Assessing significance in the CESM2 PAMIP Arctic sea ice loss experiments: signal or noise?

Examining the North Pacific jet stream response to Arctic amplification and sea ice loss in the PAMIP models

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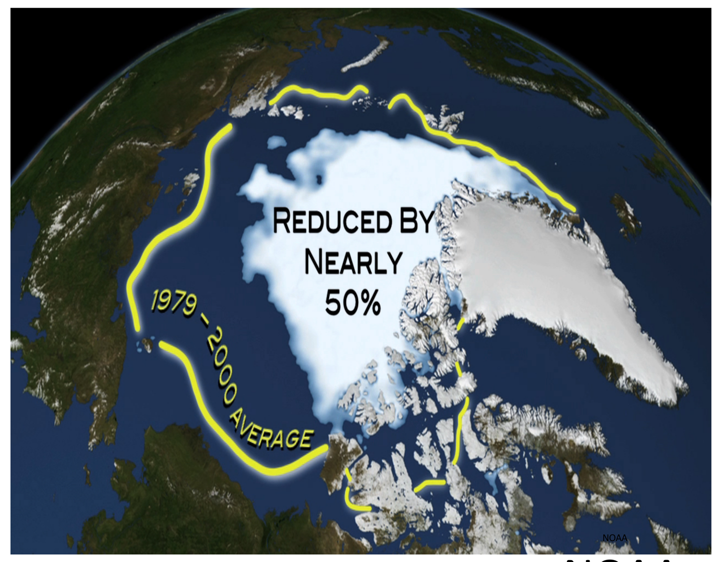
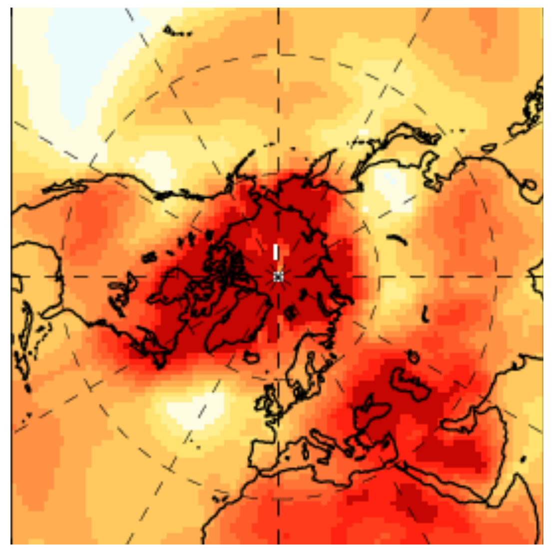
- ❖ **The Arctic is warming and sea ice loss is occurring at unprecedented rates**
- ❖ **What does this mean for large circulation changes?**
- ❖ **A recent modeling project has been launched to try and answer this:**
- ❖ **Polar Amplification Model Intercomparison Project (PAMIP)**



NOAA



Smith et al. (2019), Fig 2a: Observed temperature trend.

PAMIP Tier 1 experiments

- **100 ensemble members**
- Atmosphere only
- Changes to prescribed sea ice concentration (SIC) and sea surface temperatures (SST)

My data

- CESM2 model, zonal wind at 700 hPa
- Jan-Feb mean for each ensemble member
- Compare 2 runs: future sea ice concentrations (futSIC) and preindustrial sea ice concentrations (piSIC)
- Both have present day SST

Assessing Significance

- Standard approach: calculate 2-sample t-test, find all grid points with p-value < 0.05
- Problem: spatial autocorrelation increases likelihood of false positives
- Can use method from Wilks (2016): the False Discovery Rate (FDR)
- Improves confidence in significant signal
- Decreases false positives, but increases false negatives

References

Ronalds, Bryn and Elizabeth Barnes. 2019: "A role for barotropic eddy-mean flow feedbacks in the zonal wind response to sea ice loss and Arctic Amplification". *Journal of Climate*, Under Revision.

Smith, Doug M., James A. Screen, Clara Deser, Judah Cohen, John C. Fyfe, Javier García-Serrano, Thomas Jung, et al. 2019. "The Polar Amplification Model Intercomparison Project (PAMIP) Contribution to CMIP6: Investigating the Causes and Consequences of Polar Amplification." *Geoscientific Model Development* 12 (3): 1139–64.

