Ideal age and water isotopes in POP2

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Outline

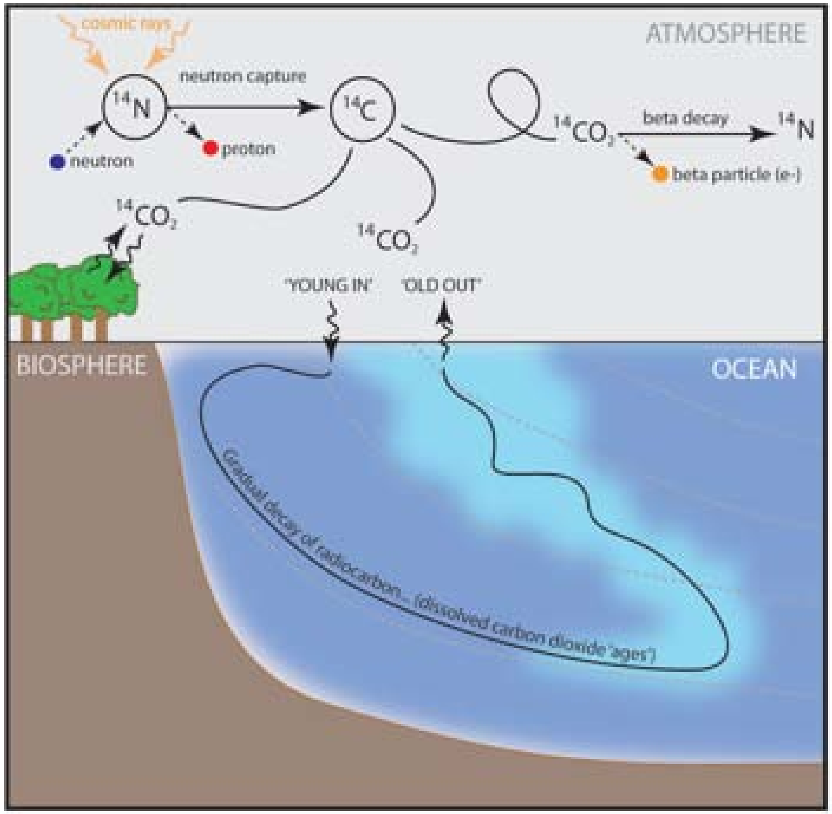
- Model description
- Ideal age (IAGE) vs. ventilation age (VAGE)
- Water isotopes in POP2
  - Observational data
  - Restoring surface boundary condition
  - Prec+Evap+Roff+Virtual flux forcing
- Summary and future plan

1. Model description

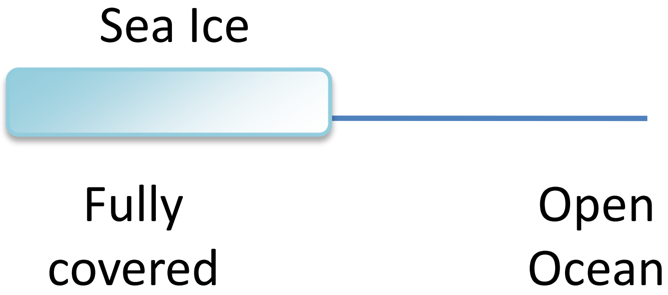
- CESM 1.0 released version 7
- Compset = C_NORMAL_YEAR, ocean-alone (POP2) forced by data atmosphere
- Resolution = gx3v7
- Revised source codes: passive tracers

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

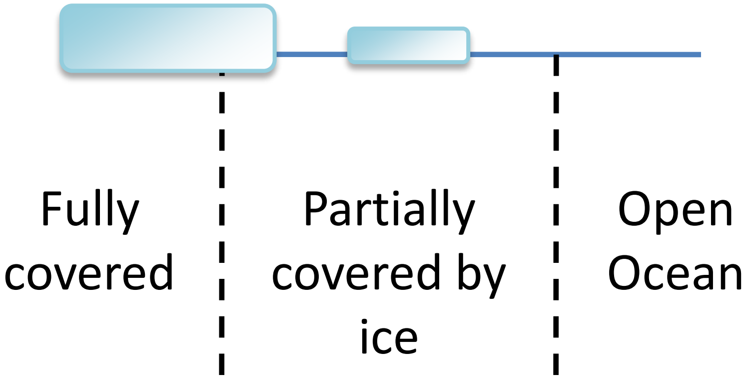


2. IAGE vs. VAGE

Ventilation age (VAGE)

