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The Leading Modes of Decadal SST Variability in the Southern Ocean in CMIP5 Simulations

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The leading modes of Sea Surface Temperature (SST) variability in the Southern Ocean on decadal and even larger time scales are analysed using Coupled Model Intercomparison Project 5 (CMIP5) model simulations and observations. We compare the modes from the CMIP5 super ensemble against several simple null hypotheses, such as isotropic diffusion (red noise) and a Slab Ocean model, to investigate the sources of decadal variability and the physical processes affecting the characteristics of the modes. The results show three main modes in the Southern Ocean: the first and most dominant mode on interannual to decadal time scales is an annular mode with largest amplitudes in the Pacific, which is strongly related to atmospheric forcing by the Southern Annular Mode (SAM) and El Nino Southern Oscillation (ENSO). The second mode is an almost basin wide monopole pattern, which has pronounced multi-decadal and longer time scales variability. It is firstly inducted by the Wave-3 patterns in the atmosphere and further developed via ocean dynamics. The third mode is a dipole pattern in the southern Pacific that has a pronounced peak in the power spectrum at multi-decadal time scales. All three leading modes found in the CMIP5 super model have distinct patterns and time scale behaviour that can not be explained by simple stochastic null hypothesis, thus all three leading modes are ocean-atmospheric coupled modes and are likely to be substantially influenced or driven by ocean dynamical processes.

The mechanism of the basin-wide mode is further analysed based on a series of idealized experiments. The results show that the monopole mode has a two-step power spectrum, with a first spectral increase on interannual time scale and a second higher up level on the multi-decadal to centennial time scales. Ocean dynamics, especially the ocean advection, transport the anomalous signals, connect the entire ocean and lead to the homogeneous-like spatial pattern even under stochastic atmospheric forcing. The ocean advection is also one key factor to create the specific structure of SST power spectrum, which concentrates the variability on interannnual scale synchronizing with the transport of Antarctic Circumpolar Current (ACC).