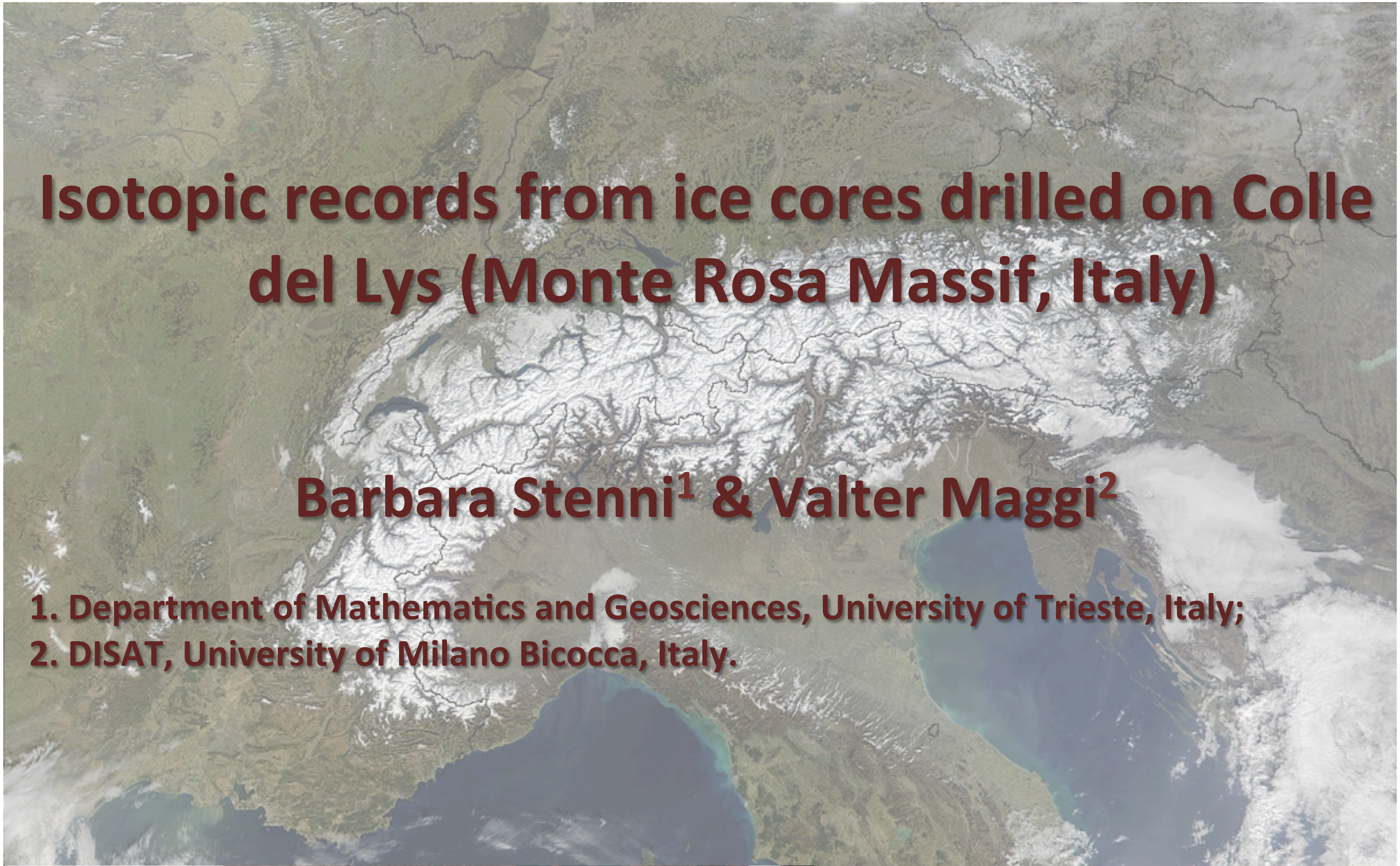

Isotopic records from ice cores drilled on Colle del Lys (Monte Rosa Massif, Italy)

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2. DISAT, University of Milano Bicocca, Italy.

XII International Conference
on Science Arts and Culutre
CLIMATE CHANGE:
MARINE AND MOUNTAIN
ECOSYSTEMS IN THE
MEDITERRANEAN REGION
27 - 30 August 2012
Veli Lošinj, Croatia

ECSAC
European Centre for Science Arts and Culture

Università degli Studi di Trieste

Università degli Studi di Milano Bicocca

Presentation outline

1. The oxygen and hydrogen stable isotopes; measurements techniques; the hydrologic cycle; the δ/T relationship.
2. The present day distribution of $\delta^{18}O$ values of precipitation.
3. General remarks on paleoclimatology and ice cores.
4. Ice core in the European Alps.
5. Isotopic records from Colle del Lys ice cores.
6. Conclusions.

1. The oxygen and hydrogen stable isotopes; measurements techniques; the hydrologic cycle; the δ/T relationship.

Oxygen and Hydrogen isotopes

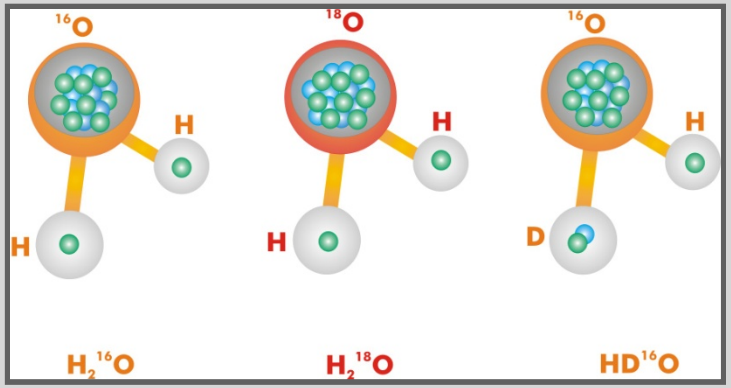
^{16}O = 99,759%
^{17}O = 0,0374%
^{18}O = 0,2039%

^{1}H = 99,9844%
^{2}H (D) = 0,0156%
[^{3}H (T) radioactive isotope]

$$\delta = [(R_{sample} - R_{standard})/R_{standard}] \times 1000$$

R = ($^{18}O/^{16}O$ o D/H)

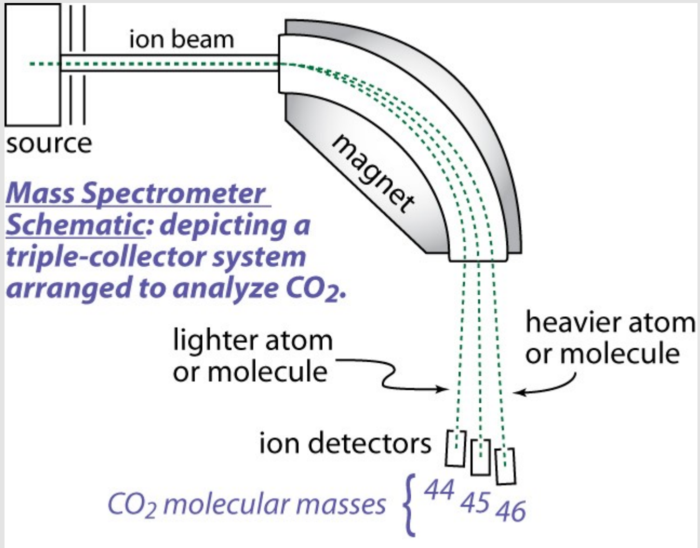
Standard: V-SMOW



Analytical techniques

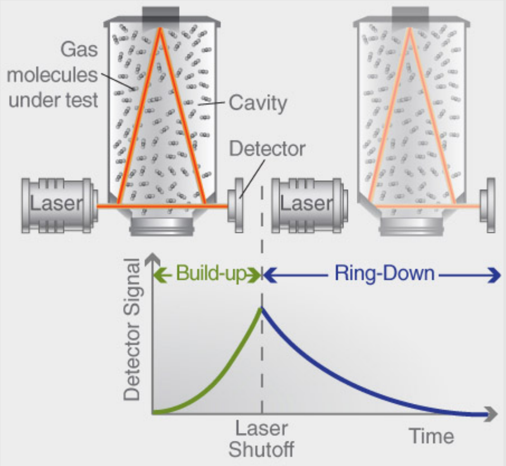
IRMS with HDO device on-line

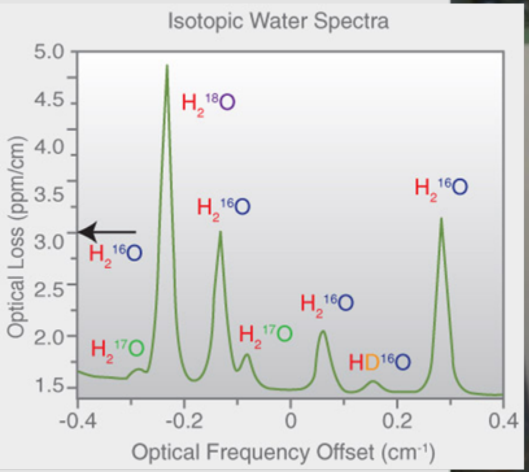
IRMS



***Mass Spectrometer Schematic:* depicting a triple-collector system arranged to analyze CO_2.**

CRDS

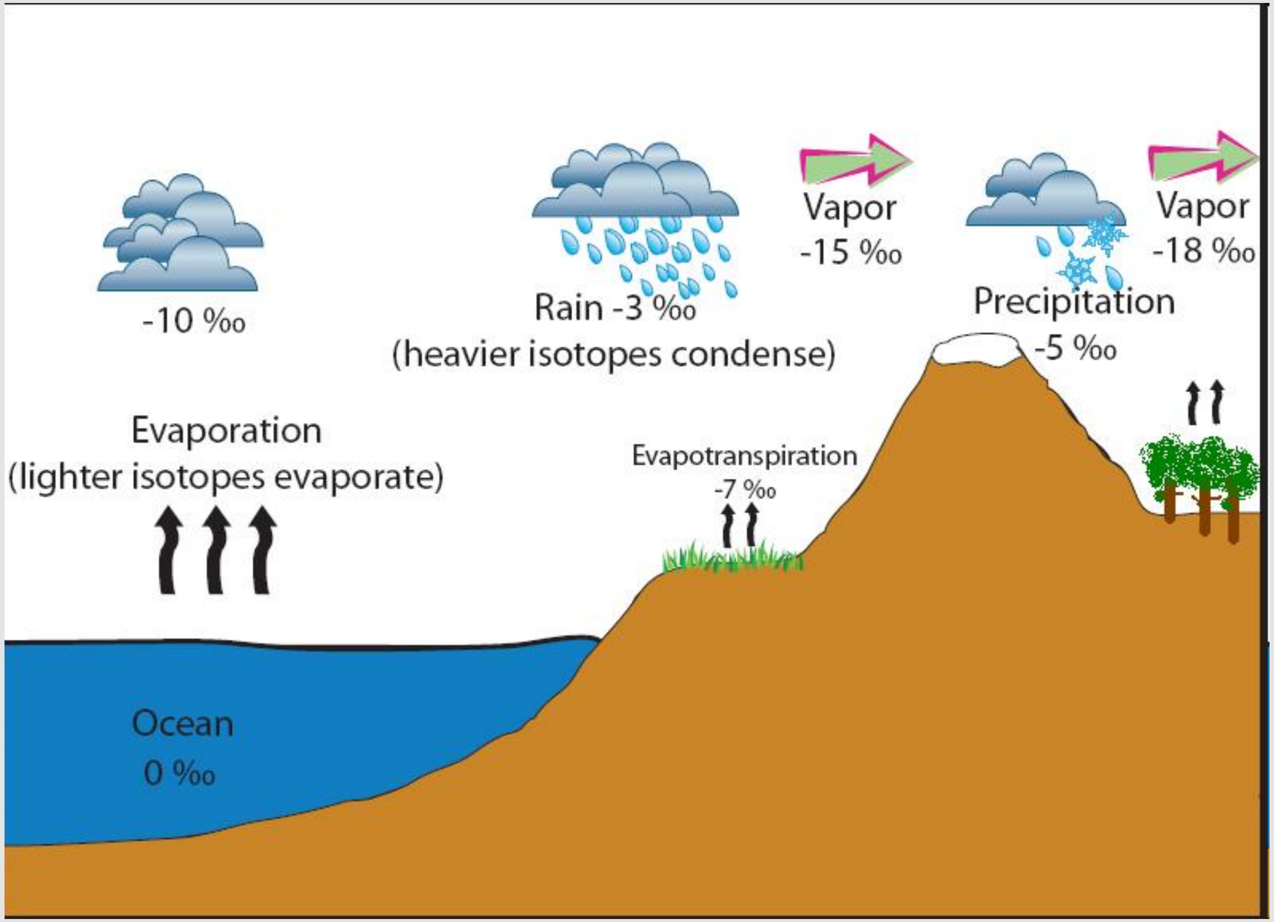




Cavity Ring-down Spectroscopy

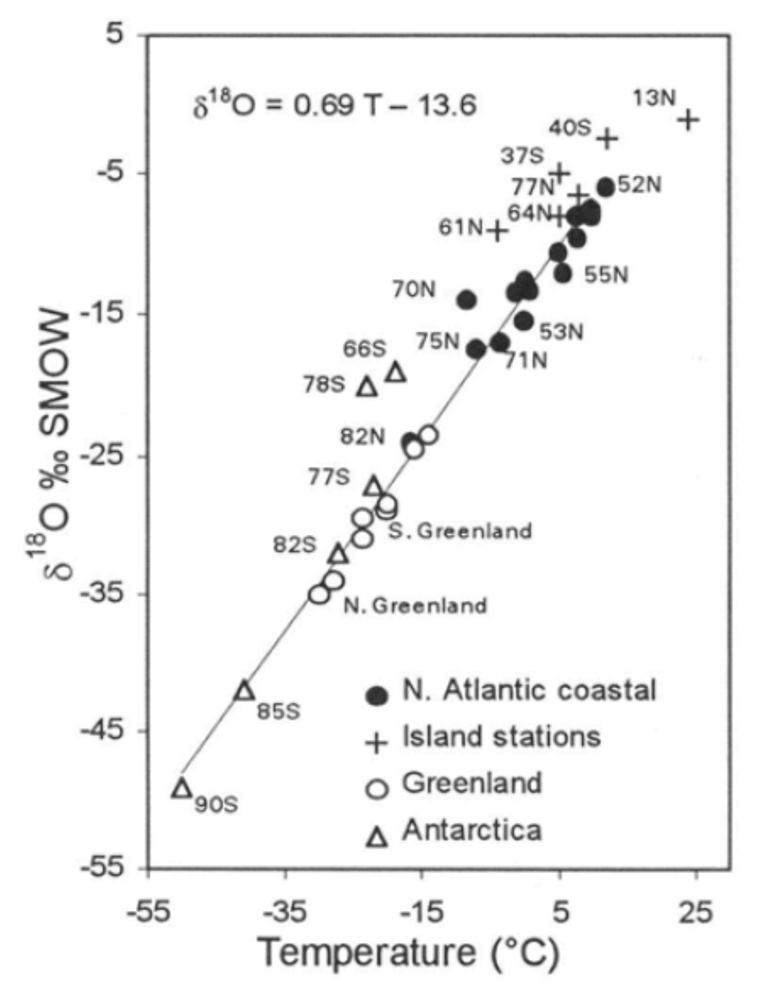
Hydrological cycle and isotopic fractionations

The relationship between the oxygen and hydrogen isotope composition of precipitation and the condensation temperature derives from the isotopic fractionations occurring at each phase change due to the vapour pressure difference of the water isotopic molecules $HH^{16}O$, $HD^{16}O$, $HH^{18}O$ (vap. p. $HH^{16}O > HH^{18}O$).



