Carbon Isotopes in the iCESM

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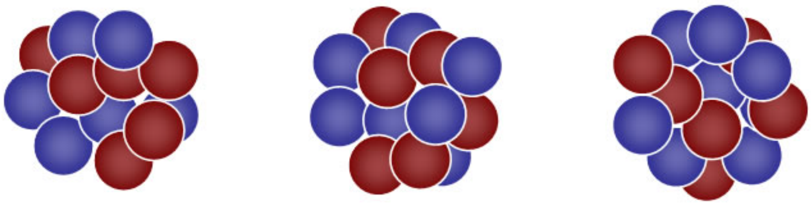
Carbon Isotopes and their usefulness

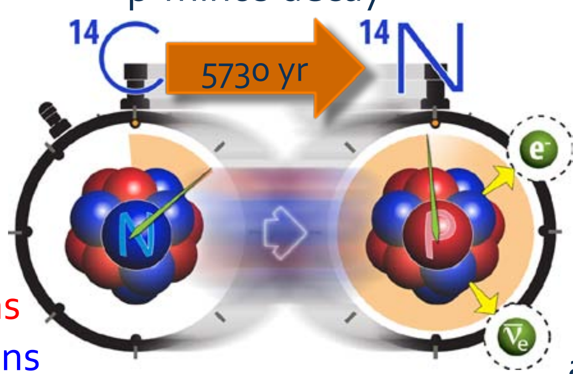


^{12}C	^{13}C	^{14}C
6 protons	6 protons	6 protons
6 neutrons	7 neutrons	8 neutrons
(stable)	(stable)	(radioactive)

Stable isotopes become preferentially concentrated because of differences in their mass: this is called fractionation

→ It allows the tracing of pathways/origins of carbon

β-minus decay



electron

7 protons

7 neutrons

antineutrino

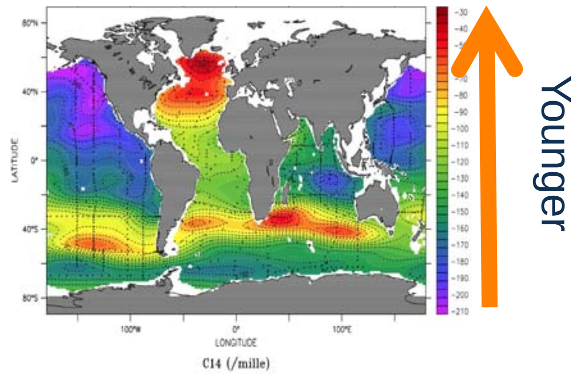
6 protons

8 neutrons

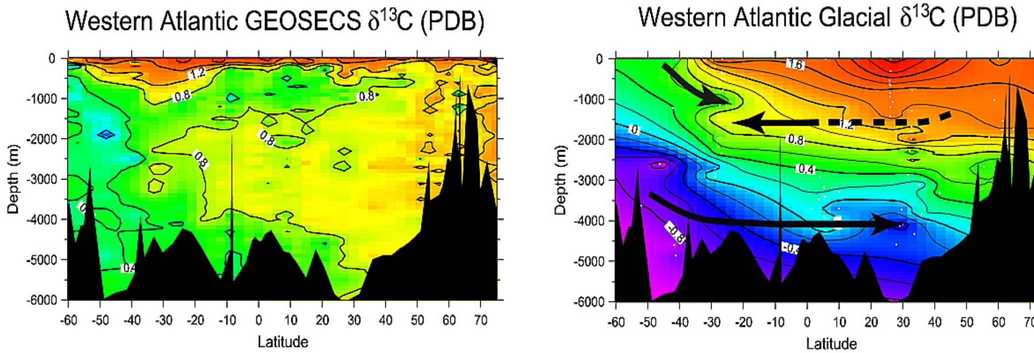
^{14}C acts as clock

Uses of Carbon isotopes

1000 m gridded GLODAP Δ14C



$\delta^{13}C$ measurements and reconstructions



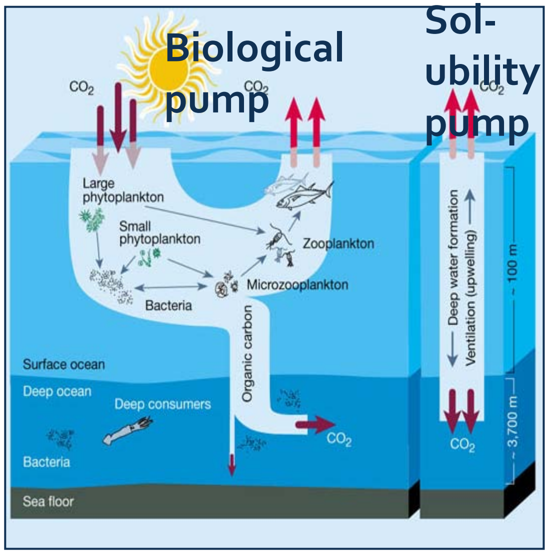
Curry and Oppo (2005)

