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Interactive Comment

Interactive comment on "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous" *by* J. Hansen et al.

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At the end of a wide-ranging paper, Hansen et al. (2015) include a short section (7.4)

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Interactive Discussion

Discussion Paper

called ‘The Anthropocene’, which addresses aspects of the early anthropogenic hypothesis. Here we point out three comments that need to be amended or deleted. The first issue is carbon burial in peats. By way of background, Elsig et al. (2009) found a small decrease in δ13C values of atmospheric CO2 during the last 7000 years and concluded that early anthropogenic emissions were minimal. But this conclusion depended on a mass-balance analysis claiming 40 Gt (billion tons) of carbon burial in peats during that interval. Ruddiman et al. (2011) later noted that earlier work by Gorham (1991) pointed to a much larger estimate, and that a comprehensive global synthesis by Yu (2011) estimated $\sim$275 GtC. Adjusting for the more negative δ13C ratio of C3 peat carbon compared to lower-latitude carbon increased this estimate to $\sim$300 GtC in its comparable effect on the δ13CO2 signal. This larger burial has to be offset by some comparably large source of terrestrial emissions, and anthropogenic emissions are a plausible candidate. Hansen et al. (2015) say “no persuasive evidence has been presented to support such a dominant role for peat in the global carbon cycle", but this is incorrect. IPCC (2013) accepted Yu’s larger estimate by noting that carbon burial in peat during the last 7000 years was equivalent to a CO2 reduction of $\sim$25 ppm. And since 2011, Zicheng Yu has taken a leadership role in peat studies by organizing PAGES workshops, heading special sessions at AGU and elsewhere, and co-authoring follow-up papers that have come to the same conclusion. In addition, several members of the Bern group co-authored a 2013 paper with Yu (Spahni et al. 2013) that arrived at a similarly large estimate of peat carbon burial. These facts directly refute the assertion by Hansen and colleagues of ‘no persuasive evidence’. The second issue is the role of the Southern Ocean in previous interglaciations controlled by natural variations, in contrast to the possible effects of anthropogenic emissions during the Holocene. Hansen and colleagues note that the CO2 declines early in previous interglaciations were (at least in part) tied to natural Antarctic cooling, which reduced regional ventilation of CO2 to the atmosphere and sequestered carbon in the deep ocean. They refer to these earlier cooling trends as caused by ‘weak natural forcing’ (orbital) and suggest that the early anthropogenic hypothesis overestimated the size of

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the anthropogenic emissions needed to counteract this natural Antarctic cooling and the accompanying CO_2 sequestration in the deep ocean late in the Holocene. One problem, discussed above, is that Hansen and colleagues rejected evidence for major late-Holocene carbon burial in peats of 300 Gt. If the amount of carbon burial was ~300 Gt (Yu, 2011), larger late-Holocene anthropogenic emissions would be required to overcome this carbon sequestration in peats that would otherwise cause a natural 25-ppm CO_2 drop and a major cooling. This would put a considerably larger demand on early anthropogenic emissions to also explain the anomalous 20-ppm CO_2 rise in ice cores. In addition, Hansen and colleagues failed to mention two recent modeling studies that suggest a prominent early anthropogenic role for the Southern Ocean during the late Holocene. Based on experiments with the CCSM3 and CCSM4 dynamical atmosphere-ocean models, Kutzbach et al. (2011, 2013) found that the proposed 40-ppm early anthropogenic CO_2 anomaly warmed the Southern ocean, reduced sea ice, and increased upwelling, all factors widely thought to increase ventilation of CO_2 from the ocean to the atmosphere. Indeed, Hansen and colleagues refer to some of these same feedback mechanisms in their discussion of the Southern Ocean and climate feedback (sections 5.2 and 5.3). While our GCM simulations lacked an interactive biogeochemical module to assess the resulting effect on atmospheric CO_2, Simmons et al. (2013) ran a relevant set of experiments using the U. Vic climate model coupled to the McGill 'green' biogeochemical model. They found that natural orbital forcing during the last 8000 years produced large enough responses in the Southern Ocean (cooling, increased sea ice) to cause a 5-15 ppm drop in atmospheric CO_2. The 10-ppm range of variation depended on varying model treatments of ice shelves. Although not a direct assessment of the role of early anthropogenic emissions, their results suggest that a CO_2 drop of ~10 ppm under natural forcing would have occurred, in contrast to the observed 20-ppm increase during the time of anthropogenic influence. Our simulations (Kutzbach et al., 2013) also found enhanced equilibrium climate sensitivity for climates associated with CO_2 levels lower than pre-industrial because of the same kinds of positive feedback factors that Hansen and colleagues cited as making the

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early anthropogenic hypothesis “more plausible” (section 7.4) The third issue concerns this comment by Hansen and colleagues: “...recent carbon-cycle models by Kleinen et al. (2015) have been able to capture CO2 changes in the Holocene and earlier interglacials without an anthropogenic source”. Two parts of this claim are incorrect: (1) Kleinen and colleagues failed to simulate the observed CO2 rise after 3000 years ago using natural factors, so they invoked substantial anthropogenic emissions; and (2) their modeled CO2 signal for stage 11 falls outside the bounds of the ice-core record throughout nearly that entire interglaciation. In addition, while the simulation by Kleinen and colleagues matched ice-core trends during the later part of interglacial stage 5e reasonably well, they omitted the key early part of that interglaciation. Their simulation started at 126,000 years ago, by which time CO2 had already declined from a peak value of 287 ppm at 128,000 years ago to the 265-275 ppm range. The problem with this truncated choice of intervals is more apparent in Ganopolski and Brovkin (2015), who used the same model. Although their simulation reproduced the general features of the CO2 record over the last 400,000 years, it did not (as they noted) perform well during the three early-interglacial intervals. Instead of capturing the swift rises to well-marked CO2 peaks at the start of stages 5, 7, and 9, their model simulated slow CO2 rises to muted peaks many thousands of years later. In short, their model simulates upward trends early in interglacial stages 5, 7, and 9, rather than the downward ones actually found in ice-core records. Their simulation also missed the small natural CO2 peak and decline early in the Holocene prior to anthropogenic interference. These studies highlight a challenge posed by Ruddiman (2008): “No model has yet reproduced both the upward gas trends during the Holocene and the downward gas trends during previous interglaciations”. Seven years later, that challenge is still unmet. The comment by Hansen et al. (2015) about Kleinen et al. (2015) misrepresents this ongoing problem with modeling attempts. We suggest that a revised paper address the above comments, all of which would imply larger early anthropogenic emissions than Hansen and colleagues infer from observations.

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