



Glaciers et Ressources en Eau dans les Andes Tropicales – Indicateurs des Changements dans l’Environnement
 Glaciares y REcursos agua en los Andes Tropicales – Indicadores de los Cambios ambiEntales

Great Ice

Observing glaciers in the Tropical Andes since 20 years



Autoridad Nacional del Agua

The Great Ice team

Great Ice

Key-dates

- **1991:** « *Neiges et Glaciers Tropicaux* » funded by IRD (ORSTOM) and equipment of the first glaciers, Zongo and Chacaltaya in Bolivia, with Bolivian partners
- **1994:** Extention of the program to Perú (Cordillera Blanca) and Ecuador (Antisana)
- **2002:** Obervatory of Research for Environment (ORE) GLACIOCLIM funded in Grenoble (France) : GLACIOCLIM organizes permanent research programs on glaciers in the French Alps, Tropical Andes, Antarctica (Terre Adélie), Himalaya and Kerguelen). Glaciers are viewed as « indicators of climate change » at world scale.
Data are available on: <http://www-igge.obs.ujf-grenoble.fr/ServiceObs/>
- **2012:** Creation of the International Mixed Laboratory *Great Ice for the 2012-2015* period
 - 20 members (10 researchers from France, 10 researchers from Andean countries)
 - France, Bolivia, Perú, Ecuador (extention to Colombia planned the next years)
 - Extension to Colombia (IDEAM, Bogota)

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The glacier observation network



- Zongo glacier recorded the largest mass balance data series in the Tropics (~40 years)
- Antisana 15 : the only glacier monitored close to Ecuador (17 years)
- Mass balance (glaciological method) : 7 (9) glaciers (Bolivia, Ecuador, Peru, Colombia)
- Hydrological balance : 4 glaciers (+ 1 in Colombia)
- Aerophotogrammetry (1956-2006): 25 glaciers in Bolivia, 3 ice-capped volcanos in Ecuador (Cotopaxi, Chimborazo, Antisana) and entire cordilleras in Peru (by the Peruvian partners)
- Topographic survey (on all the glaciers) (DGPS) + Ground Penetrating Radar (GPR)
- Energy balance (radiative, turbulent fluxes) + precipitation (amounts/nature): complete (micro)meteorological stations on Zongo and Antisana glaciers
- Reconstruction of LIA and post-LIA areas/volumes: Bolivia, Peru, Ecuador, Colombia (in progress) with dates obtained from lichenometry and from cosmogenic isotopes (this covers the post-LGM and particularly the 14th-20th centuries)
- Deep ice cores retrieved (in collaboration with other teams) on: Sajama (6540m, 1997), Illimani (6240m, 1999), Chimborazo (6240m, 2000), Coropuna (6000m, 2003), San Valentin (3900m, 2007: extratropical)
- Temperature profile in the cold firn/ice of Illimani (Bolivia, 6240m)

Great Ice Training and Publications

- **Training:**
 - 15 PhD defended (Universities of Grenoble, Montpellier, Paris)
 - 7 students from Andean countries /8 from France obtained their PhD (in France)
 - 2 Jeunes Equipes Associées à l'IRD (JEA: young team associated to IRD) (La Paz/Quito)
 - 1 LMI (International Mixed Laboratory)
 - More than 20 « Maestrias » and Masters of Sc. where Great Ice was involved
 - More than 30 trainee students
- **Publications:** 120 papers published in peer-indexed reviews (with often Andean colleagues as co-authors and first authors (Nature, Science, JGR, JoG, WR, QR, etc.)
- **Workshop organization:** ~15 workshops organized (regional and international)
- **Networks:** IRD co-funded the **Grupo de Trabajo en Nieves y Hielos** (GTNH) in 2004, a group supported since 2005 by UNESCO (PHI)
- **Sessions of GTHN organized by IRD:** Huaraz (2004), La Paz (2006), and Quito (2010)
- **Data series glaciers available on websites:** Word Glacier Monitoring Service (WGMS, Zürich), GLACIOCLIM (Grenoble), LMI Great Ice (in progress)

Great Ice Five topics of research

1. Organization and management of the permanent glacier observatory (Bolivia, Perú, Ecuador + Colombia) [GLACIOCLIM]
2. Evolution of glacier masses over time (last centuries / recent / future)
3. Observation of the physical processes (melting and sublimation) at the glacier surface (glacier-atmosphere linkage)
4. Glacier mass balance and climate variability at the Regional (ENSO-Pacific, Atlantic-Amazonian basin) and Global scale
5. Impact of glacier recession on hydrology and water resource

