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Date: 7th -11th March

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





Overview of the training

- Installing required software and packages
- For the whole of Bangladesh
- Setting up variables
- Reading all .nc files (17 models)
- Selection of representative models
- Extracting .nc files
- Temporal analysis
- Spatial analysis
- Future annual and seasonal changes






Extracting CORDEX dataset for Bangladesh

- Download CORDEX dataset (*needs registration*)
 - ESGF node: <https://esgf-data.dkrz.de/search/esgf-dkrz/>
 - IITM data download tool: <http://cccr-dx.tropmet.res.in:8000/cccrindia/>
 - ICIMOD RDS: <http://rds.icimod.org/clim>

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

ICIMOD **Regional Database System**

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Climate Data Download Tool

Data Source: CORDEX

Select or draw AOI

☒ Major Basin: --Select--

☐ Sub Basin: --Select--

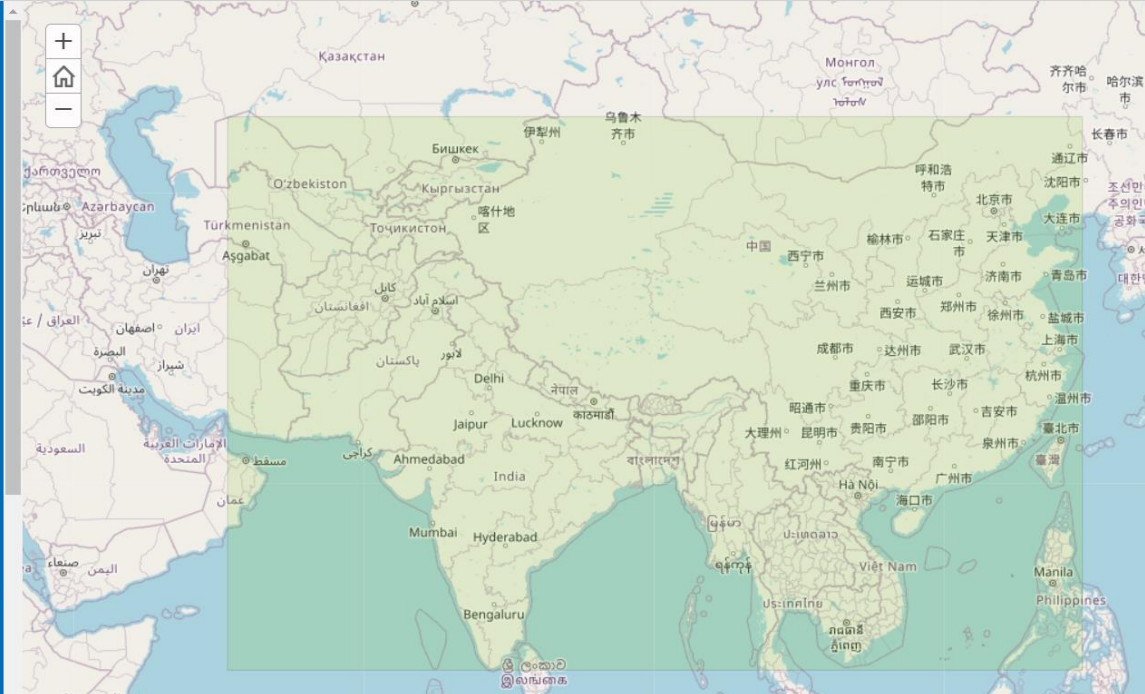
Draw:

Measurement

Parameter: Precipitation (50km)

Future Climate Model

Scenarios: Reference





Day 1 Overview



Extracting CORDEX dataset for Bangladesh

- Needs **Climate Data Operator** (CDO) in **Linux OS** to read and extract CORDEX dataset
 - <https://code.mpimet.mpg.de/projects/cdo/files>

File ^	
	cdo-development
	cdo-2.0.0rc2.tar.gz
	cdo-1.9.10
	cdo-1.9.10-cygwin64-Win10.zip

```
anonymousaurav@Saurav20h2-pc:/mnt/d/2021/Climate_Services/BNG_CORDEX_2022/CORDEX_2022/Data  
_monthly/RCP4.5/pr$ cdo
```

```
No operator given!
```

```
usage : cdo [Options] Operator1 [-Operator2 [-OperatorN]]
```

```
CDO version 1.9.9rc1, Copyright (C) 2003-2019 Uwe Schulzweida  
This is free software and comes with ABSOLUTELY NO WARRANTY  
Report bugs to <https://mpimet.mpg.de/cdo>
```



Extracting CORDEX dataset for Bangladesh

- CORDEX dataset are in the rotated coordinate system

```
Grid coordinates :  
  1 : curvilinear           : points=42251 (253x167)  
                                lon : 1.90318 to 138.0968 degrees_east  
                                lat : -25.22615 to 50.93093 degrees_north  
                                mapping : rotated_mercator  
                                x : -6300000 to 6300000 by 50000 m  
                                y : -4150000 to 4150000 by 50000 m
```

- Clipping CORDEX dataset to extent of Bangladesh
 - cdo sellonlatbox,lonmin,lonmax,latmin,latmax infile outfile

```
cdo sellonlatbox,60,120,10,70 filename BNG_filename
```

- Reprojecting to WGS system
 - cdo remapbil,mygrid infile outfile

```
cdo remapbil,mygrid filename cartesian_filename
```

```
cdo sellonlatbox,86,95,20,28 filename BNG_filename
```

```
gridtype = lonlat  
xsize    = 71  
ysize    = 71  
xfirst   = 60  
xinc     = 0.5  
yfirst   = 10  
yinc     = 0.5
```

Extracting CORDEX dataset for Bangladesh

- Calculating monthly sum for the selected netCDF file
 - For precipitation: cdo monsum infile outfile
 - For temperature: cdo monmean infile outfile

```
cdo monsum infile outfile
```

- Calculating year sum for the selected netCDF file
 - For precipitation: cdo yearsum infile outfile
 - For temperature: cdo yearmean infile outfile

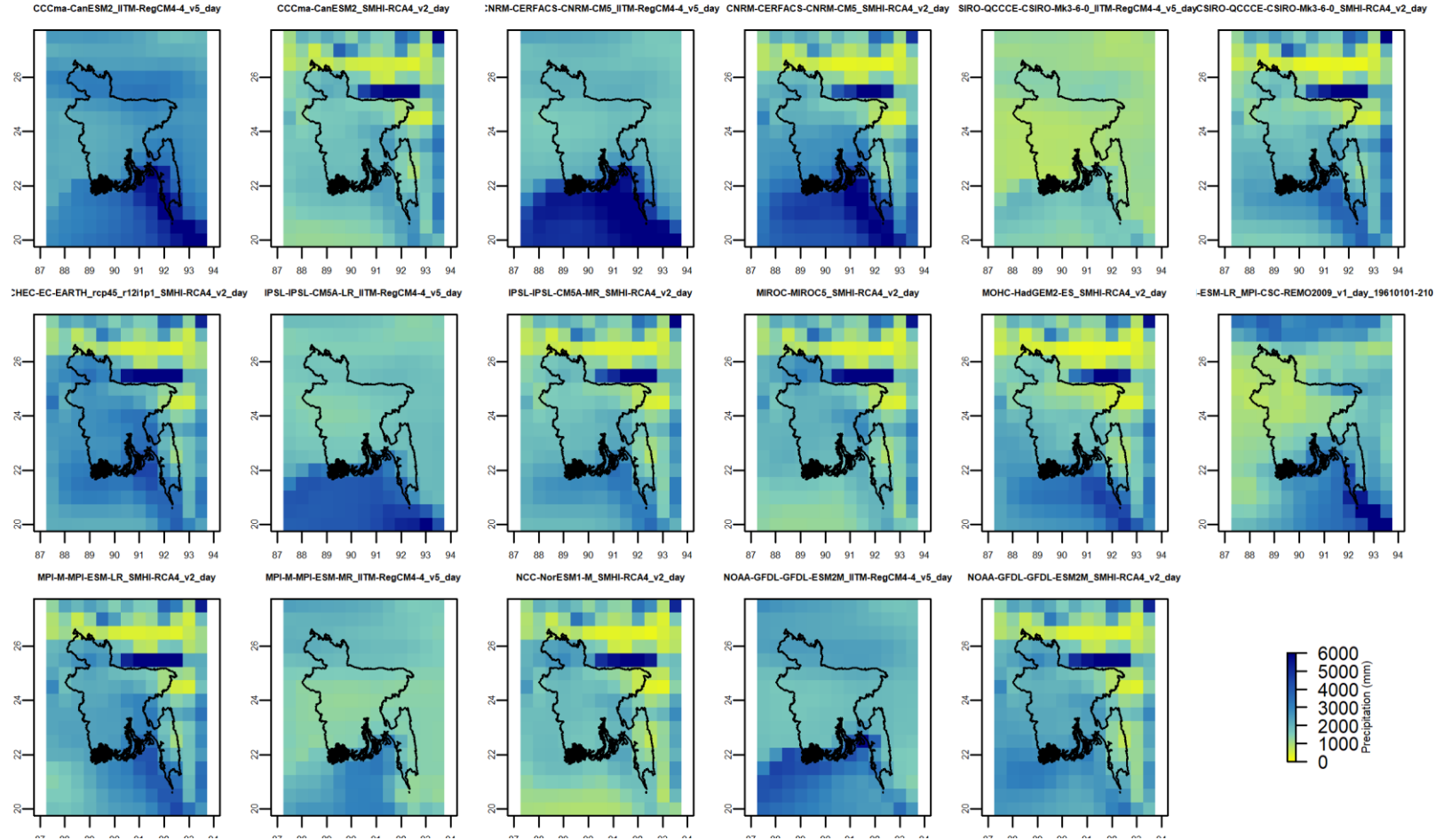
```
cdo yearsum infile outfile
```

- For more commands of CDO
 - https://code.mpimet.mpg.de/projects/cdo/embedded/cdo_refcard.pdf

