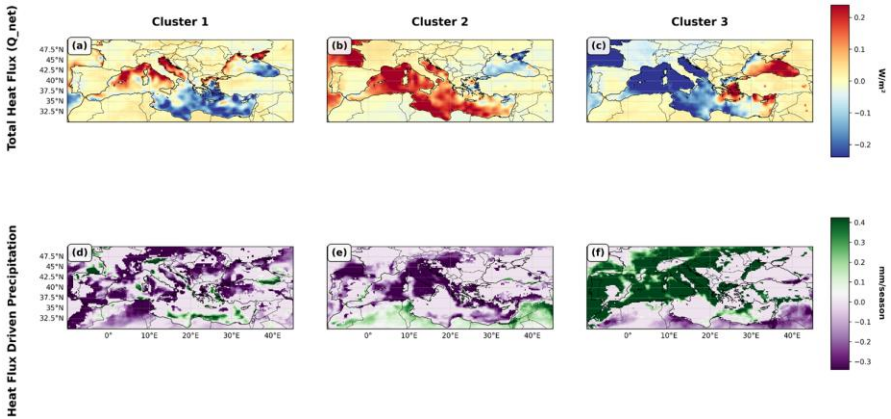
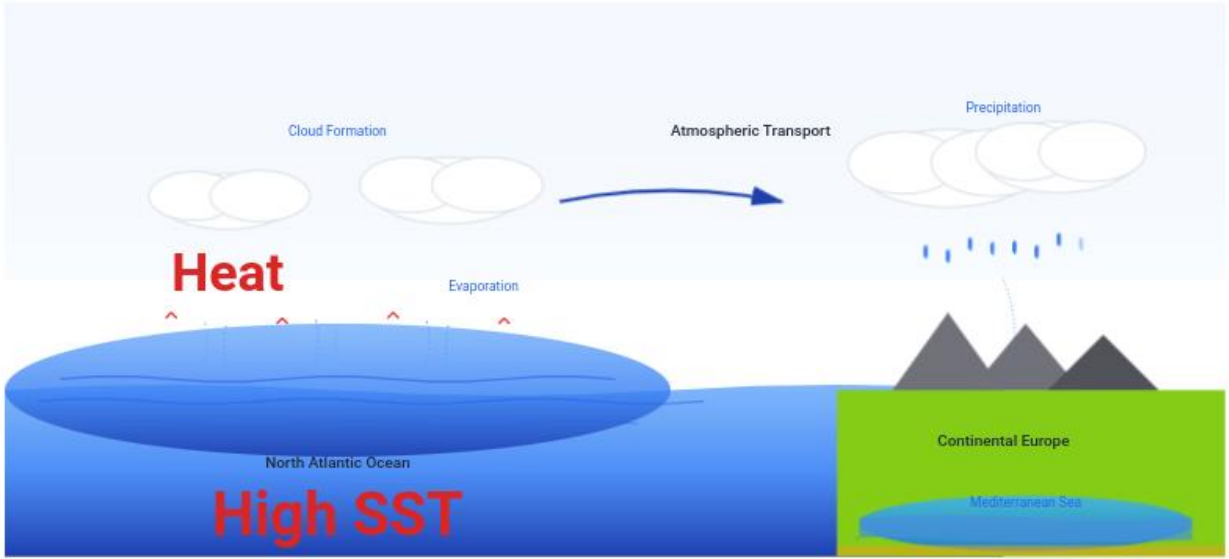
Understanding the 2022 - 2024 Mediterranean Droughts: Climatic Drivers and Regional Impacts.



By Victor Murphy

With hints from: Valerio Lembo, Simona Bordoni,Assaf Hochman

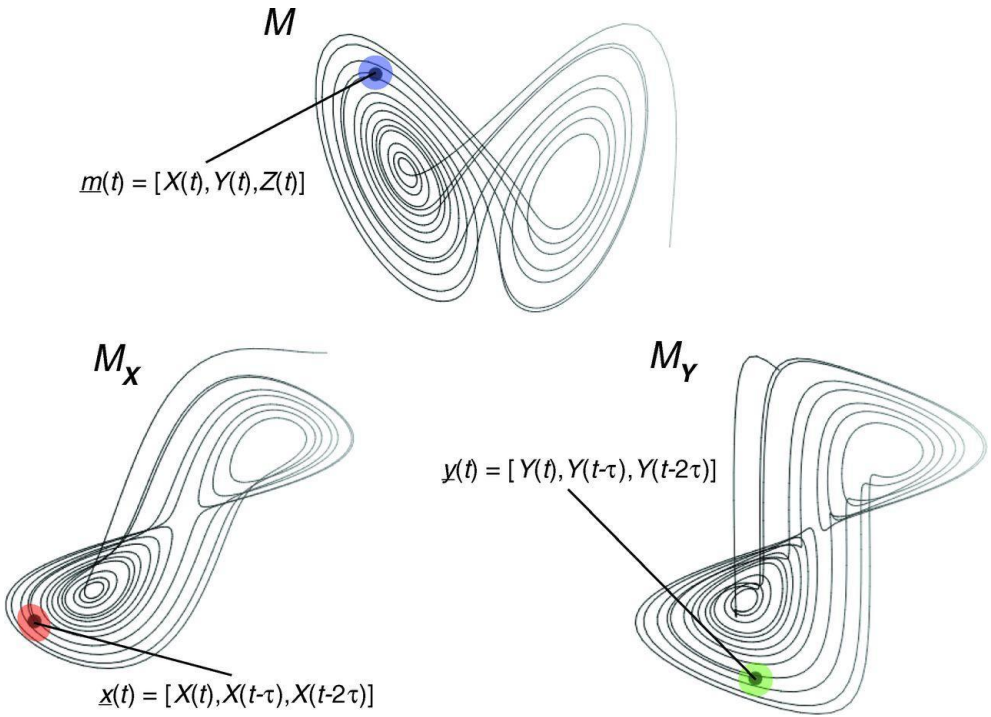
Ocean-Atmosphere Heat Transfer: From SST to Precipitation



Murphy, V., Lembo, V., Bordoni, S., Hochman, A. (2025) In preparation.

