



High-resolution global climate modeling for the Third Pole Region

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**Third Pole Climate Forum (TPCF-3)
& meeting of the
Third Pole Regional Climate Centre Network (TPRCC-Network)
Task Team**

New Delhi, India 3–5 June 2025



A Climate Change perspective

The Hindu Kush Himalayas (HKH) experienced a temperature rise of about 1.3°C during 1951–2014.

HIMALAYA VS. INDIA

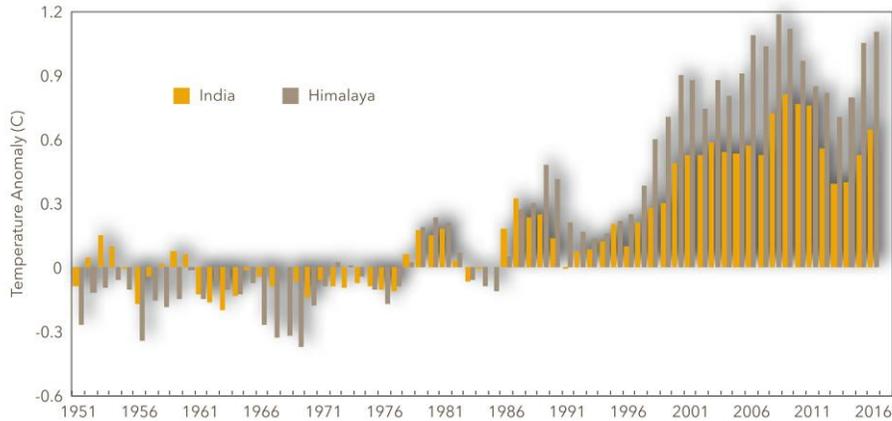
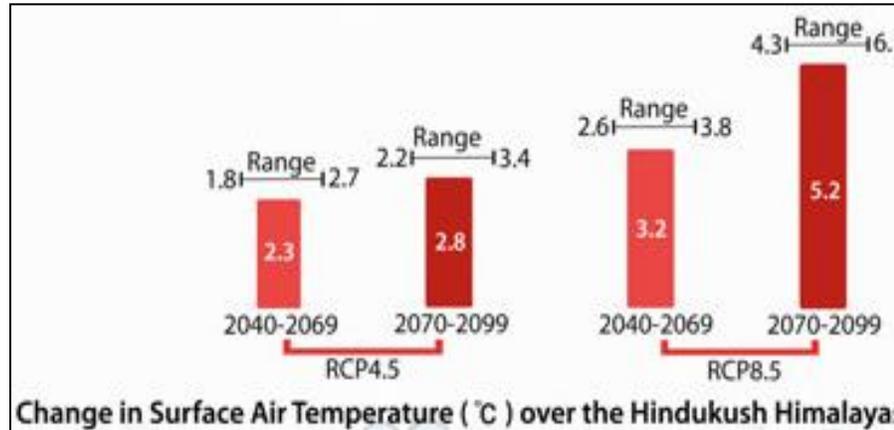


Fig. 11.2 Annual mean temperature time series (5-year running mean) averaged over HKH (grey) and Indian land mass (yellow) from 1951 to 2018

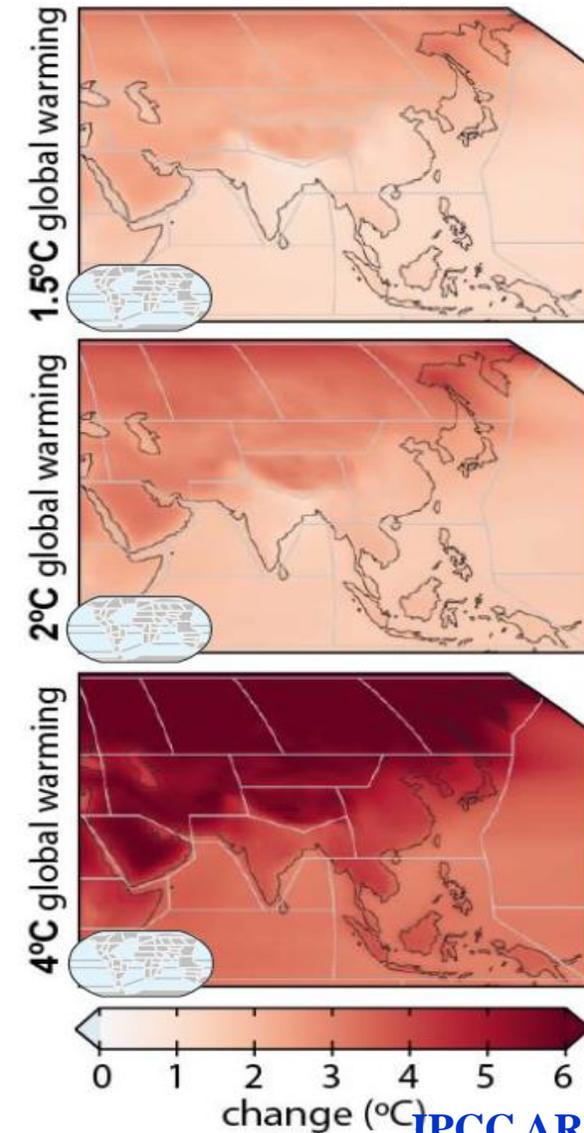
- Over HKH region glaciers have retreated and lost mass
- Snow cover area and snow volume is projected to decrease in the HKH region (Kulkarni et al., 2021)
- Future climate projections under various CMIP5 scenarios suggest warming of the HKH region in the range of 2.6–4.6 °C by the end of the twenty-first century.