CORDEX precipitation dataset

Reference period: 1976-2005

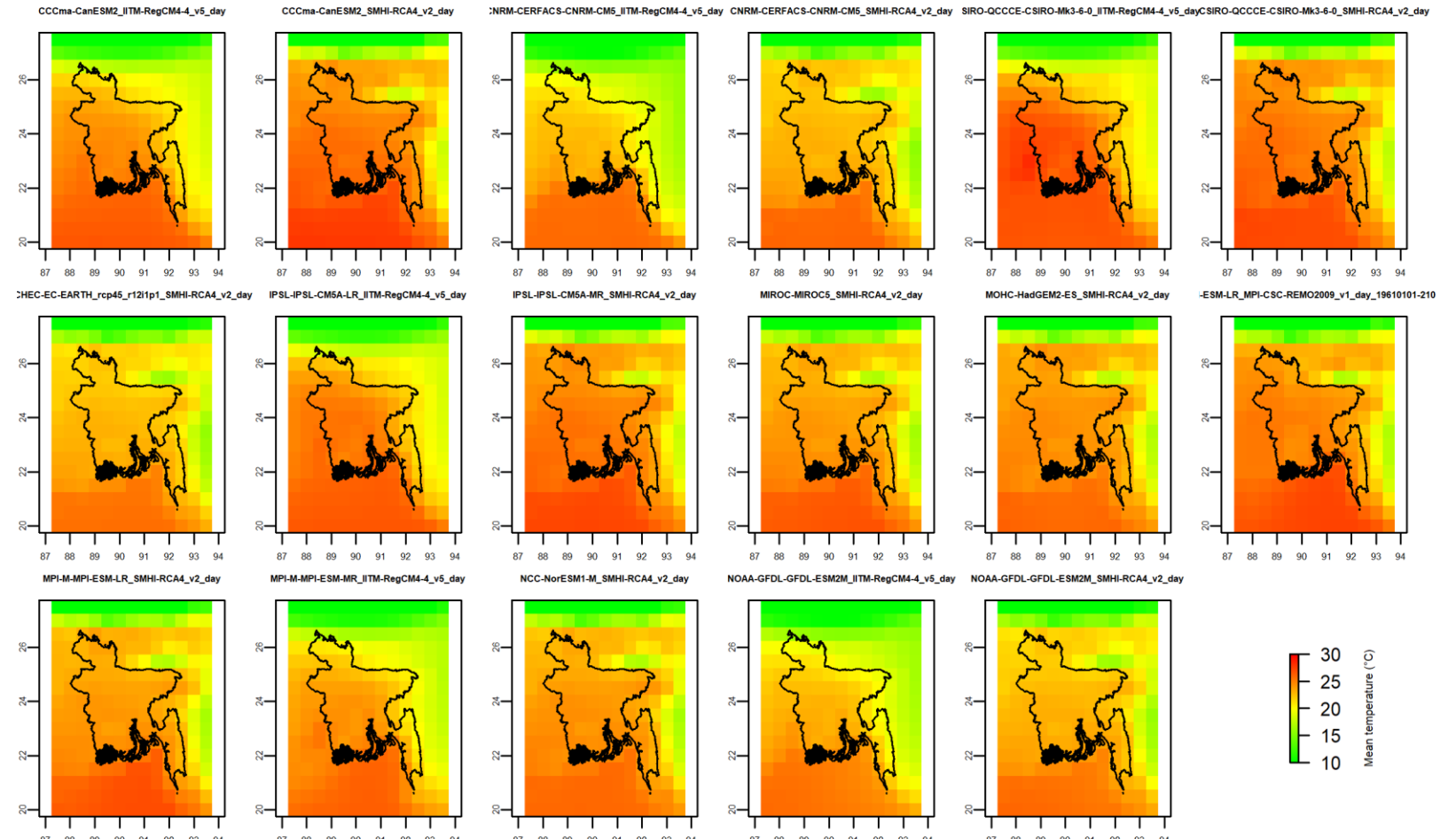
Temporal scale: Average annual



CORDEX temperature dataset

Reference period: 1976-2005

Temporal scale: Average annual



Reference dataset

Precipitation:

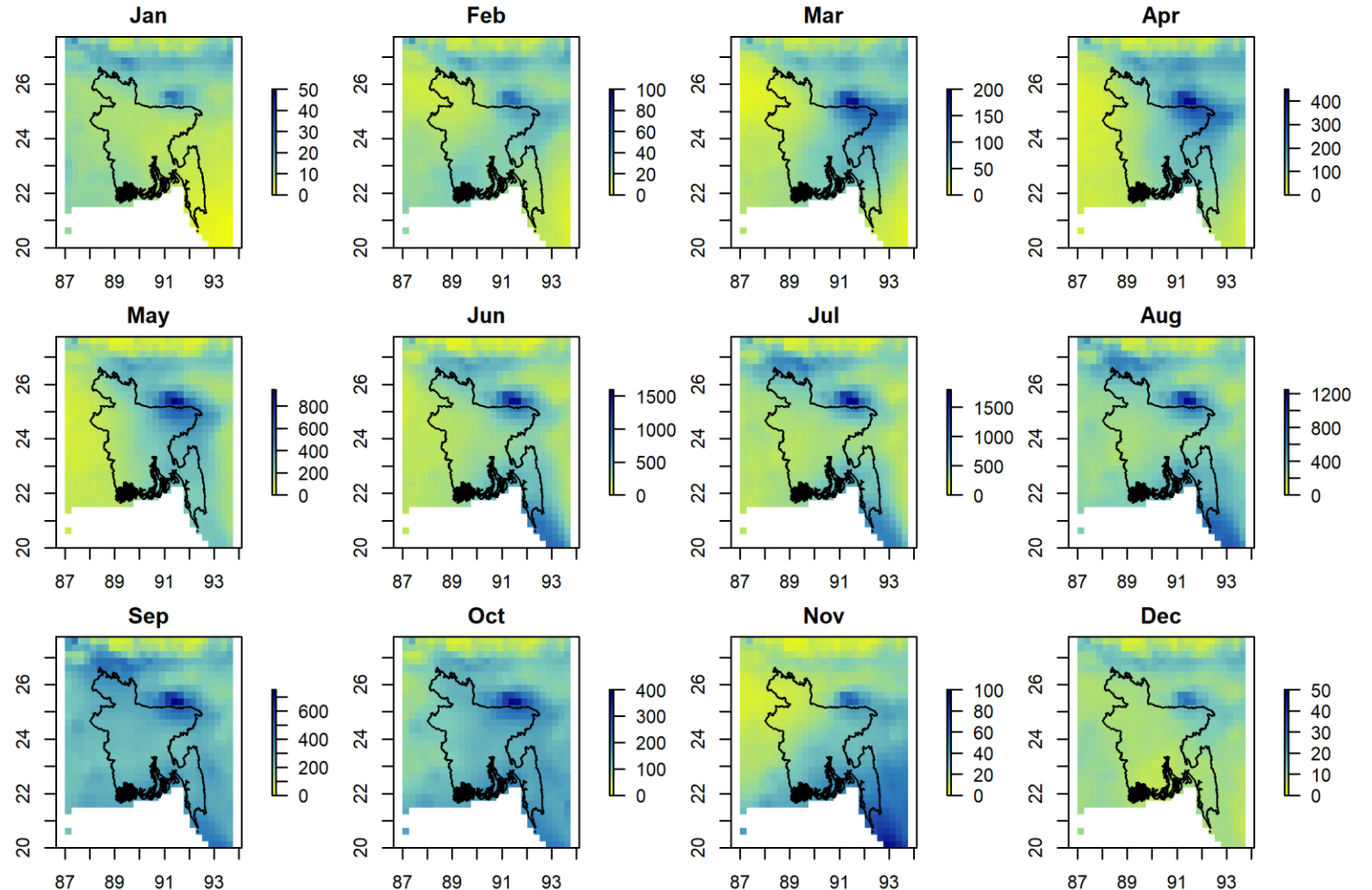
APHRODITE V1101

Over the Monsoon Asia region

Latest product for climatology

Resolution: 0.25°

http://aphrodite.st.hirosaki-u.ac.jp/product/APHRO_V1101/APHRO_MA/025deg_nc/



Reference dataset

Temperature:

