

## View point

What is what in the ice and the ocean?

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### **Abstract**

**The recently released North Greenland Ice core Project (NGRIP) data document several rapid abrupt climate changes affecting the Northern Hemisphere in the last 110 000 years. In particular, the new core shows high-resolution succession of expressed warm and cold episodes, which occurred during marine isotope substages MIS 5d**

**Some of these variations were reported earlier from the GISP2 and GRIP ice cores. In the NGRIP core, following the Intimate group recommendations, the oscillations were given labels, which are in part the same as in the marine isotope system of deep-sea sediments, but which in part are obviously not coeval. Here we recommend honoring the originally published marine designations to the maximum extent possible, but distinguishing them by a prefix referring to their recognition in the ice**

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The need for worldwide chronology requires Quaternary geoscientists to describe and label the different successions of recognized past climate episodes. Stratigraphical rules call to first define locally name at particular sites and only later integrate them into more general climatostratigraphic units of worldwide value (International Subcommission on Stratigraphic Classification, 1976; Murphy and Salvador, 1999). The practice resulted in Quaternary literature full of local names of past climate oscillations recognized from different biologic, lithologic, geochemical and geophysical paleoclimate proxies. The marine isotope stratigraphy (Emiliani, 1955; Shackleton, 1969) has been shown to be the most regionally uniform system, with a close to a world-wide validity. It is now generally recognized as a basic past climatostratigraphic subdivision.

Comparisons between the marine and terrestrial stratigraphic systems are not always based on reliable information. This holds, for example, for the correlation of the terrestrial Eemian with the marine isotope stage 5. As shown by Shackleton (Emiliani, 1955; Shackleton, 1969) only the substage MIS 5e is coeval with the European continental Eem, but only in its type area in The Netherlands (Amersfoort) (Kukla et al., 1997; Sanchez-Goni et al., 2000; Shackleton et al., 2002). Further South the Eemian forests appear to correlate not only with MIS 5e, but also with a substantial portion of subsequent MIS 5d. The comparison and correlation between land and marine records are in fact even more complex when considering older interglacial s.l. intervals, i.e. odd MIS. Studying the pollen content in marine cores off Portugal, Tzedakis et al. showed that MIS 7 and 9 show vegetation patterns, which are not mirrored in the isotope stratigraphy. They also indicate that the pattern described in substage 5e, with temperate vegetation persisting in MIS 5d, interval of ice growth, is not at all observed in these older intervals.

The ice core records firstly did not define any own chronostratigraphical framework but because of the correlation of the obvious relation of the climate events identified in the ice to those described in the marine cores, the marine isotope chronology has been applied also to the ice cores. Inversely some oscillations, such as the Dansgaard-Oeschger events (Dansgaard et al., 1985), or the Antarctic reversal events (Blunier et al., 1998; Jouzel et al., 1994) typical ice-core features, have been later applied worldwide applied to marine and terrestrial records. However the different nomenclatures were followed the same logic and principles, so that no confusion resulted.

Since the earlier GRIP record (Dansgaard et al., 1993; Johnsen et al., 1992), several oscillations spaced approximately 1500 years apart have been identified in Greenland, and named Dansgaard-Oeschger events (Broecker, 1994a; Broecker, 1994b; Dansgaard et al.,

1993; Ganopolski and Rahmstorf, 2001; Grootes et al., 1993). They were described as interstadials (IS), and labeled in several instances by the name of supposed continental equivalents of European pollen biostratigraphy (Dansgaard et al., 1993; Johnsen et al., 1992).

Presumed time-equivalent of these interstadials have also been described in North Atlantic deep-sea cores (Bond et al., 1993; Bond et al., 1992; Elliot et al., 2002; McManus et al., 1994). The corresponding intervals of relatively warm sea surface water were labeled Wx and numbered same way as those in Greenland ice (McManus et al., 1994). Thus for example, the IS 24 in the Greenland's NGRIP record is considered coeval with the W24 warm surface water interval in the North Atlantic. "C" labels named marine cold-water events, not always associated with ice rafting (IRD intervals). A cold water spell of any given number precedes a warm one of the same number (i.e. C24 precedes W24) (McManus et al., 1994). This nomenclature has been used in every marine record studied in the North Atlantic region since (paper Kreveld et al 2000), and permitted a good correlation with continental records (Kukla et al., 1997; Shackleton et al., 2002; Woillard, 1978).

