APCC Training Program on

"Generation of regional climate data derived from statistical downscaling techniques"

Practice Session

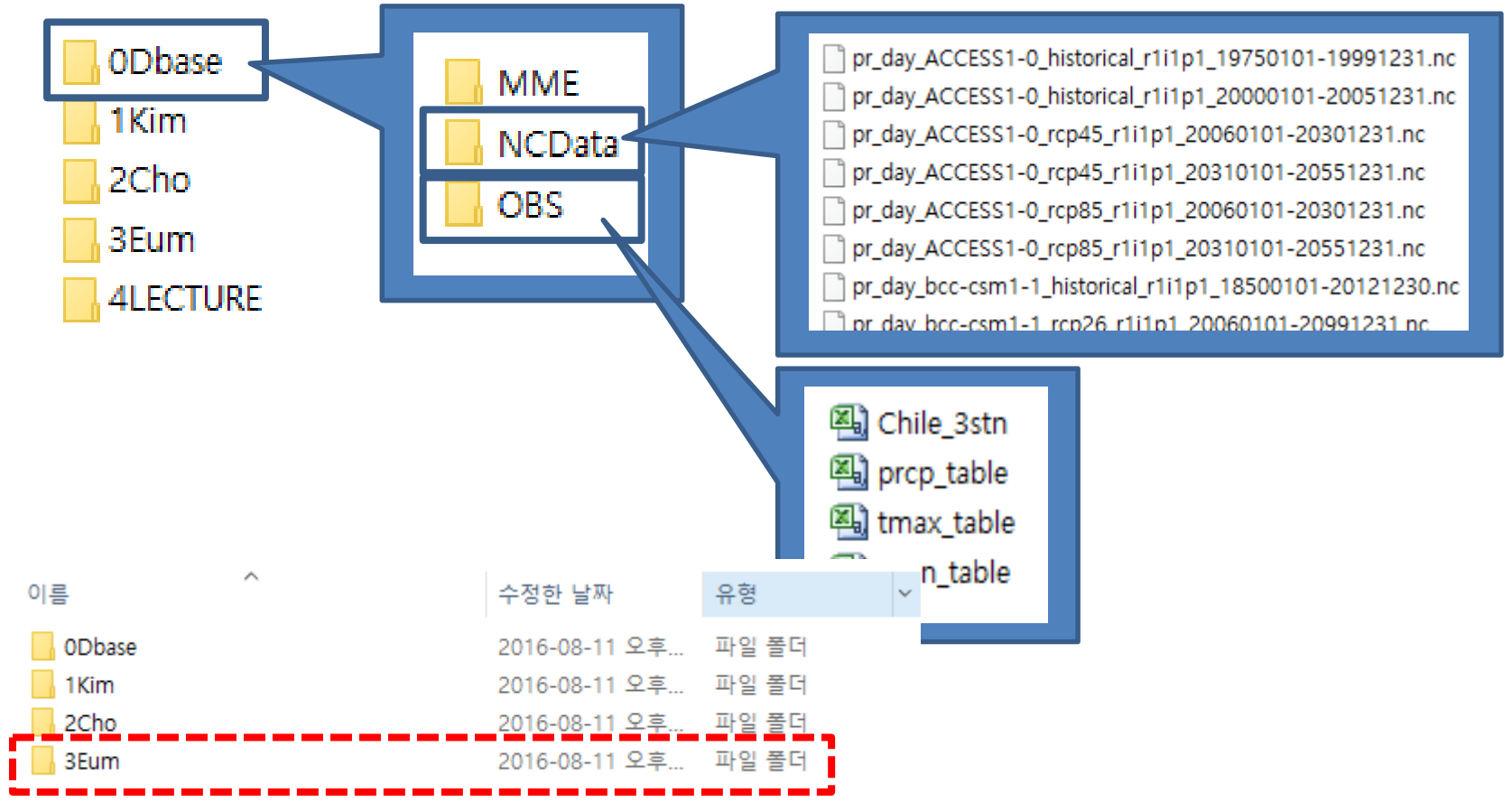
Hyung-Il Eum

APEC Climate Center (APCC)

Reminder

- **Probability Distribution**
  - Gumbel, Gamma
  - Normal
- **Quantile (Percentile)**
- **Interpolation**
- **QM**
- **DQM**
- **QDM**

Data



Copy NCData, OBS, 3Eum folders to your own folder (ex: D:/2016TP/)

Download climate projections

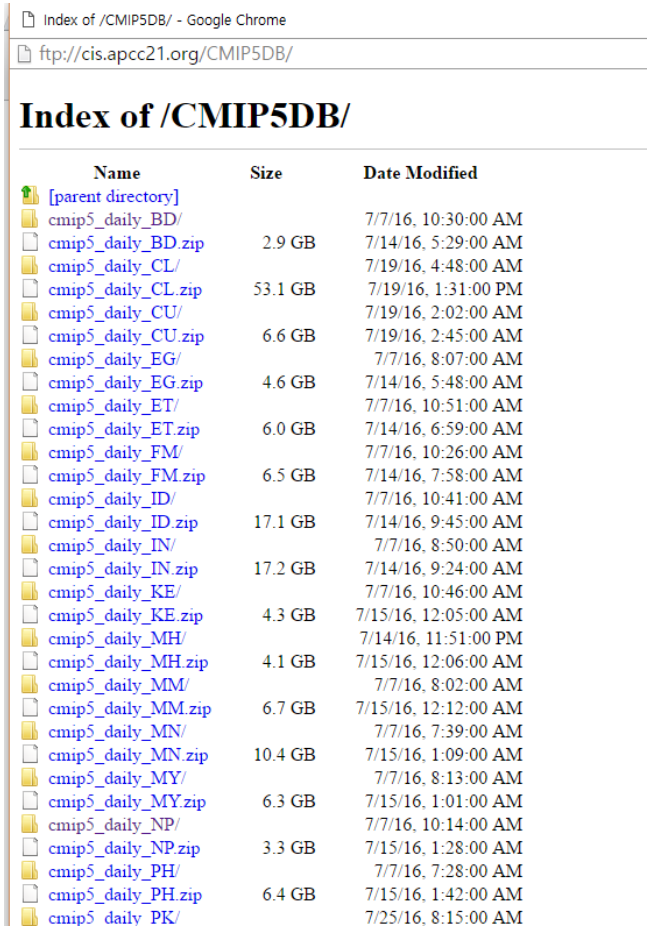
➢ Go to ADSS

- http://adss.apcc21.org/

DataSet	Areal Coverage	Grid Size	Time Step	Access	Source	Rquirements
APCC-MME(6-MON)	Global	2.5°×2.5°	Monthly	About FTP OpeNDAP	APCC	Login
APCC-MME(3-MON)	Global	2.5°×2.5°	Monthly	About FTP OpeNDAP	APCC	Login
INDIVISUAL-MODEL(6-MON)	Global	2.5°×2.5°	Monthly	About FTP OpeNDAP	APCC	Login
INDIVISUAL-MODEL(3-MON)	Global	2.5°×2.5°	Monthly	About FTP OpeNDAP	APCC	Login
CORDEX-SEA25	Regional	25km	Daily	About FTP OpeNDAP	APCC	
CORDEX-SEA44	Regional	44km	Daily	About FTP OpeNDAP	APCC	
Clipped CMIP5	National level (22 Countries)	Depending on GCMs	Daily	About FTP OpeNDAP Link	ESGF	
IRI_DATA_LIBRARY	Global	2.5°×2.5°	Various	About Link	IRI	
NCEP	Global	2.5°×2.5°	Daily	About FTP OpeNDAP	NOAA	
NCEP-SFC	Global	2.5°×2.5°	Daily	About FTP OpeNDAP	NOAA	

Download climate projections

➢ cmip5_daily_[Ncode]



Index of /CMIP5DB/ - Google Chrome

ftp://cis.apcc21.org/CMIP5DB/

Index of /CMIP5DB/

Name	Size	Date Modified
[parent directory]		
cmip5_daily_BD/		7/7/16, 10:30:00 AM
cmip5_daily_BD.zip	2.9 GB	7/14/16, 5:29:00 AM
cmip5_daily_CL/		7/19/16, 4:48:00 AM
cmip5_daily_CL.zip	53.1 GB	7/19/16, 1:31:00 PM
cmip5_daily_CU/		7/19/16, 2:02:00 AM
cmip5_daily_CU.zip	6.6 GB	7/19/16, 2:45:00 AM
cmip5_daily_EG/		7/7/16, 8:07:00 AM
cmip5_daily_EG.zip	4.6 GB	7/14/16, 5:48:00 AM
cmip5_daily_ET/		7/7/16, 10:51:00 AM
cmip5_daily_ET.zip	6.0 GB	7/14/16, 6:59:00 AM
cmip5_daily_FM/		7/7/16, 10:26:00 AM
cmip5_daily_FM.zip	6.5 GB	7/14/16, 7:58:00 AM
cmip5_daily_ID/		7/7/16, 10:41:00 AM
cmip5_daily_ID.zip	17.1 GB	7/14/16, 9:45:00 AM
cmip5_daily_IN/		7/7/16, 8:50:00 AM
cmip5_daily_IN.zip	17.2 GB	7/14/16, 9:24:00 AM
cmip5_daily_KE/		7/7/16, 10:46:00 AM
cmip5_daily_KE.zip	4.3 GB	7/15/16, 12:05:00 AM
cmip5_daily_MH/		7/14/16, 11:51:00 PM
cmip5_daily_MH.zip	4.1 GB	7/15/16, 12:06:00 AM
cmip5_daily_MM/		7/7/16, 8:02:00 AM
cmip5_daily_MM.zip	6.7 GB	7/15/16, 12:12:00 AM
cmip5_daily_MN/		7/7/16, 7:39:00 AM
cmip5_daily_MN.zip	10.4 GB	7/15/16, 1:09:00 AM
cmip5_daily_MY/		7/7/16, 8:13:00 AM
cmip5_daily_MY.zip	6.3 GB	7/15/16, 1:01:00 AM
cmip5_daily_NP/		7/7/16, 10:14:00 AM
cmip5_daily_NP.zip	3.3 GB	7/15/16, 1:28:00 AM
cmip5_daily_PH/		7/7/16, 7:28:00 AM
cmip5_daily_PH.zip	6.4 GB	7/15/16, 1:42:00 AM
cmip5_daily_PK/		7/25/16, 8:15:00 AM

A	B
NAME	Code
Bangladesh	BD
Burma	MM
Chile	CL
Cuba	CU
Egypt	EG
Ethiopia	ET
Federated States of Micronesia	FM
India	IN
Indonesia	ID
Kenya	KE
Malaysia	MY
Marshall Islands	MH
Mongolia	MN
Nepal	NP
Pakistan	PK
Samoa	WS
Tanzania	TZ
Thailand	TH
Tonga	TO
Vietnam	VN
Zambia	ZM

