Kinetic fractionation factors for ocean evaporation: limited impact of wind speed observed

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Isotope non-equilibrium fractionation effects are important during ocean evaporation and sensitive to environmental conditions such as temperature and relative humidity in the lower troposphere.

The Craig-Gordon model can be used to describe the fractionation effects involved during the evaporation process. The model can be represented as a **multi-layer model** where different isotopic effects are involved.

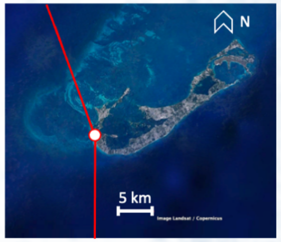
$$\delta_E = (1-k)\frac{\frac{\alpha_V(1+\delta_L)-h(1+\delta_A)}{I}}{(1-h)} - 1$$

The kinetic effects are summarized by the k value, hereafter:

$$k = \frac{\left(\frac{D}{D_i}\right)^n - 1}{\left(\frac{D}{D_i}\right)^n + \frac{\rho_T}{\rho_M}}$$

ρ_T/ρ_M can be expressed as a function of the **wind velocity vertical distribution** and ultimately to wind speed at a reference height (e.g. 10 m).

The objectives of this study are to estimate the **best k values for ocean evaporation** and to quantify the **wind speed effect** on kinetic fractionation in oceanic conditions



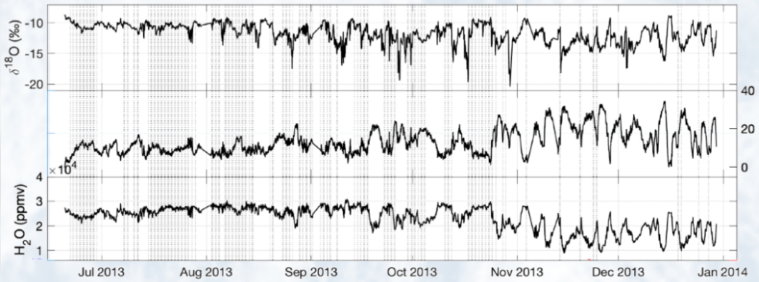
We used six months of water vapor isotopic observations collected from a meteorological tower located in the northwest Atlantic (Tudor Hill Marine Atmospheric Observatory - THMAO, Bermuda).

At THMAO, **water vapor isotopic composition was measured at two heights** between June to December 2013.

Water isotopic composition		
Water vapor $\delta^{18}O$, δD, q	THMAO Top (50 m AMSL) THMAO Bottom (2.5 m AMSL)	→ Resampled and sync., 30 min averagegd → Resampled and sync., 30 min averagegd
Ocean $\delta^{18}O$, δD	Gridded dataset Cruises Cruises/Moorings	→ Only $\delta^{18}O$, no temporal variation → Not matching observation window → Extrapolated from salinity
Meteorological data		
RH, T, WS, WS	THMAO Top (50 m AMSL)	WS adjusted to 10m height
SST	OSTIA Moorings St. George bay	→ Large scale SST, daily data → High temporal resolution (3h) → Dailiy data
BLH	ERA5, interpolated to study site	
SLP, P	Airport (TXKF)	

Observations were filtered by wind direction, time of the day, absence of precipitation, etc, reducing dataset by ~90%. Only vertical profiles with observed difference between Top/Bottom larger than instrumental precision (L2120-i) were considered.

Hereafter, minimum difference between top and bottom inlet are **0.2‰ for $\delta^{18}O$, 500 ppm for H_2O**. The vertical lines in the plot represent when the dataset meets the filtering criteria.



The **Isotopic composition of evaporation flux** was calculated with the **Craig Gordon model** and estimated from 2-inlets observations at THMAO using **Flux Gradient** and **Keeling Plot** method.

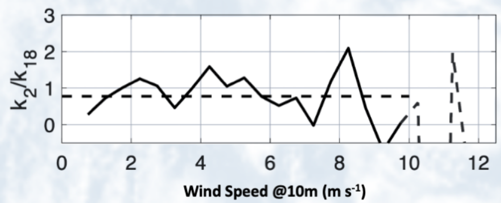
The **observed flux composition** was compared to **calculated flux composition**. This way, best kinetic fractionation values for D/H and $^{18}O/^{16}O$ were estimated by **minimization of the differences between model and observations.**

The mean k-values estimated by error minimization are: k_{18}= 5.2±0.6 ‰ and k_2= 4.3±3.4 ‰

The best-fit line between k_{18} and 10-m wind speed (m s^{-1}) is:

k_{18} = (-0.19 ± 0.04) *WS + (6.7 ± 0.3) ‰, R^2=0.52

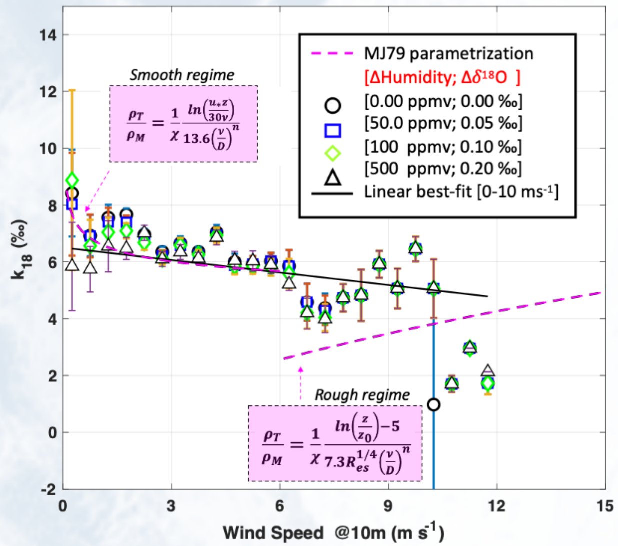
The sensitivity of k_{18} to WS is only -0.19 ± 0.06 ‰ $m^{-1}s$. k_2 observations are more affected by noise (R^2=0.11). The linear relationship between k and WS is more robust for k_{18}.



The k_2/k_{18} ratio shows no significant correlation with WS. Between 0.5 and 10 m s^{-1}, the k_2/k_{18} ratio largely varies around the mean value of 0.8 with a standard deviation of 0.6.

k_2/k_{18} = (0.8 ± 0.6) * k_{18}

Modulating the threshold of differences between water vapor observations at the two inlets affects low-wind speed observations
Wind speed sensitivity is higer at low wind speed, consistent with MJ79 smooth parametrization



This study provided **evidence of wind speed effect in modulation of kinetic fractionation factor** during ocean evaporation. This effect is very small but statistically significant.

This study **do not provide enough evidence of different wind speed regimes** (e.g. smooth and rough) modulating the kinetic fractionation effect

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