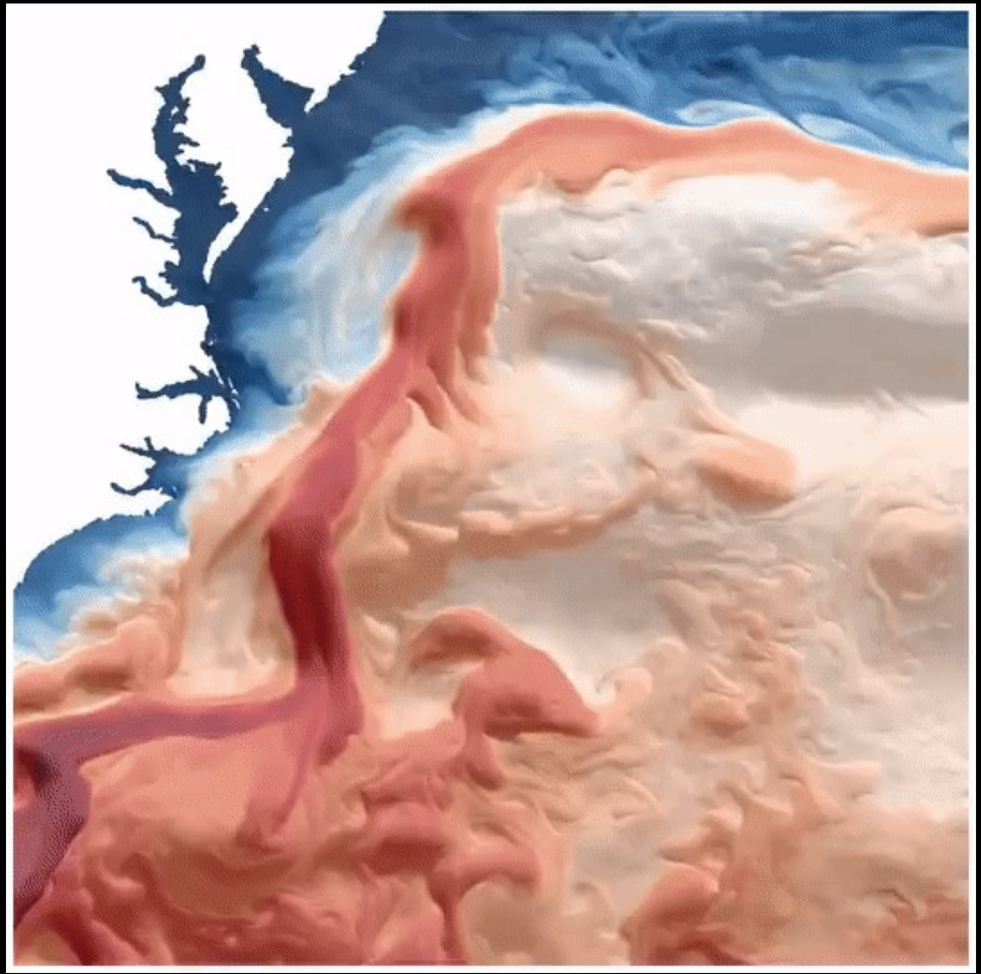
The impact of Gulf Stream precipitation on jet variability

Using pre-EERIE data



1km FESOM2 simulation (by Thomas Rackow)

With Hannah Christensen and Simon Michel

EERIE

European Eddy-Rich ESMs

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EERIE

European Eddy-Rich ESMs

NEXT SCIENCE HOUR

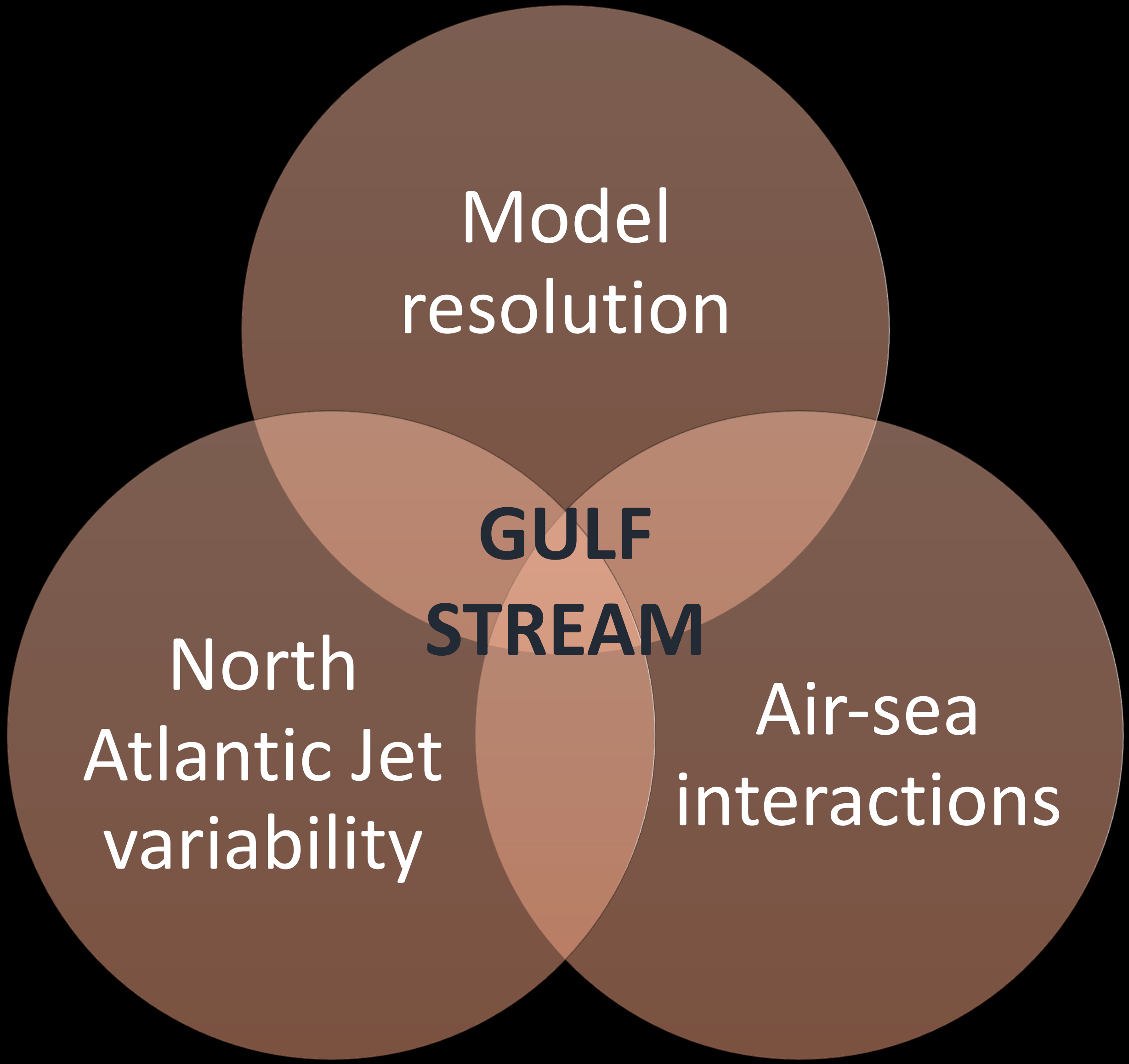
When: 2nd May 2024, 4pm CEST

What: "Inter-model differences in the representation of the AMOC forcing of the NAO"

Who: Rein Haarsma (BSC)

Where: This Zoom room (same link)

EERIE European Eddy-Rich ESMs



1. Always talking about DJF

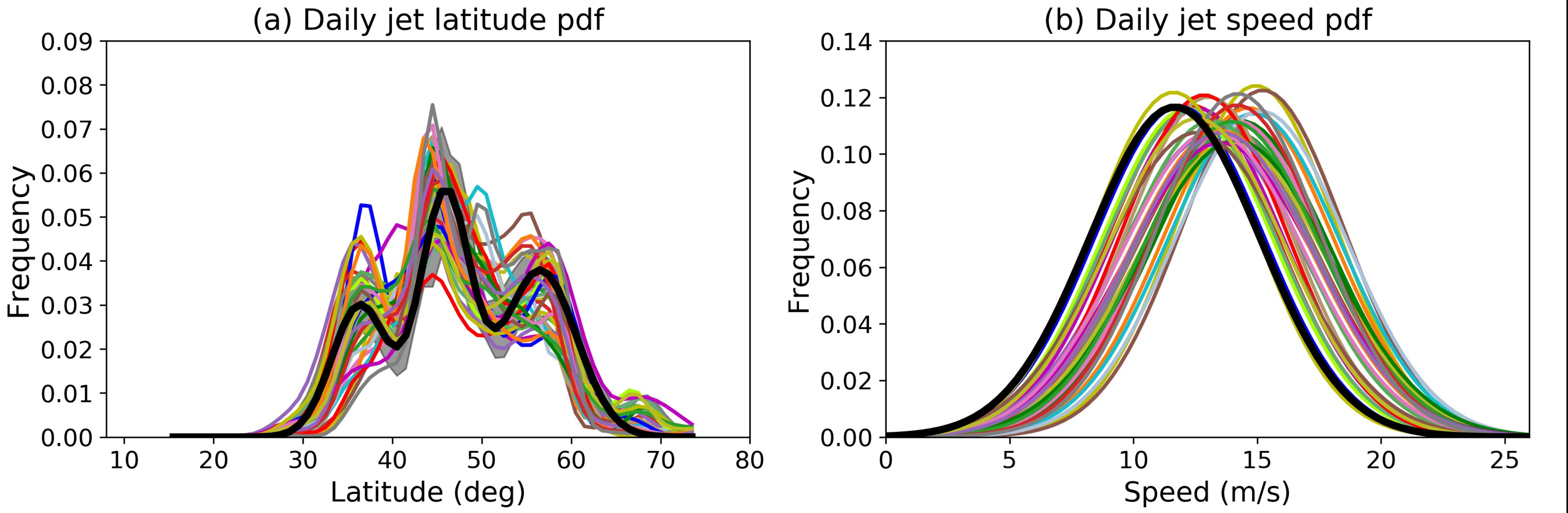
2. Always talking about 1979-2015.

