Reviewer #1 (Anders Carlson)

In the intro, there is now geochemical data from Hudson Strait (Carlson et al., 2009, GRL) and northwest Labrador Sea (Hoffman et al., 2012, GRL) that directly constrain the timing and forcing of the 8.2 ka event; be good to mention these (although it is asking to reference my work, these studies pertain to arguments that the 8.2 event wasn't caused by Lake Agassiz; e.g., Alley & Augustdottir and Rohling & Palike reviews in 2005, plus more recent arguments by Condron & Winsor, 2011, GRL).

We now reference the geochemical data and also added a sentence about some of the remaining uncertainties about the forcing of the 8.2 ka event (e.g., Rohling and Palike, 2005; Condron and Winsor, 2011; Gregoire et al., 2012; Tornqvist and Hijma et al., 2012).

Also in the intro, I would at least mention that there is still a Laurentide ice sheet before/during the 8.2 event that was still affecting climate (Carlson et al., 2008, Nature Geoscience; Renssen et al., 2009, Nature Geoscience).

We added these references and now mention the remnant Laurentide ice sheet as one way in which the background climate of the early Holocene was different from that of today.

In terms of North Atlantic records, two papers are either published/or in press from the Labrador Sea that include Mg/Ca temps and d18Osw records covering the 8.2 ka event (Hoffman et al. 2012 GRL, northwest LS; Winsor et al., 2012/in press, G3 northeast LS) that show cooling and decreased d18Osw; the cooling is likely a summer signal given the foraminifera habitat. Another two papers of Young et al. (2011 GRL; 2012 Science) provide evidence for at least ice-margin standstills in west Greenland and Baffin Island, respectively, during the 8.2 ka event; again likely summer signals.

As the resolution of these records is lower than our selection criteria, they were not included in the analysis. But, we now highlight these records in the discussion.

In the methods, over what interval must the record have </= 50 yr resolution? For many records, resolution varies. Also, some records that may not make this cutoff could be included in Fig. 5 (i.e., Cariaco Mg/Ca and Ti records for instance).

We added that the resolution criterion applies to the interval from 7.9 to 8.5 calendar ka. We agree that records with somewhat lower resolution (up to perhaps ~100 yrs resolution) can still contribute some information about the event, particularly those records with quantitative reconstructions of climate anomalies, and we have included more of these in our discussion section (see also comments from Reviewer #2 on this subject). We decided not to include them in Figure 5 because our goal was to focus on higher-resolution anomalies.

Also in terms of methods, with all these records, have the authors thought of using EOF analysis to see if these patterns hold up under such an objective analysis? EOF analysis has proven useful in defining the Younger Dryas (Clark et al., 2002, Nature; Shakun & Carlson, 2010, QSR, Clark

et al., 2012, PNAS). Just a thought that may be worth trying and easy to do if they have the records already in digital format.

We tried Principal Component (EOF) analysis, but none of the PCs showed a clear 8.2 ka event. This is likely because the duration of the event (~150-200 yrs) is similar to the uncertainty in absolute ages of the time series, so that the event anomalies don't "line up" very well across records. The analysis we present in the paper has enough flexibility to accommodate age model uncertainties and is also objective.

And, in defining magnitude of the event, I do not see a discussion of proxy uncertainty. For calibrated temps which I am more familiar with, this is no better than at least 1 C and more likely 1.2-1.5 C. Are the anomalies significant in terms of the proxy used? This should be addressed. This is an important point that was also raised by reviewer #2.

We added columns to Tables 1 and 2 with estimates of the calibration uncertainty. The calibration uncertainties are similar in size to the 8.2 ka anomalies, a significant point that we now note in a new paragraph in the discussion.

Finally, the d18O comparison, the authors mix together marine and terrestrial records; are the marine records d18Osw or just raw d18O? the former is the hydrologic record, the latter is both temp and hydrologic changes. Sufficient records exist now to define d18Osw changes during the 8.2 event (e.g., see Hoffman et al., 2012 for the North Atlantic); maybe worth breaking this down a bit more if the paper is supposed to be a benchmark for models, the users of which often mistake one proxy for another.

We separated the d18O records in Table 3 and Figure 6 into three categories: precipitation, surface waters and carbonate. These categories and their different climatic meanings are now described in more detail in the text.

Reviewer #2 (Anonymous)

Other high-resolution data which have recorded the 8.2 ka event are missing in your paper; they should be included in your synthesis. I mean: - France, lake Annecy (Magny et al, 2003); Furthermore, Magny also proposed in the same paper a regional synthesis on the 8.2 ka based on various paleoclimate records. Could you mention (discuss) this paper in your text? - Balkans: lake Malik (Bordon et al., 2009), lake Prespa (Aufgebauer et al., 2012); - Aegean Sea: SL 152 (Kotthoff et al., 2008; Dormoy et al., 2009); - Alboran Sea (Combourieu-Nebout et al.,, 2009 : pollen and SST; Dormoy et al., 2009). It is of note that several transfer functions have been applied to lot of these data to produce quantitative estimates of seasonal temperature and precipitation. I think that you can add them in your study to refine your spatial coverage in the Mediterranean area (area where models and data are not in agreement).

Thank you for pointing us to these records. The Aegean Sea and Alboran Sea records met our selection criteria and we included them in our analysis. The other records, while lower resolution, are also quite useful in that they have quantitative reconstructions. The Magny et al. 2003 synthesis, in particular, presents important ideas directly related to our

discussion of precipitation changes over Europe. So, we now reference the rest of these studies in our discussion.

Your discussion is concise but very (too?) short. In my point of view, important points are missing in a paper which focuses on proxies data: -a discussion about the seasonality: your study is a compilation of different climate signals based on pollen data, speleothems, ice records, alkenones, Mg/Ca, chironomids, forams, and isotopic data. However, some proxies reconstruct seasonal parameters (for example, lake-levels indicate summer precipitations, chironomids record summer temperatures) while other proxies rather record an annual signal. Lakes, pollen, and isotopic data can produce an opposite climate trend which can be explained by the fact that these proxies may reflect processes linked to seasonality. This is an important point which needs to be discussed. - I invite you to add a point in your discussion about the proxy uncertainties.

We added information about seasonality, where available, to the new "Climate signal" column of Table S1 and now highlight this general point about seasonal signatures in a new paragraph in the discussion.

Is the cooling of 1.0 to 1.2 _C statistically significant? For example, with such a value obtained by applying transfer functions to pollen data, you can be inside the error bar. I invite you to check this point.

This point was also raised by reviewer #1, and we have added columns to Tables 1 and 2 with estimates of the calibration uncertainty. The calibration uncertainties are similar in size to the 8.2 ka anomalies, a significant point that we now note in a new paragraph in the discussion.

Could you add more details on the methods used to provide the climate anomalies (MAT, WA/PLS. . .)? It's a very important point, because the choice of the method can induce different results (see Peyron et al 2011, for more details). You can just add a column with the method used in your table 1.

We added this information to the "Proxies analyzed" column of Table S1 and referenced Peyron et al. 2011 in the discussion.

Figure 3 a: colder (warmer) than what? Please be more precise.
We added "relative to early Holocene background climate (defined as the average between 7.4-7.9 and 8.5-9.0 calendar ka)."

Figure 4 a: drier (wetter) than what? Please be more precise.
We added "relative to early Holocene background climate (defined as the average between 7.4-7.9 and 8.5-9.0 calendar ka)."

Table S1: use the same term as in figure 1: cave or speleothem.
We changed the word "speleothem" in figure 1 to "cave."

Be careful with the terminology: pollen data is a proxy which can be analysed from lakes or marine cores (first column). I invite you to be more precise, put pollen in the column "proxies analysed" , and also add and fill another column entitled "climate signal" after the column "proxies analysed".

We reclassified all records from the "pollen" archive in Figure 1 and Table S1 to belong to the lake, marine or peat archive, as appropriate. These records now are specified as "pollen" in the "Proxies analyzed" column of Table S1 and a new column for "Climate signal" is provided for all records.

Proxy benchmarks for intercomparison of 8.2 ka simulations

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Abstract

The Paleoclimate Modelling Intercomparison Project (PMIP3) now includes the 8.2 ka event as a test of model sensitivity to North Atlantic freshwater forcing. To provide benchmarks for intercomparison, we compiled and analyzed high-resolution records spanning this event. Two previously-described anomaly patterns that emerge are cooling around the North Atlantic and drier conditions in the Northern Hemisphere tropics. Newer to this compilation are more robustly-defined wetter conditions in the Southern Hemisphere tropics and regionally-limited warming in the Southern Hemisphere. Most anomalies around the globe lasted on the order of 100 to 150 years. More quantitative reconstructions are now available and indicate cooling of 1.0 to 1.2 °C and a ~ 20% decrease in precipitation in parts of Europe, as well as spatial gradients in $\delta^{18}O$ from the high to low latitudes. Unresolved questions remain about the seasonality of the climate response to freshwater forcing and the extent to which the bipolar seesaw operated in the early Holocene.

1 Introduction

The 8.2 ka event is likely one of the best examples from the past of the climate system's reponse to North Atlantic freshwater forcing. Several lines of evidence support the hypothesis that the drainage of proglacial Lake Agassiz into the Hudson Bay at about 8.2 calendar kiloyears before present (calendar ka BP) slowed the Atlantic Meridional Overturning Circulation (AMOC) and caused the climate anomalies observed in a wide variety of proxy

records. This evidence includes the stratigraphic record of lake drainage (Barber et al., 1999), reconstructions of sea level rise (Li et al., 2012;Tornqvist and Hijma, 2012), geochemical reconstructions from the Hudson Strait and northwest Labrador Sea of freshwater discharge (Carlson et al., 2009;Hoffman et al., 2012), proxy indicators of AMOC weakening (Ellison et al., 2006;Kleiven et al., 2008), and climate model experiments testing the linkage between freshwater forcing and climate change (LeGrande et al., 2006;Wiersma and Renssen, 2006). There are some remaining uncertainties about the forcing of the 8.2 ka event, including the the possibility of multiple freshwater releases (Gregoire et al., 2012;Teller et al., 2002;Tornqvist and Hijma, 2012), the pathway of freshwater once it reached the North Atlantic (Condron and Winsor, 2011), and the contribution of other climate forcings around that time (Rohling and Pälike, 2005). Yet, t~~T~~he 8.2 ka event is unique among past meltwater events in that the hypothesized forcing ~~is~~ has been ~~relatively well~~ quantified~~, the background climate state is not too dissimilar from the present,~~ and the duration is short enough to make model simulations of the event very feasible. Also, the early Holocene background climate state was not too dissimilar from the present, with one main difference being the presence of a remnant Laurentide Ice Sheet both before and after the 8.2 ka event (Carlson et al., 2008;Renssen et al., 2009). For these reasons, the the 8.2 ka event was selected for a model intercomparison for the third phase of the Paleoclimate Modelling Intercomparison Project (PMIP3; Morrill et al., 2012).

Paleoclimate proxy data are essential as a benchmark for the model intercomparison. The last global syntheses of proxy data around 8.2 ka were published in 2005-2006 and came to several common conclusions (Alley and Ágústsdóttir, 2005;Wiersma and Renssen, 2006;Morrill and Jacobsen, 2005;Rohling and Pälike, 2005). The most robust finding was cold anomalies in Greenland of up to 7°C and in Europe of about 1°C. All also agreed on the lack of signal in the Southern Hemisphere, though few records were available at the time. Differing conclusions were reached about precipitation changes in the Northern Hemisphere tropics, with some studies arguing for drying in specific regions and another claiming that these anomalies were too long-lived to be the actual 8.2 ka event (Rohling and Pälike, 2005).

Since these previous syntheses were published, the number of high-resolution records spanning the 8.2 ka event has doubled. In this paper, we compile and analyze these proxy records. Our main goals are to update previous conclusions reached about climate anomalies at 8.2 ka, particularly those regarding the tropics and Southern Hemisphere. We also place

special attention on presenting measures of the duration and magnitude of climate anomalies that can be used to evaluate model output quantitatively.

2 Dataset description and analysis methods

We selected previously-published proxy records for our analysis based on several criteria. First, the records have a sampling resolution of 50 years or better over the interval 7.9 to 8.5 calendar ka. This cutoff was chosen so that detection of a short event (~150 years) would be feasible. Second, the records have age models with an estimated precision of better than several hundred years taking into account the precision of radiocarbon or U-Th dating and uncertainties that arise from age model interpolation between age control points. This is long relative to the estimated duration of the 8.2 ka event, but better precision is not currently available for the majority of paleoclimate records spanning this time. Third, the proxies measured have well-supported climatic interpretations based on knowledge of modern processes. A total of 249 time-series from 112 sites met the above criteria (Figure 1, Table S1).

The number of sites has doubled since the last global syntheses of the 8.2 ka event were published in 2005-2006 (Figure 1), both globally and for each continent. A large proportion of the sites meeting our selection criteria are from Europe. North America is also fairly well-represented, and other regions more sparsely sampled. The majority of sites included in this study are either lacustrine or marine. This, too, is relatively unchanged from previous syntheses. Data from about half of the sites have been publically archived and are now available as a consolidated dataset from the World Center for Paleoclimatology (ftp://ftp.ncdc.noaa.gov/pub/data/paleo/8.2ka/8.2ka-data.csv) and as supplementary material to this article. For the other half, we digitized records for the statistical analysis.

Climate anomalies were identified in these records using a statistical test following the approach of Morrill and Jacobsen (2005). First, we detrended those records with significant long-term linear trends using linear regression; this is necessary because our statistical approach loses sensitivity when background trends are present. Then, for each individual record, we measured the mean and variability of the background climate state surrounding each event by calculating the mean ($\bar{x}$) and standard deviation (σ) of proxy values for two windows between 8.5-9.0 and 7.4-7.9 calendar ka BP (Figure 2). These windows were chosen to bracket the event, while accommodating errors in the age models of several hundred years.

A small number of time-series contained too few data points in one of these windows for a robust calculation of $\bar{x}$ and σ; for these records, we shifted the windows by 100-200 years after making certain that this would not impinge upon any possible anomalous event. Given that many of these proxy records contain substantial noise and that just one outlier data point can have a large impact on the calculated standard deviation, we also calculated a series of standard deviations for each window that successively left out one data value at a time. Then, we used the lowest standard deviation along with its corresponding mean to define the upper and lower bounds of background climate variability as $\bar{x} + 2\sigma$ and $\bar{x} - 2\sigma$. The two windows commonly had different values for $\bar{x}$ and σ, so we used the maximum and minimum values for $\bar{x} + 2\sigma$ and $\bar{x} - 2\sigma$, respectively, in order to make the stricter test (Figure 2). Next, we identified all values in the proxy time-series between 7.9-8.5 calendar ka that were beyond these respective bounds. Since, on average, about 5% of data points will fall outside the 2σ bound, other criteria were set for limiting false positives. Only excursions with at least two (three for records with sub-decadal resolution) adjacent anomalous values with the same signed anomaly were indentified. This condition makes it statistically unlikely ($p < 0.05$) that the excursions are due to random variations in the time-series (Feller, 1966).

For records with a detected climate anomaly and a resolution of 15 years or better, we also report on event duration using the moving two-tailed z-test method of Wiersma et al. (2011). We limited this analysis to the highest-resolution records because only these were sampled densely enough in time to be meaningfully compared to climate model output. Data between 7.9-8.5 calendar ka BP were sampled in overlapping 30-year increments and their means compared to the mean and variance of the background climate, defined as the periods between 7.4-7.9 and 8.5-9.0 calendar ka BP. Like Wiersma et al. (2011), we defined the duration of the 8.2 ka event as the longest stretch of consecutive overlapping windows whose z-values were all significant at the 99% level.

The number of proxies that quantitatively estimate temperature and precipitation has grown greatly since 2005. We used these to calculate anomalies near 8.2 ka by again comparing values between 7.9-8.5 calendar ka BP to the average of all data falling between 7.4-7.9 and 8.5-9.0 calendar ka BP. We report quantitative estimates in two ways: as the single maximum anomaly value and as a mean value calculated over a subjectively-determined time interval covering the 8.2 ka event. The subjective approach is necessary because the resolution of many of these records is not high enough to permit a more objective measure of event

duration, such as the z-test. We note that the mean anomaly over a defined time interval is a measure that has been useful for discussing the magnitude of the 8.2 ka event (e.g., Thomas et al., 2007;Kobashi et al., 2007) and is a quantity that is easily compared to model output.