$$VAGE_{new} = VAGE_{old} * IFRAC^{\frac{\Delta t}{T}}$$

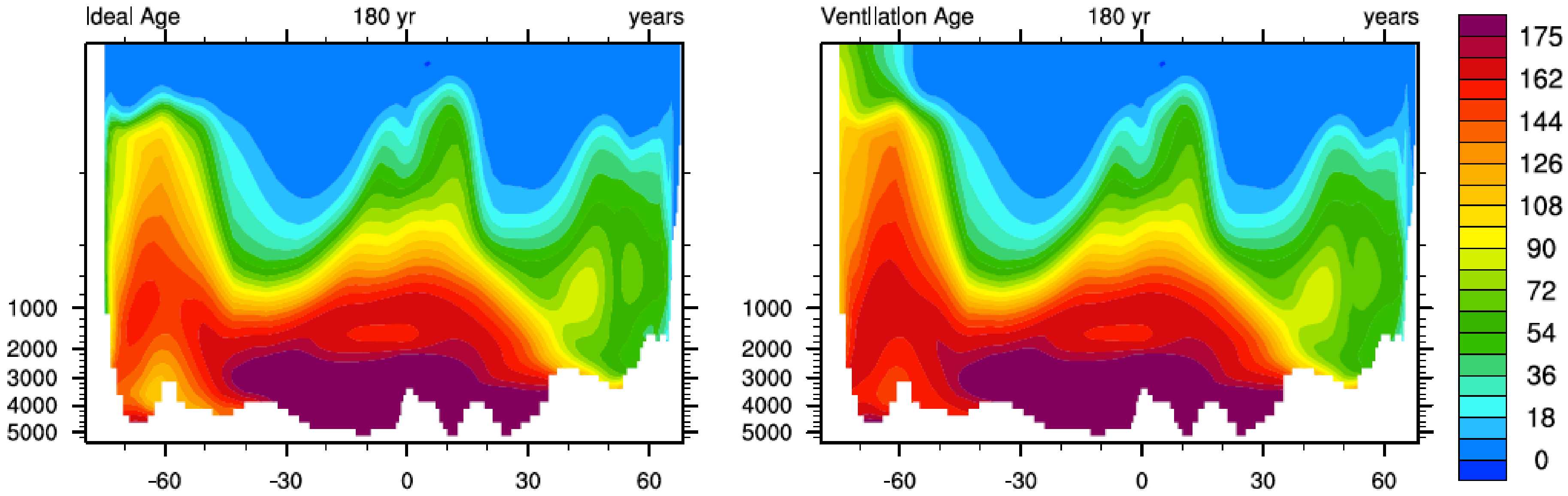
$$T = \frac{L^2}{\nu}$$



- Δt – integration time step
- T – mixing time scale
- L – grid horizontal length scale
- ν – mixing coefficient (4*10^3 m^2/s, globally constant)
- After N = T/Δt steps,

$$VAGE_{new} = VAGE_{old} * IFRAC$$

2. IAGE vs. VAGE



Annual mean IAGE vs. VAGE, along 26˚W (Atlantic)

- 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.

