Update on Ocean BGC Spinup

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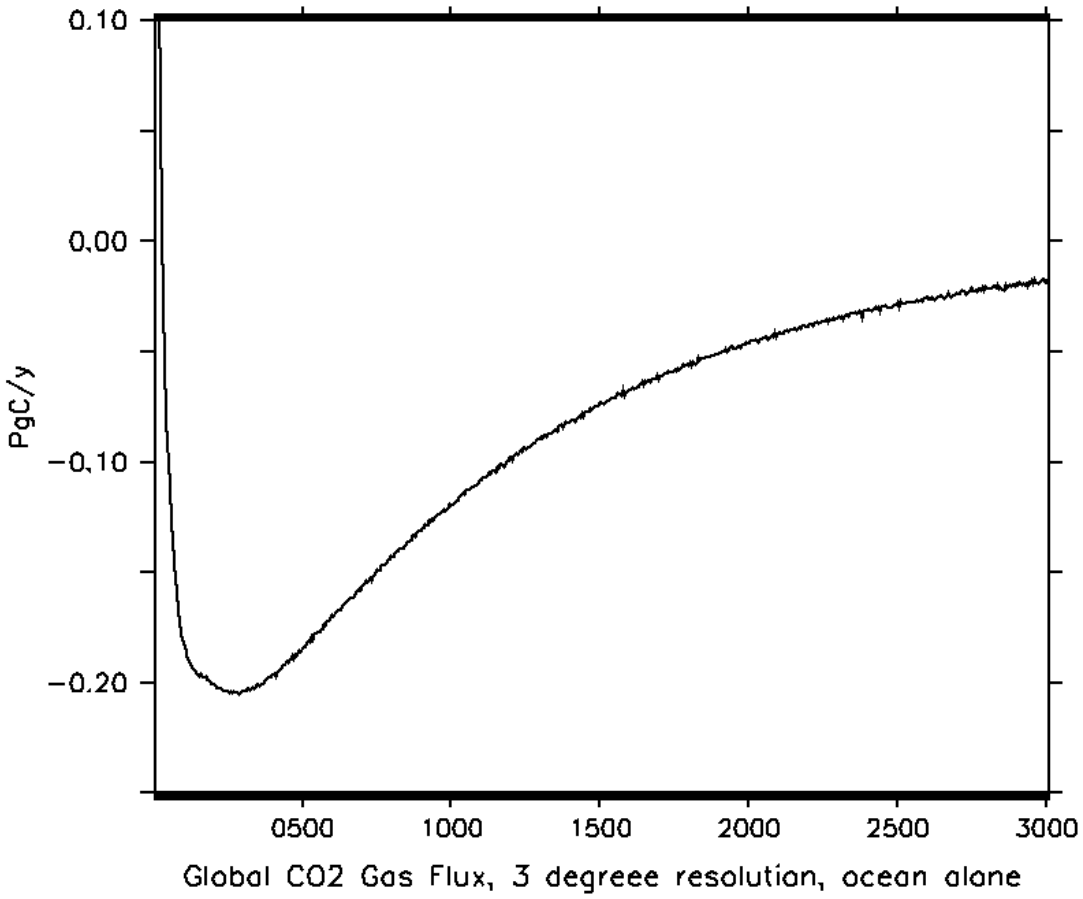
Ocean BGC Spinup

BGC tracers in the ocean, such as dissolved inorganic carbon, take thousands of years to equilibriate when run directly forward in time. Assuming a throughput rate of 20 years per day, running the model for 2000 years would take over 3 months.



Potential Ideas to Help each with big caveats (list from 12 months ago)

- Devise better BGC IC from model state.
- Separate short timescale ecosystem from long timescale BGC. Spin up ecosystem and then spin up BGC using forcings from spun up ecosystem.
- Interpolate circulation to coarser resolution and spin up there.
- Green's Function/Impulse Response techniques.
- Extrapolation of trends.

Newton-Krylov Solvers

Li & Primeau (2008) , Khatiwala (2008)

- Model Map: $u(t) = \Phi(u(0),t)$, where u is the BGC state
- Solve: $\Phi(u_0,T)=u_0$ for u_0.
- Rewrite: $F(u) \equiv \Phi(u,T)-u=0$
- Newton's Method:

  $u_{k+1} = u_k - (\partial F/\partial u)^{-1} * F(u_k)$
- Use Krylov iterative method (GMRES) to solve:

  $(\partial F/\partial u)(\delta u_k)=-F(u_k)$
- Each iteration evaluates $(\partial F/\partial u)(\delta u)$
- Finite Difference Approximation

  $(\partial F/\partial u)(\delta u) \approx (F(u+\sigma\delta u)-F(u))/\sigma$

  note this is a forward model run.

Initial Efforts w/ Newton-Krylov

- No preconditioner for linear system solve
- Spotty/Poor convergence
  - not surprising, consistent with literature
- Negative Chl values

Subsequent efforts have focused on building an effective preconditioner. Details of our model configuration different from previous studies matter!

Results for an Age Tracer, x3 grid

Direct Integration

Model Years	Change per Year
500	0.5340
1000	0.3089
1500	0.1763
2000	0.1003
2500	0.05803
3000	0.03570
3500	0.02316
4000	0.01899

Newton-Krylov
8 iterations+2 adjustment years per Newton step

Newton Iteration	Change per Year
1	0.3116
2	0.1054
3	0.0600
4	0.0481
5	0.0432
6	0.0393
7	0.0366
8	0.0344

Remaining Spinup Tasks
Some Potential Pitfalls

- Apply technique to full BGC model
  - Decouple slow tracers from fast tracers, apply Krylov step to slow tracers only, currently being tested
  - Non-linear tracer sink terms
  - Handle basic tracer interactions
- Switch from serial LU solver to parallel LU solver, needed for x1 due to size of matrix