

Using stable isotopes to estimate the time since disconnection of pools in temporary rivers

Llorens P^{1,2}, González S², Latron J^{1,2}, Múrria C^{2,3}, Bonada N^{2,3}, Gallart F^{1,2}

pilar.llorens@idaea.csic.es



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¹Institute of Environmental Assessment and Water Research (IDAEA), CSIC, Barcelona

²Freshwater Ecology, Hydrology and Management (FEHM-Lab), UB/IDAEA, Barcelona

³Department BEECA, Universitat de Barcelona, Barcelona

proof of concept
for the estimation
of the time since
disconnection of
pools

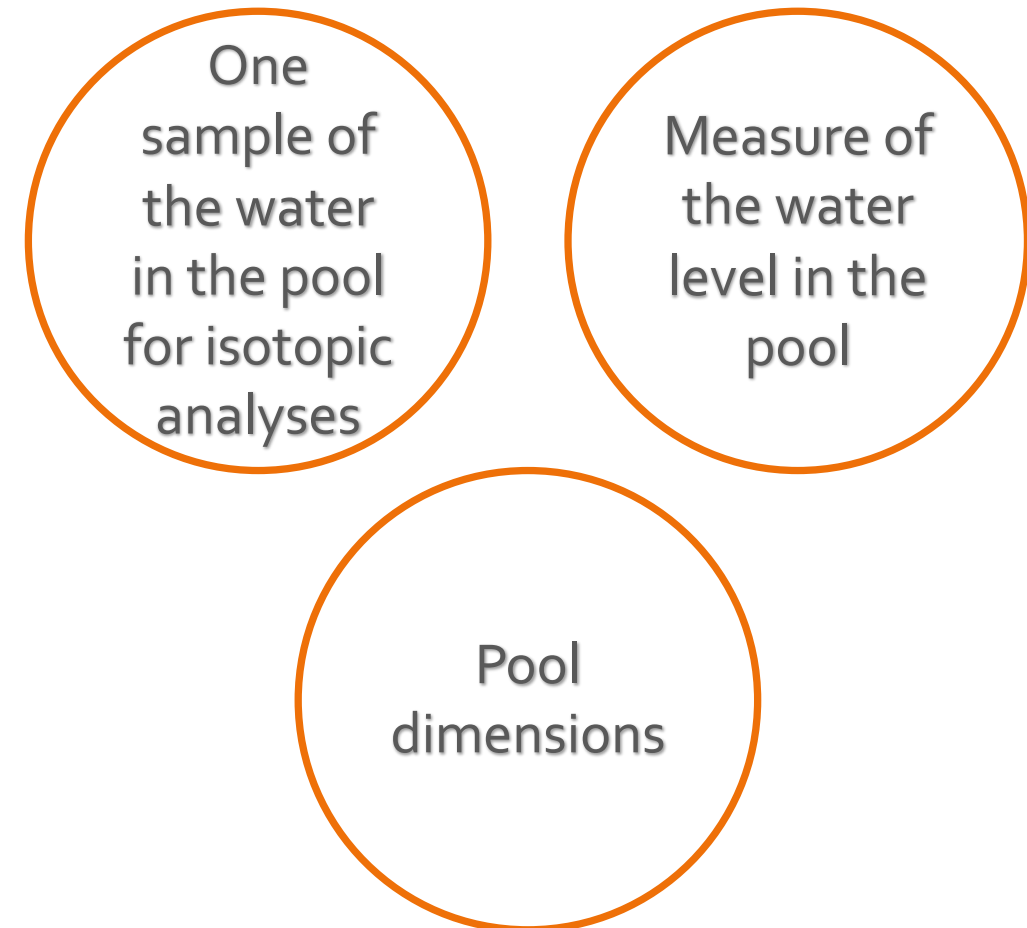
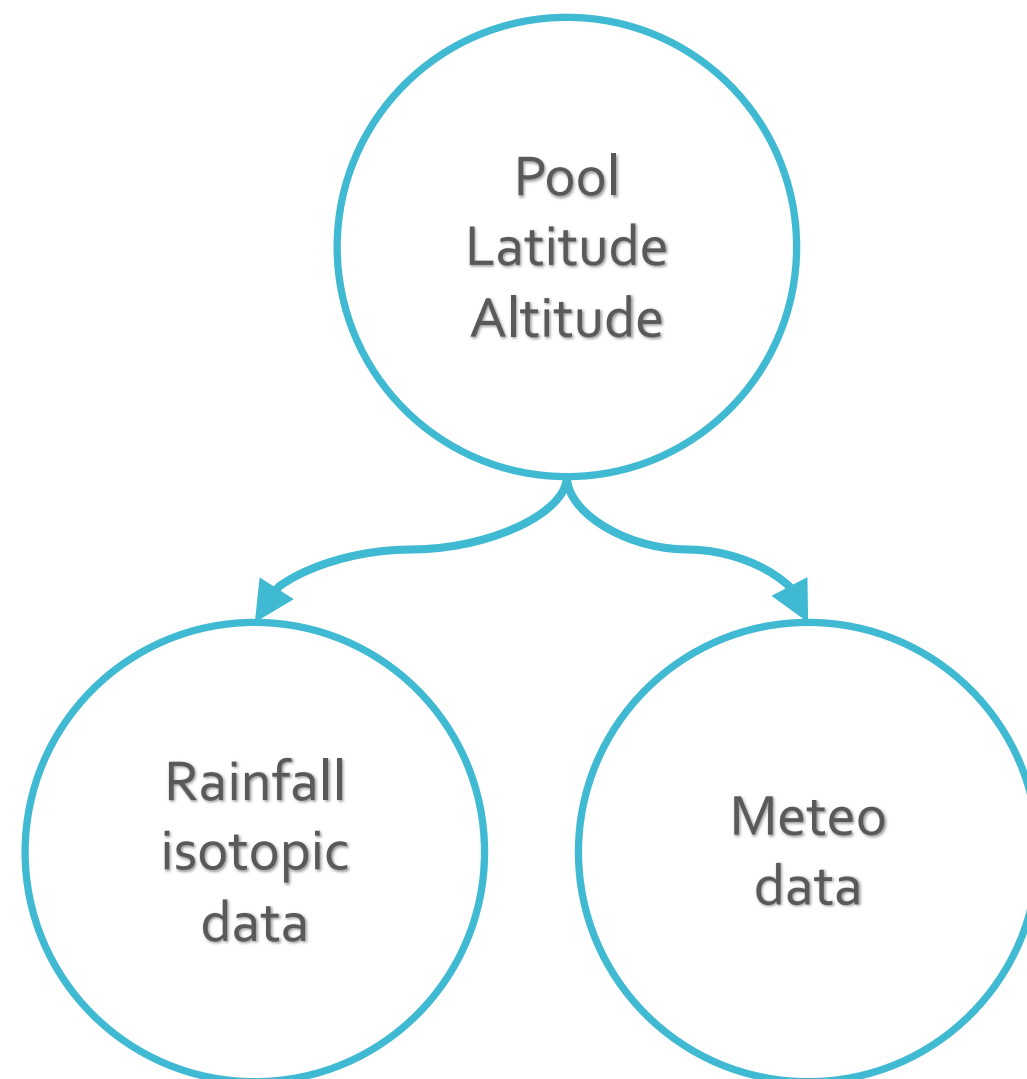
The objective of our work is to present a **methodology** to estimate the **time since disconnection of pools** from the river flow. This information is needed when the quality of the biological communities is to be studied (Bonada et al., 2021)

