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OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Workshop on “Developments in isotope ratio measurements for gas analysis”, Bern, 10.10.2019

Insights into the new tracer ^{17}O-excess: results from the Swiss precipitation network

Markus Leuenberger, Shyam Ranjan, Stéphane Affolter, Rüdiger Schanda and Peter Nyfeler

Climate and Environmental Physics Division, Physics Institute, University of Bern, Switzerland and Oeschger Centre for Climate Change Research

Isotopologues of water: Tool to retrieve information about the water cycle

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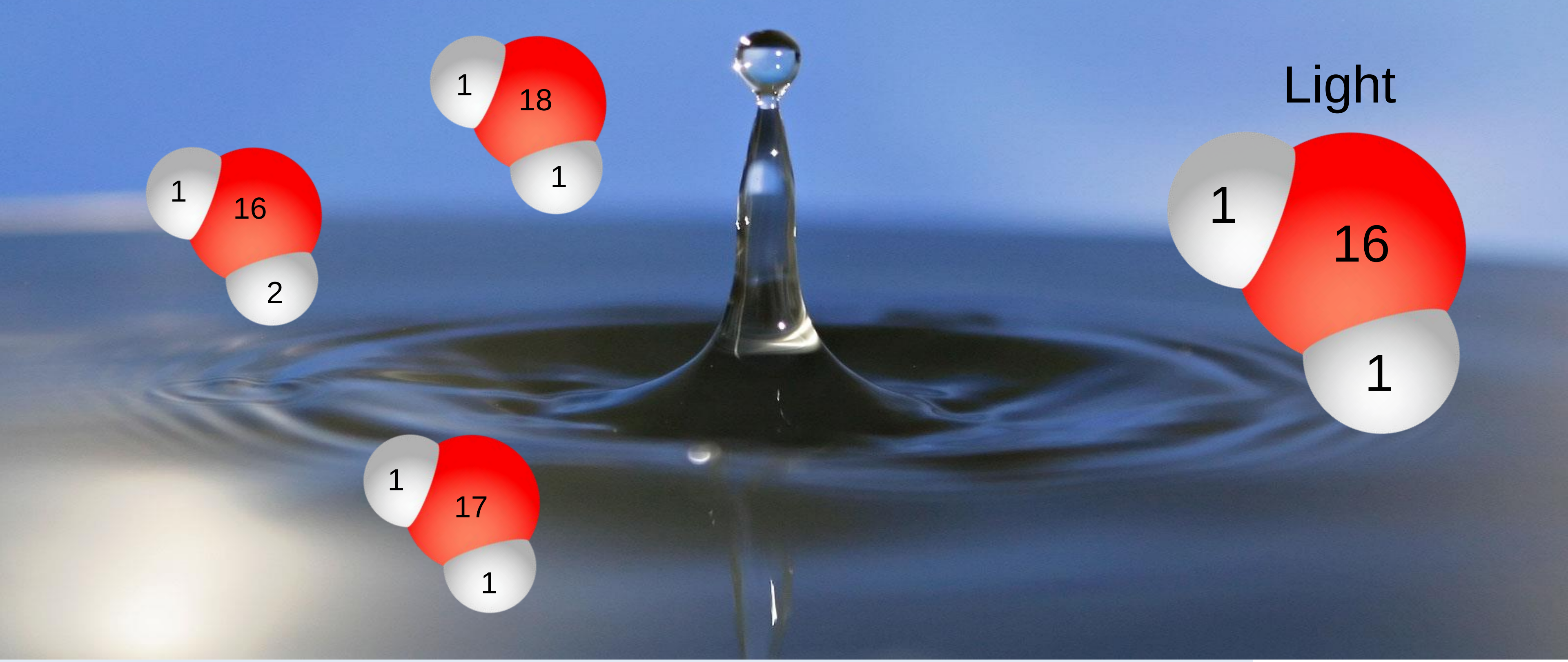
Three rare heavy Isotopologues
< 1% of all water

Most abundant
> 99 % of all water



Early steps in water isotope research
R. Gonfiantini, H. Craig and L. I. Gordon

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Water cycle processes and its implication on isotopologues

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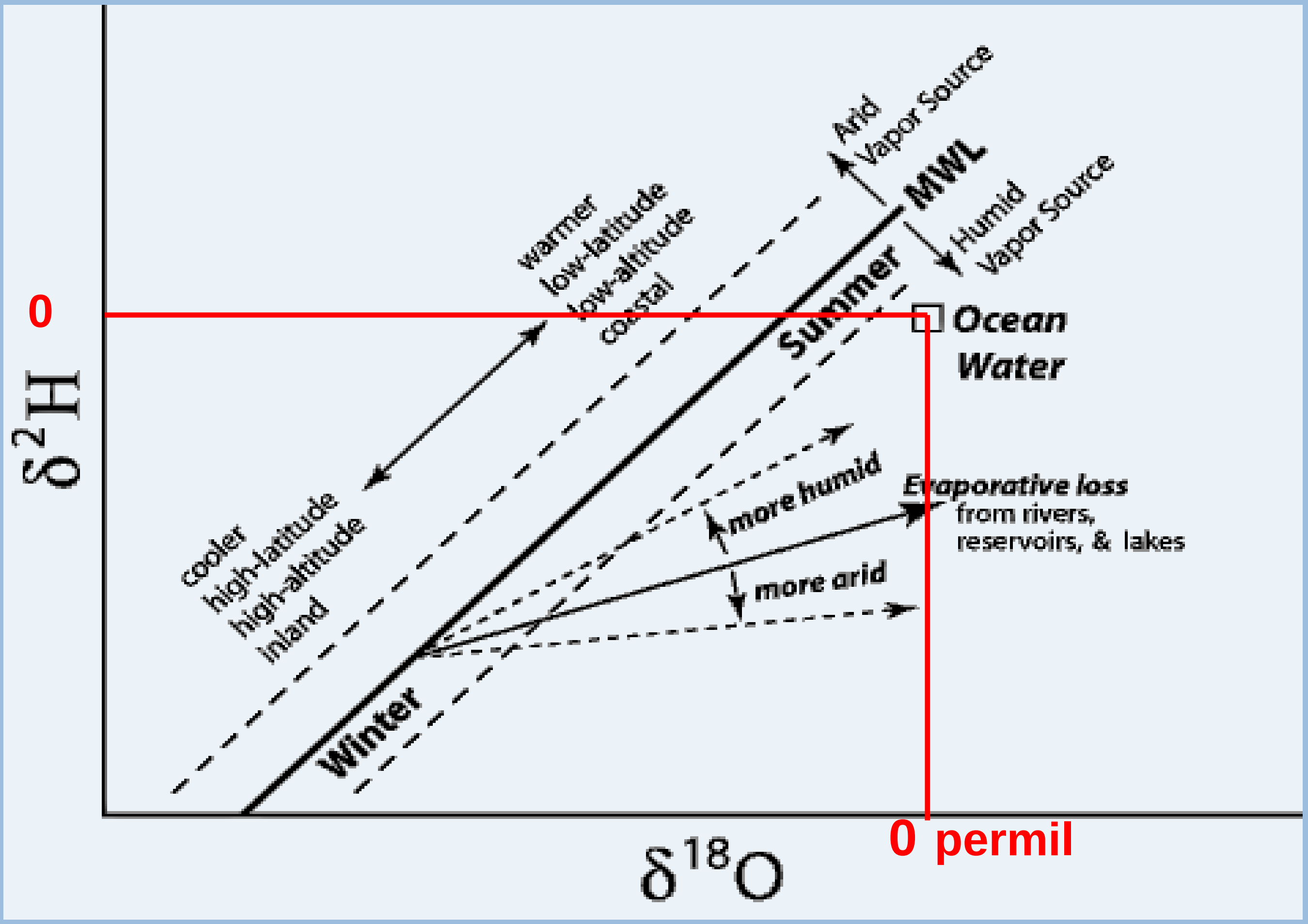
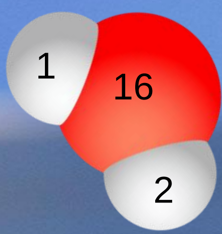
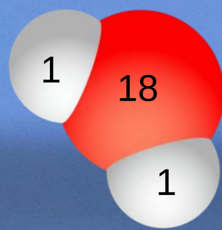


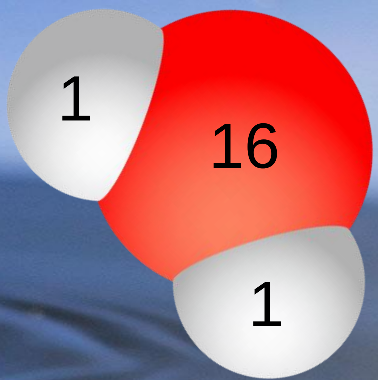
Isotopologues of water: Second order effects

d-excess in ice cores as tracer of

- **Moisture source temperature (Ciais and Jouzel, 1994)**
- **Precipitation site temperature (Stenni et al., 2010, Vimeux et al., 2002)**
- **Relative humidity at evaporation site (Jouzel, 1982, Pfahl and Sodemann, 2014, Aemisegger and Soltje 2018)**







$$\delta D - 8 \cdot \delta^{18}O = \text{d-excess}$$

(Dansgaard, 1964)

Conclusion first part

> Tools such as ^{17}O-excess and d-excess are helpful in disentangling kinetic from equilibration processes.

> We observed a clear anti-correlation between ^{17}O-excess and the stable isotopes ($\delta^{17}O$, $\delta^{18}O$ and δD) in precipitation samples in contrast to

> no or a slight positive correlation between ^{17}O-excess and the stable isotopes ($\delta^{17}O$, $\delta^{18}O$ and δD) in water vapor.

> The mean value of ^{17}O-excess of the water vapor of about +20 per meg points to an important but rather weak (10 %) kinetic (diffusive) fractionation at the source location which might probably be present during the complete vapor path from the source location to the site of precipitation.

> The correspondent value for precipitation is about +45 per meg and is expected due to the higher slope of the equilibration fractionation of 0.529 between ^{17}O and ^{18}O.

δD and d-excess values on Dome Fuji ice

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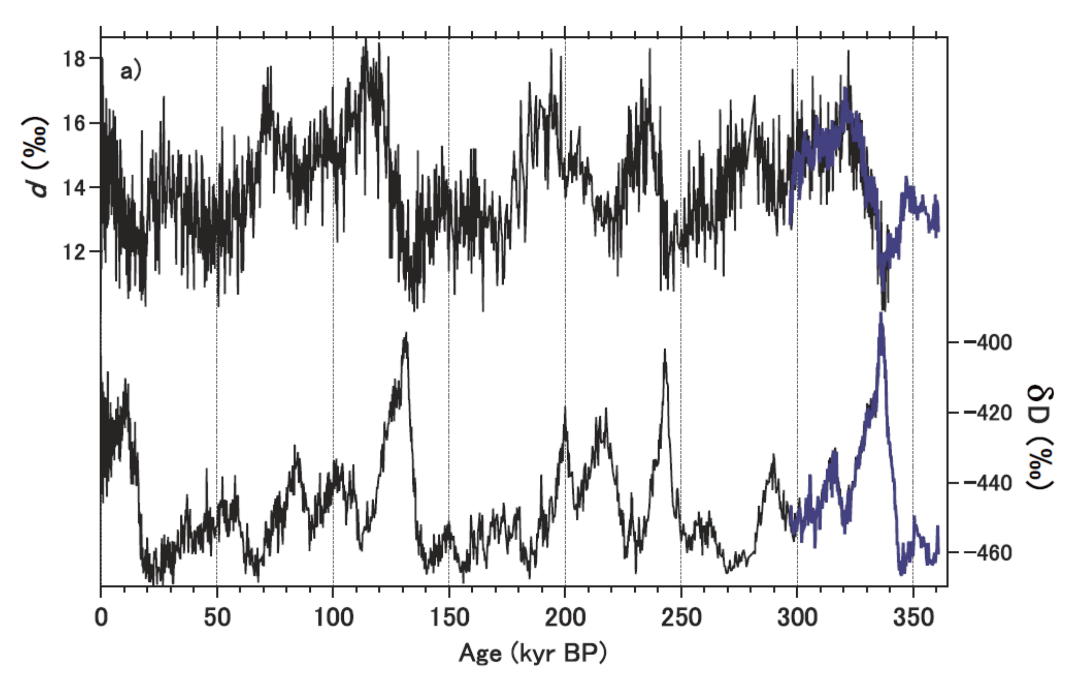

