Radiocarbon in the iCESM

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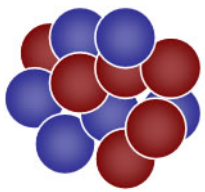
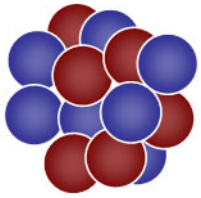
Carbon Isotopes



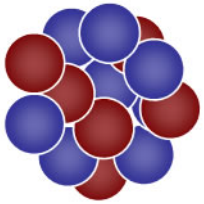
^{12}C

6 protons
6 neutrons
(stable)



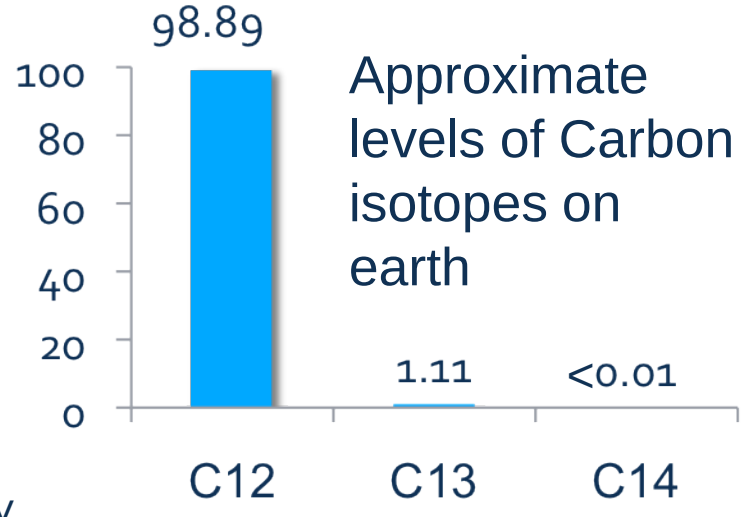
^{13}C

6 protons
7 neutrons
(stable)



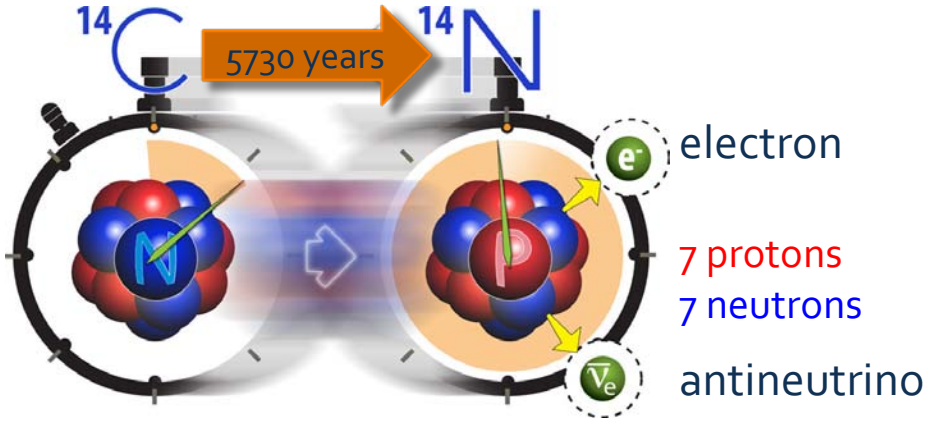
^{14}C

6 protons
8 neutrons
(radioactive)



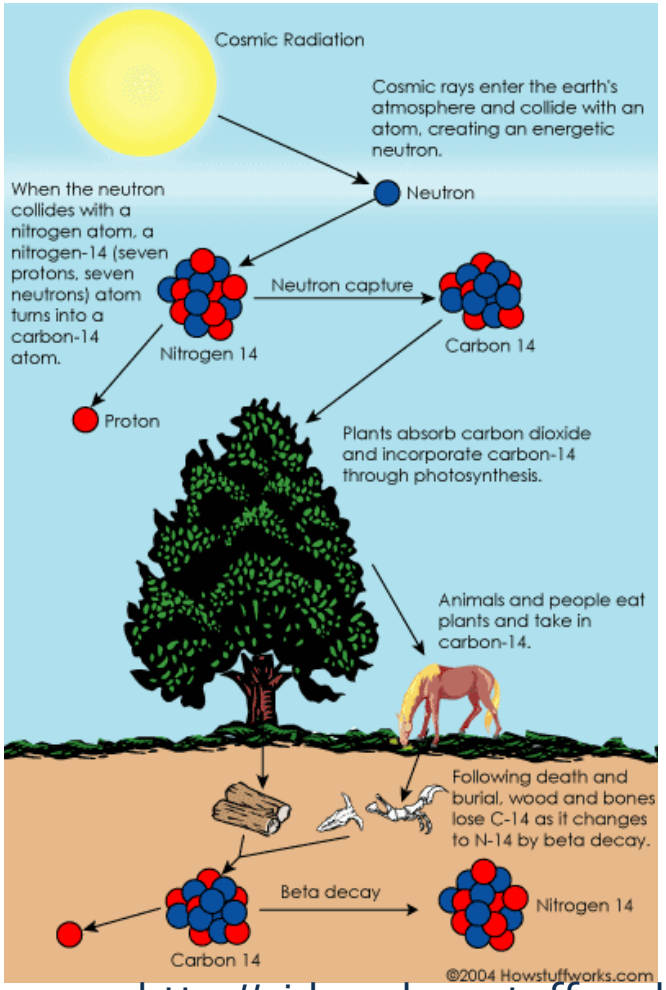
Approximate levels of Carbon isotopes on earth

