# Seasonal Air-sea Atmospheric Potential Oxygen Flux Inferred from Global Airborne Observations

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# Outline

1. Seasonal air-sea APO flux cycle of

    (1) Two hemispheres (Jin et al., 2023, *under review at GBC*);

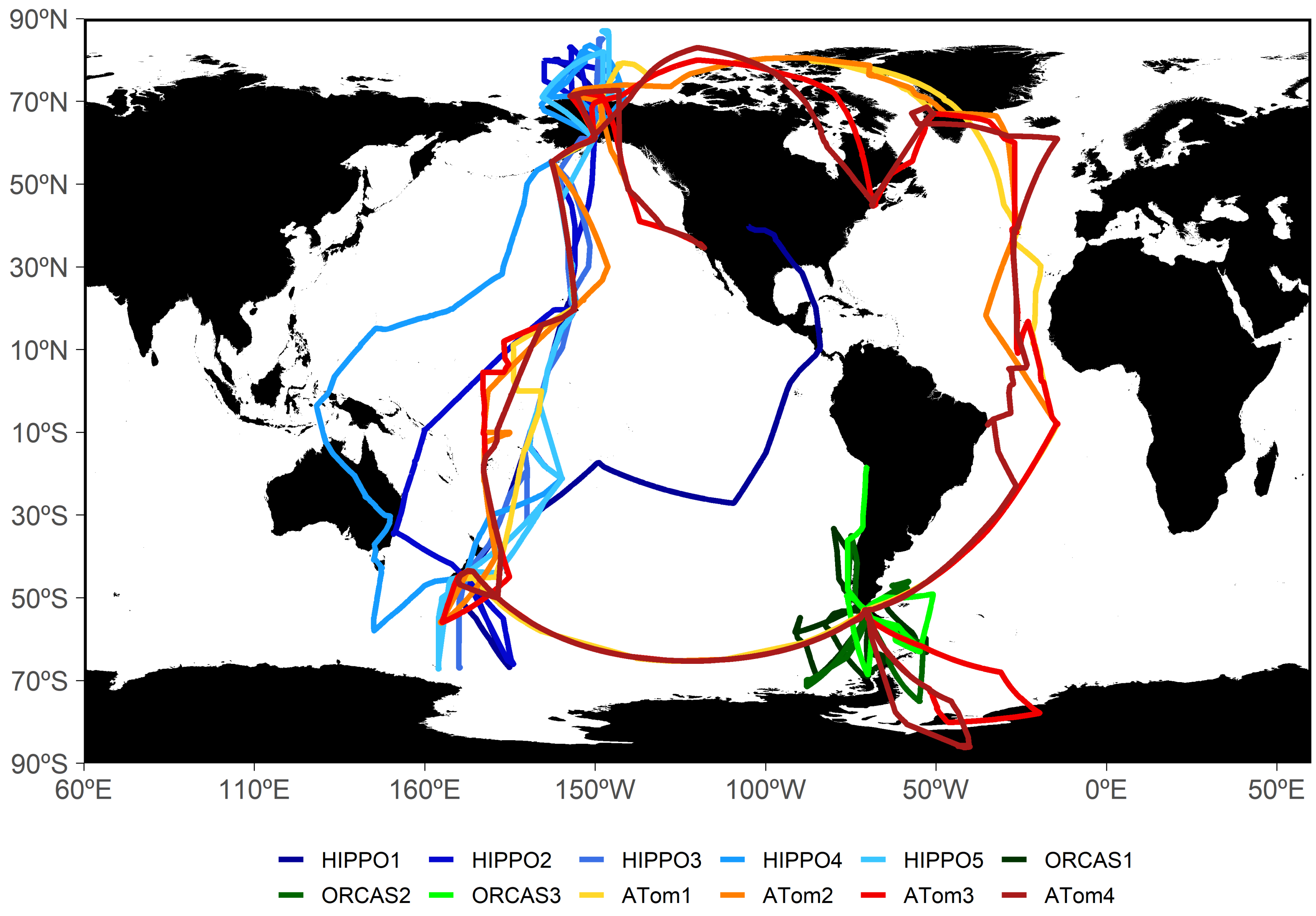
    - Discuss seasonal flux patterns in each hemisphere and hemispheric asymmetries.

    (2) Two coarse latitude bands over the mid- to high-latitudes Southern Ocean.

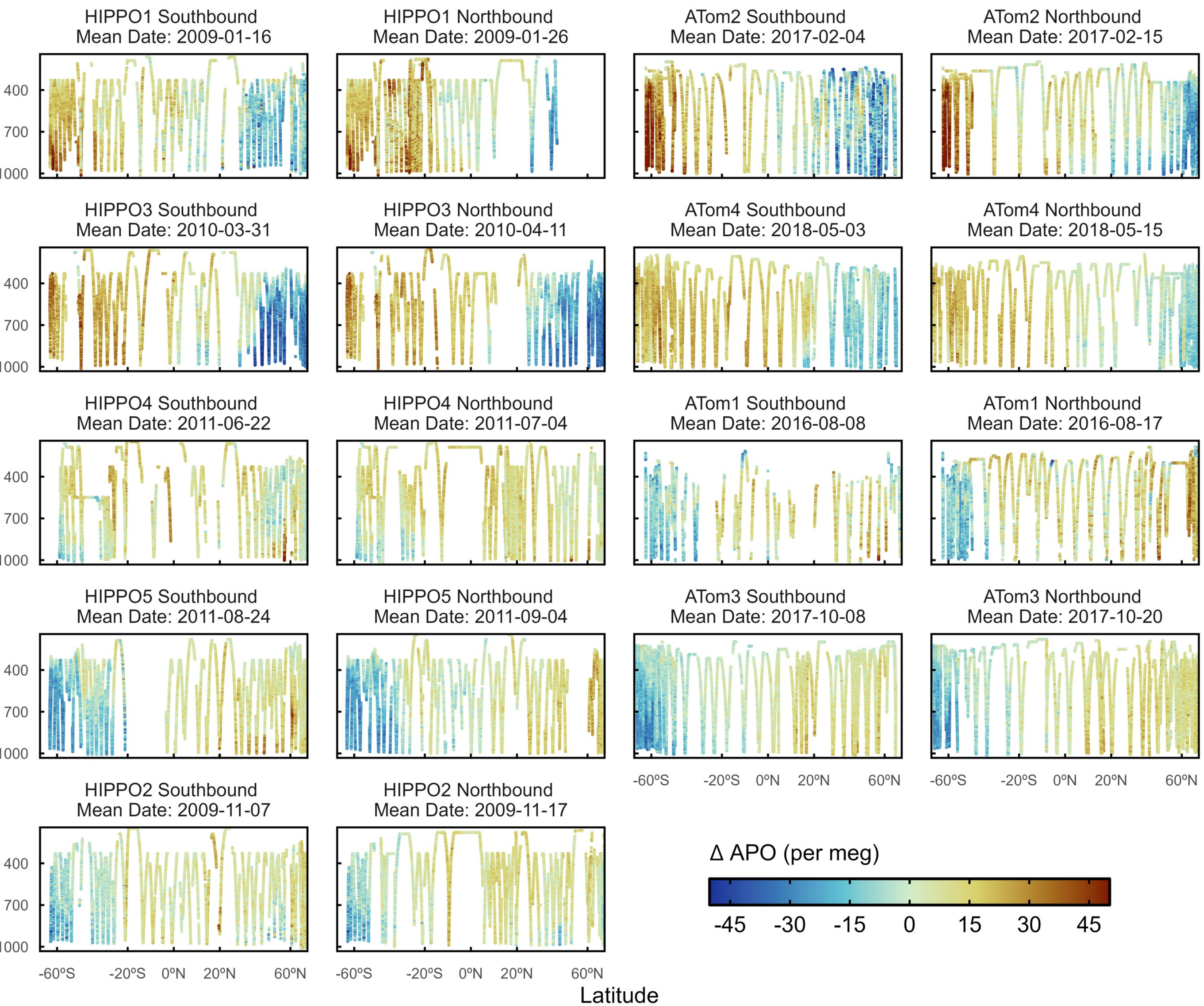
    - Discuss seasonal APO flux in two bands (polar/subpolar and subtropics).
    - Discuss implications for studying seasonal SO air-sea $CO_2$ fluxes.

