ICTP – NCP International Conference on Global Change
15-19 November, 2006, Islamabad

Climate Change Studies over South Asia Region Using Regional Climate Model RegCM3

(Preliminary Results)

Faisal S. Syed, Shahbaz M.,Nadia R.,Siraj I. K., M. Adnan Abid, M. Ashfaq, F. Giorgi, J. Pal, X. Bi

Global Change Impact Studies Centre / Pakistan Meteorological Department
Islamabad

What are Scenarios?

Scenarios are one of the main tools for assessment of future developments in complex systems and are used to determine how conditions may change in the future. A scenario can be defined as "…a coherent and internally consistent description of a possible future state of the world." it represents one of any number of possible futures, which can be used to provide data for impacts and adaptation studies

A2 Storyline and Scenario Family:

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

- The most common and widely accepted method of scenario construction involves the use of the output of Global Climate Models (GCMs). GCMs are mathematical representations of the large-scale physical processes of the Earth-atmosphere-ocean system that provide a complete and internally consistent view of future climate change

- The Global Circulation Models (GCMs) provide information about on global scale, typically in grid sizes of 300km x 300km. Whereas the grid size of a Regional Climate Model (RCM) output is typically to 50km x 50km; a 10 times better resolution than that of GCM

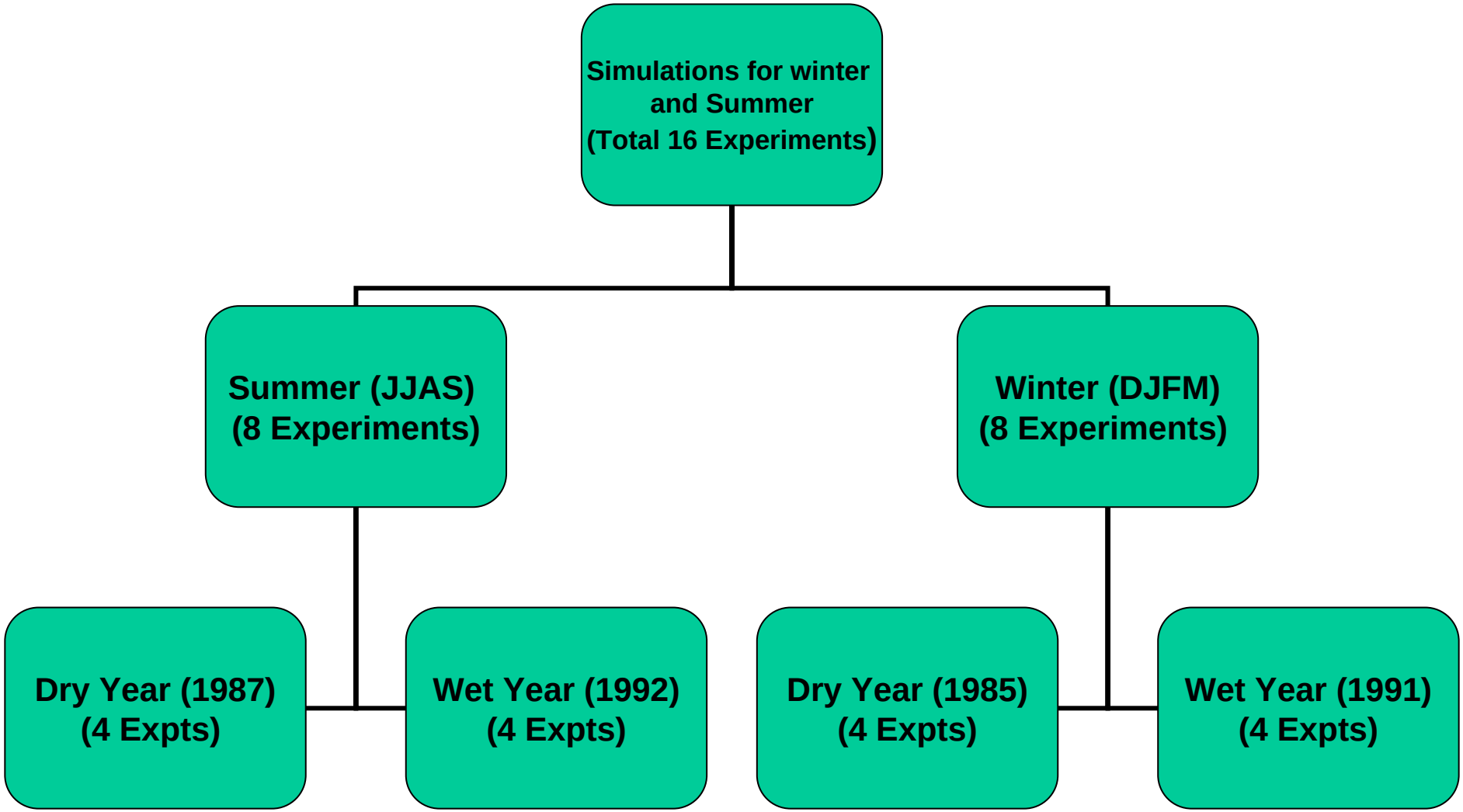
Design of Climate Change Experiments – RegCM3

Driving Data	**ECHAM** (**Max Planck Institute of Meteorology, Germany),** **FVGCM** (**National Aeronautics and Space Administration, USA)**
Resolution	50 Km — Output Data — 6 Hourly
Model Domain	South Asia (Lat 5N to 50N, Lon 55E to 100E)
Scenario	A2
Analysis Domain	Pakistan (Divided into two Sub-regions)

Data Set	Base Period	Future Period
ECHAM	1961-1990 (30 years)	2039-2069, 2071-2100 (30+30 =60 years)
FVGCM	1961-1990 (30 years)	2071-2100 (30 years)
ERA40 (Reanalysis data)	1961-1990 (30years)	NIL

Validation of the Model RegCM3

Experiments for Validation of Convective Schemes RegCM3



Domain Parameters

No. of Grid Points in y direction: 95

No. of Grid Points in x direction: 100

No. of Vertical Levels: 18

Grid Point Separation in Km: 50

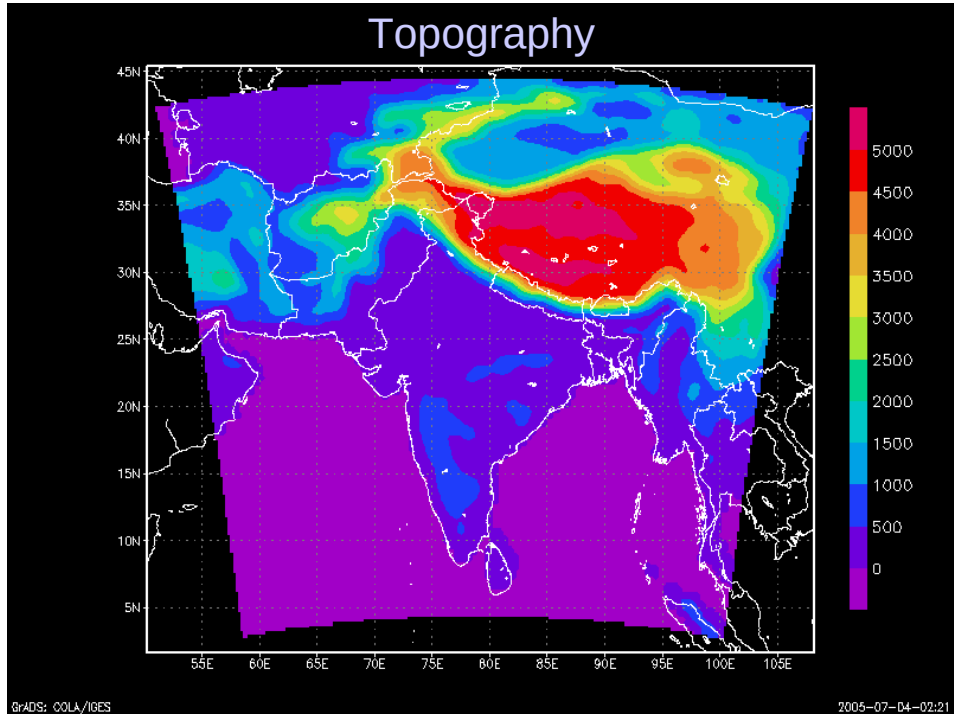
Central Latitude: 24.0

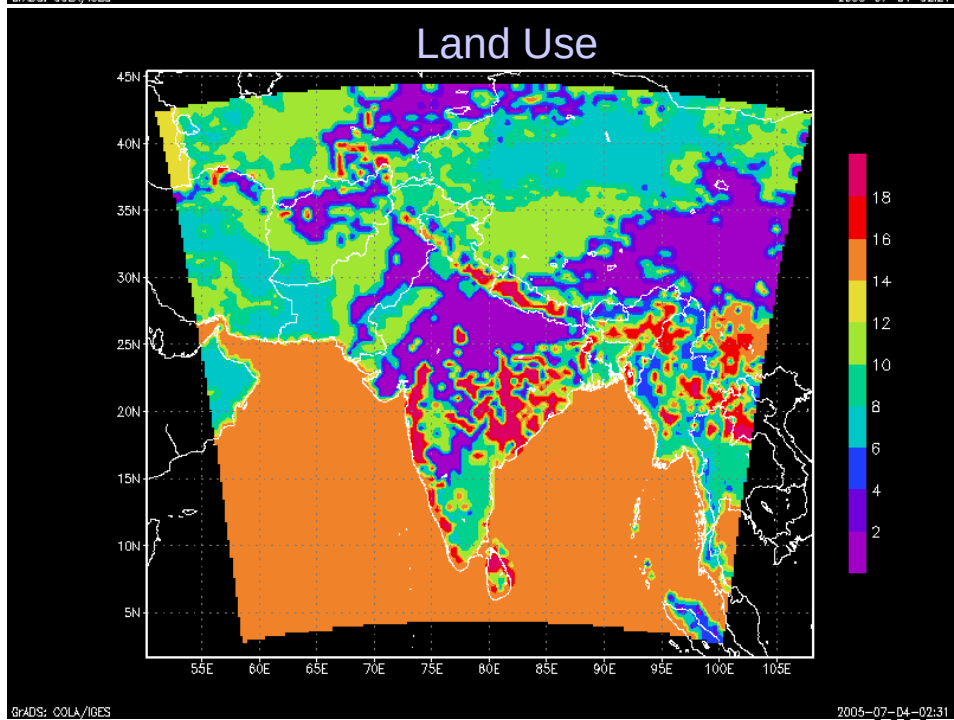
Central Longitude: 79.0

Map Projection: ROTMER

Boundary Conditions: ERA40

SST: GISST





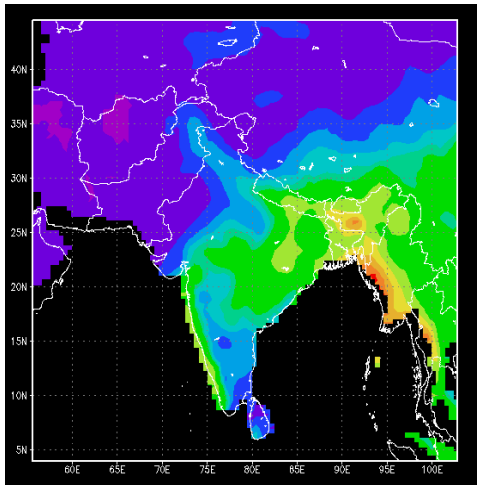
Grell Convective Scheme, Arakawa - Schubert Closure (JJAS)

Precipitation (mm/day)

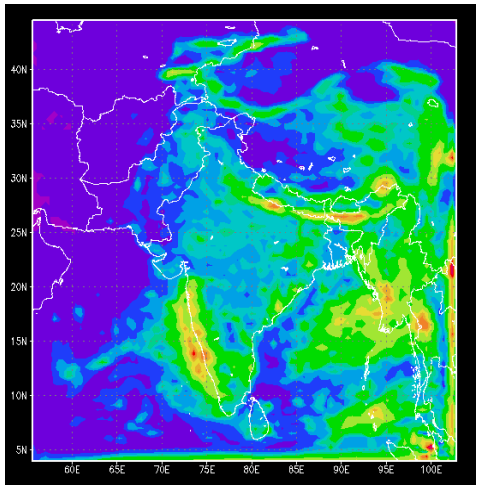
1987

1992

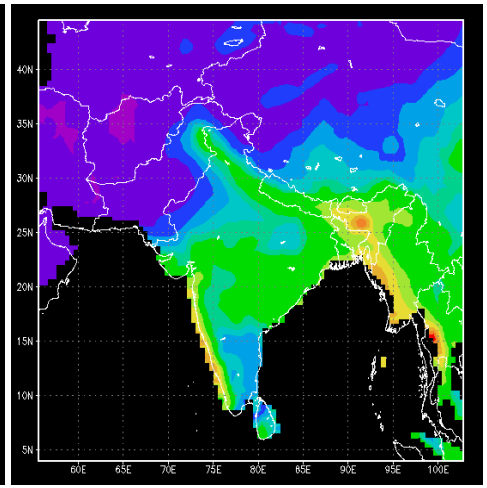
Observed



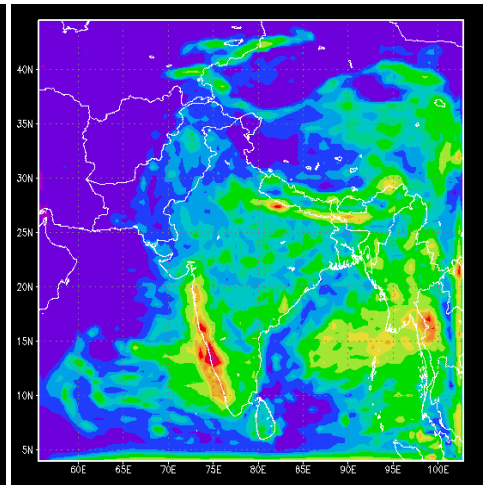
RegCM3



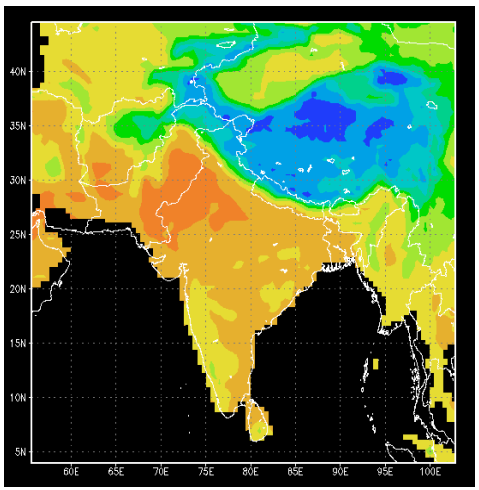
Observed

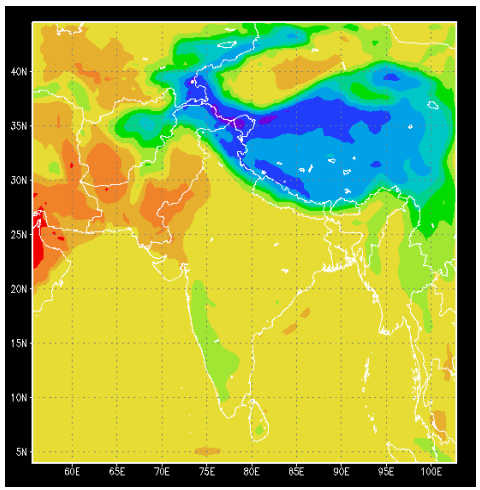


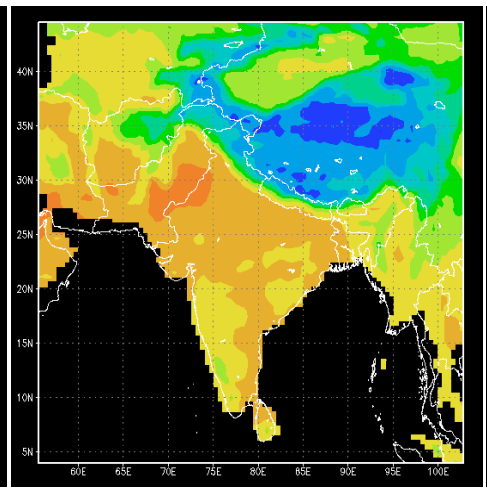
RegCM3

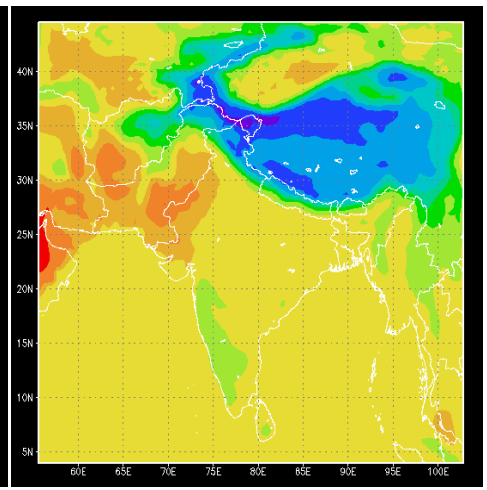


Temperature (C)









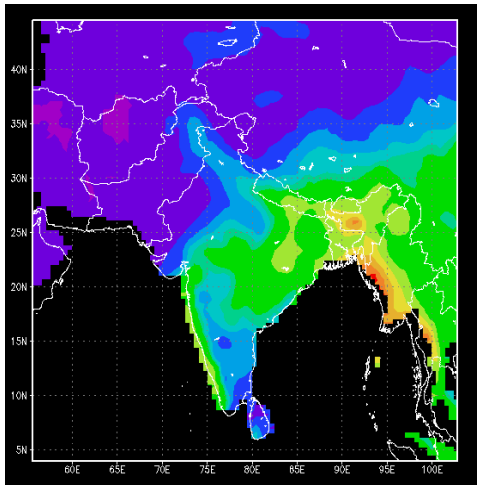
Grell Convective Scheme, Fritsch - Chappell Closure (JJAS)

Precipitation (mm/day)

