Climate Variability, Extremes and Change in West Asia

Mansour Almazroui

Center of Excellence for Climate Change Research (CECCR)
King Abdulaziz University, Jeddah, Saudi Arabia
E-mail: monsour@kau.edu.sa

Introduction

To enhance general awareness and knowledge on climate variability, weather extremes and changes in climate related issues in a region such as West Asia, the followings are needed:

- **Monitoring Climate Variability**
- **Identifying Weather Extremes**
- **Understanding Changes in Climate**

for the present and future periods

Above task requires precise climate data and identification/analysis methods.

Weather/ Weather Extremes
Climate/Climate Variability
and Climate Change

Weather: Weather is the state of the atmosphere at any given time and place.

Extremes: Severe weather events are called extremes. Examples are cyclones, tornadoes, duststorms, sandstorms, blizzards, thunderstorms, droughts, heat waves and cold waves.

Climate: Climate is the average weather in a given place, usually over a period of more than 30 years. While the weather can change in just a few hours, changes in climate occur over longer timeframes.

Climate Change: Climate change is a long-term change in the statistical distribution of weather patterns over periods of time (reference period) that range from decades to millions of years.

Climate variability: Climate variability is the change in patterns of climate elements such as rainfall and temperature distributions and magnitudes.

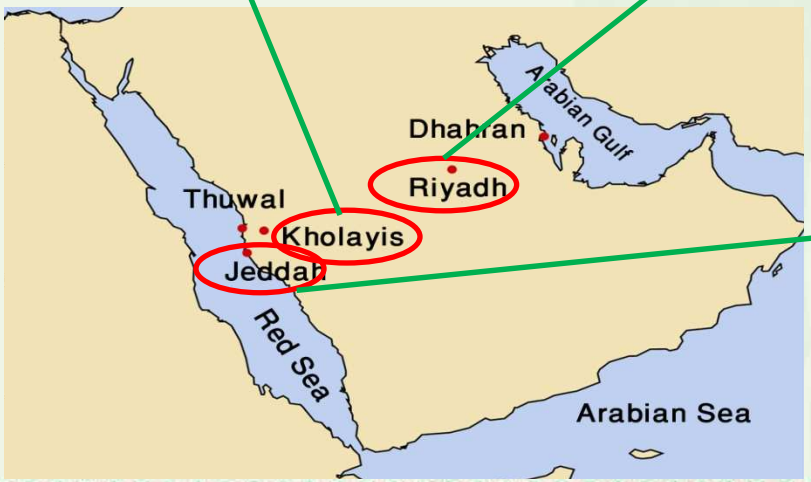
Example of Weather Event

Rainfall event

Duststorm event

Evidence of Weather Extremes at local level

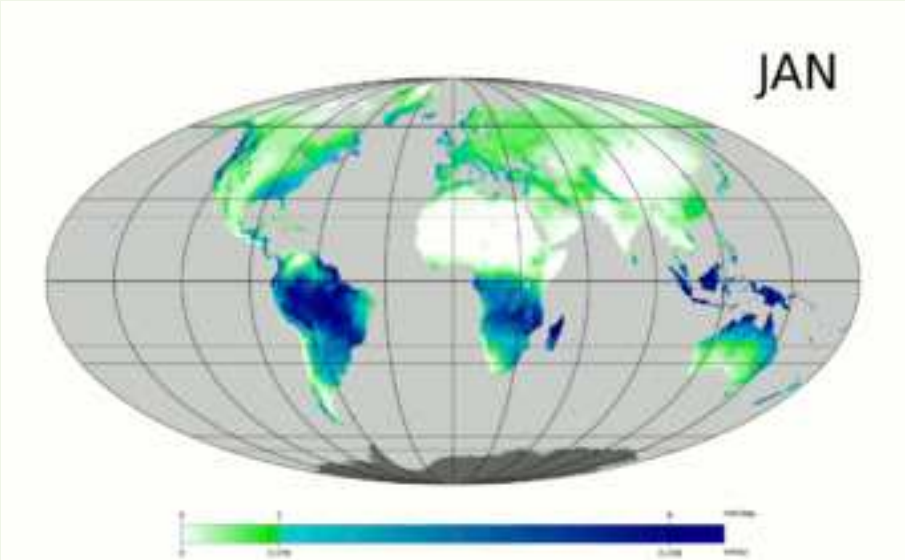
Extreme Dry Condition: Kholayis 2009

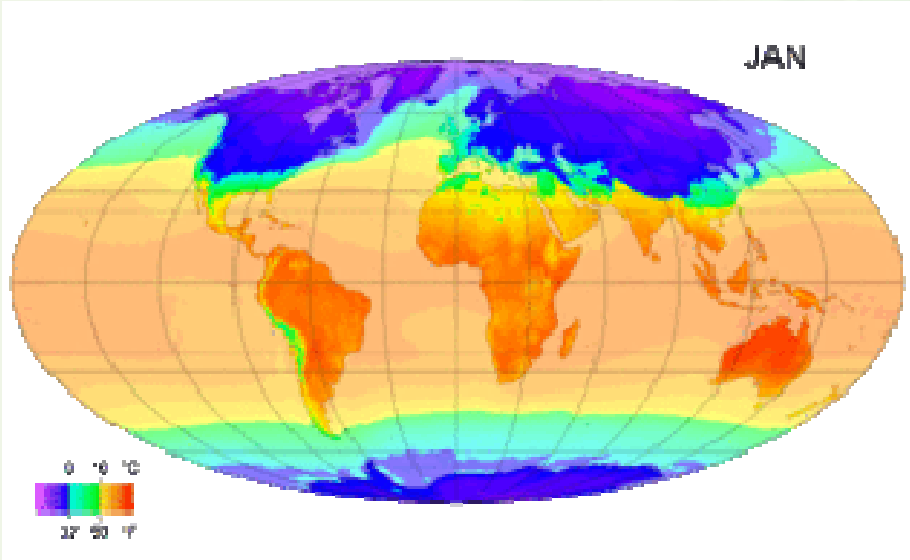


Extreme Rainfall Event in Riyadh: 05 MAY 2010

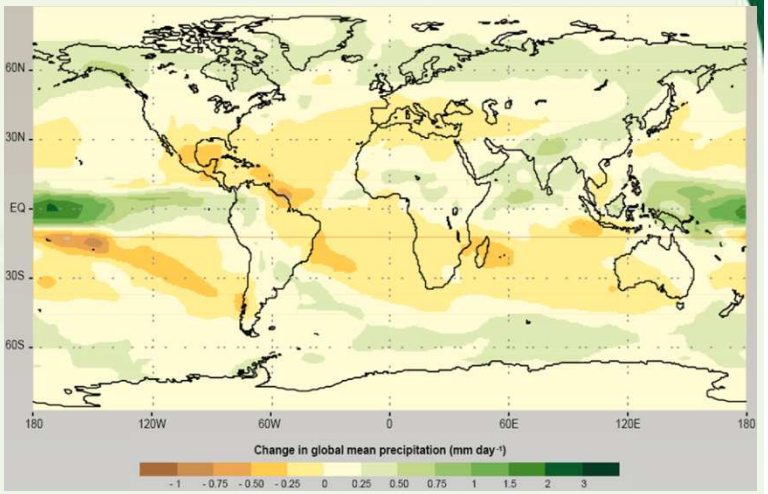
Extreme Rainfall Event in Jeddah: 25 NOV 2009

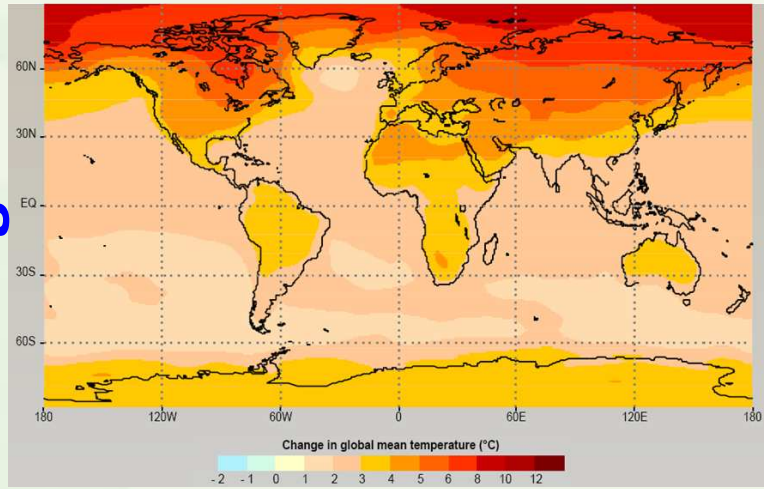
Average monthly Rainfall /Temperature in the World 2009



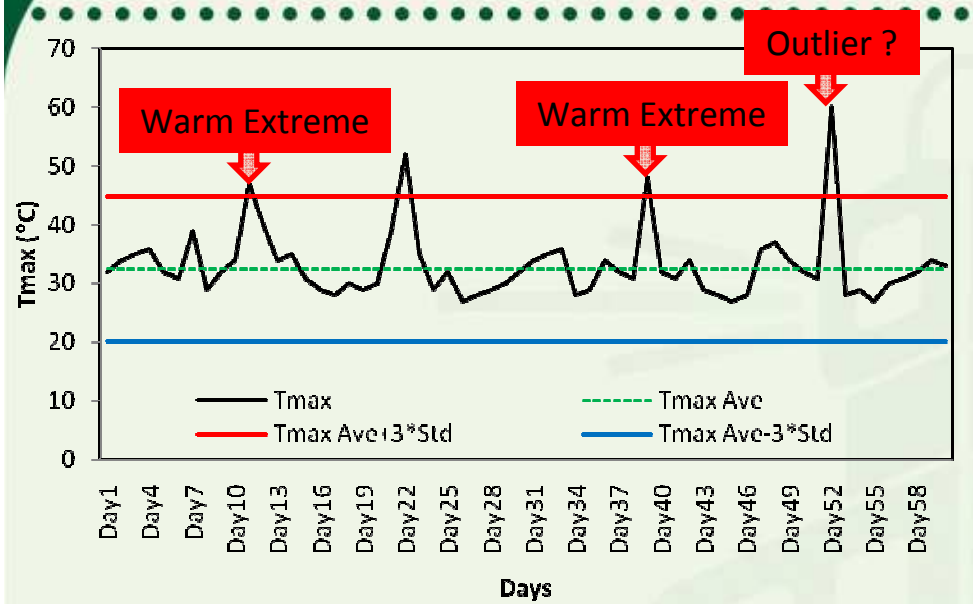


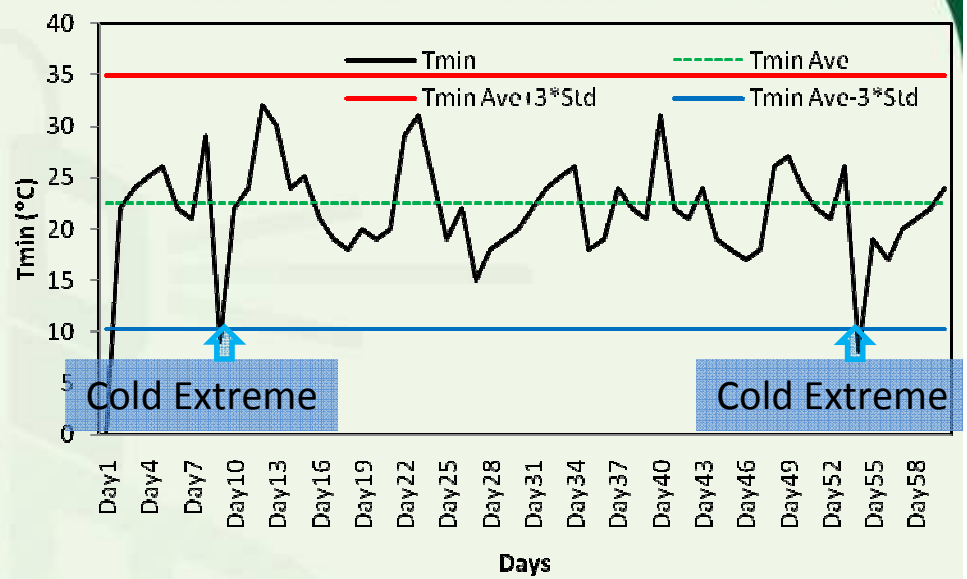
Changes in Climate





Changes of rainfall (top) and temperature (bottom) for the period 2071-2100 compared with the reference period 1961-1990.

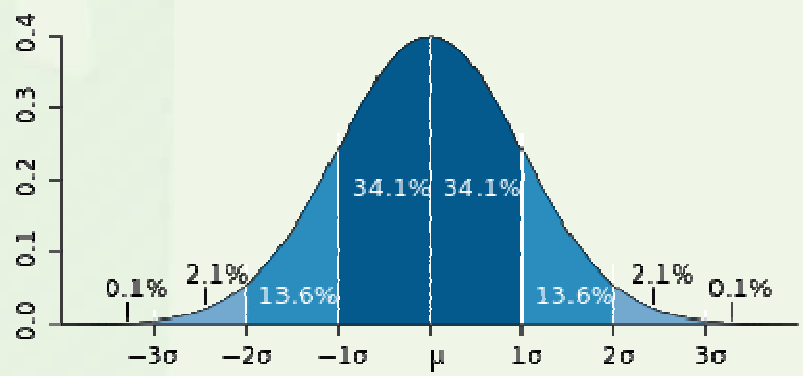




Average: Average is the mathematical mean that means add all data values and then divide by the number of data points.

Extreme: Extremes are the data values far from the mean, usually above or below a specific threshold.

Standard deviation: Standard deviation provides the spread or variation from the mean. Low (high) standard deviation means data are close (far) to (from) the mean.

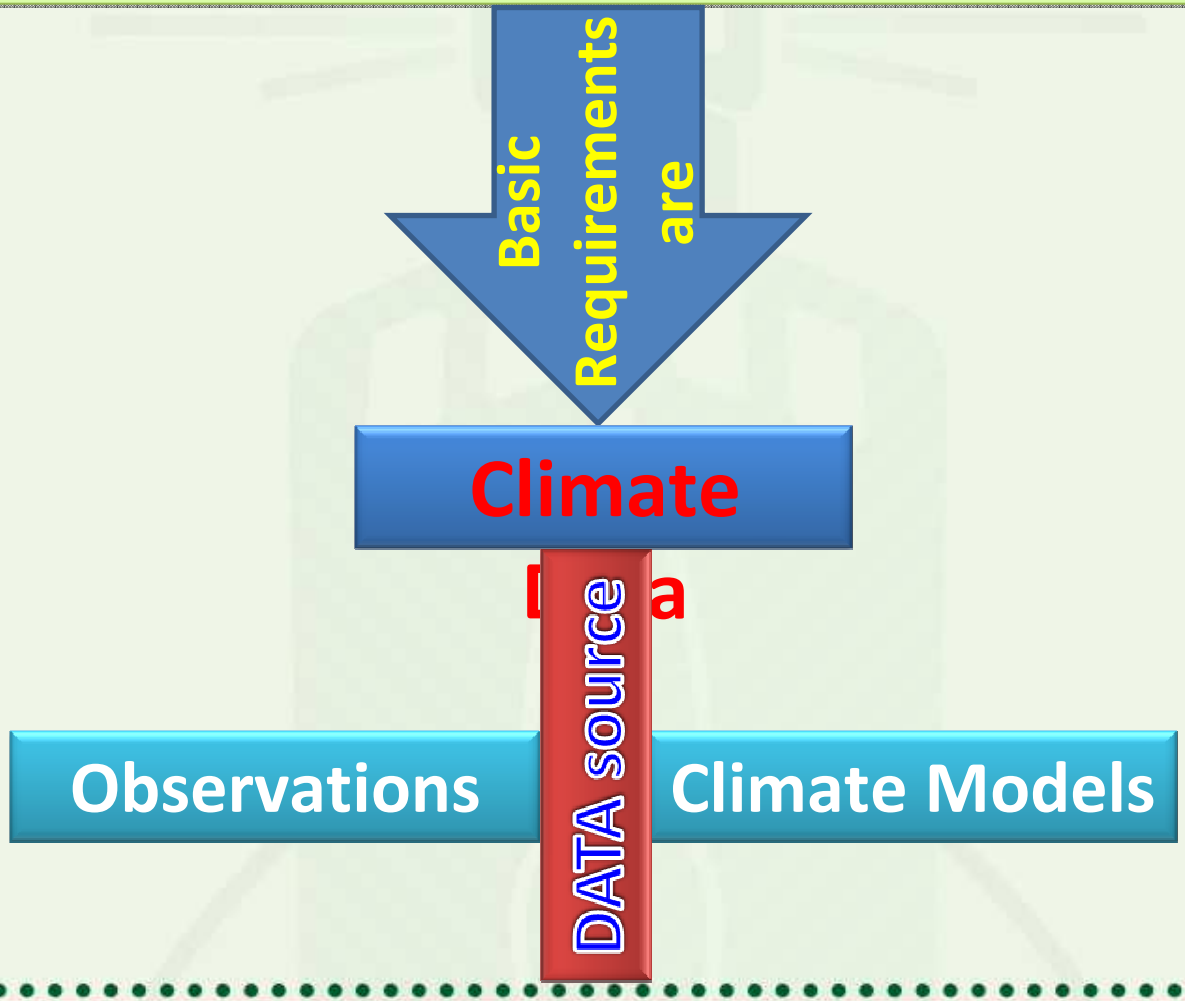


Outliers (including Extremes) lie at the upper and lower tails of the distribution curve.

