Trends in Climate Teleconnections and Effects on the Midwest

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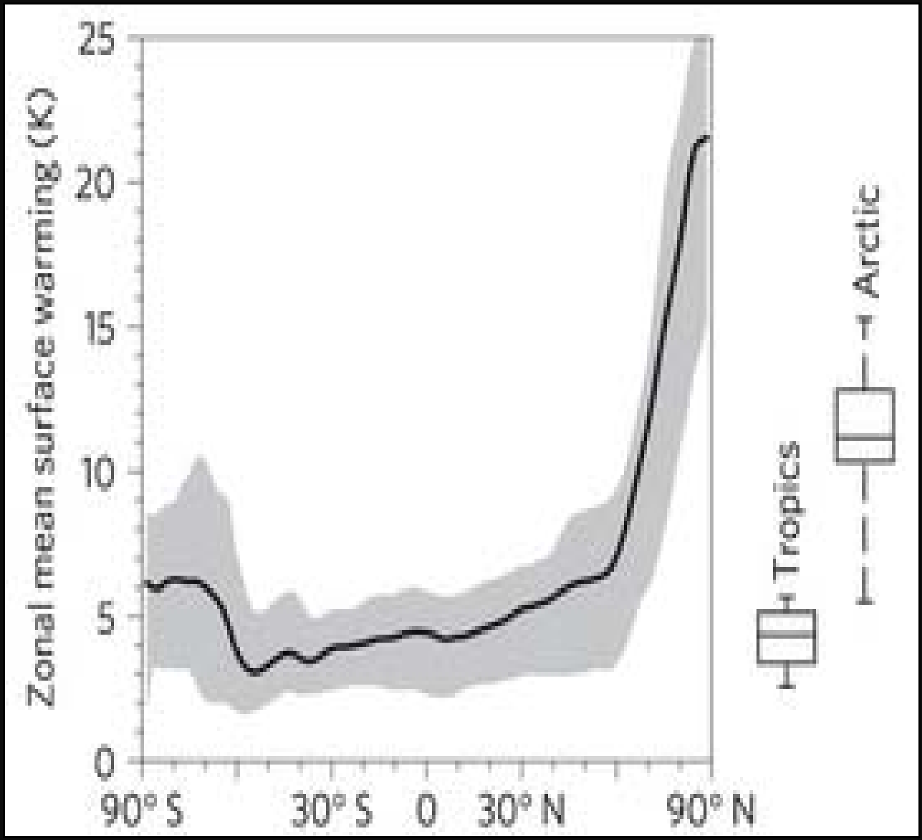
Arctic Climate Change Can Affect Midlatitudes

- Melting ice from glaciers and Greenland ice sheets add to sea level rise
- Melting ice adds fresh water to oceans, slowing down the thermohaline circulation
- Melting Permafrost emits more CO2 and CH4
- Warming Arctic ocean could release more CH4
- Rapidly warming arctic and melting of Arctic sea ice affecting circulation patterns

Previous Research: Arctic Amplification

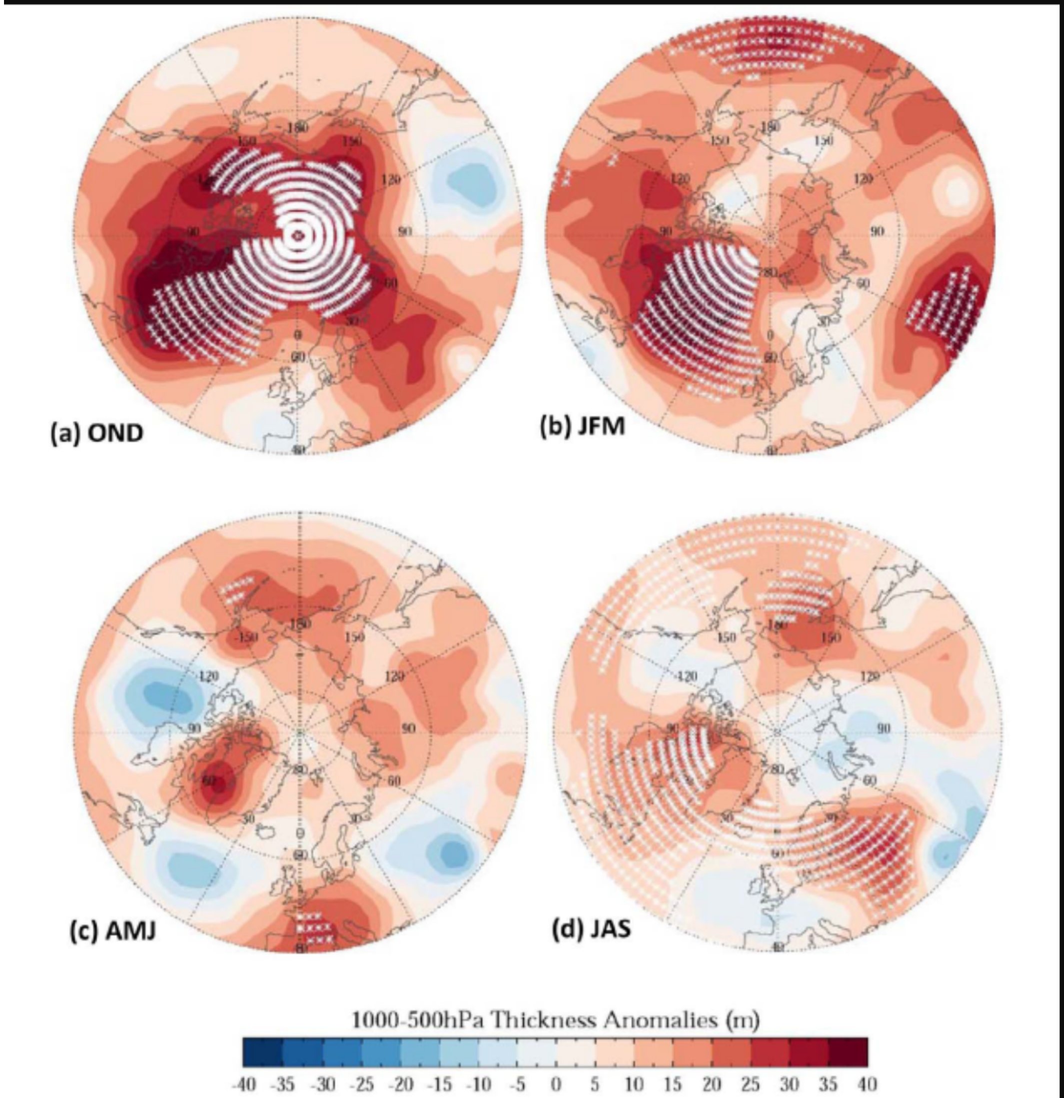


Pithan and Mauritsen (2014)

Average temperature difference in CMIP5 models for preindustrial control vs 4 x CO2 runs.

Arctic Amplification clearly evident -- largest contribution to Arctic amplification comes from heat transport and radiative properties followed by ice-albedo feedback

Previous Research: Arctic Amplification (AA)



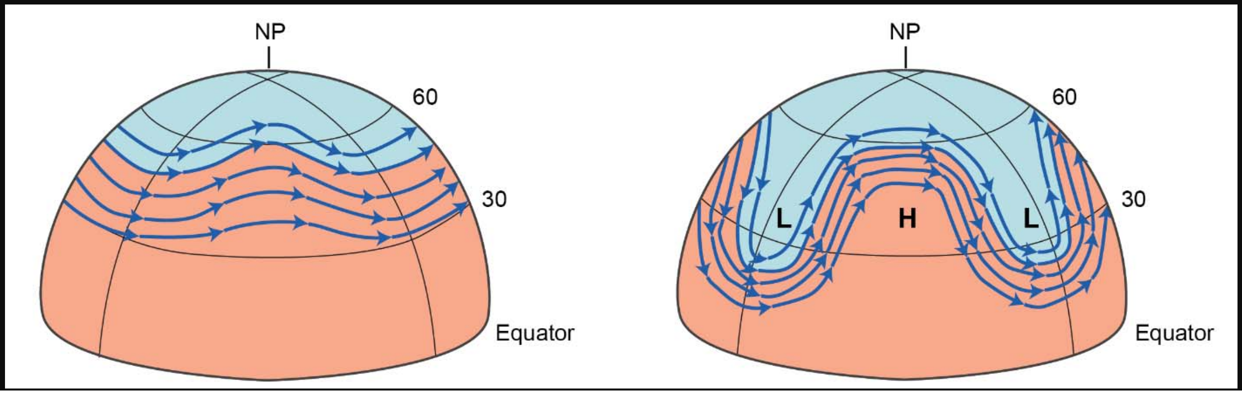
Francis and Vavrus (2012)

Recent years show seasonal geopotential height thickness anomalies as the Arctic warms quicker.

Fall and winter show highest anomalies because of the heat stored during in the summer due to decreasing sea ice coverage.

Objectives of this study

- What connection is there between the changes in Arctic sea ice in summer and the height anomalies in the following winter and spring?
- Do the evolving upper level patterns in planetary waves affect precipitation patterns in the Midwest and across the United States?
  - Specifically focus on late winter and early spring

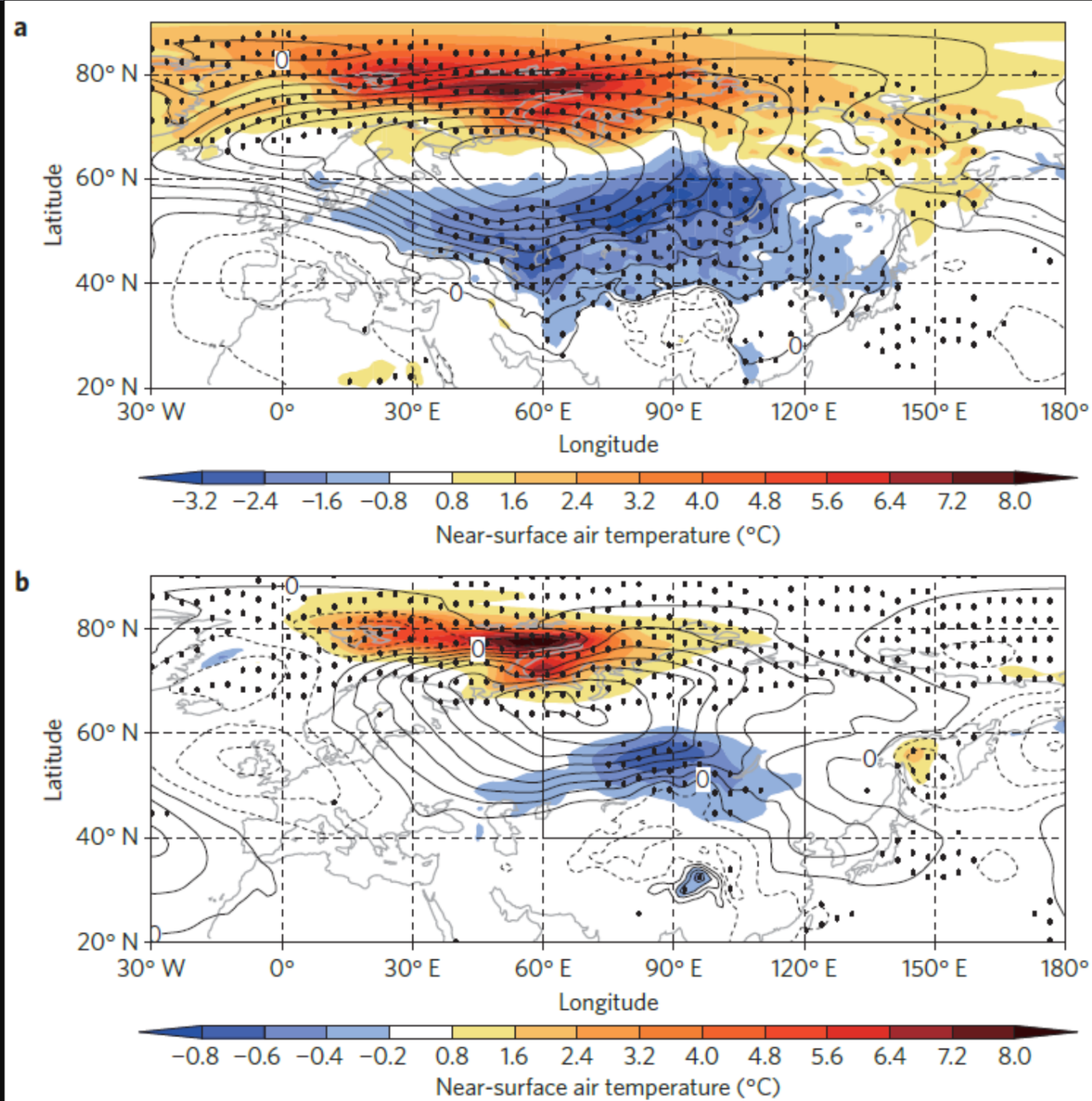


Previous Research: Mori et al. 2014

Atmospheric feedback changes in the winter time in CLOSE proximity to sea ice anomalies.