As seen in the interval dated by the NGRIP community between 130-70 kyr (North Greenland Ice Core Project, 2004), the variation of different climate proxies (including  $\delta^{18}\text{O}$ , percentages of cold planktonic foraminifera *Neogloboquadrina pachyderma* left, percentages of non arboreal pollen, etc), in both the marine and continental records, shows remarkable resemblance in the oscillation of climate indicators (Fig. 1).

It is then highly probable that the two major cold spells appearing about 4000 years apart during the glacial inception interval are coeval and then are related to similar causes. Even that some uncertainty remains on their absolute age, their synchronicity is highly probable. They are respectively designated as C24 and C23 in the deep sea, Melisey stadial and Montaigu event elsewhere on the continent, but as stadials 25 and 24 in the Greenland ice core (Fig. 1). It is unfortunate that the designation of the cold spells in ice and marine records is made in such closely similar but obviously timely different way. The ocean designation (McManus et al., 1994) has a priority, and according to the stratigraphic rules should be recognized as those valid.

Because in the interval younger than MIS5 the synchronicity of the equally numbered zones in the ice and on the land is without question, it is highly probable that even in the lower part of the records, the major climate oscillations are coeval, and the designation of the units should be done accordingly. So why such a confusion? The INTIMATE group recommended a procedure to investigate the Last Termination and named it event stratigraphy

(Björck et al 98). Using the GRIP Greenland ice-core record, the aim was to identify events of global significance and to establish a series of isotope events, applying a top-down labeling of these events. Furthermore, recognizing and accepting the previously climatostratigraphy defined in the GRIP record (Dansgaard, Johnsen) by using the numbering of the interstadial back to IS2, the INTIMATE group proposed labeling also the stadial episodes, starting from the Younger Dryas event as Greenland Stadial 1 (GS1). Such concept is certainly valuable and deserves all our attention as this seems to be the most appropriate approach to define a reliable stratigraphic subdivision of Quaternary records. Indeed it takes into consideration that both upper and lower boundaries of a climatic event are usually diachronous from place to place, according to the location of the site investigated, the proxy used to reconstruct the event, and the age scale applied. Figure 1 shows such reality even if some tuning was performed, according to a single time scale, to align the events for a better reading. Thus the INTIMATE group expanded the approach to the whole Upper Pleistocene (Last climatic cycle) (Walker et al., 1999) "inviting Quaternary scientists to adopt an inductive approach to stratigraphic subdivision, the initial stage of which is to identify local events or sequences of events at key sites on the basis of independent evidence. The second stage is to correlate these site-specific records with the type sequence, i.e. the GRIP oxygen isotope profile, on the basis of what are considered to be comparable major events. The third step (which is perhaps the most difficult, but perhaps also the most important) is to use independent dating evidence to establish the degree of synchronicity between local and GRIP events". Applying this approach to the NGRIP record (NGRIP 2004), stadial events were then labeled downward to so-called GS26 preceding IS (Dansgaard93) or GIS 25 (NGRIP 04), following the top-down counting approach (Fig. 2,3). Such new climatostratigraphy has been then immediately used as such in the literature, adopting the stadial number but providing another prefixes, i.e. keeping the marine C for terrestrial stadials (Sirocko 04), or giving. AS for Alboran stadials (Matrat 04).

The problem stemming from using numbers in describing complicated stratigraphic records is that then the succession of recognized major subdivisions gets frozen. This requires inserting more detailed subcategories as continuing investigations imposes.

In conclusion, the preference should be given to stratigraphic designations, which would indicate known or suspected time relationships as closely as possible. We propose to renumber the ice core units in NGRIP by keeping the labels consistent with the marine cold events previously described. As suggested by INTIMATE group, these new numbers could be preceded by prefixes corresponding to the record such as GS or GIS for Greenland stadials or interstadials. Doing so this would remove potential confusion with similarly designed

earlier defined deep-sea units of different age (Matrat et al., 2004; Walker et al., 1999). However North Atlantic cold or warm water events, previously labeled Cx or Wx would then be labeled NACx and NAWx. allowing on the other hand later improvements when more information becomes available such as applied for the Last Termination (Björck 98) in Greenland GRIP ice core, for the ice rafted events in North Atlantic (Bond and Lotti)

