Geophysical Research Abstracts
Vol. 13, EGU2011-11220, 2011
EGU General Assembly 2011

Large Eddy Simulation study of fully developed thermal wind-turbine array boundary layers

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It is well known that when wind turbines are deployed in large arrays, their efficiency decreases due to complex interactions among themselves and with the atmospheric boundary layer (ABL). For wind farms whose length exceeds the height of the ABL by over an order of magnitude, a “fully developed” flow regime can be established. In this asymptotic regime, changes in the stream-wise direction can be neglected and the relevant exchanges occur in the vertical direction. Such a fully developed wind-turbine array boundary layer (WTABL) has already been studied, (Calaf, et al., Physics of Fluids 2010).
Now, a suite of Large Eddy Simulations, in which the same wind turbine subgrid parameterization used in Calaf et al. (2010) is used, but now also includes thermal effects through the addition of temperature has been performed. As a first step, the temperature is taken as a passive scalar, which allows us to study the potential impact that large wind farms can have on the land-atmosphere interactions in a relatively simple configuration. Such study also helps to unravel the physics involved in extensive aggregations of wind turbines, allowing us to design better wind farm arrangements.

By considering various turbine loading factors, it has been possible to study the relationship between modified surface velocity u* and the increased surface heat fluxes due to the presence of wind turbines. Results are being used to better understand these correlated processes, and an analytical expression relating these two variables is being developed. Such results are valuable for a better assessment of wind farm placement, and atmospheric boundary layer impact.
Keywords: WTABL, surface velocity u*, heat fluxes, LES.