

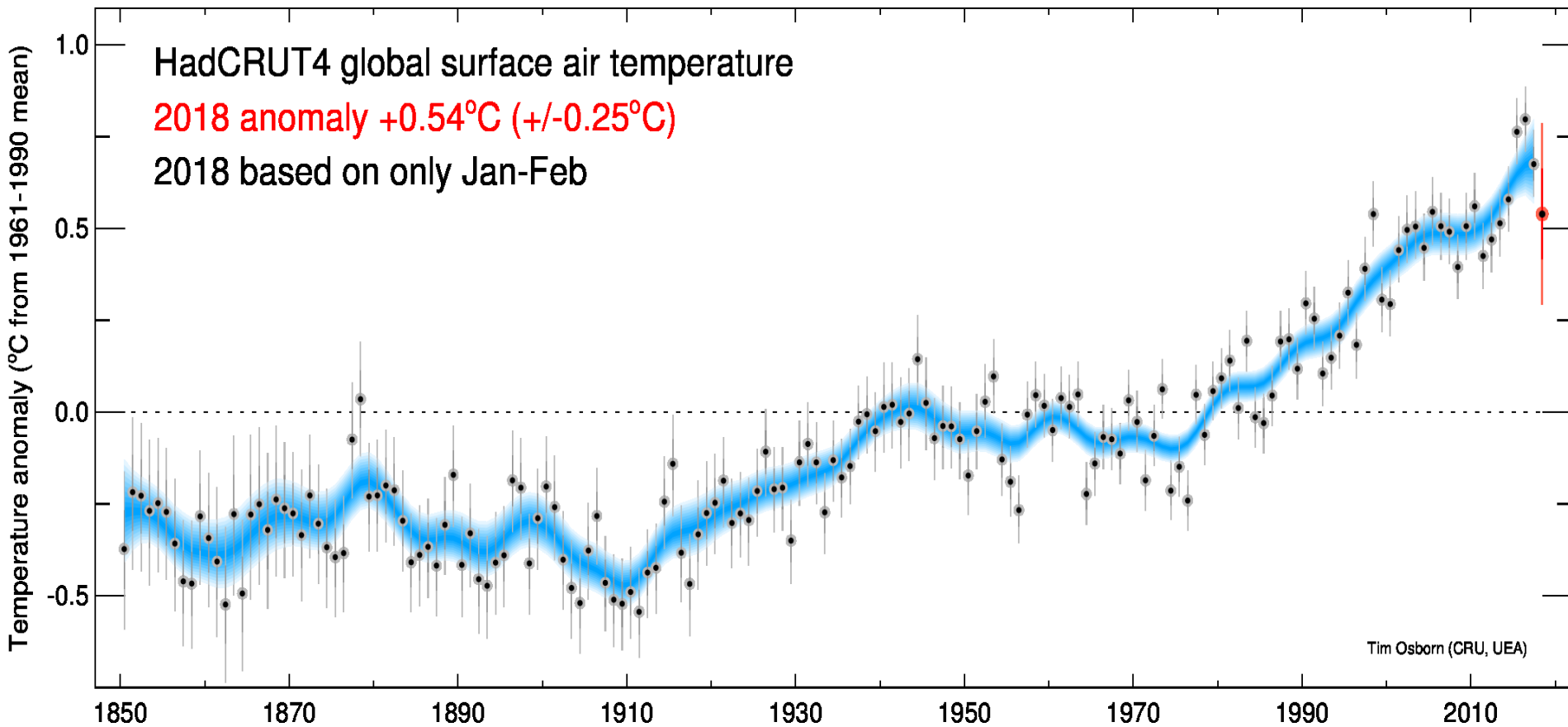
Differential 20th and 21st century warming around the Mediterranean and the MENA region

P. Hadjinicolaou, G. Zittis, and J. Lelieveld

*Atmosphere and Climate Division
Energy, Environment & Water Research Center*

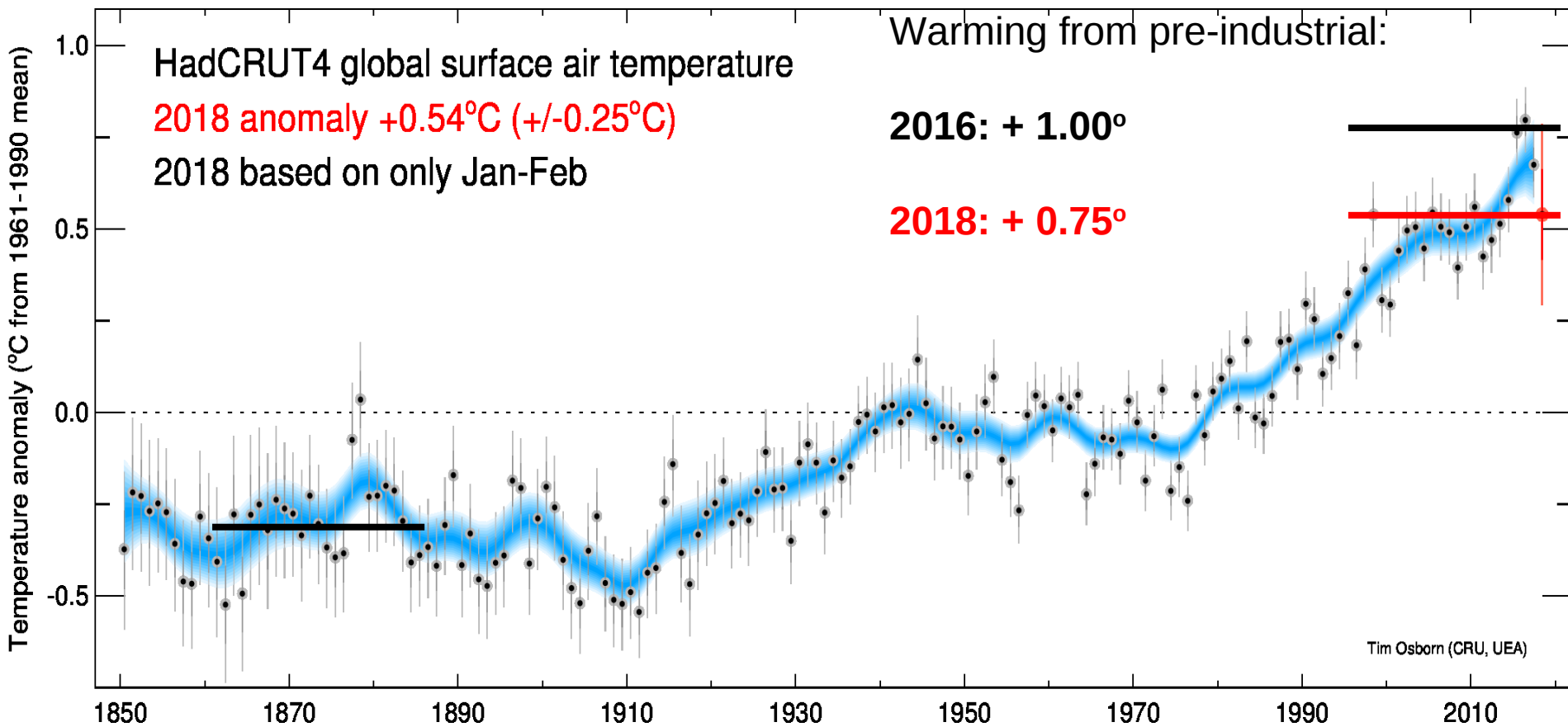
Scientific Workshop
Mediterranean & Middle East Air Pollution in a Changing Climate

Global temperature change up to 2018



https://crudata.uea.ac.uk/~timo/diag/temptps_decadesmooth_global.png

Global warming from pre-industrial

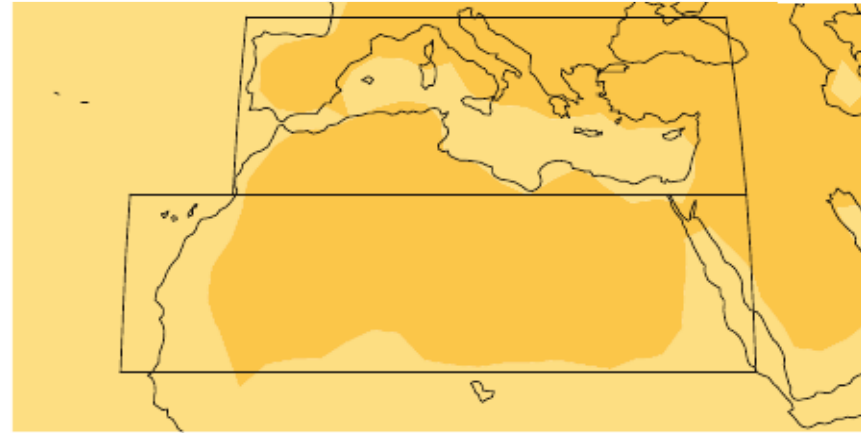


https://crudata.uea.ac.uk/~timo/diag/temptps_decadesmooth_global.png

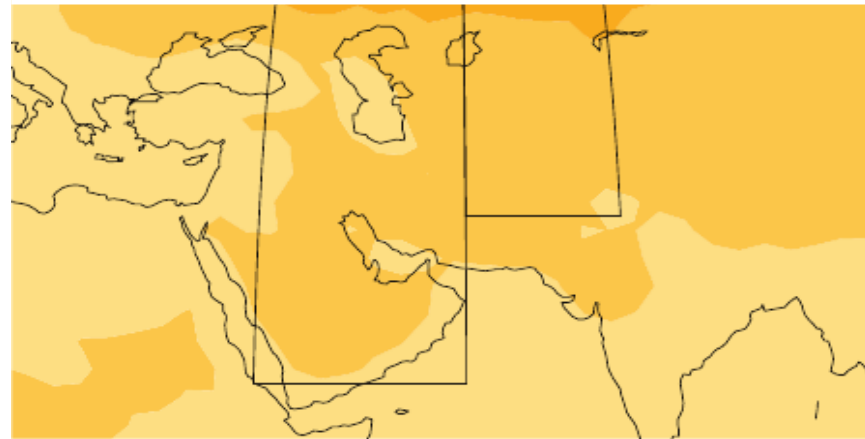
IPCC AR5 projections: regional detail?

