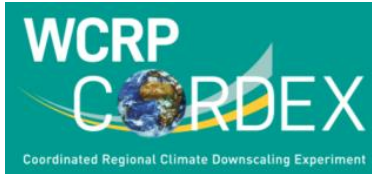


# **Spatial and temporal climate change analysis using CORDEX regional climate models over Bangladesh**

Training organised by ICIMOD, in collaboration with the UKMO, WCRP/CORDEX, SMHI,  
Bangladesh Meteorological Department (BMD) and IITM  
7-11 March 2022



Region 6: South Asia



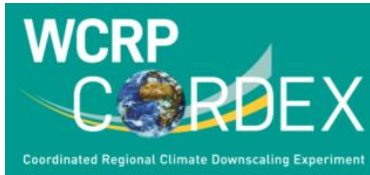
## **CORDEX-South Asia: Providing High Resolution Climate Projections in Southern Asia Region**

**Sanjay Jayanarayanan**

Scientist, Centre for Climate Change Research (CCCR)  
Indian Institute of Tropical Meteorology (IITM), Pune, India  
&  
CORDEX Science Advisory Team (SAT) Member

# Regional Climate Information for Application Studies

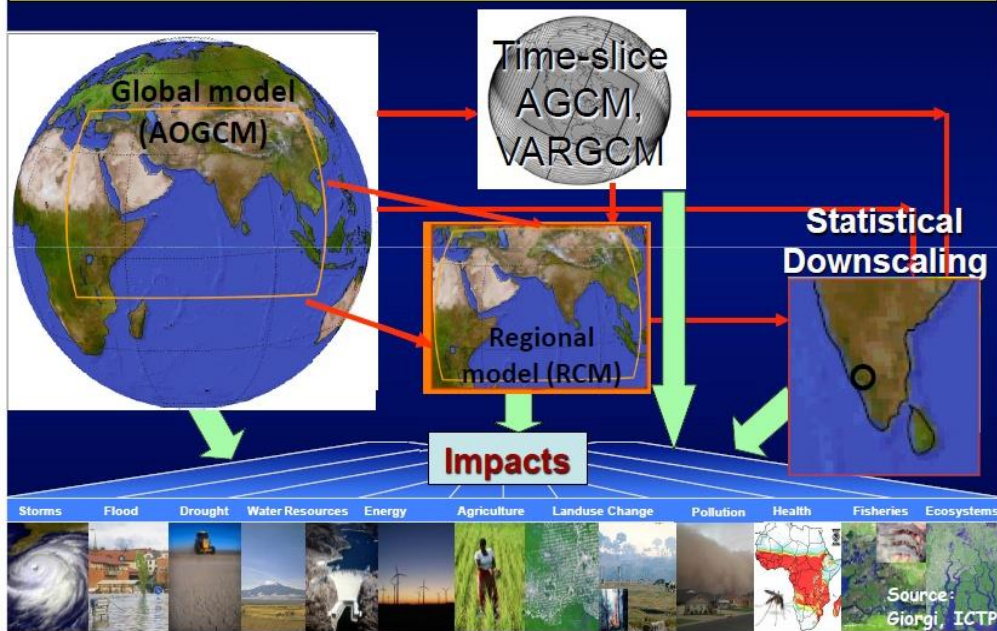
## CORDEX South Asia



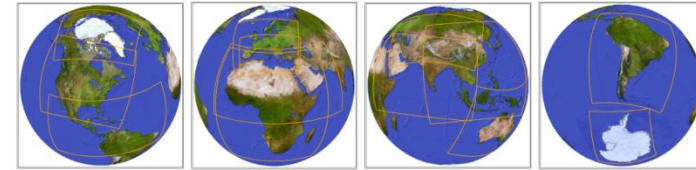
The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.

