Seasonality of the Jet Response to Arctic Warming

Bryn Ronalds
Adv: Elizabeth Barnes

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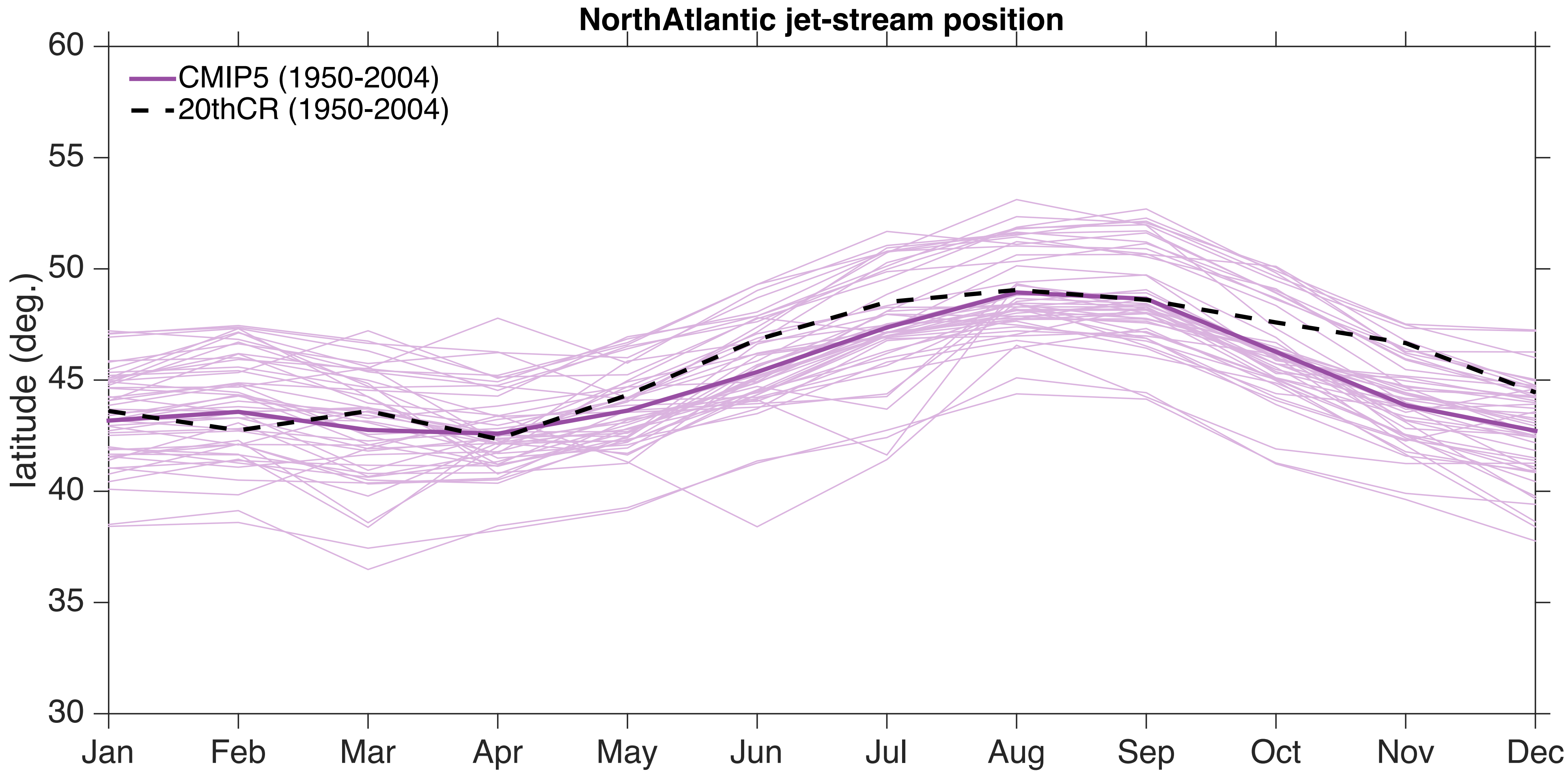
The story:

- Midlatitude jets are fundamental to weather and climate
- It is generally agreed that climate change will result in a poleward shift of the jet, although there is a seasonality to this response
- Based on fluctuation-dissipation theory, the atmosphere may respond to forcing in the way it most prefers to vary already, e.g. the leading EOF



NorthAtlantic jet-stream position
CMIP5 (1950-2004)
20thCR (1950-2004)
latitude (deg.)
60
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Jan
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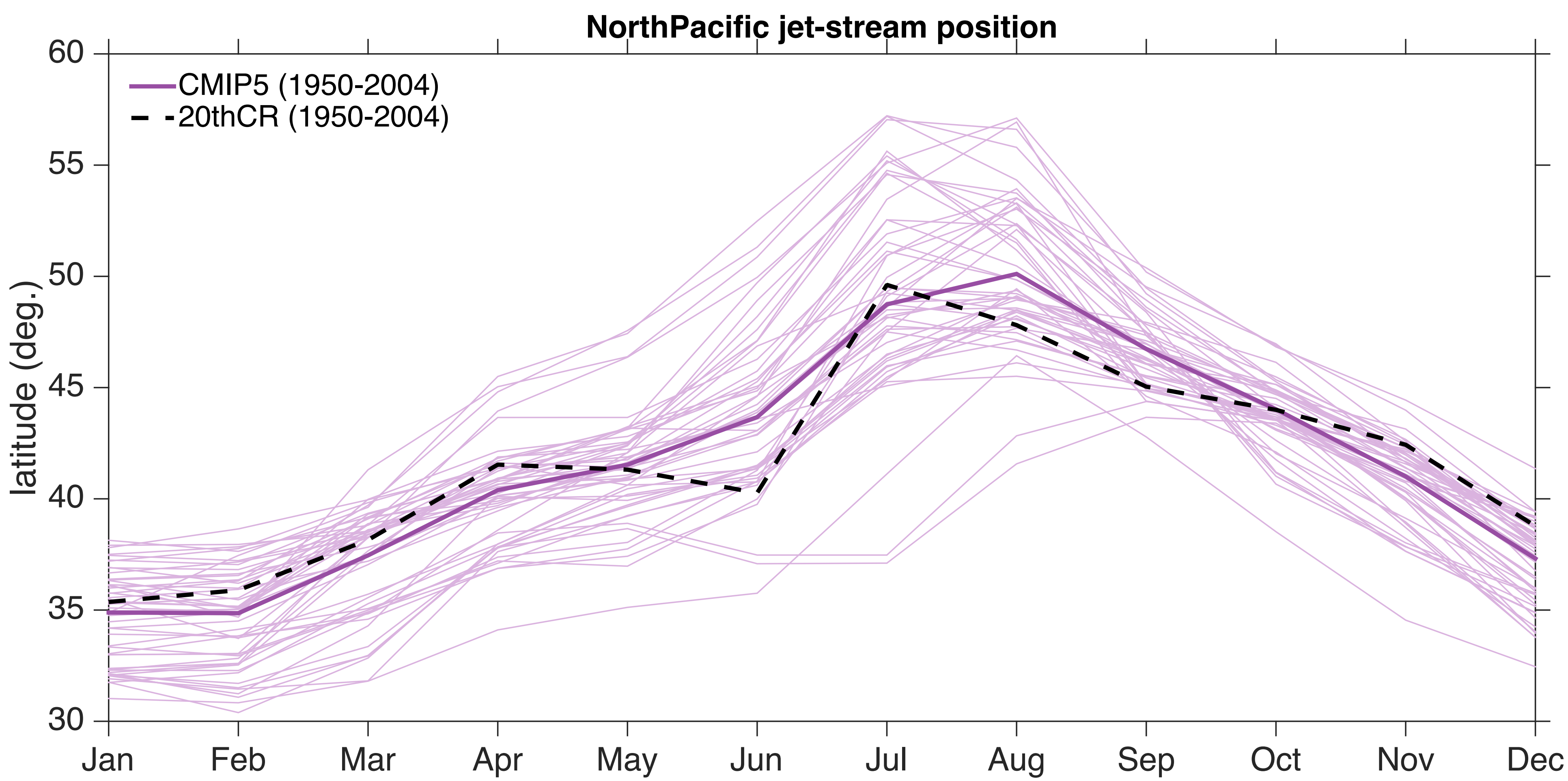

