Influence of winds on Ross Sea ice cover: Seasonal lags and explained trends

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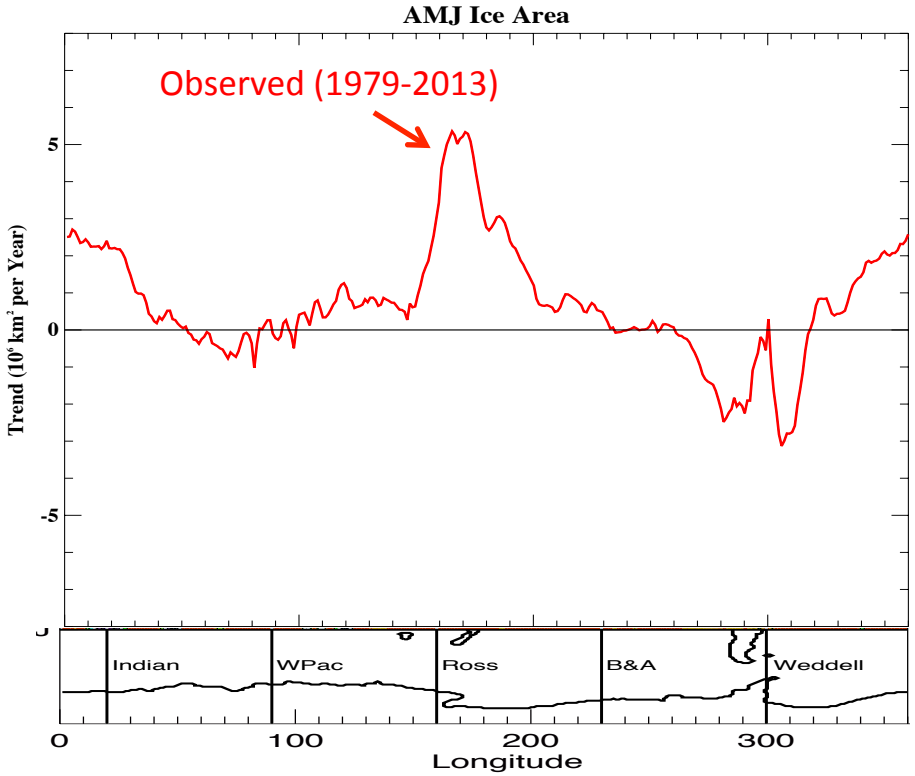
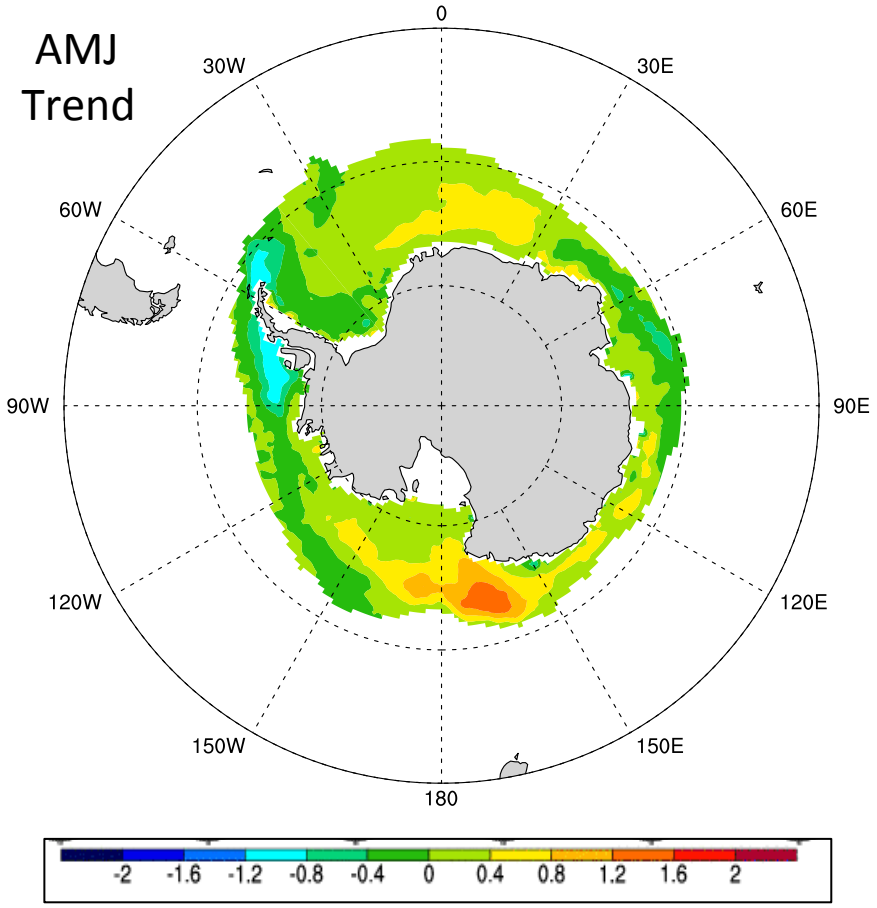
Trends in Antarctic Sea Ice

