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Climate of the Past Discussions

Interactive comment on "Tracing winter temperatures over the last two millennia using a NE Atlantic coastal record" *by* Irina Polovodova Asteman et al.

Irina Polovodova Asteman et al.

kjell.nordberg@marine.gu.se

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Author's response to reviewer 1

We sincerely thank reviewer 1, Antoon Kuijpers, for his useful and insightful comments and an advice on highly relevant references, which we missed to include. Below we respond to the comments point by point:

Comment 1: Comment/ discuss general results in context of (non-cited) highly relevant reference Luterbacher et al. 2016 Env.Res.Lett. 11.

Response: We first had troubles tracking down the suggested reference, until we have

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found out that it must be a paper by Orth et al (2016), including Luterbacher as a co-author, since it appears to be the only paper in Env.Res.Lett. 11, which, indeed, turned out to be highly relevant for our discussion. Now we included this into the discussion and added the following section under the "LIA milder episode": ÂńIndeed, several studies report an exceptional multi-month drought and long-lasting warm conditions in Europe associated with year 1540 (Casty et al., 2005; Pauling et al., 2006; Wetter et al, 2014), which given our age model uncertainty for the time interval 1538-1664 BCE (+-40 yr, see Table 2) may well fall within the warm period identified for the LIA from our BWT record. A warming around 1540 is also seen in winter temperature reconstruction for Stockholm ports and harbours based on historical records of sea ice (Leijonhufvud et al., 2009). The model-based reconstruction by Orth et al (2016) suggests that the European temperatures of 1540 exceeded those of the summer 2003, which was likely the warmest for centuries (e.g. Luterbacher et al, 2016). This is, however, difficult to deduce based on our data, since the fjord BWT record only stretches until ca 1996.Âż

Comment 2: Start of LIA : refer to Stuiver et al. 1995, Quat Res 44

Response: The reference has been included.

Comment 3: Multi-decadal variability lacking reference to possible link to Atlantic Multidecadal Oscillation (AMO). Within this context interesting to discuss results shown in Fig. 7 with peaking BWT values prior to 1920 coinciding with cold AMO / low N Atlantic sea surface salinities (Reverdin et al. 1994 Progr.Ocean. 33; Reverdin 2010, Journ Clim 23) , in following period until ca 1960 BWT at a lower level (during warm AMO), after which again peaking (e.g. at time of 'Great Salinity Anomaly', early 1970's).

Response: We added a reference to AMO (Enfield et al, 2001) and its link to the multidecadal climate variability (through AMOC) into the introduction. We also added a discussion around high fjord BWT at times of cold AMO and reduced salinities in the North Atlantic: "Our record also shows higher BWT prior to the 1920s (Fig. 8), which coincides with the cold AMO (low SSTs) and low sea surface salinities in the North

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Atlantic and Subpolar Gyre (Reverdin et al. 1994; Reverdin, 2010), while in the following period until ca 1960, the reconstructed BWT remains at a lower level (during the warm AMO, i.e. high North Atlantic SSTs), after which it peaks again at time of "Great Salinity Anomaly" during the late 1970s and late 1980s (Dickson et al., 1988; Belkin et al., 1998). It remains intriguing, though, that at both occasions (prior to the 1920s and during the 1970s/1980s) of the reduced salinities and low SSTs in the North Atlantic, our record is characterized by high temperatures of the fjord deep water, which is consistent with increasing air temperatures in instrumental datasets from Stockholm and Central England (Fig. 8). The low surface salinities of the Great Salinity Anomaly were likely driven by an increased freshwater/sea ice export from the Arctic via Fram Strait and Canadian Archipelago (Belkin et al., 1998). The increased freshwater flux into the subpolar North Atlantic, in turn, is suggested to increase salinity of the North Atlantic Current, which may reduce its predicted weakening due to enhanced freshwater fluxes and will help to restart a stronger AMOC (Hátún et al., 2005; Thornalley et al., 2009). A stronger North Atlantic Current would in turn result in an increased heat transport during winter to the Eastern North Atlantic and together with other external forcing factors (e.g. changes in NAO, volcanism, and solar activity) would contribute to the warming observed in the fjord BWT record during the early 20th century. One of those factors, the positive NAO mode, which prevailed since the 1970s/1980s (Hurrell, 1995; http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/season.JFM.nao.gif), extracts heat from the subpolar North Atlantic through increased westerlies over that region, decreases SSTs, enhances convection, increases ocean density (Delworth et al., 2016; Delworth and Zeng, 2016) and results in milder winter conditions over the north-western Europe, thus counteracting effects of the AMOC weakening, which has been suggested for the 20th century based on modeling data and proxy records (Caesar et al., 2018; Thornalley et al., 2018). Also, located within a coastal region, the Gullmar Fjord is more susceptible to wind-forced temperature changes, which follow the variability of the NAO index and drive coastal upwelling and downwelling in the fjord (Björk and Nordberg, 2003). According to Jansen et al. (2007), the late

20th century warming as demonstrated by many proxy records from the NE Atlantic (see discussion above), is unlikely to be explained by the external forcing factors and is probably linked to the anthropogenic drivers such as greenhouse gas emissions and aerosols (Booth et al, 2012), which both significantly increased since ca 1970s (Masson-Delmotte, 2013)."

Comment 4: Fig. 8: Discuss Dalton Minimum (AD 1790 - 1820) with general low T, both Tair and BWT coinciding with Gulf Stream warming (see previous remark !) , ref Van der Schrier and Barkmeijer 2005, Clim Dyn. 24

Response: We agree with the reviewer and have added a following section into the LIA-discussion:

"Another interesting feature of the LIA climate variability is associated with consistently low fjord BWT as well as reduced air temperatures during 1790 – 1820 CE as indicated by Stockholm and Central England instrumental time series (Fig. 8). Despite this time period is known to coincide with the Dalton minimum in solar activity (Grove, 1988), it is likely that solar activity played much less role than volcanic activity associated with eruptions of 1809 and 1815 (Wagner and Zorita, 2005). The role of AMOC strength in shaping the LIA cold periods is also somewhat controversial based on marine geological evidence: though the AMOC weakening was proposed as a trigger for the LIA cooling (Bianchi and McCave, 1999), it was argued against (Keigwin and Boyle, 2000) and was not statistically significant in paleoclimate modelling (Van der Schrier and Barkmeijer, 2005). It has even been suggested that Gulf Stream may have experienced warming during this period (e.g. Keigwin and Pickart, 1999), which certainly does not explain low BWT temperatures in our record, as well as low air temperatures over Stockholm and Central England during 1790 – 1820 CE. An explanation for this phenomenon has been proposed by Bjerknes (1965), who postulated, "a decrease in western European winter surface air temperatures to be related almost completely to an anomalous southward advection of cold polar air", a hypothesis later verified by a model study of Van der Schrier and Barkmeijer (2005).Âż

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2017-160/cp-2017-160-AC1-supplement.pdf

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