Install.Packages

- **Open "Packages.R"**

```
1  install.packages("RCurl")
2  install.packages("ncdf4")
3  install.packages("chron")
4  install.packages("gstat")
5  install.packages("sp")
6  install.packages("maptools")
7  install.packages("climdex.pcic")
8  install.packages("PCICt")
9  install.packages("rgeos")
```

Download climate projections

➢ R script

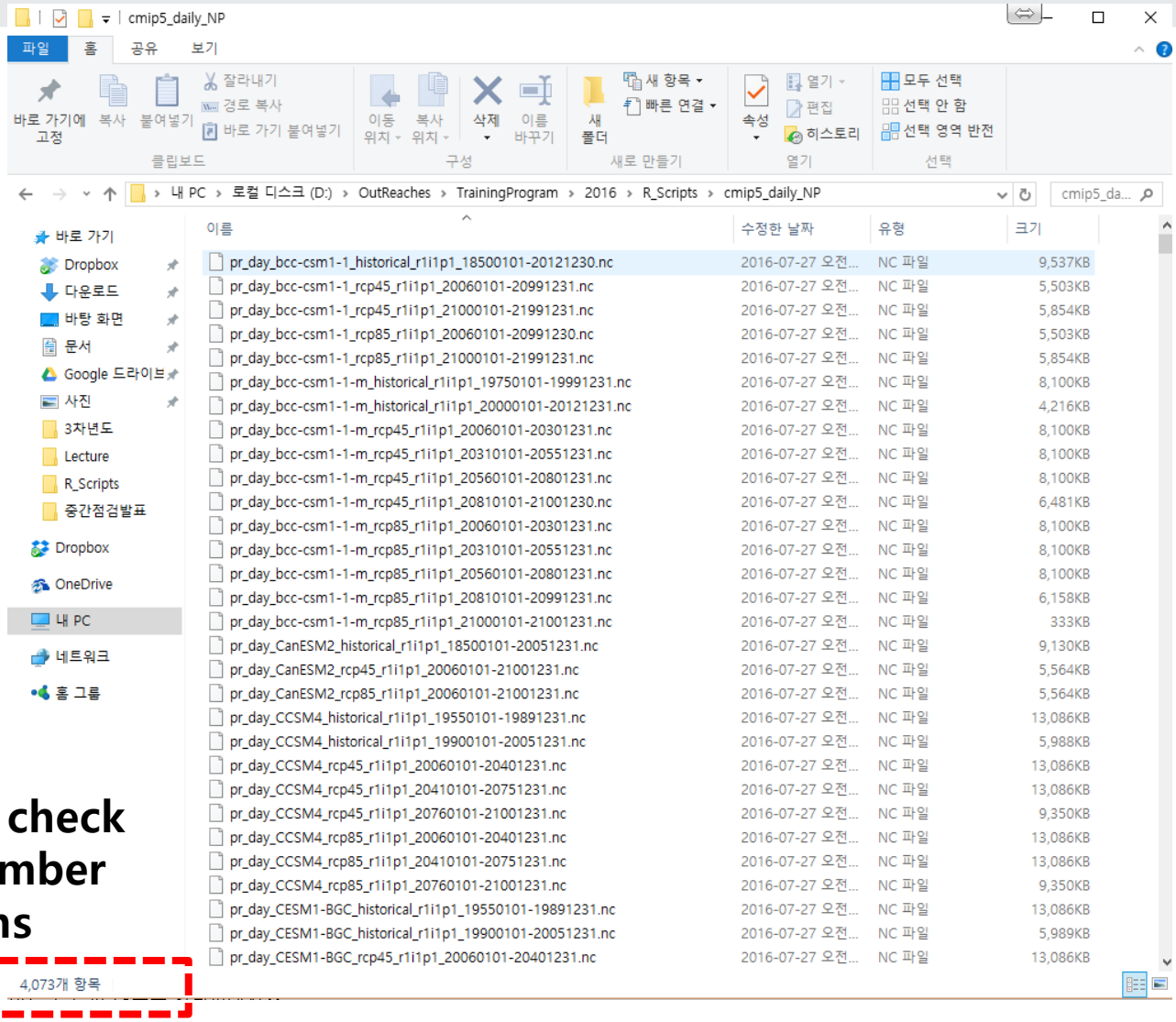
```
1
2  library("RCurl")
3
4  #User set-up
5  #=============================================================
6  ncode = "IN"
7  setwd("D:/OutReaches/TrainingProgram/2016/R_Scripts")
8  #=============================================================
9
10 DestDir<-paste("cmip5_daily_",ncode,sep="")
11 if(!file.exists(DestDir)) {dir.create(DestDir)}
12
13 adss = "ftp://cis.apcc21.org/CMIP5DB/"
14 url<-paste(adss, "cmip5_daily_", ncode, ".zip", sep="")
15 destfile<-paste(DestDir,"/cmip5_daily_",ncode,".zip",sep="")
16
17 download.file(url,destfile,cacheOK = TRUE, quiet = FALSE)
18 unzip(destfile)
19 file.remove(destfile)
```

National Code

Folder Path

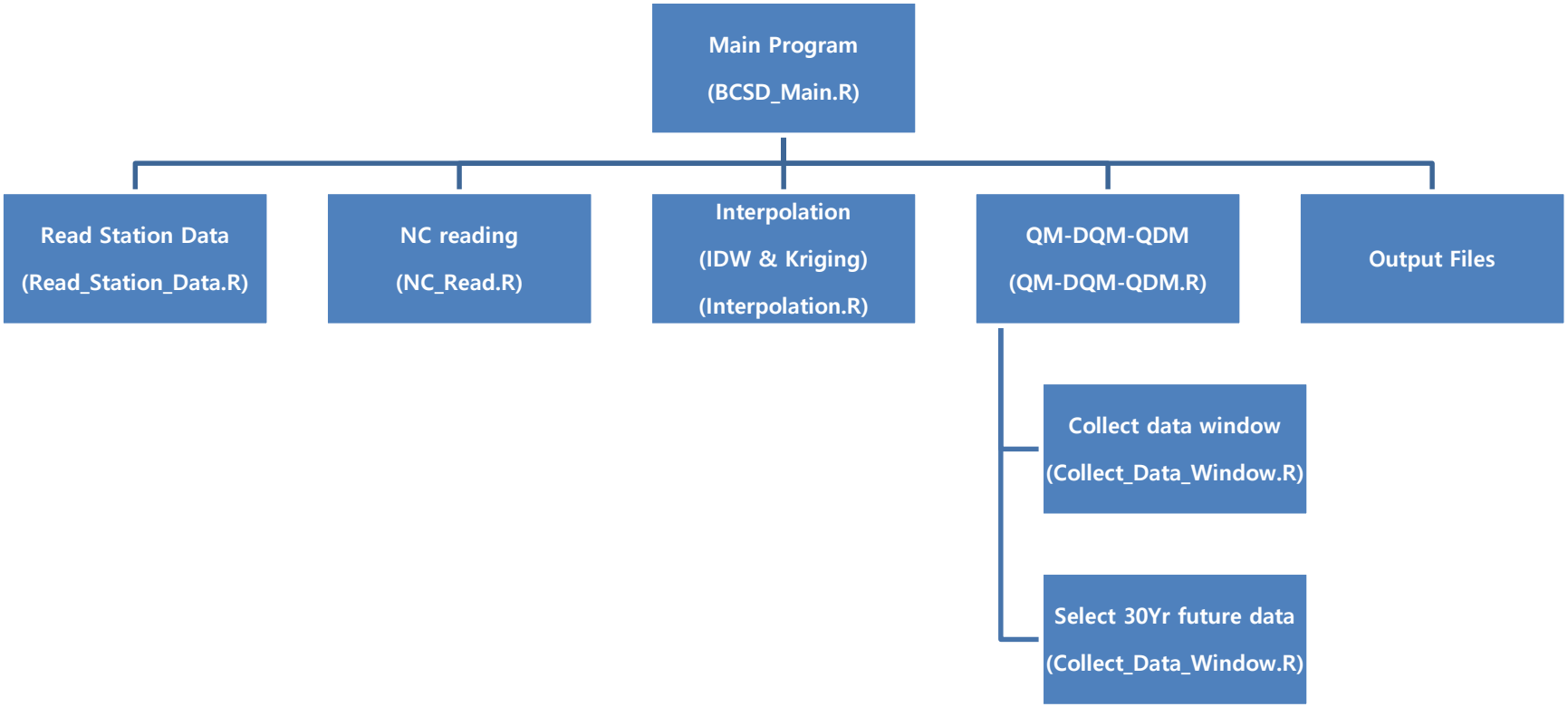
A	B
NAME	Code
Bangladesh	BD
Burma	MM
Chile	CL
Cuba	CU
Egypt	EG
Ethiopia	ET
Federated States of Micronesia	FM
India	IN
Indonesia	ID
Kenya	KE
Malaysia	MY
Marshall Islands	MH
Mongolia	MN
Nepal	NP
Pakistan	PK
Samoa	WS
Tanzania	TZ
Thailand	TH
Tonga	TO
Vietnam	VN
Zambia	ZM

Download climate projections



Please check the number of items

SDQM(DQM & QDM) structure



R scripts

- **Confirm all R scripts are in your working folder**
  - 3Eum
    - BCSD_Main.R
    - Read_Station_Data.R
    - NC_Read.R
    - Interpolation.R
    - Collect_Data_Window.R
    - QM-DQM-QDM.R

Input data

	A	B	C	D	E	F
1	Year	Month	Day	Nagarkot	Kathmand	Panipokhari
2	1976	1	1	0	0	0
3	1976	1	2	0	0	0
4	1976	1	3	0	0	0
5	1976	1	4	0	0	0
6	1976	1	5	0	0	0
7	1976	1	6	0	0	0
8	1976	1	7	0	0	0
9	1976	1	8	0	0	0
10	1976	1	9	0	0	0
11	1976	1	10	0	0	0
12	1976	1	11	0	0	0
13	1976	1	12	0	0	0
14	1976	1	13	0	0	0
15	1976	1	14	0	0	0
16	1976	1	15	0	0	0
17	1976	1	16	0	0	0
18	1976	1	17	0	0	0
19	1976	1	18	20	21	22
20	1976	1	19	7.6	9.2	4.8
21	1976	1	20	0	0	0

- **Station data set (0Dbase/OBS/)**
  - prcp_table.csv
  - tmax_table.csv
  - tmin_table.csv
  - Nation_(N)stn.csv

