Laboratoire de Glaciologie et Géophysique de l'Environnement

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Observatoire des Sciences de l'Univers de Grenoble

# Cryosphere, Atmosphere, Climate and Anthropic impacts in the Andes: Research structures and observation networks

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IRD
Institut de recherche pour le développement

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# The announced death of Chacaltaya glacier in 2010









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Senamhi

IGEMA

ihh

Universität Zürich[UZH]


*Rabatel et al., Cryosphere, 2013*

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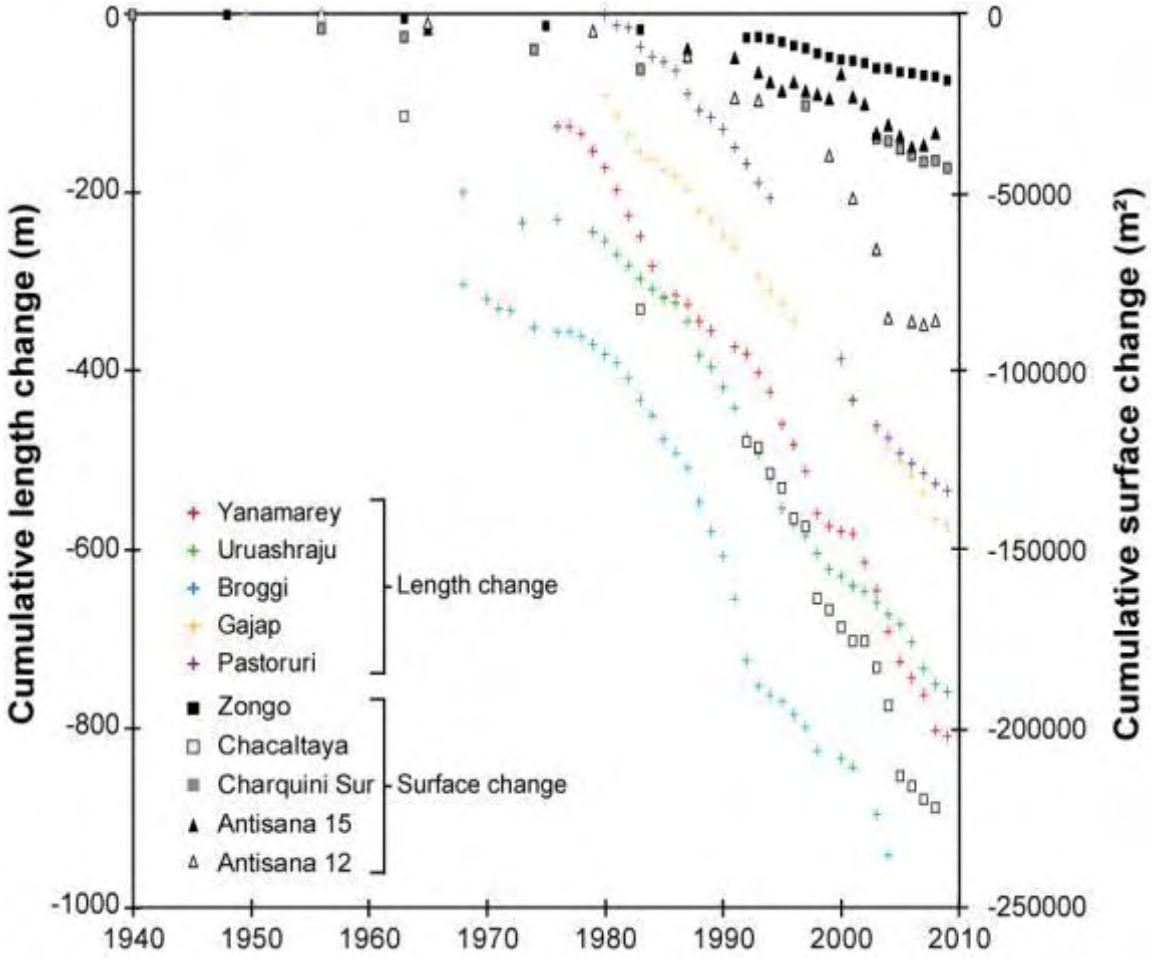
# How glaciers of the tropical Andes changed since the mid-20th century?

**Cumulative length or surface changes in the tropical Andes.**

Clear change in the late 1970s




*Rabatel et al., Cryosphere, 2013*

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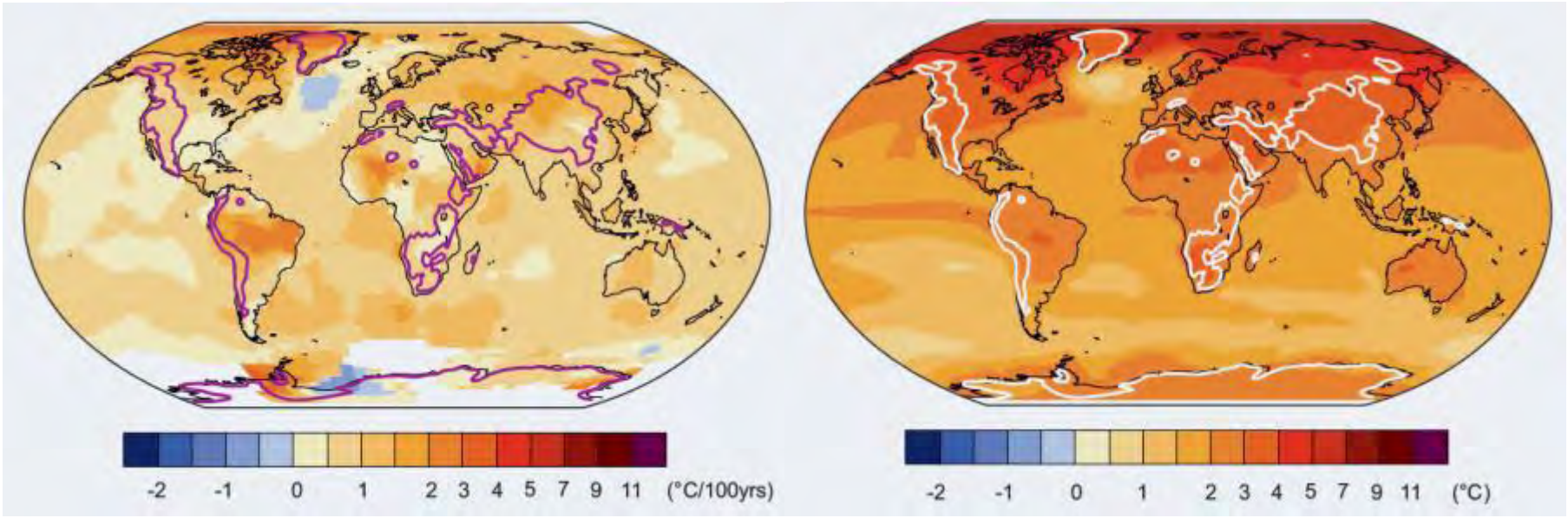
# Linking climate and glacier changes in the tropical Andes

## 1900 to 2013

## 1985–2005 to 2081–2100




**Linear trend in annual mean surface air temperature (left) from 1900 to 2013.**

**Modelled changes in temperature (right) from 1985–2005 to 2081–2100 according to a moderate-to-high emissions scenario (RCP6.0, CMIP5 Atlas subset from KNMI Climate explorer).**

**Purple and white lines indicate topography over 1000 m.**

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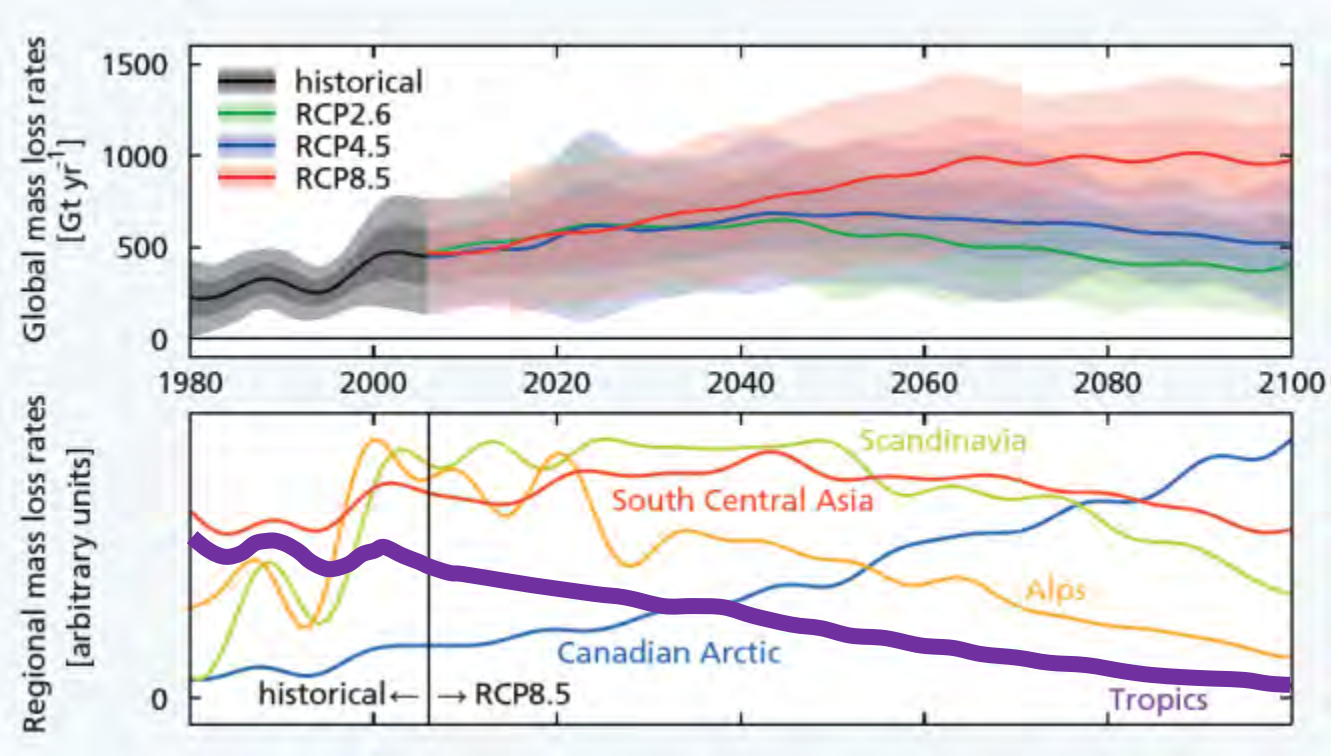
# Linking climate and glacier changes in the tropical Andes

