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Modeling low frequency climate variability

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The observed inter-annual variability of the near surface temperature is continuous, showing a power law spectrum f^{-b} with exponents b depending on location and timescale. Up to centuries long-term memory is found ($b = 0.3 - 0.6$) and beyond this timescale nonstationary behavior ($b > 1$) is observed (Huybers and Curry, 2006). Northern Hemispheric mean temperatures during the last 2k years (reconstructed by Moberg et al., 2005) indicate $b = 0.7$. Ice cores show exponents reaching $b = 2$ during ice ages. On decadal timescales instrumental observations reveal a white spectrum on the inner continents ($b = 0$) and values up to $b = 1$ over the North Atlantic Ocean. In contrast, surface pressure and precipitation are without memory beyond months. A standard tool for the analysis of low frequency variability is the Detrended Fluctuation Analysis (DFA, Peng et al., 1994).

The simulated long-term memory in complex Atmosphere Ocean GCMs agrees with the available observations; coupling of a mixed layer ocean model to an atmospheric GCM is not sufficient. Regions of long-term SST memory with scaling up to centuries are the Northern Atlantic ($b = 1$, confirmed by observations) and the Antarctic Ocean ($b = 1.3$), whereas the Pacific Ocean lacks long-term variability. Trends as in scenario simulations do not affect the underlying low frequency variability.

An ultra-long simulation (10k years) is performed with the coupled CSIRO atmosphere-ocean model under present-day conditions. The spectra found for the sea surface temperature spectrum southwest of Greenland and the GISP2 and GRIP δ^{18}O records during the Holocene reveal quantitative agreement ($b = 0.4 - 0.7$). The SST variability in the North Atlantic is related to the intense low frequency variability of the meridional overturning circulation (MOC). In the Pacific and the Antarctic Ocean the SST shows no long-term memory. External volcanic or solar forcing is not required to simulate the observed spectrum. A conceptual ocean energy balance model

with vertical heat diffusion is able to explain the SST spectrum in parts of the global ocean and suggests bounds for the deep sea heat diffusion coefficient.