	A	B	C	D	E	F
1	X	Y	Elev	ID	Ename	Syear
2	85.35625	27.70383	1337	ID1030	Kathmand	1967
3	85.52086	27.69335	2147	ID1043	Nagarkot	1971
4	85.32415	27.72864	1329	ID1039	Panipokha	1971
5						

```
1  bcc-csm1-1-m
2  CanESM2
3  CCSM4
4  CESM1-BGC
5  CESM1-CAM5
6  CMCC-CM
```

- **GCM_names.txt (3Eum)**
- **GCM climate projections (0Dbase/NCData)**
  - NetCDF format files

Set up

- **Set working directory**
  - setwd(…)
    - Ex: D:/2016TP/3Eum
- **Create Output directory**
  - if(!file.exists("Output")) {dir.create("Output")}
- **Connect R functions to main program**
  - source(…)
    - source("Read_Station_Data.R")
    - source("NC_Read.R")
    - source("Interpolation.R")
    - source("Collect_Data_Window.R")
    - source("QM-DQM-QDM.R")

Read station data

➢ Read_Station_Data.R

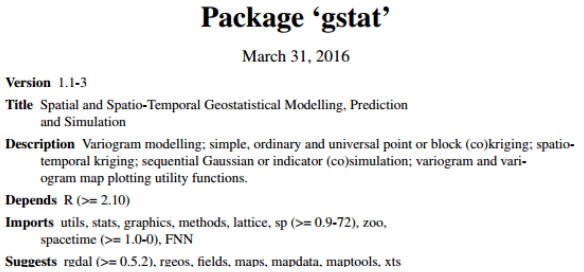
```r
# Station data reading function
# During the period of observation, this function extract a period the users specify from Start_Year to End_Year.
# Var: Variable name (prcp, tmax, or tmin)
# Path_OBS: folder path
# Start_Year: Starting year
# End_Year: Ending year
# STN_OBS: return variable
STN_Data_Read<-function(Var,STN_names,Path_OBS,Start_Year,End_Year,...){
  STN_path=paste(Path_OBS,"/",Var,"_table.csv",sep="")
  DATA_STN <-read.csv(STN_path,head=TRUE)  #Year, Month, Day
  names( DATA_STN ) <- c(
    "IYY", "IMM", "IDD",as.character(STN_names))

  if(DATA_STN$IYY[1]>=Start_Year) {
    StaYear_obs<-DATA_STN$IYY[1]
  } else {
    StaYear_obs<-Start_Year
  }

  Nlength_OBS<-length(DATA_STN$IYY)
  if(DATA_STN$IYY[Nlength_OBS]<End_Year) {
    EndingYear_obs<-DATA_STN$IYY[Nlength_OBS]
  } else {
    EndingYear_obs<-End_Year
    }

  bd.OBS<-as.Date(paste(StaYear_obs,"-01-01",sep=""))
  ed.OBS<-as.Date(paste(EndingYear_obs,"-12-31",sep=""))
  Date.OBS<-as.Date((seq(bd.OBS,ed.OBS,by="1 day")))
  STN_OBS <- DATA_STN[DATA_STN$IYY>=Start_Year & DATA_STN$IYY<=End_Year,]
  STN_OBS <- STN_OBS[,4:(3+length(STN_names))]
  STN_OBS<-cbind(Date.OBS,STN_OBS)
  return(STN_OBS)
}
```

Read GCM data

- **NC_Read.R**
  - NC_combine
    - Read_NC
    - Read_HadGEM
    - Info.NCfiles
- **NC_combine<-function(Folder,GCM_name,Variable,Ems_sce, Start_Year,End_Year,...)**
  - Folder: location or path of NC files
  - GCM_name & Variable
  - Ems: “historical”, “rcp45”, “rcp85”
  - Start_Year & End_Year: Total period (e.g. 1976-2099)

Interpolation

- **Interpolation.R**
  - Inverse distance weighting (IDW) method
  - For example…
- **Need 'gstat' package**
  - Variogram, kriging, idw, etc
- **idw.intpol<- function (Lon.Target,Lat.Target,Lon.GCM,Lat.GCM, GCM.data,First_Yr,End_Yr,...)**



Package 'gstat'

March 31, 2016

Version 1.1-3

Title Spatial and Spatio-Temporal Geostatistical Modelling, Prediction and Simulation

Description Variogram modelling; simple, ordinary and universal point or block (co)kriging; spatio-temporal kriging; sequential Gaussian or indicator (co)simulation; variogram and variogram map plotting utility functions.

Depends R (>= 2.10)

Imports utils, stats, graphics, methods, lattice, sp (>= 0.9-72), zoo, spacetime (>= 1.0-0), FNN

Suggests rgdal (>= 0.5.2), rgeos, fields, maps, mapdata, maptools, xts

Data sampling

- **Collect.Data.Window<- function (Date_Tar,Raw_Data,TimeWindow,Number_STN, …)**
  - Raw_data: 1976-01-01 2.3
- **Select.Data.30Yr<- function(End_Yr_Fut,Date_Current,Date_Period, Model.Data.All)**

Application of SDMs(QM, DQM, & QDM)

- QM-DQM-QDM.R
- QM<- function (Data.obs,Data.Window.GCM, VAR.On.Day,ratio=FALSE,trace=0.05, trace.calc=0.5*trace)
- DQM<- function (Data.obs,Data.Window. GCM.Cur,Data.Window.GCM.Fut,VAR.On.Day, ratio=FALSE,trace=0.05, trace.calc=0.5*trace)
- QDM<- function (Data.obs,Data.Window. GCM.Cur,Data.Window.GCM.Fut,VAR.On.Day,ratio= FALSE,trace=0.01, trace.calc=0.5*trace, ratio.max=2, ratio.max.trace=10*trace)

Running R scripts

Hyung-Il Eum
APEC Climate Center (APCC)

Set essential information

- **National code, csv file name, and P**

```
#=======================================
Ncode<-"NP"
csv_filename<-"Nepal_2stn.csv"
Path_OBS<-"D:/2016TP/OBS"
#=======================================
```

A	B
NAME	Code
Bangladesh	BD
Burma	MM
Chile	CL
Cuba	CU
Egypt	EG
Ethiopia	ET
Federated States of Micronesia	FM
India	IN
Indonesia	ID
Kenya	KE
Malaysia	MY
Marshall Islands	MH
Mongolia	MN
Nepal	NP
Pakistan	PK
Samoa	WS
Tanzania	TZ
Thailand	TH
Tonga	TO
Vietnam	VN
Zambia	ZM

- **Information of station data**
  - Station namelist.csv

```
Station_Info <- read.csv(paste(Path_OBS,"/",csv_filename,sep="
names( Station_Info ) <- c("STN_Lon", "STN_Lat","Height","STN_
attach(Station_Info)
```

- **Target variable and GCM names**

```
Variable_STN<-"prcp"    # prcp, tmax, tmin
Variable_GCM<-"pr"      # pr, tasmax, tasmin
```

- **Others**

```
Number_STN=as.numeric(length(Station_Info[,1
Number_GCMs=as.numeric(length(GCM_names[,1]))
First_Yr_Hist=1976
End_Yr_Hist=2005
First_Yr_Future=2006
End_Yr_Future=2099
Days.TimeWindow=15  # +-15 days

bd.Ref<-as.Date(paste(First_Yr_Hist,"-01-01",sep=""))
ed.Ref<-as.Date(paste(End_Yr_Hist,"-12-31",sep=""))
Date.Reference<-as.Date((seq(bd.Ref,ed.Ref,by="1 day")))
Num_days_current<-as.numeric(length(Date.Reference))
```

Data (station and GCMs)

➢ Read station data

```
43 #=============================================================
44 # Read observation station data
45 #=============================================================
46 STN_Data<-STN_Data_Read(Variable_STN,STN_Name,Path_OBS,First_Yr_
```

➢ Specify folder path for NetCDF files

```
47 #=====================================================
48 # Informatin reagrding GCM data (netCDF files)
49 #=====================================================
50 folder<-paste("D:/2016TP/cmip5_daily_",Ncode,sep="")
```

➢ Select a GCM among 26 GCMs

```
52 GCM_Selected<-GCM_names[1,1]  # GCM's name selected
53 #=====================================================
```

```
1  bcc-csm1-1-m
2  CanESM2
3  CCSM4
4  CESM1-BGC
5  CESM1-CAM5
6  CMCC-CM
7  CMCC-CMS
8  CNRM-CM5
9  CSIRO-Mk3-6-0
10 FGOALS-g2
11 FGOALS-s2
12 GFDL-CM3
13 GFDL-ESM2G
14 GFDL-ESM2M
15 HadGEM2-AO
16 HadGEM2-CC
17 HadGEM2-ES
18 inmcm4
19 IPSL-CM5A-LR
20 IPSL-CM5A-MR
21 IPSL-CM5B-LR
22 MIROC5
23 MIROC-ESM
24 MIROC-ESM-CHEM
25 MPI-ESM-LR
26 MPI-ESM-MR
27 MRI-CGCM3
28 NorESM1-M
```

Run SDM program

➢ Read historical and future projection

```
55  GCM_Hist_All<-NC_combine(folder,GCM_Selected,Variable_GCM,"historical",First_Yr_Hist,End_Yr_Hist)
56  GCM.Hist<-GCM_Hist_All$NCData.Tar.Period
57  lon.GCM<-GCM_Hist_All$lon.NCData  #longitude of GCM
58  lat.GCM<-GCM_Hist_All$lat.NCData  #Latitude of GCM
59
60  GCM.RCP45<-NC_combine(folder,GCM_Selected,Variable_GCM,"rcp45",First_Yr_Future,End_Yr_Future)$NCData.Tar.Period
```

➢ Spatial disaggregation

- Idw Interpolation (Idw.intepol)

```
65  #-------------------------------------------------------------------------------------------------------
66  #  Applying IDW to GCM data to distribute GCM values to stations points
67  #-------------------------------------------------------------------------------------------------------
68  GCM.Hist.intepol<-idw.intpol(STN_Lon,STN_Lat,lon.GCM,lat.GCM,GCM.Hist,First_Yr_Hist,End_Yr_Hist)
69
70  GCM.RCP45.intepol<-idw.intpol(STN_Lon,STN_Lat,lon.GCM,lat.GCM,GCM.RCP45,First_Yr_Future,End_Yr_Future)
71
72  #  GCM.RCP85.intepol<-idw.intpol(STN_Lon,STN_Lat,lon.GCM,lat.GCM,GCM.RCP85,First_Yr_Future,End_Yr_Future)
73
74  colnames(GCM.Hist.intepol)<-colnames(GCM.RCP45.intepol)
75  GCM.ALL.interpol<-rbind(GCM.Hist.intepol,GCM.RCP45.intepol)  #reference and future (1976-2099)
76
77  GCM.Hist.intepol<-data.frame(GCM.Hist.intepol)
78
79  GCM.30Yr.Cur<-cbind(Date.Reference,GCM.Hist.intepol)  # Date, observation[e.g. 1976-01-01 0.0 0.7 ....]
```

