Convection permitting regional climate simulations over the Arabian Gulf Region

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Outline

1. **Introduction**

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3. **Evaluation**

   - Comparison between model simulation and TRMM data
   - Comparison between simulations driven by reanalysis data and GCM data

4. **Future changes in precipitation and temperature**

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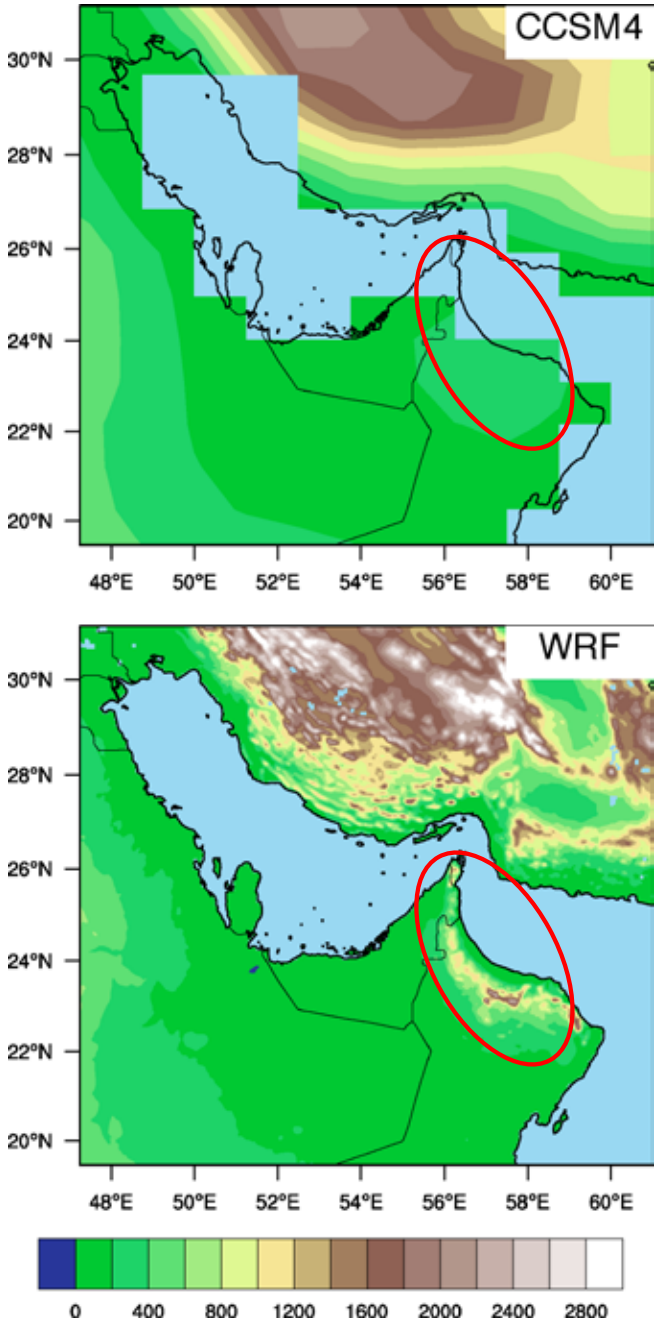
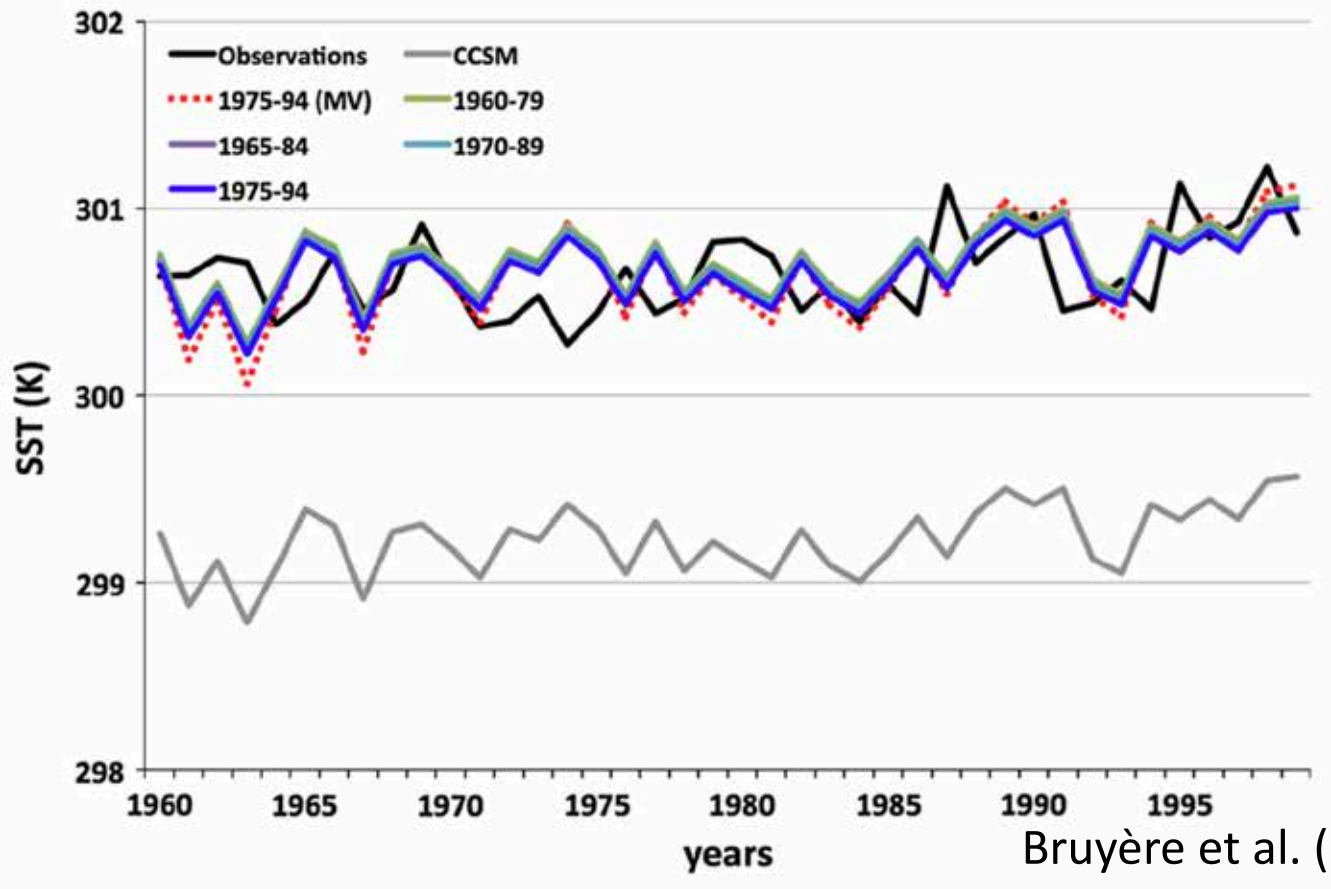
Introduction



- GCMs are often used to study the climate changes in the future.
- GCMs, such as CCSM4 with a spatial resolution of 0.9 degrees latitude x 1.25 degrees longitude, cannot adequately resolve the topography.
- Therefore, it is necessary of performing the dynamical downscaling simulations in order to provide a dataset that is appropriate for assessing climate change in the region.
- In this study, we use CCSM4 simulation output to provide the initial and boundary conditions, to drive the convection-permitting simulations using WRF.

Description of Model Simulations



Bruyère et al. (2014)

To study future changes in climatology, we need to use GCM output to drive regional climate model, however, before that, the biases in GCM output need to be corrected.

Description of Model Simulations

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

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

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

$$CCSM_{R\_future} = \overline{CCSM_{future}} + \overline{ERAINT} - \overline{CCSM_{current}} + CCSM'_{future}$$

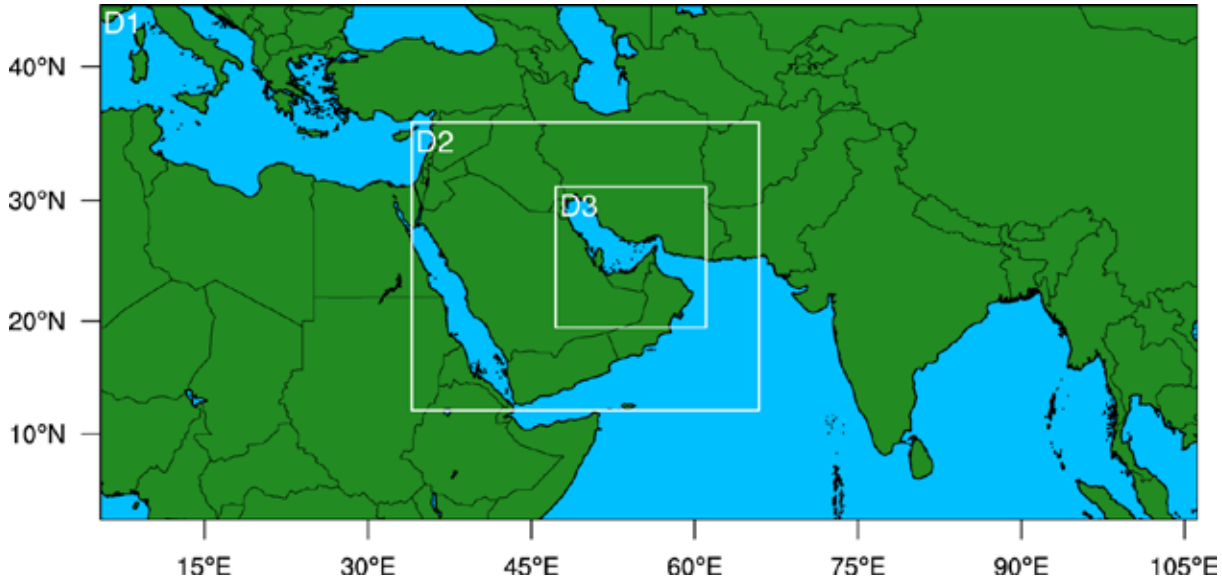
ERA-Interim driven WRF benchmark simulation for the historical period

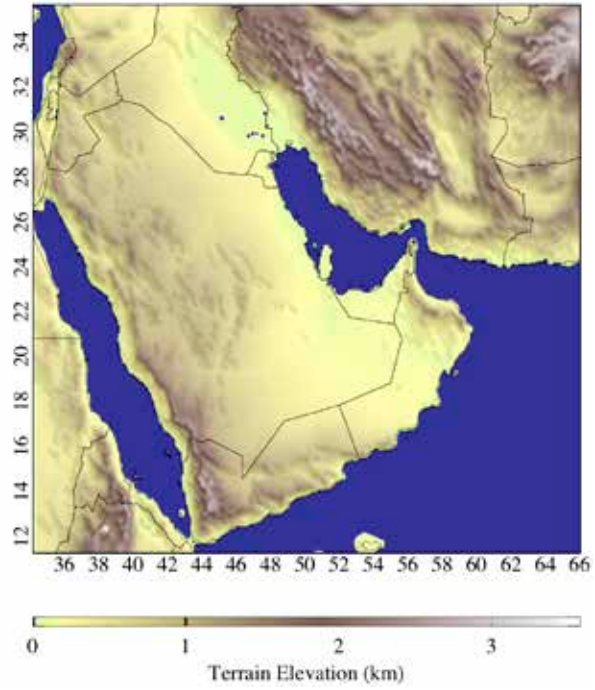
Bias-corrected-CCSM4-driven WRF climate simulation for the historical period