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### Figure caption

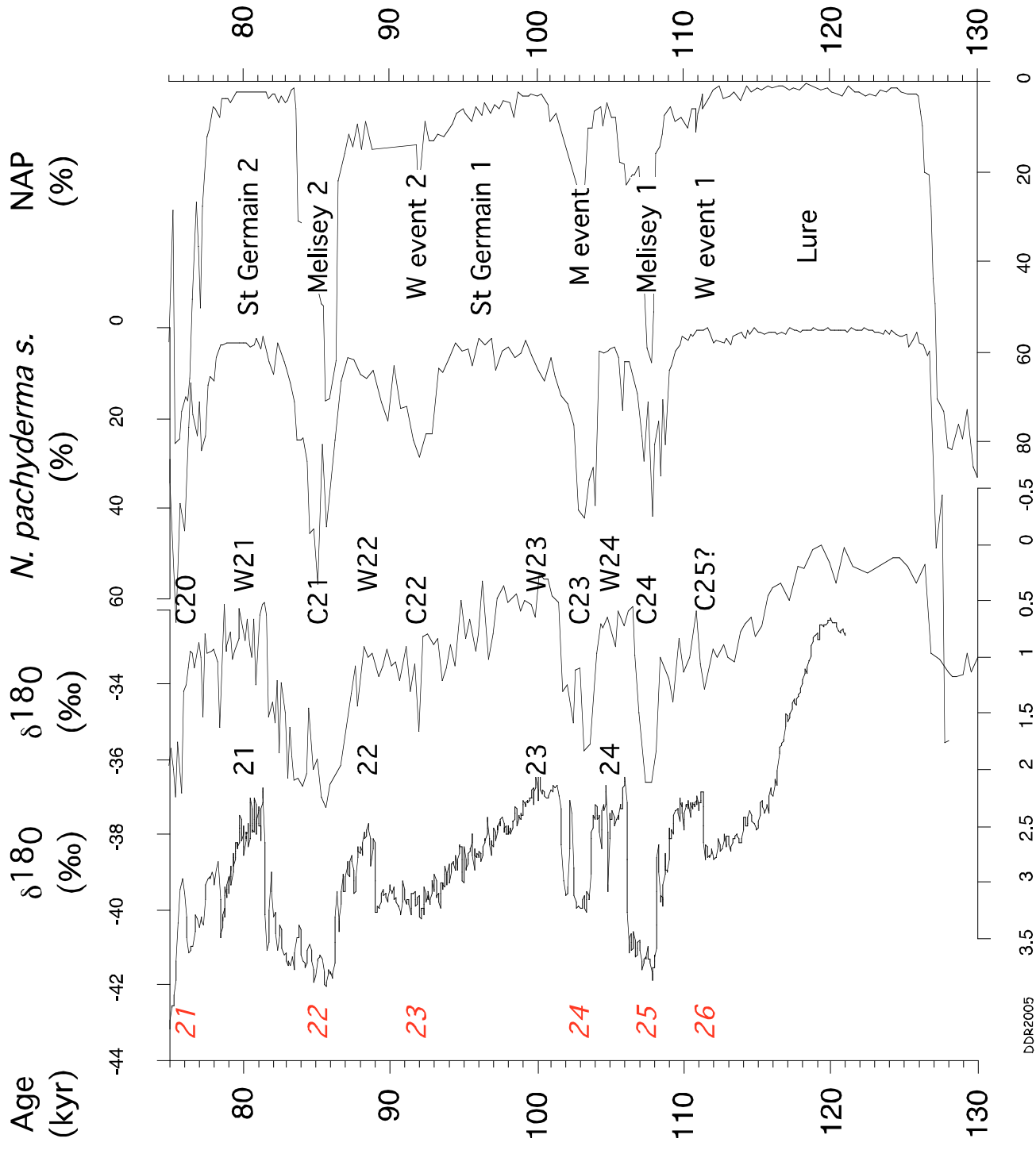
Fig. 1. Comparison of different climate proxies from ice, marine cores, and continental records for the 75-130 ka interval. All the records time scales have been tuned to the MD95-2042 chronology (Shackleton et al., 2002), as widely accepted, in order to show the irrelevance of the Greenland stadials labeling. From left to right Greenland NGRIP  $\delta^{18}\text{O}$  (North Greenland Ice Core Project, 2004), MD95-2042 planktonic  $\delta^{18}\text{O}$  (Shackleton et al., 2002), V29-191 percentages of *N. pachyderma* left (McManus et al., 1994) and Grande Pile percentage of non arboreal plants (NAP) (Kukla and Lozek, 1961; Woillard, 1978). The different labels are those originally published in the papers (see references) describing these events.

