Regional Climate Change over Southwest Asia

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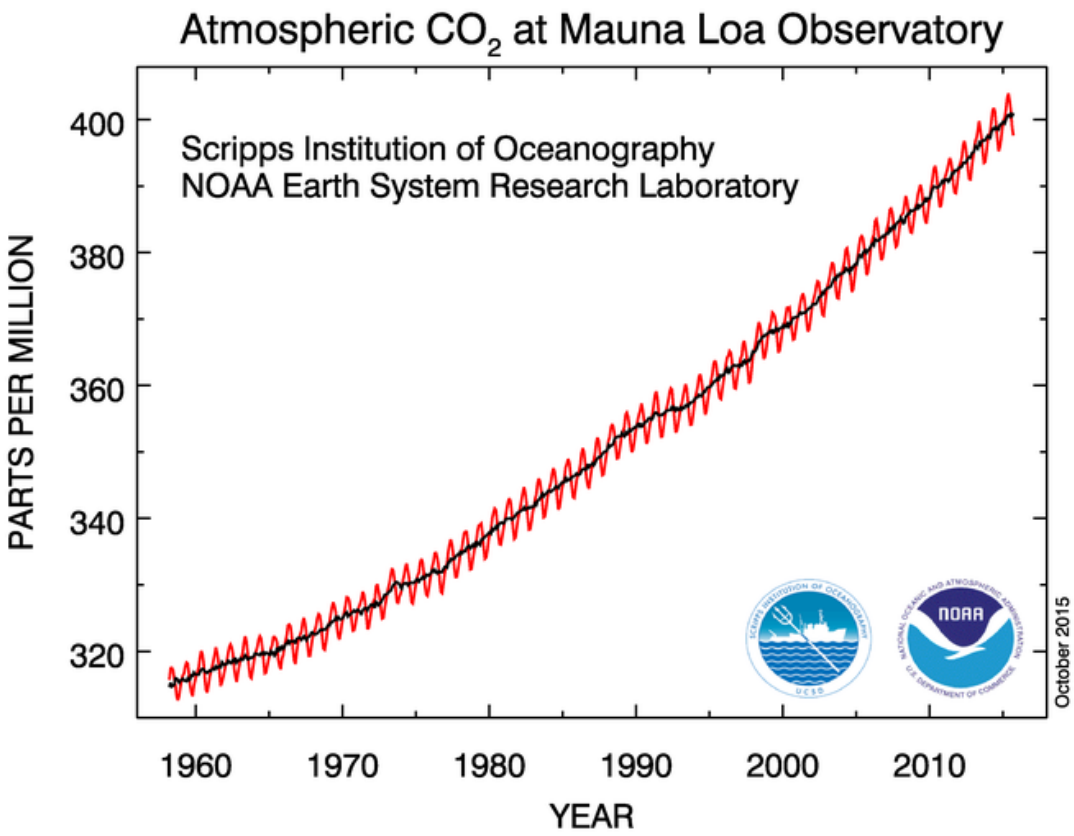
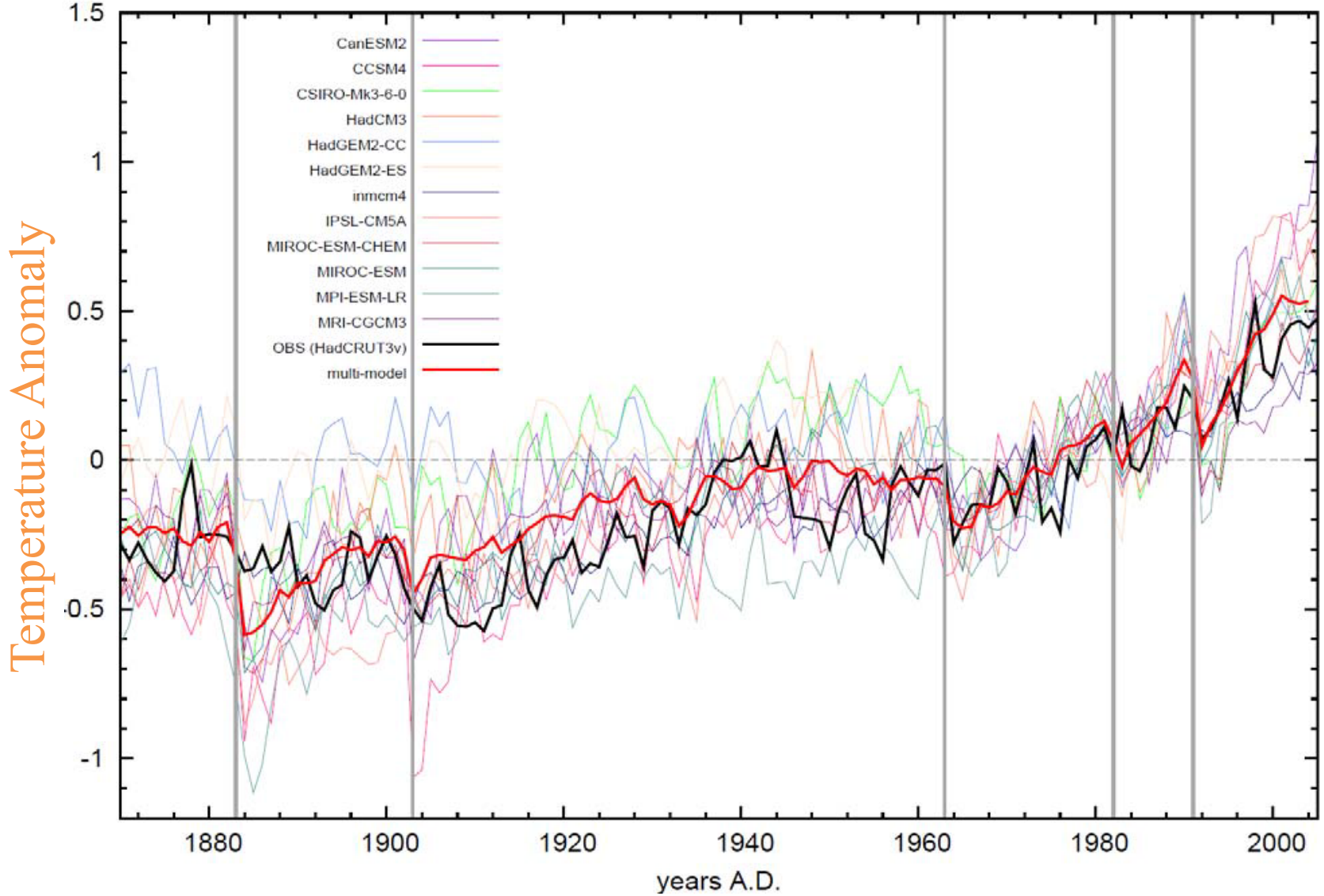
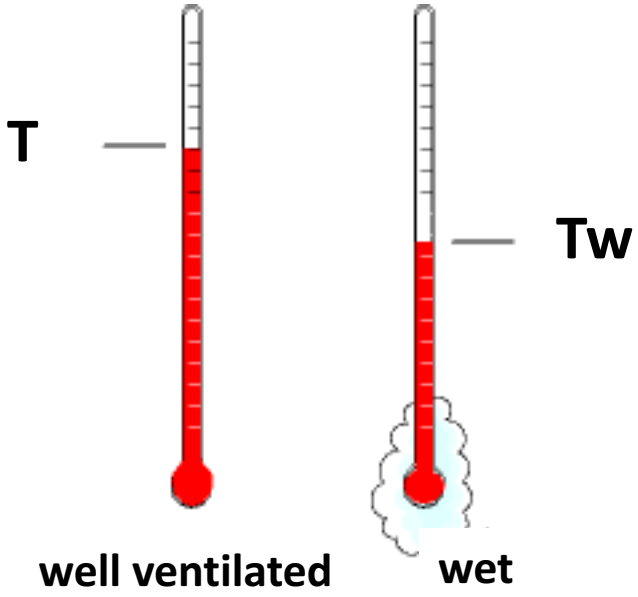

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
October 2015

Dry-bulb temperature is used widely to describe observed and modeled climate (e.g IPCC reports)



