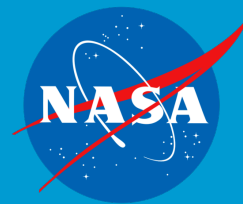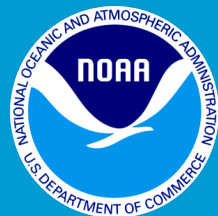# SOCCOM

Southern Ocean Carbon and Climate Observations and Modeling

Spatial and seasonal patterns of air-sea O_2 and CO_2 fluxes from profiling floats in the Southern Ocean
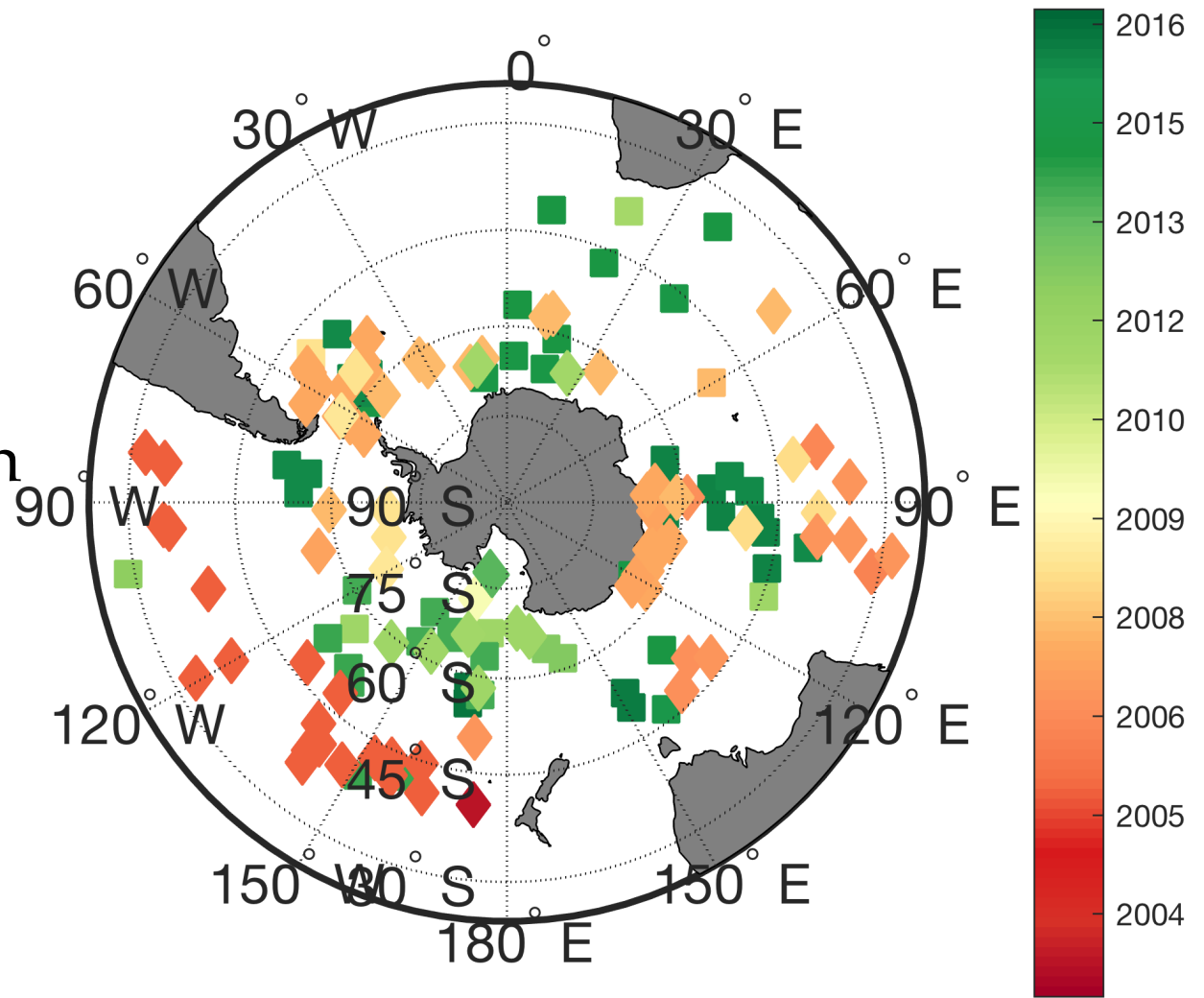
Seth Bushinsky, Alison Gray, Jorge Sarmiento, Ken Johnson, and others
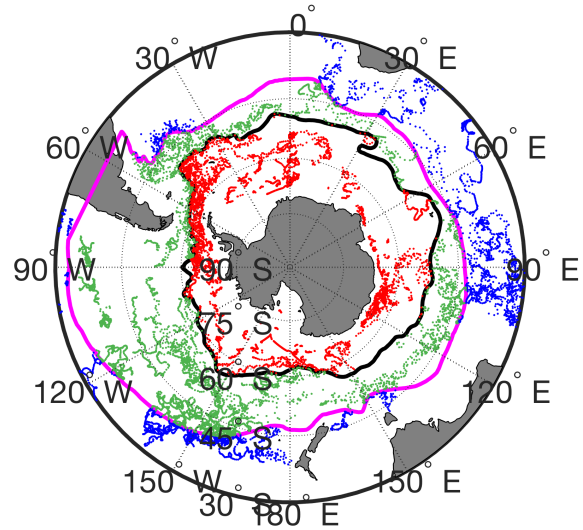
ORCAS Workshop

September 7-9, 2016

- Points indicate mean position over float lifetime
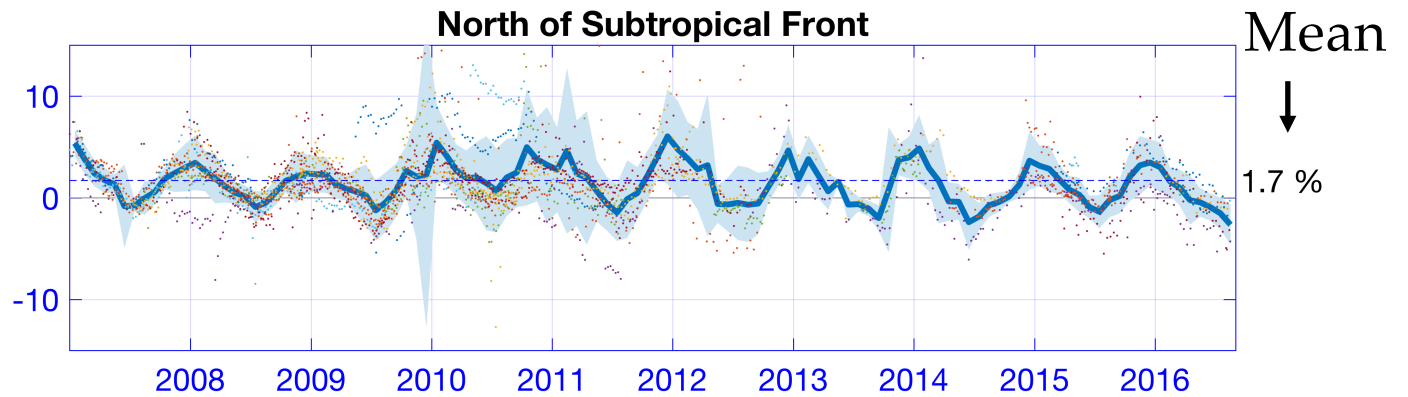- Pre-SOCCOM O_2 floats from UW O_2 dataset

Oxygen only

pH and NO$_3$ (SOCCOM)

SOCCOM — Floats and measurements

Supersaturation (%)

North of Subtropical Front

Mean ↓ 1.7 %

Subtropical Front to Polar Front

0.46 %

South of Polar Front

-3.6 %

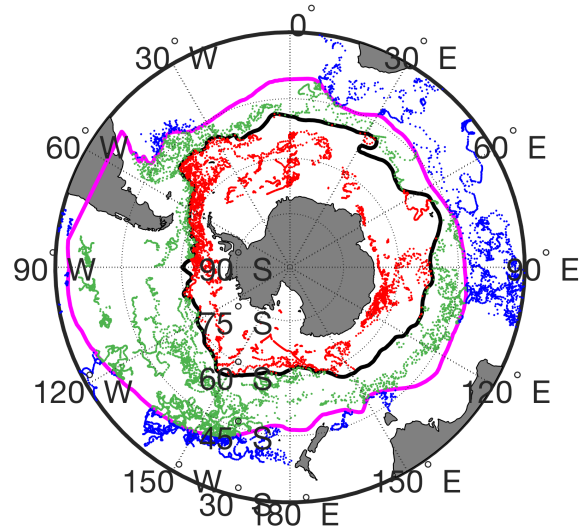Subtropical Front and Polar Front boundaries after Orsi et al. 1995
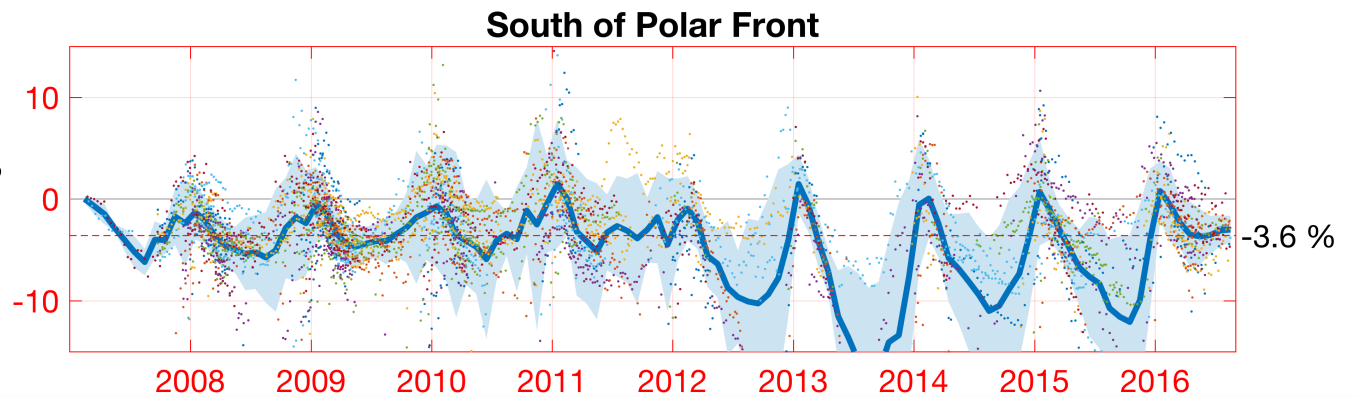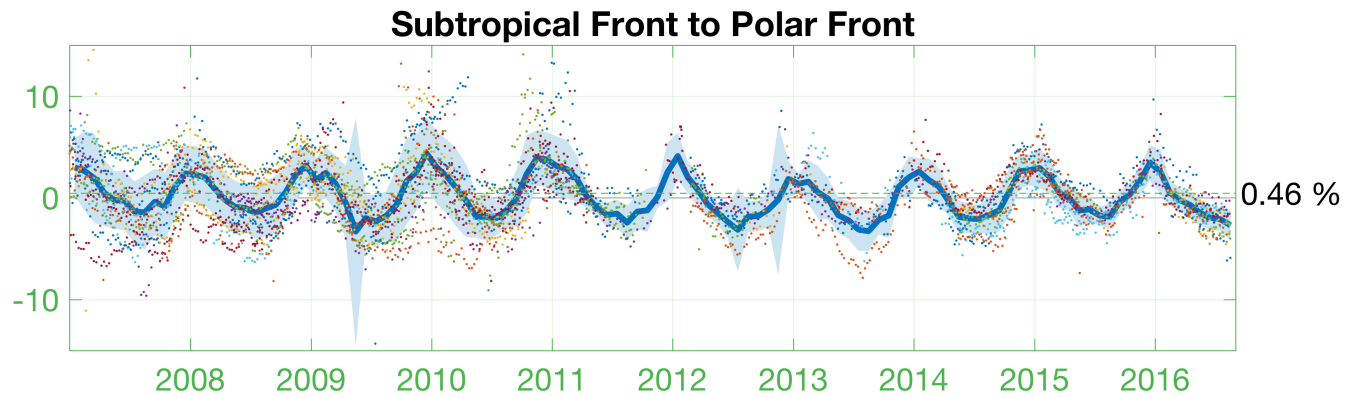
SOCCOM

O$_2$ Saturation

Blue line / area: mean / std.