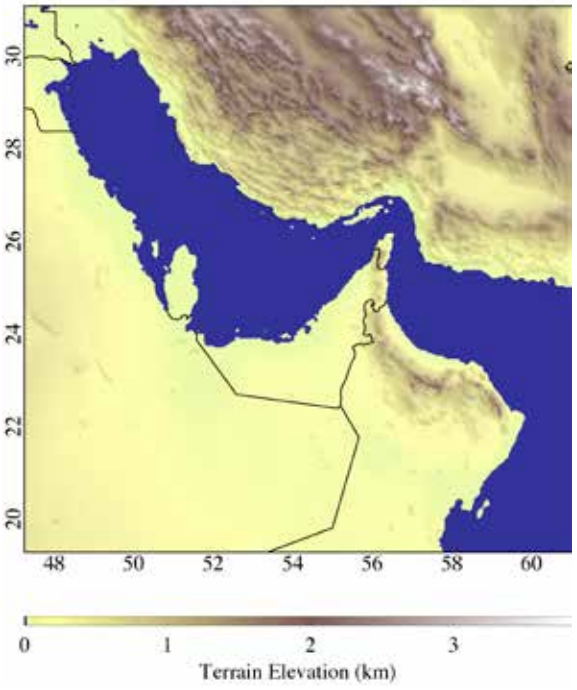
Bias-corrected-CCSM4-driven WRF climate simulation for the (future) RCP8.5 period

$CCSM_R$ combines a base, seasonally varying climate provided by ERAI with day-to-day weather, climate variability and change provided by CCSM.

WRF Simulations







- D1: 36km;
- D2: 12km;
- D3: 4km;
- 40 vertical levels;

- Lin microphysics scheme;
- RRTM longwave radiation;
- Dudhia shortwave scheme;
- MM5 surface layer scheme;
- Noah land surface model;
- YSU PBL scheme;
- Grell-Devenyi convective scheme (36-km and 12-km domains only).

These parameterizations are chosen because they yielded optimal WRF performance over UAE in our test runs.

WRF Simulations

	ERA-Interim driven simulation	Bias-corrected CCSM simulation (historical)	Bias-corrected CCSM simulation (RCP8.5)
D01 (36km)	1981-2010	1986-2005	2060-2079
D02 (12km)	1981-2010	1986-2005	2060-2079
D03 (4km)		1990-1999	2065-2074

Evaluation

WRF-TRMM comparison

Data:

- TRMM monthly precipitation product (3B43): 1998.01-2004.12, spatial resolution is 0.25˚× 0.25˚ ;
- WRF driven by bias-corrected CCSM: 6-hourly output, 1998.01-2004.12, special resolution is 12 km;

Methods:

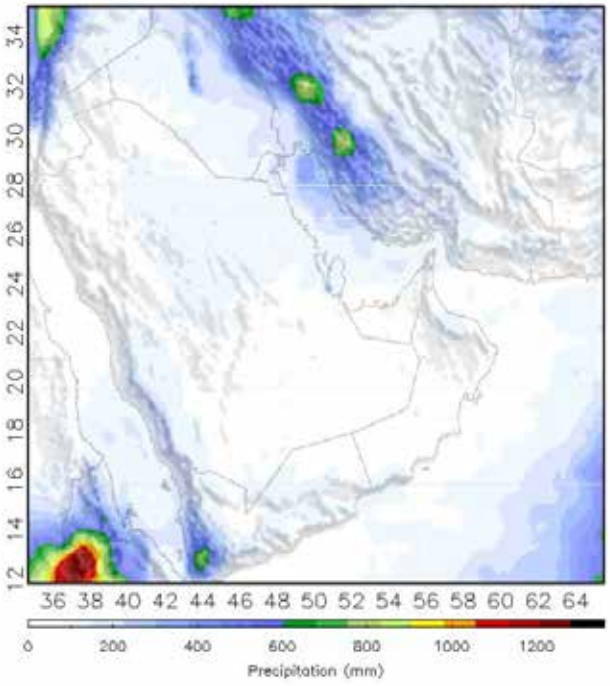
- Annual precipitation;
- Dry season precipitation (May-Oct);
- Wet season precipitation (Nov-Apr);
- To calculate the difference, we first average WRF precipitation to 24km x 24km, so the spatial resolutions are comparable, then interpolate WRF to TRMM grids using bilinear approach.

Evaluation

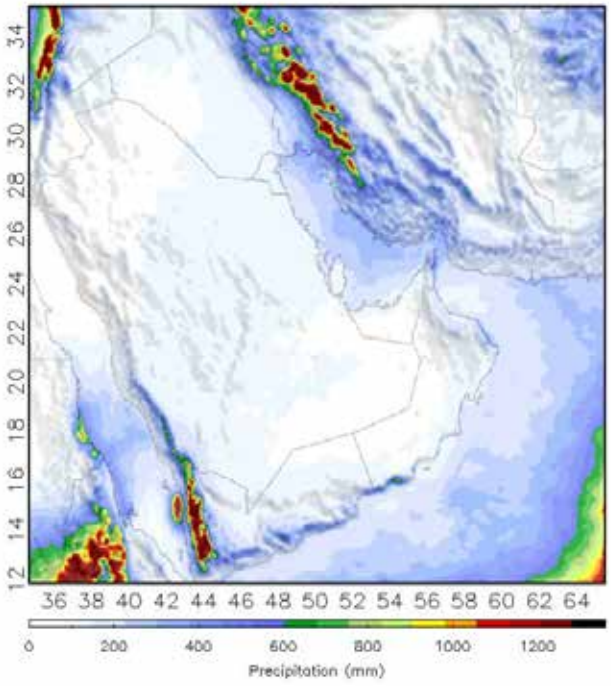
WRF-TRMM comparison

Annual Precipitation (1998-2005)

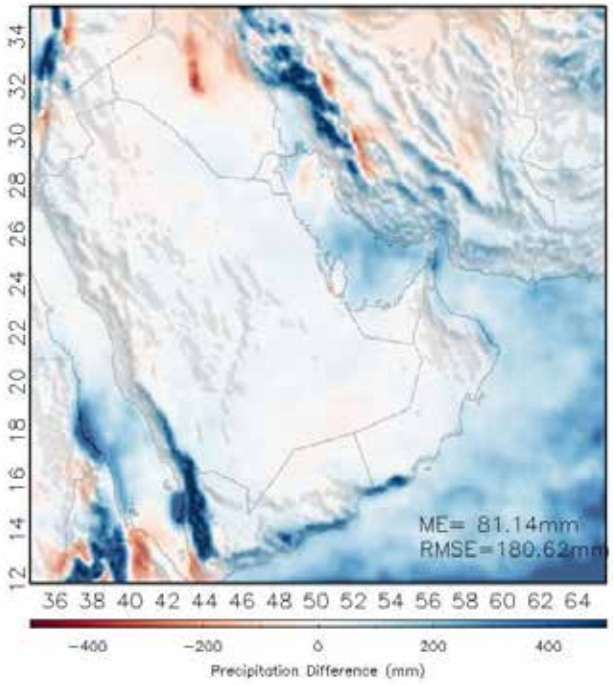
TRMM



WRF



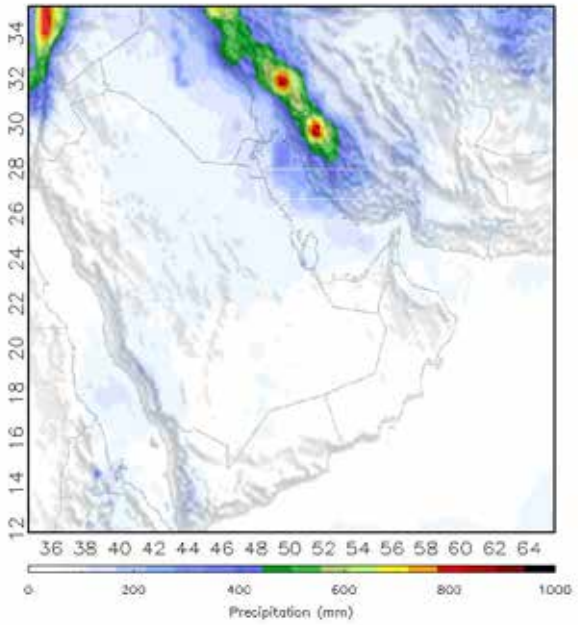
Difference (WRF-TRMM)



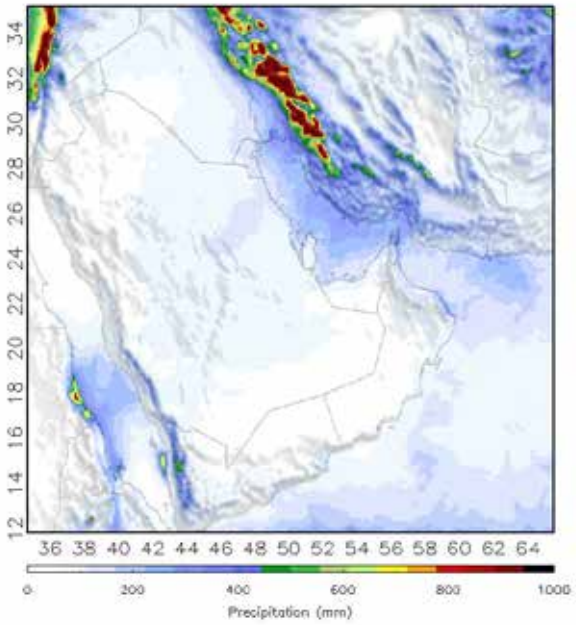
Mean bias is 81.14 mm, and RMSB is 180.62 mm. WRF estimate more precipitation, especially over mountains