β-minus decay



6 protons
8 neutrons

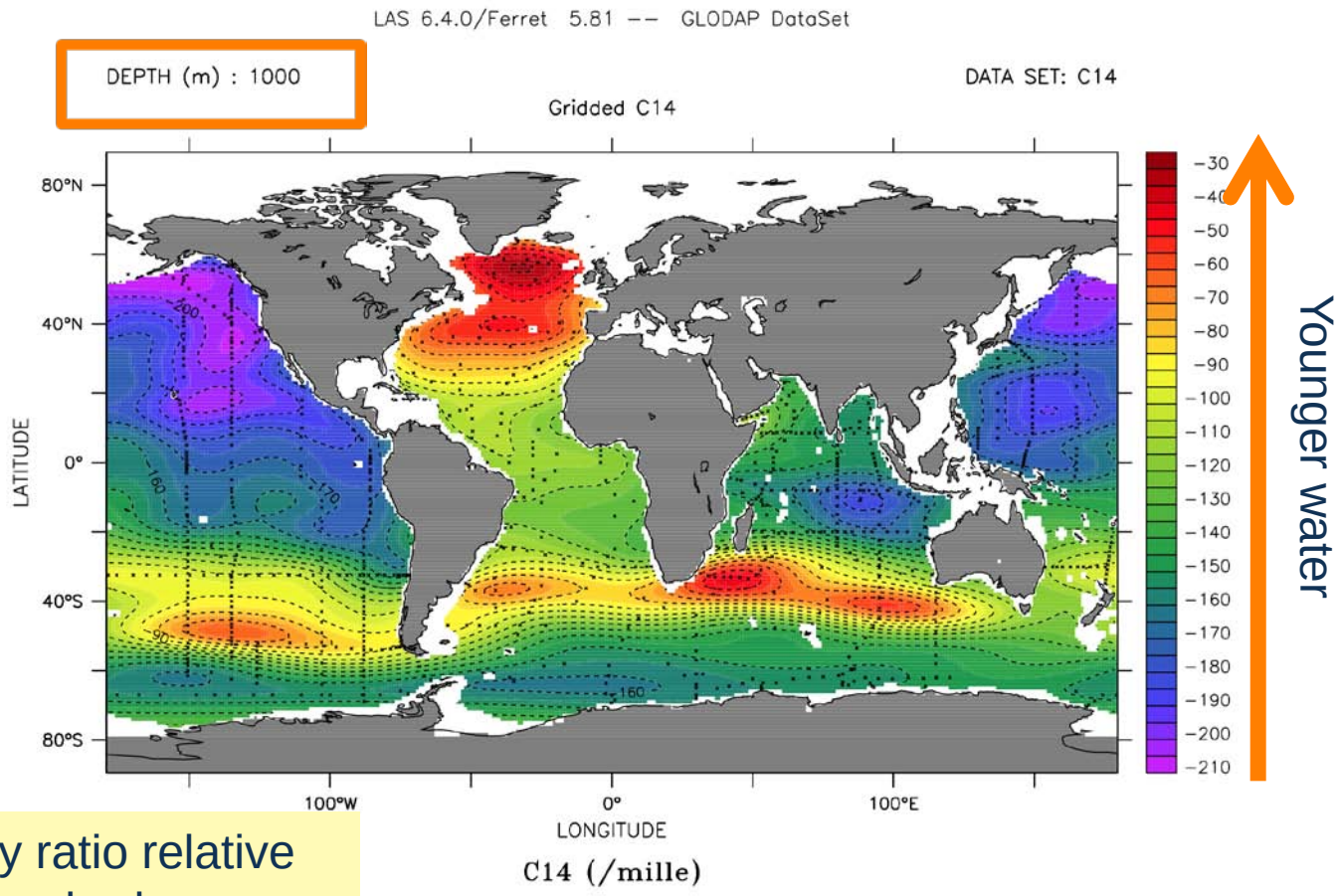
^{14}C creation and use



- ^{14}C is used for carbon dating of fossils
- ^{14}C is used as proxy for the age of water masses and to infer past and present ocean ventilation rates

