WCRP Climate Research Forum

Climate research priorities for the next decade

An online forum to discuss climate research priorities, opportunities and challenges in the next decade

Southern Asia: 30 November 2021

9:00 – 12:30 Coordinated Universal Time (UTC)

www.wcrp-climate.org/climate-research-forums

# CORDEX-South Asia: Providing High Resolution Climate Projections in Southern Asia Region

Region 6: South Asia


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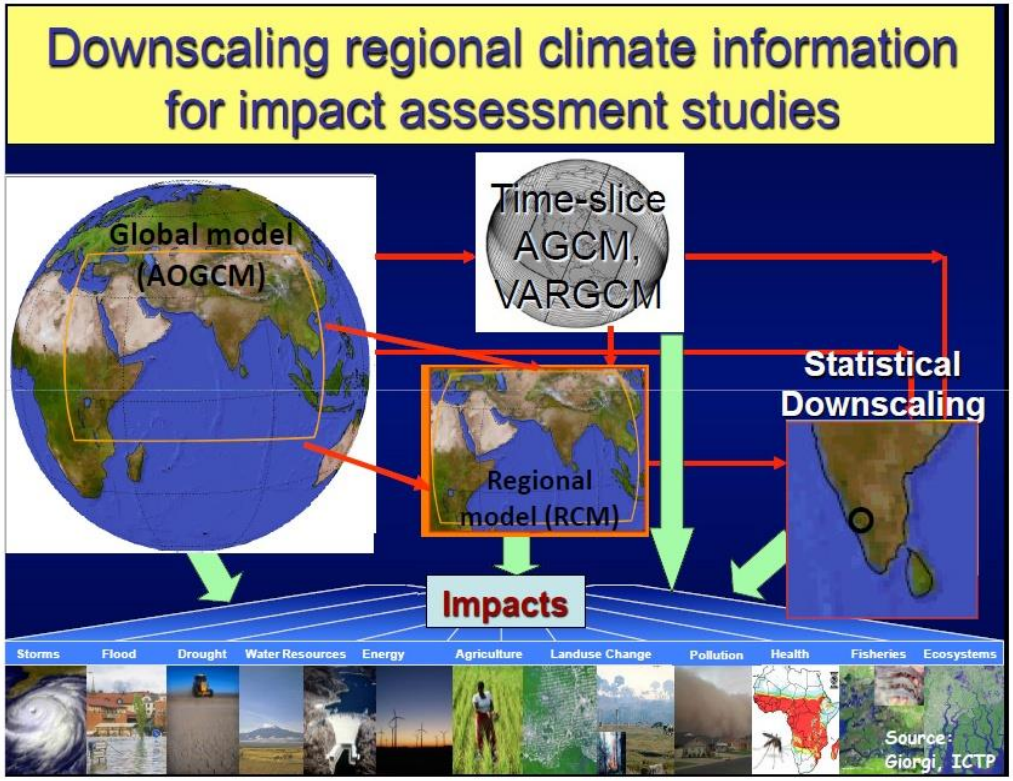
&
CORDEX Science Advisory Team (SAT) Member

# Regional Climate Information for Application Studies CORDEX South Asia

WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.

https://cordex.org/domains/region-6-south-asia-2/





**Centre for Climate Change Research**
Indian Institute of Tropical Meteorology, Pune, India

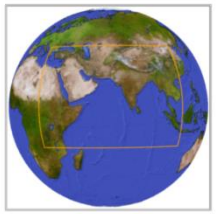
is leading CORDEX (Coordinated Regional Climate Downscaling Experiment) over South Asia Region

High Resolution (50 km) Dynamical Downscaling of CMIP5 Climate Projections based on RCP Scenarios during 1950-2100 using multiple RCMs

More information for CORDEX South Asia data access from CCCR-IITM Climate Data Portal and ESGF datanode are provided at: **http://cccr.tropmet.res.in/home/cordexsa_datasets.jsp**

WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

Region 6: South Asia



**CORDEX simulations are stored in a distributed archive (the Earth System Grid Federation, ESGF) after standardization & curation:** https://cordex.org/data-access/regional-climate-change-simulations-for-cordex-domains/

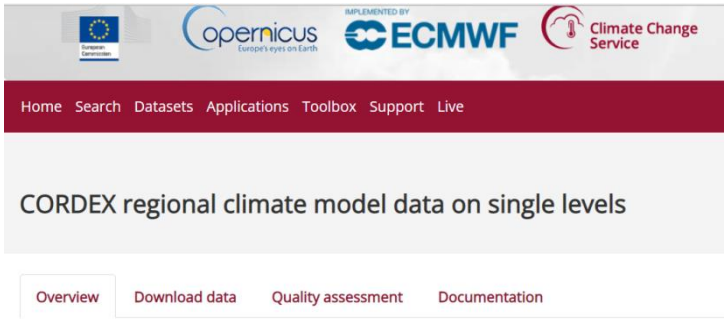
| | | ESGF | | | | | |
|---|---|---|---|---|---|---|---|
| | | models | | scenarios | | | |
| Domain | Res. | R | G | h | 26 | 45 | 85 |
| 6: South Asia (WAS) | 0.22 | 3 | 6 | 9 | 8 | 0 | 9 |
| | 0.44 | 3 | 12 | 17 | 6 | 17 | 17 |
| | total | 6 | 12 | 26 | 14 | 17 | 26 |

