Comparing weather station and isotopic data in the new Alpine ice core drilling site of Mt. Ortles (South Tyrol, Italy)

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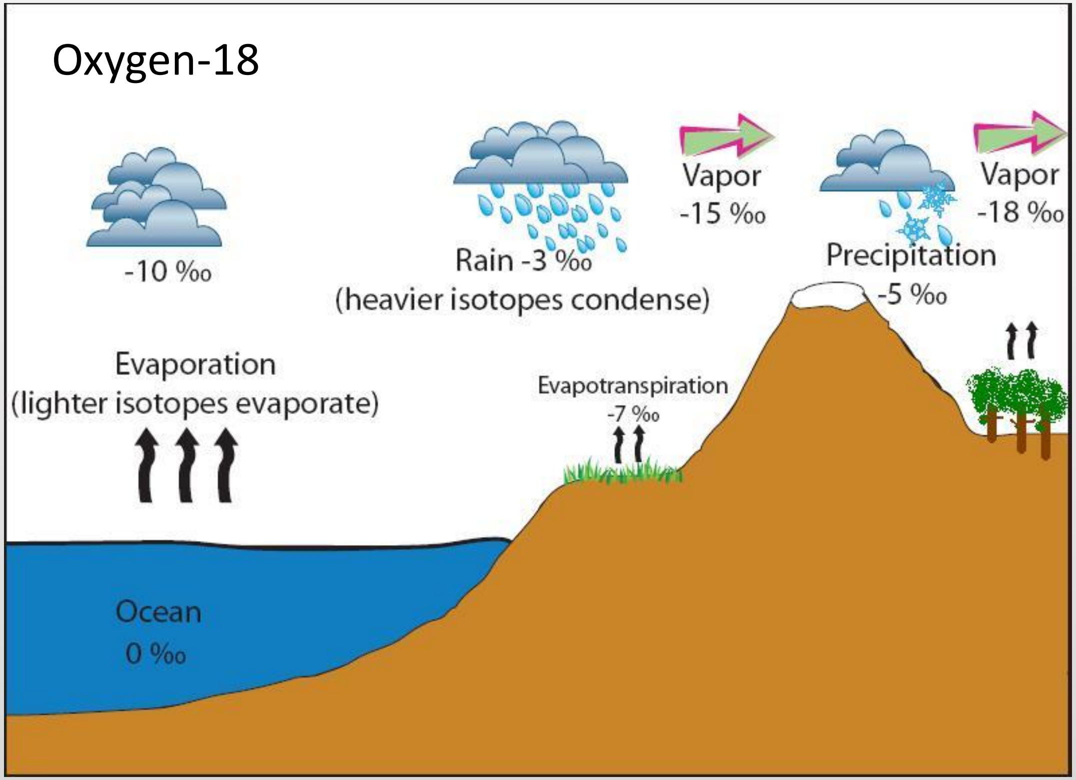
Isotopic fractionation in the water cycle



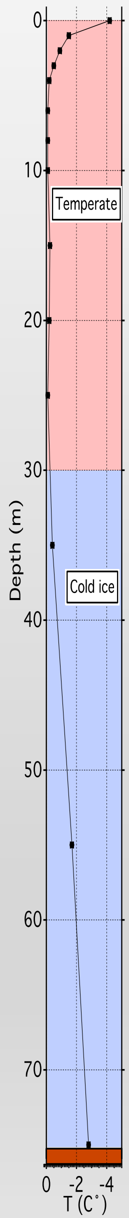
Values are expressed in terms of departures from the Standard Mean Ocean Water (SMOW) standard (Craig, 1961): **the isotopic composition**

$$\delta(‰)=\{[R(sample)-R(standard)]/R(standard)\}*1000$$

$R = [^{18}O]/[^{16}O]$ and $R = [^{2}H]/[^{1}H]$

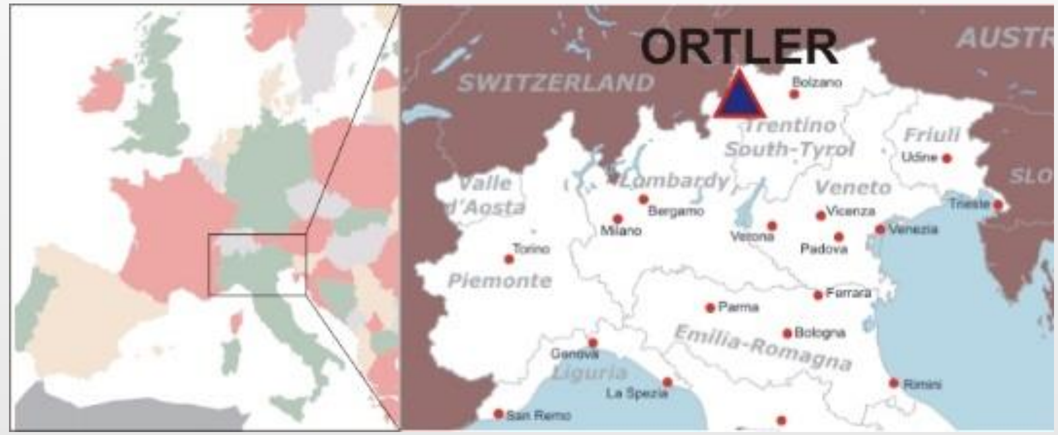
Mt. Ortles (3905 m a.s.l.)

Borehole temperature profile



The glacier is polythermal, transitioning from a cold to a temperate state
Below 30 m: cold ice

Accumulation rate: 850 mm we/a



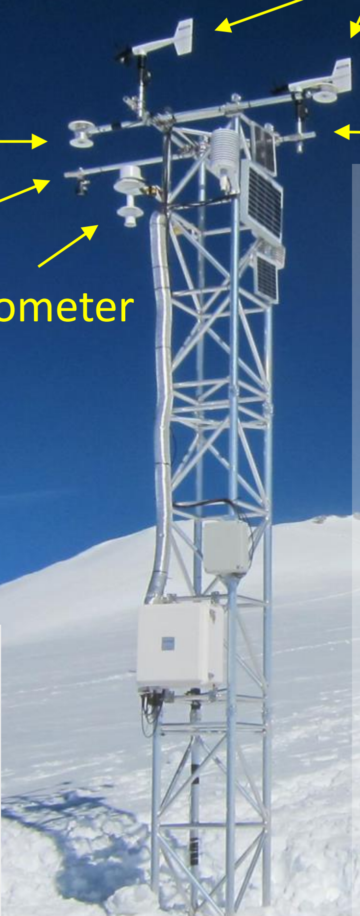
4 deep ice cores were drilled from the upper part of the Alto dell'Ortles glacier at 3859 m a.s.l. (10°32"34 E 46°30"25 N), 3 reached the bedrock (75 m)

