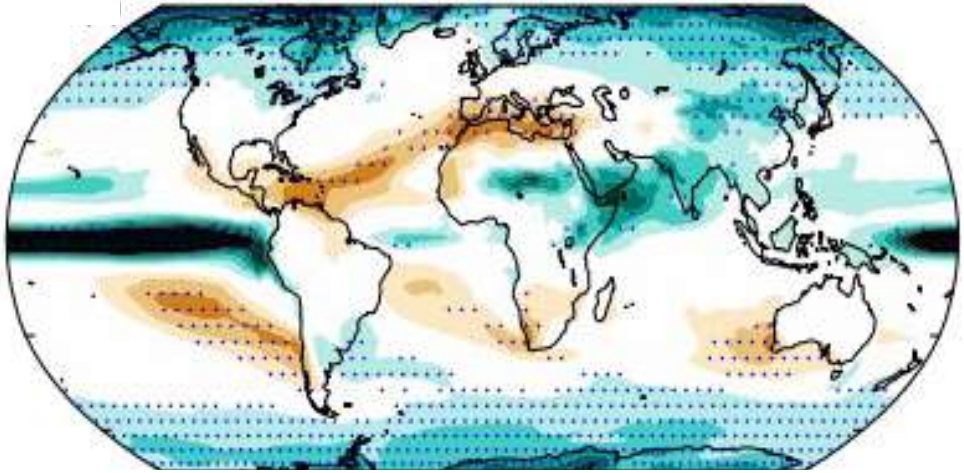
THE HEBREW UNIVERSITY OF JERUSALEM

Unravelling the large scale forcing of projected drying in the Mediterranean region



Benny Keller[1], Chaim I. Garfinkel[1]

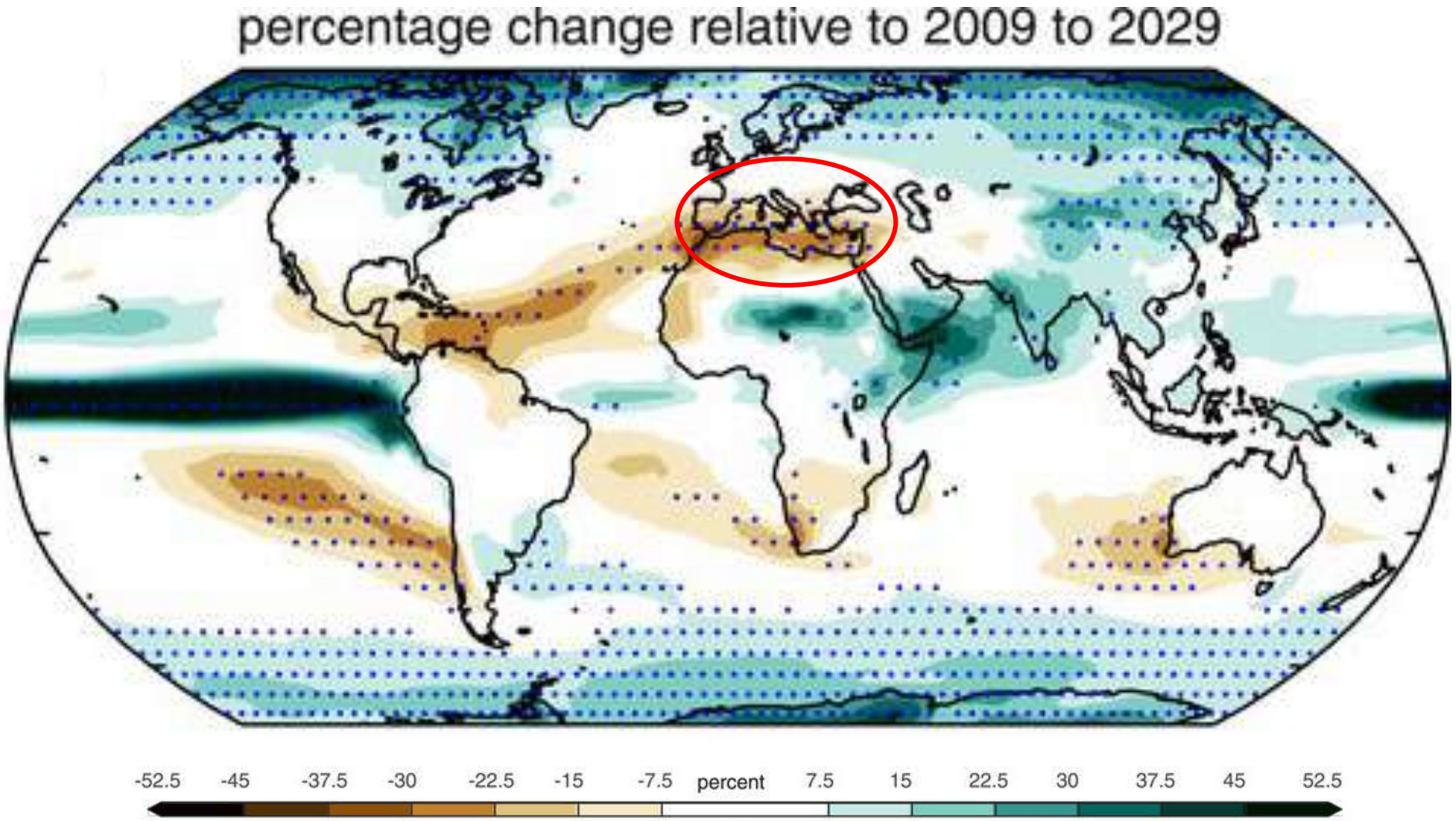
Hebrew University of Jerusalem

MEDcyclones

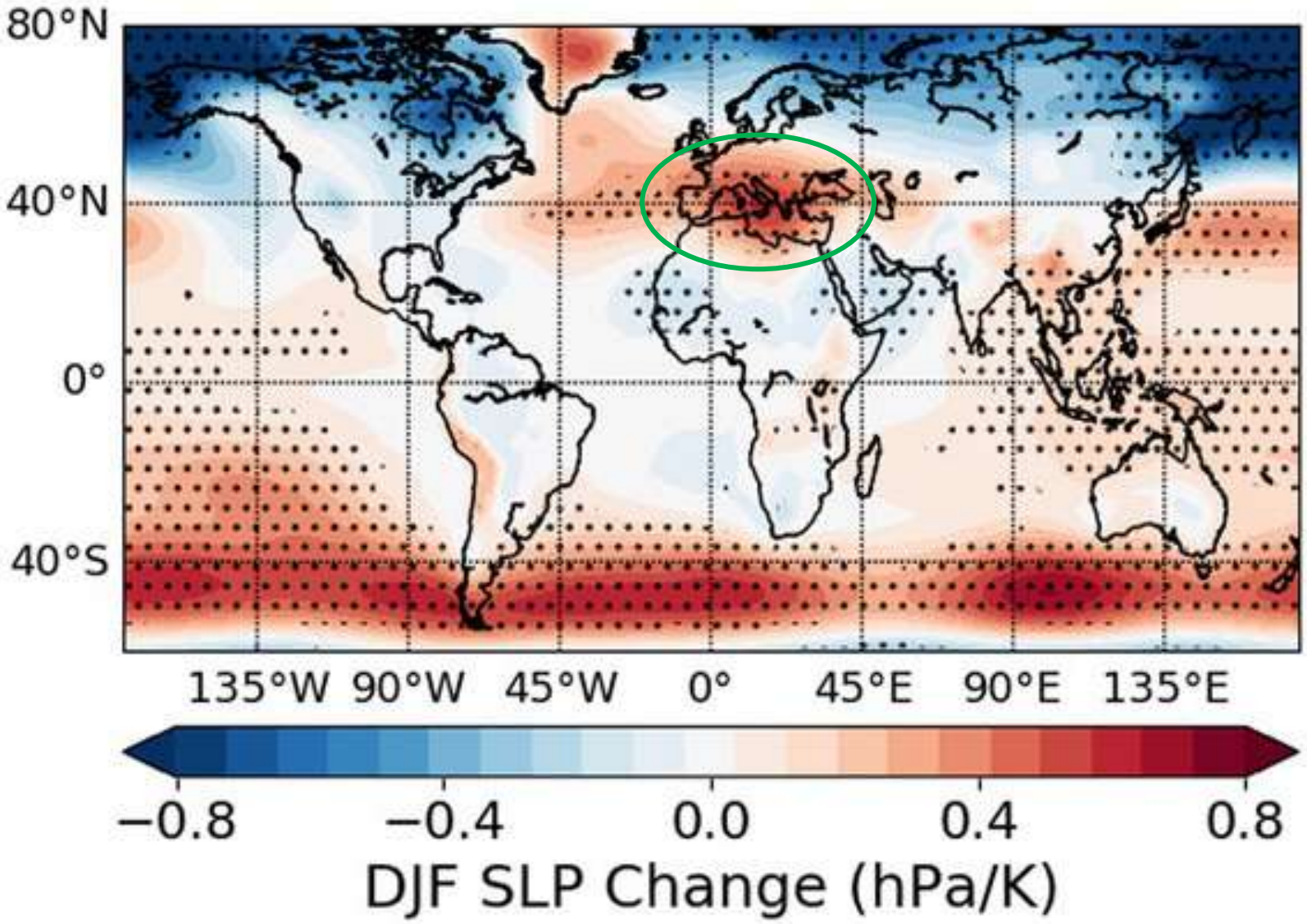
Research Motivation

- Improve the **dynamical understanding** of projected Mediterranean drying
- Better understand **the role of stationary waves** in a changing climate
- Why is the Mediterranean a climate change hot spot?

