IRD « Great Ice »

Andean Ice Coring Program

Past, Present and Future

Dr. Ginot P., « Great Ice » Team, and our international partners

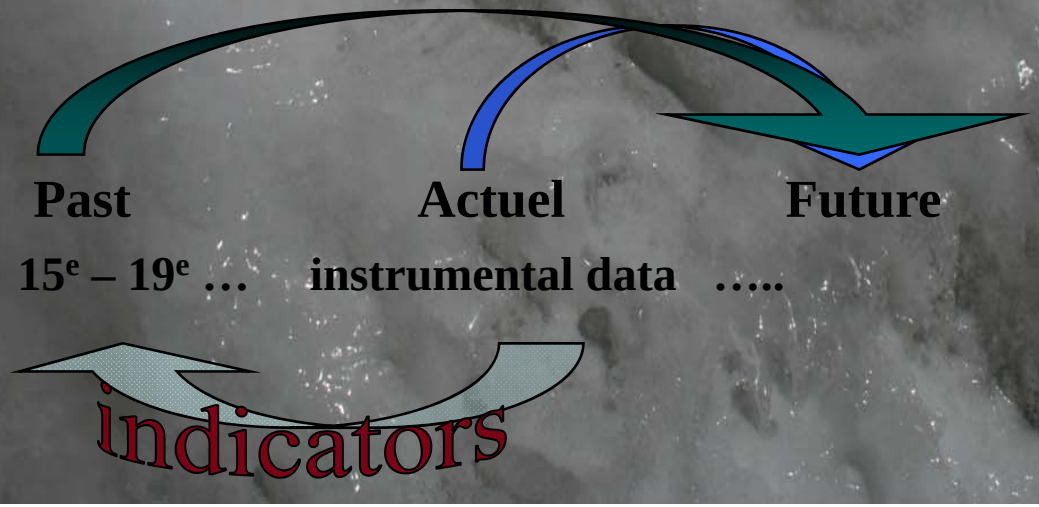
IRD Great Ice / LGGE, Grenoble, France.

Institut de recherche pour le développement

IRD performs research and manages scientific programs centered on the relations between mans and his environment in the tropics

« Glaciers et Ressources en Eau d'Altitude Indicateurs Climatiques et Environnementaux »

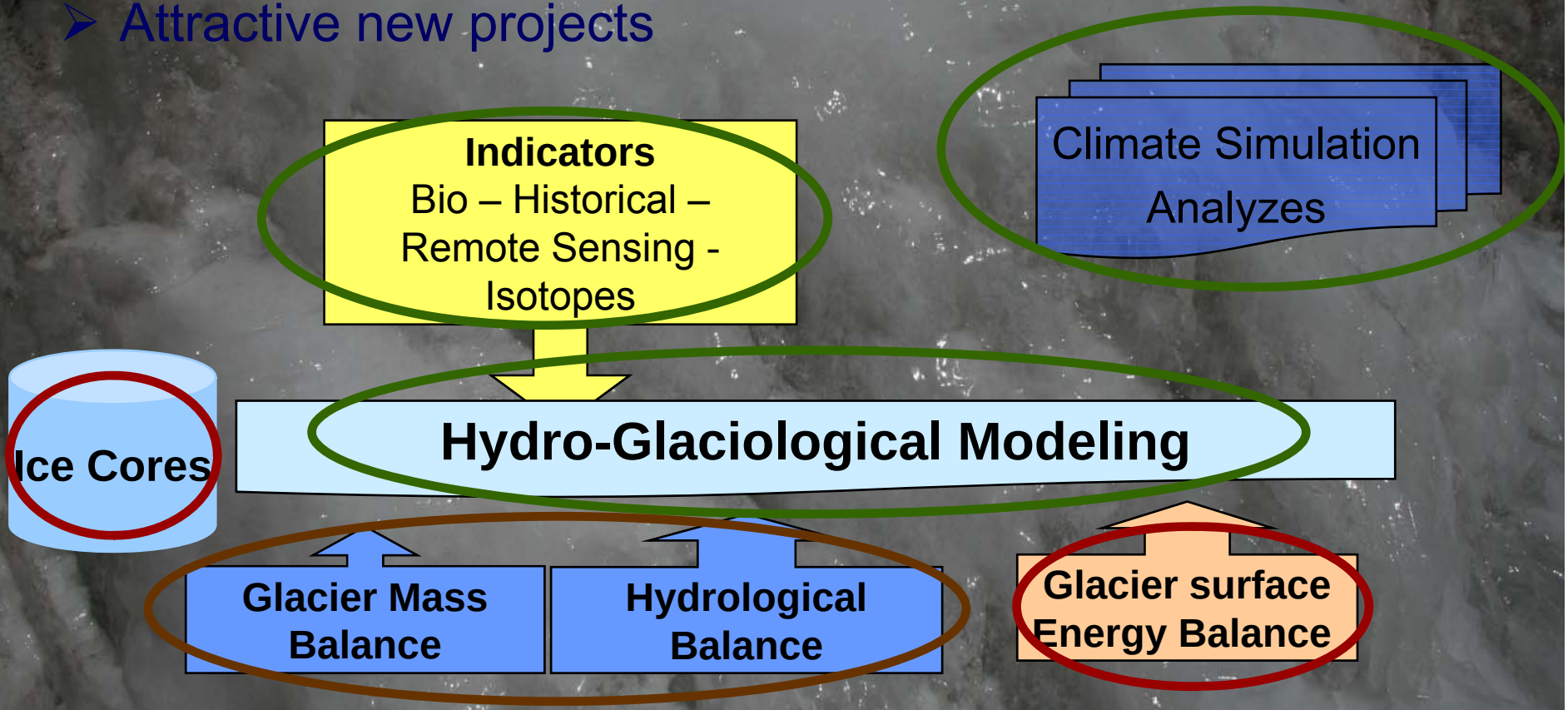
- **The water resources future**
- **The Climate – Hydro – Cryosphere variability in high altitude region**
- **Support of these research topics by our South countries partners**



Great Ice 2005 – 2008

Methods : continuity and openings

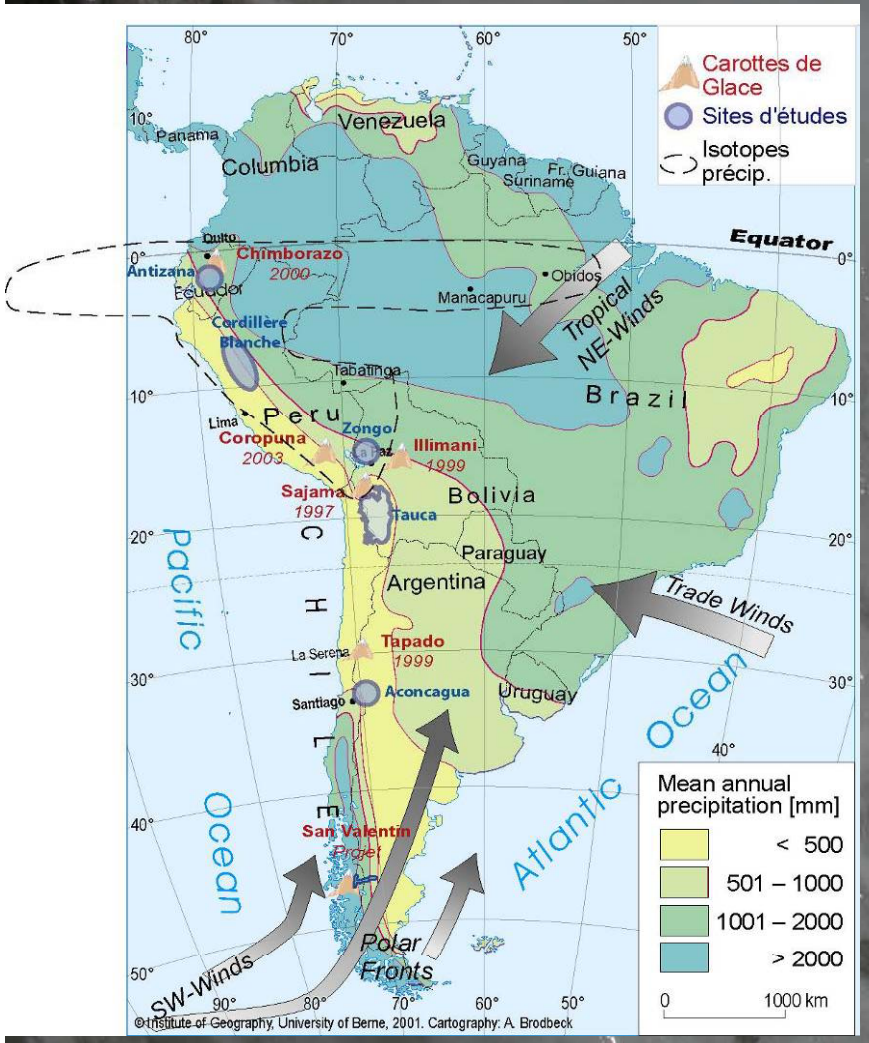
- Go on with processes study (melting, discharge, recording)
- Attractive new projects



Institut de recherche pour le développement

GREATICE

Great Ice 2005- 2008
Andean Projects



« Present »

- Precipitation network (isotopes)
- Mass & Energy & Hydrology Balances
- ENSO impacts
- Shallow Ice Cores, Post-deposition processes
- ORE Glacioclim (Ecuador, Bolivia)
- Remote sensing (SPOT 5, SRTM)

« Past »

- Little Ice Age chronology
- Glacier/Lake extension
- Ice core investigation
- Dendrochronology, Pollens, Moraines, Historical archives

Partners:

Univ. S.A. & San Marcos & Valdivia, EPN EMAP,Cobee, Senamhi, Electroperu, Inrena, Aguas de Illimani…