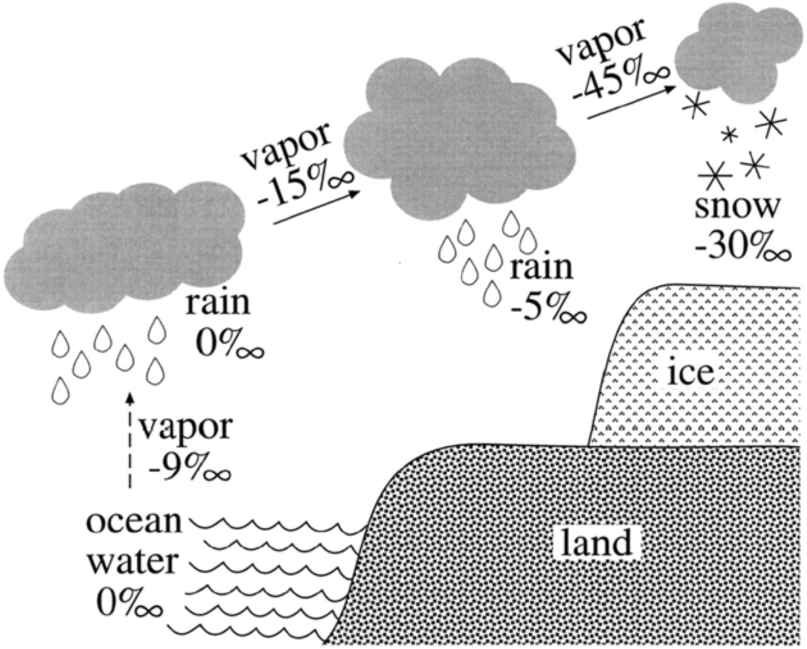
3. Water isotopes in POP2

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

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

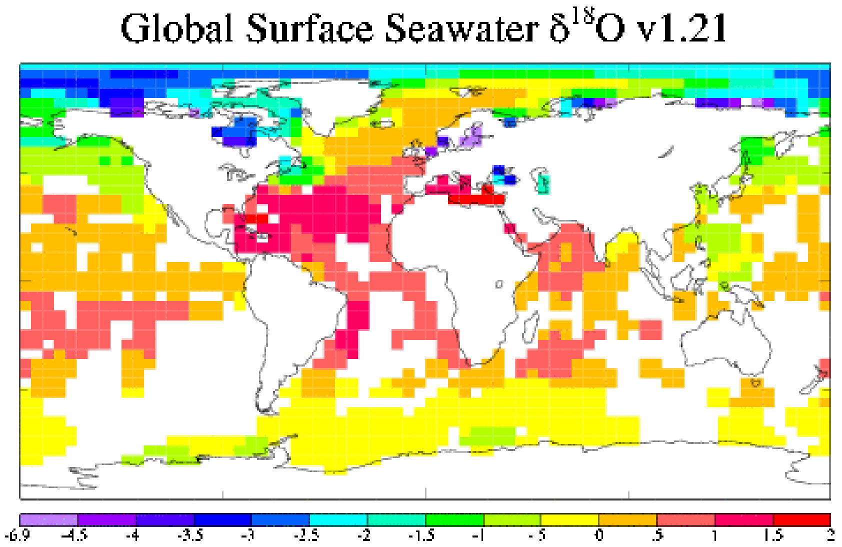
$H_2{}^{18}O$ depleted $\xleftarrow{-}$ $\delta^{18}O$ $\xrightarrow{+}$ $H_2{}^{18}O$ enriched

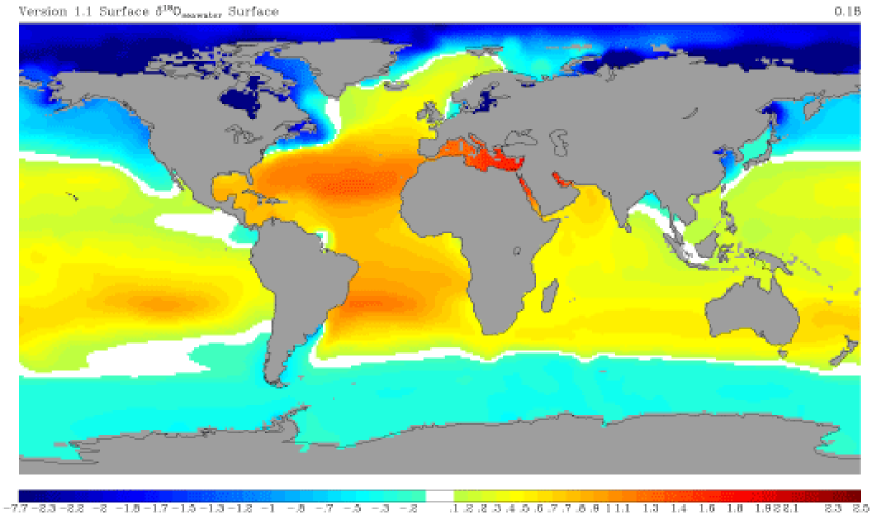
- Fractionation occurs when evaporation and condensation happens.
- CAM tracks specific humidity for each water type.
- POP is a volume-conserved ocean model.
- $\delta^{18}O$ and δD are tracked as passive tracers in ocean interior (no interaction with the ecosystem)



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





Schmidt, G.A., G. R. Bigg and E. J. Rohling. 1999. "Global Seawater Oxygen-18 Database - v1.21" http://data.giss.nasa.gov/o18data/

