

Reconstrucciones Regionales de las Variaciones Climáticas  
 en América del Sur durante el Holoceno tardío:  
 Una nueva Iniciativa de PAGES  
*Símpoio Internacional*

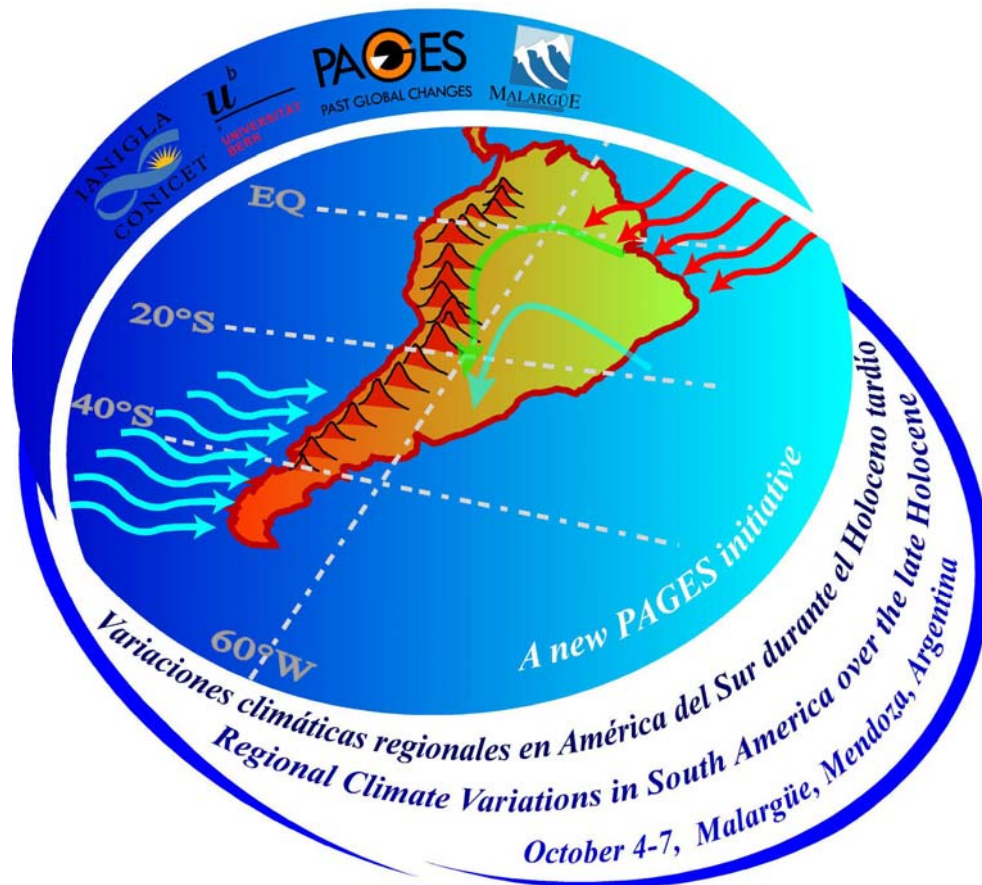
Reconstructing Past Regional Climate Variations  
 in South America over the late Holocene:  
 A new PAGES Initiative  
*International Symposium*

*Resúmenes / Abstracts*

4 al 7 de octubre de 2006  
 Malargüe, Mendoza, Argentina

October 4-7, 2006  
 Malargüe, Mendoza, Argentina





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en América del Sur durante el Holoceno tardío:  
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*Simposio Internacional*

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**El Simposio ha sido  
declarado de interés por:**

- El Honorable Consejo de Deliberante de Malargüe, Mendoza, Argentina.
- La Honorable Cámara de Diputados de la Provincia de Mendoza, Argentina.

**The Symposium has been  
declared of interest by:**

- The Honorable City Council of Malargüe, Mendoza, Argentina.
- The Honorable Chamber of Deputies of Mendoza Province, Argentina.

***Instituciones Organizadoras / Organizing Institutions***

**PAGES** (Past Global Changes), International Geosphere-Biosphere Programme, Bern, Switzerland.

**IANIGLA** (Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales), Mendoza, Argentina.

**University of Bern**, Bern, Switzerland.

**Municipalidad de Malargüe**, Mendoza, Argentina.

**CRIDC** (Centro Regional de Investigación y Desarrollo Cultural), Malargüe, Mendoza, Argentina.

***Comité Organizador Local / Local Organizing Committee***

**Ricardo Villalba**, IANIGLA, Mendoza, Argentina (coordinador/coordinator).

**Martin Grosjean**, Bern University, Switzerland (coordinador/coordinator).

**José A. Boninsegna**, IANIGLA, Mendoza, Argentina.

**María del Rosario Prieto**, IANIGLA, Mendoza, Argentina.

**Lydia Espizua**, IANIGLA, Mendoza, Argentina.

**Eduardo Piovano**, CIGES, Córdoba, Argentina.

**Antonio Lara**, Universidad Austral de Chile, Chile.

**Ricardo Scollo**, Director de Cultura, Municipalidad de Malargüe, Mendoza, Argentina.

**Fabiana González**, Directora de Turismo, Municipalidad de Malargüe, Mendoza, Argentina.

***Agradecimientos / Acknowledgements***

<b>PAGES (Past Global Changes)</b>
<b>IANIGLA (Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales)</b>
<b>Municipalidad de Malargüe</b>
<b>CONICET (Consejo Nacional de Ciencia y Técnica)</b>
<b>Agencia Nacional de Promoción Científica y Tecnológica, Secretaría de Ciencia, Tecnología e Innovación Productiva</b>
<b>Río Tinto, Potasio Río Colorado S.A.</b>
<b>Aguas Dadone S.A.</b>

## *Objetivo*

Contar con reconstrucciones climáticas regionales de alta resolución (estacionales a decenales) para los últimos 1000-3000 años es una de las áreas prioritarias dentro de los programas internacionales tales como el WCRP (World Climate Research Programme) y el IGBP (Programa Internacional de la Geósfera-Biósfera), especialmente sus sub-programas CLIVAR (Climate Variability and Predictability) y PAGES (Past Global Changes), y el WMO/UNEP IPCC (Panel Intergubernamental sobre el Cambio Climático). Sin esta información es muy difícil discriminar entre los cambios climáticos producidos por los modos de variabilidad climática natural y aquellos inducidos por el hombre. Importantes progresos se han observado recientemente en las técnicas de reconstrucción climática, en el manejo de un gran número de registros de alta y baja frecuencia, en la cantidad y calidad de las redes de registros disponibles a escalas regionales, hemisféricas y globales. Las reconstrucciones regionales son de particular importancia ya que las variaciones climáticas a escala regional y los eventos extremos asociados exhiben amplitudes mucho más importantes que las registradas a escalas hemisféricas o globales. Son precisamente a nivel regional donde los impactos de la variabilidad climática se hacen sentir más intensamente sobre las actividades socio-económicas.

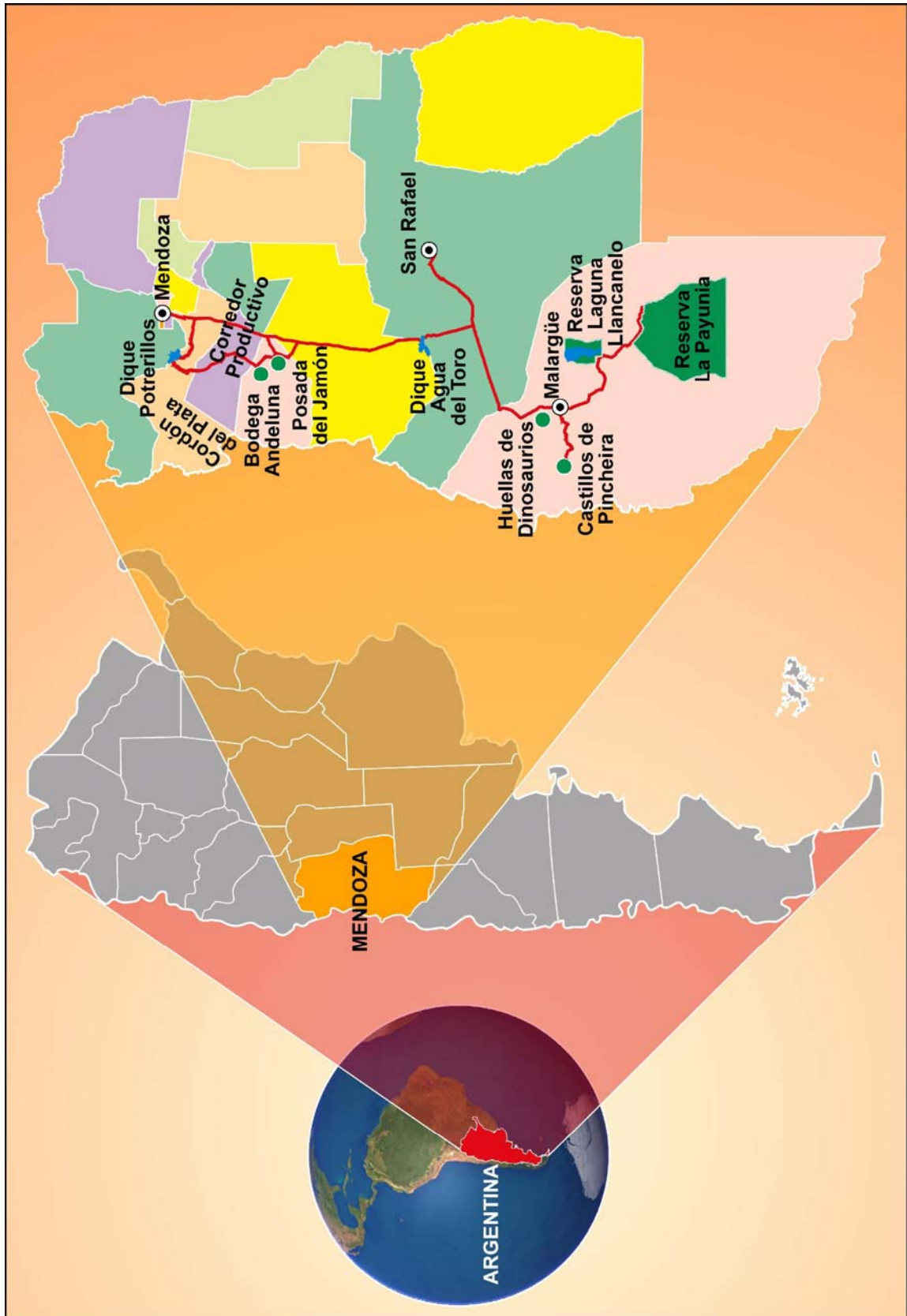
El objetivo de la Conferencia es reunir a todos los especialistas en registros paleoclimáticos de alta resolución de América del Sur para tener a través de las presentaciones de sus trabajos una visión regional de los avances logrados durante los últimos años, así como establecer normas de colaboración, manejo de información e implementación de pautas futuras para el avance de los estudios en el campo de la variabilidad climática en diferentes regiones de América del Sur.

## *Objective*

Counting with high resolution regional climatic reconstructions (seasonal to decennial) for the past 1000-3000 years is one of the priority areas within the international programmes such as WCRP (World Climate Research Programme) and IGBP (International Geosphere-Biosphere Programme), especially their sub-programmes CLIVAR (Climate Variability and Predictability) and PAGES (Past Global Changes), and the WMO/UNEP IPCC (Intergovernmental Panel on Climate Change). Without this information it is difficult to discriminate between natural and human-induced modes of climatic variability. Important progress has recently been observed in the techniques of climatic reconstruction, in the management of a large data sets, and in the quantity and quality of the networks of records available at regional, hemispheric and global scales. The regional reconstructions are particularly important, since the climatic variations at regional scale and the associated extreme events present much more important ranges than those registered at hemispheric or global scales. It is, in fact, at regional level where the impacts of the climatic variability affect more intensely the socio-economic activities.

The objective of the Conference is to gather all the experts in high resolution paleoclimatic records of South America in order to gain, through the presentations of their work, a regional vision of the advancements achieved during the last years, as well as to establish collaboration norms, information management and implementation of future guidelines for the advancement of studies in the field of climatic variability in different regions of South America.

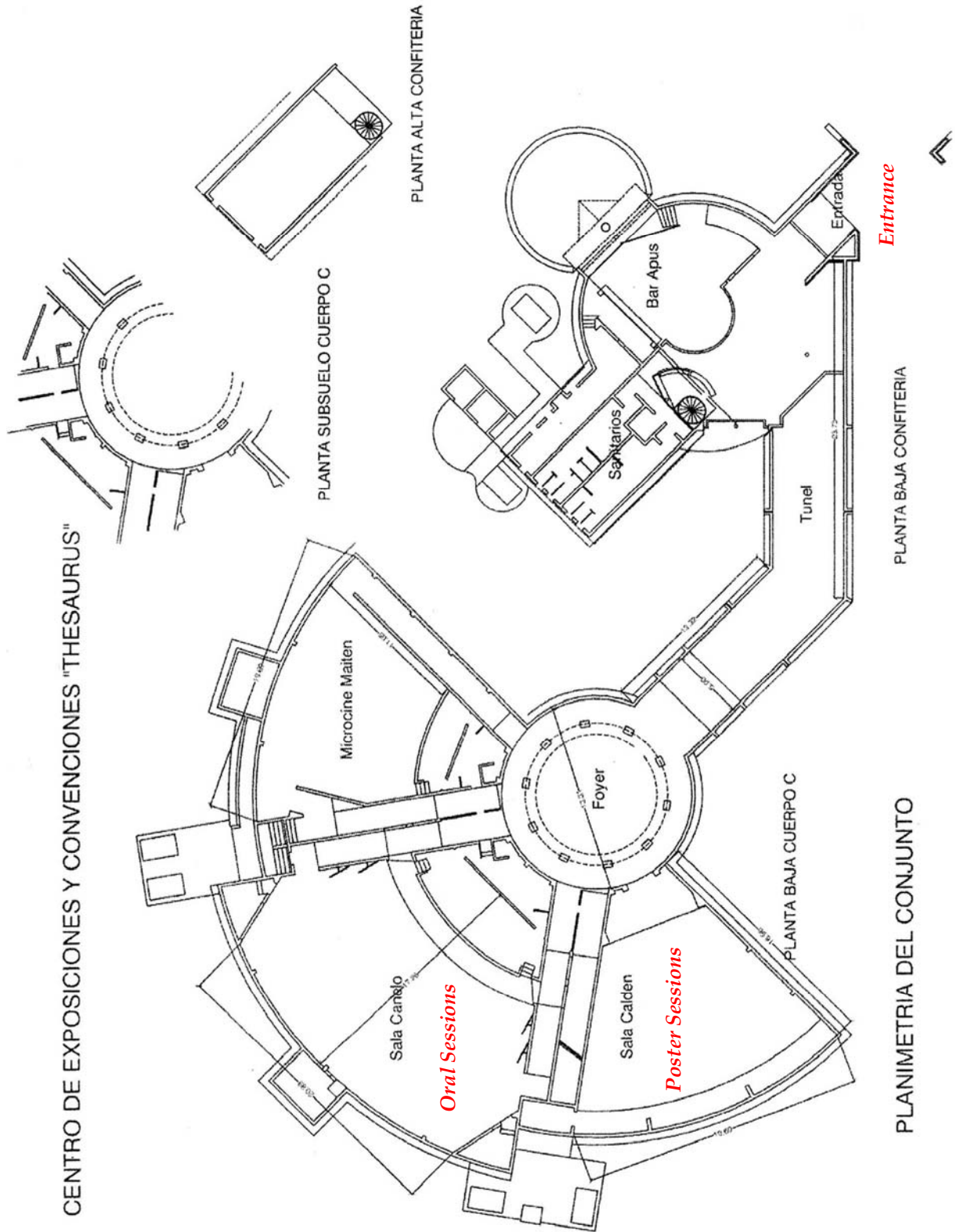
## Mapa de Ubicación/Location Map



# Ciudad de Malargüe / City of Malargüe



*"Thesaurus"*  
*Centro de Convenciones y Exposiciones / Convention and Expo Center*



CENTRO DE EXPOSICIONES Y CONVENCIONES "THESAURUS"

PLANIMETRIA DEL CONJUNTO

# Symposium Program

## October 4<sup>th</sup>

08:00	<b>Field trip Mendoza-Malargüe</b>
19:00	<b>Reception at the Thesaurus Center and Registration</b>

## October 5<sup>th</sup>

09:00	<b>Welcome to the meeting</b>		<b>Villalba / Grosjean</b>
09:15	<b>Welcome to Malargüe</b>		<b>Local authorities</b>

### Morning Session

<b>Present climate variability in South America</b>		
Moderators: Mathias Vuille and Rosa Compagnucci		
09:30	How can we link local paleoclimatic signals with global circulation anomalies?	<b>René Garreaud</b>
10:00	Climate variability in the central Andes of South America	<b>Mathias Vuille</b>
10:30	Teleconnection of Argentinean Andes Climatic fluctuations and high to low latitude processes	<b>Rosa Compagnucci</b>

11:00	<b>Coffee break</b>
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11:30	Searching present patterns of climate variability in the past: Lessons learnt from Europe	<b>Heinz Wanner</b>
12:00	Searching present patterns of climate variability in the past: How far we can go in South America?	<b>Ricardo Villalba</b>

12:30	<b>Lunch break</b>
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### Afternoon Sessions

<b>Climate variability in South America from historical documents</b>		
Moderators: María del Rosario Prieto and Alain Gioda		
14:20	Documentary and early instrumental data from southern South America: potential for climate reconstructions	<b>María del Rosario Prieto</b>
14:40	Documentary and early instrumental data from the tropical Andes: potential for climate reconstructions	<b>Alain Gioda</b>
15:00	A new chronology of El Niño events from historical documents	<b>Ricardo García Herrera</b>
15:20	Early instrumental records in South America: 18th century temperature data from Lima, Peru	<b>Carlos Carcelén Reluz</b>
15:40	Late Holocene ENSO manifestations and tropical-extratropical teleconnection patterns from geological and historical records in northern Chile	<b>Gabriel Vargas</b>

16:00	<b>Coffee break, wine break and Poster Session</b>
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<b>Climate variability in South America from tree-ring records</b>		
Moderator: José Boninsegna		
17:00	A high-resolution $\delta^{13}\text{C}$ 400-year tree-ring record for Patagonia as an indicator of past atmospheric conditions	<b>Fidel Roig</b>
17:25	Past rainfall variability reconstructed from <i>Pilgerodendron uviferum</i> tree-ring records in southernmost South America	<b>Juan Carlos Aravena</b>
17:50	ENSO variability from tree-ring records	<b>José Boninsegna</b>
18:15	Tree-ring network to reconstruct climate variability in the central Andes of Chile and Argentina.	<b>Carlos LeQuesne</b>
18:35	El Niño Southern Oscillation signal in world highest elevation tree-ring chronologies from the Altiplano Plateau at 4,600 m a.s.l.	<b>Duncan Christie</b>
18:00	International Cooperation for Earth Science Studies: The Italian Approach	<b>Gabriele Paparo</b>
18:20	<b>Adjourn for the day</b>	

## October 6<sup>th</sup>

### Morning Sessions

<b>Climate variability in South America from lake and marine records</b>		
Moderators: Martín Grosjean and Eduardo Piovano		
08:30	Lake sediments as archives for high-resolution quantitative climate reconstructions of the last 1000 years: Potential, challenges and limitations	<b>Martin Grosjean</b>
08:50	Blending historical and limnogeological records of the Little Ice Age in Southern South America	<b>Eduardo Piovano</b>
09:10	Sedimentological results from the Paleopeces research effort suggest centennial-scale shift in ocean productivity off Peru	<b>David Field</b>
09:30	1000 years record from Lagoa Grande (southeastern region of Brazil)	<b>Luiz Pessenda</b>
09:50	Climate variability in Southeastern Brazil during the last 4kyrs BP based on marine and coastal lagoons sediments	<b>Ana Luiza Albuquerque</b>
10:10	A high-resolution pollen and diatom record from Laguna Los Polulos (22°36'S/66°44'W/4500 masl), NW Argentinean Puna, since ca. 800 AD	<b>Liliana Lupo</b>
10:30	<b>Coffee break</b>	

<b>Climate variability in South America from high-resolution pollen records</b>		
Moderators: Patricio Moreno and Aldo Prieto		
11:00	High-resolution paleoecology during the Late Holocene in NW Colombia	<b>César Augusto Velásquez Ruiz</b>
11:20	Vegetation history in the Peruvian Andes	<b>Blanca León</b>
11:40	Potential for obtaining a high-resolution pollen record, showing winter precipitation in the semi-arid coast of Chile (32°S) during the last 2000 years	<b>Antonio Maldonado</b>
12:00	Vegetation history and climatic variability during the Late Holocene at Pampa grasslands: the state of the art	<b>Aldo Prieto</b>
12:20	Holocene fire, climate, and vegetation linkages in southern South America: local and regional comparisons	<b>Cathy Whitlock</b>

12:40	High environmental variability over the last 3000 years deduced from small closed-basin lakes in NW Patagonia	<b>Patricio Moreno</b>
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13:00	<b>Lunch break</b>	
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### Afternoon Session

<b>Climate variability from ice cores</b>		
Moderator: Patrick Ginot		
14:30	The 1000-year long climate history in South America from ice cores: potential and limits	<b>Patrick Ginot</b>
15:00	Firn and ice core records from high-elevation sites in the mid-latitude Andes	<b>Andrés Rivera</b>
15:30	Climate variations in Bolivia inferred from tropical ice cores	<b>Edson Ramírez</b>

16:00	<b>Coffee, wine-break and Poster Session</b>	
17:30	<b>Guided visit to the dinosaurs path field near Malargüe</b>	
20:00	<b>Friendship Dinner</b>	

## October 7<sup>th</sup>

### Morning Sessions

<b>Glacier records in South America during the past three millennia</b>		
Moderator: Lydia Espizua		
08:30	Recent dendroglaciological investigations in the Patagonian Andes of Argentina	<b>Mariano Masiokas</b>
08:55	The Little Ice Age in the Central Andes of Mendoza, Argentina	<b>Lydia Espizua</b>
09:20	Anomalous century fluctuations of Glaciar Perito Moreno, southern Patagonia	<b>Pedro Skvarca</b>
09:45	Historical glacier variations in Chile	<b>Andrés Rivera</b>
10:10	Glacier Variations in the Tropical Andes	<b>Edson Ramírez</b>

10:30	<b>Coffee break</b>	
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<b>Speleotherms</b>		
Moderator: Ricardo Villalba		
11:00	Stalagmite Evidence of Droughts in Belize at the Time of the Classic Maya Collapse and the Potential for Similar High-resolution Paleoenvironmental Records from Speleotherms in Southern South America	<b>George Brook</b>

<b>Human-climate interactions</b>		
Moderator: Rick Battarbee		
11:30	Palaeolimnology, pollution and lake restoration	<b>Rick Battarbee</b>
11:50	Paleolimnological evidence of environmental changes during the last 2000 years in south-central Chile	<b>Roberto Urrutia</b>
12:10	Climatic change and human occupation in the preandean region of NW Argentina during the Upper Holocene	<b>José Manuel Sayago</b>

12:30	<b>Lunch break</b>	
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## Afternoon Sessions

<b>Multi-proxy reconstructions and climate modeling</b>		
Moderator: Bette Otto-Bliesner		
14:30	Multiproxy climate reconstructions: The example from Europe and the potential for South America	<b>Juerg Luterbacher</b>
14:50	Climate Model Simulations of the South America Response to a Cold North Atlantic: Some Preliminary Results	<b>Bette Otto-Bliesner</b>
15:20	Climatic simulations for Middle Holocene of South America with CPTEC Model, from different contour conditions	<b>Luciene Melo</b>
15:50	Antarctic Oscillation and its implications for proxy-based reconstructions	<b>Flavio Justino</b>

16:10	<b>Coffee, wine-break and Poster Session</b>
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<b>PAGES initiative in South America</b>		
Moderators: Julie Brigham-Grette and Heinz Wanner		
17:00	PAGES: Mission and programs	<b>Brigham-Grette / Kiefer</b>
17:20	PAGES in the Southern Hemisphere: variation on orbital time scales	<b>Peter Kershaw</b>
17:40	PAGES across the Americas: from PEP I to the new initiatives	<b>Brian Luckman</b>
18:00	LOTRED South America: A new PAGES Initiative	<b>Grosjean / Villalba</b>

18:15	<b>Closure and wrap up</b>
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## October 8<sup>th</sup>

09:00	<b>Field trip to La Payunia (volcano field) and Llanquanelo Lake</b>
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## Oral Presentation Abstracts

### Present climate variability in South America

#### How can we link local paleoclimatic signals with global circulation anomalies? <sup>(1)</sup>

**René D. Garreaud**

*Department of Geophysics, Universidad de Chile. [rgarreau@dgf.uchile.cl](mailto:rgarreau@dgf.uchile.cl)*

The content of this presentation was motivated by a recurrent and very relevant question formulated by colleagues in the paleoclimatology community, namely, given a time series of, say, precipitation at a single point what can we say about the large-scale circulation? The variability in the reference time series can be derived using a variety of tools, ranging from simple visual inspection to complex wavelet analysis, and one would like interpreting such local variations in terms of large-scale circulation anomalies.