Projected Change in Precipitation

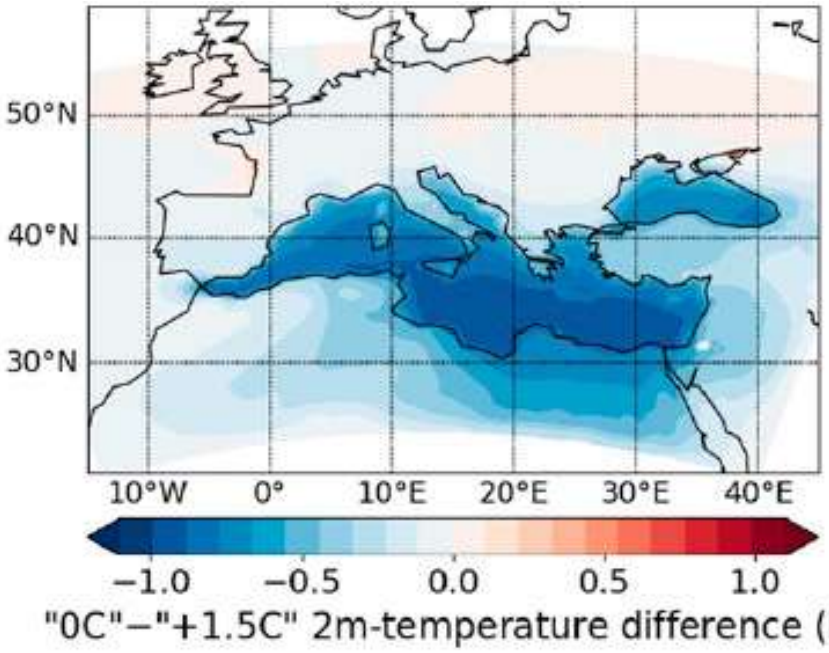


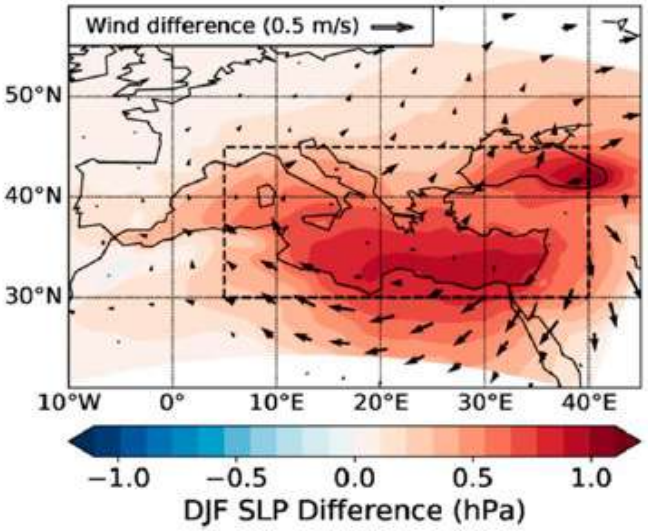
Garfinkel et al, 2020

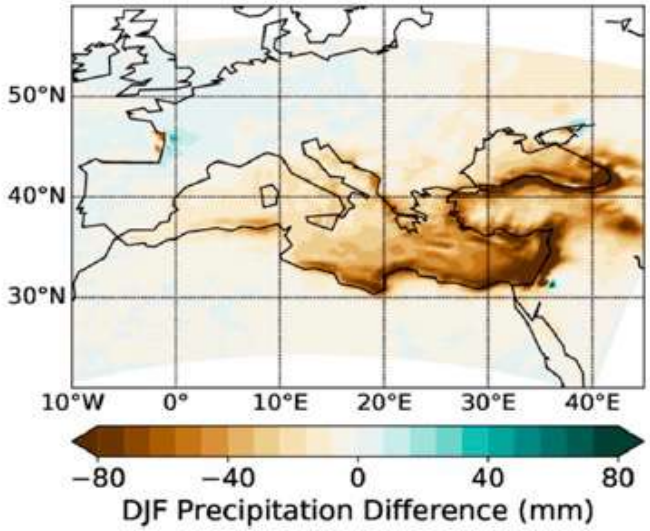


TUEL & ELTAHIR, 2020

Theories - Relative Mediterranean Cooling







Simulation Environment

- **MiMA** - Intermediate-complexity model with idealized moist atmosphere introduced by Jucker and Gerber (2017).