Run SDM program

➢ Variables related to date and initializing

```
82  #-------------------------------------------------------------------------------------------------
83  Date_end_Ref<-as.Date(paste(End_Yr_Hist,"-12-31",sep=""))
84  Date_start_Tar<-as.Date(paste(First_Yr_Hist,"-01-01",sep=""))
85  Date_end_Tar<-as.Date(paste(End_Yr_Future,"-12-31",sep=""))
86  Date_Tar_Period<-as.Date(seq(Date_start_Tar,Date_end_Tar,by="1 day")) #from 1976-01-01 to 2099-12-31
87  Date_Ref_Period<-as.Date(seq(Date_start_Tar,Date_end_Ref,by="1 day")) #from 1976-01-01 to 2005-12-31
88
89  Downscaled.Data.QM<-array(NA,dim=c(length(Date_Tar_Period),Number_STN))
90  Downscaled.Data.DQM<-array(NA,dim=c(length(Date_Tar_Period),Number_STN))
91  Downscaled.Data.QDM<-array(NA,dim=c(length(Date_Tar_Period),Number_STN))
```

Set starting and ending years to simulate

```
93   Sim_year_start<-1980
94   Sim_year_End<-1981
95   Date_start_Sim<-as.Date(paste(Sim_year_start,"-01-01",sep=""))
96   Date_end_Sim<-as.Date(paste(Sim_year_End,"-12-31",sep=""))
97   Date_Sim_Period<-as.Date(seq(Date_start_Sim,Date_end_Sim,by="1 day"))
98   for(i in 1:length(Date_Tar_Period)){
99     if (Date_Tar_Period[i]==Date_start_Sim) iSim_start=i
100    if (Sim_year_start==Sim_year_End) {
101      if (Sim_year_start %% 4 ==0) {
102        iSim_End=iSim_start+366
103      } else {
104        iSim_End=iSim_start+365
105        }
106    } else {
107      if (Date_Tar_Period[i]==Date_end_Sim) iSim_End=i
108    }
109  }
```

Finding orders of starting and ending date in total sequences

Downscaling

➢ for (i_Sim in 1: length(Date_Tar_Period) { …}

- Reference period (historical) from 1976 to 2005

```
if (Date_Tar_Period[iSim]<=Date_end_Ref) { #current(reference) period
```

  - Data collecting from observation and GCM data sets

```
#-------------------------------------------------------------------------------------------------------------
#  Collecting data within the moving time window (+- 15days) for applying BCSD
#-------------------------------------------------------------------------------------------------------------
Data.Window.obs<-Collect.Data.Window(Date_Tar_Period[iSim],STN_Data,Days.TimeWindow,Number_STN)  #Station data
Data.Window.GCM.cur<-Collect.Data.Window(Date_Tar_Period[iSim],GCM.30Yr.Cur,Days.TimeWindow,Number_STN)  #GCM data
#-------------------------------------------------------------------------------------------------------------
```

  - QM-DQM-QDM

```
for (iSTN in 1:Number_STN) {

  Downscaled.Data.QM[iSim,iSTN]<-QM(Data.Window.obs[,iSTN],Data.Window.GCM.cur[,iSTN],GCM.ALL.interpol[iSim,iSTN],ratio=TRUE)
  Downscaled.Data.DQM[iSim,iSTN]<-Downscaled.Data.QM[iSim,iSTN]
  Downscaled.Data.QDM[iSim,iSTN]<-Downscaled.Data.QM[iSim,iSTN]
}
```

Downscaling

➢ for (i_Sim in 1: length(Date_Tar_Period) { …}

- Future period
  - Define future 30 yrs & Data collection

```
129  #-------------------------------------------------------------------------------------------
130  #  Define 30-year future time window with the center of current year
131  #-------------------------------------------------------------------------------------------
132  GCM.30Yr.Fut<-Select.Data.30Yr(End_Yr_Future,Date_Tar_Period[iSim],Date_Tar_Period,GCM.ALL.interpol)
```

  - Data collecting from observation and GCM data sets

```
133  #-------------------------------------------------------------------------------------------
134  #  Collecting data within the moving time window (+- 15days) for applying BCSD
135  #-------------------------------------------------------------------------------------------
136  Data.Window.obs<-Collect.Data.Window(Date_Tar_Period[iSim],STN_Data,Days.TimeWindow,Number_STN)  #Statio
137  Data.Window.GCM.cur<-Collect.Data.Window(Date_Tar_Period[iSim],GCM.30Yr.Cur,Days.TimeWindow,Number_STN)
138  Data.Window.GCM.fut<-Collect.Data.Window(Date_Tar_Period[iSim],GCM.30Yr.Fut,Days.TimeWindow,Number_STN)
```

Downscaling

➢ QM-DQM-QDM

```
#-------------------------------------------------------------------------------------------------------------
#  Bias correction - QM, DQM, QDM
#-------------------------------------------------------------------------------------------------------------
for (iSTN in 1:Number_STN) {
  Downscaled.Data.QM[iSim,iSTN]<-QM(Data.Window.obs[,iSTN],Data.Window.GCM.fut[,iSTN],GCM.ALL.interpol[iSim,iSTN],ratio=TRUE)
  Downscaled.Data.DQM[iSim,iSTN]<-DQM(Data.Window.obs[,iSTN],Data.Window.GCM.cur[,iSTN],Data.Window.GCM.fut[,iSTN],GCM.ALL.interpol[iSim,iSTN],ratio=TRUE)
  Downscaled.Data.QDM[iSim,iSTN]<-QDM(Data.Window.obs[,iSTN],Data.Window.GCM.cur[,iSTN],Data.Window.GCM.fut[,iSTN],GCM.ALL.interpol[iSim,iSTN],ratio=TRUE)
} #iSTN
```

Output

```
#-------------------------------------------------
# Output file
#-------------------------------------------------
 dir.names<-paste("Output/",GCM_Selected,sep="")
 if(!file.exists(paste("Output/",GCM_Selected,sep=""))) {dir.create(dir.names)}


   Print.QM<-cbind(as.numeric(substr(Date_Sim_Period,1,4)),as.numeric(substr(Date_Sim_Period,6,7)),
                   as.numeric(substr(Date_Sim_Period,9,10)),Downscaled.Data.QM[iSim_start:iSim_End,])
   colnames(Print.QM)<-c("Year", "Month", "Day",as.character(STN_Name))

   Print.DQM<-cbind(as.numeric(substr(Date_Sim_Period,1,4)),as.numeric(substr(Date_Sim_Period,6,7)),
                    as.numeric(substr(Date_Sim_Period,9,10)),Downscaled.Data.DQM[iSim_start:iSim_End,])
   colnames(Print.DQM)<-c("Year", "Month", "Day",as.character(STN_Name))

   Print.QDM<-cbind(as.numeric(substr(Date_Sim_Period,1,4)),as.numeric(substr(Date_Sim_Period,6,7)),
                    as.numeric(substr(Date_Sim_Period,9,10)),Downscaled.Data.QDM[iSim_start:iSim_End,])
   colnames(Print.QDM)<-c("Year", "Month", "Day",as.character(STN_Name))


   filenames_QM<-paste(dir.names,"/",Variable_STN,"_",GCM_Selected,".daily.downscaledByBCSD_QM_",Sim_year_start,"_",Sim_year_End,".txt",sep="")
   filenames_DQM<-paste(dir.names,"/",Variable_STN,"_",GCM_Selected,".daily.downscaledByBCSD_DQM_",Sim_year_start,"_",Sim_year_End,".txt",sep="")
   filenames_QDM<-paste(dir.names,"/",Variable_STN,"_",GCM_Selected,".daily.downscaledByBCSD_QDM_",Sim_year_start,"_",Sim_year_End,".txt",sep="")


   write.table(round(Print.QM,3),file=filenames_QM,row.names = FALSE,col.names = TRUE,sep="               ")
   write.table(round(Print.DQM,3),file=filenames_DQM,row.names = FALSE,col.names = TRUE,sep="               ")
   write.table(round(Print.QDM,3),file=filenames_QDM,row.names = FALSE,col.names = TRUE,sep="               ")
```

For TMAX and TMIN

- **Change target variable**
  - Variable_STN<-”tmax”
  - Variable_GCM<-”tasmax”

```
24  Variable_STN<-"prcp"    # prcp, tmax, tmin
25  Variable_GCM<-"pr"      # pr, tasmax, tasmin
26
27  GCM_names <- read.table("GCM_names.txt")
```

Running SDM

Hyung-Il Eum
APEC Climate Center (APCC)

Simulation period

➢ Set start and ending year to simulate

```
Sim_year_start<-1981
Sim_year_End<-1981
Date_start_Sim<-as.Date(paste(Sim_year_start,"-01-01",sep=""))
Date_end_Sim<-as.Date(paste(Sim_year_End,"-12-31",sep=""))
Date_Sim_Period<-as.Date(seq(Date_start_Sim,Date_end_Sim,by="1 day"))
for(i in 1:length(Date_Tar_Period)){
  if (Date_Tar_Period[i]==Date_start_Sim) iSim_start=i
  if (Sim_year_start==Sim_year_End) {
    if (Sim_year_start %% 4 ==0) {
      iSim_End=iSim_start+366
    } else {
      iSim_End=iSim_start+365
      }
  } else {
    if (Date_Tar_Period[i]==Date_end_Sim) iSim_End=i
  }
}
```

➢ Output

- iSim_start : number of order for start year
- iSim_End: number of order for ending year

Simulations

- **Change variable**
  - tmax, tasmax…
- **Select 2-years (reference and future periods)**
  - Ex) 1980-1981 & 2040-2041
- **Run individually**

Analysis outputs I

Hyung-Il Eum
APEC Climate Center (APCC)

