The Introduction of Stable Water Isotopes to the UK Earth System Model (UKESM2)

Alison McLaren[1*], Merve Gorguner[2], Simon Wilson[3], Louise Sime[1], Jeff Ridley[4], Paul Valdes[2] and Grenville Lister[3]

[*] aliren@bas.ac.uk
[1] British Antarctic Survey, U.K.
[2]University of Bristol, U.K.
[3]National Centre of Atmospheric Sciences, U.K.
[4]Met Office, U.K.

British Antarctic Survey NATURAL ENVIRONMENT RESEARCH COUNCIL / University of BRISTOL / National Centre for Atmospheric Science NATURAL ENVIRONMENT RESEARCH COUNCIL / Met Office

Introduction

Work has recently started to introduce stable water isotopes to the UK Earth System Model (UKESM) as part of the EU Tipping Points in the Earth System (TiPES) project, with the aim of completing the development by the end of 2022. Stable water isotopes ($H_2{}^{18}O$ and $HD^{16}O$) are a valuable diagnostic tool in a coupled climate model, with several potential uses including the ability to investigate the model's hydrological cycle.

The UKESM (Sellar et al, 2019) consists of the physical global climate model HadGEM3 plus other earth system component models, such an atmosphere chemistry and aerosols model. The physical component of the UKESM2 comprises an atmosphere model (UM), an ocean model (NEMO), a sea ice model (SI^3) and a land surface model (JULES). This poster describes the general project with a focus on the atmospheric work. A companion poster by Gorguner et al. describes the work being done on the land surface model.

Development Plan

1. Addition of water tracers to the physical model components

Water isotopes are affected by the same dynamical, physical and biological processes that act on all water species. Therefore, the first stage of this development is to add an array of non-isotopic water tracers to the coupled model, which undergoes the exact same processes as water. In the atmosphere model, the water tracers are affected by: surface exchange; boundary layer mixing; convection; advection by the large-scale circulation; and microphysical processes in the clouds.

2. Addition of isotopic fractionation processes

The next step is to convert the non-isotopic water tracers to water isotopes by modelling (both equilibrium and kinetic) fractionation processes during certain phase changes. Figure 1 illustrates where fractionation will occur in the atmosphere model.

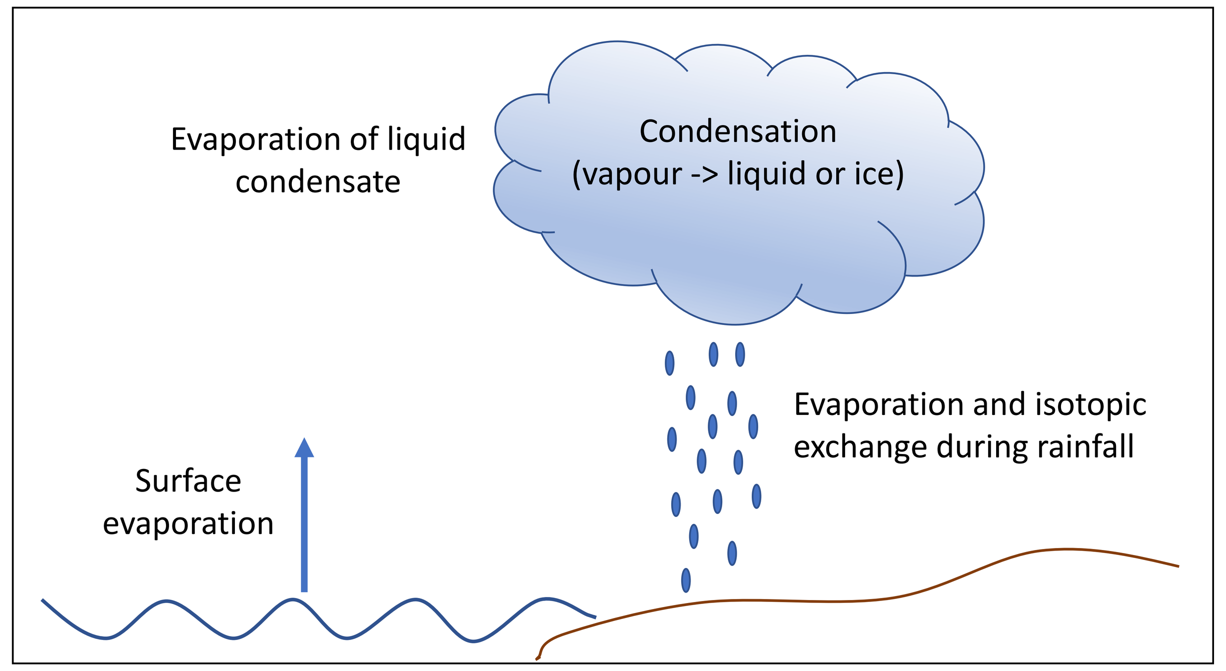

Figure 1: Diagram showing phase change processes that will cause isotopic fractionation in the atmosphere model.

