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The present-day distribution of water stable isotopes simulated in the LMDZ GCM

Camille Risi[1]* and Sandrine Bony[1]
[1]*LMD/IPSL, Paris (France)*
*contact: crlmd@lmd.jussieu.fr

Introduction

The stable isotopic composition of precipitation is a valuable tool to study past climates or constrain the water cycle. Isotopic modeling in atmospheric GCM is a promising mean to investigate the large-scale and process-scale controls of isotopic distributions.
Water stable isotopes ($H_2^{18}O$, HDO, $H_2^{17}O$) have been introduced into the **LMDZ GCM** ([2]), which is the atmospheric component of the **IPSL coupled model** used fore IPCC simulations. This GCM includes the **Emanuel convective parametrization**, which represents in detail some physical and microphysical processes such as rain reevaporation and convective downdraft, which play an important role in the isotopic composition of precipitation in convective regions ([5]).
Water stable isotopes are advected passively by the large scale dynamics. The representation of the isotopic fractionation is similar to that in other GCMs equiped with isotopes, except for a more sophisticated treatment of the rain reevaporation due to the detailed representaion of this process in the convective parametrization ([1]).

We present here the results of the last year of a two year simulation using present-day **climatological SSTs**. The goal here is to

- validate the spatial and seasonnal distribution of the isotopes in precipitation
- present some sensitivity tests.