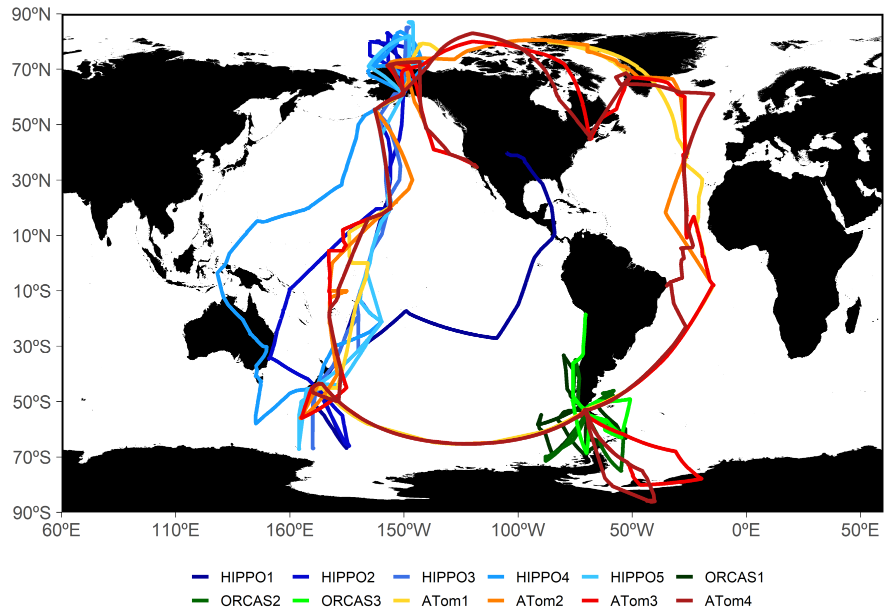
2. Implications for using Airborne APO observations (and derived flux) to constrain models (e.g., CESM and inversion).

# Global airborne campaigns and airborne APO observations



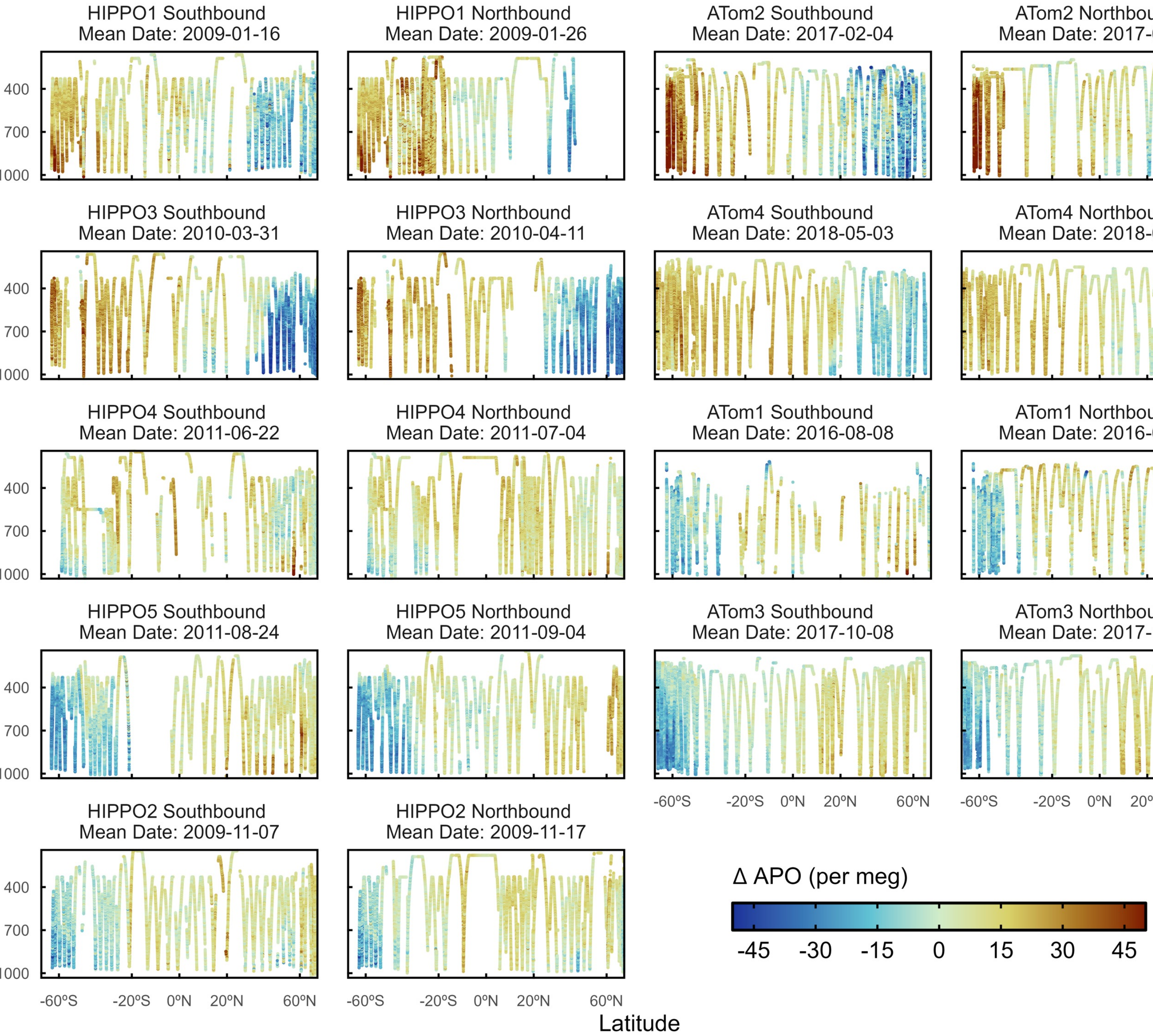
# Global airborne campaigns and airborne APO observations




- Almost Pole-to-Pole coverage
- Surface to above tropopause
- Observations in every month (different years) except December.

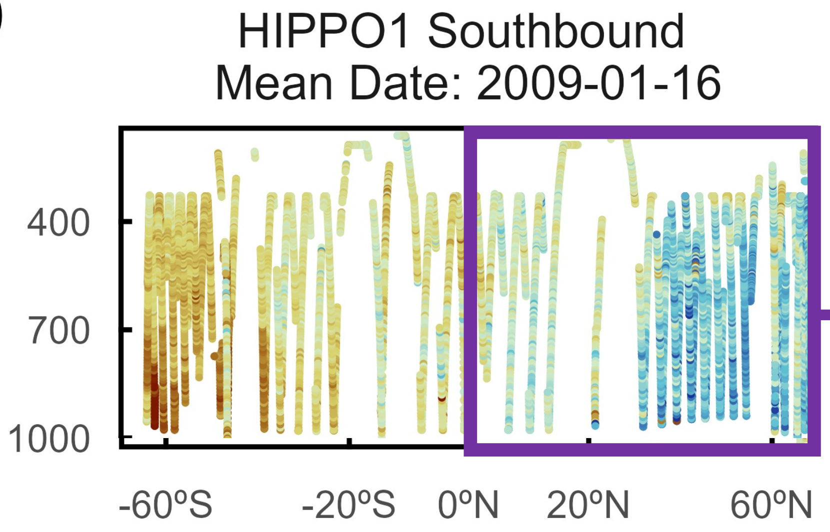
# Global airborne campaigns and airborne APO observations