3. Jet is measured at 850hPa, blocking at 500hPa.

4. Pre-EERIE data = CMIP5 + CMIP6 + HighResMIP

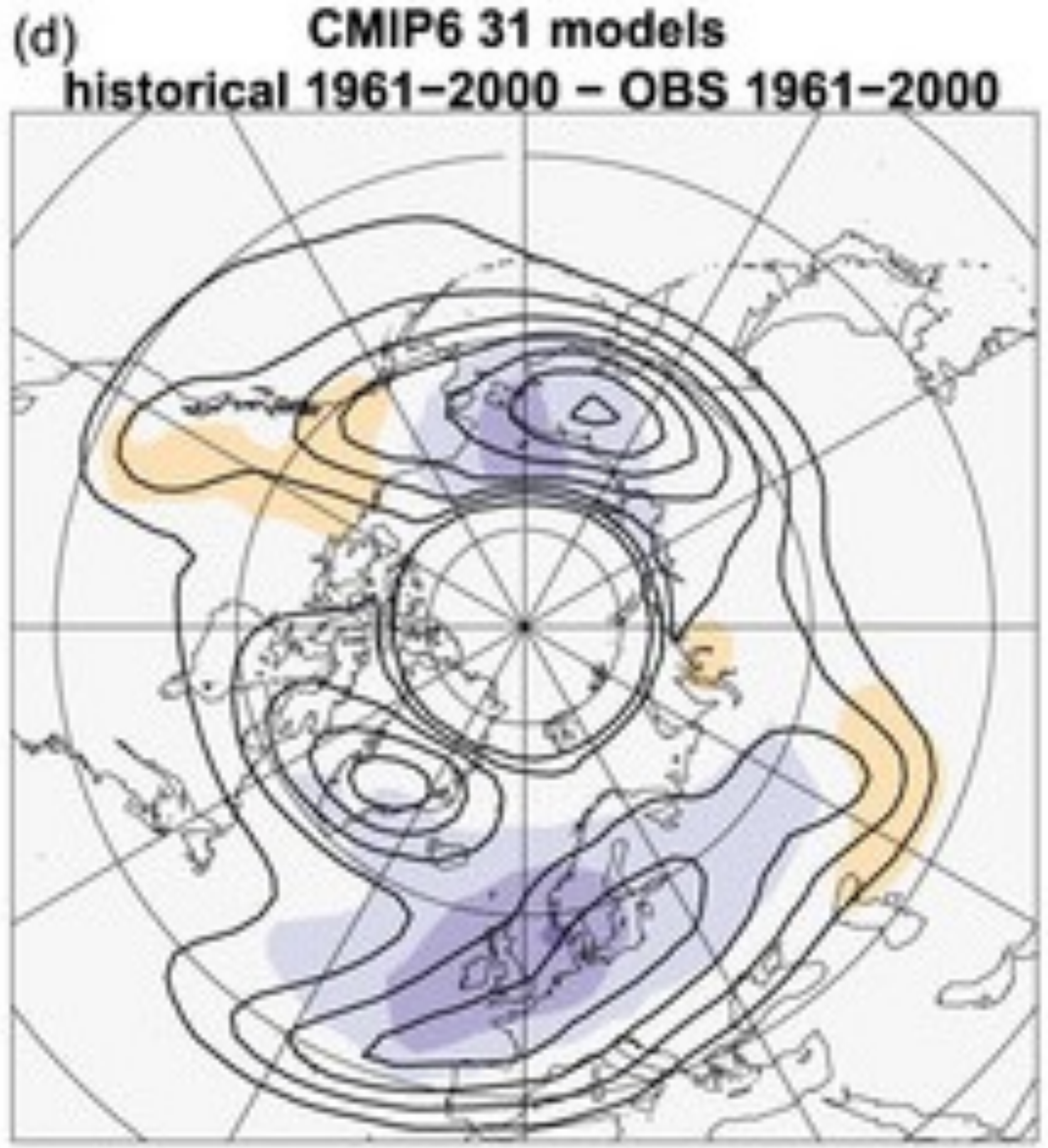
5. I don’t have time to mention all aspects.

Modulo a lot of internal variability, model jets are: too zonal/fast, underestimate European blocking, and generally don't move northwards enough.



Underestimation of European blocking

From Davini and Andrea (2020)

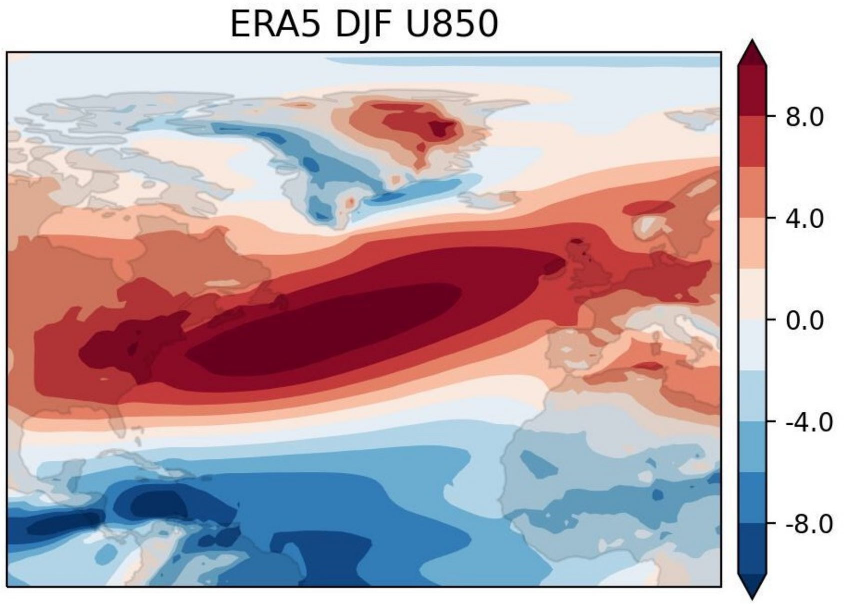


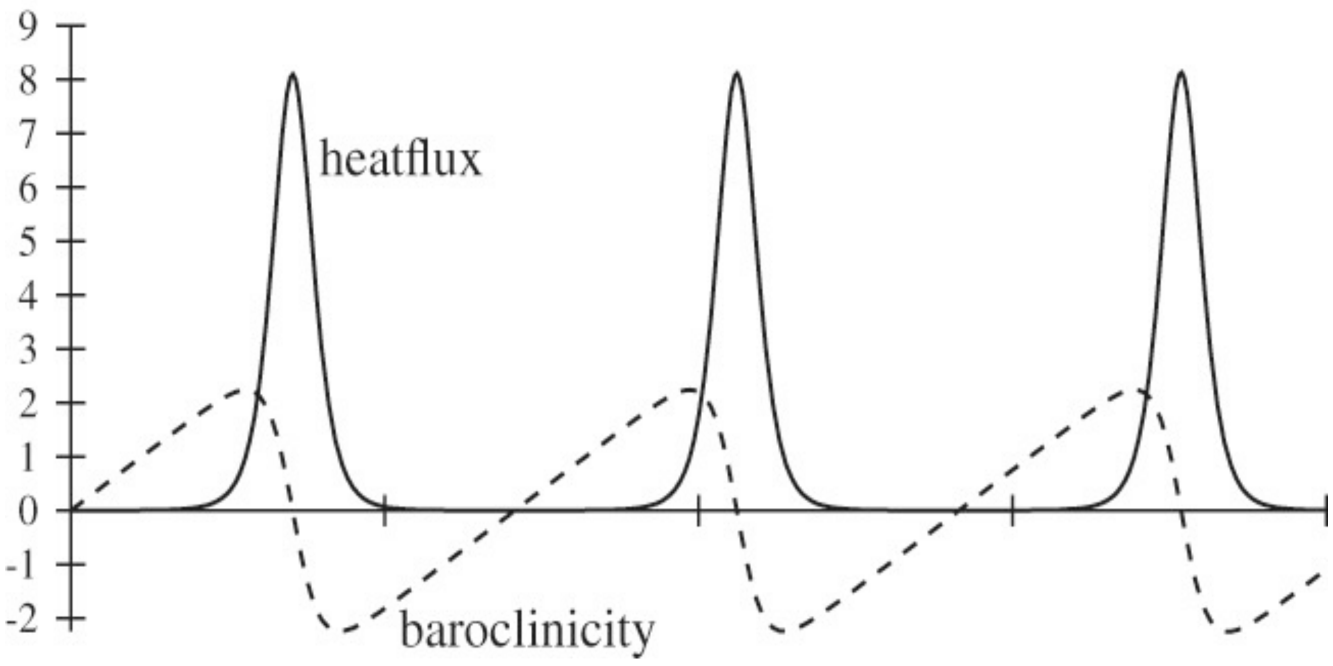
The predator-prey model of the jet

Life cycles of the jet/storm track:

1. Neutral state: zero/low baroclinicity
2. Growth: baroclinicity begins growing
3. Release: baroclinicity reaches threshold; period of enhanced eddy/storm activity; instabilities are moved polewards where they dissipate.
4. Return to neutral.

Ambaum and Novak (2014): Non-linear oscillator model





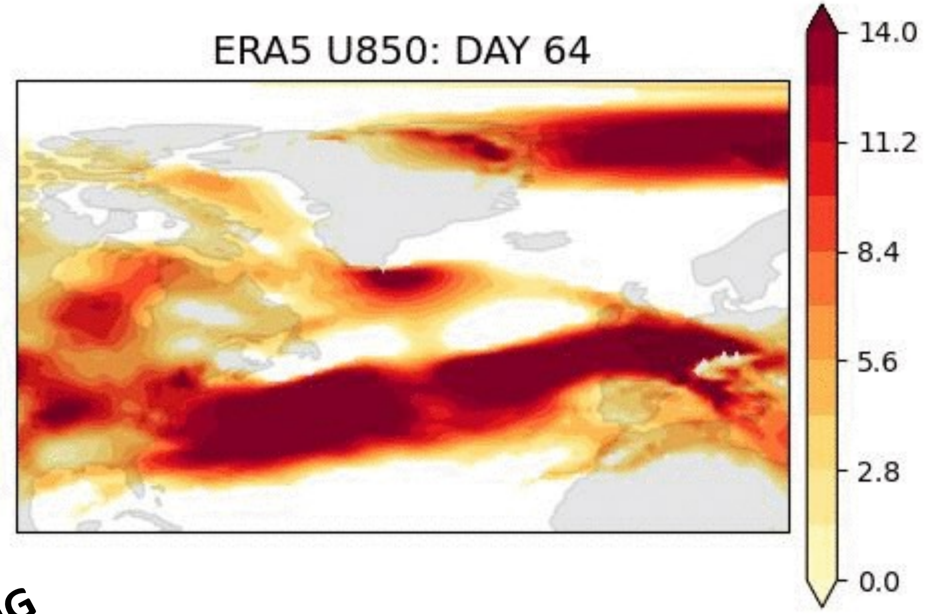
The predator-prey model of the jet

Life cycles of the jet/storm track:

1. Neutral state: zero baroclinicity
2. Growth: baroclinicity begins growing for whatever reason
3. Release: baroclinicity reaches threshold, triggers period of enhanced eddy/storm activity; instabilities are moved polewards where they dissipate.
4. Return to neutral.

