Assessment of the predictability of September sea ice concentration using sea ice thickness

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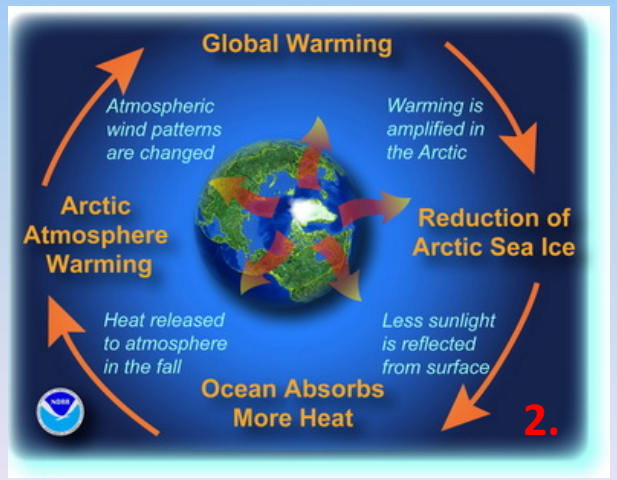
Image Credit: NOAA

Motivation

- Why Improve sea ice forecasts?
  - Important for shipping
  - Atmospheric circulation
  - Wildlife interests

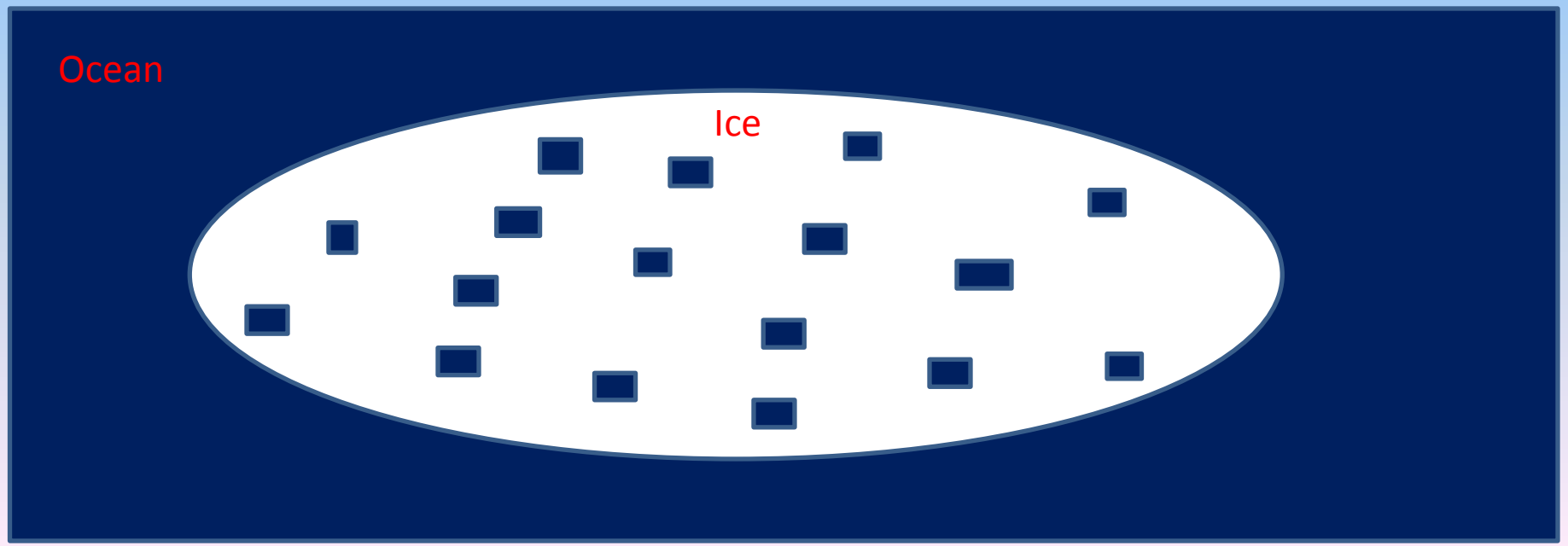


1. http://www.marineinsight.com/wp-content/uploads/2011/07/arctic-tanker.jpg
2. http://www.wwfblogs.org/climate/content/noaa-arctic-futures-site
3. http://www.polarbearsinternational.org/media/images/save-our-sea-ice-0

Sea Ice Extent (SIE) vs. Sea Ice Area (SIA)

SIE – Measure of the edge of sea ice and all of the space inside of it. Edge defined by a grid cell concentration of 15%.

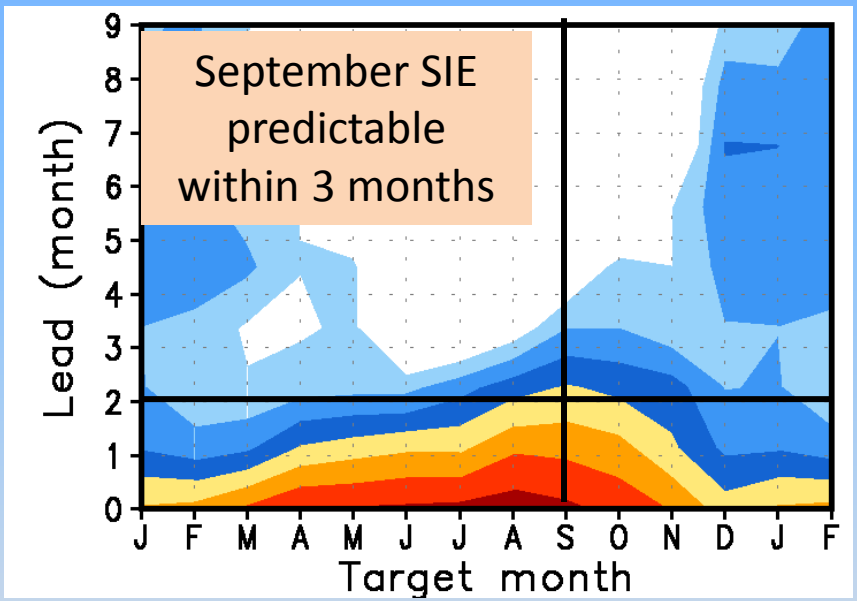
SIA – Measure of where there is ice only within the extent region.



