Carbon Isotopes in the iCESM

Alexandra Jahn

Collaborators: Keith Lindsay, Esther Brady, Bette Otto-Bliesner, Zhengyu Liu

The iCESM project is funded by DOE, Office of Science
NCAR is sponsored by the National Science Foundation

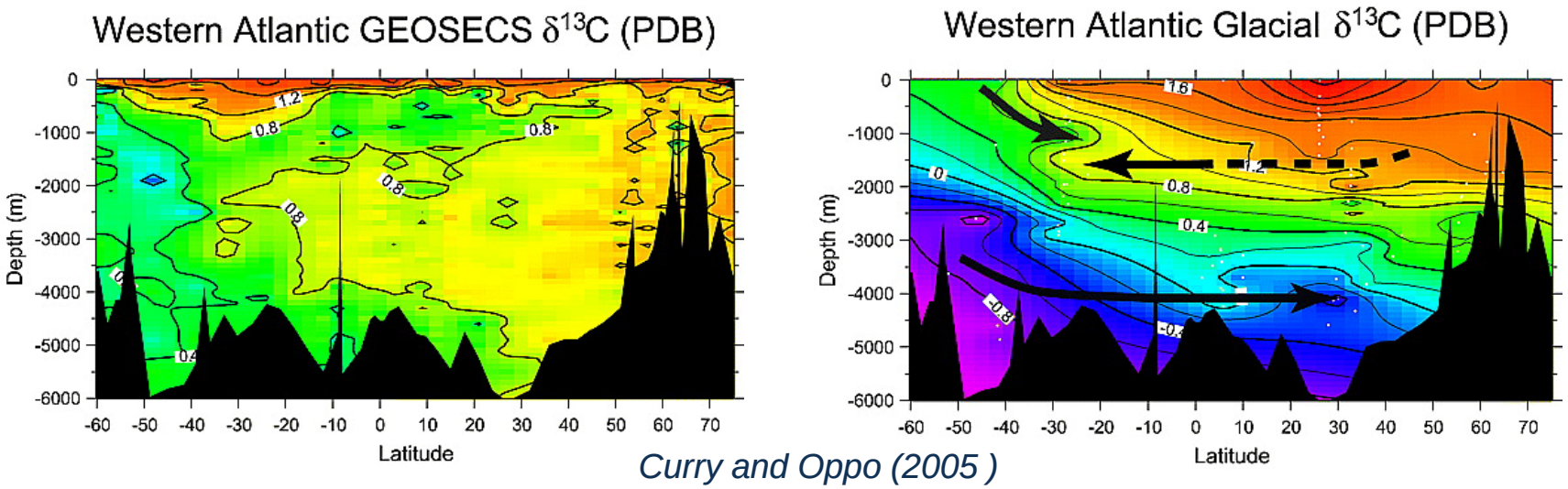
NCAR Climate & Global Dynamics

NCAR Earth System Laboratory

NSF

U.S. DEPARTMENT OF ENERGY

Motivation: Better model-data comparisons

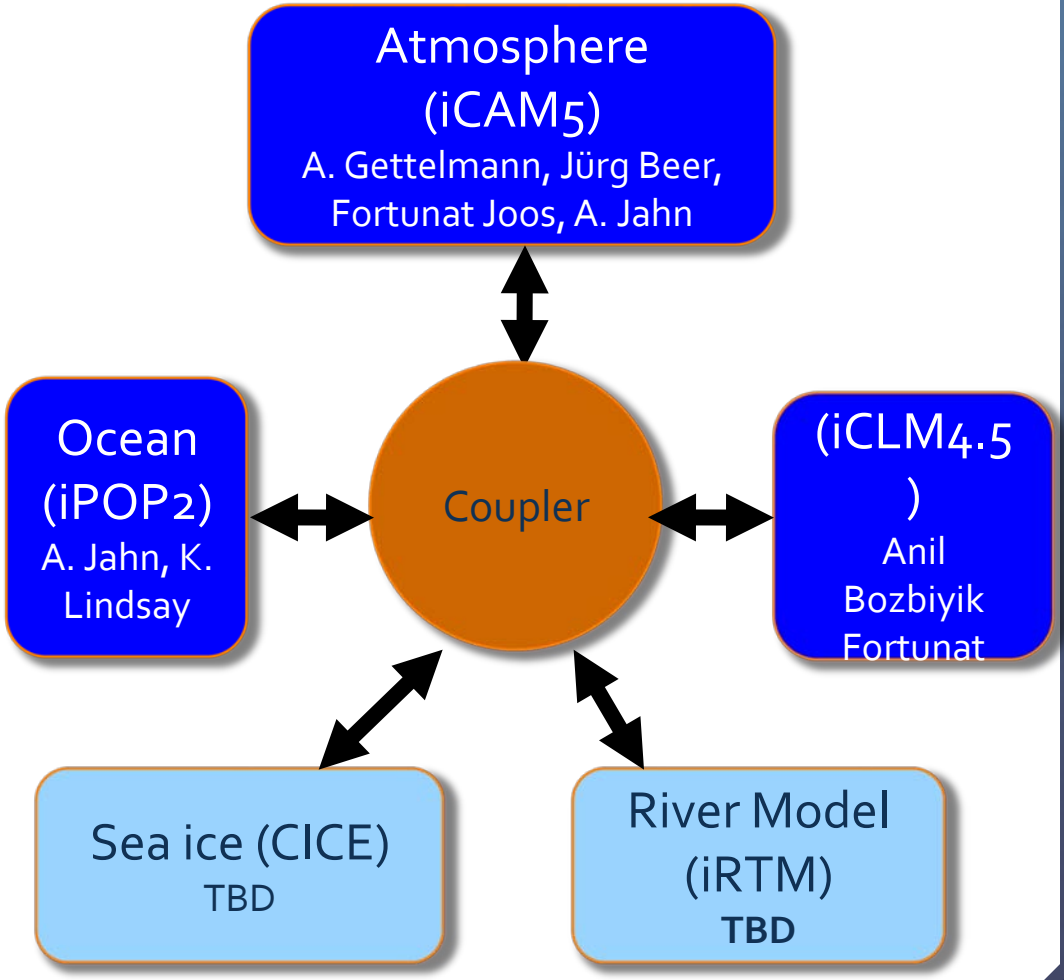


Curry and Oppo (2005)

- $\delta^{13}C$ is used to infer paleo ocean water masses (e.g., NADW)
