Forum

Rapid climate change and Arctic Ocean freshening: COMMENT and REPLY

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The Research Focus article by Peltier (2007), which is a distillation of Peltier et al. (2006), discusses the possible effects of Arctic freshwater forcing on the strength of Atlantic meridional overturning circulation (AMOC), with emphasis on the Younger Dryas cold event (YD). The cause of the YD was originally associated with northward retreat of the Laurentide Ice Sheet out of Lake Superior, rerouting continental drainage from the Mississippi to the St. Lawrence River, with the attendant increase in eastward-flowing freshwater perturbing North Atlantic climate (Johnson and McClure, 1976; Rooth, 1982). More recent work emphasizes the opening of the eastward outlet through Lake Superior that caused much of Lake Agassiz to drain rapidly, with a 1 yr flood triggering reduced AMOC (Teller et al., 2002). Lowell et al. (2005) argued that the lack of an identifiable spillway called the YD flood-trigger hypothesis into question. Peltier cites this work as the motivation for Tarasov and Peltier (2005), who concluded that freshwater routing occurred from the south to the north into the Arctic Ocean. Peltier fails to cite two recent studies that shed additional light on this question.

Meissner and Clark (2006) used the University of Victoria Climate Model to evaluate the response of AMOC to a 1 yr freshwater flood of 0.3 Sv (1 Sv = 10^6 m^3 s^{-1}), a 0.074 Sv base discharge increase from the eastward freshwater routing for the duration of the YD, and the combination of the two. The modeled AMOC response to the 1 yr flood was negligible; only with inclusion of the base discharge increase did the model simulate a reduced AMOC for the duration of the YD. Thus, any flood that Lake Agassiz may have generated at the start of the YD was incapable of affecting AMOC, and the lack of evidence for a flood does not preclude the routing of western Canada freshwater to the St. Lawrence River.

Carlson et al. (2007) demonstrated that there is a clear low-salinity signal present in planktonic $\delta^{18}O$ during the YD in the St. Lawrence Estuary after accounting for decreased sea-surface temperature. Four independent geochemical tracers showed that this freshening was from an increased freshwater flux of 0.06 ± 0.02 Sv from western Canada to the St. Lawrence Estuary at the start of the YD.

Peltier refers to "direct paleoceanographic evidence" in support of Arctic freshwater forcing. Though he provides no references for that evidence, they are presumably listed in Peltier et al. (2006). These do not show an Arctic source of freshwater at the start of the YD ~11.0 ^{14}C k.y. B.P. Light planktonic $\delta^{18}O$ anomalies are observed in the Arctic Ocean ~12.5-11.8 ^{14}C k.y. B.P. and ~10 ^{14}C k.y. B.P. (Poore et al., 1999; Andrews and Dunhill, 2004; Hall and Chan, 2004) with heavier planktonic $\delta^{18}O$ during the YD arguing against an Arctic freshwater forcing (Hillaire-Marcel et al., 2004). A light planktonic $\delta^{18}O$ anomaly in the Laptev Sea off of northeastern Russia may or may not have occurred at the start of the YD (Spielhagen et al., 2005). During the last deglaciation, the largest light planktonic $\delta^{18}O$ anomaly in Fram Strait occurred ~14.5 ^{14}C k.y. B.P. due to the disintegration of the Barents ice sheet (Koç and Jansen, 1994).

Peltier's model uses Arctic freshwater forcings of 0.3 and 1.0 Sv for 100 yr rather than the Tarasov and Peltier (2005) values of 0.12–0.22 Sv for 100 yr. The 1.0 Sv × 100 yr forcing is equivalent to a rise in eustatic sea level of 8.7 m at the start of the YD, which did not occur (Tarasov and Peltier, 2005). In neither case is the 100-yr forcing sufficient to explain the duration of the YD. The subsequent decrease in the Arctic freshwater flux to 0.05–0.07 Sv of Tarasov and Peltier (2005) continues well beyond the YD, and thus cannot explain the duration of the YD.

We conclude that there are no existing paleoceanographic records that suggest an increase in Mackenzie River discharge or an Arctic freshwater source at the start of the YD. Rather, the available paleoceanographic evidence indicates that freshwater was routed from the Mississippi River to the St. Lawrence River at the start of the YD with a base flow discharge increase sufficient to have reduced AMOC.