NORTHWARD SHIFTS

+ EUROPEAN BLOCKING



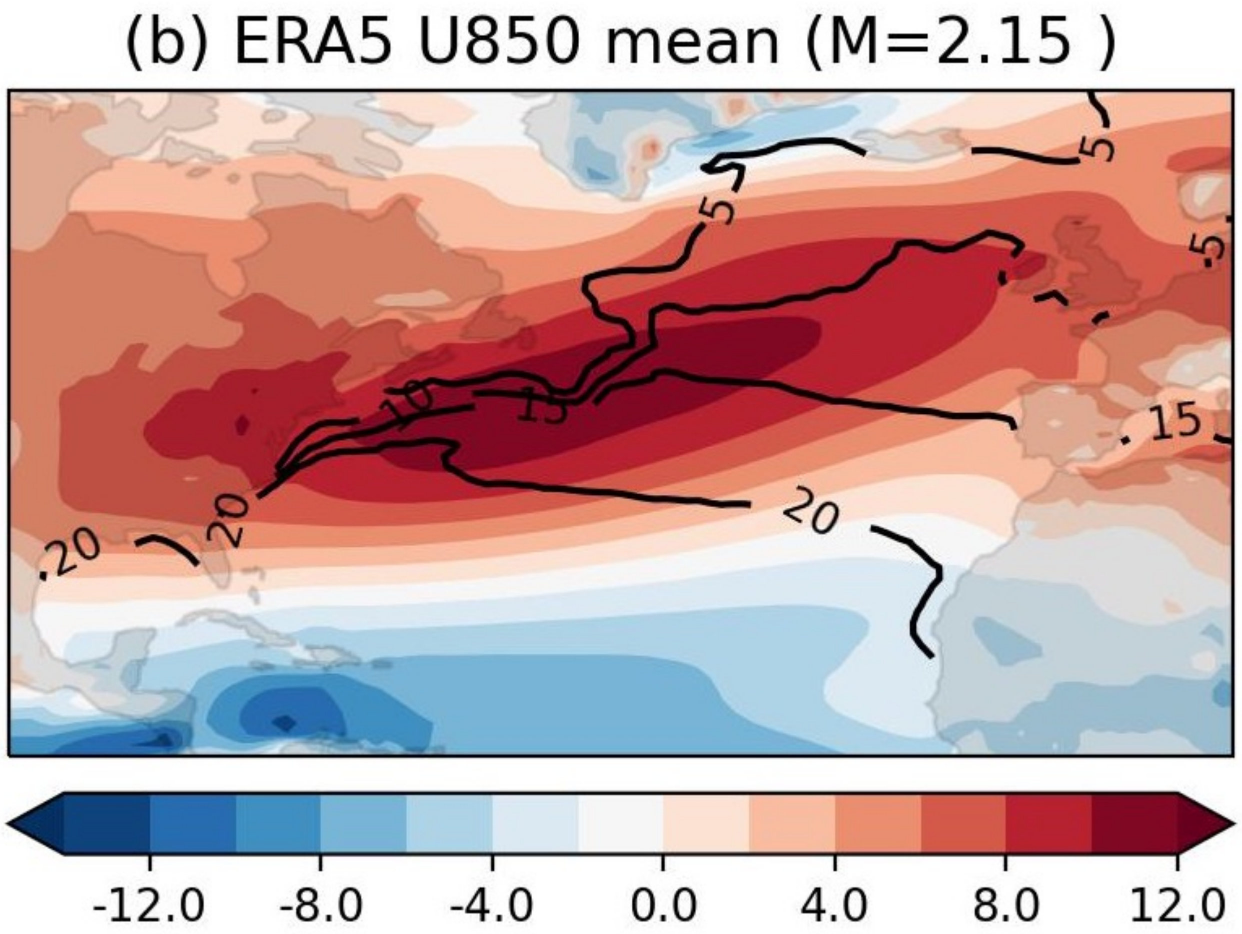
Effect of Gulf Stream variability

1. Growth phase: sharp SST gradient is a source of baroclinicity.

2. Release phase: warm waters of Gulf Stream conducive for strong heat fluxes / precipitation.

   Produces stronger/bigger cyclones that can travel further poleward.

   [Mesoscale eddies??]



Line contours = ERA5 SSTs

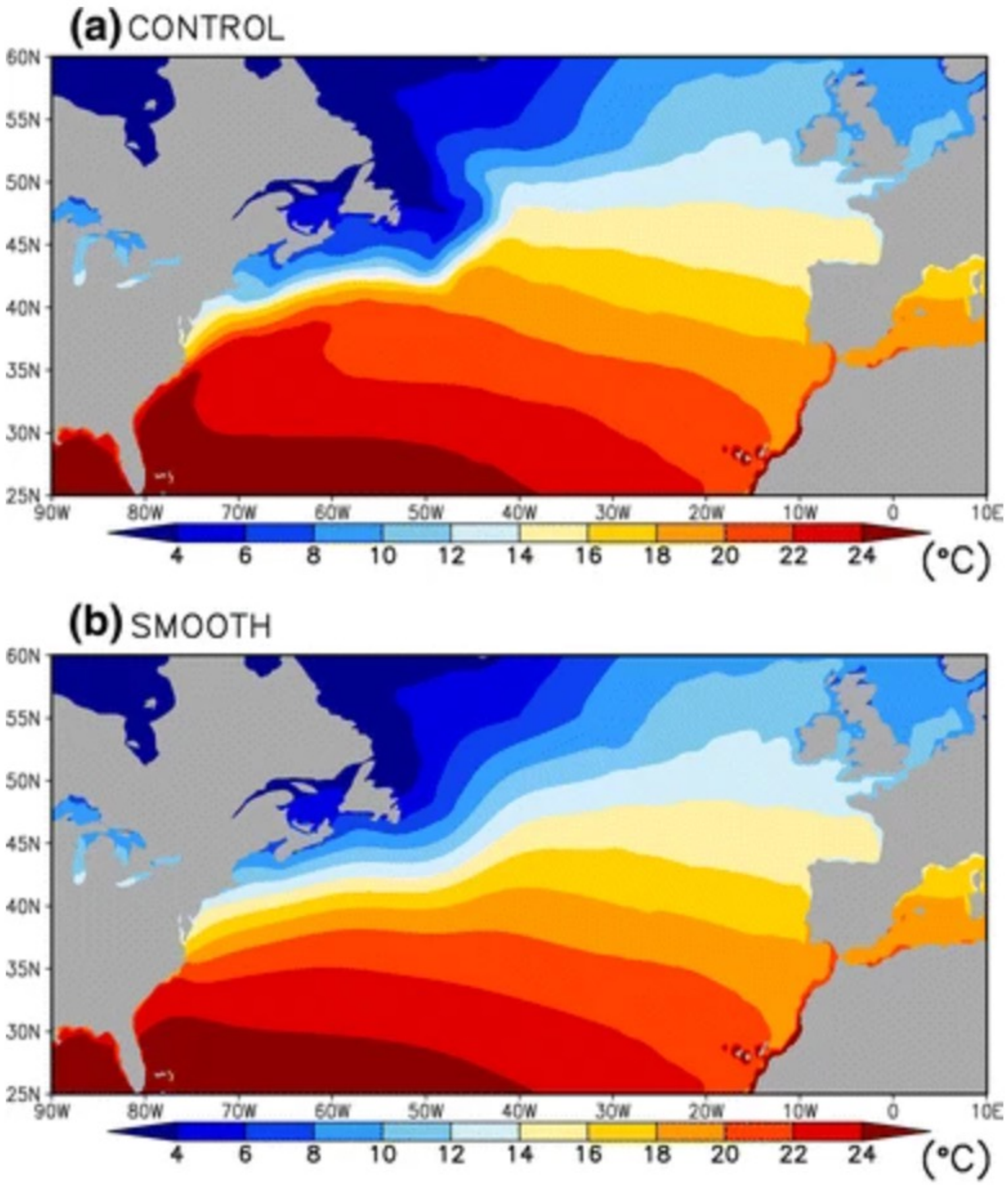
Effect of Gulf Stream variability

O'Reilly et al. (2015; 2016):

Smoothed Gulf Stream SSTs (in a GCM)

↓

Less European blocking and northern jet days.



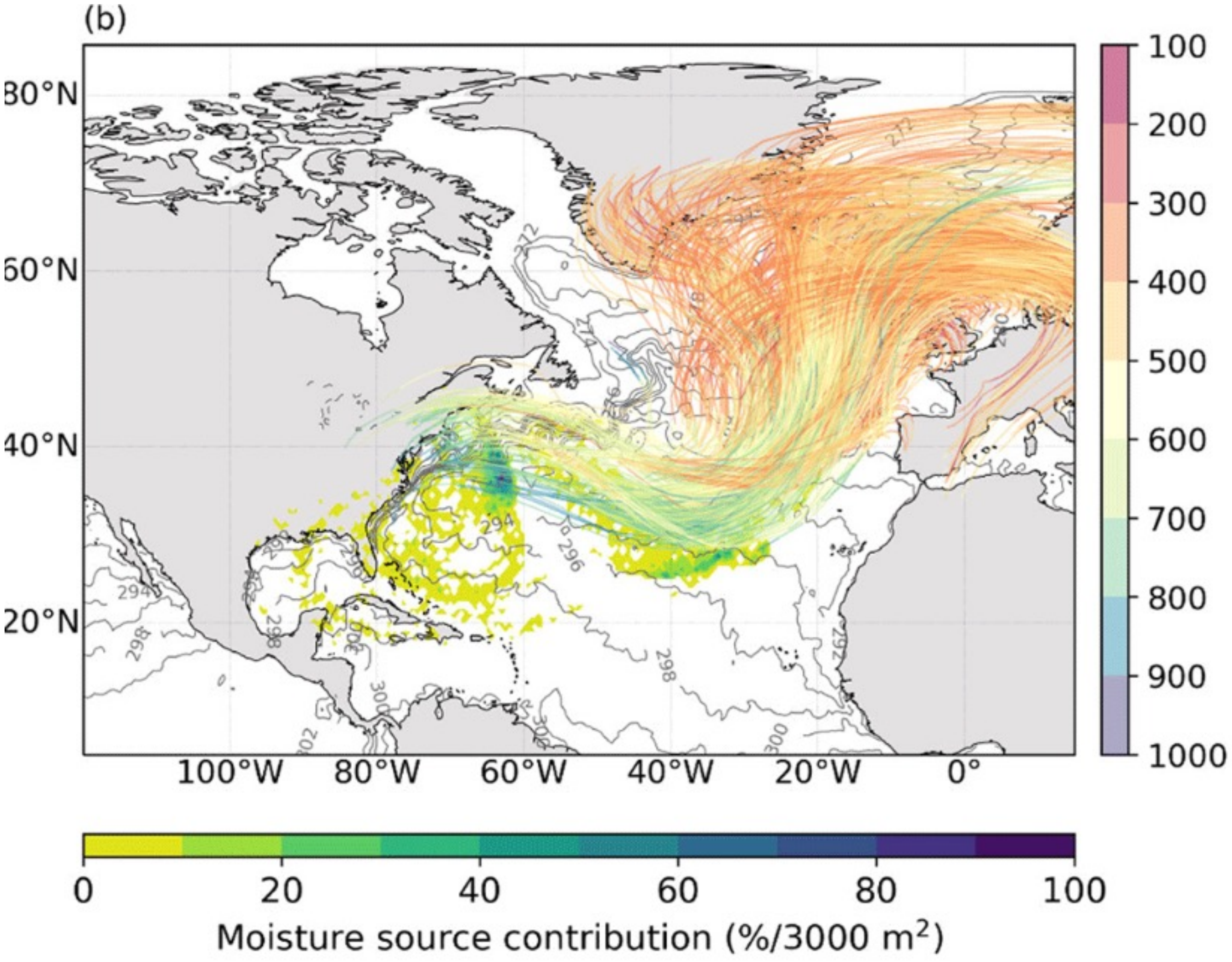
Effect of Gulf Stream variability

Many case studies arguing for role of diabatic processes around Gulf Stream

e.g. Wenta et al. (2024) WCD

+ Mathews et al. (GRL preprint)