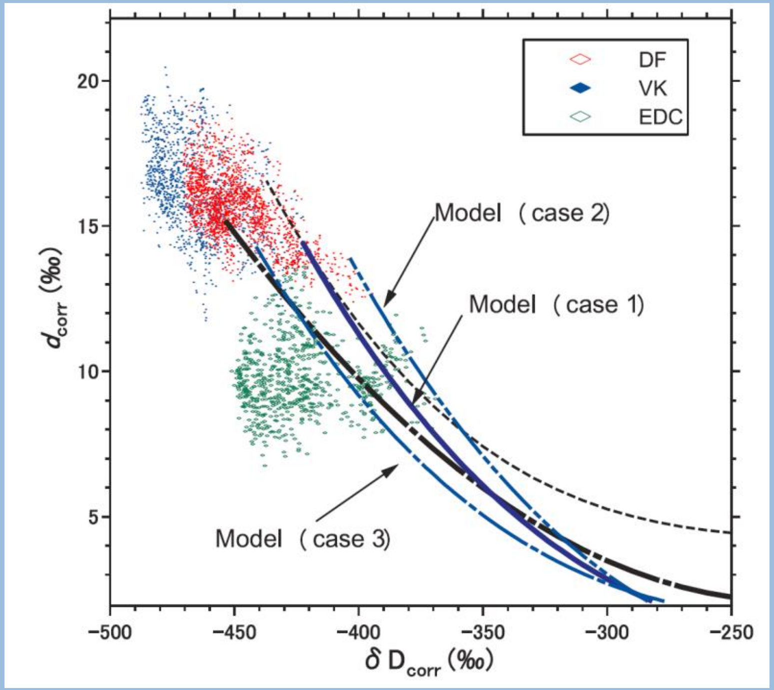

Anti-correlation between δD and d-excess

Could indicate an increased continentality effect!

Uemura et al., CP 2012

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d-excess correlations with humidity and sea surface temperatures

d_c vs. SST

d_c vs. h_s

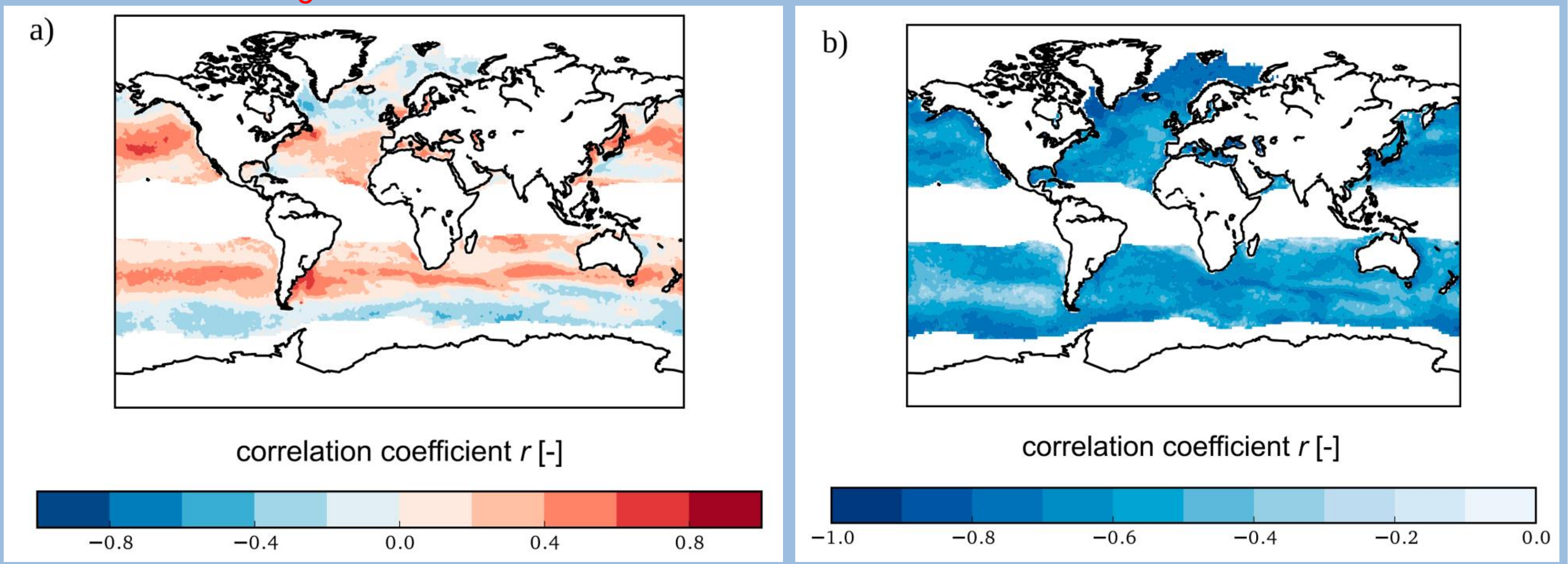
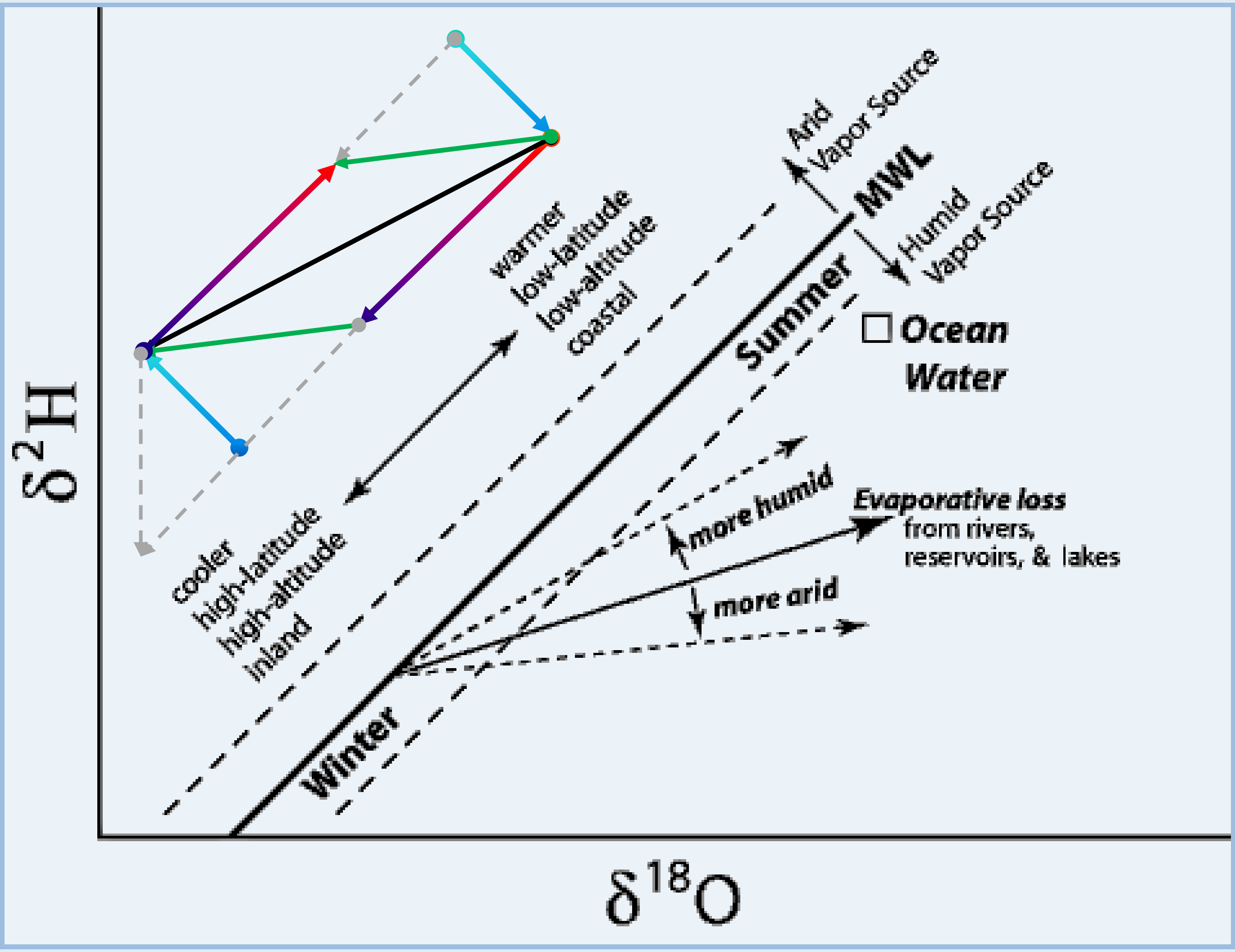


FIG. 8. Correlation of (a) dc with SST and (b) dc with hs using monthly mean data and ak(MJ79) during SLOE. Both patterns look similar when using SLH-weighted monthly means. Land areas, regions with seasonal mean SLOE frequencies below 1% (tropics), or areas with seasonal sea ice are masked. → **proxy for relative humidity**

Water cycle processes and its implication on isotopologues



Equilibrium, slope 8

Kinetic, slope 1

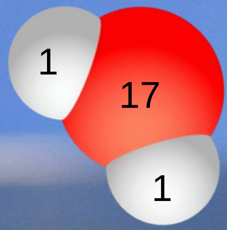
Effect on dex

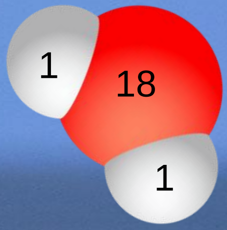
Isotopologues of water: Second order effects

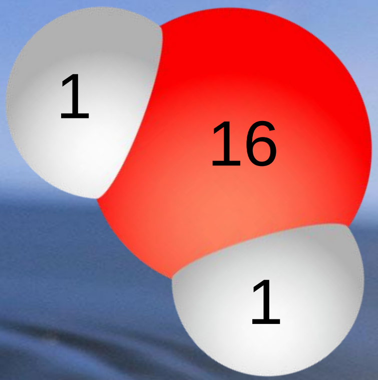
^{17}O-excess in vapour over the ocean is