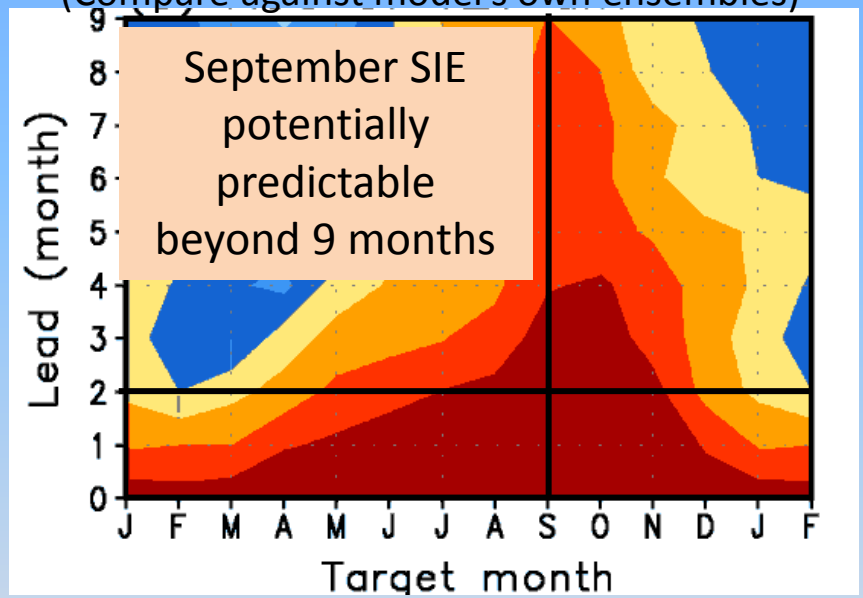
Anomaly correlation coefficient (ACC) of sea ice extent (SIE) interannual anomalies

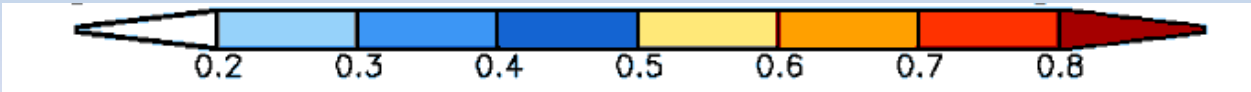
CFSv2 hindcast (1982-2007)

Actual prediction skill
(compare against observations)



Perfect model potential prediction skill
(Compare against model's own ensembles)





Consistency with relevant studies:

Merryfield et al. (2013): Skillful SIE prediction is within 2-3 month lead time.

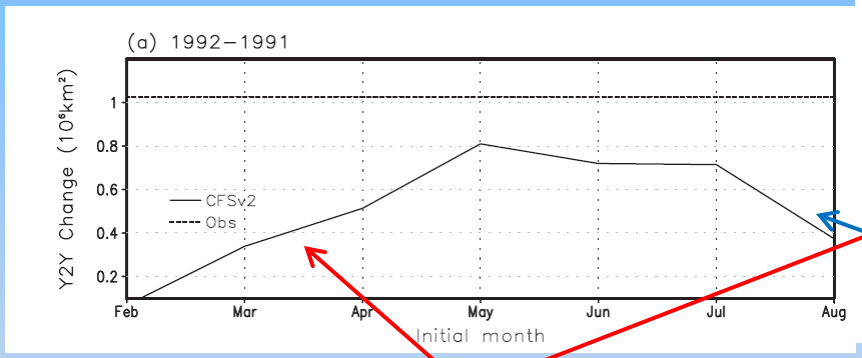
Blanchard-Wrigglesworth et al. (2011): Sea ice area *potentially* predictable beyond 1 year.

Slide courtesy of *Wang et al.* (2014), Images are 5c and 7c from *Wang et al.* (2013)

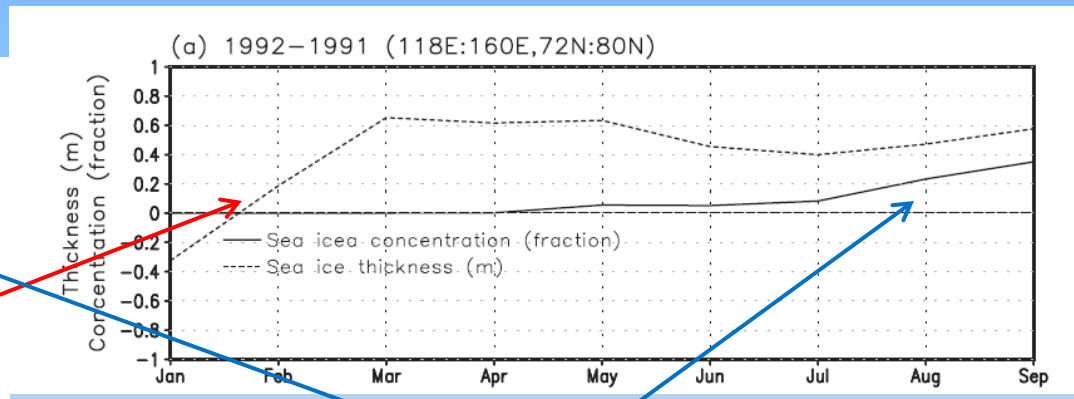
Using Thickness to Forecast SIE

Shown below are Figures 14 and 15 from *Wang et al.* (2013)

Year to year (Y2Y) change in projected **September sea ice extent** as a function of initialization month



Y2Y change in **mean sea ice thickness** and concentration for each initial month



Y2Y thickness increases in spring correspond to increases in predicted September SIE, with better agreement with observations.

Concentration increases in July-September but SIE forecasts do not improve

Sea ice thickness trends, not concentration, have better predictive skill for September SIE

Methods

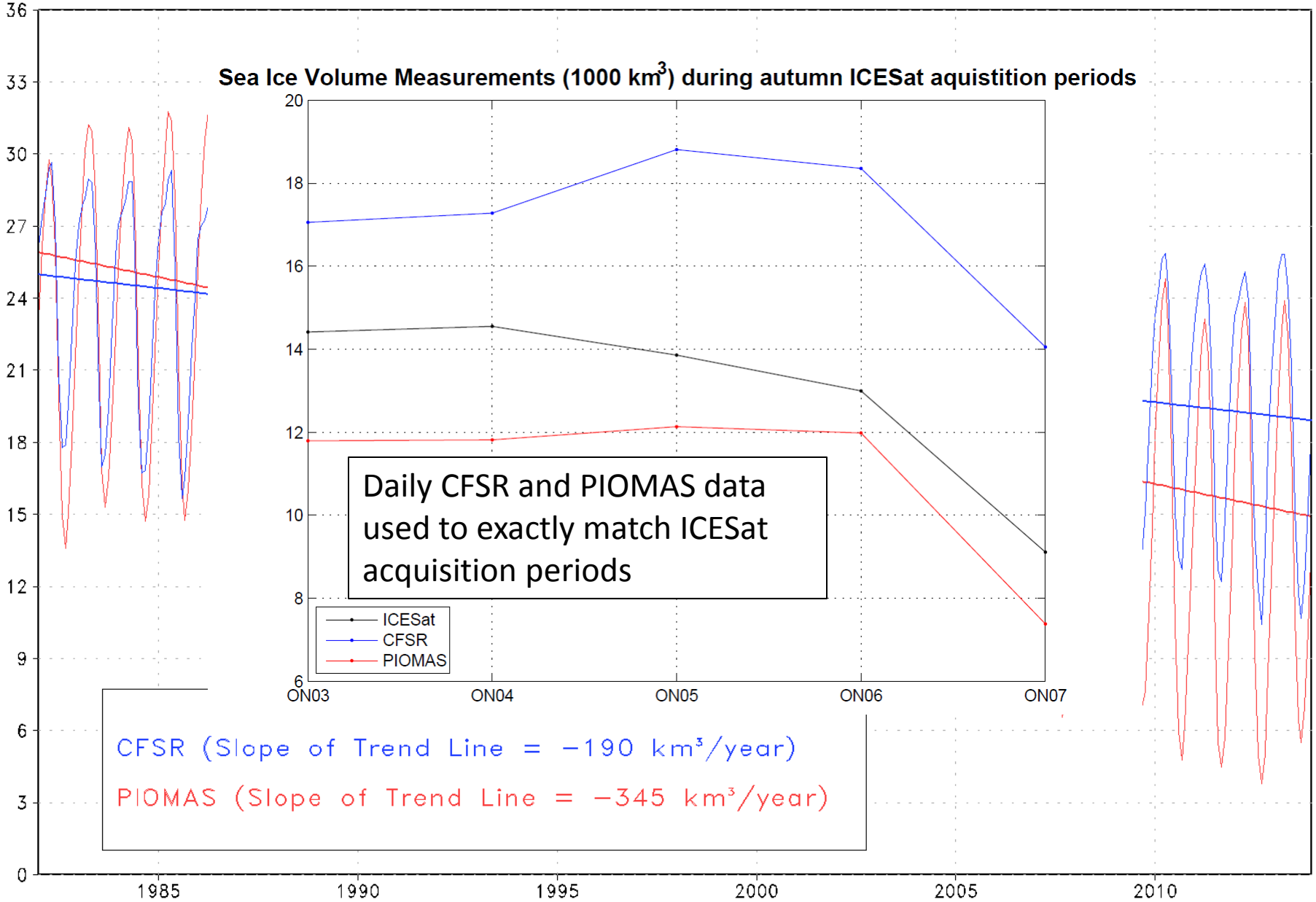
- Use sea ice thickness from Climate Forecast System Reanalysis (CFSR; *Saha et al.*, 2010) and Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS v2.1; *Zhang and Rothrock*, 2003). Unless otherwise noted all data is monthly.

