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Earth System Dynamics Discussions

Interactive comment on "Estimating maximum global land surface wind power extractability and associated climatic consequences" *by* L. M. Miller et al.

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Reply to Juan Carlos Bergmann.

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Dr. Bergmann makes several errors about our commentary that we reply to below.

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Interactive Discussion

Discussion Paper

First, he states, “Archer, Jacobson, and Sta. Maria (2010) claim complete regeneration of power density after a definite wake length.” This is not correct. We defined the wake length as the distance past the turbine at which wind speed was completely regenerated. We did not specify a definite wake length; rather we specified what the wake meant. Energy loss occurs in the wake, but not outside the wake. Observations indicate that wind speeds some distance past turbines are similar to those in front of the turbines. That distance was defined as the wake distance. If this were not the case, wind should be reduced infinitely downwind, all the way around the world back to the original turbine, which clearly does not occur.

He also states, “and the wake cannot be re-filled to the initial power density by diffusion in finite time.” We agree and never implied this. In the wake, wind speed and kinetic energy are reduced. This is clearly stated in our commentary and the point of the paper of Sta. Maria and Jacobson (2009).

He further states, “This energy-chain is flawed for several reasons. If it were correct, natural atmospheric flow without turbines would not need any external mechanical energy supply because all mechanical energy is being recycled.” Again, Dr. Bergmann misses that fact that we assume energy loss in the wake but not beyond the wake, so there is a net loss of kinetic energy in the atmosphere, not a complete recycling.

In addition, he states, “Extracted energy is utilised at far-away locations and can even be stored (e.g., as chemical energy), thus not participating in JA2010’s energy-chain.” Virtually no wind energy is stored today, and even if it were, it would eventually be used and converted to heat. The distance away from the turbines that heat is released is irrelevant, since we are talking about global energy balances, not just local. Further, pressure gradients are large-scale phenomena, operating over hundreds to thousands of kilometers, all within the area of transmission/ distribution system.

Finally, he states, “The atmospheric pressure fields would be there forever, independent of global circulation (differential heating). That would represent a perpetuummo-

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bile of the second type, which is impossible due to the second law of thermodynamics:" First, global atmospheric hydrostatic pressure is absolutely conserved regardless of the presence of wind turbines or not, as it is merely the weight of air molecules above an area (e.g., the Earth's surface area) divided by the area, and wind turbines do not reduce the number of molecules of air. Energetics redistribute the energy but don't affect the total global pressure. The redistribution of heat to "far away" locations must contribute to increasing pressure gradients, since the heat is not distributed uniformly, which would be necessary for no increase in pressure gradients. Dr. Bergmann implies that the redistribution of heat would not result in regeneration of pressure gradients. This would be true only if the heat were distributed uniformly, which it is not as he acknowledges. We believe it is unphysical to assume that heat from electricity does not go partially to re-establishing pressure gradients.

In sum, more work is needed to establish the flows of energy, but the previous models of energy transformation are incomplete and not quantified accurately; thus, not useful or applicable to analysis of atmospheric wind turbine effects.

Santa Maria, M. R. V., and Jacobson, M.: Investigating the effect of large wind farms on energy in the atmosphere, Energies, 2, 816–838, 2009.

Interactive comment on Earth Syst. Dynam. Discuss., 1, 169, 2010.