Form drag due to tidal flow past a headland in a channel:  
The importance of phasing

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A numerical model was used to study the form drag of tidal flow past a headland in a channel. It was found that the relative phase shift between the tidal velocity and the form drag has a huge impact on the power that the drag could remove from the flow. The mechanisms that create this phase shift can be seen by looking at the eddies in the dynamically active sea surface height field.

1. Form drag

What is form drag?

Drag is a force on a moving fluid that tends to slow it down. Form drag is due to the pressure gradient that a fluid feels as it flows over or around physical objects. Form drag differs from frictional drag, because it is caused by the normal forces at the boundary layer, whereas frictional drag is due to the tangential forces.

Form drag in the ocean:

In the ocean, form drag works to dissipate tidal energy, generate internal waves and eddies, and promote turbulence and mixing. Unlike frictional drag, form drag may not be well resolved in coastal and larger scale models because it isn’t known what scales of topography are most important. The goal of this work is to understand what kinds of topographic roughness should be resolved in a model, and to better parameterize the effect of unresolved roughness.

Three Tree Point:

This project is motivated by research done at Three Tree Point in Puget Sound, Washington. The topography in this location is a bump on a sloping side wall, so it acts like both a ridge and a headland. Edwards et al. (2004) found much larger amounts of form drag at this location than what can be predicted by any steady or oscillatory flow theories.  

Figure 1B: When tidal currents flow over ridges, instepals and the sea surface are depressed on the leeward side, creating a pressure difference across the bump, which can be predicted by any steady or oscillatory flow theories.

Figure 1C: When tidal currents flow around headlands, eddies form on the leeward side, creating a pressure difference across the headland. This figure shows the eddy number in large eddies always affects sea surface depressions. Form drag - $\int_{domain} \frac{\rho U^2}{dx} dA$

Form drag = $\int_{domain} \frac{\rho U^2}{dx} dA$

3. Dynamically active and pseudo form drag

To gain insight into the mechanisms that contribute to the form drag, we divide the sea surface height field into two parts: the pseudo part and the dynamically active part.

The maximum pseudo form drag occurs at $t=6$, whereas the maximum dynamic form drag occurs at $t=8$. This shift in phase is due to the dynamics of the eddies.

4. Phase shift of the drag

The relative phase difference between the velocity and the form drag determines how much power is removed from the system by the drag.

$$P = F \cdot U \cdot \cos(\phi)$$

The pseudo form drag is in quadrature with the velocity so it is unable to do work on the flow. Therefore, the dynamically active form drag accounts for all of the tidally averaged power loss.

5. Model runs: drag, phase and power

The phase and the amplitude of the drag do not always have the same trend.

6. Conclusion

Knowing the phase shift between the velocity and the form drag is just as important as knowing the amplitude of the form drag. Furthermore, the mechanisms that create this phase shift can be explained by looking at the eddies in the dynamically active sea surface height field.