- MENA is not covered completely
- Part of other continents' subsets
- Horizontal resolution: 1-2 degrees (100-200 km)

“South-Europe/Mediterranean”

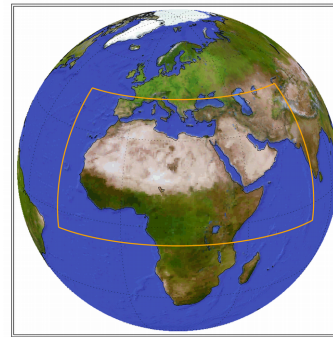
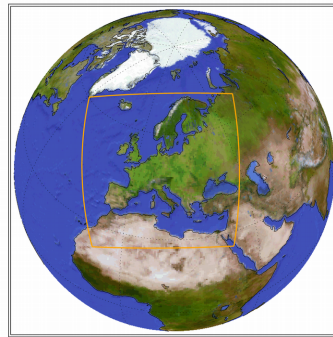
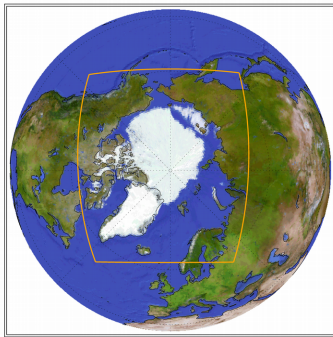


“West Asia”

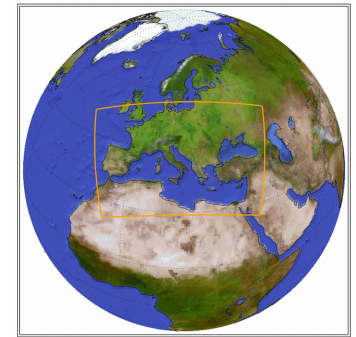


van Oldenborgh et al., IPCC, 2013: Annex I: Atlas of Global and Regional Climate Projections in: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

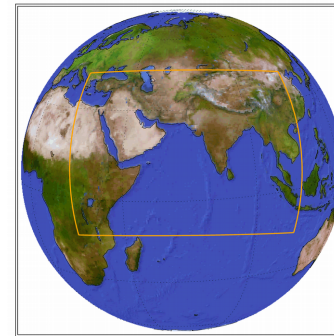
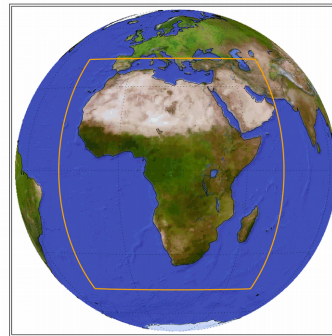
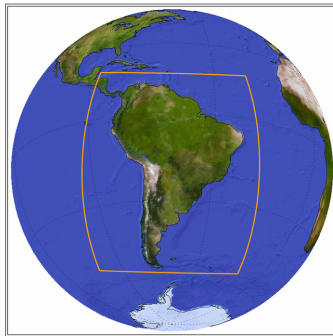
Downscaling IPCC projections: CORDEX



MENA-CORDEX



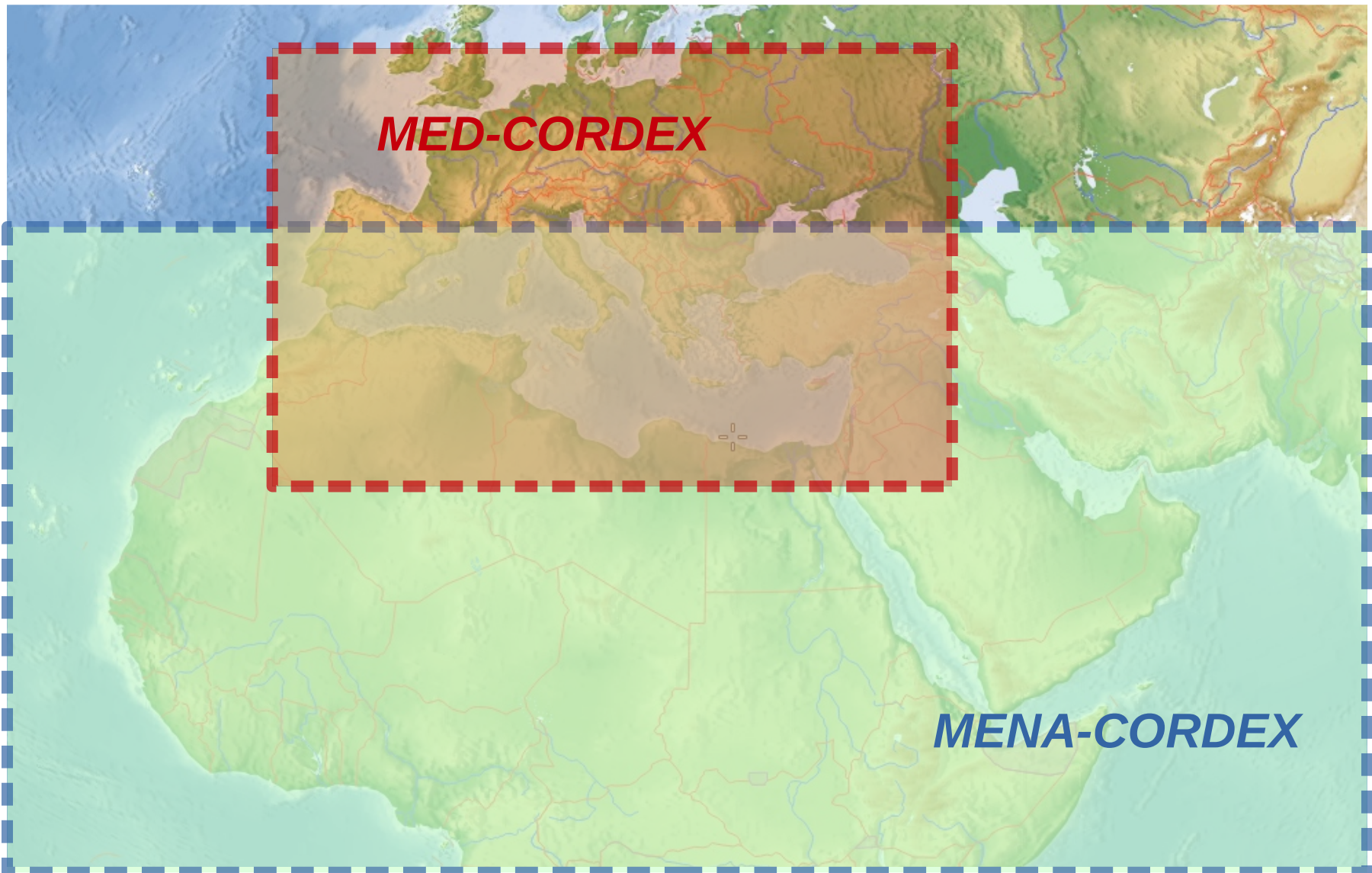
MED-CORDEX



CORDEX, a World Climate Research Program (WCRP) project, is providing global coordination of Regional Climate Downscaling for improved regional climate change adaptation and impact assessment

www.cordex.org

Mediterranean and MENA CORDEX domains



WRF downscaling: set-up

Model Version: WRF v3.6.1

Domain: MENA-CORDEX

Horizontal resolution: 0.44° (50km)

Vertical resolution: 30 levels

Model top: 50 hPa

PBL: Yonsei Univ., Radiation: LW RRTMG; SW CAM3

Cumulus Parameterization: Kain-Fritsch

Land Surface Model: NOAH, Microphysics: WSM6

Zittis, G., Hadjinicolaou, P., and Lelieveld, J. (2014) Comparison of WRF model physics parameterizations over the MENA-CORDEX domain. Am. J. Clim. Change, 03(05):490-511.

Zittis G., Hadjinicolaou P., (2017) The effect of radiation parameterization schemes on surface temperature in regional climate simulations over the MENA-CORDEX domain, Int. J. Climatol., Early View, doi: 10.1002/joc.4959.

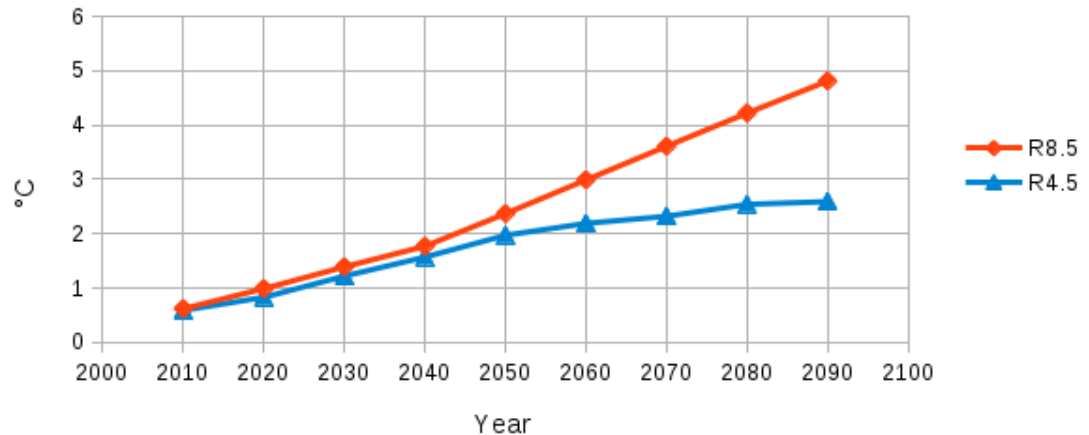
WRF downscaling: runs

“Father model”: CCSM4

NCAR’s Community Earth System Model (CESM1)

- ✓ Historical 1951-2005
- ✓ RCP4.5 2006-2100
- ✓ RCP8.5 2006-2100

CMIP5 (RCP-driven) global mean surface temperature change
relative to 1986–2005



Mean state bias-corrected with ECMWF ERA-Interim (1981-2005)

(Synoptic and climate scale variability of CESM1 maintained)

Bruyère, C. L., A. J. Monaghan, D. F. Steinhoff, and D. Yates, 2015: Bias-Corrected CMIP5 CESM Data in WRF/MPAS Intermediate File Format. TN-515+STR, NCAR, 27 pp. (DOI: 10.5065/D6445JJ7).