Wilks, D. S. 2016. "'The Stippling Shows Statistically Significant Grid Points': How Research Results Are Routinely Overstated and Overinterpreted, and What to Do about It." *Bulletin of the American Meteorological Society*, 2263–73.

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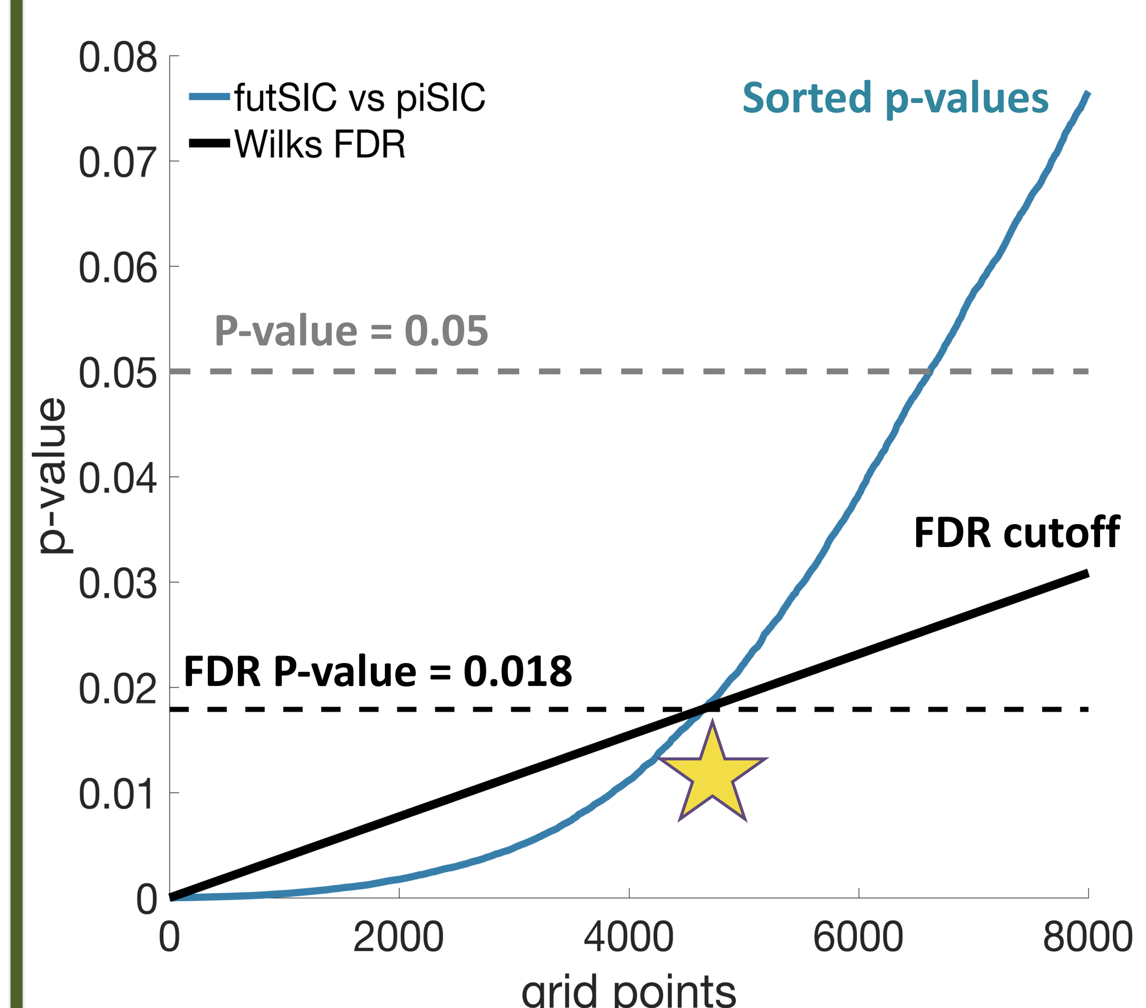
False Discovery Rate