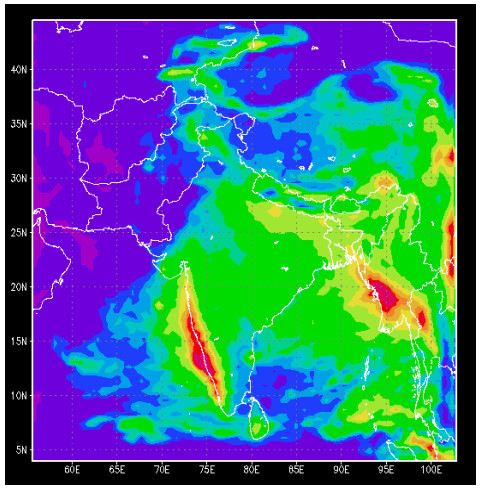
1987

1992

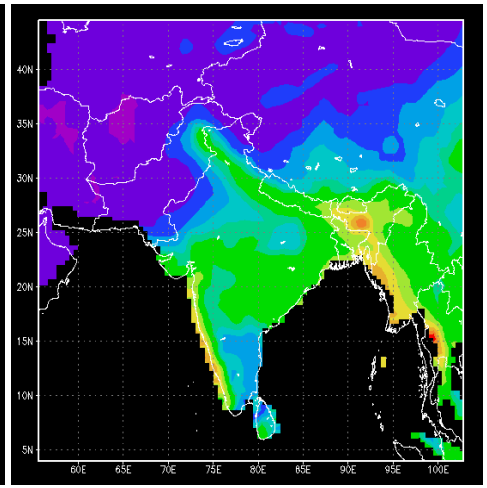
Observed



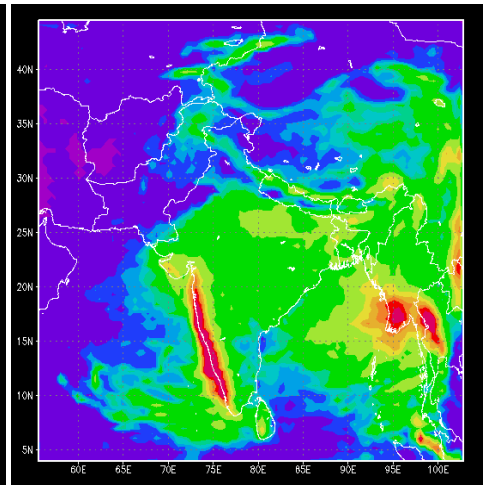
RegCM3



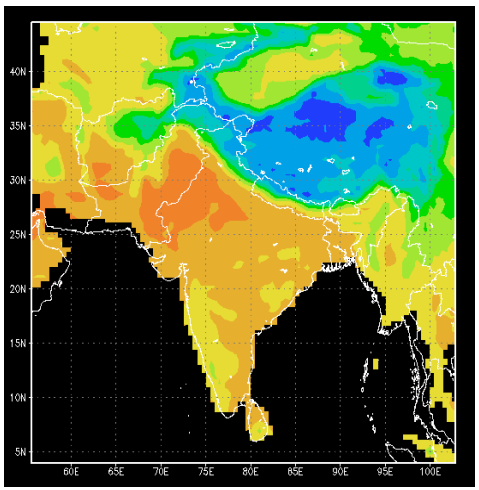
Observed

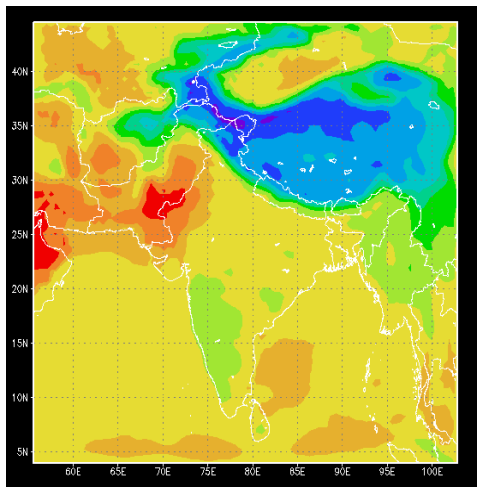


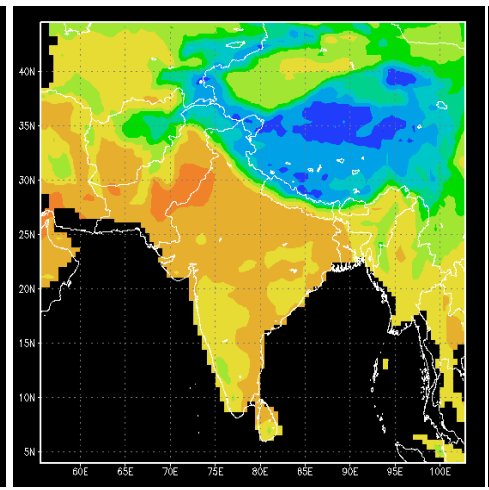
RegCM3

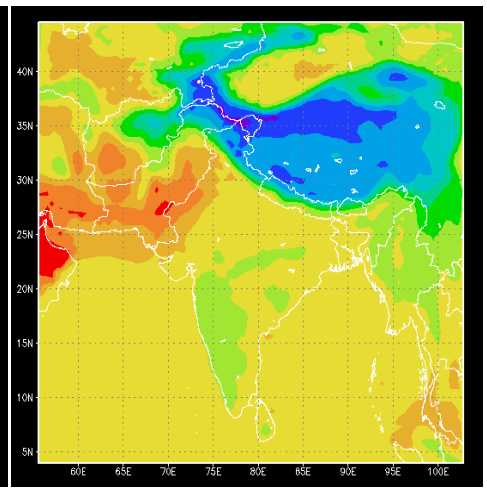


Temperature (C)









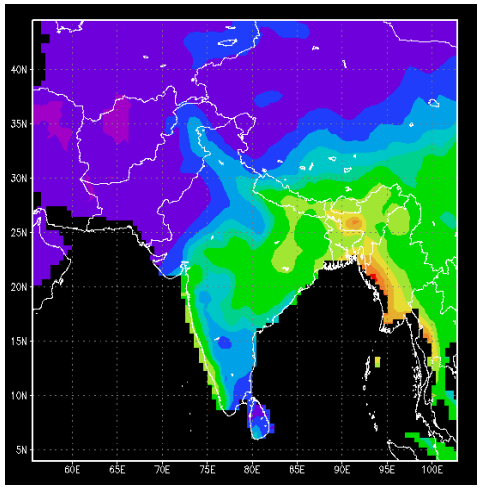
Anthes - Kuo Convective Scheme (JJAS)

Precipitation (mm/day)

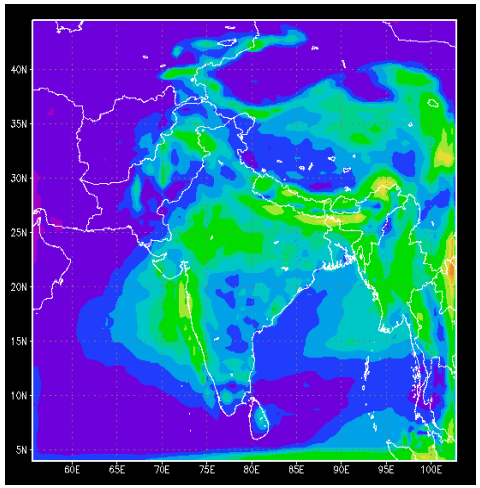
1987

1992

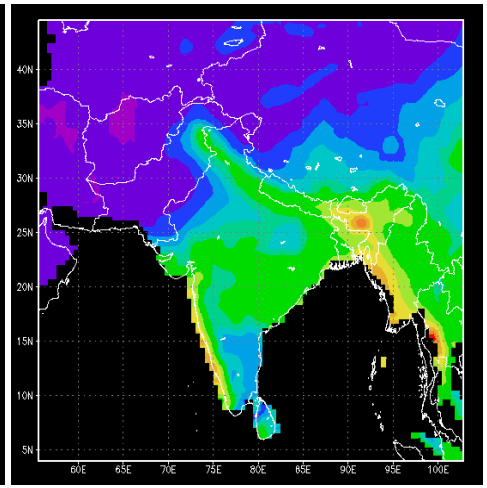
Observed



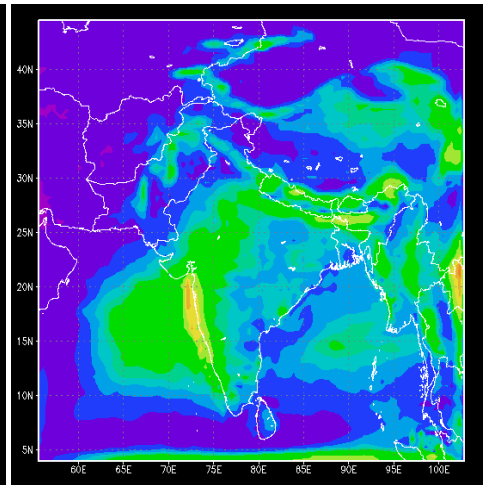
RegCM3



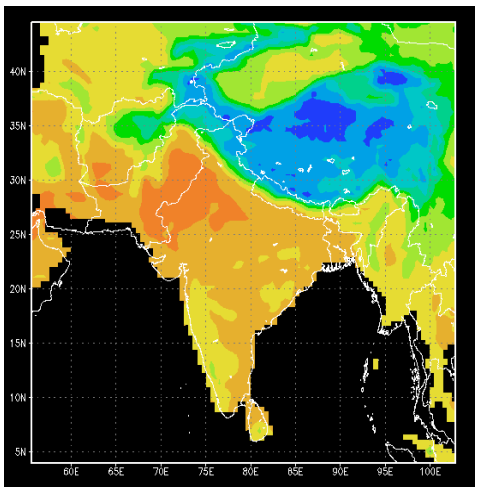
Observed

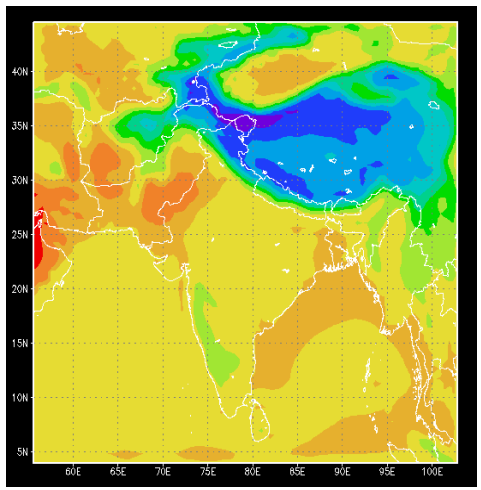


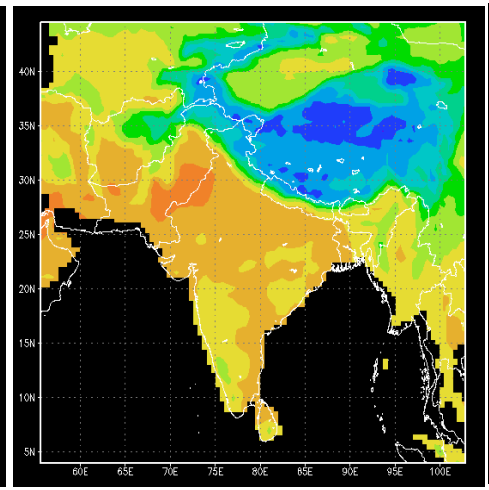
RegCM3

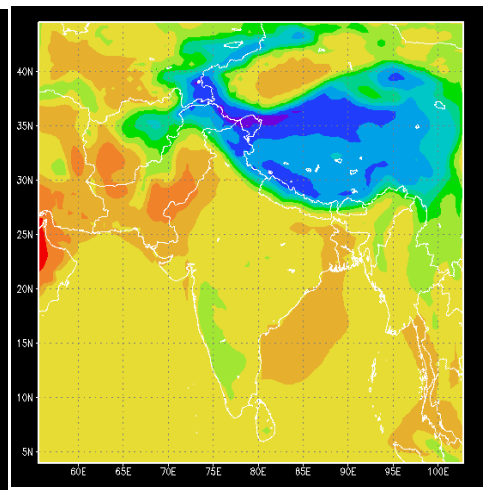


Temperature (C)









Emanuel Convective Scheme (JJAS)

Precipitation (mm/day)

1987

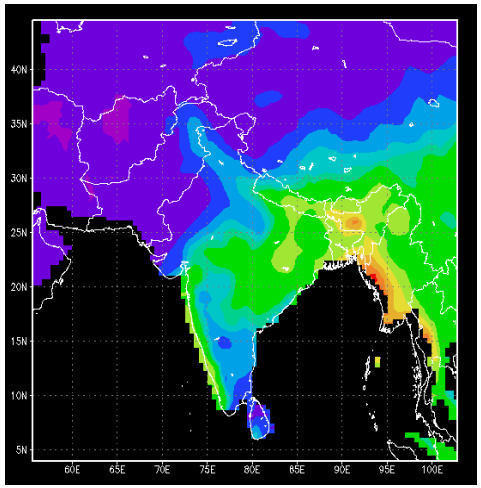
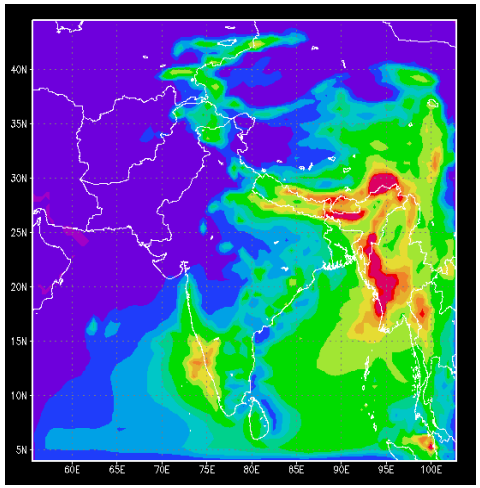
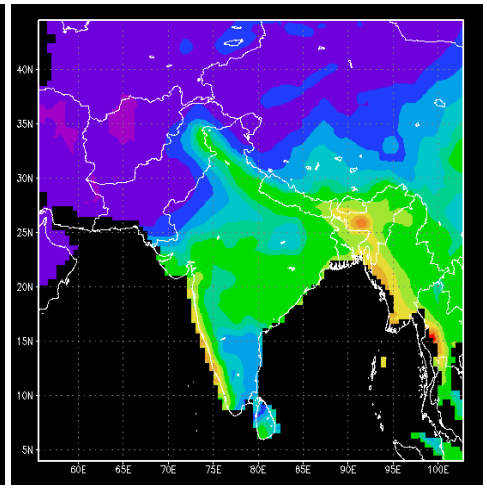
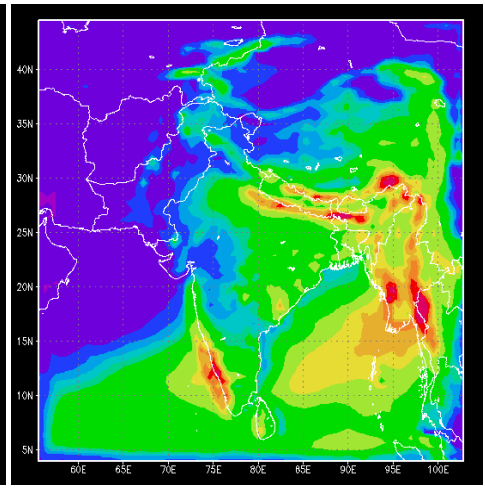
1992

Observed

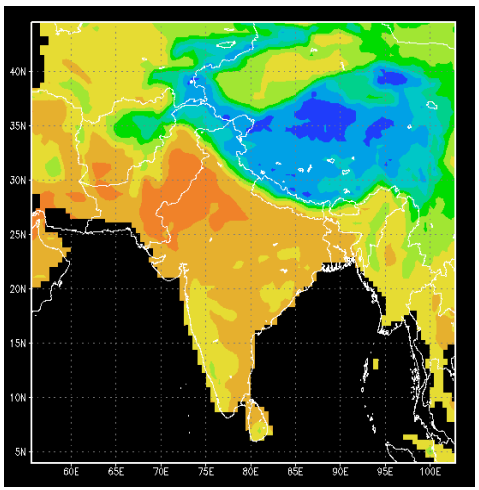
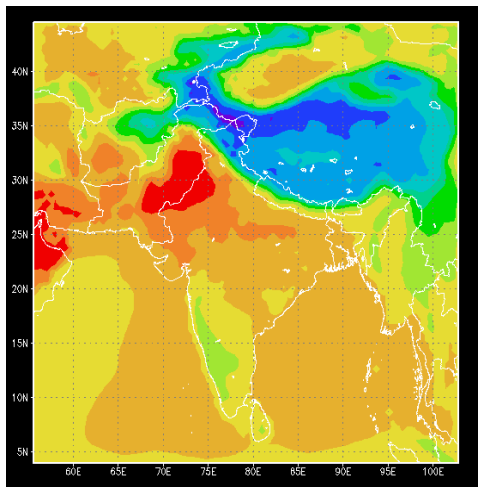
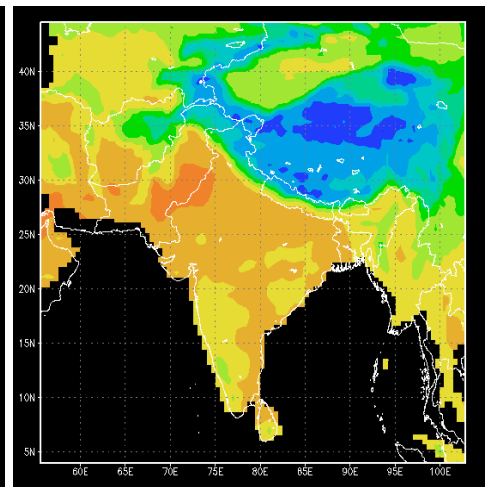
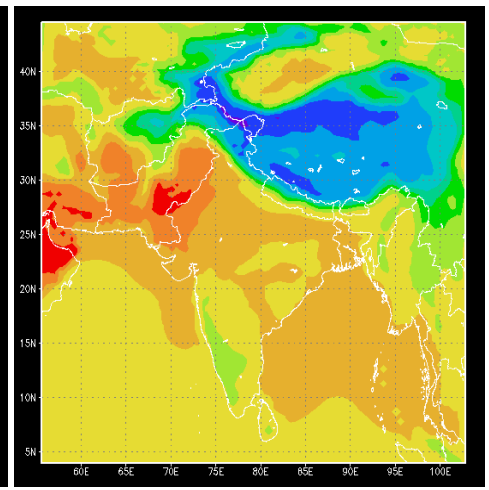
RegCM3

Observed

RegCM3

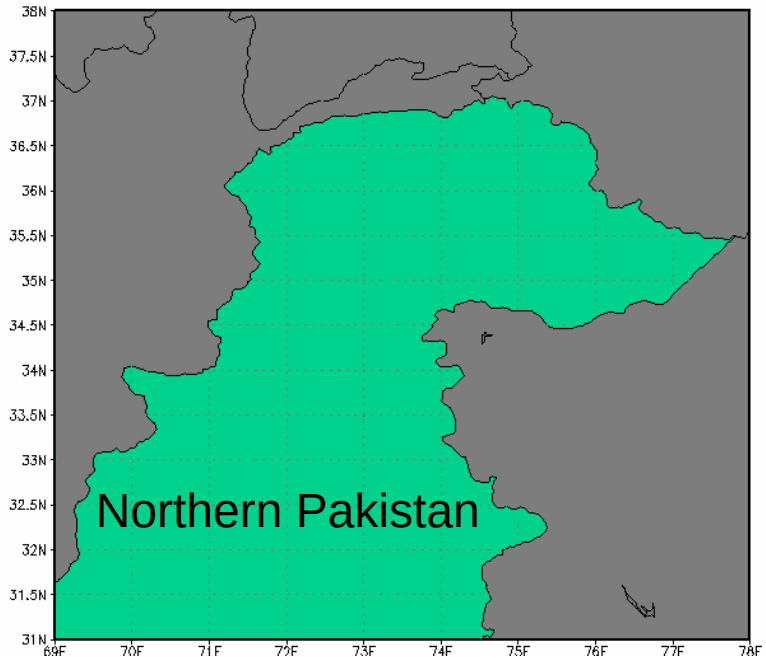





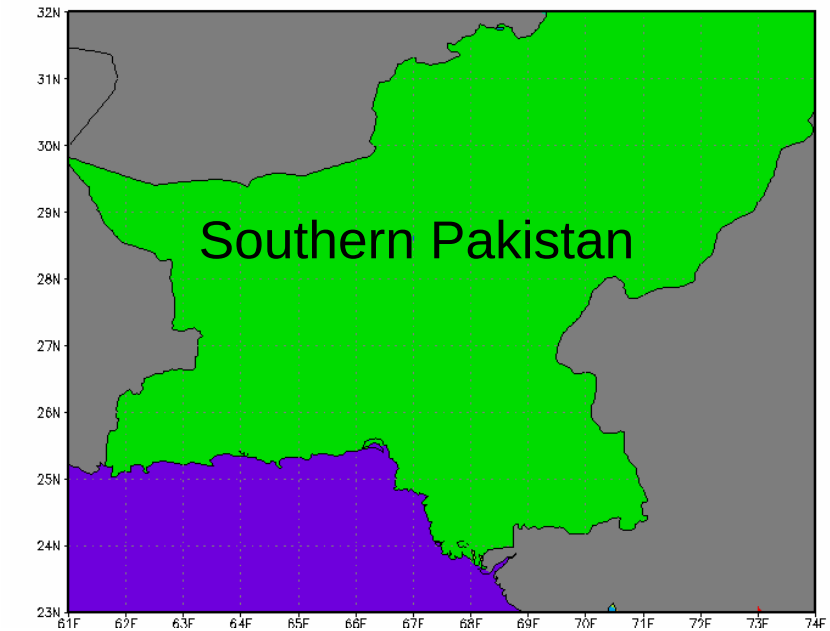
Temperature (C)