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

### Downscaling regional climate information for impact assessment studies



### The CORDEX community



The CORDEX community has grown to now include 13 domains;

- Arctic CORDEX
- North America CORDEX
- Central America CORDEX
- EURO-CORDEX
- MED-CORDEX
- CORDEX Africa
- MENA-CORDEX
- Central Asia CORDEX
- South Asia CORDEX
- East Asia CORDEX
- Australasia CORDEX
- South America CORDEX
- CORDEX Antarctica

**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](http://cccr.tropmet.res.in/home/cordexsa_datasets.jsp)

**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/>

Region 6: South Asia



Domain	Res.	ESGF					
		models		scenarios			
		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

Climate Data Store (CDS)  
CORDEX data subset






Home Search Datasets Applications Toolbox Support Live

#	Domain	GCM_run	RCM	Evaluation	Historical	RCP2.6	RCP4.5	RCP6.0	RCP8.5	Institution	Contact Info	Access (1)	License
1	6: South Asia (WAS)	ECMWF-ERAINT	COSMO-crCLIM-v1-1_v1	1979-2015	N/A	N/A	N/A	N/A	N/A	CLMcom-ETH silje soerian	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-CMS_r1i1p1	RegCM4-4_v5	N/A	1951-2005	N/A	2006-2099	N/A	2006-2099	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	N/A	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-CMS_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-44	MPI-ESM-LR_r1i1p1	REMO2009_v1	N/A	1961-2005	2006-2100	2006-2100	N/A	2006-2100	MPI-CSC (*)	ESGF	unrestricted (*)	

CORDEX regional climate model data on single levels

Overview Download data Quality assessment Documentation

- 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>

[https://cordex.org/wp-content/uploads/2020/12/CORDEX\\_simulations\\_Dec\\_2020.xlsx](https://cordex.org/wp-content/uploads/2020/12/CORDEX_simulations_Dec_2020.xlsx)



# Highlights- CORDEX Science Advisory Team (SAT)

(<https://cordex.org/about/science-adv-team/> )

## **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/experiment-guidelines/cordex-cmip6/experiment-protocol-rcms/> )

## **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/publications/white-paper/> )

## **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/> )

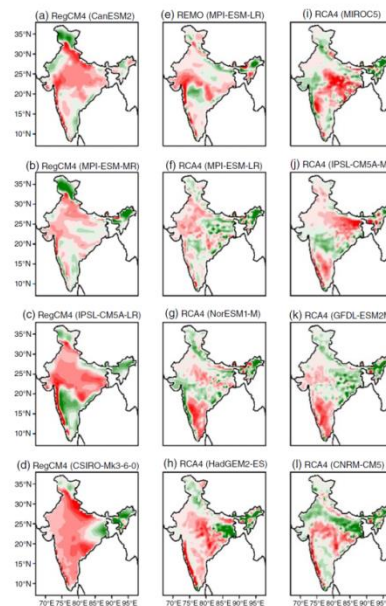
# CORDEX South Asia (WAS) Activities

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

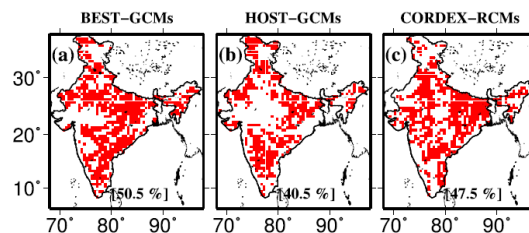
- More than 40 research publications (2014 onwards) analysed the RCM outputs from the CORDEX South Asia ensemble (see [http://cccr.tropmet.res.in/home/cordexsa\\_pub.jsp](http://cccr.tropmet.res.in/home/cordexsa_pub.jsp) )

- 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 et al. 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 et al., 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

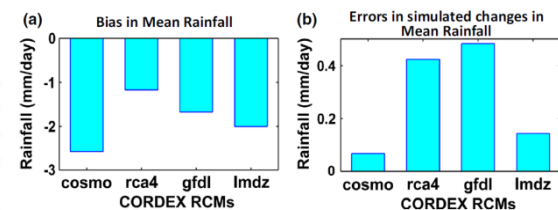
(Mishra et al., 2014)



