CLARIS | LPB

CLARIS | LPB
A Europe-South America Network for Climate Change Assessment
And Impact studies in La Plata Basin
www.claris-eu.org
Deliverables

SEVENTH FRAMEWORK PROGRAMME

Instrument: **SP1 Cooperation**

Thematic Priority: **Priority Area 1.1.6.3 "Global Change and Ecosystems"**

FP7 Collaborative Project – Grant Agreement 212492

CLARIS LPB
A Europe-South America Network for Climate Change Assessment and Impact Studies in La Plata Basin

DELIVERABLES

D3.3: Development of proxy data for the lake sites

Due date of deliverable: Month 24

Start date of project: **01/10/2008** Duration: 4 **years**

Organisation name of lead contractor for this deliverable: P13-CONICET

Deliverable No	Deliverable title	WP	Lead beneficiary	Estimated indicative person-months (permanent staff)	Nature	Dissemi nation level	Deliv ery date
D3.3	Development of proxy data for the lake sites	WP3	P13-CONICET	3	O	PU	24

Introduction

Our objective is to reconstruct the past environmental variability overall the Pampean plains of Argentina by developing hydrological reconstructions based on the multiproxy analyses of lake records. With the aim of performing a better proxy data calibration (i.e., grain size, isotope composition of carbonates, mineralogy, diatoms remains, among others) against the hydroclimate record, an integrated hydrological model of the Laguna Mar Chiquita basin (Central Argentina) was developed.

Results

We are developing limnogeological studies along a latitudinal transect across the Argentinean Pampas covering from 28°S -in the upper catchment of Laguna Mar Chiquita (Provincia de Córdoba)- to Melincúe (Provincia de Santa Fe) and Lagunas Encadenadas del Oeste de Buenos Aires (lagunas Epecuén, Del Venado, Del Monte and Cochicó; LEO) at approximately 38°S.
Our multidisciplinary approach included the analyses of:

a) Historical and instrumental records of recent lake-level changes,
b) Multi set of proxies derived from paleolimnological records,
c) Chronologies of lake sediments derived from Pb210 dating technique, used to calibrate the multi-proxy record againt the instrumental record to further reconstruct the variability for pre-instrumental record time, and
d) Hydrological modelling of lakes.

a) Historical and instrumental records of recent lake-level changes

The availability of historical information as well as instrumental data of lake levels and water salinity records are essential for calibrating the sedimentary proxies against the hydroclimatic data. The instrumental record of pampean lakes-levels show dramatic changes over the past ~120 years. For instance, the hydroclimate variability in Laguna Epecuén can be reconstructed based on historical and instrumental information of water salinity variability for the period AD 1886-2007 (Fig. 1). Water salinity values are also available for the rest of the lakes (e.g., 22.2 g L^{-1} in AD 1929; 4.0 gL^{-1} in AD 1988 in Laguna del Monte; 8.8 gL^{-1} in AD 1996 in Laguna del Venado). Lowstands, characterized by extreme salinities (e.g., 373.9 g L^{-1} in AD 1903 in Laguna Epecuén), took place overall the LEO system during a dominant dry period that extended from the end of 19^{th} century until the earlies 1970s. Highstands and comparatively lower water salinities (e.g. 37.8 gL^{-1} in AD 1987 in Laguna Epecuén) become dominant during the most recent precipitation increase after the 1970s (Fig. 1).

Salinities up to 340 gL^{-1} in Laguna Epecuén (year AD 1886) illustrate low lake levels stages during the dry phase along the end of the 19^{th} century and the early 20^{th} century. Lower salinities (Fig. 1) and therefore a lake level rise overall the LEO system, can be ascribed for the short wet spell between AD 1918 and 1927 (Fig 1D). Water salinity up to 381 g L^{-1} recorded in Laguna Epecuén by AD 1930s suggests a dramatic lake water drop during a dry phase. This period of extreme droughts, intense dust storms, cattle mortality, crop failure and rural migration is known in the area as the Pampas Dust Bowl and show comparable characteristics with the American Dust Bowl in the Northern Hemisphere.

