Decadal circumpolar variability of Antarctic sea ice revealed by satellite observation and coupled general circulation model output

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Introduction

Sea ice is an important indicatior as well as a driver of climate change. It plays a pivotal role in southern ocean biogeochemical cycling. But the decadal variability in Antrarctic sea ice and its mechanisms are not clearly understood due to the limitation in observational records. Hence this study look at the decadal variability in Antratctic sea ice and the relationship between ice, ocean and atmosphere.

Data and methods

a) Observations

- Sea ice: Satellite Sea Ice concentration data (NSIDC) [1979–2010]
- Ocean: NOAA Optimum Interpolation SST v2 [1982–2011]
- Atmosphere: Climate Prediction Center SAM index [1979–2010]

b) Model – Coupled GCM for Earth Simulator (CFES)

- Resolution: atmosphere – 1° (∼100 km) 48 levels and ocean – 0.5° (∼50 km) 54 levels
- Integration period: 120 years

The techniques used are emperical orthogonal function (EOF) analysis, regression, correlation and spectral analysis. Variables are analysed using annual average. **Running averaged (RA)** and fft filter were used to extract longterm signals.

Summary

1. Observation and model – show a coupled circumpolar variability in decadal time scale for Antractic sea ice.
2. Model shows that the oceanic variability in SST drives the variability in the sea ice by periodic decadal upwelling of warm subsurface water
3. Atmosphere and oceanic variability are coupled through dynamic and thermodynamic feedback.
4. The impact of oceanic natural decadal variability to the atmosphere is key in the coupled system and has to be investigated upon further.

Reference and ackn.

Parkinson, C. L. and D. J. Cavalieri, 2012: Antarctic sea ice variability and trends, 1979–2010. *The Cryosphere.*, **6**, 871–880.

Yuan, X. and E. Yonekura, 2011: Decadal variability in the Southern Hemisphere. *J. Geophys. Res.*, **116**, 1–12.

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Decadal variability – Observations

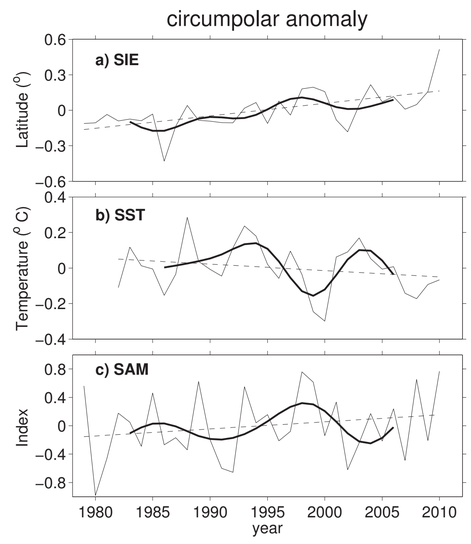

Fig. 1. a) Observed circumpolar averaged annual **sea ice edge (SIE)** anomaly time series (1979-2010) b) observed annual circumpolar **sea surface temperature (SST)** [northward 5° latitude band from the SIE] anomaly time series (1982-2010) and c) annual **southern annular mode (SAM)** index (1979-2010) from Climate Prediction Center. The bold line represents a low passed (7 years) time series using a fft filter.

- Decadal signals – SIE - 11yr to 16yr, SST - 10yr to 13yr, SAM - 11yr to 13yr.
- Negative correlation between SIE-SST (-0.68) & positive between SIE-SAM (0.78) indicating a decadal time scale coupled variability present in around 30 year observation.

Decadal variability – Model

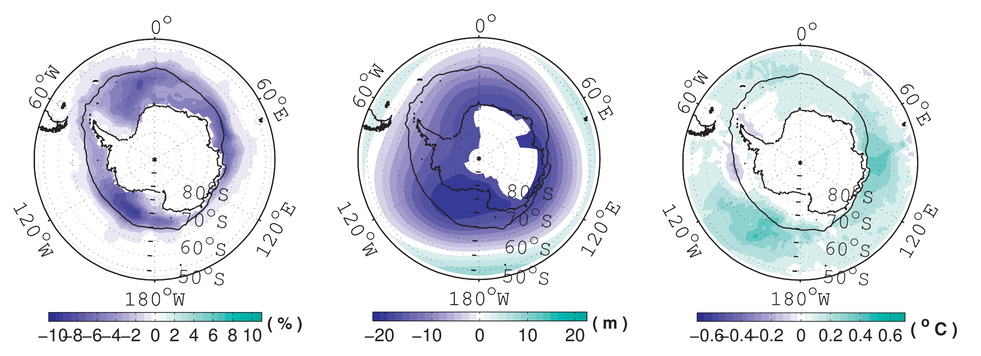

Fig. 2. Spatial patterns of leading mode of annual mean **(left panel) sea ice concentration (SIC)** anomalies [12.9% variance] **(center panel) geo-potential height (GPH)** anomalies at 700 hPa [31.3% variance] and **(right panel)** SST [13.3% variance] anomalies from CFES. The black line indicates the mean SIE of the model.

