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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 yr. 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 δ^{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 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), 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). The 8.2 ka event is unique among past meltwater events in that the hypothesized forcing is 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. 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 yr or better. This cutoff was chosen so that detection of a short event (∼ 150 yr) 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 (Fig. 1, Table S1 in the Supplement).

The number of sites has doubled since the last global syntheses of the 8.2 ka event were published in 2005–2006 (Fig. 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 Supplement 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 (Fig. 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 yr 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 (Fig. 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 yr 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-yr 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 (Fig. 3a), a result common to previous syntheses. New to this study is some evidence for warm anomalies in the Southern Hemisphere (Fig. 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 yr (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 yr, Fig. 3b). According to the moving z-test, event durations in Europe appear to be somewhat shorter than those in Greenland (100–160 yr; Fig. 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, Fig. 3a). A few estimates are available for summer and winter temperatures. Two pollen records of winter temperature from

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). 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. 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 (Fig. 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. 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, 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).

According to the moving z-test, most of the high-resolution precipitation anomalies last on the order of 100 to 150 yr (Fig. 4b). The exceptions to this general conclusion are two shorter anomalies of 30 to 50 yr in Sweden (Snowball et al., 1999, 2010) and two longer anomalies of 230 to 280 yr 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 yr (Fig. 4b), lending support to the conclusion that precipitation did decrease in these areas coincident with the 8.2 ka event.

There are just five sites with quantitative precipitation reconstructions, all of which are mean annual quantities in either Greenland or Europe. Four of these sites show precipitation decreases, including 8 % in Central Greenland and 17 % in Southeastern Europe (Table 2; Hammer et al., 1997; Rasmussen et al., 2007; Pross et al., 2009; Feurdean et al., 2008). The fifth 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 Fig. 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 δ^{18}O anomalies. It is most direct to compare modeled δ^{18}O to reconstructed seawater or precipitation values, but for some proxies, such as speleothems, it is sometimes reasonable to assume that measured values accurately reflect precipitation δ^{18}O changes. This may be less true for δ^{18}O of lake carbonates, which depending on the residence time of water in the lake, are changed through evaporative enrichment. While keeping in mind these differences, we present all δ^{18}O values together in Table 3. We also note that some of these δ^{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, 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 ‰ (Fig. 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, 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 (Sect. 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 1.0 to 1.2 °C; event duration generally of 100 to 150 yr for both temperature and precipitation; decreased precipitation in the Asian monsoon region, Central America and Northern South America; and decreases in δ^{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).

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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. It is unclear whether a similar 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.

Supplementary material related to this article is available online at: http://www.clim-past-discuss.net/8/3765/2012/cpd-8-3765-2012-supplement.zip.

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References

Alley, R. B. and Ágústsdóttir, A. M.: The 8 k event: cause and consequence of a major Holocene abrupt climate change, Quaternary Sci. Rev., 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 8200 years ago by catastrophic drainage of Laurentide lakes, Nature, 400, 344–348, 1999.

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 δ^{18}O 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.

Coplen, T. B.: 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 Sci. Rev., 26, 2012–2018, doi: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 Sci. Rev., 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 Sci. Rev., 24, 1159–1182, 2005.

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 Planet. Sc. Lett., 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, NJ, 626 pp., 1966.

Feurdean, A., Klotz, S., Mosbrugger, V., and Wolhfarth, B.: Pollen-based quantitative reconstructions of Holocene climate variability in NW Romania, Palaeogeogr. Palaeocl., 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.

Hald, M. and Korsun, S.: The 8200 cal. yr BP event reflected in the Arctic fjord, Van Mijenfjorden, Svalbard, 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, J. Paleolimnol., 34, 471–480, doi: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 Res., 73, 485–495, 2010.

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, 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 Sci. Rev., 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, P. Natl. Acad. Sci. USA, 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 Planet. Sc. Lett., 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, Clim. Past, 4, 35–45, doi:10.5194/cp-4-35-2008, 2008.

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 Sci. Rev., 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 Sci. Rev., 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 Sci. Rev., 23, 2113–2126, 2004.

Morrill, C. and Jacobsen, R. M.: How widespread were climate anomalies 8200 years ago?, Geophys. Res. Lett., 32, L19701, doi:10.1029/2005GL023536, 2005.

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, 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, 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.

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 Sci. Rev., 26, 1907–1914, 2007.

Rohling, E. J. and Pälike, H.: Centennial-scale climate cooling with a sudden cold event around 8200 years ago, Nature, 434, 975–979, 2005.

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, 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, doi: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, Nat. Geosci., 5, 46–49, doi:10.1038/NGEO1326, 2012.

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 Sci. Rev., 26, 70–81, 2007.

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 Planet. Sc. Lett., 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.

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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 Sci. Rev., 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, J. Quaternary Sci., 26, 118–127, doi:10.1002/jqs.1439, 2011.

