How do winds influence Sea Ice?

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EGU2020 Session ASS2.9/CR7

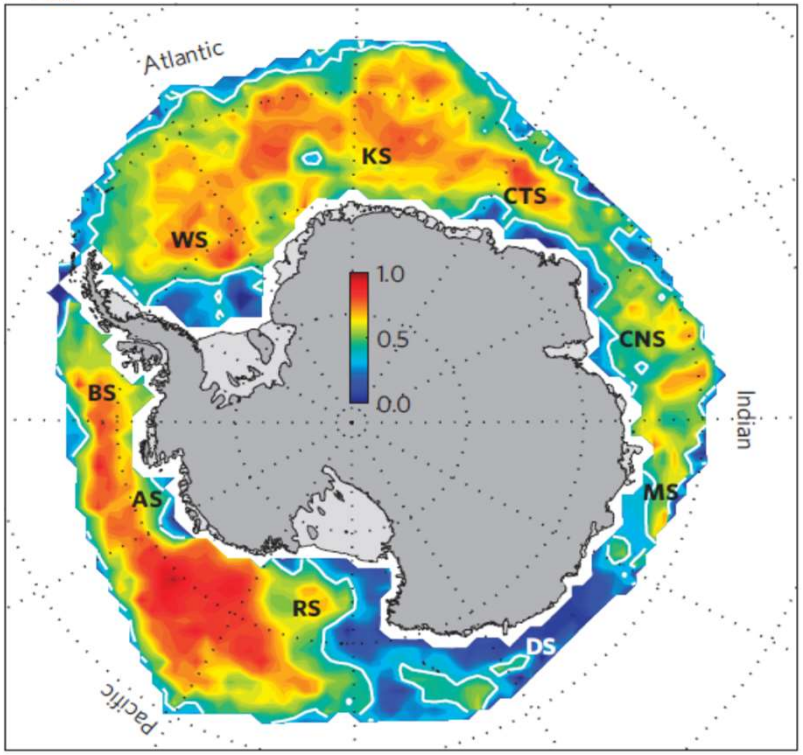
Presentation Outline

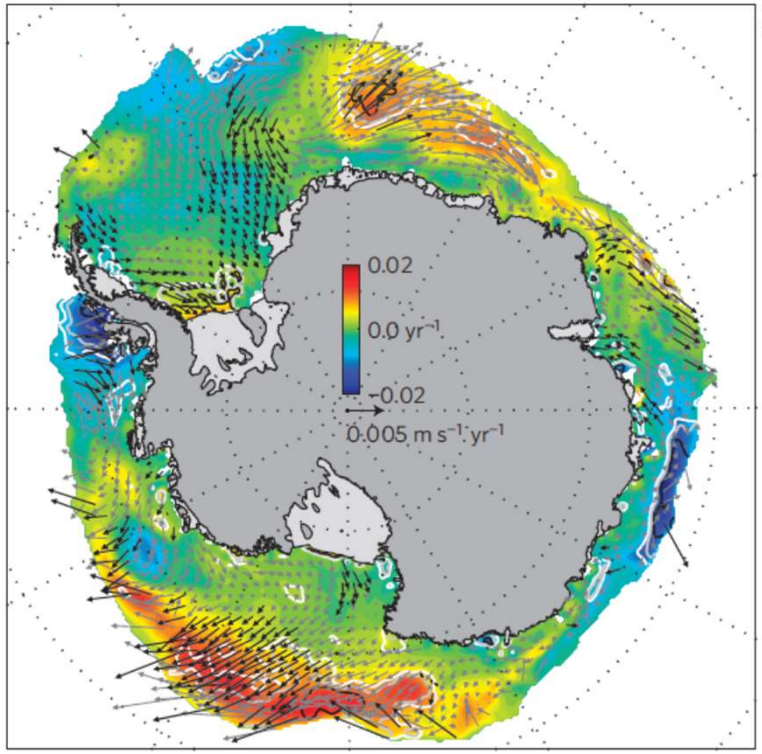
This talk describes progress towards understanding how winds influence sea ice and whether the relationship between sea ice and winds is changing.

Goal 1: Quantify the relationship between sea ice variability and winds.

Goal 2: Determine whether the relationship between sea ice variability and winds is changing.

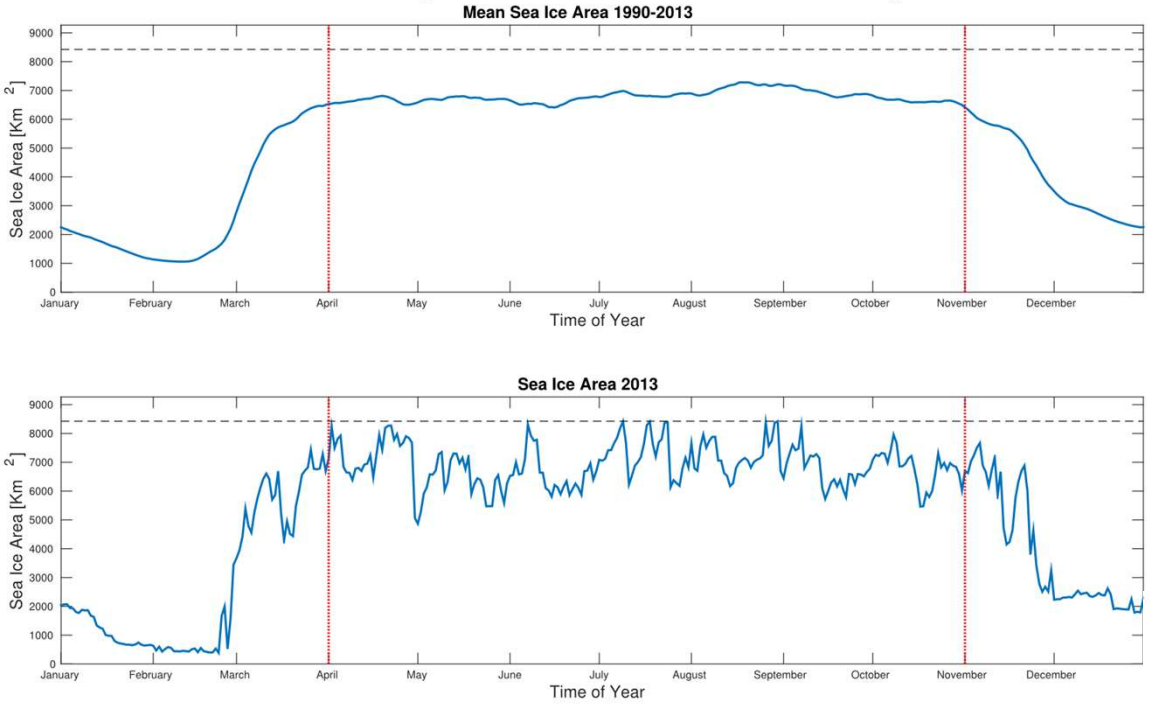
Large-scale relationships





- Correlations between sea ice drift and winds (left) shown in Holland and Kwok (2012) and corresponding relationships between sea ice drift and sea ice trends (right). **Predominantly positive relationships in highest correlation regions.**

