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The mystery of glacial terminations: evidence from Asian Monsoon records and their global correlations

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A new high-resolution and precisely dated Asian Monsoon (AM) record from Sanbao Cave, Central China characterizes glacial Terminations III and IV (T-III and T-IV) in detail. Similar to Terminations I and II (T-I and T-II) respectively, T-III and T-IV have double and single Weak Monsoon Intervals (WMIs) respectively. Analogous to our T-II correlation between a WMI and a major ice-rafted debris (IRD) event (Heinrich Event 11) recorded in North Atlantic sediments (ODP 980), we correlate a double IRD event with a double WMI around T-III. ODP 980 also has single prominent IRD event around T-IV which has a nominal duration very similar to the length of the single WMI around AM T-IV. This further supports the validity of our strategy for correlating AM WMIs to North Atlantic IRD events. Similar to our correlations between the AM and atmospheric CH_4 during T-I and T-II, the abrupt AM jumps near T-III ($\sim$242.6 ky BP) and T-IV ($\sim$336 ky BP) can be correlated to analogous abrupt CH_4 jumps recorded in Antarctic ice. Based on these marine and ice core correlations, most of the large T-II and T-IV shifts recorded at Vostok (Antarctic temperature, CO_2 and CH_4) took place during WMIs, times when not only the AM was weak but also Greenland temperatures were likely cold. The δ^{18}O of seawater or sea-level (inferred from δ^{18}O of benthic foraminifera) began T-III and T-IV shifts at the beginning of the WMIs, and reached values close to interglacial values by the end of the WMIs. The timing of the past four terminations, as established with U-Th ages of the cave deposits and our IRD and CH_4 correlations, is consistent with orbital forcing of an ice sheet pre-disposed

to collapse, perhaps because of large ice sheet volume, coupled with isostatic compensation. Once a termination starts, input of fresh water and icebergs into the North Atlantic Ocean may slow North Atlantic meridional overturning circulation and promote sea-ice formation. Resulting North Atlantic/European cooling could weaken the AM through atmospheric teleconnections, yielding the observed WMIs. This reorganization of both atmospheric and oceanic circulations would set the bipolar see-saw to the warm-south mode, resulting in the observed temperature rise in Antarctica, reduction of southern sea ice, and a southward shift of the Southern Hemisphere westerlies. One or both of the latter would promote ventilation of respired CO_2 from the ocean. The resulting (observed) increase in atmospheric CO_2 would further global warming, amplifying northern ice sheet melting, and could generate positive feedbacks to atmospheric CO_2 related to mechanisms involving ties to sea level. This termination mechanism is consistent with many old and new observations made by the scientific community over the years, and placed on an absolute time-scale through the strategies outlined above.