Geophysical Research Abstracts,
Vol. 11, EGU2009-10380-1, 2009
EGU General Assembly 2009

A high resolution history of the El Niño - Southern Oscillation and of the solar activity during the Late Glacial - Early Holocene in the subtropical Andean region.

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High-resolution laminated lacustrine sediments are excellent archives of the past hydrological changes and they provide valuable insights about the climatic processes that trigger these changes. The paleoclimatic records located in the Southern Hemisphere are fundamental for understanding the evolution of the El Niño - Southern Oscillation (ENSO) since this climatic phenomena is the main cause of droughts and floods in many areas of South America and other regions of the world, like Spain and Egypt. Available regional paleoclimate reconstructions show that modern climatic patterns in South America were established during the Late Holocene. The laminated sediments of Lago Chungará (18º 15' S - 69º 10' W, 4520 m a.s.l., Chilean altiplano) have allowed us to characterize the evolution of this climatic phenomena for the transition Late Glacial - Early Holocene (12,300 - 9,500 calendar years BP) as well as its relationship with other climate forcings, namely the solar activity.

The studied sediments correspond to the lowermost 2.4 m of 8 m long Kullemberg cores recovered from this lake. These sediments are mainly made up of greenish and whitish laminae and thin layers constituted by diatomaceous oozes with carbonates and organic matter, arranged in rhythms and cycles. X-ray fluorescence (XRF) (Al, Si, S, K, Ca, Ti, Mn, Fe, Rb, Sr, Zn, Sb and Ba) analyses, total organic carbon (TOC), total carbon (TC), x-ray diffraction (XRD), biogenic silica, stable isotopes (delta18O and delta13C) on carbonates and on diatoms (delta18O) and magnetic susceptibility were determined in order to characterize the sediments of Lago Chungará. Previous statistical studies (cluster and Principal Component Analyses (PCA)) were used to disentangle the paleoclimatic signal from the other ones (volcanic and tectonic). The chronological model framework was built using 6 radiocarbon dates, allowing us to establish that laminated couplets were deposited on a pluriannual basis. These couplets are composed of a lower light lamina, progressively grading upwards to a dark lamina. Light laminae are composed by diatom valves of a single species (Cyclostephanos cf. andinus), accumulated during short-term extraordinary diatom blooms when water column mixing took place under abrupt and short-term climatic events. Dark laminae contain a complex diatom assemblage and are rich in organic matter representing the baseline limnological conditions during several years of deposition.

Spectral analyses (Fast Fourier Transformation - FFT - and Time Frequency - TF - analyses) were performed on the isolated paleohydrological curve and on the gray color curve calculated for these laminated sediments.

The FFT analyses of the paleohydrological signal obtained from the PCA highlights the record of 35-51 years cycles, that might correspond to the solar Bruckner cycle as well as to the inter-decadal changes in the variance of the ENSO phenomena. The results of the FFT analyses carried out on the gray curve reinforce the hypothesis of the solar control on the variations in the lake productivity: the 11-years Schwabe, 22-23-years Hale, 35-years Bruckner and the approx. 90-years Gleissberg cycles, as well as a strong to very strong ENSO phenomena (8.2 and 7.5-years cycles) are recorded. The TF analyses developed on the variations of the gray-colour curve reveal that all solar frequencies have modified intensities during the Late Glacial and Early Holocene. During the low activity periods of the 11-years Schwabe cycles, strong to very strong ENSO phenomena took place. These results show that ENSO-like variability was present during the late Glacial and early Holocene in the Altiplano.