

Interactive comment on “Relationship between Holocene climate variations over southern Greenland and eastern Baffin Island and synoptic circulation pattern” by B. Fréchette and A. de Vernal

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We acknowledge the positive review of Referee #1 regarding our submitted manuscript. All suggested changes are very helpful and will be addressed in the revised version of the manuscript. Following referee’s suggestion the dinocyst records will be mentioned in the abstract. However, we will not change the title (see below). Below we placed our reply to the questions raised by Referee #1.

“The title and final sentences of the paper imply that NAO-like changes in atmospheric

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circulation are the likely causes of the spatial patterns observed in the paleo-data, yet more of the paper's discussion is devoted to the possible explanatory role of changes in surface ocean currents. Do the authors mean to imply linkages between the two?". Yes we think that there is a linkage between the two, notably between the NAO and the North Atlantic Current (NAC) strength. However, we cannot rule on what is the driven mechanism. This would be clarified in the revised version of the manuscript. The NAO affects the strength and direction of winds blowing across the North Atlantic Ocean. In turn, the winds affect the circulation of water in the ocean. During the positive phase of the NAO, the eastward wind speed is high and the northeasterward flow in the NAC appears stronger than during the negative phase of the NAO and SST gradient intensified in the NAC (e.g., Flatau et al., 2003, *Journal of Climate* 16, 2355-2369; Hurrell and Dickson, 2004 in *Marine Ecosystems and Climate Variation – The North Atlantic*, pp. 15-31). The relationship between the NAO and the Labrador Current (LC) is however less documented. Some researches suggest enhanced southward transport of cold water through the LC during the negative phase of the NAO (Marsh et al., 1999, *Fisheries Oceanography* 8, 39-49; Marsh, 2000, *Atmosphere – Ocean* 38, 367-393) or inversely, reduced LC strength during the positive phase of the NAO (Luo et al., 2006, *Continental Shelf Research* 26, 1617-1635). There is also a study suggesting that the quasi-decadal freshwater surface anomaly noted in the Labrador Sea interior was driven by the low wind speed characterizing the negative phase of the NAO (Houghton and Visbeck, 2002, *Journal of Physical Oceanography* 32, 687-701). The NAO seems also to play a role on sea-ice cover in the Labrador Sea. There are indeed some studies documenting more extended sea ice under positive NAO (e.g., Drinkwater, K. F. 2004. *Journal of Northwest Atlantic Fishery Science* 34, 1-11.; Heide-Jorgensen et al., 2007, *Journal of Marine System* 67, 170-178). The NAO also affects the cloudiness over the Labrador Sea region, possibly in relationship with sea-ice cover. Over southern Greenland, the sky is clearer during the positive phase of the NAO than during the negative phase (Previdi and Veron, 2007, *Journal of Geophysical Research* 112, D07104).

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“The RDA shows a strong correlation between winter air temperatures and pollen assemblages in the training set data. Is this surprising? Why might this be? How do the authors reconcile this with the fact that Qipisarqo and Akvaqiak have very different winter temperatures today but very similar vegetation?”. The correlation between winter air temperature and pollen assemblages is not surprising when considering the samples included in the modern database. On RDA axis 1, Greenland samples have high positive scores, samples from the Canadian Arctic Archipelago, north and west of Baffin Island, have high negative sample scores, and Baffin Island samples have both positive and negative scores (not shown in the submitted paper). *Betula*, *Ericales*, *Cupressaceae* and *Thalictrum* pollen taxa, which are abundant in Greenland samples, have high scores on RDA axis 1, whereas arctic herbs and long distance (*Picea*, *Pinus*) pollen taxa, which are abundant in the Canadian Arctic Archipelago samples, have high negative scores. Winter air temperature is the climate variable that best discriminates Greenland sites from the Canadian Arctic Archipelago sites. Annual precipitation is also important. Akvaqiak and Qipisarqo lakes have both high frequencies of *Betula* and *Ericales* and low frequencies of herbs, like in Greenland modern samples. Around both sites, shrub birches and heaths are presently growing. The pollen rain registered is thus from the local vegetation. However, the luxuriant birch population around Akvaqiak Lake is an exception on the Cumberland Peninsula. The population is isolated and no birch grew elsewhere on northern Cumberland Peninsula. It is the northernmost birch population on eastern Baffin Island. What favoured its growth there? We may suppose it is the local microclimate conditions.

