What controls the pacing of 100-ky glacial cycles?

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Climate variations over the last ˜700,000 years are characterized by orbital periodicities of 100, 41 and 23 ky. While 23- and 41-ky components are understood as linear climatic responses to forcing by precession (modulated by eccentricity) and obliquity, respectively, the 100-ky cycle cannot be explained as a linear response to eccentricity. Rather, it has been suggested that the 100-ky cycle is caused by skipping of higher frequency beats which results in the bundling of either 4 or 5 precession cycles (Raymo, Paleoceanography, 1997), or 2 or 3 obliquity cycles (Huybers and Wunsch, Nature, 2005), each grouping resulting in an average 100 ky periodicity. However, verification of these competing hypotheses has not been possible because of the lack of accurately dated climate proxies. Here, using statistical tests of newly established chronology of Antarctic climate (Kawamura et al., AGU 2006 fall meeting), we show that precession pacing is statistically more significant than obliquity pacing for the last five glacial terminations. We used the timings of Antarctic warmings at terminations from the Dome Fuji ice core for termination I to III, and from the Vostok core for termination IV. The timing of termination V was estimated by shifting the Dome C (EDC2) timescale to match the timing of peak MIS 11.3 with the Vostok record. Our results show that the null hypothesis for precession pacing can be rejected at the 5 % significance level for the last five terminations from ice cores, whereas the null hypothesis for obliquity pacing cannot be rejected. The statistical power of test for obliquity is high (98%) owing to the high accuracy of the chronology. Our results are consistent with the hypothesis that high northern latitude summer insolation is the primary pacemaker of the late Pleistocene glacial cycles.