1) Annual maps

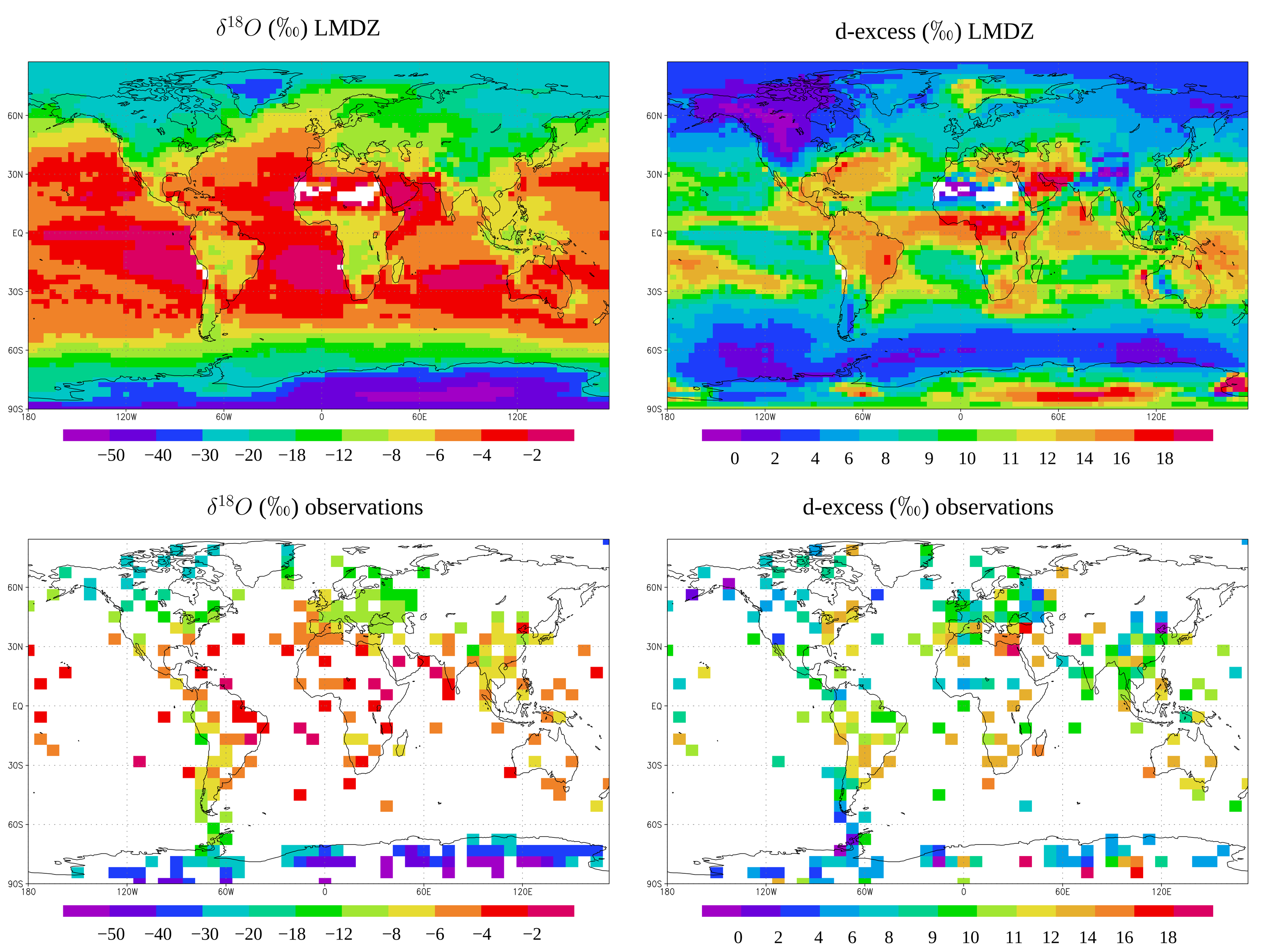

Figure 1: Annual weighted averageδD and d-excess simulated by LMDZ (above) and from observations: GNIP network ([3]) and Antarctic data ([4])