Geoscience education, Montana State University

$\delta^{18}O$/T relationship – Dansgaard 1964



Latitudinal, continental, seasonal and altitude effects.

Seasonal variations

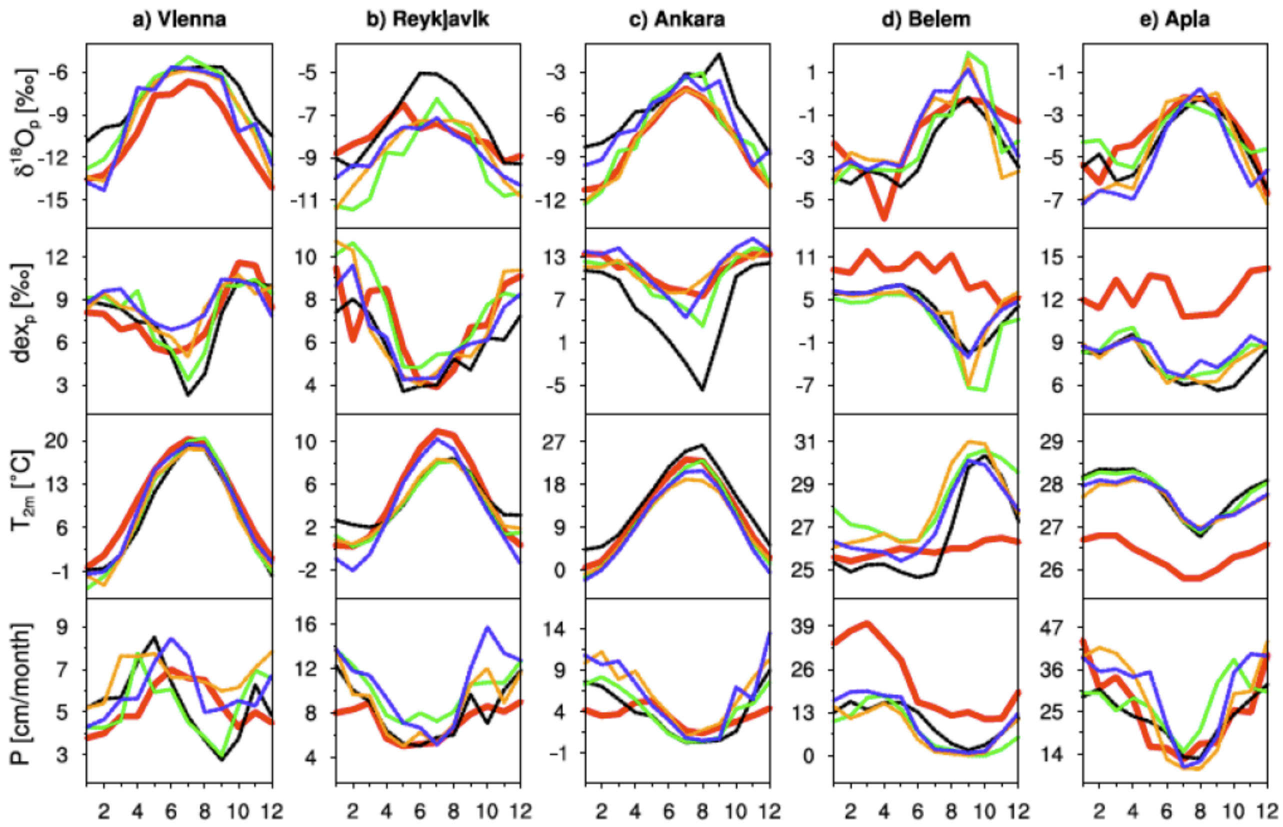
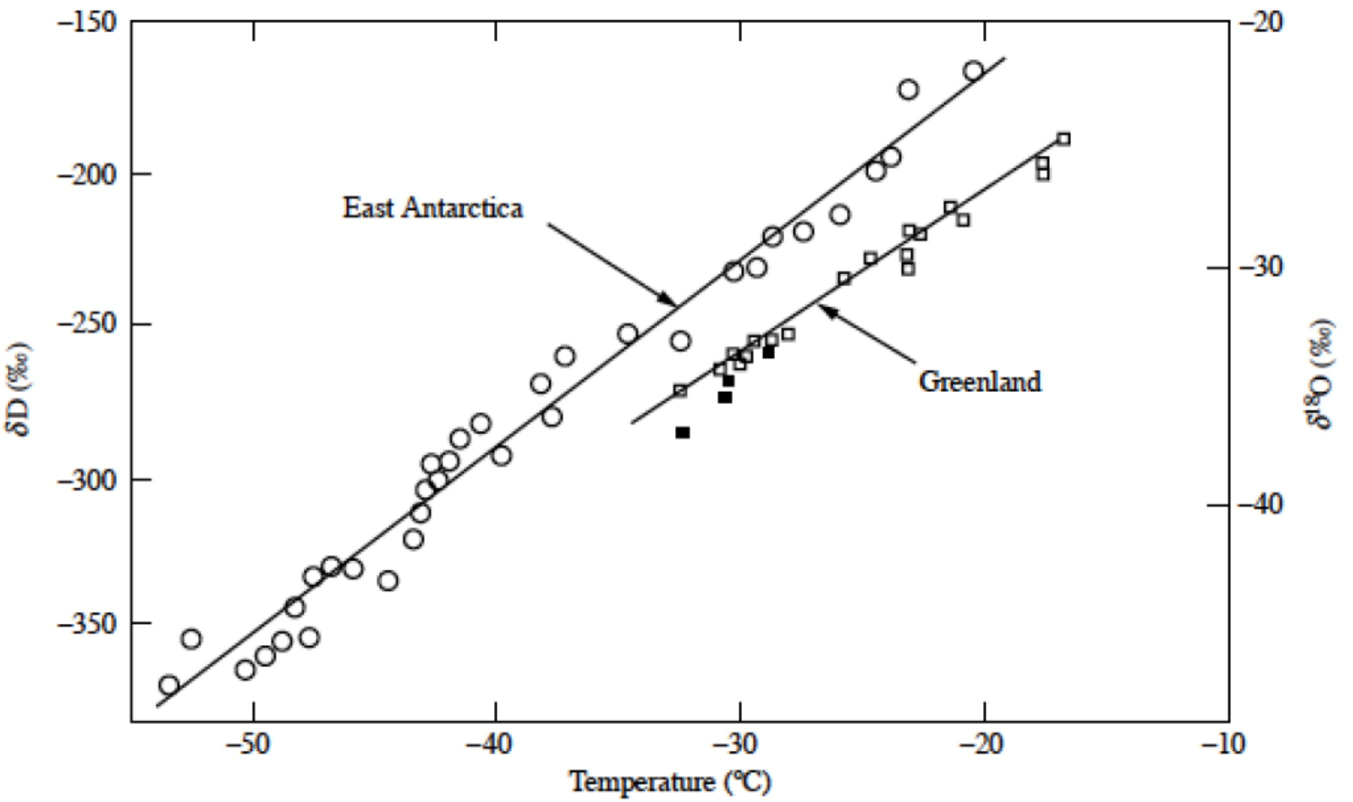


Figure 5 : Seasonal cycles of temperature T_{2m}, precipitation amount P, isotopic composition of precipitation $\delta^{18}O_p$, and Deuterium Excess values dex_p at the locations of (a) Vienna, (b) Reykjavik, (c) Ankara, (d) Belem, and (e) Apia. The bold red lines represent the observational GNIP values, while the thin colored lines indicate modelresults of four different ECHAM5-wiso simulations (from Werner et al., 2011)

Paleotemperature reconstruction from ice core are based on the empirical relationships between D/H and $^{18}O/^{16}O$ isotope ratios and condensation temperature.



Antarctica: Lorius and Merlivat, 1977

Greenland: Johnsen et al., 1989

Global meteoric water line

$$\delta D = 8\delta^{18}O + 10$$

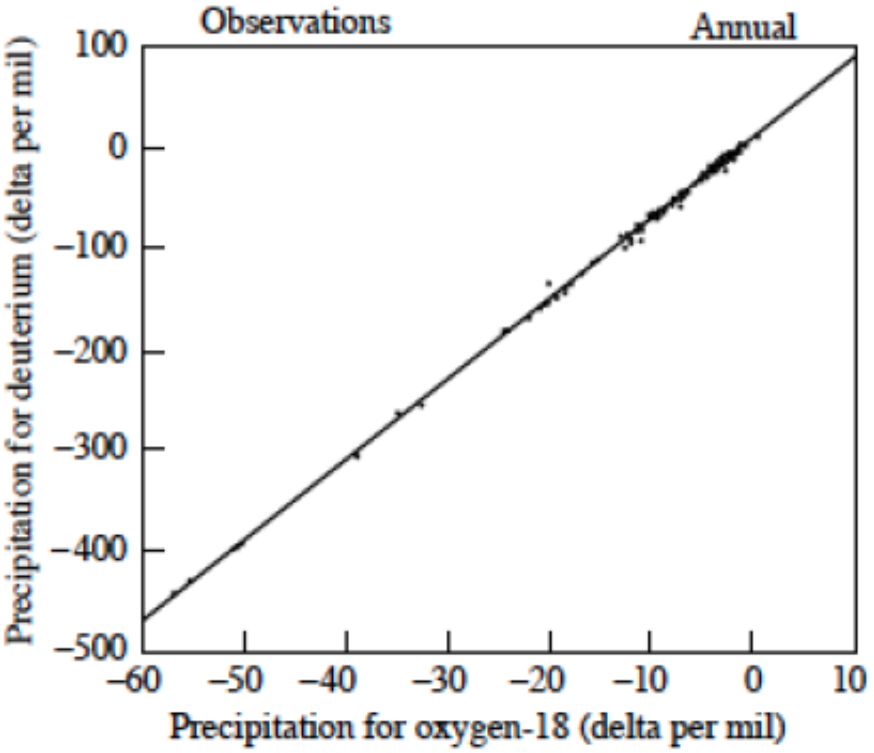
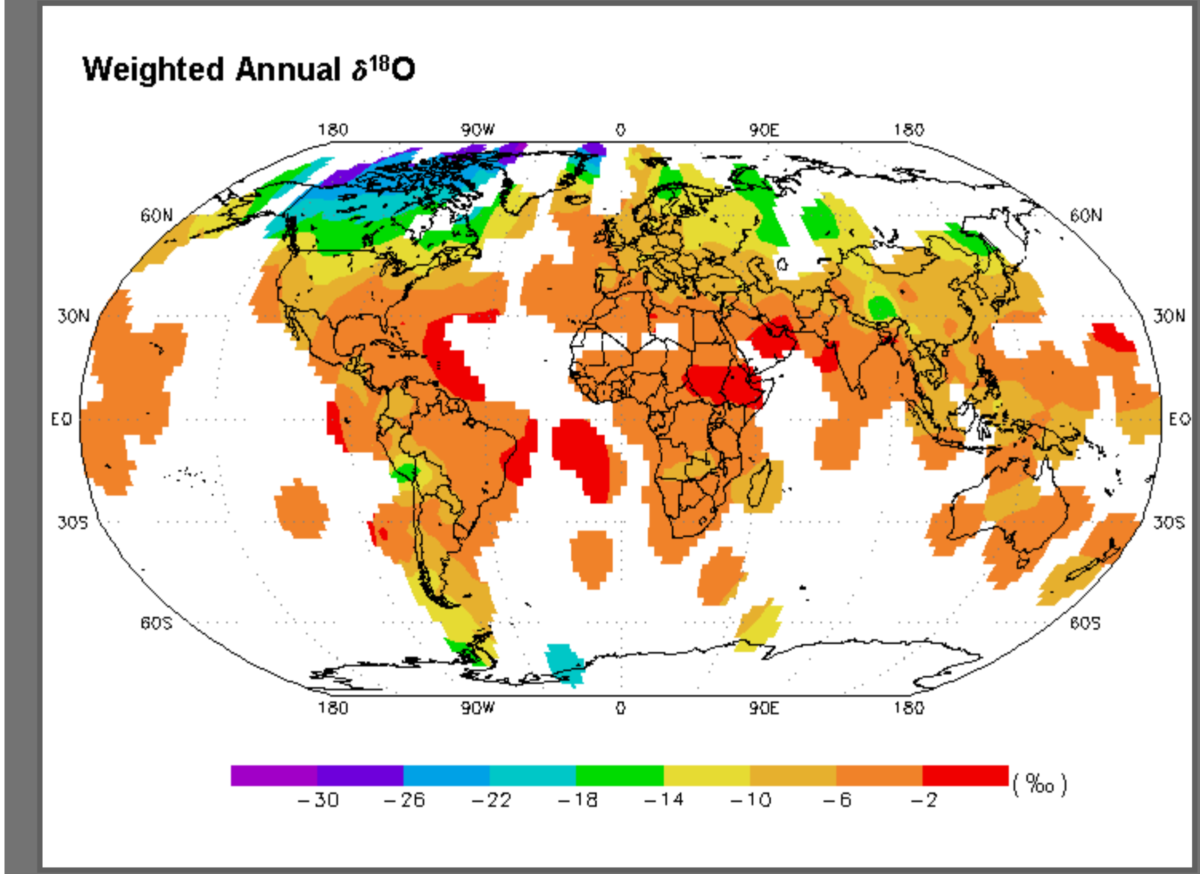


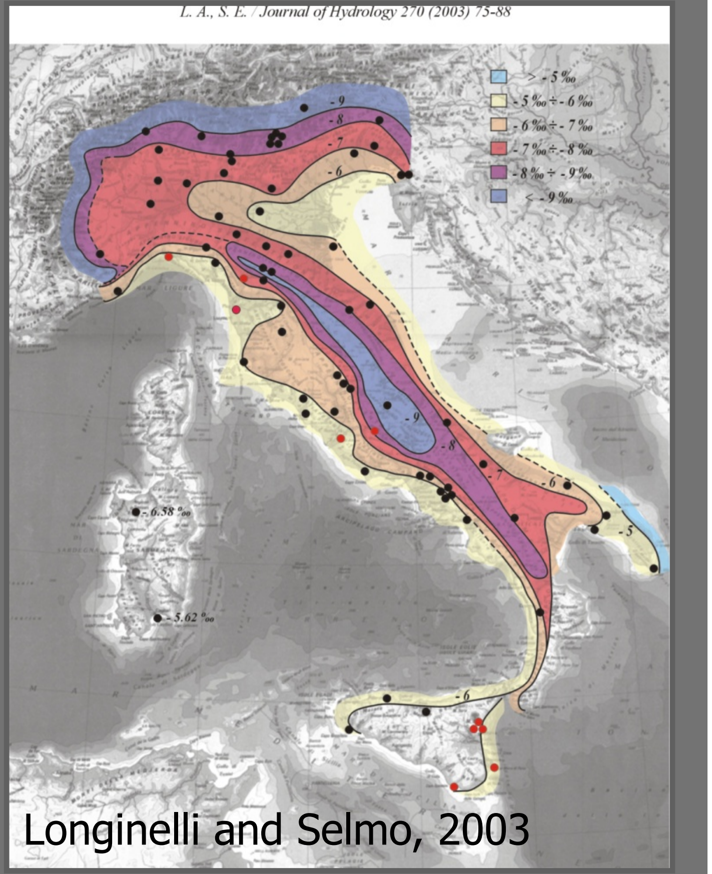
Figure 2 : Annual δD versus annual $\delta^{18}O$ in precipitation (after Jouzel et al., 1987 a).

2. The present day distribution of $\delta^{18}O$ values of precipitations

GNIP Map from International Atomic Energy Agency, Vienna.