Dry-bulb and Wet-bulb Temperatures



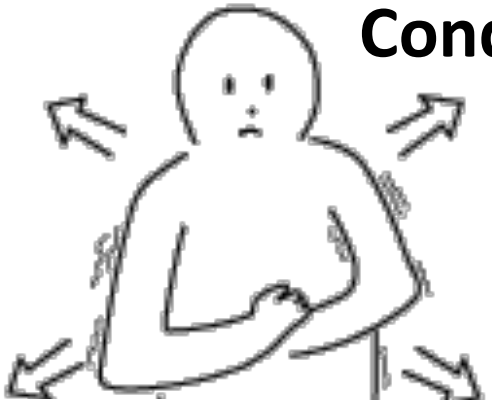
Wet-bulb Temperature (T_w)

- Temperature that an air parcel would attain if cooled by evaporating water into it till saturation.
- T_w is function of both air temperature and humidity

Cooling of the Human Body

Perspiration

Conduction



Convection

Radiation

An adaptability limit to climate change due to heat stress

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Despite the uncertainty in future climate-change impacts, it is often assumed that humans would be able to adapt to any possible warming. Here we argue that heat stress imposes a robust upper limit to such adaptation. Peak heat stress, quantified by the wet-bulb temperature T_W, is surprisingly similar across diverse climates today. T_W never exceeds 31 °C. Any exceedence of 35 °C for extended periods should induce hyperthermia in humans and other mammals, as dissipation of metabolic heat becomes impos-

Heat stress is already a leading cause of fatalities from natural phenomena (11, 12). While fatalities appear associated with warm nights (13), hot days alter the lifestyles and work productivity of those living at low latitudes (14). Both impacts will clearly worsen in warmer climates (15, 16), but most believe humans will simply adapt, reasoning that humans already tolerate a very wide range of climates today. But when measured in terms of peak heat stress—including humidity—this turns out to be untrue. We show

Credit: Youm7

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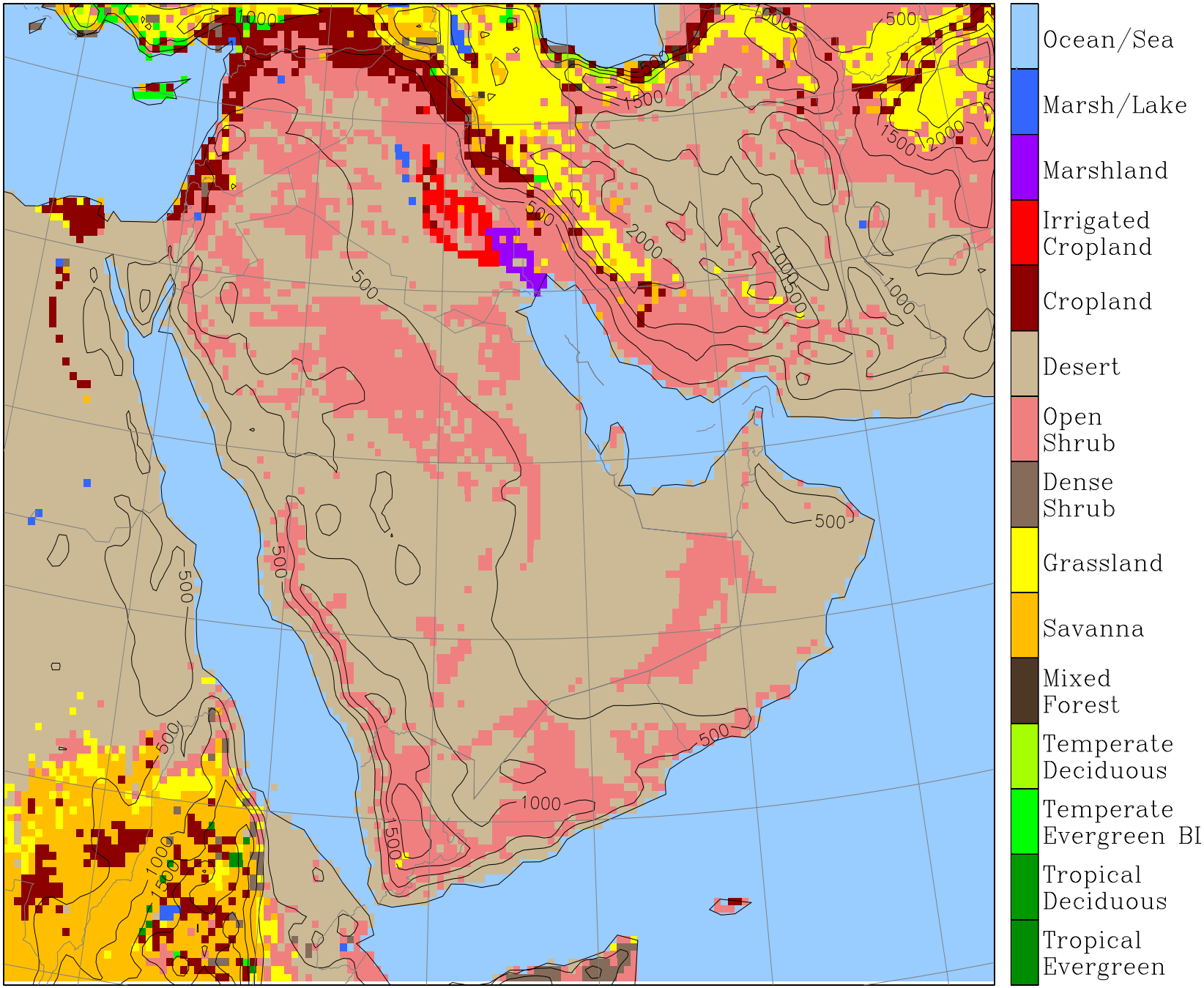
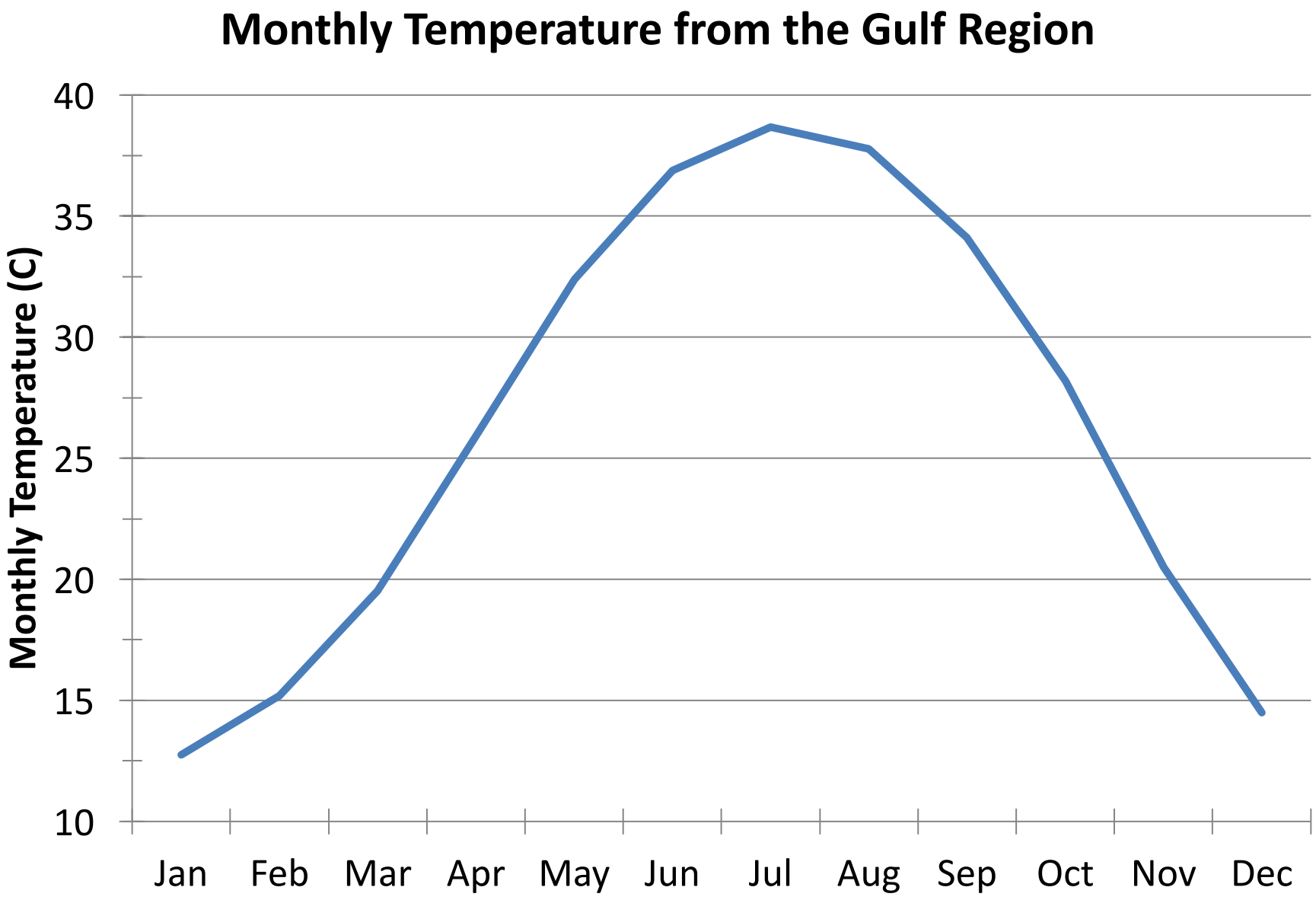