The instrumental record of water lake levels started by AD 1968/69. There is a synchronic and widespread lake levels rise after AD 1972/73 with the exception of Laguna del Venado which shows a sharp water lake drop between AD 1974 and 1977 as consequence of lake water regulations. From AD 1972 to 1981 water lake levels increased dramatically (Δ lake level: +2.6 m in Laguna Epecuén; Δ lake level: +2.8 m in Laguna del Venado and Laguna del Monte). After the end of the 1970s the LEO system experienced high water levels without precedent for the last 120 years of analyzed hydrological variability. During the last humid phase, lakes coalesced and began spilling to the terminal Laguna Epecuén. From AD 1984 to 1986, Laguna Epecuén received large spillages showing a second abrupt jump (Δ lake level: +5.6 m; Fig. 1c). The instrumental record of the LEO system indicates synchronic water level fluctuations throughout the wet period while a pronounced lake level drop started after year AD 2003.

The close relation between lake level variability and precipitations (Fig. 1A-D), as well as a similar pattern shown by a large number of lakes across the Pampean Plains (i.e., Laguna Mar Chiquita, see Fig. 2) point toward the regional magnitude of the hydroclimatic variability that started during the 1970s in Southern South America. In general, lake level records show strong positive correlations with the smoothed ARPI (average r=0.55, range 0.51–0.62, p<0.01) remarking precipitation as the main forcing behind lake level variability in the Pampean Region

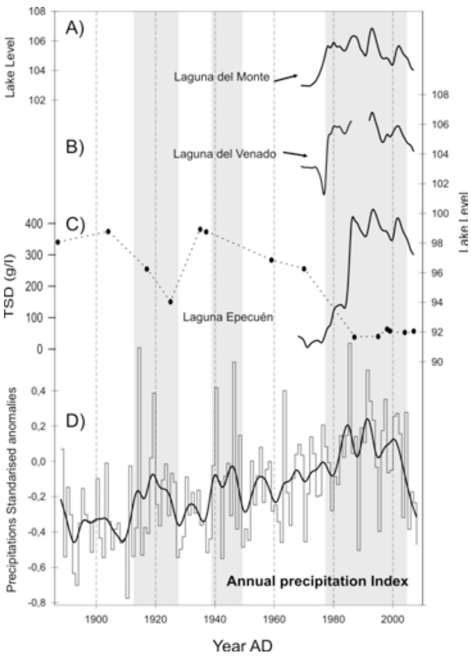

Figure 1. Comparison between water level fluctuations in the LEO system and Annual Precipitation Index. (A) Water level record at Laguna del Monte. B) Water level record at Laguna del Venado. (C) Water level record and water salinity expressed as Total Dissolved Solids concentration at Laguna Epecuén. (D) Annual Regional Precipitation Index for the period 1888–2008. A 10-yr Low-pass Gaussian filter (thick line) is shown to emphasize the low-frequency patterns in the index. Shaded bars indicate short wet spells between 1918-1927, 1940-1949 and the most recent wet period from 1976/1977 to 2005. Taken from Córdoba et al in review.

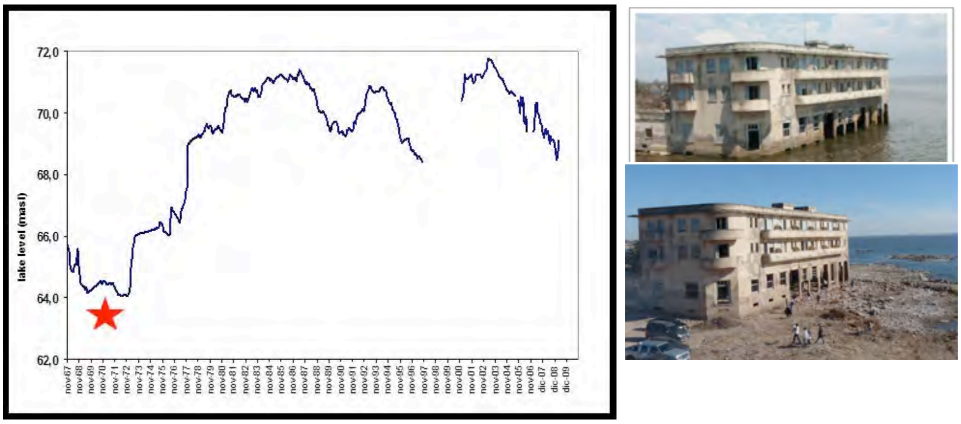

Figure 2. Instrumental record of lake water levels of Laguna Mar Chiquita covering the period from 1967-2009. Note that the highest record correspond to the year 2003 and the noticeable lake level drop that has took place after the year 2003 and it is still present. Upper right corner: Laguna Mar Chiquita during 2003. Lower right corner: Laguna Mar Chiquita during year 2009.

