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ISOTOPIC EQUILIBRIUM BETWEEN PRECIPITATION AND WATER VAPOR IN NORTHERN PATAGONIA AND ITS CONSEQUENCES ON $\delta^{18}O_{cellulose}$ ESTIMATE

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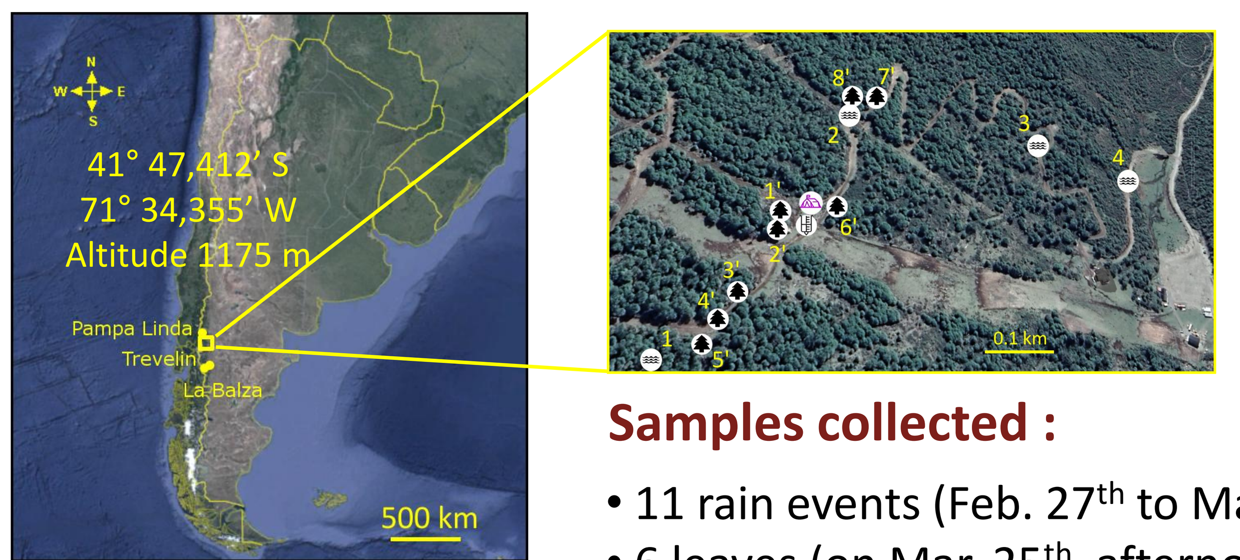
1. BACKGROUND AND OBJECTIVES

Over the last century, the western part of South America, from the Altiplano to Northern Patagonia, has experienced more frequent and longer periods of drought. This trend, which is probably partly related to the expansion of the Hadley atmospheric cell, will continue according to climate simulations (EGU2020-14820*). To improve the understanding of the processes responsible for this evolution, tree-ring parameters seem to be the most suitable archives, with an annual resolution, in this time period. The isotopic composition of tree-rings cellulose ($\delta^{18}O_{cellulose}$) is influenced by a complex mix of climatic and physiological drivers. In studies devoted to the modeling of oxygen isotopic composition in leaves and tree-rings, water vapor (rarely measured continuously in the field) is assumed in isotopic equilibrium with the source water of the tree. Here we test this hypothesis.

Are precipitation, which the tree source water is derived from, in isotopic equilibrium with the surrounding water vapor at ground level?

2. STUDY SITE AND MEASUREMENTS

Field campaign : February 24th to March 26th, 2017



Penchenat et al., (2020)

Measurements of $\delta^{18}O$

WATER VAPOR (measurements in situ) → Picarro (±0.2‰)

LIQUID WATER (precipitation, leaf water) → Finnigan MAT 252 (± 0.05‰)

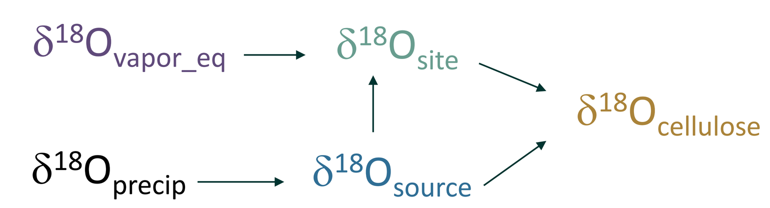
CELLULOSE → Isoprime (±0.2‰)

Samples collected :

- 11 rain events (Feb. 27th to Mar. 12th)
- 6 leaves (on Mar. 25th, afternoon)
- 5 tree cores

The isotopic composition in deuterium was measured with Picarro and Finningan MAT 252 but not shown in this poster

3. METHOD



$\delta^{18}O_{precip}$: precipitation
$\delta^{18}O_{site}$: water at the evaporation site in leaves
$\delta^{18}O_{source}$: source water (mean amount-weighted $\delta^{18}O_{precip}$)