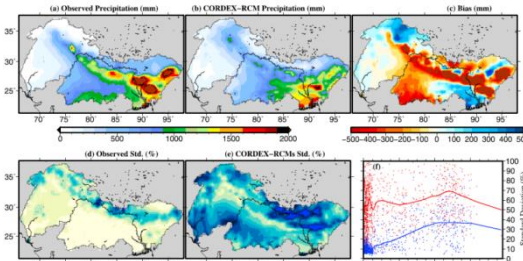
AV JJAS mean precip (Fig. 2, Choudhary et al., 2018)



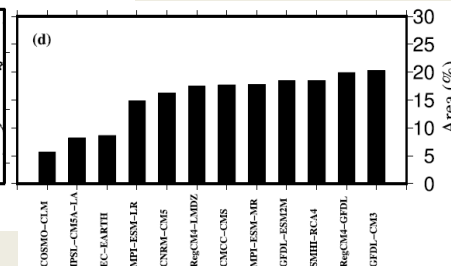
Grid cells (in red) where models show bias ( $\pm 10\%$ ) for 1 day precip maxima at 25 year return period and (d) models and the area (%) (Fig. 9, Mishra et al. 2014)



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

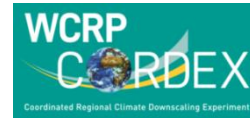


Ensemble mean JJAS 1951-2007 (Fig. 4, Mishra 2015)

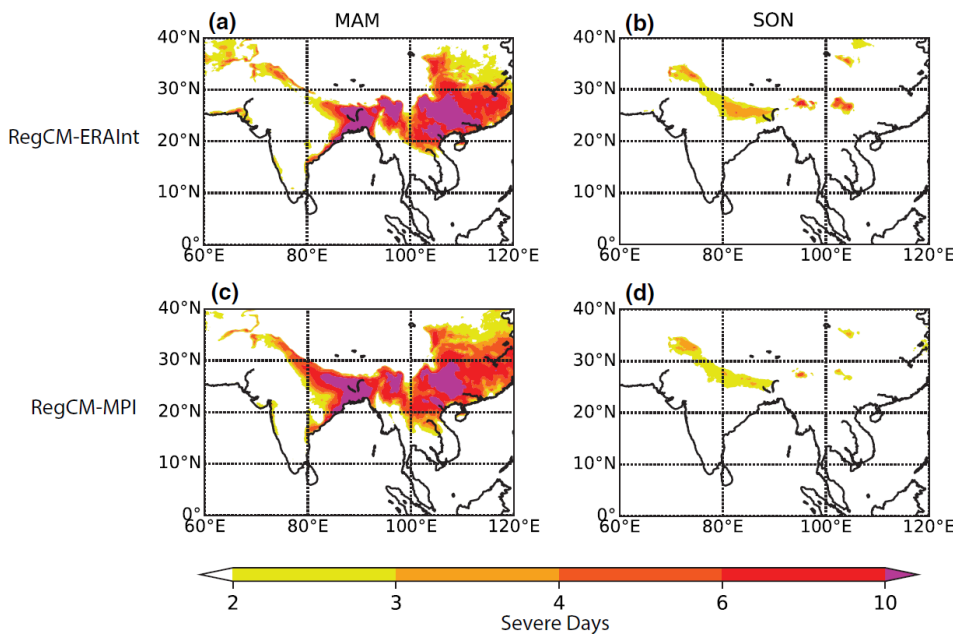


Large-scale environments supportive for severe thunderstorms are projected to increase over eastern India and Bangladesh during the warm season months in the RCP2.6 and RCP8.5 scenarios during the 21st century