Simulation Environment

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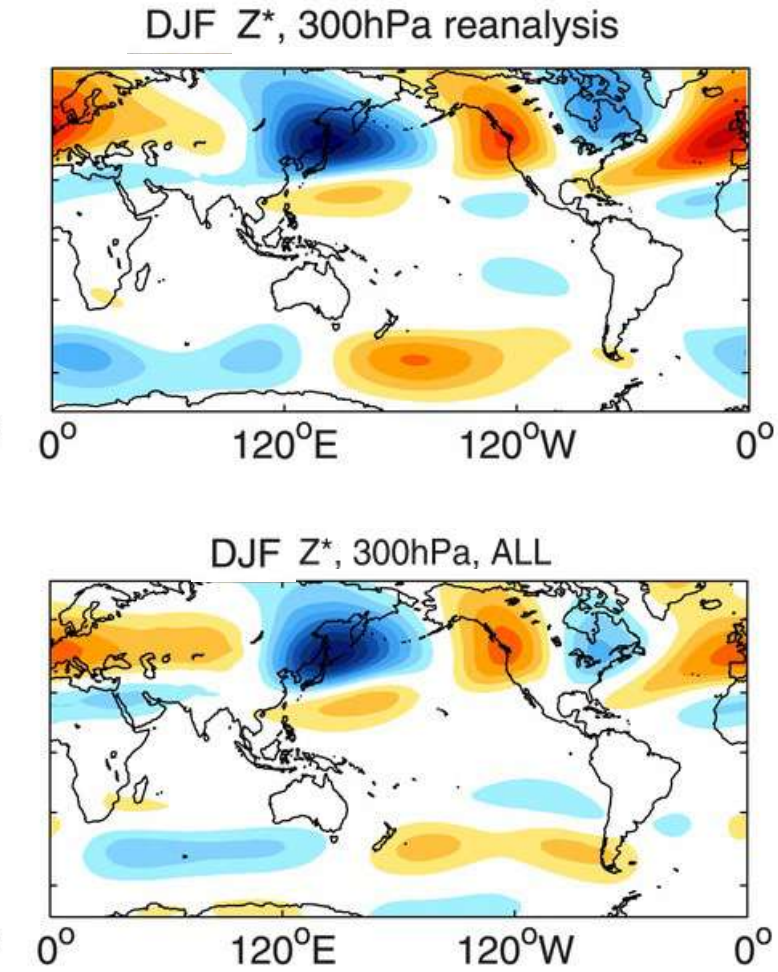
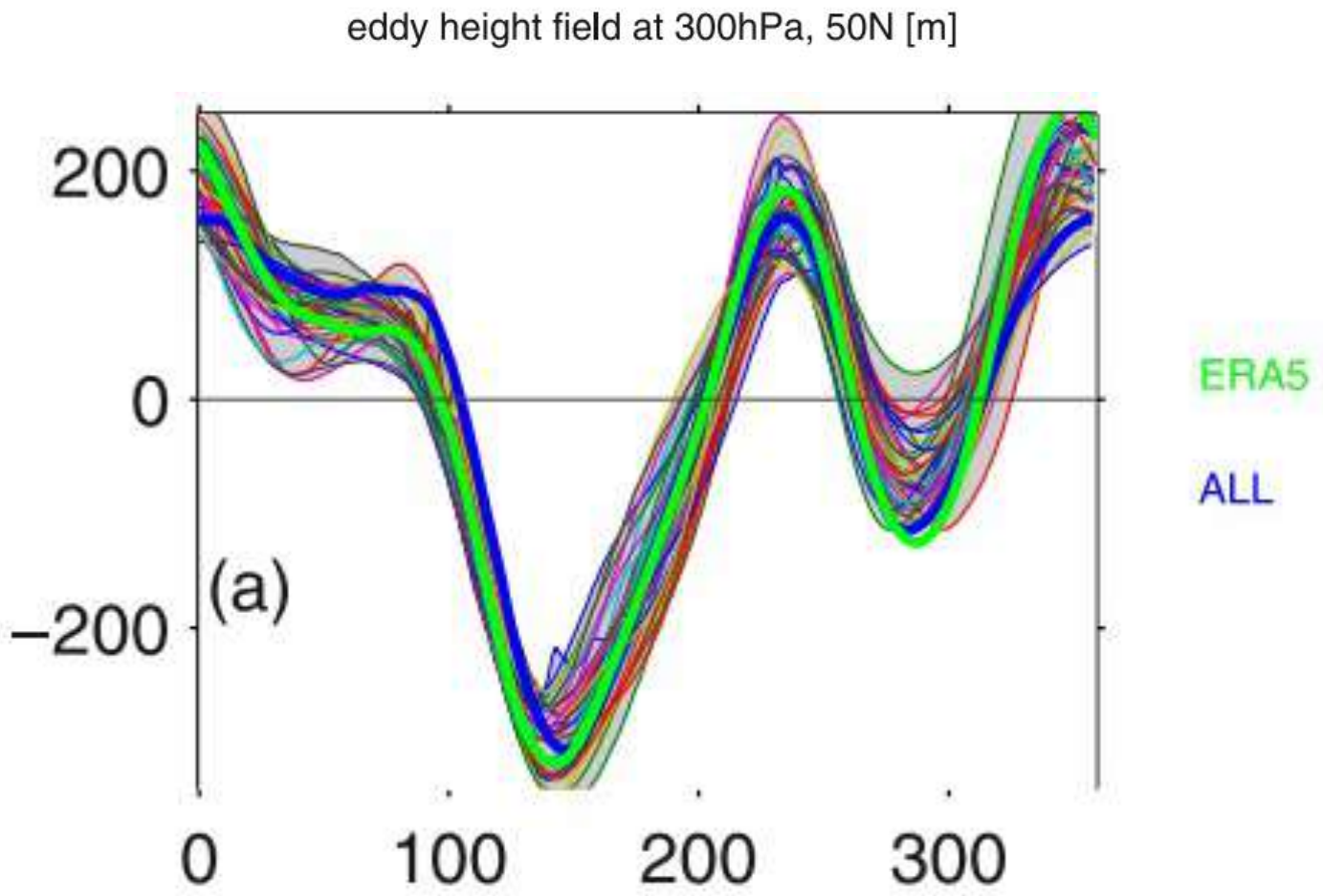
- We add **three forcing mechanisms of stationary waves** to a zonally symmetric moist aqua-planet:
  - **Orography**
  - **Ocean horizontal heat fluxes**
  - **Land-sea contrast**

Simulation Environment - MiMA



Garfinkel et al, 2020

Simulation Environment - MiMa



Garfinkel et al, 2020

Simulation Environment - MiMA

Advantages

- MiMA **captures the important processes for stationary waves** and the **linear and non-linear interaction** between their various building blocks (Garfinkel et al 2020)..

- Able to **isolate and subsequently synthesize fundamental physical processes.**

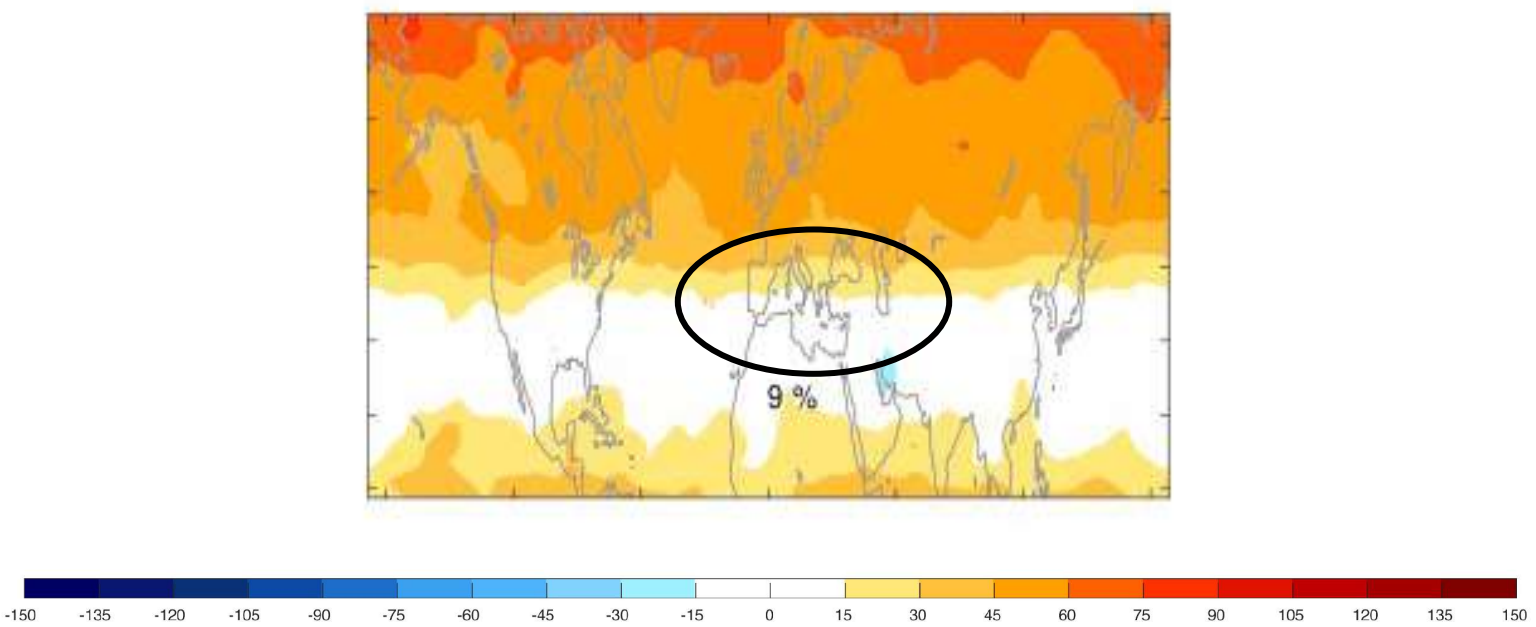
Simulation Environment - MiMA

We examined the **precipitation and geopotential height field response** to quadrupling of CO2 vs. contemporary CO2 concentrations for **different combinations of these three stationary wave forcings**

