Update on CCSM3.5 Carbon Cycle Simulations

K. Lindsay, NCAR/CGD

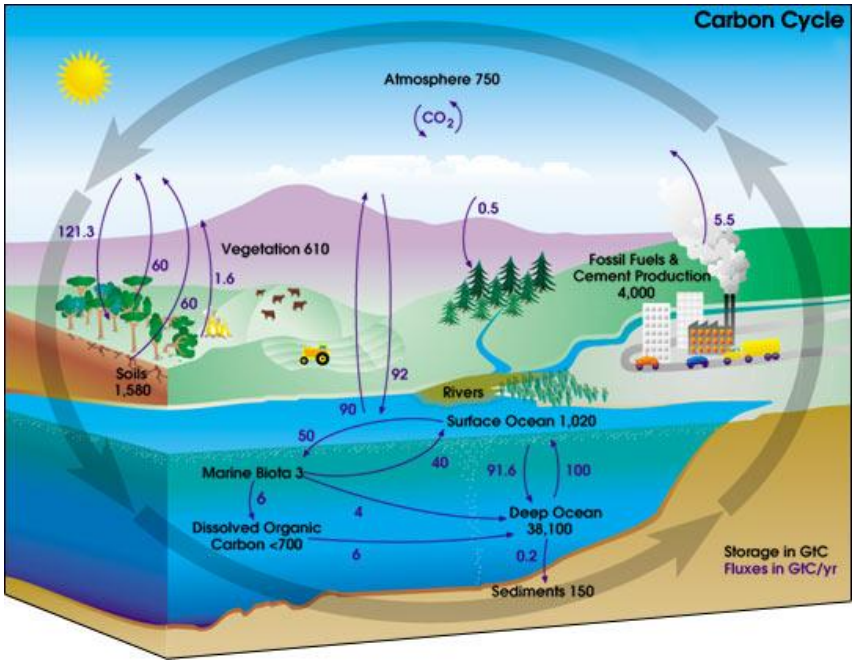
Biogeochemistry Working Group
June 2008

Background

- CCSM3.5 physics was finalized mid 2007
- This is not a public release for CCSM.
- Single resolution: FV1.9x2.5-gx1v5
- Model to be used for BGC development purposes, has changed considerably from CCSM3.0
- Step 1: spinup/stabilize physics (done)
- Step 2: spinup/equilibriate BGC

Spinning Up BGC Cycles

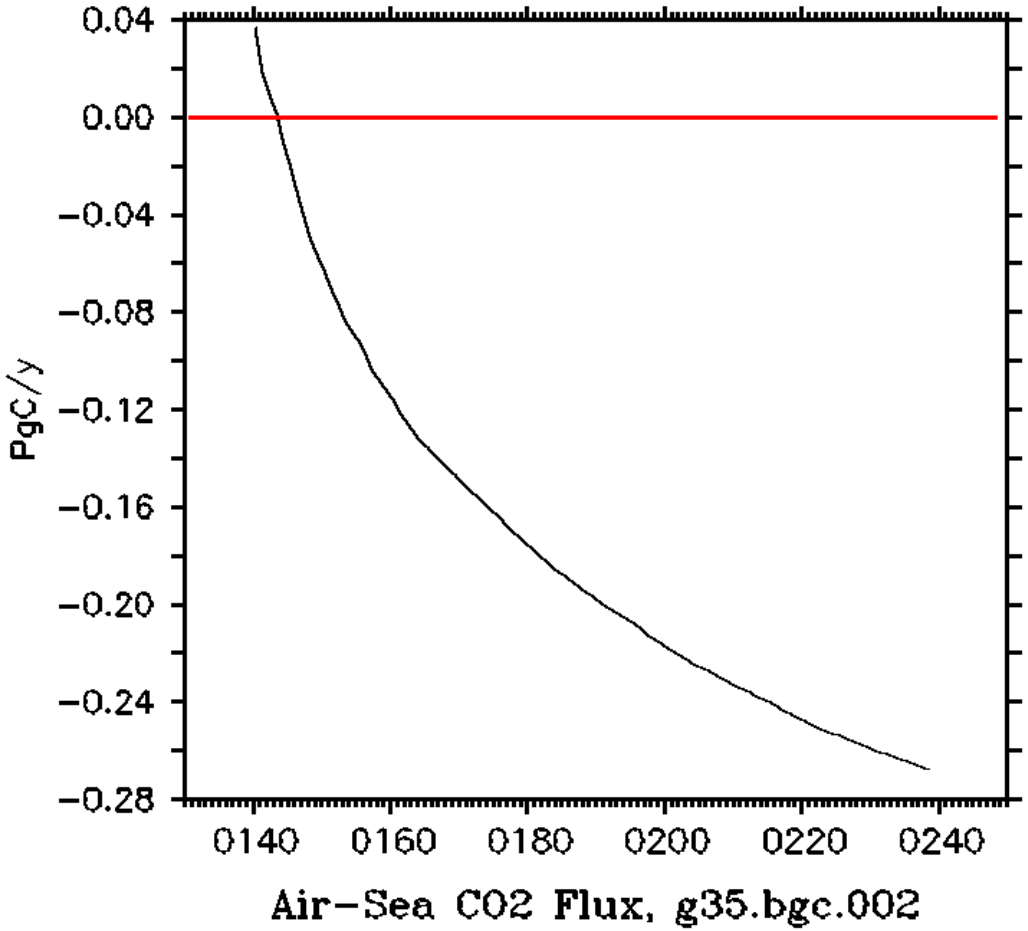
- Objective: Generate distribution of BGC pools that is in equilibrium with CCSM model climate and has atmospheric CO_2 close to a preindustrial level.