Supersaturation (%)

North of Subtropical Front

Mean ↓

1.7 %

Subtropical Front to Polar Front

0.46 %

South of Polar Front

-3.6 %

Subtropical Front and Polar Front boundaries after Orsi et al. 1995
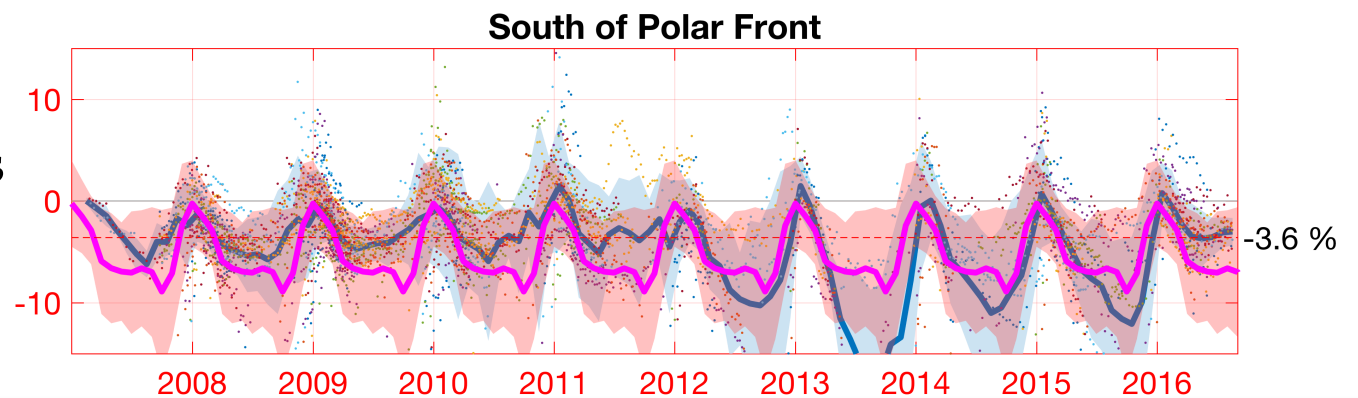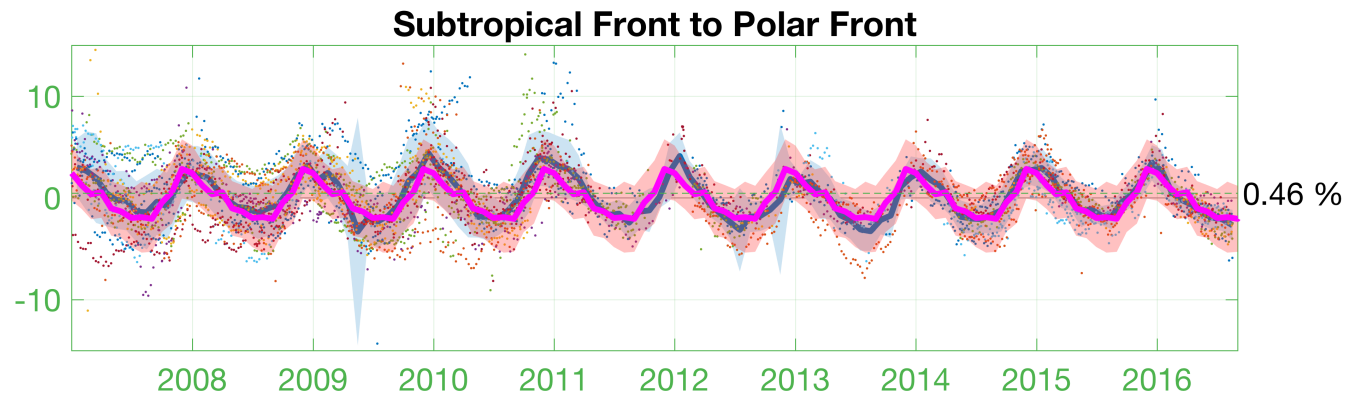
SOCCOM

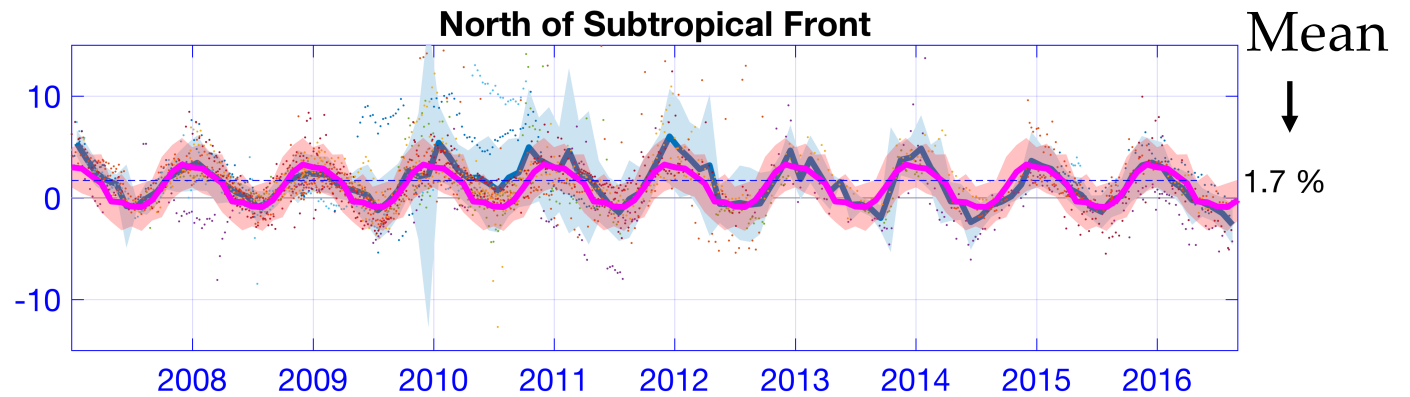O₂ Saturation vs. WOA

Blue line/area: mean/std, Magenta line/area: WOA mean/std

Air-Sea exchange flux:

$$F = k([C] - [C]_{sat}), \quad mmol \ C \ m^{-2}d^{-1}$$

$$(k_{CO2}: Wanninkhof \ 2014; \ k_{O2}: Liang \ et \ al. \ 2013)$$

pCO$_2$ from:

pH (measured) and Alkalinity (regression to float data)

$$A_T = \alpha_0 + \alpha_S S + \alpha_\theta \theta + \alpha_{NO3} NO_3$$
$$(LIAR, Carter \ et \ al. \ 2016; Williams \ et \ al. \ 2016)$$

$$fCO_2 = f(A_T, pH) \quad (\pm 10 \ \mu atm)$$
$$(CO2SYS \ v1.1 \ Lewis \ et \ al. \ 1998, \ modified \ by \ N. \ Williams)$$

SOCCOM   Flux calculations

$$\Delta pCO_2 = pCO_2^{ocn} - pCO_2^{atm}$$
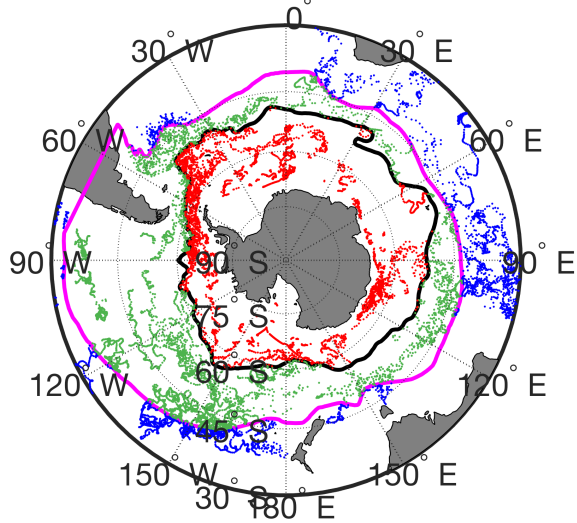