6: South Asia (WAS): https://cordex.org/domains/region-6-south-asia-2/
(*) Details on registered RCMs at https://github.com/IS-ENES-Data/cordex/blob/master/CORDEX_register.xlsx (version 10 Nov 2020); see also http://is-enes-data.github.io/CORDEX_RCMs_info.html
(1) ESGF information updated as of 23 Nov 2020 — publicly available at ESGF (23/11/2020) — available from modeling centers

| # | Domain | GCM_run | RCM | Evaluation | Historical | RCP2.6 | RCP4.5 | RCP6.0 | RCP8.5 | Institution | Contact Info. | Access (1) | License |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | WAS-22 | ECMWF-ERAINT | COSMO-crCLIM-v1-1_v1 | 1979-2015 | N/A | N/A | N/A | N/A | N/A | CLMcom-ETH | silje.soerland | ESGF | unrestricted (*) |
| 2 | WAS-22 | EC-EARTH_r12i1p1 | COSMO-crCLIM-v1-1_v1 | N/A | 1950-2005 | N/A | N/A | N/A | 2006-2099 | CLMcom-ETH | (*) | ESGF | unrestricted (*) |
| 3 | WAS-22 | MPI-ESM-LR_r1i1p1 | COSMO-crCLIM-v1-1_v1 | N/A | 1950-2005 | 2006-2099 | N/A | N/A | 2006-2099 | CLMcom-ETH | (*) | ESGF | unrestricted (*) |
| 4 | WAS-22 | NorESM1-M_r1i1p1 | COSMO-crCLIM-v1-1_v1 | N/A | 1950-2005 | 2006-2099 | N/A | N/A | 2006-2099 | CLMcom-ETH | (*) | ESGF | unrestricted (*) |
| 5 | WAS-22 | ECMWF-ERAINT | REMO2015_v1 | 1979-2017 | N/A | N/A | N/A | N/A | N/A | GERICS | (*) | ESGF | unrestricted (*) |
| 6 | WAS-22 | HadGEM2-ES_r1i1p1 | REMO2015_v1 | N/A | 1970-2005 | 2006-2099 | N/A | N/A | 2006-2099 | GERICS | (*) | ESGF | unrestricted (*) |
| 7 | WAS-22 | MPI-ESM-LR_r1i1p1 | REMO2015_v1 | N/A | 1970-2005 | 2006-2100 | N/A | N/A | 2006-2100 | GERICS | (*) | ESGF | unrestricted (*) |
| 8 | WAS-22 | NorESM1-M_r1i1p1 | REMO2015_v1 | N/A | 1970-2005 | 2006-2100 | N/A | N/A | 2006-2100 | GERICS | (*) | ESGF | unrestricted (*) |
| 9 | WAS-22 | ECMWF-ERAINT | RegCM4-7_v0 | 1979-2016 | N/A | N/A | N/A | N/A | N/A | ICTP | (*) | ESGF | unrestricted (*) |
| 10 | WAS-22 | MIROC5_r1i1p1 | RegCM4-7_v0 | N/A | 1970-2005 | 2006-2099 | N/A | N/A | 2006-2099 | ORNL | (*) | ESGF | TBC (*) |
| 11 | WAS-22 | MPI-ESM-MR_r1i1p1 | RegCM4-7_v0 | N/A | 1970-2005 | 2006-2099 | N/A | N/A | 2006-2099 | ORNL | (*) | ESGF | TBC (*) |
| 12 | WAS-22 | NorESM1-M_r1i1p1 | RegCM4-7_v0 | N/A | 1970-2005 | 2006-2099 | N/A | N/A | 2006-2099 | ORNL | (*) | ESGF | TBC (*) |
| 13 | WAS-44 | CanESM2_r1i1p1 | RegCM4-4_v5 | N/A | 1951-2005 | N/A | 2006-2099 | N/A | 2006-2099 | IITM | (*) | ESGF | TBC (*) |
| 14 | WAS-44 | CNRM-CM5_r1i1p1 | RegCM4-4_v5 | N/A | 1951-2005 | N/A | 2006-2099 | N/A | 2006-2085 | IITM | (*) | ESGF | TBC (*) |
| 15 | WAS-44 | CSIRO-Mk3-6-0_r1i1p1 | RegCM4-4_v5 | N/A | 1951-2005 | N/A | 2006-2099 | N/A | 2006-2099 | IITM | (*) | ESGF | TBC (*) |
| 16 | WAS-44 | ECMWF-ERAINT | RegCM4-4_v5 | 1979-2008 | N/A | N/A | N/A | N/A | N/A | IITM | (*) | ESGF | TBC (*) |
| 17 | WAS-44 | IPSL-CM5A-LR_r1i1p1 | RegCM4-4_v5 | N/A | 1951-2005 | N/A | 2006-2099 | N/A | 2006-2099 | IITM | (*) | ESGF | TBC (*) |
| 18 | WAS-44 | MPI-ESM-MR_r1i1p1 | RegCM4-4_v5 | N/A | 1951-2005 | N/A | 2006-2099 | N/A | 2006-2099 | IITM | (*) | ESGF | TBC (*) |
| 19 | WAS-44 | GFDL-ESM2M_r1i1p1 | RegCM4-4_v5 | N/A | 1951-2005 | N/A | 2006-2099 | N/A | 2006-2099 | IITM | (*) | ESGF | TBC (*) |
| 20 | WAS-44 | MPI-ESM-LR_r1i1p1 | REMO2009_v1 | N/A | 1961-2005 | 2006-2100 | 2006-2100 | N/A | 2006-2100 | MPI-CSC | (*) | ESGF | unrestricted (*) |
| 21 | WAS-44 | CanESM2_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | N/A | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 22 | WAS-44 | CNRM-CM5_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | N/A | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 23 | WAS-44 | CSIRO-Mk3-6-0_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | N/A | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 24 | WAS-44 | ECMWF-ERAINT | RCA4_v2 | 1980-2010 | N/A | N/A | N/A | N/A | N/A | SMHI | (*) | ESGF | unrestricted (*) |
| 25 | WAS-44 | EC-EARTH_r12i1p1 | RCA4_v2 | N/A | 1951-2005 | 2006-2100 | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 26 | WAS-44 | IPSL-CM5A-MR_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | N/A | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 27 | WAS-44 | MIROC5_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | 2006-2100 | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 28 | WAS-44 | HadGEM2-ES_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | 2006-2099 | 2006-2099 | N/A | 2006-2099 | SMHI | (*) | ESGF | unrestricted (*) |
| 29 | WAS-44 | MPI-ESM-LR_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | 2006-2100 | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 30 | WAS-44 | NorESM1-M_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | 2006-2100 | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 31 | WAS-44 | GFDL-ESM2M_r1i1p1 | RCA4_v2 | N/A | 1951-2005 | N/A | 2006-2100 | N/A | 2006-2100 | SMHI | (*) | ESGF | unrestricted (*) |
| 32 | WAS-44i | MPI-ESM-LR_r1i1p1 | REMO2009_v1 | N/A | 1961-2005 | 2006-2100 | 2006-2100 | N/A | 2006-2100 | MPI-CSC | (*) | ESGF | unrestricted (*) |