To address this question we will use short (i.e., part of last century) but comprehensive precipitation and circulation datasets, described briefly in the first part of the presentation. These datasets include atmospheric and oceanic reanalysis, as well as gridded-analysis and station-observations of precipitation and surface air temperature.

In the second part of the talk, we document the local coupling between circulation and precipitation at different time-scales. Basically, we display on a map the correlation between collocated time series of precipitation (P) and zonal (east-west) flow aloft (U). At intraseasonal and longer time-scales, both variables are positive and significantly correlated over much of the midlatitude oceans, since strong westerlies are conducive of a rapid growth and fast succession of baroclinic disturbances, leading to an increase of cyclonic/frontal precipitation. At or near the continents, the local P-U correlation is significantly perturbed by orographic effects. The clearest example occurs precisely in the southern Andes; the P-U correlation is high and positive to the west of the range, decreasing sharply and even changing its sign to the east.

In the last part of the presentation, we move from the local to the large-scale perspective. Here we review the main modes of atmospheric variability on current climate (ENSO, SAM, ZW3, PDO, etc.) with special emphasis on their fingerprints on rainfall and surface air temperature on the southern South American region.

(1) Part of this presentation is included in the work "Precipitation and circulation covariability in the extratropics" available from <http://www.dgf.uchile.cl/rene/PUBS/storm.pdf>.

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### Climate variability in the central Andes of South America

**Mathias Vuille**

*Climate System Research Center, University of Massachusetts, Amherst, USA. [mathias@geo.umass.edu](mailto:mathias@geo.umass.edu)*

A successful gridded multi-proxy reconstruction of climate parameters such as precipitation or temperature, which is both dynamically consistent and physically meaningful, requires a

detailed knowledge of the main modes of spatiotemporal climate variability. Here we discuss the spatial and temporal variability of these modes over a region which is known for its wealth of paleoclimatic information, the central Andes (~15-30°S). Evidence from a large number of observational and modeling studies suggests that the leading mode of present-day interannual climate variability is associated with El Niño - Southern Oscillation (ENSO) and that this tropical Pacific forcing can easily be identified in precipitation and temperature records, but also in proxy data such as tropical Andean ice cores. We will review the teleconnection mechanisms which lead to this dominant ENSO influence and discuss the issue of (non)-stationarity, which is very relevant in this context. In addition we will show how apparent discrepancies in the proxy record may be related to spatially varying sensitivities toward ENSO due to the complex topography of the Altiplano region. A discussion of other modes of variability (e.g. a 20<sup>th</sup> century warming trend), which are superimposed on ENSO and a presentation of a new high-resolution gridded data set of summer precipitation, which may be useful for calibration purposes, will end this presentation.

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## **Teleconnection of Argentinean Andes Climatic fluctuations and high to low latitude processes**

**Rosa Hilda Compagnucci**

*Facultad de Ciencias Exactas, Físicas y Naturales, UBA, Buenos Aires, Argentina. [rhc@at.fcen.uba.ar](mailto:rhc@at.fcen.uba.ar)*

River runoff, precipitation and temperature in the Central and South Andes of Argentina are highly correlated with the inter-annual climate variability that occurs in high and low latitudes.

The runoff variations of rivers with basins in the Central Andes Cordillera and in the Southern portion of Patagonia are significantly correlated with variations of the sea surface temperature (SST) in the Equatorial Pacific at inter annual to decadal scales. An important component of the variance can be explained by El Niño/Southern Oscillation (ENSO). Positive (negative) anomalies of the SST during the austral winter correspond with abundant (low) snow fall at high mountain altitudes, with the consequent increase (decrease) of summer streamflow.

However, the rivers with basin in the northern and central part of Patagonia do not show any signal related to ENSO. In that region, the runoff predominantly reflects the influence of ice conditions of the Bellinghausen - Amundsen and Weddell Seas. In general, positive anomalies in the concentration of sea ice ((SIC) in the Weddell Sea and in the eastern sector of the Bellinghausen Sea are associated with positive precipitation anomalies over the basins situated to the north of 45°S and with negative anomalies to the south.

We conclude that the inter annual variations of the Central and Patagonian rivers streamflows are related to the winter circulation anomalies that, in turn, are strongly influenced by particular tropical SST anomalies and/or high latitude conditions related to the quantity of sea ice.

During the summer, the precipitation in the foothills of the eastern Central Andes is related to the SST conditions in the South Atlantic Ocean and do not show any relation to ENSO.

The inter-annual variability of the precipitation is modulated by a 18 year semi-periodic cycle prior to the 1976/77 austral summer. After this year, the summer precipitation variance seems to be dominated by a longer period wave. This climatic change is associated

with a change in the teleconnection between the precipitation and the circulation conditions and SST of the South Atlantic sector

Precipitations in Patagonia also show different signal of variability for winter and summer. Furthermore, precipitation present inverse anomaly signals in the north and the south sectors.

Sea ice conditions are associated to both precipitation and temperature anomalies that occur over all the Southern part of South America due to special patterns of spatial SIC anomalies. The temporal variability of the sea ice in the Austral Seas are partially related to the ENSO cycle

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### **Searching for patterns of past climate variability: lessons learned from European studies**

**Heinz Wanner**

*NCCR Climate and Institute of Geography, University of Bern, Switzerland [wanner@giub.unibe.ch](mailto:wanner@giub.unibe.ch)*

Diagnosing the long-term state of the climate system requires the simultaneous analysis of different climatological state variables such as temperature (SAT, SST), precipitation and air pressure. These variables then form the basis of the so-called Long Term Reconstruction and Diagnostics (LOTRED) approach which aims to include reconstructed as well as model data.

Thanks to a large number of data from natural archives and, also based on a rich variety of documentary evidence, a detailed analysis of these of state variables was carried out for Europe for the last 500 years with a reasonable resolution (seasonal to monthly, grid spacing 0.5° - 5°; see the contribution by Luterbacher). These data allow the systematic classification of those seasonal climate patterns or even those climate regimes (Stephenson et al. 2004) which determined the climate dynamics during the investigated period. The combined analysis of seasonal data in the state space demonstrates the known fact that the climate system behaves nearly stochastic. On the continental to regional scale, internal variability dominates over natural forcing. It will be an exciting challenge to perform similar studies in other areas such as South America, mainly also as a basis for the combination with modeling studies.

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### **Searching patterns of climate variability in the past: How far we can go in South America?**

**Ricardo Villalba**

*Departamento de Dendrocronología e Historia Ambiental, IANIGLA, C.C. 330, (5500) Mendoza, Argentina.  
[ricardo@lab.cricyt.edu.ar](mailto:ricardo@lab.cricyt.edu.ar)*

Instrumental records provide a comprehensive view of climate variations in South America and their interactions with dominant modes of atmospheric circulation (such as ENSO, PDO, Tropical Atlantic SSTs, AAO) during the past 50-100 years. However, a longer-term perspective on climate variability across South America is vital to a comprehensive understanding of the behavior of the regional climatic system under different forcing conditions (e.g. increased CO<sub>2</sub>) and how interannual modes of climate variability interact

with decadal and centennial modes. Over recent decades, evidence from diverse proxy records has provided insight into past climate variability in South America. Although consistent patterns of variability have emerged from areas with relatively abundant proxy-information on past climate, many paleoclimatic studies (or their interpretations) remain controversial.

The new LOTRED-South America initiative is intended to provide consistent patterns of past climate variability across this region. Facing this challenge, paleoclimatologists must be concerned with the consistency and reliability of these proxy records. How well do proxy-records reflect present and past climate fluctuations? Are these results consistent with what is known about climate and physical processes recorded in the region during the 20<sup>th</sup> century? Do the presently observed relationships between climate and proxy records remain stable over time? Are we conscious of the proxy-record limitations? Examples from high-resolution proxy climate records in South America will be provided that illustrate the potential and limitations of these records and highlight the need for a multi-proxy approach to provide consistent reconstructions of past regional climates.

## Climate variability in South America from historical documents

### Documentary and early instrumental data from southern South America: potential for climate reconstruction

**María del Rosario Prieto**

*Departamento de Dendrocronología e Historia Ambiental, IANIGLA, Mendoza, Argentina. [mrprieto@lab.cricyt.edu.ar](mailto:mrprieto@lab.cricyt.edu.ar)*

En esta ponencia se ofrecerá un breve panorama sobre la potencialidad de la documentación histórica disponible en la región sur de Sudamérica, es decir Paraguay, Uruguay, Chile y Argentina, para obtener reconstrucciones continuas y rigurosas de las temperaturas, las precipitaciones y otras variables climáticas de las últimas centurias cuya ocurrencia haya quedado registrada intencionalmente o en forma casual en las fuentes.

Se dará en primer lugar un vistazo sobre la distribución espacio-temporal de la documentación histórica en la región: inicio de la misma y período que abarca, teniendo en cuenta que en la América conquistada por España la extensión temporal de las reconstrucciones climáticas varía de acuerdo con la fecha del ingreso de los españoles a cada región americana. Se debe considerar además que en algunas regiones y en relación a determinados eventos climáticos los registros son bastante tardíos (por ejemplo, la caída de granizo en Mendoza o la ocurrencia de precipitaciones nivales en la cordillera).

Hay mayor información para los tiempos de la Colonia española que durante el siglo XIX. Como el sur de Sudamérica fue una región relativamente marginal durante el dominio español los datos instrumentales fueron casi inexistentes en esa etapa. Solamente a partir del último cuarto del siglo XIX se comenzaron a registrar los eventos meteorológicos en forma sistemática. Los periódicos comenzaron a informar sobre los fenómenos del tiempo alrededor de 1830/50.

El análisis de las fuentes potenciales de información paleoclimática incluye, entre otros ítems, la exploración de los ámbitos físicos dónde rastrear la documentación, por lo que se indicarán los archivos y hemerotecas regionales y extrarregionales más relevantes. Asimismo se considerará el tipo de información necesaria para elaborar series climáticas y

los documentos que se deben buscar, teniendo en cuenta que la documentación es diferente para cada etapa , colonial y republicana.

Las fuentes potenciales específicas de información paleoclimática para América del Sur, aunque varían de región en región, incluyen, entre otras: antiguas inscripciones, anales y crónicas, registros gubernamentales, registros privados, registros marítimos y comerciales, papeles personales, como diarios y correspondencia, escritos científicos o quasi científicos, como los diarios meteorológicos (no instrumentales), tempranos registros instrumentales fragmentados , mapas, dibujos y fotografías, periódicos desde el siglo XIX en adelante y cuadernos de bitácora.

La información se puede analizar también de acuerdo a las características geográficas, dado que los grandes sistemas geográficos americanos tienen una identidad propia que se traduce en fuentes diferenciadas para su tratamiento.

- Las cordilleras: datos sobre la nieve, los glaciares y los deshielos estivales.
- Los océanos o regiones costeras: los cuadernos de bitácora o los informes sobre salidas y entradas de embarcaciones.
- En ecosistemas agrícolas: datos relacionados con la marcha de las cosechas, la cría del ganado y el precio de los productos.
- Litoral fluvial: datos sobre las grandes inundaciones y crecidas
- En todos : datos sobre temperatura, precipitaciones, anomalías climáticas

Se presentarán y comentarán los resultados obtenidos hasta la fecha en Argentina y Chile, sobre todo en cuanto a series de precipitaciones y de caudales, aclarando que es más difícil elaborar series de temperatura por la menor calidad y cantidad de los datos.

Se analizarán las perspectivas futuras: lo existente y lo que resta por hacer en este campo, tanto desde la perspectiva espacial como desde la temporal.

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## **Una nueva cronología de El Niño a partir de fuentes primarias**

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El Niño- Oscilación del Sur (ENSO en su acrónimo inglés) es la principal fuente de variabilidad del sistema climático. Comprende dos fenómenos: EL Niño, que es un calentamiento de las aguas superficiales del Pacífico oriental y la Oscilación del Sur, que es una variación a gran escala del sistema de presión atmosférica del trópico. Su impacto no se limita al Pacífico tropical, sino, que, mediante la alteración que provoca en la convección tropical, se extiende a amplias regiones del globo. El interés de su estudio radica en una serie de factores tanto climáticos como socioeconómicos. Por una parte presenta un comportamiento cuasi periódico, en torno a las 7-8 años, pero modulado por oscilaciones en escalas multidecádicas y superiores. Además, aunque se está avanzando en su predicción, no se conocen las causas capaces de desencadenar un episodio de El Niño. Sus manifestaciones más extremas incluyen inundaciones, sequías, desplazamientos de pesquerías y alteraciones en el patrón normal de temperaturas, llegando a adquirir características catastróficas. Todo ello justifica el énfasis que en los últimos años está poniendo la comunidad científica en analizar los distintos ángulos de ENSO.



Uno de los principales retos pendientes es evaluar su comportamiento pasado. Aunque parezca una paradoja, cuanto mejor conozcamos cómo ha evolucionado en el pasado, más probabilidades tendremos de entender los mecanismos físicos que lo generan y de mejorar su predicción. Si bien en la actualidad se dispone de un denso sistema de seguimiento de ENSO, a través de la medida casi continua de la temperatura de la superficie del mar Pacífico mediante un sistema que combina boyas y satélites, es obvio que las evidencias de ENSO en los siglos pasados son mucho más difíciles de encontrar, especialmente antes de 1850, ya que no hay datos procedentes de aparatos como termómetros o barómetros. Por ello es necesario recurrir a indicios indirectos como los denominados proxies que son variables no estrictamente climáticas, pero cuya variabilidad está parcialmente influenciada por el clima.

Los archivos documentales son una fuente excelente de información climática ya que pueden contener información de una gran variedad de proxies como impuestos, cosechas y de ocurrencia de eventos extremos como huracanes o inundaciones. Además, permite obtener datarlos con mayor precisión que ninguna otra fuente proxy, pudiéndose alcanzar resolución horaria.

El objetivo de este trabajo es presentar los primeros resultados sobre una nueva cronología de El Niño, obtenida después de más de tres años de trabajo con fuentes primarias en archivos peruanos y en el Archivo General de Indias. La cronología cubre el periodo 1550 a 1900. A partir de la transcripción de las fuentes documentales se elaboró un conjunto de indicadores de la ocurrencia de episodios EN en el área de Trujillo en el Norte de Perú. Se obtuvieron unos 2000 registros potencialmente útiles para la cronología. Los mismos se examinaron independiente por varios climatólogos e historiadores, llegándose finalmente a una interpretación conjunta, que permitió identificar un total de 52 episodios Niño. Los resultados así obtenidos se comparan con cronologías previas y se evalúan las principales escalas presentes en la serie temporal resultante.

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## **Registros tempranos en Sudamérica: La temperatura de Lima en el siglo XVIII**

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La elaboración del banco de datos históricos sobre el desenvolvimiento del clima en el área central del Perú durante el siglo XVIII revela hasta que punto nuestra tarea de recolección de fuentes y elaboración de series cuantitativas a llegado a buen termino, considerando el grave problema que resulta encontrar testimonios de la actividad climática en un determinado tiempo histórico.

Para la mayoría de los hombres de nuestros días resulta de poca importancia el tema, ya que sus condiciones de vida no se determinan por las estaciones y menos por las condiciones climáticas, a pesar de las repercusiones de fenómenos como El Niño, el calentamiento global y los recientes desastres en América del Norte.

En cambio para los habitantes de Lima y sus zonas aledañas en el siglo XVIII si lo era, ya que para la actividad agrícola resultaba imprescindible un conocimiento atento de los fenómenos climáticos, y para ello es bien sabido que existían métodos de reconocimiento del desenvolvimiento de las estaciones desde la época prehispánica.

Estas preocupaciones se ven reconocidas en un siglo como el XVIII donde la investigación, el descubrimiento y la racionalidad son una especie de moda e incluso forma

de vida, sobre todo desde mediados del siglo XVIII con la aparición de infinidad de estudios, ensayos, crónicas y publicaciones donde el tema recurrente es el clima y en general todo tipo de fenómeno del medio ambiente y la naturaleza.

Nuestra mayor preocupación, como investigadores, radica especialmente en el hecho de que los antiguos pobladores de Lima no dejaron muchos vestigios o testimonios definidos de las manifestaciones climáticas por ellos vividas (y hasta sufridas). Preocupación que se compensa por la gran cantidad de información proporcionada desde distintos ángulos y diversidad de fuentes, tanto de habitantes de la zona como de la gran cantidad de viajeros extranjeros.

En sociedades como la peruana del siglo XVIII, en donde los avances científicos no permitían un control más óptimo de la naturaleza, el hombre como actor social dependerá del conocimiento de las manifestaciones del clima (o estado del tiempo como se decía entonces). Este conocimiento será esencial ya que se convertía en un elemento de primera línea en el desarrollo y planificación de sus actividades productivas.

Estas variaciones según las fuentes consultadas se reflejaron en un incremento de la temperatura promedio entre los años de 1754 a 1800 en unos 0.23 grados centígrados. Mientras que las máximas en el mismo lapso de tiempo se incrementan en 0.85 grados y las mínimas bajan en unos 0.35 grados.

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## **Late Holocene ENSO manifestations and tropical-extratropical teleconnection patterns from geological and historical records in northern Chile**

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El Niño, the warm phase of the ENSO cycle, involves ocean-climate anomalies in the tropical Pacific Ocean and in the extratropics, which frequently result in heavy rainfall episodes along the equatorial and subtropical regions including the hyperarid coast of western South America.

The chronostratigraphy of debris flow deposits from northern Chile and southern Peru and its comparison with other paleoclimate records at the western side of the Andes indicate that the modern ENSO mode of climate variability operated during the second half of the Holocene. Several lines of evidence support an onset of modern El Niño manifestations at 5,300-5,500 cal BP and an increased frequency of major events during recent times.

On a shorter time-scale, the analysis of historical documentary sources from Central Chile and the Peru coastal region suggests different patterns of ENSO-teleconnection systems before and after the early nineteenth century. It is only after ~1817 AD that El Niño manifestations are characterized by both precipitation excess in winter in central Chile and anomalous summer rainfalls along the coast of Southern Ecuador and northern Peru. Before that date, and for three centuries, these classical manifestations did not occur concomitantly during any given El Niño event.

These results point to an increased influence of ENSO in the subtropical region of the southeastern Pacific during the Late Holocene, and especially since the early nineteenth century when it has been superimposed to a global warming trend.

## Climate variability in South America from tree-ring records

### A high-resolution $\delta^{13}\text{C}$ 400-year tree-ring record for Patagonia as an indicator of past atmospheric conditions

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The isotopic composition of carbon contained in tree rings may reflect the  $^{13}\text{CO}_2$  variations in the atmosphere related to the global carbon cycle. In this paper, we present a 400-year  $\delta^{13}\text{C}$  record that shows evidence of relationships with atmospheric  $\delta^{13}\text{C}$  expressed by the couples  $^{13}\text{C}_{\text{air}}-^{13}\text{C}_{\text{wood}}$  and  $\text{CO}_{2,\text{air}}-^{13}\text{C}_{\text{wood}}$ . Comparisons were supported by a well-replicated and significant cross-correlated  $^{13}\text{C}$  tree-ring conifer record from Northwest Patagonia. Thus, the strong common variability in  $^{13}\text{C}/^{12}\text{C}$  ratios among individuals provides a good representation of the  $\delta^{13}\text{C}$  trends in the region. The 400-year  $\delta^{13}\text{C}$  curve shows regular fluctuations between the 1600s and the beginning of 1800s and a long-term decline after 1840, falling most rapidly during the last 50 years. The  $\delta^{13}\text{C}$  decrease after 1950 is particularly sharper from the 1970's to date. The similar scale of change observed between our  $^{13}\text{C}_{\text{wood}}$  record and those from other regions of the World suggests that trends in Patagonia are representative of global  $^{13}\text{C}_{\text{air}}$  values. Moreover, global atmospheric  $^{13}\text{CO}_2$  and  $\text{CO}_2$  values are strongly correlated with the tree-ring isotopic record. We discuss the potential of this record as an indicator of atmospheric  $\text{CO}_2$  for both the past and present in the Southern Hemisphere.

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### Past rainfall variability reconstructed from *Pilgerodendron uviferum* tree-ring records in southernmost South America

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*Pilgerodendron uviferum* is an endemic conifer species of Chile and adjacent areas in Argentina that grows between 39° S and 54 ° S and from sea level up to the upper tree line. Tree-ring width series from this species has been reported significantly correlated with fluctuations in precipitation and temperature. There are, however, only 3 published *Pilgerodendron* chronologies from south of 44° S and no tree-ring based climatic reconstruction using this species for this region. A recently constructed network of 20 tree-ring chronologies for *Pilgerodendron uviferum* from the west coast of southernmost South America is analyzed in relation to its time series characteristics, spatial and temporal variability in the common signal of these series, and the correlation of this common signal with instrumental rainfall records. The best-correlated combinations of monthly precipitation records and tree-growth series were used to reconstruct two regional rainfall averages. The first regional average was formed with precipitation records from nine Northern Patagonia stations. The reconstructed precipitation series extends between **1625 and 1994**, explaining a **51%** of the variance. The second regional average includes

precipitation records from five Southern Patagonia stations and its reconstructed series extends from 1550 to 1994, explaining 33% of the total variance. The spectral characteristics of both reconstructed series were analyzed and their temporal and spatial variability are discussed in relation to the atmospheric circulation systems operating in this region.

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## ENSO variability from tree-ring records

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El Niño-Southern Oscillation (ENSO) has a large impact in several regions of the Southern Hemisphere. During the El Niño (La Niña) outbreaks extreme and contrasting weather conditions with wide-ranging and often severe effects occur.

Several paleo-records have been used to reconstruct ENSO low and high frequency variability. Most of these reconstructions have been done in the Northern Hemisphere where the paleo-records are more abundant, consistent and even distributed that in the South.

The number of paleo-records in the Southern Hemisphere has increased in the last years, in particular the tree-ring collections in New Zealand and in South America. We analyze the potentialities and problems to reconstruct ENSO from the new dendrochronologies with emphasis in those developed in South America. Some examples of reconstructions are also discussed.

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## Tree-ring network to reconstruct climate variability in the central Andes of Chile and Argentina

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Only about 5% of the global paleoclimate records come from the Southern Hemisphere. In the west coast of southern South America at central Chile, the moisture-sensitive coniferous *Austrocedrus chilensis* provides one of the most robust tree-ring proxies for climate variability over the last millennium. We are developing a millennial long tree-ring network through the steep precipitation gradient between the hyperarid and Mediterranean climate regime to the south (32-35°S). Using this network we have reconstructed the precipitation variability of central Chile for the last 800 years. Our results show a clear shift from decadal to increased interannual mode of variability after 1850, apparently linked to enhanced ENSO-like activity, along with an increased drought risk and sustained glacier retreat. Several multi-year drought episodes are detected (), confirming the previous paleoclimatic findings and historical records. In a human dimension context, our findings are very relevant because the zone encompass the highest populated area of Chile and one of the most important bi-national economic corridors Chile-Argentina, which largely dependents on freshwater for

urban, agricultural and industrial consumption. The future work will be focused in improve the geographic and time coverage of the network along with the development of collaborative research for interhemispheric comparisons.

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## **El Niño Southern Oscillation Signal in World Highest Elevation Tree-Ring Chronologies from the Altiplano Plateau at 4,600 m a.s.l.**

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El Niño-Southern Oscillation (ENSO) is the largest source of inter-annual variability operating in the earth's climate system, and is associated with extreme weather conditions having large social, ecological and economic impacts.

Several tree-rings records have been utilized to reconstruct past ENSO variability but none of them comes from South America. On the Altiplano plateau in the central Andes are located the world highest elevation forest composed by *Polylepis tarapacana* trees 4,000-5,000 m a.s.l. We use two tree-ring chronologies in order to analyze the regional climate and ENSO influences on *P. tarapacana* growth at the east and west Andean slopes on the Altiplano.

*P. tarapacana* growth has a strong common signal and a complex relation with summer temperature and precipitation. Ring-width has an inverse relation with temperature respect to precipitation. Temperature has a positive and negative influence on ring-width during current and previous summer, respectively. Tree-growth is positively correlated with spring-summer tropical Pacific SSTs, with a spatial pattern resembling to ENSO wedge. In general the El Niño (La Niña) events are well recorded in the chronologies, determining above (below) mean anomalies on tree-growth. *P. tarapacana* chronologies offer a good opportunity to future multi-proxy ENSO reconstructions.

## **Climate variability in South America from lake and marine records**

### **Lake sediments as archives for high-resolution quantitative climate reconstructions of the last 1000 years: potential, challenges and limitations**

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Quantitative high-resolution multi-proxy climate reconstructions at the global and regional scale have become very important in recent years. While tree rings, ice cores and documentary data are widely used for such efforts, it is extremely rare that lake sediment data series are included in such multi-proxy reconstructions. The problem is the “translation” of sediment proxies into quantitative climate state variables. This is also the case for (southern) South America, where most of the lake sediment archives are explored in

a qualitative way only (e.g. 'warmer', 'cooler', 'drier' etc. than present), and quantification remains a difficult task.

