Southern Ocean decadal climate variability and predictability in GFDL CM2.1 model

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Outline

1. Models show substantial multi-decadal to centennial variability in the Southern Ocean (SO)

2. This variability appears highly predictable

    2.1 Potential predictability estimated from control simulations

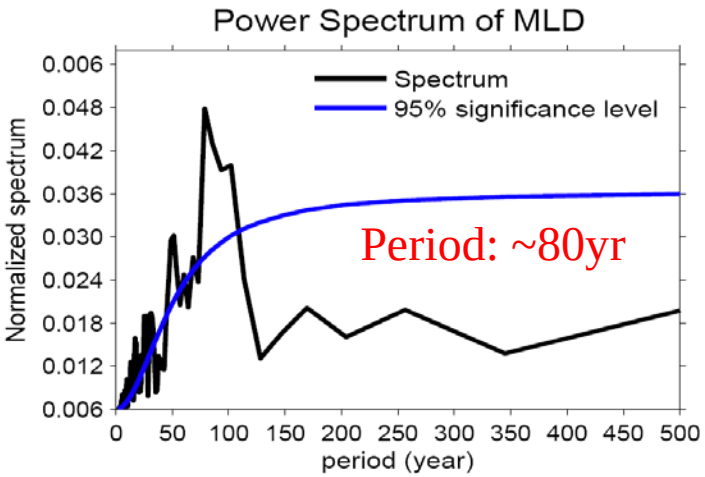
    2.2 Predictability estimated from perfect model experiments

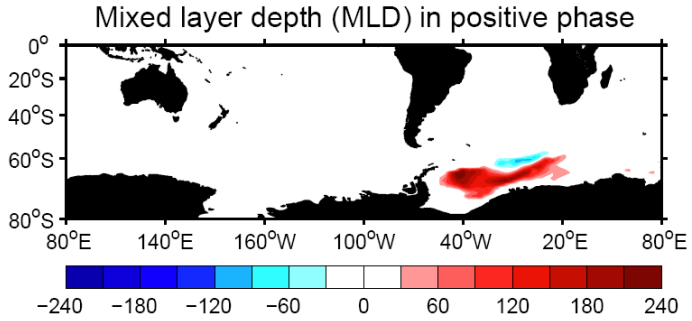
    2.3 Retrospective forecasts from observed data

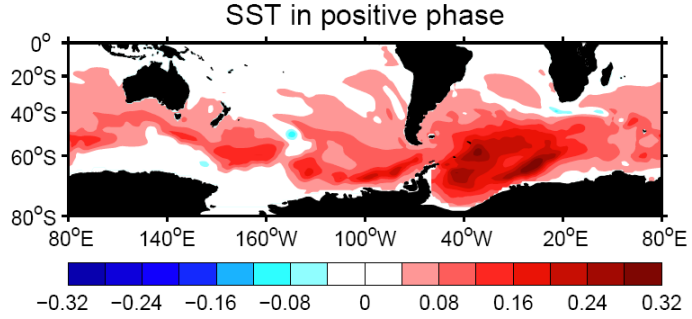
3. Model bias and observational limitations are sources of uncertainty

Low frequency climate variability over the Southern Ocean (SO)

