Monsoon Dynamics Observed Over Decades to Millions of Years

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The Asian summer monsoon leaves a rich fossil record of past changes in wind and rainfall across the land surface as well as at the sea floor, and both marine and terrestrial deposits have been extensively studied to reveal how the monsoon circulation has varied during the past ten million years. I have attempted to scale several different reconstructions to provide a sense of the amplitude of monsoon variability across five frequency bands, from 10 to 1,000,000 years, to evaluate trends as well as oscillations in the monsoon, and to evaluate the relative

sensitivity of the monsoon to different forcing mechanisms, some which are constrained to discrete frequency bands. At all scales the monsoon records reveal strong teleconnections between tropical and extratropical latitudes. Over millions of years, tectonic changes in the position and elevation of the land surface, atmospheric carbon dioxide, and the slow evolution of glacial boundary conditions are all implicated in forcing the monsoon circulation. In the Milankovitch frequency bands, direct radiative forcing and the secondary influence of changing glacial boundary conditions have both played a role. The relatively recent discovery of substantial variance in the millennial band, including abrupt changes that occurred during the last glacial period between 60,000 and 20,000 years ago that have persisted through the Holocene with smaller amplitude, has motivated a vigorous effort to understand the cause of these changes. Several hypotheses have been proposed, some considering the direct influence of solar variability, and others considering the teleconnections between low and high latitudes. Because these abrupt changes are large, and occur in some of the world's most densely populated regions where entire economies are influenced by the monsoon, understanding the cause of abrupt changes in the monsoon (and other aspects of the hydrologic cycle in the tropics) present one of the most compelling and potentially rewarding challenges in paleoclimatology today.