This paper explores the methodological challenges for lake sediment-based (sub)decadal quantitative climate reconstructions, whereby the target of the reconstruction is a time-series for a climate state variable (e.g. precipitation, temperature, ...) for a particular season (summer, winter, annual mean) which depicts climate variability in a known specific frequency band (interannual, decadal and centennial scale) with attributed uncertainties. This information is required for multi-proxy climate reconstructions.

For lake sediments, three major problems have to be solved: (1) Calibration of the lake sediment proxies with a climate variable using statistical tools (calibration "Space for Time" or "Calibration in Time"), (2) 'Best' age-depth models (for the 20<sup>th</sup> century and back in time), which is most critical if "Calibration in Time" is used, and (3) continuous sampling at a resolution that is 3-5 times higher than the frequency band of climate variability under investigation. Methodological limitations related to these three problems and additional effects such as bio-turbation lead generally to a loss of the high-frequency climate signal that may potentially be preserved in lake sediments. A particular challenge for quantitative climate reconstructions from lake sediments is the 'correct' amplitude of the low-frequency climate changes.

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## Blending historical and limnogeological records of the Little Ice Age in Southern South America

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The clear paucity of complete and well-dated paleoclimate archives covering the LIA across Southern South America has been a major difficulty for depicting the regional environmental variability during this interval. Although the precise timing of the LIA is still a matter of debate, our contribution is focused on the comparison of hydrological balances southward the Tropic of Capricorn (23.5° S) up to ca. 52° S. We reviewed the most significant published limnogeological and historical records, blending both climate archives for enlarging the environmental reconstructions for this time-window. Paleoclimate records were selected throughout a wide geographical range and climate regimes: a) Pampean plains; b) Andean Altiplano and Puna; c) Central and Southern Chile; and d) Northern Andean Patagonia and Extra Andean Southern Patagonia.

SSA climate archives show a complex pattern of timing and climate variability during the LIA. There is, however, a noticeable antiphased hydrological balance at both sides of the Arid Diagonal. Numerous paleohydrological reconstructions suggest wet conditions during the LIA, southward and westward of the Diagonal Arida (i.e., Patagonia, central and southern Chile) as well as part of Puna. Conversely, this cold climate phase in the Pampean plains and Altiplano, was represented by pervasive draught. The antiphased cold-wet vs. cold-dry hydrological conditions at different latitudes in SSA reveal that increased rainfall triggered by intensified Westerlies are synchronous with dry conditions resulting from a diminished monsoonal activity.

Several forcing factors determine the increase or decrease of moisture transport from the tropics into the Pampean plains. Ongoing limnogeological studies in Salinas de Ambargasta (29° S - 64° W) and lagunas Mar Chiquita (30° S - 62° W), Melincué (33° S - 61°W) and Encadenadas del Oeste de Buenos Aires (37 °S - 62°W) may help to disentangle the mechanisms behind the most recent and past climate variability in the subtropics of South America.

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## **Sedimentological results from the Paleopeces research effort suggest centennial-scale shift in ocean productivity off Peru**

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Laminated sediments from the Peruvian shelf provide a means to examine the role of the eastern subtropical Pacific system in decadal- to-centennial-scale variability. We describe results from the PALEOPECES research group for two different box cores that extend several centuries back in time. Cores were subsampled at multi-year resolution and dated using excess <sup>210</sup>Pb activity profiles, radiocarbon analyses, and the occurrence of several slumps that likely resulted from known tsunami events. Proxy records of ocean climate and variability are developed based on fish scales, diatoms, organic carbon and its isotopic signatures, and other sedimentological properties.

A predominant feature from the records is a rapid climate shift that occurred in the mid-19<sup>th</sup> century, whereby inferred near-surface productivity increased based on diatoms, total organic carbon, and the abundance of anchovy scales. The increase in surface productivity, presumably associated with ocean cooling, is consistent with other proxy records indicating reduced oxygen concentrations. This change suggests that rapid shifts in ocean climate may occur on centennial timescales with large effects on natural resources.

The mid-19<sup>th</sup> century shift is consistent with tree ring records that indicate warming in the Patagonian Andes and may be negatively related with ocean temperatures off the coast of Peru due to an intensification of the southeast Pacific subtropical high. The inferred increase in productivity continues during the 20<sup>th</sup> century, despite a trend towards increasing Sea Surface Temperatures (SSTs). We discuss the relative role of an increase in coastal upwelling and increasing SSTs.

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## 1000 years record from Lagoa Grande (southeastern region of Brazil)

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The study site is located in the PETAR - Parque Estadual Turístico do Alto do Ribeira, São Paulo State, southeastern region of Brazil. A sediment core of 167 cm was collected in a natural lake (Lagoa Grande) surrounded by the Atlantic Forest. Elemental and isotopic analysis of C and N, pollen and <sup>14</sup>C dating were used in order to reconstruct the vegetation history of the region during the late Holocene and its relation with climate changes.

The results of the sediment organic matter composition of Lagoa Grande indicated that the environmental conditions were relatively stable during the last 1000 years, characterized by the presence of C<sub>3</sub> plants and phytoplankton, suggesting humid climatic conditions and that probably the lake wasn't dry during the last millennium. An increase in the frequency of *Weinmannia* was observed from ~400 years BP to ~300 years BP, suggesting the presence of a warmer climate. In the same period it was observed an increase in the frequency of Cyperaceae and spores, that could be related with the colonization of lake margins by this plant, probably due to the decrease of the water column.

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## Climate variability in Southeastern Brazil during the last 4kyrs BP based on marine and coastal lagoons sediments.

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Climate variability in southeastern Brazil was studied through of confront between marine and coastal lagoons sediment cores drilled from Cabo Frio, in Rio de Janeiro coast. One of interesting feature of Cabo Frio is the occurrence of a seasonal coastal upwelling, which provide a very dry local climate (semi-arid). Our results showed an intense variability in the upwelling during the last 4kyrs cal BP, especially when compared with the early and middle Holocene. Similar variability pattern is also recorded in other parts of South America, such as Cariaco Basin in Venezuela. In both case, it is possibly correlate the high variability phase with the intensification of ENSO events after 4kyrs cal BP. Exactly the same variability pattern was also recorded in Rio de Janeiro coastal lagoon sediments. However, in sediments of coastal lagoon, we could also observe a clear tendency to drier climates to the top core, which is characterized by carbonate nodules. Time series analyses of some laminated sections of this lagoon core were studied using wavelet power tools. The results showed at least two marked cyclicities patterns of 2,5 yrs and 29,3 yrs. These cycles may be linked to large scale climate phenomenon, such as ENSO and South Atlantic Decadal Oscillations.



## A high-resolution pollen and diatom record from Laguna Los Polulos (22°36'S/66°44'W/4500 masl), NW Argentinean Puna, since ca. 800 AD

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Pollen and diatom data from Laguna Polulos are presented. L. Polulos is a brackish-saline highland lake surrounded by high Andean grasslands with a low vegetation cover (ca. 10-15%). The 120 cm long sediment core has a basal age of ~550 AD (<sup>14</sup>C y <sup>210</sup>Pb). The pollen record, analysed every 1 to 11 cm, shows several periods with dominance of littoral vegetation, which is interpreted as periods with low lake levels between 1870-1700, 1500-1400, and 1050-650 AD; and humid periods as suggested by the presence of pollen from regional terrestrial vegetation with a maximum between 1700 and 1500 AD. A trend towards more brackish conditions is suggested by the increase of *Pediastrum* abundance in the pollen spectrum since 1910 AD.

The diatom record (analysed every 2 cm) shows similar general trends, with strong short-term variability and strong lake level shifts (decadal scale; within 10-15 years). High lake levels are recognized, by benthic to plankton ratios, during the last 100-150 years, between 1660 and 1590 AD and circa 666 AD. Dry moments occurred between 1540 and 1310 AD.

We discuss the relationship of these results with previously published paleoenvironmental information from the Andean region, and with broader scale climatic changes as during the Little Ice Age (LIA) and Medieval Climatic Anomaly chronozones.

### Climate variability in South America from high-resolution pollen records

#### Paleoecología de alta resolución del Holoceno Tardío en el Noroccidente de Colombia

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Con base en dos perforaciones realizadas en lagunas del páramo de Frontino (6° 29' N; 76° 6' W), su correlación con otros registros de la zona y una alta resolución metodológica, se detectaron y caracterizaron a escala decadal cambios en el ambiente de sedimentación, clima, vegetación local y regional. La transición Holoceno Medio/Tardío fue muy húmeda y entre 3200-2650 años interpol. <sup>14</sup>C BP muy seco y posiblemente tan cálido como hoy. Entre 2650-2300 años interpol. <sup>14</sup>C BP el clima tendió a ser frío y húmedo. De 2300-1900 años interpol. <sup>14</sup>C BP se hizo un poco más cálido y seco con un pulso fuerte de sequía cerca a 2200-2100 años interpol. <sup>14</sup>C BP. Entre 1900-1200 años interpol <sup>14</sup>C BP, fue húmedo y con tendencia progresiva a enfriamiento. Desde 1300 años interpol. <sup>14</sup>C BP hasta el presente hay tendencia al calentamiento aunque con altibajos notables. Entre los pulsos fríos centrados en 1300 y en

650 años interpol. <sup>14</sup>C BP se presentó un ciclo cálido con humedad variable, que engloba el Óptimo Climático Medieval registrado en el Hemisferio Norte. En los últimos 750 años se ha presentado una fuerte variación en la vegetación y el clima. Los eventos más fríos están centrados aproximadamente en 650, 450, 330, 248, 197, 140 y 70 años interpol. <sup>14</sup>C BP que coinciden en buena medida con los llamados mínimos de radiación solar de Wolf, Spörer y Maunder y el siglo IX. Los últimos 100 años muestran fuerte tendencia al calentamiento e incremento en la humedad. Desde hace un milenio desapareció el cuerpo de agua en los sitios de estudio y ha predominado un ambiente pantanoso.

La estimación del cambio en la temperatura con base en las anomalías de temperatura del Hemisferio Norte, muestra fuertes fluctuaciones, aunque parece que ha estado siempre por debajo de la actual. Desde el punto de vista causal, la buena correlación entre las variaciones de la vegetación y el clima del páramo de Frontino con los cambios en la producción de <sup>14</sup>C atmosférico y los cambios en la temperatura del Hemisferio Norte (últimos mil años), permite concluir que la variación en la actividad solar es la causa principal de los cambios observados en este sector de la cordillera Occidental de Colombia. Los principales ciclos climáticos registrados por el polen fueron de 21-22, 44, 52-54, 77-80, 90-110 (98), 124, 200, 400 y 667 años. Todos estos ciclos muestran correspondencia con observaciones realizadas (diferentes herramientas de estudio) en otros sitios del mundo y relacionadas directamente con cambios en la actividad solar.

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## Vegetation history in the Peruvian Andes

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The flora and ecological settings of Peru are considered among the most diverse in the world. The history of their development is linked to the uplift of the Andean cordilleras and the processes that accompany climatic change. The occurrence of latitudinal and altitudinal gradients is reflected in differences in floristic composition among different slopes and basins. These differences can also be linked to the evolutionary history of the plant lineages involved. Here, we summarize what is known for the period after the mid-Holocene to develop and compare scenarios of plant cover with present day plant composition and vegetation. Because, widespread land cover alterations by people began long ago, these might have had the effect of exacerbating the isolation and fragmentation of distributions of some species. Contemporary and rapid climate change may potentially exert pressure on the physiological limits of some Andean species, and limitations on dispersal might also prevent their establishment in alternative sites. Evidence in fossil pollen proxies of widespread anthropogenic landscape alteration in northern Peru dates 3500 year ago. This means that species sensitive to burning and other habitat modifications would have been altered in their distributions and abundances, while other species might have been favored. Current climate change is thus acting upon a subset of the original Andean flora, in many cases with species relatively robust or resilient in the face of the human-caused landscape modifications, at least as judged by their continued persistence.

**Key words:** Andes, Peru, flora, vegetation, mid-Holocene

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## Potencialidad de obtener un registro polínico de alta resolución, indicador de precipitaciones invernales para la costa semiárida de Chile (32°S), durante los últimos 2000 años.

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Se presentan resultados del análisis polínico y de micropartículas de carbón del registro Palo Colorado ubicado en la costa semiárida de Chile. De acuerdo a la relación profundidad de sedimentos/fechados radiocarbónicos (AMS), es posible obtener una resolución entre muestras de 22 a 6 años por centímetro de sedimento, si embargo a la fecha el registro polínico ha sido analizado entre 1 y 9 cm/muestra y el registro de carbón, continuamente cada 1 cm.

Los análisis de carbón, muestran dos momentos con alta presencia de carbón en los sedimentos, entre ~1500-1000 años AP y a partir de 500 años AP, ambos periodos son acompañados por aumentos en las proporciones polínicas de *Escallonia*.

El registro polínico, muestra el dominio del principal indicador de humedad Mirtáceas entre 2200-1400 años AP, sin embargo con alta variabilidad y acompañado de los máximos valores de polen de plantas anuales y bulbosas, abundantes durante años anormalmente lluviosos, como son los años El Niño. Luego un periodo relativamente seco, el cual comienza a disminuir a partir de 1100 años AP. Los últimos 500 años muestran una disminución de los indicadores de humedad con máximos en torno a 330 años AP, y la posterior recuperación de este indicador.

Análisis dendrocronológicos muestran la sensibilidad del principal indicador de humedad del registro *Myrceugenia exsucca* a las precipitaciones de invierno.

Se discute la relación de los resultados con dinámicas de ocupaciones humanas y eventos de gran escala como Pequeña Edad del Hielo y Calentamiento Medieval.

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## Vegetation history and climatic variability during the Late Holocene at Pampa grasslands: the state of the art

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In the Pampa grasslands (34° - 39° S; 56° - 63° W) the vegetational history based on pollen analysis has been mainly conducted at alluvial sites since pollen records from shallow lakes are temporally and spatially limited. Even though pollen assemblages in alluvial sequences may be biased as a result of episodic and irregular accumulation of sediments, these sequences are amazingly constant over large distances and contain very well preserved pollen grains in large quantities giving us the possibility to obtain important paleoenvironmental information. In this overview, we selected key proxy palynological records with different temporal and spatial resolution in order to evaluate the response of

the vegetation to different forcings during the late Holocene and to show the advancements achieved over the last years. The vegetation changes are discussed at individual sites by comparing them with other paleoenvironmental proxy and historical data. A quantitative climatic reconstruction applying a pollen-climate calibration model is presented and discussed as an example of quantification of paleoclimatic variables. Pollen records allowed us to infer (1) a pattern of environmental variability to large-scale, mainly in precipitation and humid index during the late Holocene, (2) sea level variations as the main forcing affecting the vegetation of the southeastern coast between 6500 and 4000 yr B.P and, (3) anthropogenic impact on vegetation over the last *ca.* 300 years, which correlate accurately with evidence concerning the documentary information. In addition, pollen and no-pollen palynomorph records have recently allowed to propose an alternative explanation for the vegetational change from shallow lakes.

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## **Holocene fire, climate, and vegetation linkages in southern South America: local and regional comparisons**

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The role of fire on Holocene time scales is understood at individual sites by comparing charcoal and pollen records with other paleoenvironmental proxy and model simulations. Records from the forest-steppe ecotone in western Argentina disclose the fire and vegetation history at lat 41-43S. Prior to 13 ka, dry conditions and sparse vegetation apparently lacked sufficient fuels to burn extensively. Fire activity increased between 13 and 11.4 ka, contemporaneous with a regionally defined cold dry period. The early-Holocene period was characterized by high fire frequency in dry sites and low frequency in wet sites, and indicates a sharp decrease in moisture eastward from the Andes. A shift to a surface-fire regime occurred between 7.5 and 4.4 ka, preceding the expansion of *Austrocedrus* by 1000-1500 years at individual sites. The shift is consistent with increased interannual climate variability and the onset or strengthening of ENSO in the late Holocene.

To detect large-scale patterns in past fire activity, charcoal records were examined along a transect from subtropic to subantarctic biomes. Fire activity was greater than present at ca. 12 ka and increased further and was widespread at 9 ka. Fire activity decreased and became more spatially variable by 6 ka, and this trend continued to present. Atmospheric circulation anomalies for present-day high-fire years implicate a southward shift in westerlies to explain the early-Holocene fire maximum. Such conditions apparently prevailed for millennia when the pole-to-equator temperature gradients were weaker and annual and spring-summer temperatures were higher than present.

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## High environmental variability over the last 3000 years deduced from small closed-basin lakes in NW Patagonia

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High-resolution pollen and charcoal records from NW Patagonia (40-43°S, the Chilean Lake District) indicate millennial and multi-millennial trends in vegetation change and fire activity since the Last Glacial Maximum. Most records from this area show the following patterns over last 3000 years: (i) end of a multimillennial phase characterized by cool-wet conditions (7800-2700 cal yr BP), (ii) establishment of mixed rainforest communities (Valdivian and North Patagonian) through reshuffling of “ancestral” Holocene assemblages, (iii) expansion and dominance of tree species favored by disturbance, and (iii) increase in fire activity (high magnitude, high frequency, short fire-free intervals). Fire activity reached a maximum between 900-1100 years ago and declined thereafter until a recent increase related to disturbance by European settlers over the last two centuries. Altogether these data point to increased climate variability in the area adjacent to the SE Pacific, most likely linked to the occurrence of frequent and severe summer droughts. Negative anomalies in summer precipitation are characteristic of El Niño events in this part of southern Chile, suggesting the accentuation of a trend that had started earlier, at about 5000-5700 cal yr BP. The enigmatic drop in fire activity over the last millennium deserves detailed stratigraphic and tree ring analyses. A possibility exists that climate change related to the Little Ice Age suppressed the occurrence of fire, at least in this part of Patagonia.

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### Climate variability from ice cores

#### The 1000-year long climate history in South America from ice cores: potential and limits

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Since 1983, an international effort on ice core investigations along the Andean mountain range has been developed to infer paleoclimate and environmental information from the Equator southward to 30°S. In the northern part of this transect, from Ecuador to Bolivia in the region affected by tropical NE-winds and moisture coming from the Atlantic Ocean and the Amazonian Basin, the time range covered by the archive reaches about 25,000 years. Southern, in the Westerlies circulation pattern with Pacific Ocean moisture source, the reduced investigations allow only reaching a few centuries of reconstruction.

Tropical ice cores offer a high temporal resolution (a seasonal resolution over the last centuries), allowing a detailed study of specific events or periods, such as the Little Ice Age, the climate variability over last few centuries, the ENSO history and the 20<sup>th</sup> century with the well known abrupt feature around 1970. We focus here on chemical, insoluble dust and water isotopic analyses over the last 1000 years and we compare all the ice cores together,

discussing resemblances or differences. For example, we will focus on 1- proxies allowing to reconstruct accumulation history, 2- the common water stable isotope decadal signal over the 20th century (Quelccaya, Huascarán, Sajama and Illimani) and 3- the potential signal of global warming in some proxies.

At last, we will discuss about limits of ice cores investigations. Specifically, we will discuss about the proxy calibration and the difficulty to study strong climate modes like ENSO.

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## Firn and ice core records from high-elevation sites in the mid-latitude Andes

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Since 2001 firn and ice cores have been retrieved from high-elevation sites in the southern Andes in a joint collaboration between Paul Scherrer Institut (PSI) from Switzerland and Centro de Estudios Científicos (CECS) in Chile. PSI has been in charge of the drilling, sampling and chemical analyses of the firn and ice cores, while CECS has been responsible for glaciological characterization and site selection. The objective of the program is to retrieve firn and ice core records that can yield unique paleoclimate and paleoenvironmental records ideally spanning several centuries from mid-latitudes in the Southern Hemisphere. During the exploration phase 3 firn cores were recovered from the Southern Patagonia Icefield in 2001 (Paso Marconi, 49°11' S, 73°09' W, 1543 m a.s.l., 4 m firn core; Gorra Blanca Sur, 49°09' S, 73°07' W, 1836 m a.s.l., 3 m core; and Gorra Blanca Norte, (49°08' S, 73°03' W, 2300 m a.s.l., 5 m core), one 5.5 m firn core from Glaciar Esmeralda, Cerro El Plomo in Chile in 2003 (33°14' S, 70°13' W, 5300 m a.s.l.), and one 13.5 m firn core record from Glaciar La Ollada, Cerro Mercedario in Argentina in 2003 (31°58' S, 70°07' W, 6070 m a.s.l.). Of these cores, the sites at Gorra Blanca Norte and Cerro Mercedario proved to be adequate for paleoclimatic interpretation, while the other lower sites are not useful because of abundant melting and water percolation which obliterates the glaciochemical signals (Bolius *et al.*, in press, Schwikowski *et al.*, in press). Based on the promising paleoclimate results from the firn cores obtained at Cerro Mercedario and Gorra Blanca Norte, a main drilling phase was performed, retrieving a 104 m deep ice core at Glaciar La Ollada, Cerro Mercedario, at 6070 m a.s.l. in 2005, and a 50.6 m core at the northern plateau of Cordón Mariano Moreno, 2580 m a.s.l., Southern Patagonia Icefield, in 2006. Preliminary inspection of both these ice cores shows a good potential for obtaining long paleoclimate records. The results obtained from the analysis of the shallow firn cores will be presented and discussed, as well as the glaciological characterization of the sites. The deep ice drilling operations at Cerro Mercedario and Mariano Moreno will also be described.

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## Glacier records in South America during the past three millennia

### Recent dendroglaciological investigations in the Patagonian Andes of Argentina

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In 1998 IANIGLA started dendroglaciological investigations in the Patagonian Andes of Argentina to characterize the main spatial and temporal glacial and climatic fluctuations in the region over the last 1000 years. Eight sites with relatively small glaciers and forest-covered Neoglacial moraines were initially selected for study between 39°S and 50°S.

Aerial photographs, satellite imagery and documentary evidence showing past glacier front positions were used to evaluate glacier changes during the past century. Tree-ring/radiocarbon dating of trees growing on these moraines or affected by glacier deposits were used to obtain approximate ages for the main glacier events during the past centuries (Table 1). Tree-ring based climate reconstructions can provide annually resolved records of past temperature and precipitation variability for this region. The low-frequency climatic signal from these records will be compared with the glacial history from each study area. Mutual cross-validation from these two independent proxies should provide a reliable regional climate record over the last centuries.

Field investigations and sampling over several years, together with the laboratory analysis of the tree-ring samples collected, have established the feasibility of this project and the initial results are promising. Evidence from tree-ring based temperature reconstructions for the north and south Patagonian Andes indicate that in general periods of extended cold conditions coincide with the dendrogeomorphic dating of moraines associated with the Little Ice Age in both regions. Numerous *in situ* stumps, apparently killed during glacier advances, have been found at several study sites and will provide better definition of the glacier history at those sites.

This project represents the first attempt to integrate independent proxy climate records in the north and south Patagonian Andes of Argentina. Together with a critical analysis of 20<sup>th</sup>-century climatic variations in the region, this will allow us to evaluate the recent climatic changes in a broader, longer-term perspective.

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### The Little Ice Age in the Andes of Mendoza, Argentina

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The El Azufre and El Peñón valleys at 35° S latitude and Las Damas and Las Choicas valleys at 34°55 S latitude in the headwater of the Río Grande basin were studied since the maximum Little Ice Age (LIA) in the Central Andes of Argentina. The glaciers presents well preserved moraines attributed to former centuries. Based on morphological characteristics, the proximity to the active glaciers, and radiocarbon ages, the LIA maximum occurred in the

second half of the 15<sup>th</sup>-17<sup>th</sup> centuries, a glacier minor re-advanced occurred during the second half of the 17<sup>th</sup>-18<sup>th</sup> and in the 19<sup>th</sup> centuries. After 1894/1896 the glaciers between 33°-35° S have receded nearly continuously. Within the general retreat, the glaciers advanced during the 1980's.

**Key Words:** Little Ice Age; glacier fluctuations; Central Andes; Mendoza; Argentina.

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## **Anomalous century fluctuations of Glaciar Perito Moreno, southern Patagonia**

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While most Patagonian glaciers receded during the past century, Glaciar Perito Moreno (GPM) was advancing or in near steady state during the same period. GPM has 254 km<sup>2</sup> in area, drains the Southern Patagonian Icefield to the east, calving into Lago Argentino. It is well known for repeated formation of ice-dams and consequent ruptures over the 20<sup>th</sup> century to the present. The glacier has been advancing from 1899 until 1917, when reached the Península Magallanes for the first time. Since then GPM has been fluctuating close to the steady state. However, analysis of aerial photography and Landsat images reveal that glacier is presently at its most advanced position since 1947, with positive areal gain. Evidence of recent glacier advance was also detected at glacier margin. In addition, surface elevations measured in 2002 show a considerable ice-thickening at lower parts of ablation area, suggesting a positive mass balance which could have led to formation of the very recent ice-dams. Ice-damming occurred in 2003 and 2005, with ruptures in early 2004 and 2006, respectively. A century glacier fluctuations will be analyzed through compilation of field surveys, aerial photographs and sequential satellite images. In addition, 10-year temperature data available from automatic weather station (AWS) installed in 1995 at GPM will be presented and discussed in correlation with 5-decade record from the nearby synoptic station Lago Argentino.