Weddell Sea deep convection



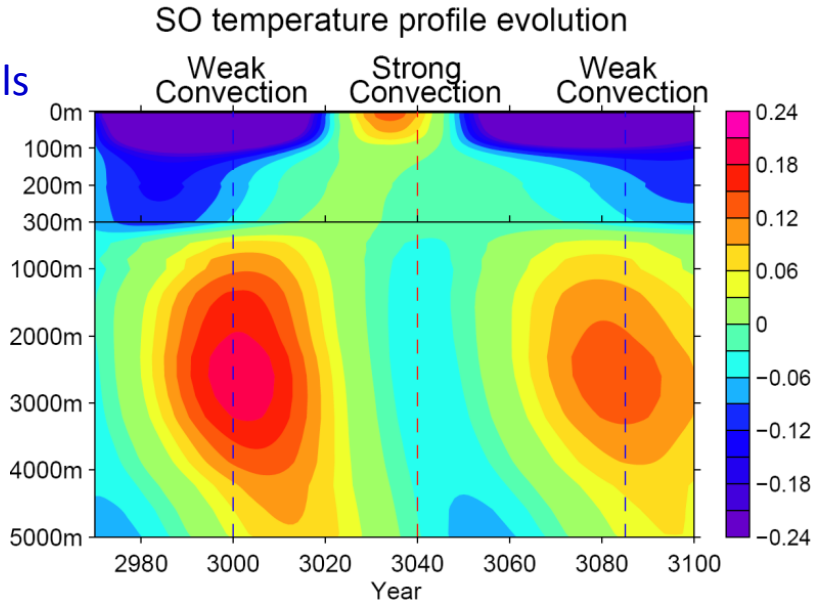


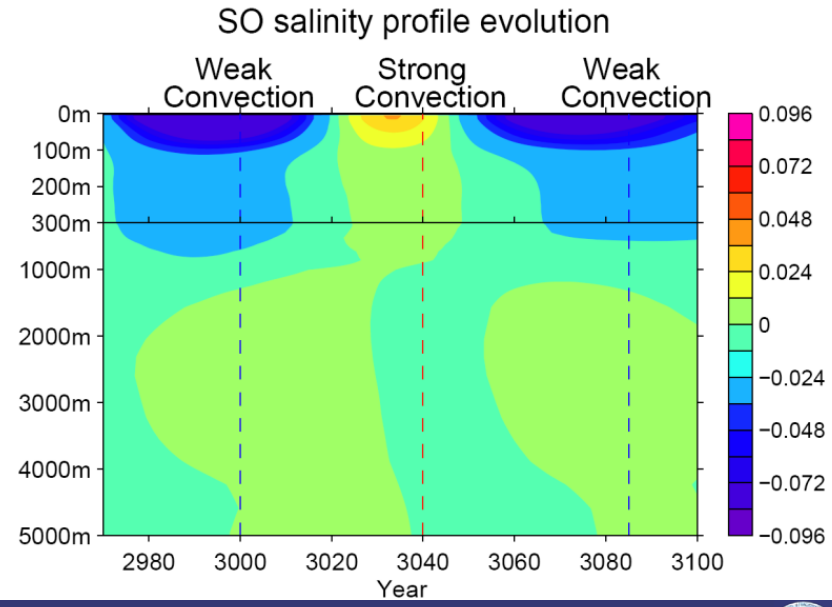


Physical controls of convection

Subsurface heat build up leads to strong convection

Surface freshening weakens convection

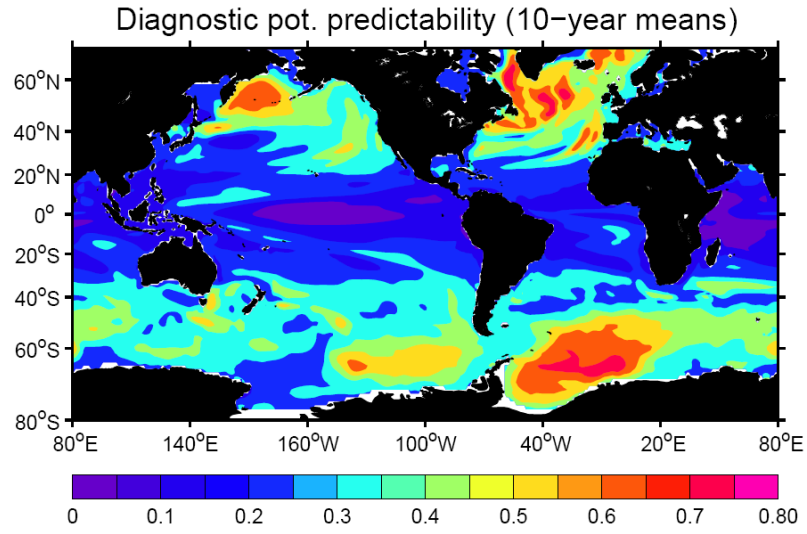




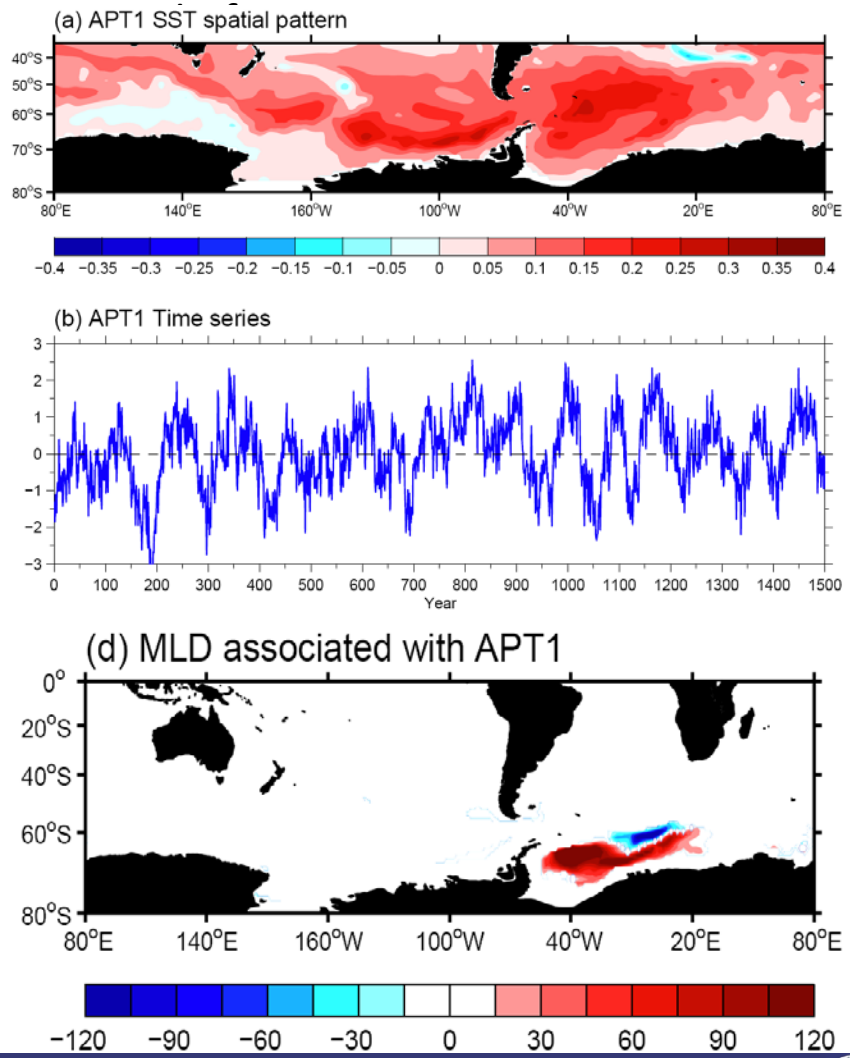
Zhang and Delworth 2016 JGR-ocean; Zhang et al. 2017a, J.Clim

Statistical diagnosis of SO SST predictability in CM2.1 long term control run