Source: http://videos.howstuffworks.com

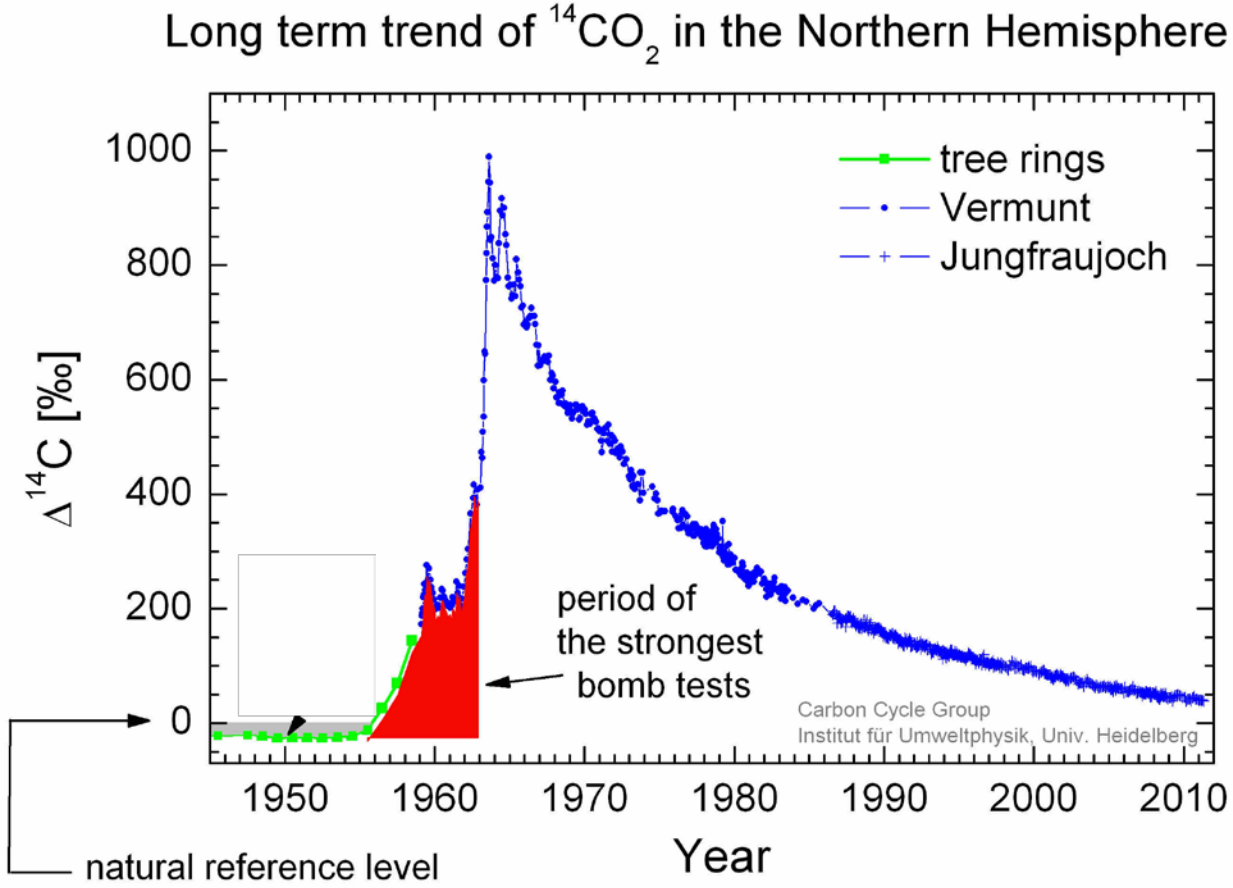
$\Delta^{14}C$ as ocean tracer for ventilation



$\Delta^{14}C$ = Activity ratio relative to a standard

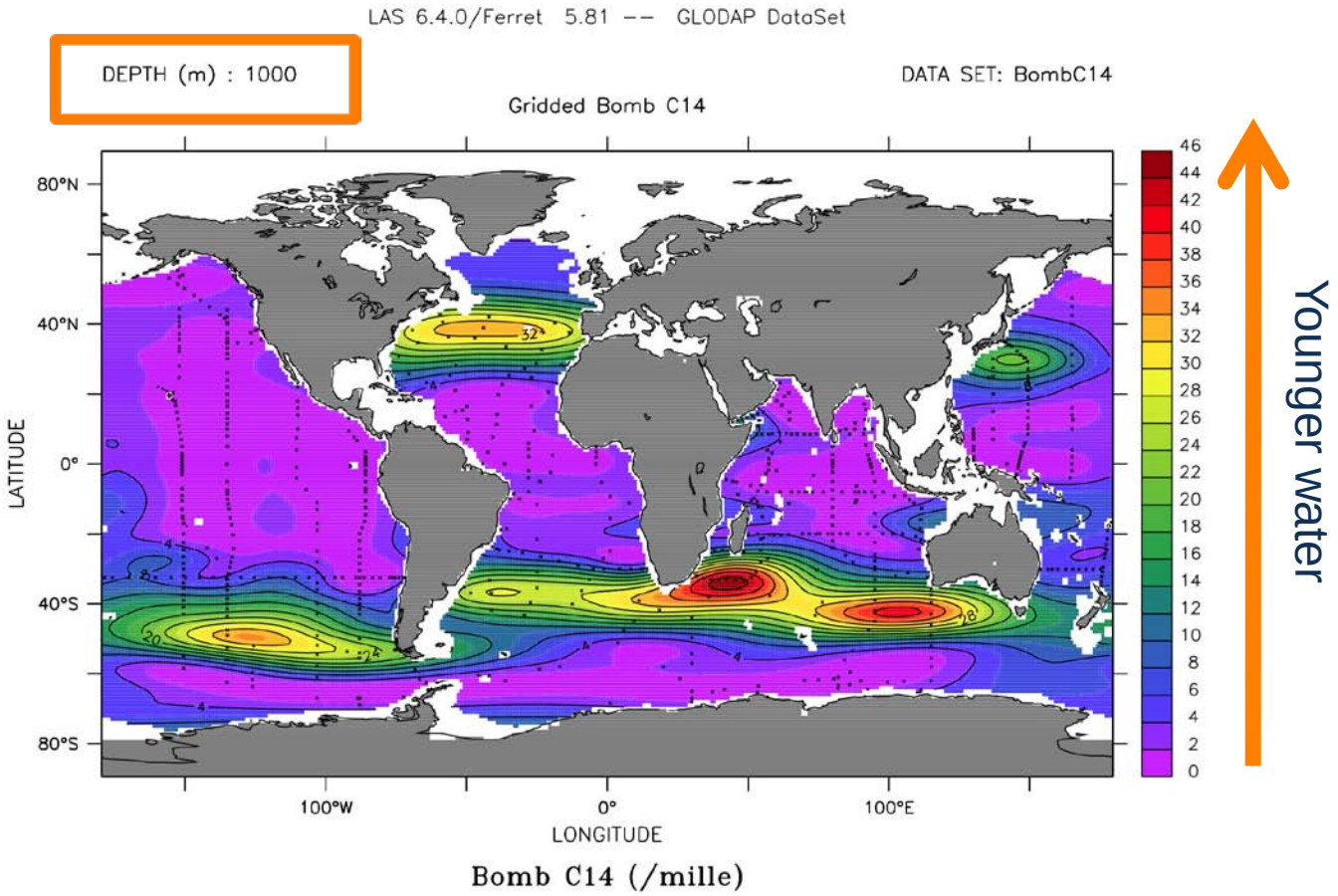
Source: GLODAP, http://cdiac3.ornl.gov/las/servlets/dataset?catitem=97