- ICTP-RegCM CORDEX-CORE WAS-22 simulations



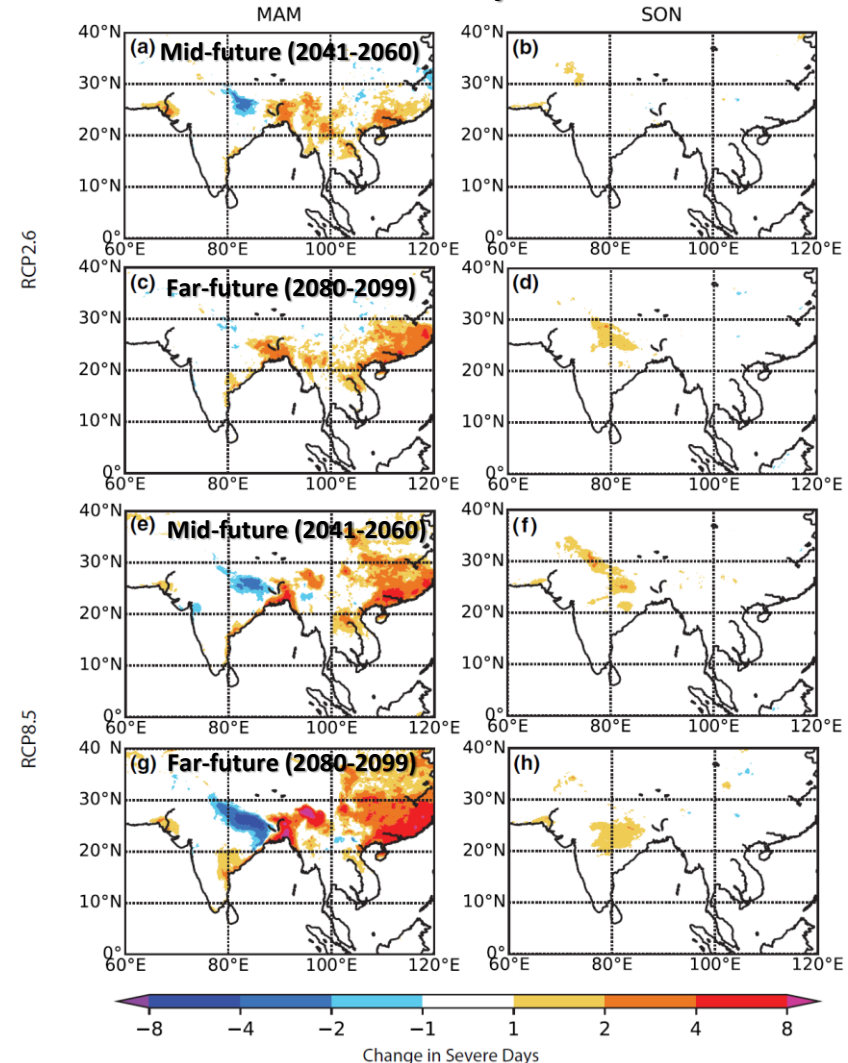
**Seasonal Mean number of Severe Days Hist 1995-2014**



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**

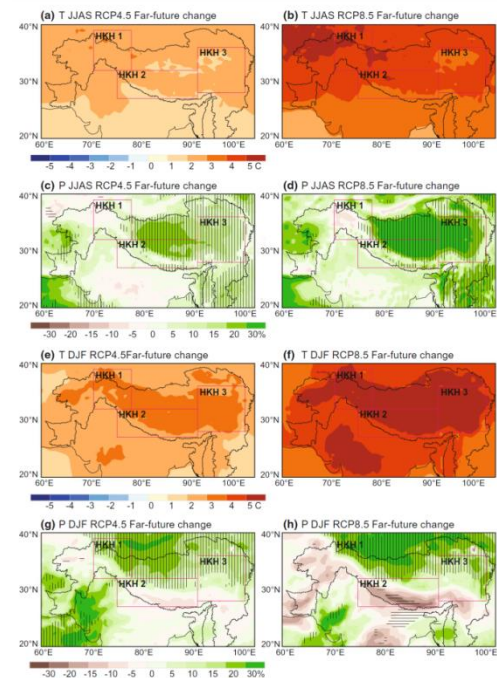




# CORDEX South Asia (WAS) Activities

## 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)

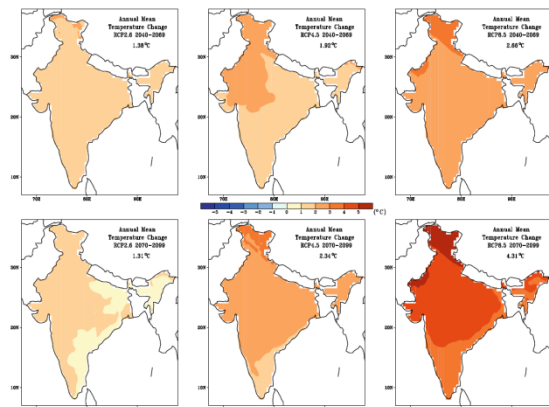


Fig. 2.7, Krishnan et al., (2020)

