

Regional climate change projections: Climate change analysis using CORDEX regional climate models over South Asia



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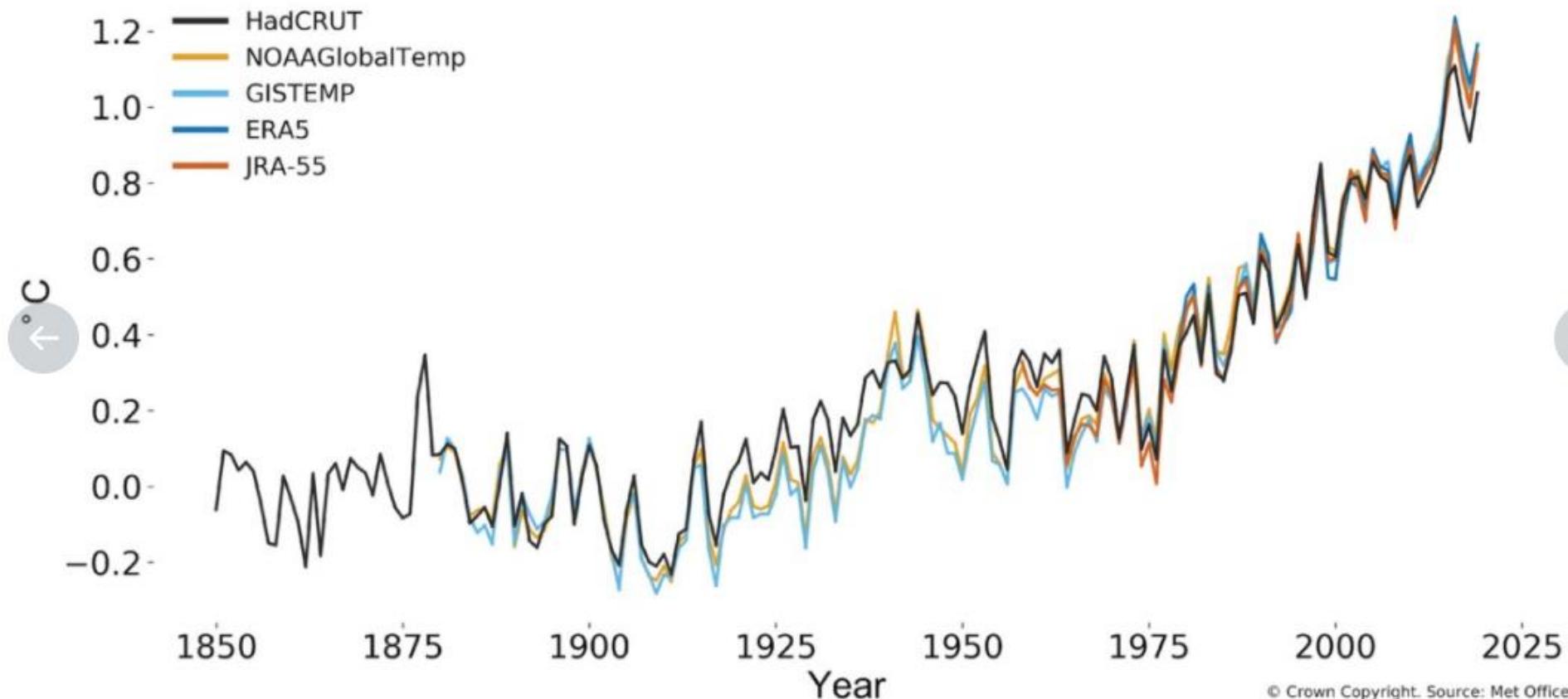
20 October 2020

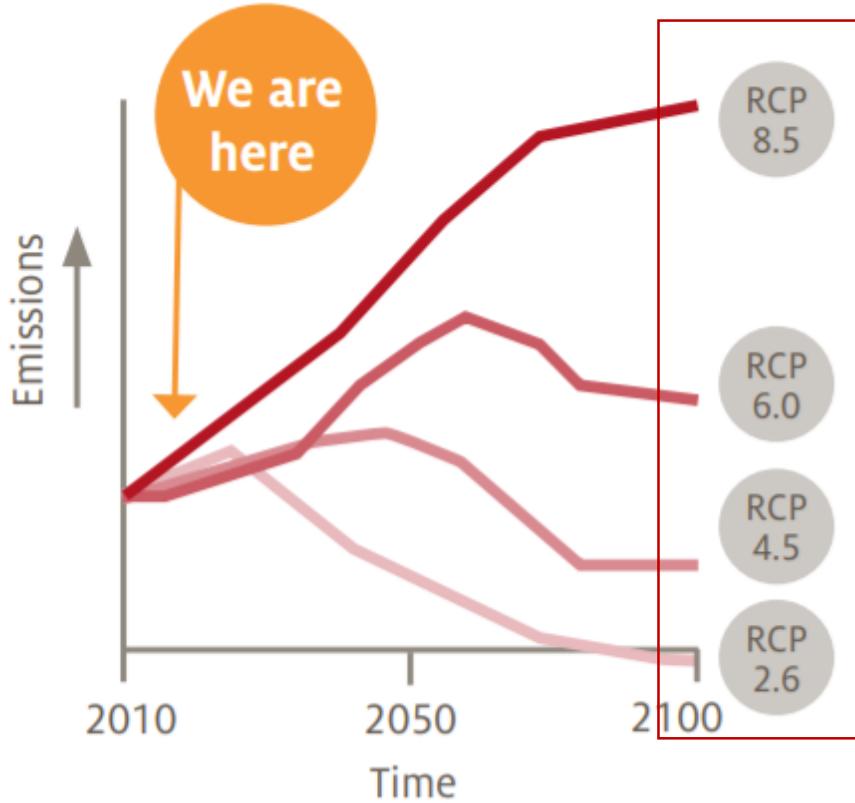
**Climate change analysis
and visualization using
CORDEX dataset**

Global climate change



Global mean temperature difference from 1850-1900 (° C)





If we follow the RCP 8.5 pathway,
more adaptation
will be needed.

