



# Frozen memories of past eruptions reveal the global risks of future ones

Michael Sigl, Climate and Environmental Physics, University of Bern

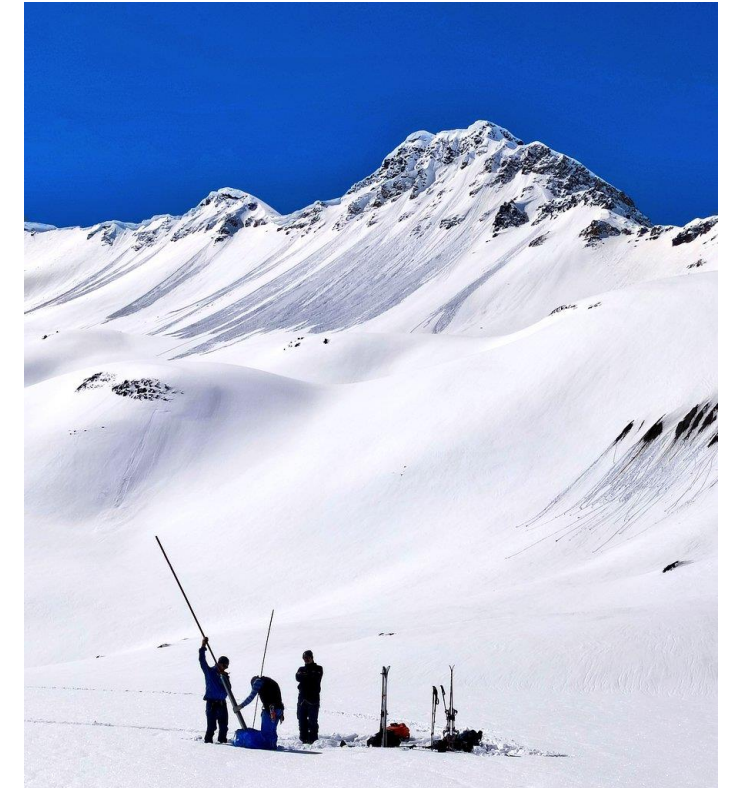
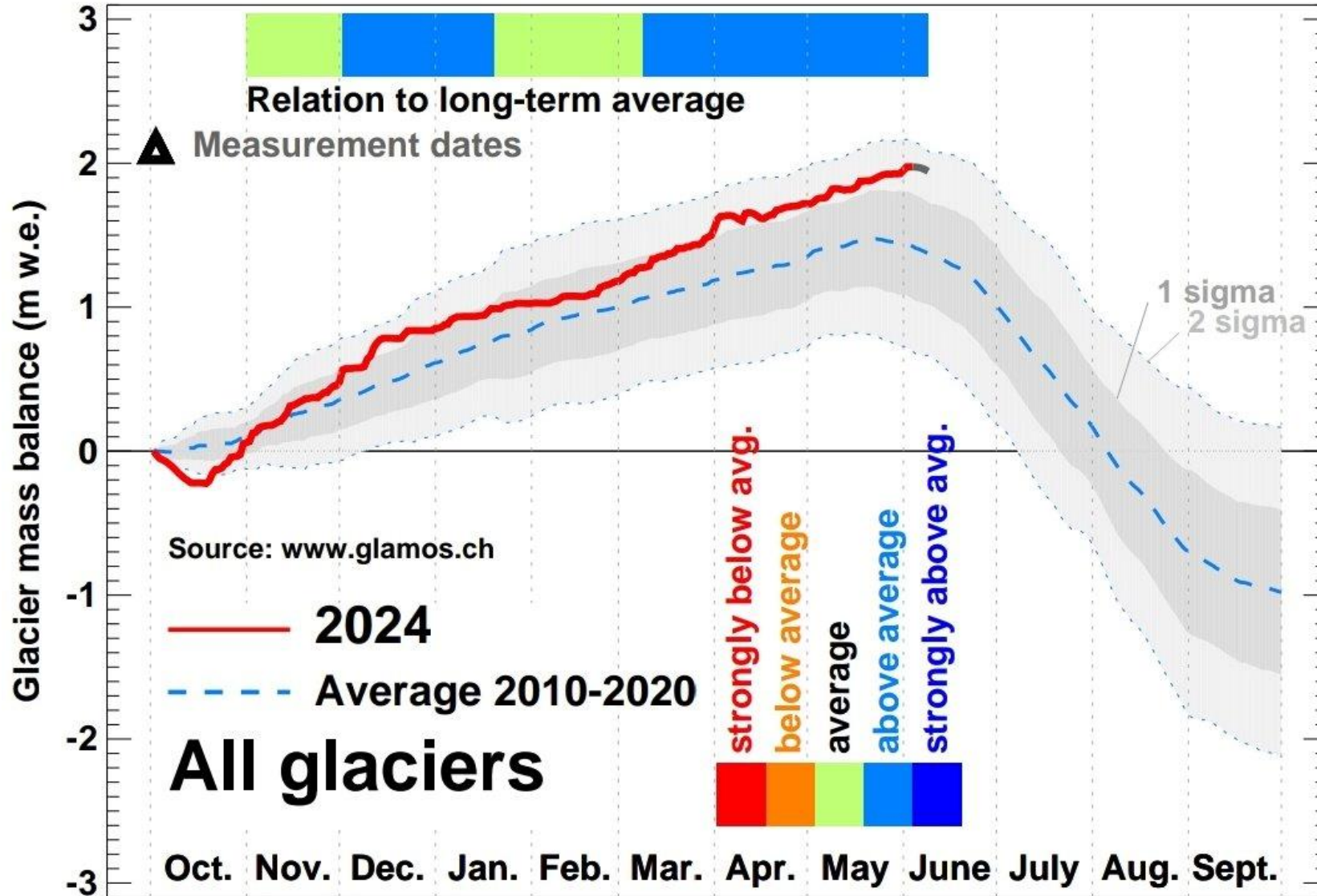
*Swiss Polar Day 2024, Fribourg, Switzerland*

**u<sup>b</sup>**

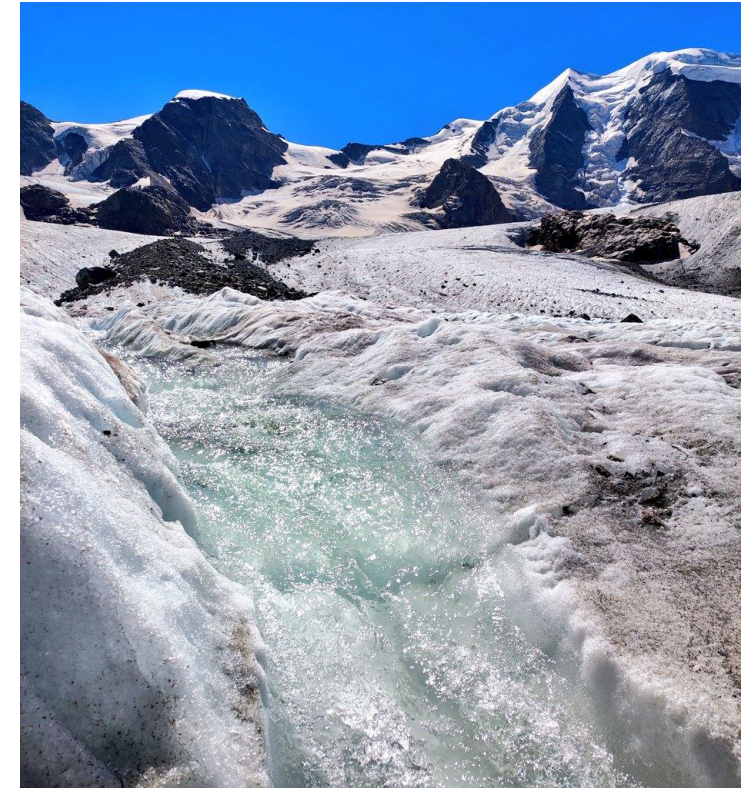
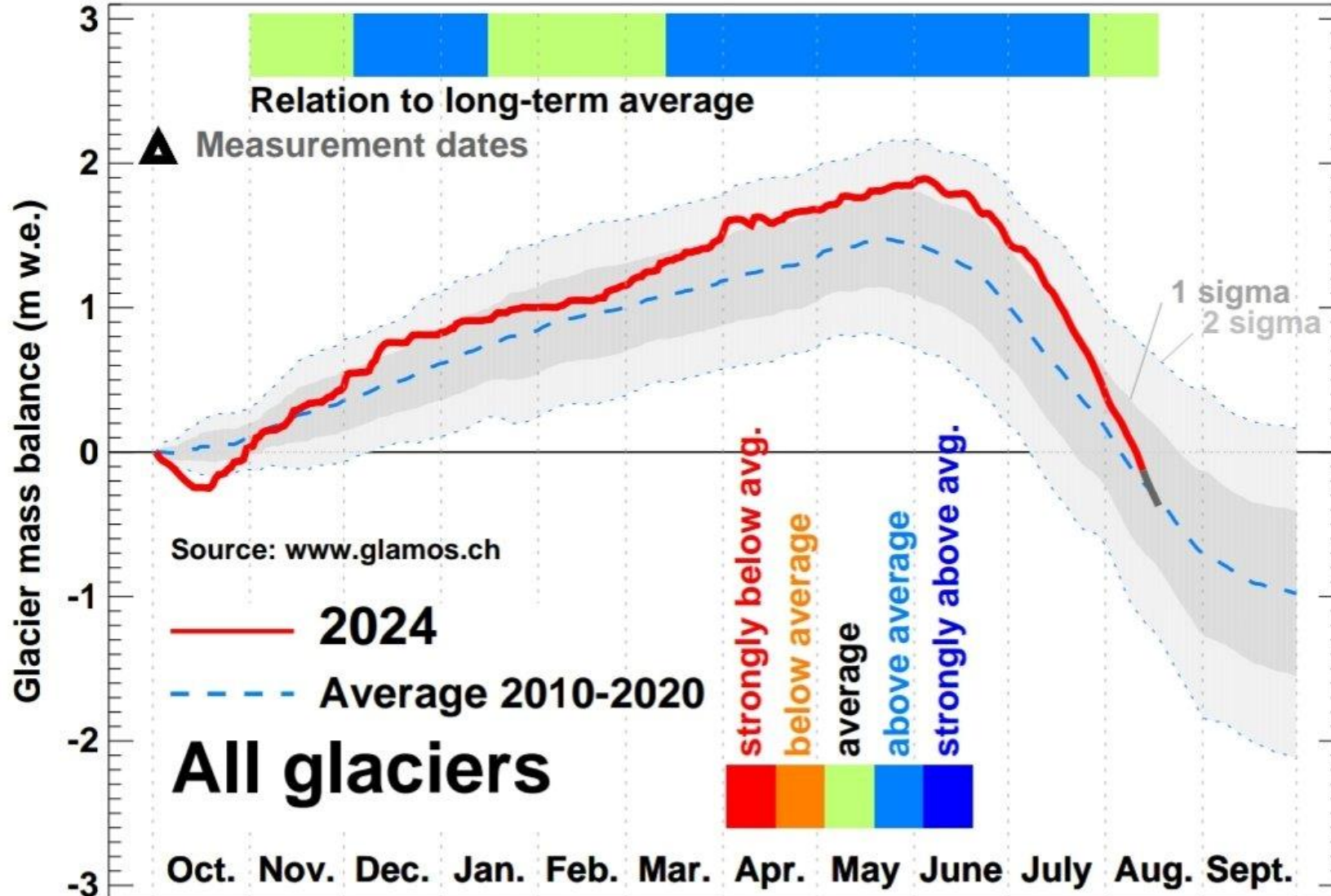
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<sup>b</sup>  
**UNIVERSITÄT  
BERN**

**OESCHGER CENTRE  
CLIMATE CHANGE RESEARCH**

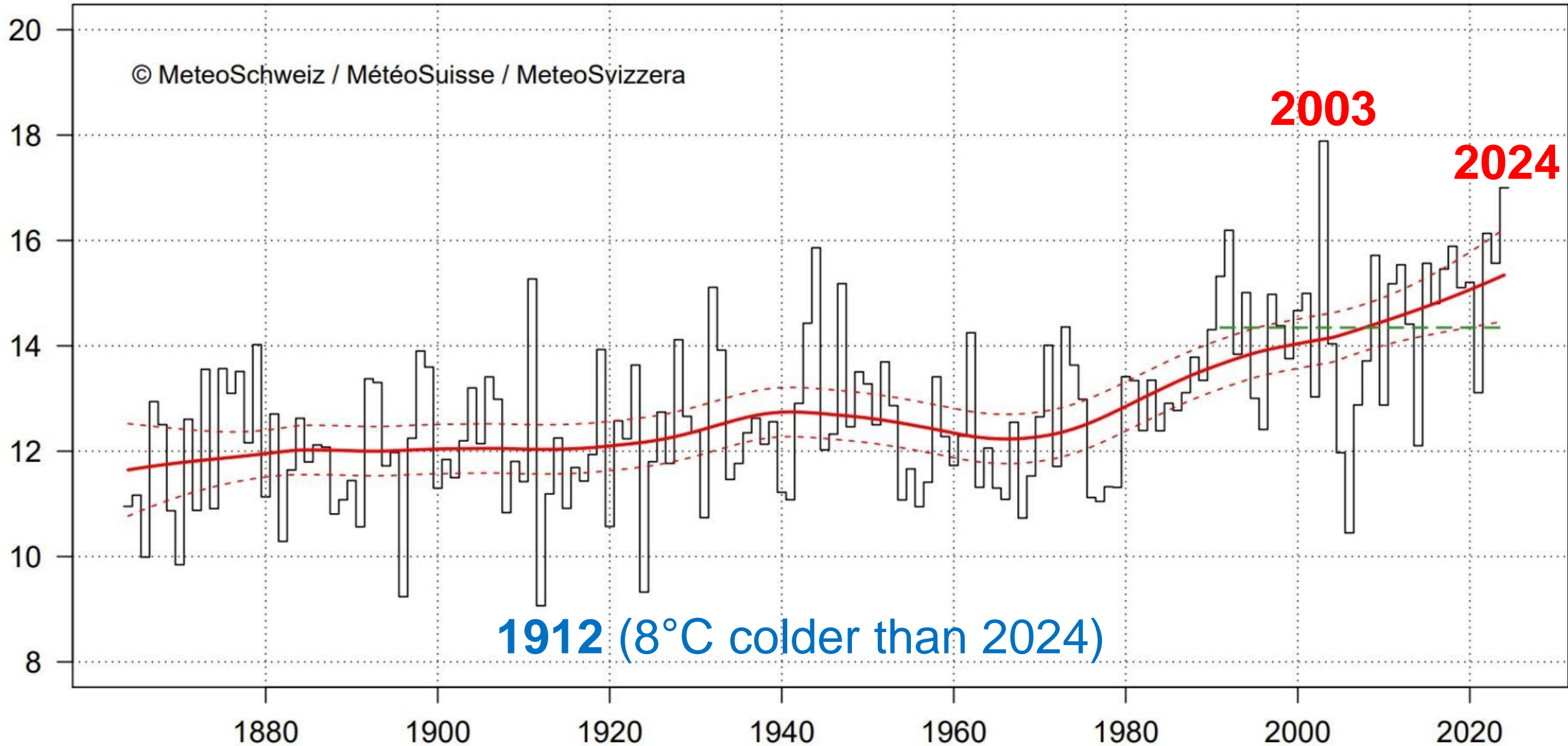


Credit: M. Huss



Credit: M. Huss

# August Temperature Switzerland since 1864



11:51



### Messwerte



Wetterstation Bern / Zollikofen



## Bern / Zollikofen

553 m ü.M.