https://cordex.org/wp-content/uploads/2020/12/CORDEX_simulations_Dec_2020.xlsx

Climate Data Store (CDS)
CORDEX data subset




- **The CDS subset of CORDEX data is an effort done by Copernicus to consolidate a World-wide CORDEX dataset, and has also contributed to the IPCC-AR6 WGI activities**

https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cordex-domains-single-levels?tab=overview

# Highlights

## CORDEX experiment design for dynamical downscaling of CMIP6

- Experiment protocol for RCMs to downscale a subset of climate scenarios from the CMIP6 ensemble of projections generated in ScenarioMIP, and to make these downscaled regional scenarios publicly available
  ( https://cordex.org/wp-content/uploads/2021/05/CORDEX-CMIP6_exp_design_RCM.pdf )

  - invites you to comment on the CORDEX-CMIP6 Variable List, see webpage:
    https://cordex.org/2021/09/30/we-invite-you-to-comment-on-the-cordex-cmip6-variable-list/

## The future scientific challenges for CORDEX

- Developed a White Paper with the purpose to point out scientific challenges in regional climate modelling for better informed decision making process in regions and setting the basis for the CORDEX science plan
  ( https://cordex.org/wp-content/uploads/2021/05/The-future-of-CORDEX-MAY-17-2021.pdf )

## The Flagship Pilot Studies (FPSs)

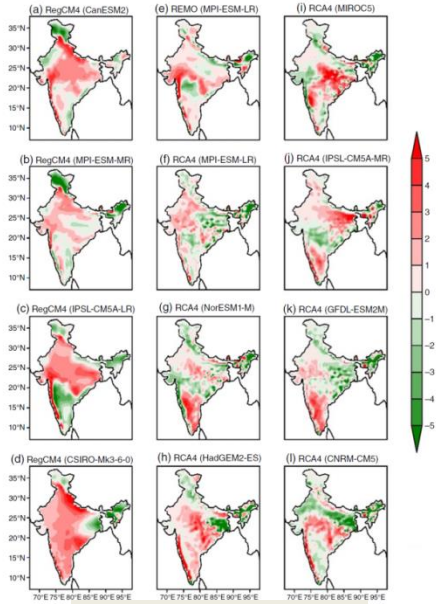
- Established with the aim of improving the capability of the models in reproducing regional climate features with a focus on extreme events with large socioeconomic impacts and can for example handle intensive rain, droughts, floods and heatwaves
  ( https://cordex.org/experiment-guidelines/flagship-pilot-studies/ )

# CORDEX South Asia (WAS) Activities

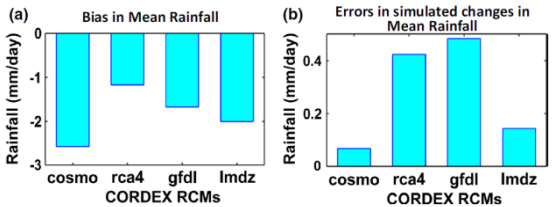
## Opportunities and Challenges for better assessment of regional climate change

- More than 40 research publications (2014 onwards) analysed the RCM outputs from the CORDEX South Asia ensemble (see http://cccr.tropmet.res.in/home/cordexsa_pub.jsp )

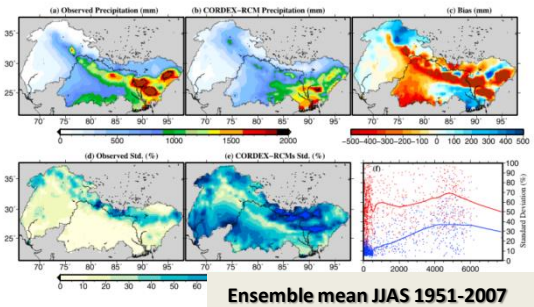
- Future global **meteorological drought** hot spots: A study based on CORDEX Data **(Spinoni et al., 2020)**
- Contrasting regional and global climate simulations over South Asia **(Rana et al., 2020)**
- **Added value** of CORDEX-SA experiments in simulating **monsoon precipitation** over India **(Choudhary etal.2018)**
- Understanding the cascade of GCM and downscaling (dynamical versus statistical) **uncertainties** in capturing the spatio-temporal variability of **hydro-climatic projections** over India **(Sharma et al., 2017)**
- Do dynamic regional models **add value** to the global model projections of **Indian monsoon**? **(Singh etal, 2017)**
- Climatic uncertainty in RCMs is far larger than observations over the **Himalayan water towers** **(Mishra 2015)**
- Reliability of regional and global climate models to simulate **precipitation extremes** over India **(Mishra et al., 2014)**