2) Seasonal cycles

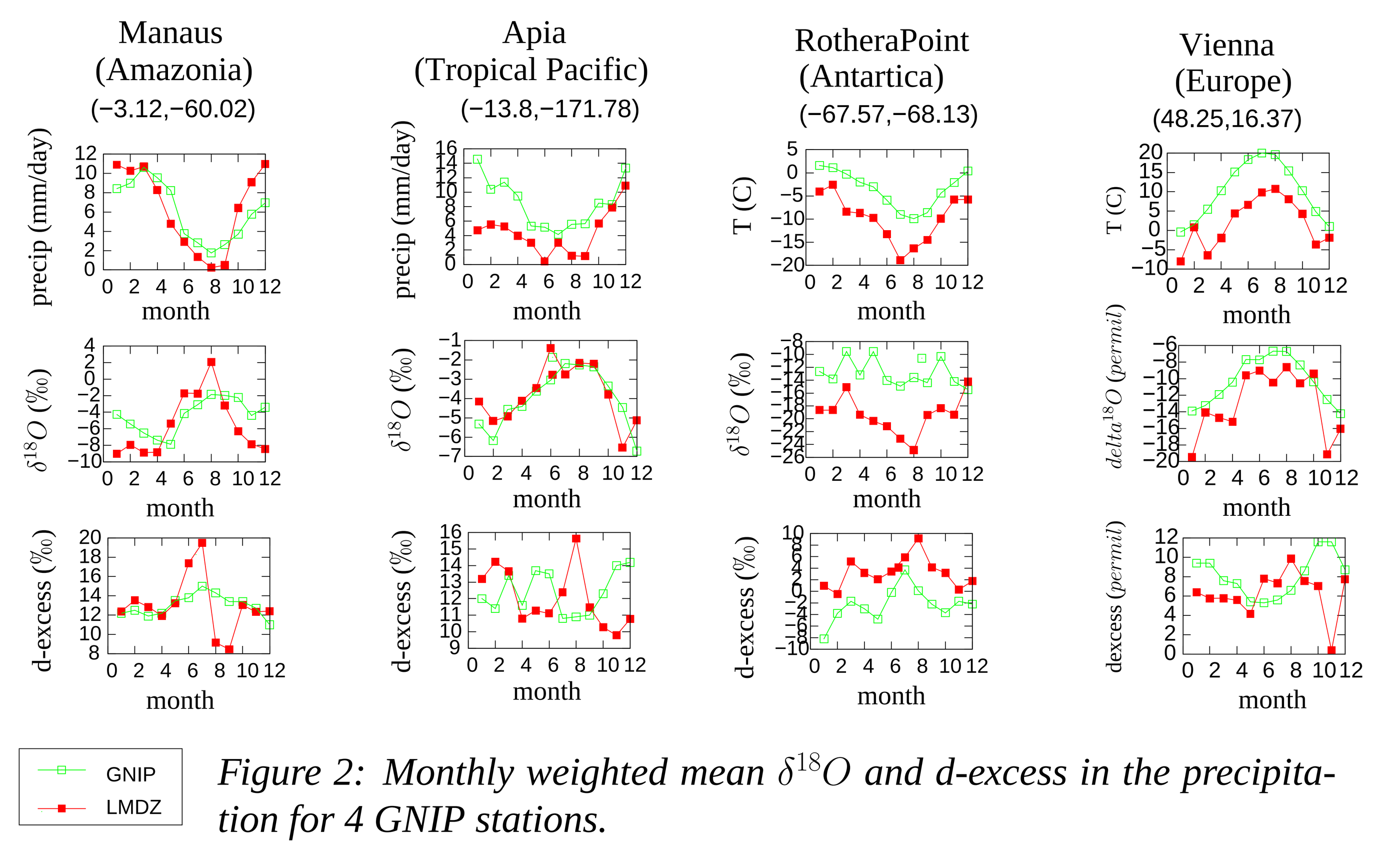

Figure 2: Monthly weighted mean $\delta^{18}O$ and d-excess in the precipitation for 4 GNIP stations.

3) Temperature and amount effects

What are the main climatic controls of the isotopic composition of precipitation? We study here how $\delta^{18}O$ relates to temperature (temperature effect) and precipitation rate (amount effect) at the **seasonal scale**, and evaluate how LMDZ reproduces this behavior (figure 3).
The temperature effect dominates in mid and high latitudes and the amount effect in the Tropics, in LMDZ as in GNIP.