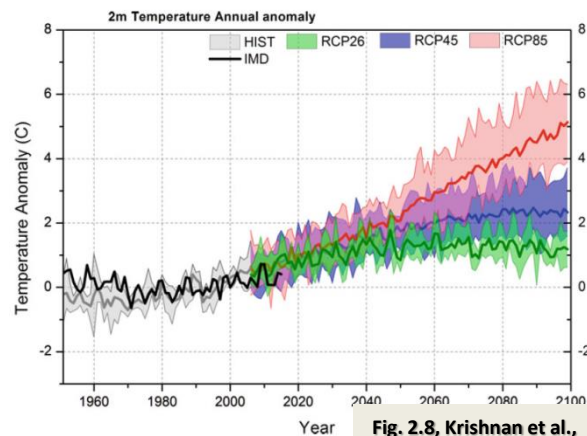
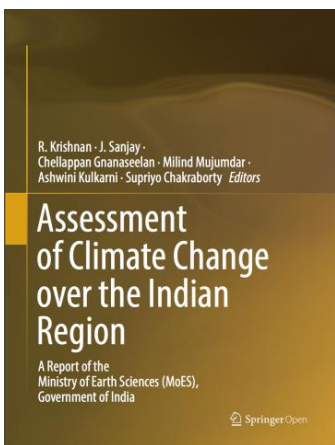
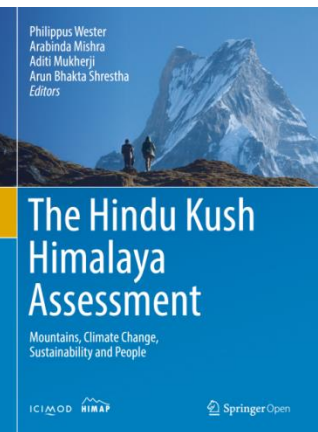


Fig. 2.8, Krishnan et al., (2020)



# CORDEX South Asia (WAS) Activities

Development of regional capacity for assessment of regional climate change



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

## First CORDEX South Asia Training Workshop- IITM, Pune, India, October 2012

(CCCR-IITM, START, ICTP, CSAG, SMHI & ICSU-ROAP)



## Science & Training Workshop on Climate Change over the High Mountains of Asia- IITM, Pune, India, October 2018

(CCCR-IITM, MoES-GoI, DCCC-IIISc, MAIRS-FE@DCCC)



