Future projections of high-impact extreme weather events in the EMME region

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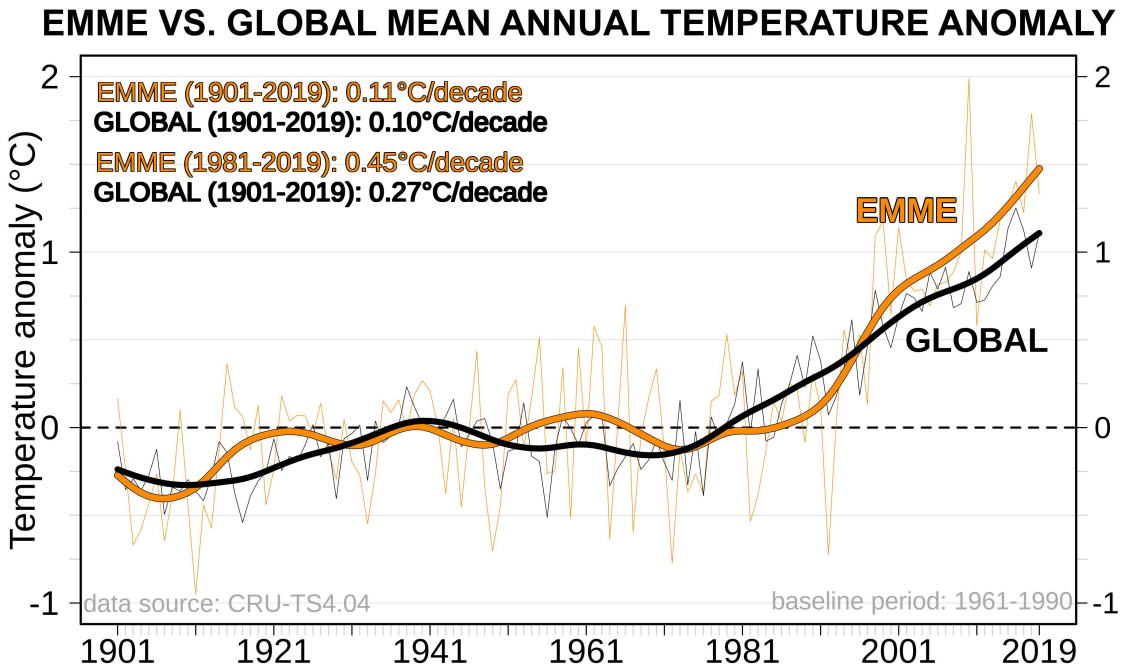
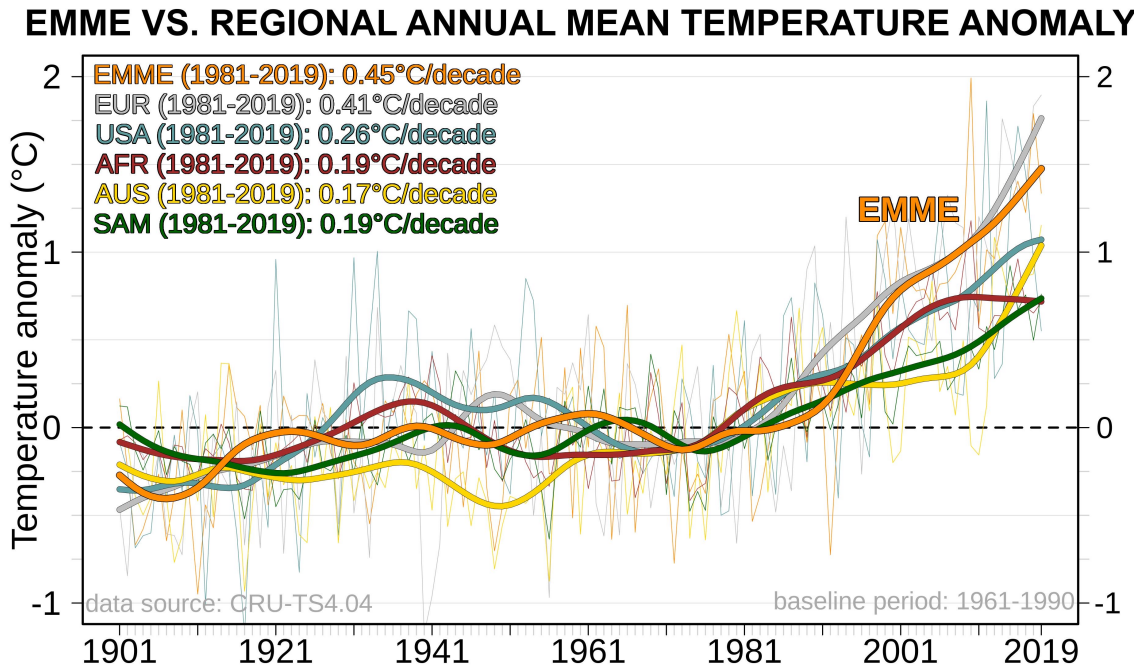
RESEARCH•TECHNOLOGY•INNOVATION

EMME-CARE
EASTERN MEDITERRANEAN MIDDLE EAST – CLIMATE & ATMOSPHERE RESEARCH CENTRE

Regional Climate Change Initiative Republic of Cyprus

❖ Observed changes in mean climate conditions

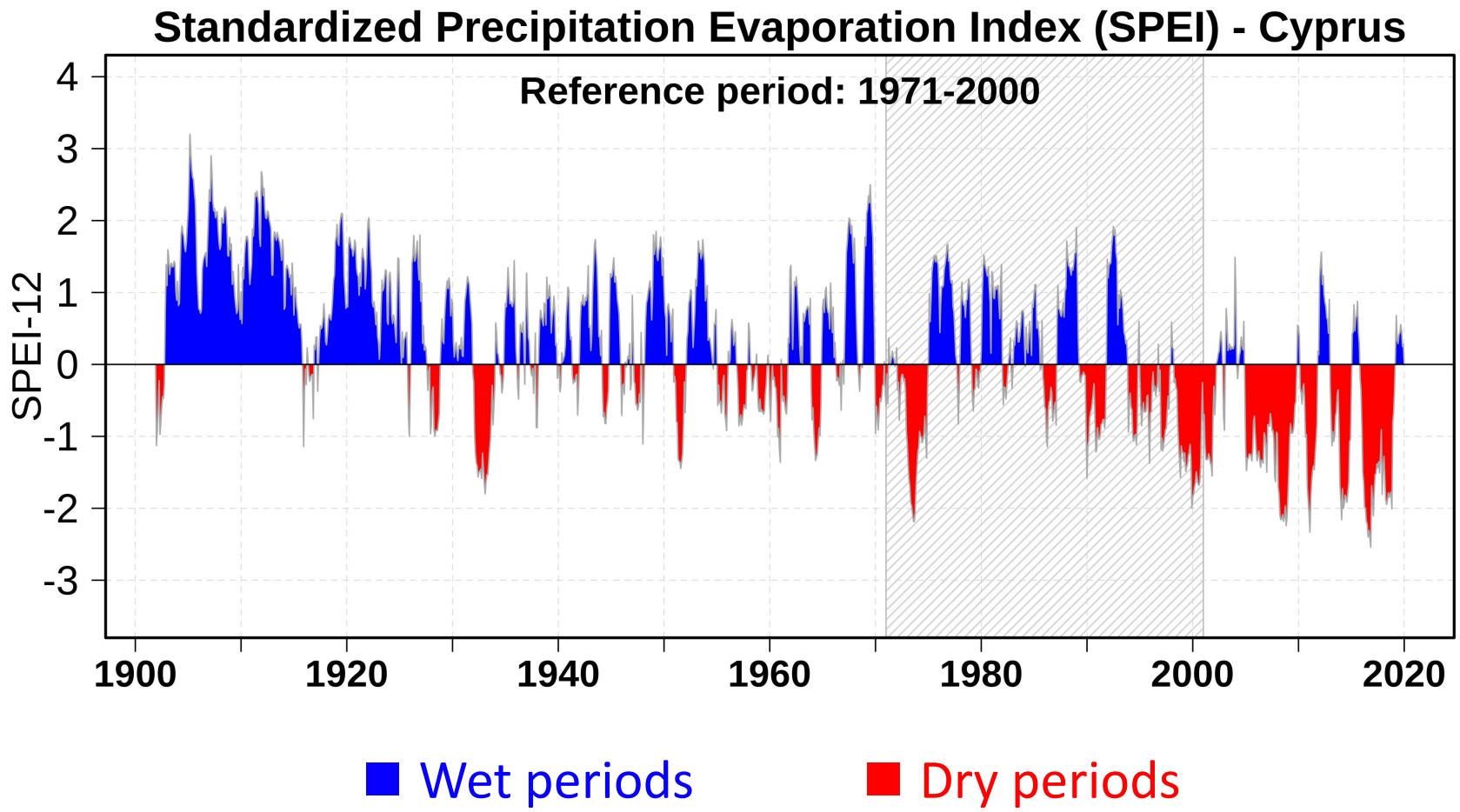




"The EMME region is warming faster than the global average, and faster than many other inhabited parts of the world"

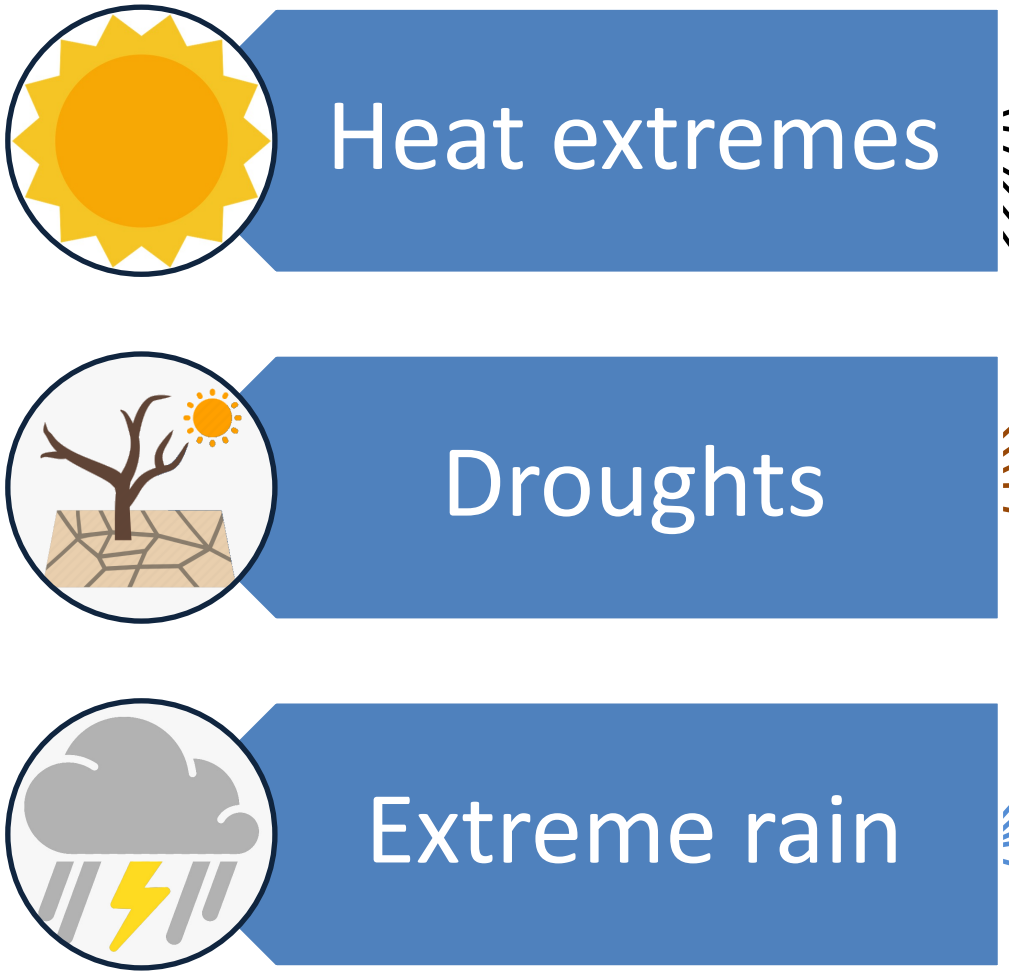
Zittis G., et al. (2021) Climate change and weather extremes in the Eastern Mediterranean and Middle East. Reviews of Geophysics (under review)