3 Climate anomaly patterns at 8.2 ka

3.1 Temperature

Temperature-sensitive proxies indicate cold anomalies around the North Atlantic at 8.2 ka (Figure 3a), a result common to previous syntheses. New to this study is some evidence for warm anomalies in the Southern Hemisphere (Figure 3a). These occur in lake records from Nightingale Island in the south Atlantic (Ljung et al., 2008) and Amery Oasis in Antarctica (Cremer et al., 2007), as well as the deuterium record from Vostok (Petit et al., 1999). At the same time, however, several additional records from the Southern Hemisphere indicate cooler conditions at 8.2 ka. Thus, temperature change in the Southern Hemisphere appears to have been regionally heterogeneous.

Isotopic records from the annual-resolved Greenland ice cores estimate the duration of temperature anomalies at 8.2 ka very precisely at 150-160 years (Thomas et al., 2007;Kobashi et al., 2007). Our analysis of event duration using the moving z-test yields similar values for the GISP2 and NGRIP ice cores in Greenland (160-180 years, Figure 3b). According to the moving z-test, event durations in Europe appear to be somewhat shorter than those in Greenland (100-160 years; Figure 3b).

Reconstructed mean annual temperature anomalies (MAT) around the circum-North Atlantic are between -0.6 and -1.2 °C with the exception of Greenland, which seems to have experienced larger cooling (Table 1, Figure 3a). A few estimates are available for summer and winter temperatures. ~~Two~~ Three pollen records of winter temperature from the Aegean Sea, Greece and Romania have 8.2 ka anomalies that are greater than those for MAT in the same region (Table 1; Pross et al., 2009;Feurdean et al., 2008;Dormoy et al., 2009). A third site in northern Europe, Vanndalsvatnet (Nesje et al., 2006), shows a winter warming, which may not be coeval with the 8.2 ka event since it immediately precedes a significant cooling. At another site, Gardar Drift (Ellison et al., 2006), the magnitude of winter cooling is quite similar to the amount of summer cooling. Lower-resolution records with quantitative reconstructions paint an equally complex picture, including inferences of greatest cooling in

summer (Magny et al., 2001), greatest cooling in the winter (Bordon et al., 2009) and equal summer and winter cooling (Rousseau et al., 1998). Thus, from these data, it is still ambiguous whether winter temperatures cooled more than summer temperatures, as suggested for the 8.2 ka event (Rohling and Pälike, 2005) and for other past freshwater events (Denton et al., 2005).

3.2 Precipitation

The pattern of precipitation anomalies at 8.2 ka includes drier conditions over Greenland, the Mediterranean, and Northern Hemisphere tropics and wetter conditions over northern Europe and parts of the Southern Hemisphere tropics (Figure 4a). While reduced rainfall in the Northern Hemisphere tropics at 8.2 ka was noted in previous syntheses, new records from South America showing wetter conditions strengthen support for the idea that the mean position of the Intertropical Convergence Zone shifted southward (Cheng et al., 2009;van Breukelen et al., 2008). ~~The pattern of precipitation anomalies over Europe is also a new finding.~~ While previous syntheses documented decreased precipitation in the Mediterranean (Magny et al., 2003), the pattern of wetter conditions in northern Europe is a newer result. Many of the records from northern Europe are indicators of increased runoff associated with the spring snowmelt (Hammarlund et al., 2005;Hede et al., 2010;Zillén and Snowball, 2009;Snowball et al., 1999;Snowball et al., 2010) while the inference of dry conditions in southern Europe comes from pollen-based reconstructions for mean annual precipitation (Pross et al., 2009;Feurdean et al., 2008;Dormoy et al., 2009).

According to the moving z-test, most of the high-resolution precipitation anomalies last on the order of 100 to 150 years (Figure 4b). The exceptions to this general conclusion are two shorter anomalies of 30 to 50 years in Sweden (Snowball et al., 1999;Snowball et al., 2010) and two longer anomalies of 230 to 280 years in the Asian monsoon region (Dykoski et al., 2005;Wang et al., 2005;Fleitmann et al., 2003). The Swedish lake records likely record changes in erosion related to spring snowmelt runoff and their shorter event duration might reflect differences in sampling for extreme events as opposed to a change in the mean state. Longer anomalies in Asia were originally discussed by Rohling and Pälike (2005) and attributed to a multi-century cooling upon which the 8.2 ka event might be superimposed. Since 2005, however, there are new precipitation records from the Northern Hemisphere tropics with event durations of < 150 years (Figure 4b), lending support to the conclusion that precipitation did decrease in these areas coincident with the 8.2 ka event.

There are just ~~five~~ six sites with quantitative precipitation reconstructions, all of which are mean annual quantities in either Greenland or Europe. ~~Four~~ Five of these sites show precipitation decreases, including 8% in central Greenland and 13-17% in southeastern Europe (Table 2; Hammer et al., 1997;Rasmussen et al., 2007;Pross et al., 2009;Feurdean et al., 2008). The ~~fifth~~ sixth record, Vanndalsvatnet, shows a precipitation increase, but again there is some ambiguity in the record as to which of several fluctuations might actually be the 8.2 ka event (Nesje et al., 2006).

3.3 Other changes

Some of the proxy records we analyzed reflect climate variables other than temperature and precipitation, or show the combined influences of temperature and precipitation (e.g., glacier advances). These records and their detected 8.2 ka anomalies are shown in Figure 5. Of particular interest are indications of reduced AMOC (Arz et al., 2001;Ellison et al., 2006), glacier advances in Europe and North America (Menounos et al., 2004;Matthews et al., 2000;Nesje et al., 2001) and strengthening of the Asian winter monsoon (Yancheva et al., 2007). We also included sea ice in this discussion, even though it has a strong connection to temperature, because it is a variable predicted by climate models and because it participates in important ocean feedbacks. Significantly, several records near convection areas in the North Atlantic indicate sea ice expansion at 8.2 ka (Jennings et al., 2002;Moros et al., 2004;Hald and Korsun, 2008;Sarnthein et al., 2003). Lastly, two varved lake records in central North America show an increase in dust flux at 8.2 ka, possibly related to exposure of Lake Agassiz sediments (Hu et al., 1999;Dean et al., 2002).

With the advent of oxygen isotope-enabled climate models, one of the more comprehensive tests of 8.2 ka simulations uses $\delta^{18}O$ anomalies. In Table 3, we present $\delta^{18}O$ anomalies separated into three categories: precipitation, surface water and carbonate. Each of these categories reflects different climatic signals. The $\delta^{18}O$ of carbonate, which is precipitated from groundwater or surface water, combines the greatest number of signals. These include the $\delta^{18}O$ signature of the host water, which records the combined influence of precipitation $\delta^{18}O$ and any evaporative enrichment, as well as the temperature-dependent fractionation of oxygen that occurs during carbonate formation. The $\delta^{18}O$ of surface water is derived from carbonate $\delta^{18}O$ using an independent temperature time series to subtract this temperature-related fractionation. It is most direct to compare modeled $\delta^{18}O$ to reconstructed seawater or

precipitation values, but for some proxies, such as ~~speleothems~~cave $\delta^{18}O$, ~~it is sometimes reasonable to assume that~~ measured values can ~~accurately~~ reflect precipitation $\delta^{18}O$ changes if changes in ambient temperature and evaporative enrichment are negligible. This may be less true for $\delta^{18}O$ of lake carbonates, which depending on the residence time of water in the lake, ~~are~~ can be significantly changed through evaporative enrichment. ~~While keeping in mind these differences, we present all $\delta^{18}O$ values together in Table 3.~~

We also note that some of these $\delta^{18}O$ values were measured relative to the Standard Mean Ocean Water (SMOW) standard while others were relative to the PeeDee Belemnite (PDB) standard. The SMOW and PDB scales are offset by ~30 ‰, but are otherwise linearly related on a nearly 1:1 line (Coplen et al., 1983;Clark and Fritz, 1997). Thus, Table 3 combines anomaly values from the SMOW and PDB scales with no conversion between the two.

In Greenland, ice cores record a decrease of -0.8 to -1.2 ‰ (Figure 6, Table 3). In the North Atlantic and Europe, the decrease is generally less, on the order of -0.4 to -0.8 ‰. These isotopic anomalies are generally thought to reflect temperature ~~changes~~effects on the $\delta^{18}O$ of precipitation, although there could be some source effect from the meltwater added to the North Atlantic, as well (LeGrande et al., 2006). The smaller changes outside of Greenland are in line with the smaller temperature changes reconstructed quantitatively from Europe (section 3.1). The Northern Hemisphere tropics record an increase of 0.4 to 0.8 ‰, indicating decreased precipitation amount. Conversely, the Southern Hemisphere tropics experienced a decrease of -0.5 to -1.3 ‰, as precipitation likely increased.

4 Discussion and conclusions

The most robust features of the 8.2 ka event from proxy records include: mean annual cooling in the North Atlantic and Europe ~~of about~~on the order of ~1 ~~1.0 to 1.2~~ °C; event duration generally of 100 to 150 years for both temperature and precipitation; decreased precipitation in the Asian monsoon region, Central America and northern South America; and decreases in $\delta^{18}O$ of -0.8 to -1.2 ‰ in Greenland, -0.4 to -0.8 ‰ in Europe and 0.4 to 0.8 ‰ in Northern Hemisphere tropics. These anomalies are all supported by consistent evidence from multiple sites and are unambiguous enough that simulations of the 8.2 ka event should reproduce them.

There are a number of proxy observations that seem likely to hold true, but are somewhat less certain because they have been found at only a few sites. These include: strengthened Asian

winter monsoon; increased precipitation in the Southern Hemisphere tropics; and reductions in precipitation on the order of 10% and 20% for Greenland and southern Europe, respectively. We have enough confidence in these observations that they could be used for model-proxy comparison, but we would not necessarily make strong statements about model skill based on whether a model can reproduce these anomalies.

Both of these sets of proxy anomalies are changes that are expected given our current understanding of how freshwater forcing of the North Atlantic impacts climate. When the AMOC slows, reduction in northward oceanic heat transport cools the Northern Hemisphere (e.g., Manabe and Stouffer, 1997). Decreased precipitation in the Northern Hemisphere is, in general, expected due to cooler sea surface temperatures and more sea ice, both leading to less evaporation from the North Atlantic, as well as decreased specific humidity in a colder atmosphere according to the Clausius-Clayperon relationship (Vellinga and Wood, 2002). Strengthening of the Asian winter monsoon is another expected consequence of a colder Northern Hemisphere (Sun et al., 2012).

It is important to emphasize that the uncertainty in the quantitative calibrations of climate is similar to the magnitude of the reconstructed climate anomalies at 8.2 ka (Table 1,2). For example, standard errors for most of the mean annual temperature calibrations are ~1 °C regardless of proxy type (Table 1). Also for the pollen calibrations, the magnitude of reconstructed climate anomalies depends strongly on the particular reconstruction technique used, particularly for seasonal temperature (Table 1; Dormoy et al., 2009;Peyron et al., 2011). This level of uncertainty reduces the confidence that can be placed in the quantitative reconstructions and limits to some extent their usefulness for model comparison. The fact that the reconstructed anomalies in mean annual temperature are consistent across vastly different proxy types does suggest, however, that they still have some utility.

Another consideration in reducing discrepancies between nearby proxy sites as well as between models and data is the seasonality of proxy records. Some proxies necessarily indicate seasonal patterns (e.g., organisms that grow during the summer will only record warm season conditions) while others reflect annual means (e.g., lake water balance integrates over the annual cycle). However, our temperature and precipitation compilations presented in Figures 3 and 4 do not discriminate between annual mean and seasonal signatures. Table S1 indicates the seasonality of each proxy, if this information is known. One goal for future compilations is to improve the separation of seasonal signals.

Some other patterns are suggested by proxy records, but so far are too uncertain to be used as benchmarks. These include: winter temperature decreases in Europe of up to 4 to 5.5 °C that are larger than summer temperature decreases; and regional variability in cold and warm anomalies in the Southern Hemisphere high latitudes. Each relates to unresolved questions about the impacts of North Atlantic freshwater forcing. Denton et al. (2005) suggest that wintertime changes were more extreme than those in summer during abrupt events of the last glacial because the Northern Hemisphere was closer to a sea-ice related temperature threshold in the winter. While some proxy records support this seasonal pattern, others indicate substantial summer changes (e.g., Hoffman et al., 2012;Winsor et al., 2012;Young et al., 2012). It is unclear whether a similar sea-ice threshold was in play during the early Holocene. While reduction of northward heat transport in the Atlantic might be expected to warm the Southern Hemisphere, as happened at times of North Atlantic freshwater forcing during the last glacial (EPICA community members, 2006), this pattern is ambiguous in proxy records of the 8.2 ka event. It remains to be explained whether oceanic heat transport changes were not large enough at 8.2 ka to cause widespread Southern Hemisphere warming, or if fundamental differences between Holocene and last glacial climate determine the likelihood of a bipolar see-saw response.

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References

Alley, R. B., and Ágústsdóttir, A. M.: The 8k event: Cause and consequence of a major Holocene abrupt climate change, Quaternary Science Reviews, 24, 1123-1149, 2005.

Arz, H. W., Gerhardt, S., Patzold, J., and Rohl, U.: Millennial-scale changes of surface- and deep-water flow in the western tropical Atlantic linked to northern hemisphere high-latitude climate during the Holocene, Geology, 29, 239-242, 2001.

Barber, D. C., Dyke, A., Hillaire-Marcel, C., Jennings, A. E., Andrews, J. T., Kerwin, M. W., Bilodeau, G., McNeely, R., Southon, J., Morehead, M. D., and Gagnon, J.-M.: Forcing of the cold event of 8,200 years ago by catastrophic drainage of Laurentide lakes, Nature, 400, 344-348, 1999.

Bordon, A., Peyron, O., Lézine, A.-M., Brewer, S., and Fouache, E.: Pollen-inferred Late-Glacial and Holocene climate in southern Balkans (Lake Maliq), Quaternary International, 200, 19-30, 2009.

Carlson, A. E., LeGrande, A. N., Oppo, D. W., Came, R. E., Schmidt, G. A., Anslow, F. S., Licciardi, J. M., and Obbink, E. A.: Rapid early Holocene deglaciation of the Laurentide ice sheet, Nature Geoscience, 1, 620-624, 2008.

Carlson, A. E., Clark, P. U., Haley, B. A., and Klinkhammer, G. P.: Routing of western Canadian Plains runoff during the 8.2 ka cold event, Geophysical Research Letters, 36, L14704, 2009.

Cheng, H., Fleitmann, D., Edwards, R. L., Wang, X., Cruz, F. W., Auler, A. S., Mangini, A., Wang, Y., Kong, X., Burns, S. J., and Matter, A.: Timing and structure of the 8.2 kyr B.P. event inferred from d18O records of stalagmites from China, Oman, and Brazil, Geology, 37, 1007-1010, 2009.

Clark, I., and Fritz, P.: Environmental Isotopes in Hydrogeology, Lewis Publishers, New York, 328 pp., 1997.

Condron, A., and Winsor, P.: A subtropical fate awaited freshwater discharged from glacial Lake Agassiz, Geophysical Research Letters, 38, L03705, 10.1029/2010GL046011, 2011.

Coplen, T. B., Kendall, C., and Hopple, J.: Comparison of stable isotope reference samples, Nature, 302, 236-238, 1983.

Cremer, H., Heiri, O., Wagner, B., and Wagner-Cremer, F.: Abrupt climate warming in East Antarctica during the early Holocene, Quaternary Science Reviews, 26, 2012-2018, 10.1016/j.quascirev.2006.09.011, 2007.

Dean, W. E., Forester, R. M., and Bradbury, J. P.: Early Holocene change in atmospheric circulation in the Northern Great Plains: an upstream view of the 8.2 ka cold event, Quaternary Science Reviews, 21, 1763-1775, 2002.

Denton, G. H., Alley, R. B., Comer, G. C., and Broecker, W. S.: The role of seasonality in abrupt climate change, Quaternary Science Reviews, 24, 1159-1182, 2005.