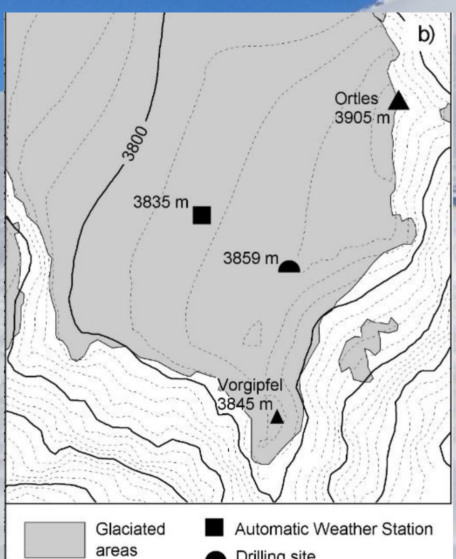
Water stable isotope archive (in progress)

- Shallow core 2009 (10 m)
- Shallow core 2010 (10 m)
- 2 Deep cores 2011 (75 m, core #1 in prog)
- Snow pit August 2008
- Snow pit June 2009
- Snow pit (AWS) June 2012
- Snow pit (drilling site) June 2012
- Snow pit (AWS) September 2012
- Snow pit (drilling site) September 2012
- Snow pit (AWS) July 2013
- Snow pit (drilling site) July 2013
- Snow pit (AWS) September 2013
- Snow pit (drilling site) September 2013

Instrumental temperatures

TESAF UNIPD AWS





Data courtesy of Carturan and De Blasi

3835 m a.s.l. temperature

Ortles reconstructed temperature 1864-2009

Based on Careser Diga meteorological station data (15 km southwest, 2605 m a.s.l.)

Fixed lapse rate between Careser Diga and Cima Beltovo (0.0072°C/m)

$$T_{Ortles}=(-(3835-2605)*0.0072)+T_{careser}$$

Monthly resolution

Ortles reconstructed temperature 2005-2013

Based on Careser Diga meteorological station data

Mean monthly lapse rate between Careser Diga and Ortles AWS temperatures (Oct 2011- Sept 2013)

$$T_{Ortles}=(-(3835-2605)*MonthLapseRate)+T_{careser}$$

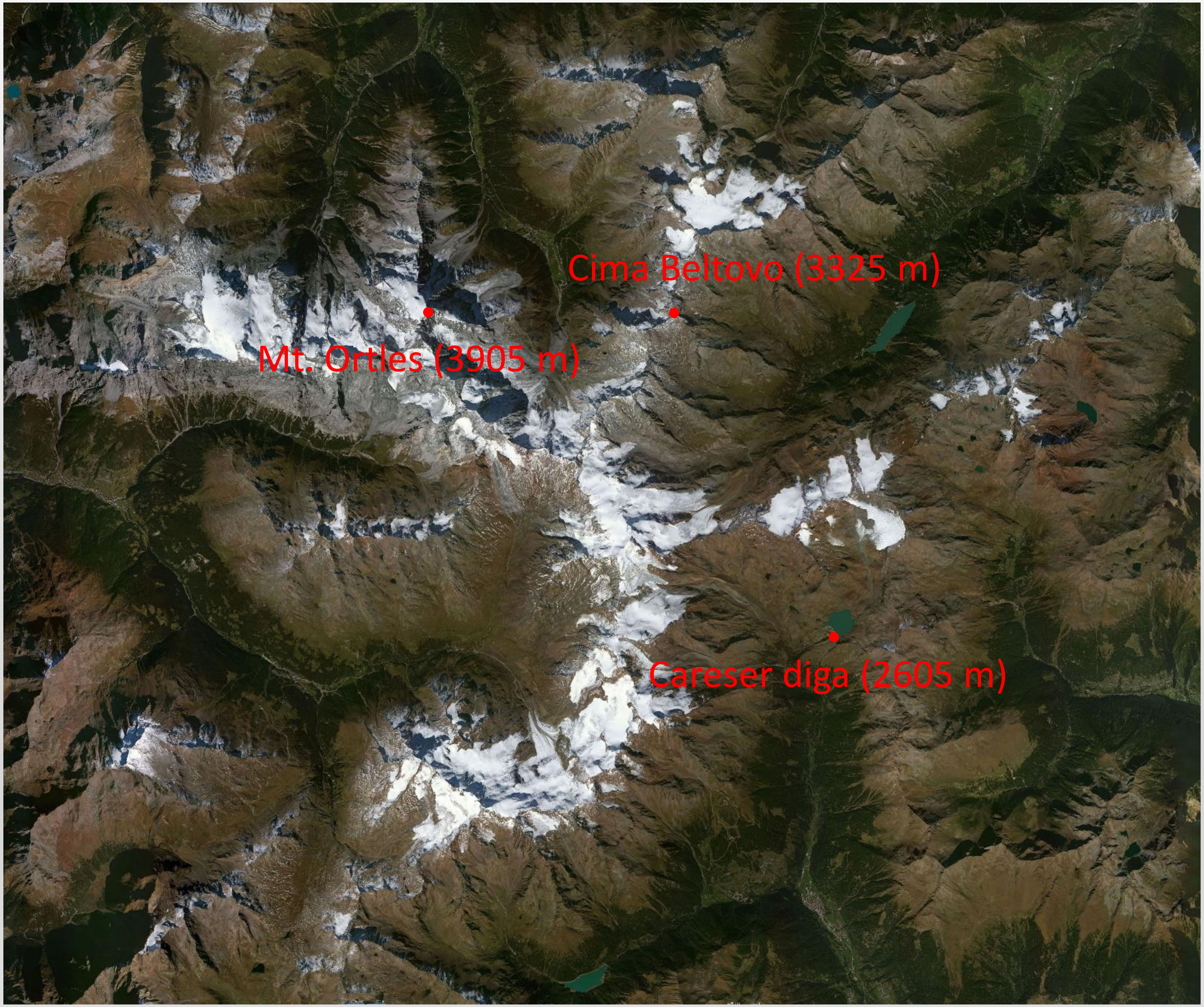
Monthly resolution

Ortles AWS temperature Oct 2011-Aug 2013

Automatic Weather Station on Alto dell'Ortles (3835 m a.s.l.)