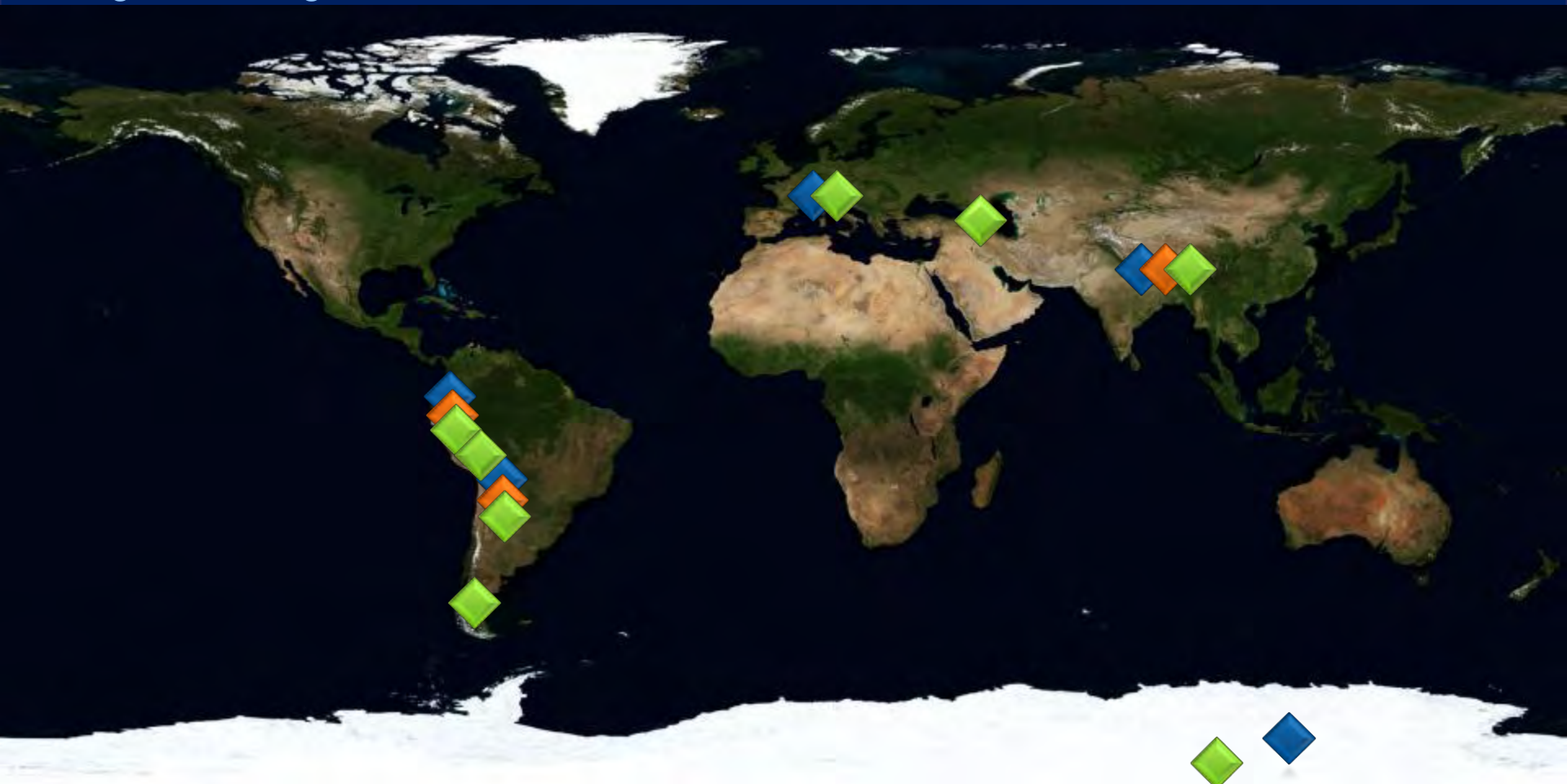



**Reconstructions and projections of global net glacier mass loss rates.**
**The upper panel shows global sums for different climate scenarios, with the solid line indicating the multimodel mean and shading indicating model uncertainty.**
**The lower panel depicts mass loss rates for selected regions. Many regional rates will begin (or have begun) to decline long before the global rate will.**

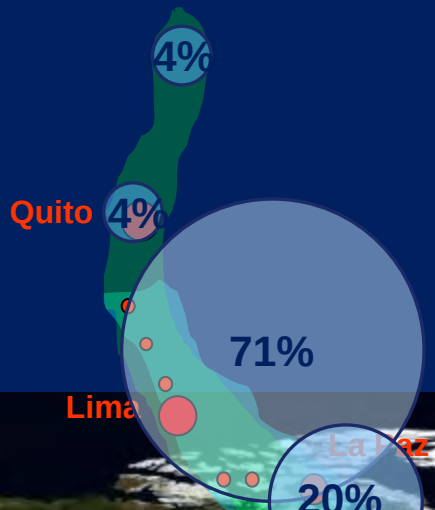
***Marzeion et al., Cryosphere, 2012***

# Main research axes and worksites

- document and understand the recent **evolution of the cryosphere in mountain basin** in link with the **climate change**
- quantify the **water resources** of the mountain basins by taking into account snow and glacier contribution in the context of **anthropogenic modifications**
- reconstruct past climate and environmental changes using **ice core archive** from high altitude glacier

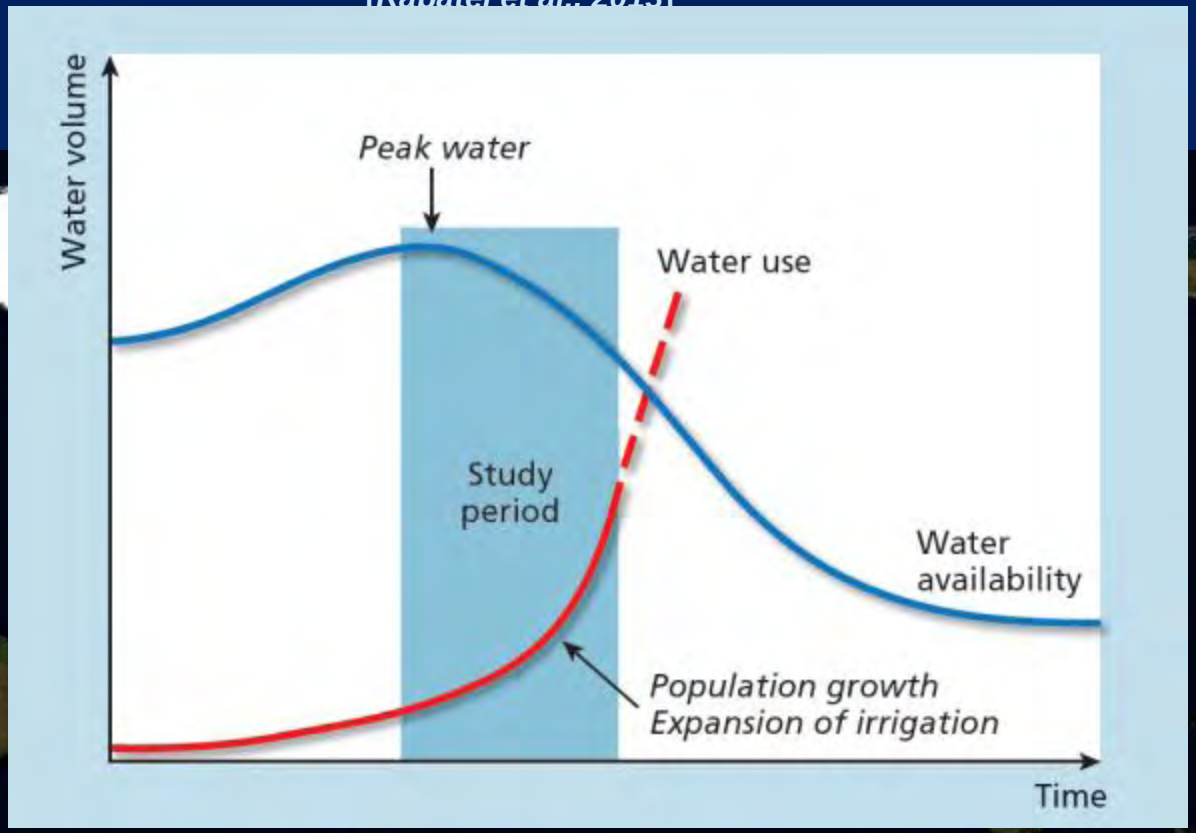


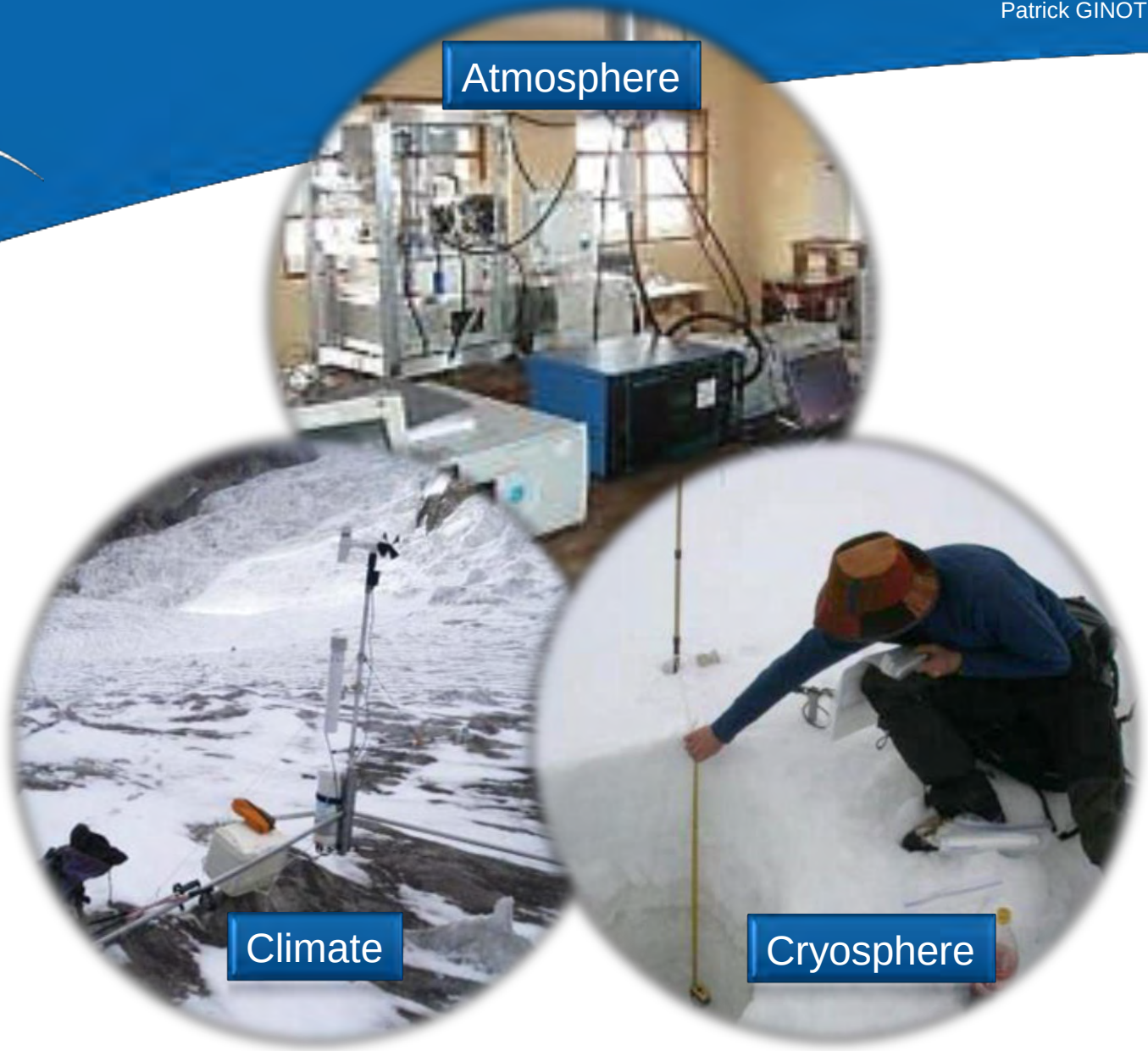
# Glacier distribution in the tropical Andes