This methodology is based on the sampling of **water stable isotopes** in disconnected pools when the biological sampling is made.

It is an alternative to simple water level change when the initial conditions are unknown or water losses other than direct pool evaporation are suspected.

This methodology has been **validated** in an **artificial pool**.

Input data



Input data

Pool
Latitude
Altitude

Vallcebre research area

Latitude: 42.2° N

Altitude: 1290 masl



Input data

Rainfall
isotopic
data

Meteo
data

Monthly $\delta^{18}\text{O}$ and $\delta^2\text{H}$

Global Network of Isotopes in Precipitation (GNIP)

<https://www.iaea.org/services/networks/gnip>



Vallcebre.

Location of the study pool

Gisclareny.

Nearest meteorological station

GNIP.

Six nearest GNIP stations

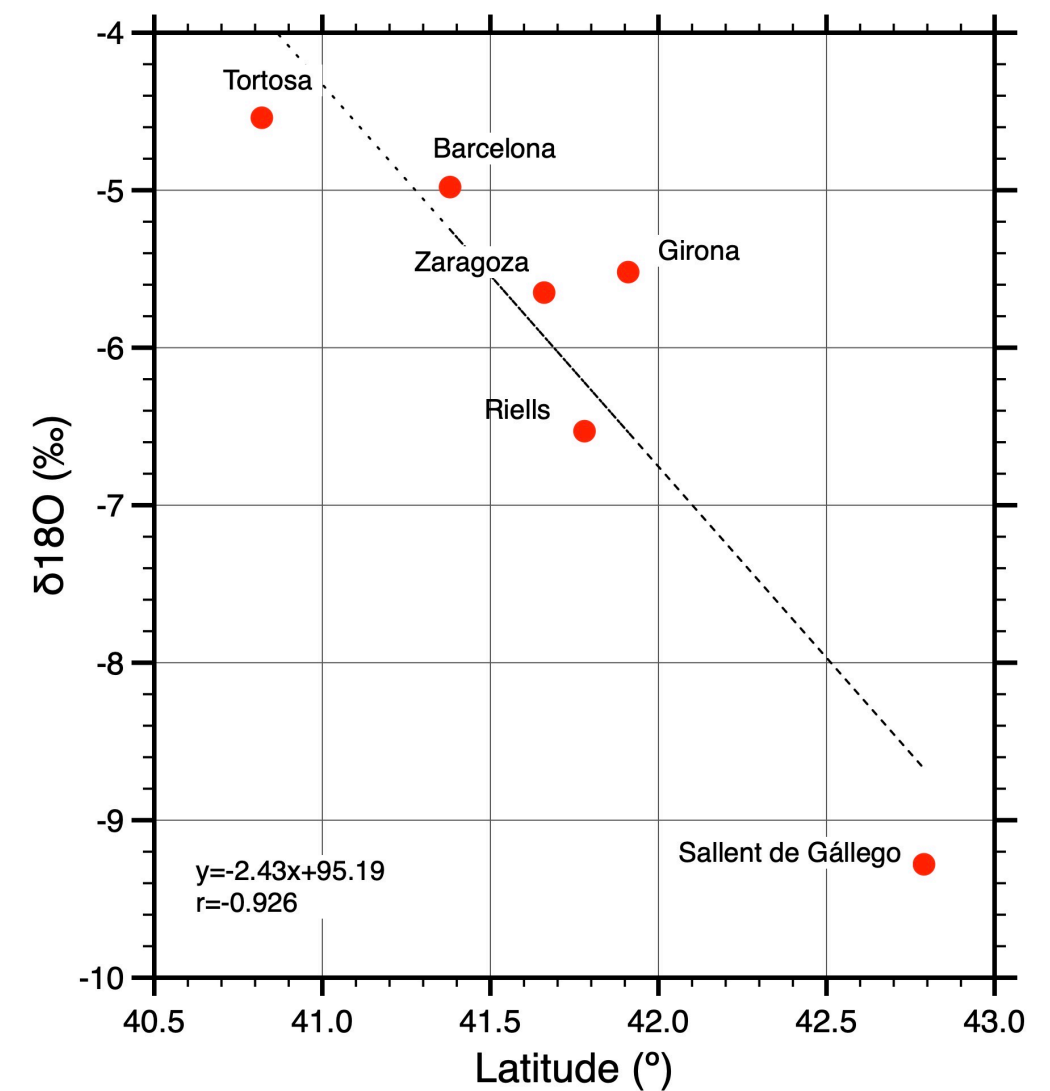
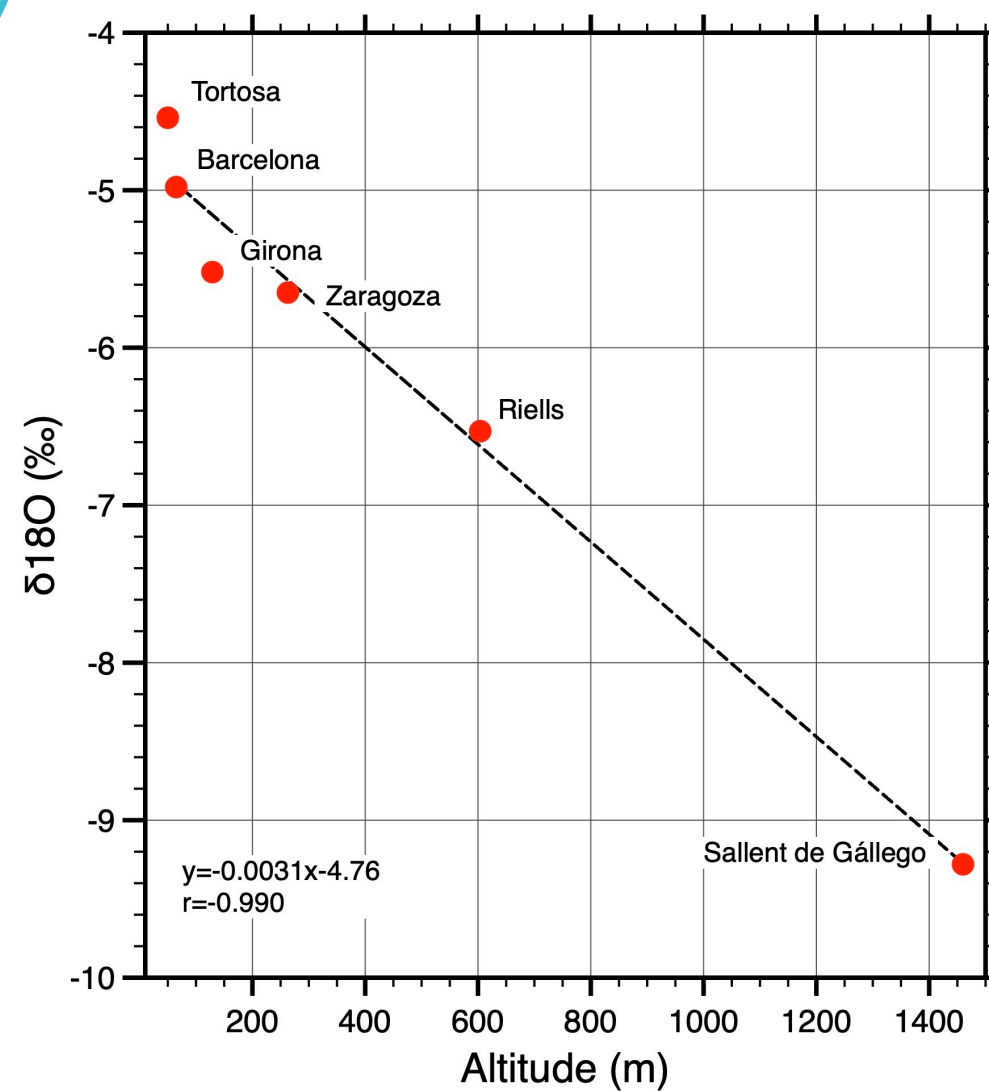
Daily temperature and daily global radiation