- Compare with NASA Team September sea ice extent and area derived from satellites (Cavalieri et al., 1996)

  Sigmond et al. (2014) show the importance of using the same observational dataset for the comparison of different forecast systems

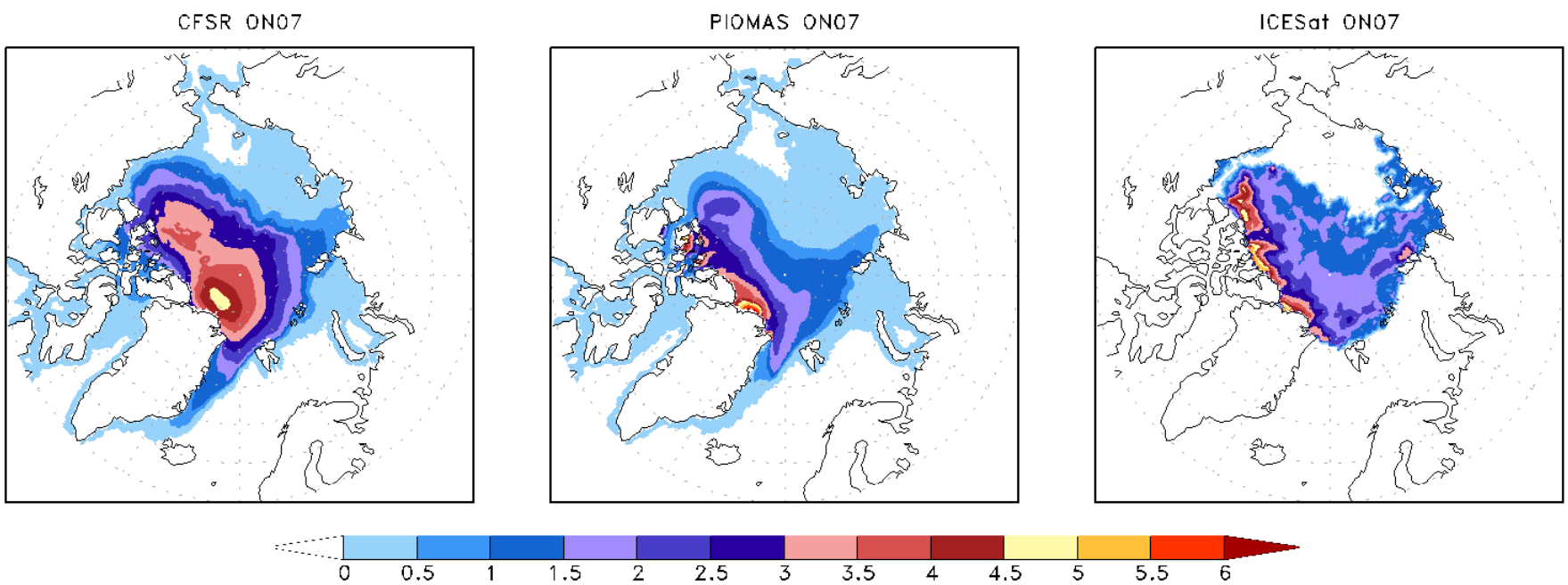
- Detrended lagged correlations using 2nd order polynomial fit

Total Sea Ice Volume (1000 km³) and Linear Trend Lines (1982–2013)



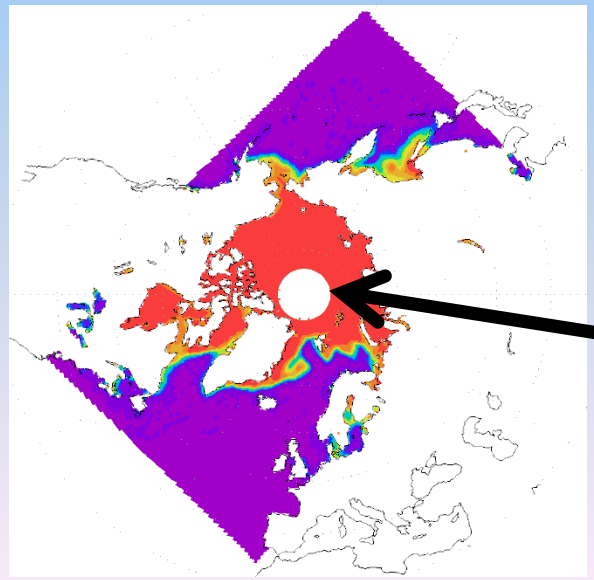
Below are observations of mean sea ice thickness (m) from CFSR, PIOMAS, and ICESat. **It is clear that PIOMAS is more similar to the ICESat observations than CFSR.** Therefore a possible correction to CFSR data using PIOMAS could yield better modeling simulations.

