SOUTHERN OCEAN OPEN-SEA CONVECTION AND TELECONNECTIONS

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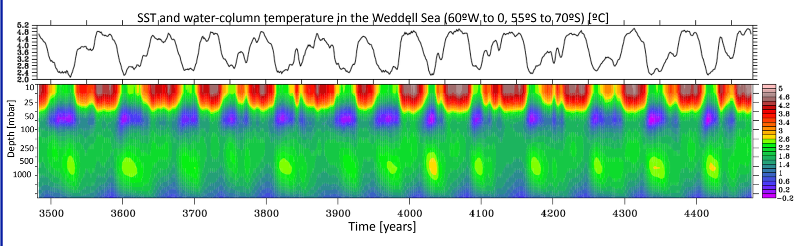
Purpose:
To study atmospheric and oceanic teleconnections created by open-ocean convectve events in the Southern Ocean

1. Abstract

• Most CMIP5 (The fifth phase of the Coupled Model Intercomparison Project) models, under preindustrial forcing, show periodic Southern Ocean (SO) open sea convection (*de Lavergne et al., 2014).* Models show a wide distribution in the spatial extent, periodicity and intensity of SO convection. Across all convective models, SO convection shuts down following climate warming before year 2100 (*de Lavergne et al., 2014), due to local warming and freshening.* ***Here we explore the implications of the SO convective mechanism, and its shutdown, for the global climate.***

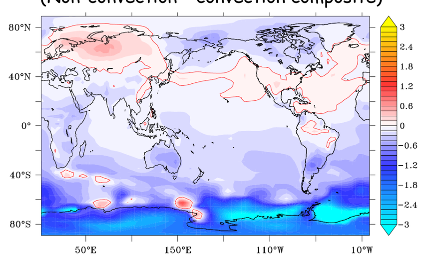
• We show that in a convective coupled model, Weddell Sea convection drives multidecadal variability in both SO and global SSTs: convective decades are warm, due to heat released from the deep SO; and non-convective decades are cold, due to subsurface storage of heat.

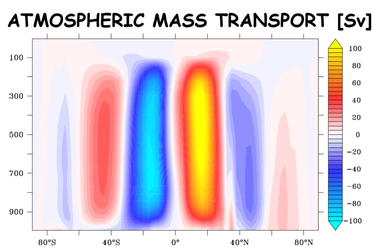


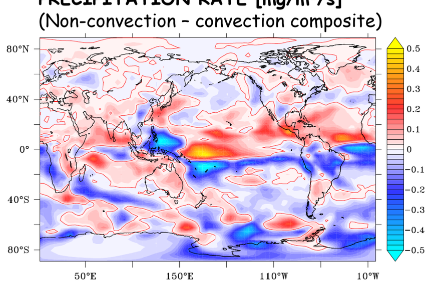
• SO convection pulses drive SST and sea ice variations, influencing absorbed shortwave (SW) and emitted longwave (LW) radiation, wind, ocean surface fluxes, cloud and precipitation patterns, with climatic implications for the low latitudes via fast atmospheric teleconnections and slower oceanic mechanisms.

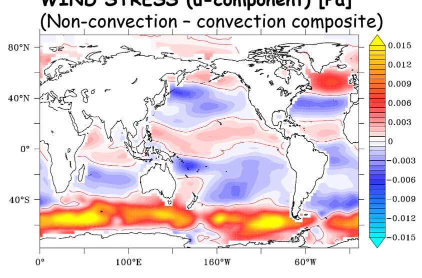
All simulations were carried out using CM2Mc (*Bernardello et al., 2014; Galbraith et al., 2011), a version* of the Geophysical Fluid Dynamics Laboratory Climate Model version 2 (GFDL CM2) with Modular Ocean Model version 4p1 (MOM4p1) at three-degree resolution.

