

## **The Amancay project: from decadal to interannual climate variability in tropical and subtropical South America**

Françoise Vimeux<sup>1</sup>, Jean-Philippe Boulanger<sup>2</sup>, Myriam Khodri<sup>3</sup>, Josyane Ronchail<sup>4</sup>, Abdel Sifeddine<sup>5</sup>, Florence Sylvestre<sup>6</sup> and Amancay participants

<sup>1</sup>- IRD, UR Great Ice, LSCE, CE Saclay, Orme des Merisiers, Bât. 701, 91191 Gif-sur-Yvette Cedex, France, Tel: 01 69 08 57 71, Fax: 01 69 08 77 16, francoise.vimeux@lsce.ipsl.fr

<sup>2</sup>- IRD, LOCEAN (IRD, CNRS, MNHN, UP6)/IPSL, Departamento de Ciencias de la Atmósfera y los Océanos, FCEN-UBA-Pabellon II-Piso 2, Capital Federal (1428)-Buenos Aires, Argentina, jpb@locean-ipsl.upmc.fr

<sup>3</sup>- IRD, UR Paléotropique, Centre de Bondy, 32 Ave. Henri Varagnat, 93143 Bondy Cedex, myriam.khodri@ird.fr

<sup>4</sup>- LOCEAN (IRD, CNRS, MNHN, UP6)/IPSL and Paris 7 University, case 100, 4 Place Jussieu, 75005 Paris, France, josyane.ronchail@locean-ipsl.upmc.fr

<sup>5</sup>- IRD, UR Paléotropique, Centre de Bondy, 32 Ave. Henri Varagnat, 93143 Bondy Cedex, Abdel.Sifeddine@ird.fr

<sup>6</sup>- IRD-CEREGE, Europôle méditerranéen de l'Arbois, BP 80, 13545 Aix-en-Provence cedex 4, France, sylvestre@cerege.fr

### **Abstract**

The Amancay project, grouping French and South American scientific teams, has been conducted for the last four years. This project aims at understanding the climate variability in tropical and subtropical South America from the seasonal to the decadal timescale. Specifically, it focuses on deciphering trend from abrupt changes and on comparing the various operating climate modes. Main questions addressed by the Amancay project are: what is the local and the regional variability? What are the regional teleconnexions?

To answer those questions, four regions influenced by the South American Monsoon have been studied: (1) the Nordeste, (2) the South of the Amazon basin, (3) the Andes and (4) the Parana-Plata basin. We also focus on two specific time periods: the abrupt climate change in the 1970's and the Little Ice Age (LIA). Our approach combines (1) documentation from past climate archives (ice cores, lake sediments, moraines, corals, instrumental precipitation and river discharges) over the last 1,000 years, (2) calibration of proxies to better interpret the climate archives using both modern observations and modeling works, and (3) ongoing modeling studies to examine possible climate mechanisms pointed out by the documentation. The main results are: (1) the abrupt feature in 1970 is a widespread event leading to a common moisture increase in tropical and subtropical South American regions and (2) the LIA is significantly recorded both in the Andean and the Parana basin climate archives but with different signatures: moist and cold conditions are shown in the Andes whereas Lake Mar Chiquita sediments in the Parana-Plata basin exhibits drier conditions in the central pampean plains of Argentina. For both periods, one of the ongoing works is to understand the mechanisms that can explain either local or common variations and the role of teleconnexions both between our key regions in South America and with the Pacific and Atlantic Oceans.

## **1- Introduction: questions and objectives**

The Amancay project groups together 15 teams from French and South American laboratories. The objective is to examine the climate variability in tropical and subtropical South America over the recent period (from the last centuries to the last 1,000 years) from various climate archives (ice cores, lake sediments, moraines, corals, instrumental precipitation and river discharges) in different regions (Nordeste, the south Amazon basin, the Andes and the Parana-Plata basin). Our method is triple:

1- To document climate variability at different time and spatial scales along the water vapor flux inland South America from the equatorial Atlantic Ocean to the Parana-Plata basin (see Figure 1 for example).