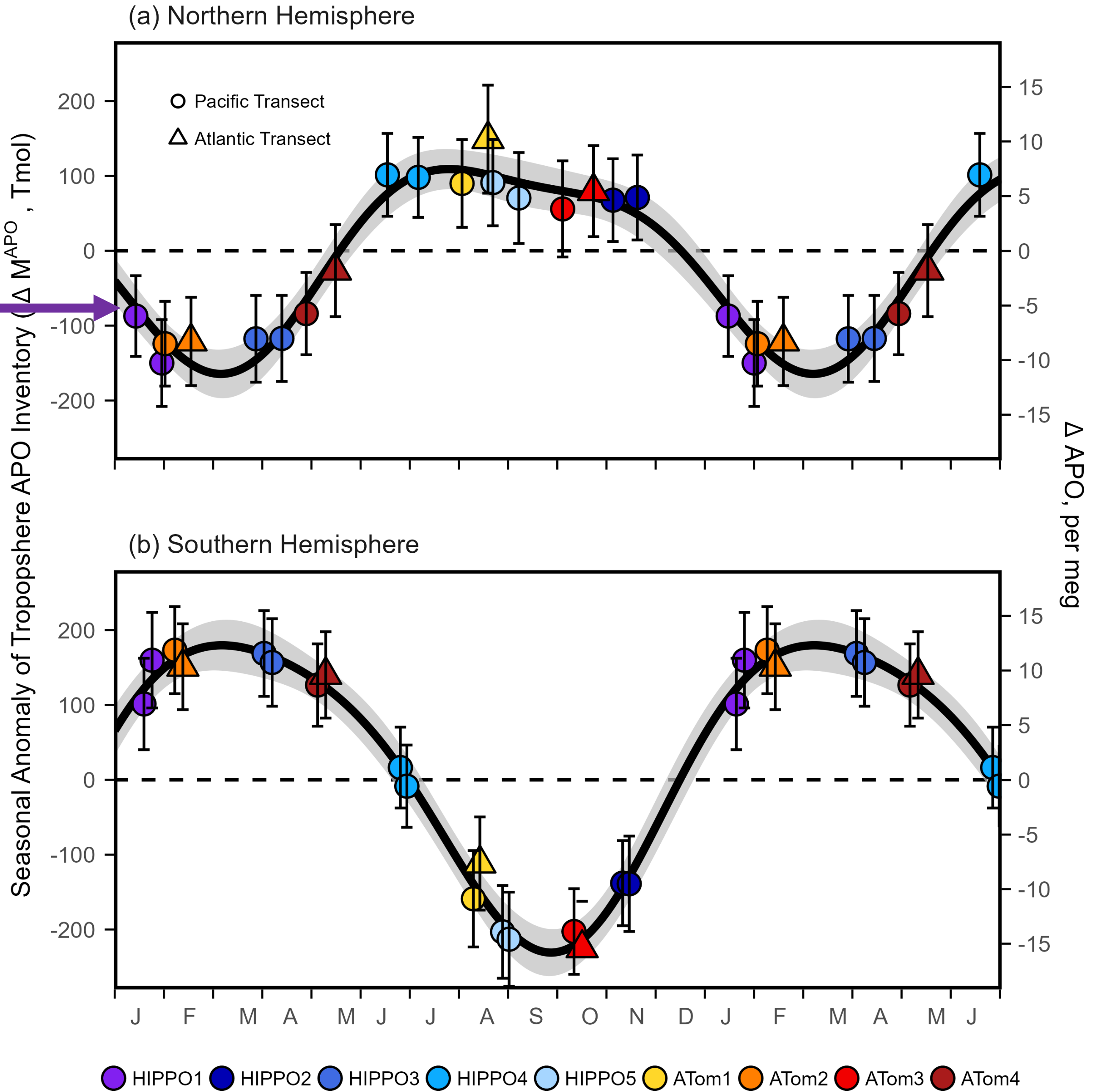

Deriving hemispheric flux from sparse atmosphere observations:

1. Resolving seasonal troposphere APO inventory cycles of each hemisphere.
2. Inverting inventory to flux using a 3-box model.

# Troposphere APO seasonal cycles

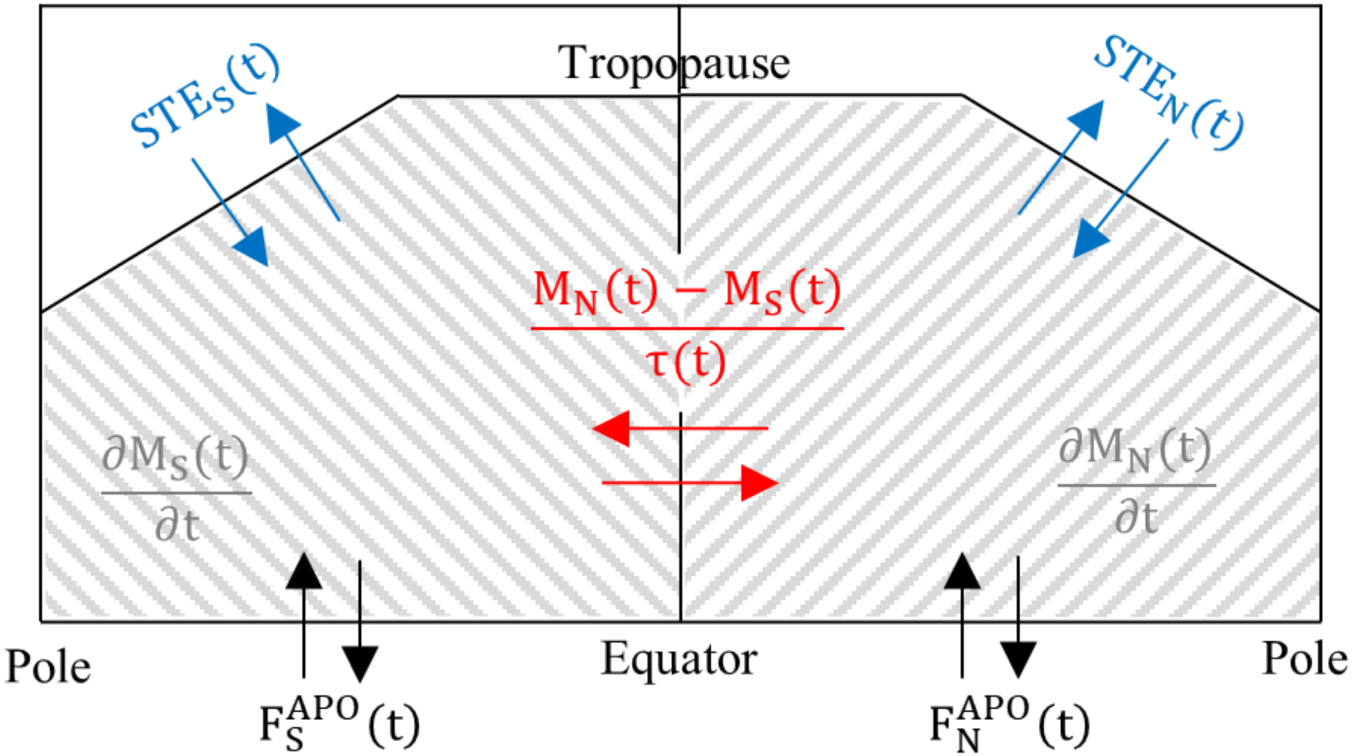



Integrating $\Delta APO$ along moist isentropes in each hemisphere to yield detrended APO inventory estimate



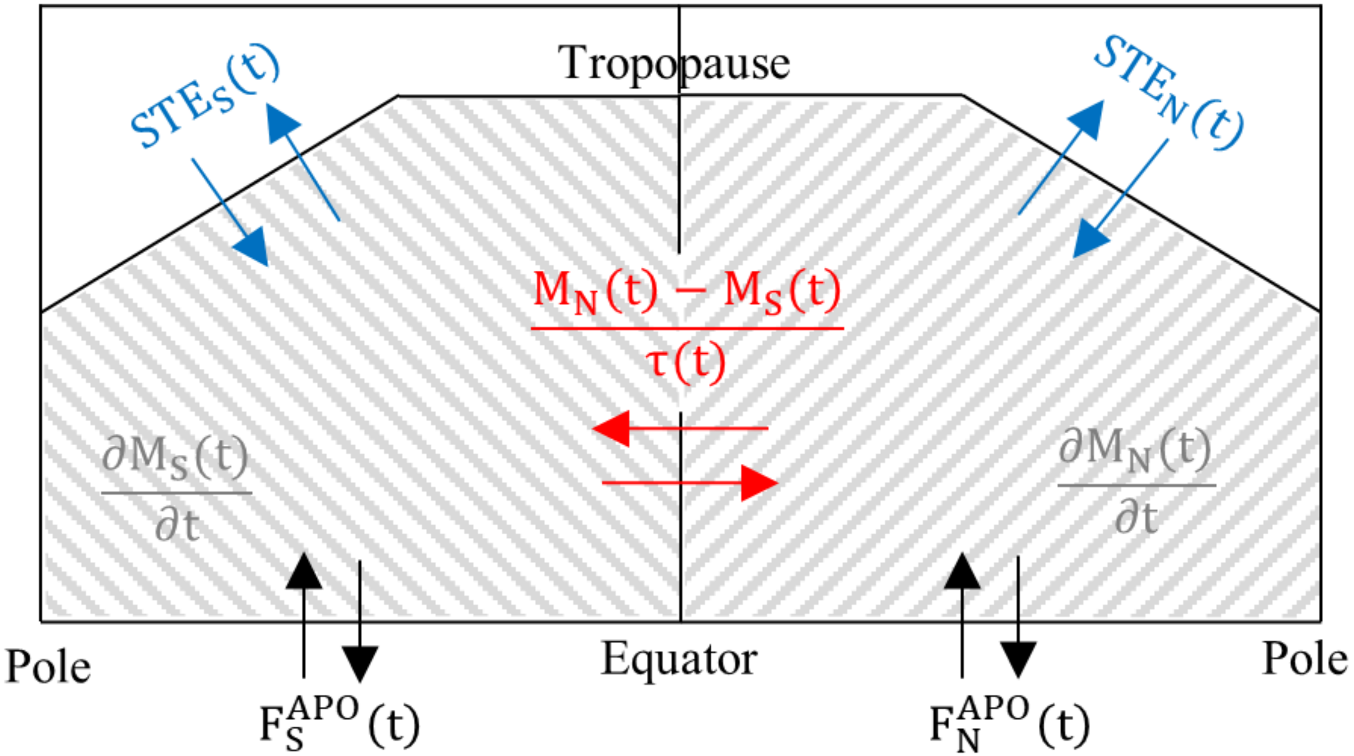

Method see Jin et al., 2021, Atom. Phys. Chem.