Italian precipitation map



Longinelli and Selmo, 2003

Isotopic Atmospheric General Circulation Models

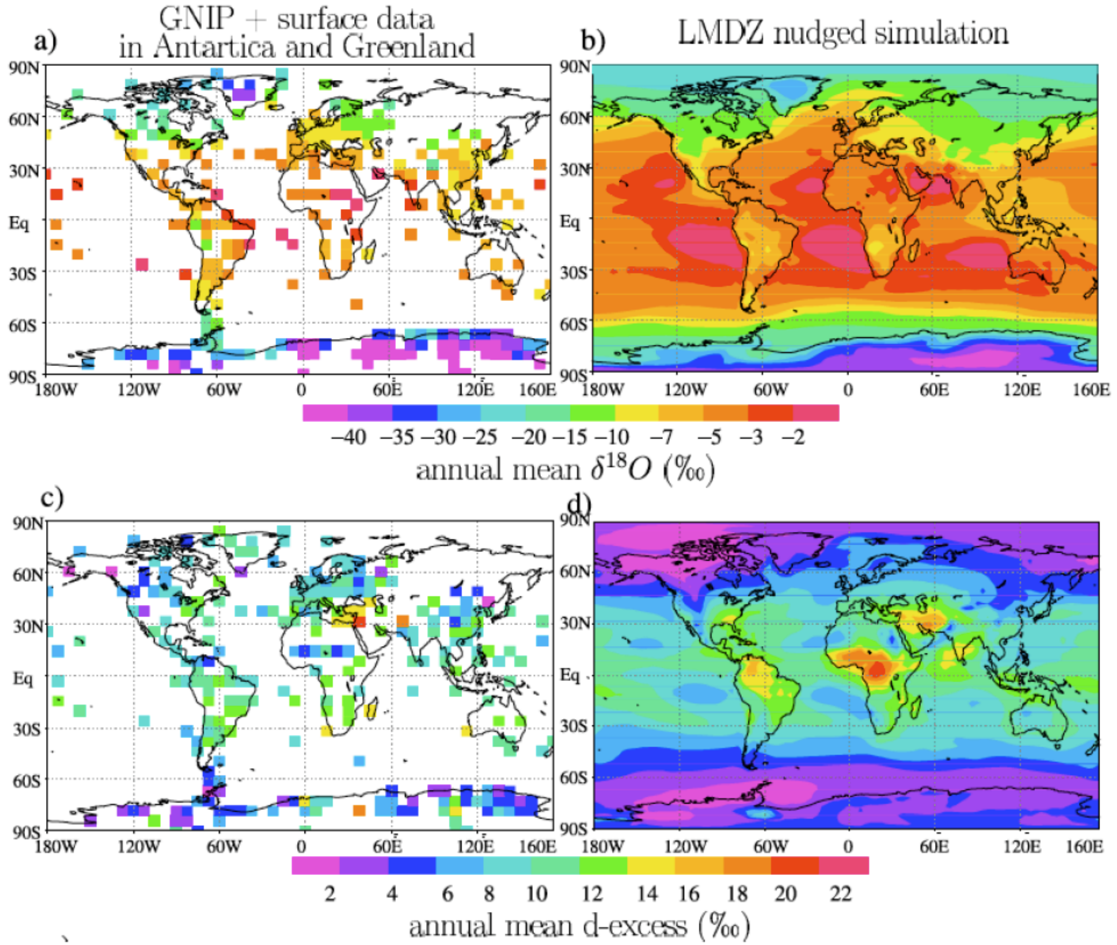
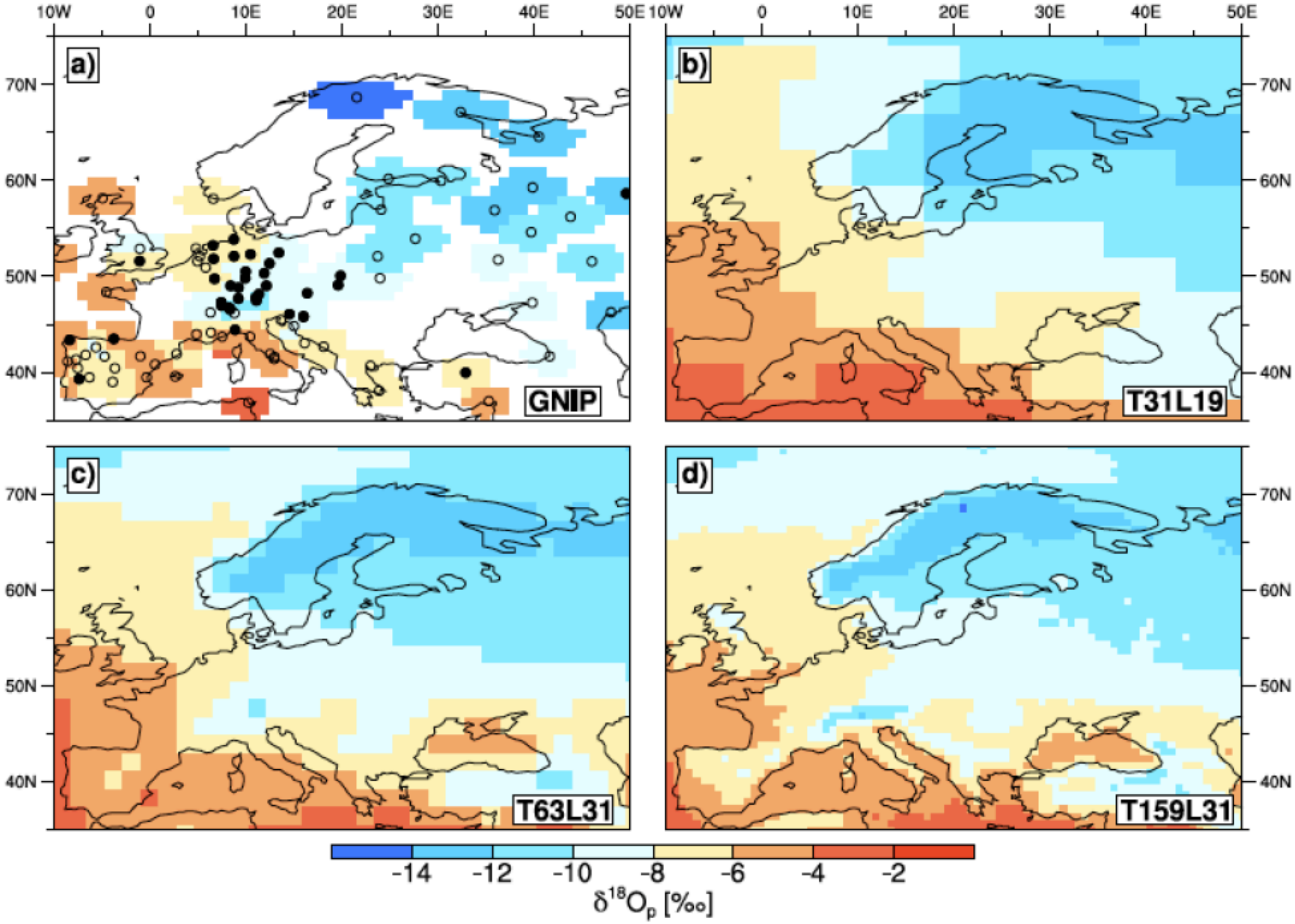


Figure 6: (a, b) Annual mean δ18O and (c, d) d excess in precipitation, in the data (Figures 2a and 2c)and the LMDZ-iso nudged simulation (Figures 2b and 2d). The data are the GNIP data (Rozanski et al.,1993), the Antarctica data from Masson-Delmotte et al. (2008), and Greenland surface data (Masson-Delmotte et al., 2005b). The data are gridded over a coarse 7.5° - 6.5° grid for visualization purpose (after Risi et al., 2010).

Figure from Jouzel 2011

Three different ECHAM5 – wiso simulations



From Werner et al., 2011

3. General remarks on paleoclimatology and ice cores

Paleoclimatology: Natural Archives

Climate Proxies

“Indicators of past climate contained in natural archives”

The climate signal must be extracted determining the mechanisms by which the signal is recorded by the proxy.

The proxy must be calibrated vs. present-day conditions (direct measurements).

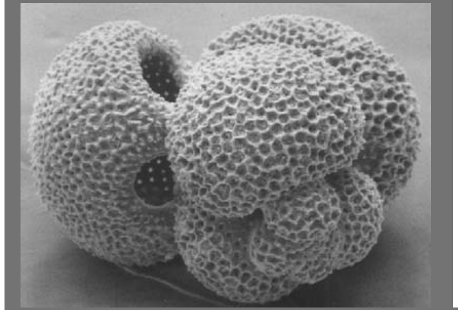
The established relationships should hold in time…

Some examples of climate proxies ……

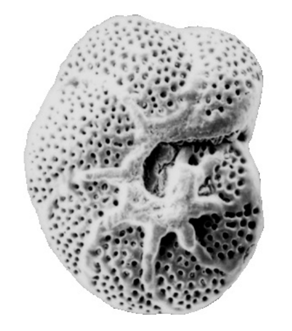
Relative abundance of planktic foraminifera, coccolithophore, diatoms and radiolaria (marine sediments) ➔ Sea-surface temperature (SST), Summer SST, sea-ice presence, etc.

δ^{13}C and δ^{18}O of planktic and benthic foraminifera ➔ Ice volume, SST, salinity, etc.

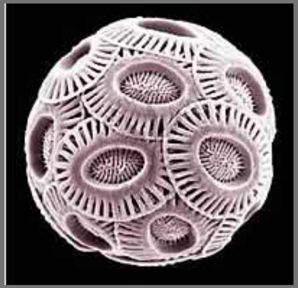
Mg/Ca ratios of foraminifera and alkenone palaeothermometry of coccolithophore ➔ SST



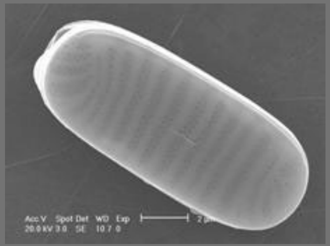
Planktonic foram
Globigerinoides ruber



Benthic foram
Cibicidoides vulgaris



Coccolithophore
Emiliania huxleyi



Diatom *Fragilariopsis curta*

Diatom
Fragilariopsis kerguelensis

Some examples of climate proxies ……

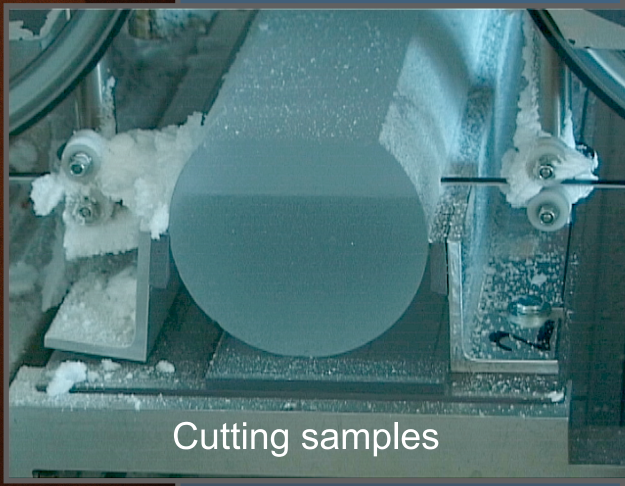
Water stable isotopes of ice cores → Local surface air temperature, moisture source conditions (SST, h).

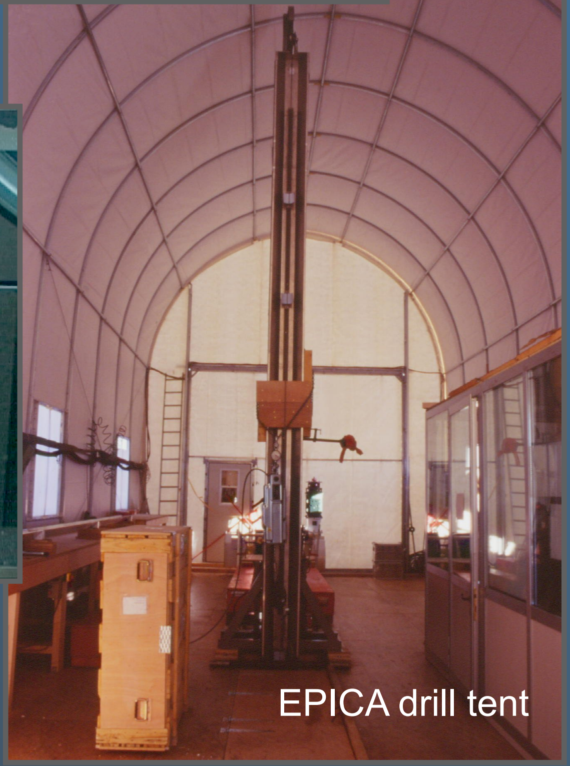
Oxygen and carbon and isotope ratios of speleothems → Cave temperature and isotopic composition of meteoric water, amount of rainfall, monsoon strenght, vegetation changes.

