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Source-sink driven planetary flows in a polar basin

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Analytical process models are developed to study linear, steady-state, source-sink and wind stress curl driven barotropic planetary flows in a circular polar basin on the sphere with simple shelf topography. The leading order dynamical balance is geostrophic except near the boundary of the basin and the shelf edge, where dissipation in the form of either linear bottom friction or eddy diffusion becomes significant. Full spherical geometry is retained in the derivation of the barotropic vorticity equation. Subsequently, an overlooked approximation in the refereed literature of the sixties is adopted whereby the latitudinal dependence in the coefficients of the vorticity equation are suppressed, hence allowing analytical solutions to be obtained we refer to this as the "beta sphere approximation". The approximation is justified, a posteriori, and the study compares the analytical solutions with numerical solutions obtained from the NEMO ocean modelling system. Numerical experiments with NEMO are used to extend the process model solutions by obtaining the steady wind and boundary forced circulation in a polar basin with open boundaries representing the Bering Strait, Canadian Archipelago and Greenland Sea, and with a continental self and a representation of the Lomonosov ridge. NEMO based experiments are also conducted to investigate the sea surface anomaly field driven by the fluctuating flow through one, or more, of the straits connecting the Arctic basin to its marginal seas. Finally, we reflect on the likely impact of sea ice on the barotropic circulation in the Arctic Ocean.