PAGES & INQUA-sponsored workshop

Millennial-scale climate variability over the last glacial period in tropical and subtropical America

Universidad de los Andes
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The LaACER initiative – objectives

Dunia H. Urrego

Abstract. The main objective of LaACER is to improve our understanding of millennial-scale climate variability over the last glacial period in tropical and subtropical America, integrating both paleodata and models. LaACER stands for Latino-American ACER (Abrupt Climate Changes and Environmental Responses) and is a newly formed subgroup of the INQUA International Focus Group (IFG) **ACER**.

The ACER IFG has made considerable advances in our understanding of millennial-scale climate variability and environmental responses (e.g. Quaternary Science Reviews vol 29, Special Issue: Vegetation Response to Millennial-scale Variability during the Last Glacial, 2010). However, the ACER global synthesis also left clear that tropical records are scarce at the resolution and span necessary to express millennial-scale climate variability. Hence, whether or not rapid events, such as Dansgaard-Oeschger warmings, Heinrich stadials and the Younger Dryas, have a signature and produce an environmental response in tropical regions remains unclear. The LaACER initiative aims to bring together Latino-American and other international scientists to discuss millennial-scale variability in tropical and subtropical America.

This first LaACER workshop aims to spark the initiative by bringing together leading experts on tropical south American climate variability. Participants will present their work on millennial-scale climate variability from ocean and terrestrial archives, as well as from model simulations. Particiants will also engage in interesting discussions about ways to move forward.

Regional signature of Daasgard-Oeschger in western Europe and the ACER initiative

Maria Fernanda Sanchez Goñi,

Abstract: Marine pollen records from the western European margin covering the Last Glacial (MIS 4, 3 and 2) indicate that there is no lag between the change in climate forcing and the vegetation response, within the limits of the dating resolution (~100 years). In general, cold SSTs characteristic of Greenland stadials were contemporaneous with the expansion of semi-desert or steppic vegetation while Greenland interstadials were synchronous with the expansion of forest. Our

data reveal that the amplitude of Atlantic and Mediterranean forest expansions differs for any given D–O warming during the glacial period (74–18 ka). In the western Mediterranean, D–O 16–17 and D–O 8 and 7 (corresponding to minima in precession) were associated with strong expansion of forest cover contrasting with weak expansion of forest cover during D–O 14 and 12; the opposite pattern is revealed at the Atlantic sites. These observations indicate that the magnitude of the change in vegetation is regionally specific and is not a simple function of either the magnitude or the duration of the change in climate as registered in Greenland ice cores. At a global scale and in the framework of the INQUA International Focus Group (IFG) ACER (Abrupt Climate Changes and Environmental Responses) we have compiled more than ninety high resolution (<1000 years/sample) marine and terrestrial pollen records covering the Last Glacial. Analyses of these data show that there is a strong response to both D-O warming events and subsequent cooling, most marked in the northern extratropics but also present in the southern hemisphere. The data show the largest changes in vegetation downstream of the North Atlantic in Europe, with more muted responses over Asia and eastern North America, and into the tropics. Unfortunately, large parts of South America, Africa and Asia are represented by very little number of records.

Modeling

The NADW in the South Atlantic since the Last Glacial Maximum - links to MWP-1A
Juliana Marson

Abstract: The location of the meltwater pulse 1A (MWP-1A), which occurred at about 14,000 years ago, is still controversial. Many recent studies have pointed out that Antarctic ice sheet has probably been the major source of this pulse. Nevertheless, many times the climate effects of a freshwater input from the Southern Ocean have been ignored or neglected. Here, we use outputs of the NCAR-CCSM3 transient simulation to analyze the impacts of the Antarctic MWP-1A on Atlantic Ocean's thermohaline structure. The results point to a crucial role of the Southern Ocean meltwater in the set-up of modern North Atlantic Deep Water thermohaline structure through the break-up of a salinity barrier at intermediate depths.

Paleoceanography/Geochemistry

Where has all the heat gone? Millennial-scale variability of the Brazil/North Brazil Currents during the last glacial
Chiessi, C.M., Mulitza, S., Silva, J.B., Arz, H.W., Duleba, W.