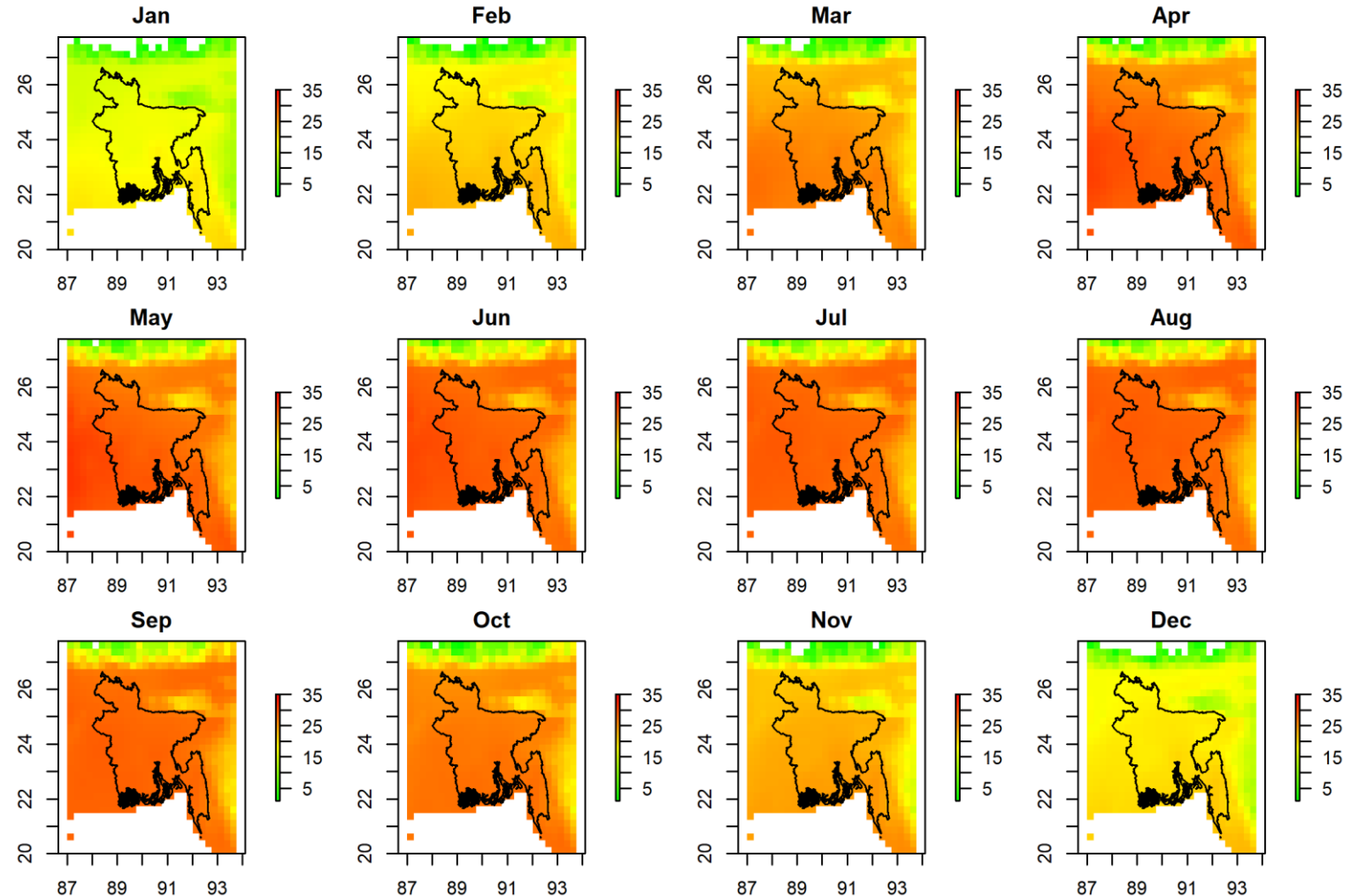
APHRODITE V1204

Over the Monsoon Asia region

Latest product for climatology

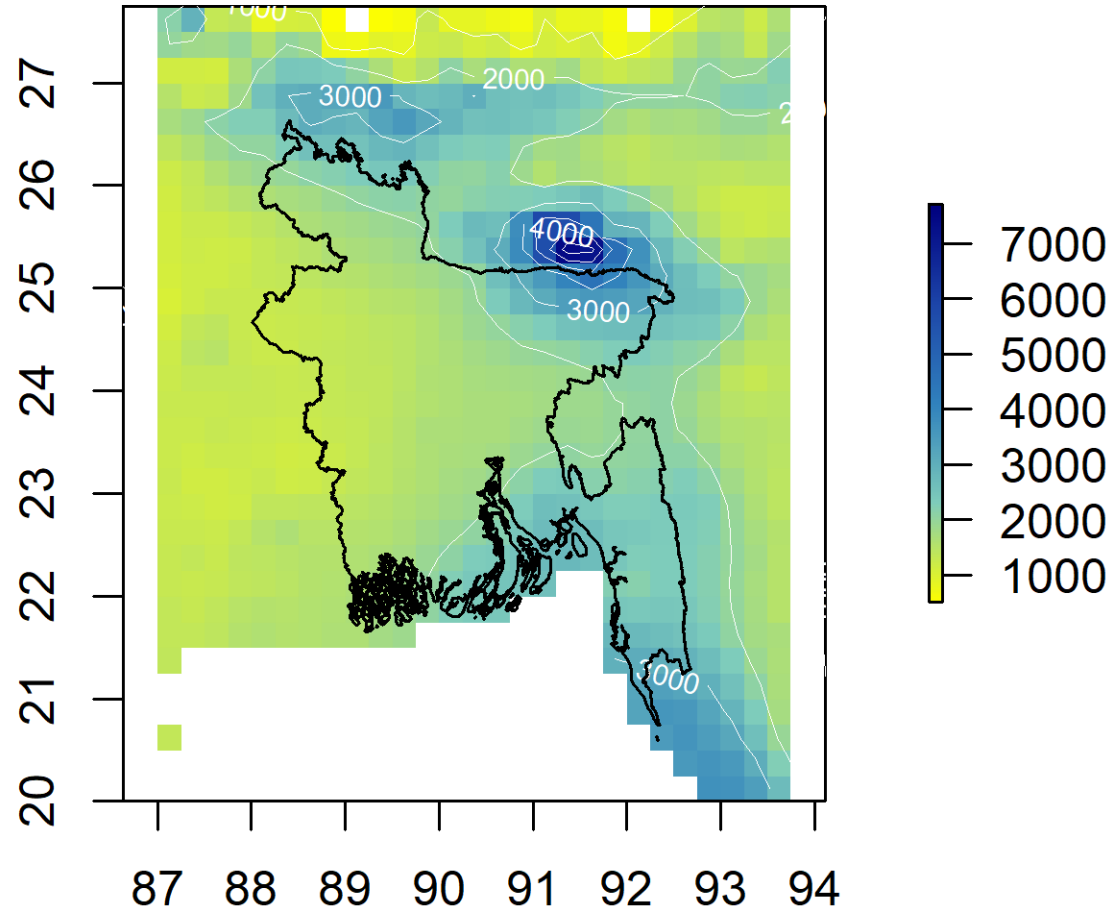
Resolution: 0.25°

http://aphrodite.st.hirosaki-u.ac.jp/product/APHRO_V1204_TEMP/APHRO_MA/025deg_nc/

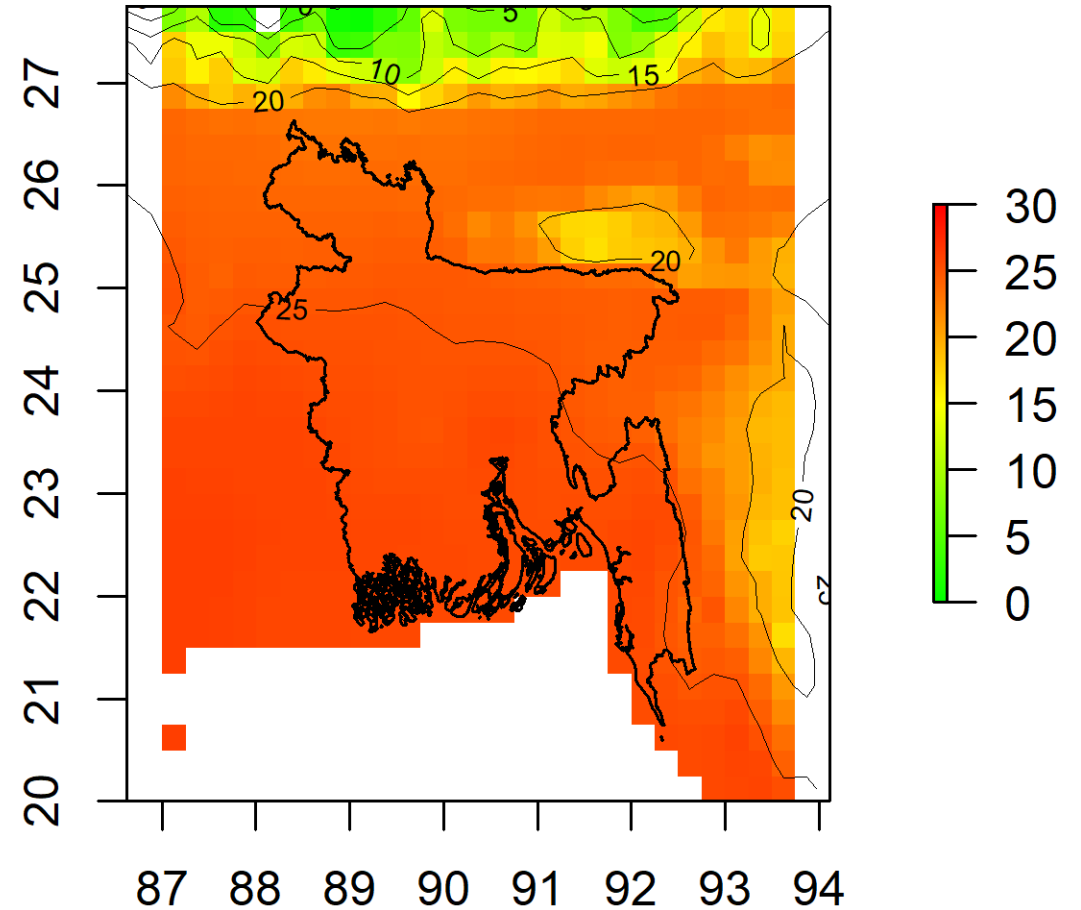


Reference dataset

Annual Precipitation (mm)



Annual mean temperature (°C)