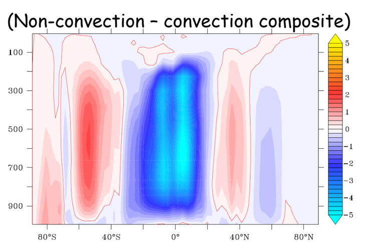
2. Motivation

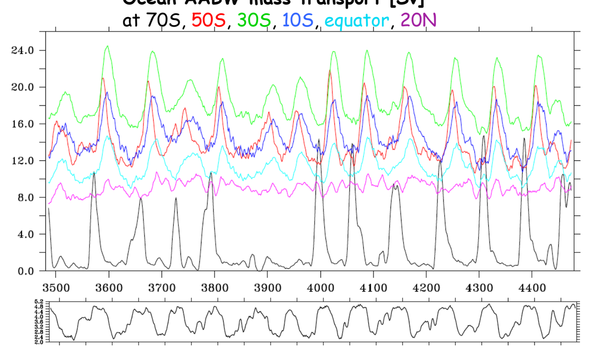






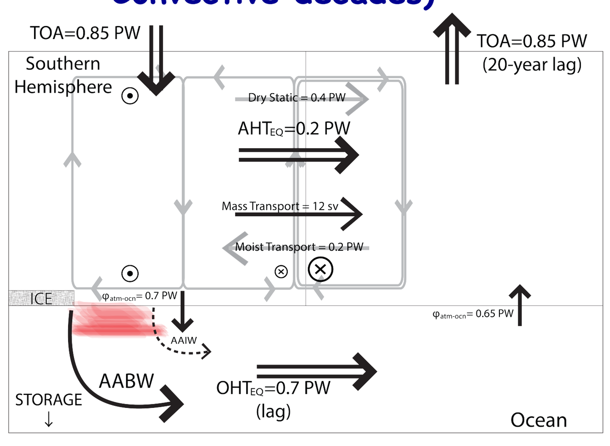




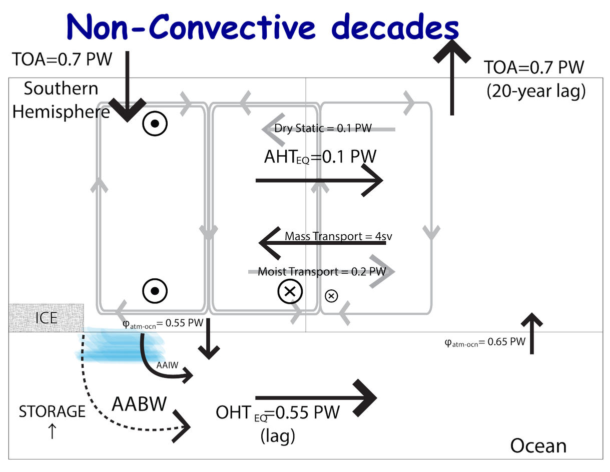


Non-convective decades → cold, intensified SH Ferrel Cell (strong Southern Ocean Westerlies), intensified SH Hadley cell (strong tropical SH trade winds), weakened NH Hadley cell (weak tropical NH trade winds) increased precipitation NH, weak AABW mass transport

Convective decades)