Trajectories of air parcels that interacted with a Feb 2019 block



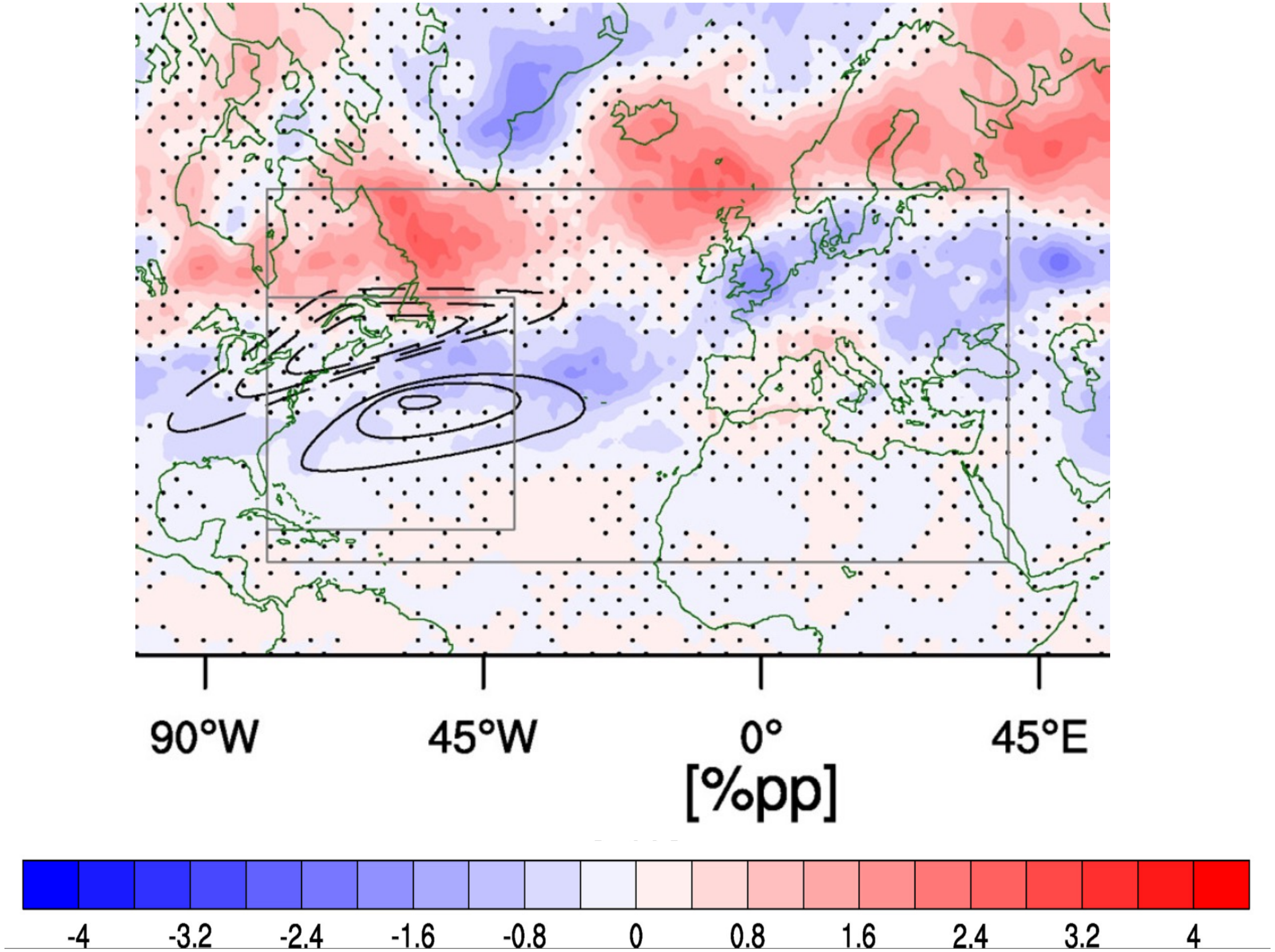
Effect of Gulf Stream variability

Schemm (2023):

Increased atmospheric resolution near Gulf Stream amplifies diabatic heating of eddies.

Schemm argues that overly zonal model jets due to poorly resolved diabatic processes.

”Adapted” from Schemm 2023

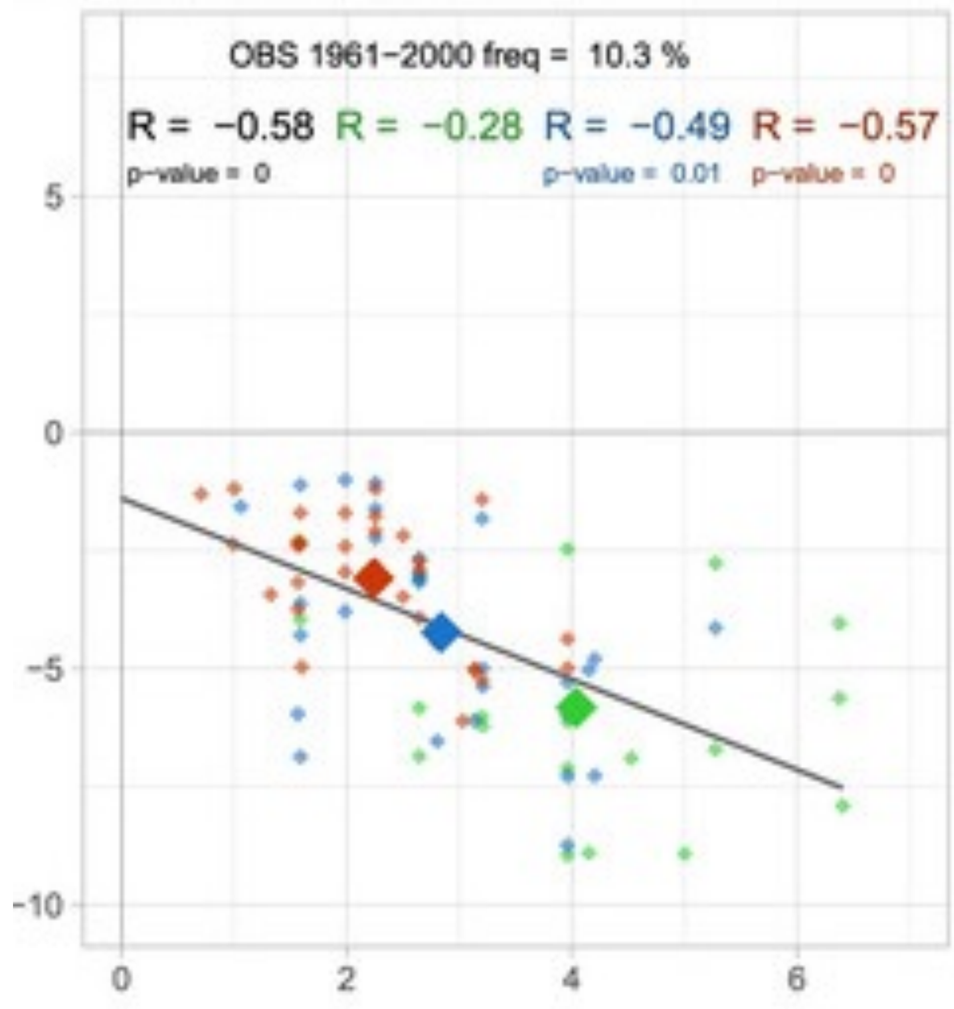


We do see improvements with resolution

Both for European blocking and northern jet latitude days

Davini and Andrea (2020)
Athanasiadis et al. (2022)
Dorrington et al. (2022)
Michel et al. (2023)

European blocking vs resolution



From Davini and Andrea (2020)

Why do we get improvements with resolution?

1. **Reduced SST biases.**
   Somewhat ambiguous evidence from Davini and Andrea (2020).

2. **Changes to SST gradients as a result of better simulated Gulf Stream.**
   Argued by both Athanasiadis et al. (2022) and Michel et al. (2023) via a comparison between coupled and AMIP models.

3. **Improved precipitation variability in Gulf Stream region.**
   Suggested by several studies based on case studies or single models (particularly Schemm 2023).

TODAY’S GOAL

EERIE
European Eddy-Rich ESMs

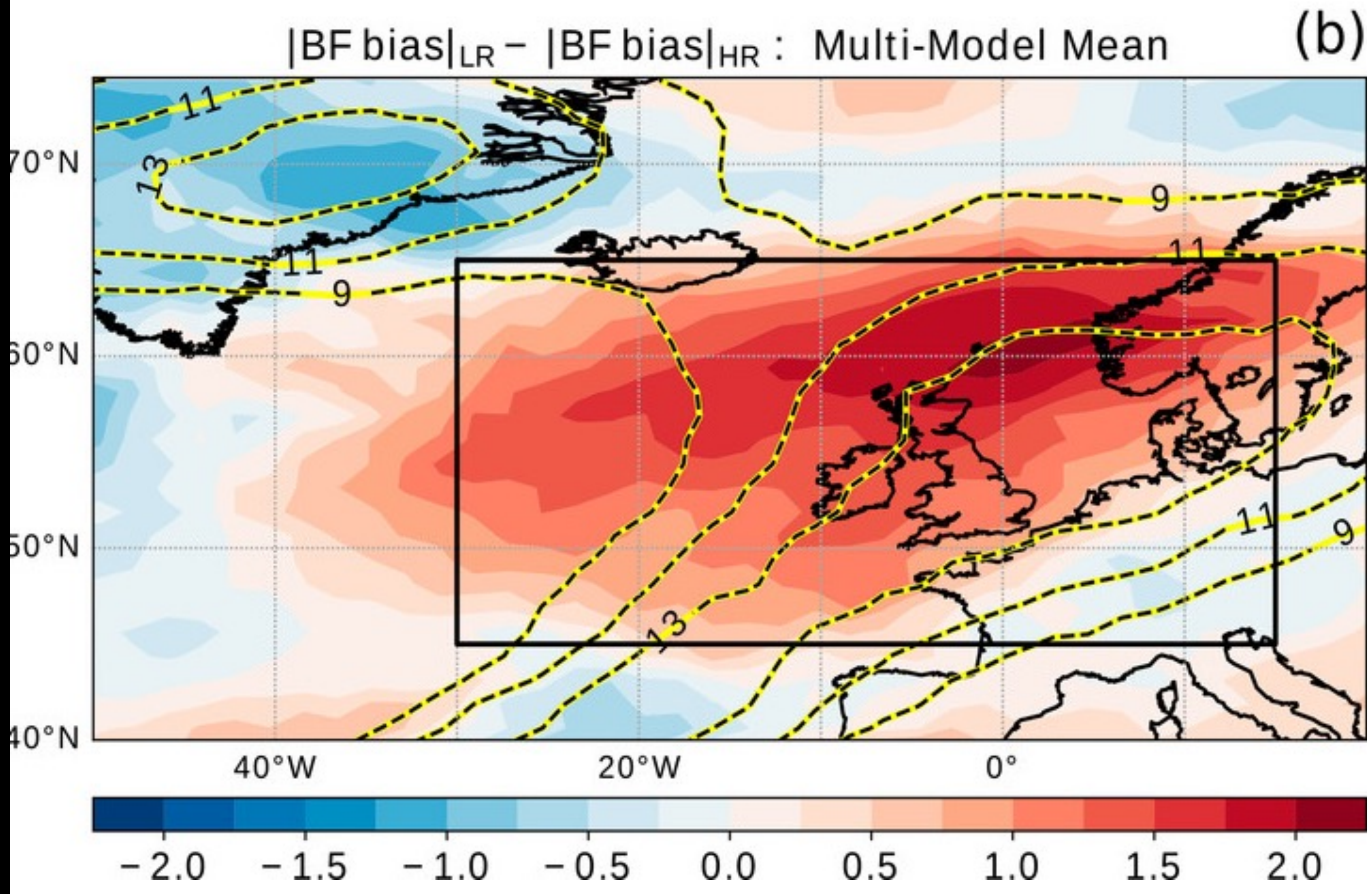
- Explore role of Gulf Stream precipitation and link with model resolution.
- Explain the pitfalls of comparing coupled and AMIP models.
- Speculation on what we might expect to see in mesoscale-resolving simulations.

