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Interactive comment on "Ice-driven CO_2 feedback on ice volume" *by* W. F. Ruddiman

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Part of Bol'shakov's criticism is directed at Milankovitch's orbital insolation theory. His argument for seasonal cancellation of the direct impacts of insolation at the precession cycle and for geographic cancellation at the obliquity cycle echo those voiced in the early-middle 1900's. Since that time, however, records in marine sediments covering the last 2.75 million years have revealed clear tilt and precession cycles in the ice-sheet responses, and phases that isolate northern summer as the critical forcing (best explained in the introduction section of Imbrie et al., 1989), These findings confirm Milankovitch's hypothesis that the response to changes in summer insolation outweighs that in winter in determining ice mass balance. A moderate amount of snow falls in winter for a range of temperatures, but warm summers can melt a much larger amount of snow and ice (Figure 9 in my paper).

As Bol'shakov states, albedo feedback is an important positive feedback on ice sheets, but the very closely studied last glacial maximum indicates that greenhouse gases are more influential. The direct feedback effects of ice-sheet albedo and greenhouse gases

are roughly comparable, so how one interprets the 'other' albedo changes determines which one has the largest feedback impact. Sea ice in the Southern Ocean has a large albedo effect, but not as a result of a connection to northern ice sheets via atmospheric dynamics. As I noted, the most likely reason for changes in southern sea ice is changes in greenhouse gases. Similarly, greenhouse gases appear to be the largest control on changes in vegetation and its effects on albedo. Overall, greenhouse gases are thus a larger feedback than ice-sheet albedo.

Finally, I followed custom in using summer insolation changes at 65N latitude as typical of the high northern latitudes where ice sheets appear. Indeed, that particular signal is reasonably representative of a wide range of latitudes.

Reference

[Imbrie, J., McIntyre, A., and Mix, A.C. (1989)]. Oceanic response to orbital forcing in the late Quaternary: Observational and experimental strategies. In: Climate and Geosciences (A. Berger et al., eds), Kluwer Academic, Boston.

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