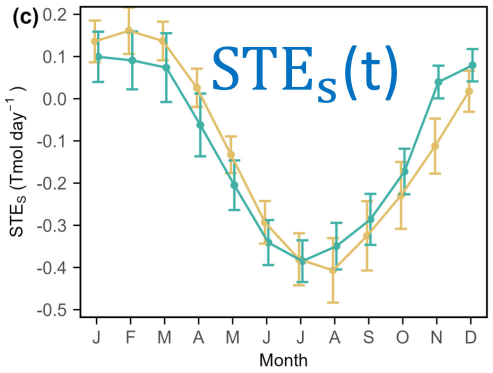
# Box-model for inverting hemispheric-scale APO flux

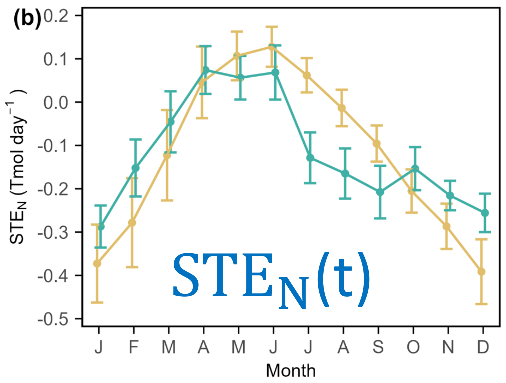


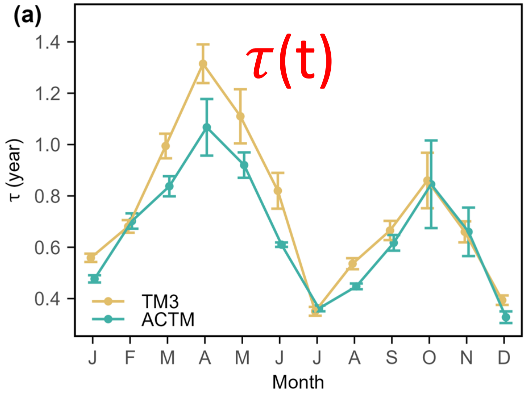

| | | | | | | |
|---|---|---|---|---|---|---|
| APO troposphere inventory change | = | Surface flux | + | Inter-hemisphere Exchange | + | Stratosphere-Troposphere Exchange |
| $\frac{\partial M_N(t)}{\partial t}$ | = | $F_N(t)$ | + | $\frac{M_N(t) - M_S(t)}{\tau(t)}$ | + | $STE_N(t)$ |