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, doi:10.1111/j.1502-3885.2009.00086.x, 2009.

Table 1. Quantitative temperature anomalies.

Site	Proxy type	Maximum (°C)	Mean (°C)	Duration (years)
	Mean annual temperature			
GISP2	δ^{15}N	−3.3	−2.2	120
Ammersee, Germany	δ^{18}O	−1.3	−1.1	90
Lake Rõuge, Estonia	pollen	−2.6	−1.2	280
Lake Arapisto, Finland	pollen	−2.2	−1.2	200
South Iceland rise (thermocline)	Mg/Ca	−1.2	−1.0	80
Steregoiu, Romania	pollen	−1.6	−1.1	190
Gulf of Mexico	Mg/Ca	−1.3	−0.9	120
Cape Ghir (surface)	alkenones	−0.7	−0.6	250
Cape Ghir (thermocline)	Mg/Ca	−1.0	−0.6	80
Gulf of Guinea	Mg/Ca	−1.9	−1.1	140
	Winter temperature			
Tenaghi Philippon, Greece	pollen	−4.0	−2.8	140
Gardar Drift	forams	−1.6	−1.3	80
Vanndalsvatnet, Norway	pollen	2.5	1.7	240
Steregoiu, Romania	pollen	−5.6	−4.2	110
	Summer temperature			
Hawes Water, UK	chironomids	−1.5	−0.8	90
Gardar Drift	forams	−2.1	−1.7	60

Table 2. Quantitative precipitation anomalies.

Site	Proxy type	Maximum (%)	Mean (%)	Duration (years)
GRIP	ice accumulation	–28	–8	120
NGRIP	ice accumulation	–18	–8	150
Tenaghi Philippon, Greece	pollen	–27	–17	110
Vanndalsvatnet, Norway	pollen	20	12	240
Steregoiu, Romania	pollen	–25	–17	110

Table 3. Oxygen isotope anomalies.

Site	Material	Maximum (‰)	Mean (‰)	Duration (years)
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	precipitation	−3.0	−2.6	80
Ammersee, Germany	ostracod $CaCO_3$	−0.8	−0.6	90
Katerloch Cave, Austria	cave $CaCO_3$	−1.3	−0.7	130
Hawes Water, UK	lake water	−0.9	−0.6	110
Gardar Drift	seawater	−0.7	−0.4	180
Igelsjon Lake, Sweden	bulk $CaCO_3$	−2.7	−2.0	250
Okshola Cave, Norway	cave $CaCO_3$	−1.0	−0.8	20
Svalbard	benthic $CaCO_3$	−0.4	−0.2	70
Pink Panther Cave, USA	Cave $CaCO_3$	−0.8	−0.4	270
Gulf of Mexico	seawater	−0.6	−0.4	150
Venado Cave, Costa Rica	cave $CaCO_3$	2.0	1.0	80
Tigre Perdido Cave, Peru	cave $CaCO_3$	−1.0	−0.5	170
Padre Cave, Brazil	cave $CaCO_3$	−1.8	−1.3	60
Qunf Cave, Oman	cave $CaCO_3$	0.7	0.4	250
Hoti Cave, Oman	cave $CaCO_3$	1.1	0.8	30
Dongge Cave, China	cave $CaCO_3$	0.9	0.4	170
Heshang Cave, China	cave $CaCO_3$	1.1	0.8	130
South China Sea	planktic $CaCO_3$	0.4	0.4	40