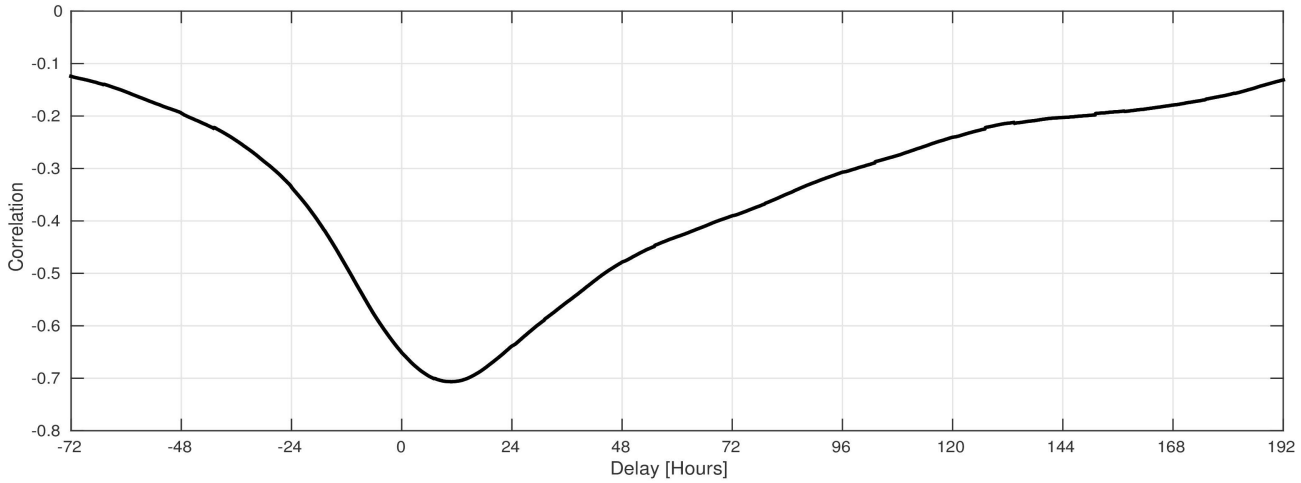
Sea Ice Area variations in the vicinity of the Ross Sea Polynya (smaller scales)



Taken from Dale et al. (2017)

- The Figures above show the mean sea ice area in the vicinity of the Ross Sea Polynya averaged between 1990 and 2013 (top) and the pattern in 2013 (bottom) from Dale et al. (2017). We examined variations in the period between 1st April and 1st November to focus on impacts in that relatively uniform period.

Relationship between Wind speed and Sea Ice Concentration in the Ross Sea Polynya (short time lagged relationships)

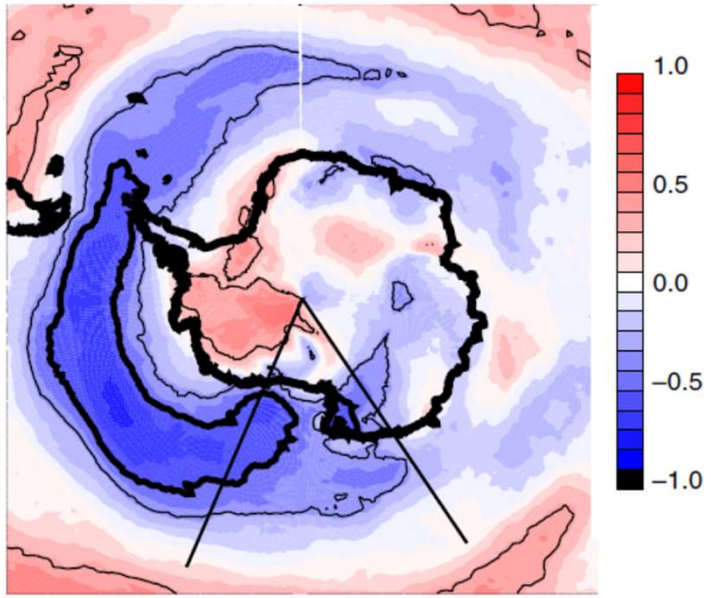


Taken from Dale et al. (2017)

- The Figure above shows the correlation coefficient between magnitude of wind vectors squared and sea ice concentration (SIC) in the vicinity of Ross Sea Polynya, with a delay applied. **Clear negative correlations in this region, though sea ice varies has a response time (time lag).**
- Lack of symmetry around minimum suggests rapid initial decrease during high wind events followed by gradual increase. This is related to the decrease being related to rapid advection and increase caused by gradual freezing.

Long time lagged relationships

- Holland et al. (2017) suggests that variability in the western Ross Sea autumn ice conditions is largely driven by springtime zonal winds in the high latitude South Pacific, with a lead-time of 5 months.
- **Enhanced zonal winds dynamically thin the ice**, allowing an earlier melt out, enhanced solar absorption, and reduced ice cover the next autumn.
- **A negative correlation between zonal winds and sea ice area at a different time scale.**
- **Note delayed impact is primarily thermodynamic.**

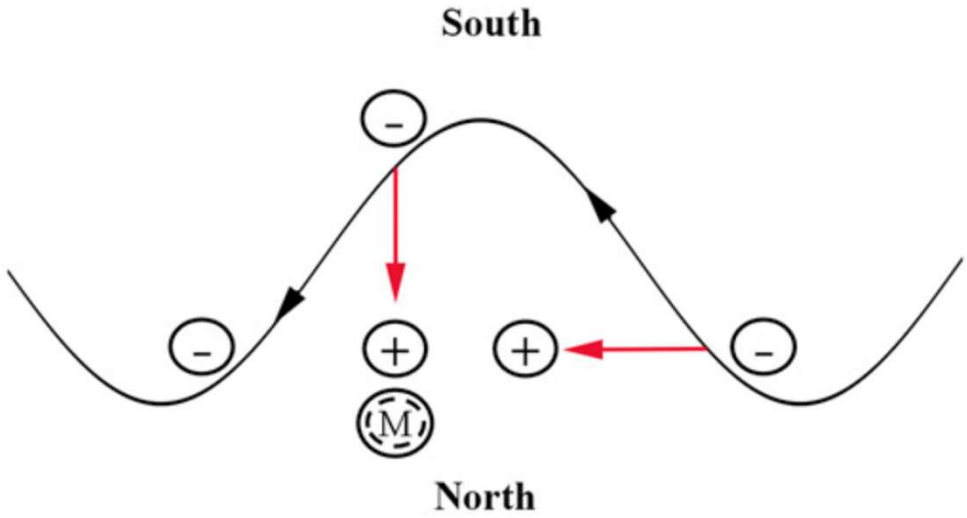


Correlation of the October zonal wind anomalies with the March western Ross Sea ice area.

