Modeling of water stable isotopes in the ECHAM6 atmospheric general circulation model: current status and perspectives

Alexandre CAUQUOIN, Martin WERNER and Gerrit LOHMANN

Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Sciences, Bremerhaven, Germany

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Context and motivation

Water stable isotopes ($H_2{}^{16}O$, $H_2{}^{18}O$, HDO) are well-known tracers of the past and present-day hydrological cycle. A key tool to improve our understanding of water isotopes in the Earth's hydrological cycle are general circulation models (GCMs) with an explicit diagnostics of stable water isotopes. Here we present the first results for present-day conditions of the ongoing implementation of water stables isotopes in the latest version of the ECHAM atmospheric GCM, ECHAM6, enhanced by the JSBACH interactive land surface scheme (ECHAM6-wiso).

This study represents the first step of the incorporation of water stable isotope tracers in all components of the fully coupled Earth system model MPI-ESM. The project is part of the PalMod initiative ("Paleo Modelling: A national paleo climate modelling initiative"), funded by the German Federal Ministry of Education and Science (BMBF).

Methodology: ECHAM6-wiso and data used

For this study, after a spin-up period of 2 years, a control run simulation of 10 years at a T63 horizontal resolution (1.88°) and with 47 vertical layers has been performed. The soil moisture in JSBACH is represented by a single bucket scheme. For the validation of ECHAM6-wiso, we compare model values to several available observational dataset and to the previous model release ECHAM5-wiso (at the same horizontal resolution but with 31 vertical layers):

- For the global validation of ECHAM6-wiso, we use the **Global Network of Isotopes in Precipitation (GNIP)** [1].
- As the ice cores in Antarctica provide an unique archive of past climate, and that this area constitutes an extreme test for isotope-enabled GCMs, we make use of the **Antarctic observational database compiled by [2]**.
- As we want to compare our results with those from ECHAM5-wiso, the same climatological boundary conditions have been prescribed, including the mean monthly AMIP sea-surface temperatures and sea-ice cover for the period 1960–1990. Potential improvements in simulating the stable water isotopes signal due to overall enhancements between ECHAM5 and ECHAM6 can be expected (treatment of shortwave radiative transfer, new surface albedo representation, new aerosol climatology, height of the model top, a more complex representation of the land surface, etc.).

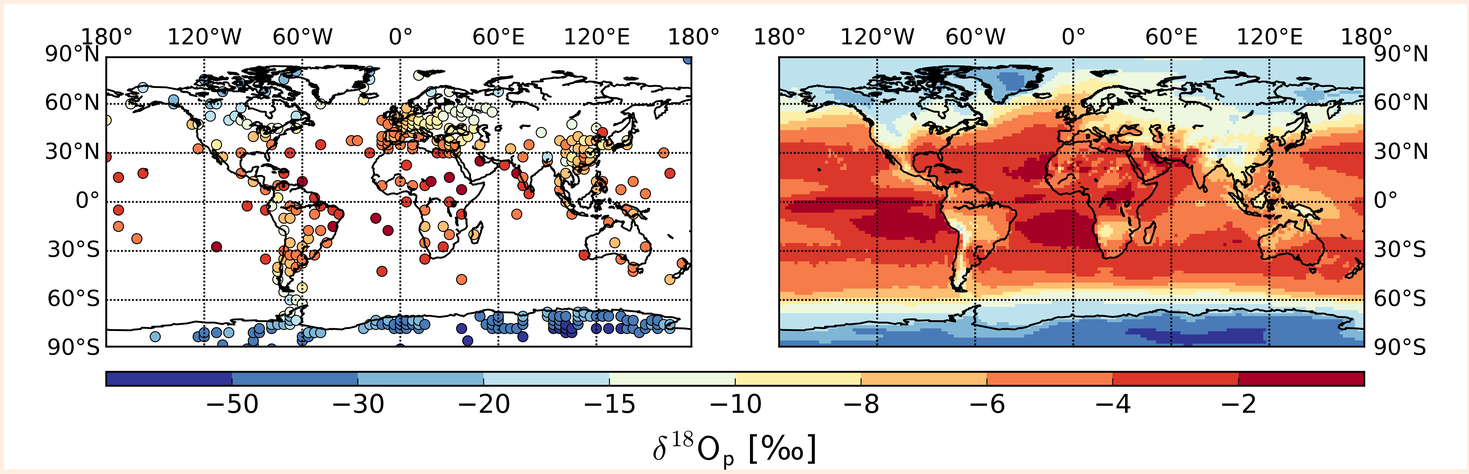
References

[1] IAEA/WMO (2016), database available at: https://nucleus.iaea.org/wiser.