- **Anitcorrelated with the relative humidity (RH) (Uemura, 2010)**

- **Can it act as RH tracer?**
- **Is there more to say?**





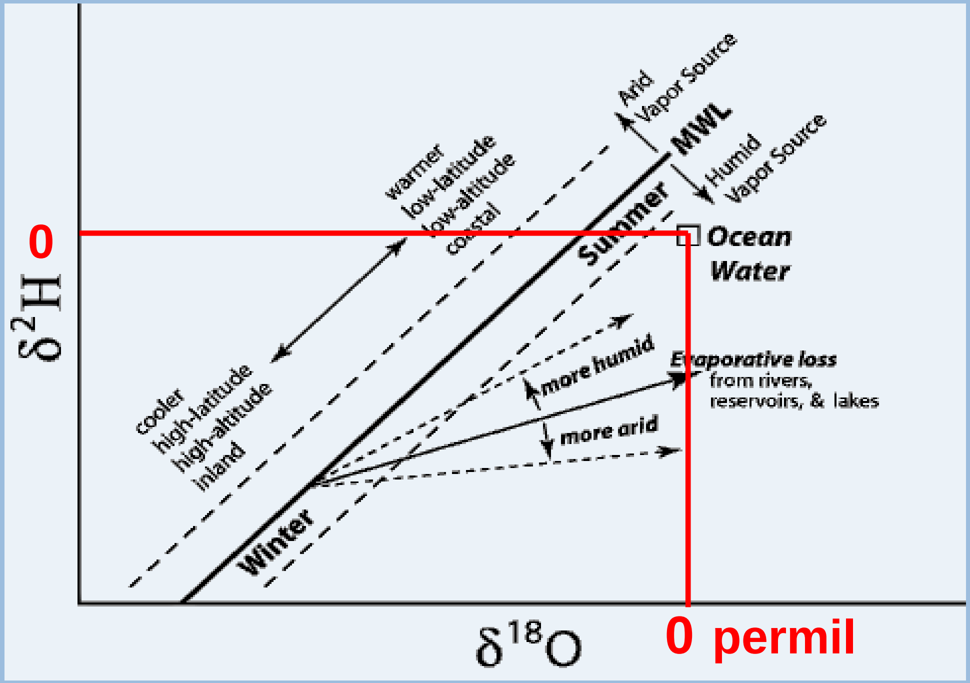


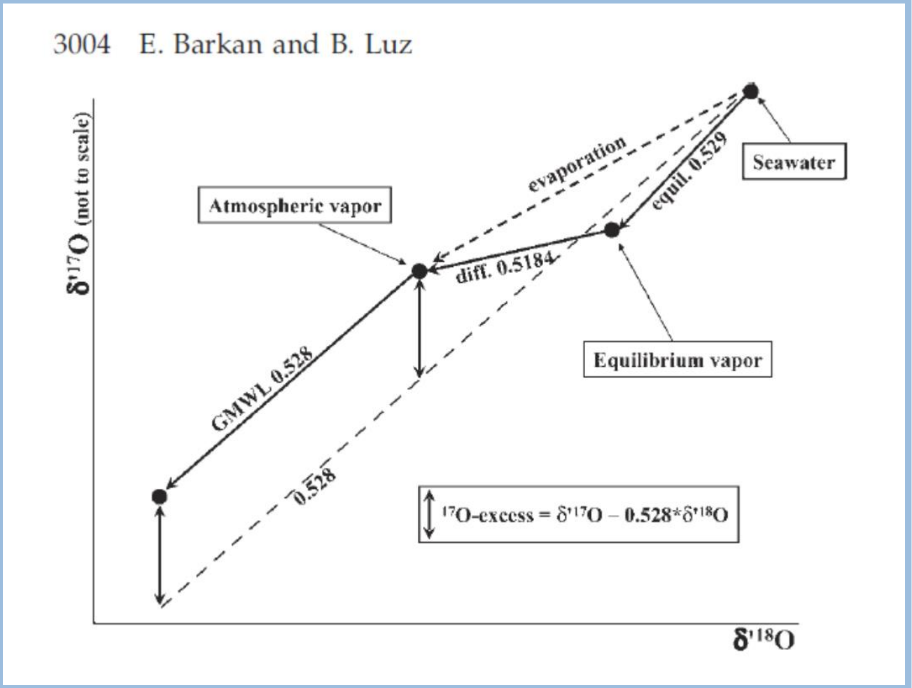
$$^{17}\text{O-excess} = \ln(\delta^{17}\text{O} + 1) - 0.528 \cdot \ln(\delta^{18}\text{O} + 1)$$

(Barkan and Luz, 2004)

Primary and second-order effects

$$^{17}\mathrm{O-excess} = -\ln\left({}^{18}\alpha_{eq}^{0.529}\left({}^{18}\alpha_{diff}^{0.518}(1-h_n)+h_n\right)\right) + 0.528\cdot\ln\left({}^{18}\alpha_{eq}\left({}^{18}\alpha_{diff}(1-h)+h_n\right)\right)$$





From equation above: about -0.001 ‰/% = -1 permeg /%!!

Barkan and Luz RCM 2007

Demands on well-calibrated and precise instrumentations are high!!

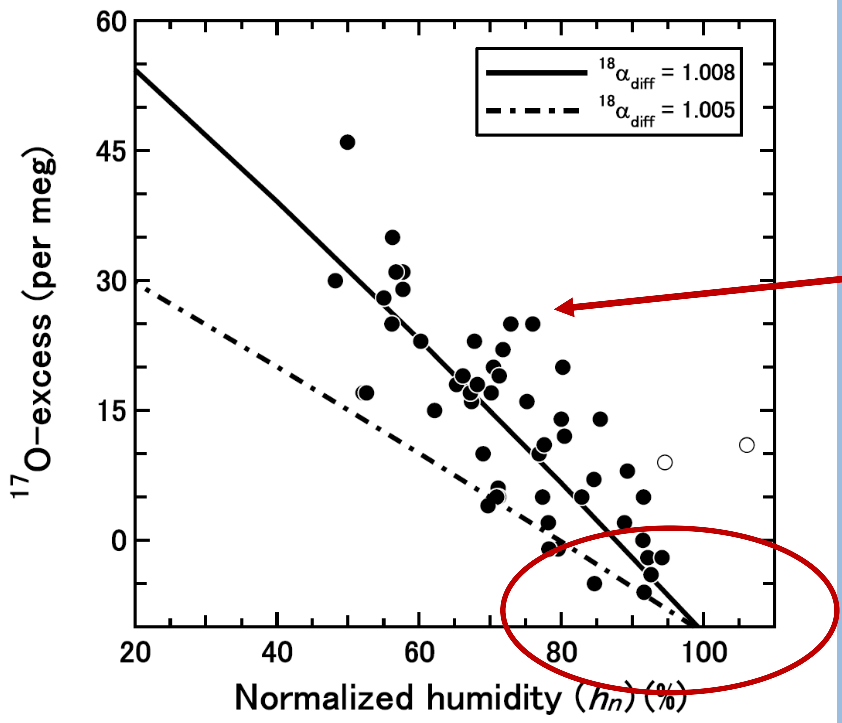


Figure 1. The ^{17}O-excess of atmospheric vapor in the ocean versus normalized humidity (h_n). Observed data (solid circles) with two outliers (open circles) are shown. The solid line is based on model calculations with optimized $^{18}\alpha_{diff}$ (1.008). The chain line is based on model calculations with the generally accepted $^{18}\alpha_{diff}$ values of 1.005.

Slope of -0.64permeg/%

Slightly negative values for high humidities

Uemura et al., GRL, 2010

Jungfraujoch monthly precipitation using a Picarro L2140-i instrument

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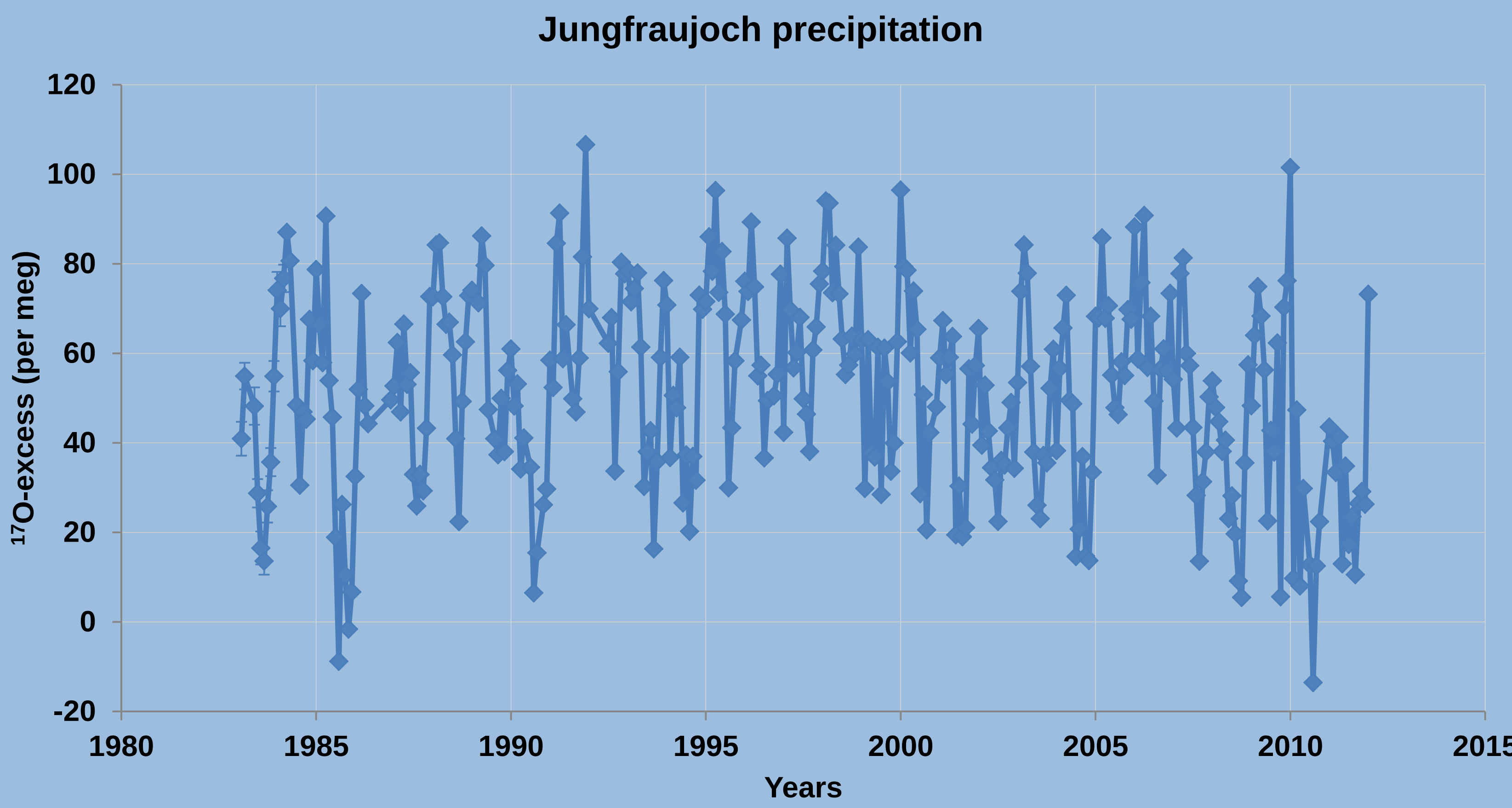

Mean of 47 ± 30 per meg → 43 (+ 23, - 28) % humidity

Jungfraujoch monthly precipitation and temperature

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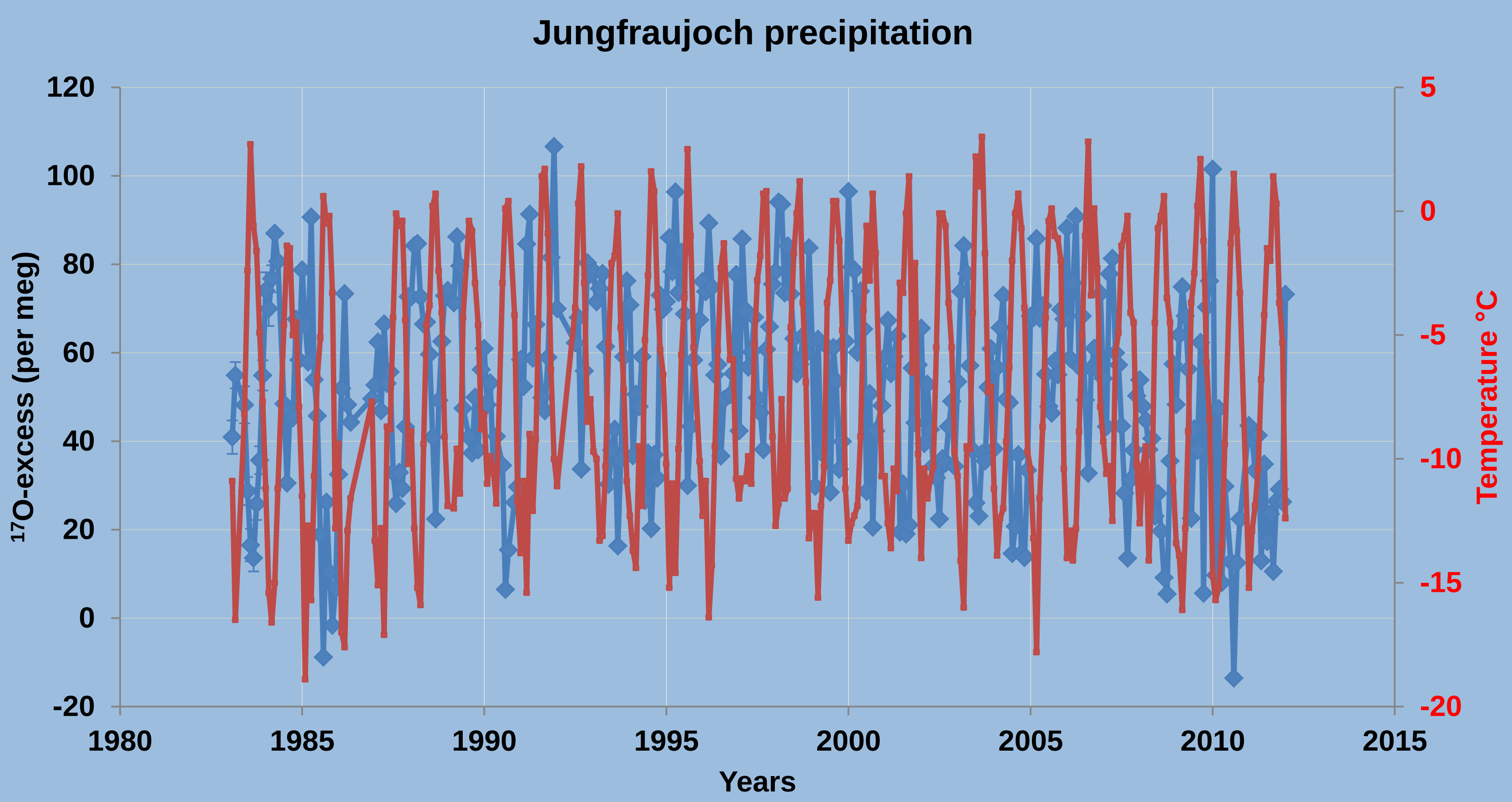

