Reply to D.B. Kirk-Davidoff

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In response to the commentary of Jacobson and Archer on the article of Miller et al. (2010), Kirk-Davidoff states that global models at course resolution that represent wind farm arrays by changing the surface roughness length give climate changes that are not chaotic put predictable. This statement illustrates a misunderstanding of our comment. Certainly, an increase in roughness length with no other changes will result in a decrease in the local wind speed, and that will feed back to other elements of the climate system. The question is whether the resulting changes (e.g., in temperature) modeled are realistic and of the correct magnitude and sign, not whether they will occur. One should be suspicious when climate responses obtained from two simulations are similar when the radiative forcings between the two simulations differ by a factor of 50-100. The usual reason for this is that the noise exceeds the signal in the climate simulation.

The reason the results of Miller et al. are likely chaotic is that Miller et al. represent a grid cell with one wind speed, whereas in the real world, an infinite number of wind speeds (and roughnesses) occur at the same time in that cell. Changing even one parameter in one grid cell of a global model by one digit in the tenth decimal place at the beginning of a simulation triggers a deterministic chaotic response that can result in a globally-averaged surface temperature difference of 0.1 K or so over two years. Since the assumption of a uniform roughness and wind speed in a global grid cell differs from reality much more than does a single random perturbation, the chaotic variation must be at least that of the random perturbation.

Kirk-Davidoff uses Frandsen (2007) and Calaf et al. (2010) to justify the use of a roughness length to represent wind farms. However, these authors simulate wind farms at the resolution of wind turbines themselves and show no application of roughness to the global scale or even the regional scale. In fact, in regional and global models, it is common practice to treat subgrid surface phenomena as subgrid and, for example, to calculate fluxes for subgrid surface types individually before averaging rather than calculating one flux for the cell directly (Jacobson, 2001). When this is done, different parts of a regional grid cell produce different ground and air surface temperatures, as shown in Figures 2 and 3 of that paper. Even applying this methodology on the global scale does not represent a wind farm correctly since flows between turbines differ from flows in the wake of a turbine. None of the studies Kirk-Davidoff or Miller et al. refer to or perform consider subgrid fluxes or show that a coarse-resolution global simulation of wind farm effects give the same results as a fine-resolution global simulation.

Jacobson, M.Z., GATOR-GCMM: A global through urban-scale air pollution and weather forecast model 1. Model design and treatment of subgrid soil, vegetation, roads, rooftops, water, sea ice, and snow, J. Geophys. Res., 106, 5385-5401, 2001.