Internal multidecadal and multicentennial variability in the Kiel Climate Model: dynamics and impacts

Mojib Latif, Wonsun Park, Torge Martin

GEOMAR

Internal climate variability on longer time scale should be considered in addition to external forcing when discussing the climate of the next decades. We present multidecadal and multicentennial variability simulated in multi-millennial long control simulations with the Kiel Climate Model (Park et al. 2009) that consists of ECHAM5 atmosphere and NEMO ocean-sea ice general circulation models coupled via OASIS3 coupler.

• Multidecadal variability of the Atlantic Meridional Overturning Circulation (AMOC) originates in the North Atlantic and is associated with the Atlantic Multidecadal Variability (AMV). (Figs. 1, 2)

• Multicentennial variability is related to a quasi-oscillatory mode driven in the Southern Ocean. The deep convection in the Weddell Sea is important in terms of the built-up of heat at mid-depth and depletion of the heat during a convective regime. (Figs. 1, 3, 4)

• The quasi-periodic occurrence of the deep convection causes variations in regional and global climates. (Fig. 5)

Rich spectrum in the Atlantic Meridional Overturning Circulation

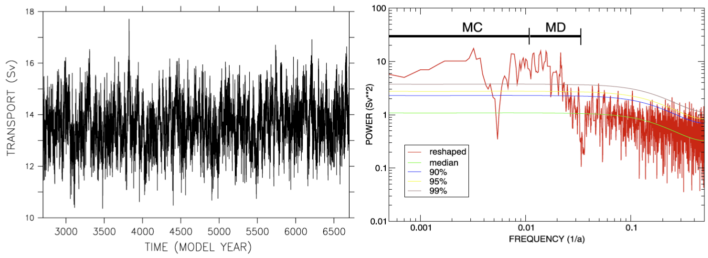

Figure 1: Unforced control integration with the Kiel Climate Model (KCM) provides rich spectrum of the Atlantic Meridional Overturning Circulation (AMOC): (left) Timeseries of the AMOC strength [Sv] defined as the maximum stream function at 30°N and (right) power spectrum of the AMOC strength [Sv^2] as function of frequency [1/a]. The multicentennial (MC) and multidecadal bands (MD) are denoted by horizontal lines. (from Park and Latif 2008).

Atlantic Multidecadal Variability

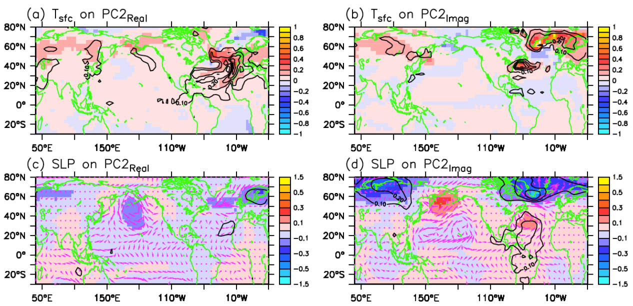

Figure 2: Atlantic Multidecadal Variability (AMV) is identified as one of the leading Principal Orthogonal Pattern (POP) modes of band-pass (30–90 years) filtered annual SST anomalies over the North Pacific and North Atlantic Oceans. Shown are the regression patterns (color) and explained variances (contour) with respect to the POP mode of (a, b) surface temperature [°C], (c, d) sea level pressure [hPa] and wind stress [Pa]. (from Park and Latif 2010)

Mechanism of the multicentennial variability

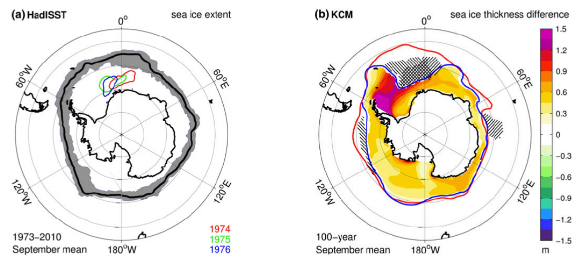

Figure 3: Weddell Sea convection is a key in the generation of the multicentennial variability in the KCM: (a) The mean observed September sea ice extent (HadISST, Rayner et al. 2003, black line) in the Southern Ocean and its maximum meridional shift (gray shaded area) for the period 1973–2010. The extent is calculated based on a 15 % ice concentration threshold. Colored lines indicate the location and extent of the Weddell Polynya during years 1974–1976 based on a 75 % ice concentration threshold. (b) Sea ice thickness differences between two model simulations (EXP–REF, colored shading) and mean state September sea ice extent from REF (blue line) and EXP (red line). Hatched areas mark regions of open ocean deep convection (REF left tilted from vertical, EXP right tilted). REF and EXP differ only in a sea ice parameter. (from Martin et al. 2013)

