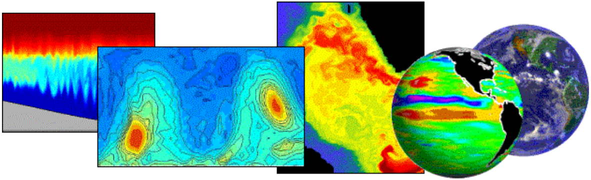
ECCO Projects Meeting

MITgcm development



Austin, TX Mar 20-22, 2024

MITgcm development

1. Recent development: quick overview
2. Momentum discretization with partial cell
3. Tracer variance budget and effective diffusivity

MITgcm recent development

1. Adjoint code improvement: thanks to Martin Losch !
   - remove TAF recomputations
   - TAF storage where it's needed, use of local storage
   - remove un-used deprecated code (e.g., ECCO_CTRL_DEPRECATED)
   - Adjoint with Tapenade (Shreyas Gaikwad)

   → faster TAF adjoint, smaller memory footprint
   → simpler code, easier to maintain and develop (e.g., with Tapenade)

2. Physics/Parameterizations
   - Langmuir effects in *pkg/ggl90* (Hajoon Song)
   - *pkg/dic* catching up (Jonathan Lauderdale)
   - GM prognostic EKE: GEOMETRIC (Julian Mak)
   - "Fast" ice (Martin)
   - idealize coupled set-up with gray-atmosphere, flat rectangular continents (swamp) and dynamical ocean: Produces ENSO variability (Philip-Joseph Tuckman, submitted)

Momentum and partial-cell

Context: Non-Hydrostatic, deep-ocean with 3-D Coriolis on Lat-Lon grid with zonally uniform ice thickness at the top (icy-moon).
Issue: fail to conserve Angular-Momentum (AM), with large discrepancy.

Found that issue is related to partial-cell (bathymetry or ice geometry).
Alternative momentum discretization related to partial-cell:

- Flux Form, Coriolis:
  fix: make sure that $\partial/\partial t(U,V) = +/- f(V,U)$
  (as in V.I. with *selectcoriScheme*=2) with $(U,V) = \int(u,v)dz$
- Vector Invariant, vorticity advection:
  fix: replace division by "hFacZ" with recip_hFacW/S
- NH-Coriolis (in $f' = 2\ \Omega\ \cos(\Phi)$, same code used in both Flux-Form & V.I.):
  apply same trick as for Flux-Form Coriolis
- alternative metric-terms expression (small effect on AM discrepancy)
- viscosity does not conserve AM (missing viscous metric terms) but contributes very little to AM budget discrepancy

Momentum and partial-cell

Evaluation in other set-up more relevant for ECCO (in progress), specially the alternative vorticity advection for V.I.:

- no effect at very coarse resolution (e.g., cs-32).
- no significant effect in exp4 (flow is strongly constrained by OB)
- trying in llc-90 ? llc-270 ?

To try, PR #809 (https://github.com/MITgcm/MITgcm/pull/809)

Tracer variance budget and effective diffusivity

Tracer equation in flux-form:

$$\delta^t(hc) = -\Delta t \sum_{i=x,y,z} \delta^i F_i(V_i, c) \quad \text{with :} \quad \delta^t h = -\Delta t \sum_{i=x,y,z} \delta^i V_i$$

Tracer variance budget, direct method:

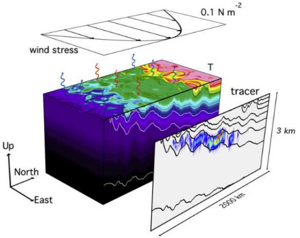
$$\begin{aligned} \delta^t(hc^2) &= -\Delta t \sum_{i=x,y,z} \delta^i \mathrm{T}_i + \Delta t \sum_{i=x,y,z} \overline{\mathrm{P}_i}^i \\ \text{with transport flux : } \mathrm{T}_i &= 2\overline{c}^{it} F_i - V_i \,\overline{(\widetilde{c}^{2t})}^i \\ \text{and production term : } \mathrm{P}_i &= 2F_i\, \delta^i \overline{c}^t - V_i\, \delta^i(\widetilde{c}^{2t}) \end{aligned}$$