Used both reanalysis (top) and 100-member ensemble of model results (bottom).

Similar to our study but for Eurasia.

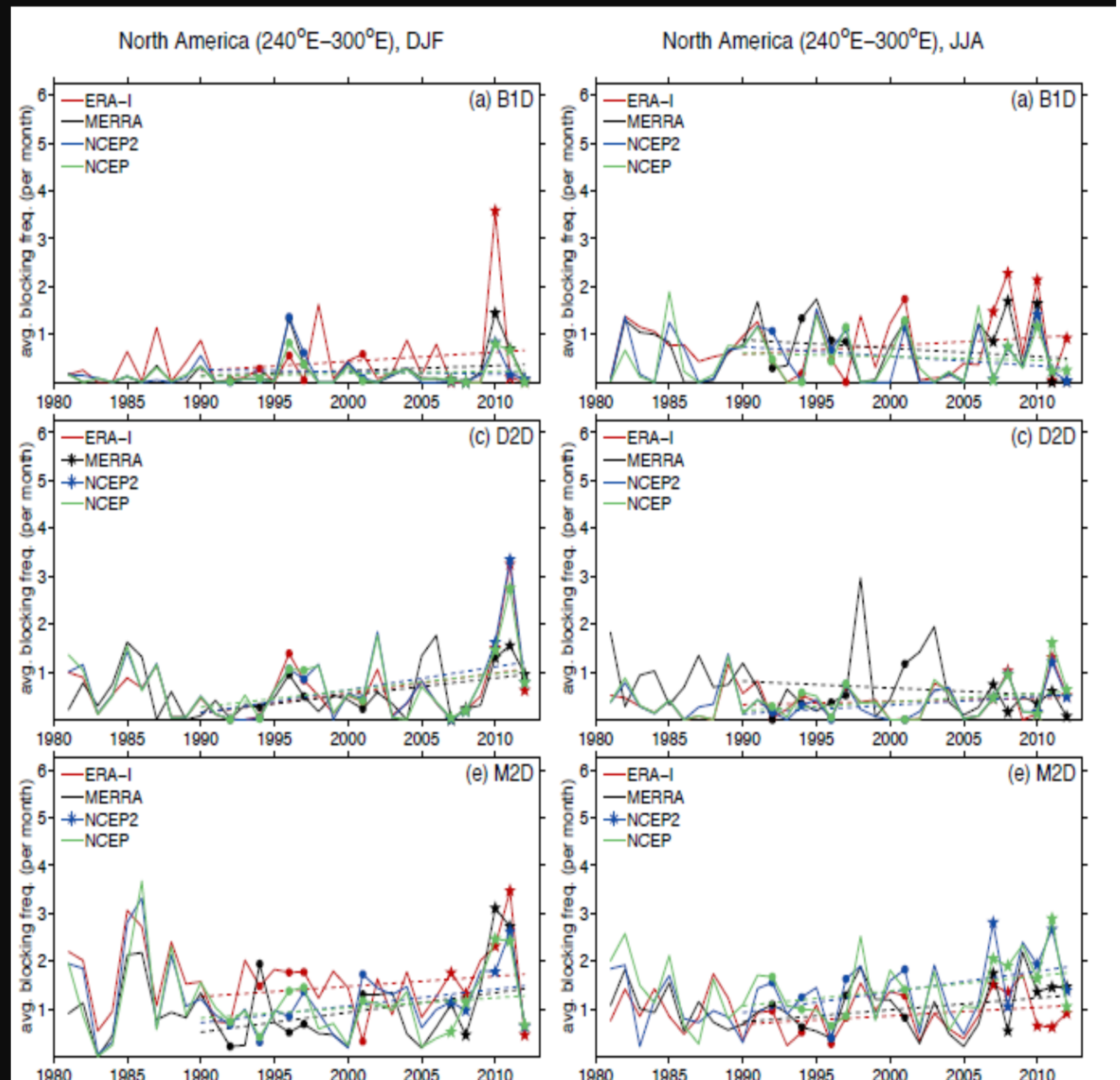


Previous Research: Barnes et al. 2014

Like our study, used height anomalies within a grid box.

Analysis over a broad area, they did not find increase in blocking frequencies.

We focus on testing for trends in jet stream amplitude without the time dependency



Average Yearly Sea Ice Concentration

- Goal: Determine if localized sea ice loss is causing/enhancing semi-persistent amplification to the jet stream in the Pacific Ocean and how this could affect regional weather extremes across the United States.

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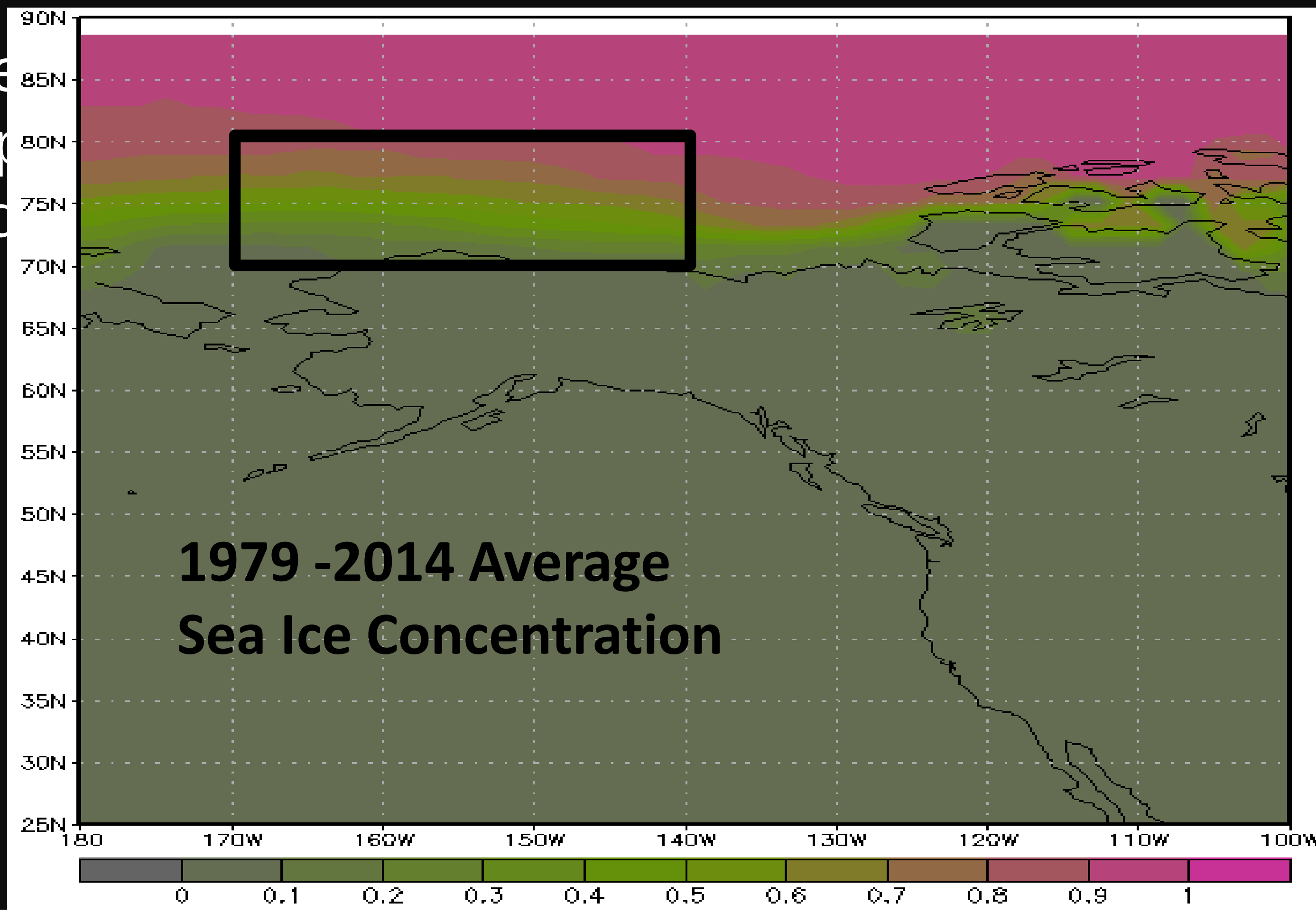
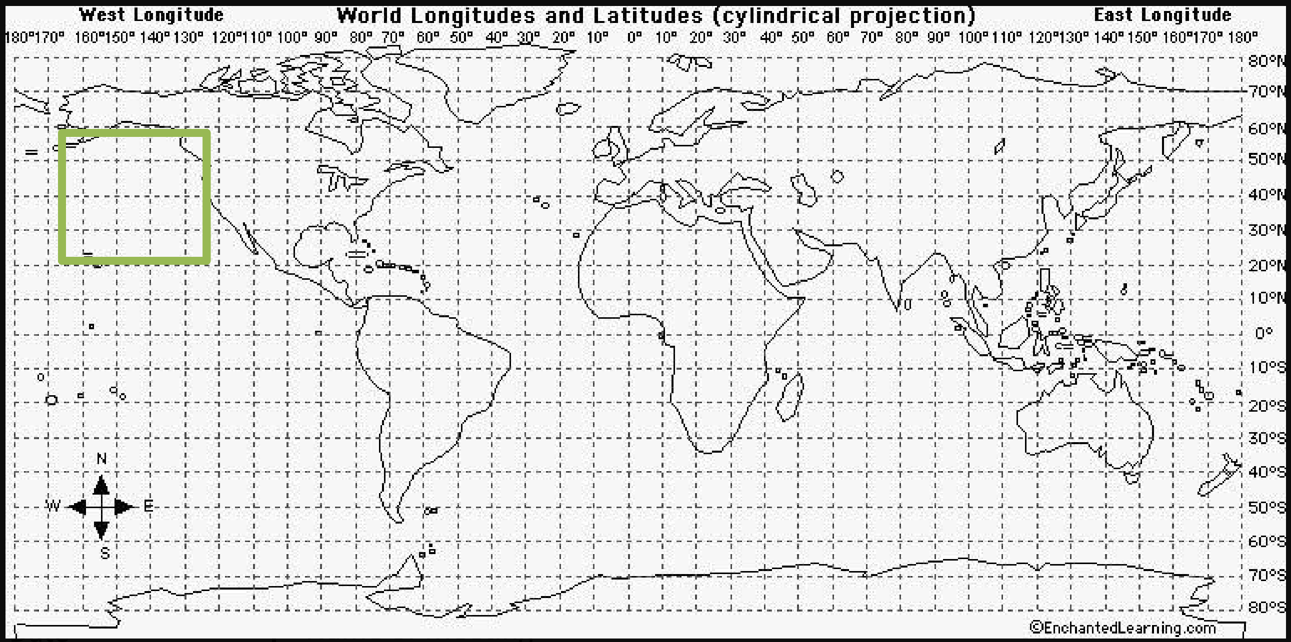


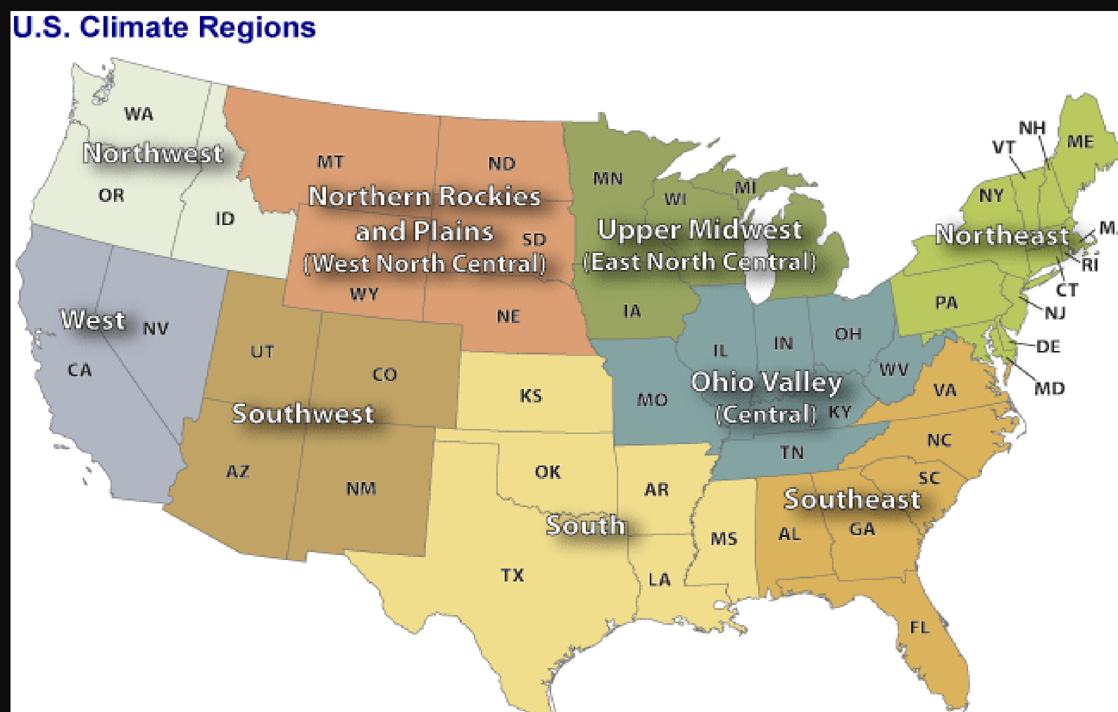
Jet Stream in the Pacific Ocean

- Goal: Determine if localized sea ice loss is causing/enhancing semi-persistent amplification to the jet stream in the Pacific Ocean and how this could affect regional weather extremes across the United States.
- Geopotential height anomalies within grid boxes mostly confined west of CONUS in between the southern coast of Alaska and the northeastern edge of Hawaii.