Atmospheric $\Delta^{14}C$ measurements



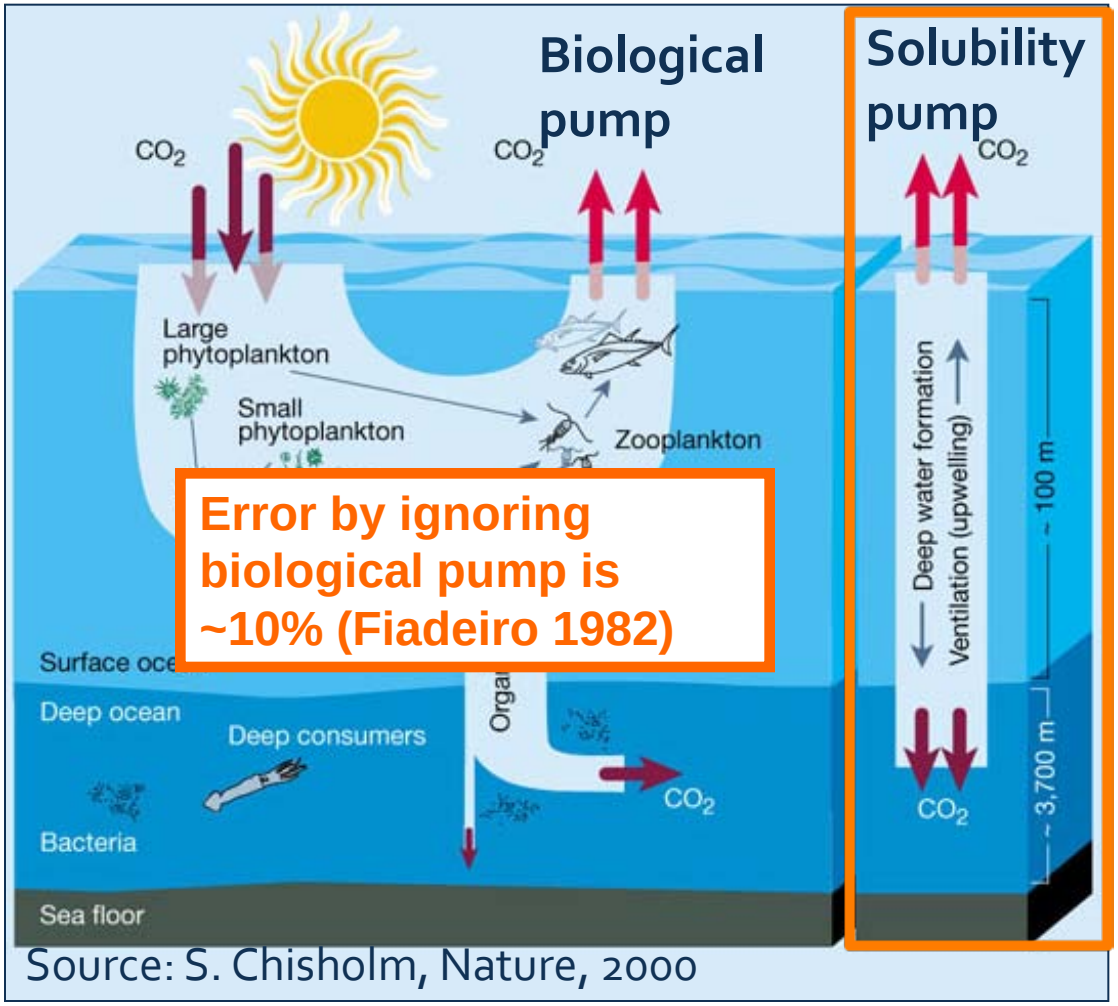
Source: http://www.iup.uni-heidelberg.de/institut/forschung/groups/kk/en/14CO2_html

Bomb $\Delta^{14}C$ as ocean tracer



Source: GLODAP, http://cdiac3.ornl.gov/las/servlets/dataset?catitem=97

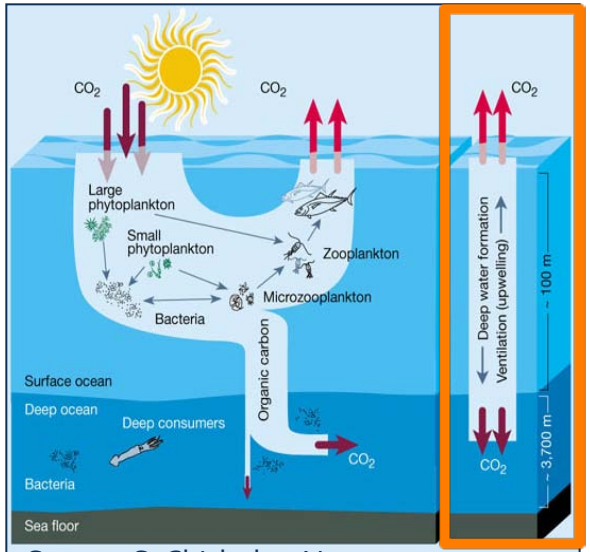
How do we get $\Delta^{14}C$ into the ocean model?