METRICS

- Blocking computed by reversal of Z500 gradient.

  European Blocking region following Athanasiadis et al. (2022)

- Gulf Stream region following Schemm 2023 (picture shortly).



METRICS

Precipitation variability = ma monthly precip obtained in Gulf Stream region across D, J and F.

Why? Because:

- Schemm shows main impact is from biggest cyclones.
- Mean precip masks large model biases.

WARNING!!!!

Do not use ERA5 precip.

Rubbish variability: "drizzle" problem.

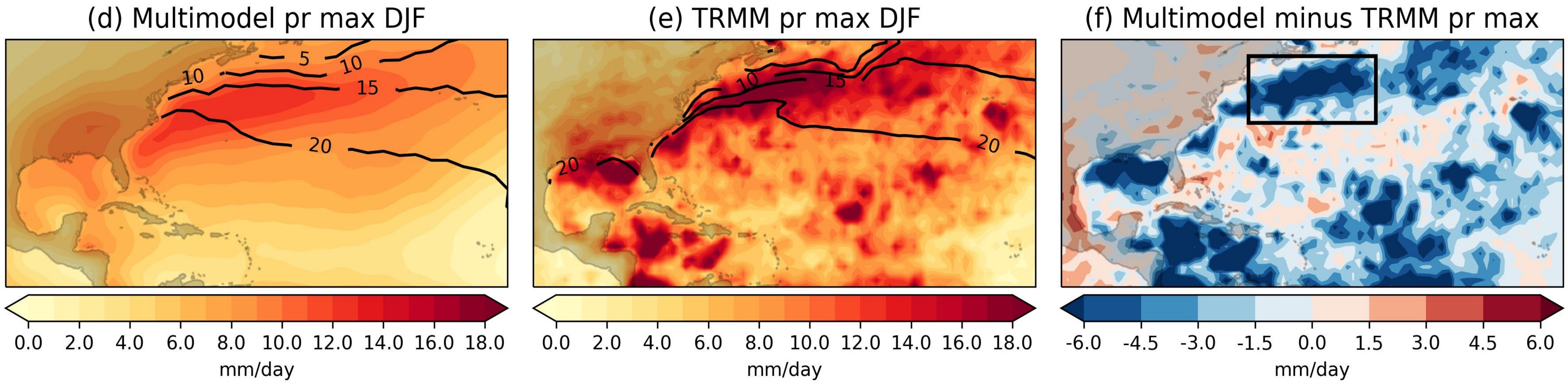
We used TRMM.

European Eddy-Rich ESMs

Gulf Stream precipitation

Models have too little precip, especially extremes.

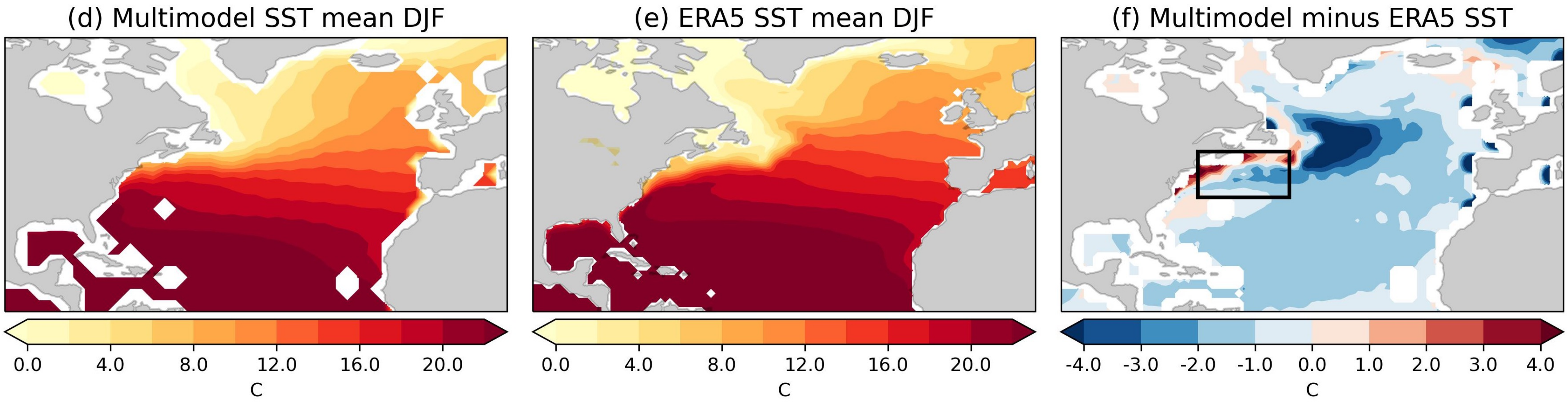
Positional bias: Gulf Stream separation fail



Gulf Stream SSTs

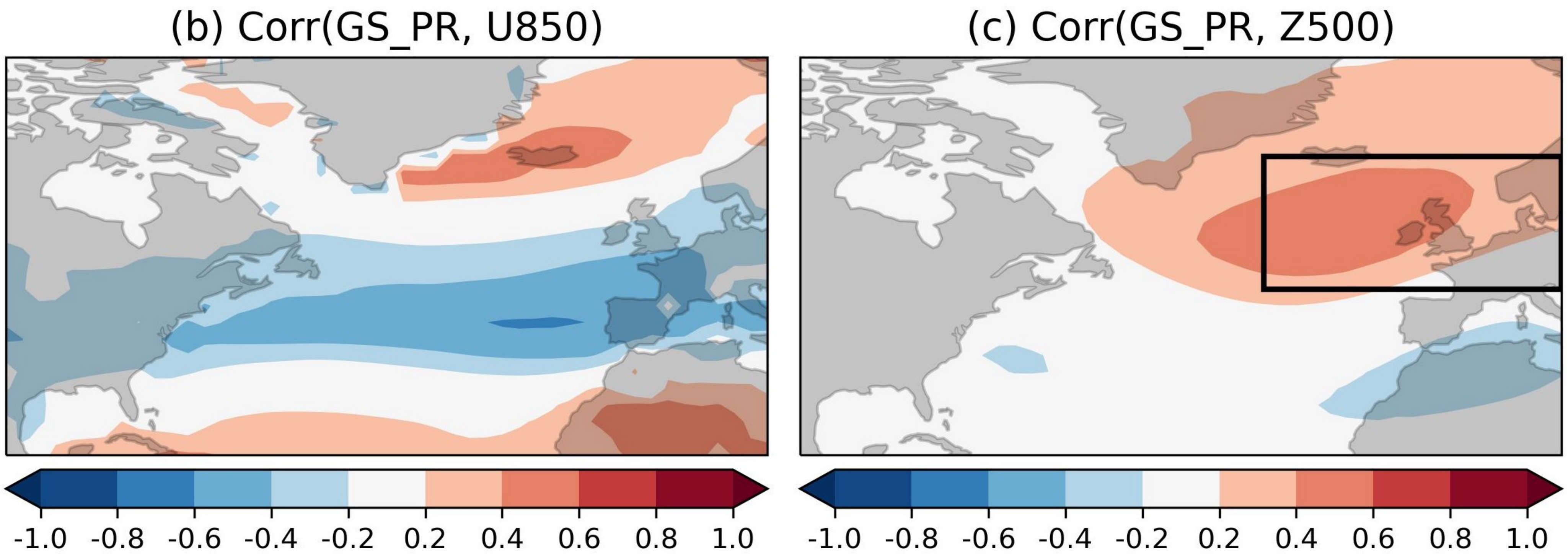
North Atlantic SST bias.

Gulf Stream SST gradient bias.



Gulf Stream precipitation

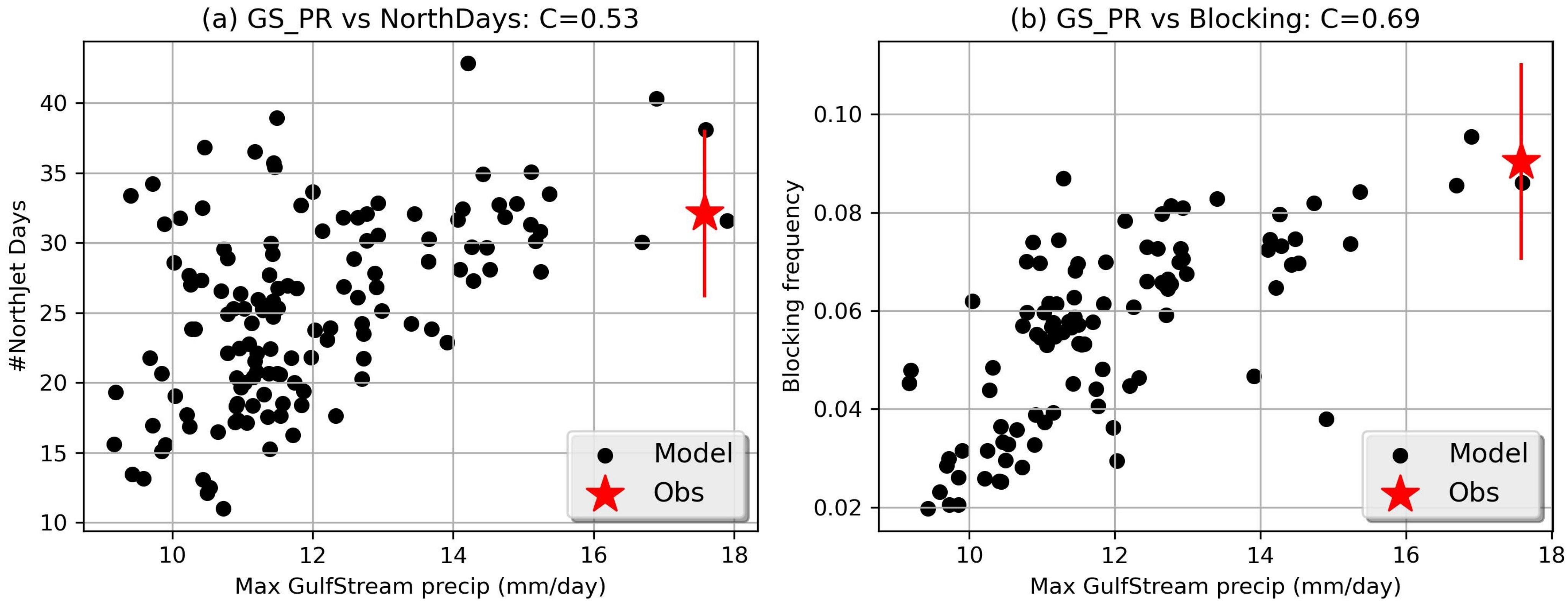
Positive correlations:
Models with greater Gulf Stream precipitation variability have a more positive climatological mean U850 / Z500 at that gridpoint.