Dormoy, I., Peyron, O., Combourieu Nebout, N., Goring, S., Kotthoff, U., Magny, M., and Pross, J.: Terrestrial climate variability and seasonality changes in the Mediterranean region between 15000 and 4000 years BP deduced from marine pollen records, Climate of the Past, 5, 615-632, 2009.

Dykoski, C. A., Edwards, R. L., Cheng, H., Yuan, D., Cai, Y., Zhang, M., Lin, Y., Qing, J., An, Z., and Revenaugh, J.: A high-resolution, absolute-dated Holocene and deglacial Asian monsoon record from Dongge Cave, China, Earth and Planetary Science Letters, 233, 71-86, 2005.

Ellison, C. R. W., Chapman, M. R., and Hall, I. R.: Surface and deep ocean interactions during the cold climate event 8200 years ago, Science, 312, 1929-1932, 2006.

EPICA community members: One-to-one coupling of glacial climate variability in Greenland and Antarctica, Nature, 444, 195-198, 2006.

Feller, W.: An Introduction to Probability Theory and Its Applications, John Wiley, Hoboken, N.J., 626 pp., 1966.

Feurdean, A., Klotz, S., Mosbrugger, V., and Wolhfarth, B.: Pollen-based quantitative reconstructions of Holocene climate variability in NW Romania, Palaeogeography, Palaeoclimatology, Palaeoecology, 260, 494-504, 2008.

Fleitmann, D., Burns, S. J., Mudelsee, M., Neff, U., Kramers, J., Mangini, A., and Matter, A.: Holocene forcing of the Indian monsoon recorded in a stalagmite from Southern Oman, Science, 300, 1737-1739, 2003.

Gregoire, L. J., Payne, A. J., and Valdes, P. J.: Deglacial rapid sea level rises caused by ice-sheet saddle collapses, Nature, 487, 219-223, 2012.

Hald, M., and Korsun, S.: The 8200 cal. yr BP event reflected in the Arctic fjord, Van Mijenfjorden, Svalbard, The Holocene, 18, 981-990, 2008.

Hammarlund, D., Björck, S., Buchardt, B., and Thomsen, C. T.: Limnic responses to increased effective humidity during the 8200 cal. yr BP cooling event in southern Sweden, Journal of Paleolimnology, 34, 471-480, 10.1007/s10933-005-5614-z, 2005.

Hammer, C. U., Andersen, K. K., Clausen, H. B., Dahl-Jensen, D., Hvidberg, C. S., and Iversen, P.: The stratigraphic dating of the GRIP ice core, Special Report of the Geophysical Department, Niels Bohr Institute for Astronomy, Physics and Geophysics, University of Copenhagen, 1997.

Hede, M. U., Rasmussen, P., Noe-Nygaard, N., Clarke, A. L., Vinebrooke, R. D., and Olsen, J.: Multiproxy evidene for terrestrial and aquatic ecosystem responses during the 8.2 ka cold event as recorded at Højby Sø, Denmark, Quaternary Research, 73, 485-495, 2010.

Hoffman, J. S., Carlson, A. E., Winsor, K., Klinkhammer, G. P., LeGrande, A. N., Andrews, J. T., and Strasser, J. C.: Linking the 8.2 ka event and its freshwater forcing in the Labrador Sea, Geophysical Research Letters, 39, L18703, 2012.

Hu, F. S., Slawinski, D., Wright, H. E., Ito, E., Johnson, R. G., Kelts, K. R., McEwan, R. F., and Boedigheimer, A.: Abrupt changes in North American climate during early Holocene times, Nature, 400, 437-440, 1999.

Jennings, A. E., Knudsen, K. L., Hald, M., Hansen, C. V., and Andrews, J. T.: A mid-Holocene shift in Arctic sea-ice variability on the East Greenland Shelf, The Holocene, 12, 49-58, 2002.

Kleiven, H. F., Kissel, C., Laj, C., Ninnemann, U. S., Richter, T. O., and Cortijo, E.: Reduced North Atlantic Deep Water coeval with the Glacial lake Agassiz freshwater outburst, Science, 319, 60-64, 2008.

Kobashi, T., Severinghaus, J. P., Brook, E. J., Barnola, J.-M., and Grachev, A. M.: Precise timing and characterization of abrupt climate change 8200 years ago from air trapped in polar ice, Quaternary Science Reviews, 26, 1212-1222, 2007.

LeGrande, A. N., Schmidt, G. A., Shindell, D. T., Field, C. V., Miller, R. L., Koch, D. M., Faluvegi, G., and Hoffmann, G.: Consistent simulations of multiple proxy responses to an

abrupt climate change event, Proceedings of the National Academy of Sciences, 103, 837-842, 2006.

Li, Y.-X., Tornqvist, T. E., Nevitt, J. M., and Kohl, B.: Synchronizing a sea-level jump, final Lake Agassiz drainage, and abrupt cooling 8200 years ago, Earth and Planetary Science Letters, 315-316, 41-50, 2012.

Ljung, K., Björck, S., Renssen, H., and Hammarlund, D.: South Atlantic island record reveals a South Atlantic response to the 8.2 kyr event, Climate of the Past, 4, 35-45, 2008.

Magny, M., Guiot, J., and Schoellammer, P.: Quantitative reconstruction of Younger Dryas to mid-Holocene paleoclimates at Le Locle, Swiss Jura, using pollen and lake-level data, Quaternary Research, 56, 170-180, 2001.

Magny, M., Bégeot, C., Guiot, J., and Peyron, O.: Contrasting patterns of hydrological changes in Europe in response to Holocene climate cooling phases, Quaternary Science Reviews, 22, 1589-1596, 2003.

Manabe, S., and Stouffer, R. J.: Coupled ocean-atmosphere model response to freshwater input: Comparison to Younger Dryas event, Paleoceanography, 12, 321-336, 1997.

Matthews, J. A., Dahl, S. O., Nesje, A., Berrisford, M. S., and Andersson, C.: Holocene glacier variations in central Jotunheimen, southern Norway based on distal glaciolacustrine sediment cores, Quaternary Science Reviews, 19, 1625-1647, 2000.

Menounos, B., Koch, J., Osborn, G., Clague, J. J., and Mazzucchi, D.: Early Holocene glacier advance, southern Coast Mountains, British Columbia, Canada, Quaternary Science Reviews, 23, 1543-1550, 2004.

Moros, M., Emeis, K., Risebrobakken, B., Snowball, I., Kuijpers, A., McManus, J., and Jansen, E.: Sea surface temperatures and ice rafting in the Holocene North Atlantic: Climate influences on northern Europe and Greenland, Quaternary Science Reviews, 23, 2113-2126, 2004.

Morrill, C., and Jacobsen, R. M.: How widespread were climate anomalies 8200 years ago?, Geophysical Research Letters, 32, L19701, 2005.

Morrill, C., LeGrande, A. N., Renssen, H., Bakker, P., and Otto-Bliesner, B. L.: Model sensitivity to North Atlantic freshwater forcing at 8.2 ka, Climate of the Past Discussion, 8, 3949-3976, 2012.

Nesje, A., Matthews, J. A., Dahl, S. O., Berrisford, M. S., and Andersson, C.: Holocene glacier fluctuations of Flatebreen and winter-precipitation changes in the Jostedalsbreen region, western Norway, based on glaciolacustrine sediment records, The Holocene, 11, 267-280, 2001.

Nesje, A., Bjune, A. E., Bakke, J., Dahl, S. O., Lie, O., and Birks, H. J. B.: Holocene palaeoclimate reconstructions at Vanndalsvatnet, western Norway, with particular reference to the 8200 cal yr BP event, The Holocene, 16, 717-729, 2006.

Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J.-M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V. M., Legrand, M., Lipenkov, V. Y., Lorius, C., Pepin, L., Ritz, C., Saltzmann, E., and Stievenard, M.: Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica, Nature, 399, 429-436, 1999.

Peyron, O., Goring, S., Dormoy, I., Kotthoff, U., Pross, J., de Beaulieu, J.-L., Drescher-Schneider, R., Vannière, B., and Magny, M.: Holocene seasonality changes in the central Mediterranean region reconstructed from the pollen sequences of Lake Accesa (Italy) and Tenaghi Philippon (Greece), The Holocene, 21, 131-146, 2011.

Pross, J., Kutthoff, U., Muller, U. C., Peyron, O., Dormoy, I., Schmiedl, G., Kalaitzidis, S., and Smith, A. M.: Massive perturbation in terrestrial ecosystems of the Eastern Mediterranean region associated with the 8.2 kyr B.P. climatic event, Geology, 37, 887-890, 2009.

Rasmussen, S. O., Vinther, B. M., Clausen, H. B., and Andersen, K. K.: Early Holocene climate oscillations recorded in three Greenland ice cores, Quaternary Science Reviews, 26, 1907-1914, 2007.

Renssen, H., Seppa, H., Heiri, O., Roche, D. M., Goosse, H., and Fichefet, T.: The spatial and temporal complexity of the Holocene thermal maximum, Nature Geoscience, 2, 411-414, 2009.

Rohling, E. J., and Pälike, H.: Centennial-scale climate cooling with a sudden cold event around 8,200 years ago, Nature, 434, 975-979, 2005.

Rousseau, D.-D., Preece, R., and Limondin-Lozouet, N.: British late glacial and Holocene climatic history reconstructed from land snail assemblages, Geology, 26, 651-654, 1998.

Sarnthein, M., van Kreveld, S., Erlenkeuser, H., Grootes, P. M., Kucera, M., Pflaumann, U., and Schulz, M.: Centennial-to-millennial scale periodicities of Holocene climate and sediment injections off the western Barents shelf, 75 N, Boreas, 32, 447-461, 2003.

Snowball, I., Sandgren, P., and Petterson, G.: The mineral magnetic properties of an annually laminated Holocene lake-sediment sequence in northern Sweden, The Holocene, 9, 353-362, 1999.

Snowball, I., Muscheler, R., Zillén, L., Sandgren, P., Stanton, T., and Ljung, K.: Radiocarbon wiggle matching of Swedish lake varves reveals asynchronous climate changes around the 8.2 kyr cold event, Boreas, 39, 720-733, 10.1111/j.1502-3885.2010.00167.x, 2010.

Sun, Y., Clemens, S. C., Morrill, C., Lin, X., Wang, X., and An, Z.: Influence of Atlantic meridional overturning circulation on the East Asian winter monsoon, Nature Geoscience, 5, 46-49, 10.1038/NGEO1326, 2012.

Teller, J. T., Leverington, D. W., and Mann, J. D.: Freshwater outbursts to the oceans from glacial Lake Agassiz and their role in climate change during the last deglaciation, Quaternary Science Reviews, 21, 879-887, 2002.

Thomas, E. R., Wolff, E. W., Mulvaney, R., Steffensen, J. P., Johnsen, S. J., Arrowsmith, C., White, J. W. C., Vaughn, B., and Popp, T.: The 8.2 ka event from Greenland ice cores, Quaternary Science Reviews, 26, 70-81, 2007.

Tornqvist, T. E., and Hijma, M. P.: Links between early Holocene ice-sheet decay, sea-level rise and abrupt climate change, Nature Geoscience, 5, 601-606, 2012.

van Breukelen, M. R., Vonhof, H. B., Hellstrom, J. C., Wester, W. C. G., and Kroon, D.: Fossil dripwater in stalagmites reveals Holocene temperature and rainfall variation in Amazonia, Earth and Planetary Science Letters, 275, 54-60, 2008.

Vellinga, M., and Wood, R. A.: Global climatic impacts of a collapse of the Atlantic thermohaline circulation, Climatic Change, 54, 251-267, 2002.

Wang, Y., Cheng, H., Edwards, R. L., He, Y., Kong, X., An, Z., Wu, J., Kelly, M. J., Dykoski, C. A., and Li, X.: The Holocene Asian monsoon: Links to solar changes and North Atlantic climate, Science, 308, 854-857, 2005.

Wiersma, A. P., and Renssen, H.: Model-data comparison for the 8.2 ka B.P. event: confirmation of a forcing mechanism by catastrophic drainage of Laurentide lakes, Quaternary Science Reviews, 25, 63-88, 2006.

Wiersma, A. P., Roche, D. M., and Renssen, H.: Fingerprinting the 8.2 ka event climate response in a coupled climate model, Journal of Quaternary Science, 26, 118-127, 10.1002/jqs.1439, 2011.

Winsor, K., Carlson, A. E., Klinkhammer, G. P., Stoner, J. S., and Hatfield, R. G.: Evolution of the northeast Labrador Sea during the last interglaciation, Geochemistry, Geophysics, Geosystems, 13, Q11006, 10.1029/2012GC004263, 2012.

Yancheva, G., Nowaczyk, N. R., Mingram, J., Dulski, P., Schettler, G., Negendank, J. F. W., Liu, J., Sigman, D. M., Peterson, L. C., and Haug, G. H.: Influence of the intertropical convergence zone on the East Asian monsoon, Nature, 445, 74-77, 2007.

Young, N. E., Briner, J. P., Rood, D. H., and Finkel, R. C.: Glacier extent during the Younger Dryas and 8.2-ka event on Baffin Island, Arctic Canada, Science, 337, 1330-1333, 2012.

Zillén, L., and Snowball, I.: Complexity of the 8 ka climate event in Sweden recorded by varved lake sediments, Boreas, 38, 493-503, 10.1111/j.1502-3885.2009.00086.x, 2009.

Table 1. Quantitative temperature anomalies from early Holocene background values.

Site	Proxy type	Maximum (°C)	Mean (°C)	Error* (°C)	Duration (years)
		Mean Annual Temperature			
GISP2	$\delta^{15}N$	-3.3	-2.2	1.1	120
Ammersee, Germany	$\delta^{18}O$	-1.3	-1.1	N/A	90
Lake Rõuge, Estonia	pollen	-2.6	-1.2	0.9	280
Lake Arapisto, Finland	pollen	-2.2	-1.2	0.9	200
South Iceland (thermocline)	Mg/Ca	-1.2	-1.0	1.0	80
Steregoiu, Romania	pollen	-1.6	-1.1	N/A	190
Gulf of Mexico (surface)	Mg/Ca	-1.3	-0.9	1.1	120
Cape Ghir (surface)	alkenone	-0.7	-0.6	~1	250
Cape Ghir (thermocline)	Mg/Ca	-1.0	-0.6	0.7	80
Gulf of Guinea (surface)	Mg/Ca	-1.9	-1.1	1.2	140
		Winter Temperature			
Tenaghi Philippon, Greece	pollen	-4.0	-2.8	2.5	140
Aegean Sea	pollen	-9.1	-5.9	6.4	120
Gardar Drift (surface)	forams	-1.6	-1.3	~1	80
Vanndalsvatnet, Norway	pollen	2.5	1.7	2.6	240
Steregoiu, Romania	pollen	-5.6	-4.2	2.6	110
		Summer Temperature			
Aegean Sea	pollen	-4.2	-2.6	3.7	120
Hawes Water, UK	chironomid	-1.5	-0.8	1.0	90
Gardar Drift (surface)	forams	-2.1	-1.7	~1	60

* Root mean square errors for the calibration as reported by original investigators, N/A = not available

Table 2. Quantitative mean annual precipitation anomalies from early Holocene background values.

Site	Proxy type	Maximum (%)	Mean (%)	Error* (%)	Duration (years)
GRIP	ice accum-ulation	-28	-8	~5	120
NGRIP	ice accum-ulation	-18	-8	~5	150
Tenaghi Philippon, Greece	pollen	-27	-17	14	110
Aegean Sea	pollen	-24	-13	35	120
Vanndalsvatnet, Norway	pollen	20	12	24	240
Steregoiu, Romania	pollen	-25	-17	17	110

* Root mean square errors for the calibration as reported by original investigators and scaled as a percentage of reconstructed early Holocene background precipitation.

Table 3. Oxygen isotope anomalies from early Holocene background values.