15-minute resolution

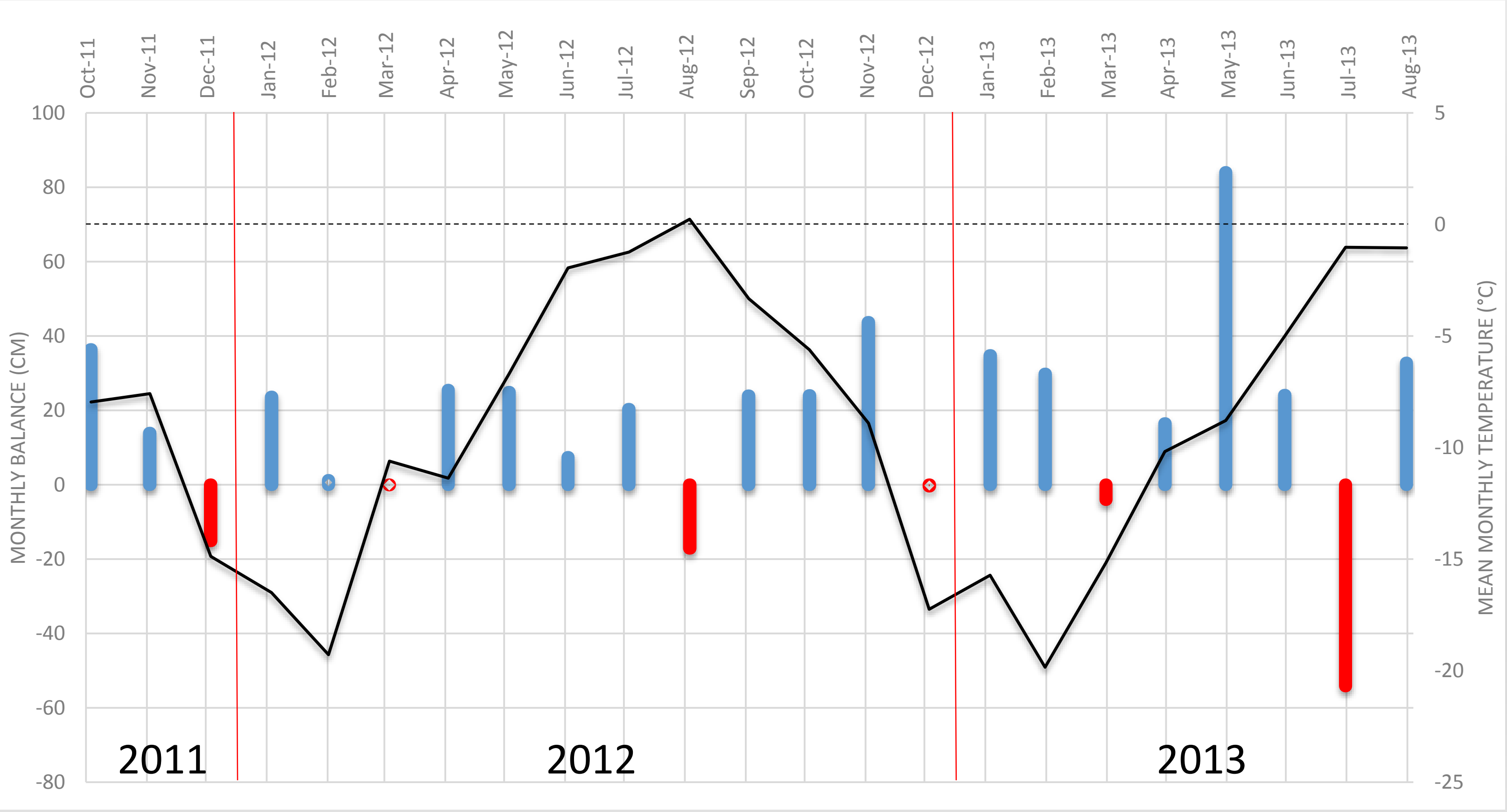
The Ortles-Cevedale Group



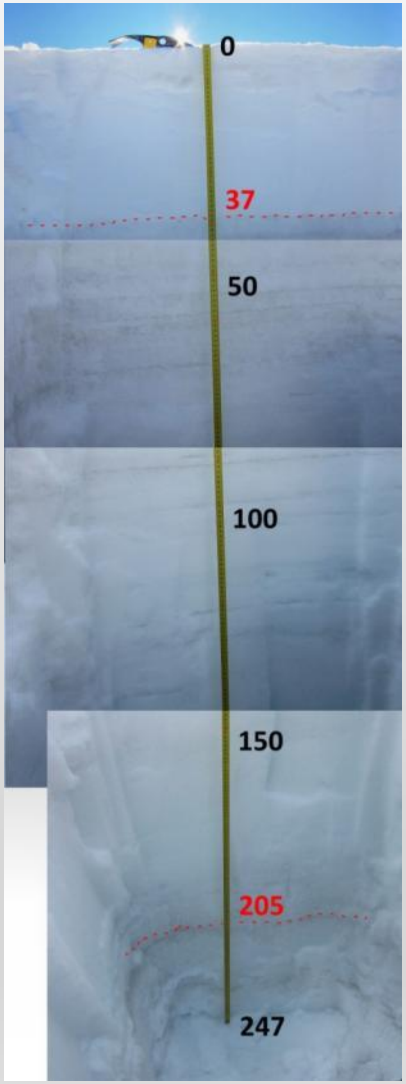
Temperature and Mass balance

Mean monthly temperature (black line) and monthly mass balance (blue bars: positive accumulation, red bars: negative) from the Ortles AWS

High intra and inter-annual variability
Winter ablation recorded in December 2011 and 2012 (wind scouring?)



Snow pit stratigraphical features



Snow stratigraphy observation

↓

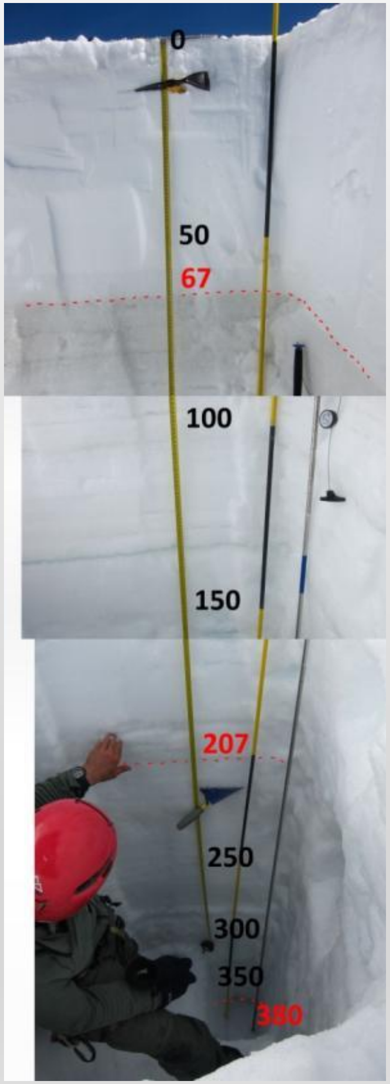
Identification of the beginning and the end of the accumulation/ablation season

↓

Temporal constraints to match isotopes and AWS data

RESULTS – MASS BALANCE MEASUREMENTS

	AWS site			Drilling site				
Year	Winter balance (mm w.e.)	Summer balance (mm w.e.)	Annual Net balance (mm w.e.)	Winter balance (mm w.e.)	Summer balance (mm w.e.)	Annual Net balance (mm w.e.)	Net balance ratio (D.S. / AWS)	Mean summer temperature (°C)*
2009	1017	134	1151	-	-	-		-1
2010	872	-433	439	-	-	-		-1.2
2011	1076	209	1285	790	137	927	0.72	-1.7
2012	748	47	795	605	55	660	0.83	-0.2
2013	1674	-454	1220	1075	-74	1001	0.82	-1.3