- $\delta^{13}C$ can be used as tracers of carbon cycle processes → e.g., used to diagnose the oceanic uptake of anthropogenic CO_2
- $\Delta^{14}C$ is used as ocean reservoir age tracer

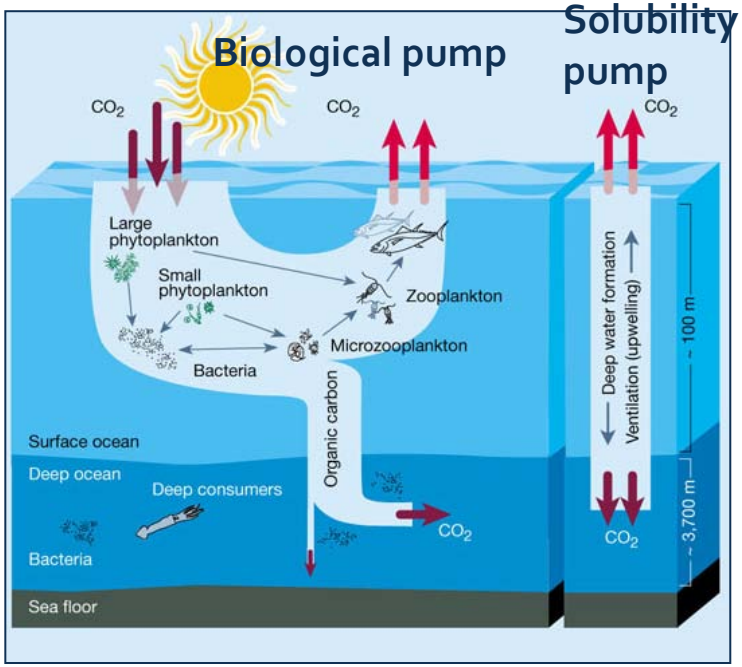
Implementation Status
Carbon Isotopes

- POP2 development + testing completed
- CLM4 development + testing completed
- RTM (needs development, river bulk Carbon transport to ocean BGC is now from data input)
- CAM5.3 (tracer development initiated)
- CICE: TBD