Emerging question: Is the hydroclimate situation that started during the 70s still going on in Central Argentina?

b) Mutlyproxy Analyses of Paleolimnological records

Lithological units (LU) were defined on the base of textures and structures, color, and organic carbon content (Figure 3). Sedimentary cores are relatively homogenous and the units were mainly distinguished by changes in sediment color and total organic carbon (TOC) contents. Overall, the cores are mostly composed of massive and massive to vaguely laminated, black and grey silts, with variations in the shades of grey. Total organic carbon contents (TOC) were measured using a CNS elemental analyzer (FISONS 1500) at CEREGE (Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement, France). Dry sediment samples were treated for carbonates removal by adding 1M HCl and then washed in deionized water. Each TOC value is an average of two measurements.

Multy-proxy records of pampean lakes offer the opportunity to disentangle past and present hydroclimate variability across the subtropics of SESA. Instrumental, historical and lake records show important surface and water level fluctuations throughout the 20th century. The multiproxy analyses of calibrated sedimentary cores allows the recognition of alternating high lake-level facies (organic matter-rich), deposited during positive hydrological balances and low lake-level facies (carbonate-rich), indicative of negative balances.

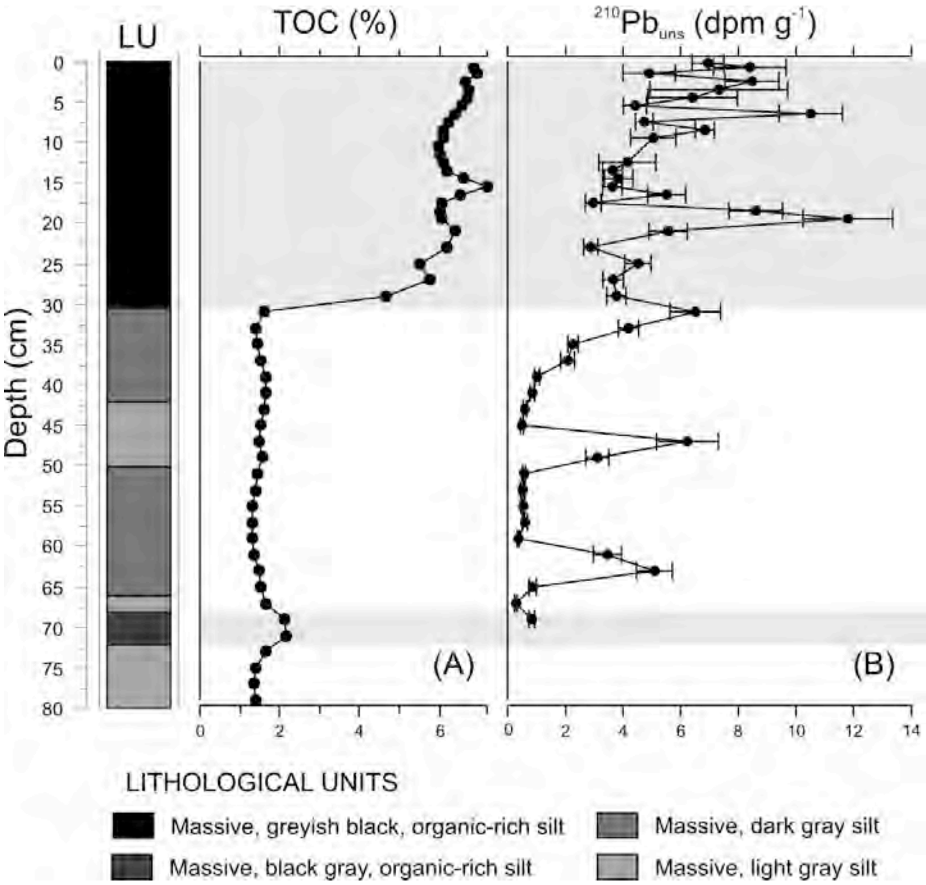

Figure 3: Lithological units (LU) and vertical profiles of (A) Total Organic Carbon (TOC) and (B) unsupported 210-Pb activity versus depth in Laguna del Venado sedimentary core (see below)

