The optimization of tidal turbine farms represented as a turbine density function

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In the design of tidal turbine farms an important question is micro-siting, i.e. the placement of individual turbines within the farm, which is complicated by the fact that each of the turbines interacts with the flow and will affect the performance of other turbines. In principle, all different configurations could be evaluated separately by running a hydrodynamic model for each of them, but due to the large number of possibilities this quickly becomes computationally infeasible even for a small number of turbines. In Funke et al. (2014) a new optimization strategy for tidal farms is proposed that relies on gradient information, i.e. the sensitivity of the outcomes with respect to the turbine positions, which is obtained by solving the adjoint to the model.

Gradient based optimization techniques help limit the number of required optimization iterations, and thus the number of model runs, even for large numbers of turbines.

In this work a variant of this approach is introduced, where instead of the positioning of each individual turbine, a turbine density function is optimized that indicates the concentration of turbines that should be placed in each area. The drag force that the turbines exert on the flow is parameterized through an increased bottom drag proportional to this density. Although the model gives a less accurate representation of the flow through the farm, the big advantage is that far less mesh resolution is required as individual turbines are no longer individually resolved. This makes it feasible to extend the model to larger areas, which is required to reliably study the influence of a farm, or multiple farms, on the large scale tidal flow with boundary conditions sufficiently far removed.

Another advantage is that this strategy can be used to determine the optimal *number* of turbines. In the strategy where individual turbine positions are optimized, the number of turbines needs to be fixed beforehand. Here however, we optimize for all possible turbine densities simultaneously, and determine the number of turbines by simply integrating the optimal density function.

Additionally, it becomes possible to enforce much more complex constraints on where turbines are allowed to be placed. Previously, it would only be possible to constrain the turbines to convex areas, and the number of turbines in each separate area would be fixed. In realistic scenarios however, bathymetric constraints for instance may introduce very complex and non-connected areas where turbines can be installed. In this way it also becomes possible to optimize multiple farm sites simultaneously.

We will demonstrate the ability of the method to predict the optimal number of turbines by comparing the results with the previous individual turbine approach run for a different number of turbines. We will also present a large-scale example where multiple sites are optimized simultaneously. We will discuss the question whether the influence of farms on the large scale flow, and thus on other farms in the vicinity needs to be taken into account in the design process of individual farms and the energy resource assessment of the region as a whole.