Variation in Tropical South American Monsoonal Precipitation in the Late Pleistocene

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The Altiplano (14 to 22ºS) is a large, closed basin at high elevation in the tropical Andes, where rain and snowfall occur primarily in the Austral summer. Moist air in the active boundary layer over the eastern lowlands of tropical South America is advected on to the Altiplano between November and May and leads to precipitation in the region (e.g. Garreaud et al., in press). This general circulation has been described as the South American Summer Monsoon (Zhou and Lou, 1998), because northwesterly flow develops seasonally at low levels along the eastern side of the Andes, which acts to bring moisture to the Altiplano. The Bolivian High is the upper tropospheric manifestation of this general circulation (Lenters and Cook, 1997), and the southerly position of the High in the Austral summer is directly related to precipitation over the Altiplano. In modern times, drier conditions occur over the Altiplano when there is upper level westerly flow, which typically occurs during the austral winter, during brief periods in the wet season, and often during the warm phase of ENSO.

A number of studies have suggested that insolation modulated by precession has had an important impact on the moisture history of the Altiplano. Lakes and glaciers in the cordillera surrounding the Altiplano have apparently been effected by insolation variations, specifically high summer insolation appears to be related to wetter conditions leading to glaciation and positive hydrologic mass balances of glacial lakes (e.g. Abbott et al., 1997; Thompson et al., 1995). Similarly, insolation may have been instrumental in forcing a positive water balance in the inter-Andean Lake Junin (11ºS) (Seltzer et al., 2000) and Lake Titicaca (16ºS) (e.g. Baker et al., 2001a), and even in modulation of ENSO frequency over the Holocene as recorded in Laguna Pallcacocha, Ecuador (Rodbell et al., 1999). Insolation has also been implicated in the formation of large lakes on the southern Altiplano over the last two precession cycles (Baker et al., 2001b). The suggestion is that insolation modulated by precession would produce a southern expansion of the Bolivian High during the austral summer and the dominance of easterly circulation at times of high insolation (Garreaud et al., in press). Assuming that there was sufficient water vapor in the active boundary layer over the eastern lowlands, this resulted in the advection and lifting of moist air masses over the tropical Andes and Altiplano and therefore precipitation.

Although insolation modulated by precession is appealing as a dominant forcing for moisture variability over the last two precession cycles in the tropical Andes, prior to ca. 50 kyr BP this simple model does not appear to function, as suggested by recent drilling in the Salar de Uyuni (20ºS) and Lake Titicaca (16ºS). In a 170,000-year record of alternating salts and lacustrine sediments from the Salar de Uyuni not all times of lacustrine deposition prior to 50 kyr BP are coincident with insolation maxima (Fritz et al., in review). At Lake Titicaca it is also clear that lake-level changes were not related to precessional forcing in a simple fashion during earlier times. Lake levels were at least 240 m lower than today >60 kyr BP (D'Agostino et al., 2002), and low lake levels were apparently sustained for considerably longer than a single precession cycle prior to ca. 80

kyr BP (Fritz et al., unpublished data). Even though lake levels were low, it also appears that glaciation continued to occur, at least in the eastern cordillera, where glacier extent is most sensitive to temperature change. Thus moisture variability in this region appears to have been modulated by insolation, but also by other important boundary conditions that we have yet to identify. At the same time, temperature apparently varied to produce more extensive glaciation during both wet and dry periods in the past.

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