Etc ……

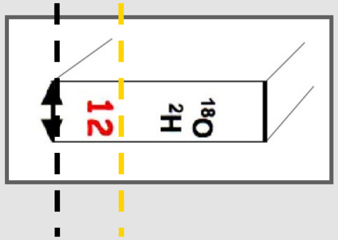
ICE CORES

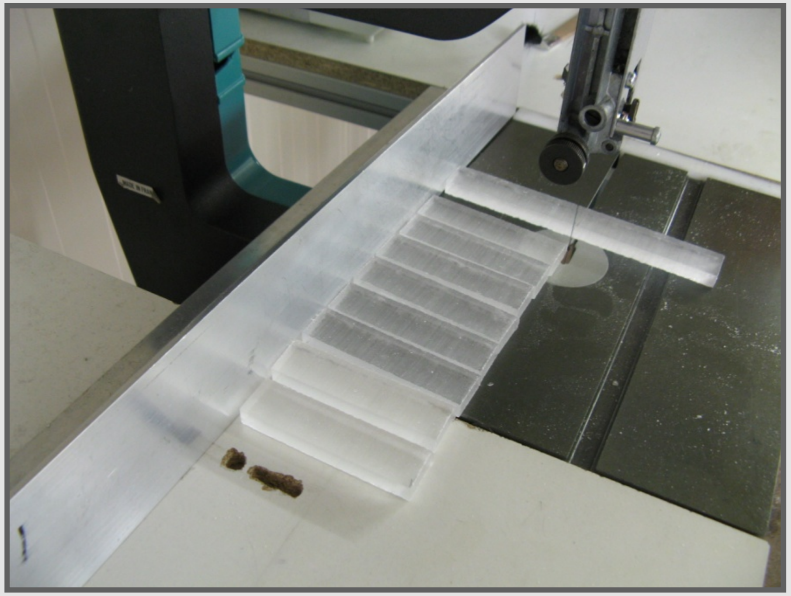

EPICA (Dome C) ice core


Cutting samples

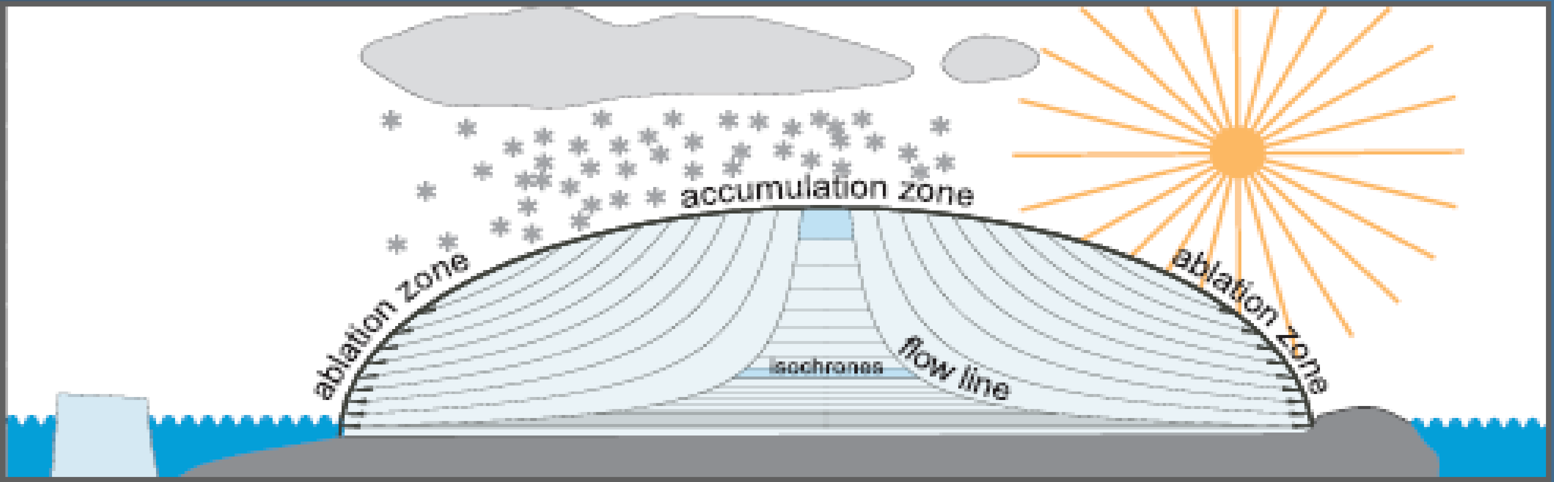

EPICA drill tent

Camera fredda (-20°C) dell'AWI

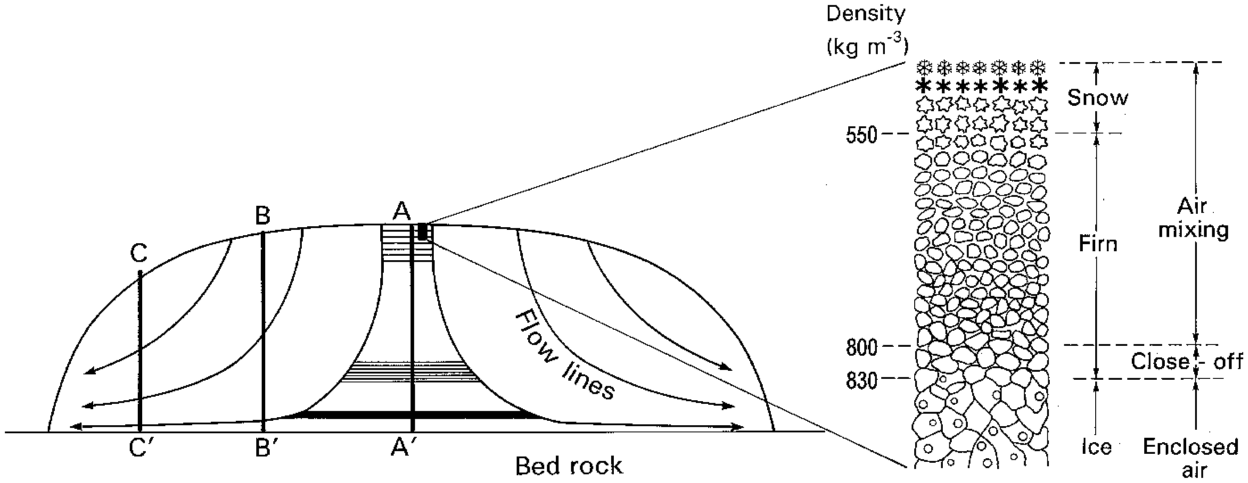


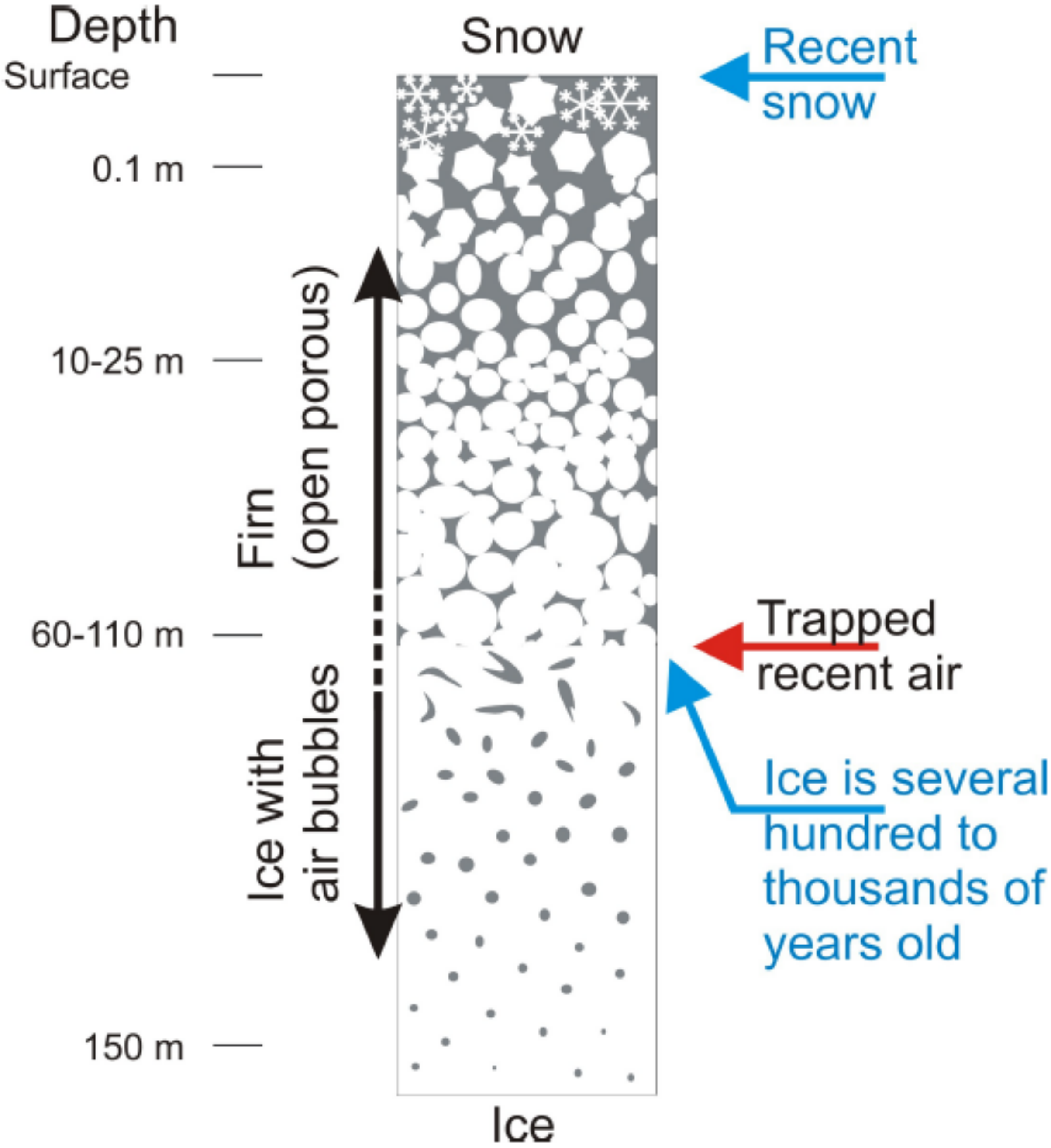


Ice sheet section



Ice and air bubbles





Depth

Surface

0.1 m

10-25 m

60-110 m

150 m

Snow

Firn (open porous)

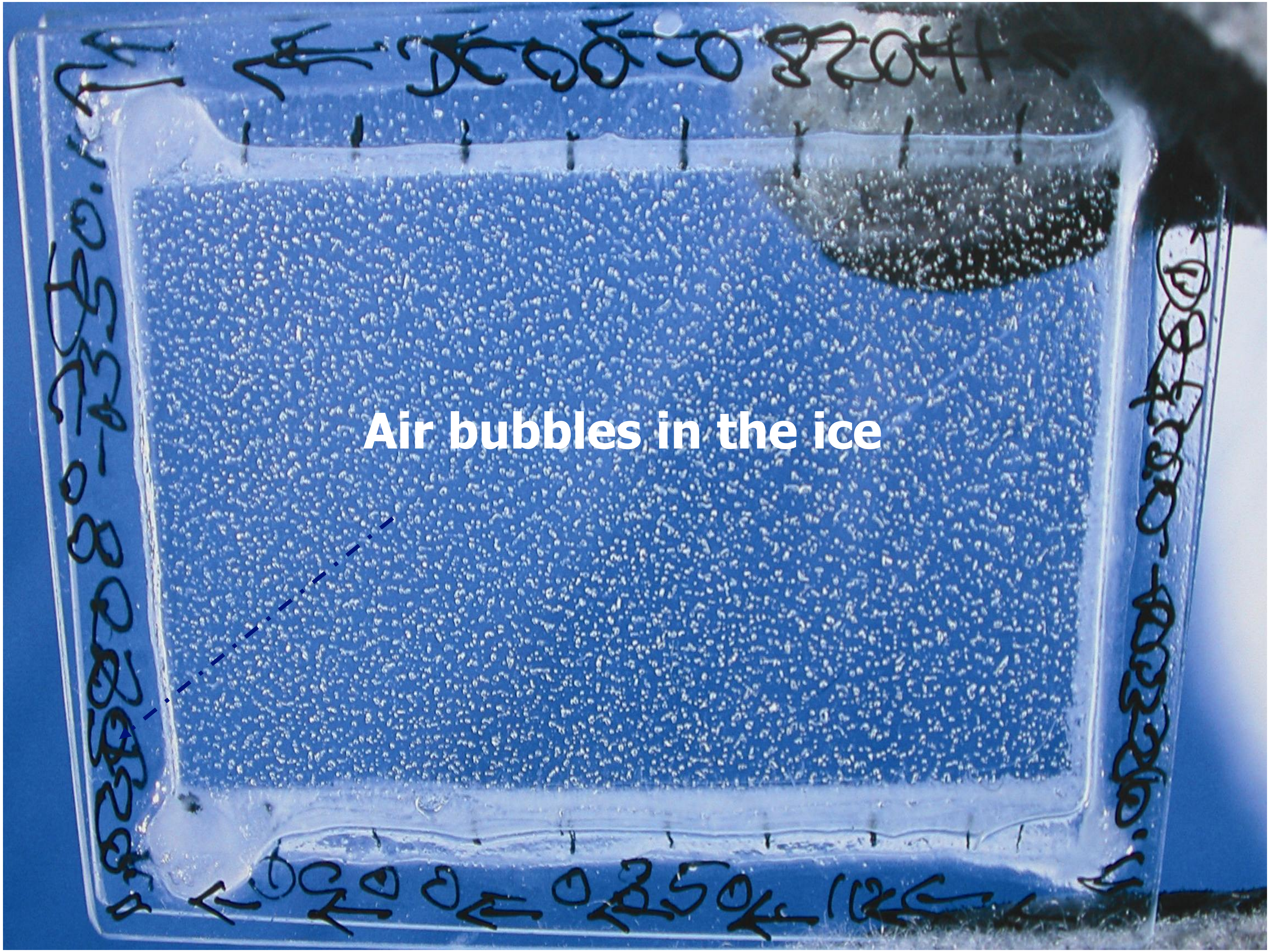
Ice with air bubbles

Ice

Recent snow

Trapped recent air

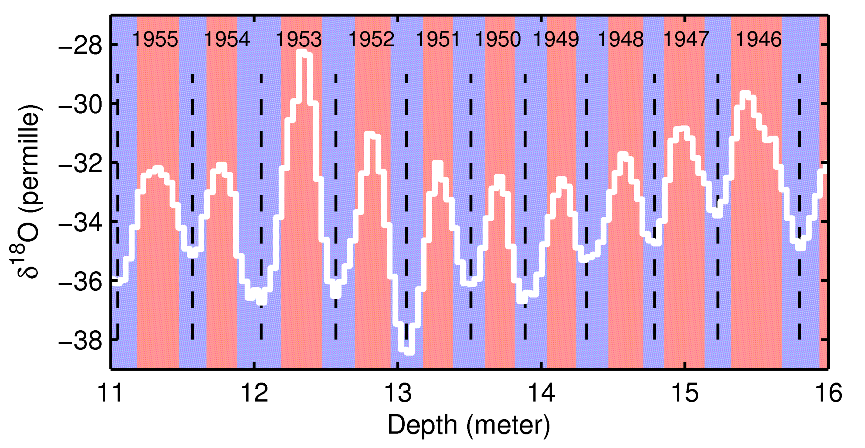
Ice is several hundred to thousands of years old



Air bubbles in the ice

Dating

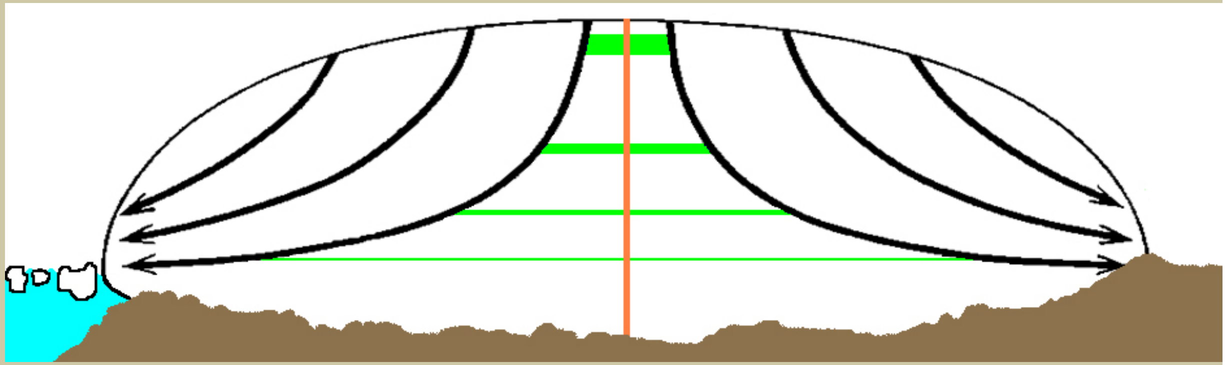
Annual layer counting (Greenland, coastal Antarctica)



