



# Regional Climate Modeling

1. Background
2. Verification of Model
3. Future Climate Projections

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Regional Climate Change Symposium  
March 14, 2017

# GCM's – A Grid of Points over Earth

(Precipitation is the most difficult modeled variable)



The diagram illustrates a global climate model (GCM) grid. It features a globe with a grid of points overlaid. The grid is composed of a series of concentric circles and radial lines, representing latitude and longitude. The globe is divided into several rectangular regions, each containing a different pattern of dots, indicating different model outputs or data sets. A red dashed arrow points from the top left towards the center of the globe. A blue rectangular box is superimposed over the center of the globe, containing the text 'Typical global climate model has 1-2 million calculation points'.

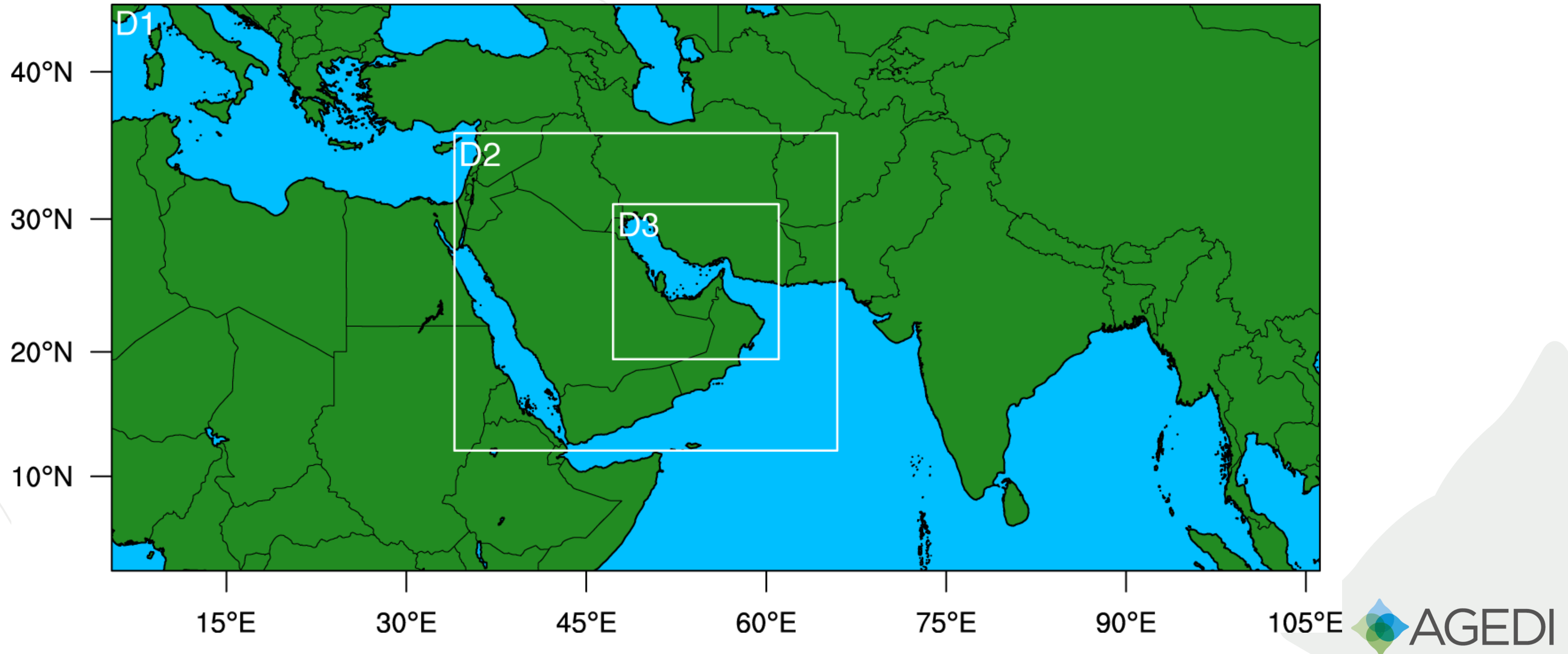
Typical global climate model has 1-2 million calculation points

# Community Atmosphere Model- 30 KM



## WRF Setup for the AGEDI Regional Climate Experiments

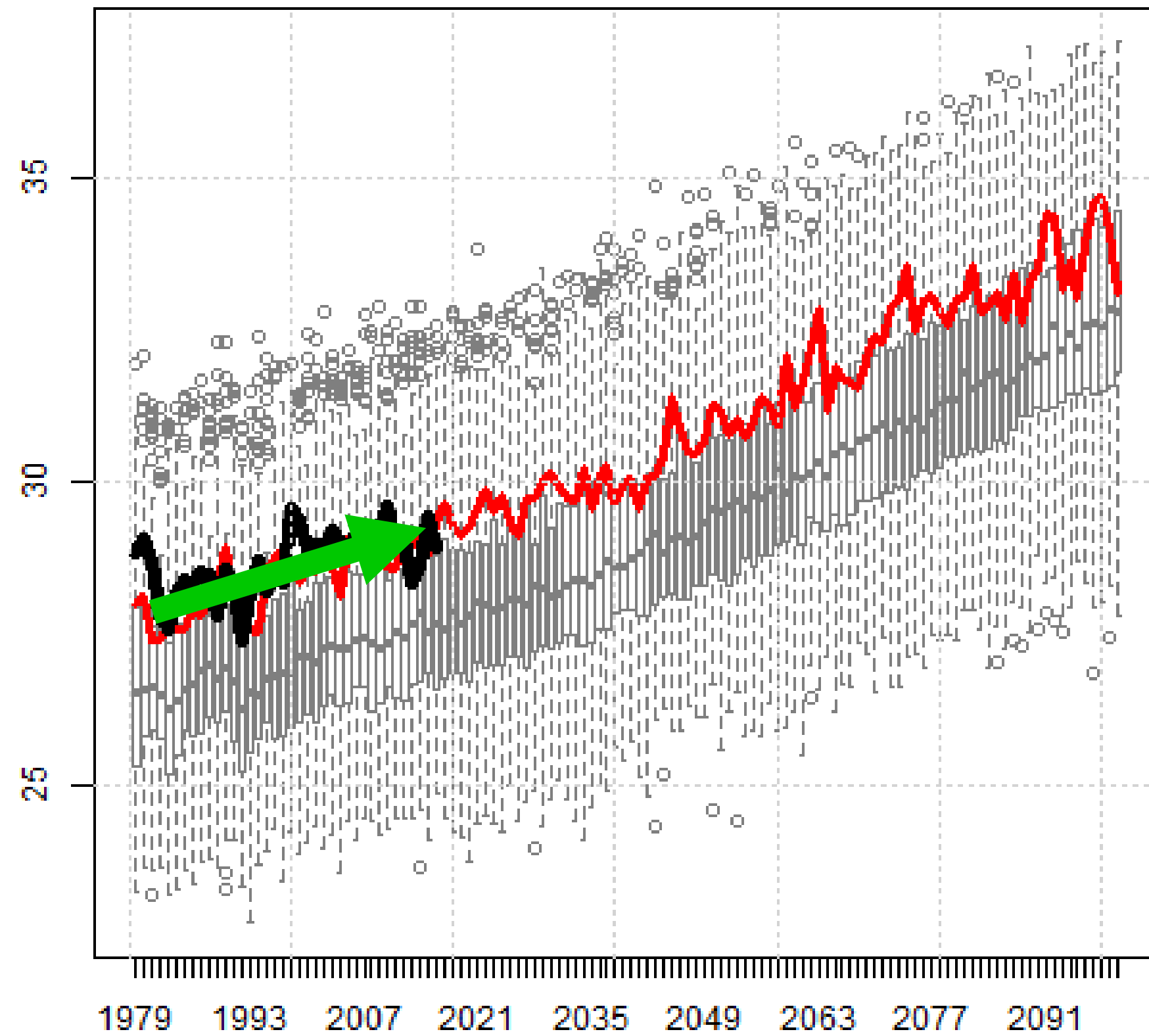
- Weather Research and Forecasting model (WRF) for dynamical downscaling
- Nested Domains: (D1= 36 km); (D2 = 12 km); (D3 = 4 km)



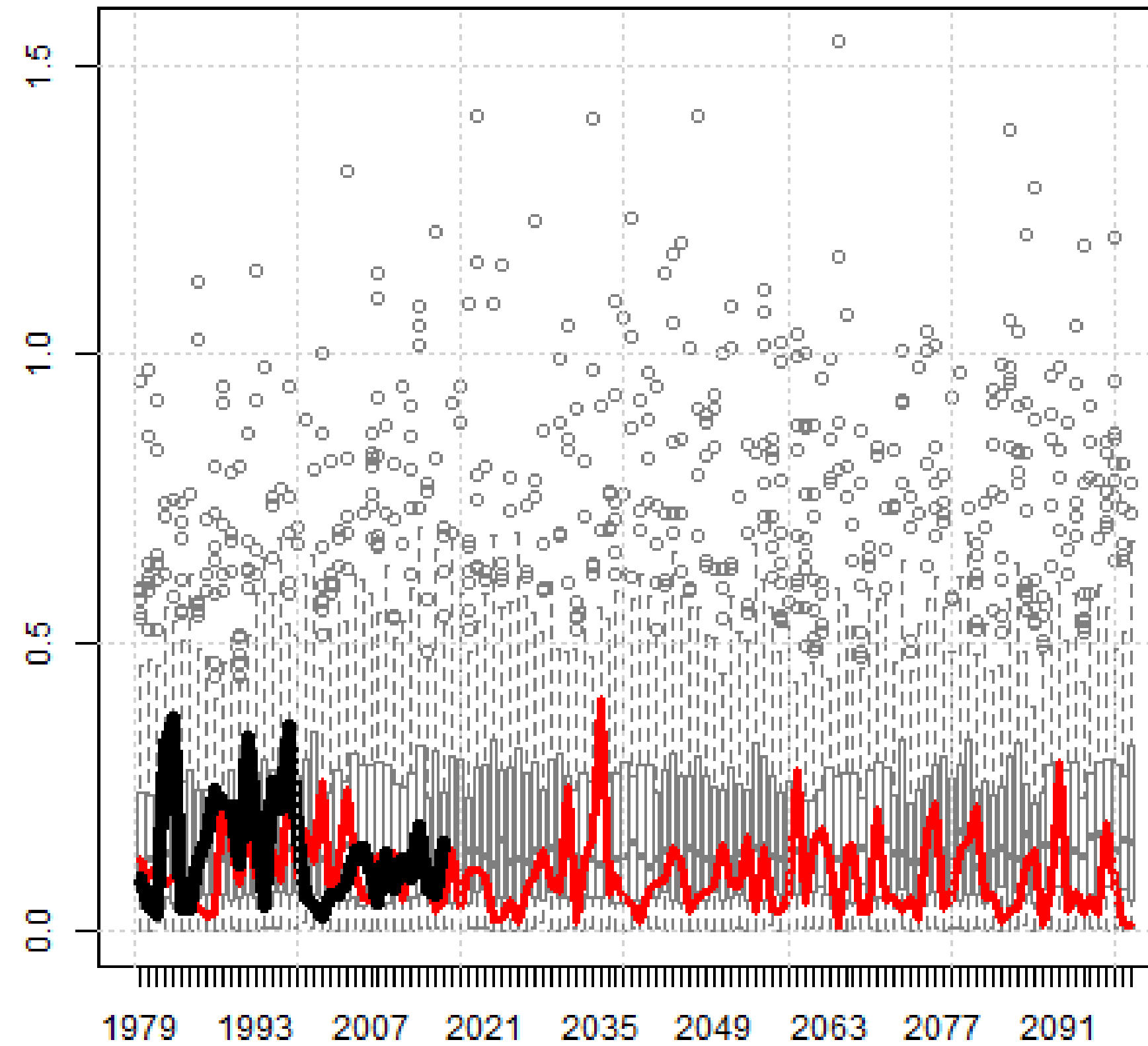
# What do the Global Climate Models Suggest for the Region?



Surface Temperature - MPI-ESM-MR r1i1p1



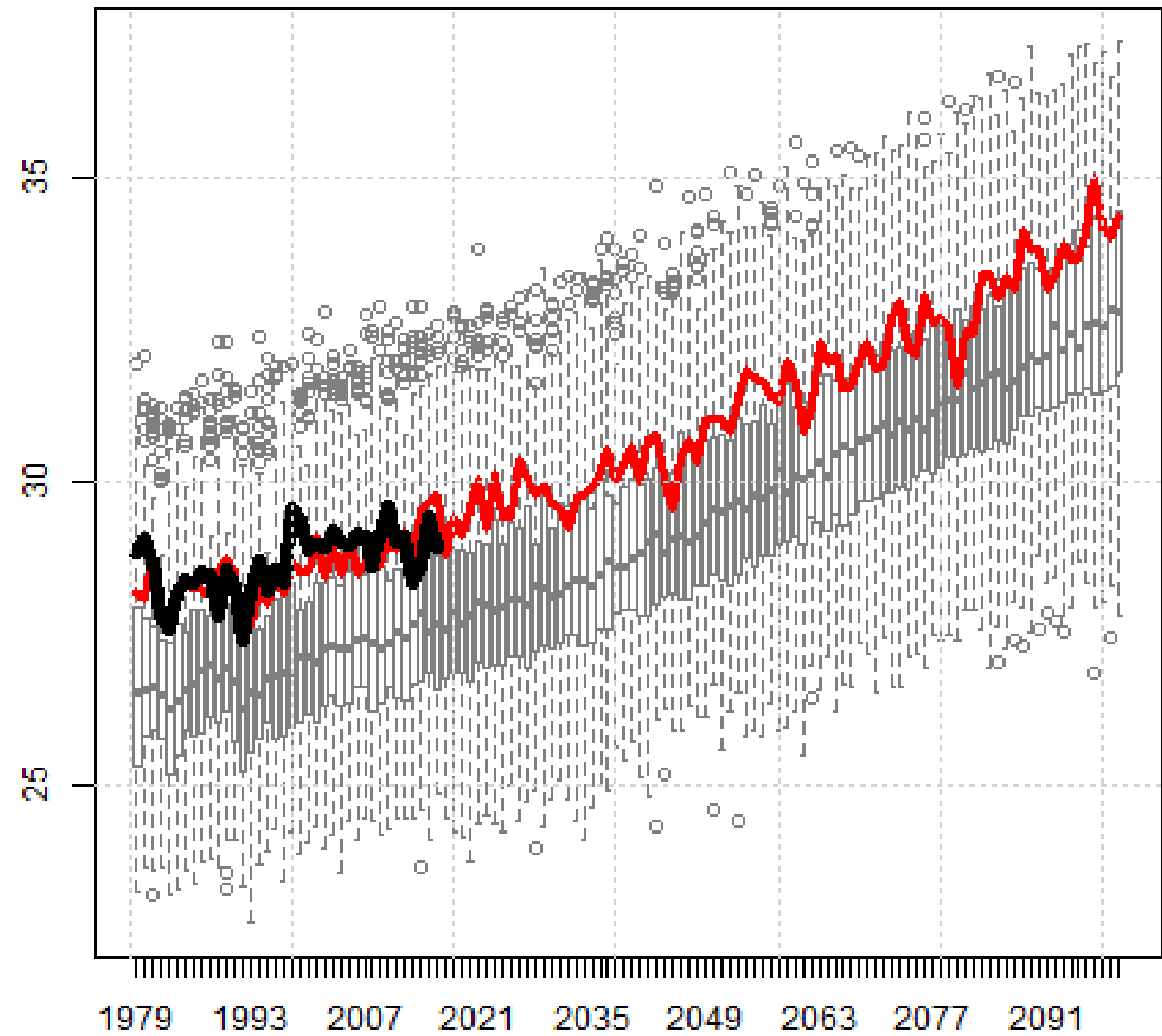
Daily Precipitation - MPI-ESM-MR r1i1p1



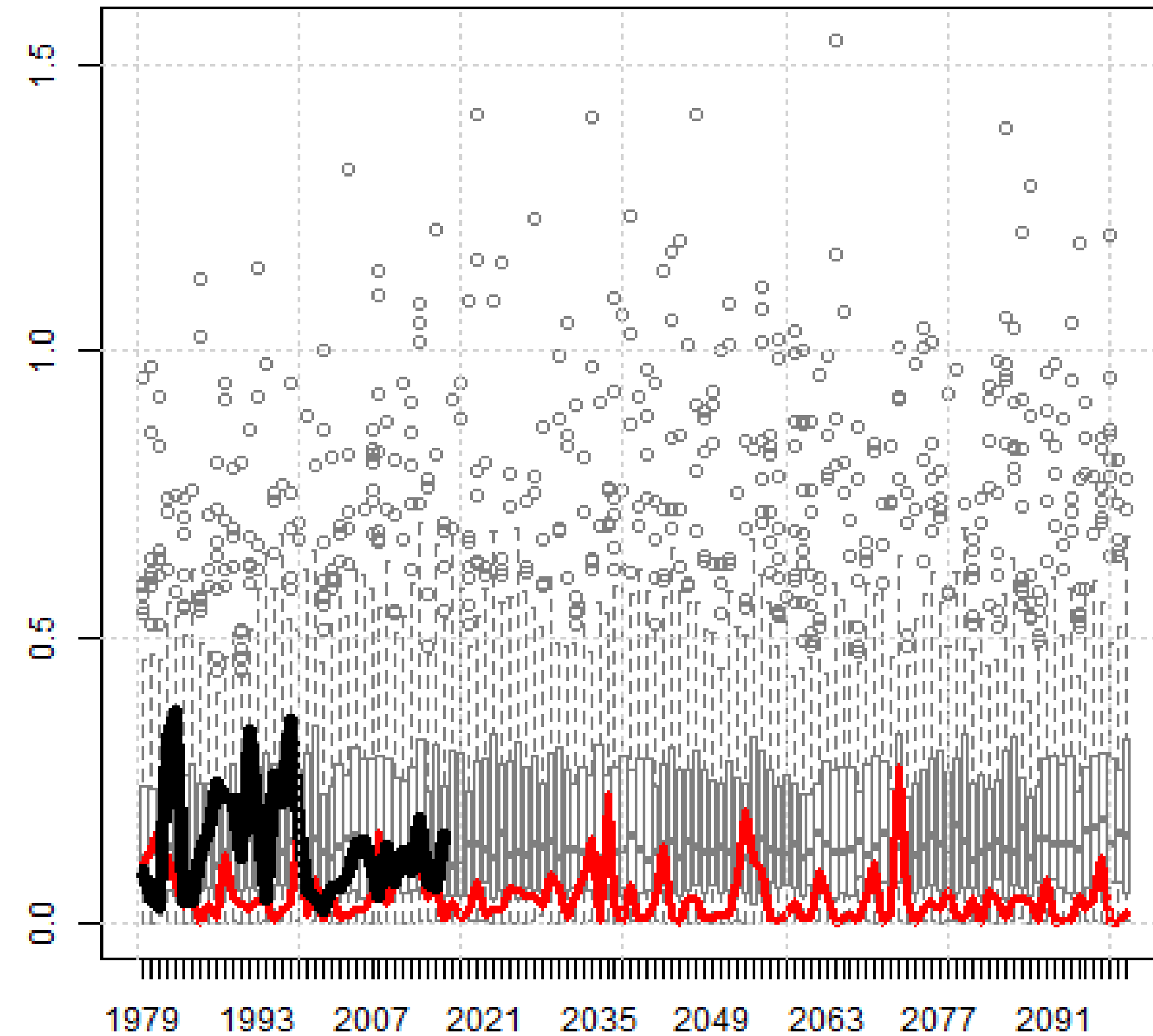
# What do the Global Climate Models Suggest for the Region?



Surface Temperature - MPI-ESM-LR r1i1p1



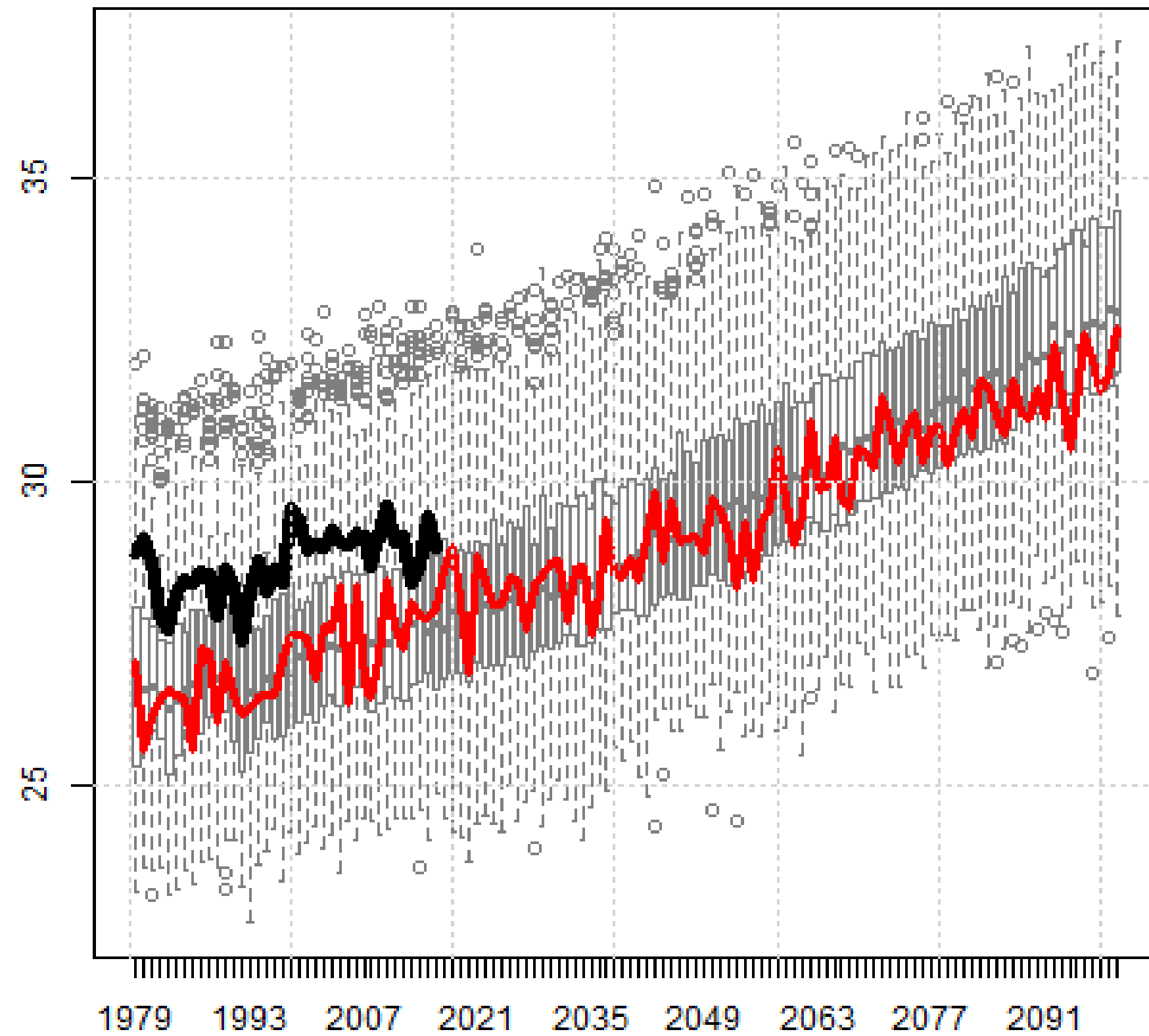
Daily Precipitation - MPI-ESM-LR r1i1p1



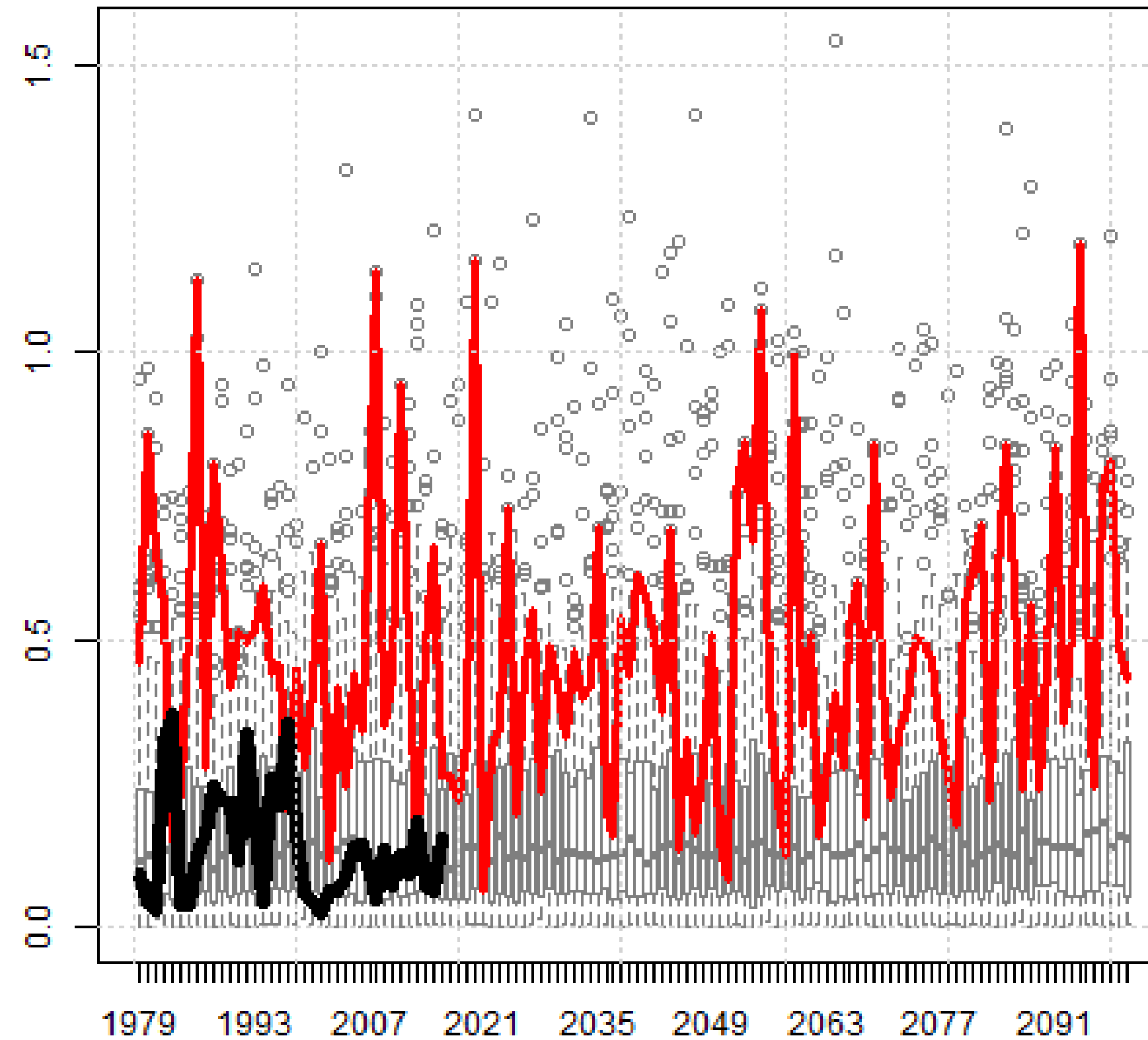
# What do the Global Climate Models Suggest for the Region?