11:40

Temperatur	17.3°C	Wind	→ 5.4 km/h
Sonnenschein	1 min	Böen	11.9 km/h
Niederschlag	0.0 mm	Föhnindex	-



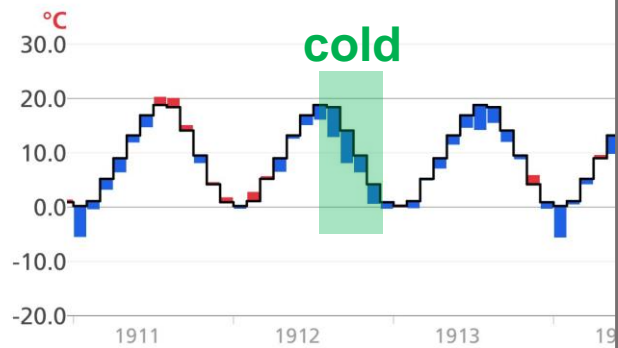
Rückblick

## Temperature

Stunden-  
werte

Tages-  
werte

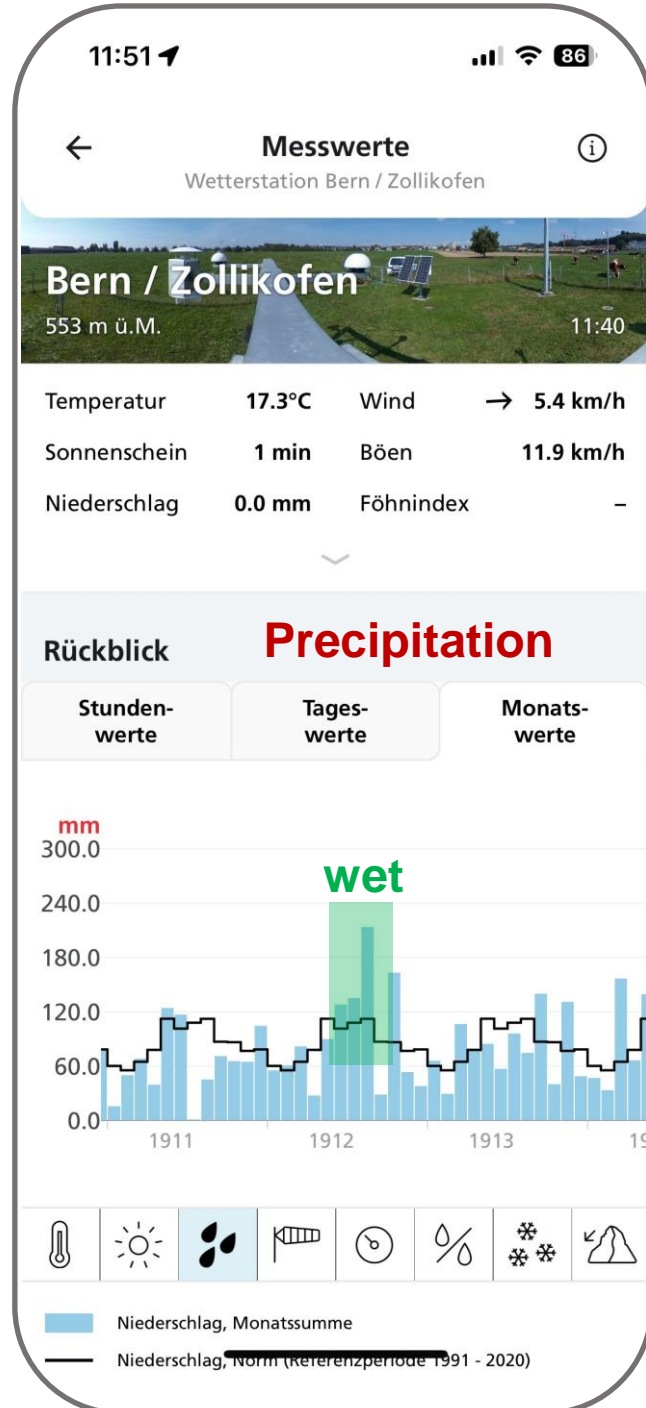
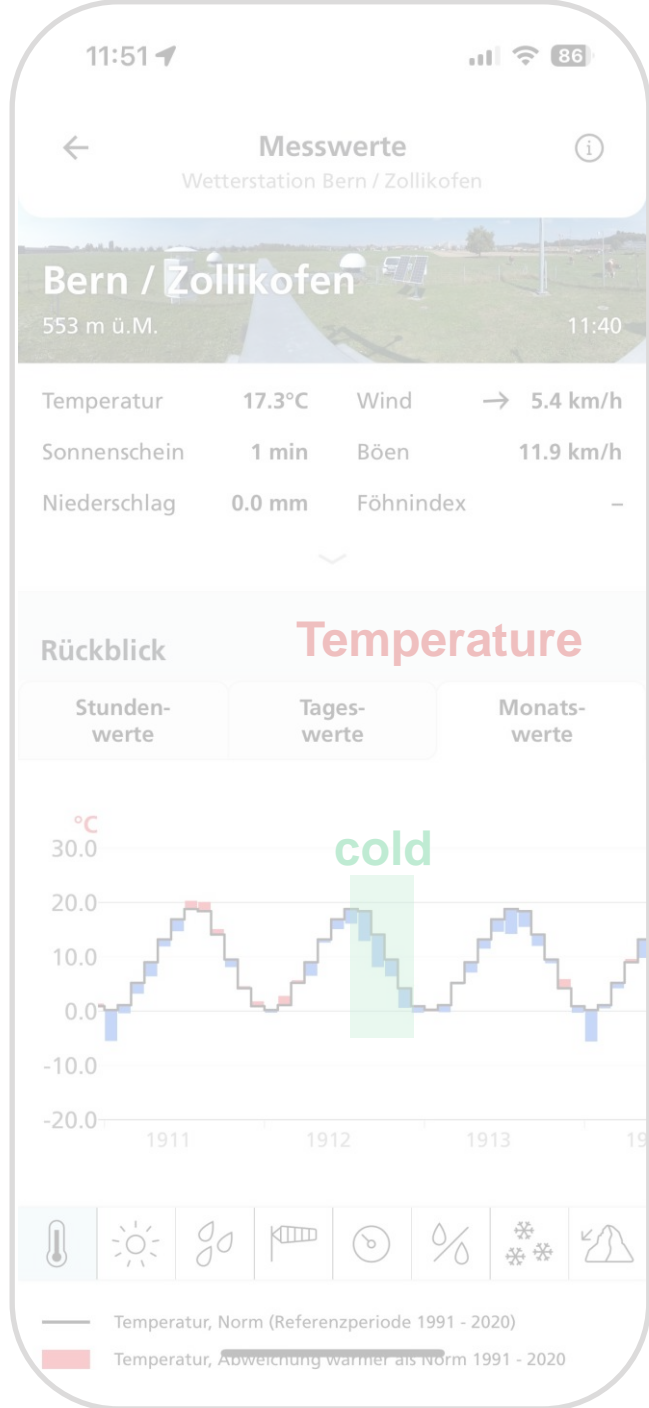
Monats-  
werte

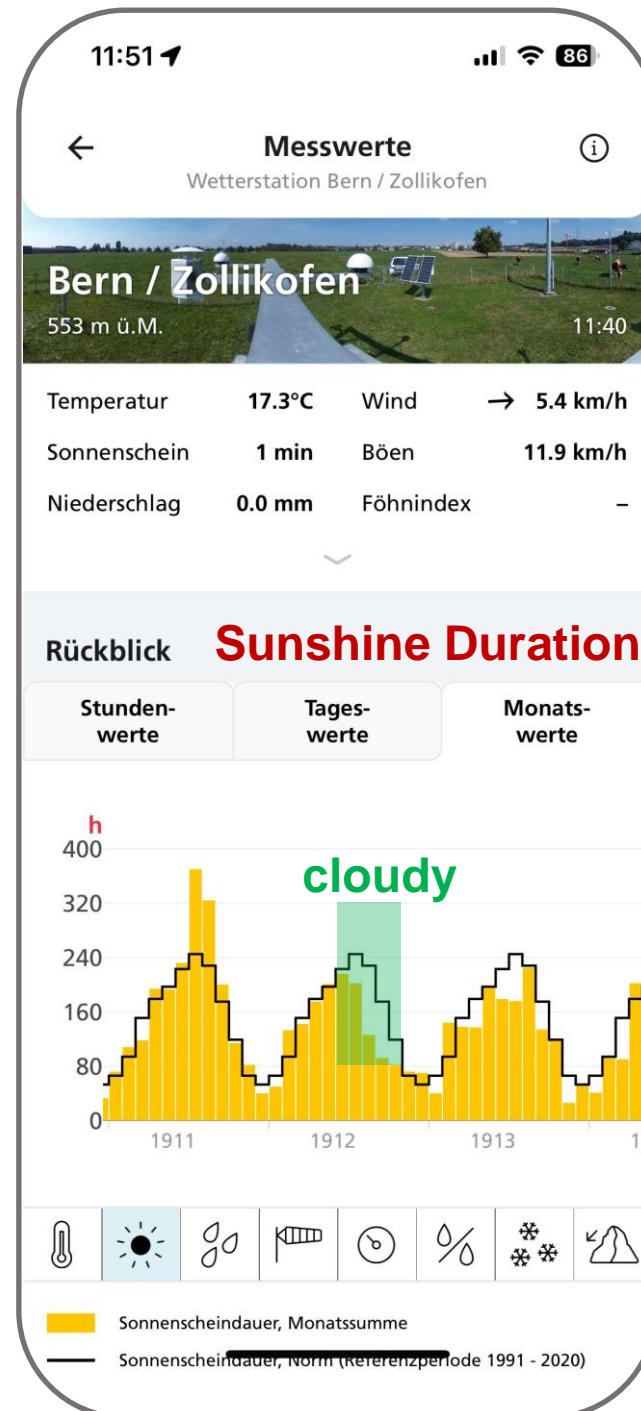
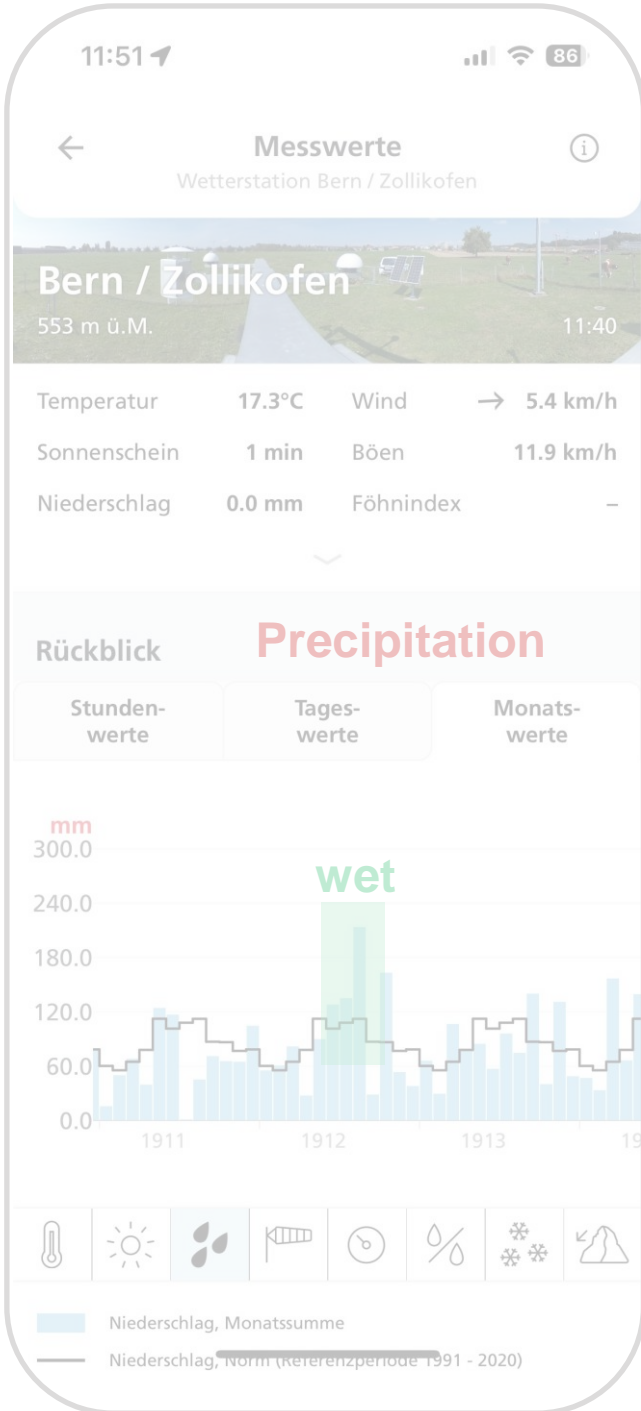
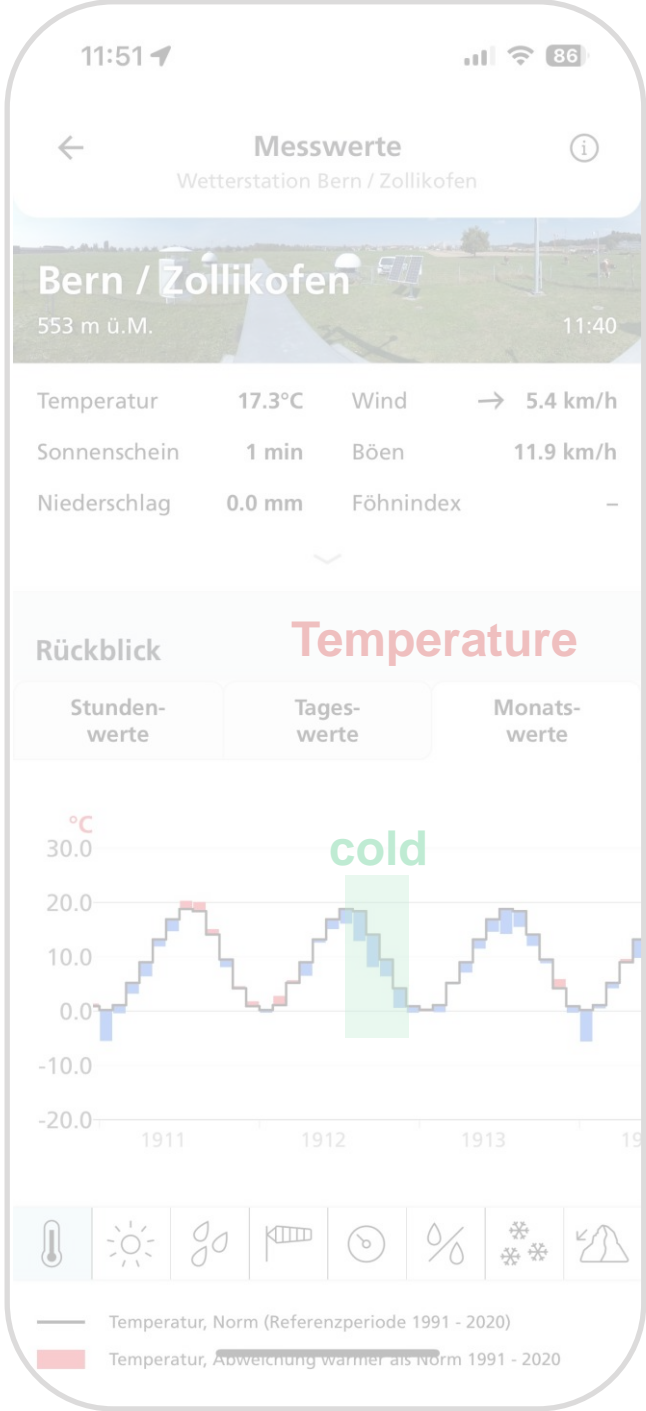