2- To translate our records in quantified climate parameters such as precipitation based on calibration studies including both observations and modeling works.

3- To understand (i) regional teleconnexions between the four regions and (ii) the regional climate response to global climate variability involving both the Atlantic and the Pacific Oceans.

We focus on two time periods that are 1- the widespread abrupt change observed in the 1970's over the four studied regions and 2- The Little Ice Age (LIA).

Here, before showing the important results in section 3 and 4, we detail in section 2 the new documentation obtained in the Amancay project as well as the calibration works.

## **2- Documentation, calibration and new modeling tools**

### *2-1 Documentation*

An important documentation has been done in the Amancay project in the four regions:

(1) In the Nordeste, corals at the sites of (i) Buzios (23°S) sensitive to polar fronts, ZCAS (South Atlantic Convergence Zone) and upwelling, (ii) Abrolhos (18°S), sensitive to polar fronts; (iii) Salvador (13°S) sensitive to polar fronts; and (iv) Atoll das Rocas (5°S) sensitive to the ITCZ (Intertropical Convergence Zone) have been studied. The objectives are to decipher for similar periods the ITCZ and the polar front movements on inter annual and decennial timescales. We have also extracted from the Boqueiro lake (2°S) two cores spanning the last century and the last millenium respectively.

(2) Rainfall and water level historical series are gathered from the national institutions in charge of the hydrological monitoring in the different countries of the Amazon Basin (Agencia Nacional de Aguas in Brazil, Servicio Nacional de Meteorología e Hidrología in Peru and Bolivia, Instituto Nacional de Meteorología e Hidrología in Ecuador and Instituto de Hidrología, Meteorología y Estudios Ambientales in Colombia). In order to obtain discharge values, rating curves have been developed using Acoustic Doppler Current Profiler (ADCP) gauging measures conducted by HYBAM researchers since 1996.

(3) In the Andes, palynological analyses have been carried out on the Coropuna glacier (Peru, 15°S). Those measurements are able to give us information related to the different origins of airmasses over the last 40 years. Also, important efforts have been done to date glacial moraines by lichenometry to obtain the maximal glaciers extent histories over the last 1,000 years. At last, the isotopic composition of Andean ice cores is also studied over the last centuries from different ice cores (Huascaran, Peru, 9°S; Quelccaya, Peru, 13°S; Illimani, Bolivia, 16°S; Sajama, Bolivia, 18°S).

(4) In the Parana-Plata basin, the Lake Mar Chiquita, a closed, shallow, hypersaline-lake in Central Argentina (30°S, 62°W) has been investigated to reconstruct its hydrological variability with a decadal resolution.

Thus, the Amancay project enables us to have new temporal records in the four key regions spanning at least the last century with a decadal resolution.

### *2-2 Calibration and modeling development*

Different calibrations and modeling studies have been done in Amancay. We briefly describe them here:

(1) In the Abrolhos regions, we calibrate the growth rate of corals with the intensity of polar fronts and the SOI (Southern Oscillation Index). This calibration shows that this region is sensitive to both global changes and interannual variations like ENSO modulating polar fronts arrival.

(2) We seek for the climate controls of the isotopic composition of Andean precipitation to better interpret the Andean ice cores records. We use: (i) event-based and monthly observations of the isotopic composition of precipitation (network of pluviometers in Ecuador, Peru and Bolivia), (ii) the meso-scale model REMO-iso centered on tropical South America and forced by the ECHAM-4 atmospheric global climate model and (iii) a 1D vertical radiative-convective model including water stable isotopes. The main result is that the isotopic composition of Andean precipitation is mainly controls by the intensity of convection over Amazonia and the North tropical Atlantic ocean.