Rapid Decline during 2014–16 Controlled by Wind-Driven Sea Ice Drift(?)

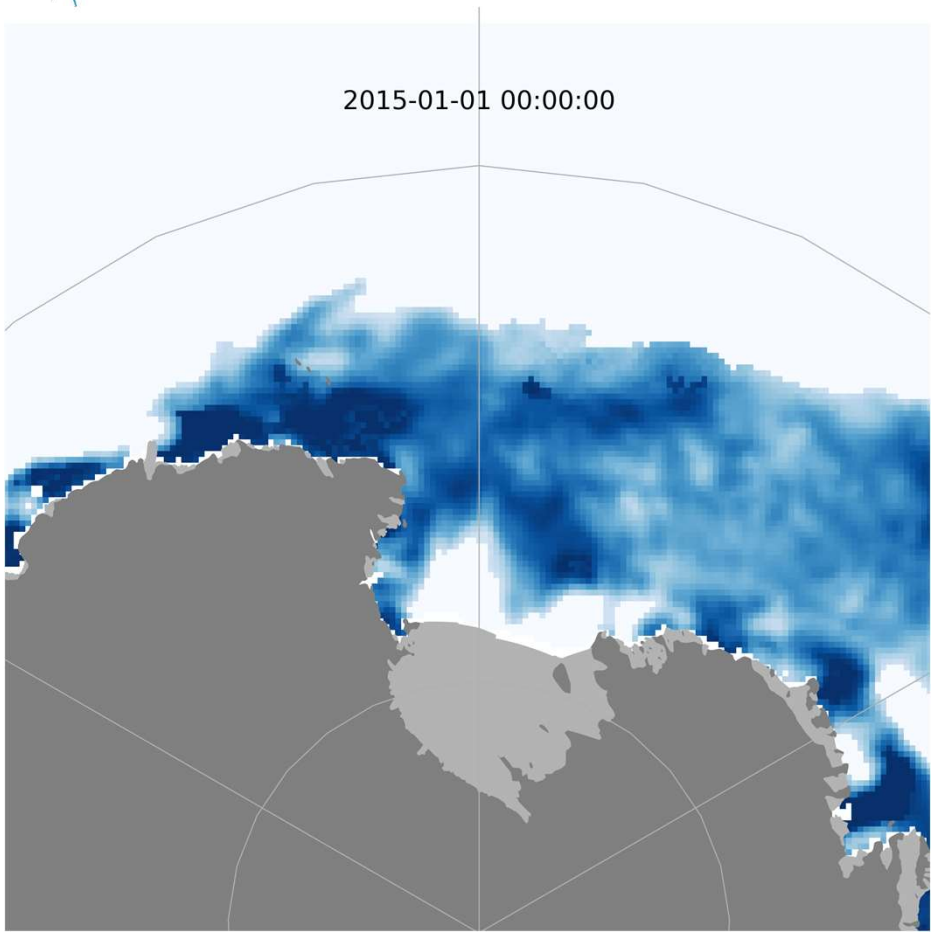
- Wang et al. (2019) used the outputs of a high-resolution, global ocean–sea ice model to show that the change recent rapid change was predominantly a result of record atmospheric low pressure systems over sectors of the Southern Ocean.

- With the associated winds inducing strong sea ice drift. Regions of large positive and negative sea ice extent anomaly were generated by both thermal and dynamic effects of the wind anomalies.



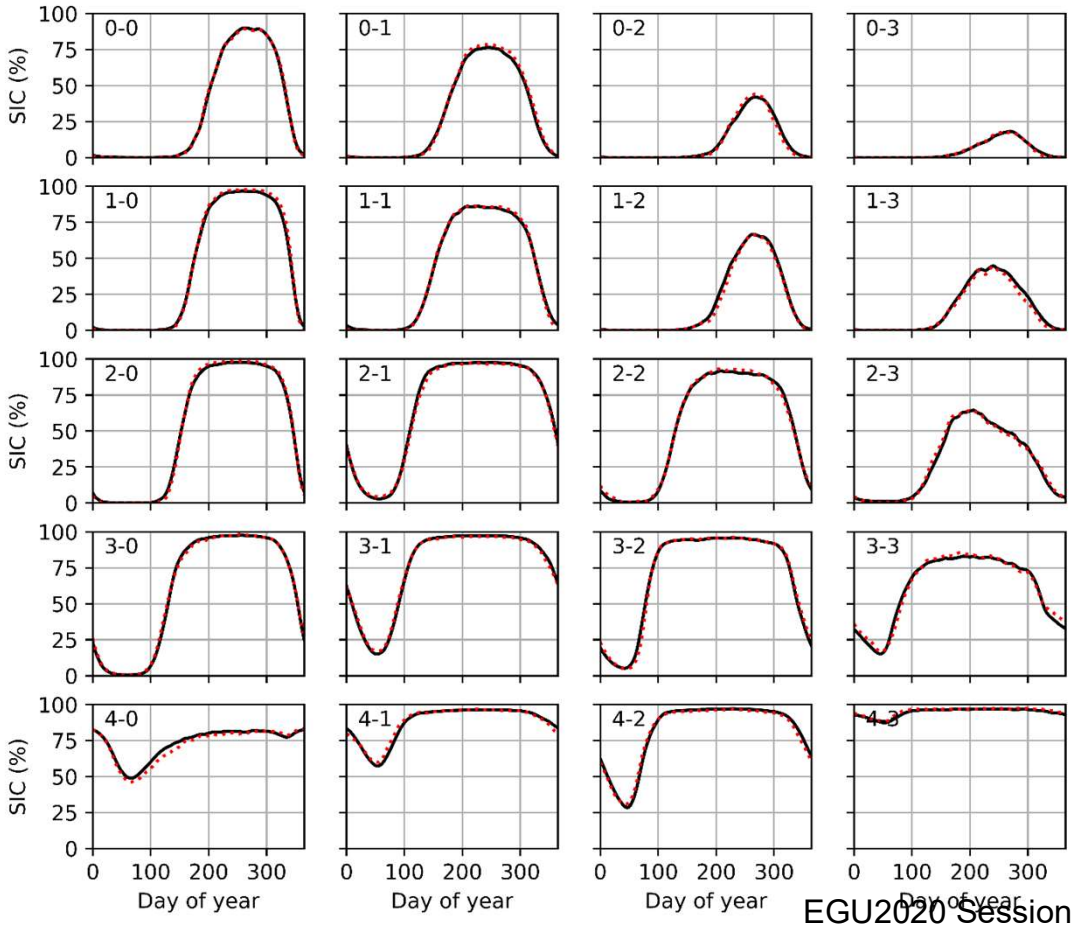
Schematic of wind-driven sea ice drift effects on SIC, with black arrows indicating wind anomalies, red ones indicating sea ice drift anomalies, ‘‘1’’ and ‘‘2’’ indicating positive and negative SIC anomaly, respectively, induced only by sea ice drift anomalies, and ‘‘M’’ standing for ‘‘melting’’ at lower latitudes.