Results

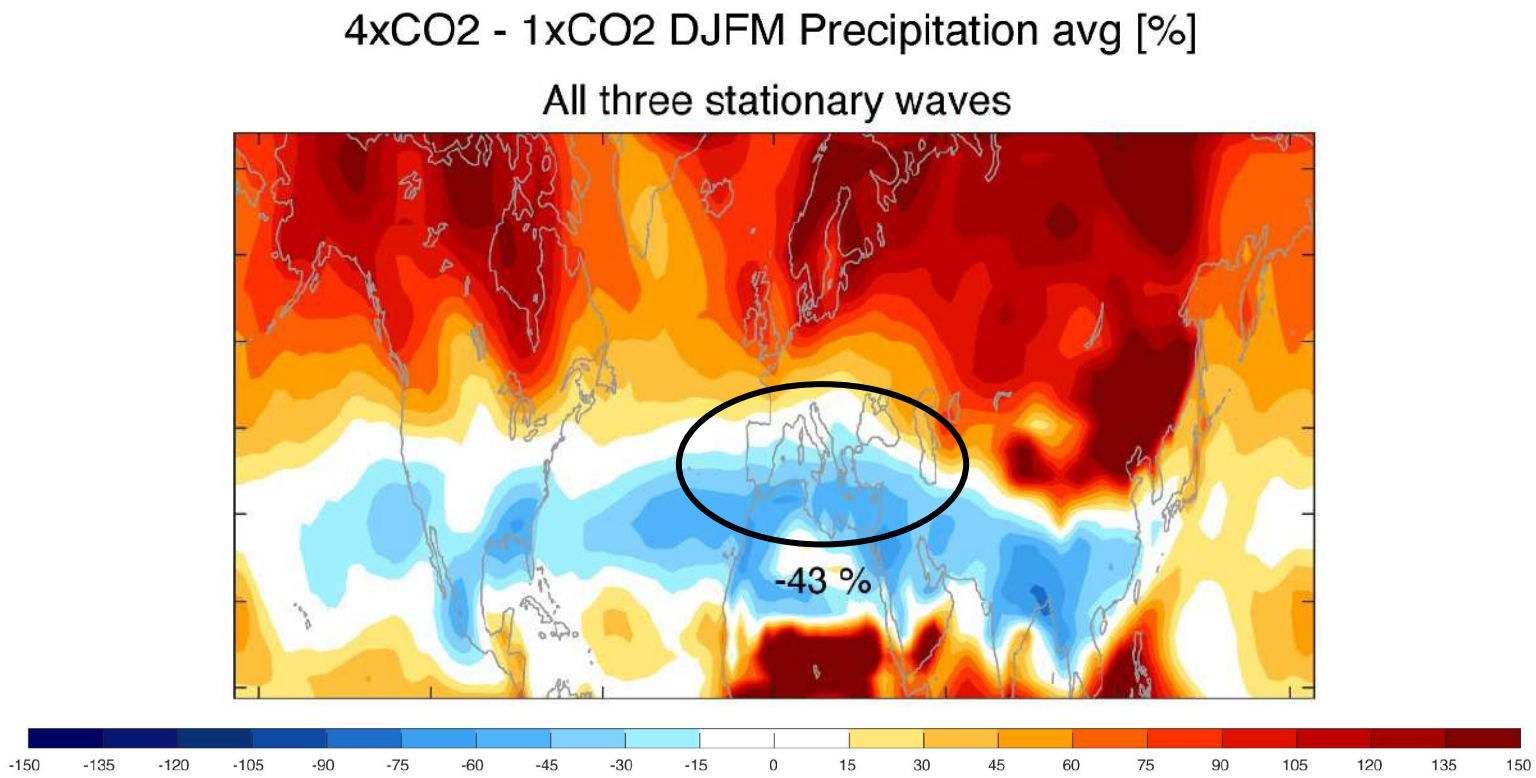
4xCO2 - 1xCO2 DJFM Precipitation avg [%]

Aqua planet



Without the stationary wave building blocks we get **no subtropical drying at all**

Results

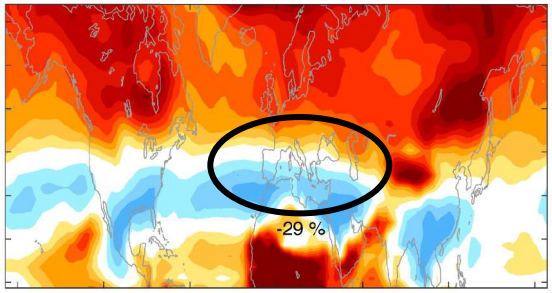


pronounced drying over the Mediterranean relative to the rest of the subtropics difference in magnitude between the north-west and south-east (consistent with e.g. Brogli et al. 2019).

Results

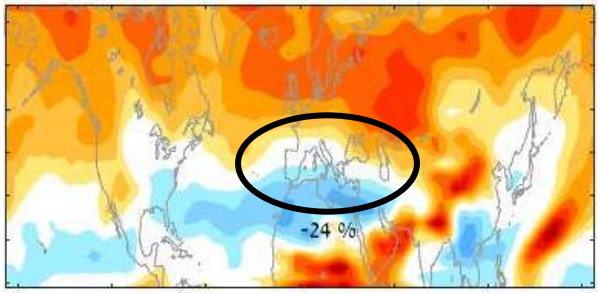
4xCO2 - 1xCO2 DJFM Precipitation avg [%]

no ocean heat fluxes



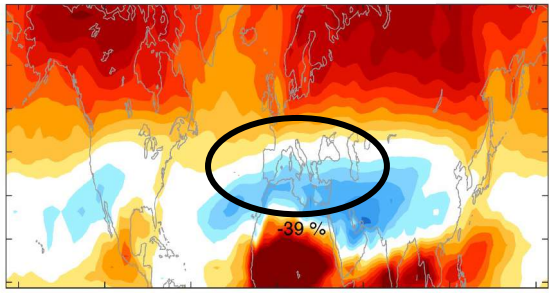
-29 %

no land-sea contrast

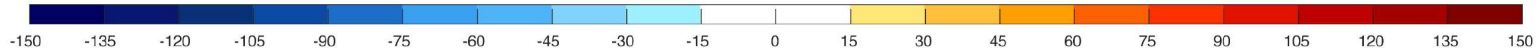


-24%

no topography



-39 %

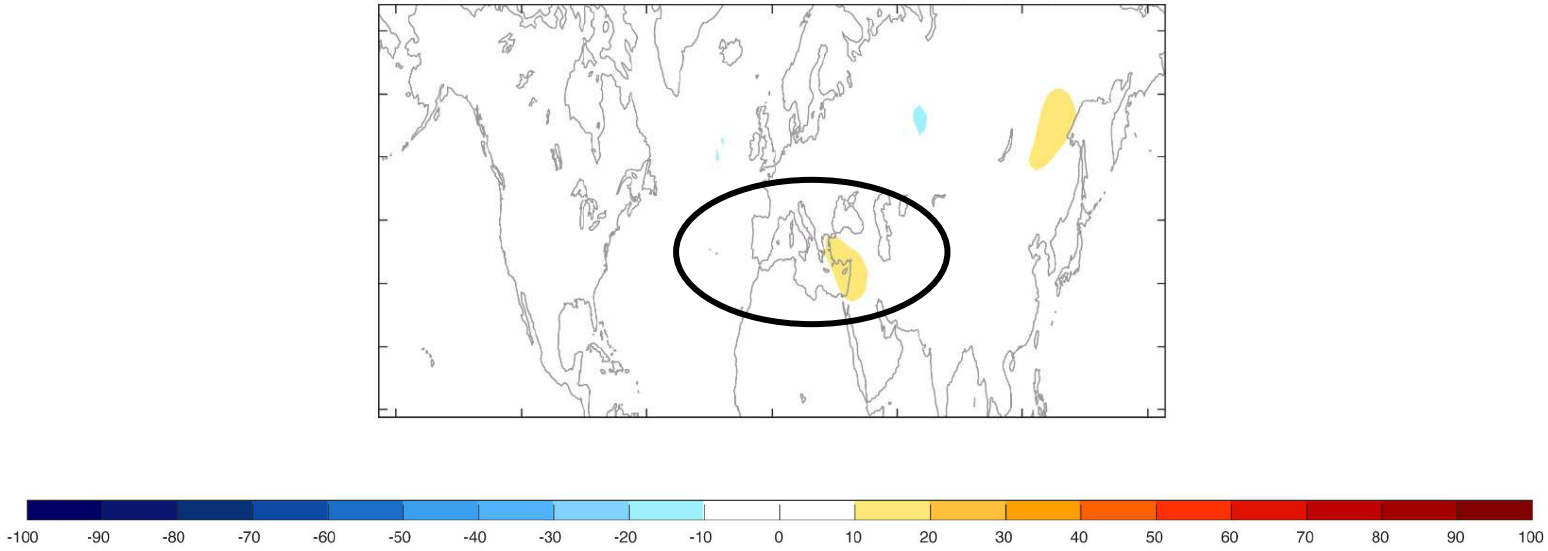


- Each of the building blocks encourages subtropical drying.
- Drying in the Mediterranean **most pronounced with land-sea contrast**.
- Significant role for **oceanic horizontal heat fluxes**.