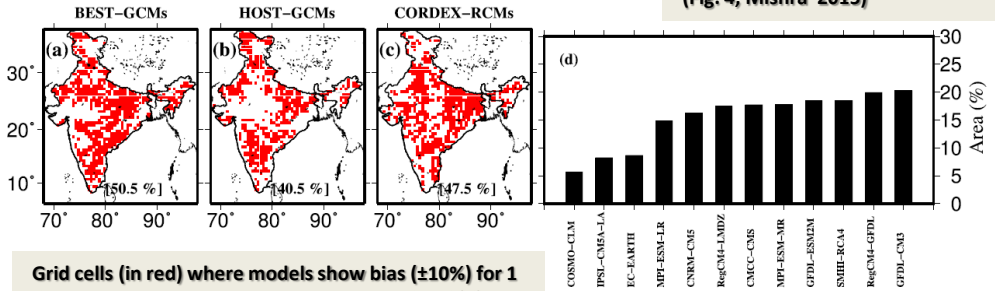

AV JJAS mean precip (Fig. 2, Choudhary et al., 2018)




ISMR (Fig. 16, Singh et al., 2017)




Ensemble mean JJAS 1951-2007 (Fig. 4, Mishra 2015)

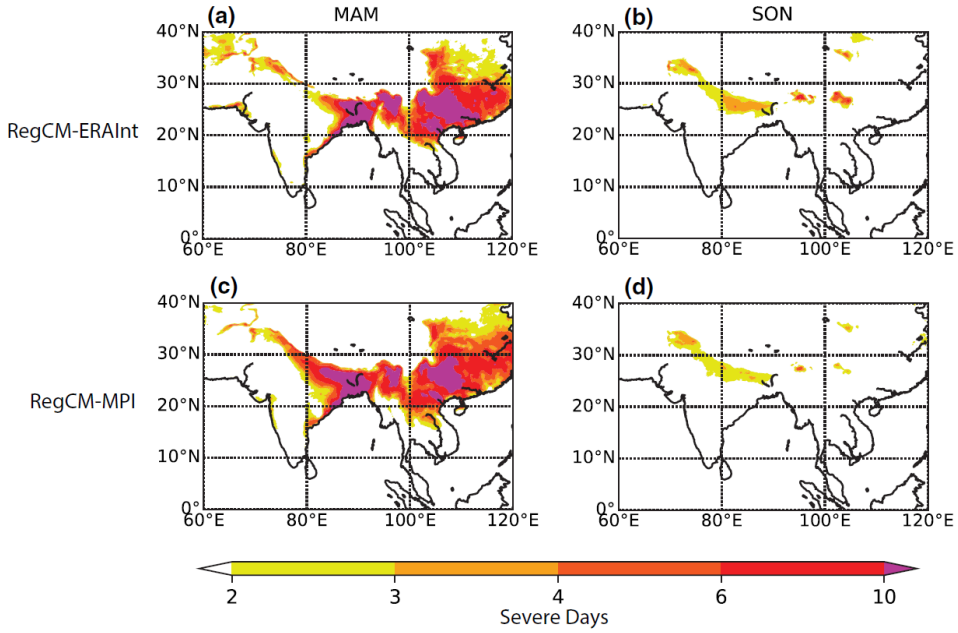



Grid cells (in red) where models show bias (±10%) for 1 day precip maxima at 25 year return period and (d) models and the area (%) (Fig. 9, Mishra et al. 2014)

# Large-scale environments supportive for severe thunderstorms are projected to increase over eastern India and Bangladesh during the warm season months in the RCP2.6 and RCP8.5 scenarios during the 21st century

## - ICTP-RegCM CORDEX-CORE WAS-22 simulations

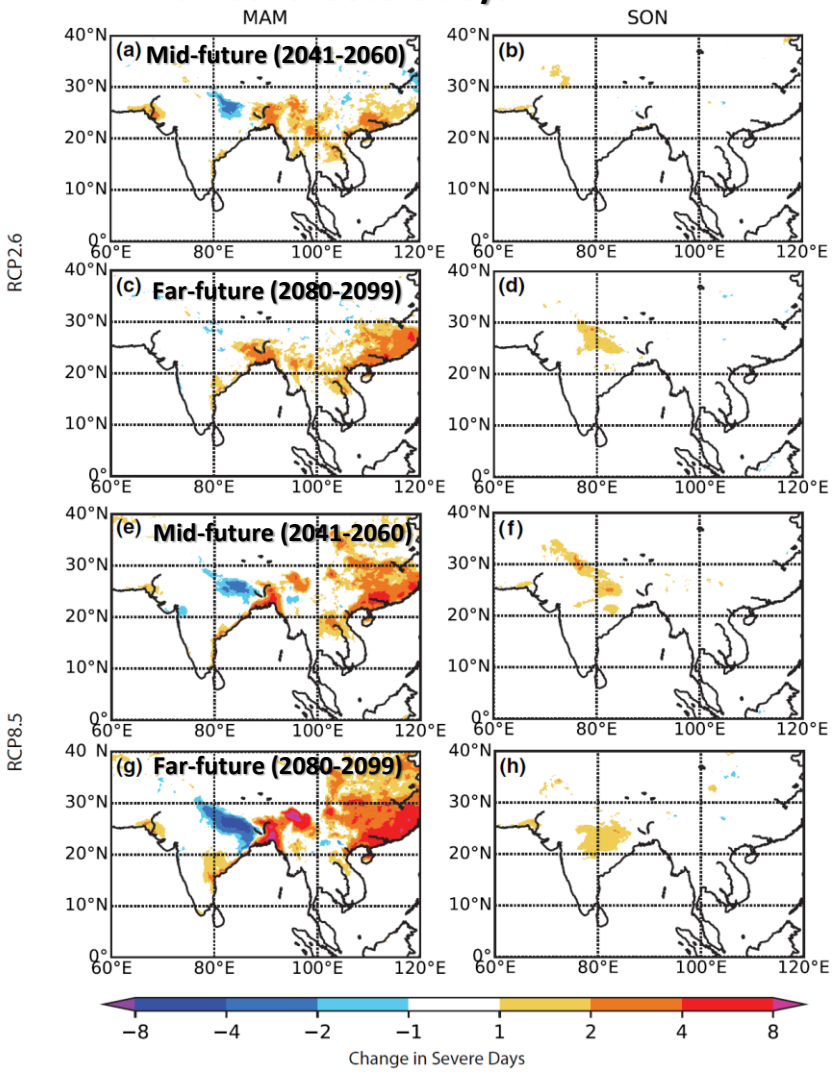
### Seasonal Mean number of Severe Days Hist 1995-2014