If we follow the RCP 2.6 pathway,
less adaptation
is needed.

RCP 8.5 leads to much greater temperature increases, and this means greater impacts and greater costs. To adapt to these changes will also cost more. A balance must be struck between the cost of impacts and the cost of adaptation.

RCPs represents GHGs concentrations trajectories adopted by IPCC for AR5

How our climate may change in future by making predictions of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities.



Warm days

max temperature >90th percentile

Highlights

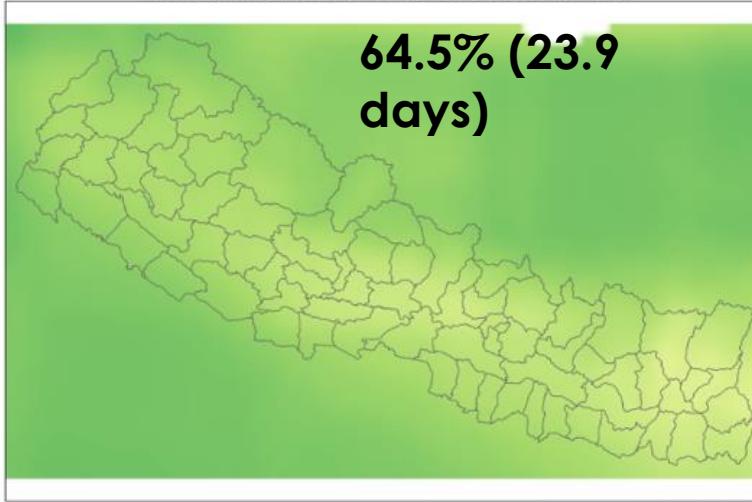
Consistent increase in warm days

Increase in average up to 46 days
(up to 70 days in some places)