To enhance better Monitoring climate elements, our aim is to find out the "Sources of Scientific Data on Climate Variability" and "Analysis Procedure to detect Weather Extremes and Changes"

Monitoring

Climate Variability, Extremes & Changes

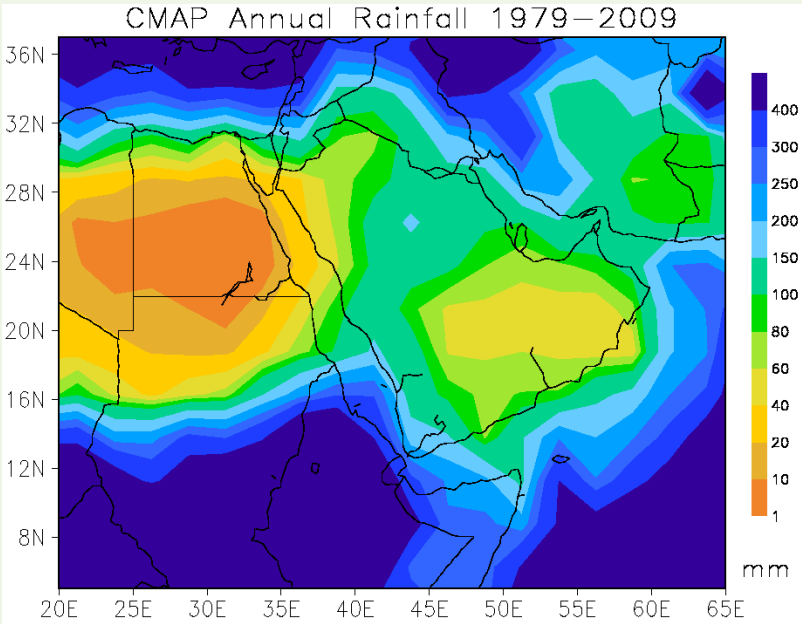


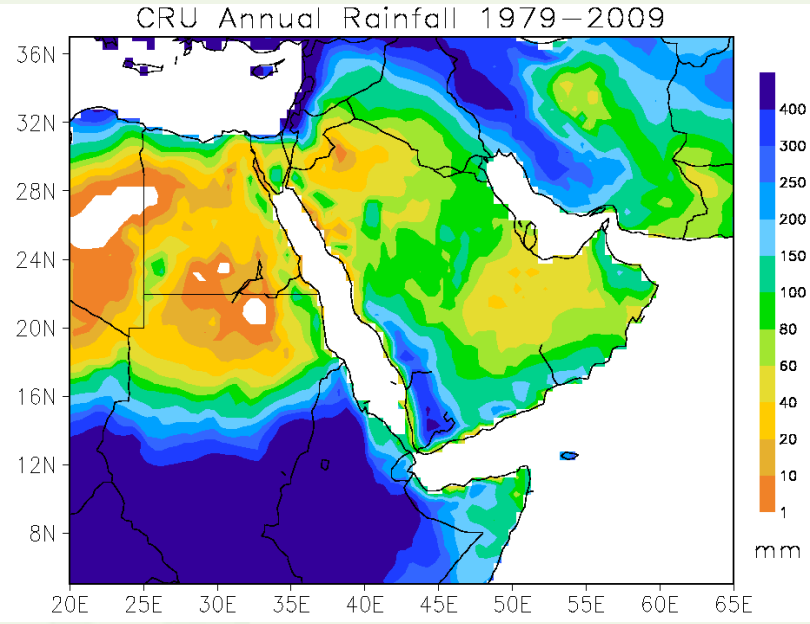
Observations
(Climate variability)

Causes of climate variability include:

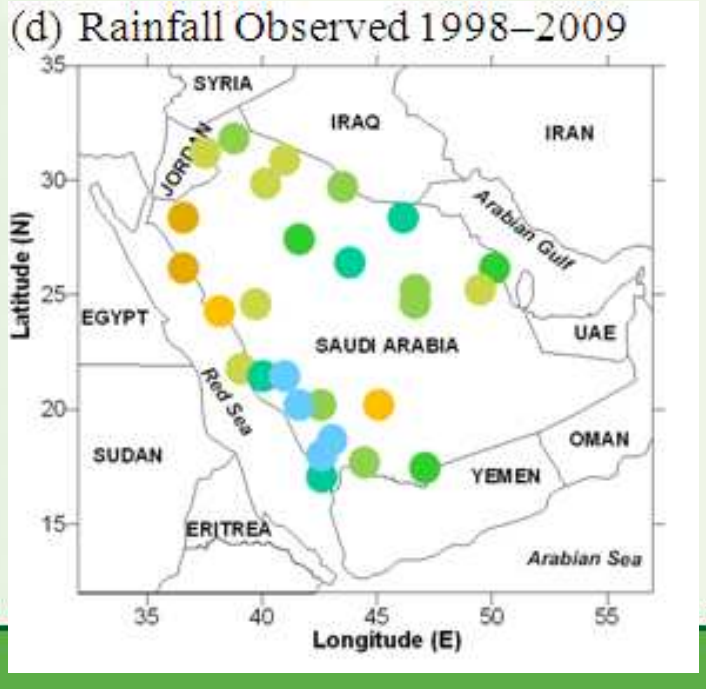
1. Changes in the Earth's orbit
2. Changes in the Sun's intensity
3. Volcanic Eruptions
   - Aerosol emissions
   - Carbon dioxide emissions
4. Changes in Greenhouse gas concentrations
5. Changes in Ocean currents

Spatial Distribution of Rainfall



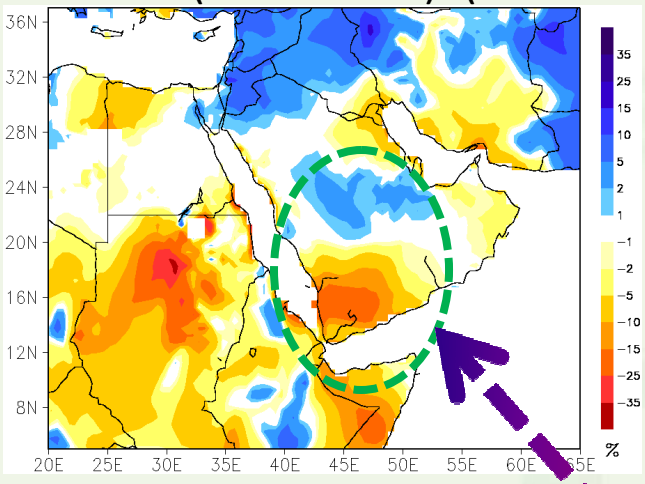


Observed climatology shows that rainfall varies from one region to another AND one location to another.

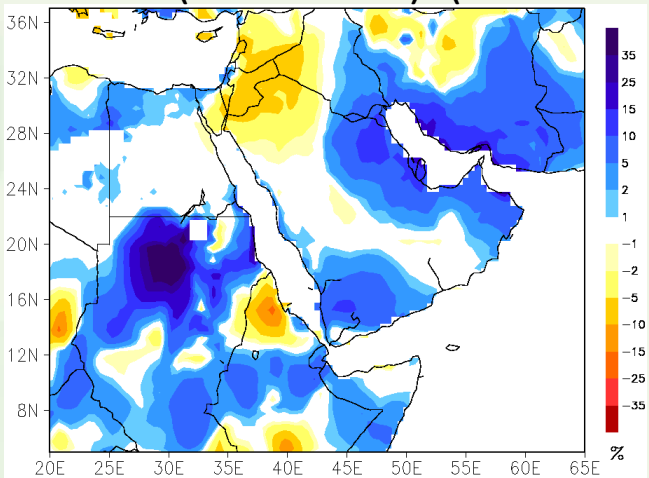


Rainfall Variability (decadal)

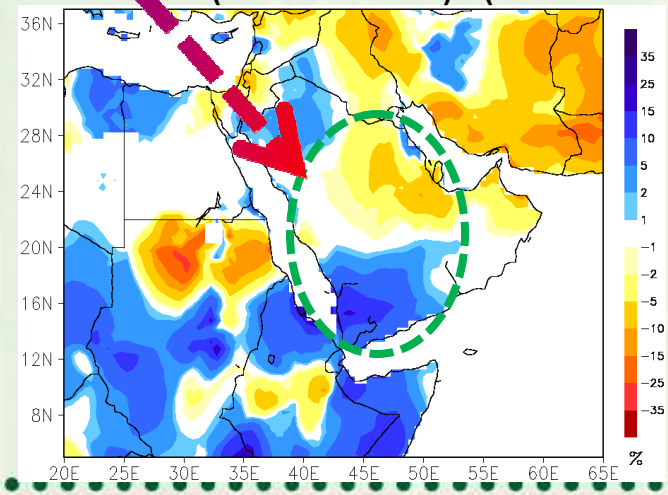
Rainfall CRU (1980–1989)–(1979–2009)



Rainfall CRU (1990–1999)–(1979–2009)

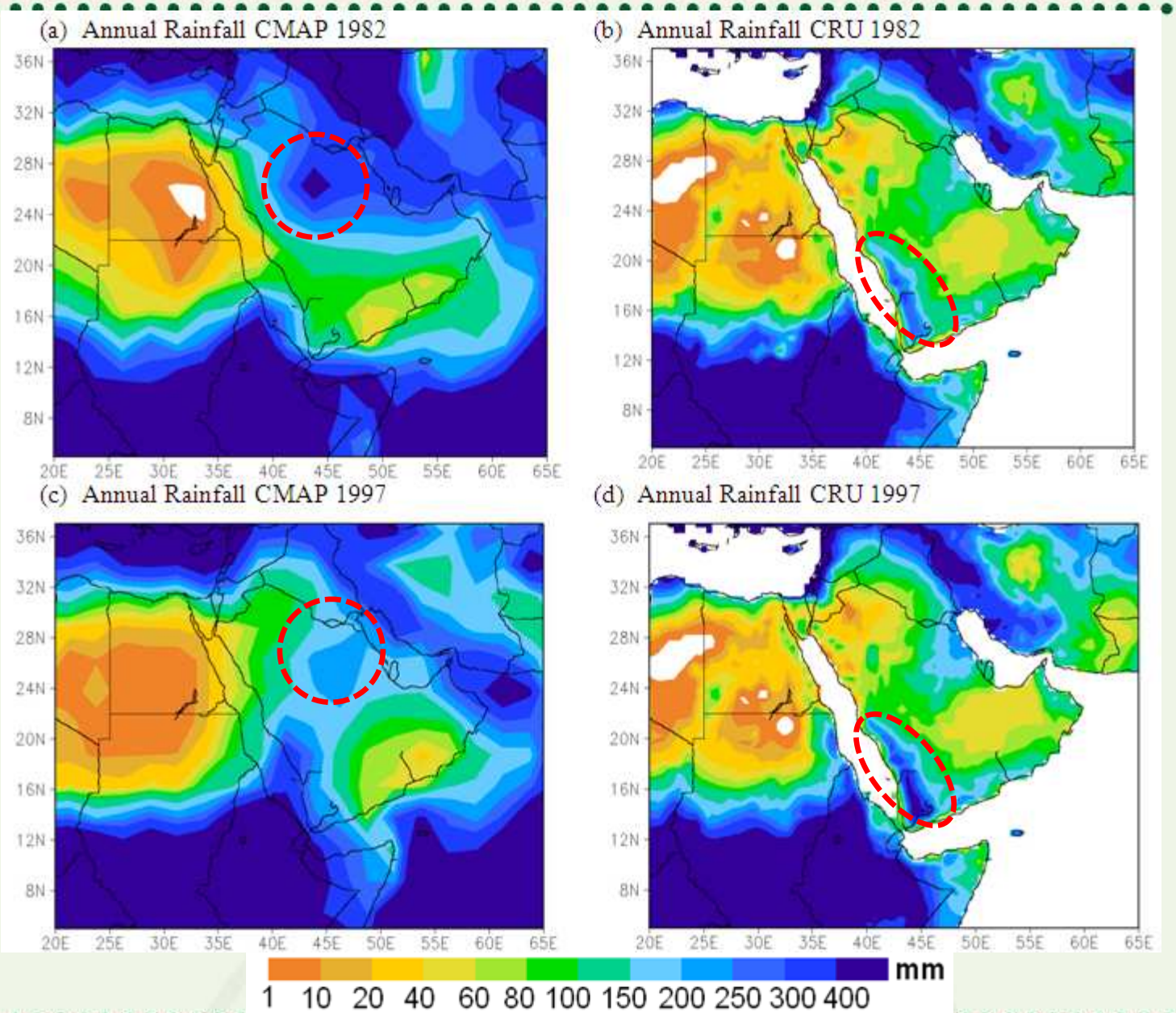


Rainfall CRU (2000–2009)–(1979–2009)



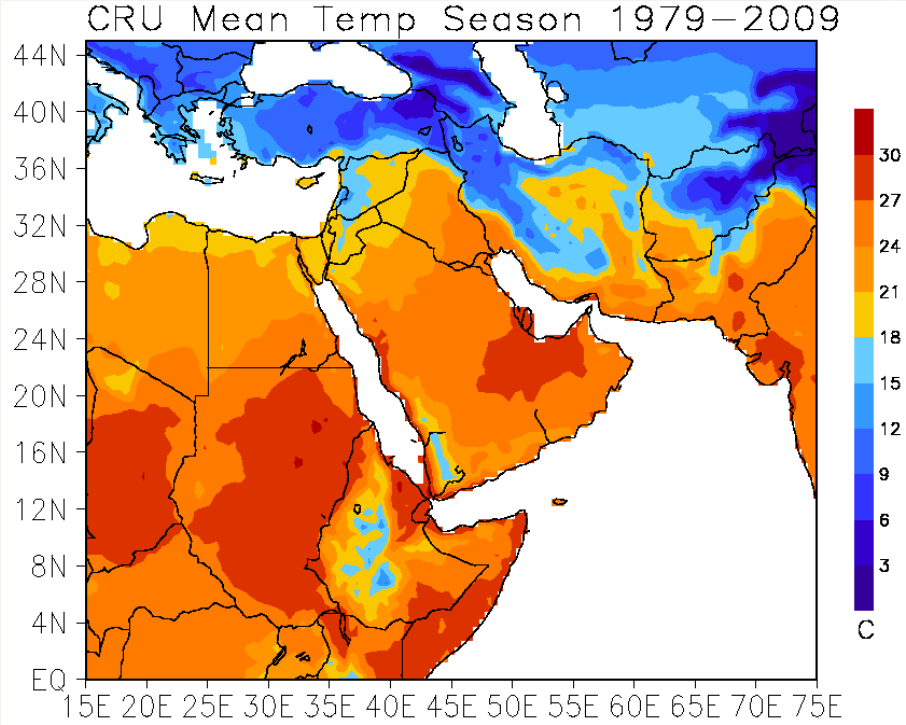
Rainfall in the DECADE 2000-2009 is completely in out-of-phase from the DECADE 1980-1989.

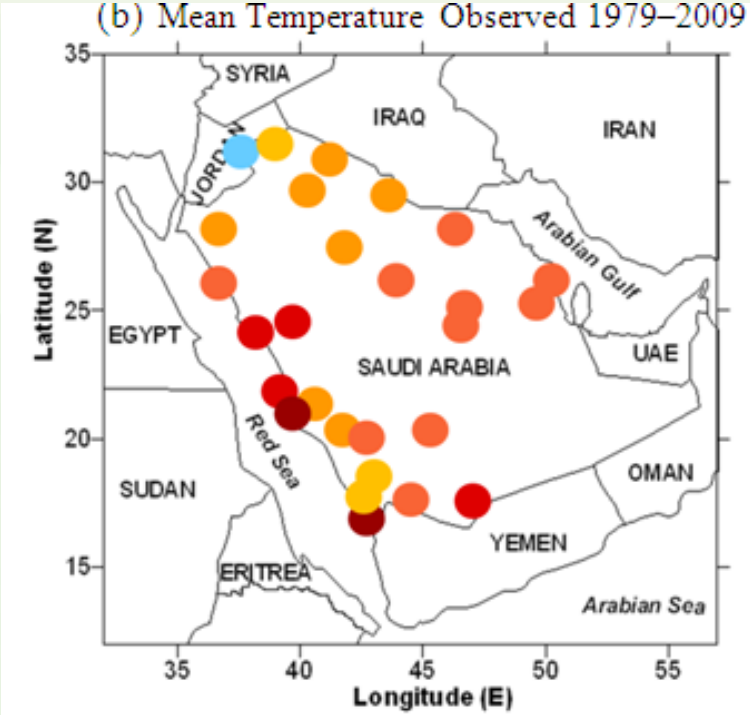
Year to Year variation of Rainfall

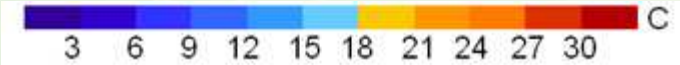


Year to year variation of rainfall is very clearly shown here.

Spatial Distribution of Tmean



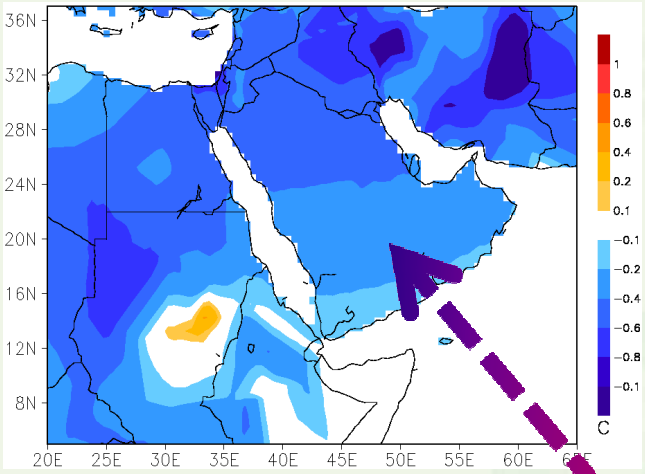




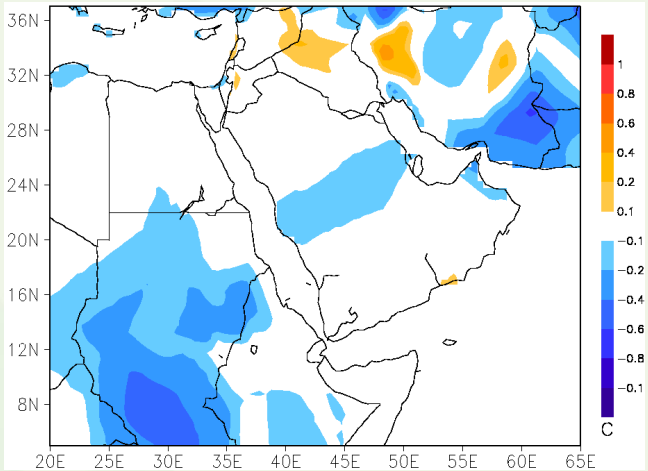
Variation of temperature is relatively less than the rainfall, however temperature variation is observed region to region.

Tmean Variability (decadal)

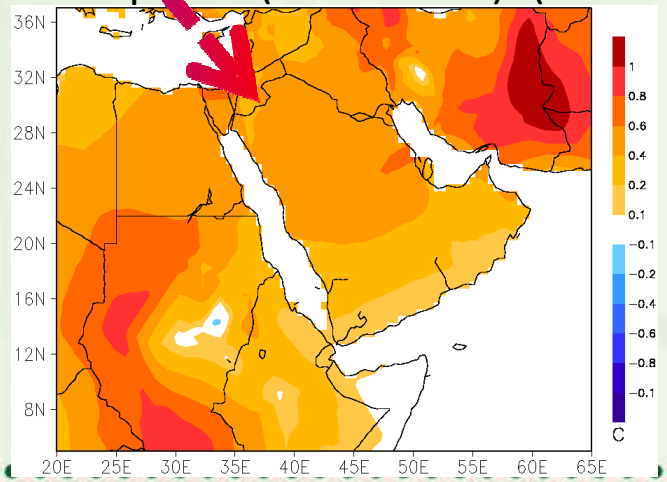
Mean Temp CRU (1980–1989)–(1979–2009)



Mean Temp CRU (1990–1999)–(1979–2009)

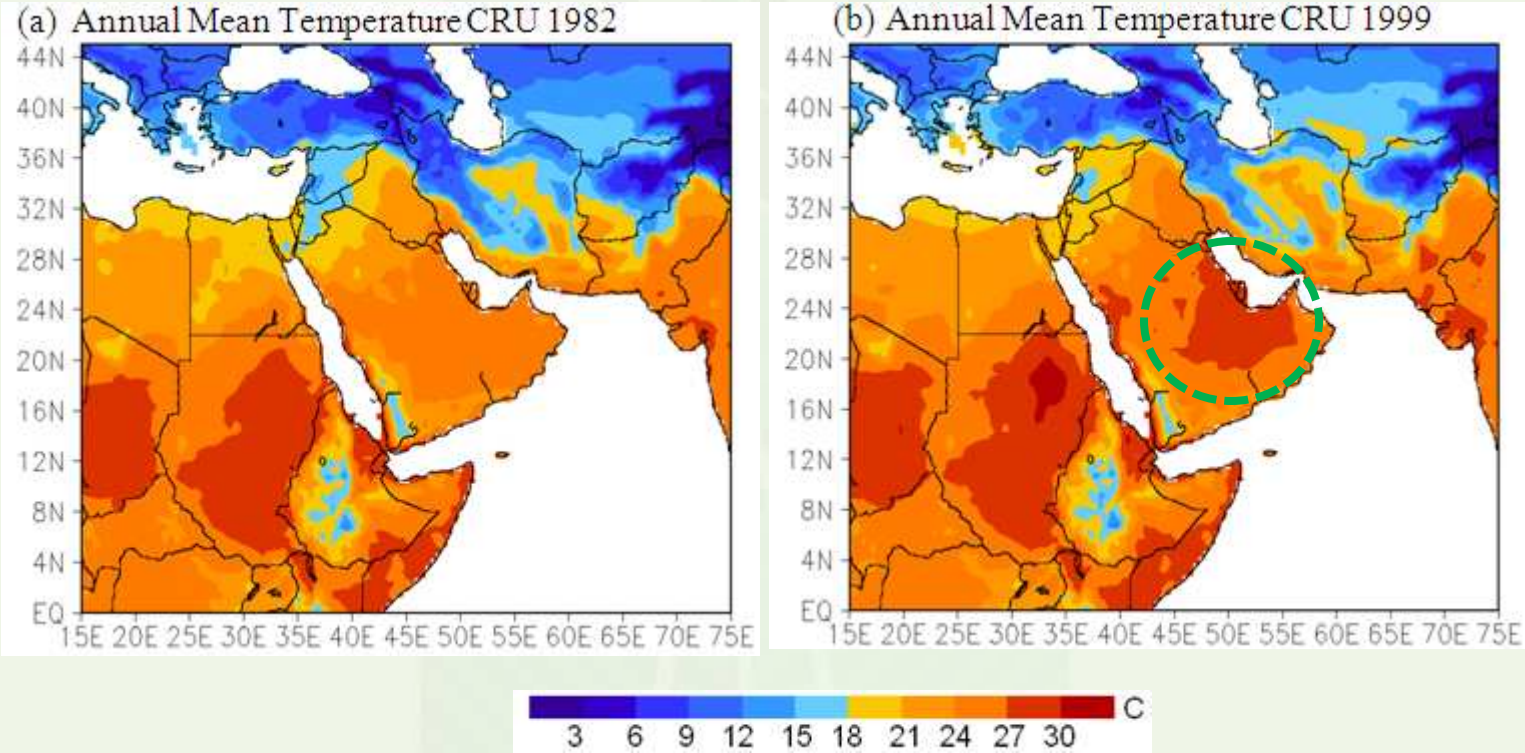


Mean Temp CRU (2000–2009)–(1979–2009)