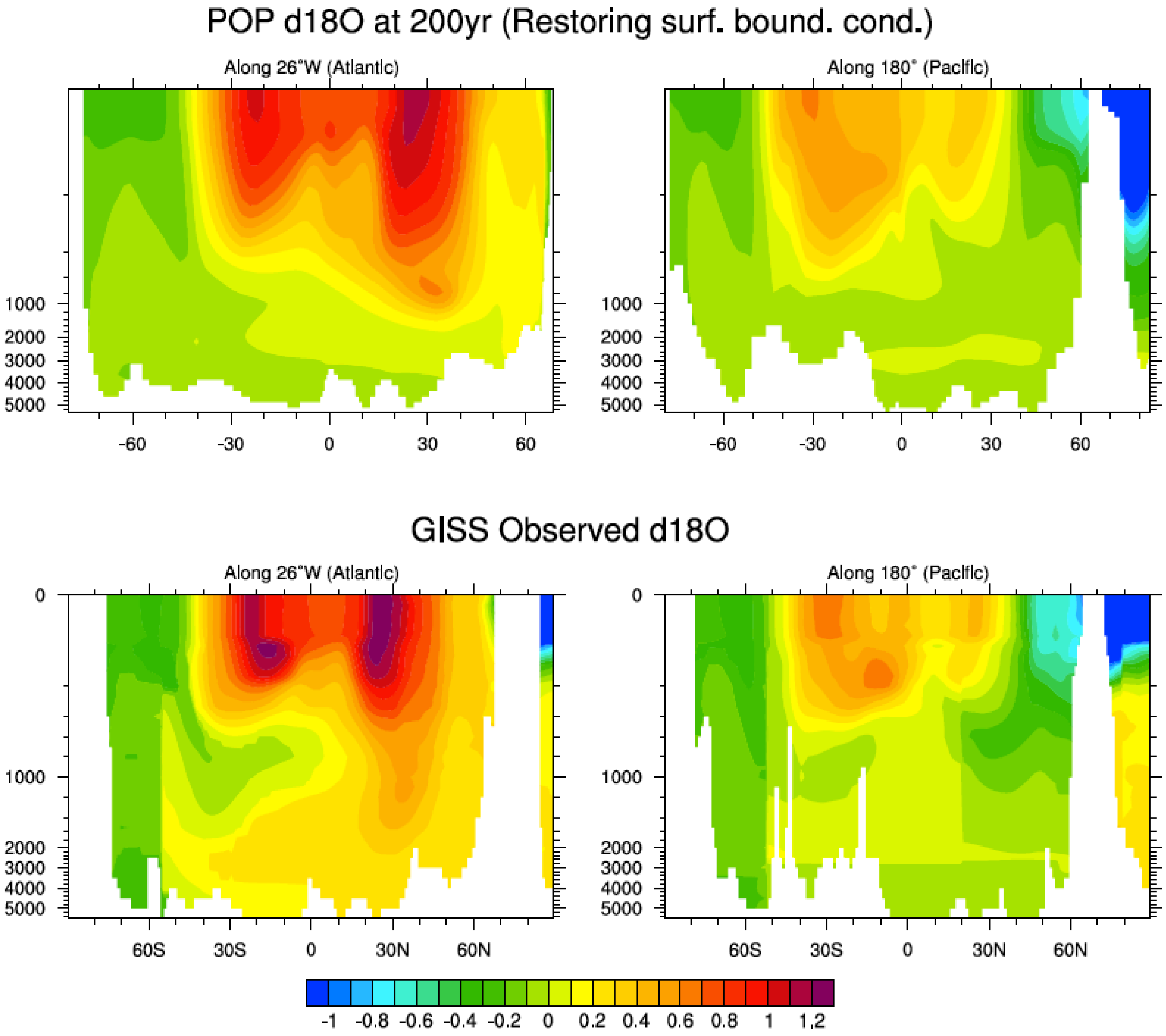
3.2. Water isotopes: Restoring BC

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

$$F_{\delta_W} = \frac{H}{\tau}(\delta_W^* - \delta_W)$$

- τ – relaxation time scale (= 30 d)
- H – upper ocean depth (1st layer)
- $\delta^*{}_W$ – prescirbed delta values
- Initial values = 0, run for 200 yr

