Antarctic Sea Ice: Mean state and variability in CCSM4 1850 control run

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Overview

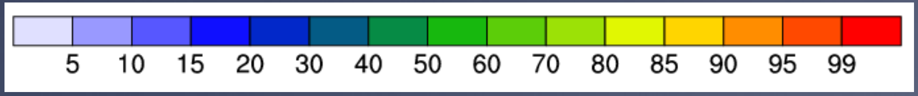
- Model years and variables
- Mean state and some comparisons with observations
- Variability in wintertime (JAS) Sea Ice Concentration (SIC)
- Sea ice advance/retreat data from daily output: mean, comparison with obs, and variability
- Thermodynamic vs. dynamic contributions: regional differences
- SIC variability and ENSO
- SIC variability and SAM
- Conclusions

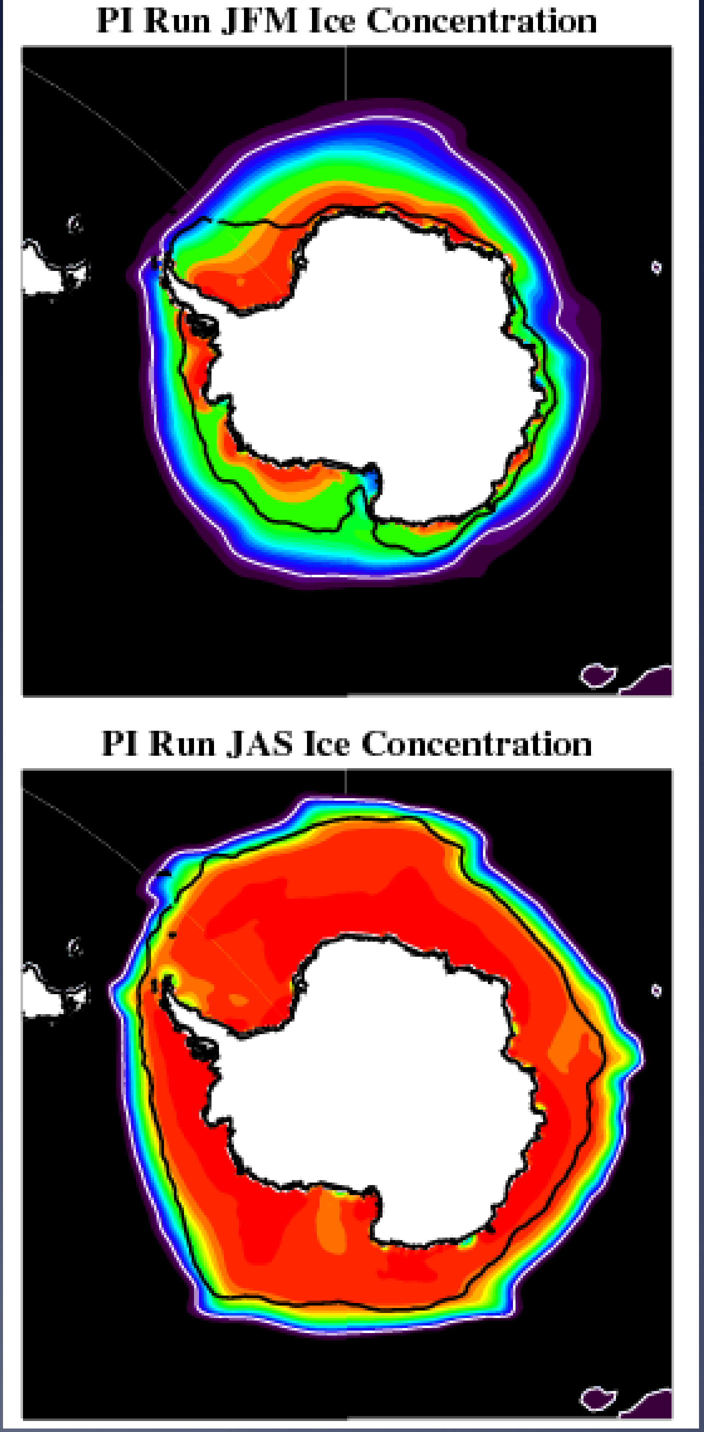
Model years and variables

- 1850 control run: fully coupled land-ocean-ice-atmosphere forced at constant, 1850 conditions
- 500 yrs of monthly data: simulation years 701-1200
- 150 yrs of daily data
- Some comparisons with observations (Antarctic Sea Ice observations are very limited: ~30 yrs)
- Some 20^{th} C ensemble run means (Dave Schneider's talk will focus more on this)