Sea ice variations in Ross Sea Region



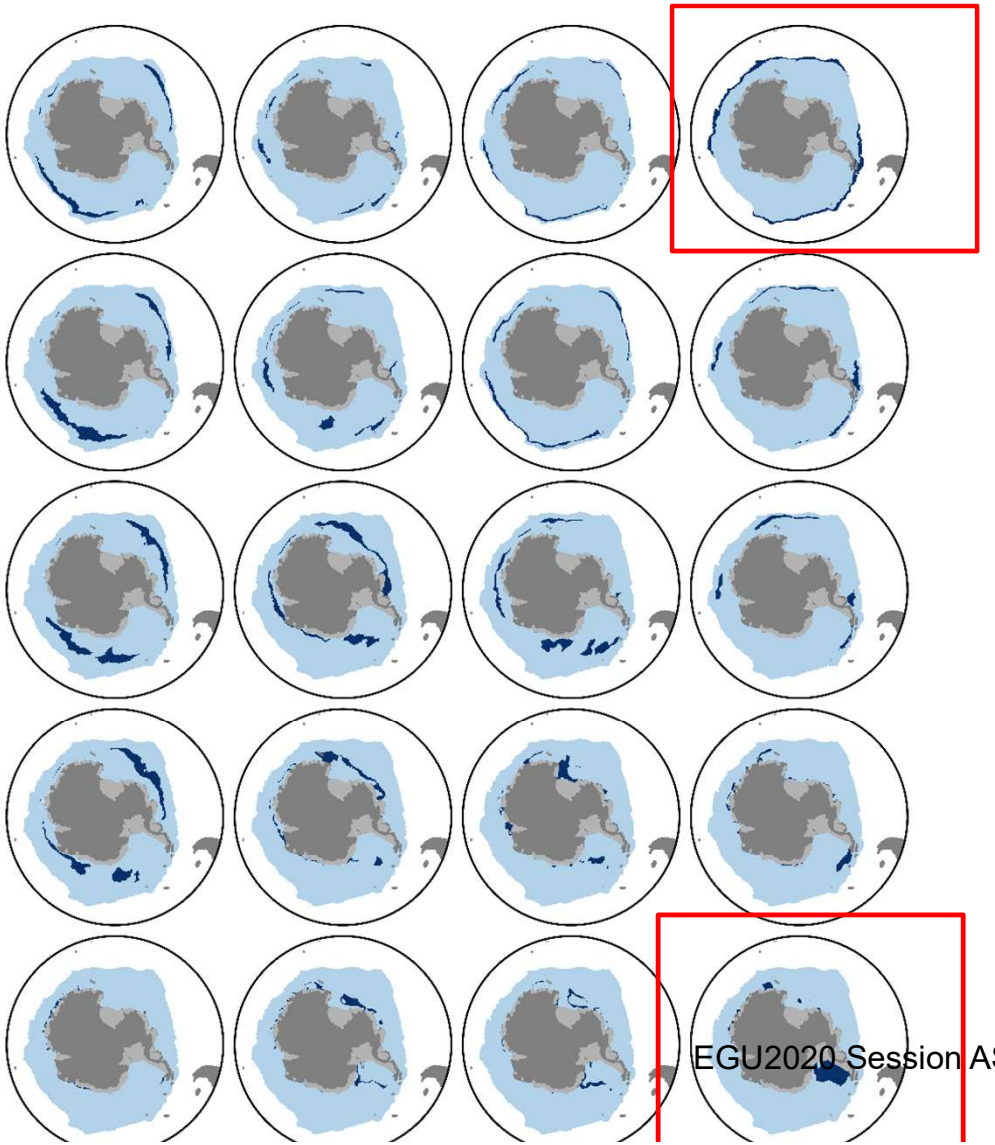
- Sea ice concentration variations in the Ross Sea region over 2015.
- Note changes can be rather rapid, this precludes oceanic motion which are slow and also likely thermodynamic processes. Thus, atmospheric forcing causing advection of sea ice and break up in polynya regions potentially important.
- **However, different types of change are observed in different regions and at different time scales. So perhaps there are ways to separate responses**

Sea ice concentration SOM



- To examine the relationship between winds and sea ice concentrations, we decided to classify sea ice regions that behave differently based on their seasonal cycle.
- Trained a Self Organizing Map on the seasonal variation in every grid point on the NSIDC bootstrap version 3.1 sea ice concentration dataset over the Antarctic from 1979 to 2018.

