Indian summer monsoon as a driver of summer heatwaves in the Eastern Mediterranean

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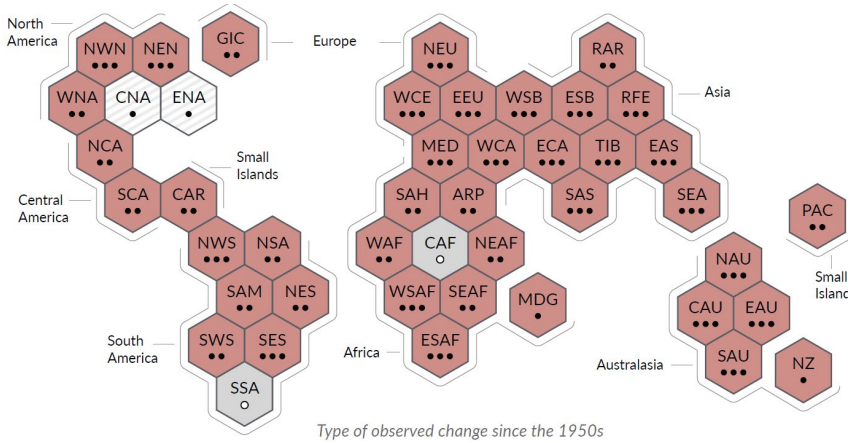
EGU – NH11.2 - Future Changes in Weather and Climate Hazards around the World

Solicited talk

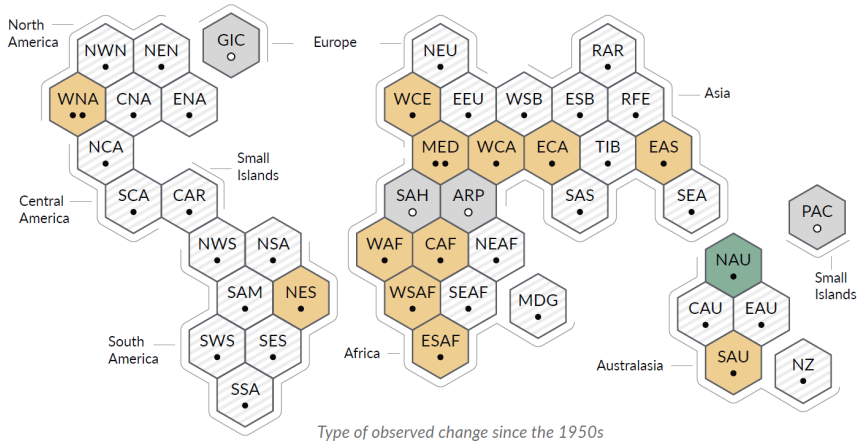
Mediterranean: climate change hotspot

IPCC - Working Group I – Sixth Assessment Report

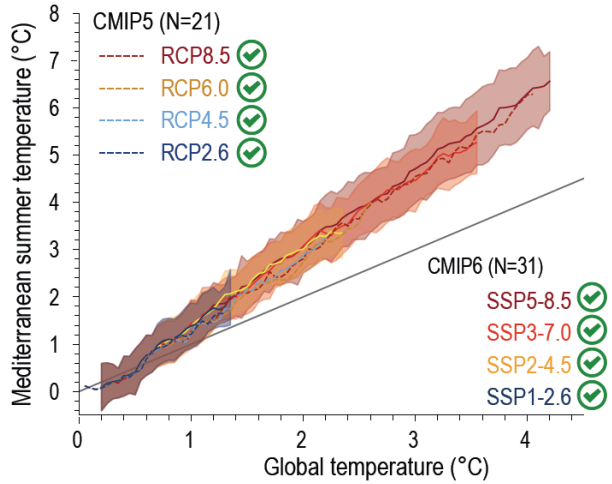
(a) Heat extremes



(b) Agricultural and ecological drought



(c) Mediterranean vs global warming



2023 summer **heatwaves**…

- Italy and Balkans heat wave
- Israel heatwaves (mid-July)
- Syria, Lebanon, Tunisia, Jordan
- Detrimental effect on human health, economy and the environment

Source: Thrace wildfire (NASA Observatory)

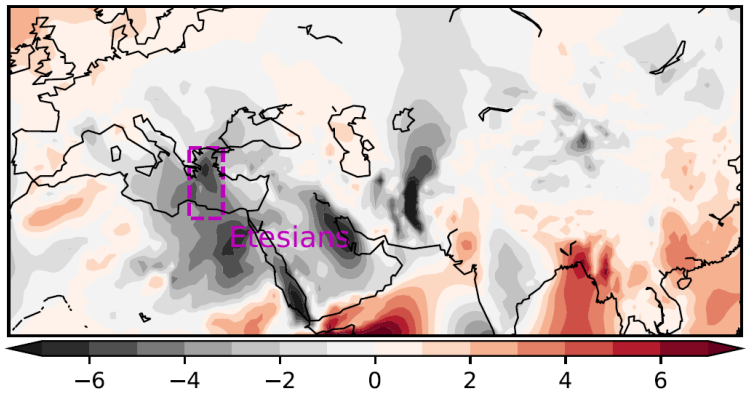
…and **wild fire**

- Rhodes, Athens (July), East Macedonia and Thrace (August, high winds and extreme temperatures)
- Algeria(34 casualties) heat dome

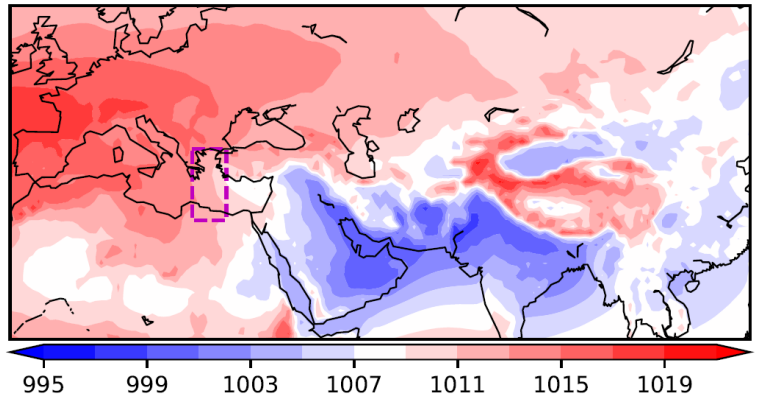
Etesians and the Eastern **Mediterranean** summer **climate**

- Persistent northerly winds, characterize background flow
- Persian low: related to the Indian summer monsoon (ISM)
- peak in July-August
- Etesians outbreaks[1]: days with enhanced northerlies
- Bring cooler air from Eurasia towards the EMed → mitigate heat waves
- Can spawn wildfires

(a) ERA5, JJAS V850 1979-2022 climatology [m/s]



(b) ERA5, JJAS MSLP 1979-2022 climatology [hPa]



Indian summer monsoon (ISM) ? → **Etesians outbreaks** → **Mitigate heatwaves**

[1]Tyrlis, E., and J. Lelieveld, 2013: Climatology and Dynamics of the Summer Etesian Winds over the Eastern Mediterranean. J. Atmos. Sci.

Causal discovery algorithm: PCMCI

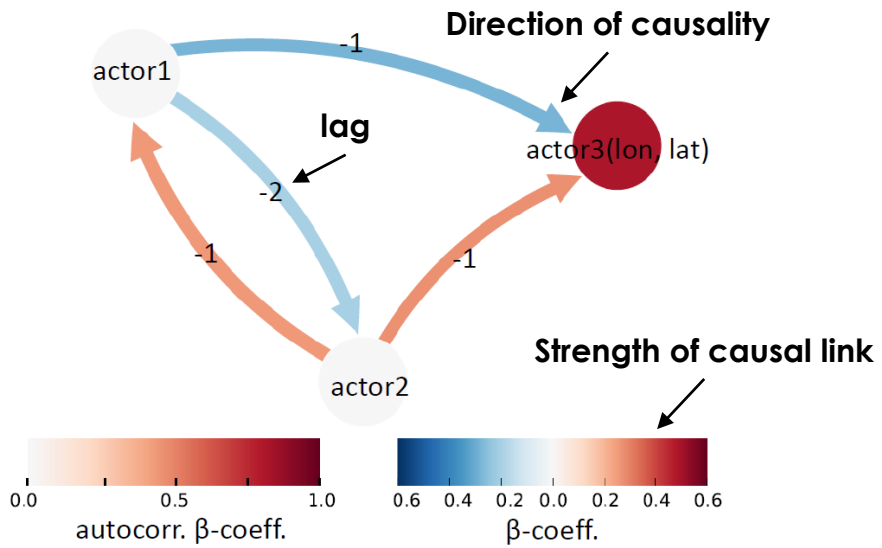
Identify the casual relationship between two (or more) 1D time series:

- autocorrelation, common drivers, indirect links can inflate correlation

Peter and Clark monetary conditional independence (PCMCI)[1] distinguish between spurious and causal links