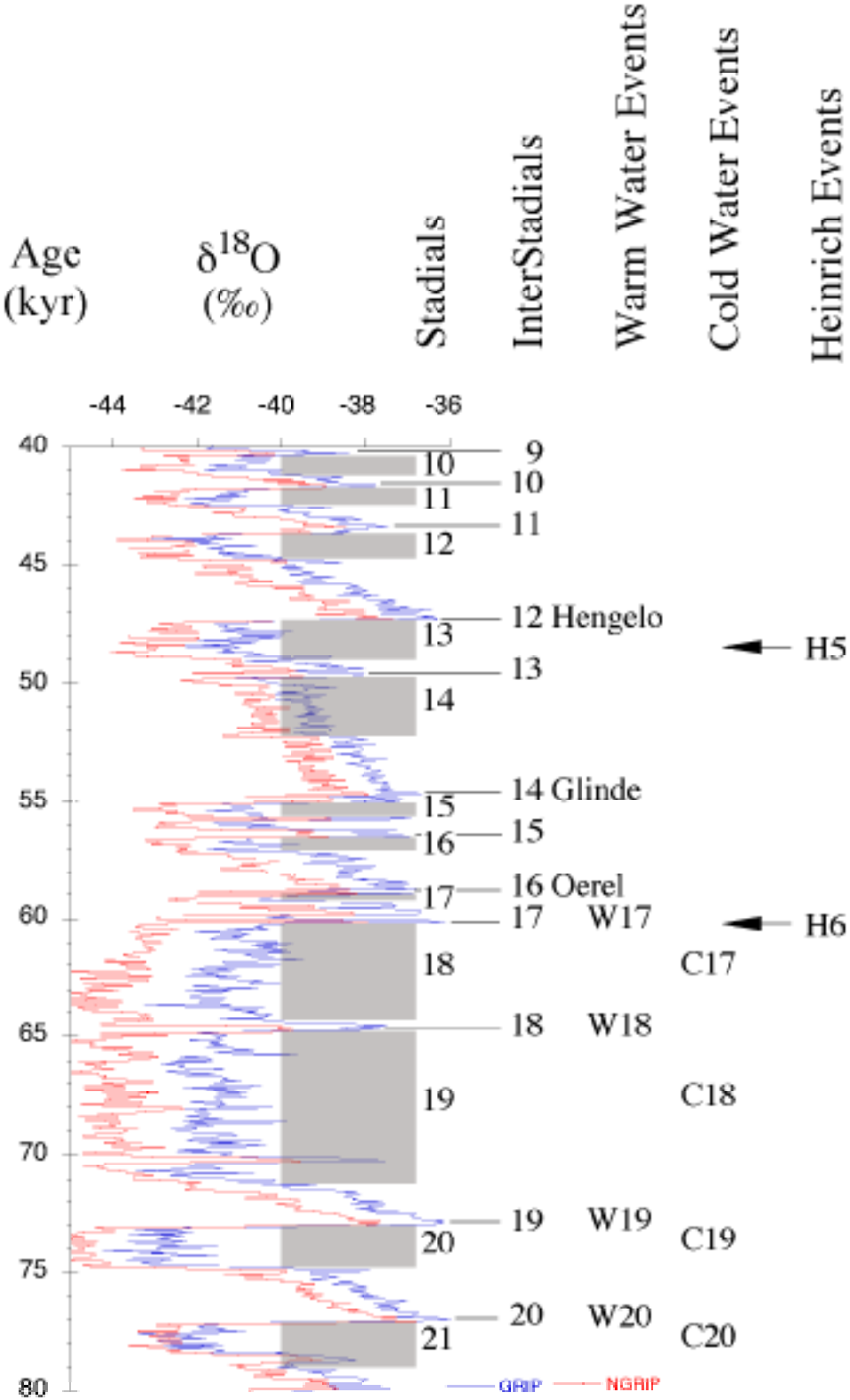
Fig. 2 Comparison of the different label protocols applied to or related to the Greenland ice cores. Because of the similarities of the ice-cores variations, we used the GRIP and North GRIP  $\delta^{18}\text{O}$  variations with the ss09sea chronology (Johnsen et al., 2001). Interstadials after Johnsen *et al.* (1992) and Dansgaard *et al.* (1993), stadials after Walker *et al.* (1999), and NGRIP (North Greenland Ice Core Project, 2004), warm water and cold water events after McManus *et al.* (1994), Heinrich events after Bond *et al.* (1992; 1995; 1999), Elliot *et al.* (1998).