NorthPacific jet-stream position
CMIP5 (1950-2004)
20thCR (1950-2004)
latitude (deg.)
60
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Jan
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Dec

Background

- Previous studies have equated the circulation response to climate change with the leading EOF (e.g. Miller et al. 2006; Woollings and Blackburn 2012; Sun et al. 2015)
- Some recent studies call this interpretation into question (e.g. Deser et al. 2010; Barnes and Polvani 2013; Simpson and Polvani 2016)
- Studies generally focus on specific months or seasons

Motivating Question

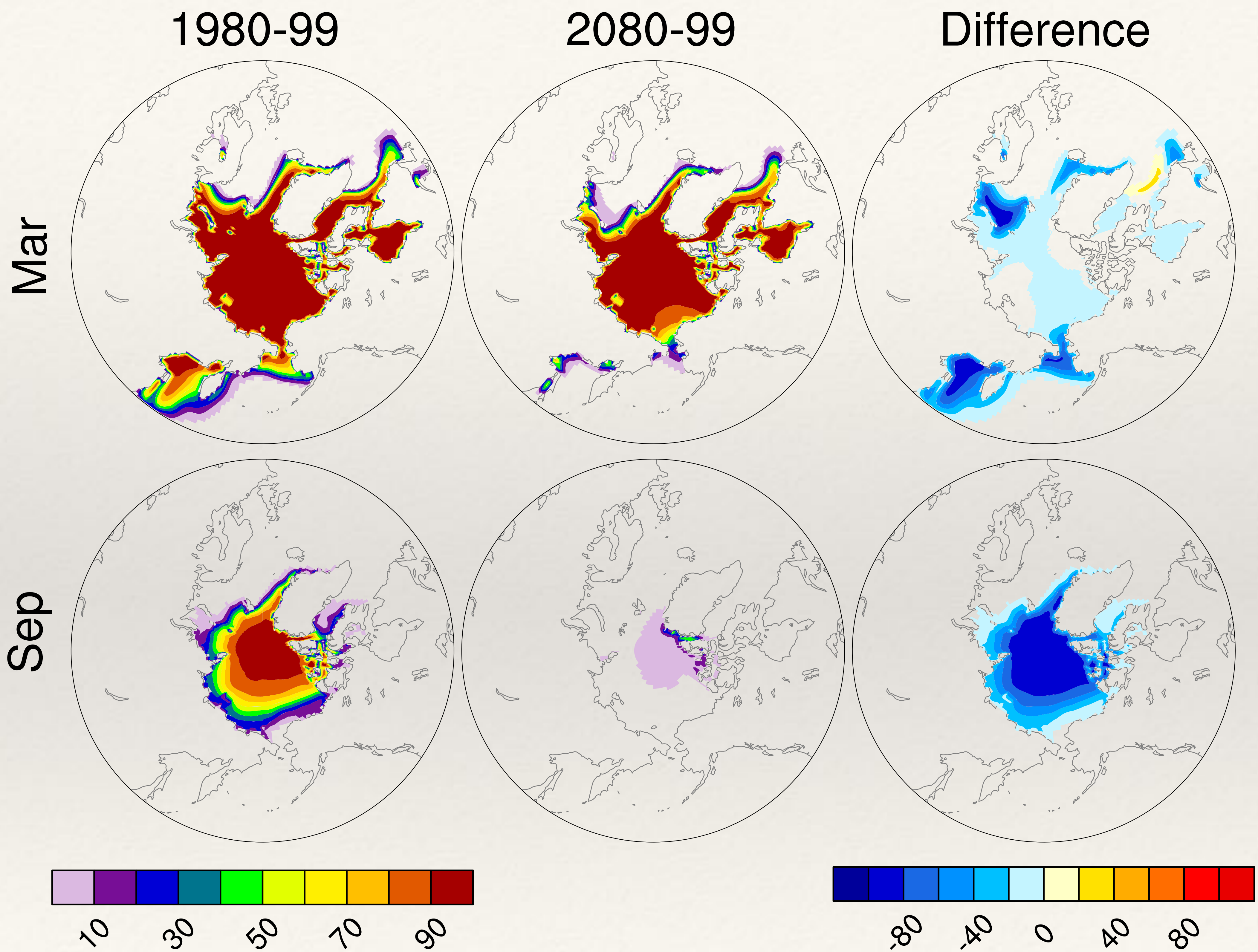
Is the seasonal jet response to Arctic warming related to its variability?

- Sub-questions:
  I. Does the jet response fully project onto the leading EOFs?
  II. Is there seasonality to this projection?
  III. Does the internal variability itself change?

Models

- Deser et al. (2016) ran a study to test importance of atmosphere-ocean coupling to the response to Arctic sea ice loss
- Compared “no ocean model” (NOM), “slab ocean model” (SOM), and “full-depth ocean model” (FOM)
- NOM (CAM4): prescribed SST and sea ice conditions
- FOM (CCSM4): Used a seasonally varying LRF -> sea ice for given GHG (only affects sea ice), method also used in Deser et al. 2015
    - Control: 1980-1999 sea ice conditions
    - Perturbed: 2080-2099 sea ice conditions, RCP8.5

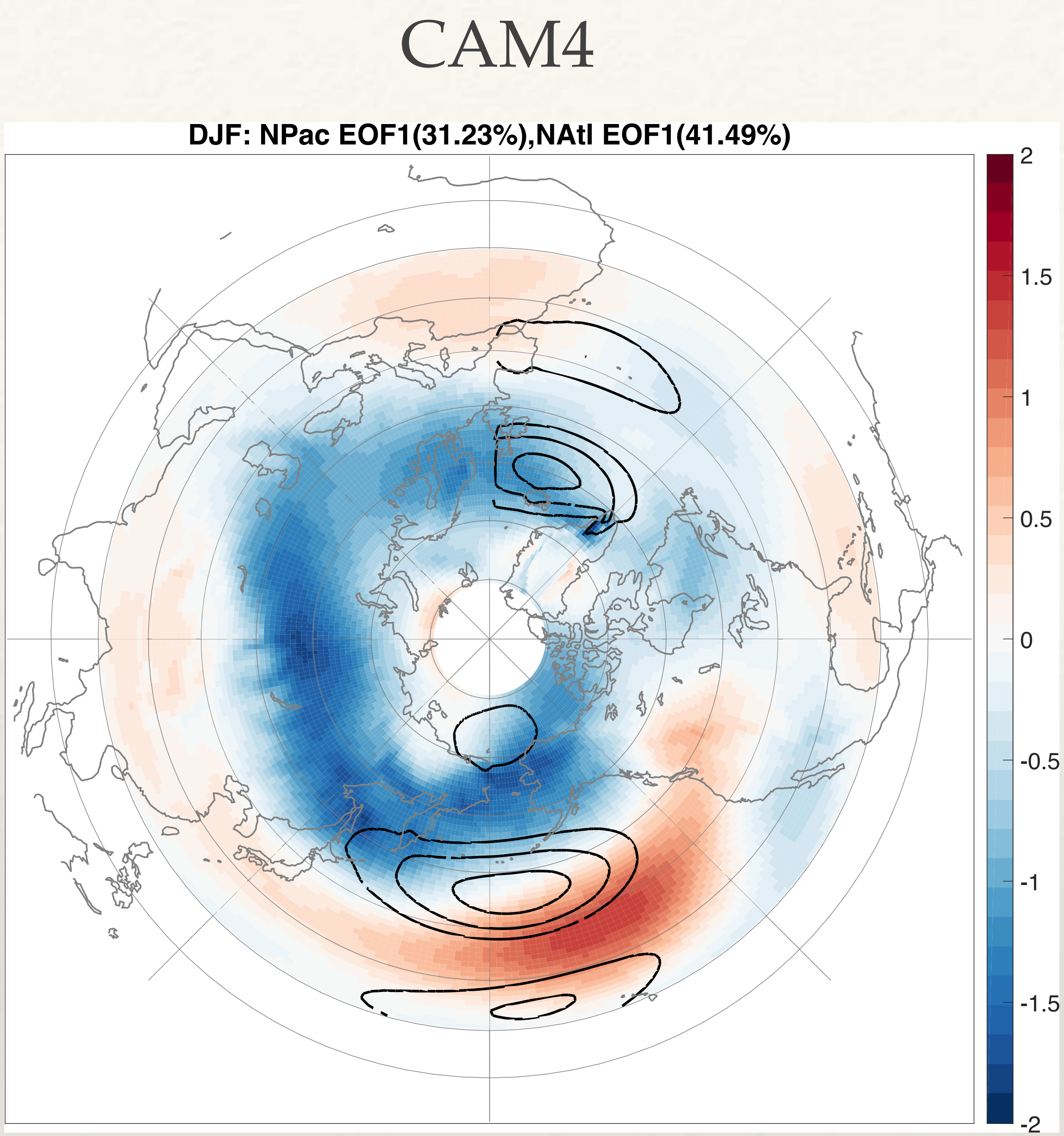
Sea Ice Concentration (%)