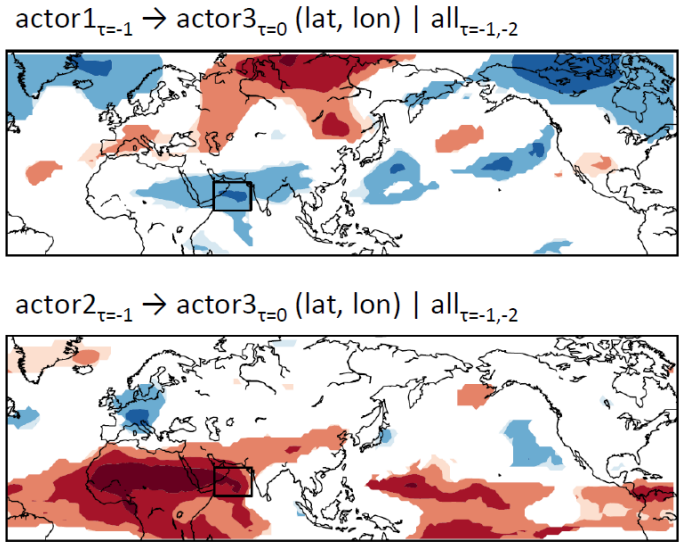
Using partial correlation to assess causal links in a set of several time series (actors)

Causal effect network



Causal maps

- Disentangle causal and spurious links on a 2D map
- Calculate a causal effect network for each grid point



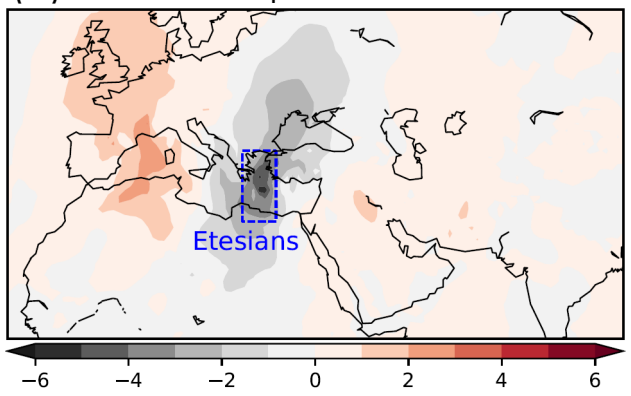
[1]Runge J., Causal network reconstruction from time series: From theoretical assumptions to practical estimation Chaos 28, 075310 (2018); https://doi.org/10.1063/1.5025050

"Tropical and mid-latitude causal drivers of the eastern Mediterranean Etesians during boreal summer"

Di Capua, Tyrlis, Matei & Donner (in review Clim. Dynamics)

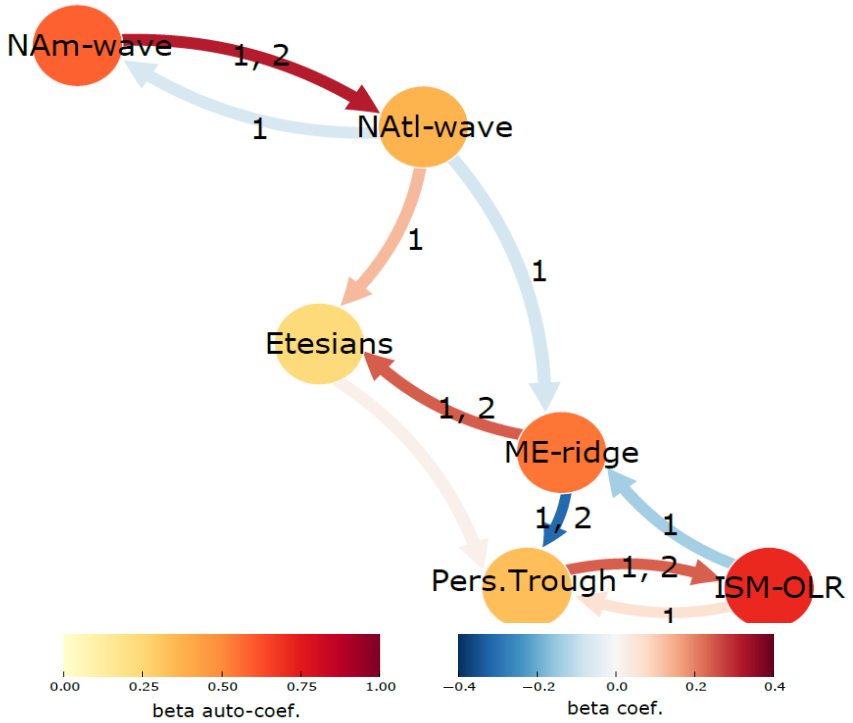
- Etesians influence climate in the eastern Mediterranean
- Causal links and dynamics of the mid-latitude and ISM influence on Etesians variability

(a) ERA5, composite V850



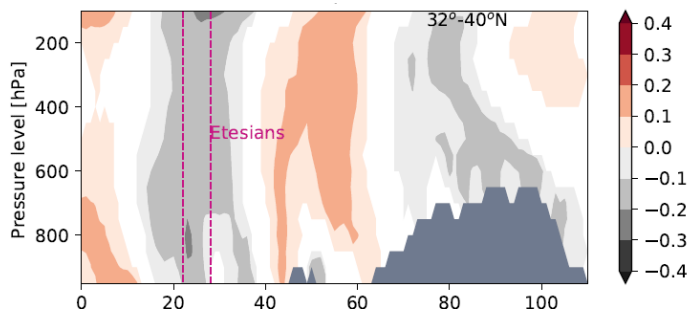
- Indirect causal pathway connecting ISM convective activity and Etesians

(b) ERA5, CEN 3-day

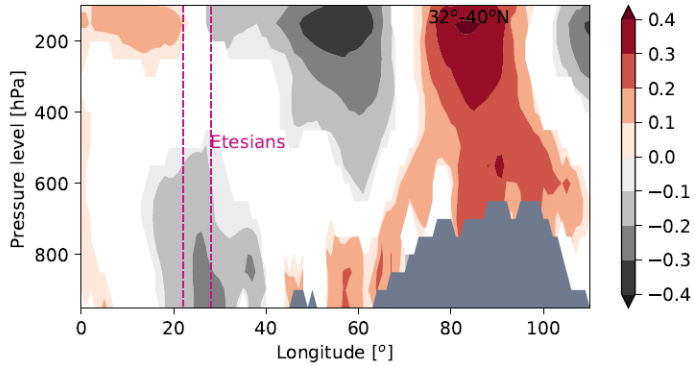


- ISM activity may provide potential for better forecasting heat waves in the Mediterranean

(c) Natl-wave → V-wind



(d) ME-ridge → V-wind

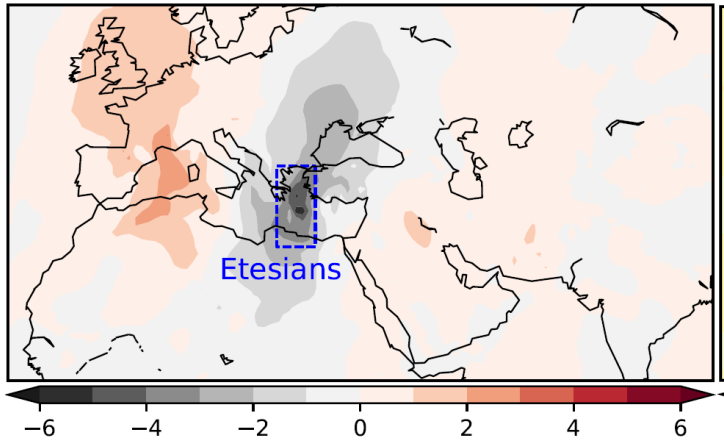


Pre-print https://www.researchsquare.com/article/rs-3903453/v1

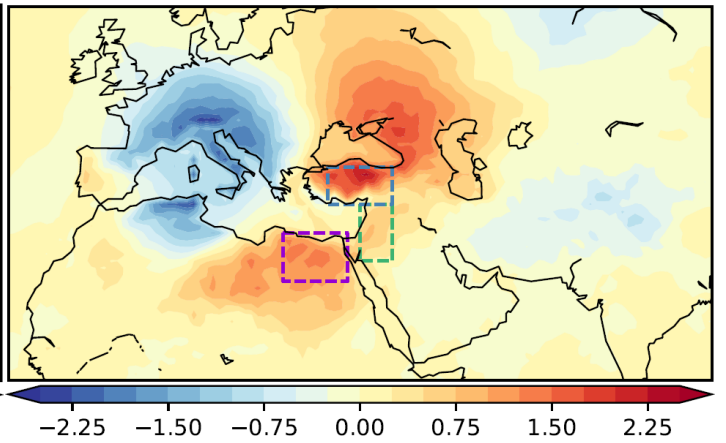
ERA5 – Etesians and extreme temperatures in the eastern Mediterranean

- ERA5, 1979-2022, 3-day time steps, JAS
- E-Med. shows temperatures anomalies **0.5-2°C** above JAS mean during weak Etesians (< 1 s.d.)
- What about specific regions?