Monthly precipitation for the reference period

Reference data (APHRODITE)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	8	21	48	114	247	377	404	327	271	143	28	9
Temperature (°C)	17.6	21.1	25.3	27.8	28.3	28.5	28.2	28.4	28.1	26.9	23.6	19.7



Day 2 Overview

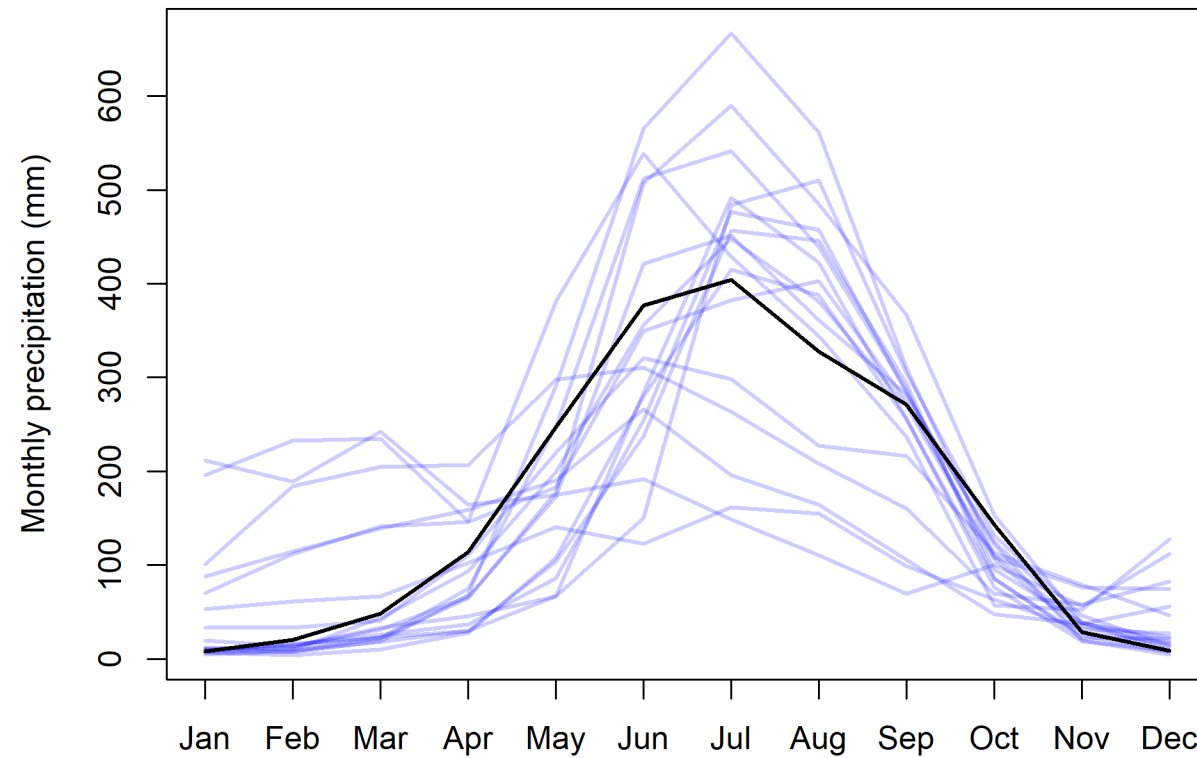


Monthly precipitation for the reference period

Model	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CCCma-CanESM2_IITM-RegCM4-4_v5	196	233	235	147	381	539	429	344	237	57	52	128
CCCma-CanESM2_SMHI-RCA4_v2	8	12	23	30	104	237	457	446	293	86	22	21
CNRM-CERFACS-CNRM-CM5_IITM-RegCM4-4_v5	70	112	141	146	183	349	382	403	275	108	76	74
CNRM-CERFACS-CNRM-CM5_SMHI-RCA4_v2	5	8	22	64	178	508	590	485	367	153	39	9
CSIRO-QCCCE-CSIRO-Mk3-6-0_IITM-RegCM4-4_v5	53	61	67	102	140	122	161	155	99	63	32	27
CSIRO-QCCCE-CSIRO-Mk3-6-0_SMHI-RCA4_v2	8	15	26	37	85	254	477	457	283	122	19	4
ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v2	11	8	19	68	291	565	667	562	310	110	35	13
IPSL-IPSL-CM5A-LR_IITM-RegCM4-4_v5	211	189	242	164	175	192	148	110	69	100	56	112
IPSL-IPSL-CM5A-MR_SMHI-RCA4_v2	7	9	18	30	66	150	484	510	304	132	46	14
MIROC-MIROC5_SMHI-RCA4_v2	12	10	43	93	200	356	448	381	269	106	29	17
MOHC-HadGEM2-ES_SMHI-RCA4_v2	6	4	10	28	108	280	415	388	255	85	25	7
MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	33	33	41	110	220	321	298	227	217	113	79	46
MPI-M-MPI-ESM-LR_SMHI-RCA4_v2	9	16	22	75	248	512	541	439	287	95	38	23
MPI-M-MPI-ESM-MR_IITM-RegCM4-4_v5	88	115	139	159	190	266	196	165	106	48	37	56
NCC-NorESM1-M_SMHI-RCA4_v2	11	12	33	46	66	284	491	423	256	76	19	9
NOAA-GFDL-GFDL-ESM2M_IITM-RegCM4-4_v5	101	184	204	207	297	311	263	208	160	70	58	83
NOAA-GFDL-GFDL-ESM2M_SMHI-RCA4_v2	19	13	31	66	172	421	451	361	282	125	38	18