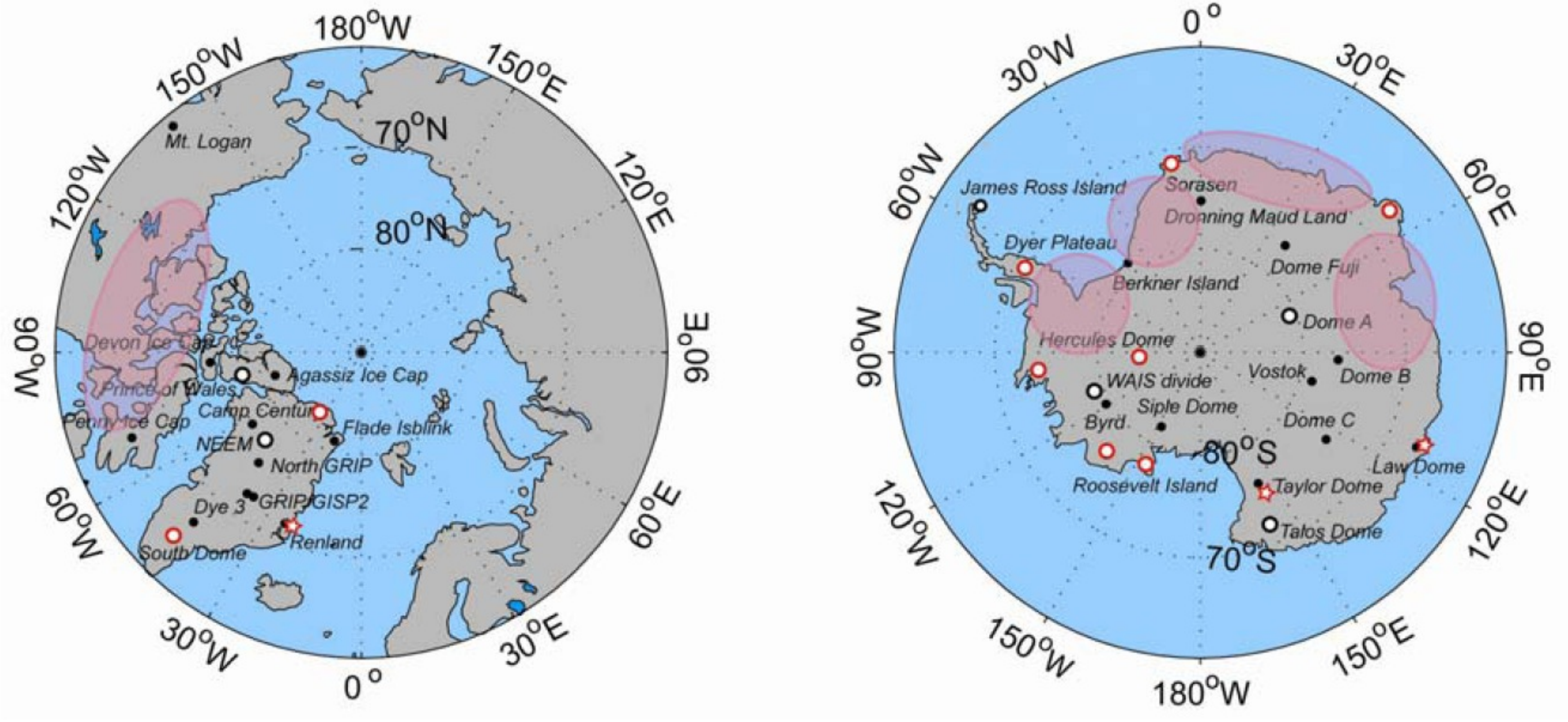
Volcanic horizons

Ice core synchronisation thanks to the well-mixed global atmospheric composition

Glaciological modeling: accumulation, thinning, ice flow



Deep Greenland and Antarctic ice cores



Maps from IPICS (http://www.pages-igbp.org/ipics/)

Greenland : ice core $\delta^{18}O$ record

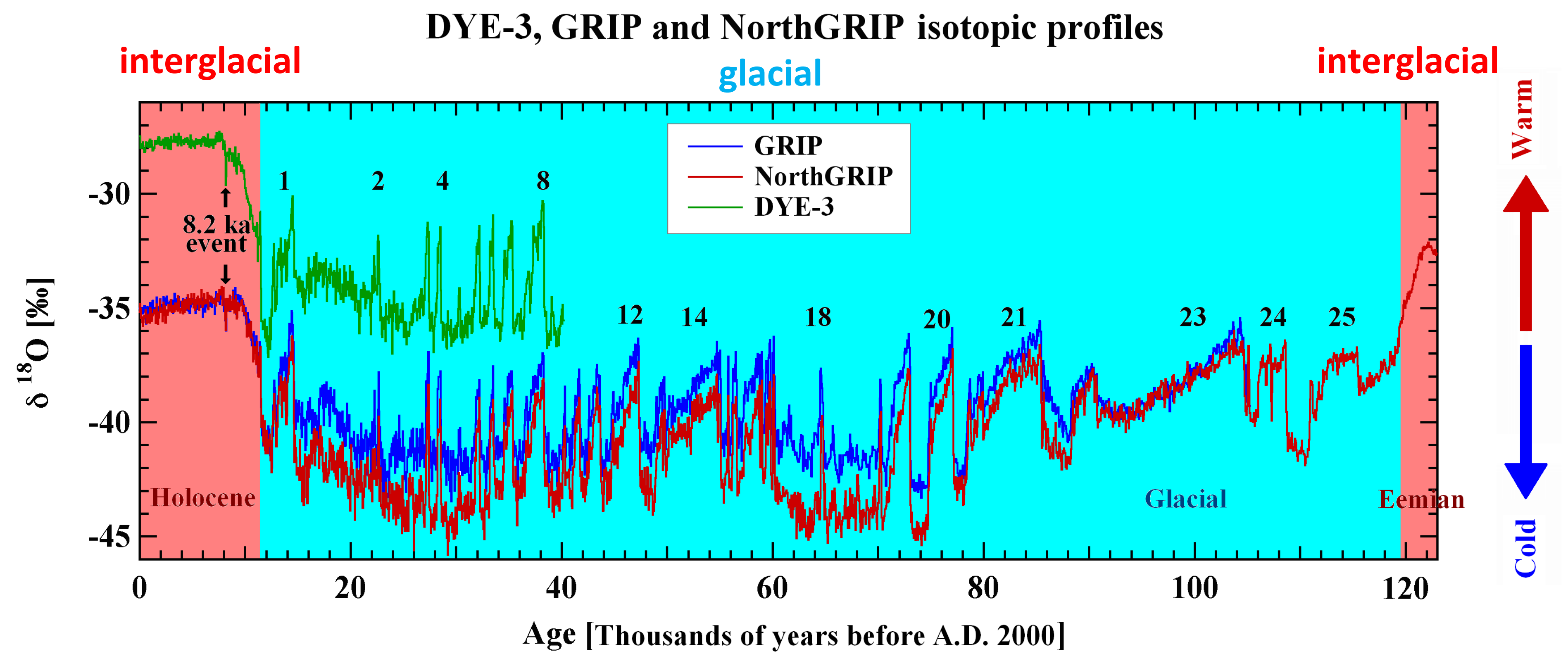
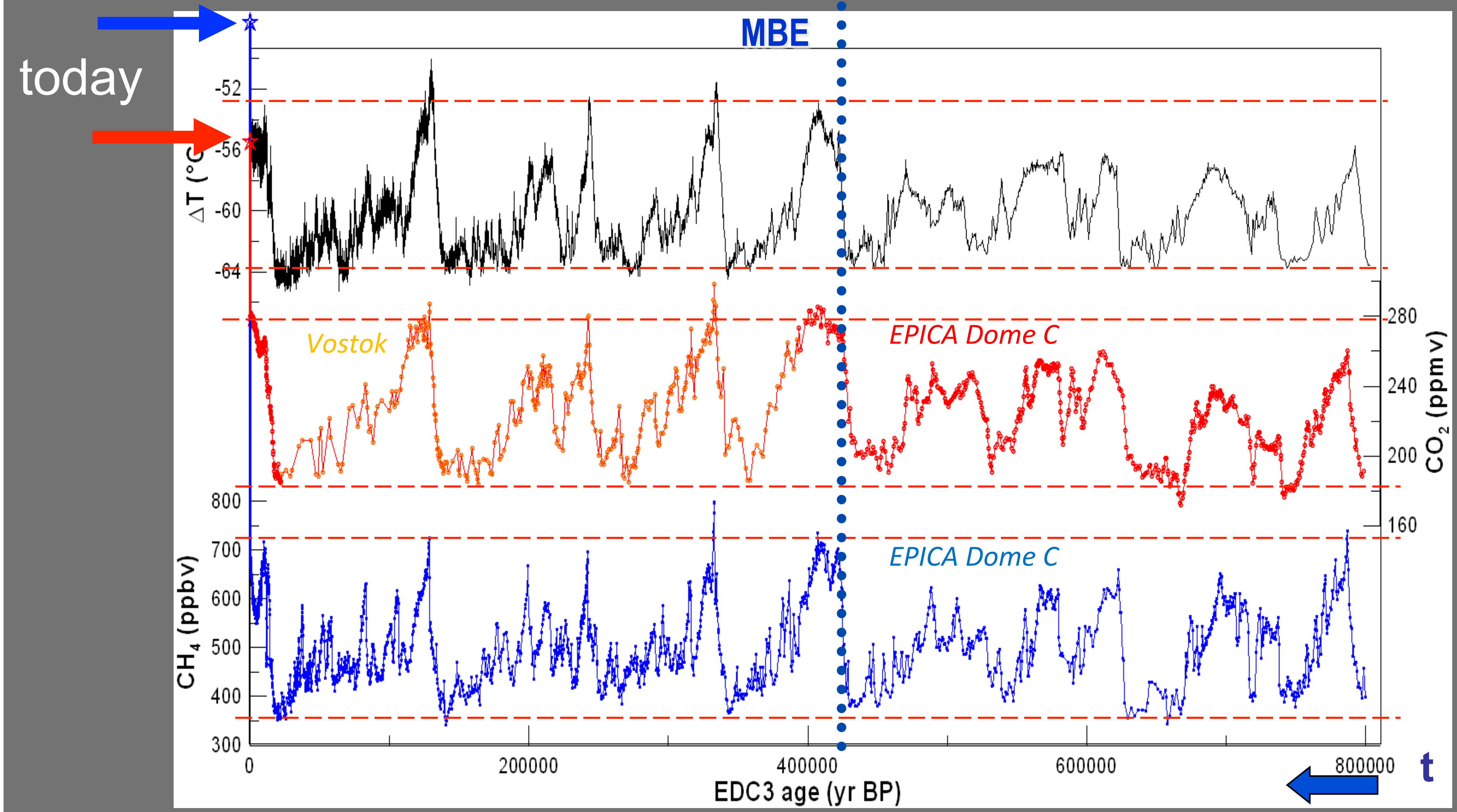


Figure from Center for Ice and Climate, Denmark

The Greenhouse Gas record from EPICA Dome C ice core



No analog of present-day values during the last 800 kyr

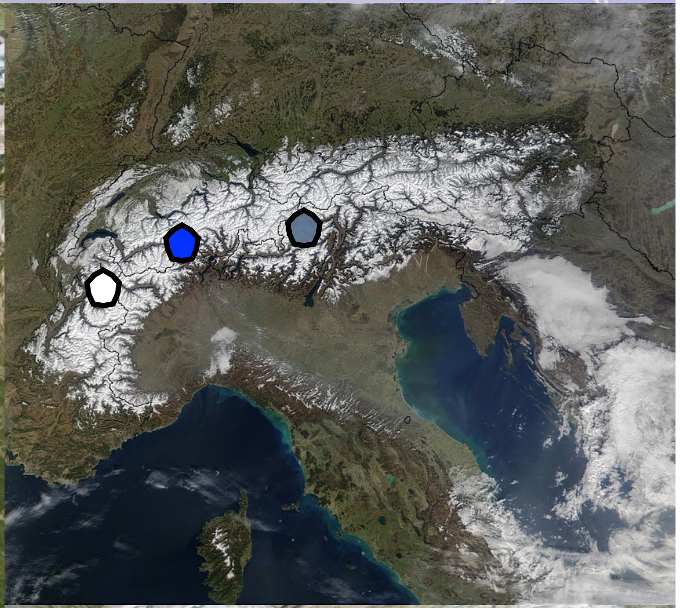
CO$_2$ (and CH$_4$, except MIS 19) show lower interglacial concentrations before 400 kyr BP

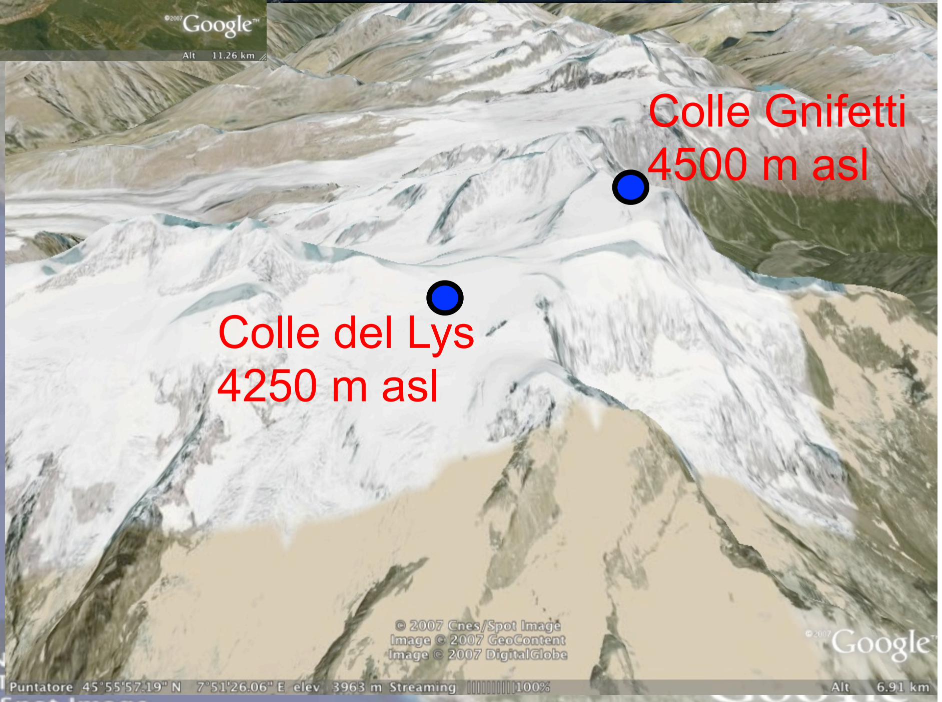
Jouzel et al., 2007; Siegenthaler et al, 2005 ; Spahni et al., 2005 ; Lüthi et al., 2008 ; Loulergue et al., 2008.

4. Ice core in the European Alps

Ice core in the European Alps

Cold glaciers are the best archive that well preserve the past and present atmospheric informations.

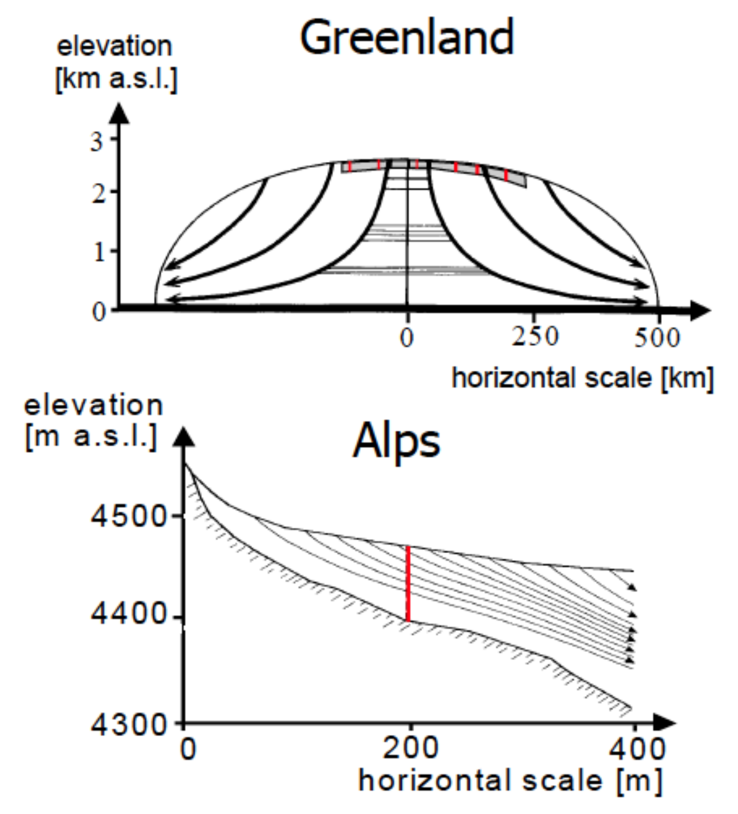




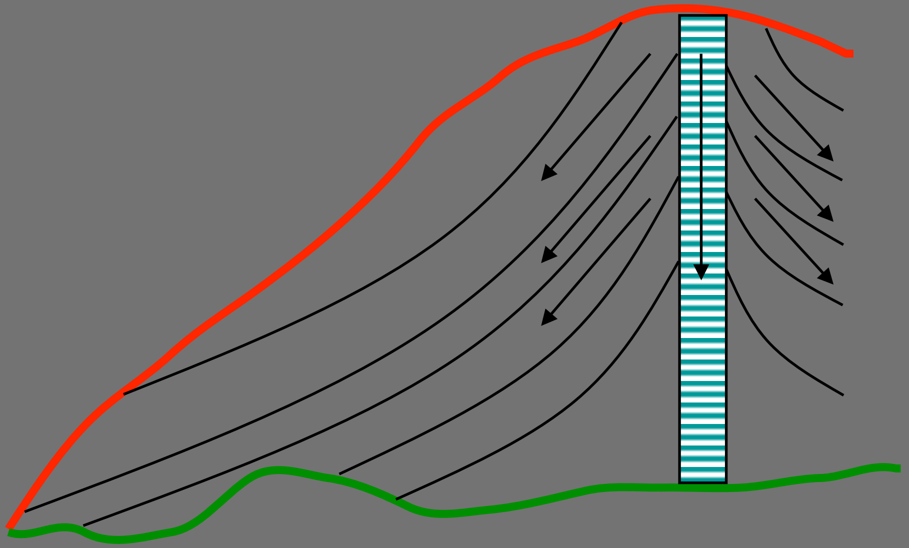
- **Monte Bianco Group**
- **Ortles-Cevedale Group**
- **Monte Rosa Group**

In the European Alps the main areas where is possible provide ice cores for environmental and climatic purpose are located in the central-western part.