ON07 = October 2 – November 5, 2007



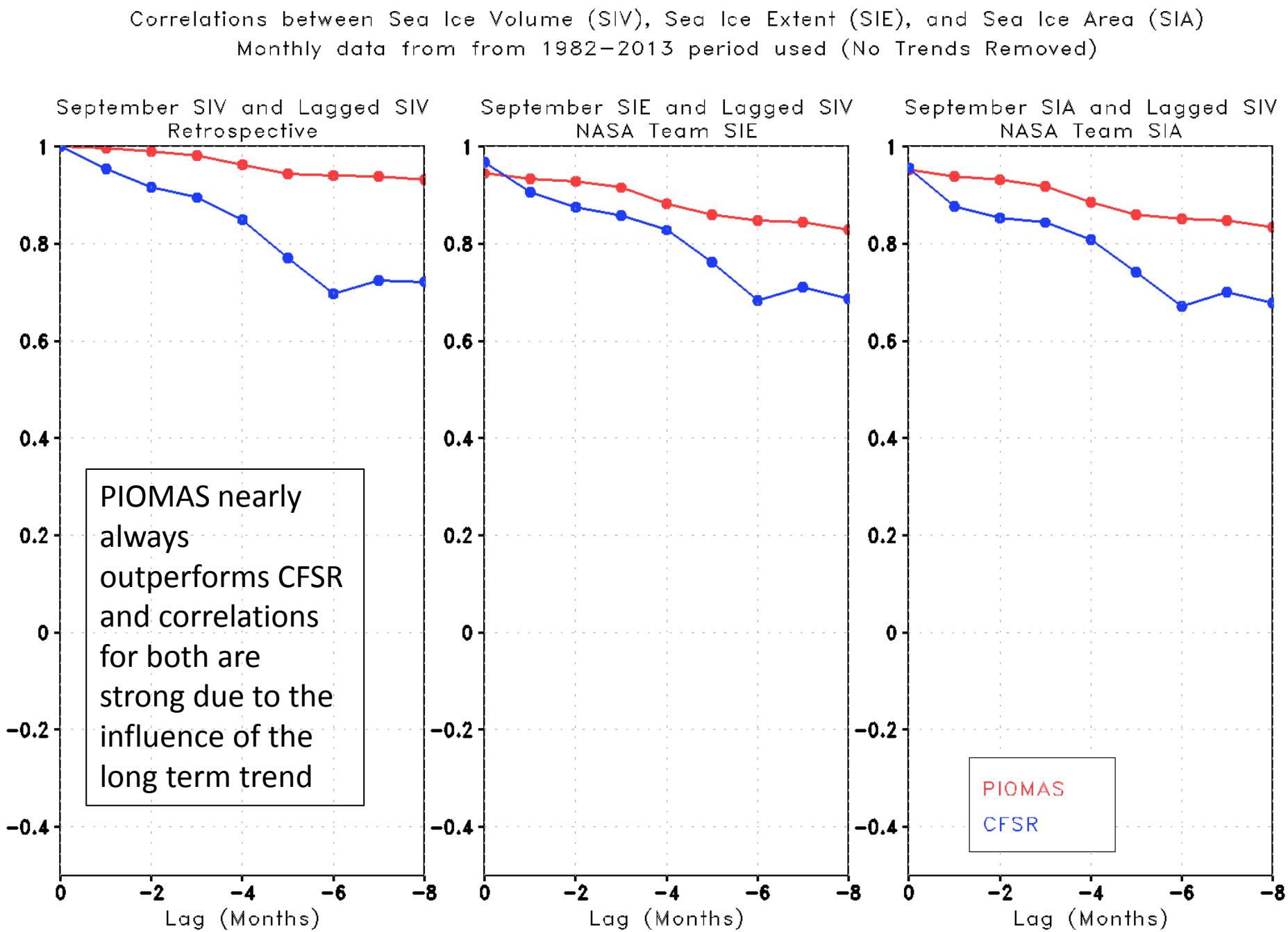
The Polar Hole

- NASA Team observations do not exist in regions north of roughly 85°N Latitude due to satellite orbit inclination.
- Therefore, this region is omitted from all analyses that follow.