# Box-model for inverting hemispheric-scale APO flux



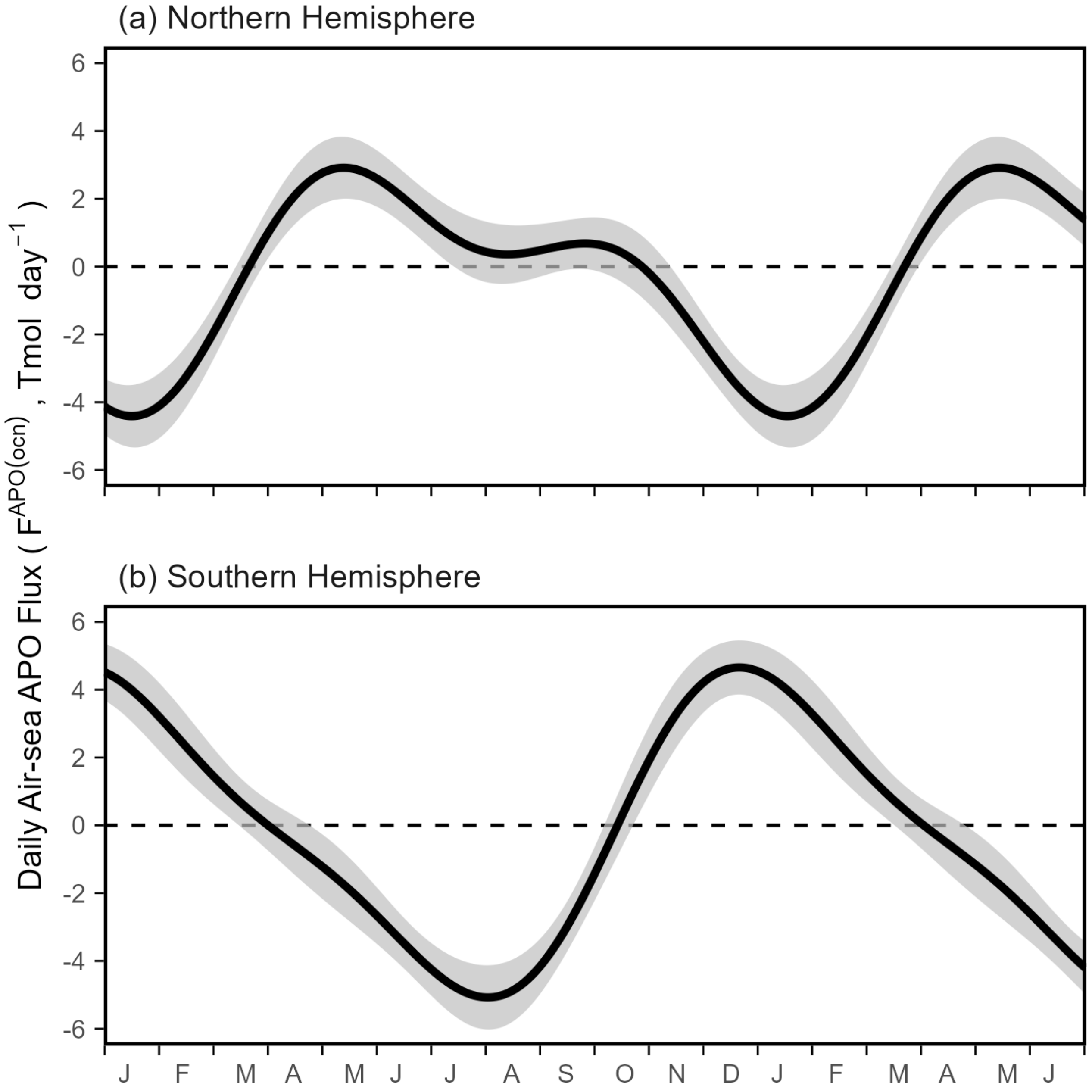



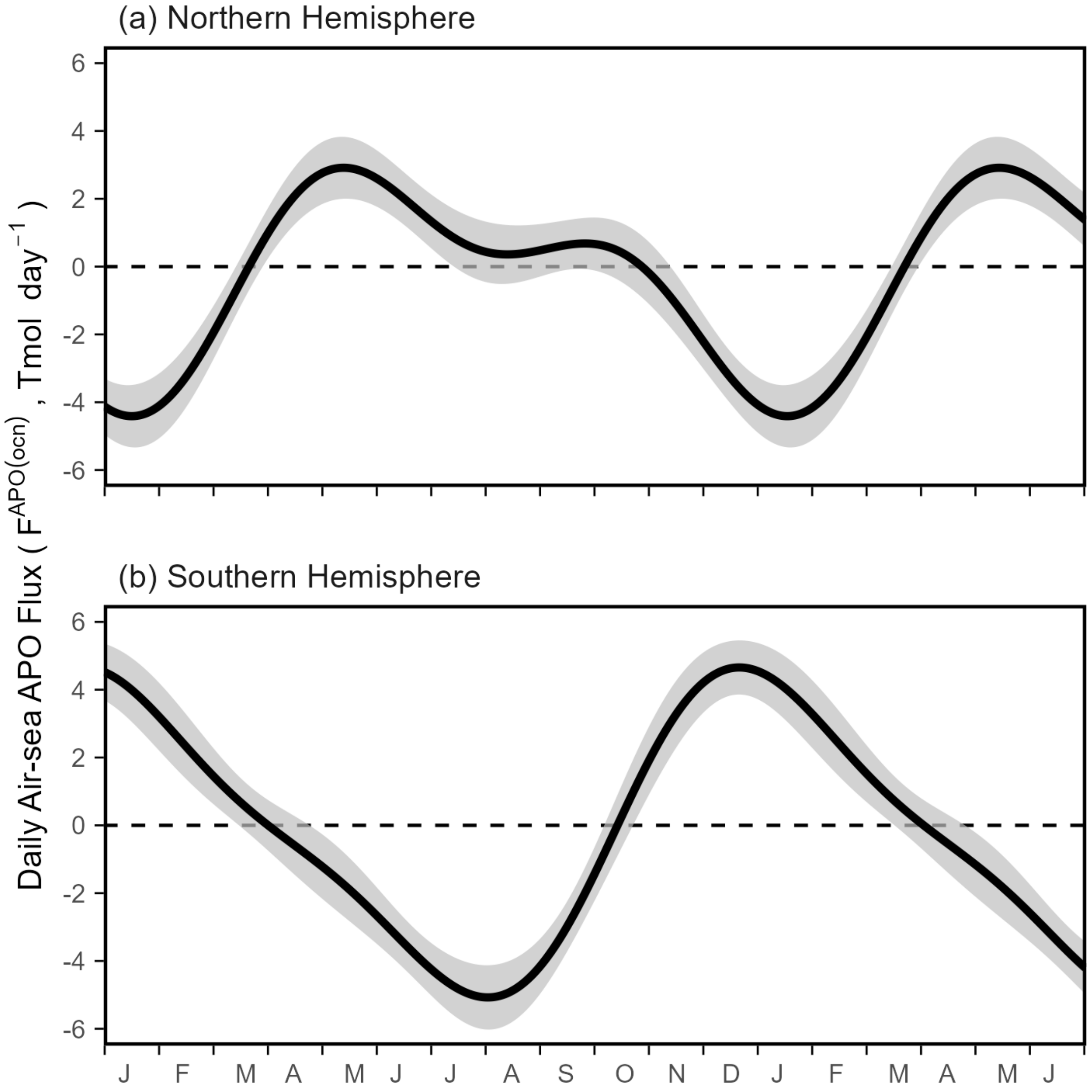

APO troposphere inventory change = Surface flux + Inter-hemisphere Exchange + Stratosphere-Troposphere Exchange

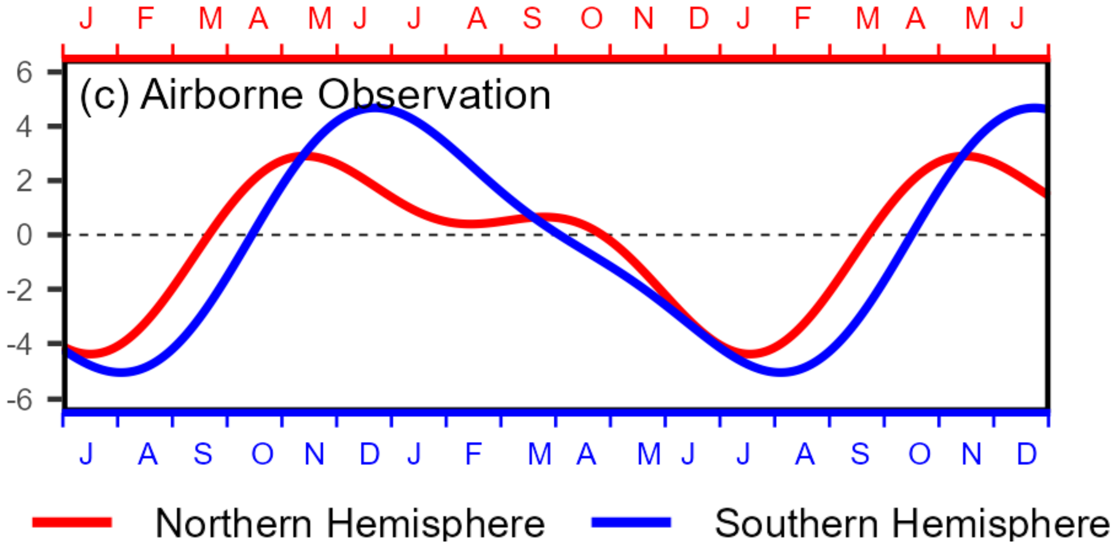
$$\frac{\partial M_N(t)}{\partial t} = F_N(t) + \frac{M_N(t) - M_S(t)}{\tau(t)} + STE_N(t)$$