pCO_2^{atm} from Cape Grim observations

Float-based estimates compare well to in situ data when available

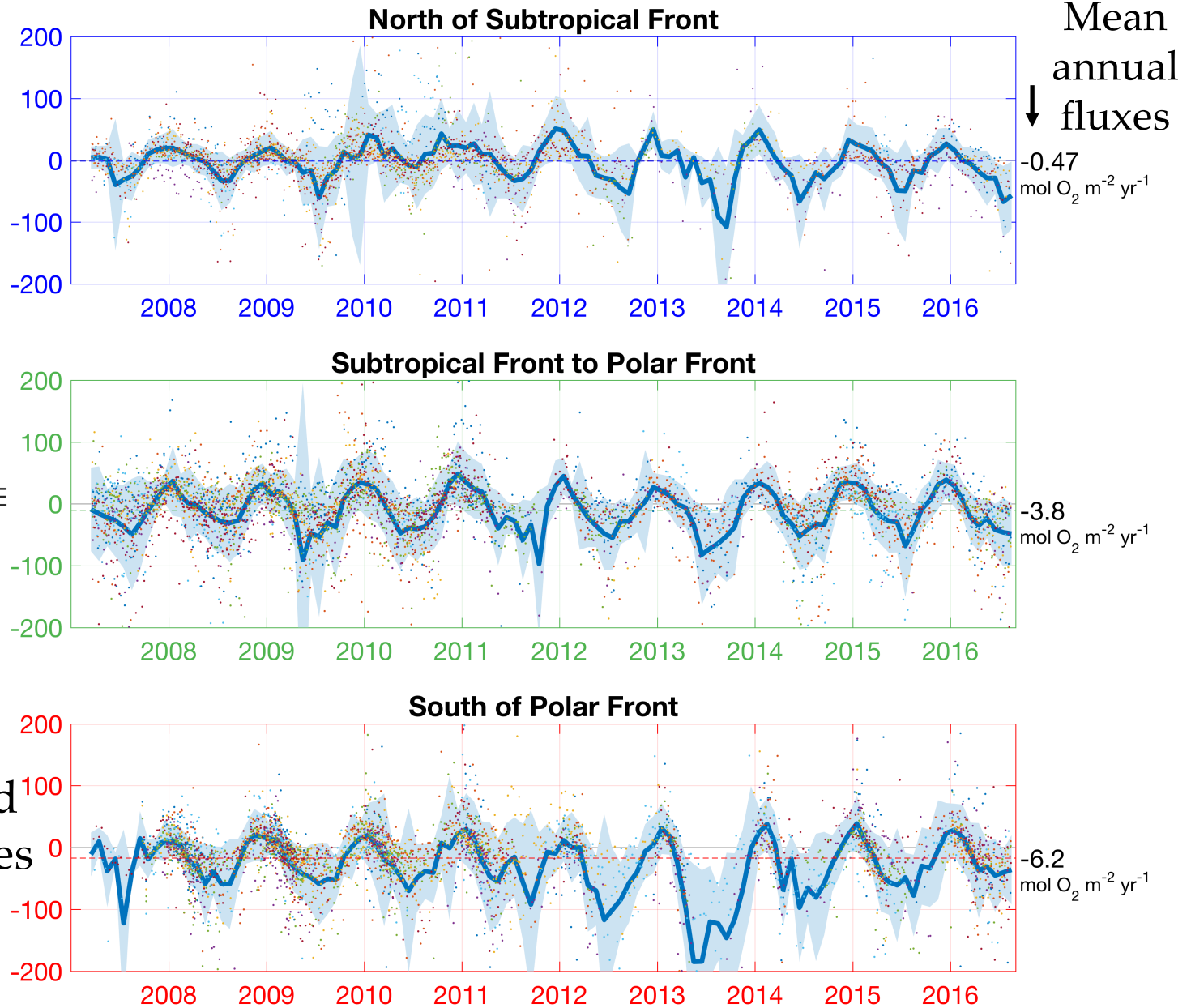Larger disagreements at higher latitudes and in winter
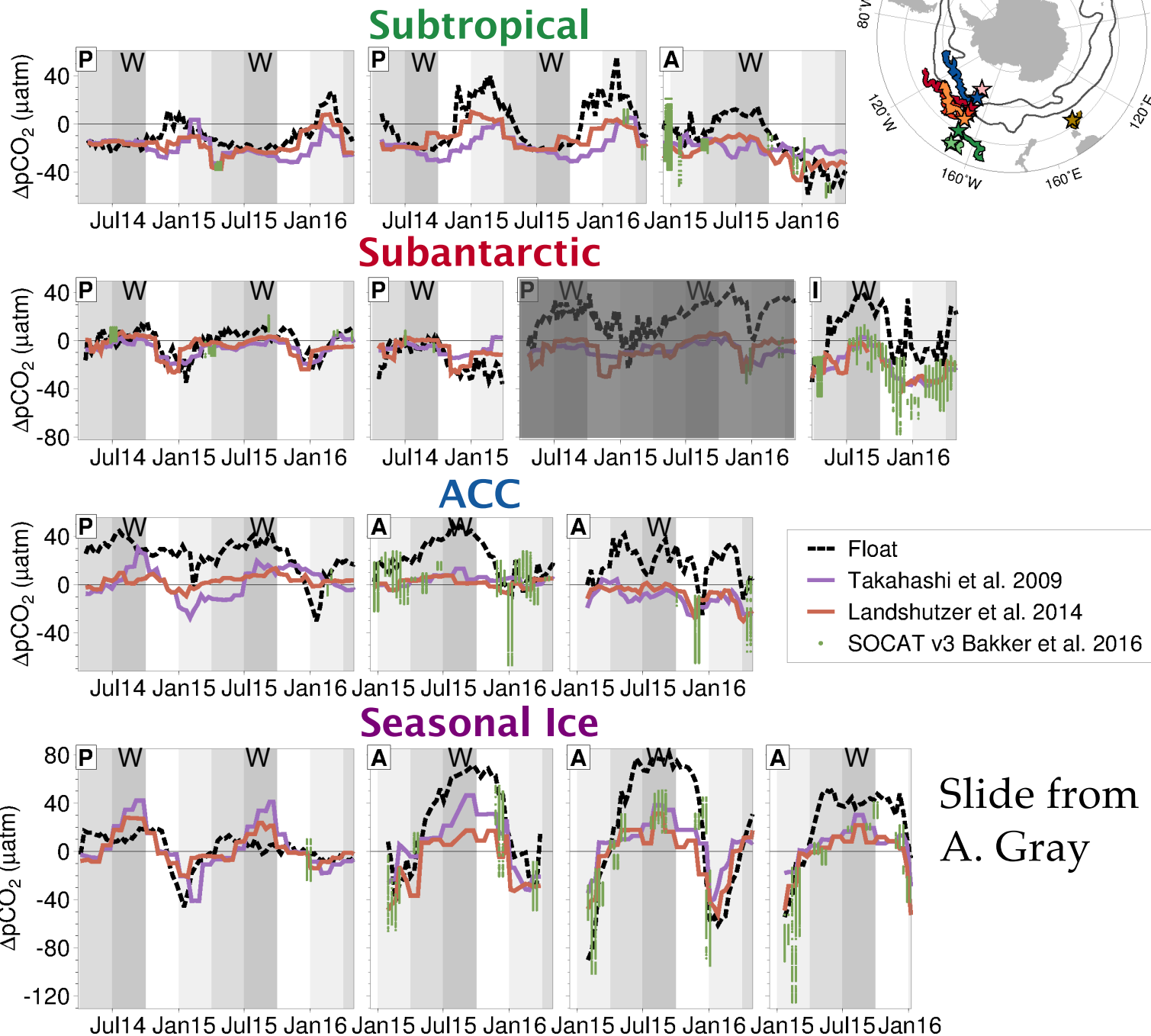
Slide from A. Gray

mmol O$_2$ m^{-2} d^{-1}

Subtropical Front and
Polar Front boundaries
after Orsi et al. 1995

North of Subtropical Front

Mean
annual
fluxes
↓
-0.47
mol O$_2$ m^{-2} yr^{-1}

Subtropical Front to Polar Front

-3.8
mol O$_2$ m^{-2} yr^{-1}

South of Polar Front

-6.2
mol O$_2$ m^{-2} yr^{-1}

SOCCOM Air-Sea O$_2$ Flux (positive to atmos.)

mmol CO$_2$ m^{-2} d^{-1}

North of Subtropical Front

Mean annual fluxes

0.16 mol CO$_2$ m^{-2} yr^{-1}

Subtropical Front to Polar Front

0.6 mol CO$_2$ m^{-2} yr^{-1}

South of Polar Front
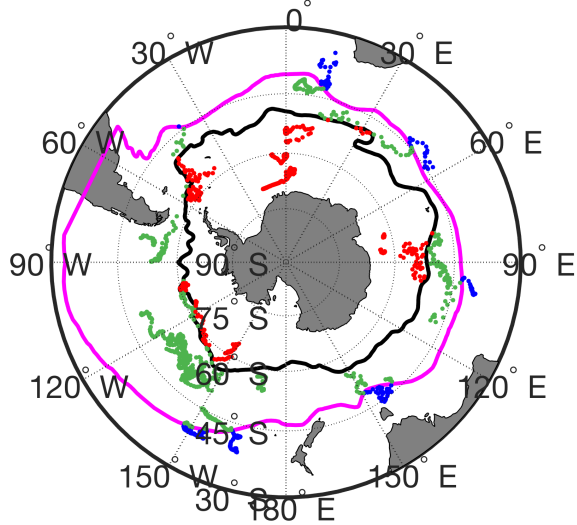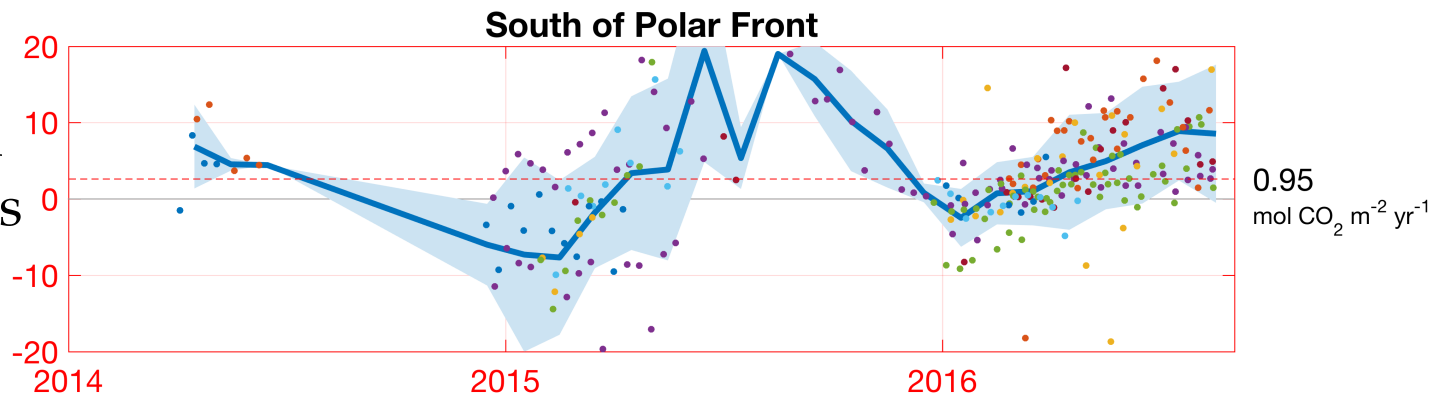
0.95 mol CO$_2$ m^{-2} yr^{-1}

