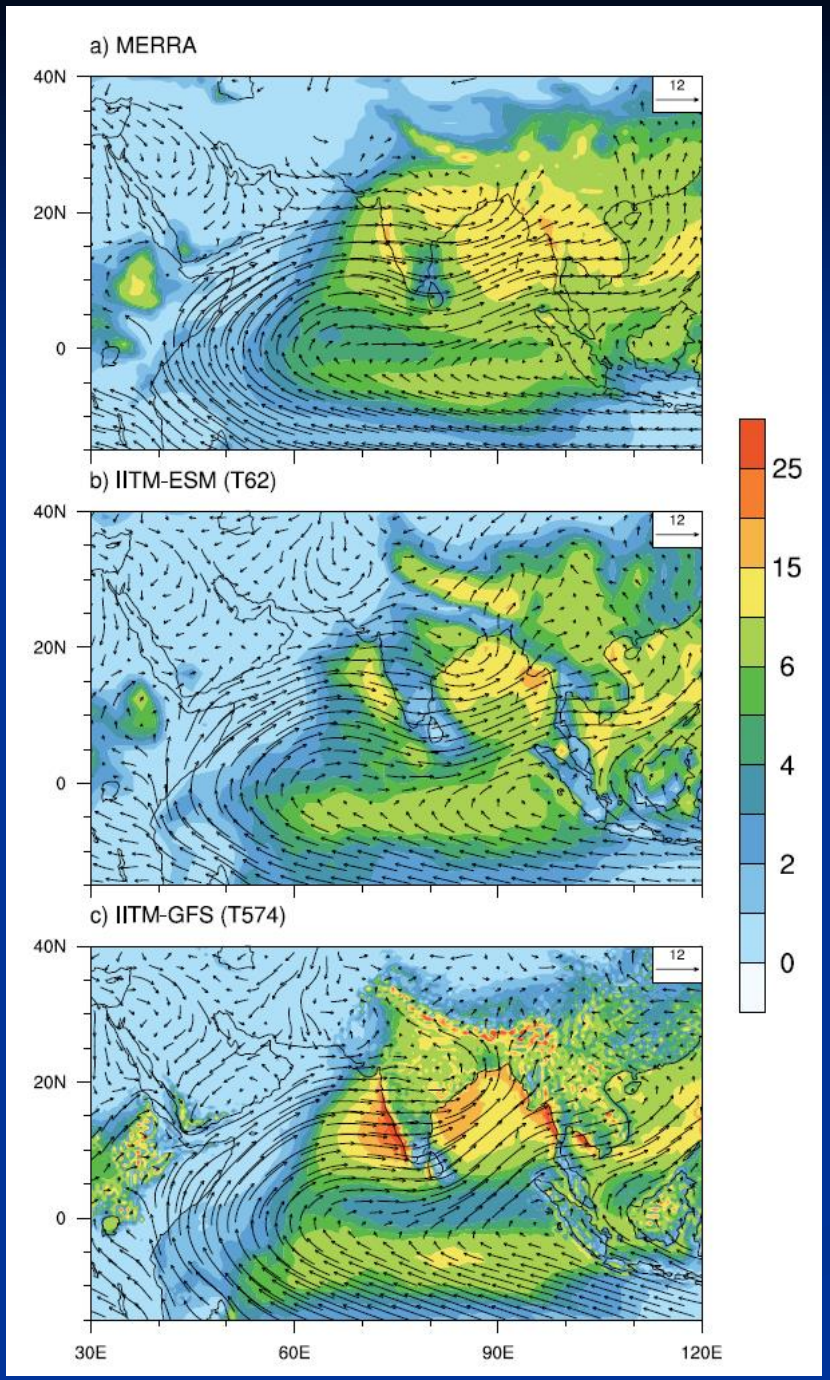
http://cccr.tropmet.res.in/home/clim_esm.jsp