WRF downscaling: other data

Variable: near-surface Air Temperature

“ERAINT”: MENA subset (and sub-regions)

Monthly means of daily means

<http://apps.ecmwf.int/datasets/data/interim-full-moda>

“CIMP5”: Multi-model mean of historical + RCP4.5/RCP8.5

Global average

Monthly means

“CCSM4”: historical + RCP4.5/RCP8.5

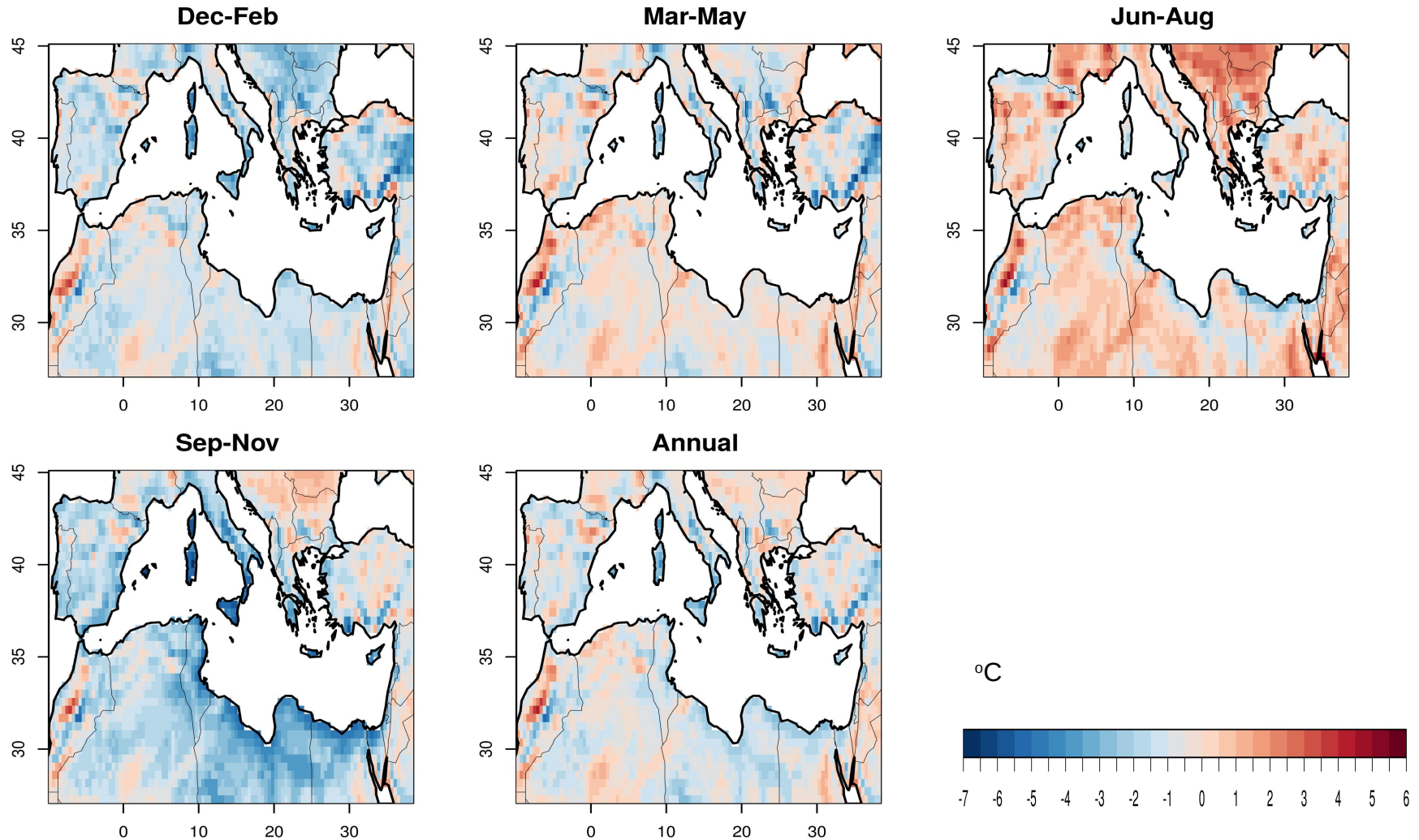
Global average; MENA subset (and Med. sub-regions)