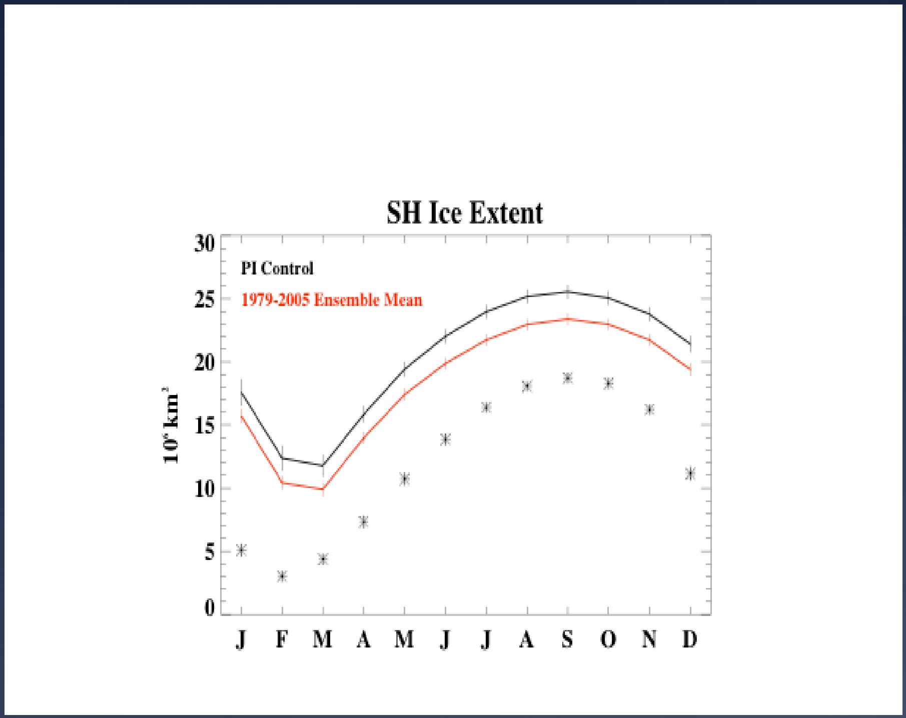
Mean State: Sea Ice Concentration

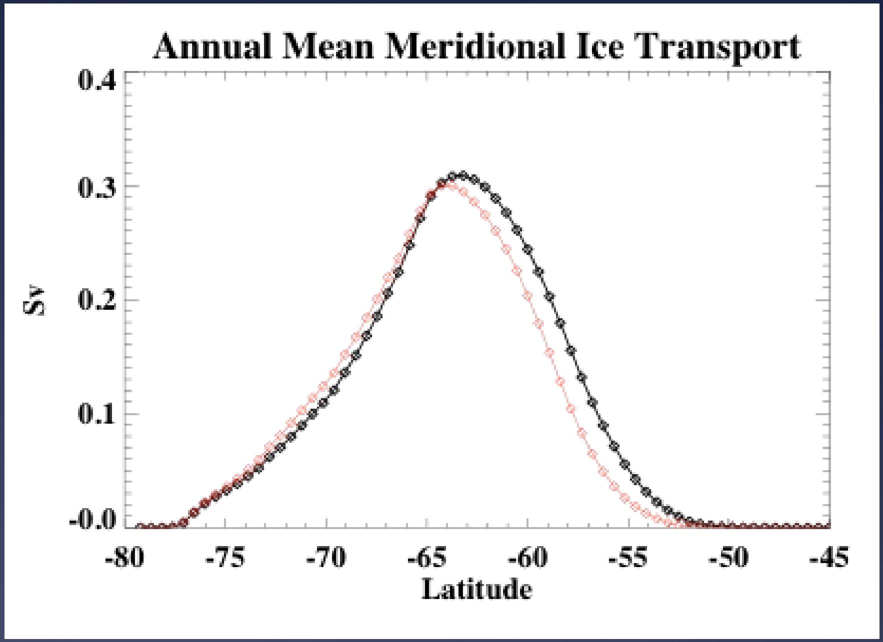
- Mean SIC too extensive – austral summer (JFM) and winter (JAS)
- Anomalously high southern ocean zonal wind stress – too much ice transported equatorwards





Mean State: Sea Ice Extent (SIE)





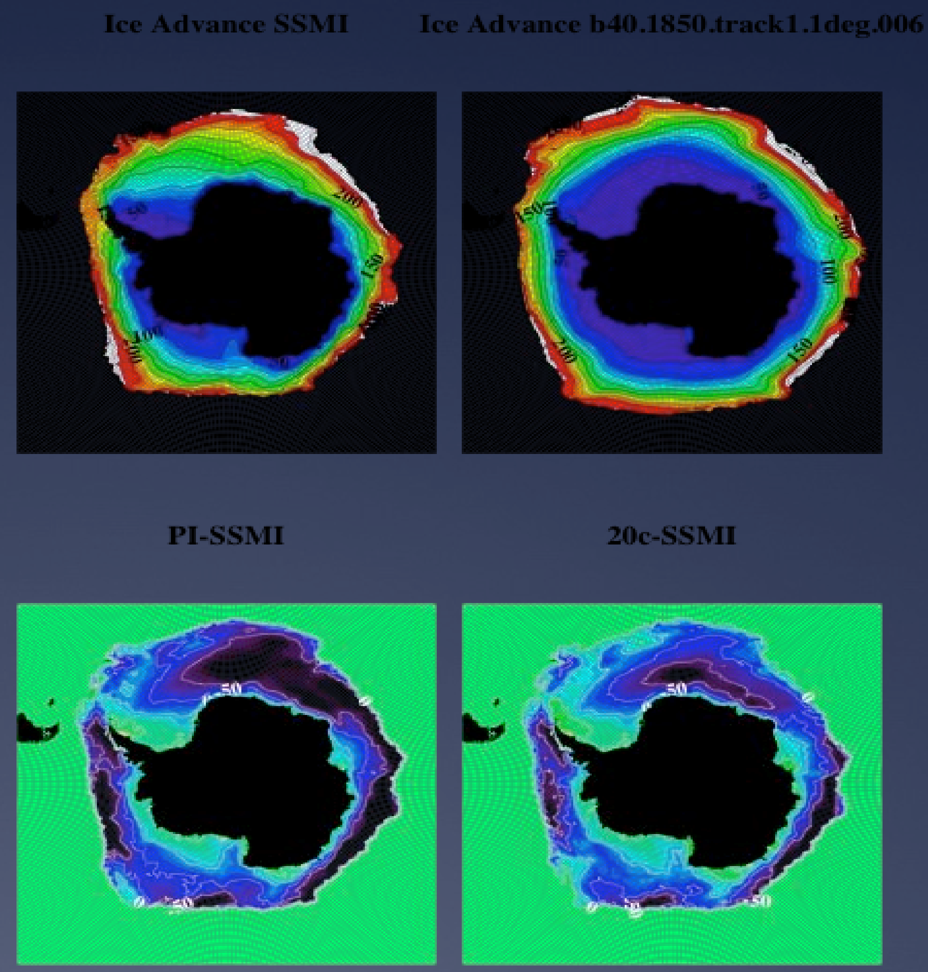
- Seasonal cycle of total Sea Ice Extent (SIE)
  - Too extensive
  - Large equatorward transport
  - Timing of seasonal cyle – ok over entire Antarctic – however not good in some regions, and specific latitudes (daily data)

Day of ice advance and retreat

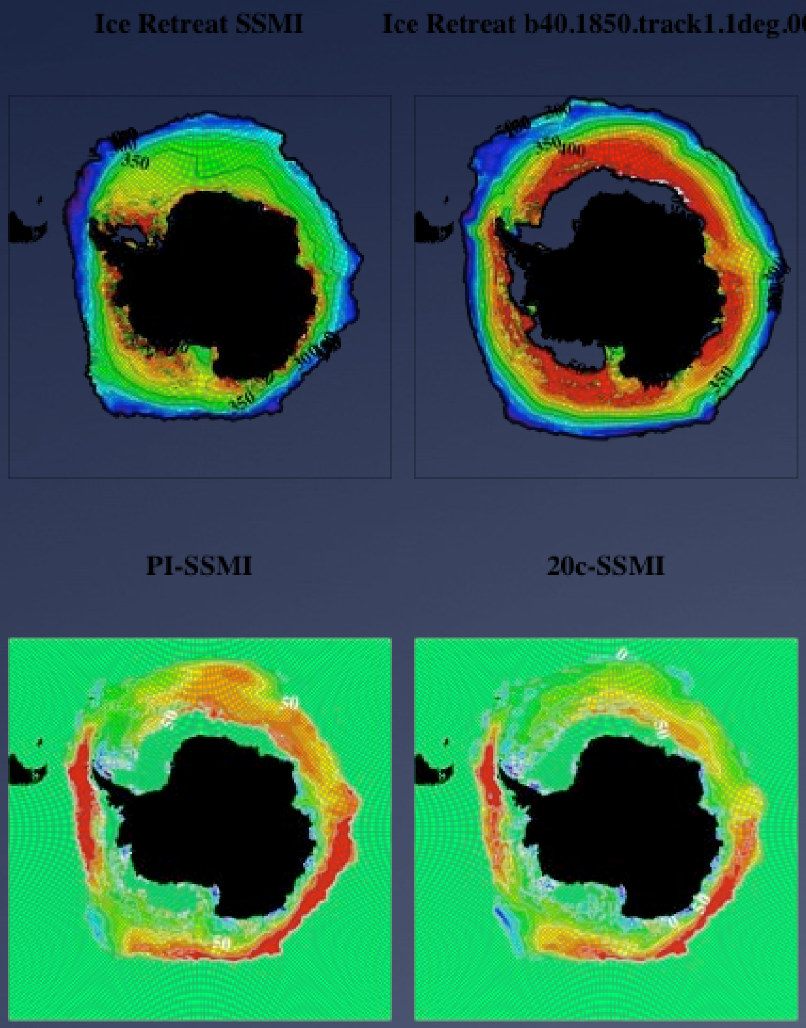
* Regional and/or seasonal differences in ice anomalies?
* 150 yrs of daily data
* Ice year = Feb. 16 – Feb 15 following year (mid-February ~ time of minimum SH ice extent)
* Day of ice advance (each grid cell): 1st day SIC>15% for 5 or more consecutive days
* Day of ice retreat: 1st day ice concentration <15% and remains so until the end of the ice year
* Ice duration (days) = day of retreat – day of advance