Projected changes in temperature over Hindukush Himalayas

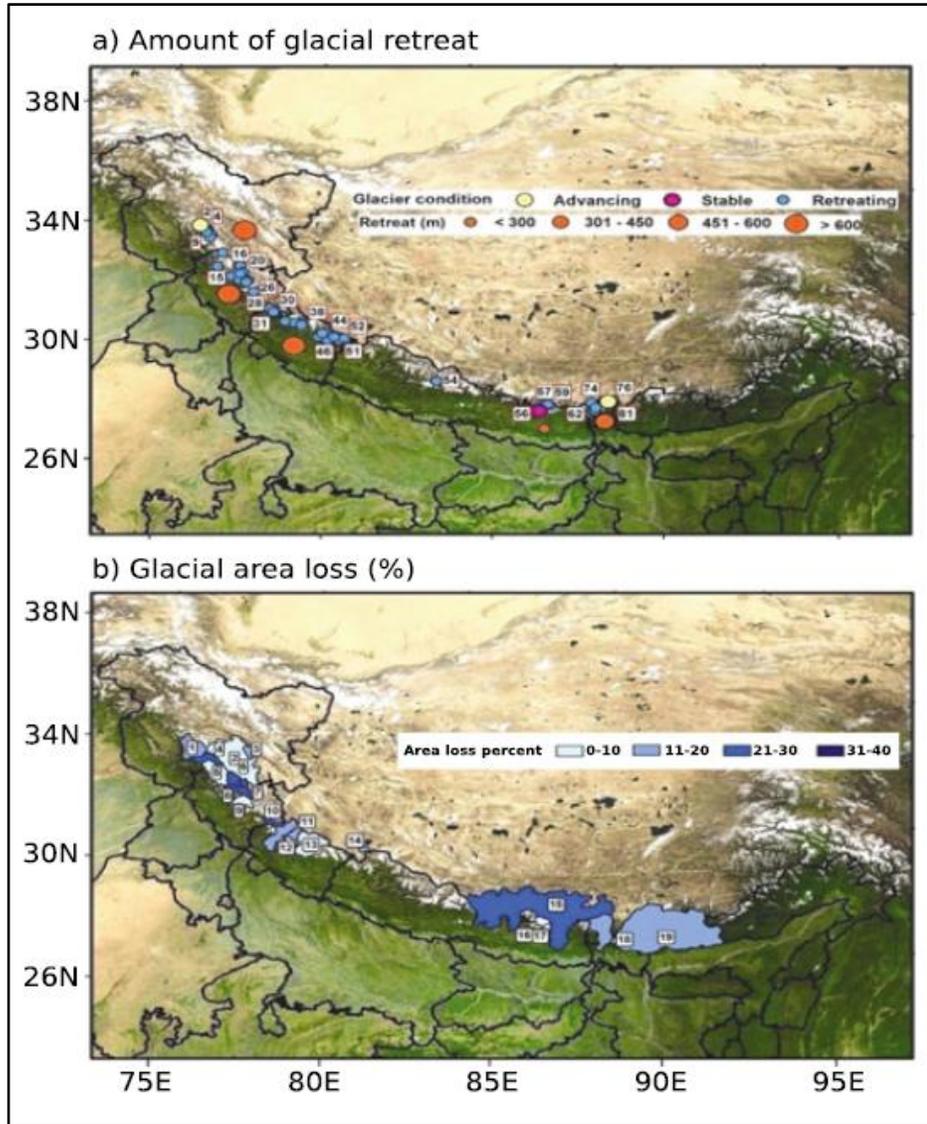


Assessment Report, MoES (Krishnan et al., 2020)

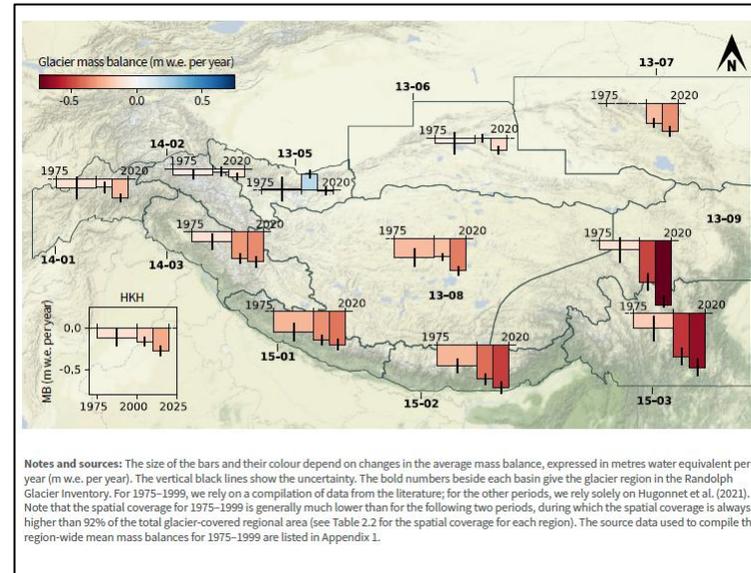
Projected Annual Mean Temperature at Global Warming Level



Glacier Retreat



Amount of glacier retreat between 1960 and 2000
Kulkarni and Kayakarte (2014)



Mass balance expressed in meters of water equivalent per year (Jackson et al., 2023)

While global climate change significantly affects the environment over the high mountain regions of Asia, its impact on the Himalayan cryosphere is a major threat to the regional water resources (ICIMOD 2007, 2011; Armstrong 2011)

A comprehensive understanding of the predictions and projected changes over Hindu Kush Himalayan region is lacking

Current generation climate models have limitations in capturing the observed hydroclimatic variations over the region

IITM-ESMv3

GFS Tco ~67 km

MOM4 ~25 km

SIS + Noah + LULC

+ Aerosol + BGC

ERPv2

Multi-physics framework:

~38 km

GFS + MOM4 + SIS + Noah



Plan

Climate and
Decadal
Projections

Ready

Seasonal
forecasts

Set

Mid-Range
forecasts

Go!