Severe potential is measured in terms of Convective Available Potential Energy (CAPE) and vertical wind-shear

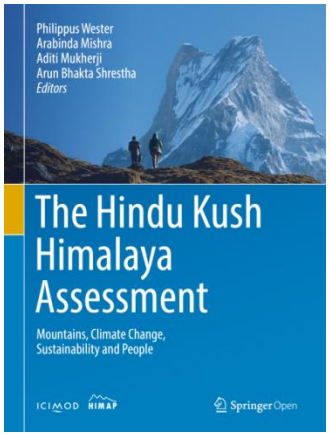
Source: Glazer et al. (2021, Climate Dynamics, https://doi.org/10.1007/s00382-020-05439-4 )

### Projected Change in Seasonal Mean number of Severe Days

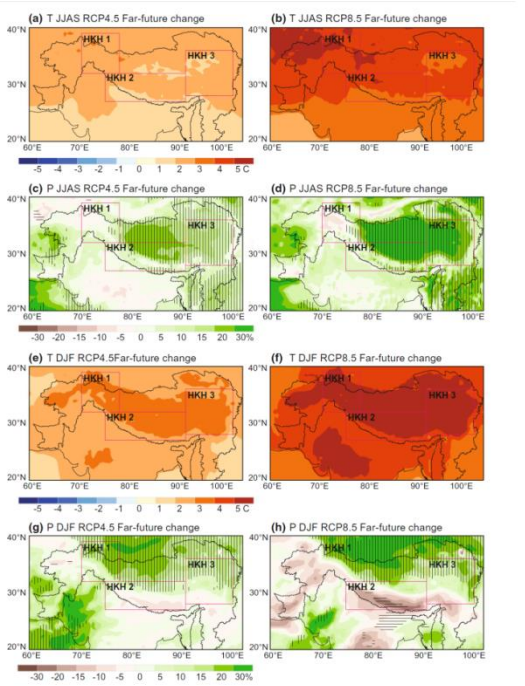


# CORDEX South Asia (WAS) Activities

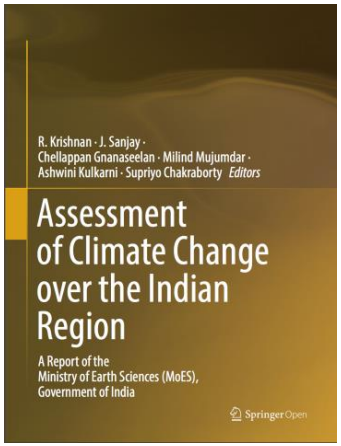
## Assessments of regional climate change




- Unravelling Climate Change in the Hindu Kush Himalaya: Rapid Warming in the Mountains and Increasing Extremes (Krishnan et al., 2019)




**CORDEX South Asia RCM ensemble mean climate change in HKH region (Fig. 3.13, Krishnan et al., 2019)**




- CORDEX South Asia future projections of regional climate change over India
  (In Krishnan et al., 2020)

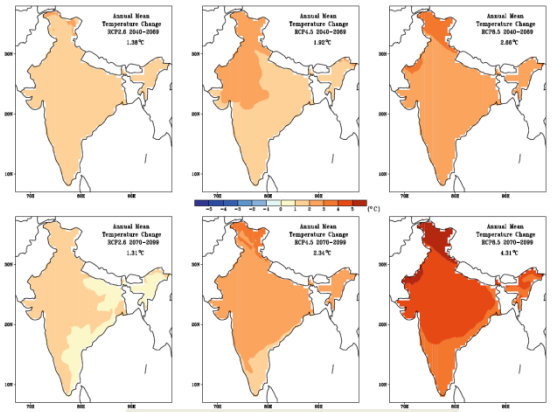


Fig. 2.7, Krishnan et al., (2020)

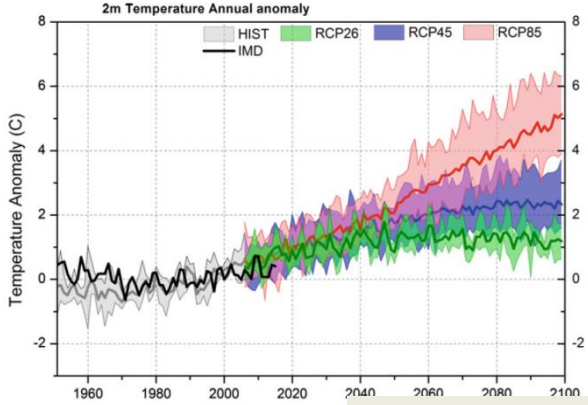



Fig. 2.8, Krishnan et al., (2020)

# CORDEX South Asia (WAS) Activities

## Development of regional capacity for assessment of regional climate change

ARRCC Asia Regional Resilience to a Changing Climate | Met Office | ICIMOD | UKaid from the British people

PROCEEDINGS OF THE TRAINING ON

**Regional climate change projections**

Climate change analysis using CORDEX regional climate models over South Asia **(ICIMOD, UKMO, WCRP & CORDEX-IPO)**

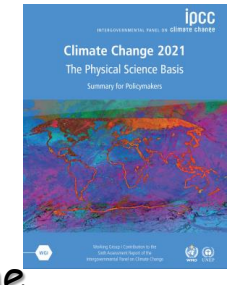
12–14 and 19–21 October 2020 | Platform: Microsoft Teams