Site	Material	Maximum (‰)	Mean (‰)	Duration (years)
	$\delta^{18}O$ of precipitation			
GISP2	ice	-1.9	-1.1	140
GRIP	ice	-2.0	-1.1	140
NGRIP	ice	-1.9	-1.0	140
Agassiz	ice	-2.0	-1.0	140
Camp Century	ice	-1.3	-0.8	160
Renland	ice	-1.8	-0.9	120
Dye 3	ice	-1.9	-1.2	140
Nordan's Pond Bog, Canada	peat cellulose	-3.0	-2.6	80
	$\delta^{18}O$ of surface water			
Gulf of Mexico	seawater	-0.6	-0.4	150
Hawes Water, UK	lake water	-0.9	-0.6	110
Gardar Drift	seawater	-0.7	-0.4	180
	$\delta^{18}O$ of carbonate			
Ammersee, Germany	ostracod	-0.8	-0.6	90
Katerloch Cave, Austria	cave	-1.3	-0.7	130
Igelsjon Lake, Sweden	bulk lake	-2.7	-2.0	250
Okshola Cave, Norway	cave	-1.0	-0.8	20
Svalbard	benthic forams	-0.4	-0.2	70
Pink Panther Cave, USA	cave	-0.8	-0.4	270
Venado Cave, Costa Rica	cave	2.0	1.0	80
Tigre Perdido Cave, Peru	cave	-1.0	-0.5	170

Padre Cave, Brazil	cave	-1.8	-1.3	60
Qunf Cave, Oman	cave	0.7	0.4	250
Hoti Cave, Oman	cave	1.1	0.8	30
Dongge Cave, China	cave	0.9	0.4	170
Heshang Cave, China	cave	1.1	0.8	130
South China Sea	planktic forams	0.4	0.4	40

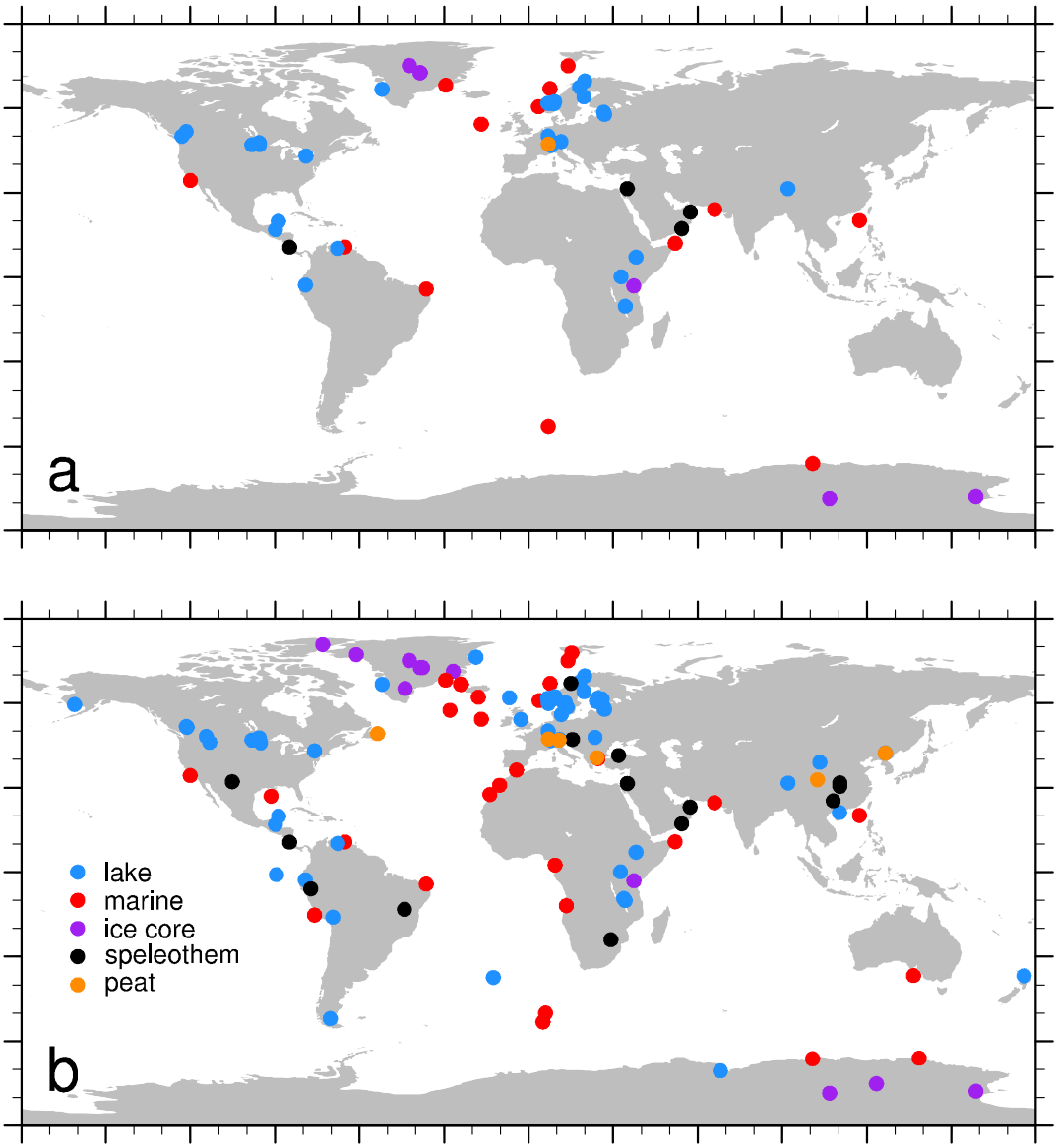

Figure 1. Location of high-resolution proxy records spanning 8.2 ka that were available in (a) 2005 (Morrill and Jacobsen, 2005) and (b) 2012.

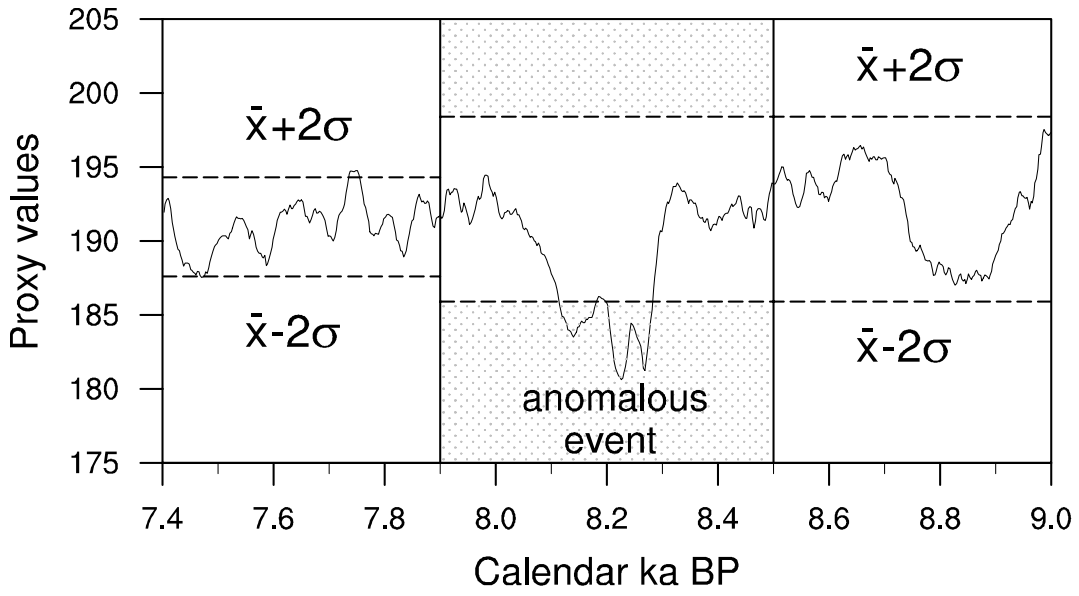

Figure 2. Schematic diagram of method used to detect climate anomalies at 8.2 ka, as described in text.

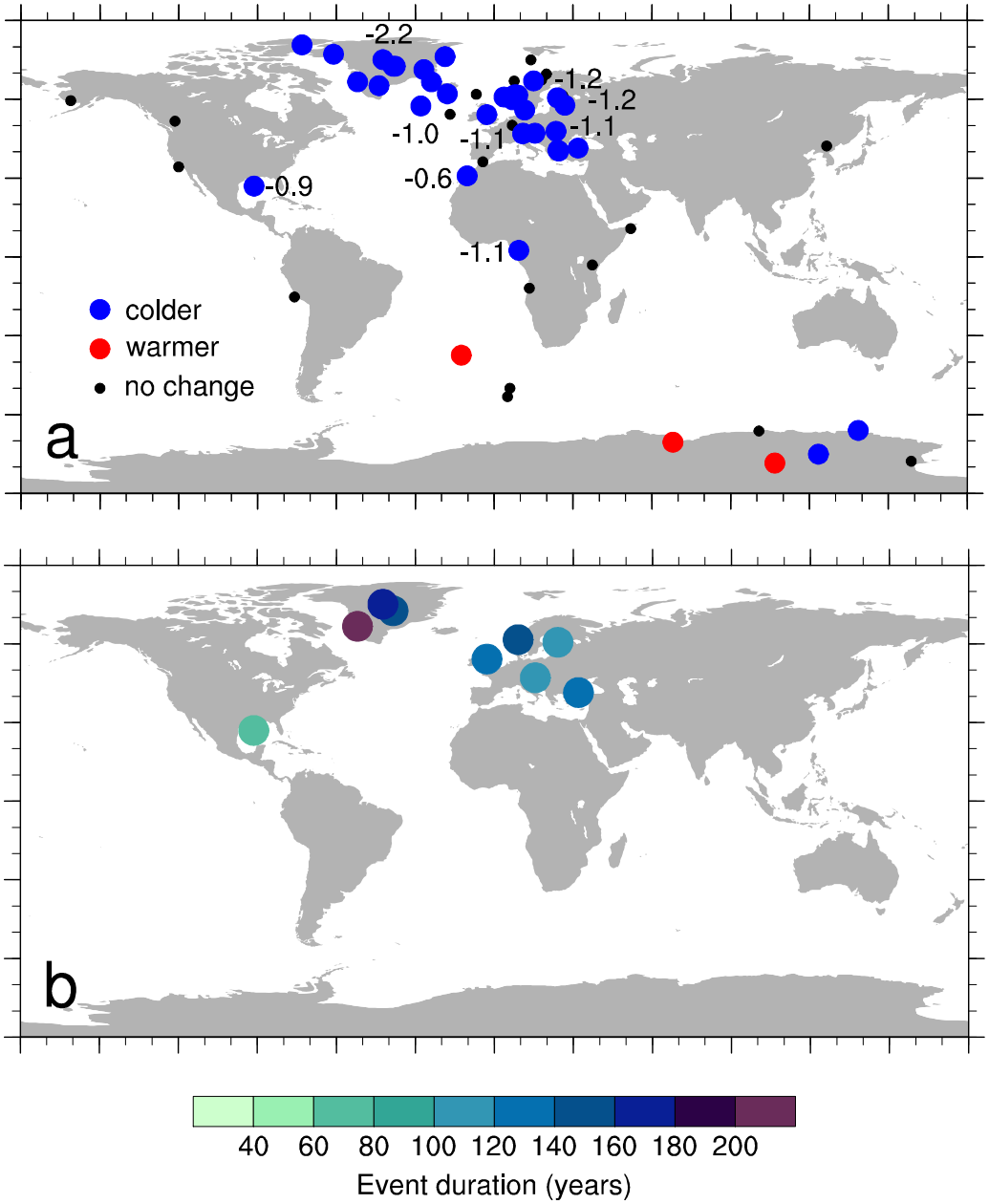

Figure 3. (a) Temperature anomalies relative to early Holocene background climate (defined as the average between 7.4-7.9 and 8.5-9.0 calendar ka) detected near 8.2 ka by the method described in text. Black dots indicate sites with temperature proxies that did not have an identifiable anomaly. Values plotted are quantitative mean annual temperature estimates in degrees Celsius and are also provided in Table 1. (b) Duration of temperature anomalies in high-resolution (better than 15 yrs/sample) proxies, as determined using the method of Wiersma et al. (2011).

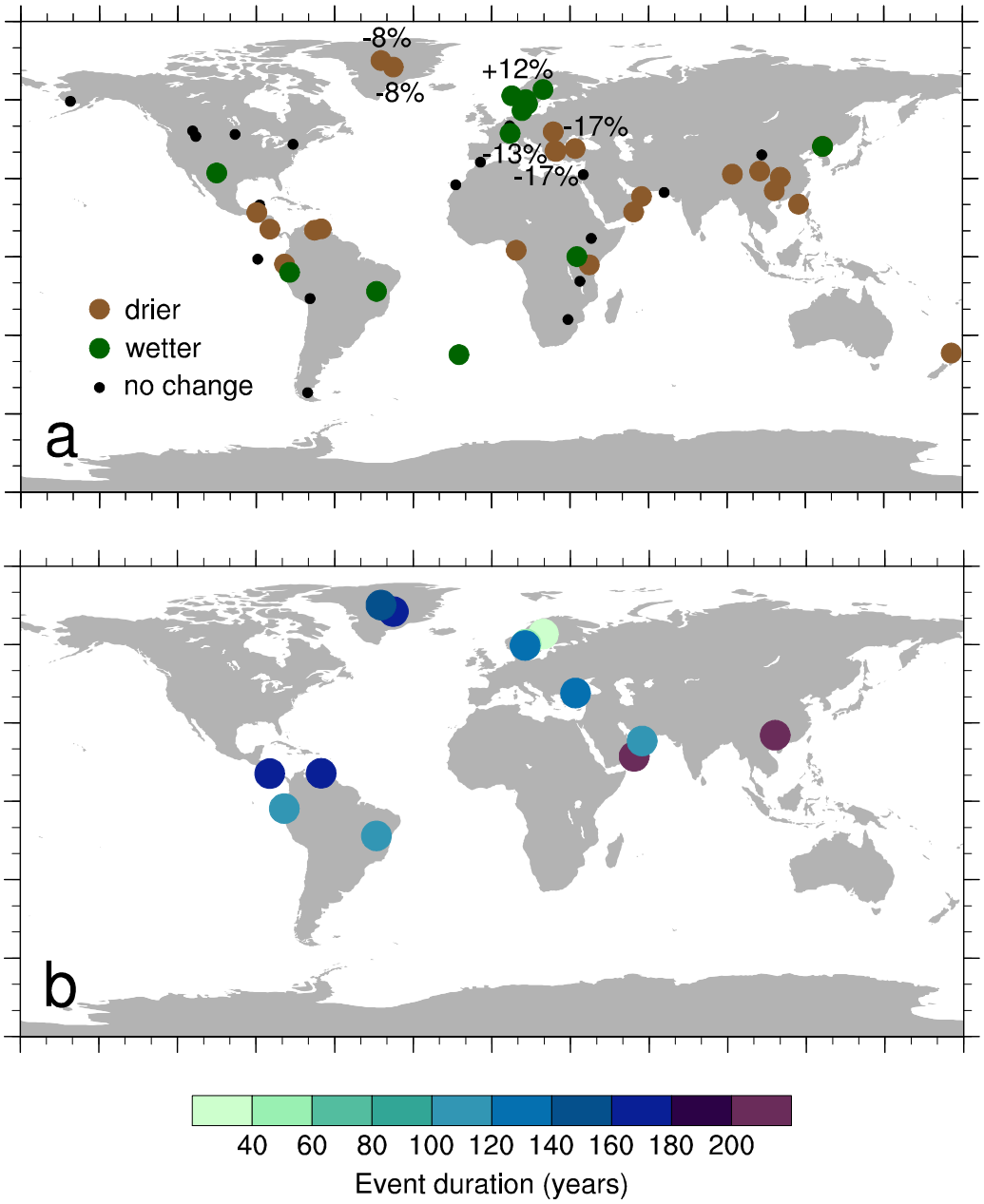

Figure 4. (a) Precipitation anomalies relative to early Holocene background climate (defined as the average between 7.4-7.9 and 8.5-9.0 calendar ka) detected near 8.2 ka by the method described in text. Black dots indicate sites with precipitation proxies that did not have an identifiable anomaly. Values plotted are quantitative mean annual precipitation estimates, expressed as a percent difference from values averaged for 7.4-7.9 and 8.5-9.0 calendar ka BP, and are also presented in Table 2. (b) Duration of precipitation anomalies in high-resolution (better than 15 yrs/sample) proxies, as determined using the method of Wiersma et al. (2011).