❖ Observed changes in mean climate conditions



Hochman A., Marra F., Messori G., Raveh-Rubin S., Yosef I., Zittis G., Pinto J.G. (2021) Extreme Weather and Related Societal Impacts over the Eastern Mediterranean: A Systematic Review. Earth System Dynamics (under review)

❖ Impacts of extreme events



- Energy demand
- Energy production
- Water demand
- Agriculture
- Tourism
- Transportation
- Human health
- Labour productivity
- Critical infrastructure

❖ Observed changes in extremes

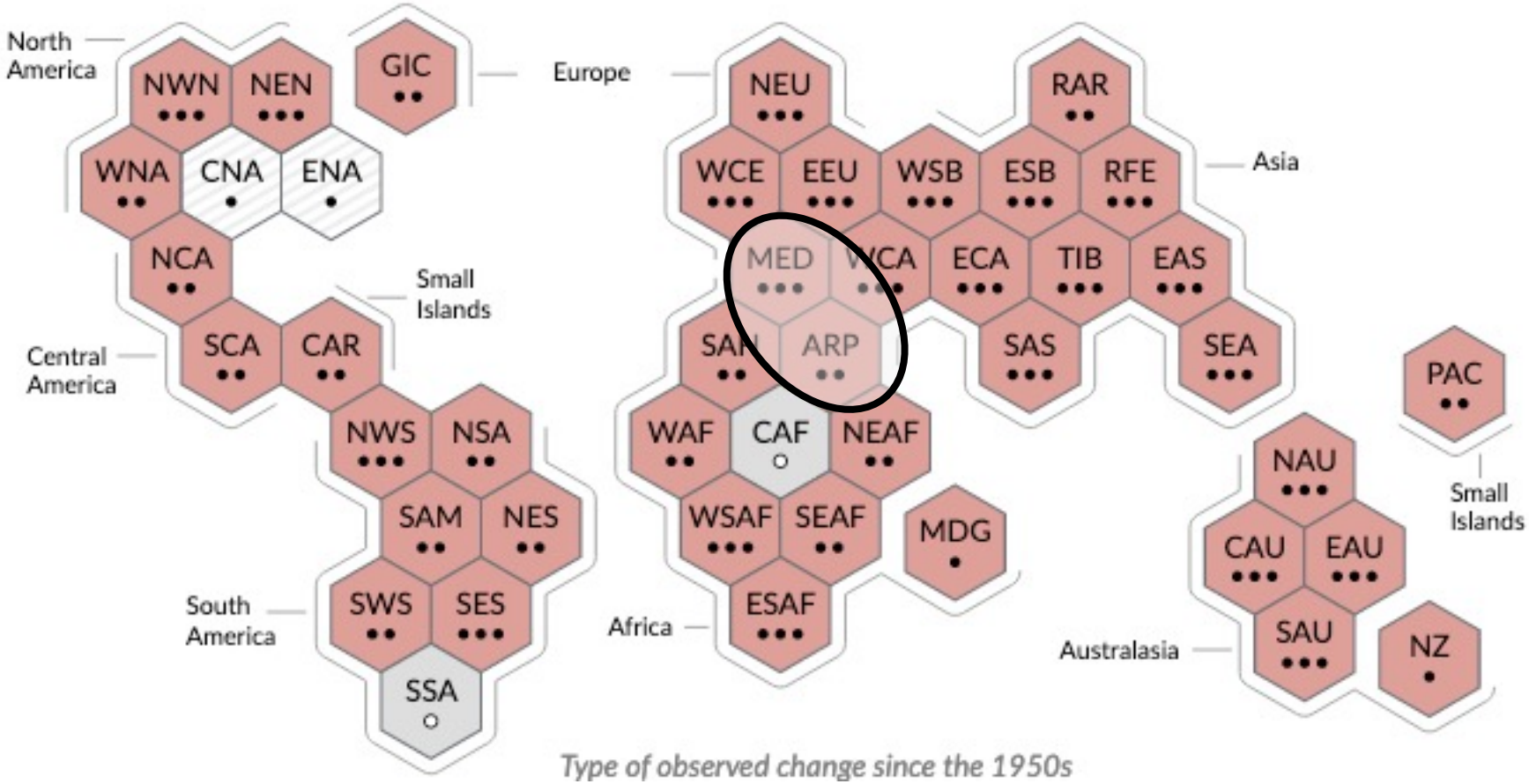
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in hot extremes

- Increase (41)
- Decrease (0)
- Low agreement in the type of change (2)
- Limited data and/or literature (2)

Confidence in human contribution
to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



IPCC AR6: Summary for policymakers (2021)

❖ Observed changes in extremes

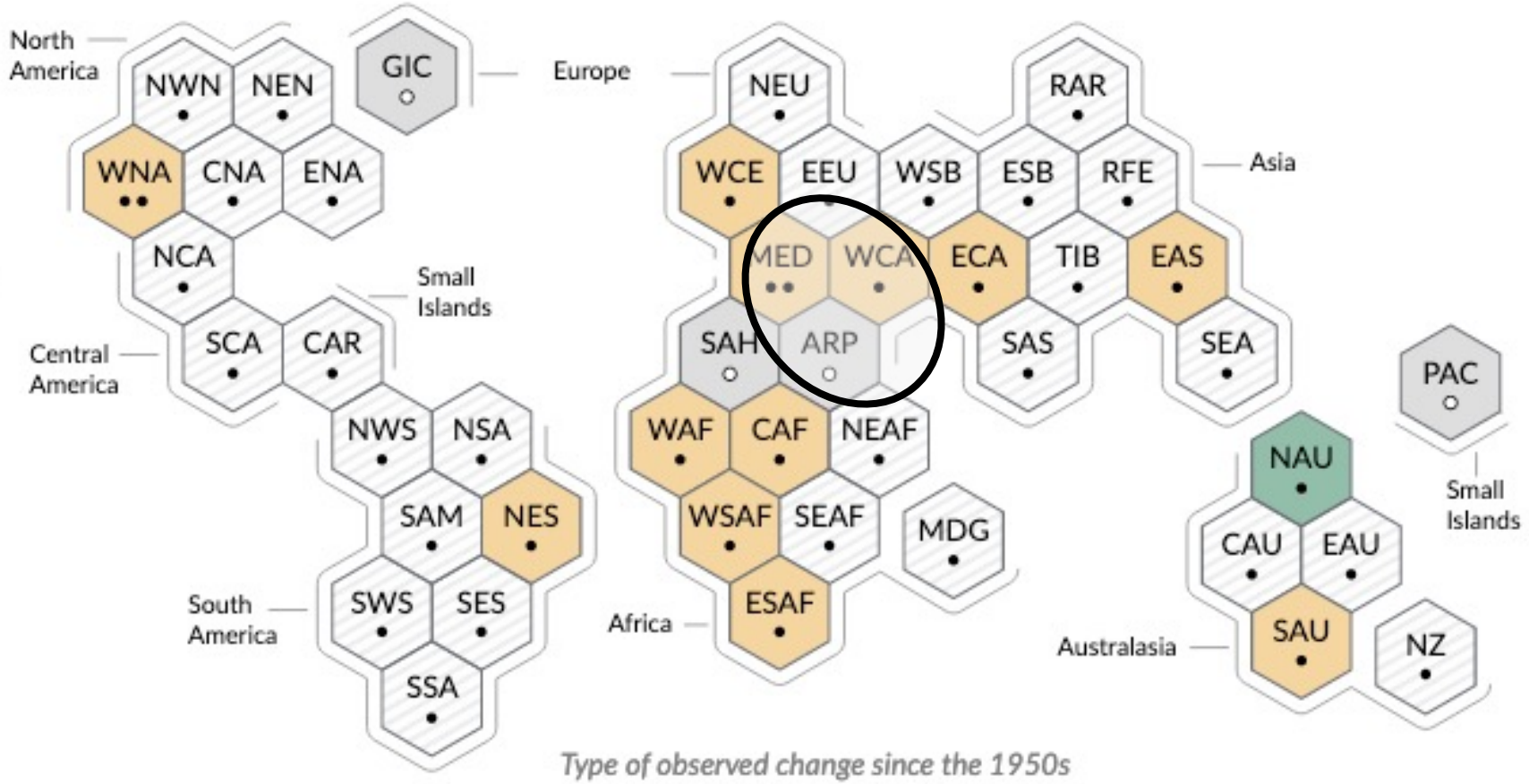
c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in agricultural and ecological drought

- Increase (12)
- Decrease (1)
- Low agreement in the type of change (28)
- Limited data and/or literature (4)

Confidence in human contribution
to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence

