Climate forcing the evolution of East Asian summer monsoon precipitation since the Miocene evidenced by Mg isotopes in Chinese loess deposits

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Interactions between the solid Earth and climate, both on local and global scales are increasingly being considered as crucial for the Earth's habitability. The most dramatic example of the solid Earth affecting climate is the proposed relationship between the Tibetan Plateau (TP) growth and global cooling during the Cenozoic as well as the initiation and development of the East Asian monsoon, which provides a large amount of precipitation to densely populated areas in East Asia. Thus, further investigation on the EASM evolution could set a typical example to explore the detail association between solid earth and atmospheric processes, and then for future climate prediction and human sustainable development.

To date, the evolution of the East Asian summer monsoon (EASM) is highly debated. It was either continuous fade following the global cooling trend or staged enhancement with the TP uplifting. The disputes mainly came from the differential of EASM proxies, because different proxies likely contained multiple different EASM signals, such as precipitation, temperature, chemical weathering, vegetable biomass and seasonality. Furthermore, one EASM signal may be different to the others in evolving history, and mixing of multiple EASM signals may be more complex. Besides, changes in provenance or grain size were also the potential factors that influence the interpretation of the EASM signals. Thereafter, hunting for reliable proxies that could separate the different EASM signals are essential to reveal the EASM evolution as well as possible forcing.

In our work, the EASM precipitation (EASM-P) was separated and reconstructed since the Miocene by a reliable precipitation proxy of magnesium isotopic composition of the secondary carbonates ($\delta^{26}Mg_{sc}$) from the Chinese loess aeolian deposits. The $\delta^{26}Mg_{sc}$-based EASM-P shows pulsed enhancement that was high around ~19.5 Ma, during ~17-13.5 Ma, at ~10 Ma and became the highest during the interglacial periods after ~2.6 Ma, additionally with large fluctuations after ~7 Ma and especially after ~2.6 Ma. Our results was supported by previous precipitation proxies of magnetic susceptibility and carbonate content from the Chinese loess deposits and clastic mass accumulation rate from the South China Sea. Comparison to possible driving factors suggested that the precipitation evolution was mainly controlled by changes in global temperature and Walker Cycle intensity, rather than by the Tibetan Plateau growth.