**Glacier surface (2000s) : 1900 km²**

*[Rabatel et al., 2013]*






# Reseach based on Observation Networks

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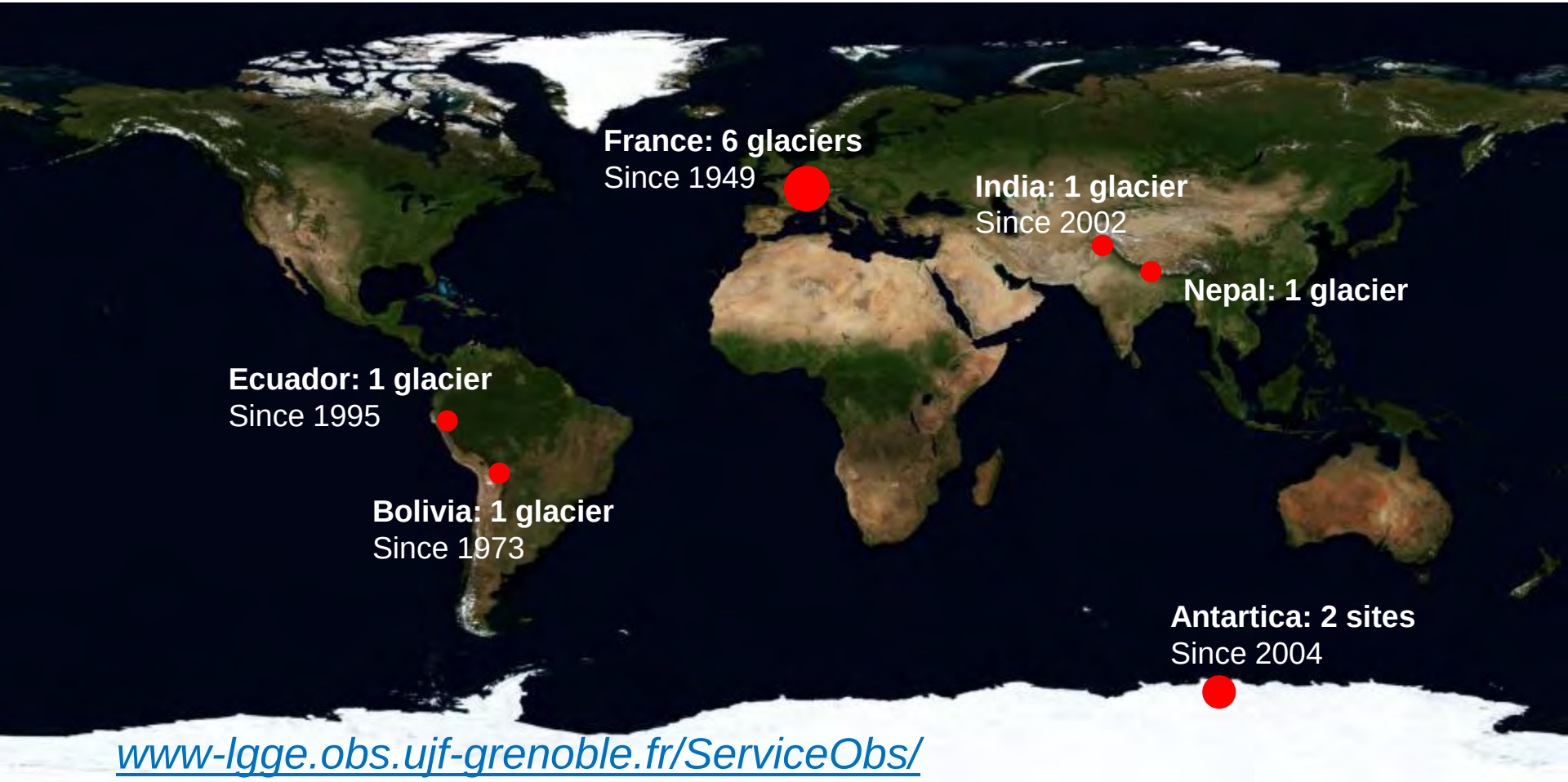
# GLACIOCLIM

## A network of ‘Reference’ glaciers…




www-lgge.obs.ujf-grenoble.fr/ServiceObs/

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GLACIOCLIM

## … strongly supported and funded…

**Who?** **~20 persons** (from France, Bolivia, Ecuador, India, Nepal) + students & post-docs

**Funding?** **~700 k€/yr** (including salaries and logistic costs)

## Links with the international community

Global Cryosphere Watch

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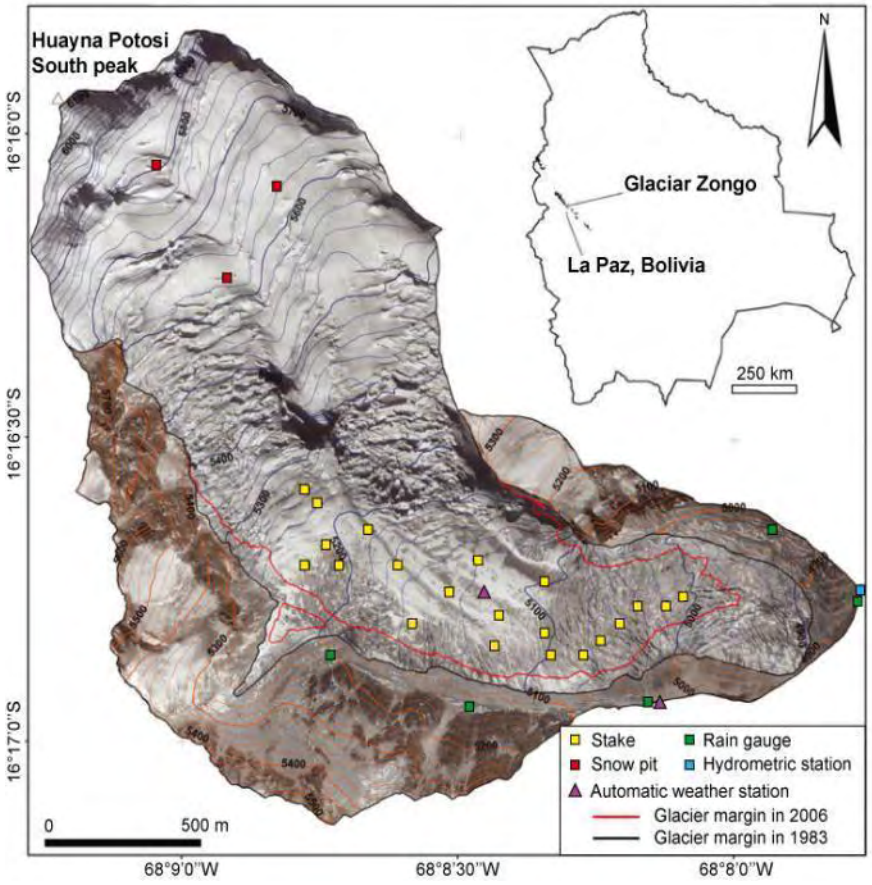
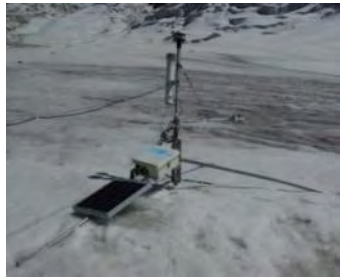
# … with extensive long term *in situ* observations …




Zongo Glacier, Bolivia (tropical Andes)

Surface mass balance
Topographical survey



Surface energy balance
Meteorological monitoring

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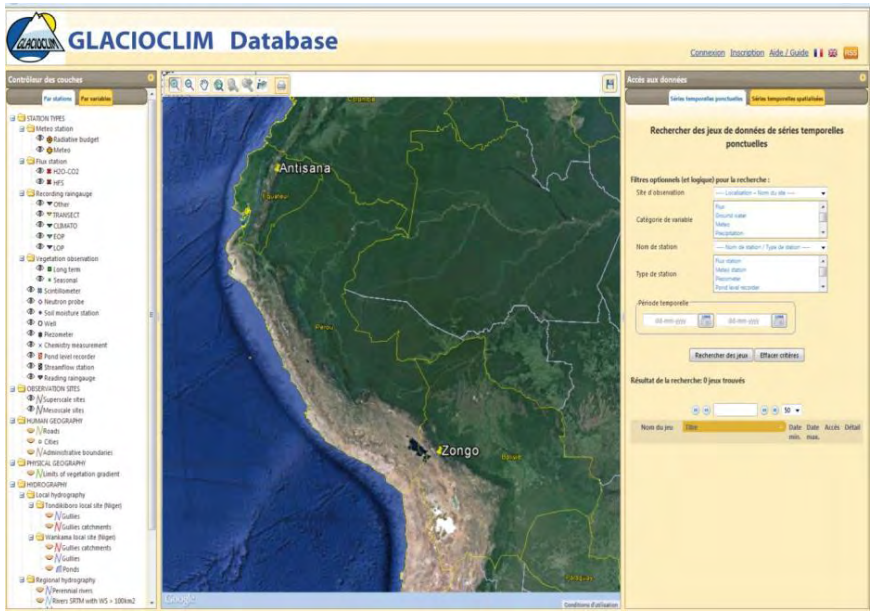
# … Freely available data

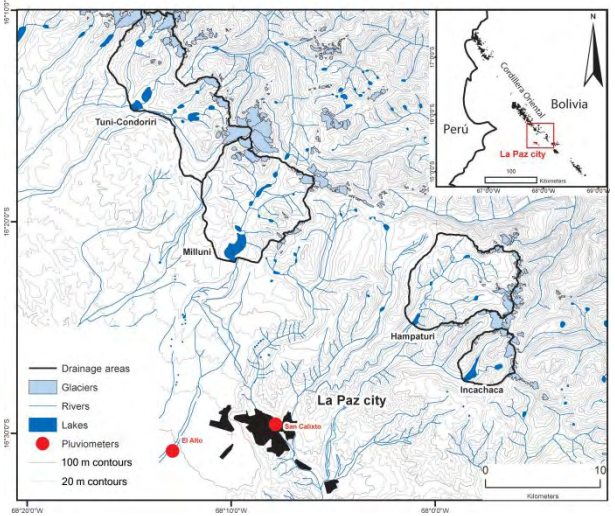
## GLACIOCLIM website

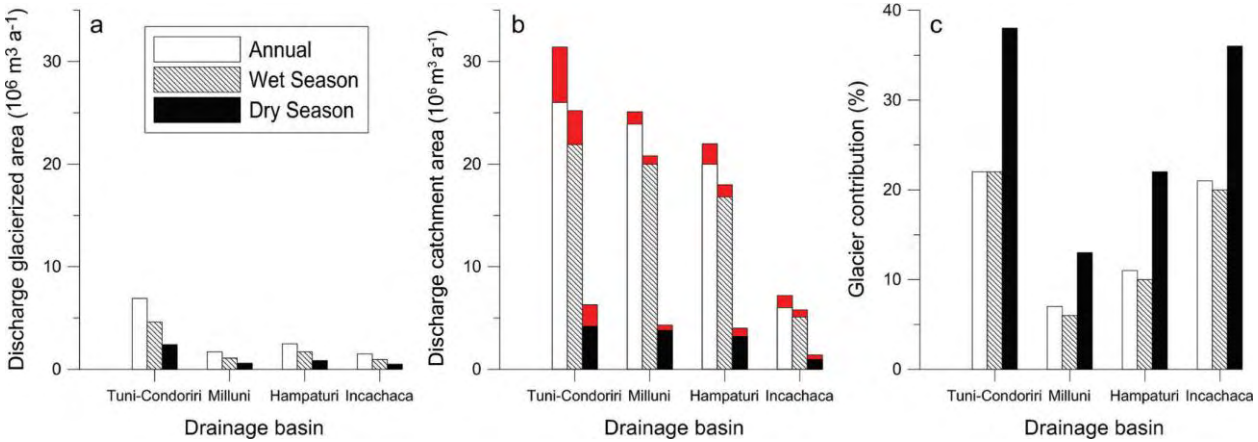
## www-lgge.obs.ujf-grenoble.fr/ServiceObs/

**Released in summer 2015**



# Contribution of glacier runoff to water resources of La Paz city, Bolivia (16° S)




**With complete glacier disappearance:**

**-12% annual scale**

**-9% wet season**

**-24% dry season**

***Soruco et al. 2015***

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# GlacioClim structure

**Organismes de tutelle du S.O.**
Univ. J. Fourier – Grenoble 1, CNRS – INSU / SIC, IRD, IPEV,IRSTEA

**Organisme de tutelle du S.O.E.R.E.**
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**S.O. / S.O.E.R.E. GLACIOCLIM**

- Volet Alpes
- Volet Antarctique
- Volet Andes
- Volet Himalaya

**L.M.I. GREAT ICE**

| Pérou | Colombie | Bolivie | Equateur | Népal |
|---|---|---|---|---|
| ANA | IDEMA | UMSA | INAMHI | ICIMOD |
| UGRH | | IHH | | |
| SENAMHI | Univ. Medellin | UMSA IGEMA | EPN | Univ. Katmandu |
| IGP | | COBEE | EPMAPS | NAST |