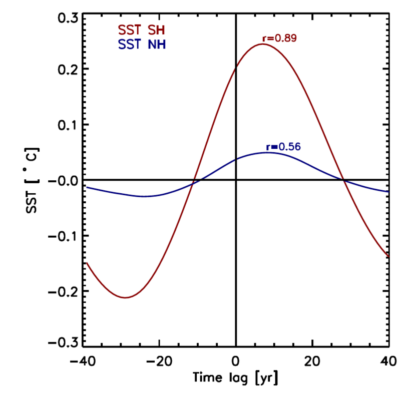


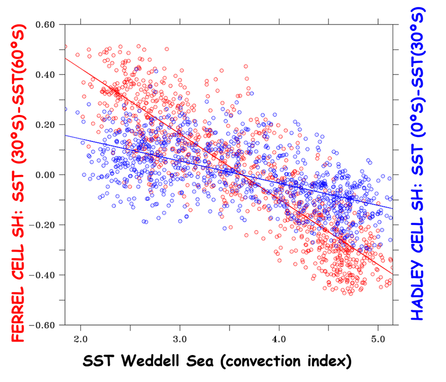
Non-Convective decades



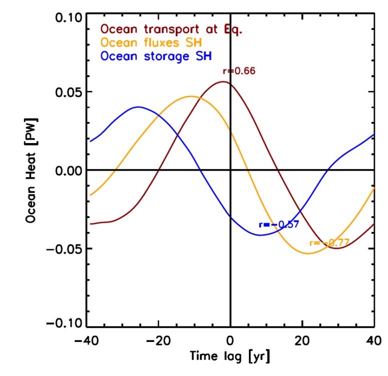
3. Mechanisms

a) Linear regression between convective index (normalized SST Weddel Sea) and SH SST with different lags shows peak in SH SST 8 years after peak in convective event (and lower peak in NH SST)

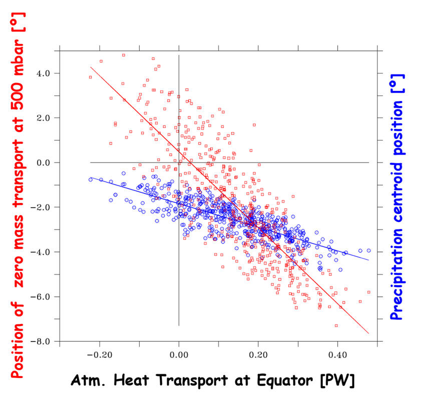




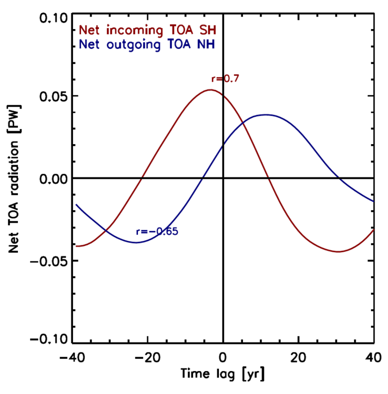
b) Larger convection weaker SH Ferrel Cell (weaker westerlies) and weaker SH Hadley Cell (weaker trade winds)

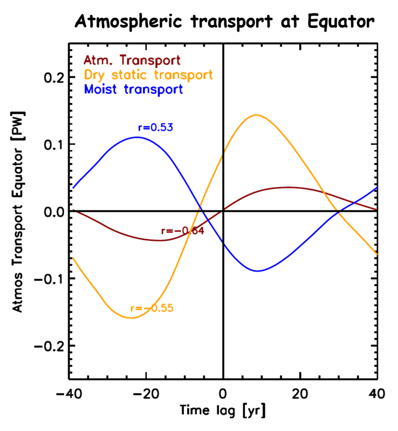


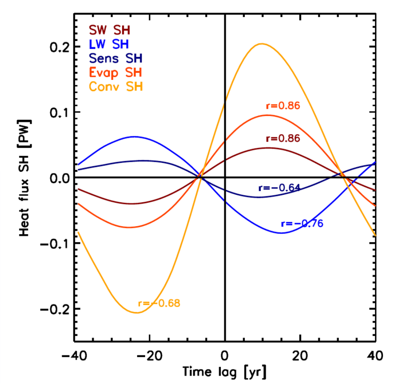
f) Ocean transport at Equator is responsible for transfer of energy from SH to NH.



c) Larger convection results in ice melting, increased SH incoming Shortwave and net TOA radiation and increased NH outgoing TOA radiation. How is energy transported from SH to NH?







d) Larger convection increases dry static transport at the Equator (upper cell) towards NH, increases moist transport at the Equator towards SH. Total atmos transport increases due to evaporation heat and SW heat, but decreases due to Sensible heat and LW heat.