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## **Historical glacier variations in Chile**

**Andres Rivera, Francisca Bown, Cesar Acuña and Gino Casassa**

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In Chile have been accounted more than 1760 glaciers with a total area of approximately 22,000 km<sup>2</sup>, however, only a hundred have been analyzed in terms of historical frontal variation and few other glaciological properties. The oldest precise historical records about a Chilean glacier was recorded in 1766 (Glaciar San Rafael), while a couple of glaciers were described in 1830 (Glaciar Pio XI) and 1842 (Glaciar Cipreces). By the end of the nineteenth century, several other have been explored and studied, especially in Patagonia, where Glaciares O'Higgins was firstly visited in 1896 and Glaciar Dickson in 1897. From all the analyzed Chilean glaciers, up to 6% have shown a net advance during different study periods, especially Glaciar Pío XI which advanced during the twentieth century between 1925 and 1928 and between 1945 and 1997. A 7% of the glaciers have shown no significant



change, while 87% showed a negative rate of variation, ranging from a few meters per year to a maximum of 792 m a<sup>-1</sup> at Glaciar Marinelli between 1992-2000. To date, the glacier retreat continues, as well as the negative mass balances and significant ice thinning rates. This shrinking process is thought to be enhanced if the observed atmospheric warming persists in the future, affecting the future availability of water resources on glacierized basins. Hence, the contribution of Chilean glaciers to eustatic global sea-level rise during the last five decades was estimated to yield 8.2% of the worldwide contribution of small glaciers on Earth, being mainly constrained by changes experienced by glaciers in Patagonia.

## Speleotherms

### **Stalagmite Evidence of Droughts in Belize at the Time of the Classic Maya Collapse and the Potential for Similar High-resolution Paleoenvironmental Records from Speleotherms in Southern South America**

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The Maya civilization in Central America peaked during a Classic Period from A.D. 25 to 900, but declined abruptly in the years A.D. 750 to 900. Reliably-dated reflectance, luminescence, stable isotope, and petrography from a stalagmite from western Belize indicate a series of droughts from A.D. 700 to 1135 coinciding with the collapse of the Maya civilization. Two earlier droughts recorded by the stalagmite coincide with the Preclassic Abandonment and the Maya Hiatus periods of decline. Comparison of the stalagmite record with distant records shows broader-scale climatic teleconnections between Central and South America.

In southern South America limestone caves are sufficiently common to allow speleothem studies in several climatic regions. These secondary carbonates can be dated accurately by U-series to ~500 ka allowing periods of growth and no-growth, which are induced by changing climatic conditions, to be defined. Speleothem carbonate and fluid inclusion O and H isotopic characteristics can indicate past temperature and moisture conditions, including information about the air masses that brought precipitation, as well as the intensity of the precipitation. Speleotherms may also trap and preserve pollen and other plant micro and microfossils, when nearby, highly-oxidized clastic sediments do not. C isotopes can be an additional source of vegetation data as they can reveal whether the plant cover above the cave consisted largely of C<sub>3</sub> or C<sub>4</sub> plants. Finally, some stalagmites have annual and even sub-annual layers so that very detailed paleoenvironmental records can be obtained, which can be compared, for example, with high-resolution tree-ring, lacustrine, and instrumental data.

**Keywords:** Classic Maya Collapse, stalagmites, South America, caves, paleoclimates.

## Human-climate interactions

### Palaeolimnology, pollution and lake restoration

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Lakes are highly distinctive features of the earth's surface. They vary greatly in distribution, size, age, origin, chemistry, biology and in the extent of their alteration by human activity. Lakes close to human settlements, receiving waste-water and run-off from agricultural land, have been very heavily modified by the effects of eutrophication, others with low natural alkalinity close to industrial areas have suffered from acidification, and in many arid and semi-arid regions of the world abstraction of fresh-water for drinking and irrigation has caused severe salinisation.

Even in the most remote regions that are relatively free from these pressures it is possible to detect the presence of long-range transported air pollutants that accumulate in the food chain. And all lakes are now exposed to additional threats from greenhouse-gas forced climate change acting both directly in terms of changing temperature, precipitation and wind regimes and indirectly through the influence of climate change on catchment land-use and on the behaviour of pollutants.

Understanding how these pressures combine and interact to change the structure and functioning of lake ecosystems on different time-scales is a central focus of limnological research requiring the combined expertise of both neo-limnologists, palaeolimnologists and lake modellers. In this presentation I will describe this approach using examples from lake acidification research and explain how we are using a palaeolimnological approach to assess lake status both at individual sites and across Europe. I will stress the importance of combining data in central databases in order to reconstruct patterns of human impact on lake at both regional and global scales.

Lake ecosystem research in PAGES is co-ordinated by the LIMPACS activity under the Focus 4 heading. For more information visit: [www.geog.ucl.ac.uk/ecrc/limpacs](http://www.geog.ucl.ac.uk/ecrc/limpacs).

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### Evidencias paleolimnológicas de cambios ambientales durante los últimos 2 mil años, en el centro sur de Chile

**Urrutia R<sup>1</sup>, A. Araneda<sup>1</sup>, F. Cruces<sup>2</sup>, L. Torres<sup>2</sup>, F. Torrejón<sup>1</sup>,  
L. Chirinos<sup>3</sup>, R. Barra<sup>1</sup>, R. Mendoza<sup>1</sup> & I. Alvial<sup>1</sup>**

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La preocupación por el cambio climático se debe principalmente al rápido y evidente incremento de la temperatura global en los últimos 150 años. Según el IPCC la temperatura promedio global durante el siglo XX aumentó en 0,6 °C ± 0,2, respecto de períodos de referencia previos. Antecedentes indican que este aumento en la temperatura global, se debe al aumento en la concentración de gases de efecto invernadero, específicamente el CO<sub>2</sub>, cuya concentración producto de la actividad antrópica se ha incrementado aproximadamente en

80 ppm desde el año 1750 hasta el año 2000. No obstante este evidente “calentamiento”, cuya responsabilidad se atribuye a la actividad antrópica, reconstrucciones recientes han indicado la existencia de una alternancia entre períodos cálidos y fríos en los últimos 2000 años, época en la cuál no existían impactos antrópicos derivados de la quema de combustibles fósiles. Por lo tanto, tales variaciones tendrían como forzante más importante a la variabilidad natural del sistema climático global. De este modo la reconstrucción de las variaciones climáticas sobre escalas de tiempo anual, interanual y decadal en los últimos 1000 años ha llegado a ser considerado como un objetivo prioritario en la investigación del cambio climático actual (WCRP CLIVAR, IGBP PAGES). De acuerdo con lo planteado anteriormente, el presente trabajo tiene por finalidad entregar antecedentes acerca del impacto antrópico y su relación con el cambio climático global, en lagos del Centro Sur de Chile.

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### **Climatic change and human occupation in the preandean region of NW Argentina during the Upper Holocene**

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Authors as O'Brien et al (1995), Van Geel & Renseen (1998), Sayago et al. (2005) postulated the existence of cool and/or wet period between 3,5 to 1,5 ky in different regions of the world that in the northwestern Argentina would have coincide with the expansion of the main agrarian cultures. During the called Formative Period in the intermontaneous valley of Trancas (Yungas forest environment) Caria and Sayago (2005) established a Candelaria occupation dated in 3400 AP, which ceramic remains in a well developed paleosols suggest wet and possible warm climate. Toward the west, in the Tafí Valley under a drier climate, several authors detected occupations from the Tafí culture between 2500 AP to 1200AP. The intensive agrarian activity in addition to polinic and palaeoedaphic evidences suggest wetter conditions than present, with a progressive tendency to dryness (Sampietro et al., 2003). The presence of extensive Formative terrace system in the Santa María Valley confirm the larger water availability during the Formative if compared with present day conditions. Strecker (1987) dated in 2190 AP fluvial back swamp sediment with a progressive transition to aridic conditions. Finally, in Antofagasta de la Sierra (Catamarca province), Tchilinguirian and Olivera, (2003) described in a cropping terrace, fluvial sediments dated in 3000 AP. In conclusion, during the 3,5 to 1,5 ky wet conditions influenced the spanction of the Formative cultures between the western Chaco and the dry Andes. The reinforcement of the Southern Atlantic High in addition to ITCZ would have influence the presence of wet and possible warmer environmental conditions between the 25° to 28° s. lat. A possible northward displacement of the Southern Pacific Polar Front would have influence the meridional Puna Altiplain during that period.

## Multi-proxy reconstructions and climate modeling

### Multi-proxy climate reconstructions: The example from Europe and the potential for South America

Jürg Luterbacher and collaborators

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The new project LOTRED-SA (Long-Term climate REconstruction and Dynamics of southern South America: A collaborative, high-resolution multi-proxy approach (<http://www.pages.unibe.ch/science/initiatives/lotred-sa/index.html>); a collaboration between PAGES; the University of Bern and IANIGLA Mendoza) aims at collating in a collaborative effort existing and new data sets from diverse sources and use sophisticated statistical methodologies to produce climate reconstructions at different temporal and spatial scales. These methods are currently tested and implemented for Europe within the Swiss National Center of Excellence in Research on Climate NCCR Climate. The importance of different South American climate proxies (documentary and from natural archives) for regional to sub-continental scale temperature and precipitation reconstructions as well as issues of stability, stationarity, amplitude and extremes, dynamical interpretations and GCM/reconstruction comparisons will be addressed.

A new PhD student will start working on these issues in October 2006, thus we will not be able to present first results yet but much interested in the new studies and data presented at the workshop. Rather, the talk will show examples from Europe, which offers a high quantity and quality of long instrumental station series, a wide range of documentary evidence (i.e. reports from chronicles, daily weather reports, ship logbooks, the time of freezing and opening up of waterways, religious ceremonies, etc.) as well as high and low spatio-temporal resolved natural proxies (tree-rings, tropical and non-tropical corals, speleothems, lake sediments, vermetid reefs, etc.). This multi-proxy climate information makes Europe ideal for climate reconstructions at different time and space scales (e.g. Luterbacher et al. 2004; Xoplaki et al. 2005; Guiot et al. 2005; Pauling et al. 2006), as well as the analysis of changes in climate extremes and socio-economic impacts prior to the instrumental period and could thus be an example for South America within the LOTRED-SA project. The talk discusses the European regional coverage and the possibilities/limitations of these proxies and presents yet unexplored archives (marine and from land) and their potential for past climate reconstructions. We also address the question on the importance of documentary and natural proxies, the location and the number of proxies for European temperature reconstructions at seasonal time scale. Methodologies of multi-proxy climate reconstructions (putting different climate related proxies together), and calibration/verification issues will be presented. The evolution of European climate and associated uncertainties, trends and extremes over the last half millennium will be discussed.

The lessons learnt from Europe and future challenges will also be addressed.

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## Climate Model Simulations of the South America Response to a Cold North Atlantic: Some Preliminary Results

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Proxy records for some regions of the Southern Hemisphere show a correlation on millennial time scales with North Atlantic cold events, including the Heinrich events, the Younger Dryas, and the 8.2 ka event. Two simulations for the mid-Holocene with the National Center for Atmospheric Research (NCAR) Community Climate System Model, version 3 (CCSM3), a global, coupled ocean-atmosphere-sea ice-land surface model, will be presented. The control simulation prescribed changes in greenhouse gases and orbital parameters appropriate for 8.5 ka. In a sensitivity simulation for 8.5 ka, we additionally induced much colder North Atlantic sea surface temperatures by adding freshwater into the North Atlantic Ocean from 50 to 70°N latitude. The North Atlantic region responds rapidly to this freshwater forcing with much colder sea surface and atmospheric temperatures, expanded sea ice, and a reduced ocean thermohaline circulation. The much colder North Atlantic induces a shift southward of the marine Intertropical Convergence Zone (ITCZ) over the tropical Atlantic Ocean, drying over the Caribbean and northern South America, and increased precipitation over the Altiplano and southern Brazil. Over the tropical eastern Pacific, colder temperatures and reduced precipitation occur north of and on the equator and warmer temperatures and increased precipitation south of 5°S latitude. In addition, the sensitivity simulation exhibits a bipolar response in the Atlantic Ocean basin with warming over the south Atlantic associated with a reversal in the meridional ocean heat transport south of the equator.

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### Simulaciones Climáticas para el Holoceno Medio sobre América del Sur con el Modelo del CPTEC, a partir de condiciones de contorno diferentes

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Se analizan las tendencias de variaciones climáticas en el Holoceno Medio (HM), dentro de un contexto de cambio climático para Suramérica, utilizando el MCG T062L28 del CPTEC. Las simulaciones son realizadas a partir de la modificación de parámetros orbitales y concentración de CO<sub>2</sub>, utilizando dos conjuntos de TSM (climatología del AMIP y generada por el MCG acoplado océano- atmósfera, del IPSL). Los resultados fueron comparados con las simulaciones realizadas por el PMIP e indicios paleoclimáticos. Observándose un comportamiento más húmedo en el nordeste, durante casi todo el año en el HM, con excepción del otoño, donde se verifica un desplazamiento más al norte de la ZCIT. La región central, sur y sudeste fue marcada por una reducción en las precipitaciones, concordando con estudios peleoambientales. En la temperatura se verificó una señal de enfriamiento durante el HM, todo el año, excepto para las regiones sur y sudeste, las cuales muestran una señal de calentamiento, concordando con resultados del PMIP.

Se verificó una reducción de la intensidad del flujo medio en 850hPa, sobre el continente, durante el HM, debido a la disminución en la variación estacional de la

insolación en el hemisferio sur, ocasionando menores gradientes de temperatura. También se comprobó la desintensificación de la circulación de la alta subtropical del Atlántico Sur, que puede estar asociada al desplazamiento para el sur de la ZCIT, y la disminución de la circulación del chorro de bajos niveles durante todas las estaciones. Esa disminución tiene un impacto significativo en el transporte de la humedad de la cuenca Amazónica hacia la cuenca de La Plata, y consecuentemente sobre la formación de la ZCAS.

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## **Antarctic Oscillation and its implications for proxy-based reconstructions**

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Through the analysis of a sequence of coupled atmosphere-ocean climate simulations, Justino and Peltier (2006, GRL, Vol. 32) demonstrated that the spatial variability of the Arctic Oscillation is expected to have been drastically different under glacial boundary conditions compared to today. In this presentation, we will present further evidence that a distinct form of temporal and spatial variability of the Antarctic Oscillation is also predicted to have existed during the LGM as compared to present-day conditions. As will be shown, these changes in the structure of extra-tropical climate variability will have to be carefully considered when temperature or precipitation/snowfall are estimated from paleo-proxy data for the LGM interval. We will furthermore discuss apparent changes in tropical-extra-tropical coupling between present-day and glacial conditions.

## **PAGES initiative in South America**

### **PAGES: Mission and Programs**

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PAGES (Past Global Changes) is a core project of the International Geosphere-Biosphere Programme (IGBP). The primary objective of PAGES is to improve our understanding of past climate and environmental change. To this end, PAGES works to promote integrative research activities and support the international paleoscience community, through fostering collaboration and communication, and ensuring access to and dissemination of results, data, and other relevant information. These objectives are achieved by means of international scientific meetings, outreach products, scientific publications, and the PAGES newsletter and website ([www.pages-igbp.org](http://www.pages-igbp.org)). While PAGES itself is not a research institution, it helps to identify overarching issues in paleoscience and ensure that they are addressed in a coherent manner. Four sets of questions of prime current interest will be targeted by PAGES in the coming years:

- *Climate Forcing and Sensitivity*: What is the history of the main climate forcing factors and the sensitivity of the climate-environment system to these forcings? In what precise sequence have changes in forcings, surface climate, and ecological systems occurred?
- *Climate Variability*: How have global climate and the Earth's natural environment changed in the past? What are the main modes of variability at orbital to sub-decadal timescales, and how do they relate to each other and to the mean state of the climate system?
- *Earth System Dynamics*: How have different parts of the Earth System interacted to produce internal feedbacks on regional and global scale? What are the causes and thresholds of rapid transitions between quasi-stable climatic and environmental states, in particular on timescales that are relevant to society? How reversible are these changes?
- *Anthropogenic Versus Natural Change*: To what extent and since when has human activity modified climate and the global/regional environment? How can anthropogenically induced change be disentangled from natural responses to external forcing mechanisms and internal system dynamics?

The recently revised framework for activities to address these questions is provided by four new thematic Foci: (1) Past Climate Forcings; (2) Reconstruction and Modeling of Regional Climates and Modes of Variability; (3) Land/Ocean/Cryosphere/Biosphere Dynamics and Linkages; and (4) Past Human-Climate-Environment Interactions. These Foci are complemented by four Cross-Cutting Themes on chronostratigraphy, proxy issues, data management, and dissemination and outreach. Several old PAGES program elements, including the Pole-Equator-Pole (PEP) transects are incorporated within this revised structure, many after a transformation to adjust them to the new scientific targets. The LOTRED-SA group can be seen as a model example of a spin-off of the PEP 1 transect through the Americas but now with a more regional and temporal focus, and with the objective of higher detail on climate reconstruction and process understanding.

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## PAGES in the Southern Hemisphere: variation on orbital timescales

**Peter Kershaw<sup>1</sup> and Jan-Berend Stuut<sup>2</sup>**

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It has been generally assumed that there has been a global pattern of climate change controlled by insolation forcing and ice volume changes in the mid latitudes of the northern hemisphere. This assumption has been strengthened by results of records from the world's oceans and from Antarctica. However, long records from the southern hemisphere are demonstrating a rather more complex pattern of climate change on land through the direct influence of insolation or its modification through ENSO activity. There is also evidence of the system being non-stationary or switching from one forcing state to another. Patterns and causes of climate change in the southern hemisphere are being addressed through a programme 'Land-Ocean Correlation of Long Records from the Southern Hemisphere at Orbital and Sub-Orbital Scales' that is hoped will become incorporated into the PAGES structure.

## PAGES across the Americas: from PEP I to the new initiatives

**Brian H. Luckman**

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The initial structure of PAGES in the Americas was highly successful. PEP-1 was well led and focused, culminating in the publication of Merida overview volume with an increased focus on Southern Hemisphere studies. The transect concept caught on and has been particularly useful leading to, *inter alia*, the Inter American Institute for Global Change Research Collaborative Research Network (CRN03) on climate variability from treeline sites. This brought together scientists from both hemispheres, establishing a continuing cooperation that has resulted in many of the high resolution records presented at this meeting. The unique configuration of this mountain transect is echoed in the recommendations from the recent CONCORD (Climate Change: Organizing the Science for the American Cordillera conference (see [http://mri.scnatweb.ch/privatedownloads/ReportWB\\_v1.pdf](http://mri.scnatweb.ch/privatedownloads/ReportWB_v1.pdf)) and the aims for the Gloria project in the Americas and the Mountain Climate observing system of GCOS.

Following Merida the momentum faltered following the illness and untimely death of Geoff Seltzer. PAGES work in the Americas must now refocus around the more thematic and regional themes currently being developed and the subject of extensive discussions at this meeting. At the largest scale climate variability remains a major issue and the provision of new data sets (particularly from the Southern Hemisphere) offers the potential for more integrated studies on ENSO and decade to century climate variability that should be the focus of ongoing PAGES-CLIVAR cooperation.

Projects associated with the new PAGES initiatives are in the process of development. I present here simply a few ideas, biased by my own interests, of possible areas where these new projects might develop. There needs to be a strong paleofocus on water availability. Critical elements are glacier loss, magnitude, frequency and extent of past droughts and the reconstruction of streamflows, all areas to which paleo data can provide significant context for future management and planning of water resources throughout the Americas. Although considerable work along these lines has been done in North America, such studies are only just beginning in Latin America and there are significant difficulties to overcome e.g. the development of compatible data bases for drainage basins spanning several national boundaries (e.g. Rio de la Plata, Amazonia) or the possibility to develop a gridded PDSI reconstruction for South America. Some of these may be overcome by new initiatives such as LOTRED but that has a southern south American focus and much work along these lines is needed in the tropics.

Another important gap is the environmental history of the twentieth century. Although we tend to think of this as “the present”, in much of the tropics and Latin America appropriate environmental records do not exist (particularly prior to 1950) and need to be developed as a context for planning. High resolution records and proxy techniques are clearly needed that would allow strong projects to develop at the interface between paleoclimate, modern process studies and human dimensions initiatives on the impacts and adjustments to these events by human populations. On a longer time frame these high resolution records are providing insight into relationships between human populations and the environment in pre- and post Hispanic America that have strong links with other IHDP programs and initiatives such as the Dark Nature Project of ICSU.



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2	Climate patterns in Patagonia during the medieval warm period and the little ice age: proxy data and depicting model	Agosta, Favier Dubois, Compagnucci
3	The 1976/77 austral summer climate transition: an interference phenomenon for the summer temperature in subtropical 'cuyo' plains leeward the Andes	Agosta and Martin
4	Local impact of Global Circulation Pattern in Synoptic Variability of Upwelling in Cabo Frio (Rio de Janeiro, Brazil). Analysis on 1971 - 1980 daily data	Andrade, Albuquerque, Turcq, Sifeddine, da Silva
5	Características de la variabilidad espacio-temporal de la temperatura invernal en capas medias de la atmósfera en relación con extremos de caudal en las regiones de Cuyo y Norte de la Patagonia	Araneo, Compagnucci
6	Déficit y superávit de caudal en los ríos Atuel y Chubut y su relación con la propagación de ondas de Rossby estacionarias	Araneo, Compagnucci
7	Secuencias Principales de altura geopotencial en los niveles de 1000 y 500 hPa asociadas a extremos opuestos de caudal para ríos de las regiones de Cuyo y Norte de la Patagonia	Araneo, Compagnucci
8	Analysis of some meteorological variables recorded at 4000 m in the Argentinean subtropical Andean region	Castañeda, Ratto
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12	Patrones asociados a extremos de temperatura mínima en el sur de Argentina	Zotelo
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13	Evaluating socio-economic change in the Andes from domestic animal densities	Chepstow-Lusty, Frogley, Leng, Cundy, Boessenkool, Bush, Gioda, Bauer
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## Poster Abstracts

### Present climate variability in South America

#### Interdecadal-to-centennial variations in temperature over subtropical Argentina and the solar forcing

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The relationship between the solar forcing and observed temperature and precipitation series from subtropical Argentina, north of 40°S, is explored using the Galactic Cosmic Rays (GCR) as a proxy data of solar forcing at interannual to multidecadal scales. The relationship is also analyzed in temperature and precipitation long reference series using reconstructed isotope Be10-solar forcing (Bard et al. 2000). Temperature series are highly associated to interdecadal variations of the solar forcing via the quasi-11-year solar cycle. The relationship can be direct or indirect, with varying phase along the annual cycle and during the century. The signal in precipitation does not seem to be clear enough as in temperature, at least linearly. Atmospheric variables are analyzed according to the phase (high or low) of the GCR flux. Some of the interdecadal changes in temperature could be attributed to thermal advection and/or to irradiative forcing under clear sky conditions, all these provoked by the dynamics of the circulation. The atmospheric circulation anomalies could be induced by the GCR ionization effects on the Atmosphere and/or to solar irradiance effects on propagation of Rossby waves in the troposphere (Shindell et al. 2001). A fraction of the warming observed in subtropical eastern Argentina since mid-19th century could be attributed to the centennial variation of the solar forcing.

#### Climate patterns in Patagonia during the medieval warm period and the Little Ice Age: Proxy data and depicting model

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The Medieval Warm Period (MWP) occurred around 800-1200 AD and is one of the most persistent climate anomalies. Normally, the MWP is associated with the occurred long-term maximum solar magnetic activity and/or with the observed long-term minimum Galactic Cosmic Rays (GCRs) input into the Atmosphere. In Patagonia, the climate anomaly is usually referred to negative precipitation anomalies (Villalba 1994, Haberzttl et al. 2005). But the analysis of different proxy-data shows a complex schedule, with differing precipitation patterns between Northern Patagonia and Southern Patagonia (Favier Dubois 2003). For

instance, there appears a development of regional soil in Southern Patagonia that is absent in Northern Patagonia (Favier Dubois 2006). From the GCR/Climate variability relationship along the quasi-11-year cycle observed in southern South America during 1958-2003, bipolar dry/wet climate composite anomalies are obtained for northern/southern Patagonia during low GCR flux years (Agosta et al. 2004). These climate anomalies are similar to those obtained by Labraga (1997), by modeling future conditions under anthropogenic warming, and they can be related to those found in the MWP through proxy-data.

Another relevant climate anomaly is the Little Ice Age (LIA) observed between 1300-1800 AD that is associated with low solar magnetic activity and/or with high GCR flux. Some hints reveal glacier advances during the LIA in both Northern and Southern Patagonia (Luckman and Villalba 2001, Glasser et al. 2004). This could be due to differing climate processes. The climate composite anomalies during high GCR flux years in the period 1958-2003 are consistent with possible glacier advances in Patagonia similar to those observed in the LIA.