Wet Seasons

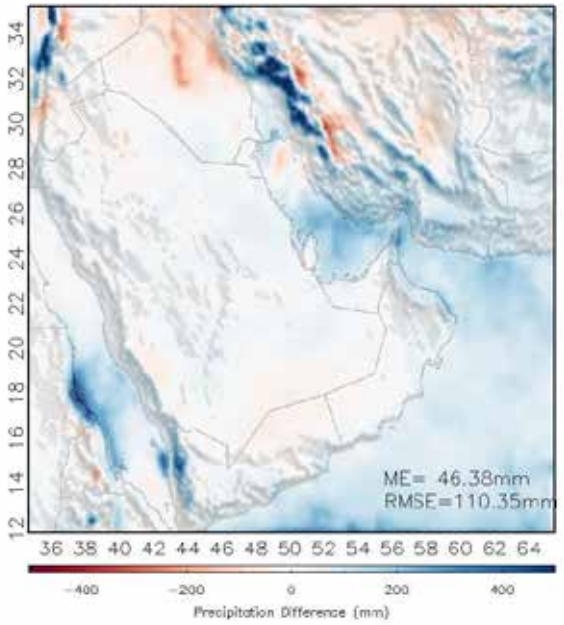
TRMM



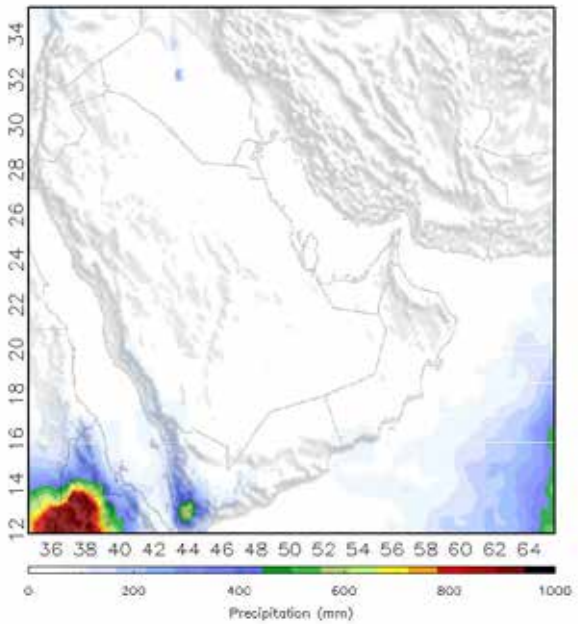
WRF

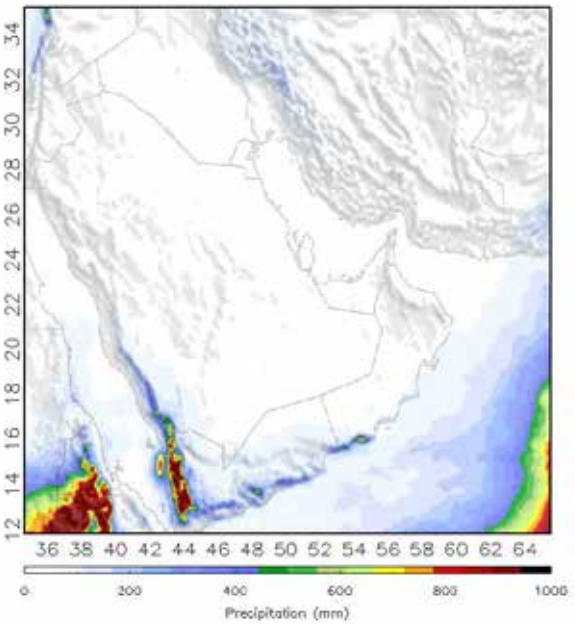


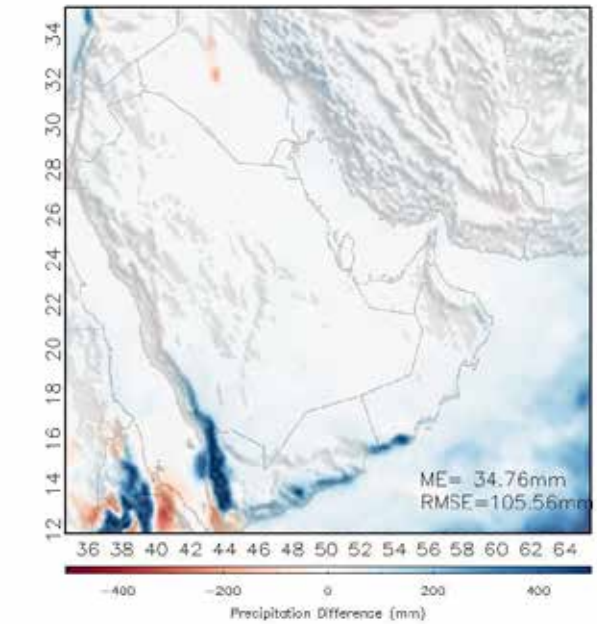
Difference (WRF-TRMM)



Dry Seasons







Limitations of TRMM

Limitations of TRMM:

- The resolution of TRMM monthly precipitation product is low: 0.25˚× 0.25˚;
- TRMM cannot capture every precipitation events;
- Random error of TRMM could be significant.

Therefore, we use the WRF simulation driven by ERA-Interim data as the benchmark simulation to evaluate bias-corrected-CCSM-driven WRF simulation.

Evaluation

Comparison between WRF simulations driven by ERA-Interim and bias-corrected CCSM

	ERA-Interim driven simulation	Bias-corrected CCSM simulation (historical)	Bias-corrected CCSM simulation (RCP8.5)
D01 (36km)	1981-2010	1986-2005	2060-2079
D02 (12km)	1981-2010	1986-2005	2060-2079
D03 (4km)		1990-1999	2065-2074

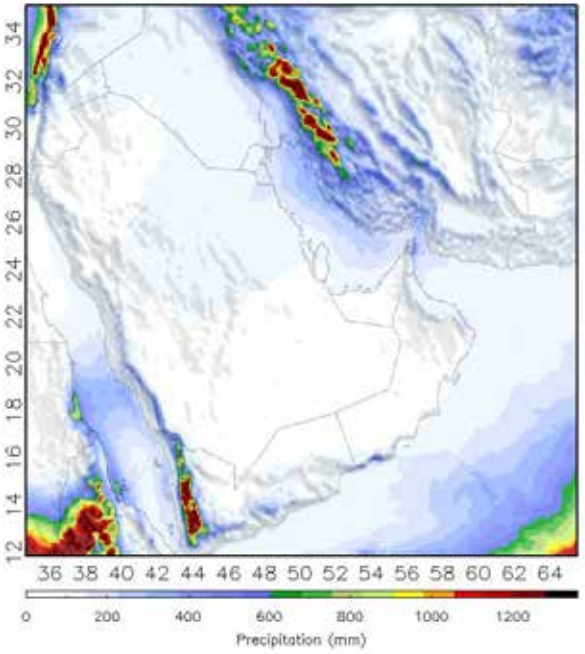
It has been demonstrated that WRF simulation driven by reanalysis data can well capture the historical climate and weather events, such as precipitation, storm tracks, snowpack, temperature, etc.

Evaluation

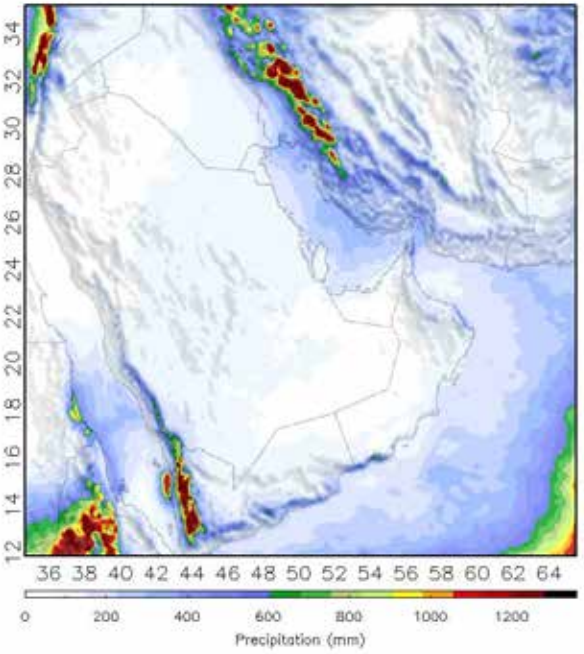
Comparison between WRF simulations driven by ERA-Interim and bias-corrected CCSM

Annual precipitation (1990-2005)

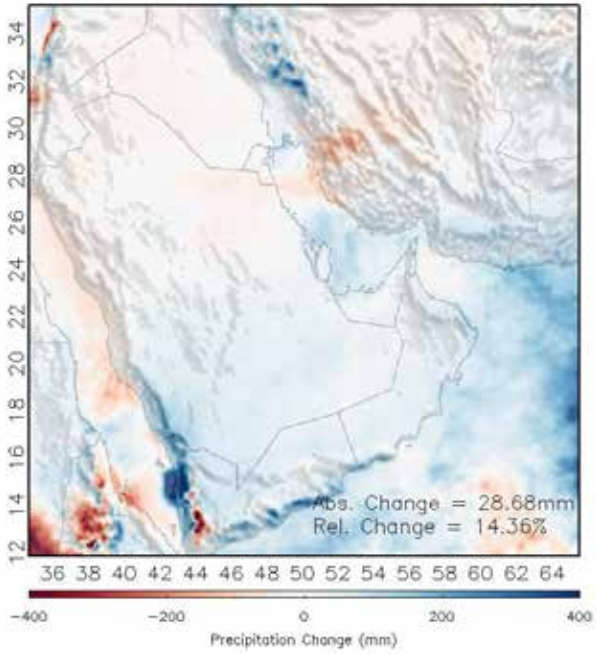
ERA-Interim



Bias corrected CCSM

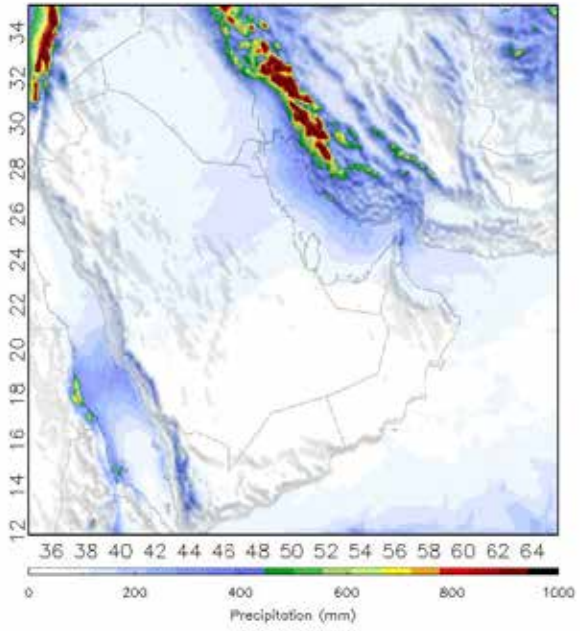


Difference (CCSM-ERA)

