EGU23-13629, updated on 15 Apr 2024
https://doi.org/10.5194/egusphere-egu23-13629
EGU General Assembly 2023

A new theoretical framework for parameterizing nonequilibrium fractionation during evaporation from the ocean

Marina Duetsch, Christopher W. Fairall, Peter N. Blossey, and Richard P. Fiorella
Department of Meteorology and Geophysics, University of Vienna, Vienna, Austria (marina.duetsch@univie.ac.at)

The evaporation isotope model proposed by Craig and Gordon (1965) is used in most atmospheric isotope models for the parameterization of fractionation during evaporation from the ocean. It describes the isotope ratios in the evaporation flux as a function of the isotope ratios in liquid water and the atmosphere, relative humidity, the equilibrium fractionation factor, and the nonequilibrium fractionation factor (k_{iso}). Of these parameters, k_{iso} is the most uncertain. Many isotope models use the formulation of Merlivat and Jouzel (1979), which parameterizes k_{iso} as a function of wind speed and distinguishes between a smooth and a rough regime to account for the fact that waves act as roughness elements, inducing perturbations that significantly influence gas transfer rates. The resulting discontinuity in k_{iso} and therefore isotope ratios, which usually occurs at around 7m/s wind speed, has been disputed by several empirical studies, based on measurements of deuterium excess and ^{17}O-excess in the near-surface boundary layer. However, a theoretical framework, which would be in line with the measurements, is still lacking. Here, we present a new approach to parameterizing k_{iso} by explicitly accounting for the influence of wave drag on the momentum flux near the surface. Following recent work by Cifuentes-Lorenzen et al. (2018), we add a third wave-induced component to the total momentum flux, in addition to the viscous and turbulent components, and extend the definition of the eddy viscosity to account for the loss of friction velocity due to ocean waves and the fall-off of turbulence close to the surface. The new scheme predicts a slight decrease of k_{iso} with wind speed, similar to the values from Merlivat and Jouzel (1979) if the smooth-regime parameterization were used at all wind speeds. In a second step, we incorporate the new parameterization into the isotope-enabled Community Earth System Model, and run nudged simulations for the years 2000-2020, to analyze the effect on vapor and precipitation isotopes. While δD and δ^{18}O remain nearly unaffected, the deuterium excess tends to be higher in the simulation with the new scheme than in the control simulation, especially in regions with high wind speeds.

References

Cifuentes-Lorenzen, A., Edson, J. B., and Zappa, C. J. (2018). Air–sea interaction in the southern ocean: Exploring the height of the wave boundary layer at the air–sea interface. *Bound.-Layer Meteorol.*, 169(3), 461-482.

Craig, H. and Gordon, L. I. (1965). Deuterium and oxygen 18 variations in the ocean and the marine atmosphere. In *Stable Isotopes in Oceanographic Studies and Paleo-Temperatures*, pp. 9–130. Lab. Geol. Nucl., Pisa, Italy.

Merlivat, L. and Jouzel, J. (1979). Global climatic interpretation of the deuterium-oxygen 18 relationship for precipitation. *J. Geophys. Res.*, 84(C8):5029–5033.