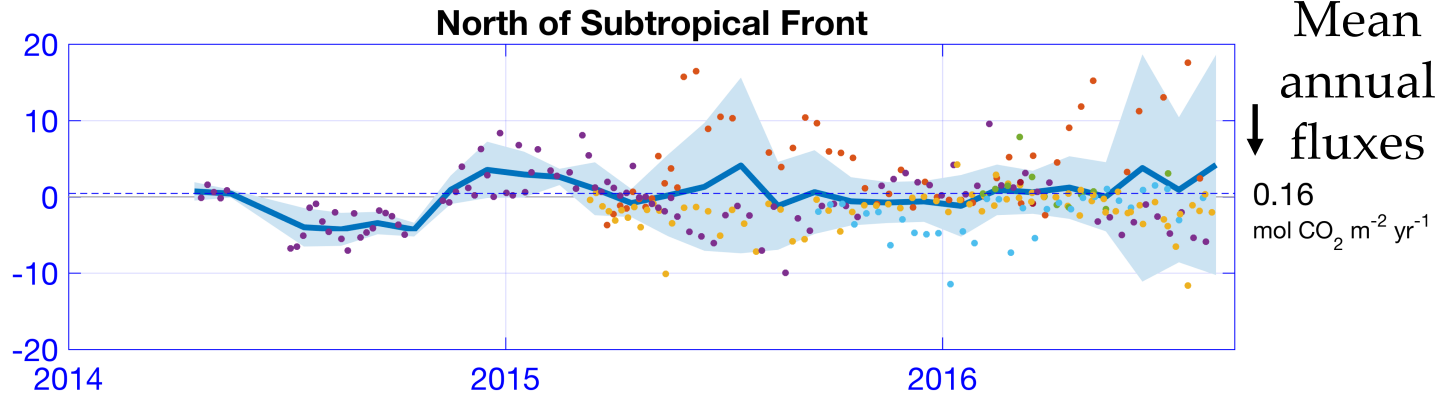Subtropical Front and **Polar Front** boundaries after Orsi et al. 1995
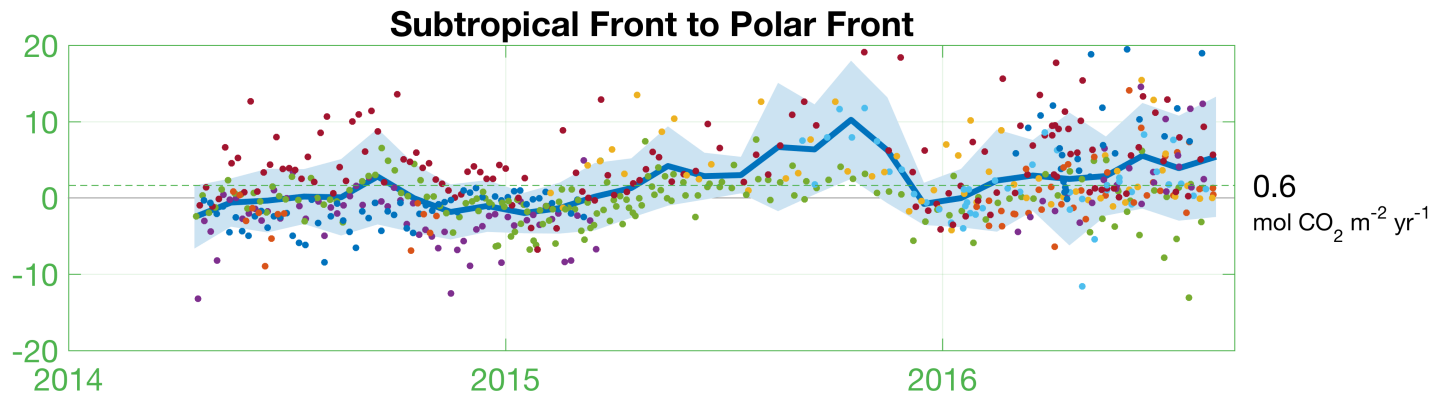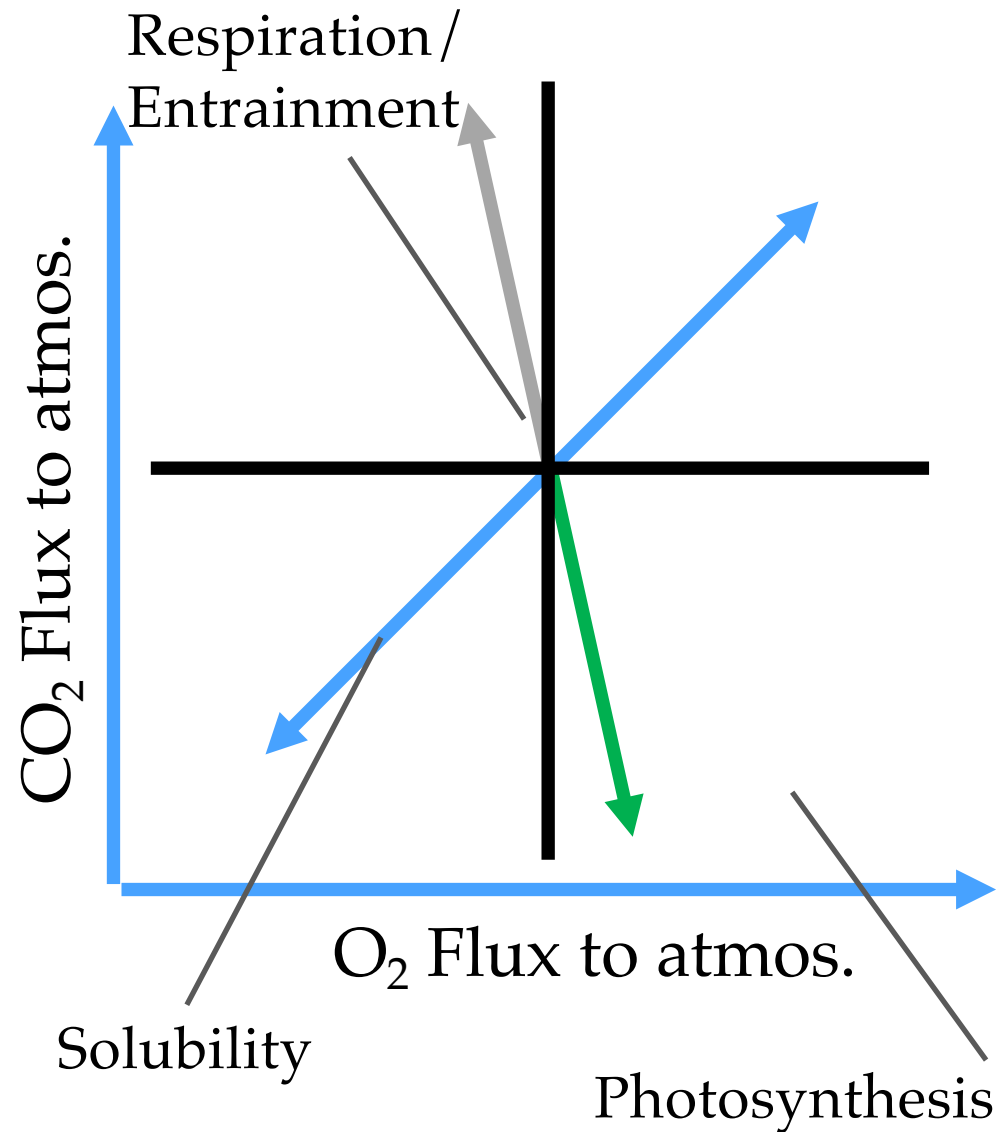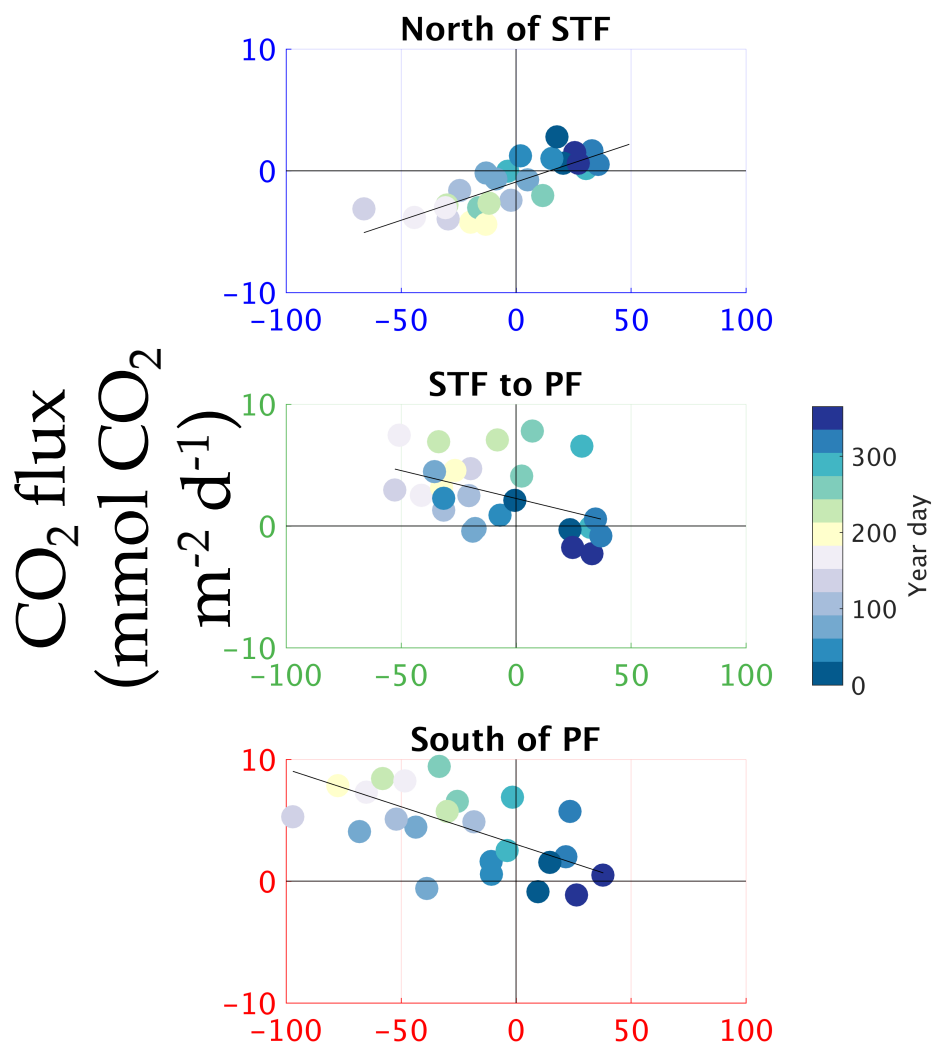
SOCCOM Air-Sea CO$_2$ Flux (positive to atmos.)