- $\Delta^{14}C$ is used as proxy for the age of water masses, circulation timescales, and to infer past and present ocean water ages
- $\delta^{13}C$ is used to infer paleo ocean water masses (e.g., NADW)

→ Simulating carbon isotopes in the model allows a more direct comparison with observations (paleo proxies and present day isotopic measurements)

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

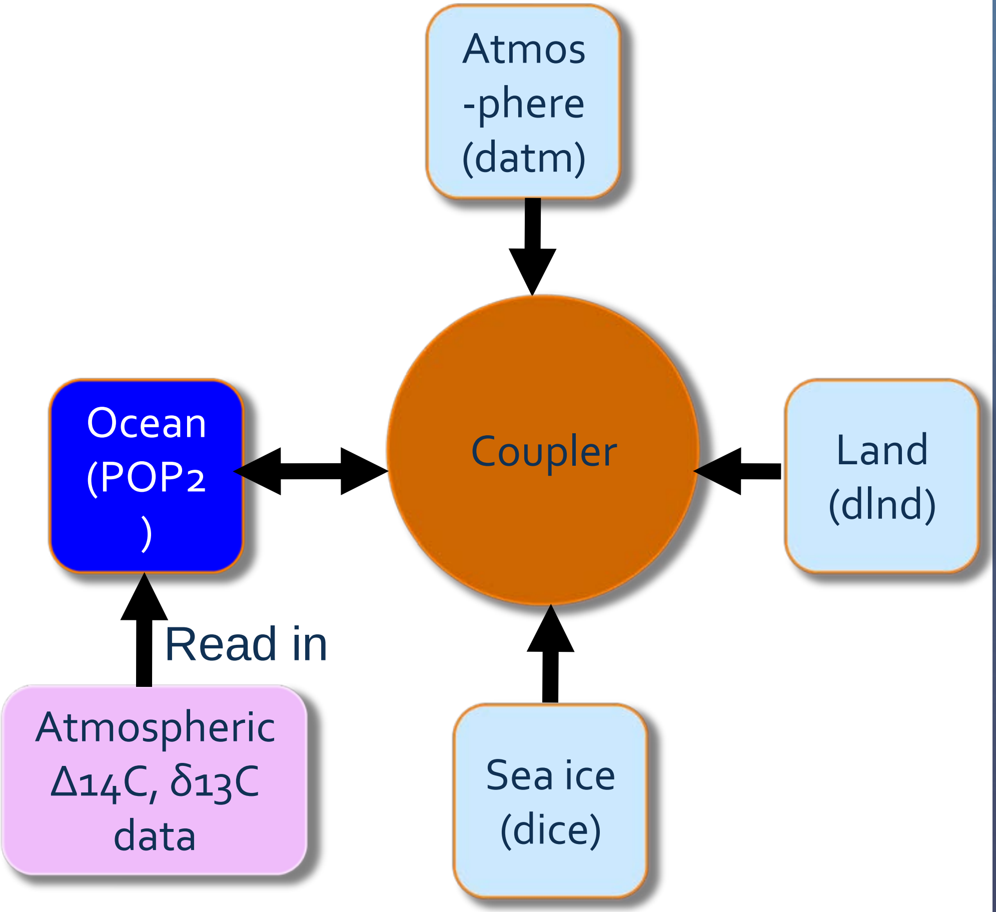
- **Two different implementations:**
  - Abiotic Radiocarbon (1 additional tracer): can be run independently of the ecosystem model, ocean-model cost increase is a factor of 1.2 compared to the normal ocean model
  - Biotic ^{13}C and ^{14}C (14 additional tracers): Carbon isotopes in all seven carbon pools currently in the ecosystem. Cost increase is by a factor of 4 compared to ocean only model. ^{13}C code was based on code from ETH (Gruber et al) developed for POP1