[2] Masson-Delmotte et al. (2008), *J. Clim.*, **21**(13), 3359–3387, doi:10.1175/2007JCLI2139.1.

Global distribution of present-day annual mean $\delta^{18}O$ in precipitation

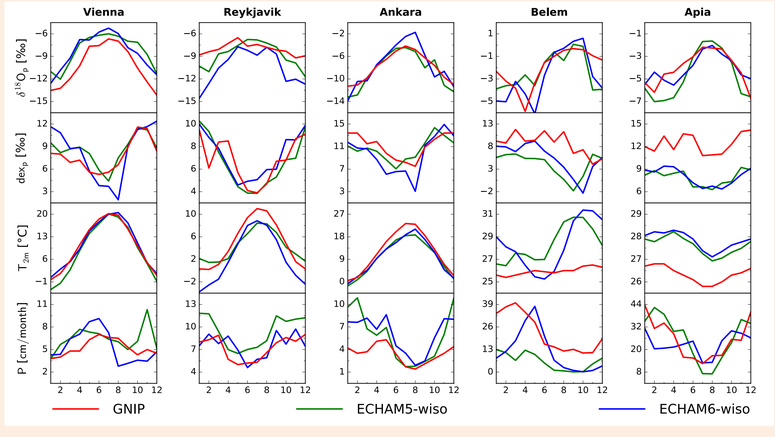
Global maps of present-day annual mean $\delta^{18}O$ in precipitation (left) based on data from the GNIP and Antarctic database [1, 2] and (right) from ECHAM6-wiso enhanced by the land surface scheme JSBACH.



ECHAM6-wiso reproduces reasonably well the present-day distribution of annual mean $\delta^{18}O$ in precipitation ($\delta^{18}O_p$). Improvements can be expected by prescribing the more complex 5-layer soil hydrology scheme instead of the single soil moisture reservoir.

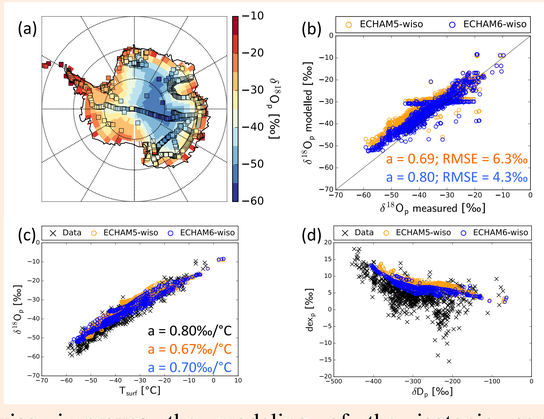
Seasonal variability

Seasonal cycles of isotopic composition of precipitation $\delta^{18}O_p$, deuterium excess values dex_p, temperature T_{2m} and precipitation amount P at five locations. The red, green and blue lines represent the observational GNIP values and the model results from ECHAM5-wiso and ECHAM6-wiso respectively.



Antarctica

(a) Observed and simulated annual mean $\delta^{18}O$ values in precipitation for Antarctica. (b) Modelled vs. observed $\delta^{18}O_p$. (c) $\delta^{18}O_p$-T_{surf} and (d) dex_p-δD_p relations according to the data [2] (black crosses), ECHAM5-wiso and ECHAM6-wiso (orange and blue circles).



ECHAM6-wiso improves the modeling of the isotopic composition of precipitation over Antarctica.

Conclusions and Perspectives

The simulations of water isotopes with the new atmospheric model ECHAM6-wiso are promising. Further tests concerning the implementation of water isotopes in the new soil scheme (5-layer soil hydrology scheme) are necessary. The next step is to implement these isotopic tracers in the oceanic component MPI-OM to be enabled to simulate water isotopes with the fully coupled model MPI-ESM.

Author Contact: alexandre.cauquoin@awi.de