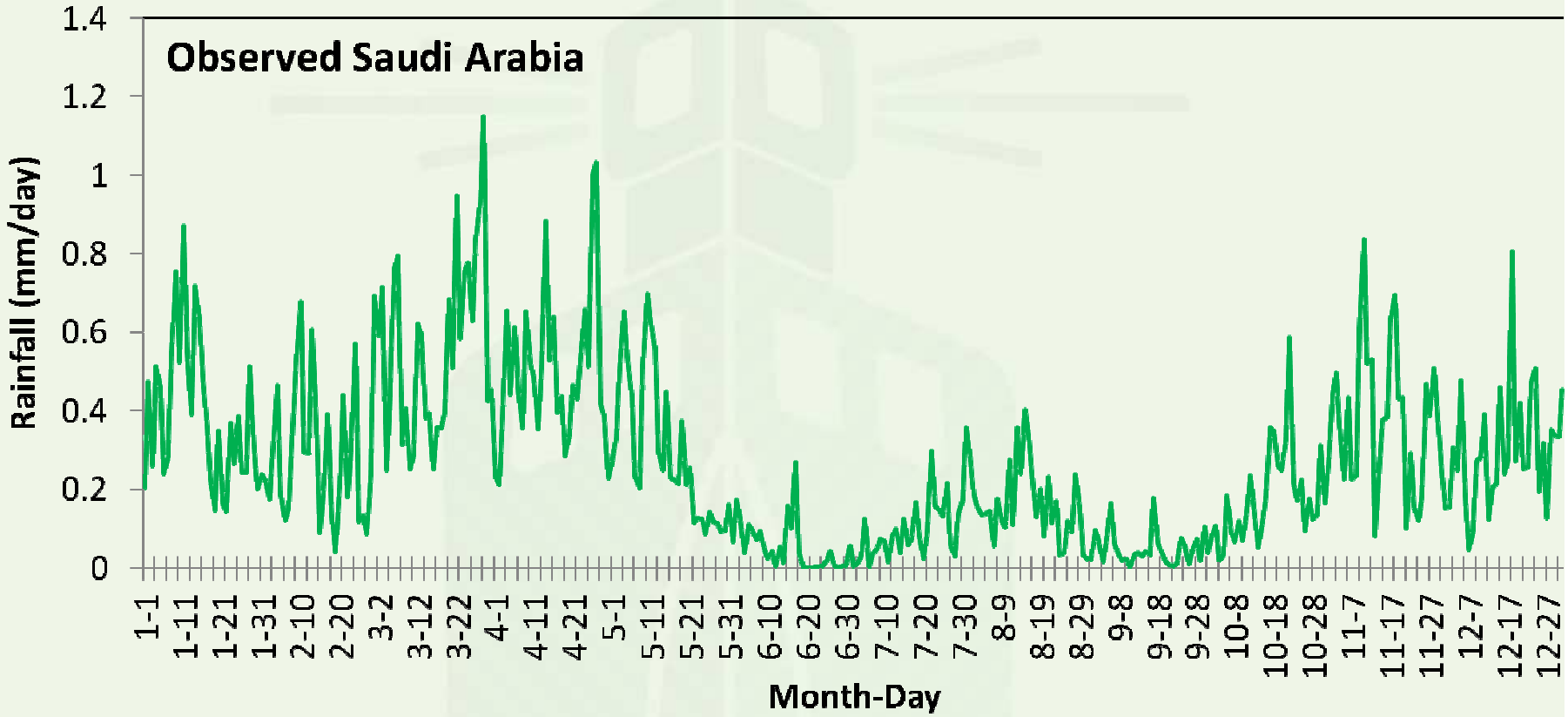
Temperature in the DECADE 2000-2009 is completely in out-of-phase from the DECADE 1980-1989. Increased temperature in the entire domain.

Year to Year variation of Tmean



Year to year variation of temperature is very clearly shown here.

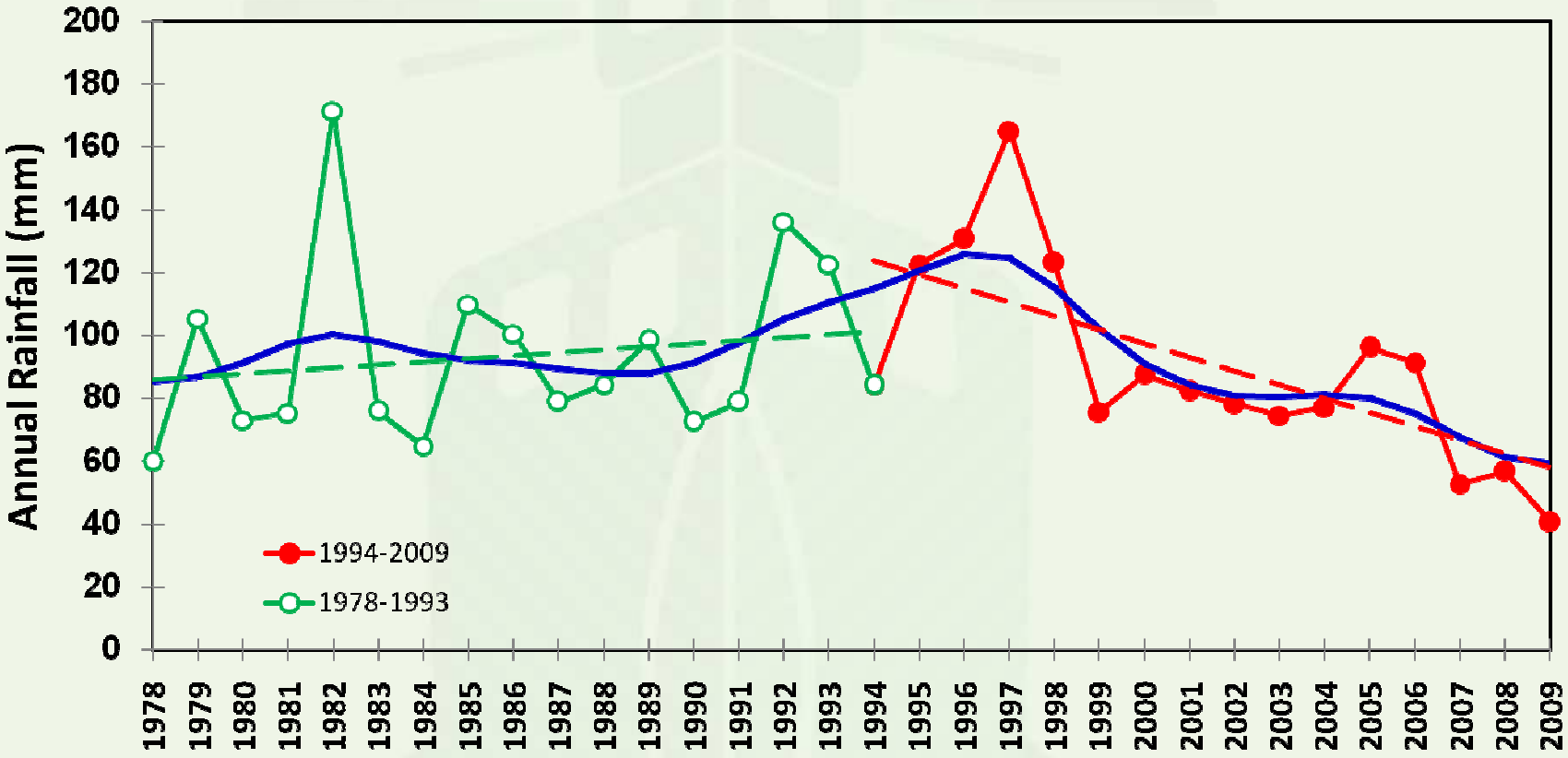
Variability of Rainfall at daily scale



Daily data averaged over 30-year period provides climate of the day. Hence the time series is climatic variation of daily rainfall in 365 days.

Interannual variability of Rainfall

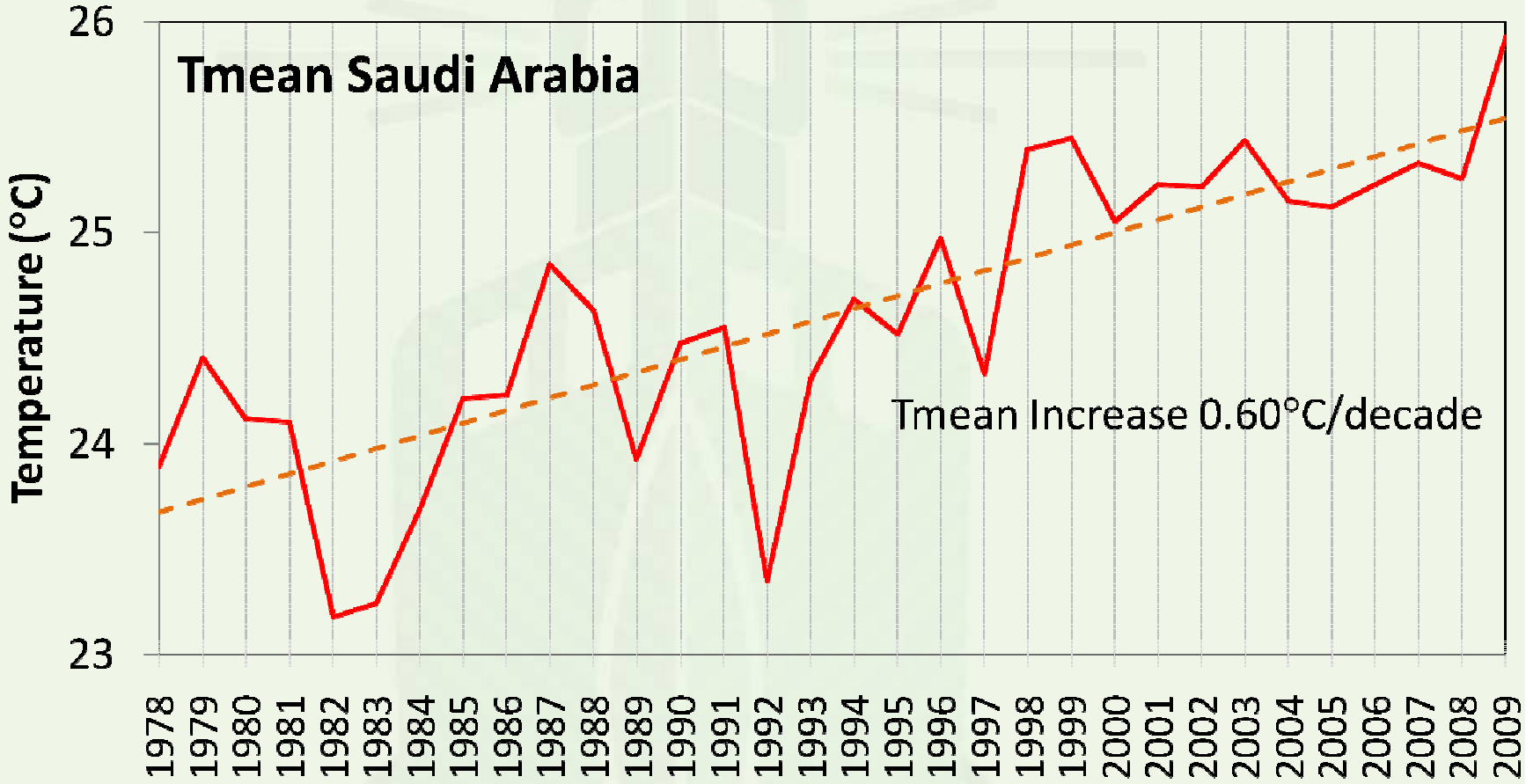
Average Annual Rainfall in Saudi Arabia (1978-2009)



Rainfall Average = 92 mm/year

Interannual variability of Tmean

Average Annual Tmean in Saudi Arabia (1978-2009)



Tmean Average = 25°C

Observations
(Weather Extremes)

Weather Extremes Calculation

- Extreme events are calculated based on the standard software developed by the Expert Team on Climate Change Detection Indices (ETCCDI, http://etccdi.pacificclimate.org/software.shtml). ETCDI is a joint WMOCCl/CLIVAR/JCOMM Expert Team.

- This calculation procedure includes percentile, threshold, absolute and duration-based indices.

- Identification of threshold-based indices, such as maximum or minimum values for daily maximum and minimum temperatures, warm and cool days/nights are highly beneficial for application-oriented sectors such as agriculture, water resources, and power generation of a country.

Weather Extremes Calculation (Arab Region)

- ✓ A workshop was held in Casablanca, Morocco, in March 2012, to enhance knowledge of climate extremes and their changes in the Arab region.
- ✓ This workshop initiated intensive data compilation activities of daily observational weather station data from the Arab region.
- ✓ After conducting careful control processes to ensure the quality and homogeneity of the data, climate indices for extreme temperatures and precipitation were calculated.
- ✓ Final outcomes of the workshop is the ISI publication.

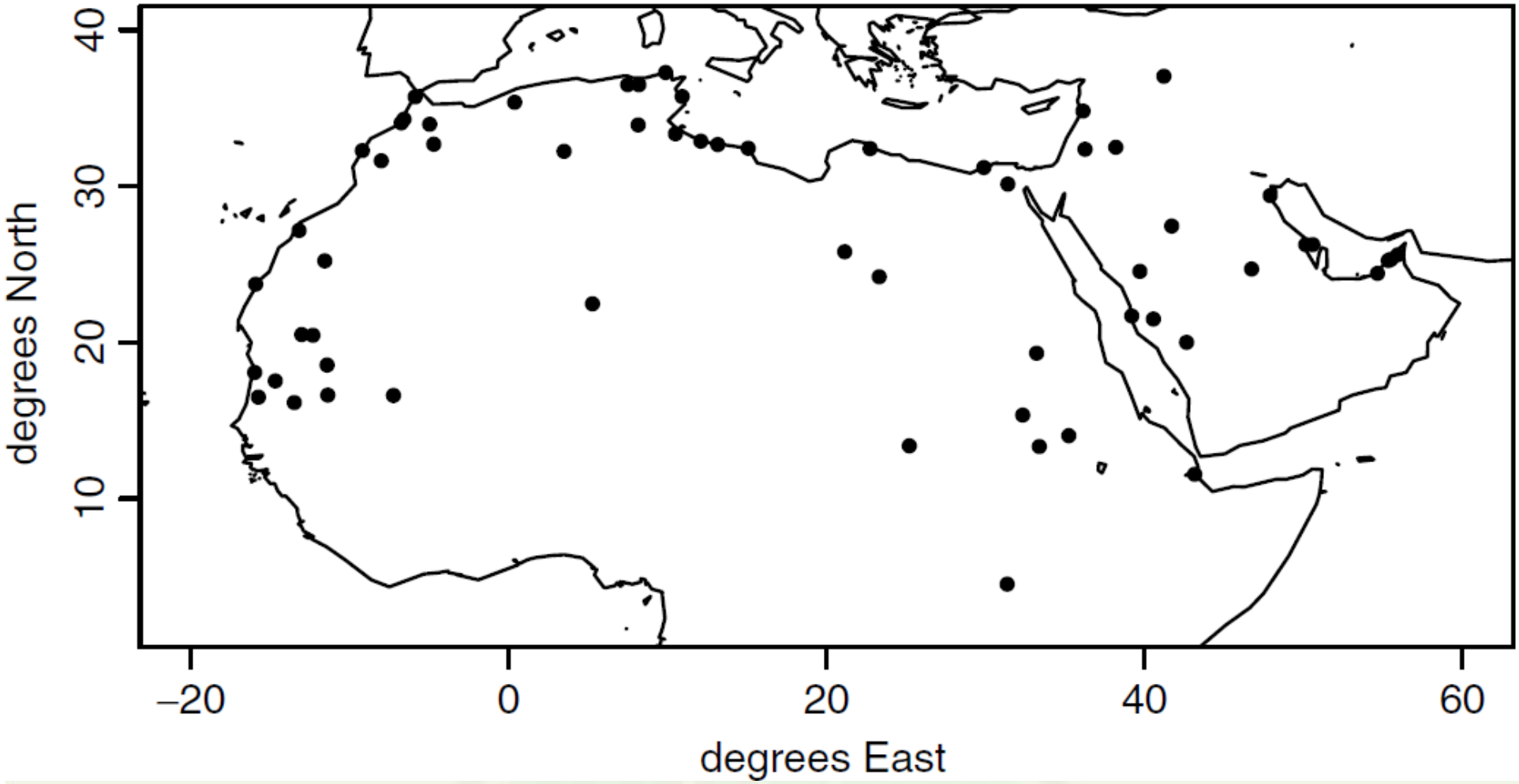
INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2013)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3707

RMetS
Royal Meteorological Society

Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO

M. G. Donat,[a,b*] T. C. Peterson,[c] M. Brunet,[d,e] A. D. King,[a,b] M. Almazroui,[f] R. K. Kolli,[g] et al.

Weather Extremes Calculation (Arab Region)



Locations of data used in Morocco workshop

Weather Extremes Calculation (Saudi Arabia)

- ✓ **Daily maximum and minimum temperatures across Saudi Arabia are used to construct 13 extreme temperature indices using RClimDex software.**
- ✓ **Quality checks on the daily data are carried out using the built-in tools in the RClimDex software, which identified potentially unrealistic climatic records or outliers, if any.**
- ✓ **A homogeneity test is performed for each station using another piece of software i.e. RClimDex-Rhtest.**
- ✓ **Final outcome is the ISI publication.**

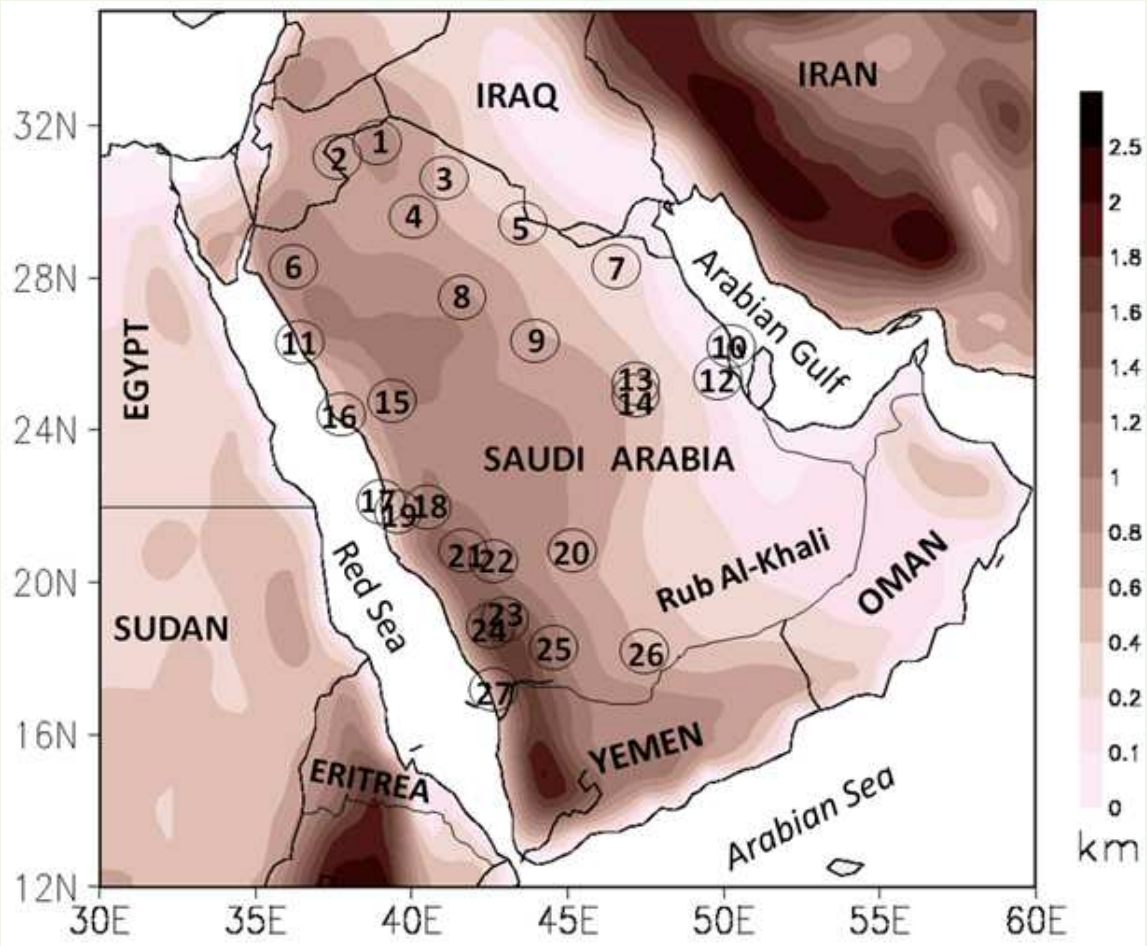
INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2013)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3722