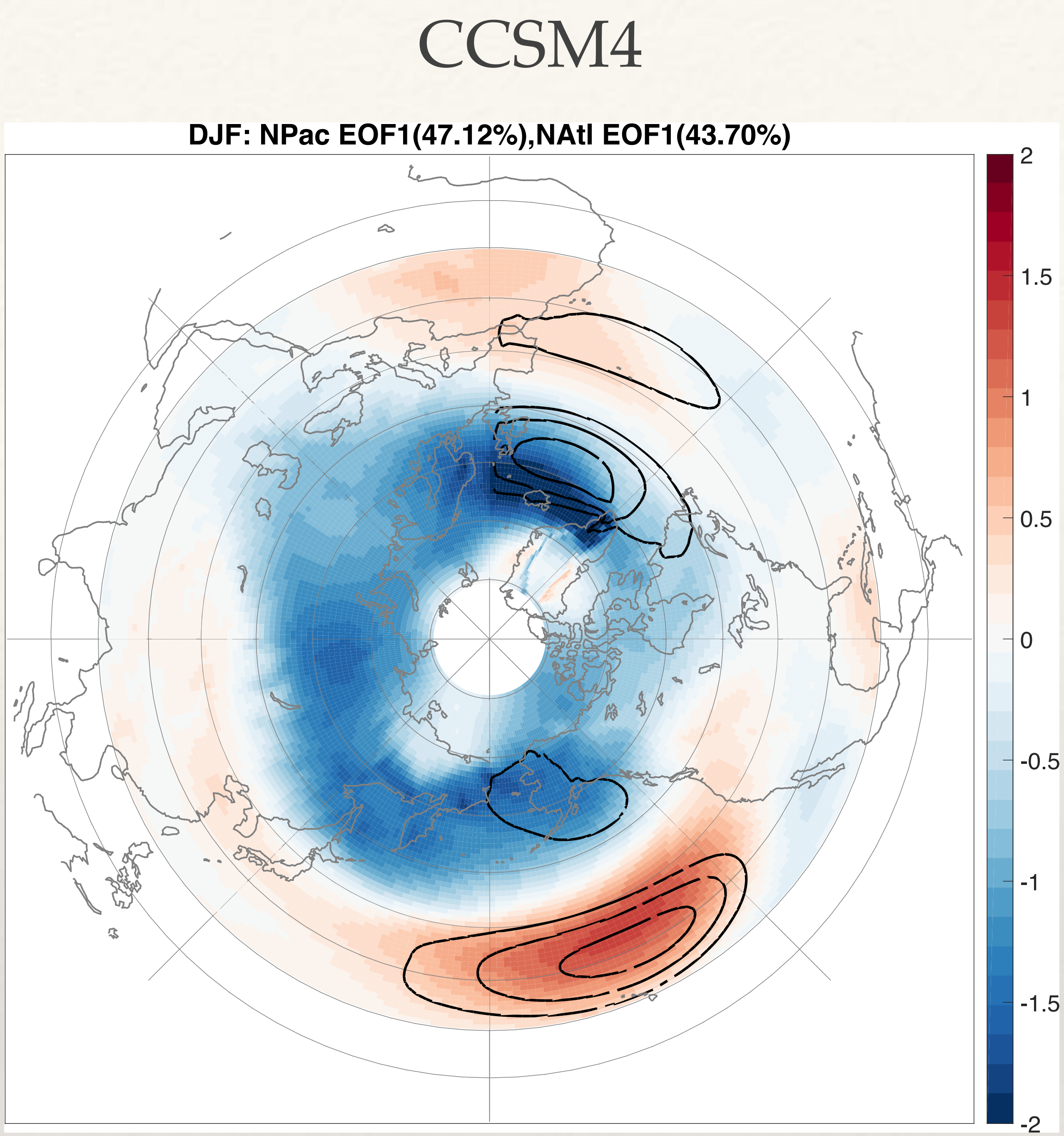


Deser et al. 2015

Models

- We used the zonal wind outputs from this experiment, from both the CAM4 and the CCSM4 (thank you Clara and Lantao!)
- 260 years each (after spin-up removal), take a running seasonal mean reduced this to 258 years
  - Jet response anomalies = U(ptrb) - U(ctrl), at 750 hPa
  - EOF1 based on U(ctrl) at 750 hPa, calculated in North Atlantic and North Pacific separately (regions of interest)