Southward opening …

Climate Simulation Analyzes

Andean Ice Cores

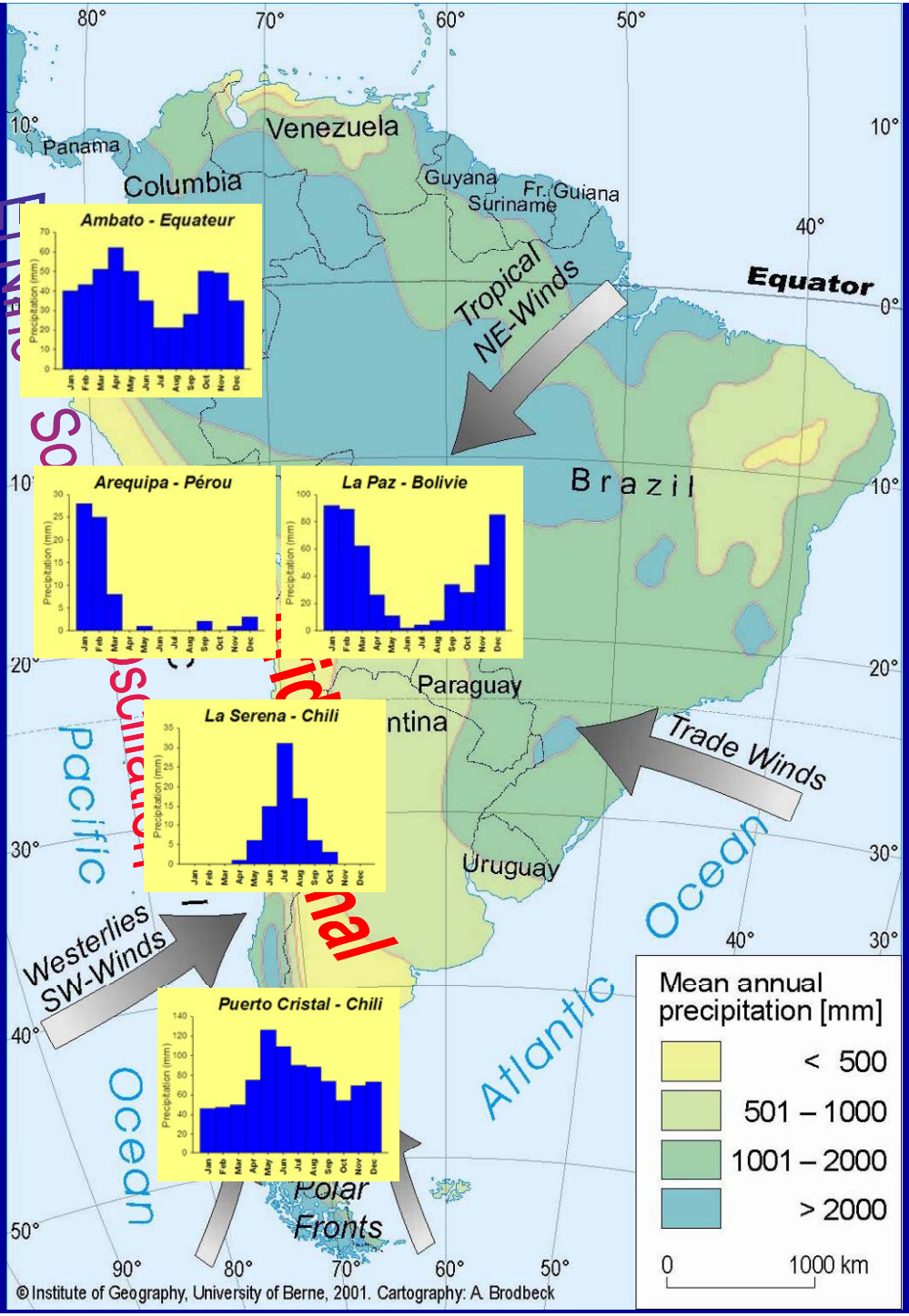
- ✓ In 1976, the first ice core was extracted from the tropical glacier Quelccaya in Peru, by L.G. Thompson.
- ✓ Since then, several places were investigated along the Andes, and the oldest record reaches back to 25,000 years.
- ✓ The ice cores provide a wide range of data (stable isotopes, aqueous chemistry, particles…), but their interpretations have to consider the specific boundary of conditions of this region, and the particularity of each glacier.
- ✓ The goal is to understand how present climatic and environmental situations are recorded in the snow in order to reconstruct past years, decades, centuries…

General Climatology

1. Atmospheric Circulation:
- *Atlantic & Amazonian* Sources
- *Pacific* Source
- *ITCZ* Position

3. ENSO Influence

3. Annual Distribution of Precipitations
- *Length of the dry season*
- *1 or 2 wet seasons*



Selected Glaciers

Sajama (Bolivia)
1997
40m

Cerro Tapado (Chile)
1998 and 1999
36m to bedrock

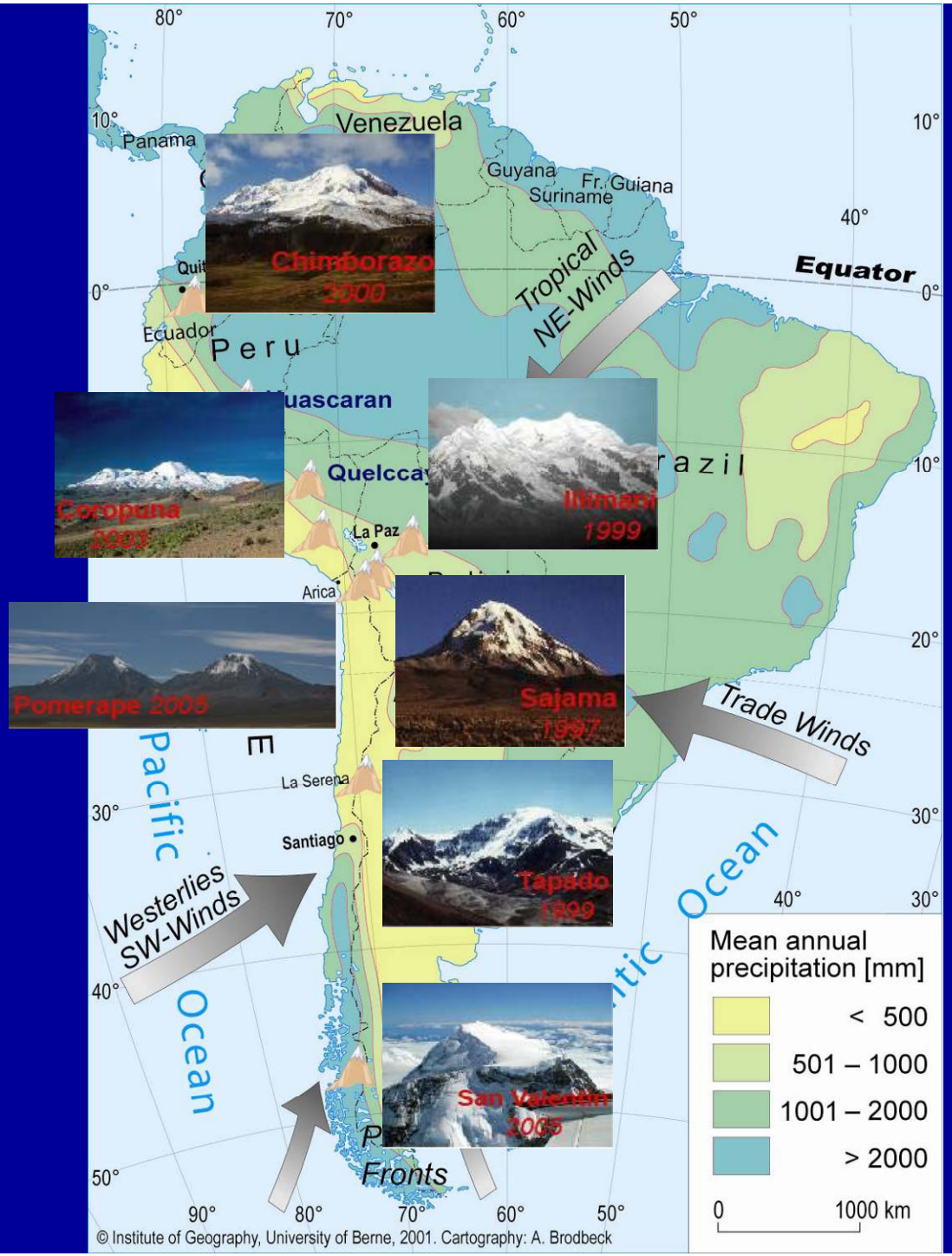
Illimani (Bolivia)
1998 and 1999
138m to bedrock

Chimborazo (Ecuador)
1999 and 2000
54m to bedrock

Coropuna (Peru)
2003
34m to bedrock

San Valentin (Chile)
2005
15m (exploration)

Pomerape (Bolivia)
2005
7m (exploration)




Past projects...
❖ Sajama (Bolivia)
❖ Cerro Tapado (Chile)
❖ Illimani (Bolivia)
❖ Chimborazo (Ecuador)

Significant Publications: *Sajama, Cerro Tapado, Illimani, Chimborazo*

• Thompson, L.G., M. Davis, E. Mosley-Thompson, T.A. Sowers, K.A. Henderson, V.S. Zagorodnov, P.-N. Lin, V.N. Mikhalenko, R.K. Campen, J.F. Bolzan, J. Cole-Dai, and B. Francou, A 25000-year tropical climate history from Bolivian ice cores, *Science*, 282, 1858-1864, 1998.

• Ginot, P., C. Kull, M. Schwikowski, U. Schotterer, and H.W. Gäggeler, Effects of post-depositional processes on snow composition of a subtropical glacier (Cerro Tapado, Chilean Andes), *Journal of Geophysical Research*, *106* (D23), 32375-32386, 2001.

• Stichler, W., U. Schotterer, K. Fröhlich, P. Ginot, C. Kull, H.W. Gäggeler, and B. Pouyaud, The influence of sublimation on stable isotopes records from high altitude glaciers in the tropical Andes, *Journal of Geophysical Research*, *106* (D19), 22613-22621, 2001.

• Schotterer, U., W. Stichler, and P. Ginot, The influence of post-depositional effects on ice core studies: examples from the Alps, Andes, and Altaï, in *Earth Paleoenvironments: Records preserved in Mid- and Low-Latitude Glaciers*, edited by L. De Wayne Ceciel, J.R. Green, and L.G. Thompson, pp. 39-60, Kluwer Academic Publishers, 2004.

• De Angelis, M., J.C. Simões, H. Bonnaveira, J.D. Taupin, and R.J. Delmas, Volcanic eruptions recorded in the Illimani ice core (Bolivia): 1918–1998 and Tambora periods, *Atmospheric Chemistry and Physics*, 3, 1725-1741, 2003.

• Knüsel, S., P. Ginot, U. Schotterer, M. Schwikowski, H.W. Gaeggeler, B. Francou, J.C. Simões, J.R. Petit, and J.D. Taupin, Dating of two nearby ice cores from the Illimani, Bolivia., *Journal of Geophysical Research*, 108 (D6), 4181, 2003.

• Correia, A., R. Freydier, R.J. Delmas, J.C. Simões, J.-D. Taupin, B. Dupré, and P. Artaxo, Trace elements in South America aerosol during 20th century inferred from a Nevado Illimani ice core, Eastern Bolivian Andes (6350m a.s.l.), *Atmospheric Chemistry and Physics*, 3, 2143–2177, 2003.

• Correia, A.L., R.J. Delmas, R. Freydier, J.C. Simões, J.-D. Taupin, B. Dupre, and P. Artaxo, Heavy metals in South America aerosol during 20(th) century from Illimani ice-core, Eastern Bolivian Andes, *Journal de Physique IV*, 107 (Part 1), 333-336, 2003.

• Ramirez, E., G. Hoffmann, J.D. Taupin, B. Francou, P. Ribstein, N. Caillon, F.A. Ferron, A. Landais, J.R. Petit, B. Pouyaud, U. Schotterer, J.C. Simões, and M. Stievenard, A new Andean deep ice core from Nevado Illimani (6350 m), Bolivia, *Earth and Planetary Science Letters*, 212, 337-350, 2003.

• Hoffmann, G., E. Ramirez, J.D. Taupin, B. Francou, P. Ribstein, R. Delmas, H. Dürr, R. Gallaire, J. Simões, U. Schotterer, M. Stievenard, and M. Werner, Coherent isotope history of Andean ice cores over the last century, *Geophysical Research Letters*, 30 (4), 1179, 2003.

• Hoffmann, G., Taking the Pulse of the tropical water cycle, *Science*, 301, 776-777, 2003.

• Schotterer, U., M. Grosjean, W. Stichler, P. Ginot, C. Kull, H. Bonnaveira, B. Francou, H.W. Gäggeler, R. Gallaire, G. Hoffmann, B. Pouyaud, E. Ramirez, M. Schwikowski, and J.D. Taupin, Glaciers and climate in the Andes between the Equator and 30°S: What is recorded under extreme environmental conditions?, *Climatic Change*, *59*, 157-175, 2003.