Selected Regions of Pakistan

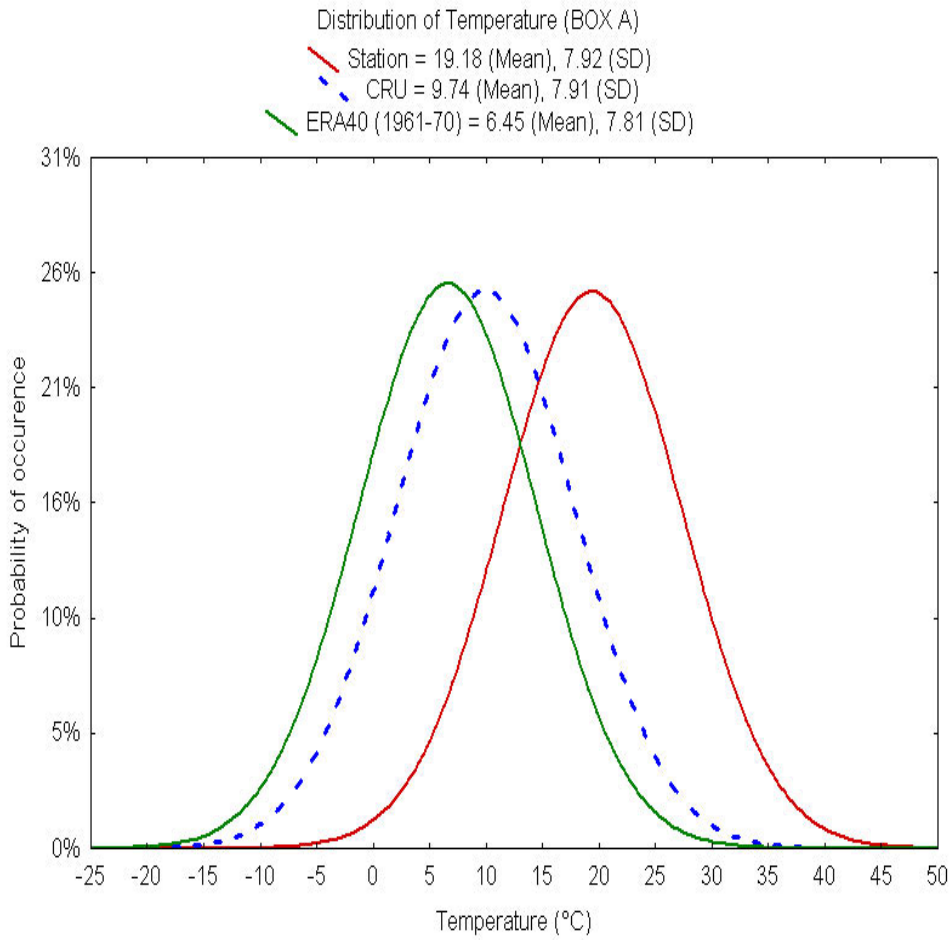
BOX A

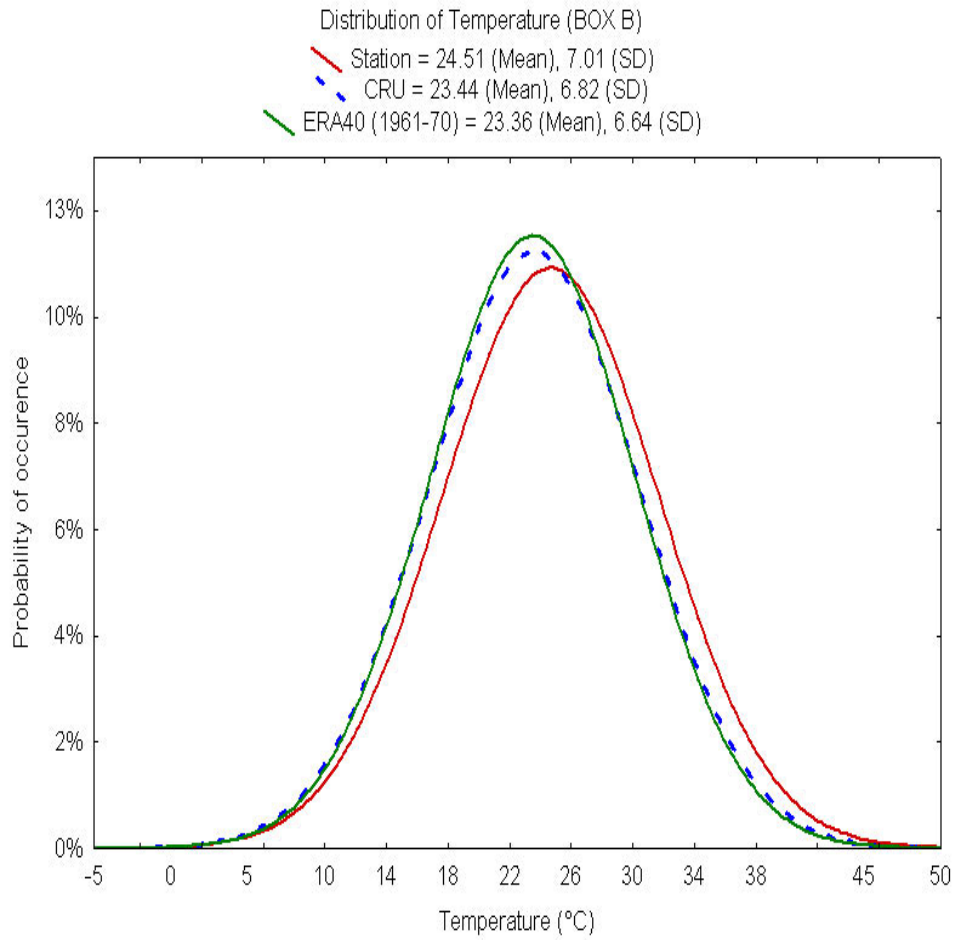




BOX B

PDFs of Temperature (Box A and Box B)

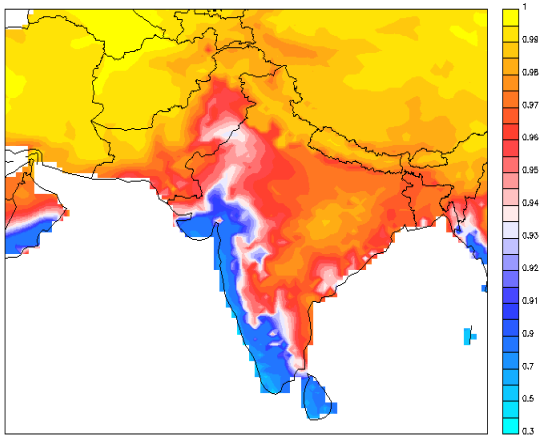




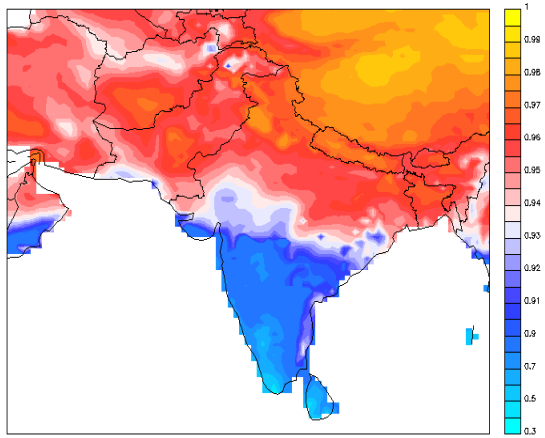
Temperature
Base (1961-1970)

Correlation Maps

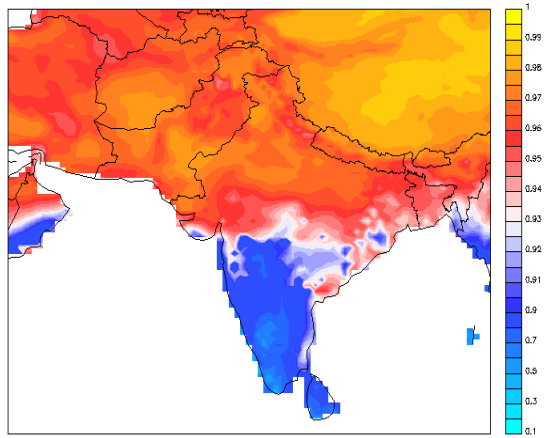
Correlation of Temperature(ERA40 & CRU)



Correlation of Temperature(ECHAM & CRU)

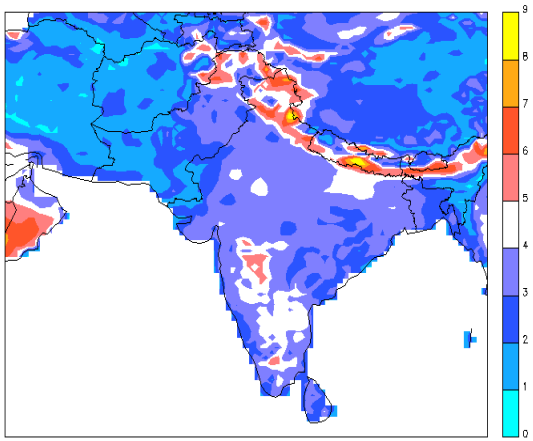


Correlation of Temperature(FVGCM & CRU)

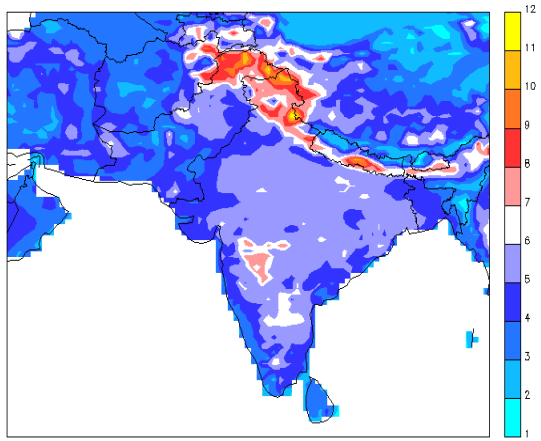


RMSE Maps

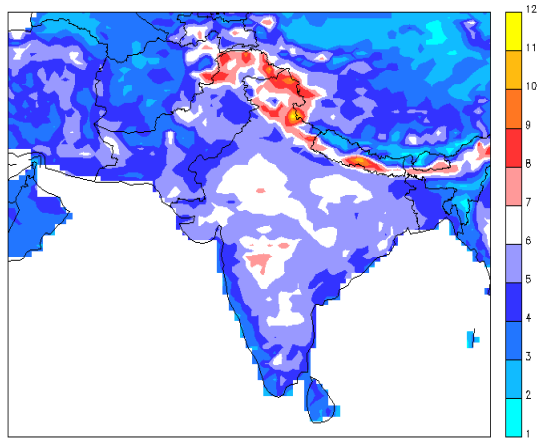
RMSE of Temperature(ERA40 & CRU)



RMSE of Temperature(ECHAM & CRU)

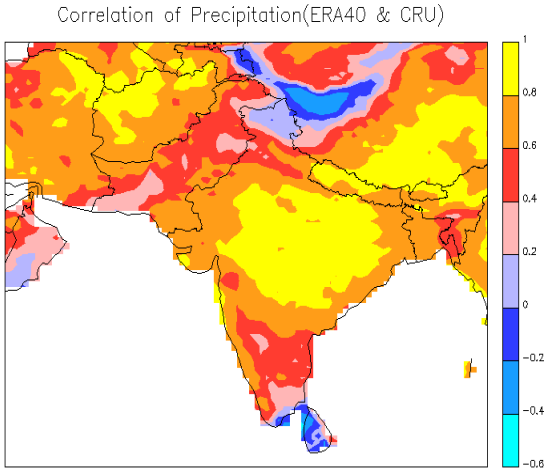


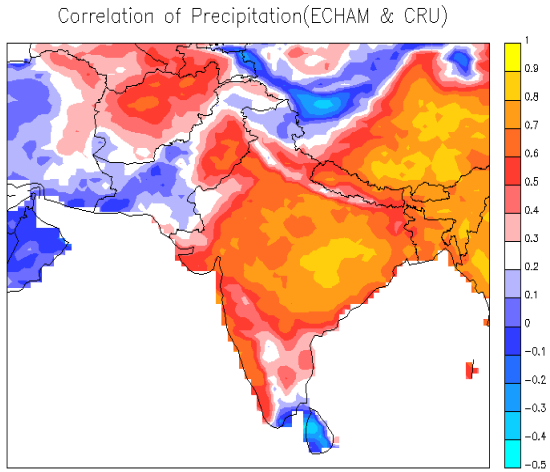
RMSE of Temperature(FVGCM & CRU)

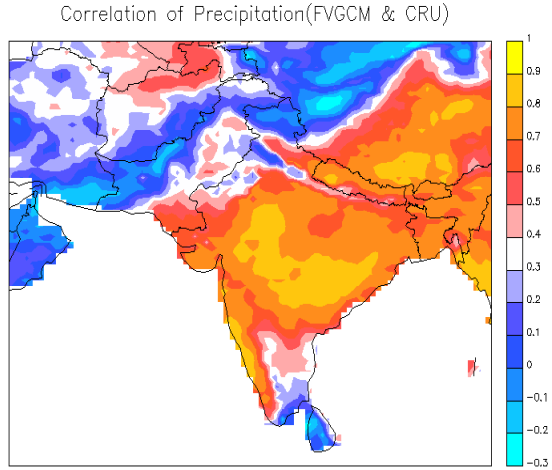


Precipitation
Base (1961-1970)

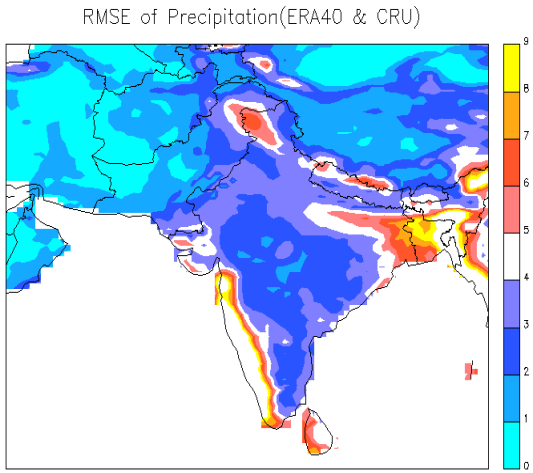
Correlation Maps

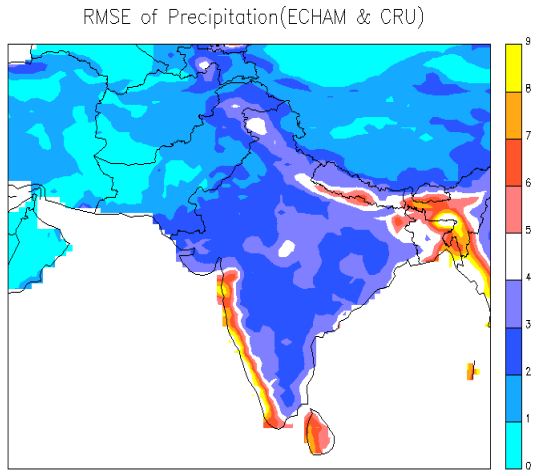


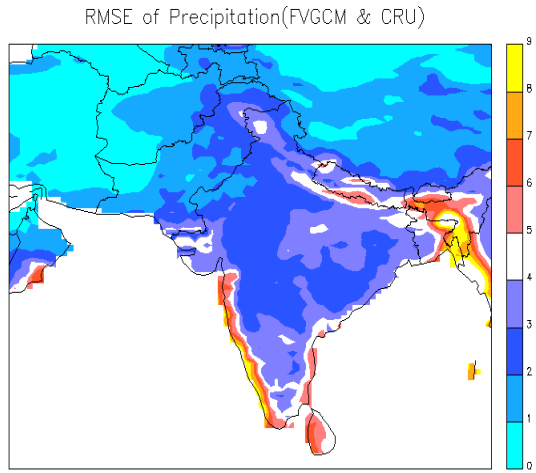




RMSE Maps



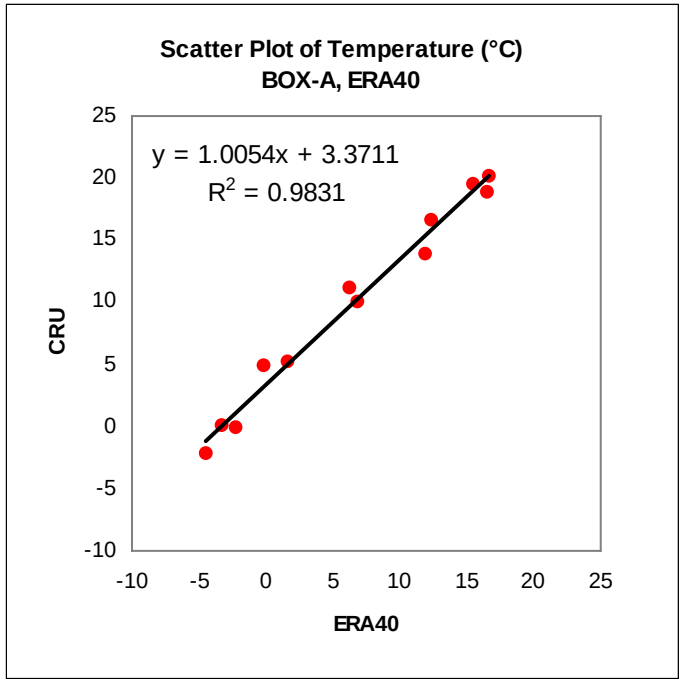


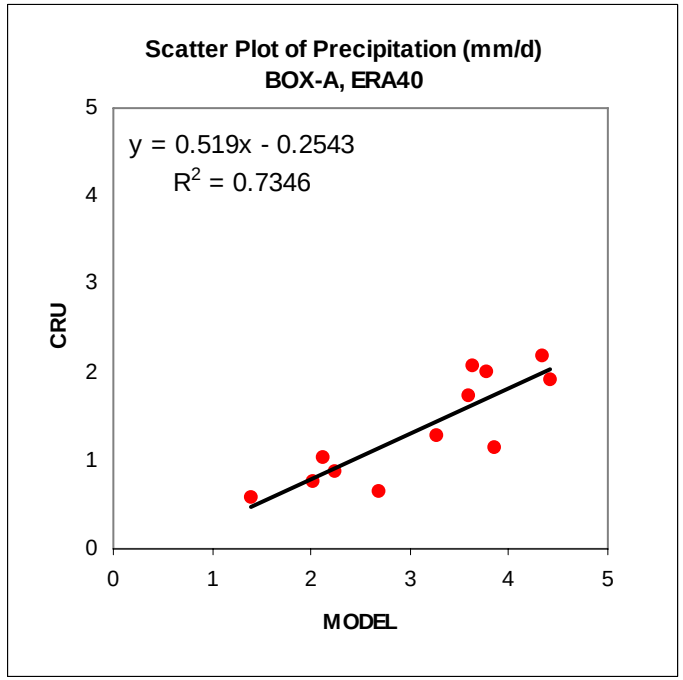


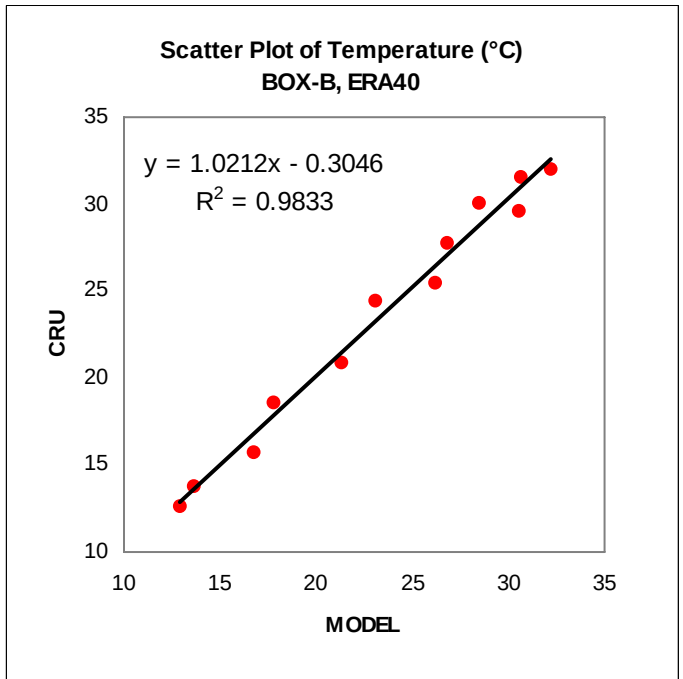
Summary of Precipitation and Temperature over Selected Regions

