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Perspectives of data assimilation for the climate of the Last Glacial Maximum

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We are convinced that to further advance our understanding of the climate of the Last Glacial Maximum (LGM, 19,000- 23,000 years before present) it is necessary to apply data assimilation techniques to paleo-data and rigorously constrain the uncertainties of models as well as data.

In the traditional ("forward") method, models are tuned to reproduce observations by adjusting a small number of parameters and repeating simulations in an ad-hoc fashion. Although it would be possible to compute an explicit objective function, this is rarely done. There are a number of "inverse" methods that use variational, filtering and statistical techniques to overcome this crude tuning procedure and combine paleo-data with a numerical model in a much more systematic way. In these methods, the model (or even an ensemble of models) is integrated repeatedly and variables that control the solution are adusted to minimize the departure from the data.

For illustration, we used a classical energy balance climate model and applied the so-called "adjoint method" to minimize the misfit between our model and sea-surface temperature data for the Last Glacial Maximum (LGM, 19,000- 23,000 years before present), taken from the Multiproxy Approach for the Reconstruction of the Glacial Ocean surface (MARGO 2009). The "adjoint model" (derivative code) was generated by an "adjoint compiler". We optimized three parameters: the thermal diffusion coefficient, and two constants in the parameterization of the outgoing longwave radiation that are related to the sensitivity to changes in the zonal-mean surface temperature and the atmospheric CO_2 concentration.

Using our simple example, we discuss the benefits as well as the issues of the adjoint method. For example, by computing model sensitivities it may guide observational efforts. However, it is still questionable whether the paleo-data available for the LGM is accurate enough and its coverage sufficient to be useful for our purpose.