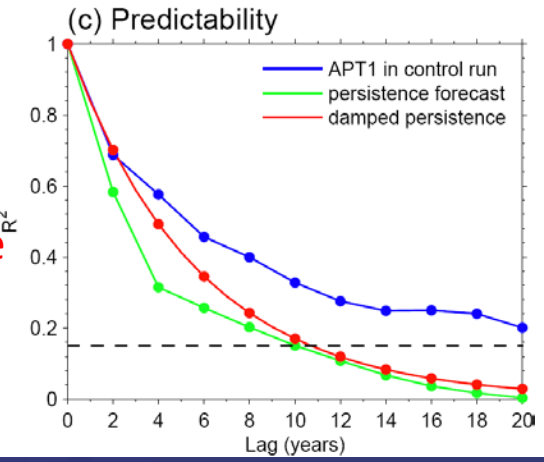
Potential predictability: Low frequency variance is divided by total variance



Average predictability time (APT) method, similar to EOF, but decompose predictability



The most predictable pattern is closely related to the mature phase of SO deep convection



Zhang et al. 2017a, J.Clim

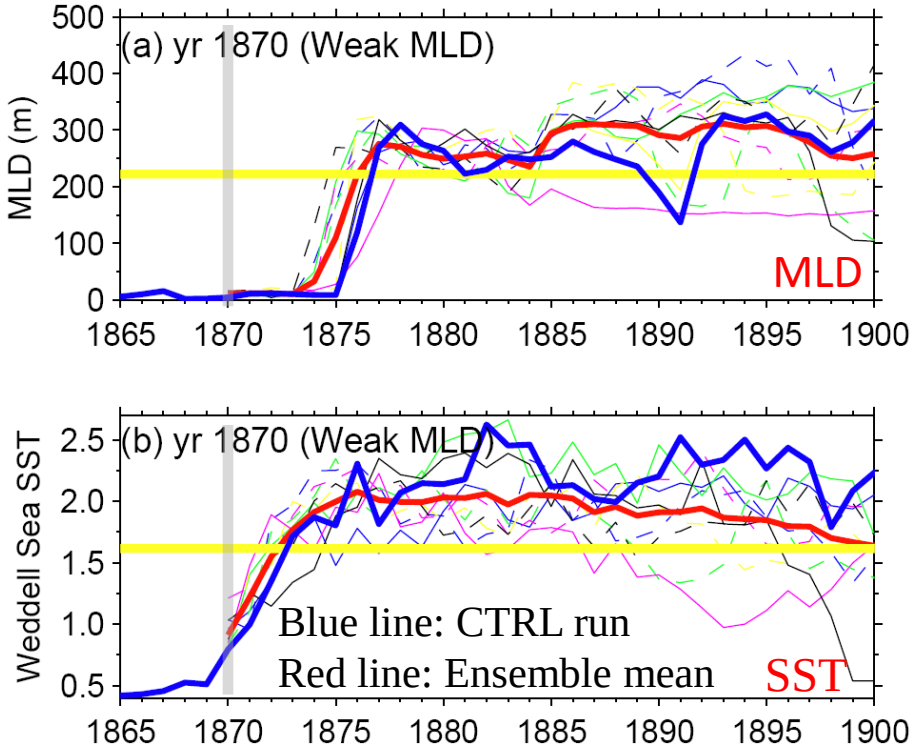
Southern Ocean decadal predictability in "Perfect model" experiments