IRD JEAI GRANT 2007-10

IRD JEAI IMAGE 2009-12

**Réseaux internationaux**

wgms

GCW Global Cryosphere Watch

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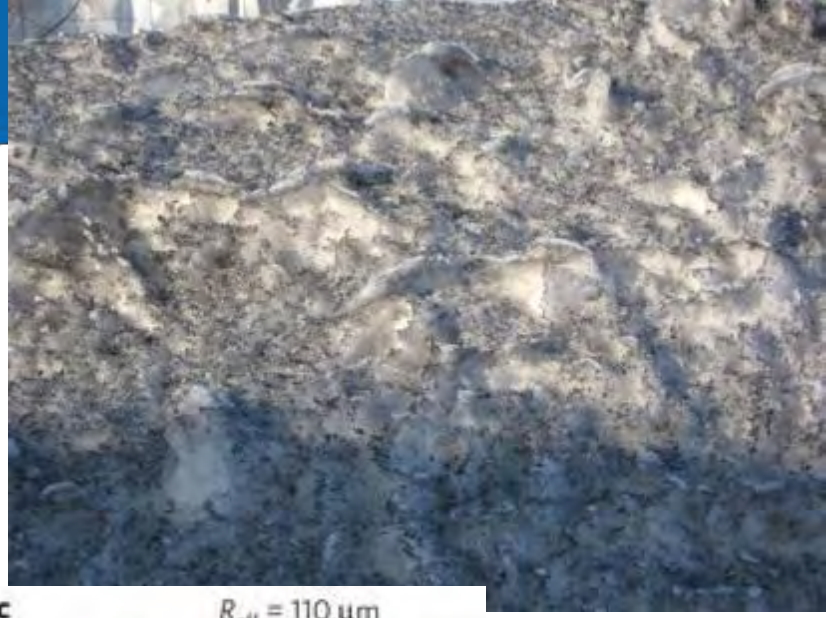
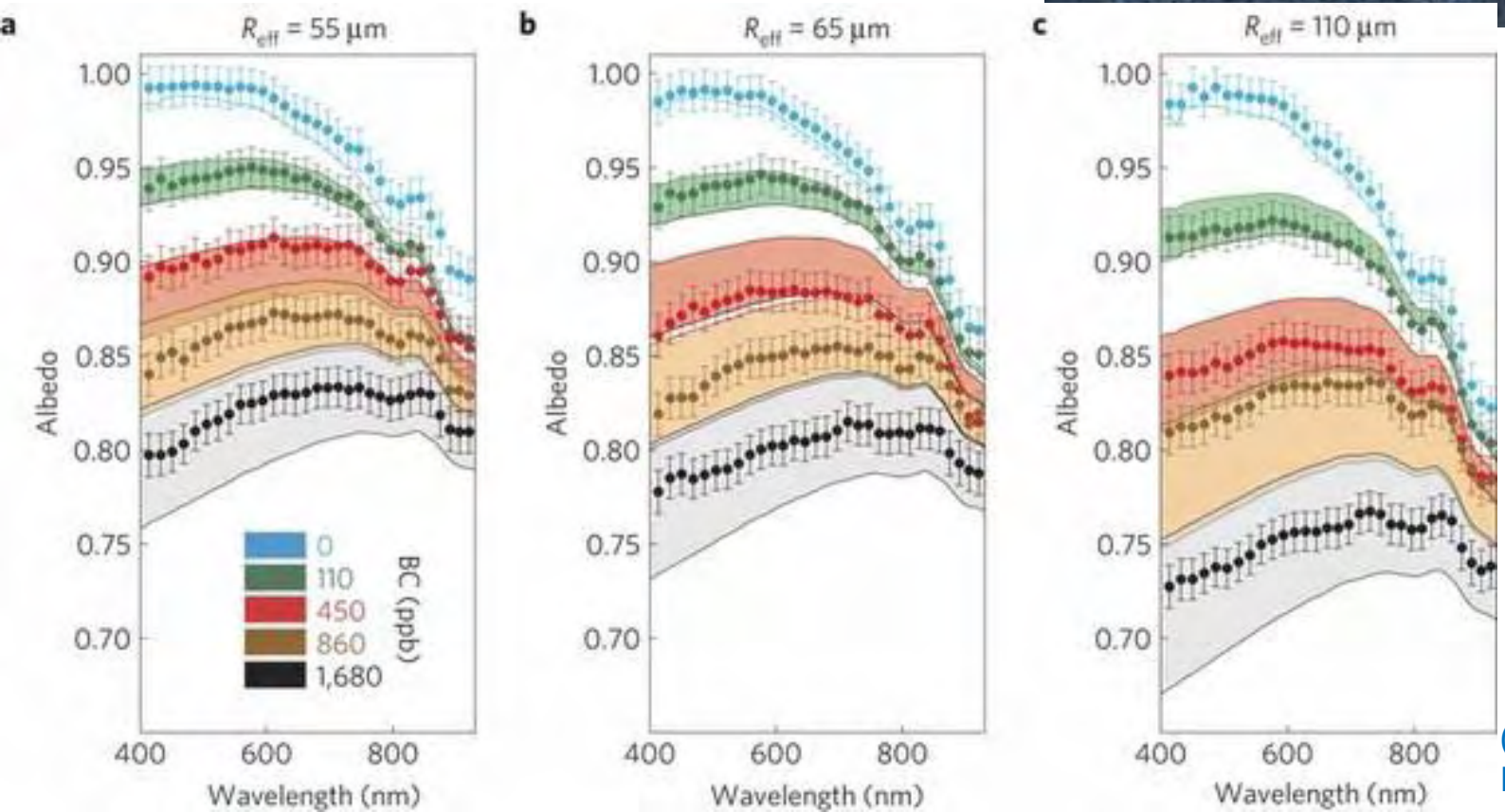


# Black Carbon increases snow/ice melting




(*Hadley et al.*, 2012)
In Science

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# Black Carbon emission in South America increase since decades

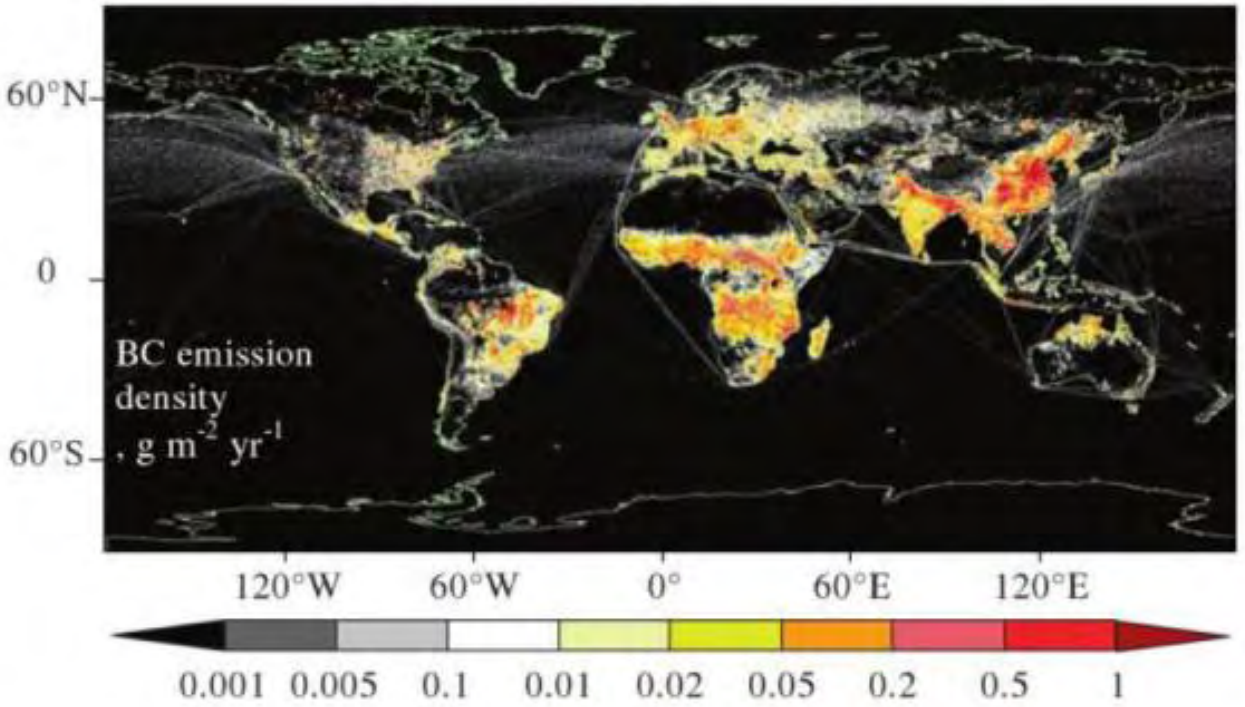
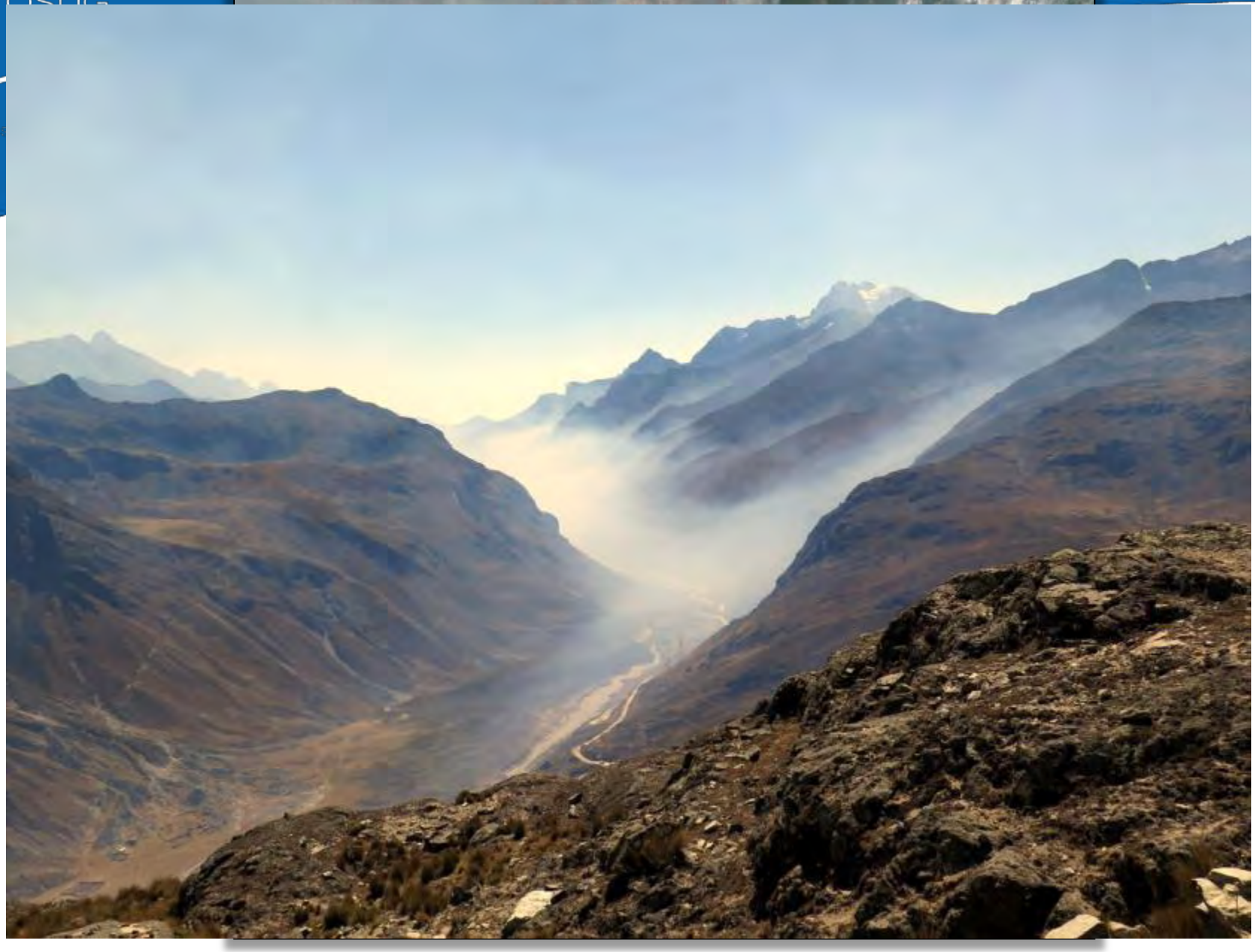