<https://en.meteocat.gencat.cat/xema>

All isotopic data available at nearest GNIP stations

Rainfall isotopic signature at the study pool

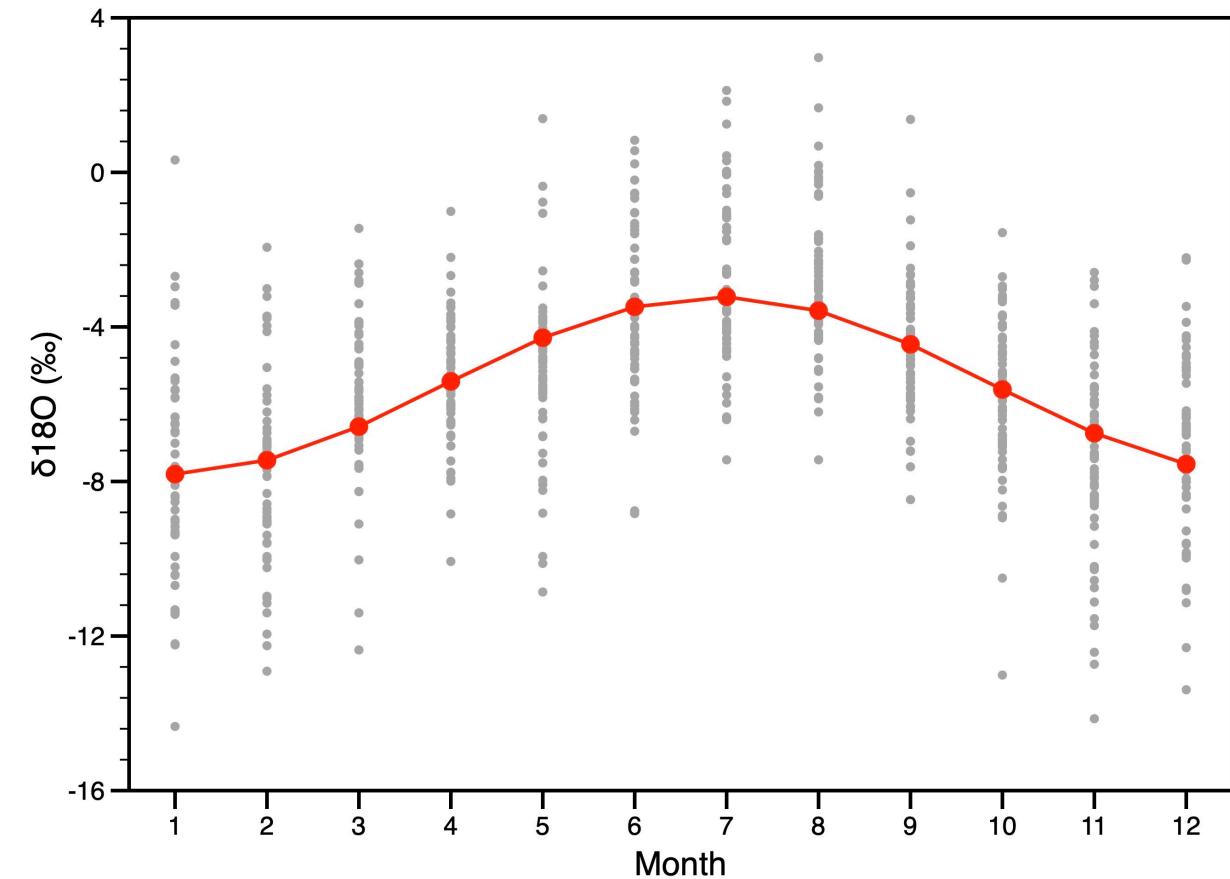
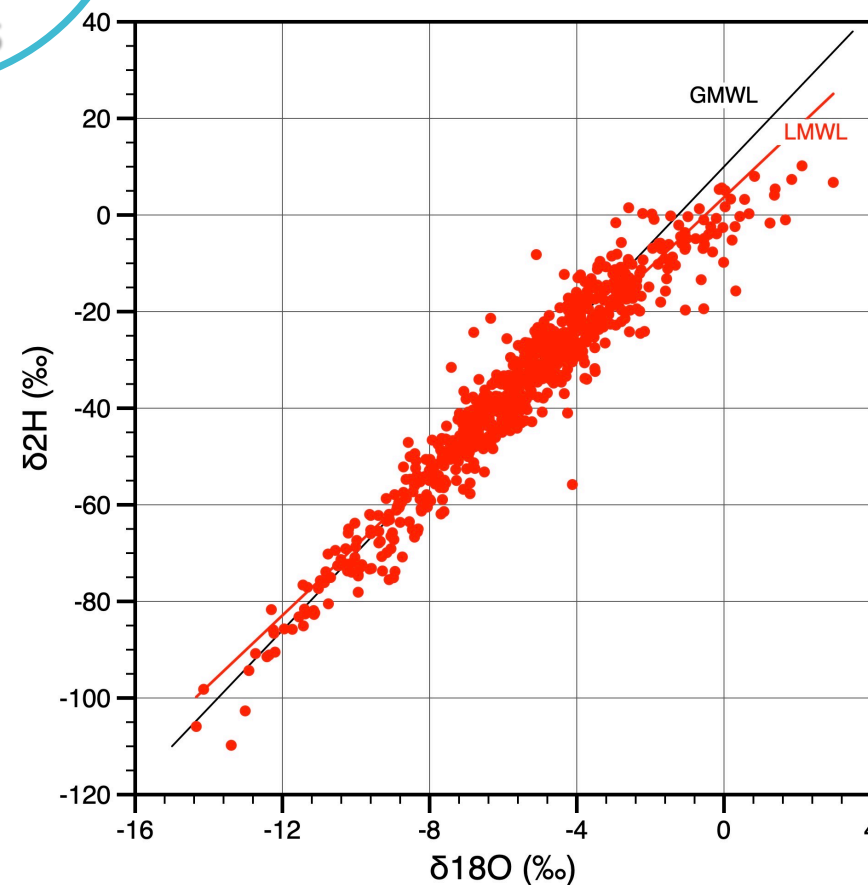
Determination of the relationship between **isotopic composition of rainfall** at the nearest GNIP stations and **altitude and latitude** of these locations.



All isotopic data available at nearest GNIP stations

Rainfall isotopic signature at the study pool

Determination of the **Local Meteoric Water Line (LMWL)** and a master **sinusoidal curve** of the isotopic composition of precipitation



The **Global Meteoric Water Line (GMWL)** describes the global long-term covariation of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ ratios in natural meteoric waters. The **Local Meteoric Water Line (LMWL)** represents the site-specific long-term covariation of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ ratios.