• Ginot, P., M. Schwikowski, U. Schotterer, H.W. Gäggeler, R. Gallaire, and B. Pouyaud, Potential for climate variability reconstruction from Andean glaciochemical records, *Annals of Glaciology*, *35*, 443-450, 2002.

• Ginot, P., C. Kull, U. Schotterer, M. Schwikowski, and H.W. Gäggeler, Glacier masse balance reconstruction by sublimation induced enrichment of chemical species on Cerro Tapado (Chilean Andes), *Climate of the Past*, Submitted.

• Ginot, P., U. Schotterer, W. Stichler, M. Schwikowski, M.A. Godoi, and B. Francou, Influence of recent local volcanic eruption on chemical and isotopic signals recorded in Chimborazo ice cores, Ecuador, in preparation.


Present projects...
Coropuna (Peru)
San Valentin (Chile)

Glaciological Investigations on Nevado Coropuna (Peru)

AIM:

Reconstruction of Past Climatic and Environmental conditions along the Andes

Situation

Coropuna, 6425m a.s.l.
S15°32', W72°39'

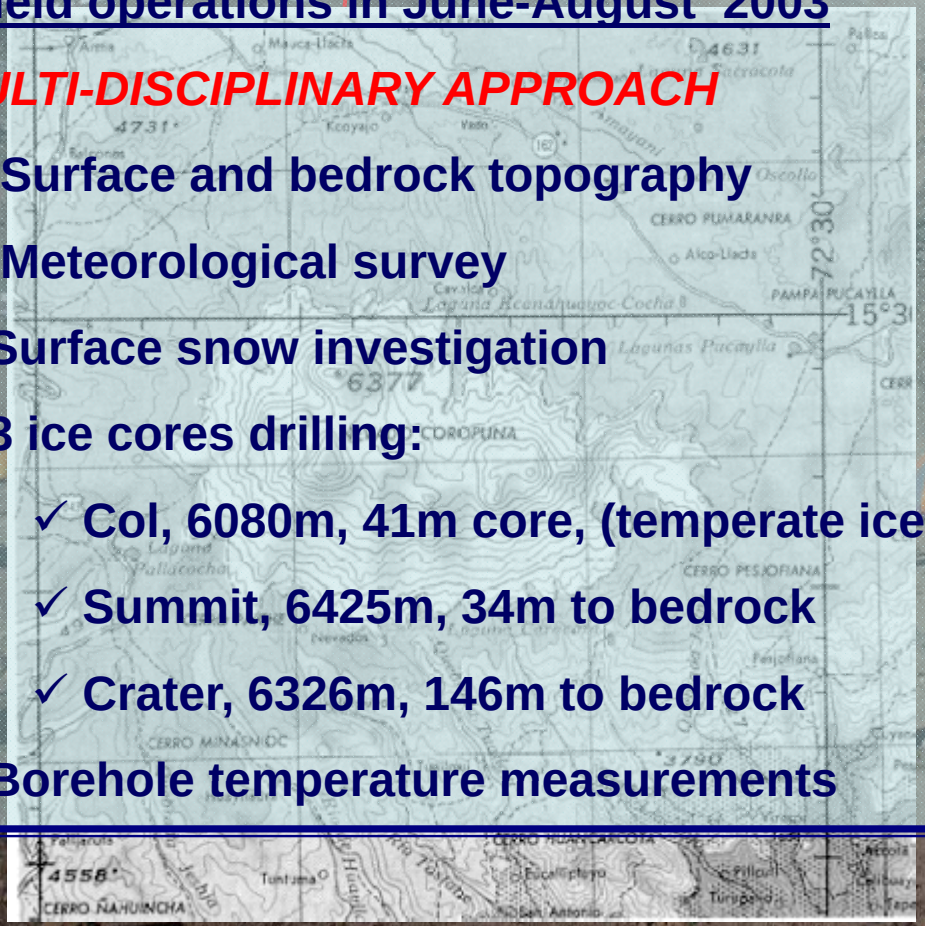
Summit & Crater
6425m

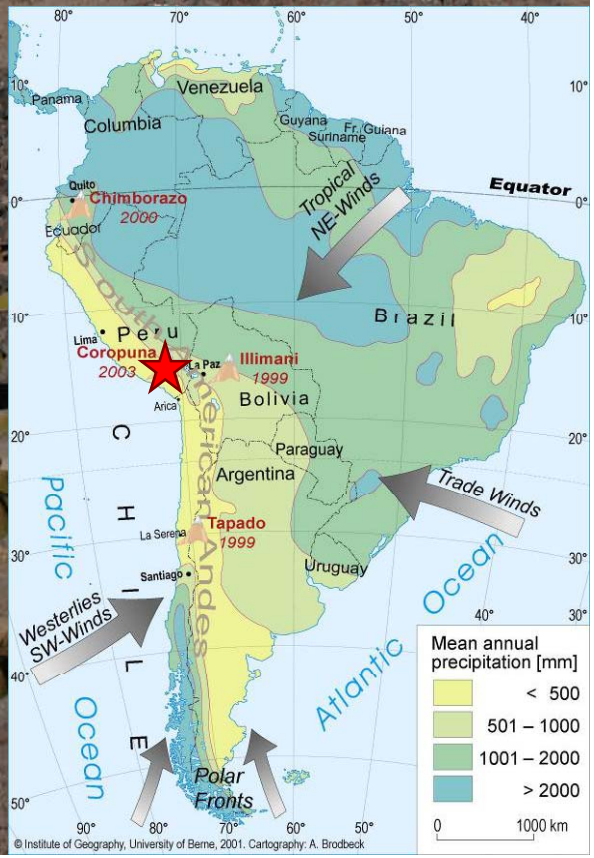
Col
6080m

2 field operations in June-August 2003

MULTI-DISCIPLINARY APPROACH

- Surface and bedrock topography
- Meteorological survey
- Surface snow investigation
- 3 ice cores drilling:
  - ✓ Col, 6080m, 41m core, (temperate ice)
  - ✓ Summit, 6425m, 34m to bedrock
  - ✓ Crater, 6326m, 146m to bedrock
- Borehole temperature measurements