Abstract: Glacial millennial-scale weakening events of the Atlantic meridional overturning circulation (AMOC) are supposedly associated with major changes in the surface hydrography of the western South Atlantic, i.e., in the Brazil/North Brazil Currents. It was suggested that the Brazil Current would strengthens (weakens) and the North Brazil Current would weakens (strengthens) during slowdown (speed-up) events of the AMOC. This antiphase pattern was claimed to be a necessary response to the decreased North Atlantic heat piracy during periods of weak AMOC. Part of the heat not transported to the Northern Hemisphere by the North Brazil Current would be shunted southward into higher latitudes of the Southern Hemisphere via the Brazil Current under a stalled AMOC. Nevertheless, a direct sea-surface temperature comparison of the Brazil/North Brazil Currents was not possible so far, mainly due to the lack of high temporal resolution records from the Brazil Current. In our presentation we will show the first high temporal resolution (i.e., 60 years between adjacent samples) sea-surface temperature record covering the last glacial from the Brazil

Current and critically compare it to available paleoceanographic records from the Atlantic Ocean and paleoclimatic records from South America.

Atmospheric Teleconnections between the Intertropical Convergence Zone and Southern Westerly Wind belt during the last termination: a model data comparison
Vincent Montade, Masa Kageyema, Nathalie Combourieu-Nebout, Marie-Pierre Ledru, Elisabeth Michel, Giuseppe Siani, Catherine Kissel

Abstract: Since the Southern Westerly Wind belt (SWW) were proposed by climate simulation as one of the main factor controlling atmospheric CO2 degassing through westerlies-driven upwelling in the Southern Ocean during glacial-interglacial transitions, the link between SWW belt and atmospheric CO2 changes have been the topic of intensive researches. Recent study have hypothesized that North Atlantic cooling at the onset of the last deglaciation triggered Southern Westerly Wind belt (SWW) southward shift via an atmospheric teleconnection resulting from a southward shift of the Intertropical Convergence Zone (ITCZ). Is this mechanism was active throughout the last deglaciation? Our records are sensitive to ITCZ changes from northeastern Brazil and SWW belt changes from southwestern Chile and illustrate a strong influence of the ITCZ during abrupt climatic events such as the Antarctic Cold Reversal or the Yonger Dryas. This view is supported by general circulation model experiments in which a fresh water flux is imposed in the North Atlantic to force fluctuations of the Atlantic Meridional Overturning Circulation. We propose that the Atlantic Meridional Overturning Circulation represent the main climatic factor triggering this atmospheric teleconnection throughout the last deglaciation.

Late Quaternary paleohydrological changes in arid Mexico in time and space: teleconnections and possible forcing mechanisms
Priyadarsi Roy, David Quiroz, Claudia Chavez, Rufino Lozano, Nayeli López, Socorro Lozano, Ligia Pérez

Abstract: The arid northern Mexico belongs to the Sonora and Chihuahua Deserts and forms the southern part of the North American Desert system. The multi-proxy data from lacustrine deposits present between 24° N and 31° N (paleolakes Santiaguillo, Babicora and San Felipe) provide spatio-temporal and millennial-scale paleohydrological records over the last glacial period related to the dynamics of summer precipitation (NAM?) as well as westerly winter storms. The inverse relationship between the proxy records of runoff into Babicora and winter precipitation over the southwestern USA indicate the westerly winter storms had minimal influence at 29° N and the paleohydrological changes are mainly summer precipitation controlled. During the cold stadials, the westerly winds transported minimally chemically altered sediments from the dry watershed and the basin received more than average runoff during the warm interstadials. High-resolution geochemical proxies suggest lower than average runoff and higher than average lake water salinity during the Younger Dryas and Heinrich events 1, 2 and 3. However the uncertainties associated with 14C based age model, hiatus in sedimentation and extrapolation of the age model for the lower part of core could be the reason behind the lack of above mentioned observations during rest of the Heinrich events.