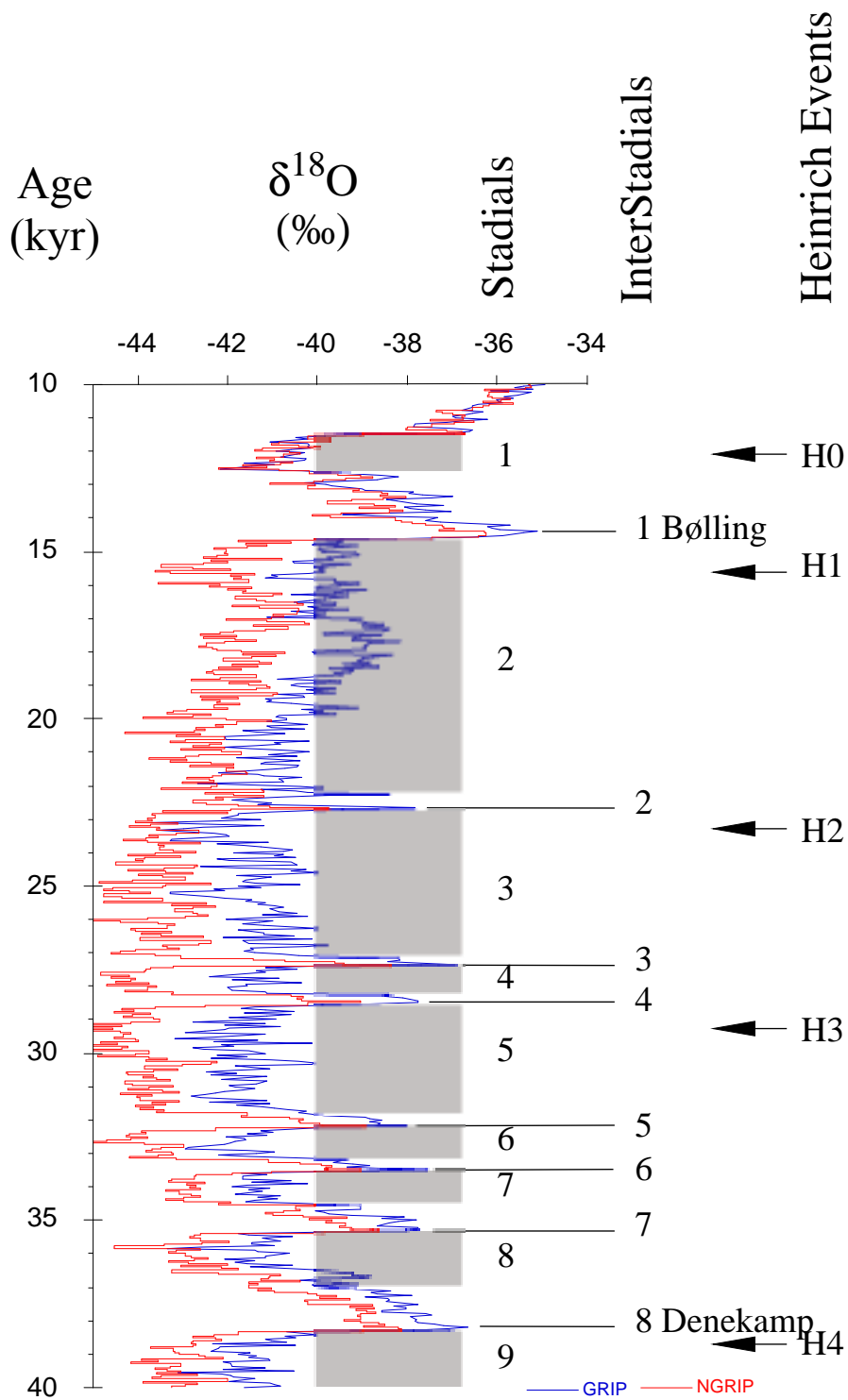
a) variation between 40 and 80 kyr ; b) variation between 10 and 40 kyr; b).