Eastern region has higher increase
than western

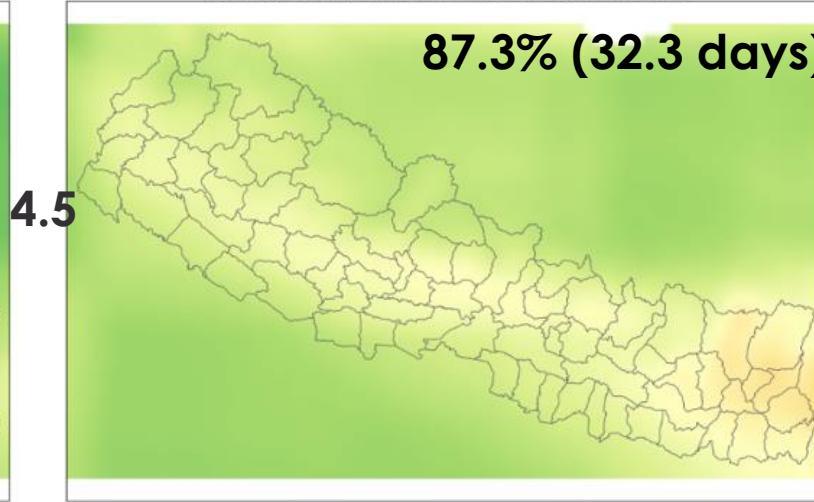
Medium-term

% Change in Warmday for RCP 4.5 2016-2045 vs 1981-2010



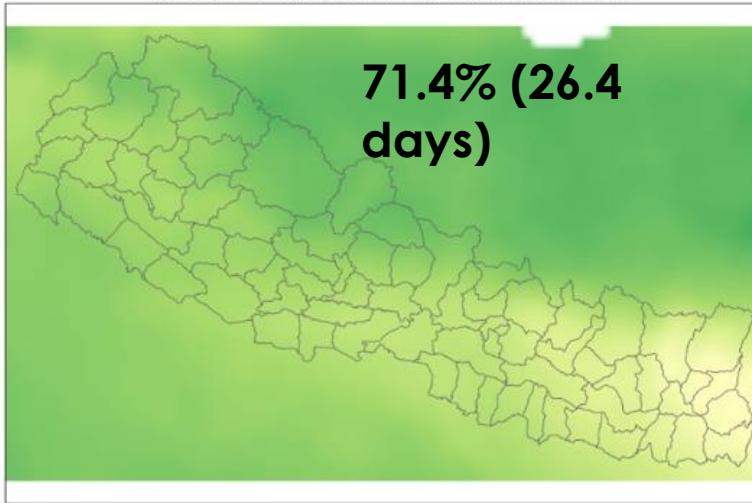
Long-term

% Change in Warmday for RCP 4.5 2036-2065 vs 1981-2010



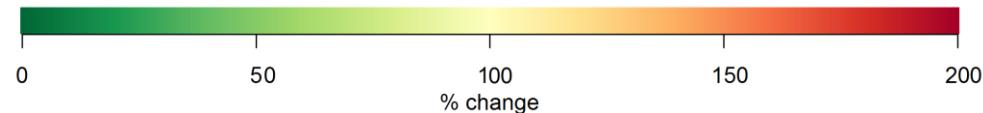
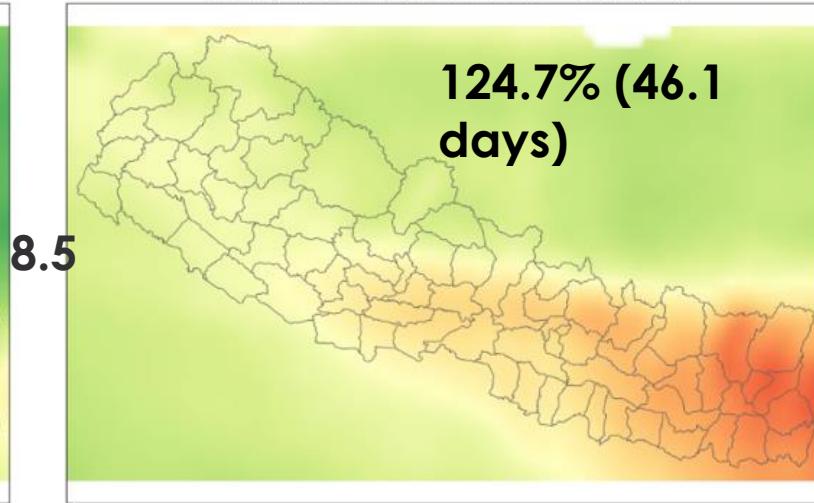
71.4% (26.4 days)

% Change in Warmday for RCP 8.5 2016-2045 vs 1981-2010



124.7% (46.1 days)

% Change in Warmday for RCP 8.5 2036-2065 vs 1981-2010



Warm days

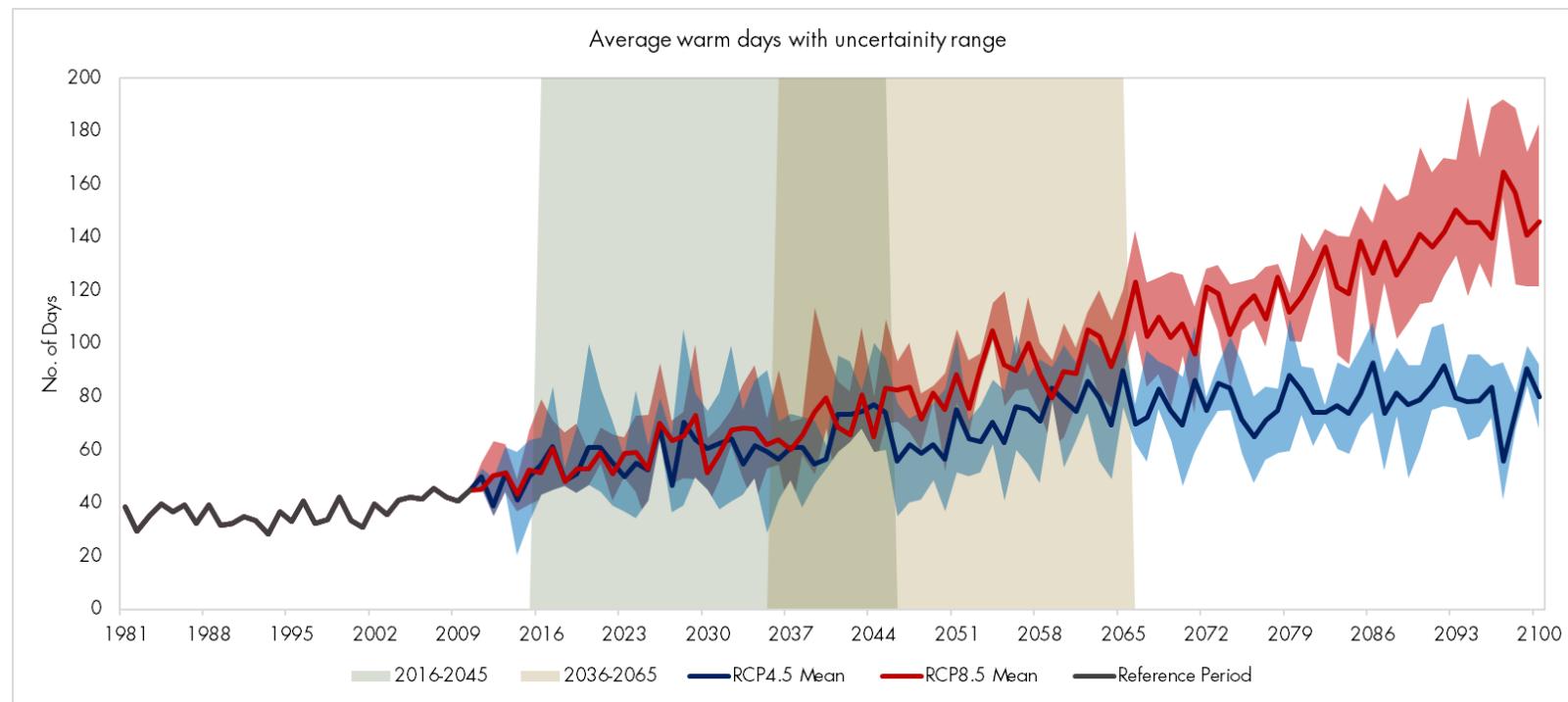
max temperature >90th percentile

Highlights

Consistent increase in warm days

Increase in average up to 46 days
(up to 70 days in some places)

Eastern region has higher increase
than western



Seasonal changes in P and T

Highlights

Increase in precipitation in most of the seasons while decrease during pre-monsoon

