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Interactive Comment

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 #2 is concerned about the appropriateness of my prediction of an imminent possible new ice age trigger. In my opinion this prediction is sufficiently well based to go on the record and it would prevent the climate science community from being blind-sided by the event if it occurs in the next decade or two. As suggested by my Figure 11, the predicted pattern of ever-greater annual penetration of the Spitsbergen/Atlantic Current (SAC) flow into the polar ocean, which might lead eventually to the ice-free Baffin Bay and ice age threshold climate, could be easily observed with remote sensing technology. Such observations, stimulated by this paper, would lend support to an early confirmation of the initiating mechanism. Testing the mechanism by numerical modeling would be questionable, I think, because of the lack of precisely known ini-

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tial conditions and other unquantified factors in the multistep mechanism. With regard to the influence of the changing Mediterranean salinity and outflow on the Greenland Sea salinity, if the Milankovitch cooling in Canada did not trigger the last ice age and if my proposed mechanism did, then one must ask what delayed the triggering for the 6000 year duration of the interglacial? The proposed explanation is that at the start of the interglacial the Greenland Sea salinity was too low to enable sufficiently strong NADW formation and SAC flow to penetrate into the polar ocean north of Greenland, and this weakness was a consequence of the lower salinity and weaker outflow of the Mediterranean under a more pluvial regime caused by strong African monsoons. As orbitally controlled insolation weakened the monsoons, the regional climate became dryer, the Mediterranean became more saline and the outflow became stronger thus transmitting more salt to the Greenland Sea until the salinity there became high enough several thousand years later to enable the SAC flow to penetrate north of Greenland. As shown in my Figure 11, the midwinter SAC flow in 2014 penetrated to latitude 83degrees north, almost far enough to begin to block the flow of polar water into the east Greenland Current and then penetrate into the area north of Greenland. Comparing the April position of the SAC penetration to the Spitsbergen south coast about 90 yrs ago (Lamb, 1972) with today's April penetration to slightly beyond the north coast, an increase in salinity of the Greenland Sea is implied. The source of this added salinity is not certain, but the Mediterranean must have contributed because the damming of all significant Mediterranean rivers began about 60 yrs ago and a conference news article in Science (vol 293, p. 483, 1998) displays an illustration with the measured salinity of the deep western Mediterranean rising by about 0.05‰ (by slight extrapolation) from 1960 to present. The rate of outflow is directly related to the salinity difference of about 2‰ between Atlantic and Mediterranean water. Consequently, both the salinity and the rate of the outflow have increased, and even this small increase above the nominal 2‰ may have caused the significant increase in Greenland Sea salinity and northward penetration of the SAC over the last 90 yrs. In regard to my non-Milankovitch hypothesis for the initiation of the last ice age, the reviewer states that recent climate models show that the “Milankovitch theory does work.” In one sense I must agree, because I made the first accurate determination of the Earth’s last (Brunhes/Matuyama) magnetic reversal at 790,000 yr BP by using marine and orbital insolation correlations (Johnson, 1982). But climate model conclusions should replace real world data only with great care. One or more internal (stochastic) variables in the climate system frequently overwhelm the Milankovitch factor. Perhaps the most notable of these variables, a melt water flood through the Mediterranean, resulted in the anomalous high sea level ∼5 m above present about 136,000 yr BP near a Northern Milankovitch insolation minimum. The high sea level was documented by Chappell (1974) on New Guinea and Johnson (2001 on Barbados. The proposed cause of the anomaly involved a cessation of the deep-ocean oscillation modeled in this paper as described in section 6, and a failure of the oxygen isotope proxy for world glacial ice volume. The alternative initiation of the last ice age at 120,000 yr BP by conversion of the winter sea ice area of Baffin Bay and the Labrador Sea to open water is another exception to the Milankovitch model. The very first snows of the Early Wisconsin glaciation on Devon Island at the north end of Baffin Bay occurred under warmer conditions (Koerner et al., 1988) with implied freedom from winter sea ice. This change was very likely coeval with much warmer marine conditions east of southern Baffin Island at about 62 degrees north (Fillon, 1985). The weakness of Milankovitch forcing of climate change in the face of stochastic factors has been discussed in detail by Wunsch (2004) who says that the record variance due to orbital change never exceeds 20%. He also concludes that the control of the 100 ka glacial/interglacial cycle is as likely due to stochastic forcing as it is to orbital effects. Nevertheless, the small effect of orbital change can at times be critical for climate change. One of the most relevant consequences of the Milankovitch precessional effect is its role in the variation of the African monsoon. In section 3.4 of the Quaternary Science Review by Wanner et al. (2008) they state: “It is generally accepted that increased Northern Hemisphere solar forcing in the early and middle Holocene was the major external driver of the intensified Afro-Asian summer monsoon.” As mentioned in my section 10, with the African monsoon at its strongest at the beginning of interglacials the Mediterranean salinity would be at its lowest. As the precessional effect on the monsoons weakens, the Mediterranean salinity rises and the teleconnection between Mediterranean outflow and the Greenland Sea causes the salinity there to also increase. Eventually with the aid of a Bond oscillation maximum it reaches a level sufficient to enable the Spitsbergen/Atlantic Current to send Atlantic water into the sea north of Greenland and remove the winter sea ice in Baffin Bay. It is by this proposed mechanism that Milankovitch insolation variation triggers new glaciation at the end of the later Pleistocene interglacials. The reviewer questions the mysterious 1500 yr Bond cycle with its proposed connection to the deep-ocean oscillation driven by North Atlantic Deep Water formation. Like the Milankovitch orbital cycles, the effects of the deep ocean oscillation in both Southern and Northern high latitudes tend to be overprinted by chaotic variations of the world climate system. Lamb (1995) devotes much of his book to the extremely different climatic effects that accompanied the Little Ice Age in northern Europe during the minimum in the Bond cycle. The overprinting seems to be more severe earlier in the Pleistocene, where more proxies for climate parameters must be used, than in the last millennium, and more research is needed to explain this. The duration of the Bond cycle maximum in the sinusoidal model is only 200-300 yrs, and this can explain the abruptness of the onset of the last ice age as inferred from the probably much less than 300 yr rise in the erosion pulse inferred from the sediment record of Adkins et al. (1997) in section 8 of my paper.

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