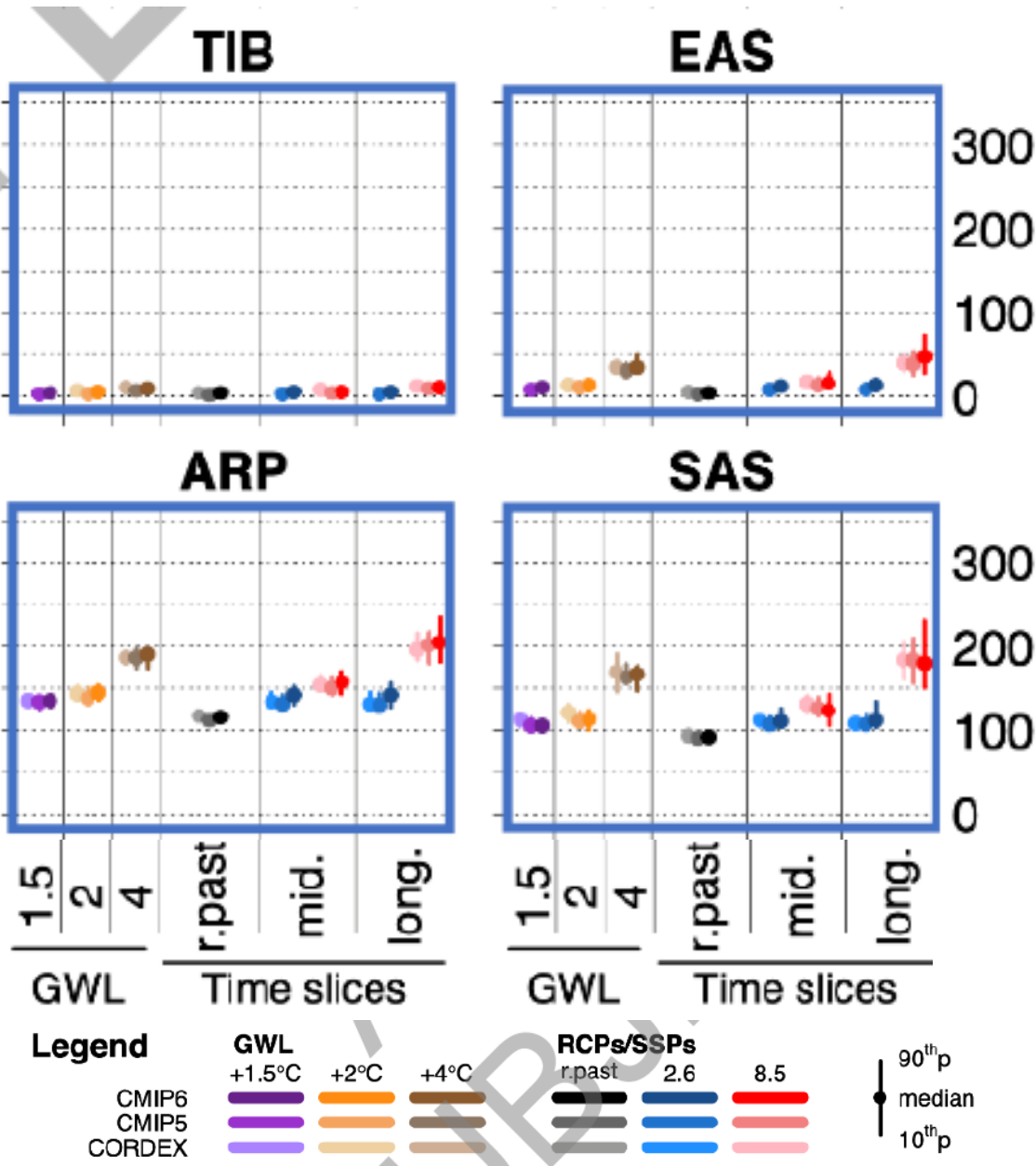
## Second CORDEX Science and Training Workshop in South Asia- ICIMOD, Kathmandu, Nepal, August 2013

(WCRP-CORDEX, MAIRS, APN, ICIMOD, CCCR-IITM & IAP)