Precipitation: Speleothems/Paleolimnology – Universidad de los Andes

Characterization of monsoon precipitation over low land tropical South America during abrupt millennial events: HS1, B-A, YD and Bond events

Nicolas M. Strikis; Cruz Jr, F.W.; Novello, V.F.; Karmann, I.; Cheng, H.; Edwards, R.L.; Auler, S. A.

Abstract: Here we present a paleoprecipitation reconstruction covering the last 20 kyr B.P. from central-eastern Brazil, where the precipitation is exclusively due to activity of South America Monsoon System (SAMS). Our record is based on well dated speleothem oxygen isotope record from Lapa Grande and Lapa Sem Fim cave. We intend to discuss the positive impact of the cold millennial-scale events in Northern Hemisphere such as Heinrich Stadial 1, Young Dryas, 8.2 ky and Bond events on precipitation that occur within SAMS area of activity. We call attention to the striking similarity in timing and also in structure of these events between cave site and marine records of sea surface temperatures over different latitudes in North Atlantic. Besides, the relative amplitude variation of summer monsoon intensity between the Young Dryas and Heinrich stadial 1 event observed in our record is similar to the δ18O variations in the Greenland ice core record. On the other hand, there is an expressive reduction in monsoon precipitation during the abrupt Bølling-Allerød warm event. During the 8.2 our record also shows the same double plunge structure observed in monsoon records from eastern China, Oman and northeastern Brazil.

High-resolution records of climate change during the Holocene in Brazil and Mexico
Juan Pablo Bernal

Abstract: Stalagmites are among the most robust archives of past climates. Using Laser-ablation ICPMS it is possible to obtain very high-resolution records from the stalagmites, potentially with temporal resolution of few-years or less, depending on the growth rate of the stalagmite. The resulting records allow the unraveling of the fine-structure of climate events and thus, further the understanding of the climate dynamics.

Here I present two absolutely-dated, high-resolution Holocene trace element records from Mexico and Brazil obtained by LAICPMS. Both samples have been previously analyzed for δ18O and interpreted to reflect changes in regional Monsoon intensity during the Holocene. The presence (or absence) and structure of the main climatic events of the Holocene is discussed; moreover, spectral analysis of the time-series allows to identify the main processes modulating the arrival of moisture in Brazil and Mexico.

Matches and mismatches in millennial scale climate oscillations from the southern tropical Andes
Mark B. Bush

Abstract: Fossil pollen and isotopic records from Ecuador, Peru, and Bolivia show a strong coherence with oscillations in sea-surface temperature in the tropical North Atlantic for much of the last ice age. Cold events in the tropical Atlantic Ocean were generally wet events in the ever-wet regions of western Amazonia and the Andes. The pattern was also shaped by precession, but both precession and the north Atlantic seem to lose their influence on the region in the period between c. 40 ka and 17 ka. As the records resume a degree of synchrony, the H1 event, is evident as a wet forcing, but H0, the Younger Dryas, is less securely identified. An oscillation that could be the Younger Dryas is documented in a number of records, but is consistently dated to begin before the onset of the North Atlantic event. Will improved chronologies re-align records to the North Atlantic or indicate that the Amazon and Andes were somewhat decoupled from the North Atlantic as the Laurentide ice-sheet contracted?

A ~43-ka record of paleoenvironmental change in the Central American lowlands inferred from stable isotopes of lacustrine ostracods

Jaime Escobar

Abstract: We present a continuous ostracod isotope (δ18O and δ13C) record from Lake Petén Itzá, Petén, Guatemala, in the northern, lowland Neotropics that spans the last ~43 cal ka BP. During the last glacial period, the greatest δ18O and δ13C values coincide with gypsum deposited during lake lowstands under arid climate conditions that were correlated previously with North Atlantic Heinrich events. In contrast, interstadials and the entirety of the Last Glacial Maximum (~24-19 cal ka BP) are marked by clay deposition and lower δ18O and δ13C values, reflecting higher lake levels and relatively moister climate. Isotope results show the early deglacial period (~19-15 cal ka BP) was the time of greatest aridity and lowest lake stage of the past 43 ka. This period occurred during Heinrich Stadial 1 (HS 1), when an extensive tropical megadrought has been postulated (Stager et al., 2011). Heinrich Stadial 1 is represented by two episodes of gypsum precipitation and high δ18O and δ13C values in Petén Itzá, interrupted by an intervening period of lower δ18O and δ13C and clay deposition centered on ~17 cal ka BP. The two periods of inferred maximum cold and/or arid conditions at ~17.5 and 16.1 cal ka BP coincide approximately with two pulses of ice-rafted debris (IRD) recorded off southern Portugal (Bard et al., 2000). Precipitation changes during the last glacial period in the northern hemisphere Neotropics were closely linked with freshwater forcing to the high latitude North Atlantic, and sensitive to changes in the location of meltwater input.