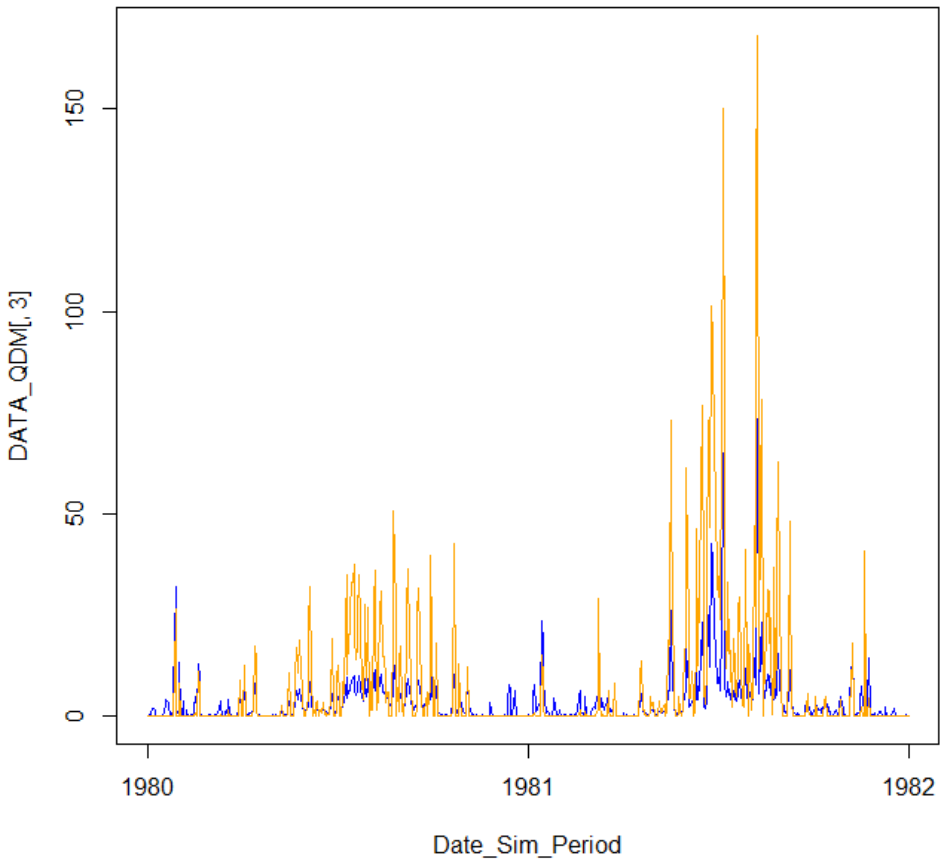
Time series plot

➢ Open data we generated

```
183     Path_output<-"D:/2016TP/3Eum/Output/bcc-
184     filenames_QDM<-paste(Path_output,"prcp_b
185     filenames_DQM<-paste(Path_output,"prcp_b
186     filenames_QM<-paste(Path_output,"prcp_bc
187
188     GCM.ALL.interpol<-data.frame(GCM.ALL.int
189     GCM.ALL.interpol_date<-cbind(Date_Tar_Pe
190     GCM.ALL.interpol_Sim<-GCM.ALL.interpol_c
191     DATA_QDM <-read.table(filenames_QDM,heac
192     DATA_QDM<-cbind(Date_Sim_Period,DATA_QDM
193     DATA_DQM <-read.table(filenames_DQM,heac
194     DATA_DQM<-cbind(Date_Sim_Period,DATA_DQM
195     DATA_QM <-read.table(filenames_QM,head=T
196     DATA_QM<-cbind(Date_Sim_Period,DATA_QM[,
```

➢ Plot

```
198     plot(Date_Sim_Period,DATA_QDM[,3],type
199     lines(Date_Sim_Period,GCM.ALL.interpol
200     lines(Date_Sim_Period,DATA_DQM[,3],typ
201     lines(Date_Sim_Period,DATA_QM[,3],type
```

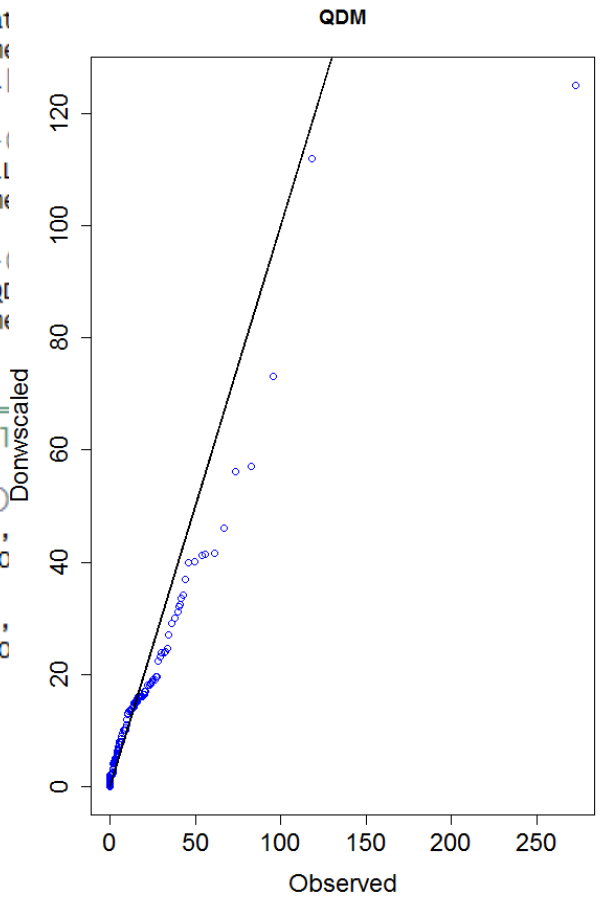


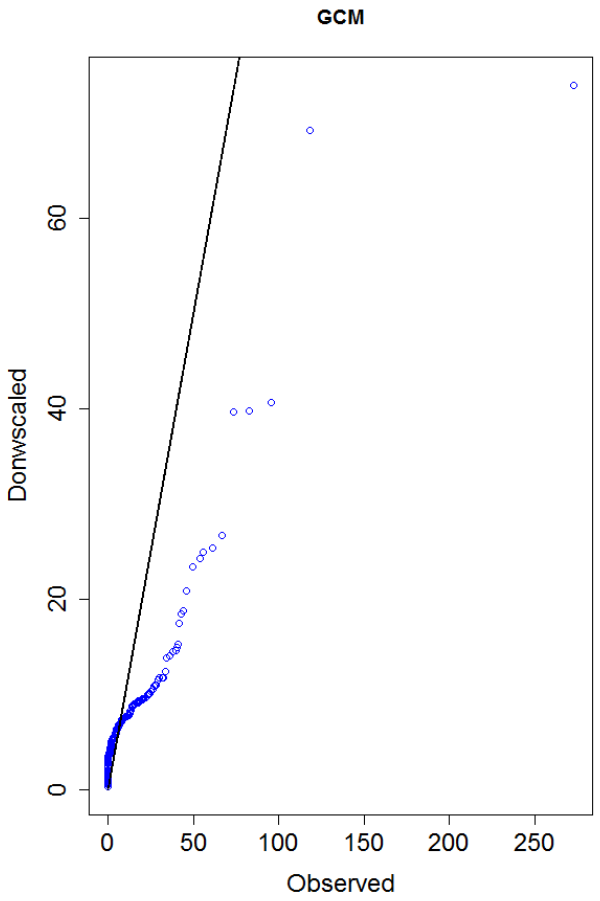
Quantile-Quantile (Q-Q) plot

➢ Summer (JJA)

```
204     Index.Obs.Summer<-(
205     OBS_Summer<-STN_Dat
206     OBS_STN1<-OBS_Summe
207     OBS_STN1<-OBS_STN1|
208
209     Index.GCM.Summer<-(
210     GCM_Summer<-GCM.ALL
211     GCM_STN1<-GCM_Summe
212
213     Index.QDM.Summer<-(
214     QDM_Summer<-DATA_QD
215     QDM_STN1<-QDM_Summe
```

```
217 #==================
218   # Quantile-Quantil
219
220     par(mfrow=c(1,2))
221     qqplot(OBS_STN1,
222     lines(OBS_STN1,Q
223
224     qqplot(OBS_STN1,
225     lines(OBS_STN1,Q
226
```



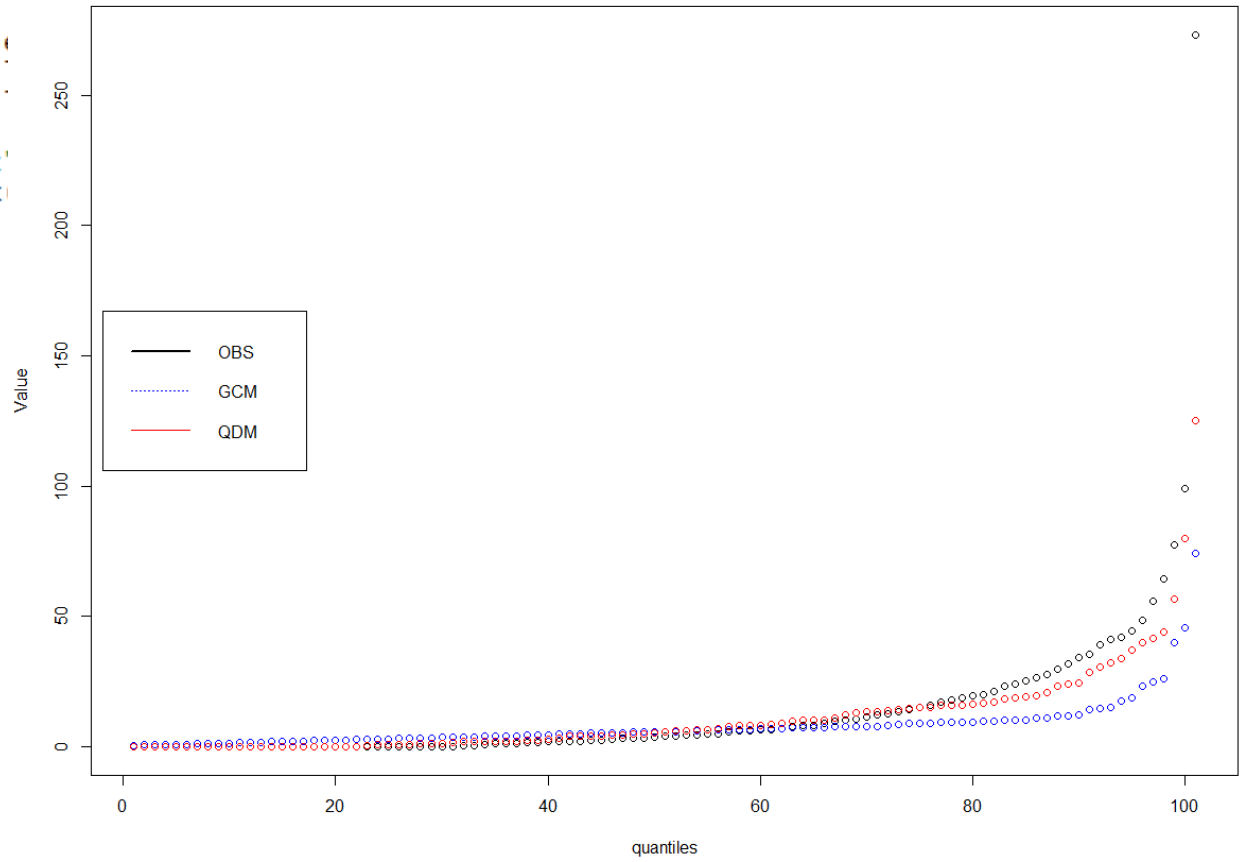



```
)8")

str(GCM.ALL.in

)8")

:

="QDM")

="GCM")
```