Ocean/Sea
Marsh/Lake
Marshland
Irrigated Cropland
Cropland
Desert
Open Shrub
Dense Shrub
Grassland
Savanna
Mixed Forest
Temperate Deciduous
Temperate Evergreen BI
Tropical Deciduous
Tropical Evergreen

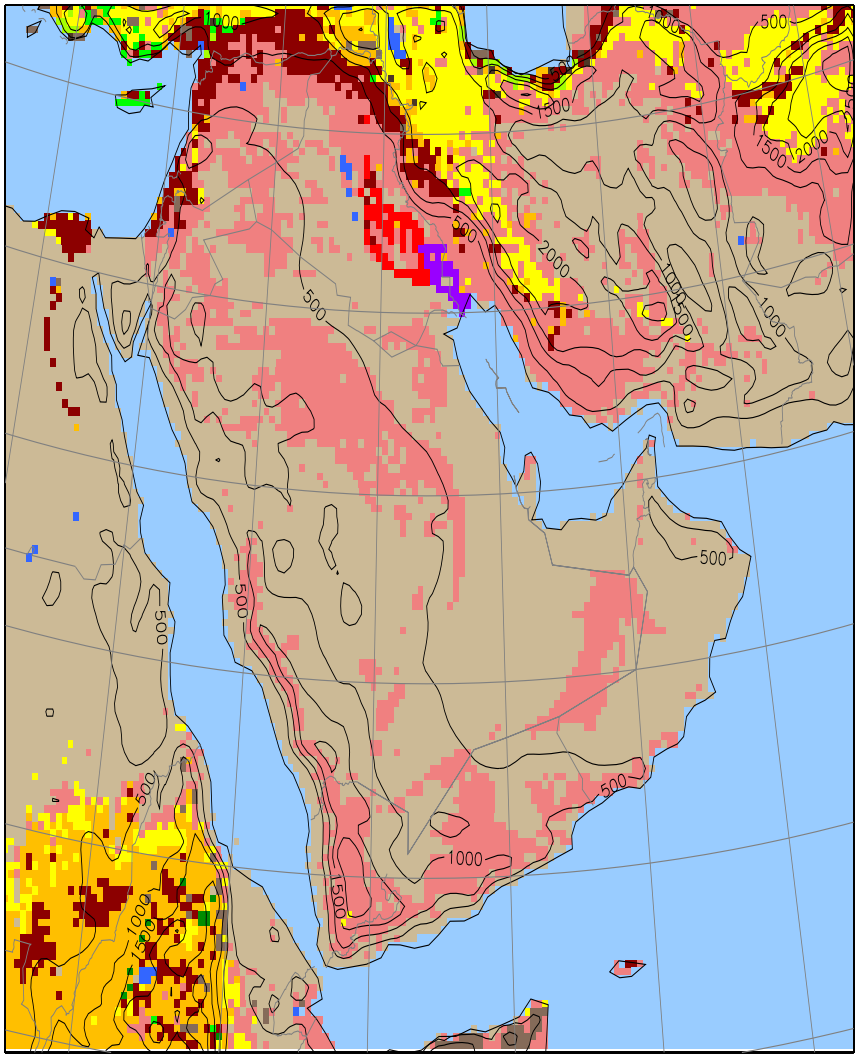

Monthly Temperature from the Gulf Region
Monthly Temperature (C)
40
35
30
25
20
15
10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Numerical Experiments

MIT Regional Climate Model (MRCM)

Based on RegCM3 (Pal et al 2007) with:

- Dust (Marcella & Eltahir 2010)
- Convective cloud water, rainfall scheme, and PBL (Gianotti & Eltahir 2012)
- IBIS Land Surface (Winter et al 2009)
- New Land Cover Types – Marshland and Irrigated Crop, NASA SRB Soil Albedo, MODIS Desert Emissivity (Pal & Eltahir 2015)