Trends in AMJ Ice Area with Longitude



AMJ Trend

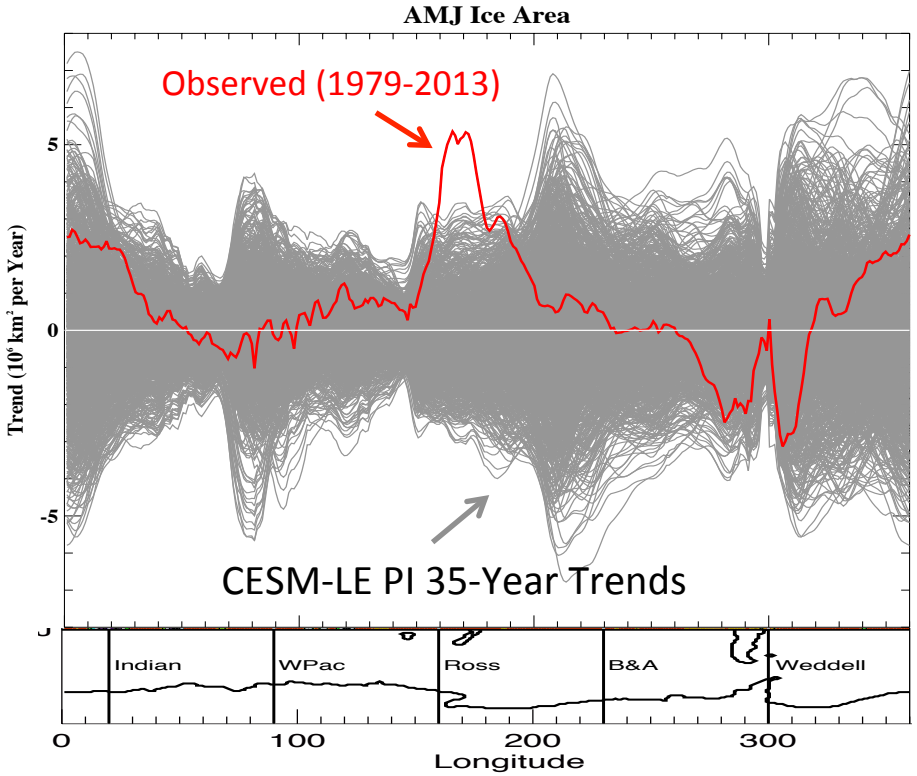


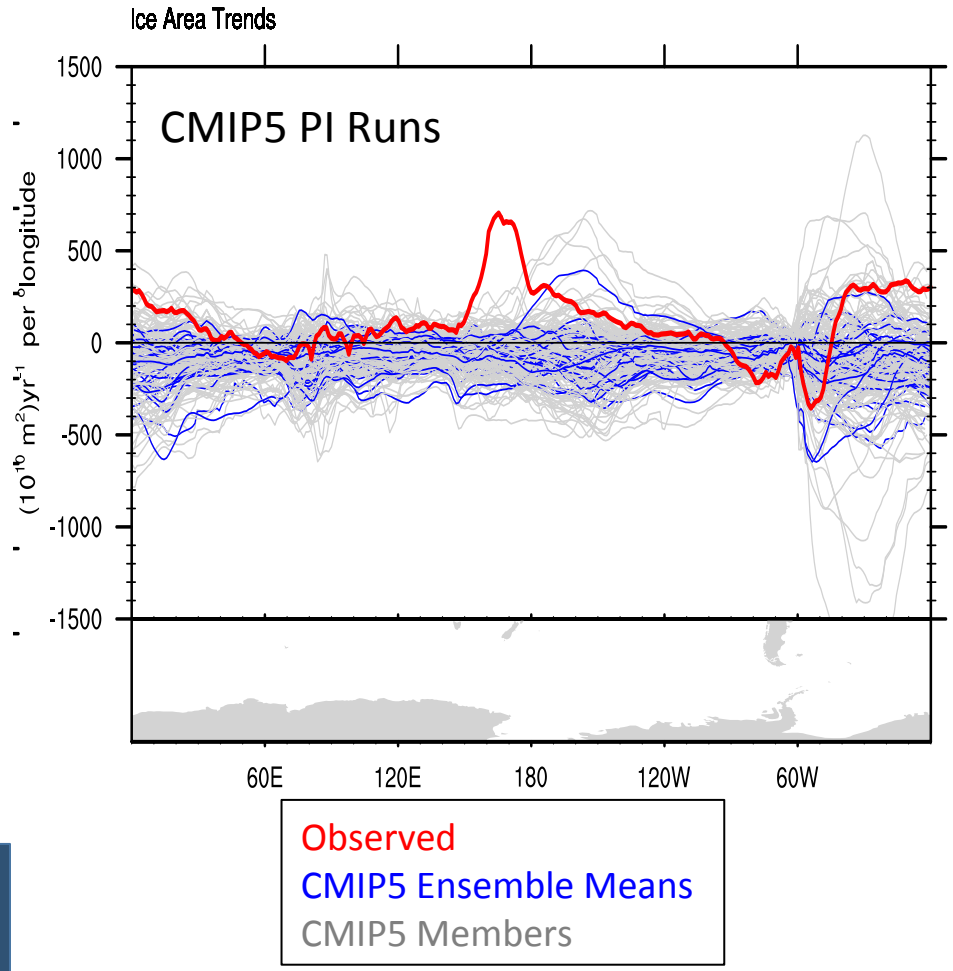
Observed Sea Ice Trends

Largest increases occur in the ice advance season (austral fall) in the Ross Sea. Accounts for >60% of total ice area trend.

Trends in Antarctic Sea Ice

Trends in AMJ Ice Area with Longitude





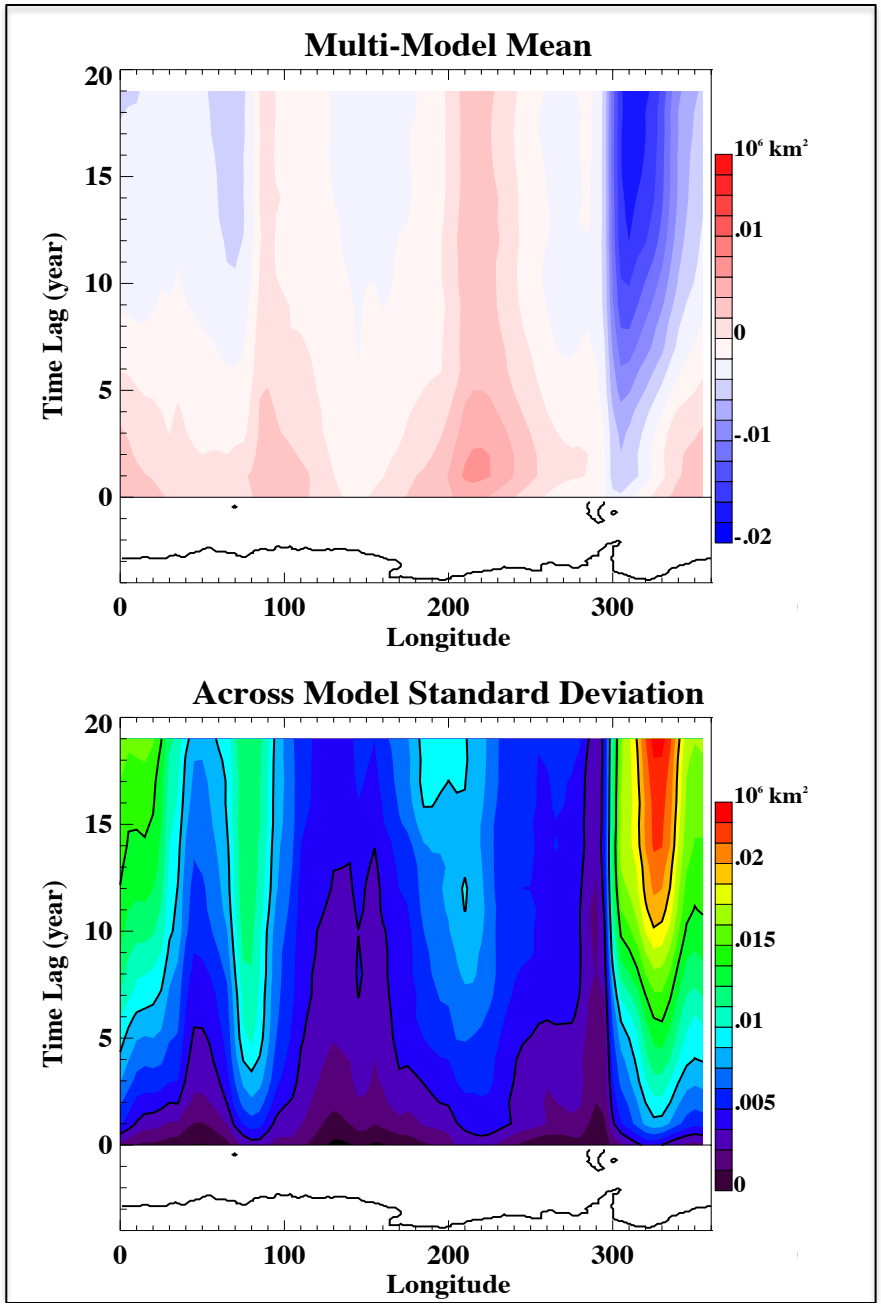
Regionally –

- Observed ice area trends are within PI control run
- Except in the western Ross Sea where large ice increases are observed

For Ross Sea increases –

- Could be model biases

What is the role of SAM (and potential ozone links)?



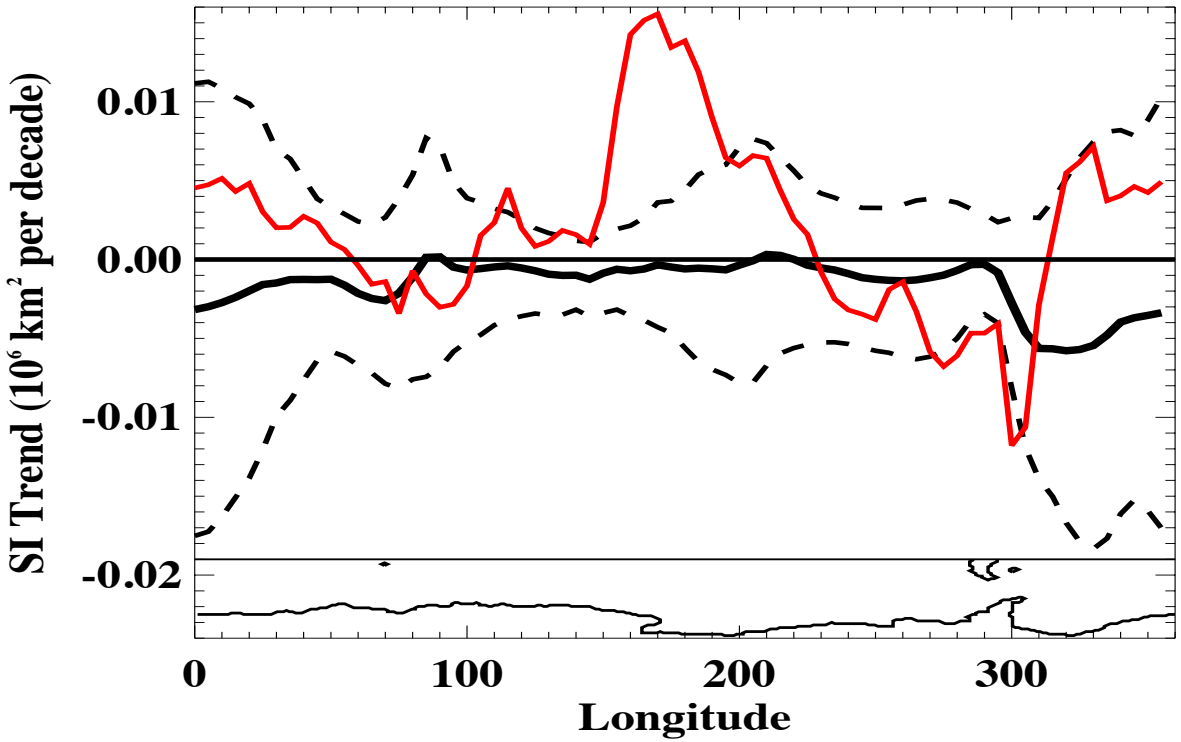
- Using the CMIP5 PI runs, we obtain the modeled response function of longitude-dependent sea ice to SAM variations

$$SI(t) \approx \sum_{i=0}^{I} G(\tau_i) SAM(t - \tau_i) \Delta\tau + \varepsilon$$