Source: S. Chisholm, Nature, 2000

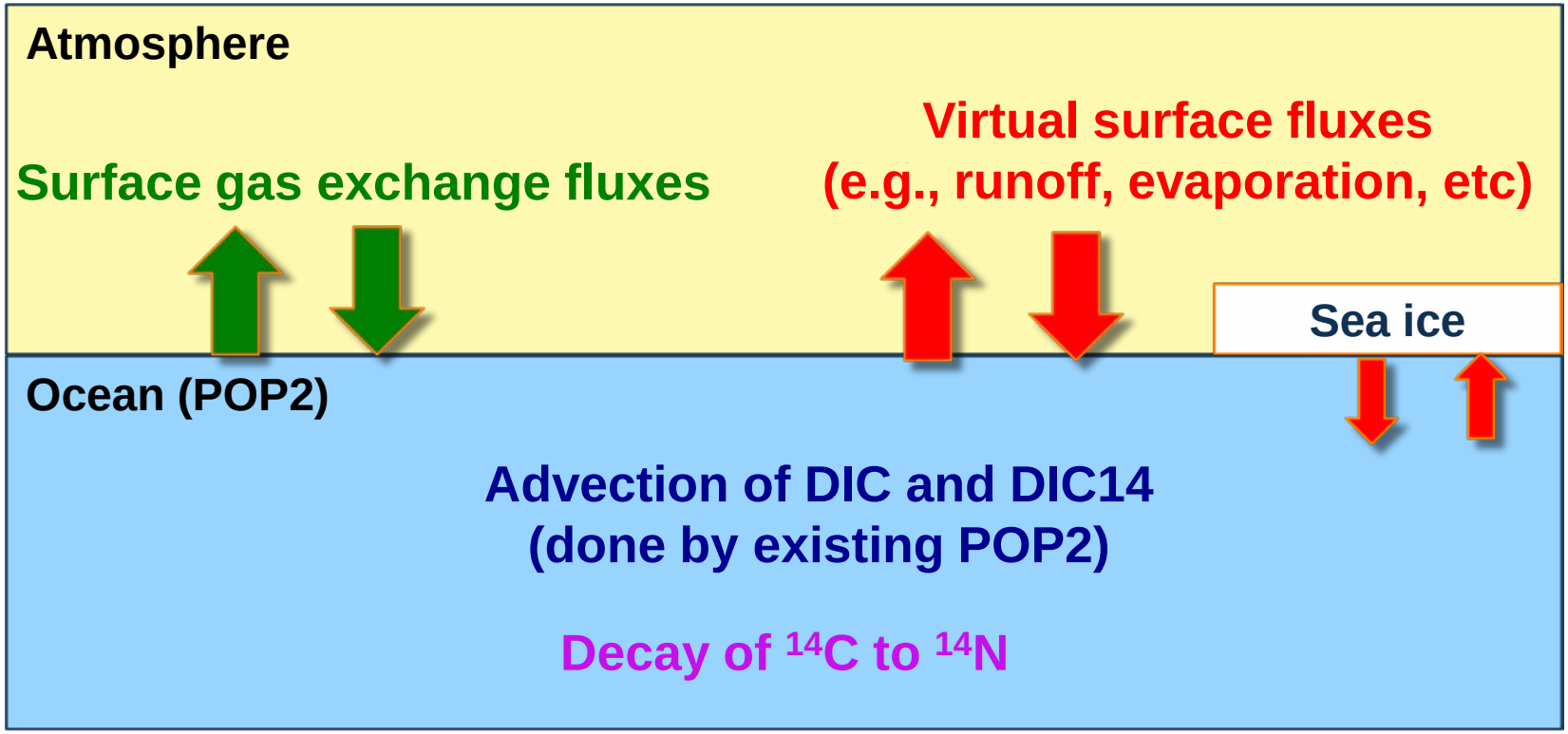
How do we get $\Delta^{14}C$ into the ocean model?

- Follow the OCMIP-2 (**Ocean Carbon-Cycle Model Intercomparison Project Phase 2 (1998-2000)** abiotic protocol to implement abiotic DIC and DIC14: http://ocmip5.ipsl.jussieu.fr/OCMIP/phase2/simulations/Abiotic/HOWTO-Abiotic.html



Source: S. Chisholm, Nature, 2000

What does the oceanic abiotic DIC & DIC14 tracer module need to do?