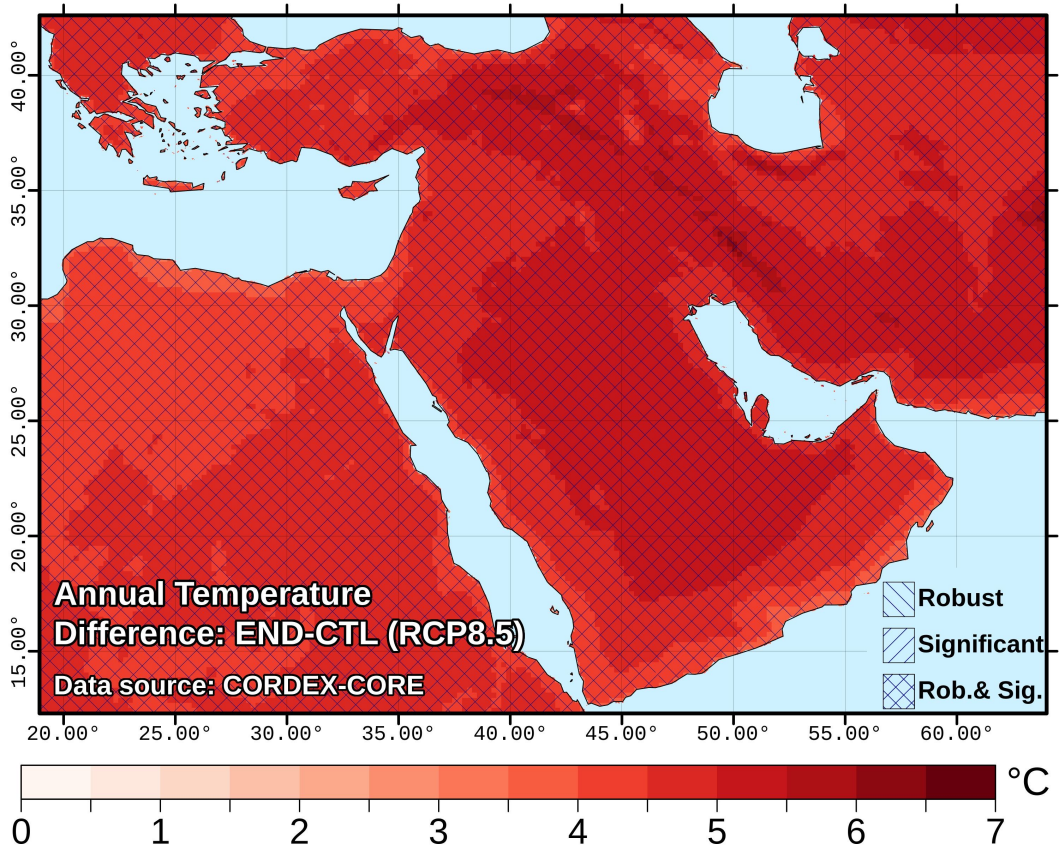


Type of observed change since the 1950s

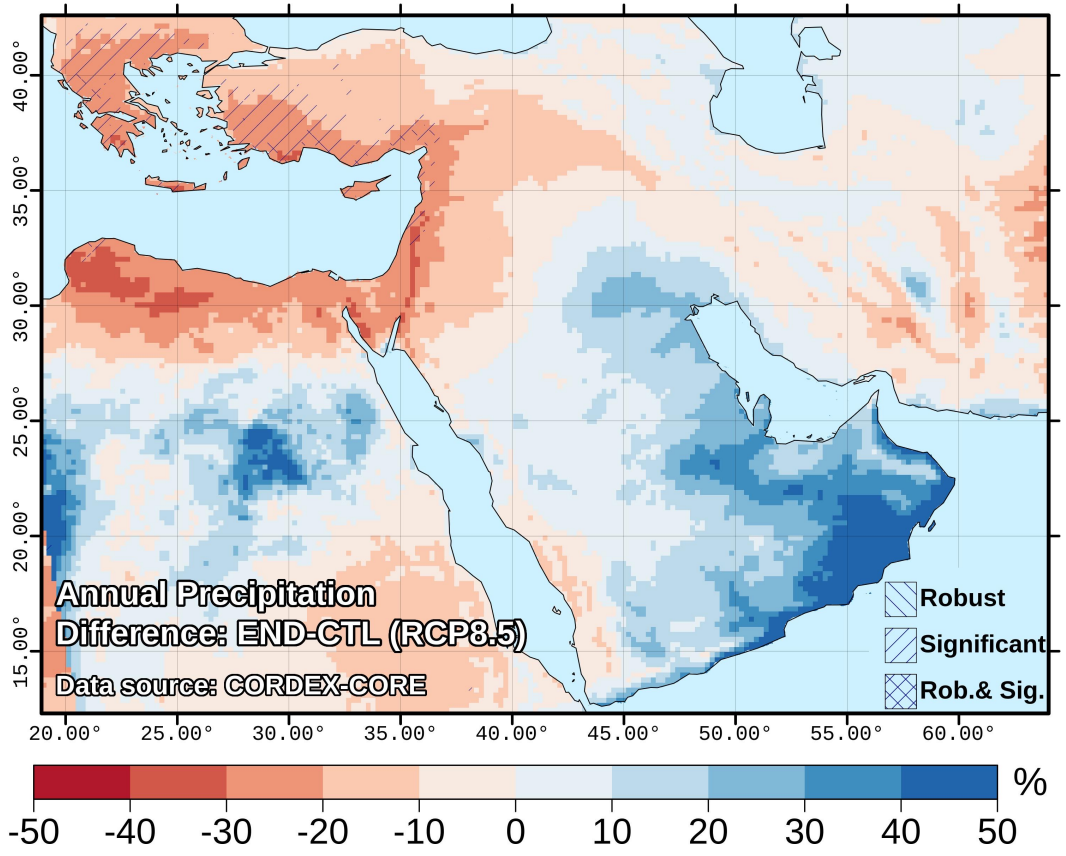
IPCC AR6: Summary for policymakers (2021)

❖ Projections in mean climate conditions

Temperature



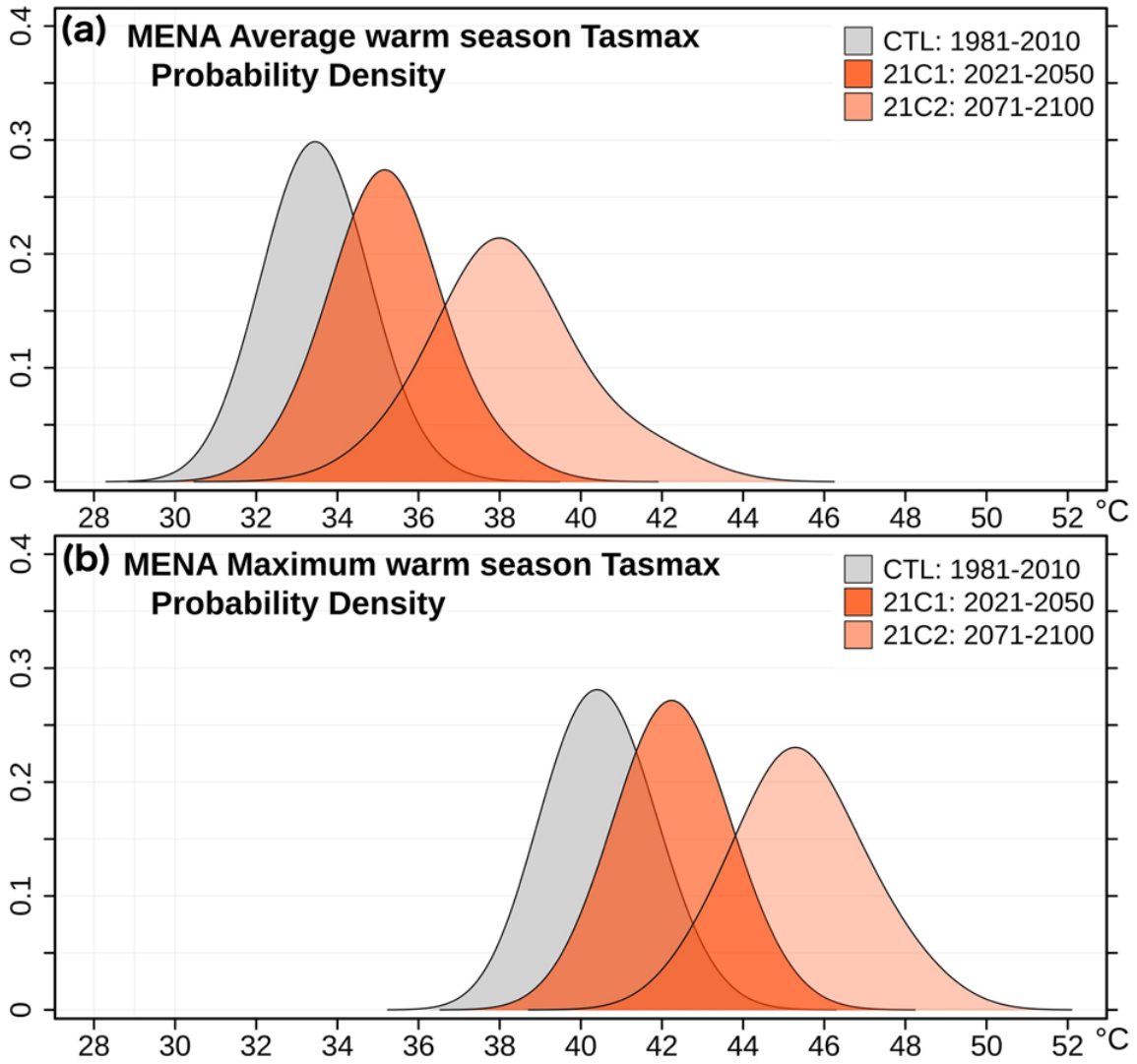
Precipitation



Zittis G., et al. (2021) Climate change and weather extremes in the Eastern Mediterranean and Middle East. Reviews of Geophysics (under review)

Future projections of high-impact extreme events: Heatwaves

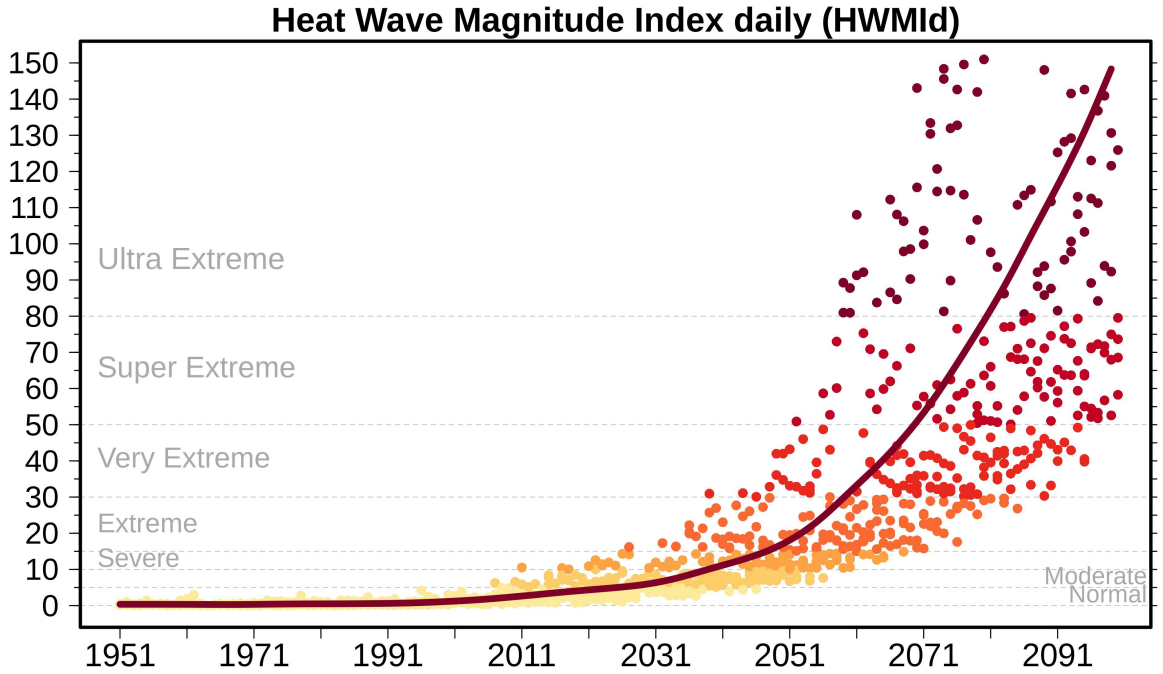
Extreme events: Heatwaves

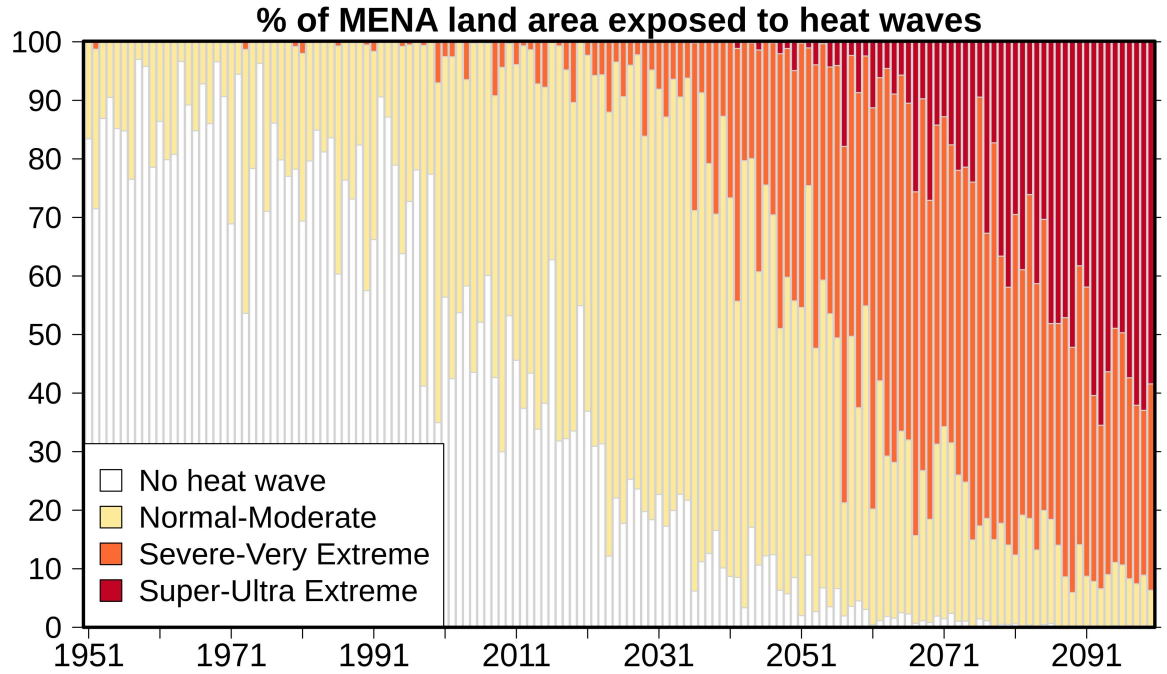


Zittis, G., Hadjinicolaou, P., et al. (2021). Business-as-usual will lead to super and ultra-extreme heatwaves in the Middle East and North Africa. *Npj Climate and Atmospheric Science*, *4*(1), 20. https://doi.org/10.1038/s41612-021-00178-7

Projected changes of maximum temperature. Probability density curves for simulated historical and projected future warm- season average (a) and absolute maximum (b) daily maximum temperature.