Searching for ecological tipping points in mid-altitude, tropical ecosystems
Margarita Caballero, Lozano-García S., Zawizsa E., Rieradevall M., Sánchez Y., Ortega B.

Abstract: Millennial-scale Holocene climatic variability is controlled by changes in insolation, the early Holocene (10-7 ka) characterized by the highest summer insolation and tropical monsoon activity and the late Holocene (4.2-0ka) by the opposite. Ecosystems, however, display non linear behaviors and if the intensity of these changes doesn't reach threshold values they might not react to the changing environment. This can be the case in low altitude tropics, while mid-altitude tropical sites are closer to climatic thresholds. Tacambaro (19°12'40"N 101°27'30°W, 1,460 m asl) is such a site, as it is at the ecotone between tropical deciduous and temperate (pine-oak) forests. Diatom, cladocera, chironimidae, and palynological data from an 8.5 m core give evidence of increasingly eutrophic conditions during the early Holocene (9000 – 5000 cal BP), with species indicative of an effective mixing in the lake and the presence of temperate forests. By ca. 5000 cal BP a sharp transition is recorded with the expansion of tropical taxa and a drastic change in mixing pattern (meromixis), with limited nutrient recirculation and bottom anoxia. Meromixis is possible in nutrient rich, deep, small, tropical lakes such as Tacambaro. We believe that these changes are related with increasing winter insolation that controls winter mixing and limits the distribution of tropical taxa. After AD1100, the modern eutrophic, warm monomictic lake is established.

Vegetation: Pollen/Charcoal records

Millennial-Scale Ecological Changes in Tropical South America Since the Last Glacial Maximum
Dunia H. Urrego, Mark B. Bush, Miles R. Silman, Alexander Correa-Metrio, Marie-Pierre Ledru, Francis E. Mayle, Gina Paduano, and Bryan G. Valencia

Abstract. We present an analysis of rates of ecological change (RoC) from thirteen pollen records from tropical South America. The analysis aims to identify the periods of fastest change since the last glacial maximum (LGM) and possible driving mechanisms. RoC analysis showed that millennial-scale changes likely accelerated during the Holocene both in the eastern Andes and western Amazonia. Drought and human expansion were the most likely drivers of this acceleration. Most importantly, our analysis showed that sedimentation rates and time-resolution of available records made millennial-scale variability difficult to pinpoint in the region.

Late Quaternary temperature change velocity in Mesoamerica
Alexander Correa Metrio

Abstract: Quaternary climate has been highly variable, and yet few quantitative continental reconstructions are available for tropical areas. An extensive survey of modern pollen samples and two long sedimentary records (30,000 and 86,000 years for highlands and lowlands, respectively) were used to estimate past temperatures based on fossil pollen. Derived temperature profiles show a parallel long-term trend and a similar cooling during the Last Glacial Maximum in the lowlands and highlands of Mexico and Guatemala. Using a digital elevation model, we ere able to reconstruct the velocity at which isotherms displaced to produce the observed temperature anomalies. Spatial velocities of temperature change in the studied areas were at least four times slower than values reported for the last 50 years, but also at least twice as fast as those obtained from recent models. This study demonstrates that modern temperature change has no precedent within the last 86,000 years, but also that tropical climate has been more variable than it has been assumed to date.

Centennial-scale biome dynamics and climate variability during the last glacial cycle in the Colombian Andes
Henry Hooghiemstra with Zaire González-Carranza, César Verlásquez & Project Team Members

Abstract: Climate variability was studied at high resolution in new cores from North Andean sedimentary basins. We analysed downcore pollen spectra, grain size distributions, organic content, and XRF-based geochemical compositions to integrate the dynamic histories of the regional forest and páramo vegetation, the local aquatic vegetation in the basin, and the changes in sedimentary and geochemical environments.

