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Numerical investigation of the turbulent oscillating boundary layer with applied wind stress

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The flow in the Westerschelde estuary in the southern part of the Netherlands is mainly driven by moon and sun tides. Large velocities of 0.2 to 1 m/s are reached during high and low tide, which result in a typically large Reynolds number. In addition to the tides the wind (5 m/s) exerts a stress at the free surface driving the upper fluid layers.

To investigate this flow we perform resolved Large Eddy Simulations for a periodic channel domain. The domain is vertically bounded by a no-slip boundary at the bottom and by a free surface at the top. The tidal flow is mimicked by enforcing an oscillating pressure gradient over the channel length. The LES has to resolve the wall stress on the bottom wall as currently no wall models are available for an oscillating flow in combination with the applied wind stress. In the simulations the Reynolds number has to be decreased slightly compared to the Reynolds number found in the Westerschelde while keeping the other dimensionless numbers fixed.

A similar study has been performed for the Gulf of Trieste [1] but without a wind acting at the free surface. Here, turbulence is created near the bottom due to the oscillation of the flow and penetrates the upper layers making the entire fluid column turbulent. With a wind stress present turbulence is also created at the free surface and travels to the lower fluid layers. Hence, the turbulence in the fluid column stems from both mechanisms. The upper fluid layers are moving in the same direction as the wind stress, while the lower fluid layers are oscillating due the tidal effect. This strong shear results in a strong creation of turbulence near the free surface.

[1] S. Salon, V. Armenio and A. Crise, A numerical investigation of the Stokes boundary layer in the turbulent regime, Journal of Fluid Mechanics 570, 2007