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## **The 1976/77 austral summer climate transition: An interference phenomenon for the summer temperature in subtropical 'Cuyo' plains leeward the Andes**

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The summer (Oct-Mar) temperature in the subtropical 'Cuyo' plains, leeward the Andes (SCP, roughly between 28°-36°S and 65°-70°W), shows both spatial and time-phase coherence at interannual to interdecadal scales (Agosta et al. 2004). Thus, it can be considered as a thermally climatic region. In addition, this region seems to be sensitive to changes in the climate system, such as the 1976/77 austral summer climate transition (ASCT) thoroughly studied (IPCC 2001, Huang et al. 2005). For example, Compagnucci et al. (2002) found that the summer precipitation variability in the region underwent a shift towards lower frequencies attributable to the ASCT, giving rise to a prolonged wet period from mid-1970s until the early 2000s. The ASCT seems to have provoked changes in the atmospheric circulation over southern South America (Camilloni et al. 2005, Agosta and Compagnucci 2006). Its effects are also evident in temperature as an interference phenomenon. It is found that temperature variability shows significant quasi-oscillations in the bands around 11 and 18 years. The former is interrupted by mid-1970s, recovered since the late 1980s and strongly linked to the solar forcing. The latter appears as a consequence of the ASCT, filling the gap left by the quasi-11-yr. cycle between 1977 and 1988 roughly. It is to note that the ASCT produces changes in the centers of action of the atmospheric circulation associated to the interannual temperature variability. It is derived that the solar forcing plays a relevant role in the interannual-to-interdecadal temperature variability beyond the predominant atmospheric circulation conditions established over the SCP.

## **Local impact of Global Circulation Pattern in Synoptic Variability of Upwelling in Cabo Frio (Rio de Janeiro, Brazil). Analysis on 1971 - 1980 daily data.**

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Cabo Frio coastal upwelling is a very dynamic system, which is basically controlled by regional winds pattern. This study had as subject the better understanding in the synoptical scale the wind and sea surface temperature (SST) relationship. The first step consisted by a characterization of SST and winds considering their frequency, intensity and persistency patterns. Our results showed the absence of significant direct correlation between wind and SST. However, a cross-correlation between these two parameters showed that is necessary a lag-time of ca. -2 days in persistent NE winds to promote cold waters upwelling. Thereafter, the more interesting and surprising results was the clear local expression of some global climate patterns, such as NAO, SOI and PDO indexes. One of drastic examples is the year of 1976, which was completely anomalous in Cabo Frio upwelling, and was also marked by abrupt change in PDO index. Maybe, it could be explained by the changes in the position and intensity of high pressure centers, especially in the South Atlantic Subtropical Highs.

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## **Características de la variabilidad espacio-temporal de la temperatura invernal en capas medias de la atmósfera en relación con extremos de caudal en las regiones de Cuyo y Norte de la Patagonia**

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En este trabajo se analizan las características de la distribución espacial de las anomalías de temperatura en la capa 1000-500 hPa, asociadas a años de déficit y superávit de caudal en los ríos Atuel y Chubut, cuyo comportamiento temporal es representativo del observado para los ríos de las regiones de Cuyo y el Norte patagónico respectivamente.

Para ambos ríos, tanto las anomalías compuestas de espesores de la capa 1000-500 hPa, como las temperaturas en el nivel de 700 hPa, revelan los mismos patrones, con centros positivos ubicados sobre el Pacífico Sur y negativos el Pacífico central y el Atlántico Sur, extendiéndose sobre el continente hasta alcanzar la cordillera por su flanco oriental. Los patrones observados para casos de déficit de caudal, exhiben campos similares pero con anomalías de signos opuestos.

Estas configuraciones de anomalías de temperatura, responden casi perfectamente a las advecciones térmicas inducidas por los campos anómalos de circulación, con centros negativos sobre regiones dominadas por flujos anómalos del Sur y positivos con flujos anómalos del Norte.

Las diferencias entre los campos observados para cada río, manifiestan una tendencia al aumento de temperatura sobre el Pacífico frente a las costas de Chile al sur de 35°S y una disminución al norte y sobre el Atlántico; para el caso de exceso de caudal en Atuel y déficit en Chubut, y viceversa.

Por otra parte, el análisis espectral de las series temporales del módulo del gradiente de espesores en el área de la cordillera, revela una tendencia al aumento en la frecuencia de pasajes frontales sobre la región para años de superávit de caudal.

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## **Déficit y superávit de caudal en los ríos Atuel y Chubut y su relación con la propagación de ondas de Rossby estacionarias**

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La variabilidad temporal mostrada por los caudales de los ríos Atuel y Chubut es buena indicadora de la correspondiente a los ríos de las regiones de Cuyo (desde el río Jáchal hasta el Colorado) y el Norte de la Patagonia (desde el río Neuquén hasta el Senguer) respectivamente.

Mediante el estudio de los vectores definidos por Plumb, derivados del Flujo de Eliassen-Palm y calculados en base a las anomalías de función corriente, en este trabajo se estudian las características generales de la propagación de ondas de Rossby estacionarias, asociadas a extremos observados en el escurrimiento anual de los ríos Atuel y Chubut.

En el caso de excesos de caudal en Atuel, los vectores revelan una onda que se propaga casi zonalmente en dirección a la región de Cuyo proveniente del Pacífico central, con un centro ciclónico en altura a barlovento de la cordillera. Una onda secundaria atraviesa el Pacífico desde el Ecuador en dirección al Polo con una alternancia de anomalías de circulación ciclónica y anticiclónica. En los casos de déficit, esta segunda onda se manifiesta con mayor claridad e incluso continúa hacia el Atlántico, atravesándolo con dirección SO-NE, mientras que la primera se ubica más al Sur, recorriendo la Patagonia. Adicionalmente, los centros de circulación invierten su sentido con respecto a los observados para los casos de exceso de caudal.

En el caso de Chubut, las configuraciones son similares a las observadas para Atuel, aunque retiradas algo más al Sur.

La divergencia de los flujos de Plumb revela la interacción entre las perturbaciones trancientes y el flujo básico, el cual parece aumentar al barlovento de la Cordillera en los casos de superávit de caudal.

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## **Secuencias Principales de altura geopotencial en los niveles de 1000 y 500 hPa asociadas a extremos opuestos de caudal para ríos de las regiones de Cuyo y Norte de la Patagonia**

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A lo largo de la Cordillera de los Andes pueden identificarse dos regiones en las cuales la variabilidad temporal de los caudales de sus ríos muestra características similares. Dichas fluctuaciones están bien representadas por las observadas para los ríos Chubut (sobre el Norte de la Patagonia) y Atuel (sobre Cuyo).



Si bien no es común encontrar años con anomalías extremas de signos contrarios para los escurrimientos anuales de estos dos ríos, existen excepciones tales como el año 1986, en el que se registra superávit en el derrame del Atuel y déficit en el del Chubut o el año 1971 en el que se observa lo contrario.

Mediante un Análisis de Secuencias Principales multinivelado de cinco días, aplicado a los campos de alturas geopotenciales de 1000 y 500 hPa, en el presente trabajo se estudian los principales patrones de circulación a escala sinóptica, observados durante la estación fría (Mayo–Octubre) correspondiente a los años mencionados, analizando las distintas características que derivan en presencia de extremos opuestos de caudal en los ríos Atuel y Chubut.

Los patrones obtenidos muestran coeficientes de carga con tendencia a signos opuestos entre los años estudiados, en 12 de las 18 componentes retenidas, lo cual pone de manifiesto la inversión en las características de la circulación para ambos períodos.

Las configuraciones sinópticas exhibidas por las componentes, muestran el desplazamiento de los sistemas sinópticos responsables de la generación de precipitación en una de las regiones estudiadas y de la inhibición de la misma en la otra, con características opuestas en cada año.

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## **Analysis of some meteorological variables recorded at 4000 m in the Argentinean subtropical Andean region**

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Large interdiurnal variability was recorded in most variables; which is not unexpected given the geographical location. Daily fields of the NCEP /NCAR Reanalysis relate the dates of large variability to cold surges affecting the region. Hourly frequency of winds show preferential directions of SW-NW, presenting the largest variability during November and December that allows to presume a dampness contribution to the region from different sources.

An automatic weather station was installed in January 2004, at the Destacamento La Gruta of Gendarmería Nacional (26° 52' 35"S - 68° 18' 37"W, 4000 m) in the subtropical Andes of the province of Catamarca. The mountain weather conditions were observed from April through December in order to better understand the upper level atmospheric signals in the region. The design of the weather station as well as the description of its installation and operation and a preliminary analysis of the data recorded is shown. The variables recorded were air temperature, maximum and minimum temperatures, humidity, rainfall and wind. The presence of fallen snow was informed by the Border Police Force staff, and satellite images confirm it. Most of the variables showed a great interdiurnal variability, which is to be expected given the geographic location of the study area. Daily fields of the NCEP /NCAR Reanalysis relate the dates of large variability to cold surges affecting the region. Hourly frequency of winds was greater for winds blowing from the SW-NW. The greater variability in wind direction observed towards the end of the year can indicate that the moisture flux to the region comes from different sources.

## The 20<sup>th</sup> century limnological and rainfall variation across the Pampean plains of central Argentina.

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Paleoenvironmental research in South American extratropics suggests that an integrated network of archives is essential to define regional climate reconstructions. The analyses of long-term hydro-climatological series are crucial to calibrate proxy climate archives for an improved reconstruction of past Earth-system interactions at middle latitudes.

Hydroclimatic records across central Argentina, show contrasting hydrological balances during the last 110 years. The 20<sup>th</sup> century lake level records of Laguna Mar Chiquita (30°E, 62°W), Laguna Melincue (33°E, 61°W) and Lagunas Encadenadas del Oeste (LEO) (37°E, 62°W), highlight the sensitivity of these lakes to temporal hydrological unevenness. Rainfall analysis and lake-water levels during the 20<sup>th</sup> century reveal: a) high annual precipitations and thus comparatively higher lake levels during 1914, 1915, 1919 and 1923; b) a long dry interval and extremely low lake levels from 1930 to 1970, including a hydrological reverse during the late 50's and early 60's, and c) an outstanding humid phase since the 70's that triggered pervasive lake level increases across the Pampean region, synchronous with changes in the Río de la Plata basin. Both, the dry and wet phases have profoundly disrupted social activities in the region.

Further studies on the limnogeological record the pampean lakes will offer the opportunity to improve the understanding of past changes in the meridional atmospheric circulation. In particular, the climate archive of LEO will provide important clues on the past monsoonal activity at its southernmost influence and a better definition of the antiphased hydrological balance that is present at both sides of the Arid Diagonal.

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## Recent lake level variability in Patagonia, Argentina

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As a geomorphologic relict of Pleistocene glaciations, a string of numerous proglacial lakes borders the Patagonian Andes (South of ~38°S). We have inspected the anomalous departures from seasonal variations in instrumental records (at most ~45 years-long) collected in several lakes: Lacar, Mascardi, Steffen, Escondido, Puelo, Vinter, Argentino, and Rico. Lakes north of 41°S show maximum gage (water) level during (southern) winter months; lakes between ~42°S and ~45°S appear as transitional; lakes south of ~50°S show maximum gage level in early fall. Most lakes show a pronounced level fluctuation throughout the available yearly records and, in general, violate homoscedacity. Lake Argentino shows narrow water level variability (5-9%), and most vary between 20 and 30%. Seasonal Kendall test shows that, in general, there are no trends in anomalous lake water levels (i.e., desesasonalized). Lake Mascardi (mostly fed by meltwater from the retreating Tronador Glacier) is a contrasting example, showing a decreasing trend in level anomalies during summer months. Likewise, the Manso River (both, feeding and draining the Mascardi) shows a decreasing trend in historical discharge anomalies. The harmonic analysis

of anomalous lake levels shows interannual and decadal periodicities in lakes Mascardi, Escondido, Lacar, and Argentino. In addition, a quasi-decadal oscillation was also observed in lakes Steffen, Puelo, and Vinter. There are indications that there is a significant coherence between water level anomalies among lakes and also with ENSO occurrences in the Pacific. The associated phase spectra indicate that there are 12-15 months lags between ENSO occurrences and its effect on anomalous lake water levels.

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## Climatic jumps for 500 hPa geopotential height monthly anomalies in the Caribbean and South America

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The scope of this work is to detect climatic jumps in 500 hPa geopotential height monthly anomalies at 18 rawinsonde stations of South America and Caribbean. To do this, inter-annual variability is analyzed applying the Yamamoto test to the monthly anomalies dataset. 500 hPa geopotential height is obtained from rawinsondes at the following stations: Grantley Adams (TBPB, 78954), Piarco International Airport (TTPP, 78970), Hato Airport (TNCC, 78988), Rochambeau (SOCA, 81405), Brasilia (SBBR, 83378), Galeão (SBGL, 83746), Curitiba (SBCT, 83840), Porto Alegre Aero (SBPA, 83971), Antofagasta (SCFA, 85442), Quintero (SCER, 85543), Puerto Montt (SCTE, 85799), Punta Arenas (SCCI, 85934), Salta Aero (SASA, 87047), Resistencia Aero (SARE, 87155), Córdoba Aero (SACO, 87344), Ezeiza Aero (SAEZ, 87576), Santa Rosa Aero (SAZR, 87623), Neuquén Aero (SAZN, 87715), Comodoro Rivadavia Aero (SAVC, 87860). The dataset cover the period January 1973 – July 2006.

Climatic jumps are detected as follows (*year [station]*):

Jan 1985 [SAVC]  
Feb 1980 [SAZR, SCCE]; 1987 [SASA]  
Mar 1983/4 [SOCA]; 1992 [SBPA]; 2000 [SBPA]  
Apr 1980 [SBPA]; 1981/2 [SASA]; 1983/4 [SBCT]; 1984 [SARE]; 1989 [SBBR]  
May 1979/80 [SCTE]; 1980 [SAZN]; 1981/2 [SAEZ]; 1983 [SOCA]; 1989 [SBBR]; 1990/1 [SOCA]  
Jun 1986 [SCCI]; 1988/1989/1990 [SBBR]; 1997 [TNCC]; 1999/2000 [SBPA]  
Aug 1980/1 [TNCC]  
Sep 1983/4 [SOCA]; 1992 [SOCA]  
Oct 1984/5 [SOCA]; 1990/1/2 [SOCA]  
Nov 1979 [SAZR]; 1979/1980/1981 [SBGL]; 1983/4/5 [87155]; 1985/6 [SASA]  
Dec 1979 [SBBR]; 1983/4 [SOCA]; 1993 [SASA]

No stations jumps are detected for July. Summarizing, the Caribbean region present climatic jumps only during Southern Hemisphere (SH) winter months (Jun-Jul-Aug). Climatic jumps at Equatorial South American stations (5° N – 5° S) are present in all seasons, except for SH winter months. Climatic jumps in Central South America (5° S – 40° S) are present all year long; however, the number of stations with a detected jumps is maximum during SH fall months (Mar-Apr-May). Finally, climatic jumps at Southern South American stations (south of 40° S) are present in all seasons except for SH spring months (Sep-Oct-Nov).

## Patrones asociados a extremos de temperatura mínima en el sur de Argentina

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En general los estudios sobre eventos extremos de temperatura en Sudamérica, se centran en el análisis de las características de las tendencias de temperaturas, medias, máximas y mínimas y su relación directa o indirecta con el cambio climático. Sin embargo, existen pocos antecedentes bibliográficos en Argentina sobre estos eventos extremos en escalas subclimáticas. El objetivo principal de este trabajo consiste en obtener un modelo simple y directo, capaz de predecir dichos sucesos con un alto grado de precisión. Para ello se estudiaron los eventos climáticos extremos durante el invierno en el período 1959-2001 en la región patagónica, determinándose umbrales en la temperatura mínima en cada estación, se caracterizaron climáticamente dichos eventos en magnitud, frecuencia y extensión territorial y se determinaron los patrones de circulación general asociados en los meses previos a fin de proporcionar al pronosticador una nueva herramienta para ser considerada en estos casos.

### Climate variability in South America from historical documents

#### Evaluating socio-economic change in the Andes from domestic animal densities

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Here we present an alternative method of reconstructing socio-economic shifts in a rural Andean setting from the analysis of the frequency of oribatid mite remains present in a sedimentary lake sequence. Oribatid mites are soil-dwelling microarthropod detritivores, some of which inhabit areas of grassland pasture. One of the primary controls governing their abundance in such habitats is the level of animal dung deposited. We propose that past fluctuations in mite remains can be related to the density of domestic animals using the area of pasture and, by extension, may provide a proxy for human population shifts in the area through time. To test this hypothesis, we analysed a high-resolution (~6 years) mite record from a sequence of well-dated sediments from Marcacocha, a climatically-sensitive lake site located close to an important Inca trading route across the Andes. The timing and magnitude of mite fluctuations at Marcacocha since the 1530s show remarkable correspondence with a series of major, well-documented socio-economic shifts in the region relating political and climatic pressures. This provided the confidence to extend the record back a further 700 years and reconstruct changes in domestic herbivore densities for a period of time that lacks historical documentation and thereby infer changes in human occupation of the basin. In particular, high mite abundances appear to correspond clearly with the rapid rise and fall of

the Inca Empire (c. AD 1400-1532). We speculate that small lake basins such as Marcacocha may be particularly suitable for obtaining continuous oribatid mite records and providing the possibility of reconstructing large herbivore abundances in the Andes and elsewhere.

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## Historia del clima de Colombia

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Las fases extremas de variabilidad climática y el cambio climático inciden de diversa forma en la sociedad generando impactos socioeconómicos y ambientales de gran magnitud. Una de las formas en que las variaciones del clima repercute en la sociedad es a través de la disponibilidad de agua. Periodos con déficit de precipitación genera sequías con los correspondientes impactos en la agricultura y ganadería, en el abastecimiento para la población y en la salud; los períodos con exceso de precipitación propician la ocurrencia de desbordamientos, deslizamientos e inundaciones con consecuencias catastróficas en la población y en las actividades que esta desarrolla.

Se tiene establecido que diversa regiones del planeta son vulnerables en diverso grado ante las fases extremas de la variabilidad climática asociadas a los fenómenos El Niño y La Niña; igualmente, diferentes regiones y sectores socioeconómicos de los países son vulnerables ante un cambio climático. Es necesario reducir esta vulnerabilidad y una forma es generar conocimiento sobre los diversos aspectos de la variabilidad climática y del cambio climático, así como a través del conocimiento de los impactos y la respuesta de la sociedad a eventos que ocurrieron en el pasado. El conocimiento de las experiencias vividas por la sociedad en el pasado servirá de lección que permitirá al país prepararse mejor para afrontar las fases extremas de variabilidad climática y el cambio climático que se expresará marcadamente en los decenios venideros. El conocimiento de la historia climática del pasado, de las oscilaciones climáticas de diversa escala temporal y de los impactos que en cada época ha tenido el clima en la sociedad y el medio natural, tiene valor práctico como herramienta básica para diagnosticar la relación clima-sociedad en el presente y prever lo que podría ocurrir en el futuro y asegurar respuestas efectivas a las condiciones que sobrevengan.

Colombia esta expuesta a las fases extremas de la variabilidad climática (*Montealegre & Pabón, 2000; CAF, 2000*) y al cambio climático (*Pabón 2003*). Es necesario entonces dar una mirada retrospectiva al clima y a su relación con la sociedad colombiana. Eventos climáticos pasados, su impacto y la respuesta de la sociedad a los mismos sirven de escenarios de orientación de lo que podría suceder si se presentaran nuevamente dichas condiciones ahora (con características socioeconómicas diferentes) o en años y decenios futuros en un clima cambiado.

Con base en lo anterior, en este trabajo se propone realizar el estudio de la historia del clima de Colombia de los últimos quinientos años, en la medida como las fuentes de información lo permitan. En un proyecto interinstitucional, con la participación del Departamento de Geografía de la Universidad Nacional de Colombia y el Archivo General de la Nación, se explorarán diversas fuentes en las que habría la posibilidad de encontrar información referente al clima de diferentes regiones de lo que hoy constituye el territorio colombiano, acorde a lo planteado en un análisis de antecedentes por *Pabón & Torres (2004)*.

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## Contribution to the knowledge of Buenos Aires climate in the period previous to the instrumentation

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The present text gathers and analyzes the varying temperature on the period going from the Independence to the first years of the National Organization. It is based upon daily series published in the *Registro Estadístico de la Pcia. de Buenos Aires* (1822-1825), series gathered and published by R. Trelles in the *Registro Estadístico del Estado de Buenos Aires* on the 1850's (dealing with data from the 1820's and 1830's), as well as information published in the journal *The British Packet and Argentine News* from 1826 until the late 1860's.

The report focuses in two research projects which are in current development.

The first one approaches the problem of the relationship between technology and slavery from a socio-technical perspective. It analyzes the characteristics of the sea transport of slaves, where the climate variables are fundamental.

The second project aims, in its first stage, at studying the climate variables that took place on the last few years, modifying the environmental characteristics and having an impact on the cycle of rains. The study is oriented towards the formulation of a predictable model of such cycle, and the way it impacts on the margins of river *Salado*. Many cities are located at scarce centimetres over the floodplain. But over *which* floodplain? The cities development has been calculated in a short term projection. This resulted in floods taking place, at present, in areas where the phenomenon was previously unknown. Therefore, the climatic characteristics of the Pampas tend to a progressive and quick modification as well as the wet weather flow that will impact on the cities and their current infrastructure.

## Climate variability in South America from tree-ring records

### Tree-ring based reconstructions of snow avalanches along an environmental gradient in southern Patagonia

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Meteorological factors such as the amount and type of precipitation, air temperature, wind speed and direction, influence the occurrence of snow avalanches in mountainous regions. In forested areas, trees growing along avalanche tracks allow reconstructing past avalanche events with year accuracy. Scar and reaction wood formation, stem eccentricity variations and abrupt growth changes are common features observed in trees impacted by avalanche events. In the Patagonian Andes, the marked precipitation gradient in west-east direction

determines differences in the amount and type of snow, which in turn affects the avalanche regimes across the Andes. In this paper we report the development of tree-ring based avalanche chronologies along the west-east precipitation gradient from the humid Laguna del Desierto (49°04' S, 72°51' W) to the mesic Laguna Madre-Hija (49°18' S, 72°57' W) sites, El Chaltén, Santa Cruz, Argentina. At these sites, *Nothofagus pumilio* (southern-hemisphere beech) is the dominant tree species. Avalanche chronologies were compared with regional climate data to determine the climatic conditions more strongly related to avalanche events along the precipitation gradients. Reconstructed chronologies in the region back to early 18<sup>th</sup> century and provide a reliable record of extreme past avalanche events.

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## **Dendroclimatological reconstruction in the Cordillera Real (Bolivia): Preliminary results**

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High resolution proxies in the tropical Andes are extremely limited. In this study we analyzed the links between climate and the growth of *Polylepis pepeii*, a species that lives in high Amazonian side altitude valleys of the tropical Andes. Trees were selected in Zongo valley (Cordillera Real) near La Paz (Bolivia) at 4200 m asl. 12 trees were sampled on a gentle lateral moraine and 11 others on a scree slope.

The common time window of the two chronologies extends over the last sixties years. Correlation functions with climatic data were carried out. On both sites, the variation of the ring-width depends on one hand of precipitations occurring in October (rain season) of the growth year and on the other hand on rare rainy events occurring in June during the dry season. However, the two sites show a different relationship with temperature. On the scree slope a negative relationship is observed between the ring-width and temperature of the coldest month of the year (July), while cold temperatures observed during the dry season do not affect significantly the trees which grow on the moraine. The openwork texture of the scree slope allows a better thermal conductivity and affects the growth of the trees. From our dendroclimatic reconstructions we can highlight decadal variations of precipitation which occurred during the last sixty years, especially the dryness of the Forties. Extreme events are also recorded, especially El Niño events which occurred in 1982-83 and in 1997-98.

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## Dominant patterns of tree growth in North-western Argentina: Their relationships with climate

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The mountain topography in North-western Argentina (NOA) originates a wide range of environmental gradients along which tree growth responds differentially to climate. Thus, tree growth can be influenced by temperature (in moist, cool sites), or by precipitation (dry, warm sites). Since 1980's two tree species from the montane forests have been studied: *Juglans australis* ("nogal criollo" Juglandaceae) and *Cedrela lilloi* ("cedro rosado" Meliaceae). Up to now, 34 ring-width chronologies have been developed from these species. Previous studies indicate large differences of interannual variations in tree growth between sites and a wide variety of responses to climate across different environments.

In this presentation we determine the range of tree growth responses of *Juglans* and *Cedrela* to climatic variations in NOA. We emphasized the identification of common signals between sites and species, in order to determine the dominant patterns of tree growth and their relationships with climate. Based on the similarity in interannual growth variations between sites, individual chronologies were grouped into regional chronologies. This procedure is expected to enhance the regional climatic signal present in the tree-ring records. The regional signal in the chronologies is strengthened when a large number of samples from environmentally similar sites is included in a common record, which eventually will lead to better reconstructions of the past climate variations in the NOA region.

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### Reconstrucción histórica de los caudales del Río Bermejo a partir de registros dendrocronológicos

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Estudiar las variaciones temporales y espaciales de largo plazo del sistema climático, así como la identificación de señales antrópicas superimpuestas en la variabilidad natural del clima, requiere contar con series temporales extensas que cubran desde las algunas centurias hasta el último milenio.