Carturan, personal communication

AWS daily temperature

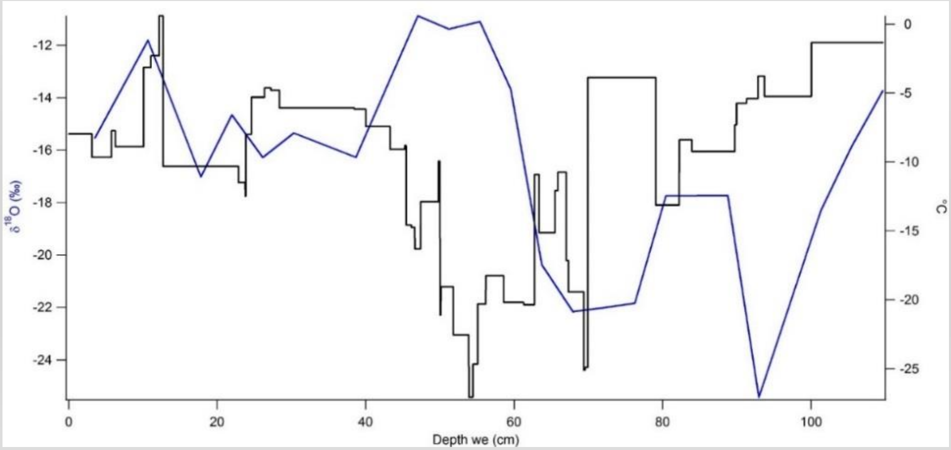
AWS snow height

Formation temperature for each snow event

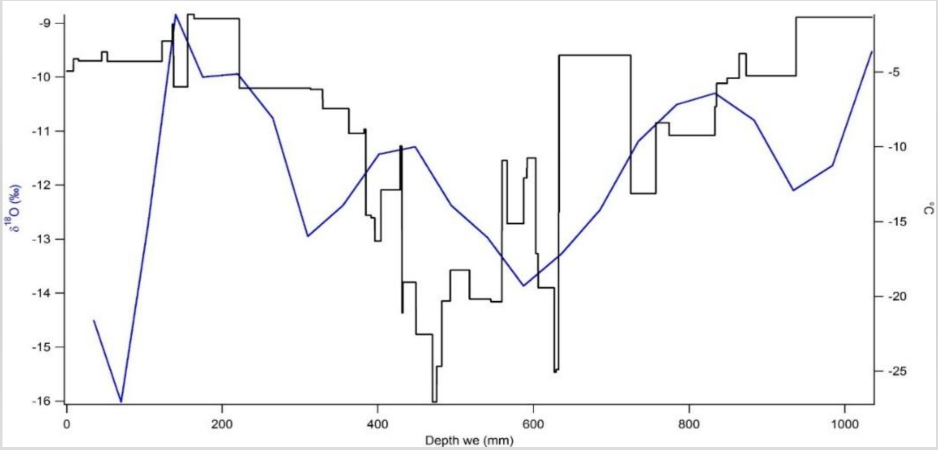
to each millimeter of snow has been assigned the temperature of the day in which the snow has fallen

Drilling site snow pits

July 2013 and September 2013 oxygen-18 profile (blue line) and reconstructed snowpack formation temperature (black line) comparison



