

## WHEN DID GLOBAL WARMING START?

### *An Editorial Comment*

With a bolt from the blue William Ruddiman has forced scientists and broader elements of society to contemplate the possibility that the anthropogenic era of greenhouse forcing began thousands of years ago. Even as a long-time admirer of Bill Ruddiman, I admit to having been almost taken aback when I first read the title of the paper in this issue ('The Anthropogenic Greenhouse Era Began Thousands of Years Ago'). But when I started reading the paper, I could not help but wonder whether he just might be on to something.

The origin of the 'outrageous hypothesis' begins with Ruddiman's analysis of the Pleistocene CO<sub>2</sub> record from the Vostok ice core. His long time experience in analysis of Pleistocene time series gives him a great deal of credibility in this analysis. He concludes that the CO<sub>2</sub> interglacial life cycle in the present interglacial has been different than the three other interglacials in the last 400,000 years in the sense that CO<sub>2</sub> levels tended to peak in the early part of the interglacial and then either stabilized or gradually decreased. For the Holocene interglacial, however, an early downdip follows the first peak and then CO<sub>2</sub> levels start to go back up. Analysis of the methane record shows a similar unusual trend with respect to prior interglacials.

Ruddiman suggests that the only real difference in climate forcing during the middle part of the last four interglacials has been the rise of land clearing and agriculture. Land clearing can increase atmospheric CO<sub>2</sub> in two ways – simple burning and decomposition of downed vegetation and, perhaps more importantly, increased weathering of soil carbon in a disturbed system. He extensively reviews evidence for when such changes may have occurred and estimates that the potential carbon disturbance changes are quite large, possibly enough to account for the ~20 ppm atmospheric CO<sub>2</sub> increase during the late Pleistocene. These estimates may be reasonable but certainly will have to be tested with some carbon models, because some of this carbon dioxide is going to go back in the ocean, especially on time scales of thousands of years. Ruddiman further estimates that the enhanced greenhouse perturbation should have caused a global warming of 0.8 °C. This estimate is on the high end of climate sensitivity estimates to ~0.6 W/m<sup>-2</sup> forcing from an increase in carbon dioxide and methane; a best guess sensitivity value would cause about a 0.3–0.4 °C warming.

Ruddiman goes on to suggest that the CO<sub>2</sub> changes during the last millennium were too large to be explained by external forcing changes but instead were caused by forest regrowth after outbreaks of bubonic plague, and that such changes were



a significant cause of the Little Ice Age. I am less sanguine about this idea. Using middle of the road climate sensitivity estimates one can rather easily demonstrate with climate and geochemical models that most of the CO<sub>2</sub> changes can be driven by solar variability and volcanism; furthermore the equilibrium cooling to even a high-end estimate of 10 ppm CO<sub>2</sub> drop is only about 0.2° C – substantially less than the cooling estimated for that time.

The most important question to ask is whether Ruddiman is right on his main point. One cannot say at this time. But I can say that he is a careful researcher and spends a great deal of time reading and reflecting on supporting material. One can also point out that Ruddiman was successful once before with a ‘semi-outrageous hypothesis’. In the late 1980s he was at the very forefront of the effort (one can even argue he was the originator) to point out the importance of changing topography on the evolution of the Earth’s climate on tectonic time scales. He wrote a key paper summarizing all the geological evidence from many different regions that indicated significant global average changes in elevation during the Cenozoic. Much of the subsequent emphasis on this topic by geologists, climate, and geochemical modelers is indebted to the stimulus Ruddiman provided by his careful summary of the geologic data.

It is almost trite to state that only time will tell if Ruddiman is right. One can however predict the paper is almost certain to stir up interest and perhaps not a little controversy. Greenhouse skeptics will no doubt be aroused to ire but they will focus on an unflappable scientist who is at least as well read and certainly has less of an agenda than most of his will-be accusers. Readers, enjoy the article.

### Reference

Ruddiman, W., 2003: ‘The Anthropogenic Greenhouse Era Began Thousands of Years Ago’, *Clim. Change* **61**, this issue.

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