Extreme events: Heatwaves





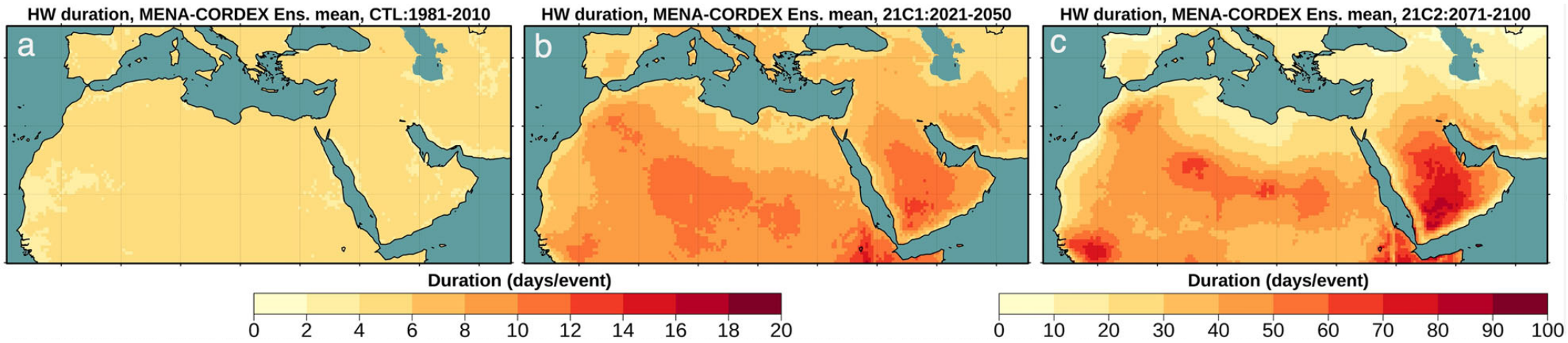
Annual values of the daily Heat Wave Magnitude Index (HWMId) for individual models (dots) and ensemble mean (curve) (left) and percentage of MENA land area annually exposed to several heatwave categories (right) for the period 1951–2100. Projections correspond to pathway RCP8.5.

Zittis, G., et al. (2021) *Npj Climate and Atmospheric Science*

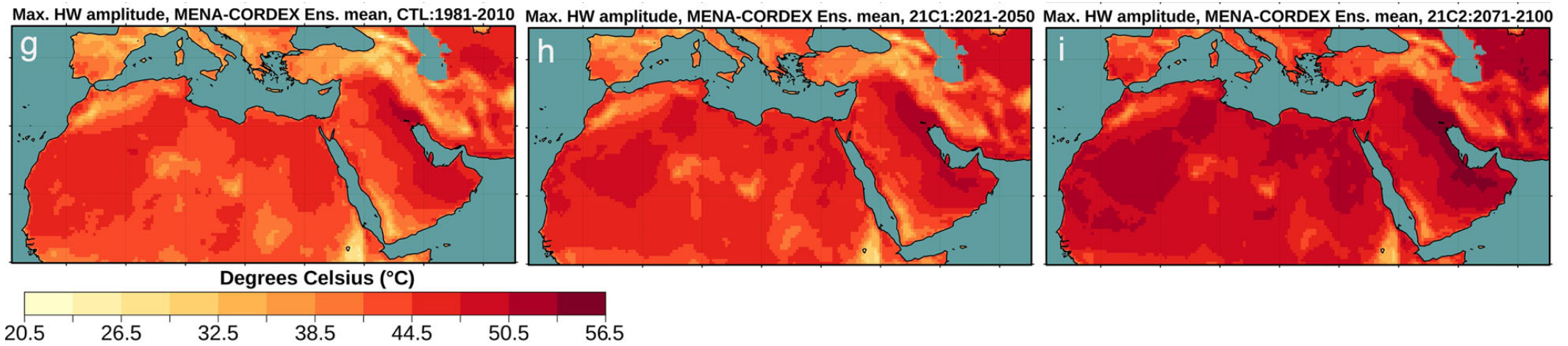
Extreme events: Heatwaves

CTL: 1981–2010 **21C1: 2021–2050** **21C2: 2071–2100**

Heatwave **Duration**

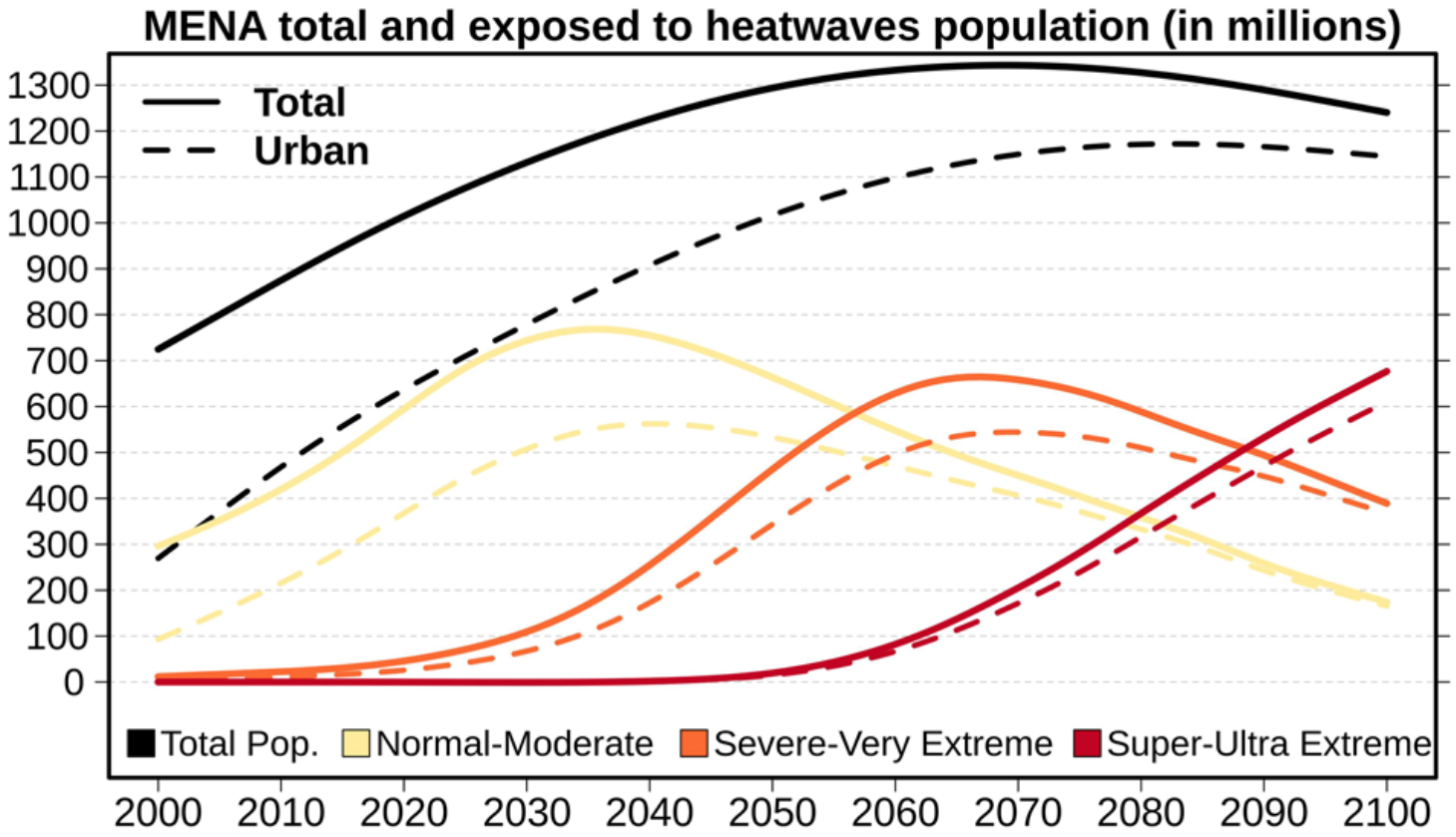


Heatwave **Amplitude**



Zittis, G., et al. (2021) *Npj Climate and Atmospheric Science*

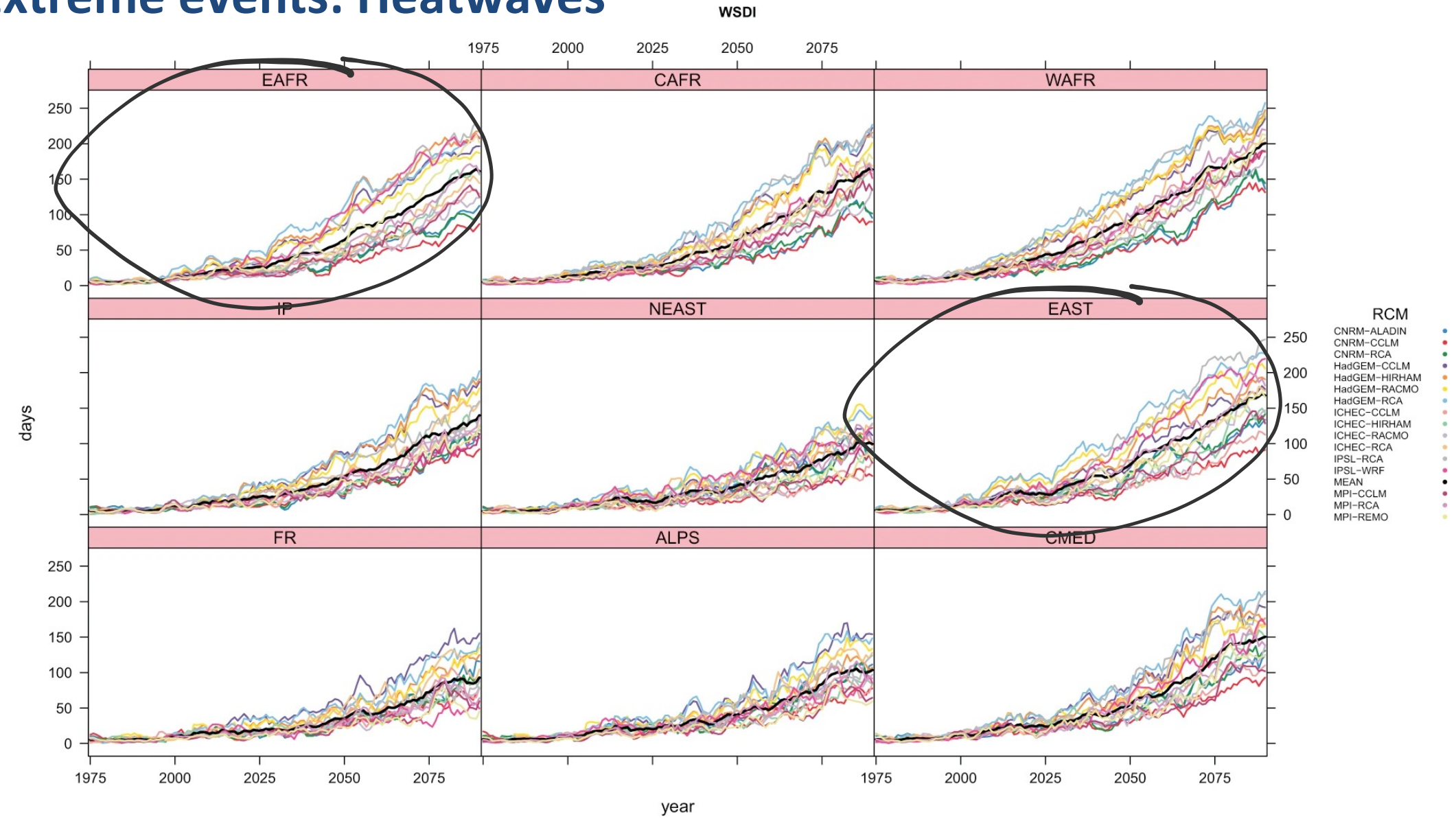
Extreme events: Heatwaves



Total MENA population according to the SSP5 narrative and population that is projected to be exposed to events with heatwave events of various magnitudes. Solid curves represent the total and dashed curves the urban population.