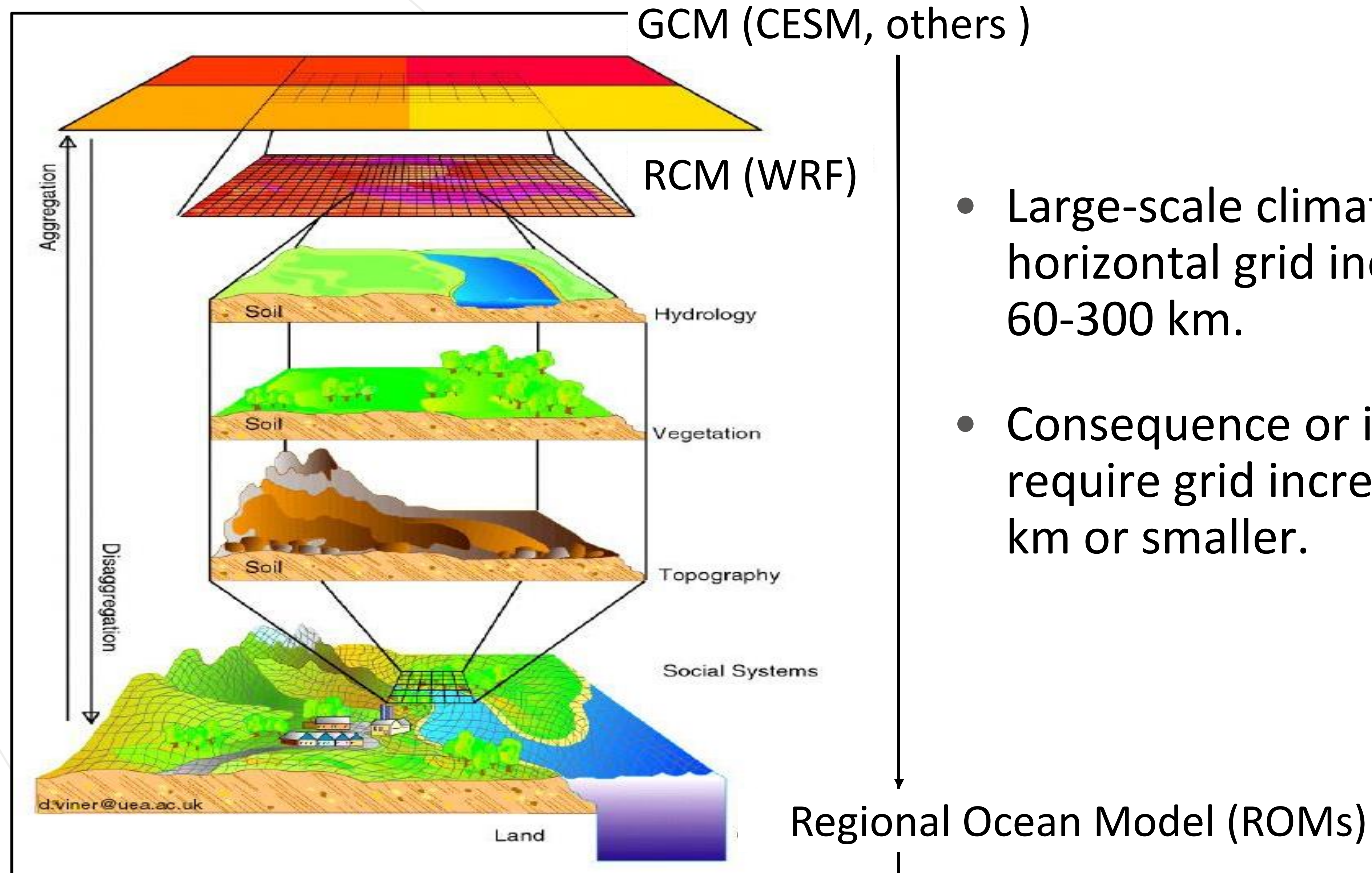
Surface Temperature - CCSM4 r6i1p1



Daily Precipitation - CCSM4 r6i1p1



# Motivation and Approach- GCM to RCM to ROM



Adapted from David Viner, Climatic Res. Unit, Univ. of East Anglia, UK.

# Challenges to Address....

## Computational Requirement

- Downscaling can be computationally expensive. How did we perform the downscaling to meet needs?

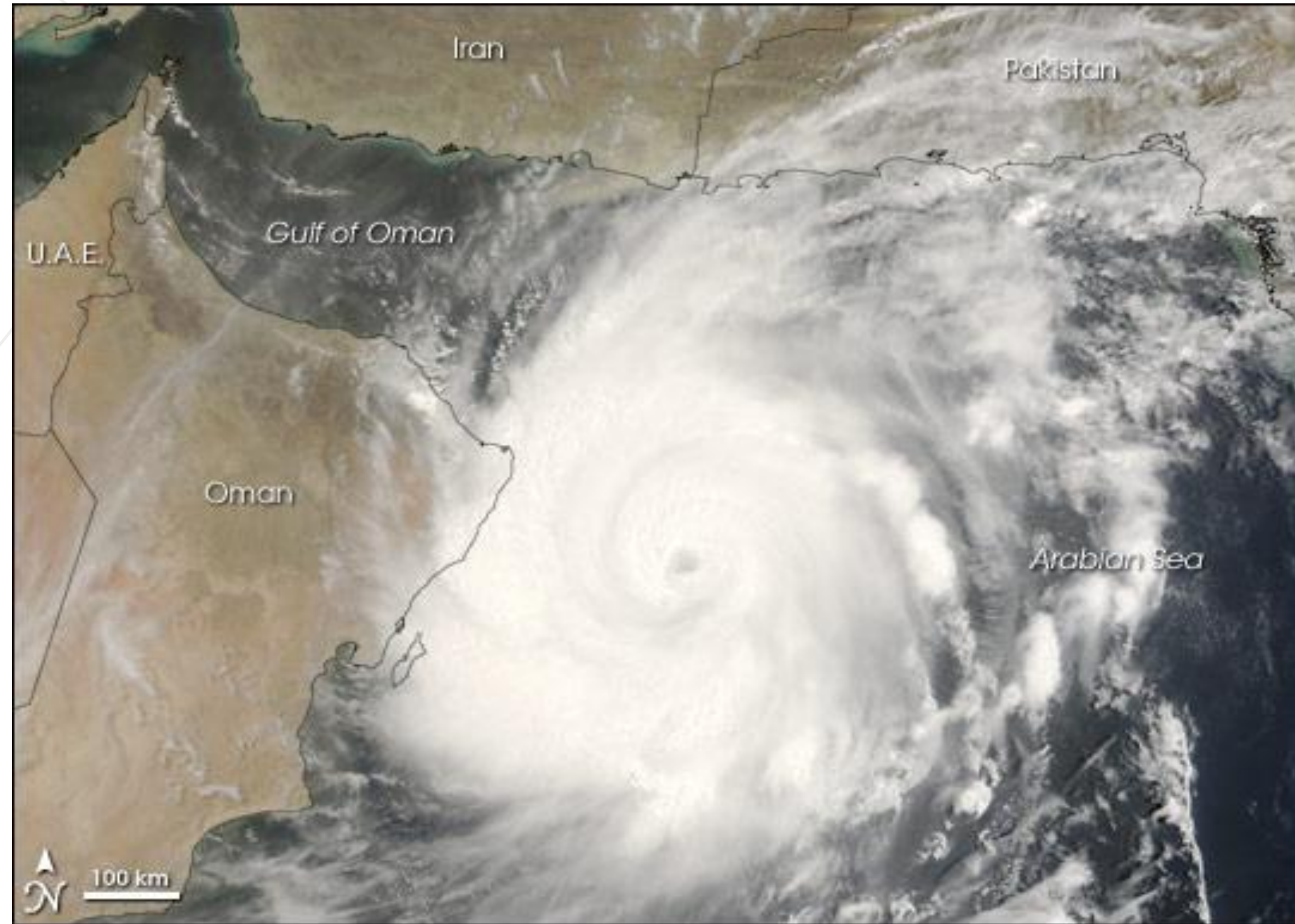
## Model Uncertainty

- There are many global climate models (GCMs). Which climate model should we downscale?
- GCMs are imperfect. How did we address deficiencies in a given GCM?

# WRF TESTS : TROPICAL CYCLONE GONU, JUNE 1-7 2007

## BACKGROUND

- Strongest Tropical Cyclone Ever Recorded in Arabian Sea
- Extensive damage to Oman, Iran and Pakistan (UAE?)
- Imperative that we simulate extremes such as GONU

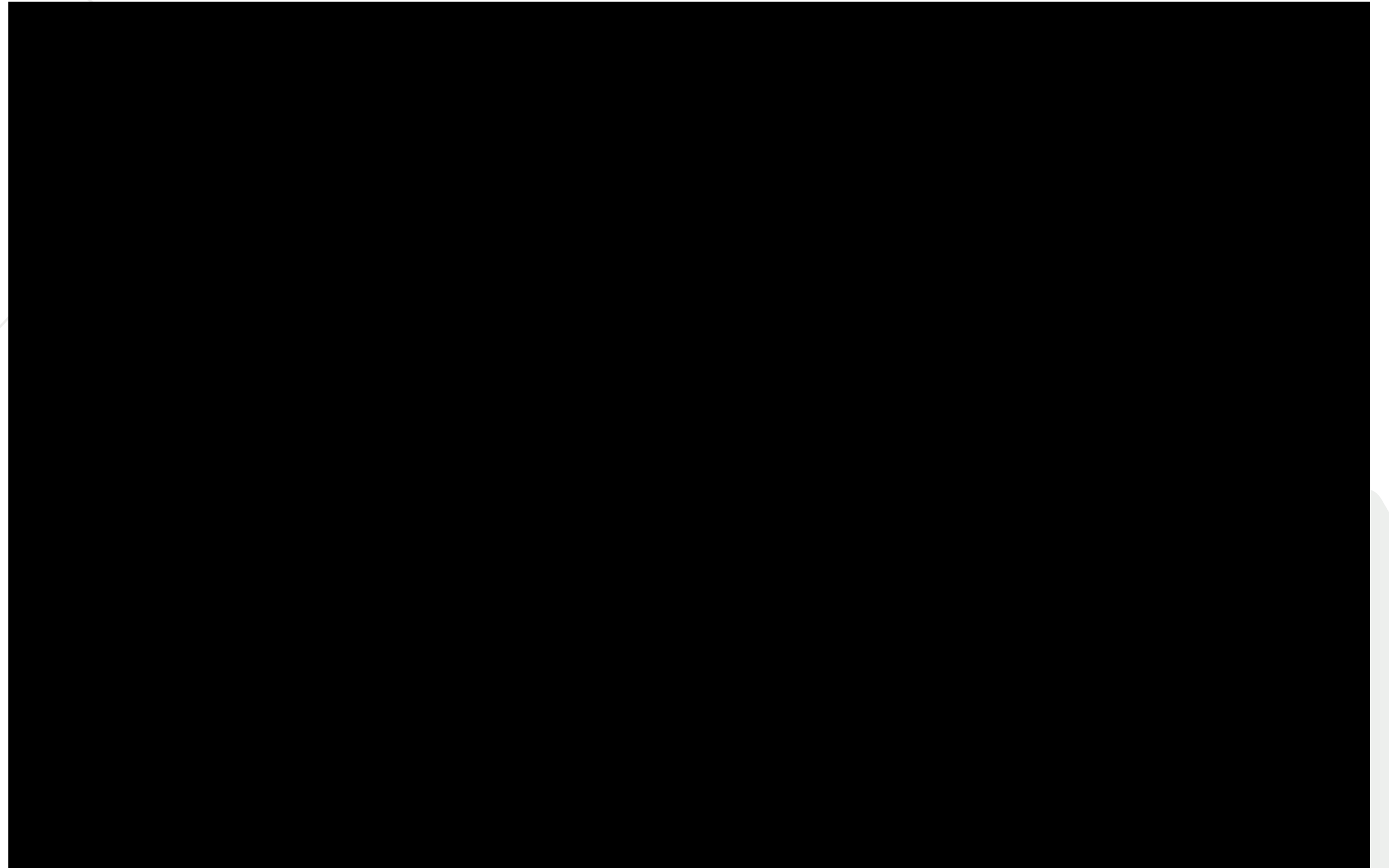


MODIS Image courtesy NASA Earth Observatory

# WRF TESTS: TROPICAL CYCLONE GONU- WIND TRAJECTORIES ANIMATION

## THIS MOVIE

- Shows wind Trajectories for TC Gonu
- Colors are Wind Speed (blue = slower, red = faster)

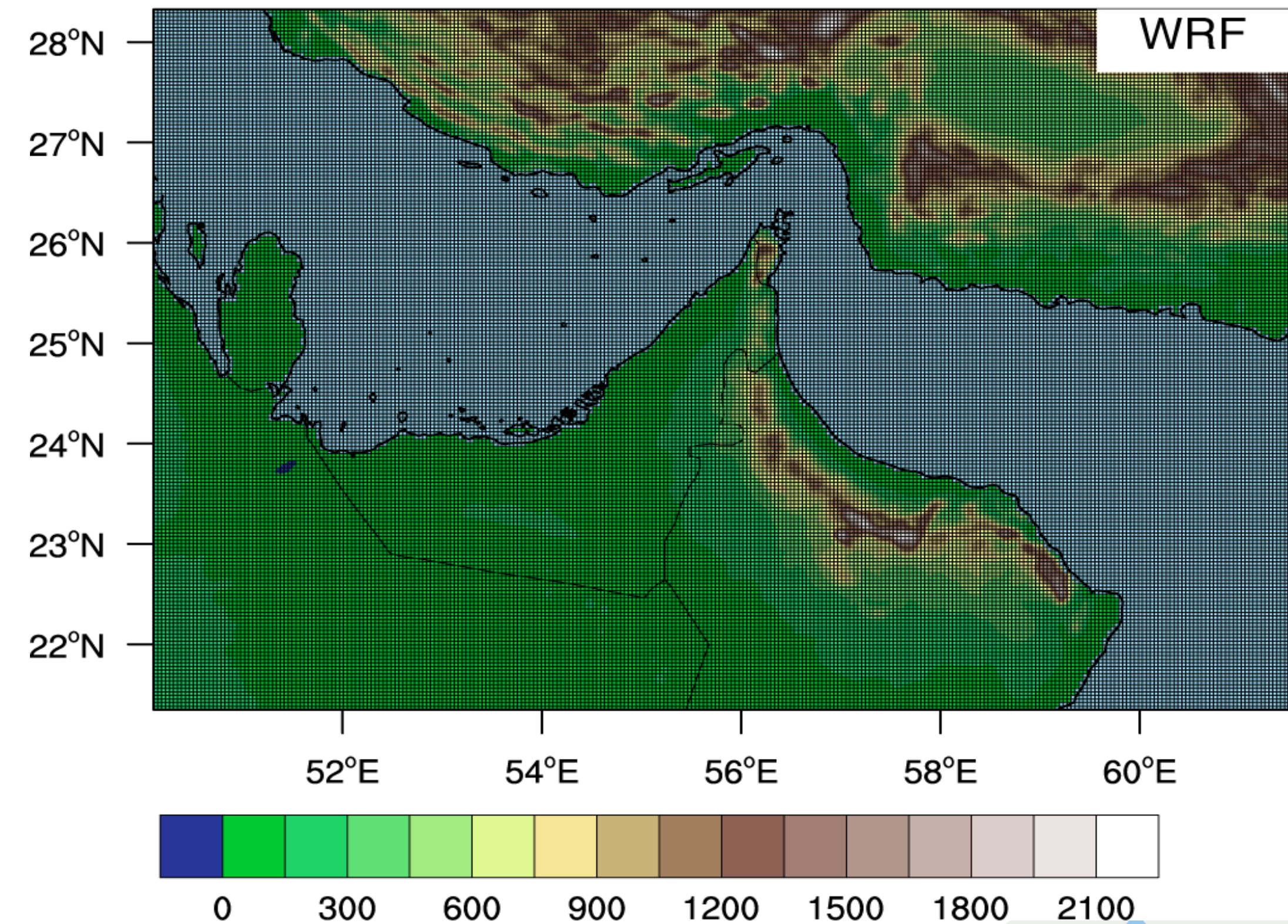
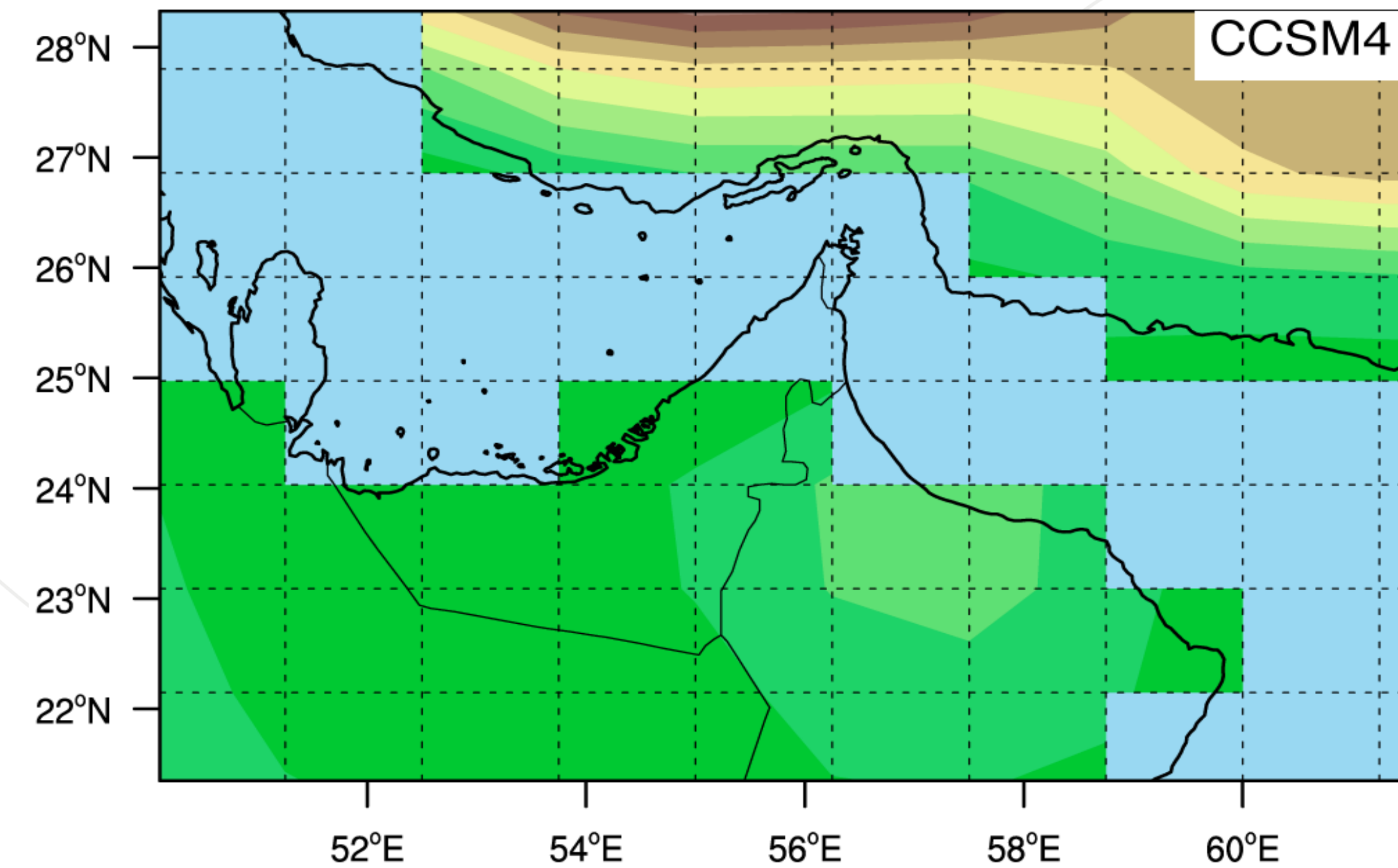


# Key Goal: Capture local scale meteorological processes, to more realistically consider future change

GCM (~100km)



RCM (4-km)

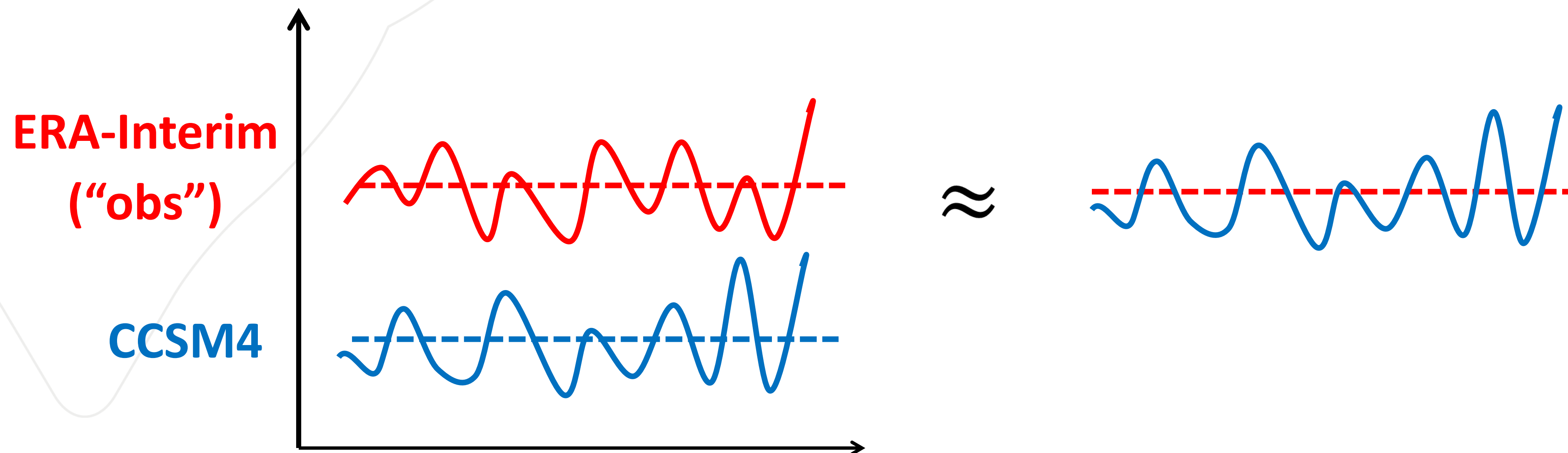


# Modeling Approach- Bias Correction of Forcing Data

- Retains 'mean' state of ERA-Interim and the 'weather' state from CCSM4.
- The 'mean' state is 25-year period, 1980-2005, which ensures that the *climate change* signal is included in the perturbation for CCSM4.