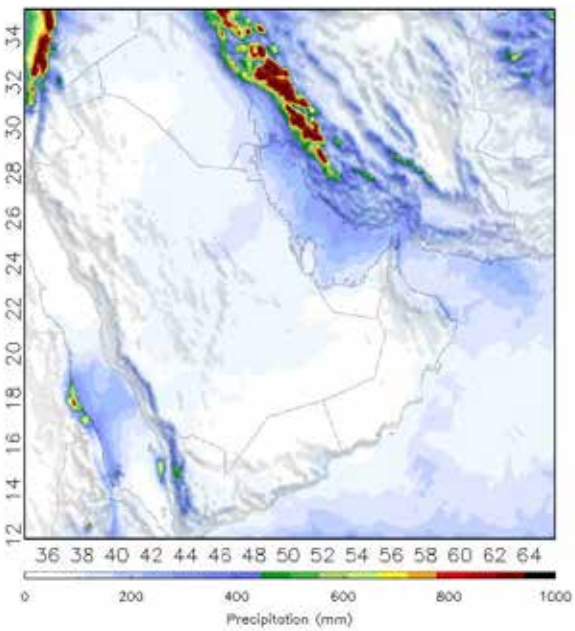


Wet Seasons

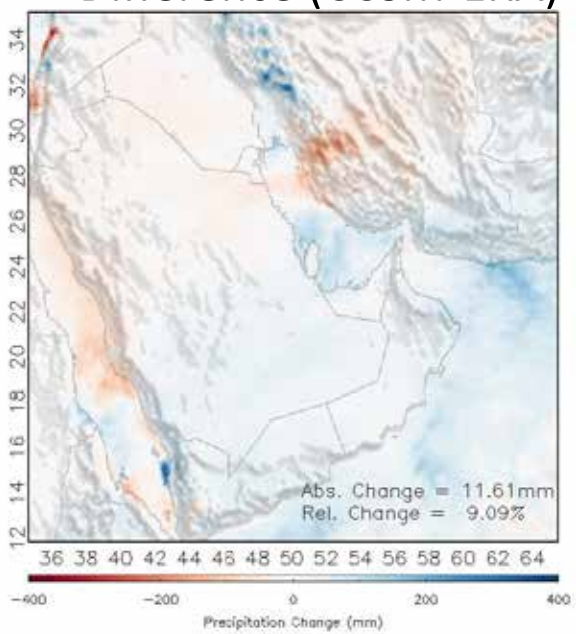
ERA-Interim



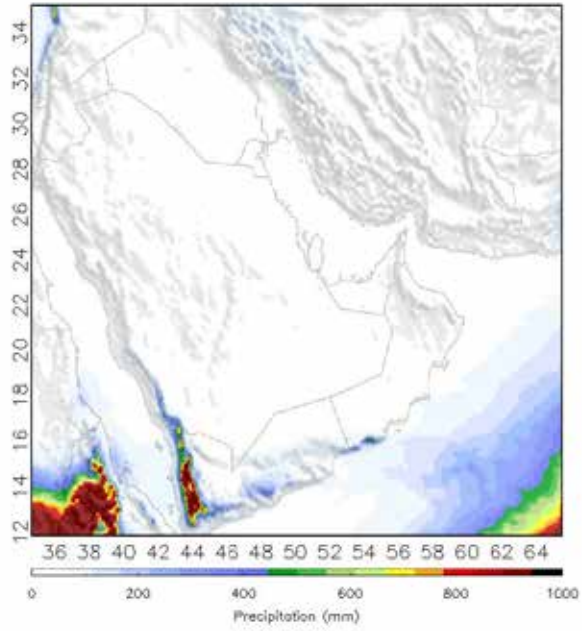
Bias corrected CCSM

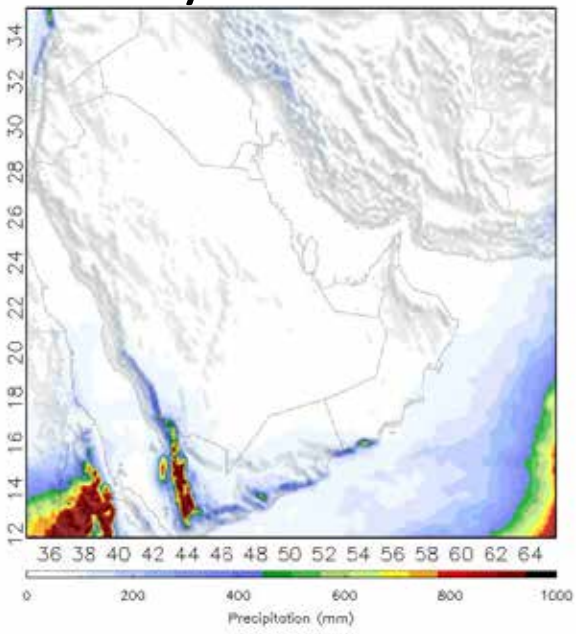


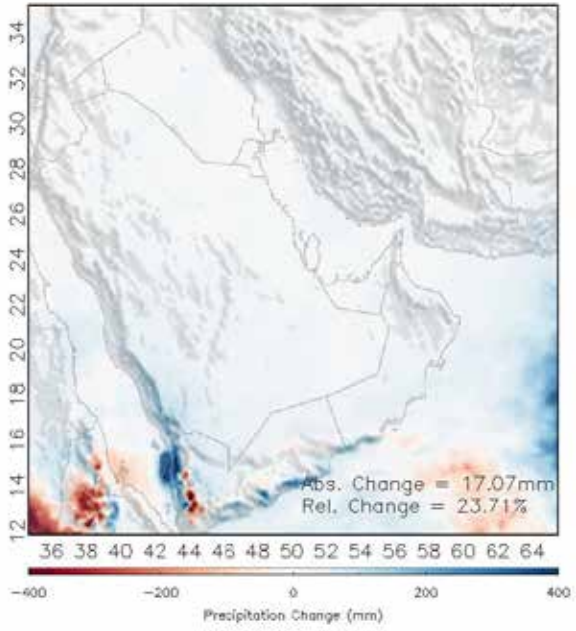
Difference (CCSM-ERA)