(3) To better interpret the lake Mar chiquita hydrological variability, we develop both a calibration of the geochemical and biological proxies and a model for the lake hydrology. Both salinity and lake levels fluctuations have been reconstructed and interpreted in terms of climate and hydrological controls.

(4) At last, we develop a meteorological database on instrumental period with homogenized data.

### **3- The 1970 feature**

The new datasets we obtain enable us to point out:

(1) A decrease of polar front arrivals in the Nordeste from 1972.

(2) An increase of river discharge in the main stem of the Amazon river (Obidos station) at the beginning of the 1970's associated to an increase of river discharges in the southern Amazon basin (in observed and simulated data from the IPSL land surface scheme ORCHIDEE).

(3) Strong precipitation upstream the Andes between 1970 and 1990 and then a return to pre-1970 precipitation conditions.

(4) An abrupt change in the hydrological conditions in Lake Mar Chiquita at the beginning of the 1970's without precedent during the last 1,000 years.

In summary, all our observations show a strong and abrupt increase of precipitation in tropical and subtropical South America from 1970 (Figure 1). One of our initial questions dealt with the origin of this abrupt change in 1970: is it natural or anthropogenic ? Our results suggest that although this change is abrupt, it may be not related to an abrupt feature toward a new climate mean mode. Most of our time series in the Andes and in Amazonia exhibit a return to pre-1970 meteorological conditions after 1995. An intriguing result is that this reversal is observed almost in all records except in the Parana-Plata region

The question we ask now is: what are the possible climate mechanisms responsible for such an abrupt change ?

The study of ECMWF and NCEP reanalyses geopotential height, humidity and wind fields helps us to detect some possible causes for this common increase of precipitation from 1970:

(1) Stronger tradewinds from both the northern and the southern tropical Atlantic basins and, as a consequence, a stronger water vapor transport inland over tropical and subtropical South American regions. Both wind and water vapor transport anomalies are in agreement with a stronger 850 hPa geopotential height over the north tropical Atlantic and the SE Brazil. Furthermore, a southern wind anomaly driven by a positive geopotential height anomaly over subtropical Chile and featuring enhanced extratropical perturbations, favours convergence particularly over the Parana-Plata basin.

(2) A southward shift of the Hadley circulation with an intensification of ascent over tropical and subtropical regions.

What do we learn for the relationship between global and regional climates ?

From reanalyses and satellite data, it appears that over the last 50 years, an important decadal variability can be seen in the tropical band. We aim at understanding the relationships between the positive trend of tropical SST affecting the regional climate and this decadal variability. The question is now: is 1970 an abrupt change or the regional signature of a decadal variability originating in the Indo-Pacific ?

#### **4- The Little Ice Age (LIA) feature**

The new datasets we obtain enable us:

(1) To point out that there is a glacial extension in the Andes over the last millenium that is comparable in amplitude and in the timing with the one experienced in Europe. However, we show that this extension is not synchronous in the tropical Andes: most of the glaciers show a first maximal extension around 1300-1350 AD and a second one in 1630-1680 AD in Peru and Bolivia and around 1730 AD in Ecuador.

(2) to show that the following glacial retreat between 1650 and 1950 AD is comparable with the recent glacier retreats from 1950 AD that is to say a decrease of 30% of their total length between the maximal extension and the twentieth century.

(3) to point out that the LIA signature is different from one region to another: it corresponds to a dry period in the Parana-Plata basin whereas the Nordeste is wetter and the Andes are colder and wetter.

We thus point out that the four regions can have different climate responses contrasting to what we observe from the 1970's period (Figure 2). Differently to the 1970's, we can assume that there are no anomalies of geopotential in SE Brazil and trade winds, offering the possibility of a northward shift of extra-tropical fronts. As no convergence is favoured over the Parana-Plata basin, dry conditions can occur differently from the other regions.

We have still important questions regarding our results:

(1) What are the mechanisms explaining the asynchronicity between 0° and 20°S in glacial extent reconstructions ?

