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Forecasting the weather
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Large-Scale Wind-Energy Utilisation and some open Questions in Atmospheric-Boundary-Layer Energetics

J. C. Bergmann
Hamburg, Germany (aeolicus@aol.com)

Basically, energetics in an atmospheric boundary layer (ABL) without energy extraction by turbines is simple: The potential energy (PE) of the pressure-field is transformed to kinetic energy (KE) of the wind by down-gradient volume-flow. KE is further transformed to turbulent KE (TKE), which is dissipated to heat by viscous processes at the smallest turbulence scales. In stable stratification, a small fraction of the TKE is transformed to PE by mixing the stratified fluid.
Energy-extraction by turbines is primarily on expense of the KE, but especially in large-scale utilisation there are necessarily also effects on TKE and dissipation.
If the large-scale input of PE to the ABL is a constant, which is a reasonable first assumption, dissipation must become smaller by the amount of extracted energy, and thus also TKE as source for dissipation processes must become smaller.
This is in contradiction to the usual conception that turbines increase the turbulence.
Open questions: Is the variability added by the turbines really turbulence? If it is – where does all the energy come from?

The input of PE to the ABL is equal to the scalar product of surface stress τ with geostrophic wind Ug. Thus, the cosine of the angle between these vectors enters directly the PE input.
Usually it is assumed that τ and near-surface wind U0 are parallel and the equation of motion is solved with this boundary condition. The resulting idealised neutral ABL wind profiles have a pronounced super-geostrophic speed-maximum at about half to 2/3 of the ABL height.
However, observed profiles at near-ideal conditions do not show a trace of such maximum. Integration of observed profiles for an independent determination of the angle between the vectors regularly arrives at angles close to 45° - the classical Ekman value!
Thus, with the usual angle of ca. 15° for smooth terrain the PE input is already over-estimated by ca. 1/3. If resource assessment is influenced by the non-existent maximum, the over-estimation is much more pronounced. The latter could be the case for very tall turbines under somewhat stable off-shore conditions, which are most frequent in spring and summer.
Open questions: What is the real direction of the surface-stress vector (literally as force per unit surface-area)? What is the real ABL-wind-speed profile?

With regard to the effect of flow-impediment on drainage of the PE reservoir, the ABL is completely different from non-rotating systems.
In non-rotating systems all flow is down-gradient, and additional flow-impediment like surface-roughness or turbines reduces the flow. Thus, the drainage of the PE reservoir (down-gradient flow) is reduced by turbines!
In the ABL flow-impediment leads to less cross-gradient- (geostrophic) and more down-gradient- (ageostrophic) flow. Thus, the ABL's PE reservoir is drained more strongly than without turbines.
Open question: How strong is the drainage of the PE reservoir, and how strong is the effect of the resulting reduction of geostrophic wind speed on the wind-energy resource?