Controls on the water vapor isotopic composition near the surface of tropical oceans and role of boundary layer mixing processes

Introduction
Understanding what controls the water vapor isotopic composition of the sub-cloud layer (SCL) over tropical oceans (δD_SCL) is a first step towards understanding the water vapor isotopic composition everywhere in the troposphere. We propose an analytical equation that predicts δD_SCL based on a simple box model.

Box model
The box model extends [Merlivat and Jouzel, 1979] closure and builds on [Benetti et al., 2015]. Assumptions are:
1. steady state
2. α_eff is a function of z_orig and h_orig, the altitude at which the air originates.
3. Horizontal advection is characterized by ω. 
4. Rain evaporation is a function of mass export N.

We get:
\[
\delta D = \alpha_{eff} \cdot \frac{q_{orig}}{q_{orig} + q_{evap}} \cdot \frac{1}{(1 - \delta D_L)}
\]

For δD-based estimates of z_orig to be useful, we need a precision that is better than what we already know of mixing processes: a few hundred meters in deep convection regions and smaller than 20 m in stratocumulus regions. We quantify the different sources of uncertainties on z_orig:
- daily measurements of δD in multi-tropical sites
- accurate measurements of δD in stratocumulus clouds, which is currently difficult to obtain
- information on the horizontal distribution of δD in account for horizontal advection effects
- δD profiles to quantify the sensitivity associated with assuming that δD profiles follow Rayleigh distillation

Conclusions of δD-based estimates of z_orig, if we get [Mielke and Band, 1979] closure.

What controls the spatial and seasonal variations in δD_SCL?
- We use an AMIP-type LMDZ simulations (Risi et al., 2010) and diagnose all variables from it.
- We calculate z_orig and h_orig predicted by Eq. 1 from the simulated δD_SCL.
- We decompose the simulated δD_SCL into different contributions based on equation 1.
- We further decompose z_orig into the different contributions based on:
  \[
  z_{orig} = \sum \alpha \cdot \chi
  \]

Perspectives
- water tagging to check z_orig estimates in LMDZ
- large-scale simulations (e.g. Moore et al., 2016)

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References


Camille Risi1, Joseph Galeyowski2, Gilles Reverdin3, Florent Breizet
1 Laboratoire de Météorologie Dynamique, IPSL-CNRM, Observatoire de Paris, France
2 Department of Earth and Planetary Sciences, University of New South Wales, Australia
3 CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

Contact: Camille.Risi@ipsl.fr