Gulf Stream precipitation

Gulf stream precip variability strong predictor of European blocking / Northern Jet biases in models.

Up to 50% of intermodel spread

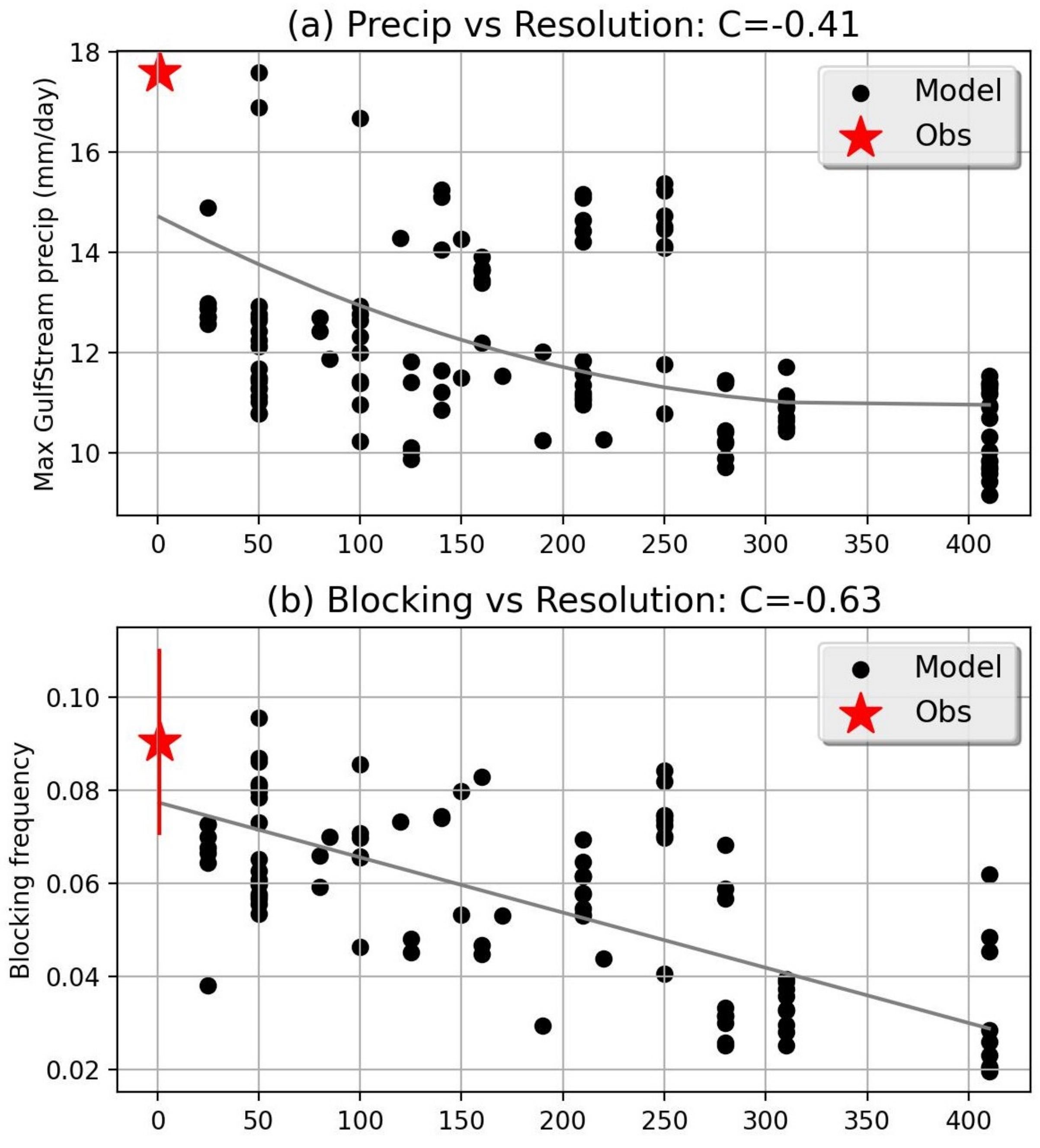


Precipitation variability goes up with resolution

Quadratic fit produces correlation of ~0.75.

This has been noted in targeted experiments.
(e.g. Scher et al. 2017)

Expected due to atmospheric resolution alone.



SUMMARY SO FAR

- Gulf Stream precipitation variability tightly linked to European blocking frequency
- This variability increases with resolution.
- Statistical tests for mediation support the basic pathway
  increased resolution → increased precip variability → increased blocking

Things I didn’t discuss that could play a role

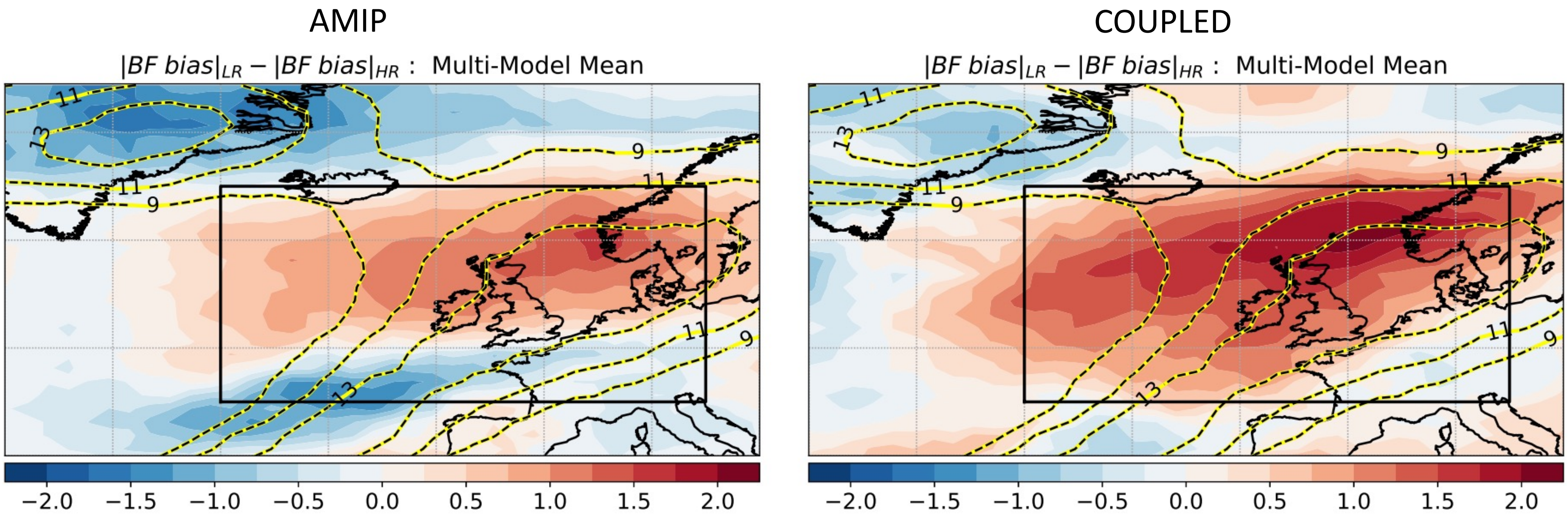
1. Indirect effects from jet speed and southern jet (subtropical jet)
2. Model tuning issues. Increasing resolution often degrades model mean state!
3. Model dependence more broadly. Compensating biases etc.
4. Two-way coupling; multiple timescales.
5. Greenland tip-jet events?

It's hard to disentangle atmospheric vs oceanic resolution

The link between jet variability and resolution is smaller in AMIP models.

Interpreted as evidence for role of oceanic resolution
(as opposed to atmospheric)

Athanasiadis et al. (2019)
Michel et al. (2023)



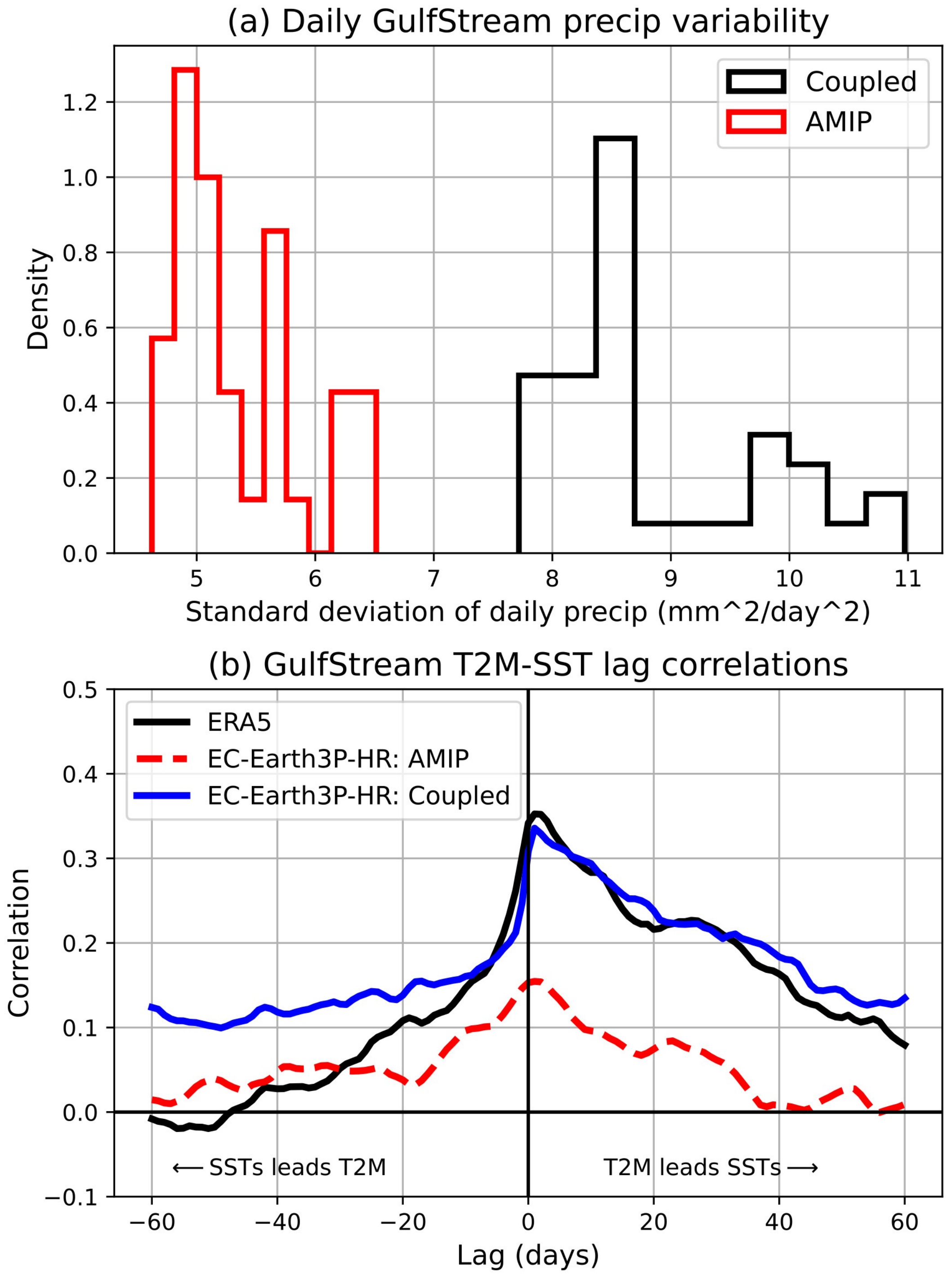
Athanasiadis et al. (2019)