**Fig. 7.2** Spatial distribution of BC emission in 2007 according to the PKU-BC-2007 inventory at a resolution of 0.1° × 0.1°. Reproduced with Permission (Wang et al. 2014a)



Smoke transported above Andean mountains


Escorpion
Glacier melting
health
tems
Biomass burning
09.09.2010

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# Chacaltaya (CHC)

## A "Global Atmospheric Watch" (GAW) Station in the high Andes

## Running since 2011

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## «CLimate relevant Aerosol Properties from near surface Observations » – CLAP

**Objectives:**

- **observe and study atmospheric aerosol**, with the aim to understand its sources (natural / anthropogenic, primary / secondary), and its climate impact (direct and indirect)

- **target variables** are: the concentrations of particles (number per size range), chemical composition, and their optical properties (absorption, scattering)

- on sites (1) of **regional and global relevance** operated in whole or in part by French teams and (2) that have demonstrated their ability to conduct observations over long periods

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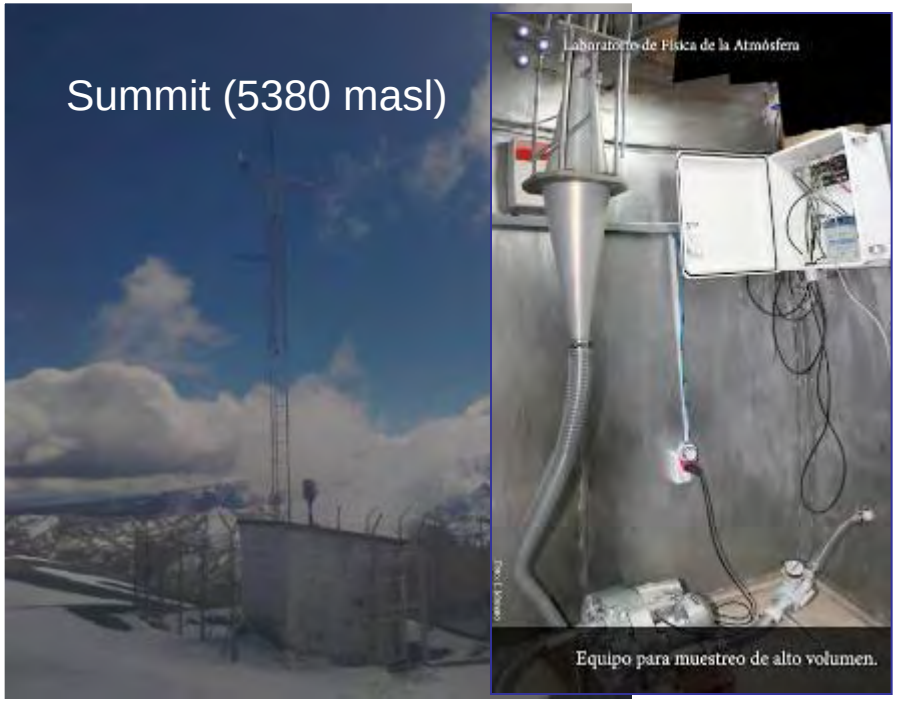
# GAW/CHC Chacaltaya Station (5240 masl)





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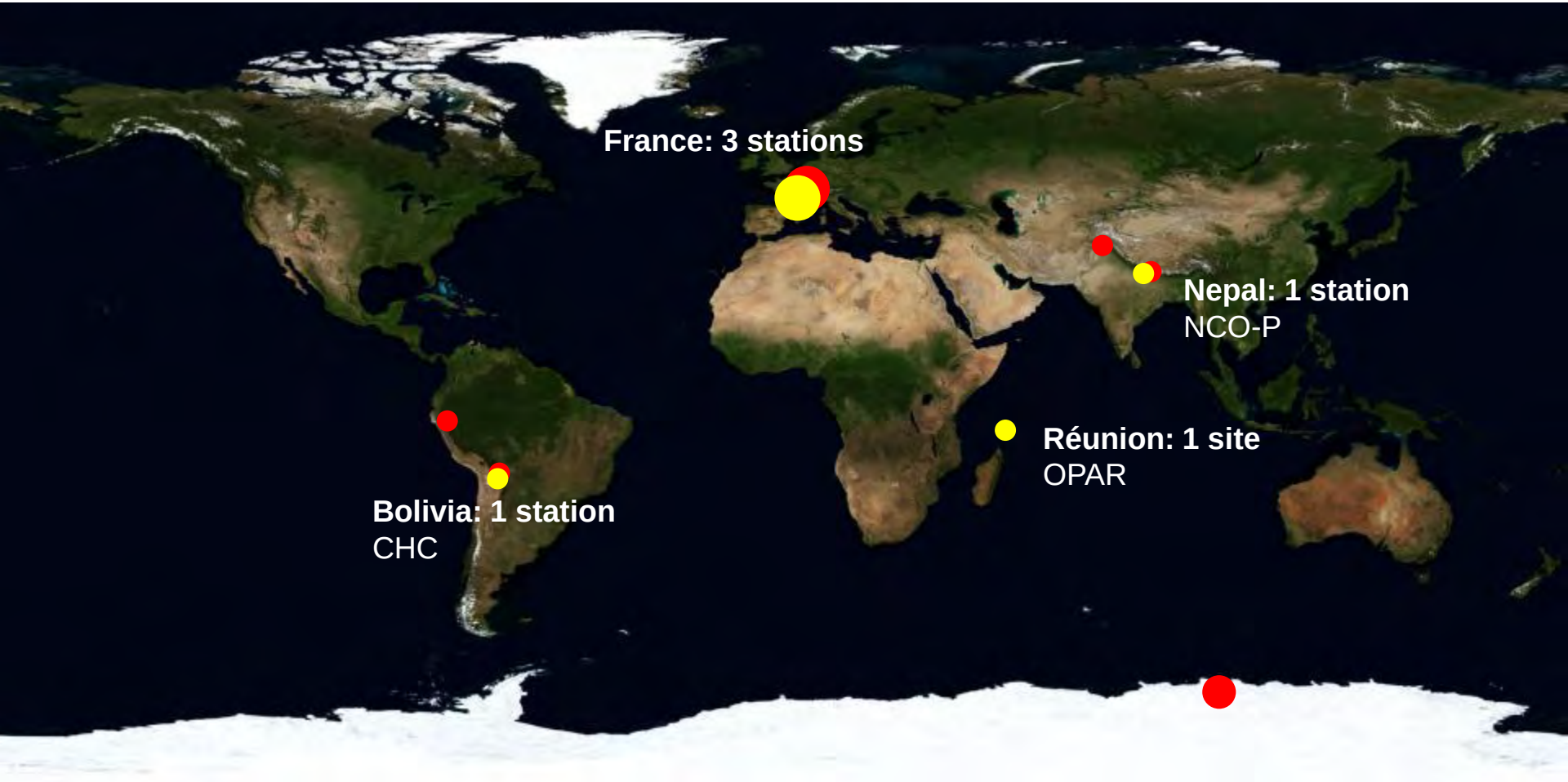
# SO-CLAP atmospheric monitoring stations



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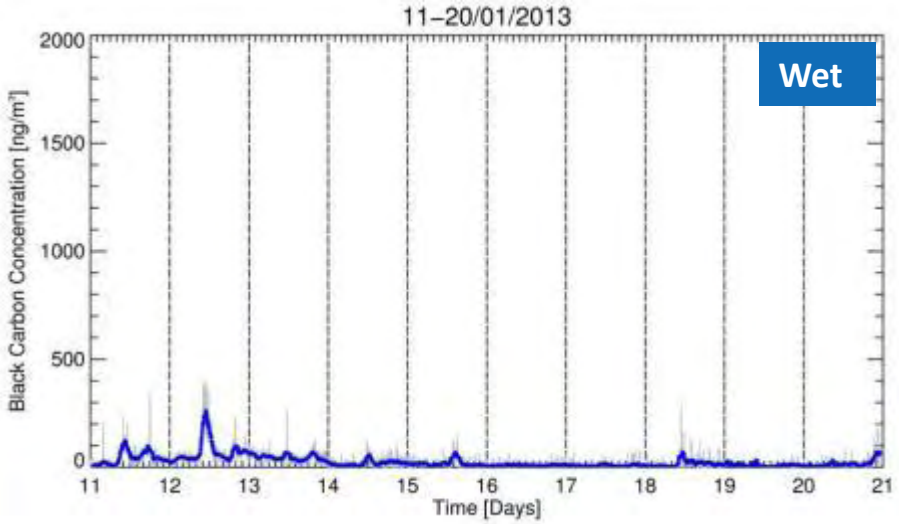
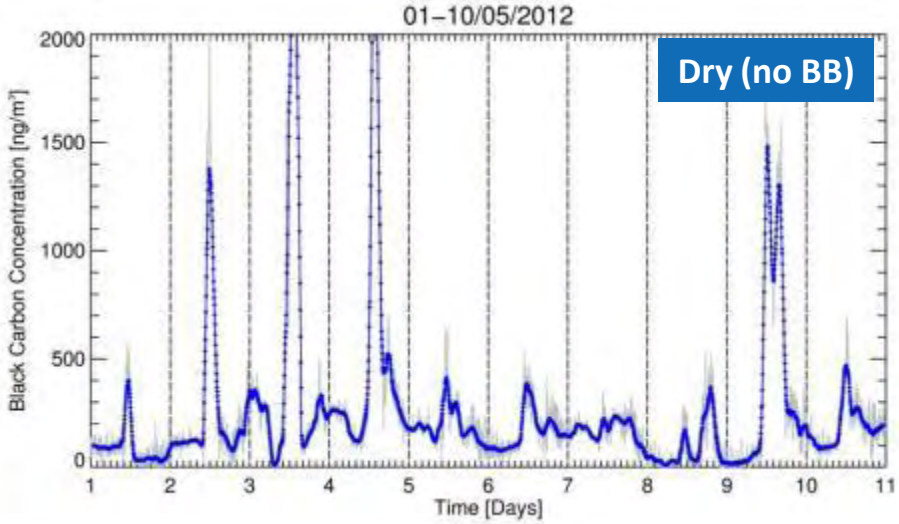
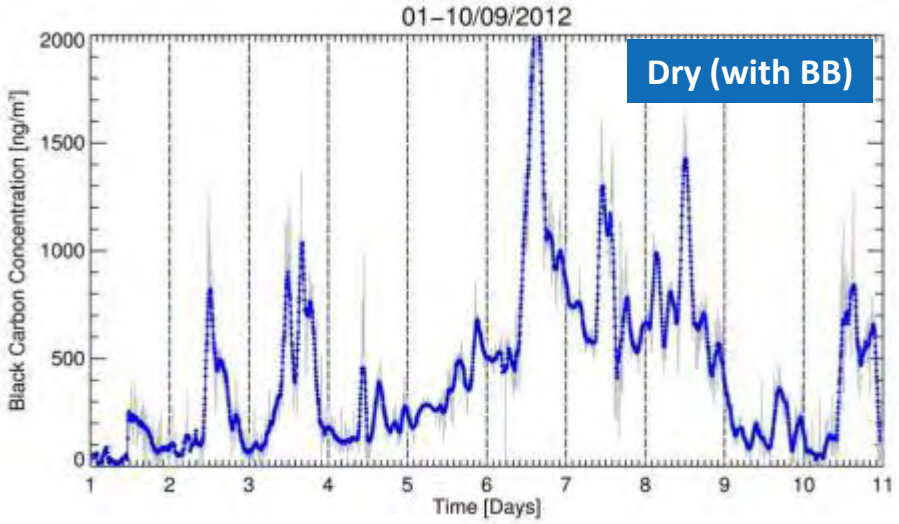
# Atmospheric Black Carbon