Results

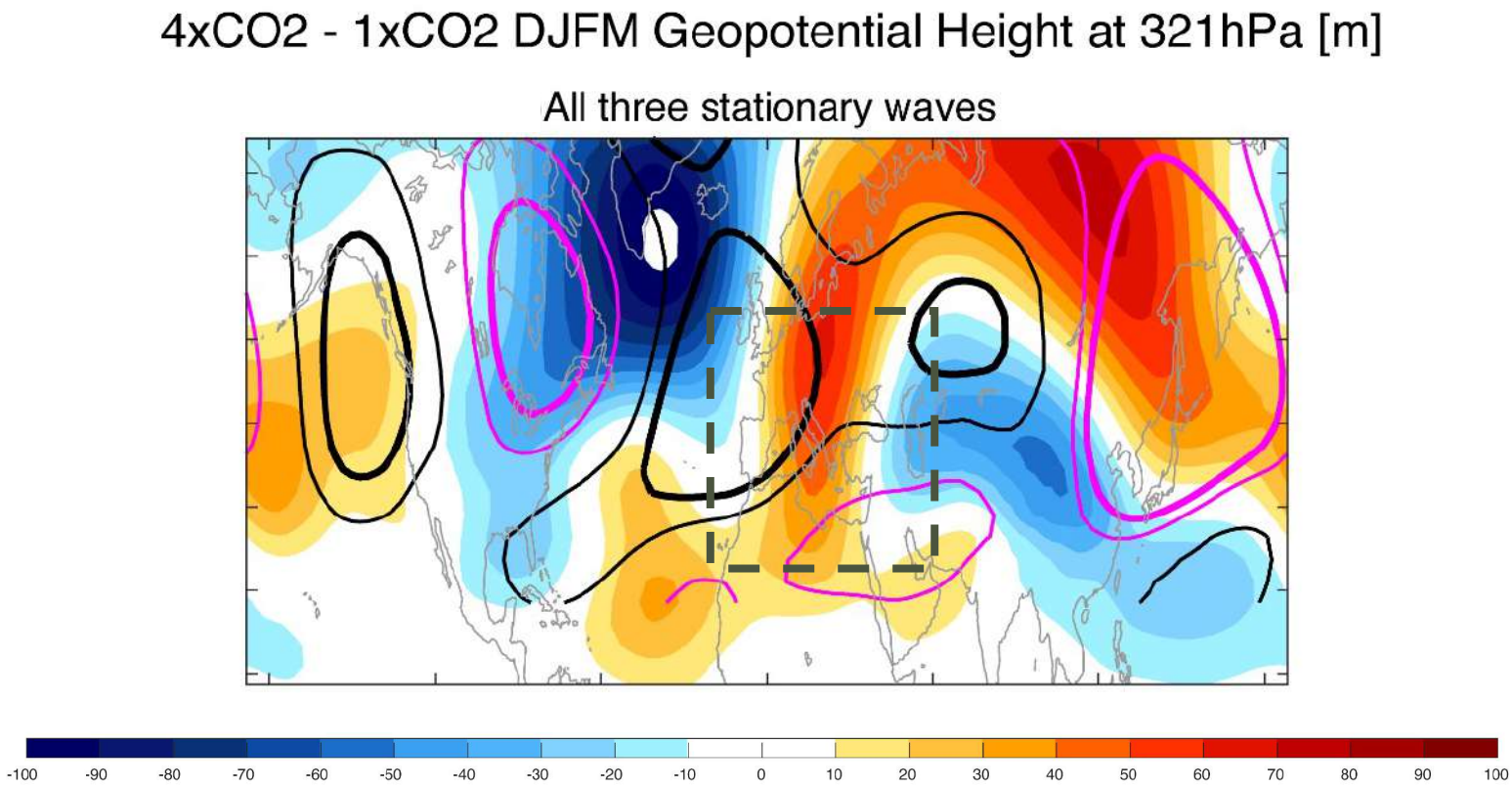
4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]

Aqua planet



Without the stationary wave building blocks we get **no significant anomalous ridge** over the Mediterranean

Results

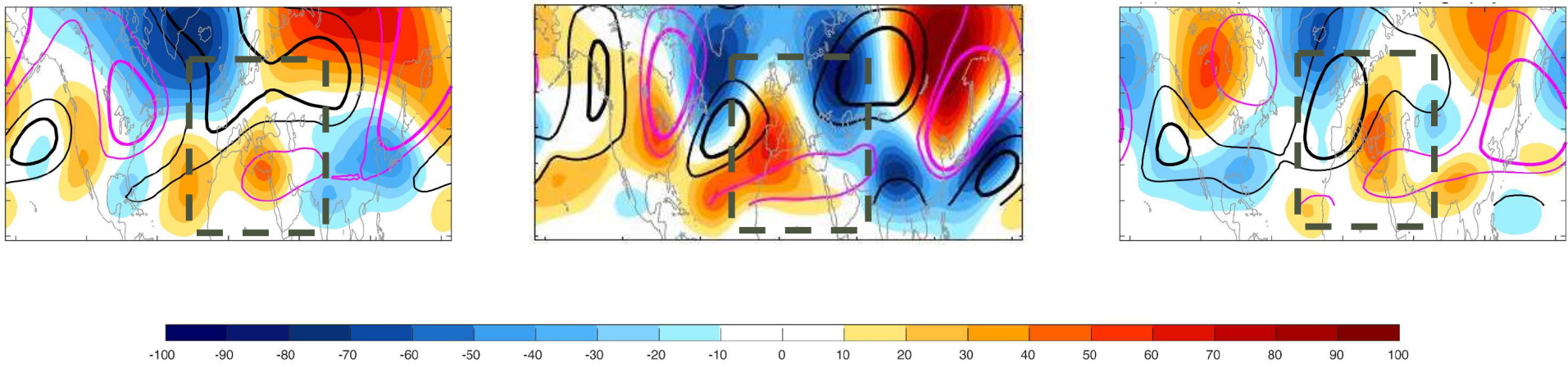


A **strong anomalous ridge** over the Mediterranean region, consistent with previous work

Results

4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]

no ocean heat fluxes **no land-sea contrast** **no topography**

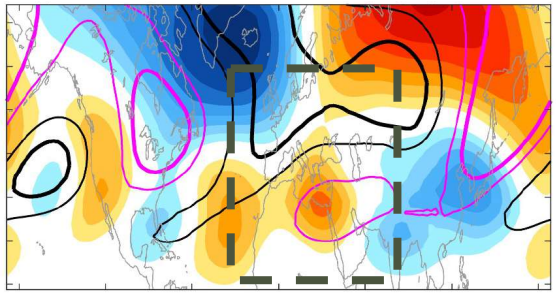


Changes in the oceanic horizontal heat fluxes seem to account for a significant part of the **amplitude** of the ridge while changes in the land-sea contrast are crucial for the **zonal position**

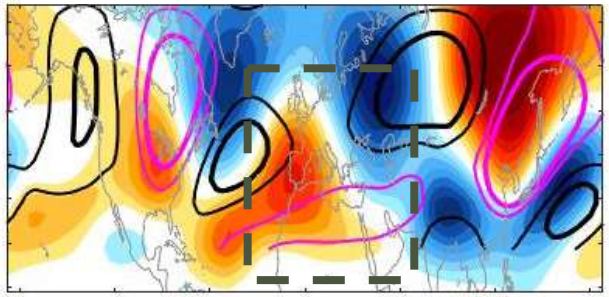
Results

4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]