Climatology of all 17 models

Climatology of 17 CORDEX models

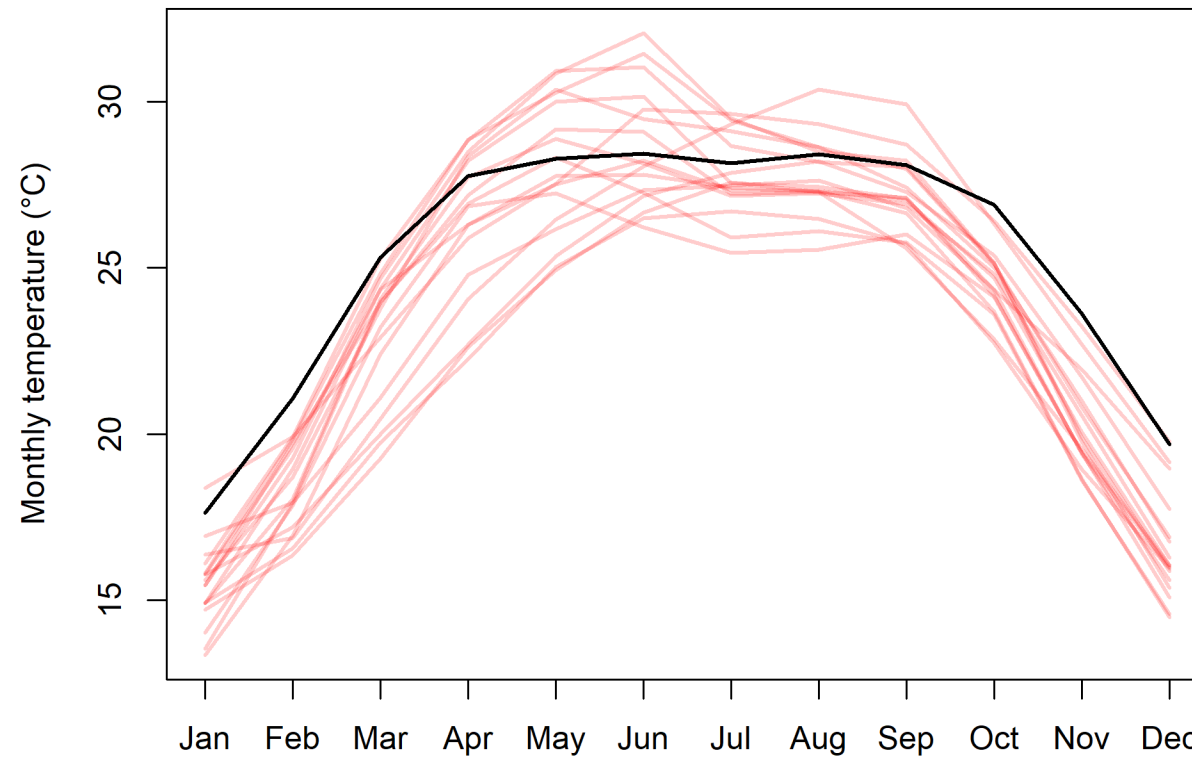


Monthly temperature for the reference period

Model	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CCCma-CanESM2_IITM-RegCM4-4_v5	16.9	17.9	21.1	24.8	26.2	27.3	27.5	27.6	26.8	24.3	21.9	18.9
CCCma-CanESM2_SMHI-RCA4_v2	15.8	19.8	24.8	28.9	30.3	31.4	29.4	28.6	28.0	25.1	20.8	16.9
CNRM-CERFACS-CNRM-CM5_IITM-RegCM4-4_v5	14.9	16.6	19.7	22.3	25.0	26.5	26.7	26.5	25.7	22.7	18.9	15.9
CNRM-CERFACS-CNRM-CM5_SMHI-RCA4_v2	13.5	17.9	24.0	26.9	28.3	27.3	25.9	26.1	25.8	23.6	18.6	14.6
CSIRO-QCCCE-CSIRO-Mk3-6-0_IITM-RegCM4-4_v5	18.4	19.9	22.9	25.9	27.5	29.8	29.6	29.3	28.7	26.4	23.2	19.8
CSIRO-QCCCE-CSIRO-Mk3-6-0_SMHI-RCA4_v2	16.1	19.9	25.3	28.9	30.9	31.1	28.7	28.2	28.0	25.1	19.8	15.4
ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v2	14.0	17.8	23.2	26.9	27.2	26.2	25.5	25.5	26.0	24.1	19.4	15.1
IPSL-IPSL-CM5A-LR_IITM-RegCM4-4_v5	16.4	16.9	20.5	24.1	26.5	28.1	29.3	30.4	29.9	26.3	22.7	19.1
IPSL-IPSL-CM5A-MR_SMHI-RCA4_v2	15.4	19.3	24.7	28.5	30.9	32.1	29.5	28.5	28.2	25.1	19.9	15.9
MIROC-MIROC5_SMHI-RCA4_v2	15.8	19.6	24.4	26.3	27.5	28.2	27.4	27.3	27.0	24.7	20.1	16.0
MOHC-HadGEM2-ES_SMHI-RCA4_v2	14.9	18.9	24.4	28.2	30.0	30.2	27.6	27.4	27.1	24.3	19.4	15.6
MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	15.6	18.7	23.8	28.4	30.4	29.5	29.1	28.6	27.4	25.0	21.0	16.8
MPI-M-MPI-ESM-LR_SMHI-RCA4_v2	14.9	18.0	24.1	27.7	28.9	28.1	27.2	27.2	26.9	24.8	20.6	16.3
MPI-M-MPI-ESM-MR_IITM-RegCM4-4_v5	15.8	17.2	20.0	22.7	25.4	27.2	27.9	28.2	27.3	25.4	21.7	17.7
NCC-NorESM1-M_SMHI-RCA4_v2	15.4	19.7	23.9	27.2	29.2	29.1	27.2	27.3	27.1	24.2	19.4	16.0
NOAA-GFDL-GFDL-ESM2M_IITM-RegCM4-4_v5	14.7	16.3	19.3	22.6	24.9	26.7	27.6	27.3	25.6	22.8	19.5	16.0
NOAA-GFDL-GFDL-ESM2M_SMHI-RCA4_v2	13.3	16.9	22.4	26.3	27.8	27.8	27.4	27.3	26.7	23.7	18.7	14.5

Climatology of all 17 models

Climatology of 17 CORDEX models

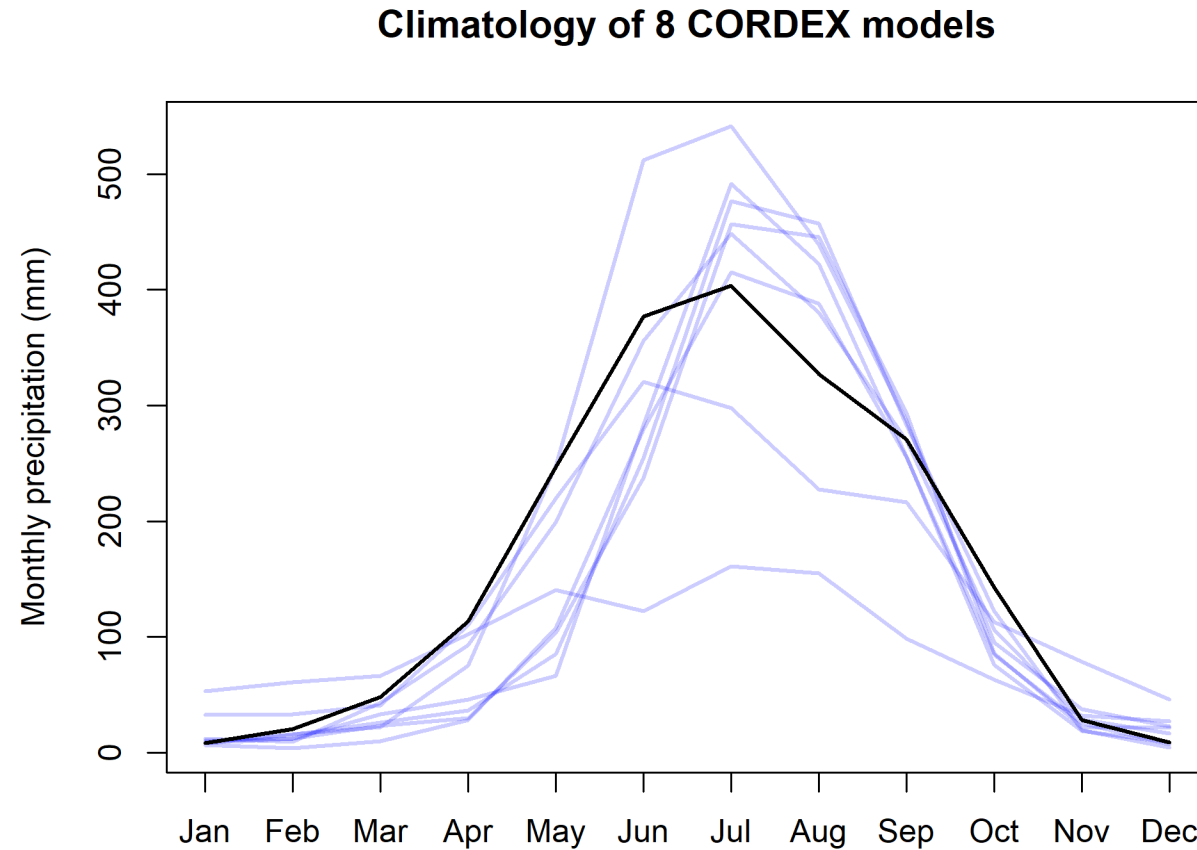


Model selection

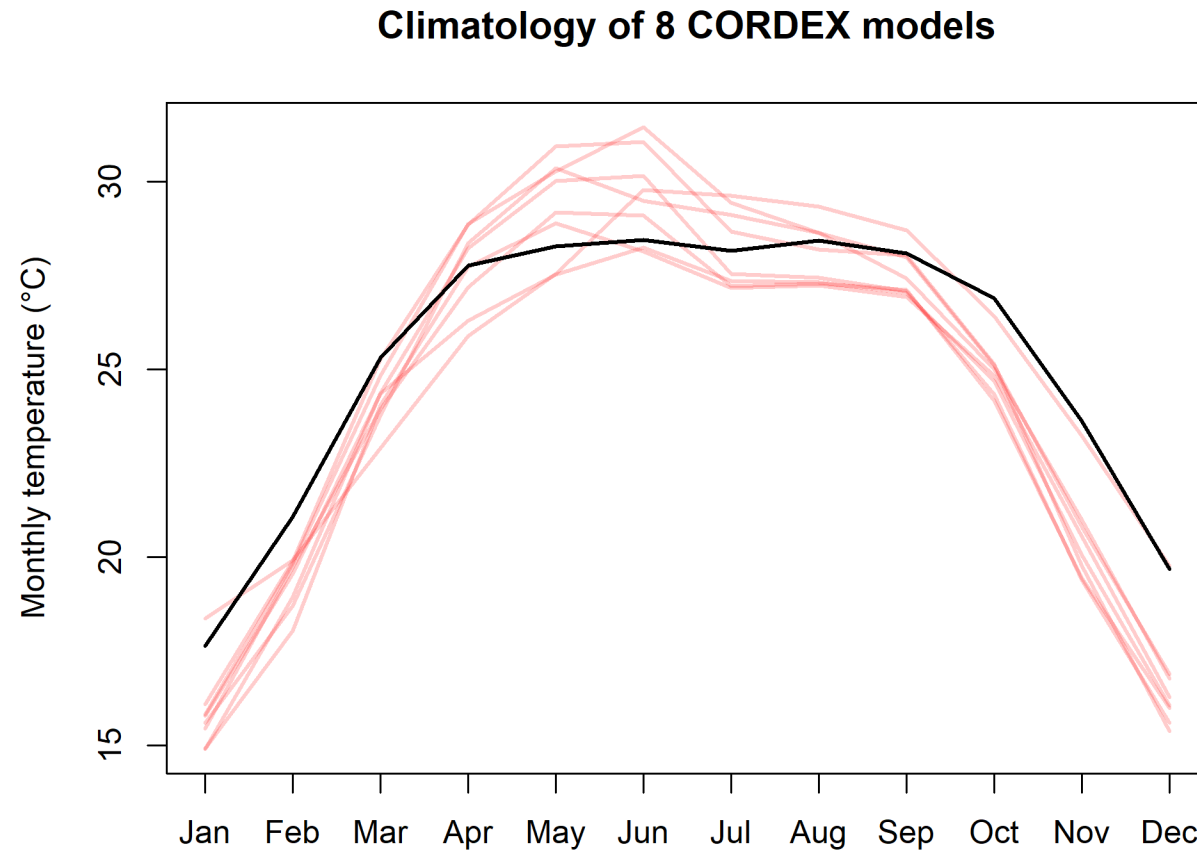
Step 1: based on seasonal bias (**shape**)

- 4 seasons: Winter – **Dec, Jan, Feb**; Pre-monsoon – **Mar, Apr, May**; Monsoon – **Jun, Jul, Aug, Sep**; Post-monsoon – **Oct, Nov**
- **Monsoon** precipitation bias(Jun – Sep) for precipitation
- Average absolute bias of **all seasons** for mean temperature