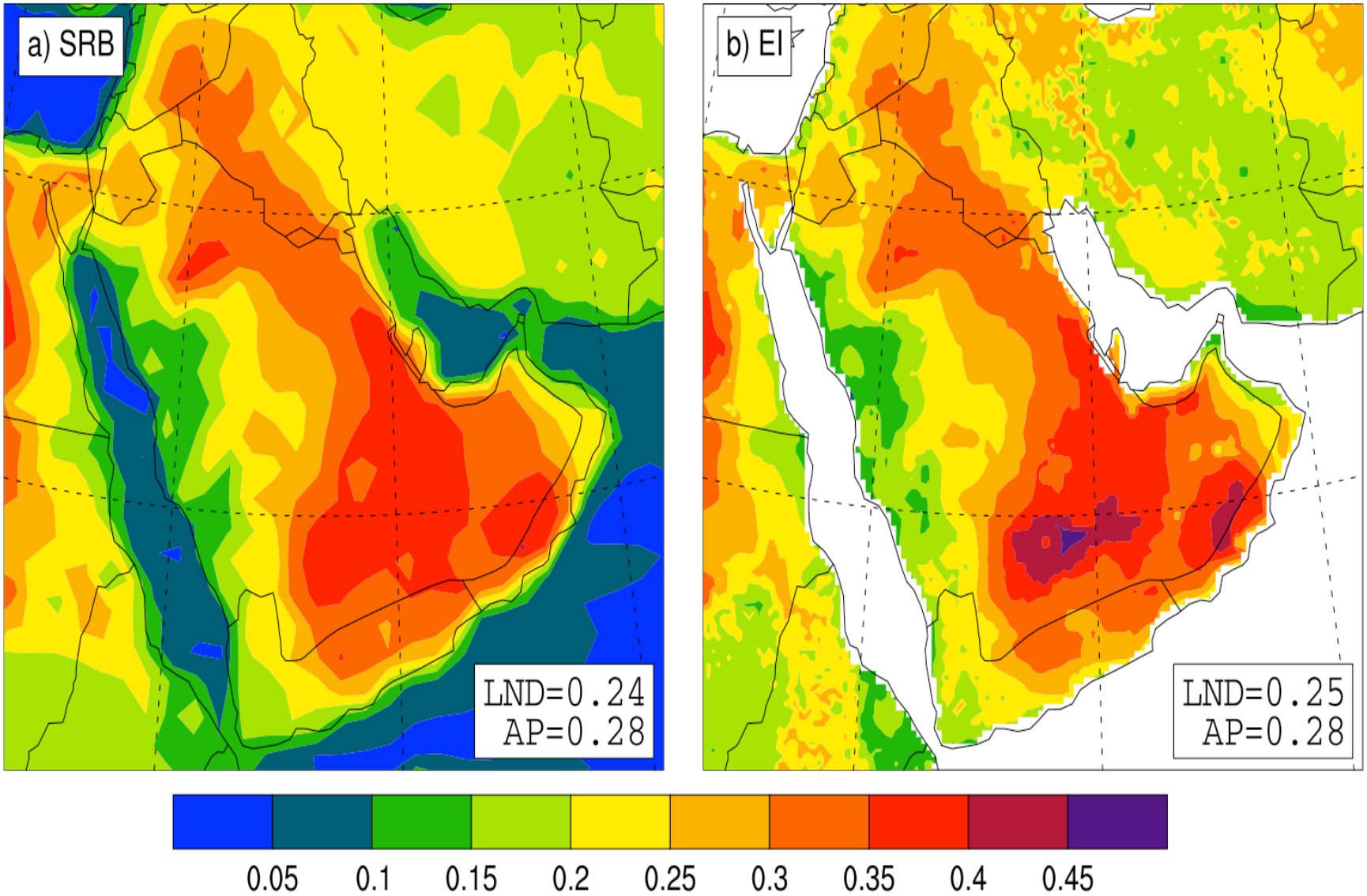


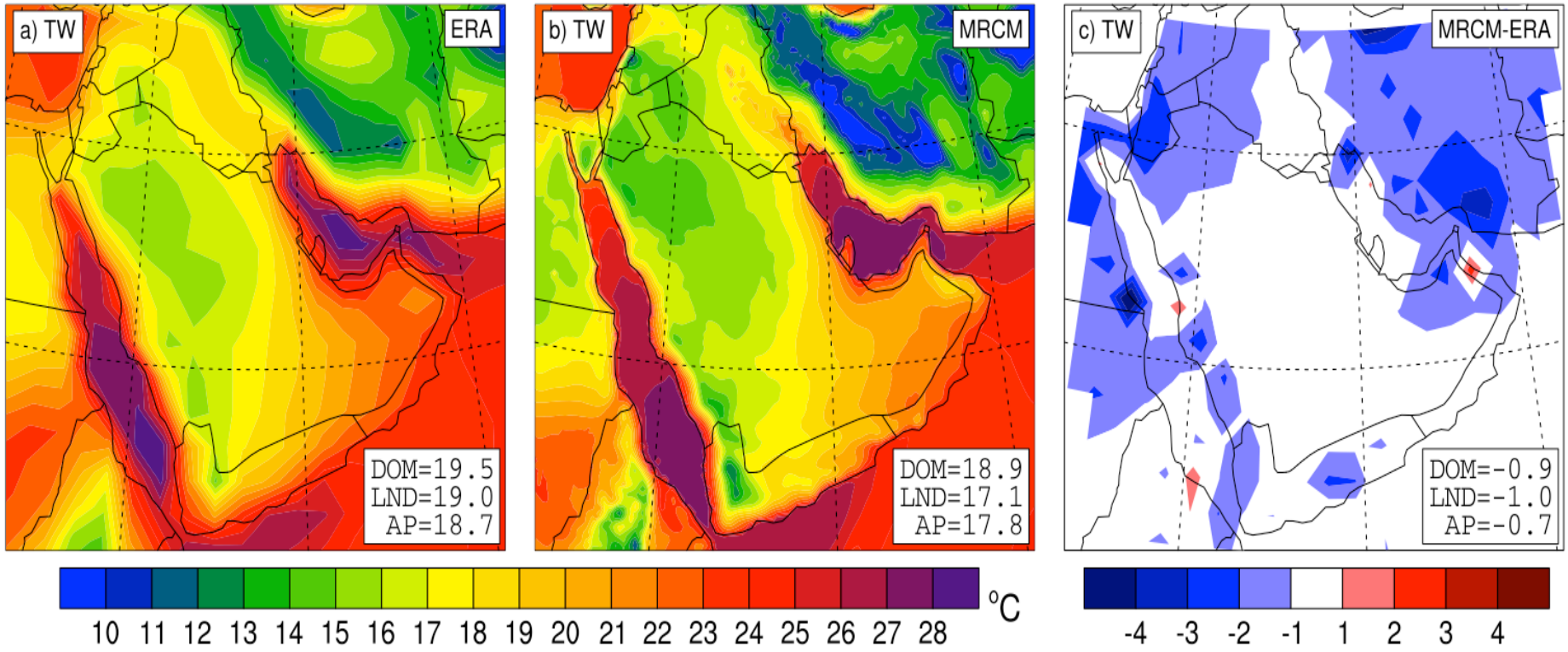
Model Domain:

25-km; nx = 144; ny = 130, nz = 18

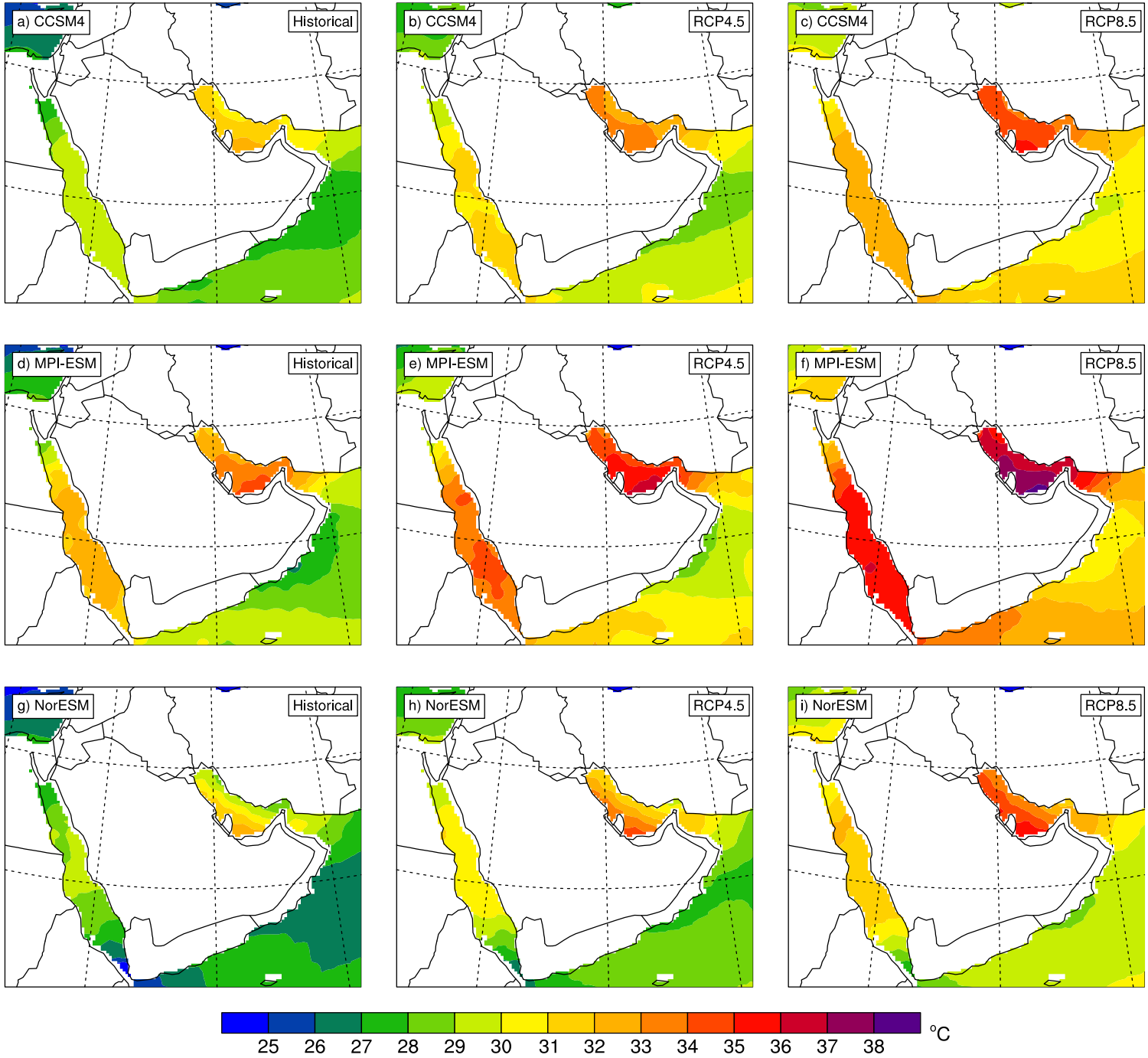
Deserts of Arabia and Africa are more reflective than deserts of the Southwest

