Geophysical Research Abstracts
Vol. 18, EGU2016-13850, 2016
EGU General Assembly 2016

Critical insolation-CO_2 relation for diagnosing past and future glacial inception

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Past rapid growth of Northern Hemisphere continental ice sheets, which terminated rather stable and warm climate periods, is generally attributed to reduced summer insolation in boreal latitudes (Milanković , 1941; Hays et al., 1976, Paillard, 1998). Yet pertinent summer insolation is near to its minimum at present (Berger and Loutre, 2002), and there are no signs of a new ice age (Kemp et al., 2011). This challenges our scientific understanding of the mechanisms driving glacial cycles and our ability to predict the next glacial inception (Masson-Delmotte et al., 2013). Here we propose a fundamental functional relationship between boreal summer insolation and global CO_2 concentration, which explains the beginning of the past eight glacial cycles and can anticipate future periods when glacial inception may occur again. Using a simulations ensemble generated by an Earth system model of intermediate complexity constrained by paleoclimatic data, we show that glacial inception was narrowly missed before the beginning of the Industrial Revolution. This can be explained by the combined effect of relatively high late-Holocene CO_2 concentration and low orbital eccentricity of the Earth (Loutre and Berger, 2003). Additionally, our analysis shows that even in the absence of human perturbations no significant buildup of ice sheets would occur within the next several thousand years and that the current interglacial would likely last for another 50,000 years. However, moderate anthropogenic cumulative CO_2 emissions of 1000 to 1500 GtC may already postpone the next glacial inception by at least 100,000 years (Archer and Ganopolski, 2005; Paillard, 2006). Our simulations demonstrate that under natural conditions alone the Earth system would be expected to stay in the delicate interglacial climate state, steering clear of both large-scale glaciation of the Northern Hemisphere and its complete deglaciation, for an unusually long time.