Earth Syst. Dynam. Discuss., 1, C167–C170, 2011
www.earth-syst-dynam-discuss.net/1/C167/2011/

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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Received and published: 28 January 2011

Response to M. Z. Jacobson & C. L. Archer on "Comment on 'Estimating maximum global land surface wind power extractability and associated climatic consequences' by L.M. Miller, F. Gans, and A. Kleidon"

L.M. Miller, F. Gans, and A. Kleidon

A detailed response to M.Z. Jacobson & C.L. Archer's comment in addition to related comment responses (D.B. Kirk-Davidoff, 2010; J.C. Bergmann, 2010) and the response comments by Jacobson & Archer (2010b, 2010c) are included as supplementary material.

We thank M.Z. Jacobson and C.L. Archer (Jacobson & Archer, 2010a) for their comment. We would also like to thank D.B. Kirk-Davidoff (Kirk-Davidoff, 2010) and J.C. Bergmann (Bergmann, 2010) for responding to the Jacobson & Archer (2010a) comment and then to M.Z. Jacobson and C.L. Archer (Jacobson & Archer, 2010b, 2010c) for replying to the comments by D.B. Kirk-Davidoff and J. C. Bergmann. In our response here, we will incorporate the associated responses to Jacobson & Archer (2010a) by J.C. Bergmann (2010) and D. Kirk-Davidoff (2010) and the subsequent responses by Jacobson & Archer (2010b, 2010c).

Authors conclusions — To estimate maximum global land-based wind power extraction potential, the thermodynamic efficiencies of kinetic energy generation within the atmosphere must first be acknowledged. This generation rate is the critical component to any estimate of very large-scale wind power estimate. We have been highly critical of nearly all comments by Jacobson & Archer (2010a, 2010b, 2010c) because their engineering approach is in direct conflict to the 1^{st} and 2^{nd} law of thermodynamics. Their statements such as "Energy loss occurs in the [wind turbine] wake, but not outside the wake," (from Jacobson & Archer, (2010b)) and "whereas in the real atmosphere in the presence of wind turbines, F_{acc} [generation rate of kinetic wind energy] would increase by the rate of momentum extraction by wind turbines," (from Jacobson & Archer (2010a)) are in direct contradiction to our understanding of the Earth system. We appreciate the efforts of J.C. Bergmann (2010) and D.B. Kirk-Davidoff (2010), who both attempted to correct confusion regarding Jacobson & Archer (2010a) with comment responses, but Jacobson & Archer (2010b) and Jacobson & Archer (2010c) never acknowledge their lack of a physics-based understanding regarding wind power.

Previous studies have confirmed that the generation rate of kinetic wind energy in the Earth's atmosphere is already maximized (Lorenz, 1960; Kleidon, 2003; Kleidon, 2006, Kleidon, 2010b) and this study found a similar atmospheric response with our simulations of surface-based wind power extraction. We also confirmed previous smaller-scale work suggesting much less than the generation rate of kinetic energy into a system can actually be extracted (Lanchester, (1915); Betz, (1920), Garrett & Cummins (2007)) and must be associated with climatic consequences (Keith et al., (2004), Kirk-Davidoff & Keith, (2004), Barrie & Kirk-Davidoff (2009), Wang & Prinn (2010)). Our revised range of general circulation model simulations with multiple horizontal and vertical resolutions (in part suggested by Archer & Jacobson, (2010a)) will increase the scientific validity of our estimates while clearly identifying their variations. These variations can be improved by accounting for a more detailed interaction scheme of wind turbines with the surrounding atmosphere and more model

complexity based on a more clear understanding of Earth system processes. Still, the fundamental limits of thermodynamics must not be contradicted — ignoring them will result in exaggerated estimates of potential wind power extractability at any scale.

Please also note the supplement to this comment:
http://www.earth-syst-dynam-discuss.net/1/C167/2011/esdd-1-C167-2011-supplement.pdf

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