



Space-time structure of climate variability

Thomas Laepple (1), Maria Reschke (1), Peter Huybers (2), Kira Rehfeld (1), and the ACER SST Team

(1) Alfred-Wegener-Institut, Helmholtz Centre for Polar and Marine Research, Helmholtz Young Investigators Group ECUS, Potsdam, Germany (tlaepple@awi.de), (2) Earth and Planetary Sciences, Harvard University, Cambridge MA, USA

The spatial scale of climate variability is closely linked to the temporal scale. Whereas fast variations such as weather are regional, glacial-interglacial cycles appear to be globally coherent. Quantifying the relationship between local and large-scale climate variations is essential for mapping the extent of past climate changes.

Larger spatial scales of climate variations on longer time scales are expected if one views the atmosphere and oceans as primarily diffusive with respect to heat. On the other hand, the interaction of a dynamical system with spatially variable boundary conditions — for example: topography, gradients in insolation, and variations in rotational effects — will lead to spatially heterogeneous structures that are largely independent of time scale. It has been argued that the increase in spatial scales continues across all time scales [Mitchell, 1976], but up to now, the space-time structure of variations beyond the decadal scale is basically unexplored.

Here, we attempt to estimate the spatial extent of temperature changes up to millennial time-scales using instrumental observations, paleo-observations and climate model simulations. Although instrumental and climate model data show an increase in spatial scale towards slower variations, paleo-proxy data, if interpreted as temperature signals, lead to ambiguous results. An analysis of a global Holocene stack [Marcott et al., 2013], for example, suggests a jump towards more localized patterns when leaving the instrumental time scale. Localization contradicts physical expectations and may instead reflect the presence of various types of noise.

Turning the problem around, and imposing a consistent space-time structure across instruments and proxy records allows us to constrain the interpretation of the climate signal in proxy records. In the case of the Holocene stack, preliminary results suggest that the time-uncertainty on the Holocene records would have to be much larger than published in order to achieve consistency in the spatial structure. Such a finding, if it holds, has implications for regional and global temperature reconstructions. Ultimately, more complete knowledge of space-time scaling should improve physical understanding of climate variability and allow for better use of the paleoclimate record to map past variations.