Monthly means

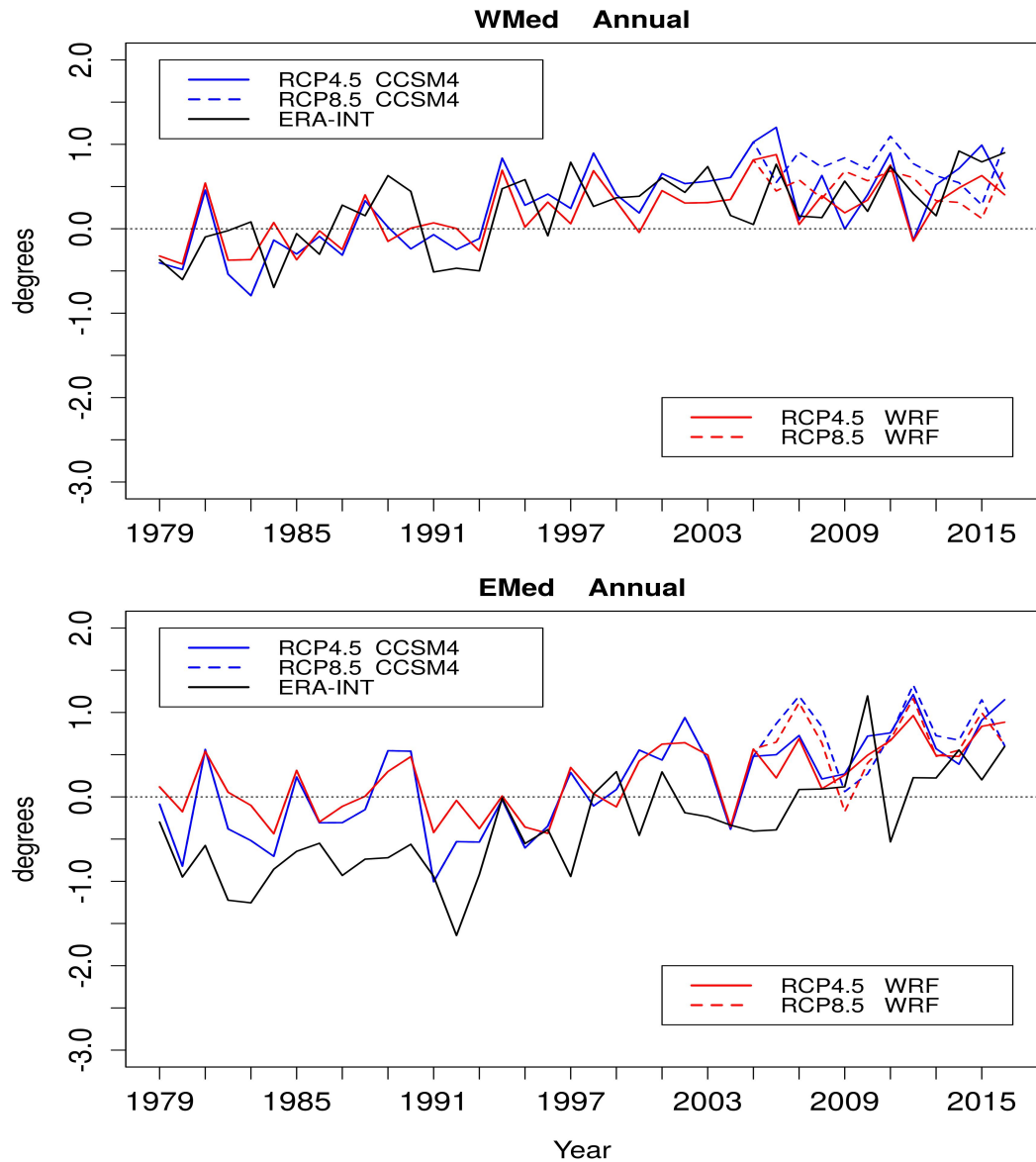
<https://climexp.knmi.nl/>

Bias WRF RCP4.5 vs ERAINT

1979-2016

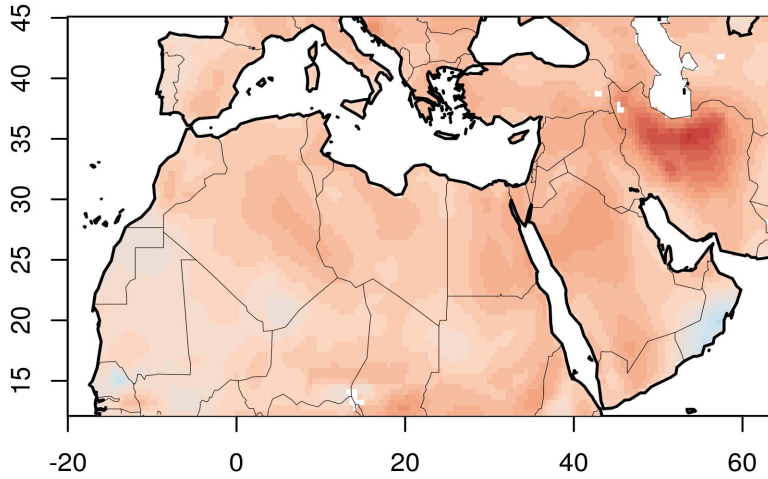


ERA-Int period: anomalies from 1979-1999

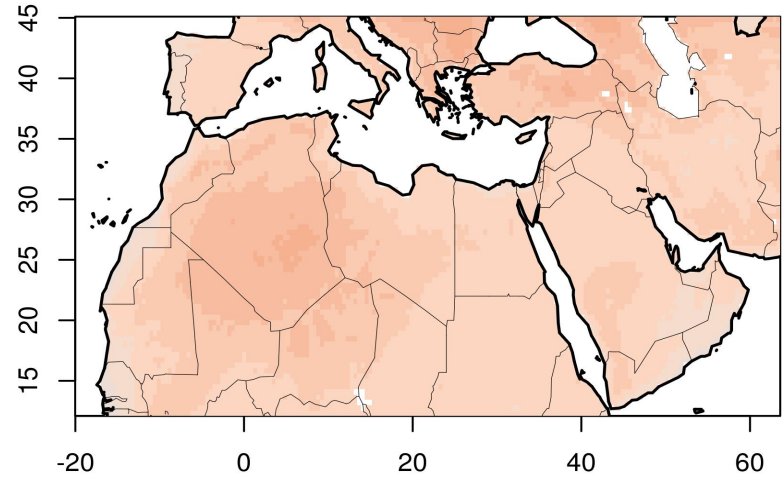


Trend 1979-2016 Annual

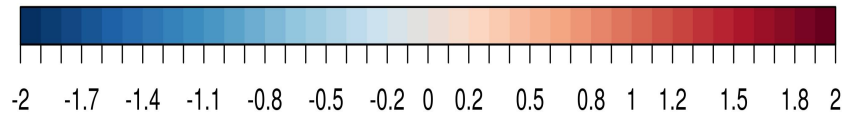
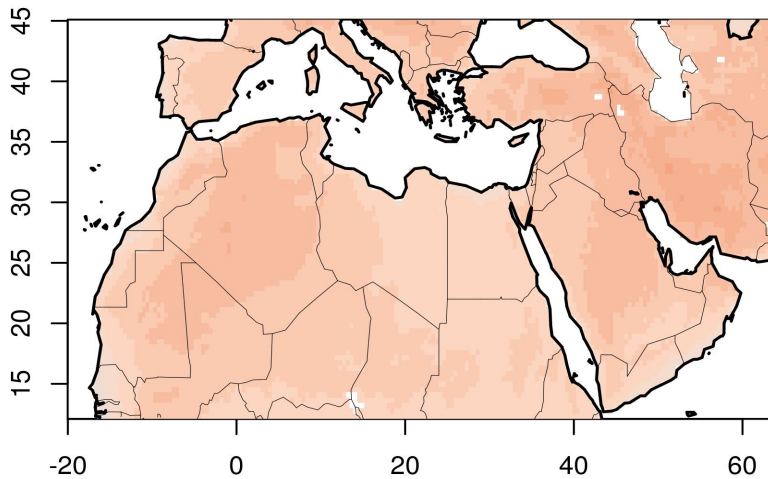
ERAINT



WRF RCP4.5



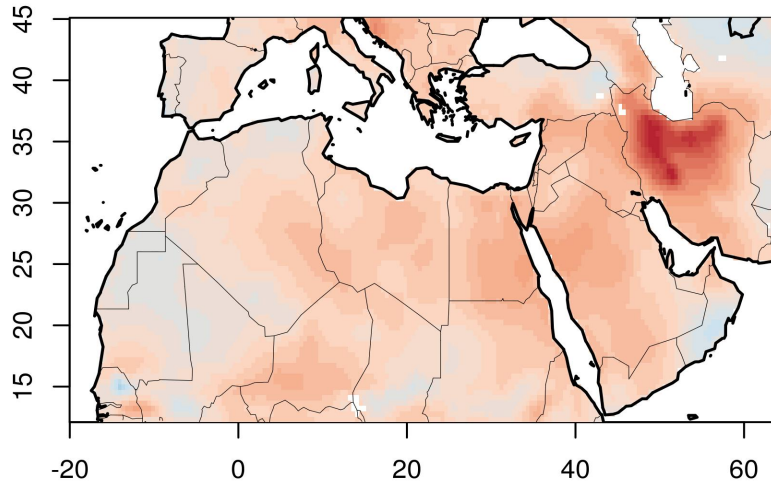
WRF RCP8.5



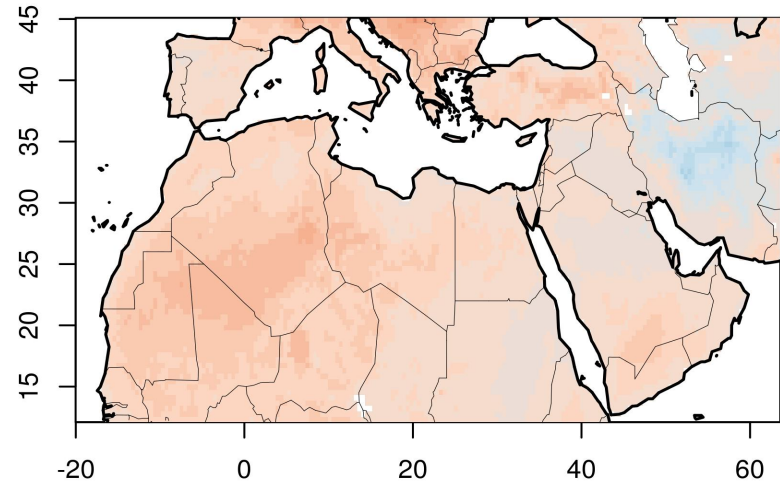
°C/decade

Trend 1979-2016 Dec-Feb

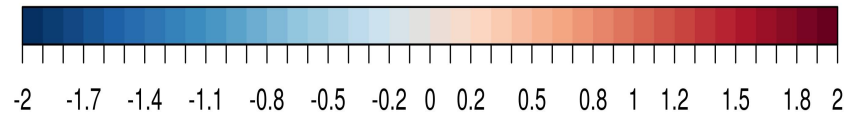
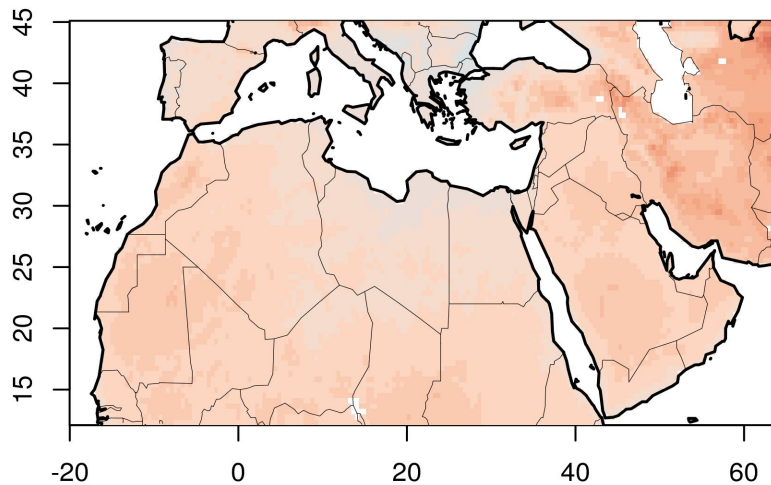
ERAINT



WRF RCP4.5



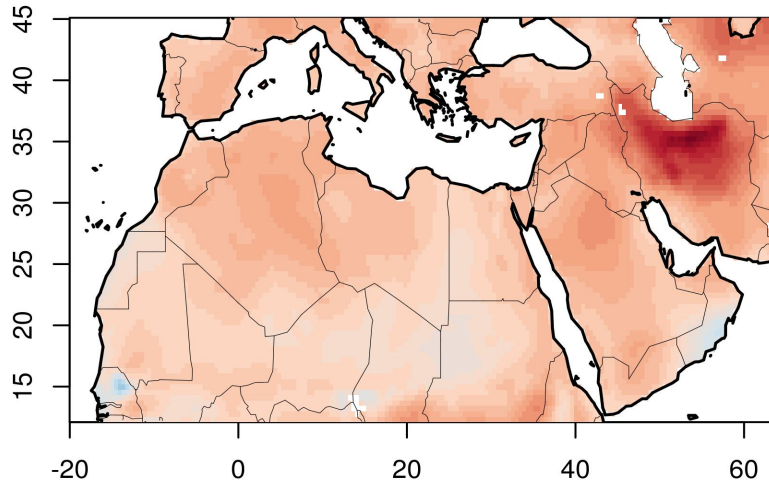
WRF RCP8.5



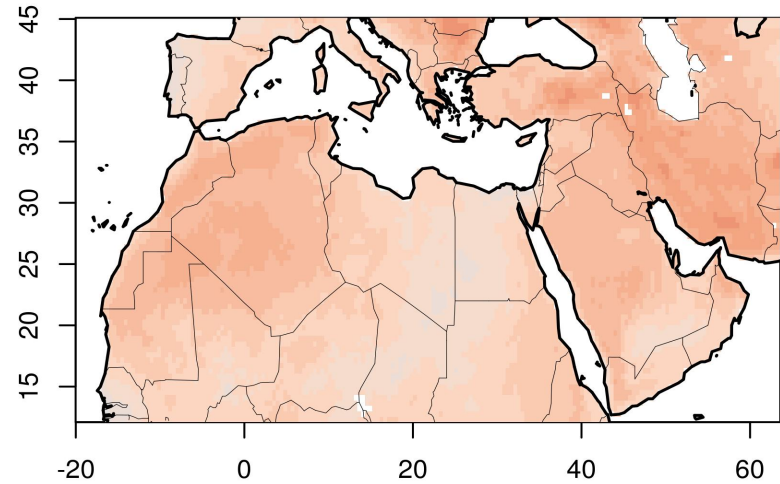
°C/decade

Trend 1979-2016 Mar-May

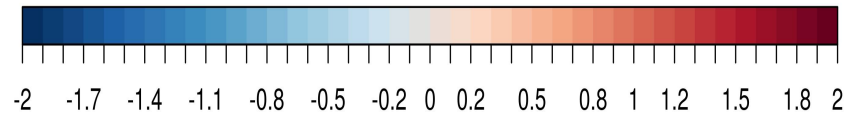
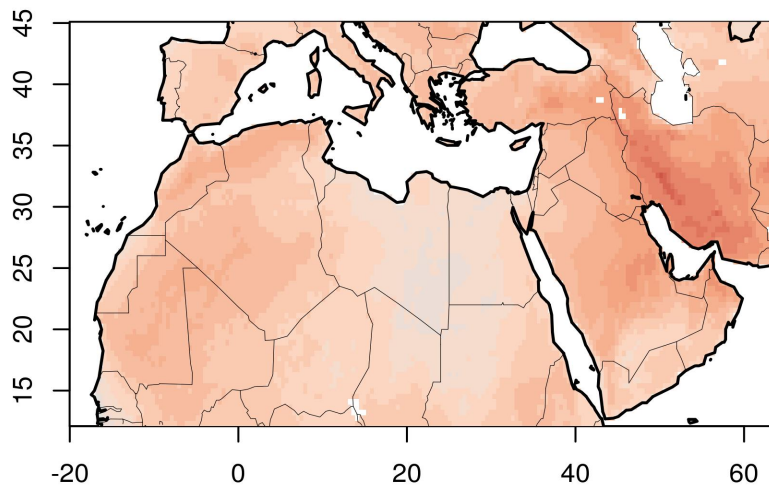
ERAINT