# Air-sea APO flux cycles



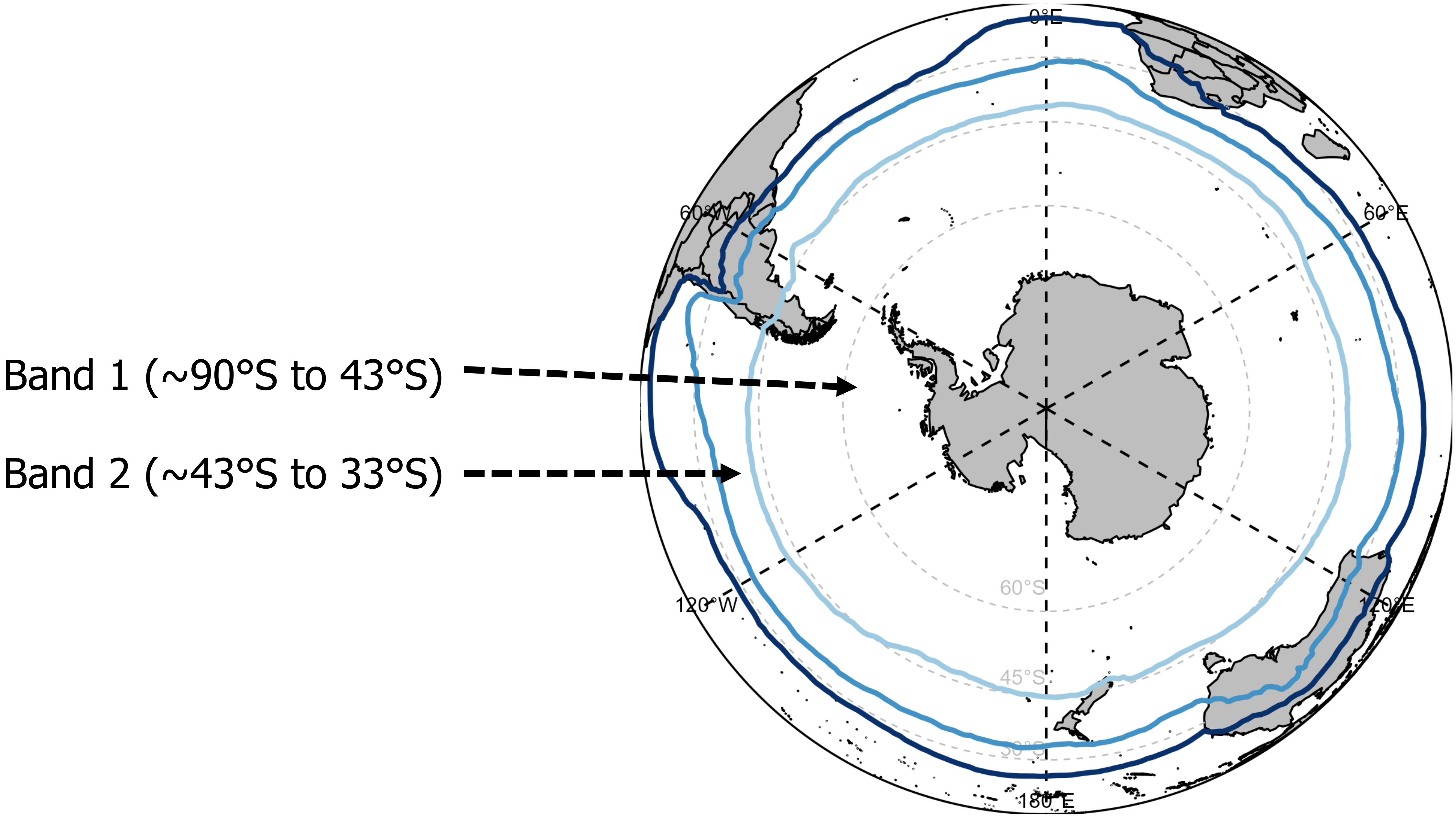
# Air-sea APO flux cycles



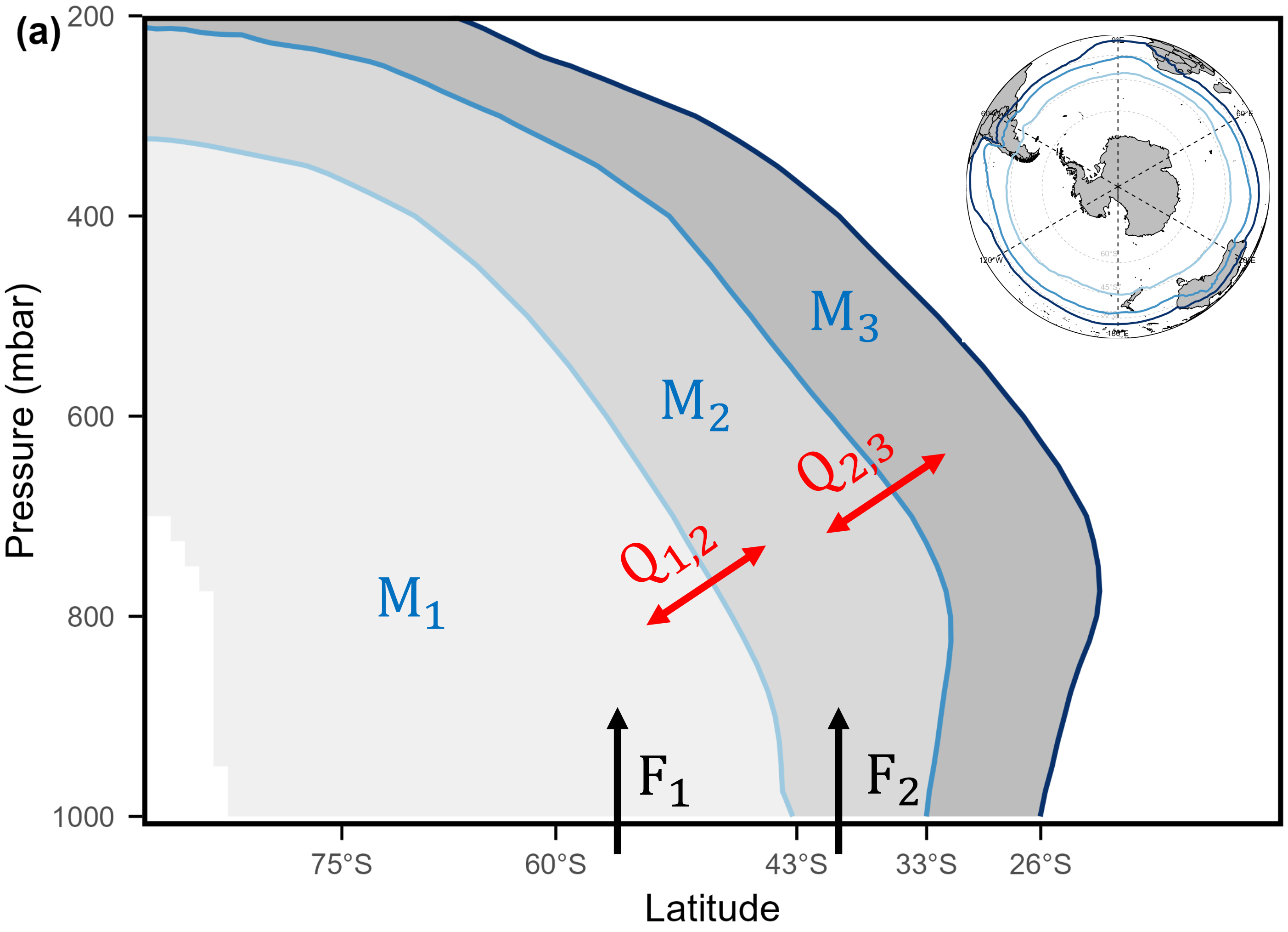




The NH features (relative to the SH):

1. Smaller flux seasonal amplitude and seasonal net outgassing
2. A summer plateau and fall outgassing
3. Earlier seasonal APO outgassing by ~ a month


Band 1 (~90°S to 43°S)
Band 2 (~43°S to 33°S)
0°E
60°E
120°E
180°E
120°W
60°W
60°S
45°S
30°S

# Box-model for inverting SO APO flux




APO inventory change = Surface Flux + Diabatic Transport

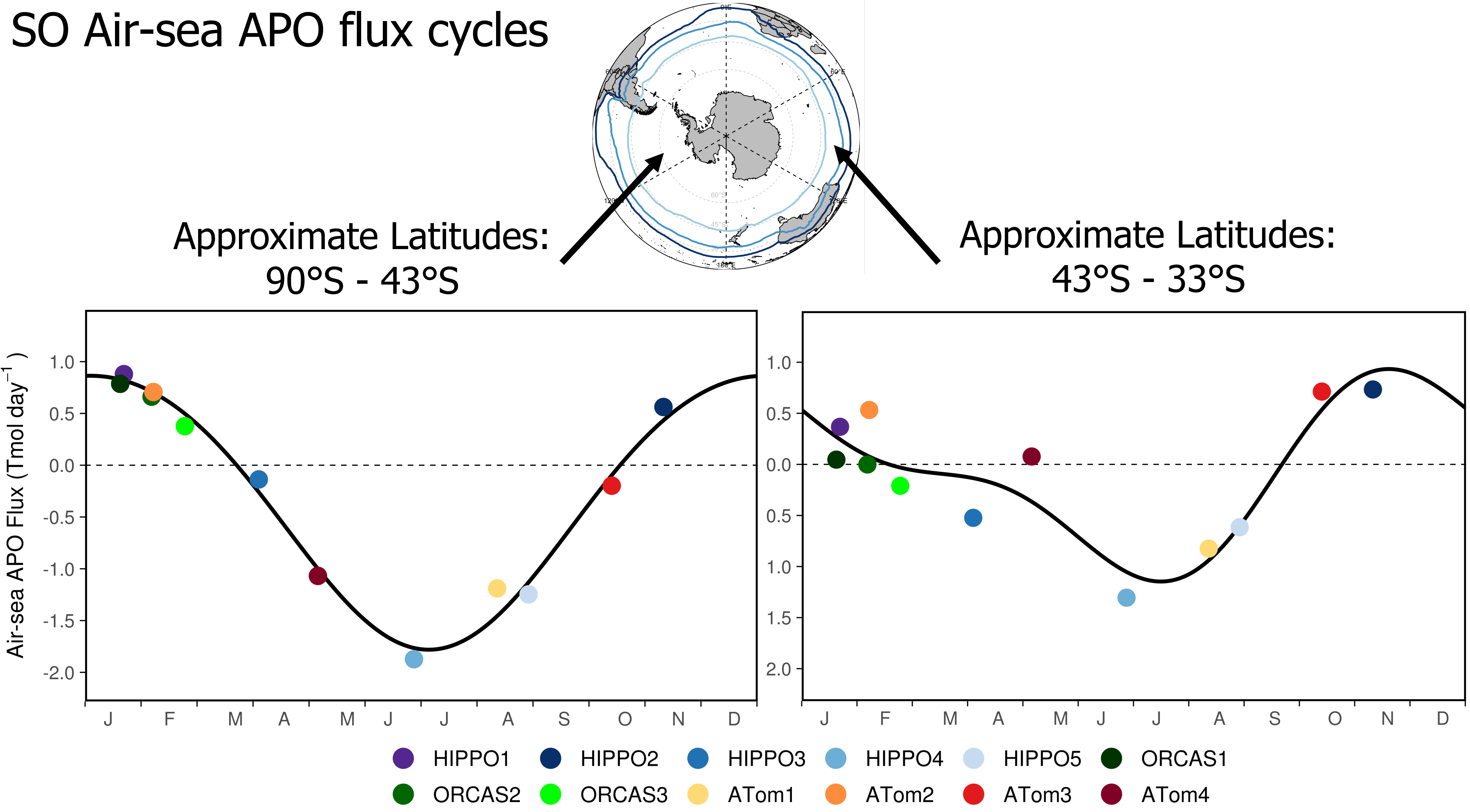
$$\frac{\partial M_i}{\partial t} = \begin{cases} \mathbf{F_i} + Q_{i,i+1} & i = 1 \\ \mathbf{F_i} + Q_{i,i+1} - Q_{i-1,i} & i = 2 \end{cases}$$

$$Q_{i,i+1} = \mathbf{D_{i,i+1}} \cdot (\chi_{i+1} - \chi_i)$$

Diabatic Mixing Rate ($kg\ yr^{-1}$)