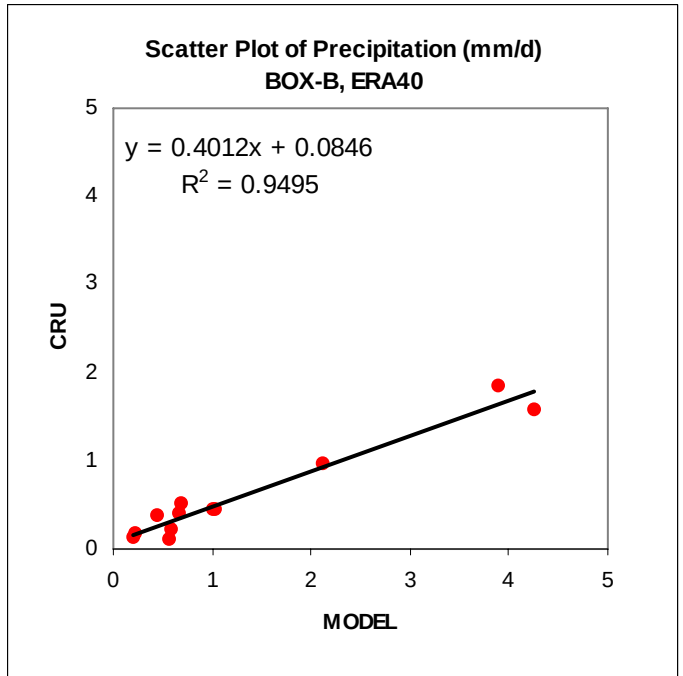
PRECIPITATION (Monthly)			
	CORR	**RMSE (mm/d)**	**% diff (mm/d) (model-cru)/cru *100**
ERA40			
BOX A	0.62	2.07	124.98
BOX B	0.86	1.21	112.48
ECHAM			
BOX A	0.42	1.43	64.70
BOX B	0.46	0.99	22.33
FVGCM			
BOX A	0.18	1.42	46.02
BOX B	0.68	1.16	86.78

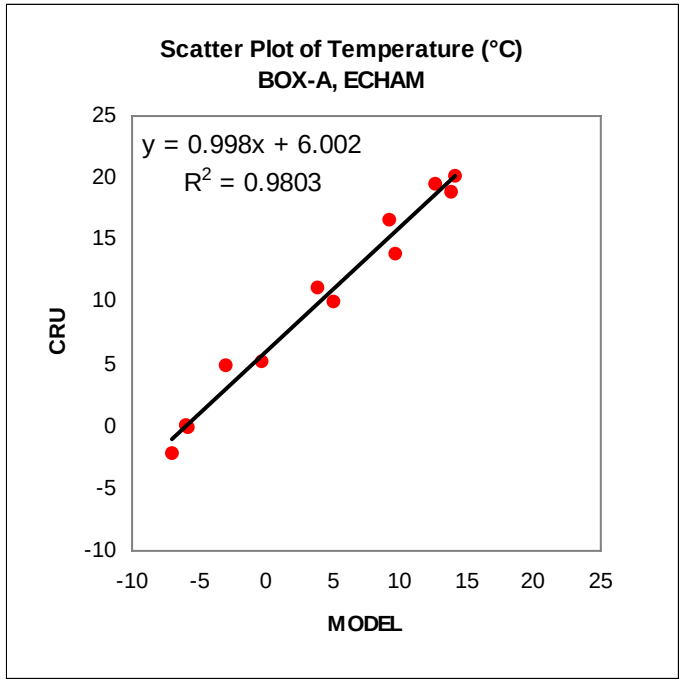
TEMPERATURE (Monthly)			
	CORR	**RMSE (°C)**	**Diff (°C) (model-cru)**
ERA40			
BOX A	0.99	3.48	-3.29
BOX B	0.99	1.06	-0.08
ECHAM			
BOX A	0.97	6.27	-5.99
BOX B	0.97	3.35	-2.67
FVGCM			
BOX A	0.98	5.89	-5.57
BOX B	0.98	3.74	-3.24

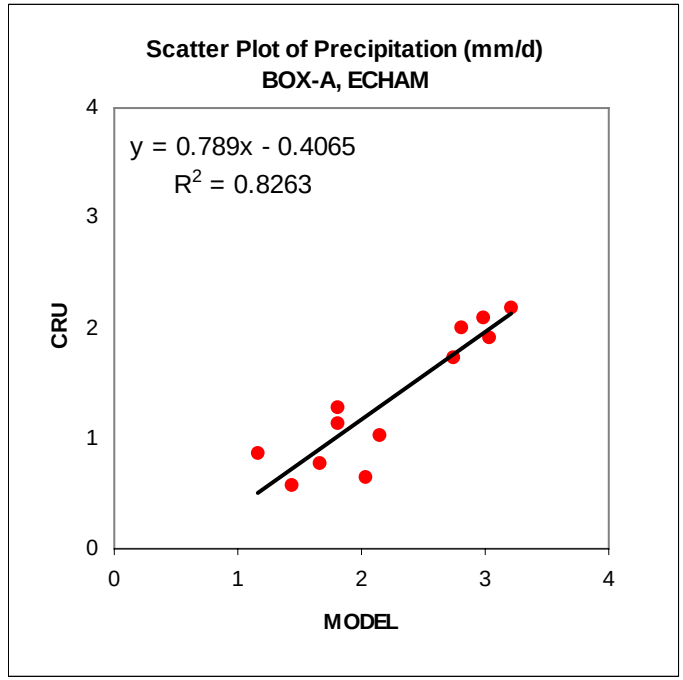

Scatter Plot of Temperature (°C)
BOX-A, ERA40
y = 1.0054x + 3.3711
R2 = 0.9831
CRU
ERA40
25
20
15
10
5
0
-5
-10
-10
-5
0
5
10
15
20
25

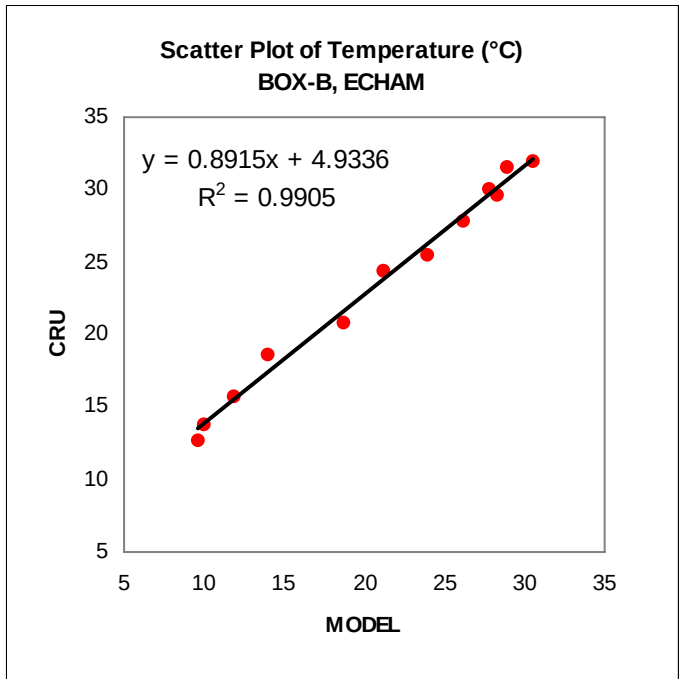

Scatter Plot of Precipitation (mm/d)
BOX-A, ERA40
y = 0.519x - 0.2543
R2 = 0.7346
CRU
MODEL
5
4
3
2
1
0
0
1
2
3
4
5

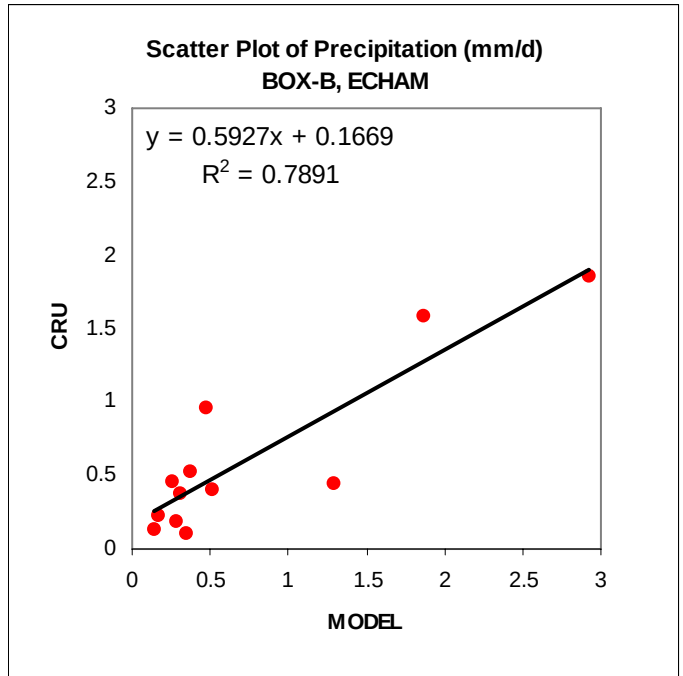

Scatter Plot of Temperature (°C)
BOX-B, ERA40
y = 1.0212x - 0.3046
R2 = 0.9833
CRU
MODEL
35
30
25
20
15
10
10
15
20
25
30
35

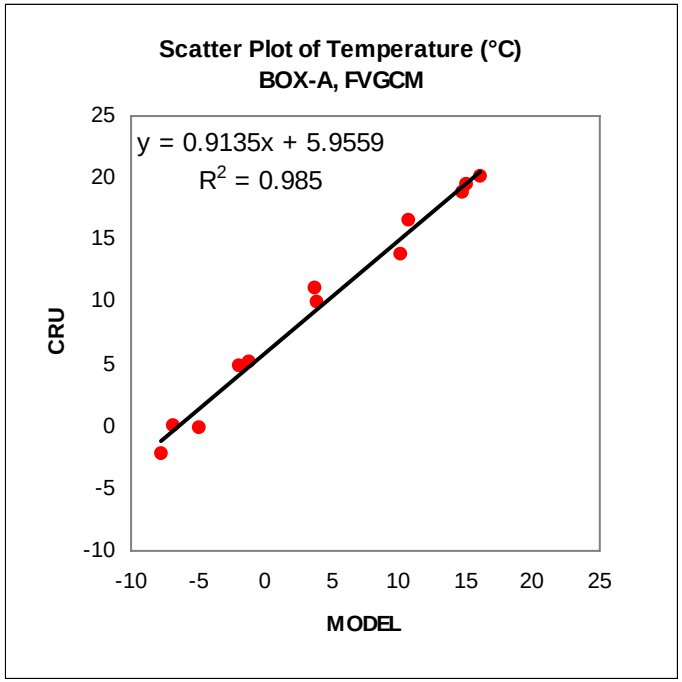

Scatter Plot of Precipitation (mm/d)
BOX-B, ERA40
y = 0.4012x + 0.0846
R2 = 0.9495
CRU
MODEL
5
4
3
2
1
0
0
1
2
3
4
5

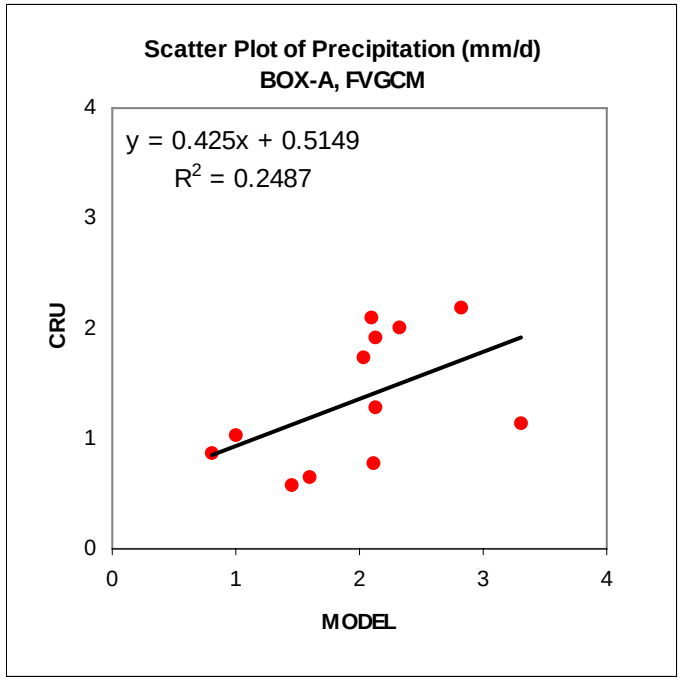

Scatter Plot of Temperature (°C)
BOX-A, ECHAM
y = 0.998x + 6.002
R2 = 0.9803
CRU
MODEL
25
20
15
10
5
0
-5
-10
-10
-5
0
5
10
15
20
25

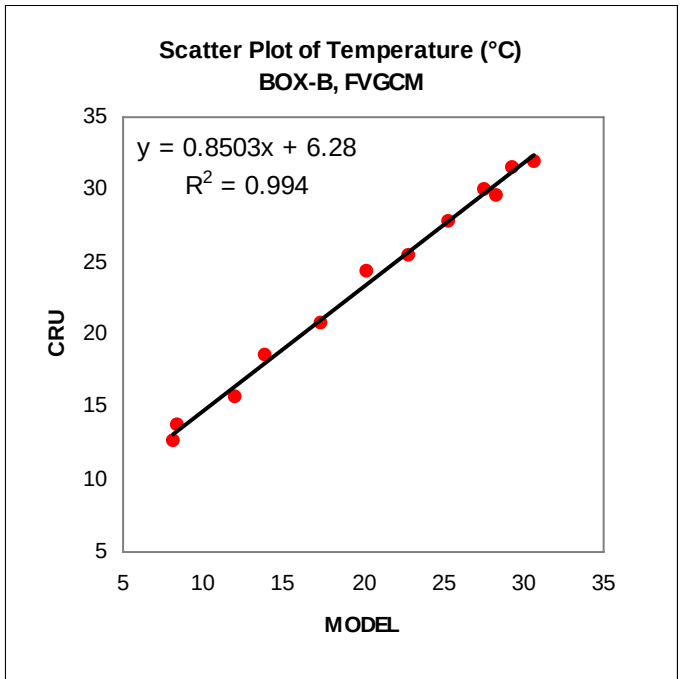

Scatter Plot of Precipitation (mm/d)
BOX-A, ECHAM
y = 0.789x - 0.4065
R2 = 0.8263
CRU
MODEL
4
3
2
1
0
0
1
2
3
4

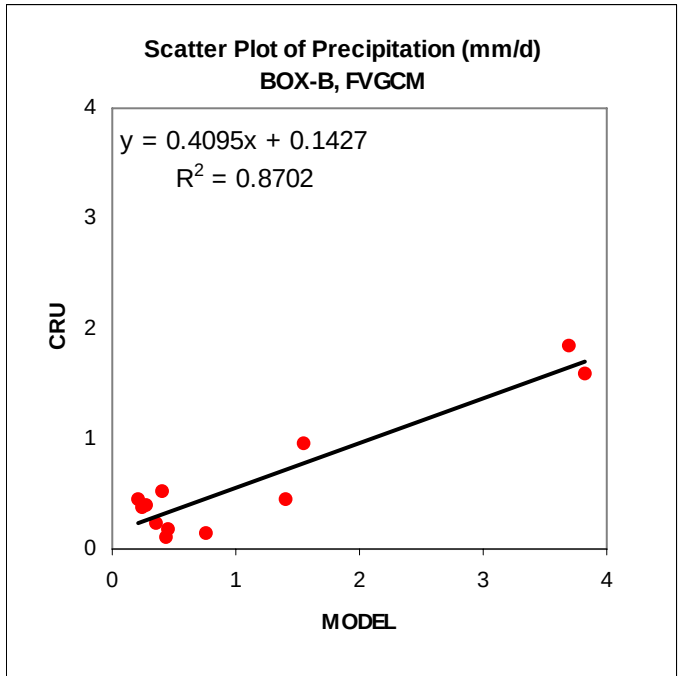

Scatter Plot of Temperature (°C)
BOX-B, ECHAM
y = 0.8915x + 4.9336
R2 = 0.9905
CRU
MODEL
35
30
25
20
15
10
5
5
10
15
20
25
30
35


Scatter Plot of Precipitation (mm/d)
BOX-B, ECHAM
y = 0.5927x + 0.1669
R2 = 0.7891
CRU
MODEL
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3


Scatter Plot of Temperature (°C)
BOX-A, FVGCM
y = 0.9135x + 5.9559
R2 = 0.985
CRU
MODEL
25
20
15
10
5
0
-5
-10
-10
-5
0
5
10
15
20
25