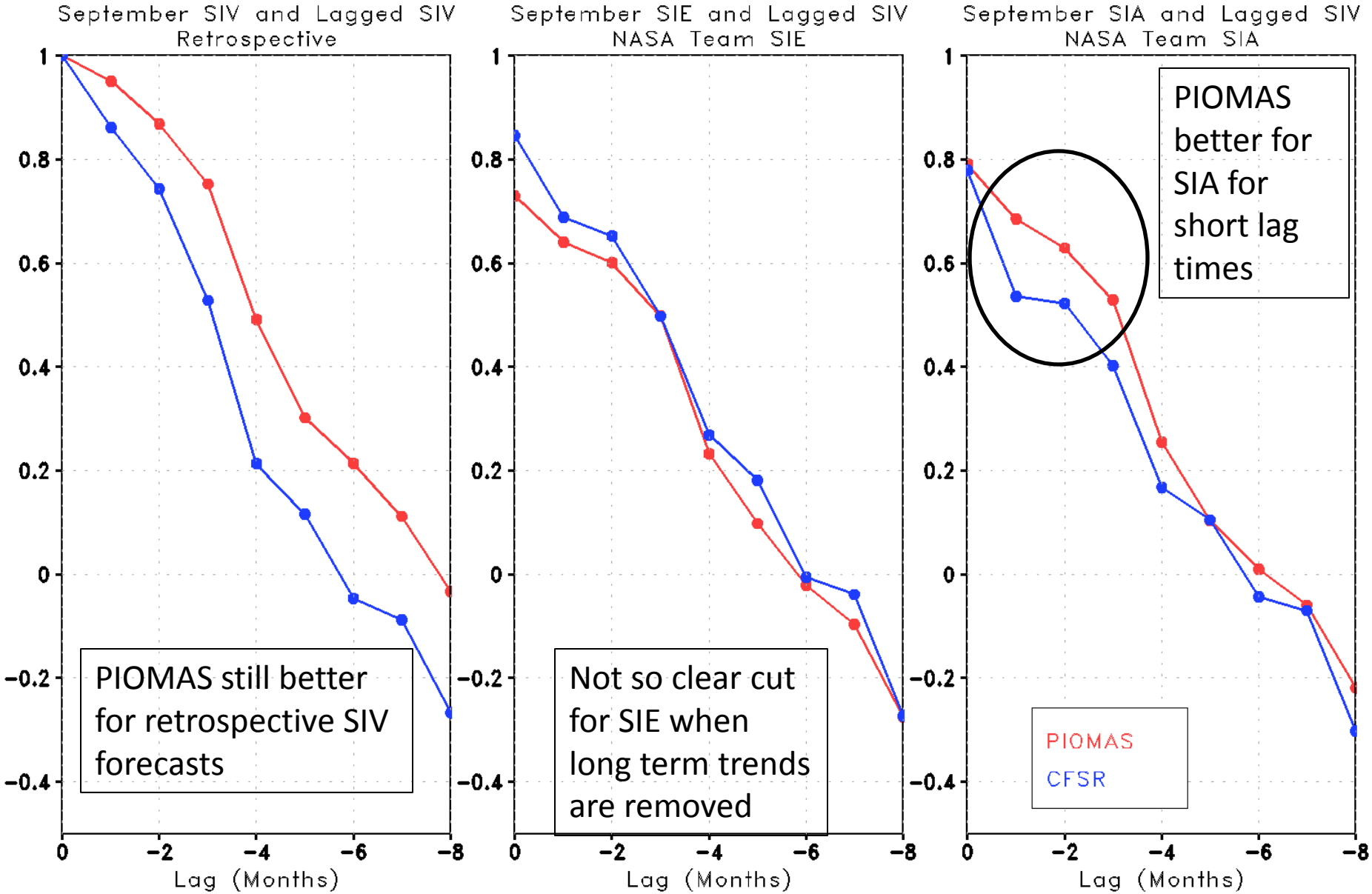


Ex. NASA Team sea ice concentration from September 1982

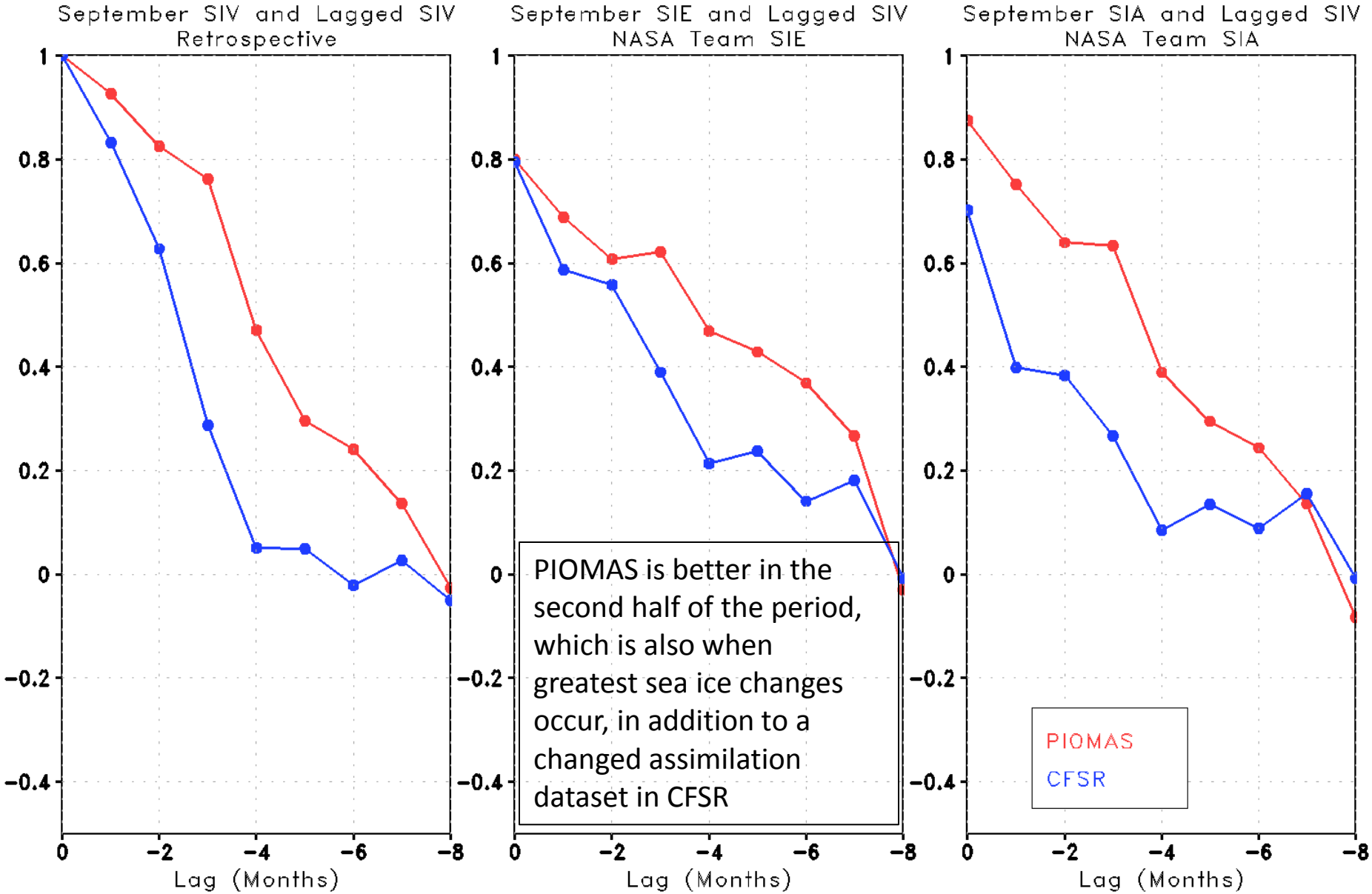
Polar Hole


Correlations between Sea Ice Volume (SIV), Sea Ice Extent (SIE), and Sea Ice Area (SIA)
Monthly data from from 1982–2013 period used (No Trends Removed)
September SIV and Lagged SIV
Retrospective
September SIE and Lagged SIV
NASA Team SIE
September SIA and Lagged SIV
NASA Team SIA
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
0
−2
−4
−6
−8
Lag (Months)
PIOMAS nearly always outperforms CFSR and correlations for both are strong due to the influence of the long term trend
PIOMAS
CFSR

Correlations between Sea Ice Volume (SIV), Sea Ice Extent (SIE), and Sea Ice Area (SIA)
Monthly data from from 1982–2013 period used (2nd Order Polynomial Trends Removed)



Correlations between Sea Ice Volume (SIV), Sea Ice Extent (SIE), and Sea Ice Area (SIA)
Monthly data from from 1998–2013 period used (2nd Order Polynomial Trends Removed)

