Geophysical Research Abstracts, Vol. 7, 10566, 2005
SRef-ID: 1607-7962/gra/EGU05-A-10566

Wakes within and downwind of large offshore wind farms

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A major uncertainty in predicting power output from large offshore wind farms relates to losses generated by individual and combined wind turbine wakes. These are predicted by state-of-the art models to be of the order 10% of total power output for wind farms with 80-100 wind turbines in the megawatt class. However, there is also significant discrepancy between different model predictions that stem in part from assumptions and partly from the procedures used to compute wake interactions. This paper will present an overview of single wake model performances in the offshore environment through comparison with meteorological data from masts at small offshore wind farm in Denmark (Vindeby) and from a campaign using ship mounted sodar to determine wakes at different distances from a turbine (1.7 to 7.1 rotor diameters). Further a new analytical model will be presented which has been developed to assess the interactions between turbine clusters in large wind farms (i.e. the wake recovery distance) and hence the optimal distance between wind farm clusters for developments in the 100 turbine ($>$100MW) size range. One of the main advantages of the model is that it is designed to link wake development with turbine induced feedback from the atmospheric boundary layer. Wind speed recovery distances in the wake of a large offshore wind farm will be compared from a number of models including WAsP, CFD and an added roughness model in addition to the new analytical model.