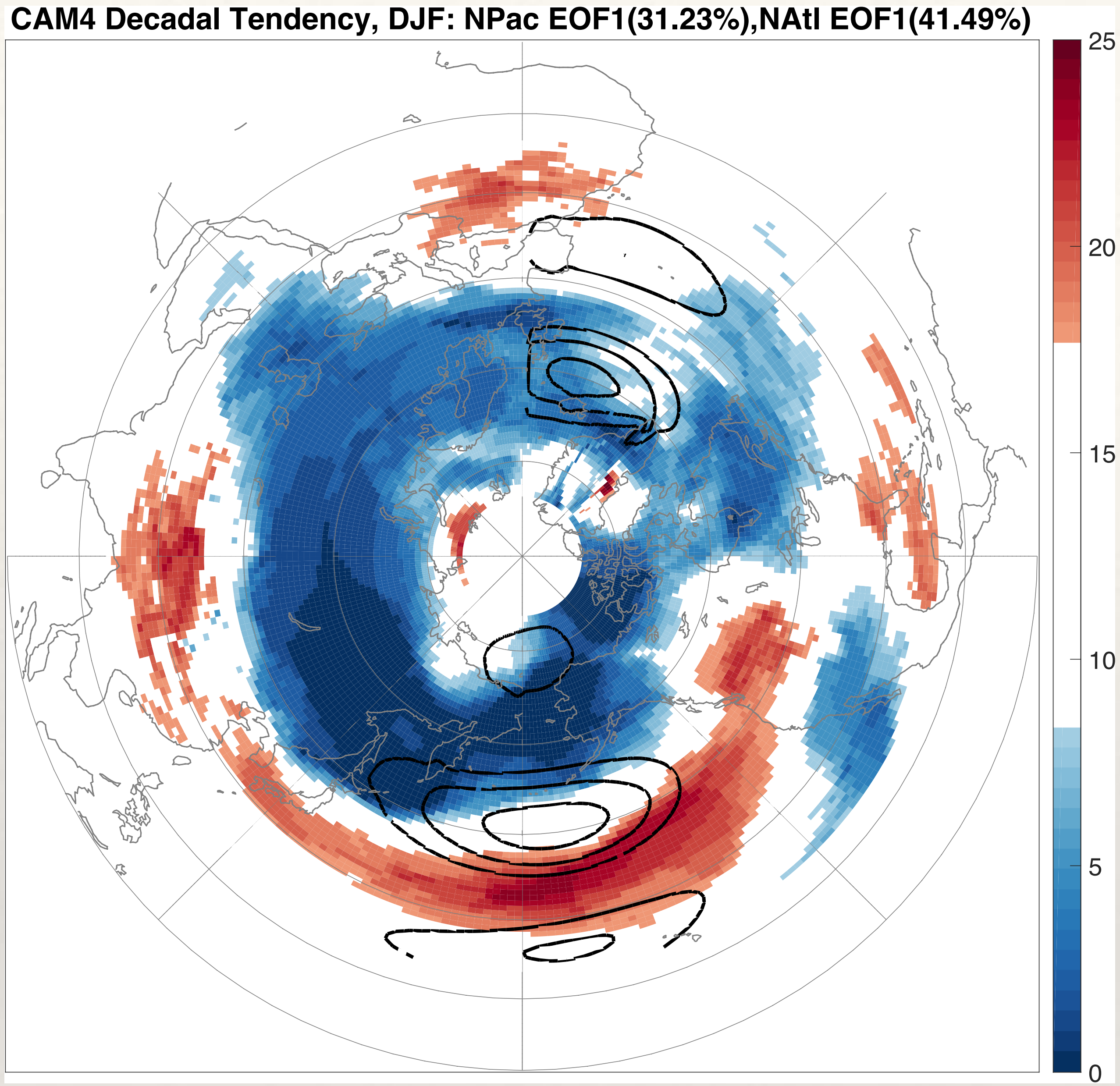




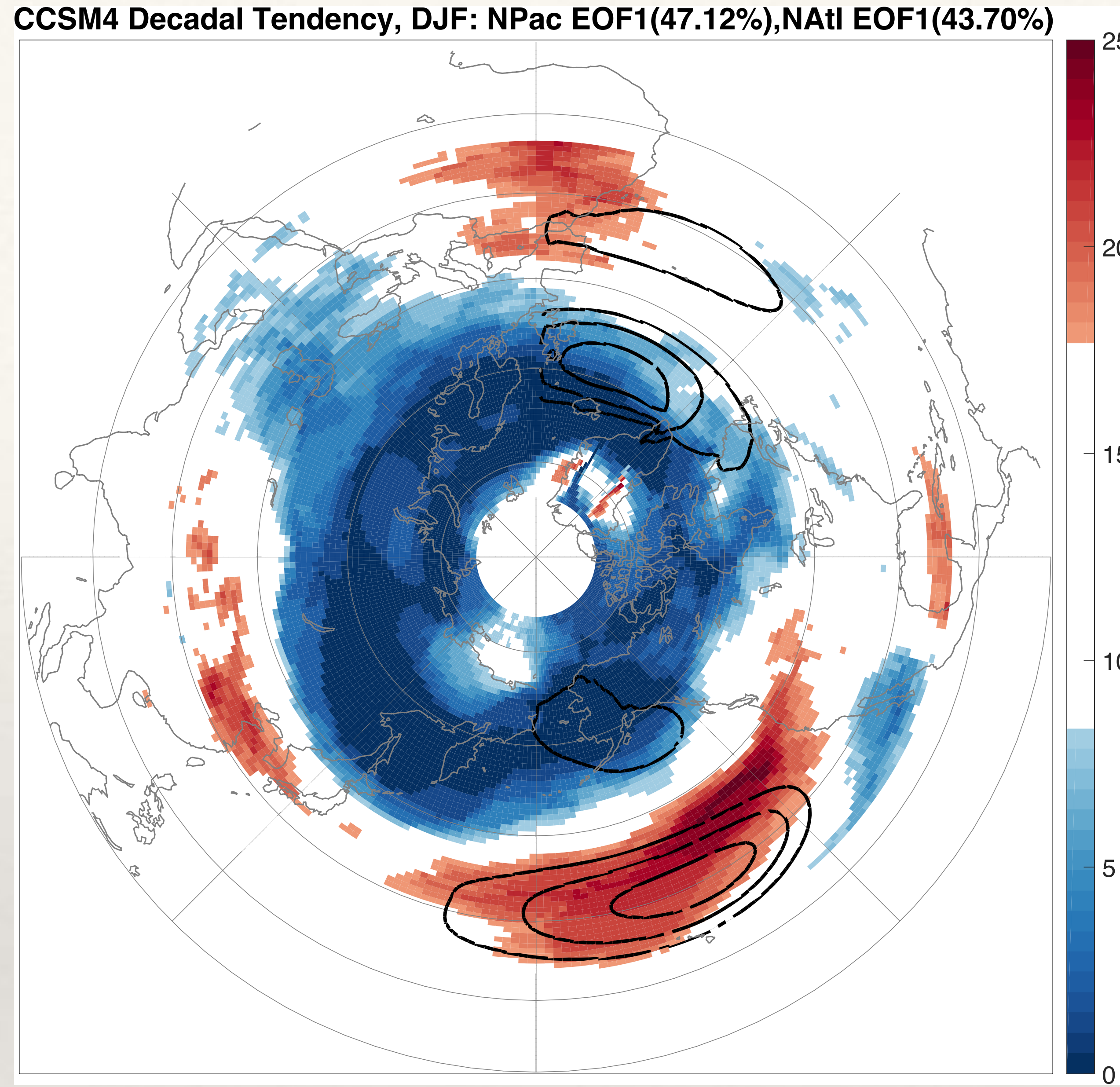
- N.Pac.: EOF1 (contour) does not resemble response anomalies (shaded)
- N.Atl.: Negative response anomalies closer to the pole

- Response anomalies are stronger
- Line up better with EOF1, which also explains more variance

CAM4



CCSM4



Break 258 years into 25 chunks of 10yrs:

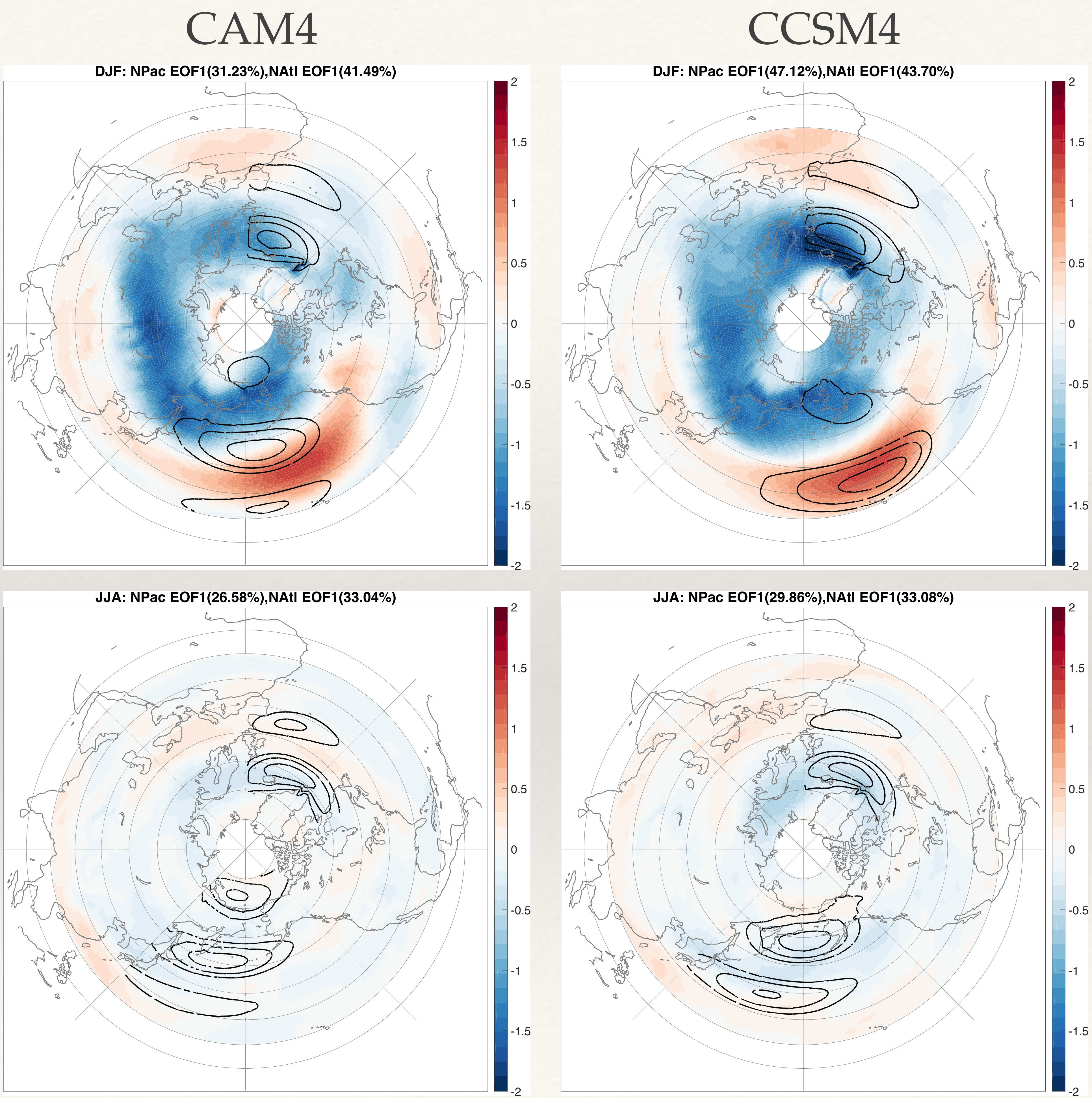
How many decades agree on anomalies>0?