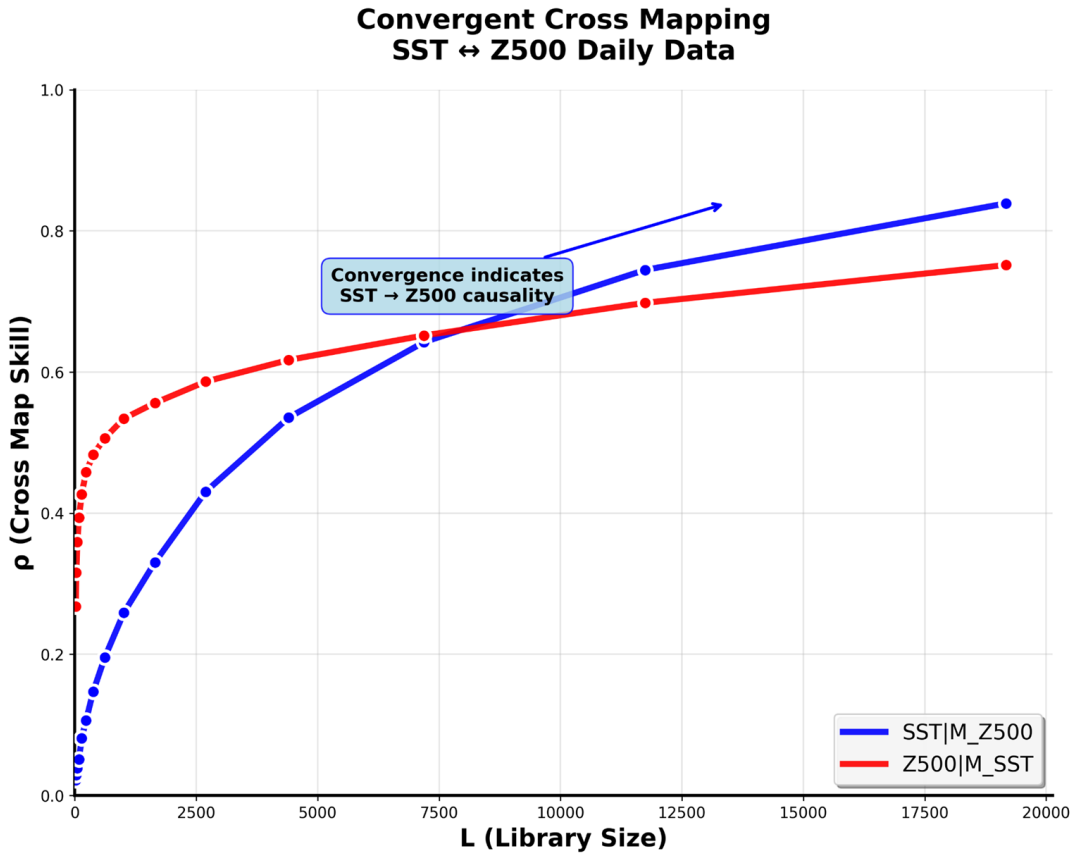
On going debate, is it SSTs influencing Atmosphere or the other way around?

How does Convegence Cross Mapping work?



Sugihara, G., May, R., Ye, H., Hsieh, C. H., Deyle, E., Fogarty, M., & Munch, S. (2012). Detecting causality in complex ecosystems. *science*, *338*(6106), 496-500. https://www.science.org/doi/10.1126/science.1227079

Causality between SST to Z500 by way of CCM



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Methods - *Data & Approach*

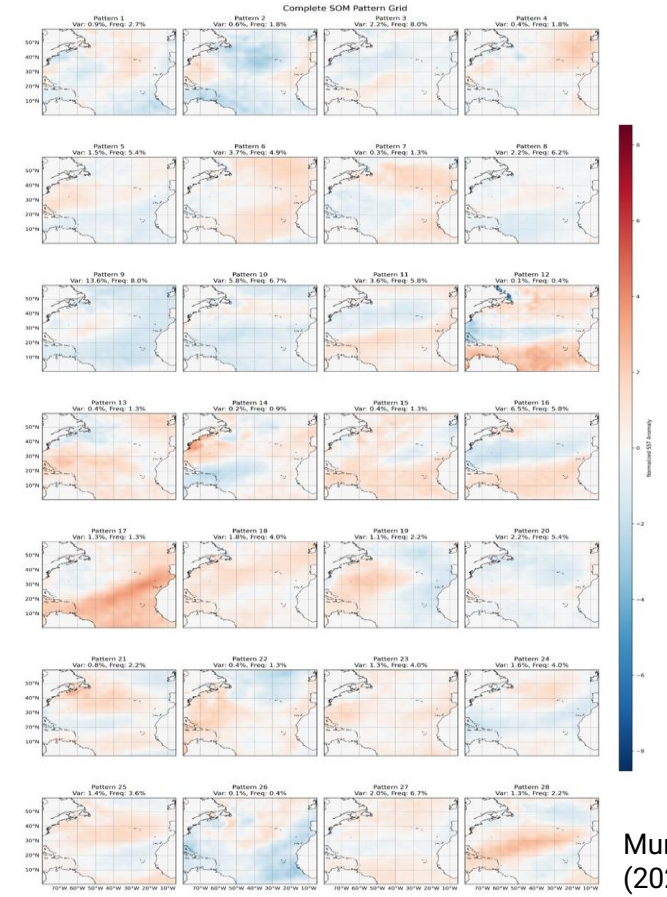
Data - HadISST (monthly avg. SST)

- December, January, February
- Focus on the years of 1950 to 2024(eoy)
- North Atlantic Area (-80W, -5W to 0N, 60N)

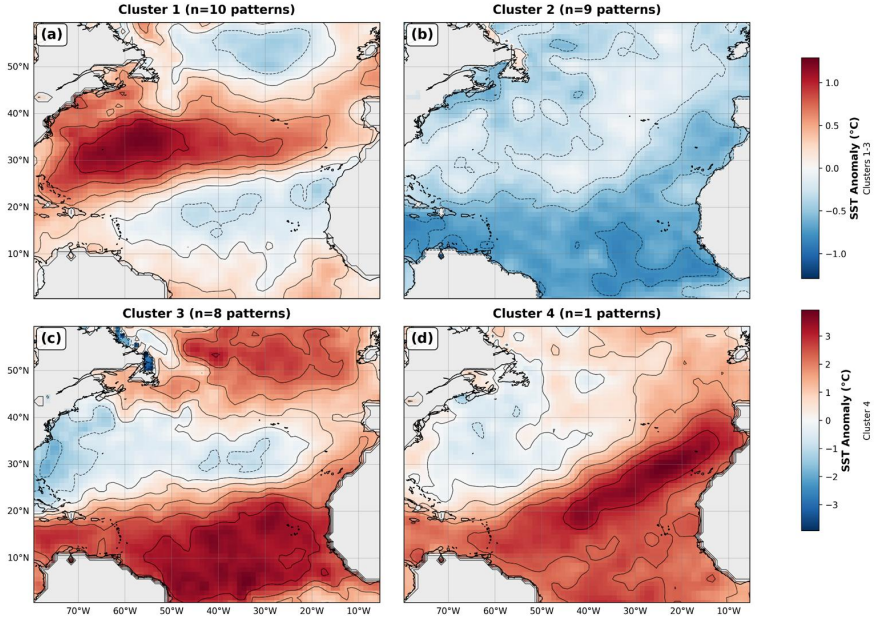
Self Organising Maps

K-Means Clustering

Self Organising Maps (SOM) to Clusters (DJF)