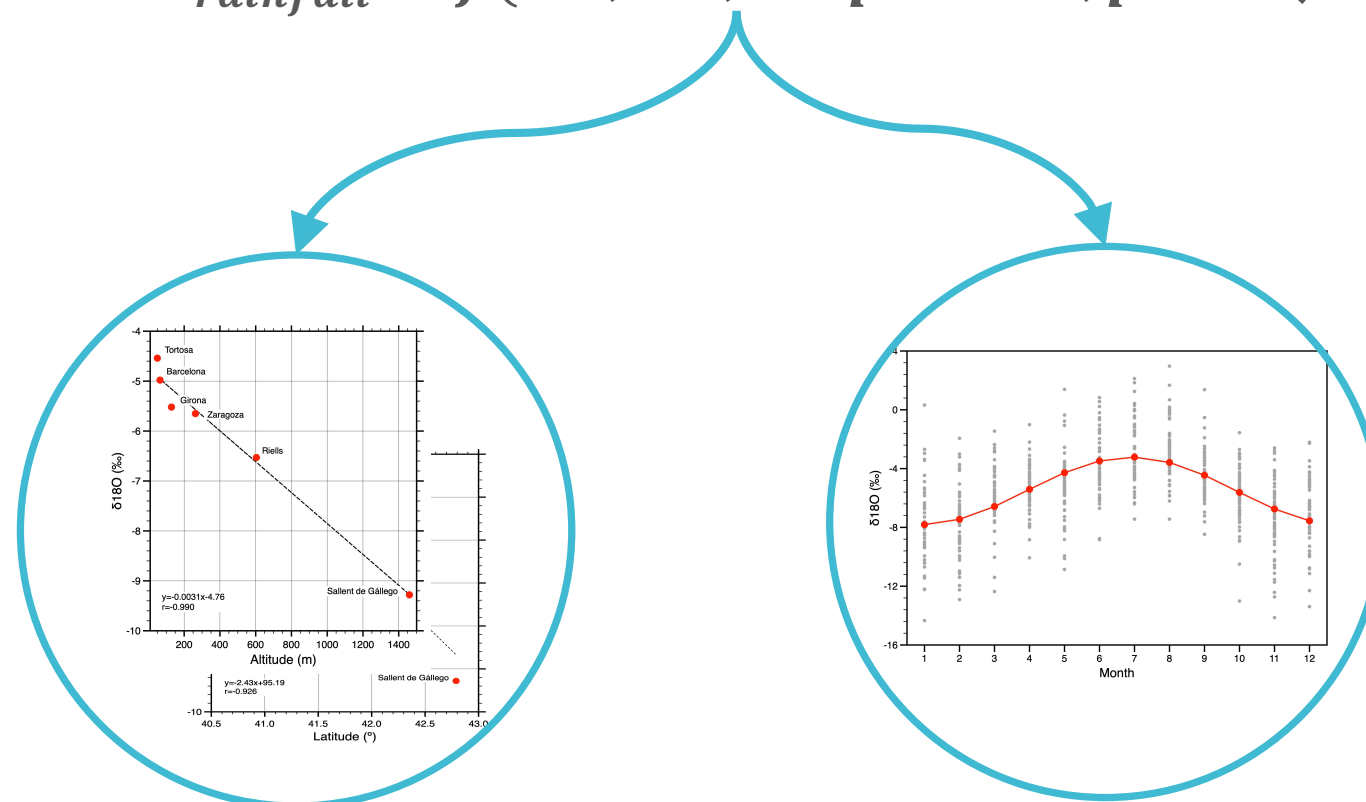
All isotopic data available at nearest GNIP stations

Rainfall isotopic signature at the study pool

The rainfall isotopic composition at the study pool is calculated from the combination of:

- Multiple regression with altitude and latitude
- Amplitude and phase of the master sinusoidal curve

$$\delta_{rainfall} = f(alt, lat, amplitude, phase)$$



Vallcebre example results

$$\delta^{18}O = -0.002 \, alt - 0.731 \, Lat + 2.30 \cdot \sin\left(\frac{2\pi(month-3.92)}{12}\right) + 25.425$$

$$\delta^2H = -0.016 \, alt - 5.015 \, Lat + 16.17 \cdot \sin\left(\frac{2\pi(month-4.03)}{12}\right) + 177.179$$