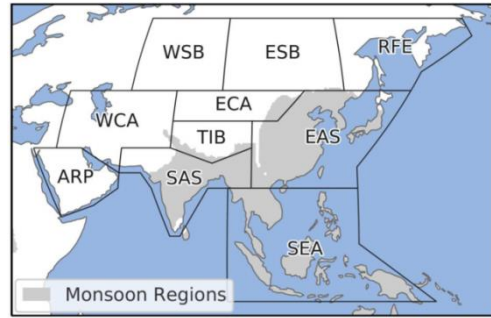




# Number of days per year with daily maximum temperature > 35°C in AR6 selected Asia regions



- 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



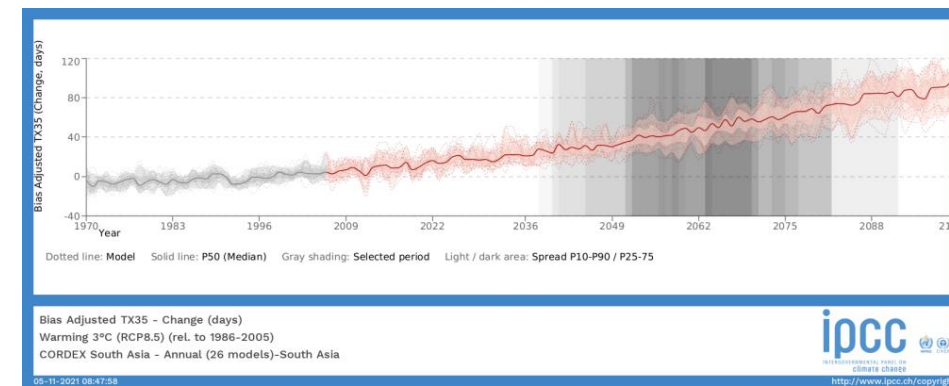
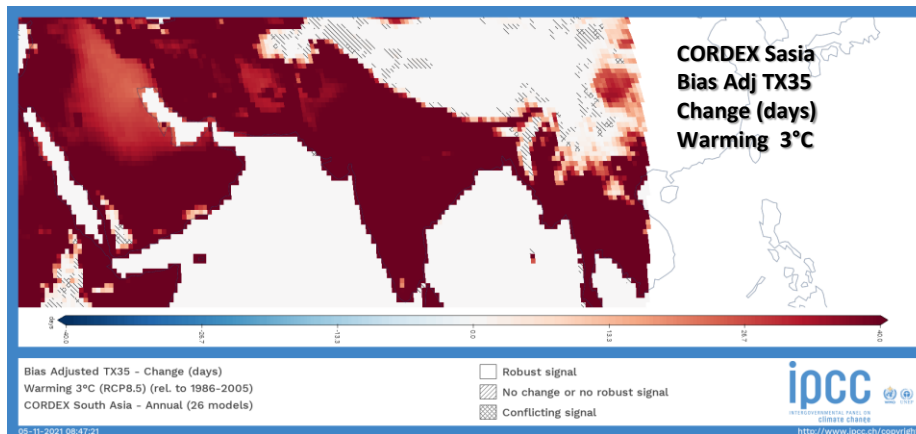
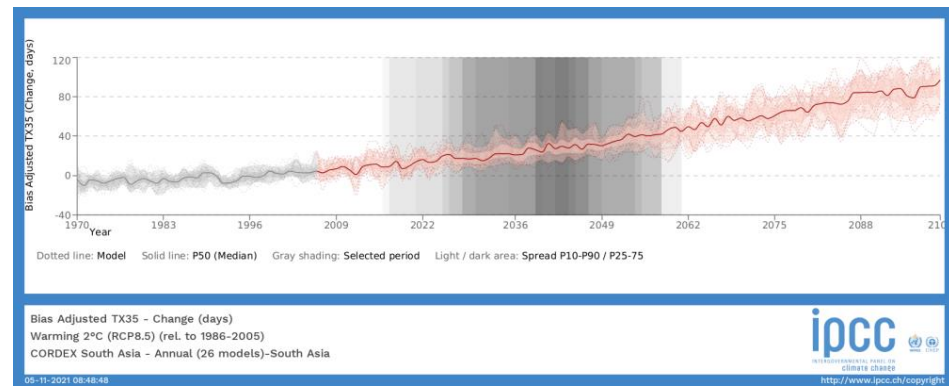
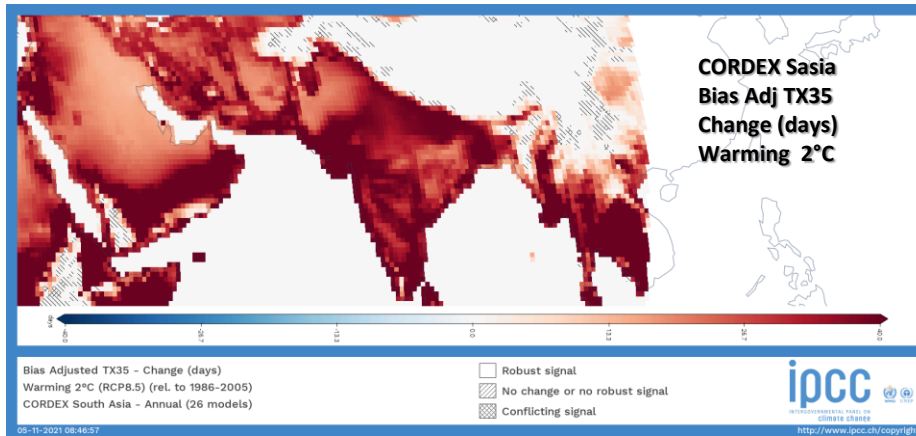
Adapted from IPCC AR6 WGI:  
 Figure 12.SM.1: Regional projections for the number of days per year with maximum temperature exceeding 35°C.....  
 (Ranasinghe, et al. 2021;  
[https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC\\_AR6\\_WGI\\_Chapter\\_12.pdf](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_12.pdf) )