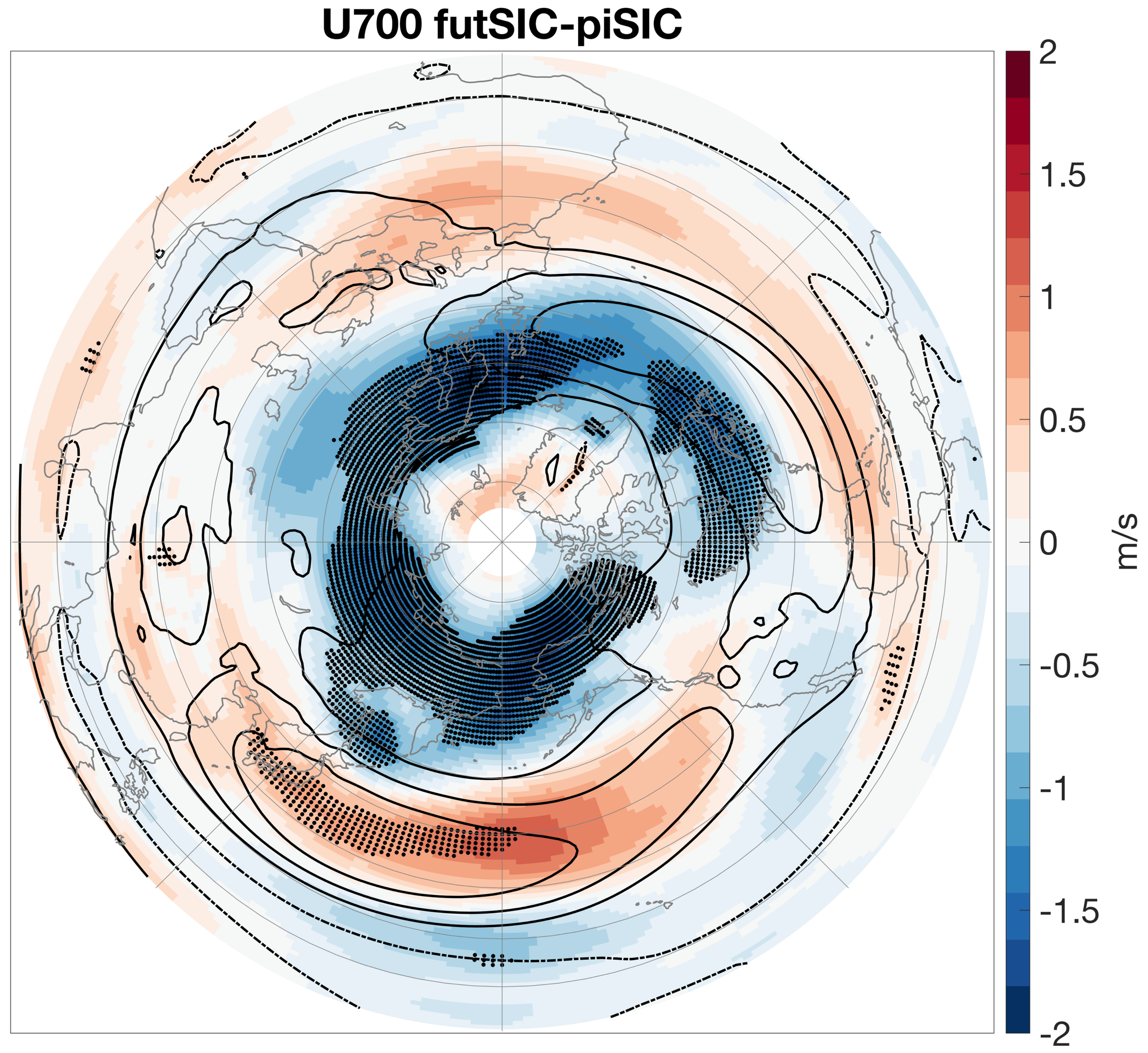
- Given e-folding distance of atmospheric phenomenon (~2000 km), define $\alpha_{FDR} = 2\alpha$, where α is the desired p-value, 0.05 (i.e. 95% confidence level)
- Calculate the FDR cutoff: $^{i}/_{N} \times \alpha_{FDR}$, where i represents the grid points (black line)
- Calculate the p-values of the data at every grid point (blue curve)
- FDR P-value is maximum p-value that is **less than** the FDR cutoff: ★



Sorted p-values of Jan-Feb mean U700 (blue), calculated using 2-sample t-test between futSIC and piSIC. FDR cutoff line (black), using $\alpha_{FDR} = 0.1$, corresponds to 95% confidence.