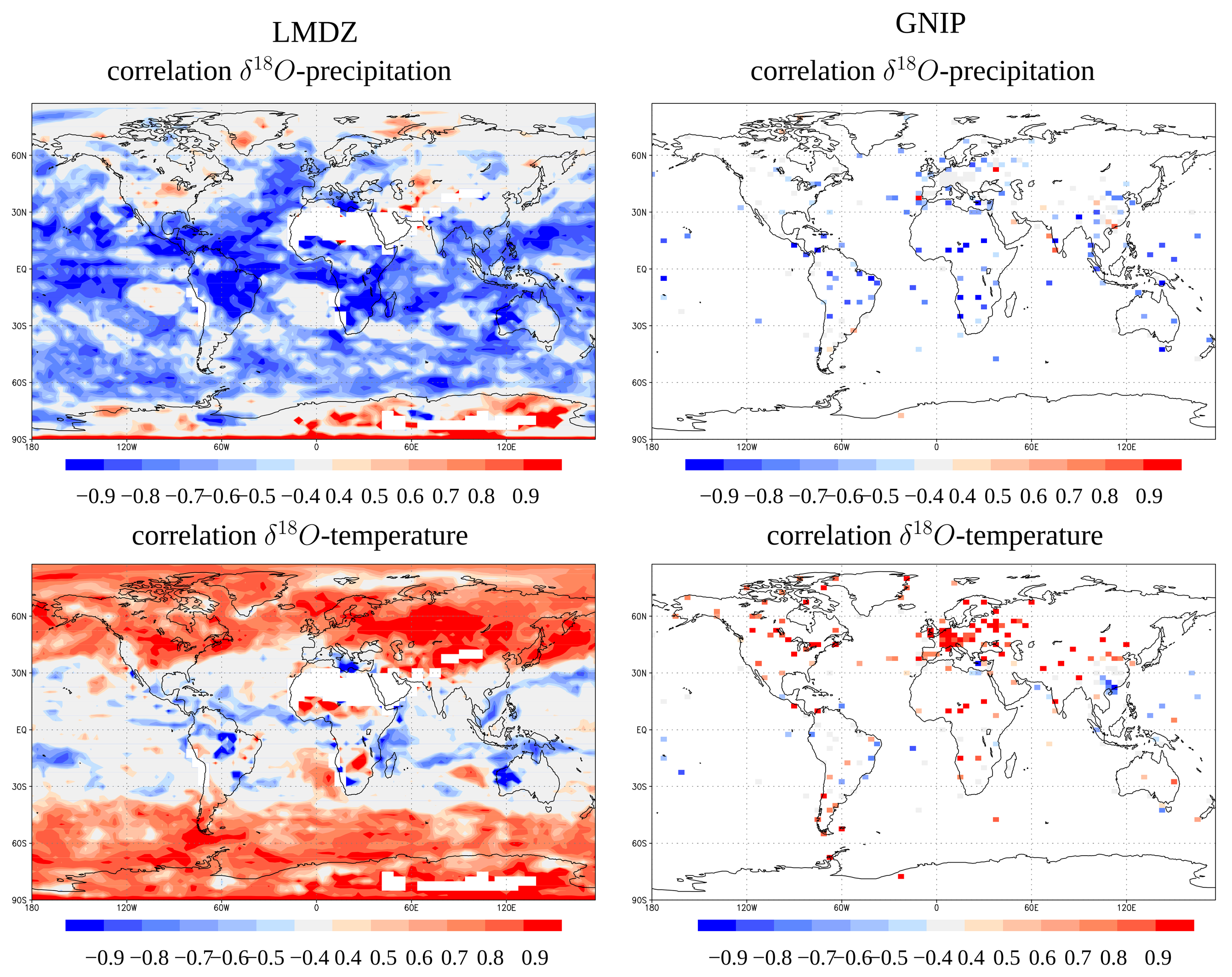

Figure 3: Map of partial correlation between $\delta^{18}O$ and temperature at a fixed precipitation and the partial correlation between $\delta^{18}O$ and precipitation at a fixed temperature (figure 4), for both LMDZ (left) and GNIP data (right). Correlations are calculated for weighted monthly averages.

4) Sensitivity to kinetic effects

The simulated isotopic composition is very sensitive to the representation of kinetic effects:

- d-excess in Antarctic is particulary sensitive to the representation of kinetic effects during snow formation (parameter λ, figure 4)
- How the tropical isotopic composition depends on the precipitation rate (amount effect) is particulary sensitive to kinetic fractionation during rain reevaporation (figure 5).

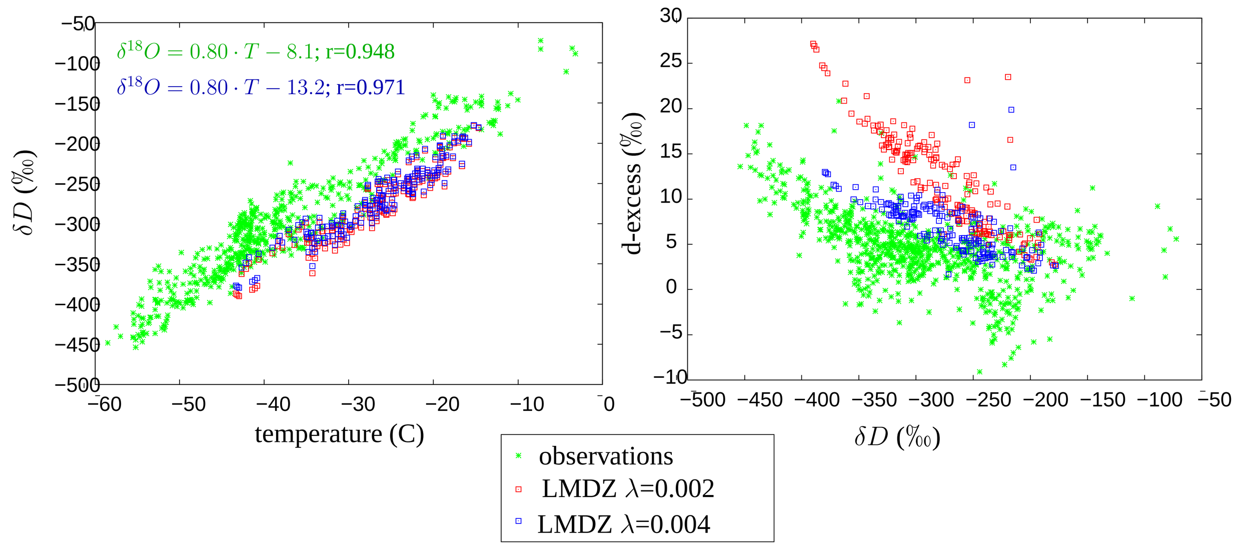

Figure 4: Relationship between temperature, δD and d-excess over ***Antarctica****, at the annual scale. Data are snow observations from [4]. Parameter λ controls kinetic effects during snow formation.*

