Ideal age and water isotopes in POP2

Jiaxu Zhang¹, Esther Brady², Keith Lindsay²
Zhengyu Liu¹, Bette Otto-Bliesner²

¹ University of Wisconsin-Madison
² National Center for Atmospheric Research
Outline

• Model description
• Ideal age (IAGE) vs. ventilation age (VAGE)
• Water isotopes in POP2
  – Observational data
  – Restoring surface boundary condition
  – Prec+Evap+Roff+Virtual flux forcing
• Summary and future plan
1. Model description

• CESM 1.0 released version 7
• Compset = C_NORMAL_YEAR, ocean-alone (POP2) forced by data atmosphere
• Resolution = gx3v7
• Revised source codes: passive tracers
2. IAGE vs. VAGE

Radiocarbon $^{14}$C

half life = 5730 yr

- Ideal age (IAGE) also plays as a clock in the water.
- Initialized as zero everywhere
- Set to zero at the ocean surface

[Diagram of radiocarbon cycle and ocean levels]
Ventilation age (VAGE)

\[ VAGE_{new} = VAGE_{old} \ast IFRAC^{\frac{\Delta t}{T}} \]

\[ T = \frac{L^2}{\nu} \]

- \( \Delta t \) – integration time step
- \( T \) – mixing time scale
- \( L \) – grid horizontal length scale
- \( \nu \) – mixing coefficient (4*10^3 m^2/s, globally constant)
- After \( N = \frac{T}{\Delta t} \) steps,

\[ VAGE_{new} = VAGE_{old} \ast IFRAC \]
2. IAGE vs. VAGE

- Water that sink under open ocean has the same age.
- Water that sink under sea ice has older VAGE, compared with IAGE.
- Both IAGE and VAGE will be available in the future released versions.
3. Water isotopes in POP2

- Major water isotopes: $H_2^{16}O$, $H_2^{18}O$ and HDO

$$
\delta^{18}O = \left[ \frac{(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{VSMOW}}{(^{18}O/^{16}O)_{VSMOW}} \right] \times 1000 \%_0
$$

- Fractionation occurs when evaporation and condensation happens.
- CAM tracks specific humidity for each water type.
- POP is a volume-conserved ocean model.
- $\delta^{18}O$ and $\delta D$ are tracked as passive tracers in ocean interior (no interaction with the ecosystem)
3.1. Water isotopes in POP2: Observational data

- GISS Global Seawater Oxygen-18 Database
- A collection of over 26,000 seawater O-18 values made since about 1950
- 3D gridded data, 33 Levitus levels, at 1°x1° resolution

3.2. Water isotopes: Restoring BC

- To test the interior dynamics: Restoring surface boundary condition (Paul et al. 1999).

\[ F_{\delta_w} = \frac{H}{\tau} \left( \delta_{w}^{*} - \delta_{w} \right) \]

- \( \tau \) – relaxation time scale (= 30 d)
- \( H \) – upper ocean depth (1\textsuperscript{st} layer)
- \( \delta_{w}^{*} \) – prescribed delta values
- Initial values = 0, run for 200 yr
3.2. Water isotopes: Restoring BC
3.3. Water isotopes: PER flux forcing

- $\delta^{18}O$ flux to the ocean surface (Delaygue et al. 2000)

$$F_{\delta} = E(\delta_W - \delta_E) - P(\delta_W - \delta_P) - R(\delta_W - \delta_R)$$

$$= (E - P - R)\delta_W - (E\delta_E - P\delta_P - R\delta_R)$$

- Unit: per mil $\times$ cm/s
- Negative flux = losing heavy water/gaining light water

Virtual Flux
3.3. Water isotopes: PER flux forcing

- $P\delta_P$ : isoCAM3 preindustrial monthly-mean climatology
- $R\delta_R$ : ROFF_F $\times \delta_P$
3.3. Water isotopes: PER flux forcing

\[
\delta_E = \frac{1 - K}{1 - h} \left[ \alpha_{WV} (\delta_W + 10^3) - h(\delta_A + 10^3) \right] - 10^3
\]

- Schmidt et al. (1999)
- \( K = 0.006 \) is the kinetic fractionation parameter
- \( \alpha_{WV} = f(TS) \) water to vapor fractionation factor
- \( h \) – near-surface relative humidity (isoCAM)
  (where \( h > 0.8, h = 0.8 \))
- \( \delta_A \) – delta value of marine air (isoCAM)
  (where \( \delta_A < -16, \delta_A = -16 \))
3.3. Water isotopes: PER flux forcing

POP2, dynamic $E^*\delta_E$, Year 5

POP2, dynamic $E^*\delta_E$, Year 200

isoCAM3 $E^*\delta_E$ ann climatology
3.3. Water isotopes: PER flux forcing
3.3. Water isotopes: PER flux forcing

POP2 simulation
Year 200

GISS Observations
3.3. Water isotopes: PER flux forcing

POP d18O at 0200yr (P+E+R+Virt)

Along 26°W (Atlantic)

Along 180° (Pacific)

POP d18O at 200yr (Restoring surf. bound. cond.)

Along 26°W (Atlantic)

Along 180° (Pacific)
4. Summary and future plan

• VAGE will be a new variable along with IAGE.
• Water isotopes: restoring boundary condition => realistic interior dynamics
• P+E+R+V flux forcing
• Future plan
  1) To add melt water flux
  2) To add HDO, using the same method
  3) Ready to couple with other components -> to move the evp flux computation into coupler
  4) Paleoclimate applications (e.g. LGM, north/south source water)