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Warming projections of eastern Mediterranean in CMIP6 simulations according to SSP2-4.5 and SSP5-8.5 scenarios

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INTRODUCTION & AIM

The Mediterranean is considered as a vulnerable region regarding the climate change. Previous studies have shown that the warming over this sensitive area has accelerated exceeding the global mean rates (Urdiales-Flores et al., 2023; Zittis et al., 2022).

*This study investigates the temperature changes over **eastern Mediterranean "climate Hot Spot"** during the 21st century. The analysis uses results from seventeen (17) CMIP6 model simulations under SSP2-4.5 and SSP5-8.5 scenarios. The ERA5 reanalysis is used as a reference dataset in order to investigate the performance of CMIP6 simulations to capture & reproduce temporal and distributional features of CMIP6 mean surface temperature over eastern Mediterranean (EMed).*

Findings show that models simulations project warming for the EMed even though CMIP6 vary regarding their efficiency to capture and reproduce the mean EMed temperature.

DATA & METHODS

DATA

- For the analysis monthly mean near surface temperature (T) of:
  - 17 CMIP6 model simulations (**Table 1**) - SSP2-4.5 and SSP5-8.5 scenarios - and
  - ERA5 reanalysis dataset, were used | (*ERA5 was used as a reference dataset*).
- The analysis is focused on the EMed (*15°to 40°E, 30° to 45°N*) covering
  - the historical period from 1970 to 2015 and
  - future period till 2100 (mainly is focused on the last period from 2070 to 2100).

Table 1. *List of CMIP6 model simulations that were used in this study.*

Model	Institute (country)	Resolution (lon/lat)	Ensemble
ACCESS-CM2	Australian Community Climate and Earth System Simulator Climate Model Version 2 (Australia)	192 x 144	r1i1p1f1
ACCESS-ESM1-5	Australian Community Climate and Earth System Simulator Earth System Model Version 1.5	192 x 145	r1i1p1f1, r2i1p1f1, r3i1p1f1
AWI-CM-1-1-MR	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	384 x 192	r1i1p1f1
CAMS-CSM1-0	Climate Academy of Meteorological Sciences - Climate Simulation Model	320 x 160	r1i1p1f1
CanESM5	Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada	128 x 64	r1i1p1f1
CMCC-CM2-SR5	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy	288 x 192	r1i1p1f1
CNRM-CM6-1-HR	Centre National de Recherches Meteorologiques, Centre Europeen de Recherche et de Formation Avancee en Calcul Scientifique, France	256 x 128	r1i1p1f2
GFDL-ESM4	National Oceanic and Atmospheric Administration, Geophysical Fluid Dynamics Laboratory, USA	360 x 180	r1i1p1f1
GISS-E2-1-G	Goddard Institute for Space Studies, USA	144 x 90	r1i1p1f2
HadGEM3-GC31-LL	Met Office Hadley Centre, UK	92 x 144	r1i1p1f3
INM-CM5-0	Institute for Numerical Mathematics, Russian Academy of Science, Russia	180 x 120	r1i1p1f1
IPSL-CM6A-LR	Institut Pierre Simon Laplace, France	144 x 143	r2i1p1f1
KACE-1-0-G	National Institute of Meteorological Sciences/Korea Meteorological Administration, Climate Research Division, Republic of Korea	192 x 144	r1i1p1f1
MIROC6	Japan Agency for Marine-Earth Science and Technology , The University of Tokyo, Japan	256 x 128	r1i1p1f1
MIROC-ES2L	Japan Agency for Marine-Earth Science and Technology , The University of Tokyo, Japan	128 x 64	r1i1p1f1
MPI-ESM1-2-LR	Max Planck Institute for Meteorology, Germany	192 x 96	r1i1p1f1
MRI-ESM2-0	Meteorological Research Institute, Japan	128 x 64	r1i1p1f1

PERFORMANCE OF CMIP6 to simulate the annual mean T avg. over EMed

- The Kling-Gupta Combined Statistical Index is calculated (KGE, using Eq. 1) for each one of GCMs (ERA5 was used as reference data for the historical period from 1970 to 2000 (basis period)

$$KGE = 1 - \sqrt{(r-1)^2 + (^{\sigma_s}/_{\sigma_0} - 1)^2 + (^{\mu_s}/_{\mu_0} - 1)^2}, \qquad \text{(Eq. 1)}$$

METHODS

- Timeseries of annual mean EMed T are calculated for SSPs,
- Maps of T diff. between last period of 21st century and the historical basis period (1970-2005) are constructed for each one of the model simulations,
- T trends for each one of the model simulations are calculated during the period from 2070 to 2100 (for stat. sign. of trends, the Man-Kendall test is revealed at level of sign. 99%),
- Monthly mean EMed T anomalies for periods from 2020 to 2050 and 2070 to 2100 wrt basis period according to studied scenarios are calculated for each CMIP6, respectively.

RESULTS

- 5 out of 17 simulations show better performance to capture temporal and distributional features of annual mean EMed T (*0.4≤KGE<0.47*) (**Fig. 1**).
- CMIP6 simulations show warming over EMed:
  - for SSP5-8.5 the warming ranges from 4°C to 8°C and
  - for SSP2-4.5 from 2°C to 4°C, till the end of 21st century, (**Fig. 2**).