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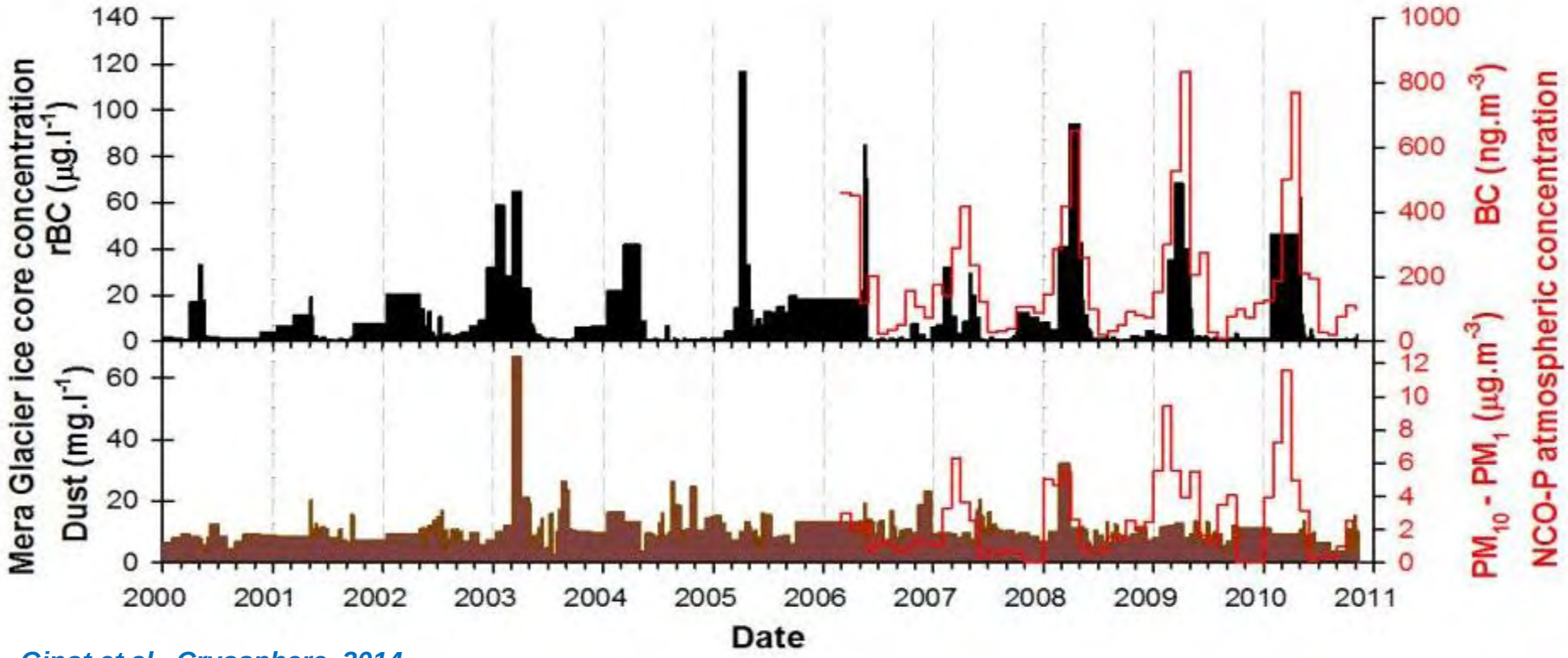
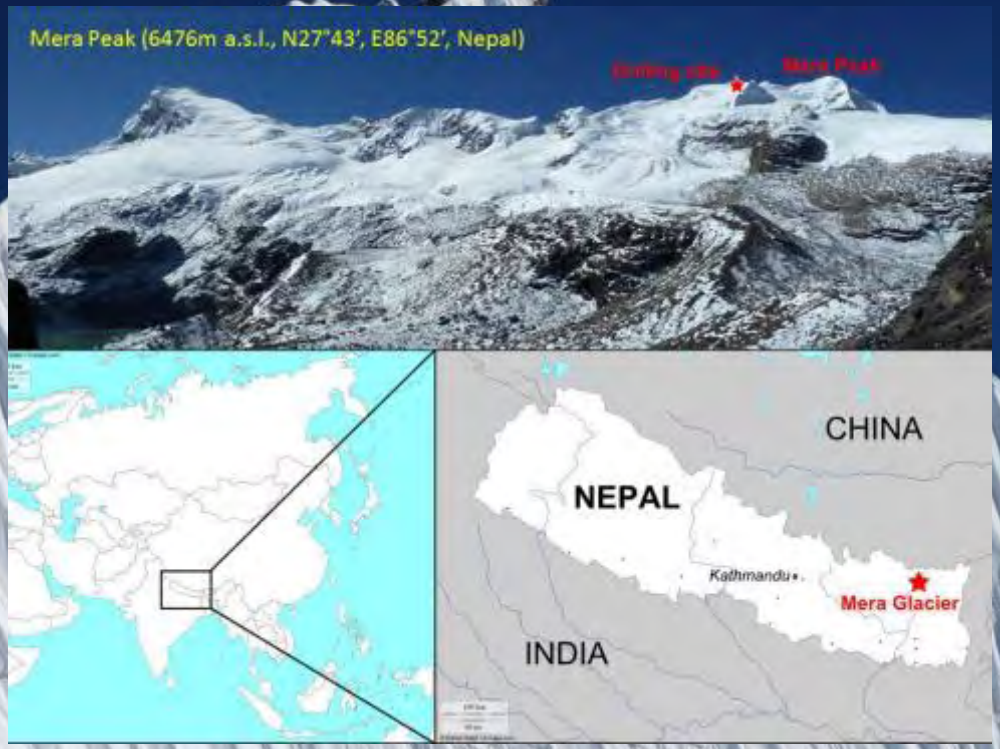
# Comparison between atmospheric and ice core concentrations (NCO-P station Nepal)




*Ginot et al., Cryosphere, 2014*

# Black carbon and dust impact on Himalayan glacier melting




- At 5400m, impurities controls 12-23% of melting, when rBC alone accounts for 5-9% only
- On whole Mera Glacier, rBC **increases melting of 1- 5%**
- **Melting can occur over 6000m**

Ginot et al., The Cryosphere,

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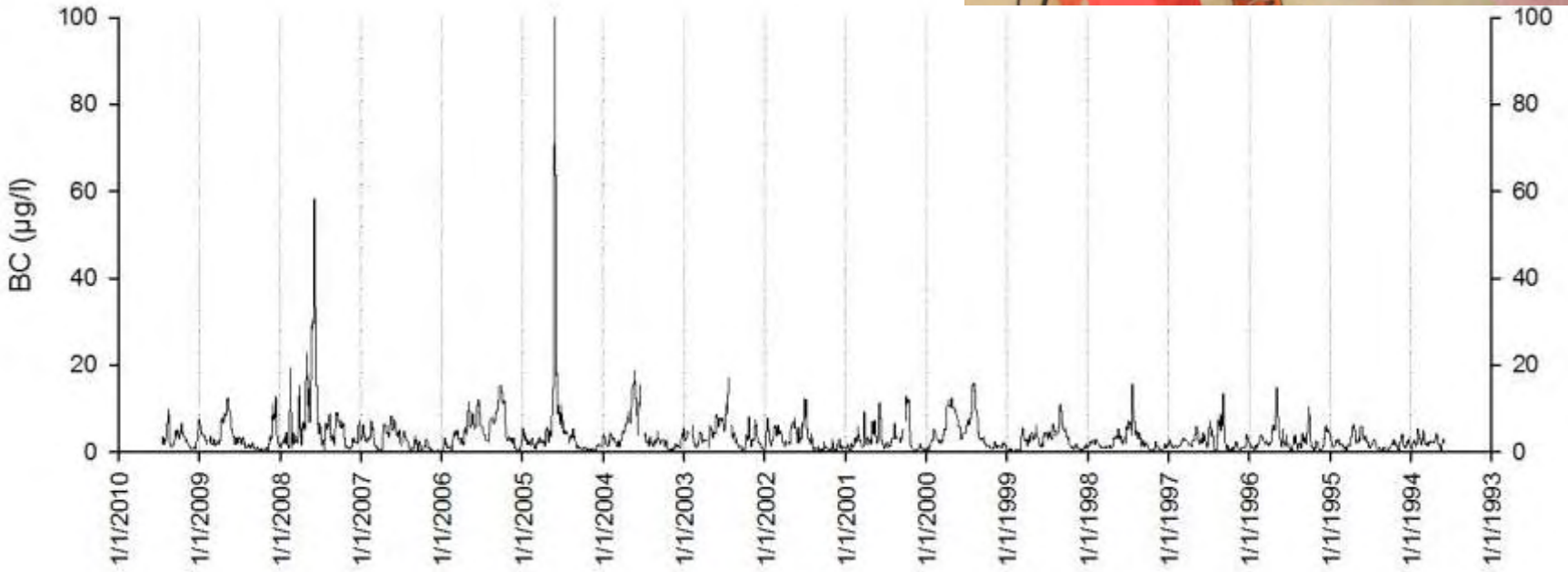
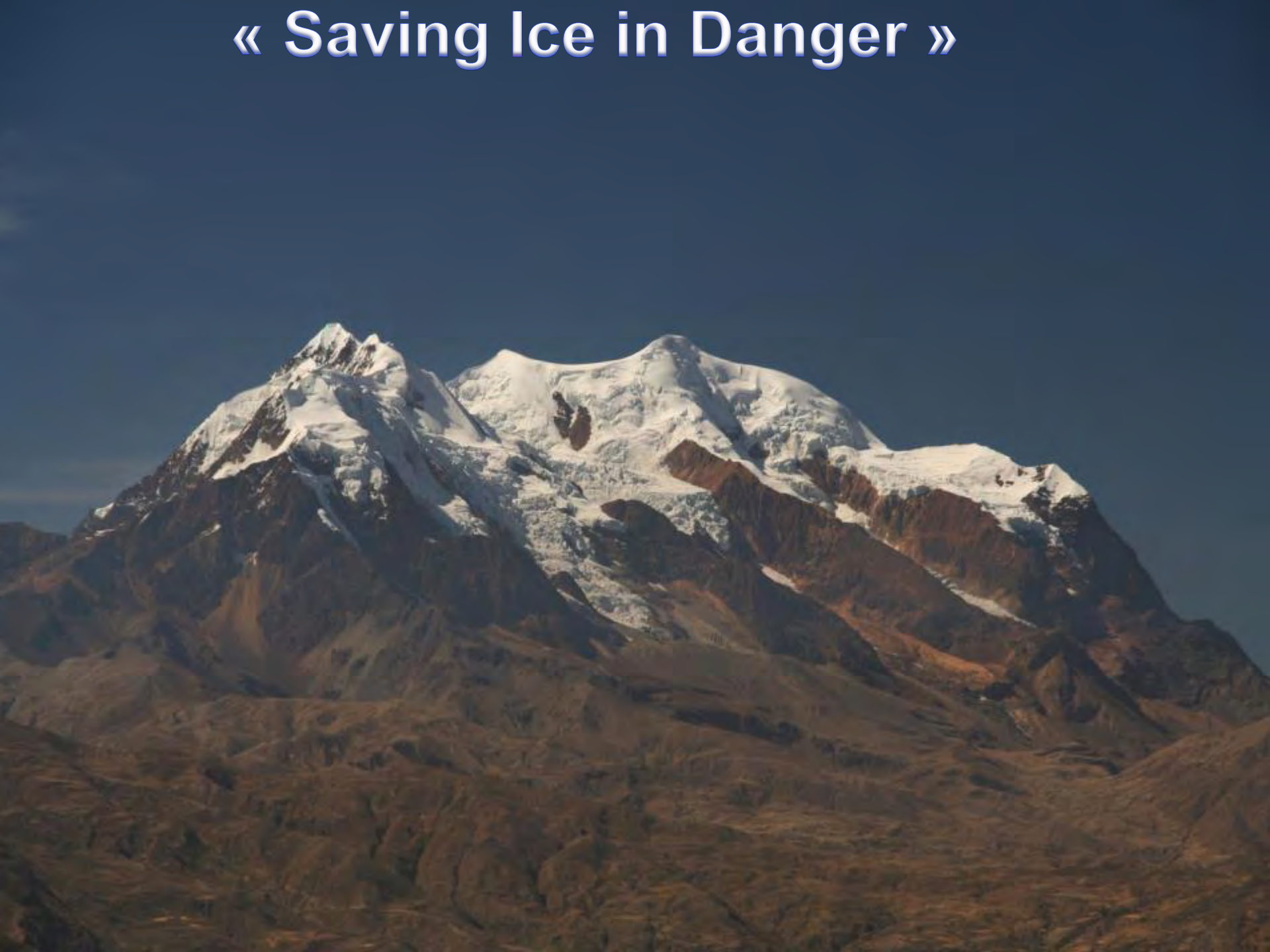
## Black Carbon at 6300m in **Illimani ice core**
## - similar to Himalayan glacier levels