3.2. Water isotopes: Restoring BC



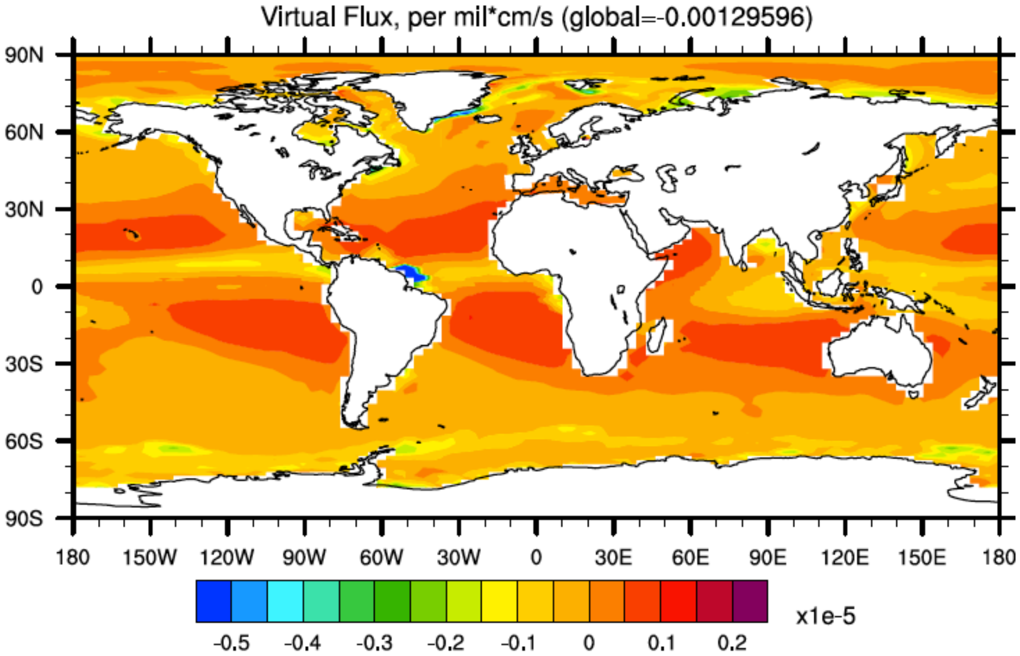
3.3. Water isotopes: PER flux forcing

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

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

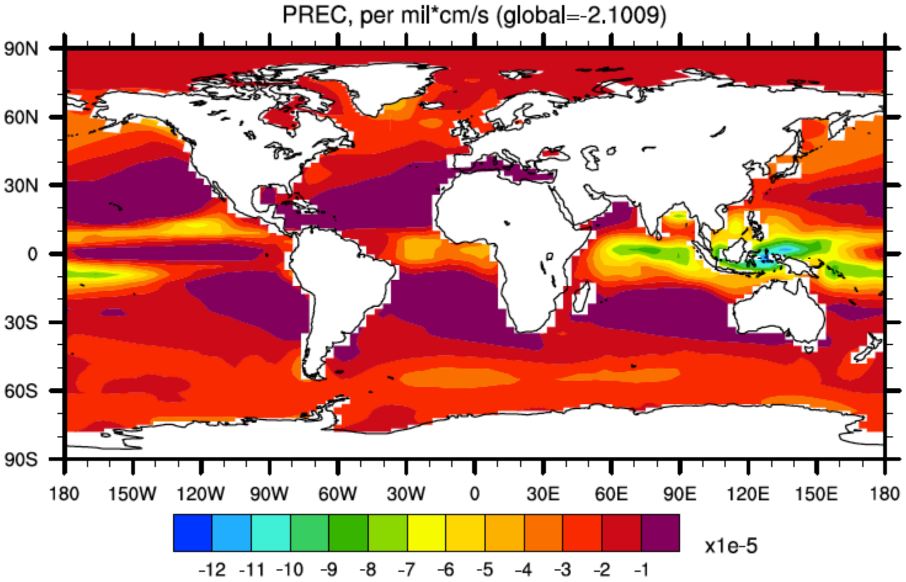
$$= \underbrace{(E - P - R)\delta_W}_{\text{Virtual Flux}} - (E\delta_E - P\delta_P - R\delta_R)$$

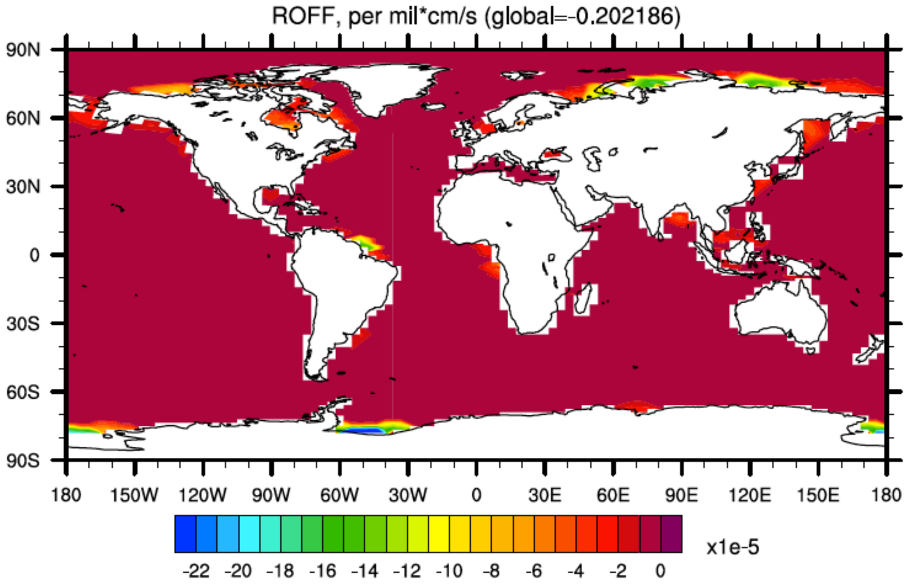
- Unit: per mil * cm/s
- Negative flux = loosing heavy water/gaining light water



3.3. Water isotopes: PER flux forcing

- $P\delta_P$: isoCAM3 preindustrial monthly-mean climatology
- $R\delta_R$: ROFF_F * δ_P


PREC, per mil*cm/s (global=-2.1009)


ROFF, per mil*cm/s (global=-0.202186)

