

## ***Interactive comment on “Potential climatic impacts and reliability of very large-scale wind farms” by C. Wang and R. G. Prinn***

**Anonymous Referee #2**

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Research leading to this report uses a global climate model with altered surface roughness to simulate changes in global climate conditions stemming from widespread installation of wind farms, both on-shore and off-shore. This is a highly relevant scientific question that is approached with a method that uses a model built on fundamental classical physical principles. The paper uses a widely accepted model with assumptions similar to those used by previous related studies (which, however, will be called into question later in this review). The experiments are clearly defined and could easily be replicated by others. Conclusions of the authors are supported by the results of the model (provided the model is appropriately configured to answer the basic question, which will be discussed later). The title and abstract are appropriate, and the paper is clearly and concisely written.

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The mechanism for generation of turbulence kinetic energy (TKE) in the model and consequences for surface budgets needs clarification and justification. Current turbines are mounted on towers with hub heights of 80-100m and plans are in place to put them even higher. Blade diameters currently are 80m or larger. Space and time scales of TKE generated by interaction of mean flow with such a dynamic obstacle likely are not well represented by drag forces at the earth's surface. Such turbines will tap into the lower part of the low-level jet, particularly in regions such as the US Great Plains. In such cases, turbines will encounter higher winds at night than during the day (M. Lange and U. Focken, "Physical approach to Short-Term Wind Power Prediction," Springer, 2005.), opposite to the diurnal patterns at the surface. Turbulence intensity will increase at the surface, particularly at night, within wind farms compared to the undisturbed landscape. Mean wind speed also is likely to increase at night due to enhanced coupling of free atmosphere winds with the surface due to the enhanced TKE generated by the turbines.

In the model described in this manuscript, the effect of turbines is introduced by an enhanced surface drag that is calculated from surface wind speed and a drag coefficient. This has the effect of reducing surface wind and therefore reducing the magnitude of surface exchange processes for heat, moisture, momentum and CO<sub>2</sub>. Therefore, the parameterization used in this model is not consistent with observed behavior of the atmospheric boundary layer described in the previous paragraph. All of this calls into question the results of the paper which show a weakened near-surface turbulent transport due to turbines when their effects are parameterized by an increased surface friction.

Without prior reference in the body of the paper, the third paragraph of the conclusions states: "Environmental effects increase with power generated and decrease with conversion efficiency. Also, for the widely spaced wind turbines simulated in our runs, the environmental effects appear small when they are generating less than 1TW globally even with current technologies." The authors do not define "environmental effects" of

C6937

turbines, but DOE does: impacts on birds, bats, false echoes on weather radars, and ambient noise levels. It is not at all clear what the authors mean by environmental effects. The potentially more significant environmental effect of turbines in grasslands, shrubland or crop land (where a vast majority will be located in the US Great Plains) is the impact on plant-atmosphere exchange of heat, moisture, momentum, and CO<sub>2</sub> due to the altered surface turbulence created by the turbines. Potential drying and increased vulnerability to dust storms (suggested by the conceptual model I have presented) would not be a welcome environmental effect for this region, which suffered enormous loss of topsoil in the continental scale dust storms of the 1930s. Reconsideration must be given to the suggestion of environmental effects.

Figure 1 shows that no turbines are located south of about 55 degrees S and only relatively few south of 30 degrees S. Yet substantial cooling is simulated on Antarctica (Figure 2) extending to the South Pole. What mechanism is able to create such a vast region of remote cooling, especially one that is dynamically isolated from lower latitudes by the circumpolar vortex?

In summary, this paper addresses an important issue for consideration due to projected expansion of wind farms. However, I strongly question whether the approximation used to simulated momentum extraction by turbines in the model is plausible. At the very least, the authors must demonstrate that extracting momentum at the surface through surface drag will have the same effect on surface budgets as extracting momentum in an elevated layer 80 m above the surface by turbines.

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