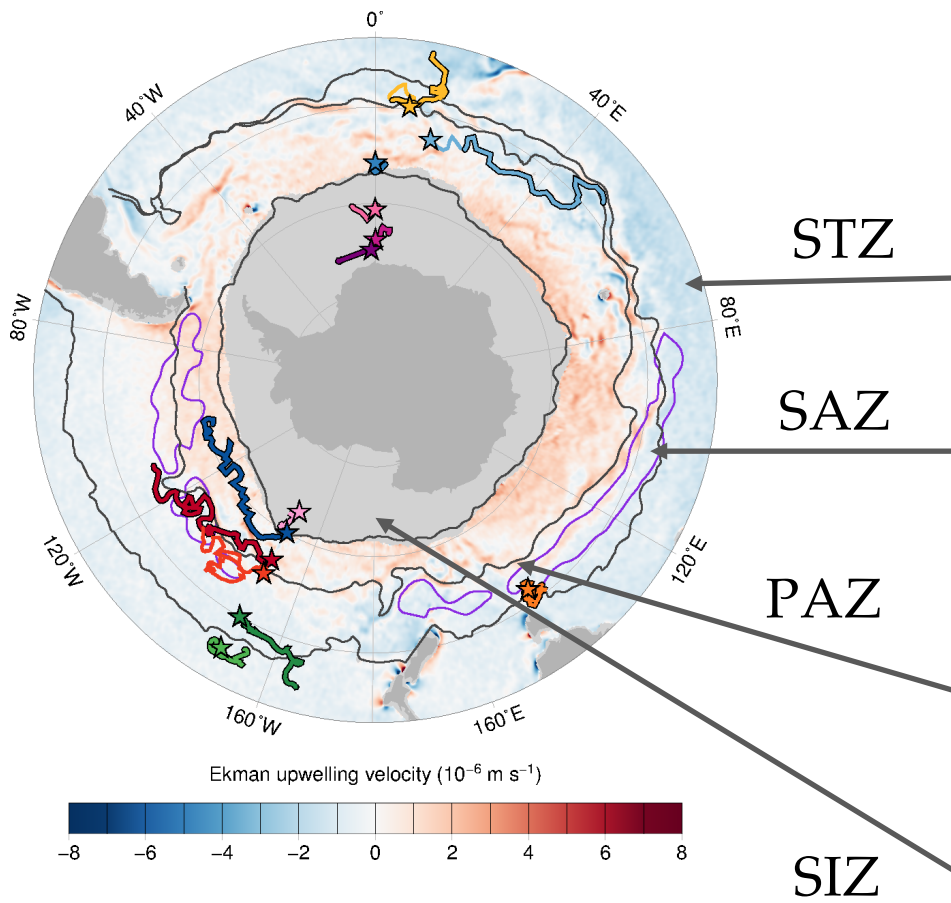# North of STF

STF to PF

South of PF

CO_2 flux ($mmol\ CO_2\ m^{-2}\ d^{-1}$)

O_2 flux ($mmol\ O_2\ m^{-2}\ d^{-1}$)

Year day

Respiration/ Entrainment

CO_2 Flux to atmos.

O_2 Flux to atmos.

Solubility

Photosynthesis

(note: scale of diagram matches scale of plots 1:10 CO_2:O_2)

SOCCOM — CO_2:O_2 flux ratios – all years

Net Flux (Pg C yr⁻¹)

Ekman upwelling velocity (10⁻⁶ m s⁻¹)

Slide from A. Gray

a Total SO Flux

STZ

b

SAZ

c

PAZ

d

SIZ

e
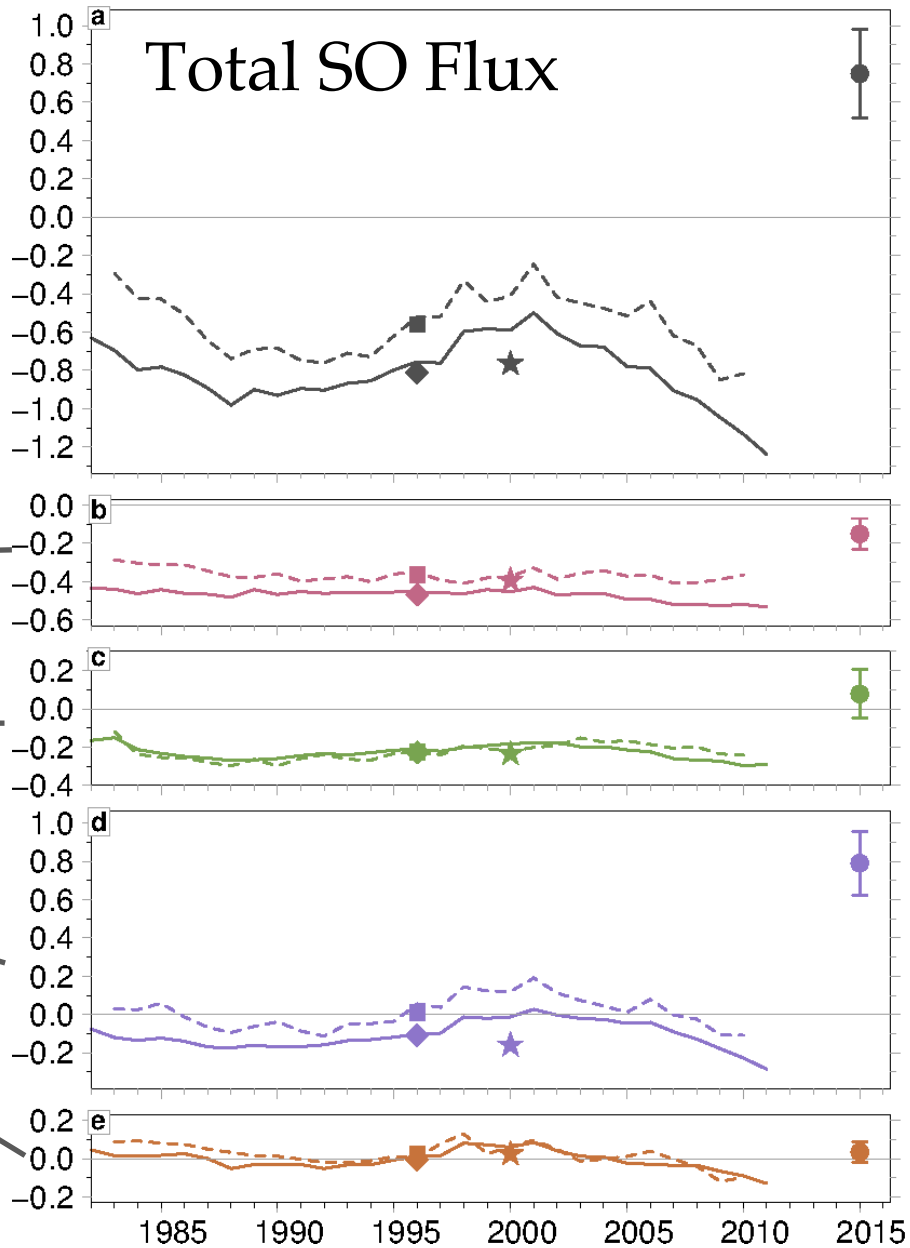
Net CO₂ Fluxes

Neural network and climatology compared to SOCCOM estimates

Progress on oxygen and carbon dioxide fluxes:
- Flux ratios indicate solubility changes dominate in subtropics, biology/entrainment in polar region
- Significant net outgassing of CO_2, contradicts climatological/neural network estimates

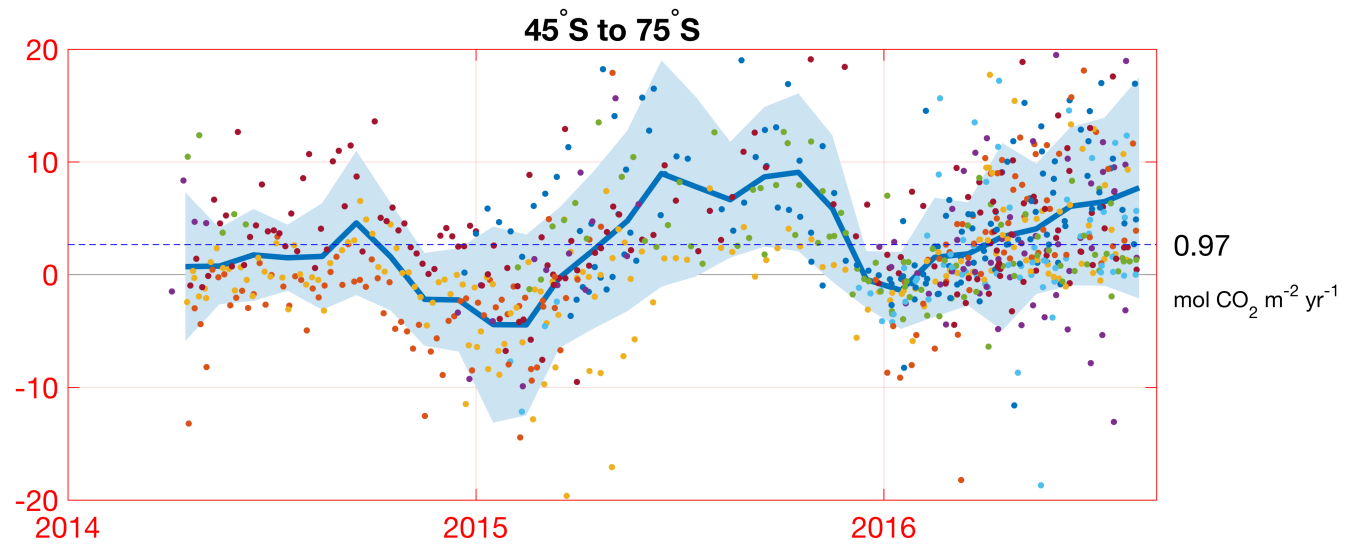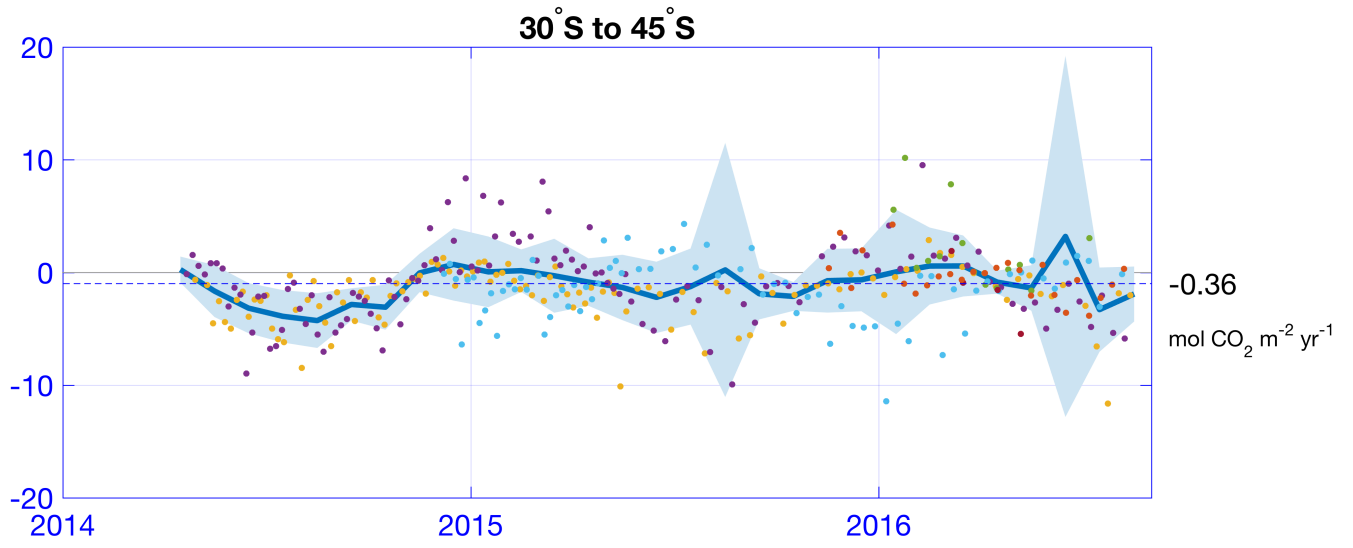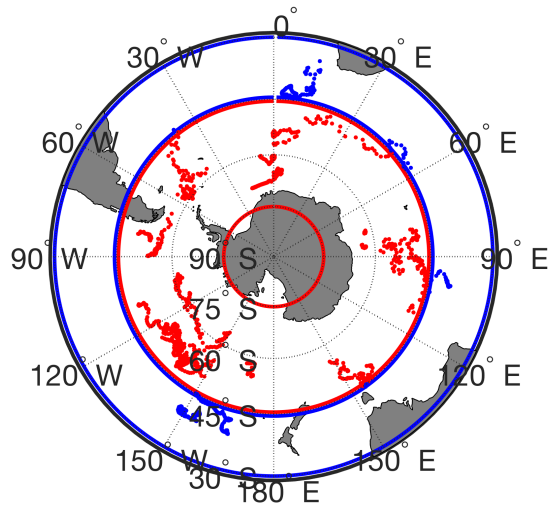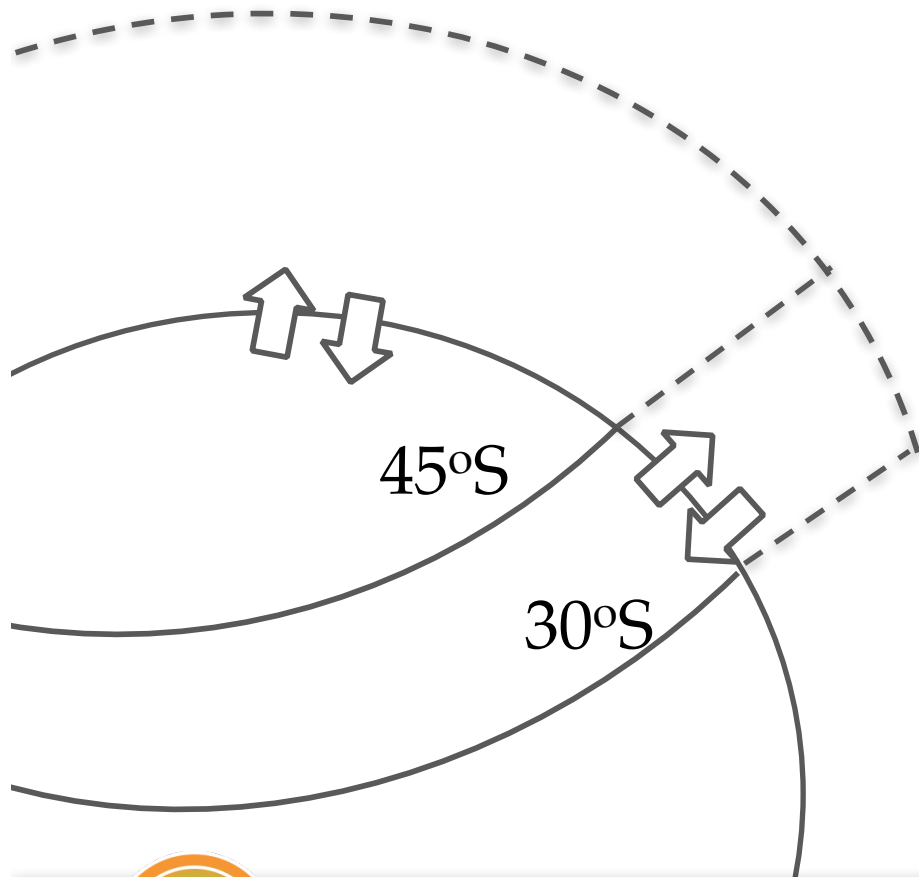How do these flux estimates relate to atmospheric measurements/interpretation?