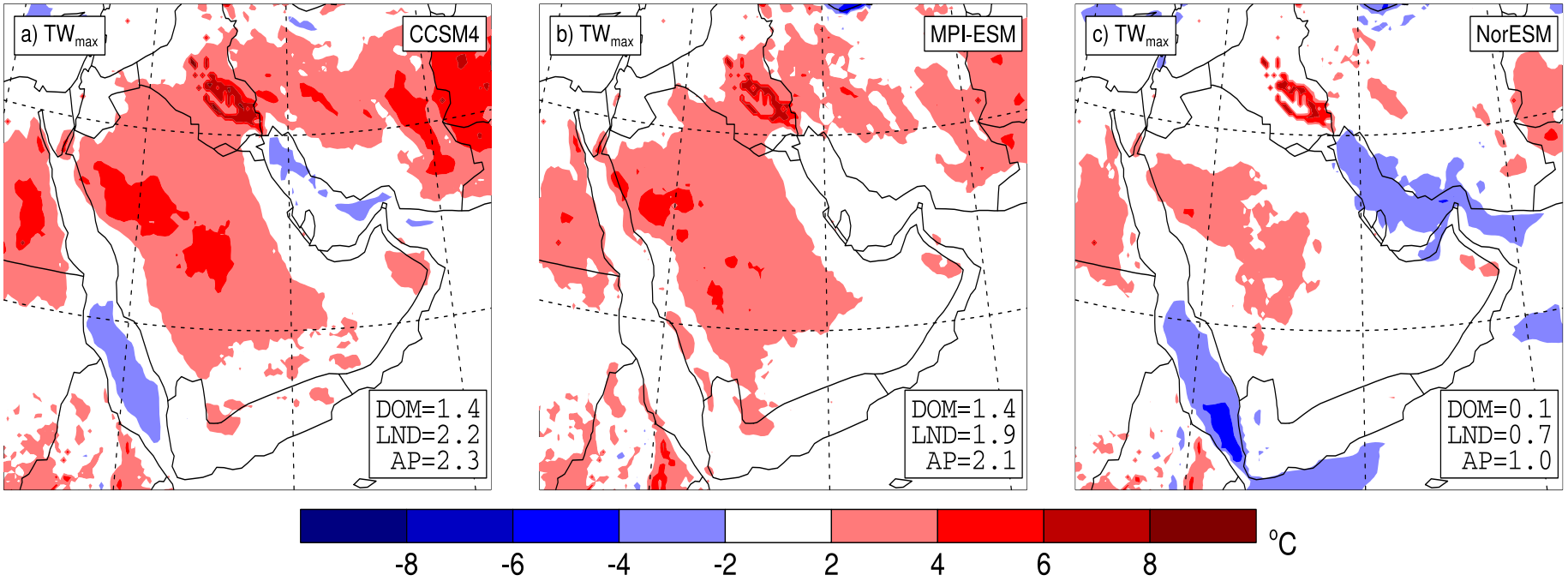
NASA

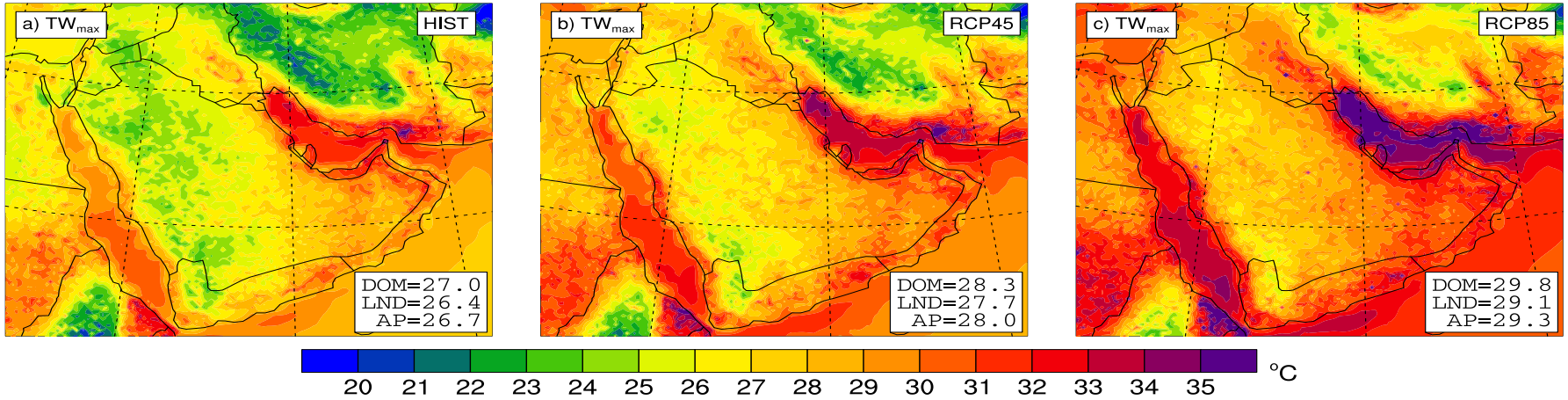

a) SRB
LND=0.24
AP=0.28
b) EI
LND=0.25
AP=0.28
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


a) TW
ERA
DOM=19.5
LND=19.0
AP=18.7
b) TW
MRCM
DOM=18.9
LND=17.1
AP=17.8
c) TW
MRCM-ERA
DOM=-0.9
LND=-1.0
AP=-0.7
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
°C
-4 -3 -2 -1 1 2 3 4

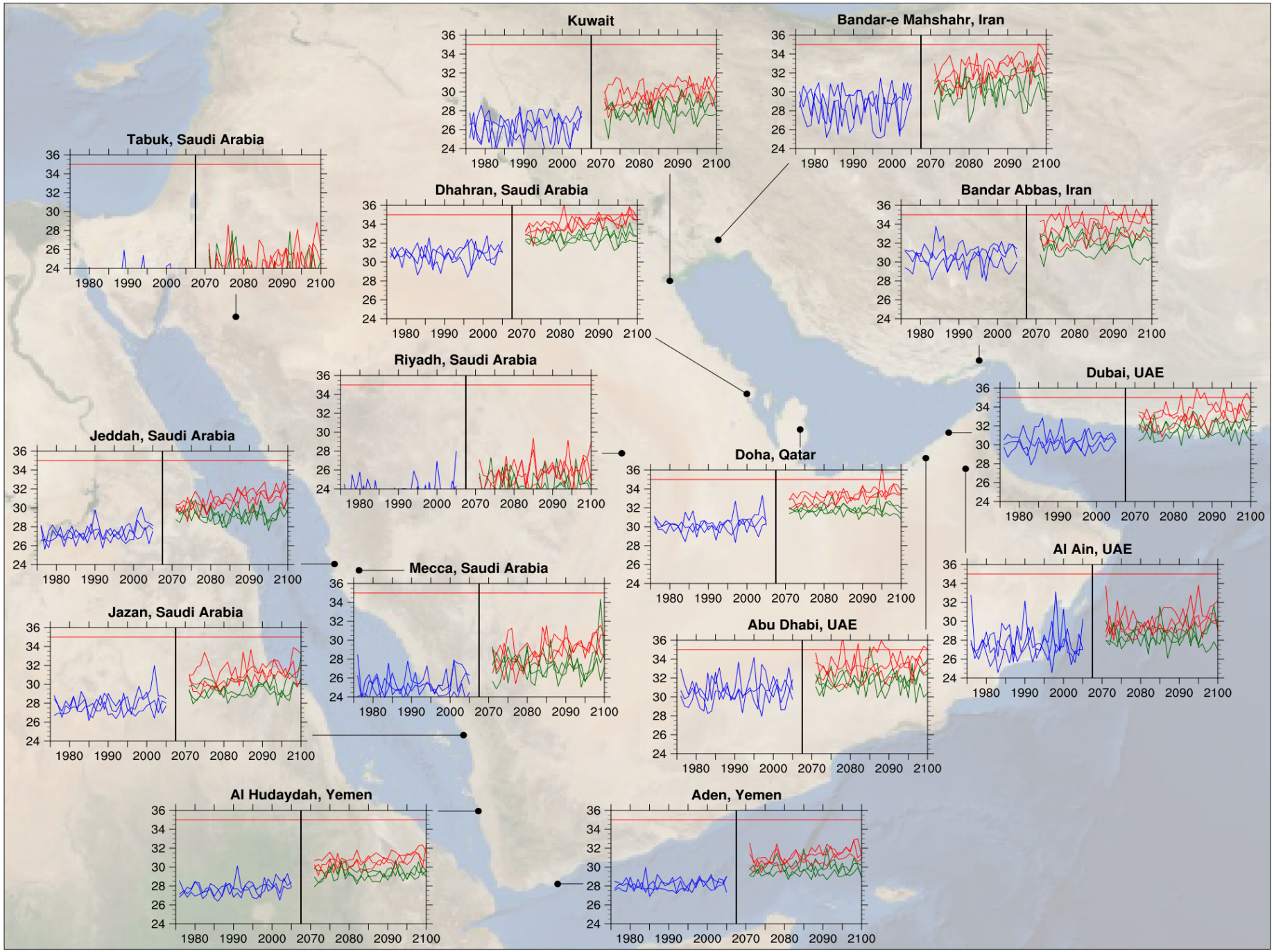
GCM	Atmosphere	Ocean
CCSM4	0.9°x1.25°	1.11°x0.27° – 0.54°
MPI-ESM	T63/1.875°	0.4°x0.4°
NorESM	1.875°x2.5°	1°x1°

