

The role of volcanism for abrupt climate change during the last glacial period

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During the last glacial period, abrupt climate events known as Dansgaard-Oeschger (DO) and Heinrich events have been observed in various types of Northern Hemispheric paleoclimate archives. It has been speculated that volcanism may play a role in the abrupt climate variability, for example as a trigger of abrupt changes. The investigation of a possible link between abrupt climate events and volcanic eruptions has been hampered by the

lack of a global volcanic eruption record from the last glacial period. A recent identification of 80 major bipolar volcanic eruptions in Greenland and Antarctic ice core records within the interval 12-60 ka BP now enables us to investigate this link. Here we test the possible relation between global volcanism and the onset of DO events in a statistical framework under the null hypothesis of random and memoryless volcanic activity.

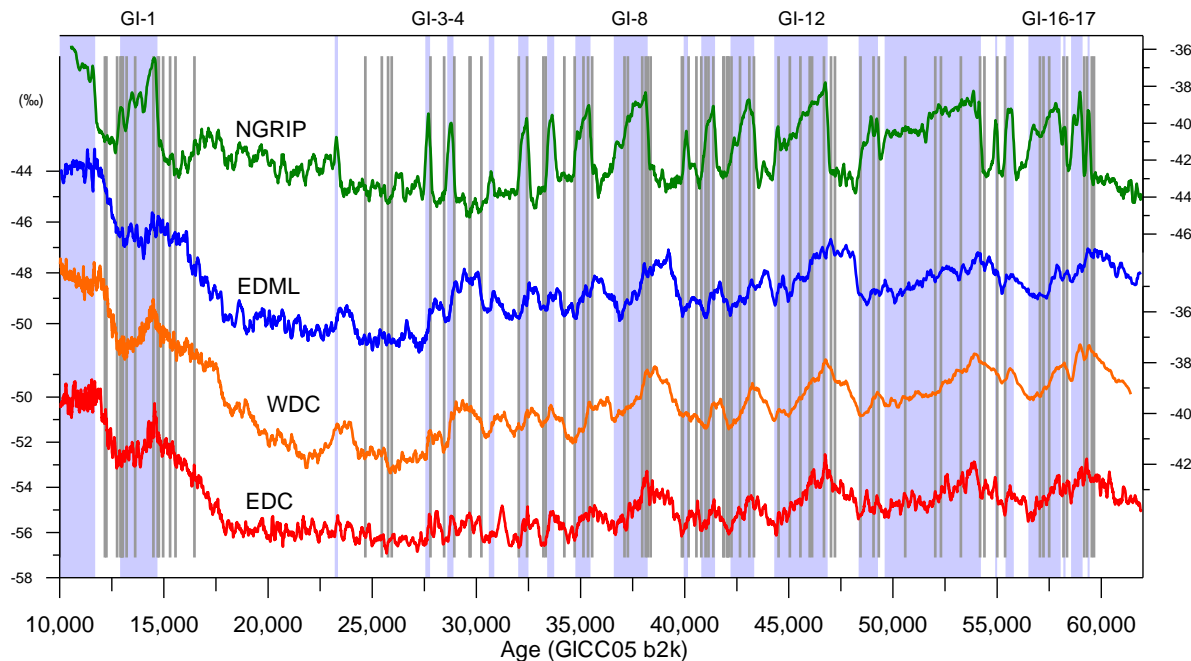
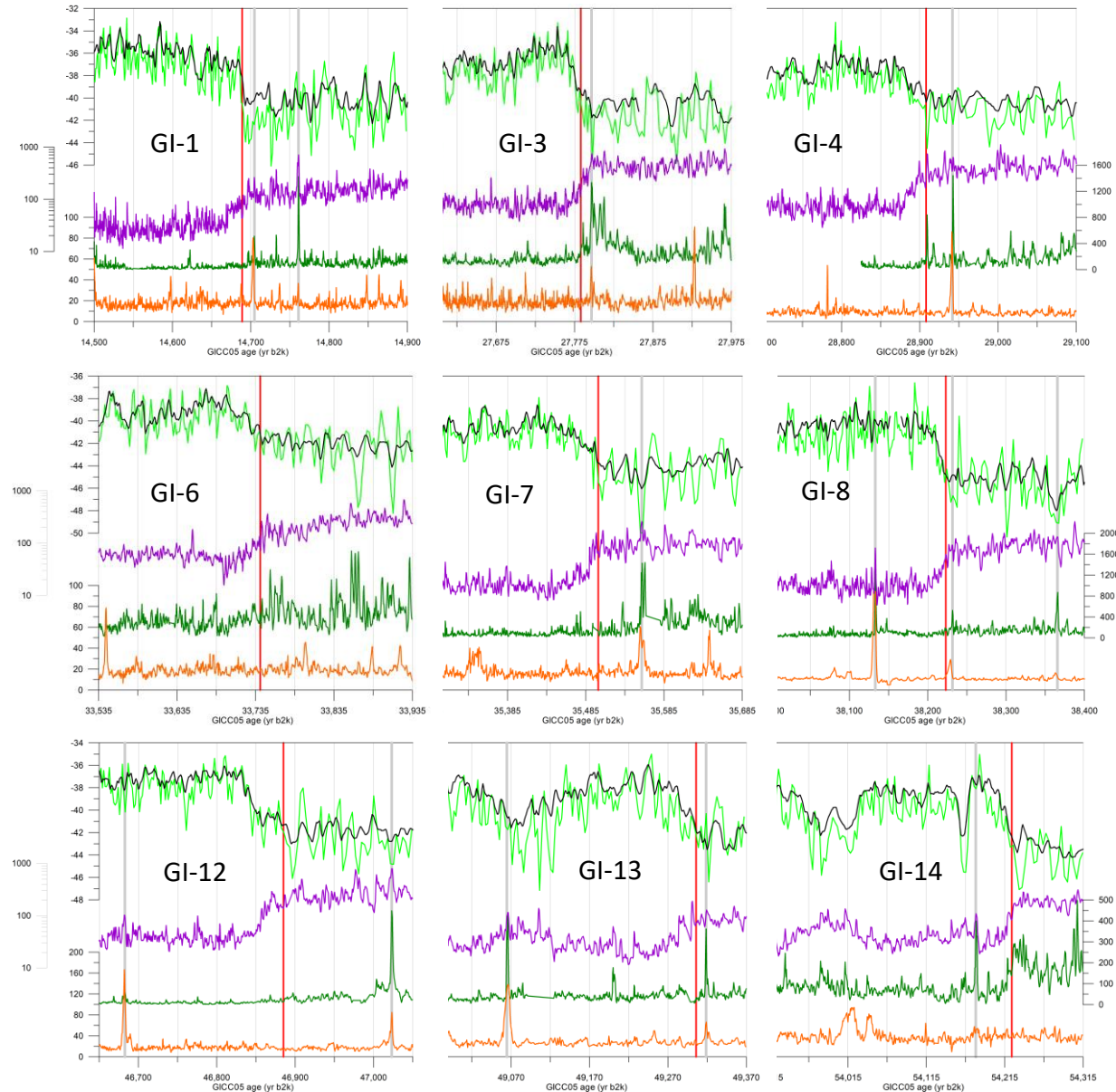
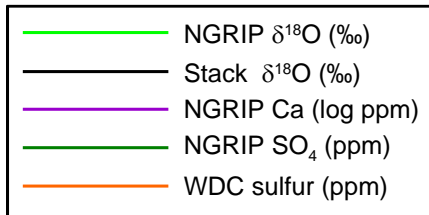