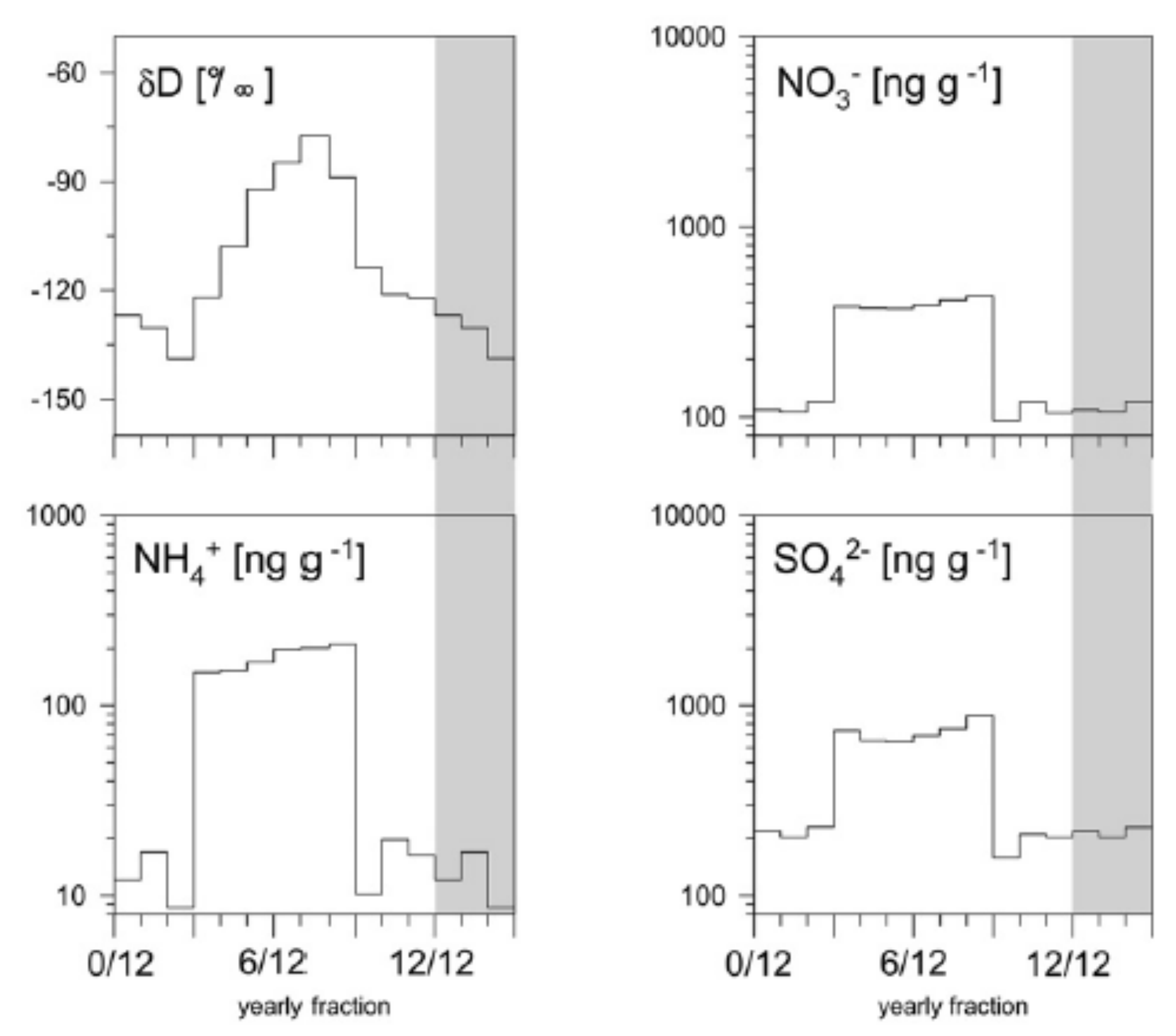
Strong horizontal gradients at Alpine sites



After Wagenbach, 2003, ALP-IMP Project.

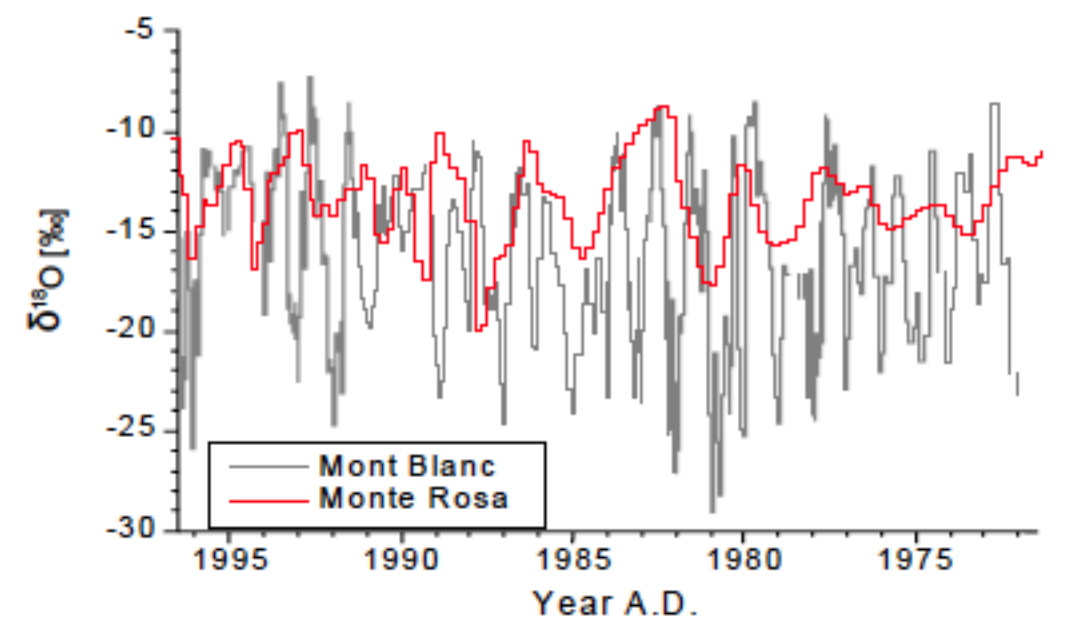


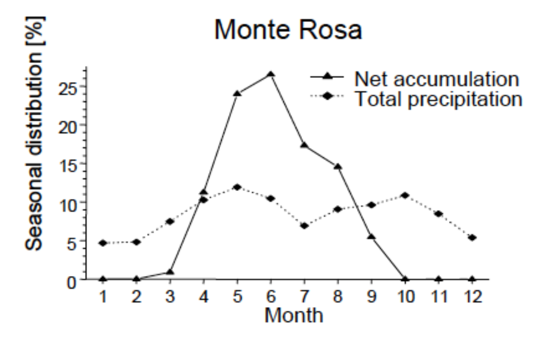
Mean seasonal cycles of δD and major ions extracted from the upper 25 m w.e. of the Col du Dôme C10 core.



After Wagenbach, 2012.

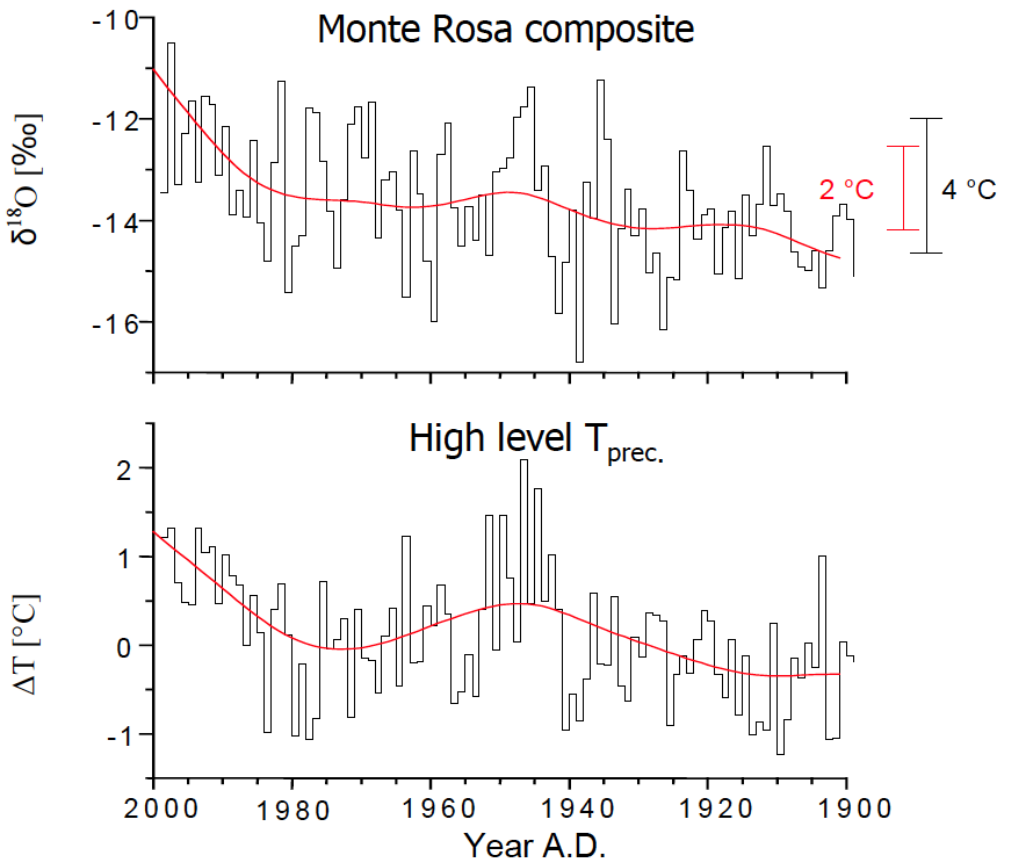
Colle Gnifetti vs. Col du Dôme isotopic records



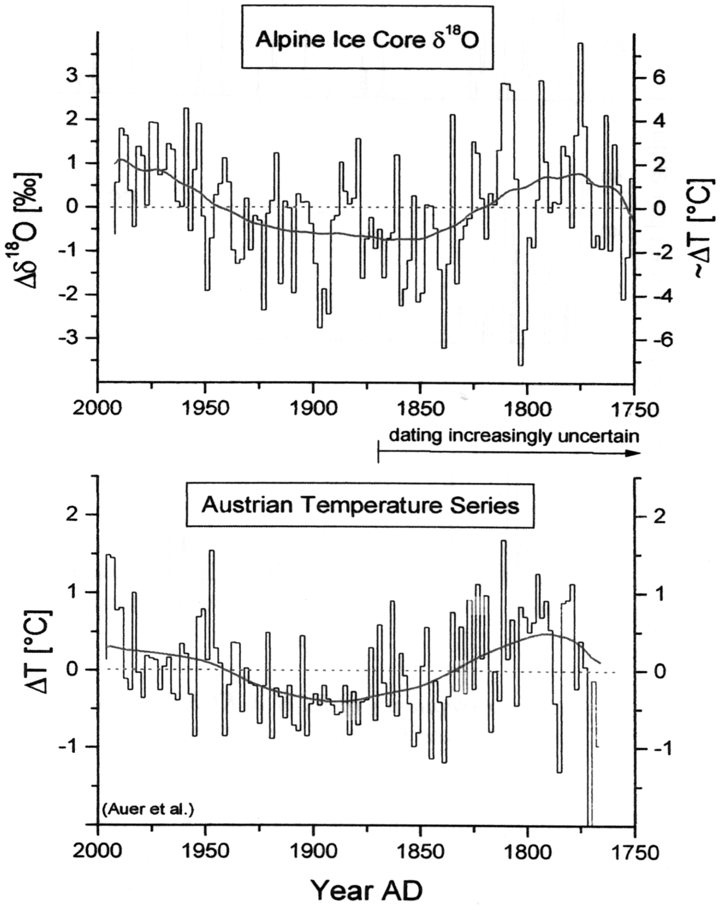


After Wagenbach, 2003, ALP-IMP Project.

Decadal trends of T and isotopes



After Wagenbach, 2003, ALP-IMP Project.



Auer et al., 2007

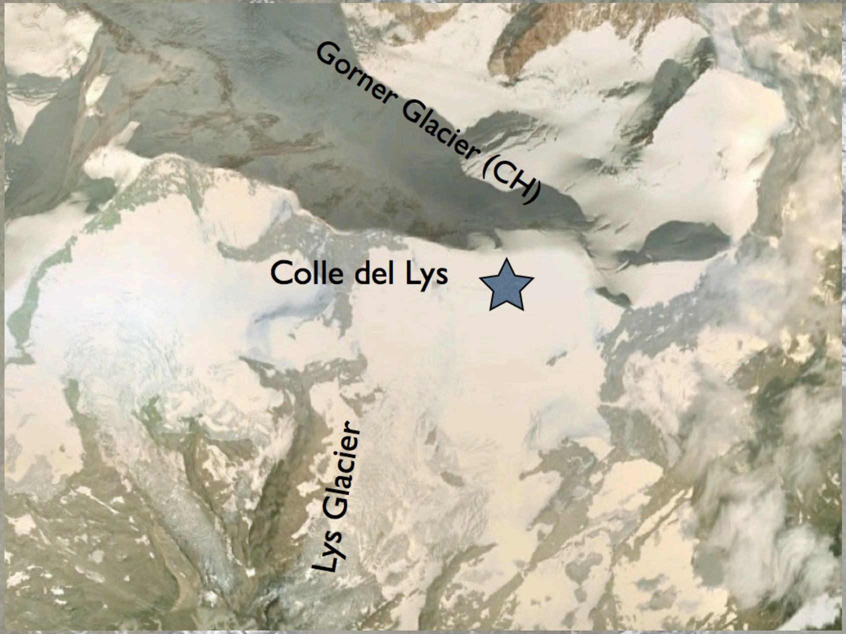
A good correlation between isotopic and temperature records is observed in the decadal trends although the comparison at annual scale is not realistic. Moreover, the isotope sensitivity is more than two times higher than expected.

