Numerical study of wind-farm gravity waves: Impact of wind-farm configuration

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Background

Several numerical studies have found that large wind farms can excite atmospheric gravity waves (AGWs) in the free atmosphere above the boundary layer [1-3]. AGWs arise when stably stratified flow is displaced vertically, upon which buoyancy acts as the restoring force and induces an oscillation in the wind, temperature, density, and pressure fields in the atmosphere. AGWs originate from various sources, most notably topographical features such as mountains, hills and ridges. In a wind farm, conservation of mass dictates that the deceleration of the incoming flow by the wind turbines must be accompanied by an upward flow deflection, which then leads to the excitation of AGWs (see, e.g., figure 1).

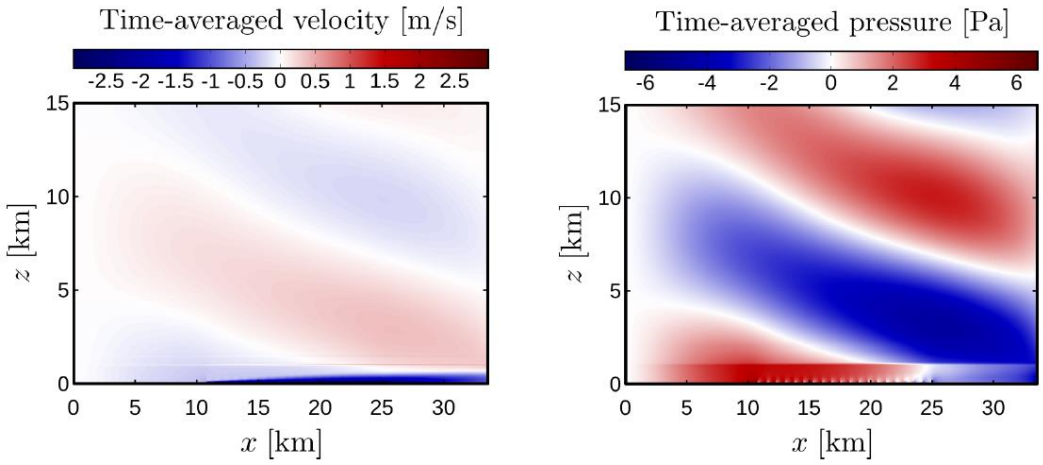

Figure 1: Perturbations to the velocity (left) and pressure (right) fields due to atmospheric gravity waves caused by a large wind farm [1].

Wind-farm-induced gravity waves may have important consequences for the energy production of a wind farm because the pressure perturbations imposed by these waves introduce a two-way feedback mechanism between the energy production and the atmospheric flow. To date, the physics of windfarm-induced gravity waves are not entirely understood, and they are therefore an active research topic.

Objective

The objective of the thesis is to perform CFD- and model simulations of large wind farms and investigate the excitation of atmospheric gravity waves and their impact on wind farm performance, and investigate the sensitivity to the wind-farm configuration, such as wind-farm layout and aspect ratio, turbine spacing, hub height, rotor diameter, horizontal and vertical staggering, farm shape, and power density.

References

[1] Allaerts, D., Meyers, J., 2017. Boundary-layer development and gravity waves in conventionally neutral wind farms. Journal of Fluid Mechanics 814, 95–130. https://doi.org/10.1017/jfm.2017.11

[2] Allaerts, D., Meyers, J., 2018. Gravity Waves and Wind-Farm Efficiency in Neutral and Stable Conditions. Boundary-Layer Meteorol 166, 269–299. https://doi.org/10.1007/s10546-017-0307-5
[3] Wu, K.L., Porté-Agel, F., 2017. Flow Adjustment Inside and Around Large Finite-Size Wind Farms. Energies 10, 2164. https://doi.org/10.3390/en10122164