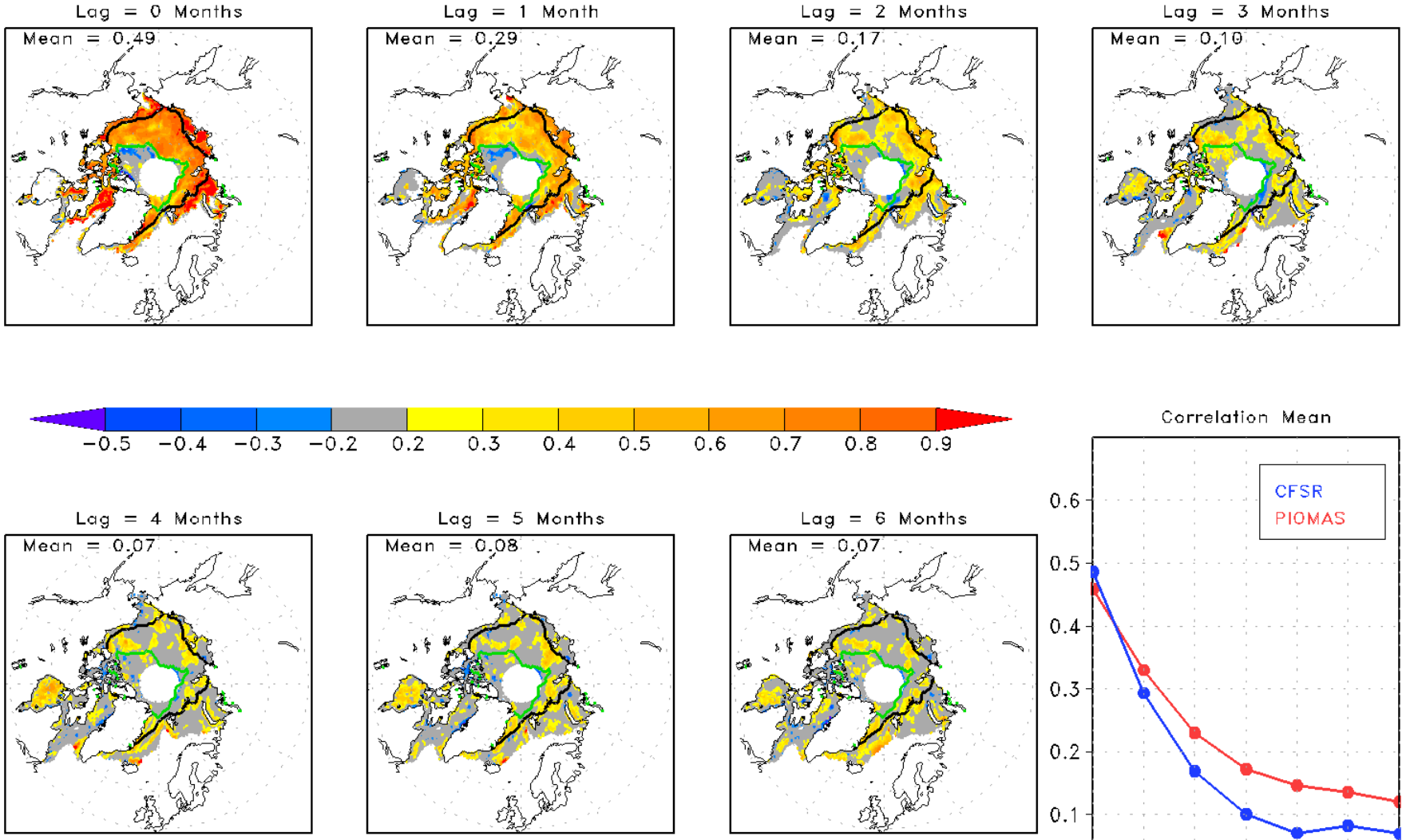


PIOMAS is better in the second half of the period, which is also when greatest sea ice changes occur, in addition to a changed assimilation dataset in CFSR

- Instead of comparing SIV, SIA, and SIE, which are global variables, look into grid point scale SIC and SIT.
- Each grid cell has it’s own time series of SIC and SIT rather than a single time series representing the entire globe.
- Using SIC and SIT allows analysis of regional patterns, which likely cannot be explained by the global patterns of SIE, SIA, and SIV.

Lagged Correlation between CFSR Grid Cell Monthly Sea Ice Thickness
and September NASA Team Sea Ice Concentration (2nd Order Polynomial Trends Removed)

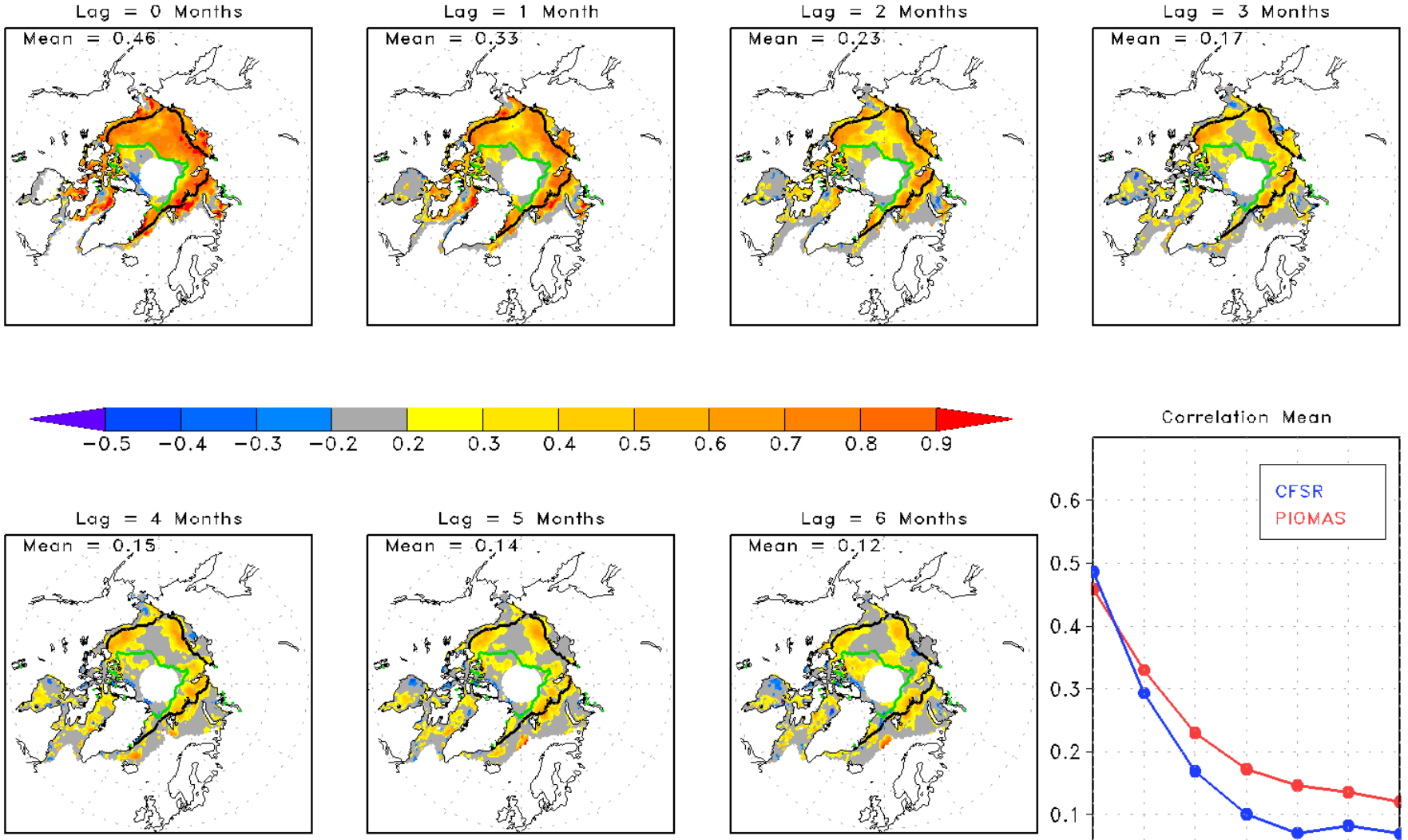
Black Line – Climatological Highest Latitude of September Sea Ice Concentration = 0.15
Polar Hole Excluded



1982-2013

Lagged Correlation between PIOMAS Grid Cell Monthly Sea Ice Thickness
and September NASA Team Sea Ice Concentration (2nd Order Polynomial Trends Removed)

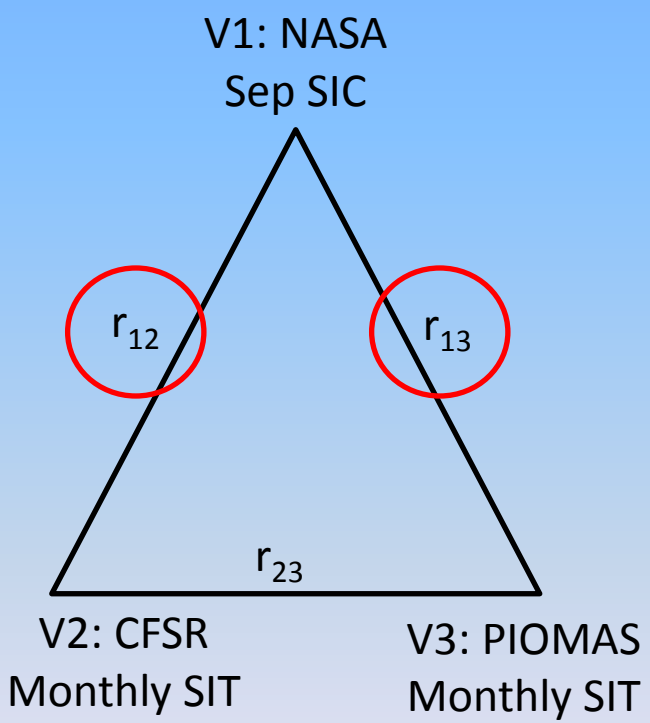
Black Line – Climatological Highest Latitude of September Sea Ice Concentration = 0.15
Polar Hole Excluded



1982-2013

Are the Changes Significant?