Day of Ice Advance: mean

- Day of ice advance – up to 50 days early (compared to observations)
- Improved modestly in 20th C runs



Mean Day of Ice Retreat



- Day of ice retreat – 50+ days later in CCSM4 than obs (with modest improvement in 20th C runs)
- Excessively long ice season – implications for 20C runs, simulation of SH water mass formations, biological models and biogeochemical cycles

JAS SIC variability: EOFs

- 500 yrs of monthly data: removed monthly climatology
- calculated seasonal (e.g. JAS sea ice extent) and/or annual means
- EOF analysis: EOFs and accompanying PCs
- All maps are shown with original field regressed onto standardized PC time series to show units/standard deviation

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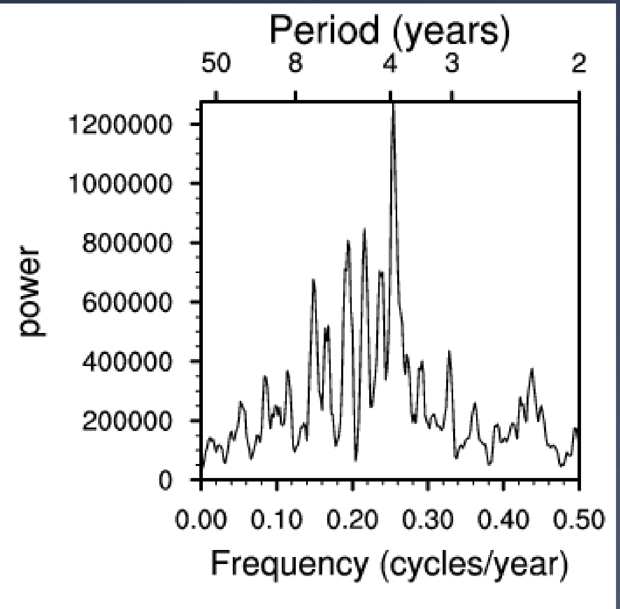
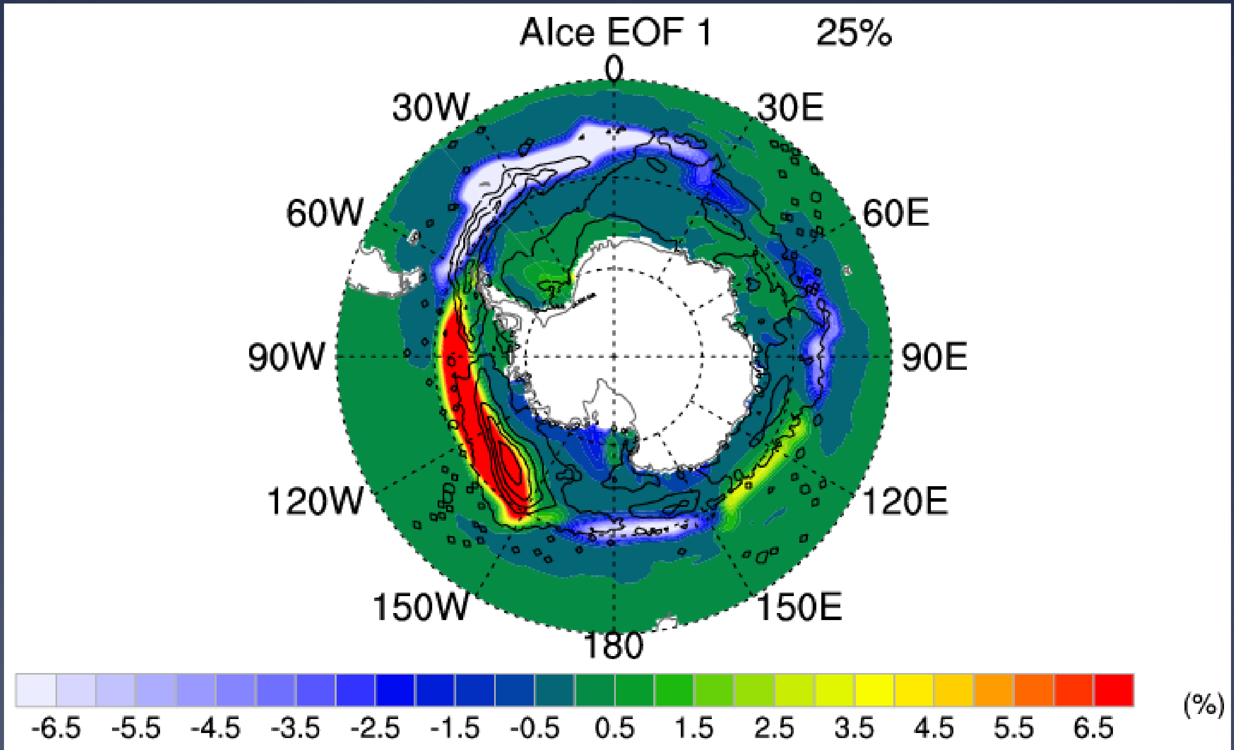
JAS SIC variability: EOFs

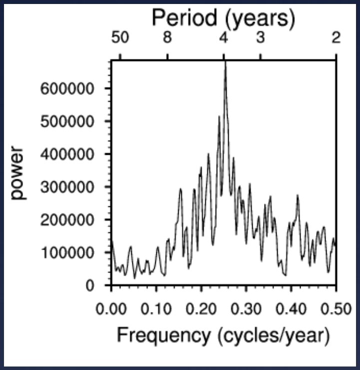
Leading order EOF of JAS SIC, 701-1200 of 1850 control run:

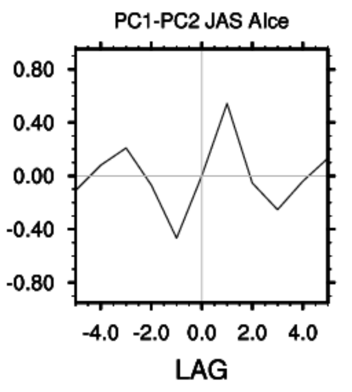
- S. Pacific-S. Atlantic Dipole pattern
- Contours from 1979-2005 satellite data (SSMI)
- 1850 control run – similar pattern but further north than obs
- Spectral peak at 4 yrs - ENSO