WRF RCP4.5



WRF RCP8.5

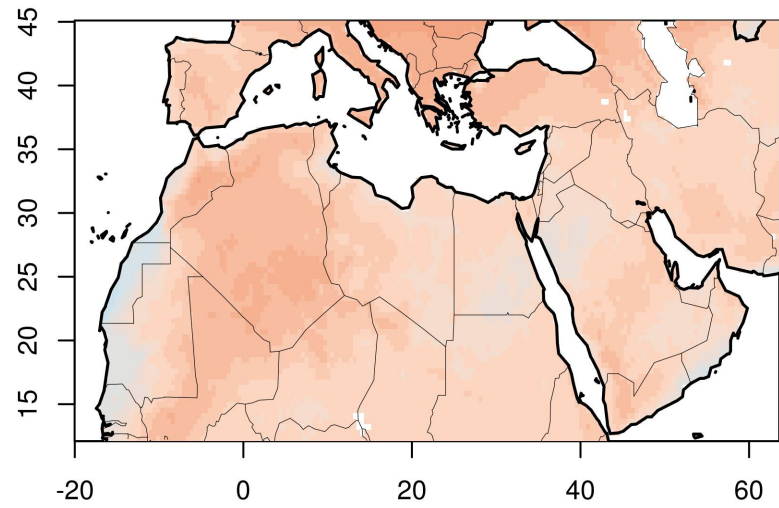
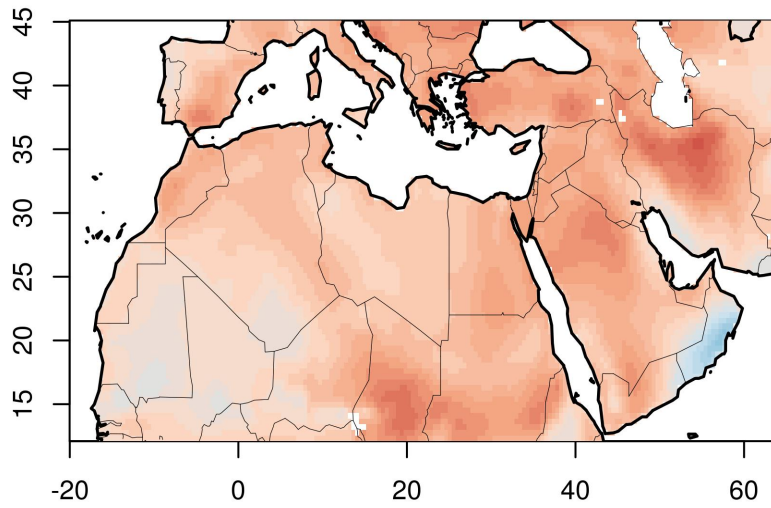


°C/decade

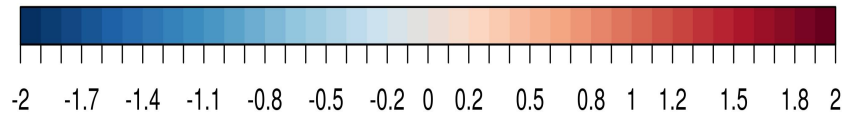
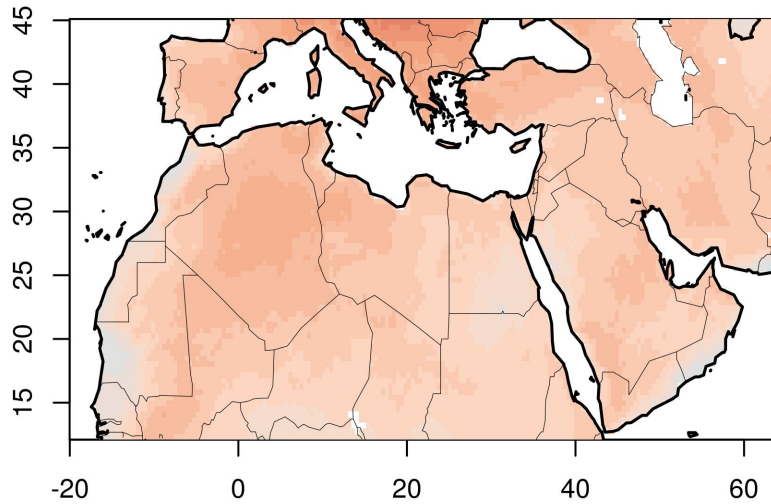
Trend 1979-2016 Jun-Aug

ERAINT

WRF RCP4.5

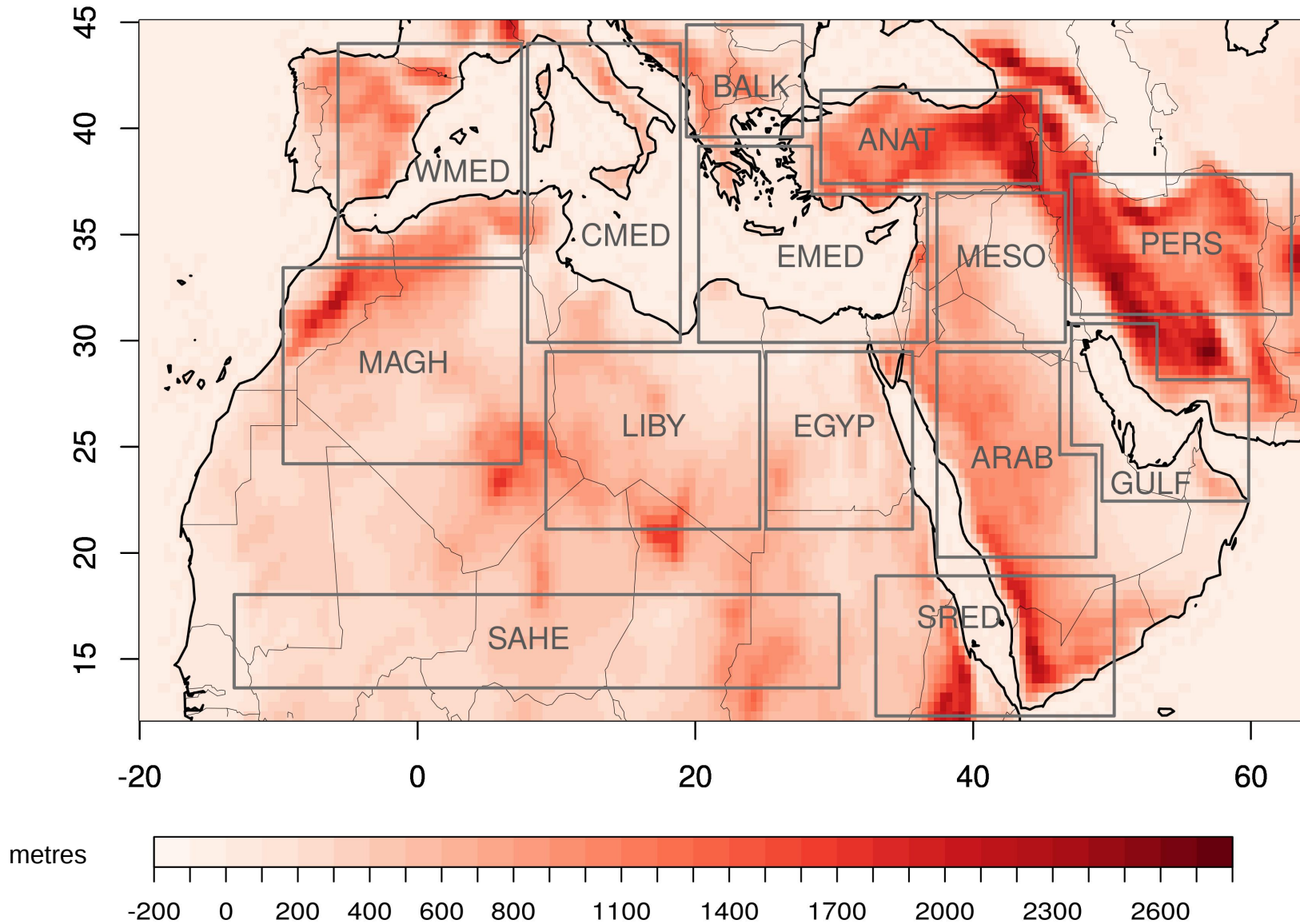


WRF RCP8.5



°C/decade

Mediterranean and MENA sub-regions



Trend 1979-2016 Sub-regions

Units:	ANN			DJF			MAM			JJA		
°C /decade	ERAINT	RCP4.5	RCP8.5	ERAINT	RCP4.5	RCP8.5	ERAINT	RCP4.5	RCP8.5	ERAINT	RCP4.5	RCP8.5
WMED	0.32	0.28	0.34	0.11	0.22	0.18	0.48	0.34	0.39	0.47	0.35	0.42
CMED	0.38	0.32	0.33	0.26	0.27	0.1	0.47	0.31	0.28	0.42	0.35	0.51
EMED	0.42	0.29	0.31	0.33	0.17	0.14	0.43	0.3	0.33	0.53	0.29	0.38
BALK	0.45	0.45	0.39	0.34	0.39	0.04	0.45	0.49	0.42	0.66	0.56	0.65
ANAT	0.42	0.4	0.42	0.2	0.25	0.27	0.47	0.48	0.52	0.66	0.39	0.43
MESO	0.52	0.28	0.41	0.48	0.09	0.29	0.67	0.45	0.55	0.6	0.23	0.33
PERS	0.76	0.27	0.49	0.8	-0.12	0.47	1.08	0.56	0.69	0.67	0.24	0.37
GULF	0.37	0.27	0.45	0.38	0.06	0.37	0.5	0.5	0.73	0.32	0.28	0.35
ARAB	0.49	0.27	0.4	0.47	0.11	0.31	0.53	0.44	0.54	0.59	0.24	0.33
SRED	0.43	0.25	0.28	0.31	0.17	0.24	0.44	0.32	0.34	0.49	0.28	0.3
EGYP	0.45	0.27	0.27	0.46	0.17	0.18	0.3	0.21	0.18	0.53	0.16	0.22
LIBY	0.37	0.36	0.3	0.36	0.27	0.17	0.36	0.25	0.19	0.35	0.29	0.36
MAGH	0.34	0.41	0.41	0.19	0.32	0.26	0.48	0.49	0.43	0.35	0.42	0.44
SAHE	0.27	0.3	0.32	0.23	0.24	0.29	0.24	0.23	0.3	0.37	0.27	0.28