Si deseáramos realizar un análisis de la variabilidad climática en escala de décadas a centurias no podríamos hacerlo sobre la base de series hidrometeorológicas instrumentales, debido a la limitada extensión de estos registros en Argentina y en particular en el noroeste argentino donde raramente superan los 60 años.

La Dendrocronología es una herramienta adecuada para extender series de variables climáticas en el pasado. Los anillos de los árboles proveen series continuas, precisamente datadas con un nivel de resolución anual.

En este estudio, las variaciones interanuales en el crecimiento de los anillos del nogal criollo (*Juglans australis* Griseb) y del cedro tucumano (*Cedrela lilloi* C.DC) han sido empleadas para reconstruir la variaciones de caudales estacionales del Río Bermejo desde el



año 1791. Hemos elegido esta variable hidrometeorológica por ser una excelente expresión del ciclo hidrológico en la naturaleza, ya que integra precipitación, infiltración y evapotranspiración sobre grandes áreas.

Para vincular caudales y crecimiento anual de los anillos hemos utilizado una rama de la Inteligencia Artificial denominada *Redes Neuronales Artificiales*, siendo aplicado durante la etapa de aprendizaje o calibración del modelo el algoritmo Back Propagation.

**Palabras Clave:** dendrocronología, variabilidad climática, caudales, redes neuronales artificiales

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## **Potencialidad dendrocronológica de las especies de la Chiquitanía (15-20°S), Santa Cruz, Bolivia**

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En Bolivia, el estudio de la variabilidad climática está limitado por la falta y poca extensión de los datos instrumentales. Por lo tanto, resulta de gran interés recurrir a indicadores o archivos ambientales que puedan proveer información proxy-climática que permita reconstruir los cambios ambientales a escala regional. Entre estos indicadores están los anillos de los árboles que proveen series continuas que pueden ser modeladas para reconstruir, con precisión, las variaciones anuales de la temperatura, la precipitación y la presión atmosférica durante las últimas centurias. En este trabajo se presenta los resultados preliminares de un inventario dendrológico de 15 especies del Cerrado Boliviano (Chiquitanía) y sus áreas de transición al bosque húmedo Amazónico y el Parque Chaqueño seco, destinado a determinar la presencia de especies con anillos de crecimiento bien definidos, con buenas características dendrocronológicas (anillos de carácter anual, uniformidad circular), que permitan reconstruir las variaciones de los parámetros climáticos durante las últimas centurias en distintas eco-regiones del Cerrado Boliviano. En aquellas especies con anillos de crecimiento definidos, estos fueron visualmente datados y finalmente medidos con una precisión de 0.01 mm. Del total de especies examinadas hasta el presente, solo 2 de ellas *Anadenanthera colubrina* (curupaú) y *Centrolobium microchate* (tarara amarilla) poseen anillos anuales de crecimiento cuyas variaciones interanuales correlacionan entre radios de un mismo árbol y entre individuos de un mismo sitio. Las muestras analizadas de estas especies alcanzan edades próximas a los cien años, pero creemos que es posible obtener material más longevo, el que permita reconstruir las variaciones pasadas del clima de los llanos de Bolivia durante las últimas centurias.

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## Dendroclimatological potential of *Araucaria angustifolia*

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*Araucaria angustifolia* is a promising species for studies of climatically sensitive growth ring series from tropical and subtropical rain forests. This conifer lives on mountain ecosystems of Southeastern South America, a transition region between tropical and temperate climates. Anatomic and isotopic evidence indicated that growth rings of *A. angustifolia* are seasonally formed. Furthermore, good growth-ring synchronicity among individuals within a forest stand has been reported. Nevertheless, the association between the growth-ring series and climate conditions is not yet known.

This study aims to build a growth-ring chronology of *A. angustifolia* and to investigate its association with meteorological time series. Increment borer samples of 41 trees (2-4 samples/tree) were collected in São Francisco de Paula, RS, Brazil. The samples were prepared, measured, and cross-dated according to standard dendrochronological methods. Because of anatomical irregularities, mainly missing-rings and density fluctuations, only 17 trees could be correctly cross-dated and used to construct an average ring-width chronology for the site.

The chronology covers the 1940 - 2003 period, with a mean correlation among individuals of  $r=0.47$ . Correlation analysis indicates that *A. angustifolia* growth is directly associated to precipitation during the spring-summer season (Sep-Mar), and inversely to the maximum temperature at the beginning of the spring (Oct-Nov). Previous March to June temperature is directly related to growth. These results show that *A. angustifolia* is sensitive to water supply during the growing season, especially on the first months when high maximum temperature may cause water deficits. High temperature conditions on March to June might induce carbohydrate formation to be used in the following growing period. These evidences support that *Araucaria angustifolia* is a climate sensitive species, with good potential for dendroclimatological studies.

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## The potential of *Rhizophora* for climate reconstructions in the tropics

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*Rhizophora* is a pantropical genus dominant in mangroves. As it grows in the ocean-continent ecotone it is expected to respond quickly to sea level rise caused by global warming and to secular changes of temperature of the Pacific Ocean produced by ENSO. *Rhizophora* is also affected by temporal oscillations of water salinity because of rainfall pulses and their effects on streamflow discharged by rivers to the ocean. Even though for more than 70 years scientists denied the existence of annual growth rings in *Rhizophora*, recent reports from America and Africa found, not only annual rings but also a strong relation between them

and climate. In the mangroves of the Cispatá Bay, Colombian Caribbean region, this work demonstrates the existence of annual growth rings in *Rhizophora mangle*. They are formed by alternate bands of earlywood and latewood. Earlywood characterized by dark color, low density and low number of vessels per unit area, while latewood had light color, high wood density and abundant vessels. Wood densitography was made by Computerized Axial Tomography. We found high correlations between several variables: porosity and annual rainfall ( $r=0.84$ ;  $P=0.008$ ), wood density and streamflow ( $r=-0.79$ ;  $P=0.006$ ), and wood density and relative humidity of the air ( $r=-0.63$ ;  $P=0.048$ ). These results suggest the tremendous potential to reconstruct the past tropical climates using live and dead trees as we detect semi-fossils *Rhizophora* trees buried thousands years ago in the peat swamps near to mangrove forests. The importance of such approach is evident in locations where long term instrumental data are not available, which are common around the tropics.

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### **Tree-ring and isotopic variations of *Nothofagus Pumilio* forests along an altitudinal gradient in El Chalten, Santa Cruz, Argentina**

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*Nothofagus pumilio* tree-ring and  $\delta^{13}\text{C}$  variations along an altitudinal gradient in El Chalten, Santa Cruz, Argentina were investigated in relation to climate variations during the 20th century. Three sampled plots were established in the upper- middle- and low-sectors of the forest. All trees were measured and cored with increment bores. Samples from three individuals from each altitudinal stand were isotopically analyzed. The upper-limit forest presents healthy, snow-stunted individuals with diameter <40cm. The radial growth of these trees is characterized by a marked positive trend during the 20th century in response to the increase in regional temperature. Due to an increase in photosynthetic rate, individuals in the upper treeline show an increase in water use efficiency, as indicated by the  $\delta^{13}\text{C}$ . In the lower limit, dieback is common among trees resulting in an over-matured stand with low density and coverage. Establishment of new individuals is rare whereas a high rate of mortality is observed during the past 40 years, likely related by the regional increase in temperature and reduced precipitation during the past decades. The radial growth at the lower treeline shows a negative trend during the 20th century. However, trees at this altitudinal level also show a significant increase in water use efficiency, but more likely related to stomatal conductance than photosynthetic rate changes. At middle elevations, the forest presents intermediate characteristics between those recorded for the forests at the upper-lower limits. We speculate that the recorded patterns along the altitudinal gradient are reflecting the dominant climatic trends during the 20th century. The gradual increase in temperature has favored tree growth at the upper treeline. In contrast, higher temperatures, in combination with reduced precipitation, have enhanced water deficit resulting in progressively lower radial growth at the lower treeline.

### Utilización de morfogrupos de foraminíferos del Holoceno Medio-Tardío para la interpretación paleoambiental del golfo Nuevo, provincia del Chubut, Argentina

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Se realizaron inferencias paleoambientales a partir de la fauna de foraminíferos bentónicos recuperados de cuatro testigos del golfo Nuevo. La edad de los sedimentos abarca desde el Holoceno Medio hasta el Holoceno Reciente. Las especies predominantes en general fueron *Buccella peruviana* f. *campsi* (Boltovskoy), *Buliminella elegantissima* (d'Orbigny) y *Bulimina patagonica* d'Orbigny. Esta asociación estaría indicando un ambiente de plataforma interna.. En base a los morfogrupos se puede determinar que se presentaron en general un mayor número de individuos infaunales que epifaunales. La relación entre estos individuos indicaría variaciones en cuanto al contenido de oxígeno y materia orgánica, que serían los principales factores ambientales que afectarían la distribución de los foraminíferos. Las condiciones reductoras inferidas por la presencia de ejemplares piritizados fundamentalmente de la especie *Buliminella elegantissima* encontradas en el golfo Nuevo, ciertas asociaciones faunísticas (como el hallazgo de especies oportunisticas como, *Buliminella elegantissima* y especies de los géneros *Bolivina*, *Globobulimina*, *Bulimina* y *Uvigerina*) y los resultados de los análisis cuantitativos estarían reflajando una tendencia durante el Holoceno Medio, desde condiciones marinas normales de plataforma interna a condiciones marinas marginales, hacia el Holoceno Reciente. Este cambio habría comenzado entre los 6.900 y 6.600 años BP, sugiriendo fluctuaciones en la dinámica circulatoria del golfo provocadas posiblemente por un cambio climático, representado por un aumento en las precipitaciones y en la descarga fluvial.

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### Luminescence Dating of Relict Lake Shorelines and Relict Dunes: A Late Quaternary Wet or Dry History of the Etosha Pan Region of Namibia

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Pans cover 5637 km<sup>2</sup> of the Etosha National Park in northern Namibia. By far the largest is Etosha Pan extending 55 km north to south and 120 km east to west, with an area of 4760 km<sup>2</sup>. Relict shorelines at ca. 5, 2.5 and 1 m above the present pan surface on the slope of a lunette at the western end of Etosha Pan indicate higher and more prolonged lake conditions than today, while relict linear dunes suggest much drier and windier periods in the past. OSL analyses of shoreline sediments provide ages of ca. 5.4, 2.5, and 0.9 ka respectively with the youngest shoreline sediments resting on an ancient pan surface dating to ca. 11 ka. The evidence indicates dry conditions in the pan at ca. 11 ka, wetter conditions and higher lake levels in the early to middle Holocene, followed by a decline in flood levels to the present. However, periods of inundation were of sufficient duration to produce shorelines at the southwestern end of the pan due to the prevailing northeasterly winds that would have

maximized wave action along this section of the pan margin. OSL ages for the upper 6 m of sand in a relict linear dune near Oshivelo at the eastern end of Etosha Pan suggest dune activity at 55-46, 33-27, and 18 ka.

Comparison with other paleoenvironmental records from Namibia, Botswana and the Northern Cape, South Africa, suggest increased wetness in the region during the late Quaternary at ca. 16-12, 7.0-4.7, 3.6-2.2, and 1.8-0.8 ka. Prior to ca. 8.0 ka the Etosha evidence indicates a climate drier than today. Dry intervals are suggested at 50, 30 and 20 ka. The wet interval at Etosha Pan at 7.0-4.7 ka, and the dry interval in the Oshivelo dune at 20 ka, are well documented at many sites and correlate with the period of maximum wetness at 7-6 ka, and a prominent dry interval at 20 ka, evident in South Atlantic marine sediment cores off the Namibian coast.

**Keywords:** Etosha Pan; OSL dating; Namibia; late Quaternary climate change, relict dunes.

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## **OSL Dating of Fluvial and Lacustrine Sediments in Quaternary Studies: The Late Pleistocene-Holocene History of Lake Ngami, Botswana, Southern Africa**

**George A. Brook**

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Lake Ngami is a 3000 square km internal drainage basin at the distal end of the Okavavango Delta in Botswana. The Thaoge River in the west and the Kunyere in the east feed most water to the lake. At low lake levels the Nchabe River, which joins the Kunyere before it enters the lake basin, may also supply water to the basin; at high lake levels the Nchabe serves as a discharge route for lake overflow. The lake was extensive in the late 1800s when visited by David Livingstone. It has been dry since the 1980s but flooded for the first time in 25 years in 2004. Floodplain, deltaic, and lacustrine sediments at the eastern end of the Lake Ngami basin record high lake levels at ca. 50, 36-25, and 6-1 ka based on OSL 4.0 mm aliquot minimum ages for fluvial sands. The fluvial sands record active flow of the Kunyere and perhaps also the Nchabe River into the Lake Ngami basin. As the lake filled with water the fluvial deposits were submerged with deposition of clays and diatomites. Diatoms in diatomite layers above the sands fall into three main assemblages that correspond with the three age ranges of the underlying sands. These indicate that Lake Ngami reached successively lower elevations over time from ca. 50-1 ka. Eventual shallowing of the lake led to incision of previously deposited sediments. Cycles of filling and draining produced a nested sequence of younger fluvial and lake sediments in the eroded sections of earlier deposits. The three Lake Ngami high-stands correspond with evidence of increased rainfall in other parts of Southern Africa.

**Keywords:** Lake Ngami; OSL dating; Botswana; diatomites; climate change.

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## **Cambios en la productividad marina en los últimos ~300 años, a partir del análisis multiproxy de sedimentos laminados de alta resolución en la Bahía de Mejillones (23°S), norte de Chile**

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Se caracterizaron sedimentos laminados de Bahía de Mejillones, Chile (23°S) con el fin de estudiar los cambios en la productividad marina y su relación con las fluctuaciones de la temperatura superficial del mar (TSM) durante el pasado reciente, a través de un análisis multi-proxy que incluyó carbono orgánico, nitrógeno total, *clorins*, alquenonas, ópalo biogénico y diatomeas. Se analizaron los primeros 30 centímetros de la columna de sedimento (muestreada con Box corer) que corresponden a los últimos ~300 años. El carbono orgánico fluctuó entre 1 y 11%, el nitrógeno total entre 0.1 y 1%, la concentración de *clorins* entre 197 y 736 nmol g<sup>-1</sup> y de alquenonas entre 1.6 y 21.5 µg g<sup>-1</sup>. El contenido de ópalo biogénico fluctuó entre 7 y 23%. Las diatomeas fueron el grupo más abundante (8x10<sup>7</sup>-1x10<sup>9</sup> valvas g<sup>-1</sup>sc), aportando el 99% del total de organismos silíceos (silicoflagelados, radiolarios, espículas de esponjas). Las diatomeas de surgencia dominaron el registro, caracterizado por esporas de *Chaetoceros*, que aportaron el 79% al total de diatomeas. La estimación de la TSM a partir de alquenonas osciló entre los 15.5 y 18.7°C. Del análisis multi-proxy se infiere que la productividad marina total aumentó a partir de ~1800 al presente, coincidiendo con una disminución de la TSM de ~2°C, probablemente debido a la intensificación de los eventos de surgencia costera. Es interesante destacar que en los primeros 5 cm de sedimento (~50 años) se observó una caída del ópalo biogénico y valvas de diatomeas presumiblemente debido a procesos de mezcla.

**Palabras claves:** alquenonas, ópalo biogénico, diatomeas, sedimentos laminados, Chile, productividad silícea.

**Agradecimientos:** Centro FONDAP-COPAS, Proyecto FONDECYT 1040503, Escuela de Graduados de la Universidad de Concepción.

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## **Registro paleolimnológico de cambios ambientales en el Lago Laja (Chile Central) durante los últimos 1000 años.**

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A través del análisis de diversos proxies preservados en la matriz sedimentaria, se realizó una reconstrucción de las condiciones ambientales en el Lago Laja durante los últimos 1000 años. Para ello, se extrajo un núcleo de sedimento desde la zona de mayor profundidad del lago, estableciéndose la edad de los estratos mediante la actividad de los radioisótopos <sup>210</sup>Pb y <sup>14</sup>C. El perfil fue caracterizado mediante el análisis de parámetros físico-químicos

(características texturales, materia orgánica y sílice biogénica), y se reconstruyeron los ensambles de diatomeas, quironómidos y polen. Los ensambles de diatomeas presentaron una importante disminución de las especies *Fragilaria construens* y *Fragilaria pinnata* hacia la actualidad, en tanto que aumentó la abundancia de los taxa *Asterionella formosa*, *Aulacoseira distans* y los del género *Cyclotella*; al mismo tiempo se observó una drástica disminución en la concentración de diatomeas en los estratos con material volcánico. Los quironómidos también muestran una clara relación con la depositación de estos estratos, disminuyendo la abundancia de los taxa *Parachironomus*, *Paratanytarsus* y *Macropelopia* junto con el índice de diversidad, el cual aumenta progresivamente hacia los estratos superficiales de la columna sedimentaria. El polen evidencia fluctuaciones en la humedad, reflejado por cambios en *Nothofagus* tipo *dombeyi*, Poaceae y *Ephedra*; por otra parte se registra un fuerte impacto antrópico durante los últimos 100 años, inferidos por la aparición de *Plantago* y el incremento de Poaceae y Asteraceae subf. Cichorioidae. Finalmente, es posible indicar que los cambios en los proxies analizados, estarían asociados principalmente a la actividad volcánica, y que en tiempos recientes los cambios se relacionan con la actividad antrópica.

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## **A paleolimnological reconstruction for the last millennium from Lago Lepué (~43°S), Isla Grande de Chiloé, based on diatom analysis: preliminary results**

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Here we report a high-resolution diatom record from a NW Patagonian lake spanning the last 1000 years. The record from Lago Lepué (~43°S) shows 104 taxa, with many species known only from subantarctic areas, along with a significant number (29) of unidentified and/or presumably new taxa. The available information on the ecological attributes of the most representative taxa allows some preliminary inferences on past fluctuations in pH, trophic status and water level. The diatom stratigraphy over the last 1000 years is represented mainly by the alternation of assemblages dominated by the benthic *Encyonopsis difficilis*-*Brachysira brebissonii* and the planctonic *Aulacoseira distans*-*A. alpigena*. We identify three stages in the recent paleolimnological history of Lago Lepué: (i) the interval between 1000-900 yr BP is characterized by a progressive increase lake level and a reconstructed decrease in nutrient availability, (ii) a high lake level stands occurred between 900-700 yr BP maintaining an stable oligotrophic condition, and (iii) a declining lake level trend since 700 yr BP showing an increase in nutrient concentrations, mainly since the most recent ~200 years and probably related to human activities.

The inferred low stand in lake levels between 1000-900 yr BP are contemporaneous with peak fire activity, as indicated by a high-resolution charcoal record from the same lake sediment core. On the other hand, the inferred high-lake level stand in Lago Lepué between 900-700 yr BP was coeval with a prominent decline in fire activity. While, diminished lake level indicated by diatoms from 700 yr BP (specially the last ~200 yr BP) is correlated with the increased fire activity by human colonization.

Considering that Lago Lepué is a small closed-basin lake, fed almost exclusively by rainfall, we suggest variations in the amount of precipitation brought by the westerly winds

over the last millennium, with an apparent maximum between 900-700 yr BP just before the onset of the Little Ice Age.

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## **Sedimentary and micropaleontological response to Mid Holocene sudden sea level falls in Buenos Aires coast: a paleoclimatic perspective**

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A sedimentary core collected from -12.8 m at 36°45'43"S - 56°37'13"W, Southwest Atlantic, reveals the Mid-Holocene history of the northern Argentine inner shelf. Paleoenvironmental changes and paleo-sea-level trends were reconstructed from 6000 to 3000 years BP using benthic foraminifera. The primary evidence strongly supports two secondary, high-frequency sea level falls reflected by two pulses of mud deposition in the shoreface toe. Paleosalinities reached maximum values at ~5500 years ago and thereafter declined continuously to modern values, whereas paleoproductivity and diversity decreased strongly during sea level falls. The timing of these Mid-Holocene sea level oscillations was compared with the decadal-scale periodicity observed in a proxy record of solar variability, the sunspot number reconstructed by Solanski et al (2004, 2005), and with atmospheric CO<sub>2</sub> concentration considering Taylor Dome geochemistry series (Grootes et al., 1994, 1999). During the time elapsed by the core, two intervals of unusually low sun activity occurred, whereas CO<sub>2</sub> concentration increases quasi-monotonically. This allows us to infer that the two episodes of sudden sea level fall recognized are related with an abrupt climatic change to cooler and probably drier conditions contemporary of a decrease in solar irradiance. The two successive episodes of sea level fall coincide with abrupt increased of sea ice in the South Atlantic and climatic cooling and/or changes in moisture conditions in various regions of both hemispheres. This period corresponds to the onset of the Neoglaciation.

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## **500-year-record multiproxy paleolimnology study of a shallow pampean lake and GCR flux**

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Short sediment cores from Chascomús Lake, a shallow lake in the Pampas from Buenos Aires province, Argentina (35°36'S-58°00'W) were investigated to reconstruct high-frequency climatic variations for the last 500 years. Our analysis of cores focuses on changes in sedimentological, paleontological, geochemical, and rock-magnetic parameters in order to characterize the physical and chemical paleohydrology and river influence on the lake, and allow for the correlation among cores for lake-level reconstructions. The chronology is constrained by AMS <sup>14</sup>C dating (1460 AD, at ~35 cm depth). As a working hypothesis, we



consider a constant sedimentation rate since there is no drastic changes in sedimentary facies. Two increases in lake-level associated with pulses of fluvial input were recognized around 1725 AD and 1880 AD. Clastic sediment flux as indicated by grain size remained minimal during low lake-level stages, when *Limnocythere*-dominated assemblages reflect high alkalinity and groundwater input. Thereafter, *Cyprideis*-dominated assemblages, lower organic carbon content, increase grain size and concentration/grain size magnetic parameters indicate increased fluvial influence to the lake, and the presence of diluted, low salinity waters. We compare the timing of these lake-level fluctuations with the galactic cosmic ray flux (GCR) calculated from the Taylor Dome dataset. Low lake levels coincide with intervals of unusually high GCR flux (=low solar activity), related with the Maunder and Dalton Solar Minima. This allows to infer that lake sediments in the Argentine Pampas contain valuable paleoclimate information related with high frequency climatic variability.

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## **The Cauca Lake: a potential high-resolution climate record from tropical America for the Late Holocene**

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Among three terrace levels, exposed along the Cauca River in northwestern Colombia, the San Nicolas terrace contains a lacustrine succession of laminated sediments. The San Nicolas lake episode was ~50km long and ~110 m deep and originated from the damming of the Cauca River by the Guasimo landslide, triggered by tectonic activity during the late Holocene. Laminae possibly represent annual to seasonal events of riverine input and lacustrine sedimentation controlled by the dynamics of the intertropical convergence zone (ITCZ) and the ENSO phenomenon. The 30 m thick succession is exposed along La Batea Creek, where three segments containing mud-silt laminae, four volcanic ash and two hardground(?) layers, and a mollusk horizon, are recognized. Five radiocarbon dates show that the basal paleosol is 20ky BP, and that sediment deposition was, apparently, continuous from 3ky BP onwards. Preliminary sediment accumulation rates are suggestive of ~1.5 cma<sup>-1</sup>. Therefore, we expect to reconstruct the sub-decadal climate history of northwestern South America from a site close to the Panama Isthmus, where large amounts of moisture are exported from the Caribbean to the Pacific, and the ENSO influence is felt through the Choco jet.

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## Marine productivity and sea surface temperature changes in Northern Patagonia during the last 1,800 years inferred from a multi-proxy analysis of Jacaf channel sediments (Chile, 44° S)

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A multi-proxy approach based on the abundance of siliceous microorganisms (diatoms, silicoflagellates, chrysophyte cysts), organic geochemical proxies ( $Si_{OPAL}$ ,  $C_{org}$ , C/N ratio) and alkenones (as proxies of sea surface temperature) preserved in the sediments of the Jacaf channel (St. 33; 44° 21'S, 72° 58'W, 510 m water depth), Chilean fjords, evidence major paleoproductivity and sea surface temperature (SST) changes over the last ~ 1,800 years. The downcore record clearly shows two productivity modes: The first period, prior to ~800 cal yr BP, is characterized by decreased marine productivity and a reduced continental signal, pointing to reduced precipitation, and runoff in a relatively warmer climate. In contrast, the second period between ~700 and 72 cal yr BP is characterized by high productivity accompanied by an increased continental signal, suggesting higher precipitation and runoff in a colder climate scenario. Both time intervals are separated by an abrupt transition of ca. 100 years which roughly coincides with the beginning of the Little Ice Age (LIA). In addition to an overall general cooling trend, the record based on alkenone-derived SSTs shows two marked cold periods, 730-580 cal yr BP (1220-1370 AD) and 430-264 cal yr BP (1520 -1686 AD), which roughly coincide with tree ring data from Patagonia (Villalba, 1990 *Quaternary Research* 34, 346-360). The correspondence between our results and other paleoclimate studies carried out in South America and Antarctica, demonstrates that the fjord area of Northern Patagonia is not only sensitive to local climatic variability but also responds to regional and possibly global variability.