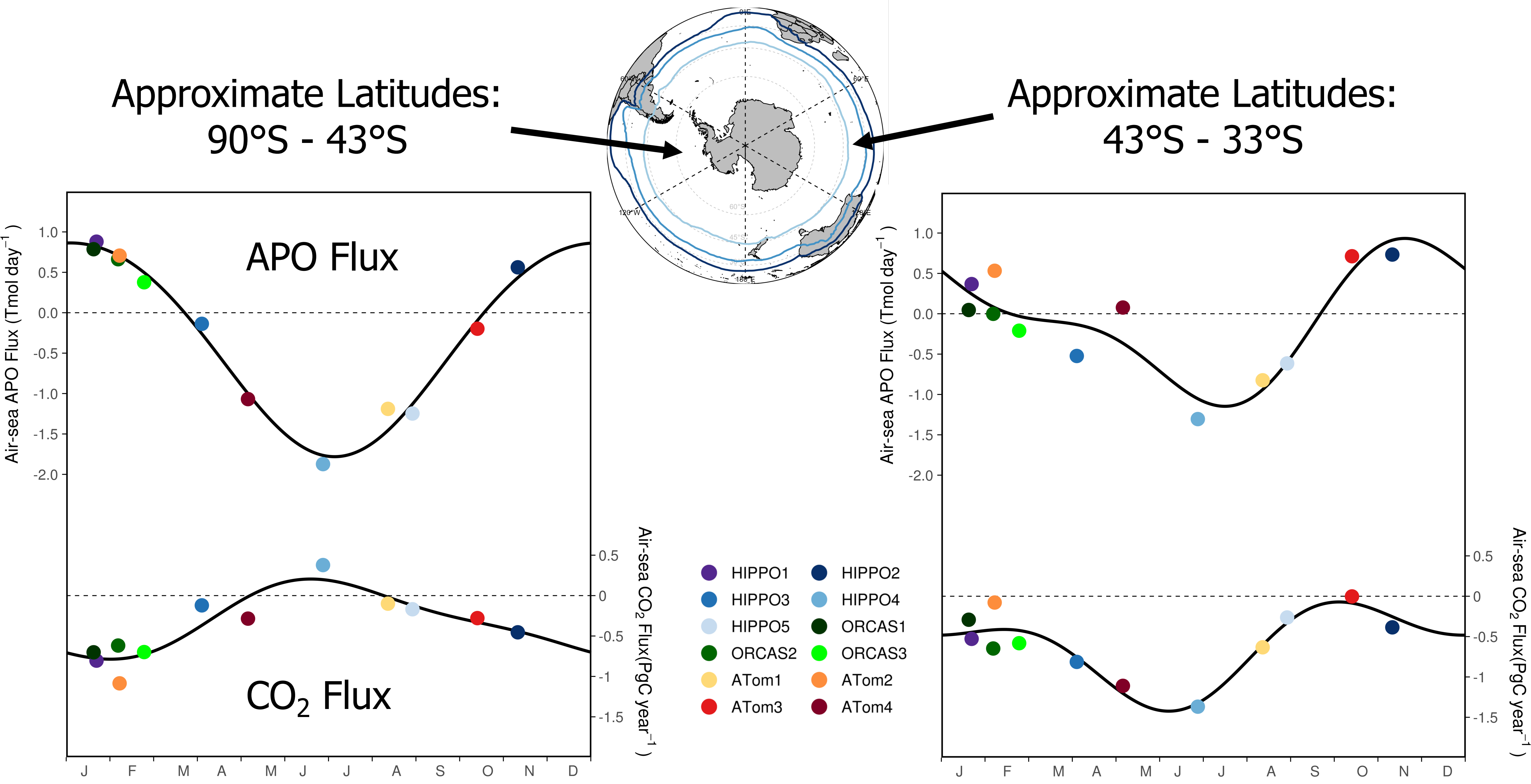
APO gradient (mol)

Method from Jin et al., 2023, under review at PNAS

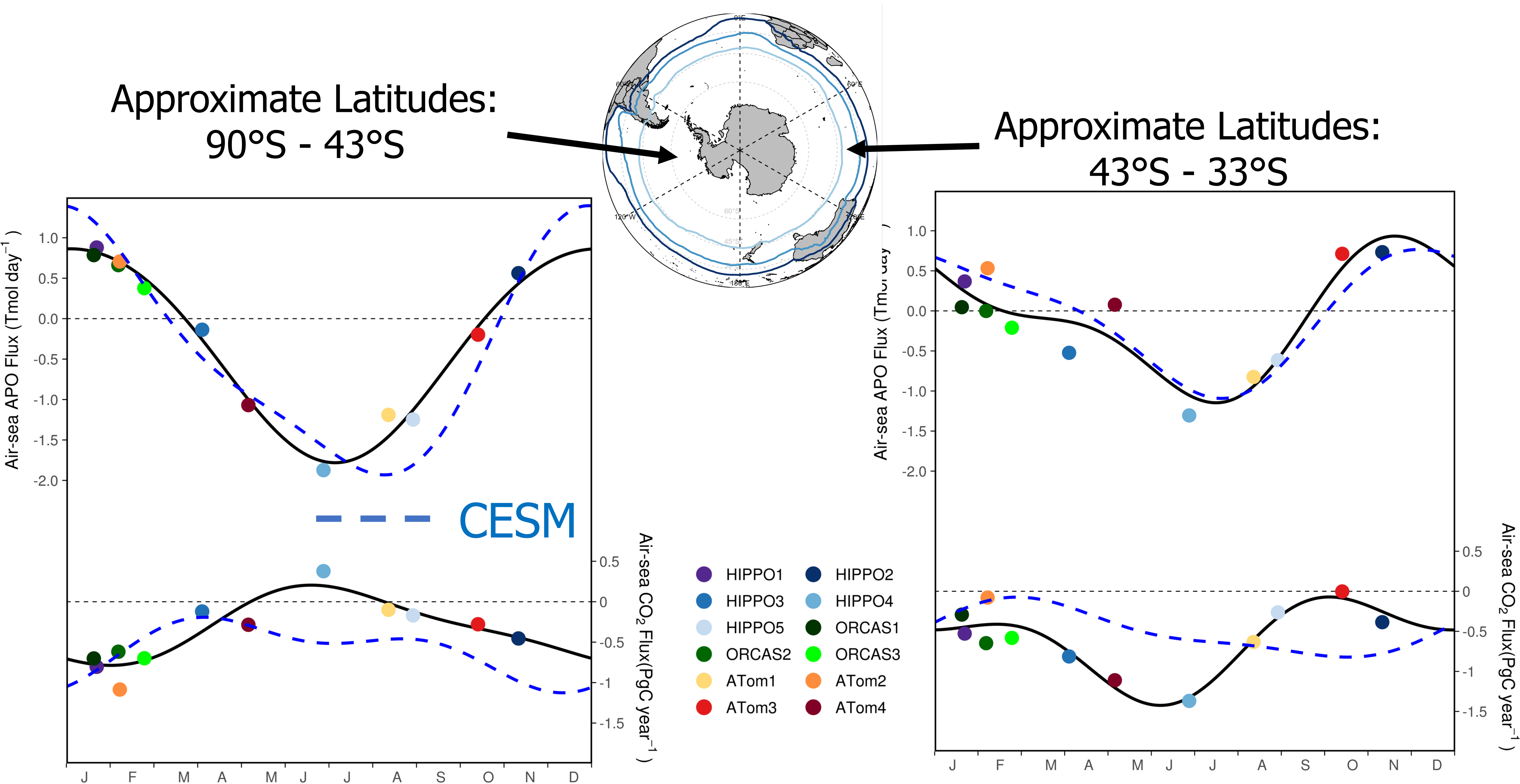


SO Air-sea APO flux cycles
Approximate Latitudes:
90°S - 43°S
Approximate Latitudes:
43°S - 33°S
Air-sea APO Flux (Tmol day$^{-1}$)
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
J F M A M J J A S O N D
1.0
0.5
0.0
0.5
1.0
1.5
2.0
J F M A M J J A S O N D
HIPPO1
HIPPO2
HIPPO3
HIPPO4
HIPPO5
ORCAS1
ORCAS2
ORCAS3
ATom1
ATom2
ATom3
ATom4