## BIAS-CORRECTION METHOD (Current Climate)

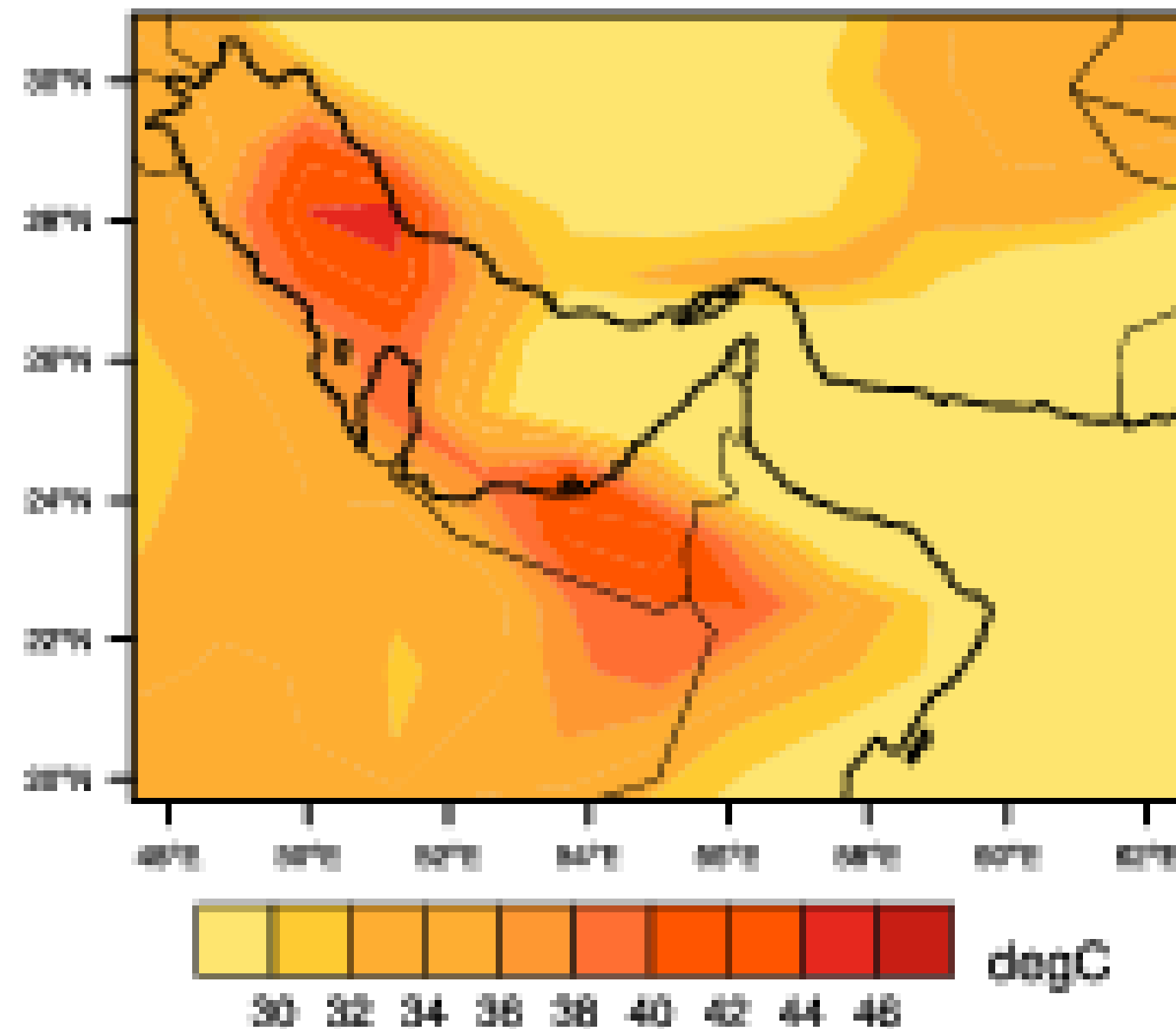
$$CCSM_R = \overline{ERAINT} + CCSM'$$



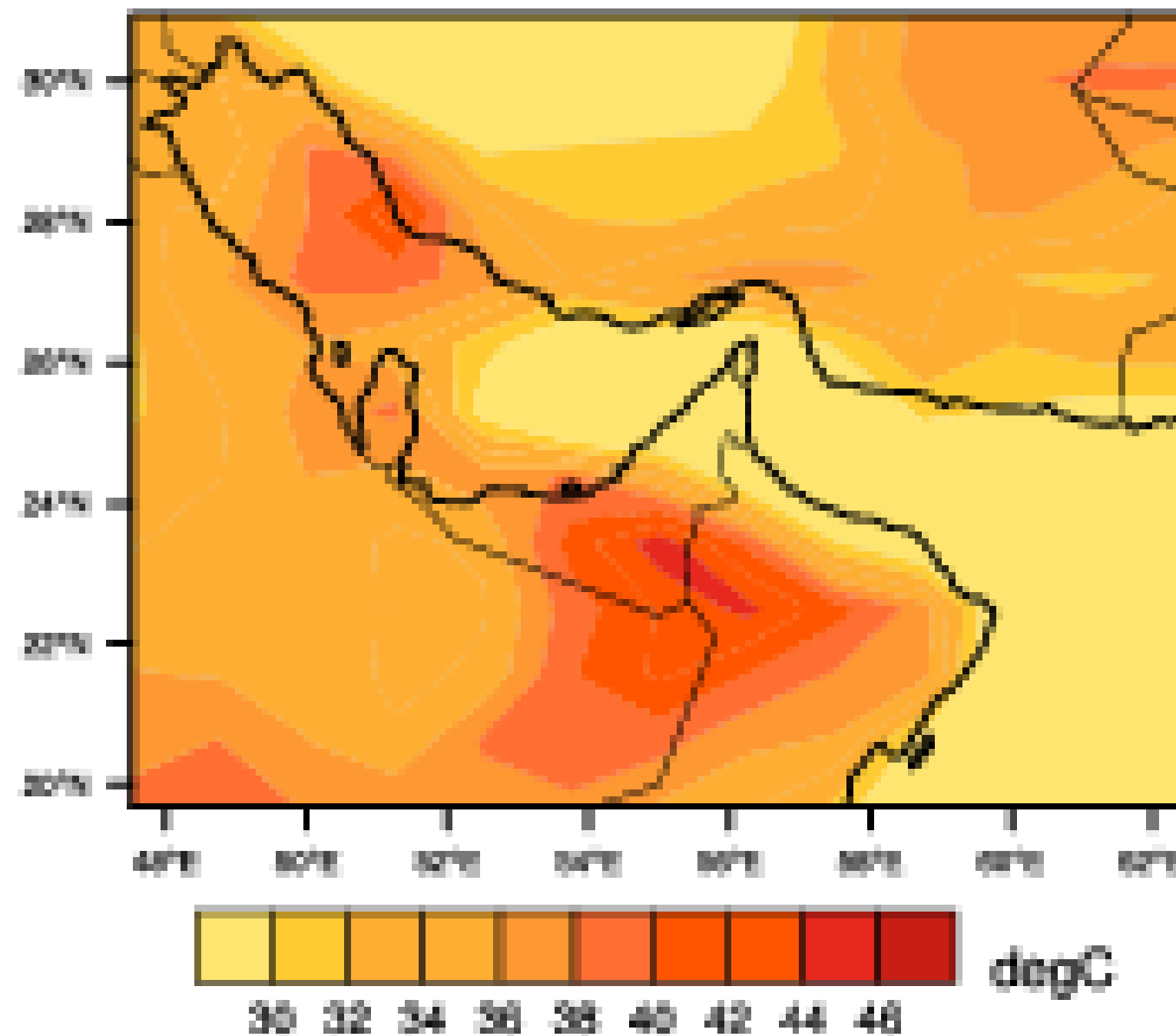
# Examples of Bias-Correction

CCSM4 Bias Correction - T2 - 15 July 2000 0600 UTC

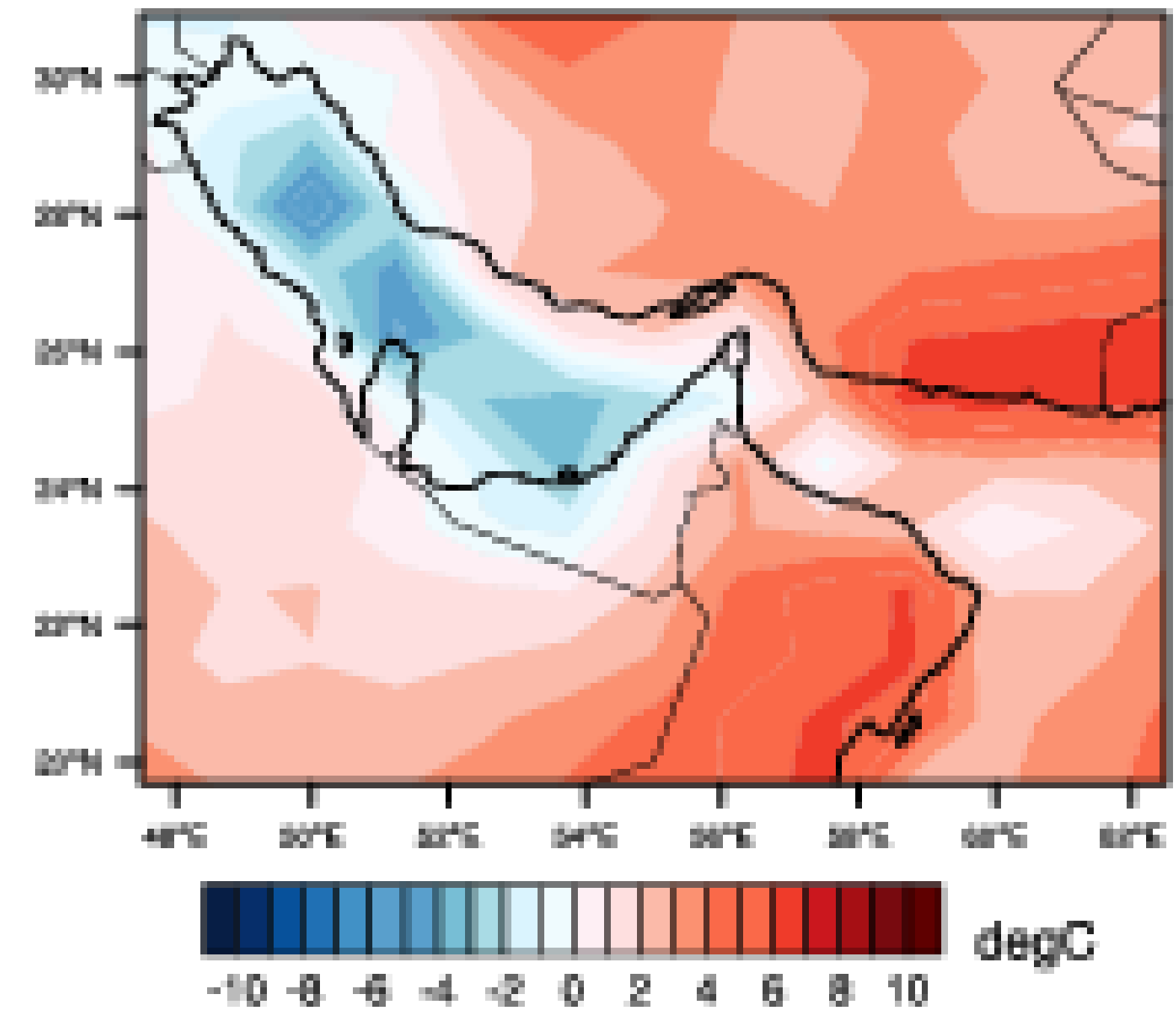
CCSM4



Bias Corrected CCSM4



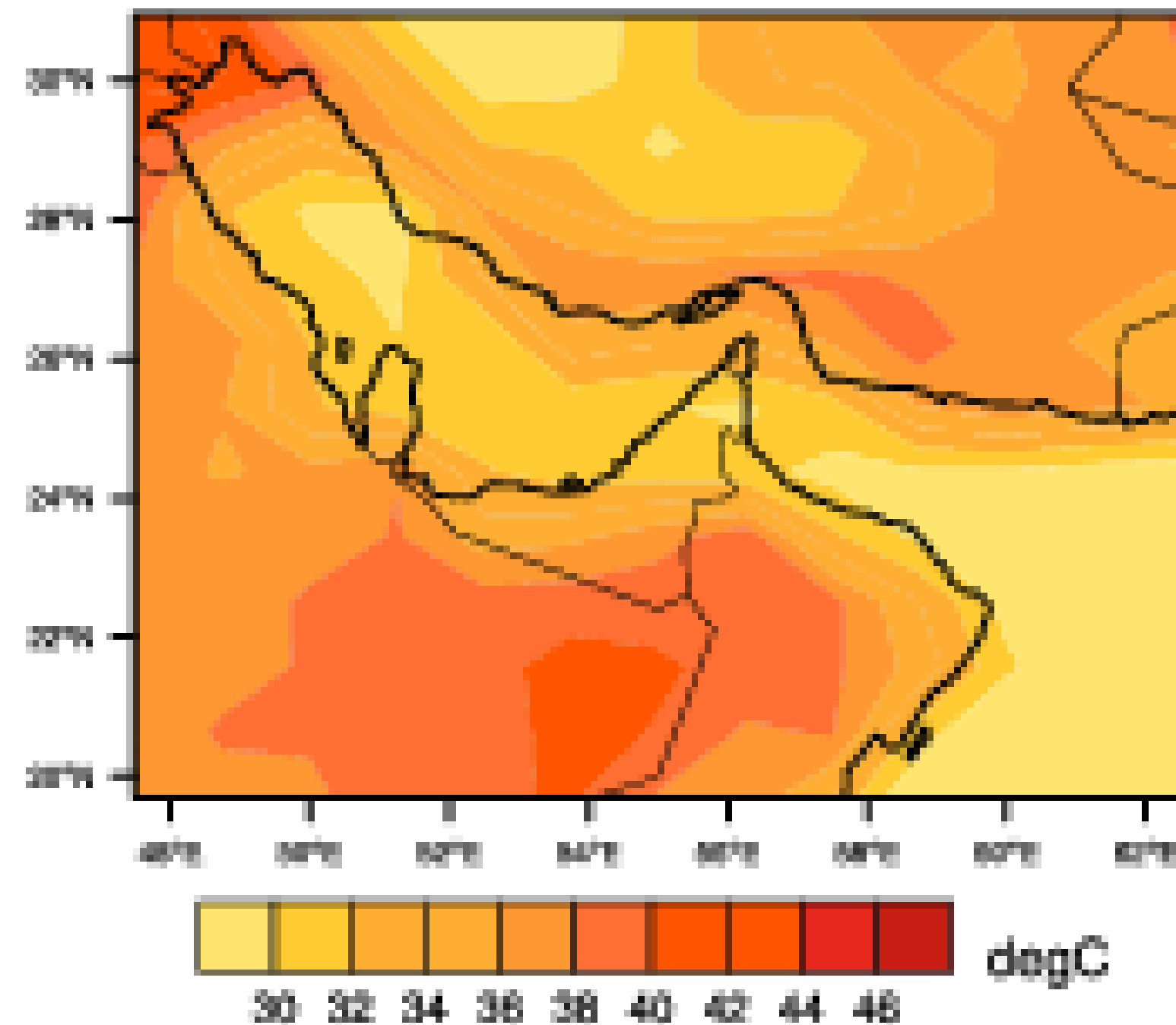
Applied Correction



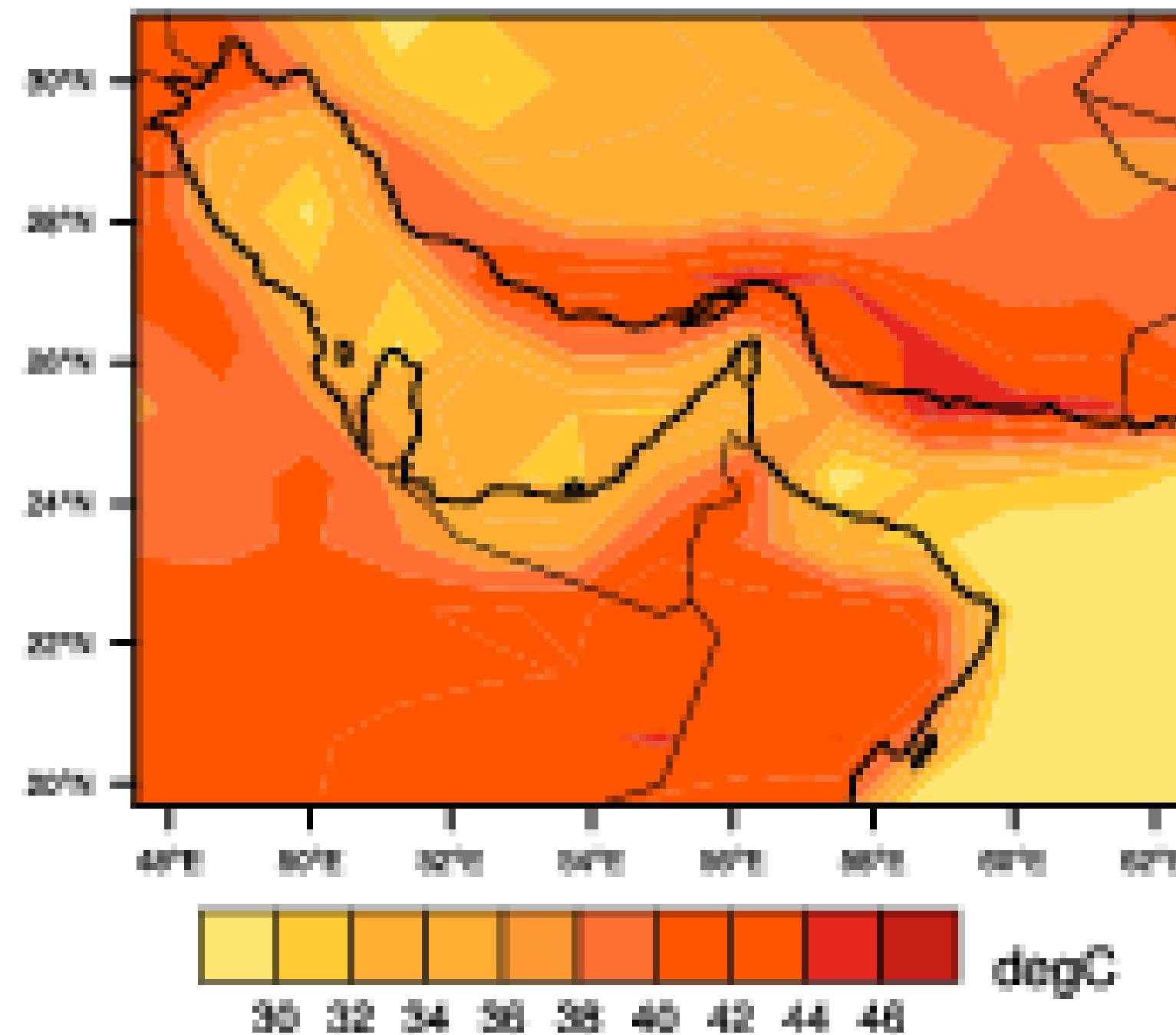
# Examples of Bias-Correction

CCSM4 Bias Correction - TSK/SST - 15 July 2000 0600 UTC

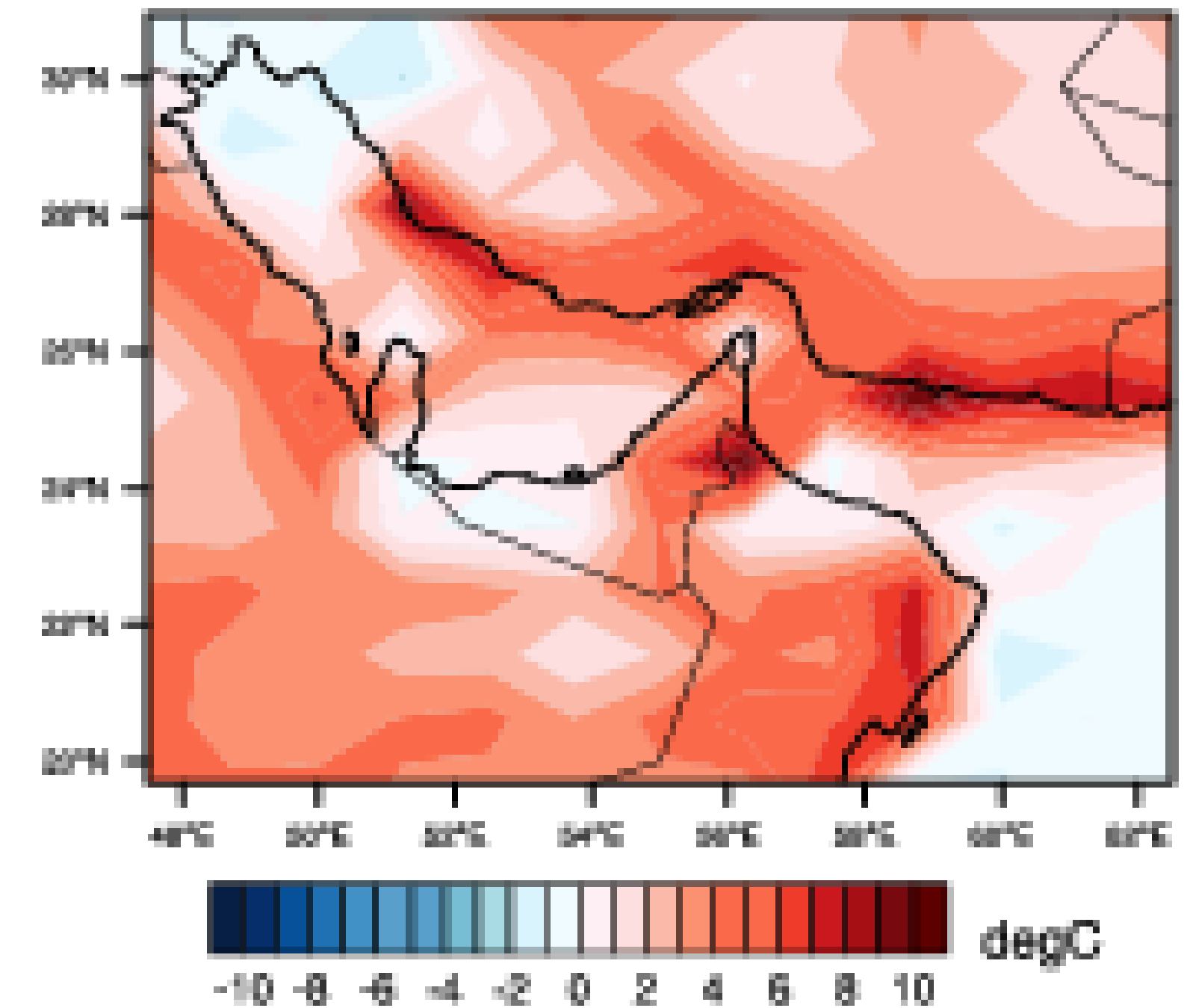
CCSM4



Bias Corrected CCSM4

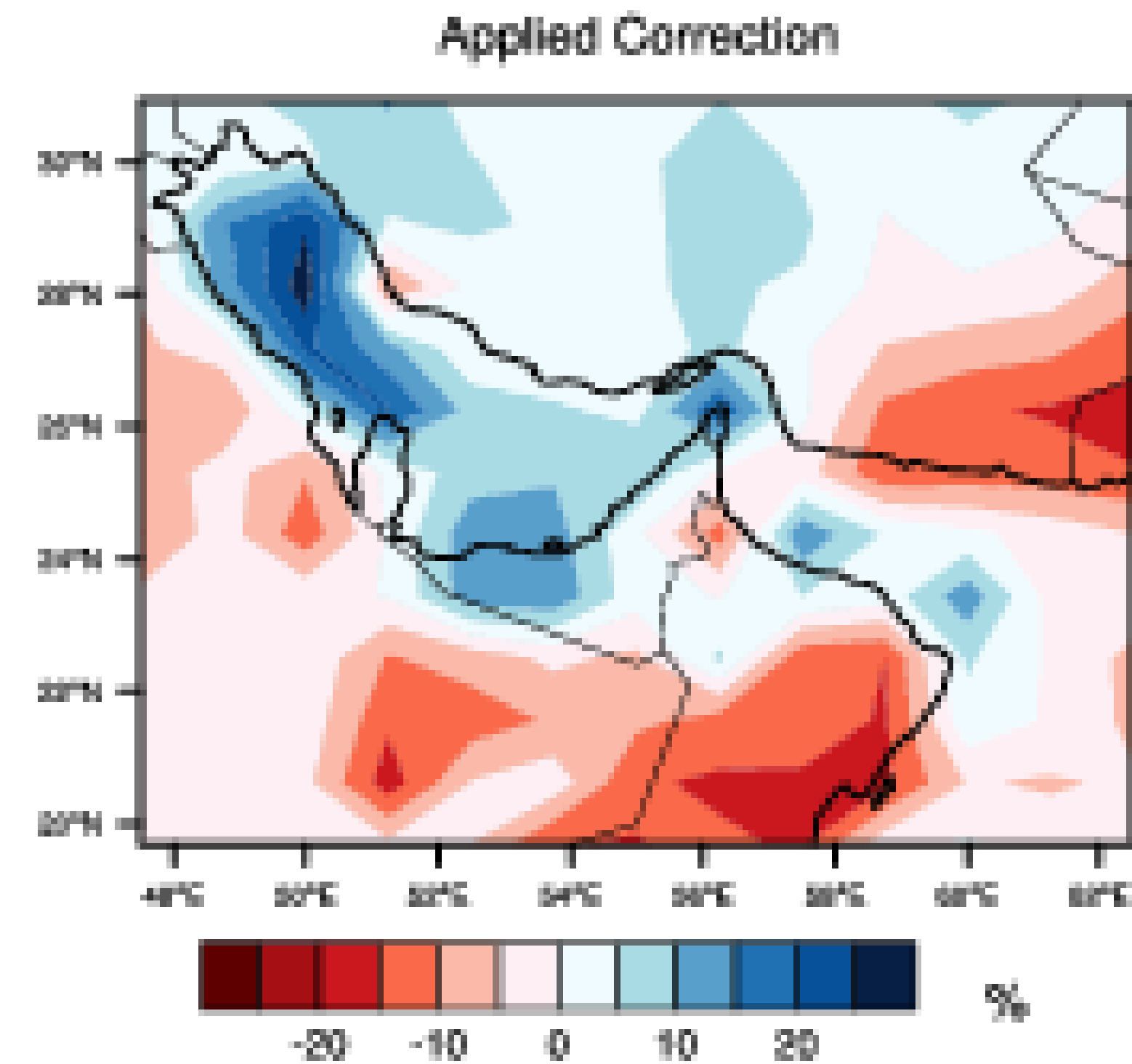
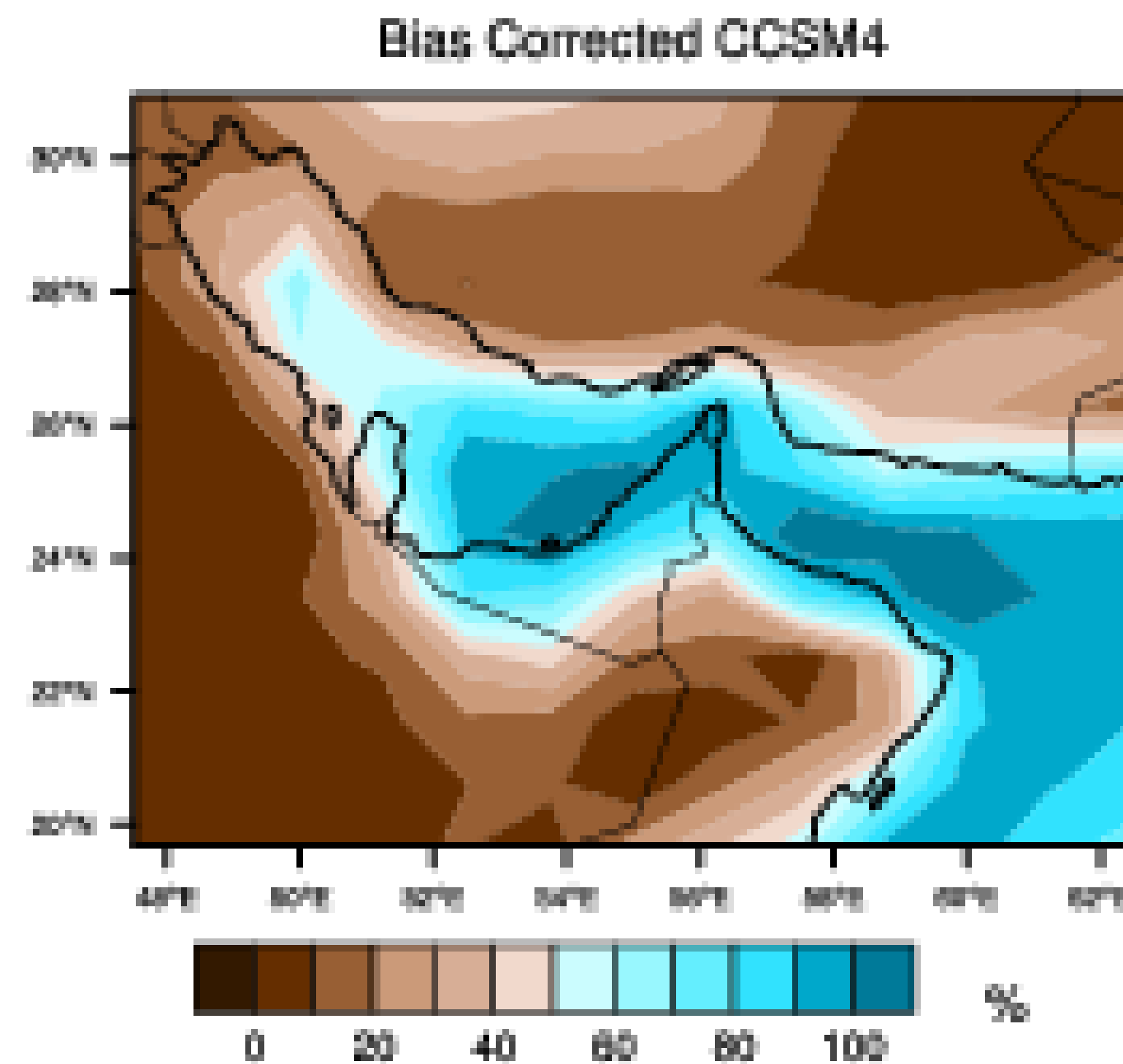