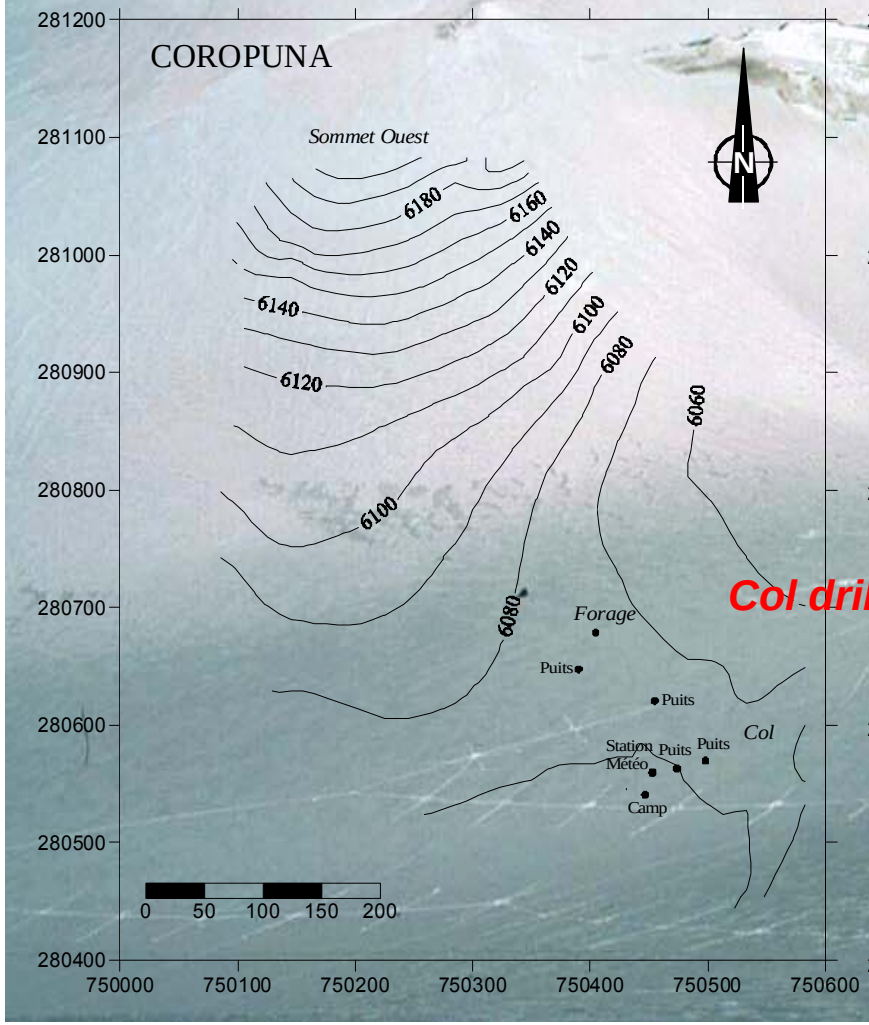


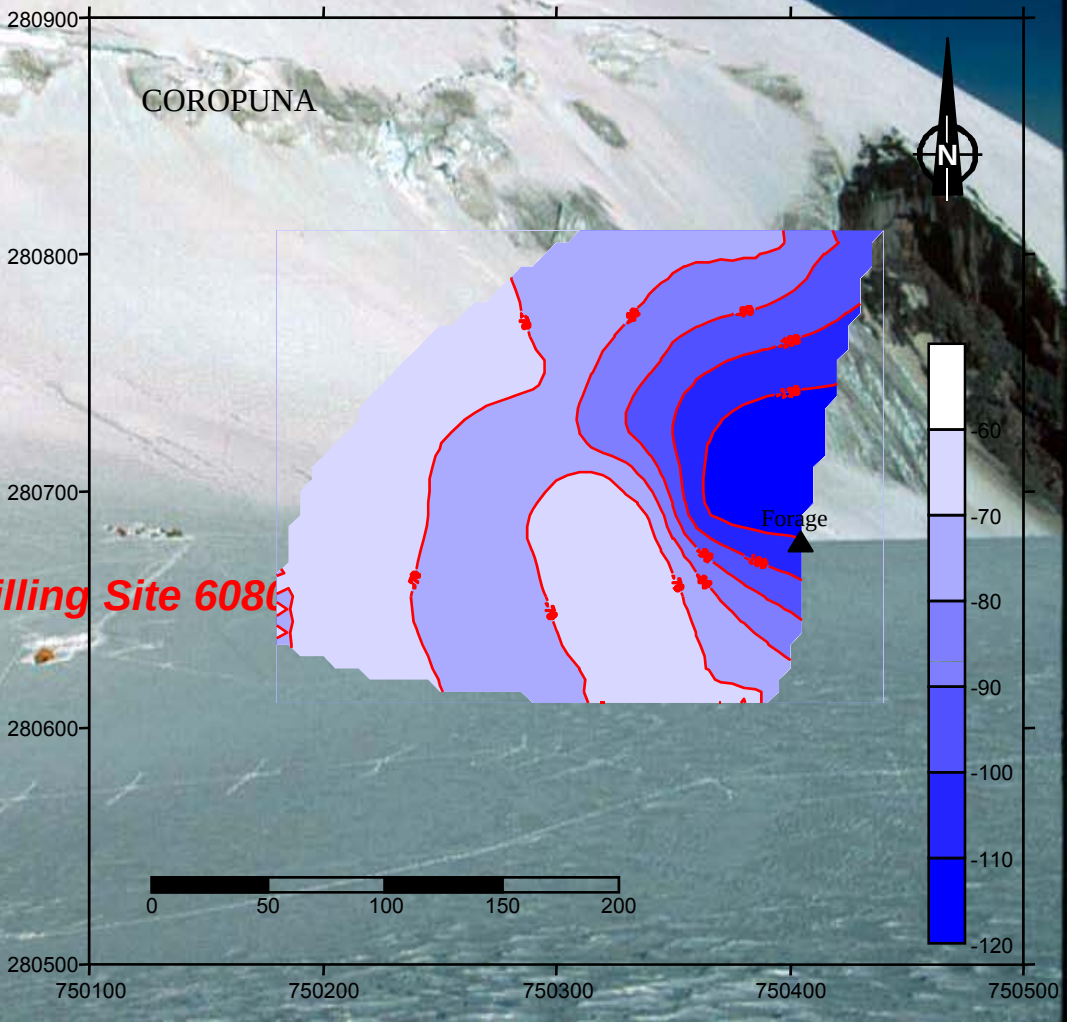


Surface and Bedrock topography

Summit 6425m

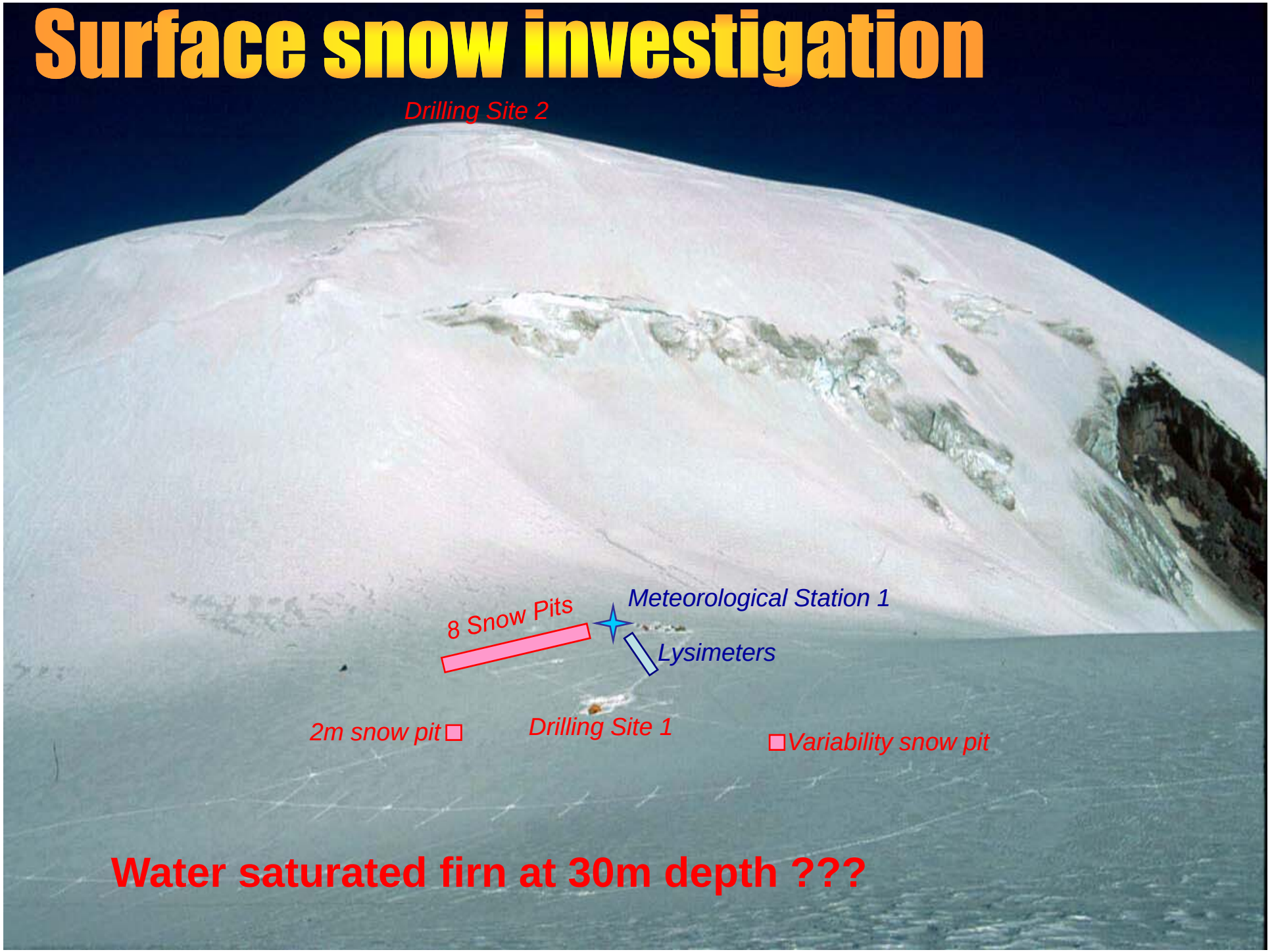
Christian VINCENT - LGGE



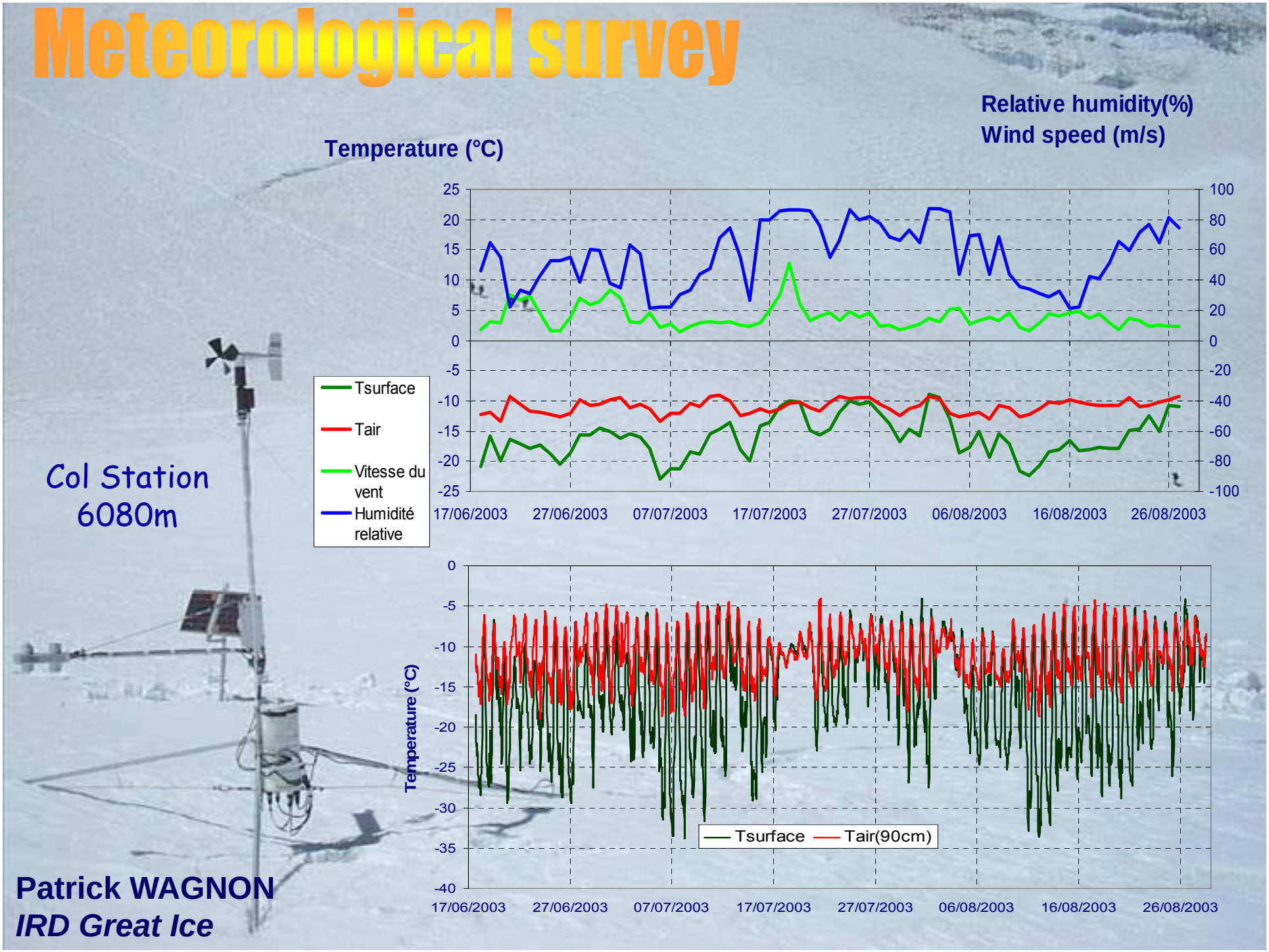


Col drilling Site 6080

Surface snow investigation

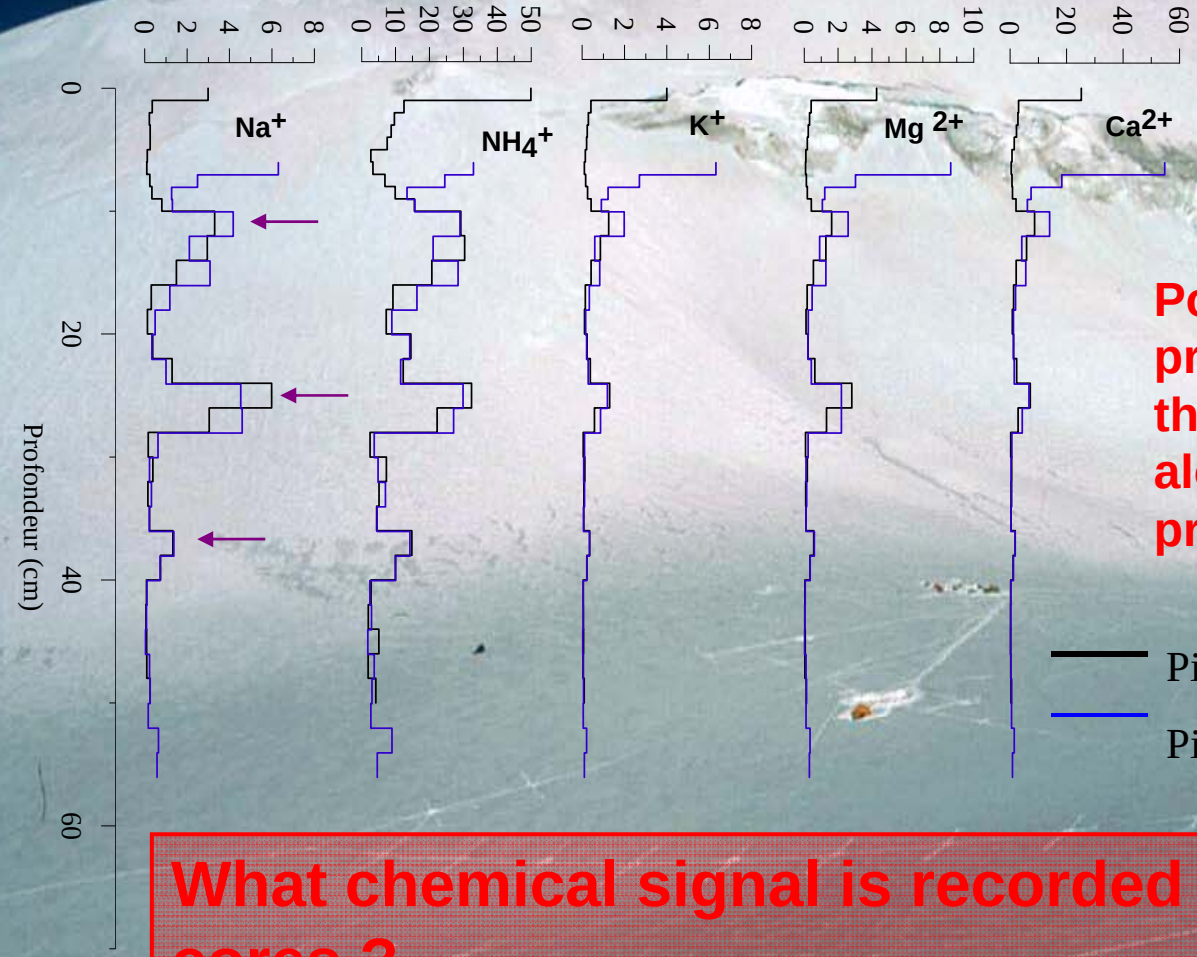


Meteorological survey



Patrick WAGNON
IRD Great Ice

Surface snow investigation (Col)