<u>For a SAM step increase</u>

- On short timescales, the multi-model mean exhibits increased sea ice except in the Weddell Sea.
- This becomes ice loss on longer timescales, which is particularly large in the Weddell Sea
- Models differ considerably in response

What is the role of SAM (and potential ozone links)?

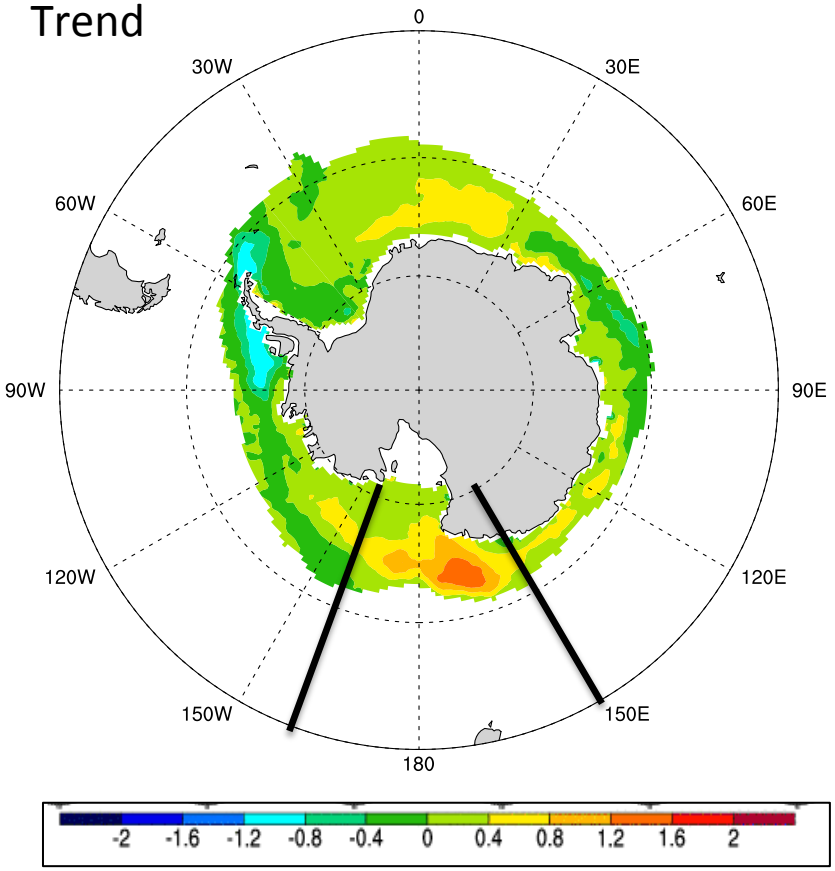


Observed trend

Trend explained by SAM using modeled CMIP5 response function
(Solid = multi-model mean
Dash = Across-model standard deviation)

- If we apply the modeled response functions to the observed timeseries of SAM variations, we obtain ice trends that are attributable to the SAM (based on models)
- Models suggest that variations in SAM can not explain the western Ross Sea ice trends

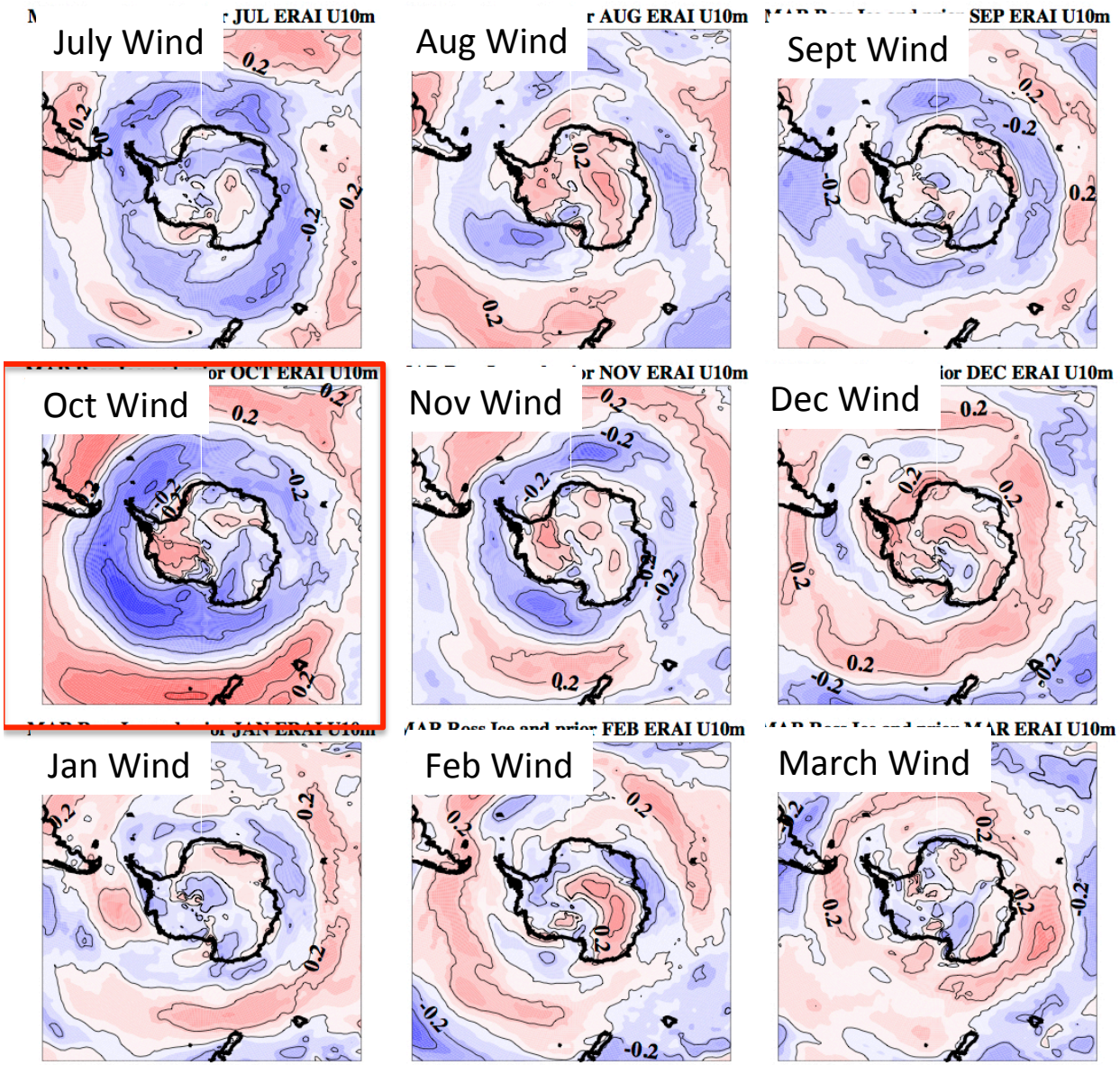
AMJ
Trend



What drives variations in Ross Sea ice cover during Fall ice advance?

Does this provide information on the trends in this region?