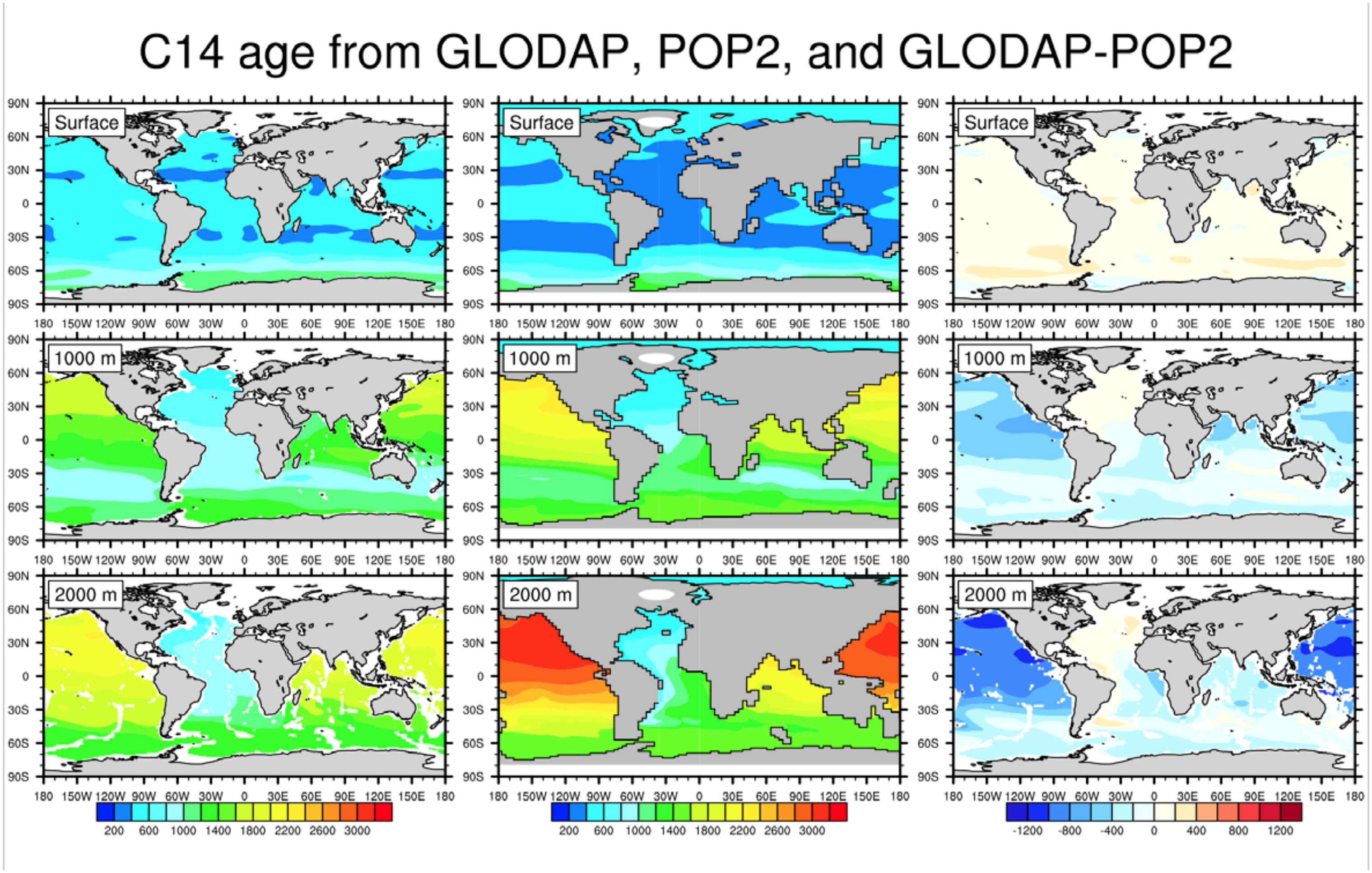
- **Status update:**
  - Abiotic Radiocarbon is implemented, spun-up in the 3° model, and tested
  - Biotic ^{13}C & ^{14}C are implemented and spin-up in the 3° model is under way

Model set-up

- Simulations are forced by prescribed atmospheric CO_2, Δ14C, δ13C data
- Spin-up simulations are forced with constant pre-industrial CO_2 (278 ppm or 284 ppm), Δ14C (0 permil), δ13C (-6.379 permil)
- Simulations are performed in the ocean-active-only 3° POP2 model, forced by CORE normal year atmospheric forcing (C-Compset)