Intercomparision of quantiles

```
228  windows()
229  prob<-seq(0,1,0.01)
230  quantile.obs<-quantile(OBS_STN1,prob)
231  quantile.GCM
232  quantile.QDM
233
234  plot(quantil
235  lines(quanti
236  lines(quanti
237
238  legend("left
239         lty=c
```

```
t = 300)
```



CLIMATE CENTER

Analysis outputs II

Hyung-Il Eum
APEC Climate Center (APCC)

Climate signals

- **Install.packages(…)**
  - "climdex.pcic"
  - "PCICt"
- **Function (Cal_Signal.R)**
  - Cal.signal <- function (ref_start, ref_end, future_start,future_end, Table)

Expert Team on Climate Change Detection and indices (ETCCDI)

No.	ID	Related variable	Description	Unit
1	SU	TMAX	Summer day, TMAX > 25°C	Days
2	ID		Ice days, TMAX < 0°C	Days
3	TX_n		Min TMAX	°C
4	TX_x		Max TMAX	°C
5	TX10p		Cool days, TMAX < 10th percentile	%
6	TX90p		Warm days, TMAX > 90th percentile	Days
7	WSDI		Warm spell duration, TMAX > 90th percentile	Days
8	FD	TMIN	Frost days TMIN < 0°C	Days
9	TR		Tropical nights, TMIN > 20°C	Days
10	TN_n		Min TMIN	°C
11	TN_x		Max TMIN	°C
12	TN10p		Cool nights, TMIN < 10th percentile	%
13	TN90p		Warm nights, TMIN > 90th percentile	%
14	CSDI		Cold spell duration, TMIN < 10th percentile	Days
15	DTR	TMAX & TMIN	Diurnal temperature range	°C
16	GSL		Growing season length	Days
17	CDD	PRCP	Consecutive dry days, PRCP < 1mm	Days
18	CWD		Consecutive wet days, PRCP ≥ 1mm	Days
19	PRCPTOT		Annual total PRCP in wet days (daily PRCP ≥ 1mm)	mm
20	Rx1day		Max 1-day precipitation	mm
21	Rx5day		Max 5-day precipitation	mm
22	R95pTOT		Annual total PRCP when daily PRCP > 95 percentile	mm
23	R99pTOT		Annual total PRCP when daily PRCP > 99 percentile	mm
24	SDII		Simple daily intensity index	mm/day

Sample data

- **CCSM4**
- **Downscaled at 60 stations from 1976 to 2099**
  - TMAX
  - TMIN
  - PRCP

1	1976	1	1	4.6000	-2.8000	0.0000
2	1976	1	2	5.5000	-0.4000	0.0000
3	1976	1	3	6.5000	0.4000	0.0000
4	1976	1	4	7.2000	0.8000	0.0000
5	1976	1	5	9.0000	1.0000	0.0000
6	1976	1	6	8.5000	2.7000	0.0000
7	1976	1	7	10.5000	2.2000	0.0000
8	1976	1	8	6.0000	-3.0000	0.0000
9	1976	1	9	2.5000	-4.4000	0.0000
10	1976	1	10	1.1000	-4.7000	0.0000
11	1976	1	11	3.8000	-3.1000	0.0000
12	1976	1	12	6.8000	-0.3000	0.0000
13	1976	1	13	7.1000	-1.7000	0.0000
14	1976	1	14	3.6000	-1.4000	0.0000
15	1976	1	15	5.0000	-2.6000	0.0000
16	1976	1	16	5.1000	-1.1000	0.0000
17	1976	1	17	6.6000	0.7000	0.0000
18	1976	1	18	7.4000	-1.5000	0.0000
19	1976	1	19	4.4000	-2.5000	0.0000
20	1976	1	20	6.7000	-0.7000	0.0000
21	1976	1	21	12.7000	5.9000	0.8000
22	1976	1	22	10.7000	-0.1000	0.0000
23	1976	1	23	4.5000	-3.7000	0.1000
24	1976	1	24	6.1000	-2.9000	0.0000
25	1976	1	25	5.4000	-6.5000	0.0000

Climate signals.r

```
install.packages("climdex.pcic")
install.packages("PCICt")

library(climdex.pcic)
library(PCICt)
#library(kSamples)

setwd("D:/OutReaches/TrainingProgram/2016/R_Scripts/Analysis")
source("Cal_Signal.R")

Station_Info <- read.table("Station_XYZ.prn",header=TRUE)
names( Station_Info ) <- c("STN_Name", "STN_Num", "Lon", "Lat","Height")
attach(Station_Info)

GCM_names <- "CCSM4"
#=========================================================================
Number_GCMs=1
Number_STN=60
Timewindow=30
First_Yr_Hist=1976
End_Yr_Hist=2005
First_Yr_2020=2006
End_Yr_2020=2035
First_Yr_2050=2036
End_Yr_2050=2065
First_Yr_2080=2066
End_Yr_2080=2095
Total_Year=2099-First_Yr_Hist+1
Total_Year_KS=End_Yr_Hist-First_Yr_Hist+1
N_CLIMDEX=24
```

Climate signals.r

➢ Define matrix sizes for variables

- 24 ETCCDI
  - Obs, CM, QM, DQM, and QDM

```
 32 #---------- Observed station data
 61 #---------- GCMs
 90 #---------- QM
119 #---------- DQM
148 #---------- QDM
177 #=========================================
178 #   Spatially averaged values
179 #=========================================
180 #---------Observed station
209 #---------- GCMs
238 #---------- QM
267 #---------- DQM
296 #---------- QDM
325
326 #
```

Run script and save images

```
[1] "CCSM4"
[1] 1
[1] 2
[1] 3
[1] 4
[1] 5
[1] 6
[1] 7
[1] 8
[1] 9
[1] 10
[1] 11
[1] 12
[1] 13
[1] 14
```

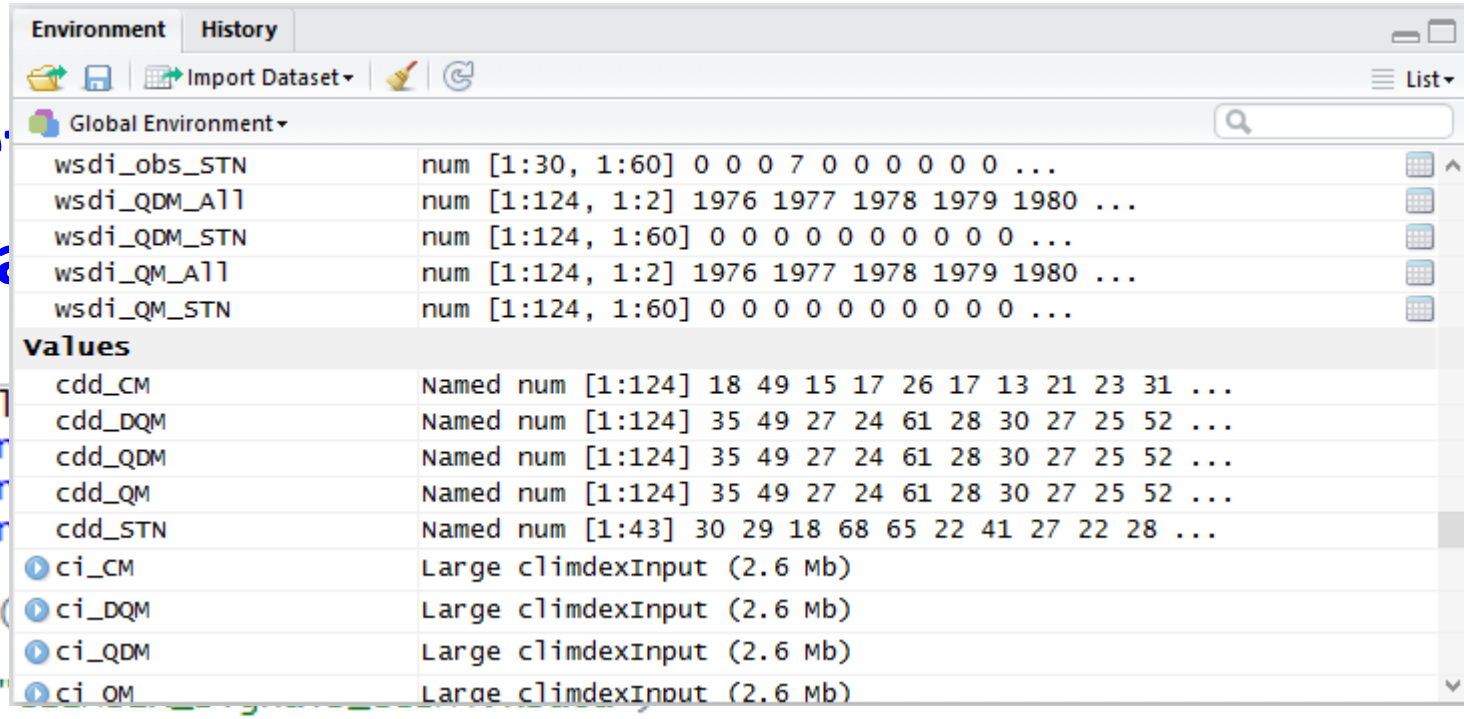
GCM name

Station number
(1 to 60)

```
save.image("CLIMDEX_Signals_CCSM4.RData")
```

CLIMDEX_Singnal_Plot.R

- Install.packages(…)
  -
- se
- loa



Relative change bias

- **Difference of signals between downscaling and climate models**

```
10  Relative_change_bias_QM_2020 <- Signal_QM_2020-Signal_CM_2020
11  Relative_change_bias_QM_2050 <- Signal_QM_2050-Signal_CM_2050
12  Relative_change_bias_QM_2080 <- Signal_QM_2080-Signal_CM_2080
13
14  Relative_change_bias_DQM_2020 <- Signal_DQM_2020-Signal_CM_2020
15  Relative_change_bias_DQM_2050 <- Signal_DQM_2050-Signal_CM_2050
16  Relative_change_bias_DQM_2080 <- Signal_DQM_2080-Signal_CM_2080
17
18  Relative_change_bias_QDM_2020 <- Signal_QDM_2020-Signal_CM_2020
19  Relative_change_bias_QDM_2050 <- Signal_QDM_2050-Signal_CM_2050
20  Relative_change_bias_QDM_2080 <- Signal_QDM_2080-Signal_CM_2080
21
```