Short-Range
forecasts

**Monsoon Mission Coupled
Forecast System version 2.0
(MMCFSv2)**

GFS-SL ~38 km

MOM6 0.5° x 0.25°

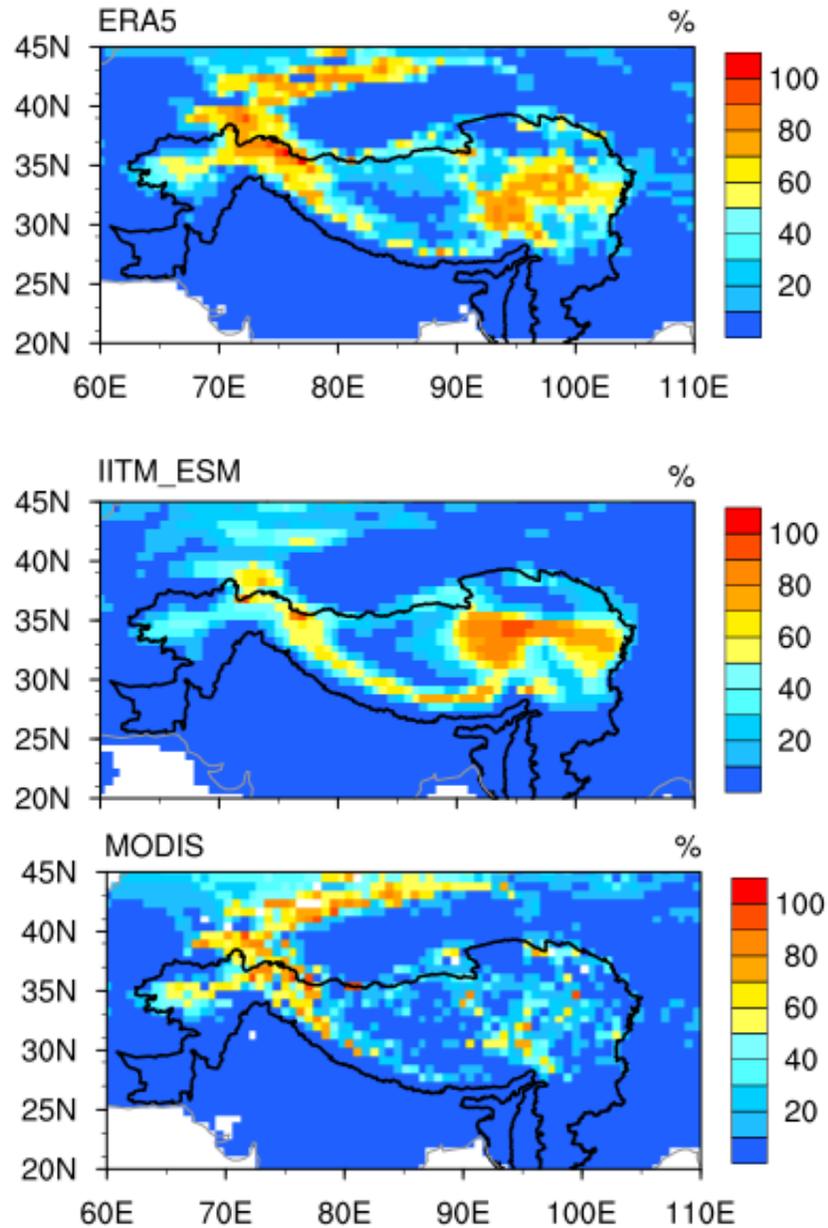
CICE5

Noah

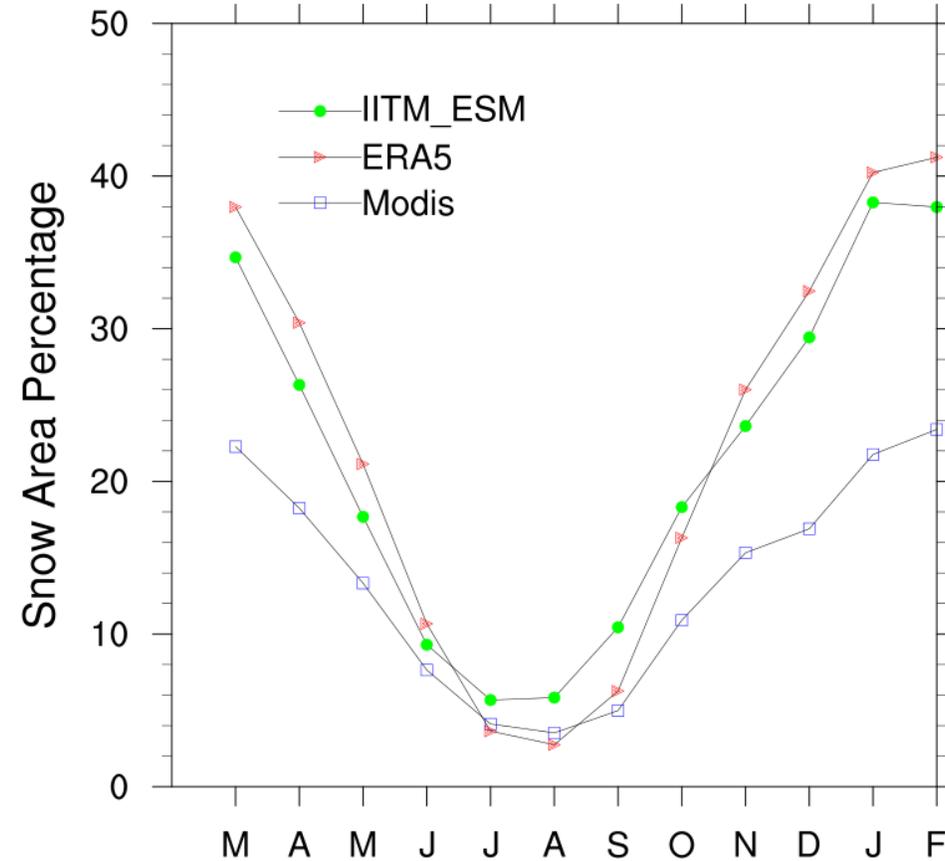
BharatFS ~6 km
Triangular Cubic-
octahedral based GFS