“Regarding the discussion of *Alnus* migration/colonization: What is the distance between the sites on either end of the transect? Wouldn't 3500 years be a very slow migration over this distance, and what could explain that?”. The distance between the sites on either end of the transect is about 600 km. This information will be added in the revised manuscript. We do not know what is the cause of the apparent 3500 years gap and what could have happened to alder populations at the southern sites (60°N). Presently, alder (*Alnus*) is absent in south Greenland. In west Greenland, where it

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presently occurs, it prefers inland settings (Fredskild, 1996, *Meddelelser om Gronland Bioscience* 45). The marked decrease in *Alnus* pollen influx at ca. 3000-4000 cal. years BP at southern sites (Isoetes, Spongilla, Kloftso) is difficult to explain. Nevertheless, we may propose a hypothesis based on the late Holocene sea-level rise in Greenland (e.g., research by Antony Long, University of Durham). One consequence of the sea-level rise in southern Greenland was that the Paleo-Eskimo settlements may have been transgressed by the sea at about 4000 cal. years BP (cf. Sparrenbom et al., 2006, *Boreas* 35, 171-187). Sparrenbom et al. (2006) suggested that sea level has risen around 3 m since 4000 cal. years BP in the Qaqortoq area (ca. 60.7°N, 46°W). Therefore, present coastal areas in southern Greenland might have been in more inland position during early-mid Holocene. Because alder prefers the inland, this late Holocene marine transgression might have favoured its disappearance and/or its migration from the region. Other studies are needed for a demonstration. This will be shortly discussed in the revised version of the manuscript and more thoroughly in a forthcoming paper on the vegetation history at Qipisarqo Lake. The pollen analysis of another Greenland site (Sved Lake, 62°N, 150 km north of Qipisarqo) is also underway. This new pollen record will possibly give us the missing information on *Alnus* migration/colonization in southwest Greenland.

“Some proxies from the Baffin region – for example, Agassiz ice cap melt layers and lake proxies (biogenic silica, midges) from some sites on Baffin Island – show strong early Holocene warming. How can the pollen and dinocyst data be reconciled with those other records? Is it possible that the records presented here, which begin at 8 ka, do not capture peak early Holocene warmth on Baffin Island? In other words, could the major difference between Baffin and West Greenland be in the timing of maximum Holocene warmth, rather than necessarily its amplitude?”. The lake proxies records you are talked about are from CF3 Lake (Briner et al., 2006, *Quaternary Research* 65, 431-442) and CF8 Lake (Axford et al., 2009, *Quaternary Research* 71, 142-149). These two lakes are very close to each other and are located in northeastern Baffin Island about 500 km north of Akvaqiak Lake. On Baffin Island, only these two ter-

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restrial sites show such early Holocene warming. However, in northern Baffin Bay, dinocyst records indicate early Holocene optimum conditions (Levac et al., 2001, *Journal of Quaternary Science* 16, 353-363; de Vernal and Hillaire-Marcel, 2006, *Global and Planetary Changes* 54, 263-290; Ledu et al., 2008, *Canadian Journal of Earth Sciences* 45, 1363-1375), which are consistent with the data of Agassiz and Devon Island ice caps. Therefore, the northern Baffin Bay signal seems to be regionally consistent but differs from the climate record at lower latitudes on Baffin Island and in Labrador Sea. At Akvakiak Lake, the loss-on-ignition (LOI) values, which are generally comparable in trend to biogenic silica (Kaplan et al., 2002 *Quaternary Research* 58, 149-159), are very low in the pre-8000 cal. years BP samples ($3.8 \pm 2.1\%$) whereas they are high in the post-8000 cal. years BP sediments ($16.4 \pm 3.5\%$) (not shown in the paper). At Qipisarqo, LOI values markedly increased at ca. 9500 cal. years BP; mean LOI value is $17.4 \pm 2.8\%$ between the LIA and 9500 cal. years BP and $5.2 \pm 0.6\%$ for the pre-9500 cal. years BP period (Kaplan et al., 2003). It is possible that Akvakiak site does not capture the Holocene warmth on Baffin Island, but it seems unlikely. The study of other lakes from southern and northeastern Baffin Island would help to make a stronger demonstration. In this perspective, the pollen analysis of CF8 Lake will be undertaken next fall.

“I couldn’t find an explanation in the text for ages given throughout the manuscript – ie are they calibrated years BP or 14C years BP?”. The ages given in the text are either calibrated years BP or uncalibrated 14C years BP. The ages 14C years BP are only used in the section 5.1 : Mid-Holocene alder occurrence in southwest Greenland. In that section, we used 14C years BP to compare Qipisarqo pollen record with other pollen records from southwest Greenland (Fredskild, 1973, 1983; Kelly and Funder, 1974). The mean values of *Alnus* and total pollen influxes from Fredskild, and Kelly and Funder studies were estimated from age-depth models derived from uncalibrated radiocarbon dates. It could have been possible to change the chronology of sedimentary logs of Fredskild, and Kelly and Funder in calibrated years BP but not the influx values. In order to keep consistency between Qipisarqo and the other southwest Greenland

pollen records we choose to discuss the results in that section according to a 14C years BP chronology. This will be clarified in the revised version of the manuscript and a calibrated years chronology will be added on Figure 7.

On the behalf of Anne de Vernal, Bianca Fréchet

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