July 2013



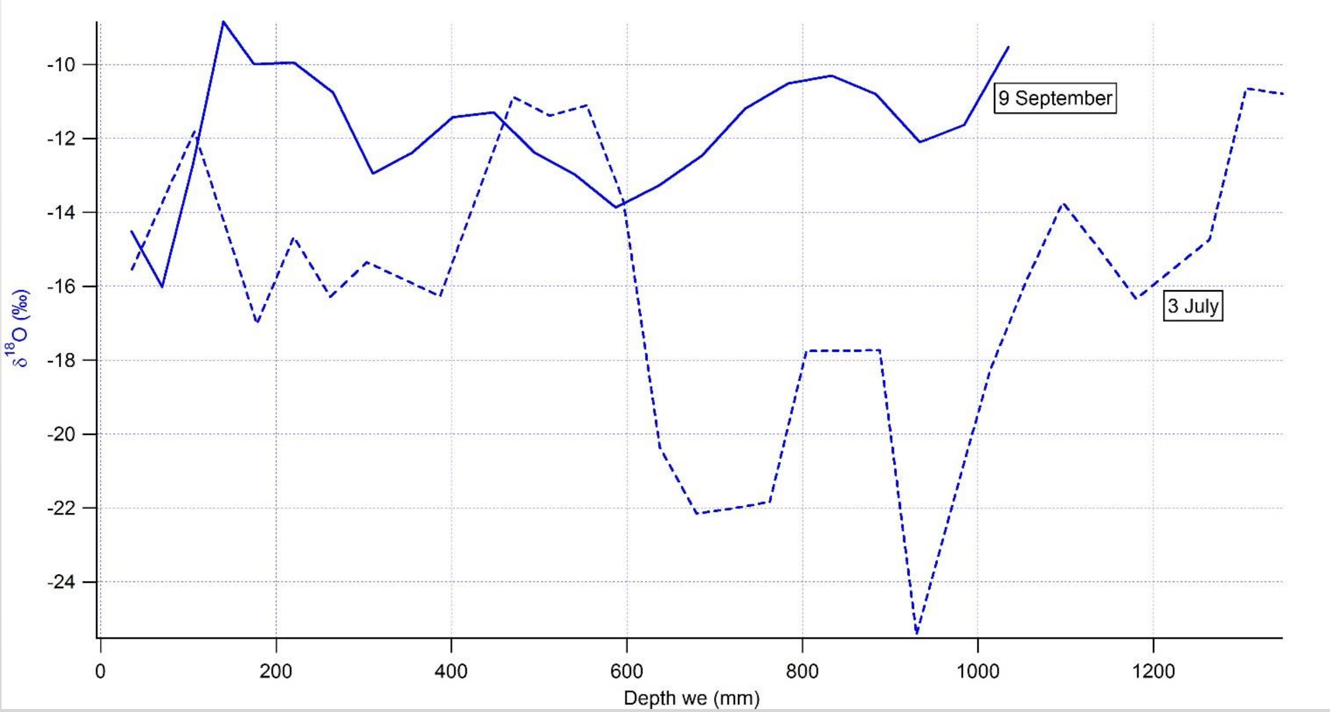
September 2013

Drilling site snow pits

2 snow pits digged in 2013 at the same site

1. 03 July 2013 2. 09 September 2013

The oxygen-18 signal shows significant variations



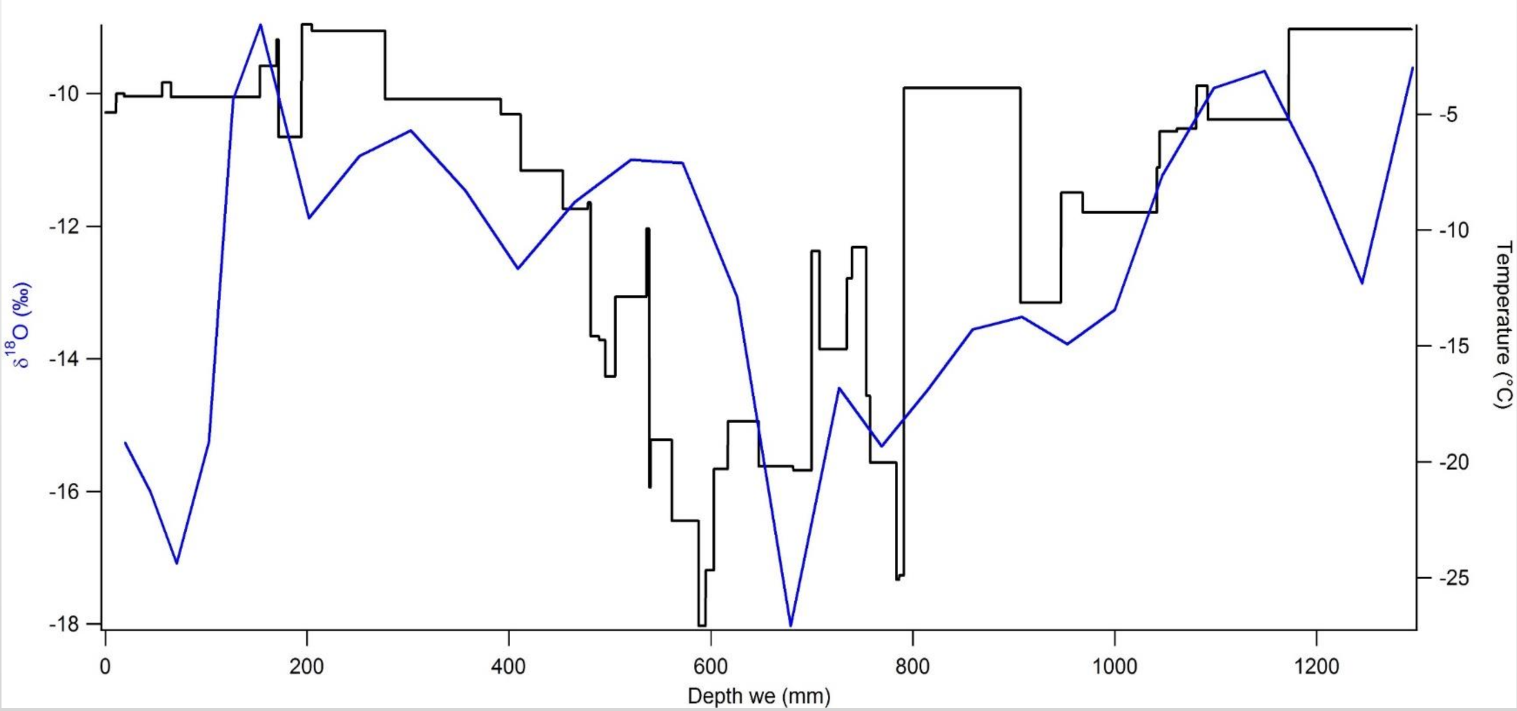
2013 summer balance: -74 mm

Summer post-depositional effects on oxygen-18

→loss of seasonal variations →positivization of the signal

AWS September 2013 snow pit

Oxygen-18 profile and reconstructed snowpack formation temperature

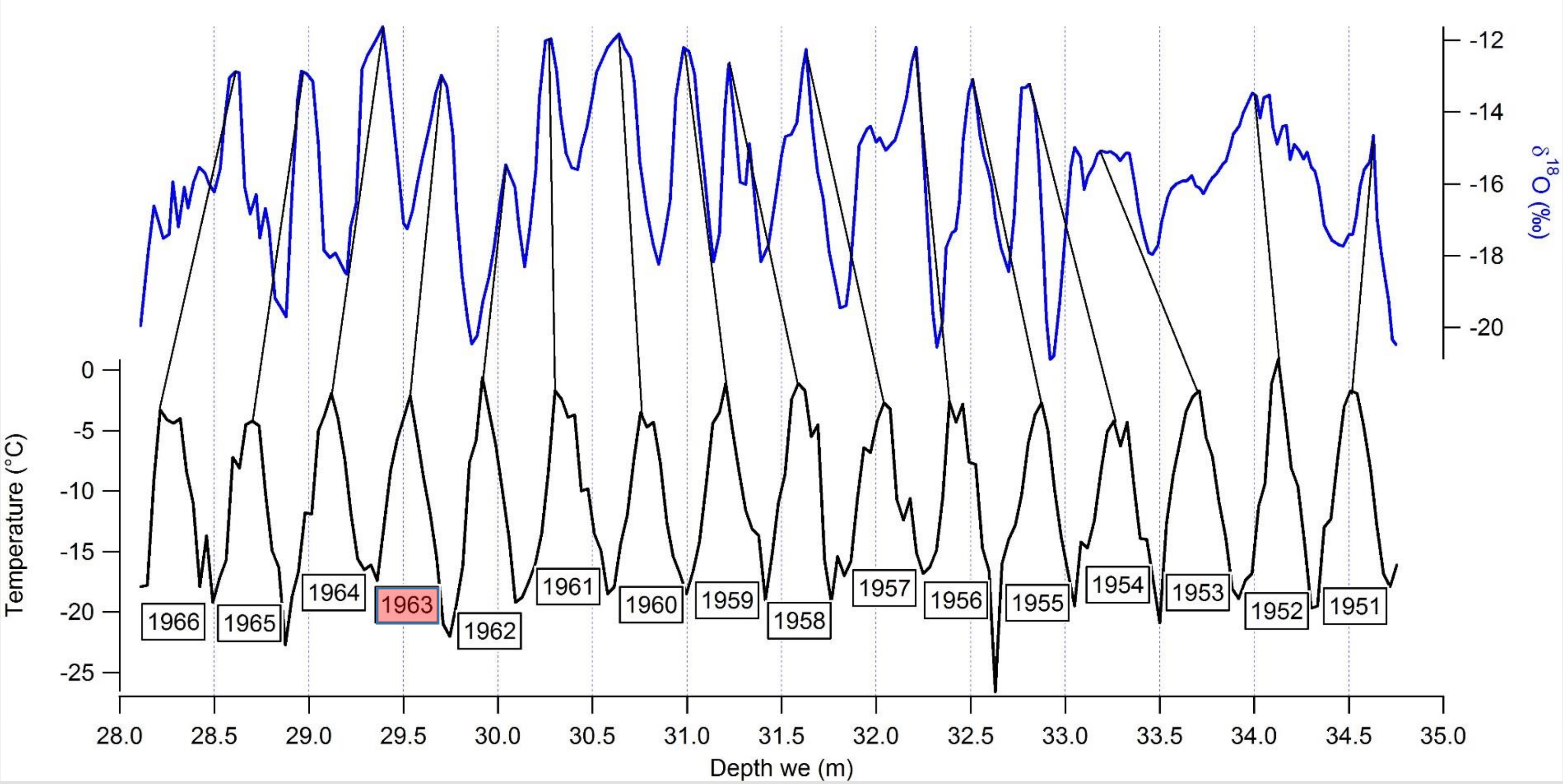


- Much better visual correlation then for the drilling site
- Oxygen-18 August minimum is close to the winter lowest value

Ortles core #2 (75 m)

Oxygen-18 seasonality well preserved below the firn-ice transition (cold ice), around the tritum peak absolute age marker (1963)

Identification of annual oscillations for comparing the Ortles reconstructed temperature series (black line) with the $\delta^{18}O$ record (blue line)



Temperature and oxygen-18 correlation (core #2)