Increase in temperature higher in the winter and post-monsoon seasons

	RCP 4.5			RCP 8.5		
	2016-2045	2036-2065	2071-2100	2016-2045	2036-2065	2071-2100
Change in precipitation (%)						
Winter	-5.8	13.6	24.4	7.2	5.0	20.9
Pre-monsoon	-5.0	-7.4	-7.8	-4.0	4.2	-3.1
Monsoon	2.7	9.4	12.4	7.8	13.6	27.1
Post-monsoon	18.6	20.3	16.5	6.0	19.0	22.9
Change in temperature (°C)						
	RCP 4.5			RCP 8.5		
Winter	1.0	1.5	2.1	1.2	2.0	4.0
Pre-monsoon	0.7	1.0	1.2	1.0	1.6	3.4
Monsoon	0.8	1.1	1.4	0.8	1.5	3.0
Post-monsoon	1.3	1.8	2.5	1.4	2.4	4.5



Change in P and T in physiographic region

Highlights

Increase in temperature
higher in mountain
region than whole Nepal
average

	RCP 4.5			RCP 8.5		
	2016-2045	2036-2065	2071-2100	2016-2045	2036-2065	2071-2100
Change in precipitation (%)						
High Mountain	2.57	9.46	12.55	7.96	14.36	25.1
Middle Mountain	1.66	7.59	10.3	6.29	12.42	21.66
Hill	2.14	7.18	9.86	5.81	11.16	22.55
Siwalik	1.56	7.44	9.85	5.84	11.08	21.86
Terai	2.11	7.25	10.16	5.44	10.56	22.71
Whole Nepal	2.1	7.9	10.7	6.4	12.1	23
Change in temperature (°C)						
	RCP 4.5			RCP 8.5		
High Mountain	0.95	1.36	1.79	1.09	1.86	3.61
Middle Mountain	0.89	1.27	1.66	1.04	1.76	3.44
Hill	0.9	1.26	1.69	1.06	1.8	3.56
Siwalik	0.94	1.29	1.72	1.1	1.87	3.66
Terai	0.93	1.29	1.73	1.11	1.87	3.69
Whole Nepal	0.92	1.3	1.72	1.07	1.82	3.58



Today overview

Setting up variables (variables, RCPs, time period, analysis period etc)

Extraction of future climate data for different variables

Reading selected .nc files

Extracting .nc files in rows/columns

Temporal aggregation: Daily mean of all grids, monthly, yearly

Future changes of climatic variables (precip and temp)

Plotting relevant maps

In the future trainings:

We will try to cover other different aspects

Spatial analysis

Seasonal analysis

Ensemble mean

Uncertainty analysis



Code snippet

```
# define variables
var <- "tas"

#define the capital city
city <- "Kathmandu"

#scenarios
scenarios <- c("rcp45","rcp85")

#generate list of all the files
filelist <- list.files(paste(indir,city,sep=""),recursive = T,pattern = ".nc$")
filelist

#models
models <- c("CCCma-CanESM2_RegCM4-4", "CNRM-CERFACS-CNRM-CM5_RCA4")
```



Plot Code snippet

```
#listing the future data from netCDF files for the selected model
rcp45_IITM_file <- rcp45_file[1]
rcp45_SHMI_file <- rcp45_file[2]

rcp85_IITM_file <- rcp85_file[1]
rcp85_SHMI_file <- rcp85_file[2]

#reading the historical data from netCDF files for the selected model
rcp45_IITM <- retrieve.rcm(paste0(indir,city,"/",rcp45_IITM_file),param=var)
rcp45_SHMI <- retrieve.rcm(paste0(indir,city,"/",rcp45_SHMI_file),param=var)

rcp85_IITM <- retrieve.rcm(paste0(indir,city,"/",rcp85_IITM_file),param=var)
rcp85_SHMI <- retrieve.rcm(paste0(indir,city,"/",rcp85_SHMI_file),param=var)

#extracting the raw data from netCDF files for the selected model
raw_rcp45_IITM <- coredata(rcp45_IITM)
raw_rcp45_SHMI <- coredata(rcp45_SHMI)

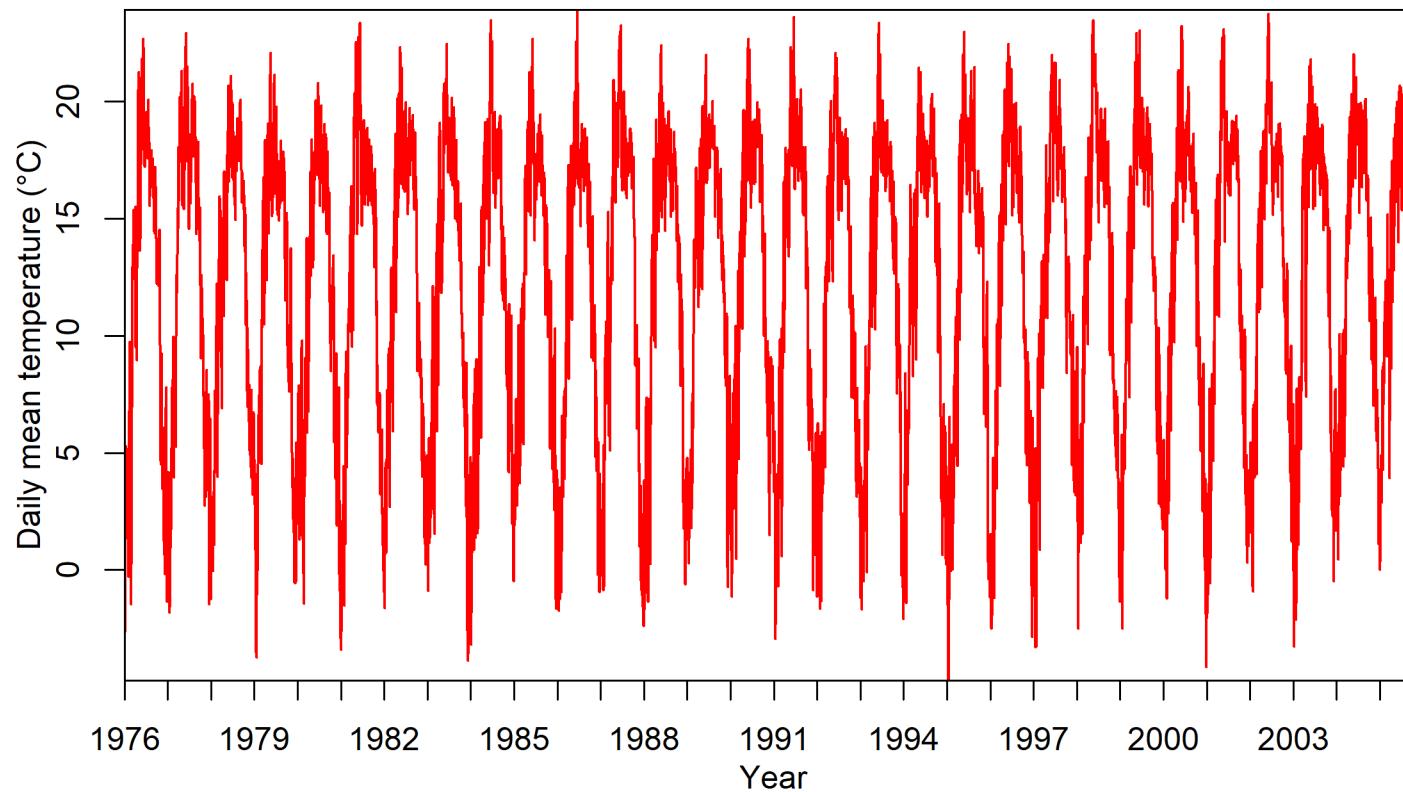
raw_rcp85_IITM <- coredata(rcp85_IITM)
raw_rcp85_SHMI <- coredata(rcp85_SHMI)

#converting the units of precipitation variable to mm and temperature to degree Celsius
raw_rcp45_IITM <- raw_rcp45_IITM-273.15
raw_rcp45_SHMI <- raw_rcp45_SHMI-273.15
raw_rcp85_IITM <- raw_rcp85_IITM-273.15
raw_rcp85_SHMI <- raw_rcp85_SHMI-273.15
```