IITM ESM & IITM high resolution GFS



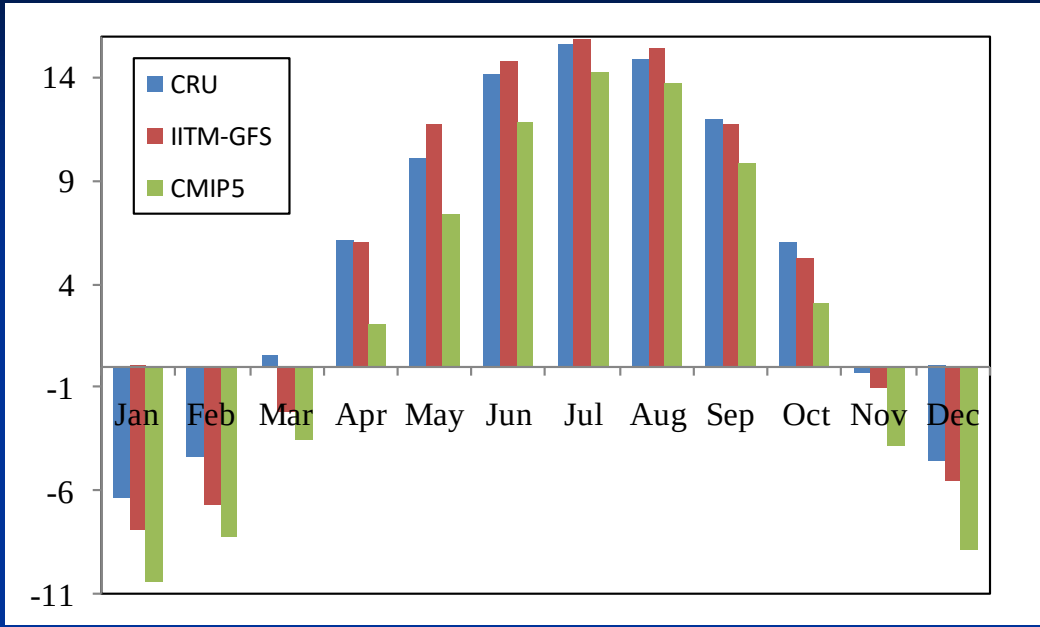


Clear Improvement in precipitation pattern is vissible in IITM ESM and GFS simulation.

Narrow orographic precipitation over the western Ghats and precipitation over the monsoon trough is significantly improved in 27km version.

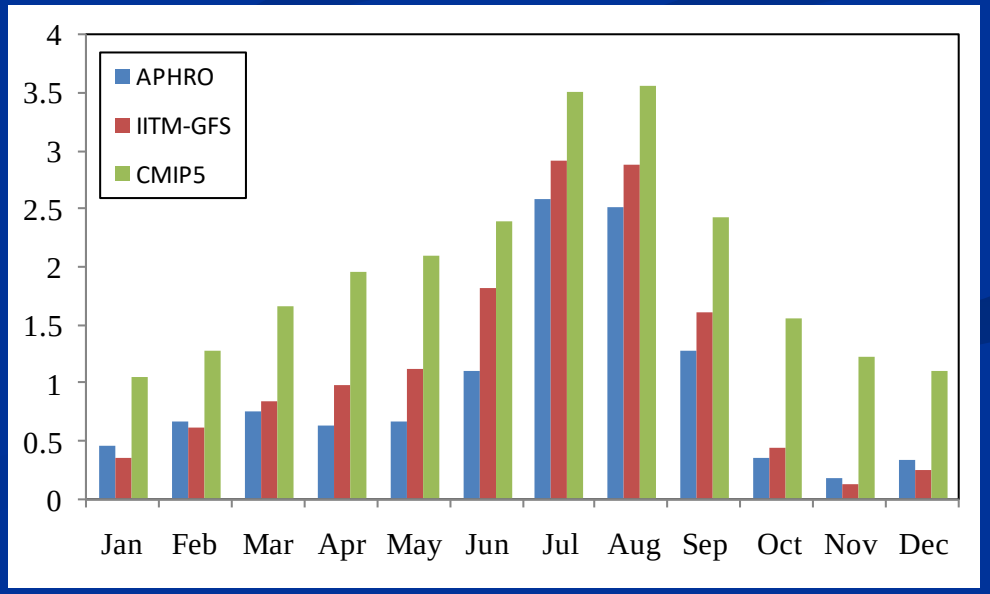
We will be contributing to IPCC CMIP6 assessment with this model.