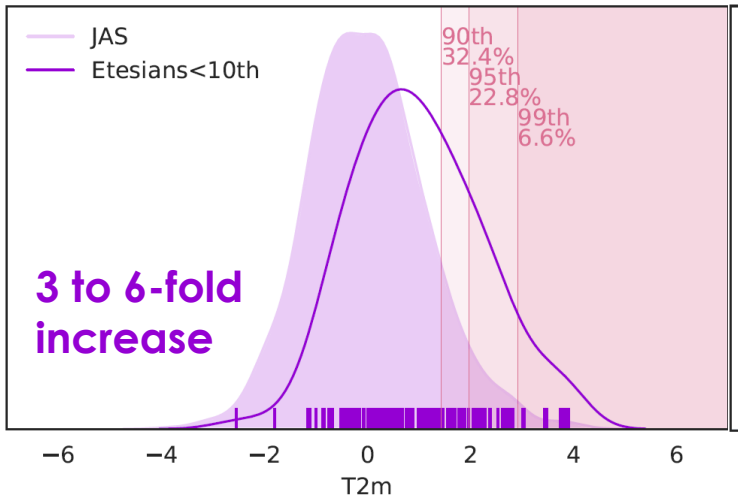
(a) Composite V850



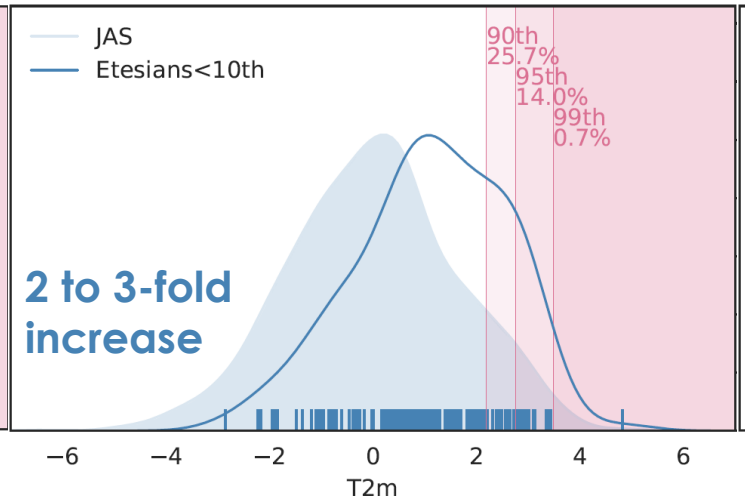
(b) Composite T2m



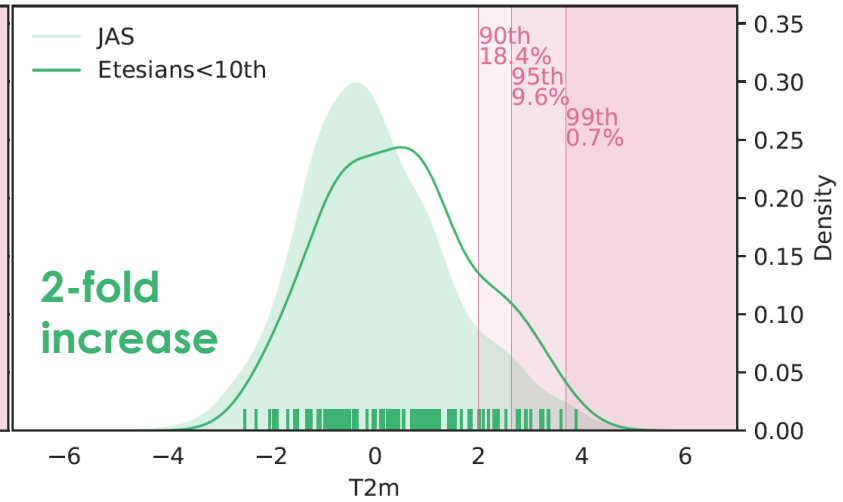
(c) PDF T2m Egypt



(d) PDF T2m Turkey



(e) PDF T2m Middle East

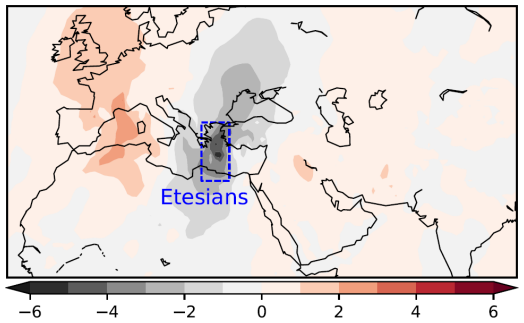


ERA5 – causal driver of high temperatures in the eastern Mediterranean

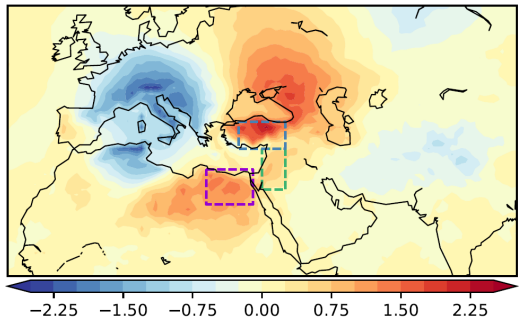
- Di Capua et al. (Clim. Dynamics in review)
- Causal link: **ISM → ME-ridge → Etesians** (3-day)
- Can we show a causal link towards **T2m**?

- **ISM → ME-ridge → Etesians → T2m** ✓
- Causal link to T2m **negative**: weaker Etesians lead to higher temperature anomalies