## 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/](http://rcg.gvc.gu.se/cordex_fps_cptp/)

### **Lead investigator**

[Deliang Chen](#), [University of Gothenburg](#), Sweden

### **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



CORDEX-FPS: CPTP



# 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](https://www.pco-prime.com/tougou2021_ws/poster/A3-26_Andreas_Prein.html)



## 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.

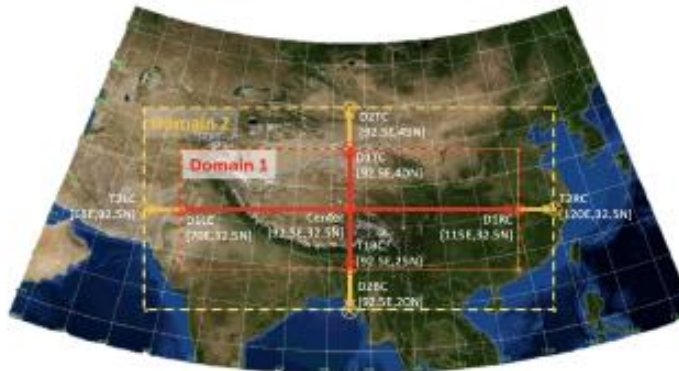


Fig. 1 - Common domain setup. While covering the central points (D1LC, D1TC, D1RC, and D1BC) in the kilometer-scale model domain is mandatory, the corner locations of the domain can vary due to differences in RCM projections.

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

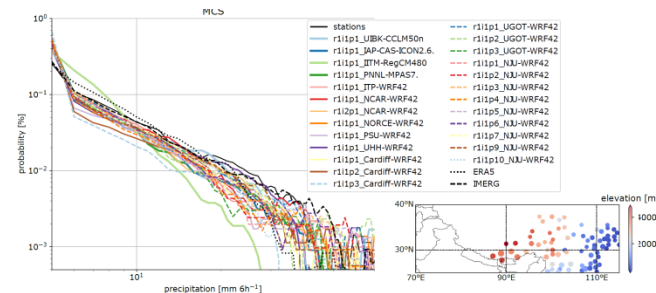
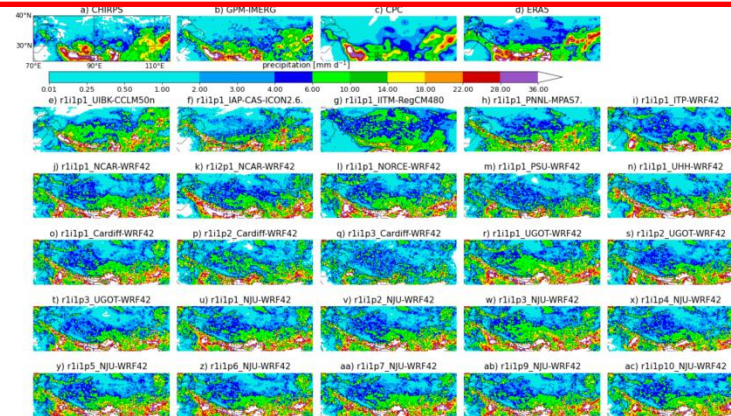


Fig. 5 - Probability density function of 6-hourly precipitation at the location of rain gauges (shown in the bottom right inset; larger circles indicate longer data coverage).

Thanks for your attention

[sanjay@tropmet.res.in](mailto:sanjay@tropmet.res.in)

Thank You

- Training organisers ICIMOD, UK Aid-funded ARRCC
- UKMO, WCRP/CORDEX, SMHI, BMD & IITM
- Director IITM
- CORDEX South Asia Team Members