70mm ablation
~ 1 mm/day

Post depositional processes constructs the chemical signals along the snow/ice profile

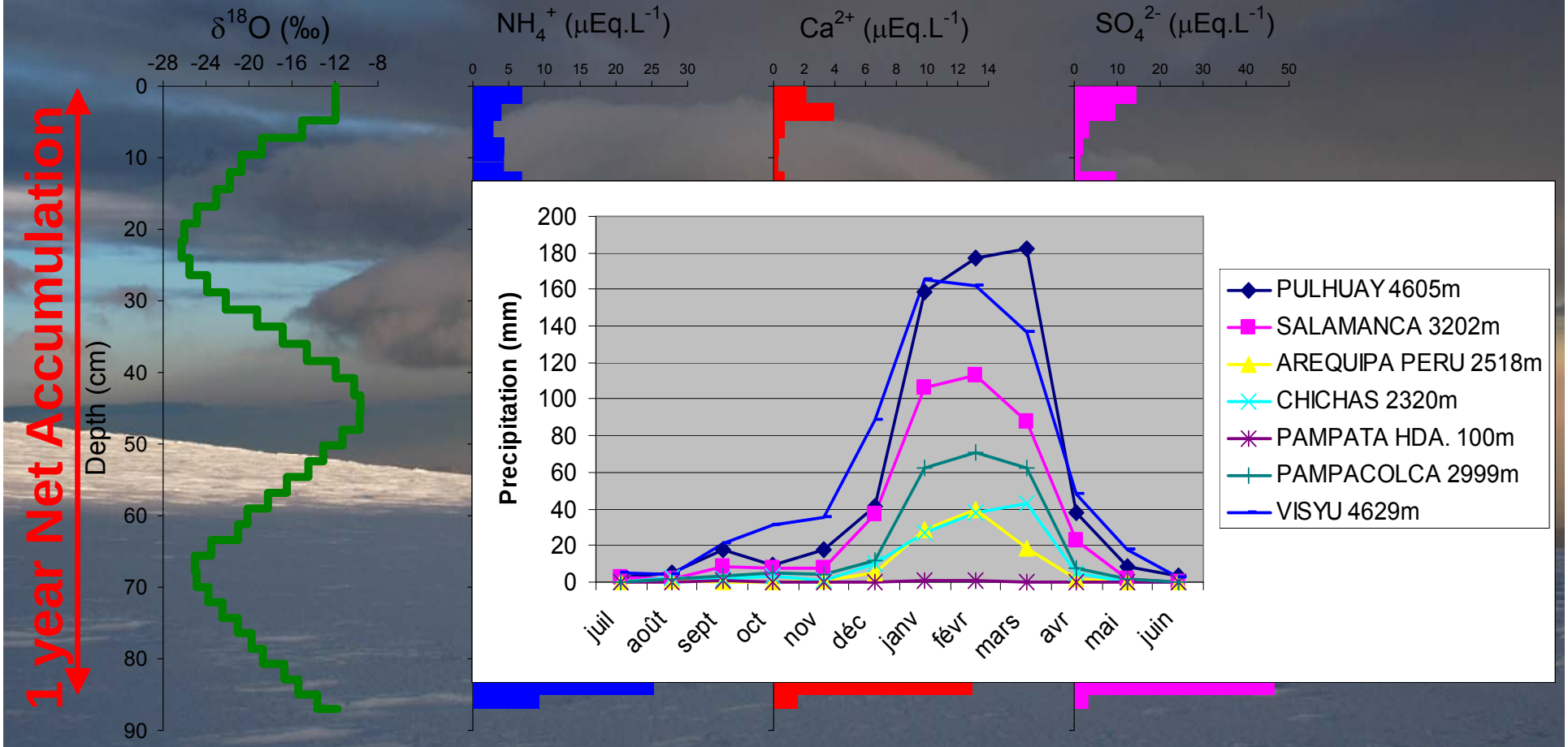
Pit 7 : July 1st, 2003

Pit 8 : August 29th, 2003

What chemical signal is recorded in this site ice cores ?

Summit Snow Pit

Accumulation June 2003 – June 2004: *85 cm = 320 mm weq*



What isotopic signal is recorded in this site ice cores ?

Summit ice core

34m long to bedrock
-10°C at 10m depth

High resolution sampling (2,5cm)

Analyzes:

Major ions (sodium, ammonium, calcium, nitrate, chloride, sulfate…)

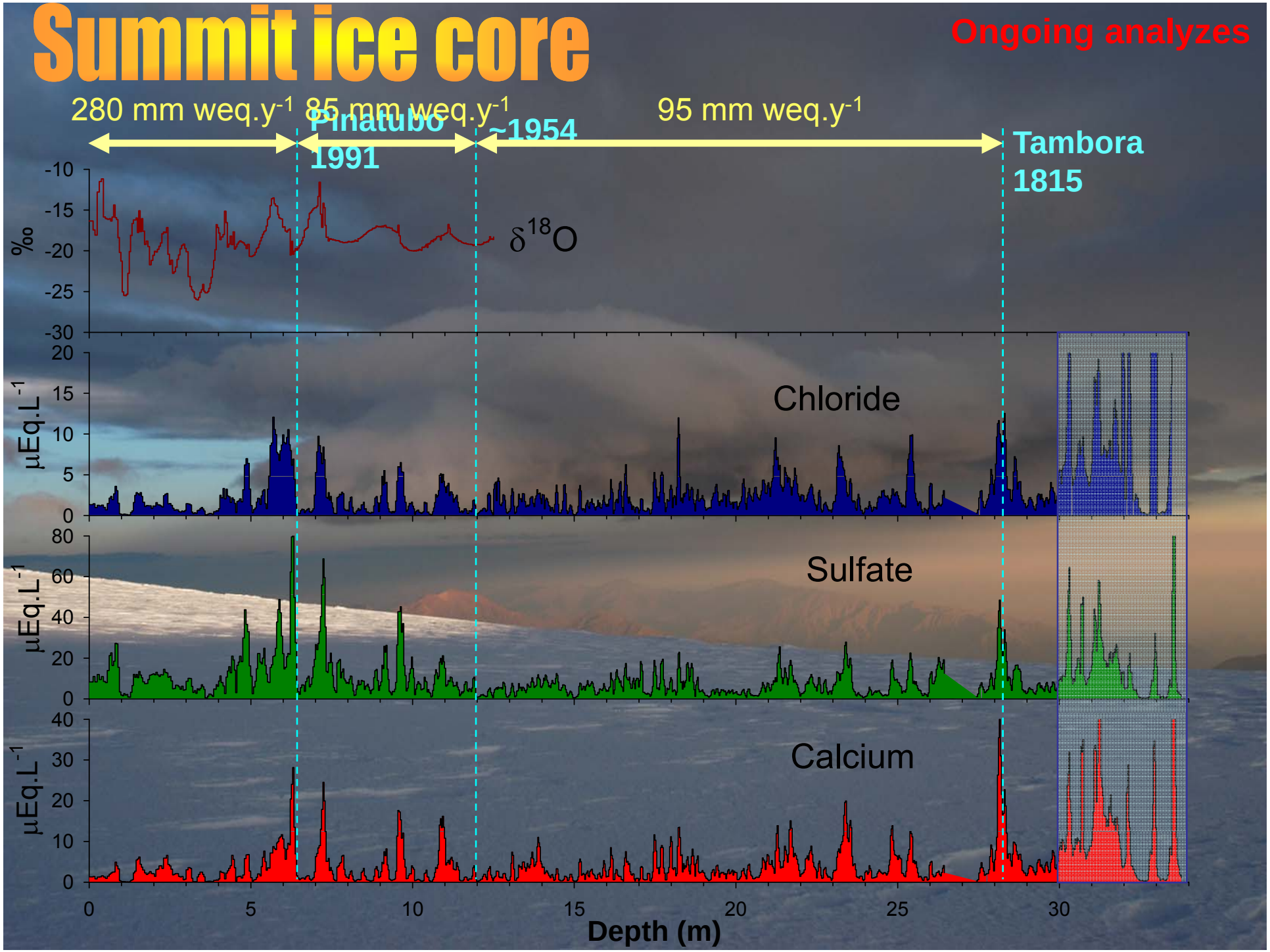
Carboxylic acids (acetate, formate, propionate, gluconate, succinate, oxalate…)

Stables isotopes ($\delta^{18}O$, δD)