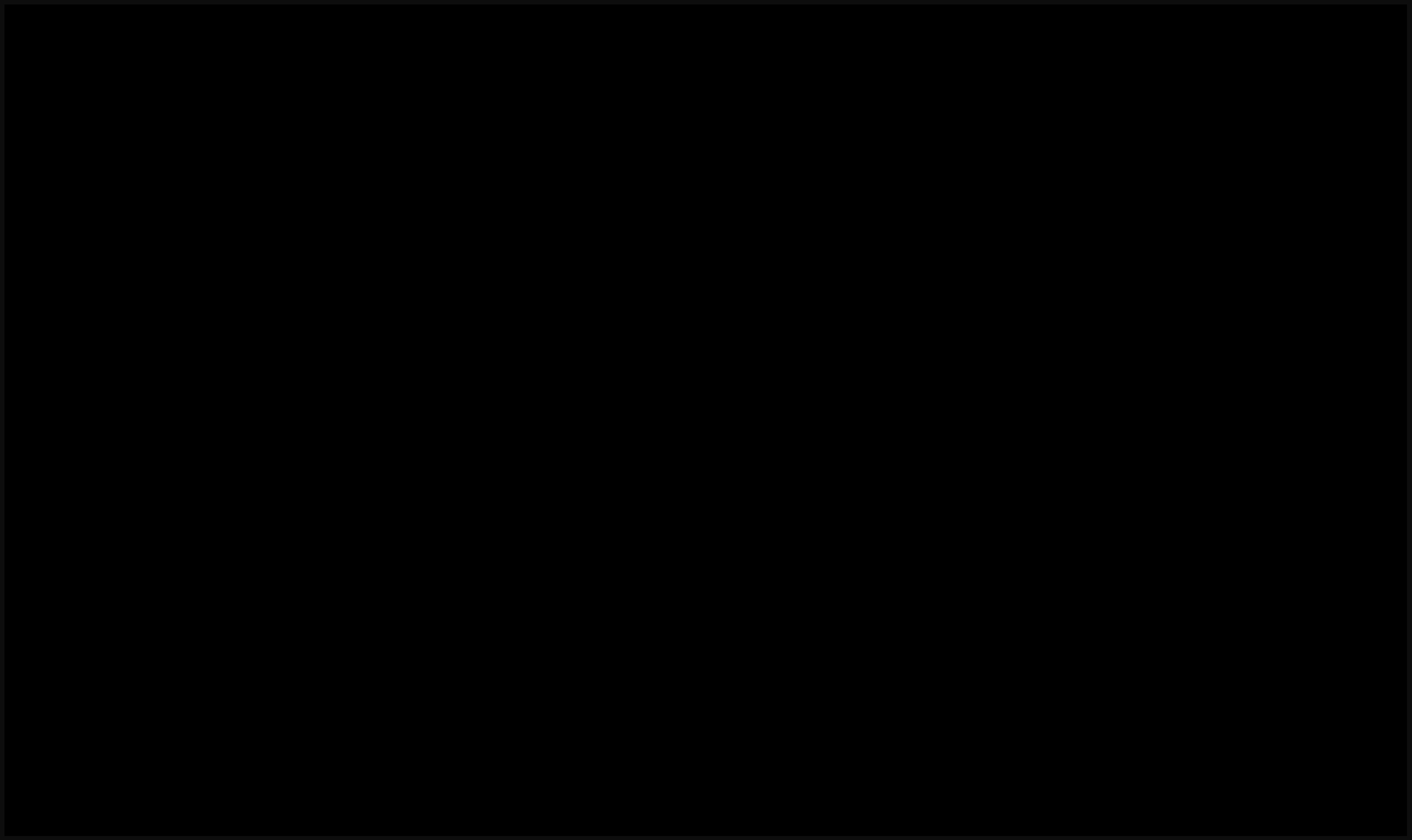


NCDC Climate Regions

- Goal: Determine if localized sea ice loss is causing/enhancing semi-persistent amplification to the jet stream in the Pacific Ocean and how this could affect regional weather extremes across the United States.
- Examine the teleconnections height anomalies have on monthly precipitation in 8 climate regions across the continental U.S.



Challenges of this study

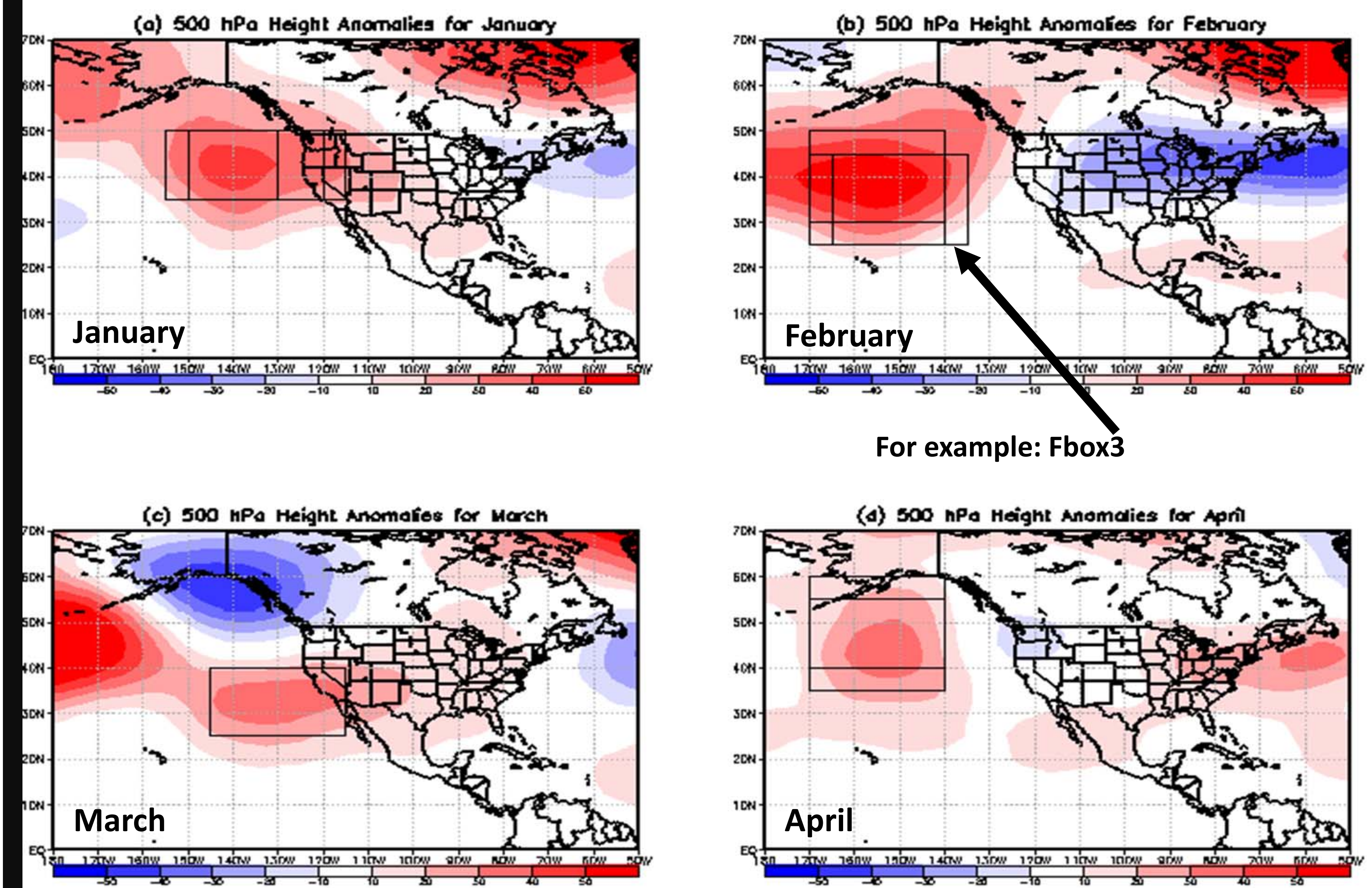


- Short time frame of reliable observations (only since 1979)
- The jet stream is never constant in time or space making it hard to quantify.

Data Used in the Analyses

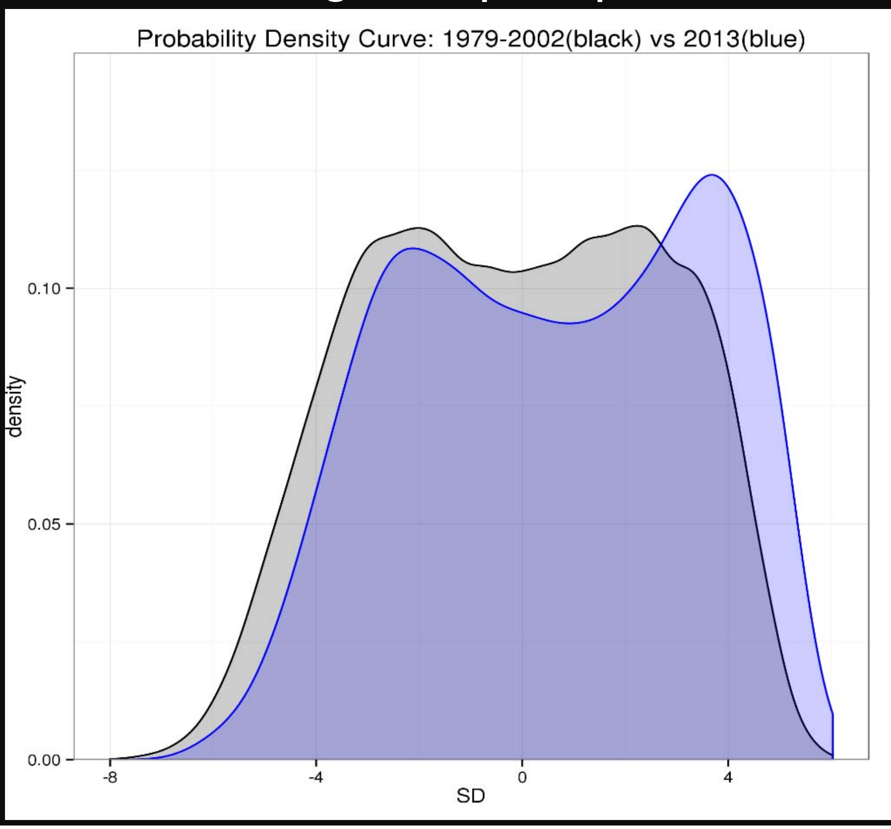
- Geopotential height anomalies and sea ice concentration: NCEP-DOE AMIP-II Reanalysis (R-2) (Kanamitsu et al., 2002)
  - Extends from 1979-2014; incorporates satellite data
- Interim European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-Interim) (Dee et al. 2011) was used to verify R-2 data and conclusions.
- The monthly precipitation anomalies are retrieved from NCDC data available online (http://www.ncdc.noaa.gov).

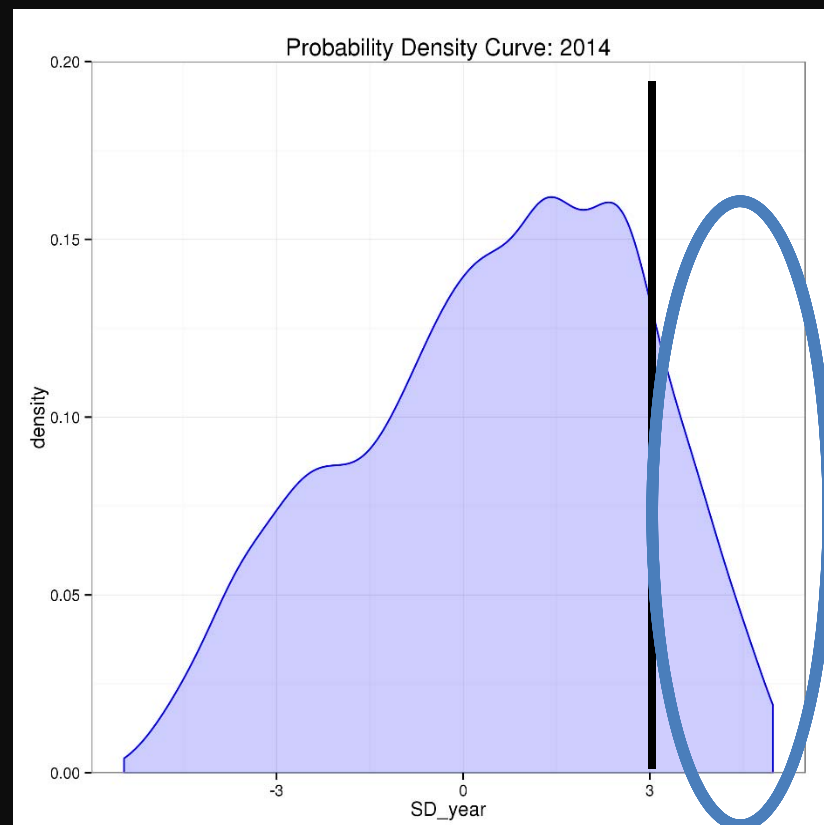
January to April Height Anomalies (R-2)



Procedure

- Calculate the number of standard deviations between each grid point and the seasonal mean.
- Find the total number of times each month that a grid point is equal to or greater than the threshold.
- Calculate the correlation between right/positive tail of the PDF curve and regional precipitation.