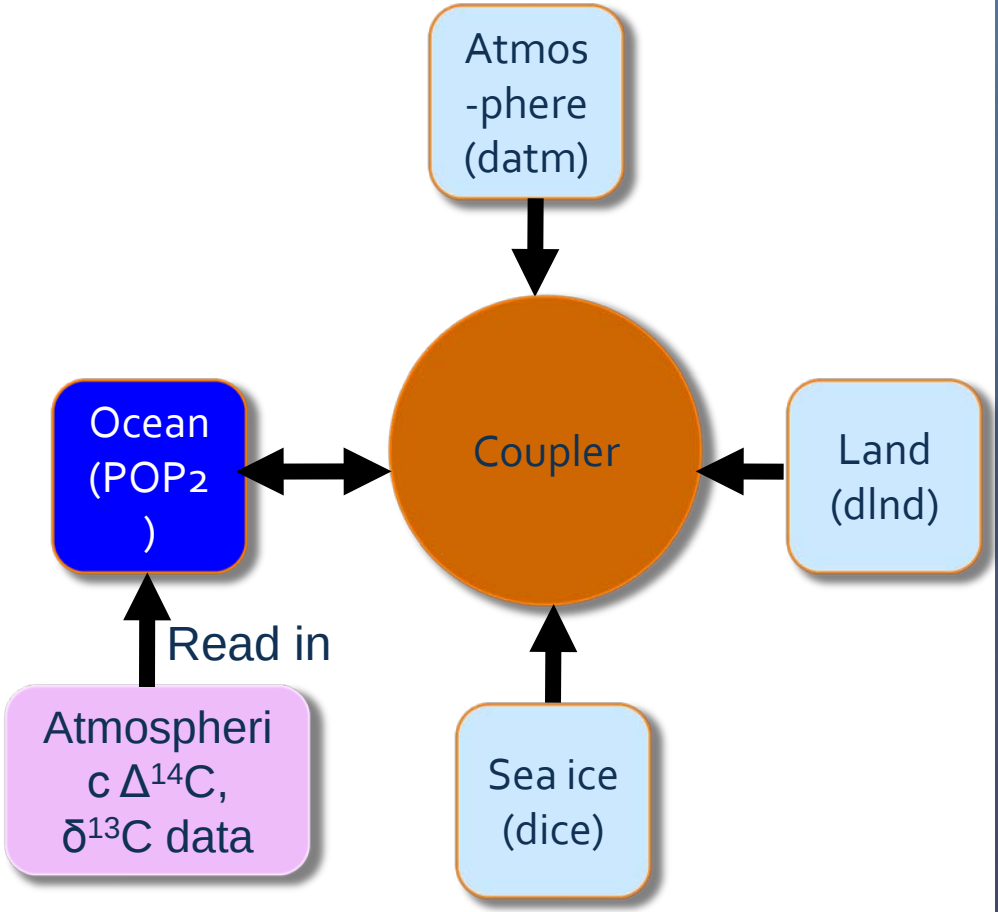
Implementation of Carbon isotopes in POP2 (as additional passive tracers)

- **Two different implementations:**
  - Abiotic Radiocarbon (2 additional tracers): can be run independently of the ecosystem model, ocean-model cost increase is a factor of 1.2 compared to the normal ocean model
  - Biotic ^{13}C and ^{14}C (14 additional tracers): Carbon isotopes in all seven carbon pools currently in the ecosystem. Cost increase is by a factor of 4 compared to ocean only model and 1.4 compared to the normal ocean-ecosystem model