Anticorrelation with temperature indirect effect

Jungfraujoch precipitation vs. temperature

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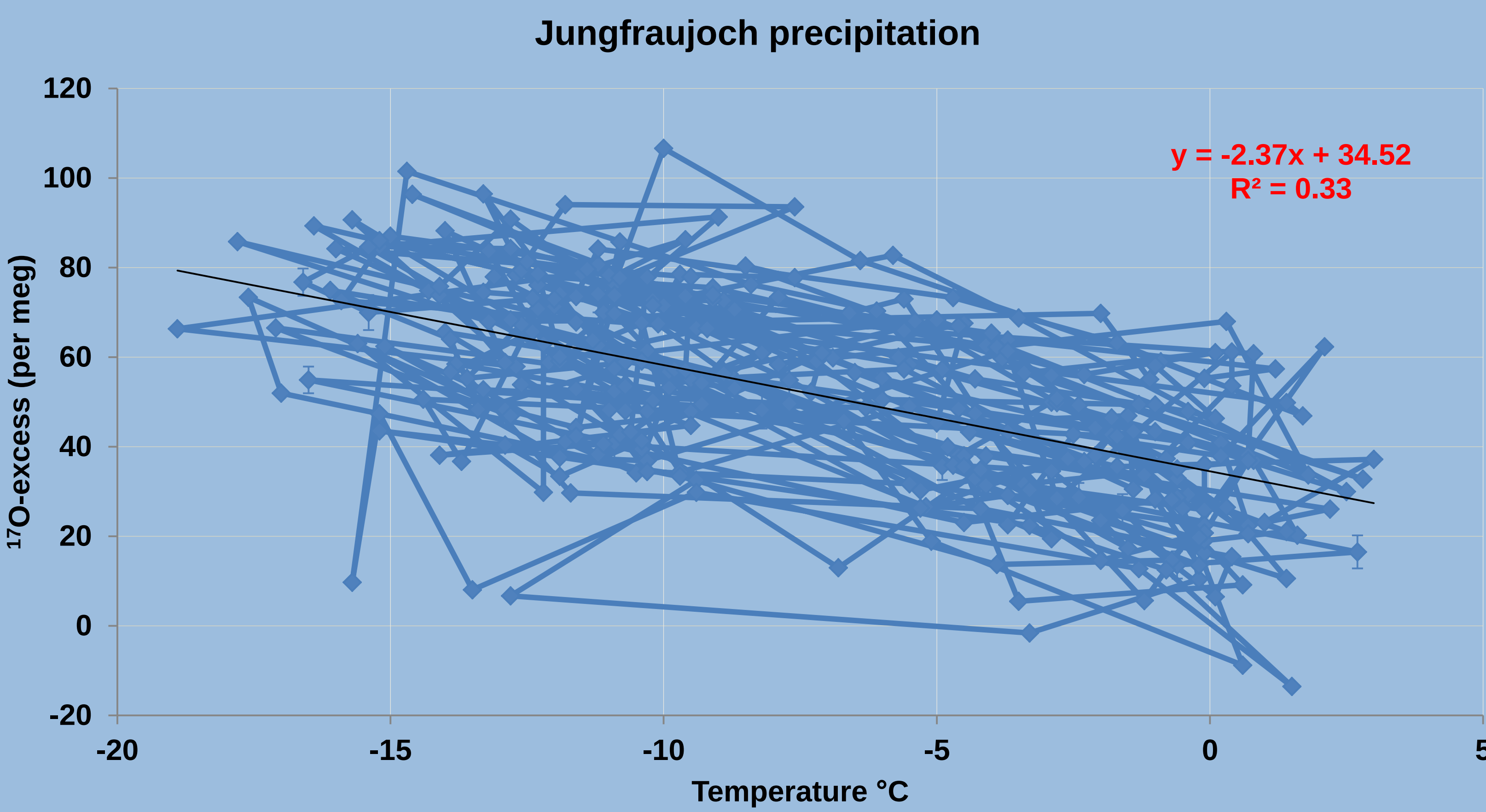

Anticorrelation with temperature indirect effect

Jungfraujoch precipitation

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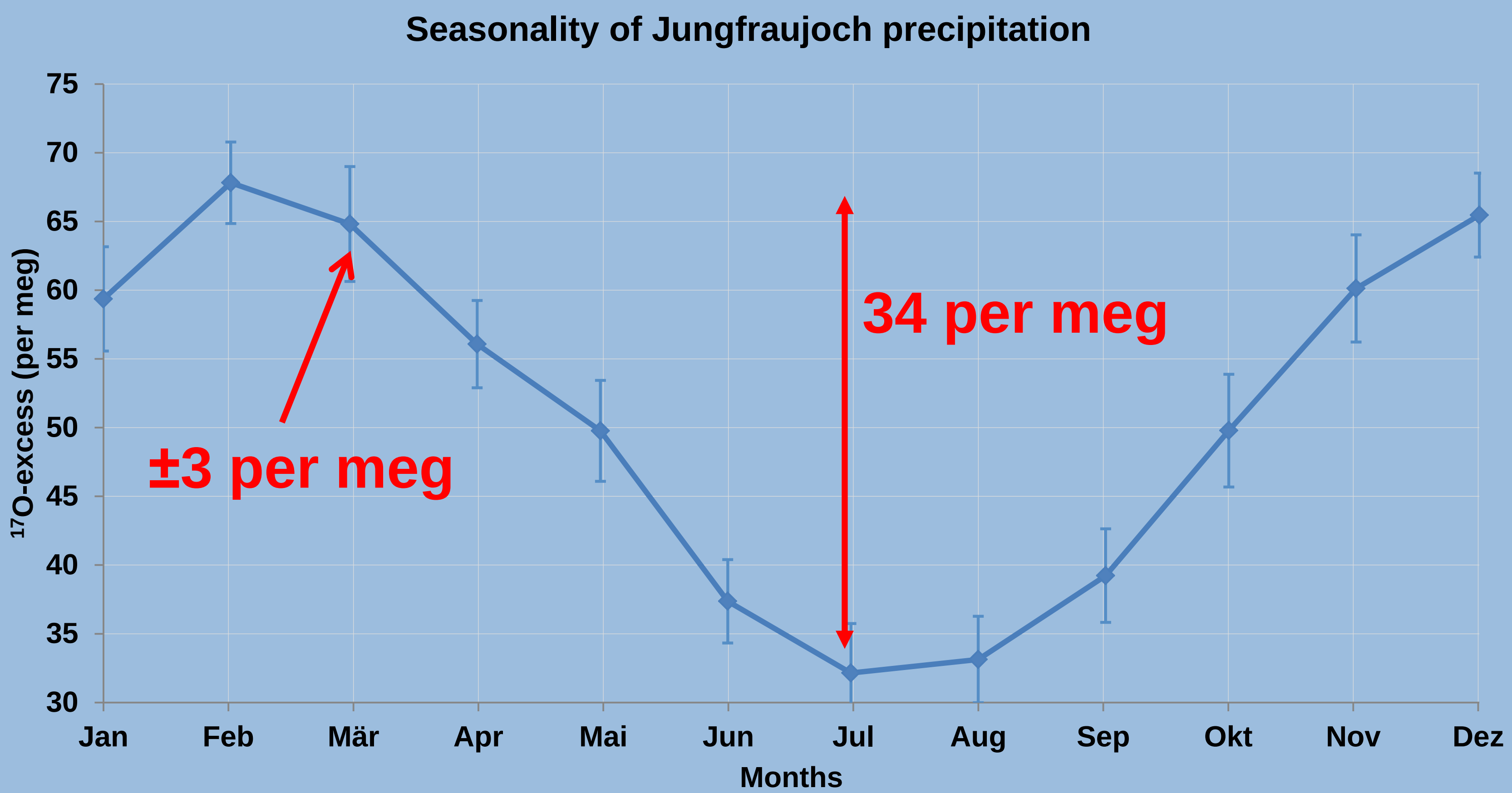

Seasonality with an amplitude of 34 per meg and a monthly uncertainty of ±3 per meg i.e. relative humidity changes 43 (+ 17, -14) %.