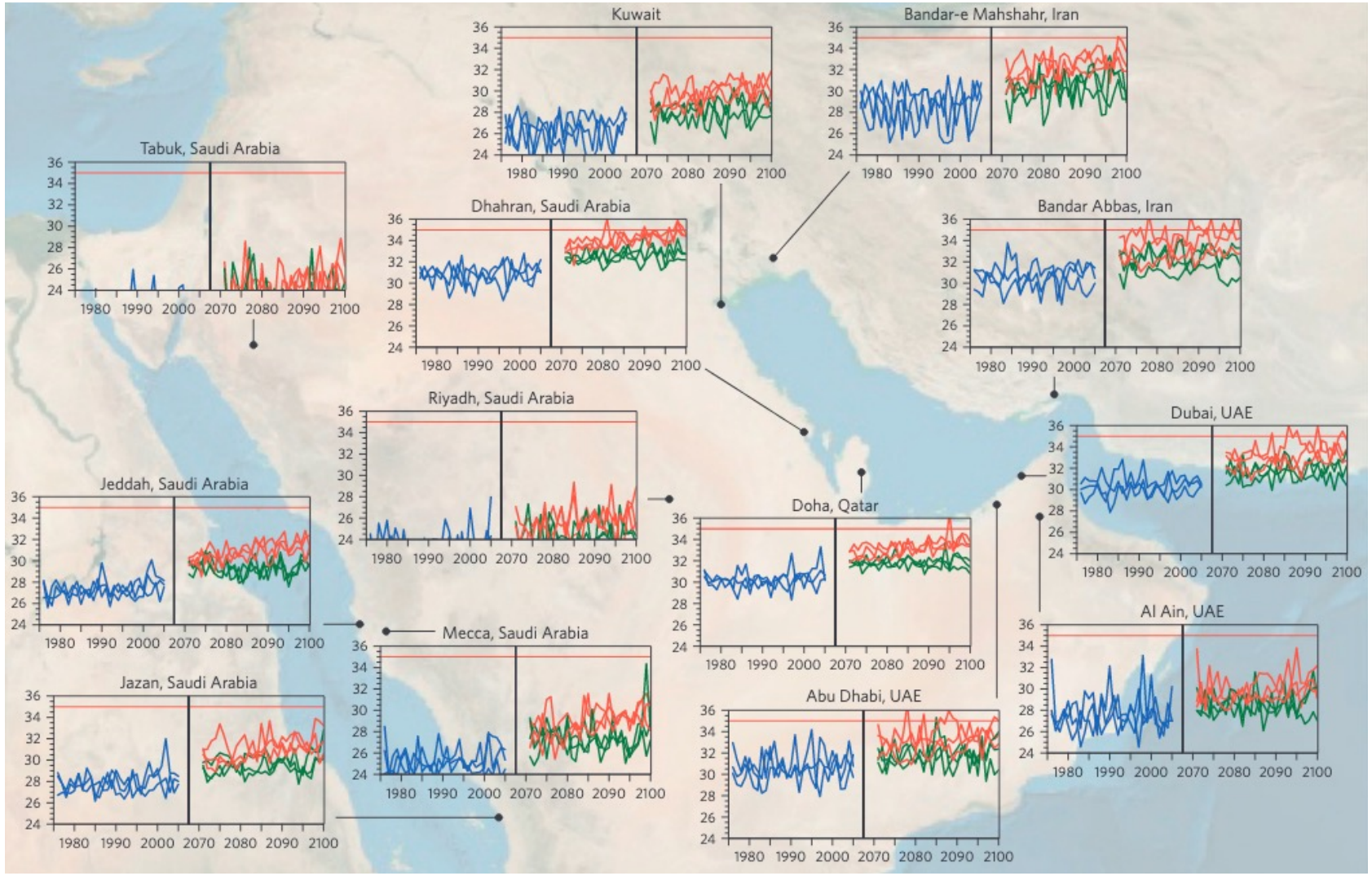
Zittis, G., et al. (2021) *Npj Climate and Atmospheric Science*

Extreme events: Heatwaves



Molina, M. O., Sánchez, E., & Gutiérrez, C. (2020). Future heat waves over the Mediterranean from an Euro-CORDEX regional climate model ensemble. *Scientific Reports*, *10*(1), 8801

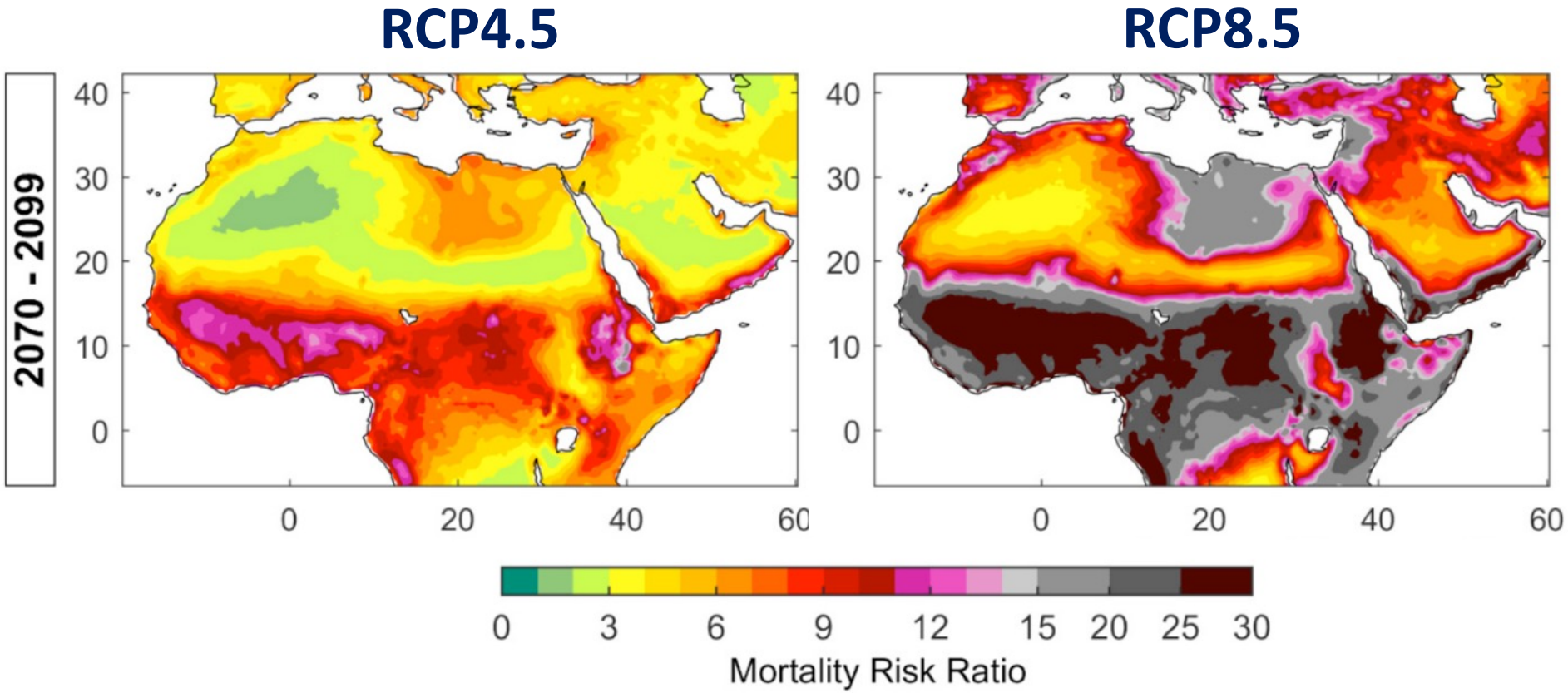
Extreme events: Heatwaves



Pal, J. S., & Eltahir, E. A. B. (2016). Future temperature in southwest Asia projected to exceed a threshold for human adaptability. *Nature Climate Change*, *6*(2), 197–200.

Time series of the annual maximum TWmax. Blue, green and red lines represent the historical (1976–2005), RCP4.5 (2071–2100) and RCP8.5 (2071–2100) scenarios, respectively.

Extreme events: Heatwaves



Ahmadalipour, A., Moradkhani, H. (2018). Escalating heat-stress mortality risk due to global warming in the Middle East and North Africa (MENA). *Environment International*, *117*, 215–225.

Projected decadal **mortality risk ratio** compared to the historical mortality risk. The figure represents the ensemble mean of 17 RCMs and shows the exacerbation rate of mortality risk compared to the historical period (1951-2005).

Extreme events: Heatwaves

Darmaraki, S., Somot, S., et al. (2019). Future evolution of **Marine Heatwaves** in the Mediterranean Sea. *Climate Dynamics*, *53*(3–4), 1371–1392.