Sedimentary organic matter content, expressed as TOC, is a good proxy of primary productivity and lake water salinity in Pampean shallow lakes. High TOC contents indicate an enhanced primary productivity during high lake levels and low salinities due to wet climate spells. Conversely, comparatively lower TOC contents are the consequence of a decreased primary productivity at low lake levels and high salinities during dry climate spells. For instance, all cores exhibit an uppermost organic carbon-rich unit that is recording a primary productivity enhancement as a consequence of reduced salinities during the most recent highstand after year AD 1977-1978 (see Fig. 1). In addition, higher TOC concentration in the lower half of cores can be ascribed to lake level increase during the wet periods from AD 1918-1927. The uppermost organic carbon-rich unit, recording the most recent lake level rise, is present overall the retrieved cores in the pampean plains remarking its value as a stratigraphic age marker for core correlation.

c) Chronologies of lake sediments

To extend the hydroclimate reconstruction backward in time is crucial to develop highly precise and accurate chronological models along the climate archives. 210-Pb radiochronology is a common technique for deriving sediment ages on time-scales spanning the past 100-150 years.

Figure 4 shows a typical 210-Pb -uns activity profiles of sedimentary cores. 210-Pb activity ranges from 11.8 dpm g-1 to 0.3 dpm g-1 in core VT23-07 (average= 4.0 dpm g-1) while in the core GT10-07 values ranges between 27.6 dpm g-1 and 0.4 dpm g-1 (average= 4.3 dpm g-1). 210-Pb -uns activities deviate significantly from the theoretical exponential distribution of the 210-Pb -uns showing multiple peaks throughout the cores. Shifts in the 210-Pb -uns activity profiles are more frequent along the uppermost lithological unit.

Non-linear and non-monotonic 210-Pb -uns vertical profiles suggest, among other causes, a non steady sediment accumulation rate and/or a variation of 210-Pb -uns flux (i.e., rate of supply) to sediments over the time. These complex features observed in the 210-Pb profiles preclude the direct use of any 210-Pb classical models. Thus, marked irregularities observed in the 210-Pb -uns vertical profiles provided a unique challenge to identify the most suitable 210-Pb model to be applied for dating sediments accumulated under contrasting hydroclimate conditions.

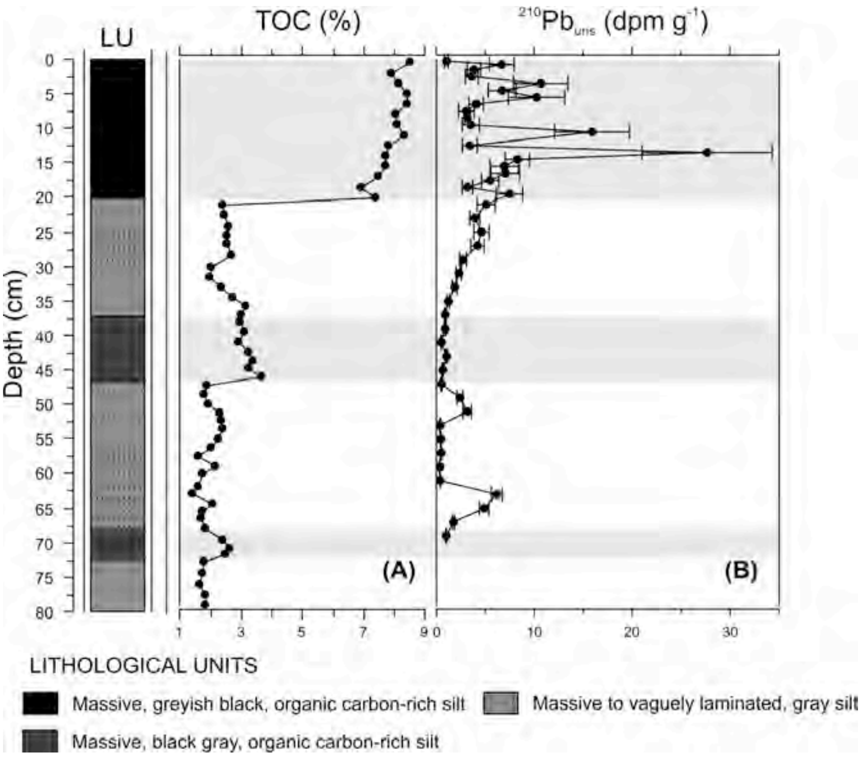

Figure 4: Lithological units (LU) and vertical profiles of (A) Total Organic Carbon (TOC) and (B) unsupported 210-Pb activity versus depth in Laguna del Monte sedimentary core.