SOCCOM

30°S to 45°S

−0.43
mol O₂ m⁻² yr⁻¹

45°S to 75°S

−6.2
mol O₂ m⁻² yr⁻¹
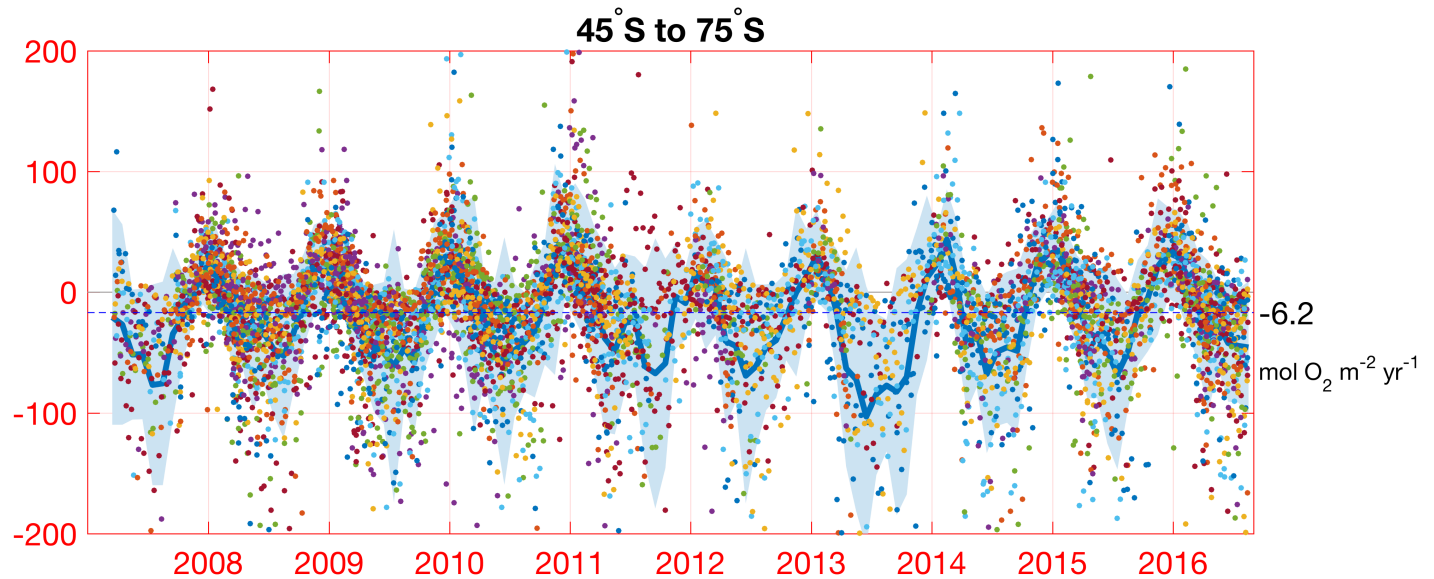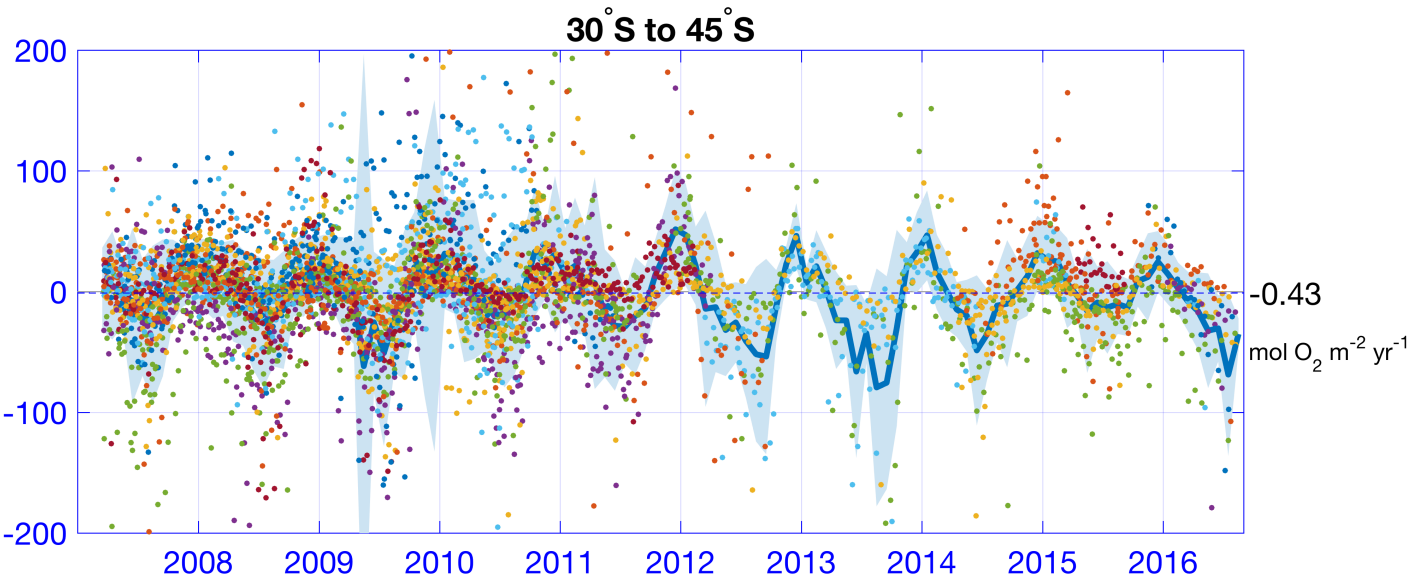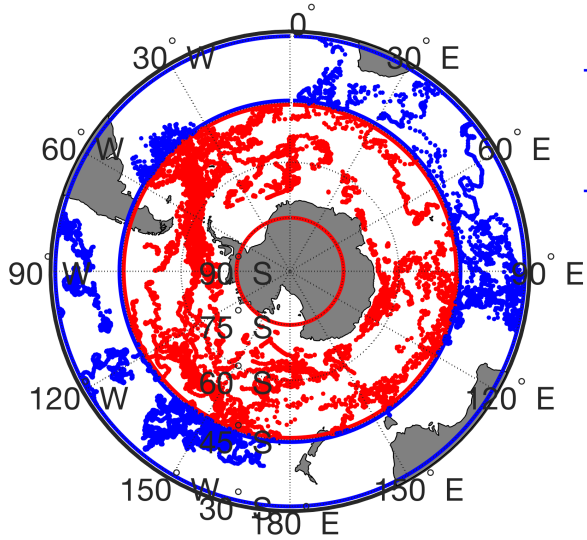
SOCCOM

O₂ flux: latitude bounds

30°S to 45°S

-0.36

mol CO₂ m⁻² yr⁻¹

45°S to 75°S

0.97

mol CO₂ m⁻² yr⁻¹

SOCCOM

CO₂ flux: latitude bounds

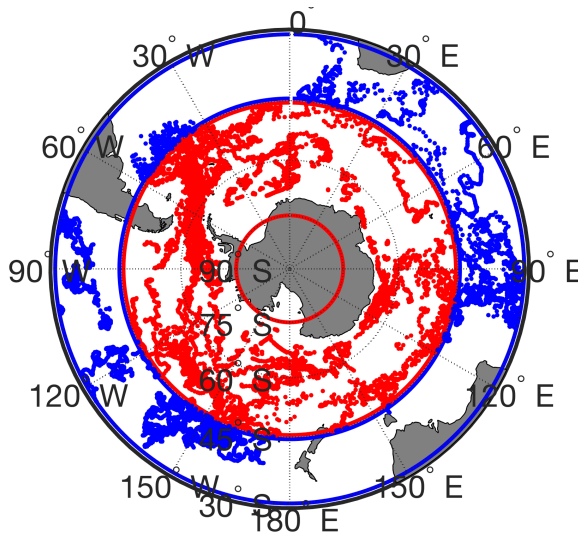# Simple calculation of expected atmospheric changes due to air-sea fluxes

