Indian monsoon variability in a warmer world: Exploring IODP Expedition 353 Miocene sediment archives

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IODP Expedition 353 (iMonsoon) targeted the reconstruction of Indian Ocean surface and deep water circulation and Indian Monsoon precipitation through the Miocene in its core geographic region of influence, the margins of the Bay of Bengal. The deep-time objectives of this expedition were to assess (1) the relative sensitivity of the monsoon to external insolation forcing and internal climate boundary conditions including the export of latent heat from the southern hemisphere, the extent of global ice volume and greenhouse gas concentrations, (2) the extent to which Indian and East Asian monsoon winds and precipitation are coupled and at what temporal and geographic scales, (3) the influence of monsoonal discharge and wind forcing on the oceanography of the northeastern Indian Ocean, and (4) the timing and conditions under which monsoonal circulation initiated and evolved. A detailed record of monsoon evolution is central to testing models that link the climatic evolution of South Asia to the tectonic development of the Himalaya and rising of the Tibetan Plateau.

Site U1443 (2925 m water depth) drilled on the crest of the Ninetyeast Ridge at the southern end of the Bay of Bengal, provided the first complete, continuous record of Indian Ocean deep water paleoceanography extending back to the early Miocene. High-resolution benthic stable oxygen (d^{18}O) and carbon (d^{13}C) isotope records as well as X-ray fluorescence (XRF) scanner elemental records track the abrupt onset and development of the Miocene Climatic Optimum (MCO) from 16.9 to 14.8 Ma followed by a transitional climatic phase (14.8 Ma to 13.8 Ma) and a two-stepped d^{18}O increase at 13.8 and 13.1 Ma, reflecting global cooling and ice expansion over Antarctica. Carbonate records indicate episodic carbonate dissolution events correlated with low d^{18}O and d^{13}C during warm climate phases at eccentricity maxima. The late Miocene benthic δ^{18}O curve reveals a pronounced warming episode at 10.8-10.7 Ma, which was previously reported from ODP Site 1146 in the South China Sea. This transient warming coincides with a marked negative δ^{13}C shift and is reminiscent of high-amplitude thermal events, which are paced by 100 kyr variability and characterize the warmer climate mode of the MCO. Decreasing carbonate content together with a marked decrease in sedimentation rates from 0.6 to 0.2 cm/kyr at ˜13.2 Ma signal the onset of a prolonged and intense carbonate dissolution episode in the northeastern tropical Indian Ocean, which lasted until ˜8.5 Ma and correlates with the “Carbonate Crash” identified in the Equatorial Pacific and Atlantic Oceans.

Two sites (U1447, 1392 m water depth and U1448, 1098 m water depth), drilled in the Andaman Sea, recovered extended upper Miocene successions, which provide an outstanding opportunity to assess the sensitivity of the Indian Monsoon to insolation forcing and to climate boundary conditions such as the extent of global ice volume and greenhouse gas concentrations on a warmer-than-present Earth. Based on a composite record from Sites U1447 and U1448, we are currently developing an orbitally-tuned benthic isotope stratigraphy over the interval 10 to 3 Ma as well as high-resolution monsoonal run-off records from XRF-scanning elemental data coupled with sea surface temperature/salinity reconstructions from paired stable isotopes and Mg/Ca paleothermometry. Cold stages T4 to TG34, identified between 5 and 6 Ma, coincide with pronounced coolings of Indian Ocean surface and intermediate waters.

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