Dry Seasons



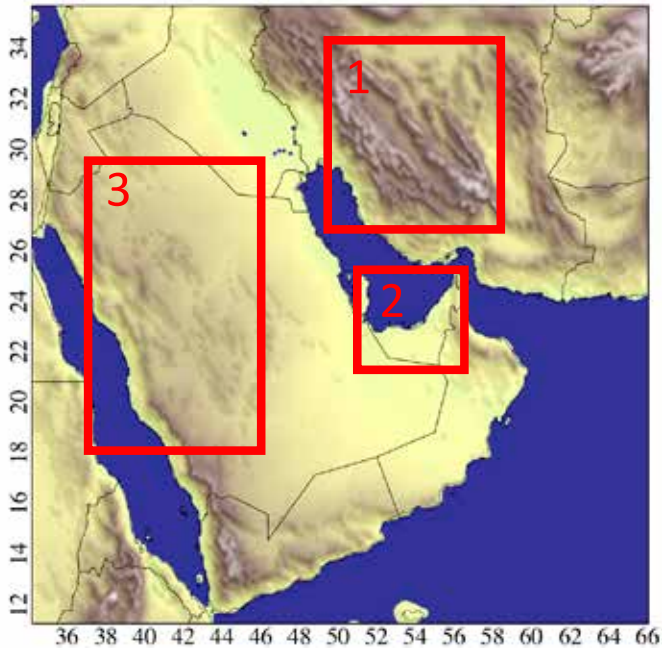


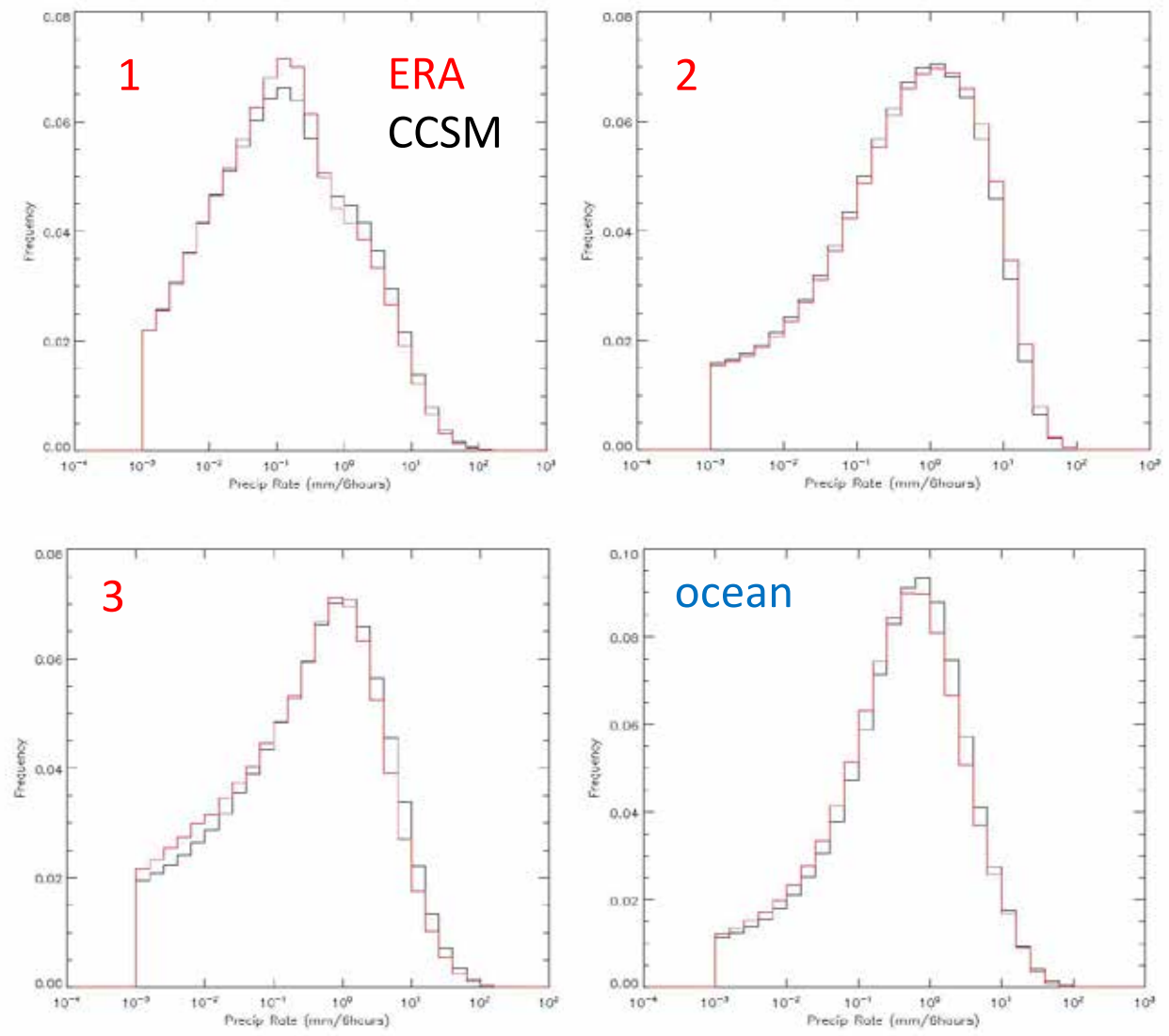


Evaluation

Comparison between WRF simulations driven by ERA-Interim and bias-corrected CCSM

Precipitation Variability





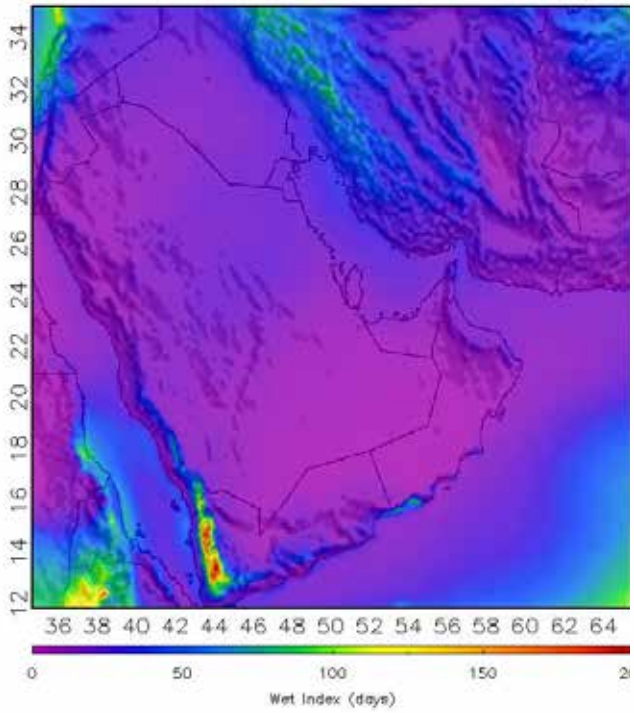
Evaluation

Comparison between WRF simulations driven by ERA-Interim and bias-corrected CCSM

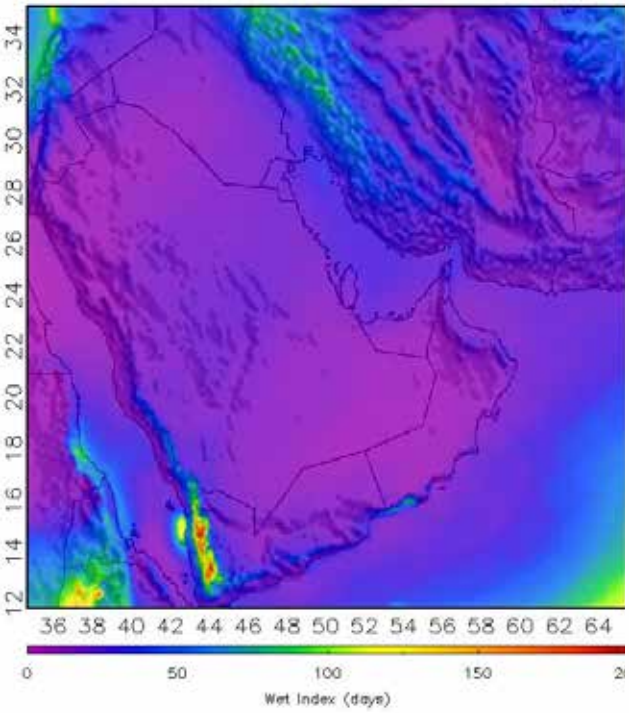
Wet Index

number of days per year with precipitation greater than 1mm

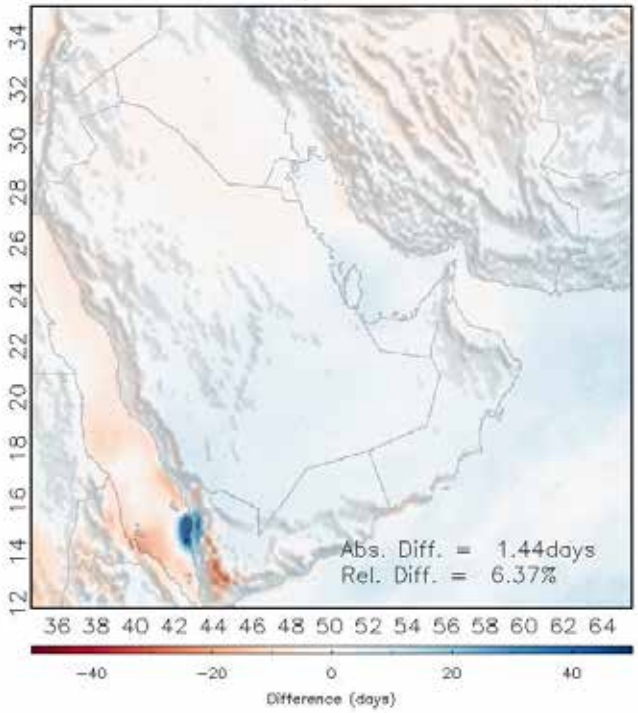
ERA-Interim



Bias corrected CCSM



Difference (CCSM-ERA)



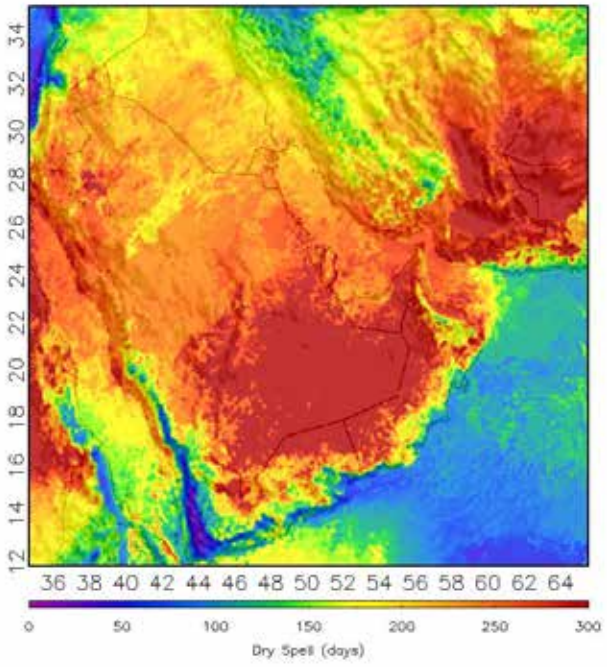
Evaluation

Comparison between WRF simulations driven by ERA-Interim and bias-corrected CCSM

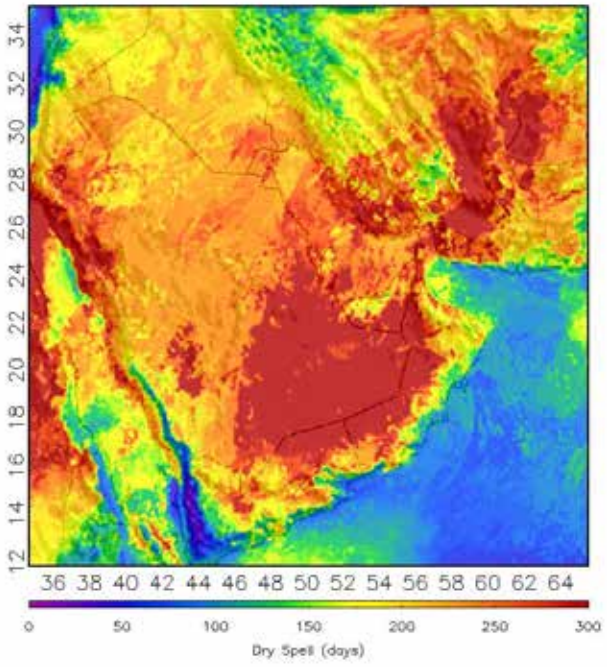
Maximum dry spell

consecutive days with precipitation less than 0.1mm

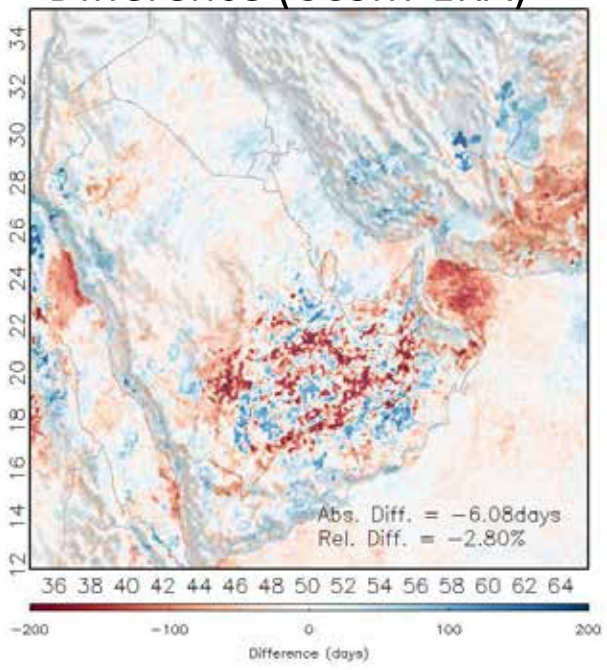
ERA-Interim



Bias corrected CCSM



Difference (CCSM-ERA)



Similar patterns.

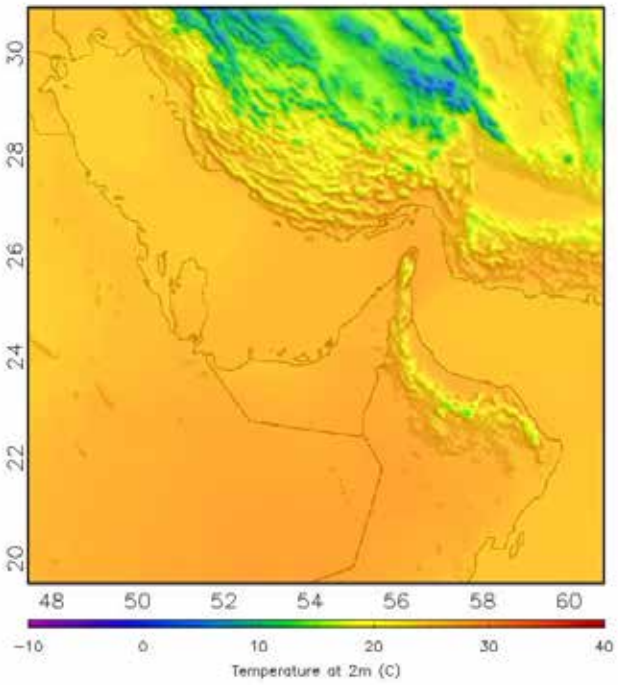
Future changes

	ERA-Interim driven simulation	Bias-corrected CCSM simulation (historical)	Bias-corrected CCSM simulation (RCP8.5)
D01 (36km)	1981-2010	1896-2005	2060-2079
D02 (12km)	1981-2010	1896-2005	2060-2079
D03 (4km)		1990-1999	2065-2074

