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Feeling the Earth's pulse from global monsoon records

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While Quaternary paleoclimatologists are still puzzled by the absence of 400-kyr signals in the ice-age records ("the 400-kyr problem"), the low frequency cycles have come to emerge in the quantitative Paleogene and Neogene paleo-climate records. Of particular interest is the 400-kyr long eccentricity which is considered as "the tuning fork of geological time" used in cyclostratigraphy since the early Mesozoic (Matthews and Froelich, 2002), and as the "heartbeat" of the climate system in the Oligocene (Palike et al., 2006). The long eccentricity cycle is amplified inδ^{13}C records by the long residence time of carbon in the ocean, with heaviest values of carbon (δ^{13}Cmax) and oxygen isotopes occurring at eccentricity minimum. Although the 400-kyr cycle disappeared from the Pleistocene isotope records, it was replaced by a 500-yrs cycle in the carbon isotope records of the last million years (Wang et al., 2003; 2004), and the δ^{13}C and δ^{18}O sequences became decoupled at the long eccentricity band since 1.6 Ma. Why the "arrhythmia" occurs in the "heartbeat" records of the climate system ?

To explain the phenomena, isotopic and other climate records over the last 5 myr from various oceans were examined. In the Pliocene, the long eccentricity cycles existed not only in the oceanic carbon reservoir (carbon isotope and carbonate content), but also in proxies such as eolian dust flux, weathering intensity, and ocean productivity, all related to monsoon circulations. Since the global summer monsoon intensity is controlled by precession, and the amplitude of climate precession is modulated by eccentricity, we hypothesize that the observed 400-kyr cycles in oceanic carbon reservoir originate from the global monsoon intensity. The co-variations of δ^{13}C and δ^{18}O until the Pliocene may imply a coupled response of hydrological processes and oceanic carbon cycling to the precession-driven low-latitude processes, the global monsoon. Quaternary δ^{13}Cmax events (δ^{13}Cmax-II around 0.5 Ma, δ^{13}Cmax-III around 1.0 Ma) neither correspond to eccentricity minimum nor δ^{18}O maximum, but likely repre-

sent climate episodes when the carbon reservoir and the upper ocean structure in the global ocean experienced profound reorganization, most probably associated with abnormally intensive global monsoons.

Therefore, paleo-monsoon should be studied on a global scale rather then as local or regional phenomena only. The oceanic carbon reservoir does not passively follow ice-sheet changes, but has its own response to orbital forcing and its own history. As the Earth system is now again passing through a new eccentricity minimum and a new carbon event (δ^{13}Cmax-I), it is crucial to feel the "heartbeat" of the Earth system and to understand the physical and climatic meanings of the long-term carbon cycles.