(2) How explaining the end of the LIA and how deciphering it from mechanisms of global change, especially from 1850 ? Actually, isotopic records from Andean ice cores show a rather linear positive trend over the last 250 years without any slope breaking.

(4) Is there any decadal variability during the LIA comparable with the 1970's one ?

## **5- Outputs**

We would like to valid our assumptions regarding the two studied periods and to improve our understanding of the relationships between regional and global climate by examining coupled climate simulations. Especially, we would like to examine a continuous simulation over the last 1,000 years to answer our main questions.

Using observations, we would like to improve our knowledge about the regional atmospheric causes of the pluriannual recent hydrological changes.

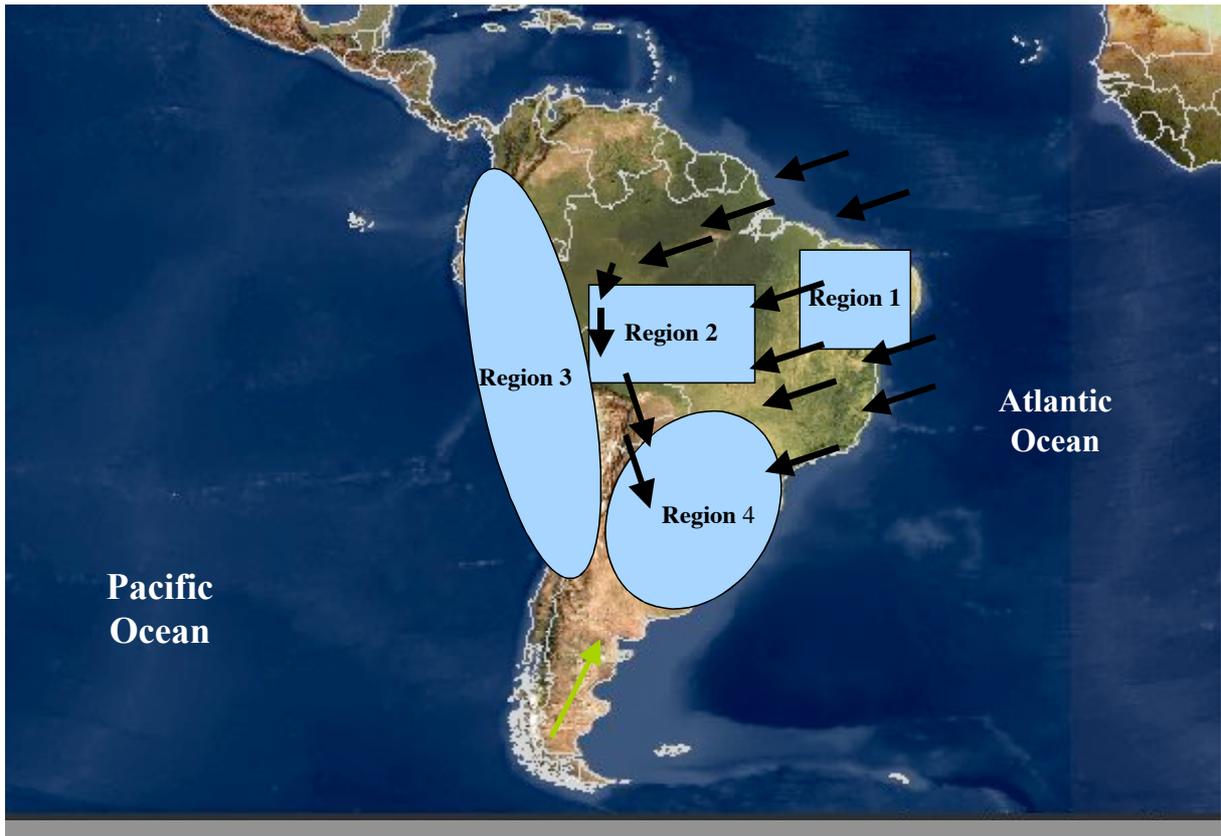


Figure 1: Synoptic situation during the 1970's. The blue color indicates an increase of precipitation in all regions. The black arrows show how the water vapor flux can penetrate inland with a southward shift of the Hadley circulation. The green arrow shows the potential southern water vapor transport.