k-means clustering



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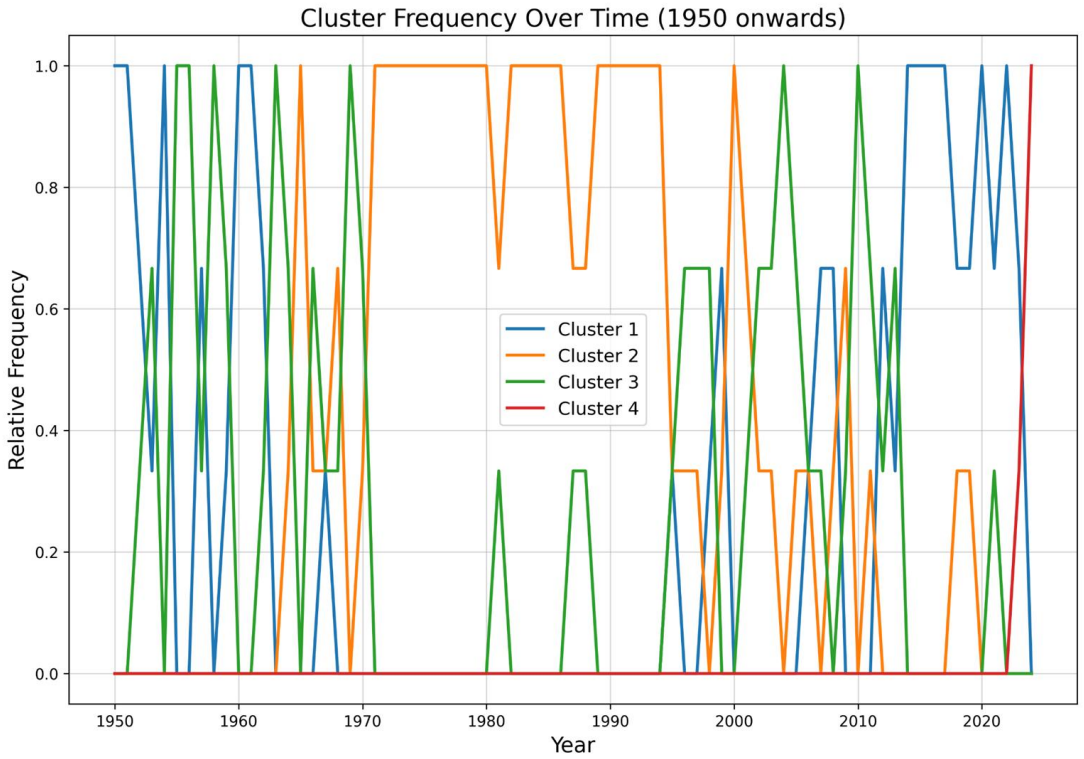
Frequency of SST clusters



Three distinct phases:

- 1950-1970: Cluster 1 and Cluster 3 alternate, with rare occurrences of Cluster 2;
- 1970-1995: Cluster 2 dominates;
- 1995-2021: Clusters 1, 2 and 3 alternate;

What happens after 2022??