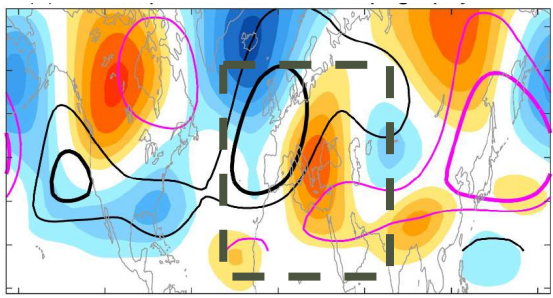
no ocean heat fluxes



no land-sea contrast



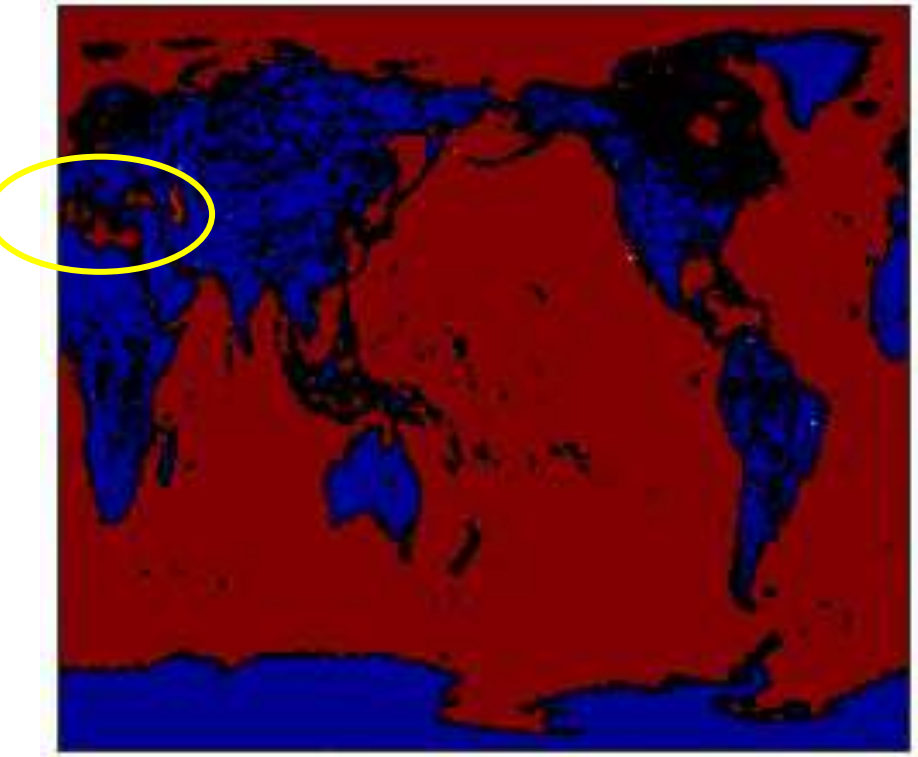
no topography



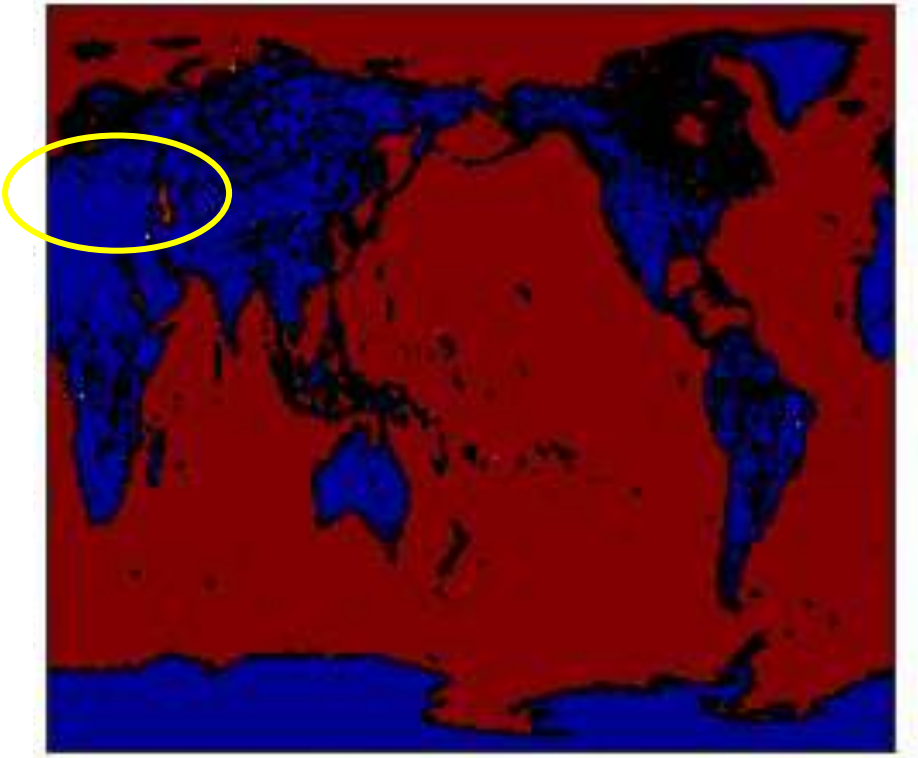
Can we isolate the role of the relative Mediterranean cooling?