Assumptions:
- Only fluxes impacting atmospheric concentrations are ocean-atmosphere
- 10 km lower atmosphere mixing layer
- Constant N_2

45ºS

30ºS

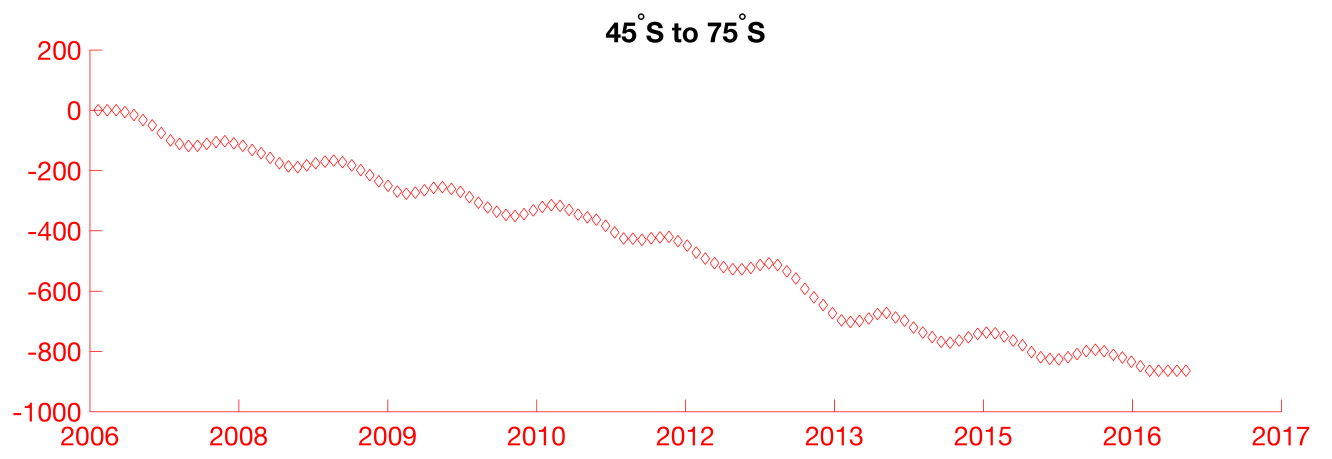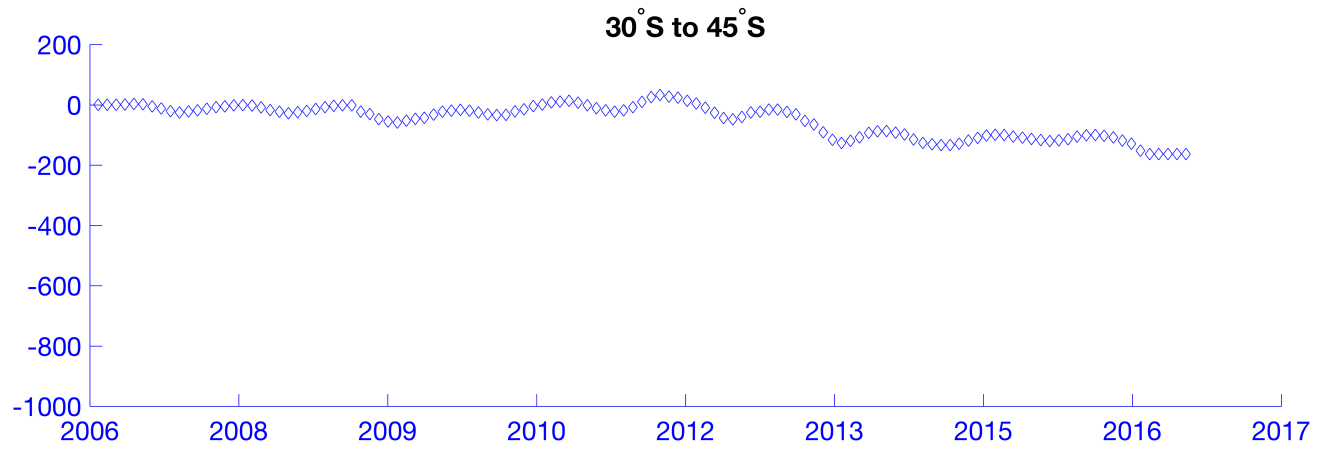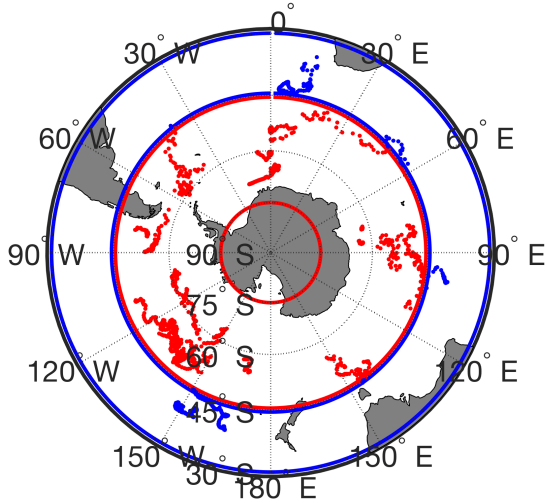**SOCCOM** Impact of ocean fluxes on atmos.

δ(O₂/N₂) (per meg)

30°S to 45°S

45°S to 75°S

SOCCOM   Impact of ocean fluxes on atmos.

pCO$_2$ (ppm)