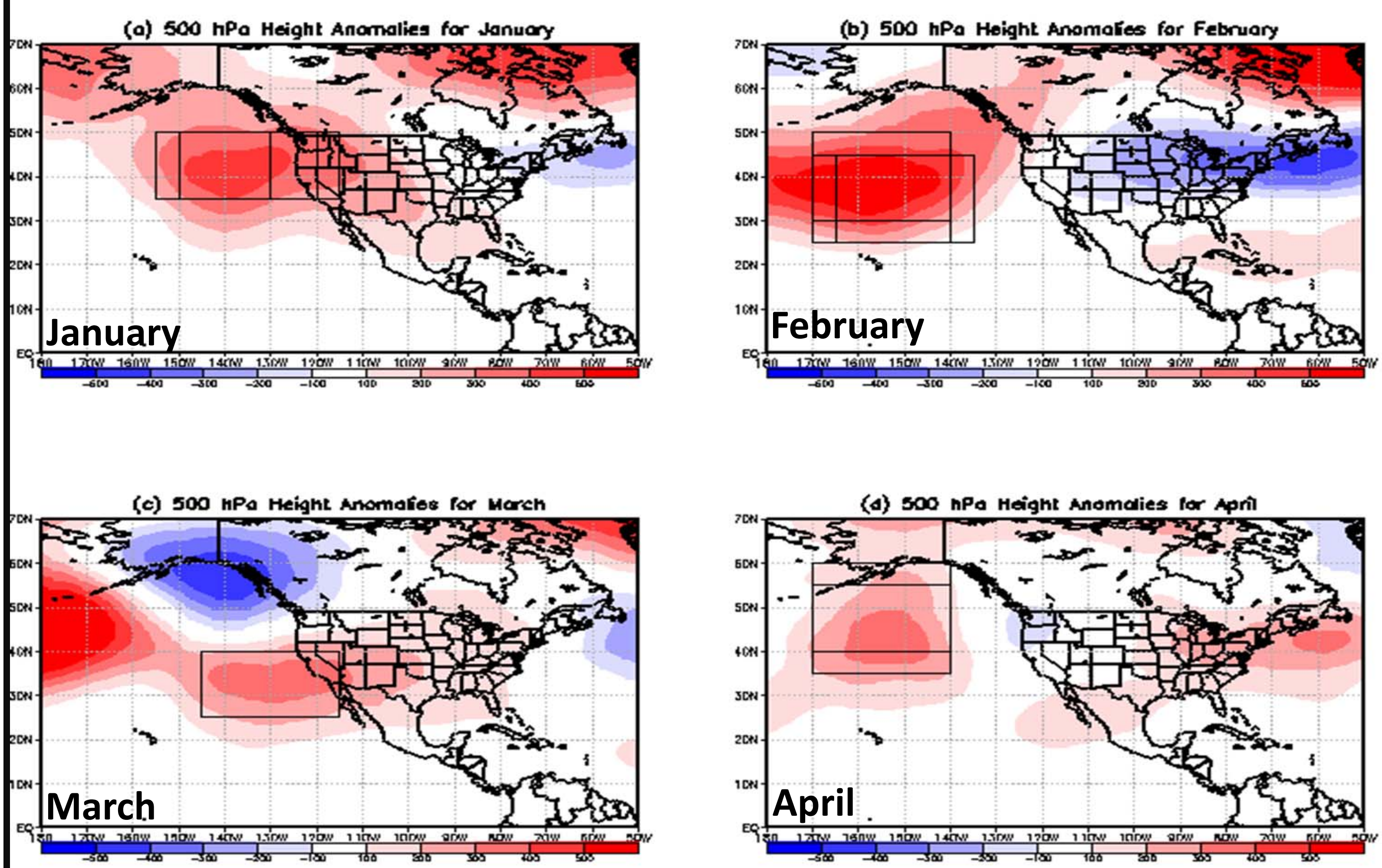




R-2 and ERA-Interim: give same findings

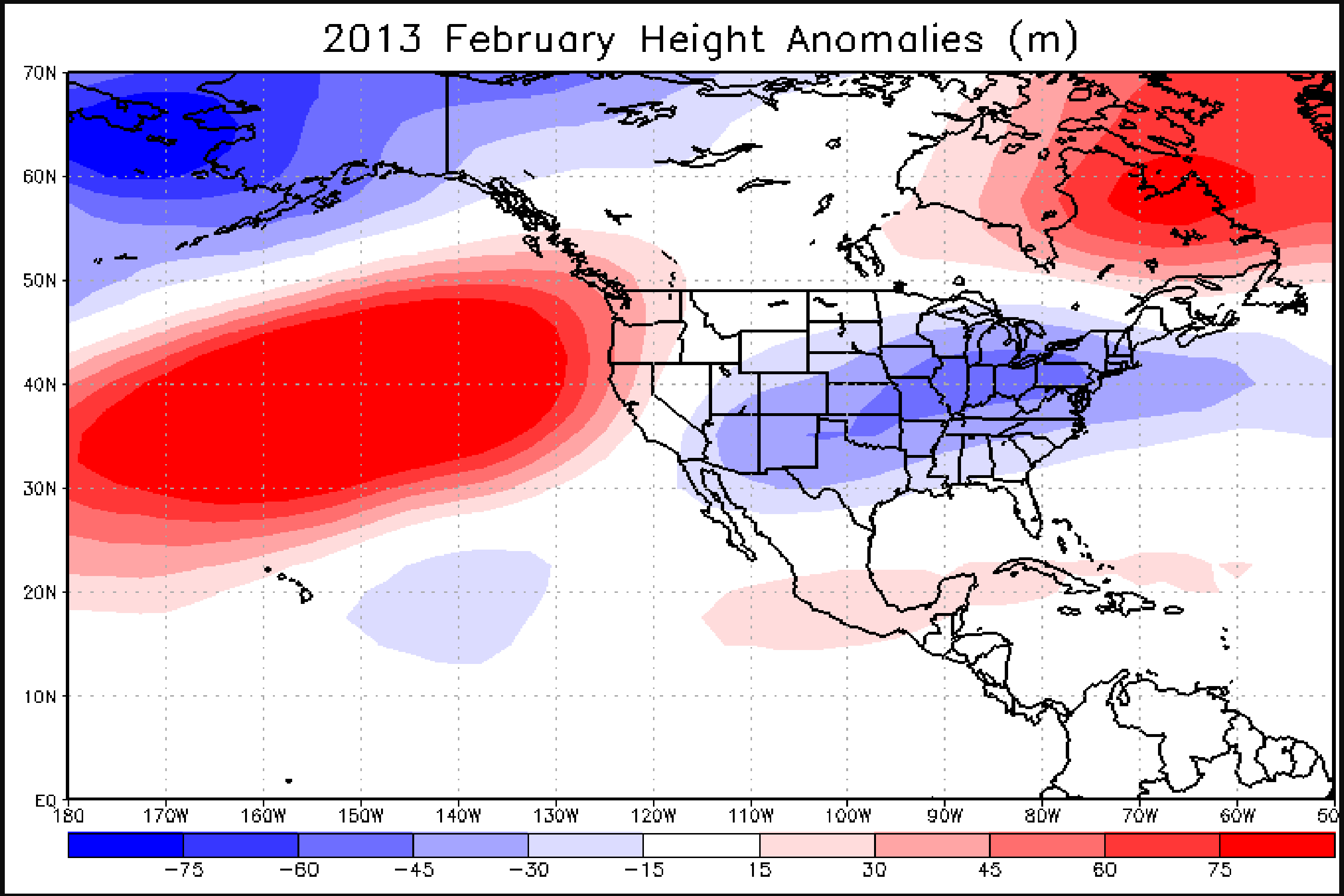
Correlation coefficient for height anomalies: ERA-Interim vs R-2:

January	February	March	April
.9943	.9748	.9938	.9812

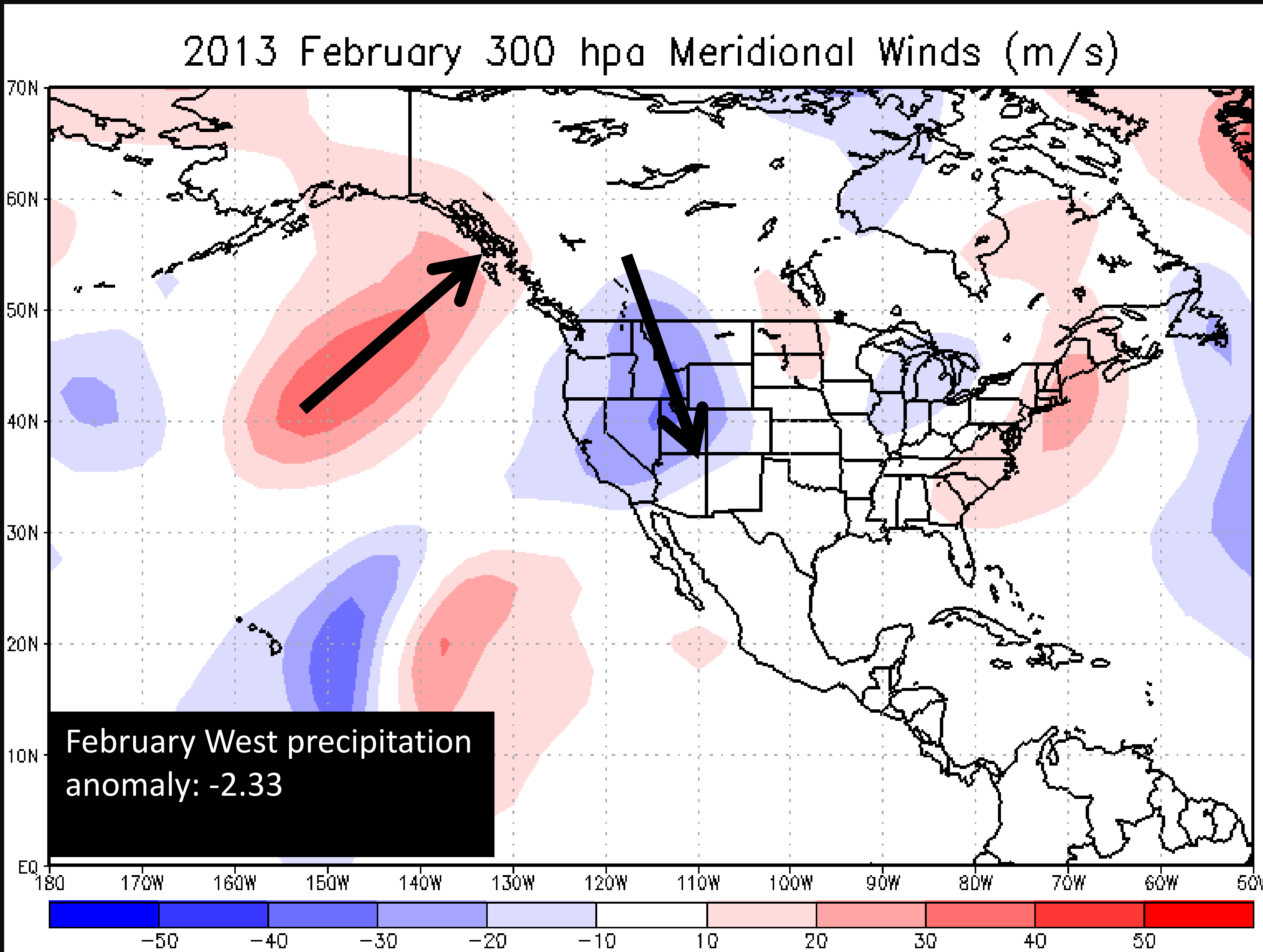


Storm track effect on regional precipitation

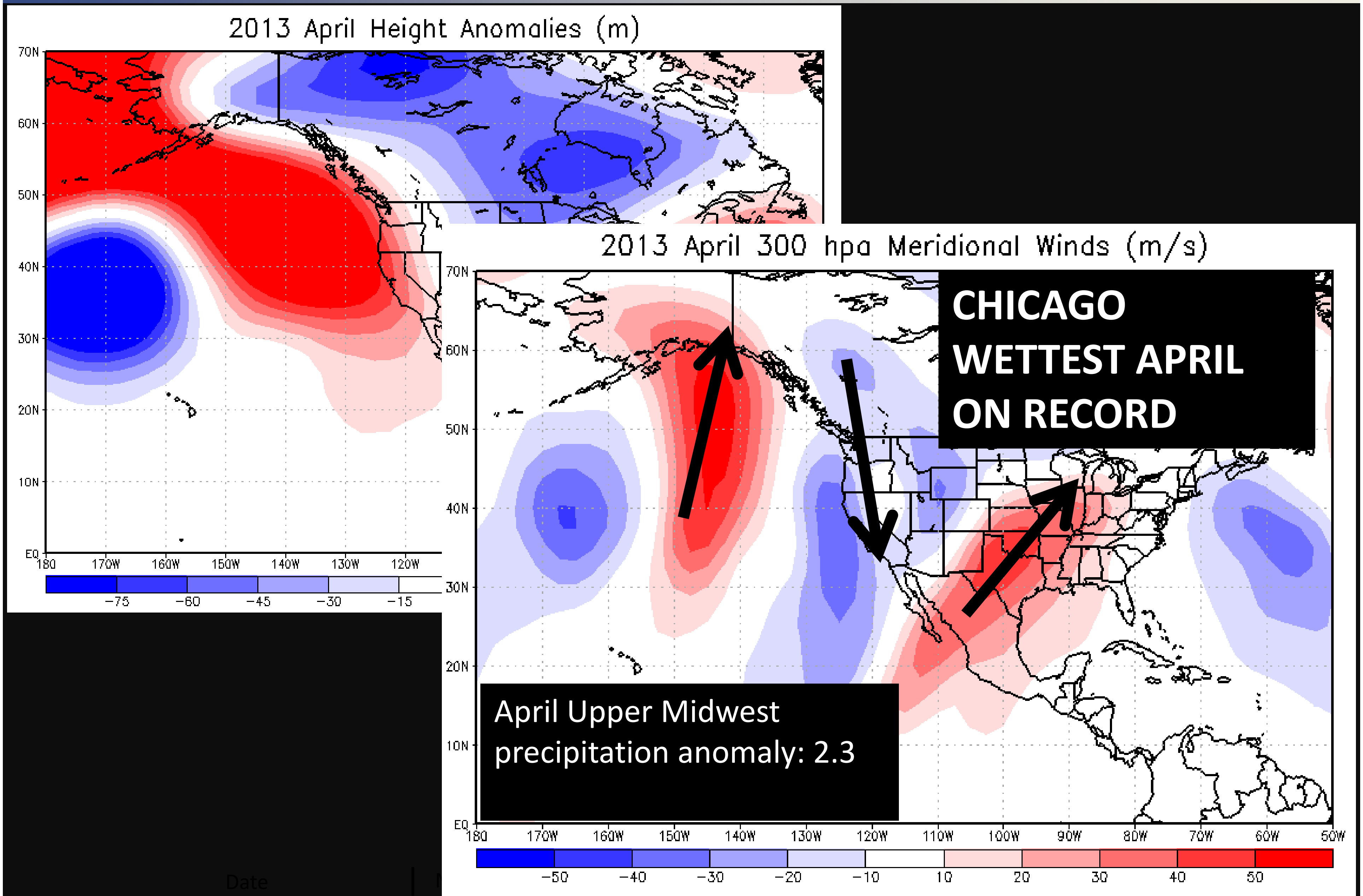
- How can height anomalies in these locations affect the precipitation patterns in certain regions of the United States?
- Use height anomalies and meridional winds in February and April of 2013 as an example.



Storm track affect on regional precipitation



Storm track effect on regional precipitation

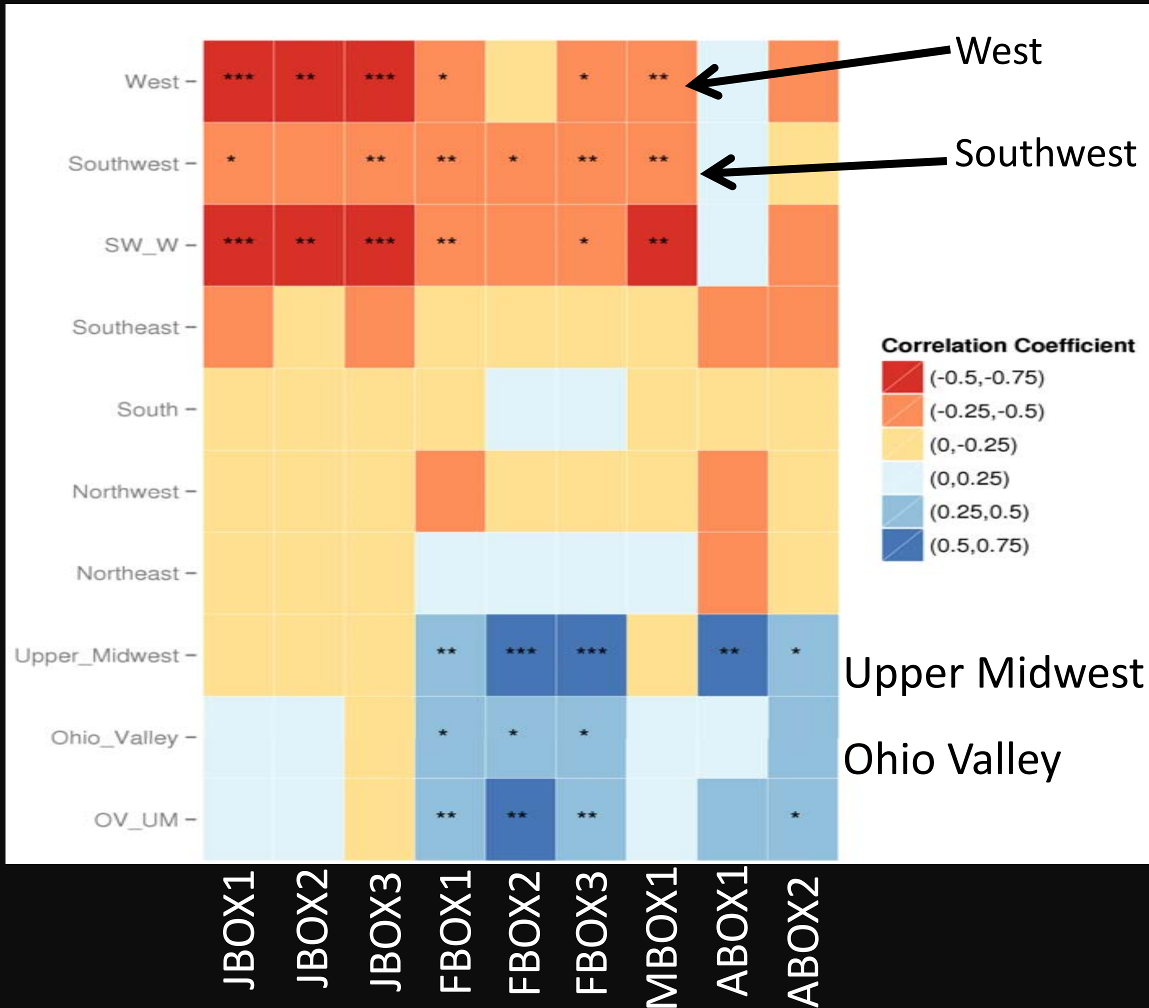


Results: Teleconnections on precipitation

- Stars represent significance levels:
  - *   95% confidence
  - **   99%
  - *** 99.9%

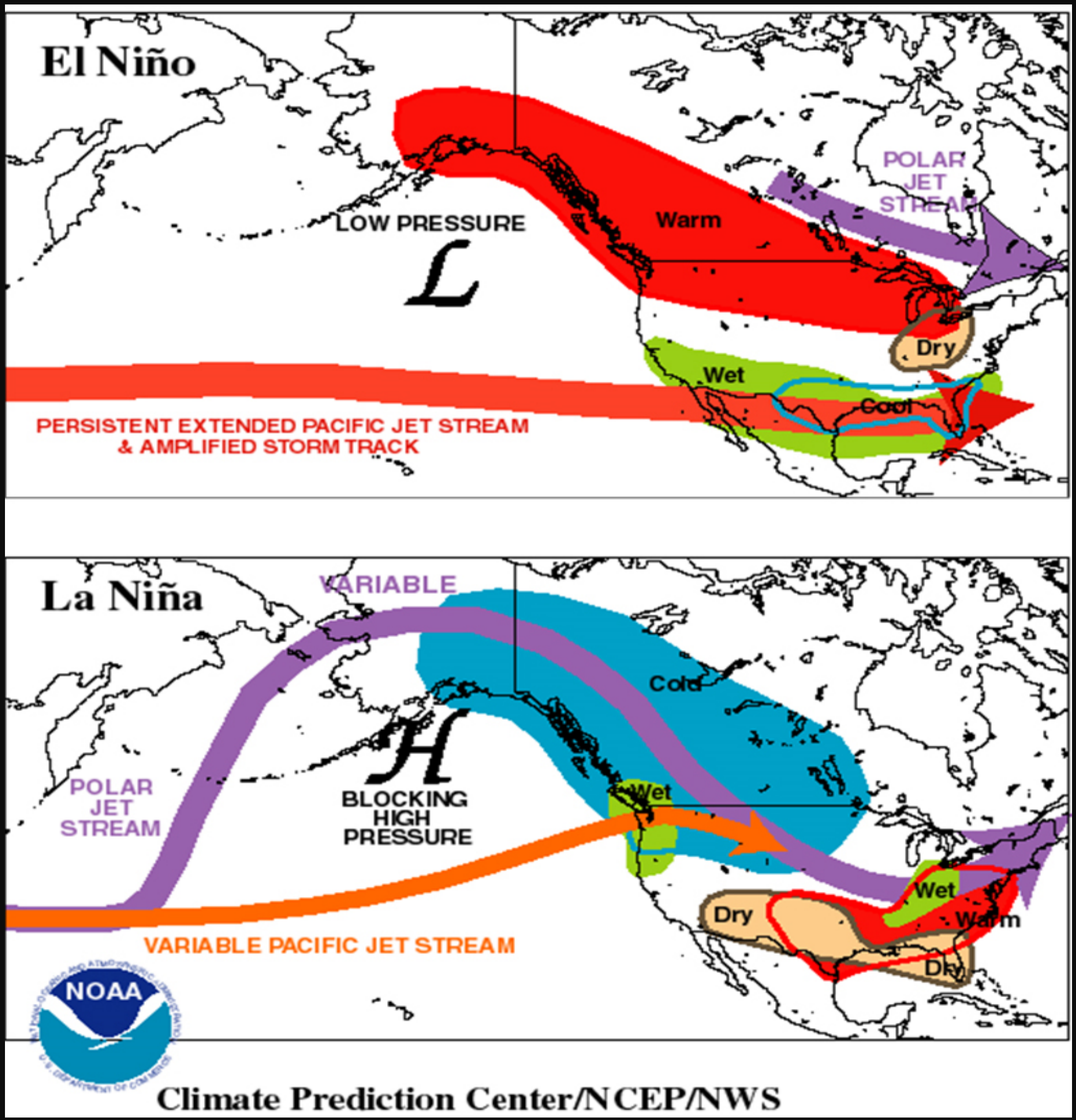
- Western and Midwestern parts of the country show the strongest correlation.

- Negative/positive correlation means an increased frequency in ridging ridging led to less/more precipitation.



Is SOI phase important?

Could ENSO or PDO or other ocean cycles affect the long term trends we are examining?