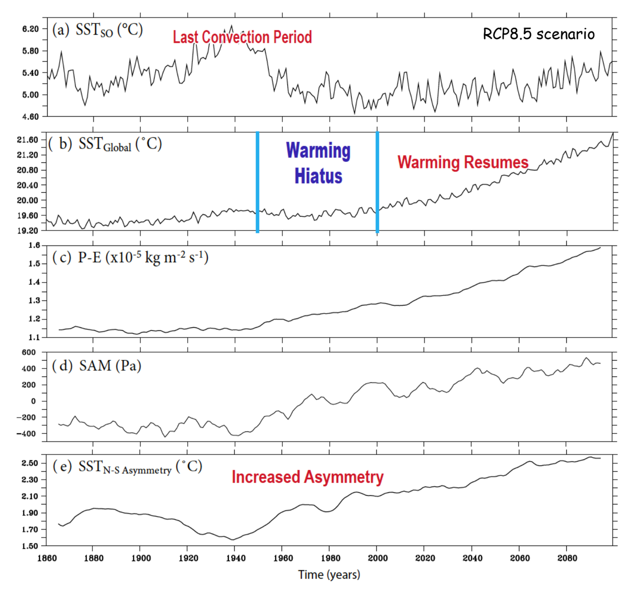
e) Increased atm. Transport at Equator, southward shift of tropical precipitation and Hadley Cell.

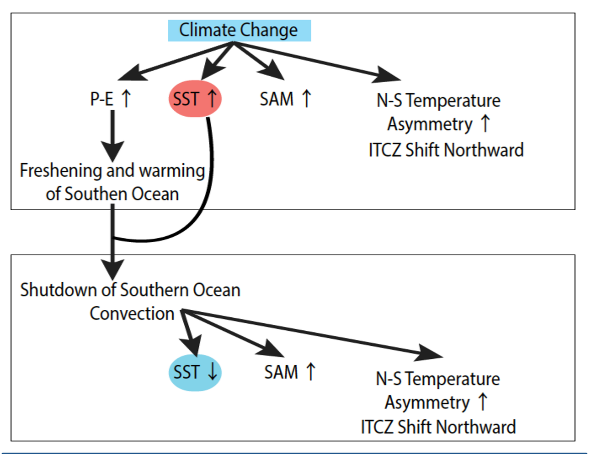
$$\nabla\cdot F_{ATMOS} = \Phi_{SW} + \Phi_{LW} + L\cdot E + \Phi_{SENS} \quad (W/m^2)$$

$$\nabla\cdot F_{DRY} = \Phi_{SW} + \Phi_{LW} + L\cdot P + \Phi_{SENS} \quad (W/m^2)$$

$$\nabla\cdot F_{MOIST} = L\cdot (E-P) \quad (W/m^2)$$

4. Climate change consequences





We propose that Intensity of Convection in the control (preindustrial) state determines sensitivity of the SO to climate change:
Highly convective models compared to non-convective models:
• are warmer to start with
• experience shutdown of convection by year 2100
• this shutdown acts against global warming to cool temporarily the SO → less net warming in SO temperatures over the 21st century.
• Shutdown of SO convection happens in the model around 1950 and acts against global warming to cool temporarily the SO, which results in temporary "hiatus" in the global SST increase
• SO westerlies intensify throughout the hiatus period
• SAM intensifies
• N-S temperature asymmetry intensifies

References:

• Bernardello, R., I. Marinov, J. B. Palter, E. D. Galbraith, and J. L. Sarmiento (2014), Impact of Weddell Sea deep convection on natural and anthropogenic carbon in a climate model, Geophys. Res. Lett., doi:10.1002/(ISSN)1944-8007.
• de Lavergne, C., J. B. Palter, E. D. Galbraith, R. Bernardello, and I. Marinov (2014), Cessation of deep convection in the open Southern Ocean under anthropogenic climate change, Nature Climate Change, 4(4), 278–282, doi:10.1038/nclimate2132.
• Galbraith, E. D. et al. (2011), Climate Variability and Radiocarbon in the CM2Mc Earth System Model, J. Climate, 24(16), 4230–4254, doi:10.1175/2011JCLI3919.1.