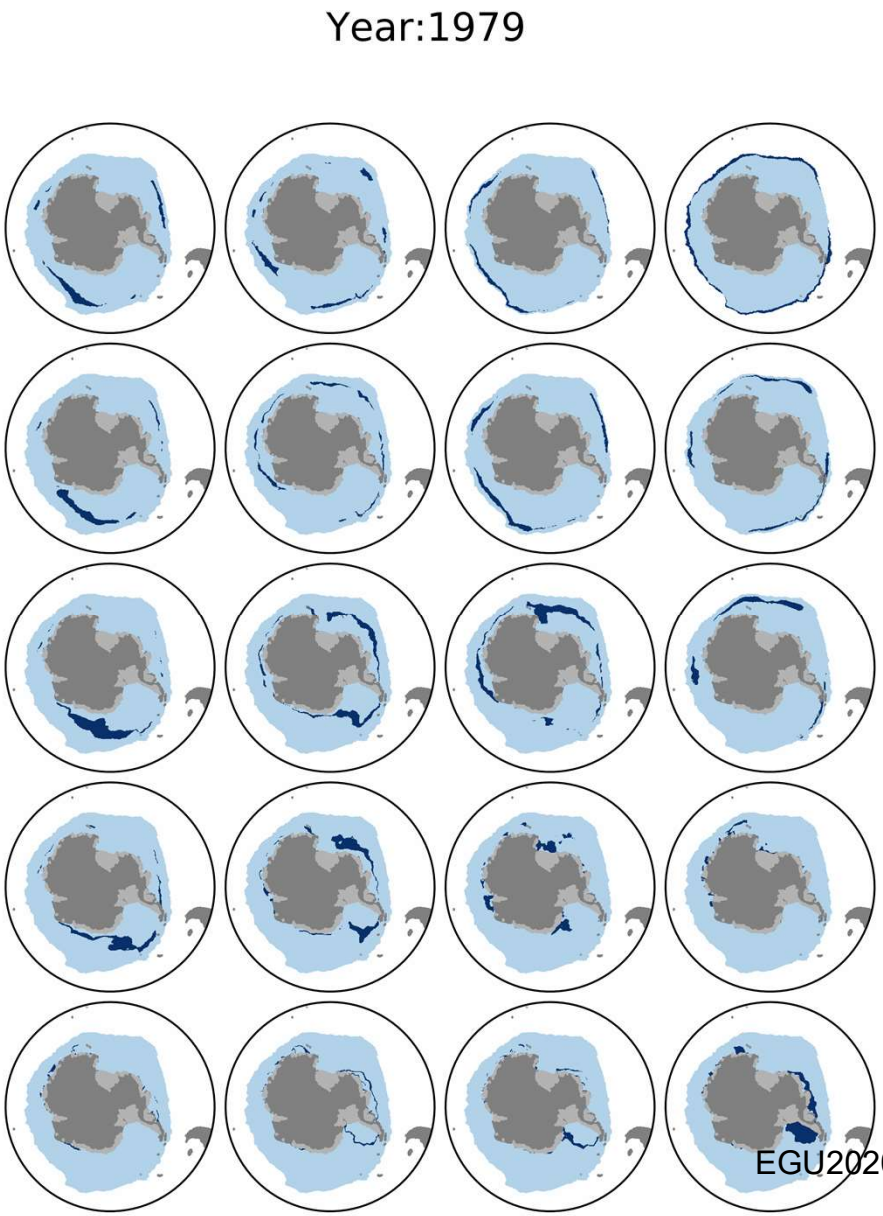
Sea ice concentration SOM



Marginal Ice Zone at maximum

- The SOM produced shows clear ordering from bottom to top (lower SIC on top row, higher on bottom row) and left to right (changes in seasonal cycle form).
- When looking at the geographical position of the SOM elements we also see sensible ordering and classes linked to specific defined regions.

Multi-year sea ice



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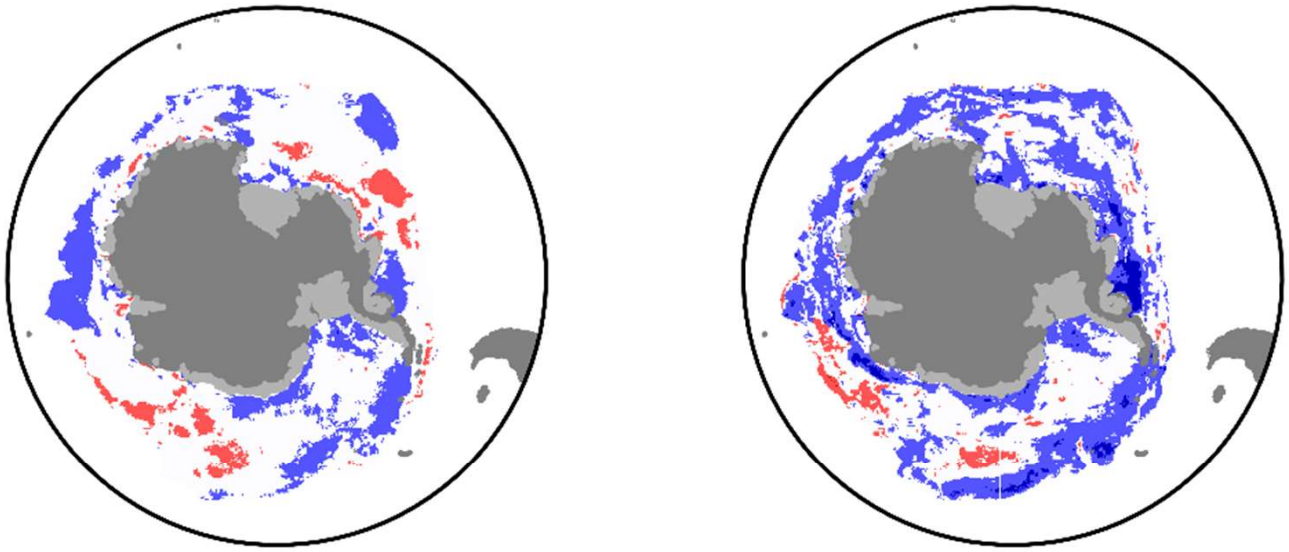
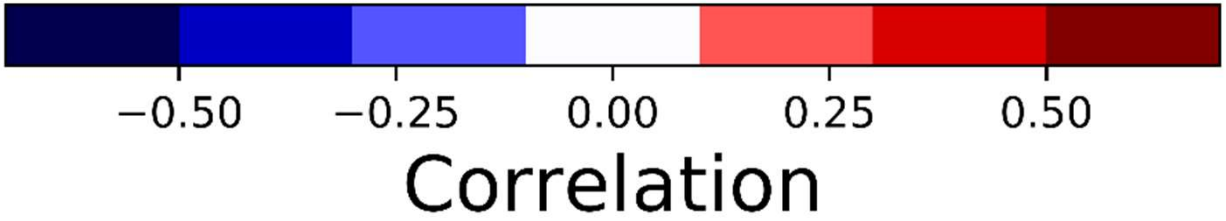
- The areas defined by different seasonal cycle patterns also clearly change from year-to-year as we might expect given previous work.