Accounting for long-term ocean cycles

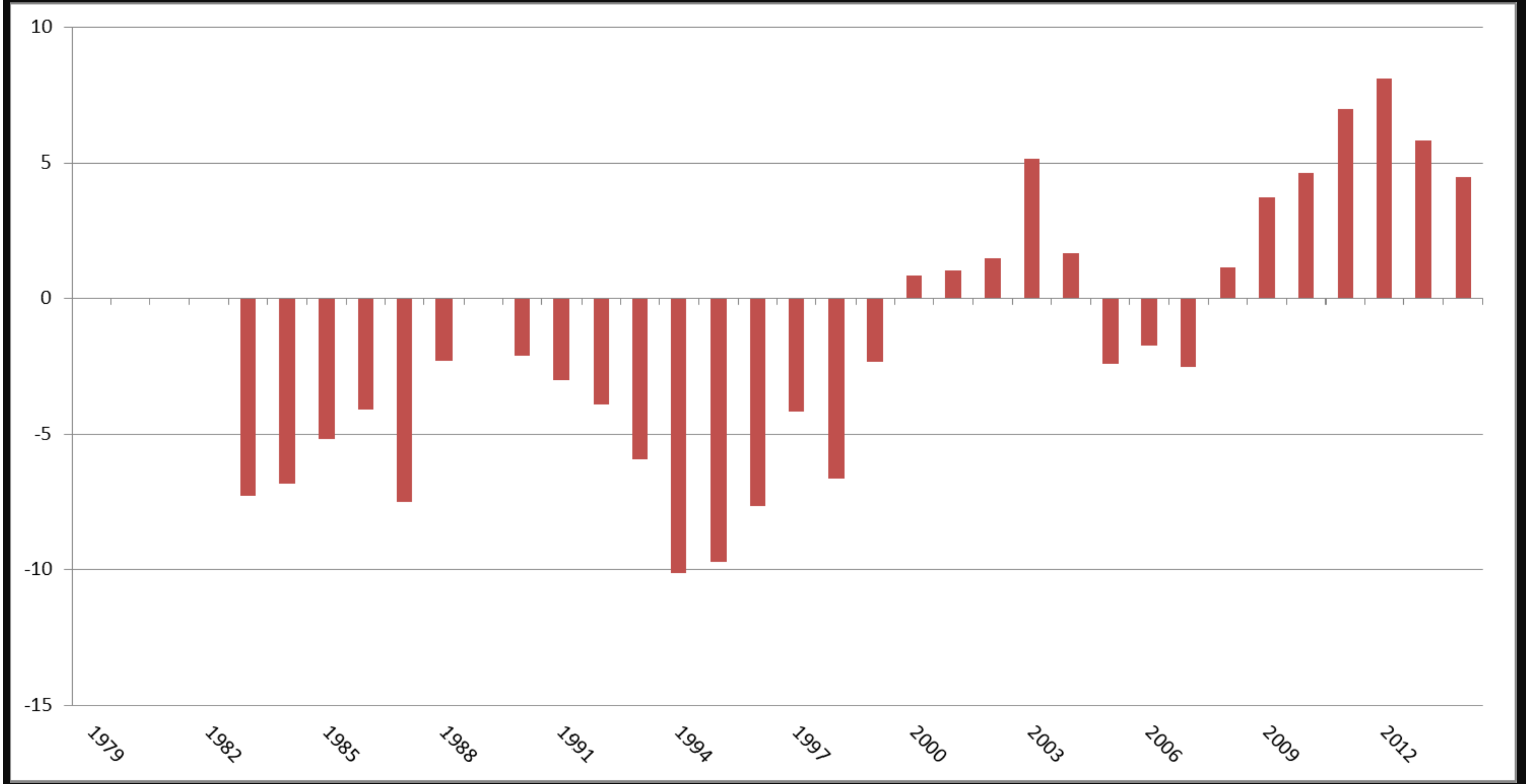
- Determine if localized sea ice loss could be causing a trend toward increased height anomalies that is independent of ocean cycles such as Pacific Decadal Oscillation (PDO) and Southern Oscillation Index (SOI)

- Monthly SOI and PDO values from: National Oceanic and Atmospheric Administration (NOAA) teleconnections page (https://www.ncdc.noaa.gov/teleconnections).

- Shift in SOI could lead to false signal of an increasing ridge

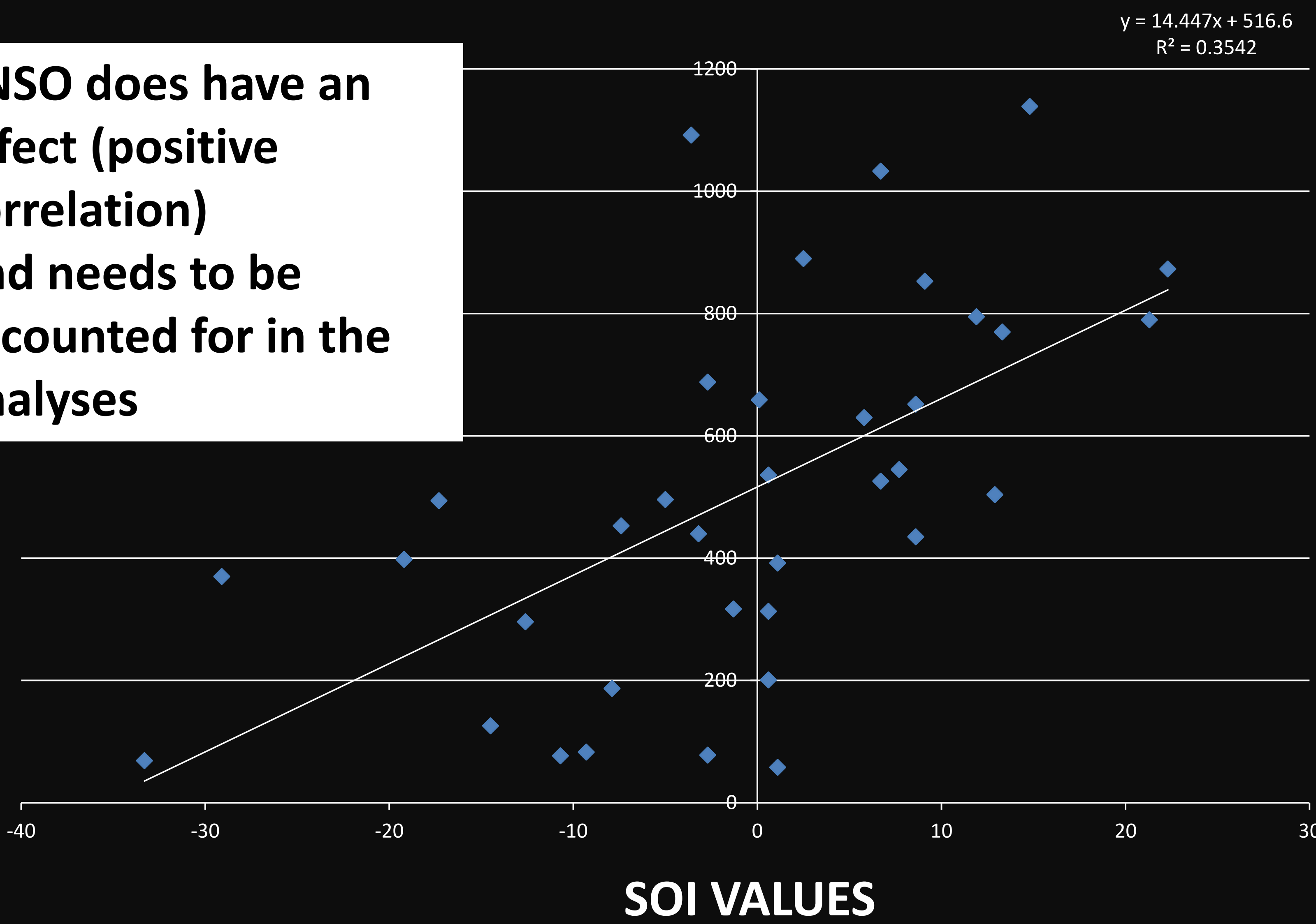
Shift has been from mostly El Niño to mostly La Niña

JFMA SOI VALUES: 5 Year Running Mean



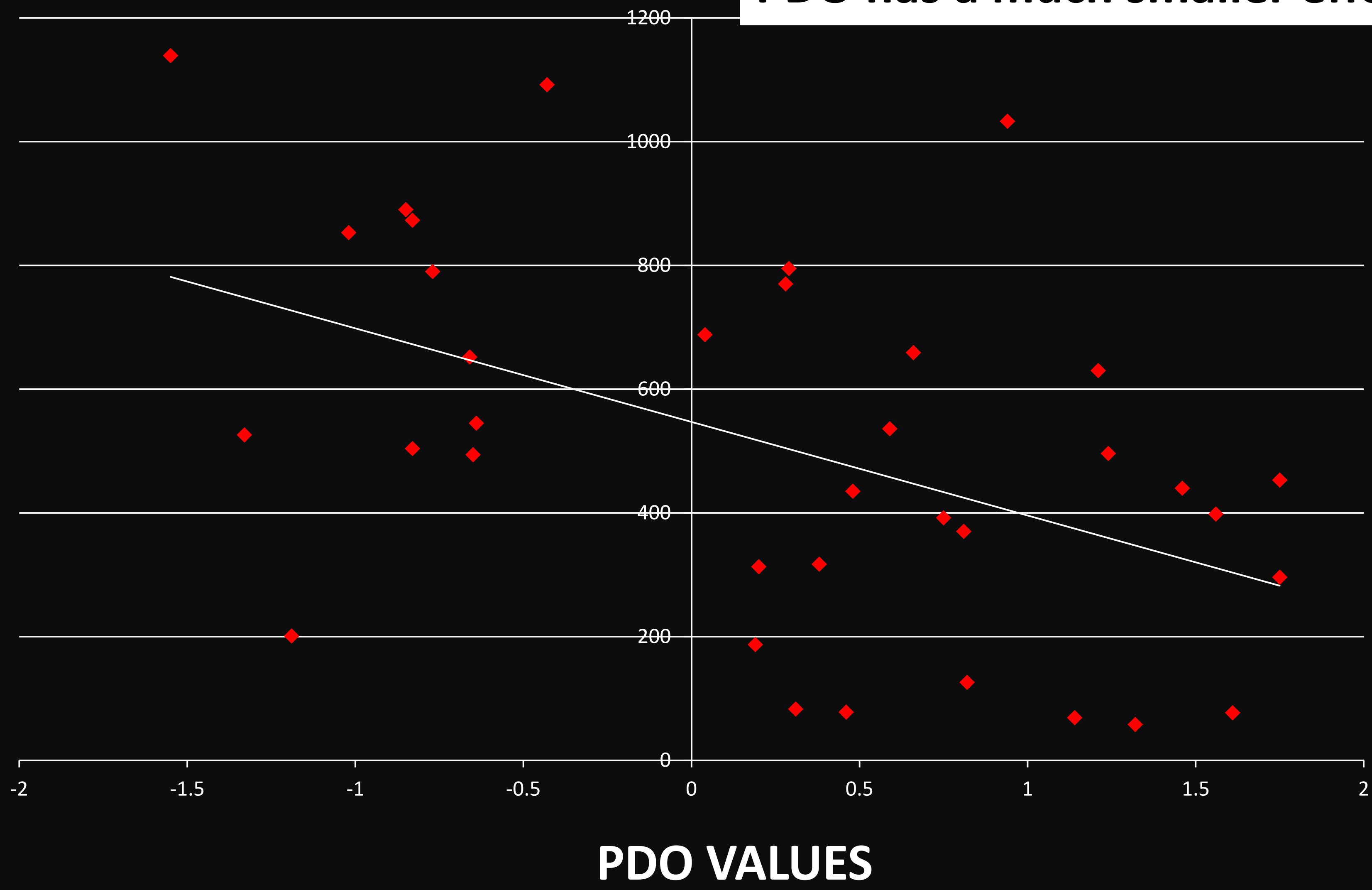
February: SOI vs Height threshold count

ENSO does have an effect (positive correlation)
and needs to be accounted for in the analyses