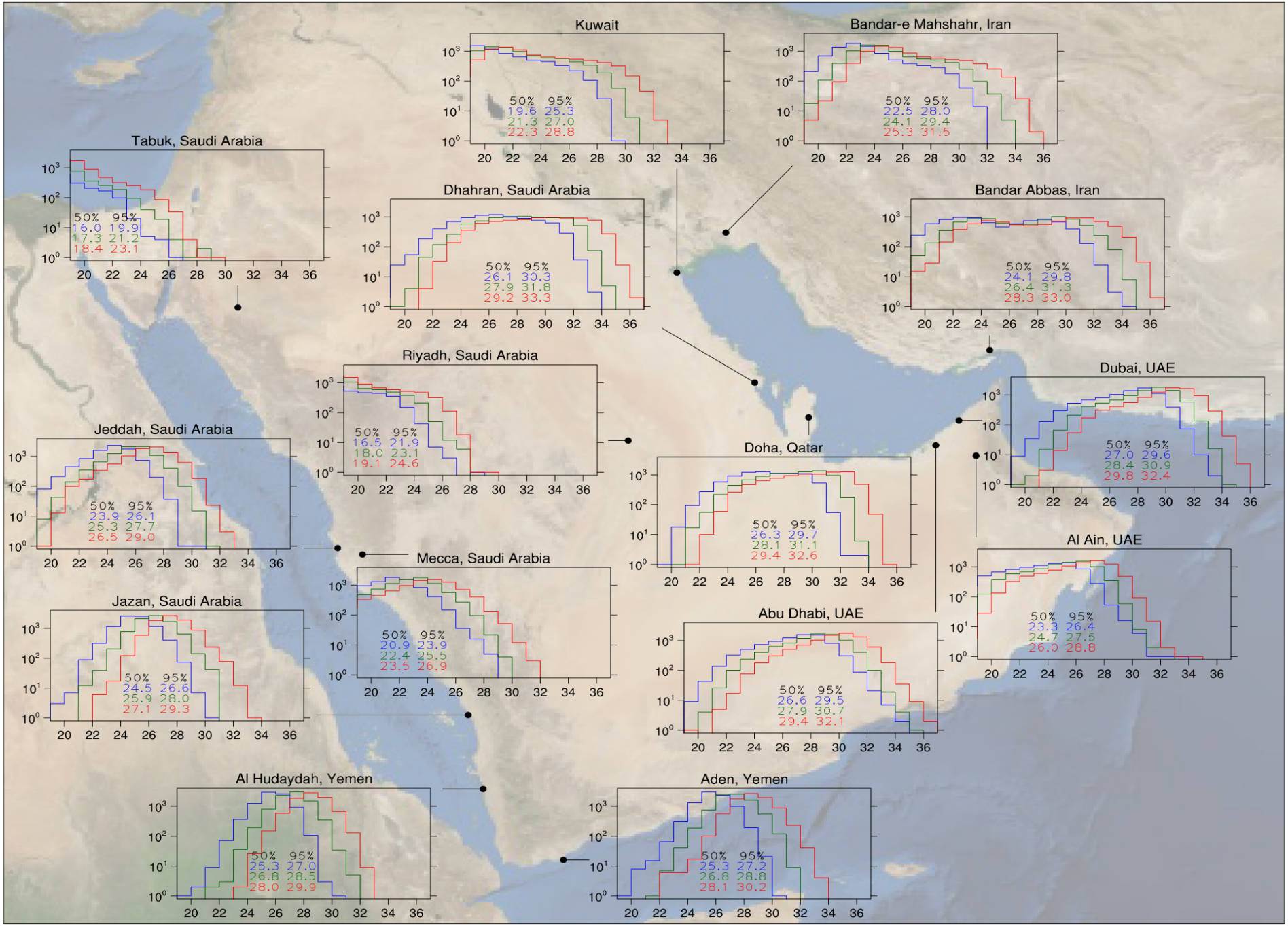

a) CCSM4
Historical
b) CCSM4
RCP4.5
c) CCSM4
RCP8.5
d) MPI-ESM
Historical
e) MPI-ESM
RCP4.5
f) MPI-ESM
RCP8.5
g) NorESM
Historical
h) NorESM
RCP4.5
i) NorESM
RCP8.5
25 26 27 28 29 30 31 32 33 34 35 36 37 38
°C


a) TW$_{max}$
CCSM4
DOM=1.4
LND=2.2
AP=2.3
b) TW$_{max}$
MPI-ESM
DOM=1.4
LND=1.9
AP=2.1
c) TW$_{max}$
NorESM
DOM=0.1
LND=0.7
AP=1.0
-8
-6
-4
-2
2
4
6
8
°C