But AMIP models are very different to coupled models

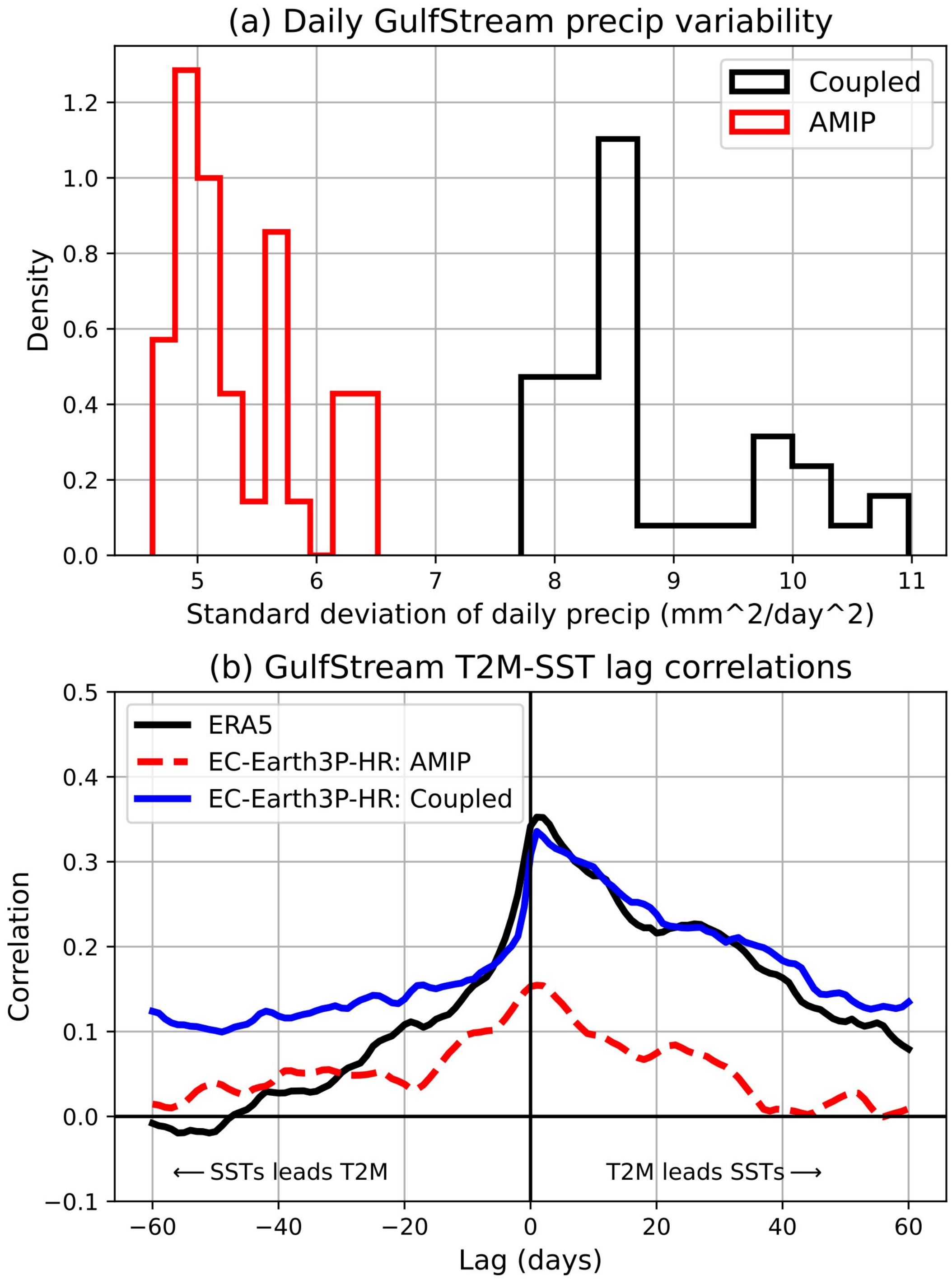
AMIP models have much greatly reduced temperature and precip variability due to excess thermal damping

(Battisti and Barsugli 1998)

Smaller signal in AMIP models therefore expected *a priori*!
(i.e. even in absence of any increased ocean resolution)

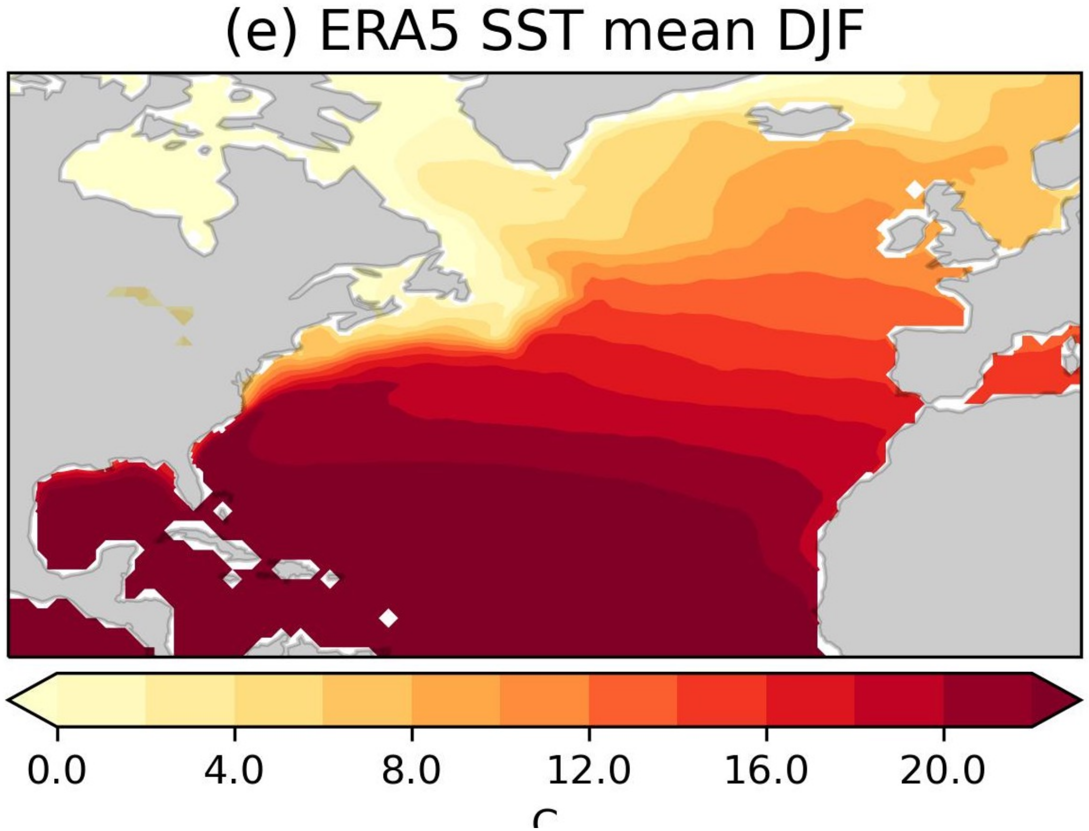


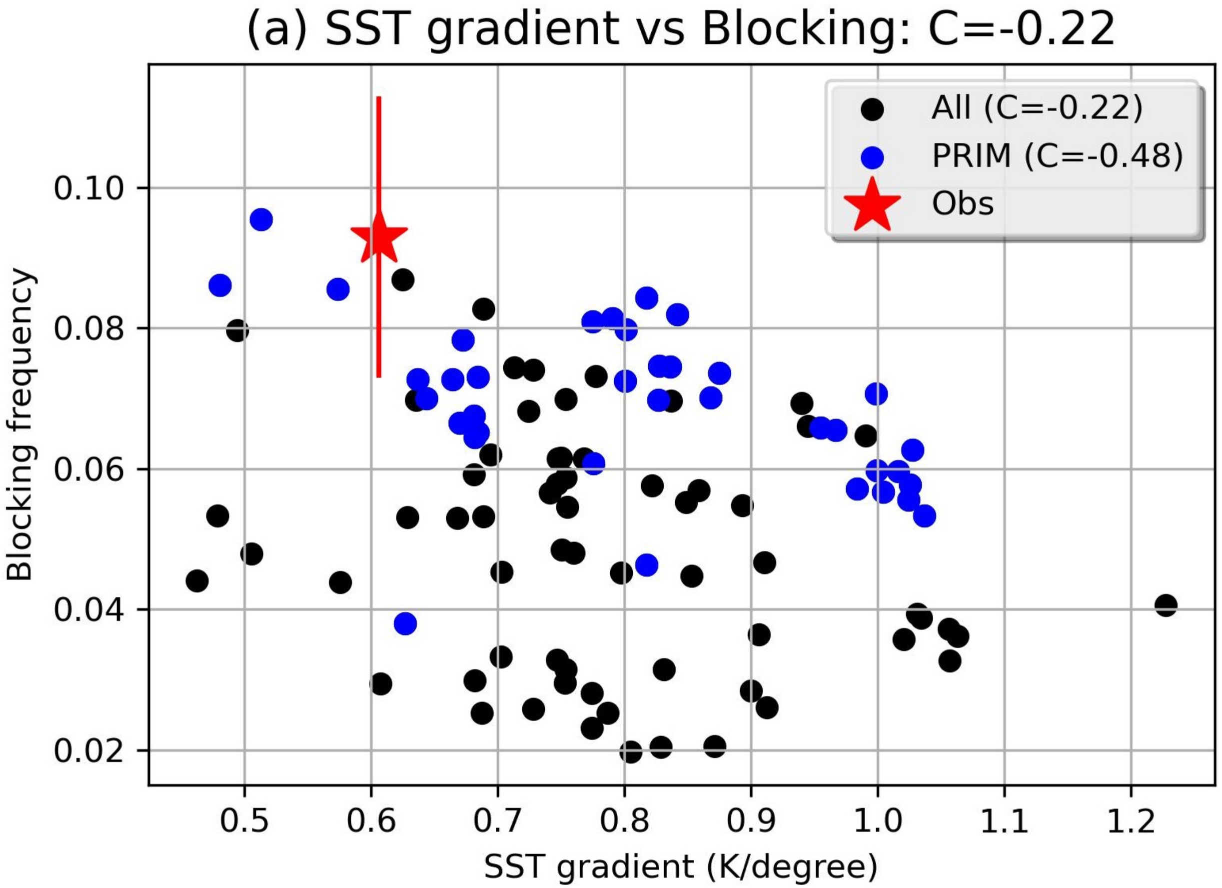
This poses a challenge for EERIE!



