Prismatic setup of the inverse finite-element ocean circulation model (IFEOM)

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The inverse finite-element ocean model (IFEOM) estimates the ocean circulation by assimilating hydrographic data. It solves stationary equations for velocity and sea surface height (SSH), and treats the advective-diffusive tracer balances for temperature and salinity (T and S) as soft constraints. IFEOM uses prismatic discretization of the model domain with $P_1^{NC}(x,y)P_1(z)$ representation for the horizontal velocity field, $P_1(x,y)$ for SSH, and $P_1(x,y)P_1(z)$ for tracer fields and the potential Φ of the vertical velocity ($w=\delta\Phi/\delta z$).

The forward model first solves for vertically integrated velocity and elevation. Discretized vertically integrated momentum and continuity equations can be solved with the use of a direct solver, while the solution for full velocity (when elevation is found) can be obtained with iterative solver if the Reverse Cuthill McKee Ordering is applied. The introduction of the potential Φ for the vertical velocity allows satisfying both boundary conditions on w (at the bottom and surface) and makes the problem elliptic in z .

Solving separately for the barotropic and full velocities requires different treatment of the horizontal viscosity near the bottom. This partially destroys the vertically integrated continuity balance for the full velocity in places with strong topographic features. The barotropic velocity correction cures the problem and is orders of magnitude smaller than the full velocity. However, despite the small magnitude of this correction its contribution into the vertically integrated divergence balance is significant.

IFEOM seeks for the T and S fields, wind stress, and velocities at open boundaries which give minimum to its objective function. The latter penalizes residuals in the tracer equation, deviations of model variables from data available and also misfit between diagnosed deep velocities and that of the prognostic run of a prismatic version of FEOM. The deep velocity constraint is applied below 2000 m and turns to be crucial in keeping the integral properties of the diagnosed circulation consistent. The physical motivation behind this constraint is that the deep ocean circulation is relatively stable and should not be influenced much by assimilation.

The structure and basic principles of IFEOM are presented as well as results of its application to estimating the circulation in the North Atlantic by assimilating several climatological datasets.