210-Pb numerical models like CRS, CIC, CFCS and SIT (constrained and unconstrained) were employed to analyze 210-Pb uns profiles in LEO. Dating models are often compared with diagnostic environmental stratigraphic chronomarkers of known age to independently verify the resulting 210-Pb -based chronologies.

In order to constrain the resulting 210-Pb age models in LEO cores, changes in lithologies and in the TOC were selected as discrete chronostratigraphic markers. The presence of a top organic-matter rich lithological unit (i.e., massive grayish black, organic carbon-rich silt, Fig. 3) is a widespread characteristic overall the Pampean lakes, interpreted as the late 1970s hydrological change record. Following this assumption, the uppermost TOC increase in cores VT23-07 (level 29.0 cm) can be related to the primary productivity enhancement that, according to the instrumental record, took place in the LEO system after AD 1978-1979 (Fig. 1). The organic-matter rich uppermost lithological unit is a ubiquitous characteristic in all the retrieved cores along the LEO system. The TOC shift was detected in samples taken above the base (sharp contact) of the uppermost lithological unit, allowing to propose the age of AD 1980 ± 2 yrs for the time-marker T1. The age of T1 spans the transition between lowstand/highstand up to the deposition of organic matter-rich sediments after the hydrological change.Time markers T1GT10-07 (AD 1980.0 ±2) and T2GT10-07 (1923.0 ±5) are established in the sedimentary record of Laguna del Venado at levels 19.5 cm and at 69.0 respectively (Fig.5).

Fig. 5a shows the results when using the different dating models. The CIC, CRS and CRCF derived-chronologies show noticeable inconsistencies and therefore they can not be used for developing 210-Pb ages in the Laguna del Monte sedimentary record. Only the results of a constrained SIT model allow to estimate 210-Pb ages in agreement with the defined time marker. The corresponding model fitted to the data and associated probability distribution for the age-to-depth profile obtained from constrained SIT model are showed in Fig 5.

The results highlight that sediment records from shallow lakes located in regions with high inter-annual and inter-decadal precipitation variability must be carefully analyzed to develop a reliable chronological framework. The reliability of 210-Pb dating method of sediments accumulated in lake systems under a scenario of hydroclimatic change was analyzed by comparing the result of four well-known and widely used numerical models. The analyses of the hydroclimatic record, as well as the use of independent chronostratigraphic markers, are critical to select the most suitable model. CFCS, CIC and CRS models predict inconsistent age-depth profiles because the main assumptions of each model are not satisfied (i.e., constant flux of 210-Pb). There are strong evidences to consider that the 210-Pb atmospheric flux is highly controlled by long-term rainfall variability (i.e., ~120 yrs.) and therefore the results obtained by using classical models (i.e., CFCS, CIC and CRS) must be carefully considered. Several indicators (i.e., correlation of precipitation and 210-Pb flux, time markers) reinforce that the SIT-model is the most appropriated for assigning dates to lake sediments accumulated under interannual rainfall variability. In contrast to other models, the SIT-model has the advantage that no a-priori assumptions need to be made (i.e., constant flux of 210-Pb ; constant sedimentation rate) and therefore it can be applied when sedimentation rates and fluxes of 210-Pb uns vary with time. The SIT-model appears to be a valid and powerful technique for establishing the age of recently deposited sediments with non-exponential decay 210-Pb uns profiles. We recommend to use this alternative model when the input of 210-Pb to sediments is not homogeneous and constant over time.

