



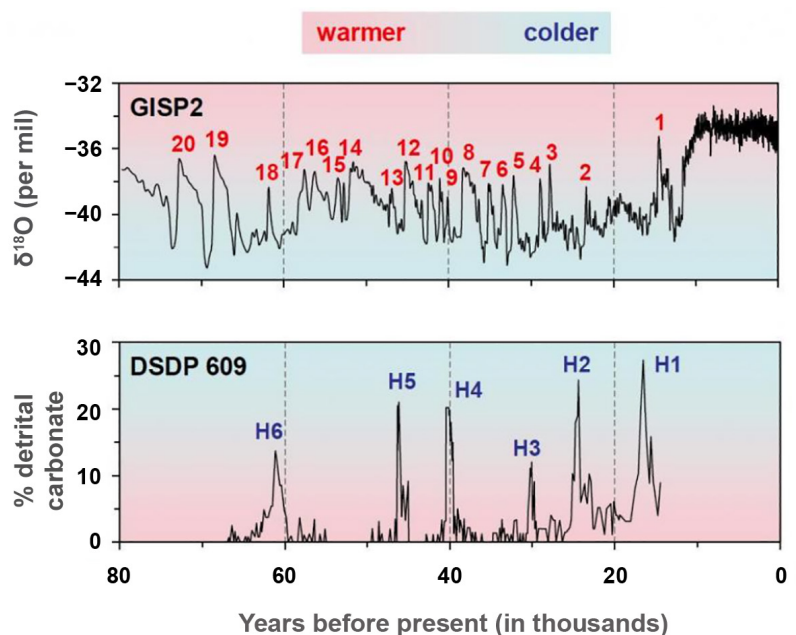
Heinrich and Dansgaard–Oeschger Events

Climate during the last glacial period was far from stable. Heinrich and Dansgaard–Oeschger events occurred repeatedly throughout most of this time.

Scientists Willi Dansgaard and Hans Oeschger first reported the Dansgaard–Oeschger (D–O) events in Greenland ice cores. Each of the 25 observed D–O events consisted of an abrupt warming to near-interglacial conditions that occurred in a matter of decades and was followed by a gradual cooling.

Related to some of the coldest intervals between D–O events were six distinctive events, named after paleoclimatologist Hartmut Heinrich, that are recorded in North Atlantic marine sediments as layers with a large amount of coarse-grained sediments derived from land. These layers, which are continuous across large areas of the North Atlantic, are evidence for both an increase in icebergs discharged from the Laurentide ice sheet in North America and a southward extension of cold, polar waters ([Bond et al. 1992](#)). Icebergs carry sand-sized grains eroded by ice sheets.

When icebergs encounter warmer ocean water, they melt and drop their sediment load onto the seafloor. A southward extension of cold, polar waters allowed icebergs to travel farther before melting. Heinrich events occurred less frequently than D–O events. D–O events repeated every several thousand years on average, while ~10,000 years elapsed between Heinrich events. Neither of the two types of events is strictly periodic, however.



The $\delta^{18}\text{O}$ record from the GISP2 ice core in Greenland (top), showing 20 of the 25 observed Dansgaard–Oeschger events during the last glacial period ([Grootes et al. 1993](#)). A record of ice-rafted material during Heinrich events (bottom) from a deep-sea core in the North Atlantic ([Bond and Lotti 1995](#)).

What caused Heinrich and Dansgaard–Oeschger events?

The cause of these glacial events is still under debate. During the last glacial time, large ice sheets rimmed the North Atlantic. At certain times, these ice sheets released large amounts of freshwater into the North Atlantic. Heinrich events are an extreme example of this, when the Laurentide ice sheet disgorged excessively large amounts of freshwater into the Labrador Sea in the form of icebergs. Scientists have hypothesized that these freshwater dumps reduced ocean salinity enough to slow deepwater formation and the thermohaline circulation. Since the thermohaline circulation plays an important role in transporting heat northward, a slowdown would cause the North Atlantic to cool. Later, as the addition of freshwater decreased, ocean salinity and deepwater formation increased and climate conditions recovered.

Evidence for changes in deepwater formation supports the freshwater forcing hypothesis. Measurements from deep-sea sediments in the North Atlantic indicate reduction of deepwater formation during Heinrich events ([McManus et al. 2004](#)). Evidence for freshwater forcing and reduced deepwater formation during D-O events is more ambiguous. The initial trigger for freshwater releases has not yet been identified. One suggestion is that small, gradual changes in solar output could have influenced the timing of abrupt changes. Other ideas call upon natural oscillations of the ice sheets themselves or of ocean processes.

How widespread were climate changes?

Heinrich and D-O events had a global footprint. During cold phases in the North Atlantic, large regions of North America and Eurasia became colder and drier ([Benson et al. 1996](#); [Allen et al. 1999](#); [Genty et al. 2003](#); [Wagner et al. 2010](#); [Asmerom et al. 2010](#)). A southward shift of the tropical rain belt caused drier conditions in the Northern Hemisphere while moistening many parts of the Southern Hemisphere ([Wang et al. 2001](#); [Cruz et al. 2005](#); [Leduc et al. 2007](#); [Kanner et al. 2012](#); [Deplazes et al. 2013](#)). Antarctic ice cores show warming, consistent with a reduction of northward heat transport from the Southern Hemisphere ([Brook et al. 2005](#); [EPICA Community Members 2006](#)). The climate anomalies are consistent with a slowdown of the thermohaline circulation and reduced ocean heat transport into the northern high latitudes.



An iceberg spotted from NOAA Ship Fairweather during a mission to map areas of the Arctic. (NOAA)

Some important datasets related to Heinrich and Dansgaard–Oeschger events:

- [Bond et al. \(1992\)](#), ice-rafted material from marine sediment cores in the [North Atlantic](#)
- [Grootes et al. \(1993\)](#), ice core $\delta^{18}\text{O}$ from [GISP2](#) in Greenland
- [Benson et al. \(1996\)](#), lake sediment data from [Owens Lake](#) in California
- [Allen et al. \(1999\)](#), pollen from [Lago Grande di Monticchio](#) in Italy
- [Wang et al. \(2001\)](#), speleothem record from [Hulu Cave](#) in China
- [Genty et al. \(2003\)](#), stable isotopes from [Villars Cave](#) in France
- [McManus et al. \(2004\)](#), sediment geochemistry of core [OCE326-GGC5](#), Bermuda Rise
- [Brook et al. \(2005\)](#), stable isotopes from [Siple Dome](#) ice core in West Antarctica
- [EPICA Community Members \(2006\)](#), stable isotopes from [Dronning Maud Land](#) ice core in Antarctica
- [Cruz et al. \(2005\)](#), speleothem record from [Botuvera Cave](#) in Brazil
- [Leduc et al. \(2007\)](#), ocean sediment records from the [Pacific Ocean](#)
- [Asmerom et al. \(2010\)](#), speleothem record from [Fort Stanton Cave](#), New Mexico
- [Wagner et al. \(2010\)](#), speleothem record from [Cave of the Bells](#), Arizona
- [Kanner et al. \(2012\)](#), speleothem record from [Pacupahuain Cave](#), Peru
- [Deplazes et al. \(2013\)](#), ocean sediment records from the [Cariaco Basin and Arabian Sea](#)