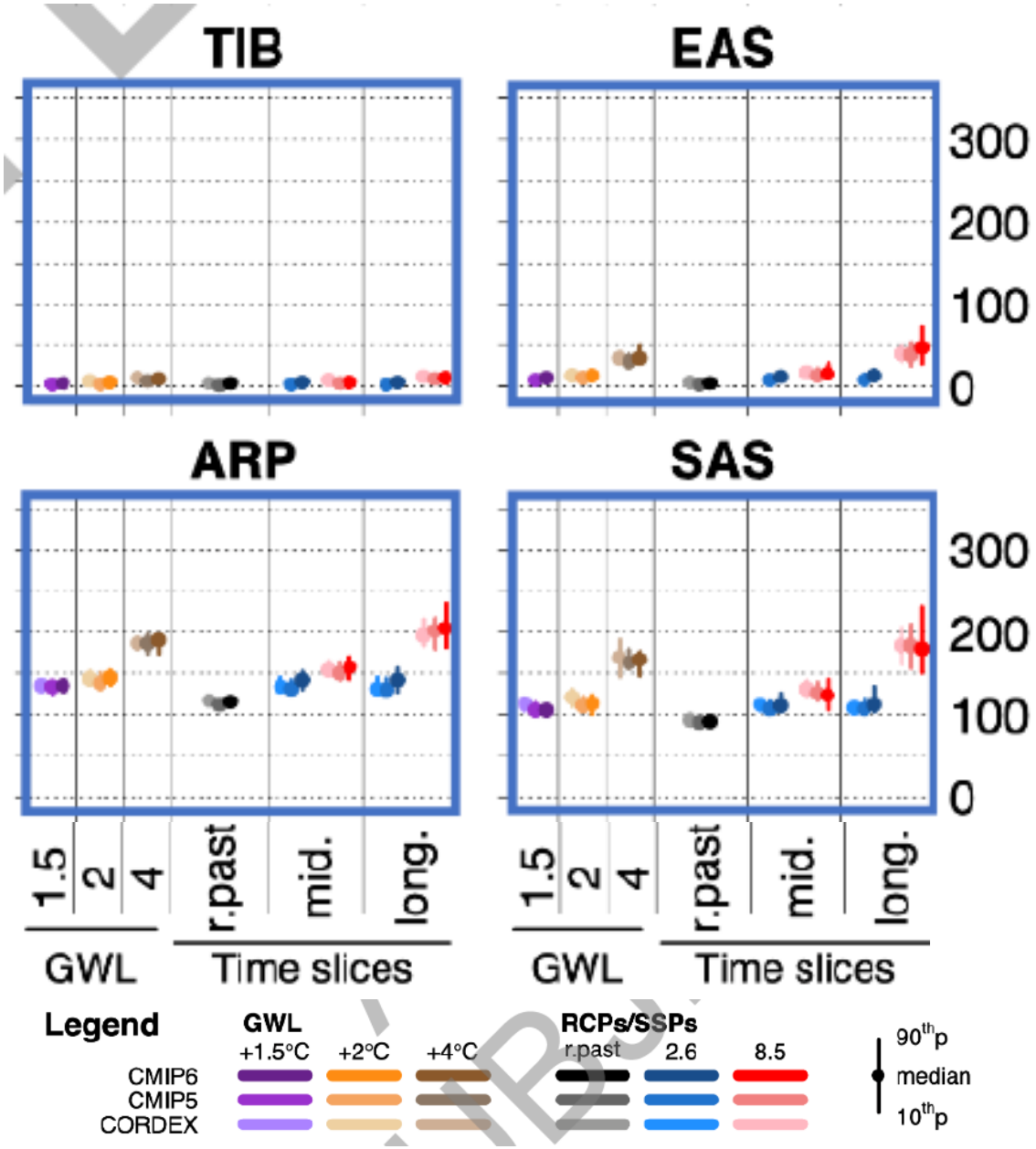
**Science & Training Workshop on Climate Change over the High Mountains of Asia- IITM, Pune, India, October 2018**
(CCCR-IITM, MoES-GoI, DCCC-IISc, MAIRS-FE@DCCC)

**First CORDEX South Asia Training Workshop- IITM, Pune, India, October 2012**
(CCCR-IITM,START,ICTP,CSAG,SMHI & ICSU-ROAP)

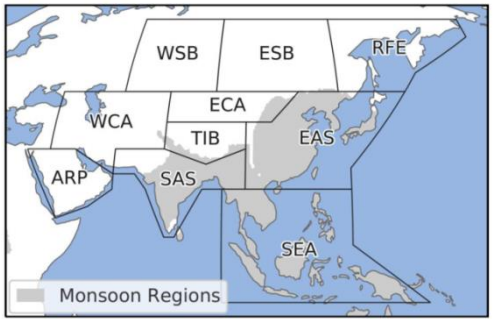
**Second CORDEX Science and Training Workshop in South Asia- ICIMOD, Kathmandu, Nepal, August 2013**
(WCRP-CORDEX, MAIRS, APN, ICIMOD, CCCR-IITM & IAP)

# Number of days per year with daily maximum temperature > 35°C in AR6 selected Asia regions



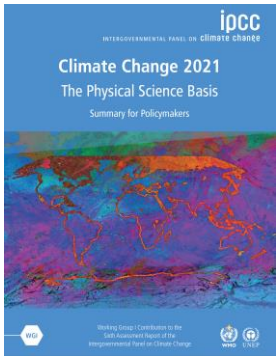




- The uncertainty in the assessment of changes in Climatic-impact drivers (CIDs) due to climate models, time, scenarios and regional downscaling are illustrated in figures by comparing the CMIP5, CMIP6 and CORDEX ensembles for global warming levels (GWLs) 1.5°C, 2°C & 4°C