Results from abiotic Radiocarbon: ^{14}C age



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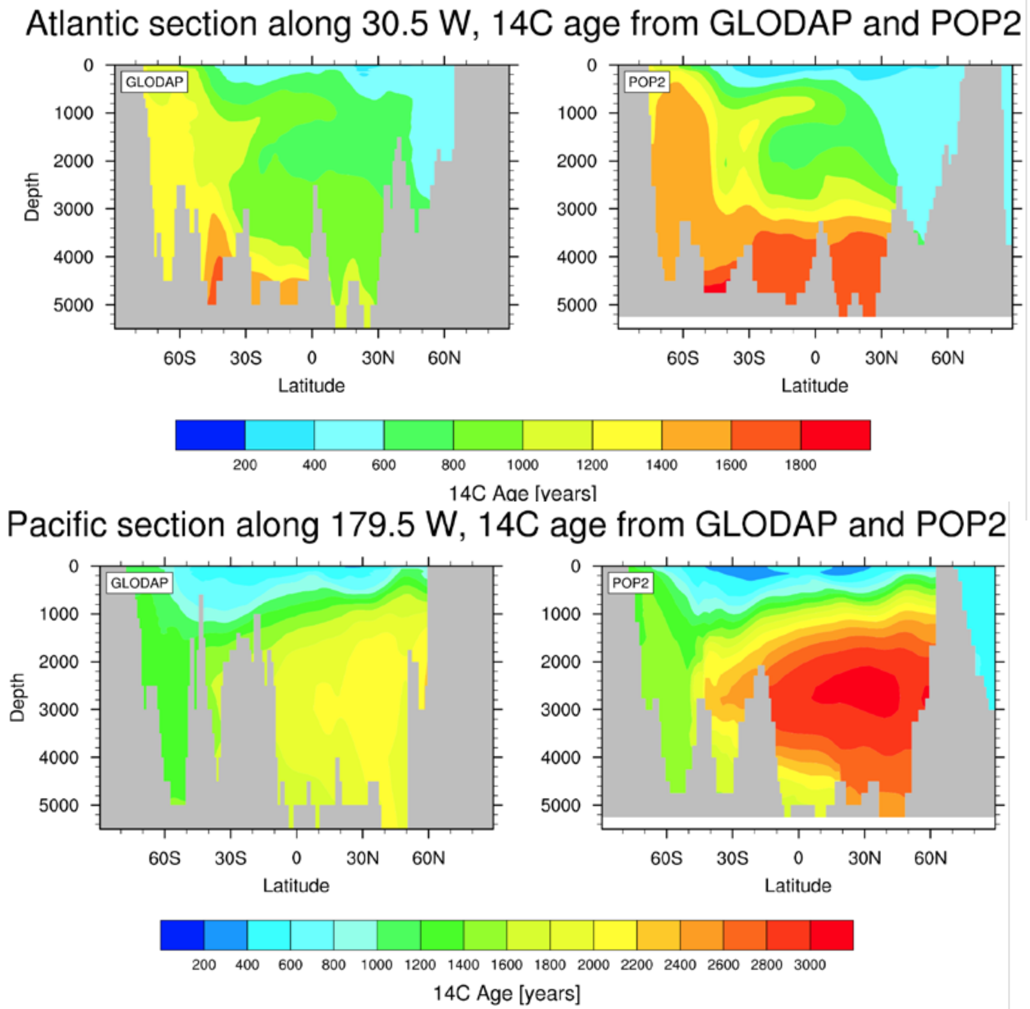
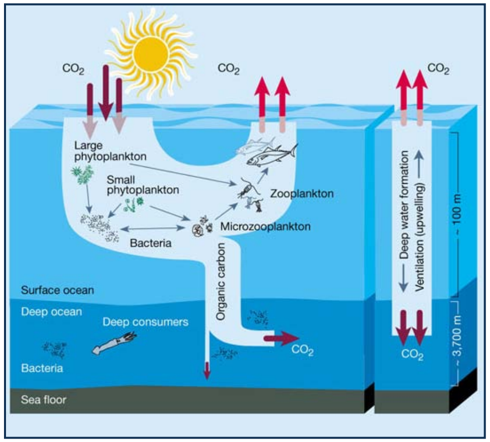


