LESSONS FROM THE EARTH'S PAST

Jeffrey Kiehl[1] in his perspective "Lessons from Earth's Past" computes a climate feedback factor of ~2 $^{o}C\ w^{-1}m^{2}$ by computing the difference in mean global temperature ~35 million years ago during the late Eocene compared to pre-industrial times and the net radiative forcing due to the difference in carbon dioxide concentrations between these two times. This method of computing the feedback factor implicitly assumes that the difference in carbon dioxide concentrations (~1000 ppmv vs ~300 ppmv) is the only relevant factor that could be responsible for the temperature difference. Indeed, in arguing for this he first accounts for the slight difference in solar constant over this period and then maintains that the paleogeography ~35 Myr ago "was not radically different from present-day geography". From this he concludes that Earth's sensitivity to changes in CO_2 concentrations may be much larger than that obtained from climate models. There are good reasons to be cautious about this conclusion.

It is well known that the amount of carbon dioxide required to produce sufficient warmth at high latitudes during the Eocene would result in too high a temperature in the tropics.[2] The concern that CO_2 forcing is not adequate to explain the temperature difference between the present and the Eocene has also been raised by P.K. Eijl, et al.[3], the source used by Kiehl to determine the temperature at that period. These authors found that the cooling during the Eocene occurred mainly at the poles and, if this cooling were due to a reduction in CO_2 concentration, the tropical regions should also have cooled. Since their data shows that they did not, the authors suggested that high-latitude climate feedbacks such as differences in cloud and water vapor distributions might have been much more important than previously thought. There is good reason to believe that this may have been the case. Meridional temperature gradients were much smaller during the Eocene, and perhaps the most important outstanding question about climate during that period is the mechanism that would allow warm poles without warming the tropics. The argument can, of course, be reversed: if the increased temperature at the poles going from the late to early Eocene were due to CO_2, the tropics should have been much warmer than was the case.

Kiehl's claim that "The paleogeography of this time was not radically different from present-day geography" is simply incorrect. As seen in the figure, the paleogeography ~35 Myr ago *was* significantly different than today. In particular, the Isthmus of Panama was open as was what is today the Mediterranean to the Indian Ocean. The closing of the Isthmus of Panama is thought by many to have contributed to the initiation of the cyclic ice ages. The formation of the isthmus took some 10-15 million years. After its final closure 3 million years ago, it cut off the Atlantic and Pacific oceans forcing a reorganization of global ocean currents. Although there are indications from modeling studies that North Atlantic deep water formed during the Eocene,[4] the reorganization following the closure likely also included the thermohaline circulation in the Atlantic.

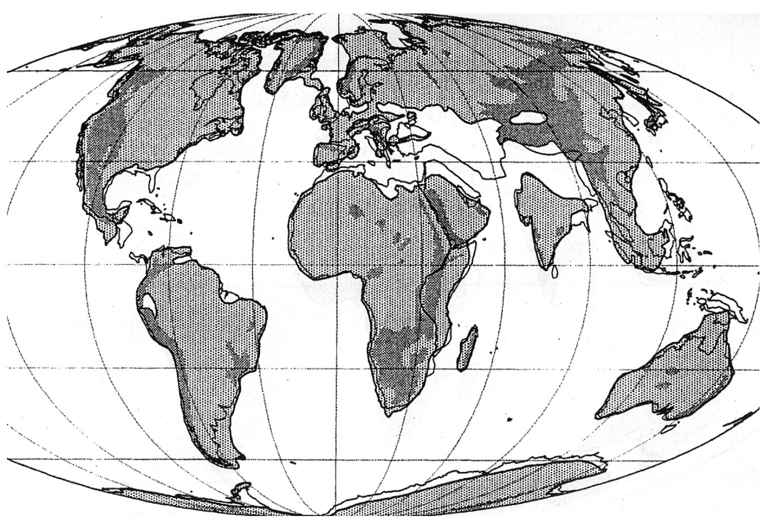

Fig. 1. Oligocene paleocoastline map—30 Myr ago. Note the gap between south and north America and the opening of what later became the Mediterranean into the Indian Ocean. (Adapted from A.G. Smith, D.G. Smith and B.M. Funnell, *Atlas of Mesozoic and Cenozoic Coastlines* (Cambridge University Press, Cambridge 1994).

It is very likely that the distributions of water vapor and clouds were significantly different during the period considered by Kiehl compared to today, and that the climate feedback factor was no where near as large as calculated by him.

[1] J. Kiehl, "Lessons from Earth's Past", *Science* **331**, 158 (2011).

[2] P.J. Valdes, "Warm climate forcing mechanisms", in: B.T. Huber, K.G. Macleod, and S.L. Wing, *Warm Climates in Earth History* (Cambridge University Press, 2000) and references therein.

[3] P.K. Bijl, et al., "Early Palaeogene temperature evolution of the southwest Pacific Ocean", *Nature* **461**, 776-779 (2009).

[4] M. Huber and L.C. Sloan, "Heat transport, deep waters, and thermal gradients: Coupled simulation of an Eocene Greenhouse Climate", *Geophys. Res. Lett*. **28**, 3481-3484 (2001).