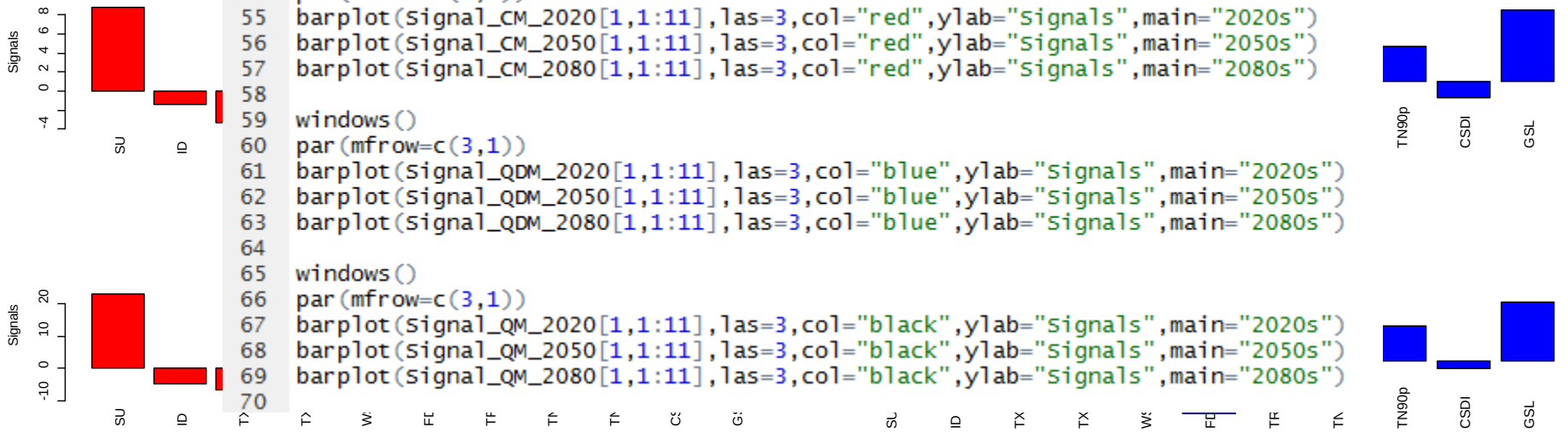
Set column names of signals

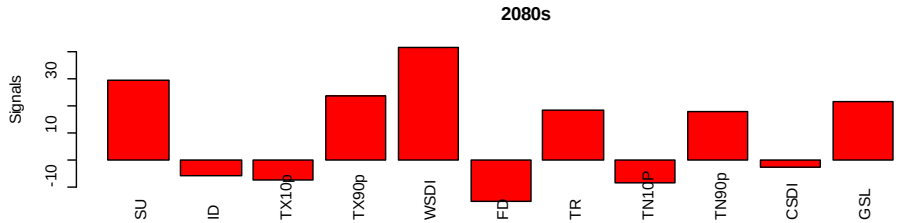
```
#-------------------------------------------------------------------------------------------------------------------
#   Column names
#-------------------------------------------------------------------------------------------------------------------
colnames(Signal_CM_2020)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_CM_2050)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_CM_2080)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_QDM_2020)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_QDM_2050)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_QDM_2080)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_QM_2020)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_QM_2050)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")
colnames(Signal_QM_2080)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                            "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                            "SDII","CDD","CWD")

```

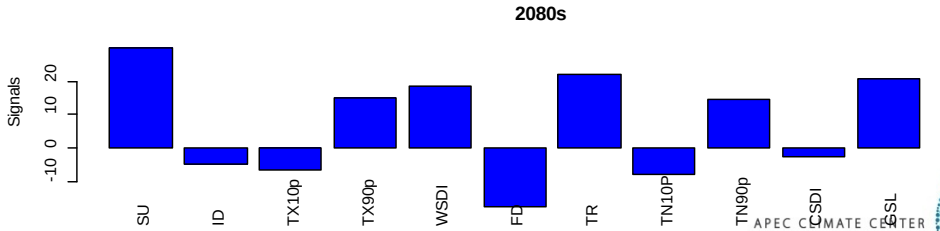
Barplot

- **par(mfrow=c(3,1))**

```
windows()
par(mfrow=c(3,1))
barplot(Signal_CM_2020[1,1:11],las=3,col="red",ylab="Signals",main="2020s")
barplot(Signal_CM_2050[1,1:11],las=3,col="red",ylab="Signals",main="2050s")
barplot(Signal_CM_2080[1,1:11],las=3,col="red",ylab="Signals",main="2080s")

windows()
par(mfrow=c(3,1))
barplot(Signal_QDM_2020[1,1:11],las=3,col="blue",ylab="Signals",main="2020s")
barplot(Signal_QDM_2050[1,1:11],las=3,col="blue",ylab="Signals",main="2050s")
barplot(Signal_QDM_2080[1,1:11],las=3,col="blue",ylab="Signals",main="2080s")

windows()
par(mfrow=c(3,1))
barplot(Signal_QM_2020[1,1:11],las=3,col="black",ylab="Signals",main="2020s")
barplot(Signal_QM_2050[1,1:11],las=3,col="black",ylab="Signals",main="2050s")
barplot(Signal_QM_2080[1,1:11],las=3,col="black",ylab="Signals",main="2080s")
```







Plotting other ETCCDI

- **Signal_CM_2020**
  - 24 ETCCDI
- **Plot precipitation-related ETCCDI**

```
barplot(Signal_CM_2020[1,c("PRCPTOT","R95ptot","R99ptot","RX1day","RX5day")],las=3,col="red",
        ylab="Signals",main="2020s")
```

Plot relative change bias

- **Set column names for relative change bias variables**

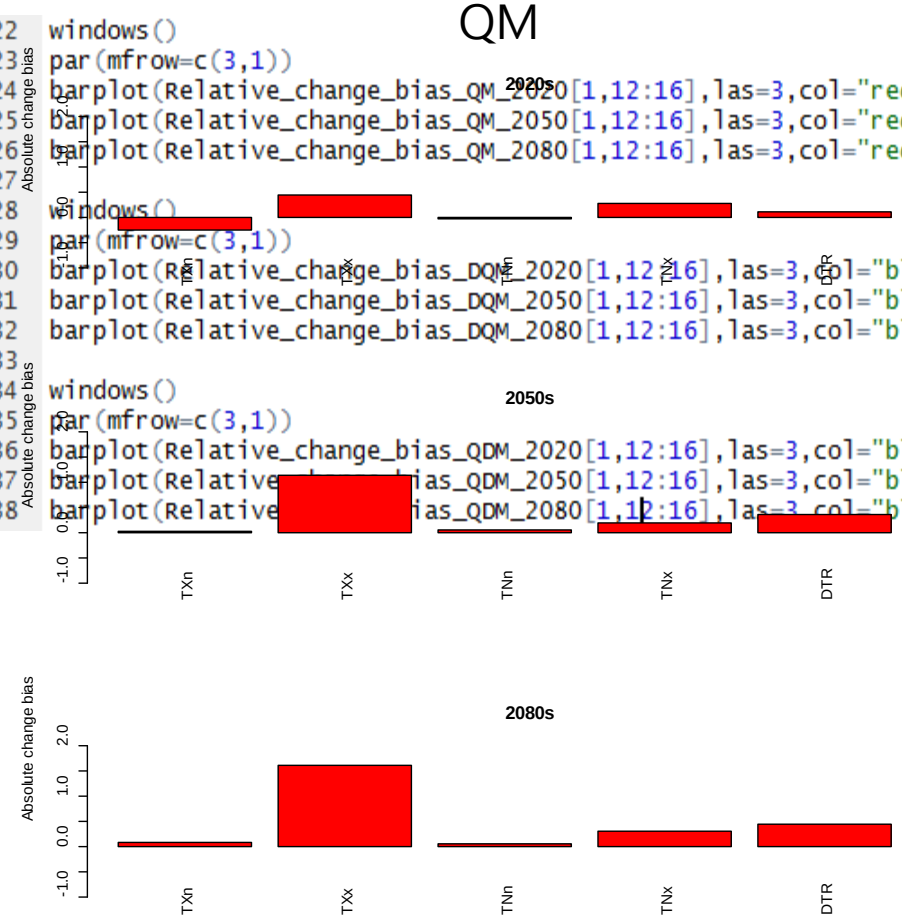
```
colnames(Relative_change_bias_QM_2020)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                          "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                          "SDII","CDD","CWD")
colnames(Relative_change_bias_QM_2050)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                          "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                          "SDII","CDD","CWD")
colnames(Relative_change_bias_QM_2080)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                          "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                          "SDII","CDD","CWD")
colnames(Relative_change_bias_DQM_2020)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                           "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                           "SDII","CDD","CWD")
colnames(Relative_change_bias_DQM_2050)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                           "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                           "SDII","CDD","CWD")
colnames(Relative_change_bias_DQM_2080)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                           "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                           "SDII","CDD","CWD")
colnames(Relative_change_bias_QDM_2020)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                           "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                           "SDII","CDD","CWD")
colnames(Relative_change_bias_QDM_2050)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                           "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                           "SDII","CDD","CWD")
colnames(Relative_change_bias_QDM_2080)<-c("SU","ID","TX10p","TX90p","WSDI","FD","TR","TN10P","TN90p","CSDI","GSL",
                                           "TXn","TXx","TNn","TNx","DTR","PRCPTOT","R95ptot","R99ptot","RX1day","RX5day",
                                           "SDII","CDD","CWD")
```