3. Model evaluation

Finally, the model isotopic simulation will be evaluated using available water isotope data e.g. comparison with the Global Network of Isotopes in Precipitation (GNIP) observations.

Potential uses of water tracers/isotopes in Earth System Models

- They allow climate model simulations to be evaluated against isotopic ice core measurements (Figure 2) (e.g. Holloway et al., 2017).
- They allow relationships between climate variables and isotopic measurements to be investigated and better understood, which can help interpret ice core data (e.g. Sime et al., 2009).
- They can be used to investigate the hydrological cycle of the model (Noone and Sturm, 2010). For example, water tracers can be used to track water originating from a specified source region, allowing water pathways to be investigated in an atmosphere model.

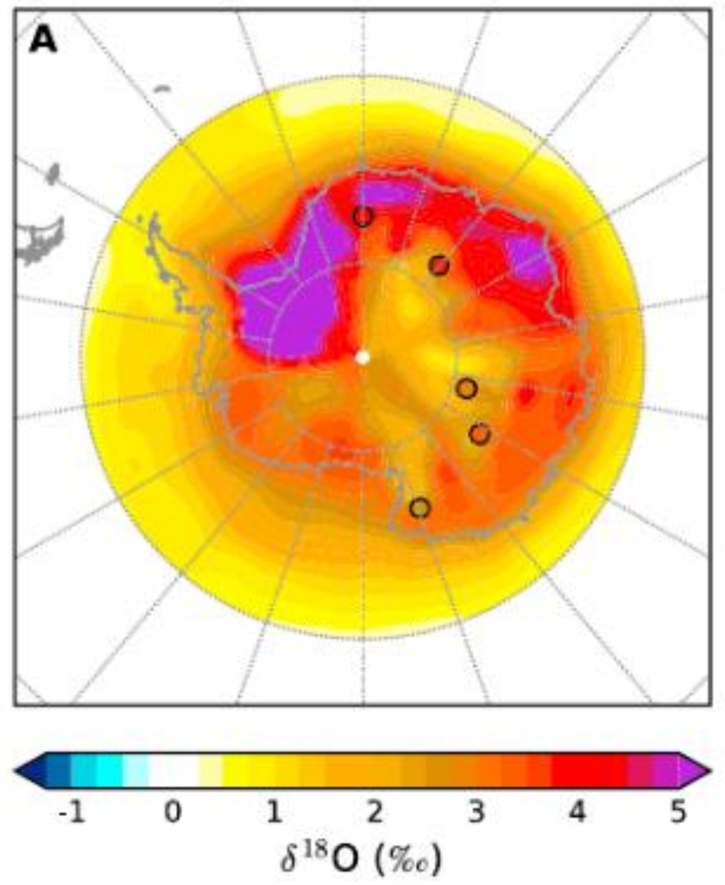

Figure 2: Example of use of ice core data to evaluate a climate model simulation (which includes water isotopes) for the Last Interglacial (taken from Holloway et al., 2017).

The plot shows the $\delta^{18}O$ anomalies in response to a forced sea ice retreat from the climate model HadCM3 (coloured contours) together with ice core data at 128 ka (filled circles).

References

Holloway, M. D., Sime, L. C., Allen, C. S., Hillenbrand, C.-D., Bunch,P., Wolff, E., & Valdes, P. J. (2017). The spatial structure of the 128 ka Antarctic sea ice minimum. *Geophysical Research Letters*, 44, 11,129–11,139. https://doi.org/10.1002/2017GL074594

Noone, D. and Sturm, C (2010). Comprehensive dynamical models of global and regional water isotope distributions. In Isoscapes: Understanding Movement, Pattern, and Process on Earth Through Isotope Mapping, J.B. West et al. (eds.), DOI 10.1007/978-90-481-3354-3_10

Sellar, A. A., Jones, C. G., Mulcahy, J.P., Tang, Y., Yool, A., Wiltshire, A., et al. (2019). UKESM1: Description and evaluation of the U.K. Earth System Model. *Journal of Advances in Modeling Earth Systems*, 11, https://doi.org/10.1029/2019MS001739.

Sime, L., Wolff, E., Oliver, K. et al. (2009) Evidence for warmer interglacials in East Antarctic ice cores. *Nature* 462, 342–345. https://doi.org/10.1038/nature08564