Seasonality of the Jet Response to Arctic Warming

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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
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:
  1. Does the jet response fully project onto the leading EOFs?
  2. Is there seasonality to this projection?
  3. 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
The local SST increase associated with Arctic sea ice loss, determined by averaging SSTs for all grid cells experiencing SIC loss in the late twenty-first century compared to the late twentieth century, shows maximum values in July–September (2.8°C in RCP8.5 and 1.75°C in ICE_coupled) and minimum values in January–April (0.8°C in RCP8.5 and 0.4°C in ICE_coupled).

Sea ice concentration (%) distributions in (top) March and (middle) September from the late (left) twentieth-century and (center) late twenty-first-century coupled experiments and (right) their difference. (bottom) Monthly Arctic sea ice extent (10^6 km^2) during the late twentieth century (solid lines) and late twenty-first century (dashed lines) from the historical and RCP8.5 CCSM4 experiments (red) and the Arctic sea ice coupled experiments (blue).
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 = $U(\text{ptrb}) - U(\text{ctrl})$, at 750 hPa
  - EOF1 based on $U(\text{ctrl})$ 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
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:

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

NPac: DJF

47\%(45\%)
22\%(22\%)

NPac: SON

34\%(29\%)
19\%(21\%)

EOF1
EOF2
Uz maxLAT

EOF1
EOF2
Uz maxLAT
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
References


THANK YOU!