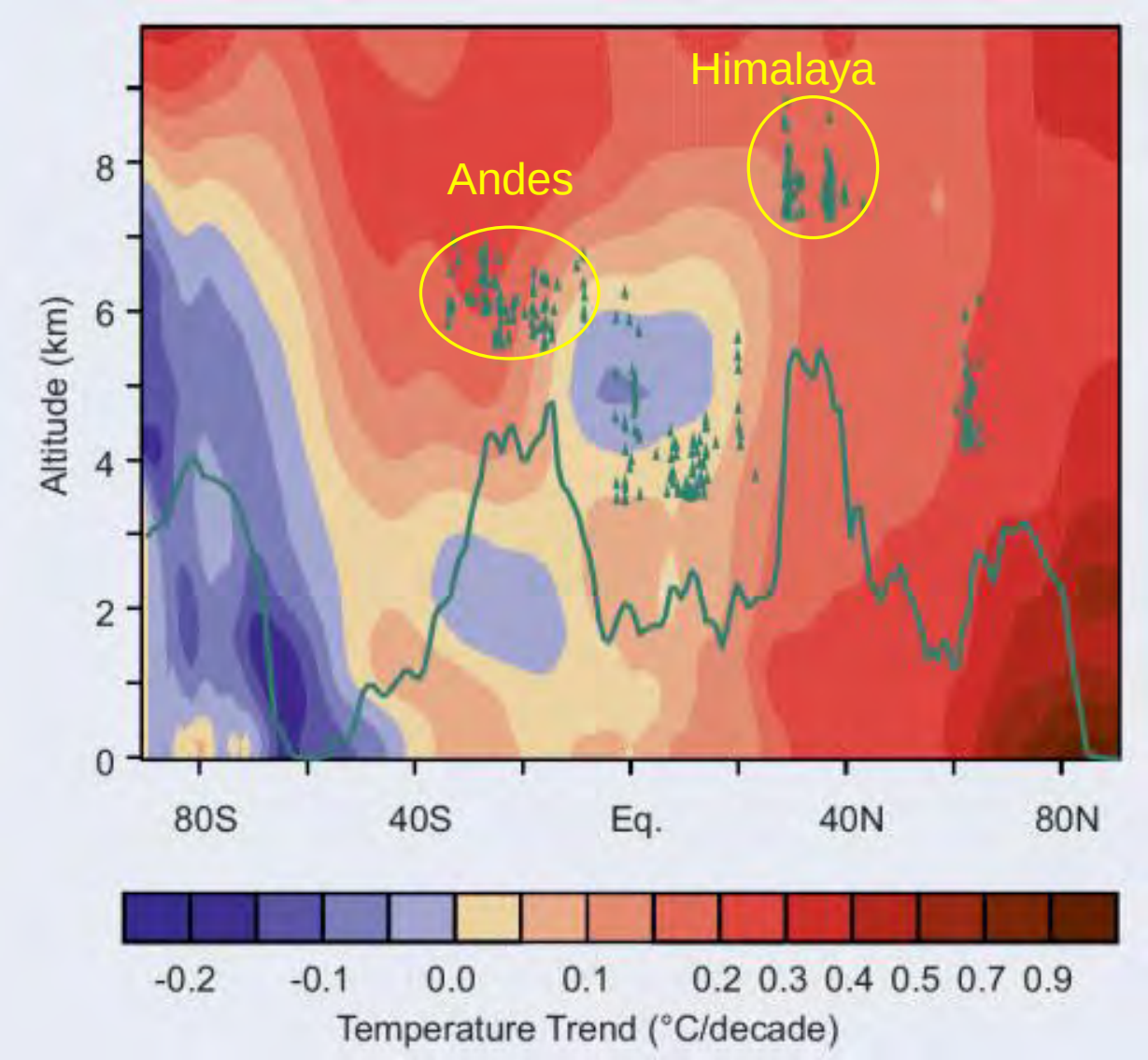


# « Saving Ice in Danger »



# « Saving Ice in Danger »






**Linear trend in zonal annual mean temperature from 1979 to 2013.**
**The green line denotes the heights of large mountain ranges (e.g. Andes ca. 4 000 m near 20° S, Tibetan Plateau ca. 5 000 m near 30° N); individual peaks are shown as green triangles.**
**Data source: ERA-Interim reanalysis**

# « Saving Ice in Danger »

- Warming of non-polar glaciers pushes them toward temperate conditions, unsuitable for climate/environmental reconstructions.
- “Ice cores” are the main climate archives which will disappear forever from the Earth’s surface

- It is our responsability as scientists to preserve good quality ice cores from some of these glaciers, to be used in the future
- Propose a concerted international strategy for recovering and storing new ice cores

FONDATION

Université Joseph Fourier

# Saving Ice in danger

**Help us compile a unique archive of Ice core records, a truly world-class Global Climate Legacy to be handed down to future generations**

## The ice tells the story of our climatic and environmental past

Glacial ice holds a wealth of information about past changes in climate and the environment, such as variations in temperature, greenhouse gases and pollutants. Mountain glaciers at high altitude are the only indirect records which allow us to reconstruct climate and environmental changes in detail and over extended periods (up to 25,000 years on Sajama, Bolivia).

## Climate memory living on borrowed time

Unfortunately, the mountain glaciers are retreating unrelentingly and these extremely fragile ice core records are now at risk. Their quality is suffering as a result of global warming and, eventually, they will quite simply disappear.

## Building a legacy for future generations

We have a chance, at least for a few more years, to build a legacy of intact ice cores taken from these endangered glaciers.

**If we act now and create this legacy, scientists in centuries to come will have access to high-quality scientific resources.** They will then be able to conduct unprecedented analyses made possible by the development of techniques and the emergence of new ideas.

## The project

The project focuses on high-altitude sites validated via previous studies, but which are at risk of disappearing :

- Col du Dôme (4,350 m) on the Mont Blanc massif
- Illimani (6,432 m) in Bolivia. This site has been identified as the most at risk in the Andes

Three complete ice cores will be drilled on each glacier – one will be analysed to provide a detailed reference and two will be stored in Antarctica for legacy records.

These are complex missions requiring great care and skill both in human and in technical terms:
- 20 days in the field for six scientists on the Col du Dôme at an altitude of 4,350 m with rotation by helicopter
- 50 days in the field for eight scientists on Illimani at an altitude of 6,300 m with guides and local stakeholders

The ice cores are extracted using technology developed right here in Grenoble, each one measuring over 130 m long.

An extremely strict cold chain will be established from the glacier to the storage location in Antarctica. There, the ice cores will be handed over to the French Paul-Emile Victor Polar Institute for safe storage at a temperature of -50°C at the Concordia base.

An international scientific committee comprising members of partner organisations and under the auspices of international organisations (committee of scientists working on ice cores, UNESCO, etc.) will ensure the preservation as well as the exceptional and appropriate use of these samples by future generations.

# Project Partners :

The project contributes to the **UNESCO International Hydrological Programme (IHP)** within the framework of the snow, glacier and water resources activities of the IHP-VIII (2014-2021) '*Water Security: Responses to Local, Regional and Global Challenges'.*

# Under the patronage of :

***Jean Jouzel***, climatologist and vice-president of the IPCC

***Luc Jacquet***, french filmmaker and Oscar-winner for "March of the Penguins" and currently releasing his latest film « Ice & Sky ».

# Funded through private and industrial sponsorship (2 M€)

# DES ARCHES DE NOÉ DANS LES PÔLES

**Pour conserver des archives climatiques menacées de disparition, des morceaux de glacier du Mont-Blanc et de la cordillère des Andes seront stockés au pôle Sud.**

Le biblique Noé conservait, dit-on, des animaux dans son arche pour les préserver du déluge. Mais ça, ce sont des fables. En revanche, le déluge de degrés qui s'annonce est, lui, bien réel et amorcé depuis longtemps. Le réchauffement climatique, outre les tragédies qu'il promet aux populations, entraîne aussi des pertes irrémédiables pour la connaissance scientifique. Notamment avec la fonte des glaciers de montagne. En analysant des bulles d'air emprisonnées dans la glace, on peut retracer l'évolution du climat sur vingt mille ans. Des témoins clés du passé, donc, sans lesquels les négationnistes du réchauffement climatique auraient eu la part belle.

Seulement, les glaciers fondent. La Terre devrait se réchauffer d'environ 5 degrés au cours du XXIe siècle, et au Mont-Blanc la température a déjà augmenté de 1,5 degré ces dix dernières années. Les glaciers contiennent donc des données vouées à disparaître avant même d'avoir été exploitées par les scientifiques. Une solution serait de les conserver au frigo (les glaciers, pas les scientifiques). Mais un vrai frigo peut tomber en panne et il faut du personnel pour l'entretenir, il est donc à la merci de toutes sortes d'événements. Comment faire ? Des chercheurs ont eu une idée. Il existe un frigo capable de garder des carottes de 140 mètres sans jamais tomber en panne, quoi qu'il arrive : c'est l'Antarctique. Il y fait une température moyenne de -50 degrés, ce qui laisse de la marge, même si là-bas aussi le réchauffement est en marche. Et quand bien même une guerre nucléaire décimerait la planète, on peut espérer que le pôle Sud soit l'une des dernières régions touchées.

C'est ainsi qu'est né le projet « Patrimoine de carottes glaciaires ». Un programme international dont l'un des principaux porteurs est Patrick Ginot, chercheur à l'Institut de recherche pour le développement[1] : « *Nous allons prélever des carottes de 10 cm sur 140 m de longueur, dans des glaciers de montagne, puis les stocker en Antarctique dans la base scientifique franco-italienne Concordia. Cela permettra aux scientifiques du futur de les étudier avec les nouvelles technologies dont ils disposeront.* » Si tout se passe comme prévu, le premier forage aura lieu en 2016 au col du Dôme, au Mont-Blanc, à 4 300 mètres. Et le deuxième, en 2017, à l'Illimani, un sommet bolivien de 6 300 mètres qui domine la ville de La Paz. En 2019, les précieuses carottes seront enfin conduites (en plusieurs morceaux) en Antarctique, où elles seront gelées pour éviter justement d'être cuites.


## PAROLES, PAROLES, PAROLES...

En fait, ce projet s'inspire d'une réalisation qui, elle, existe depuis 2008. Ici, il ne s'agit pas de glace, mais de graines. Et nous ne sommes pas en Antarctique, mais à l'autre bout de la Terre, sur l'île du Spitzberg, dans l'océan Arctique norvégien. La réserve mondiale de semences du Svalbard est un bunker construit dans une ancienne mine de charbon à 120 mètres de profondeur. Des millions d'échantillons de graines, de toutes les cultures de la planète, y sont précieusement conservés pour être ressuscités en cas de perte irrémédiable sur Terre (et ce ne sont pas les raisons qui manquent : catastrophes naturelles, guerres, manque de ressources, mais aussi changement climatique ou altération de la diversité due aux pratiques agricoles telles que les OGM...).