**Suite of Indigenously Developed Models at
IITM to cater the need across scales**

High resolution IITM-ESM (67Km) – HKH region

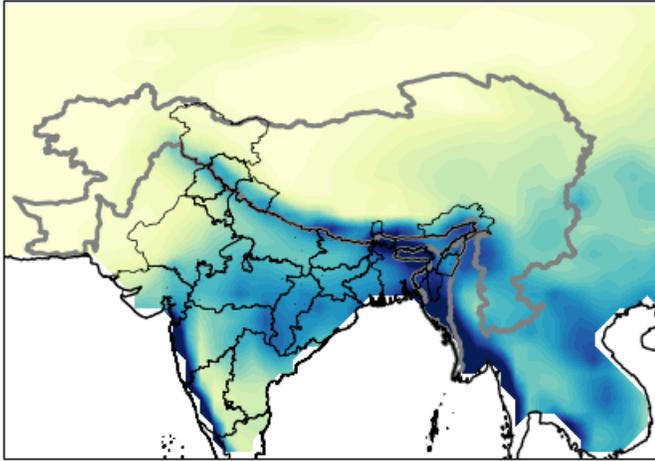


Seasonal Cycle of snow cover area (%)

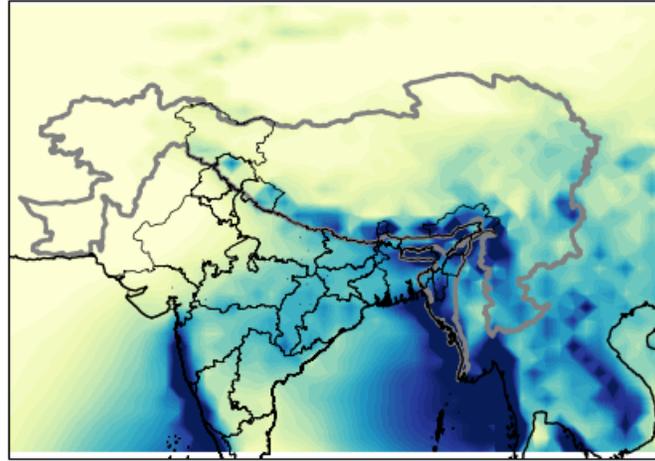


JJAS mean Precipitation (1991-2016)

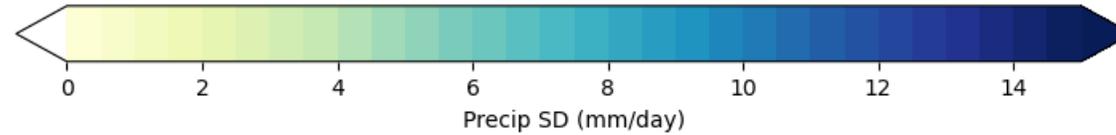
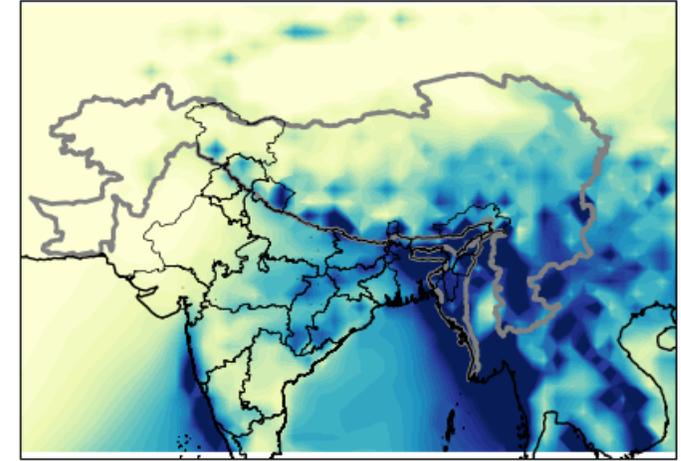
CRU



MMCFSv1



MMCFSv2

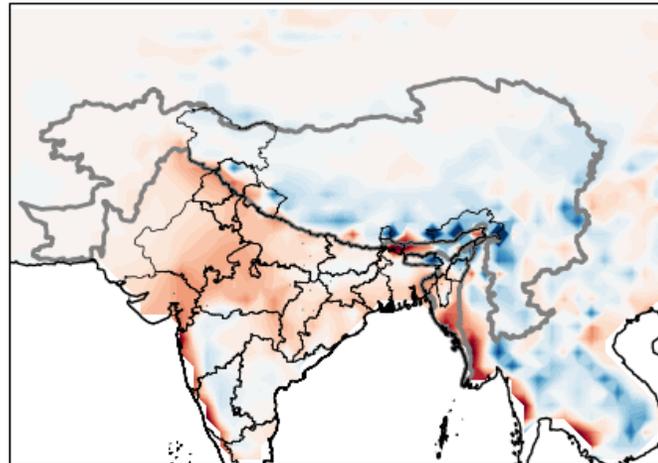


JJAS mean Precipitation bias

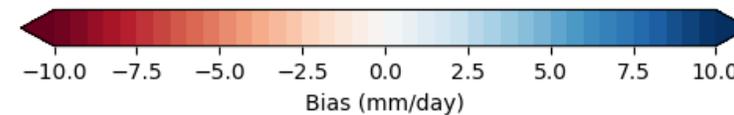
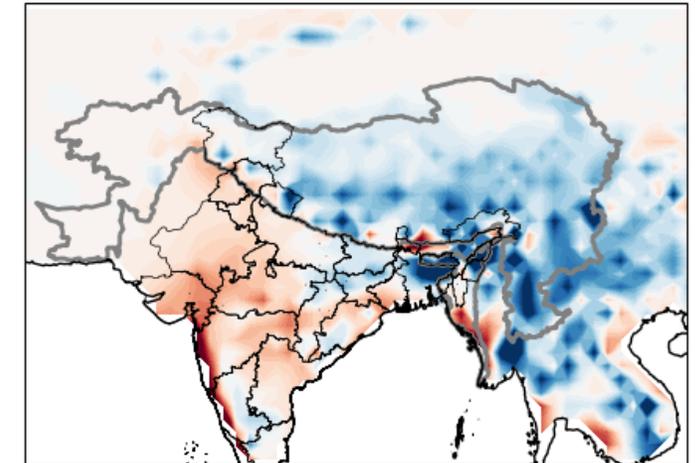
Models simulate a wet bias over the HKH region, especially in the southern region