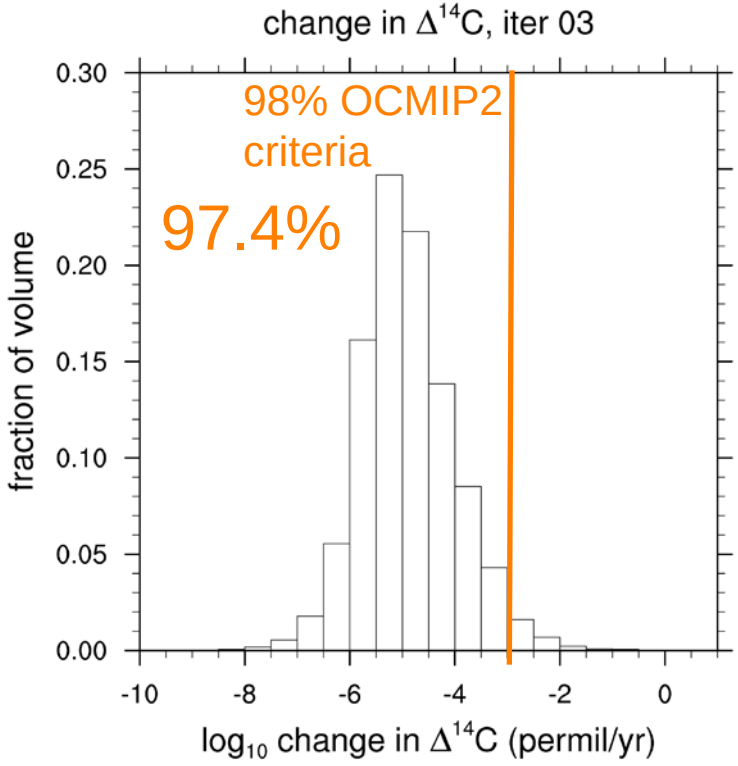
Model set-up

- All simulations were ocean-active-only simulations
- Spin-up simulations are forced with constant pre-industrial CO_2 (278 ppm), $\Delta^{14}C$ (0 permil), $\delta^{13}C$ (-6.379 permil)
- Simulations from 1765 to 2010 were forced with prescribed changing CO_2, $\Delta^{14}C$, $\delta^{13}C$
- Using CESM1.0.5

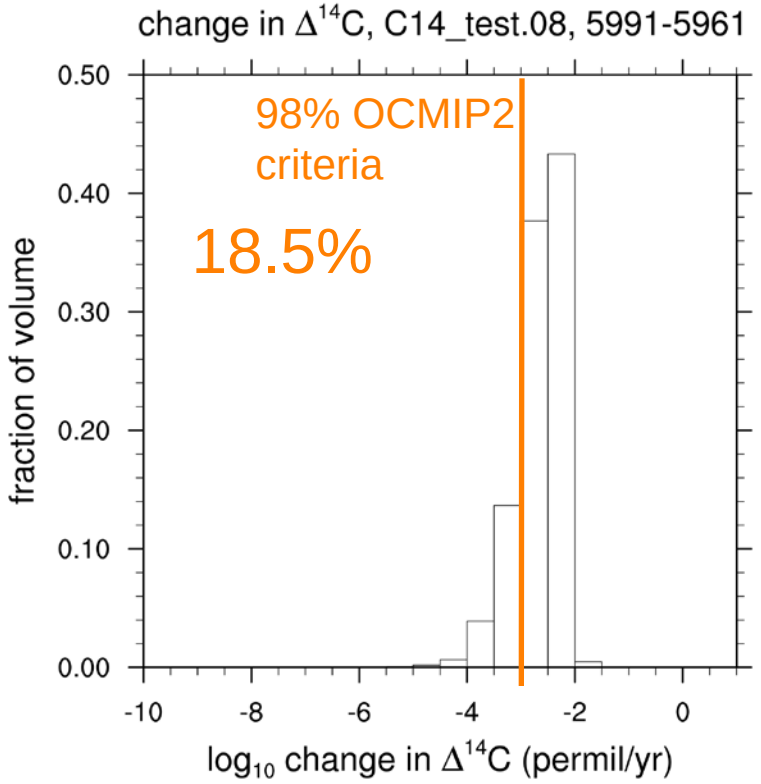


Fast spin-up of abiotic radiocarbon with Newton-Krylov (K. Lindsay)