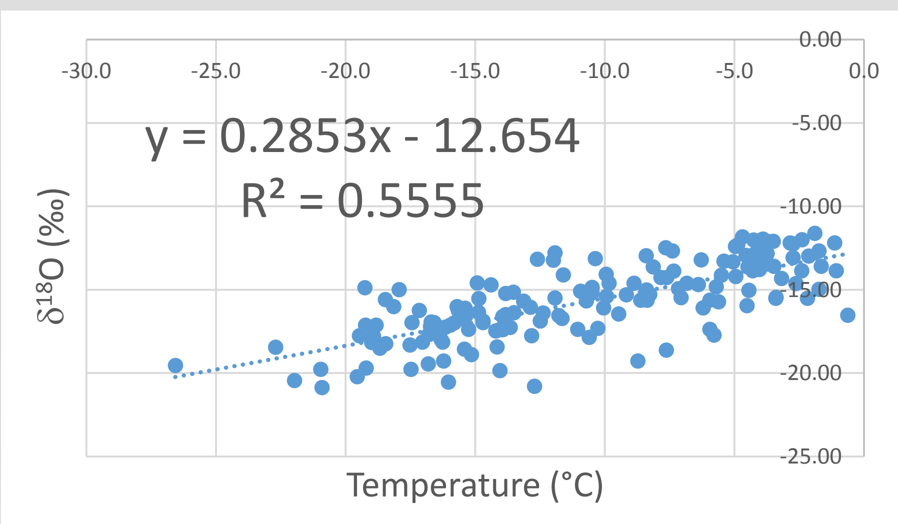
To calculate the **linear regression** between temperature and oxygen-18 we need the same point number in both series

Temperature: monthly resolution (12 data per year)

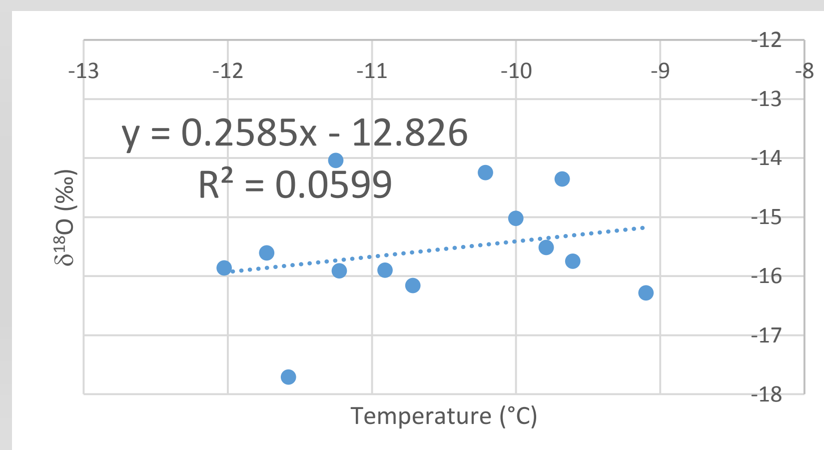
$\delta^{18}O$: variable resolution (10-22 data per year)

→ HAND PICKING

Monthly values
1953-1965 ‰/°C



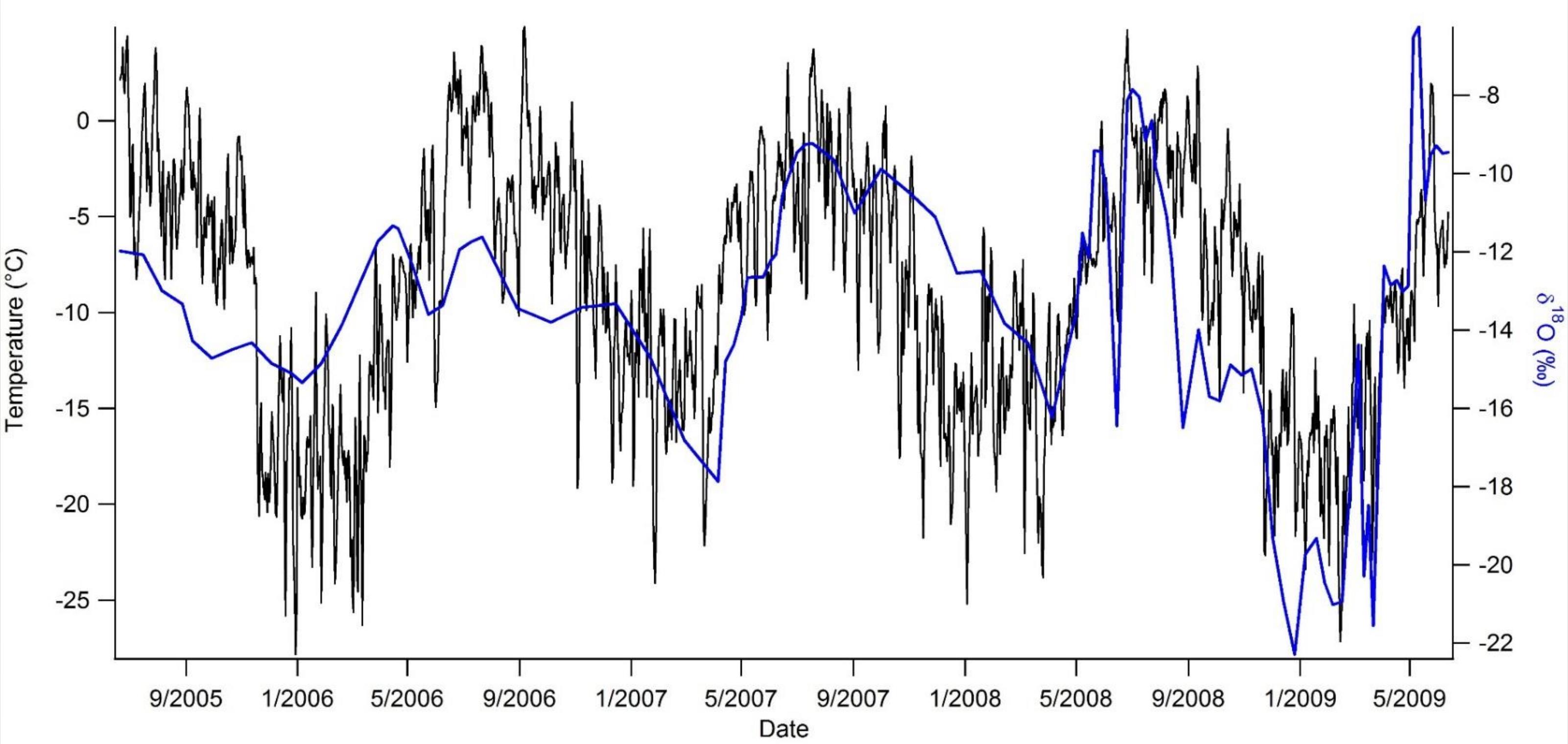
Mean annual values
1953-1965 ‰/°C



Temperature and oxygen-18 correlation (shallow core 2009)

Dating based on the counting of different pollen species, characterized by different flowering periods (Festi *et al.*, unpublished)

Comparison between the shallow core oxygen-18 record (blue line) and the Ortles reconstructed temperature 2005-2009 (black line)

