Low-Frequency SST Variability in the Southern Ocean

Gang Wang, Dietmar Dommenger and Claudia Frauen
Monash Weather and Climate, Monash University, Clayton VIC, Australia
gang.wang@monash.edu

Motivation
- Possibly long-term variability on decadal and longer scale exists in the Southern Ocean under global warming.
- Knowing the long-term variability in the Southern Ocean is a very important step to understand the climate system in the globe as well as in Australia.

Data and Methodology
- Data
  - CMIP5 pre-industrial results (10 models * 500 years)
  - Variable: Sea Surface Temperature (SST)
- Method
  - EOF Pattern Comparisons
- Numerical Experiments
  - No ocean dynamics:
    - Slab Ocean Model (ACCESS) 200 years
    - Fixed Mixed Layer Depth 50m
    - N48 (2.5°x2.5°)
  - No atmospheric dynamics:
    - CMIP Run (HYCOM) 1000 years
      - 2.5°x2.5° vertical 22 layers with climatological forcing

Model Evaluation
- Lack of in-situ observations
- Inconsistency between CMIP models and “observed” datasets

Result – Spectrum
- Divide the spectrum of each grid into two parts, and see the integral percentage of the low-frequency part (period>10yrs)
- Long-term variability dominates the Southern Ocean
- Slab Ocean (50m) cannot capture the spatial structure of long-term variation

Result – Leading Modes
- Monthly Mean
- Annual Mean
- 5yr Low-pass
- Spectrum
- Fig 5 Leading three EOF modes of CMIP models on different time scales. The spectrum is based on the annual mean analysis.
  - EOF-1 Annuar mode
  - EOF-2 3 waves Monopole
  - EOF-3 Dipole in South Pacific
  - Decadal peaks on EOF-2 and EOF-3

Mode 1 - Annuar Mode
- Different factors in Pacific and Indo-Atlantic
  - EOF Time series regression/reconstruction
  \[ H_s = a_1 t + b_1 \text{Nino}3.4 + y + b_2 \text{SAM} + f \]
- Pacific: SAM + strong ENSO influence
- Indo-Atlantic: SAM influence

Mode 2 - Monopole
- Transformation from wave-3 structure to monopole with the increase of eigenvalue as time scale gets longer
- Wave-3 anomalies from the atmosphere
  - Fig 7 Monopole EOF mode on different time scales
- Wave-3 pattern on surface air temperature EOF-1. Right: Correlation between the surface air temperature PC1 and SST PC2 time series.

Mode 3 – South Pacific Dipole
- Local mode within South Pacific
- Mechanism:
  - Atmosphere–inductor: Similar patterns in the importers and Slab Ocean
  - Ocean–capacitor: It keeps the long-term variability in the ocean (spit)

Discussion
- Role of Mixed Layer Depth (MLD)
  - MLD affects the distribution of long-term variation
- Ocean dynamics influences the structure of modes
  - No significant changes of modes from 50m slab to real MLD without ocean dynamics. The structures of modes CANNOT be captured even with the real MLD (see Fig 12).

Summary
- Several long-term modes are discussed in the Southern Ocean

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