ECCO summer school 2019

Friday Harbor Labs, May 19-31, 2019

Ocean Modeling, part II

Chris Hill & Jean-Michel Campin
M.I.T., Cambridge, MA

Plan

Part I

- Ocean Model equations
- Discretised equations, mainly focus on MITgcm formulation
- some modeling recipe (stability, accuracy, conservation)

Part II

- Forcing and interface with other components
- diagnostics
- interface with SGS parameterisation
- perspective

Model Forcing

- Define a set of primary forcing fields:
  directly enter RHS of ocean model equations
- Provide a different set of input fields
  to compute primary forcing using, e.g., bulk-formula
- other components (e.g., seaice) can modify primary forcing fields

Primary forcing fields:

- surface Q_{net} (in W/m^2), include the short-wave component Q_{sw}
- surface Fresh-water flux ($E - P$ in $kg/m^2/s$), including river run-off
- surface salt flux (e.g., from salty seaice)
- surface pressure loading (from atmosphere and/or seaice)
- surface wind-stress
- tidal potential (i.e., horizontal geopotential anomaly)
- geothermal heat flux (in W/m^2)

Free surface and fresh-water flux

- No approximation (e.g., ECCO-v4):
  Non-linear free-surface (NLFS) → water column changes according to η

  $$\frac{\partial \eta}{\partial t} + \nabla \int_{-H}^{\eta} \mathbf{v}_h dz = \frac{1}{\rho_c}(P - E)$$

  and Real-Fresh-Water flux (*useRealFreshWaterFlux*=.TRUE.,)
  → add fresh-water and model takes care of salinity dilution
  → need to account for heat and tracer content content of $P - E$

- Linear free-surface approximation ($\eta \ll H$):
  → model domain is fixed (disconnected from η)

  $$\frac{\partial \eta}{\partial t} + \nabla \int_{-H}^{0} \mathbf{v}_h dz = \frac{1}{\rho_c}(P - E)$$

  → not conserving due to $w_{surface} \neq 0$
  Real-Fresh-Water flux ↔ $P - E$ added to $\frac{\partial \eta}{\partial t}$
  needs to convert $P - E$ to "salt-flux" since model domain is unaffected

Seaice - Ocean dynamical coupling

Thermodynamics

change seaice mass by melting/freezing ↔ add/remove water:

→ contribute to $\frac{\partial\eta}{\partial t}$ (*useRealFreshWater*)

but total hydrostatic pressure does not change $\rho g \frac{\partial\eta}{\partial t} + g \frac{\partial}{\partial t} M_{ice} = 0$

⇒ only consider ice loading (M_{ice}) if *useRealFreshWater*

Dynamics

sea-surface slope contributes to seaice acceleration, leading to strong coupling between seaice motion, ocean current (divergence) and SSH:

$M_{ice} \rightarrow p_{hyd} \rightarrow \frac{\partial\eta}{\partial t}$

$\nabla\eta \rightarrow \mathbf{v}_{ice} \rightarrow \frac{\partial}{\partial t} M_{ice}$

⇒ careful coupling (and time-stepping) of the 2 components

Diagnostic of derived quantities

- Important to be consistent with model formulation, specially discretisation in space: some numerical mode/pattern that do not contribute to model dynamics will show up in derived diagnostic if done differently from the model.
  $\Rightarrow$ Need to stay as closed as possible to model discretisation

- A simple example: geostrophic balance

$$\bcancel{\frac{\partial v}{\partial t}} + fu = -\frac{1}{\rho_c}\frac{\partial p}{\partial y} \; - \; \cancel{\mathbf{v}\cdot\nabla u} \; - \; \cancel{\nabla\cdot(-\nu\nabla u)}$$

Discretised (Vector Invariant) $(-fu)$ as: $-\overline{f}^{i}\,\overline{\overline{u\Delta y_g}^{j}}^{i}/\Delta y_c$ (diagnostic: "Vm_Cori ") and pressure gradient as: $-\frac{1}{\rho_c}\delta^{j}p/\Delta y_c$ closely match (Model geostrophic balance)

But simply considering: $u_{geo} = -\frac{1}{f\rho_c}\delta^{j}p/\Delta y_c$ might be far from a realistic geostrophic velocity.