Tritium

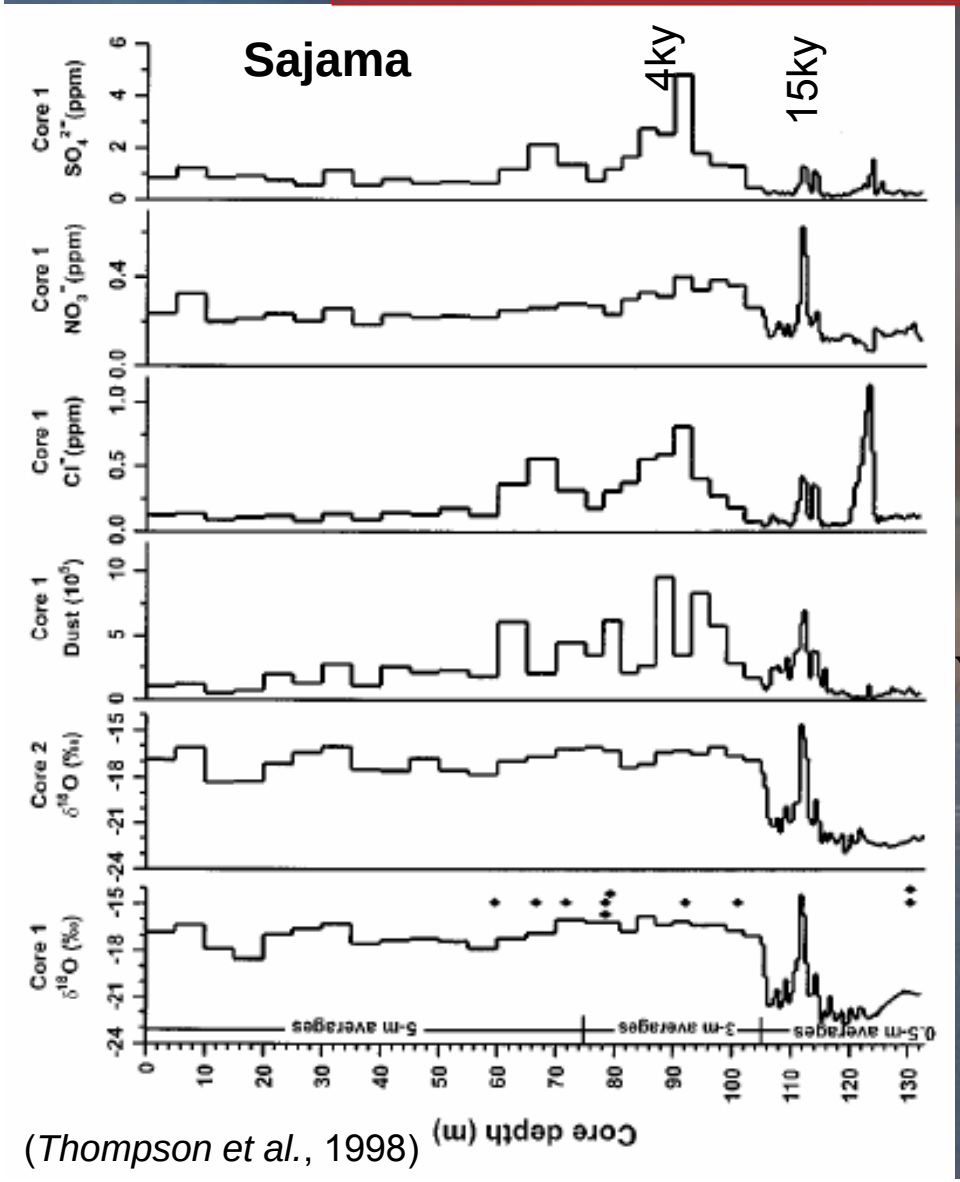
^{210}Pb

(Pollen?)

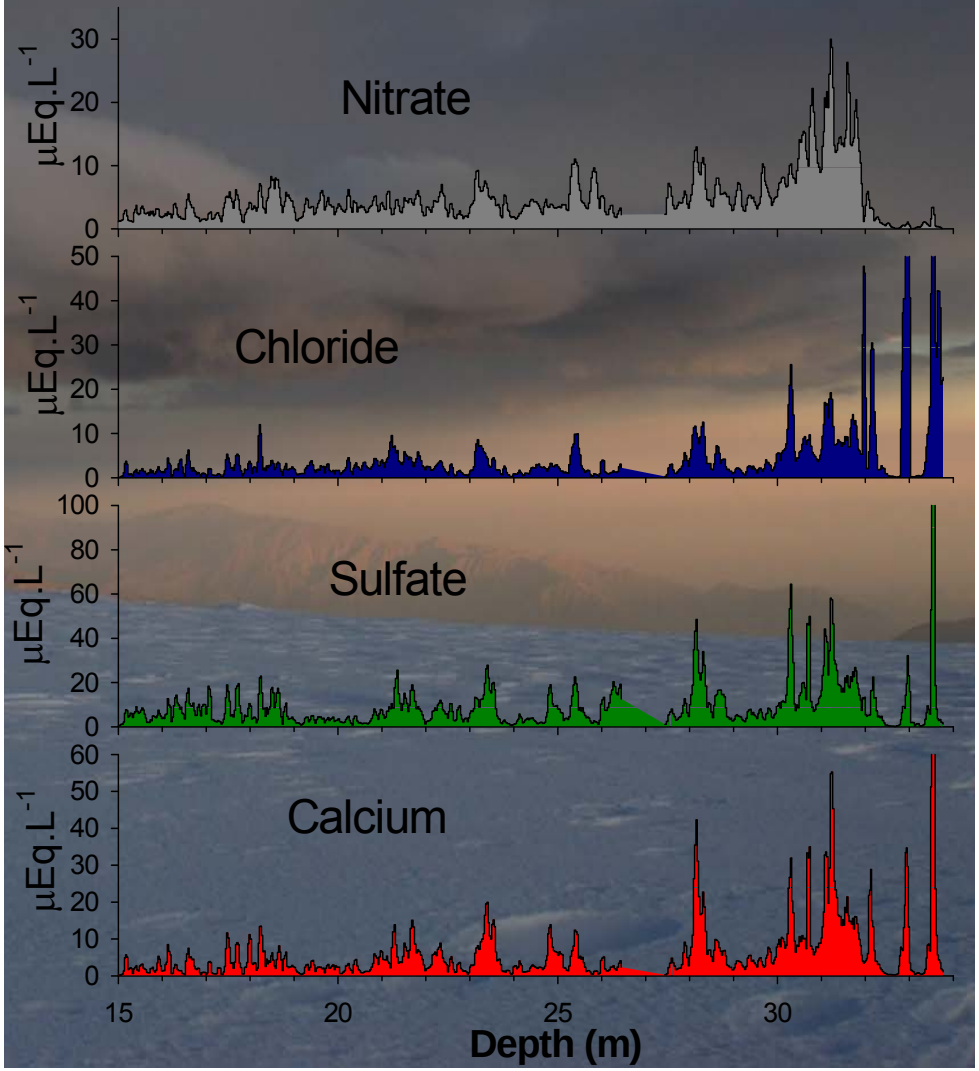

Summit ice core
Ongoing analyzes
280 mm weq.y-1
85 mm weq.y-1
95 mm weq.y-1
Pinatubo
1991
~1954
Tambora
1815
‰
δ18O
-10
-15
-20
-25
-30
µEq.L-1
Chloride
20
15
10
5
0
Sulfate
80
60
40
20
0
Calcium
40
30
20
10
0
0
5
10
15
20
25
30
Depth (m)

Summit ice core

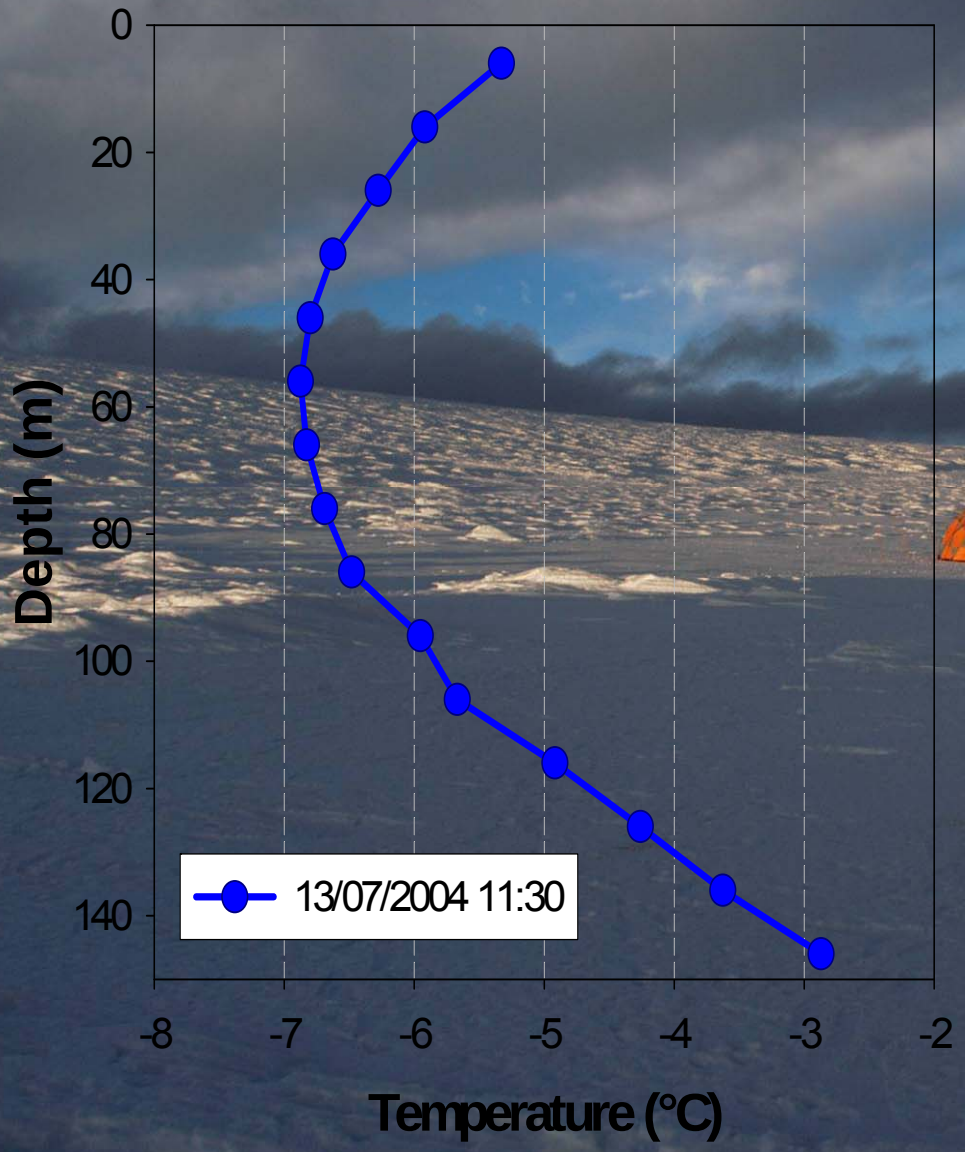
A new 20ky Andean ice core record …???



(*Thompson et al.*, 1998)



Borehole temperature



Thermistor chain 146m:

Installation: August 28th, 2003

First measurement: August 29th, 2003

Last measurement: July 13th, 2004

Surface temperature increase of about +2°C over the last decades

Coropuna Conclusions

1) The use of an ice core as paleoclimatic and environmental archives needs an interdisciplinary approach

2) Surface snow experiments and samplings are essential to define post-deposition effects and understand ice core recorded chemical and isotopic signals