Sea ice concentration versus wind speed

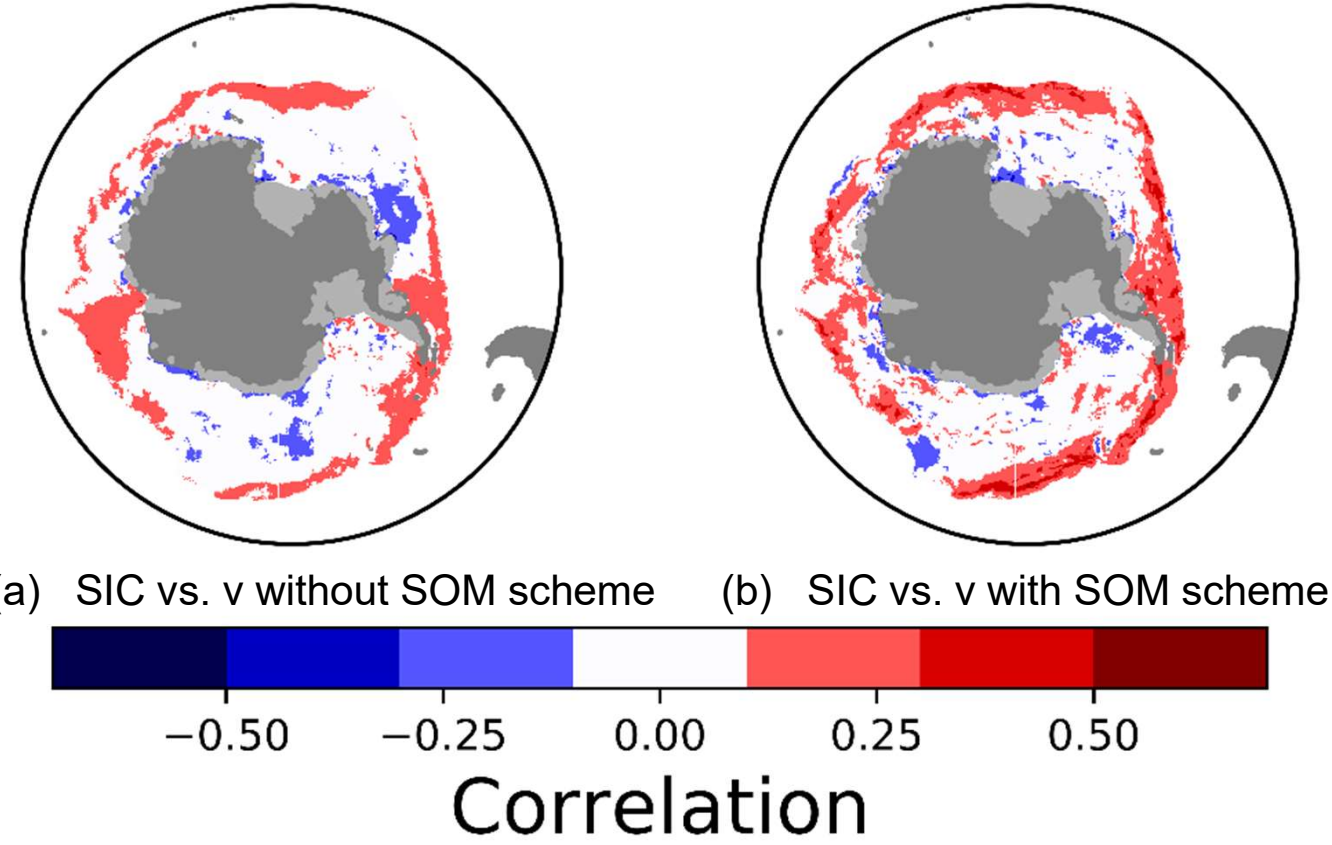


(a) SIC vs. WS without SOM scheme (b) SIC vs. WS with SOM scheme



- The Figures to the left show correlations with and without anomaly removal defined by the SOM seasonal cycle.
- Removing seasonal cycles defined by the SOM effectively separates faster and slower responses for specific classes and focuses analysis.
- The spearman rank correlation between 10m wind speed from ERA5 and sea ice concentrations (a) and wind speeds and SIC anomalies derived using the SOM seasonal patterns (b).

Sea ice concentration versus meridional (north-south) winds



- The Figures to the left show correlations with and without anomaly removal defined by the SOM seasonal cycle.
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- The spearman rank correlation between 10m meridional winds from ERA5 and sea ice concentrations (a) and meridional wind speeds and SIC anomalies derived using the SOM seasonal patterns (b).

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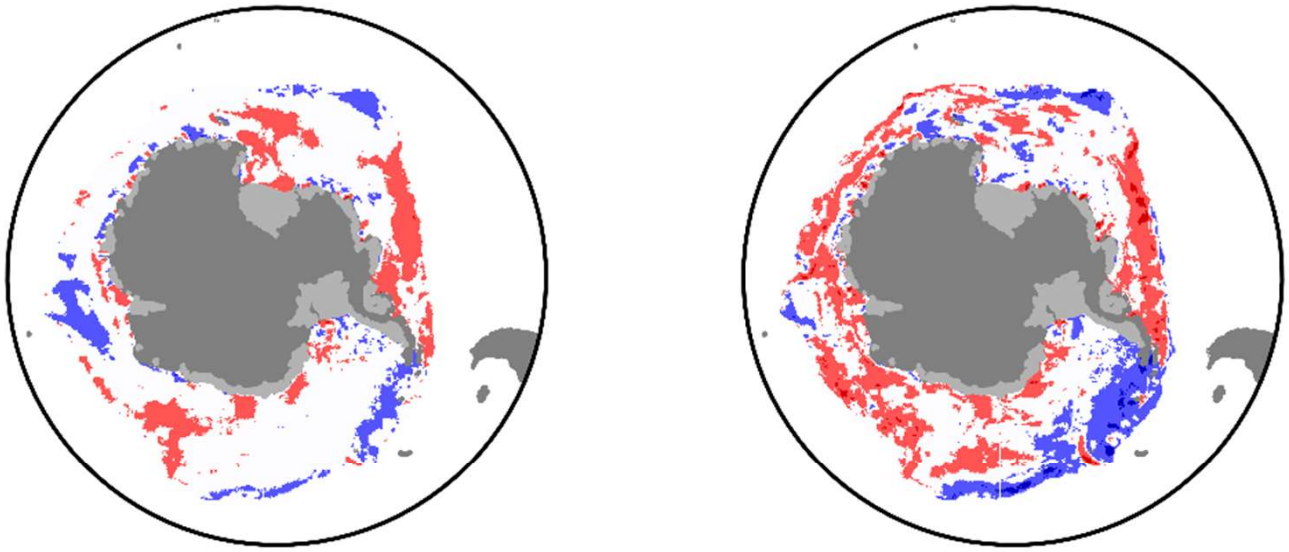
Sea ice concentration versus zonal (east-west) winds