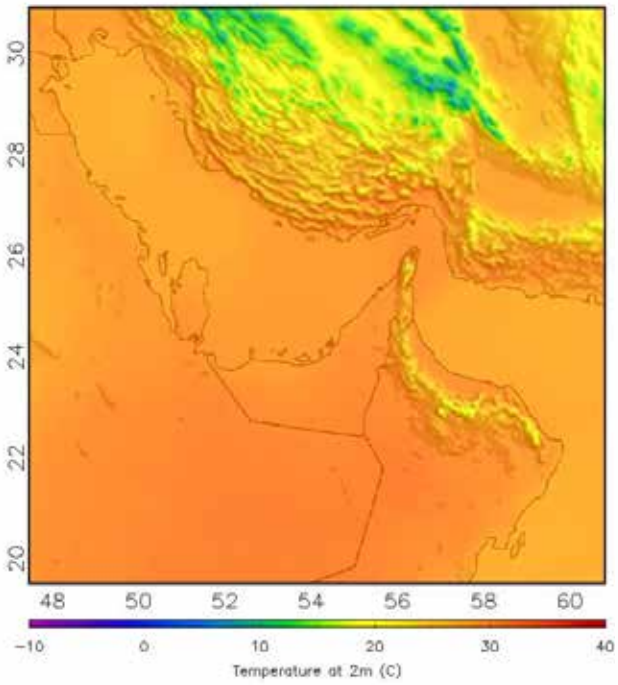
Future Changes in Temperature Predicted by WRF

Mean temperature

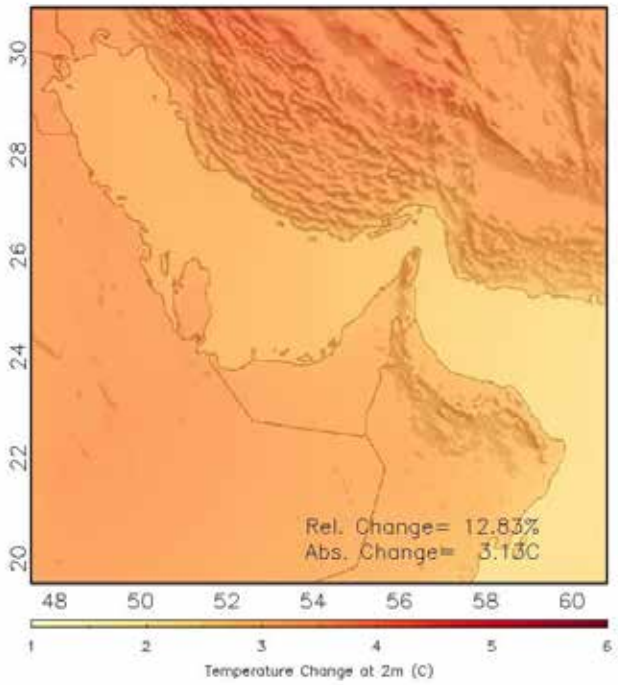
Current



Future



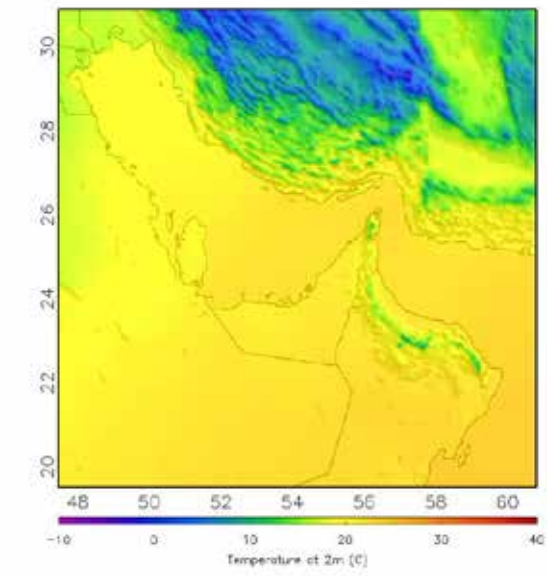
Change (Future-Current)



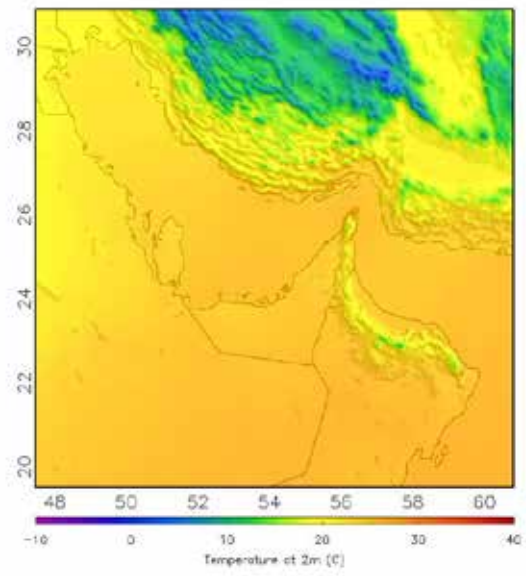
More significant warming over land than ocean

Wet Seasons

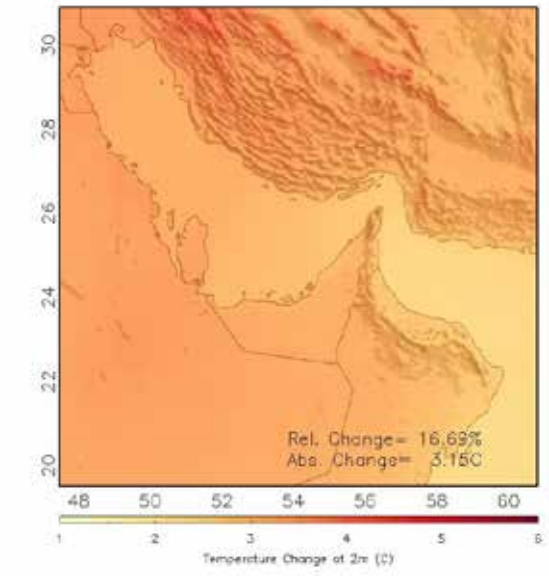
Current



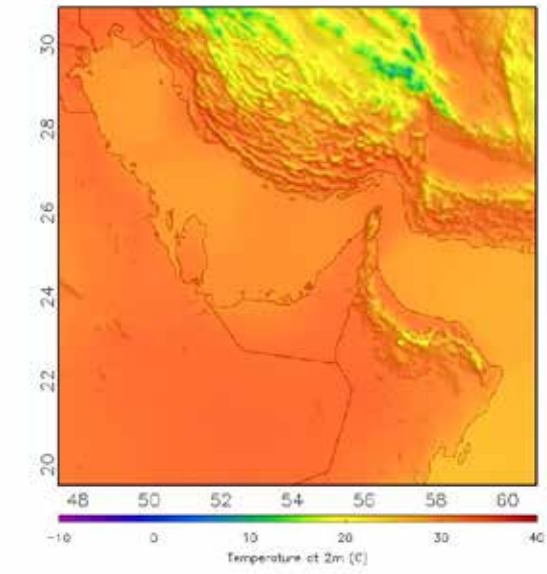
Future

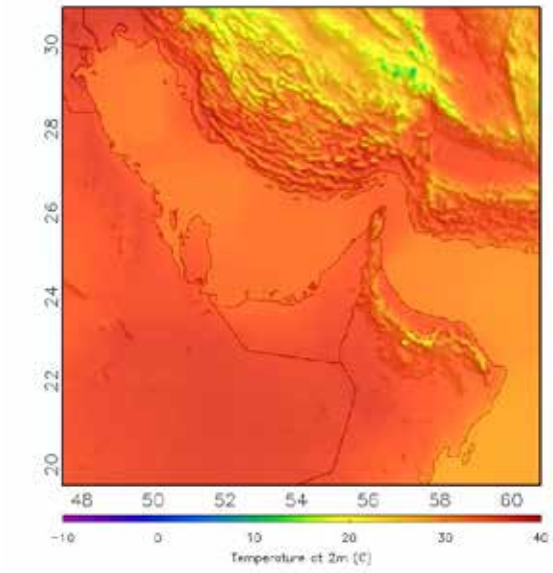


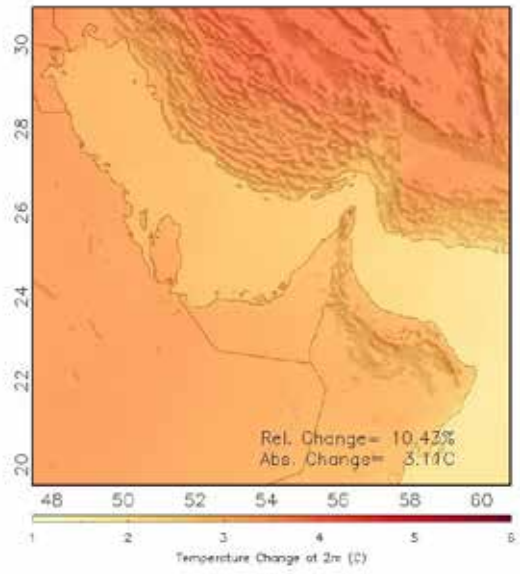
Change (Future-Current)



Dry Seasons



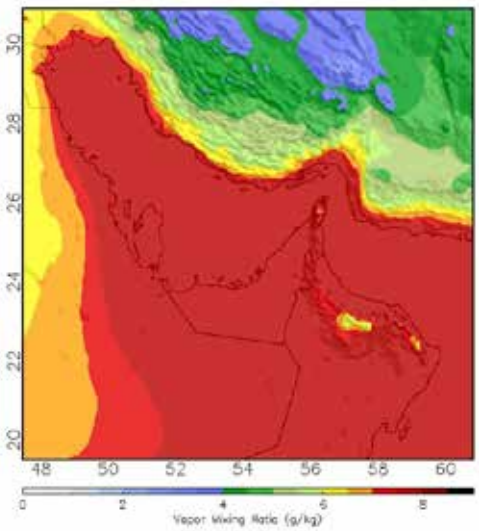


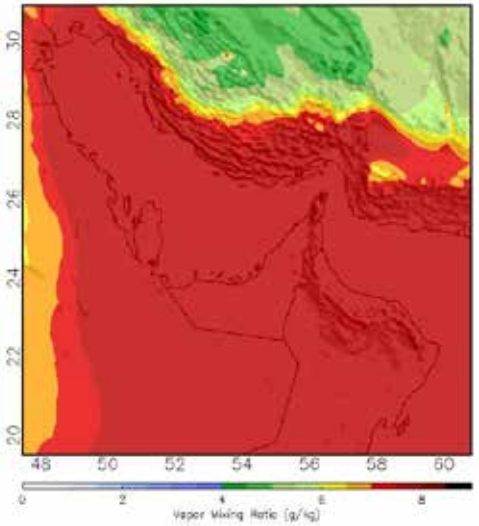


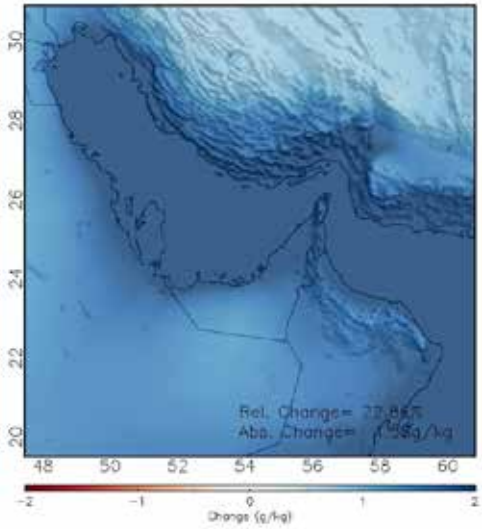
Future Changes in Specific Humidity

Wet Season 10-m Specific Humidity

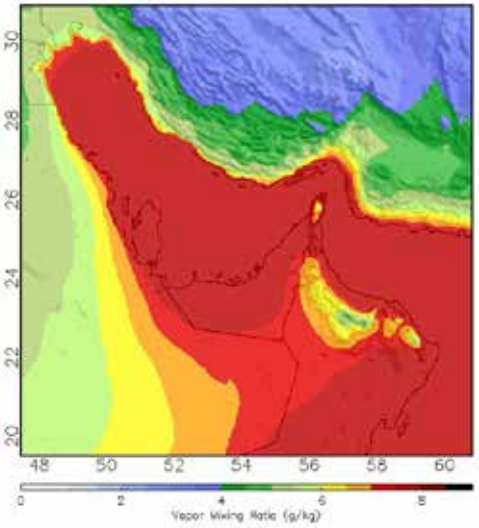
Current | Future | Change (Future-Current)