D [DIC]/dt = L ([DIC]) + Jv + J

D [DIC14]/dt = L ([DIC14]) + Jv14 + J14 – Lambda * [DIC14]

Implementation in the POP2 model

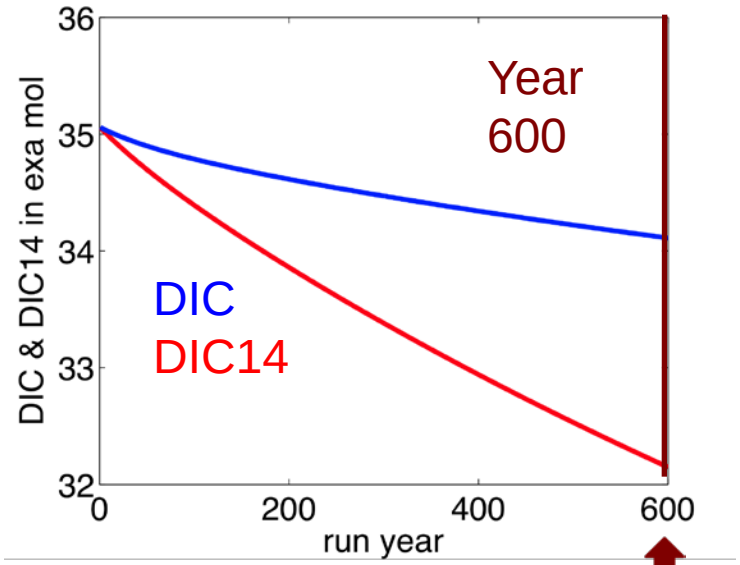
- Added abiotic DIC and DIC14 as a separate tracer module (similar to CFC11, CFC12, and IAGE), following OCMIP-2
  - ABIO_DIC and ABIO_DIC14 were added as tracers in nmol/cm3, $\Delta^{14}C$= (DIC14/DIC -1) *1000 is written out as diagnostic
- Some changes compared to the OCMIP-2 protocol:
  - We will use model-generated ice concentration and windspeed to calculate the Piston velocity
  - We use a constant global reference value for the virtual fluxes in order to conserve tracers (instead of annually varying reference values as proposed by OCMIP-2)
  - We use a different relationship for Alkalinity for the Baltic and Blacks Seas so that it works with the initial DIC conditions we use

Some very preliminary first results

- Initialized from DIC initial conditions constructed from GLODAP
- Run with Compset C (normal year forcing, ocean only model), ocean resolution x3
- Run for 600 years so far → **this is far from equilibrium**, which is expected around 10,000 -15,000 years (OCMIP-2)

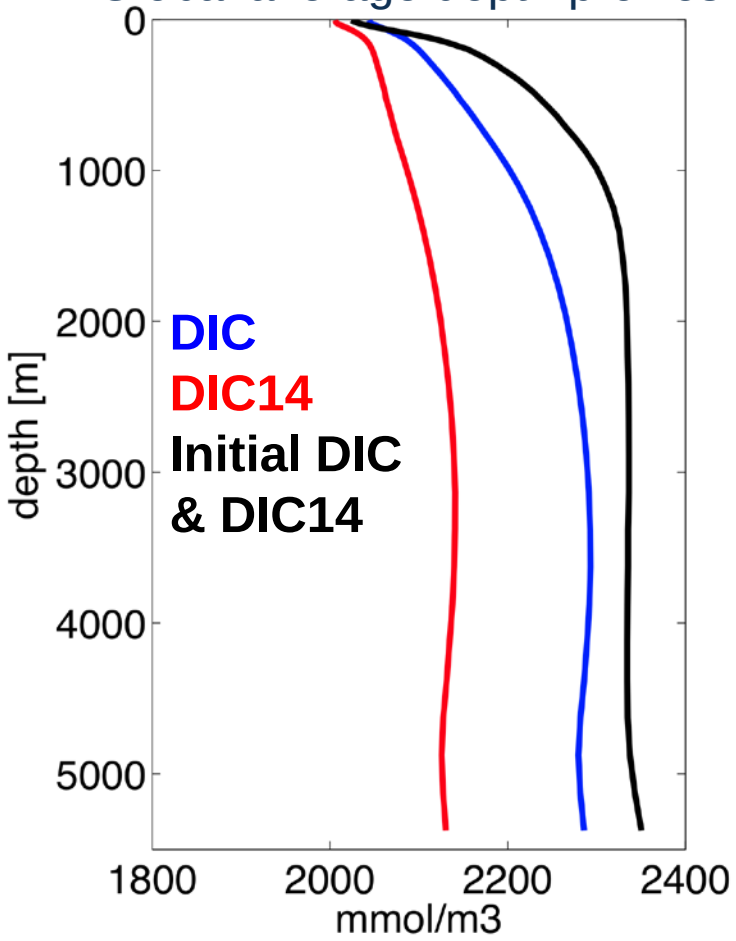
Some very preliminary first results

Total oceanic DIC and DIC14



Far from equilibrium!