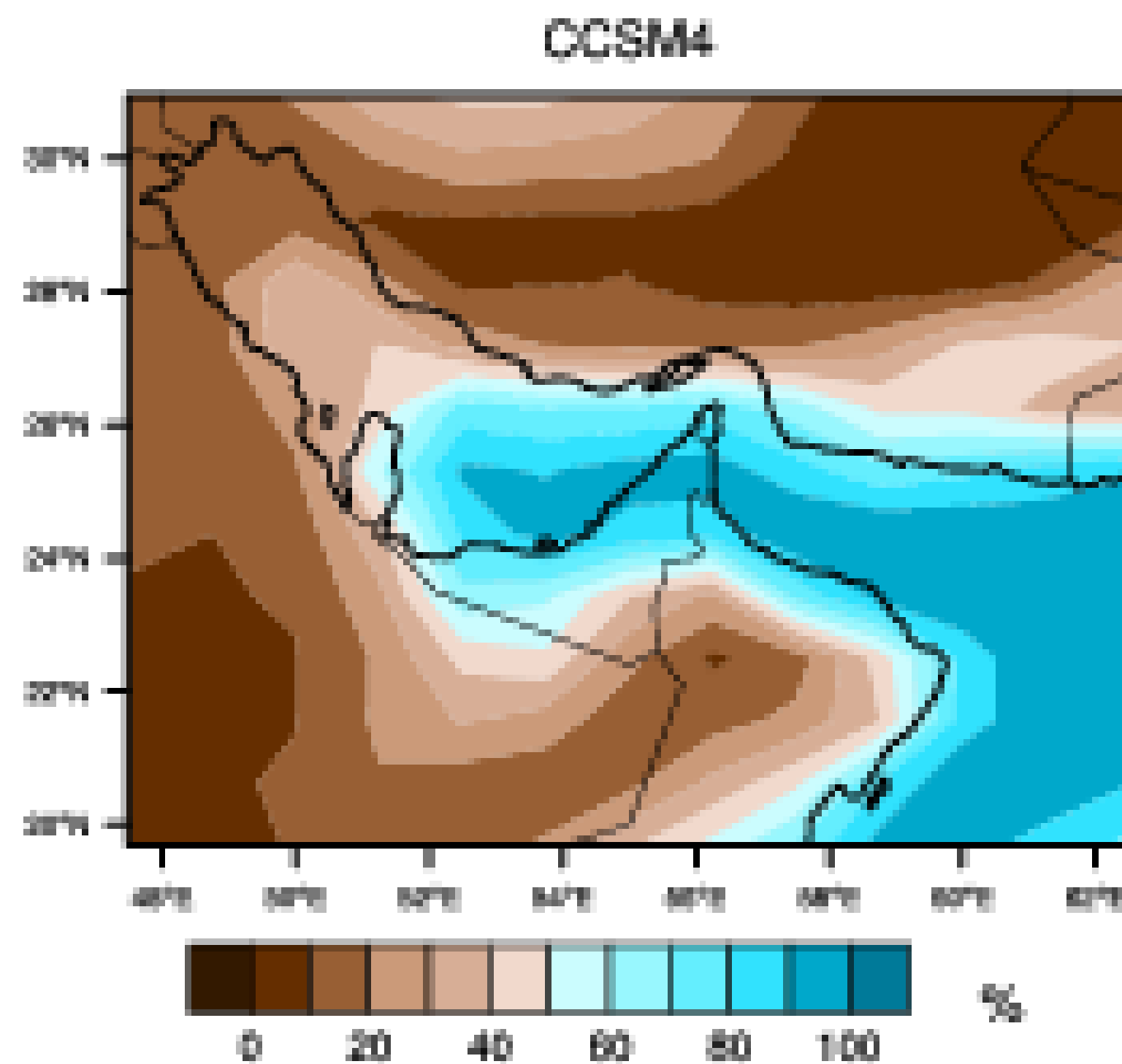


Applied Correction



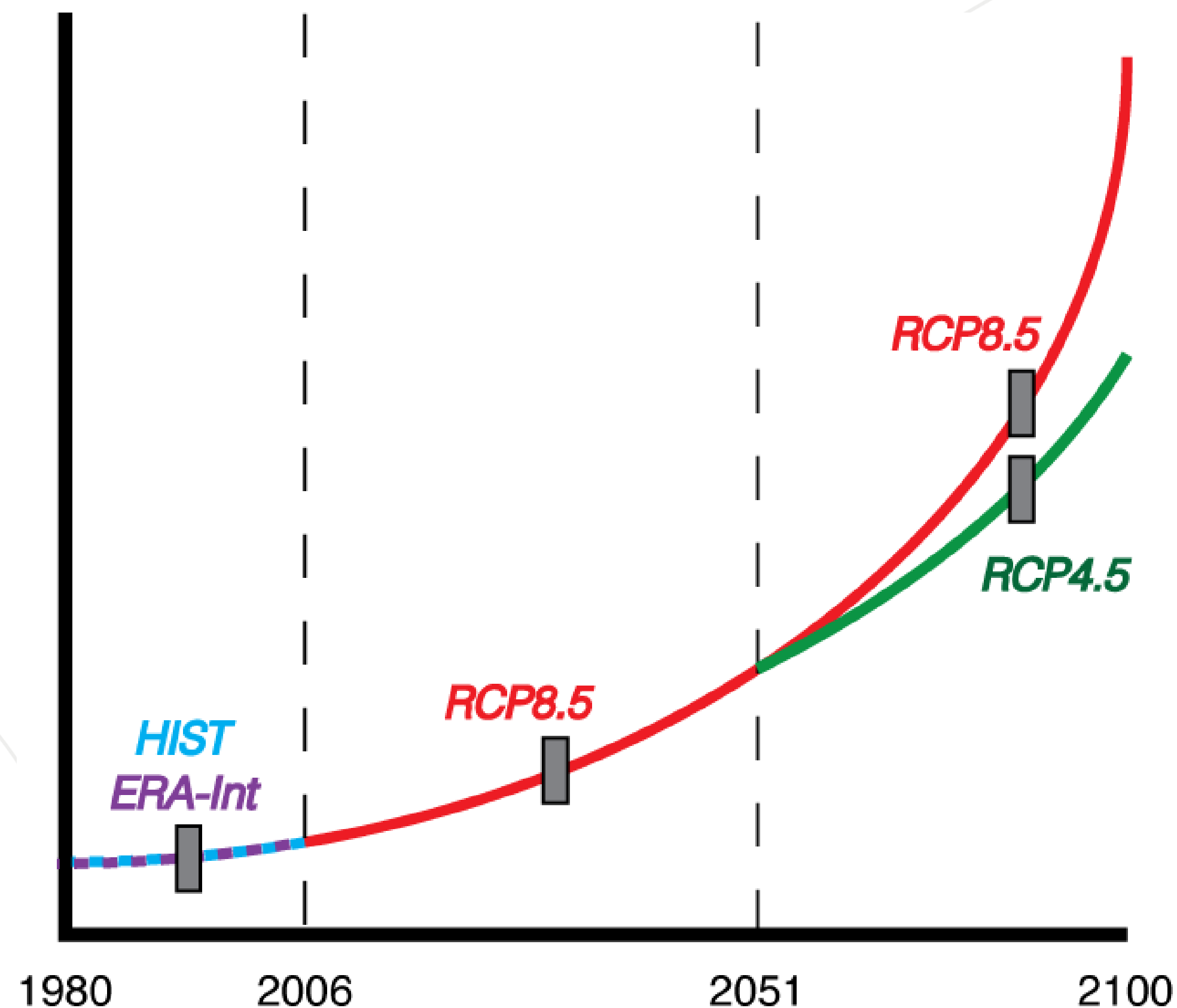
# Examples of Bias-Correction

CCSM4 Bias Correction - RH2 - 15 July 2000 0600 UTC



## OUR EXPERIMENTAL DESIGN / MODELING APPROACH, PART 2

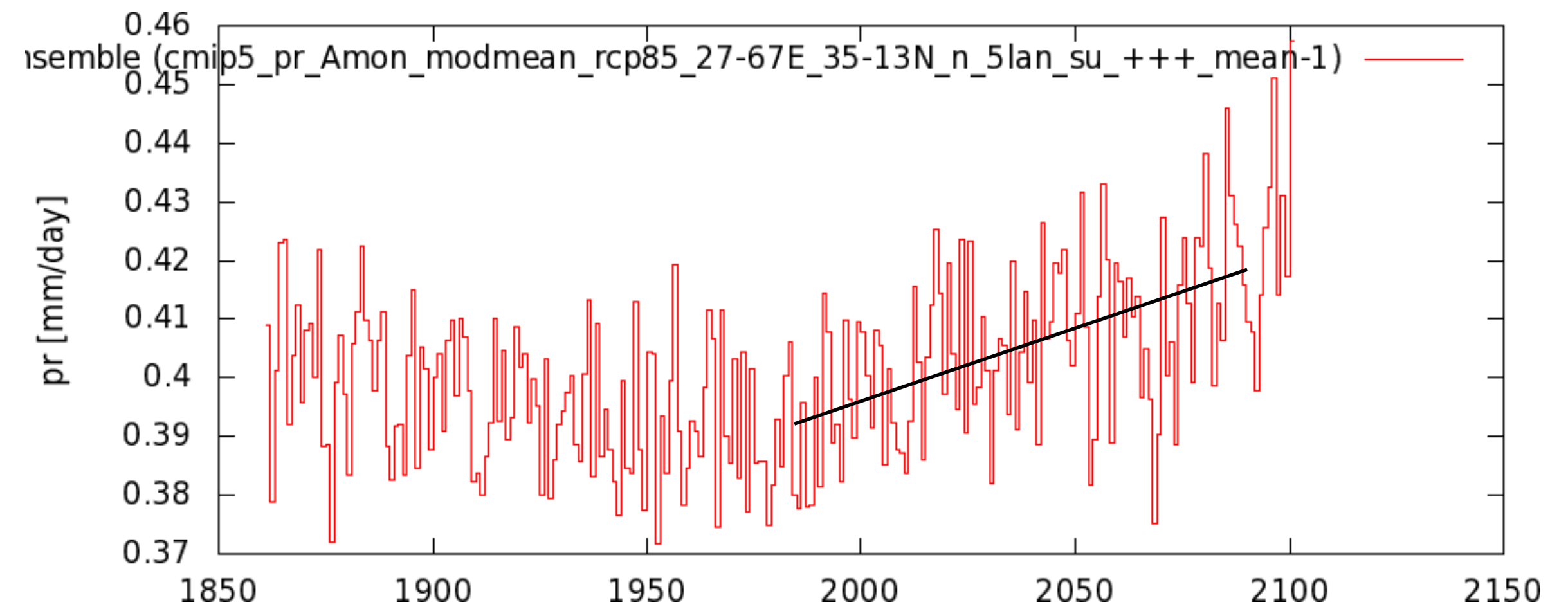
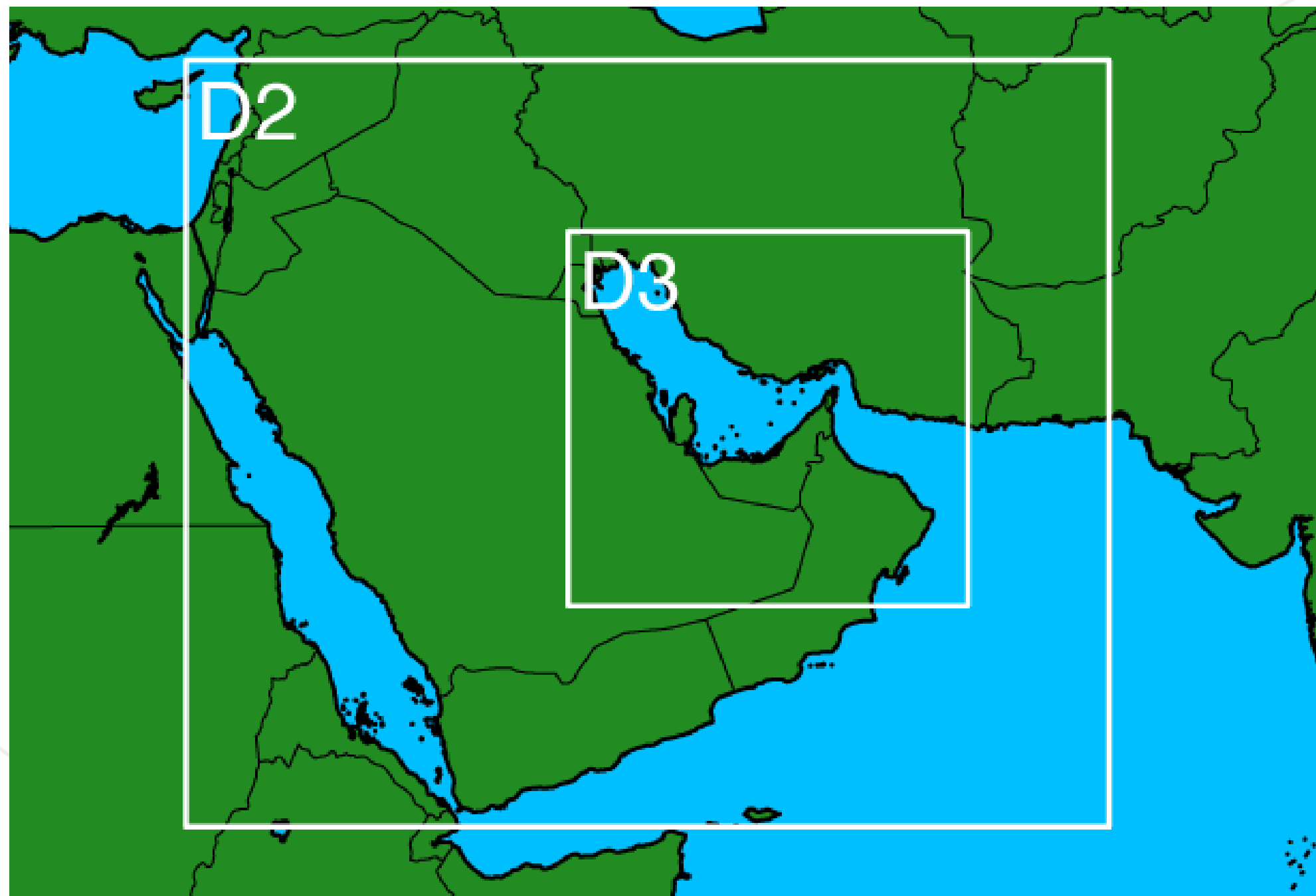
- 25-year Historical simulations from **1980-2005**. WRF driven with ERA-Interim
- 120-year Historical+Future simulation with **CCSM4 RCP8.5** simulation ('business as usual' emissions scenario)
- 50-year Future "branch" simulation with **CCSM4 RCP4.5** simulation (moderate emissions scenario)
- 10-year Future Time-Slices, with the 4-km Domain active.