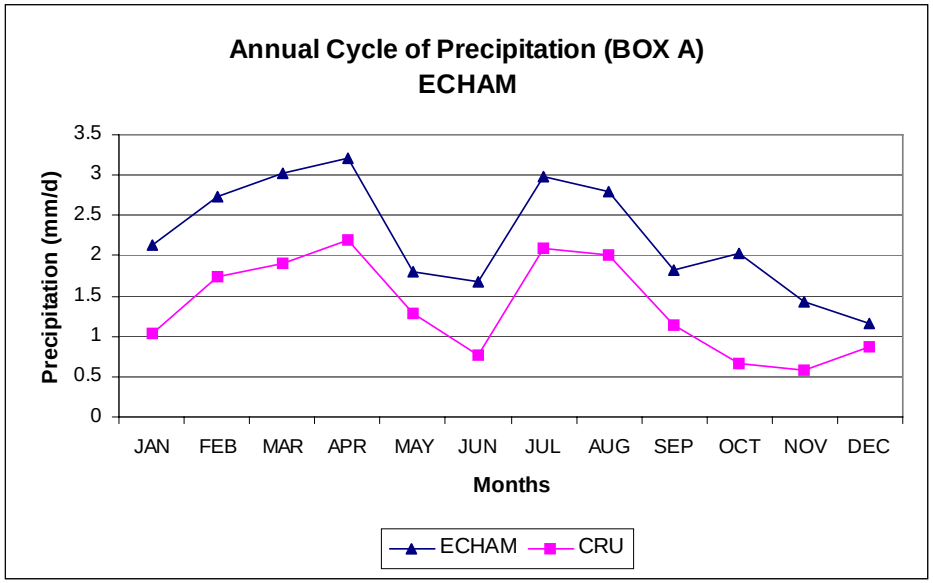

Scatter Plot of Precipitation (mm/d)
BOX-A, FVGCM
y = 0.425x + 0.5149
R2 = 0.2487
CRU
MODEL
4
3
2
1
0
0
1
2
3
4

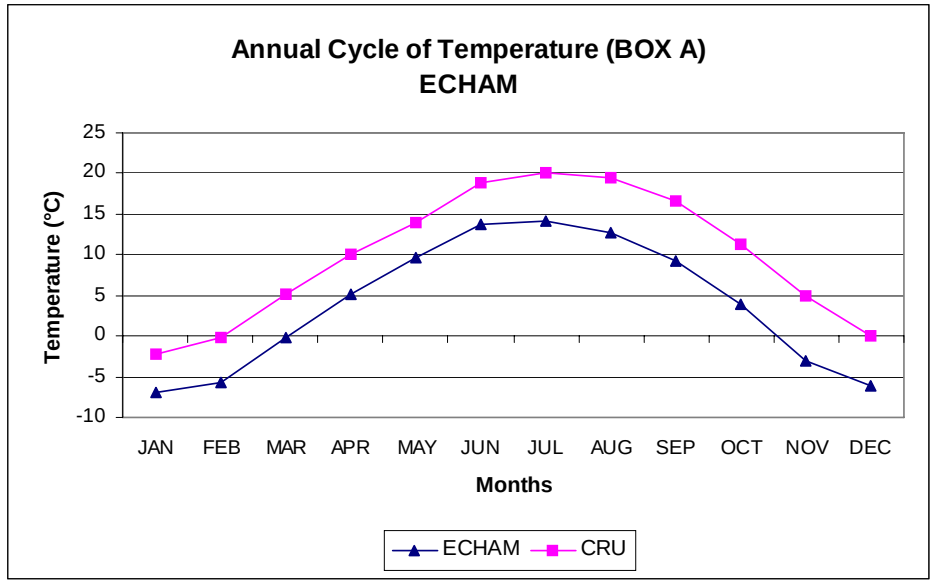

Scatter Plot of Temperature (°C)
BOX-B, FVGCM
y = 0.8503x + 6.28
R2 = 0.994
CRU
MODEL
35
30
25
20
15
10
5
5
10
15
20
25
30
35

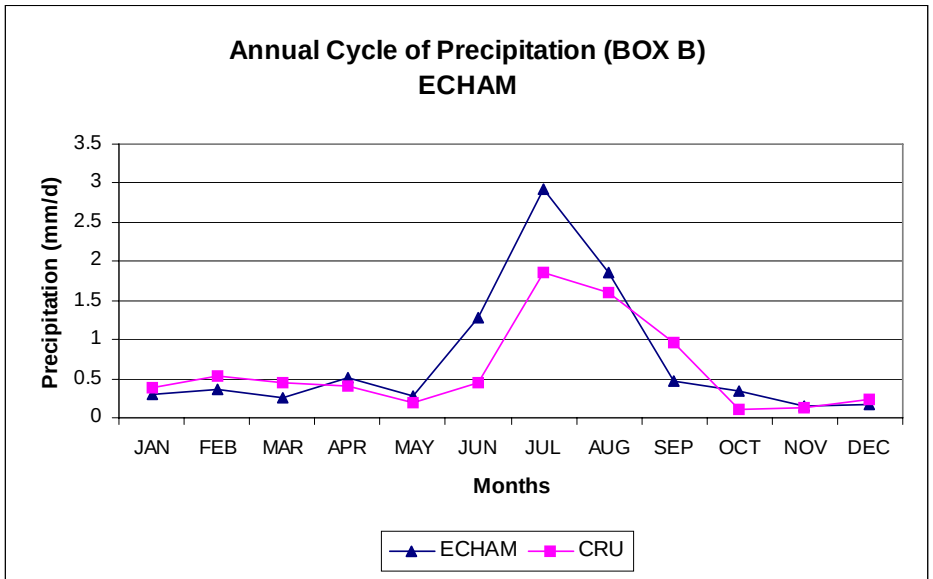

Scatter Plot of Precipitation (mm/d)
BOX-B, FVGCM
y = 0.4095x + 0.1427
R2 = 0.8702
CRU
MODEL
4
3
2
1
0
0
1
2
3
4

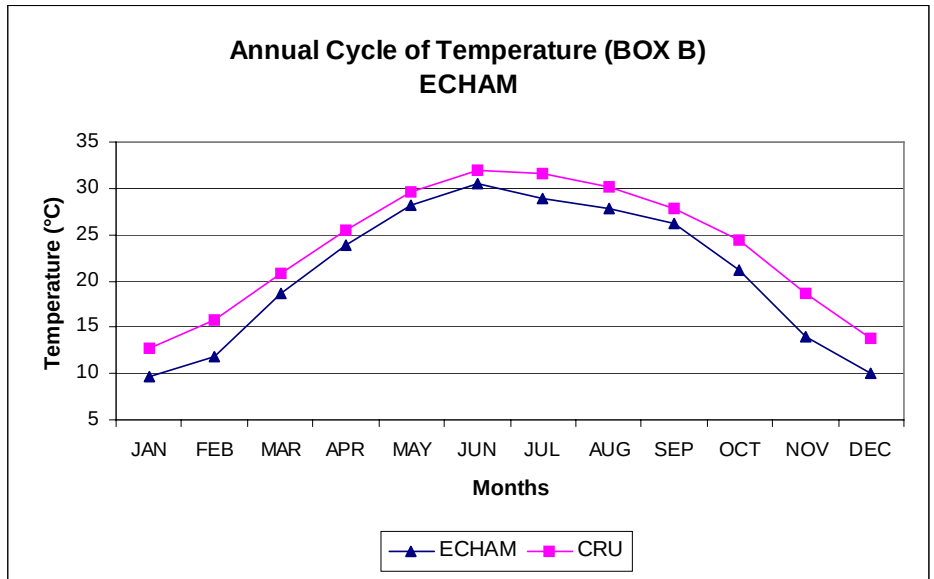
Annual Cycle of Temperature Selected Regions of Pakistan

ECHAM



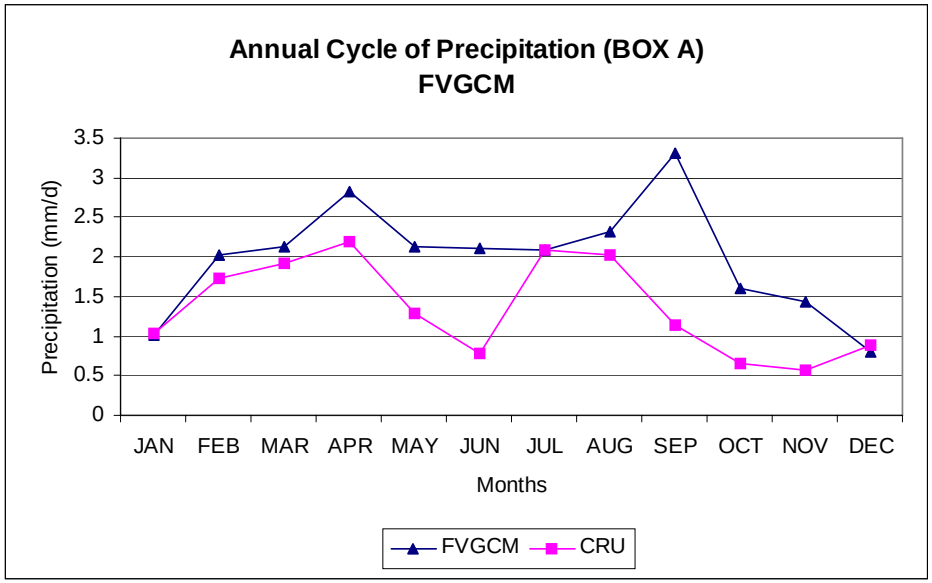


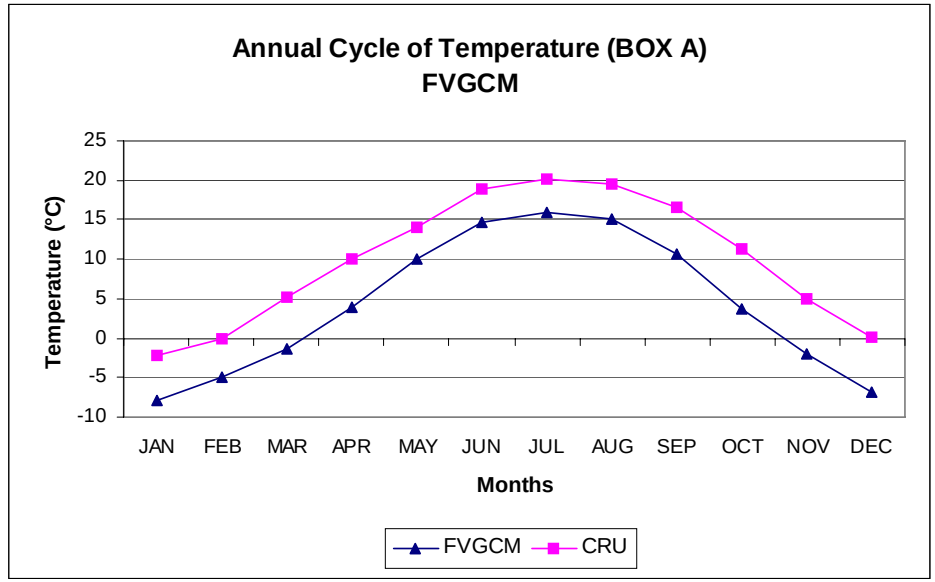


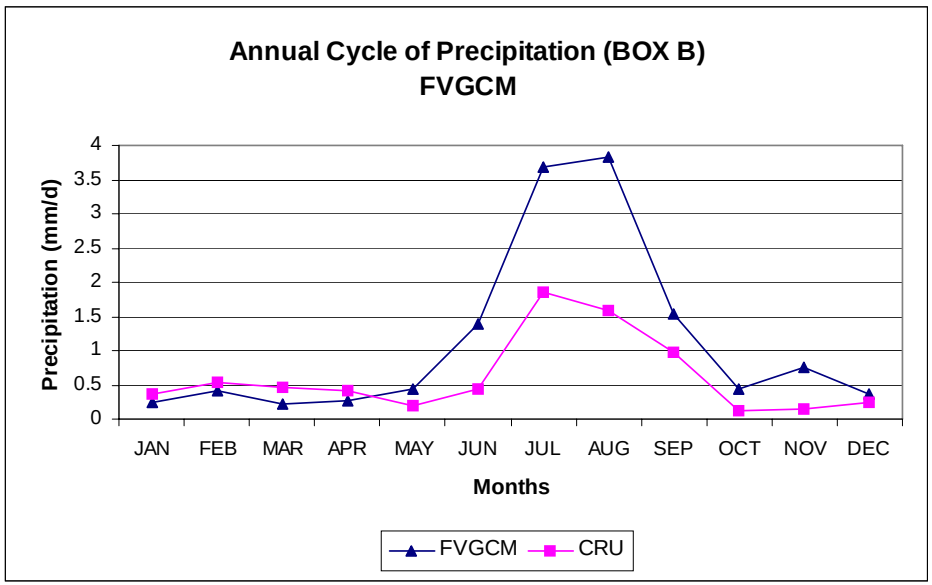


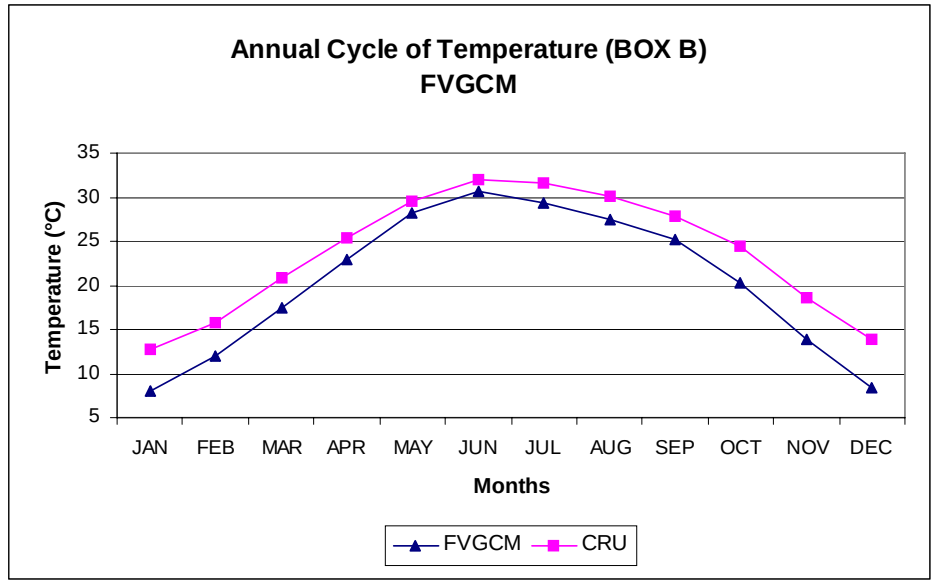
Annual Cycle of Temperature Selected Regions of Pakistan

FVGCM









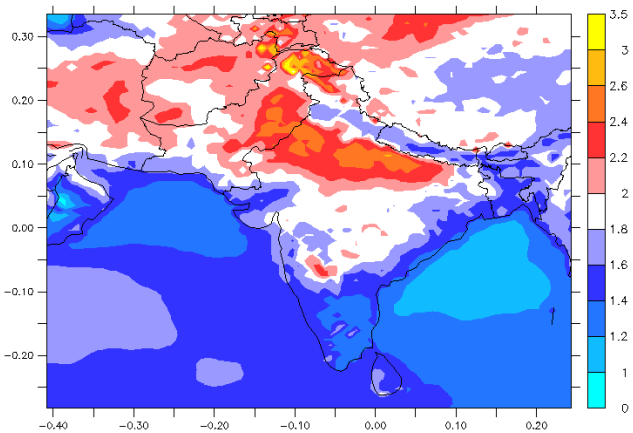
Climate Change - Annual

F1 =2050s

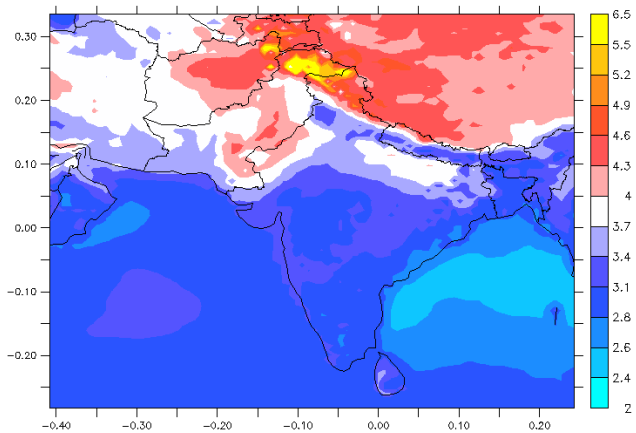
F2 =2080s

Temperature Change (°C)

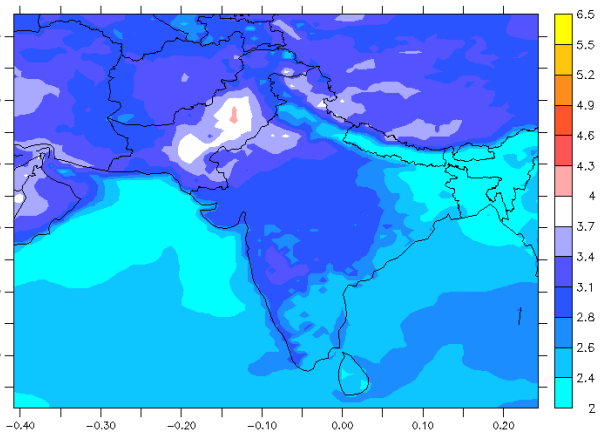
ECHAM - F1



ECHAM - F2



FVGCM - F2

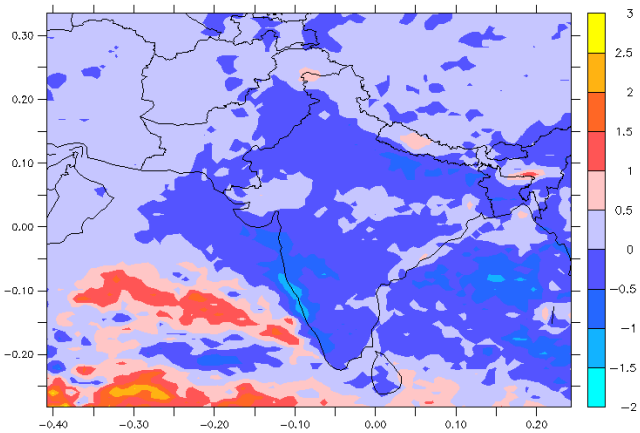


F1 =2050s

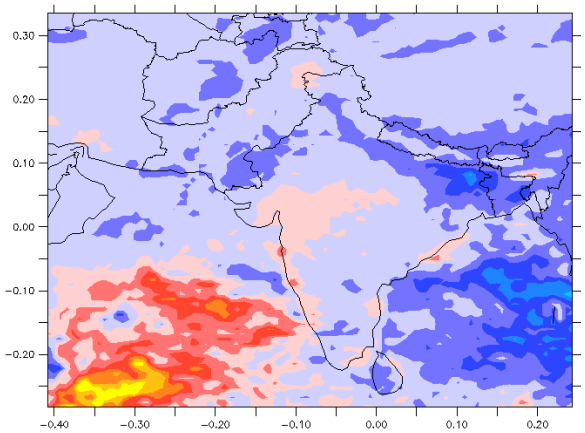
F2 =2080s

Absolute Change in Precipitation (mm/day)