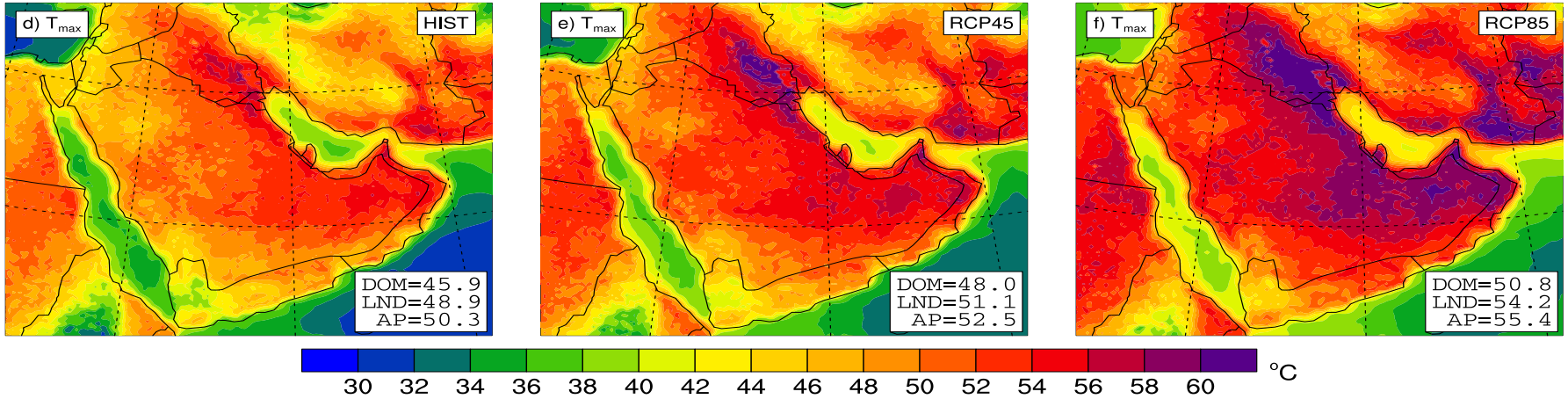


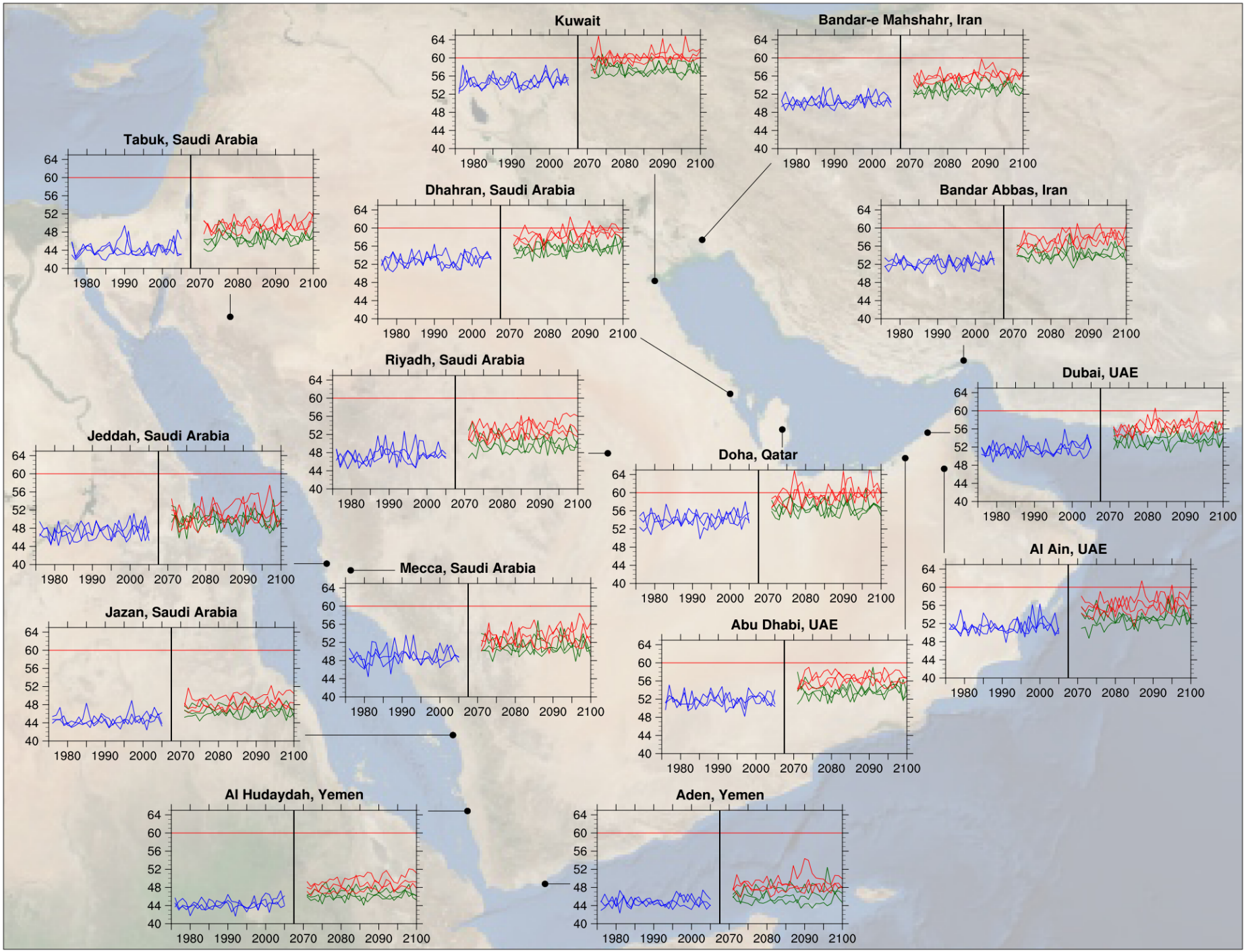
Annual maximum wet-bulb temperature, Tw_{max} under historical, RCP4.5, and RCP8.5 scenarios

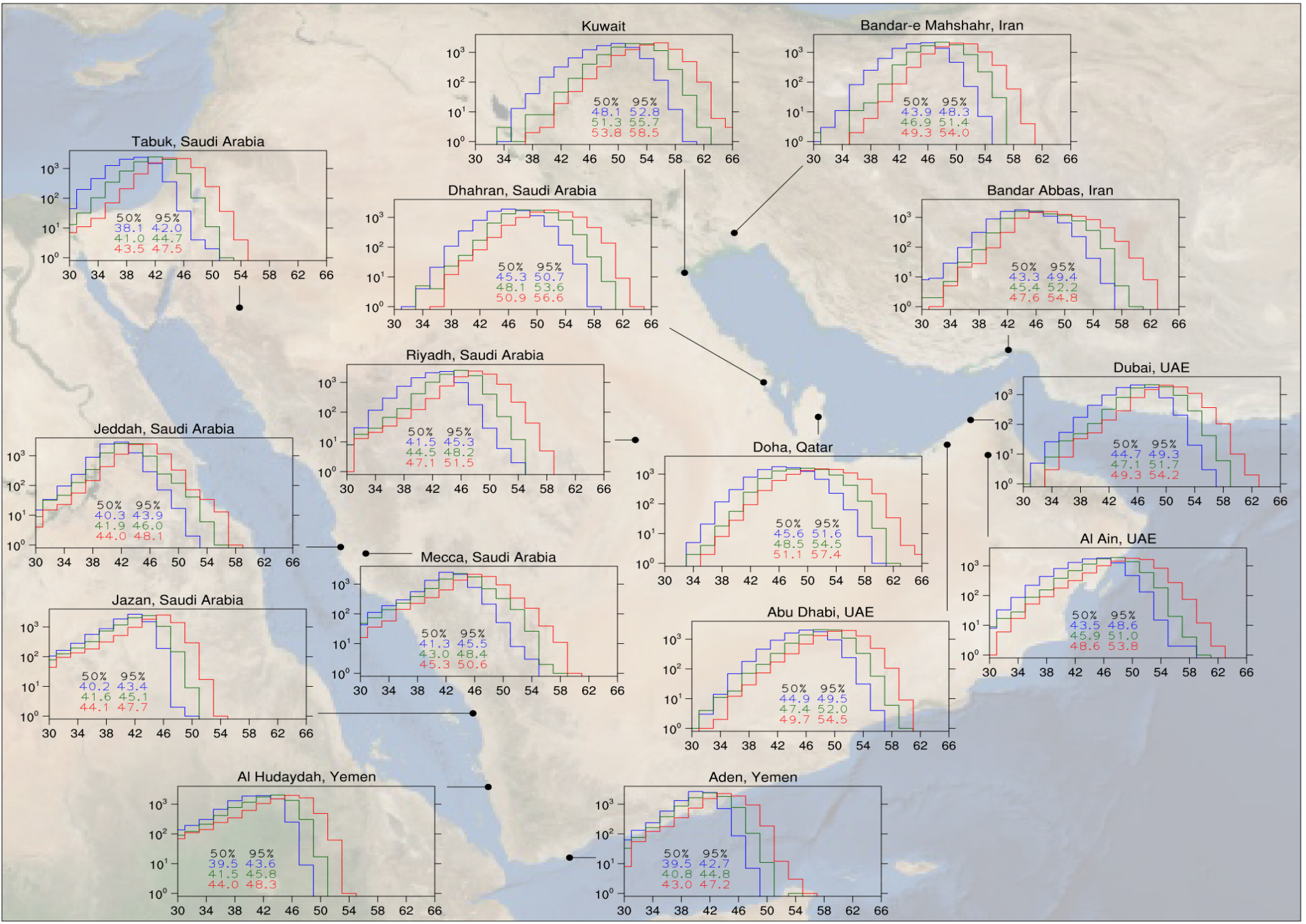

Kuwait
Bandar-e Mahshahr, Iran
Tabuk, Saudi Arabia
Dhahran, Saudi Arabia
Bandar Abbas, Iran
Riyadh, Saudi Arabia
Dubai, UAE
Jeddah, Saudi Arabia
Doha, Qatar
Mecca, Saudi Arabia
Al Ain, UAE
Jazan, Saudi Arabia
Abu Dhabi, UAE
Al Hudaydah, Yemen
Aden, Yemen
24 26 28 30 32 34 36
1980 1990 2000 2070 2080 2090 2100