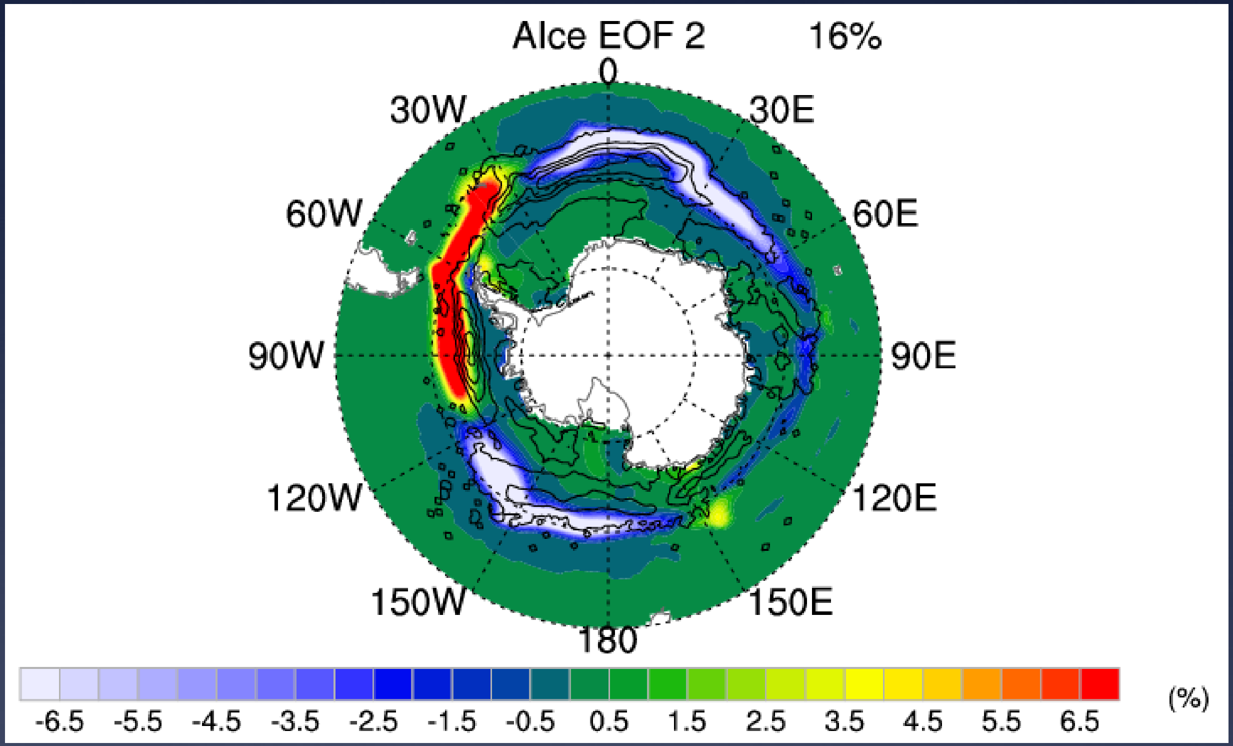




Second Order EOF of JAS SIC

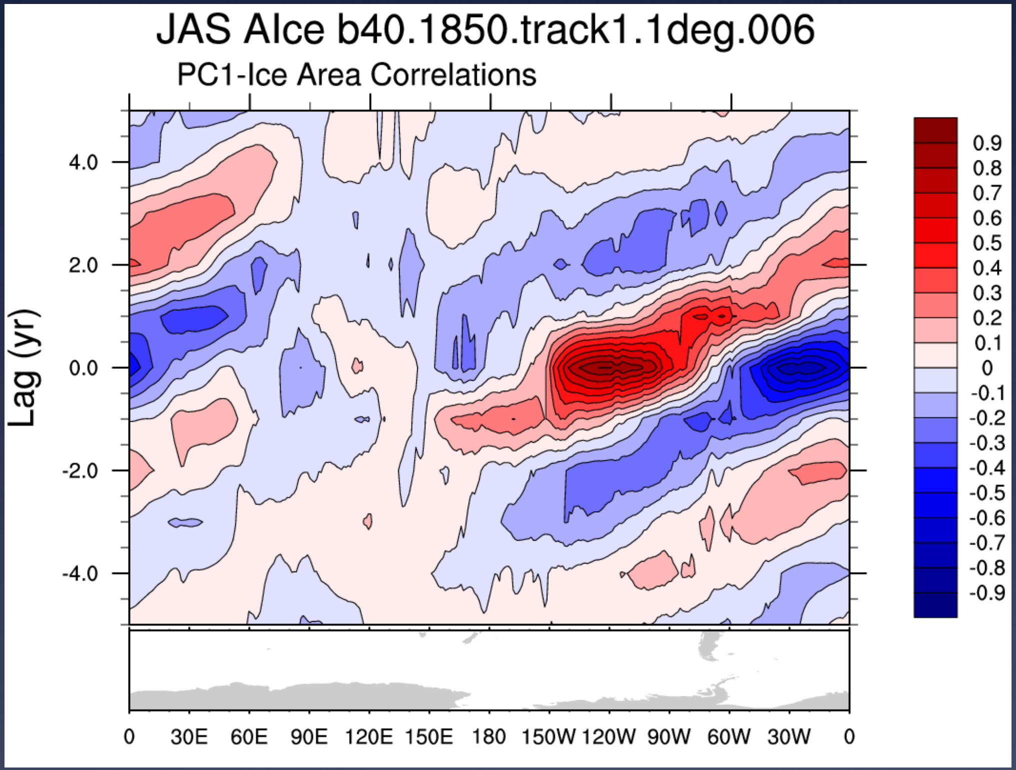






- Max. centered in Drake Passage between 2 min. 180° apart
- Anomalies more equatorward than obs. EOF2 of obs. Doesn't extend through Drake Passage
- 4 yr spectral peak
- Positively correlated with EOF1 at 1 year lag (EOF1 leading EOF2)
- propagating pattern?

Do anomalies propagate?



- Correlation of JAS SIC PC1 and Sea Ice Area (SIA=SIC*grid cell area then summed over each longitude)
- Wintertime anomalies travel eastward, ~7-8 cm/s (consistent with mean surface ocean currents)
- Decay by mid-eastern S. Indian ocean
- Anomaly propagates from year to year through sea surface temperature (“ocean memory”)

