Earth Syst. Dynam. Discuss., 1, C43–C44, 2010
www.earth-syst-dynam-discuss.net/1/C43/2010/

Earth System Dynamics Discussions

Interactive comment on "The problem of the second wind turbine – a note on a common but flawed wind power estimation method" *by* F. Gans et al.

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Received and published: 19 July 2010

In principle, the article's argument is correct. The criticised concepts need to assume replenishment of kinetic energy on turbine level by turbulent transport from above (without specifying this process). It is, however, impossible to maintain the free-flow velocity at turbine level by turbulent transport: a velocity gradient is inevitable in turbulent transport. Also, the article's concept does not specify how the kinetic energy is renewed at turbine-level in order to be extracted as supposed. But it is easy to demonstrate that the turbulent-transport replenishment concept even reduces the down-stream distance at which energy conservation is violated.

The usual assumption for energy-replenishment is that additional kinetic energy is being diffused downward to the turbines from an infinite reservoir of kinetic energy aloft. The obvious limitation of the reservoir by the height of the atmospheric boundary layer (ABL) in relation to the height covered by turbine rotors is one aspect of error, which has been accounted for in the article's channel model (height of ABL). Energy flux density in turbulent transport is equal to shear stress times flow velocity, JE = τ u. The turbines exert an additional drag, i.e., stress is assumed to be increased above the turbines and flow velocity is reduced as compared to a free surface without turbines. If we, for simplicity, assume zero velocity-gradient above turbine height for the free surface, we can account the entire velocity reduction delta u relative to the 'free flow' to turbine influence, as well as the entire shear-stress increase delta τ. (The article's concept is equivalent by not considering friction at the channel's walls.) The difference to the free-surface energy flux density is delta JE = delta τ u. That looks fine! However, it is not yet accounted for increase in dissipation, delta epsilon = (τ + delta τ) delta u! Free-surface dissipation is taken as zero-level by neglecting the corresponding velocity gradient above turbine-level. The balance for delta τ = τ (doubling of stress by turbine-influence) and delta u = 0.2 u is a net energy transport to the turbine layer of only 0.6 delta JE. Thus, maintaining the velocity level at 0.8 of the free-flow velocity (half power of free flow) is only possible at 60% energy efficiency!

Limited efficiency of turbulent transport demonstrates that the turbulent-transport concept even reduces the down-stream distance of violation of energy conservation – provided that the turbines really produce that amount of turbulence necessary for turbulent transport. In-wake measurements down-stream offshore wind farms do not indicate significant increase in turbulence (or of derived sea-surface roughness). Turbulence intensity above turbine-level seems even reduced as compared to turbine level! Thus, there is still a lot to investigate and new concepts are required in order to deal with observed effects.

Interactive comment on Earth Syst. Dynam. Discuss., 1, 103, 2010.