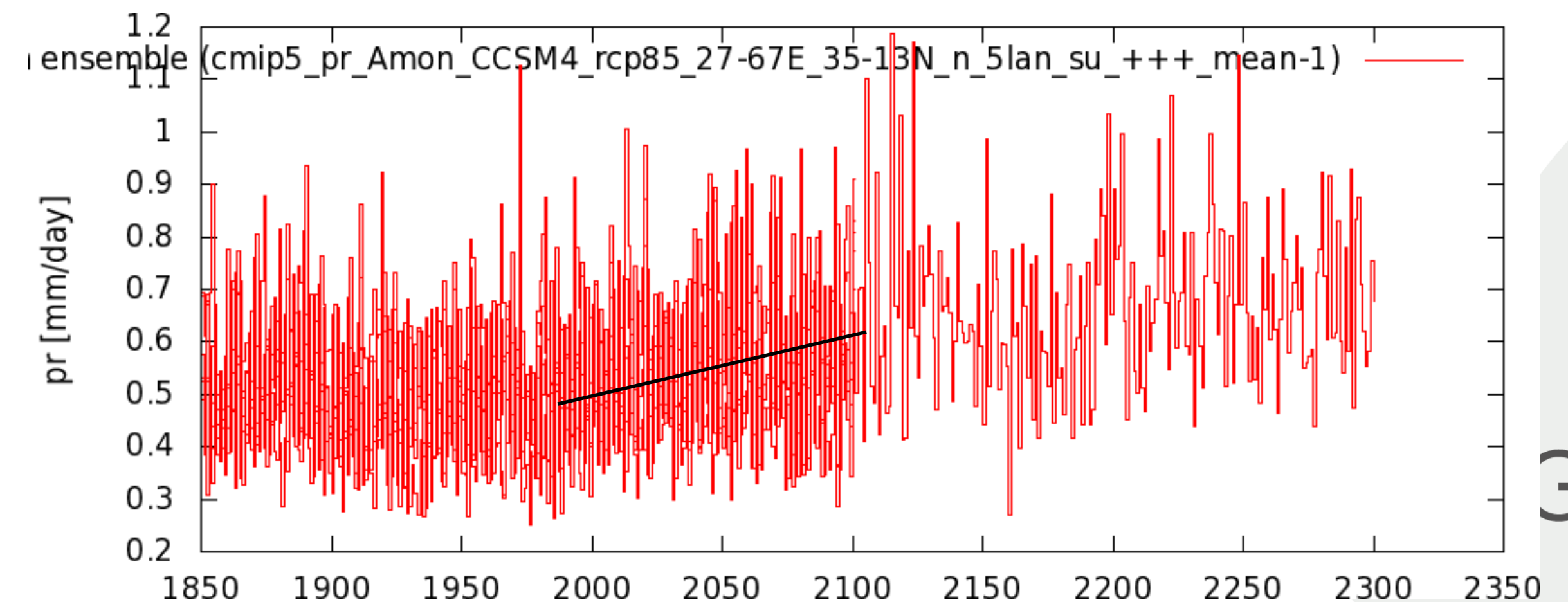
Computational Cost: ~800,000 core hours  
~60 TB for full experiment (3-d volumes)  
~2 TB for 2-d, hourly surface fields

# RCP8.5- Future Precipitation for Region

## Multi-Model Ensemble Mean over D2



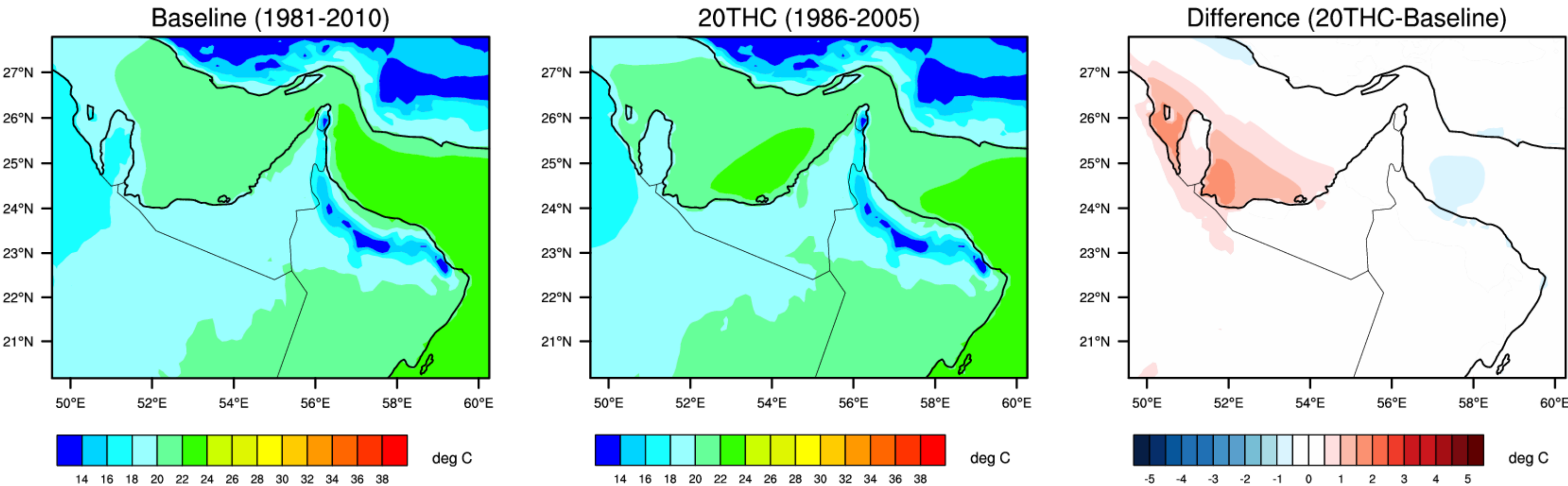
## NCAR-CCSM4 Projection (6 ensembles)



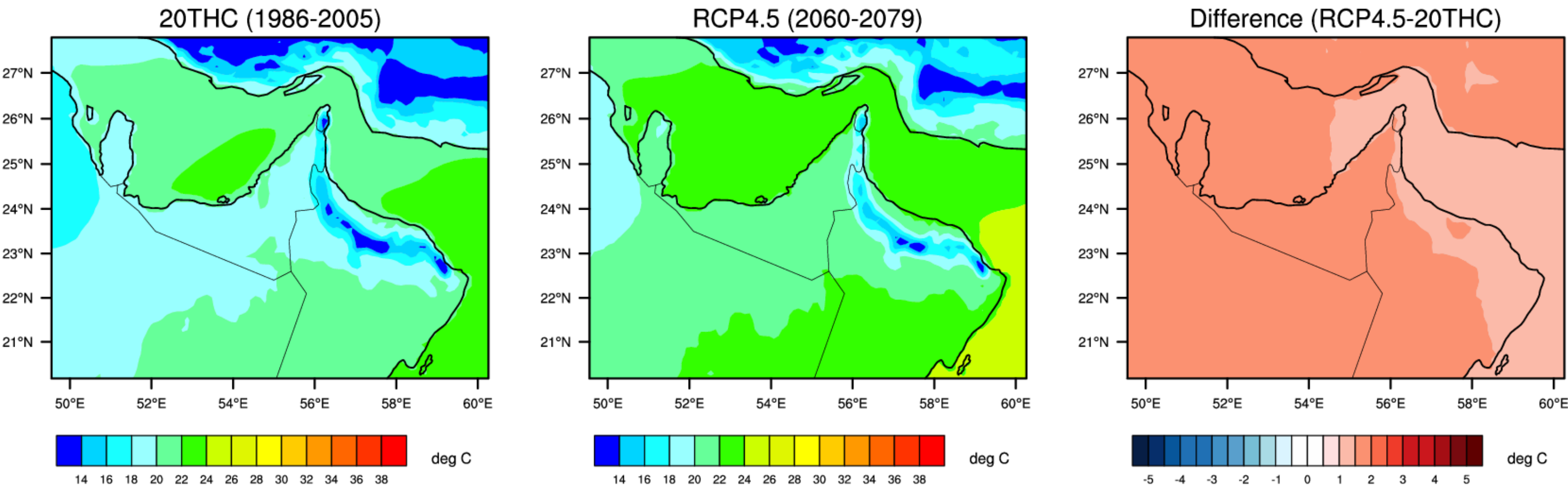
# Regional Temperature (winter)

12-km Domain Average 2-m Air Temperature

VERIFICATION



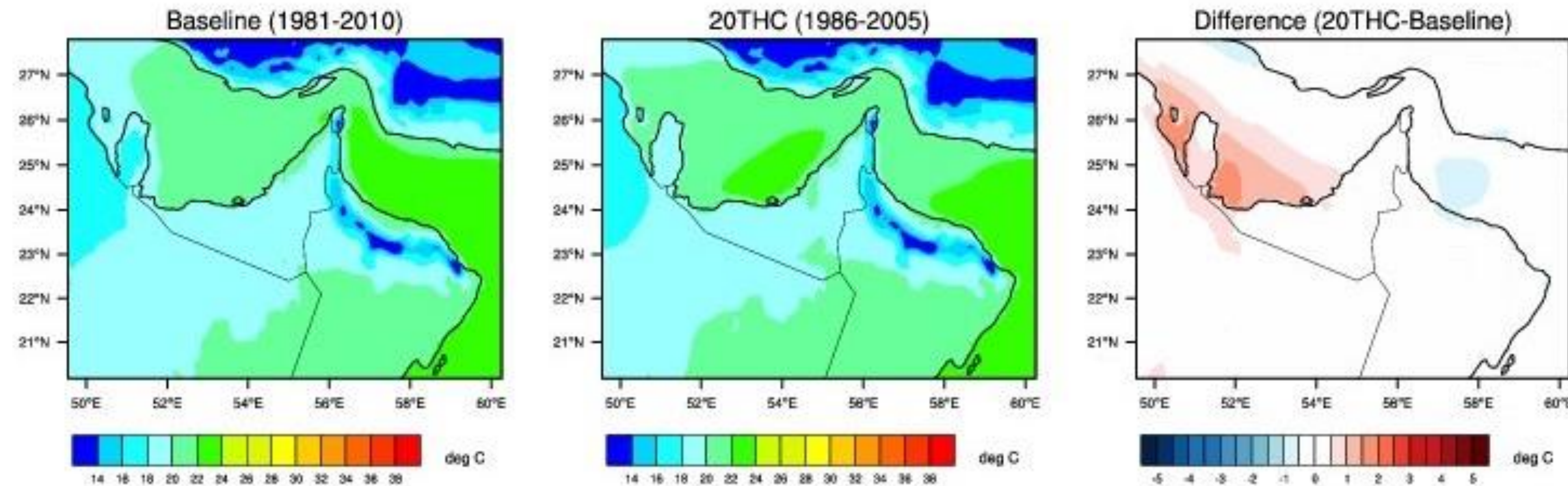
12-km Domain Average 2-m Air Temperature



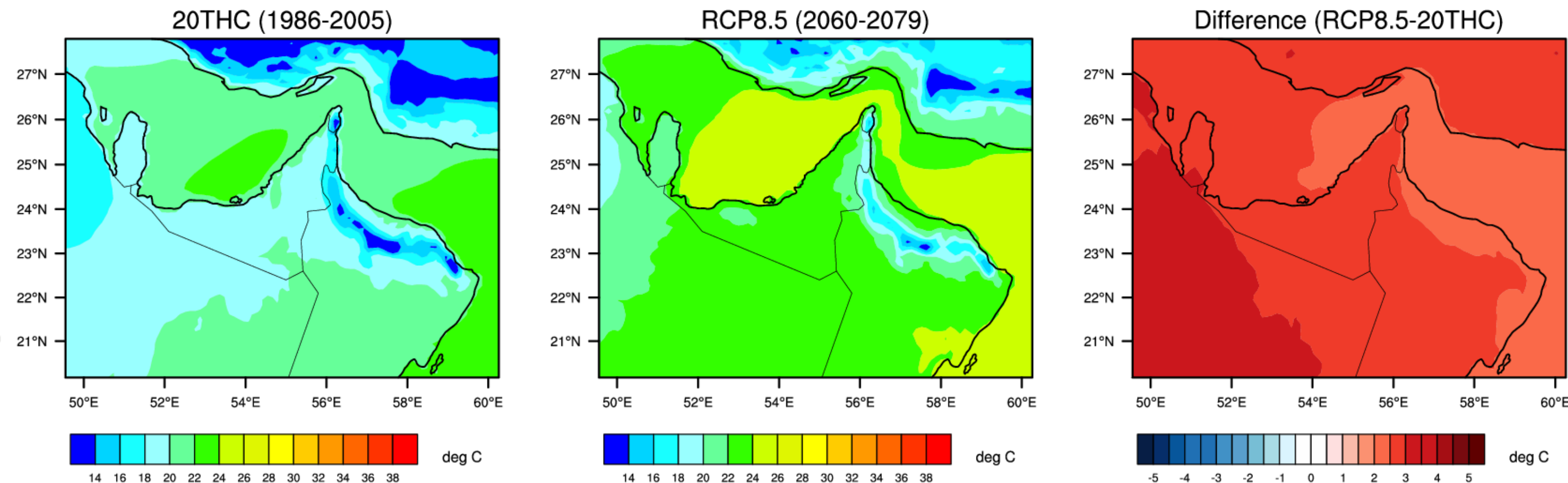
# Regional Temperature (Winter)

VERIFICATION

12-km Domain Average 2-m Air Temperature



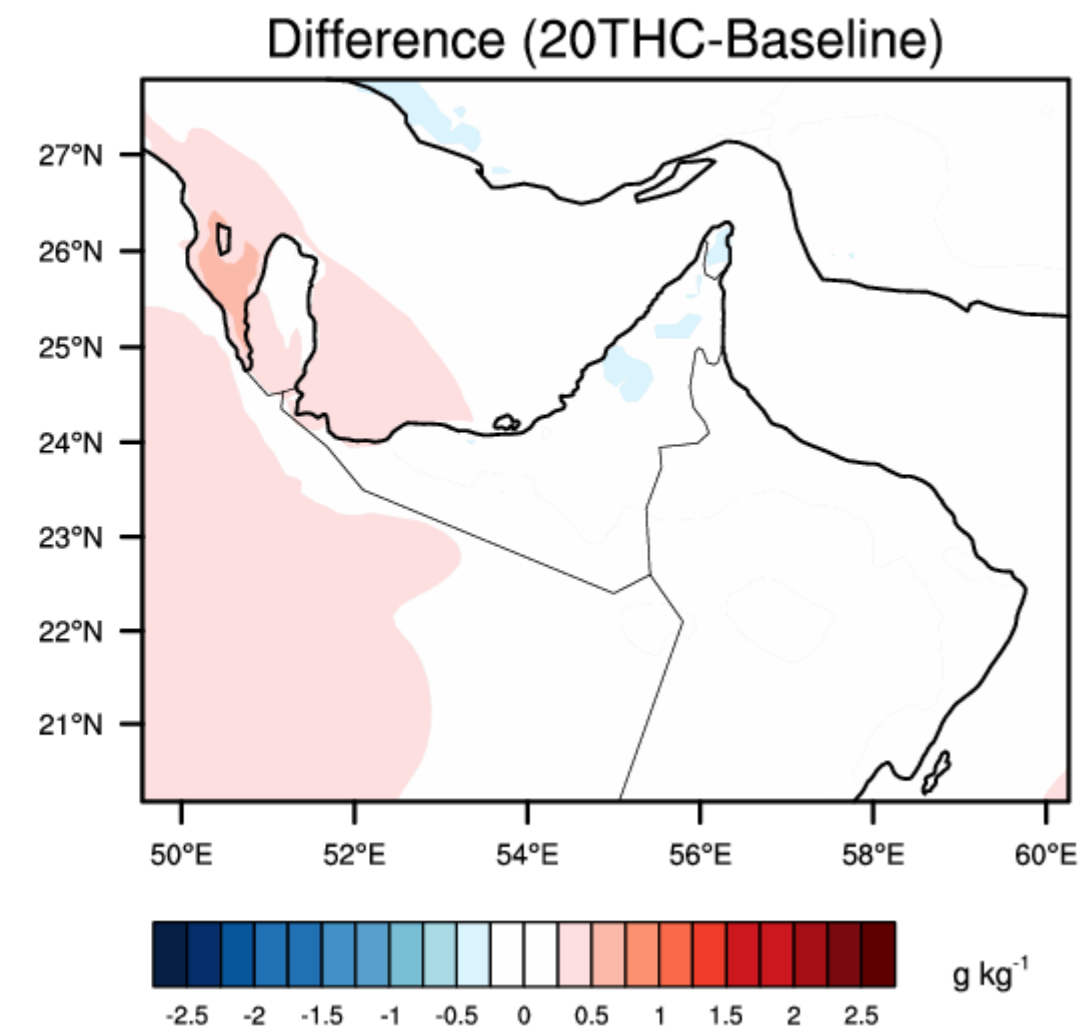
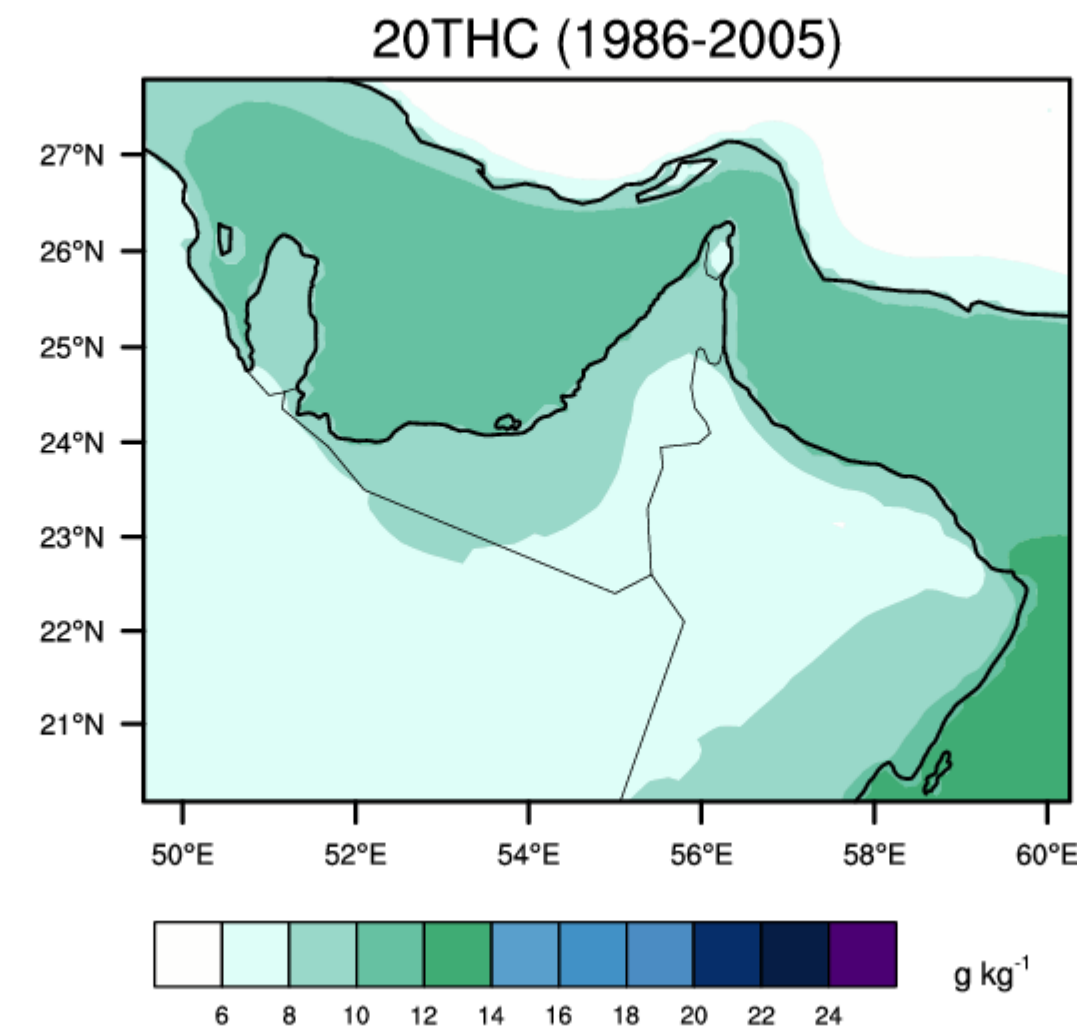
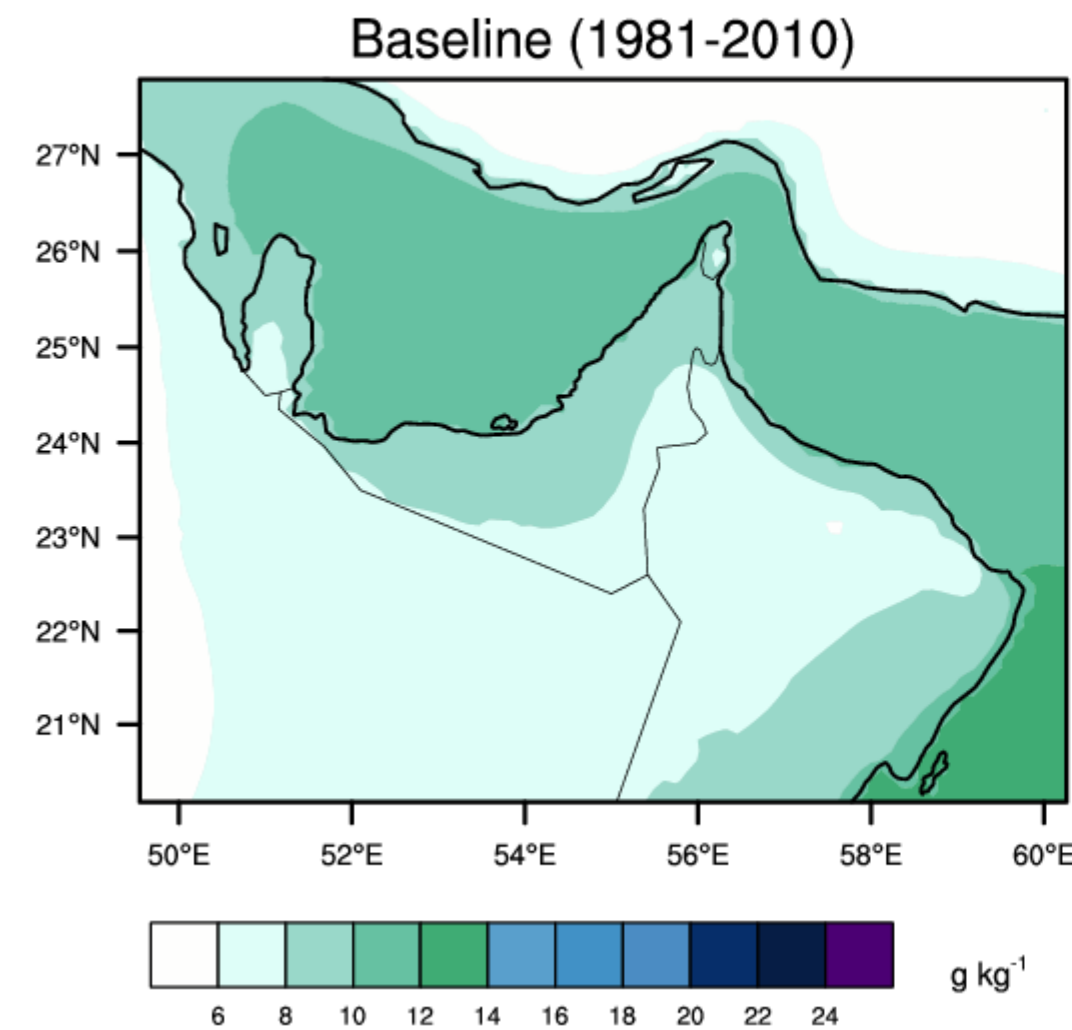
12-km Domain Average 2-m Air Temperature