RMetS
Royal Meteorological Society

Trends of temperature extremes in Saudi Arabia

Mansour Almazroui,[a*] M. Nazrul Islam,[a] Ramzah Dambul[a] and P. D. Jones[a,b]
[a] *Center of Excellence for Climate Change Research/Department of Meteorology, King Abdulaziz University, Jeddah, Saudi Arabia*
[b] *Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK*

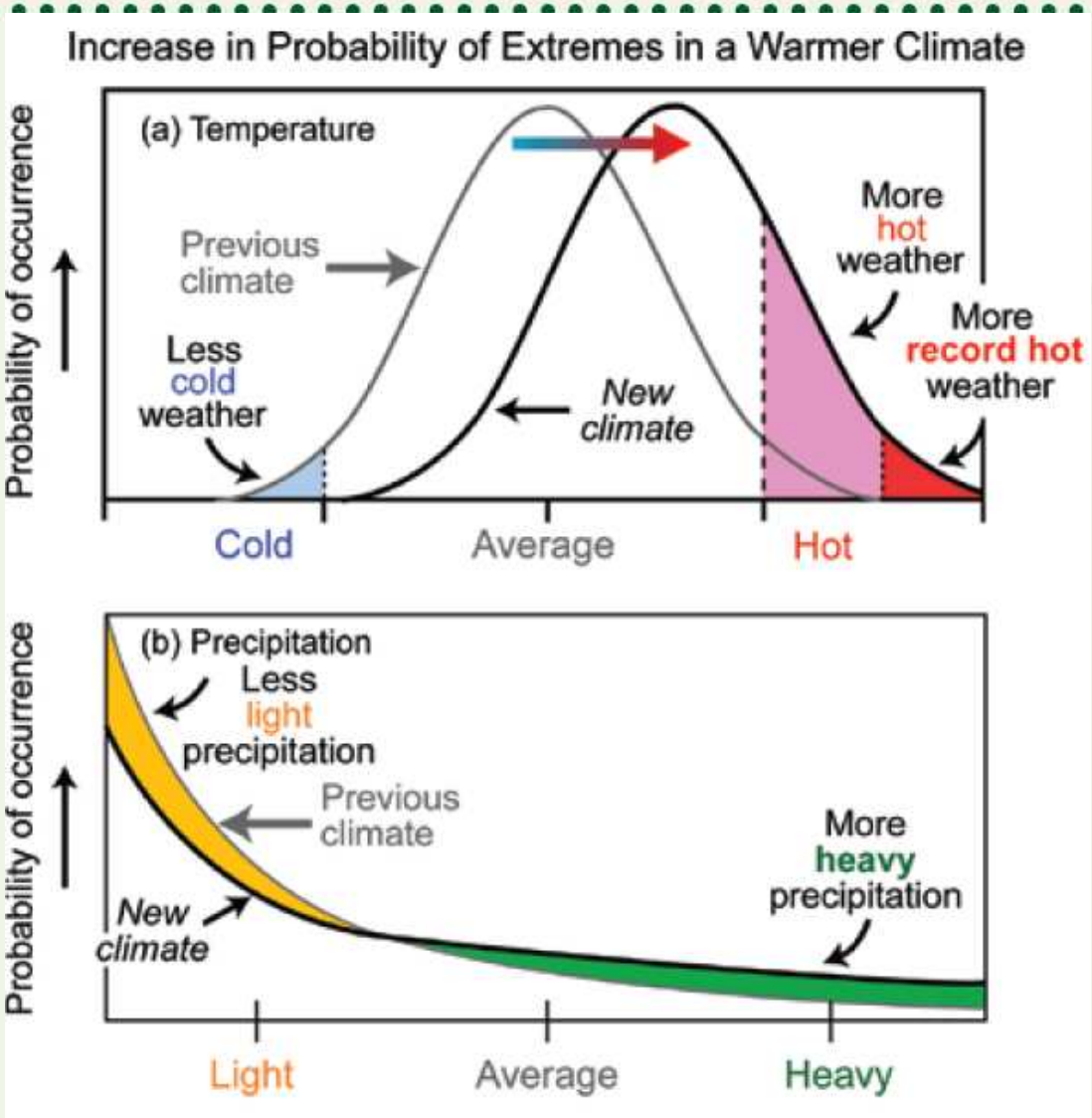
Weather Extremes Calculation (Saudi Arabia)



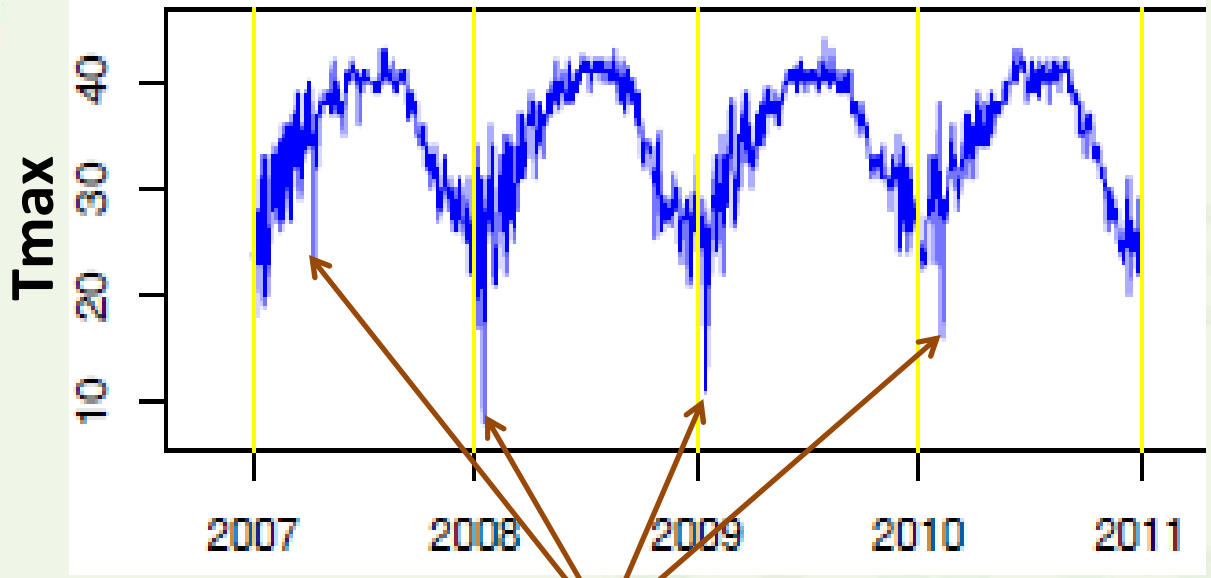
Topography (in km) of Saudi Arabia and its surroundings. The surface observation sites across the country are shown with open circles and the numbers are for the stations running from north to south.

Extreme indices calculated for Saudi Arabia. TX and TN represent daily maximum and minimum temperature respectively.

SL	Indices	Name	Definition	Units
1.	TXx	Max Tmax	Monthly maximum value of daily maximum temp	ºC
2.	TXn	Min Tmax	Monthly minimum value of daily maximum temp	ºC
3.	TNx	Max Tmin	Monthly maximum value of daily minimum temp	ºC
4.	TNn	Min Tmin	Monthly minimum value of daily minimum temp	ºC
5.	TX90p	Warm days	Annual count of days when TX > 90th percentile	Days
6.	TX10p	Cool days	Annual count of days when TX < 10th percentile	Days
7.	TN90p	Warm nights	Annual count of days when TN > 90th percentile	Days
8.	TN10p	Cool nights	Annual count of days when TN < 10th percentile	Days
9.	CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN < 10th percentile	Days
10.	WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX > 90th percentile	Days
11.	TR20	Tropical nights	Annual count when TN (daily minimum) > 20ºC	Days
12.	TRnn	Tropical nights	Annual count when TN (daily minimum) > user defined temp.	Days
13.	DTR	Diurnal temperature range	Monthly mean difference between TX and TN	ºC



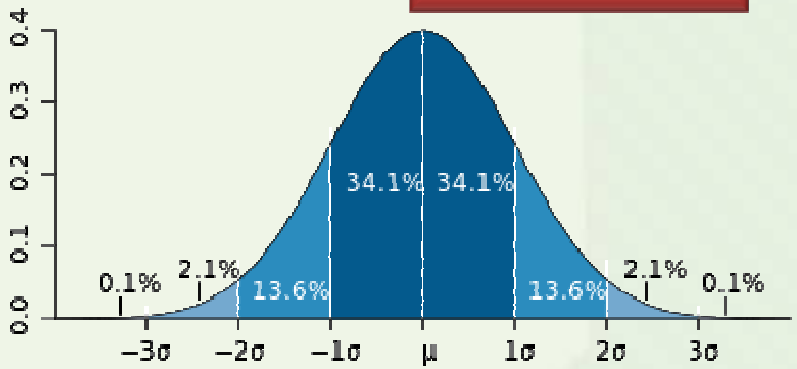
Simplified depiction of the changes in temperature and precipitation in a warming world. Changes mean/median and variations indicate the possibility of increase of extremes.

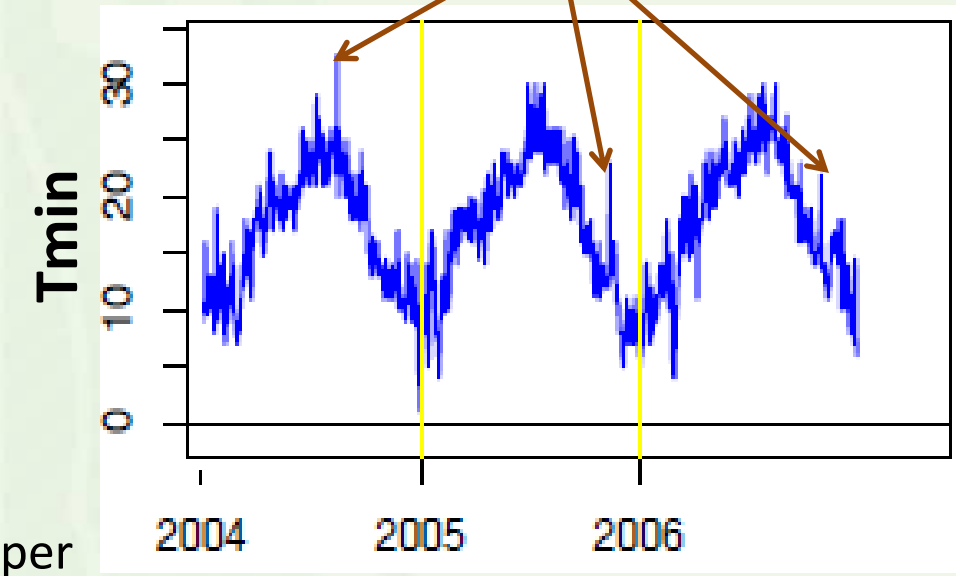


Outliers can be either true Extremes or False value

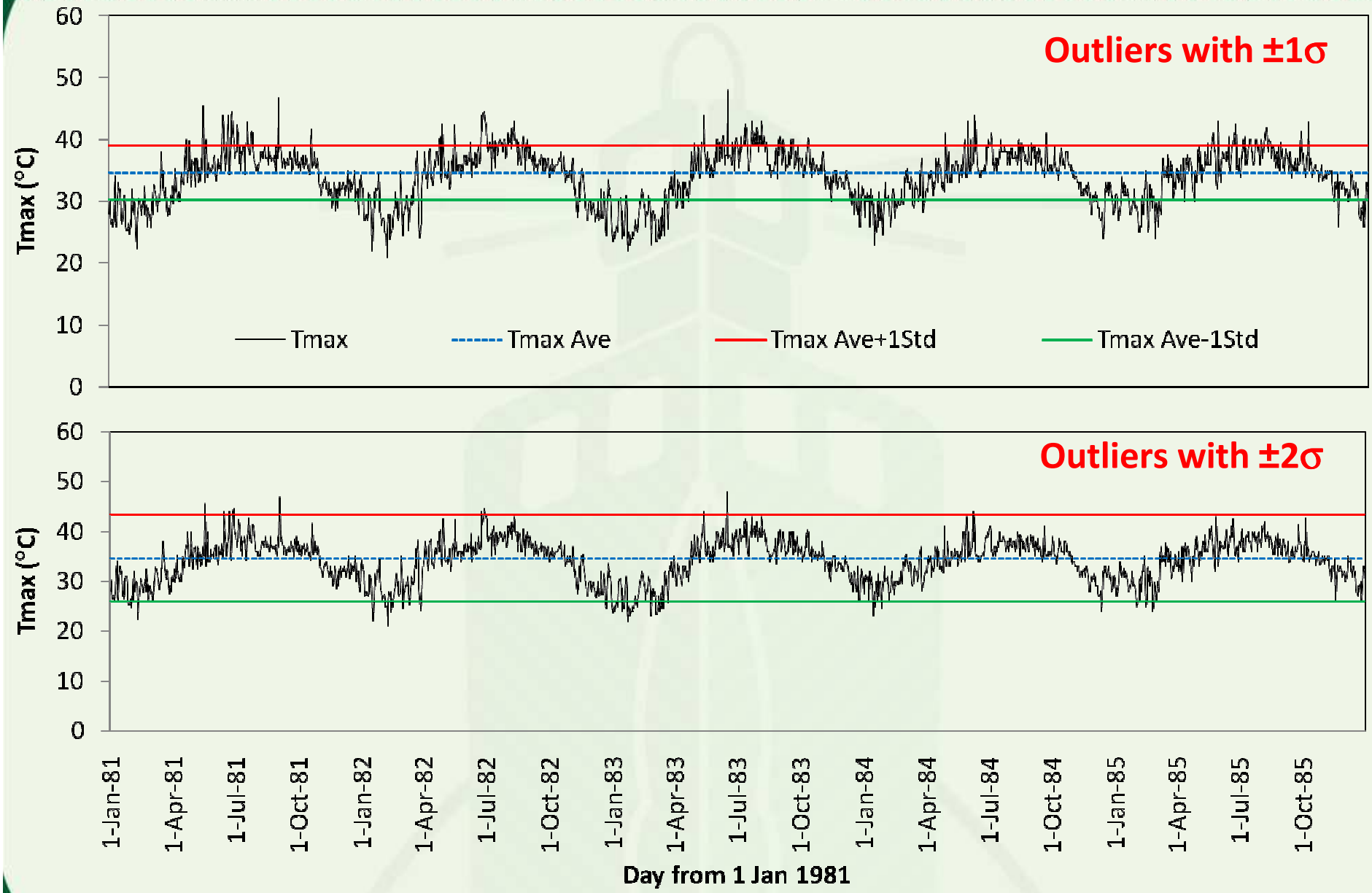
Outliers ?

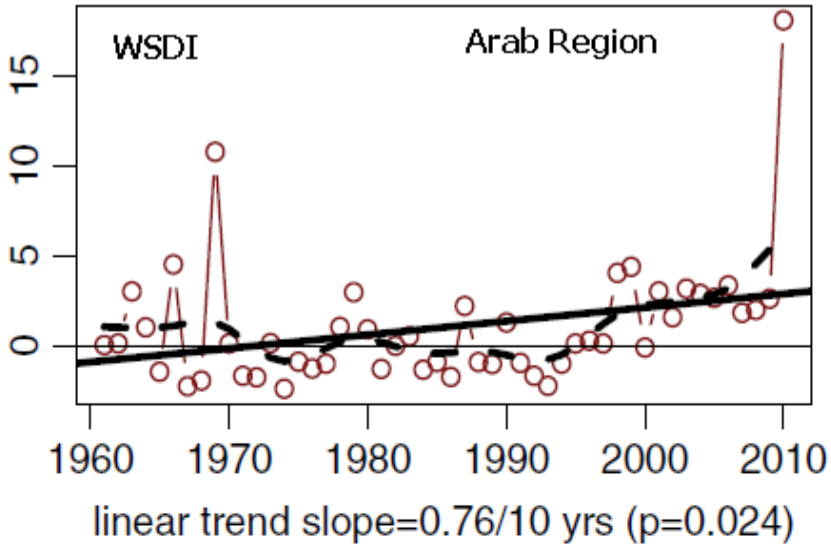
Outliers ?

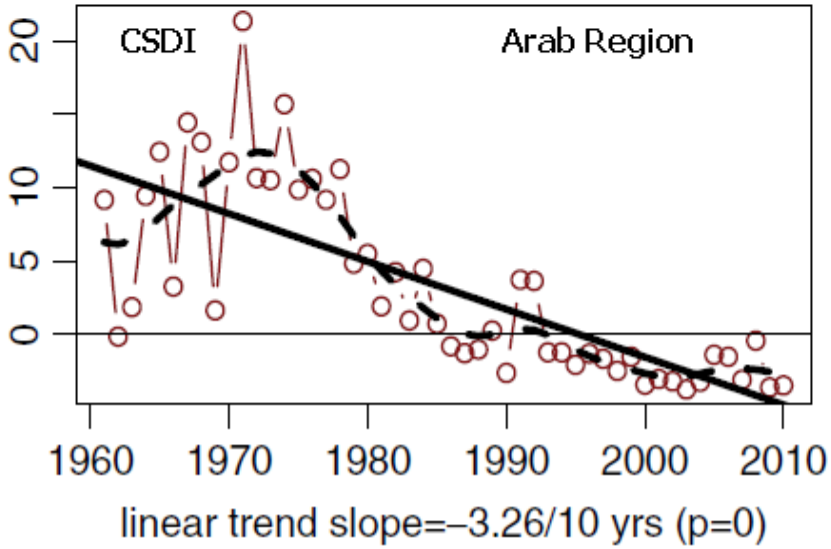


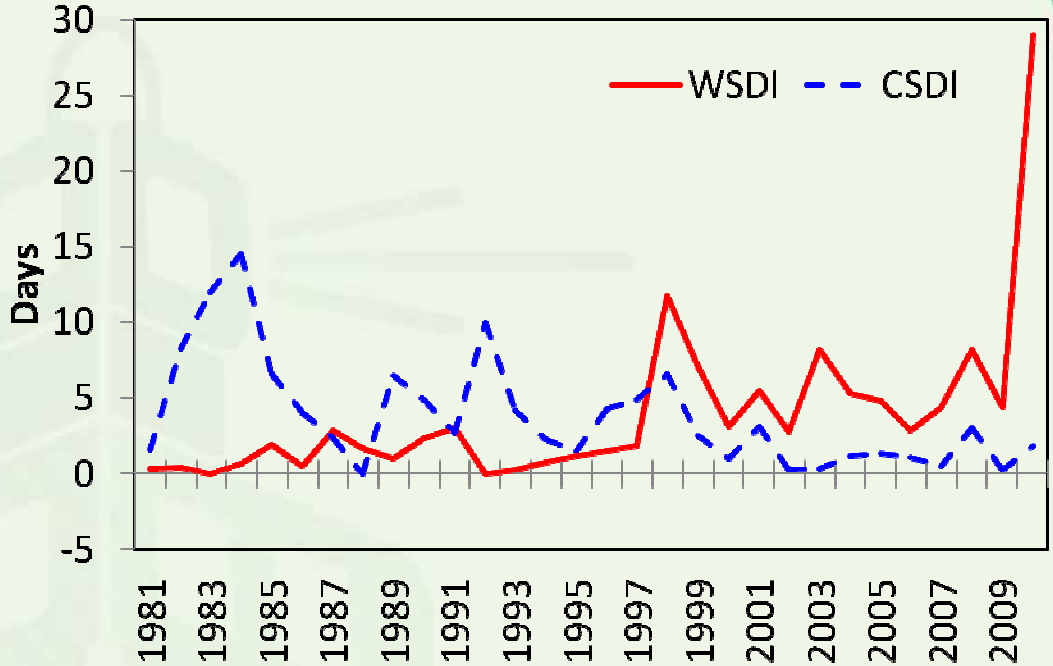


Outliers (including extremes) lie in the upper and lower tail in the distribution curve.