Correlation of Ross Sea Ice in March with Zonal Winds in prior Months



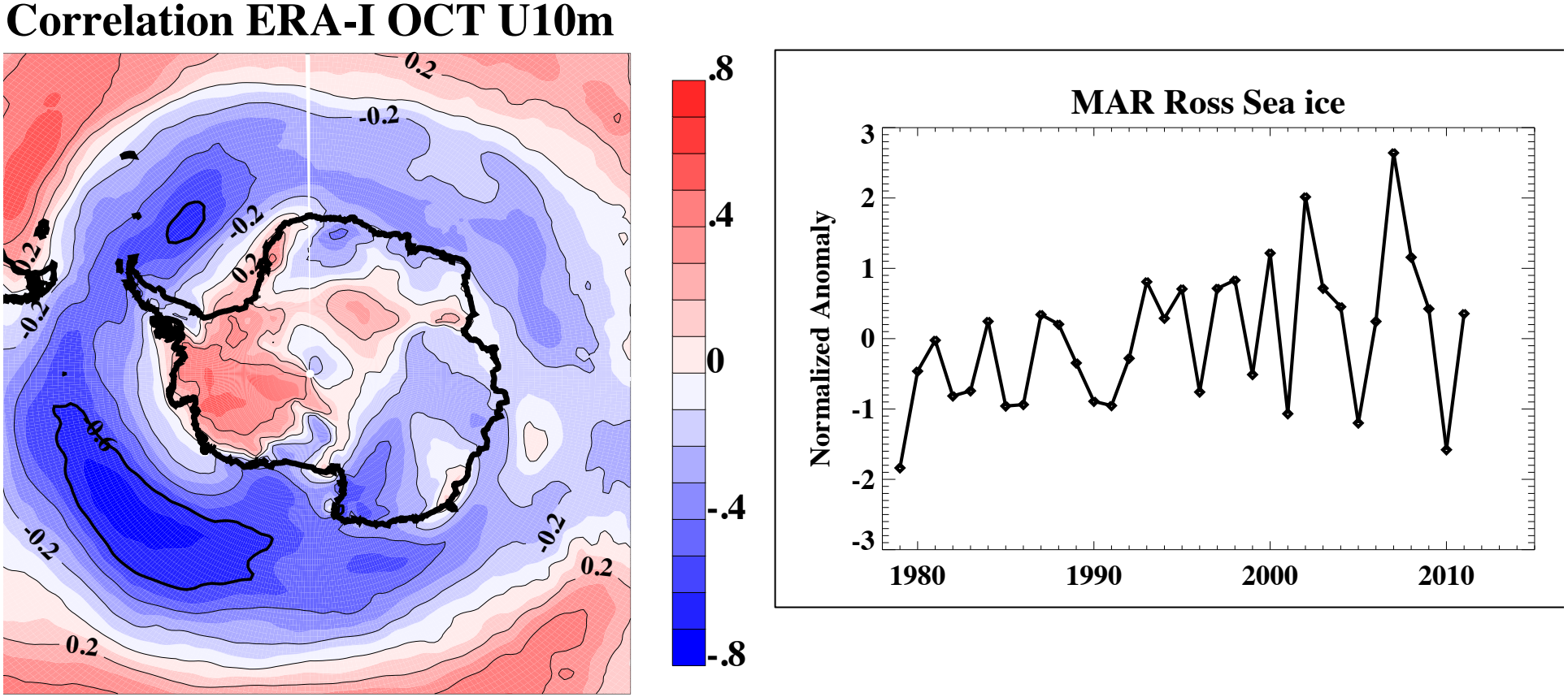
Previous studies suggest wind forcing is key

For autumn Ross Sea ice cover, largest correlations are with:

- Zonal Winds
- In the previous October

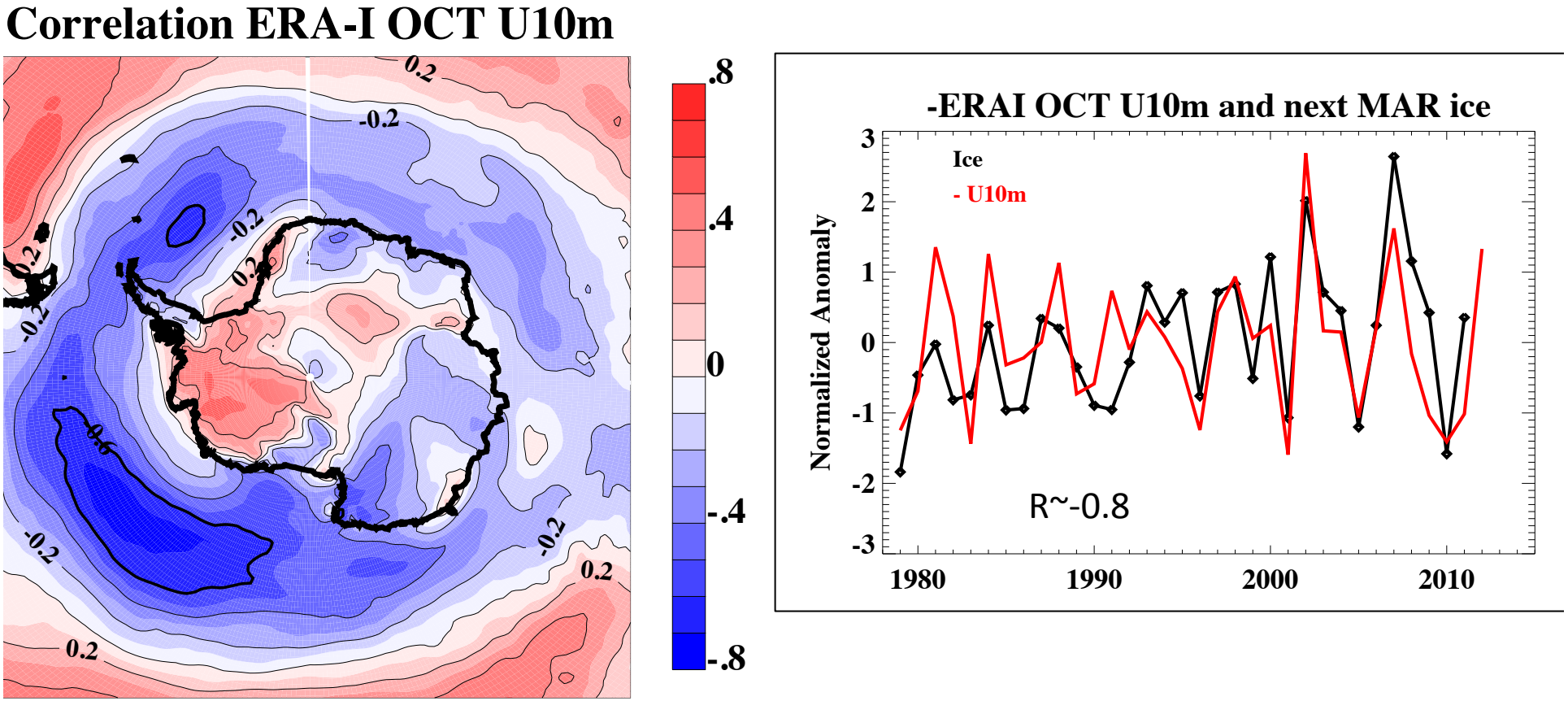
Using ERA-I Winds

Ross Sea Ice in March/April is highly related to zonal winds in previous October



Weaker October zonal winds related to increased Ross Sea Ice area in March, April, May