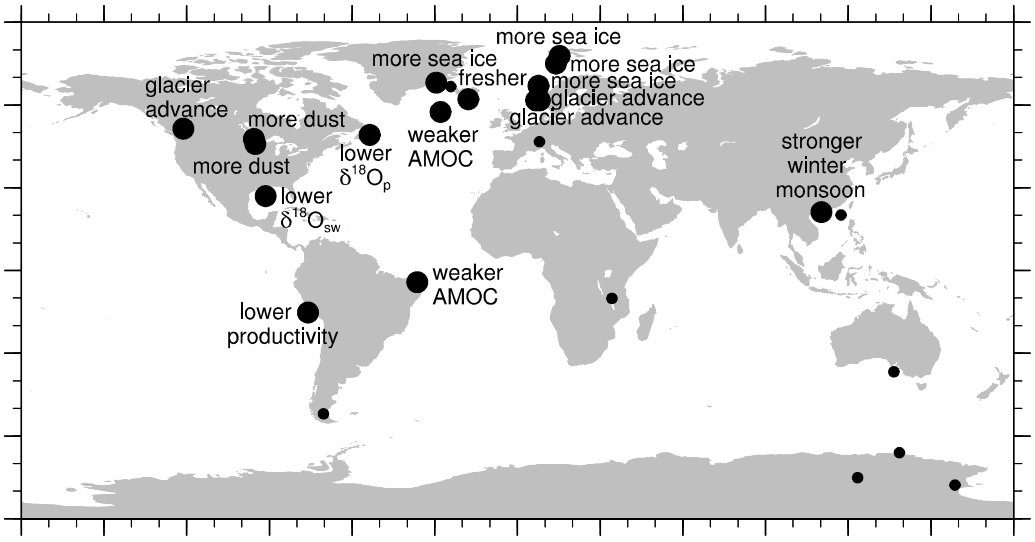

Figure 5. Climate anomalies detected near 8.2 ka that were not easily categorized in terms of temperature or precipitation. Small black dots indicate sites without an identifiable climate anomaly.

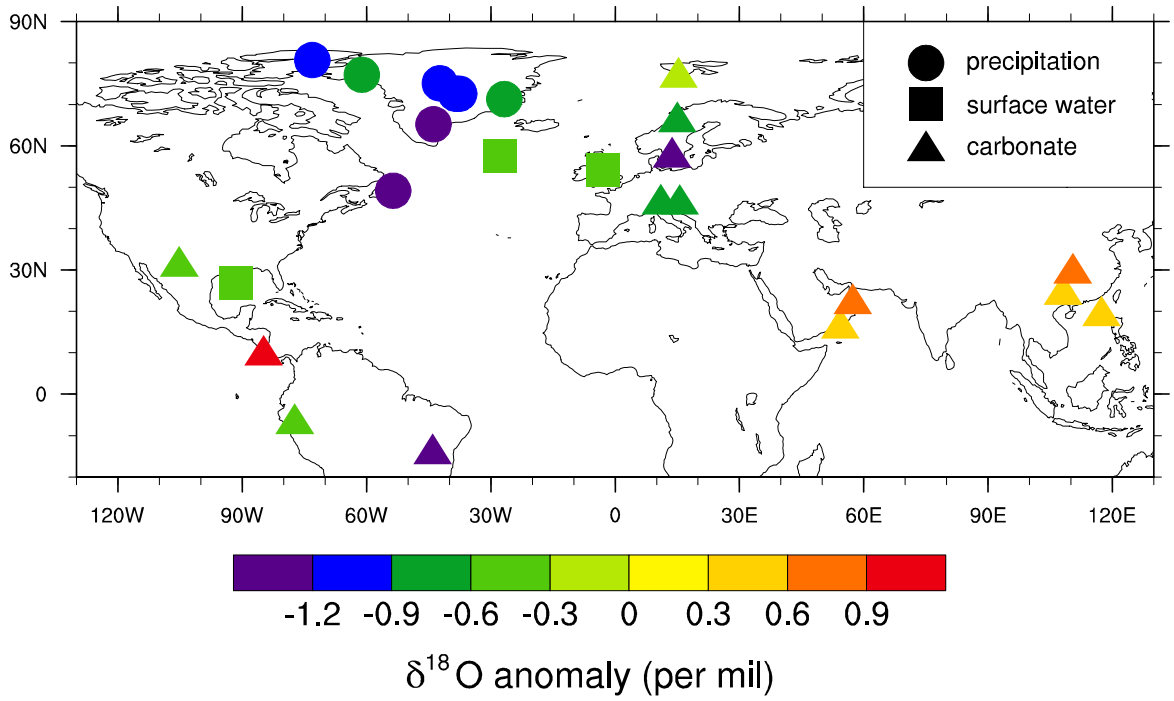

Figure 6. Anomalies in $\delta^{18}O$ detected using method described in text. Sites plotted here are also provided in Table 3.

Table S1. Records used in compilation

Site name	Archive	Lat	Lon	Proxies analyzed[1,2]	Climate signal[1]	Reference
Adélie Land (MD03-2601)	Marine	-66.0	138.6	**F. curta/F. kerguelensis** Chaetoceras resting spore Sortable silt Number of laminae Al	**Growing season temperature** Meltwater input Bottom water production Bottom water production Bottom water production	Denis et al. (2009)
Aegean Sea (GeoTü SL152)	Marine	40.1	24.6	**Tree pollen** **Quercus index** **Sediment lightness** **Pollen (PLS)** Pollen (PLS) **Pollen (PLS)** **Pollen (PLS)** **Pollen (PLS)**	**Winter precipitation** **Precipitation seasonality** **Runoff** **Annual precipitation** Summer precipitation **Winter precipitation** **Coldest month temperature** **Warmest month temperature**	Kotthoff et al. (2008), Dormoy et al. (2009)
Agassiz	Ice	80.7	-73.1	**$\delta^{18}O$**	**Temperature**	Fisher et al. (1995), Vinther et al. (2008)
Ahung	Lake	31.4	92.0	% Total organic carbon % Carbonate **Carbonate $\delta^{13}C$**	Precipitation Precipitation **Precipitation**	Morrill et al. (2006)
Alboran Sea (ODP 976)	Marine	36.2	-4.3	% Temperate pollen Pollen (PLS) Pollen (PLS) Pollen (PLS) Pollen (PLS) Pollen (PLS)	Temperature, precipitation Annual precipitation Summer precipitation Winter precipitation Coldest month temperature Warmest month temperature	Dormoy et al. (2009), Combourieu Nebout et al. (2009)
Amery Oasis	Lake	-70.6	68.0	**% Total carbon**	**Summer temperature**	Cremer et al. (2007)
Ammersee	Lake	48.1	11.5	**Ostracod $\delta^{18}O$**	**Annual temperature**	von Grafenstein et al. (1998)
Arabian Sea (63KA)	Marine	24.0	66.0	*Globigerinoides ruber* $\delta^{18}O$	Annual precipitation	Staubwasser et al. (2002)
Arabian Sea (NIOP 905)	Marine	12.0	52.0	*Globigerina bulloides* $\delta^{18}O$	Summer sea surface temperature	Jung et al. (2004)
Arapisto	Lake	60.6	24.1	**Pollen (WA-PLS)**	**Mean annual temperature**	Sarmaja-Korjonen and Seppä (2007)
Arolik	Lake	59.5	-161.1	Biogenic silica	Temperature, precipitation	Hu et al. (2003)

Atlantic (ODP 1078C)	Marine	-11.9	13.4	*Cibicidoides wuellerstorfi* $\delta^{18}O$	Intermediate water temperature	Rühlemann et al. (2004)
Atlantic (VM29-191)	Marine	54.3	-16.8	Hematite-stained grains Icelandic glass	Temperature Temperature	Bond et al. (2001)
Barents Shelf (GIK23258-2)	Marine	75.0	14.0	Planktic forams (ANN) Planktic forams (ANN) Planktic forams (SIMMAX) Planktic forams (SIMMAX) **Grain size >63 μm** **Planktic forams/g** **Benthic forams/g**	Winter sea surface temperature Summer sea surface temperature Winter sea surface temperature Summer sea surface temperature **Winter sea ice formation** **Winter sea ice formation** **Winter sea ice formation**	Sarnthein et al. (2003)
Big	Lake	51.7	-121.5	Beta carotene amount	Temperature	Bennett et al. (2001)
Brazilian Shelf (GeoB 3910-2)	Marine	-4.2	-36.3	**Ca**	**Atlantic Meridional Overturning Circulation**	Arz et al. (2001)
Brunnboden	Peat	46.8	10.8	**Pollen concentration** **% Cyperaceae**	**Summer temperature** **Summer temperature**	Kofler et al. (2005)
Bunger Oasis (PG1173)	Marine	-66.3	100.8	% Ice diatoms	Temperature	Kulbe et al. (2001)
Camp Century	Ice	77.2	-61.1	**$\delta^{18}O$**	**Temperature**	Vinther et al. (2009)
Cape Ghir (GeoB 6007-2)	Marine	30.8	-10.3	**Alkenone Uk'_{37}** ***Hyalinea balthica* Mg/Ca** *Hyalinea balthica* $\delta^{18}O$ *Hyalinea balthica* $\delta^{13}C$	**Annual sea surface temperature** **Intermediate water temperature** $\delta^{18}O_{seawater}$ Local upwelling	Kim et al. (2007), Bamberg et al. (2010)
Cape Yubi (GeoB 5546-2)	Marine	27.5	-13.7	K	Precipitation	Kuhlmann et al. (2004)
Cariaco Basin (ODP 1002)	Marine	10.7	-65.2	**Grayscale** **% Ti**	**Trade wind intensity** **Precipitation**	Hughen et al. (2000) Haug et al. (2001)
Chichancanab	Lake	19.8	-88.8	% S %$CaCO_3$	Precipitation-evaporation Precipitation-evaporation	Hodell et al. (1995)
Cold Air	Cave	-24.0	29.2	$\delta^{18}O$ $\delta^{13}C$	Precipitation Vegetation	Holmgren et al. (2003)
Dalsvatnet	Lake	61.7	8.0	**% Loss on ignition**	**Glacier advance**	Matthews et al. (2000)
Danntjorn	Lake	61.6	9.0	**% Loss on ignition**	**Summer temperature**	Nesje et al. (2004)
Deep	Lake	47.7	-95.6	**Varve thickness**	**Dust availability**	Hu et al. (1999)

Djupall Trough (KN 158-4-72GGC)	Marine	66.7	-24.2	Basalt/plagioclase	Storminess	Andresen et al. (2005)
Dongge	Cave	25.3	108.1	**$\delta^{18}O$**	**Precipitation**	Dykoski et al. (2005), Wang et al. (2005)
Duck and Melles	Lake	76.3	-18.7	**% Sulfur** **% Total organic carbon**	**Summer temperature** **Summer temperature**	Klug et al. (2009b), Klug et al. (2009a)
Dye 3	Ice	65.2	-43.8	**$\delta^{18}O$**	**Temperature**	Vinther et al. (2009)
El Junco	Lake	-0.9	-89.5	% Clay % Silt % Sand	Precipitation Precipitation Precipitation	Conroy et al. (2008)
Elk	Lake	47.0	-95.5	**Varve thickness**	**Dust availability**	Dean et al. (2002)
EPICA Dome C	Ice	-75.1	123.4	**δD** $\delta^{18}O$ **Deuterium excess** Non sea-salt Ca Sea-salt Na Dust CH_4	Temperature Temperature Sea surface temperature Dust availability, transport vigor Sea ice area, transport vigor Dust availability, transport vigor Tropical wetland area	Stenni et al. (2001), Röthlisberger et al. (2002), EPICA community members (2004), Jouzel et al. (2007)
Etang de la Gruere	Peat	47.2	7.0	**% Absorbance**	**Precipitation-evaporation**	Roos-Barraclough et al. (2004)
Fayetteville Green	Lake	43.0	-79.0	Carbonate $\delta^{18}O$ Carbonate $\delta^{13}C$	Winter precipitation Summer precipitation	Kirby et al. (2002)
Fiskvatnet	Lake	69.6	19.9	S-ratio % Loss on ignition	Summer temperature Summer temperature	Paasche et al. (2004)
Foy	Lake	48.2	-114.4	Benthic diatoms	Precipitation	Stone and Fritz (2006)
Gardar Drift (MD99-2251)	Marine	57.4	-27.9	**Planktic forams (MAT)** **Planktic forams (MAT)** **Sortable silt** **% *N. pachyderma s.*** ***Globigerina bulloides* $\delta^{18}O$** *Globigerina bulloides* Mg/Ca	**Summer sea surface temperature** **Winter sea surface temperature** Bottom current speed Summer temperature $\delta^{18}O$ seawater Summer sea surface temperature	Ellison et al. (2006), Farmer et al. (2008)

GISP2	Ice	72.6	-38.5	**$\delta^{18}O$** Na Ca **CH_4** **$\delta^{15}N$**	**Temperature** Sea ice area, transport vigor Dust availability, transport vigor **Tropical wetland area** **Temperature**	Grootes et al. (1993) Cuffey and Clow (1997), Mayewski et al. (1997), Kobashi et al. (2007)
Green	Lake	50.0	-123.0	**% Loss on ignition**	**Glacier advance**	Menounos et al. (2004)
Greenland NAUJG1	Lake	66.7	-52.0	**% Residue on ignition**	**Summer temperature**	Willemse and Tornqvist (1999)
GRIP	Ice	72.5	-38.5	**$\delta^{18}O$** **Accumulation**	**Temperature** **Precipitation**	Hammer et al. (1997), Rasmussen et al. (2006)
Gulf of Guinea (GeoB4905-4)	Marine	2.5	9.4	***Globigerinoides ruber* Mg/Ca** ***Globigerinoides ruber* $\delta^{18}O$** ***Globigerinoides ruber* Ba/Ca**	**Annual sea surface temperature** **Annual sea surface salinity** **Precipitation**	Weldeab et al. (2007)
Gulf of Mexico (MD02-2550)	Marine	27.0	-91.4	***Globigerinoides ruber* Mg/Ca** ***Globigerinoides ruber* $\delta^{18}O$**	**Annual sea surface temperature** **Annual $\delta^{18}O$ seawater**	Lo Dico et al. (2006)
Hani	Peat	42.2	126.5	**Peat cellulose $\delta^{13}C$** Peat cellulose $\delta^{18}O$	**Summer precipitation** Mean annual temperature	Hong et al. (2005), Hong et al. (2009)
Hawes Water	Lake	54.2	-2.8	**Chironomids (WA-PLS)** **Calcite $\delta^{18}O$**	**July temperature** **$\delta^{18}O$ lakewater**	Marshall et al. (2007)
Heshang	Cave	30.4	110.4	**$\delta^{18}O$**	**Precipitation**	Hu et al. (2008)
Hojby So	Lake	55.9	11.6	**Thermophilous trees** **Mineral accumulation rate** **Chlorophyll A** Diatom accumulation rate	**Temperature** **Precipitation** **Precipitation** Precipitation	Hede et al. (2010)
Holebudalen	Lake	59.8	7.0	**Tychoplanktonic diatoms** **Periphytic diatoms**	**Temperature** **Temperature**	Panizzo et al. (2008)
Holzmaar	Lake	50.1	6.9	Organic matter $\delta^{13}C$ Pollen (PDF) Pollen (PDF) Pollen (PDF)	Productivity July temperature January temperature Mean annual precipitation	Lücke et al. (2003), Litt et al. (2009)
Hongyuan	Peat	32.8	102.5	***Carex mulieensis* $\delta^{13}C$**	**Summer precipitation**	Hong et al. (2003)
Hoti	Cave	23.1	57.4	**$\delta^{18}O$**	**Precipitation**	Neff et al. (2001)