Daily plots

SMHI daily average Mean temperature

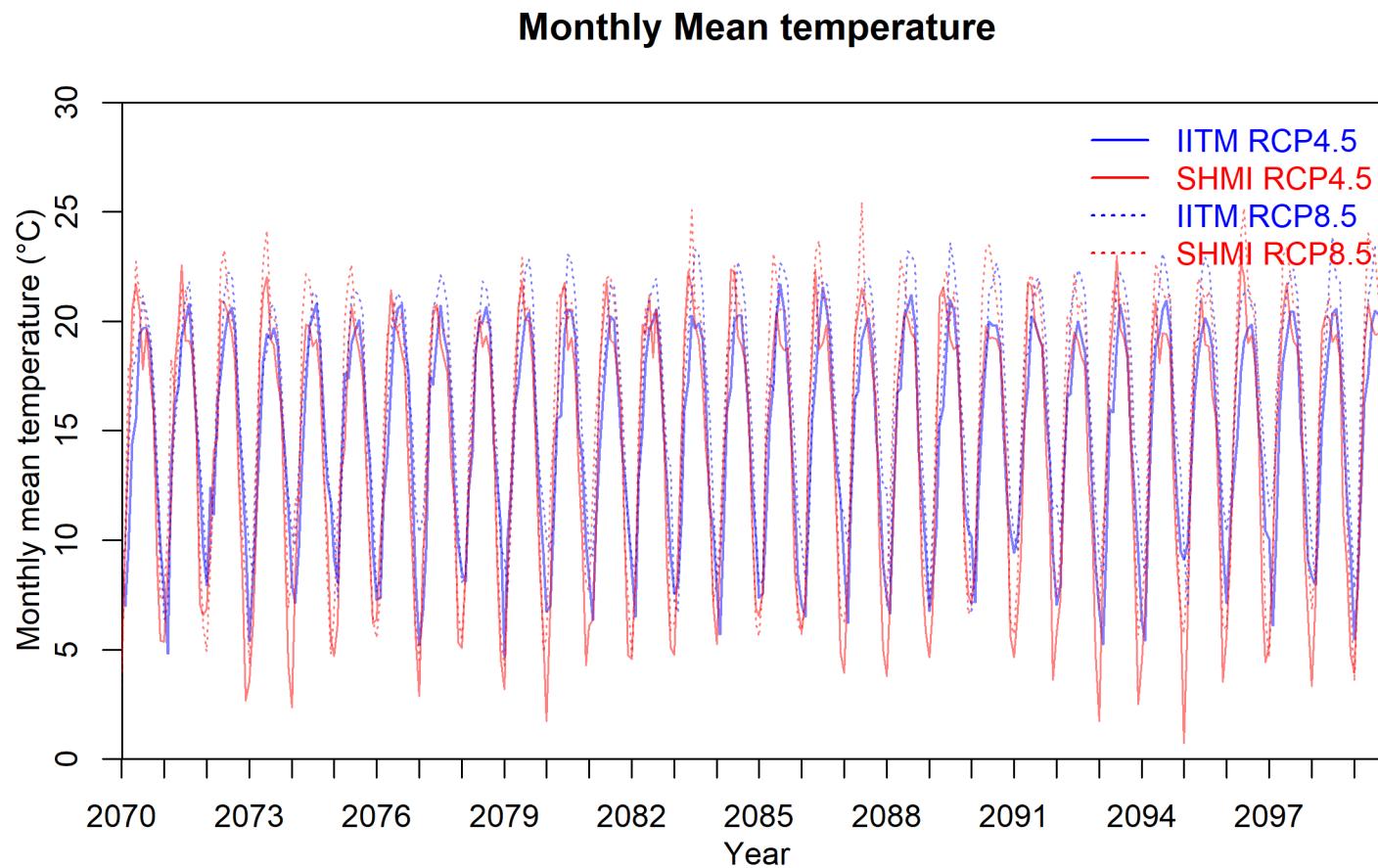


Plot Code snippet

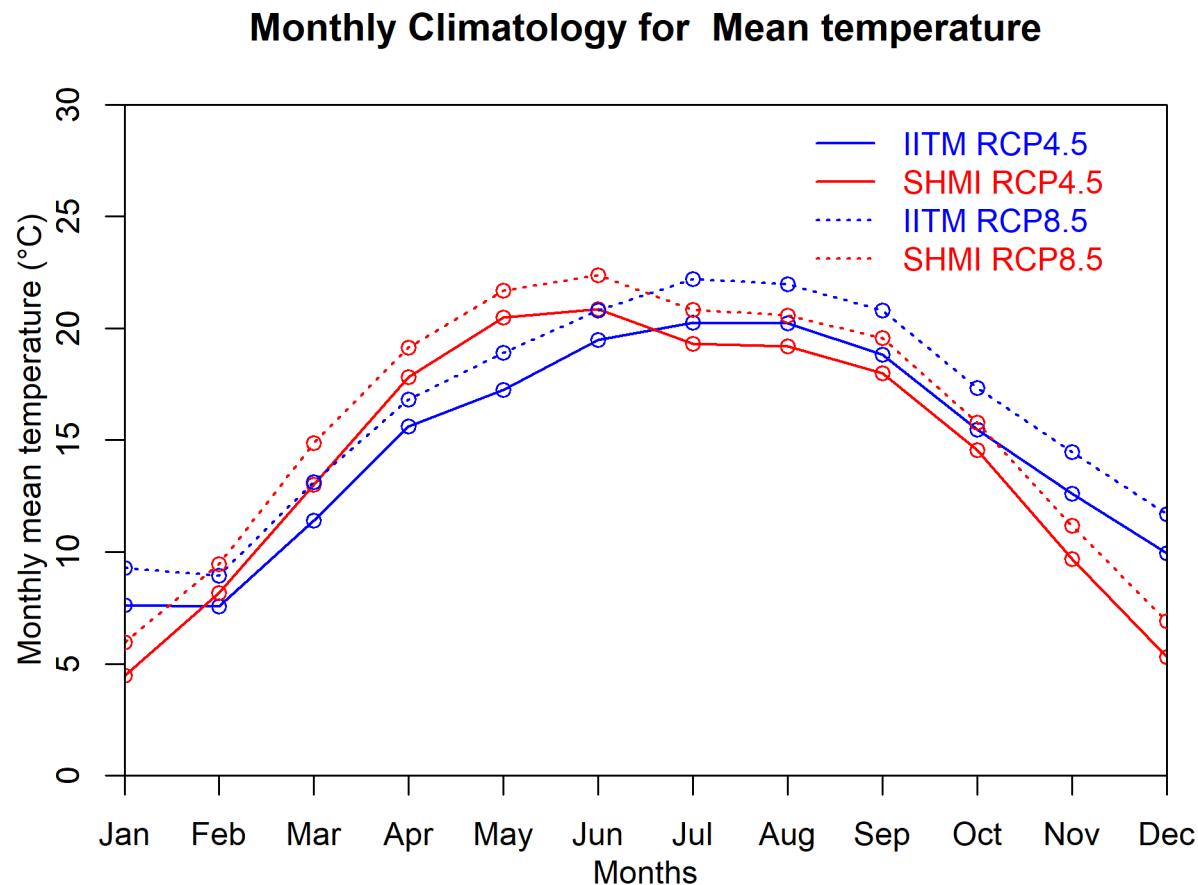
```
#saving the monthly plot
{
  png(paste0(outdir,city,"_",var,"_fut_1_monthly_plot.png"),width = 2400, height = 1600, units = "px",
      pointsize = 12,bg = "white", res = 300)
  plot(date_axis_m,monthly_average_rcp45_IITM$x,col=rgb(red = 0, green = 0, blue = 1, alpha = 0.5),
        type = "l",lwd=1.5,ylab = NA,xlab = NA,xaxt="n",ylim =c(ymin_m, ymax_m),xaxs="i",yaxs="i")
  lines(date_axis_m,monthly_average_rcp45_SHMI$x,col=rgb(red = 1, green = 0, blue = 0, alpha = 0.5),
        ylim =c(ymin_m, ymax_m))
  lines(date_axis_m,monthly_average_rcp85_IITM$x,col=rgb(red = 0, green = 0, blue = 1, alpha = 0.5),lty=3,
        ylim =c(ymin_m, ymax_m))
  lines(date_axis_m,monthly_average_rcp85_SHMI$x,col=rgb(red = 1, green = 0, blue = 0, alpha = 0.5),lty=3,
        ylim =c(ymin_m, ymax_m))
  axis(1,at=date_axis,labels = seq(2070,2100))
  mtext(xlab,side=1,col="black",line=2)
  mtext(ylab_m,side=2,col="black",line=2)
  legend(as.Date("2092-03-01"),ymax_m, c("IITM RCP4.5","SHMI RCP4.5","IITM RCP8.5","SHMI RCP8.5"),
         lty=c(1,1,3,3),col=c("blue","red"),
         lwd=c(1.5,1.5), text.col = c("blue","red"),cex = 1,bty = "n")
  title(paste0("Monthly ",varname))
  dev.off()
}
```