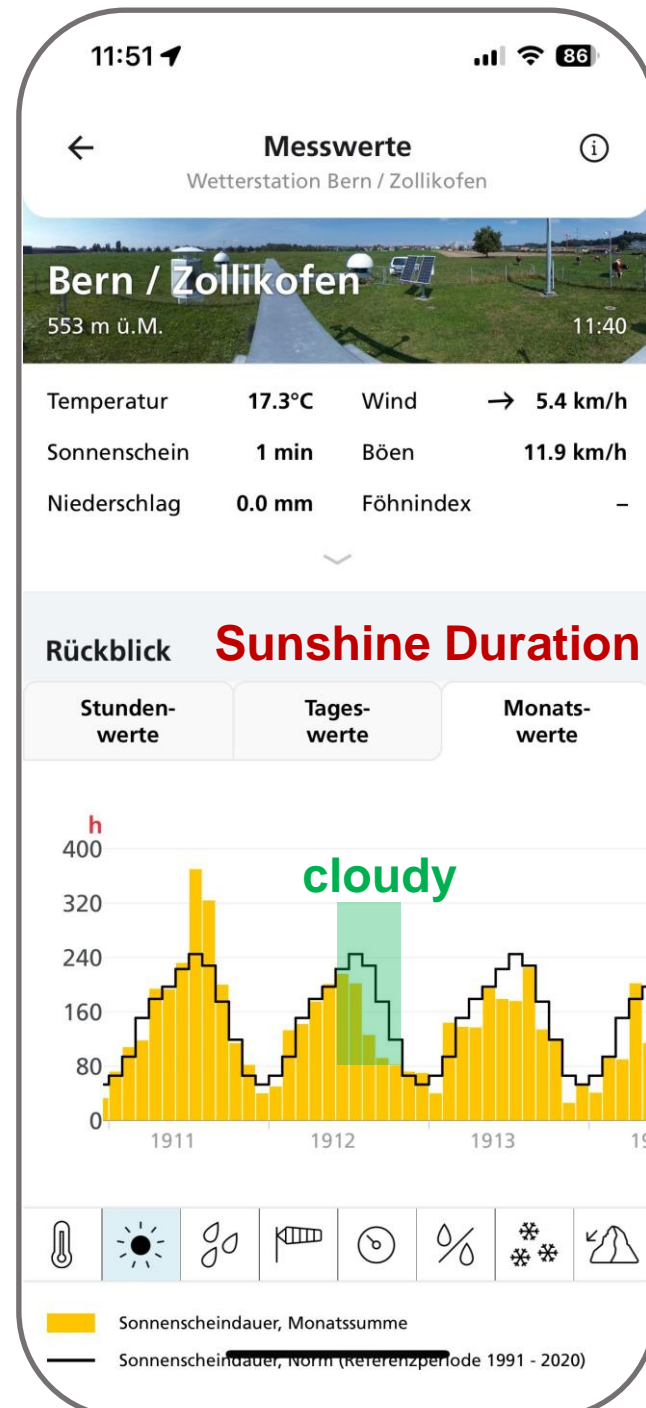
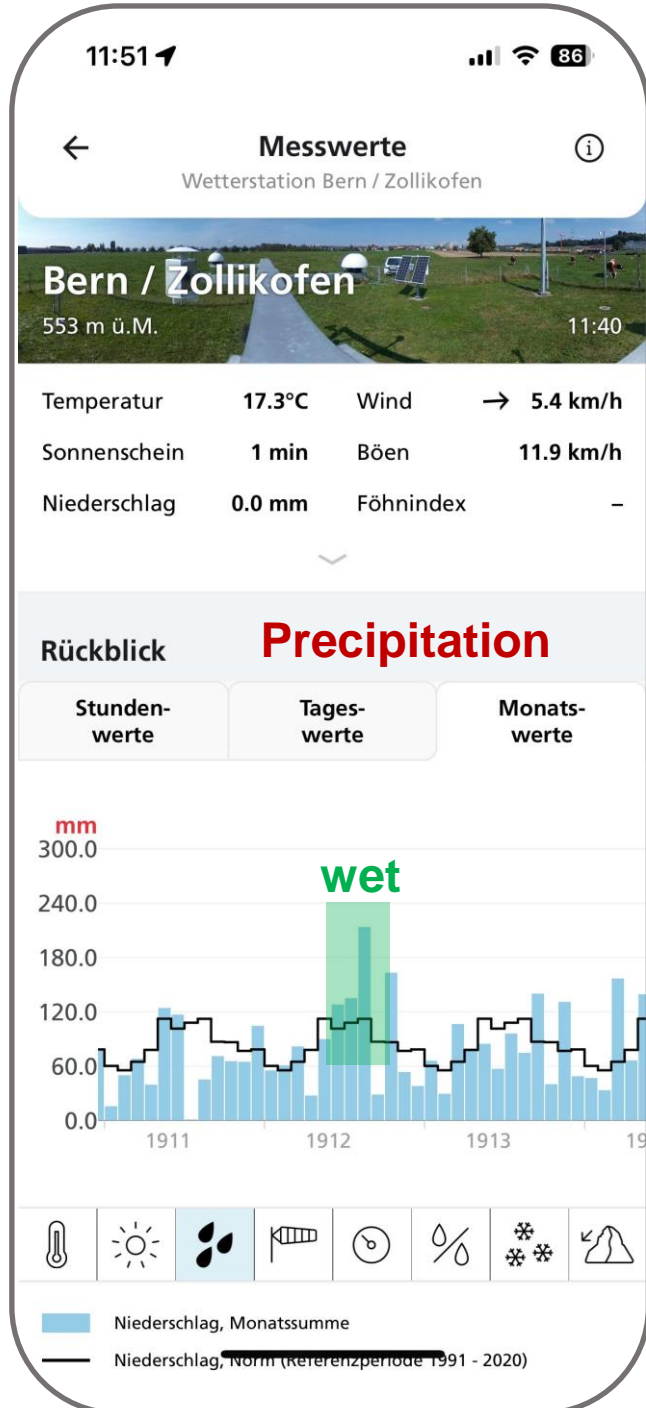
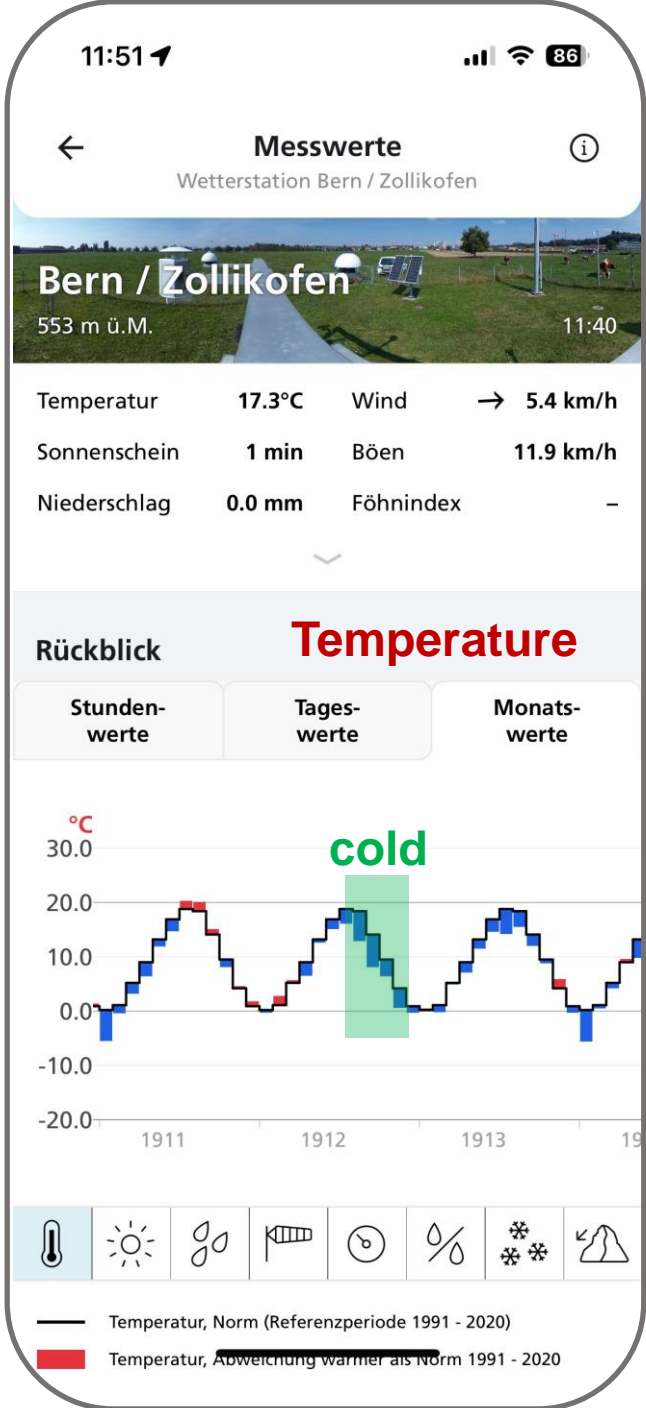
— Temperatur, Norm (Referenzperiode 1991 - 2020)

■ Temperatur, Abweichung wärmer als Norm 1991 - 2020













„It was an **unusually wet summer**; during their stay (22 June -31 July) it rained on one day out of three.“