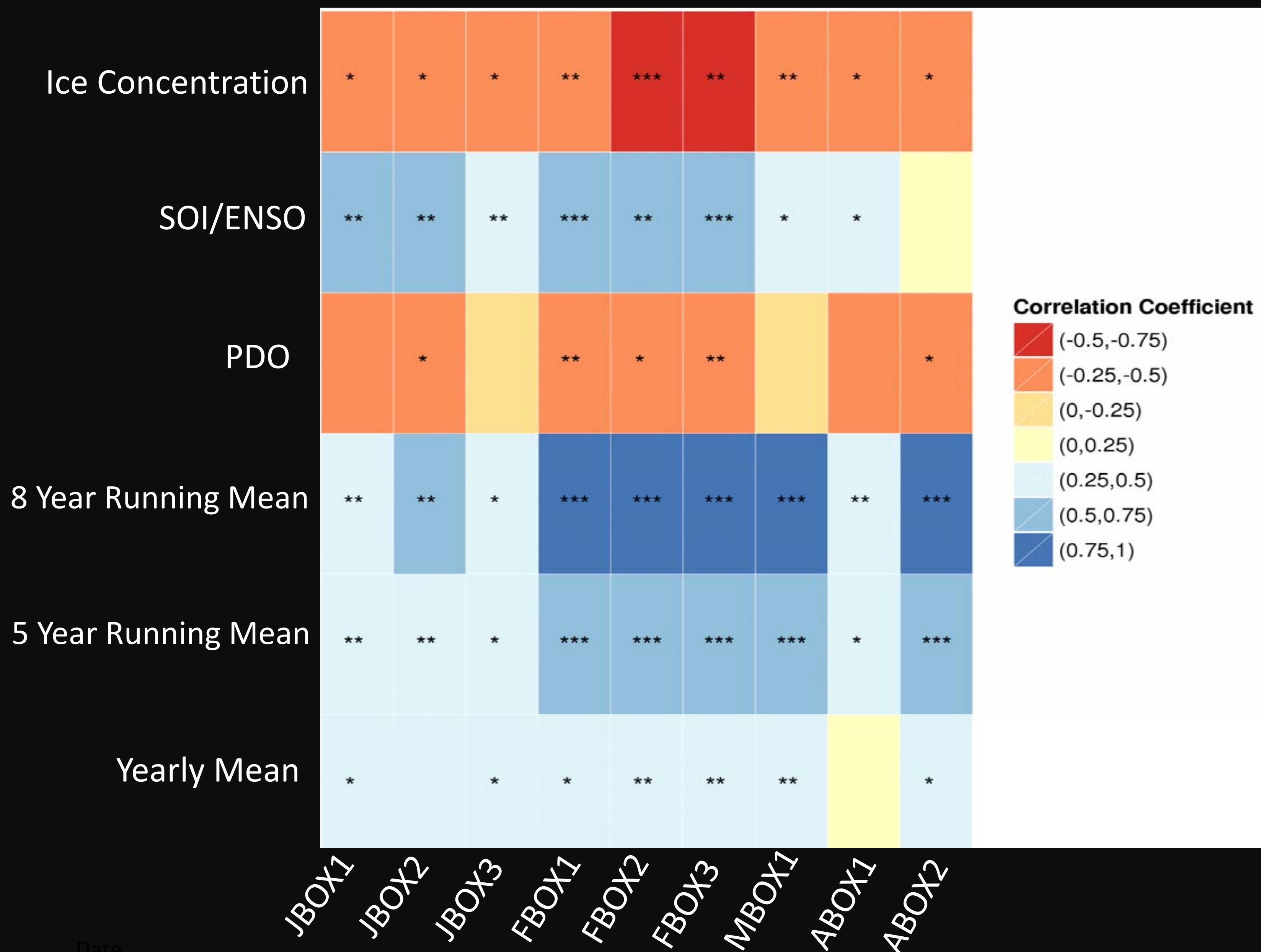


February: PDO vs Height threshold count

PDO has a much smaller effect



ENSO and PDO Impact



Accounting for long-term ocean cycles

Determine if localized sea ice loss could be causing a trend toward increased height anomalies that is independent of ocean cycles such as Pacific Decadal Oscillation (PDO) and Southern Oscillation Index (SOI):

$$\overset{}{zcount_{adjust}} = \overset{1}{zcount_{original}} - \overset{2}{((|SOI_x| * \overline{zcount})^{\frac{1}{2}}} * \overset{3}{\frac{SOI_x}{|SOI_x|}} \quad \overset{4}{}$$

[redacted]

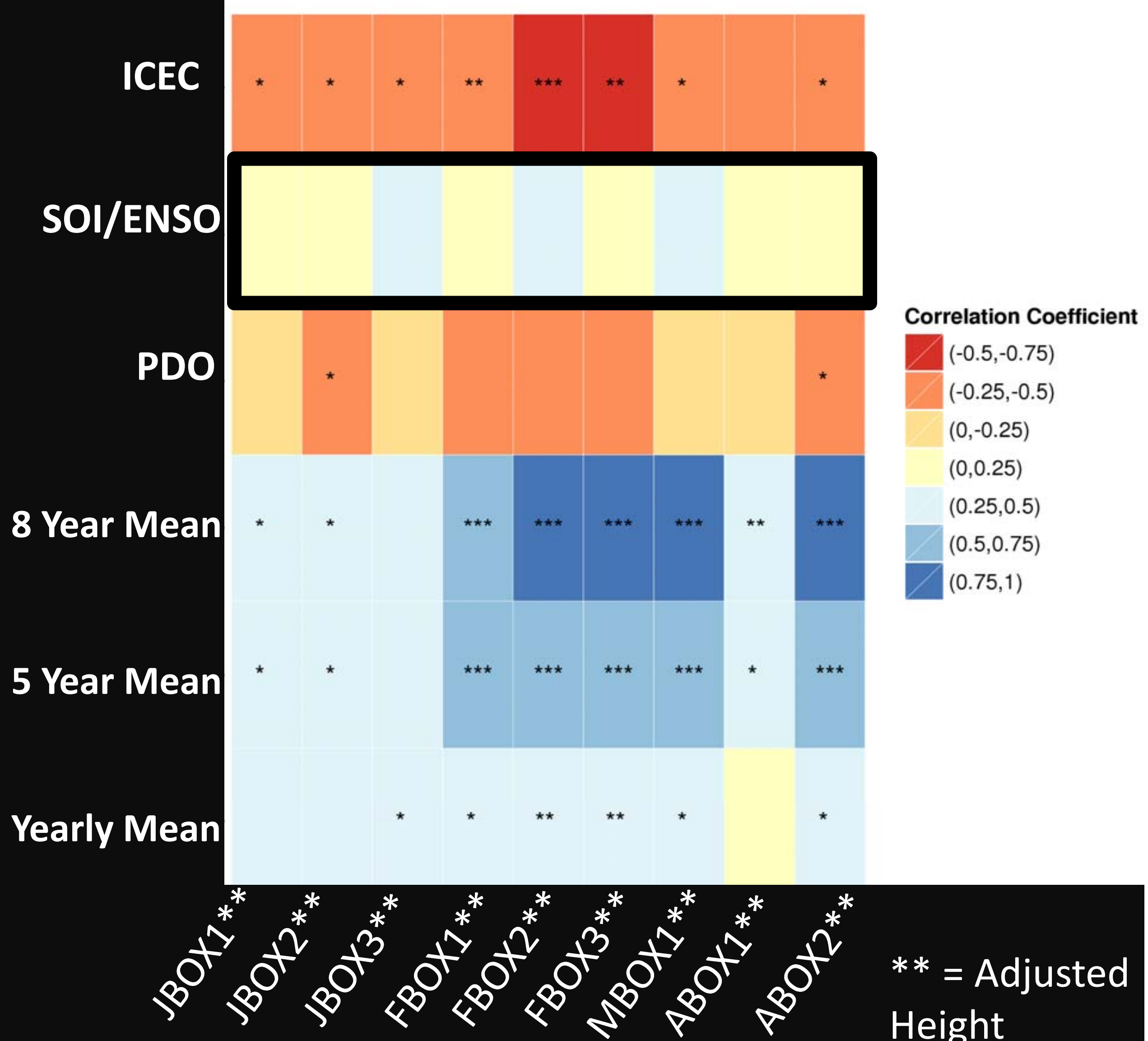
- Term 1: The original height count
- Term 2: The SOI index for x month and year multiplied by the average threshold count for that month during the time period.
- Term 3: SOI phase
- Term 4: This ratio is typically used as a way to test the linearity in a simple regression problem. (Dodge and Rousson, 2000)

Results: Accounting for long-term ocean cycles

Using equation reduced correlation coefficient between SOI and grid boxes to ~0 in all boxes.

Slight significance remains with PDO and height anomalies.

Yearly and running means remain statistically significant -- trend toward more amplified ridging.

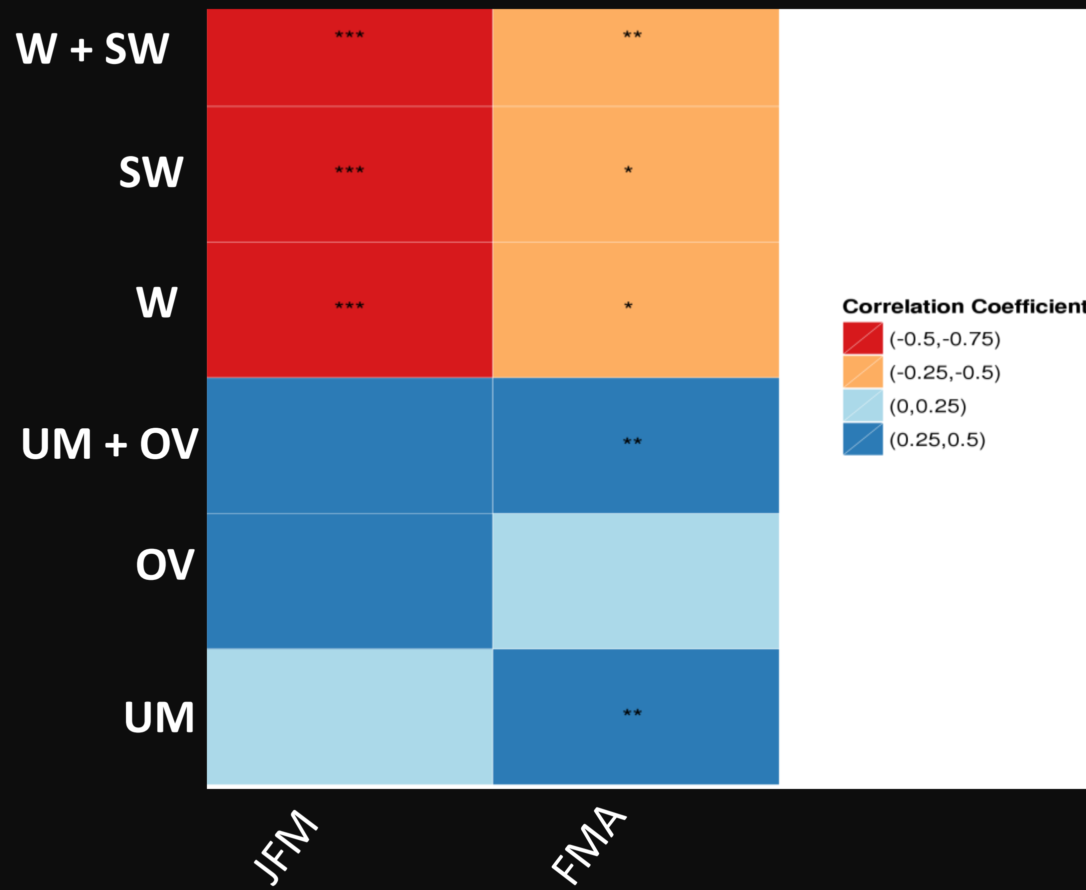


** = Adjusted Height Anomalies

Multi-month teleconnections on precipitation

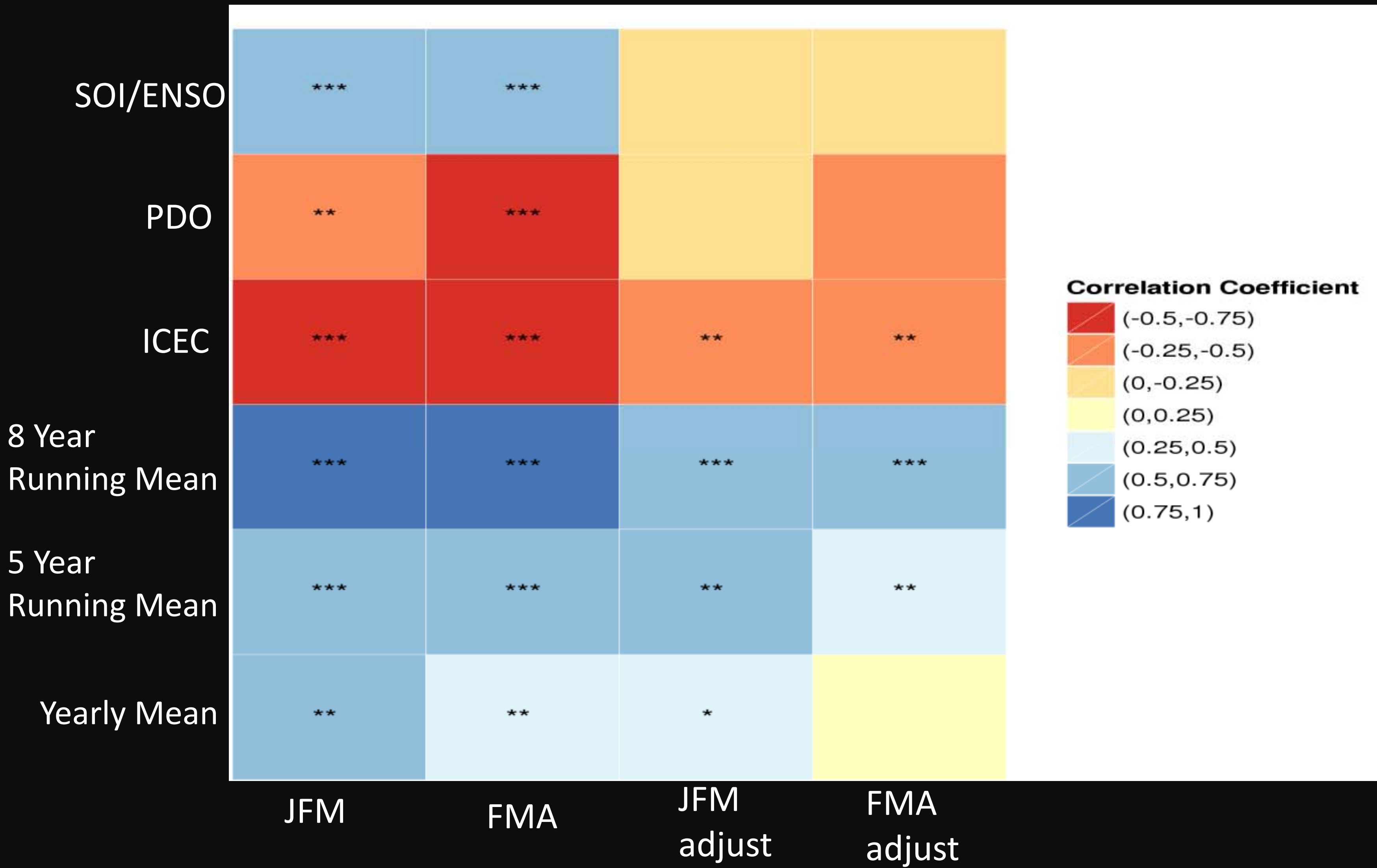
Multi-month periods of persistent precipitation patterns leading to increased potential for long-term floods and droughts.