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## Hydrological changes in a subtropical saline complex - Modern and Late Quaternary sediments of Salina de Ambargasta, central Argentina

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Salina de Ambargasta is a discharge playa with a water deficit of 850 mm/year, occupying a topographically closed depression (ca. 9500 km<sup>2</sup>) in central Argentina (29°S-64°W). The Ambargasta depositional complex is ruled by the regional hydrology, the semiarid climate and the tectonic setting. Geomorphology, mineralogy, instrumental data and image analyses

allowed the characterization of clastic/saline mudflats, ephemeral lakes as well as a paleo dune field and paleofloodplains.

Variations in sedimentary environments respond to seasonality that is undoubtedly recorded through instrumental data (e.g., precipitation). Lakes are filled with brines during the austral summer (December to March) switching to clastic and saline surfaces until the next rainy season. The sensitivity of the system to hydrological changes throughout time can be tracked using sedimentary cores retrieved in the saline-clastic mudplain and studied with a quantitative multiproxy approach including petrophysical properties, microstratigraphy, organic-inorganic geochemistry and mineralogy. Preliminary vertical facies analyses allow reconstructing the Ambargasta paleodepositional evolution. The lowermost units record fluctuating ephemeral lakes including laminated, organic matter-bearing, gypsum and halite-rich clays. The uppermost sections were deposited in a clastic mudflat, dominated by red massive clays and the intrasedimentary growth of gypsum and halite. Sand layers and phytoliths represent rapid and high energy events. Ongoing investigations (stable isotopes and dating) will allow to unravel the environmental history of this system during the Late Quaternary. The further combination of this record with similar studies stemming from central Argentina will provide critical data to reconstruct the role of the middle latitudes during times of major climatic reorganization.

## Climate variability in South America from high-resolution pollen records

### Postglacial forest history at the forest-steppe ecotone in Northern Patagonia,

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High-resolution pollen records from Laguna el Trébol in the Nahuel Huapi area and Lago Mosquito, 150 km to the south, as well as published records provide information on the long-term vegetational changes that occurred near the forest-steppe ecotone between lat. 41° to 42.5° S. during late-glacial and Holocene periods.

Prior to 15 ka, the L. el Trébol area was characterized by steppe vegetation with forest patches. Between 15 - 11.4 ka, this mosaic was replaced by open *Nothofagus* forest. This forest developed and diversified in the early Holocene and *Austrocedrus chilensis* expanded at 5.9 ka. The present-day *Nothofagus* forest with lesser amounts of *A. chilensis* was established at 3.5 ka. At L. Mosquito, a steppe-shrubland vegetation developed prior to 9 ka and was replaced by open *Nothofagus* forest between 9 - 4 ka. The expansion of *A. chilensis* occurred about two thousand years later than in the L. el Trébol region. A shift towards *Nothofagus-Austrocedrus* forest started at 2.7 ka, and continued to the present. The history of the steppe forest ecotone is linked to long-term climate trends, including warming in the late-glacial, a steepening of moisture gradients in the early Holocene, and greater climate variability in the late Holocene. The role of human activity along this ecotone may also have been significant.

# Changes in forest cover, the southern westerlies, fire regimes, and human disturbance associated with the Little Ice Age in SW Patagonia (51°S), Chile

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Here we report a high-resolution pollen record spanning the last 1100 years obtained from Lago Eberhard (51°34'S, 72°40'W), a small closed-basin lake located in SW Patagonia, Chile. The record shows the continuous dominance of *Nothofagus* forests between 900-1890 AD under cool-wet conditions. Within this background, we identify a rise in *Nothofagus* and decline in grasses starting at 1400 AD, suggesting an increase in precipitation. An abrupt decline in forest vegetation occurred at 1890 AD, along with an increase in grasses, the exotic *Rumex*, and intense fire activity.

We interpret past variations in the percent abundance of the submerged aquatic plant *Myriophyllum* as indicative of past lake level fluctuations. Today *Myriophyllum* forms a dense cover near the littoral zone of Lago Eberhard. We infer that lake-level lowering associated with dry periods in the past, will drive expansions of *Myriophyllum* to the deep portions of the lake (and viceversa). The pollen record from Lago Eberhard shows important increases in *Myriophyllum* between 1150-1350 and 1890-2004 AD, and its absence in the intervening periods. Based on this data and their close agreement with variations in the upland vegetation (forest cover), we propose that increased precipitation of westerly origin during the Little Ice Age (LIA) drove a rise in lake level, expansion of *Nothofagus*, and a decline in fire activity in SW Patagonia. These conditions ended abruptly at the culmination of the LIA, accentuated by large-scale disturbance by means of fire, livestock grazing, and agriculture associated with the arrival of European settlers.

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## Climate change approach in the Colombian Caribbean since the Holocene

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The Colombian Caribbean coast encompasses an area of 194.513 km<sup>2</sup> and a shoreline about 1820 km long. Present vegetation cover reflects SW-NE climatic gradient characterized by tropical rain forest to the southern part and tropical dry forest and subtropical desert scrubland towards the north. Environmental history has recorded several changes since the early Holocene related to fluvio-marine dynamics, mainly flooding, sedimentation and erosion processes, and relative sea level changes, as a response not only to the global and regional climate changes, but also to local tectonic processes and anthropogenic disturbances.

Palynological records performed on coastal lagoon sediments have recorded lake formations and mangrove establishment since Holocene climatic optimum. Other records are showing recent sea level rise and inland mangrove colonization. Instrumental climate records evidence rainfall decreases during last 50 years at the northern zone, which has

affected extension, composition and productivity of the ecosystems. Stream flow monitoring in the Sinú delta has also shown Enso related variations and sea level rise during last 40 years.

In order to contribute to the knowledge of ecosystem alterations and its relation to present climate change, we are performing multi-proxy analysis at different scales and resolutions. Those analysis include proxies such as satellital images, microfossils, mainly pollen and foraminifera, corals, geochemical proxies and isotopic dating.

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## Vegetation, climate, and fire history in SW Patagonia over the last 3300 years

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In this study we address these fundamental questions: How did the southern edge of the westerly wind belt change during the last three millennia? Is there a discernable effect of these changes in the regional vegetation? Did these shifts in vegetation modulate the occurrence of natural (or human-induced) fires? Or viceversa? High-resolution pollen and charcoal records from Lago Guanaco (51°S, 71°W) afford a detailed account of changes in vegetation, climate, and fire regimes in SW Patagonia. The site is located in the centre of Torres del Paine National Park, close to the ecotone between *Nothofagus*-dominated forests and the Patagonian steppe. The geographic position and floristic composition of this vegetation boundary is largely controlled by precipitation of westerly origin that spills eastward over the Andean massif, along with local edaphic conditions and disturbance regimes. We identify two discrete pulses of arboreal expansion at 2800 and 600 yr BP which led to the establishment and persistence of woodland and forest communities, respectively. We interpret these data as indicating a stepwise encroachment and/or eastward shift of *Nothofagus*-dominated communities driven by increases in westerly precipitation. Superimposed upon this trend we observe a decrease in forest understorey herbs and an increase of open shrubland taxa between 1900-600 yr BP, suggestive of greater discontinuity/patchiness of the *Nothofagus*-dominated woodland. Dense *Nothofagus* forests dominated between 600-60 yr BP. This condition ended abruptly at the end of the 19<sup>th</sup> century through a nearly instantaneous transformation to grass-dominated communities, driven by the onset of large-scale disturbance by fire and overgrazing brought by European settlers.

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## South Atlantic island records show highly variable Holocene climate

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By studying terrestrial climate archives, such as peat and lake sediments, on islands it is possible to obtain well dated high-resolution paleoclimate records from locations where

otherwise only marine records are available. This is advantageous since it gives a direct atmospheric climate signal and allows for reliable radiocarbon dating, i.e. no reservoir effects. One of the main aims of the ATLANTIS-project is to correlate the late Quaternary climate history of Southern and Northern hemispheres in the Atlantic and adjacent areas along an island transect. Apart from Antarctic Peninsula sites, two sites are studied in the southern hemisphere: the Tristan da Cunha island group in the central South Atlantic, and Isla de los Estados in easternmost Tierra del Fuego. These studies are carried out with a multiproxy approach including pollen, diatom and geochemical analyses, paleomagnetic measurements, and detailed radiocarbon dating.

On Tristan da Cunha low lake-level with peat growth during the early Holocene indicates drier condition than at present. At 9500-9000 cal. yr BP lake levels rose and conditions became wetter and more variable, with recurring periods of high precipitation. These changes are possibly linked to regional and global circulation changes, such as the strength of the thermohaline circulation and position/strength of major circulation systems.

During field work in 2005 on Isla de los Estados several cores were collected, with almost complete Holocene coverage. Many of the records show large lithologic variability, and the results from these cores will be an important data set for future studies of north-south climate linkages and the role of the Atlantic for the Holocene climate development.

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## **Late Holocene Moisture Balance Variability Inferred from Stable Isotopes and Pollen, Southwest Patagonia, Chile**

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Here we present late Holocene lacustrine records of climate change related to westerly wind variability from southwest Patagonia, Chile. We focus on Lago Guanaco (51°S, 72°W), a small hydrologically closed-basin lake, and use stable isotope and pollen data from this site and three additional lakes in order to reconstruct changes in moisture balance related to the westerlies. Changes in moisture balance and forest density/proximity are primarily reflected in downcore variations in  $\delta^{18}\text{O}_{\text{bivalve}}$ , the *Nothofagus/Poaceae* paleovegetation index, and the C/N ratio of organic matter. These variables document changes in the isotopic composition of the lake water, which is strongly influenced by evaporation, as well as shifts in the forest/steppe ecotone during the last 1800 years. More negative isotopic values at ~1350 cal yr BP and at the onset of the Little Ice Age (LIA) at ~450 cal yr BP correspond to cooler and/or wetter conditions. Increases in C/N and paleovegetation index values culminate between 100 and 400 cal yr BP and are indicative of forest expansion and increased terrestrial organic matter input to the lake. Coincidentally, enrichment of  $\delta^{18}\text{O}_{\text{bivalve}}$  and  $\delta^{18}\text{O}_{\text{ostracode}}$  are indicative of increased evaporation during spring/summer months. Taken together, the data indicate that during peak LIA conditions, summer precipitation was reduced while annual moisture balance increased to allow for forest expansion. A poleward displacement of the southern margin of the westerlies can account for the observed change in the precipitation/evaporation regime.

## Variabilidad ambiental del Holoceno en regiones áridas y semiáridas del centro-oeste de Argentina

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La comprensión de la variabilidad natural del Holoceno radica en la resolución cronoestratigráfica y en la correlación de los eventos detectados en diferentes tipos de registros (vegas, secuencias aluviales y lacustres y sitios arqueológicos). La respuesta diferencial de los *proxies* (estratigrafía, sedimentología, polen, carbón vegetal, diatomeas, moluscos) es dependiente de la localización de los registros en los diferentes gradientes altitudinales y latitudinales. Los estudios multidisciplinarios realizados entre los 32°-38° S permiten discutir las hipótesis sobre los cambios climáticos del Holoceno medio y tardío. La variación regional de la vegetación, a escalas de centurias y milenios, evidencia el incremento de condiciones áridas desde *ca.* 9.500 <sup>14</sup>C años AP. Entre los *ca.* 5.000-6.000 <sup>14</sup>C años AP en alta montaña comienza la acumulación sedimentaria en los ambientes de vega actuales, se inicia la excavación en afluentes del curso medio del río Tunuyán y ocurren cambios en los niveles lacustres de Salina del Bebedero. Las asociaciones polínicas señalan vegetación Andina, del Monte y del Monte-Espinal y comunidades halófitas e hidrófitas que reflejan la dinámica de los sistemas fluvial y lacustre. En el último milenio se evidencian fluctuaciones en el transporte sedimentario y de las asociaciones polínicas en Precordillera y una degradación (excavación vertical) en la cuenca media de los ríos Tunuyán y del Atuel. La respuesta diferencial de los ambientes se discute en relación con las ocupaciones humanas.

Contribución a los Proyectos PIP 5819, UNMdP-EXA 275/03, 354/06, PICT03-04-14695, UNLPam 186

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## Late Holocene pollen records from Laguna Las Vizcachas and Laguna Chaltel (49°-51°S; 71°-72°W), Santa Cruz, Argentina

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The pollen records of two lakes from southern Patagonia were studied to provide new paleoenvironmental information within the multiproxy approach of the SALSA project. We analysed a 83 cm long core (VIZ 05/6) from Laguna Las Vizcachas (50°42,390'S; 71°58,640'W) which is located at 1100 m a.s.l. in Las Vizcachas plateau and surrounded by a grassland of *Festuca palleascens*. Three dates show a basal age of 1537 cal. yr. BP and the pollen spectra represent a grass steppe accompanied by *Nassauvia*, Asteraceae subfam. Asteroideae, *Empetrum* and *Acaena*. The other core (CHA 04/5) was recovered from the border of the maar Laguna Chaltel (49°57,650'S; 71°07,670'W), located in the Pampa Alta volcanic plateau at 800 m a.s.l. The area is covered by the *Nassauvia glomerulosa* semidesert and surrounded by the

*Verbena tridens* shrublands and the *Festuca pallescens* grasslands. The analysis was focused on a laminated section located from 69 to 104 cm depth, below an unconformity. Two dates show that the section encompasses from 3520 to 3955 cal. yr. BP and the pollen assemblage represents a grass steppe along with high diversity of other types as *Senecio*, *Ephedra frustillata*, *Nassauvia* and *Acaena*. In both records *Nothofagus dombeyi* type and the algae taxon *Botryococcus* are present with higher values in Las Vizcachas. *Pediastrum* was also found in these sequences with low proportion. The comparison with other records as Laguna Potrok Aike pointed out similar trends in the pollen spectra.

Contribution to de projects: UNMdP-EXA 275/03, 334/06; SALSA - BMBF 01 LD 0034/0035.

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## **Late Holocene quantitative paleoclimatic reconstruction from pollen records at Pampa grasslands**

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The Pampa grasslands are the most extensive region covered by grasses in Argentina (32° - 39° S). These grasslands represent one of the highest diversity grasslands in the world and their distribution is climatically determined. Nowadays, natural grasslands are partially substituted for agroecosystems since the region has an important economic value. Accurate reconstructions of late Holocene climate are needed to better understand the grasslands response to climate change. Using a calibration modern pollen-climate data set, two late Holocene fossil pollen records [Empalme Querandíes (EQ), in central Pampa grasslands and Sauce Chico (SCh), in the southwest boundary of Pampa grasslands] are interpreted in terms of mean annual precipitation (MAP) and annual humid index (AHI) by applying the modern analogue technique. During the last 3000 <sup>14</sup>C yrs B.P estimated MAP and IHA values in EQ showed fluctuations of ca. 100 mm around the modern values. Estimated MAP and IHA values in SCh showed fluctuations of high frequency (200 to 300 mm) between ca. 4500 and ca. 1500 <sup>14</sup>C years B.P. These values become higher than modern ones (up to 200 mm) between ca. 1500 and 1000 <sup>14</sup>C years B.P. and decreased (up to 100-150 mm) during the last ca. 500 <sup>14</sup>C years B.P. The reconstruction shows significant variability in the hydric regimen (MAP and AIH) during the late Holocene and the recent establishment of the modern climatic conditions. Further improvement of these quantitative reconstructions and an adequate chronological control for a meaningful correlation will allow testing the existence of a regional large-scale climatic variability.

Contributions to Projects CONICET PIP PIP5667 and UNMDP Exa 349/06

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## Vegetation and climatic history of the coast of central Chile over the last 3000 yr: The Laguna Matanzas record (~34°S)

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The transitional character of central Chilean climate and the influence of El Niño-Southern Oscillation (ENSO) make this a key region for monitoring past climatic changes. This area is, however, poorly known in terms of paleoclimate. Here, I report a pollen, microalgae and charcoal record from Laguna Matanzas (33°45-46 S; 71°40-42' W), a lagoon located on the coast of Central Chile, that documents high climatic variability over the last 3000 cal yr. High percentages of Gramineae and Cyperaceae, along with herbs and traces of arboreal taxa dominate the record between 3000 and 2800 cal yr B.P. An increase of the percentages of Chenopodiaceae and decline of Gramineae, suggest a decrease of precipitation between 2800 and 2500 cal yr B.P. An increase in precipitation is inferred based on a rise of arboreal elements, Gramineae, herbaceous and aquatics taxa between 2500-600 cal yr B.P. Large amplitude fluctuations of pollen, microalgae and charcoal accumulation rates during this lapse suggest high precipitation variability. The abrupt drop in accumulation rates value observed in all taxa, between 1300 and 600 yr cal. B.P., will be caused by high sediments variability and dunes formation events. At 600 yr cal, the increases of the arboreal and shrub taxa indicate the establishment of sclerophyllous coastal forest. Over the last 60 cal yr the sclerophyllous vegetation has been replaced by *Pinus* and *Eucalyptus* forests. The precipitation variability documented in this record is compatible with the idea that the mediterranean climate of central Chile during late Holocene has been modulated by ENSO.

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## Glacier records in South America during the past three millennia

### Identification to cryospheric geoindicators in the high mountains from NW of Argentine

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Geoindicators are measures (magnitudes, frequencies, rates and trends) of geological processes and phenomena that occur at or near the Earth's surface and subject to changes that are significant for understanding environmental change over periods of 100 years or less. The geoindicators concept can be applied to understanding past environmental changes. In the high mountain is recommendable identify cryospheric geoindicators related to snow cover, glaciers, permafrost and solifluction processes.

The mountain geomorphology in the high andean altitudinal belts from NW of Argentine preserved generally geocryogenic forms: Rock glaciers are detected at the Nevados of Acay, Chañi, Cachi and Santa Victoria Ranges. At the Aconquija, Quilmes and

Calchaquies Ranges recent fieldworks reveals abundance of active rock glaciers, indicators of discontinuous mountain permafrost, and associated suites the geoforms (talus, gelifluction, block fields, patterned ground and thermokarst fusion forms).

Cryospheric geoindicators have been identified that are applicable to monitoring and assessing geological changes in this mountain region. Examples of typical cryospheric geoindicators are given and briefly described.

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## Reconstrucción de sistemas paleo-glaciares de los Volcanes Villarrica y Mocho en la Región de Los Lagos, Chile

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Se presenta una propuesta metodológica para la reconstrucción de sistemas paleo-glaciares de los centros volcánicos Villarrica (39° 25' 12" S, 71° 56' 27" W, 2847 m.s.n.m.) y Mocho (39° 55' 48" S, 72° 01' 46" W, 2422 m.s.n.m.) de la Región de Los Lagos del sur de Chile. Las condiciones y características de esta región permiten el análisis de la respuesta glacial frente a los cambios climáticos tanto actuales como pasados y la influencia de la actividad volcánica sobre la dinámica glacial.

La reconstrucción de los sistemas glaciares se concentrará en las cuencas de los glaciares Pichillancahue-Turbio del Volcán Villarrica y Huilo-Huilo del Volcán Mocho, donde ya han sido descritos algunos de los sistemas morrénicos de la Glaciación Llanquihue (Última Glaciación). Se analizarán fotografías aéreas e imágenes satelitales Terra ASTER, con el fin de determinar otros sistemas morrénicos adyacentes a los volcanes. La determinación de la geomorfología glacial se completará con estudios de terreno, donde se observarán rasgos superficiales que indiquen la presencia de depósitos glaciares.

La determinación de la geomorfología glacial permitirá construir los perfiles glaciares sobre la base de la formulación propuesta por Nye (1952) y utilizada por diversos autores para la reconstrucción de sistemas glaciares y sus perfiles topográficos (Glasser y Jansson, 2005). La determinación de estos perfiles teóricos se corregirá con los espesores actuales calculados para ambos glaciares y con la resultante topografía subglacial.

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## Glacier fluctuations at Cerro Tupungato

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In the surroundings of Cerro Tupungato (6800 meters), Province of Mendoza, Argentina, there are ones of the main groups of glaciers at the mountain range of the Andes. As other glaciers in the world, these also have been submitted to climatic changes that have led to their regression since the beginning of the 20<sup>th</sup> century. The fact that glaciers have a big significance as water resources, even more for the oasis of Mendoza, justify to know how they have behaved in the last years studying their fluctuations. This study is based on interpretation of historical material from 1912, aerial photographs of 1962 and LANDSAT-5

satellite images from 1987 to 2005 that allow us to reconstruct the recent glacier fluctuations. These kinds of valley glaciers have a collective field of accumulation area with radial flow on the slope of the volcano Tupungato. Measures of their lengths and areas have been done to evaluate their behavior throughout the last century. A general retreat of these glaciers has been observed, although this regression is not very significant in the last years since glaciers present certain stability with few variations in their lengths and areas.

**Key words:** climatic change, glacier fluctuations, remote sensing.

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## **Delimitation of the geocryogenic processes and associated geomorphic belts in Los Alisos National Park, Tucumán.**

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The Los Alisos National Park is located in the Eastern slope of the Aconquija Range. It extends from the 874 to 5200 m a.s.l. and covering an approximated area of 10.000 hectares. Its more outstanding altitude is the C° de la Bolsa (5200 m a.s.l.).

Through the interpretation of satellite images and aerial photography and with the support of the field control the distribution of cryogenic geofoms was determined.

Within this belt two altitudinal levels could be differentiated: The *parageocryogenic zone* (paraperiglacial), from 2000 m to 4000 m a.s.l. This is the seasonal ground freezing area located below the lowest terminus of rock glaciers. The slopes in this zone are smooth and usually showing the action of needle ice and soil solifluction. The older morainic level occur in this region. The *geocryogenic zone* (periglacial) is located above 4000 m a.s.l. Its lowest limit is indicated by the lowest terminus of active rock glaciers. In this zone, the cryofragmentation and the criofluction processes prevail. The slopes are steep and it is characterized by the following geocryogenic features: block gelifluction, tongue gelifluction with vegetation or not, talus, active sorted patterned ground, unsorted patterned ground with vegetation, active rock glaciers and inactive rock glaciers. There are two levels of lateral moraines evidence of a holocene activity glacial. Active rock glaciers indicate high mountain permafrost.

The simultaneous coexistence of different ages and activity geofoms in the altitudinal belts reflects alternate paleoclimatic conditions, during the different phases from humidity and drying of the Holocene.

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# **Trends in historical and recent glacier variations in subtropical high mountain areas: Case examples from the Karakoram Mountains in regard to the glacier dynamics in the Aconcagua-Juncal Massifs (Andes)**

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The presentation focuses on the historical and recent glacier dynamics in the subtropical mountain range of the Karakoram on the base of field observations carried out in the period of 1992 – 2006 on over 40 glaciers. Moreover, historical documents, such as photographs and travel reports, as well as air and satellite images have been included in the compilation, in order to provide an overview on the trend of glacier dynamics in the 20<sup>th</sup> century. Further indicators for glacier fluctuations are the formation of ice-dammed lakes, which have been included in the study.

The Karakoram possess the longest valley glaciers outside of the polar regions reaching of up to 72 km in length. Even though a considerable part of the Karakoram glaciers have shown signs of glacier retreat, most of the longer glaciers (> 45 km), such as the Baltoro, Batura, Khurdopin glaciers have been almost stagnant in the last century. Even some of the clean-type glaciers (“Blankeisgletscher”), such as the Yazghil and the Barpu glaciers, did not retreat. However, many glaciers have mainly shrunk by downwasting rather than by ice-frontal recession. At the same time a lot of glaciers, in particular the purely avalanche-fed glaciers, have shown considerably high amounts of vertical changes of the glacier surface. The Karakoram glaciers are accompanied by lateral moraine complexes over several decakilometers in length. Therefore observations from the lateroglacial environments and their morphodynamic will be presented. The Great Lateral Moraine (GLM), mainly attributed to the Little Ice Age, is even today overtopped by glacier thickening in the middle and lower parts of the glaciers.

The Karakoram is well known for glacier surges, such as the Hassanabad and Kutiah glaciers, which supposed to have advanced about 10 km in only a few months in historical and recent times. In the last decade (1990s), glacier advances have as well been reported from this mountain area. Such catastrophic advances have been mainly confined to medium sized glaciers. However, it must be considered that sudden advances of tributary glaciers have another genetic background than surges of trunk glacier tongues.

Glacier fluctuations have received increasingly more attention using them as indicators for climate change. The reactions of the individual glaciers on climate change in the 20<sup>th</sup> century differ considerably in respect to time-scale. In the whole, the dynamic of the Karakoram glaciers proves to be rather different from the neighbouring mountain ranges, such as the Pamir, Himalayas and Tienshan, which are characterized by a general glacier retreat. It might be assumed that especially the longer Karakoram glaciers will react delayed to a global temperature warming. Moreover, topographical factors play a major role in glacier fluctuations. Therefore advancing and retreating glaciers occur in adjacent valleys – a phenomenon which is also rather common in other mountain ranges. Regularly observations on individual glaciers are still not available for the Karakoram and especially the surging glaciers have been mostly visited only once. However, some of the more obvious glacier dynamics is not climatic-controlled but rather a result of the individual topographical setting of the glacial catchment areas. Therefore it needs a careful selection of glaciers when using glaciers as climatic indicators. The glaciers of the Aconcagua and Juncal Massifs in the Andes show partly similar glacier types to those of the Karakoram, even though their spatial extent

is much lower than in the Karakoram. Glacier dynamics in reaction to climatic change shall be discussed in the light of an interhemispherical comparison.

