

The hydrodynamics of soft-fouling

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ABSTRACT

Turbulent boundary layer (TBL) flow over biofouled surfaces has been well-studied for cases with calcareous fouling (barnacles, tubeworms, oysters, etc), however the fully-coupled problem involving biofilms and soft-fouling is not well-understood. The biofilms of interest in the present work are typical of the ones that grow on naval vessels under shear and consist of a flat base to which streamers are attached. Their hydrodynamic interactions with the turbulent boundary layer developing on the side of a naval vessel are highly complex, and as of today, have been seldomly studied primarily via laboratory experiments. We will report direct numerical simulations of TBL over these surfaces, where the complex fluid structure interactions (FSI) are directly resolved using a cost-efficient numerical method tailored to this class of problems. In our approach, the equations governing the dynamics of each filament are solved in a Lagrangian reference frame and are coupled to fluid flow equations solved on a fixed Cartesian grid. An example computation is shown in the figure below for the case of a turbulent channel flow at $Re_\tau = 1000$, where different streamer coverages are considered ($\lambda = 1.3$ and $\lambda = 2.6$ corresponding to 20 and 40 thousand streamers respectively). We will show that such biofilms extract energy from the flow through the roughness of the biofilm surface as well as the flapping streamers and investigate how small scale turbulence near the bed, which is important for transport of nutrients as well as the hydrodynamic forces, is affected by the solidity and streamer properties (i.e. length, material properties, etc).

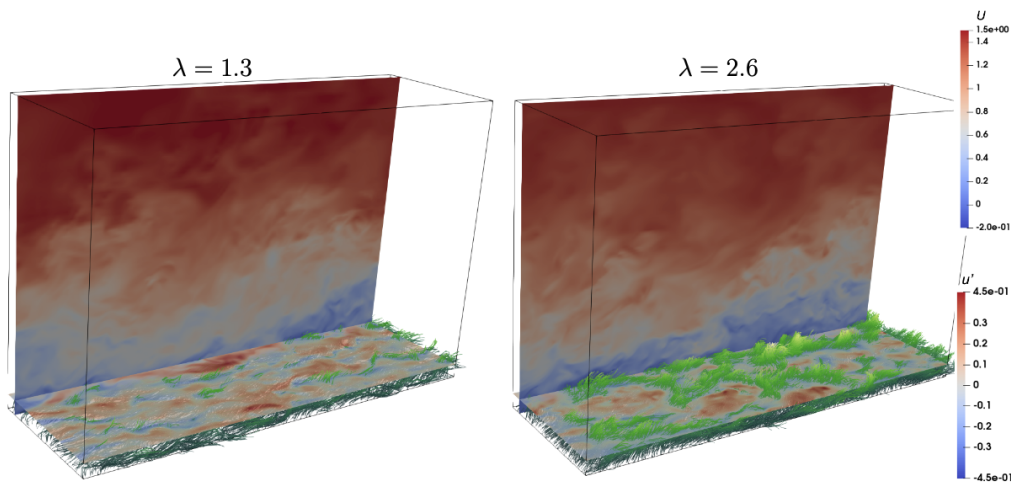


Figure 1: Instantaneous flow visualization showing contours of streamwise velocity on a vertical $x - y$ plane and streamwise velocity fluctuations on a horizontal $x - z$ plane. The filaments are shown in green and colored by their vertical coordinate. The left has solidity, $\lambda = 1.3$ and the right $\lambda = 2.6$