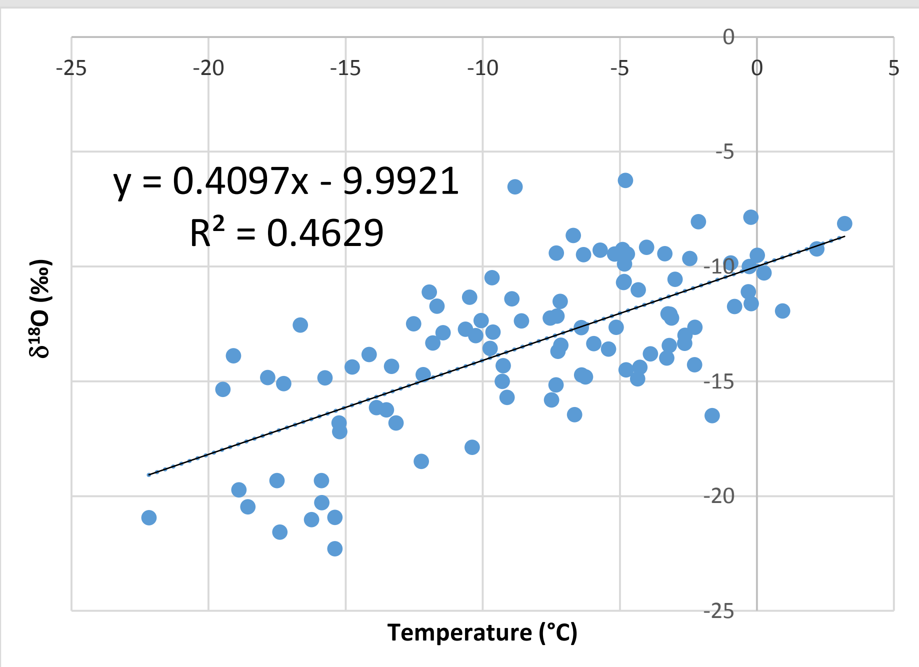


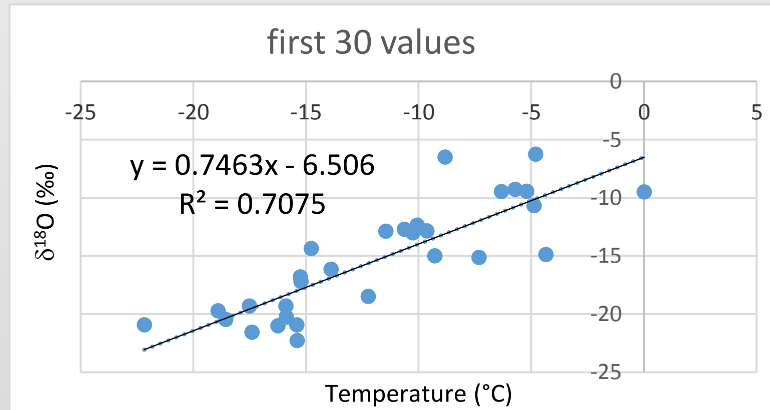
Temperature and oxygen-18 correlation (shallow core 2009)

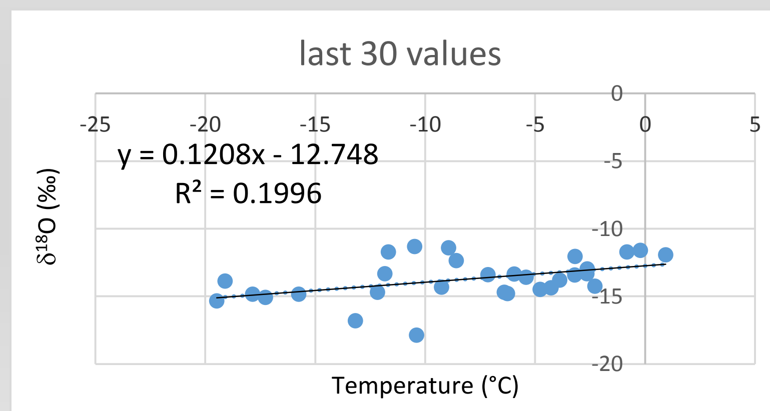
The resolution of temperature and isotope data is different
→Averaged temperature of few days before and after the isotope sample date has been used to equalize the two series and calculate the linear regression

The correlation is much better (R^2=0.71) using the first 30 values and much worse using the last 30 (R^2=0.20)