# Regional Humidity (Winter)

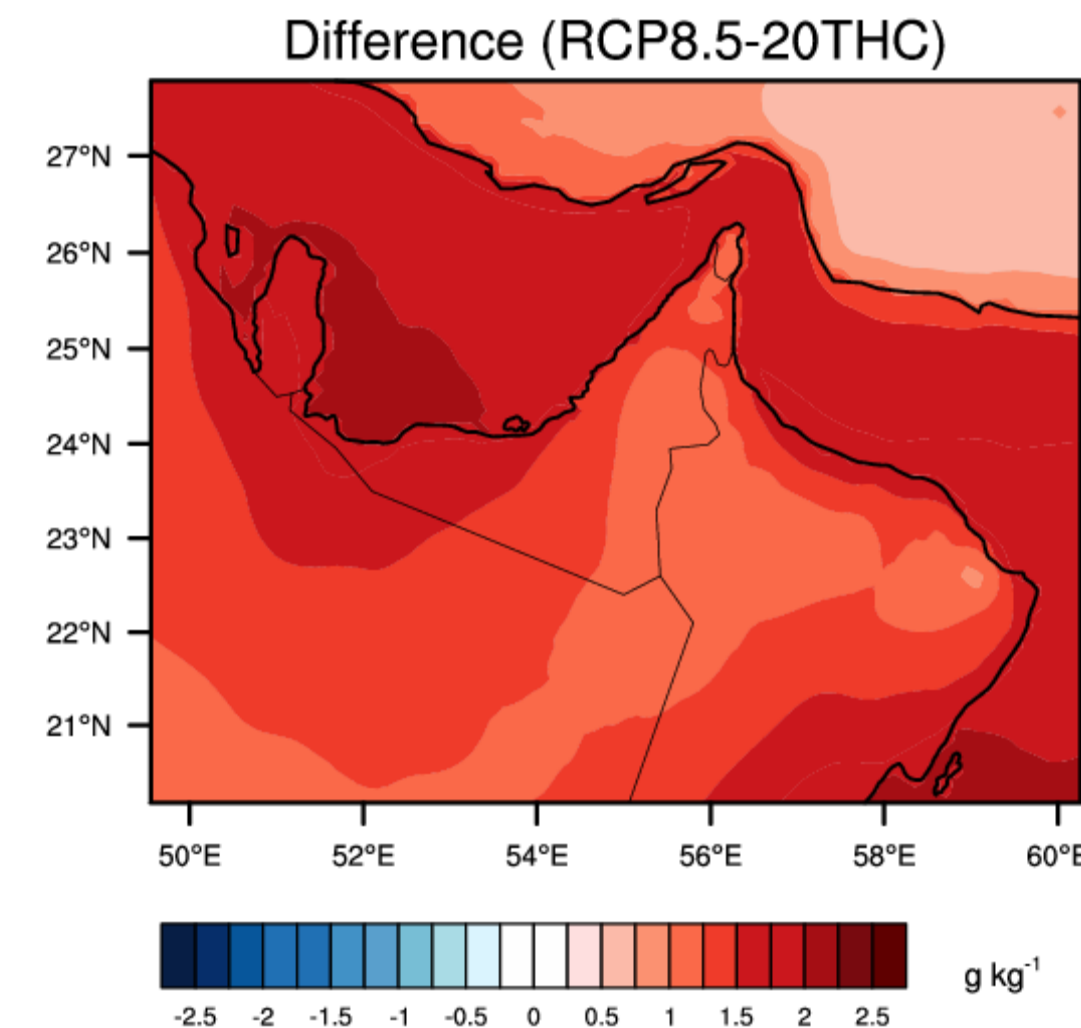
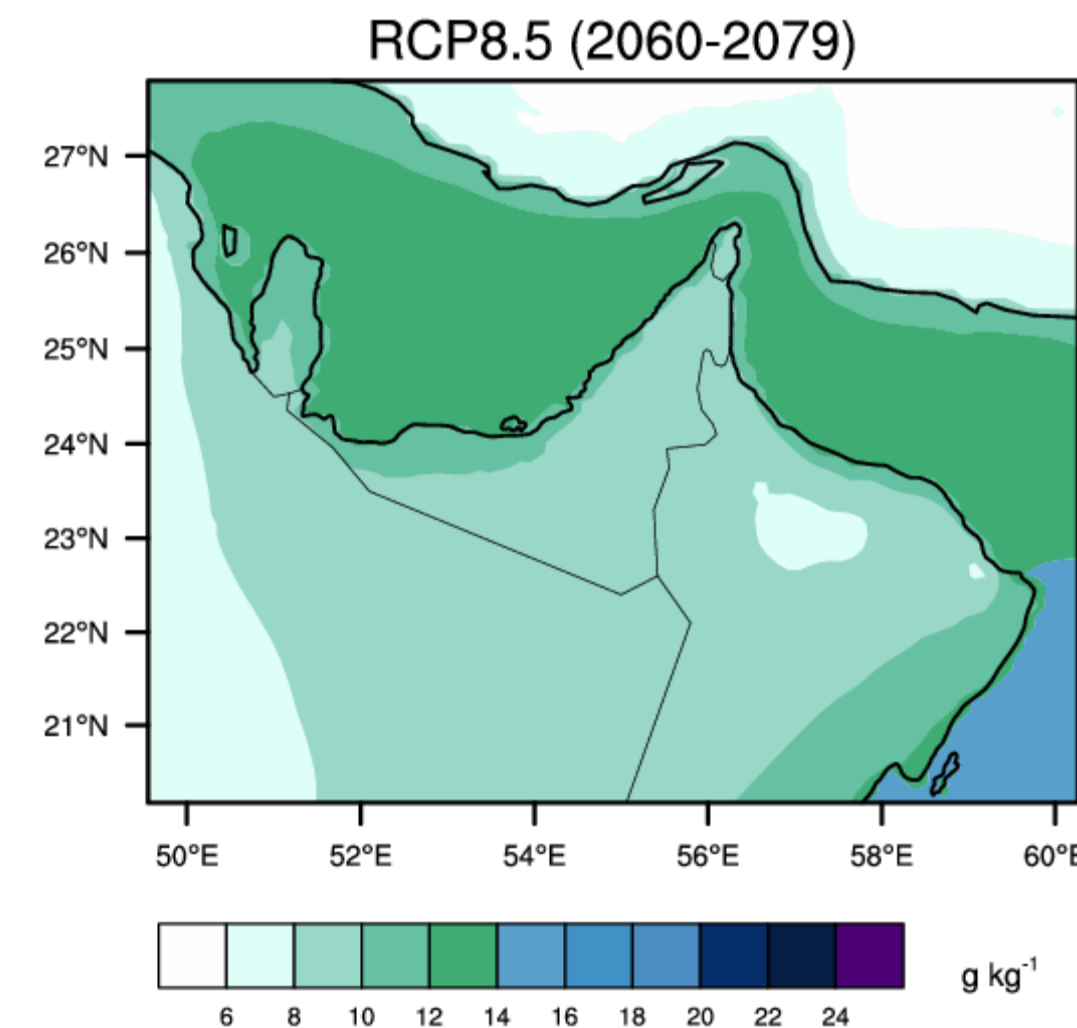
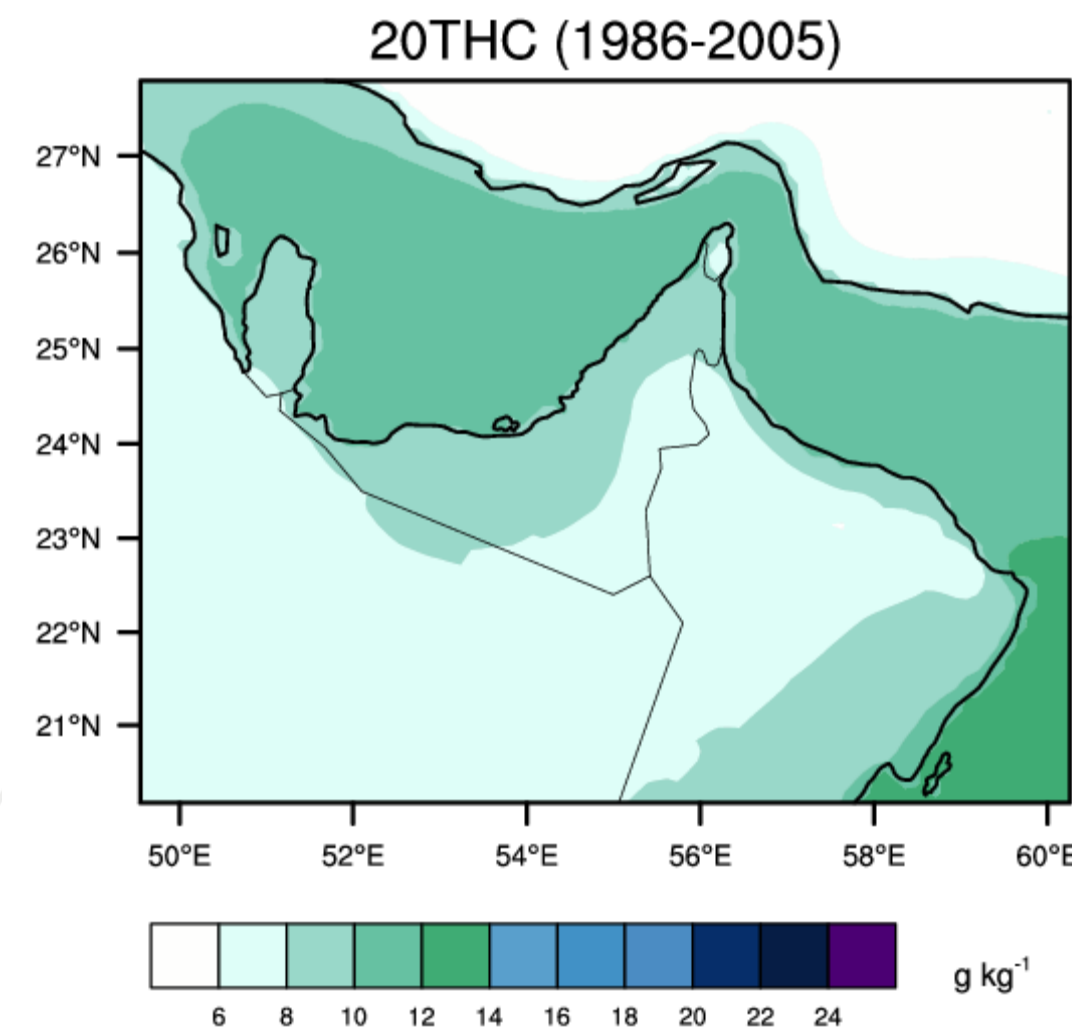
12-km Domain Average 2-m Specific Humidity

VERIFICATION



DJF

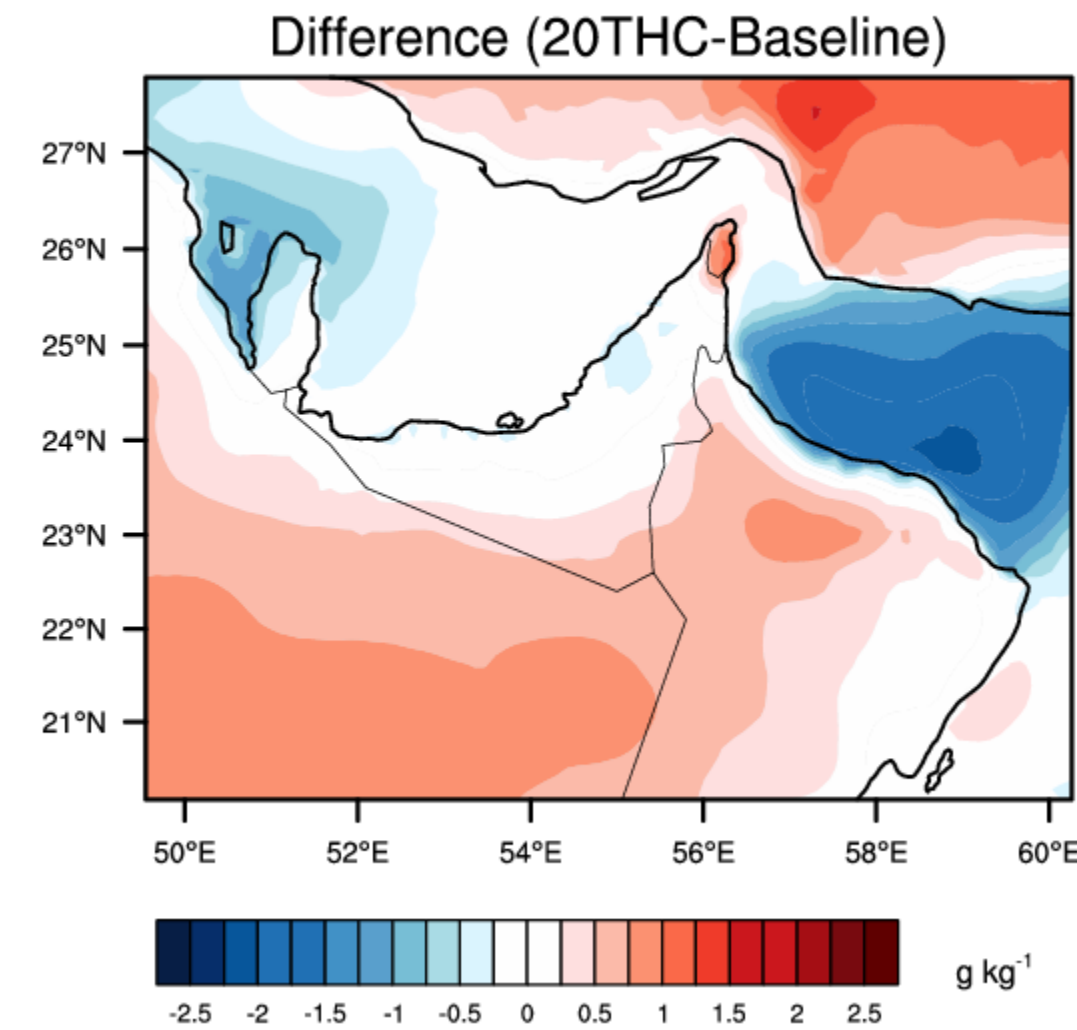
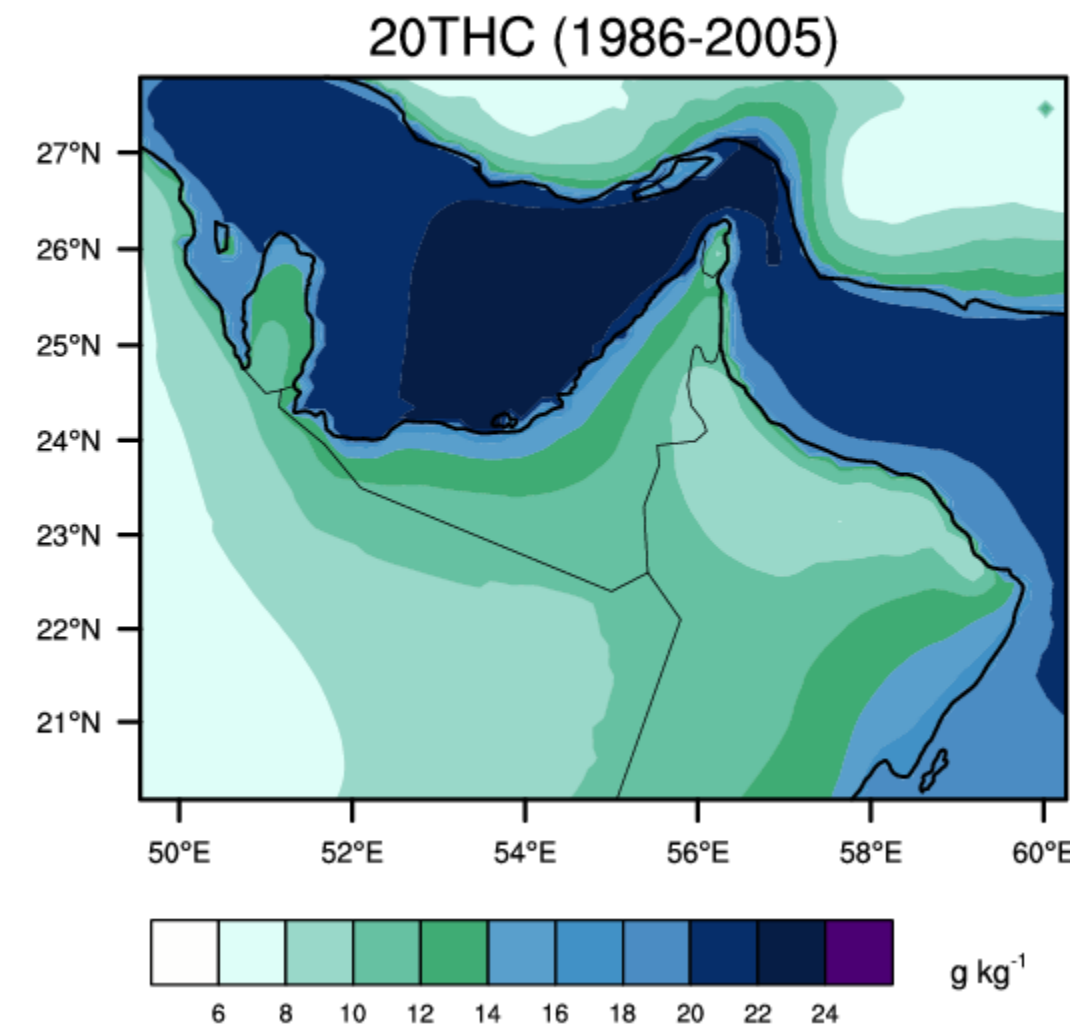
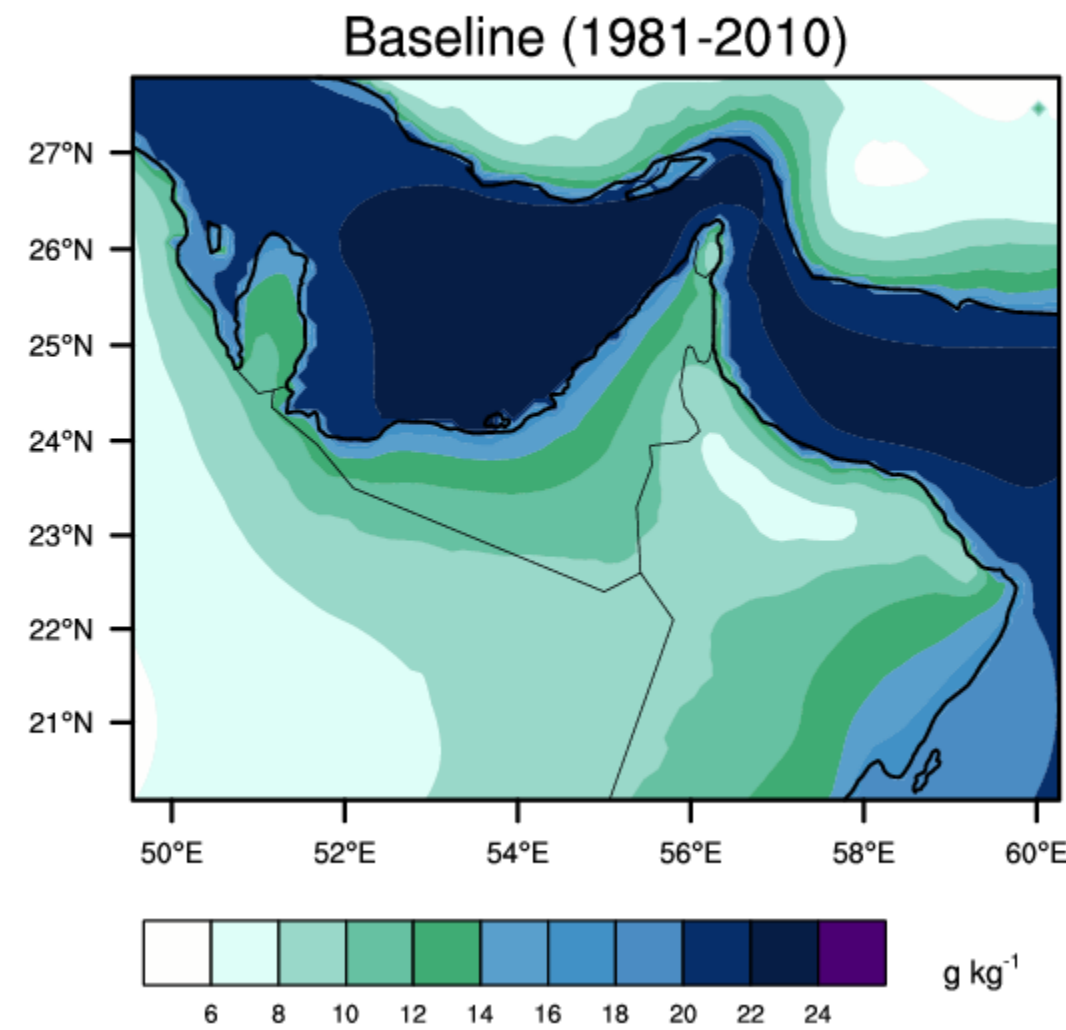
RCP 8.5