Land mask Manipulation - No Mediterranean

Real land mask



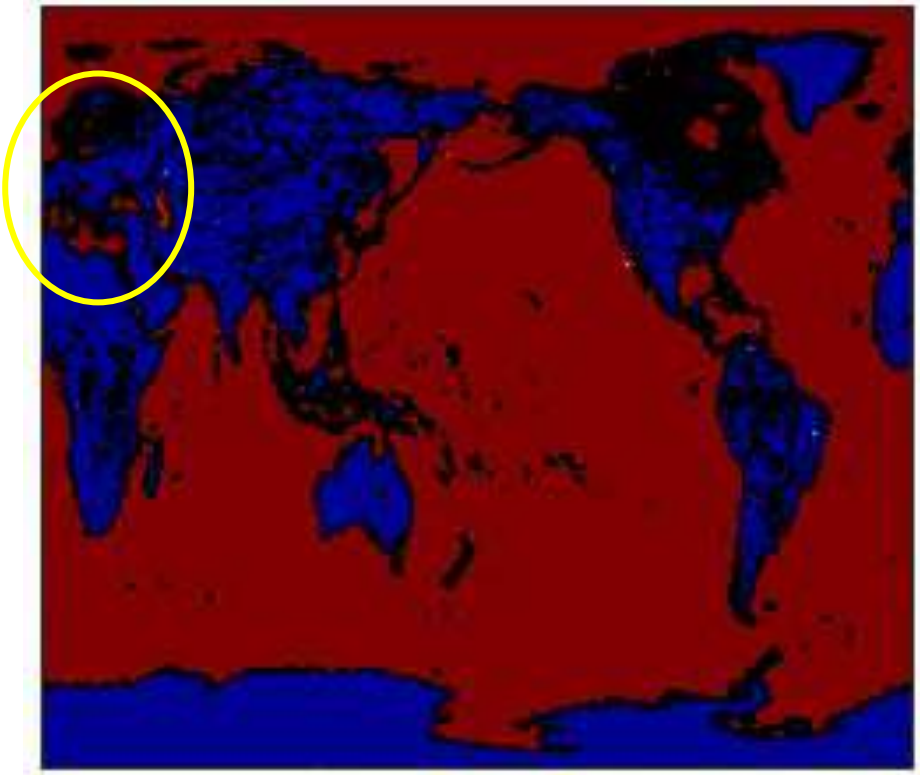
manipulated land mask



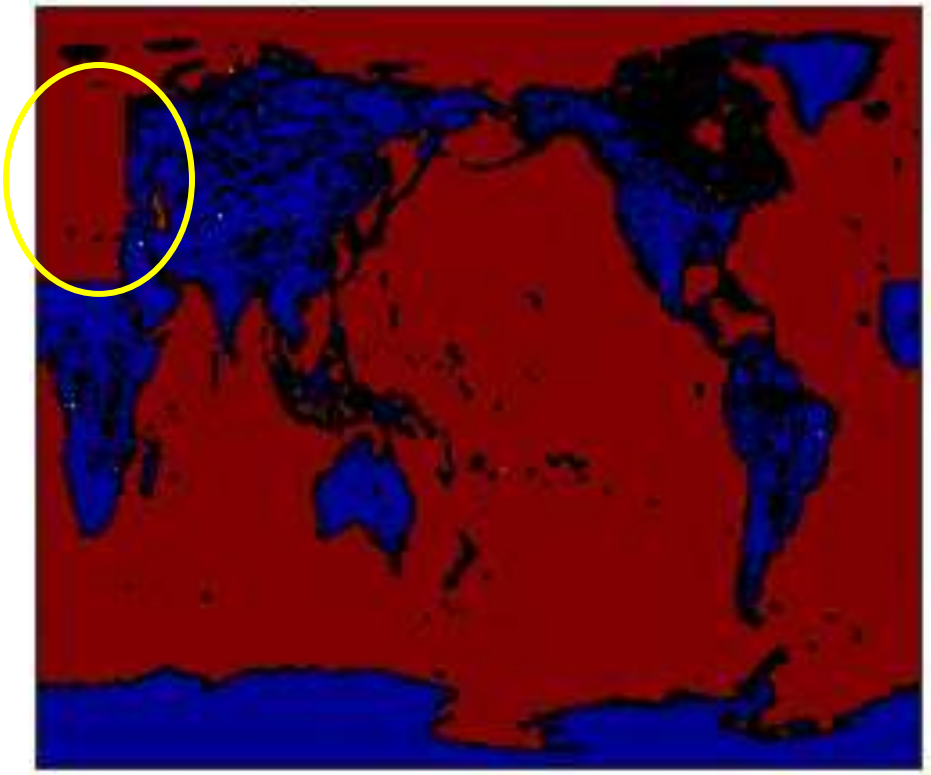
Land mask Manipulation -

No Europe & no North Africa

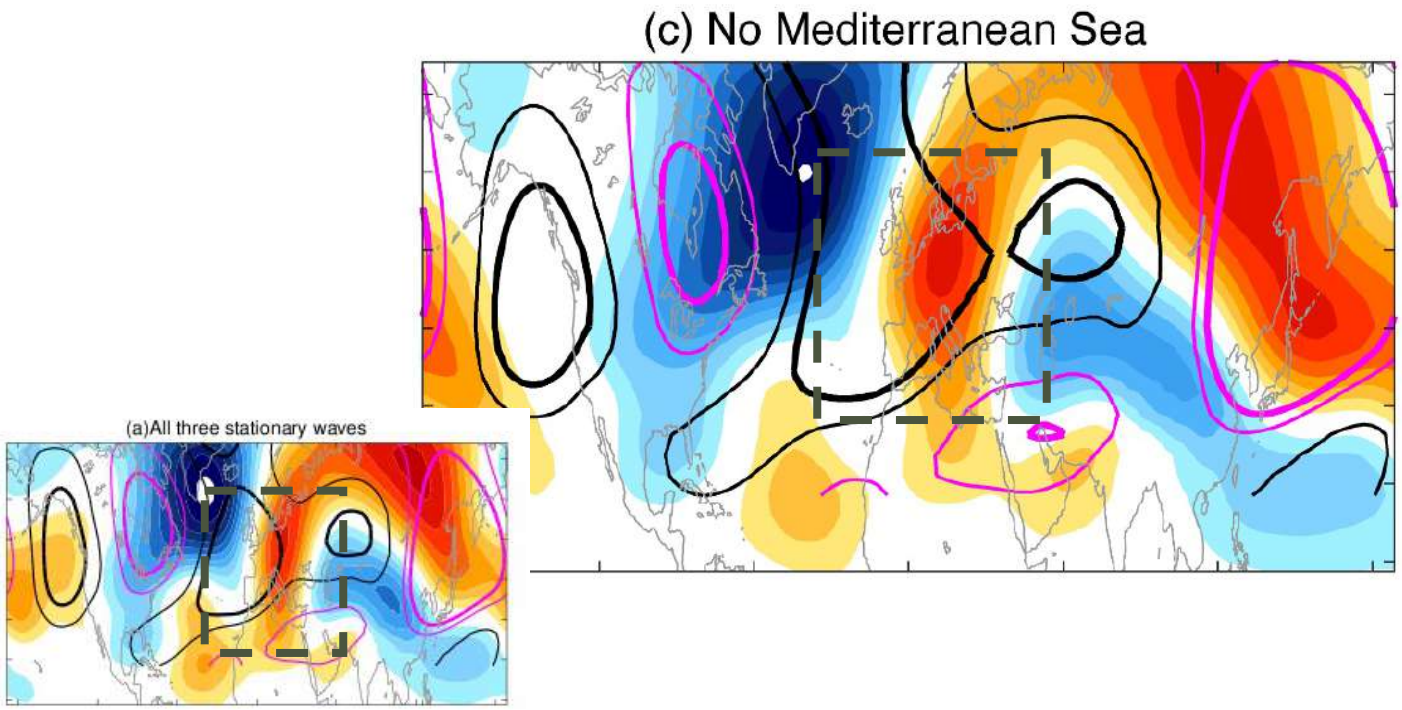
Real land mask



manipulated land mask

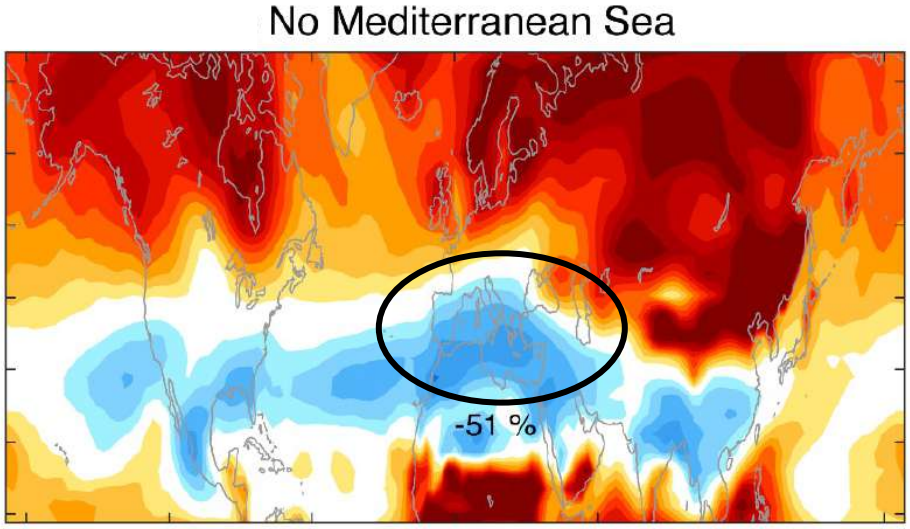


4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]



The anomalous ridge above the Mediterranean is **similar with and without the Mediterranean Sea**

4xCO2 - 1xCO2 DJFM Precipitation avg [%]

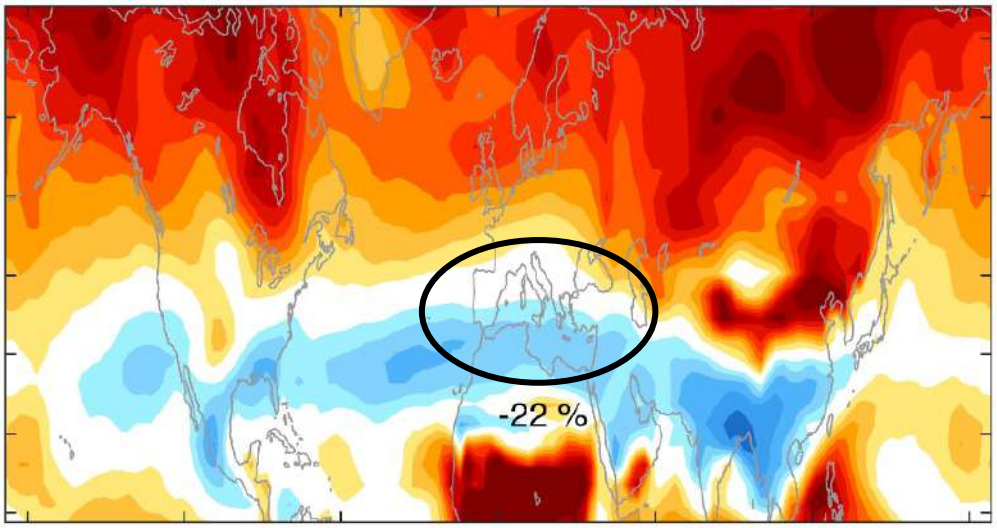


When the Mediterranean sea is changed to land we get an even **stronger decline in precipitation** than before the change

The projected precipitation decline seems independent of the relative Mediterranean cooling

4xCO2 - 1xCO2 DJFM Precipitation avg [%]