- Approach: Steiger's Z Test for dependent correlations (*Steiger*, 1980)



$$z(r) = 0.5 * \ln \frac{1+r}{1-r} \qquad rm^2 = \frac{(r_{12})^2 + (r_{13})^2}{2}$$

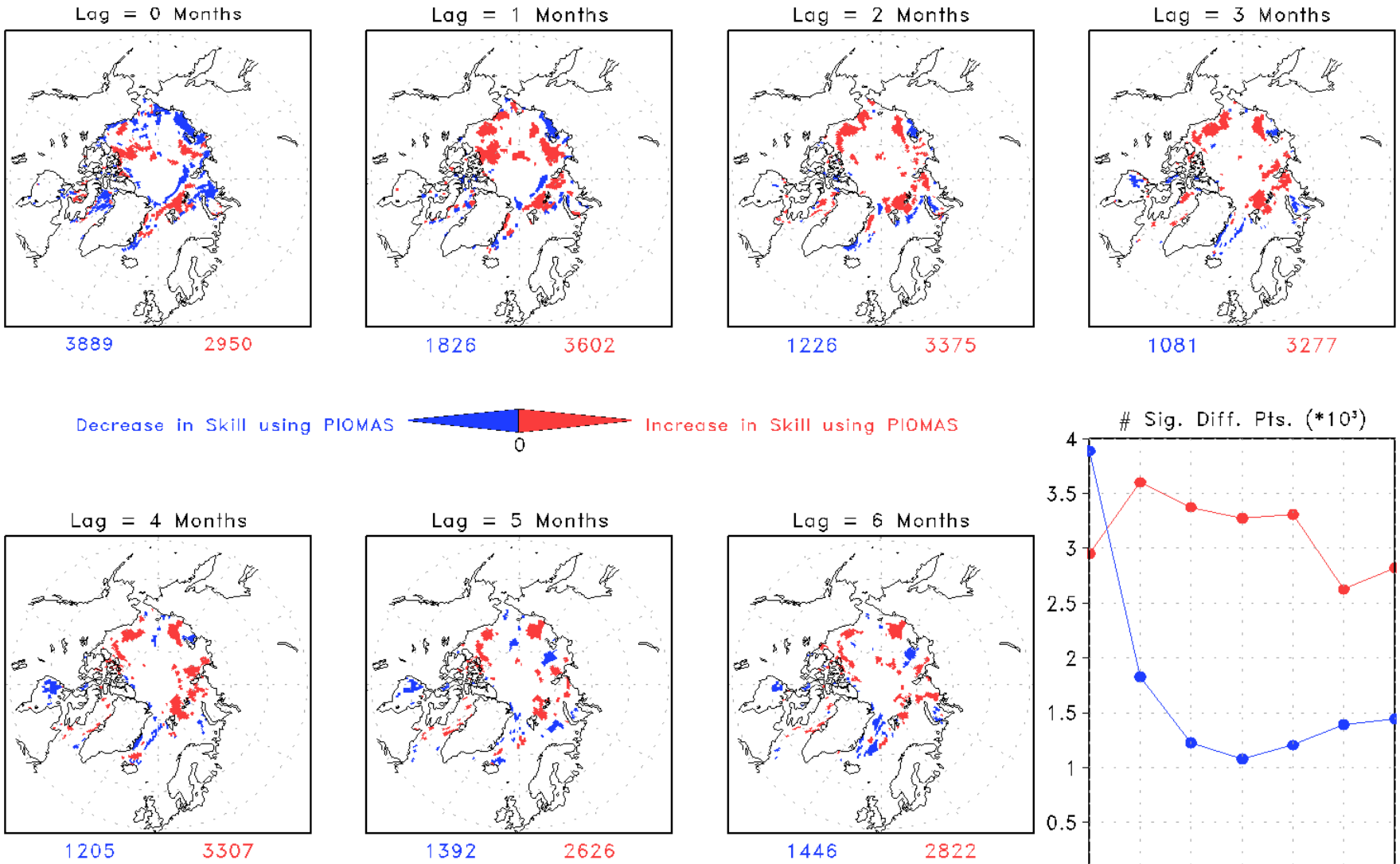
$$f = \frac{1 - r_{23}}{2 * [1 - rm^2]} \qquad h = \frac{1 - [f * rm^2]}{1 - rm^2}$$