After 3 *Newton-Krylov iterations* *(1 degree model, took < 24 h)*

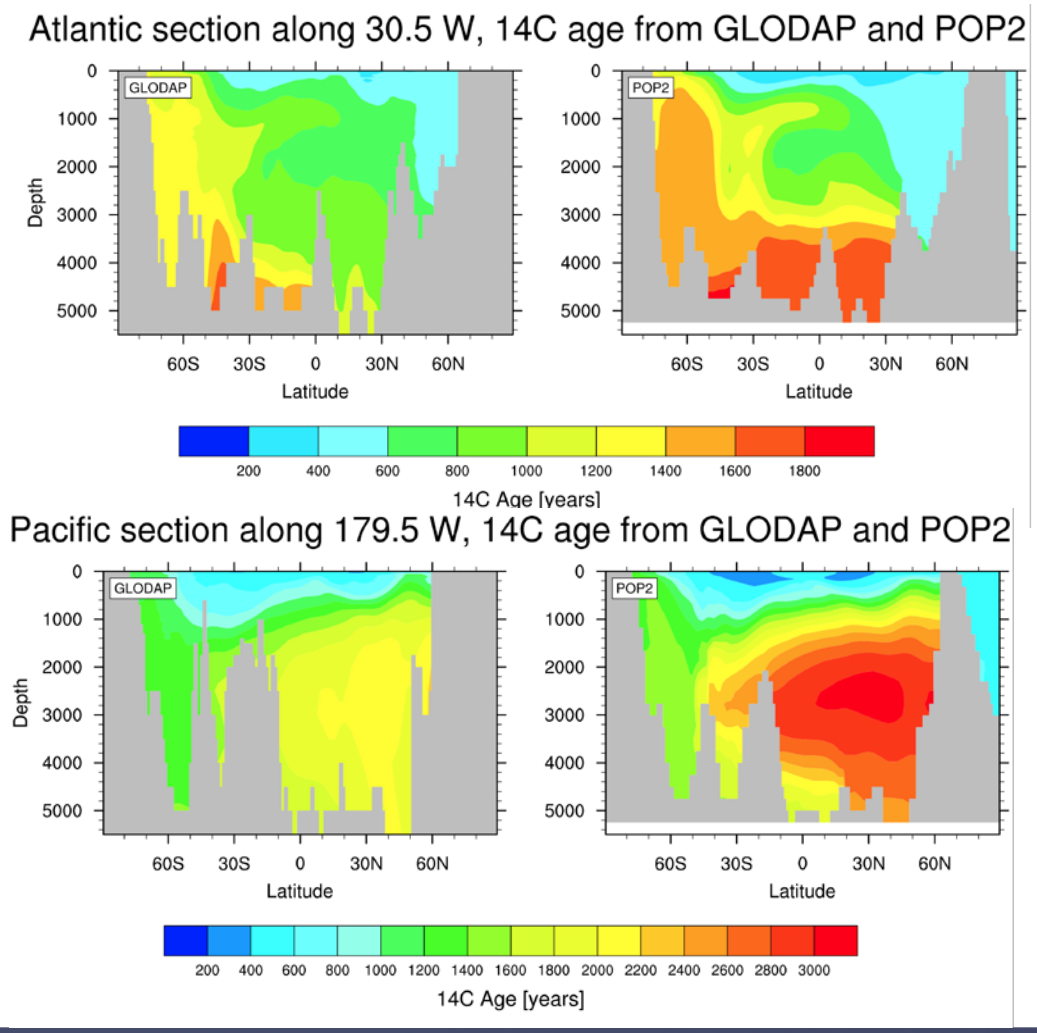


After 6000 model years (took ~2.5 months)