Monthly plots



Monthly climatology plot



Code snippet

```
# Future Changes Calculation -----
#calculate daily average for all years (2006-2099)
all_daily_average_rcp45_IITM <- rowMeans(raw_rcp45_IITM)
all_daily_average_rcp45_SHMI <- rowMeans((raw_rcp45_SHMI)[1:(nrow(raw_rcp45_SHMI)-365),])

all_daily_average_rcp85_IITM <- rowMeans(raw_rcp85_IITM)
all_daily_average_rcp85_SHMI <- rowMeans((raw_rcp85_SHMI)[1:(nrow(raw_rcp85_SHMI)-365),])

#aggregate daily values to yearly values
all_yearly_average_rcp45_IITM <- aggregate(all_daily_average_rcp45_IITM,FUN=stat,by=list(format(date_IITM, "%Y")))
all_yearly_average_rcp45_SHMI <- aggregate(all_daily_average_rcp45_SHMI,FUN=stat,by=list(format(date_SHMI, "%Y")))

all_yearly_average_rcp85_IITM <- aggregate(all_daily_average_rcp85_IITM,FUN=stat,by=list(format(date_IITM, "%Y")))
all_yearly_average_rcp85_SHMI <- aggregate(all_daily_average_rcp85_SHMI,FUN=stat,by=list(format(date_SHMI, "%Y")))

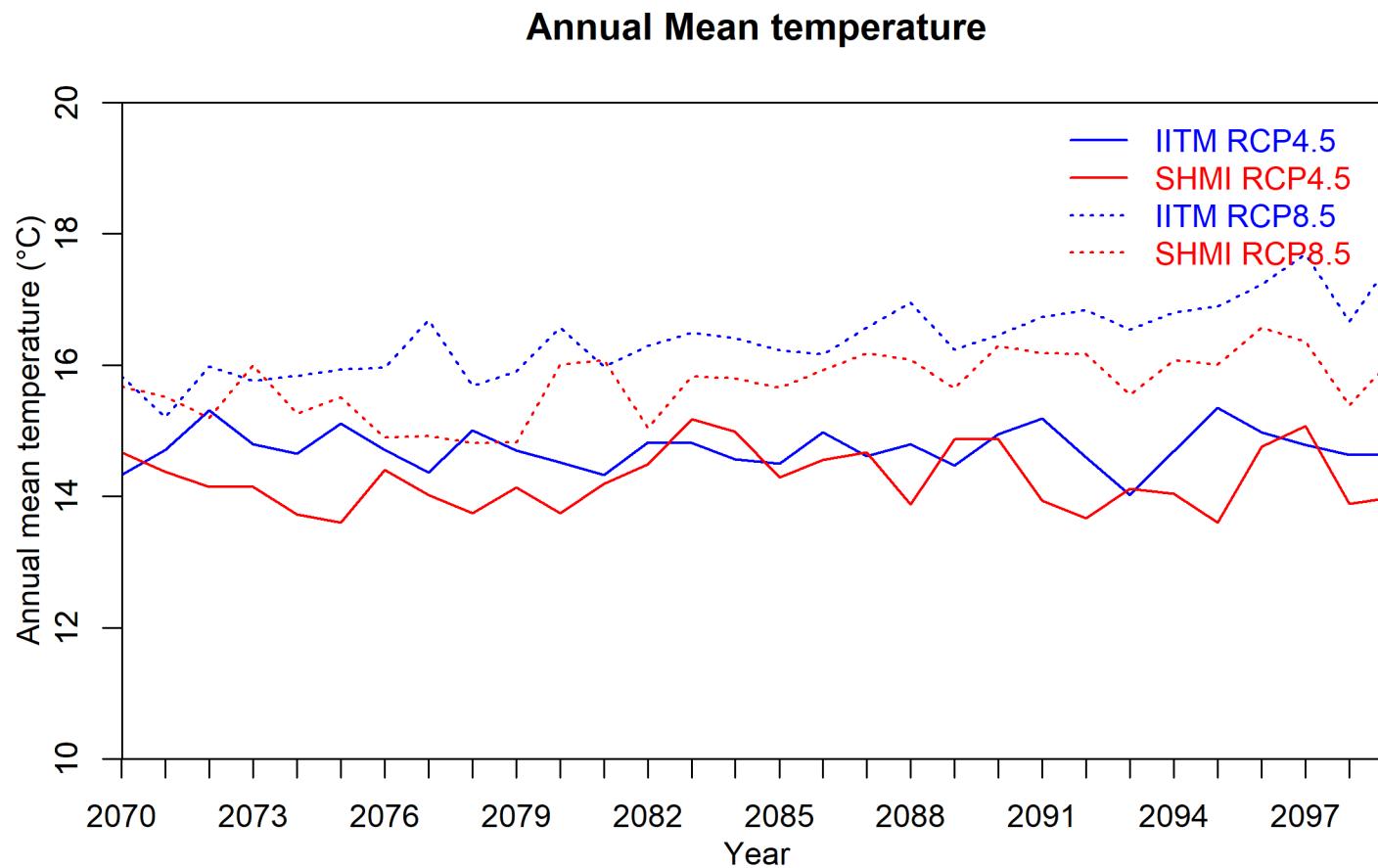