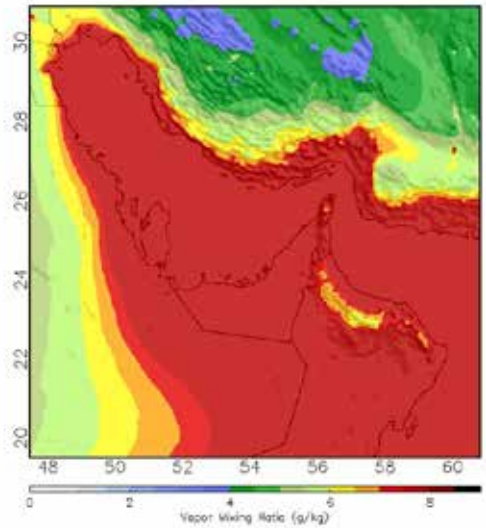


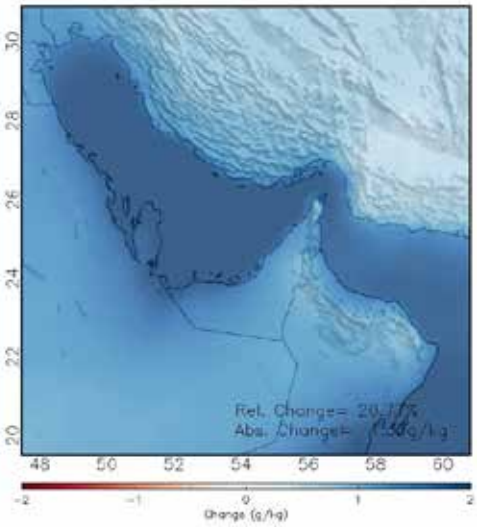




Dry Season 10-m Specific Humidity





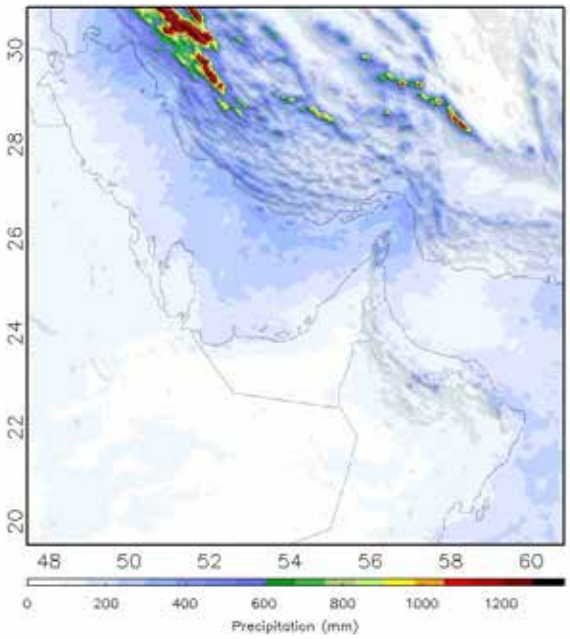


Strong moisture enhancement over ocean than land

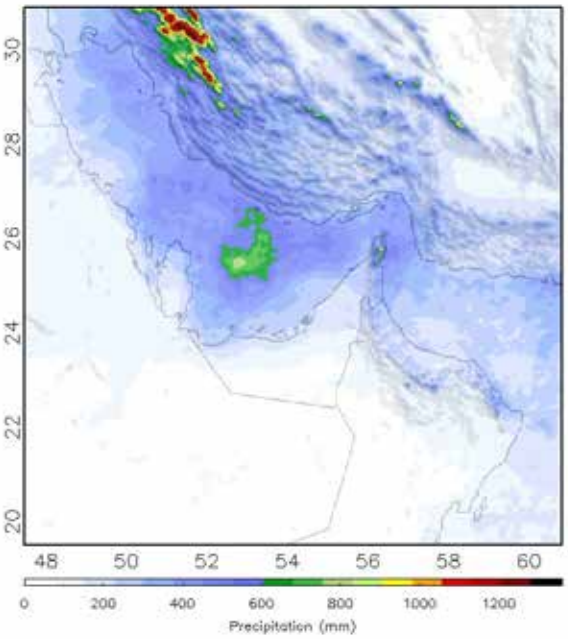
Future Changes in Precipitation Predicted by WRF

Annual precipitation

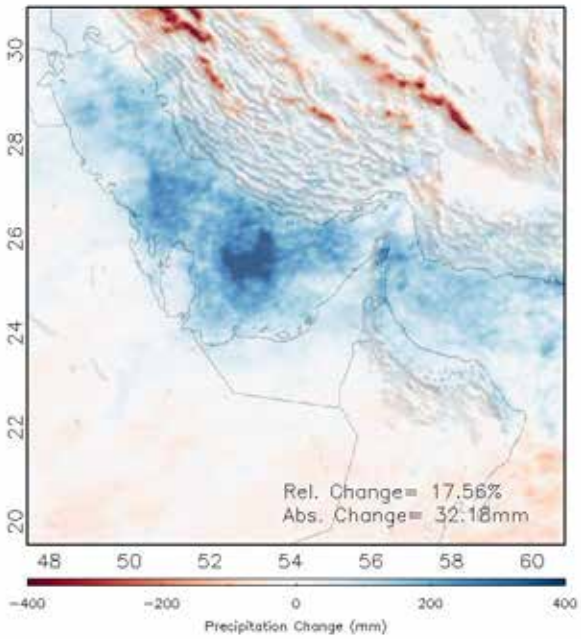
Current



Future



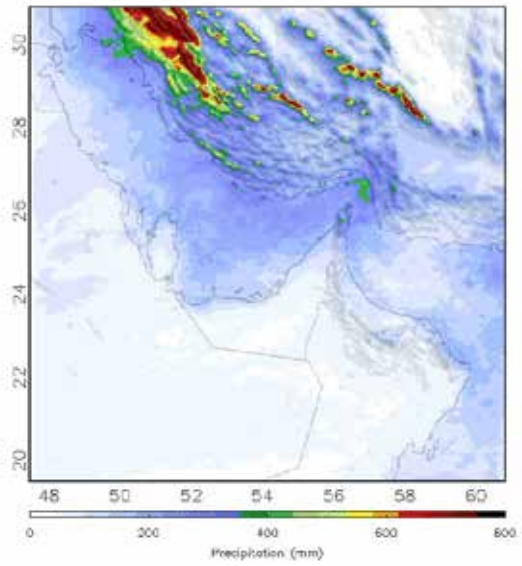
Change (Future-Current)



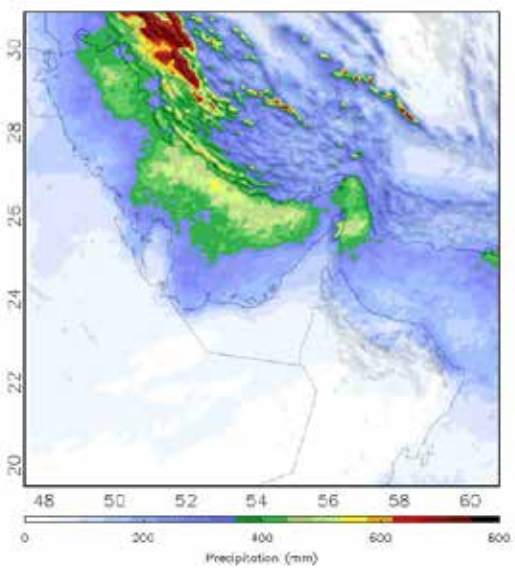
Stronger enhancement of humidity and weaker warming over ocean results in more precipitation increase over ocean than land (thermodynamic impact).