- darker red = more decades have + sign
- darker blue = more decades have - sign

What about seasonality?

- Seasonality present in the jet response anomalies (stronger in the winter and weaker in the summer, as expected)

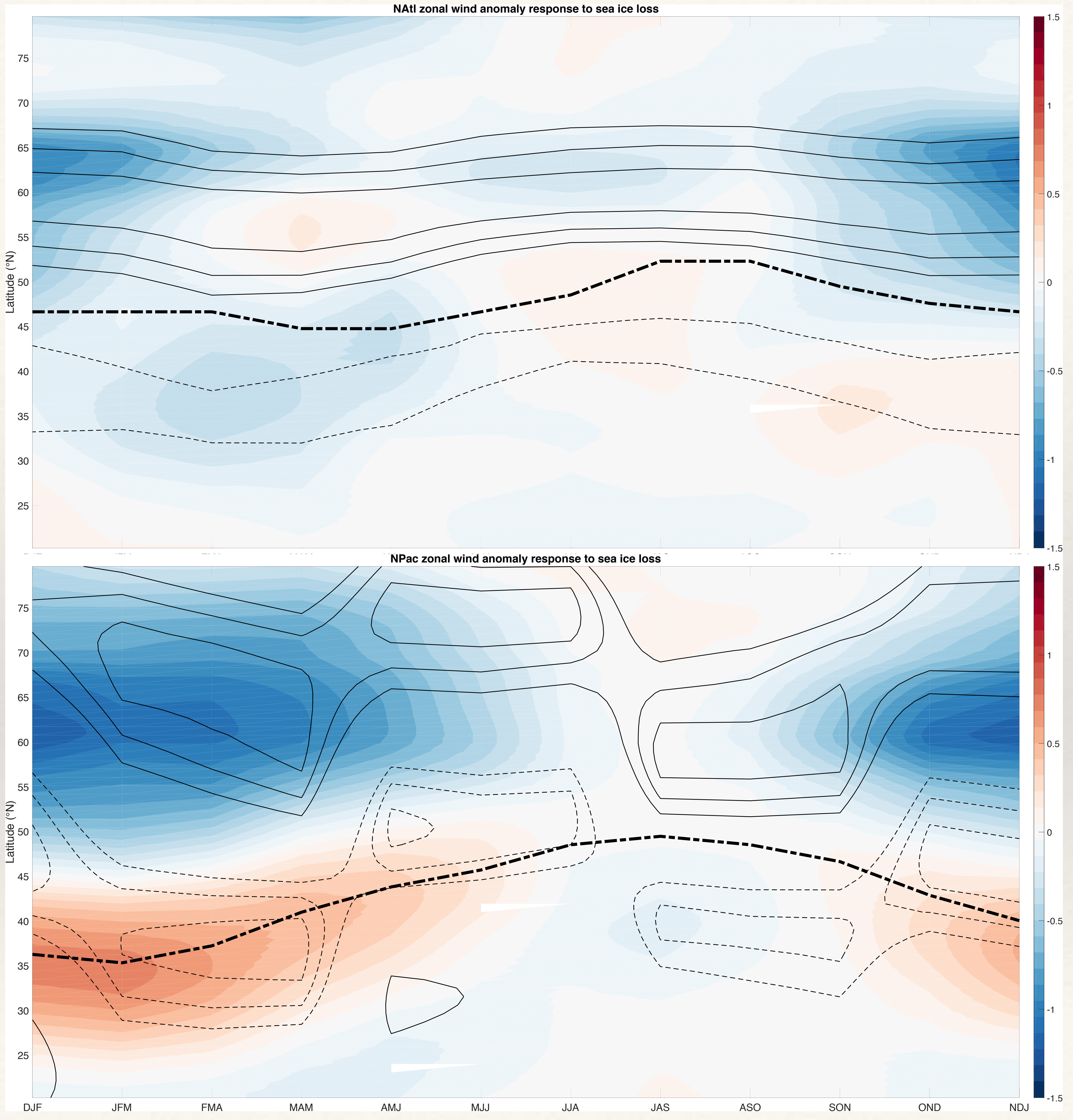
- Seasonality in the EOF1 pattern (and magnitude, though not shown here because they have been normalized per month)



- Comparing 2 seasons doesn’t quite get at this issue of seasonality, and remaining in 2D would require a lot of plots…
- Take zonal mean of both the jet response anomalies and EOF1
- In the North Pacific and North Atlantic *ONLY*

CAM4:

- Shading = jet response anomalies
- Contours (solid and dashed) = EOF1
- Black dot-dash = jet latitude



CCSM4:

