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Bayesian comparison of conceptual models of abrupt climate changes during the last glacial period

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Records of oxygen isotope ratios and dust concentrations from the North Greenland Ice Core Project (NGRIP) provide accurate proxies for the evolution of Arctic temperature and atmospheric circulation during the last glacial period (12ka to 100ka b2k) [1]. The most distinctive feature of these records are sudden transitions, called Dansgaard-Oeschger (DO) events, during which Arctic temperatures increased by up to 10 K within a few decades. These warming events are consistently followed by more gradual cooling in Antarctica [2]. The physical mechanisms responsible for these transitions and their out-of-phase relationship between the northern and southern hemisphere remain unclear. Substantial evidence hints at variations of the Atlantic Meridional Overturning Circulation as a key mechanism [2,3], but also other mechanisms, such as variations of sea ice extent [4] or ice shelf coverage [5] may play an important role. Here, we intend to shed more light on the relevance of the different mechanisms suggested to explain the abrupt climate changes and their inter-hemispheric coupling. For this purpose, several conceptual differential equation models are developed that represent the suggested physical mechanisms. Optimal parameters for each model candidate are then determined via maximum likelihood estimation with respect to the observed paleoclimatic data. Our approach is thus semi-empirical: While a model's general form is deduced from physical arguments about relevant climatic mechanisms — oceanic and atmospheric — its specific parameters are obtained by training the model on observed data. The distinct model candidates are evaluated by comparing statistical properties of time series simulated with these models to the observed statistics. In particular, Bayesian model selection criteria like Maximum Likelihood Ratio tests are used to obtain a hierarchy of the different candidates in terms of their likelihood, given the observed oxygen isotope and dust time series.

[1] Kindler et al., Clim. Past (2014)
[2] WAIS, Nature (2015)
[3] Henry et al., Science (2016)
[4] Gildor and Tziperman, Phil. Trans. R. Soc. (2003)
[5] Petersen et al., Paleoceanography (2013)