- Cluster 4 Grounds for case Study

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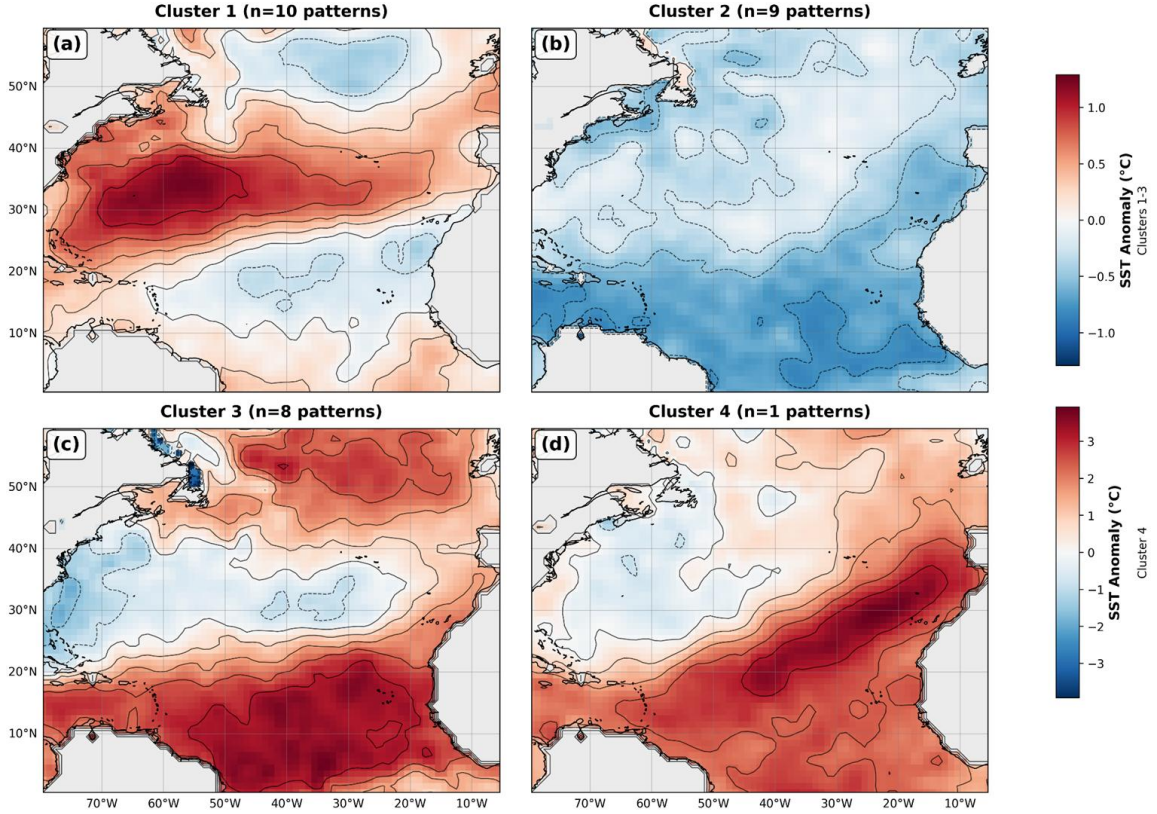
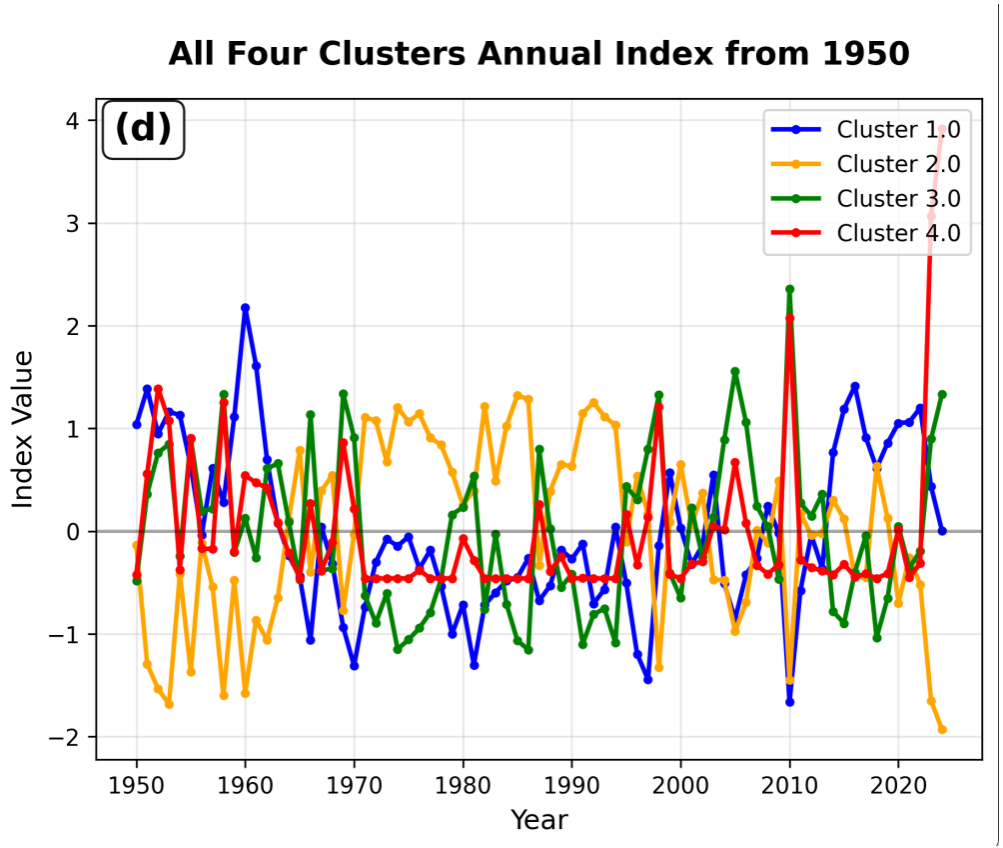
Now that we have SST SOM Clusters, the key question becomes: HOW do these patterns drive atmospheric responses?

SST SOM Clusters Named





Cluster 4 traces Cluster 3. However, from slide slide 7, Cluster 4 is not present until we move beyond 2022.