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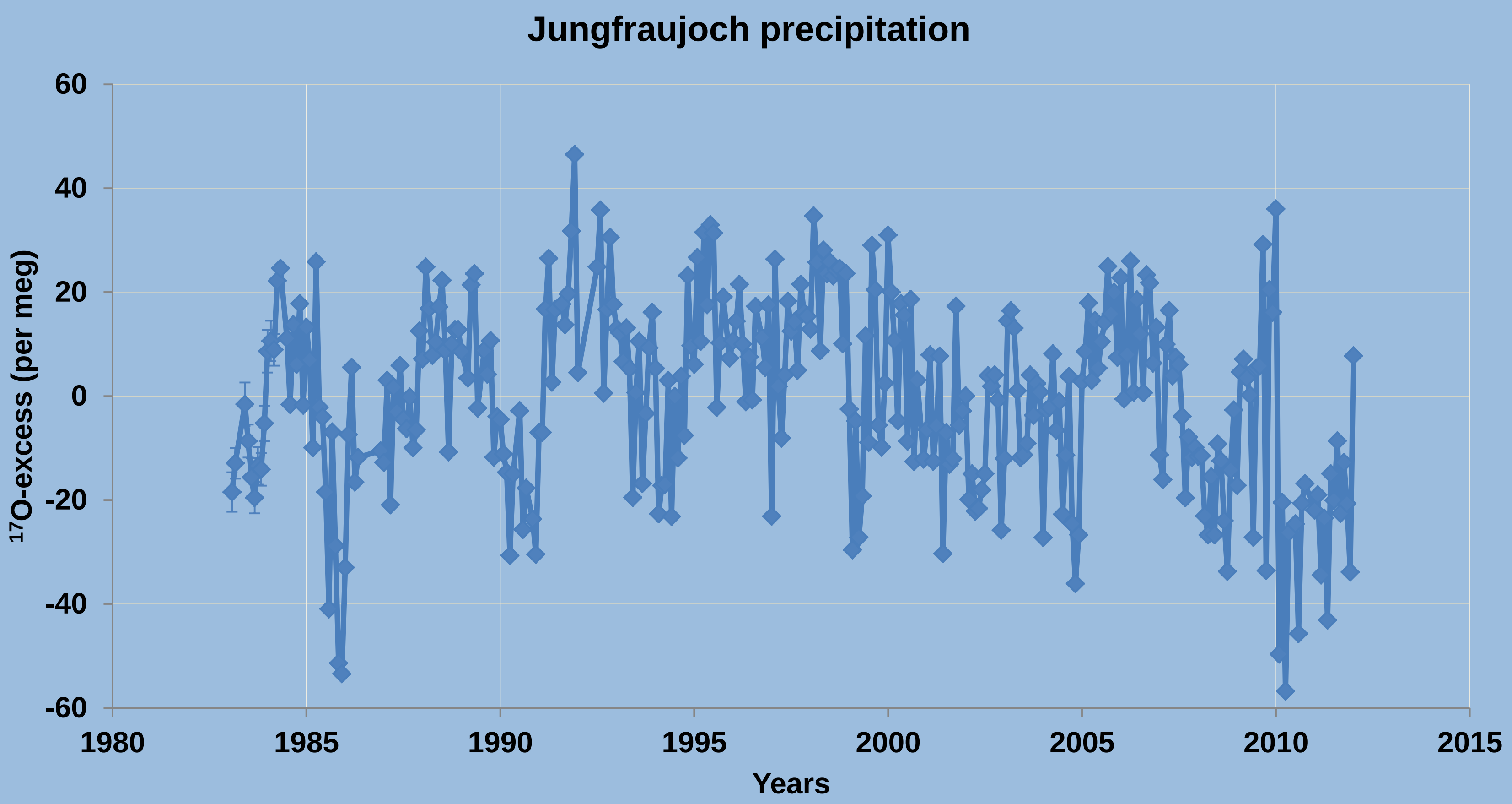
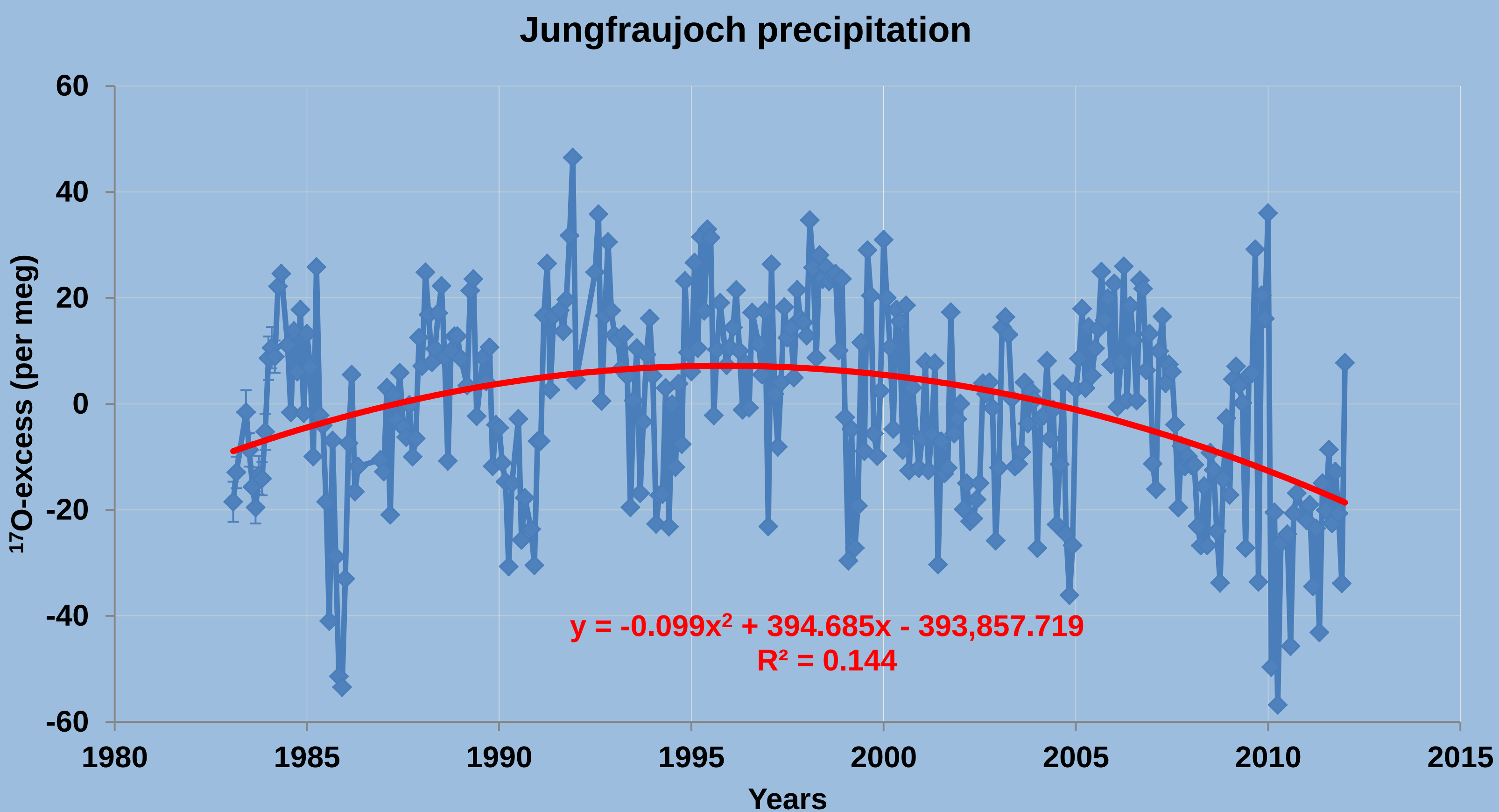
Jungfraujoch monthly precipitation variations around the mean



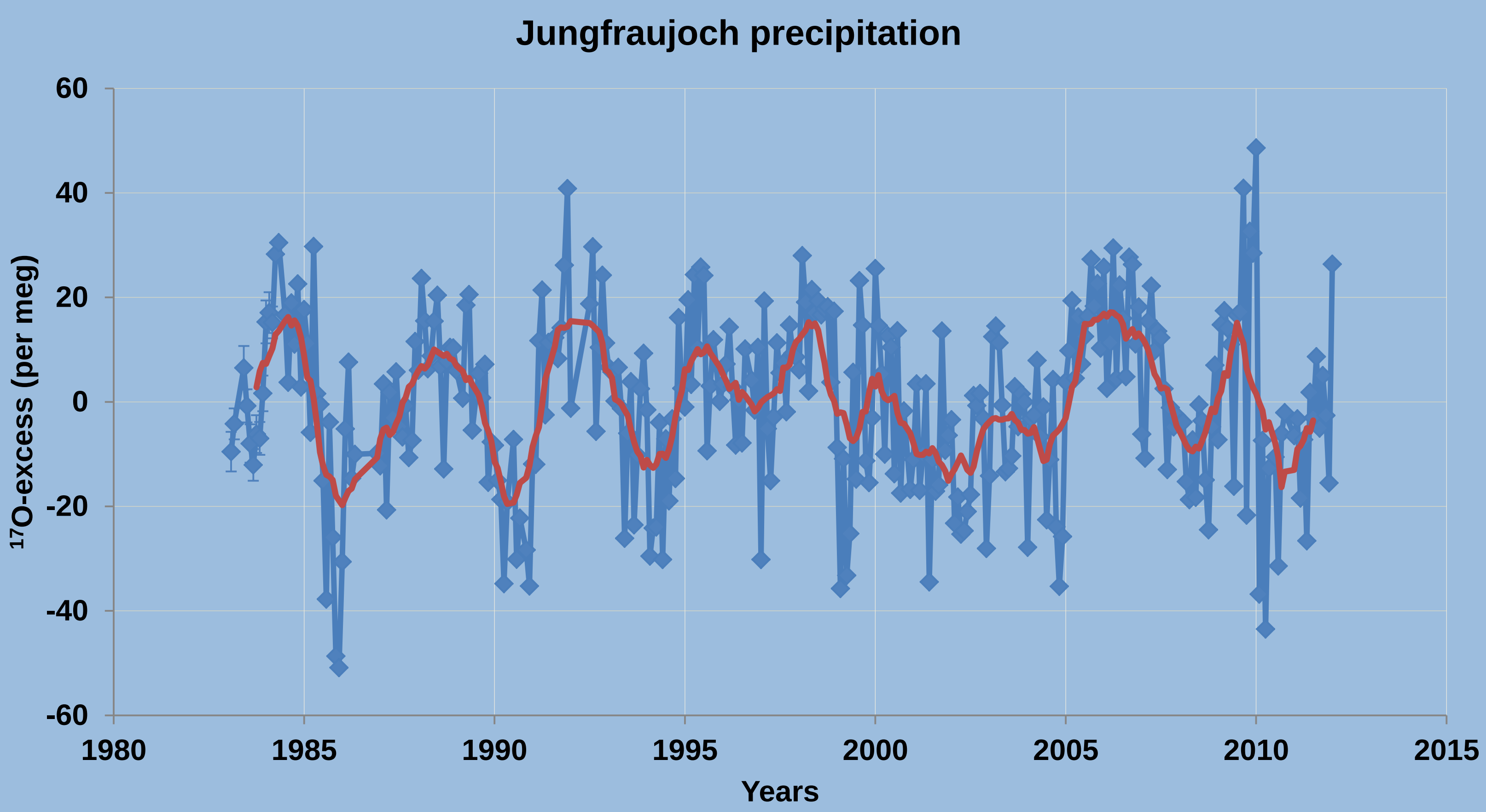
Decadal and interannual variations

Jungfraujoch monthly precipitation variations around the mean



Dedacal trend (reason yet unkonwn)

Jungfraujoch precipitation



Interannual variations (might be connected to NAO)

Jungfraujoch precipitation

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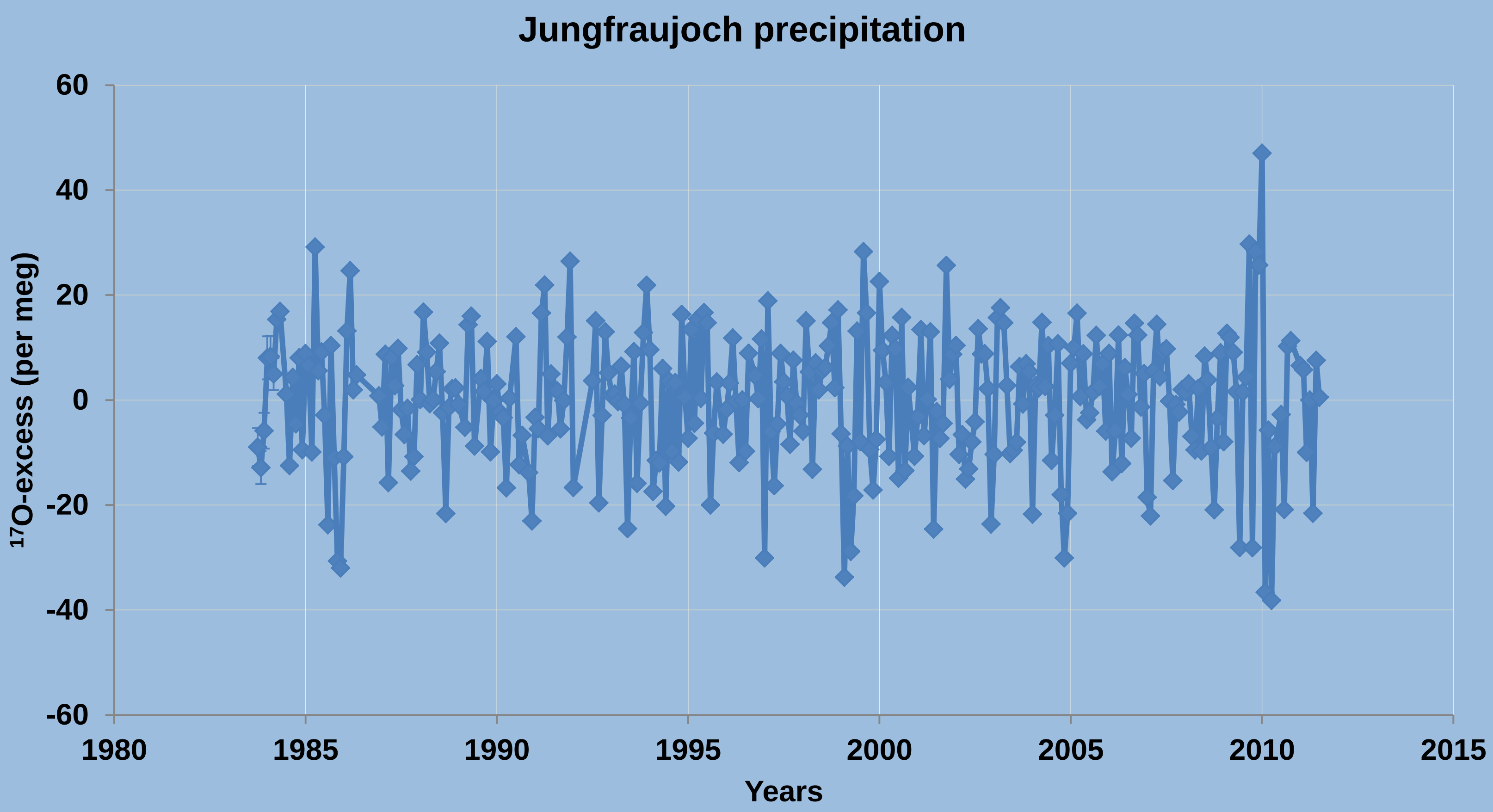

