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Interactive comment on "Past and future ice age initiation: the role of an intrinsic deep-ocean millennial oscillation" *by* R. G. Johnson

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Reviewer #1 is concerned that I did not provide a thorough review of the existing literature, and I thank him for mentioning papers that would have been appropriate. However this is not a review paper and its main goal was to propose an explanation for the abruptness of the initiation of the last ice age and its relevance to the possible future climate change. The intrinsic deep-ocean oscillation that explains the Bond cycles plays an important role in explaining this abruptness, and no "global scale" event or unique condition is required. Therefore the first part of the paper focuses on the mechanism of the deep-ocean oscillation, which is followed by the description of the regional conditions of northeastern Canada under which the last ice age abruptly began about 120,000 yr BP. At that time the regional climate west of Greenland switched

from a relatively dry interglacial state to meteorological conditions favoring extremely heavy precipitation. Erosion effects due to the switch are found as an $\sim$500 yr pulse in a deep sea sediment record (Adkins et al. 1997) in which hematite-stained sand grains appeared, and the clay eroded from the lands around Baffin Bay increased abruptly by a factor of three, well within the $\sim$300 yr separation of sediment data points. The key to my specified mechanism for the deep-ocean oscillation is the analysis of Weyl (1968) who pointed out that the slightly warmer and more saline admixture of North Atlantic intermediate-level Deep Water (NADW) in the Southern Ocean would by means of deeper convection tend to melt away sea ice frozen at the beginning of the austral winter season. Consequently the total amount of sea ice on the Southern Ocean at the end of winter must be minimal when the NADW concentration is large and maximal when the concentration is small. From that relation between Southern winter sea ice and NADW concentration I constructed the new hypothesis as described in sections 2, 3, 4, and 5, which details how the oscillation is driven. In my view, a successful test of the new hypothesis is the consistency between the approaching maximum of Antarctic winter sea ice area and the related approaching minimum of Antarctic Bottom Water production at $\sim$2125 AD in the model (Fig. 6) when compared with the present observed record maximum area of winter sea ice and the corresponding observed record minimum of Bottom Water production. This test requires that the phases of the model components be consistently set at the maximum in NADW production as described in section 5. That maximum occurred about 1000 AD during the warm Medieval Climate Anomaly (MCA) in North Atlantic high latitudes when the North Atlantic Drift and it is heat and salt transport were inferred to be at maximum rates. Other climate conditions outside the North Atlantic region are not relevant at this time. I described some of the details of the high latitude MCA-Little Ice Age transition to show that they are consistent with the model. Although Bond et al. (2000) also proposed the transition to be part of a natural oscillation, no driving mechanism for the oscillation was specified. In my model the correct prediction of a real world record maximum in austral winter sea ice area as the model ice nears a maximum depends specifically on the dynamics that involve the negative feedback effect of Antarctic Bottom water on NADW production as Antarctic Bottom Water accumulates in the North Atlantic, and the positive effect of NADW on Antarctic Bottom water production as NADW accumulates in the intermediate levels of the Southern Ocean. As indicated in the sinusoidal model of Figure 6, the duration of the maximum in the deep-ocean oscillation and the Bond cycle is only 200-300 yrs. In its proposed role of maximizing the NADW formation rate with the resulting penetration of the Spitsbergen/Atlantic Current flow into the sea north of Greenland, the deep-ocean oscillation provides the explanation for the abrupt initiation of the last ice age. This new hypothesis has other useful aspects as described in section 6 and in the reply to reviewer #2.

Interactive comment on Earth Syst. Dynam. Discuss., 5, 545, 2014.