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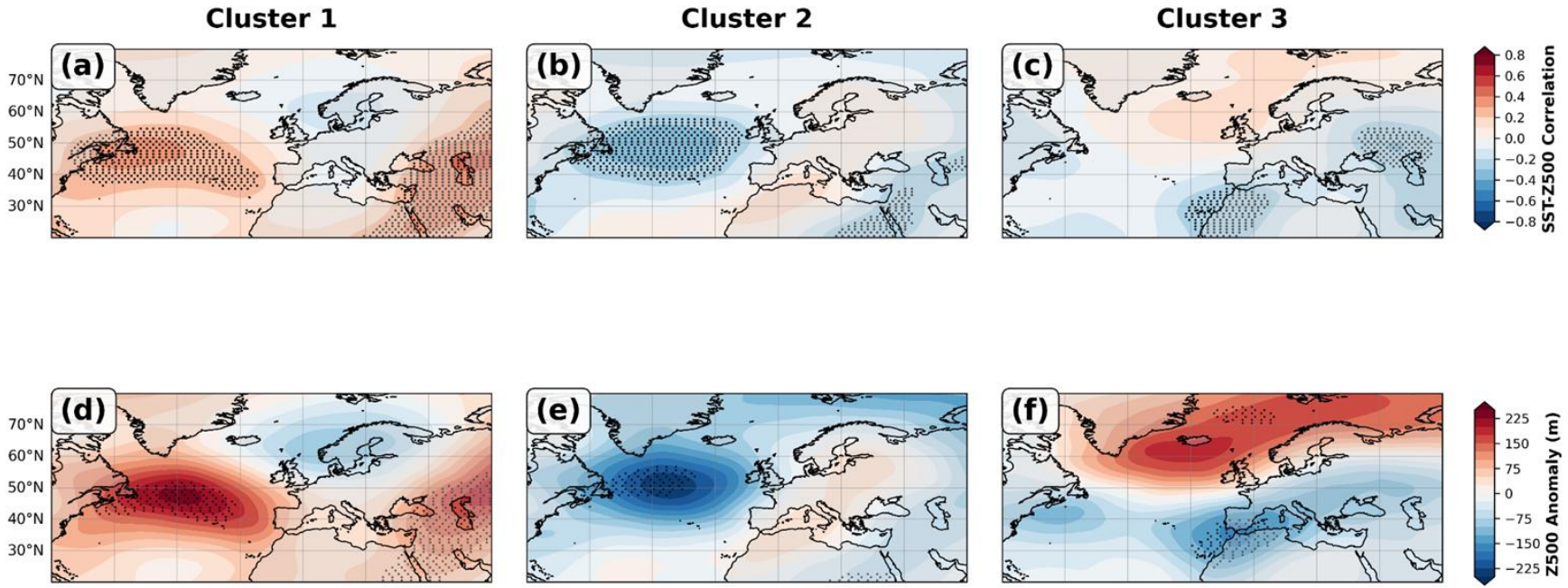
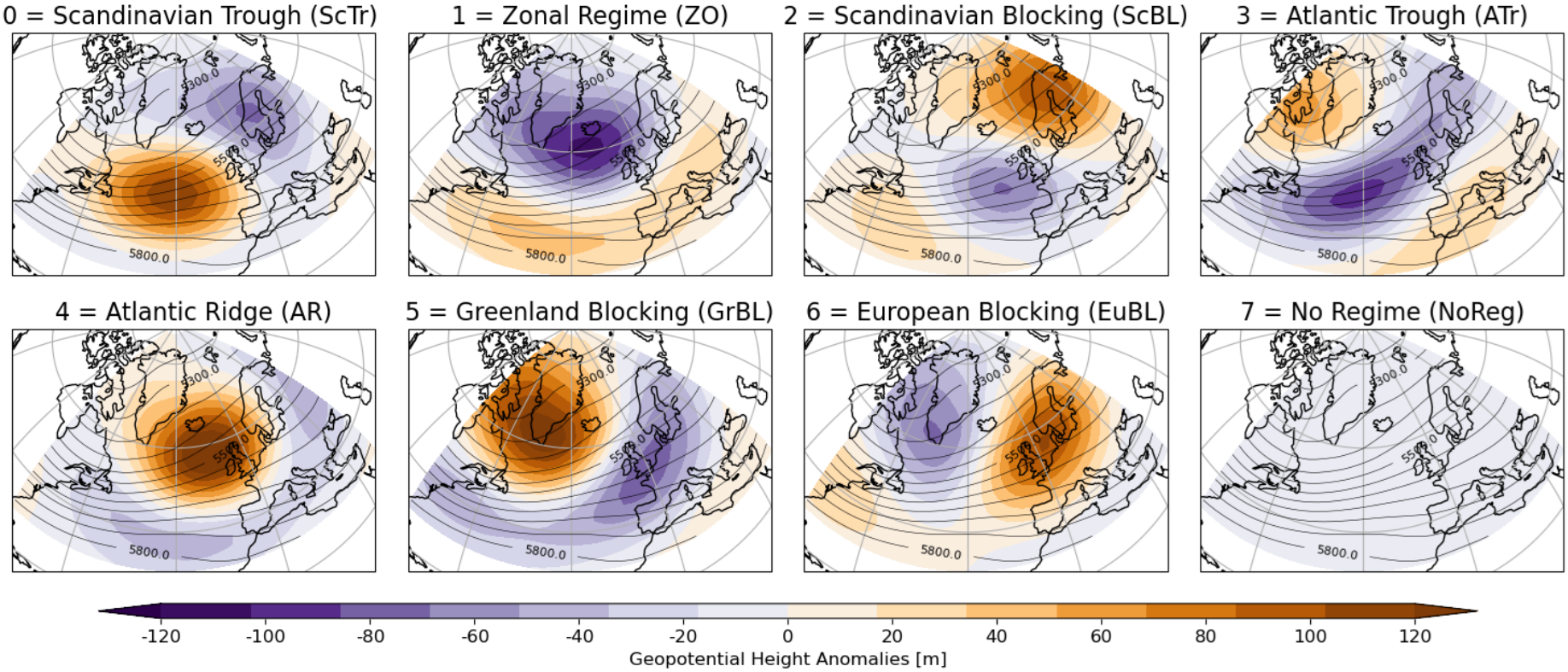
Clusters 1, 2, 3 Correlated to Z500 and Z500 Anomalies

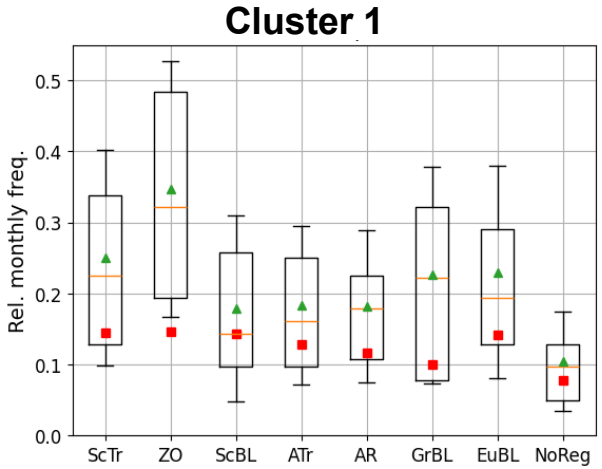


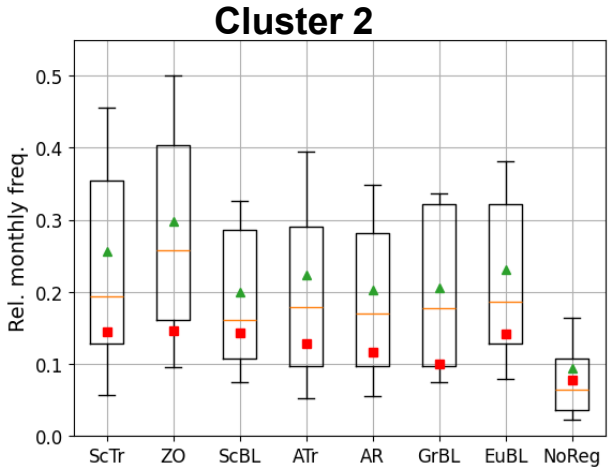
Murphy, V., Lembo, V., Bordoni, S., Hochman, A. (2025) In preparation.

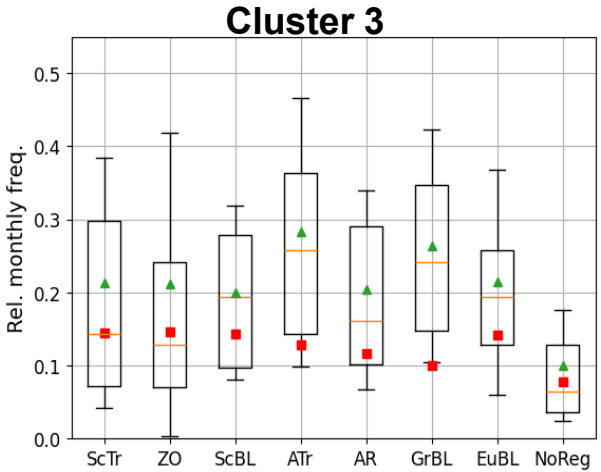
Year-round weather regime patterns (after Grams et al. 2017)