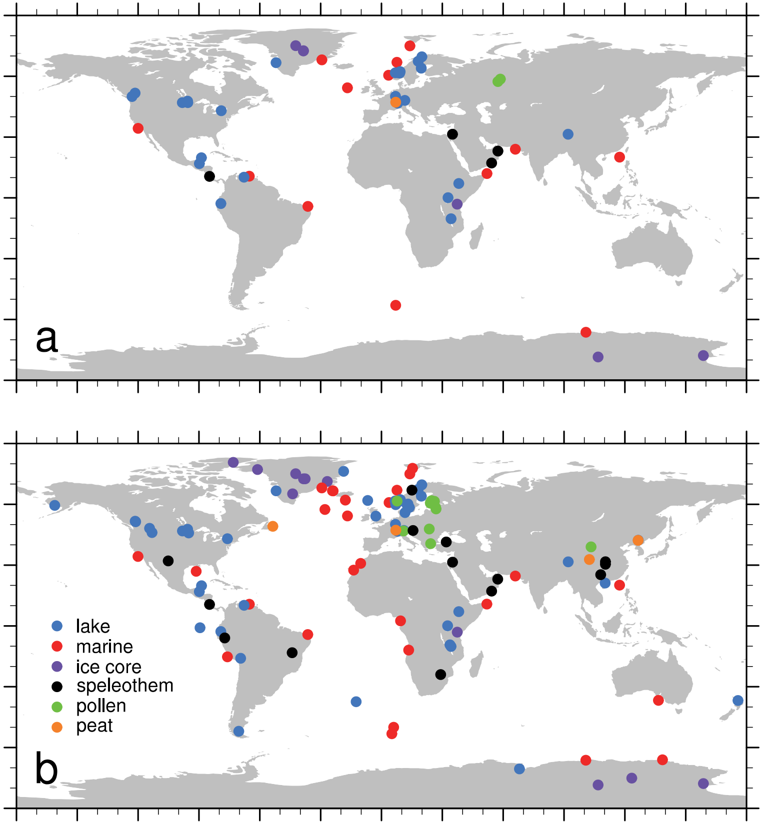

Fig. 1. Location of high-resolution proxy records spanning 8.2 ka that were available in **(a)** 2005 (Morrill and Jacobsen, 2005) and **(b)** 2012.

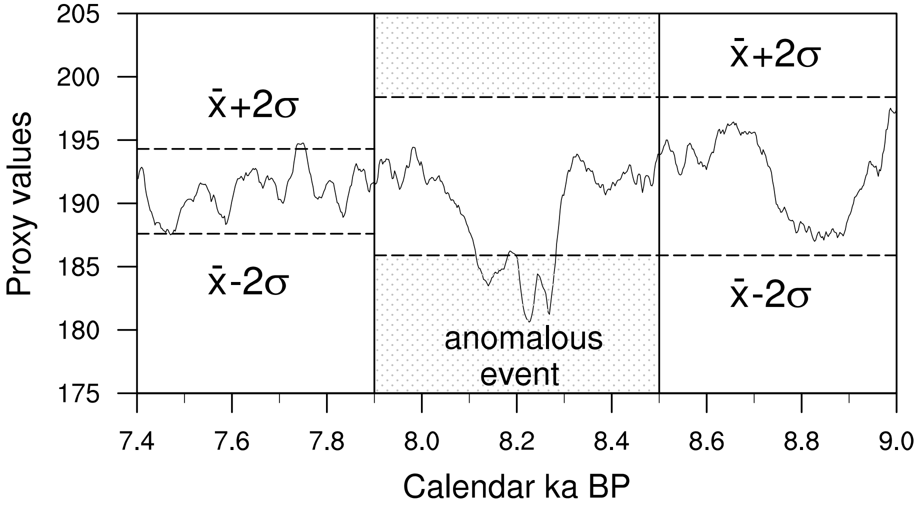

Fig. 2. Schematic diagram of method used to detect climate anomalies at 8.2 ka, as described in text.

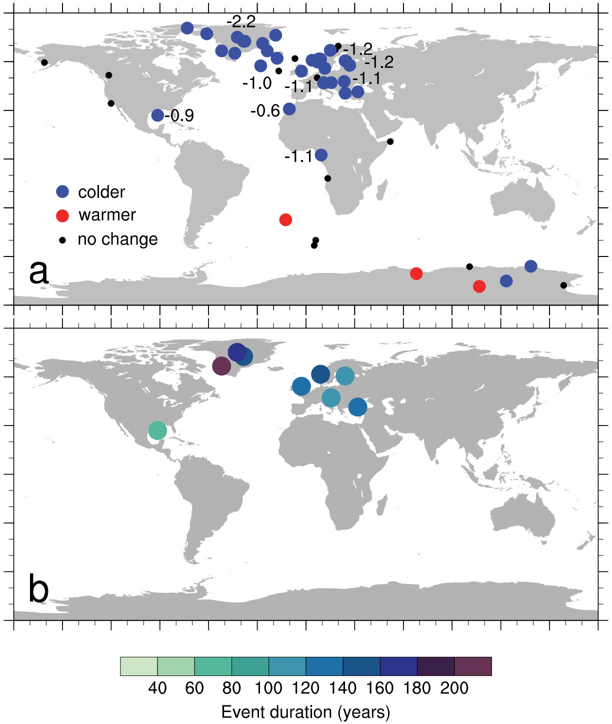

Fig. 3. (a) Temperature anomalies detected near 8.2 ka by the method described in text. Black dots indicate sites with temperature proxies that did not have an identifiable anomaly. Values plotted are quantitative temperature estimates in degrees Celsius and are also provided in Table 1. **(b)** Duration of temperature anomalies in high-resolution (better than 15 yr/sample) proxies, as determined using the method of Wiersma et al. (2011).