Isotopic data for one month before sampling

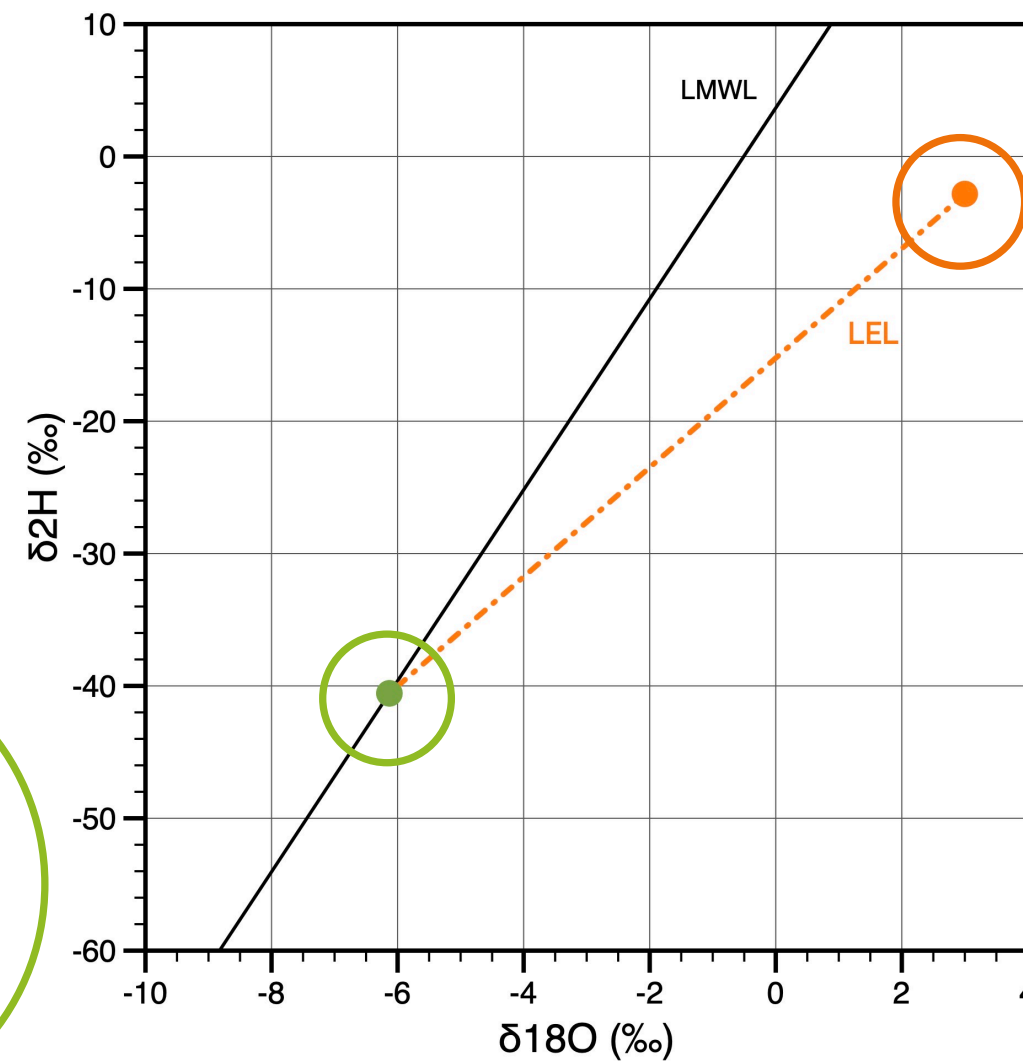
Local Evaporation Line

The isotopic composition of the pool when it was disconnected is estimated by the **intersection between the LEL and the LMWL**

Inferred Isotopic composition of the pool when was disconnected

Determination the **slope of the Local Evaporation Line (LEL)**. Gibson et al (2008) [eq. 1].

$$\text{Slope LEL} = f(\delta_{\text{rainfall}}, \delta_{\text{atmospheric vapor}}, T, RH)$$



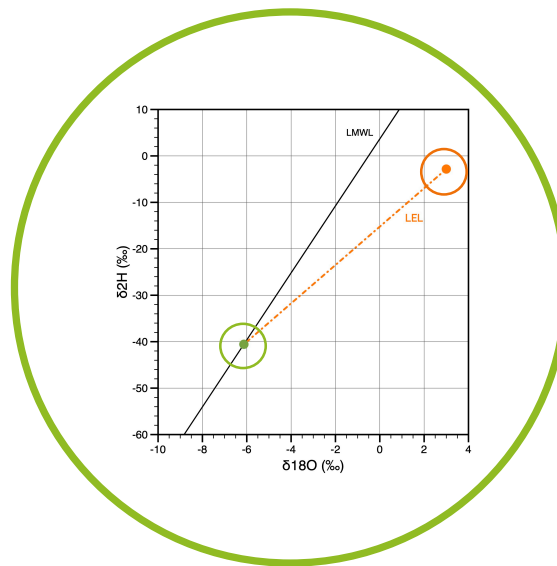
One sample of the water in the pool

Sampling date:
06/08/2020