Intermonthly variations and measurement uncertainty

Swiss precipitation stations

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Station	Abbreviation	Alt.m (a.s.l)	Long. WGS (deg)	Lat. WGS (deg)
Basel	BAS	292	7.582	47.541
Locarno	LOC	379	8.787	46.172
Bern	BER	541	7.439	46.951
Meirengen	MER	598	8.178	46.727
Guttannen	GUT	1055	8.292	46.656
Grimsel	GRI	1980	8.332	46.571
Jungfraujoch	JFJ	3580	7.985	46.548

Swiss precipitation stations

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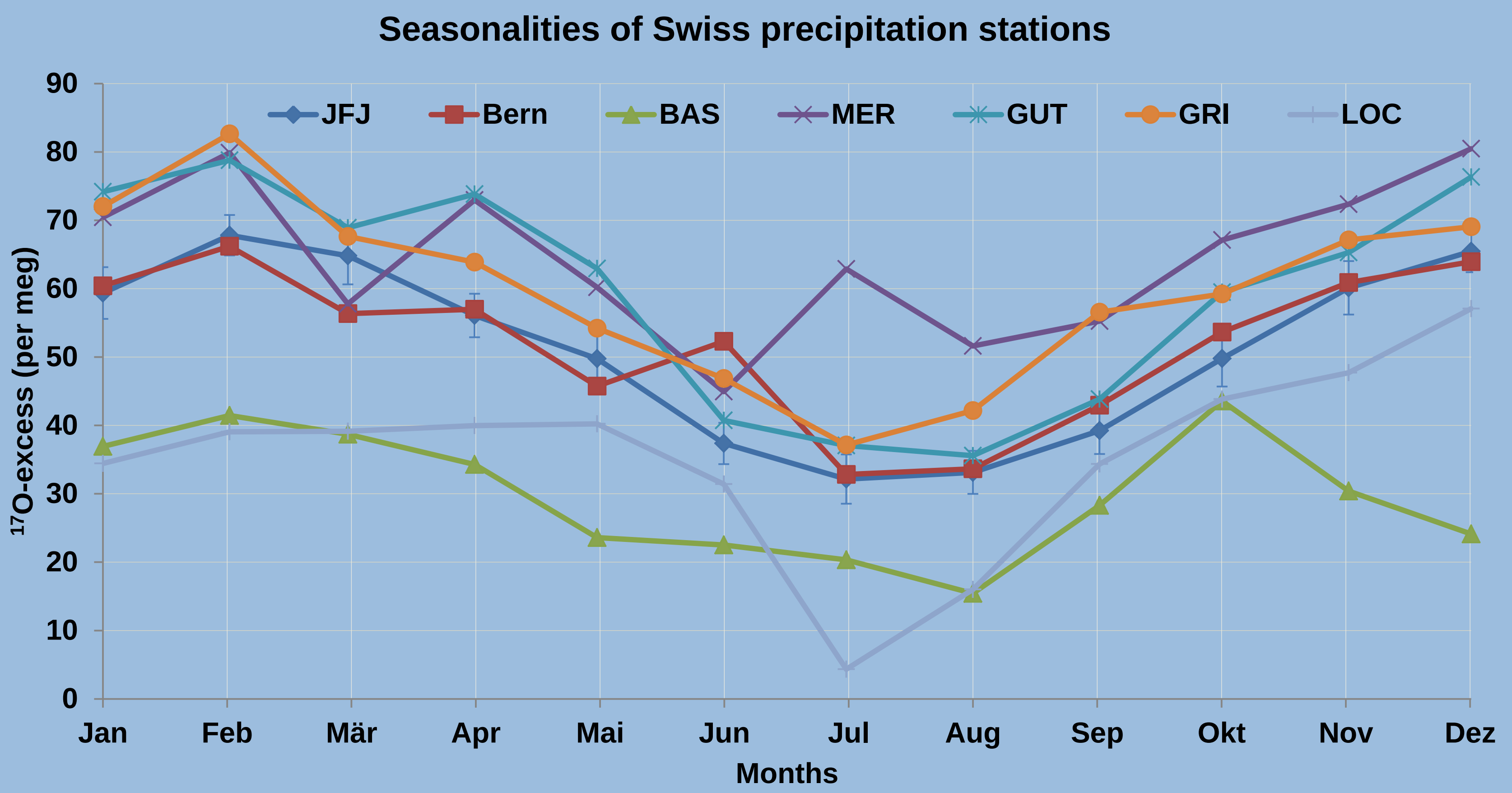

Amplitudes are between 28 and 52 per meg, means between 30 and 65 per meg.

Swiss precipitation stations

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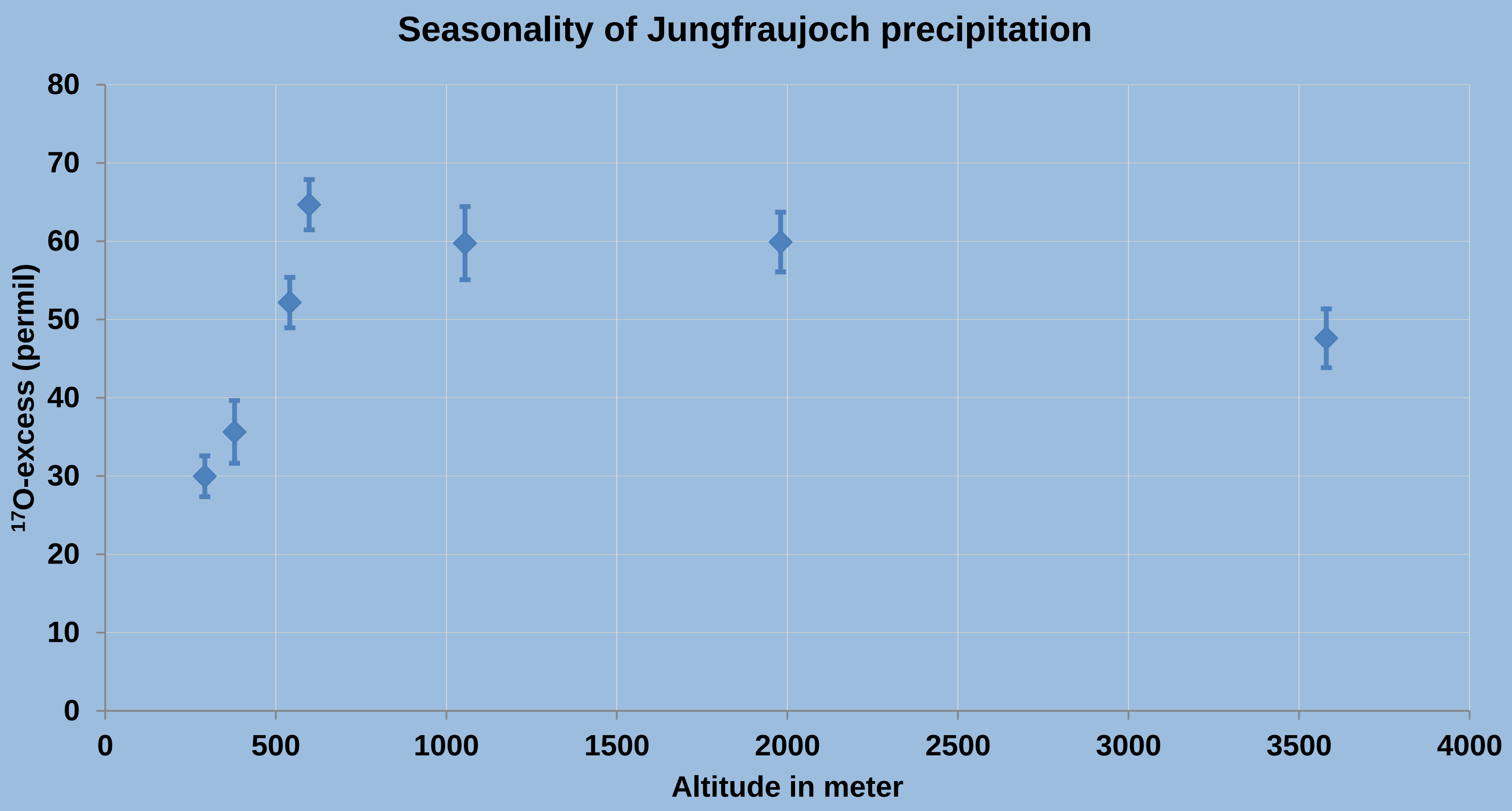

There might be constrasting dependencies at low and high altitudes, respectively (boundary layer influence, e. g. Kern et al, 2014)

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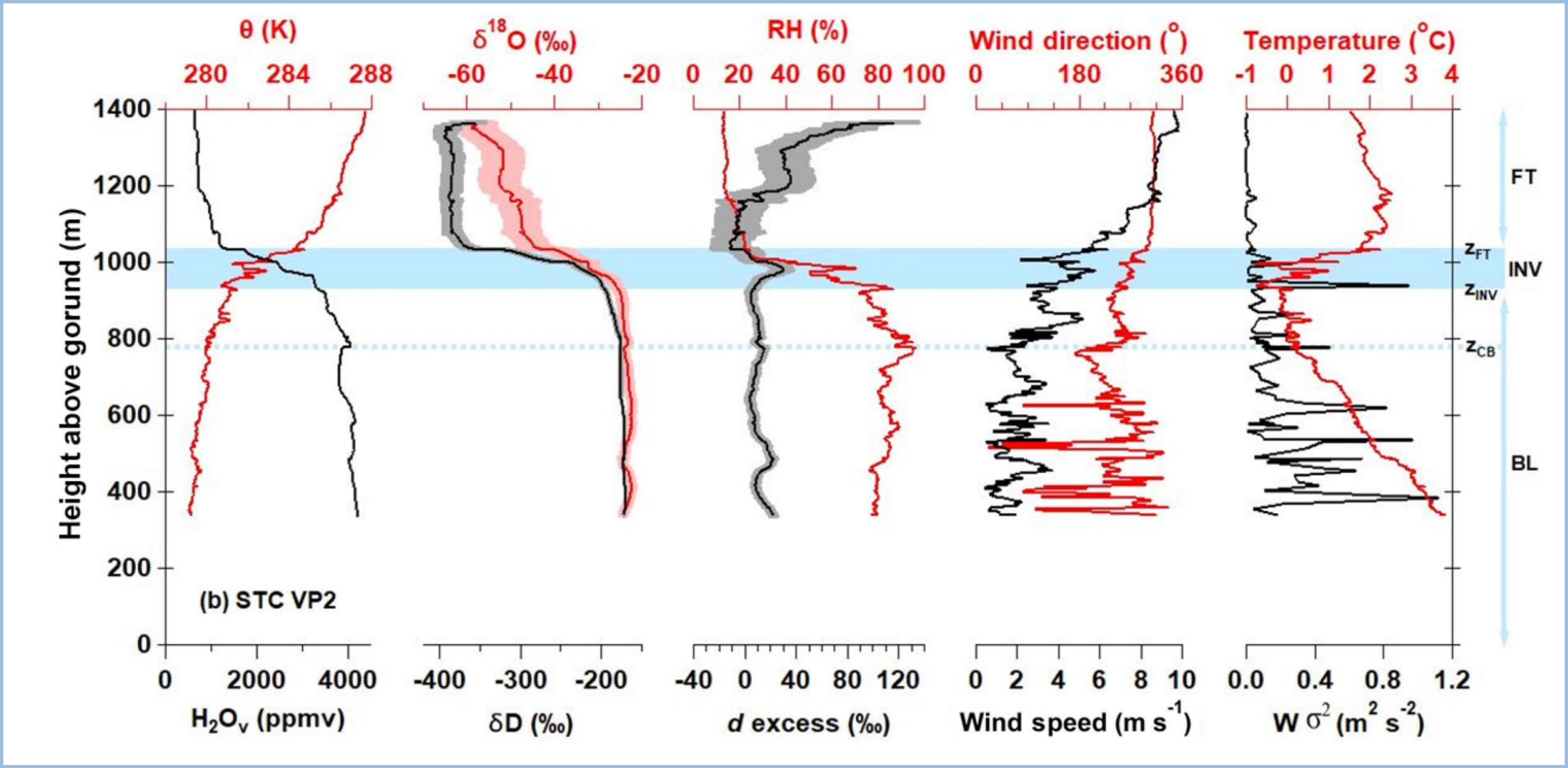
Difficulty of measurements, in particular at lower concentrations (vertical profile)