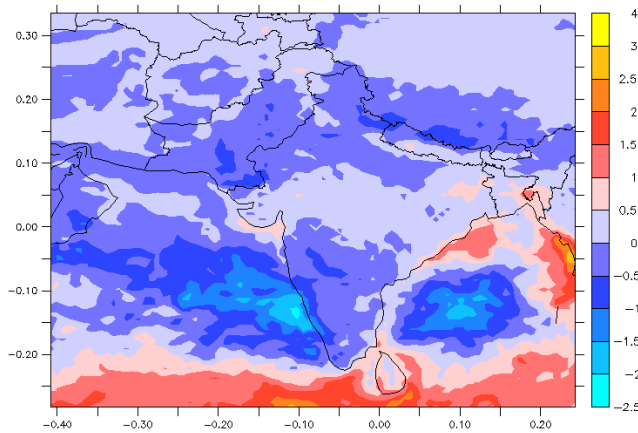
ECHAM - F1



ECHAM - F2

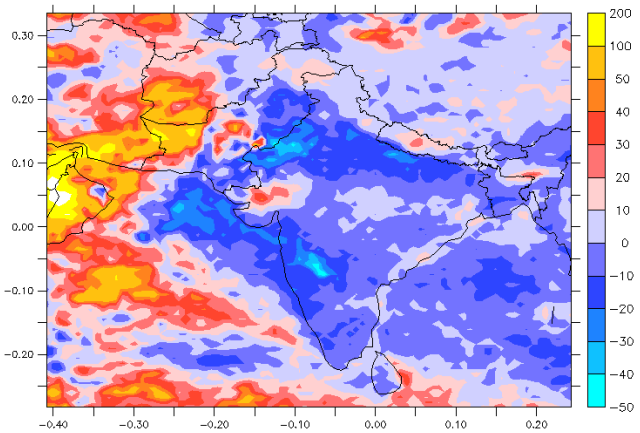


FVGCM - F2

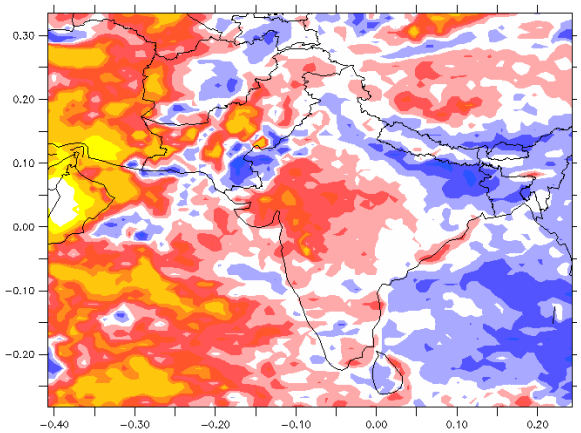


Percentage Change in Precipitation (%)

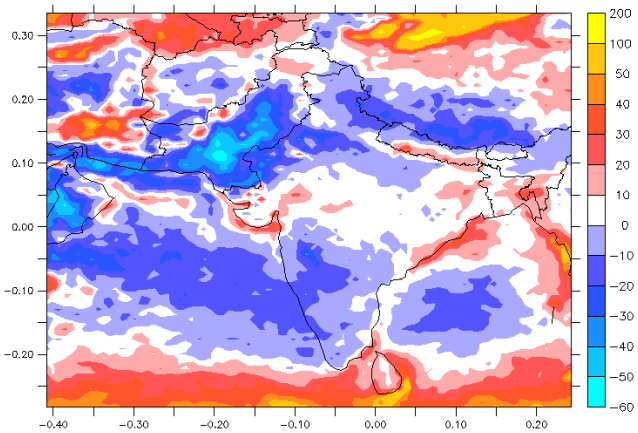
ECHAM - F1



ECHAM - F2



FVGCM - F2



Climate Change - Summer

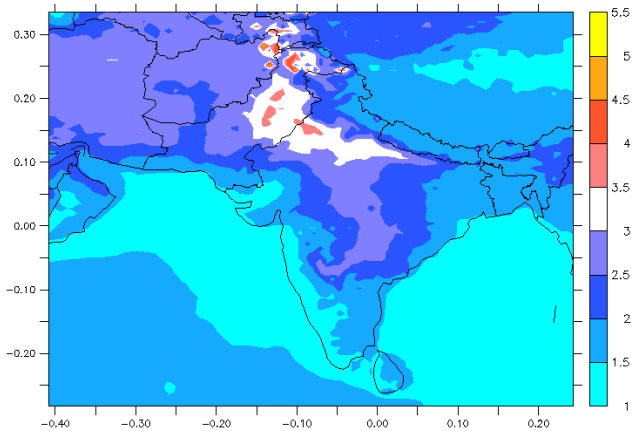
F1 =2050s

F2 =2080s

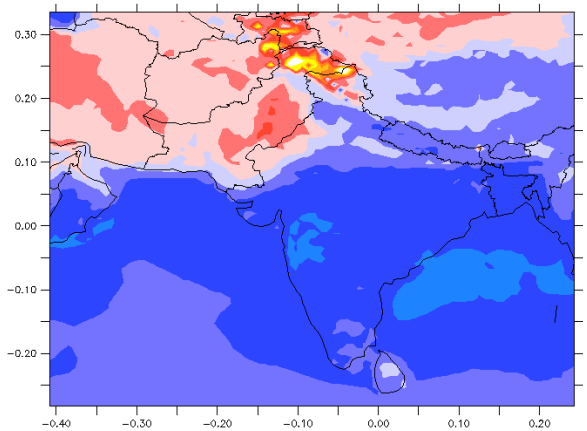
Temperature Change (°C)

Summer (JJAS)

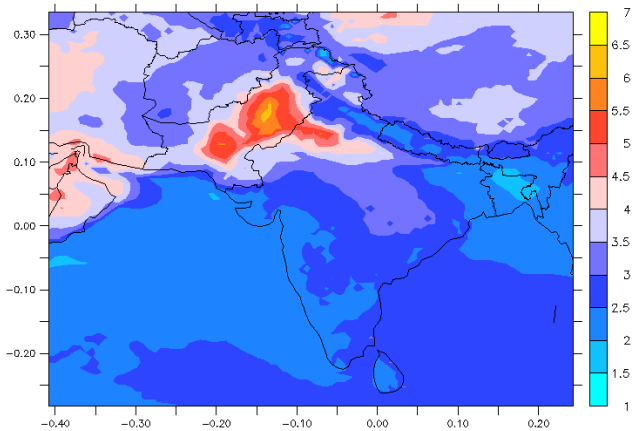
ECHAM - F1



ECHAM - F2



FVGCM - F2

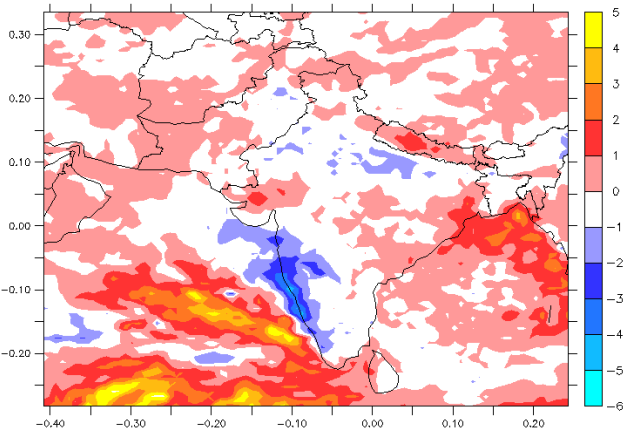


F1 =2050s

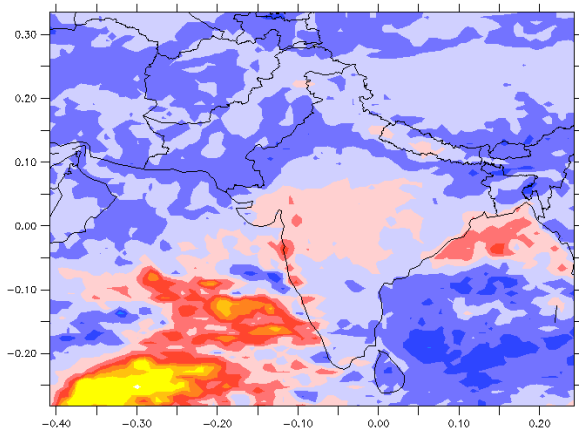
F2 =2080s

Absolute Change in Precipitation (mm/day)

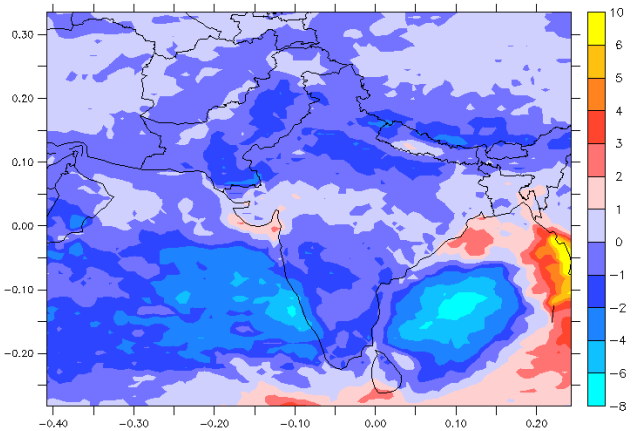
ECHAM - F1



ECHAM - F2

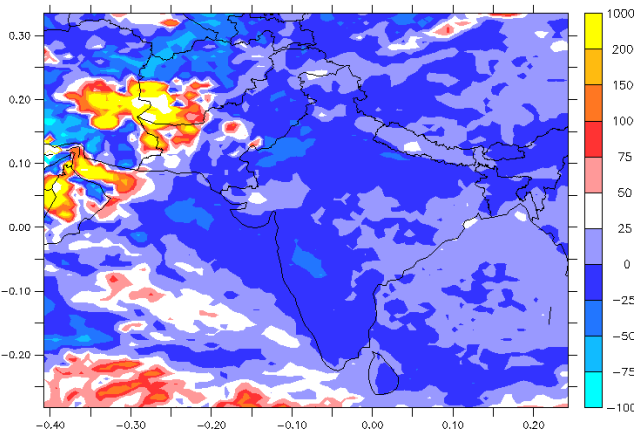


FVGCM - F2

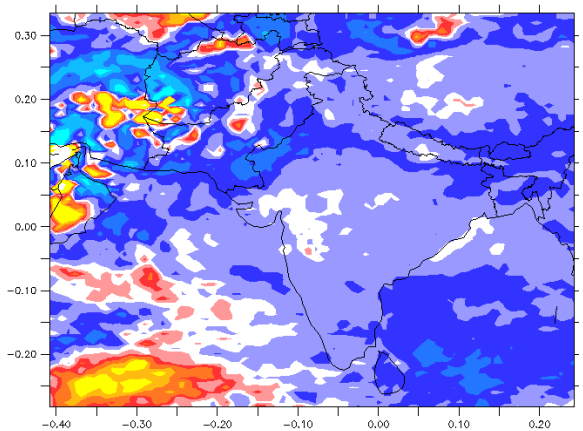


Percentage Change in Precipitation (%)

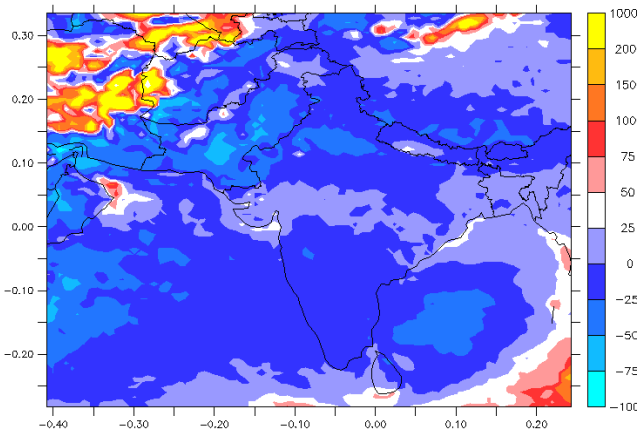
ECHAM - F1



ECHAM - F2



FVGCM - F2



Climate Change - Winter

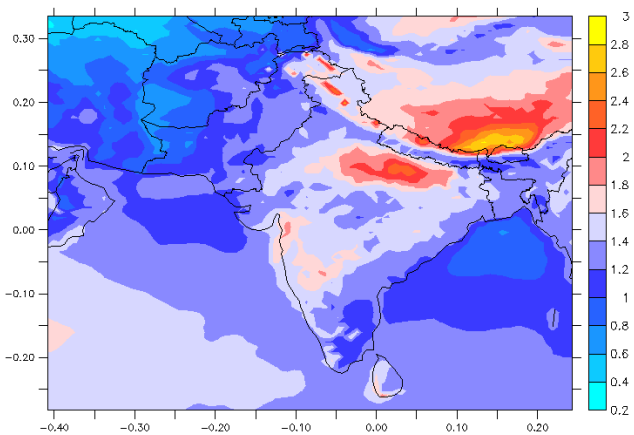
F1 =2050s

F2 =2080s

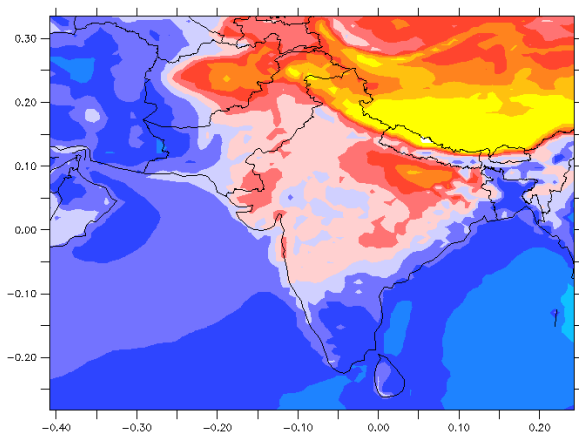
Temperature Change (°C)

Winter (DJFM)

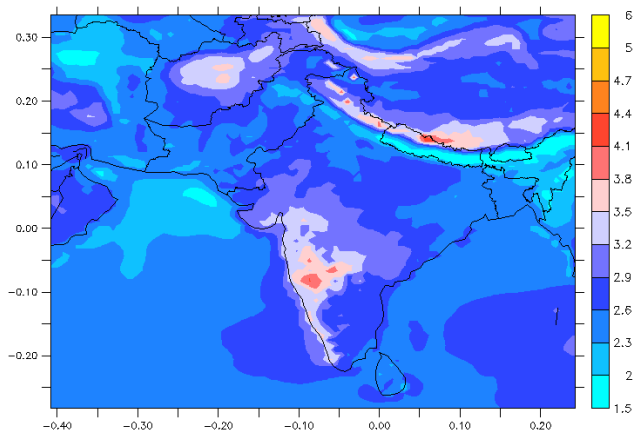
ECHAM - F1



ECHAM - F2



FVGCM - F2

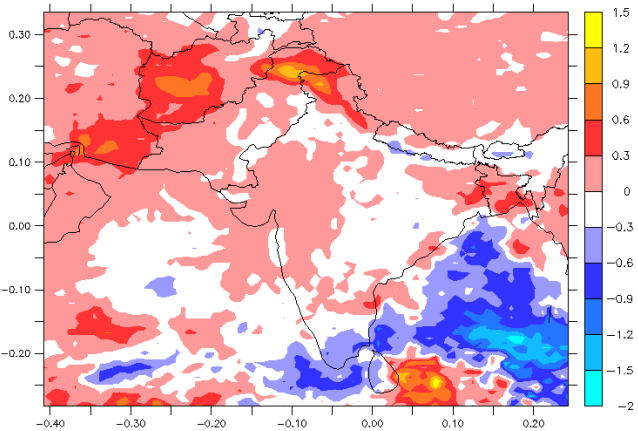


F1 =2050s

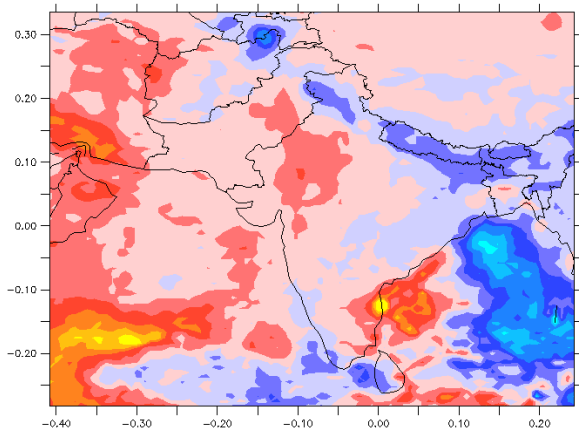
F2 =2080s

Absolute Change in Precipitation (mm/day)

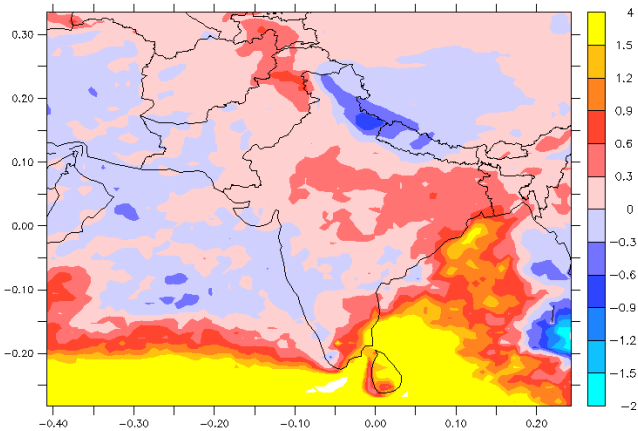
ECHAM - F1



ECHAM - F2

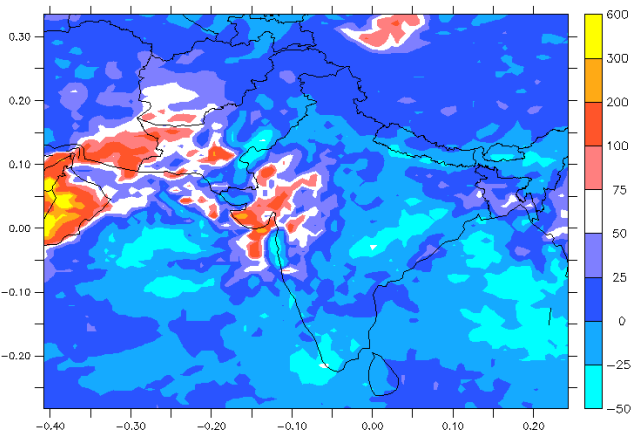


FVGCM - F2

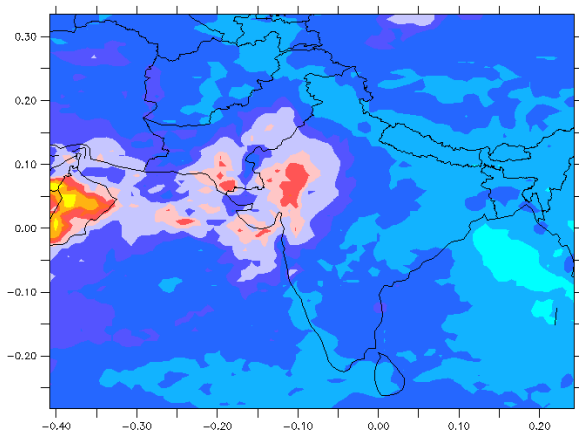


Percentage Change in Precipitation (%)