Huguang Maar	Lake	21.2	110.3	**Ti** **Magnetic susceptibility** **S-ratio**	**Winter monsoon strength** **Winter monsoon strength** **Winter monsoon strength**	Yancheva et al. (2007)
Iceland Shelf (MD99-2269)	Marine	66.6	-23.8	*Coccolithus pelagicus* **Irminger Water species** % Quartz	Temperature **Temperature** Temperature	Giraudeau et al. (2004), Moros et al. (2006)
Igelsjon	Lake	58.5	13.7	**% Total organic carbon** **% Minerogenic** **Bulk carbonate $\delta^{13}C$** **Bulk carbonate $\delta^{18}O$**	**Summer precipitation** **Summer precipitation** **Precipitation-evaporation** **Precipitation-evaporation**	Hammarlund et al. (2005)
Jarbuvatnet	Lake	61.7	6.8	**% Loss on ignition**	**Glacier advance**	Nesje et al. (2001)
Jones	Lake	46.1	-113.2	Bulk carbonate $\delta^{18}O$	Precipitation-evaporation	Shapley et al. (2009)
Kalksjon	Lake	60.2	13.0	**%Total organic carbon** **Ti**	**Winter precipitation** **Winter precipitation**	Snowball et al. (2010)
Katerloch	Cave	47.1	15.6	**$\delta^{18}O$**	**Annual temperature**	Boch et al. (2009)
Kilimanjaro	Ice	-3.1	37.3	$\delta^{18}O$ **Cl**, **F**, **Na**, NO_3, **Ca, K, Mg,** SO_4	Temperature **Precipitation**	Thompson et al. (2002)
Laihalampi	Lake	61.5	26.1	Pollen (WA-PLS)	Mean annual temperature	Heikkila and Seppä (2003)
Lisa	Lake	61.8	8.2	**% Loss on ignition**	**Summer temperature**	Nesje and Dahl (2001)
Lykkjuvotn	Lake	61.9	-6.8	Biogenic silica	Temperature	Andresen et al. (2006)
Malawi	Lake	-10.3	34.3	Biogenic silica	Wind strength	Johnson et al. (2002)
Masoko	Lake	-9.3	33.8	Magnetic susceptibility	Precipitation	Garcin et al. (2006)
Moon	Lake	47.0	-98.2	Diatoms (WA)	Precipitation-evaporation	Laird et al. (1998)
Motterudsjarnet	Lake	59.6	12.7	Magnetic susceptibility	Winter precipitation	Zillén and Snowball (2009)
Murray Canyon (MD03-2611)	Marine	-36.7	136.6	*Globigerinoides ruber* $\delta^{18}O$ *G. ruber-G. bulloides* $\delta^{18}O$	Surface water temperature Depth of thermocline	Moros et al. (2009)
Nansen Trough (JM96-1206)	Marine	68.1	-29.4	**# Ice-rafted grains**	**Sea ice amount**	Jennings et al. (2002)
Nautajarvi	Lake	61.8	24.7	Pollen (WA-PLS)	Growing degree days	Ojala et al. (2008)
NGRIP	Ice	75.1	-42.3	**$\delta^{18}O$** **Accumulation**	**Temperature** **Precipitation**	Rasmussen et al. (2006), Rasmussen et al. (2007)
Nightingale	Lake	-37.4	-12.5	**%Total inorganic carbon** C/N	**Temperature, precipitation** Temperature, precipitation	Ljung et al. (2008)
Nordan's Pond	Peat	49.2	-53.6	***Sphagnum* $\delta^{18}O$**	**$\delta^{18}O$ precipitation**	Daley et al. (2009)

North Sea (Core 28-03)	Marine	60.5	3.5	**% N. pachyderma s.**	**Summer sea surface temperature**	Klitgaard-Kristensen et al. (1998)
Norwegian Sea (MD 95-2011)	Marine	66.9	7.6	% >63μm **Quartz/plagioclase** Planktic forams (WA-PLS, IK)	Sea ice amount **Sea ice amount** August sea surface temperature	Moros et al. (2004), Berner et al. (2011)
Okshola	Cave	67	15	**$\delta^{18}O$** **$\delta^{13}C$**	Annual temperature Precipitation	Linge et al. (2009)
Padre	Cave	-13.2	-44.0	**$\delta^{18}O$**	Precipitation	Cheng et al. (2009)
Pallcacocha	Lake	-2.8	-79.2	**Redscale**	Precipitation	Moy et al. (2002)
Peru-Chile margin	Marine	-15.2	-76.0	Alkenone Uk'_{37} Alkenone C_{37} **Biogenic silica**	Annual sea surface temperature Productivity **Productivity**	Chazen et al. (2009)
Peten-Itza	Lake	16.9	-89.8	*Cochliopina sp.* $\delta^{18}O$ *Pyrgophorus sp.* $\delta^{18}O$ % $CaCO_3$ **% Total organic carbon** **Sediment density**	Precipitation-evaporation Precipitation-evaporation Precipitation-evaporation **Precipitation-evaporation** **Precipitation-evaporation**	Curtis et al. (1998), Hillesheim et al. (2005)
Pink Panther	Cave	32.1	-105.2	**$\delta^{18}O$**	**Precipitation**	Asmerom et al. (2007)
Potrok Aike	Lake	-52.0	-70.4	%Total inorganic carbon Ca, Ti/Ca % Andean pollen taxa	Precipitation-evaporation Runoff Westerly strength	Haberzettl et al. (2007), Mayr et al. (2007)
Pupuke	Lake	-36.8	175.8	**Mean grain size** **> 32 microns** C/N	**Runoff** **Runoff** Runoff	Augustinus et al. (2008)
Qunf	Cave	17.2	54.3	**$\delta^{18}O$**	**Precipitation**	Fleitmann et al. (2003)
Raigastvere	Lake	58.6	26.6	Pollen (WA-PLS)	Mean annual temperature	Seppä and Poska (2004)
Renland	Ice	71.3	-26.7	**$\delta^{18}O$**	**Temperature**	Johnsen et al. (1992), Vinther et al. (2008)
Rouge	Lake	57.4	26.5	**Pollen (WA-PLS)**	**Mean annual temperature**	Veski et al. (2004)
Sagistalsee	Lake	46.7	8.0	C-ratio	Runoff	Hirt et al. (2003)
Sanbao	Cave	31.7	110.4	$\delta^{18}O$	Precipitation	Dong et al. (2010)

Santa Barbara (AII-125 JPC-76)	Marine	34.3	-120.0	*Globigerina bulloides* $\delta^{18}O$ *Neogloboquadrina pachyderma* $\delta^{18}O$ *Neogloboquadrina* dextral:sinistral % *Globigerina quinqueloba* % Planktic foram warm species	Mixed layer temperature Thermocline temperature Sea surface temperature Upwelling Surface temperature	Friddell et al. (2003), Fisler and Hendy (2008)
Sarsjon	Lake	64.0	19.6	**Paramagnetic susceptibility**	**Winter precipitation**	Snowball et al. (1999)
Sihailongwan	Lake	42.3	126.6	**Biogenic silica**	**Summer precipitation**	Schettler et al. (2006)
Sjuodjijaure	Lake	67.4	18.1	Pollen (WA-PLS) Chironomids (WA) Diatoms (WA-PLS)	July temperature July temperature July temperature	Rosen et al. (2001)
Snoheim	Lake	62.3	9.2	% Loss on ignition	Glacier advance	Nesje and Dahl (2001)
Sofular	Cave	41.4	31.9	**$\delta^{18}O$, $\delta^{13}C$**	**Temperature, precipitation**	Fleitmann et al. (2009)
Soreq	Cave	31.4	35.0	$\delta^{18}O$	Precipitation	Bar-Matthews et al. (1999)
South China Sea (17940)	Marine	20.1	117.4	% Clay ***Globogerinoides ruber* $\delta^{18}O$** Modal grain size	Summer precipitation **Summer precipitation** Winter monsoon strength	Wang et al. (1999a), Wang et al. (1999b)
South Iceland Rise (RAPiD-12-1k)	Marine	62.1	-17.8	*Globigerina bulloides* Mg/Ca *Globigerina bulloides* $\delta^{18}O$ ***Globorotalia inflata* Mg/Ca** ***Globorotalia inflata* $\delta^{18}O$**	Sea surface temperature Sea surface salinity Sea surface density **Thermocline temperature** **Thermocline salinity** **Thermocline density** Thermocline-surface density	Thornalley et al. (2009)
Southern Ocean (TTN057-13)	Marine	-53.2	5.1	Ice-rafted quartz	Temperature	Hodell et al. (2001)
Southern Ocean (TTN057-17)	Marine	-50	6	Diatoms (MAT) Diatoms (MAT) Diatoms (MAT)	Feb sea surface temperature August sea surface temperature Months of sea ice	Nielsen et al. (2004)
Steregoiu	Lake	47.8	23.6	**Pollen (MAT)** **Pollen (MAT)** Pollen (MAT) **Pollen (MAT)**	**Mean annual precipitation** **Mean annual temperature** Warm month temperature **Cold month temperature**	Feurdean et al. (2008)
Svalbard (MD99-2305)	Marine	77.8	15.3	***Cassidulina reniforme* $\delta^{18}O$**	**Sea ice amount**	Hald and Korsun (2008)

Taylor Dome	Ice	-77.8	158.7	$\delta^{18}O$ δD Na Ca	Temperature Temperature Sea ice area, transport vigor Dust availability, transport vigor	Mayewski et al. (1996), Steig et al. (1998), Steig et al. (2000)
Tenaghi Philipon	Peat	40.6	24.2	**Pollen (MAT)** **Pollen (MAT)** Pollen (MAT)	**Mean annual precipitation** **DJF temperature** JJA temperature	Pross et al. (2009)
Tigre Perdido	Cave	-5.9	-77.3	**$\delta^{18}O$**	**Precipitation**	van Breukelen et al. (2008)
Tilo	Lake	7.1	38.1	Diatom (G)	Precipitation-evaporation	Telford and Lamb (1999)
Titicaca	Lake	-16.0	-69.4	Bulk organic $\delta^{13}C$	Precipitation-evaporation	Baker et al. (2005)
Valencia	Lake	10.2	-67.8	*Heterocypris communis* $\delta^{18}O$ **% $CaCO_3$**	Precipitation-evaporation **Precipitation-evaporation**	Curtis et al. (1999)
Vanndalsvatnet	Lake	61.6	7.7	Pollen (WA-PLS) **Pollen (WA-PLS)** **Pollen (WA-PLS)**	July temperature **January temperature** **Mean annual precipitation**	Nesje et al. (2006)
Venado	Cave	10.6	-84.8	**$\delta^{18}O$**	**Precipitation**	Lachniet et al. (2004)
Victoria	Lake	0.1	32.8	**Principal components of diatoms**	**Precipitation-evaporation**	Stager and Mayewski (1997)
Vostok	Ice	-78.5	106.8	**δD**	**Temperature**	Petit et al. (1999)
Zhuyeze	Lake	39.0	103.3	% *Picea+Pinus* Mountain pollen concentration	Runoff Runoff	Chen et al. (2006)

[1] Proxies with detected 8.2 ka anomaly in bold.

[2] Method used for climate reconstruction in parentheses: PLS=Partial least-squares regression, WA-PLS=Weighted-averaging partial least-squares regression, ANN=Artificial Neural Network Technique, SIMMAX=SIMMAX transfer function, MAT=Modern Analogue Technique, WA=Weighted-averaging, IK=Imbrie and Kipp transfer function, G=Gasse transfer function

References

Andresen, C. S., Bond, G., Kuijpers, A., Knutz, P. C., and Björck, S.: Holocene climate variability at multidecadal time scales detected by sedimentological indicators in a shelf core NW off Iceland, Marine Geology, 214, 323-338, 2005.

Andresen, C. S., Björck, S., Rundgren, M., Conley, D. J., and Jessen, C.: Rapid Holocene climate changes in the North Atlantic: evidence from lake sediments from the Faroe Islands, Boreas, 35, 23-34, 2006.

Arz, H. W., Gerhardt, S., Patzold, J., and Rohl, U.: Millennial-scale changes of surface- and deep-water flow in the western tropical Atlantic linked to northern hemisphere high-latitude climate during the Holocene, Geology, 29, 239-242, 2001.

Asmerom, Y., Polyak, V., Burns, S., and Rassmussen, J.: Solar forcing of Holocene climate: New insights from a speleothem record, southwestern United States, Geology, 35, 1-4, 2007.

Augustinus, P., Bleakley, N., Deng, Y., Shane, P., and Cochran, U.: Rapid change in early Holocene environments inferred from Lake Pupuke, Auckland City, New Zealand, Journal of Quaternary Science, 23, 435-447, 10.1002/jqs.1153, 2008.

Baker, P. A., Fritz, S. C., Garland, J., and Ekdahl, E.: Holocene hydrologic variation at Lake Titicaca, Bolivia/Peru, and its relationship to North Atlantic climate variation, Journal of Quaternary Science, 20, 655-662, 2005.

Bamberg, A., Rosenthal, Y., Paul, A., Heslop, D., Mulitza, S., Rühlemann, C., and Schulz, M.: Reduced North Atlantic Central Water formation in response to early Holocene ice-sheet melting, Geophysical Research Letters, 37, L17705, 10.1029/2010GL043878, 2010.

Bar-Matthews, M., Ayalon, A., Kaufman, A., and Wasserburg, G. J.: The Eastern Mediterranean paleoclimate as a reflection of regional events: Soreq Cave, Israel, Earth and Planetary Science Letters, 166, 85-95, 1999.

Bennett, J. R., Cumming, B. F., Leavitt, P. R., Chiu, M., Smol, J. P., and Szeicz, J.: Diatom, pollen, and chemical evidence of postglacial climatic change at Big Lake, South-Central British Columbia, Canada, Quaternary Research, 55, 332-343, 2001.

Berner, K. S., Koç, N., Godtliebsen, F., and Divine, D.: Holocene climate variability of the Norwegian Atlantic Current during high and low solar insolation forcing, Paleoceanography, 26, PA2220, 10.1029/2010PA002002, 2011.

Boch, R., Spotl, C., and Kramers, J.: High-resolution isotope records of early Holocene rapid climate change from two coeval stalagmites of Katerloch Cave, Austria, Quaternary Science Reviews, 28, 2527-2538, 2009.

Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M. N., Showers, W., Hoffmann, S., Lotti-Bond, R., Hajdas, I., and Bonani, G.: Persistent solar influence on North Atlantic climate during the Holocene, Science, 294, 2130-2136, 2001.

Chazen, C. R., Altabet, M. A., and Herbert, T. D.: Abrupt mid-Holocene onset of centennial-scale climate variability on the Peru-Chile Margin, Geophysical Research Letters, 36, L18704, 10.1029/2009GL039749, 2009.

Chen, F.-H., Cheng, B., Zhao, Y., Zhu, Y., and Madsen, D. B.: Holocene environmental change inferred from a high-resolution pollen record, Lake Zhuyeze, arid China, The Holocene, 16, 675-684, 2006.

Cheng, H., Fleitmann, D., Edwards, R. L., Wang, X., Cruz, F. W., Auler, A. S., Mangini, A., Wang, Y., Kong, X., Burns, S. J., and Matter, A.: Timing and structure of the 8.2 kyr B.P. event inferred from d18O records of stalagmites from China, Oman, and Brazil, Geology, 37, 1007-1010, 2009.

Combourieu Nebout, N., Peyron, O., Dormoy, I., Desprat, S., Beaudouin, C., Kotthoff, U., and Marret, F.: Rapid climatic variability in the west Mediterranean during the last 25000 years from high resolution pollen data, Climate of the Past, 5, 503-521, 2009.

Conroy, J. L., Overpeck, J. T., Cole, J. E., Shanahan, T. M., and Steinitz-Kannan, M.: Holocene changes in eastern tropical Pacific climate inferred from a Galapagos lake sediment record, Quaternary Science Reviews, 27, 1166-1180, 2008.

Cremer, H., Heiri, O., Wagner, B., and Wagner-Cremer, F.: Abrupt climate warming in East Antarctica during the early Holocene, Quaternary Science Reviews, 26, 2012-2018, 10.1016/j.quascirev.2006.09.011, 2007.

Cuffey, K. M., and Clow, G. D.: Temperature, accumulation, and ice sheet elevation in central Greenland through the last deglacial transition, Journal of Geophysical Research, 102, 26383-26396, 1997.

Curtis, J. H., Brenner, M., Hodell, D. A., Balser, R. A., Islebe, G. A., and Hooshiemstra, H.: A multi-proxy study of Holocene environmental change in the Maya Lowlands of Peten, Guatemala, Journal of Paleolimnology, 19, 139-159, 1998.