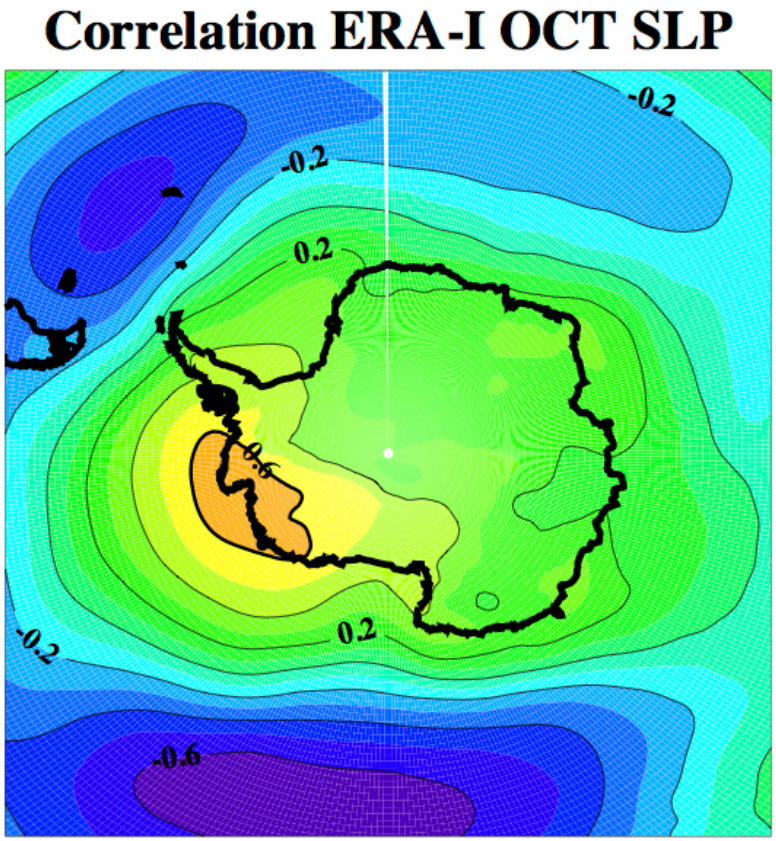
Ross Sea Ice in March/April is highly related to zonal winds in previous October



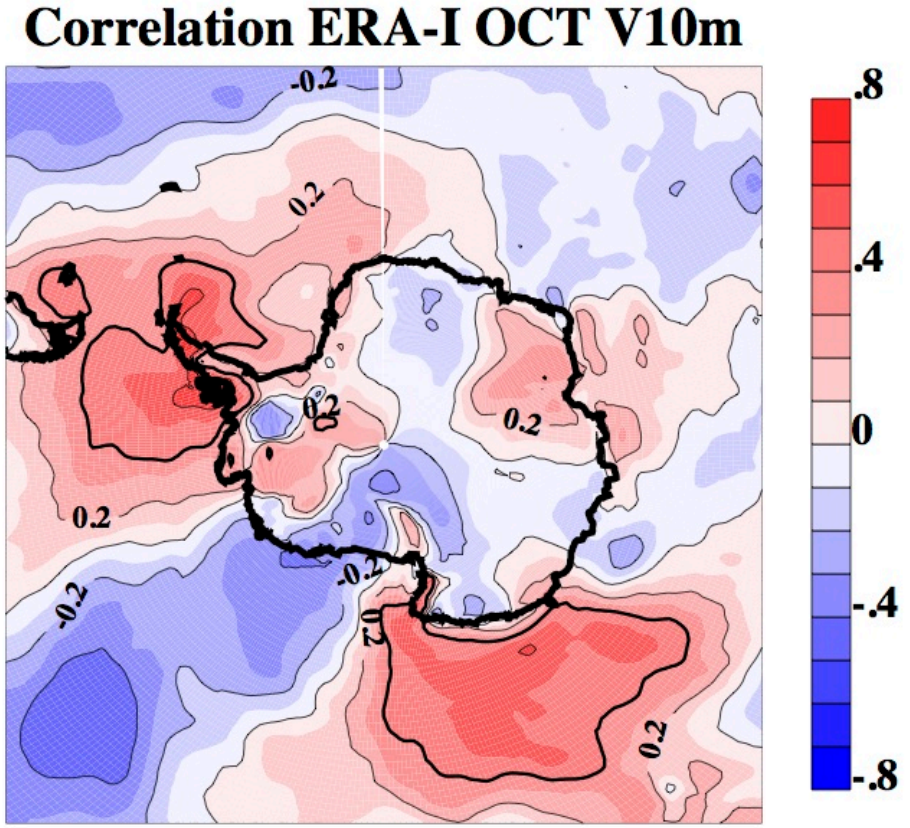
The wind relationship is robust to different reanalysis products

October zonal wind anomalies are:

- Associated with large-scale circulation variability (ASL variability – R~-0.8; Deeper ASL -> less ice)
- Consistent with relationships between Ross ice and SLP/ Meridional winds



Correlation of March Ross Ice to previous Oct SLP



Correlation of March Ross Ice to previous Oct Meridional Winds

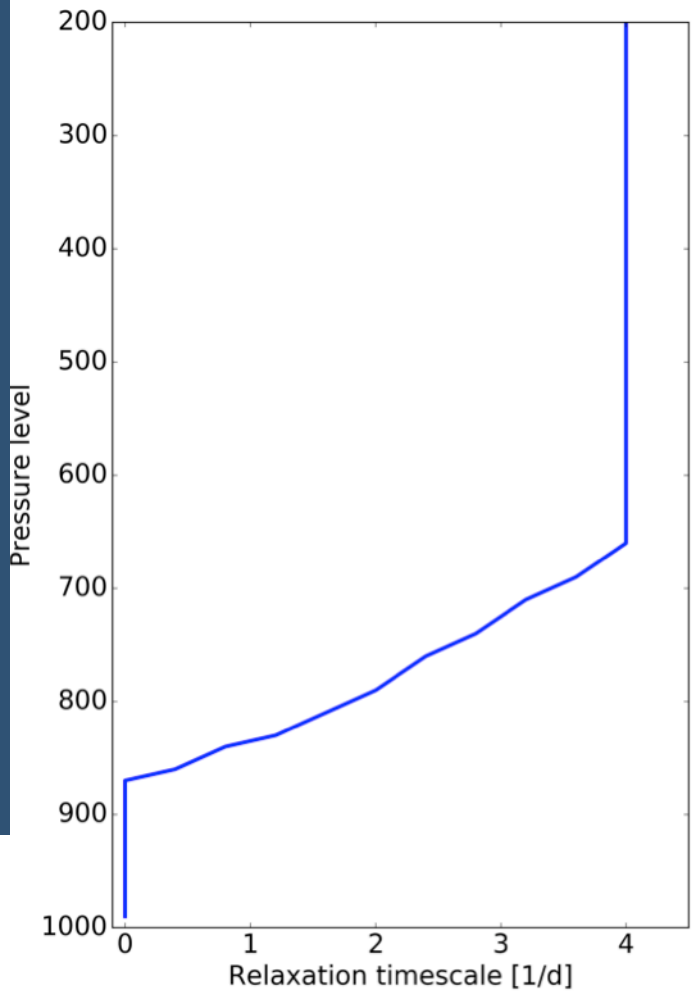
October winds and March Ross Sea ice: mechanisms

GCM "nudging" (~SD) simulation:

CESM fully coupled model

Winds and temperature in the atmosphere are "nudged" to MERRA conditions for 1979-2005:

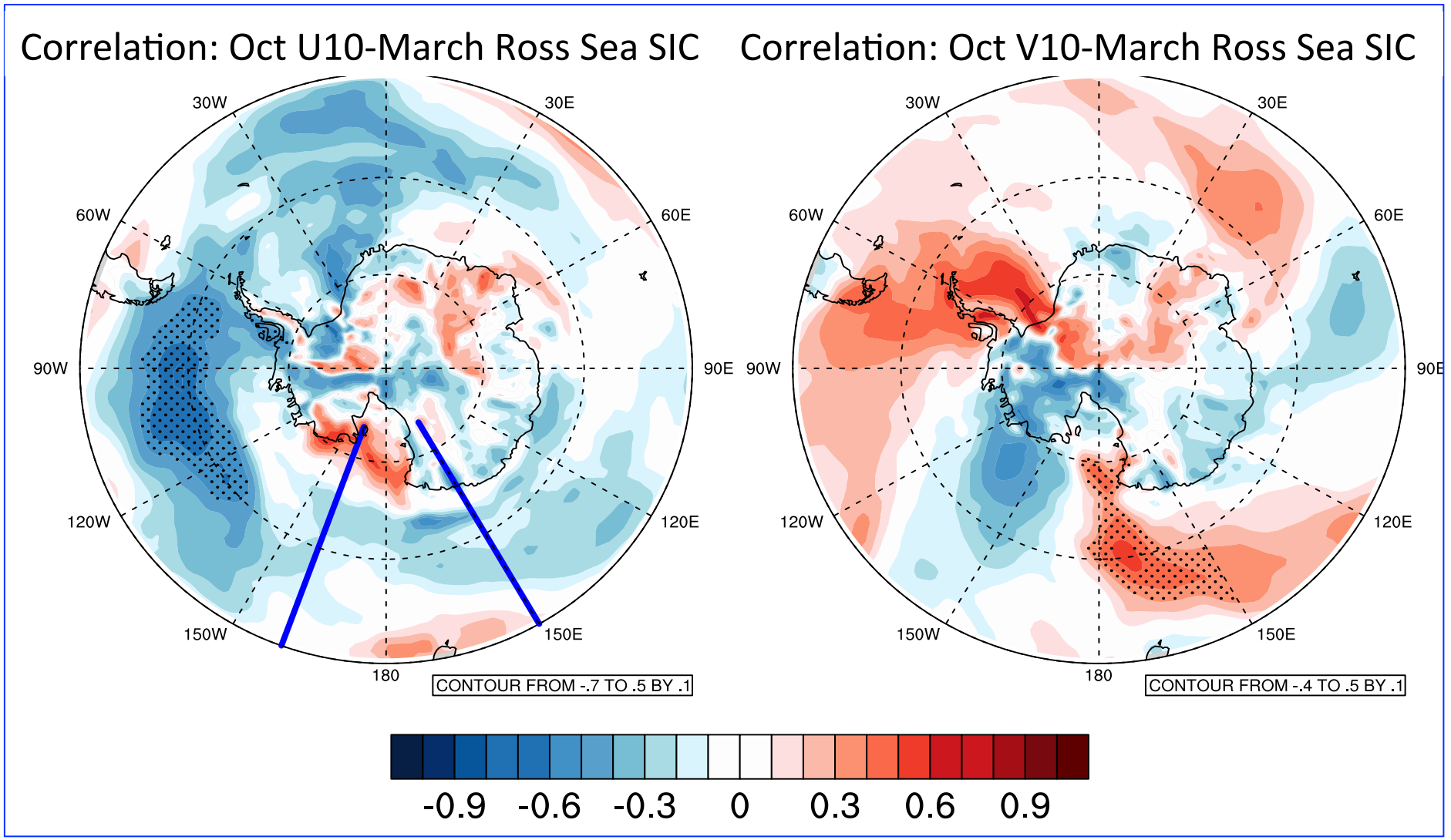
- Surface atmosphere free to respond
- Higher levels nudged at 4x/day timescale
- Intermediate levels relaxation timescale linear from 0-4/day



Thanks to Matt Long, NCAR for performing and making available these runs!

Mechanism (bmerra run, 1979-2005)

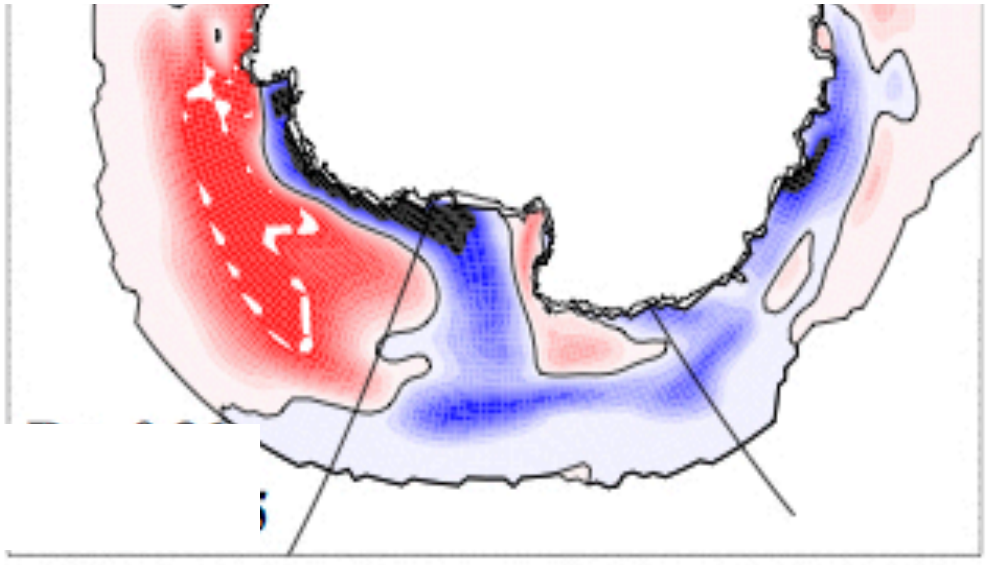
October zonal (left) and meridional (right) winds show similar correlations to March Ross Sea ice as in observations



Mechanism – bmerra run

Stronger **Oct** U10 (southward Oct V) related to:

- Increased dynamical ice loss in Ross Sea region in October/November
- Thinner ice and earlier melt out in spring/summer

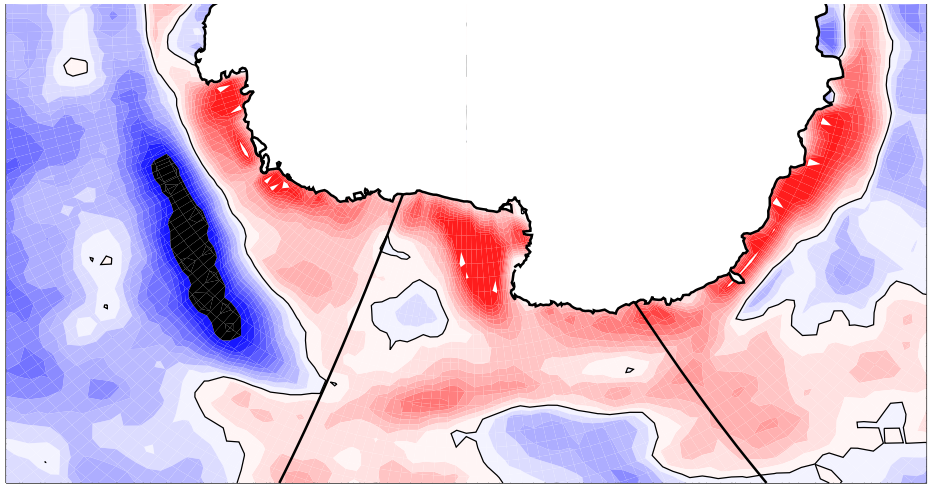


Regression of Oct U10 and
November ice thickness

Mechanism – bmerra run

Stronger **Oct** U10 (southward Oct V) related to:

- Increased dynamical ice loss in Ross Sea region in October/November
- Thinner ice and earlier melt out in spring/summer
- Enhanced shortwave absorption and ocean warming