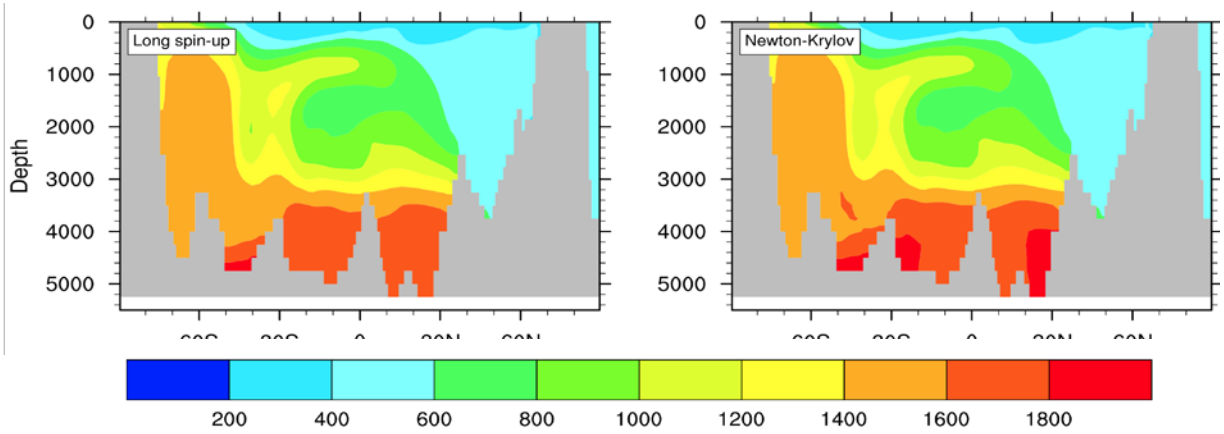
Plots courtesy of Keith Lindsay, NCAR

Results from abiotic Radiocarbon: ^{14}C age

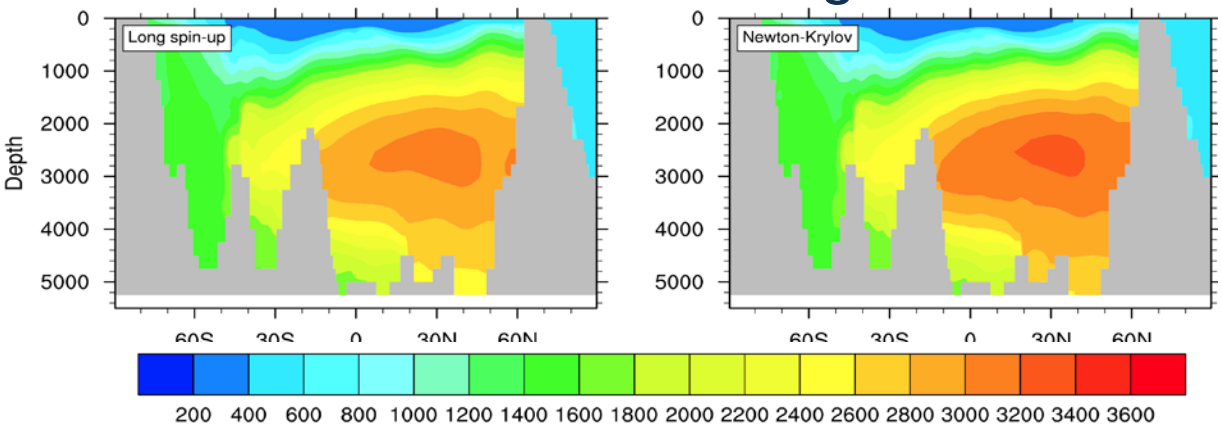


Impact of fully spinning up the radiocarbon

Atlantic section along 30.5 W

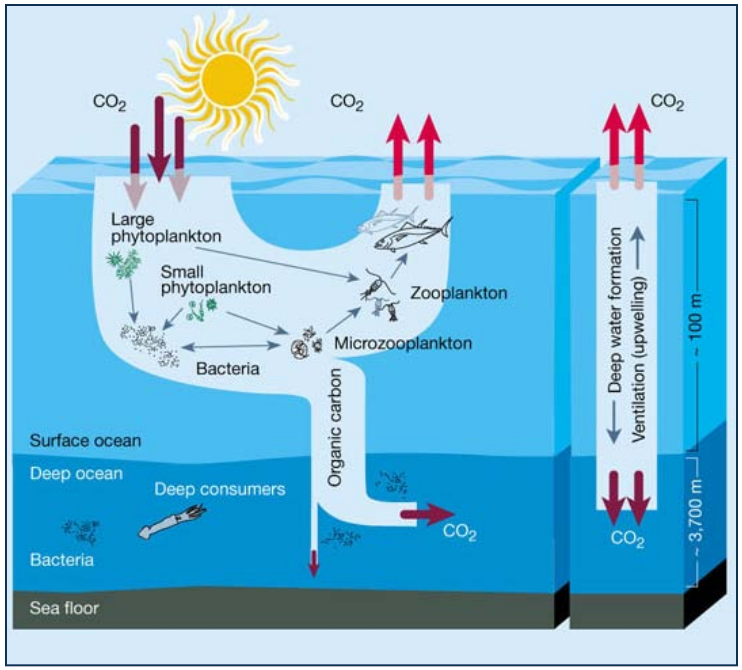


Pacific section along 179.5 W



