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Preface

Monsoons and global linkages on Milankovitch and sub-Milankovitch time scales

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Climatologically, monsoon regions are the most convectively active areas on Earth and account for the majority of global atmospheric heat and moisture transport. The most active systems include the Indian, Asian, and Australian monsoons (Fig. 1). Within the tropical Indian and western Pacific Oceans, the mass flux associated with these three monsoon systems (80 Gkg s^{-1}) is over twice the mass flux associated with Pacific Ocean Walker Circulation (33 Gkg s^{-1}) and over 70% of the total Indo-Pacific mass flux (Webster, 1998). Both modern and paleo studies have demonstrated that monsoon systems are highly variable over annual to orbital time scales (Charles et al., 1997; Clark et al., 2000; Clemens et al., 1996; Meehl, 1997; Saji et al., 1999; Wang et al., 2001; Webster, 1998; Webster et al., 1999). Enhanced understanding of the factors governing variability in the flux of heat and moisture within these systems is critical to our ability to predict the response of these systems within the context of future climate change scenarios.

From a paleoclimate perspective, these three monsoon systems have largely been studied independently both in terms of their geographic variability and their time scales of variability. In contrast, the trend in modern monsoon studies has been toward an understanding of the 'global' monsoon by studying the dynamic links between these regional subsystems over a wide variety of time scales (Trenberth et al., 2000; Wang et al., 2001; Webster, 1998). This effort has been fueled by the rapid increase in global-scale meteorological/oceanographic data sets and has advanced our understanding of how the modern Indo-Pacific monsoon systems are dynamically linked to one another and to other phenomena (e.g. El Niño/Southern Oscillation – ENSO, Tropical Biennial Oscillation – TBO). Similarly, progress in understanding paleomonsoon variability can be made through integrating regional results across a wide variety of time scales. For example, recent modeling efforts suggest a link between interannual climate variability associated with ENSO and Milankovitch-scale variability associated with orbital precession (Clement et al., 1999). These model results suggest that orbital forcing alters the temporal evolution of ENSO events, which in turn changes the mean tropical climate state. This provides a framework for evaluating orbital-scale paleomonsoon variance in the context of ocean–atmosphere dynamics operating on the seasonal and interannual scales.

Paleoclimatic and paleoceanographic records of monsoon variability are measured through indirect (proxy) indicators. These proxy indicators may be biotic, geochemical, isotopic, or physical in nature, but their variability is related, in part, to changes in the environment associated with the monsoon circulation. However, individual proxy records also contain variability not uniquely asso-

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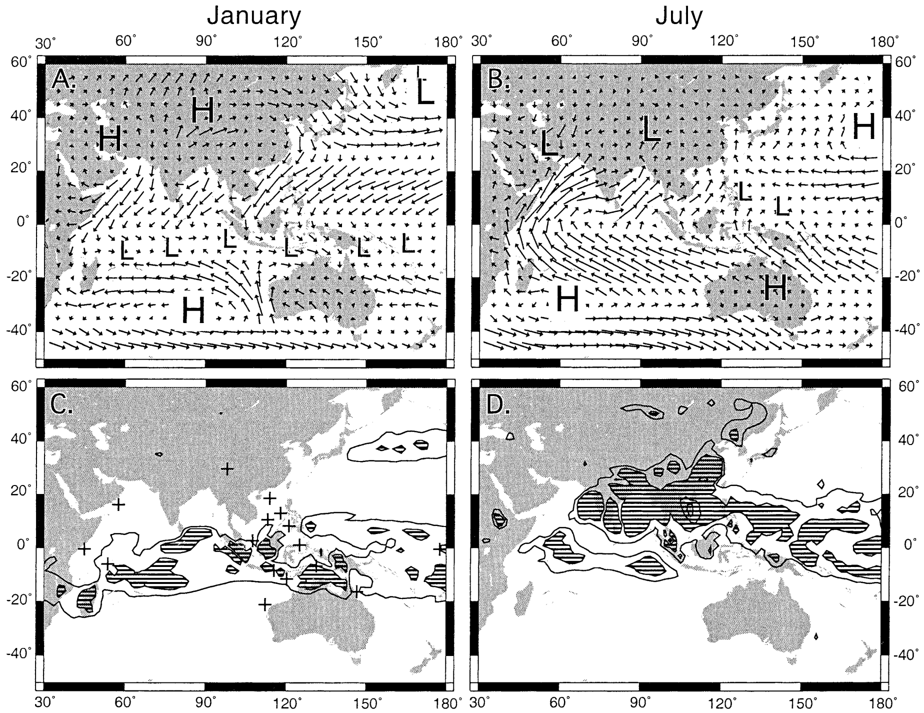

Fig. 1. Climatology of the January and July monsoon circulation. Sea level pressure and surface winds (A,B). Longer arrows indicate stronger winds; the strongest winds (panel B; July, Arabian Sea) are approximately 15 m/s. Precipitation (C,D) is indicated by contours (6 mm/day) and hatching (> 9 mm/day). The South China Sea has a strong summer-monsoon precipitation response as well as a strong winter-monsoon wind response. Monthly data for 1990–1997 from NOAA NCEP-NCAR CDAS-1 (Kalnay et al., 1996). + symbol in panel C indicates the approximate geographic locations of paleomonsoon data sets presented in this volume (two additional records off Christmas and Palmyra Islands, central equatorial Pacific are not shown). Redrawn from Wang et al., 2000.

ciated with the monsoon. Examples of such sources of variability are preservation processes, nonmonsoonal environmental changes, and global-scale changes in sea level and climate on glacial–interglacial scales. Hence all proxies must be carefully evaluated to determine how much of their variability is uniquely associated with monsoon dynamics. In this volume more than a dozen proxies are used to evaluate aspects of monsoon variability. In many cases, several proxies are internally consistent in terms of the timing and amplitude of change but certainly not in all cases; it is the variance held in common among these many proxies that most likely reflects monsoon circulation.

The long-term goal is to understand the extent to which the Indian, Asian, and Australian monsoon systems are coupled or independent relative to one another and relative to other tropical climate phenomena across Milankovitch and sub-Milankovitch time scales. This requires development of an array of summer- and winter-monsoon proxy records from each region coupled with clear identification of the uniquely monsoon-related variance within each proxy. This is crucial to a reliable understanding of monsoon variance within the context of regional forcing mechanisms and to understanding potential couplings among the three monsoon systems at various time scales. This volume initiates the process, bringing together modeling efforts as well as an array of proxies from the three monsoon regions, including records derived from marine sediments, lake sediments, corals, and ice cores. We hope this will encourage further development of reliable regional proxies, in-depth comparison of the mechanisms driving variability within each system across Milankovitch and sub-Milankovitch time scales, and further interaction among the communities that generate these diverse proxy data sets and modeling studies.

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