OVERSIMPLIFYING THE GREENHOUSE

An Editorial Essay

A recent paper by James Hansen and colleagues from the NASA Goddard Institute for Space Studies has received a lot of attention from the media and from industrial lobbyists. This paper, entitled 'Global warming in the twenty-first century: An alternative scenario' was published in the Proceedings of the National Academy of Sciences in August, 2000. As an example of how the press has interpreted this article, the Daily Telegraph in London cites this paper by stating that 'the scientist who alerted the world to the consequences of the greenhouse effect admits today that carbon dioxide from burning fossil fuels was not the main cause of rapid warming of the Earth in recent decades'. They also cite the paper for its optimistic viewpoint that 'global warming can be prevented "without any economically wrenching actions"'. Similarly misleading is the press release put out by the Global Climate Coalition which has the headline 'NASA's Hansen: CO_2 not main cause of rapid global warming in recent decades'.

While the Hansen et al. paper has clearly been misunderstood by the press, there are several lessons along the way that warrant discussion because they have led to these misinterpretations. The paper by Hansen et al. is divided into two primary sections, one reviewing the past radiative forcing on climate from greenhouse gases, from aerosols, and from other forcings, and the other section proposing a new 'scenario' for future forcing that could be met with only a 1 Wm^{-2} increase in radiative forcing over the next 50 years. Although it could be argued perhaps that such papers appearing in the Proceedings do not warrant much consideration because these papers are not peer reviewed, I think special discussion of this paper is warranted here because of concerns relating directly to potential oversimplifying interpretations that can be made of the issues associated with past changes in climate and projections of future changes in climate.

In a simple tabular form, the paper reviews the radiative forcing on climate from 1850 to 2000 in a globally averaged sense. While this sort of analysis has been useful by the international assessments led by the Intergovernmental Panel On Climate Change (IPCC) as well as by others (I've used it myself in various papers, e.g., Wuebbles et al., 1999) to give a sense of the relative importance of various forcings on climate over this time period, it is also very misleading, particularly as used by Hansen et al. to suggest that one can balance off the warming effects of carbon dioxide (CO_2) and the cooling effects of aerosols because they both come primarily from combustion sources. However, the radiative forcing of CO_2 and the other greenhouse gases vary with latitude and season (e.g., Jain et al., 2000) so

Climatic Change **52:** 431–434, 2002.

that the globally averaged forcing does not represent correctly the regional forcing on climate. More importantly, because of their short atmospheric lifetimes (a few days to a few weeks), the sulfate aerosols and other particles are not homogenously distributed. This means that the aerosols have large inhomogeneous variations in their radiative forcing on climate. In fact, because of differing variations in the distributions of carbon aerosols (which have a warming tendency) and sulfate aerosols (which cool), the net influence of aerosols on climate can be either a warming or a cooling tendency at various locations around the planet. In addition, much of the sulfate aerosols, the primary cooling influence, come from burning coal at midlatitudes of the Northern Hemisphere, limiting their radiative forcing effects primarily to those latitude regions.

If the sum of all of the radiative forcings from 1850 to 2000 had added to zero, one might assume, based on the discussion in Hansen et al., that there would not be expected to be any climate change (to be fair, Hansen et al. mention much later in the paper that there is heterogeneity in the distributions of aerosols, but not where they consider the balancing of CO_2 and aerosols). However, due to the large variation in homogeneities discussed above, there would still be expected to be significant climate change even if the total globally averaged forcing were zero.

In addition, the authors did not consider the timing of the forcing. For example, following the recent paper by Andronova and Schlesinger (2000), if one looks at the change in the radiative forcing with time over the last 150 years, there has been little increase in the radiative forcing from aerosols for the last 30 years. This analysis implies that much of the recent large increases in globally averaged temperatures are primarily due to the increase in radiative forcing over this time period from CO_2 and other greenhouse gases, with CO_2 providing the most dominant change in radiative forcing during this time period. During this time period, there is clearly no 'balancing' of the radiative forcing from CO_2 and aerosols.

The discussion above also means that Hansen et al. should not have made the statement that 'the processes producing the non-CO_2 greenhouse gases (GHGs) have been the primary drive for climate change in the past century'. Clearly, all of the forcings have contributed to the climate change and have not made their contributions in a simple linear or time-independent way where one can simply balance off various parts of the forcing. One cannot simply add up linearly the globally averaged forcings over the 1850-2000 period as was done in this paper and get the correct picture of what is driving climate. This also means that one cannot use the traditional simple linear relationship between radiative forcing and resulting change in temperature.