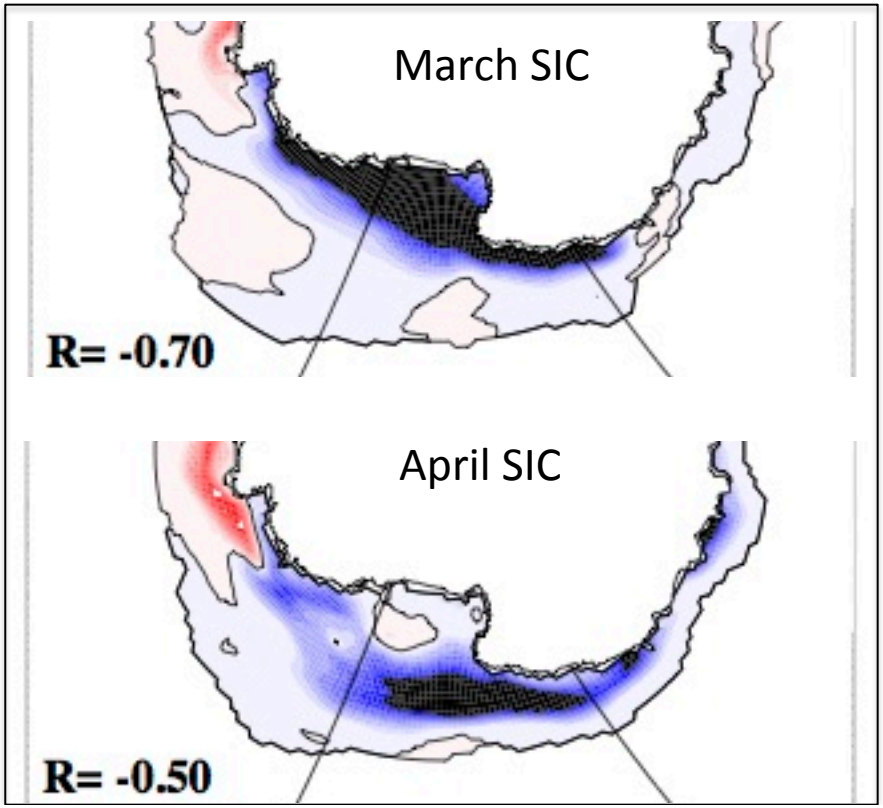


Regression of Oct U10 and
December net SW

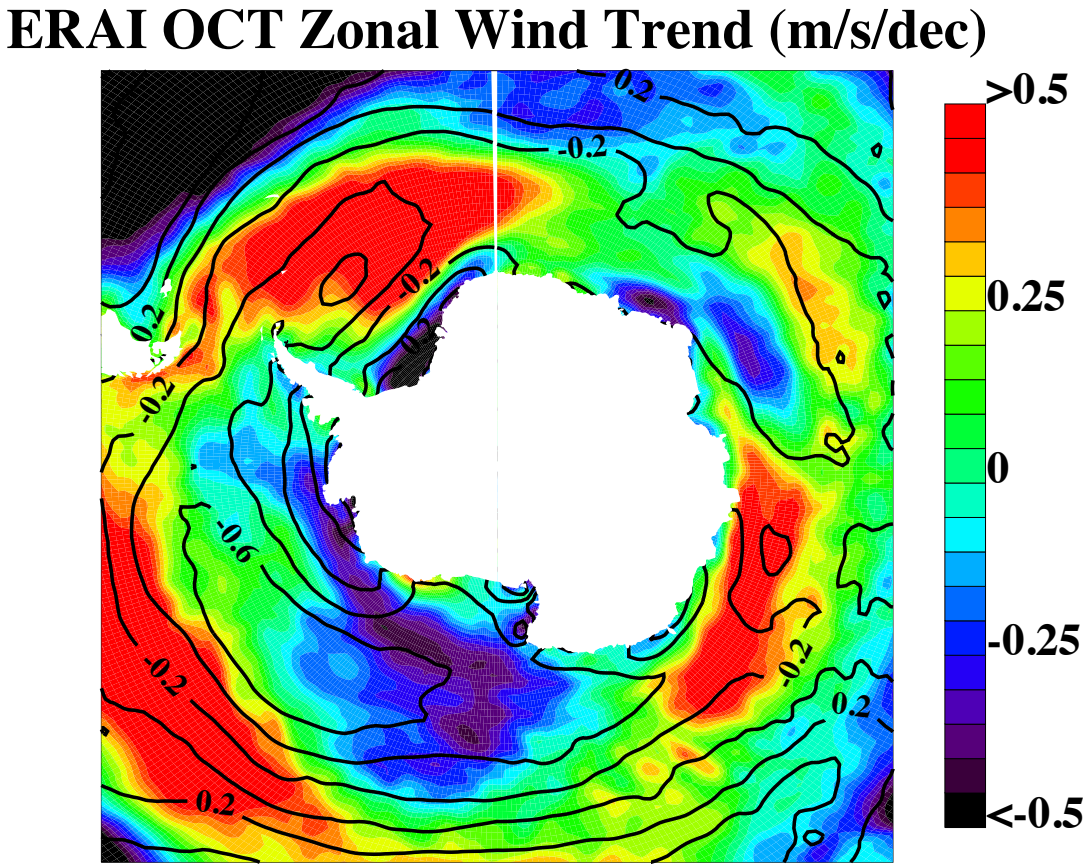
Mechanism – bmerra run

Stronger **Oct** U10 (southward Oct V) related to:

- Increased dynamical ice loss in Ross Sea region in October/November
- Thinner ice and earlier melt out in spring/summer
- Enhanced shortwave absorption and ocean warming
- Delayed melt onset and reduced ice cover in March and April



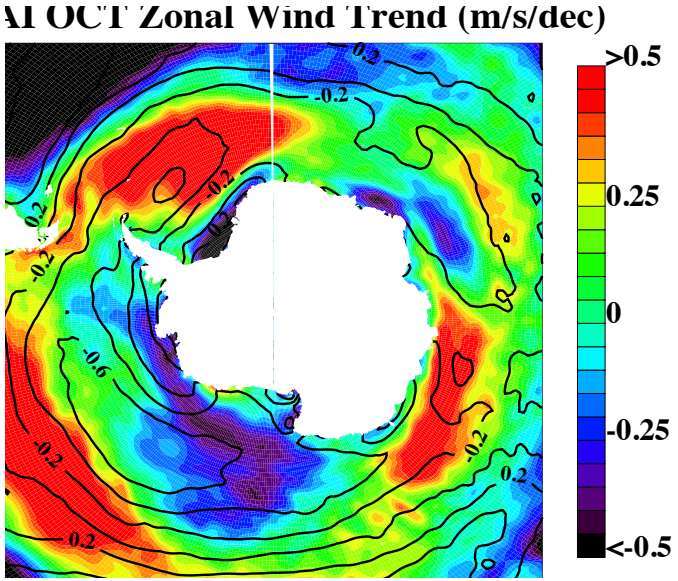
Can October winds explain fall Ross Ice trends?

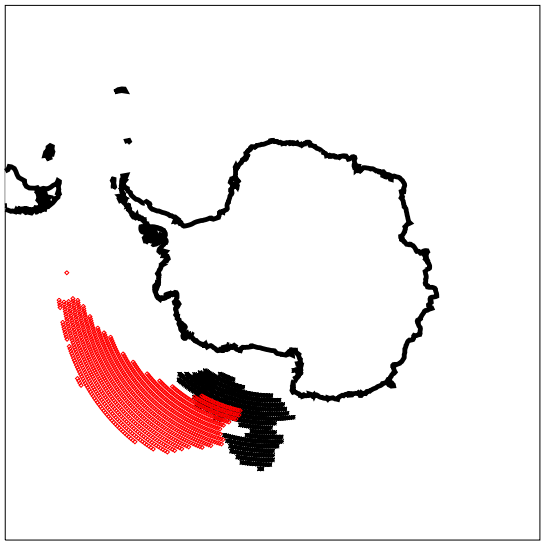


ERA-I Oct wind trend 1979-2012 in color;
Correlation with ice in lined contours

Region of highest correlation is not region with a large trend

How much of Ross fall ice trend might be explained by interannual relationship to Oct winds ?