- Coupled relation [low/high SST corresponding to negative/positve SAM leads to increased/decreased SIC] qualitatively similar to observations seen in model as well.
- Similar quantitative relation can also be observed with 1^oC change in circumpolar SST causes 1.4^o extension/retreat of SIE in model and 0.4^o in observations.

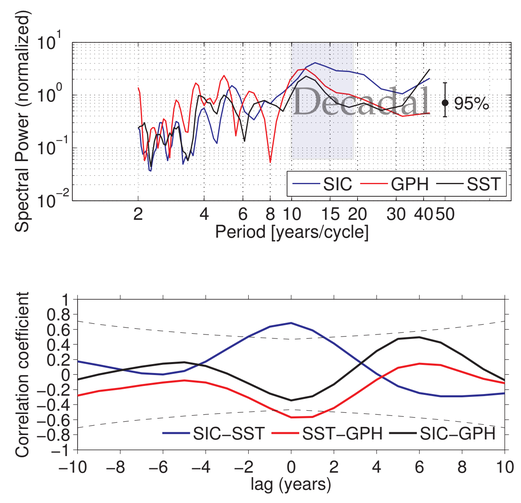

Fig. 3. **(top panel)** Power spectrum of the principal components of first modes. **(bottom panel)** Lagged correlation between the 5 year RA principal components of the first modes of SIC and SST (blue line)[r = 0.69 at 0 lag], SST and GPH (red line)[r = -0.57 at 0 lag] and SIC and GPH (black)[r = -0.35 at 0 lag]. The dotted line indicates the 95% confidence limit.

Mechanism of decadal variability from the model

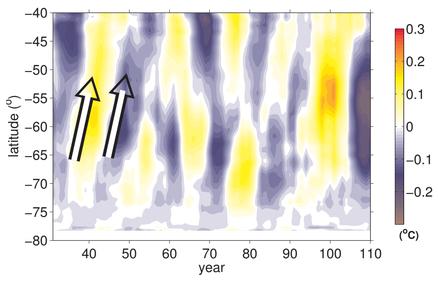

Fig. 4. Latitude-time diagram of zonal mean of **mixed layer temperature (MLT)** (7-21 years band passed RA filter).

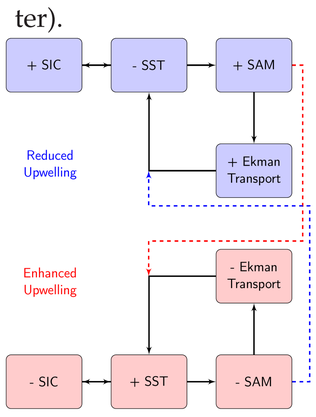

Fig. 6. Schematic on the role of ocean in setting the decadal time scale of the coulpled variability of sea ice–ocean–atmosphere system.

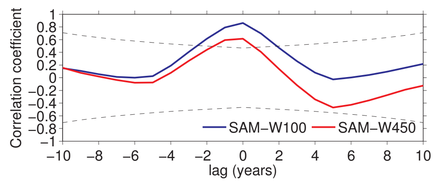

Fig. 5. Lagged correlation between the principal component time series (5 RA) of the first modes of GPH and **oceanic vertical velocity (W)** at 100 m (blue line)[r = 0.86 at 0 lag] and GPH and W at 450 m (red line)[r = 0.78 at 0 lag].

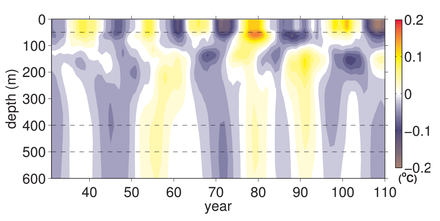

Fig. 6. Temporal distribution of zonally averaged vertical oceanic temperature (7-21 years band passed RA filter) anomaly (^oC) at 65^oS.

- Zonal MLT anomaly has a decadal periodicity of 12-14 years (Fig. 4). The equatorward propagation speed (0.45 km/day) roughly corresponds mean meridional ocean surface velocity (0.59 km/day).
- SAM has its influence at the subsurface depths (Fig. 5).
- The temperature anomalies at 65^oS (corresponding to highest upwelling area) advects upwards indicating an upwelling signal (Fig.6) and the time scale of upwelling from 400-500m (depth of temperature maximum) at mean vertical velocity of 24.8 m/yr is 14-18 years.