5. Isotopic records from Colle del Lys ice cores

Ice core activities on Colle del Lys

Ice cores
1996 of 80 m
2000 - 2 ice core. 11 and 24 m
2003 of 106 m
2012 of 32 m

Snow pits:
1996 of 1,5 m
2000 of 1,5 m
2003 of 2,3 m
2012 of 1.4 m

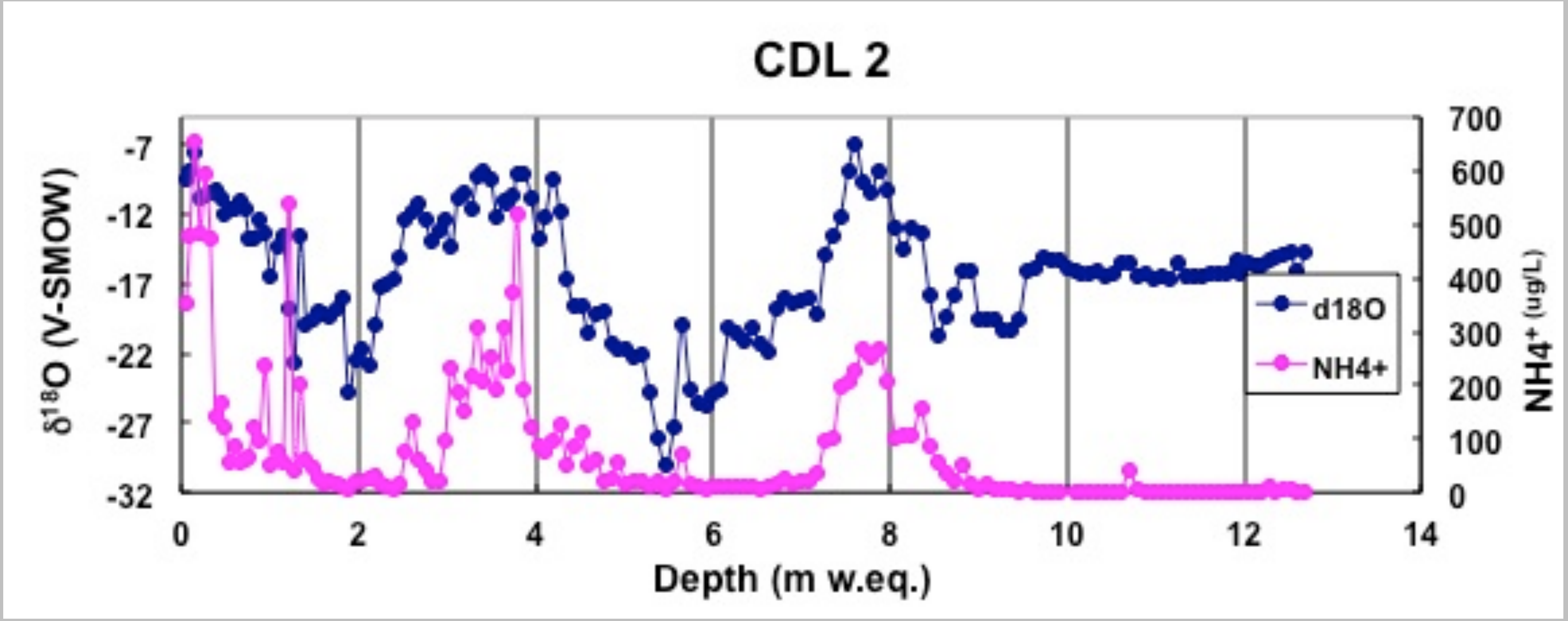


Colle del Lys is a saddle between Lys Glacier (Italy) and Gorner Glacier (Switzerland) at 4250 m asl
Temperature at 10 m depth -11°C
Mean annual accumulation rate:1.3-4.0 m w.e.

National collaborations

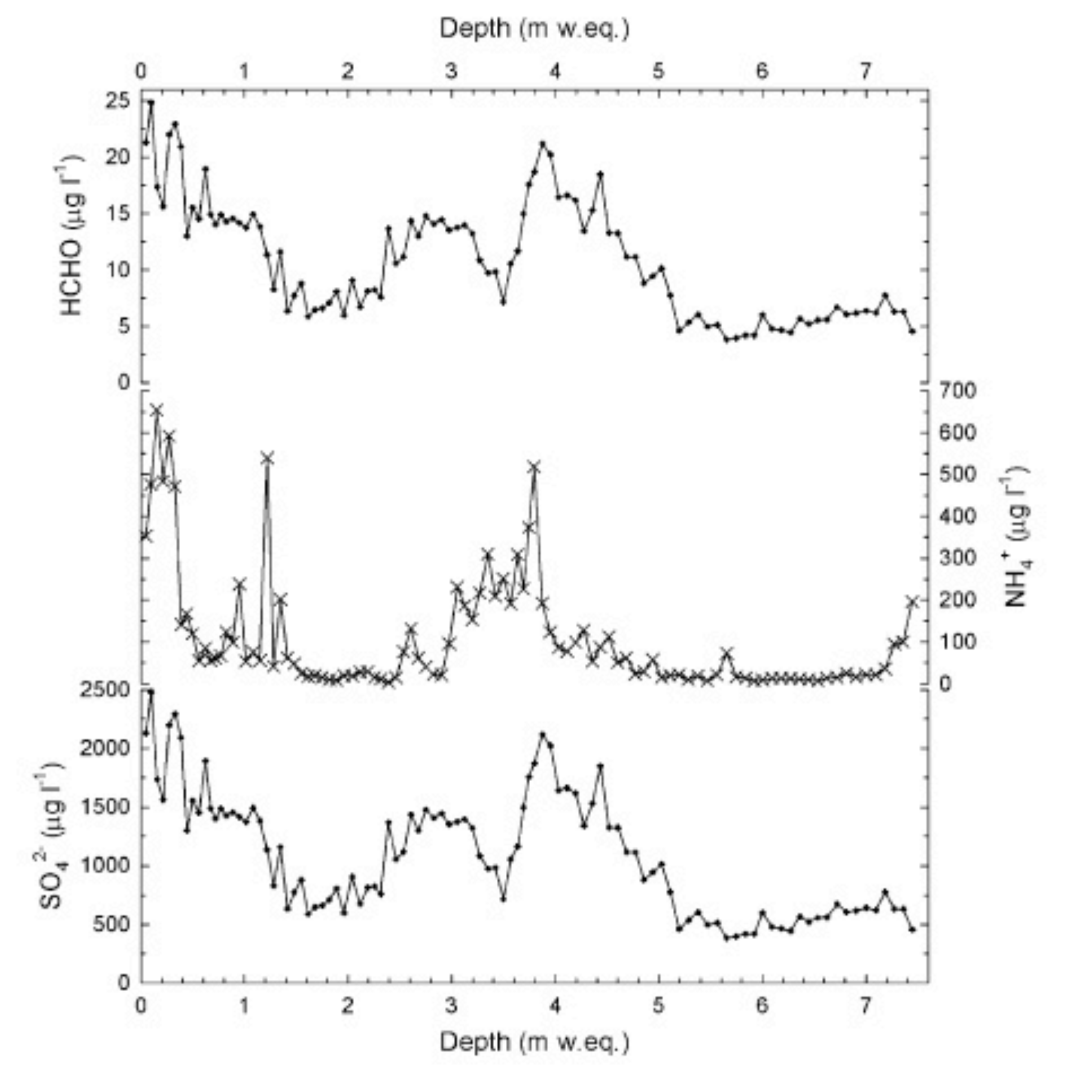
- Università di Milano Bicocca (DISAT)
  - Coordinator
  - Ice core management
  - Core processing and sasmpling
  - Mineral dust
  - Organic chemistry (POP, VOC, PCB' s....)
- ENEA and PNRA
  - Drilling activities
- Università di Trieste (DST)
  - Stable isotopes O and H
  - Trizio (^{3}H)
- Università di Firenze
  - inorganic chemistry (IC)
- INFN (Frascati e Bicocca)
  - Radioactivity, REE, mineralogy of dust
- Other collaborations
  - EV-K2-CNR, CNR, Stanford LLSR, Oxford Diamond, UNIVE, UNIPG, Local Administrations

CDL2000/2 firn core: seasonal resolution



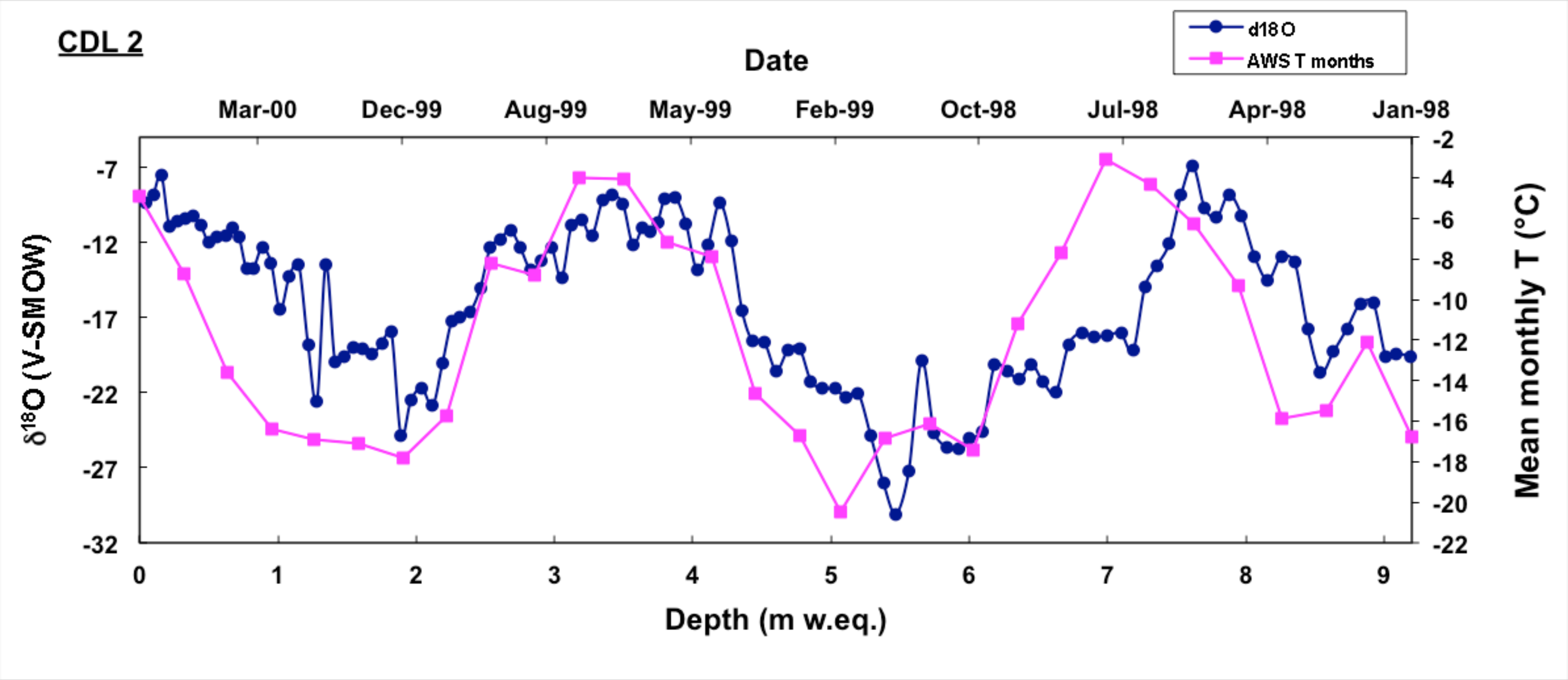
Colle del Lys is a high-resolution site, with a mean annual accumulation between 1.3 to 4.0 m water equivalent (w.eq.). This permits to have seasonal resolution. The length of the CDL 2000 is 24 m. *$\delta^{18}O$ data from Stenni, unpublished.*

CdL2000/2 firn core: seasonal resolution

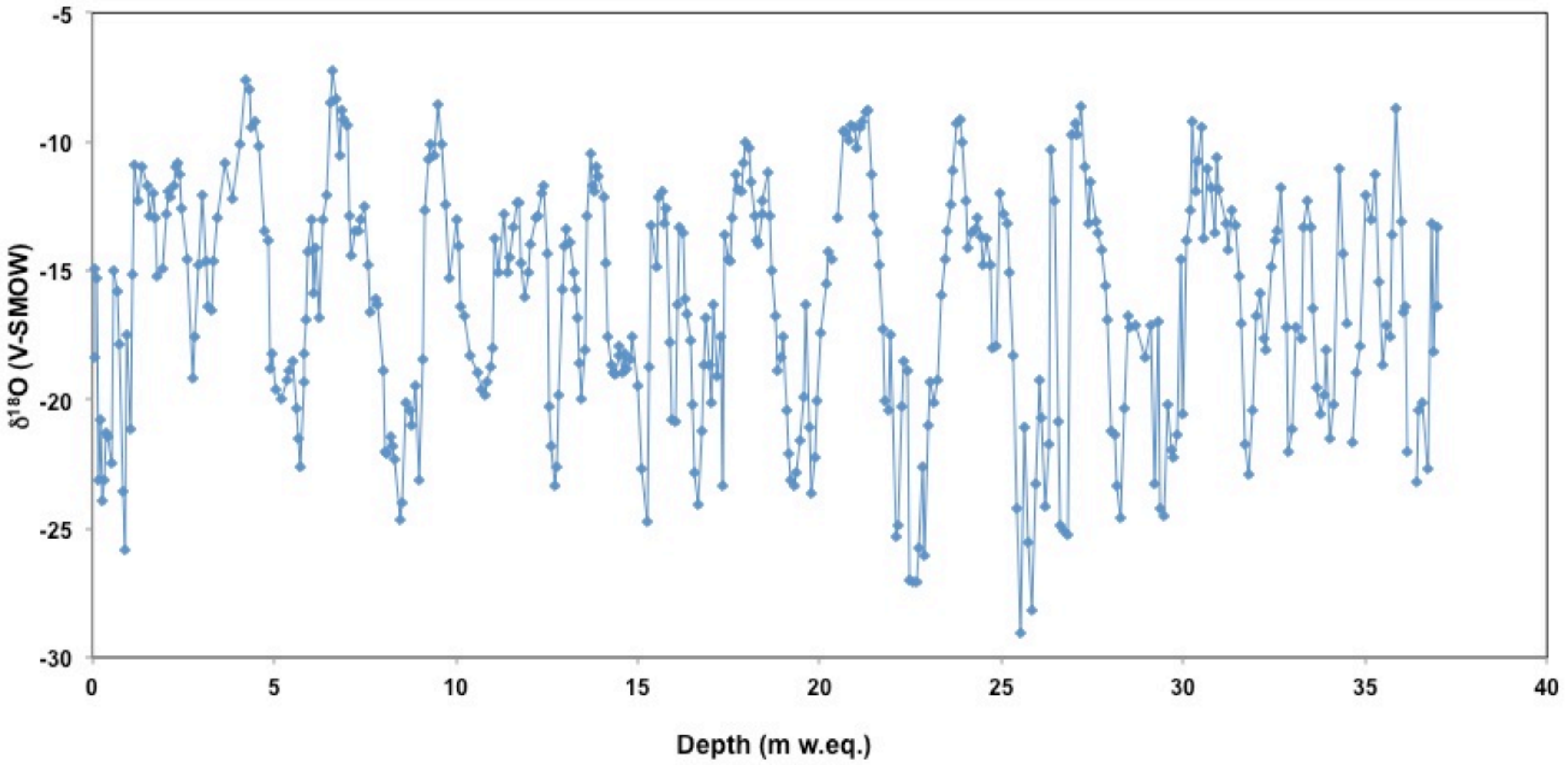


Sulphate , ammonia and formaldehyde records from CdL2000/2 firn core (Largiuni et al., 2003).