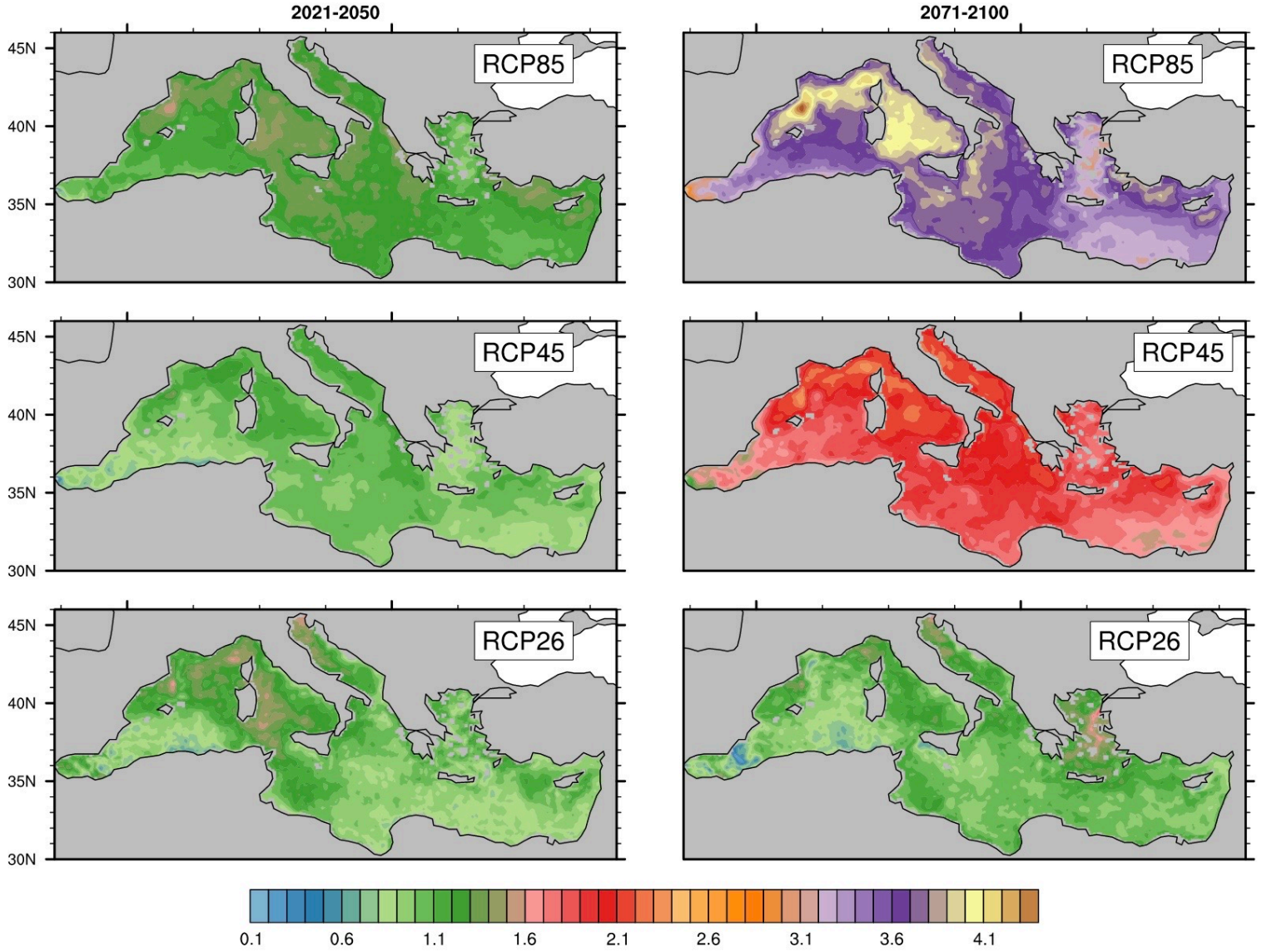
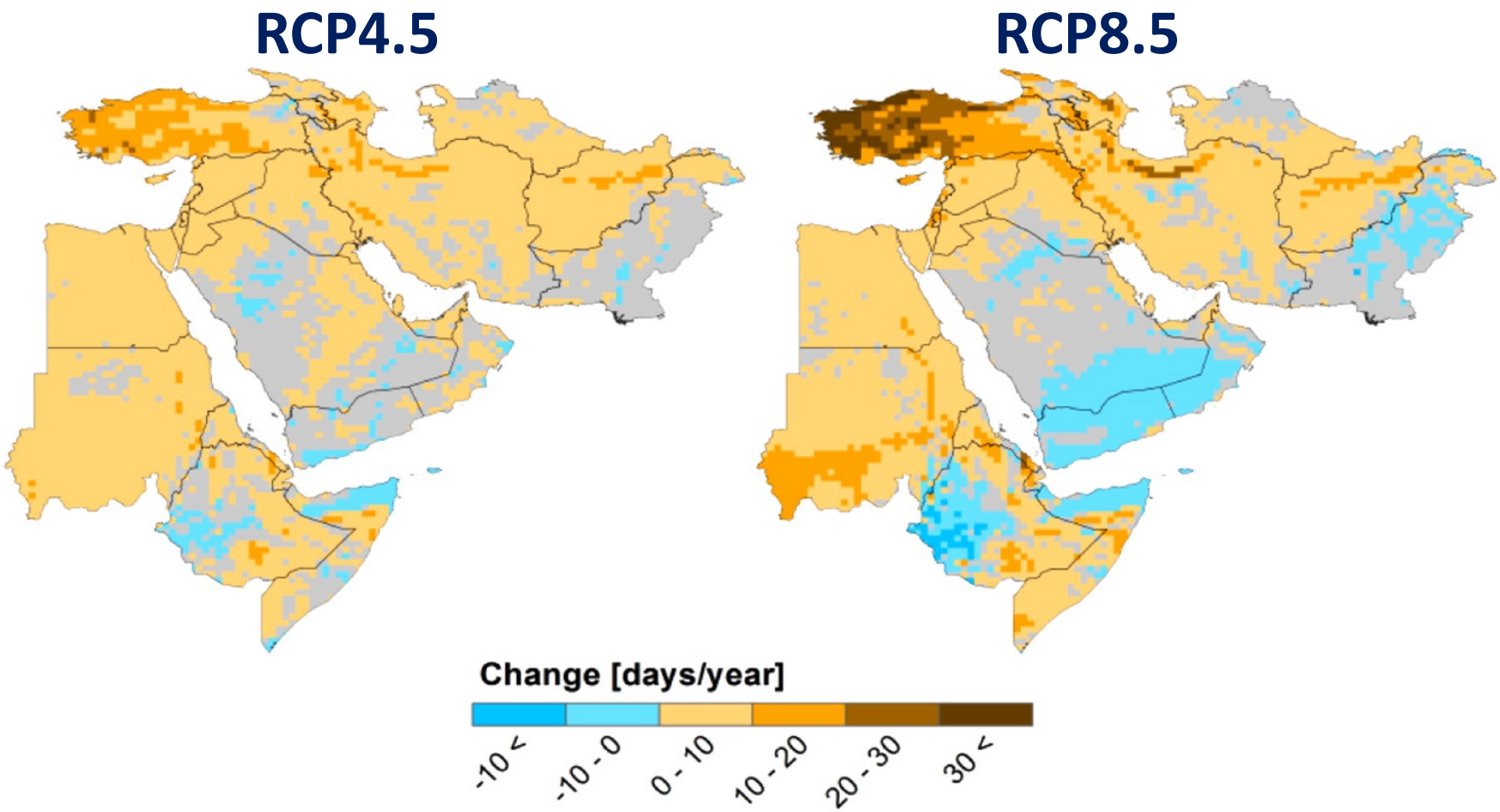


Fig. 8 Multi-model average anomaly of extreme SST_{99Q} (°C) with respect to corresponding ensemble mean HIST (1976-2005) of each scenario, for the near and far future. The RCP2.6 scenario has only one simulation (CNRM)

Future projections of high-impact extreme events: Droughts

Extreme events: Droughts



Tabari, H., & Willems, P. (2018). More prolonged droughts by the end of the century in the Middle East. *Environmental Research Letters*, *13*(10), 104005.

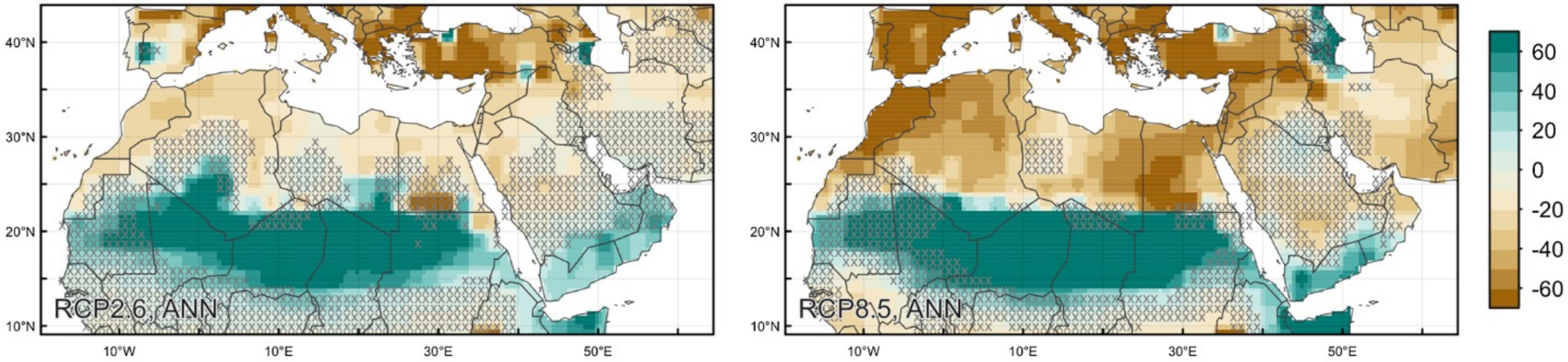
Projected changes in **number of dry days** between 1971–2000 and 2070–2099 based on the median ensemble of seven WAS-CORDEX RCM runs. Values are masked in gray where the changes are not robust .

Extreme events: Droughts

Waha, K., et al. (2017). Climate change impacts in the Middle East and Northern Africa (MENA) region and their implications for vulnerable population groups. *Regional Environmental Change*, *17*(6), 1623–1638.

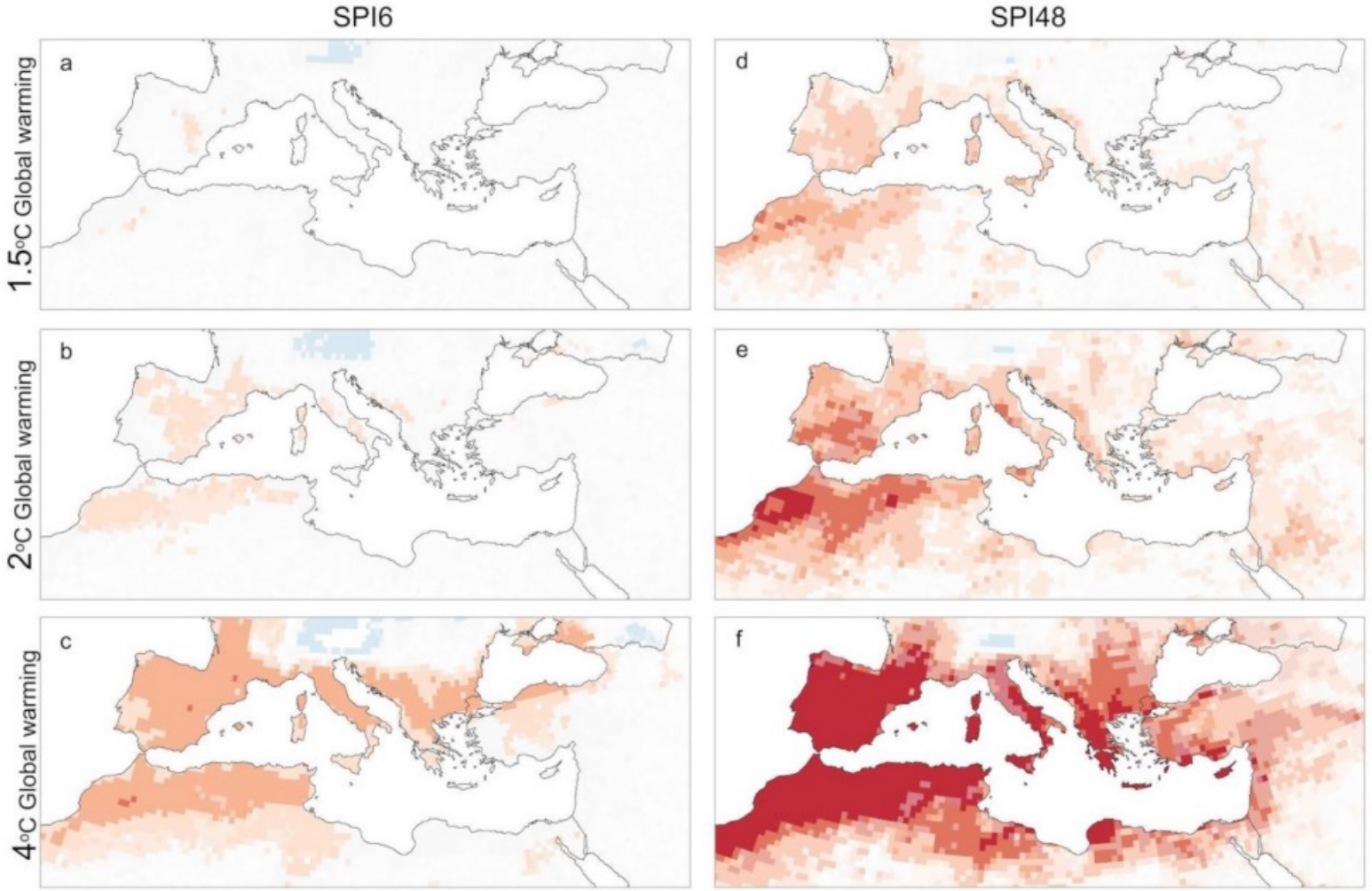
RCP2.6

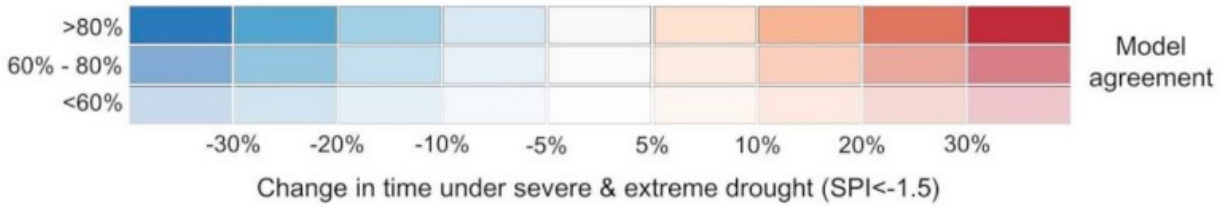
RCP8.5



The percentage change in the **aridity index** by 2071–2099 relative to 1951–1980. Hashed areas indicate uncertain results, with models disagreeing on the direction of change.