Figure 1. The phasing of Greenland (NGRIP) and Antarctic (EDML, WDC, and EDC) ice-core climate records ($\delta^{18}\text{O}$) throughout the 10-60 ka time interval based on volcanic matching (Svensson et al., CPD, 2020). Grey vertical lines show the position of 80 bipolar volcanic match points, and blue-shaded intervals indicate the Greenland Interstadial (GI) periods. The bipolar synchronization of the 16.5-24.5 ka interval is tentative as there are no bipolar match points in that interval.



Phasing of global volcanism and DO onsets

Figure 2. Examples of DO warming events as they appear in Greenland water isotopes ($\delta^{18}\text{O}$) in NGRIP and in a stack of four cores, in NGRIP Calcium concentrations (log scale), in NGRIP sulfate concentrations and in the Antarctic WDC sulfur concentrations. Red vertical lines indicate the start of the warming transition based on the stacked $\delta^{18}\text{O}$ record. Grey vertical lines indicate the positions of bipolar volcanic eruptions.



Results and conclusion

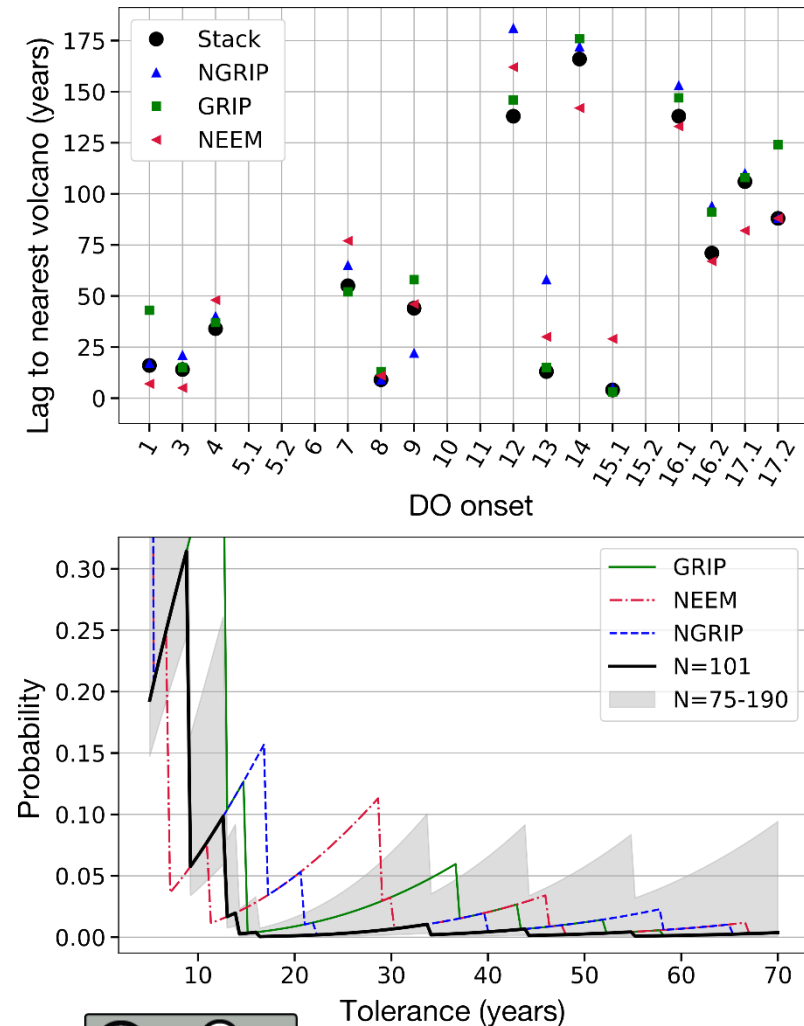


Figure 3 (right). Examples of the identification of the start of DO warming transitions (red dotted line) based on the $\delta^{18}\text{O}$ record (blue curve). The vertical yellow line indicates the position of the nearest large volcanic eruption before the onset.

Figure 4 (top left). Time lag to nearest bipolar volcanic eruption occurring before the start of a DO warming transition. The start of the DO onset is determined separately from the $\delta^{18}\text{O}$ record in three Greenland ice cores and for a stack of the three. The variability in the time lag among the cores mainly reflects the different shapes of the onsets in the cores.

Figure 5 (bottom left). p-value for the observed number of volcanic eruptions to occur within a time window (tolerance) before the DO event onsets under the null hypothesis that volcanoes occur as a random, memory-less process, independent of DO events. For $p < 0.1$ we can reject the null hypothesis at 90% confidence. N refers to the number of large volcanic eruptions occurring in the interval 12-60 kyr BP. The list of 80 bipolar eruptions indicated in Fig. 1 is not exhaustive, and the total number of large eruptions is neither known nor well defined.

In conclusion, there are large volcanic eruptions occurring within 25 years before the onset of DO events in 5 out of 20 events. For 10 out of 20 events there is no relation between the DO onset and volcanism (lag > 100 years). To investigate the relation further we need to better constrain the total number of large volcanic eruptions during the last glacial.