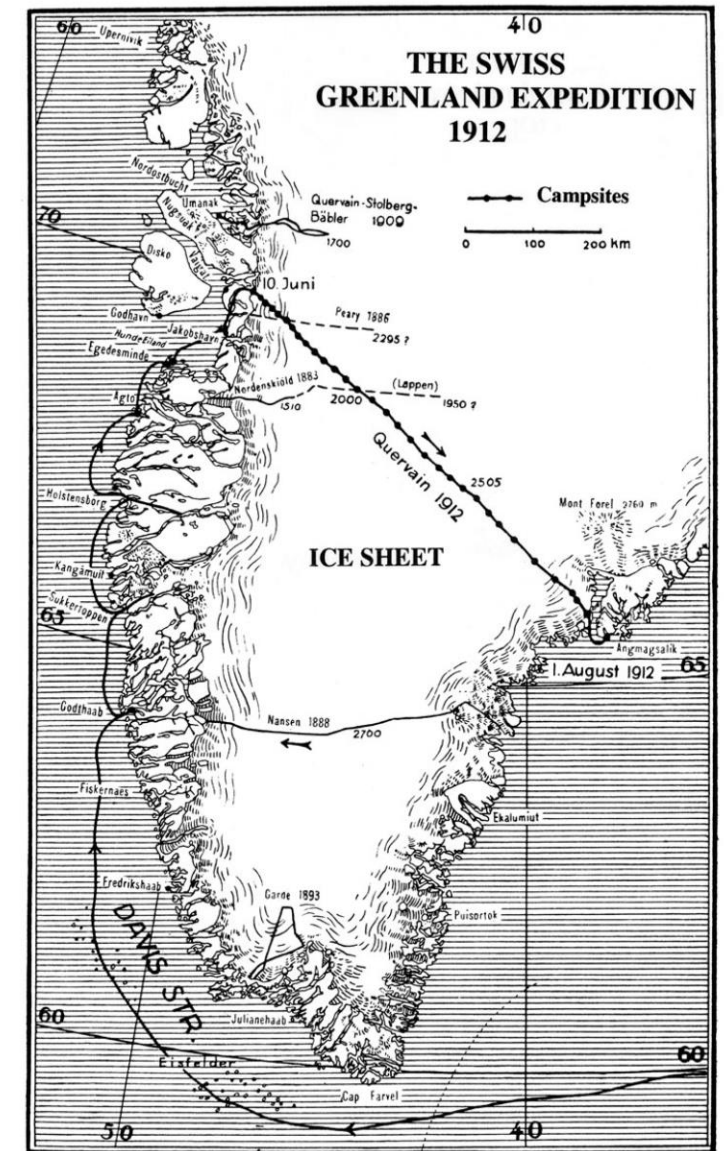
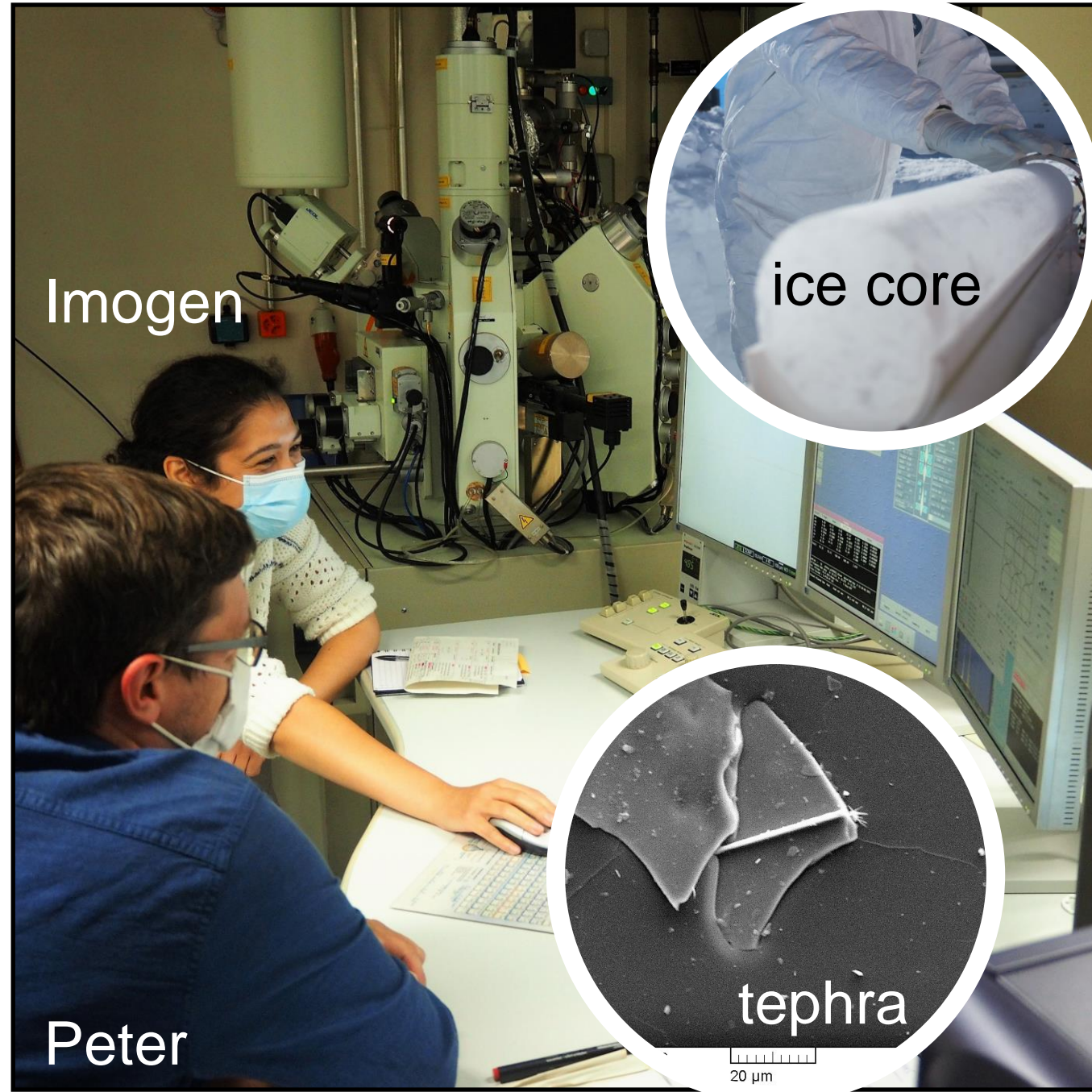
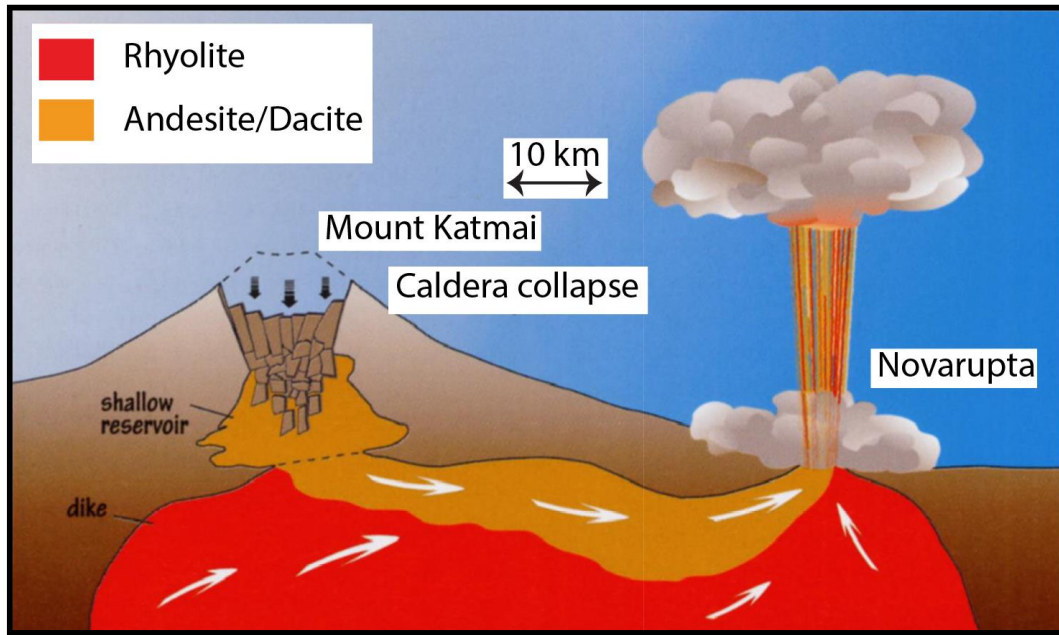


Fig. 2. Map showing routes of de Quervain's 1909 and 1912 expeditions, and of various earlier expeditions on the Greenland ice cap (based on map in de Quervain 1914).

W. Barr (2015): Alfred de Quervain's Swiss Greenland expeditions, 1909 and 1912

# Katmai/Novarupta (VEI=6)

6 June 1912



Peter

# Volcanic Eruptions (VEI, M)

Scale

Volume of volcanic  
ejecta

0

0.00001 km<sup>3</sup>

1

0.001 km<sup>3</sup>

2

0.01 km<sup>3</sup>

3

0.1 km<sup>3</sup>

4

1 km<sup>3</sup>

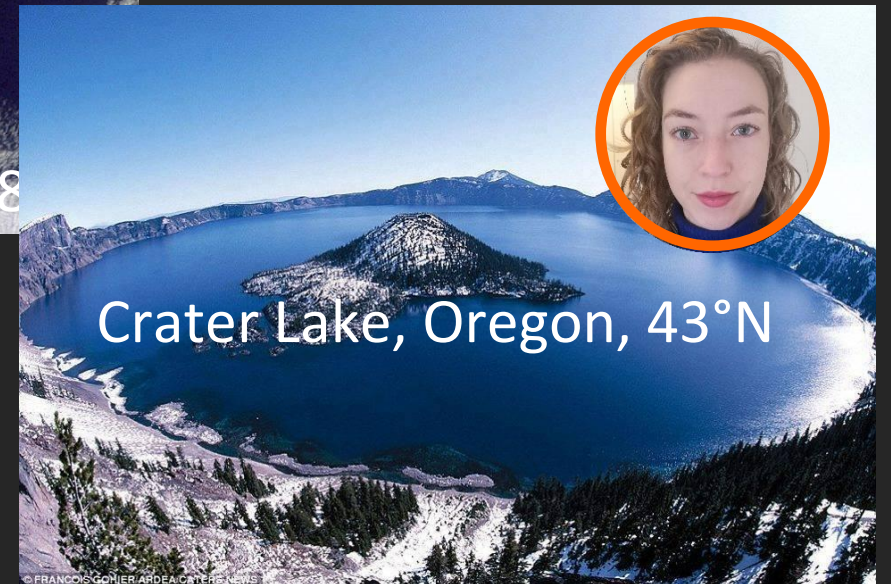
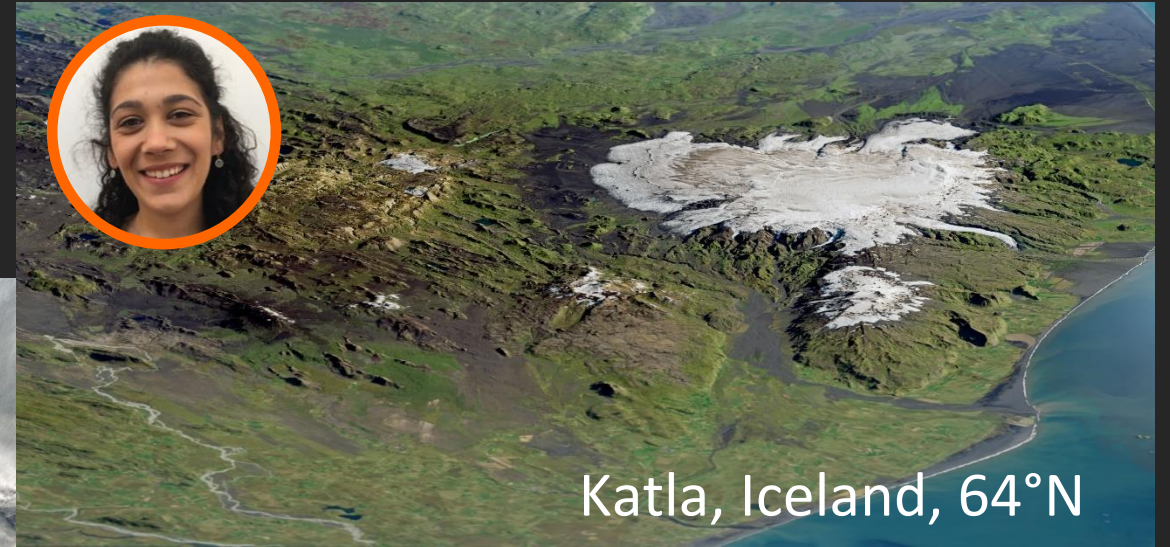
5

10 km<sup>3</sup>

6

100 km<sup>3</sup>

7



Hrafnkatla, 763 CE

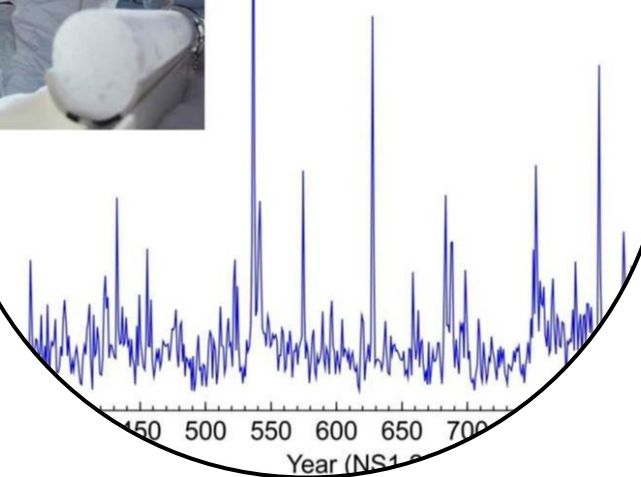
Zavaritskii, 1831 CE

Mazama, Crater Lake 5622 BCE



sulfur

TUNU2013



Plinian

Ultra-Plinian

Colossal

Super-eruption

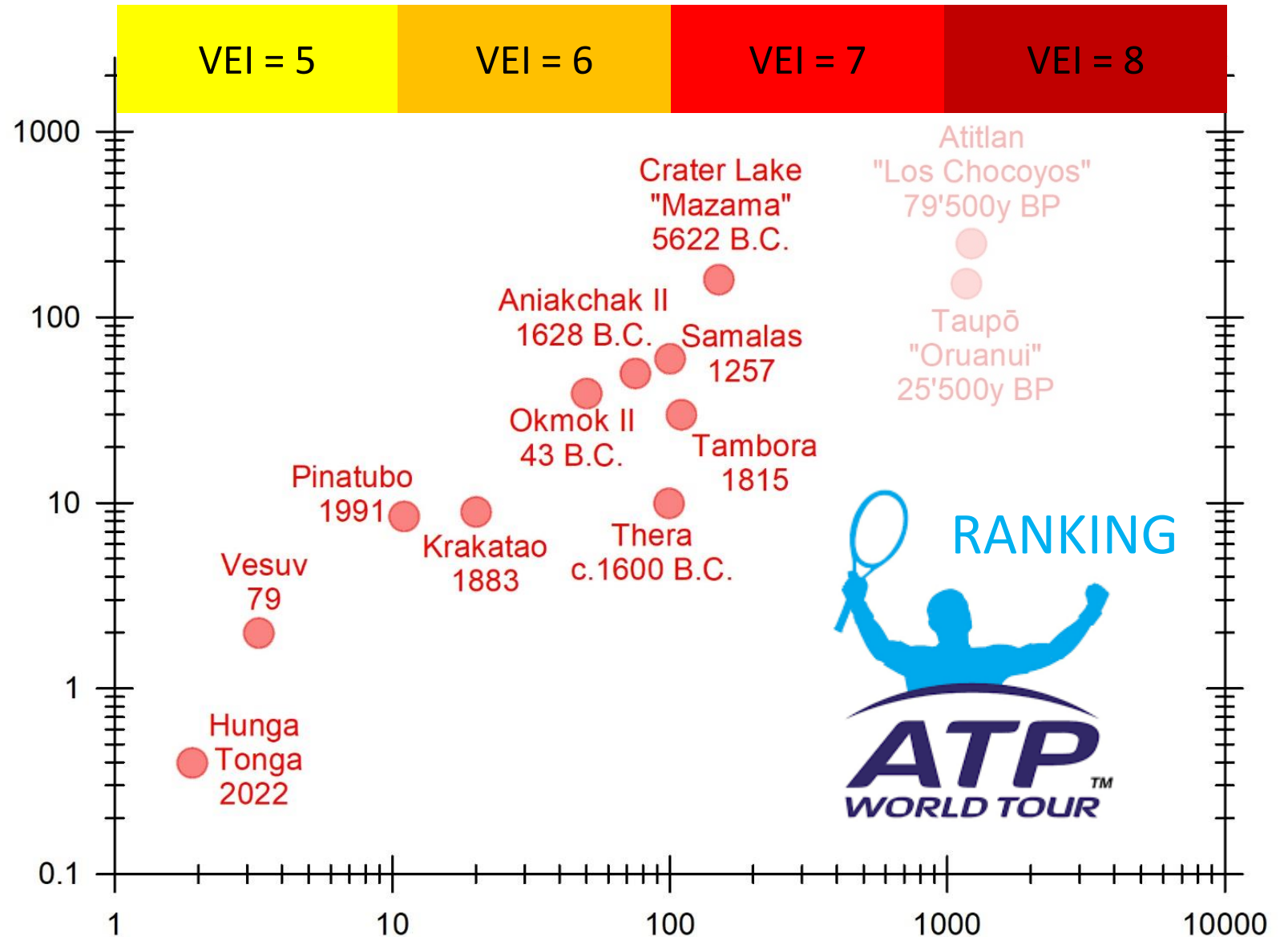
VEI = 5

VEI = 6

VEI = 7

VEI = 8

Schwefel (Tg)