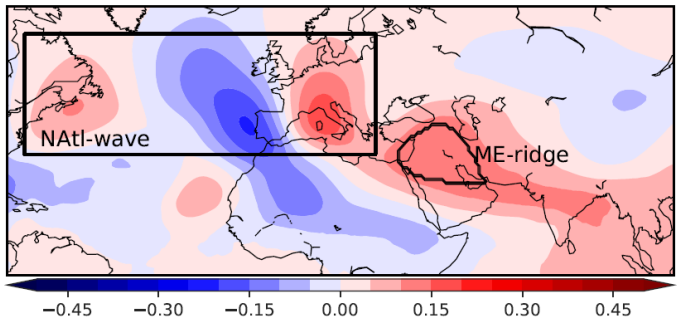
(a) Composite V850



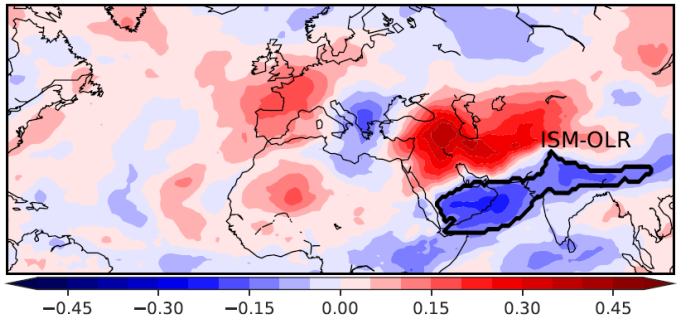
(b) Composite T2m



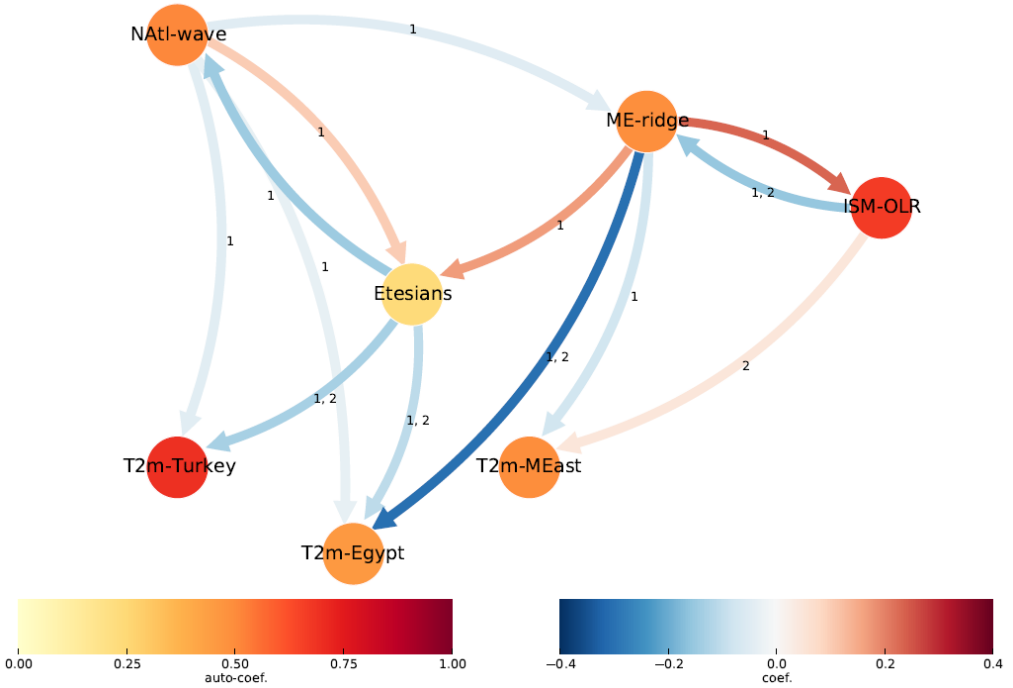
(c) Corr. Map Etesians – Z200; lag -1



(d) Corr. Map ME-ridge – OLR; lag -1



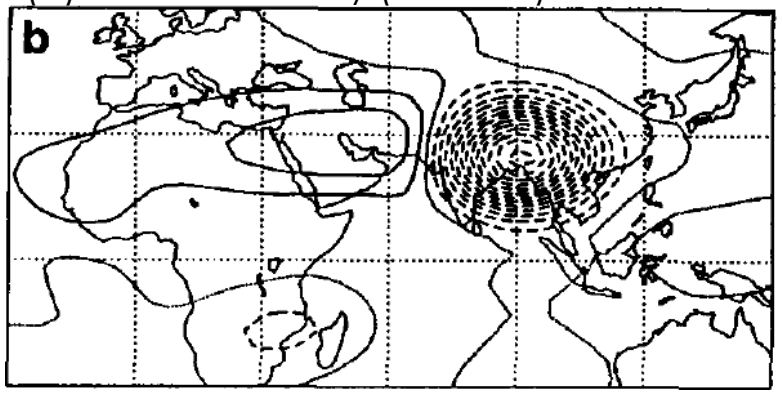
(e) CEN – Etesians drivers and T2m; 3-day



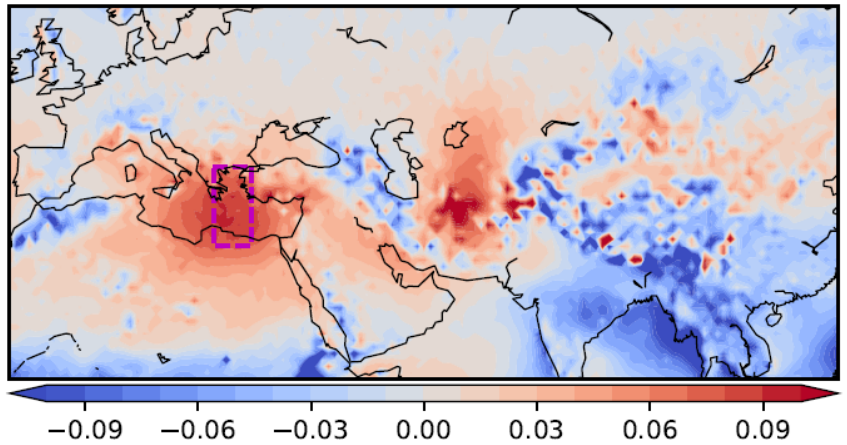
Monsoon – desert mechanism

- **Rodwell & Hoskins** (**1996**) latent heat released over ISM → Rossby waves response to the west
- Enhanced subsidence over North Africa

(a)Vertical velocity (477 hPa)

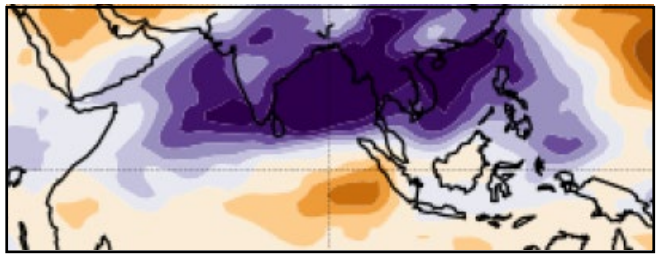


(b) ERA5, JJAS W500 1979-2022 clim. [Pa/s]

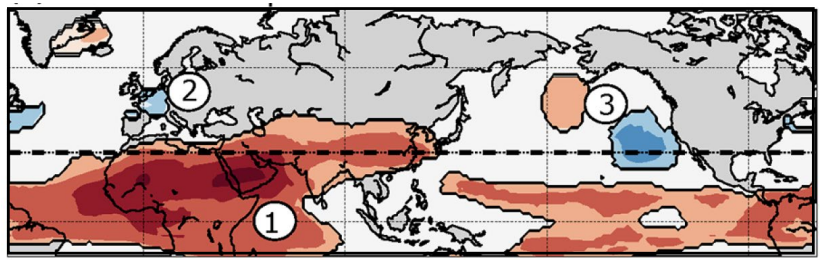


- **Di Capua et al.** (**2020**), **Di Capua et al.** (**2023**)
- ISM → Z200 ridge over North Africa
- SEAS5 underestimates this link

(c) ERA5, 1979-2020, ISM



(d) ERA5, 1979-2020, 7-day, ISM → Z200



Research question: can weak (or strong) Indian summer monsoon **seasons** influence the probability of heat waves in the eastern Mediterranean?

Di Capua et al. (2020) https://wcd.copernicus.org/articles/1/519/2020/ Di Capua et al. (2023) https://wcd.copernicus.org/articles/4/701/2023/

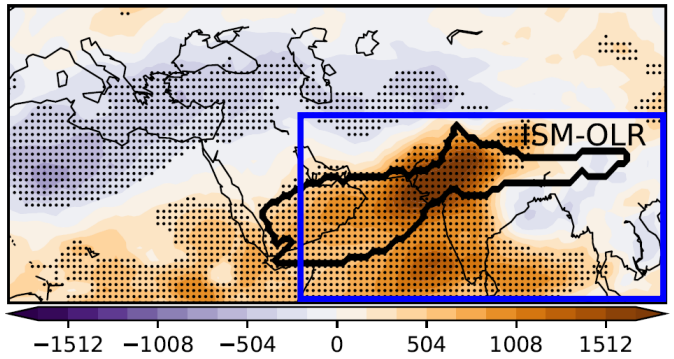
ERA5 – **weak** Indian summer monsoon (**ISM**) and **Etesians** drivers

- Outgoing longwave radiation (OLR): proxy for convective activity
  higher OLR → weaker/drier ISM

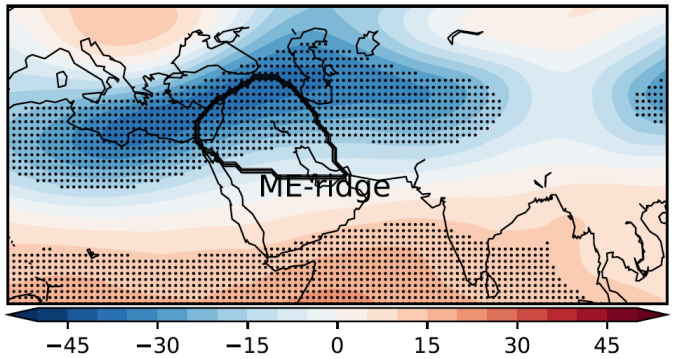
Composites for 4 years (JAS) with lowest ISM OLR over blue box:

- Positive OLR anom. (weaker ISM)
- negative Z200 anom.
- Positive V850 anom. (weaker Etesians)

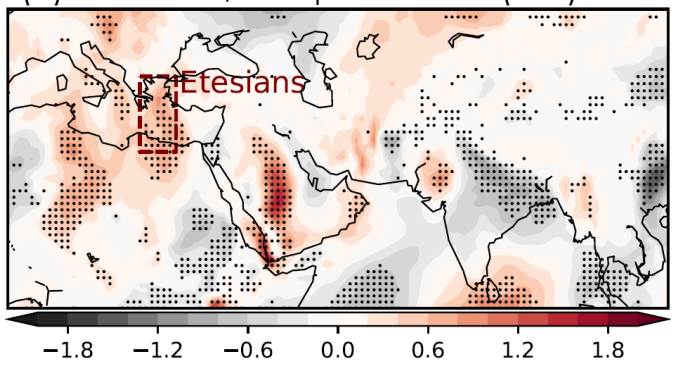
(a) Weak ISM, composite OLR (JAS)



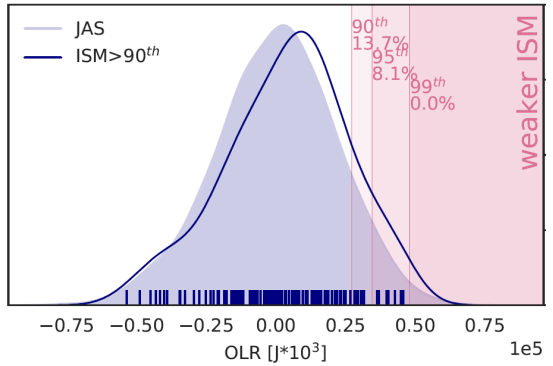
(b) Weak ISM, composite Z200 (JAS)



(c) Weak ISM, composite V850 (JAS)