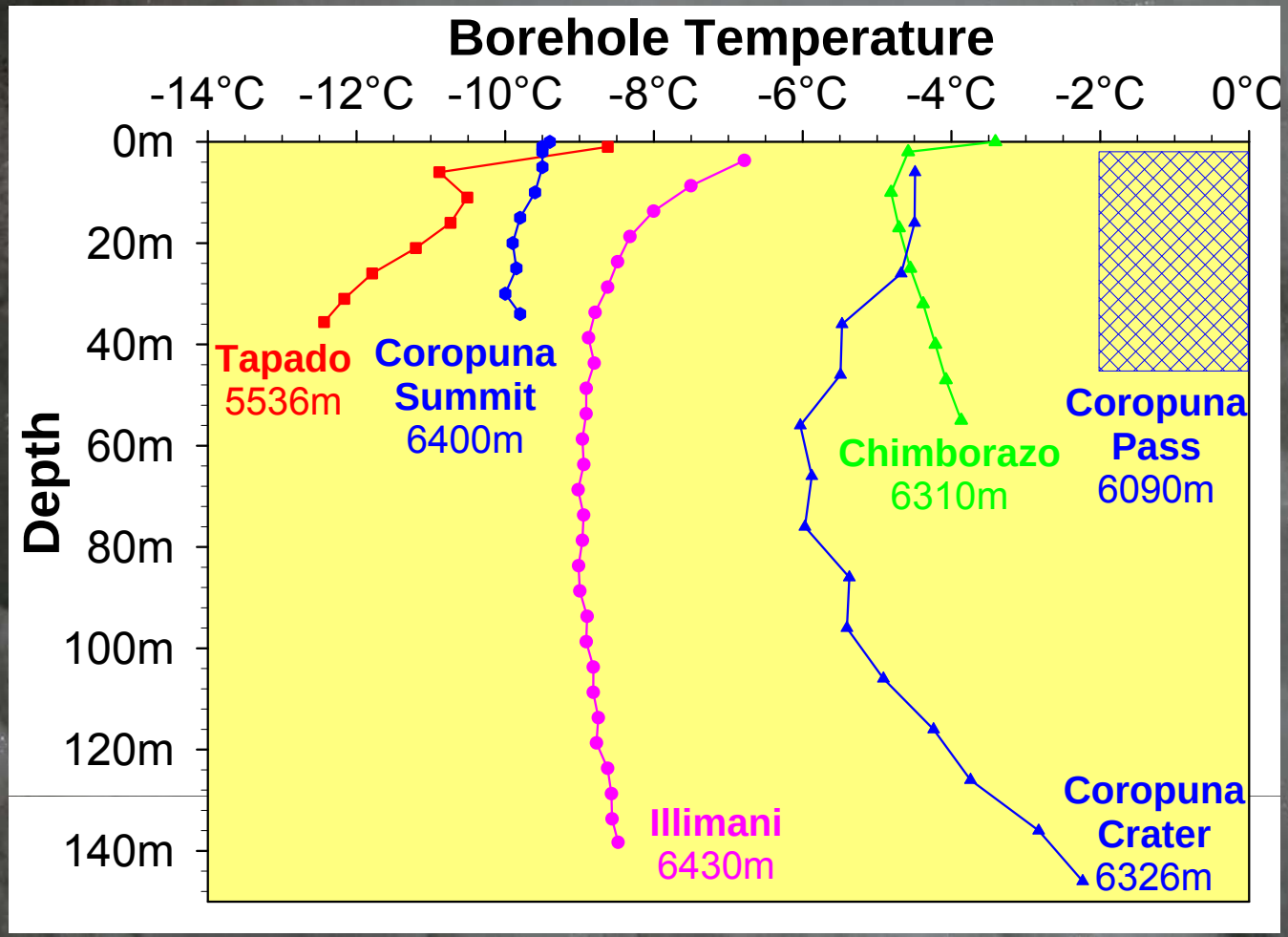
3) Presence of natural water saturated firn over 6000m

4) Drastic change of net accumulation on Coropuna summit around 1990

5) +2°C surface air temperature increase during the last decades

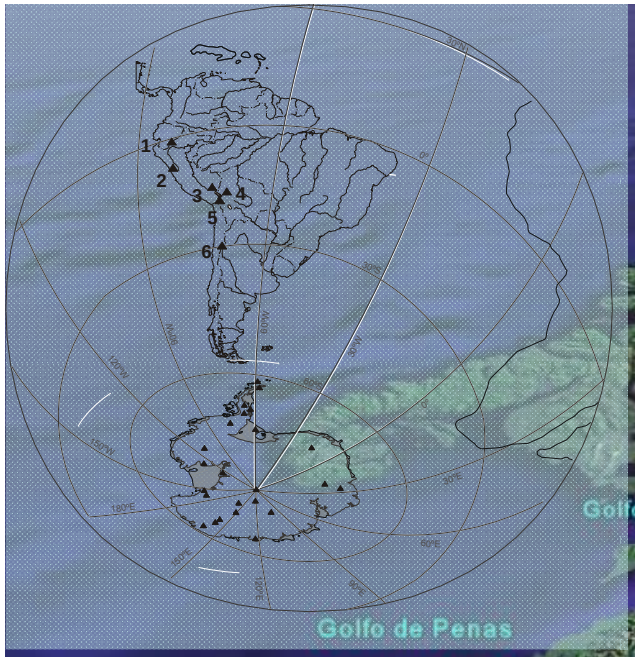
6) The 34m ice core may cover 20ky…

... but these precious archives are melting !

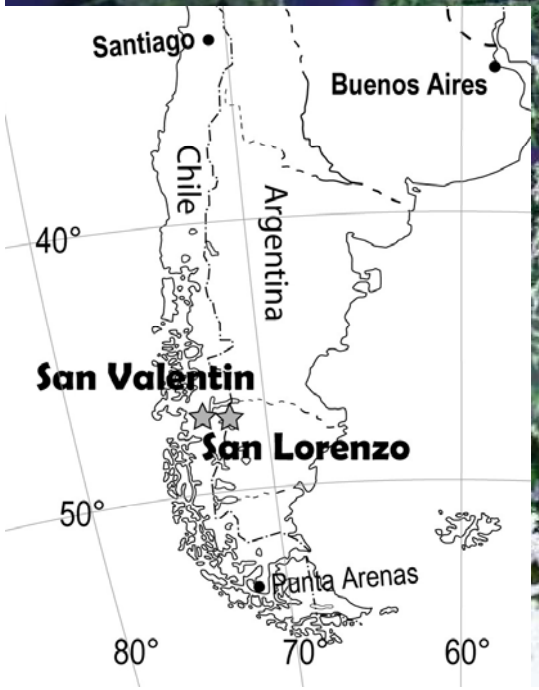


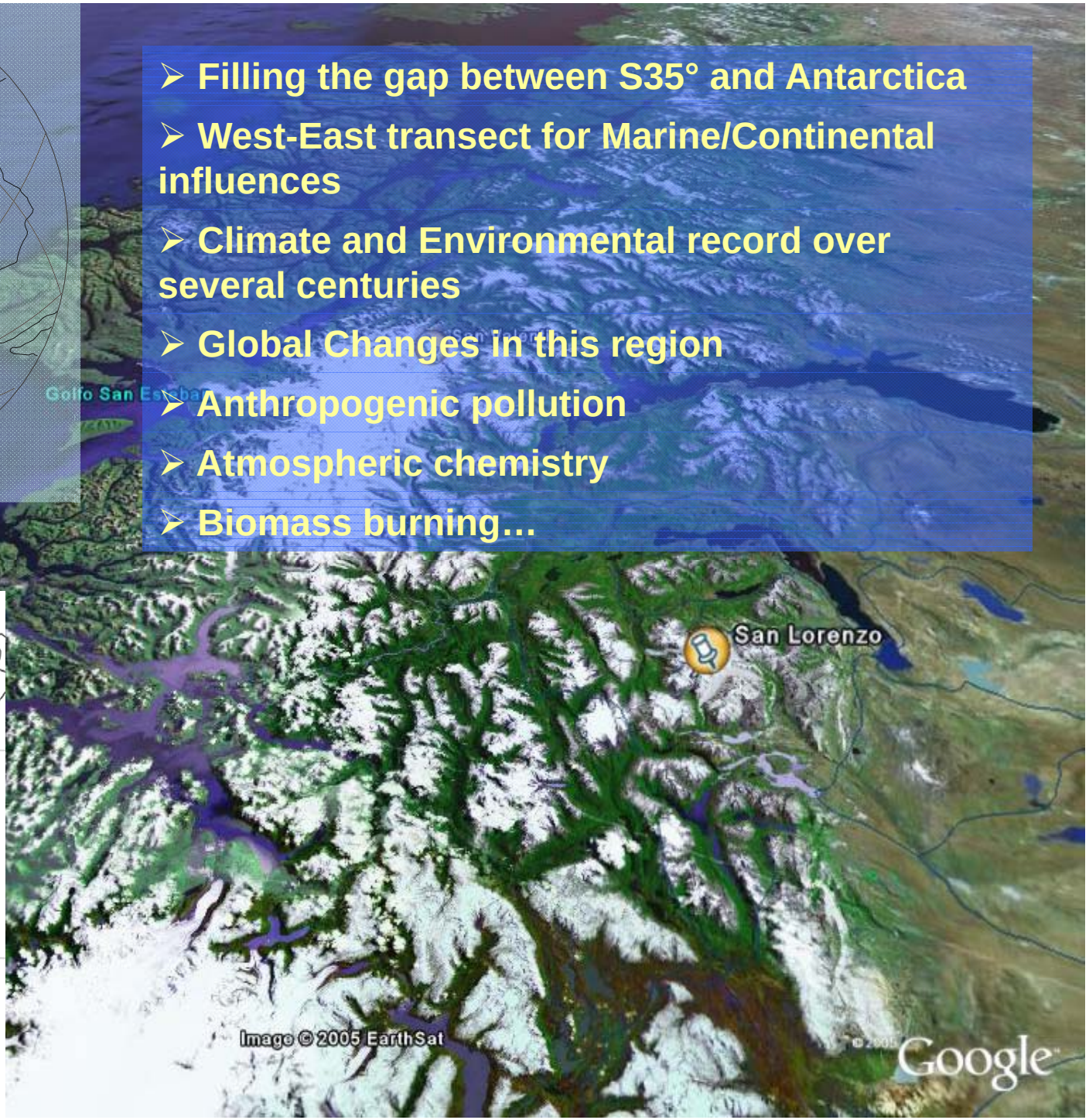

Future projects...
San Valentin (Chile) & San Lorenzo (Chile/Argentina)
Central Andes (Bolivia/Chile/Argentina)

San Valentin (Chile)
San Lorenzo (Chile/Argentina)



- Filling the gap between S35° and Antarctica
- West-East transect for Marine/Continental influences
- Climate and Environmental record over several centuries
- Global Changes in this region
- Anthropogenic pollution
- Atmospheric chemistry
- Biomass burning…