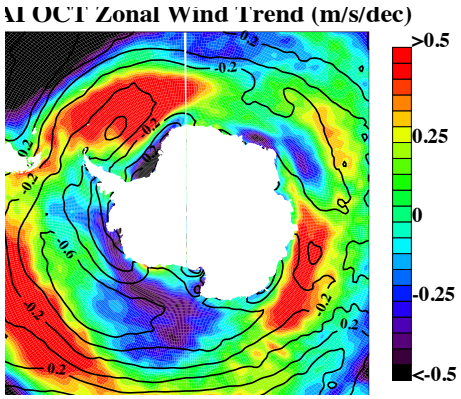


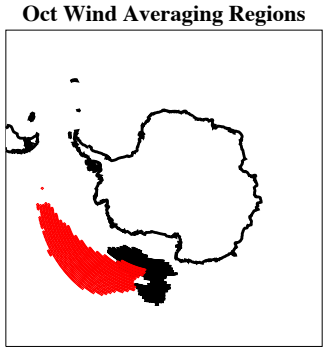


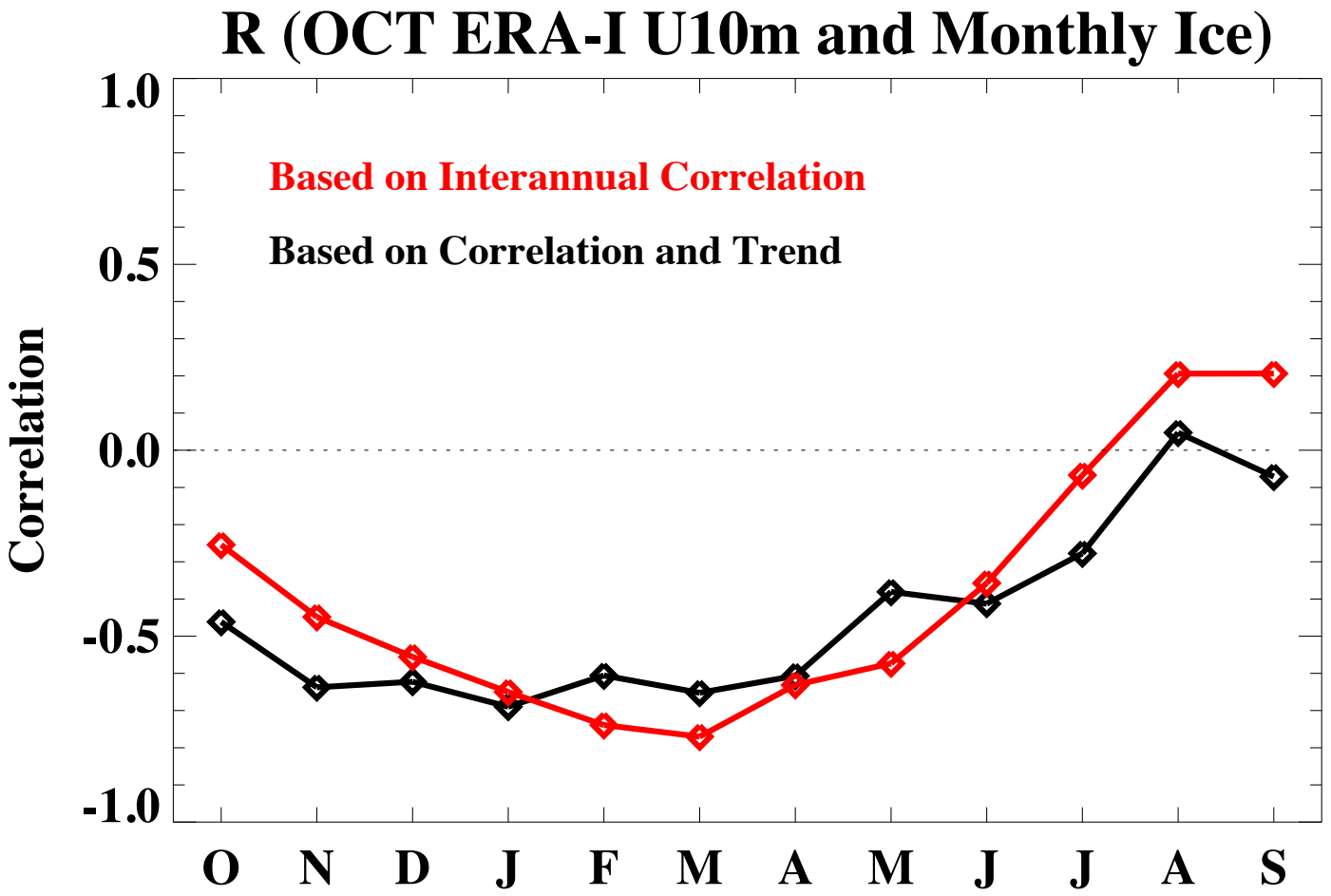
Assess regional averages of Oct winds for:

- Region with high correlation to interannual sea ice anomalies (<-.6) – red region
- Region with negative wind trend and relatively high ice correlation (<-.4)

How much of Ross fall ice trend might be explained by interannual relationship to Oct winds ?

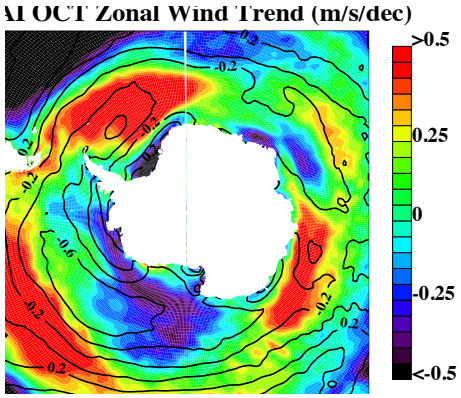


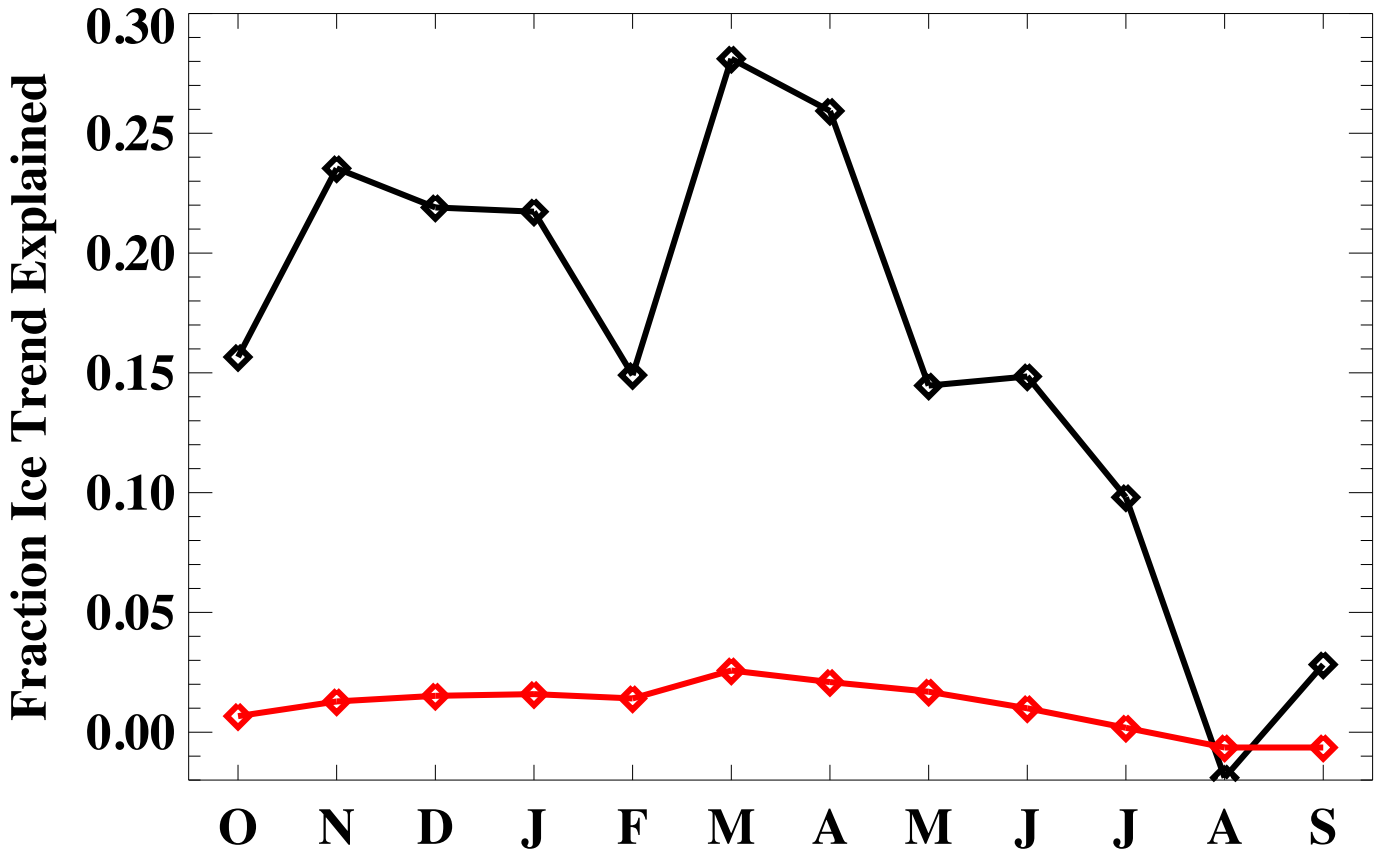




Oct zonal winds in both regions are highly correlated to Ross Sea ice area in following months

How much of Ross fall ice trend might be explained by interannual relationship to Oct winds ?





Based on regression analysis, trends in the regional October zonal winds could explain 25-30% of Ross ice area trend in March and April

Final Thoughts

- Observed fall sea ice trends in the Ross Sea are outside of simulated natural variability
- These trends are also not attributable to observed SAM trends (if we believe the model's SAM response)
- Interannual variations in fall Ross Sea ice cover are strongly related to the previous October winds
- This might help to explain a fraction of the observed increases in sea ice in this region