Where:

$$\delta^{18}O_{vapor\_eq} = \frac{\delta^{18}O_{prec} + 1}{\alpha_{eq}} - 1$$

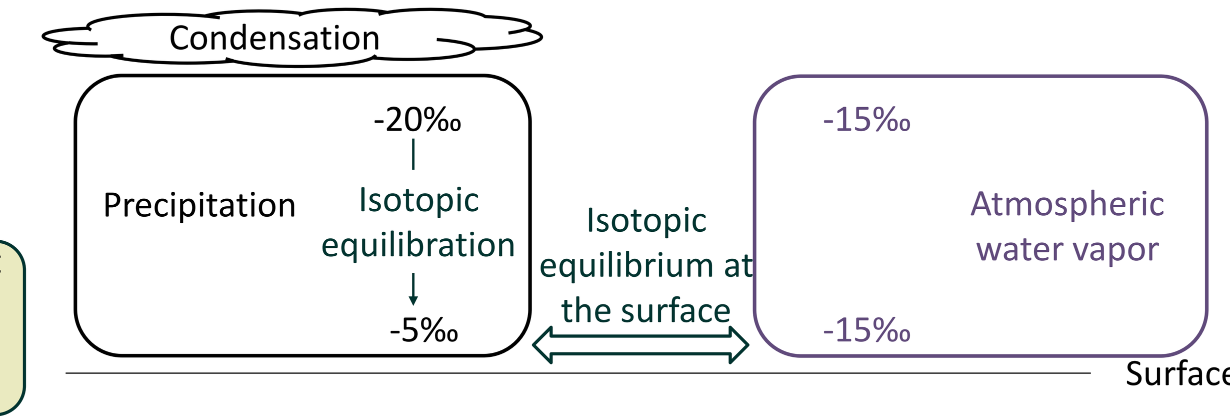
$$\Delta_{site} = (1+\varepsilon^{*}) \times \left[(1+\varepsilon_k) \times \left(1 - \frac{w_a}{w_i}\right) + \frac{w_a}{w_i}(1+\Delta_{vap})\right] - 1 \quad [1]$$

isotopic enrichment of atmospheric vapor compared to source water

$$\delta^{18}O_{site} = \Delta_{site} + \left(\frac{\delta^{18}O_{source} \times \Delta_{site}}{1000}\right) + \delta^{18}O_{source} \quad [2]$$

$$\delta^{18}O_{cellulose} = f_0 \times (\delta^{18}O_{source} + \varepsilon_{bio}) + (1 - f_0) \times (\delta^{18}O_{site} + \varepsilon_{bio}) \quad [3]$$

Isotopic equilibrium



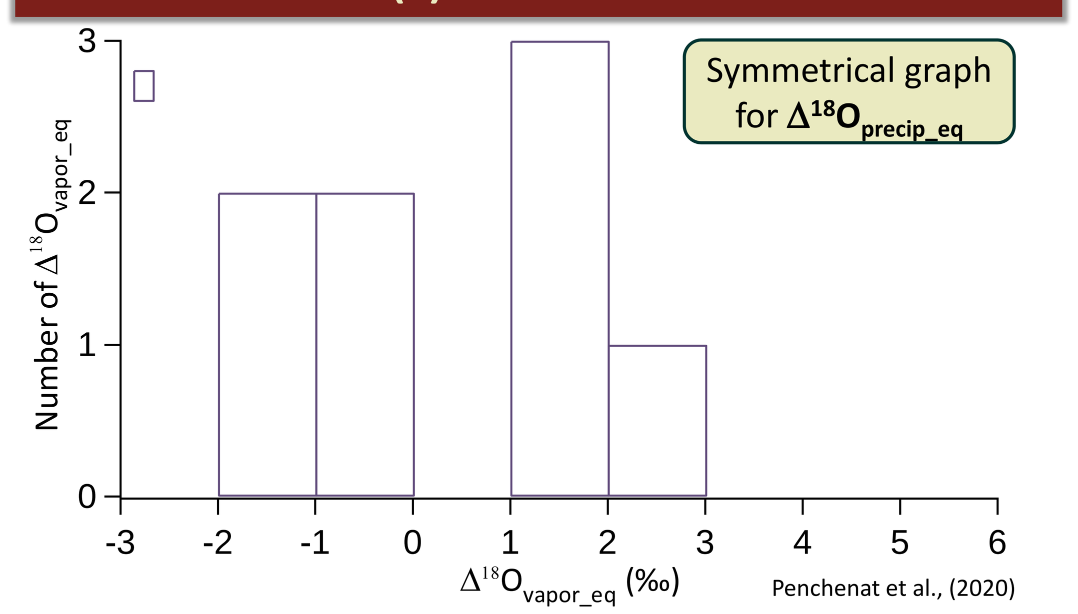
Definition of disequilibrium

Vapor : $\Delta^{18}O_{vapor} = \delta^{18}O_{vapeur\_obs} - \delta^{18}O_{vapeur\_eq}$

Precipitation : $\Delta^{18}O_{precip} = \delta^{18}O_{precip\_obs} - \delta^{18}O_{precip\_eq}$

measured values | *calculated values*

4. RESULTS (I): DISEQUILIBRIUMS



Disequilibriums between -2.0 et 4.1‰

→ Precipitation and the surrounding water vapor **are not in isotopic equilibrium** at the study site during February and March.