Weather regimes and SST patterns

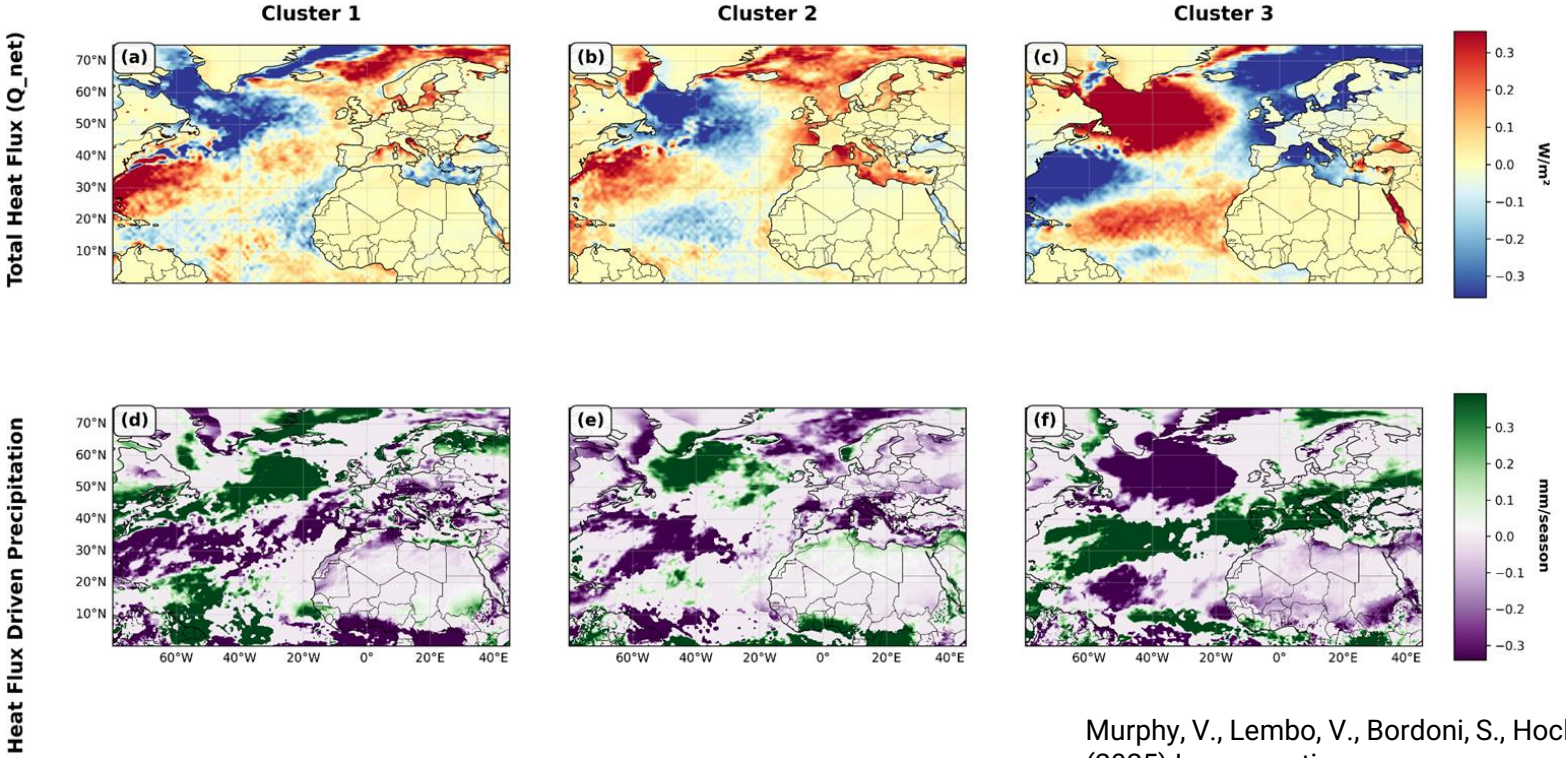






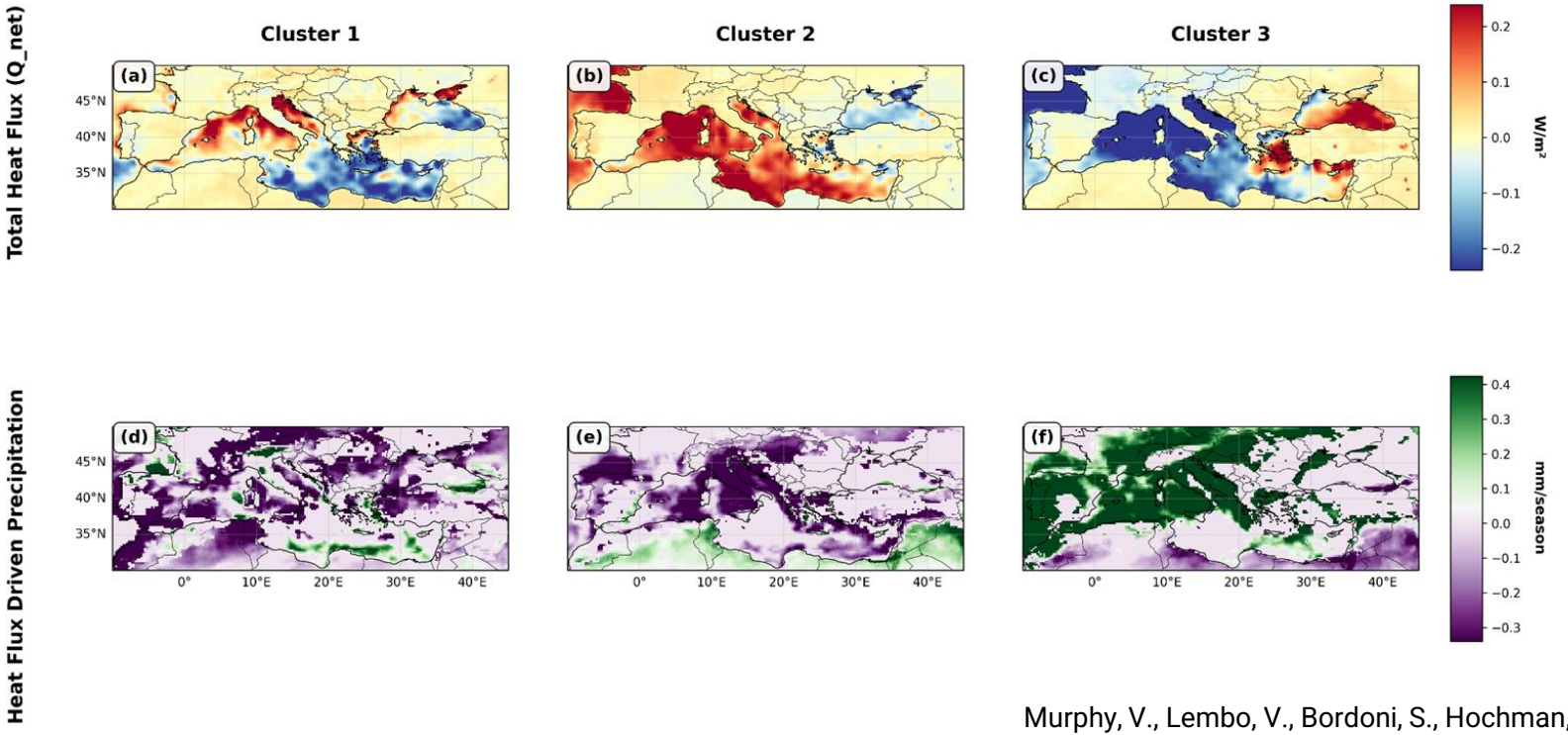
Murphy, V., Lembo, V., Bordoni, S., Hochman, A. (2025)
In preparation.

