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Vacillating jets: baroclinic turbulence and topography

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Observations from satellite altimetry and output from high-resolution ocean models indicate that the Southern Ocean is characterised by an intricate web of narrow, meandering, filamentary jets. These jets undergo spontaneous formation, merger and splitting events, and rapid latitude shifts over periods of weeks to months. The role of topography in controlling jet variability is explored using a doubly-periodic, forced-dissipative, two-layer quasi-geostrophic model. The system is forced by a baroclinically-unstable, vertically-sheared mean flow in a domain that is large enough to accommodate multiple jets. The dependence of (i) meridional jet spacing, (ii) time scales of jet variability and (iii) large-scale, domain-averaged transport properties on changes in the length scale and steepness of simple sinusoidal topographical features is analysed.

The Rhines scale ℓ_β measures the meridional extent of eddy mixing by a single jet, and the ratio ℓ_β/ℓ_T, where ℓ_T is the topographic length scale, determines jet behaviour. Multiple, steady jets with fixed meridional spacing are observed when $\ell_\beta \gg \ell_T$ or when $\ell_\beta \approx \ell_T$. However when $\ell_\beta < \ell_T$, a pattern of perpetual jet formation and jet merger dominates the time evolution of the system. This unsteady structure significantly alters the large-scale energetics and transport properties, leading to a reduction in transport by a factor of two if the topography consists of zonally-invariant ridges, and an increase in transport by an order of magnitude or more if the topography consists of two-dimensional sinusoidal bumps. For certain parameters, bumpy topography gives rise to periodic oscillations in jet structure between purely-zonal and topographically-steered states. In these cases, transport is dominated by bursts of mixing associated with the shifts between the two regimes. Unsteady jet behaviour depends crucially on the feedback between changes in mean flow orientation, caused by topographic steering, and the conversion of potential energy to kinetic energy through baroclinic instability, as well as on asymmetric Reynolds stresses created by topographical modifications to the large-scale potential vorticity gradient. It is likely that these processes play a role in the dynamic nature of Southern Ocean jets.