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Subtropical Lacustrine Geochemical Evidences for Holocene East Asian Monsoon Instability: Links to Solar and Tropical Pacific Forcing

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The detailed (∼80-100 yr resolution), radiocarbon dated (8 AMS and 2 conventional dates to ∼10250 cal yr BP) subalpine sedimentary geochemical records of Retreat Lake in subtropical Taiwan document the unstable East Asian monsoon (EAM) climate during the Holocene with abrupt and large-scale changes in its intensity. The well-defined geochemical records of total organic carbon, carbonorganic: nitrogentotal ratio, magnetic susceptibility, chemical index of alteration, Rb/Sr ratio, and K/Rb ratio demonstrate clear, long-term patterns of Holocene EAM: cool, glacial conditions with weakest EAM during the early Holocene (∼10250-8640 cal yr BP), the strongest EAM during the Holocene optimum (8600-4500 cal yr BP) with minor, centennial-scale fluctuations, and relatively dry conditions due to weakness/failure of monsoon after 4500 cal yr BP. The onset of postglacial EAM was abrupt, occurring within the decades (8640-8600 cal yr BP), along with the initiation of Megahumid Holocene optimum. Detrital records such as Ti, Zr, Ti-based detrital %, molar SiO2/Al2O3, and detrital quartz counts authenticate the EAM instability and also strongly exhibit the presence of few weak monsoon periods (7040, 6600, and 5610 cal yr BP) within the Holocene optimum. The geochemical records of Retreat Lake exhibit strong correlation with climatic records from China, marginal seas of the western tropical Pacific, West Pacific Warm Pool, and far distance areas including South America, the Gulf of Mexico, the North Atlantic, and the Northern Hemisphere, thus providing robust evidences for globally-mediated current, interglacial climate. Although our records broadly correlate with solar activity after ca.8600 cal yr BP, the abrupt phase shifts and the weak monsoon intervals consistent with stalagmites and marine records lead us to link mechanisms that are related to ocean-atmospheric interactions. The heat transport from western tropical Pacific to North Pacific by warm Kuroshio Current and the development of late Holocene El-Niño-Southern Oscillation appears to corroborate the Holocene EAM changes, especially at two phase shifts, early to mid-Holocene (8640-8600 cal yr BP) and mid- to late Holocene (ca.4500 cal yr BP) transitions. Our study specifies the importance of additional, high-resolution climatic records in subtropical Taiwan and along the path of Kuroshio Current to establish more precise land-sea correlation and, in turn, to strengthen the monsoon, tropical Pacific, and ENSO linkage.