L'idée d'utiliser les pôles pour conserver des données périssables est très louable. Mais c'est quand même dommage d'être obligé d'en arriver là. Heureusement, toutefois, que des scientifiques innovent pour trouver des moyens de sauver, tant bien que mal, ce qui reste de notre planète. Pendant que le monde politique, lui, préfère se tourner les pouces en faisant de beaux mais inutiles discours. ■

1. Ce programme implique de nombreuses institutions : Laboratoire de glaciologie et géophysique de l'environnement (Grenoble), CNRS, Fondation de l'université Joseph-Fourier de Grenoble, Unesco... Il est également sous le haut parrainage de Luc Jacquet, réalisateur de *La Marche de l'empereur* et, plus récemment, de *La Glace et le Ciel*, documentaire présenté en clôture du Festival de Cannes 2015 et qui dresse le portrait de Claude Lorius, le glaciologue qui a établi la relation entre le climat et la composition des glaces.

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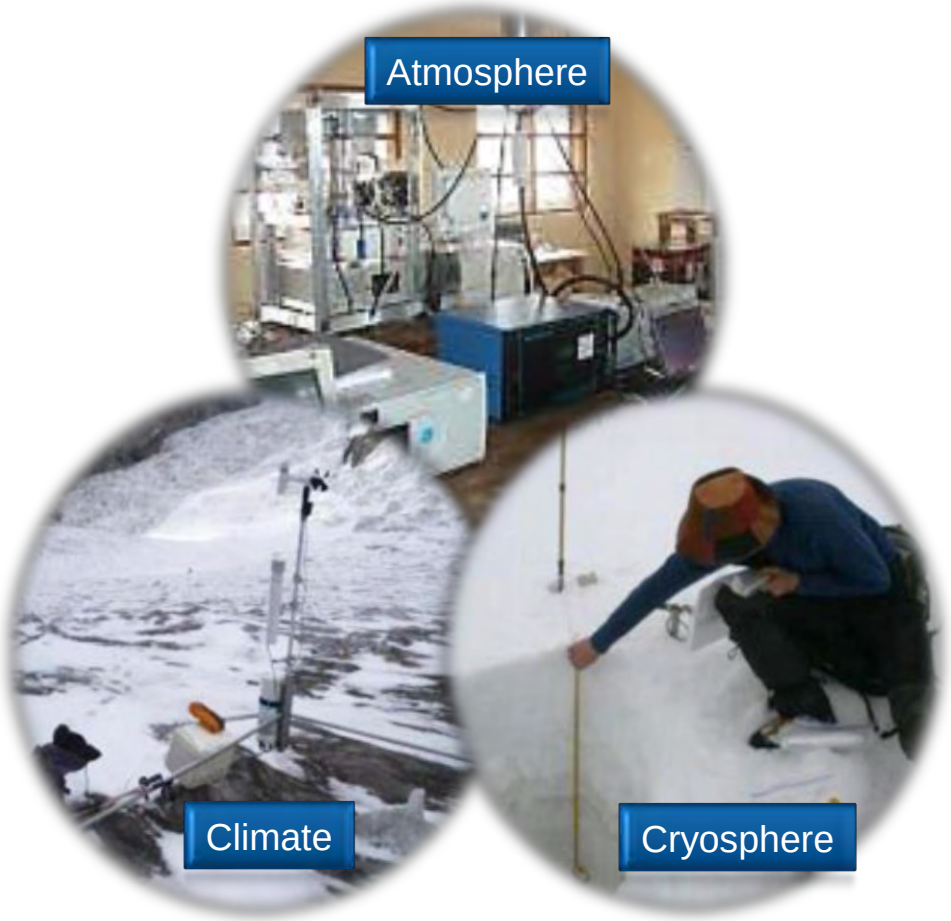
# Conclusion 1




**Long termes and structured « Observation Networks » are essential for climate relevant research**

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# Conclusion 2


**It is not too late for saving some ice**

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LGGE
Laboratoire de Glaciologie et Géophysique de l'Environnement
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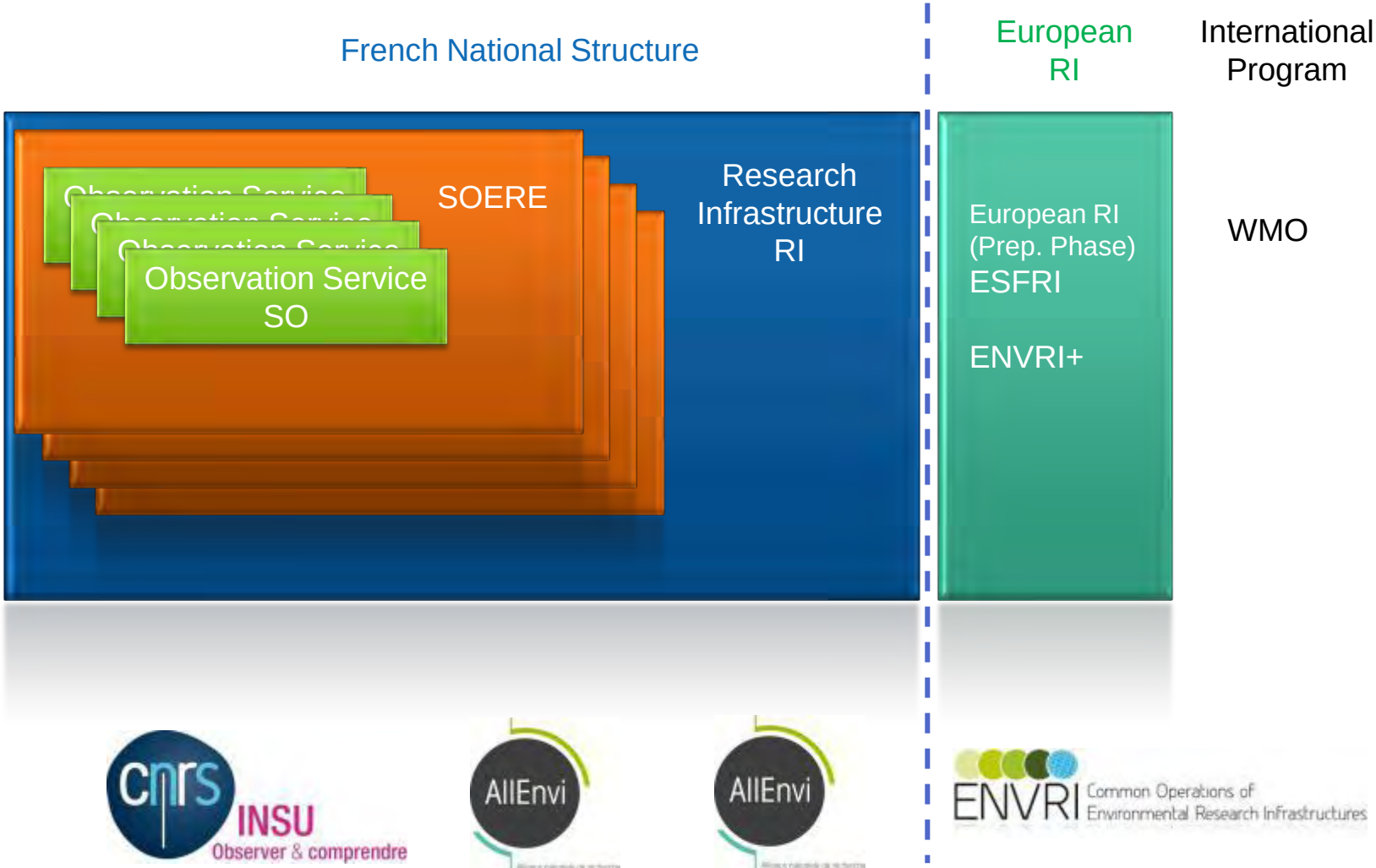
# Observation structures



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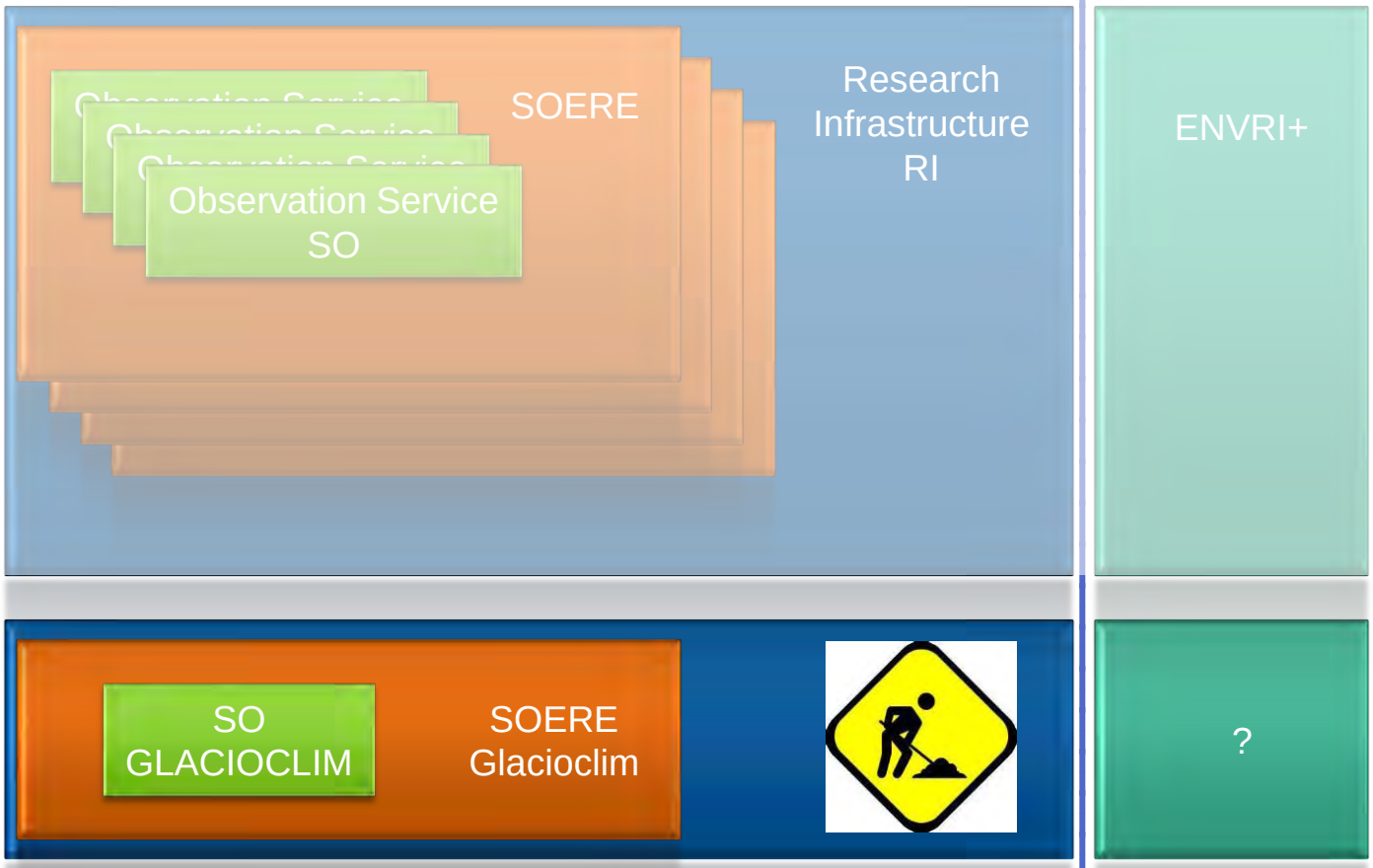
# Observation structures

National Structure

European RI

International Program




*Cryosphere*

WGMS
GCW
…

**Label « Sud »**
**LMI Great Ice**
**JEAI «GRANT» & «IMAGE»**

IRD Institut de recherche pour le développement

OSUG

# Observation structures