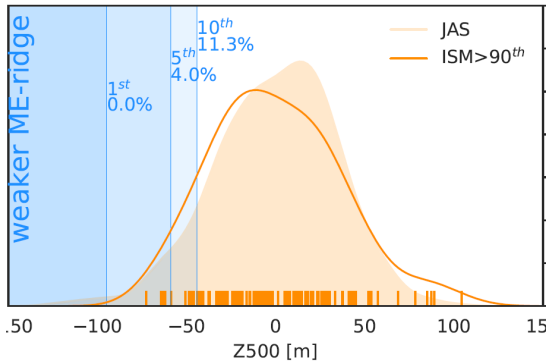


(d) PDF ISM-precursor 3-day



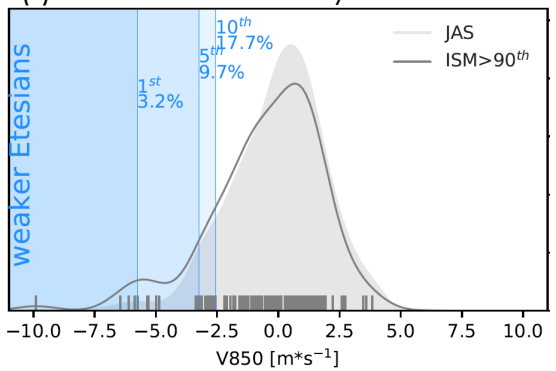
Higher probability weaker ISM

(e) PDF ME-ridge 3-day



Higher probability weaker ME-ridge

(f) PDF Etesians 3-day



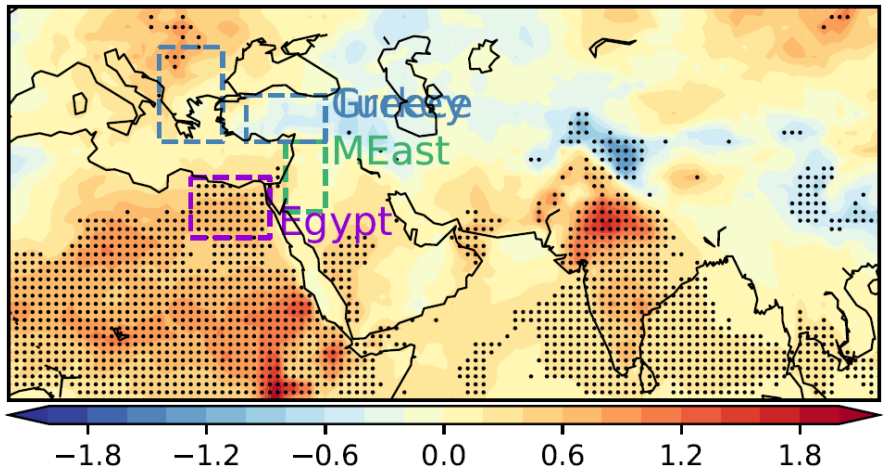
Higher probability weaker Etesians

ERA5 – **Weak** Indian summer monsoon (**ISM**) and **heatwaves** probability

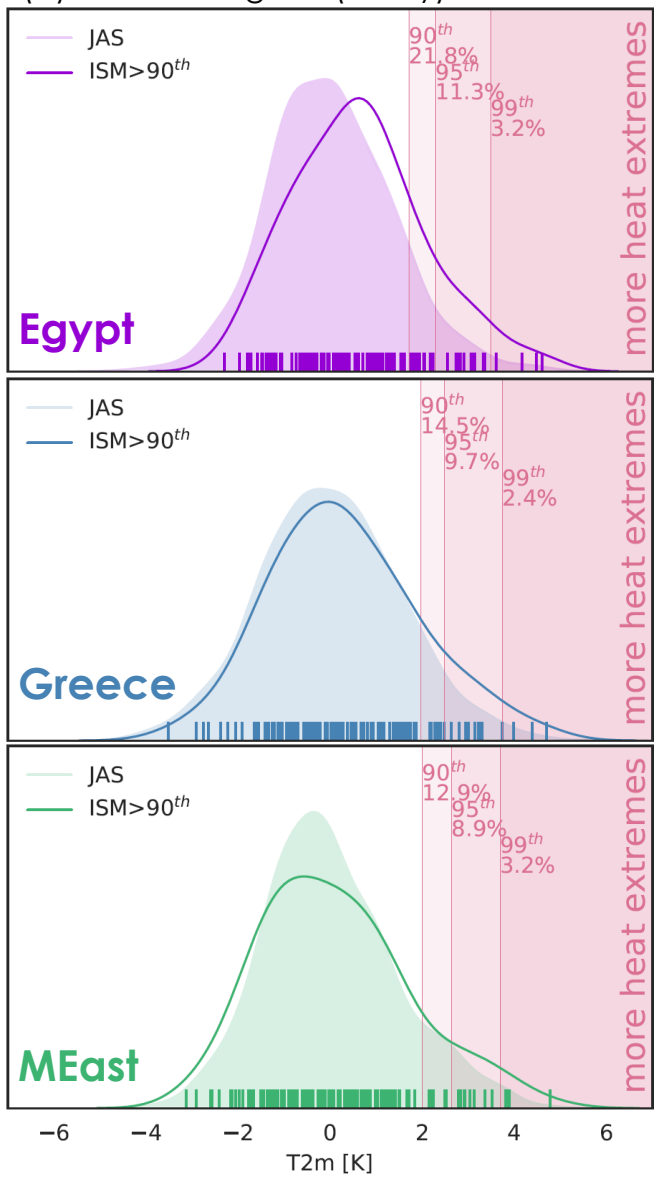
Composites for 4 years (JAS) with lowest ISM OLR (weak ISM)

- Positive T2m anomalies over Egypt, Greece, Balkans and Middle East
- Negative T2m anomalies over Turkey towards Caspian Sea

(a) Weak ISM, composite T2m (JAS)



(b) PDF T2m regions (3-day)



2 to 3-fold increase in probability extremes T2m-Egypt

1.5 to 2-fold increase in probability extremes T2m-Greece

1.3 to 3-fold increase in probability extremes T2m-MEast

SEAS5 – ECMWF seasonal forecasts

Seasonal forecasts: long-range predictions over periods of a few weeks or months

- changes slow-varying fields (e.g. SST, snow cover)
- Climate models: atmosphere, ocean and land surface
- Model ensembles

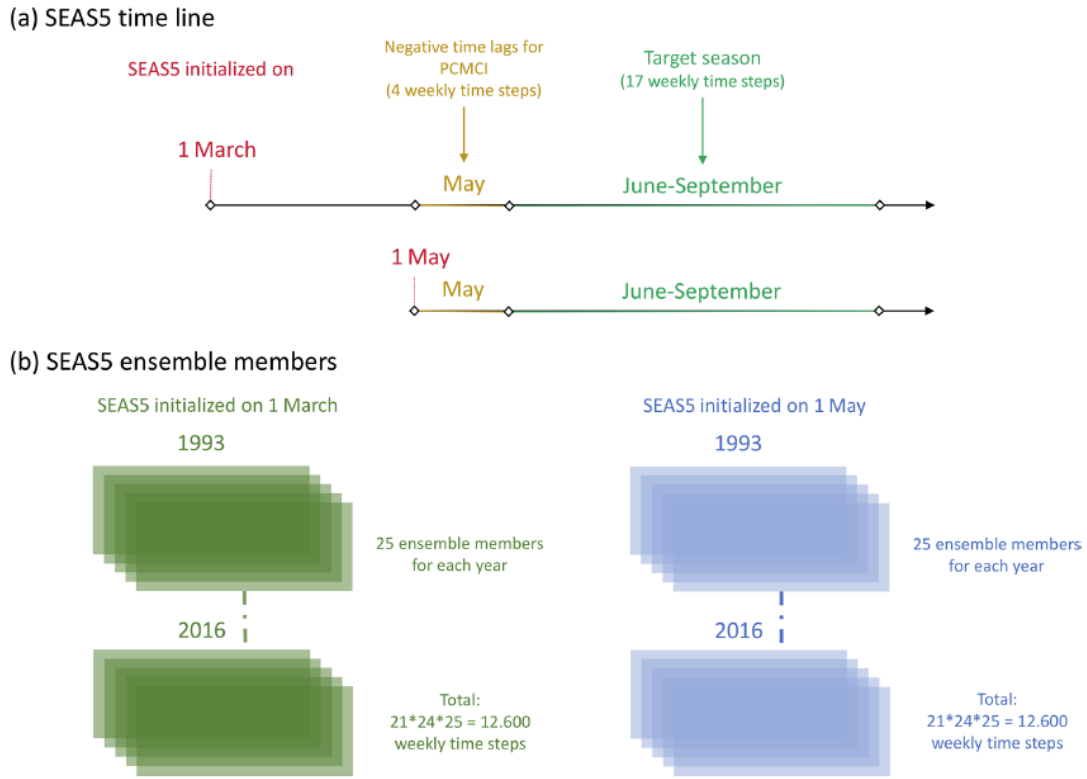
Advantages:

- model representation of physical mechanisms
- Large ensemble
- Initialized with observation every year

What is SEAS5?