Extreme events: Droughts

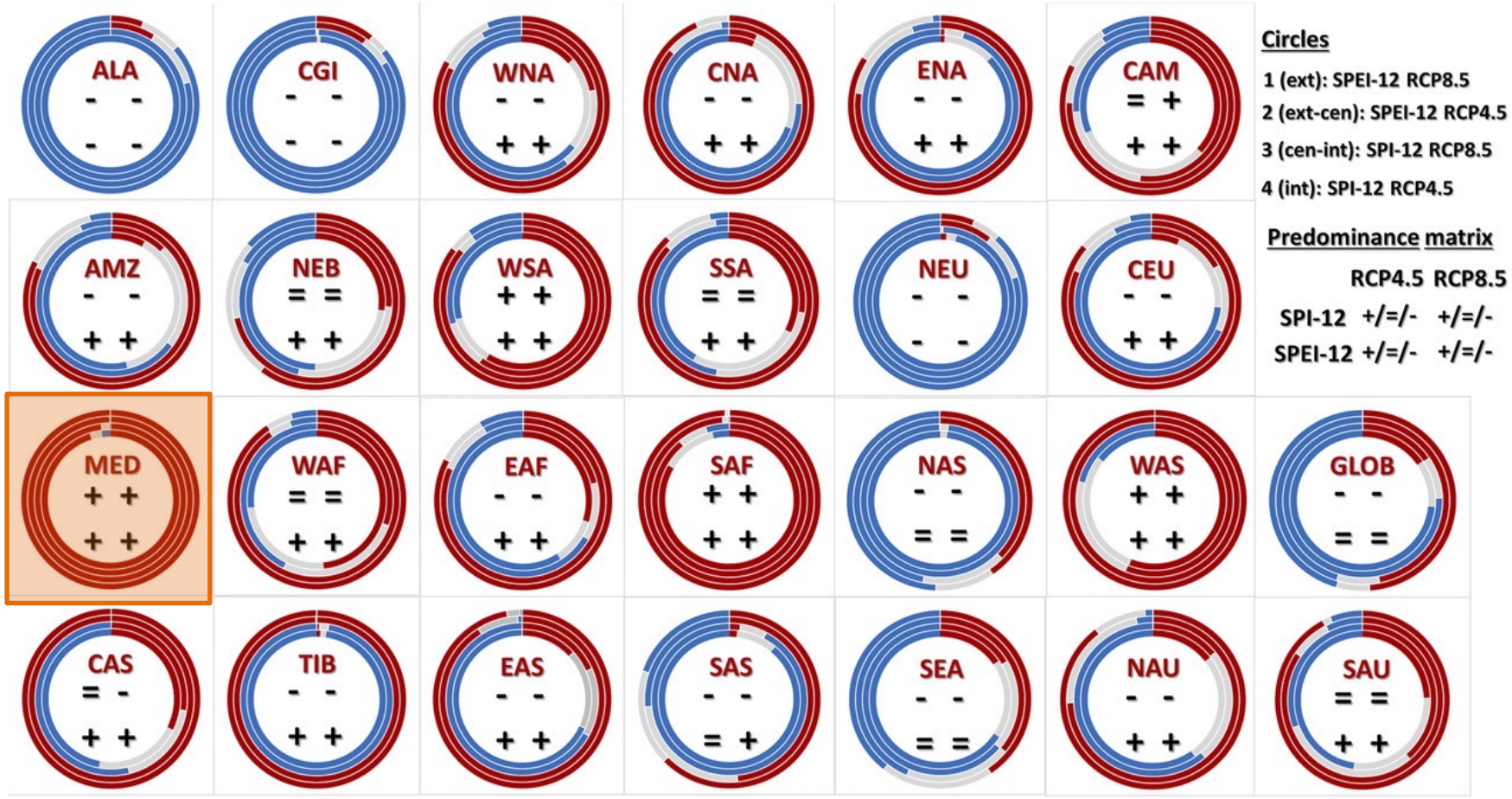




Tramblay, Y., Koutroulis, A., Samaniego, L., Vicente-Serrano, S. M., Volaire, F., Boone, A., et al. (2020). Challenges for drought assessment in the Mediterranean region under future climate scenarios. *Earth-Science Reviews*, *210*, 103348. https://doi.org/10.1016/j.earscirev.2020.103348

Mediterranean areas projected to experience increases in time under **severe and extreme drought** (SPI < -1.5).

Extreme events: Droughts



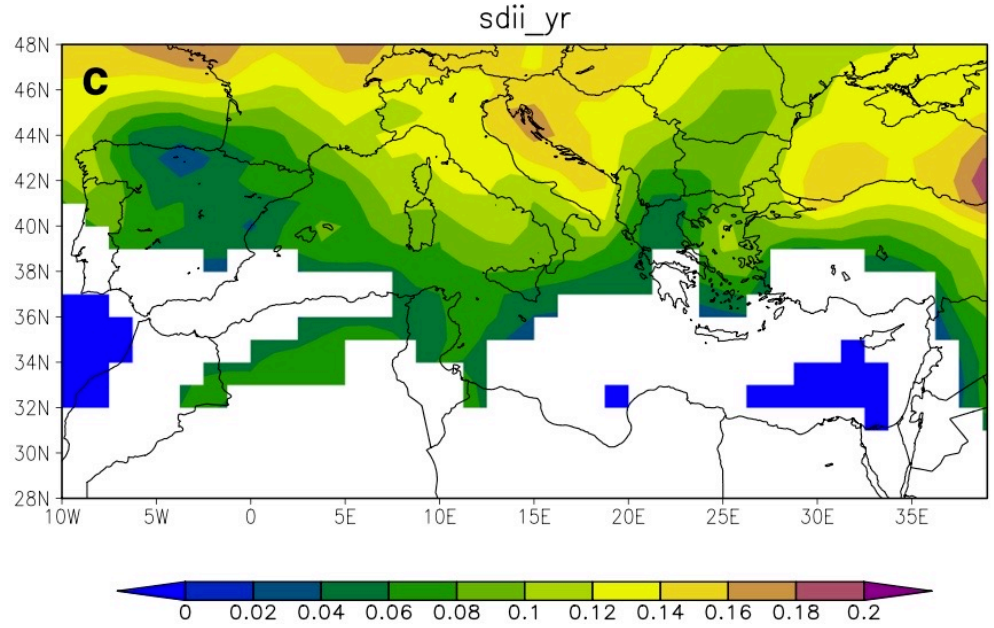
Simultaneous increase (red) or decrease (blue) in frequency and severity of drought events from 1981-2010 to 2071-2100

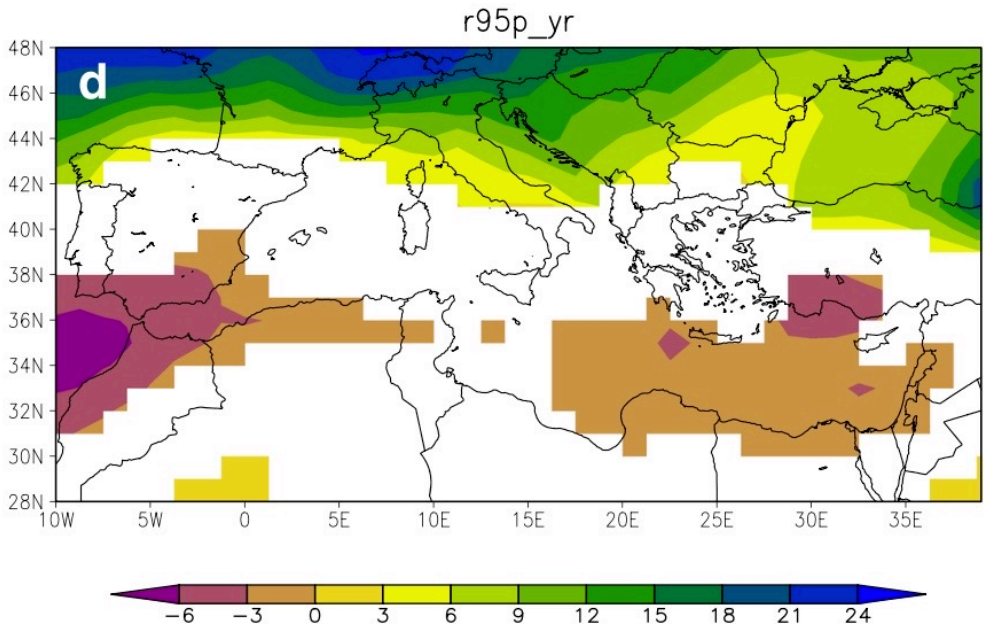
×□□W !"#$%&'()*+,-./012345 Bucchignani, E., Cassano, J., Cavazos, T., Christensen, J. H., et al. (2020). Future global meteorological drought hot spots: A study based on CORDEX data. Journal of Climate, 33(9), 3635–3661.

Percentage of areas projected to experience an increase (red) or decrease (blue) in both drought frequency and severity from 1981–2010 to 2071–2100. Gray refers to either mixed or not robust changes.

Future projections of high-impact extreme events: Extreme precipitation

Extreme events: Extreme Precipitation

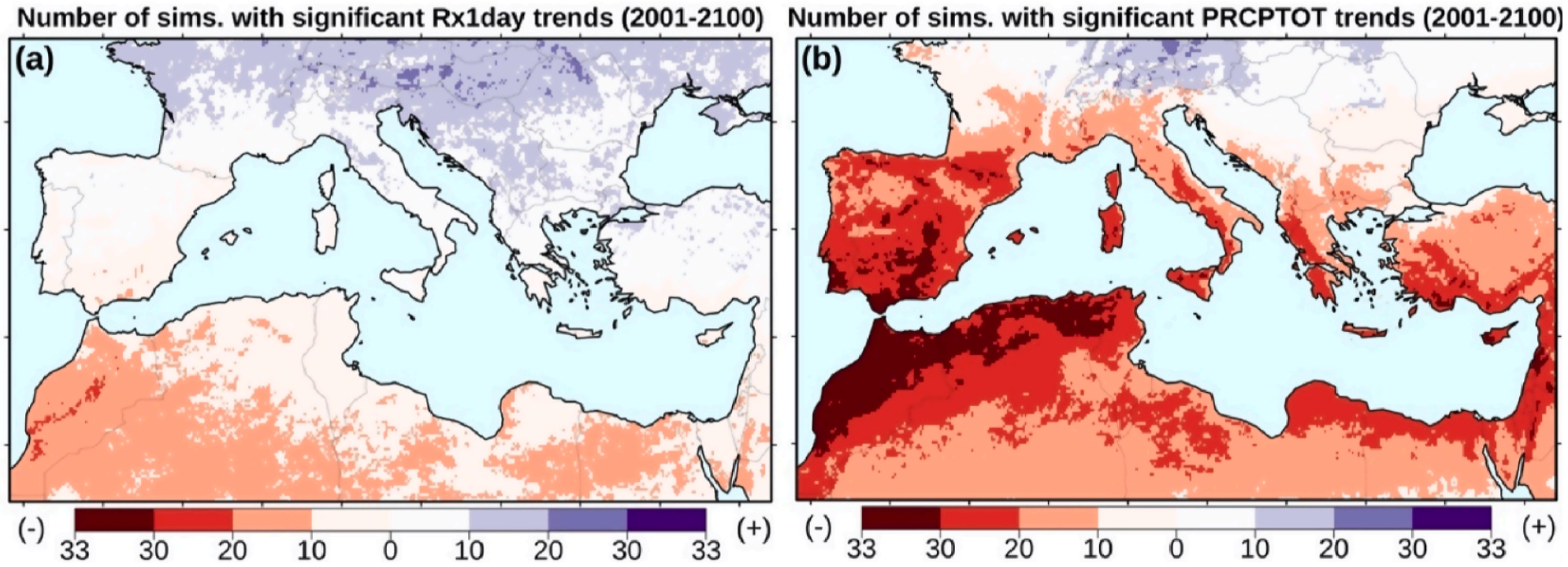




Lionello P., Scarascia, L. (2020). The relation of climate extremes with global warming in the Mediterranean region and its north versus south contrast. Regional Environmental Change, 20(1), 31.