In looking at future emissions and climate changes, Hansen et al. attempt to add to the growing literature examining controls on future emissions of greenhouse gases and particle precursors. Unfortunately, the 'alternative' scenario presented in Hansen et al. for future emissions and radiative forcing is largely done with a lot of handwaving and little analysis. The basis behind the Hansen et al. 'alternative' scenario is to propose a climate forcing scenario that only adds about 1 Wm^{-2} in the next 50 years. They accomplish this by adding 1 Wm^{-2} for CO_2, a net decrease in radiative forcing for the greenhouse gases, and a balancing of the net cooling effect of sulfate aerosols and warming influence of carbon aerosols. While this is a worthy goal, little analysis is presented to justify such a scenario. Not only is there a lot of handwaving in the paper in defining this scenario, this scenario shows little basis compared to other studies projecting future emissions. That is not to say that such emissions and corresponding net radiative forcing could not be met, but it would require a significant effort internationally to achieve this.

First of all, even if one accepted their aerosol scenario, one would still have the inhomogeneities in the aerosol distributions and resulting forcing that was discussed earlier. The discussion of the aerosol portion of the scenario is quite confusing, but basically assumes that there would be a reduction in the emissions and radiative forcing (of about 0.5 Wm^{-2}) of black carbon aerosols balanced by a reduction in emissions of sulfate aerosols with a corresponding increase in radiative forcing (of about 0.5 Wm^{-2}) from reducing the sulfate cooling effect. Now if one looks at the standard set of scenarios produced by IPCC for business-as-usual, the SRES scenarios, the sulfur emissions are much lower in all cases than the earlier IS92 scenarios (based on expected controls on sulfates for health reasons), but show a wide range of possible future emissions. Case A2 in the SRES scenarios gives a large increase in sulfur emissions by 2050, while B1 and B2 give decreases approaching about 20%. However, such a decrease would not be sufficient in even the lowest of the four SRES scenarios to approach a net increase of 0.5 Wm^{-2}. In addition, a recent paper by Mark Jacobson suggests that the total direct forcing from carbon aerosols over the last 150 years may have been as much as +0.5 Wm^{-2} (Jacobson, 2000) therefore, it may be quite difficult to reduce carbon aerosols enough to produce a net change in radiative forcing of 0.5 Wm^{-2} over the next 50 years (although indirect effects on availability of cloud condensation nuclei may also contribute).

Secondly, the assumption of 1 Wm^{-2} increase over the next 50 years for CO_2 is smaller than that for any of the SRES scenarios. The SRES scenario B1 has the smallest increase in CO_2 radiative forcing over this period, 1.22 Wm^{-2} (based on our model) with the largest increase being 1.93 Wm^{-2} from 2000 to 2050 in scenario A1. While achievable, I would not call these differences 'consistent' with the SRES scenarios. The methane reduction in the 'alternative' scenario is also achievable but with much effort, as discussed for example in Hayhoe et al. (1999).

In addition, Hansen et al. doesn't cite the existing, extensive peer reviewed literature looking at various options for reducing future forcing on climate. There are a variety of papers in the peer reviewed literature examining stabilization approaches to radiative forcing, discussing basket approaches for greenhouse gas emissions reductions, and evaluating the need for incentives to reduce emissions.

The bottom line is that the scenario developed by Hansen et al. is not given sufficient analysis or perspective relative to other analyses of future emissions, at least not well enough to be used in any sense as a strategy, particularly given the inhomogeneities in the aerosol distribution and radiative forcing. Nonetheless, if the paper by Hansen et al. serves to raise the public conscientiousness towards the necessity to reduce future emissions of greenhouse gases and particles, then it will have served an important purpose.

References

Andronova, N. G. and Schlesinger, M. E.: 2000, 'Causes of Global Temperature Changes during the 19th and 20th Centuries', *Geophys. Res. Lett.* **27**, 2137–2140.

Hansen, J., Sato, M., Ruedy, R., Lacis, A., and Oinas, V.: 2000, 'Global Warming in the Twenty-First Century: An Alternative Scenario', *Proceedings of the National Academy of Science (PNAS)*, published August 15, 2000 (early edition).

Hayhoe, K., Jain, A., Pitcher, H., MacCracken, C., Gibbs, M., Wuebbles, D., Harvey, R., and Kruger, D.: 1999, 'Cost Implications of Multi-Greenhouse Gas Reduction Targets for the U.S.' *Science* **286**, 905–906.

Jacobson, M.: 2000, 'A Physically-Based Treatment of Elemental Carbon Optics: Implications for Global Direct Forcing of Aerosols, *Geophys. Res. Lett*. **27**, 217–220.

Jain, A. K., Briegleb, B. P., Minschwaner, K., and Wuebbles, D. J.: 2000, 'Radiative Forcings and Global Warming Potentials of Thirty-Nine Greenhouse Gases', *J. Geophys. Res.*, in press.

Wuebbles, D. J., Jain, A., Edmonds, J., Harvey D., and Hayhoe, K., 1999: 'Global Change: The State of the Science', *Environmental Pollution* **100**, 57–86.

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