Spinning Up the Carbon Cycle

- Incrementally couple BGC, leading to fully prognostic carbon cycle, to stable 1870's configuration without BGC.
- 1) Peform short run of base coupled model to generate surface forcing for ocean BGC spinup.
- 2) Spinup ocean BGC with forcing from 1). Cycle POP physics to avoid drift away from model of Step 1). Fixed CO_2. This step is a big hurdle. How spunup do we need to be?

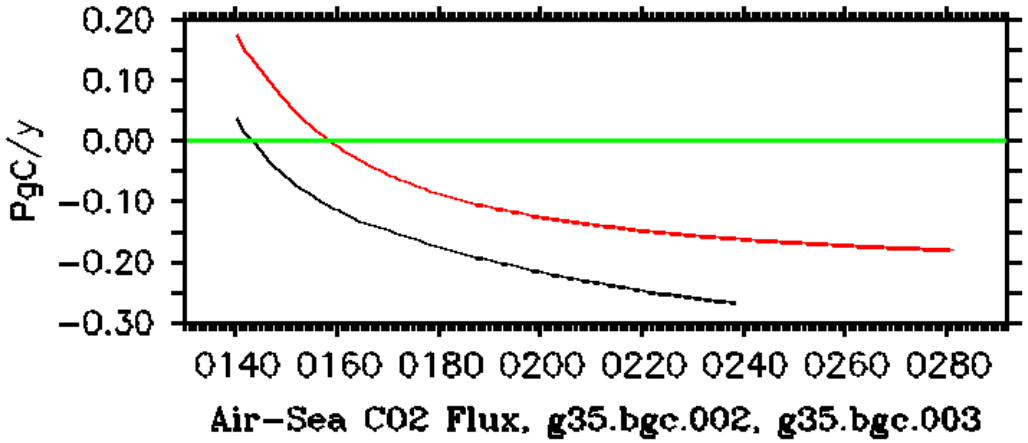
Step 2), Initializing Ocean Tracers with Observations

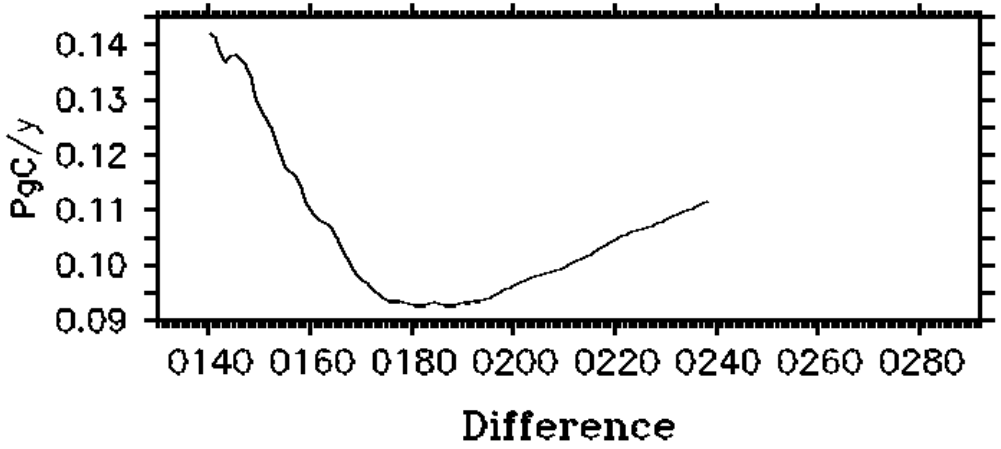


Potential Ideas to Help 2), each with big caveats

- 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.

Merge Spunup BGC from CCSM3.1 with Physical State of CCSM3.5





Biogeochemistry Working Group
June 2008

Potential Ideas to Help 2), each with big caveats

- ~~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.

Newton-Krylov Solvers

- Model Map: $u(t) = \Phi(u(0),t)$
- 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

Current Efforts on Newton-Krylov

- Develop preconditioner based on simplified representation of circulation
- Offline transport is side benefit
  - quickly generate better IC for N-K
- Do not explicitly include short timescale variables in solver
  - separate out long timescale tracers
  - use longer time span in iterations to allow short timescale variables to adjust

Is there a missing source of C?