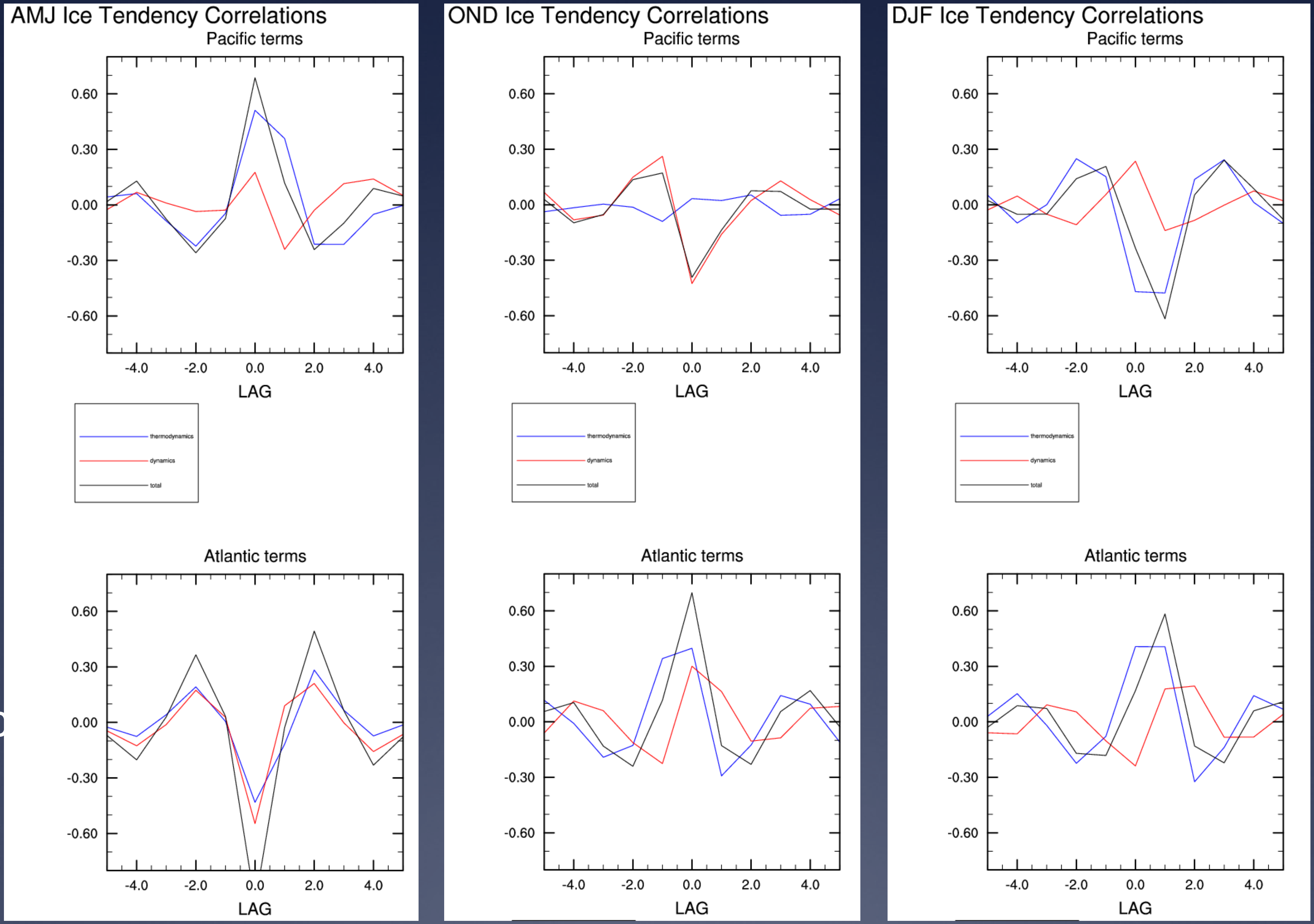
Pacific vs. Atlantic: seasonality and thermodynamic vs dynamic contributions to JAS SIC variability

* Thermodynamic contributions (within a grid cell) to sea ice concentration: melt and growth (congelation)
* Dynamic contributions: advection of ice into/out of grid cell as well as ridging within a cell
* Computed area-weighted averages of thermodynamic and dynamic contribution variables in the Pacific and Atlantic regions of high wintertime SIC anomaly (SIC>10%/SD in EOF1)
* Correlated this time series with PC1 of wintertime SIC anomaly

Correlations: PC1 of JAS SIC to:

Pacific

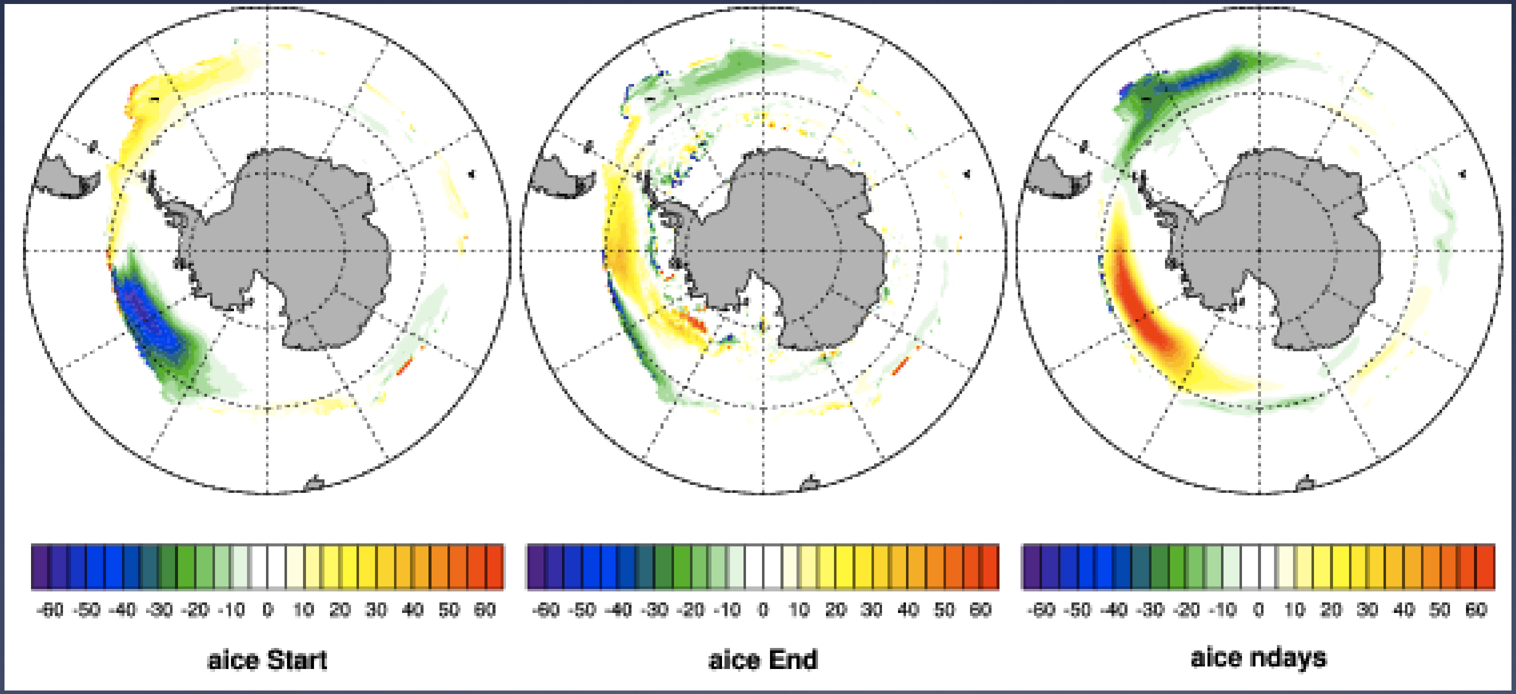
Atlantic



AMJ OND DJF

Day of advance/retreat and wintertime SIC anomaly

* Regressed day of ice advance/retreat and duration onto PC1 of wintertime SIC

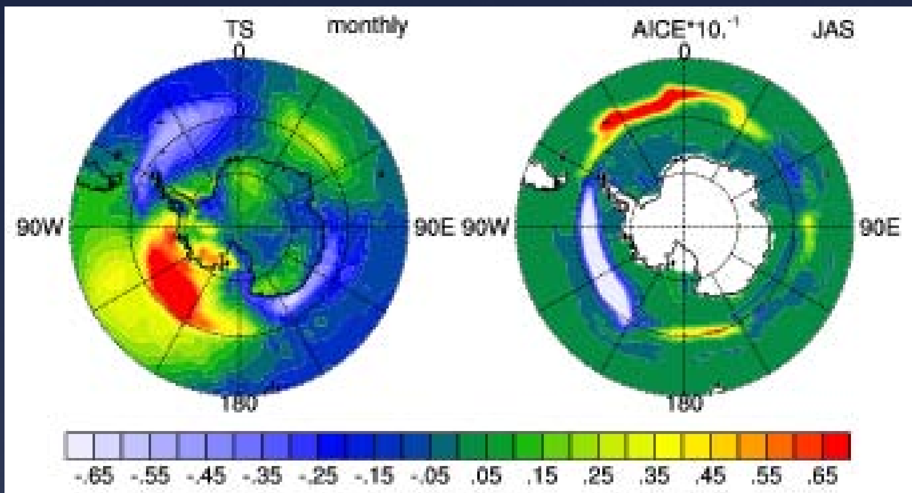


JAS SIC variability and ENSO

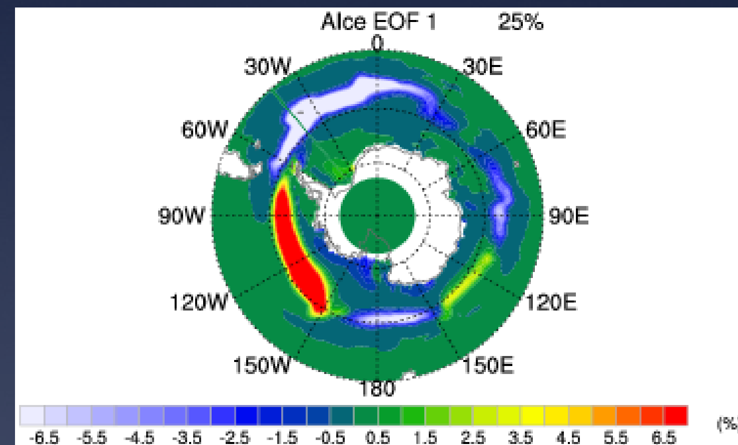
- Wintertime SIC anomalies – PCs clear 4 yr peak (like CCSM4 ENSO)
- ENSO and teleconnections with SH SSTs, SLP (although observations are limited)
- Regressed CCSM4 control run monthly Nino3.4 with monthly surface temperature (TS), monthly sea level pressure (SLP) and DJF Nino3.4 with JAS SIC

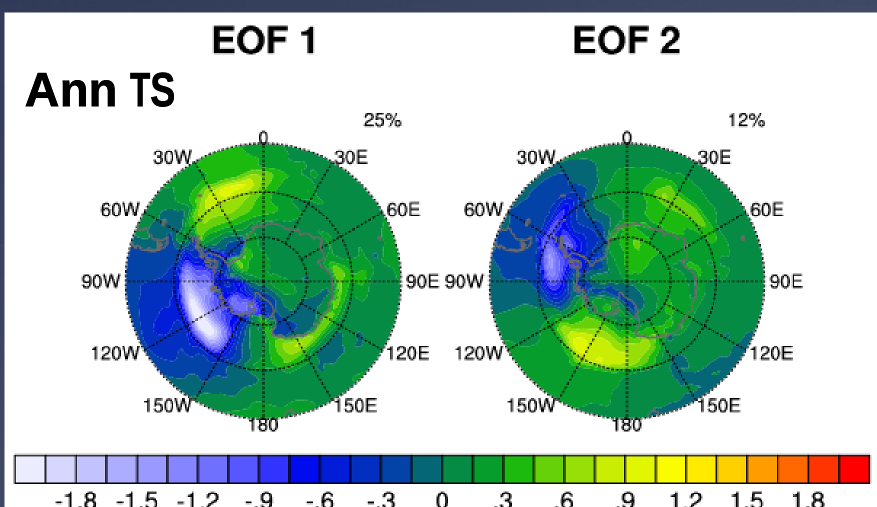
ENSO and sea ice

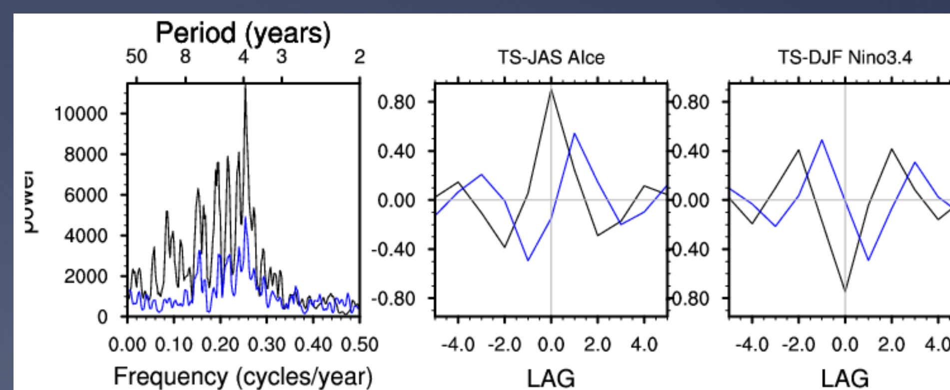
TS, SIC regressed onto Nino34.