→ Small observed isotopic disequilibriums

The different processes that can induce a disequilibrium between water vapor and precipitation :

❑ $\Delta^{18}O_{vap\_eq} < 0$ (and $\Delta^{18}O_{prec\_eq} > 0$)

- **evaporation of raindrops during their fall**: $\delta^{18}O_{vapor}$ slightly lower than $\delta^{18}O_{vapor\_ep}$. Evaporation rates = 1 to 4%.
- ~~**evaporation of soil water**: inconsistent results between $\delta^{18}O$ and δD.~~

❑ $\Delta^{18}O_{vap\_eq} > 0$ (and $\Delta^{18}O_{prec\_eq} < 0$)

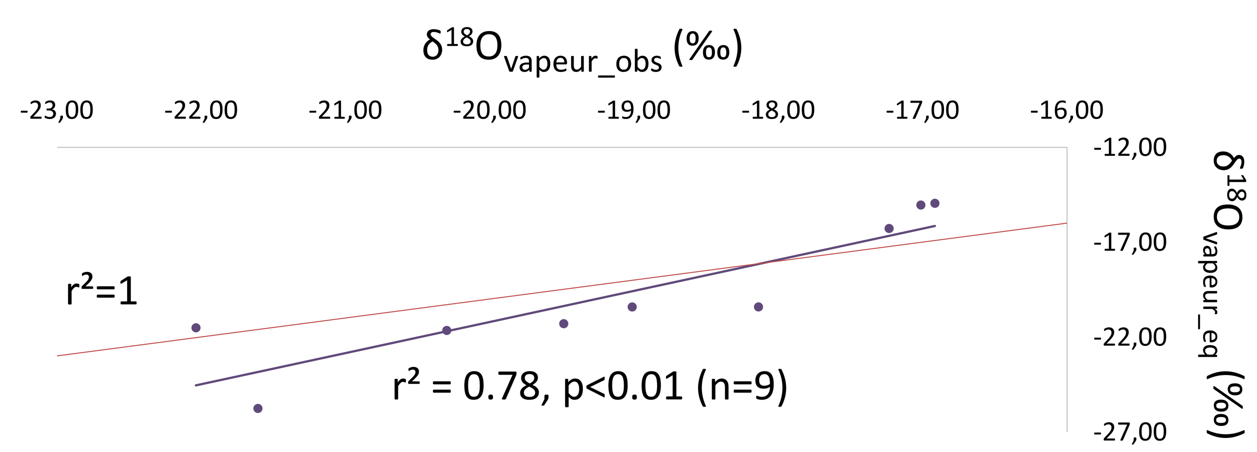
- **condensation of water vapor at very high altitude**
- **size of droplets**

} Impossible to quantify

- **transpiration from vegetation**: possible contribution of transpired vapor to atmospheric water vapor between 14 and 29%.

→ Isotopic equilibrium between water vapor and precipitation at the individual rain events scale not TRUE over the study period : valid approximation.

→ No physical mechanism to explain this relationship.



5. RESULTS (II): ESTIMATION OF $\delta^{18}O_{cellulose}$

What is the impact of disequilibriums on the estimation of the isotopic composition of cellulose?

$\delta^{18}O_{vapor\_obs}$ averaged from February 24th to March 26th → calculation of $\delta^{18}O_{source}$ in equilibrium with $\delta^{18}O_{vapor\_obs}$ → calculation of $\delta^{18}O_{site}$ and $\delta^{18}O_{cellulose}$

$\delta^{18}O_{cellulose}$ calculated = 29.8±0.7 ‰

$\delta^{18}O_{cellulose\_obs}$ measured = 30.4±0.2 ‰

→ By assuming an averaged isotopic equilibrium over several weeks between water vapor and precipitation, it is possible to calculate a $\delta^{18}O_{cellulose} \sim \delta^{18}O_{cellulose\_obs}$.

6. CONCLUSION

→ Small disequilibriums between water vapor and precipitation at the rain event scale.

→ Several processes can be invoked to explain the deviation from the isotopic equilibrium.

→ Isotopic equilibrium between water vapor and precipitation is a valid approximation at the intra seasonal scale.

BUT

→ **What mechanism could explain a continuous equilibrium between water vapor and water source given that we show disequilibriums at the individual rain event scale and that $\delta^{18}O_{vapor\_eq}$ and $\delta^{18}O_{source}$ have different integration times?**

References

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*EGU2020-14820: Villamayor et al. , Long-term variability of central Andes precipitation in the IPSL-CM6A-LR model: origin and causes.Session CL2.10 – Recent progress in understanding the hydro-climate system of the Andes: Physical processes and resources for Andean populations.

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