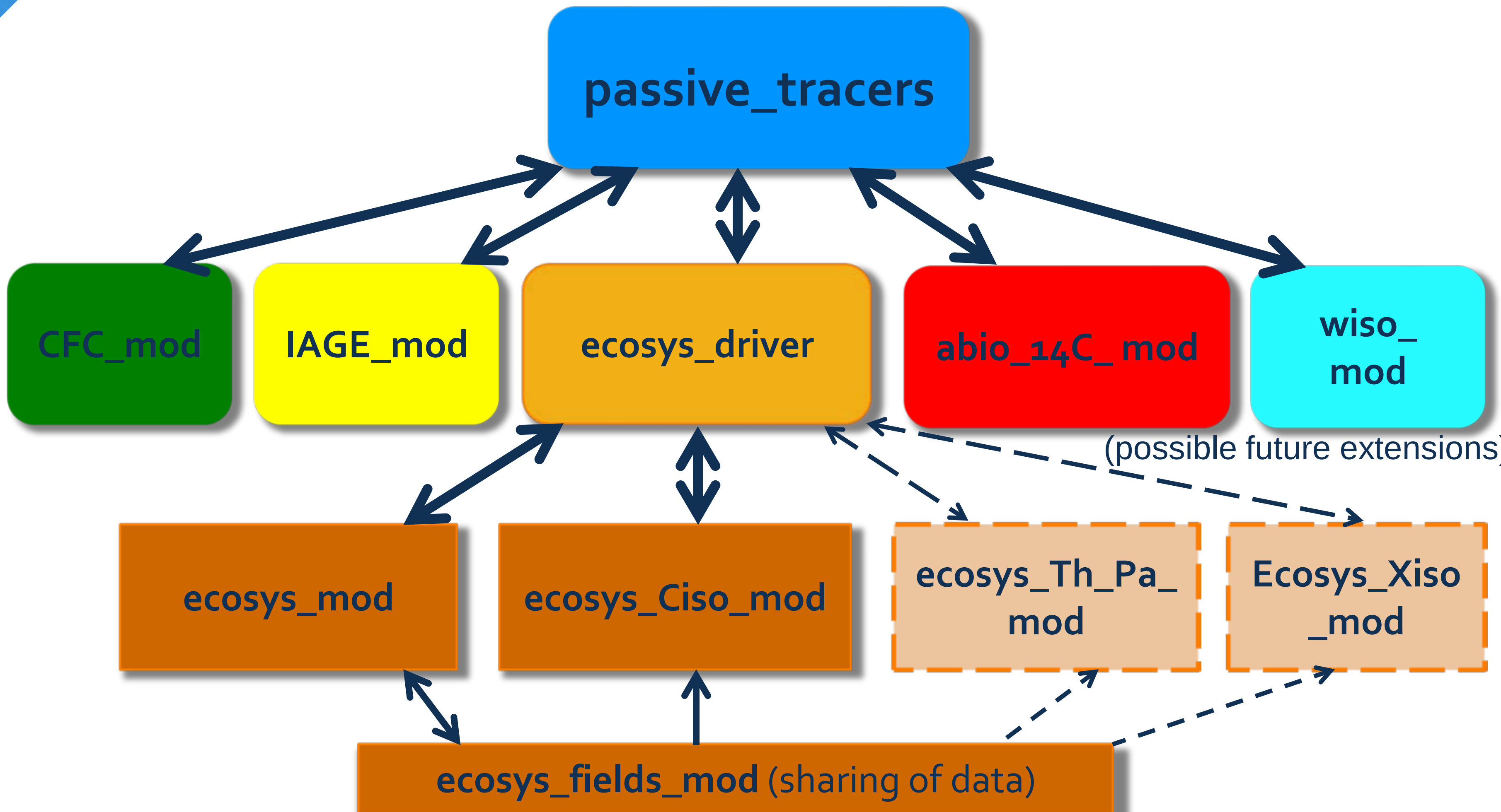
Adding the biological pump

- Currently there are 7 carbon pools in the ecosystem model (DIC, DOC, small phytoplancton, diatoms, diazotrophs, zooplankton, $CaCO_3$)
- Each Carbon isotope adds 7 tracers
  - Currently the ecosystem model has 24 tracers
  - The 14 additional carbon isotopes increases the ocean-model computation cost by:
    - a factor of 1.4 compared to just running the ecosystem model,
    - a factor of 4 compared to just running the ocean-only model without the ecosystem