Fig. 3. Proposal for renumbered GRIP –North GRIP stadials and labels in Greenland ice cores and North Atlantic. a) between 130 and 80 kyr; b) between 80 and 40 kyr; c) between 40 and 10 kyr. Same time scale as in Fig. 2

# Greenland N. Atlantic W. Europe

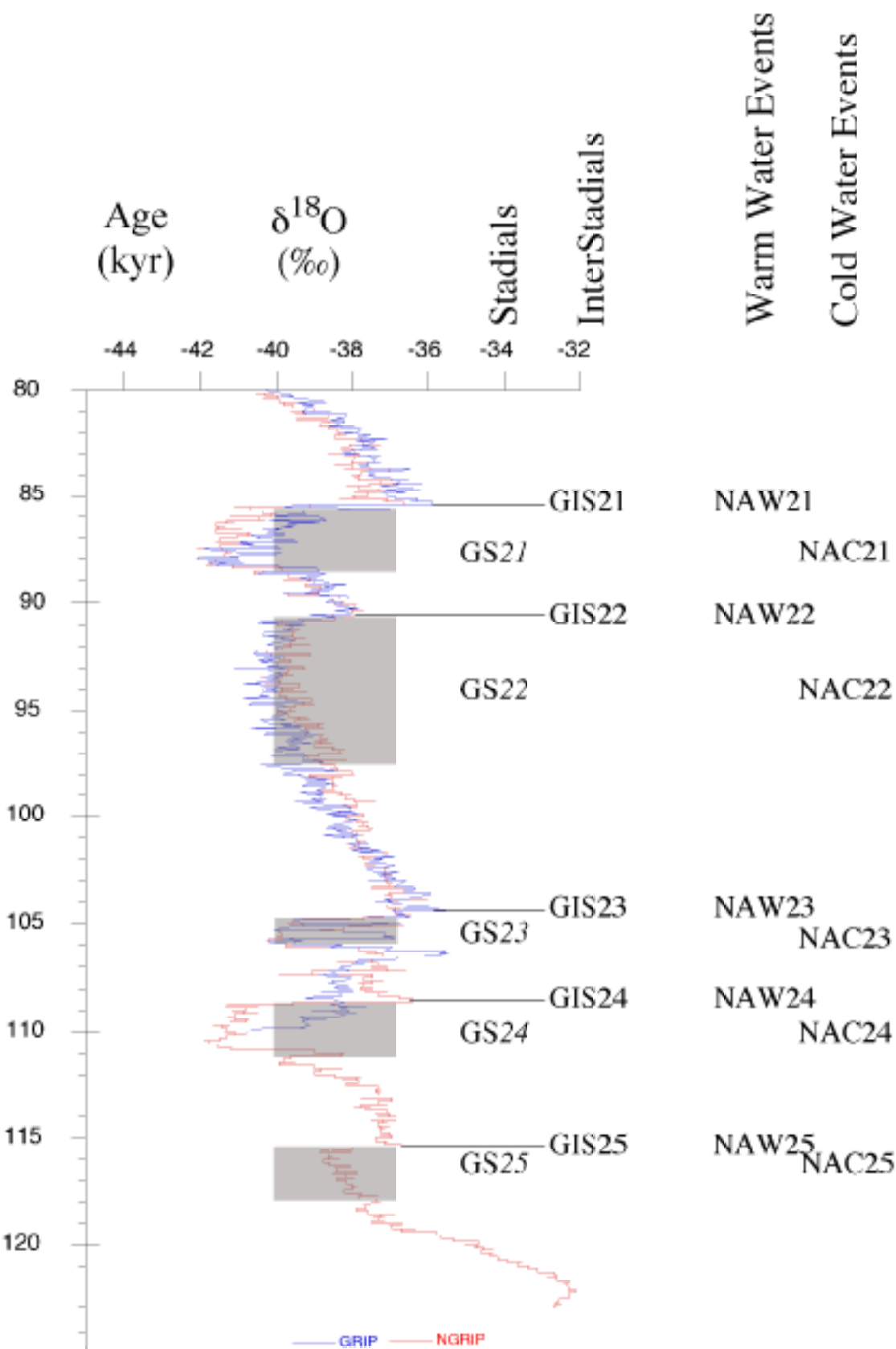






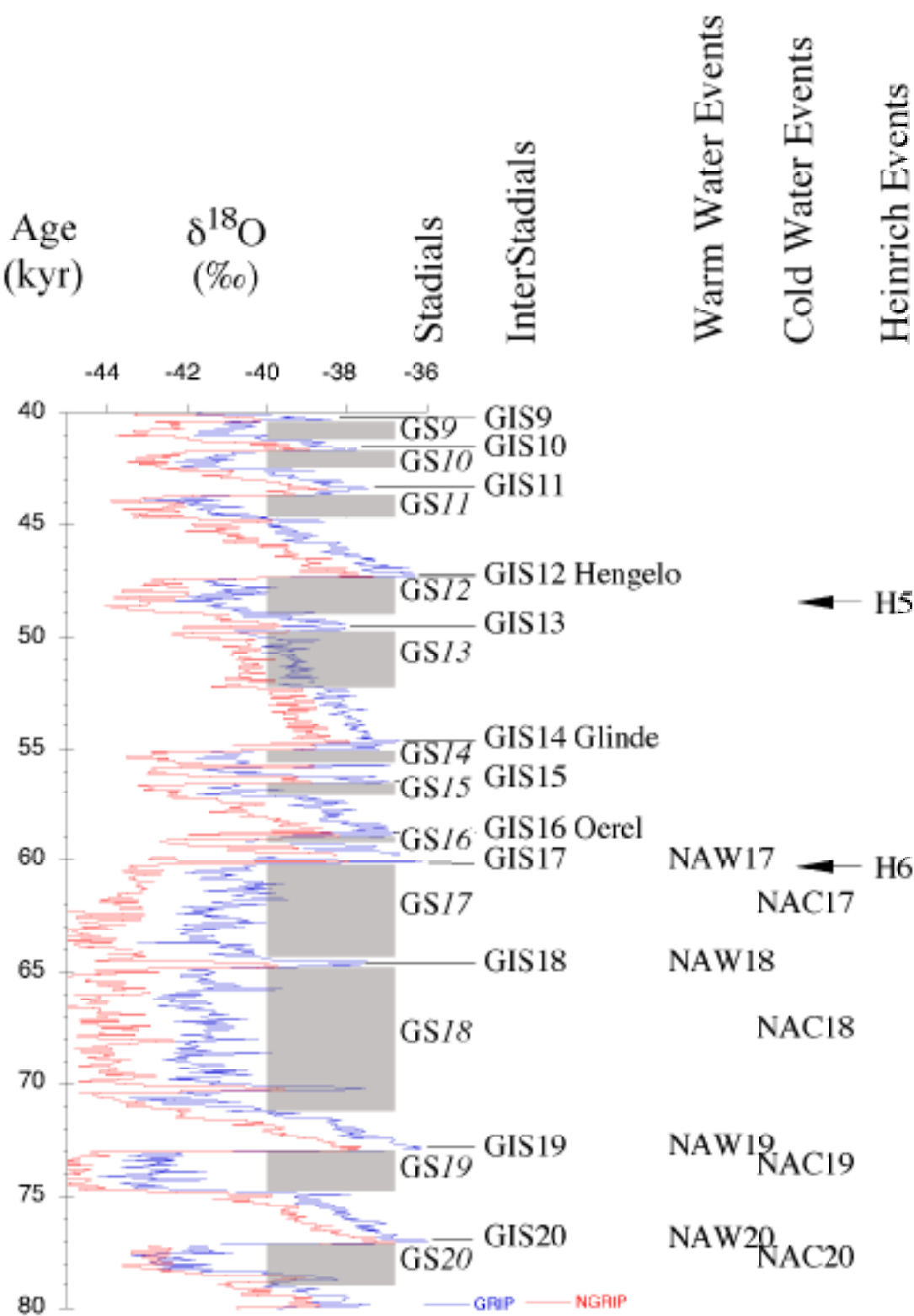
# Greenland

# North Atlantic



# Greenland

# North Atlantic



Greenland

North  
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