Plot relative change bias

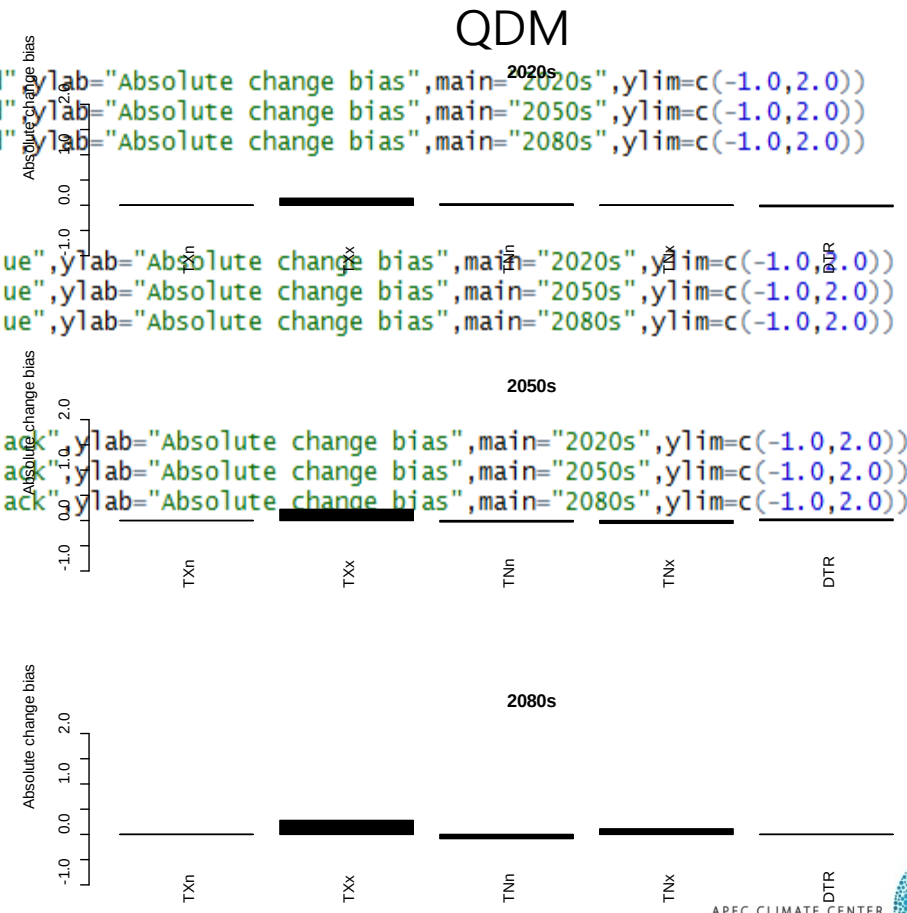
➢ Plot

```
windows()
par(mfrow=c(3,1))
barplot(Relative_change_bias_QM_2020[1,12:16],las=3,col="red",ylab="Absolute change bias",main="2020s",ylim=c(-1.0,2.0))
barplot(Relative_change_bias_QM_2050[1,12:16],las=3,col="red",ylab="Absolute change bias",main="2050s",ylim=c(-1.0,2.0))
barplot(Relative_change_bias_QM_2080[1,12:16],las=3,col="red",ylab="Absolute change bias",main="2080s",ylim=c(-1.0,2.0))

windows()
par(mfrow=c(3,1))
barplot(Relative_change_bias_QDM_2020[1,12:16],las=3,col="blue",ylab="Absolute change bias",main="2020s",ylim=c(-1.0,2.0))
barplot(Relative_change_bias_QDM_2050[1,12:16],las=3,col="blue",ylab="Absolute change bias",main="2050s",ylim=c(-1.0,2.0))
barplot(Relative_change_bias_QDM_2080[1,12:16],las=3,col="blue",ylab="Absolute change bias",main="2080s",ylim=c(-1.0,2.0))

windows()
par(mfrow=c(3,1))
barplot(Relative_change_bias_QDM_2020[1,12:16],las=3,col="black",ylab="Absolute change bias",main="2020s",ylim=c(-1.0,2.0))
barplot(Relative_change_bias_QDM_2050[1,12:16],las=3,col="black",ylab="Absolute change bias",main="2050s",ylim=c(-1.0,2.0))
barplot(Relative_change_bias_QDM_2080[1,12:16],las=3,col="black",ylab="Absolute change bias",main="2080s",ylim=c(-1.0,2.0))
```

QM

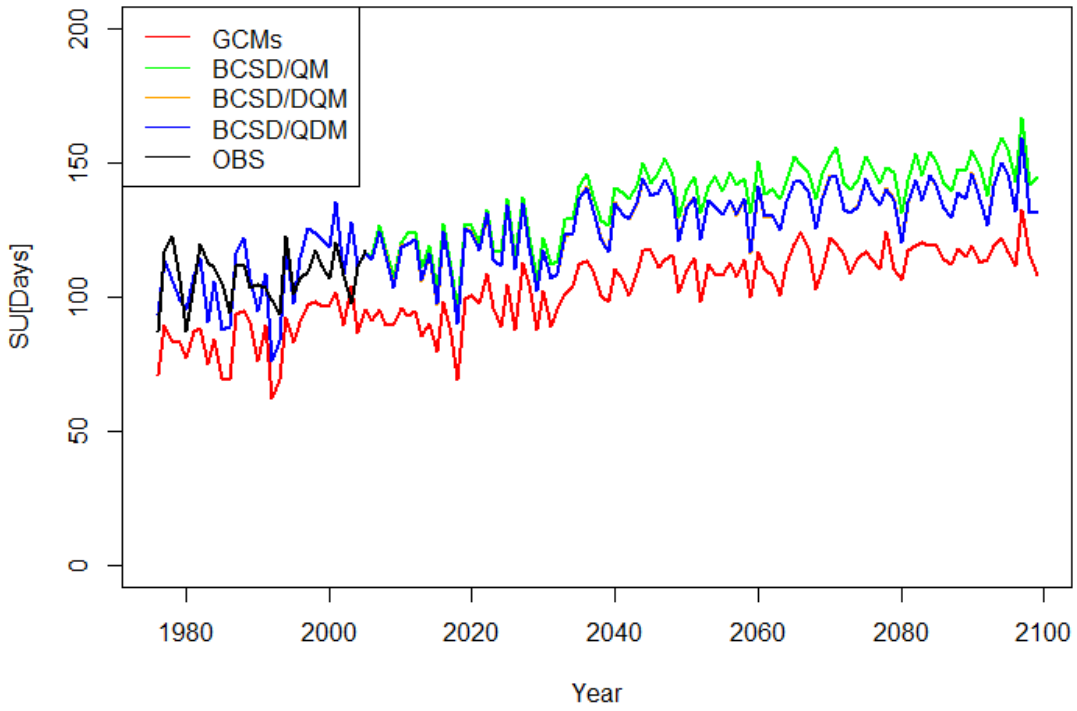


QDM



Plot SU time series

```
160  plot(c(First_Yr_Hist:2099),su_Ave_CM,type="n",xlab="Year",ylab="SU[Days]",ylim=c(0,200))
161  lines(c(First_Yr_Hist:2099),su_Ave_CM,col="red",lwd=2)
162  lines(c(First_Yr_Hist:2099),su_Ave_QM,col="green",lwd=2)
163  lines(c(First_Yr_Hist:2099),su_Ave_DQM,col="Orange",lwd=2)
164  lines(c(First_Yr_Hist:2099),su_Ave_QDM,col="blue",lwd=2)
165  lines(c(First_Yr_Hist:2005),su_Ave_obs,col="black",lwd=2)
166  legend("topleft",legend=c("GCMs","BCSD/QM","BCSD/DQM","BCSD/QDM","OBS"),
167         col=c("red","green","Orange","blue","black"),bg="white",lty=1,text.font = 100)
```

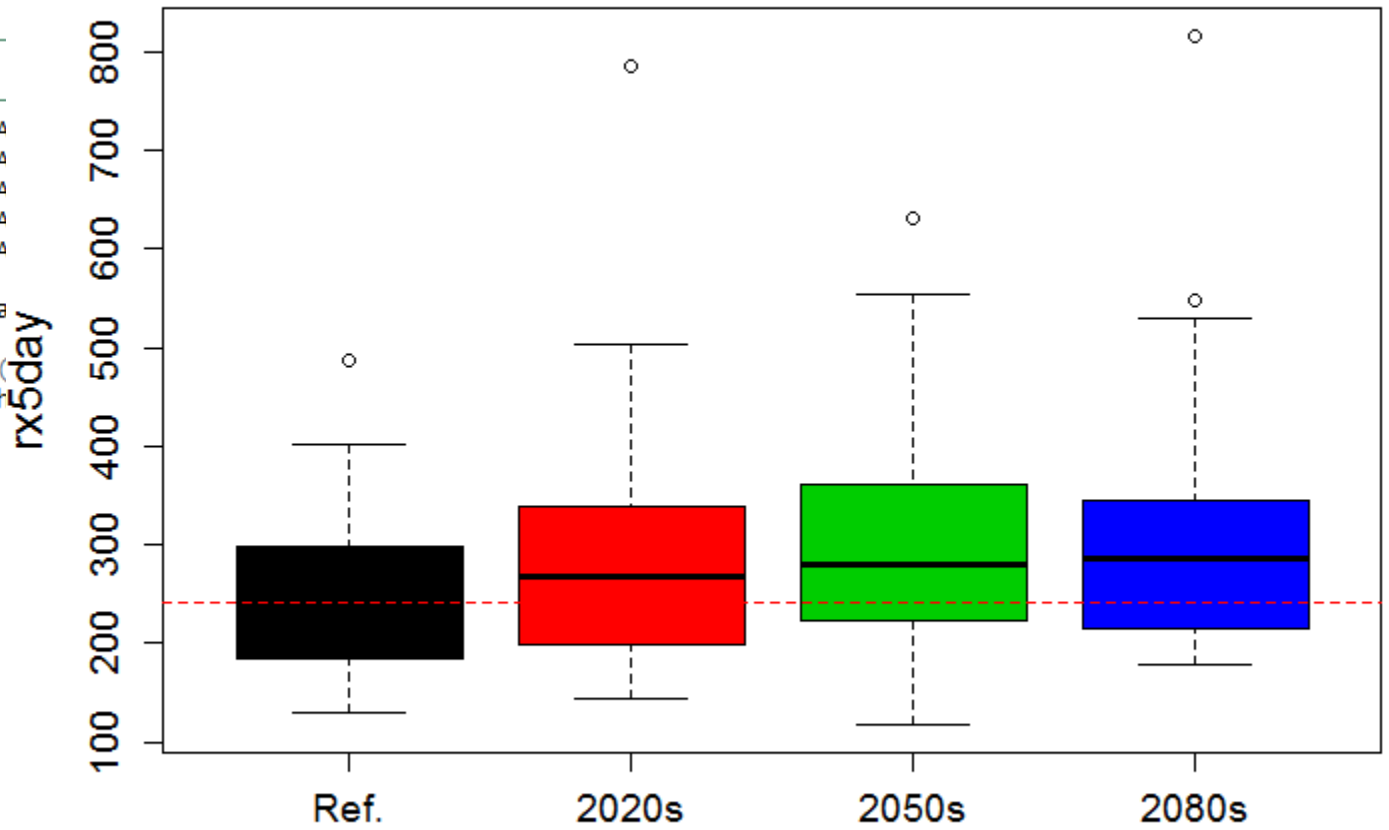


Plot other variables

- **FD**
  - Fd_Ave_CM, Fd_Ave_QM, Fd_Ave_DQM, Fd_Ave_QDM
- **Annual precipitation**
  - Prcptot_Ave_CM, Prcptot_Ave_QM, Prcptot_Ave_DQM, Prcptot_Ave_QDM

Boxplot

```
199 #-------
200 #
201 #-------
202 rx5day_A
203 rx5day_A
204 rx5day_A
205 rx5day_A
206 rx5day_A
207
208 rx5day_a
209
210 boxplot(
211 abline(h
```




```
QDM_2080[,2])

x.axis=1.2)
```

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