Wet Season precipitation

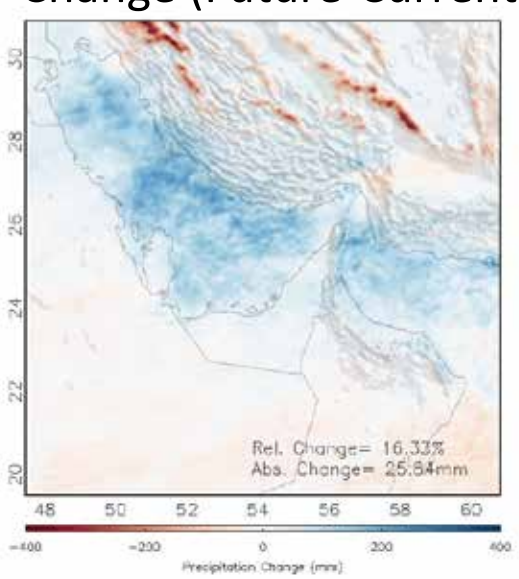
Current



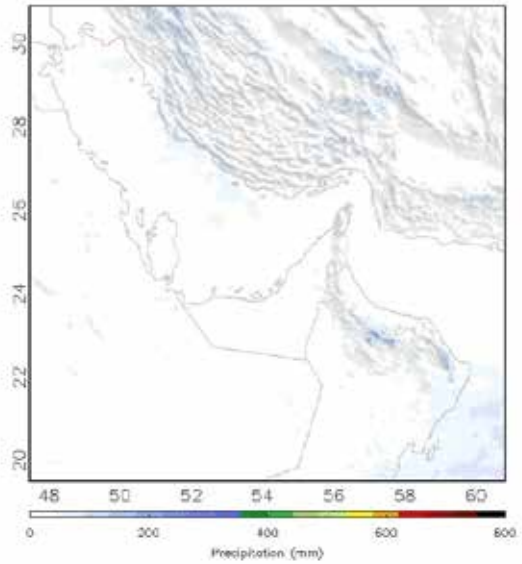
Future

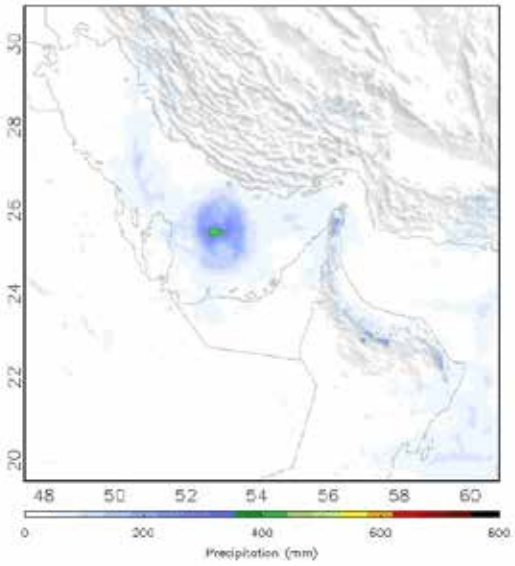


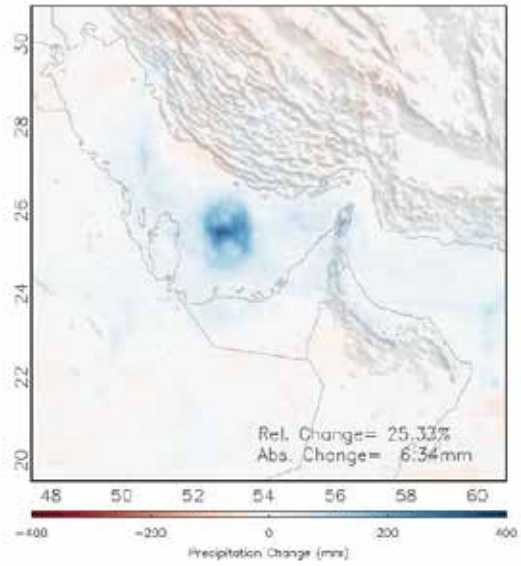
Change (Future-Current)



Dry Season precipitation



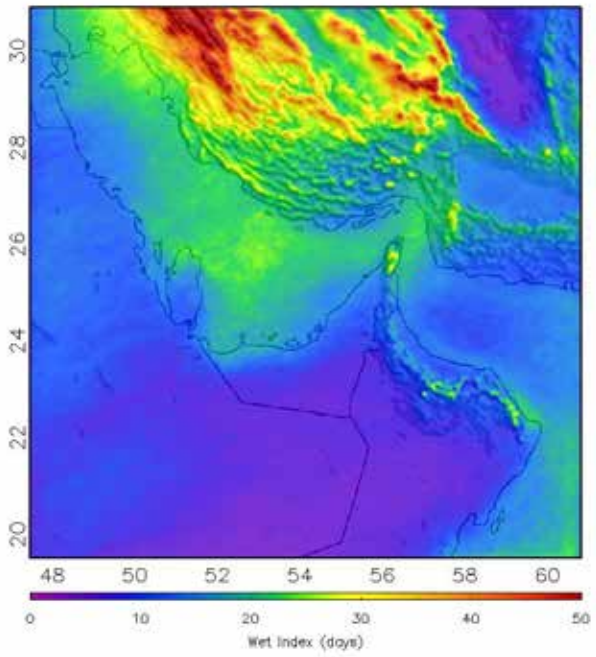




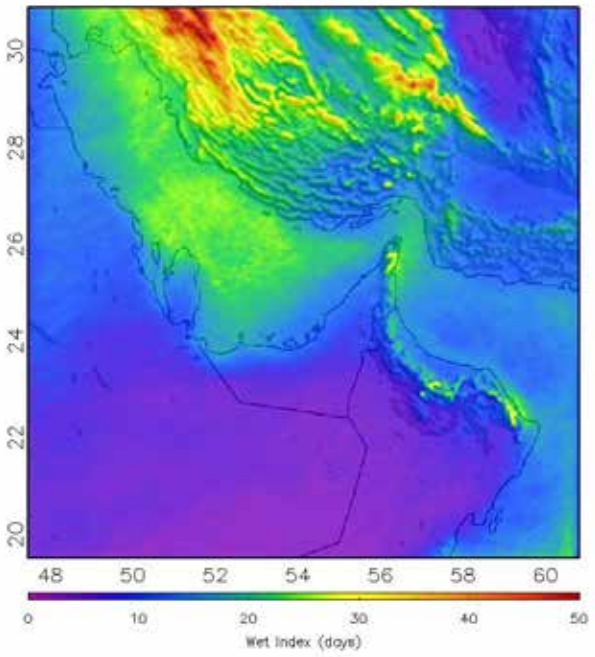
Future Changes in Precipitation Predicted by WRF

Wet Index

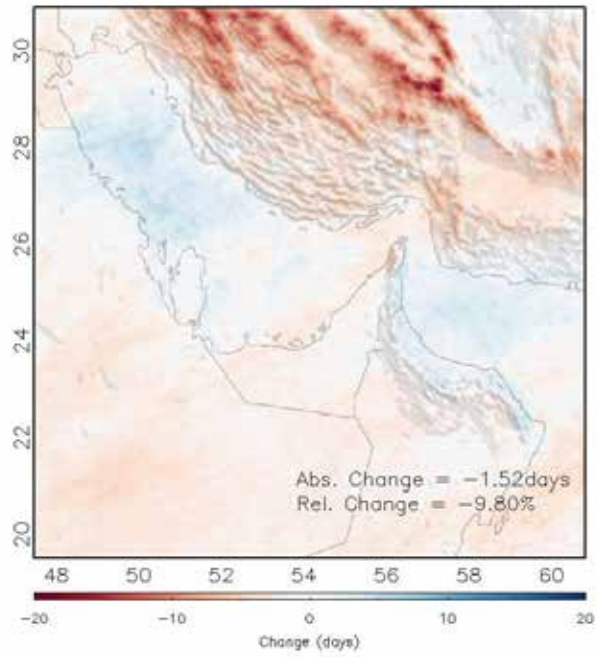
Current



Future



Change (Future-Current)

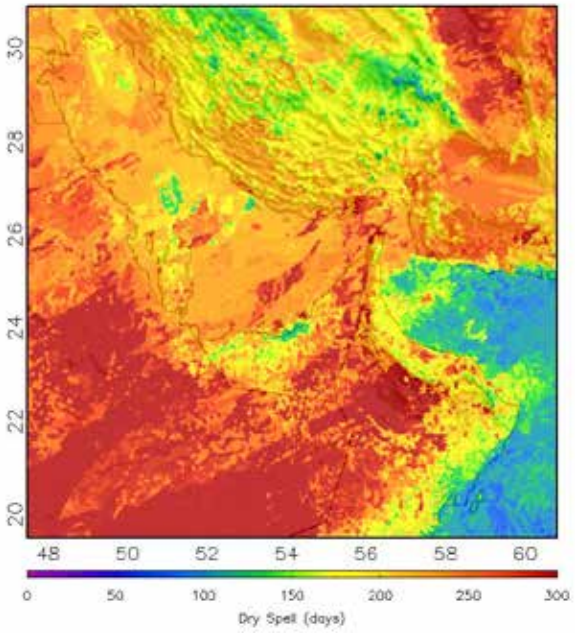


Not only the total precipitation increases (decreases) over ocean (land), but also the wet index.

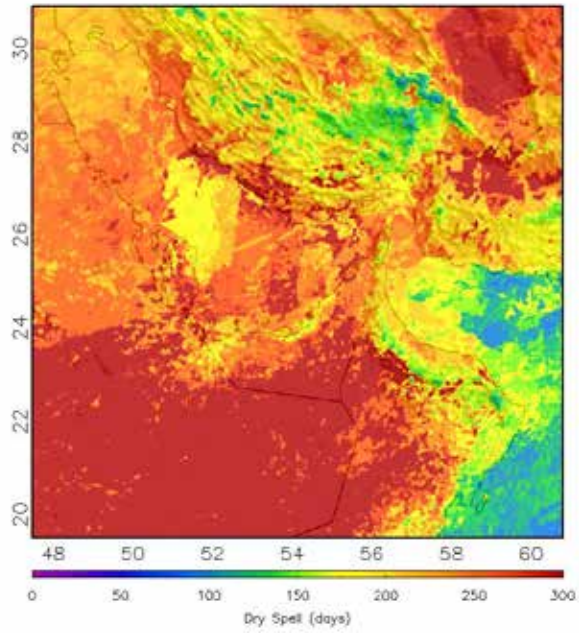
Future Changes in Precipitation Predicted by WRF

Maximum Dry Spell

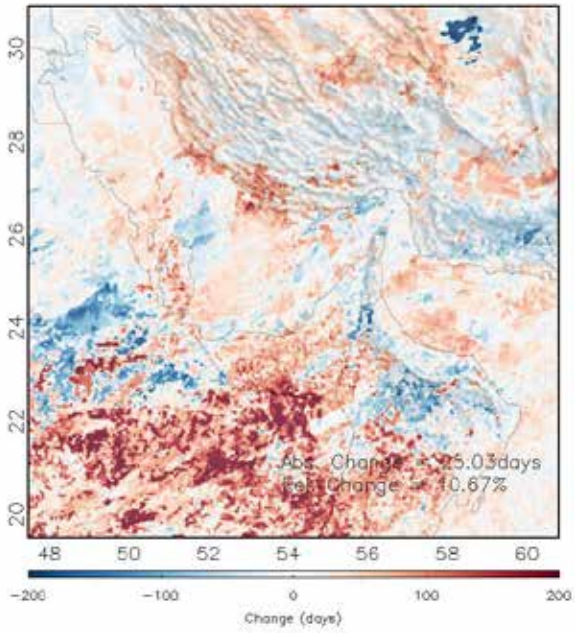
Current



Future



Change (Future-Current)



Averagely, the maximum dry spell increased by 25 days (11.7 %)

Conclusions

Convection-permitting regional climate simulations are performed using WRF driven by bias-corrected-CCSM for both the current and future (RCP8.5) climate. ERA-Interim-driven WRF simulation is performed to evaluate the bias-corrected-CCSM-driven WRF simulation.

Comparison between TRMM and the bias-corrected-CCSM-driven WRF simulation indicate the simulation can well capture the precipitation distribution in the Arabian Gulf Region.

Comparison against the benchmark simulation driven by ERA-Interim data indicates the bias-corrected-CCSM-driven WRF simulation can well capture the mean precipitation distribution, as well as the precipitation variability.

Using the bias-corrected-CCSM-driven WRF simulations, the future (RCP8.5) climate in the Arabian Gulf Region is studied, the results show:

- The precipitation increases over ocean and decreases over land because of the stronger moisture enhancement and weaker warming over ocean.
- The wet index also increases over ocean and decreases over land.
- The maximum dry spell increases in most areas of the Arabian Gulf Region.

Next Step

- More evaluation of the model output with station data.

- Analyze the mean sounding over the land and ocean between historical and future to see how the instability is changed. Also, low level wind over ocean will be compared to see if any dynamical contribution to the surface fluxes of moisture and heat in the future.

Thank you!

Questions/suggestions?