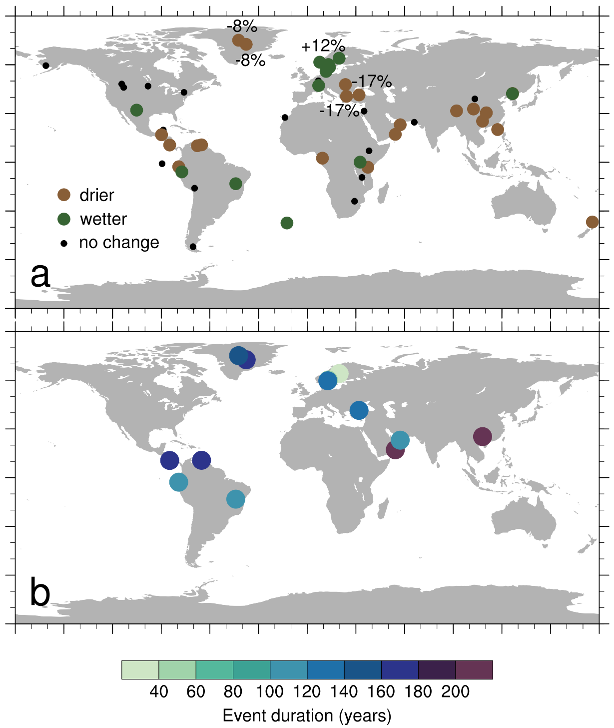

Fig. 4. (a) Precipitation anomalies detected near 8.2 ka by the method described in text. Black dots indicate sites with precipitation proxies that did not have an identifiable anomaly. Values plotted are quantitative precipitation estimates, expressed as a percent difference from values averaged for 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 yr/sample) proxies, as determined using the method of Wiersma et al. (2011).

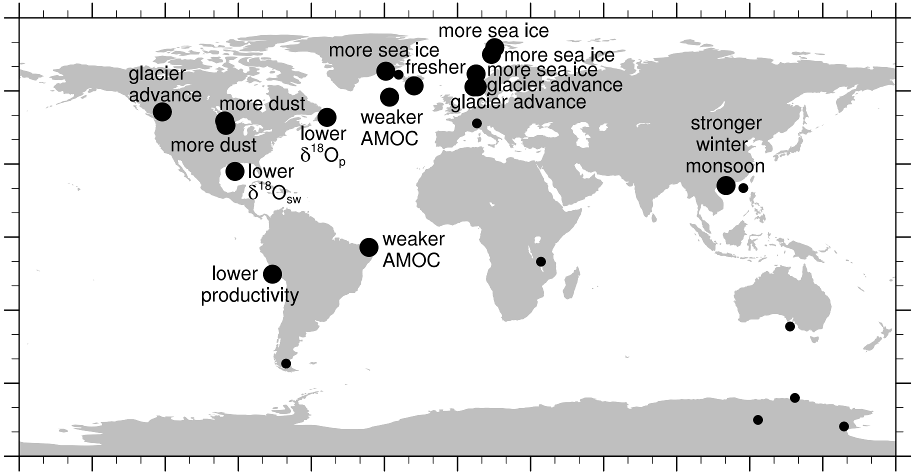

Fig. 5. Climate anomalies detected near 8.2 ka that were not easily categorized in terms of temperature or precipitation. Small black dots indicate sites without an identifiable climate anomaly.

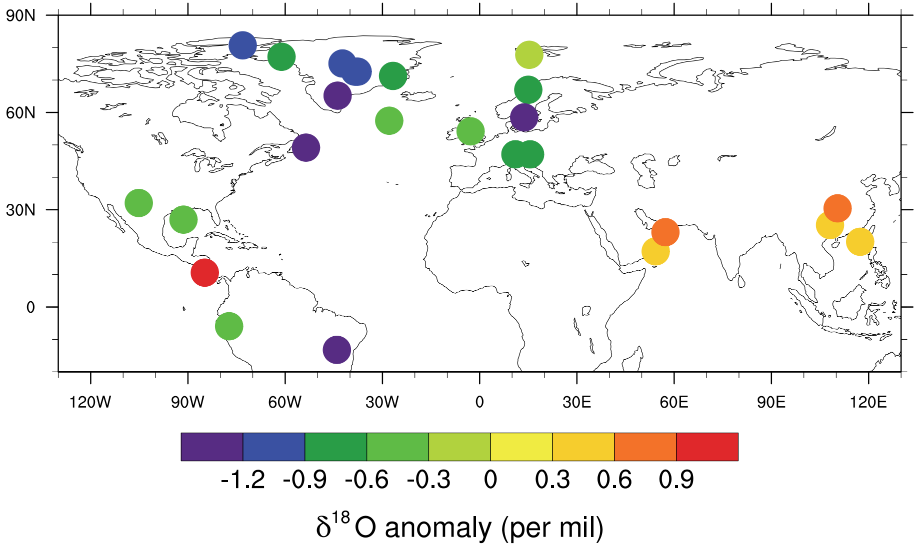

Fig. 6. Anomalies in δ^{18}O detected using method described in text. Sites plotted here are also provided in Table 3.