2005-2009 ‰/°C

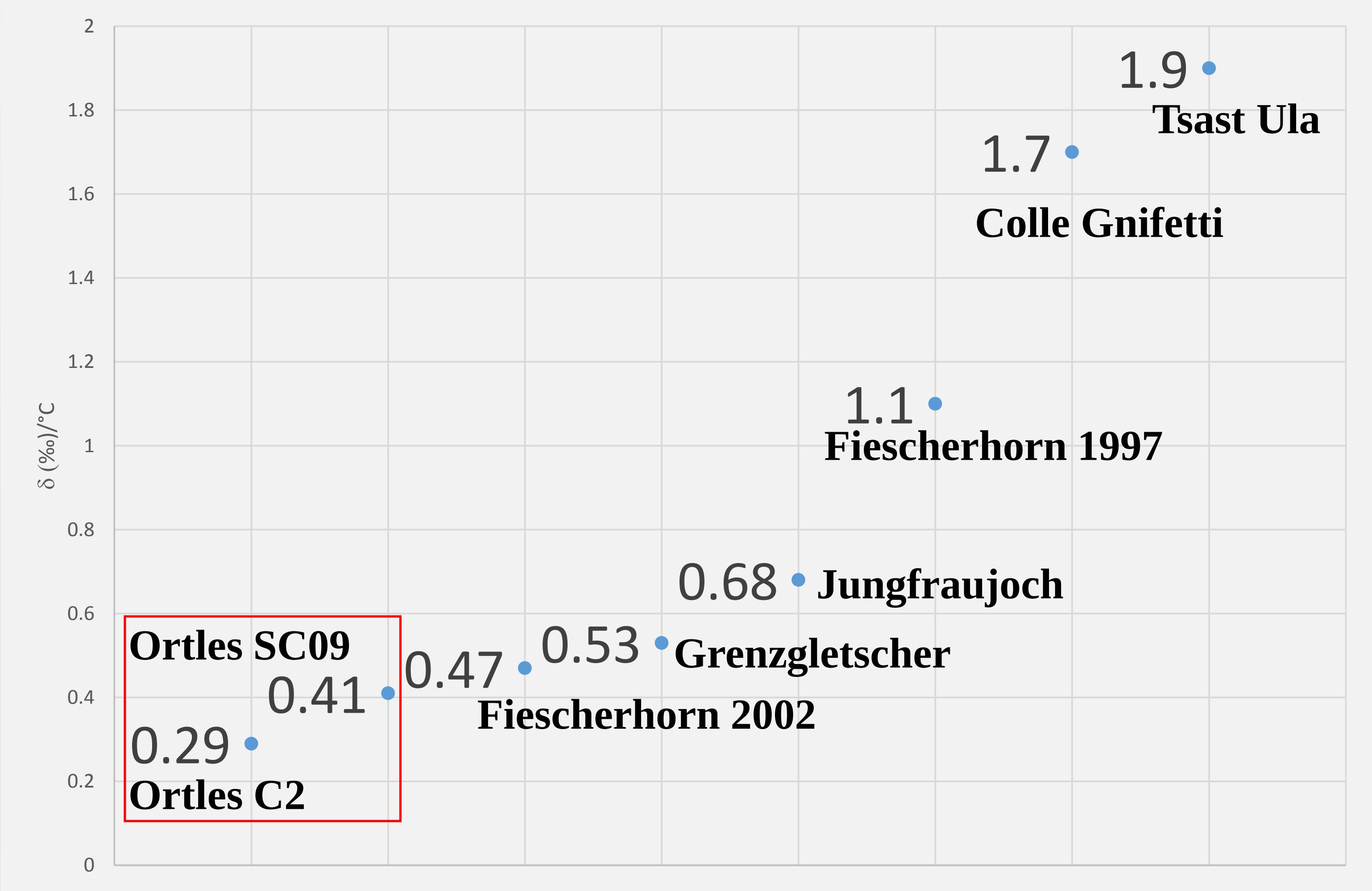






Slope comparison among different Alpine ice cores

Ortles slopes are the lowest → The isotope thermometer appears to be not very sensitive



Mariani et al. (2014), Kech (2001), Schotterer et al. (1997), Rozanski et al. (1992)

Conclusions

- Good correlation between temperature and the isotope signal in ice cores when seasonality is preserved
- Need to improve the reconstruction of the snowpack formation in order to obtain a better correlation with isotopes
- $\delta^{18}O$/temperature slope is surprisingly low when compared to other alpine sites
- Post-depositional processes are significant: summer → melting/evaporation, winter → wind scouring
- Winter layers, already affected by wind erosion, might be overprinted by percolation during major melting events (last decades)

→positivization of the isotope signal

Thanks for your attention

References

Carturan L. 2013. Personal communication

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Craig H. 1961. Isotopic variations in meteoric waters. Science 133, 1702-1703

Festi D., Kofler W., Bucher E., Mair V., Gabrielli P., Oeggl K. Unpublished. Pollen based high resolution ice core dating of a firn core of the Mt. Ortles glacier (Eastern Italian Alps)

Mariani I., Eichler A., Jenk T.M., Brönnimann S., Auchmann R., Leuenberger M.C., Schwikowski M. Temperature and precipitation signal in two Alpine ice cores over the period 1961–2001. Clim. Past, 10, 1093–1108, 2014

Rozanski K., Araguas-Araguas L., Gonfiantini R. 1992. Relation Between Long-Term Trends of Oxygen-18 Isotope Composition of Precipitation and Climate. Science, New Series, Vol. 258, No. 5084, pp. 981-985

Schotterer U., Fröhlich K., Gäggeler H.W., Sandjordj S., Stichler W. 1997, Isotope records from Mongolian and Alpine ice cores as climate indicators: Climatic Change, v. 36, p. 519-530

Oxygen-18 data (depth scale)

Density

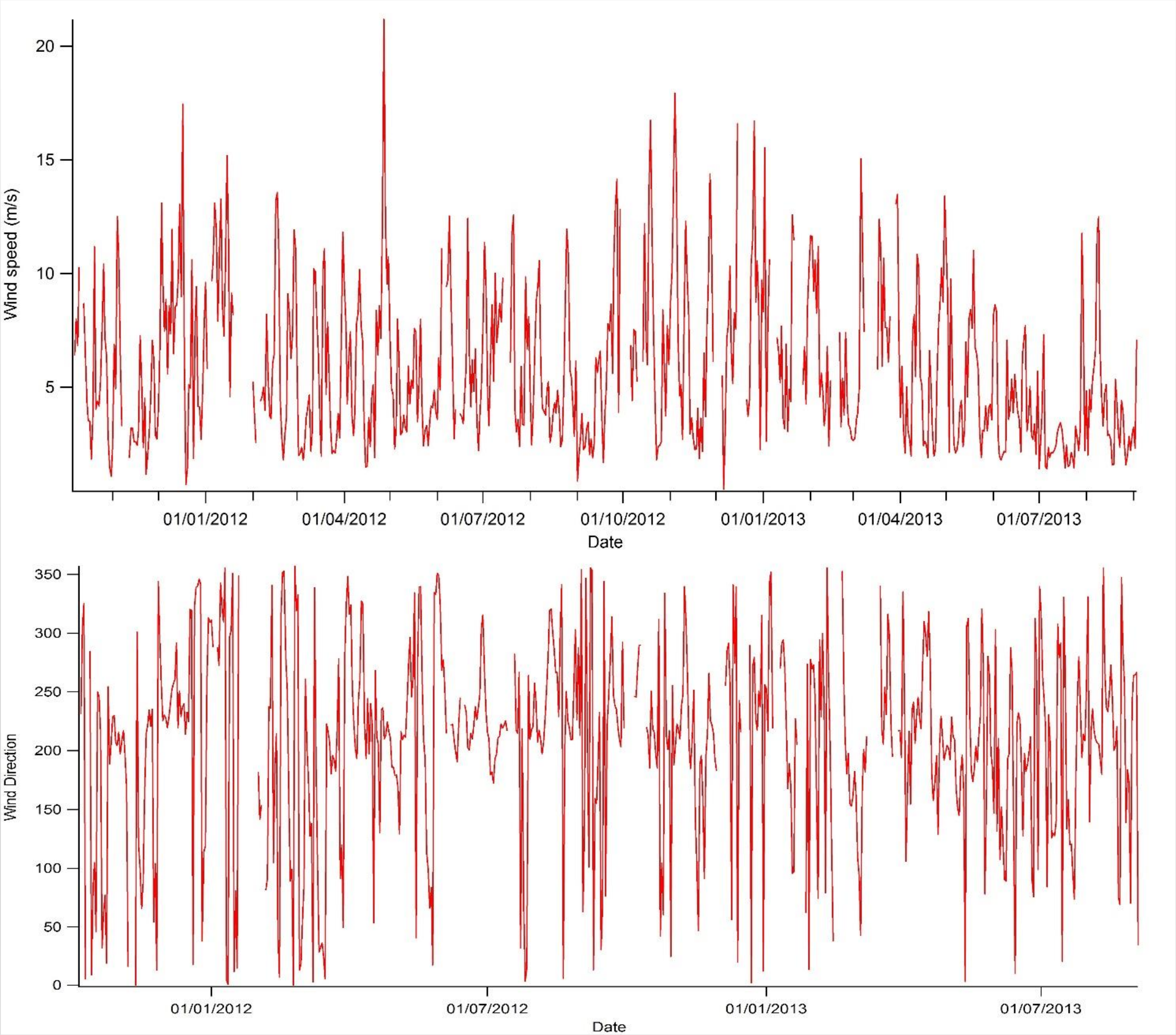
Depth in water equivalent

Temporal constraints

- Surface
- End of summer

AWS DATA: temporal scale

Appendix



Wind speed (m/s)
20
15
10
5
01/01/2012
01/04/2012
01/07/2012
01/10/2012
01/01/2013
01/04/2013
01/07/2013
Date
Wind Direction
350
300
250
200
150
100
50
0
01/01/2012
01/07/2012
01/01/2013
01/07/2013
Date