# SO Air-sea APO and $CO_2$ flux cycles



# Application 1:
# Constraining model simulated SO air-sea APO and $CO_2$ flux (e.g., CESM)

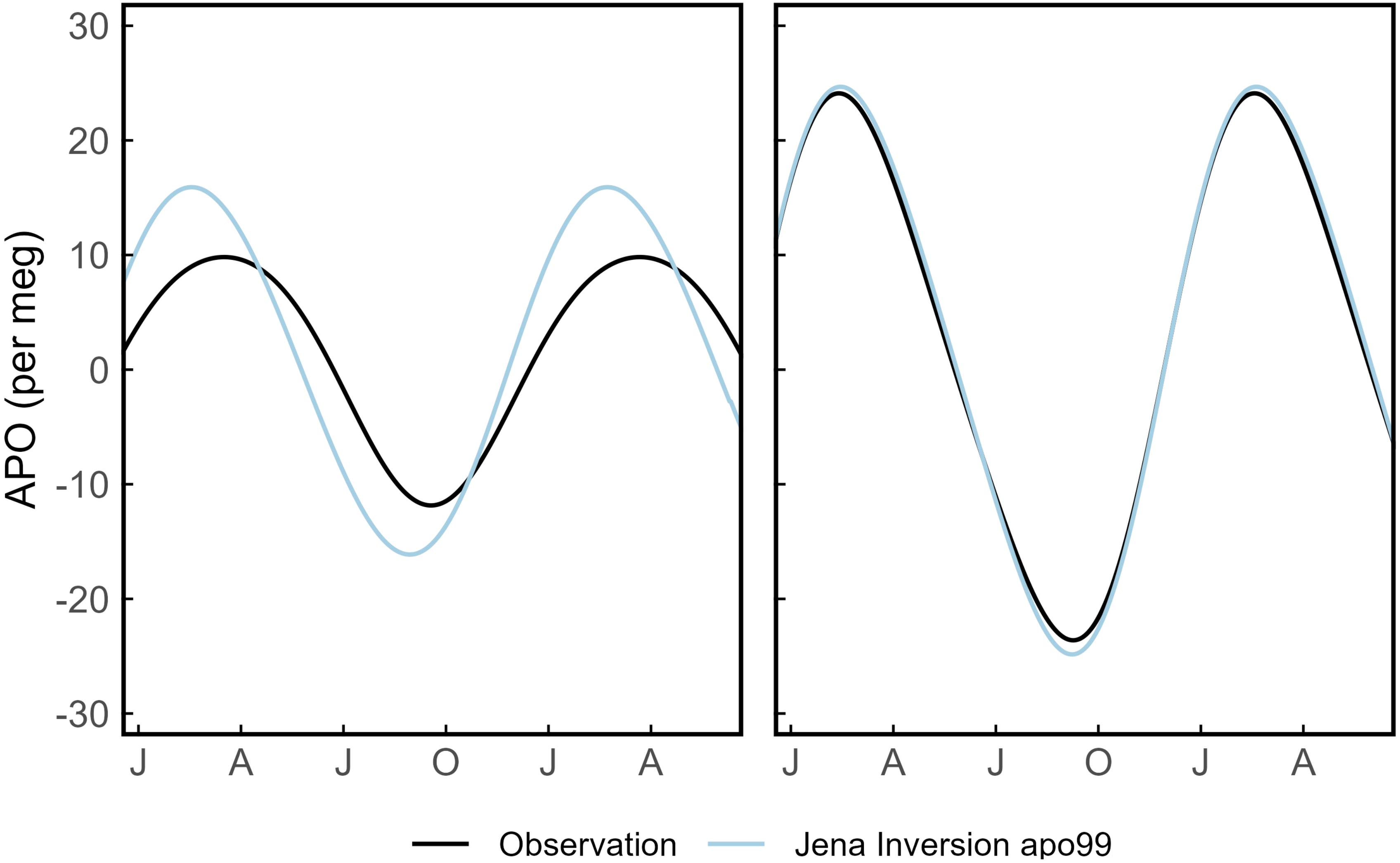


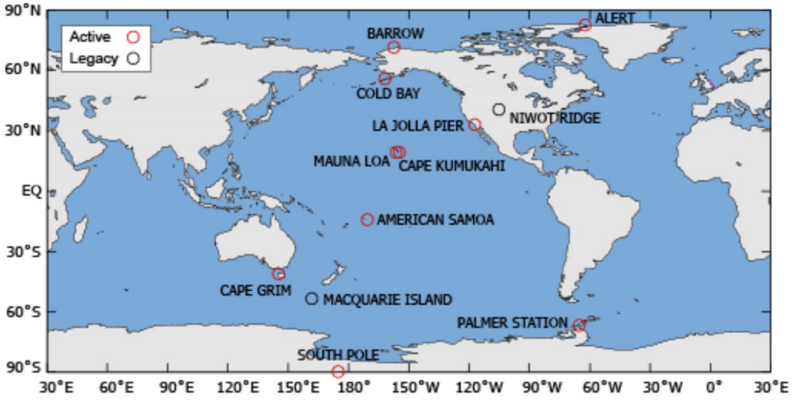
Approximate Latitudes:
90°S - 43°S
Approximate Latitudes:
43°S - 33°S
Air-sea APO Flux (Tmol day⁻¹)
Air-sea CO2 Flux(PgC year⁻¹)
CESM
HIPPO1
HIPPO2
HIPPO3
HIPPO4
HIPPO5
ORCAS1
ORCAS2
ORCAS3
ATom1
ATom2
ATom3
ATom4
J F M A M J J A S O N D

# Application 2:
# Constraining APO inversion products
# (e.g., Jena APO inversion)

## Low-latitudes SH (~ 10-35°S)

## Mid- to high-latitudes SH (~ 35-90°S)



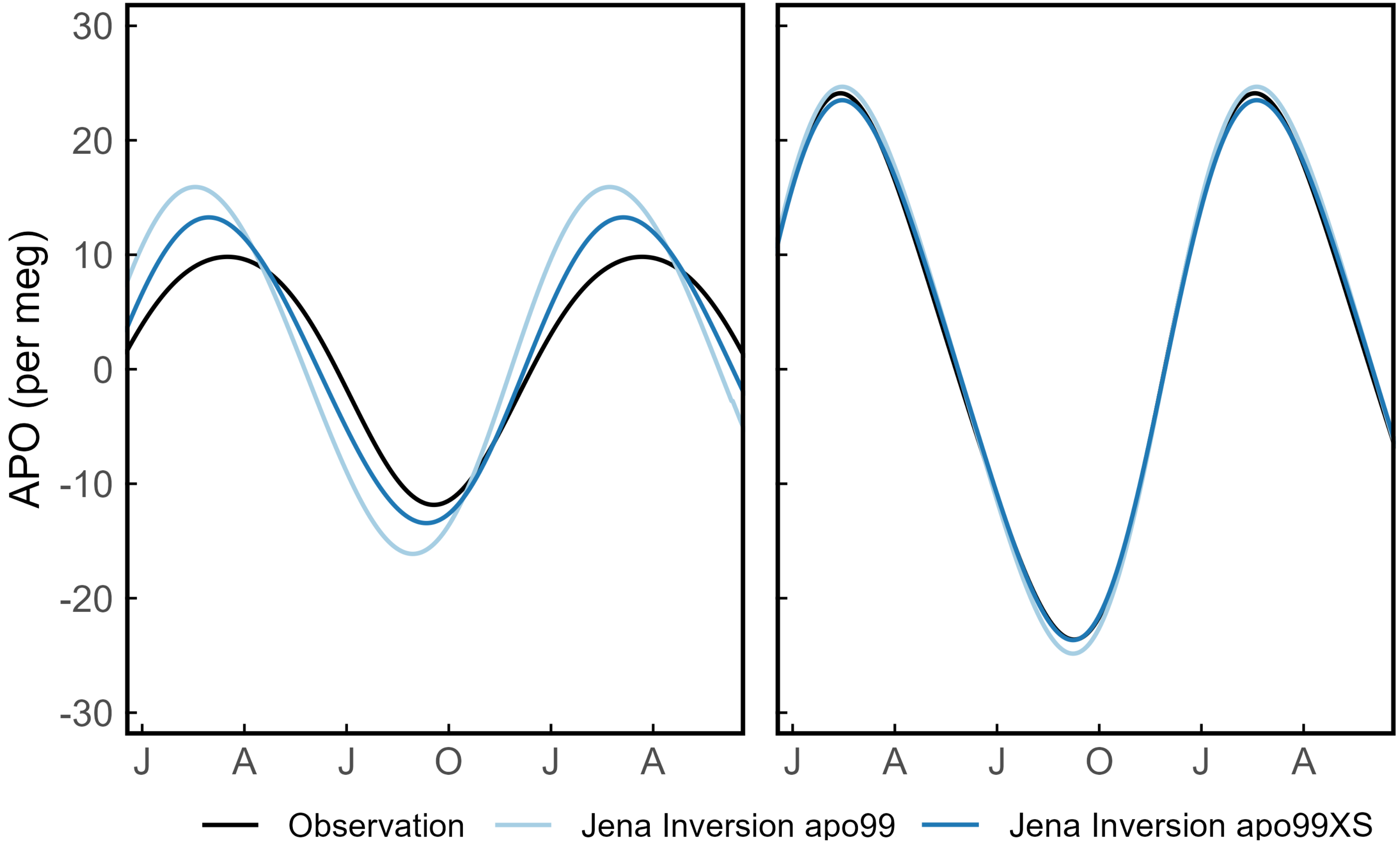



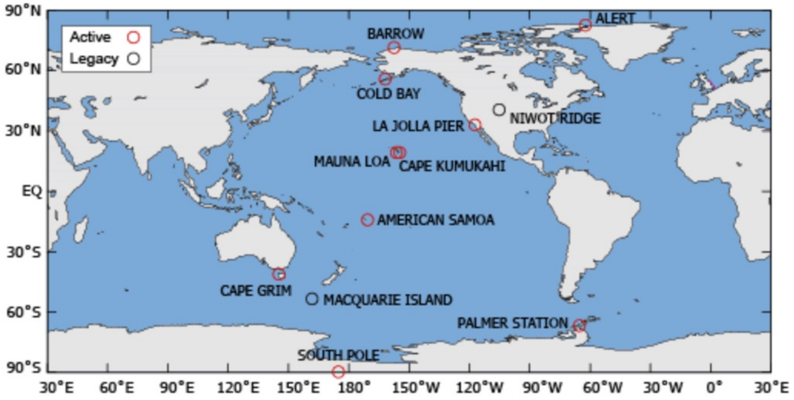

Jena inversion apo99 uses $O_2$ data from

**Scripps network**

Low-latitudes SH
(~ 10-35°S)

Mid- to high-latitudes SH
(~ south of 35°S)




Jena inversion apo99XS uses $O_2$ data from Scripps network + HAT(24.05°N 123.8°E) + **Western pacific ship data (40°S - 30°N, Tohjima et al. 2019)**