CdL2000/2 firn core: $\delta^{18}O$/T calibration

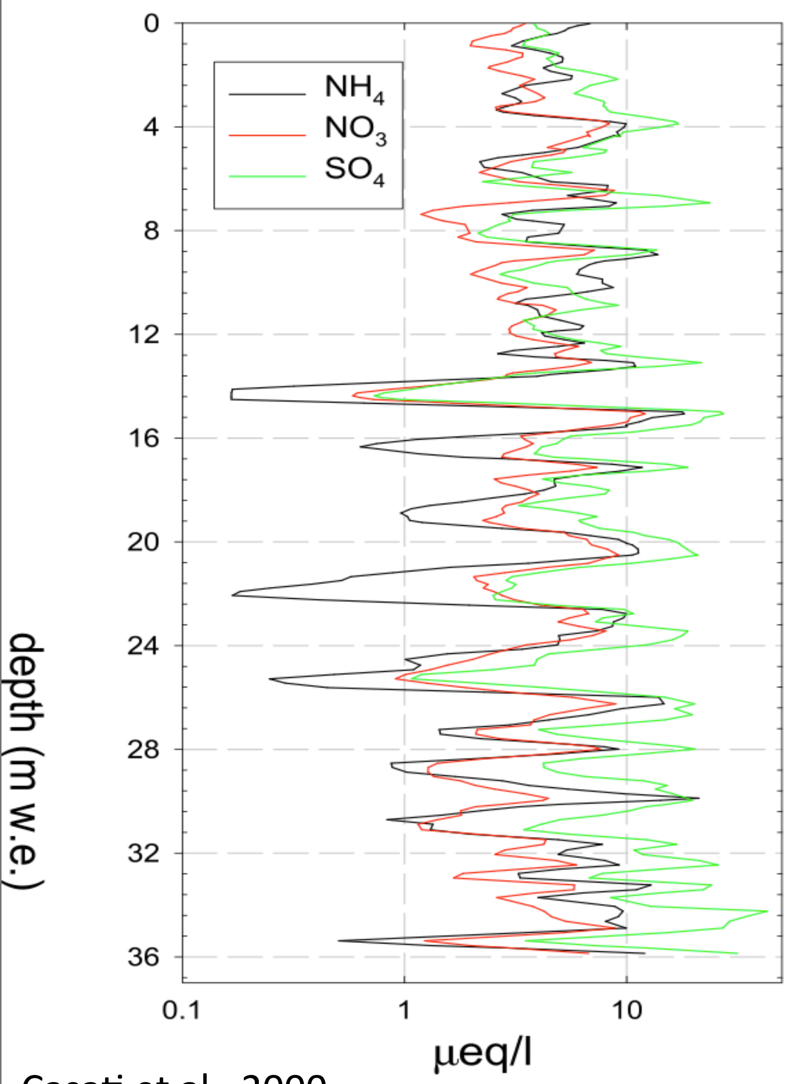


Colle del Lys 1996 $\delta^{18}O$ record against depth



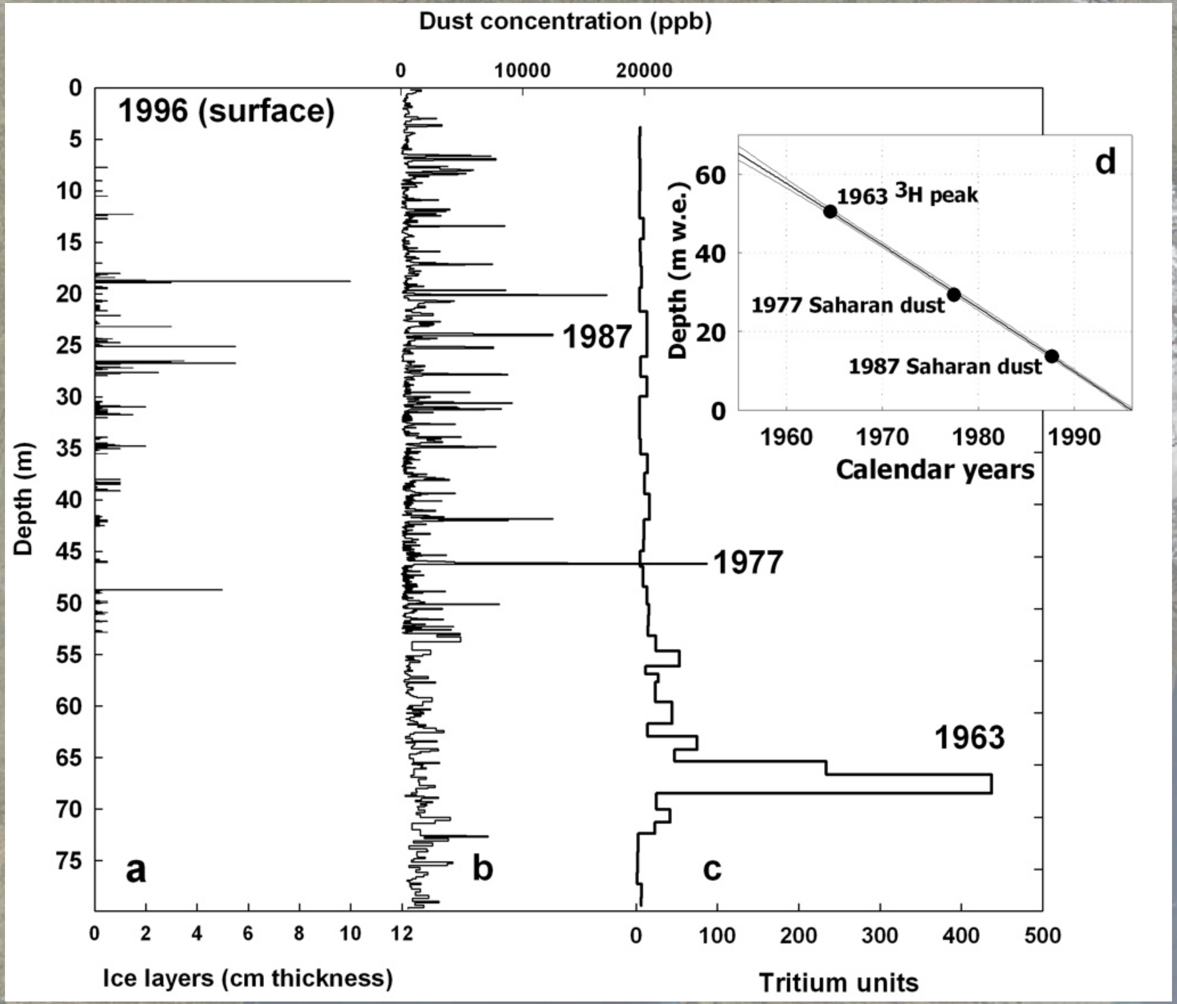
(upper 53 m, 37 m w.eq.) *$\delta^{18}O$ data from Stenni, unpublished*.

Seasonal cycles of NH_4^+, NO_3^- and SO_4^{2-} extracted from the upper 37m w.eq. of the Colle del Lys 1996 ice core.



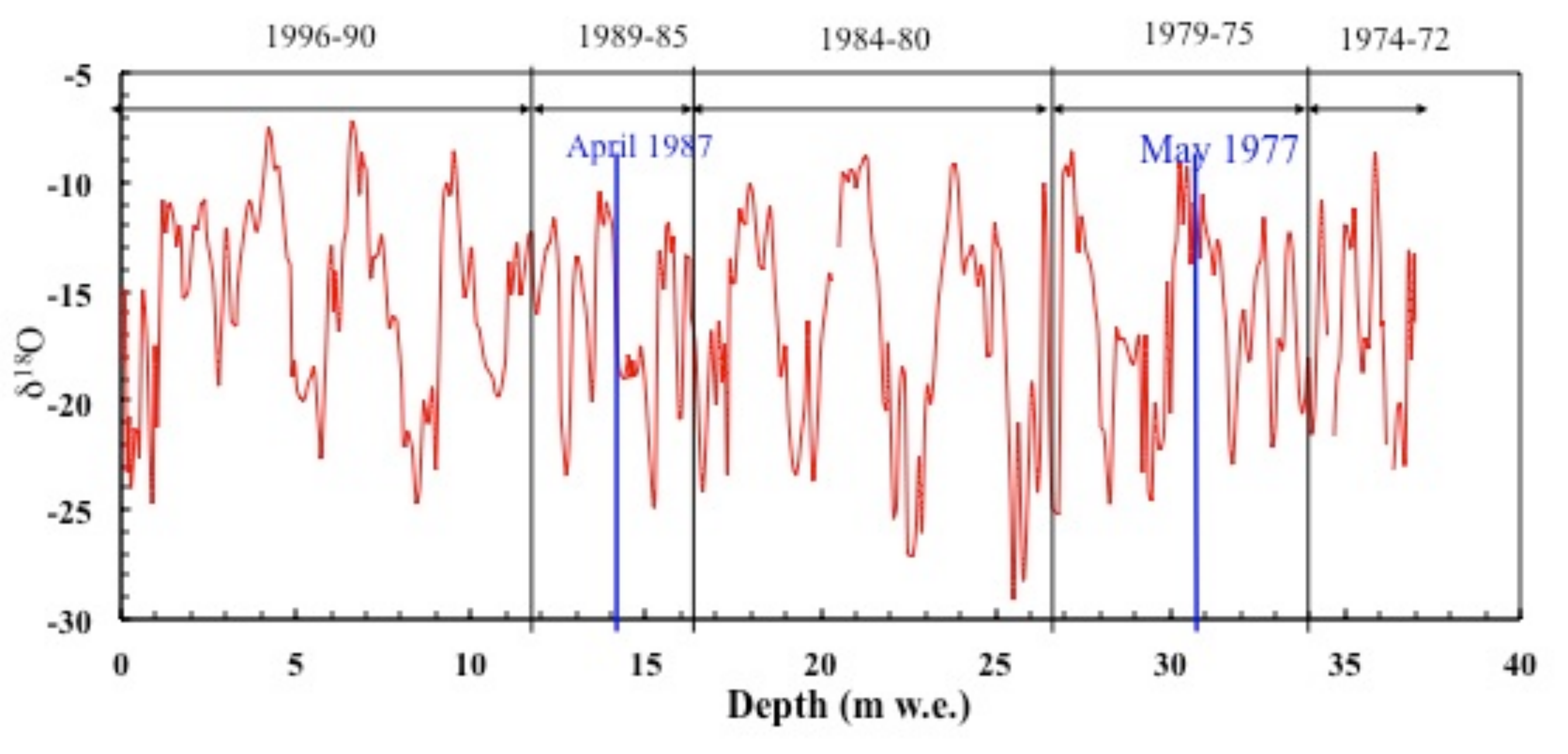
Casati et al., 2000

Colle del Lys 1996 (80 m) ice core dating



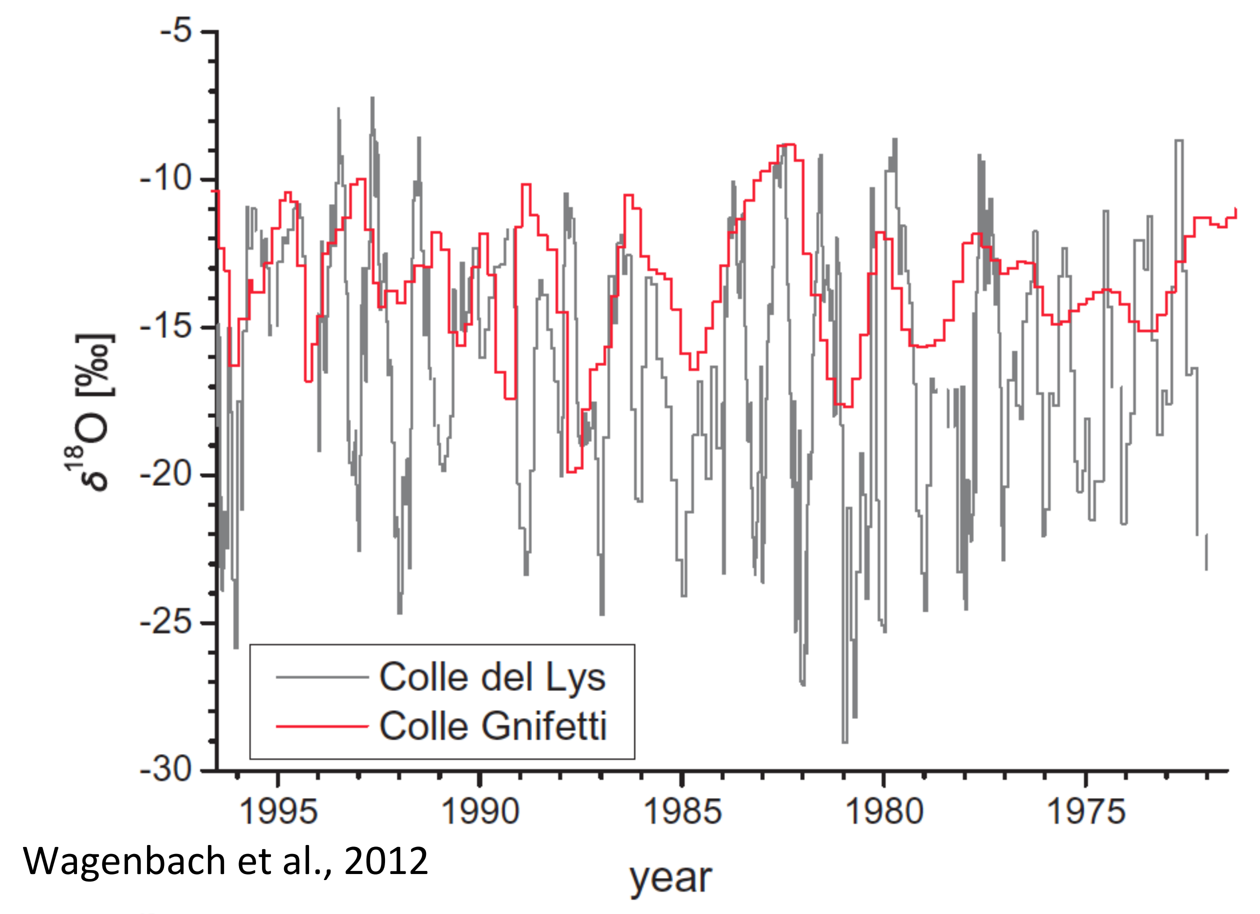
Ice lens and ice layers provide information to the climatic effect of warm summers frequencies. The atmospheric dust record, and especially the well-known Saharan Dust Events help dating the ice core . Tritium record, with the 1963 artificial fallout is one of the most important reference horizon. From Maggi et al., in preparation.

Colle del Lys 1996 $\delta^{18}O$ record against age



$\delta^{18}O$ data from Stenni, unpublished.

Colle del Lys vs. Colle Gnifetti



Wagenbach et al., 2012

The stable isotope records from Colle del Lys permit a seasonal record while the Colle Gnifetti record provides only a summer record.

6. Conclusions

Conclusions

- ✓ Polar ice sheets are among the most powerful natural archives preserving climate information from our “recent” past to the last glacial/interglacial cycles.
- ✓ Deep ice cores, drilled both in Greenland and Antarctica are documenting the natural climate variability experienced by the high latitude regions over the late Pleistocene.
- ✓ Ice cores from high-elevation sites in the Alpine region preserve shorter climate information than polar ice cores.
- ✓ Alpine records may be biased by snow accumulation seasonality effects.
- ✓ High accumulation rate sites are best suited for preserving climate information at annual scale, while low accumulation sites show a good correlation between isotopic and temperature records at the decadal scale.
- ✓ The isotope sensitivity to temperature changes seems to be higher than expected.

Thanks for your attention