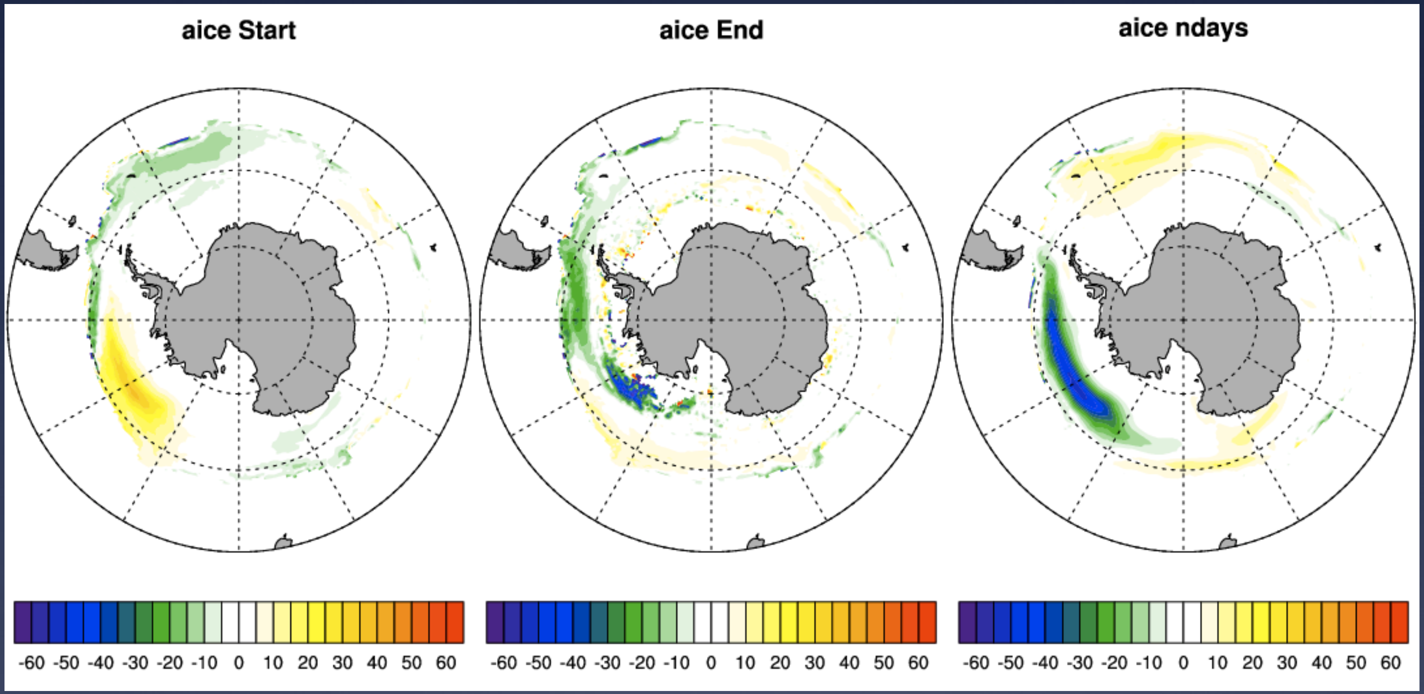
JAS SIC EOF1







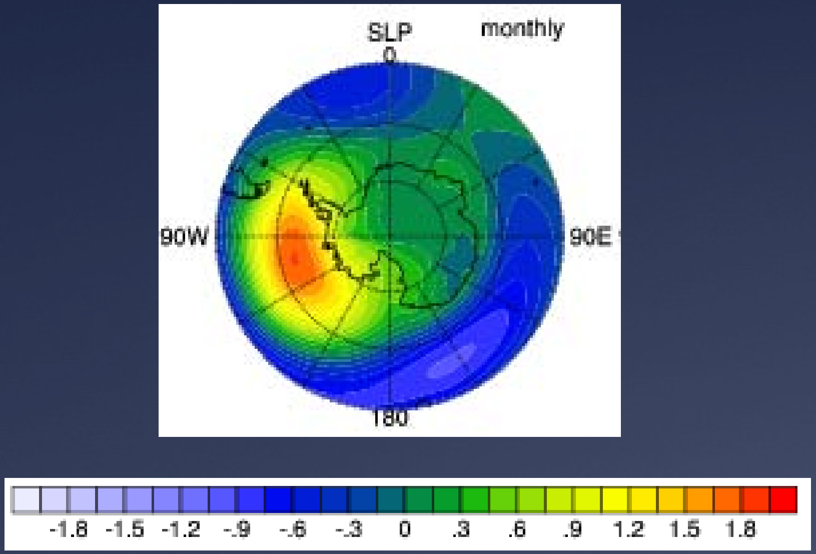
ENSO and day of advance/retreat



- Day of ice advance and retreat regressed onto DJF Nino3.4
- Dipole pattern present and stronger in Pacific sector
- Equal influence on advance and retreat in S. Pacific – perhaps more on advance in S. Atlantic?

ENSO and sea ice: SLP

SLP regressed onto Nino34.



* SLP regressed onto Nino3.4: very similar to SAM (next!)

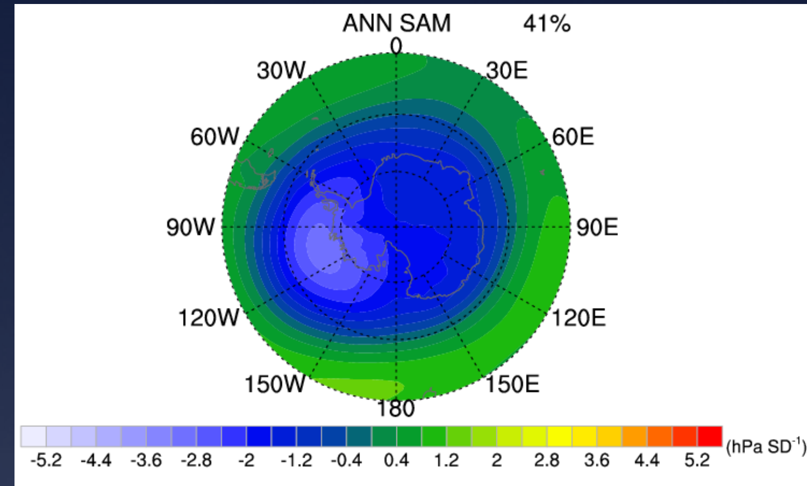
- wintertime SIC anomaly strongly linked to ENSO in CCSM4
- Positive ENSO (El Nino): warm TS anomalies in Pacific sector, cold TS anomalies in Atlantic sector + decrease/increase in meridional winds lead to net decrease/increase in Pacific/Atlantic wintertime SIC
- Sea Ice anomaly propagates through surface temperatures and with Antarctic Circumpolar current

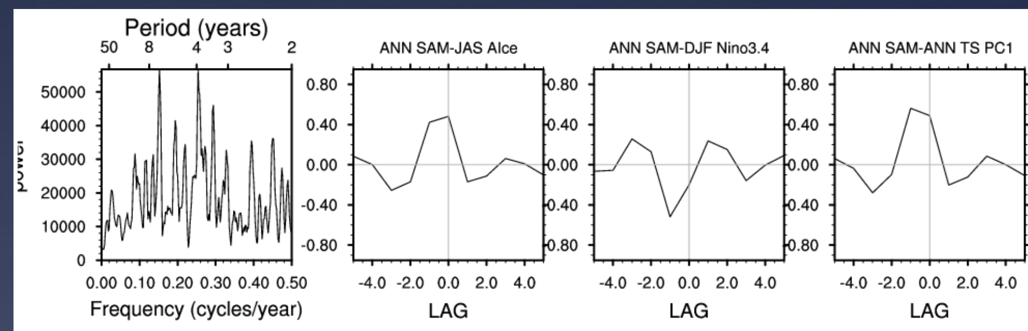
JAS SIC variability and Southern Annular Mode (SAM)

* SAM: leading order EOF of southern hemisphere (20°S-90°S) annual Sea Level Pressure
* Annual: all seasons of SAM have similar patter
* Annual SAM 41% of variability in SLP (only OND is higher at 53%)
* Annual SAM – highest correlation with wintertime JAS

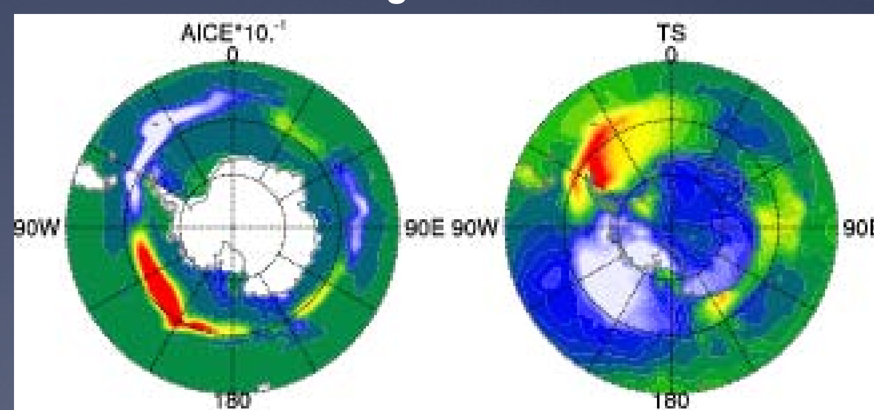
SAM

- SAM: moderately (compared with ENSO) correlated with PC1 JAS SIC, ann TS
- Some ENSO-SAM influence
- positive SAM: increase in zonal winds (+SAM and –ENSO reinforce one another)