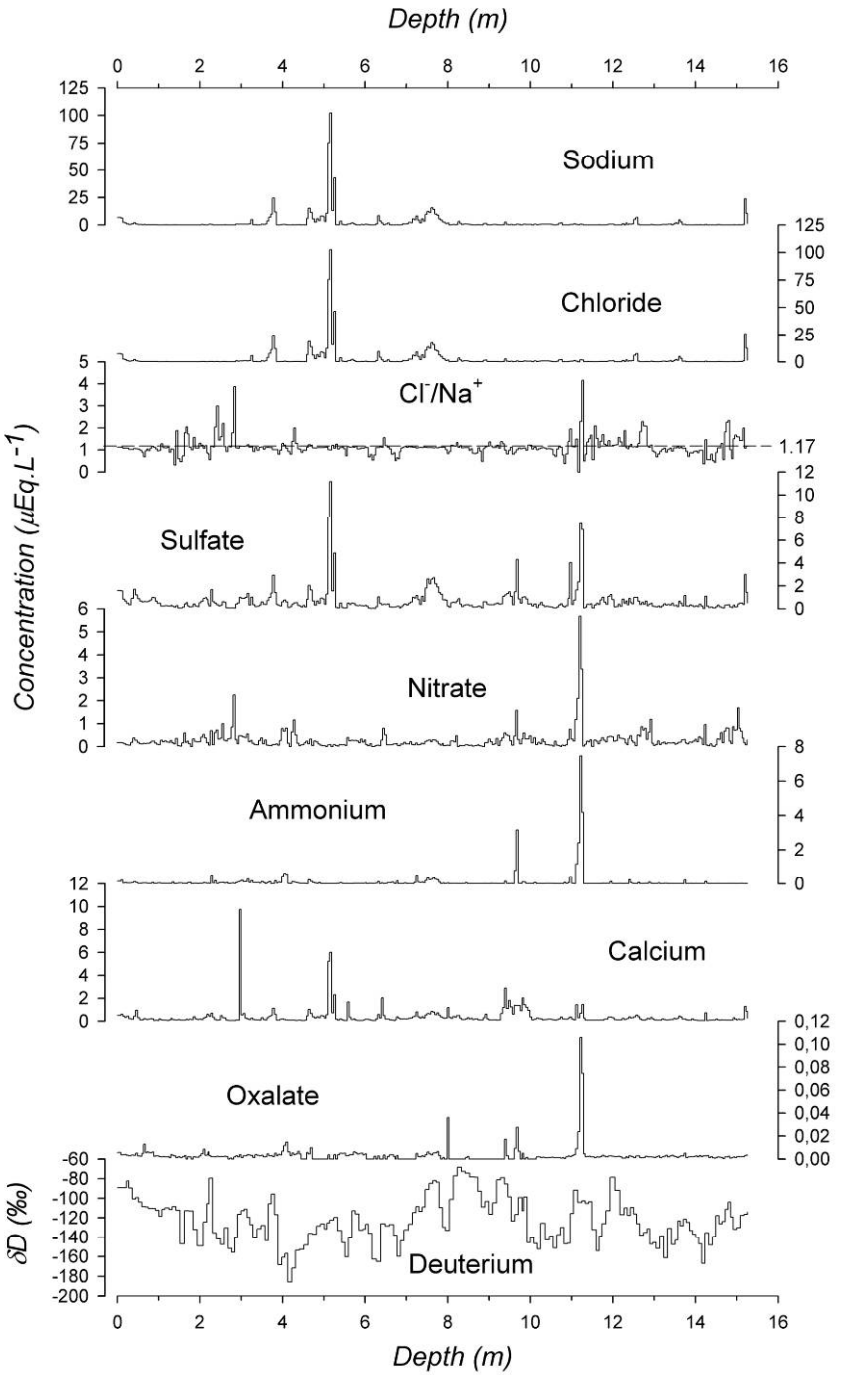


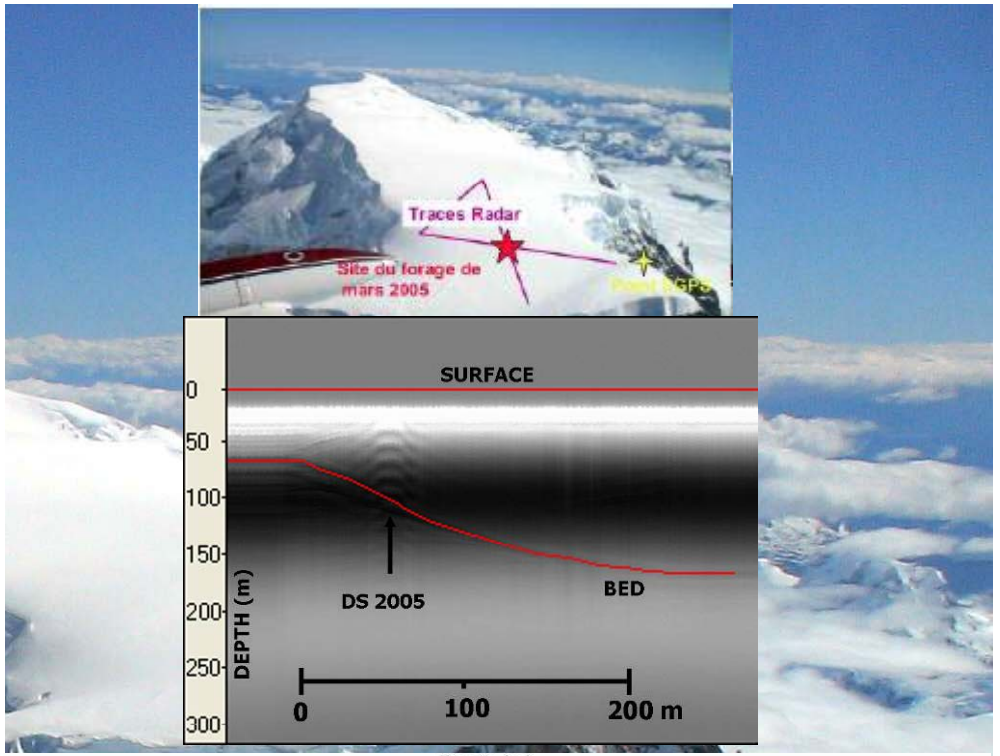

March 2005

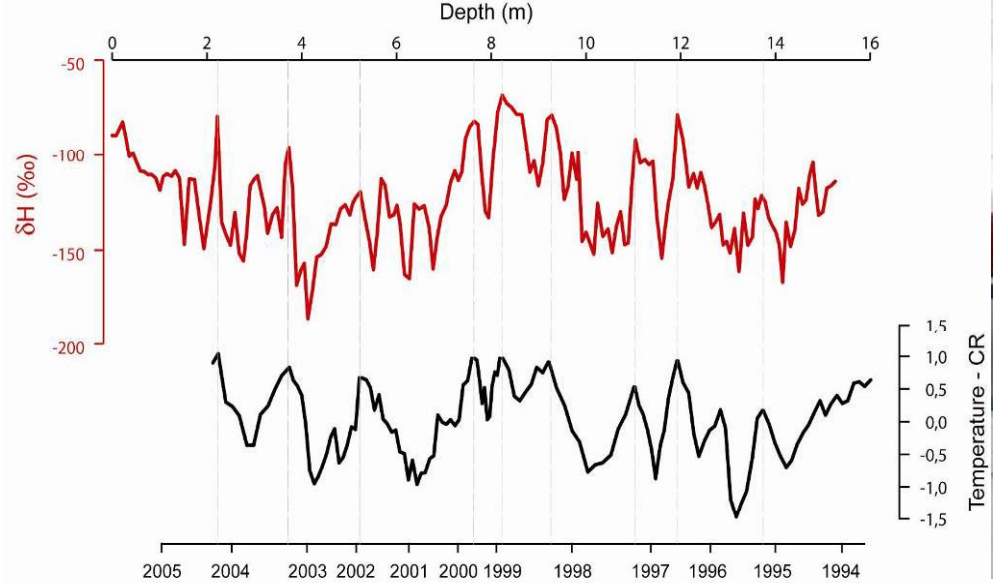

Helicopter transport
C-12


16m shallow drilling


Radar Sounding







Temperature = -12°C at 10m **Accumulation = 700mm/y**

At least 500 years high resolution record

San Valentin (Chile)
San Lorenzo (Chile/Argentina)

- **Deep drilling in March 2006 on both glaciers**
- **Funded by: IRD, French ANR, Chilean FONDECYT (???), etc…**
- **Ice core investigations: France (IRD Great Ice, LGGE, LSCE, LMTG, etc…), Chile (CECS), Argentina (CRISYT-LEGAN), Brazil…**
- **join our forces & resources: cold room installation, analytical devices, knowledge…**
- **“South American Network for Ice Core Investigation”**

San Lorenzo

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40m

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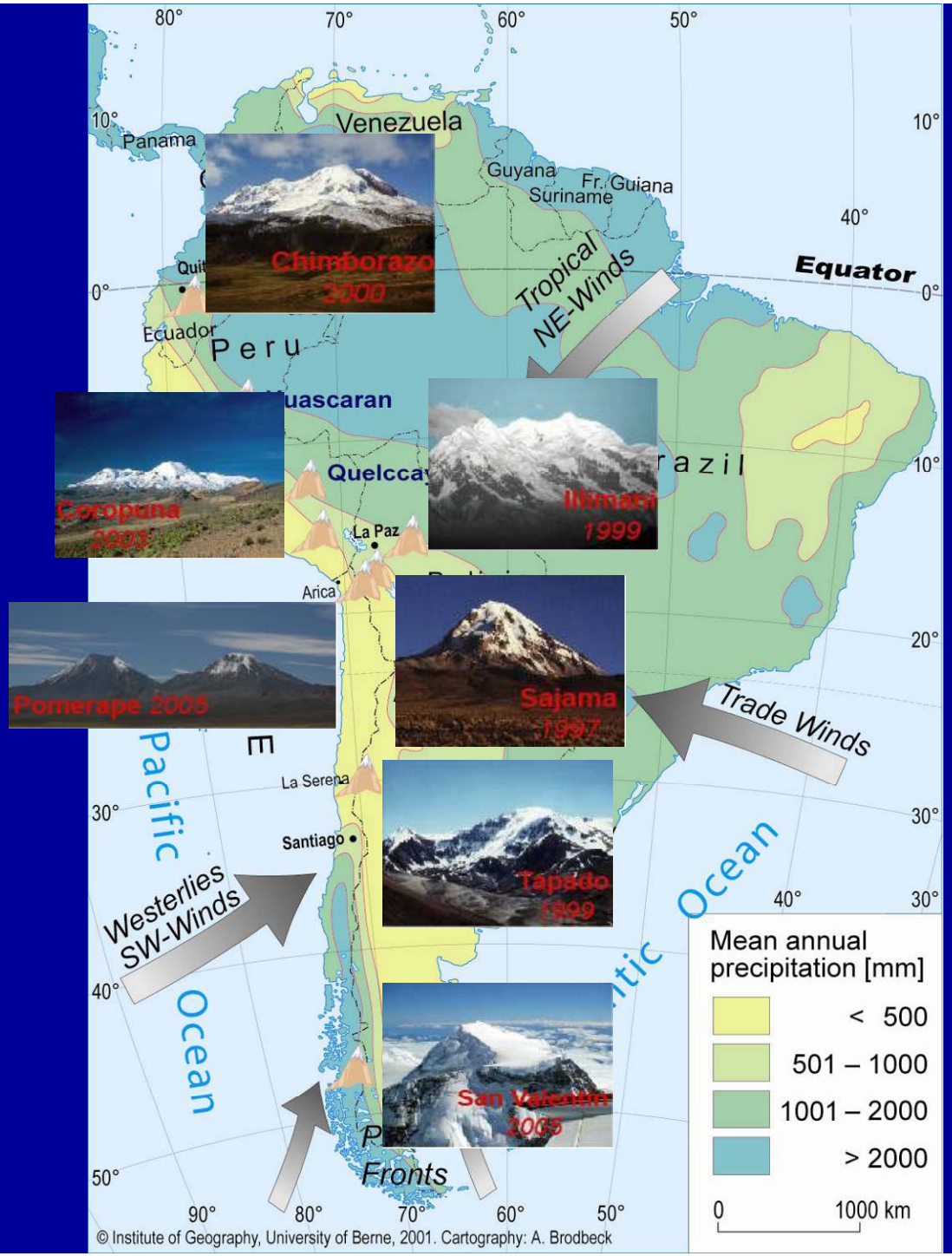

Conclusions

- The IRD has three main missions: research, consultancy and training. It conducts scientific programs contributing to the sustainable development of the countries of the South, with an emphasis on the relationship between man and the environment (*www.ird.fr*)
- IRD *Great Ice* is involved and recognized in Andean Ice Core investigations since 1997.
- We possess or have easy access to important drilling and analytical facilities and experiences since we are currently working with national (*IRD, LGGE, LSCE, LMTG…*) and international (*Berne University, Ohio State BPRC…*) partners laboratories.
- For our future ice coring program in Patagonia and Central Andes, we want to develop and mutualize some drilling and analytical facilities, funding, experiences and knowledge in the Andes in order to increase research levels, publications and formation.

Acknowledgements

- Ambassade de France en Argentine
- Comisión Nacional de Energía Atómica, Buenos Aires, Argentina
- CRISYT / LEGAN, Argentina
- IRD *Great Ice*, France


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