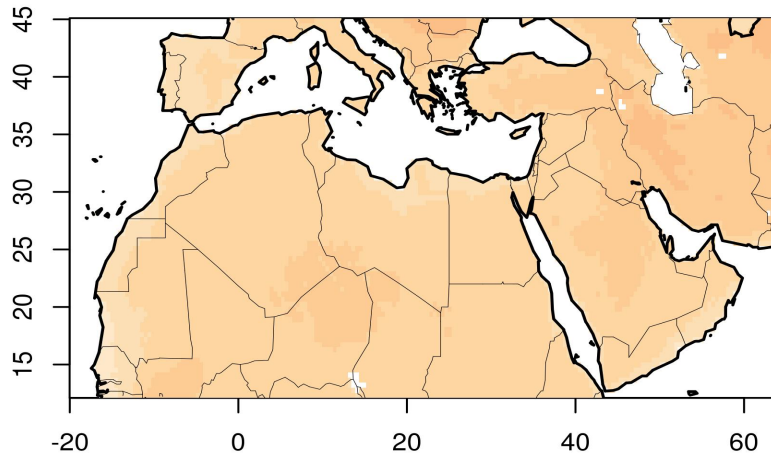
Summary for 1979-2016 comparison

WRF historical run vs ERA-Int:

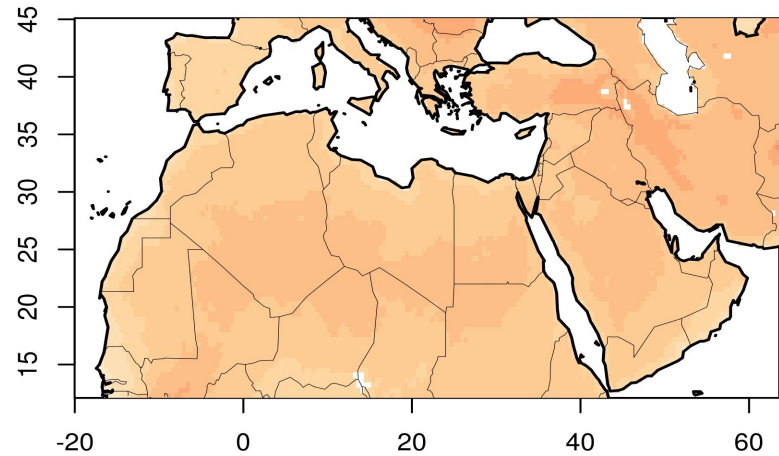
- within $\pm 2^\circ$ in annual climatology (with larger differences in seasons)
- follows the 'observed' evolution (1990's warming, post-2000 'hiatus')
- similar larger inter-annual variance for EMed
- captures features of sub-regional decadal trends (but underestimates magnitude)
- Iran: distinct warming in ERA-Int (and in WRF RCP8.5; signal of high-emissions world?)

Change from 1991-2015 WRF Annual

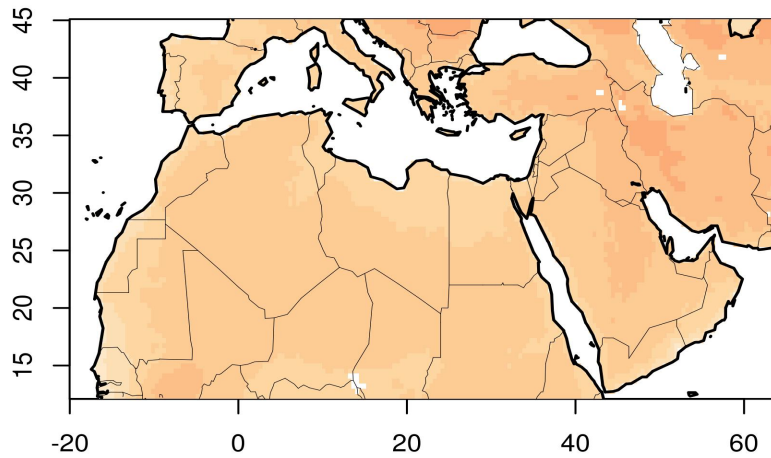
RCP4.5 MID



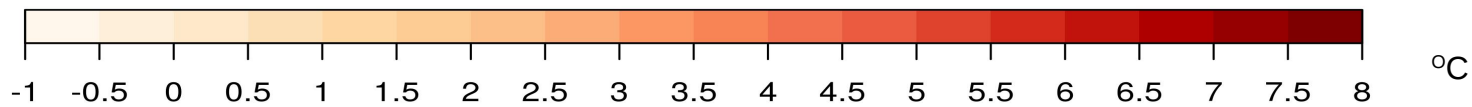
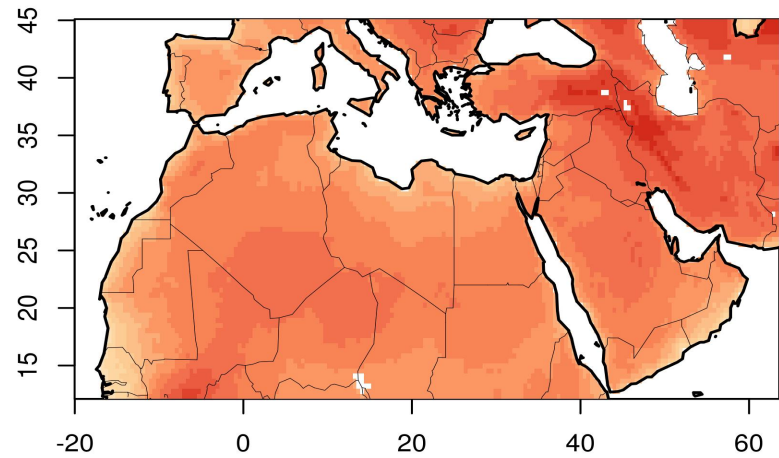
RCP8.5 MID