Impacts of the multicentennial variability

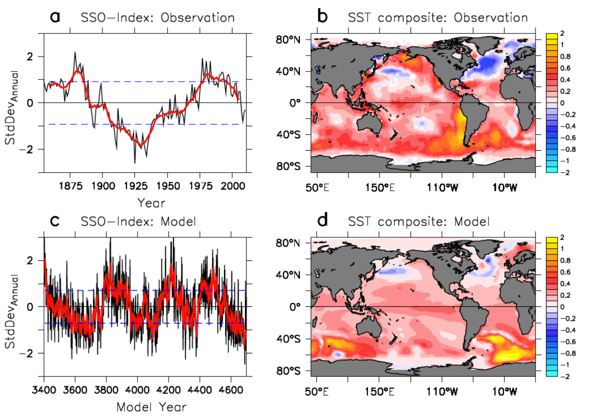

Figure 5: The Southern Ocean sea surface temperature (SST) depicts strong centennial variability in both the observations (a, b; 1854-2010, ERSSTv3b) and the KCM simulation (c, d; 1,300years). (a, c) The SSO index which is defined by the annual SST anomalies zonally averaged over the latitude band 50°S-70°S, de-trended and normalized by the long-term standard deviation. (b, d) SST composite pattern (°C, high-low) associated to the SSO index using the thresholds shown as dashed blue lines in (a) and (c). The thresholds are defined as plus and minus one standard deviation of the 11-year running mean-filtered SSO index which are shown as red bold lines. (from Latif et al. 2013)

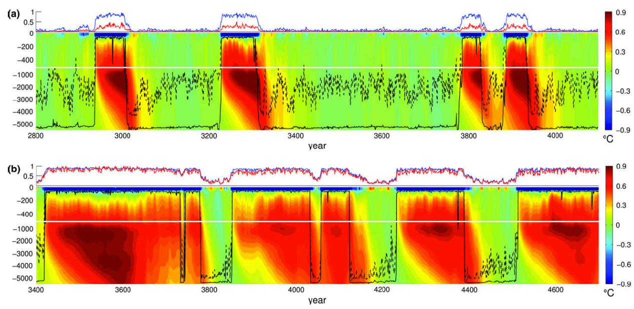

Figure 4: Heat accumulation in the mid-depth is important in the state of the convection: Hovmoeller diagrams of annual mean oceanic potential temperature anomalies averaged over the convection region in the Weddell Sea for (a) REF and (b) EXP. Anomalies are calculated as deviation from a 100-year mean vertical profile of potential temperature during active convection for each experiment. Time series of September mean mixed layer depth (MLD) are shown for the median (dashed black line) and maximum depths (solid black line) in the Weddell Sea convection region. Additionally, time series of September mean sea ice thickness (red line) and ice concentration, i.e. ice covered area fraction (blue) for the convection region are shown at the top of each panel. Note: the y-axis scale changes at 0 and -500 m. Negative numbers on the y-axis are depth in m; positive numbers are ice thickness (in m) and ice concentration (1 = 100 %) (from Martin et al. 2013)

THOR

References

• Park, W. and Latif, M. (2008) Multidecadal and Multicentennial Variability of the Meridional Overturning CirculationGeophysical Research Letters, 35 . L22703. DOI 10.1029/2008GL035779.
• Park, W., Keenlyside, N., Latif, M., Ströh, A., Redler, R., Roeckner, E. and Madec, G. (2009) Tropical Pacific climate and its response to global warming in the Kiel Climate Model Journal of Climate, 22 . pp. 71-92. DOI 10.1175/2008JCLI2261.1.
• Park, W. and Latif, M. (2010) Pacific and Atlantic Multidecadal Variability in the Kiel Climate Model Geophysical Research Letters, 37 . L24702. DOI 10.1029/2010GL045560.
• Martin, T., Park, W. and Latif, M. (2013) Multi-Centennial Variability Controlled by Southern Ocean Convection in the Kiel Climate Model Climate Dynamics . DOI 10.1007/s00382-012-1586-7.
• Latif, M., Martin, T., and Park, W. (2013) Southern Ocean Sector Centennial Climate Variability: Dynamics and Implications for Recent Decadal Trends. Joural of Climate. in Review

HELMHOLTZ GEMEINSCHAFT