The Fúquene-9C record (4°N, 2540 m) shows the interval of 284-27 ka with a resolution of 60 yr. Climate change is mainly temperature and pCO2 driven. Submillennial-scale variability corresponds with the records of D-O cycles from Greenland and Antarctic ice cores. Rates of Change vary from 2-3.5°C/100 yr increasing up to ~10°C/100 yr at Terminations. Pollen record Llano Grande-1 (6°N, 3460 m) also shows at the Lateglacial-Holocene transition an abrupt altitudinal migration of ~700 m (reflecting ~3.5°C) in ~200 yr.

The La Cocha-1 record (1°N, 2780 m) from the Amazonian flank shows the last 14 ka with a resolution of ~25 yr. Post-glacial temperature increase shows a remarkably long lasting trend from ~12 to 2 cal ka explained by the buffering capacity of high moisture supplied by abundant orographic rains. Abrupt oscillations superimposed cuased that the shrubpáramo biome temporally disappeared repeatedly indicating that the migration capacity of cool montane forest exceeds the migration capacity of shrubpáramo with relevant implications for Global Change scenarios

Millennial-scale climate variability during MIS 3 and MIS 2 at Lake Chalco, central Mexico
Esperanza Torres, Lozano, Socorro, Roy, Priyadarsi, López, Nayeli, Ortega, Beatriz and Caballero, Margarita

Abstract: The Basin of Mexico (20ºN, 99ºW; 2240 m.a.s.l.) is present at the northern limit of the American tropics and is surrounded by up to 5400 m high mountains. The Lake Chalco is situated at the southern part of the basin and spreads over 120 km2. The precipitation in the modern era is influenced by the seasonal displacement of the Intertropical Convergence Zone and the high-pressure belt located at about 35 °N. Five cores were drilled (up to 122.5 m depth) in order to document the millennial-scale variability in paleohydrological conditions and vegetation history during the late Quaternary. The age model includes several 14C dates and tephra layers present in the upper 25 m of the core. The millennial-scale events during MIS 2 and 3 are based on geochemical data (total organic carbon (TOC), total inorganic carbon (TIC), C/N ratio) and abundance of charcoal particles. Lake productivity (more TOC) increased during the interstadials, whereas higher charcoal particles and inorganic carbonate precipitation during the stadials suggest drier conditions in the basin. We document increase in lake water salinity and fire events in the basin surroundings during the H5 event.

Ecosystem responses to late Quaternary climate change in central Mexico
Socorro Lozano García, Alexander Correa, Rodrigo Velázquez, Susana Sosa

Abstract: A significant amount of information regarding the glacial history of volcanoes and vegetation history of the Trans Mexican Volcanic Belt (TMVB) is available. The TMVB is a volcanically active complex highland area, and during its geological history numerous lakes basins have been formed. To explore the response of vegetation to late glacial climatic and geological change, pollen records of lacustrine sequences from a series of lakes in the western and central sections of the TMVB has been under analysis. Calculated ecological change and its associated rates (RoCs) for six sites that follow an altitudinal and longitudinal gradient of central Mexico offer information of vegetation dynamics of the area. Most of these records show high variability. Dry periods in Lakes Cuitzeo and Zacapu (the mot western and lower locations) show high RoC and seem to coincide with Heinrich events (H4 and 5). Contrastingly, RoC in Chalco and Texcoco records (the eastern and higher locations) seem more variable. The observed patterns are most likely the result of the confluence of climate, geologic events, and human occupation, all of them interacting at different time scales and posing difficulties when interpreting fossil sequences from the area.