IITM –GFS (T574) 27km : How this model performing over Himalaya…

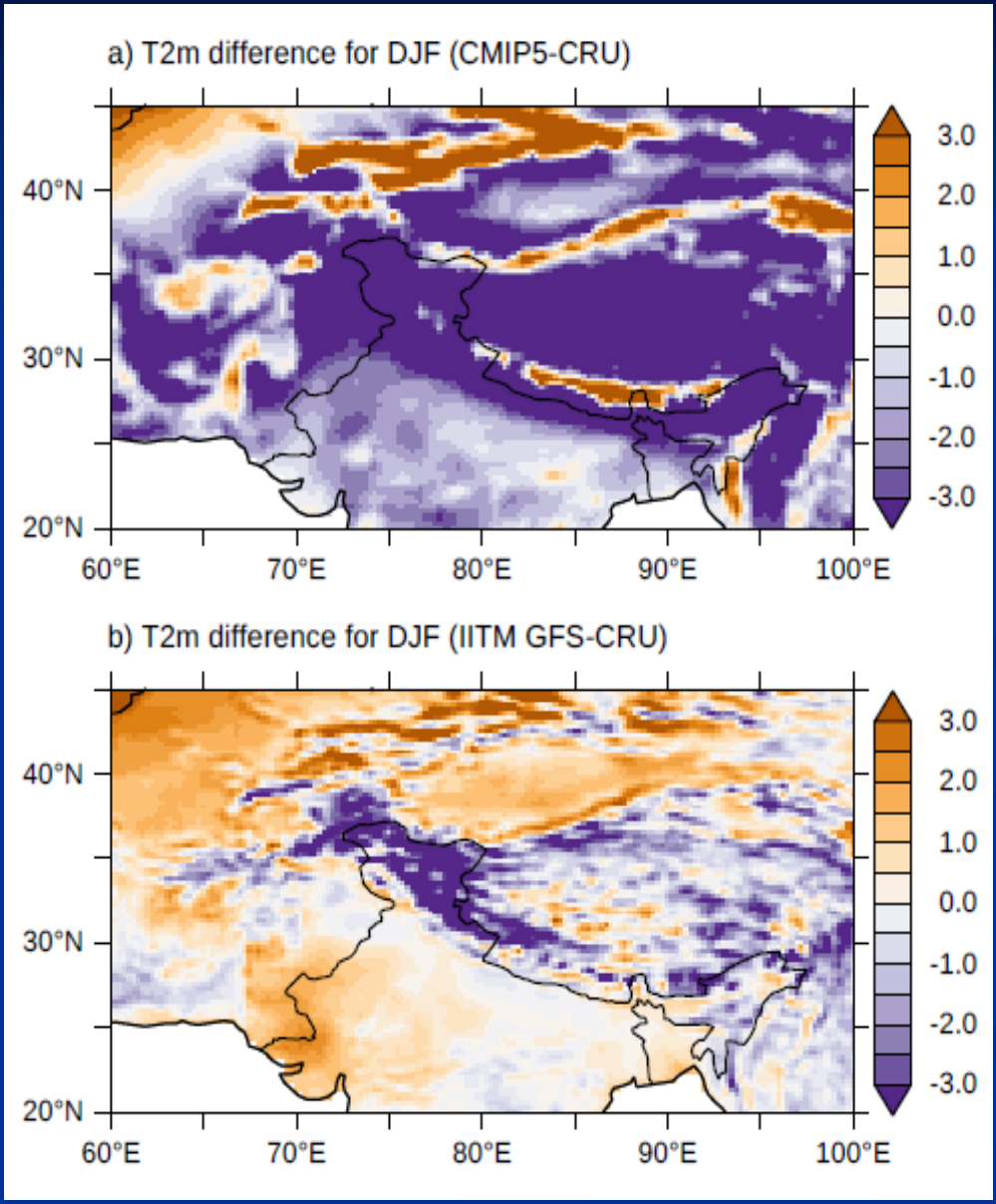


Annual cycle of temperature over Himalaya (70:90E;28:38N) from observation, IITM-GFS &CMIP5

Annual cycle of precipitation over Himalaya (70:90E;28:38N) from Observation, IITM-GFS &CMIP5