- ECWMF seasonal forecasts, runs for ~9 months
- Init 1 May, 25 ens. m. for each year
- 1981-2022

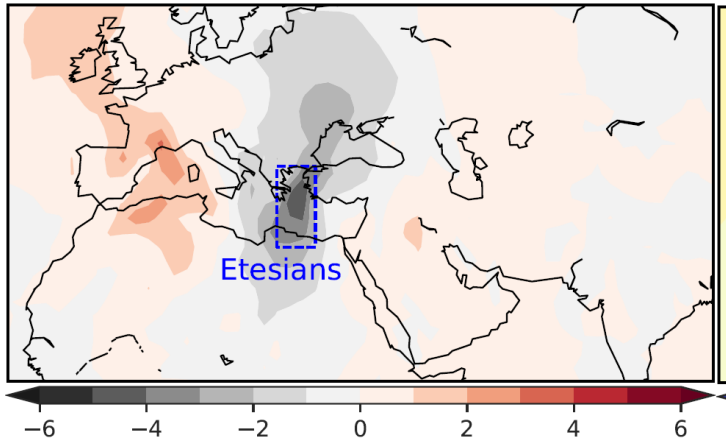
Fig. 1 Di Capua et al. (2023)



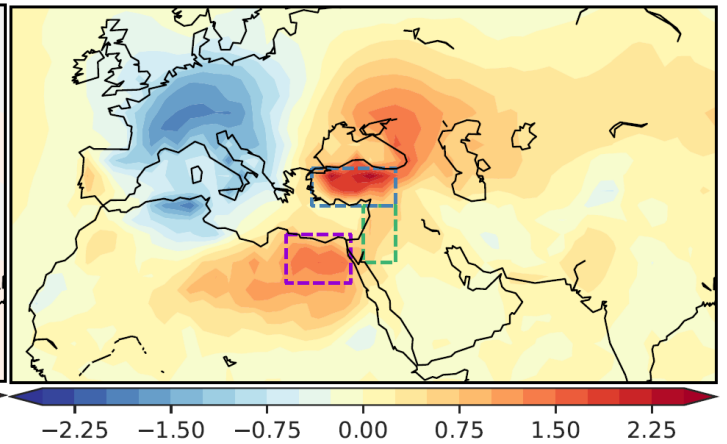
SEAS5 - Etesians and extreme temperatures in the eastern Mediterranean

- SEAS5, init May, 3-day time steps, JAS
- E-Med.: temperatures anomalies **0.5-2°C** above JJA mean during weak Etesians (< 1 s.d.)
- **Good agreement with ERA5!**

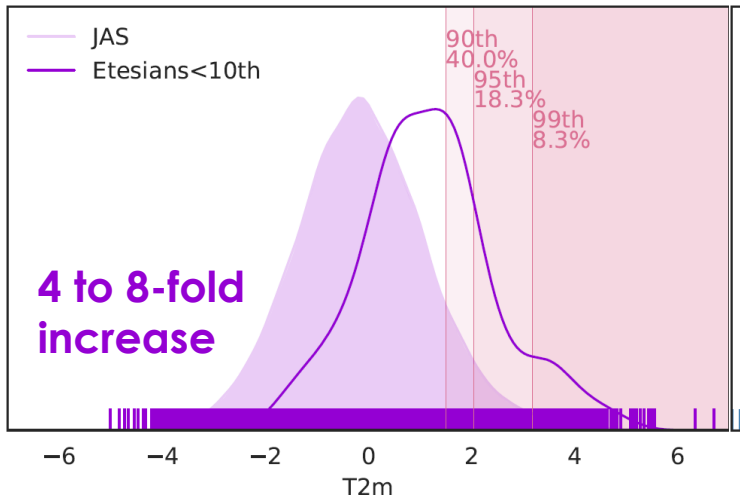
(a) Composite V850



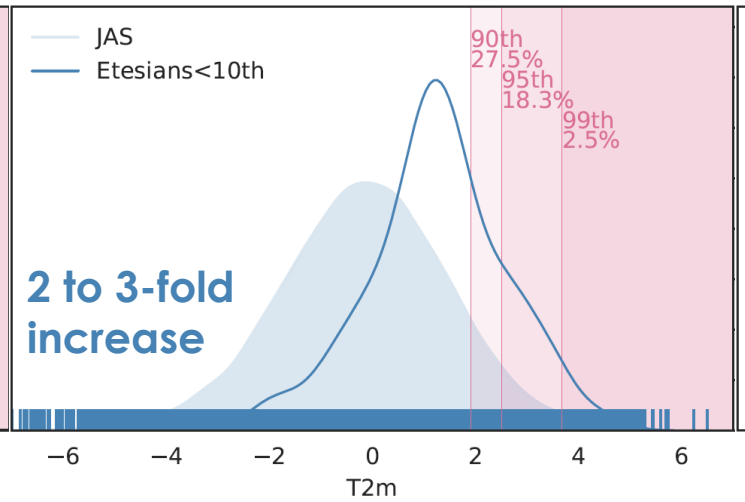
(b) Composite T2m



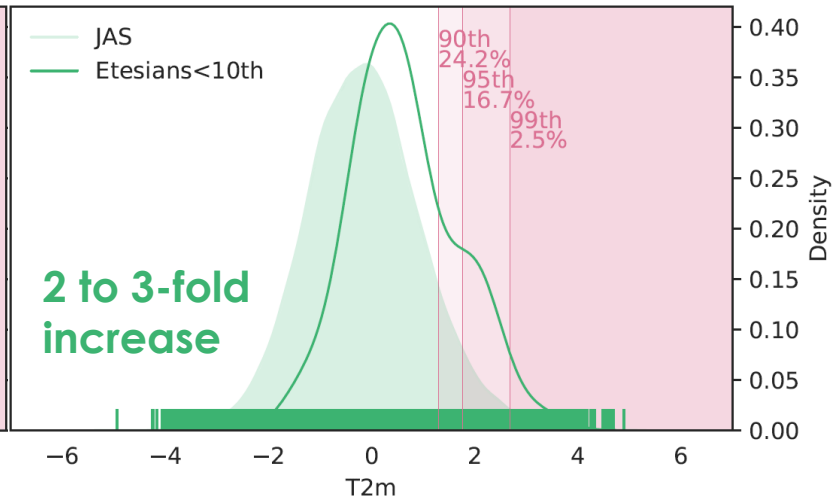
(c) PDF T2m Egypt



(d) PDF T2m Turkey



(e) PDF T2m Middle East



SEAS5 – **weak** Indian summer monsoon (**ISM**) and drivers of **Etesians**

- 1050 years in total (25*42)

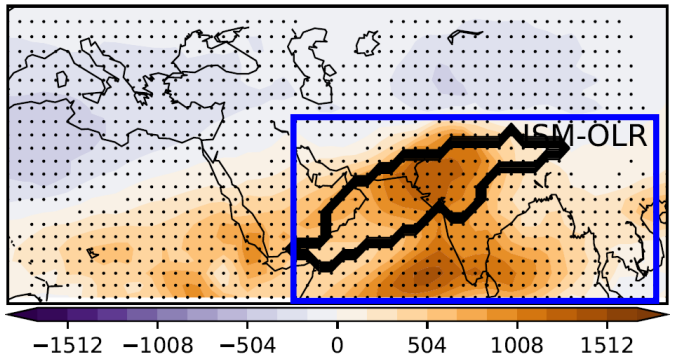
Composites for 100 years (JAS) with lowest ISM OLR over blue box:

- Positive OLR anom. (weaker ISM)
- negative Z200 anom.
- Positive V850 anom. (weaker Etesians)

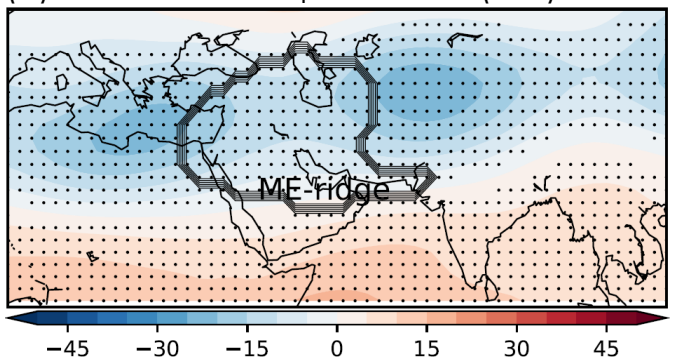
SEAS5 and **ERA5**:

- qualitatively agree
- magnitudes anomalies weaker in SEAS5

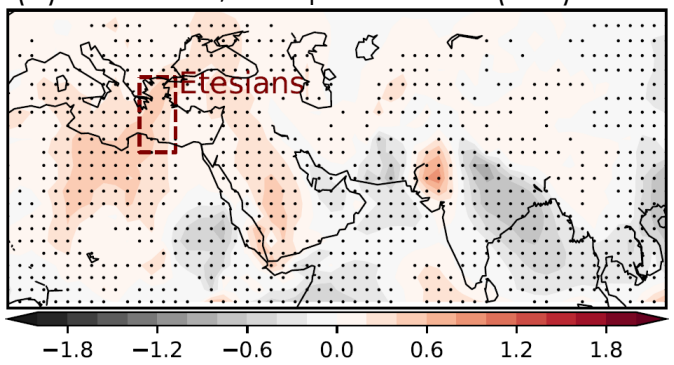
(a) Weak ISM, composite OLR (JAS)



(b) Weak ISM, composite Z200 (JAS)



(c) Weak ISM, composite V850 (JAS)



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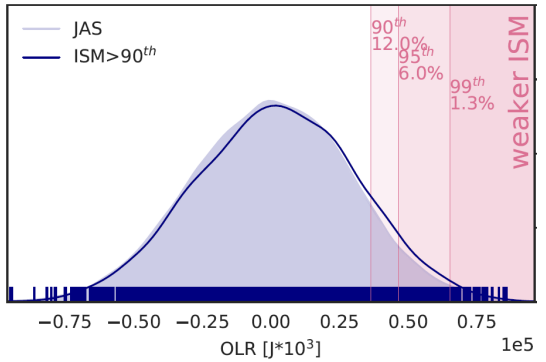
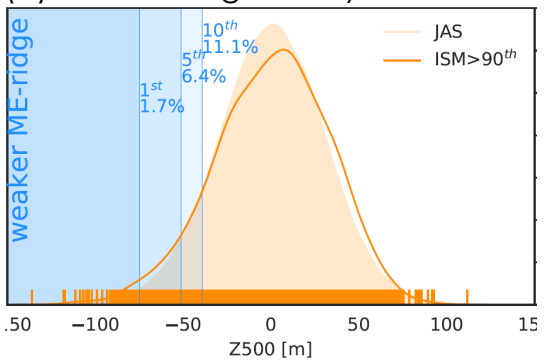


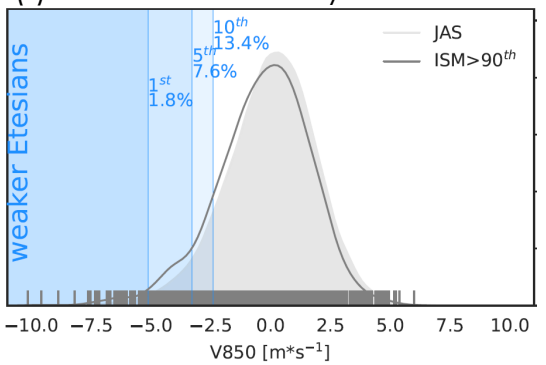
Higher probability weaker ISM

(e) PDF ME-ridge 3-day



Higher probability weaker ME-ridge

(f) PDF Etesians 3-day



Higher probability weaker Etesians

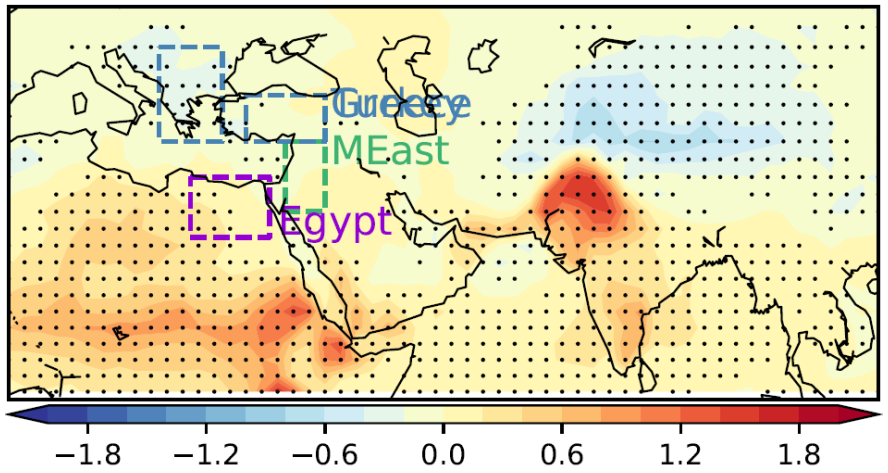
SEAS5 – **Weak** Indian summer monsoon (**ISM**) and **heatwaves** probability

Composites for 100 years (JAS) with lowest ISM OLR (weak ISM)

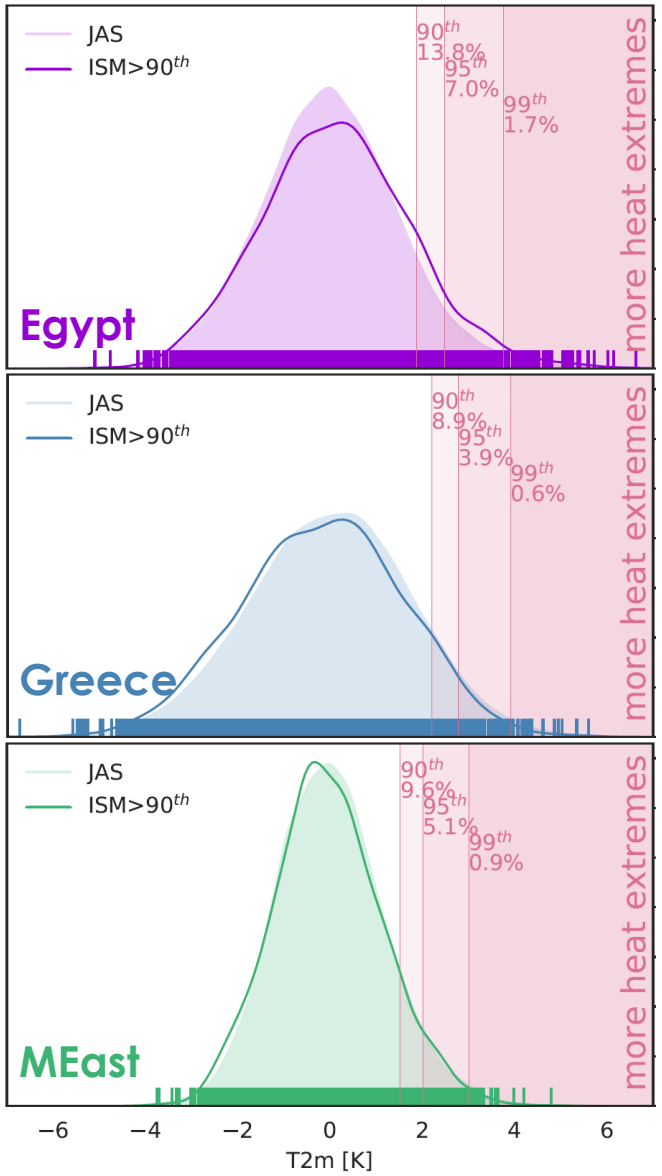
- Positive T2m anomalies over Egypt
- Negative T2m anomalies over Greece, Balkans and Middle East and Turkey

SEAS5 and **ERA5** qualitatively agree only over North Africa

(a) Weak ISM, composite T2m (JAS)



(b) PDF T2m regions (3-day)



1.4 to 2-fold increase in probability extremes T2m-Egypt

Decrease in probability extremes T2m-Greece

No change in probability extremes T2m-MEast

Next steps – Causality on **monthly** time scales

- From composites to causality (monthly)

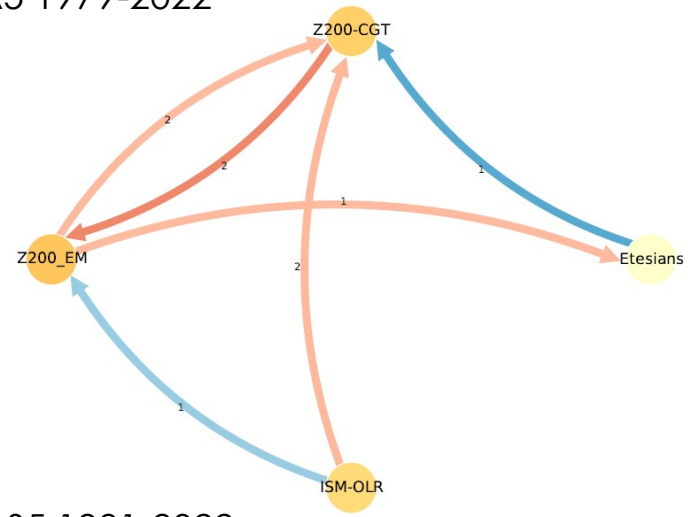
Causal maps:

- weak but consistent positive effect of ISM-OLR on temperature over north Africa (1-month lead)