HKH region is indicated in gray

MMCFSv1 - CRU

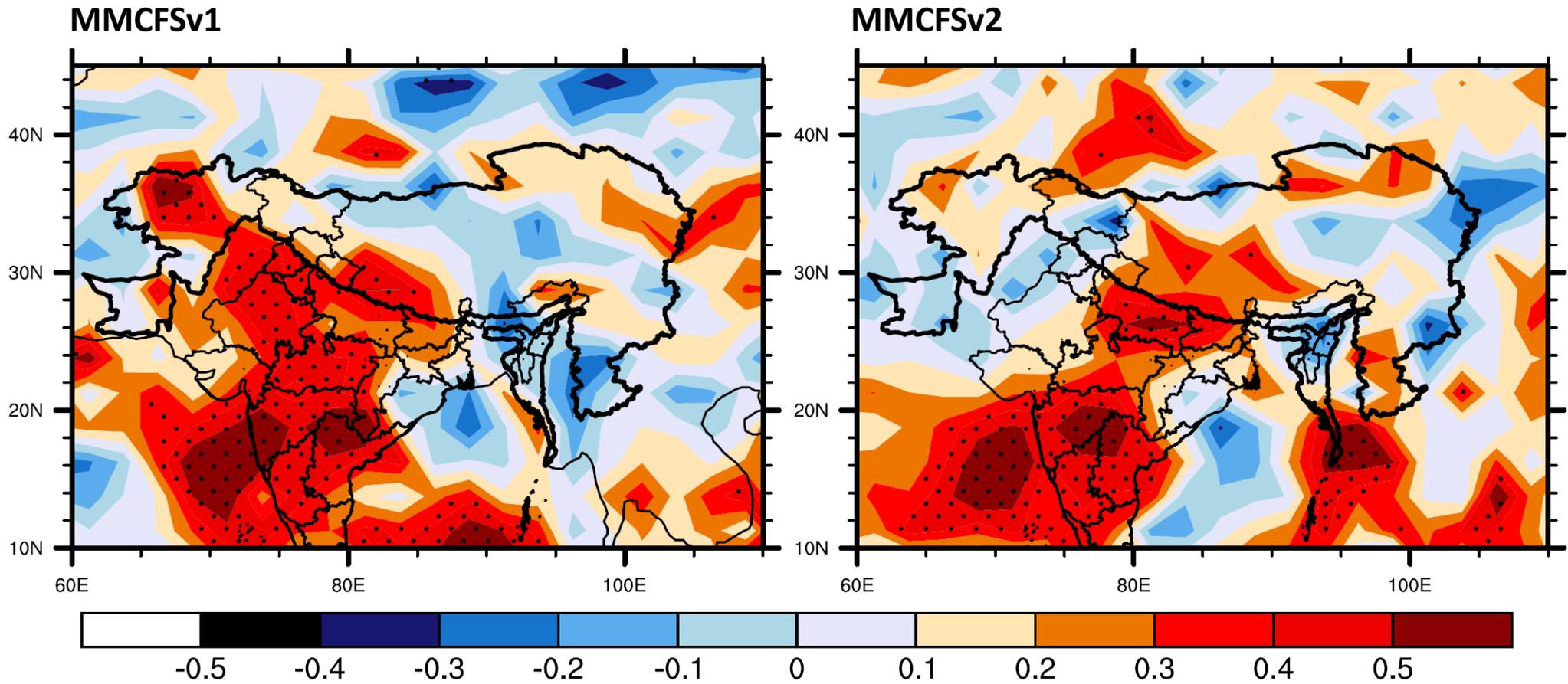


MMCFSv2 - CRU



MMCFSv2: April IC

Ready
Seasonal
forecasts



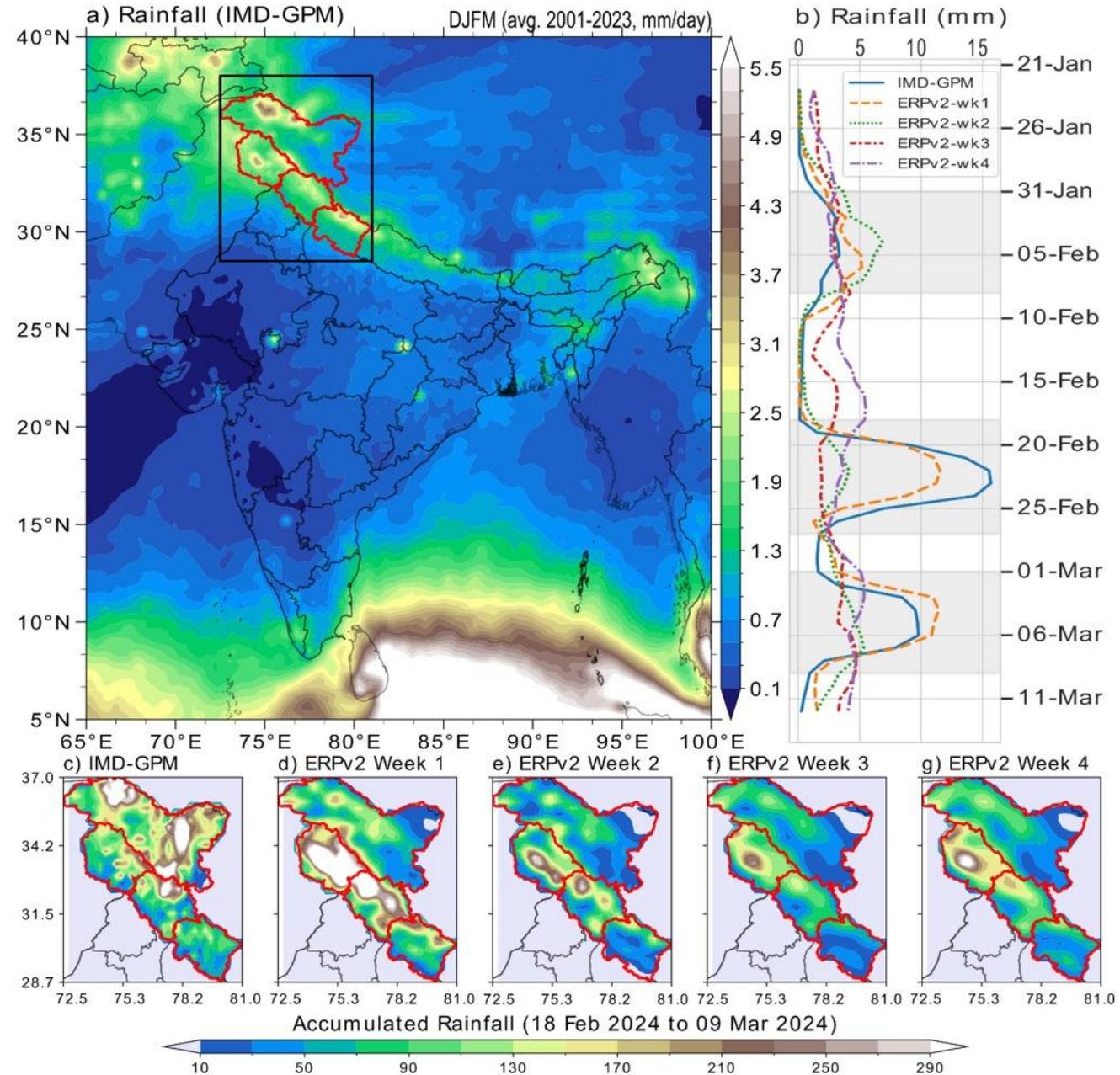
JJAS mean ACC for Precipitation (1991-2016)

