Turbulent boundary layers interacting with groups of obstacles

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When wind or water meets an obstacle it is surprising how little is known about the interaction they have. When building a city or planning on positioning wind or tidal turbines it would be useful to know how the wind will react to the placement of objects. Our current understanding of turbulent flows interacting with solid obstacles relies on theories that have been developed for two limiting conditions: (i) flows impinging on a uniformly-distributed array of elements whose size is large compared with the characteristic length scales of the flow, and (ii) flows impinging on single isolated obstacles such as a sphere, a cylinder, an aerofoil or a bluff body of any shape. The intermediate condition, where turbulent flows interact with a small number of obstacles in an isolated group, has received much less investigation. Examples of such flows include: atmospheric boundary layers over a forest patch, groups of wind turbines or outstanding buildings in cities, marine turbines in tidal channels, river flows over 'patchy' vegetated beds, marine currents impinging on offshore structures. The relevant research questions associated with these flows include the estimation of drag forces that the flow exerts on the group and the modelling of the turbulent wake occurring behind the obstacles. Such information is extremely important for the purpose of, for example, predicting the amount of power that a group of turbines (wind or marine) can generate, estimating carbon dioxide exchange between forests and the atmosphere, or modelling flood routing in rivers with patchy vegetation.

The current literature pertaining to this class of flows is limited to either the case of a few obstacles or to a large number of obstacles within a 2-Dimensional (2-D) flow, where mean turbulent properties are uniform (or almost uniform) along one direction. However, in many applications, groups of obstacles experience 3-Dimensional (3-D) flow conditions as in the case of atmospheric flows over wind farms or marine turbines in tidal channels. Certainly, with respect to the 2-D flow condition, 3-D effects are likely to trigger a significantly different flow behavior in terms of drag forces and wake development. In order to fill this gap in the current knowledge, a series of wind tunnel and flume experiments will be carried out using 3-D flows around idealized groups of obstacles for a wide range of obstacle densities (i.e. number of obstacles per unit ground area, figure 1) and group shape. The experimental plan involves detailed force and velocity measurements, which will be used to provide effective parameterizations of drag forces and length and time scales associated with the wake development behind the obstacles.

![Figure 1. Groups of obstacles with different density](image-url)