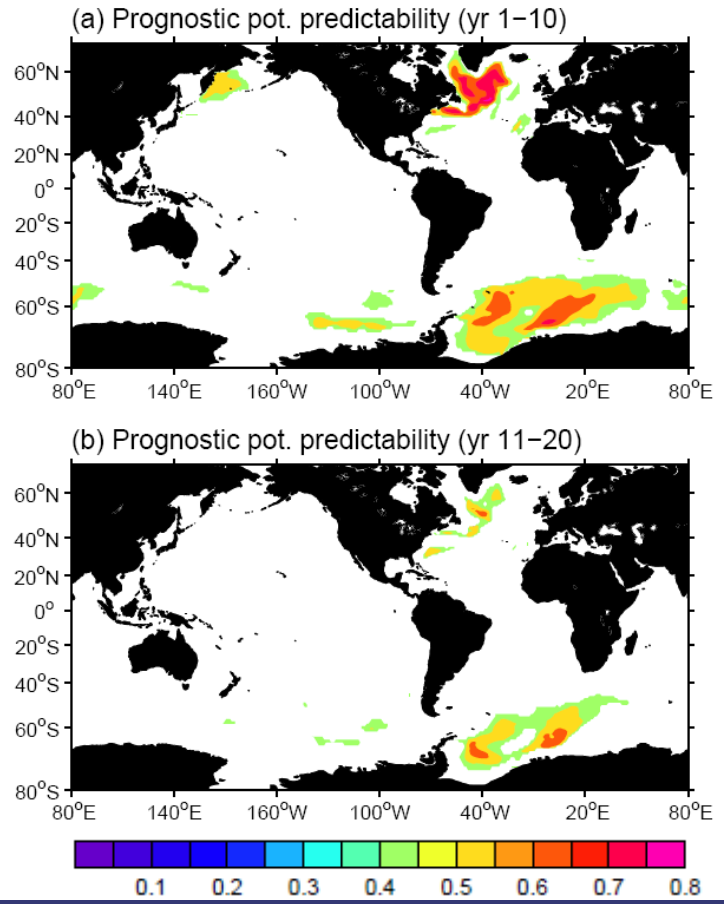
"Perfect Model" predictability run:
Each ensemble consists of ten members with perturbed atmospheric states but with the same oceanic initial conditions. Each run integrates forward for 30 years.

Ensemble spread can be interpreted as the predictability skill

Prognostic potential Predictability (PPP)
Large PPP value means small ensemble spread and high predictability

