Flow Past a Cylinder Including Bottom Friction

Authors: David R. Munday, David P. Marshall, & Matthew D. Piggott

Observations of flow past islands in the coastal zone of the oceans have shown a variety of behaviour bearing a resemblance to the classical fluid dynamics problem of flow past a cylinder. This behaviour ranges from the case of fully attached flow, through steady separation, to a von Kármán vortex street-like structure of shed eddies. In the case of a separated flow, observations have also elucidated the presence of intense shear layers along the edge of the separation bubble. Whilst Ekman spin-down processes, due to friction with the bottom, result in the presence of vertical motions and secondary circulations.

In the case of Rattray Island (Queensland, Australia), several numerical modelling attempts have been made in the wake of an extensive set of field observations of the tidally varying flow. These numerical experiments have met with different degrees of success. However, the combined results appear to indicate that the presence of a secondary wake circulation is crucially tied to the presence, or absence, of the observed shear layers. Furthermore, there have been several reports in which a parameterisation of the shear layers greatly improves the accuracy of the simulation.

We report on the results of some simple experiments on flow past a cylinder in which the traditional 2D domain has been expanded to three dimensions. The bottom boundary condition is then set to noslip and the model domain becomes suitable for the study of idealised flow past islands. These experiments concentrate on the case of steady, rather than tidally varying, flow for the sake of simplicity.

By using the Imperial College Ocean Model in a dynamically adaptive mode, we are able to explicitly resolve the shear layers that form in the event of flow separation. The results, at a range of parameter values, reveal complex secondary circulations and vertical motions both up- and down-stream of the cylinder. Those in the wake can be attributed to Ekman spin-down processes. However, those upstream of the cylinder are more likely to be due to the combined effects of shear and flow curvature. In the past, it has been argued that island wakes are closed and cut off from any exchange with the free stream. We present evidence contrary to this and show flow configurations in which the flow crosses the shear layers to enter the wake.