REFERENCES CITED

Andrews, J.T., and Dunhill, G., 2004, Early to mid-Holocene Atlantic water influx and deglacial meltwater events, Beaufort Sea slope: Arctic Ocean: Quaternary Research, v. 61, p. 14–21, doi: 10.1016/j.yqres.2003.08.003.

Carlson, A.E., Clark, P.U., Haley, B.A., Klinkhammer, G.P., Simmons, K., Brook, E.J., and Meissner, K.J., 2007, Geochemical proxies of North American freshwater routing during the Younger Dryas cold event: Proceedings of the National Academy of Sciences of the United States of America, v. 104, p. 6556–6561, doi: 10.1073/pnas.0611313104.

Hall, J.M., and Chan, L.-H., 2004, Ba/Ca in *Neogloboquadrina pachyderma* as an indicator of deglacial meltwater discharge into the western Arctic Ocean: Paleoceanography, v. 19, PA1017, doi: 10.1029/2003PA000910.

Hillaire-Marcel, C., deVernal, A., Polyak, L., and Darby, D., 2004, Size dependent isotopic composition of planktic foraminifers from Chukchi Sea vs. NW Atlantic sediments—Implications for the Holocene paleoceanography of the western Arctic: Quaternary Science Reviews, v. 23, p. 245–260, doi: 10.1016/j.quascirev.2003.08.006.

Johnson, R.G., and McClure, B.T., 1976, A model for Northern Hemisphere continental ice sheet variation: Quaternary Research, v. 6, p. 325–353, doi: 10.1016/0033-5894(67)90001-4.

Koç, N., and Jansen, E., 1994, Response of the high-latitude Northern Hemisphere to orbital forcing: Evidence from the Nordic Seas: Geology, v. 22, p. 523–526, doi: 10.1130/0091-7613(1994)022<0523:ROTHLN>2.3.CO;2.

Lowell, T.V., Waterson, N., Fisher, T., Loope, H., Glover, K., Comer, G., Hajdas, I., Denton, G., Schaefer, J., Rinterknecht, V., Broecker, W., and Teller, J., 2005, Testing the Lake Agassiz meltwater trigger for the Younger Dryas: EOS (Transactions, American Geophysical Union), v. 86, p. 365–373, doi: 10.1029/2005EO400001.

Meissner, K.J., and Clark, P.U., 2006, Impact of floods versus routing events on the thermohaline circulation: Geophysical Research Letters, v. 33, doi: 10.1029/2006GL026705.

Peltier, W.R., 2007, Rapid climate change and Arctic Ocean freshening: Geology, v. 35, p. 1147–1148, doi: 10.1130/focus122007.1.

Peltier, W.R., Vettoretti, G., and Stastna, M., 2006, Altantic meridional overturning and climate response to Arctic Ocean freshening: Geophysical Research Letters, v. 33, doi: 10.1029/2005GL025251.

Poore, R.Z., Osterman, L., Curry, W.B., and Phillips, R.L., 1999, Later Pleistocene and Holocene meltwater events in the western Arctic Ocean: Geology, v. 27, p. 759–762, doi: 10.1130/0091-7613(1999)027<0759:LPAHME>2.3.CO;2.

Rooth, C., 1982, Hydrology and ocean circulation: Progress in Oceanography, v. 11, p. 131–149, doi: 10.1016/0079-6611(82)90006-4.

Spielhagen, R.F., Erlenkeuser, H., and Siegert, C., 2005, History of freshwater runoff across the Laptev Sea (Arctic) during the last deglaciation: Global and Planetary Change, v. 48, p. 187–207, doi: 10.1016/j.gloplacha.2004.12.013.

Tarasov, L., and Peltier, W.R., 2005, Arctic freshwater forcing of the Younger Dryas cold reversal: Nature, v. 435, p. 662–665, doi: 10.1038/nature03617.

Teller, J.T., Leverington, D.W., and Mann, J.D., 2002, Freshwater outbursts to the oceans from glacial Lake Agassiz and their role in climate change during the last deglaciation: Quaternary Science Reviews, v. 21, p. 879–887, doi: 10.1016/S0277-3791(01)00145-7.

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