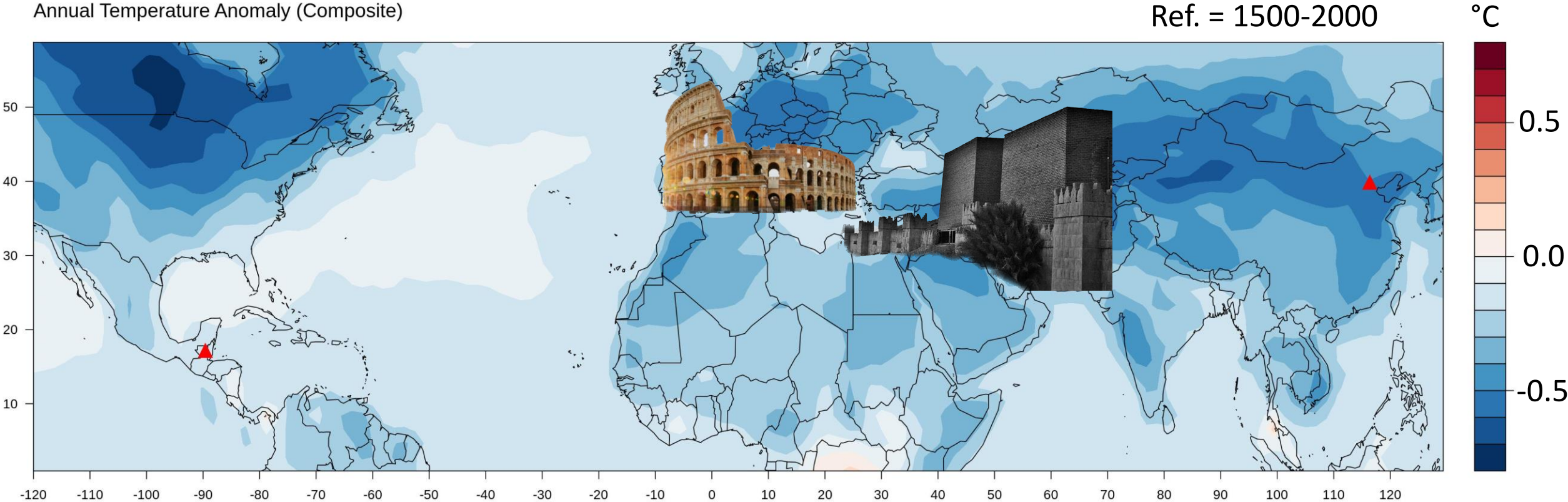
Gesamtvolumen (km³)



**Name:** Katmai  
**Region:** Alaska  
**Year:** 1912  
**S (Tg):** 5  
**ATP#:** 330

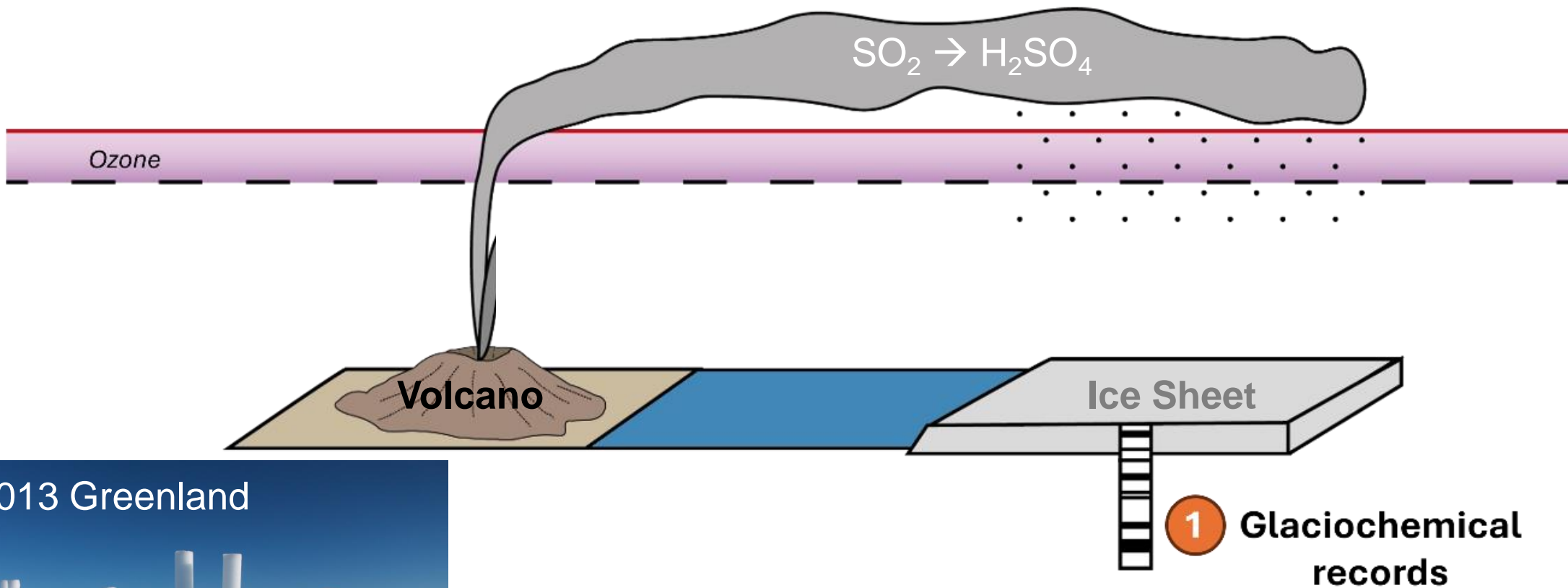


# Average 2-yr annual temperature response to the 18 largest volcanic eruptions since 1400 CE

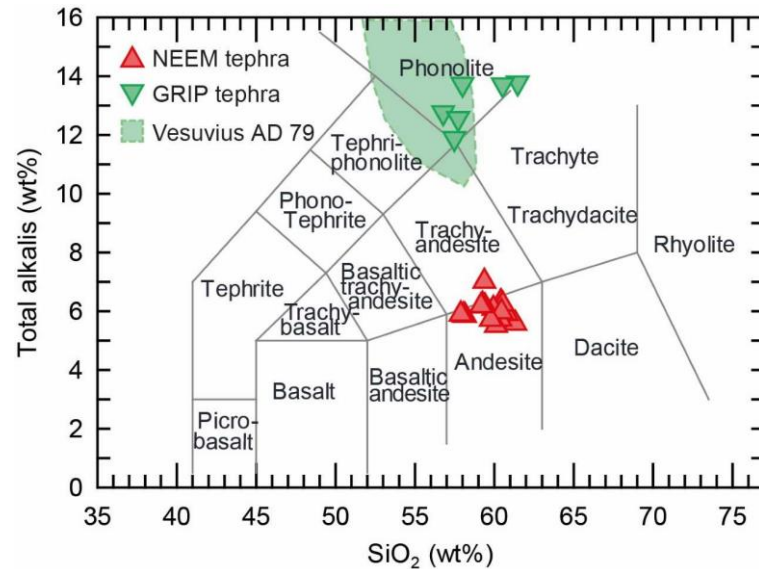
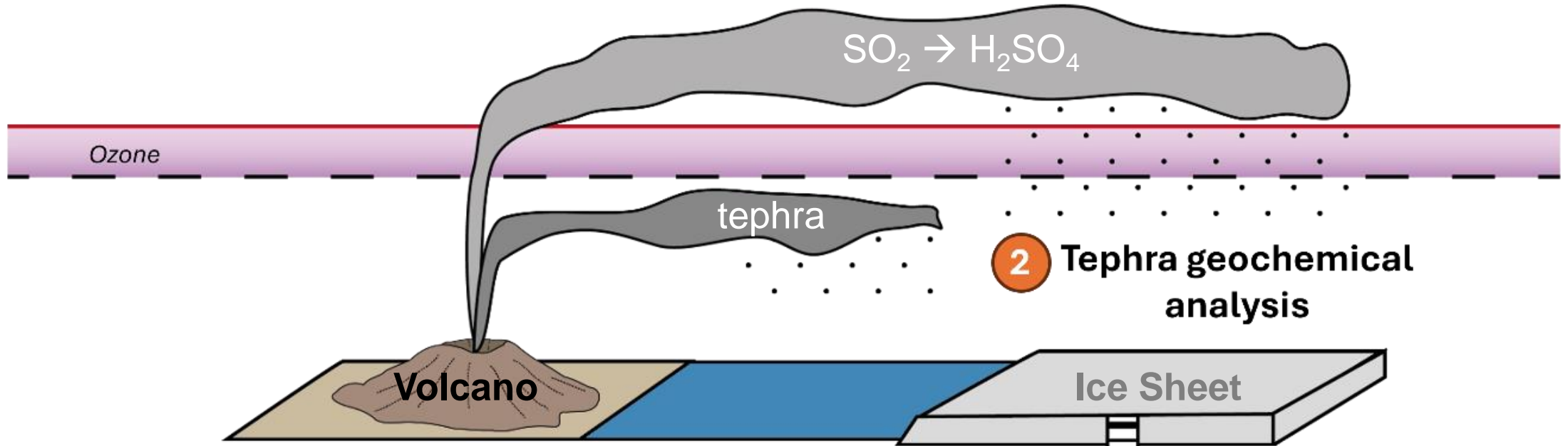


Data from Valler et al. 2024, *SciData*

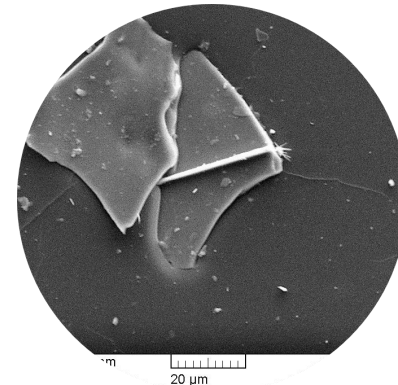
# Stratosphere (lifetime 1-3 yrs)



# Stratosphere (lifetime 1-3 yrs)



**1 Glaciochemical records**

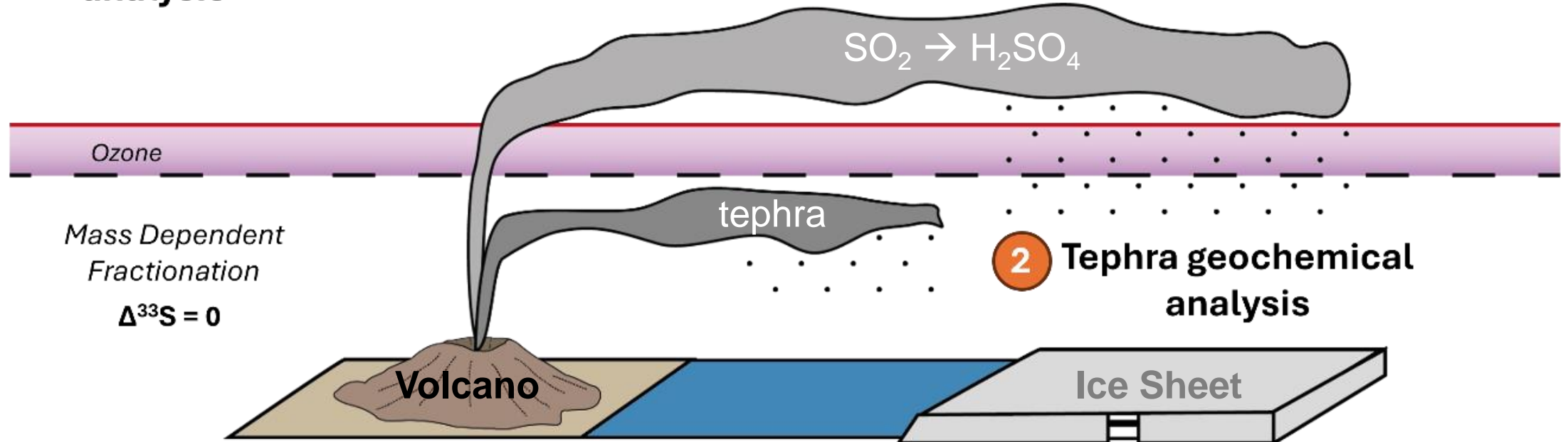




Mass Independent Fractionation  
 $\Delta^{33}\text{S} \neq 0$

**3** Sulfur isotope analysis

Stratosphere (lifetime 1-3 yrs)