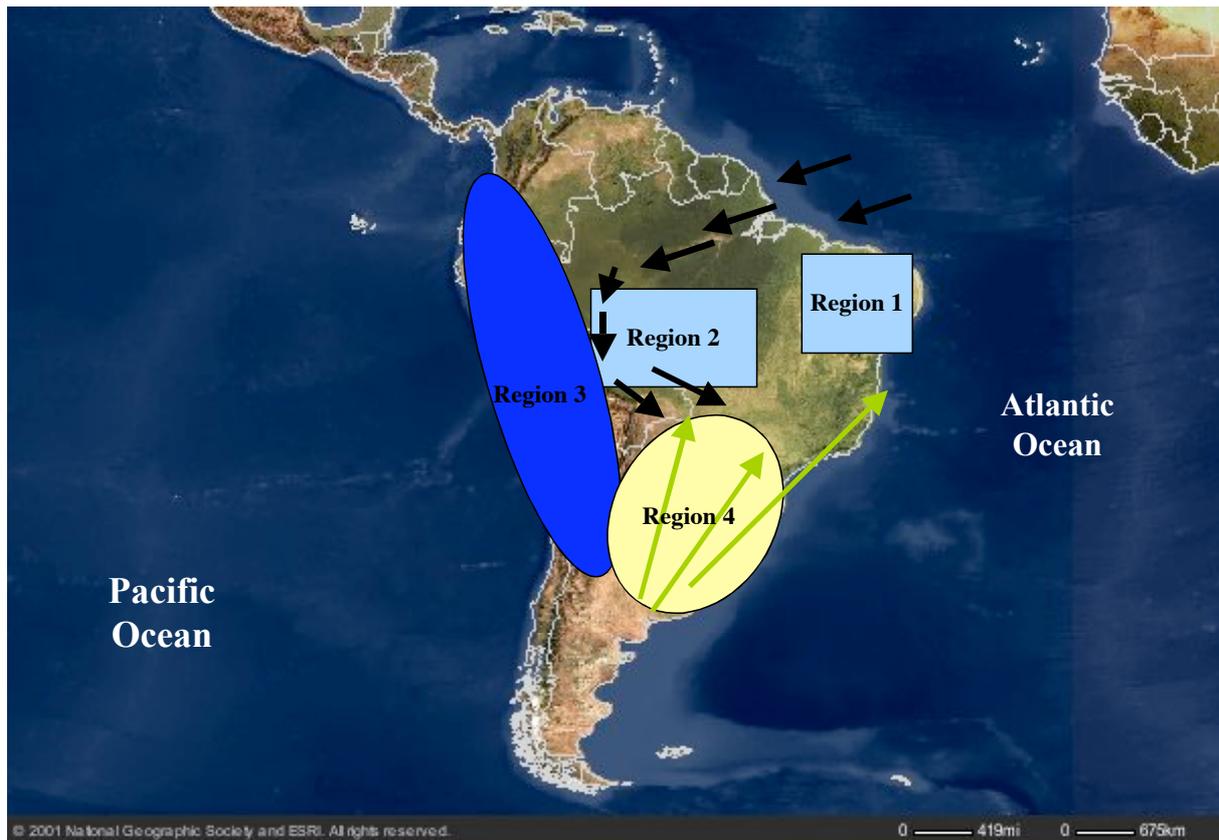


Figure 2: Synoptic situation during the LIA. The light blue color indicates wetter conditions, the dark blue color indicates both colder and wetter conditions and the yellow color indicates drier conditions. We also show the possible interaction between the water vapor flux from the Atlantic ocean (black arrows) and the polar fronts arrival (green arrows).