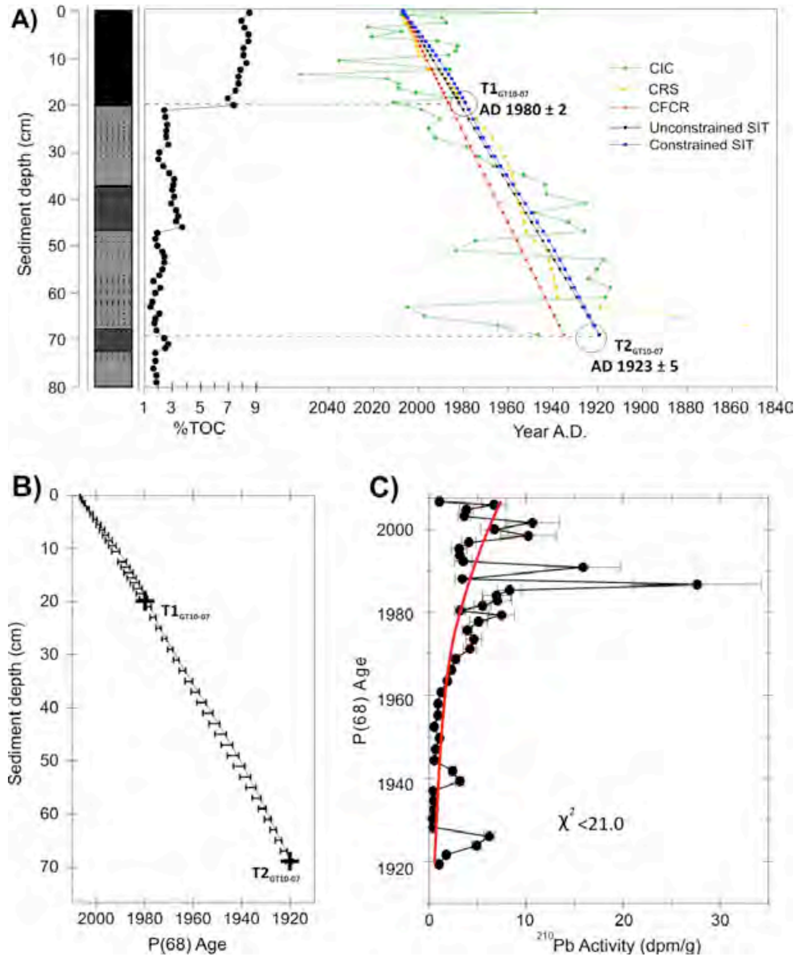

Figure 5. Laguna del Monte ^{210}Pb chronology: A) Depth-age profiles obtained using CRS, CIC, CFCS, constrained SIT and unconstrained SIT models. Time markers ($T1_{GT10-07}$: AD 1980.0 ±2; $T2_{GT10-07}$:AD 1923.0 ±5) are defined base on the TOC (see text for explanation). The constrained SIT model gives the most plausible dates when compared with $T1_{GT10-07}$ and $T2_{GT10-07}$. B) Probability distribution of age-to-depth variations using constrained SIT model; the two crosses represent time markers $T1_{GT10-07}$ and $T2_{GT10-07}$. C) Measured ^{210}Pb (dpm/g) activity and associated errors versus calendar age. The superposed theoretical curve (red line) represents the best fitting to the data using constrained SIT model..

The findings show that strongly non-monotonic 210-Pb uns sediment profiles, without a simple exponential depth decline in 210-Pb uns concentrations, cannot be directly used to estimate ages since the proposed chronology will vary depending on the considered assumptions about the supply of 210-Pb to the sediments and the dynamic of sedimentation. To select the most suitable dating model, it is necessary to understand the main acting mechanism delivering 210-Pb uns to sediments and to evaluate its possible impact on the radiometric record. In addition, the 210-Pb -derived geochronologies must be checked by using at least two independent time markers in different sections of the profile to assess and select the most reliable dating model.

d) Hydrological modelling of lakes

At present there is a growing concern to better understand the ongoing hydroclimatic variability. We developed an integrated hydrological model of the Laguna Mar Chiquita basin (Central Argentina), able to predict the lake response under various climatic conditions. Our results aimed to assess the applicability of SWAT (The Soil Water Assessment Tool model) for simulating the Sali-Dulce Basin discharge, responsible for the lake level rise in the early 70s. The climatic conditions of the 1973-2006 time period, including consecutively 10 wet and 10 dry years, allowed us to perform a cross calibration in order to evaluate and compare the transferability of SWAT parameters. We defined three climatic scenarios for the calibration, referred as wet (A: 1973-1983; ΔP = +28%), dry (B: 1984-1994; ΔP = -23%), and mixed (C: 1973-1994; ΔP = +0.03%). SWAT fairly performed in simulating baseflow, peak flow, and capturing the seasonal and annual variations in surface runoff. The validation on the climatologically opposite period underlined an improvement in model performance when the parameters are transferred from dry to wet climatic period. We determined a better simulation of peak flow than baseflow with a calibration during wet period, while the reverse was obtained for dry conditions. Therefore, if the modelling objectives is to simulate the rainfall-runoff response during contrasted climatic conditions, this study suggested a more strongly transferability of SWAT parameter with a calibration under mixed conditions. The coupling between SWAT and the lake water balance during the 1973-2006 time period provided satisfactory results comparable to those with observed runoff. Finally, we propose a coupled basin-lake hydrological modelling forced with limited meteorological data for the 1926-2006 time period, that pointed out the perspectives of this integrated hydrological approach to simulate long-term variations of the Laguna Mar Chiquita water level.