Mass Dependent Fractionation  
 $\Delta^{33}\text{S} = 0$

**2** Tephra geochemical analysis

**1** Glaciochemical records

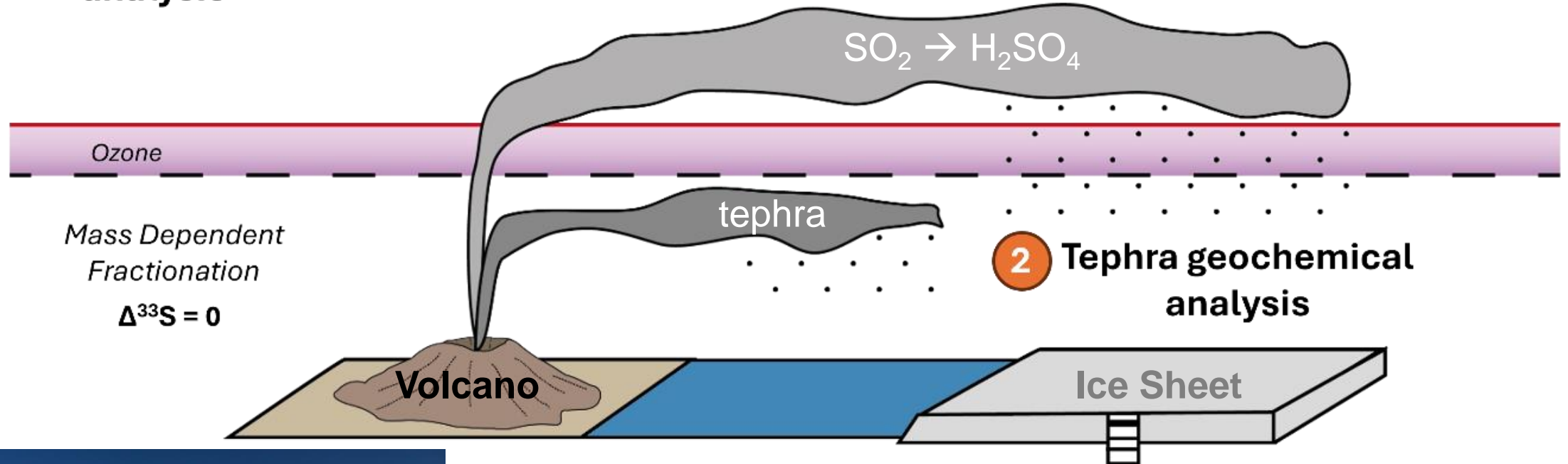


Mass Independent  
Fractionation

$$\Delta^{33}\text{S} \neq 0$$

**3** Sulfur isotope  
analysis

**Stratosphere** (lifetime 1-3 yrs)



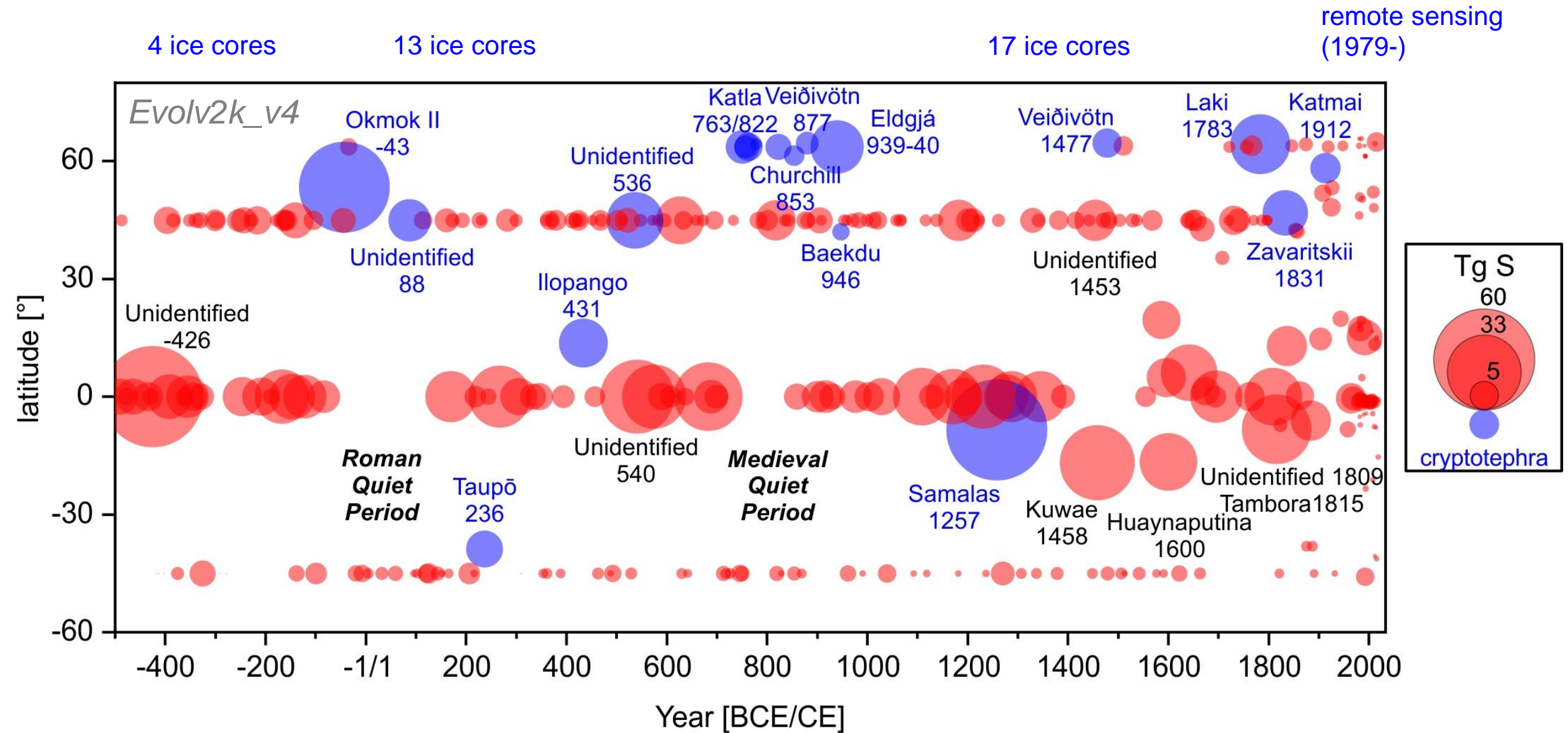
**2** Tephra geochemical  
analysis

TUNU2013 Greenland



- ✓ When did the eruption occur?
- ✓ Where did it happen?
- ✓ How much  $\text{SO}_2$  was injected?
- ✓ How much into the stratosphere?

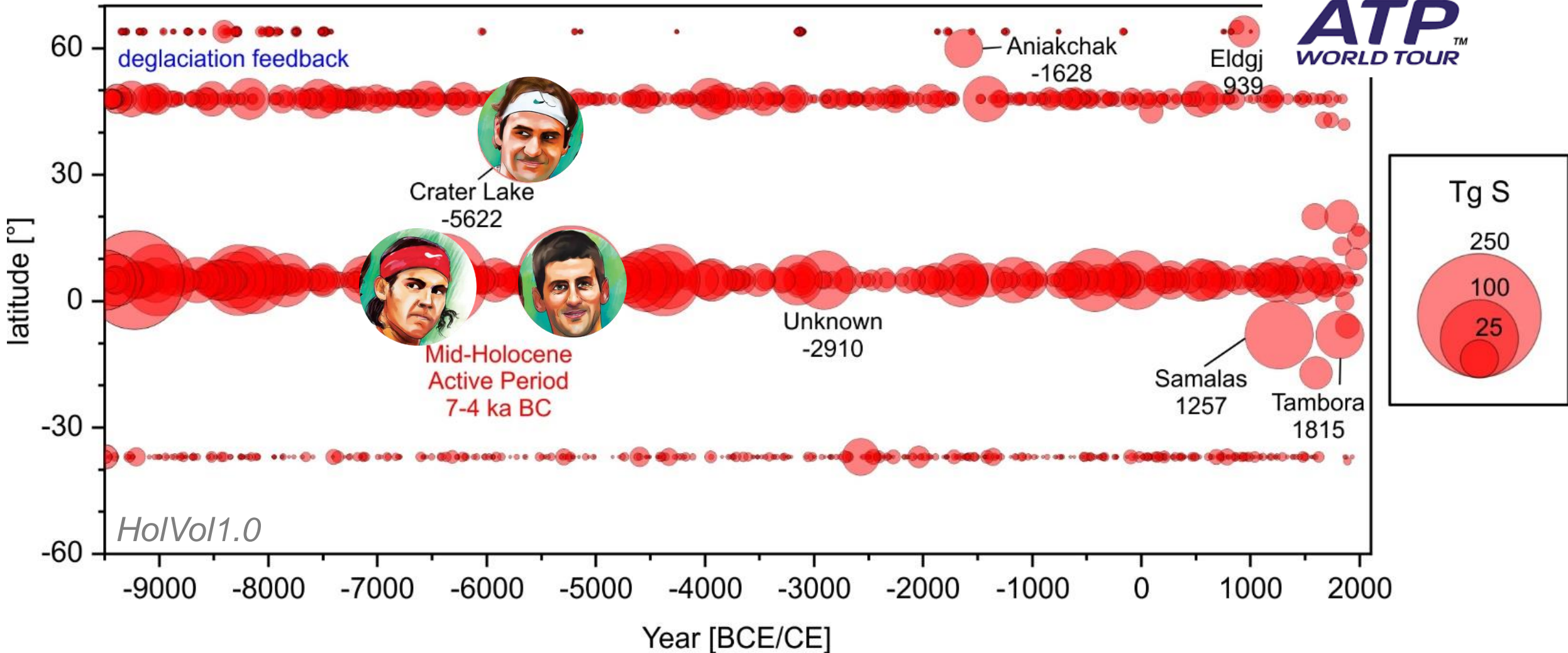
# Volcanism during the Common Era



# Volcanism during the Holocene



4 ice cores



WD2014



**Name:**

**Region:**

**Year:**

**S (Tg):**

**ATP#:**



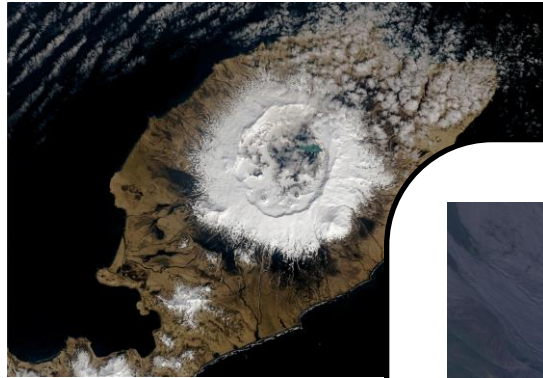
**Name:** Hrafn

**Region:** Iceland

**Year:**

**S (Tg):** 5

**ATP#:** 366



**Name:** Okla

**Region:** A

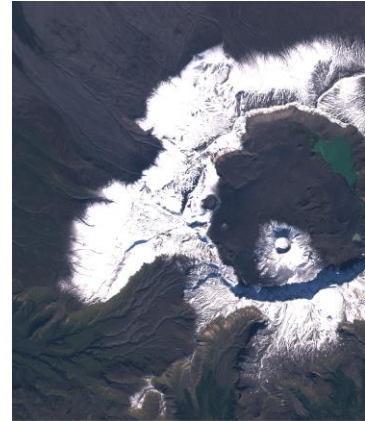
**Year:** 4

**S (Tg):**

**ATP#:**

5

366



**Name:** Ania

**Region:** A

**Year:** 1628 B.C.

**S (Tg):** 52

**ATP#:** 18



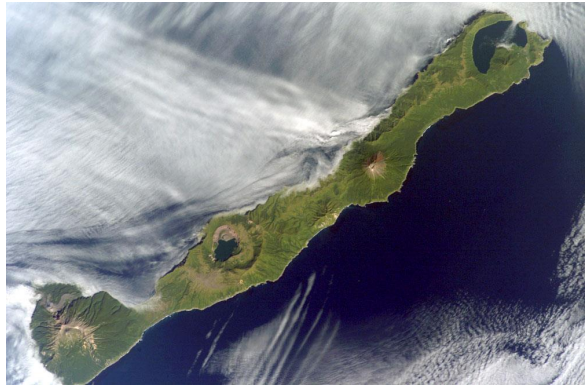
**Name:** Crater Lake

**Region:** Oregon

**Year:** 5622 B.C.

**S (Tg):** 162

**ATP#:** 2



**Name:** Zavaritskii

**Region:** Kurils

**Year:** 1831

**S (Tg):** 13

**ATP#:** 152

## Zavaritskii caldera (Simushir Island), Kurils



- ✓ **Largest** eruption in the past 200 years, since Tambora 1815
- ✓ Youngest eruption seen in ice cores not linked to a **source volcano**
- ✓ Droughts, crop failures & **famines** in Africa, India & Japan
- ✓ **Extreme weather** in the Alps
- ✓ **Glacier advances** (Little Ice Age)



Jakob Ludwig Felix Mendelssohn Bartholdy

\* 3. Februar 1809 in Hamburg

† 4. November 1847 in Leipzig

## A Midsummer Night's Dream - Scherzo

Composer: Felix Mendelssohn

Arranger: A.J. Johnson

*Molto Allegro*

*mp*

7

14

*mf*

*cresc.* - - - - -

21

27

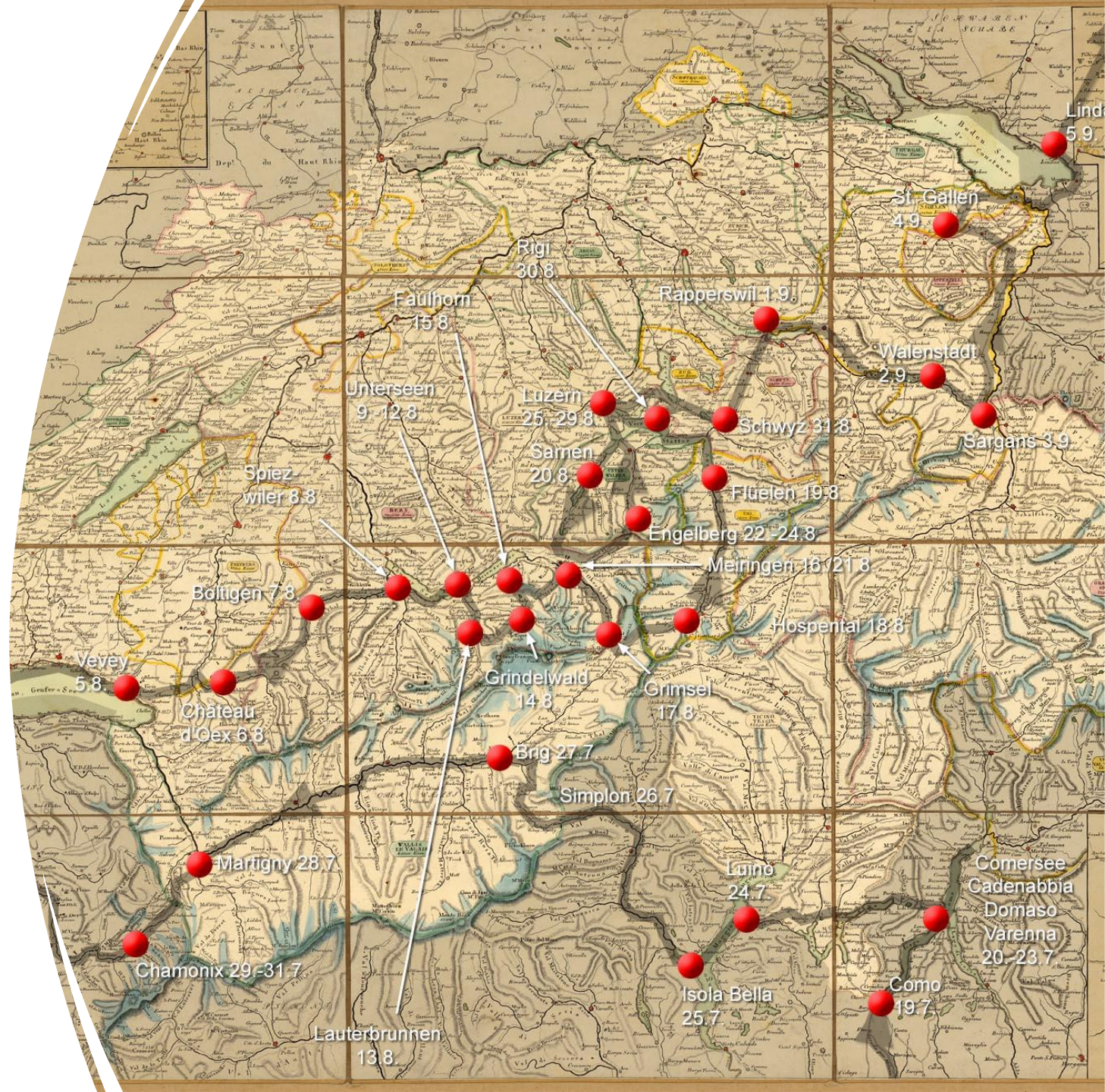
3

A musical score for a piano arrangement of Felix Mendelssohn's Scherzo from A Midsummer Night's Dream. The score is in 3/8 time and B-flat major. It consists of five systems of two staves each (treble and bass clef). The first system starts with a piano (*mp*) dynamic. The second system is marked with a 7. The third system is marked with a 14 and a mezzo-forte (*mf*) dynamic. The fourth system is marked with a 21 and a crescendo (*cresc.*) marking. The fifth system is marked with a 27 and a triplet (*3*) marking. The score includes various musical notations such as notes, rests, and dynamic markings.

