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Reply to Miller et al. (2013) Substantial agreement on the timing and magnitude of Late Holocene ice cap expansion between east Greenland and the eastern Canadian Arctic: a commentary on Lowell et al. (2013)

Glaciers are sensitive indicators of climate change. Thus recent warming has led to general recession, producing glacier forefields that yield valuable information on the Little Ice Age and the Medieval Warm Period, as well as on older Holocene climate changes. Such forefields in the Swiss Alps and the Canadian Rockies reveal remains of trees killed during past intervals of glacier expansion. From “kill dates” of overridden trees, former glacier advances can be reconstructed in detail. For example, kill dates of larch trees allowed an advance of Gorner Glacier in the Swiss Alps to be tracked for a distance of 1000 m between 1327 AD and a maximum achieved in 1385 AD just short of the Little Ice Age Hochstand of 1859 AD (Holzhauser, 1995; Holzhauser et al., 2005). The same approach was used at Robson Glacier in the Canadian Rockies to show expansion between 1150 and 1350 AD (Luckman, 1995, 2000); an earlier Holocene advance of Peyto Glacier was tracked by kill dates of overridden trees (Luckman et al., 1993).

Glacier recession has also occurred on Baffin Island and Greenland. Miller et al. (2012) concluded that kill dates on the resulting forefields on Baffin Island are restricted to in-situ moss remains that became exposed by receding ice during the year of sample collection. Each radiocarbon date of such moss pinpoints a time of ice-free conditions at the sample site. The inference is then drawn that each moss sample was buried immediately thereafter by ice or snow in order to be preserved until again exposed by recent glacier recession. Miller et al. (2013) advised against using other organic material from Arctic forefields to reconstruct past glacier fluctuations. Their protocol excluded samples of moss collected more than several meters from receding ice fronts, of woody remains of Salix, and of organic material from beneath till. In particular, they point out that woody remains can linger for years on Arctic forefields before being buried by ice or snow. Thus, they caution that, although useful for identifying ice-free conditions at collection sites, the age of such samples should not be employed as kill dates for subsequent burial by ice or snow.

Miller et al. (2012) reported 94 radiocarbon dates of moss samples that fall between 800 and 2000 AD and that were collected under the protocol of Miller et al. (2013) from alongside 50 Baffin ice caps spread along a transect nearly 1000 km in length. Although valuable in its own right, such a data set has several limitations. All the moss samples came from within 1–3 m of the 2005–2010 ice margins. Therefore, burial and preservation of such samples only tracks glacier expansion over these recently exposed ice-marginal zones. From these data alone, it can not be determined how far the ice margin advanced beyond the sample sites. For example, the lack of kill dates outboard of these recent marginal zones precluded reconstruction of glacier expansions through forefields toward Little Ice Age limits, in contrast to the detailed depictions made possible by the wood kill dates on forefields in the Swiss Alps and Canadian Rockies. Also the protocol of Miller et al. (2013) does not include dating of Little Ice Age moraines, thus precluding glacier reconstructions that would allow estimates of snowline, and hence temperature depression compared to today’s values. The result is that major conclusions about the Little Ice Age are drawn without moraine chronologies or values for snowline lowering. All the radiocarbon dates of moss collected in Baffin Island under this sampling protocol are plotted in the cumulative probability density function given in Figure 2, panel C, of Miller et al. (2012). The peaks in this probability function are interpreted as the time of ice-cap expansion over the marginal zones of AD 2005–2010, the years of sample collection. Two intervals of such expansion stand out, one between 850 and 950 AD and the other between 1275 and 1455 AD. The second interval is interpreted to represent the abrupt onset of the Little Ice Age between 1275 and 1300 AD, followed by intensification at 1430–1455 AD. The near lack of moss kill dates between 1455 AD and the past century is attributed to continuous ice burial during the remainder of the Little Ice Age. In contrast, the near lack of moss kill dates in the interval between 950 and 1275 AD is attributed to ice melt, representing three centuries of glacier contraction before the inferred abrupt onset of the Little Ice Age.

We prefer an alternate strategy that takes advantage of a wide variety of data from the forefields of selected Arctic ice caps. Pertinent information could include, but is not restricted to, maps of glacial geomorphology, analysis of glacial stratigraphy, radiocarbon dating of wood and other organic materials throughout the forefields, dating of Little Ice Age moraines, and coring of threshold lakes (Briner et al., 2010) near the Little Ice Age limit. In this context we agree with Miller et al. (2013) that radiocarbon ages of woody

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plants, moss, and other fossil plants such as those collected by Lowell et al. (2013) near the present-day Istorvet ice cap in east Greenland can not be interpreted as kill dates. Indeed, Lowell et al. (2013) used such ages only to identify times when sample sites were ice free, as well as to afford maximum-limiting values for subsequent burial by ice.

We offer one example of the value of an integrated approach in appraising Arctic glacier history. A core from Bone Lake shows that the Istorvet ice cap in east Greenland had advanced through the forefield and over a threshold located 365 m from the Little Ice Age limit by ~1150 AD (Lowell et al., 2013). It follows that this advance, which was of greater extent than any previous Holocene expansion, must have been underway prior to that time. From the west margin site of Istorvet, Lowell et al. (2013) estimated that this advance began ~1025 AD, on the basis of eight dates of plant remains, all of which have emerged from beneath ice and some of which are from beneath till. The individual calibrated ages range from 790 ± 105 to 1005 ± 20 AD. The overall collection of ages affords a maximum-limiting value for expansion across the west margin site, because the plants grew at a time when the ice-cap margin was inboard of the sample localities. Lowell et al. (2013) estimated that ice expansion over the west margin site occurred when the calibration summed probabilities of the ages dropped to near zero, indicating that the growth of all sampled plants must have ceased by ~1025 AD (Fig. 6, Lowell et al., 2013). However, there are potential problems with this estimate, both because these samples do not afford kill dates and because the youngest plant material may not have been collected and dated. Miller et al. (2013) suggested a revision of this estimate of over-ripping to ~965 AD (or perhaps as late as 1000 AD) by averaging the three youngest dates at the west margin site, even though the dated samples do not fit within their protocol. The two estimates differ by 25–60 years.

In any case, the different age estimates are probably unimportant, because there is no firm evidence linking ice expansion over the west margin site to the overtopping of the Bone Lake threshold. The only indisputable reconstruction of an advance through the Istorvet forefield and across the threshold toward the Little Ice Age limit would come from kill dates along the flow path, as done in the examples from Gorner and Robson Glaciers discussed above. But because such kill dates are lacking, we are left simply with the conclusion drawn from the Bone Lake sediment core that the Istorvet ice cap advanced outboard of the threshold ~1150 years AD, where it apparently remained until the end of the Little Ice Age. In our view, this conclusion is inconsistent with the Baffin ice-cap history of Miller et al. (2012), as the advance over the threshold occurred near the middle of the ice-melt interval between 950 and 1275 AD depicted in their Figure 2, panel C.

References


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