Clusters Applied to Q_net and Heat Flux Driven Precipitation



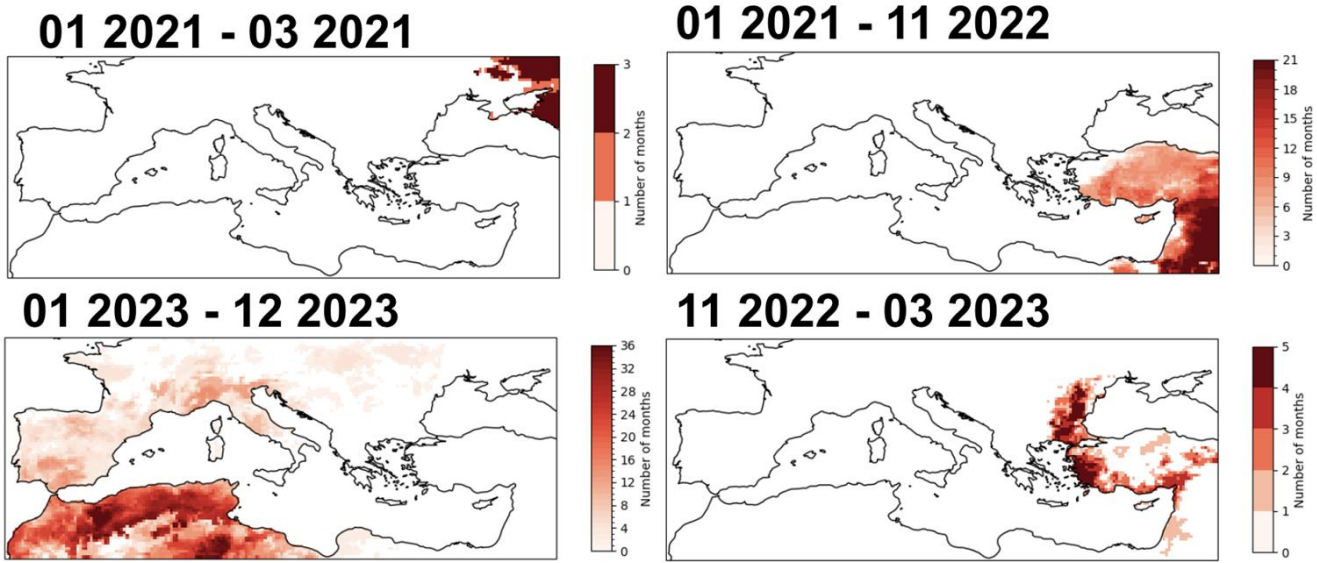
Murphy, V., Lembo, V., Bordoni, S., Hochman, A. (2025) In preparation.

Clusters Applied to the Mediterranean.



Murphy, V., Lembo, V., Bordoni, S., Hochman, A. (2025) In preparation.

K-means clustering of SPEI index



- Minimum size of the event (for one time step): 50 000 km^2
- Minimum distance between two events in space: 150 km
- Overlapping area between two time steps: 10%

(Courtesy of Greta Cazzaniga)

Take-Home Messages

1. SST Drives Mediterranean Climate

- North Atlantic SST causally drives atmospheric circulation (CCM verified)
- 4 distinct SST regimes identified: Clusters 1-2 similar, Cluster 3 opposite, Cluster 4 unprecedented (2022+)

2. Quantified Regional Impacts

- SST clusters drive 25-40% of Mediterranean winter precipitation variability
- Cluster 3: +20-30% precipitation West Med, -15-20% East Med
- Heat flux anomalies strongly correlate with drought indices (r = 0.60-0.70)

3. Climate Regime Shifts Link to Droughts

- 1970-1995: Persistent Cluster 2 coincides with Sahel drought
- 2022-2024: Novel Cluster 4 emergence coincides with Mediterranean mega-drought
- Provides real-time case study for understanding SST-drought mechanisms

4. Next Steps & Open Questions

- Work underway on SST regime predictability for drought forecasting
- Physical mechanisms still being investigated - preliminary results
- Workshop discussion invited on operational applications