# *Felix Mendelssohn's Alpenreise 1831*

19.7. – 5.9.

**Walter Bersinger, pers.  
communications**





«Desolate weather, it has rained again all night and all morning, it is as cold as in winter, there is already deep snow on the nearest hills...

♦♦♦

Good night, it strikes eight o'clock in F minor and rains and storms in F-sharp minor or G-sharp minor in all possible sharp keys.»

(Sargans, Switzerland, September 3<sup>rd</sup> 1831)



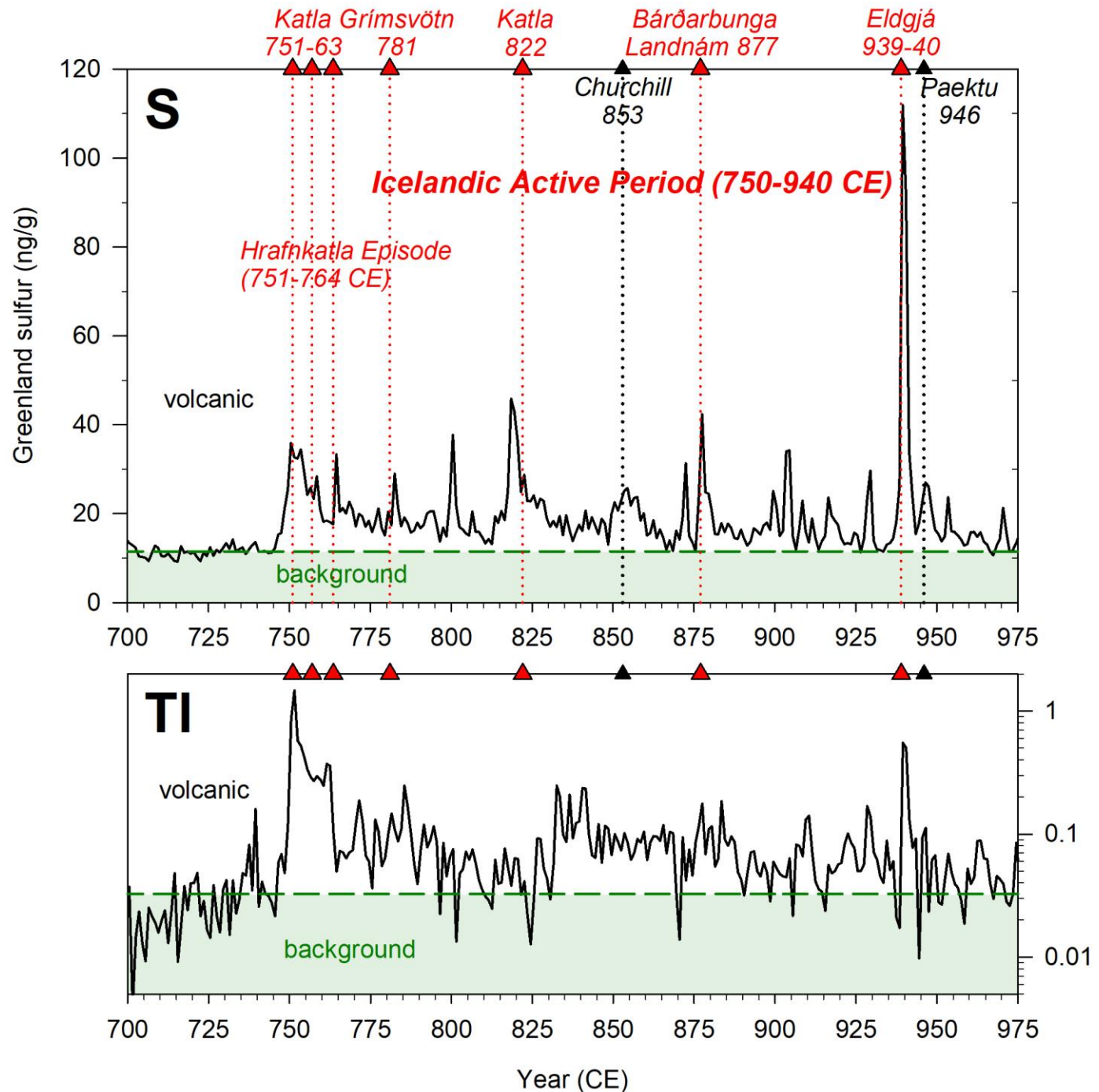
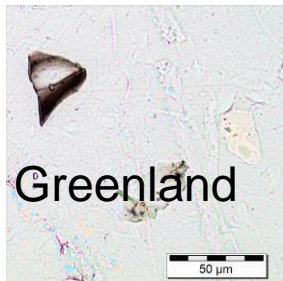
**Name:** Hrafnkatla

**Region:** Iceland

**Year:** 763

**S (Tg):** 5

**ATP#:** 366



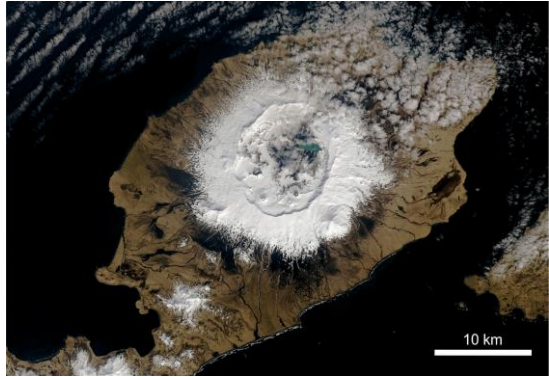


**Hrafnkatla 763**



**Eisberge  
am Bosphorus**

# Disproportionately strong forcing from extratropical eruptions



Okmok  
43 BC

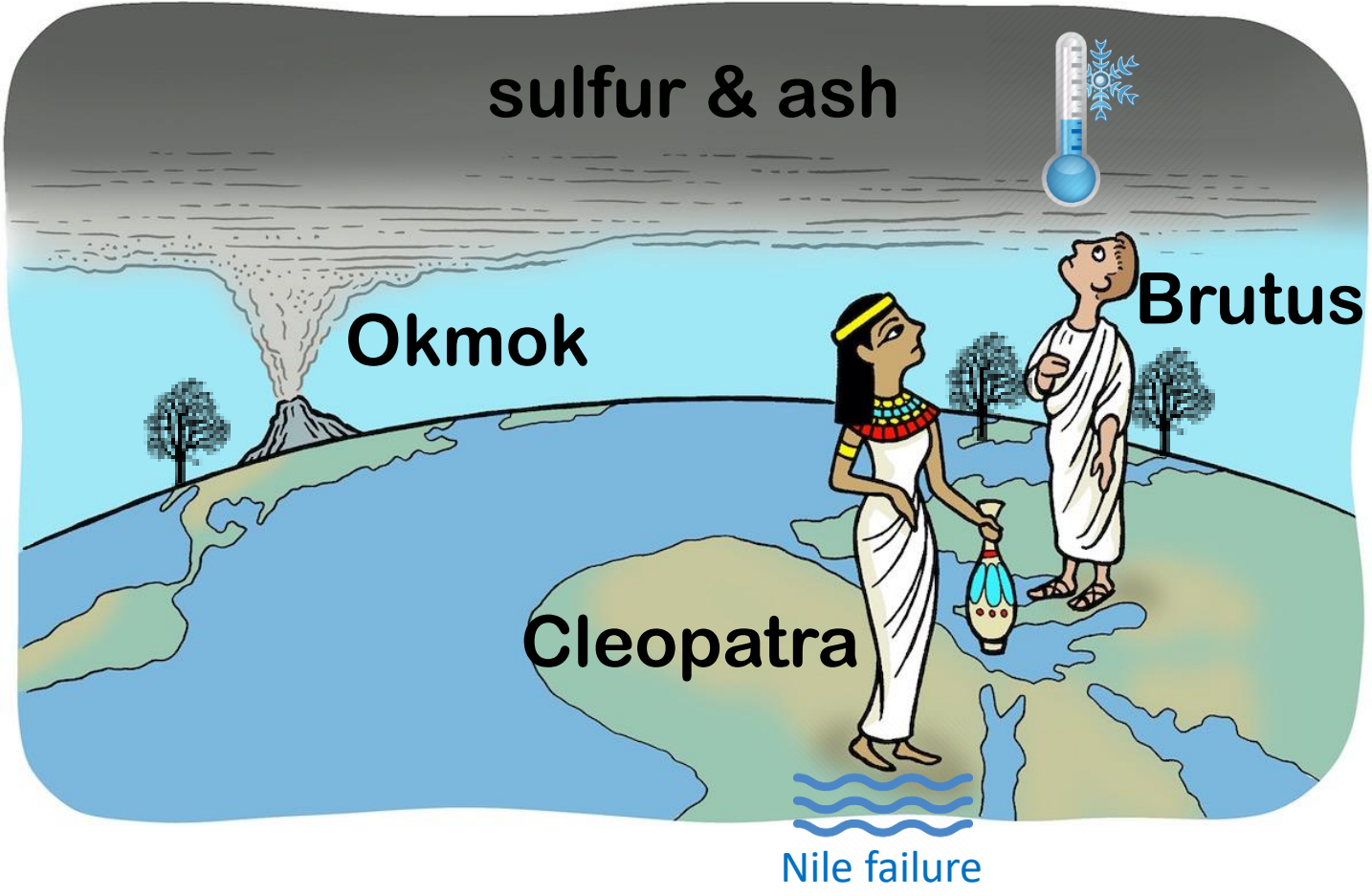
**Name:** Okmok II  
**Region:** Alaska  
**Year:** 43 B.C.  
**S (Tg):** 48  
**ATP#:** 21



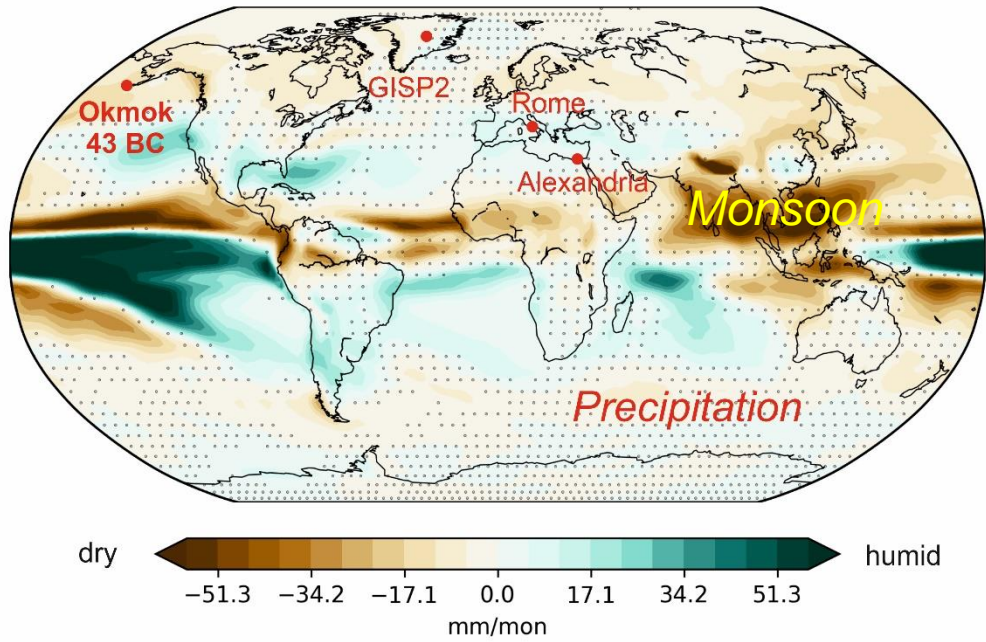
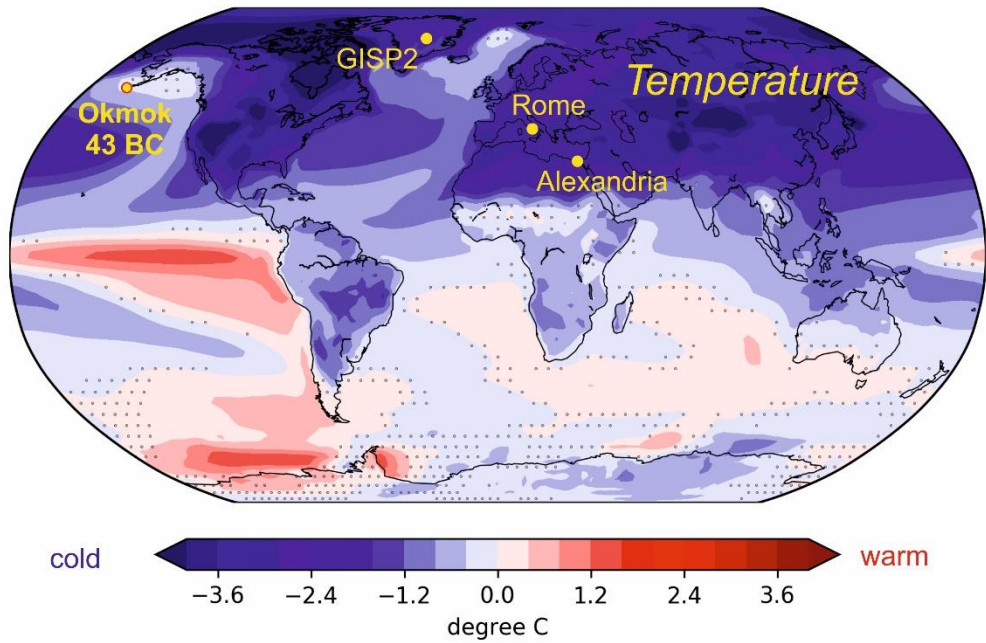
Aniakchak  
1628 BC