Climatology of 8 models selected from step 1



Climatology of 8 models selected from step 1



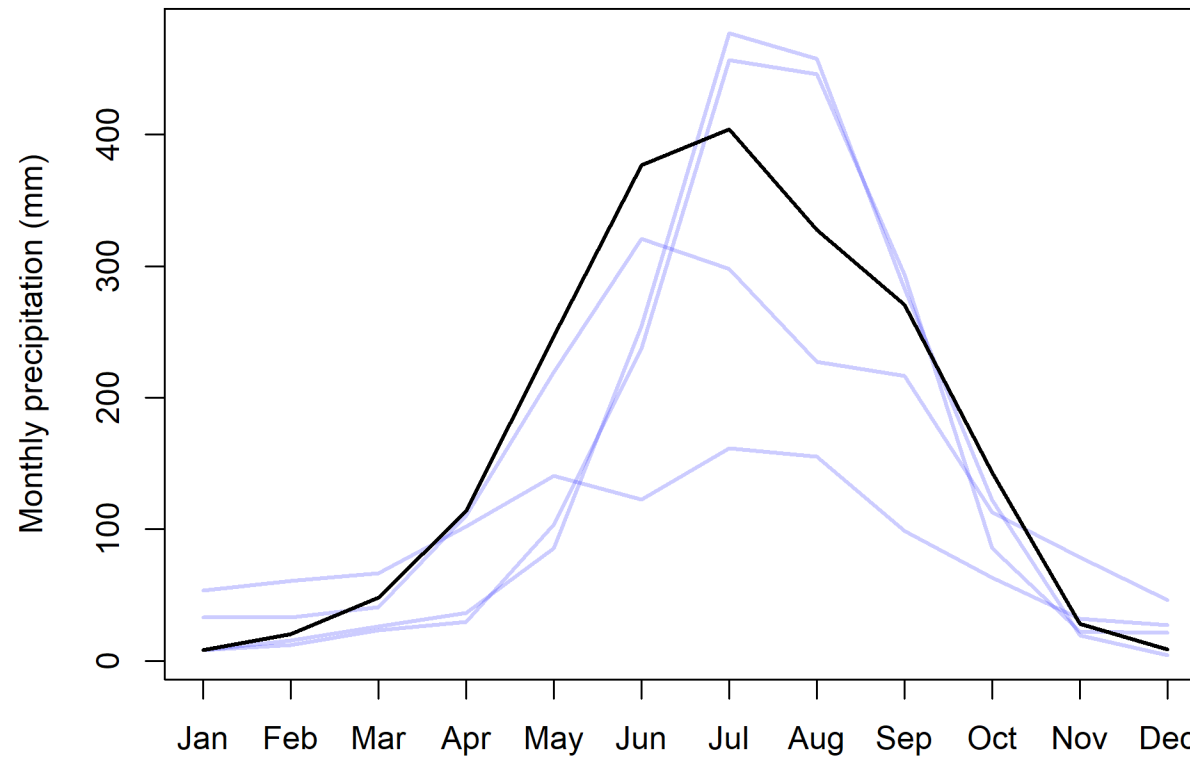
Model selection

Step 2: based on annual bias (**total volume**)

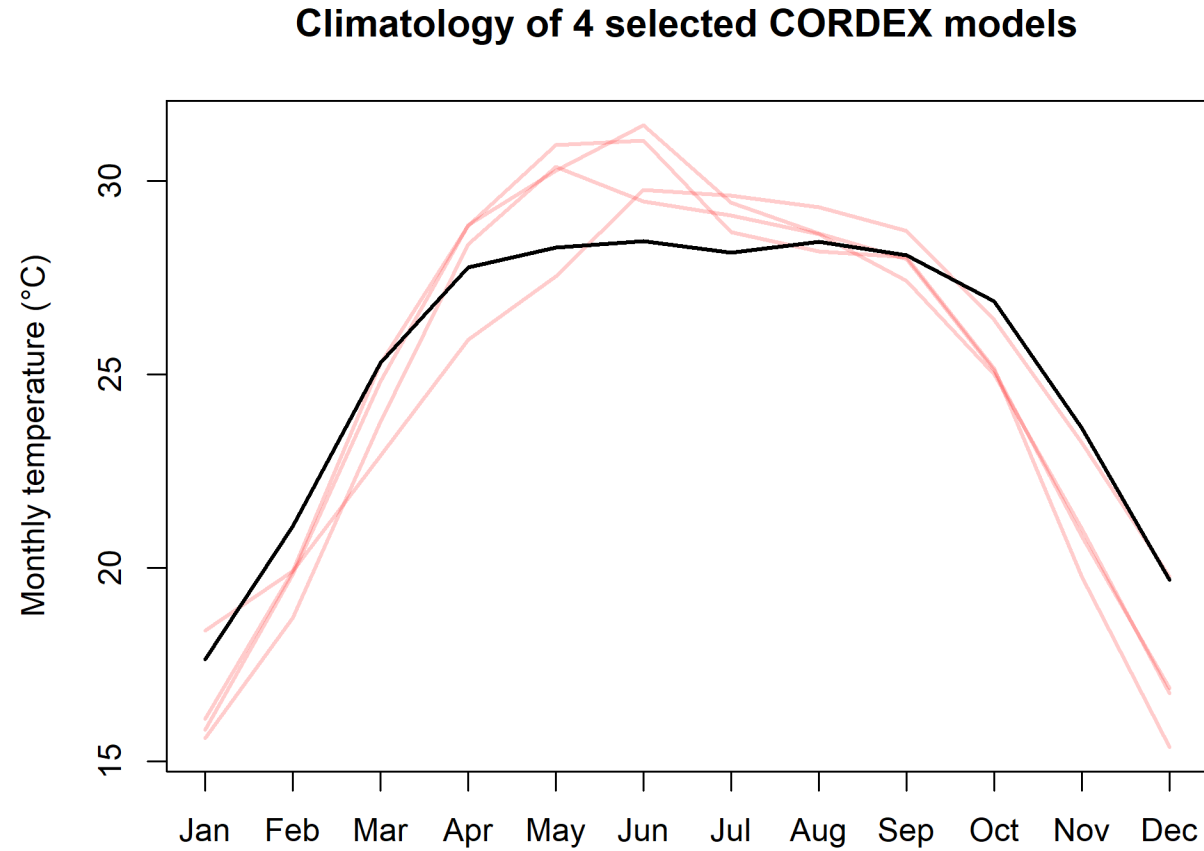
- Total annual precipitation sum
- Average annual mean temperature