Outliers with ±1σ
Tmax (°C)
60
50
40
30
20
10
0
Tmax
Tmax Ave
Tmax Ave+1Std
Tmax Ave-1Std
Outliers with ±2σ
Tmax (°C)
60
50
40
30
20
10
0
1-Jan-81
1-Apr-81
1-Jul-81
1-Oct-81
1-Jan-82
1-Apr-82
1-Jul-82
1-Oct-82
1-Jan-83
1-Apr-83
1-Jul-83
1-Oct-83
1-Jan-84
1-Apr-84
1-Jul-84
1-Oct-84
1-Jan-85
1-Apr-85
1-Jul-85
1-Oct-85
Day from 1 Jan 1981







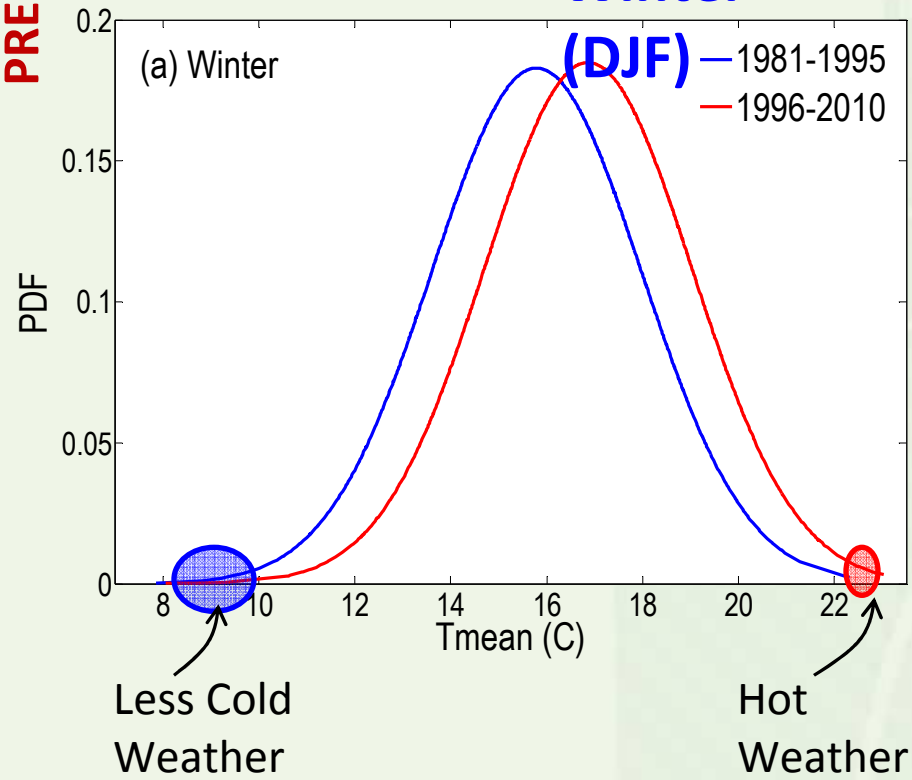
Saudi Arabia:

The average number of events per year averaged across 27 stations for two indices: **warm spell duration indicator (WSDI)** and **cold spell duration indicator (CSDI)**. The CSDI/WSDI is significantly (at 99% level) decreasing/increasing at the rate of 2.42/3.65 events per decade.

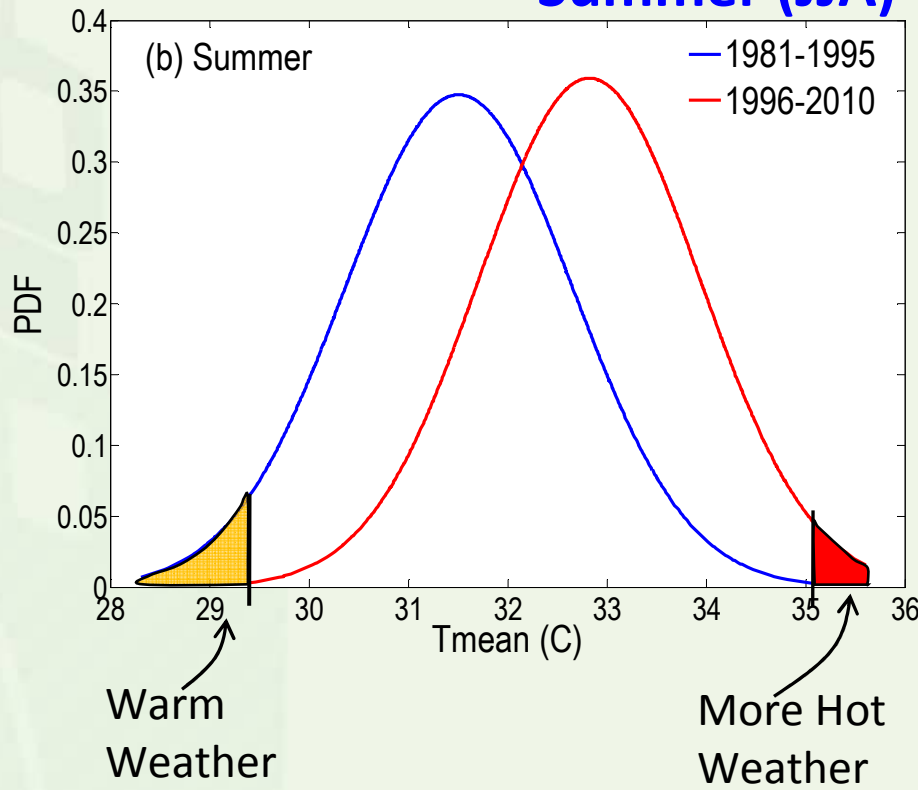
Temperature Extreme shift in Saudi Arabia

PRESENT

Winter (DJF)



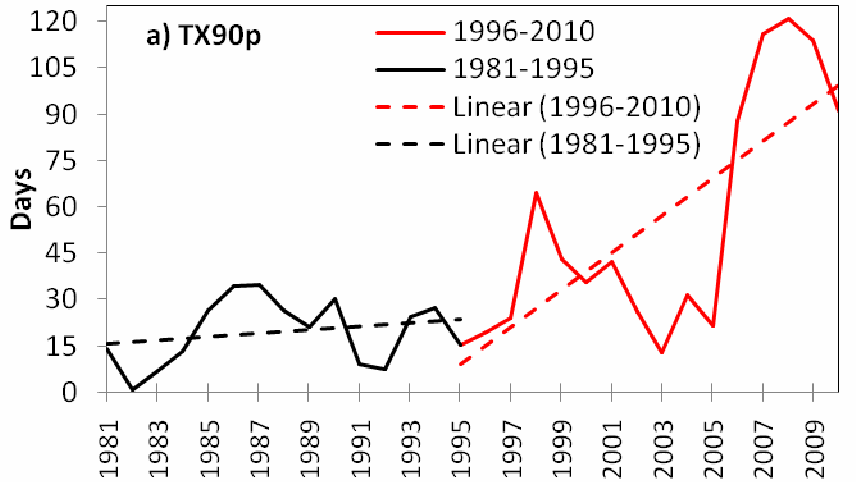
Summer (JJA)



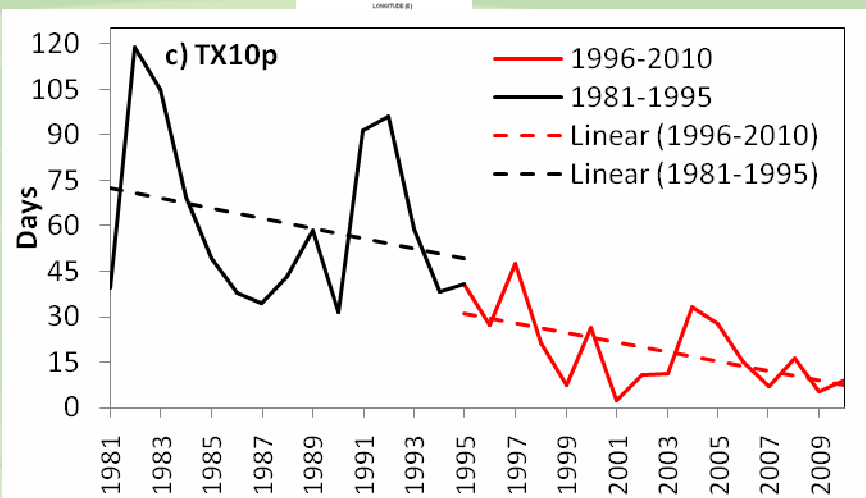
There is a distinct change in the mean or median between the two periods. Climate change not only affects the magnitude of the mean temperature, it also causes extremes which are in general existed in the upper or lower tail of the probability distribution. Hence, the shift of mean temperature to a higher level indicates changes in the frequency of extremes in Saudi Arabia.

PRESENT

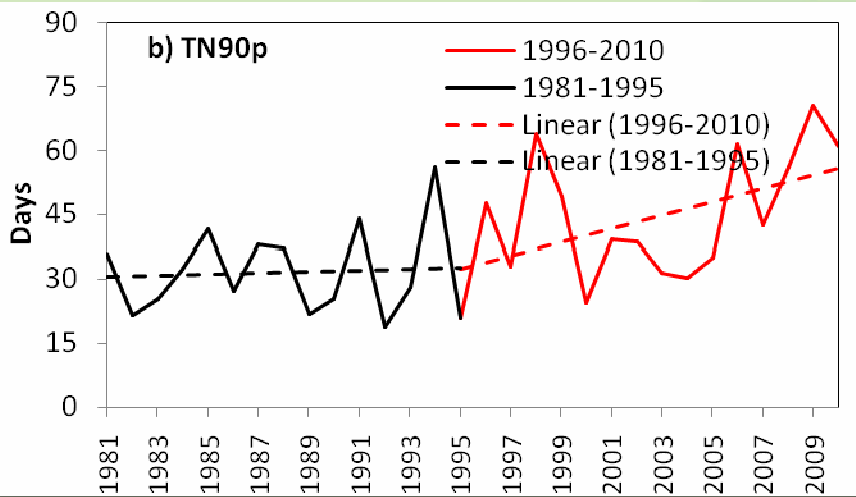
Temperature Extremes at local level: JEDDAH



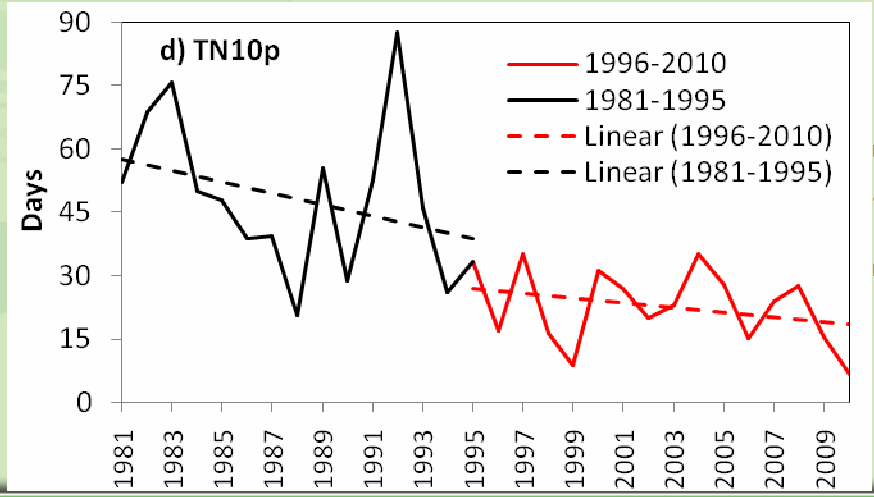
warm days



cool days



warm nights

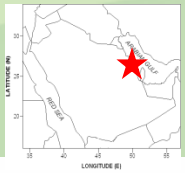


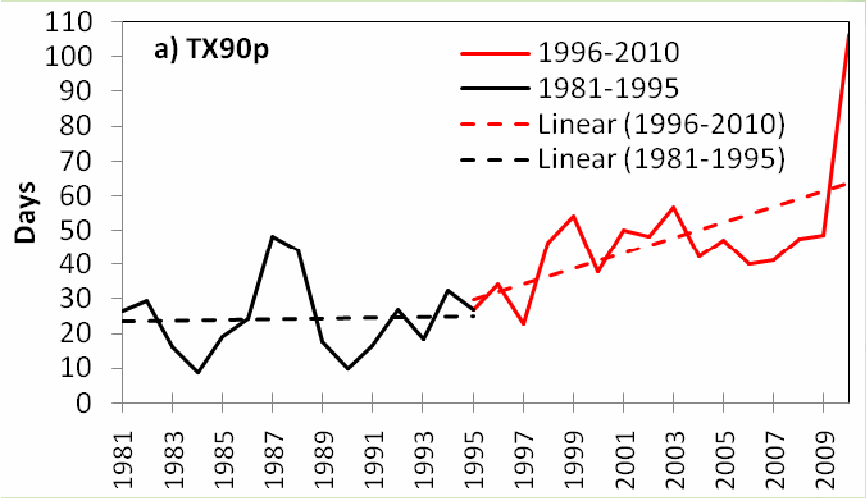
cool nights

PRESENT

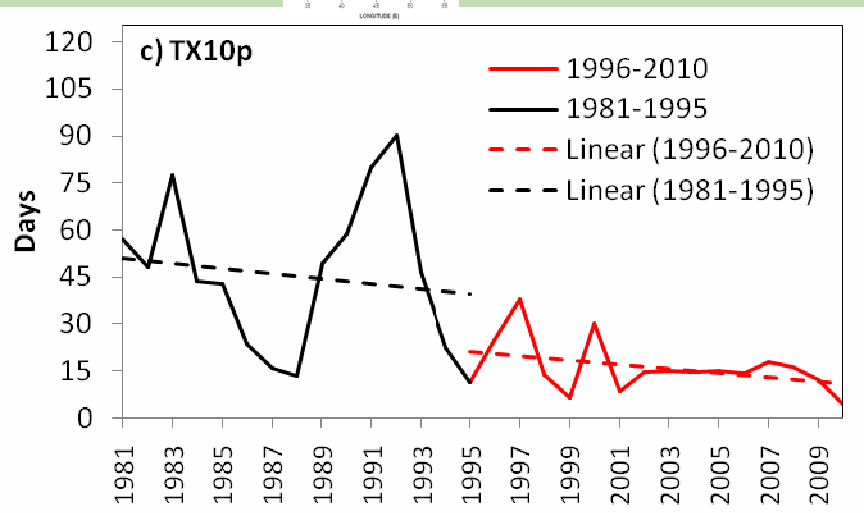
Temperature Extremes at local level:

DHAHRAN

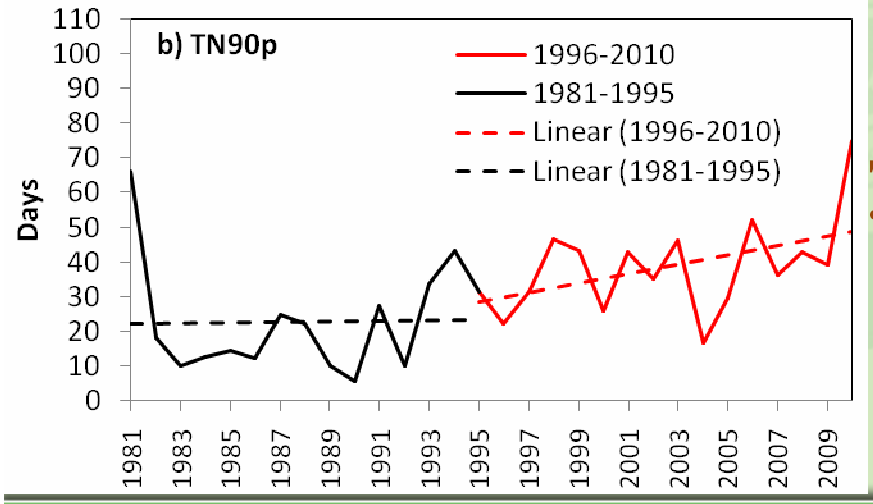




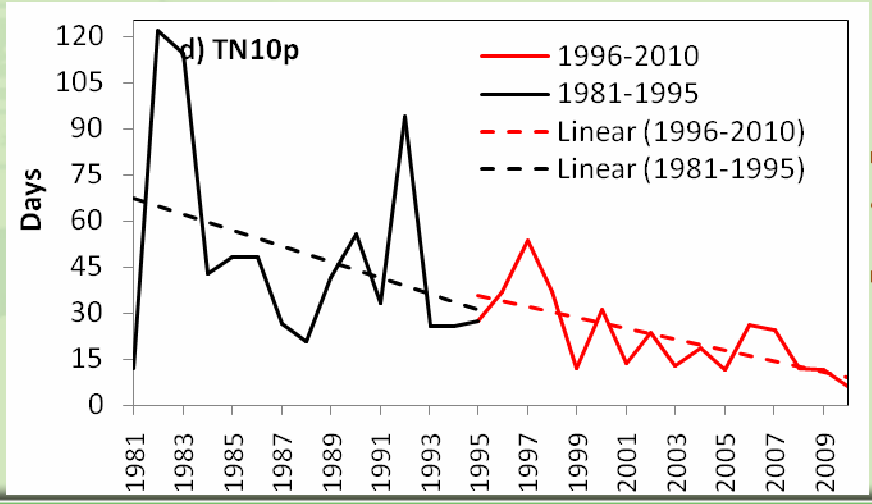
warm days



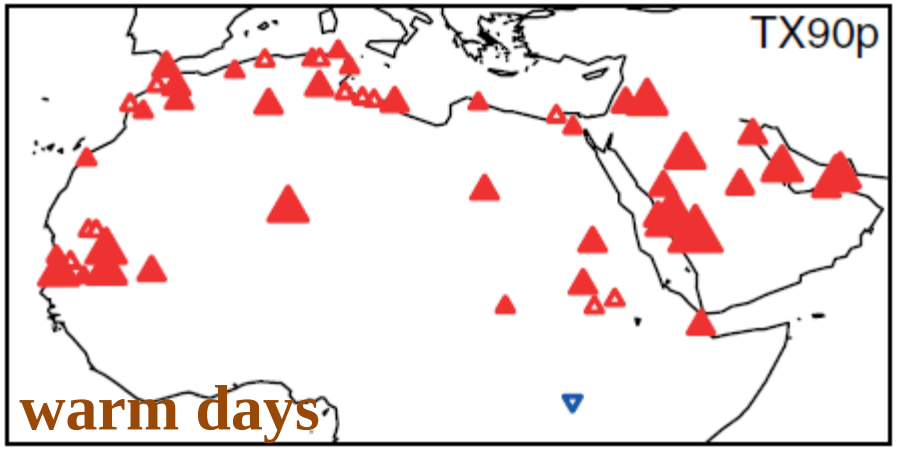
cool days

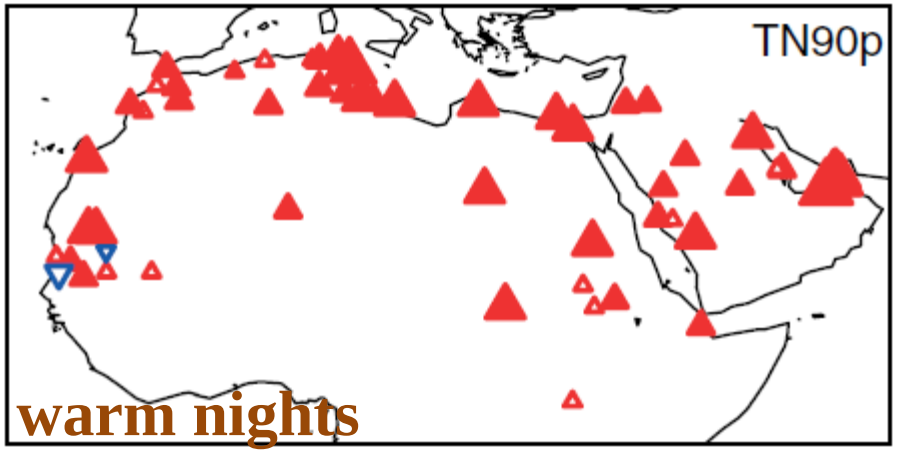


warm nights

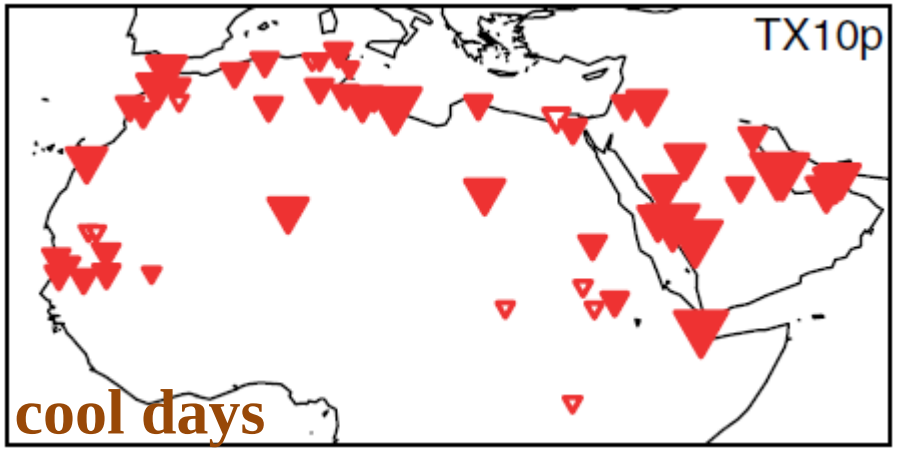


cool nights





> 6 > 4 > 2 > 0 < 0 < –2 < –4 < –6



> 6 > 4 > 2 > 0 < 0 < –2 < –4 < –6

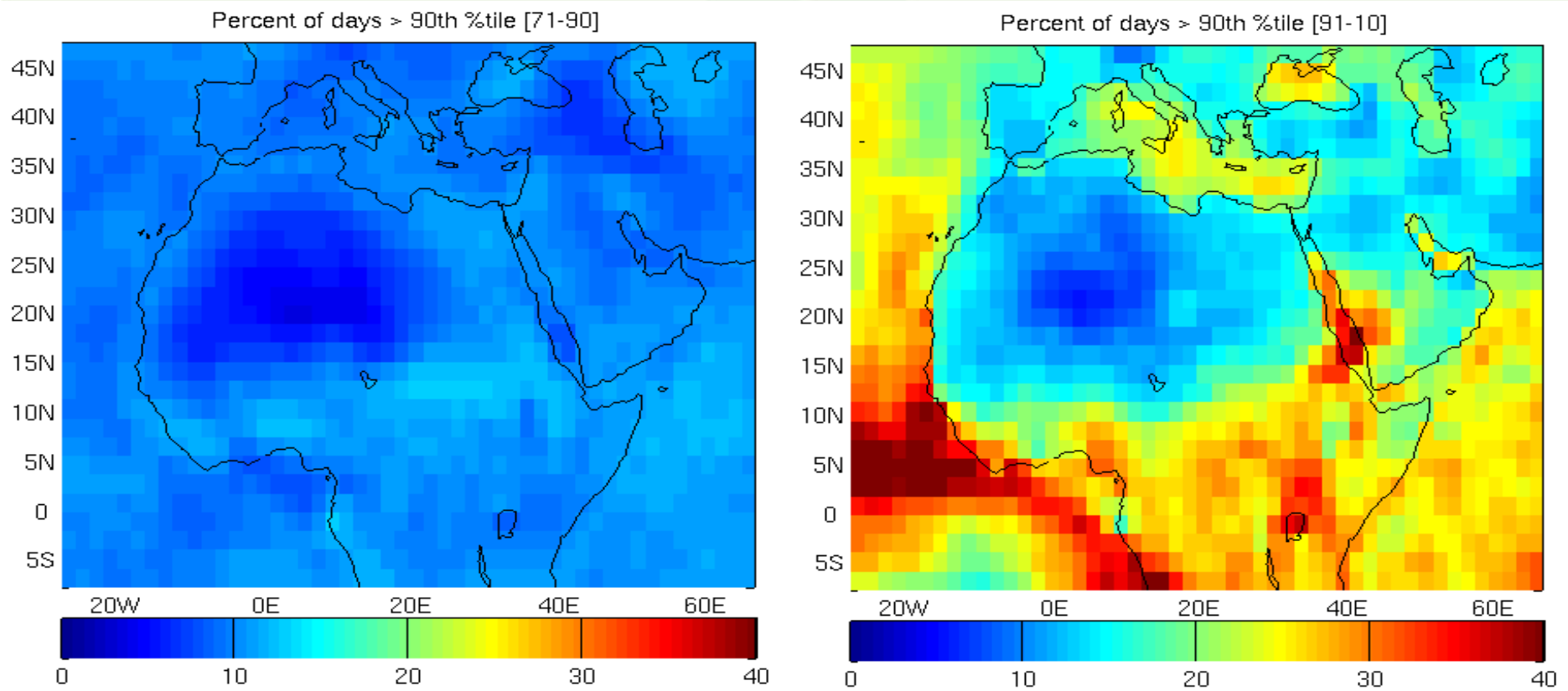
Observations
(Changes in Climate)

PRESENT

Temperature Extreme in the Arab Region

Temperature Extreme Days (%) >T90p

Period1: 1971-1990 **Period2: 1991-2010**

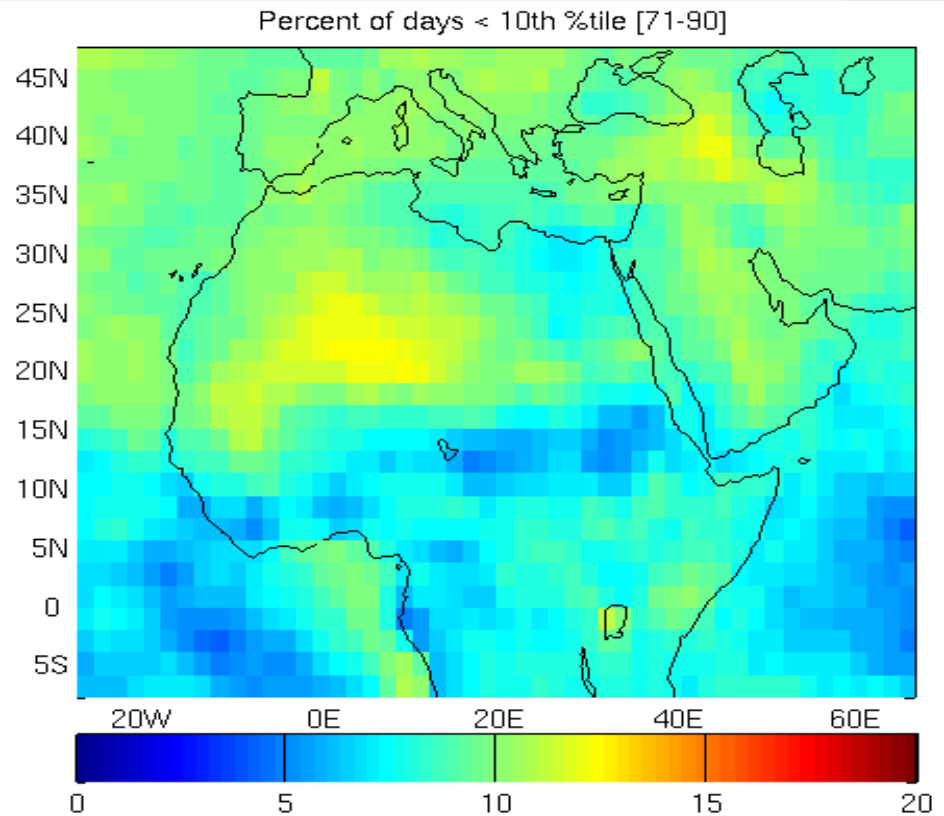


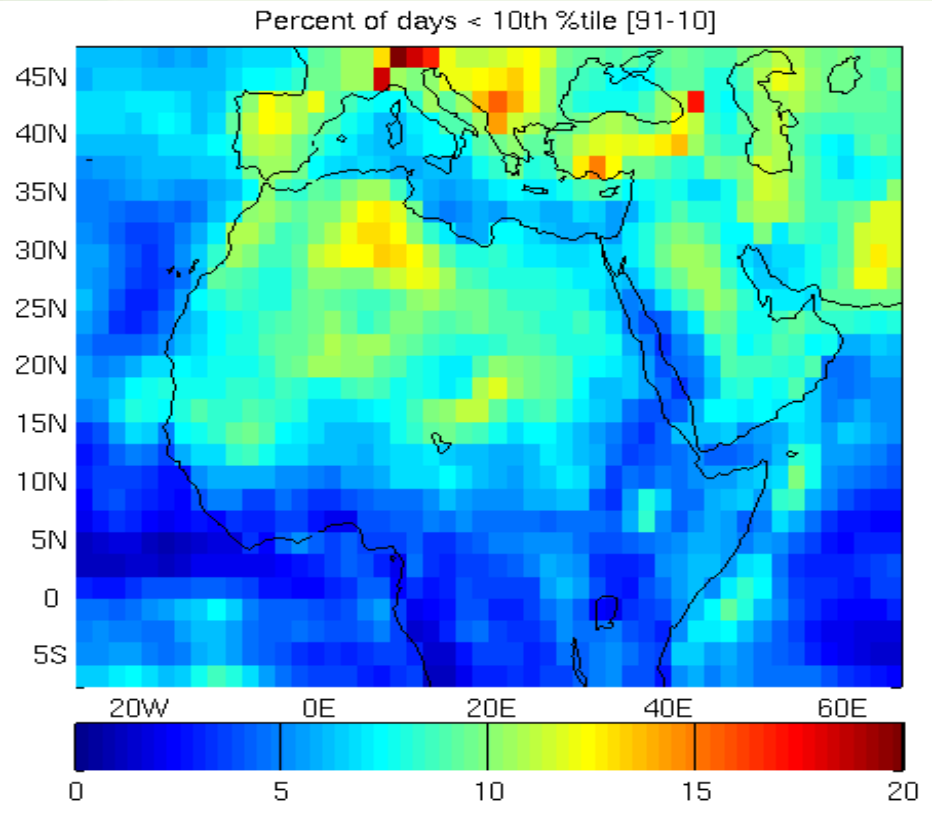
PRESENT

Temperature Extreme in the Arab Region

Temperature Extreme Days (%) <T10p

Period1: 1971-1990 **Period2: 1991-2010**



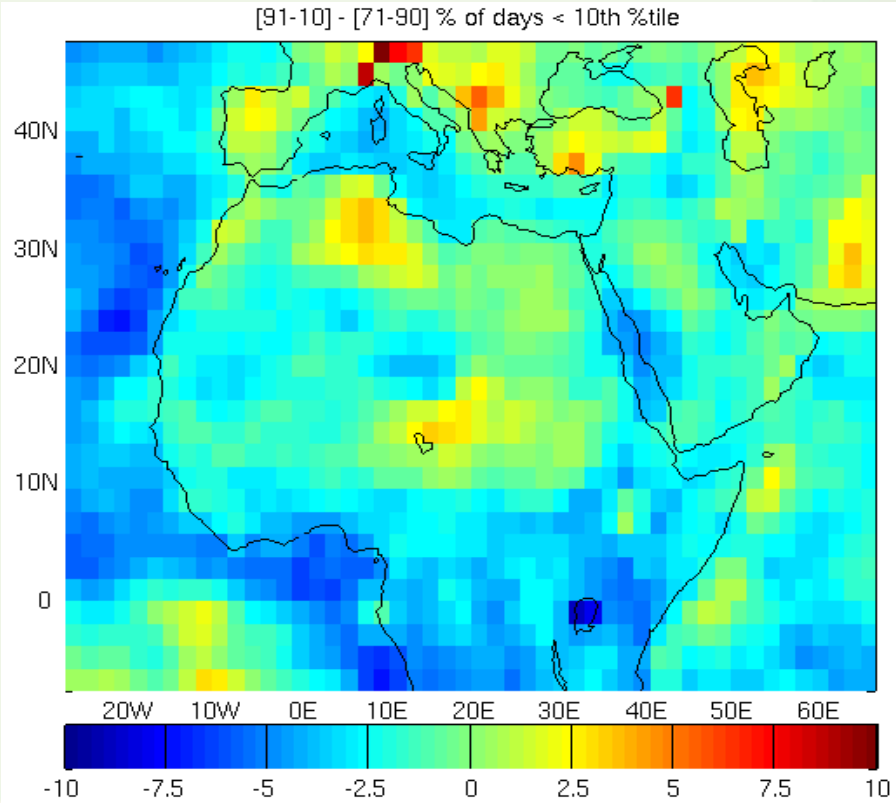


PRESENT

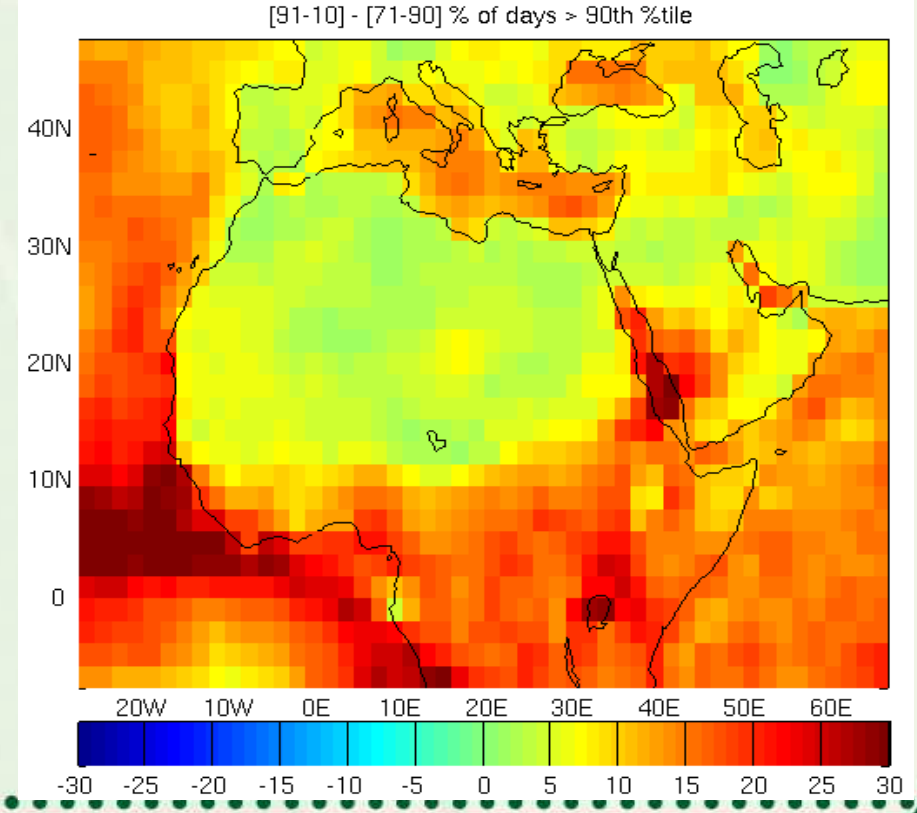
Temperature Extreme in the Arab Region

Change of temperature extremes (% of Days)

Change (% of days) <T10p: (1991-2010) – (1971-1990)



Change (% of days) >T90p: (1991-2010) – (1971-1990)



Climate Models

Center of Excellence for Climate Change Research (CECCR)

Global Climate Models (GCMs)

CECCR Focuses

Regional Climate Models (RCMs)