Great Ice

Glaciers constantly monitored

Main glaciers with ground observations



Zongo, 16°S, Bolivia, 1991



**Chacaltaya, 16°S,
Bolivia
1991-2009**



Charquini Sur, 16°S, Bolivia,
2002



Antisana 15α, 0°28S,
Ecuador, 1994



Antisana 12, 0°28S,
Ecuador, 2004



Carihuayrazo, 1°S,
Ecuador, 2003



Artesonraju, 9°S, Perú,
1994



Yanamarey, 9°S,
Perú, 1994

Great Ice *What is measured and for what?*

- **Glacier mass balance** (glaciological method : stakes and pits)
- **Glacier hydrological balance** (rain gauges and runoff stations)
- **Glacier mass balance** (global approach by areophotogrammetry)
- **High resolution topographical survey** (snout location, surficial velocity, ice tongue thickness)
- **Past fluctuations**: aerophotogrammetry (last 50 years), moraine dating (since 14 kyr), area and volume reconstruction from DTMs
- **(Micro)meteorology** : Energy balance, precipitation (amounts/phase)
- **Climatology**: statistical analysis of variable measured in the meteorological stations and available from reanalysis
- **Hydrology**: quantifying impact of glacier recession on hydrologic regimes
- **Palaeoclimatic reconstruction from ice cores**: stable isotopes, chemical species, palaeotemperatures (direct measurements)
- **Modelling climate/glacier relationship for future simulations**

Measuring glaciers....



accumulation



Accumulation pits



Ablation stakes



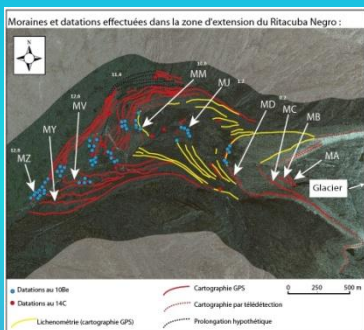
Rain gauges



Runoff stations



Topographic survey



Datation of moraines and glacier area/volume reconstruction in the past



Ice cores and climate reconstruction



Analysing ablation processes from energy balance (SEBs)



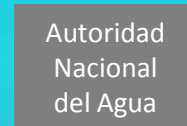
Great Ice Institutions and Members



Institutions	Sites	Members by institution
LTHE (IRD)	Grenoble	2, dont le porteur français
LGGE (OSUG et IRD)	Grenoble	2
HSM (IRD)	Montpellier	2
LGP (CNRS)	Paris	1
EPN (DICA)	Quito Equateur	2, dont le co-porteur andin
INAMHI	Quito Equateur	2
UGRH (ANA)	Huaraz Pérou	3
SENAMHI	Lima Pérou	4
UMSA (IHH)	La Paz Bolivie	1
UMSA (IGEMA)	La Paz Bolivie	1



Members	Speciality and time	Institution
Bernard Francou (DR0)	Glaciologist(50%)	IRD : Rep. Quito (LTHE)
Jean-Emmanuel Sicart (CR1)	Glaciologist (70%)	IRD : LTHE (affect. La Paz)
Antoine Rabatel (Phys. Obs)	Glaciologist (70%)	OSUG-LGGE (Grenoble)
Thomas Condom (M.Conf.)	Hydrologist(30%)	Dét.IRD/Univ. Bordeaux 3)
Patrick Wagnon (CR1)	Glaciologist (30%)	IRD : LTHE (Grenoble)
Vincent Jomelli (DR2)	Géomorphologist (20%)	CNRS : LGP (Meudon)
Patrick Ginot (IR)	Glaciologist (30%)	IRD : LGGE (Grenoble)
Jean-Denis Taupin (CR1)	Geochemist (30%)	IRD : HSM (Montpellier)
Nicolas Patris (IR)	Geochemist (20%)	IRD : HSM (Montpellier)
Marcos Villácis (Pr.PhD)	Hydrologist(70%)	EPN (Quito)
Bolívar Cáceres (IR)	Glaciologist (80%)	INAMHI (Quito)
Remigio Galárraga (Pr.PhD)	Hydrologist (50%)	EPN (Quito)
Luis Maisincho (IR)	Glaciologist (80%)	INAMHI (Quito)
Edson Ramírez (Pr PhD)	Glaciologist (30%)	UMSA (IHH) (La Paz)
Alvaro Soruco (Pr PhD)	Glaciologist (70%)	UMSA (IGEMA) (La Paz)
Wilson Suarez (Ing. PhD)	Hydrologist (70%)	SENAMHI (Lima)
Jesus Gómez (IE)	Glaciologist (70%)	ANA (UGRH) (Huaraz)
Waldo Lavado (Ing.P hD)	Hydrologist (30%)	SENAMHI (Lima)
Luis Metzger (IR)	Hydrologist (30%)	SENAMHI (Lima)
Carlos Peralta (IR)	Hydrologist (30%)	ANA (UGRH) (Huaraz)
Elisabeth Sylvestre (Pr PhD)	Climatologist (30%)	Ex SENAMHI



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