Climatology of 4 selected models

Climatology of 4 selected CORDEX models

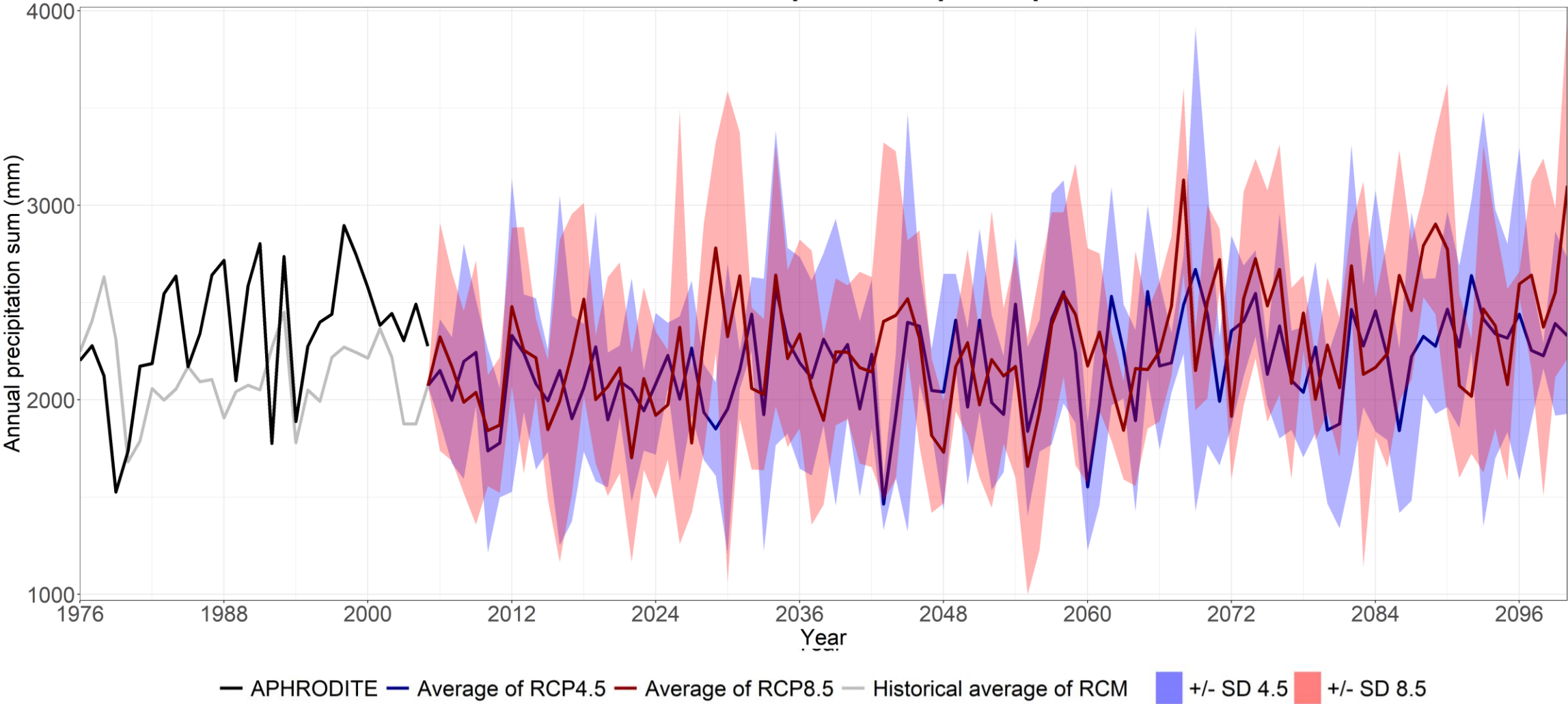


Climatology of 4 selected models



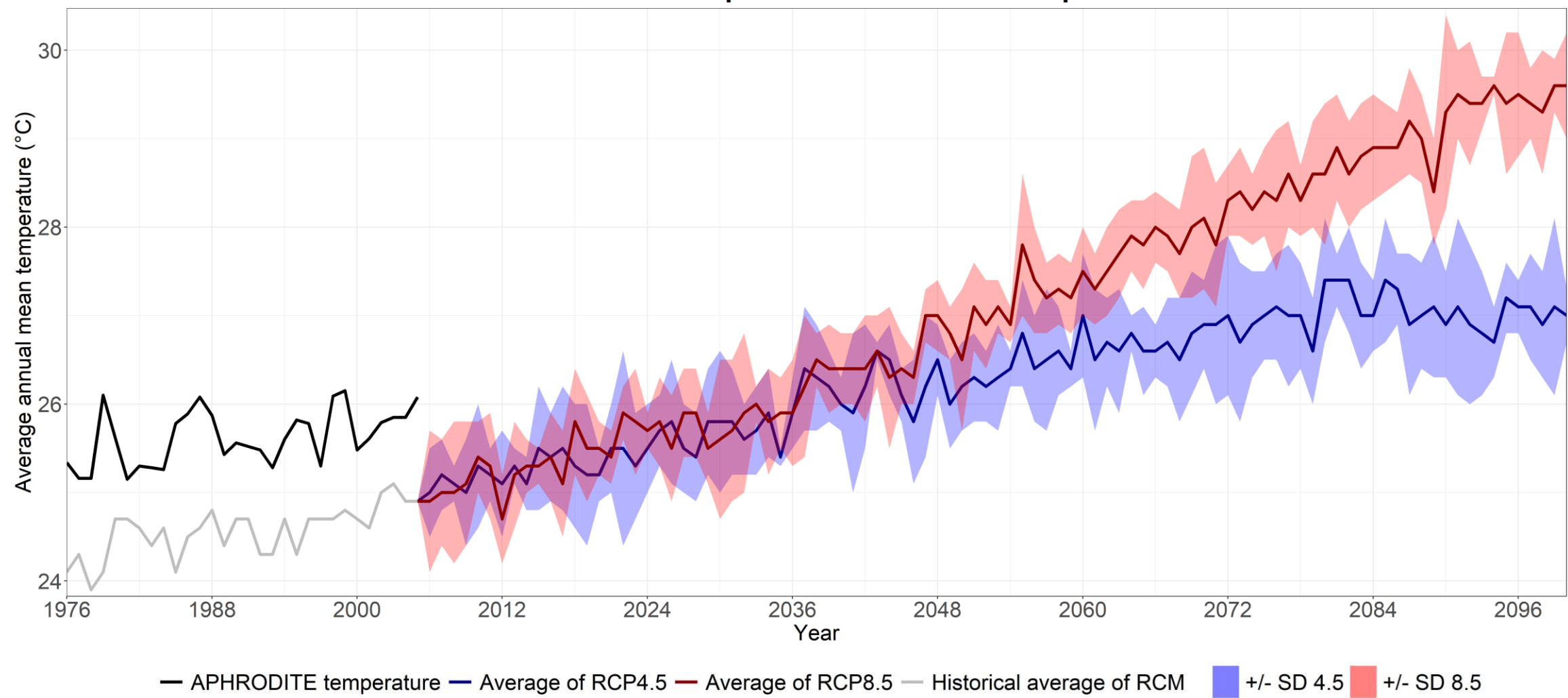
Ensemble plot for the period of 1976 – 2099

Ensemble band plot for precipitation



Ensemble plot for the period of 1976 – 2099

Ensemble band plot for mean temperature



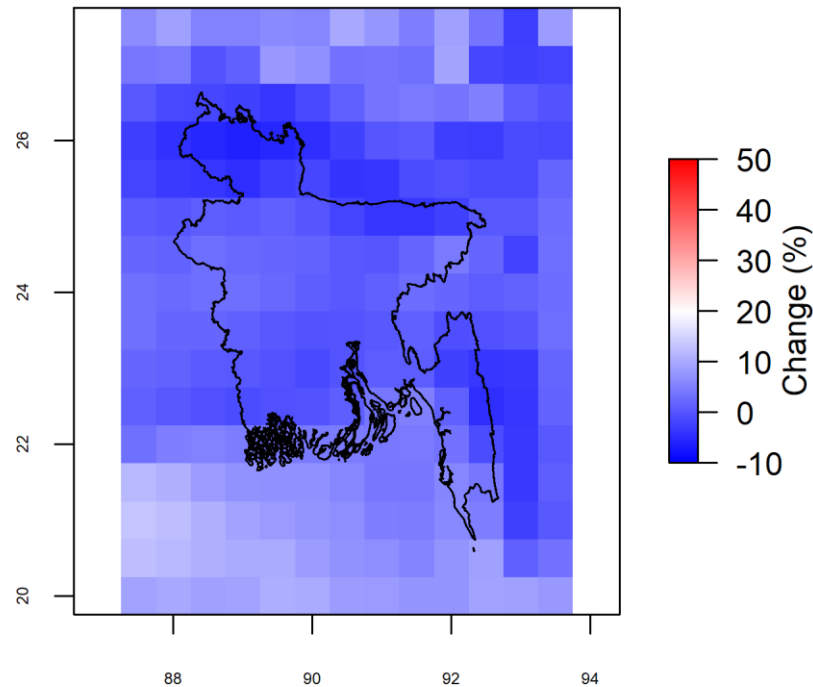
Delta change between (2075-2099) and (1976-2005)

RCP	Change	CCCma.CanESM2_SMHI.RCA4_v2_day	CSIRO.QCCCE.CSIRO.Mk3.6.0_IITM.RegCM4.4_v5_day	CSIRO.QCCCE.CSIRO.Mk3.6.0_SMHI.RCA4_v2_day	MPI.M.MPI.ESM.LR_MPI.CSC.REMO2009_v1_day_19610101.21001231.nc
RCP4.5	Precipitation (%)	17.56	-7.08	-4.86	-3.96
	Temperature (°C)	2.34	2.79	2.83	2.03
RCP8.5	Precipitation (%)	22.9	1.21	12.34	-6.18
	Temperature (°C)	4.23	4.38	4.17	4.25