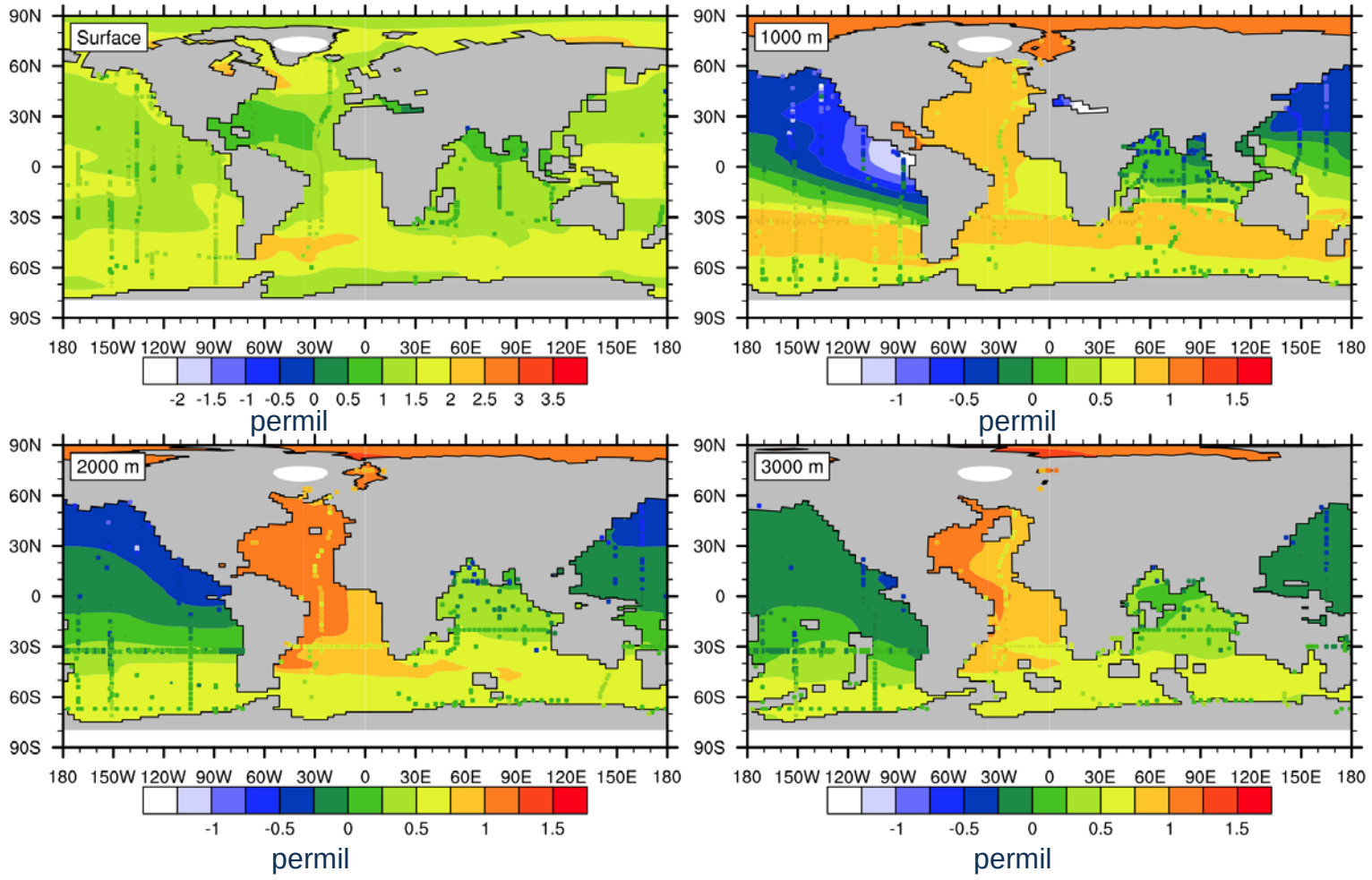
Adding the biological pump and ^{13}C

- Currently there are 7 carbon pools in the ecosystem model (DIC, DOC, small phytoplankton, diatoms, diazotrophs, zooplankton, $CaCO_3$)
- Accounts for fractionation effects during gas exchange, photosynthesis, etc