**Name:** Aniakchak  
**Region:** Alaska  
**Year:** 1628 B.C.  
**S (Tg):** 52  
**ATP#:** 18



43/42 BC



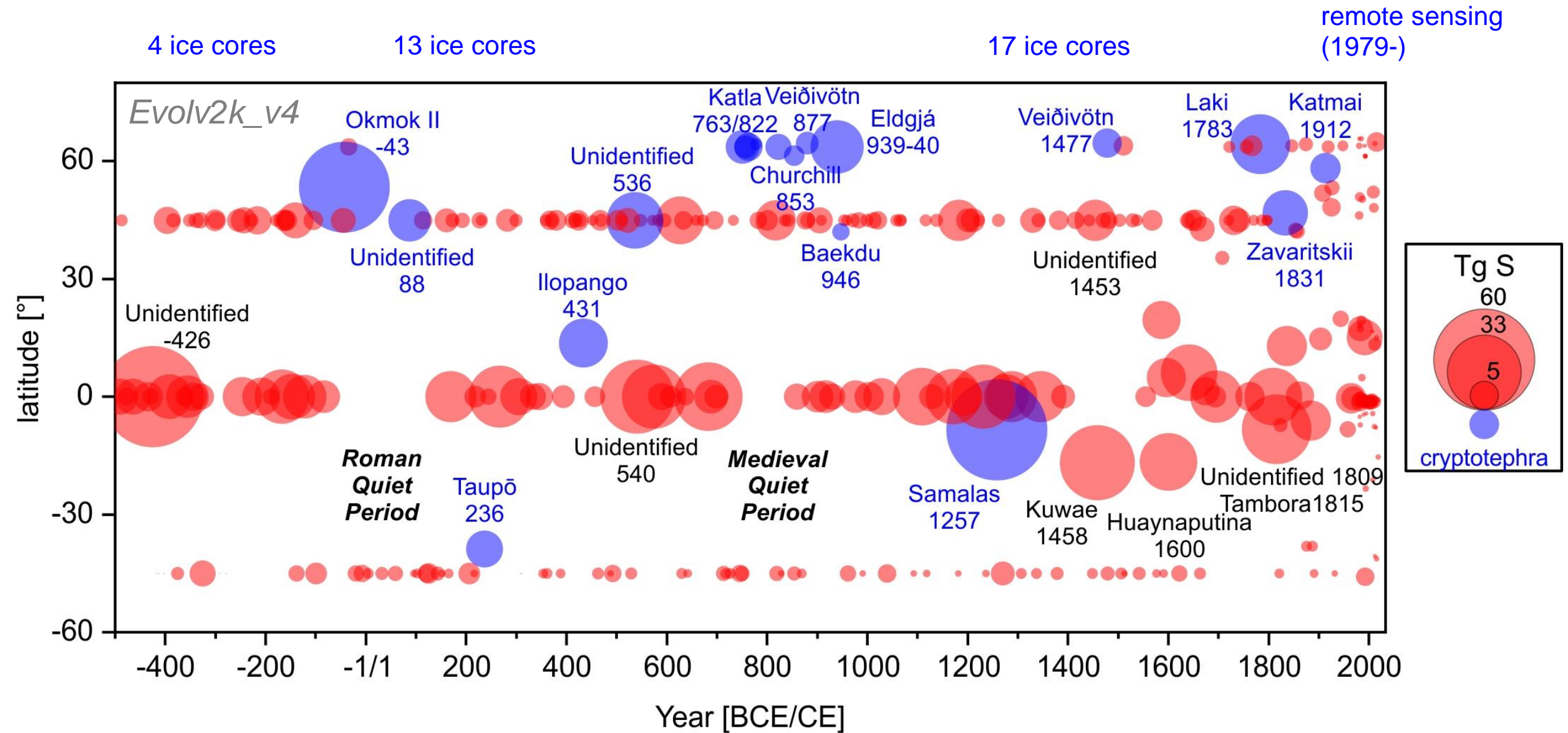
Manning et al. 2017; *Nature Communications*; McConnell et al. 2020, *PNAS*

# Volcanic impacts on monsoon, streamflow, agriculture and ancient societies



Manning et al. 2017; *Nature Communications*; McConnell et al. 2020, *PNAS*; Gao et al. 2021 *Commun. Earth Environ.*

# Volcanism during the Common Era



# Mazama (Crater Lake) – the Greatest of all time?



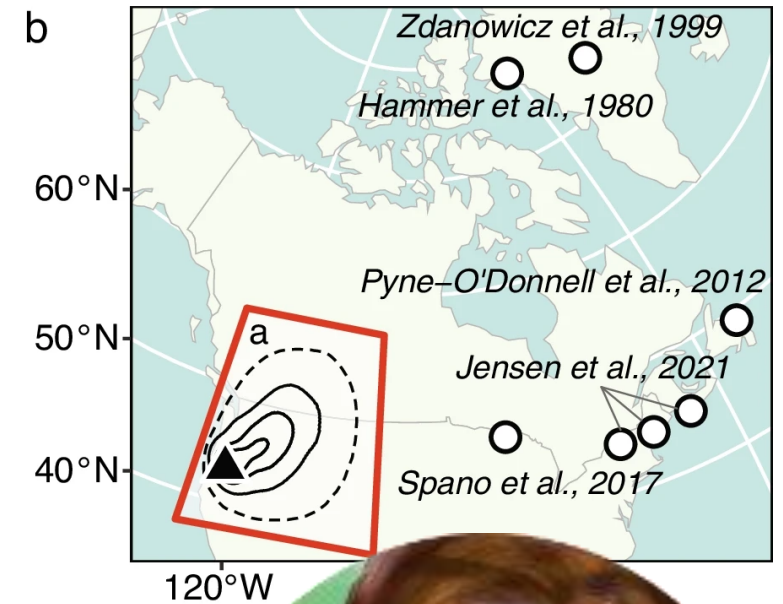
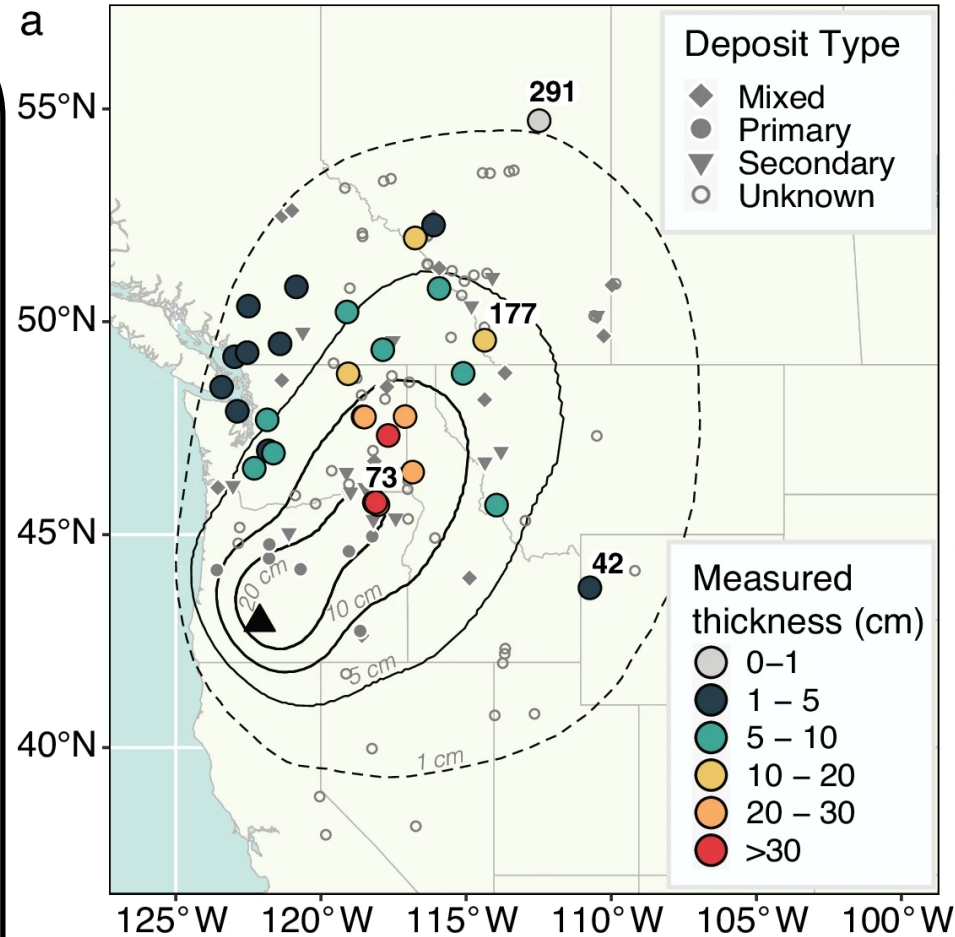
**Name:** Crater Lake

**Region:** Oregon

**Year:** 5622 B.C.

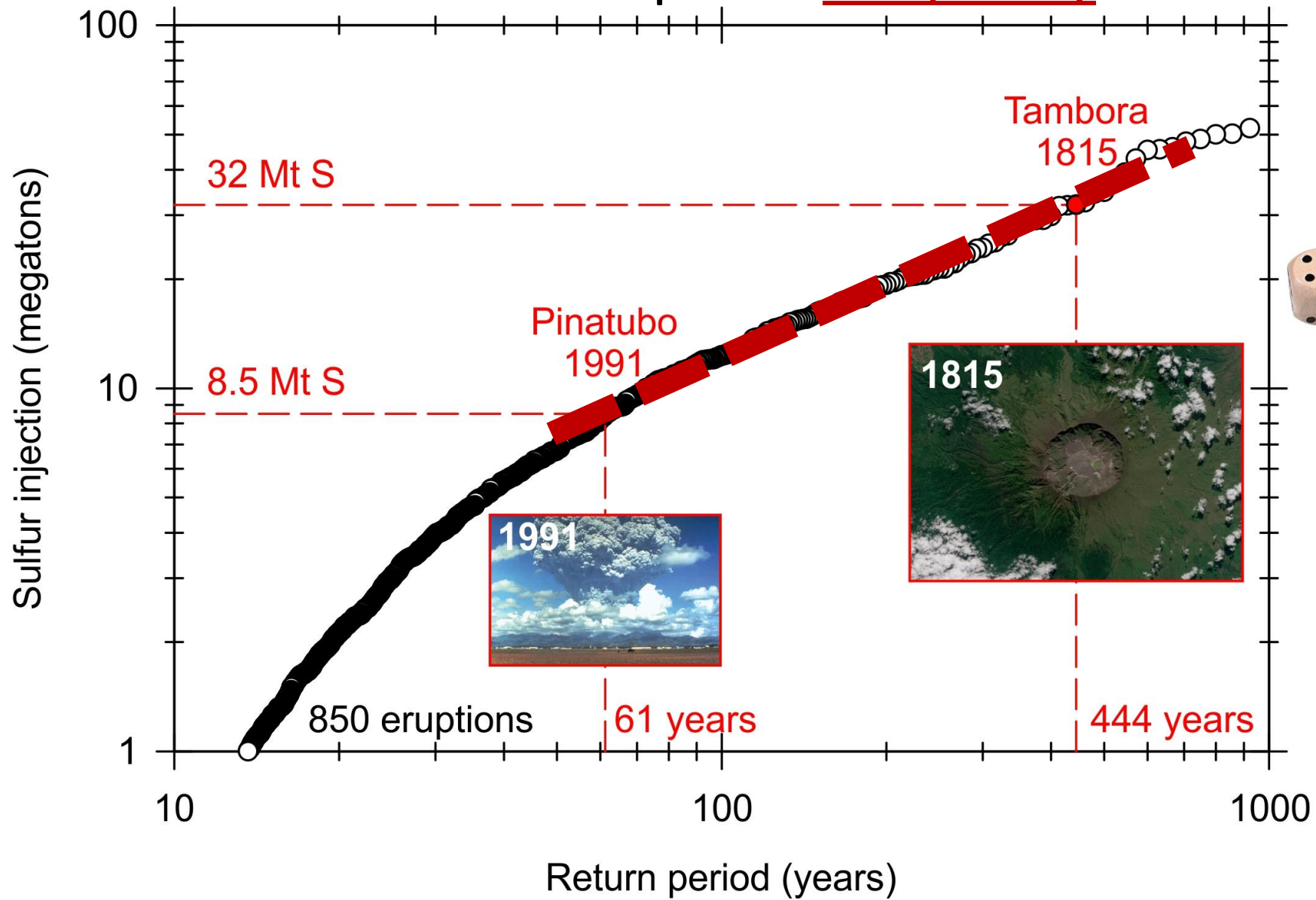
**S (Tg):** 162

**ATP#:** 2





# Risk = Impact x Frequency



Global catastrophic risk from lower  
magnitude volcanic eruptions,  
Mani et al., 2021, Nature Communications

Aviation

# Global Warming

Energy

Communication

Agriculture

Infrastructure

Transportation



# Learning from the Past

- (1) “More must be done to **forecast** and try to **manage** globally disruptive volcanic eruptions. The risks are greater than people think!” (Cassidy & Mani, *Nature* 2022)
- (2) Volcanic eruptions are more than just a “year without a summer”
- (3) Often, it’s not the prominent “**celebrity volcanoes**” that matter (e.g. Thera, Vesuvius) but previously under-researched volcanoes (e.g. Katla, Okmok, Aniakchak)





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Established by the European Commission

## Timing of Holocene Volcanic Eruptions and Radiative Aerosol Forcing