Adapted from IPCC AR6 WGI:
Figure 12.SM.1: Regional projections for the number of days per year with maximum temperature exceeding 35°C.....
(Ranasinghe, et al. 2021;
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_12.pdf )

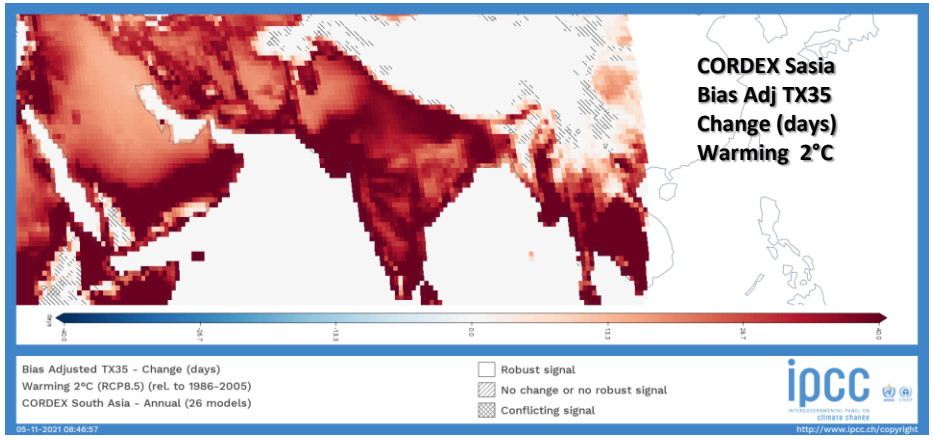
IPCC Working Group I (WGI): Sixth Assessment Report

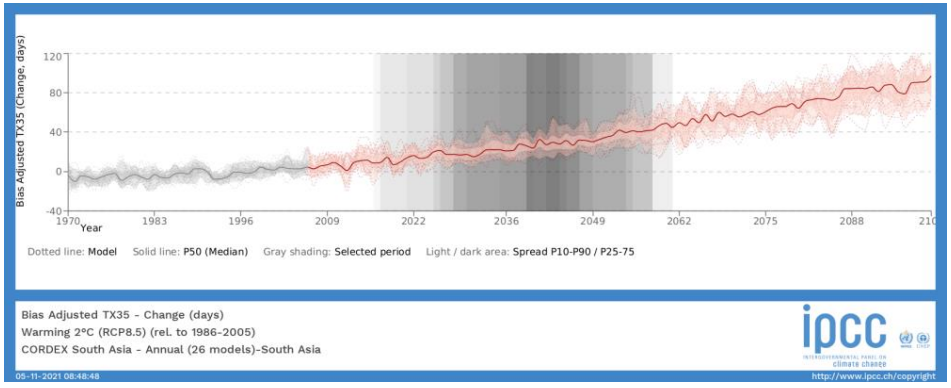


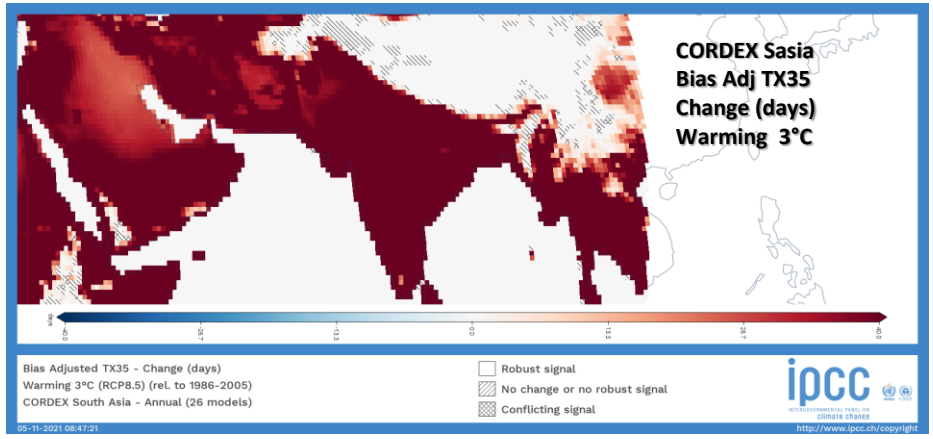

## IPCC WGI Interactive Atlas

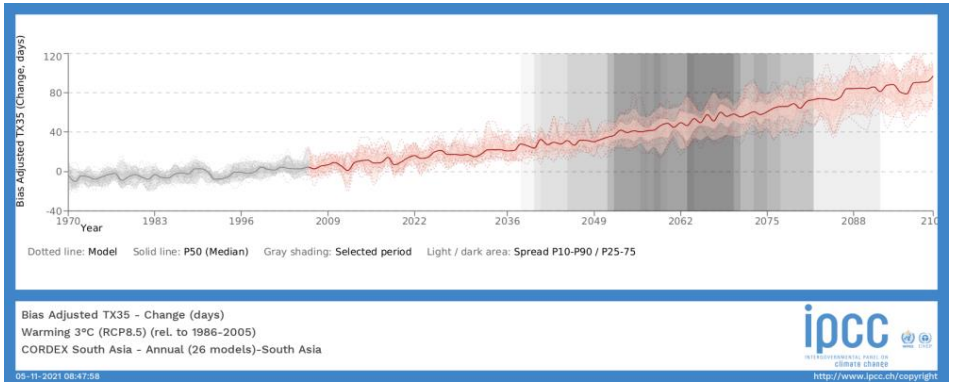
A novel tool for flexible spatial and temporal analyses of much of the observed and projected climate change information underpinning the Working Group I contribution to the Sixth Assessment Report, including regional synthesis for Climatic Impact-Drivers (CIDs).


https://interactive-atlas.ipcc.ch/



# Convection-Permitting Third Pole (CPTP)

## CORDEX-FPS: High resolution climate modeling with a focus on mesoscale convective systems and associated precipitation over the Third Pole region

CCCR-IITM is a modeling partner in this five year (2020-2024) International CORDEX Flagship Pilot Study (FPS) project

- This FPS aims to better understand the regional characteristics of water cycle and its variabilities and changes over the TP and adjoining regions using a set of coordinated high resolution regional climate downscaling experiments carried out by international participants with a focus on convection-permitting simulations (2-5 km) using different models or model setups.