Salmon et al., ACP 2019

Difficulty of measurements, in particular at low concentrations

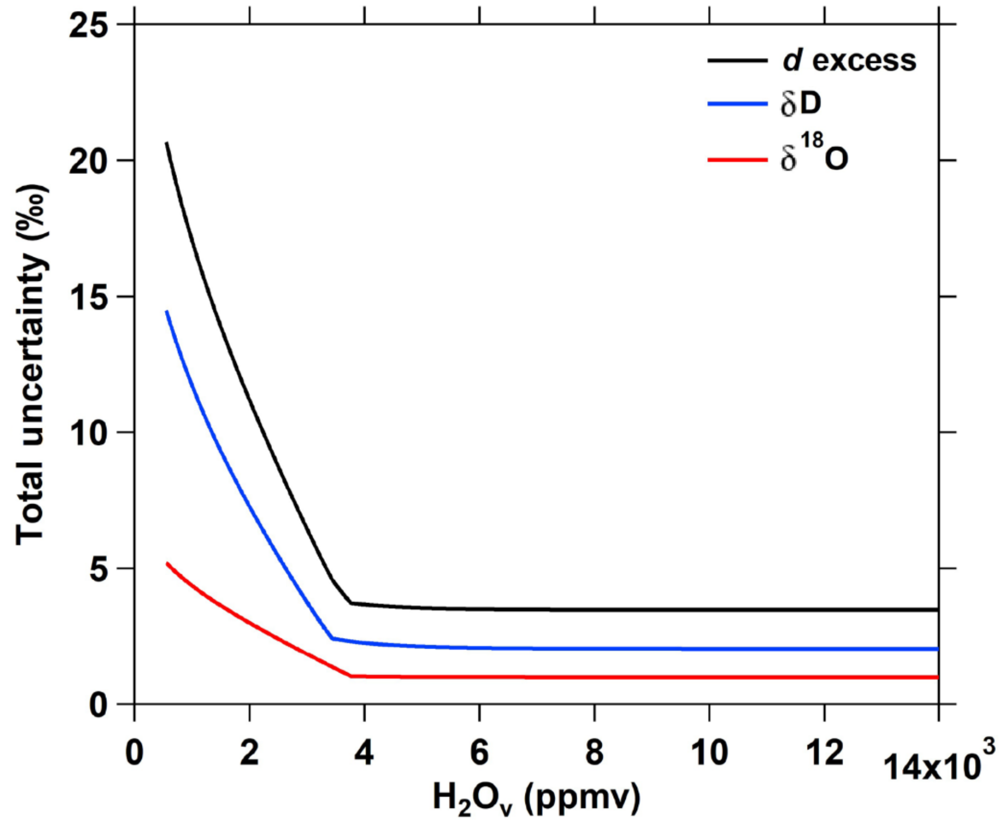


Figure 1. Total uncertainty of δD, $\delta^{18}O$, and *d* excess over the range of H_2O_v mole fractions observed in flight.

Salmon et al., ACP 2019

Jungfraujoch precipitation

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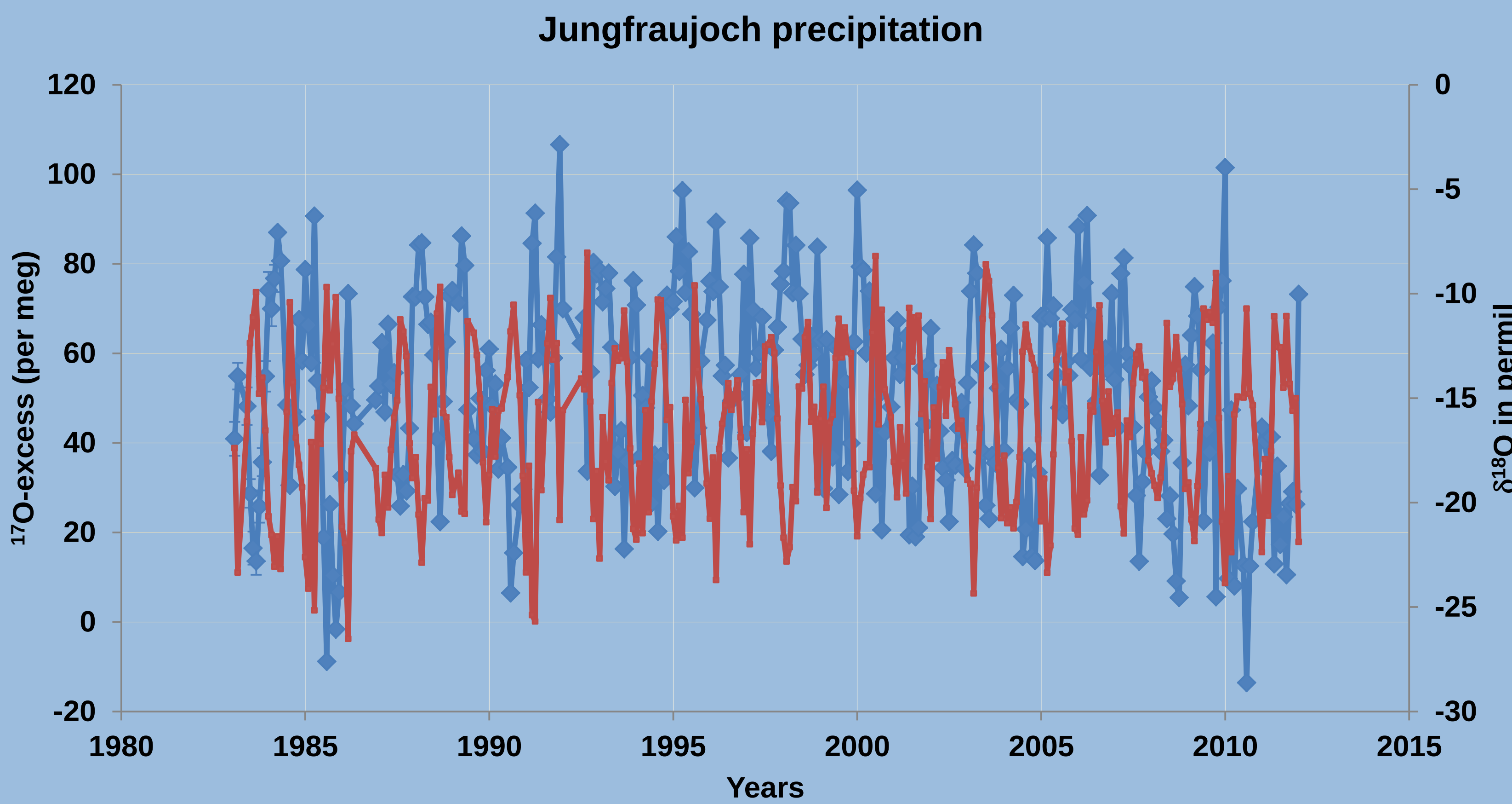

^{17}O-excess is anticorrelated with $\delta^{18}O_{precip}$

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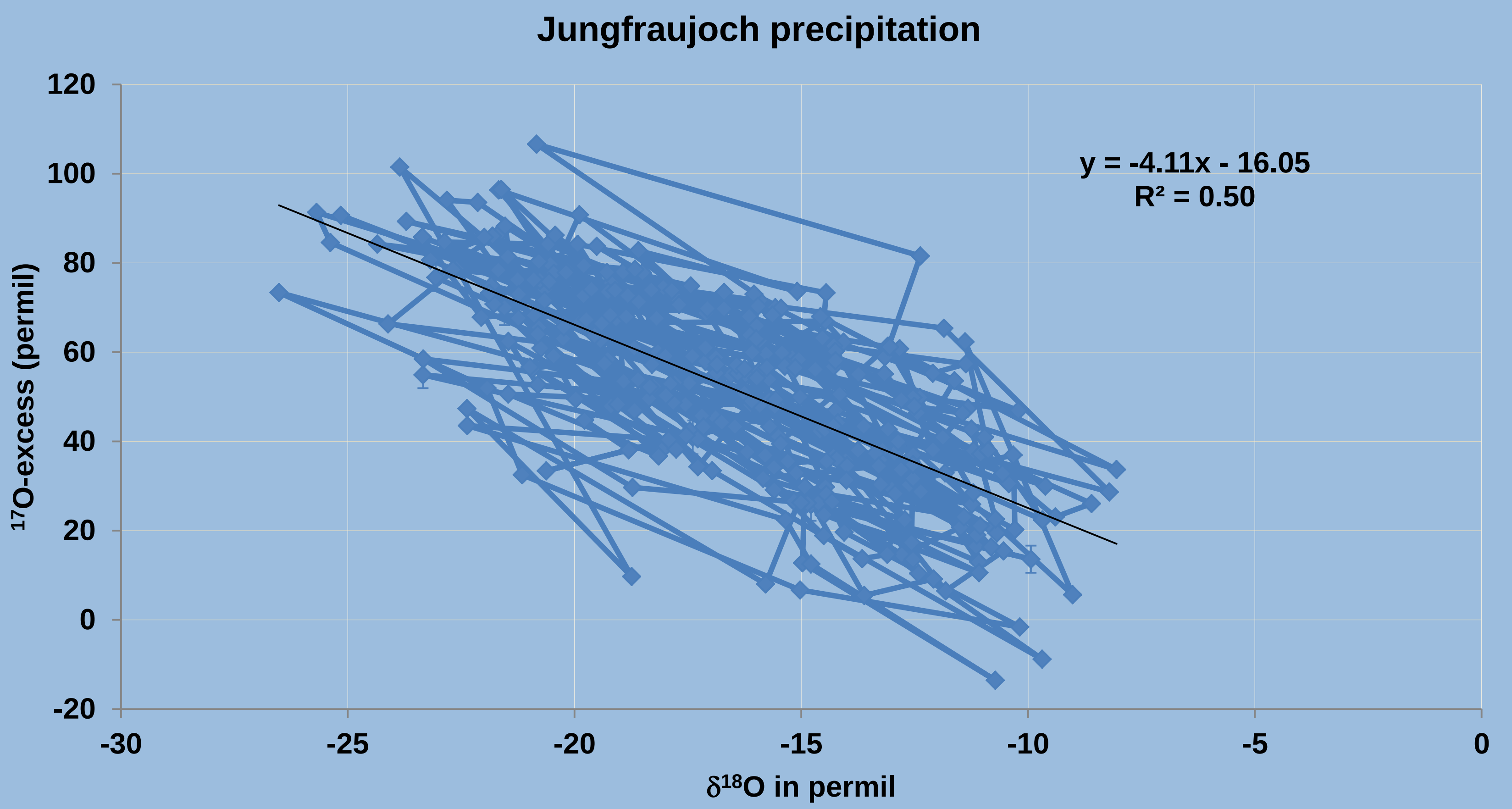
Jungfraujoch precipitation