Rate of change with global temperature for **simple precipitation intensity index** (SDII; units, mm/K) – left and precipitation during **intense rain days** (R95pTOT, daily rain total in days with precipitation above the 95th percentile; units, mm/K) – right.

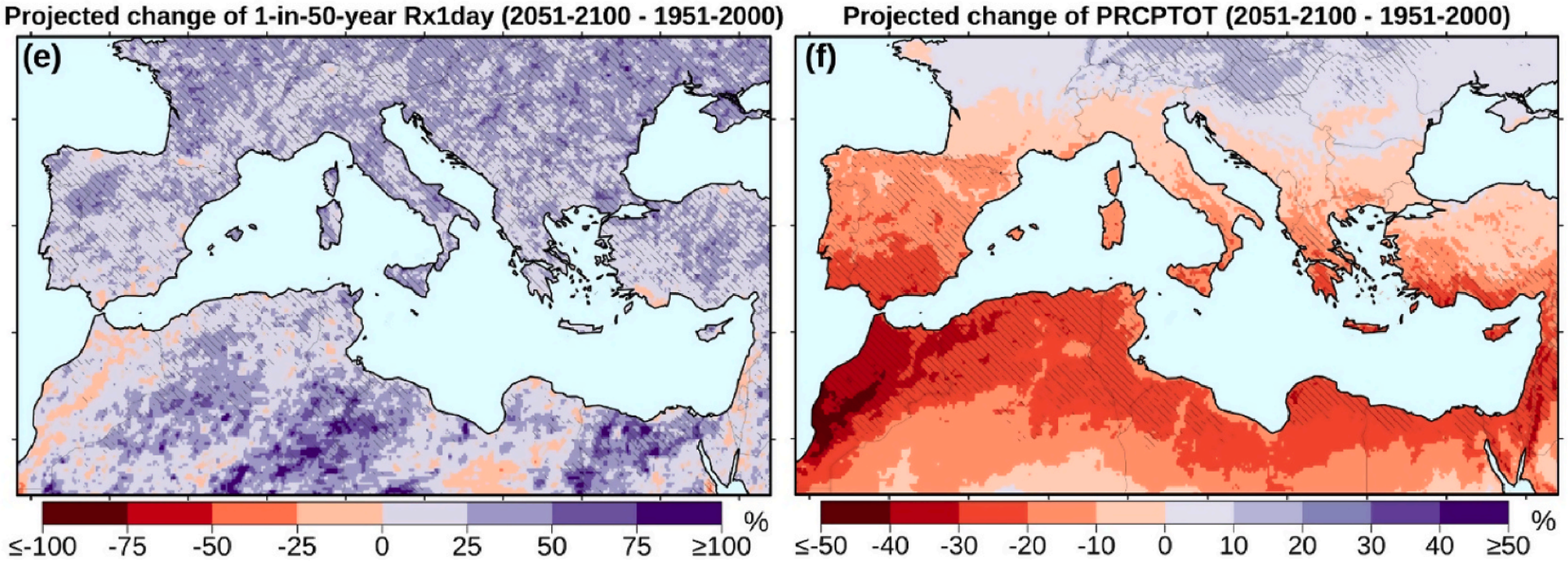
Extreme events: Extreme Precipitation



Zittis, G., Bruggeman, A., & Lelieveld, J. (2021). Revisiting future extreme precipitation trends in the Mediterranean. *Weather and Climate Extremes*, *34*, 100380.

Number of model simulations with significant (p-value < 0.05) positive (blue) and negative (red) non-parametric trends of **daily precipitation extremes** (Rx1day, left panel) annual precipitation (PRCPTOT, right panel) for the 21st century.

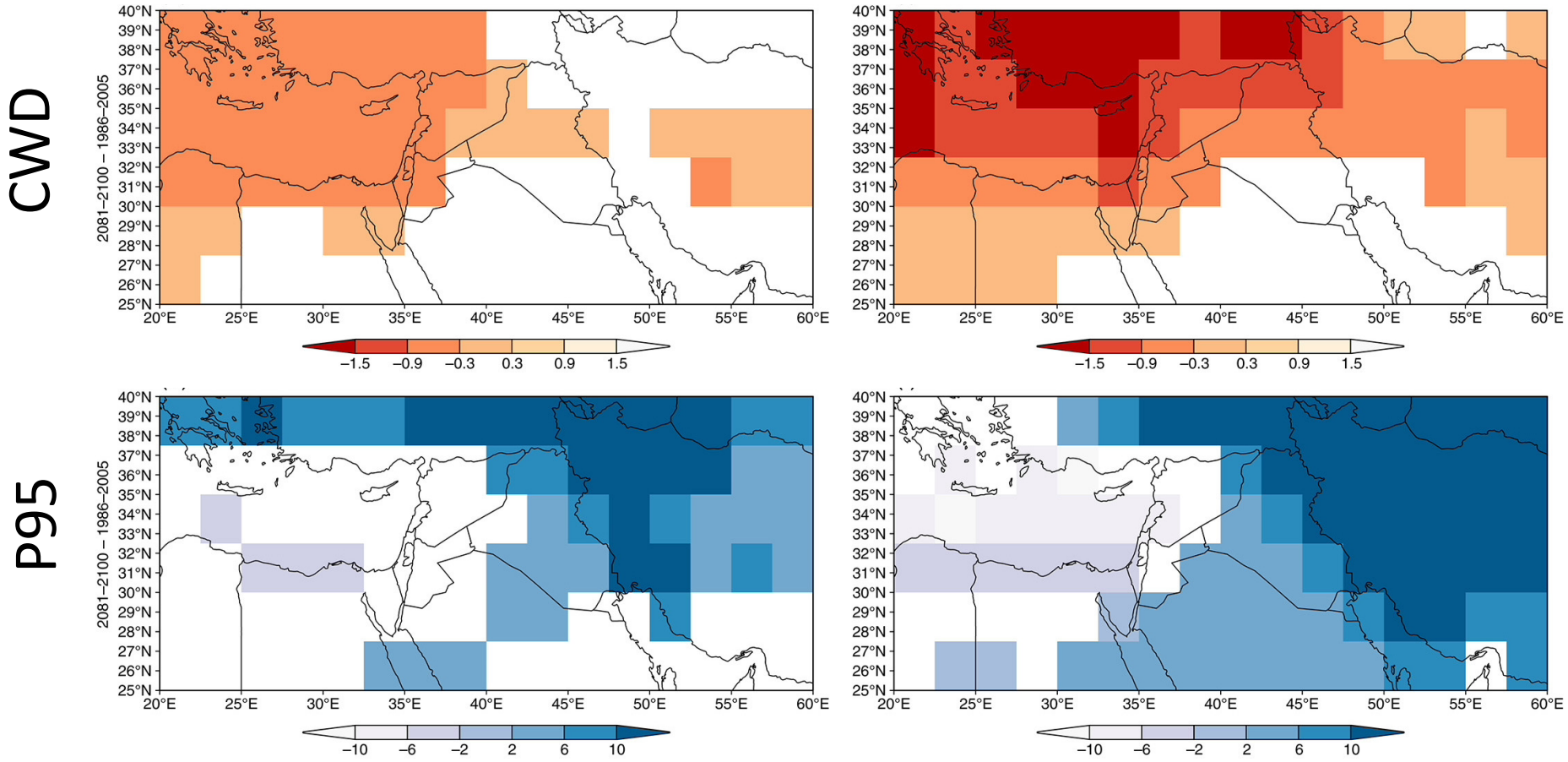
Extreme events: Extreme Precipitation



Zittis, G., Bruggeman, A., & Lelieveld, J. (2021). Revisiting future extreme precipitation trends in the Mediterranean. *Weather and Climate Extremes*, *34*, 100380.

Projected changes of end-of-century **maximum daily precipitation** (Rx1day, left panel) and total annual precipitation (PRCPTOT, right panel).

Extreme events: Extreme Precipitation



Samuels, R., Hochman, A., et al. (2018). Evaluation and projection of extreme precipitation indices in the Eastern Mediterranean based on CMIP5 multi-model ensemble. *International Journal of Climatology*, *38*(5), 2280–2297.

Projected end-of-century changes for the number of **consecutive wet days** (CWD) and **extremely wet days** (P95) based on CMIP5 global models.

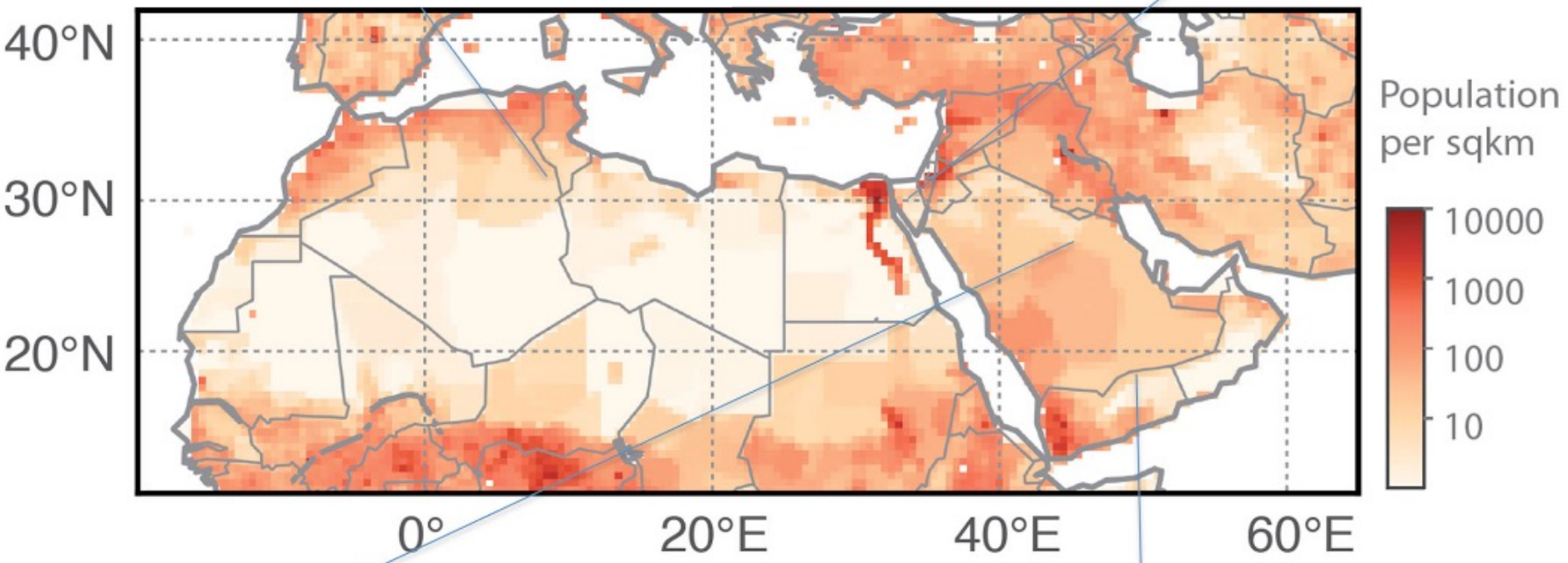
Summary

Mashrek /Eastern MENA

- Unusual heat
- Decrease in annual precipitation increases aridity
- Likely decrease of snow water storage and river runoff

Implications

- *Mostly for rain-fed agricultural and food production*
- *For farmers' livelihood, country economy, and food security*
- *Risk for accelerated migration flows to urban areas, social uprising and violent conflict.*



Central Arab Peninsula

- Unusual heat extremes
- Uncertain trend of annual precipitation.

Implications

- *Decreased thermal comfort, labour productivity and health*

Southern Arab Peninsula

- Increase in annual precipitation, but negligible
- Sea level rise in the Arabian Sea likely higher than at Mediterranean and Atlantic Coast

Implications

- *Risk of storm surges and damage to infrastructures*
- *Increased thermal discomfort, posing risk to labor productivity and health*

Waha, K., et al. (2017). Climate change impacts in the Middle East and Northern Africa (MENA) region and their implications for vulnerable population groups. *Regional Environmental Change*, *17*(6), 1623–1638.

Thank you for your kind attention!!

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