Abstract

Wind farms and gravity waves

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The effect of wind-turbine wake interactions on loading and wind-farm energy efficiency have been recognized since the 1970s (Lissaman 1979). In the last decade, the use of Large-Eddy Simulation (LES) has become quite popular to study turbine wake interactions, as well as the interaction between wind farms and the background turbulent Atmospheric Boundary Layer (see, e.g., Calaf et al. 2010). The main paradigm in these LES, and many other simplified wind-farm models, has been that wind farms are immersed in the inner layer of the Atmospheric Boundary Layer (ABL), so that interactions with outer-layer effects can be neglected. As a result, in a large majority of wind-farm LES, the forcing is simplified to a pressure-driven boundary layer instead of taking into account the more complex geostrophic forcing and free-atmosphere stratification present in the ABL. However, given the continuing increase of wind-turbine, as well as wind-farm size, the assumptions that wind-turbines remain in the inner layer of the ABL is no longer valid. The largest wind turbine to date reaches over 200 meter, while the height of the ABL can drop well below 500m, in particular in offshore conditions.

In recent years, a number of researchers have started to use geostrophic forcing in LES of wind-farm boundary layers (e.g., Churchfield et al. 2012, Abkar and Porté-Agel 2013, Goit and Meyers 2013, Allaerts and Meyers 2015, among others). Moreover, at KU Leuven, we further focused on improving the free-atmosphere boundary conditions in our LES, including stratification, and a capping inversion. When combined with the simulation of large wind-farms, we found that atmospheric gavity waves can be excited by slow-down of the boundary layer in the wind farms, and the resulting displacement of the stably stratified atmosphere above (Allaerts and Meyers 2017a). Next to that, the development of an internal boundary layer above the wind farm was identified that can possibly interact with the capping inversion, in particular in situations with a low ABL height. It was further found that wind-farm efficiency is influenced by these atmospheric gravity waves, in particular in situations where the atmospheric surface layer transitions from neutral to stable stratification (Allaerts and Meyers 2017b). In the present contribution, these results are reviewed. Moreover, properties that influence the strength of wind-farm induced gravity waves are discussed based on linear theory.

References

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