We have also provide an integrated basin-lake model forced by downscaled large-scale climate variables. First, large-scale precipitation and temperature downscaled from NCEP/NCAR reanalyses and LMDZ were statistically generated with the CDF-t approach at local scale; and second, these data were used as input to the SWAT model to simulate the Rio Sali-Dulce discharge; third, the level of fluctuations of Laguna Mar Chiquita were simulated during the 1950-2005 time period by a lake water balance model forced by the outputs of SWAT.

The results showed the ability of the downscaling method for reproducing the seasonal patterns and daily variabilities of precipitation and temperature in the Sali-Dulce Basin. The forcing of the SWAT model by the generated local-scale climate variables downscaled from the NCEP/NCAR reanalyses regions averaged over the Rio Sali-Dulce Basin gave good results. However, the most robust results were obtained using the downscaled LMDZ4 data averaged over two regions (boxes B and C) located at lower altitudes. The coupling between SWAT and the lake water balance model showed more realistic lake level simulations with SWAT forced by the two downscaled LMDZ boxes B and C, confirming a strong tropical climatic influence on the lake level fluctuations. Our results suggested that large-scale precipitation simulated by our GCM forced by HadISST1 provided the climatic forcing for the lake level fluctuations. Finally, Laguna Mar Chiquita can be considered as an integrator of large-scale climate changes since the forcing scenarios giving best results are those given by the global climate model simulations.

These results reveal the ability of the combination of large-scale climatic data derived from the LMDZ model with a statistical downscaling approach to reproduce regional climate features and establish how this integrated climate-basin-lake model is a promising approach for understanding and simulating long-term lake variations. This modeling approach may be used as a valuable tool for simulating future hydrological responses and for reconstructing past climate conditions, which will improve our understanding of climate variability in this region of South America.

General remarks

The paleolimnological research allows reconstructing back in time the regional hydroclimate behaviour in central Argentina over longer timescales (ca. last 300 years) than the existing instrumental data.
The instrumental record of lakes-level variability can be used to summarize the hydrological variability that took place in Central Argentina from the end of the XIX century to the present. The matching between the 20th century hydrological variability overall Pampean lakes and large-scale fluvial systems (e.g., Río Paraná; Río Paraguay) highlights the significance of lake archives for reconstructing the past activity of the South American Monsoon System in a large area of SESA. Our results assess how unusual has been the recent past, particularly the "hyper-wet period" after the mid-1970s until the "hydrological reversal" shown by Pampean lake systems after the year 2003.
Paleohydrological proxies for cold periods indicate negative hydrological balances in the Pampean region. Conversely, paleolimnological reconstructions suggest wet conditions during warm phases.

Authors involved in D3.03:

Eduardo Piovano (P13-CONICET and Universidad Nacional de Córdoba-ARG)
Florence Sylvestre (P1-IRD),
Christine Vallet-Coulomb (CEREGE),
Daniel Ariztegui (P20-UNIGE)
Magalí Troin (CEREGE)
Francisco Cordoba (P13-CONICET and Universidad Nacional de Córdoba-ARG)
Lucía Guerra (P13-CONICET and Universidad Nacional de Córdoba-ARG)

Institutes and contact address:
EDUARDO L. PIOVANO (epiovano@efn.uncor.edu)
FRANCISCO CÓRDOBA (franciscocordoba@efn.uncor.edu)
CICTERRA-CONICET, Universidad Nacional de Córdoba, Av Velez Sarsfield 1611, X5016GCA, Córdoba, Argentina

DANIEL ARIZTEGUI (daniel.ariztegui@unige.ch)
Section of Earth & Environmental Sciences, University of Geneva, 1205 Geneva, Switzerland

FLORENCE SYLVESTRE (sylvestre@cerege.fr)
CHRISTINE VALLET-COULOMB
MAGALI TROIN
CEREGE, Université Aix-Marseille, CNRS, IRD, Europôle méditérranéen de l'Arbois, BP 80, 13545 Aix-en-Provence cedex 4, France