Geophysical Research Abstracts, Vol. 7, 06300, 2005
SRef-ID: 1607-7962/gra/EGU05-A-06300

Quantifying the Northern Hemisphere Glaciation

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The Northern Hemisphere Glaciation (NHG) in the Pliocene was a climatic change from a greenhouse world to a state with periodically waxing and waning ice sheets. Marine sedimentary records of ice-rafted debris and oxygen isotopic composition (δ^{18}O) reveal major glacial expansions 2.5 Myr and 2.7 Myr ago. Obstacles to a quantitative and causal understanding of the NHG are that δ^{18}O reflects not only ice volume but also regional water temperature and that the NHG start (before about 3 Myr) has not yet been accurately estimated. We use 45 δ^{18}O records from benthic and planktonic foraminifera and globally distributed sites to reconstruct the dynamics of the NHG. We compare the δ^{18}O amplitudes with those of temperature proxy records and estimate the global ice-volume related increase. By extracting the ice-volume signal from the data we find that the NHG started several hundred thousand years earlier than previously assumed, and ended at 2.4 Myr. This long-term increase points to slow, tectonic forcing such as closing of ocean gateways or mountain building, as the root cause of the NHG. We discuss a few of such mechanisms. We present geographical maps of deep and bottom water oceanic cooling across the NHG, estimate the increase in ^{18}O variability across the NHG, show a new Pliocene biomagnetostratigraphic timescale and quantify the time constant of fluctuations in Northern Hemisphere ice mass.