Limited forecast skill except for some regions

Ready
Seasonal
forecasts

ERPV2 captures precipitation for week-1 forecast

Boreal winter-time precipitation statistics analyzed over the Indian subcontinent. (a) India map displaying December to March rainfall climatology based on IMD-GPM merged data, with a black box highlighting the Ladakh, Jammu & Kashmir, Himachal Pradesh, and Uttarakhand (LJKHPU) regions of Western Himalaya. (b) Time series of 5-day running mean rainfall during 2024, this covers prominent Western Disturbance (WD) events that caused widespread precipitation (31 Jan–8 Feb, 18–27 Feb, and 1–9 Mar 2024, shaded region), comparing IMD-GPM rainfall with Week 1 to Week 4 lead ERPv2 model forecasts averaged over the red line marked region in (a). (c-g) Spatial maps showing rainfall accumulation from 18th Feb to 9th March: (c) IMD-GPM data and (d-g) Week 1 to Week 4 lead ERPv2 forecasts, respectively, over LJKHPU region.



India's Landmark Achievement in Earth Sciences

Development of Bharat Forecast System



- Bharat Forecast System is a **triangular-cubic octahedral (TCO) grid** based global forecast model developed by IITM
- This grid enhances resolution specifically over the tropics, and the current version of the model runs at the horizontal resolution of about **6 km** over the tropics.

- The model was tested for last 3 years and after evaluation handed over to IMD on 26th May 2025 for operational forecasting. Now, India is the only country running global model with such a high resolution operationally.