**Project coordination:**

CORDEX-FPS: CPTP project webpage:
http://rcg.gvc.gu.se/cordex_fps_cptp/

**Lead investigator**

Deliang Chen, University of Gothenburg, Sweden

CORDEX-FPS: CPTP

**Co-leaders for WGI: modelling**

Andreas F. Prein, National Center For Atmospheric Research (NCAR), USA
Nikolina Ban, University of Innsbruck, Austria

**Co-leaders for WGII: data**

Tandong Yao, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, China
Hans Christian Steen-Larsen, University of Bergen, Norway

# CPTP MCS Case Study results presented in the poster session of the Fifth Convection-Permitting Modeling Workshop 2021 (CPM2021):

https://www.pco-prime.com/tougou2021_ws/poster/A3-26_Andreas_Prein.html

## The Convection-Permitting Third Pole (CPTP) CORDEX Flagship Pilot Study

AF Prein (prein@ucar.edu), N Ban,D Chen, S Jayanarayanan, S Sobolowski, X Chen, T Ou, X Zhou, H-W Lai, S Sugimoto, D Belusic, J Tang, K Furtado, L Li, L Zou, R Leung, S Hasson, P Li, M Ekstrom, HC Steen-Larsen, L Dietrich, PK Pothapakula, P Sheridan, R Stuart, K Sakaguchi, J Kukulies, J Curio

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

## Experimental Design

The minimum domain setup (Domain 1) for experiments in the CPTP project is shown in Fig. 1. An intermediate nest with coarser grid spacing is recommended to reduce the scale difference between the driving data -the ERA5 reanalysis or GCM data - and the convection-permitting model simulation.

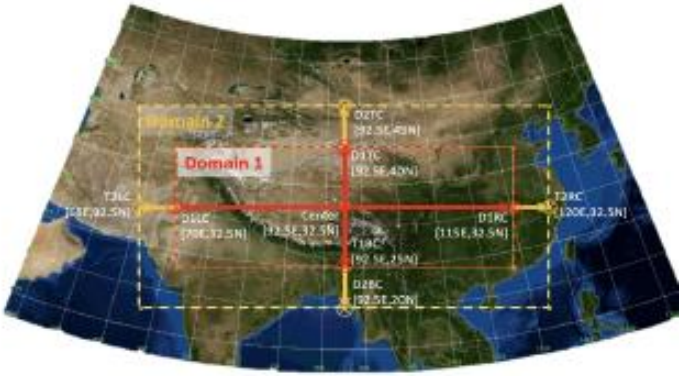


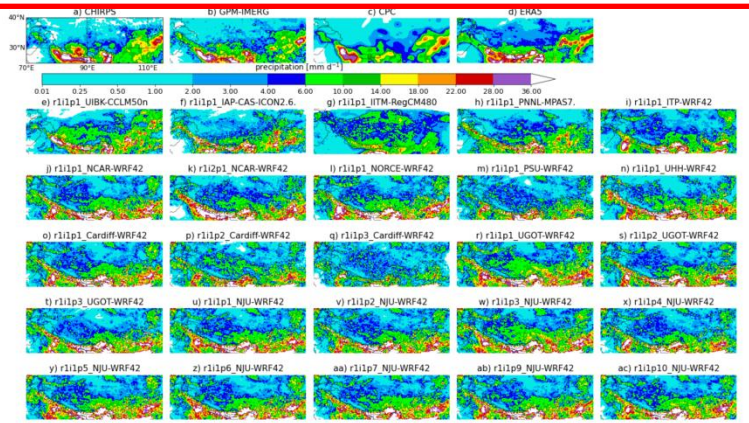

Fig. 1 - Common domain setup. While covering the central points (D1LC, D1TC, D1RC, and D1BC) in the kilometer-scale model domain is mandatory, the corne locations of the domain can vary due to differences in RCM projections.

Three case study experiments were performed by each participating modeling center to get an overview of how the modeling systems are performing in simulating various atmospheric processes in the region. The three test cases are:

- **MCS case**
  July 14, 2008, 0 UTC — July 24, 2008, 0 UTC
- **Monsoon case**
  July 27, 2014, 0 UTC — September 1, 2014, 0 UTC
- **Snowfall case**
  October 4, 2018, 0 UTC — October 9, 2018, 0 UTC

## The main findings are:

- Performance differences between modeling systems are larger than differences between the WRF physics ensemble members
- Most CPMs largely improve the probability density function of 6-hourly precipitation from ERA5
- Large observational uncertainties complicate the evaluation of convection-permitting models in the TP region



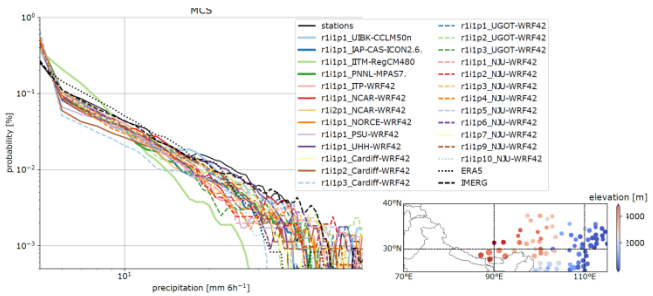




Fig. 5 - Probability density function of 6-hourly precipitation at the location of rain gauges (shown in the bottom right inlet; larger circles indicate longer data coverage).

# Thanks for your attention

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## Thank You

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