# reading historical dataset
yearly_average <- read.csv(paste("C:\\CORDEX_training\\Cordex_plots\\Day4\\",city,"_",var,"_yearly_average.csv",sep=""))

yearly_average_IITM <- yearly_average[,c(1,2)]
names(yearly_average_IITM) <- c("Group.1","x")
yearly_average_SHMI <- yearly_average[,c(1,3)]
names(yearly_average_SHMI) <- c("Group.1","x")

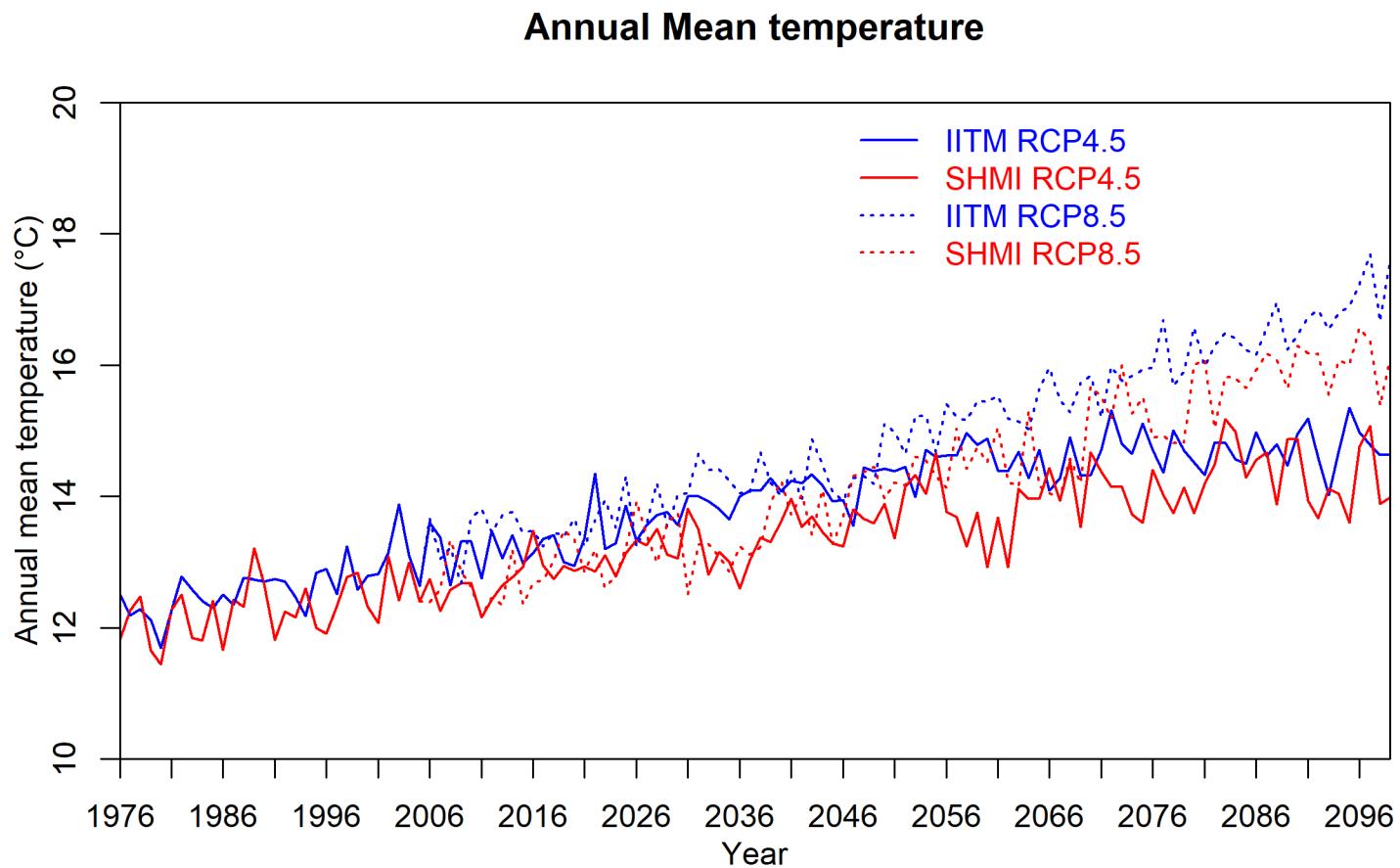
#combine the data for 1976-2099
all_yearly_rcp45_IITM <- rbind(yearly_average_IITM,all_yearly_average_rcp45_IITM)
all_yearly_rcp85_IITM <- rbind(yearly_average_IITM,all_yearly_average_rcp85_IITM)
all_yearly_rcp45_SHMI <- rbind(yearly_average_SHMI,all_yearly_average_rcp45_SHMI)
all_yearly_rcp85_SHMI <- rbind(yearly_average_SHMI,all_yearly_average_rcp85_SHMI)
```



Annual plot



Timeseries plot



Change in temperature by the end of the century

RCP	Model	Change
RCP4.5	CCCma-CanESM2_RegCM4-4 (IITM)	2.11
RCP4.5	CNRM-CERFACS-CNRM-CM5_RCA4 (SMHI)	1.97
RCP8.5	CCCma-CanESM2_RegCM4-4 (IITM)	3.78
RCP8.5	CNRM-CERFACS-CNRM-CM5_RCA4 (SMHI)	3.42



Thank you

Protect the pulse.