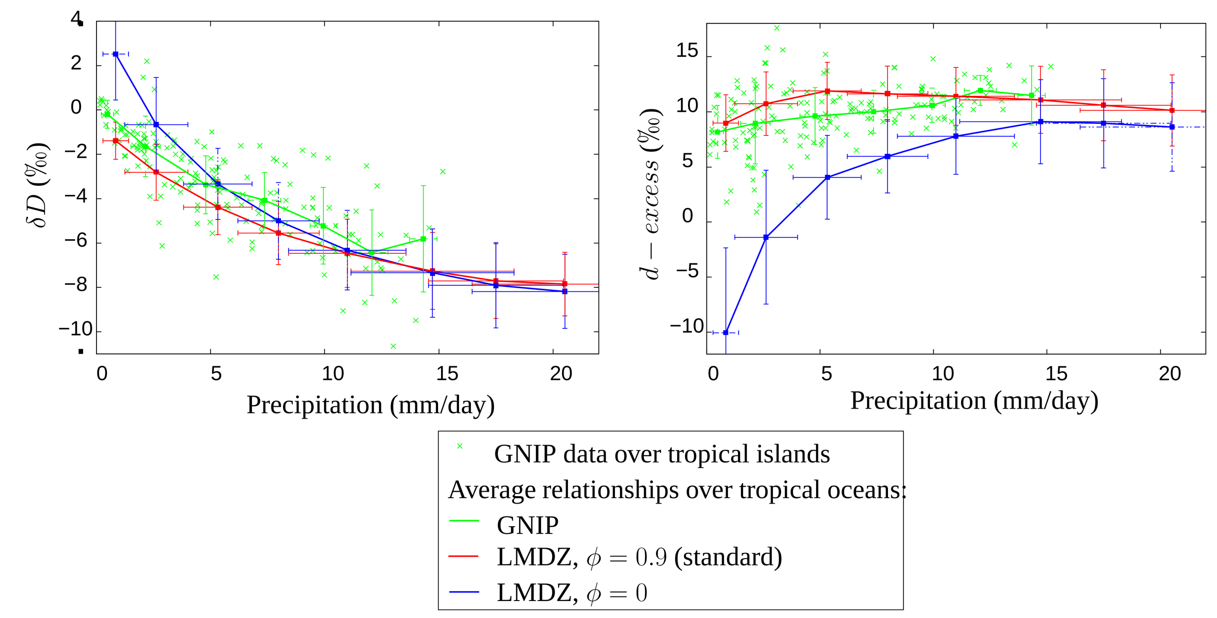

Figure 5: Average relationship between precipitation rate and $\delta^{18}O$ (left) and d-excess (right) over ***tropical oceans****, at the monthly scale. Data are GNIP stations over tropical islands. Parameter ϕ controls kinetic effects during rain reevaporation (the relative humidity at the droplet contact is given by $h = \phi + (1 - \phi) \cdot h_d$, with h_d the relative humidity in the downdraft in which the droplets fall; ϕ is set to 0.9 in the standard case).*

Conclusion and perspectives

LMDZ predicts reasonable spatial and seasonal distributions of the isotopic composition of precipitation, and can thus be used as a tool to better understand and quantify what information is recorded in the isotopic archives. For this purpose, we plan to:

- run an AMIP simulation and analyse of how the inter-annual variability is recorded in the isotopic composition of precipitation
- use the zoom option in LMDZ (stretched grid) to perform regional analyses: West Africa (interpretation of the isotopic composition of rain samples collected during the AMMA campaign), South America (interpretation of andean ice cores).
- implement water stable isotopes in ORCHIDEE, the land surface scheme of the IPSL model, and run surface-atmosphere coupled simulations.

References

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