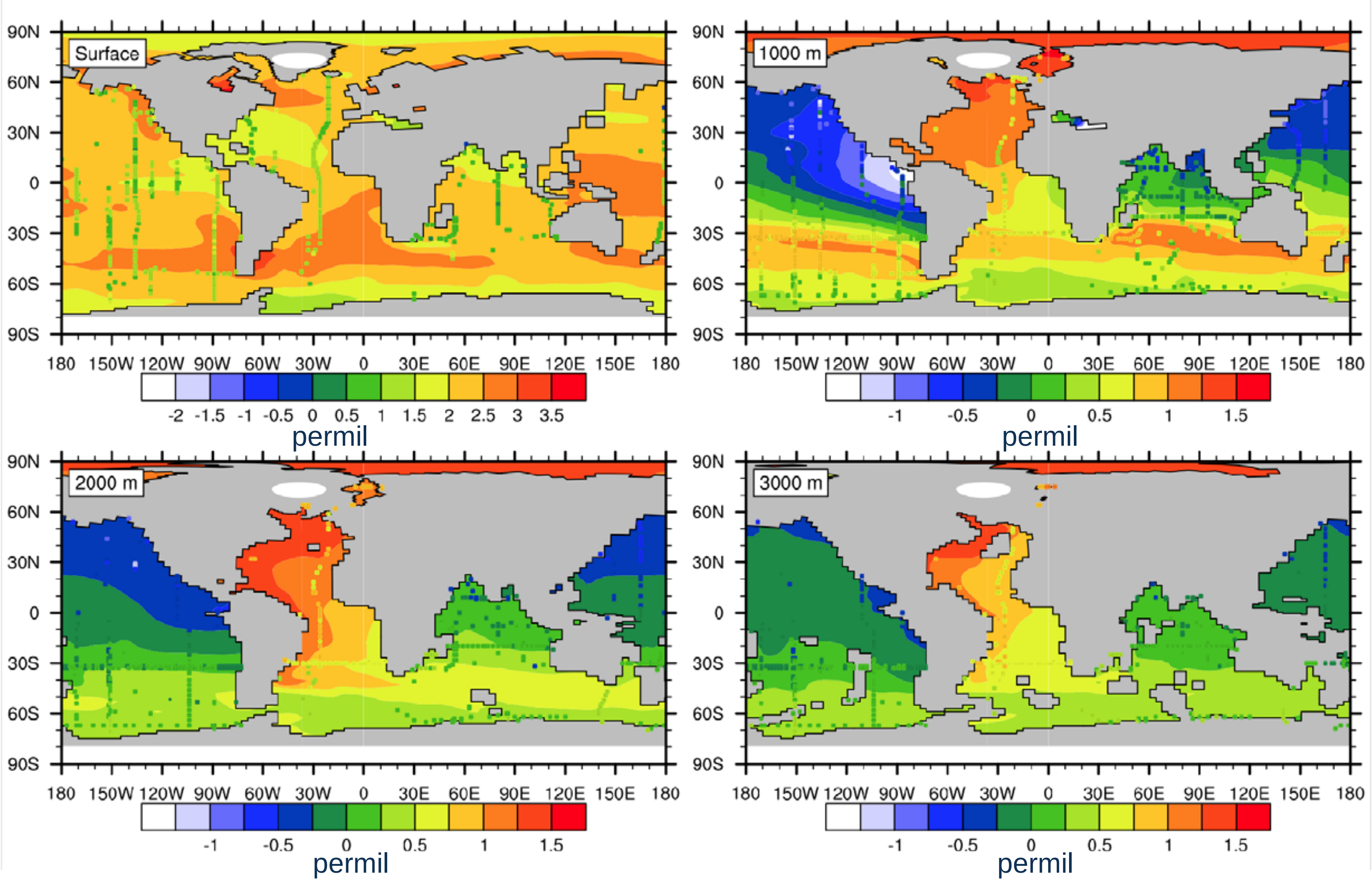


"Complete"
=
Include both biological effects and solubility effects

Adding an ecosystem driver

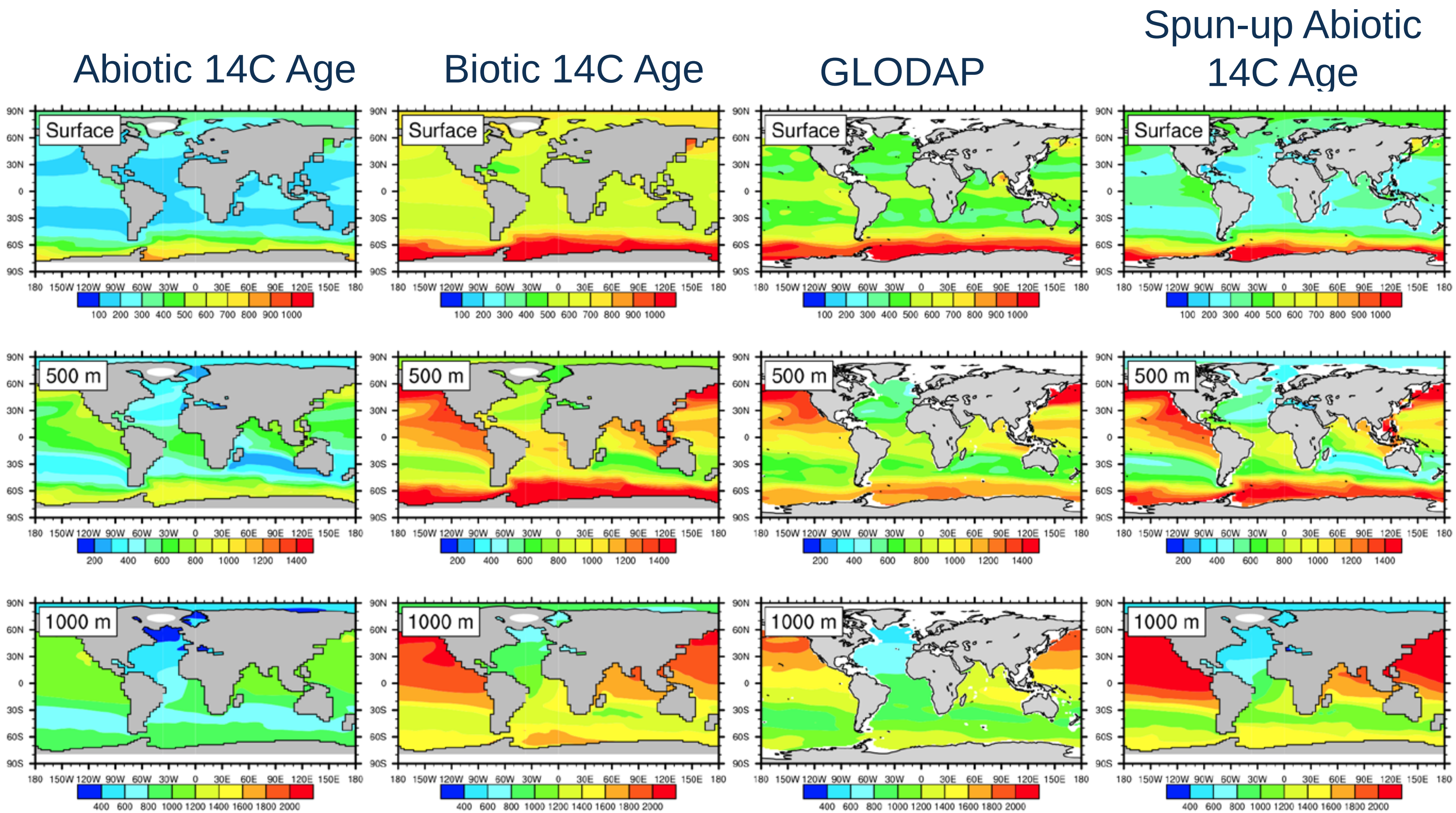


First, very preliminary results from the spin-up of biotic ^{13}C isotope simulation (year 1500)