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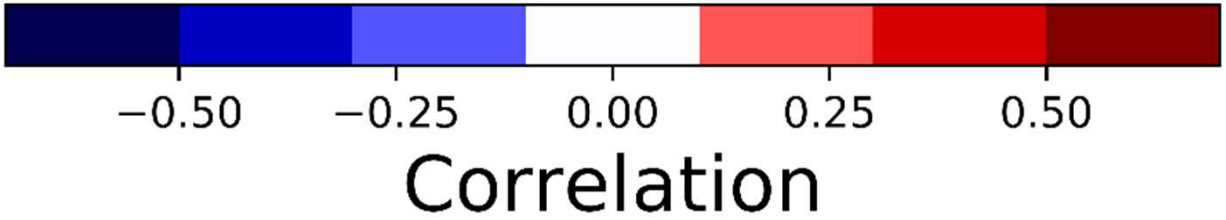

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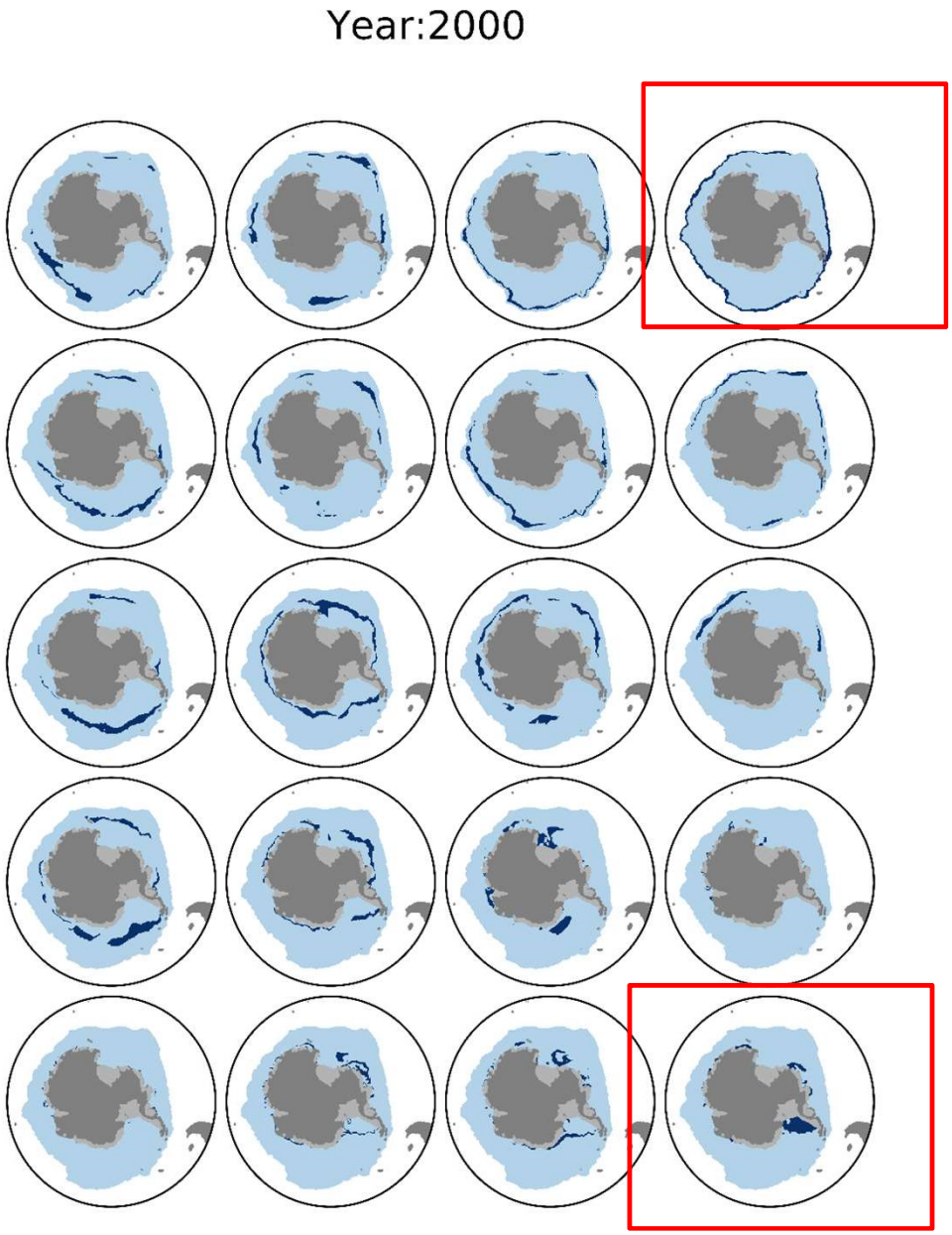
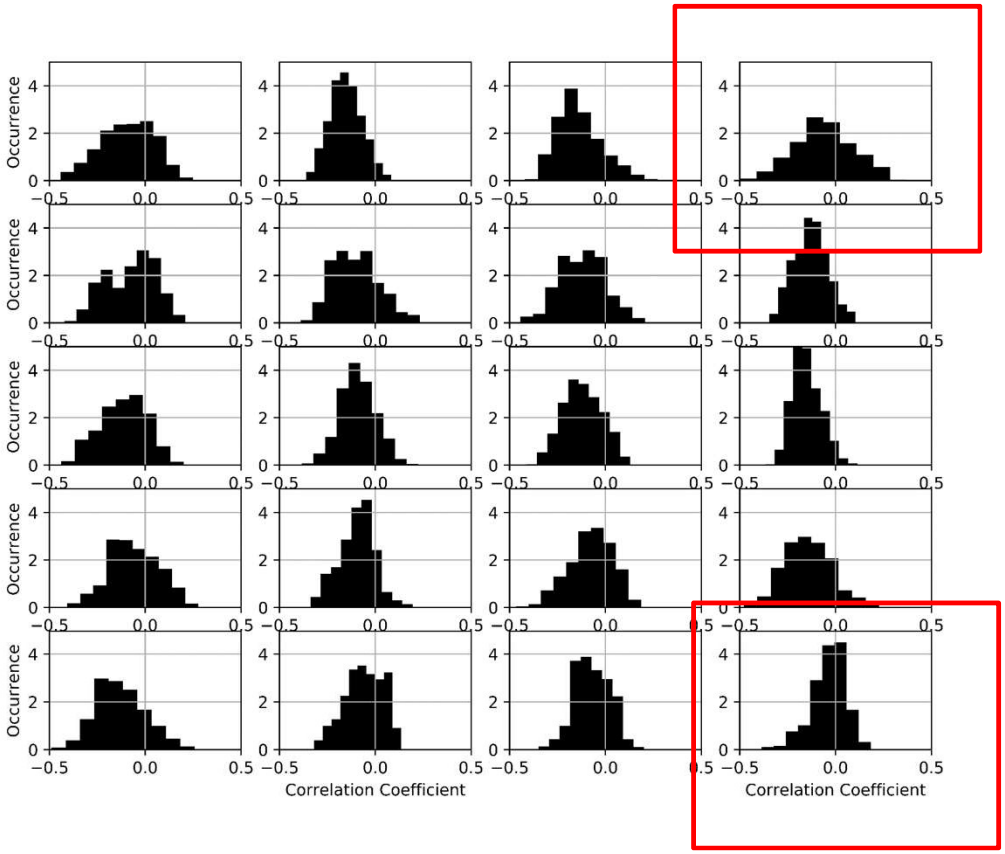
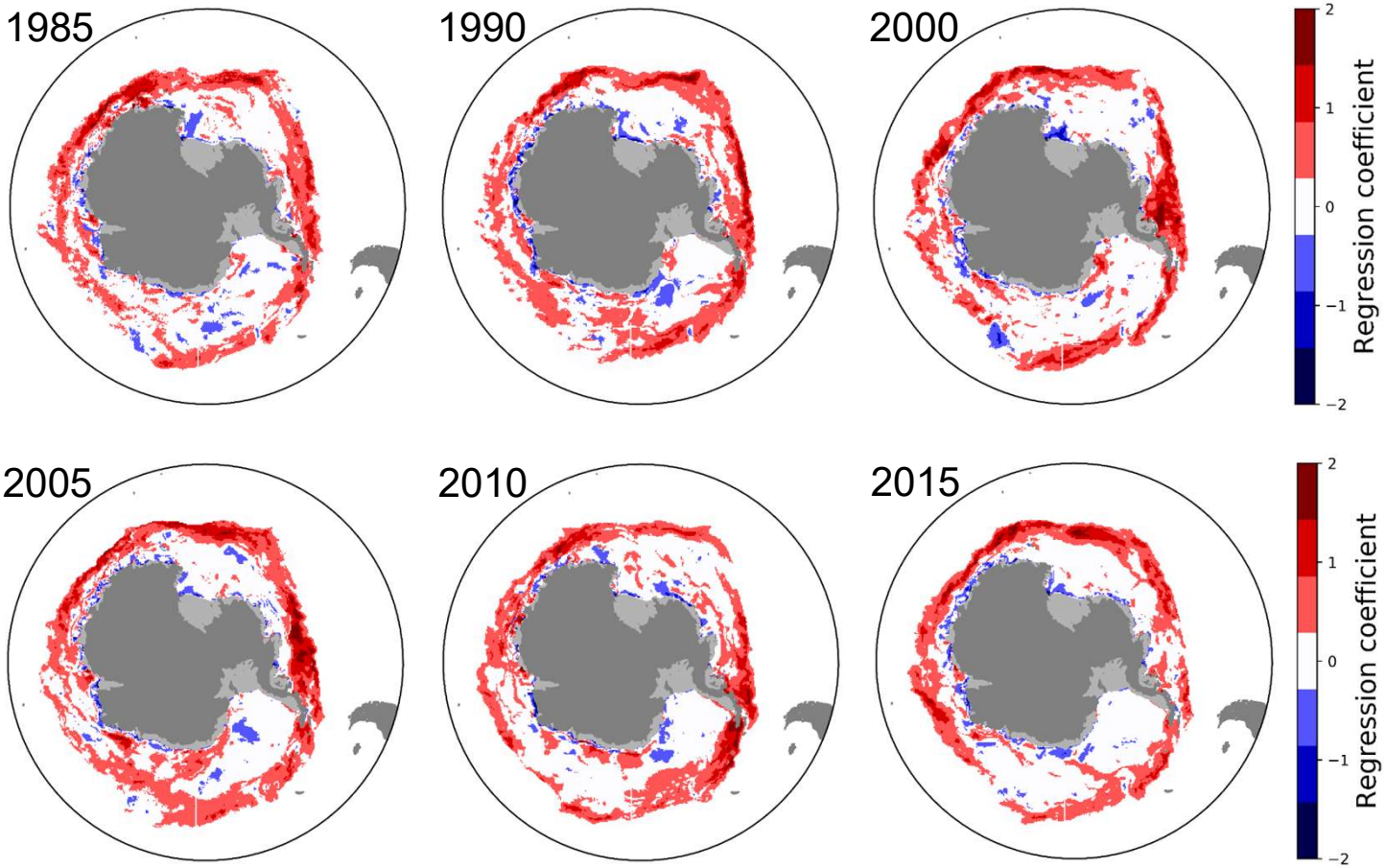


Marginal Ice Zone at maximum



Multi-year sea ice

Regression coefficients between sea ice concentration anomalies and meridional winds



- The regression coefficient between meridional winds and sea ice concentration anomalies allows us to quantify the overall sensitivity of sea ice to meridional winds.
- Variations in this measure might be useful in quantifying changes in the drivers of sea ice change. **Does it tell me anything about thinning sea ice?**

Conclusions

- Sea ice concentrations vary significantly at the Antarctic wide scale in response to winds.
- Previous work shows that at large scales winds and sea ice concentration predominantly display positive correlations, while at small scales connected to the coastal polynya, winds are negatively correlated with winds. There are also time lags between winds and sea ice concentration changes at short and long time scales.
- Application of a Self-Organizing Map analysis shows promise for identifying different sea ice regimes which appear to be sensible in their geographic form and identify known regimes. The SOM regimes also behave in a more coherent way with respect to winds.
- They also allow SIC anomalies to be calculated in a coherent way for different regions which enhances the correlations observed between sea ice concentrations and. But, this is still early work.
- Examination of how regression coefficients (a measure of sensitivity of SIC to winds) changes has now begun.