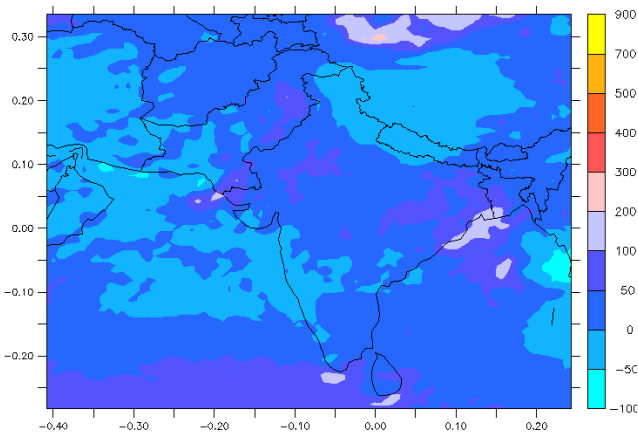
ECHAM - F1



ECHAM - F2



FVGCM - F2



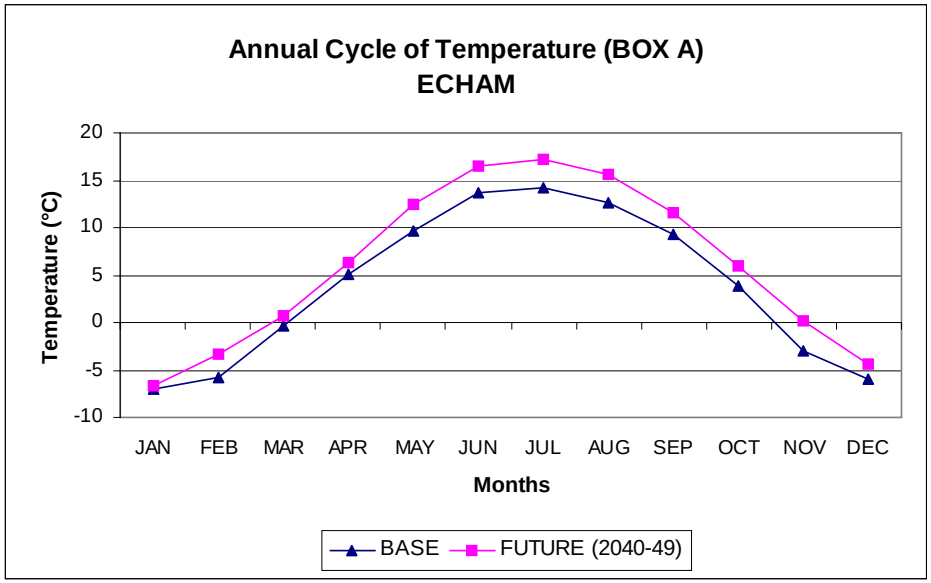
Climate Change - Summary of Precipitation and Temperature Changes over Selected Regions

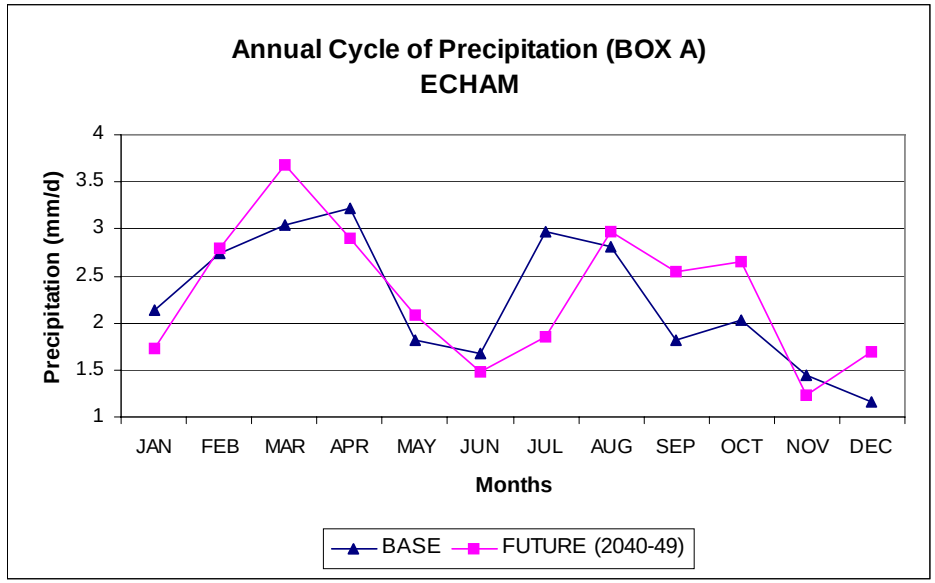
PRECIPITATION (mm/d) % Change			
(ECHAM, 2040-49)			
	Annual	**Summer (JJAS)**	**Winter (DJFM)**
BOX A	2.81	-4.60	15.84
BOX B	3.60	-3.17	60.18
(ECHAM, 2071-80)			
BOX A	7.61	6.91	-6.62
BOX B	14.03	-3.51	62.17
(FVGCM, 2071-80)			
BOX A	-0.47	-15.21	7.26
BOX B	-13.20	-17.94	3.35

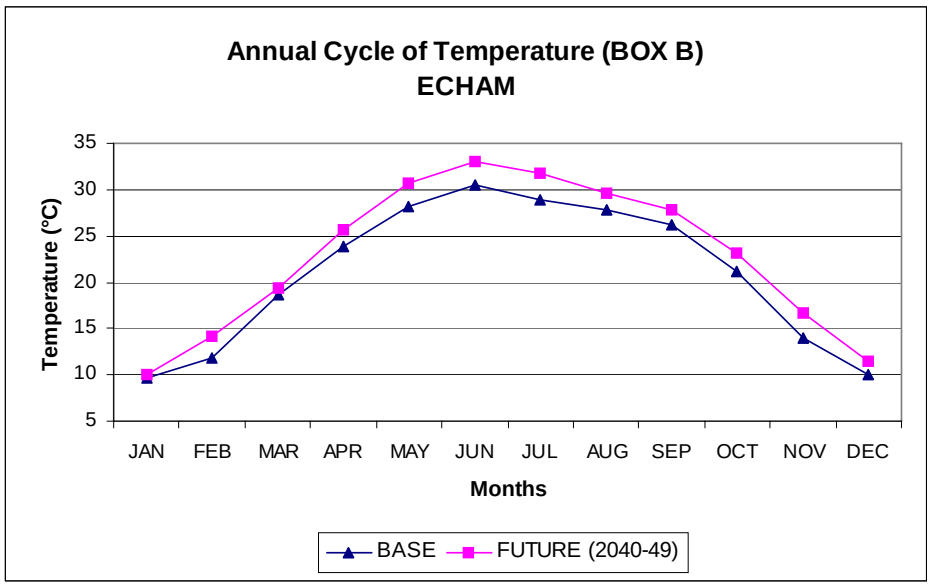
TEMPERATURE (°C) Change			
(ECHAM, 2040-49)			
	Annual	**Summer (JJAS)**	**Winter (DJFM)**
BOX A	2.16	2.72	1.61
BOX B	1.89	2.20	1.74
(ECHAM, 2071-80)			
BOX A	4.40	4.58	4.30
BOX B	2.55	3.90	3.35
(FVGCM, 2071-80)			
BOX A	3.19	3.58	3.09
BOX B	3.12	3.59	2.76

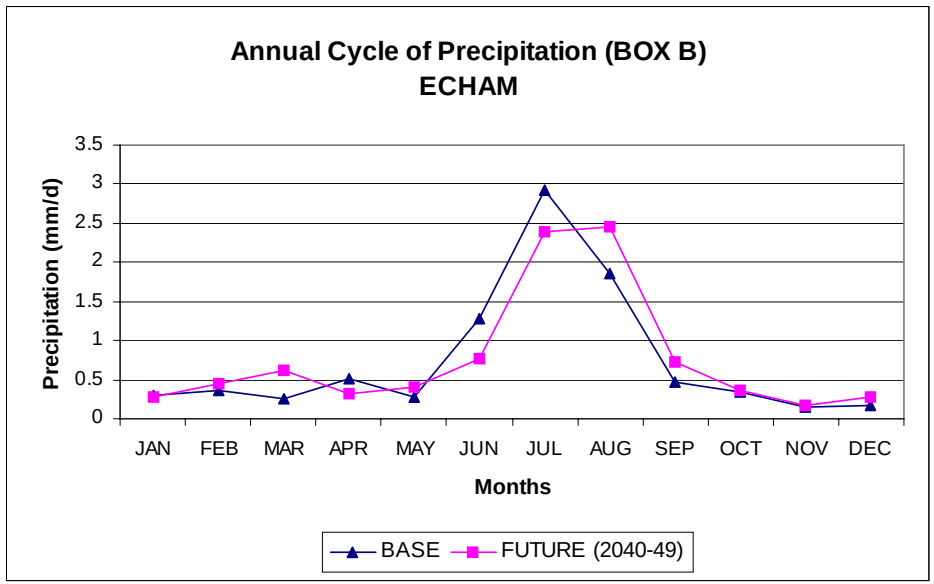
Climate Change - Annual Cycle of Temperature over Selected Regions of Pakistan

ECHAM



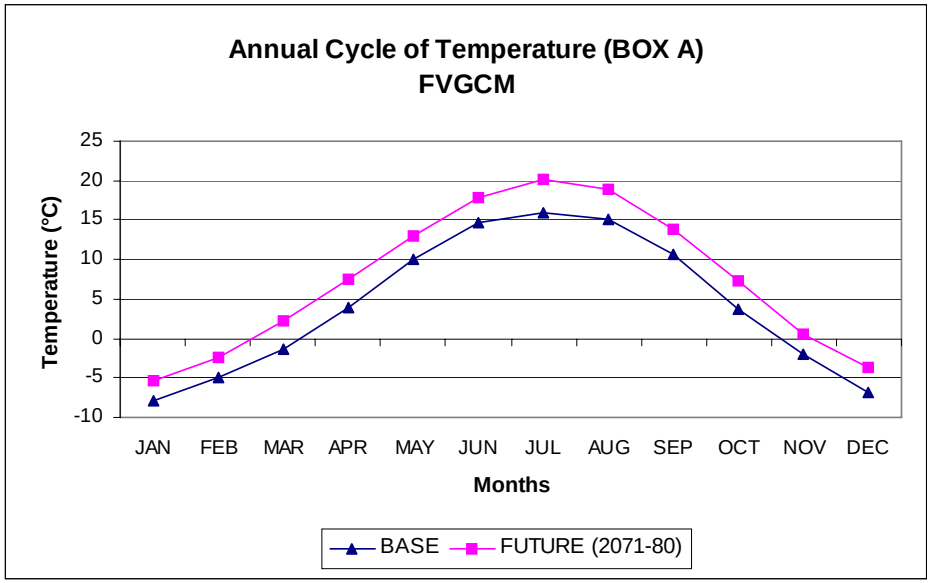


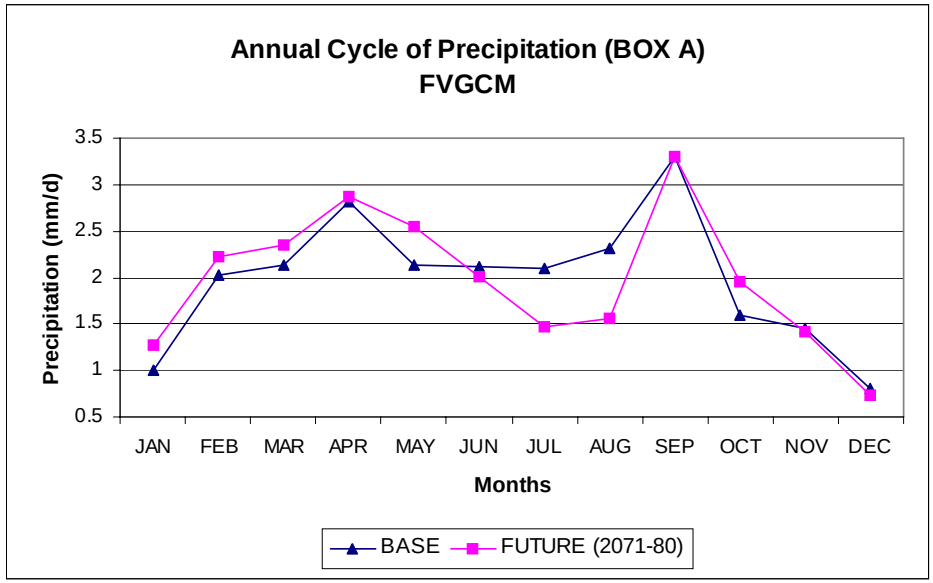


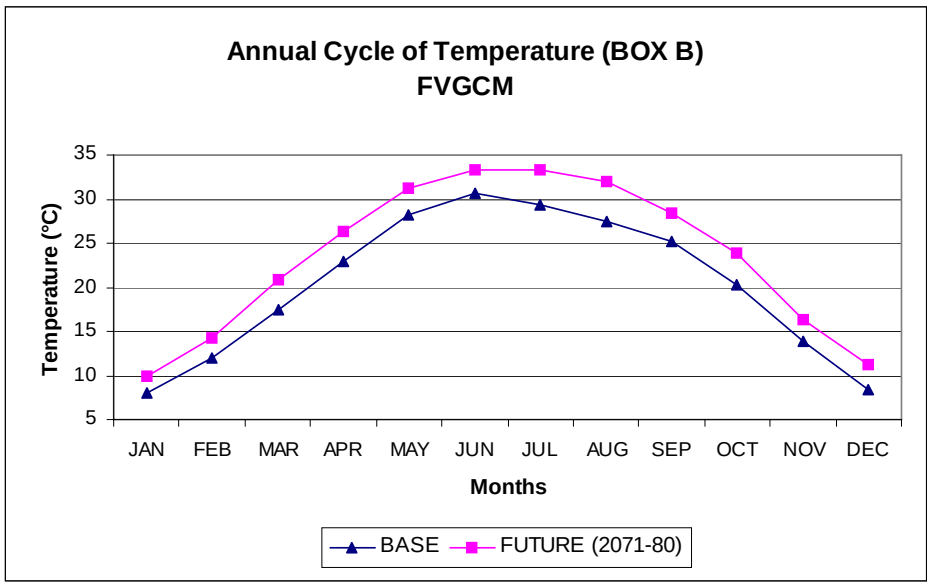


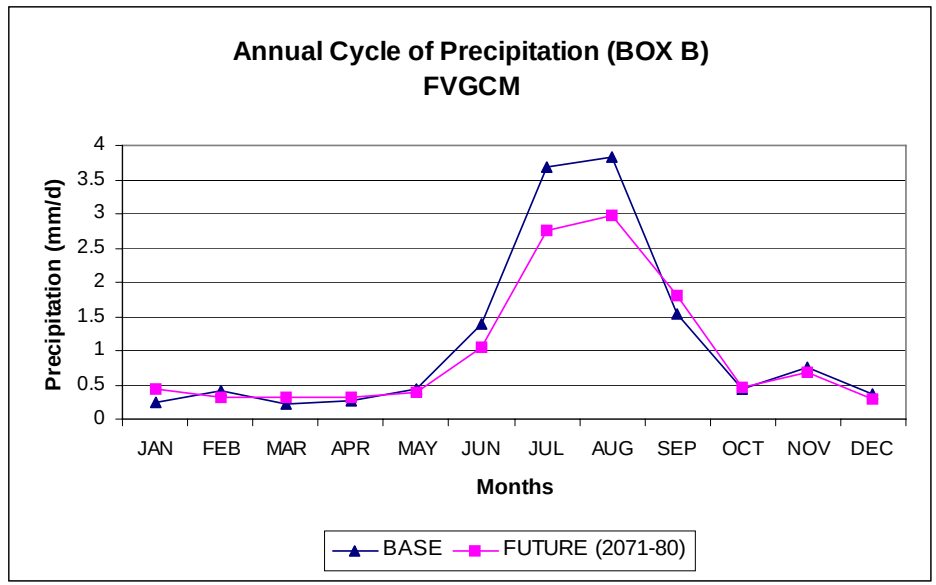
Climate Change - Annual Cycle of Temperature over Selected Regions of Pakistan

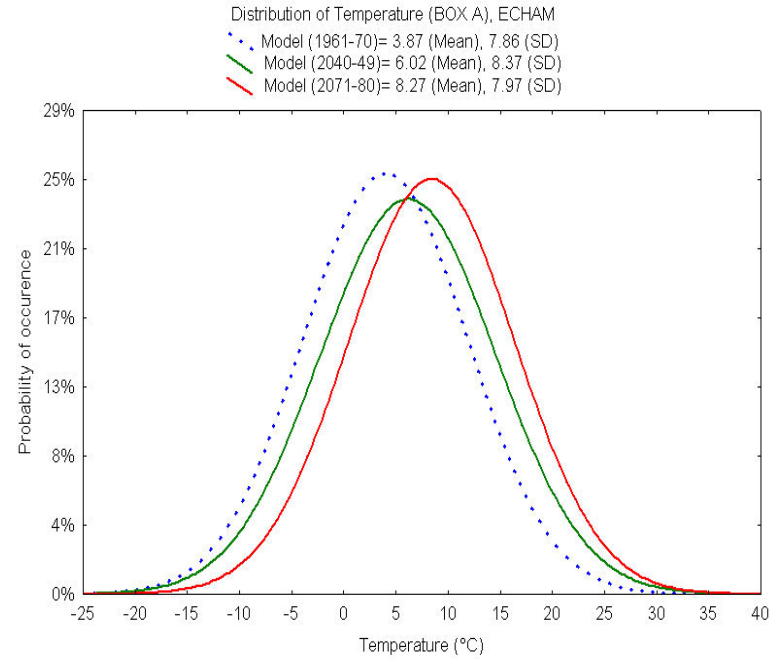
FVGCM

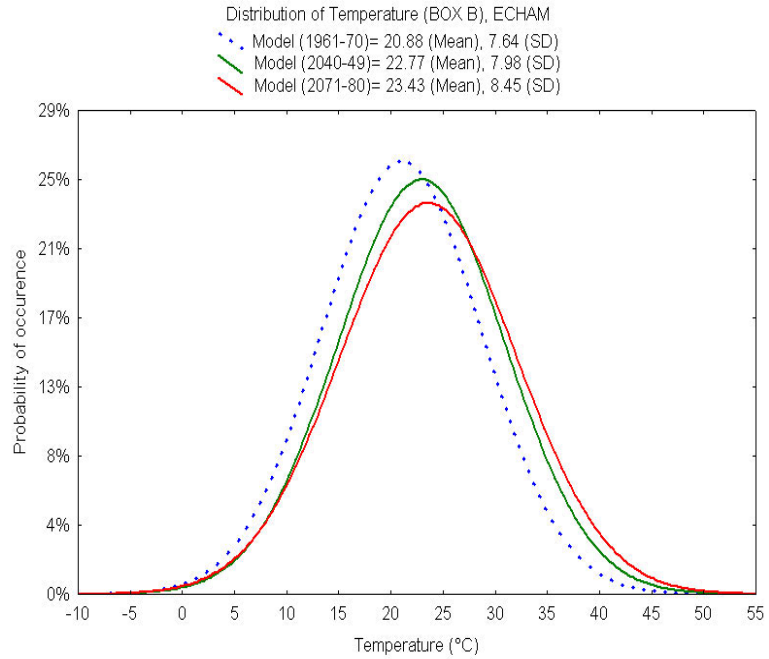


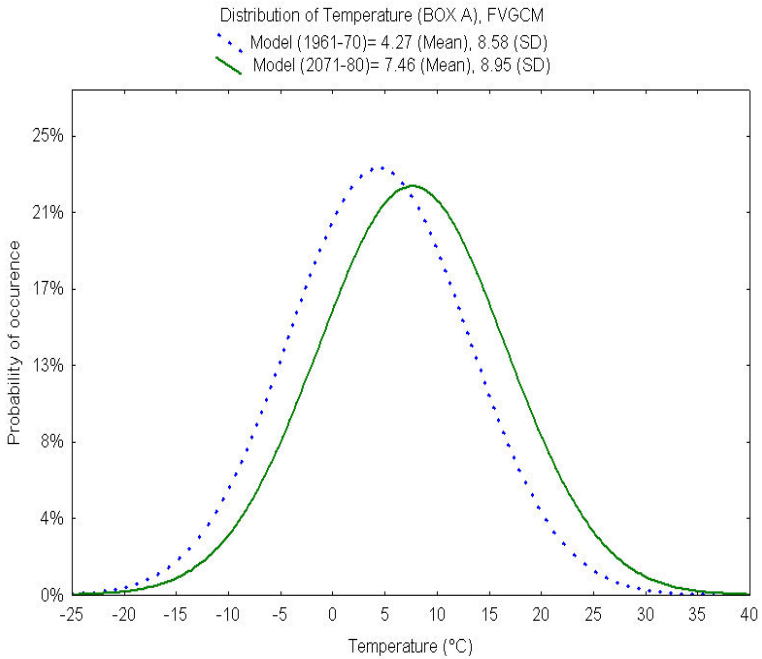


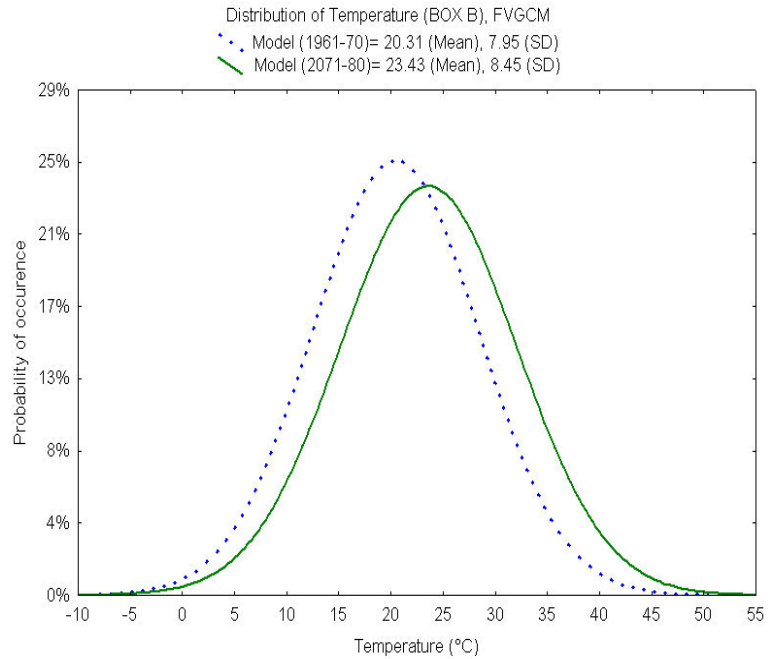





Distribution of Temperature (BOX A), ECHAM
Model (1961-70)= 3.87 (Mean), 7.86 (SD)
Model (2040-49)= 6.02 (Mean), 8.37 (SD)
Model (2071-80)= 8.27 (Mean), 7.97 (SD)
Probability of occurence
Temperature (°C)