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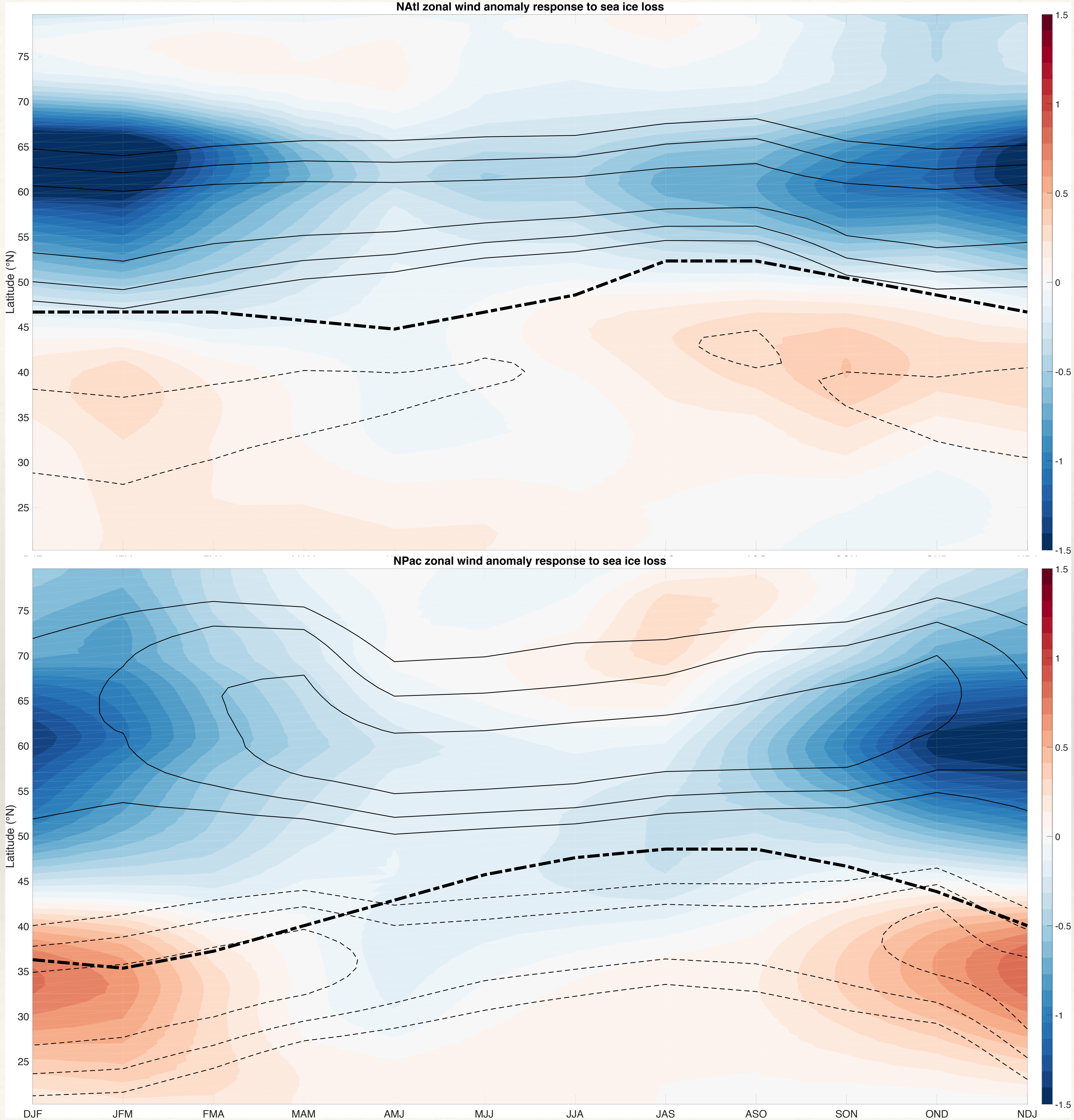
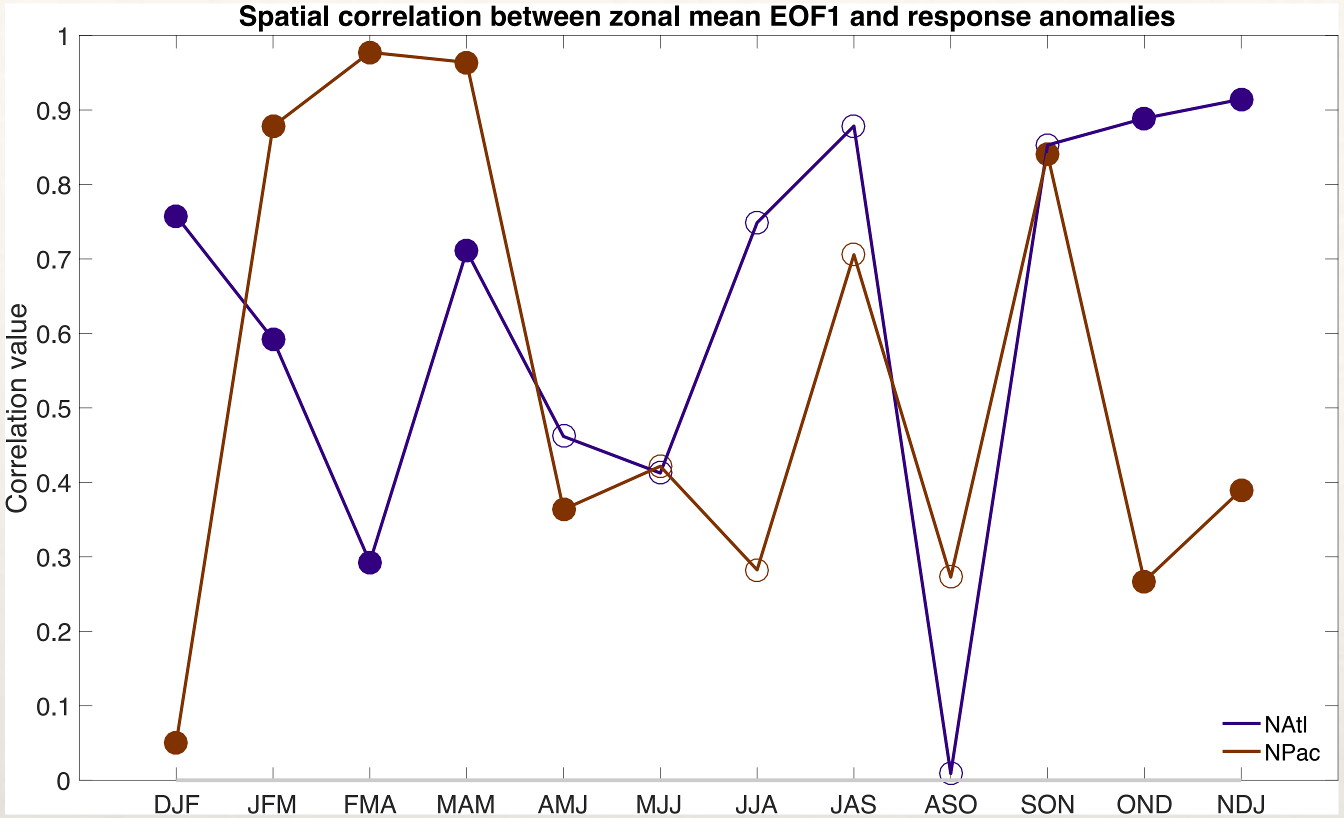
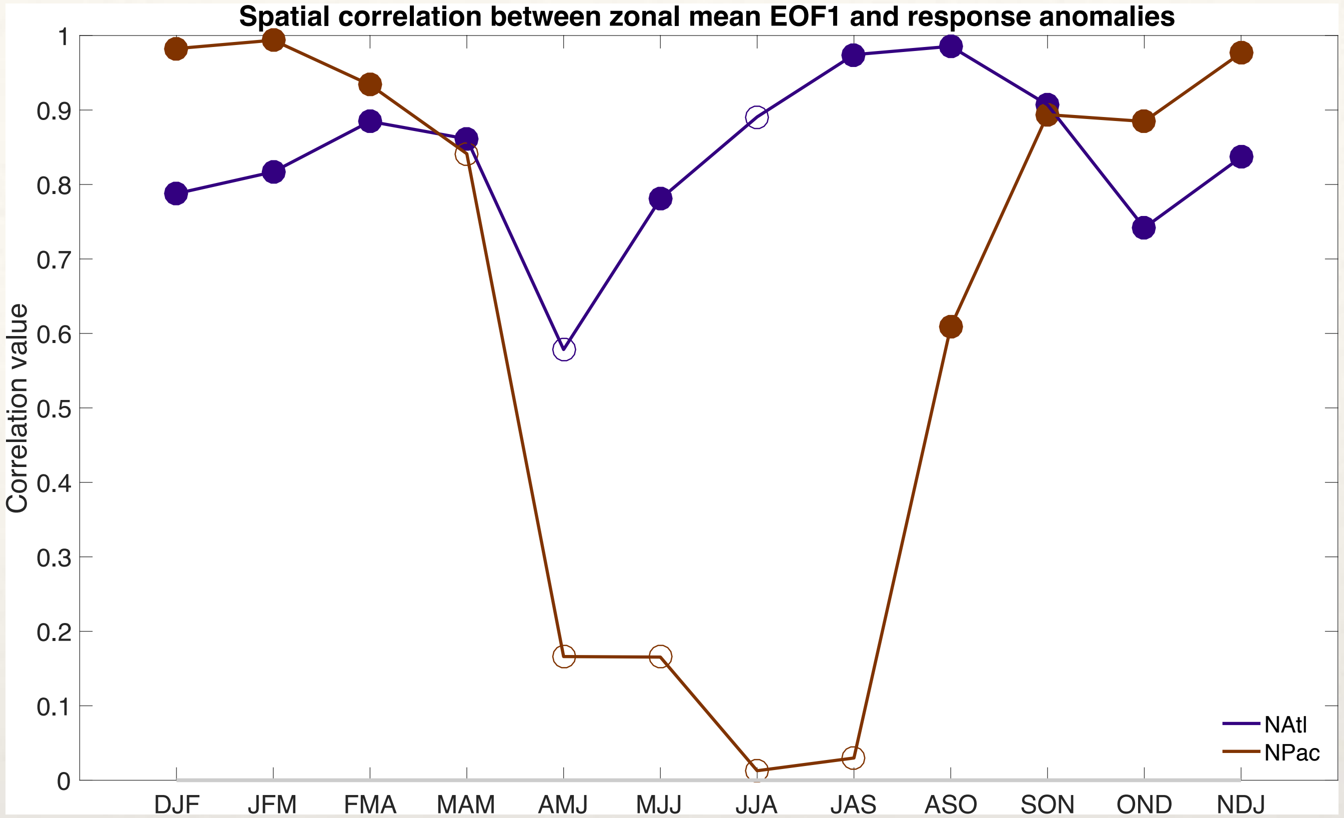