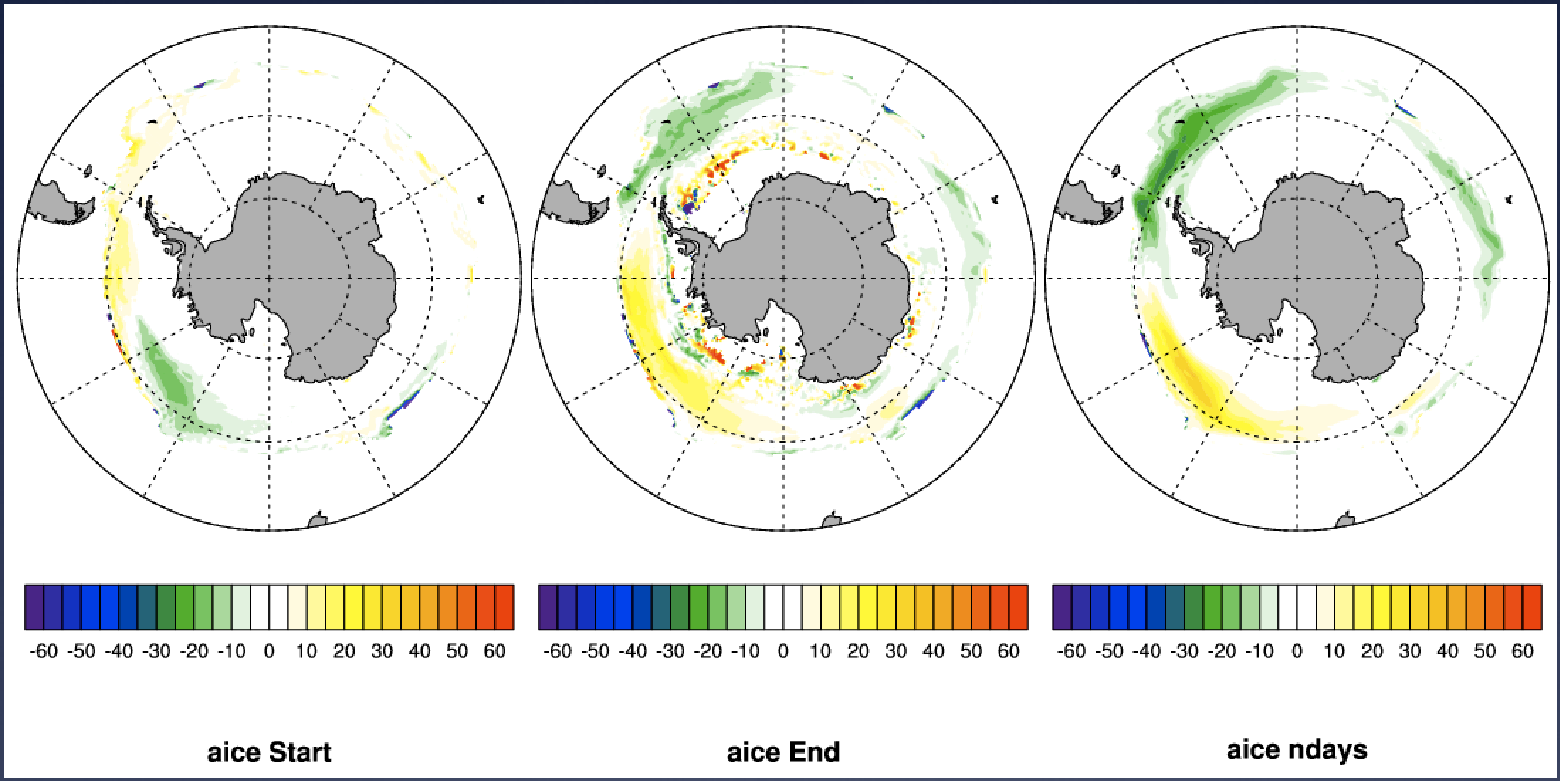




JAS SIC and ann TS regressed onto SAM PC



SAM and advance/retreat



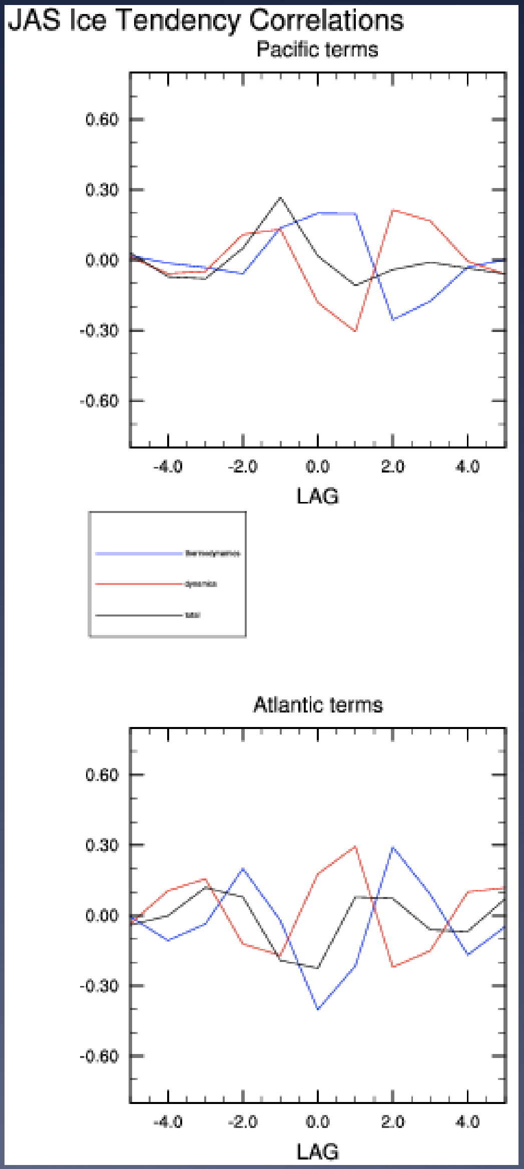
- Dipole pattern – opposite in sign to ENSO regression
- Equally strong in S. Atlantic and S. Pacific sectors
- Greater influence on day of retreat

Conclusions: Mean state

- CCSM4 Antarctic Sea Ice is too extensive compared to observations
- Large meridional transport of sea ice
- Seasonal cycle too far north – i.e. at a given latitude, ice advances early and retreats late compared to obs)

Conclusions: Variability

* Anomalies: dipole pattern between S. Pacific and S. Atlantic
* Anomalies propagate eastward at rates comparable to Antarctic Circumpolar Current
* Anomalies propagate from year to year through surface temperatures
* S. Pacific anomalies appear to be due primarily to thermodynamics in austral fall, dynamics in austral spring
* S. Atlantic anomalies: thermodynamics and dynamics in both fall and spring
* ENSO predominant - particularly in the S. Pacific (also present in S. Atlantic)
* SAM influence in both S. Pacific and S. Atlantic
* Some ENSO modulation of SAM
* +SAM –ENSO (La Nina) – reinforce ice response
* Patterns of anomalies, as well as relationships to TS, SLP, ENSO/SAM resemble those in [limited 20thC] observations – except too far north


JAS Ice Tendency Correlations
Pacific terms
0.60
0.30
0.00
-0.30
-0.60
-4.0
-2.0
0.0
2.0
4.0
LAG
Atlantic terms
0.60
0.30
0.00
-0.30
-0.60
-4.0
-2.0
0.0
2.0
4.0
LAG