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Flow past topography in relation to the Antarctic Circumpolar Current

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The wind-stress impinging upon the Antarctic Circumpolar Current (“ACC”) in the Southern Ocean is substantial at around 0.2 Nm^{-2}. The associated northward-flowing Ekman drift must be opposed by a southward geostrophic mass flux below the mixed layer. However, the nature of the balancing geostrophic flow is hotly debated with the principal contenders being either transient jets and eddies or the time mean flow.

This problem is rendered more tractable by using scaled idealised domains in which multiple sensitivity tests can be evaluated in a computationally efficient manner. Fluidity–ICOM (http://amcg.ese.ic.ac.uk/) is being used, which utilises unstructured meshes and a new stable mixed discontinuous/continuous finite element pair ($P1_{DG}$–P_2). This combination allows small–scale processes in high Reynolds number flows to be modelled and analysed.

The classical problem of flow past a cylinder is broadly analogous to flow past topographic highs in the ACC. The model set–up incorporates a barotropic flow in a non–dimensional, periodic, beta–plane channel. The flow structure is dependent on Reynolds numbers, the non–dimensional beta parameter and the shape of the obstacles included in the channel. Both prograde and retrograde flows have been simulated in Reynolds number and beta-parameter regimes that are equivalent to the Southern Ocean. Low beta–parameter regimes have been verified against theoretical, laboratory and other modelling studies.

The high Reynolds number flows lead to the formation of eddies and Rossby waves down-stream of the cylinder and the creation of jets through the bunching of pressure contours upstream. Analysis of the transient small–scale eddy structures associated with the wake provides additional insight into the role of the various forces acting upon the ACC. The variation of the form drag, frictional stresses and the boundary layer associated with an obstacle illustrates the change in the dominance of the different terms in the momentum equation as the flow evolves from laminar to vortex shedding and then to turbulence. New techniques to decompose the momentum balance into its rotational and divergent parts have been used to further elucidate the balance of terms and the eddy forces associated with the Reynolds stresses.

These simulations highlight the importance of jets and eddies in closing the momentum balance in the Southern Ocean circulation.