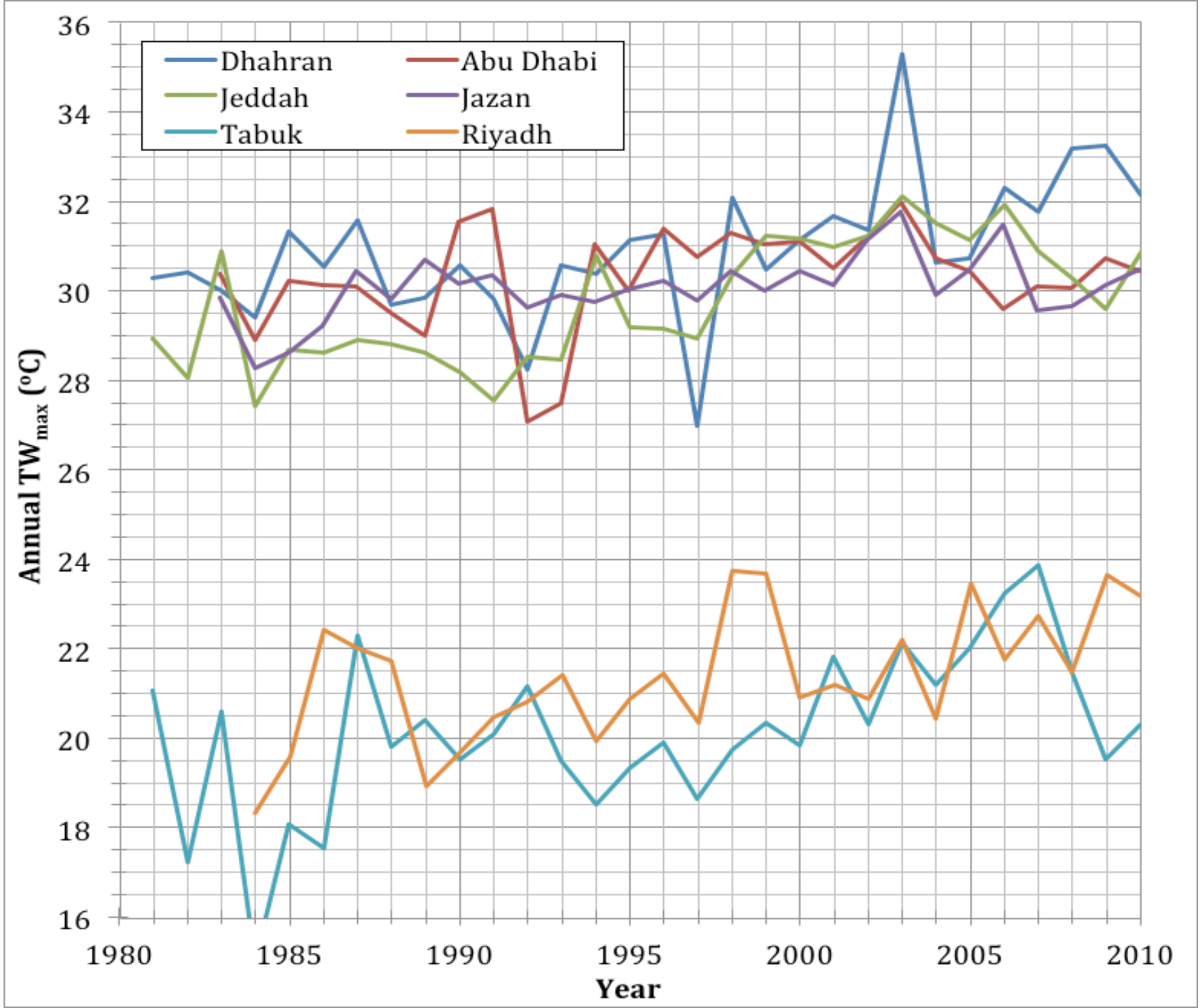

Kuwait
50% 95%
19.6 25.3
21.3 27.0
22.3 28.8
Bandar-e Mahshahr, Iran
50% 95%
22.5 28.0
24.1 29.4
25.3 31.5
Tabuk, Saudi Arabia
50% 95%
16.0 19.9
17.3 21.2
18.4 23.1
Dhahran, Saudi Arabia
50% 95%
26.1 30.3
27.9 31.8
29.2 33.3
Bandar Abbas, Iran
50% 95%
24.1 29.8
26.4 31.3
28.3 33.0
Riyadh, Saudi Arabia
50% 95%
16.5 21.9
18.0 23.1
19.1 24.6
Dubai, UAE
50% 95%
27.0 29.6
28.4 30.9
29.8 32.4
Jeddah, Saudi Arabia
50% 95%
23.9 26.1
25.3 27.7
26.5 29.0
Doha, Qatar
50% 95%
26.3 29.7
28.1 31.1
29.4 32.6
Mecca, Saudi Arabia
50% 95%
20.9 23.9
22.4 25.5
23.5 26.9
Al Ain, UAE
50% 95%
23.3 26.4
24.7 27.5
26.0 28.8
Jazan, Saudi Arabia
50% 95%
24.5 26.6
25.9 28.0
27.1 29.3
Abu Dhabi, UAE
50% 95%
26.6 29.5
27.9 30.7
29.4 32.1
Al Hudaydah, Yemen
50% 95%
25.3 27.0
26.8 28.5
28.0 29.9
Aden, Yemen
50% 95%
25.3 27.2
26.8 28.8
28.1 30.2

Annual maximum dry-bulb temperature, T_{max} under historical, RCP4.5, and RCP8.5 scenarios




Kuwait
Bandar-e Mahshahr, Iran
Tabuk, Saudi Arabia
Dhahran, Saudi Arabia
Bandar Abbas, Iran
Riyadh, Saudi Arabia
Dubai, UAE
Jeddah, Saudi Arabia
Doha, Qatar
Mecca, Saudi Arabia
Al Ain, UAE
Jazan, Saudi Arabia
Abu Dhabi, UAE
Al Hudaydah, Yemen
Aden, Yemen
64
60
56
52
48
44
40
1980
1990
2000
2070
2080
2090
2100


Kuwait
50% 95%
48.1 52.8
51.3 55.7
53.8 58.5
Bandar-e Mahshahr, Iran
50% 95%
43.9 48.3
46.9 51.4
49.3 54.0
Tabuk, Saudi Arabia
50% 95%
38.1 42.0
41.0 44.7
43.5 47.5
Dhahran, Saudi Arabia
50% 95%
45.3 50.7
48.1 53.6
50.9 56.6
Bandar Abbas, Iran
50% 95%
43.3 49.4
45.4 52.2
47.6 54.8
Riyadh, Saudi Arabia
50% 95%
41.5 45.3
44.5 48.2
47.1 51.5
Dubai, UAE
50% 95%
44.7 49.3
47.1 51.7
49.3 54.2
Jeddah, Saudi Arabia
50% 95%
40.3 43.9
41.9 46.0
44.0 48.1
Doha, Qatar
50% 95%
45.6 51.6
48.5 54.5
51.1 57.4
Al Ain, UAE
50% 95%
43.5 48.6
45.9 51.0
48.6 53.8
Mecca, Saudi Arabia
50% 95%
41.3 45.5
43.0 48.4
45.3 50.6
Jazan, Saudi Arabia
50% 95%
40.2 43.4
41.6 45.1
44.1 47.7
Abu Dhabi, UAE
50% 95%
44.9 49.5
47.4 52.0
49.7 54.5
Al Hudaydah, Yemen
50% 95%
39.5 43.6
41.5 45.8
44.0 48.3
Aden, Yemen
50% 95%
39.5 42.7
40.8 44.8
43.0 47.2


Dhahran
Abu Dhabi
Jeddah
Jazan
Tabuk
Riyadh
Annual TW$_{max}$ (°C)
36
34
32
30
28
26
24
22
20
18
16
1980
1985
1990
1995
2000
2005
2010
Year

nature climate change

LETTERS

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Future temperature in southwest Asia projected to exceed a threshold for human adaptability

Jeremy S. Pal[1,2] and Elfatih A. B. Eltahir[2]*

Conclusions

- Southwest Asia is the main producer and consumer (per capita) of fossil fuel, and likely to be a hotspot for impacts of climate change.
- In terms of combined temperature and humidity measures, the Gulf region summer may be the hottest in the world, for current and future climates.
- Under business as usual scenario, this region may reach the 6-hour, 35 C, Tw threshold well within the 21st century.
- Reasonable mitigation (RCP 4.5) reduces the intensity of future heat waves significantly.
- Countries of South West Asia can gain significantly from supporting serious mitigation efforts.
- We are currently investigating other regions.

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