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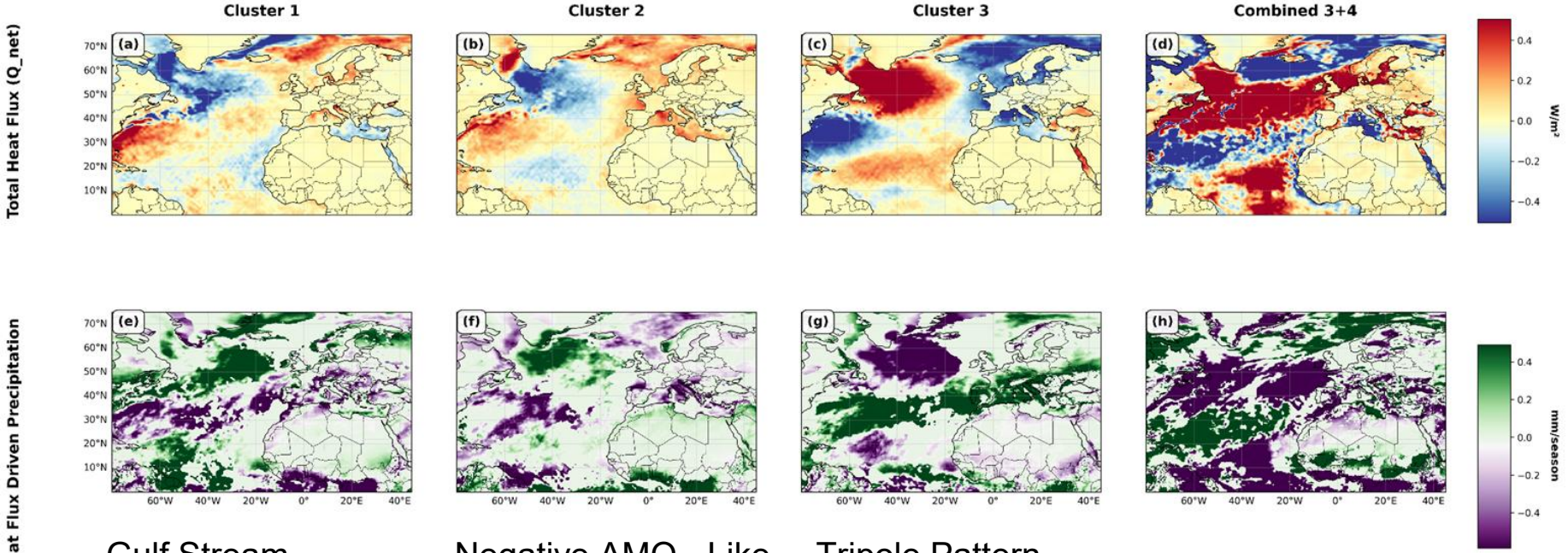
Something extra if I need it



Gulf Stream Displacement

Negative AMO - Like

Tripole Pattern

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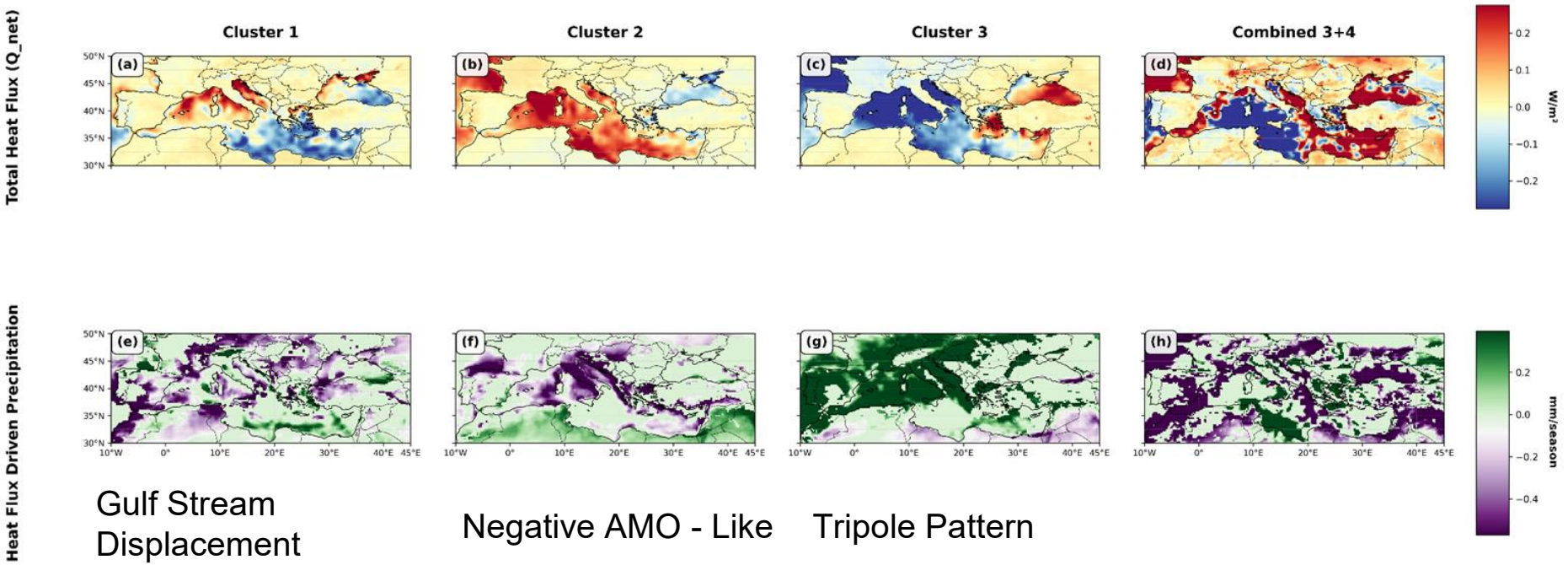

Gulf Stream Displacement

Negative AMO - Like

Tripole Pattern

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Hebrew University of Jerusalem victor.murphy@mail.huji.ac.il https://en.earth.huji.ac.il/

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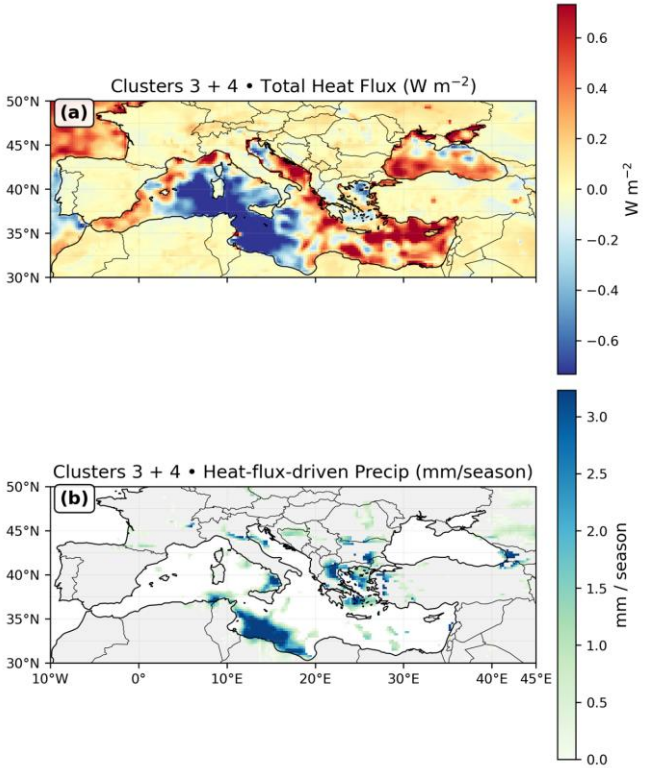

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Thank you very much for your attention…