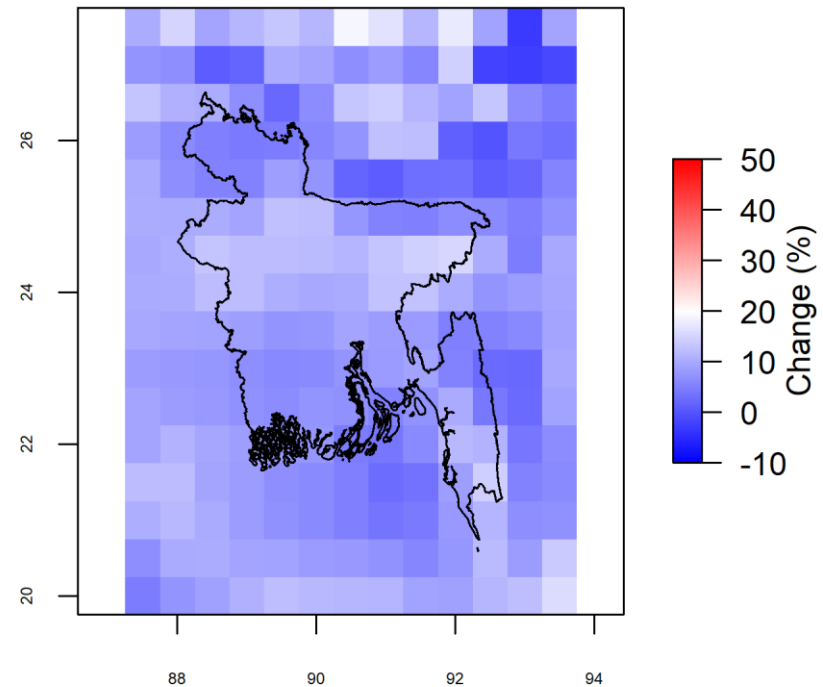


Spatial change between (2075-2099) and (1976-2005) for precipitation

Change in annual precipitation for RCP4.5

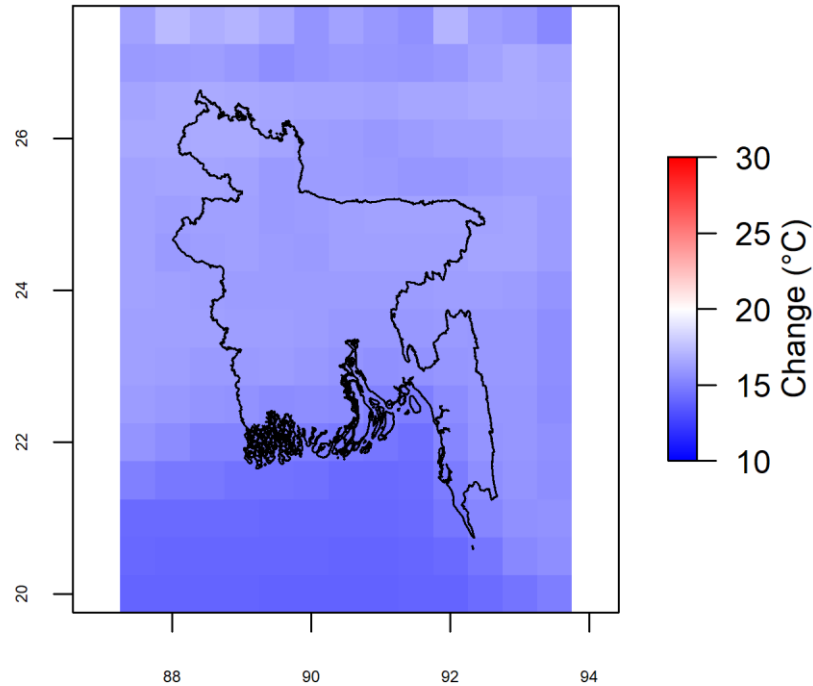


Change in annual precipitation for RCP8.5

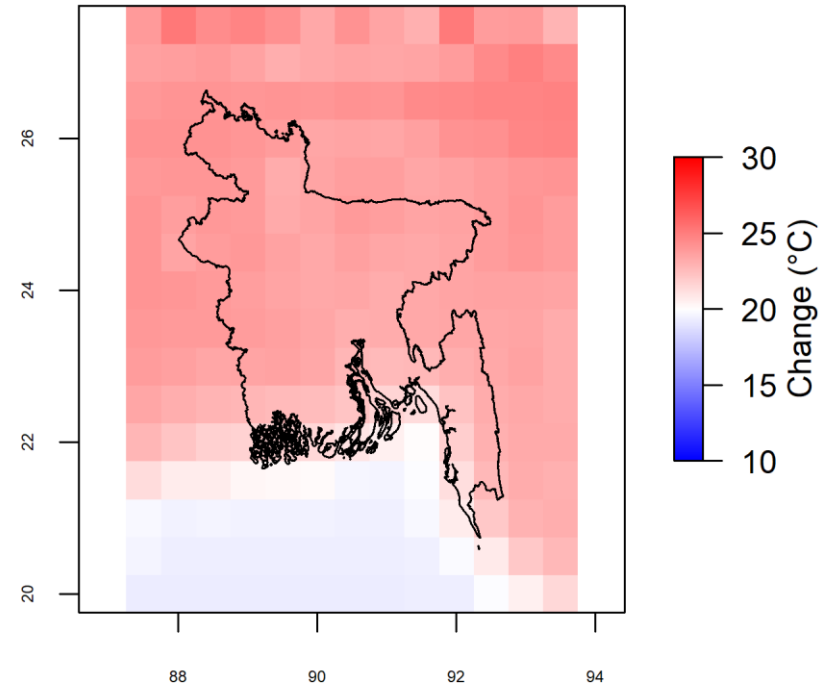


Spatial change between (2075-2099) and (1976-2005) for mean temperature

Change in annual temperature for RCP4.5



Change in annual temperature for RCP8.5



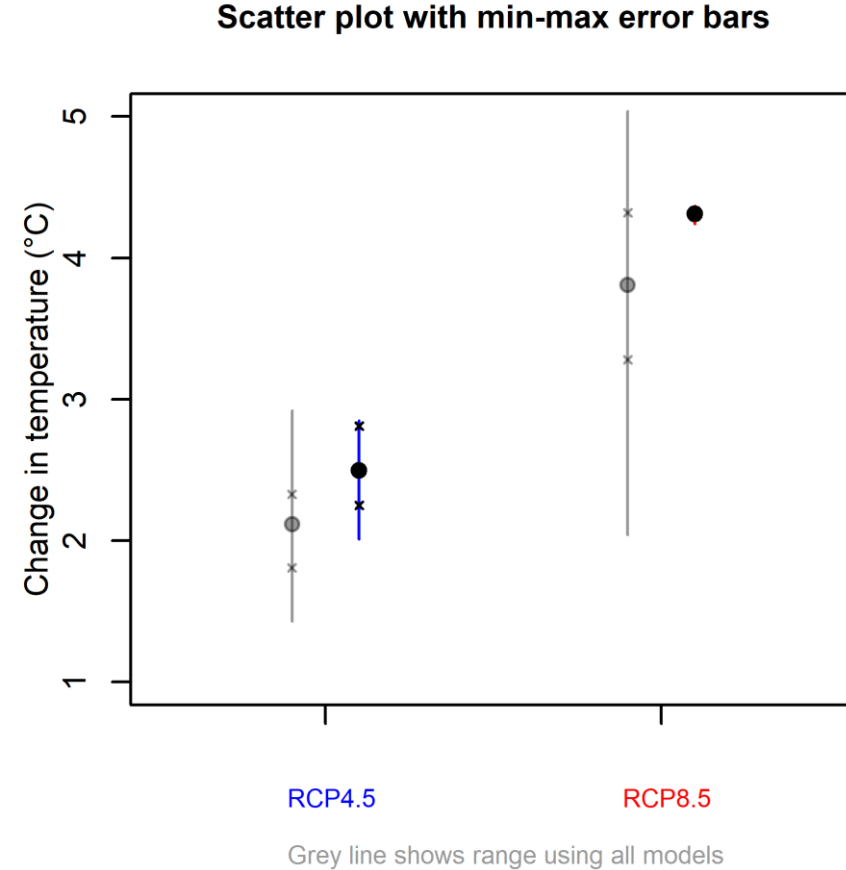
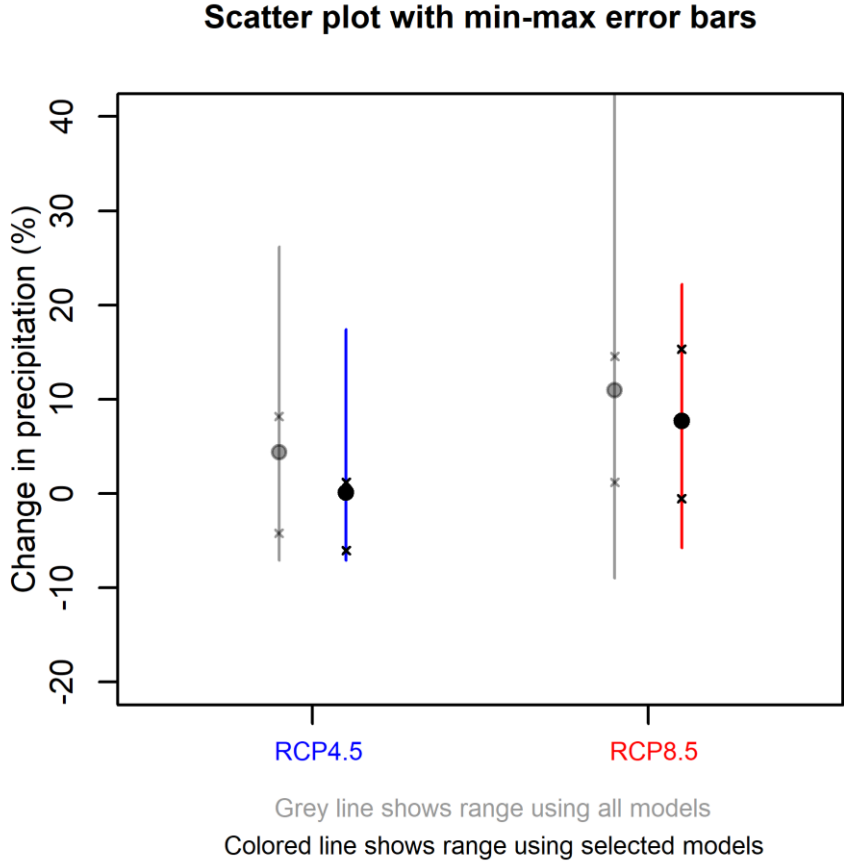
Seasonal change in precipitation between (2075-2099) and (1976-2005)

RCP	Model	Winter	Pre-monsoon	Monsoon	Post-monsoon
RCP4.5	CCCma-CanESM2_SMHI-RCA4_v2	-14.53	21.01	17.34	8.68
	CSIRO-QCCCE-CSIRO-Mk3-6-0_SMHI-RCA4_v2	34.05	-12.55	-6.42	-13.62
	CSIRO.QCCCE.CSIRO.Mk3.6.0_IITM.RegCM4.4_v5	-58.69	7.85	27.9	-10.22
	MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	-38.61	-2.46	5.54	-1.92
RCP8.5	CCCma-CanESM2_SMHI-RCA4_v2	-4.26	28.78	25.39	-7.16
	CSIRO-QCCCE-CSIRO-Mk3-6-0_SMHI-RCA4_v2	2.22	25.61	12.97	10.21
	CSIRO.QCCCE.CSIRO.Mk3.6.0_IITM.RegCM4.4_v5	-70.43	44.24	41.44	-4.3
	MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	-62.54	-21.34	4.81	-16.29

Seasonal change in mean temperature between (2075-2099) and (1976-2005)

RCP	Model	Winter	Pre-monsoon	Monsoon	Post-monsoon
RCP4.5	CCCma-CanESM2_SMHI-RCA4_v2	2.61	2.19	1.98	2.29
	CSIRO-QCCCE-CSIRO-Mk3-6-0_SMHI-RCA4_v2	3.3	2.46	2.67	2.96
	CSIRO.QCCCE.CSIRO.Mk3.6.0_IITM.RegCM4.4_v5	3.69	2.95	2.33	2.46
	MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	2.54	2	1.63	1.3
RCP8.5	CCCma-CanESM2_SMHI-RCA4_v2	4.91	3.91	3.56	4.23
	CSIRO-QCCCE-CSIRO-Mk3-6-0_SMHI-RCA4_v2	5.15	3.68	3.9	4.43
	CSIRO.QCCCE.CSIRO.Mk3.6.0_IITM.RegCM4.4_v5	5.75	5.39	3.98	4.51
	MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	5.06	4.55	3.47	3.39

Uncertainty in the projection





Thank you

**Let's protect
the pulse.**