Estimation of the volume of evaporated water

Knowing the **isotopic composition** of the water when the **pool was disconnected** and the isotopic composition of the **pool at the sampling date** the **relative volume of water evaporated** could be calculated for each isotope. Gonfiantini (1986) [eq. 2].

$$\text{Relative volumes} = f(\delta_{\text{pool when disconnected}}, \delta_{\text{pool sampling date}})$$



Vallcebre example results

$$\text{LEL} = 7.32x + 5.55$$

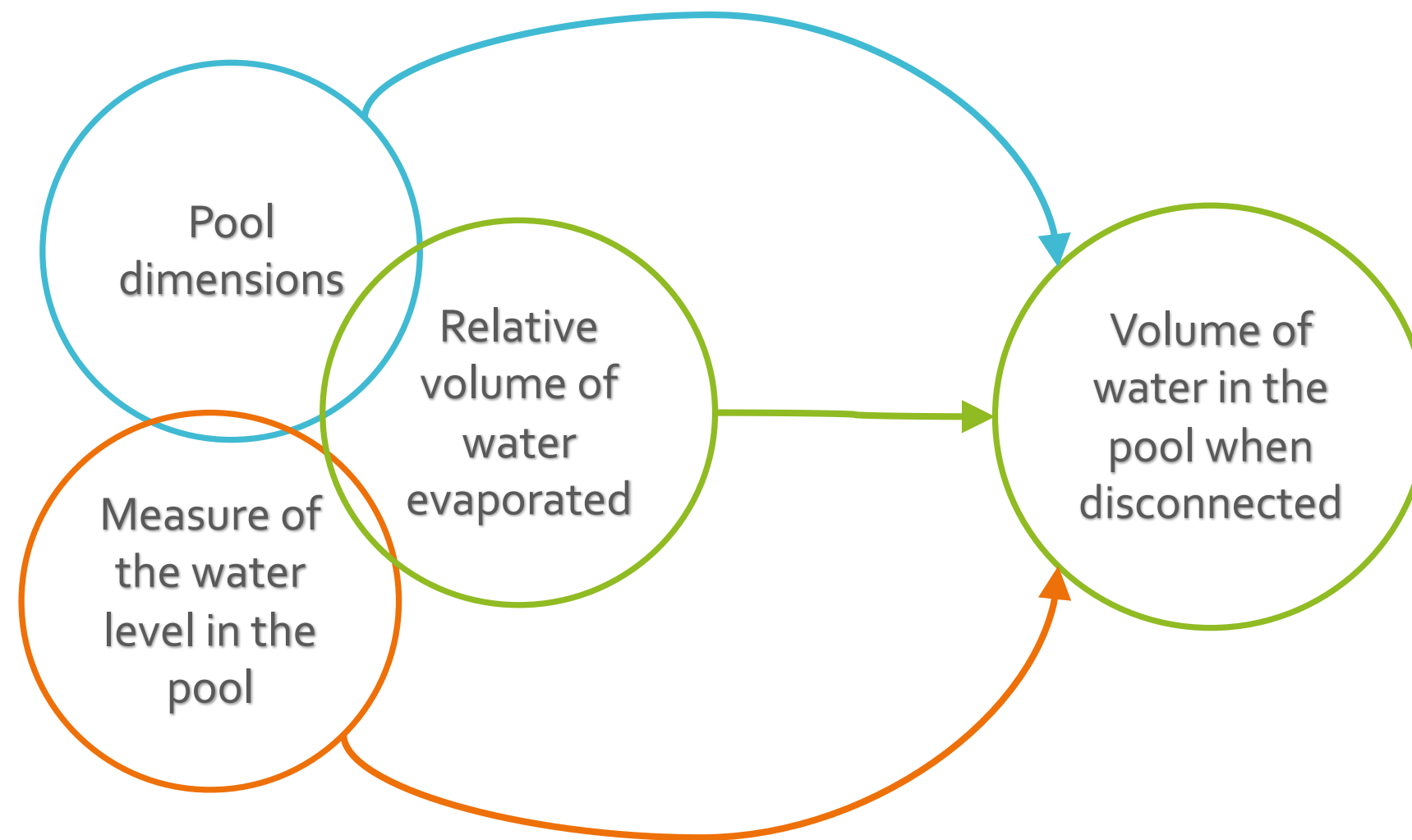
Sampling date: $\delta^{18}\text{O} = 3.0$ and $\delta^2\text{H} = -2.83$