CAM4



CCSM4



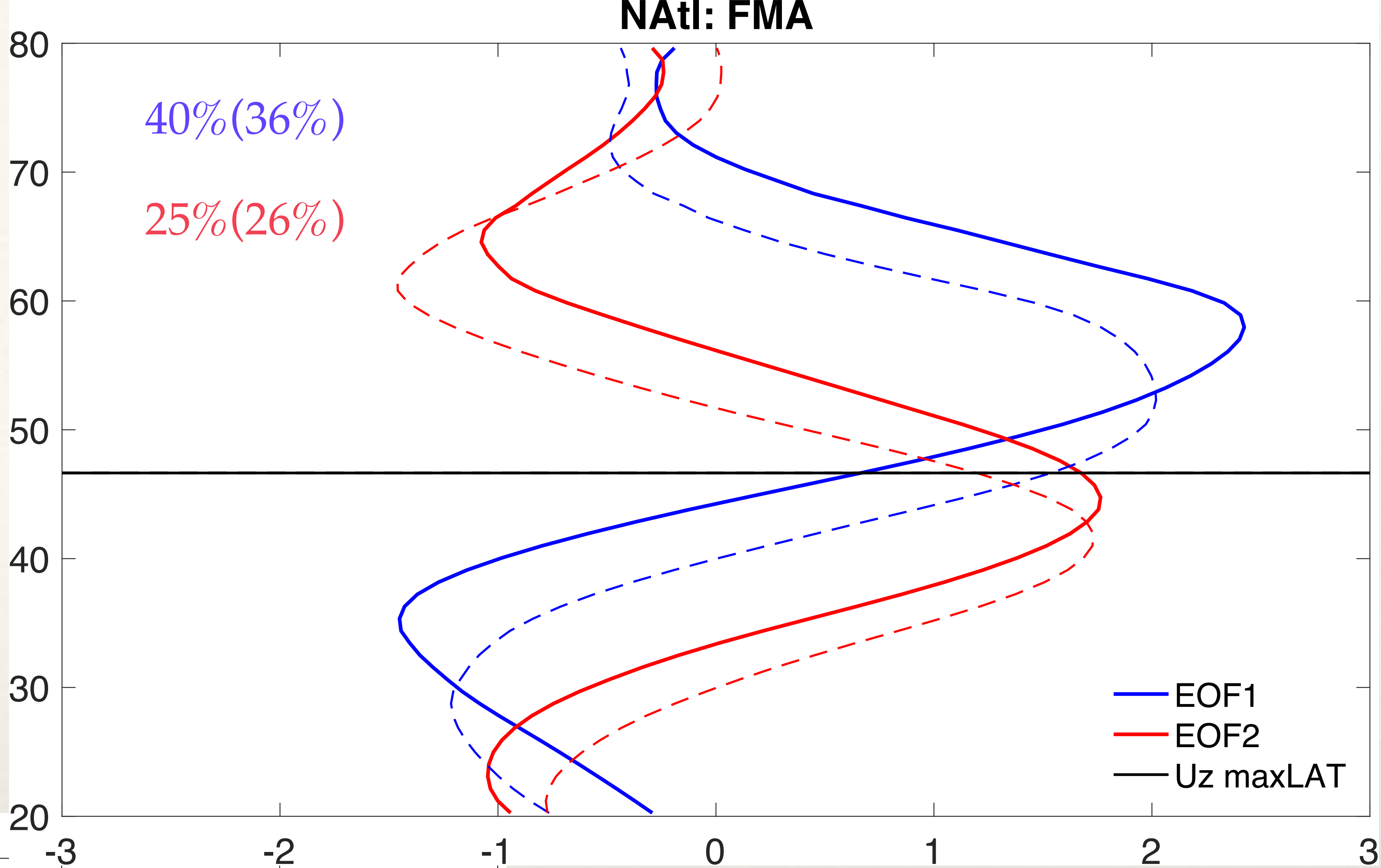
- Absolute value spatial correlations of zonal mean EOF1 and jet response in both basins
- Bit of a mess in the CAM4, but clear seasonality in CCSM4
  - N.Pac. especially weak correlation in the summer months
  - Note that this is most likely due to very weak response anomalies (open circles for when max value does not exceed 0.5 m/s)

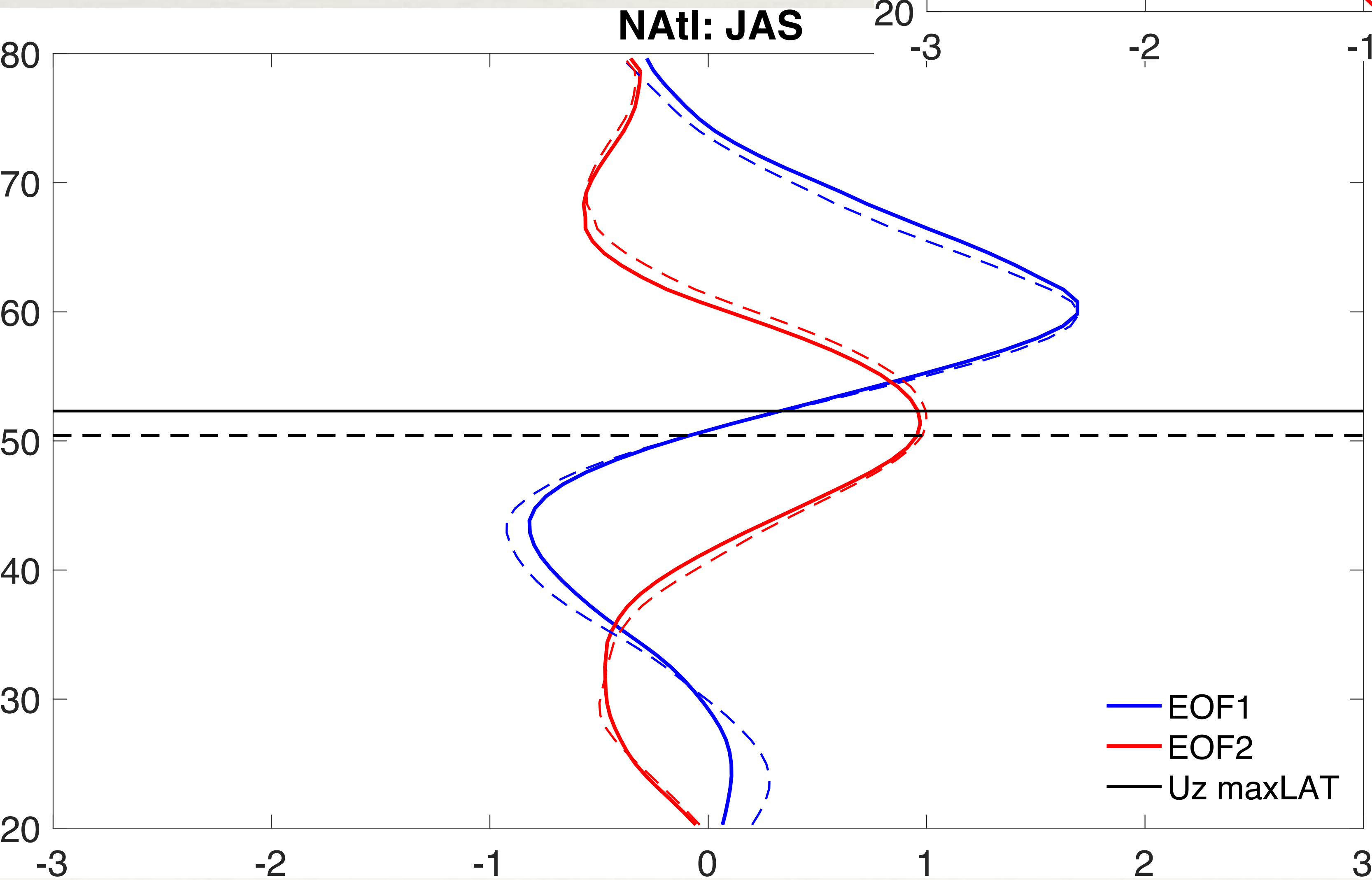
Summary thus far

- The latitude of the maximum jet response anomaly magnitudes does not fully align with those of the first EOF nodes (zonal/monthly plots)
- The spatial correlations between the two are higher in the winter than in the summer in the CCSM4
    - Seasonality in the projection of the jet response onto the leading mode of variability
    - Regional differences: stronger response and seasonal cycle in the North Pacific