Global average depth profiles

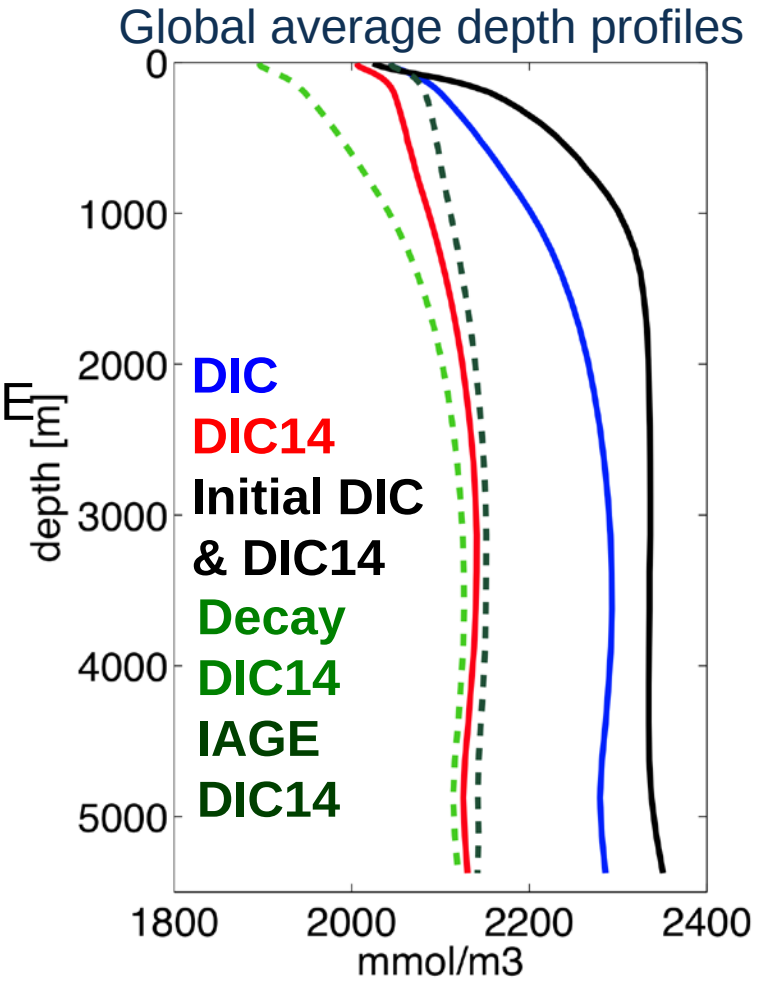


Some very preliminary first results

Theoretical DIC14:
Lambda is the C14 decay constant
lambda= ln(2)/5730 year = $1.2097e^{-4}$ yr^{-1}

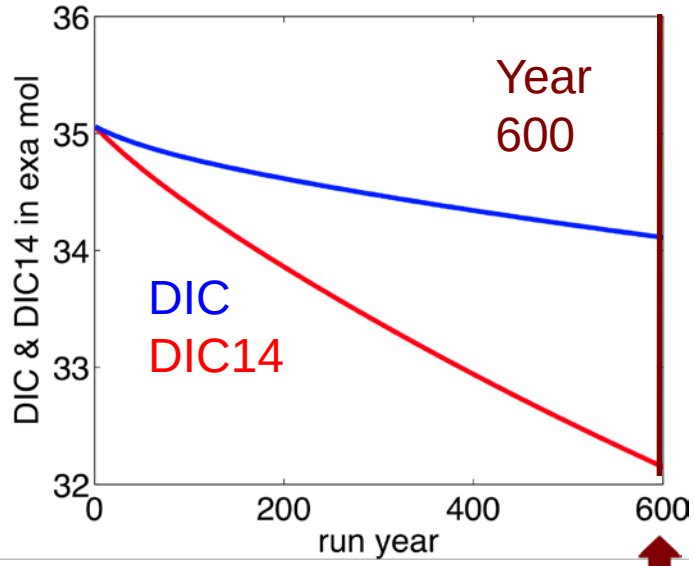
Decay DIC14 = DIC – DIC * lambda * yr
IAGE DIC14 = DIC – DIC * lambda * IAGE

At depth:
DIC14 is close to Decay DIC14 & IAGE DIC14
At the surface:
IAGE DIC14 > DIC14 > Decay DIC14
➡ caused by ventilation and surface equilibration



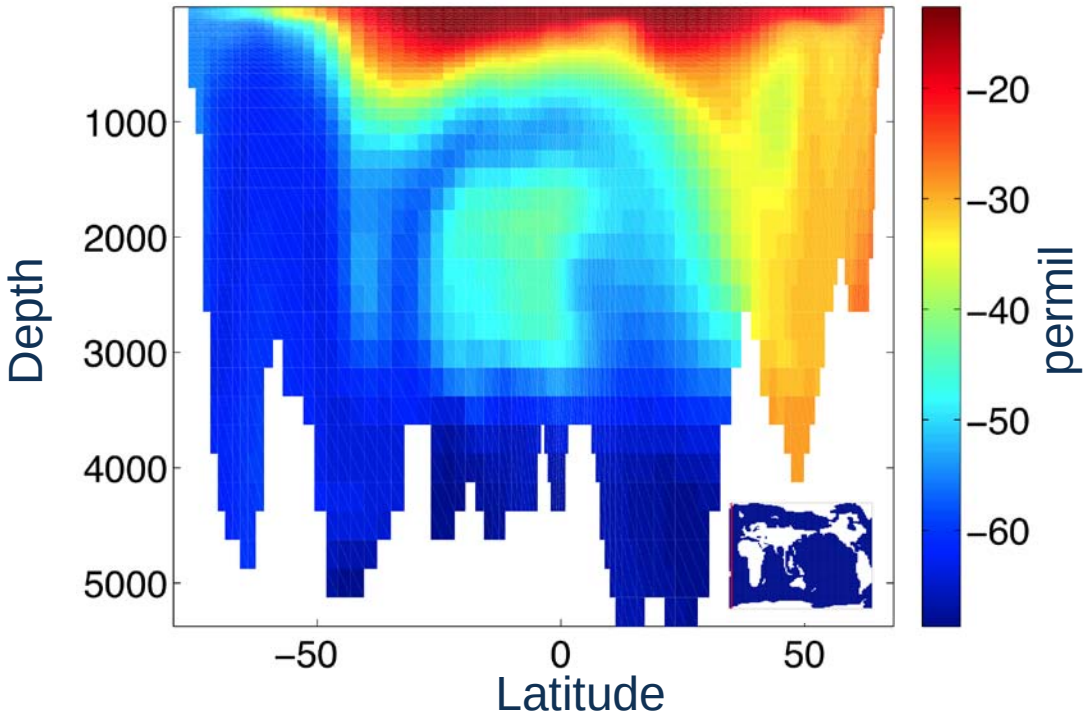
Some very preliminary first results

Total oceanic DIC and DIC14



Far from equilibrium!