Case: Year 1870



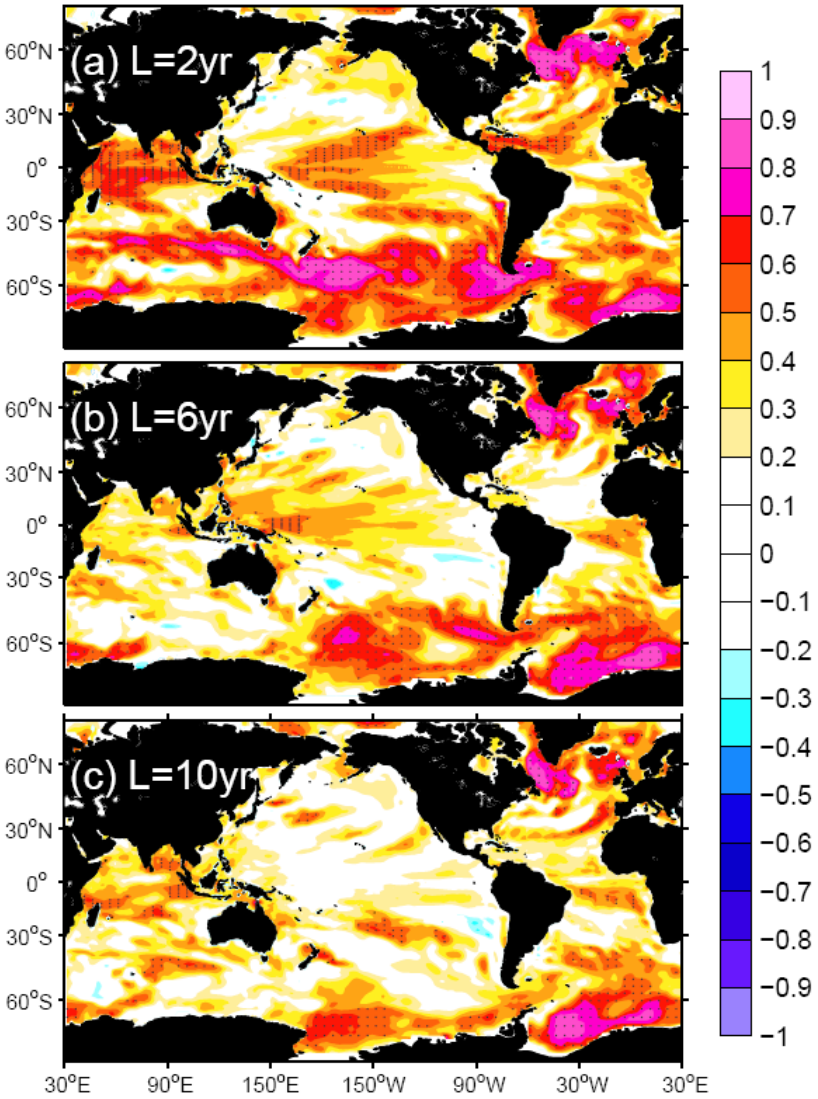


SST Spatial Pattern of PPP averaged in lead yr 1-10 and yr 11-20

Zhang et al. 2017b, J.Clim

Southern Ocean SST prediction skill in decadal hindcasts/forecasts initialized from ECDA

SST Correlation: hindcast data VS ECDA

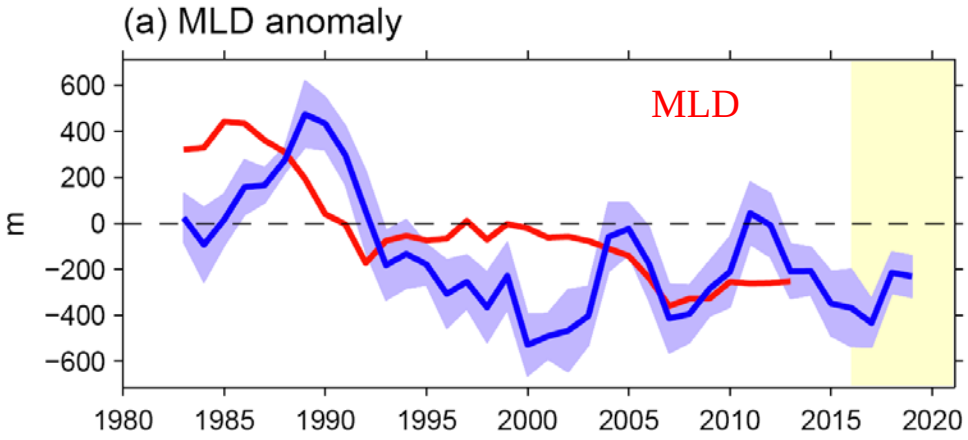


The success of SST prediction over the SO appears related to initialization of the SO deep convection internal variability into the model

Blue line: lead 1-10yr mean Hindcast/forecast (shading is ensemble spread)

Red line: ECDA

Yellow: forecast period



Sparse observations over the Southern Ocean create large uncertainties in prediction

Zhang et al. 2017b, J.Clim

Conclusion and Caveats

Summary:

- In the CM2.1 model, deep convection over the Southern Ocean (SO) has multi-decadal fluctuations on a ~80-yr time scale
- Slow variability, especially subsurface, leads to decadal predictability of SO SST
- Hindcast success related to initialization of the strength of SO deep convection

Caveats:

- Sparse observation
- model physics, especially ocean model (e.g., bias, mean state) and resolution
- Time scale of deep convection variability