Synchronous reduction in Indian summer and winter monsoon intensity during the northern hemisphere cold episodes: possible implications on climate modelling

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The economy of most Asian countries including India by and large depends on the monsoon conditions. There has been a growing interest in recent years to understand better the dynamics of the monsoon climate and factors driving changes in the monsoon circulation and to evolve predictive models. Enhanced understanding of variability pattern of the seasonal monsoon wind systems (southwesterly in summer and northeasterly in winter) and its relationship with other climate components of the Earth is critical to our ability to predict monsoon in the context of current climate change scenario. A wide range of palaeontological, mineralogical, geochemical and isotopic signatures recorded from the marine archives are used to document past changes in the monsoonal climate. The tests of the microscopic fauna and flora preserved in the ocean sediments provide reliable indicators of past climatic conditions, as they are remarkably sensitive to minor changes in oceanic environment induced by monsoon circulation pattern. The sedimentary records of the Arabian Sea are the best archives of Indian monsoon history, as the physico-chemical condition and biology of this basin is primarily influenced by the seasonal changes in monsoon circulation. In the recent past, there have been a number of studies from the Arabian Sea on reconstruction of palaeo-monsoon history using micropalaeontological, isotopic and geochemical tracers. Palaeoclimatic reconstructions and climate modelling studies have demonstrated that the Indian monsoon system is highly variable over the longer to shorter timescales. Most of these studies were focused on the summer monsoon variability and as a result substantial understanding of its driving mechanism has been gained by now. Summer monsoon variation on longer timescales (glacial/interglacial) is generally explained by the orbital precession that affects the insolation reaching the Earth[1,2]. Earlier studies have demonstrated that summer monsoon on millennial scales is linked with short-term high-latitude northern hemisphere climatic events[3,4]. The current picture of the Indian monsoon variability remains incomplete because the temporal dynamics of the winter monsoon on shorter timescale has never been fully investigated from this region.

Recently, Singh *et al.*[5], based on the last 70,000 years microfossil record of planktic foraminifera (shelled protozoans living in surface ocean waters) from the eastern Arabian Sea, demonstrated winter monsoon variability pattern on millennial scale in this region. They developed time series of abundance variations in selected planktic foraminaferal species sensitive to surface water nutrient condition (eutrophic versus oligotrophic species) and organic carbon content indicating primary productivity driven by the seasonal monsoon wind strengths. The sediment archives used for the reconstruction of palaeo-monsoon history come from the northern part of the Arabian Sea Indian margin, where productivity condition today is primarily controlled by the northeasterly winter monsoon winds, thus ideal for deciphering winter monsoon history. The time series indicates long-term changes overprinted by the short-term millennial scale changes. The study suggests that the long-term change in winter monsoon is linked with the Earth's precessional variation resulting significant changes in insolation flux. Singh *et al.*[5] inferred that the winter monsoon was intensified during the periods of insolation minima, when summer monsoon is known to be significantly weakened. Thus there is an opposite relationship between summer and winter monsoon strengths on longer timescales, supported also by the climate models[1]. Previous studies have indicated that summer monsoon on millennial scale varied in tune with the high-latitude northern hemisphere climatic oscillations with its strengthening during short-term warm episodes (the interstadials) and weakening during cold episodes (the stadials). Considering the view of opposite phase relationship between summer and winter monsoon strength, one might expect enhancement in winter monsoon wind strength during northern hemisphere cold events as was documented previously from the East Asia[6]. On the contrary, Singh *et al.*[5] found that the winter monsoon circulation (northeasterly winds) over the Arabian Sea region was at its weaker mode during the cold phases. They put forth a hypothesis that might explain a plausible mechanism responsible for reduction in winter monsoon circulation during the northern hemisphere cold phases over the Indian region. They suggested the role of southwardly positioned and intensified westerly airflow over the Arabian Sea during the stadials in the weakening of northeasterly winds. However, further research and modelling efforts are required to test this hypothesis.

This new finding[5] on the Indian winter monsoon history has major impact on our present understanding of the dynamics of monsoon variability and its governing factors on regional and global scales, and also on our capability of simulating predictive models. The new data[5] provoke further research on the Asian monsoon system, as this study demonstrates a decoupled winter monsoon evolution in its two components, the India and the East Asian sectors at the shorter timescale. The finding of a reduction in strength of summer and winter monsoon synchronously in the Indian region during northern hemisphere cold phases is intriguing. This study might provide an insight into understanding the mechanisms of monsoon variability that operate differently over Asia on different timescales.

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