Curtis, J. H., Brenner, M., and Hodell, D. A.: Climate change in the Lake Valencia Basin, Venezuela, ~12600 yr BP to present, The Holocene, 9, 609-619, 1999.

Daley, T. J., Street-Perrott, F. A., Loader, N. J., Barber, K. E., Hughes, P. D. M., Fisher, E. H., and Marshall, J. D.: Terrestrial climate signal of the "8200 yr B.P. cold event" in the Labrador Sea region, Geology, 37, 831-834, 10.1130/G30043A.1, 2009.

Dean, W. E., Forester, R. M., and Bradbury, J. P.: Early Holocene change in atmospheric circulation in the Northern Great Plains: an upstream view of the 8.2 ka cold event, Quaternary Science Reviews, 21, 1763-1775, 2002.

Denis, D., Crosta, X., Schmidt, S., Carson, D. S., Ganeshram, R. S., Renssen, H., Bout-Roumazeilles, V., Zaragosi, S., Martin, B., Cremer, M., and Giraudeau, J.: Holocene glacier and deep water dynamics, Adélie Land region, East Antarctica, Quaternary Science Reviews, 28, 1291-1303, 2009.

Dong, J., Wang, Y., Cheng, H., Hardt, B., Edwards, R. L., Kong, X., Wu, J., Chen, S., Liu, D., Jiang, X., and Zhao, K.: A high-resolution stalagmite record of the Holocene East Asian monsoon from Mt Shennongjia, central China, The Holocene, 20, 257-264, 2010.

Dormoy, I., Peyron, O., Combourieu Nebout, N., Goring, S., Kotthoff, U., Magny, M., and Pross, J.: Terrestrial climate variability and seasonality changes in the Mediterranean region between 15000 and 4000 years BP deduced from marine pollen records, Climate of the Past, 5, 615-632, 2009.

Dykoski, C. A., Edwards, R. L., Cheng, H., Yuan, D., Cai, Y., Zhang, M., Lin, Y., Qing, J., An, Z., and Revenaugh, J.: A high-resolution, absolute-dated Holocene and deglacial Asian monsoon record from Dongge Cave, China, Earth and Planetary Science Letters, 233, 71-86, 2005.

Ellison, C. R. W., Chapman, M. R., and Hall, I. R.: Surface and deep ocean interactions during the cold climate event 8200 years ago, Science, 312, 1929-1932, 2006.

EPICA community members: Eight glacial cycles from an Antarctic ice core, Nature, 429, 623-628, 2004.

Farmer, E. J., Chapman, M. R., and Andrews, J. E.: Centennial-scale Holocene North Atlantic surface temperatures from Mg/Ca ratios in Globigerina bulloides, Geochemistry, Geophysics, Geosystems, 9, Q12029, 10.1029/2008GC002199, 2008.

Feurdean, A., Klotz, S., Mosbrugger, V., and Wolhfarth, B.: Pollen-based quantitative reconstructions of Holocene climate variability in NW Romania, Palaeogeography, Palaeoclimatology, Palaeoecology, 260, 494-504, 2008.

Fisher, D. A., Koerner, R. M., and Reeh, N.: Holocene climatic records from Agassiz Ice Cap, Ellesmere Island, NWT, Canada, The Holocene, 5, 19-24, 1995.

Fisler, J., and Hendy, I. L.: California current system response to late Holocene climate cooling in southern California, Geophysical Research Letters, 35, L09702, 10.1029/2008GL033902, 2008.

Fleitmann, D., Burns, S. J., Mudelsee, M., Neff, U., Kramers, J., Mangini, A., and Matter, A.: Holocene forcing of the Indian monsoon recorded in a stalagmite from Southern Oman, Science, 300, 1737-1739, 2003.

Fleitmann, D., Cheng, H., Badertscher, S., Edwards, R. L., Mudelsee, M., Gokturk, O. M., Fankhauser, A., Pickering, R., Raible, C. C., Matter, A., Kramers, J., and Tuysuz, O.: Timing and climatic impact of Greenland interstadials recorded in stalagmites from northern Turkey, Geophysical Research Letters, 36, L19707, 2009.

Friddell, J. E., Thunell, R. C., Guilderson, T. P., and Kashgarian, M.: Increased northeast Pacific climate variability during the warm middle Holocene, Geophysical Research Letters, 30, 10.1029/2002GL016834, 2003.

Garcin, Y., Vincens, A., Williamson, D., Guiot, J., and Buchet, G.: Wet phases in tropical southern Africa during the last glacial period, Geophysical Research Letters, 33, 10.1029/2005GL025531, 2006.

Giraudeau, J., Jennings, A. E., and Andrews, J. T.: Timing and mechanisms of surface and intermediate water circulation changes in the Nordic Seas over the last 10000 cal years: A view from the North Iceland Shelf, Quaternary Science Reviews, 23, 2127-2139, 2004.

Grootes, P. M., Stuiver, M., White, J. W. C., Johnsen, S., and Jouzel, J.: Comparison of oxygen isotope records from the GISP2 and GRIP Greenland ice cores, Nature, 366, 552-554, 1993.

Haberzettl, T., Corbella, H., Fey, M., Janssen, S., Lücke, A., Mayr, C., Ohlendorf, C., Schabitz, F., Schleser, G. H., Wille, M., Wulf, S., and Zolitschka, B.: Lateglacial and Holocene wet-dry cycles in southern Patagonia: chronology, sedimentology and geochemistry of a lacustrine record from Laguna Potrok Aike, Argentina, The Holocene, 17, 297-310, 2007.

Hald, M., and Korsun, S.: The 8200 cal. yr BP event reflected in the Arctic fjord, Van Mijenfjorden, Svalbard, The Holocene, 18, 981-990, 2008.

Hammarlund, D., Björck, S., Buchardt, B., and Thomsen, C. T.: Limnic responses to increased effective humidity during the 8200 cal. yr BP cooling event in southern Sweden, Journal of Paleolimnology, 34, 471-480, 10.1007/s10933-005-5614-z, 2005.

Hammer, C. U., Andersen, K. K., Clausen, H. B., Dahl-Jensen, D., Hvidberg, C. S., and Iversen, P.: The stratigraphic dating of the GRIP ice core, Special Report of the Geophysical Department, Niels Bohr Institute for Astronomy, Physics and Geophysics, University of Copenhagen, 1997.

Haug, G. H., Hughen, K. A., Sigman, D. M., Peterson, L. C., and Rohl, U.: Southward migration of the intertropical convergence zone through the Holocene, Science, 293, 1304-1308, 2001.

Hede, M. U., Rasmussen, P., Noe-Nygaard, N., Clarke, A. L., Vinebrooke, R. D., and Olsen, J.: Multiproxy evidene for terrestrial and aquatic ecosystem responses during the 8.2 ka cold event as recorded at Højby Sø, Denmark, Quaternary Research, 73, 485-495, 2010.

Heikkilä, M., and Seppä, H.: A 11,000-year palaeotemperature reconstruction from the southern boreal zone in Finland, Quaternary Science Reviews, 22, 541-554, 2003.

Hillesheim, M. B., Hodell, D. A., Leyden, B. W., Brenner, M., Curtis, J. H., Anselmetti, F. S., Ariztegui, D., Buck, D. G., Guilderson, T. P., Rosenmeier, M. F., and Schnurrenberger, D. W.: Climate change in lowland central America during the late deglacial and early Holocene, Journal of Quaternary Science, 20, 363-376, 2005.

Hirt, A. M., Lanci, L., and Koinig, K.: Mineral magnetic record of Holocene environmental changes in Sagistalsee, Switzerland, Journal of Paleolimnology, 30, 321-331, 2003.

Hodell, D. A., Curtis, J. H., and Brenner, M.: Possible role of climate in the collapse of Classic Maya civilization, Nature, 375, 391-394, 1995.

Hodell, D. A., Kanfoush, S. L., Shemesh, A., Crosta, X., Charles, C. D., and Guilderson, T. P.: Abrupt cooling of Antarctic surface waters and sea ice expansion in the South Atlantic sector of the southern ocean at 5000 cal yr BP, Quaternary Research, 56, 191-198, 2001.

Holmgren, K., Lee-Thorp, J. A., Cooper, G. R. J., Lundblad, K., Partridge, T. C., Scott, L., Sithaldeen, R., Talma, A. S., and Tyson, P. D.: Persistent millennial-scale climatic variability over the past 25,000 years in Southern Africa, Quaternary Science Reviews, 22, 2311-2326, 2003.

Hong, Y. T., Hong, B., Lin, Q. H., Zhu, Y. X., Shibata, Y., Hirota, M., Uchida, M., Leng, X. T., Jiang, H. B., Xu, H., Wang, H., and Yi, L.: Correlation between Indian Ocean summer monsoon and North Atlantic climate during the Holocene, Earth and Planetary Science Letters, 211, 371-380, 2003.

Hong, Y. T., Hong, B., Lin, Q. H., Shibata, Y., Hirota, M., Zhu, Y. X., Leng, X. T., Wang, Y., Wang, H., and Yi, L.: Inverse phase oscillations between the East Asian and Indian Ocean summer monsoons during the last 12000 years and paleo-El Nino, Earth and Planetary Science Letters, 231, 337-346, 2005.

Hong, Y. T., Hong, B., Lin, Q. H., Shibata, Y., Zhu, Y. X., Leng, X. T., and Wang, Y.: Synchronous climate anomalies in the western North Pacific and North Atlantic regions during the last 14,000 years, Quaternary Science Reviews, 28, 840-849, 2009.

Hu, C., Henderson, G. M., Huang, J., Xie, S., Sun, Y., and Johnson, K. R.: Quantification of Holocene Asian monsoon rainfall from spatially separated cave records, Earth and Planetary Science Letters, 266, 221-232, 2008.

Hu, F. S., Slawinski, D., Wright, H. E., Ito, E., Johnson, R. G., Kelts, K. R., McEwan, R. F., and Boedigheimer, A.: Abrupt changes in North American climate during early Holocene times, Nature, 400, 437-440, 1999.

Hu, F. S., Kaufman, D., Yoneji, S., Nelson, D., Shemesh, A., Huang, Y., Tian, J., Bond, G., Clegg, B., and Brown, T.: Cyclic variation and solar forcing of Holocene climate in the Alaskan Subarctic, Science, 301, 1890-1893, 2003.

Hughen, K. A., Southon, J. R., Lehman, S. J., and Overpeck, J. T.: Synchronous radiocarbon and climate shifts during the last deglaciation, Science, 290, 1951-1954, 2000.

Jennings, A. E., Knudsen, K. L., Hald, M., Hansen, C. V., and Andrews, J. T.: A mid-Holocene shift in Arctic sea-ice variability on the East Greenland Shelf, The Holocene, 12, 49-58, 2002.

Johnsen, S. J., Clausen, H. B., Dansgaard, W., Fuhrer, K., Gundestrup, N., Hammer, C. U., Iversen, P., Jouzel, J., Stauffer, B., and Steffensen, J. P.: Irregular glacial interstadials in a new Greenland ice core, Nature, 359, 311-313, 1992.

Johnson, T. C., Brown, E. T., McManus, J., Barry, S., Barker, P., and Gasse, F.: A high-resolution paleoclimate record spanning the past 25,000 years in southern east Africa, Science, 296, 113-114,131-132, 2002.

Jouzel, J., Masson-Delmotte, V., Cattani, O., Dreyfus, G., Falourd, S., Hoffmann, G., Minster, B., Nouet, J., Barnola, J.-M., Chappellaz, J., Fischer, H., Gallet, J. C., Johnsen, S., Leuenberger, M., Loulergue, L., Luethi, D., Oerter, H., Parrenin, F., Raisbeck, G., Raynaud, D., Schilt, A., Schwander, J., Selmo, E., Souchez, R., Spahni, R., Stauffer, B., Steffensen, J. P., Stenni, B., Stocker, T. F., Tison, J. L., Werner, M., and Wolff, E. W.: Orbital and millennial Antarctic climate variability over the past 800,000 years, Science, 317, 793-796, 2007.

Jung, S. J. A., Davies, G. R., Ganssen, G. M., and Kroon, D.: Synchronous Holocene sea surface temperature and rainfall variations in the Asian monsoon system, Quaternary Science Reviews, 23, 2207-2218, 2004.

Kim, J.-H., Meggers, H., Rimbu, N., Lohmann, G., Freudenthal, T., Muller, P. J., and Schneider, R. R.: Impacts of the North Atlantic gyre circulation on Holocene climate off northwest Africa, Geology, 35, 387-390, 2007.

Kirby, M. E., Mullins, H. T., Patterson, W. P., and Burnett, A. W.: Late glacial-Holocene atmospheric circulation and precipitation in the northeast United States inferred from modern calibrated stable oxygen and carbon isotopes, Geological Society of America Bulletin, 114, 1326-1340, 2002.

Klitgaard-Kristensen, D., Sejrup, H. P., Haflidason, H., Johnsen, S., and Spurk, M.: A regional 8200 cal. yr BP cooling event in northwest Europe, induced by the final stages of the Laurentide ice-sheet deglaciation?, Journal of Quaternary Science, 13, 165-169, 1998.

Klug, M., Bennike, O., and Wagner, B.: Repeated short-term bioproductivity changes in a coastal lake on Store Koldeway, northeast Greenland: an indicator of varying sea-ice coverage?, The Holocene, 19, 653-663, 2009a.

Klug, M., Schmidt, S., Bennike, O., Heiri, O., Melles, M., and Wagner, B.: Lake sediments from Store Koldeway, Northeast Greeland, as archive of Late Pleistocene and Holocene climatic and environmental changes, Boreas, 38, 59-71, 110.1111/j.1502-3885.2008.00038, 2009b.

Kobashi, T., Severinghaus, J. P., Brook, E. J., Barnola, J.-M., and Grachev, A. M.: Precise timing and characterization of abrupt climate change 8200 years ago from air trapped in polar ice, Quaternary Science Reviews, 26, 1212-1222, 2007.

Kofler, W., Krapf, V., Oberhuber, W., and Bortenschlager, S.: Vegetation responses to the 8200 cal. BP cold event and to long-term climatic changes in the Eastern Alps: possible influence of solar activity and North Atlantic freshwater pulses, The Holocene, 15, 779-788, 2005.

Kotthoff, U., Pross, J., Müller, U. C., Peyron, O., Schmiedl, G., Schulz, H., and Bordon, A.: Climate dynamics in the borderlands of the Aegean Sea during formation of sapropel S1 deduced from a marine pollen record, Quaternary Science Reviews, 27, 832-845, 2008.

Kuhlmann, H., Meggers, H., Freudenthal, T., and Wefer, G.: The transition of the monsoonal and the N Atlantic climate system off NW Africa during the Holocene, Geophysical Research Letters, 31, 10.1029/2004GL021267, 2004.

Kulbe, T., Melles, M., Verkulich, S. R., and Pushina, Z. V.: East Antarctic climate and environmental variability over the last 9400 years inferred from marine sediments of the Bunger Oasis, Arctic, Antarctic and Alpine Research, 33, 223-230, 2001.

Lachniet, M. S., Asmerom, Y., Burns, S. J., Patterson, W. P., Polyak, V. J., and Seltzer, G. O.: Tropical response to the 8200 yr BP cold event? Speleothem isotopes indicate a weakened early Holocene monsoon in Costa Rica, Geology, 32, 957-960, 2004.

Laird, K. R., Fritz, S. C., Cumming, B. F., and Grimm, E. C.: Early-Holocene limnological and climatic variability in the Northern Great Plains, The Holocene, 8, 275-285, 1998.

Linge, H., Lauritzen, S.-E., Andersson, C., Hansen, J. K., Skoglund, R. Ø., and Sundqvist, H. S.: Stable isotope records for the last 10000 years from Okshola cave (Fauske, northern Norway) and regional comparisons, Climate of the Past, 5, 667-682, 2009.

Litt, T., Schölzel, C., Kühl, N., and Brauer, A.: Vegetation and climate history in the Westeifel Volcanic Field (Germany) during the past 11000 years based on annually laminated lacustrine sediments, Boreas, 38, 679-690, 10.1111/j.1502-3885.2009.00096, 2009.

Ljung, K., Björck, S., Renssen, H., and Hammarlund, D.: South Atlantic island record reveals a South Atlantic response to the 8.2 kyr event, Climate of the Past, 4, 35-45, 2008.

