What controls the spatio-temporal distribution of D-excess and O17-excess in precipitation? A general circulation model study

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Introduction

- d-excess=$d=\delta D - 8 \cdot \delta^{18}O$ (in ‰)⟶additional constraints on the water cycle and past climates compared to $\delta^{18}O$ alone (e.g. [1, 10]).
- ^{17}O-excess=$\left(\ln(\delta^{17}O/1000+1) - 0.528 \cdot \ln(\delta^{18}O/1000+1)\right) \cdot 10^6$ in permeg ⟶ information on evaporative conditions at the source of moisture in high latitudes ([2, 7]), and on convective processes in the tropics ([3]).

What controls the spatio-temporal distribution of d and ^{17}O-excess?

⟹ use the general circulation model LMDZ ([6]), with $H_2^{17}O$ implemented for the first time.

1. Evaluation of ^{17}O-excess for present-day and LGM

- Right order of magnitude in low/mid latitudes.
- Underestimate ^{17}O-excess in high latitudes.
- Underestimate the effect of surface relative humidity (RH_s).

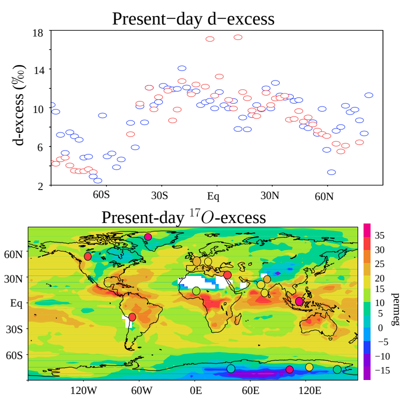

Fig 1. Annual mean precipitation d and ^{17}O-excess in LMDZ and observations: precipitation d from GNIP, snow ^{17}O-excess from [2], ^{17}O-excess in various meteoric waters from[5].

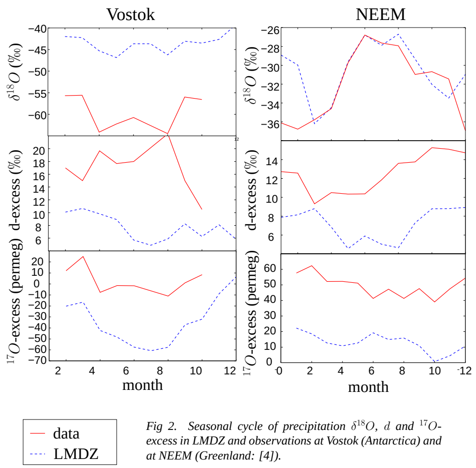

Fig 2. Seasonal cycle of precipitation $\delta^{18}O$, d and ^{17}O-excess in LMDZ and observations at Vostok (Antarctica) and at NEEM (Greenland: [4]).

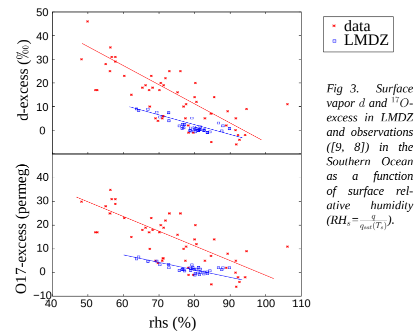

Fig 3. Surface vapor d and ^{17}O-excess in LMDZ and observations ([9, 8]) in the Southern Ocean as a function of surface relative humidity ($RH_s = \frac{q}{q_{sat}(T_s)}$).

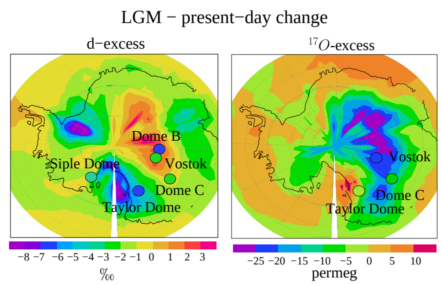

Fig 4. LGM - present day (PD) difference in precipitation d-excess and ^{17}O-excess in LMDZ and observations in Antarctica ([2, 11]).

2. Controls on precipitation $\delta^{18}O$, d and ^{17}O-excess

Decompose isotopic signals into 4 processes:

- effect of post-condensational processes: compare precipitation and vapor composition
- effect of evaporative conditions:
  - SST: compare control and simulation with SST=15°C during surface evaporation fractionation
  - RH_s: compare control and simulation with RH_s=60% during surface evaporation fractionation
- effect of super-saturation: compare control ($\lambda = 0.004$) and simulation with $\lambda = 0$.
- Distillation/transport: simulation with SST=15°C and RH_s=60% during surface evaporation fractionation and with $\lambda = 0$.

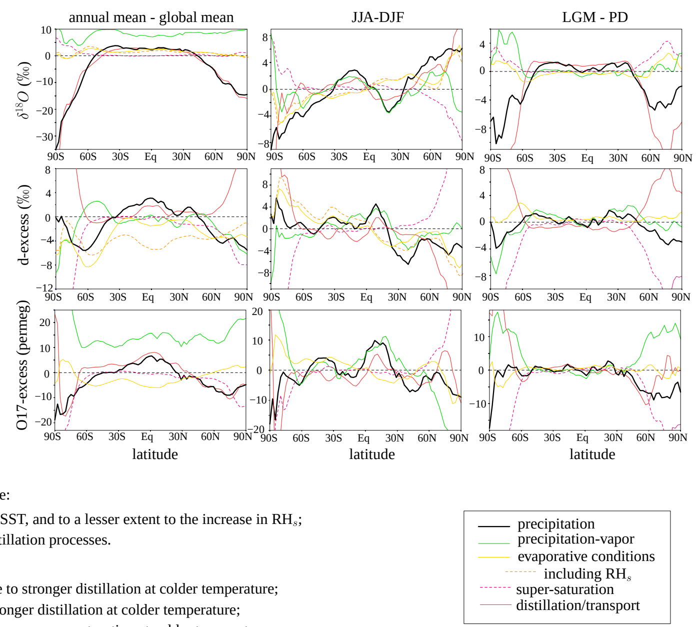

Fig 5: effect of different processes on the meridional gradient, seasonal cycle and LGM-PD difference of $\delta^{18}O$, d and ^{17}O-excess.

Main results:

- Meridional gradients: decrease with latitude:
  - decrease in d mainly due the decrease in SST, and to a lesser extent to the increase in RH_s;
  - decrease in ^{17}O-excess mainly due to distillation processes.
- Seasonal cycles in polar regions: in winter:
  - higher d in Antarctica and Greenland due to stronger distillation at colder temperature;
  - higher ^{17}O-excess in Greenland due to stronger distillation at colder temperature;
  - lower ^{17}O-excess in Antarctica due to stronger super-saturation at colder temperature.
- At LGM in polar regions:
  - lower d due to lower SST and higher RH_s (half); stronger super-saturation at colder temperature (half);
  - lower ^{17}O-excess due to stronger super-saturation at colder temperature.
- Results in high latitudes are very sensitive to the super-saturation parameterization.
- Limitation: LMDZ might underestimate the effect of RH_s

Perspectives

- ^{17}O-excess is very difficult to simulate for a GCM; numerical instabilities depending on advection scheme.
- need to better calibrate super-saturation function: vapor + precip along transects in Antartica?
- need to better evaluate post-condensational processes: simultaneous vapor + precip measurements?
- role of land surface fractionation?

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