When disconnected: $\delta^{18}\text{O} = -6.56$ and $\delta^2\text{H} = -42.46$

Relative volumes: 0.46 and 0.51 (for $\delta^{18}\text{O}$ and $\delta^2\text{H}$)

Estimation of the volume of evaporated water

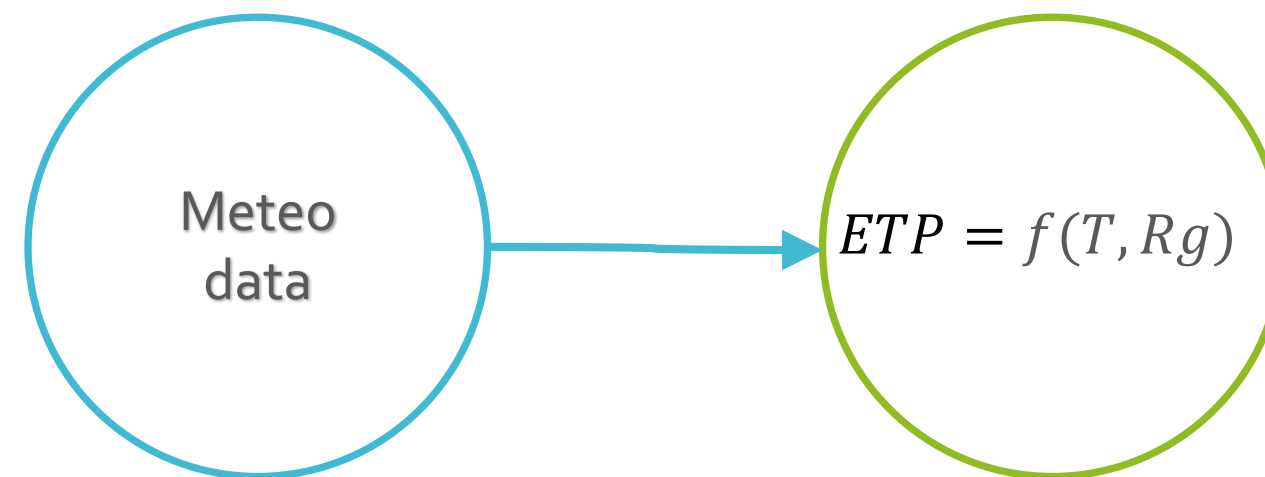
Knowing the the **water level** in the pool the date when the sample was taken, the **pool dimensions** (at least the the two main axes) and the **relative volume of water evaporated**, the **volume water in the pool when disconnected** could be calculated.



Calculation of the daily potential evaporation

The daily **potential evapotranspiration** in which the pool is considered to have been disconnected is estimated from Hargreaves and Samani (1985) [eq. 3].

- i. The air temperature at the nearest official meteorological station and corrected by altitude ($0.65^{\circ}\text{C}/100\text{m}$).
- ii. The global radiation (measured) or estimated from the monthly extraterrestrial radiation.