Priority is given to develop

KAU-CGCM

Forecasting

Refined Climate Database

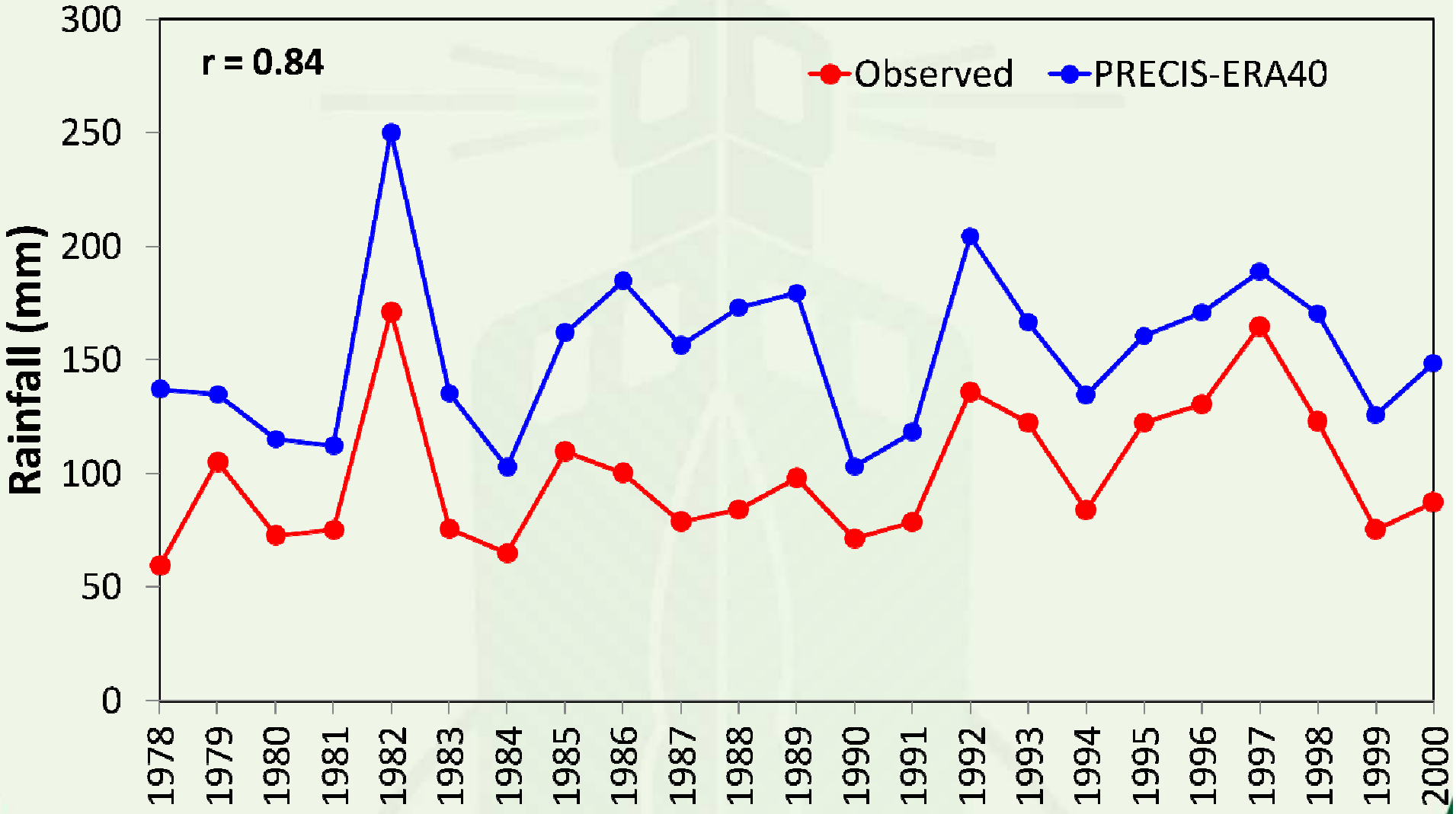
Impact studies

RCMs

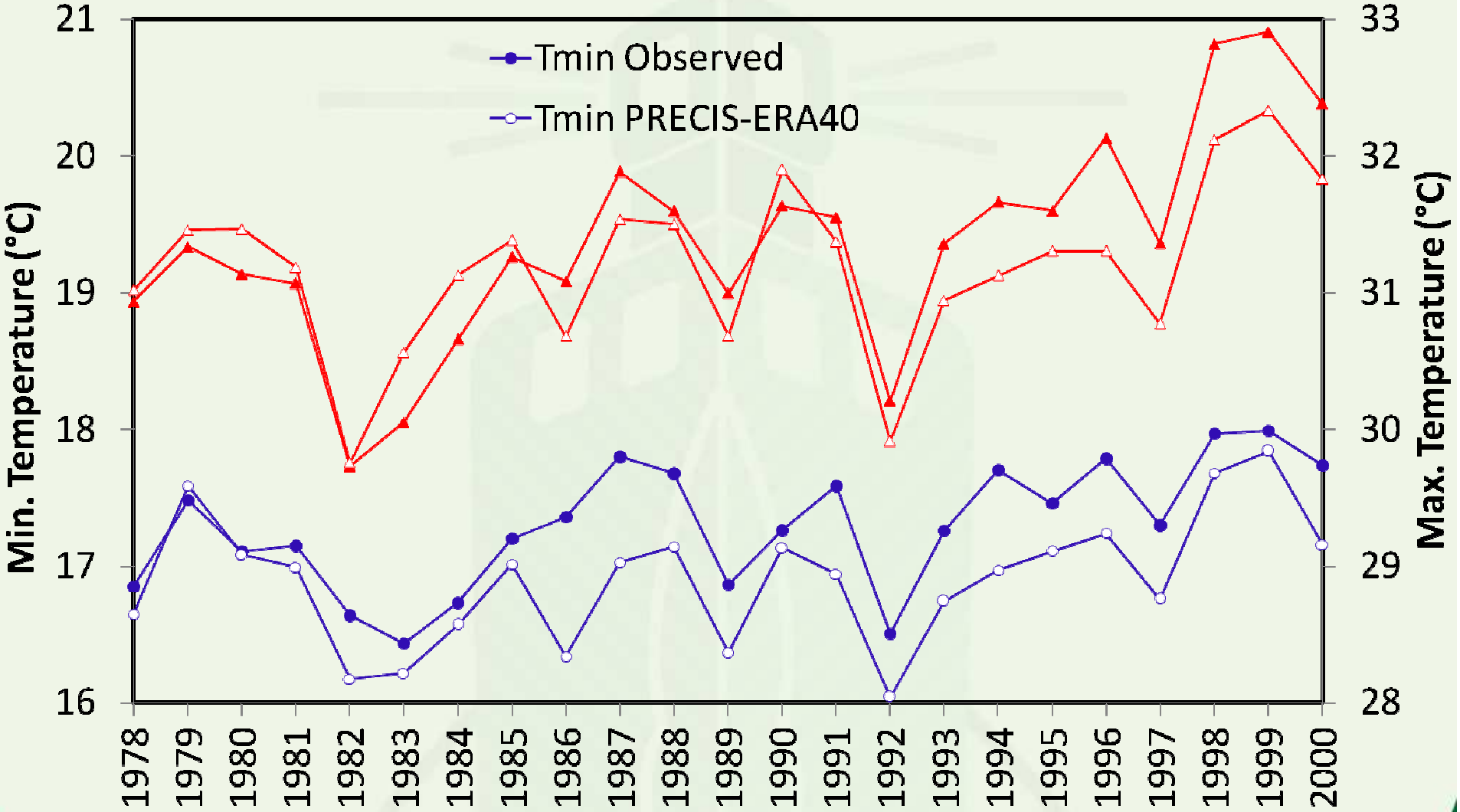
Input of

Climate Models
(Variability)

Interannual variability of Model & Observed Rainfall



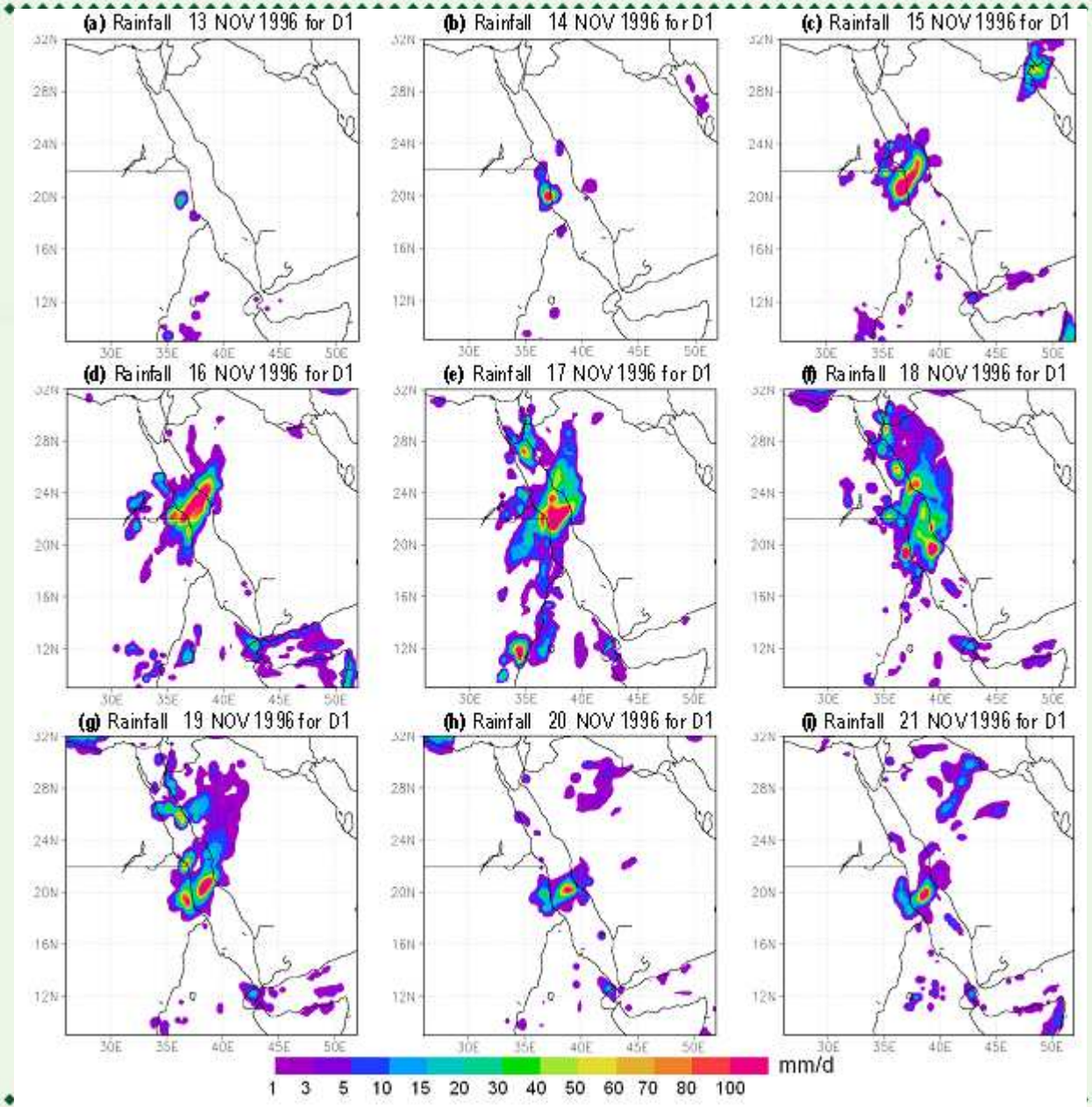
Interannual variability of Model & Observed Temp



Climate Models
(Weather Extremes)

RCM Activity

Rainfall: Jeddah NOV 1996



Atmósfera 25(1), 23-41 (2012)

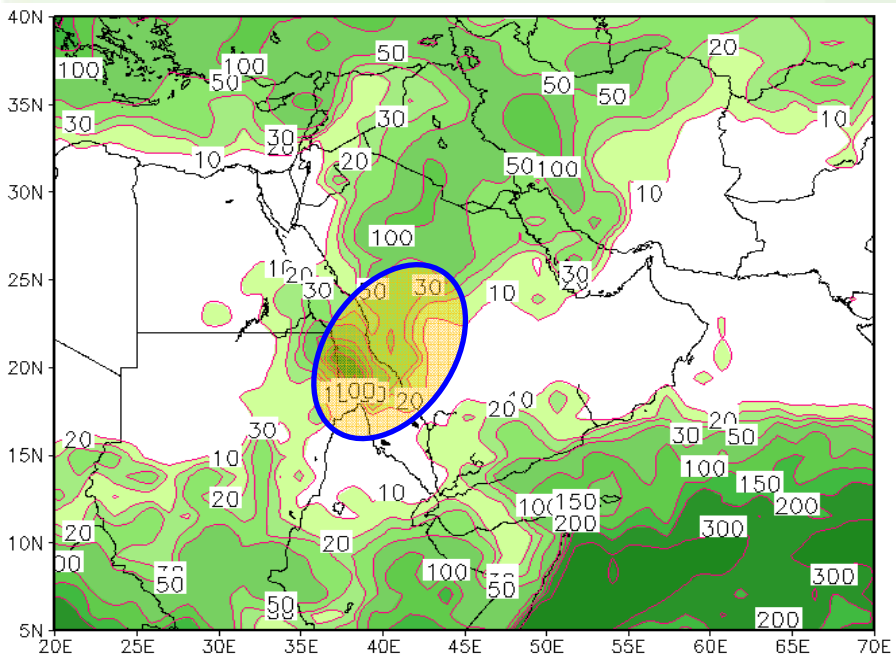
The life cycle of extreme rainfall events over western Saudi Arabia simulated by a regional climate model: Case study of November 1996

M. ALMAZROUI

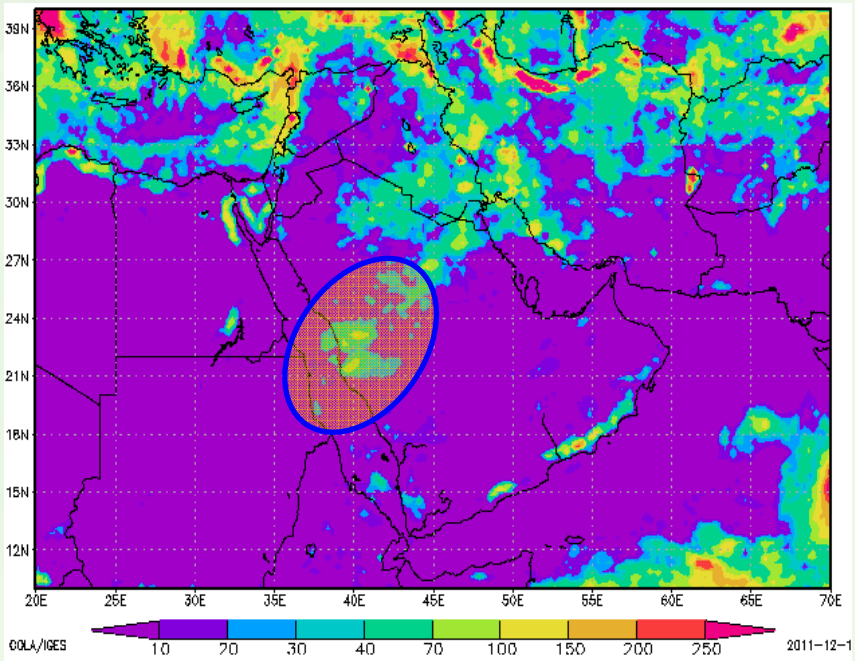
GCM Activity

Rainfall: Jeddah 25 NOV 2009

KAU-CGCM: T106L44 (~ 125 km)
Total Rainfall (mm/month)



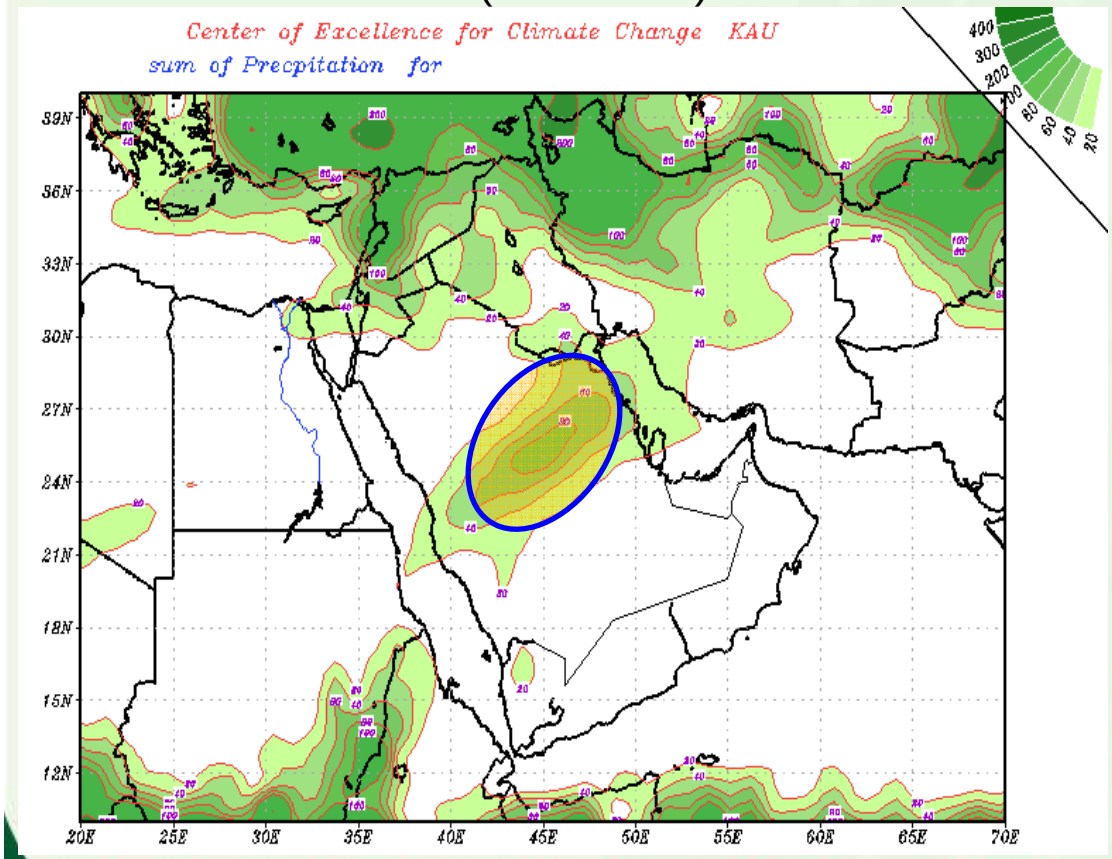
Observed: TRMM Nov 2009
Total Rainfall (mm/month)



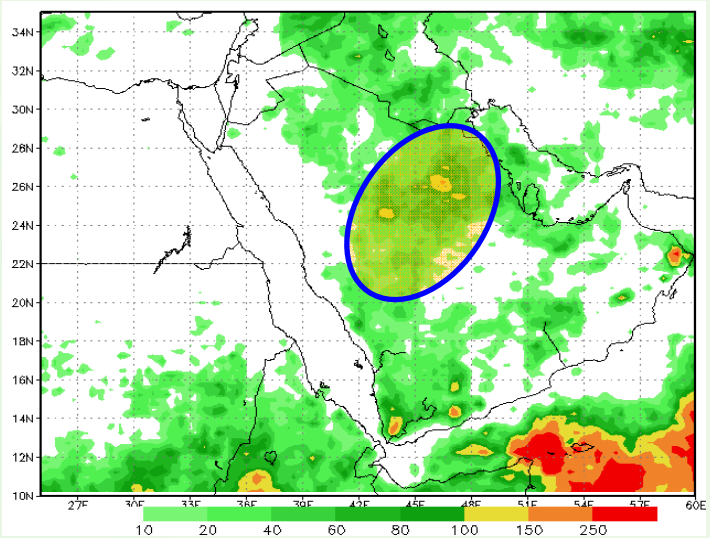
GCM Activity

Rainfall: Riyadh 5 MAY 2010

KAU-CGCM: T106L44 (~ 125 km)
Total Rainfall (mm/month)

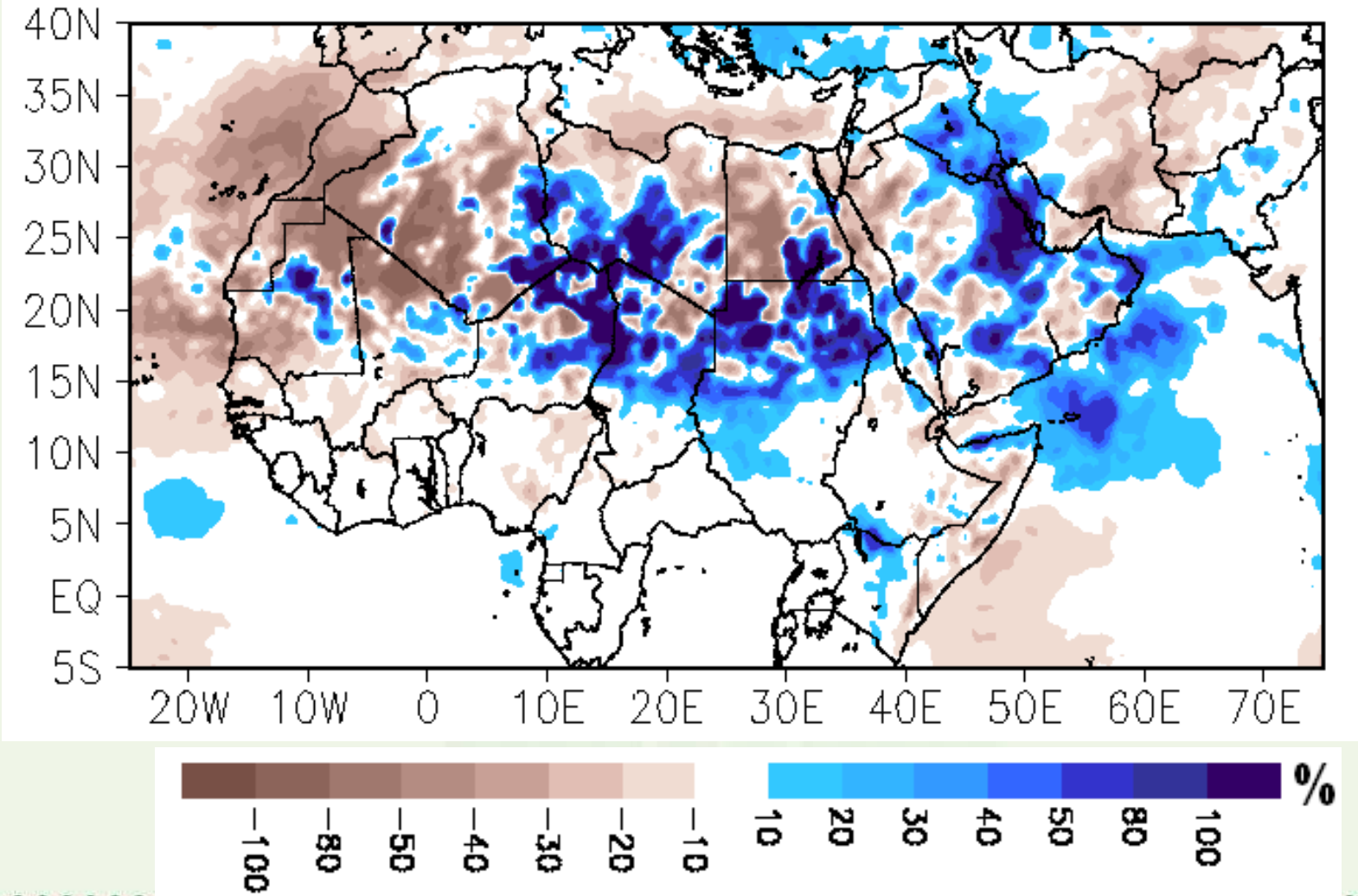


Observed: TRMM May 2010
Total Rainfall (mm/month)