^{17}O-excess is anticorrelated with $\delta^{18}O_{precip}$

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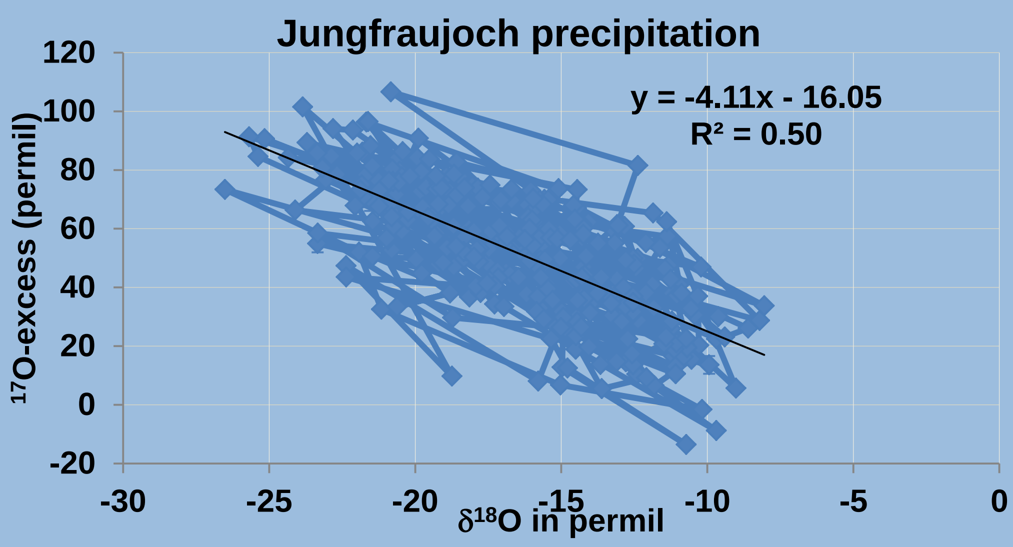
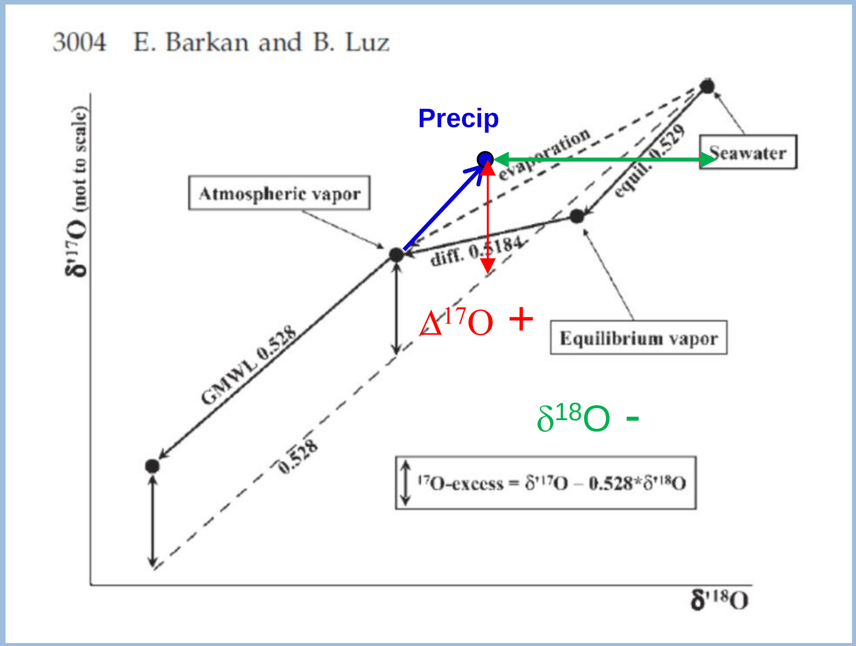
Jungfraujoch precipitation





^{17}O-excess is anticorrelated with $\delta^{18}O_{precip}$

Jungfraujoch trapped water vapor

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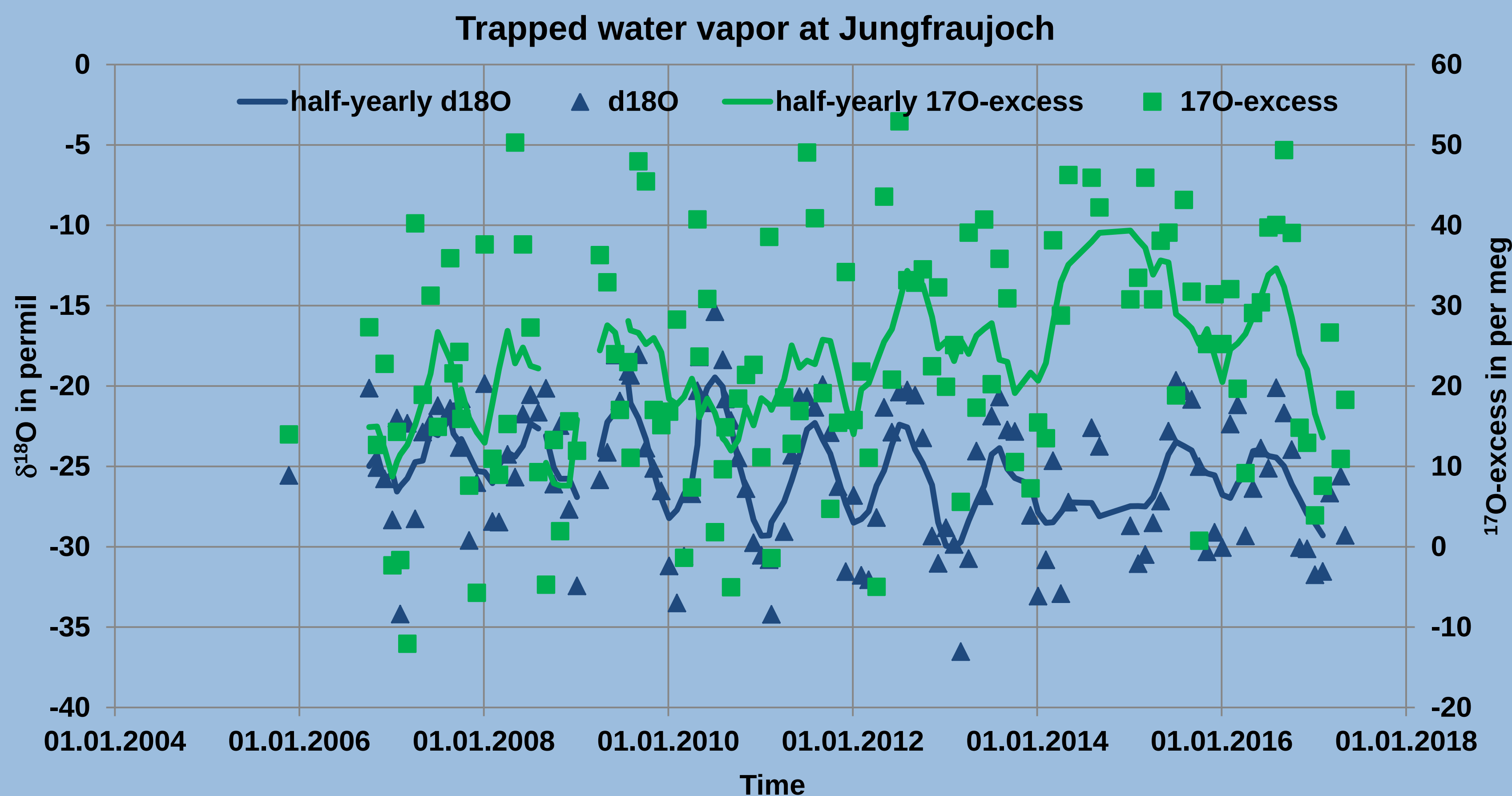

Comparison between ^{17}O-excess and δ^{18}O of vapor

Jungfraujoch precipitation

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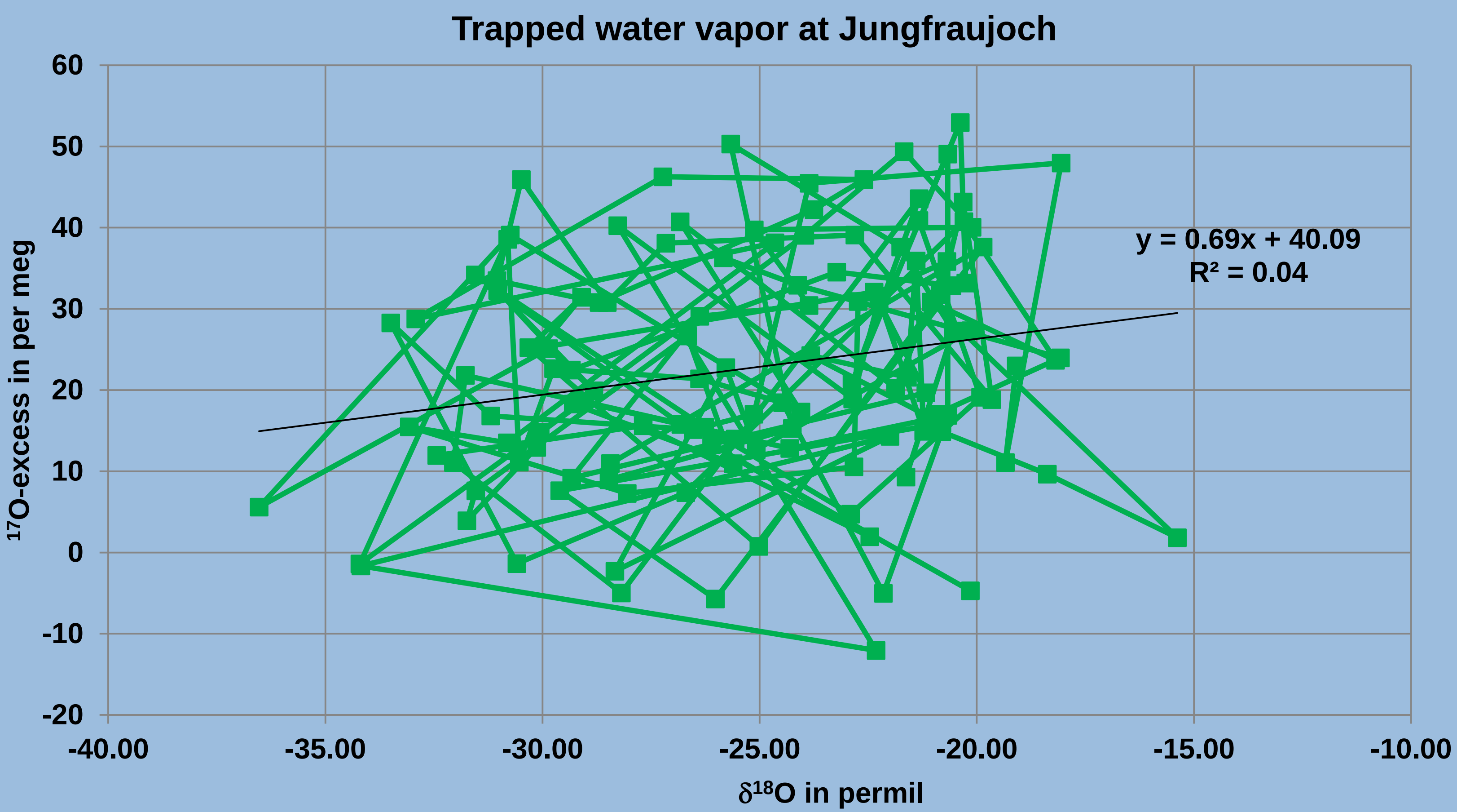

No or a slight positive correlation

Thank you for your attention

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