Assume each month's height anomalies will develop independent of each other.



***Seasonal height threshold count values are generated by taking a grid box from each of the months for 3 months.

Multi-month results accounting for long-term ocean cycles

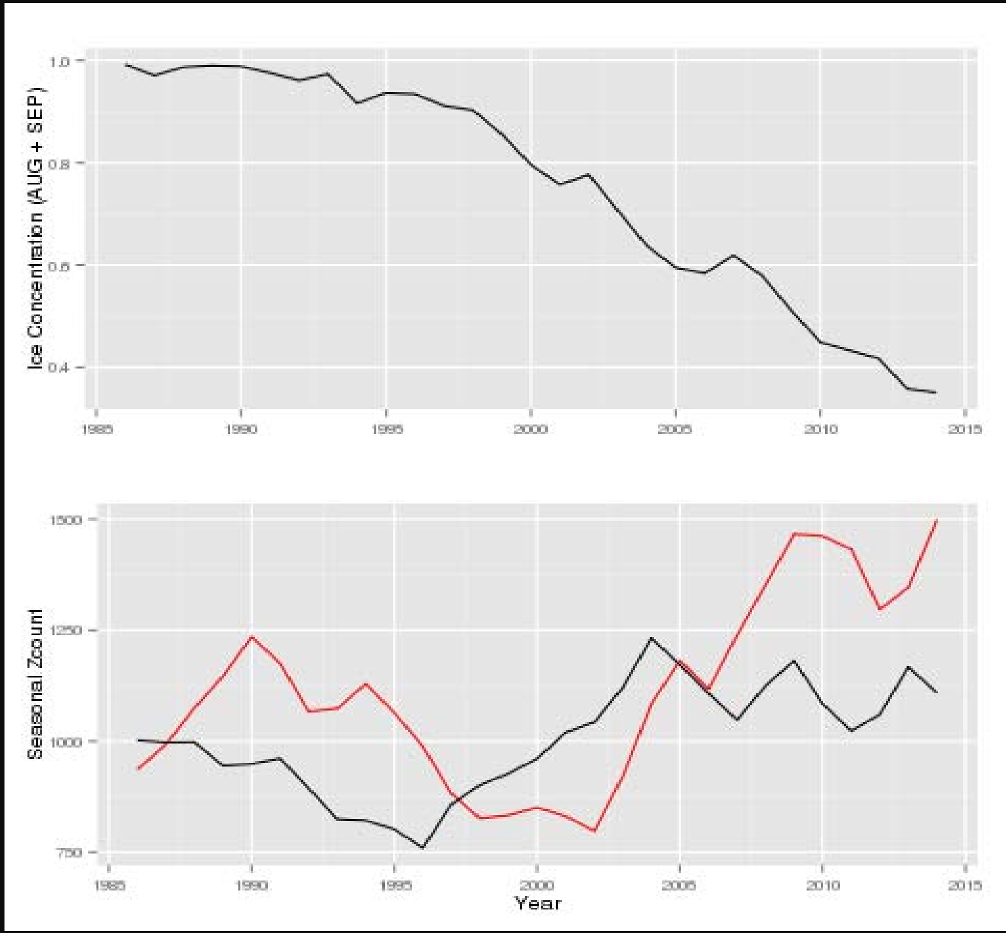


Sea Ice Teleconnections

Rapid sea ice decline occurring while ridging becomes more persistent.

Our results suggests that the Arctic may be acting as an amplifier of jet amplitude rather than the cause.

These changes will be regional, seasonable, and will vary yearly based on background atmospheric and surface conditions. (Overland et al., 2015)



8 year running mean for August + September sea ice concentration (top); 8 year running means for seasonal height count (bottom): JFM (red) and FMA (black)

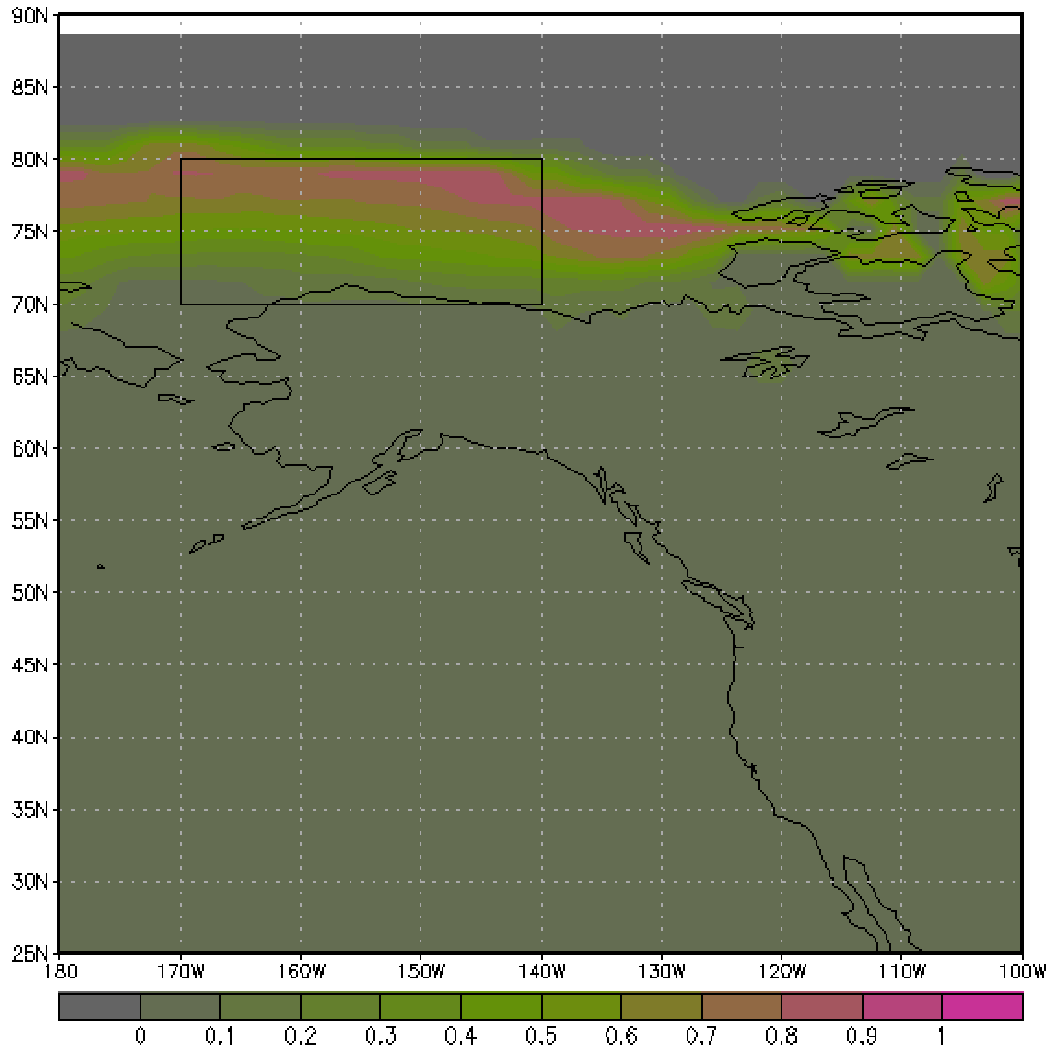
What results may say about Sea Ice Free Year(s)

"Ice free" years become more frequent in the coming decades.

Research suggests the Arctic could be ice free consistently in 2 to 4 decades. (Wang and Overland 2009; Stroeve et al. 2007)

Current sample size of ice free years TOO SMALL, but 2013 showed signs that 2012 record low sea ice had an impact

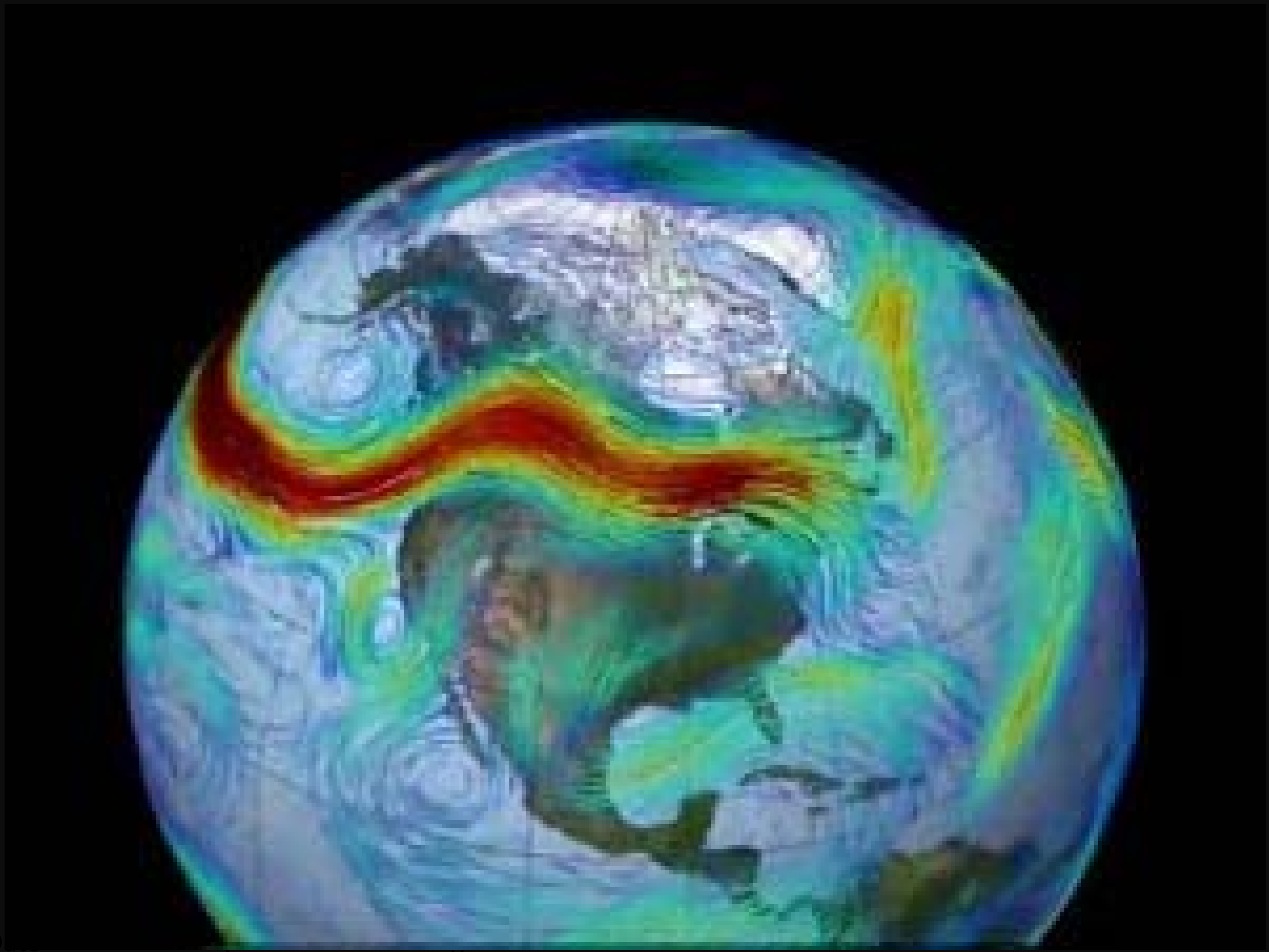
2012 Sea Ice Concentration Anomaly



Conclusions

- Our results indicate that late winter and early spring months are trending toward more ridging in the Pacific Ocean and that this may be independent of the ENSO.
- Ridging in these locations is leading to monthly and seasonal precipitation trends across the United States, especially:
  - Increased trend for precipitation in the Midwest U.S. during late winter/early spring.
  - Decreased trend for precipitation in the Western U.S.
- Could there be implications for forecasting in the future? More study needed.

THANK YOU



Arctic Amplification and the jet stream

The issue of how Arctic amplification is affecting the jet stream in the mid-latitudes

How can Arctic amplification affect mid-latitude weather?

- Reduces the strength of pole to mid-latitude temperature gradient.
- In theory, this reduces the upper level zonal winds at these locations.

Previous Research

- Francis and Vavrus (2012): observational evidence that AA may be causing more persistent weather patterns
- Screen et al. (2013/2014): decreasing summer sea ice is causing precipitation pattern changes in Europe.
- Close proximity to sea ice negative anomalies.