Estimation of the days since the pool was disconnected

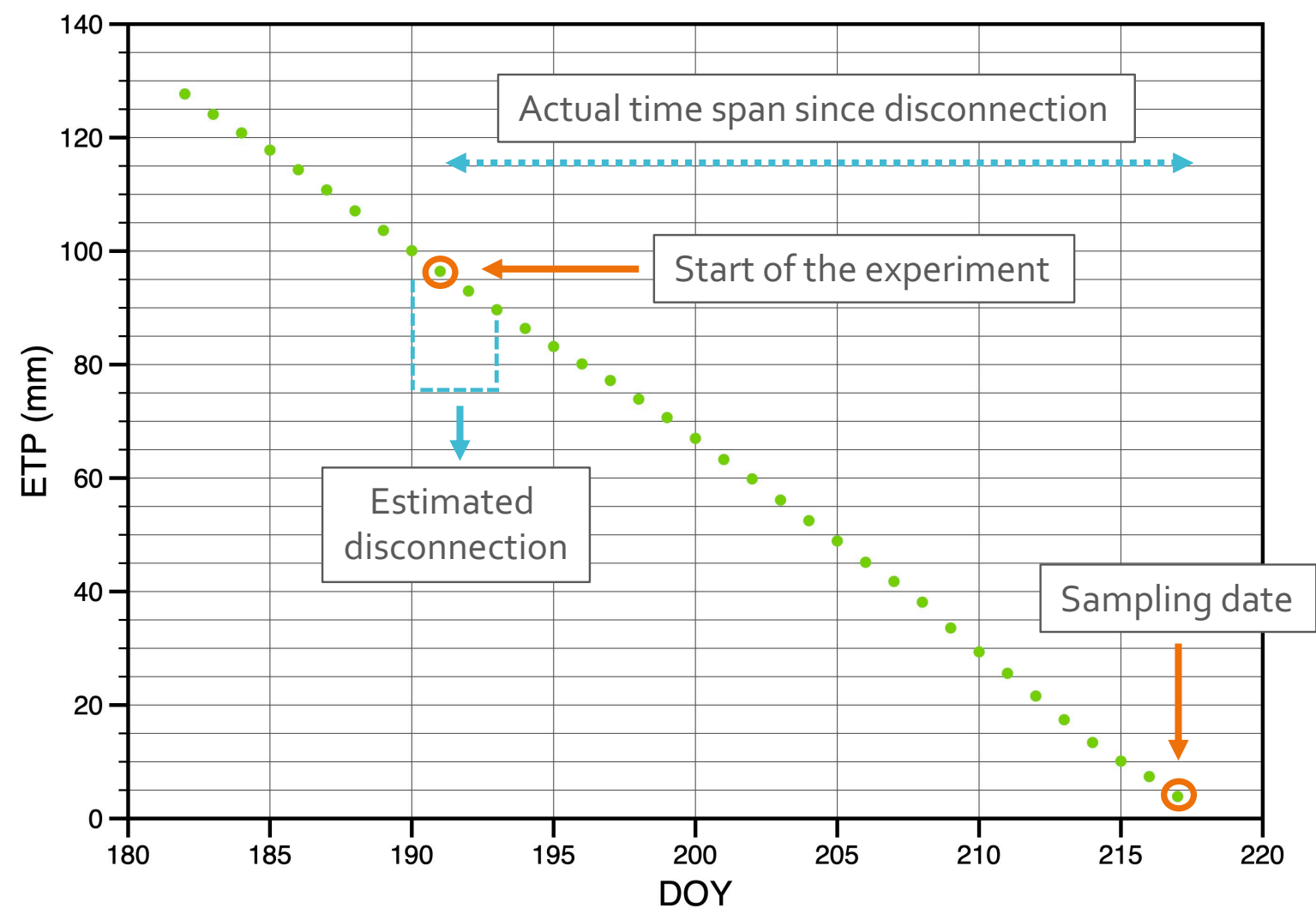
$$ETP = f(T, Rg)$$

Vallcebre example results

The estimated time since disconnection is between 24 and 29 days, depending if is calculated from $\delta^{18}\text{O}$ or $\delta^2\text{H}$ isotopic signature.

The start of the experiment was 28 days before the sampling date.

The estimation of the days since the pool was disconnected is calculated accumulating the daily ETP till the day when the cumulative ETP equals the volume of evaporated water estimated.



Limitations, opportunities and further work

Limitations: Significant precipitation after pool disconnection, intricate pool geometry, poor pool aeration and/or sunshine illumination.

Opportunities: valid for operational application, potentially revealing exchanges with underground water, of value for sustaining wealthy lentic aquatic life.

Further work: ongoing tests with true natural pools.

Supp. material

[eq. 1] Gibson et al (2008)

$$S_{LEL} = \frac{\left[\frac{h(\delta_A - \delta_P) + (1 + \delta_P)(\varepsilon_k + \varepsilon^+/\alpha^+)}{h - \varepsilon_k - \varepsilon^+/\alpha^+} \right] {}^2H}{\left[\frac{h(\delta_A - \delta_P) + (1 + \delta_P)(\varepsilon_k + \varepsilon^+/\alpha^+)}{h - \varepsilon_k - \varepsilon^+/\alpha^+} \right] {}^{18}O}$$

h = Relative humidity (%)
 δ_A = Isotopic composition of atmospheric vapour (‰)
 δ_P = Isotopic composition of rainfall (‰)
 ε_k = Kinetic fractionation factor
 ε^+ and α^+ = Equilibrium fractionation factors

[eq. 2] Gonfiantini (1986)

$$\delta_L = (\delta_0 - \delta^*)(1 - x)^m + \delta^*$$

δ_L = Isotopic composition of residual water (‰)
 δ_0 = Initial isotopic composition (‰)
 δ^* = Limiting isotopic composition (‰)
 x = Fraction of the initial volume of water that has evaporated
 m = Temporal enrichment slope

[eq. 3] Hargreaves and Samani (1985)

$$ETP = 0.00135(t_{\text{mean}} + 17.78)R_s$$

ETP = Potential evapotranspiration (mm)
 t_{mean} = Mean air temperature (°C)
 R_s = Solar radiation (mm day⁻¹)

Gibson, J. J., Birks, S. J., Edwards, T. W. D. (2008). Global prediction of δA and δ^2H - $\delta^{18}O$ evaporation slopes for lakes and soil water accounting for seasonality. *Global biogeochemical cycles*, 22(2).

Gonfiantini, R. (1986). Environmental isotopes in lake studies. *Handbook of environmental isotope geochemistry*, 2, 113-168.

Hargreaves, G. H., Samani, Z. A. (1985). Reference crop evapotranspiration from temperature. *Applied engineering in agriculture*, 1(2), 96-99.