Towards understanding 20th century Antarctic sea ice trends: Exploring the links between SAM and sea ice

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Why look at SAM?
Antarctic ocean and ice response to abrupt ozone loss

Do we see evidence of this in the sea ice response to internal variability?
How does this compare across various climate models?
Does this influence simulated 20th century ice trends?

Fast response
($\approx$ year)

<table>
<thead>
<tr>
<th>Pole</th>
<th>60°S</th>
<th>40°S</th>
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Slow response
($\approx$ decade)

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<tr>
<th>Pole</th>
<th>60°S</th>
<th>40°S</th>
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Increased Sea Ice Extent
Decreased Sea Ice Extent

Helps explain results in:
Sigmond & Fyfe, 2010;
Bitz & Polvani, 2012
CESM Large Ensemble
Sea Ice Climatology

CESM Simulates relatively good mean Antarctic sea ice properties
However, members do not bracket observed trends

AMJ Ice Area Trends 1980-2005

OBS
Ensemble Mean
Individual Members

Range across members
DJF Southern Annular Mode Trends

• 50 year trends

Thanks to Adam Phillips for variability metrics (via CVDP)
DJF Southern Annular Mode Trends

- 50 year trends
- Discernible positive shift in the late 20C trend distribution
- Simulations bracket observations

Thanks to Adam Phillips for variability metrics (via CVDP)
Simulations with larger DJF SAM trends have larger ice loss.

Thanks to Adam Phillips for variability metrics (via CVDP).
Simulations with larger SAM trends have more upper ocean warming
This is associated with a changing ocean circulation
Consistent with long-timescale response

Simulations with larger DJF SAM trends have larger ice loss
What about CMIP5 20th Century Scatter?

CESM-LE Simulations

(Using 28 CMIP5 Models)
What about CMIP5 20th Century Scatter?

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(Using 28 CMIP5 Models)
Pre-industrial Run Analysis

Comparing SAM-sea ice relationships across CMIP5 models
Within PI control:

- Overall ice increase a few months after +summer SAM (but with large spatial variations)

Correlation Ice and DJF SAM
- No Filtering
- High Pass Filtered
Within PI control:

- Overall ice increase a few months after +summer SAM
- For low-pass filtered timeseries, ice declines several years following +SAM
Correlation of DJF SAM and SH Ice Extent

Two Other Models

Correlation of Raw Timeseries

24 CMIP5 Models

Have only used models with > 200 Years of output and small sea ice trends (well-equilibrated)
Most models exhibit a significant increase of sea ice in April-May following a positive summer SAM index.
From low-pass filtered time series, many models also exhibit ice loss following a positive SAM at a 2-10 year time lag.

CESM flavors have some of the strongest relationships and shortest timescales.
Conclusions

• CESM-LE has somewhat larger 20C ice loss in members with larger SAM trends

• This is associated with changing ocean circulation and increased upwelling

• CMIP5 models show a weaker relationship

• From an analysis of pre-industrial control runs, it appears that CESM simulates a relatively strong low-frequency response to SAM trends compared to other models
Models with stronger (negative) low-frequency Ice-SAM relationships in pre-industrial control runs generally have larger 20th century sea ice loss.

Does not imply causality

Instead low-frequency SAM relationship and 20C Ice Trends are likely both related to other model properties (ice state, ocean structure, etc.)