Evidence for improvements due to better *actual* Gulf Stream seems weak

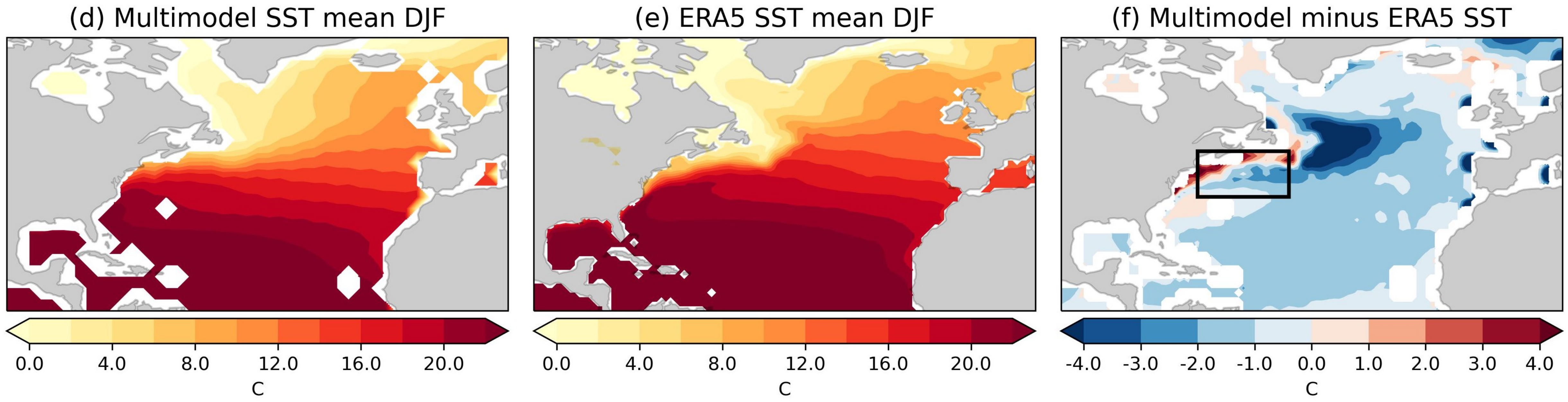
"Only HadGEM3-CG3.1-HH with an ocean eddy-resolving resolution of 1/12◦ and atmosphere resolution of 50 km correctly simulates this separation."
Tsartsali et al. (2022)





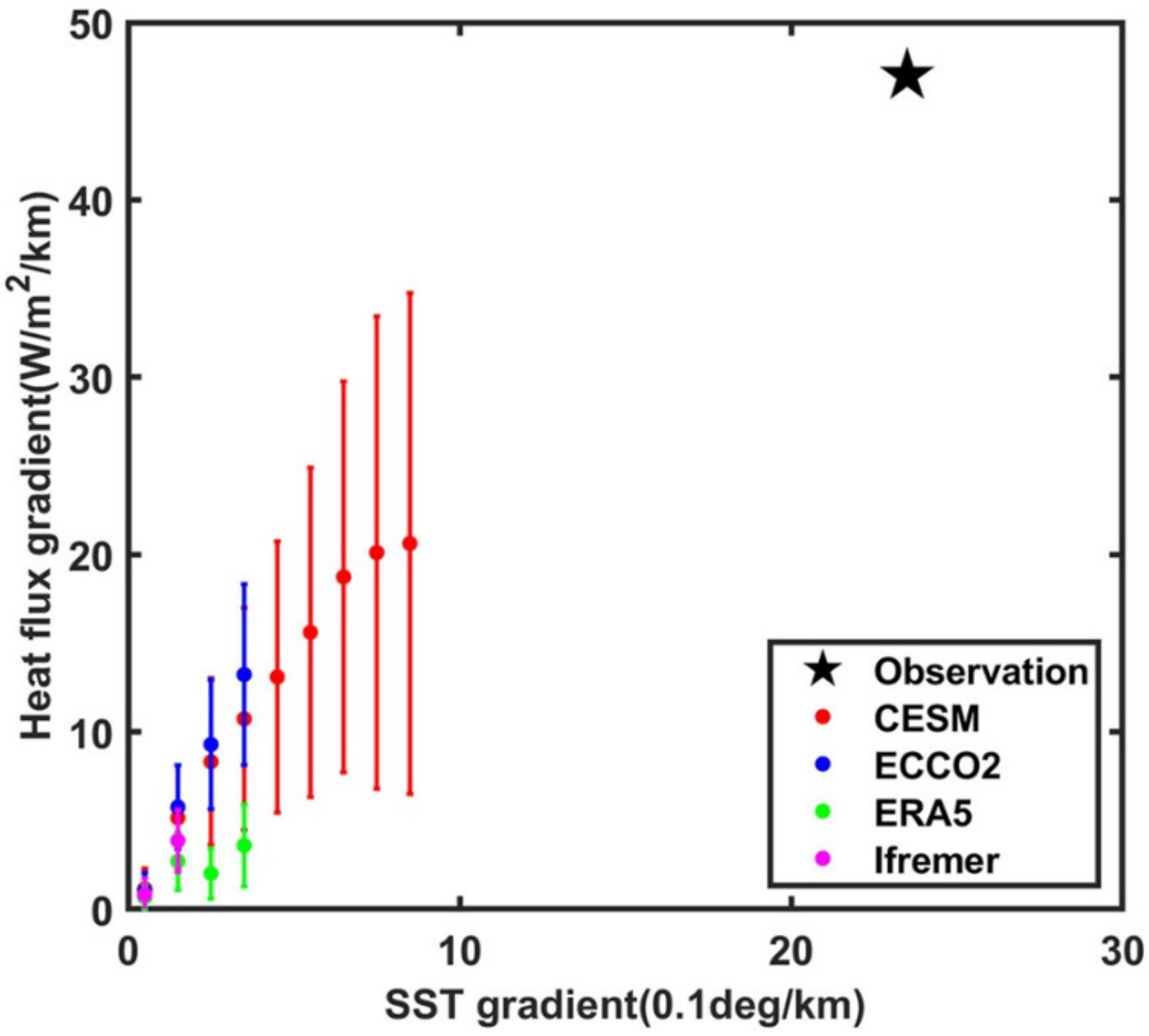
What might we gain from mesoscale?

Consistent Gulf Stream separation?
Northwest corner?
North Atlantic SST biases?



“Observations Reveal Intense Air-Sea Exchanges Over Submesoscale Ocean Front”
(Yang et al. 2024, GRL)

Increased intense precipitation with resolution may come from both atmospheric and oceanic resolution.



Yang et al. (2024)

“Observations Reveal Intense Air-Sea Exchanges Over Submesoscale Ocean Front”
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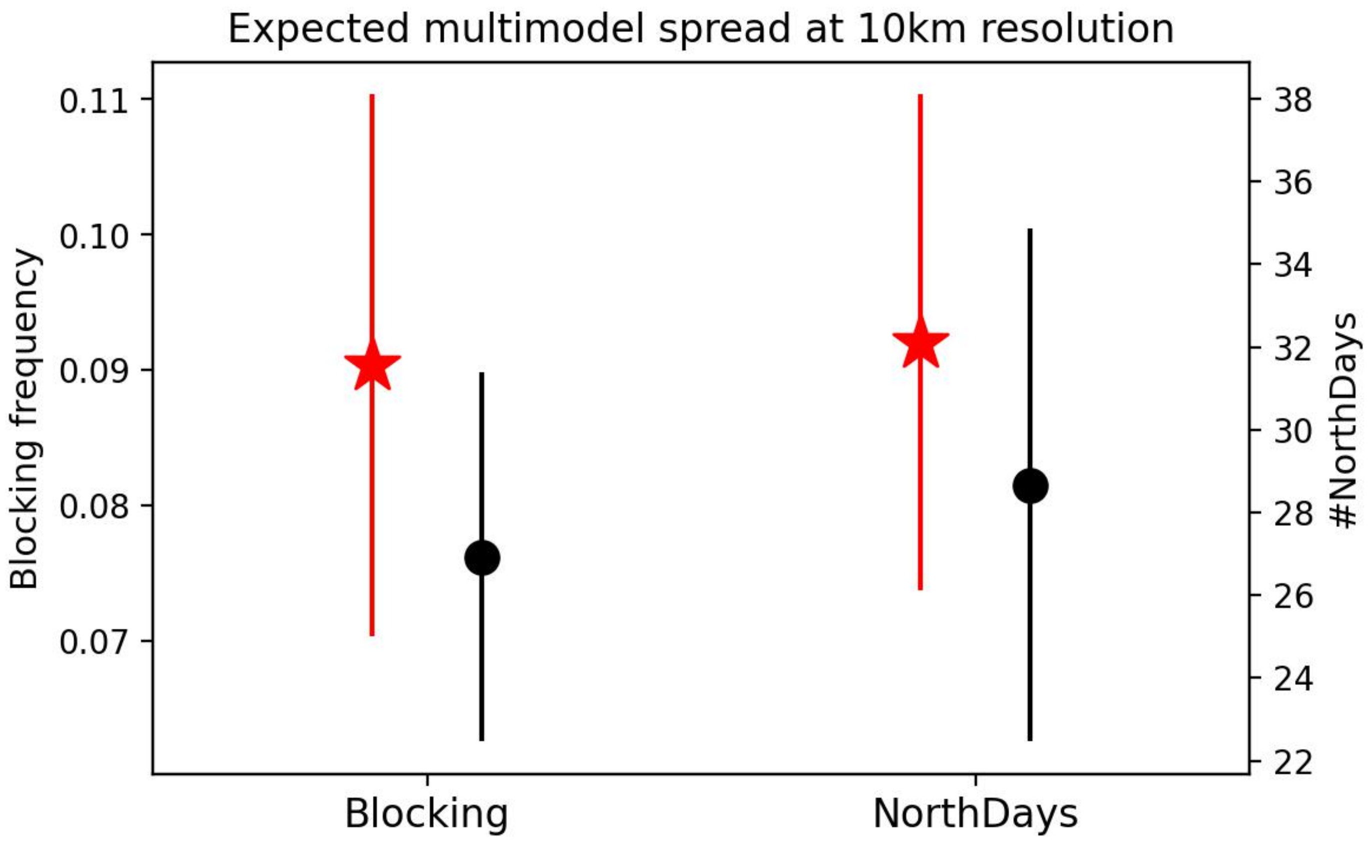
Increased intense precipitation with resolution may come from both atmospheric and oceanic resolution.

Will this reduce biases beyond what’s expected from current extrapolation?



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CONCLUSION

- Diabatic processes in Gulf Stream clearly linked to European Blocking frequency in models.
- Higher resolution → better precipitation → reduced blocking biases.
- Challenges attributing to atmospheric vs oceanic resolution.
- Step change when resolving mesoscale?

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