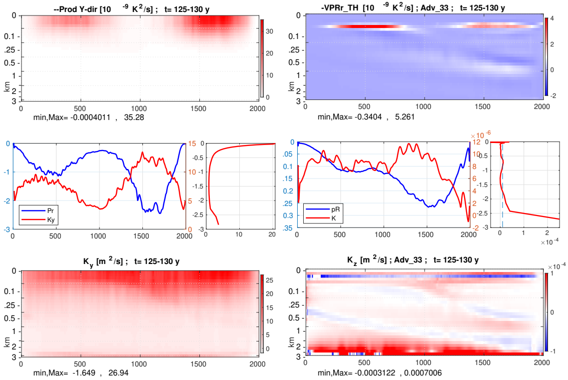
Effective diffusivity:

$$\kappa_i^\sigma = \frac{-\mathrm{P}_i}{2(\delta^i c^t)^2} \frac{1}{\Delta d_i} \qquad \text{with geometric factor} \Delta d_x = (\Delta y \Delta z)/\Delta x$$

- exact variance budget
- account for grid-cell thickness variations (e.g., z* or isopycnal coords.)
- splitted by direction → diffusivity in each direction
- accuracy: recover pure diffusion case and 1rst Order upwind scheme diffusivity.
- better than Kingbeil *etal*, 2014, with some adv. scheme, e.g., with Lax-Wendroff.

Method evaluation





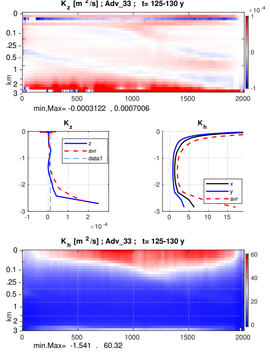
To compare methods with different advection schemes, use same eddying channel set-up as in Hill *etal*, Oce.Mod., 2012 ($\Delta_{x,y} = 5$ km, 30 levels, zonally symetric reentrant channel).

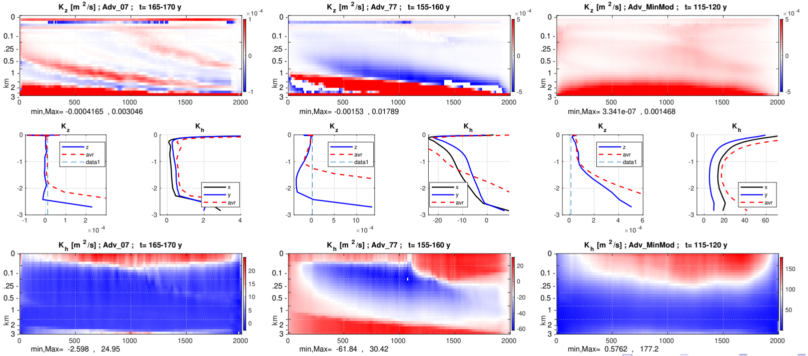
Using DST 3rd Order advection-scheme with flux-limiter (AdvScheme=33), show variance destruction and effective diffusivity (over 5.yr and L$_x$) in both Y and Z directions.

Method evaluation (cont)

Vertical and horizontal diapycnal effective diffusivity obtained with 4 advection schemes:

- DST-3 with flux-limiter (33, top)
- 7^{th} order with flux-limiter (7, bottom left)
- 2^{nd} order with Super-bee limiter (77, bot. center)
- 2^{nd} order with Min-Mod limiter (77, bottom right)





Conclusion

Tracer variance budget diagnostics

1. closed budget, distinguish transport and production (and forcing), locally and in each direction
2. useful to understand/interpret model results
3. effective diffusivity in each direction

Future work:

- implement for second-order moment advection scheme (Prather)
- evaluate in realistic set-up