$$Z = (z_{13} - z_{12}) \sqrt{\frac{N-3}{2 * [1 - r_{23}] * h}}$$

N = # of points, so for 1982-2013, N=32

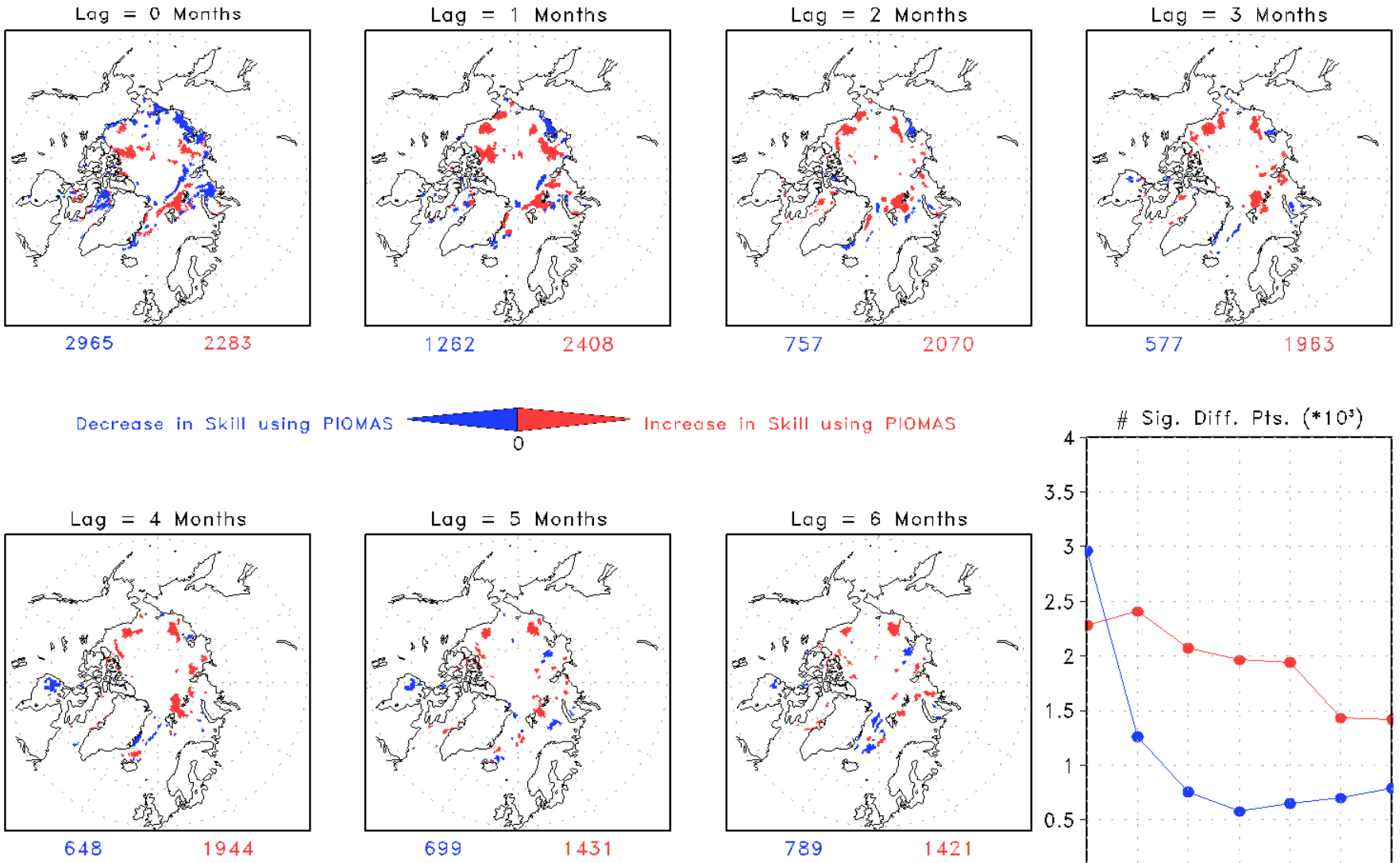
If |Z| ≥ 1.28: Significant at 80% Confidence (2 Tailed)
If |Z| ≥ 1.65: Significant at 90% Confidence (2 Tailed)
If |Z| ≥ 1.96: Significant at 95% Confidence (2 Tailed)

Regions of Significant Correlation Differences between CFSR and PIOMAS
Steiger's Z Significance Test for Dependent Variables, 80% Confidence



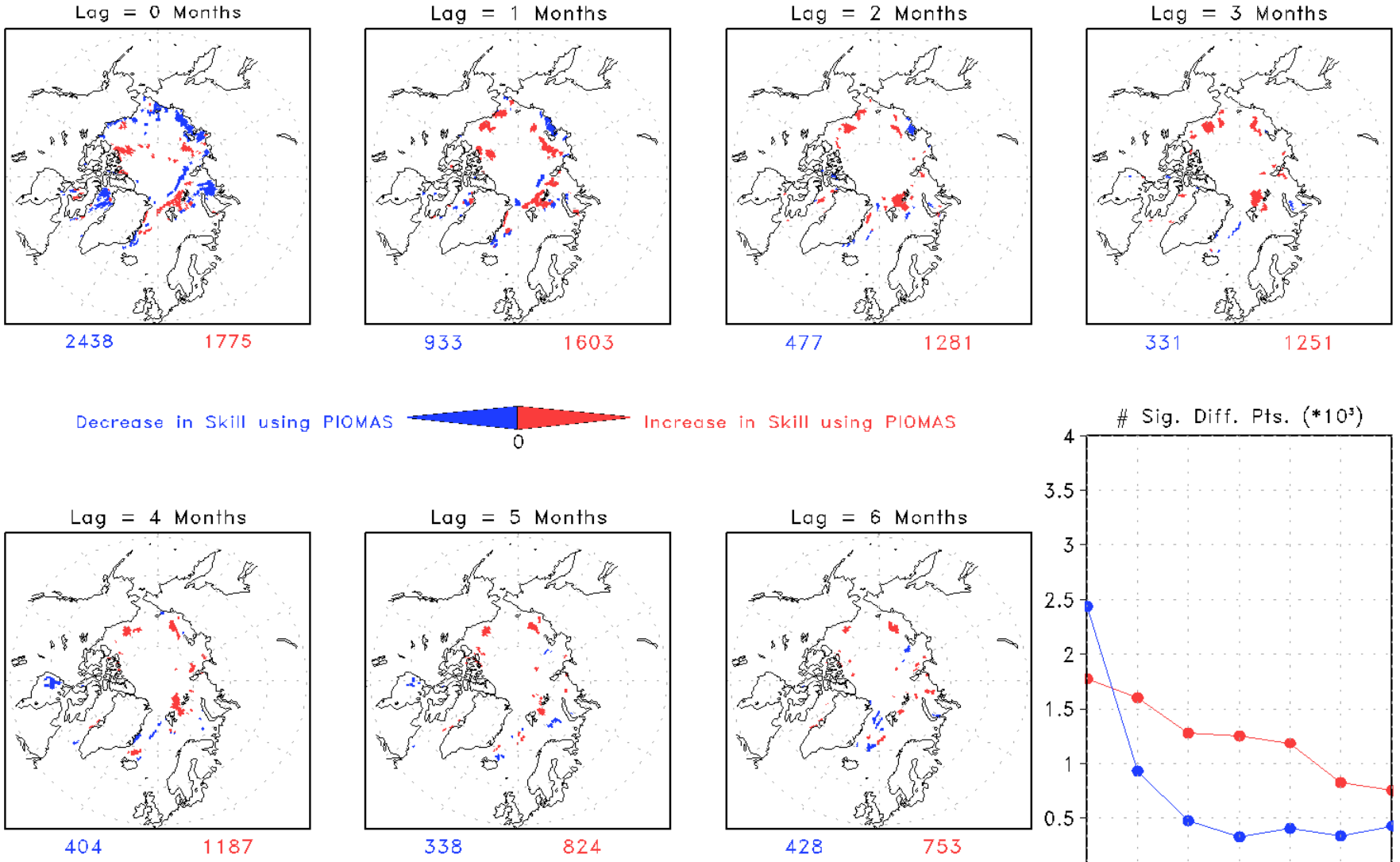
1982-2013

Regions of Significant Correlation Differences between CFSR and PIOMAS
Steiger's Z Significance Test for Dependent Variables, 90% Confidence



1982-2013

Regions of Significant Correlation Differences between CFSR and PIOMAS
Steiger's Z Significance Test for Dependent Variables, 95% Confidence



1982-2013

Conclusions

- When long term trends are not removed, PIOMAS SIV is a better predictor of SIE and SIA than CFSR SIV
- Little to no improvements resulted from using SIV to predict September SIE and SIA if trends are removed, although improvements were seen if only the second half of the period was considered corresponding with different assimilated sea ice data in CFSR
- However, more significant improvements from PIOMAS were seen when individual grid points were looked at (SIT/SIC). The number of points with significant improvements outnumbered points with significant decreases in skill in all lag months except the initial month for 80%, 90%, and 95% confidence intervals.
- Most significant changes appear focused along the edge or the Arctic, rather than the interior.
- Results presented here justify the use of PIOMAS sea ice thickness data to initialize CFSv2 in hopes of improving sea ice predictions

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