A 40,000-year fire history from lowland Bolivia and regional synthesis of Neotropical biomass burning records
Mitchell J. Power, Bronwyn Whitney, Francis Mayle and GPWG data contributors

Abstract: A 40,000 year fire history reconstruction from lowland Bolivia provides insights into millennial-scale climate drivers during the glacial-interglacial transition and the development of the seasonally-deciduous tropical forest (SDTF). Contiguous charcoal samples from Laguna La Gaiba, located in the Chiquitano SDTF in lowland Bolivia, were used to reconstruct the frequency of fires events through the last glacial period. Paleofire reconstructions were compared with multiproxy evidence from the La Gaiba record as well as regional paleoclimate and charcoal reconstructions to explore regime shifts and millennial-scale climate drivers across the Neotropics. Published charcoal records from the northern and southern hemisphere (30°N-30°S) of Central and South America were combined to examine regional trends in biomass burning. Fires were infrequent in lowland Bolivia during the glacial period, from 40,000 to 19,500 cal yr BP, when tree pollen was low and tropical forests were generally absent as cold-than-present glacial conditions persisted. After 19,500 cal yr BP, gradual warming allowed for the establishment of a seasonally dry forest near Laguna La Gaiba,

dissimilar in pollen spectrum to the SDTF today, as fire frequency remained low across the region. After 19,500 regional fire activity begins to increase in the southern hemisphere tropics, peaking around 15,500 cal yr BP, but fire activity remained lower-than present in the northern hemisphere tropics until approximately 13,000 cal yr BP. A regime shift toward a wetter climate, between 13,000 and 12,000 cal yr BP is captured by an abrupt increase in Neotropical fire records and increased fire frequency at La Gaiba as grasslands developed around the pantanal wetlands.

Before and after 60 kyr: contrasting millennial scale climate patterns from nothern South America
Catalina González

Abstract: Sediments from the Cariaco Basin preserve an almost continuous record of unparallel temporal resolution showing evidence for abrupt climate changes in terrestrial and marine systems from northern South America. The comparison of pollen and spores (terrestrial proxies) with dinoflagellates cysts (marine proxy) provides important information on land-sea interactions. Back through marine isotope stage (MIS) 4 the palynological record displays a clear North Atlantic climatic variability. Here, north Atlantic warm periods are characterized by low reflectance values, enhanced marine productivity, increased precipitation and river discharge, and expanded semi-deciduous forests, which are related to a northward shift in the mean latitudinal position of the Intertropical Convergence Zone (ITCZ). During cold stadial periods the opposite trend reveals a southward migration of the ITCZ. However, palynological results from core MD03 -2622 suggest an opposite pattern for MIS 5. Dinocyst assemblages change at around 60 ka from a more autotrophic–dominated towards a more upwelling-dominated phytoplankton community. During MIS 5 light-coloured intervals, high percentages of runoff indicators and low percentages of upwelling dinocysts suggest that colder intervals during MIS5 coincided with more humid conditions, opposed to what happens from MIS 4 on. These sudden changes in phytoplankton communities seem to be related to reorganizations of the local-regional hydrography, which has a tight relationship with regional climate. By comparing these results to other available data we discuss about the possible link between hydrological changes in northern South America and changes in orbital precession.

Assessing temporal uncertainty of the Latin-American pollen database
Suzette Flantua, University of Amsterdam, The Netherlands

Abstract: Mapping past vegetation dynamics from fossil-pollen records face the challenge of temporal uncertainty. Before studies engage into paleovegetation mapping and spatial comparisons, the temporal uncertainty of a database should be assessed. The latest update of the Latin American Pollen Database (LAPD) inventory shows a growing collection of densely sampled fossil-pollen records with diverse accuracy, range and quality in their chronologies. We plan to assess the overall reliability of the chronology of the LAPD, and more specifically from Northern South America, to identify the periods that are best suitable for spatial interpretations. While in the meantime completing the LAPD list of pollen sites (which will be available soon through NEOTOMA), we plan to develop a conceptual framework for ranking the quality of individual ^{14}C ages and site chronologies that assesses the possible sources of error. Then we will apply this framework to identify the pollen records, time periods and lower temporal limit for interpretation that are most suitable to provide mapped syntheses of pollen data.

This assessment is the first step of the current PhD project of S.Flantua, University of Amsterdam in collaboration with the University Los Andes-Bogotá, University La Javeriana-Bogotá, National University-Bogota, National University-Medellin.