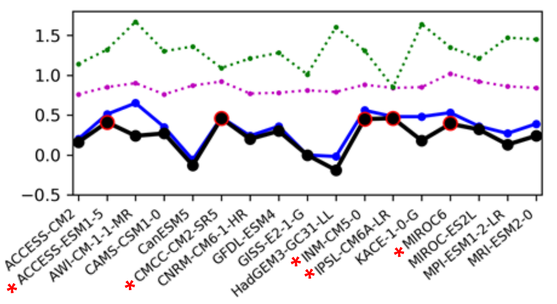

Fig. 1. Corr. coef. (blue line), bias ratios ($^{\mu_s}/_{\mu_0}$; magenta line), variability ratios ($^{\sigma_s}/_{\sigma_0}$; green line) and KGE indices (black line) of the EMed T for CMIP6 simulations wrt ERA5 basis period. The red cycles & star indicate the CMIP6 with KGE values larger than 0.4 (KGE>0.4).

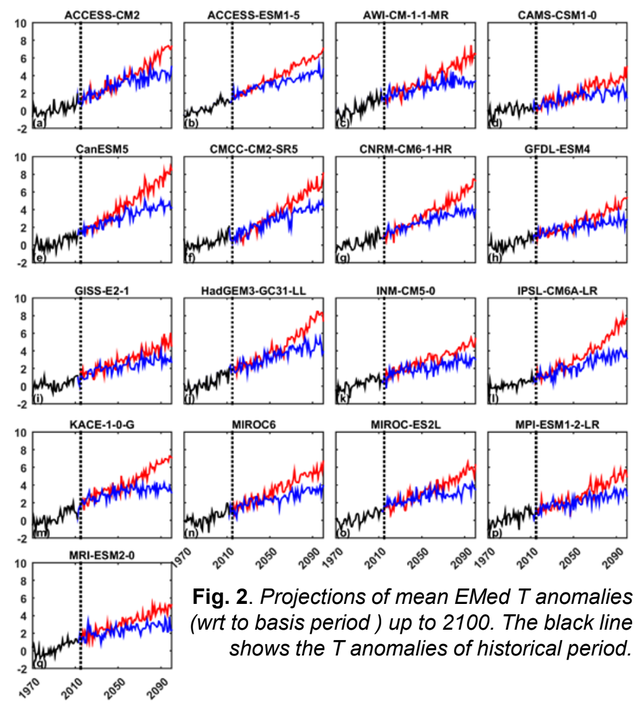

Fig. 2. *Projections of mean EMed T anomalies (wrt to basis period) up to 2100. The black line shows the T anomalies of historical period.*

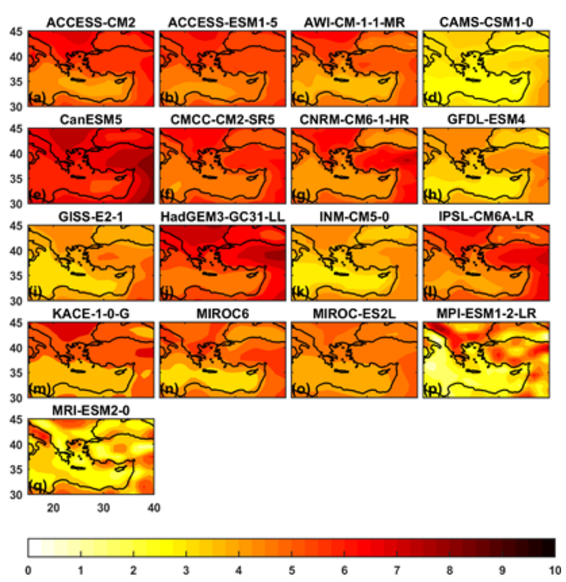

Fig. 3. *Composite difference of mean EMed T between future period from 2070 to 2100 and basis period for SSP5-8.5 scenario.*

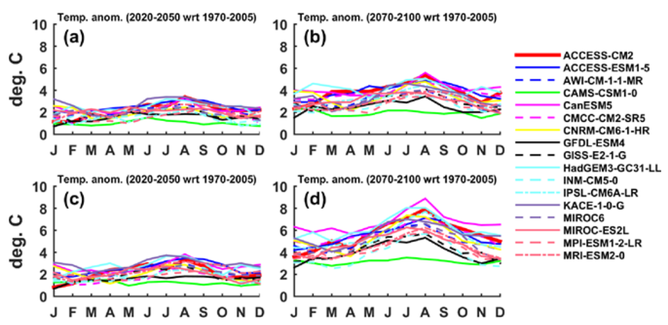

Fig. 4. *Monthly mean EMed T anomalies for periods from 2020 to 2050 and 2070 to 2100 wrt basis period according to (a,b) SSP2-4.5 and (c,d) SSP5-8.5 scenarios.*

- EMed warming varies among the CMIP6 simulations,
- The maximum warming is shown during the last period of 21st century (**Fig. 3**),
- The warming trend:
  - for SSP2-4.5 scenario ranges from 0.0 to 0.4 °C/ decade and
  - for SSP5-8.5 scenario from 0.4 to 1.5 °C/ decade, respectively,

- Focusing on last period of 21st century, all CMIP6 simulations show that all seasons project a warming wrt basis period,
  - The maximum warming is shown during summer season (**Fig 4)**

CONCLUSION

- CMIP6 show different skills to capture & reproduce mean EMed T (as compared to ERA5),
- All model simulations show warming (~ 4°C to 8°C for SSP5-8.5 scenario and ~2°C to 4°C for SSP2-4.5 till the end of 21st century),
- Maximum changes are presented during the last period of 21st century and mainly they are identified over continental areas of Balkan Peninsula and Turkey,
- Seasonal temperature projections show that JJA period shows the maximum warming.

REFERENCES

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