# Regional Humidity (Summer)

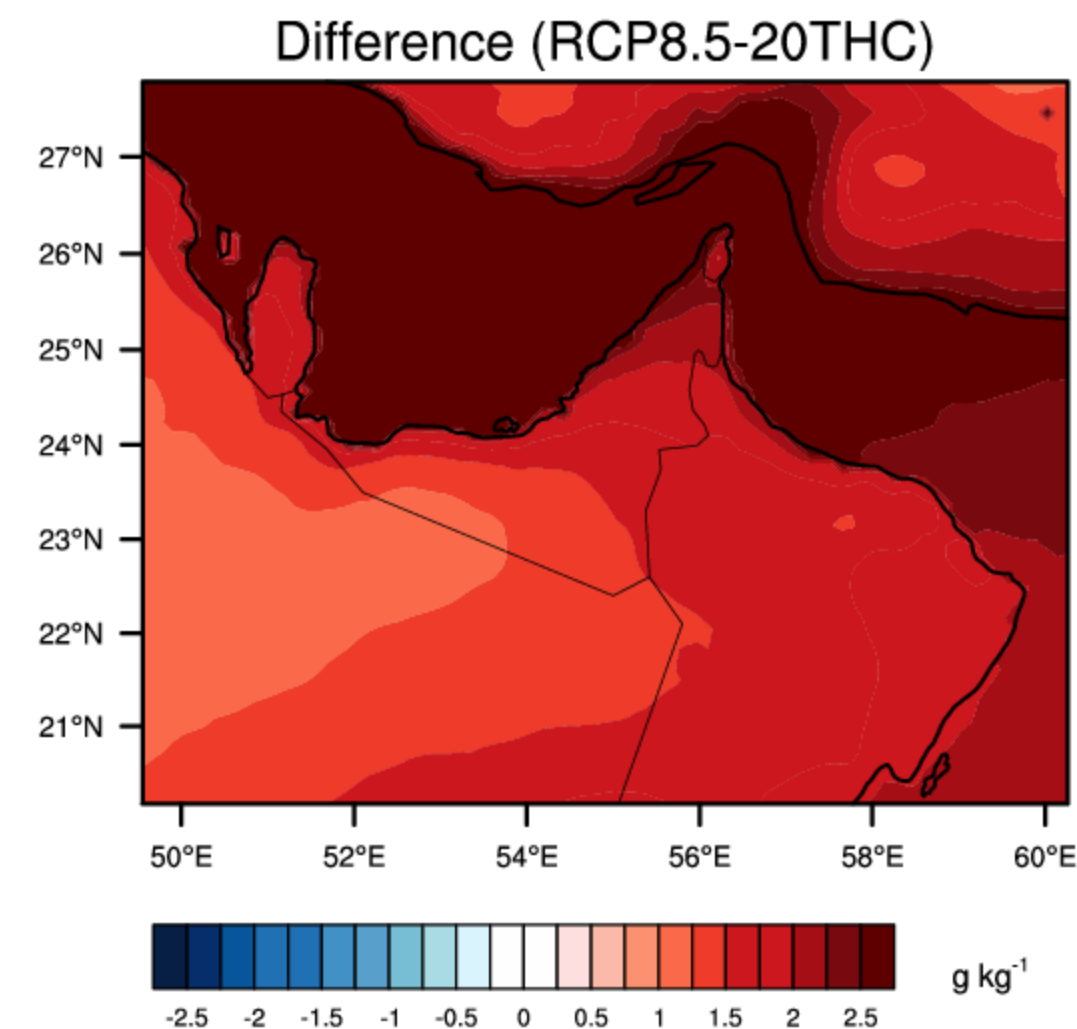
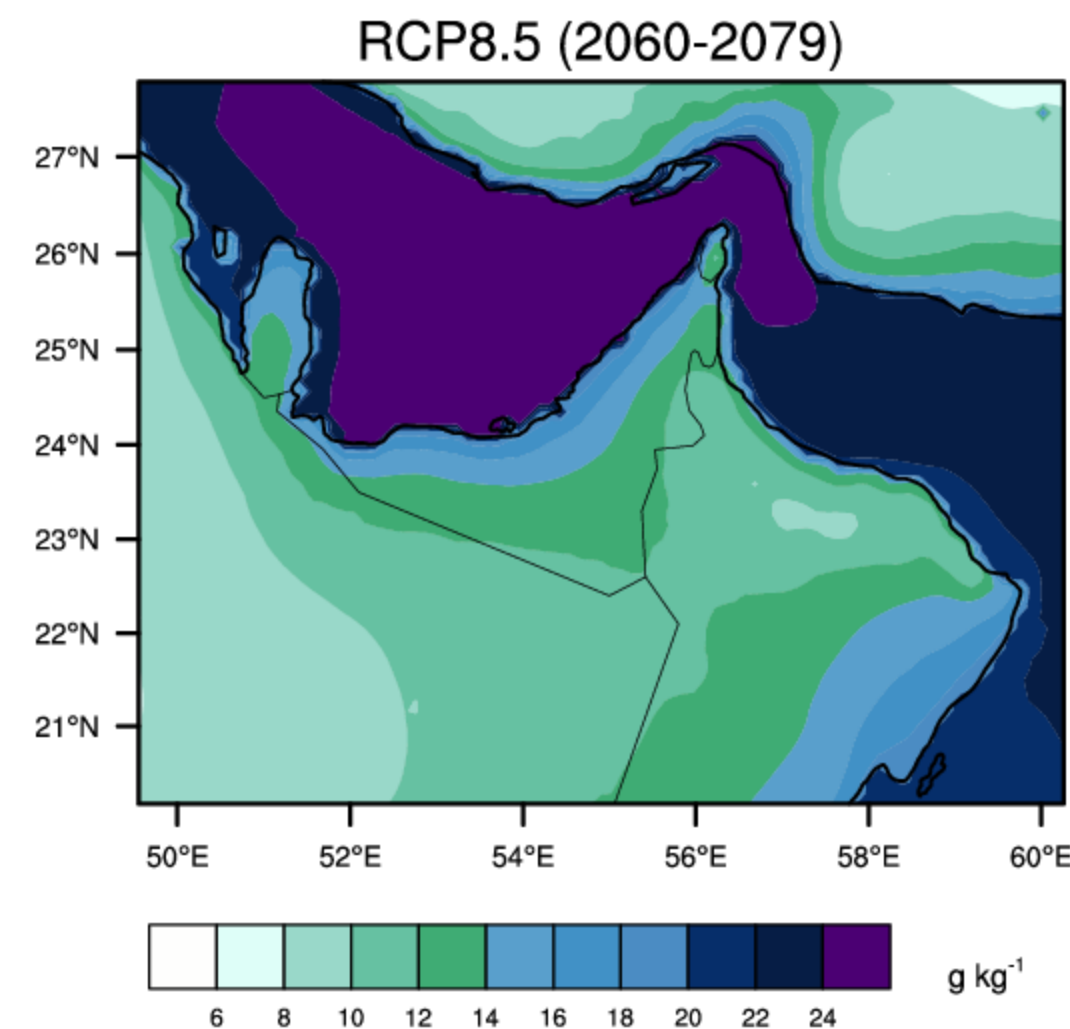
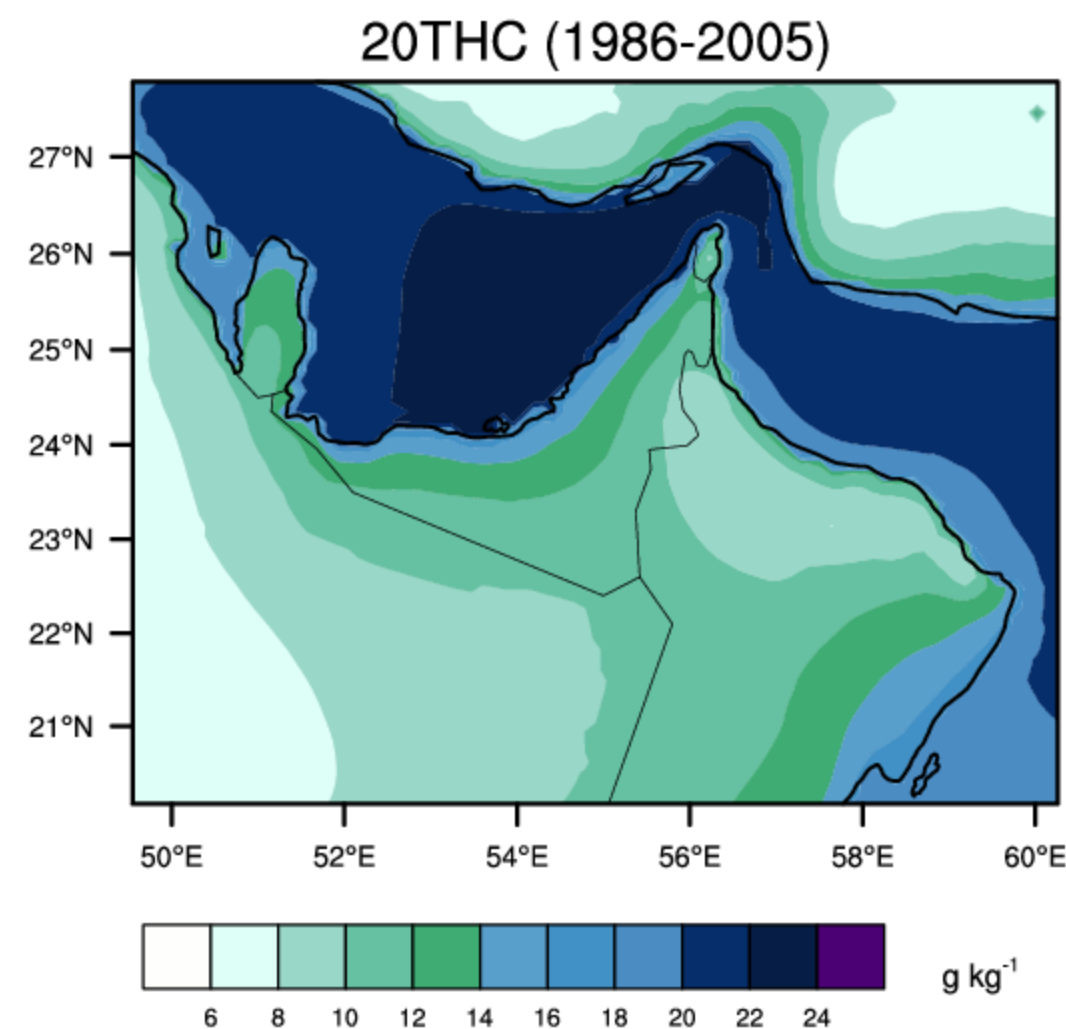
12-km Domain Average 2-m Specific Humidity

