Memory effects in the socio-climatic response

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Analysis of climatic time series, in particular of instrumental and proxy-reconstructed global temperatures, show that they are well described as persistent fractional Gaussian noises with spectral exponents $\beta \approx 1$. Global circulation climate models also exhibit this long-range memory on time scales up to several centuries, if the ocean component of the model involves heat exchange between the mixed surface layer and the deep ocean. Ocean models that only simulate the mixed layer do not exhibit this scaling on time scales beyond a decade, so it seems reasonable to assume that the main memory effect is associated with the large thermal inertia of the deep ocean. During the historic period with large anthropogenic climate forcing we have observed an increasing radiative energy imbalance with accumulation of heat in the deep water masses and a relatively weak warming of the surface. Analysis shows that the climate system will continue to accumulate heat for centuries even if the atmospheric CO_2 concentration is stabilized at the present level. The latent "warming in the pipeline" due to these memory effects amounts to an additional degree Celcius for the next hundred years. The memory in the climate response also influences the attribution of historical warming to various components of natural and anthropogenic climate forcing, with higher weight to the anthropogenic component. To investigate the memory impact on future warming, we select idealized scenarios for CO_2 emissions which consist of the present exponential growth which is stabilized at a specific time t_c relative to the present, and then compute the level at which the temperature is finally stabilized as a function of t_c. The same function is also computed for a climate system with no memory in its response. The purpose of this simple exercise is to create a pedagogical tool which connects the physical idea of the climate as a long-memory linear response filter to the consequences of delayed societal action towards mitigation of global warming.

[1] Rypdal, M., and Rypdal, K., *Long-memory effects in linear-response models of Earth's temperature and implications for future global warming.* J. Climate **27**, 5240–5258, (2014).

[2] Rypdal, K., Rypdal, M, and Fredriksen, H.-B., *Spatiotemporal Long-Range Persistence in Earth's Temperature field: Analysis of Stochastic-Diffusive Energy Balance Models*, Submitted to J. Climate (2015).