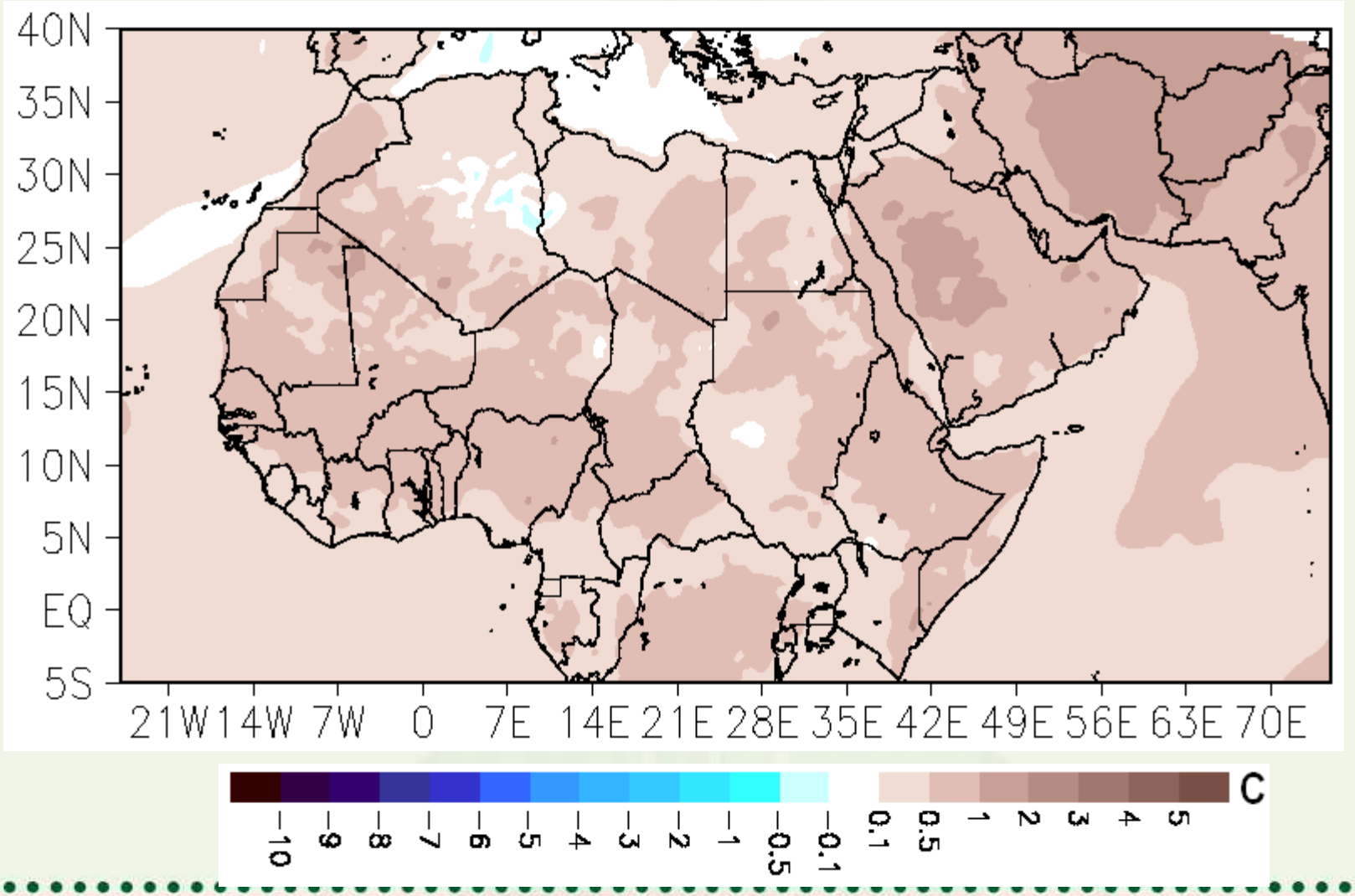


Climate Models
(Changes in Climate)

Rainfall Change (2021-2030) minus (1991-2000)



Temperature Change (2021-2030) minus (1991-2000)



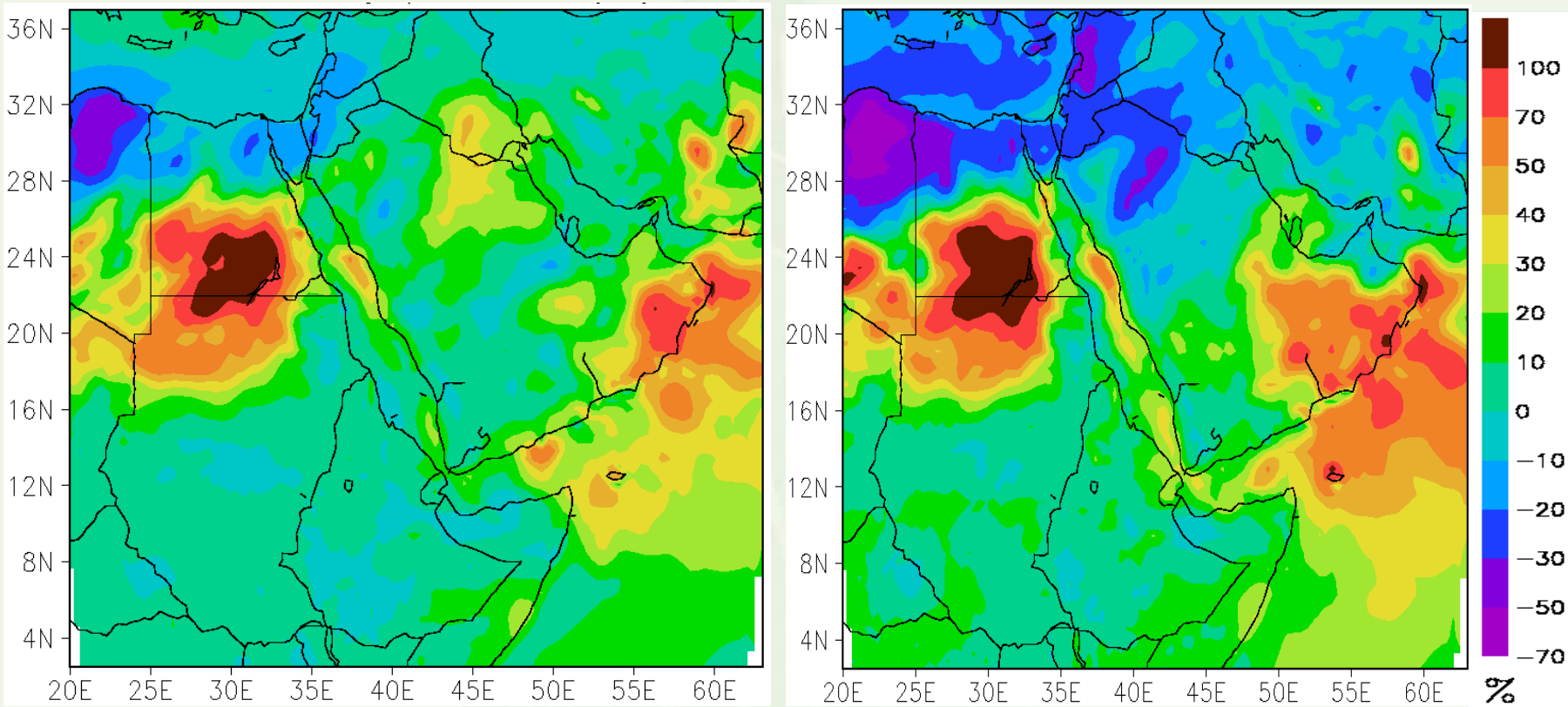
Rainfall Projection for the West Asia

RCM Projection

2000

Rainfall Change PRECIS-ECHAM5 2021-2050

Rainfall Change PRECIS-ECHAM5 2041-2070



INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2013)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3721

RMetS
Royal Meteorological Society

Simulation of present and future climate of Saudi Arabia using a regional climate model (PRECIS)

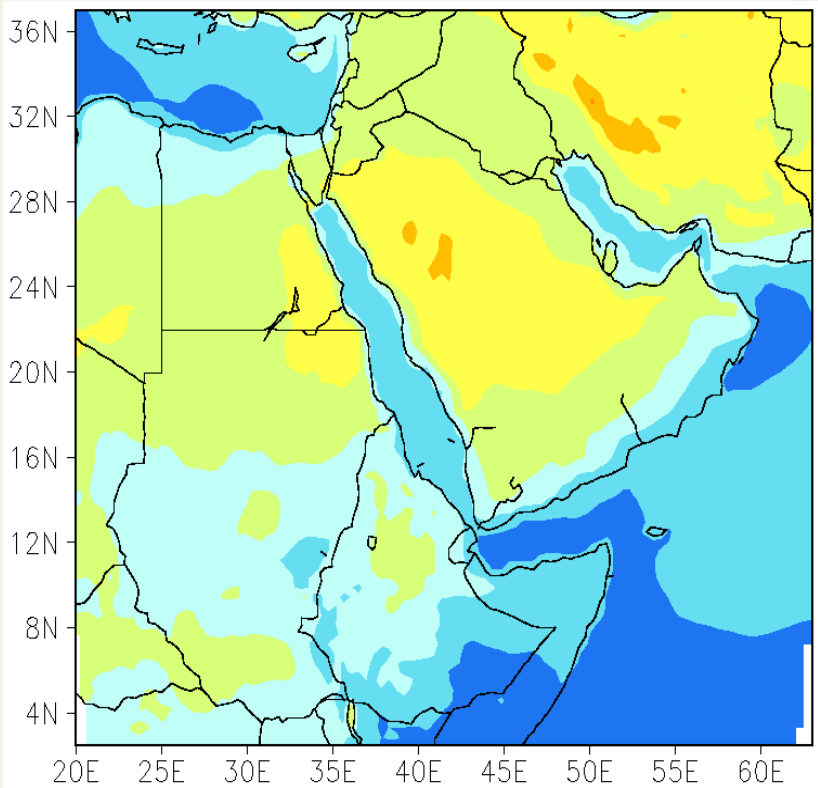
Mansour Almazroui*

Temperature Projection for the West Asia

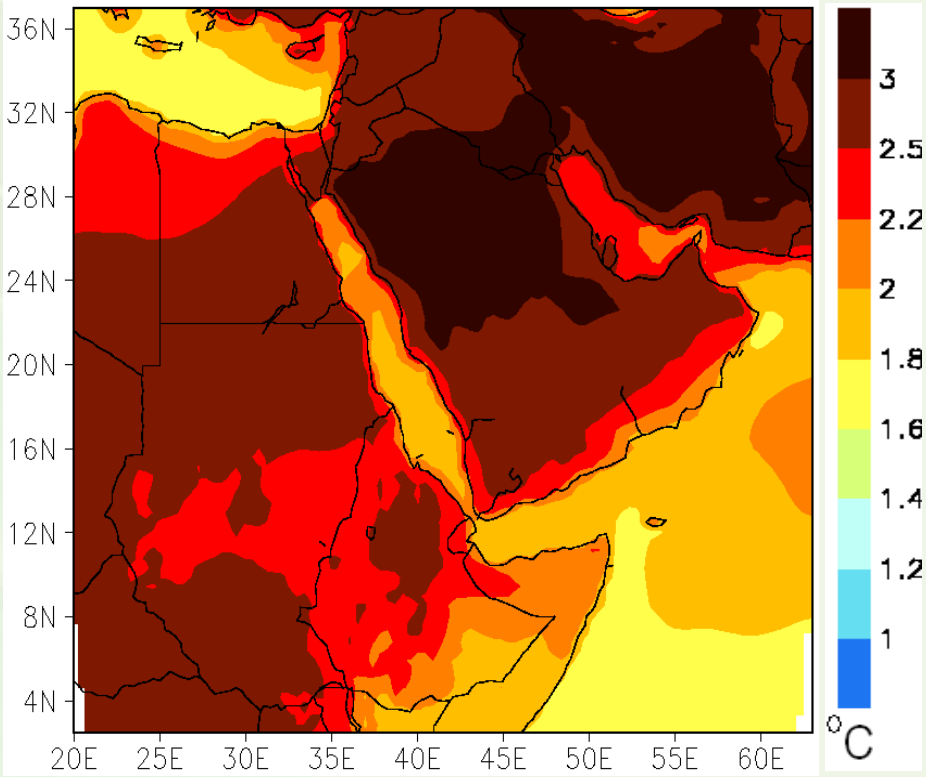
RCM Projection

2000

Tmean Change PRECIS-ECHAM5 2021-2050



Tmean Change PRECIS-ECHAM5 2041-2070



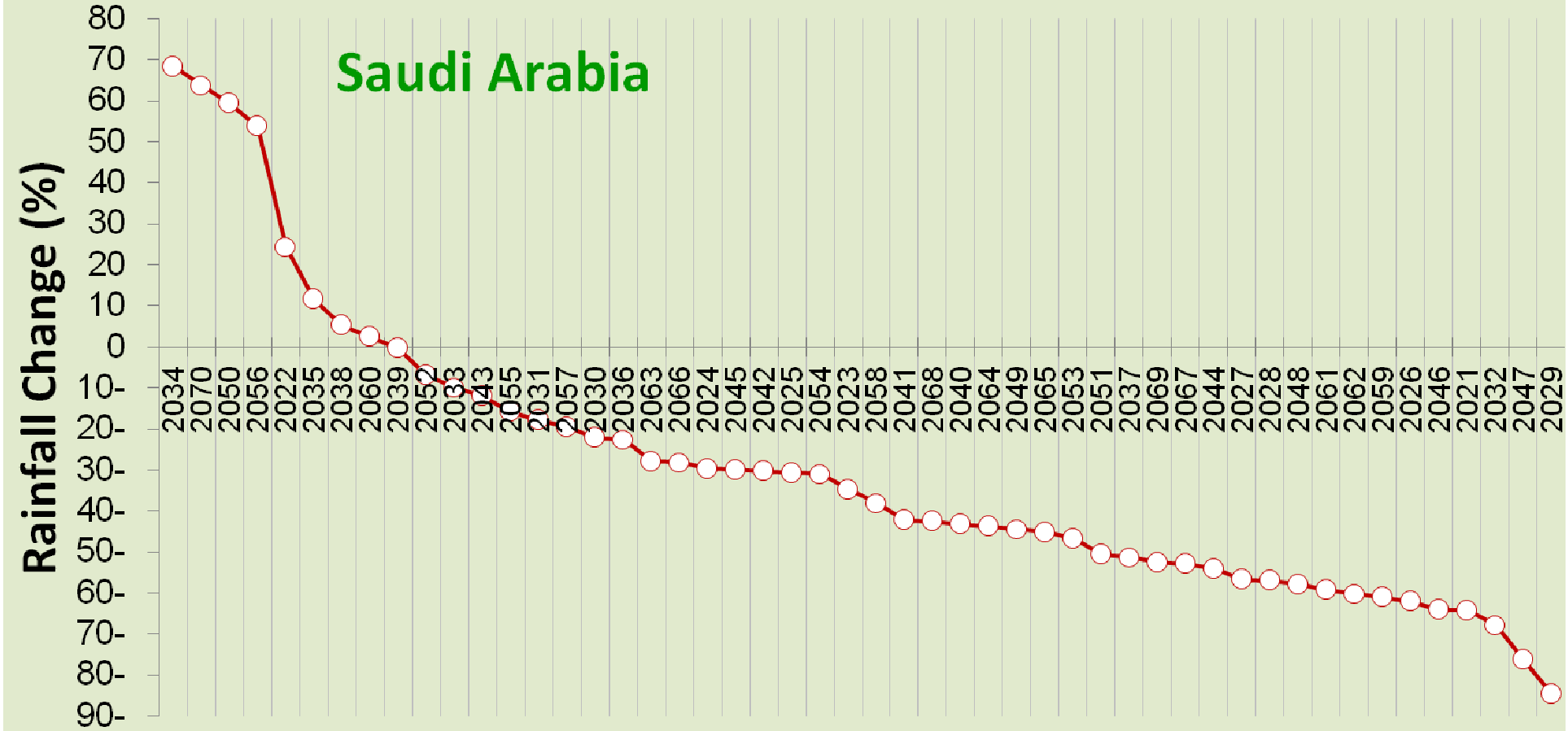
INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2013)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3721

RMetS
Royal Meteorological Society

Simulation of present and future climate of Saudi Arabia using a regional climate model (PRECIS)

Mansour Almazroui*

Possible Change in Rainfall (%)



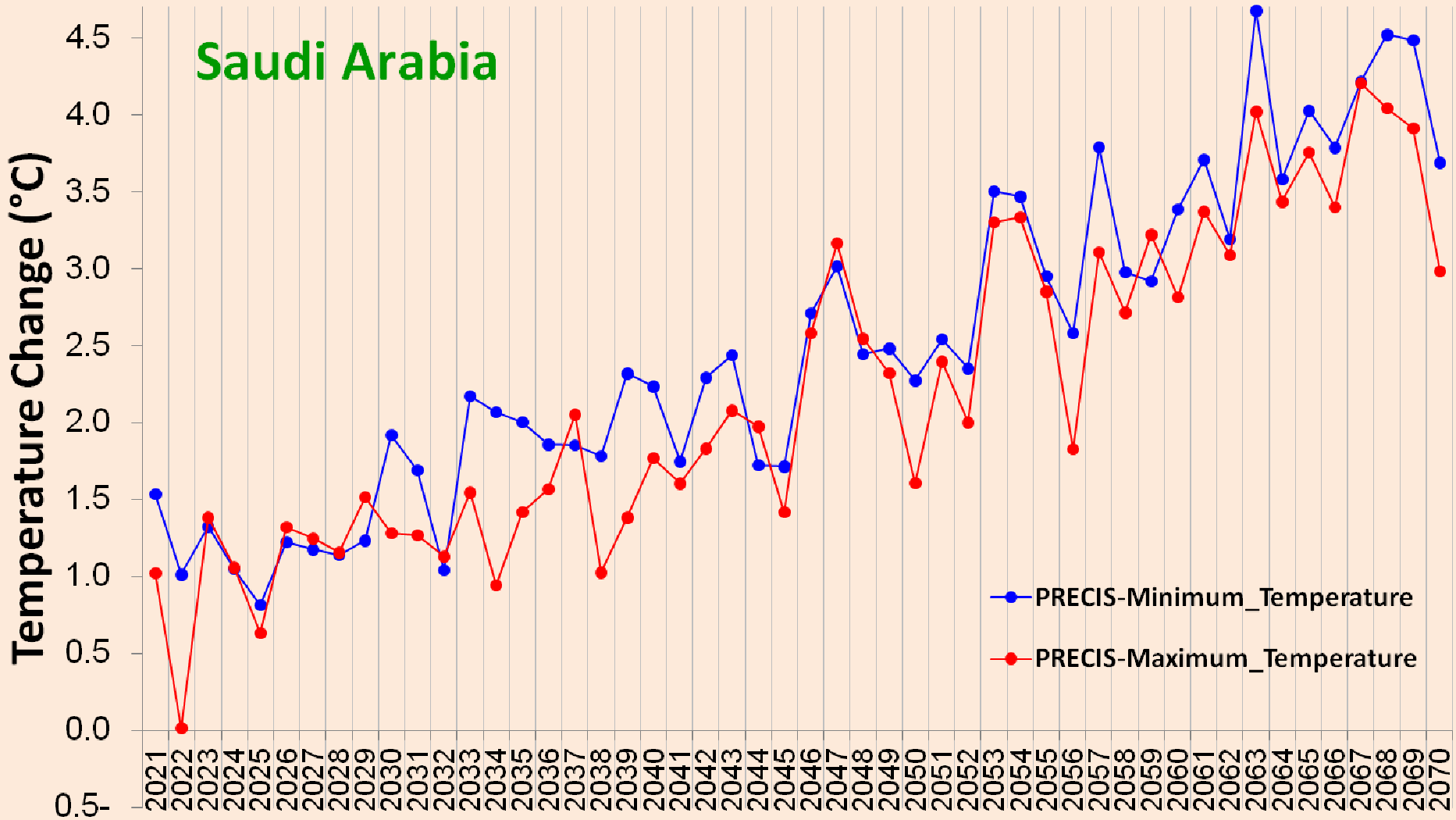
INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2013)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3721

RMetS
Royal Meteorological Society

Simulation of present and future climate of Saudi Arabia using a regional climate model (PRECIS)

Mansour Almazroui*

Possible Change in Temp (°C)



Concluding Remarks

- At far future (2041-2070), rainfall tends to increase/decrease in the South/North of West Asia
- At far future (2041-2070), temperature tends to increase above 3°C(2.5°C) in Saudi Arabia expanded NE(rest of West Asia)
- Well agreement between observed and model climate variability infers trust on Climate Model data
- Weather extremes e.g. drought frequency in Saudi Arabia tends to increase at the middle of 21st Century
- Cold (Warm) temperature extremes will be more in the North (South) of the West Asia
- Climate Models Projections are useful for monitoring of Extremes and Changes in future climate

Thank You All