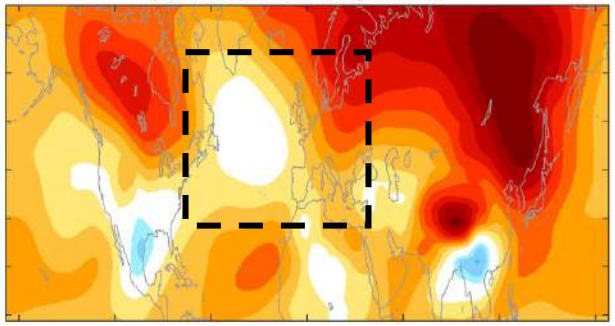
(d) No North Africa No Europe



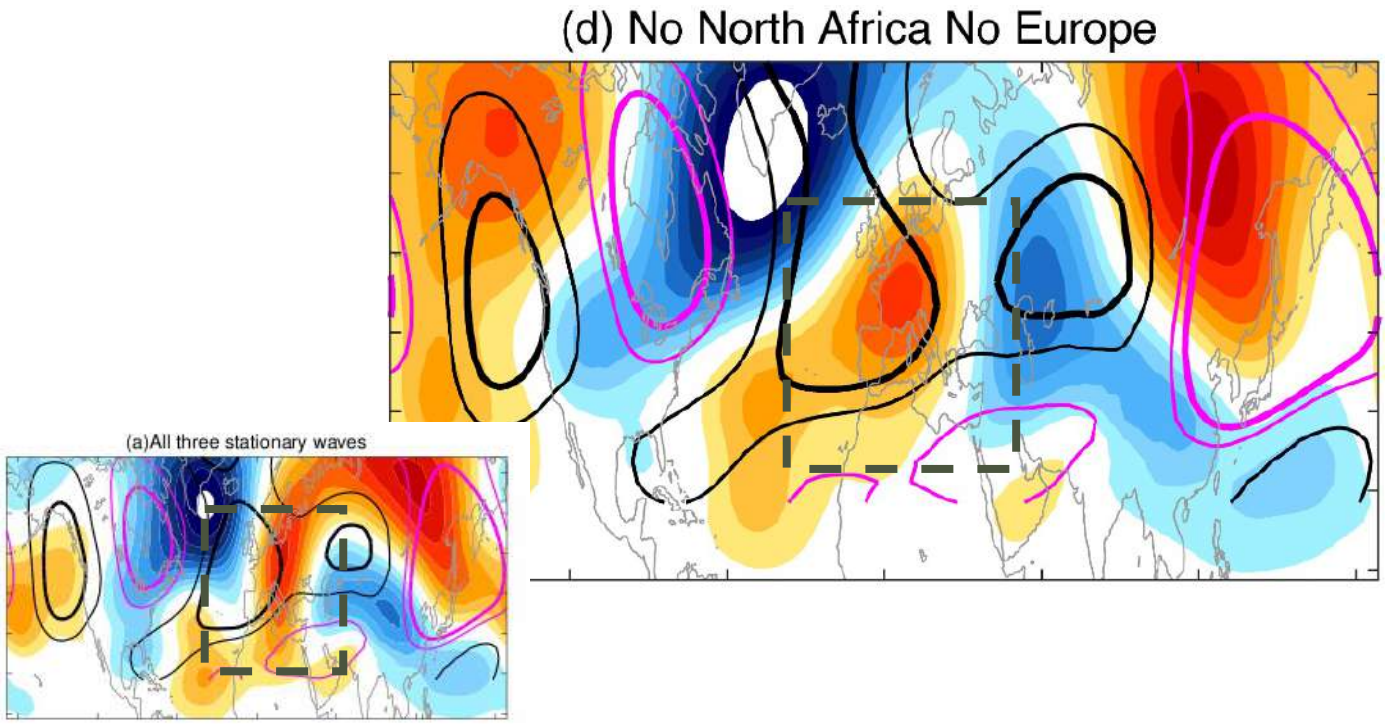
We see a **significant decline in precipitation**

Relative Atlantic cooling?

4xCO2 - 1xCO2 DJFM
Temperature at 850 hPa [K]

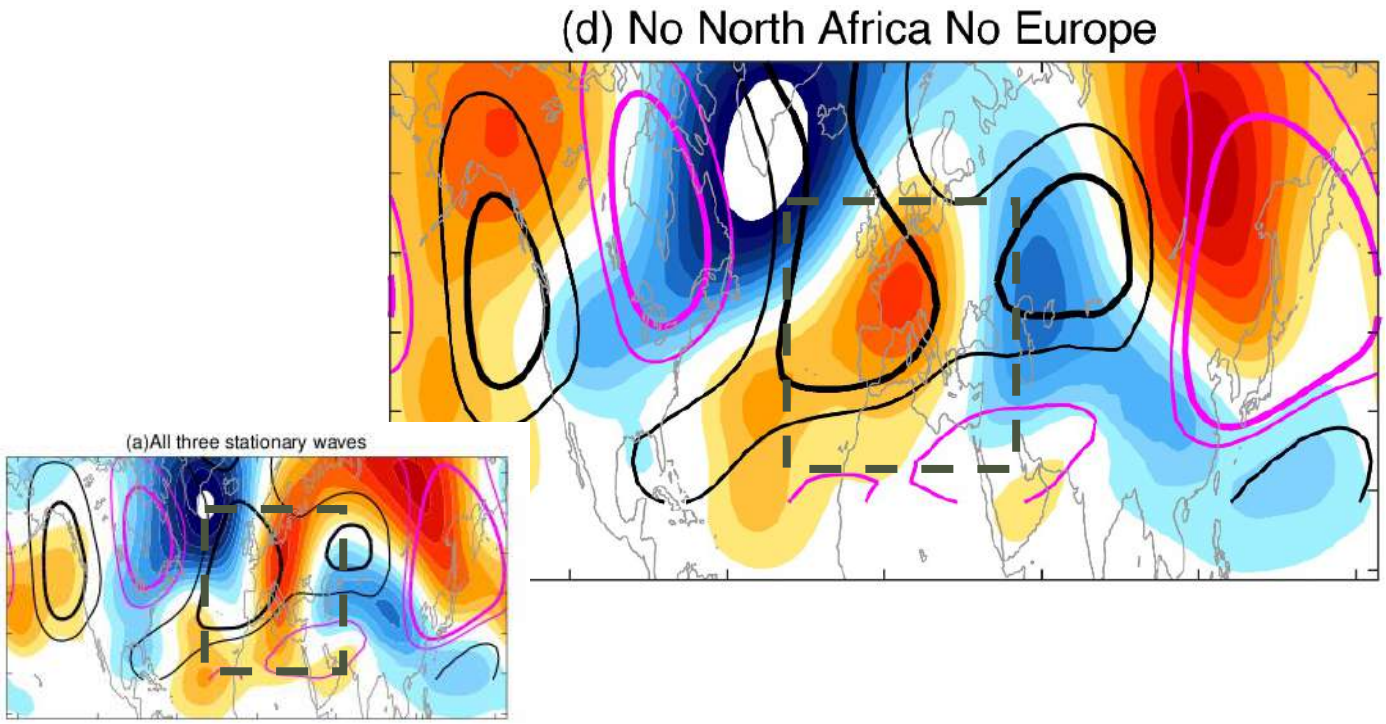


4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]



we get a **westward shift of the ridge**, similar to when we subtract land-sea contrast

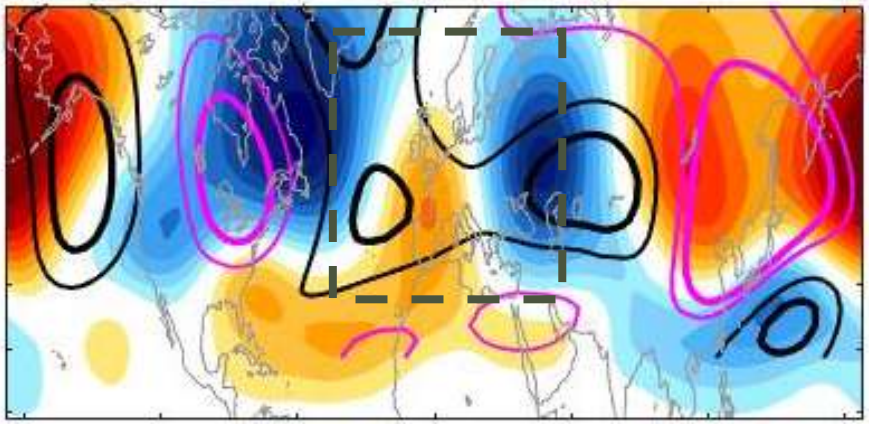
4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]



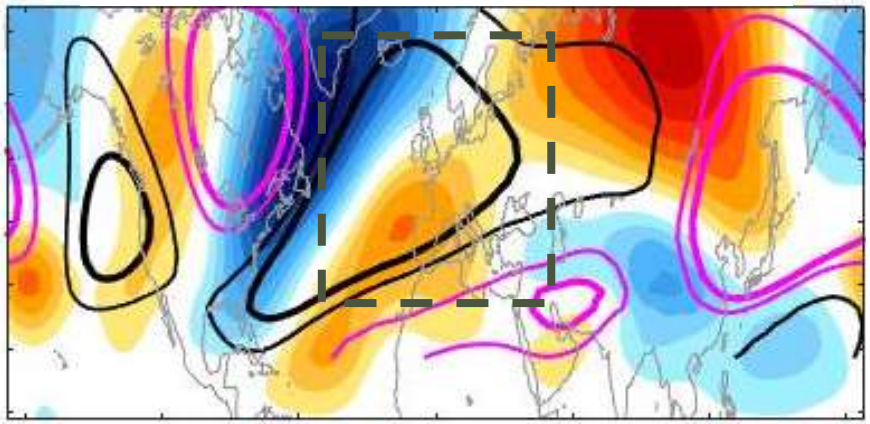
The Atlantic land-sea gradient seems more important than the Mediterranean gradient

4xCO2 - 1xCO2 DJFM Geopotential Height at 321hPa [m]

no Asia



no North-America



Each of the continents accounts for part of the downstream shift associated with the change in the land-sea contrast induced stationary-wave, and also for **part of the magnitude of the ridge**.

Conclusion

- All three stationary wave building blocks encourage subtropical drying; **land-sea contrast has biggest effect on Mediterranean drying**.
- The stationary waves forced by **oceanic heat fluxes seems the dominant forcing encouraging the anomalous ridge** above the Mediterranean in future projections while change in **land-sea contrast is crucial for the downstream shift**.
- Our **results do not support relative Mediterranean cooling as a dominant cause** for the projected drying in the region.
- **Ongoing work**: Understand the role of **horizontal ocean heat fluxes – tropics related or perhaps the Gulf Stream**?