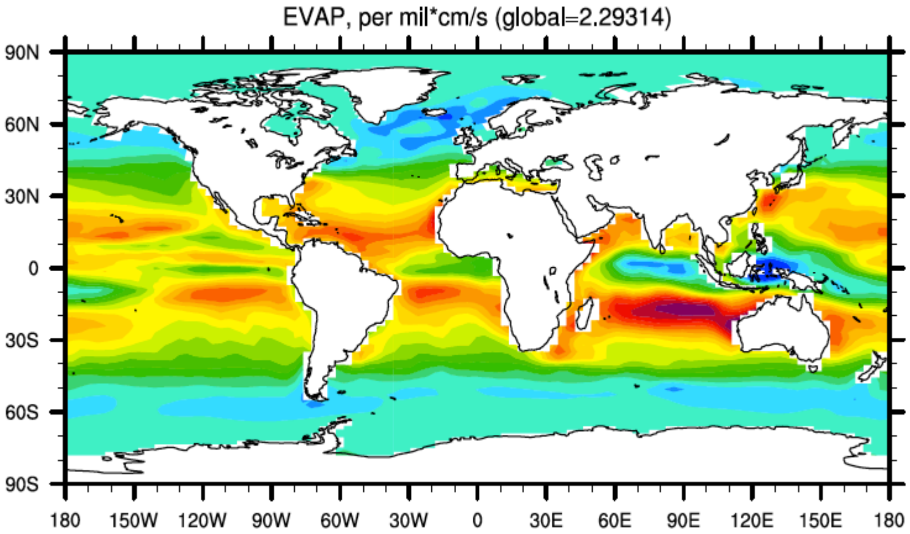
3.3. Water isotopes: PER flux forcing

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

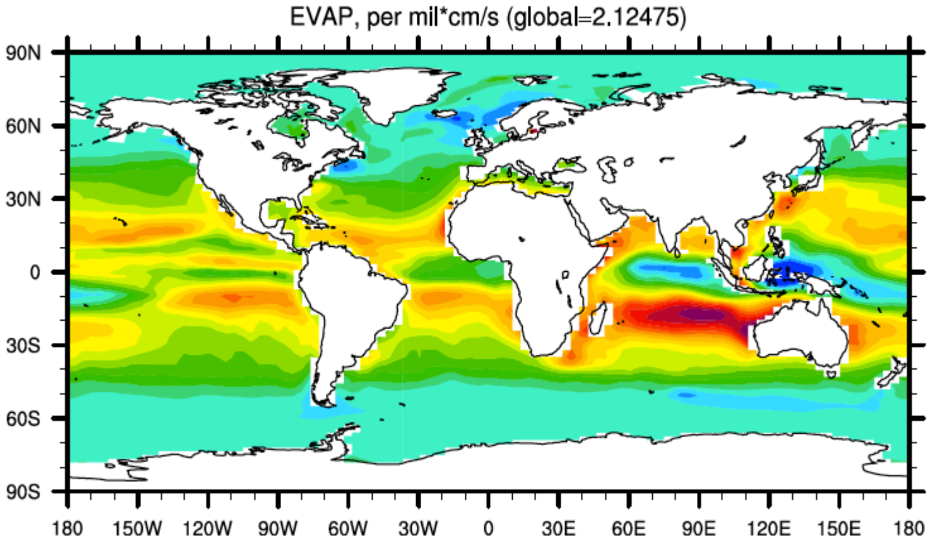
- Schmidt et al. (1999)
- K = 0.006 is the kinetic fractionation parameter
- α_{WV} = f(TS) water to vapor fractionation factor
- h – near-surface relative humidity (isoCAM)
  (where h > 0.8, h = 0.8)
- δ_A – delta value of marine air (isoCAM)
  (where $\delta_A < -16$, $\delta_A = -16$)