VERIFICATION



JJA

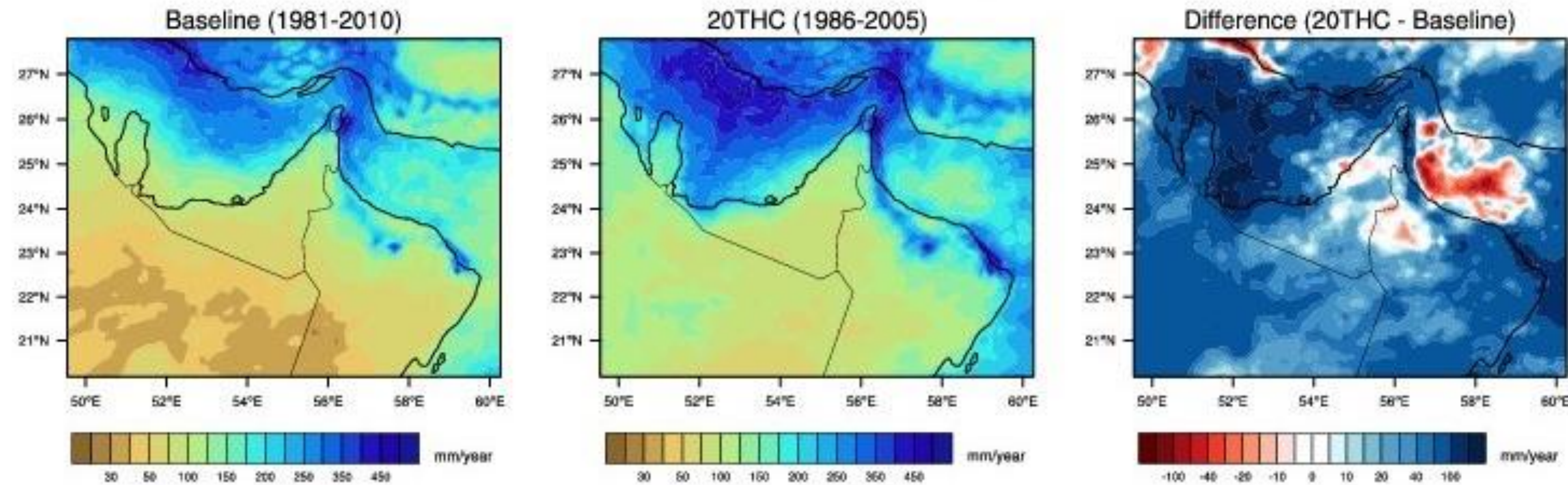
RCP 8.5



# Regional Rainfall

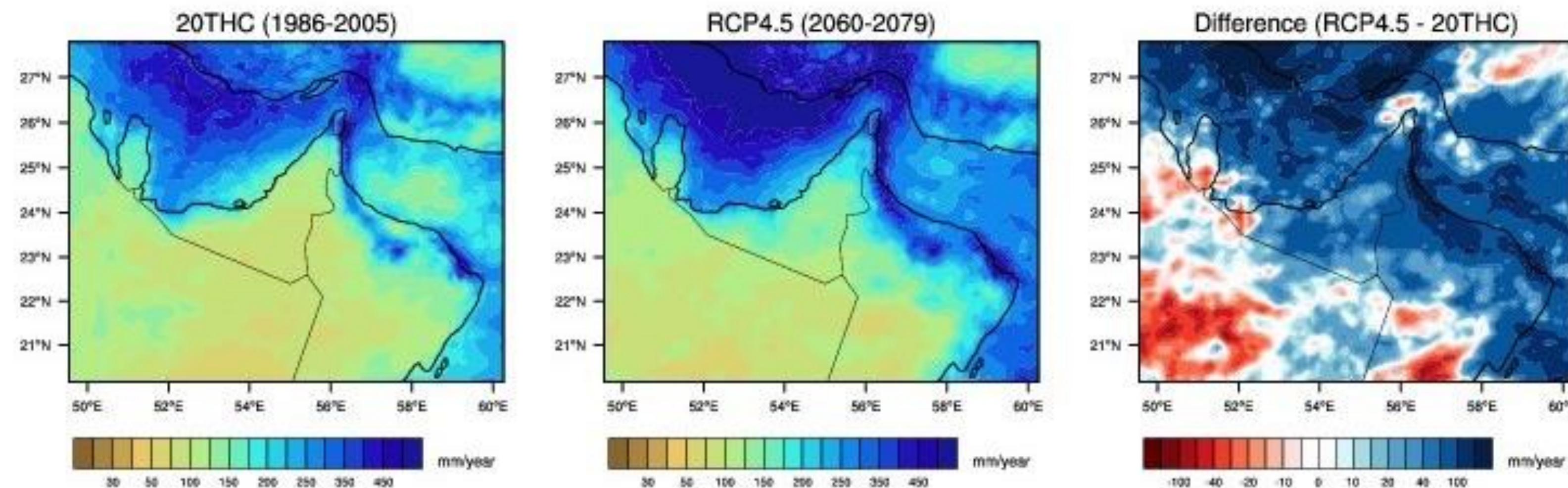
VERIFICATION

12-km Domain Average Annual Rainfall



RCP 4.5

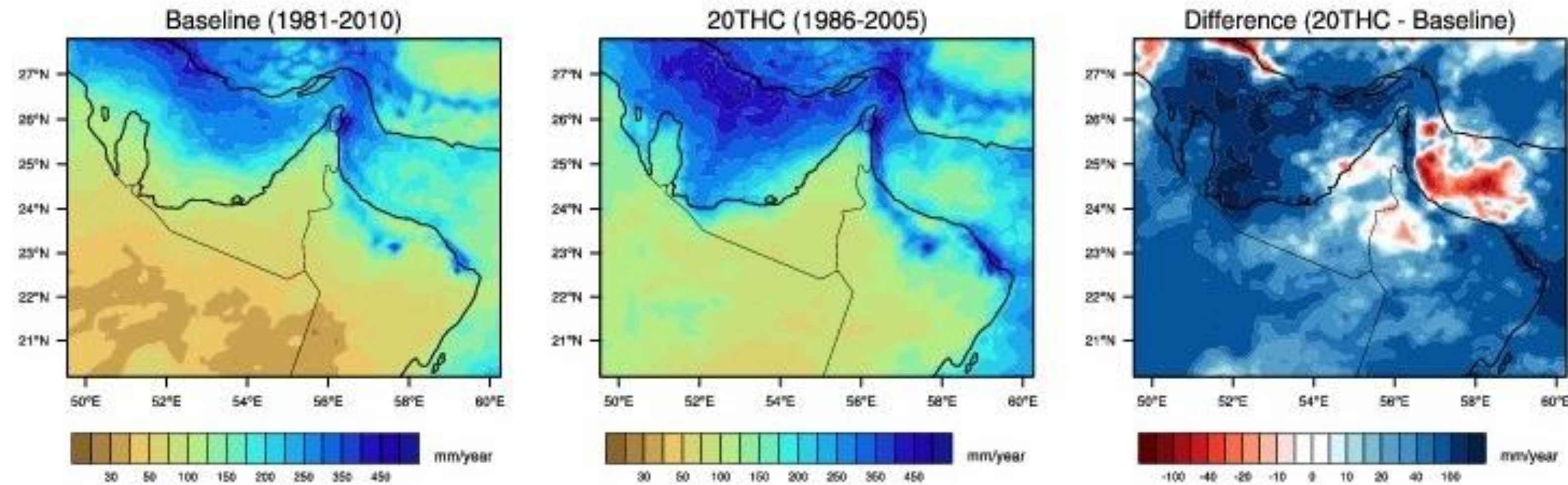
12-km Domain Average Annual Rainfall



# Regional Rainfall

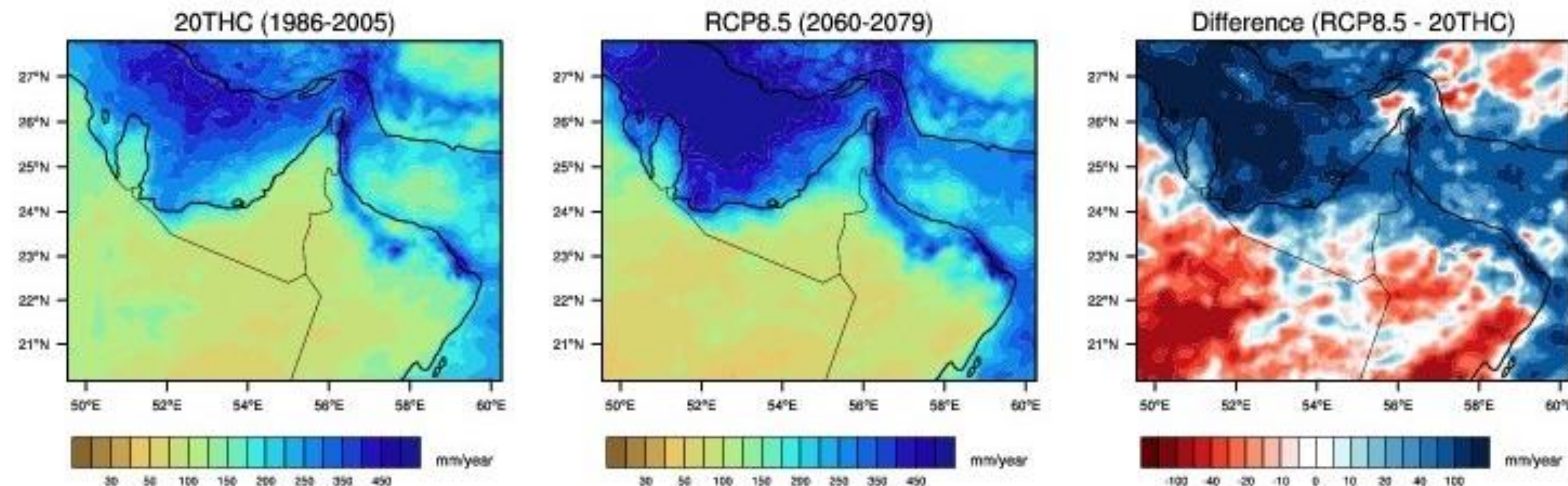
VERIFICATION

12-km Domain Average Annual Rainfall



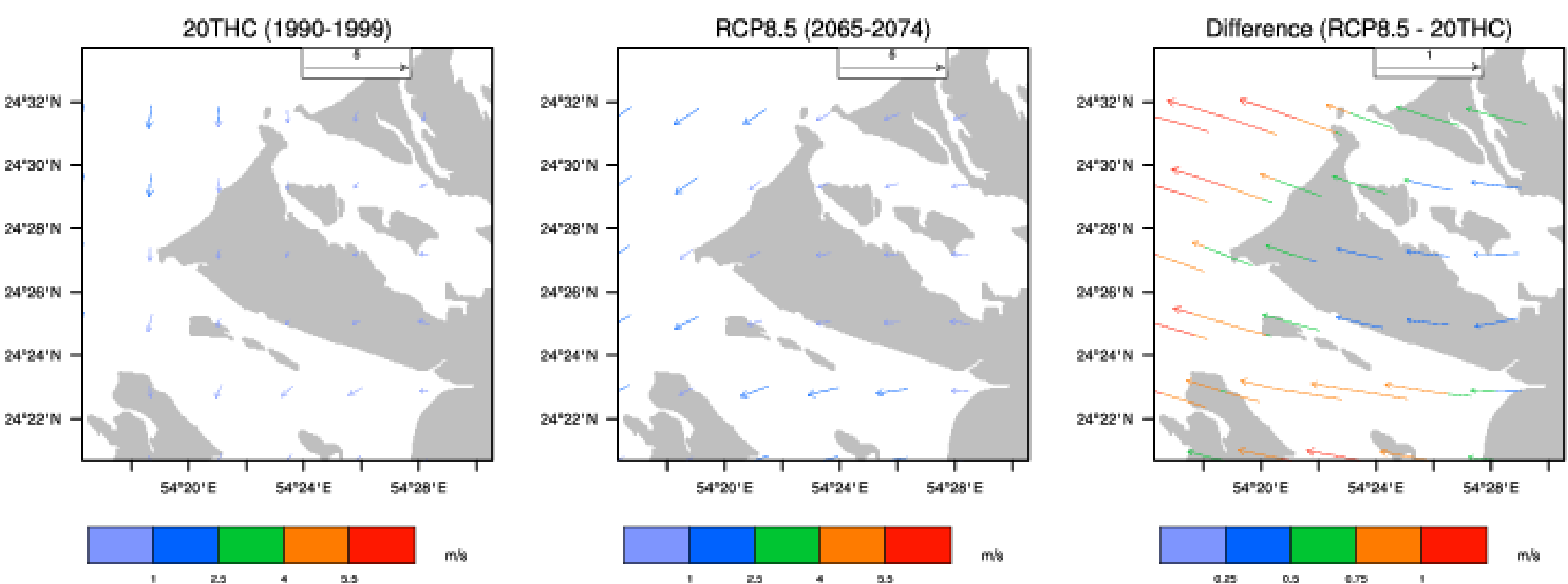
RCP 8.5

12-km Domain Average Annual Rainfall

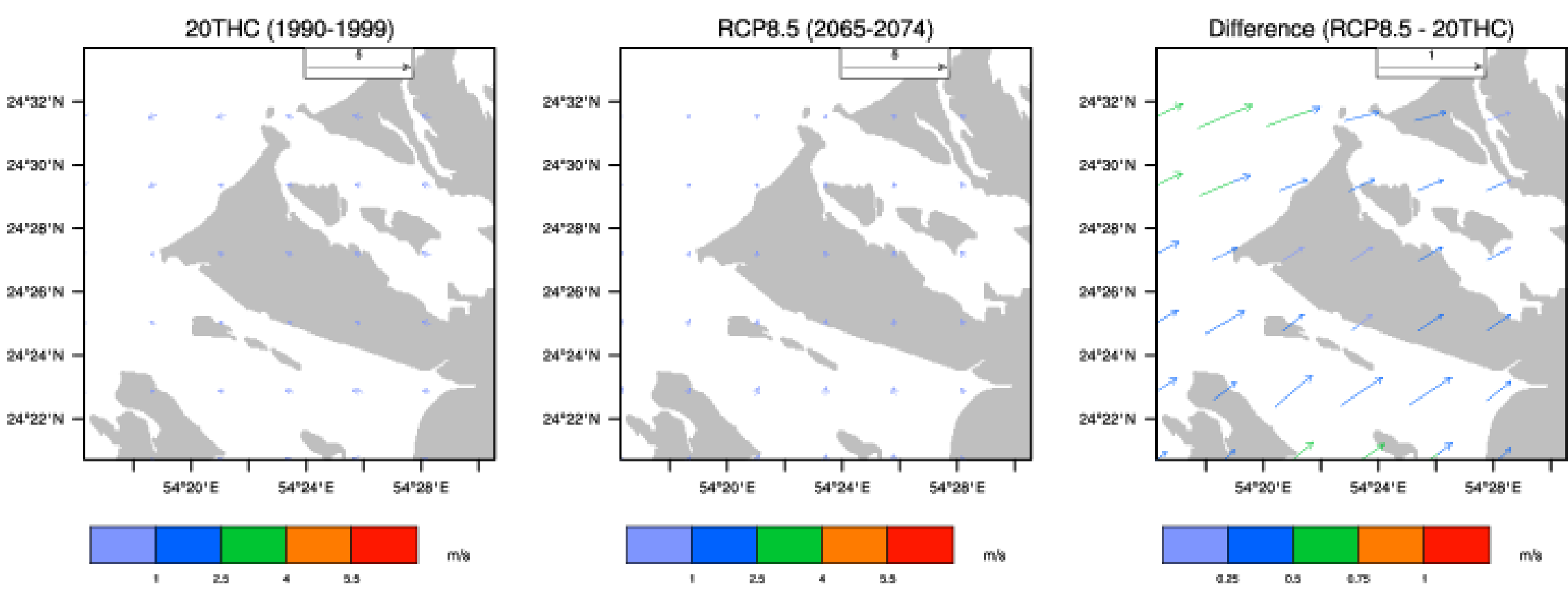


# 4-km Resolution Results

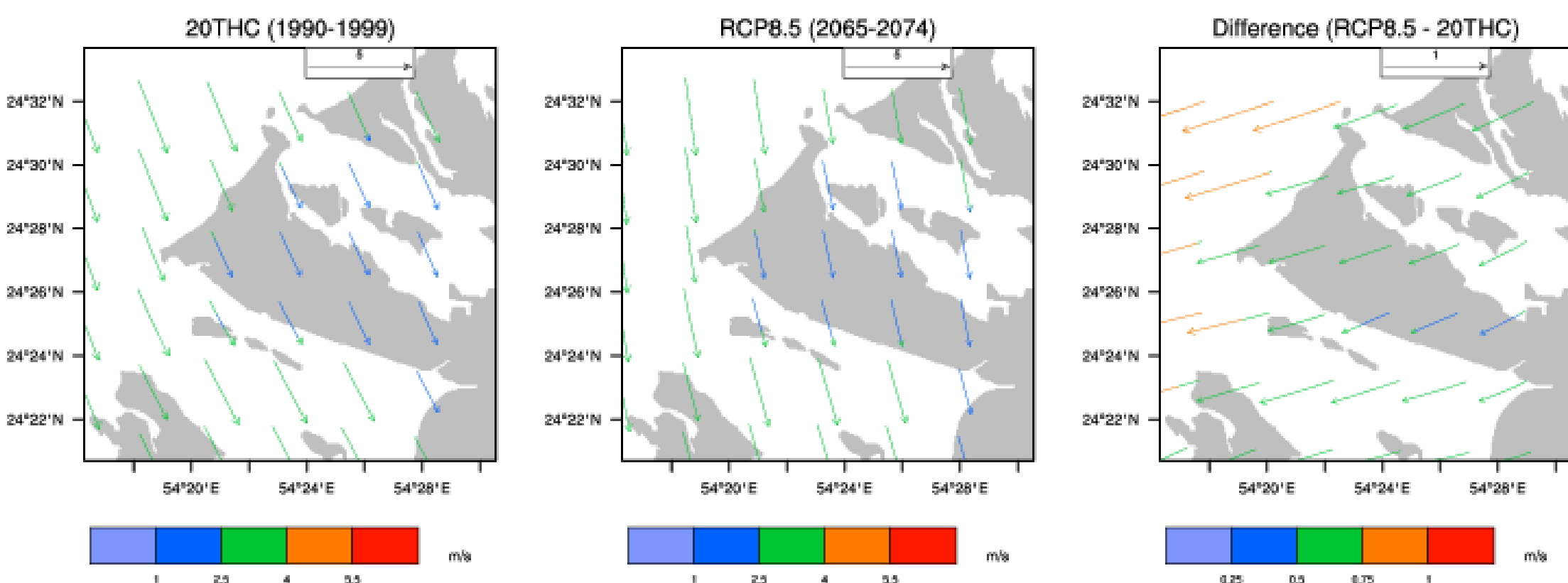
Abu Dhabi 10-m Winds DJF 0600



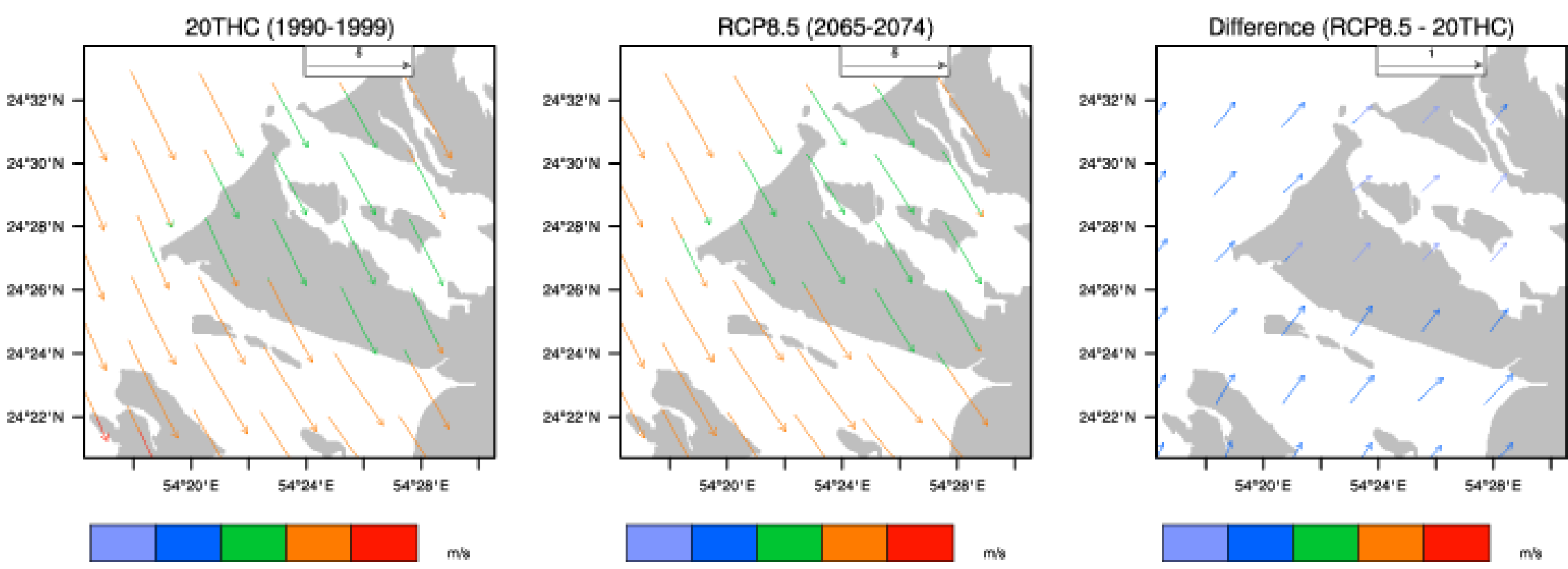
Abu Dhabi 10-m Winds JJA 0600



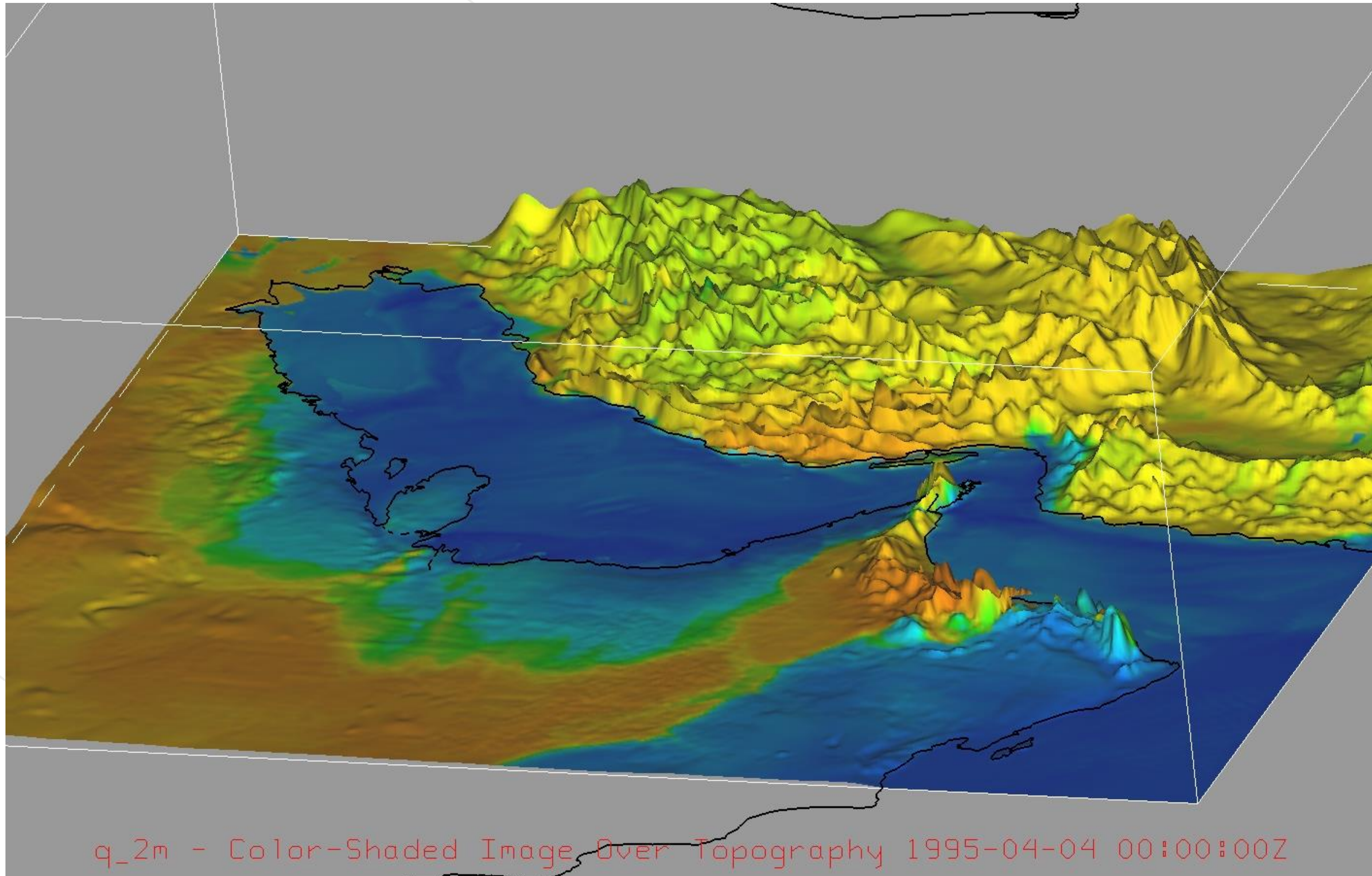
Abu Dhabi 10-m Winds DJF 1800



Abu Dhabi 10-m Winds JJA 1800

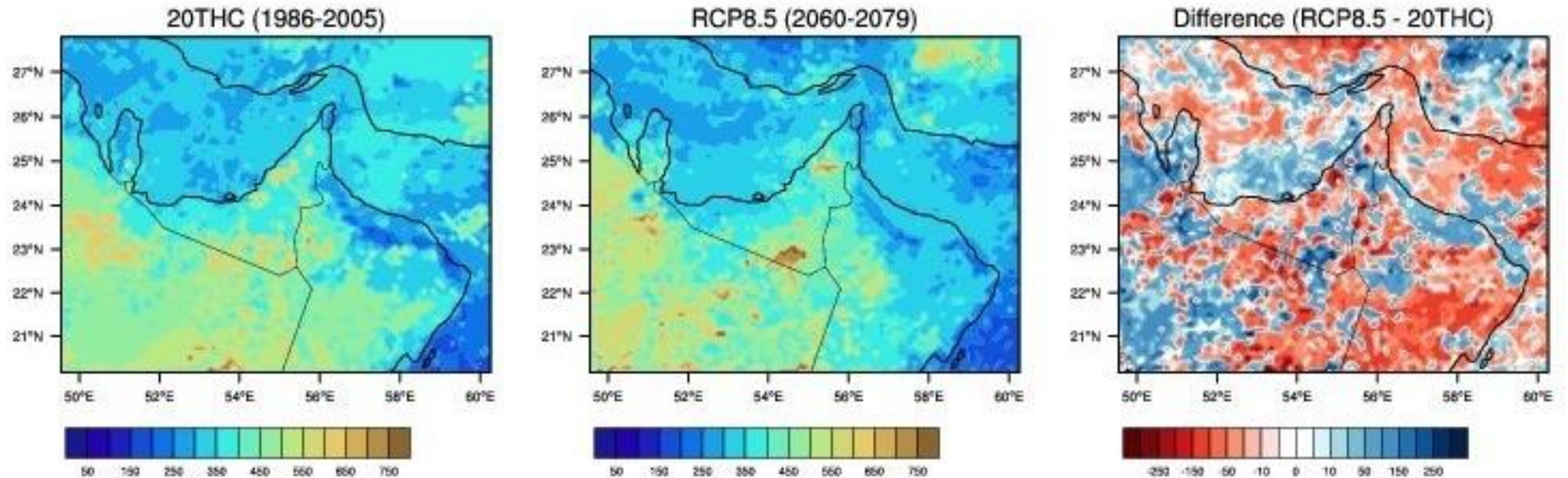


## Example: Surface Humidity At 4km-Res



# Example Climate Index

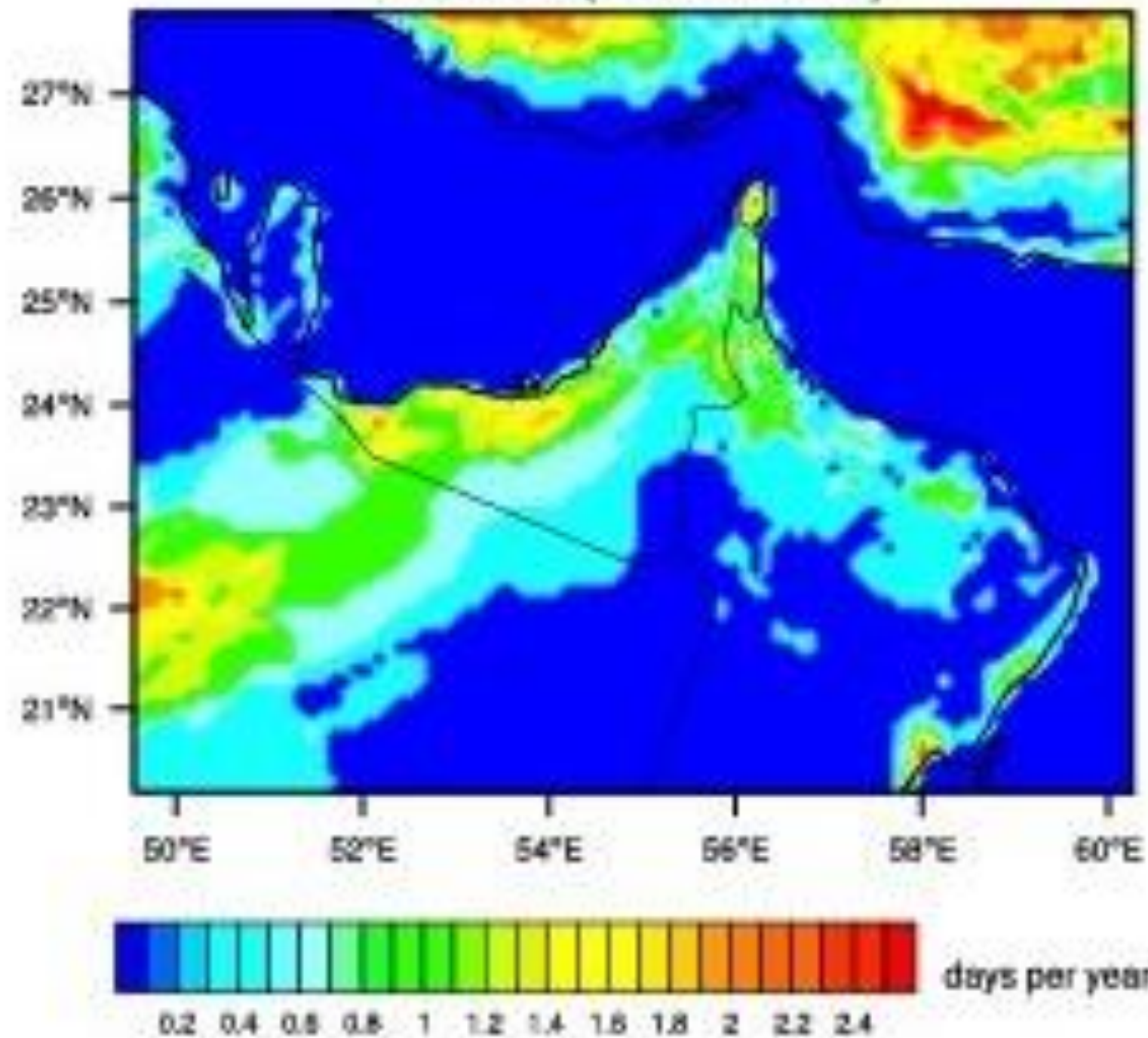
## Consecutive Dry Days Index



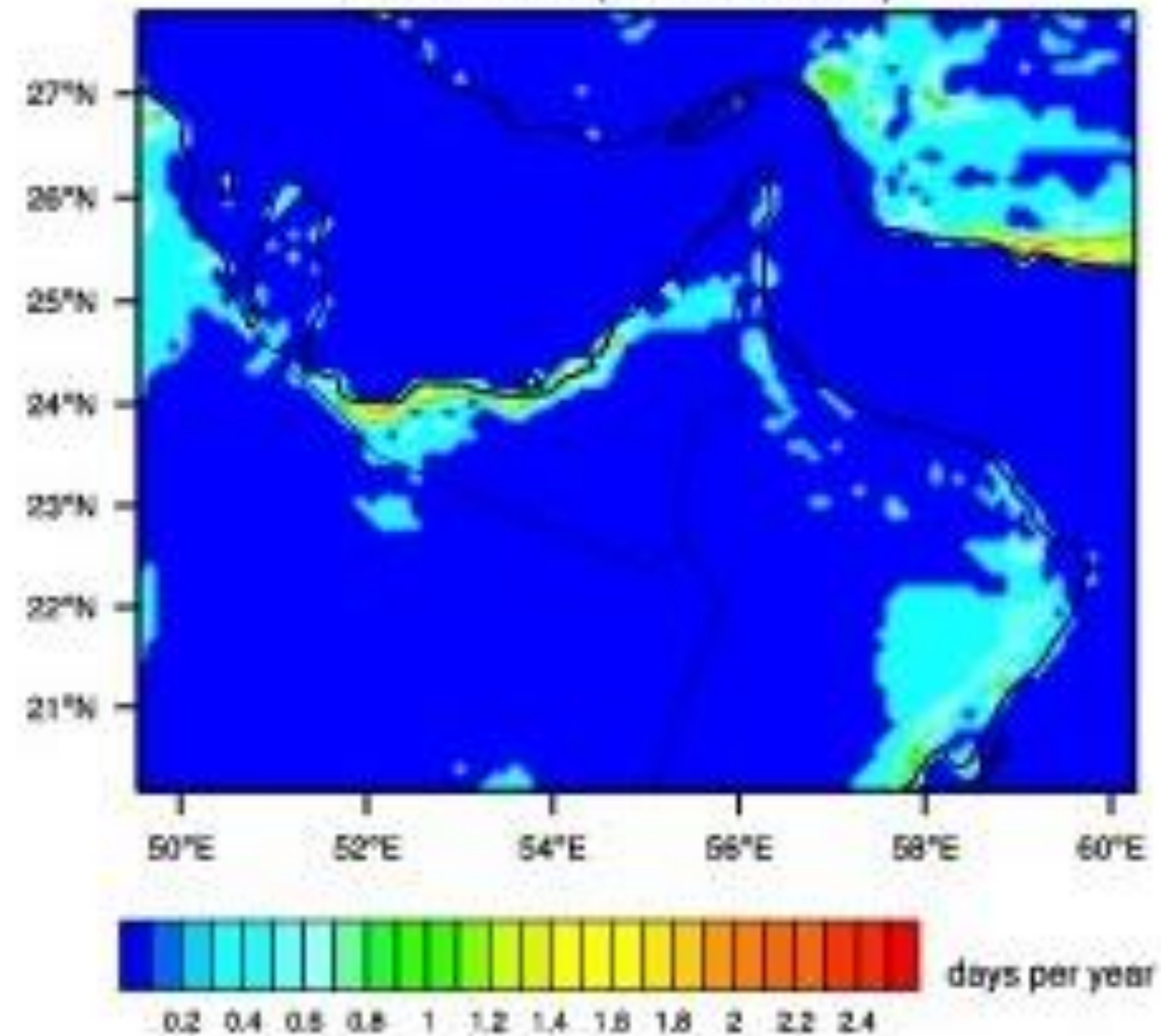
# Example Climate Index

## Heat Wave Duration Index

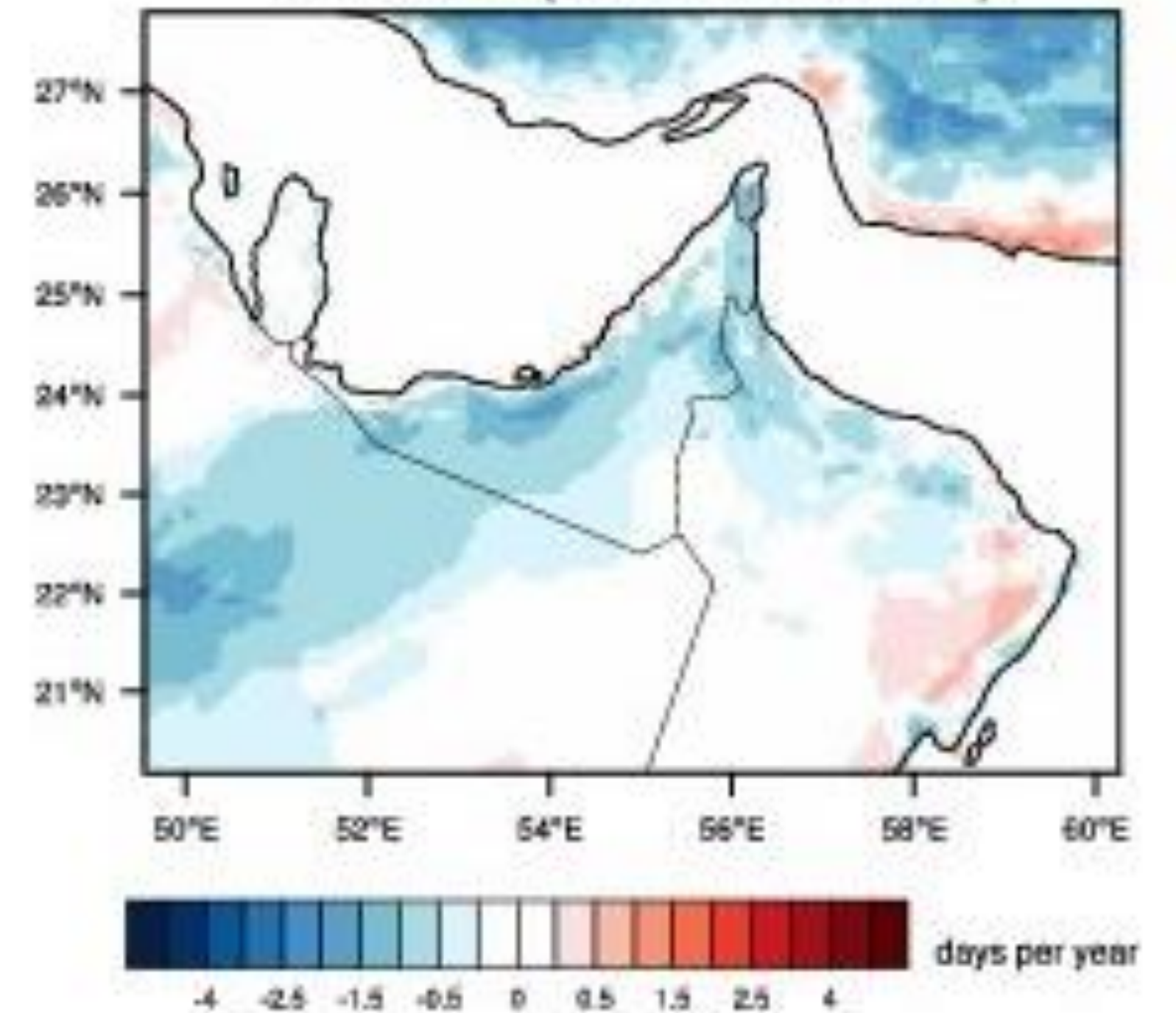
20THC (1986-2005)



RCP8.5 (2060-2079)



Difference (RCP8.5 - 20THC)



\*\* A counter-intuitive result?



**What Might be Next? ...**

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