Distribution of Temperature (BOX B), ECHAM
Model (1961-70)= 20.88 (Mean), 7.64 (SD)
Model (2040-49)= 22.77 (Mean), 7.98 (SD)
Model (2071-80)= 23.43 (Mean), 8.45 (SD)
Probability of occurence
Temperature (°C)


Distribution of Temperature (BOX A), FVGCM
Model (1961-70)= 4.27 (Mean), 8.58 (SD)
Model (2071-80)= 7.46 (Mean), 8.95 (SD)
Probability of occurence
Temperature (°C)


Distribution of Temperature (BOX B), FVGCM
Model (1961-70)= 20.31 (Mean), 7.95 (SD)
Model (2071-80)= 23.43 (Mean), 8.45 (SD)
Probability of occurence
Temperature (°C)

Acknowledgement

We are thankful to Earth System Physics Group (ESP), of Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste Italy for Providing the GCMs Data and Technical Support.

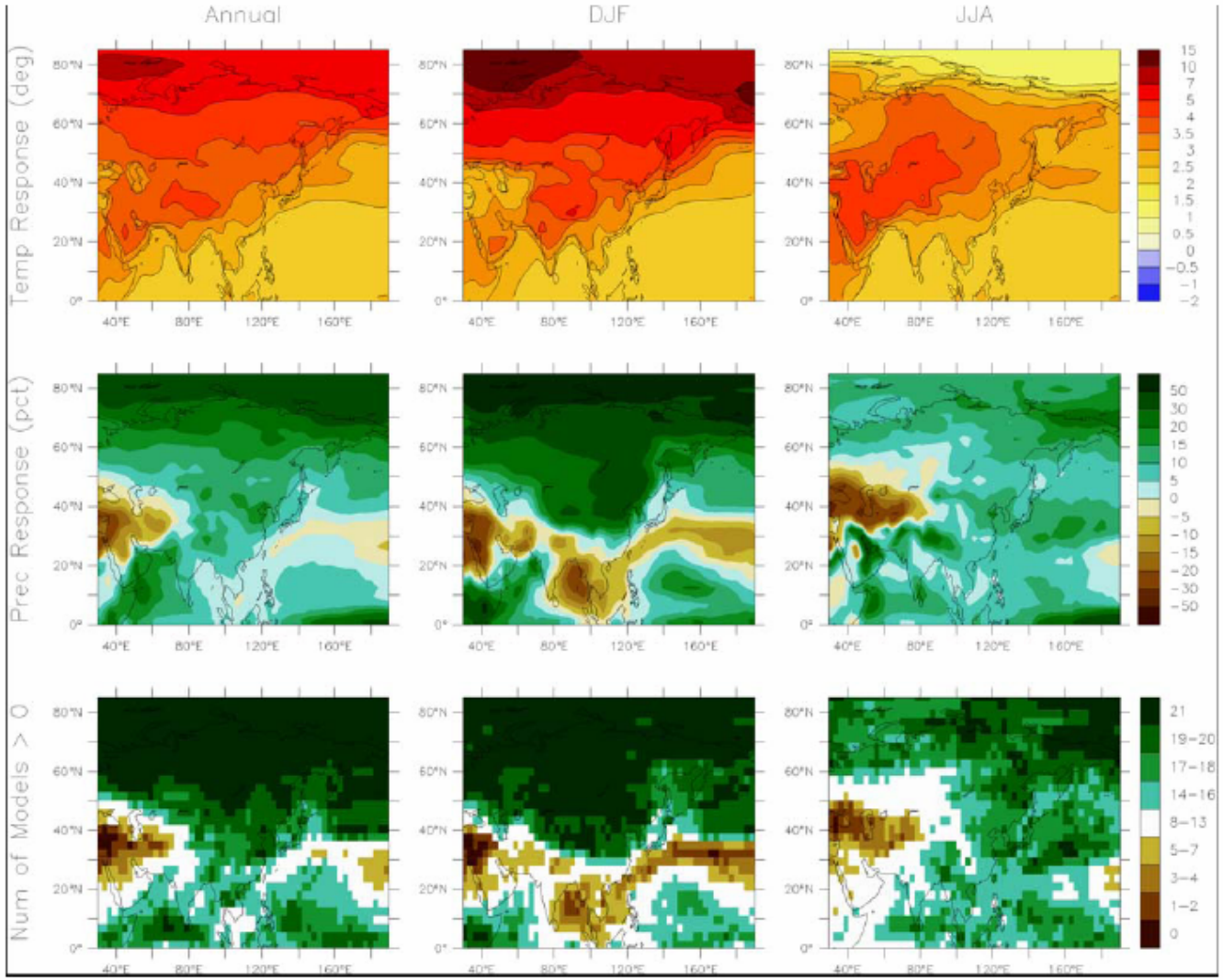


Figure 11.3.4.4. Consensus AR4 GCM A1B temperature and precipitation changes over Asia. Top row: Annual mean, December-January-February, and June-July-August temperature change between 1980–1999 in the 20C3M simulations and 2080–2099 in A1B, averaged over 21 models. Middle row: same for fractional change in precipitation. Bottom row: number of models out of 21 that project precipitation to increase.

a)

b)

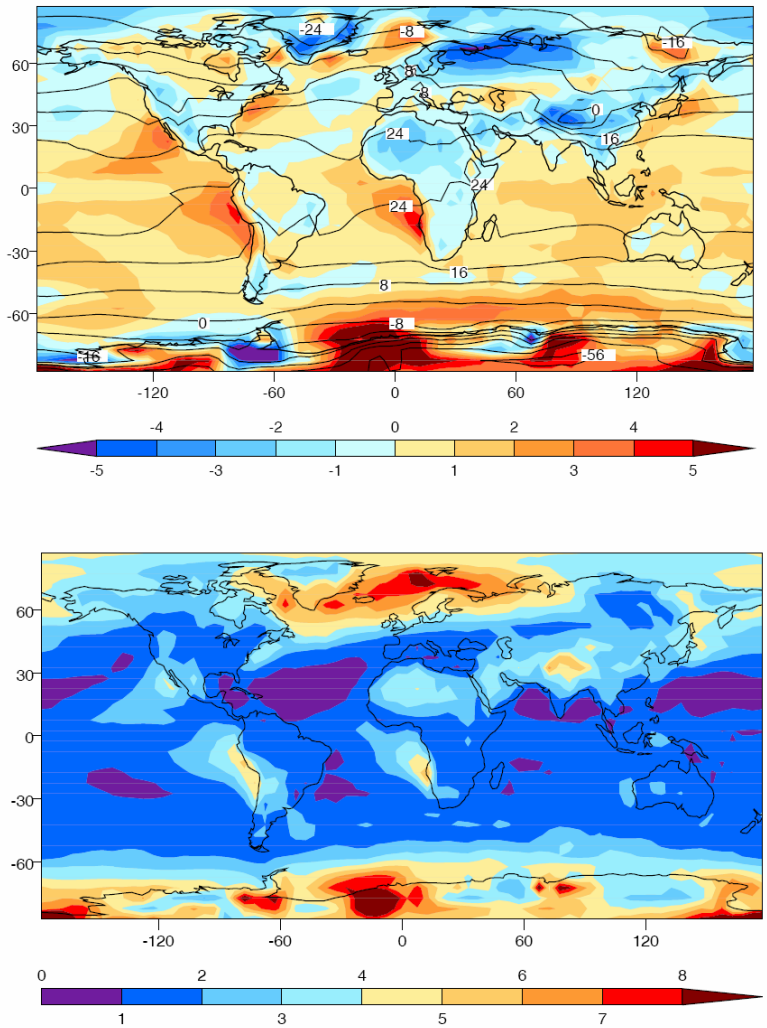
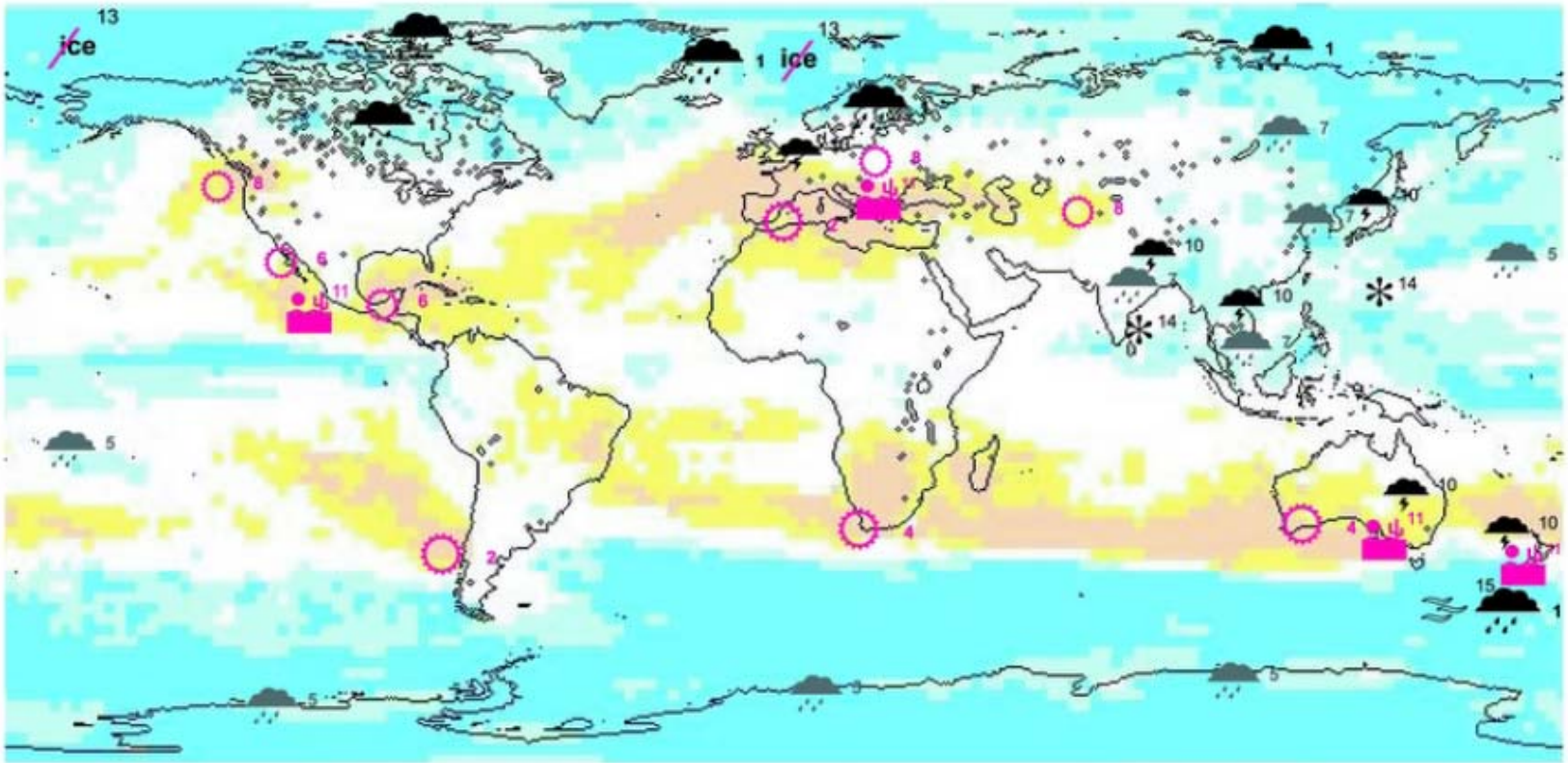


Figure 8.3.1. Observed climatological annual-mean sea surface temperature (SST) and, over land, surface air temperature (labeled contours in panel a) and the multi-model mean error in these temperatures, simulated minus observed (color-shaded contours in panel a); also typical model error, as gauged by the root-mean-square model error in this temperature, based on all available IPCC model simulations (panel b). The observations are from the CRU merged SST and surface air temperature dataset for the period 1961–1990 (Jones et al., 1999), and the model results are from years 1980-1999 of the CMIP 20th Century simulations. Temperature units are °C.

June-July-August (JJA)

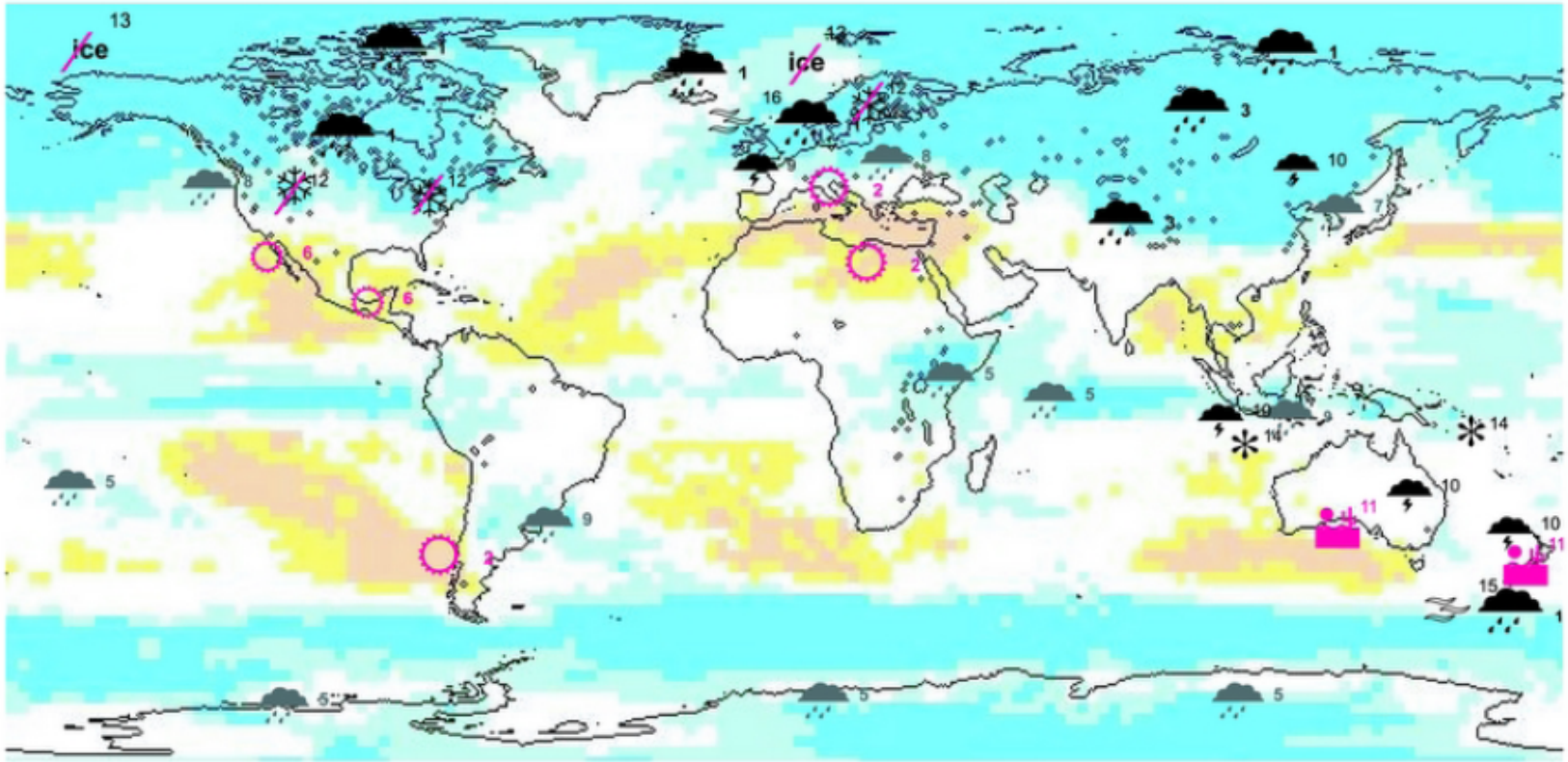


Precipitation increase in ≥90% of simulations
Precipitation increase in ≥75% of simulations
Precipitation decrease in ≥75% of simulations
Precipitation decrease in ≥90% of simulations

Based on regional studies assessed in chapter 11:

Precipitation decrease – very likely
Precipitation decrease – likely
Precipitation increase – very likely
Precipitation increase – likely
Increased drought – likely
Precipitation extreme increase – likely
Increased extreme winds – likely
Less snow – very likely
Increased peak intensity of TCs – likely
Reduced sea Ice – very likely

December-January-February (DJF)



Precipitation increase in ≥90% of simulations
Precipitation increase in ≥75% of simulations
Precipitation decrease in ≥75% of simulations
Precipitation decrease in ≥90% of simulations

Based on regional studies assessed in chapter 11:

- Precipitation decrease – very likely
- Precipitation decrease – likely
- Precipitation increase – very likely
- Precipitation increase – likely
- Increased drought – likely
- Precipitation extreme increase – likely
- Increased extreme winds – likely
- Less snow – very likely
- Increased peak intensity of TCs – likely
- Reduced sea Ice – very likely