RCP4.5 END

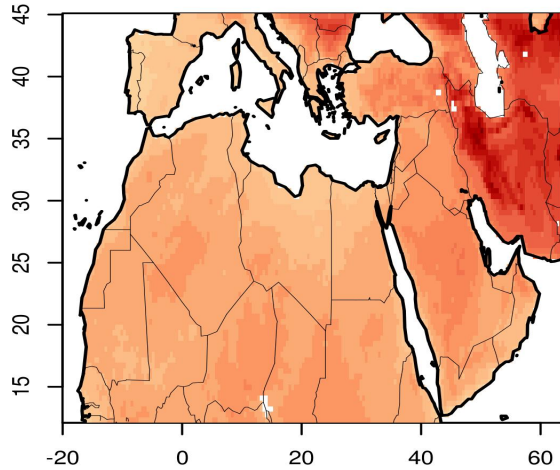


RCP8.5 END

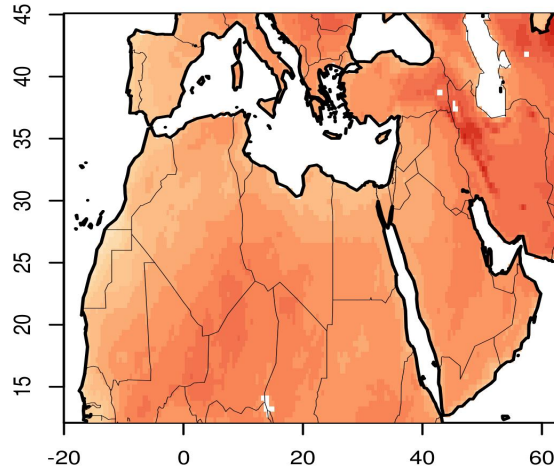


Change from 1991-2015 RCP4.5 2041-65

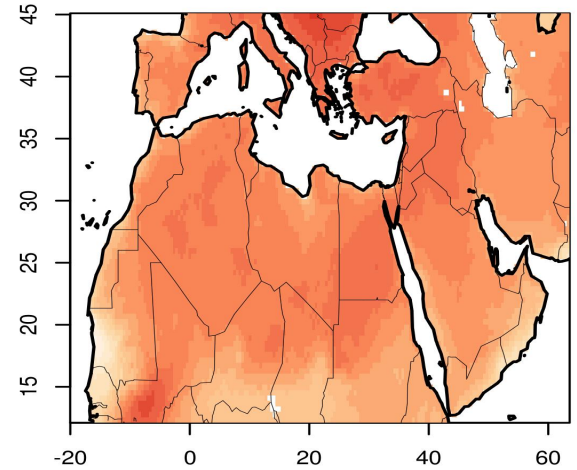
Dec-Feb



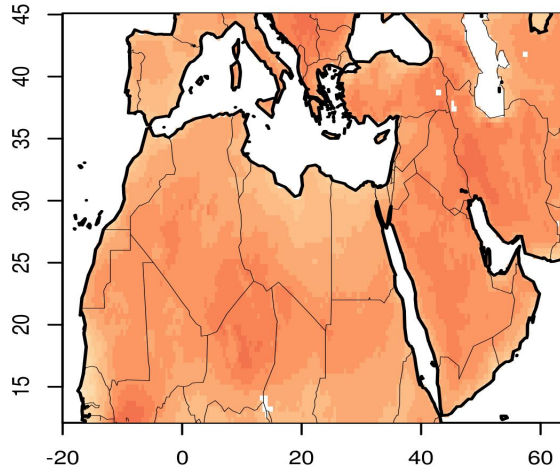
Mar-May



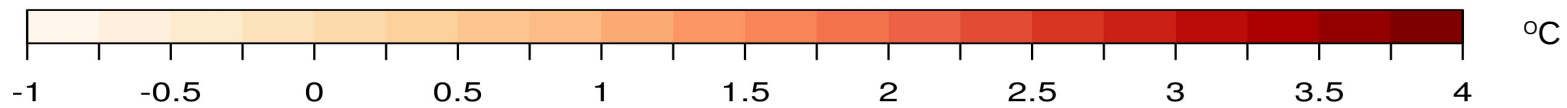
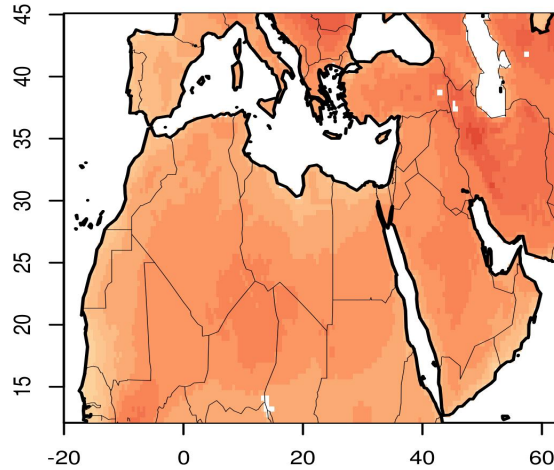
Jun-Aug



Sep-Nov



Annual



Trend 2001-2100

Sub-regions

Units:	ANN		DJF		MAM		JJA		SON	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
°C/decade										
GLOBAL	0.245	0.559	0.261	0.593	0.236	0.531	0.233	0.539	0.249	0.571
MENA	0.174	0.441	0.163	0.414	0.169	0.451	0.203	0.465	0.160	0.433
WMED	0.154	0.398	0.114	0.249	0.152	0.401	0.224	0.536	0.126	0.405
CMED	0.143	0.367	0.081	0.248	0.135	0.358	0.227	0.490	0.130	0.371
EMED	0.160	0.392	0.122	0.316	0.158	0.393	0.215	0.485	0.144	0.373
BALK	0.218	0.501	0.178	0.434	0.239	0.526	0.265	0.605	0.190	0.437
ANAT	0.206	0.512	0.181	0.475	0.219	0.542	0.228	0.555	0.196	0.476
MESO	0.210	0.506	0.192	0.497	0.200	0.548	0.236	0.504	0.213	0.473
PERS	0.233	0.542	0.317	0.616	0.203	0.594	0.234	0.496	0.176	0.460
GULF	0.205	0.485	0.235	0.522	0.199	0.557	0.210	0.434	0.176	0.427
ARAB	0.199	0.479	0.213	0.486	0.187	0.509	0.213	0.464	0.181	0.455
SRED	0.163	0.403	0.157	0.365	0.187	0.473	0.160	0.390	0.149	0.383
EGYP	0.151	0.417	0.118	0.348	0.135	0.379	0.225	0.517	0.126	0.423
MAGH	0.165	0.451	0.134	0.345	0.135	0.433	0.232	0.536	0.158	0.491

Summary for overall 21st projections

Both emission scenarios and timrame:

- RCP8.5 end-century strongest warming, in mid-century RCP4.5 and RCP8.6 effects comparable (similar magnitude and spatial pattern)

Mid-century RCP4.5:

- MENA wide 2° warming in summer
- Winter and spring “hot-spot” over Iran
- North-Eastern domain warming faster than global average

Definition of a '1.5°C world'

A '1.5°C world' is defined as one in which temperatures averaged over a multi-decadal timescale are expected to be **1.5°C above the pre-industrial** reference period.

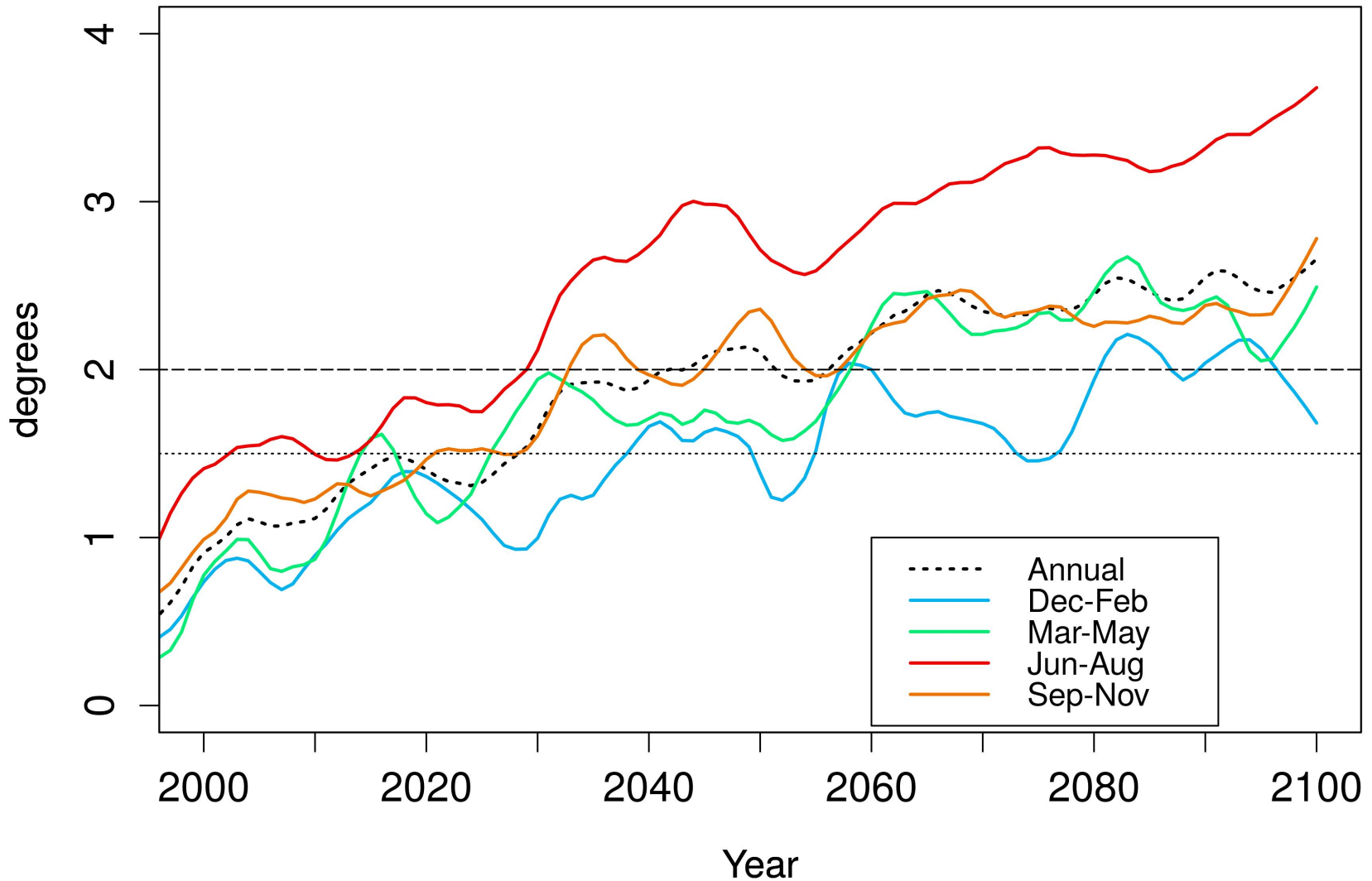
'temperatures': global mean near-surface air temperature