- The forecast at real time for 3 days is available at IMD webpage

https://nwp.imd.gov.in/bharatfsproducts_cycle00_mausam_ar.php

- The 10 days forecast, and the archive is available at IITM webpage

<https://srf.tropmet.res.in/srf/smrps/index.php>

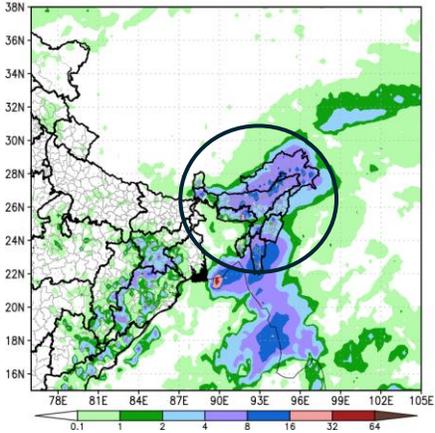


Extremely Heavy Rainfall over North-East Region on 31 May 2025

Go!
Short-Range
forecasts

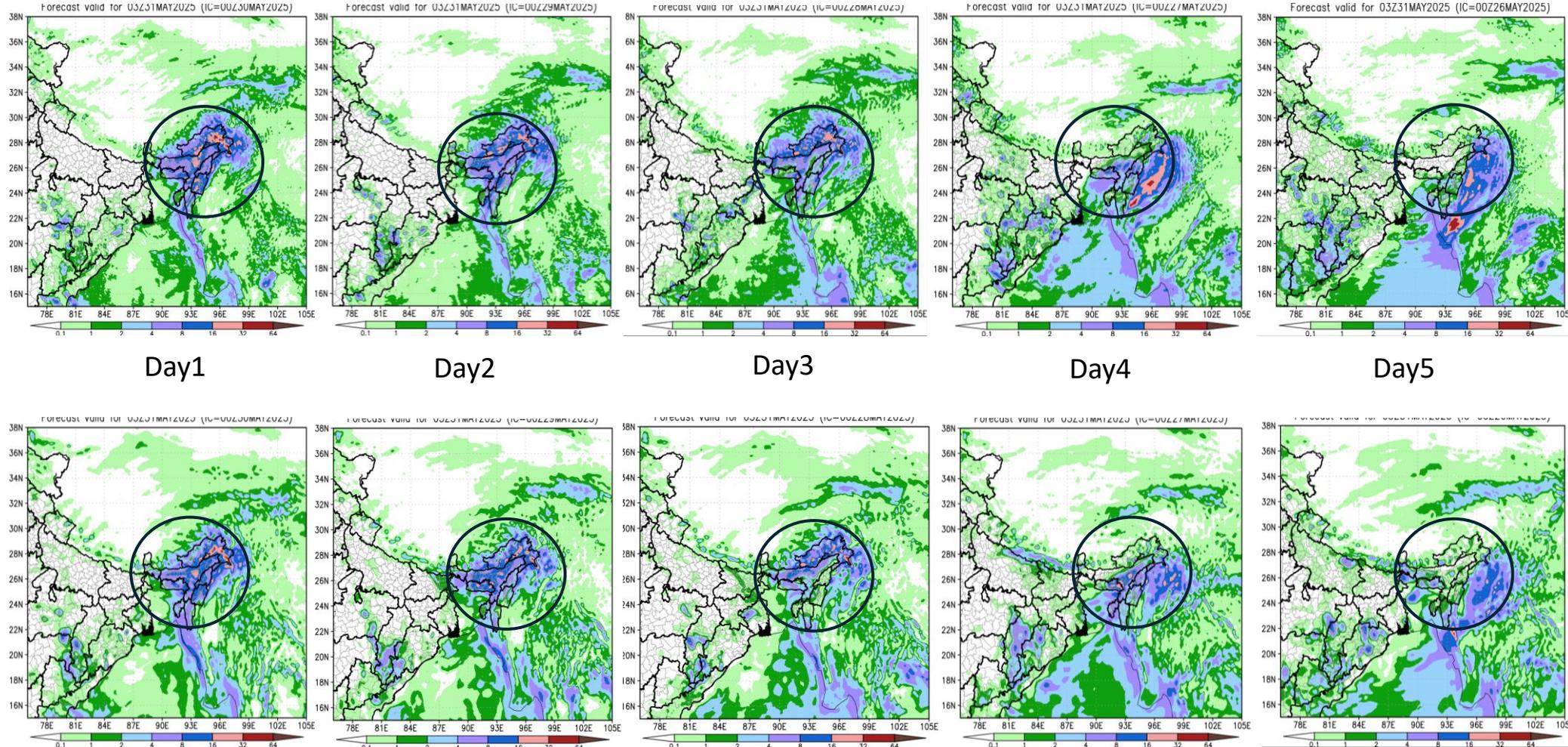
IMD-GPM

IMD : Rainfall (cm/day)
valid for 31052025



BharatFS Exceptionally well predicted the rainfall amount, higher than IMD gridded data but comparable with station recorded rainfall higher than 10 cm

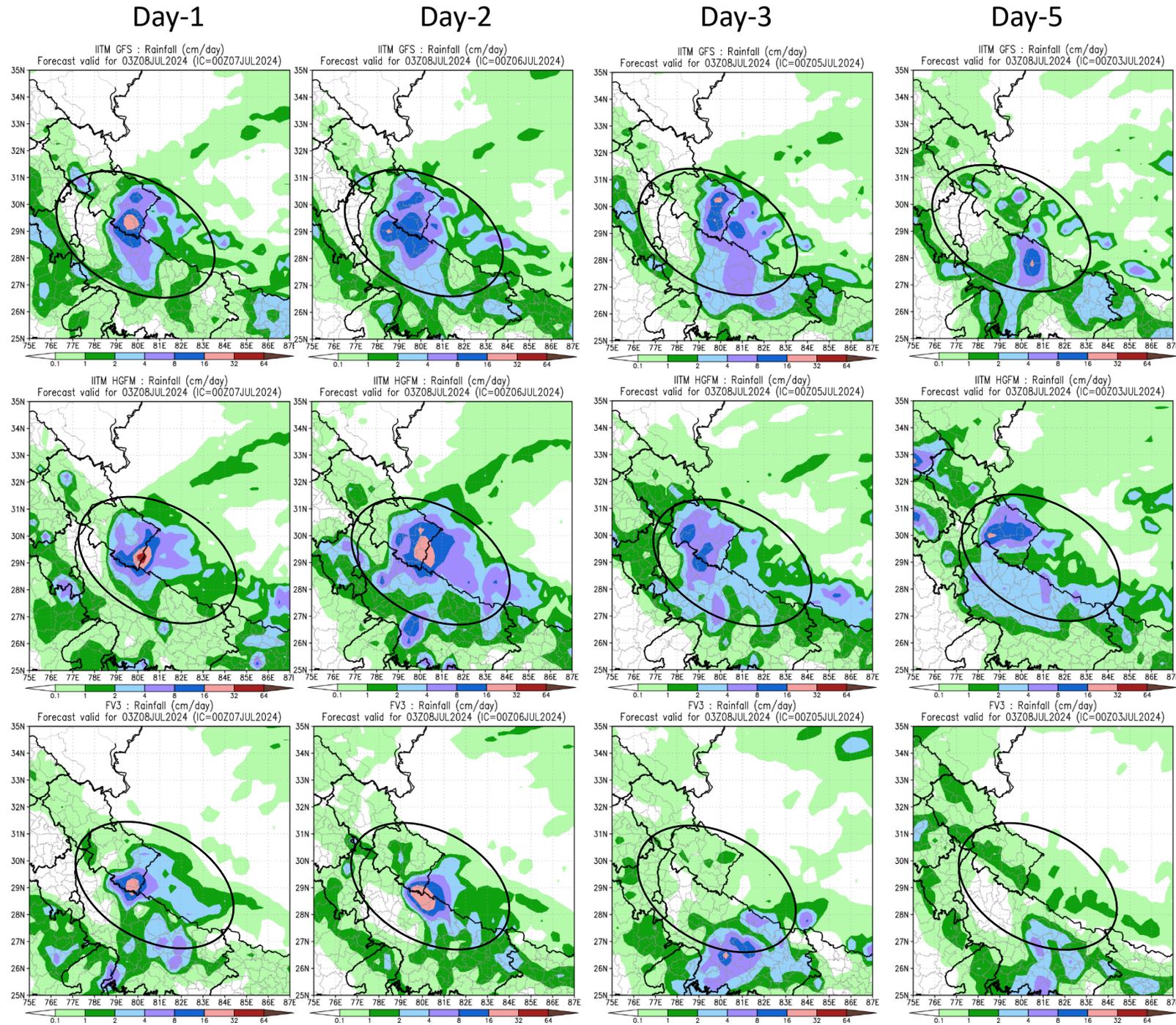
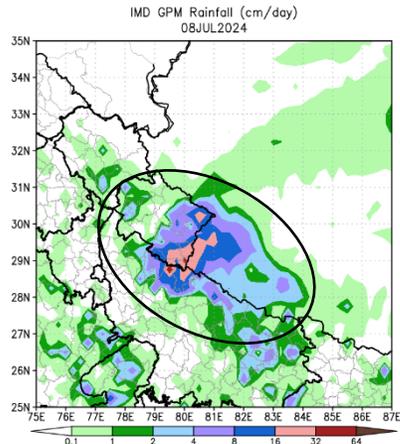
BharatFS 6 km resolution