Model compared to the d13C dataset complied by Schmittner et al (2013)

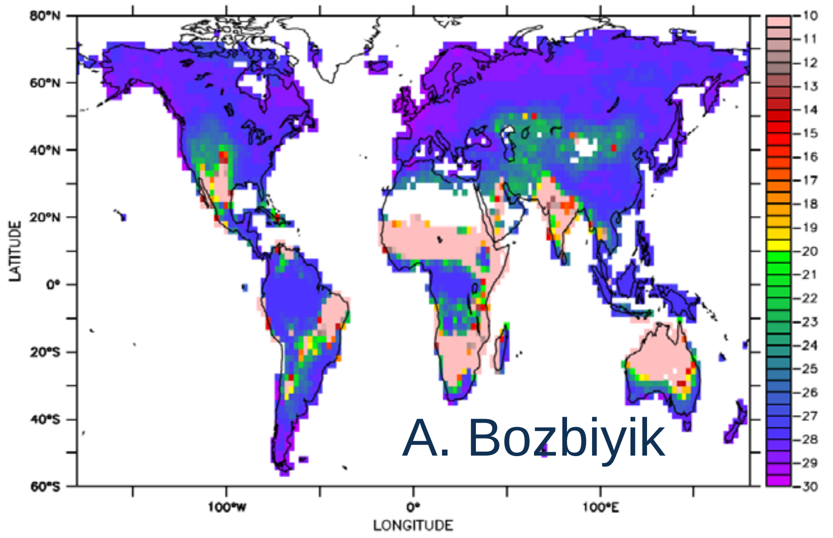
First, very preliminary results from the spin-up of biotic ^{14}C isotope simulation (year 1500)



Update: Carbon isotopes in the land model (CLM4.5)