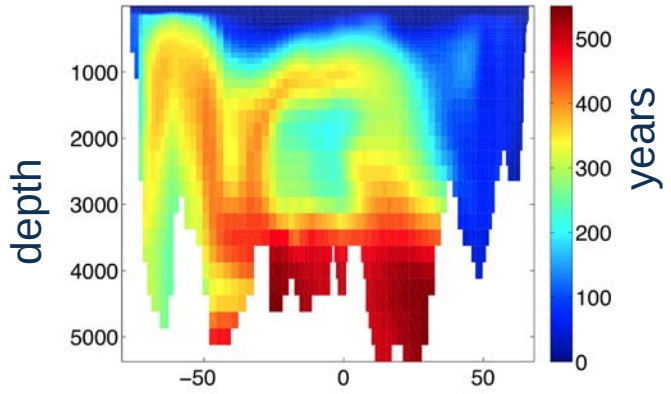
$\Delta^{14}C$ in the Atlantic at year 600



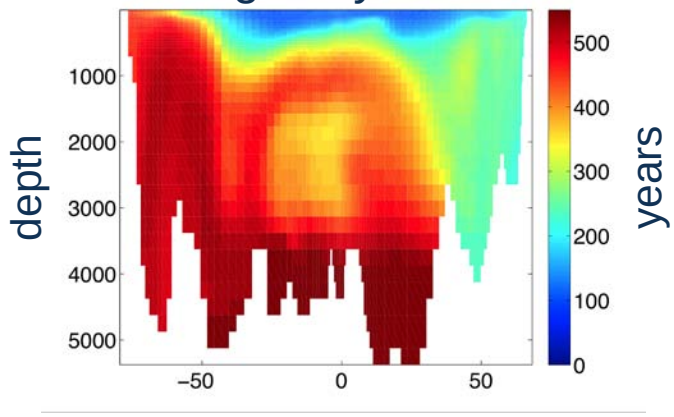
$\Delta^{14}C = (DIC14/DIC - 1) * 1000$

Some very preliminary first results

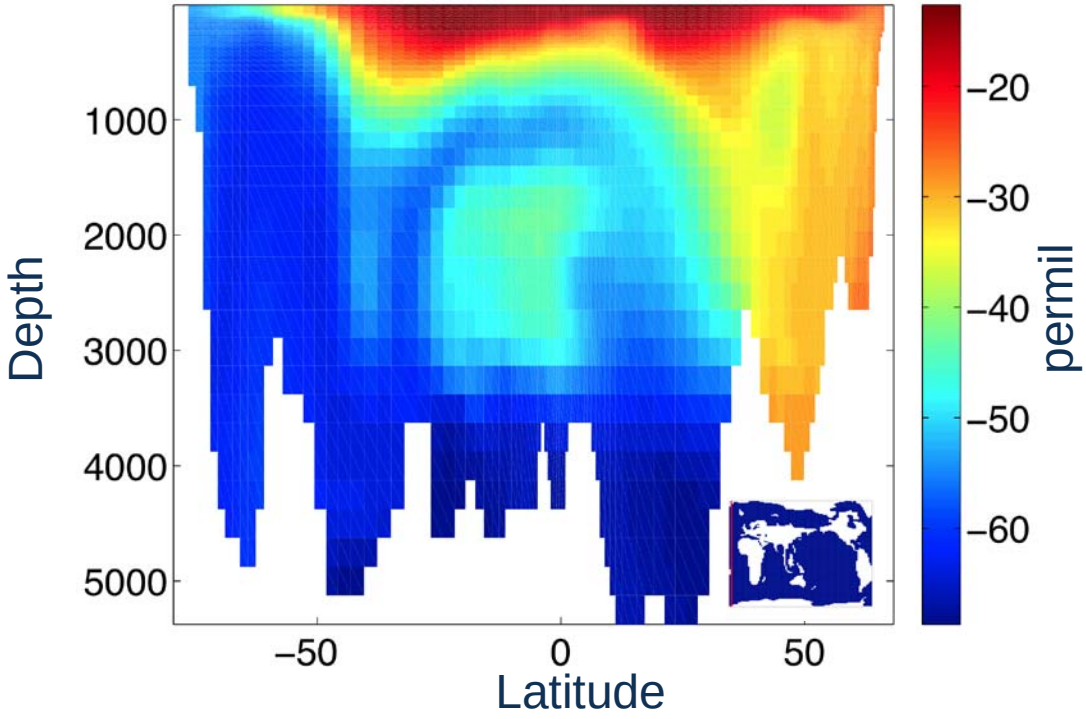
Ideal age at year 600



C^{14} age at year 600



$\Delta^{14}C$ in the Atlantic at year 600



C^{14} age = -8033 ln (1 + $\Delta^{14}C$/1000)

Future work

- Spin-up the abiotic DIC14 (probably around 15,000 years)

  → Anyone have any ideas on better initial conditions or the spin-up?

- Carry out the 1870-2000 nuclear bomb-^{14}C simulations from OCMIP-2 and compare results with published OCMIP-2 studies

- Incorporate Radiocarbon as standard tracer in the CESM-POP2

- Add a δ13 C as a tracer in the ecosystem module of the CESM (following the implementation by N. Gruber et al., (ETH) in POP1)

- Add tracers for Protactinium (Pa) and Thorium (Th) to the ecosystem model of the CESM

Thanks!

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