❖ **Recalculate significance using t-test with the new p-value threshold**

Results



- ❖ **Easterly anomalies in vicinity of sea ice loss and weakened temperature gradients**
- ❖ **Westerly anomalies within the North Pacific jet**

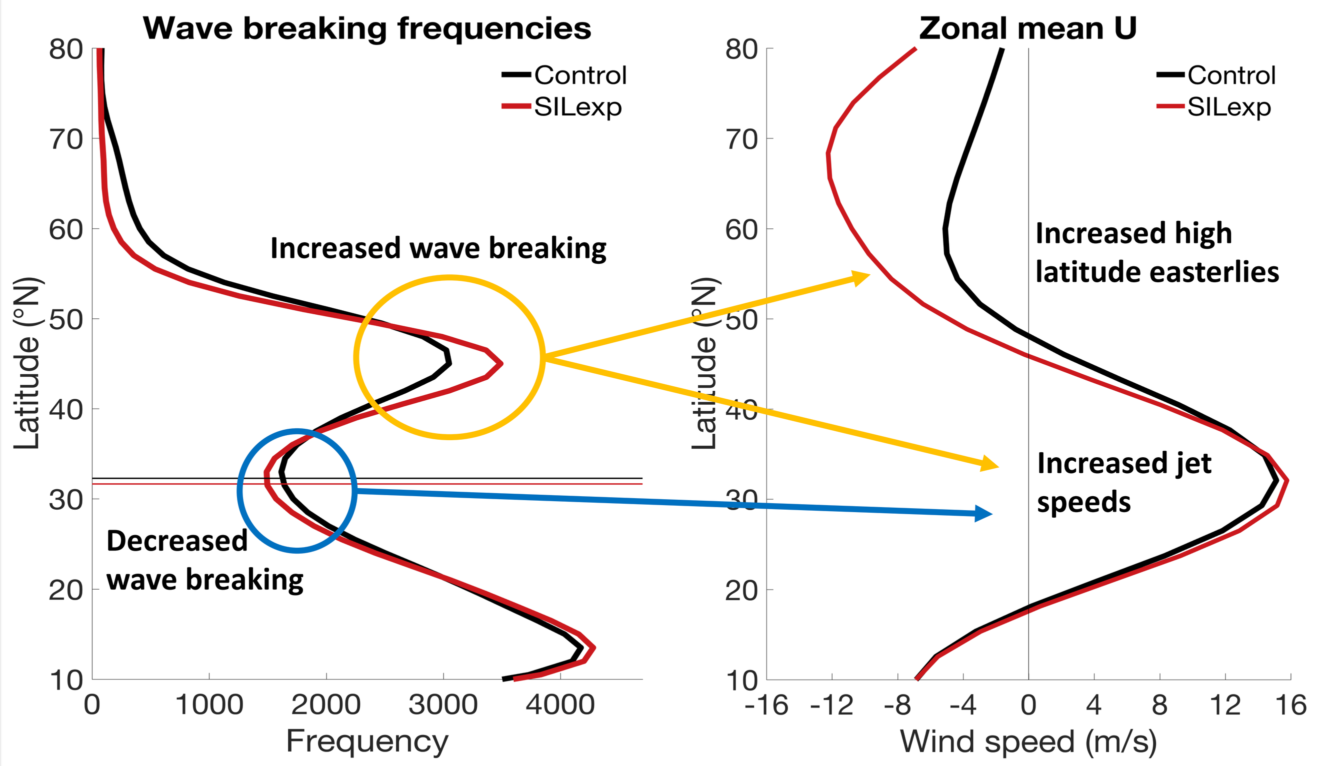
Mechanism:

- → High latitude easterlies = **baroclinic response** (thermal wind balance).
- → Narrows the jet on the poleward flank, increasing the meridional wind shear.
- → More waves able to propagate poleward and break (linear wave theory).
- → Frequencies and location of wave breaking changes due to the narrowing = **barotropic response.**

Mechanism

Examine this in a barotropic model:

- **Control**: apply stirring mask to simulate the jet stream.
- **SILexp**: apply an easterly torque poleward of the stirring, simulates the initial, baroclinic response to sea ice loss.
- North Pacific set-up has the stirring at 30N and the easterly torque at 70N.



This work is currently accepted pending revisions (Ronalds and Barnes 2019).

Key Points

- ❖ **Using FDR allows for greater confidence in signal.**
- ❖ **Sea ice loss causes easterly anomalies at high latitudes and westerly anomalies at midlatitudes.**
- ❖ **Baroclinic arguments can explain the easterlies.**
- ❖ **Barotropic arguments involving changes in wave propagation and wave breaking frequencies and locations can explain the westerlies**