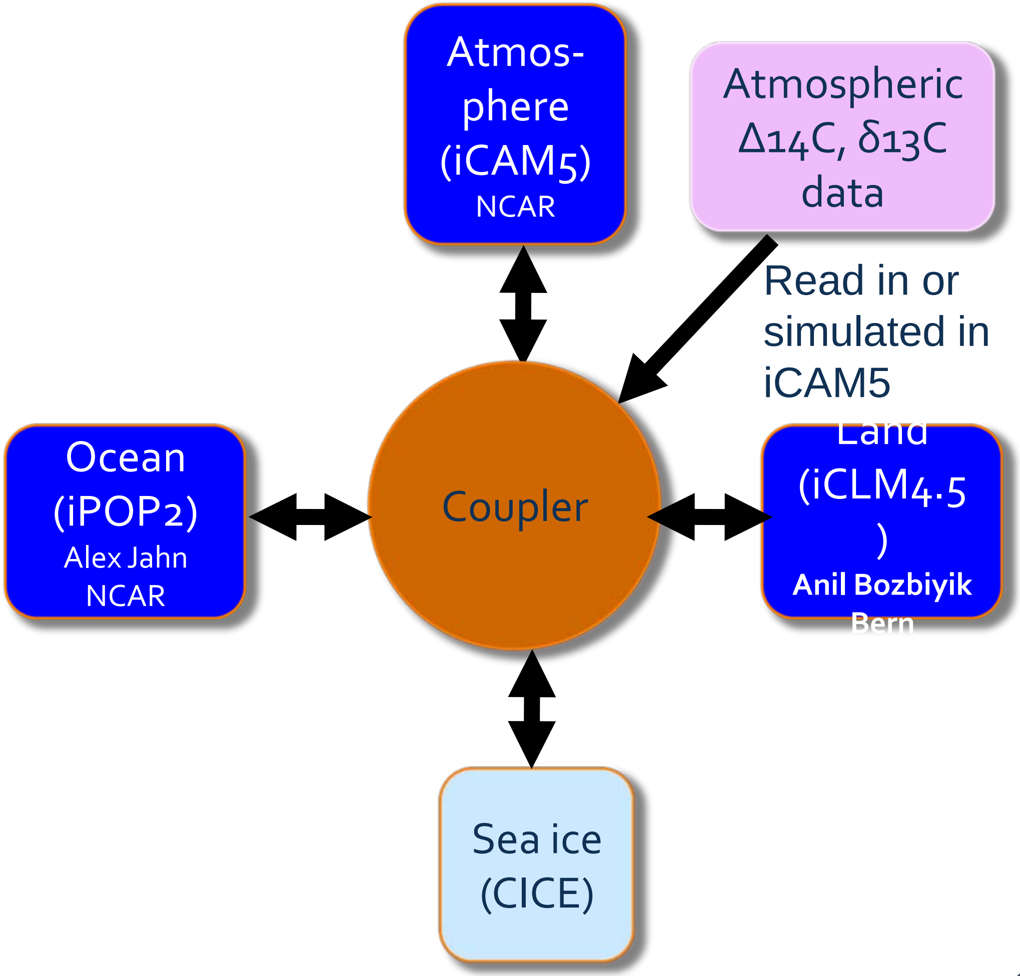
- ^{13}C and ^{14}C tracers have been added to the CLM4.5 land model as fully-prognostic variables
- The CLM4.5 has been spun-up in stand-alone mode for over 7000 years to equilibrium and more testing is under way
- **Developers: A. Bozbiyik**, J. Fortunat (University of Bern), W. Riley, C. Koven (LBNL), D. Lawrence (NCAR)

Global $\delta^{13}C$ of the Total Vegetation



Next steps for the Carbon isotope development in CESM

- Add ^{13}C and ^{14}C isotope tracers to the atmosphere
- Couple the carbon isotope enabled iCAM5, iCLM4.5, and iPOP2 for a coupled carbon isotope simulation
- Consider adding carbon isotopes in CICE?



Future work

- Complete and analyze the biotic POP2 Carbon isotope spin-up simulation
- Spin-up carbon tracers for use in the the 1° coupled CESM (need fast spin-up technique for this)
- Include tracers in paleo simulations
  - Use the coupled carbon isotopes to investigate the Mystery Interval and the LGM
  - Compare simulations to observations, using the new tracers for more direct (but still not "apple to apple") comparisons
  - Investigate how the physical climate parameters from the model (temperature, density, etc) relate to the simulated geochemical tracers
- Add tracers for Protactinium (Pa) and Thorium (Th) to the ecosystem model of the CESM as additional tracer for the strength of the overturning circulation

Thanks!

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