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Validation of the Craig-Gordon isotopic model for lake evaporation

Wei Xiao[1], Xuhui Lee[1,2], Xuefa Wen[3], Shoudong Liu[1], Hanchao Li[1]

[1]Yale-NUIST Center on Atmospheric Environment, Nanjing University of Information Science & Technology, Nanjing 210044, China; wei.xiao@nuist.edu.cn

[2]School of Forestry and Environmental Studies, Yale University, New Haven, Connecticut 06511, USA

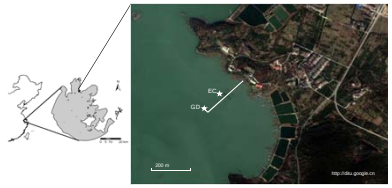
[3]Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Introduction

- The theory on isotopic composition of evaporation (δ_E) of open water was first proposed by Craig and Gordon in 1965 (C-G model) and has since been widely employed in studies of isotope hydrology and ecology.
- In a typical application, the interfacial surface water layer is assumed to be well-mixed so that the isotopic composition of the evaporating surface is equal to that of the bulk water.
- To date, the C-G model and the associated well-mixed assumption have not been validated against field measurements over natural water bodies.
- In this study, in-situ measurement of δ_E was made on a near-continuous basis using the flux-gradient approach over Lake Taihu, a large shallow lake in East China.

Site and Instruments

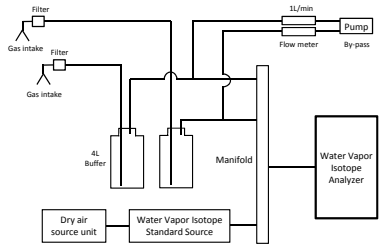
The experiment site (31°24′N, 120°13′E) was in the north part of Lake Taihu, which is the third largest freshwater lake in China, with a water surface area of 2400 km^2 and a mean water depth of 1.9 m.



The key instrument was a water vapor analyzer based on the off-axis integrated cavity output spectroscopy. The analyzer switched between the two intakes at the 1.1 and 3.5 m height above water surface every 30s, measuring the $H_2{}^{16}O$, HDO and $H_2{}^{18}O$ water vapor mixing ratios. It was calibrated every 3 h against a vapor standard at 5 concentrations that bracketed the ambient humidity.

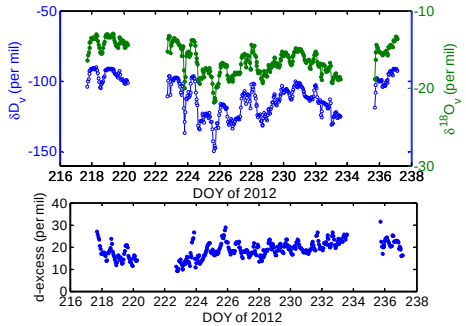
An eddy covariance system was installed at the same site, with a distance of 100 m from the GD intakes.

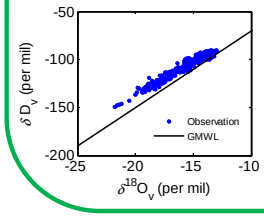
Schematic Design Diagram



The flux-gradient method was used to obtain the isotopic compositions of lake evaporation. Buffer volumes were used to improve the accuracy of the gradient measurement. Small short tubing was used between the manifold and the analyzer to minimize the transient time between valve switching.

Observed water vapor δ

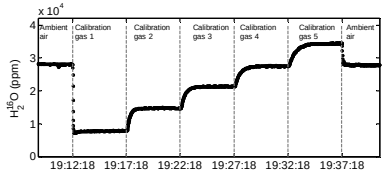


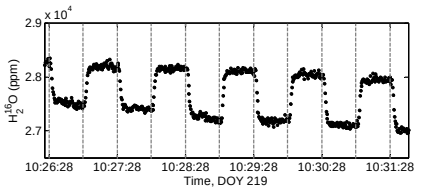


The observation has continued to date since Aug 2012. For the period shown here, the vapor δD ranged from -149.5 to -90.4‰ and δ^{18}O from -21.8to -13.0‰.

Instrument Performance

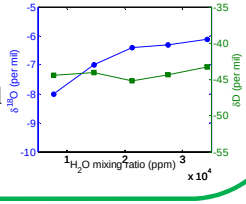
To eliminate the effect of non-linearity and signal drift, we calibrated the analyzer every 3 h against 5 water vapor standards of identical isotopic compositions.



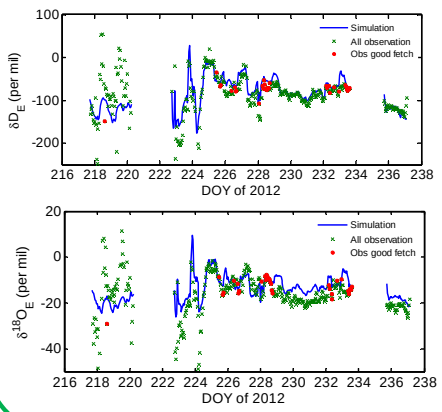


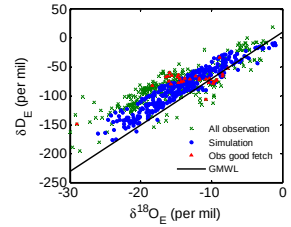
When measuring the ambient air, the manifold switched between the two intakes every 30 s. The measurement approached steady state in less than 10 s after each switching.

The analyzer displayed nonlinear behavior. The measured δ^{18}O and δD of the calibration gases ranged from -8.0 to -6.1‰ and -45.2 to -43.3‰, respectively. The true values were -7.0‰ and -44.0‰, respectively.



Validation of the Craig-Gordon Model





- The CG model captured the temporal variations in evaporation δ.
- The model showed better agreement with observation for D than for ^{18}O.
- The modeled δD_E and $\delta^{18}O_E$ were much closer to GMWL than the observations.

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