3.3. Water isotopes: PER flux forcing

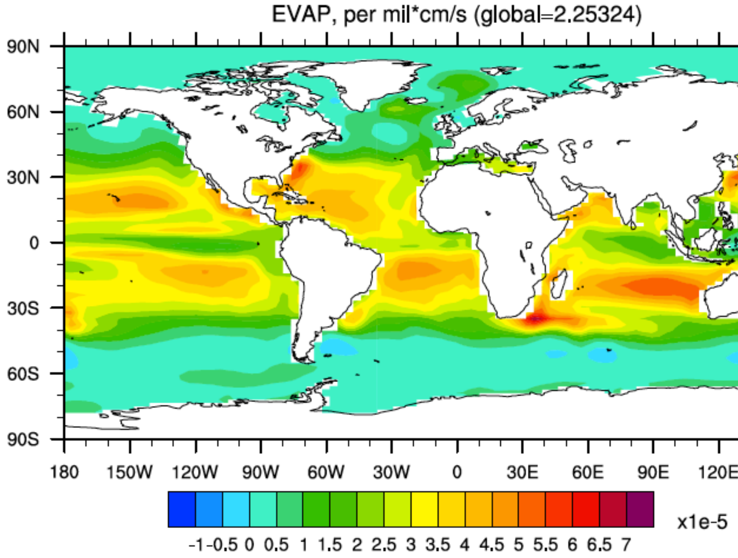
POP2, dynamic E*δ_E , Year 5



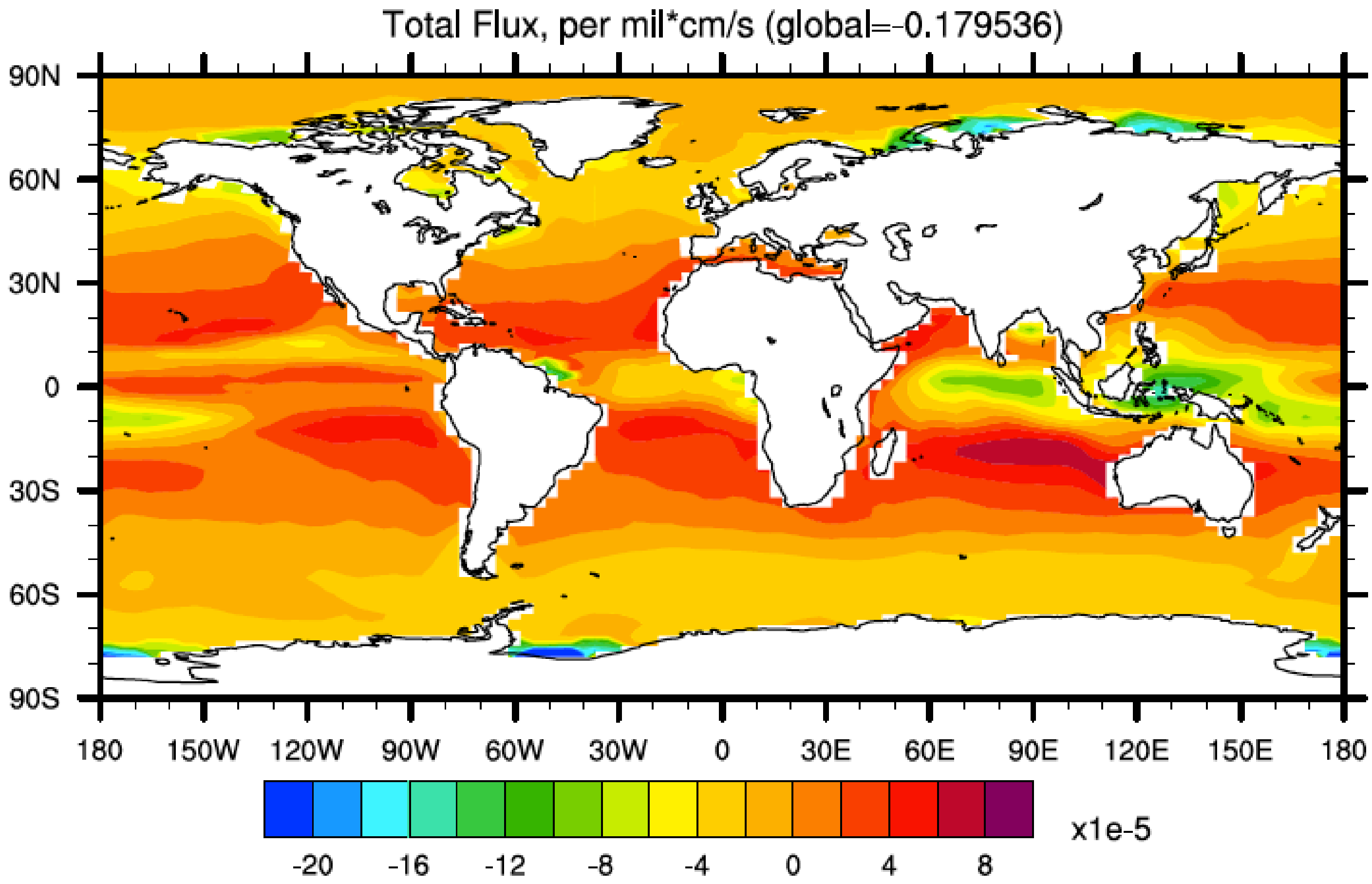
POP2, dynamic E*δ_E , Year 200



isoCAM3 E*δ_E ann climatology

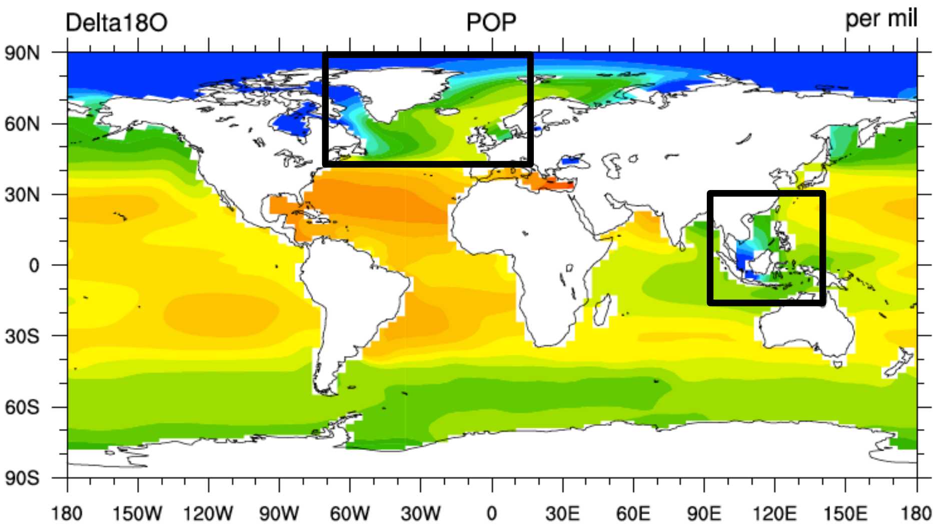


3.3. Water isotopes: PER flux forcing

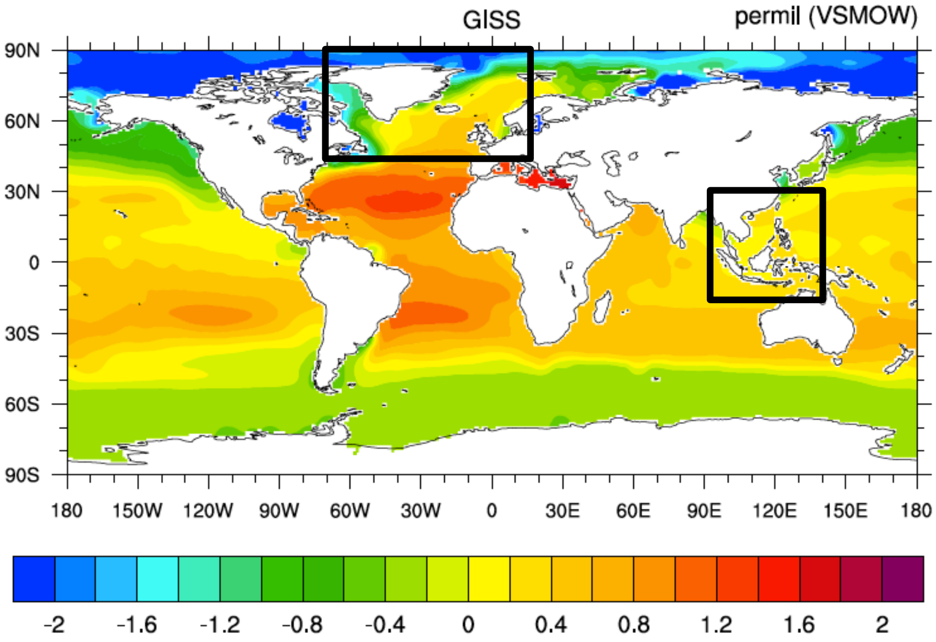