IMD GFS 12 km resolution

8th July 2024
Exceptionally heavy rainfall
Event caused major flash floods
West Uttar Pradesh and Uttarakhand

IMD Gridded Data



IMD GFS
12 km resolution

BharatFS
6 km resolution



NCEP GFS (FV3)
13 km resolution

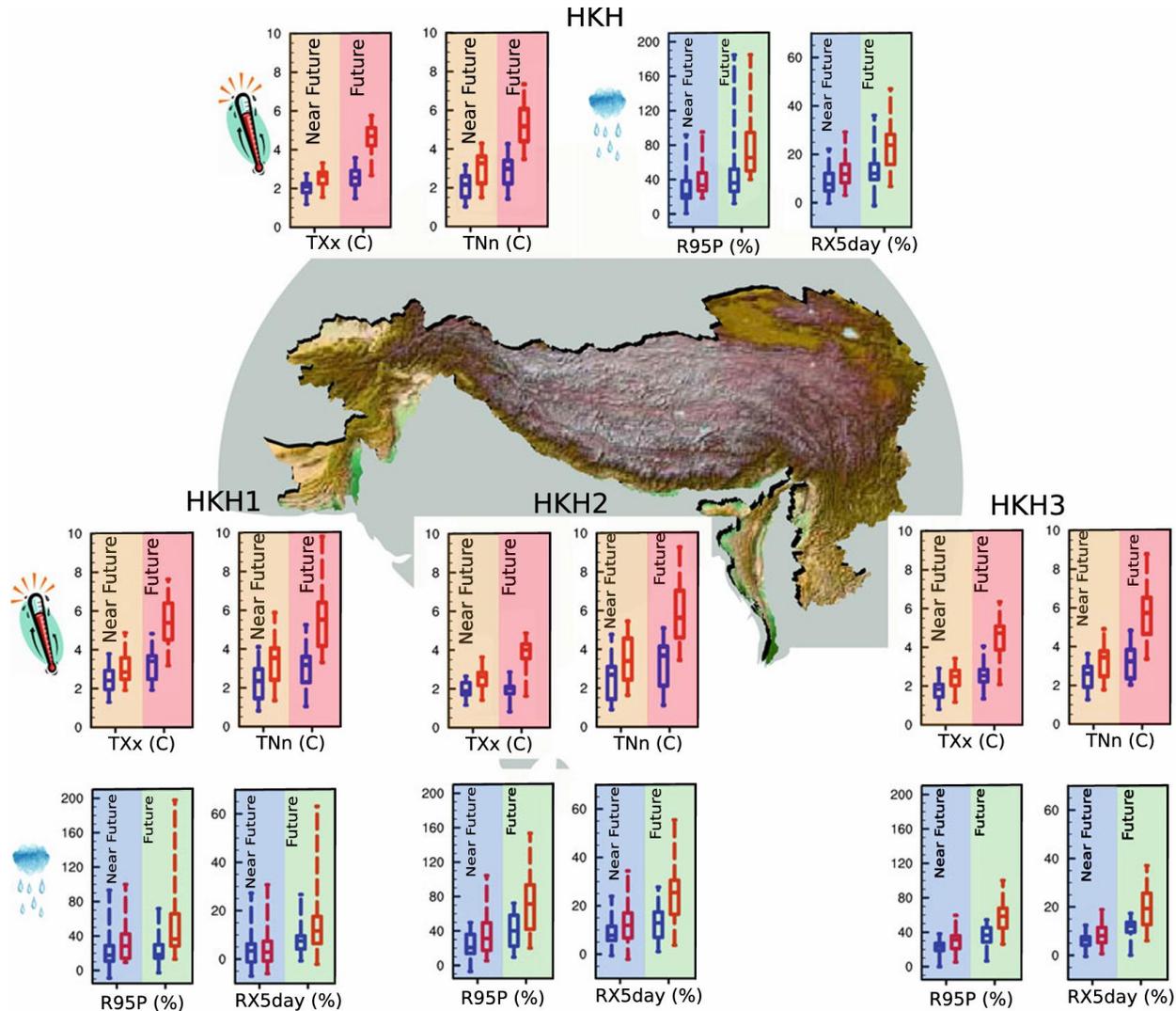
BharatFS
Exceptionally well predicted the rainfall amount and location

Conclusions

- Climate projections indicate rapid changes to the cryosphere in the Third Pole.
- IITM's modelling systems show varied levels of skill at short-to-seasonal time-scales:
 - A wet-bias over HKH region, with some regions depicting reasonable skill.
 - Week-1 forecasts capture precipitation associated with western disturbances
 - Short-range forecasts from BFS indicate better representation of extremes in high-altitude regions.
- A systematic assessment to include more case studies required to ascertain the robustness of modelling systems.

THANK YOU

Projected Changes



Projected changes in temperature in °C (yellow and pink) and precipitation in % (blue and green) extremes over HKH and its three sub-regions (as shown in Fig.11.1) from CMIP5 models. Changes with respect to present-day mean are shown as box whiskers from RCP4.5 (blue colour) and RCP8.5 (red colour). The ranges between the 25th and 75th quantiles are indicated by boxes, the MME medians are indicated by the horizontal lines within boxes, and the extreme ranges of models are indicated by whiskers