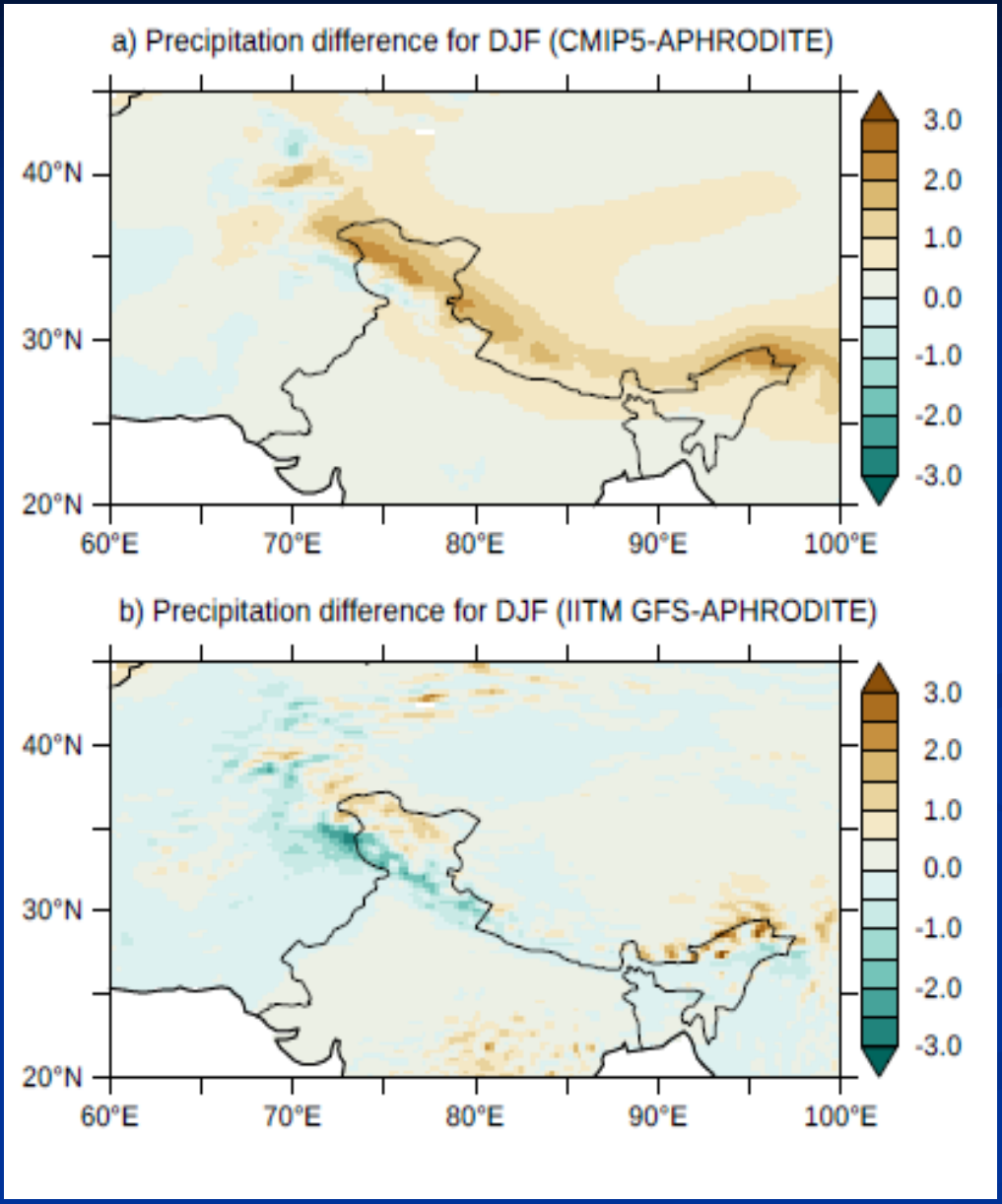
Bias in simulated wintertime surface temperature…..



CMIP5 models shows large cold bias over Himalaya during wintertime

Cold bias is reduced considerably in the IITM-GFS

Bias in simulated wintertime precipitation…..



CMIP5 models shows large wet bias over Himalaya during winter months

Bias in simulated precipitation is relatively less in the IITM-GFS

Summary

- CMIP5 models projects a consistent increase in surface temperature and decrease in snowfall over the Himalaya in 21st century

- The study emphasizes the requirement of the high-resolution simulation for better representation of weather and climate of South Asia

- High resolution LMDZ simulation able to provide vital information regarding the precipitation changes over the different sectors of the Himalaya

- The multi centaury long climate simulation provide information regarding the possibility of enhanced WD activity over the western Himalaya in the 21st century

- The 27km IITM GFS shows significant improvement in simulating the wintertime climate over the Himalayan region with reduced bias in both precipitation and temperature

- We will be using this 27 km global IITM-GFS model for our future high resolution simulation required for various assessments

Thank You.