3.3. Water isotopes: PER flux forcing

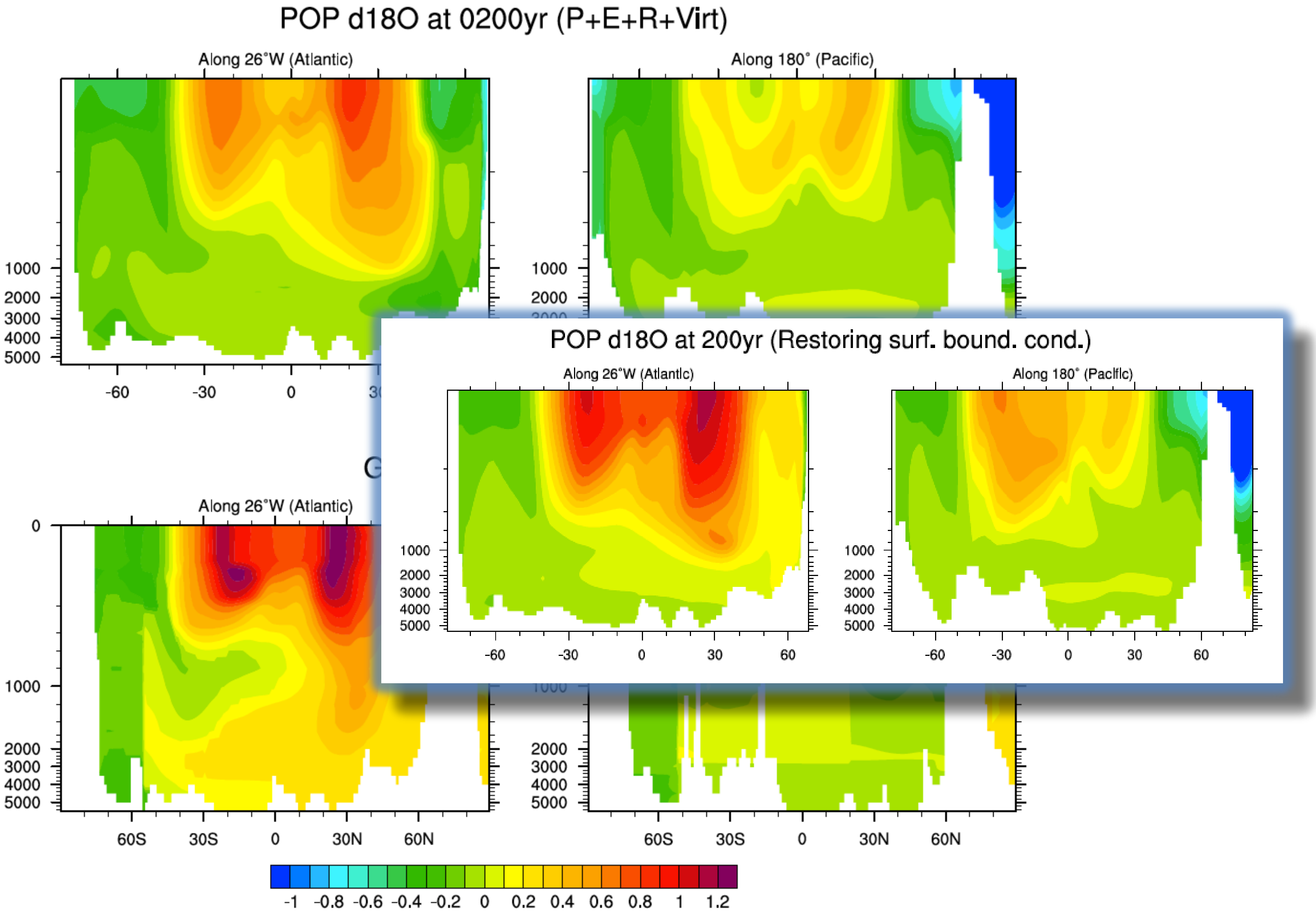
POP2 simulation
Year 200



GISS
Observations



3.3. Water isotopes: PER flux forcing



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

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

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)