'multi-decadal' here: 25 years

'pre-industrial period' here: 1861-1885

Towards a +1.5° Med: seasons

RCP4.5 AMed WRF

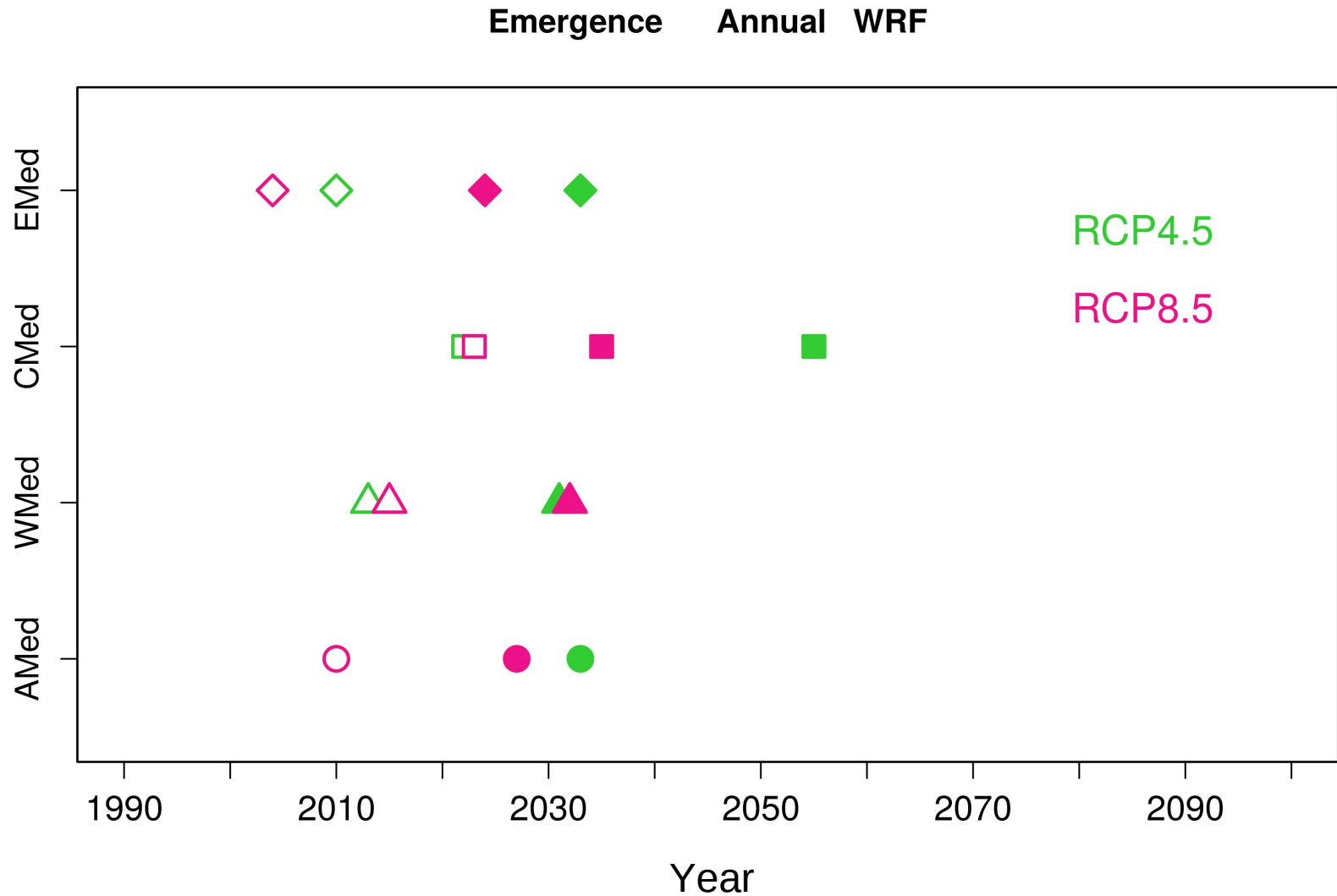


Occurrence of +1.5°: definitions

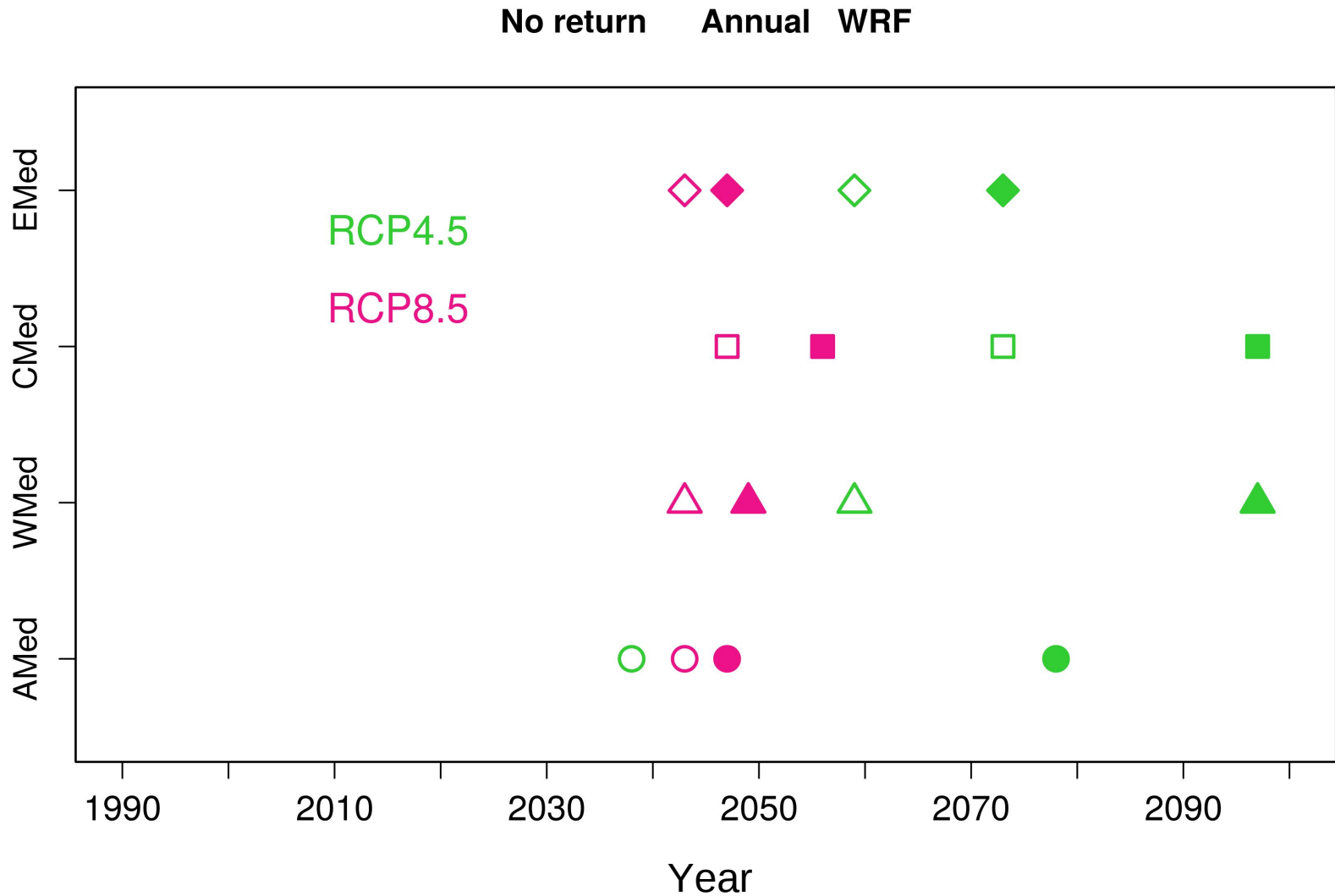
'Emergence' year: the first year of the 25-year period in the timeseries with average warming $> 1.5^\circ$

'No return' year: the first year in the timeseries with all subsequent years warmer than 1.5°

Occurrence of +1.5°/2°: emergence



Occurrence of $+1.5^{\circ}/2^{\circ}$: no return



Summary for 1.5° warming

- Warming evolves faster in summer (and spring) and breaking the 1.5° mark, earlier in the century than the other seasons
- Milestone properties of 1.5°-2° warming differ among MENA (Mediterranean) sub-regions

Further work

- Complete for all sub-regions warming properties
- Explore more the RCM added value vs GCM
- Align 1.5° warming analysis with emerging IPCC knowledge
- Look at additional RCMs

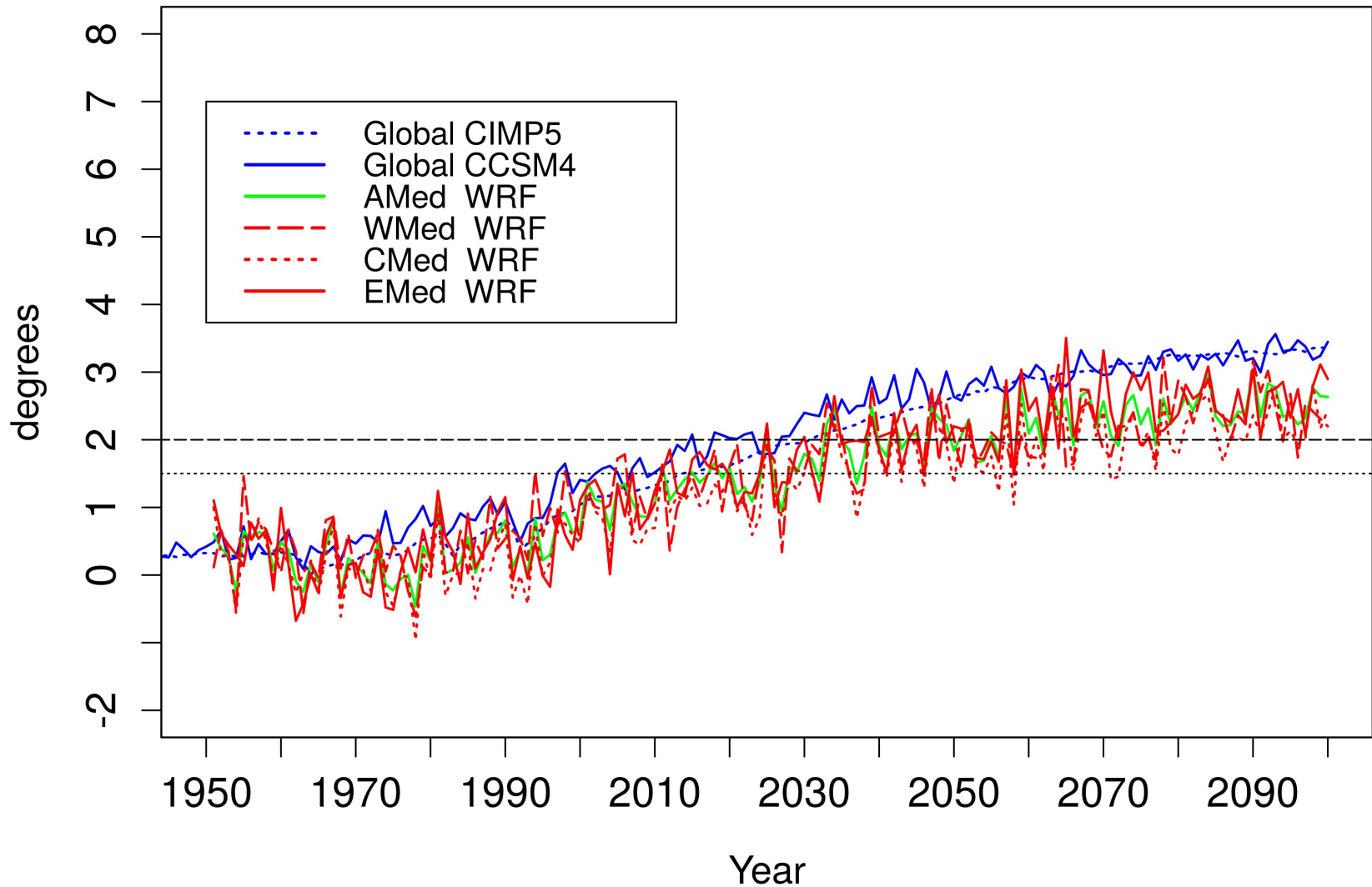
Thank you!

p.hadjinicolaou@cyi.ac.cy

Auxiliary material

Towards a +1.5° Med: sub-regions

RCP4.5 Annual



Towards a +1.5° Med: WRF vs CCSM4

RCP4.5 Annual

