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

Nicosia, Cyprus
16 May 2018
Global temperature change up to 2018

HadCRUT4 global surface air temperature
2018 anomaly +0.54°C (+/-0.25°C)
2018 based on only Jan-Feb

https://crudata.uea.ac.uk/~timo/diag/temps_decadesmooth_global.png
Global warming from pre-industrial

HadCRUT4 global surface air temperature
2018 anomaly +0.54°C (+/-0.25°C)
2018 based on only Jan-Feb

Warming from pre-industrial:
2016: + 1.00°
2018: + 0.75°
IPCC AR5 projections: regional detail?

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

Downscaling IPCC projections: 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

WRF downscaling: runs

“Father model”: CCSM4
NCAR’s Community Earth System Model (CESM1)

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

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

(Synoptic and climate scale variability of CESM1 maintained)

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

[Diagram showing anomalies for the ERA-Int period from 1979 to 1999 for different models and observational data.]
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
<table>
<thead>
<tr>
<th>Units: °C/decade</th>
<th>ANN</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERAINT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCP4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCP8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMED</td>
<td>0.32</td>
<td>0.28</td>
<td>0.34</td>
<td>0.11</td>
</tr>
<tr>
<td>CMED</td>
<td>0.38</td>
<td>0.32</td>
<td>0.33</td>
<td>0.26</td>
</tr>
<tr>
<td>EMED</td>
<td>0.42</td>
<td>0.29</td>
<td>0.31</td>
<td>0.33</td>
</tr>
<tr>
<td>BALK</td>
<td>0.45</td>
<td>0.45</td>
<td>0.39</td>
<td>0.34</td>
</tr>
<tr>
<td>ANAT</td>
<td>0.42</td>
<td>0.4</td>
<td>0.42</td>
<td>0.2</td>
</tr>
<tr>
<td>MESO</td>
<td>0.52</td>
<td>0.28</td>
<td>0.41</td>
<td>0.48</td>
</tr>
<tr>
<td>PERS</td>
<td>0.76</td>
<td>0.27</td>
<td>0.49</td>
<td>0.85</td>
</tr>
<tr>
<td>GULF</td>
<td>0.37</td>
<td>0.27</td>
<td>0.45</td>
<td>0.39</td>
</tr>
<tr>
<td>ARAB</td>
<td>0.49</td>
<td>0.27</td>
<td>0.4</td>
<td>0.48</td>
</tr>
<tr>
<td>SRED</td>
<td>0.43</td>
<td>0.25</td>
<td>0.28</td>
<td>0.31</td>
</tr>
<tr>
<td>EGYP</td>
<td>0.45</td>
<td>0.27</td>
<td>0.27</td>
<td>0.46</td>
</tr>
<tr>
<td>LIBY</td>
<td>0.37</td>
<td>0.36</td>
<td>0.3</td>
<td>0.36</td>
</tr>
<tr>
<td>MAGH</td>
<td>0.34</td>
<td>0.41</td>
<td>0.41</td>
<td>0.19</td>
</tr>
<tr>
<td>SAHE</td>
<td>0.27</td>
<td>0.3</td>
<td>0.32</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Sub-regions
Summary for 1979-2016 comparison

WRF historical run vs ERA-Int:

- within ± 2° 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

°C
Change from 1991-2015 RCP4.5 2041-65
<table>
<thead>
<tr>
<th>Units:</th>
<th>ANN</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C/decade</td>
<td>RCP4.5</td>
<td>RCP8.5</td>
<td>RCP4.5</td>
<td>RCP8.5</td>
<td>RCP4.5</td>
</tr>
<tr>
<td><strong>GLOBAL</strong></td>
<td><strong>0.245</strong></td>
<td><strong>0.559</strong></td>
<td><strong>0.261</strong></td>
<td><strong>0.593</strong></td>
<td><strong>0.236</strong></td>
</tr>
<tr>
<td>MENA</td>
<td>0.174</td>
<td>0.441</td>
<td>0.163</td>
<td>0.414</td>
<td>0.169</td>
</tr>
<tr>
<td>WMED</td>
<td>0.154</td>
<td>0.398</td>
<td>0.114</td>
<td>0.249</td>
<td>0.152</td>
</tr>
<tr>
<td>CMED</td>
<td><strong>0.143</strong></td>
<td>0.367</td>
<td><strong>0.081</strong></td>
<td><strong>0.248</strong></td>
<td><strong>0.135</strong></td>
</tr>
<tr>
<td>EMED</td>
<td>0.160</td>
<td><strong>0.392</strong></td>
<td>0.122</td>
<td>0.316</td>
<td>0.158</td>
</tr>
<tr>
<td>BALK</td>
<td>0.218</td>
<td>0.501</td>
<td>0.178</td>
<td>0.434</td>
<td><strong>0.239</strong></td>
</tr>
<tr>
<td>ANAT</td>
<td>0.206</td>
<td>0.512</td>
<td>0.181</td>
<td>0.475</td>
<td>0.219</td>
</tr>
<tr>
<td>MESO</td>
<td>0.210</td>
<td>0.506</td>
<td>0.192</td>
<td>0.497</td>
<td>0.200</td>
</tr>
<tr>
<td>PERS</td>
<td>0.233</td>
<td>0.542</td>
<td><strong>0.317</strong></td>
<td><strong>0.616</strong></td>
<td>0.203</td>
</tr>
<tr>
<td>GULF</td>
<td>0.205</td>
<td>0.485</td>
<td>0.235</td>
<td>0.522</td>
<td>0.199</td>
</tr>
<tr>
<td>ARAB</td>
<td>0.199</td>
<td>0.479</td>
<td>0.213</td>
<td>0.486</td>
<td>0.187</td>
</tr>
<tr>
<td>SRED</td>
<td>0.163</td>
<td>0.403</td>
<td>0.157</td>
<td>0.365</td>
<td>0.187</td>
</tr>
<tr>
<td>EGYP</td>
<td>0.151</td>
<td>0.417</td>
<td>0.118</td>
<td>0.348</td>
<td><strong>0.135</strong></td>
</tr>
<tr>
<td>MAGH</td>
<td>0.165</td>
<td>0.451</td>
<td>0.134</td>
<td>0.345</td>
<td><strong>0.135</strong></td>
</tr>
</tbody>
</table>
Summary for overall 21\textsuperscript{st} projections

Both emission scenarios and timrane:

- 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\textdegree 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

degrees

Year

2000  2020  2040  2060  2080  2100

- Annual
- Dec-Feb
- Mar-May
- Jun-Aug
- Sep-Nov
Occurrence of $+1.5^\circ$: 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 $1.5^\circ$
Occurrence of $+1.5^\circ/2^\circ$: emergence

![Graph showing the occurrence of +1.5\(^\circ\)/2\(^\circ\): emergence.](image-url)
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

degrees


Year

Global CIMP5
Global CCSM4
AMed WRF
WMed WRF
CMed WRF
EMed WRF
Towards a +1.5° Med: WRF vs CCSM4

RCP4.5  Annual

- Global CIMP5
- Global CCSM4
- AMed CCSM4
- AMed WRF

degrees

1850 1890 1930 1970 2010 2050 2090

Year