Comments on "Global Climate Change and Tropical Cyclones": Part II

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Lighthill et al. (1994, hereafter identified as L94) address the question of whether the anticipated greenhouse gas–induced warming of the next 60–70 years will increase the frequency and intensity of tropical cyclones. They conclude that any effects will be quite small compared to natural variability. While we have no strong disagreement with this conclusion, we have serious reservations about the authors' evaluation of the different methods that were used (or not used) to address the question.

We believe that L94 are being cavalier in dismissing the possibility that global climate models can provide useful information about the sensitivity of tropical cyclone climate to increased greenhouse gases. While there are many unresolved issues about the utility of climate models for studying the tropical cyclone climatology, we believe L94 give an unduly pessimistic view of their value. They justify their position by focusing on the potential weaknesses of using climate models for this purpose and emphasizing the strengths of the two empirical approaches that they prefer. We provide a different perspective by examining their arguments for dismissing the results from climate models and by making a more critical examination of their empirical methods.

The argument for discarding results from climate models, briefly outlined in their paper's appendix, seems to concern two issues: 1) the spatial resolution of current climate models, and 2) the inconsistency in the response of different climate models to greenhouse gas increases. We agree that current climate models, with their limited horizontal resolution, are incapable of simulating the structure of the inner core of tropical cyclones. Thus, the relevant issue is whether or not the tropical vortices that occur in climate model integrations are similar enough to their real counterparts to respond in the same way to the physical mechanisms controlling their development, maintenance, and decay. Evidence suggests that such a similarity may exist. Current climate models can simulate many of the features of observed tropical cyclones that have spatial scales resolvable by such models. These include the characteristic warm core structure (upper-tropospheric anticyclonic circulation above cyclonic low-level circulation) and the existence of strong upward motion, often oriented in a comma-shaped pattern, accompanied by heavy precipitation near the storm center (Manabe et al. 1970; Bengtsson et al. 1982, 1995; Broccoli and Manabe 1990). In addition, the geographical distributions, seasonality, and interannual variability of simulated storms are similar to those observed (Broccoli and Manabe 1990, 1992; Wu and Lau 1992; Haarsma et al. 1993; Bengtsson et al. 1995). Finally, tropical cyclone forecasts with global numerical weather prediction models have indicated a relatively smooth increase in maximum wind speed and a decrease in radius of maximum winds as horizontal resolution is increased (Krishnamurti et al. 1989; Krishnamurti and Oosterhof 1989). The gradual improvement of model performance with increasing resolution does not suggest that the resolution of current climate models is below the critical limit beneath which simulated tropical vortices lose all resemblance to real tropical cyclones. Therefore, we do not believe there is enough evidence to totally dismiss the results from climate models on the basis of inadequate resolution.

Lighthill et al. also argue that the inconsistencies in simulations of greenhouse gas–induced tropical cyclone changes (e.g., Broccoli and Manabe 1991; Haarsma et al. 1993; Bengtsson et al. 1994) are further evidence for disregarding the model results. Discrepancies can appear among the results from different models for a variety of reasons. They may be due to the unrealistic representation of some of the relevant physical processes, or they may be caused by sampling error associated with highly variable phenomena such as tropical cyclones. To disregard model results when they differ is to ignore a potentially useful source of information. Climate models provide a physically consistent framework in which it is often possible to determine the reasons for such disagreement, and hence highlight which physical mechanisms are important. Thus, although a lack of consensus among climate models is a good reason for caution when making an assessment of future changes in tropical cyclone climate, it is premature to conclude that such models cannot provide useful information.

In contrast to this pessimistic view of the utility of global climate models, the discussion of the other two methods lacks critical evaluation. The use of empirically derived criteria for tropical cyclogenesis (e.g., Gray 1979) for assessing future changes in tropical cyclone climate, as in Ryan et al. (1992), has a number of potentially serious weaknesses. First, and most importantly, these criteria were derived based on the present climate. There is no a priori way of knowing how well they would govern tropical cyclogenesis in a different climate. Second, even if one were to assume that these criteria are equally valid for other climate states, these methods cannot predict changes in the probability that strong storms will maintain their strength outside the regions of cyclogenesis. Finally, nothing in L94 suggests that the authors examined output from climate models to see if the distributions of low-level vorticity, vertical wind shear, static stability, or midtropospheric relative humidity change in response to greenhouse gas increases. Instead, they assume that there will be no change in the spatial distribution of these quantities by arguing, without substantiation, that they are fundamentally invariant.

There are also problems with L94's second method, examining the historical tropical cyclone record. They cite the absence of a strong correlation between local sea surface temperature (SST) and storm intensity as evidence that global warming does not have an important influence on tropical cyclone distribution and frequency. This is of questionable relevance to the effect of a widespread increase in SST such as that predicted by climate models in response to increased greenhouse gases. Correlation of observed numbers of tropical cyclones with global temperatures is potentially a better approach. However, the relatively small magnitude of interannual temperature variability, the relatively large interannual variability of tropical cyclone numbers, and the shortness of the satellite-derived global tropical cyclone record would require the sensitivity of tropical cyclone frequency to global temperature to be very strong in order to be discernible. Even if such strong sensitivity existed, there are two reasons why the analysis presented by L94 (and illustrated in their Fig. 2) might not show it. First, they used land temperatures (from the Northern Hemisphere where most land is located in high latitudes) rather than tropical ocean temperatures. Second, they chose a statistic (the ratio of "major" tropical cyclones to all tropical cyclones) that might not be strongly affected, since both the numerator and denominator could experience changes in the same direction.

Progress in understanding the effects of climate change on the tropical cyclone climate requires the use of a variety of techniques. We do not agree with L94 that their empirical approaches are "thoroughly sound and appropriate" while the use of current climate models is "not a methodology from which useful information is available." Each of these methods has strengths and weaknesses. If one is mindful of the limitations of *all* of the methods for studying this issue, the use of existing climate models appears to be no worse than the methods employed by L94. In fact, we believe that this approach has much better potential for future improvement than the other empirical approaches, because the rapid increase of computing power will enable us to continuously improve climate models by increasing their computational resolution and employing more realistic parameterizations of relevant physical processes.

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