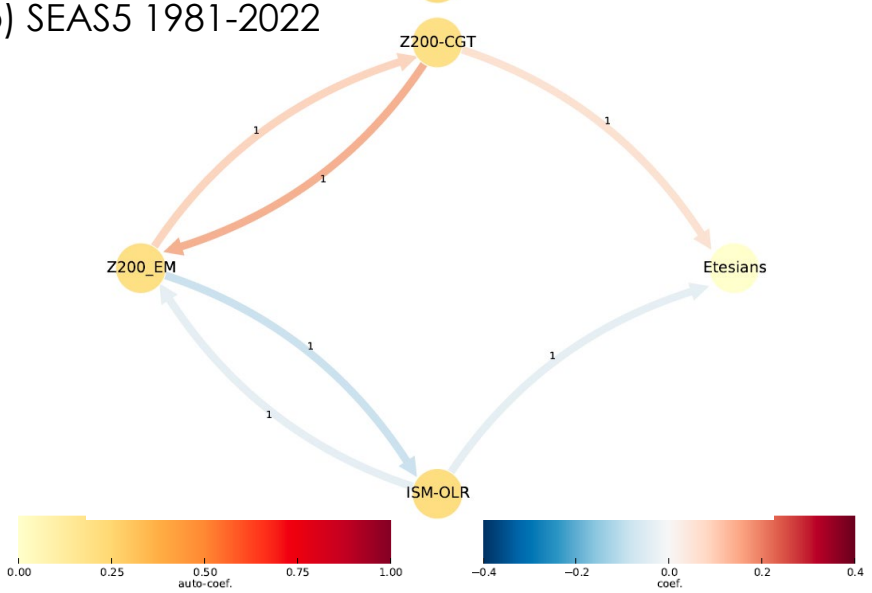
CEN:

- ISM → EMed-Z200 → Etesians pathway both in ERA5 and SEAS5. Differences need further investigation.

(a) ERA5 1979-2022

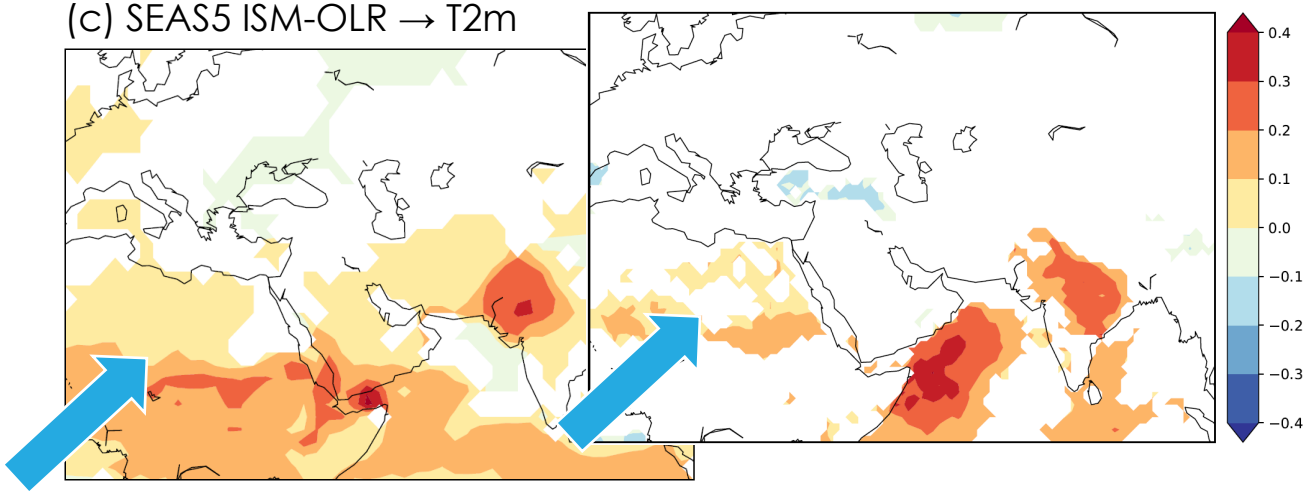


(b) SEAS5 1981-2022



(c) SEAS5 ISM-OLR → T2m

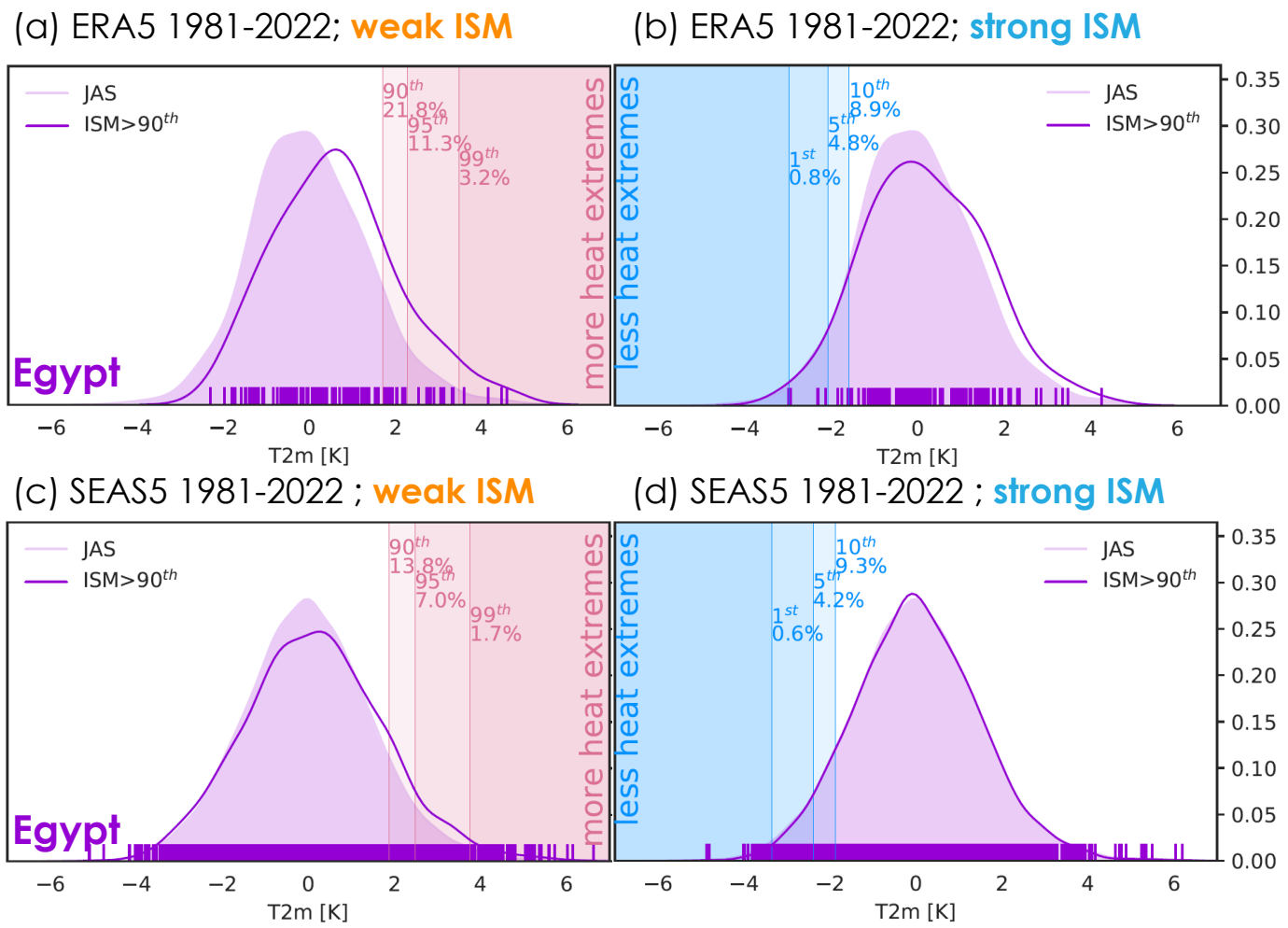
(d) ERA5, ISM-OLR → T2m



SEAS5 underestimates the monsoon-desert mechanism

Di Capua et al. (2023) **Validation of boreal summer tropical–extratropical causal links in seasonal forecasts** https://wcd.copernicus.org/articles/4/701/2023/

Is the **potential response** to the **ISM linear**?



- Egypt shows consistent relationship between ISM, Etesians and temperature in ERA5 and SEAS5

- Both in SEAS5 and ERA5, stronger ISM does not decrease probability of having high temperatures extremes

- Relationship seems to be nonlinear → no mitigation effect provided

Conclusions – Indian summer monsoon (**ISM**), **Etesians** and **heatwaves** in the eastern **Mediterranean**

- Intraseasonal (3-day) time scales: the Etesians winds prominently and consistently (model and observations) influence temperature extremes in the eastern Mediterranean

- Intraseasonal (3-day) time scales: the ISM convective activity influences the Etesians via the ME-ridge (indirect causal pathway to temperature in the area)

- Interannual time scales: weaker ISM leads to increase in probability of extreme temperature in ERA5, but only partly in SEAS5 (Egypt)

- The ISM may provide potential for seasonal forecasts of heat extremes in the eastern Mediterranean

- ISM projected to increase under climate change but relationship seems nonlinear → missed potential heatwave mitigation effect


Thank you for listening!
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