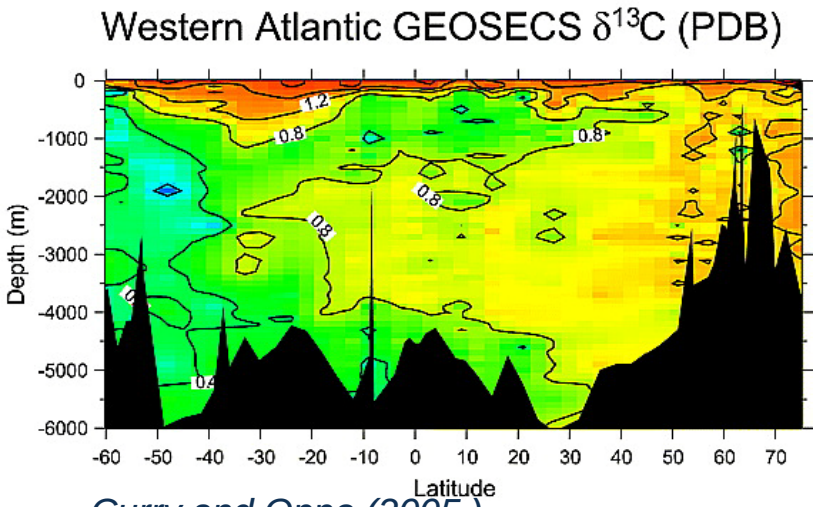
"Biotic C isotopes"
=
Includes both biological effects and solubility effects

First results from the biotic $\delta^{13}C$ isotope simulation (1990s)

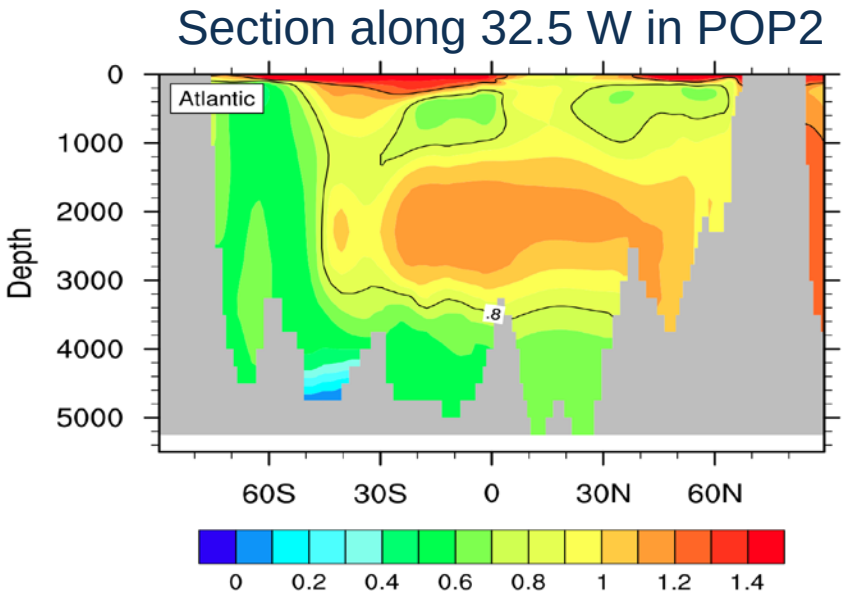


Model compared to the present-day $\delta^{13}C$ dataset complied by Schmittner et al (2013)

Atlantic $\delta^{13}C$ (1990s)



Curry and Oppo (2005)



Carbon isotopes in the atmosphere

- $^{14}CO_2$ and $^{13}CO_2$ will be carried in the atmosphere as tracers in addition to the current CO_2 tracer, and will be exchanged with the ocean and land through the calculated surface fluxes.
- For ^{14}C we need an atmospheric production term:
  - We will include a 2-D 14C production field (height and latitude), supplied by Fortunat Joos, Ulla Heikkilae, and Jürg Beer

Next steps

- Investigate relationship between δ13C and physical model variables under different MOC strengths
- Include abiotic radiocarbon in at least one ensemble member for the Last Millennium large ensemble, using the Newton-Krylov fast spin-up technique to obtain initial conditions
- Add Pa/Th to the ocean model as additional tracer (hopefully also Neodymium)

Thanks!

Contact: ajahn@ucar.edu

NCAR Earth System Laboratory
Climate & Global Dynamics
NCAR Earth System Laboratory
NSF
U.S. DEPARTMENT OF ENERGY