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## Rock glaciers in the Río Cerrillos basin, Catamarca province

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The Río Cerrillos Basin is located in the west slope of Aconquija Range. The study area covers 29.57 km<sup>2</sup> with SE- NW runoff trend. It contains six sub-basins, showing asymmetrical slopes, talus accumulation, rock glaciers and lateral moraines. The greatest altitudes come up to 5200 m. A.S.L. (C° Tipillas) and 5500 m. A.S.L. (C° Chimberí, C° del Bolsón). The interesting area has a semi-arid climate, with precipitations lower than 200mm, and an annual average of temperature under 8° C. Through the interpretation of aerial photographs and satellite images we were made the inventory of macroforms and a detail map. There was identified 19 rock glaciers, covering 1,11 km<sup>2</sup> of the basin area. These active forms are indicators of mountain permafrost.

Following the genetic classification of Corte, only one type of primary or talus rock glacier has been identified: 14 active rock glaciers shows upper 30° slopes, flow lines and movement marks. The average of active front altitude is 4500 m. A.S.L., covering an area of 0.90 km<sup>2</sup>.

Since an average of 4100 m. A.S.L. at two central basins there are 5 secondary or glacial origin rock glaciers. There are connected to a lateral moraines system (since 4000 m. A.S.L.), evidence of a former holocene glacial activity. Its area covers 0.21 km<sup>2</sup>.

The rock glaciers in the Río Cerrillos basin shows seven classes of exposure, the SW class (26.31 %) includes the most important geoforms concentration.

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## Registros históricos sobre el avance del glaciar San Rafael (Patagonia septentrional): Otra huella de la Pequeña Edad del Hielo en Chile?

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A partir de fuentes históricas documentales que datan desde mediados del siglo XVII a inicios del siglo XX, escritas por exploradores españoles y luego por chilenos, que visitaron la laguna San Rafael, se describe el comportamiento pasado del glaciar San Rafael. La evidencia histórica muestra claramente un pulso de enfriamiento en la zona, que generó un avance del glaciar. El registro indica condiciones cálidas para 1675, quizás similares a las actuales, donde el glaciar no penetraba al interior de la laguna. Posteriormente, durante el siglo XIX, se habría producido un notorio avance del glaciar hacia el interior de la laguna, el que se

hace evidente en el año 1875. En 1904 se reconoce un leve retroceso del glaciar respecto de las condiciones existentes 29 años atrás. El período de enfriamiento antes mencionado, estaría dentro de la ventana temporal de la ocurrencia de la Pequeña Edad de Hielo en Europa, de esta manera las fuentes históricas confirmarían, de forma independiente, la manifestación de este fenómeno en el sur de Chile.

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## **Late Quaternary glacial chronologies in the Chilean and Argentinean Andes (30-40°S) based on Surface Exposure Dating**

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The Chilean and Argentinean Andes from 30-40°S are a key area for a better understanding of the climate system, because they mark the transition zone between the moisture-bearing westerlies to the south and the 'Arid Diagonal' to the north. Late Quaternary changes in the latitudinal position or the intensity of the westerlies should therefore be sensitively recorded in suitable paleoclimate archives.

We apply surface exposure dating on moraines along a N-S transect in order to determine timing and extent of the last glaciation: First exposure ages from ~30°S show that glaciers reached maximum extents during the Lateglacial (14-12 ka BP) and at ~30 ka BP (Zech et al. 2006, *Palaeo3* 234 (2-4): 277-286; Zech et al., submitted). The lateglacial advances correlate with corresponding events on the Altiplano (glacial advances and lake transgression phases) and in SE-Brazil (e.g. speleothem data), indicating the southward influence of the intensified tropical circulation. So far, we could not date lateglacial moraines south of ~30°S, whereas the maximum ice extent at ~39°S is also documented by moraines dated to 30 ka BP. We tentatively infer that the moisture source at 30 ka BP was mainly the westerlies. They seem to have provided more moisture than during the global temperature minimum at ~20 ka BP.

Within the ongoing research we try to (i) extend the glacial chronologies spatially, (ii) refine the chronologies temporally and (iii) to quantify the paleoclimatic conditions (temperature versus precipitation).

### Transporte eólico de partículas en Mejillones, Chile (~23°S) e implicancias paleoceanográficas

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En la península de Mejillones (~23°S) vientos predominantes del S-SW transportan partículas líticas hacia el norte y generan surgencia en Punta Angamos, favoreciendo altas tasas de producción primaria en bahía Mejillones. Así, sedimentos laminados líticos y biogénicos en fondo de la bahía permiten reconstrucciones paleoceanográficas de alta resolución.

Mediante perfiles verticales de viento en Pampa Mejillones se determinó la velocidad de fricción ( $u^*$ ) y el parámetro de rugosidad ( $z_0$ ). Mediciones continuas de viento permitieron estimar la variabilidad de  $u^*$  y de un índice de surgencia. El flujo eólico horizontal de partículas (G) se determinó mediante sistemas captoreadores de polvo.

El viento a 4 m de altura en la estación Orica presenta un ciclo anual influenciado por el anticiclón subtropical y el gradiente termal tierra-mar, generándose velocidades máximas durante primavera y verano. El  $z_0$  calculado (~10<sup>-5</sup> m) resultó inferior al esperado, explicándose por la extrema planicie de la pampa.

Los valores máximos de  $u^*$  preceden a los de G. Este desfase indicaría una preparación previa del suelo durante periodos con  $u^* > 0.5$  m/s, que favorecería la erosión y el transporte en los periodos siguientes.

La utilización de partículas líticas en el sedimento marino potencia reconstrucciones cuantitativas del viento favorable a la surgencia a escalas decadal a milenaria, habiéndose así inferido un incremento de la intensidad del viento en la zona a partir del último siglo.

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### Lichenometry in the Patagonian Andes: A study of *Rhizocarpon geographicum* growth rates in relation to climatic variations.

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Although lichenometry has a large potential for dating glacier fluctuations during recent centuries, it has rarely been used in the Patagonian Andes. We evaluate the usefulness of *Rhizocarpon geographicum* for dating glacier deposits based on the development of lichenometric growth curves. Five glacier forelands, two in the north (41° S) and three in the south (49° S) sectors, were investigated along the Patagonian Andes. Lichen diameters were measured in surfaces previously dated using historical photographs and tree-ring methods. *R. geographicum* growth rates range between 0.09 and 0.56 mm yr<sup>-1</sup>. Growth rates are significantly higher in wetter than in drier sites. Rates of growth generally reflect the steep west-east gradient in precipitation across the Andes. Logarithmic and linear growth curve

models were identified. The logarithmic model better fits the growth rates in wetter sites, whereas the linear model does in drier sites. We conclude that *R. geographicum* growth is affected in larger degree by moisture conditions (as related to the precipitation gradient) than by latitudinal differences. To increase our confidence in the use of lichenometry across the Patagonian Andes, more glacier forelands will be surveyed and additional control points with well-documented ages identified.

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## Southwestern-South Atlantic Paleoclimate Reconstruction by Geochemistry and Sclerochronology of Brazilian Corals

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It is acceptable that physical and chemical changes in the marine environment, induced by ocean-atmospheric processes, can be imprinted in massive coral skeletons. Interannual variations of sea surface temperature (SST), salinity and sediment apportionment are recorded in the high and low density bands of coral growth skeleton. The use of spectral analyses as the Morlet wavelet decomposition and the iterative regression applied to Southwestern-South Atlantic coral growth and to climatic parameters (SST, air temperature, precipitation, SOI and solar irradiation) indicate a significant inverse relationship between SOI and coral growth at the 4 yr – 8 yr frequency band. These results suggest that annually produced coral growth bands are affected by El Niño and La Niña events through their climate teleconnections in the South Atlantic continental region. In addition, for the long-term variation (8 yr – 11 yr frequency band), solar irradiance together with air temperature and precipitation were significantly correlated to coral growth. At present time, a drilling program is being conducted at the Brazilian coast (from the latitude 03°51'S - 22°44'S) which aims at searching evidences of long-term associations between the coral sclerochronology and geochemistry with respect to climate parameters, along the mid-Holocene.

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## Landslides: a climate change signal in the Central Andes

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Even though landslides can be related to shaking movements in seismic areas, they have been widely linked to climate forcing. Their relation with extraordinary climate phenomena such as El Niño has been broadly referred for different regions around the world as well. Hence, frequency and activity grade of landslides generated by rainstorms constitute good proxies for climate change.

Along the Mendoza river (32°S), in the Central Andes, summer rainstorms are a major factor for landslide distribution. The recurrence of rockfall and debris flows, varying from months to years in different places, is boosting due to climate change related to both



precipitation and temperature increase in the Andes ranges. Greater water availability as consequence of the rapid snow thawing caused by higher temperatures, and intense rainfalls favour hillslope instability in this arid region. So, landslide frequency has been growing during the last three decades. Moreover, landslide frequency increases during ENSO warm episodes associated with increased precipitation, both greater snow accumulation during winter, as well as intense summer rainstorms are recorded in these periods.

As a consequence of global climate change, we suspect that landslide frequency may be higher in the future. These findings evidencing a greater potential landslide hazard regard to economical impact on our regional economy as an international road connecting Mendoza with Santiago de Chile is settled along the Mendoza river where more than 300 thousands vehicles are moving per year.

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## South Atlantic Changes in Precipitation during the Mid-Holocene

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The Mid-Holocene (6000 years ago - 6K) is a period characterized by variations in the earth's orbital parameters, leading to a climate very different than today's. It is known for the different seasonal and latitudinal distribution of incoming solar radiation at the top of earth's atmosphere as compared to the present day. In order to investigate the differences in rainfall between the two periods for the South Atlantic Region, two very different numerical models are used. They are i) National Center for Atmospheric Research Community Climate System Model (NCAR CCSM, version 3) and ii) Institut Pierre Saint-Laplace General Circulation Model (IPSL GCM) Results show that the major differences in precipitation are confined south of the equator. Differences in the annual averaged precipitation decrease over the Amazon region and increase over the adjacent ocean. Higher rainfall values in the mid-Holocene can be noticed over the South Atlantic in both models results. The results suggests that during this period the Intertropical Convergence Zone (ITCZ) remained in the Southern Hemisphere longer than during the present, mainly within the CCSM3 results. Over the South American continent conditions were dryer in the mid-Holocene when compared to the present (approximately 0.3mm/day). With respect to the seasonal climatology, the main differences in precipitation is observed during summer for both models results. Precipitation shows positive values (about 0.8 mm/day) over the ocean during the mid-Holocene summer. The Intertropical Convergence Zone is displaced further south in this period.

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## **Paleoenvironmental reconstruction of the Payenia and Laguna Llanquanelo Natural Reserves, Mendoza, Argentina: Paleovolcanism and Paleolimnology**

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The region of Payenia and Laguna Llanquanelo Natural Reserves evolved during the Holocene mainly in response to volcanic and climatic forcings. These two aspects have interacted conditioning biodiversity, human settlement and land use.

Climatic characteristics are complex due to interaction among the climates of southwestern Pampas, northwestern Patagonia and the Andes. Following the Last Glacial Maximum, climatic fluctuations were significant, particularly in the late Holocene when alternating cold (Neoglacial) and warm periods occurred accompanied by changes in the rains and winds patterns as well as in fluvial and glacial dynamics.

Volcanism was an important factor since pre-Holocene times, participating in the modelling of the landscape by producing extensive lava flows, hundreds of monogenic cones, fields of pyroclastic ejecta and other pyroclastic features. Some field evidences reflect the wind dynamics during volcanic eruptions and are important for understanding climate-volcanism interaction.

A research project aimed at reconstructing the regional paleoenvironmental evolution is presently being planned. The objective is to understand the geological and climatic processes that intervened in the late Holocene history. Volcanic, climatic, environmental, limnological and pedological studies are some aspects to be studied in surface and subsurface volcanic and sedimentary sequences.

Geophysical surveys will be performed in order to obtain subsurface structural characteristics and rocks-sediments properties as well as to determine the thickest sedimentary sequences suitable for drilling and recovering of continuous sedimentary columns. Once the sedimentary cores were obtained, proxies such as sedimentology, petrography, biostratigraphy, geochemistry and geochronology will be used for reconstructing paleoenvironmental, volcanic and climatic aspects.

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### **Paleoenvironments of the Holocene deposits of Cortaderas (Argentina): Malacological assemblages**

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Terrestrial mollusk fauna are very good indices of past continental environments. Their study is particularly poorly developed in Argentina. Thus the proposed study aims to be a case study for further investigations in South America. Doing so, the Holocene site of Cortaderas yielded a sedimentary record indicating the alternation between fluvial loams and paleosols. The sediment was sampled for the mollusk content and shows terrestrial and fresh water species. Their analysis indicates, through the biological successions, the record of

environmental variations and their correlation with more general climatic events occurring at the same time. The comparison between the mollusk record and other studies performed in the studied area supports the interpretation proposed in term of paleoenvironment and paleoclimate, especially precipitation. Considering the modern interference of climatic factors, this study supports the proposal of isohyets displacements in relation to the displacement of Convergence Intertropical's Zone (ITZC), as responsible for the variation of precipitations.

*Key words:* continental mollusks, paleoenvironments, paleoclimate variations, precipitation regime, Holocene.

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## **Eolian events in Médanos Grandes dune field (San Juan province) during the late Holocene**

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Although eolian sand is ubiquitous in western intermontane valleys of Argentina, reflecting significant climate variability in the Late Quaternary and Holocene, this record has not yet adequately deciphered. A first dating of eolian sand in Médanos Grandes dune field (MG) have allowed obtaining several ages from the last 2200 yrs. MG dune field, located to the south of San Juan province, is one of the largest and tallest intermountain eolian system in Argentina. It is placed in one of the driest region of Argentina, with a mean annual precipitation of 88.3 mm/yr and >80% of the precipitation occurring between October and March (1901-1990) and where austral summer temperatures can often exceed 40°C. The resultant drift potential are due north at 352°, characterized by low energy winds. MG dune field is formed by a complex dune-field pattern pointing out the superimposition of different dune types due to several episodes of eolian construction/reactivation. At Lizard section (31° 41,957' S; 68° 9,76' W), to the northwest of MG dune field, eolian units cover alluvial gravel and are represented by sand sheet deposits. OSL ages for quartz extracts from that eolian sands indicate depositional ages of 2070 ± 150, 600 ± 40, 400 ± 45 and 410 ± 40 yrs BP.

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## **Identifying key tephra layers for paleoclimate reconstructions in Northern Patagonia.**

**Gustavo Villarosa and Valeria Outes**

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Several studies based on lacustrine records provide detailed Postglacial paleoclimate reconstructions for Northern Patagonia. Recent evidence of a cool episode occurred during the Late-Glacial, between 11,400 and 10,200 <sup>14</sup>C yr BP was provided by Ariztegui et al., 1997, Hajdas et al., 2003, Whitlock et al., 2006. This event has been associated to the Younger Dryas and Gerzensee/Killarney oscillation identified in the northern hemisphere. Tephra derived

from explosive eruptions of Andean volcanoes can provide precise chronologies and reliable stratigraphic markers allowing correlation and dating of this and other climatic events in records from both sides of the Andes.

Five well-defined macroscopic tephra layers identified in Lake Mascardi deposited during the Huelmo/Mascardi Cold Reversal (Hajdas et al., 2003) are considered good regional markers to trace this episode. Their glass separates have been characterized using major, trace and rare earth elements geochemistry and pyroclasts morphology. They range in composition from basaltic andesite to dacite.

Dating of these tephras is based on a refined AMS chronological model (Hajdas et al., 2003). MT10-7 layer (9,900 <sup>14</sup>C yr BP) presents a characteristic bimodal glass composition: a dark grey andesitic fraction and an olive grey dacitic population. Pyroclastic layers with similar petrographic characteristics have been identified in several lakes of the Chilean Lake District, their possible correlation is being studied.

A conspicuous white tephra layer was deposited at 8600 <sup>14</sup>C yr BP, after the culmination of this cold period. Another thick white dacitic lapilli layer marks the beginning of the Late Holocene in Lake Mascardi record at 4,400 <sup>14</sup>C yr BP. These markers can be traced along the northern Nahuel Huapi area.

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## **Past and present atmospheric circulation: Understanding the spatial and temporal fluxes variation and provenance of dust in southern South America**

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We operate a network of five dust sampling station along the Patagonian coast (Trelew, San Julián and Río Grande, 43°S-54°S) and at Central Argentina (Marcos Juárez and Bahía Blanca, 33°S-39°S). Additionally, we collected top soils samples from the three most important dust sources in southern South America (SSA). The main objective is to characterize the dynamic of vertical and horizontal fluxes and determine the different sources of dust transported in the region. The dust samples from the different sampling sites and samples from the potential sources areas are being characterized by different methods: e.g., grain-sized and mineralogical analyses (X-ray diffraction and SEM), chemical measurements (major, trace elements/ REEs) and isotopic composition (Sr, Nd and Pb).

Preliminary results indicate seasonal variation and clear latitudinal difference of dust fluxes. The highest mean vertical dust fluxes are observed at the northern sampling stations according to increasing precipitations. On the contrary, the highest mean annual horizontal dust fluxes are recorded in the Patagonian region in agreement with persistent and higher wind velocities.

The mineralogical, chemical and isotopic composition of dust samples from the different sampling sites are heterogeneous and point to different regional provenance. By comparing this information with similar data determined at the different present dust sources in SSA it allows to estimate present and past atmospheric circulation and climatic changes (increase/decrease aridity) across the region.

### Cambios climáticos y poblamiento humano en el Holoceno tardío de Patagonia Austral

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La Patagonia Austral se caracteriza por ser un ambiente mayoritariamente semidesértico, en el cual se produjeron importantes variaciones climáticas a lo largo del Holoceno (Stine y Stine 1990, González 1994). En investigaciones que se vienen llevando a cabo desde hace varios años en la región de los lagos Cardiel/Strobel, Posadas/Salitroso, Belgrano/Burmeister y San Martín/Tar (entre otros Goñi *et al.* 2000 -2002 y 1999, Goñi y Barrientos 2004, Aschero *et al.* 2005), se han marcado relaciones consistentes entre el poblamiento humano en el pasado y tales cambios climáticos. En este trabajo se focalizará la atención en los últimos 2500 años, durante los cuales se produjeron fuertes descensos de la humedad ambiental a nivel regional (Stine 1994). En tal sentido, estas desecaciones habrían afectado notablemente la movilidad de las poblaciones humanas, generando un nuevo escenario social. La denominada Anomalía Climática Medieval (Stine 2000), fenómeno climático de escala global, cobra especial importancia para el estudio de la región bajo análisis. Entonces, se presentarán los resultados obtenidos en las investigaciones de estos diferentes sectores del extremo sur, a los fines de discutir cómo desde la arqueología es posible también discutir fenómenos climáticos y ambientales de escala amplia, dado que los mismos conforman el escenario en el cual se desarrollaron las sociedades cazadoras en el pasado.

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### Contributions to the paleoenvironmental studies of southern Mendoza: Archaeological perspective

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Archaeological record constitutes a valid approach to understand the relationships between humans and environment. It not only constitutes a paleoecological record because of the biological evidences associated to human occupations but due to the fact that humans themselves are significant components of past ecosystems. Human paleoecology allows to explore the variability of the archaeological record in terms of human strategies as well as to offer perspectives for the understanding of past evolutionary processes.

Results of archaeological research guided by this perspective are presented. This studies involved research lines in: zoo-archaeology, taphonomy, archaeobotanic, bioanthropology, and geoarchaeology.

It is showed a synthesis with the <sup>14</sup>C trend related to archaeological record from Mendoza. Aspects of human biogeography and settlement in different environments since 12.000 years BP are introduced. Information on the environmental setting and expected human strategies is discussed.

Human adaptations to arid-semiarid high cordillera and lowland plain regions of southern Mendoza, and their relationships with environmental changes in the last 1000 years are especially developed. The selected sites to illustrate land use and natural resource management by prehistoric societies are from Diamante lagoon, Atuel river valley, Llacanelo lagoon and Payunia.

Considering their archaeological record, intensification strategies (greater foraging efficiency in response to resource scarcity) and exchange with societies from the other side of cordillera are discussed. Cases of environmental information recovered (volcanic, archaeobotanic and faunistic record, pollen, etc) are presented. Understand human occupations imply the comprehension of making decisions within a particular environmental context and improve the knowledge about past human impact on regional ecosystems.

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## **Geomorfología Dinámica Holocena y Contexto Climático durante la Ocupación del Sitio Arqueológico Temprano Santa Julia, Los Vilos**

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Este trabajo trata del contexto climático y fisiográfico en que se desarrollaron ocupaciones humanas en Los Vilos, Norte Chico de Chile, desde el Pleistoceno tardío hasta tiempos históricos.

La distribución altimétrica de tres terrazas de abrasión marina alzadas, probablemente durante el Pleistoceno, sugieren una configuración espacial similar a la actual.

Dos plataformas marinas, una a  $-130 \pm 10$  m b.n.m. y otra a  $-50 \pm 10$  m b.n.m., indican que el nivel del mar, según datos globales, estuvo a esas profundidades durante el Último Máximo Glacial (LGM) y hace 10 mil años atrás, respectivamente.

Edades <sup>14</sup>C de sitios arqueológicos asociados a cinco sistemas dunarios muestran que hubo vientos intensos desde el SW y suficiente disponibilidad de arena en una plataforma marina expuesta durante el LGM, hace 16 mil, 11 mil y 7.500 años cal. A.P.

Tres terrazas aluviales fueron depositadas en la quebrada Mal Paso. La más antigua habría sido generada producto del bloqueo de la escorrentía hace 16 mil años y está constituida por la Unidad Turbas de Santa Julia, cuya base corresponde al nivel arqueológico paleoindio Santa Julia datado en 12.900 años cal. A.P., y por la Unidad Aluvial Santa Julia. Éstas unidades sugieren: escasas a débiles precipitaciones entre los 12.900 y 4.560 años, y lluvias torrenciales entre los 4.560 y 2.700 años. El desbloqueo e incisión final de la quebrada más la generación de dos terrazas aluviales encajadas constituidas por bloques posiblemente evidencia una intensificación de las lluvias torrenciales a partir de los últimos 2.700 años.

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## Humidity changes in the Northern Atacama around Palpa-Nasca (14°30'S) during the Holocene

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Today the Atacama desert is one of the driest places on earth. However, in the study area around Palpa and Nasca, South Peru (75-76°W, 14-15°S), palaeoclimate proxies show several semi-arid phases throughout the Holocene:

- A more humid period during the early Holocene favoured an open grass land, which allowed the accumulation of desert loess (Eitel et al., 2005).
- The Paracas and Nasca cultures existing in that region between the 9<sup>th</sup> century BC and 7<sup>th</sup> century AD had propitious conditions to evolve and to settle close to the rivers fed by the monsoonal precipitation in the Cordillera Occidental.
- Culminating aridity after 600 AD might have caused the collapse of the Nasca civilisation.
- The onset of semi-arid climate towards the end of the Late Intermediate period (~ 14<sup>th</sup> century AD), allowed a reoccupation of the area.

Here we present <sup>14</sup>C-data (a) from loess snails (*Scutalus sp.*) found at the loess basis, indicating an onset of the loess sedimentation between 13.4 and 11.2 ka cal BP; (b) from sediments of river terraces, a debris-flow and again loess snails (*Scutalus sp.*), indicating appreciable geomorphic activity between 1390 and 1714 cal AD. This latter phase is isochronous to the Little Ice Age period on the northern hemisphere and to an increase in the ice accumulation on the Quelccaya glacier in the Peruvian Altiplano (Thompson et al., 1985; Unkel et al., 2006, submitted). A comparison to the El Niño record of Rein and colleagues (2004) offshore Peru is also discussed.

## Multi-proxy reconstructions and climate modeling

### Climatic change of the Argentina in the last 1000 years: A multiproxy analysis

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The periods of great solar activity coincide with a minimum flow of galactic cosmic rays (GCR), while those of minimum solar activity generate a maximum flow of GCR. An analogy between these periods and such events as the Medieval Thermal Maximum (MTM, 800-1200 AD), and the Little Ice Age (LIA, 1550-1900 AD) is proposed. During these periods, anomalies are generated in the precipitations and temperatures in different regions of the southern South America that include modifications in the seasonal patterns. These modifications are reflected in the distributions of the mammals and other faunal elements in the late Holocene. The MTM determined the extension of the distribution range of chacoan micromammals into the east of the pampean region (i.e.: *Desmodus* sp., *Pseudorizomys waurini*, *Bibimys chacoensis* in Buenos Aires Province); outside of it, stenoid mammals are recorded in the central counties of Argentina (*Cavia aperea*, *Myocastor coypus* in Santiago del Estero Province), and an important pedogenetic event is verified in Patagonia. In the south of the Mesopotamia, for the same lapse a period of aridity is observed (an assemblage of terrestrial gastropods near Diamante city, Entre Ríos Province). The LIA was manifested during the XVIII and XIX centuries by a strong aridity. Central and patagonian mammals are recorded at this moment in areas currently above 900 mm of middle annual precipitation



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