LoDico, J. M., Flower, B. P., and Quinn, T. M.: Subcentennial-scale climatic and hydrologic variability in the Gulf of Mexico during the early Holocene, Paleoceanography, 21, 10.1029/2005PA001243, 2006.

Lücke, A., Schlesser, G. H., Zolitschka, B., and Negendank, J. F. W.: A lateglacial and Holocene organic carbon isotope record of lacustrine palaeoproductivity and climatic change derived from varved lake sediments of Lake Holzmaar, Germany, Quaternary Science Reviews, 22, 569-580, 2003.

Marshall, J. D., Lang, B., Crowley, S. F., Weedon, G. P., van Calsteren, P., Fisher, E. H., Holme, R., Holmes, J. A., Jones, R. T., Bedford, A., Brooks, S. J., Bloemendal, J., Kiriakoulakis, K., and Ball, J. D.: Terrestrial impact of abrupt changes in the North Atlantic thermohaline circulation: Early Holocene, UK, Geology, 35, 639-642, 2007.

Matthews, J. A., Dahl, S. O., Nesje, A., Berrisford, M. S., and Andersson, C.: Holocene glacier variations in central Jotunheimen, southern Norway based on distal glaciolacustrine sediment cores, Quaternary Science Reviews, 19, 1625-1647, 2000.

Mayewski, P. A., Twickler, M. S., Whitlow, S. I., Meeker, L. D., Yang, Q., Thomas, J., Kreutz, K., Grootes, P. M., Morse, D. L., Steig, E. J., Waddington, E. D., Saltzman, E. S., Whung, P.-Y., and Taylor, K. C.: Climate change during the last deglaciation in Antarctica, Science, 272, 1636-1638, 1996.

Mayewski, P. A., Meeker, L. D., Twickler, M. S., Whitlow, S., Yang, Q., Lyons, W. B., and Prentice, M.: Major features and forcing of high-latitude northern hemisphere atmospheric circulation using a 110,000-year long glaciochemical series, Journal of Geophysical Research, 102, 26345-26366, 1997.

Mayr, C., Wille, M., Haberzettl, T., Fey, M., Janssen, S., Lücke, A., Ohlendorf, C., Oliva, G., Schabitz, F., Schleser, G. H., and Zolitschka, B.: Holocene variability of the Southern Hemisphere westerlies in Argentinean Patagonia (52 S), Quaternary Science Reviews, 26, 579-584, 2007.

Menounos, B., Koch, J., Osborn, G., Clague, J. J., and Mazzucchi, D.: Early Holocene glacier advance, southern Coast Mountains, British Columbia, Canada, Quaternary Science Reviews, 23, 1543-1550, 2004.

Moros, M., Emeis, K., Risebrobakken, B., Snowball, I., Kuijpers, A., McManus, J., and Jansen, E.: Sea surface temperatures and ice rafting in the Holocene North Atlantic: Climate influences on northern Europe and Greenland, Quaternary Science Reviews, 23, 2113-2126, 2004.

Moros, M., Andrews, J. T., Eberl, D. D., and Jansen, E.: Holocene history of drift ice in the northern North Atlantic: Evidence for different spatial and temporal modes, Paleoceanography, 21, PA2017, 10.1029/2005PA001214, 2006.

Moros, M., De Deckker, P., Jansen, E., Perner, K., and Telford, R. J.: Holocene climate variability in the Southern Ocean recorded in a deep-sea sediment core off South Australia, Quaternary Science Reviews, 28, 1932-1940, 2009.

Morrill, C., Overpeck, J. T., Cole, J. E., Liu, K.-B., Shen, C., and Tang, L.: Holocene variations in the Asian monsoon inferred from the geochemistry of lake sediments in central Tibet, Quaternary Research, 65, 232-243, 2006.

Moy, C. M. S., G. O., Rodbell, D. T., and Anderson, D. M.: Variability of El Nino/Southern Oscillation activity at millennial timescales during the Holocene epoch, Nature, 420, 162-165, 2002.

Neff, U., Burns, S. J., Mangini, A., Mudelsee, M., Fleitmann, D., and Matter, A.: Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago, Nature, 411, 290-293, 2001.

Nesje, A., and Dahl, S. O.: The Greenland 8200 cal. yr Bp event detected in loss-on-ignition profiles in Norwegian lacustrine sediment sequences, Journal of Quaternary Science, 16, 155-166, 2001.

Nesje, A., Matthews, J. A., Dahl, S. O., Berrisford, M. S., and Andersson, C.: Holocene glacier fluctuations of Flatebreen and winter-precipitation changes in the Jostedalsbreen region, western Norway, based on glaciolacustrine sediment records, The Holocene, 11, 267-280, 2001.

Nesje, A., Dahl, S. O., and Li, O.: Holocene millennial-scale summer temperature variability inferred from sediment parameters in a non-glacial mountain lake: Danntjorn, Jotunheimen, central southern Norway, Quaternary Science Reviews, 23, 2183-2205, 2004.

Nesje, A., Bjune, A. E., Bakke, J., Dahl, S. O., Lie, O., and Birks, H. J. B.: Holocene palaeoclimate reconstructions at Vanndalsvatnet, western Norway, with particular reference to the 8200 cal yr BP event, The Holocene, 16, 717-729, 2006.

Nielsen, S. H. H., Koç, N., and Crosta, X.: Holocene climate in the Atlantic sector of the Southern Ocean: Controlled by insolation or oceanic circulation?, Geology, 32, 317-320, 2004.

Ojala, A. E. K., Alenius, T., Seppä, H., and Giesecke, T.: Integrated varve and pollen-based temperature reconstruction from Finland: evidence for Holocene seasonal temperature patterns at high latitudes, The Holocene, 18, 529-538, 2008.

Paasche, O., Lovlie, R., Dahl, S. O., Bakke, J., and Nesje, A.: Bacterial magnetite in lake sediments: late glacial to Holocene climate and sedimentary changes in northern Norway, Earth and Planetary Science Letters, 223, 319-333, 2004.

Panizzo, V. N., Jones, V. J., Birks, H. J. B., Boyle, J. F., Brooks, S. J., and Leng, M. J.: A multiproxy palaeolimnological investigation of Holocene environmental change, between c. 10700 and 7200 years BP, at Holebudalen, southern Norway, The Holocene, 18, 805-817, 10.1177/0959683608089217, 2008.

Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J.-M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V. M., Legrand, M., Lipenkov, V. Y., Lorius, C., Pepin, L., Ritz, C., Saltzmann, E., and Stievenard, M.: Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica, Nature, 399, 429-436, 1999.

Pross, J., Kutthoff, U., Muller, U. C., Peyron, O., Dormoy, I., Schmiedl, G., Kalaitzidis, S., and Smith, A. M.: Massive perturbation in terrestrial ecosystems of the Eastern Mediterranean region associated with the 8.2 kyr B.P. climatic event, Geology, 37, 887-890, 2009.

Rasmussen, S. O., Andersen, K. K., Svensson, A. M., Steffensen, J. P., Vinther, B. M., Clausen, H. B., Siggaard-Andersen, M.-L., Johnsen, S. J., Larsen, L. B., Dahl-Jensen, D., Bigler, M., Röthlisberger, R., Fischer, H., Goto-Azuma, K., Hansson, M. E., and Ruth, U.: A new Greenland ice core chronology for the last glacial termination, Journal of Geophysical Research, 111, 10.1029/2005JD006079, 2006.

Rasmussen, S. O., Vinther, B. M., Clausen, H. B., and Andersen, K. K.: Early Holocene climate oscillations recorded in three Greenland ice cores, Quaternary Science Reviews, 26, 1907-1914, 2007.

Roos-Barraclough, F., van der Knaap, W. O., van Leeuwen, J. F. N., and Shotyk, W.: A late-glacial and Holocene record of climatic change from a Swiss peat humification profile, The Holocene, 14, 7-19, 2004.

Rosen, P., Segerstrom, U., Eriksson, L., Renberg, I., and Birks, H. J. B.: Holocene climatic change reconstructed from diatoms, chironomids, pollen and near-infrared spectroscopy at an alpine lake (Sjuodjijaure) in northern Sweden, The Holocene, 11, 551-562, 2001.

Röthlisberger, R., Mulvaney, R., Wolff, E. W., Hutterli, M. A., Bigler, M., Sommer, S., and Jouzel, J.: Dust and sea salt variability in central East Antarctica (Dome C) over the last 45 kyrs and its implications for southern high-latitude climate, Geophysical Research Letters, 29, 10.1029/2002GL015186, 2002.

Rühlemann, C., Mulitza, S., Lohmann, G., Paul, A., Prange, M., and Wefer, G.: Intermediate depth warming in the tropical Atlantic related to weakened thermohaline circulation: Combining paleoclimate data and modeling results for the last deglaciation, Paleoceanography, 19, 10.1029/2003PA000948, 2004.

Sarmaja-Korjonen, K., and Seppä, H.: Abrupt and consistent responses of aquatic and terrestrial ecosystems to the 8200 cal. yr cold event: a lacustrine record from Lake Arapisto, Finland, The Holocene, 17, 457-467, 2007.

Sarnthein, M., van Kreveld, S., Erlenkeuser, H., Grootes, P. M., Kucera, M., Pflaumann, U., and Schulz, M.: Centennial-to-millennial scale periodicities of Holocene climate and sediment injections off the western Barents shelf, 75 N, Boreas, 32, 447-461, 2003.

Schettler, G., Liu, Q., Mingram, J., Stebich, M., and Dulski, P.: East-Asian monsoon variability between 15000 and 2000 cal yr BP recorded in varved sediments of Lake Sihailongwan (northeastern China, Long Gang volcanic field), The Holocene, 16, 1043-1057, 2006.

Seppä, H., and Poska, A.: Holocene annual mean temperature changes in Estonia and their relationship to solar insolation and atmospheric circulation patterns, Quaternary Research, 61, 22-31, 2004.

Shapley, M. D., Ito, E., and Donovan, J. J.: Lateglacial and Holocene hydroclimate inferred from a groundwater flow-through lake, Northern Rocky Mountains, USA, The Holocene, 19, 523-535, 2009.

Snowball, I., Sandgren, P., and Petterson, G.: The mineral magnetic properties of an annually laminated Holocene lake-sediment sequence in northern Sweden, The Holocene, 9, 353-362, 1999.

Snowball, I., Muscheler, R., Zillén, L., Sandgren, P., Stanton, T., and Ljung, K.: Radiocarbon wiggle matching of Swedish lake varves reveals asynchronous climate changes around the 8.2 kyr cold event, Boreas, 39, 720-733, 10.1111/j.1502-3885.2010.00167.x, 2010.

Stager, J. C., and Mayewski, P. A.: Abrupt early to mid-Holocene climatic transition registered at the equator and the poles, Science, 276, 1834-1836, 1997.

Staubwasser, M., Sirocko, F., Grootes, P. M., and Erlenkeuser, H.: South Asian monsoon climate change and radiocarbon in the Arabian Sea during early and middle Holocene, Paleoceanography, 17, 10.1029/2000PA000608, 2002.

Steig, E. J., Brook, E. J., White, J. W. C., Sucher, C. M., Bender, M. L., Lehman, S. J., Morse, D. L., Waddington, E. D., and Clow, G. D.: Synchronous climate changes in Antarctica and the North Atlantic, Science, 282, 92-95, 1998.

Steig, E. J., Morse, D. L., Waddington, E. D., Stuiver, M., Grootes, P. M., Mayewski, P. A., Twickler, M. S., and Whitlow, S. I.: Wisconsin and Holocene climate history from an ice core at Taylor Dome, Western Ross Embayment, Antarctica, Geografiska Annaler, 82A, 213-235, 2000.

Stenni, B., Masson-Delmotte, V., Johnsen, S., Jouzel, J., Longinelli, A., Monnin, E., Rothlisberger, R., and Selmo, E.: An oceanic cold reversal during the last deglaciation, Science, 293, 2074-2077, 2001.

Stone, J. R., and Fritz, S. C.: Multidecadal drought and Holocene climate instability in the Rocky Mountains, Geology, 34, 409-412, 2006.

Telford, R. J., and Lamb, H. F.: Groundwater-mediated response to Holocene climatic change recorded by the diatom stratigraphy of an Ethiopian crater lake, Quaternary Research, 52, 63-75, 1999.

Thompson, L. G., Mosley-Thompson, E., Davis, M. E., Henderson, K. A., Brecher, H. H., Zagorodnov, V. S., Mashiotta, T. A., Lin, P.-N., Mikhalenko, V. N., Hardy, D. R., and Beer, J.: Kilimanjaro ice core records: Evidence of Holocene climate change in tropical Africa, Science, 298, 589-593, 2002.

Thornalley, D. J. R., Elderfield, H., and McCave, I. N.: Holocene oscillations in temperature and salinity of the surface subpolar North Atlantic, Nature, 457, 711-714, 2009.

van Breukelen, M. R., Vonhof, H. B., Hellstrom, J. C., Wester, W. C. G., and Kroon, D.: Fossil dripwater in stalagmites reveals Holocene temperature and rainfall variation in Amazonia, Earth and Planetary Science Letters, 275, 54-60, 2008.

Veski, S., Seppä, H., and Ojala, A. E. K.: Cold event at 8200 yr BP recorded in annually laminated lake sediments in eastern Europe, Geology, 32, 681-684, 2004.

Vinther, B. M., Clausen, H. B., Fisher, D. A., Koerner, R. M., Johnsen, S. J., Andersen, K. K., Dahl-Jensen, D., Rasmussen, S. O., Steffensen, J. P., and Svensson, A. M.: Synchronizing ice cores from the Renland and Agassiz ice caps to the Greenland Ice Core Chronology, Journal of Geophysical Research, 113, D08115, 10.1029/2007JD009143, 2008.

Vinther, B. M., Buchardt, S. L., Clausen, H. B., Dahl-Jensen, D., Johnsen, S. J., Fisher, D. A., Koerner, R. M., Raynaud, D., Lipenkov, V., Andersen, K. K., Blunier, T., Rasmussen, S. O., Steffensen, J. P., and Svensson, A. M.: Holocene thinning of the Greenland ice sheet, Nature, 461, 385-388, 10.1038/nature08355, 2009.

von Grafenstein, U., Erlenkeuser, H., Muller, J., Jouzel, J., and Johnsen, S.: The cold event 8200 years ago documented in oxygen isotope records of precipitation in Europe and Greenland, Climate Dynamics, 14, 73-81, 1998.

Wang, L., Sarnthein, M., Erlenkeuser, H., Grootes, P. M., Grimalt, J. O., Pelejero, C., and Linck, G.: Holocene variations in Asian monsoon moisture: A bidecadal sediment record from the South China Sea, Geophysical Research Letters, 26, 2889-2892, 1999a.

Wang, L., Sarnthein, M., Grootes, P. M., and Erlenkeuser, H.: Millennial reoccurrence of century-scale abrupt events of East Asian monsoon: A possible heat conveyor for the global deglaciation, Paleoceanography, 14, 725-731, 1999b.

Wang, Y., Cheng, H., Edwards, R. L., He, Y., Kong, X., An, Z., Wu, J., Kelly, M. J., Dykoski, C. A., and Li, X.: The Holocene Asian monsoon: Links to solar changes and North Atlantic climate, Science, 308, 854-857, 2005.

Weldeab, S., Lea, D. W., Schneider, R. R., and Andersen, N.: Centennial scale climate instabilities in a wet early Holocene West African monsoon, Geophysical Research Letters, 34, 10.1029/2007GL031898, 2007.

Willemse, N. W., and Törnqvist, T. E.: Holocene century-scale temperature variability from West Greenland lake records, Geology, 27, 580-584, 1999.

Yancheva, G., Nowaczyk, N. R., Mingram, J., Dulski, P., Schettler, G., Negendank, J. F. W., Liu, J., Sigman, D. M., Peterson, L. C., and Haug, G. H.: Influence of the intertropical convergence zone on the East Asian monsoon, Nature, 445, 74-77, 2007.

Zillén, L., and Snowball, I.: Complexity of the 8 ka climate event in Sweden recorded by varved lake sediments, Boreas, 38, 493-503, 10.1111/j.1502-3885.2009.00086.x, 2009.