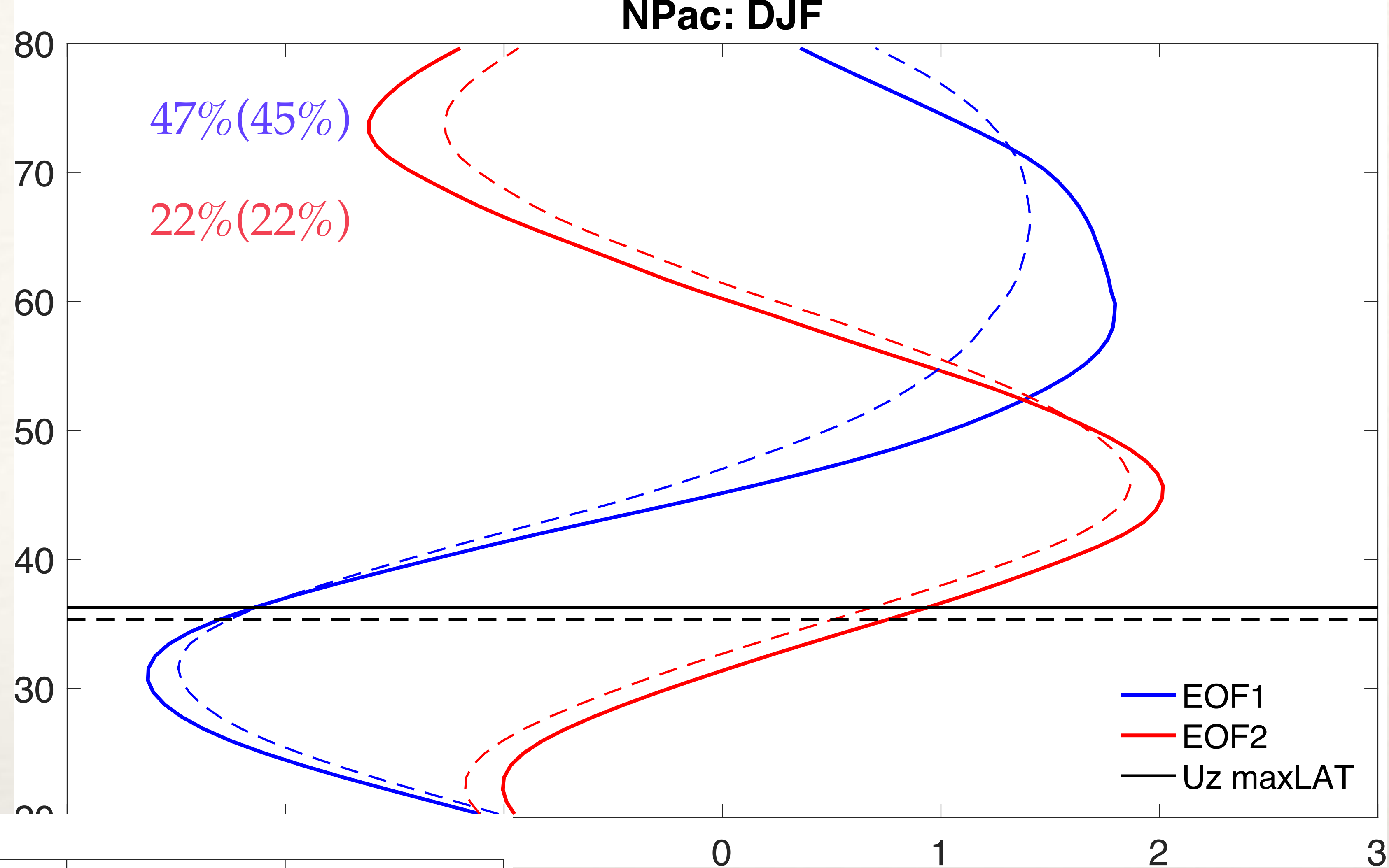
- Okay, but what if the EOF’s themselves are changing?
- That might account for some of the differences we have seen
- Focus on CCSM4

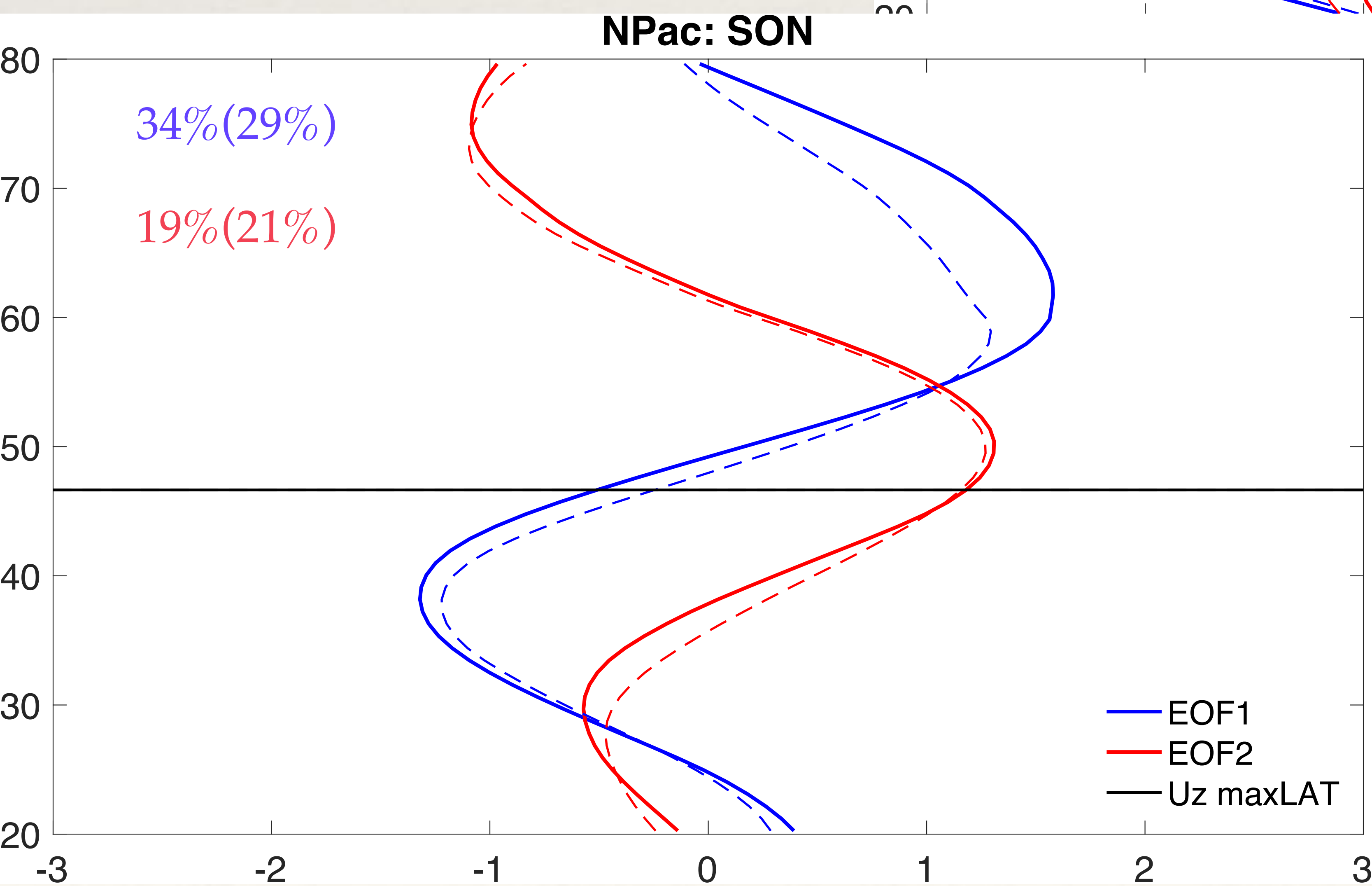
CCSM4
North Atlantic





CCSM4
North Pacific





Future Work

- Mechanisms for possibility that Response $\neq$ EOF1, and why EOF itself would change
- Try to tease out the Arctic warming signal in the CMIP5 models and redo analysis -> does the story change?
- Can also try something similar in the LENS in order to further quantify the internal variability

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THANK YOU!