Tropical ice core records of changes in symmetry, position and/or intensity of the Hadley Circulation on Milankovich, millennial, and centennial time scales.

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Ice core records from South America, Africa, the Himalayas and the Tibetan Plateau provide evidence of past changes in position and intensity of the Hadley circulation. Cores from seven sites at elevations greater than 5600 m asl suggest that the climate (temperature and precipitation) from either side of the equator is out of phase. These records are combined with more than 120 other paleoclimate records to produce a global map of effective moisture changes between the Last Glacial Maximum (LGM) and the Early Holocene (EH). The global pattern of changes in the tropical hydrological system between these two periods has been zonally symmetrical; for example, the zonal belts in the deep tropics that experienced greater aridity during the LGM attained maximum humidity in the EH, while at the same time the humid subtropical and mid-latitude belts generally became drier. In this paper we examine the spatial symmetry and asymmetry of these changes about the equator through time. A strong role for the Hadley circulation is suggested such that its position, its intensity, or both were altered as the Earth moved from glacial to interglacial conditions.

The ice core records from these low-latitude, high-elevation sites also raise questions about; (1) the synchroneity of glaciation, (2) the relative importance of temperature and precipitation in governing the growth and decay of ice fields north and south of the equator, and; (3) the relative role that the strength and position of the Hadley circulation plays in determining the geographical distribution of low latitude ice fields. Cores from Huascarán, Peru (9^{o}S) and Sajama, Bolivia (18^{o}S) yield continuous records back to ~19 ka and 25 ka, respectively and thus extend into the Last Glacial Stage (LGS). Both glaciers undoubtedly survived the EH warm period (10 to 6 ka), but neither contains a record of the entire LGS back to the previous interglacial. Moreover, the ice core records from Kilimanjaro, Tanzania (3^{o}S) start only at ~11.7 ka. Thus, these mountains, among the highest in the Southern Hemisphere, appear to have been ice-free during a time when the Earth was in the grip of a "global" glaciation. In the Northern Hemisphere, the subtropical ice core records from the Dasuopu (28^{o}N) and Puruogangri (34^{o}N) ice caps on the Tibetan Plateau suggest that ice existing today in the Himalayas and central Tibet formed during the EH warm period. Therefore, glacier formation/starvation in the tropics and subtropics appears to be controlled by wetter/drier conditions in response to precession-driven changes in solar radiation which in turn may be related to the intensity and/or position of the Hadley circulation.

While Sajama shows little isotopic trend throughout the Holocene, Huascarán and Kilimanjaro nearer the equator show a distinct trend toward more negative oxygen isotopic ($\delta^{18}O$) values until very recently, when both show a significant ^{18}O enrichment. However, north of the equator, the isotopic trends in the Dasuopu and Puruogangri cores show enrichment throughout their records, while Guliya (the most northern site) shows this enrichment only after the EH. For the more recent past when annual layers can be discerned in the ice cores, a detailed picture of both $\delta^{18}O$ (temperature) and net balance (accumulation) is examined both north and south of the Equator to

address the more recent variations in the strength and position of the Hadley circulation. Particular emphasis is placed on understanding changes that might have occurred in the late 20th Century due to the recent global climate change.