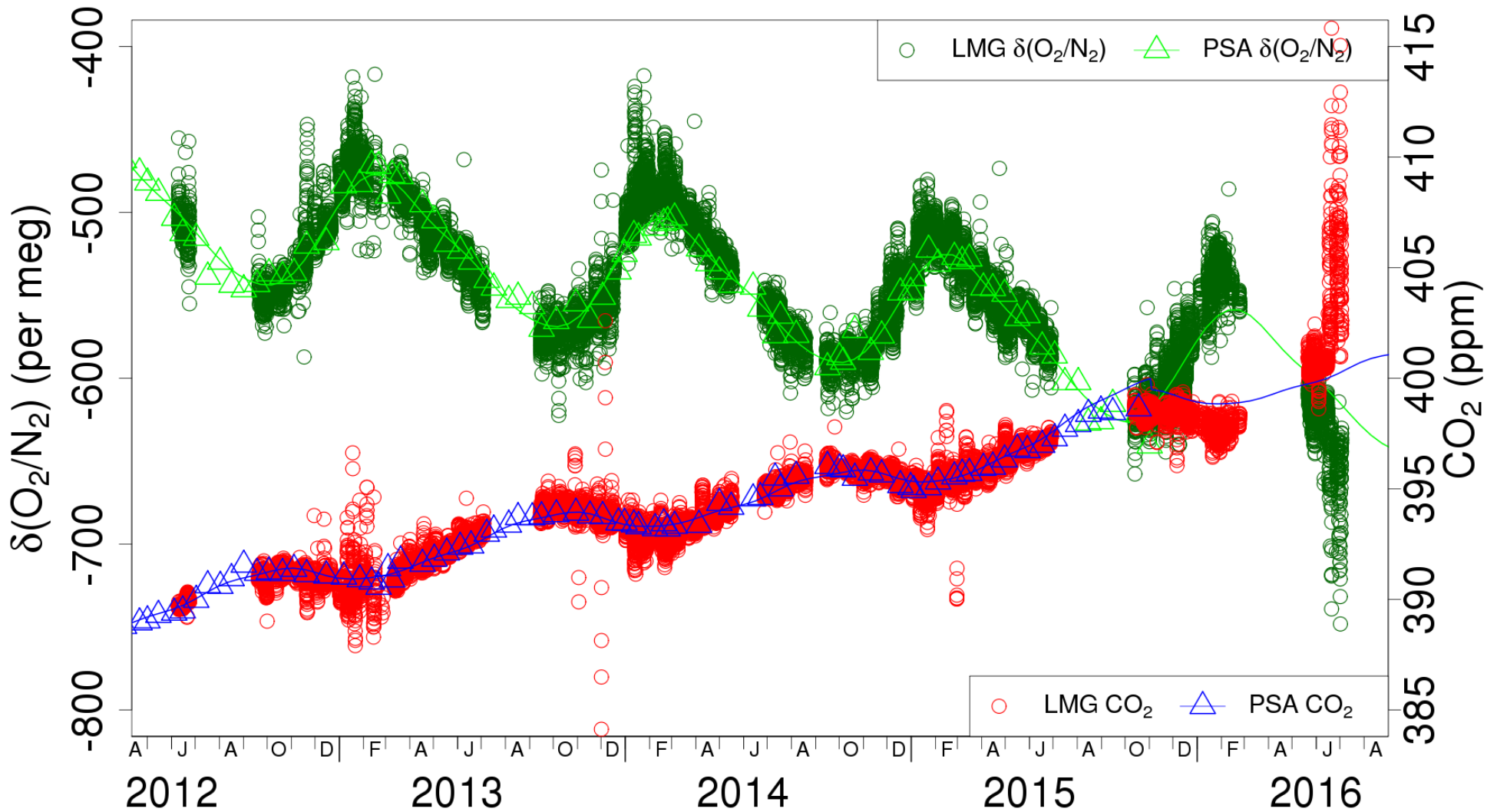30°S to 45°S
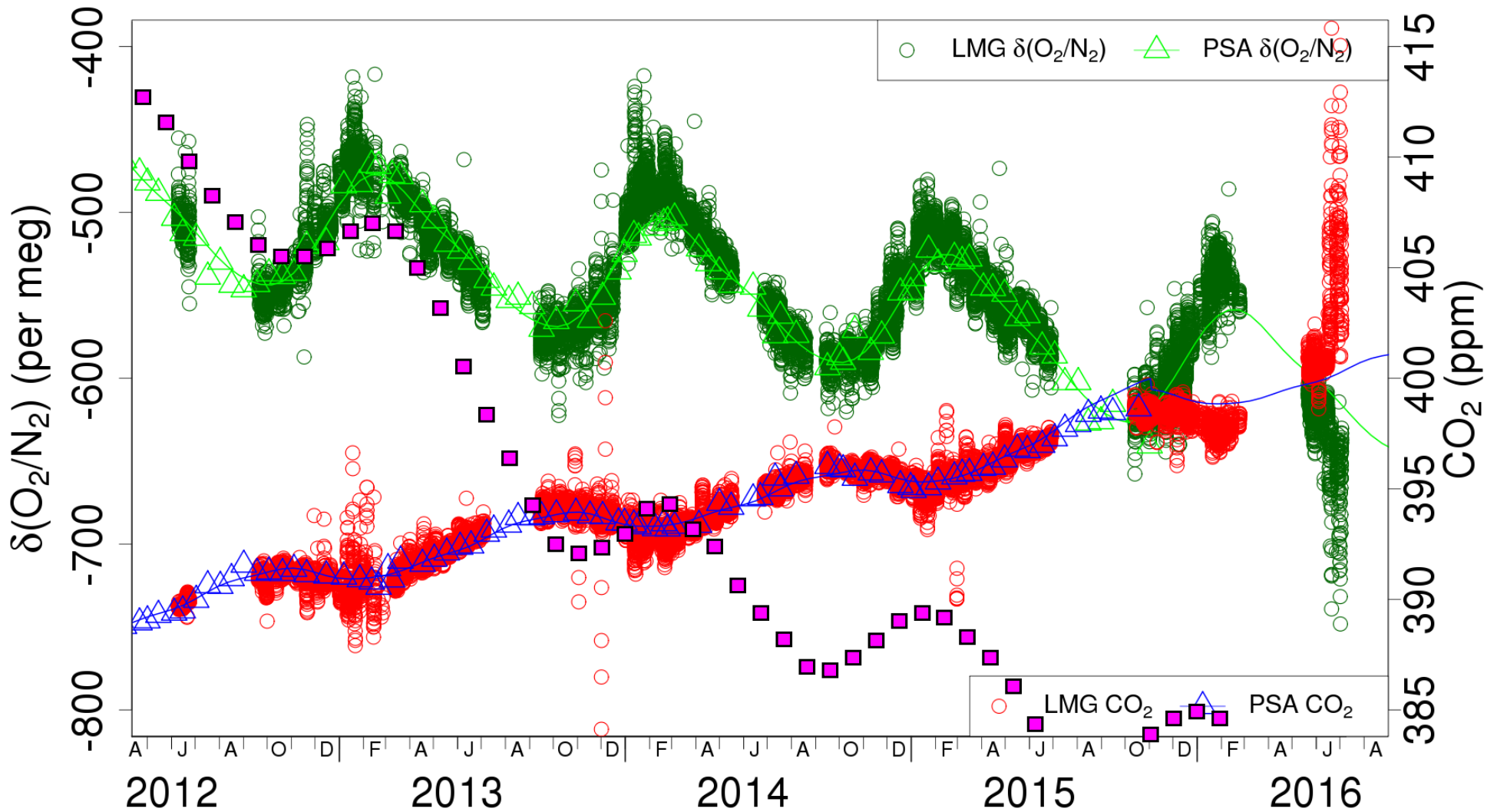
45°S to 75°S
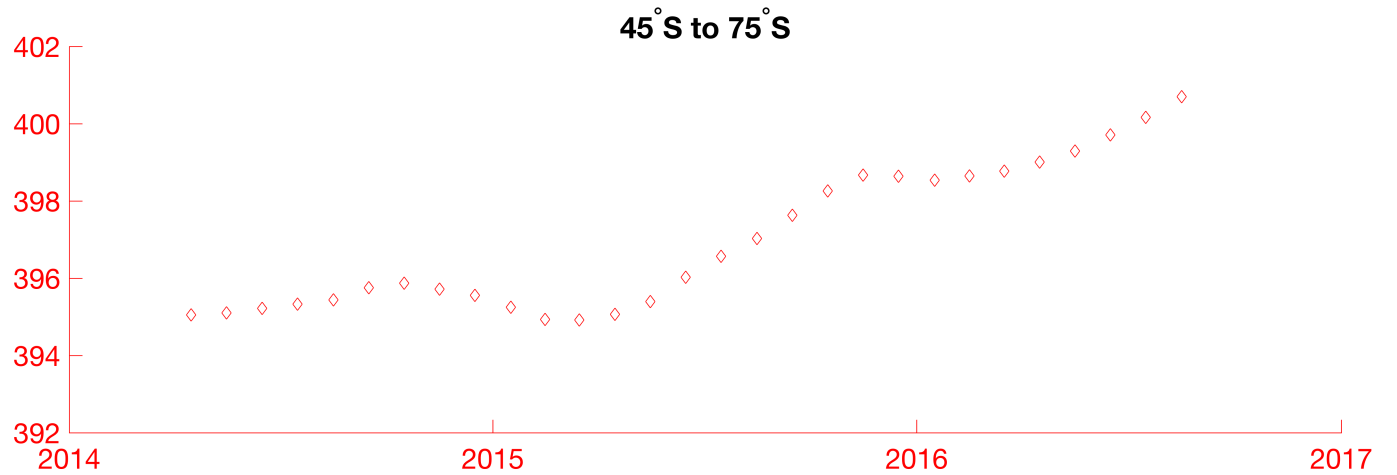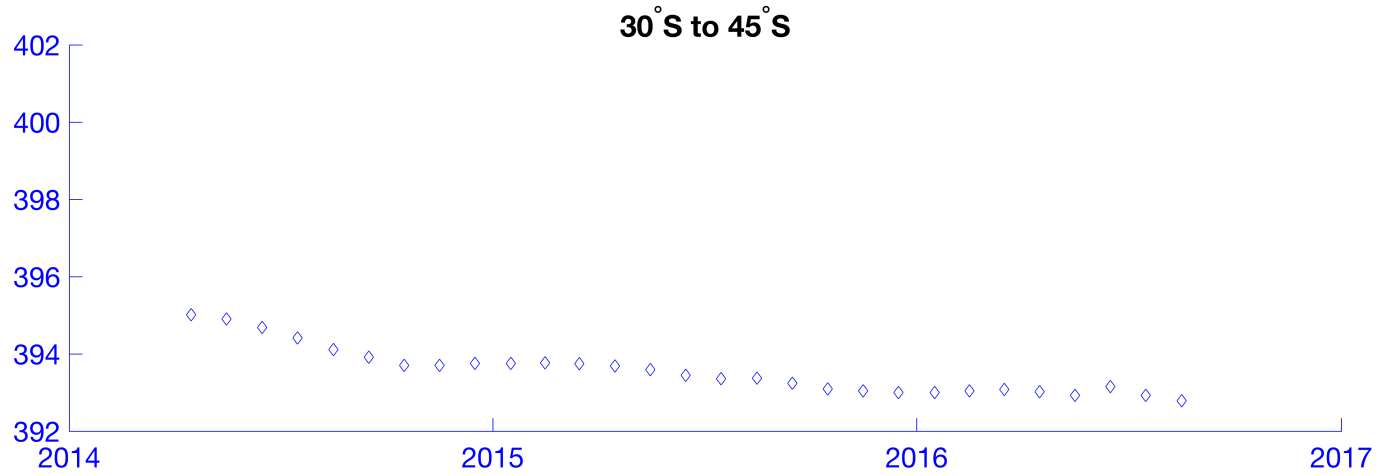
SOCCOM **Impact of ocean fluxes on atmos.**

SOCCOM **Drake Passage Atmospheric Data**

Figure courtesy of B. Stephens
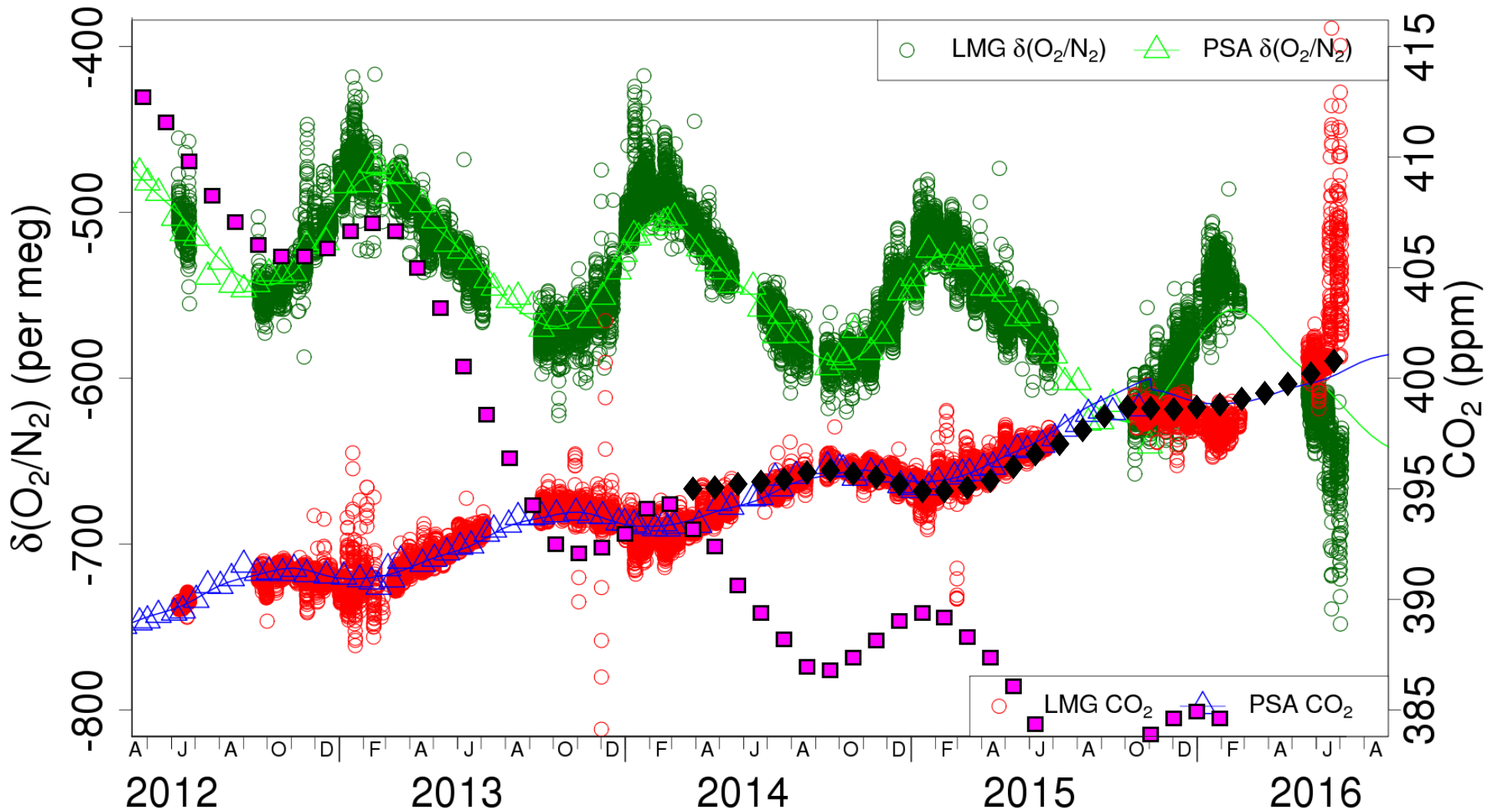
Expected from float fluxes: Oxygen ▪

SOCCOM **Atmospheric – impact of fluxes**

Comparing 45-75°S estimated atmospheric changes

Comparing 45-75ºS estimated atmospheric changes

Questions to answer:
- Are air-sea fluxes a useful constraint on atmospheric measurements?
- What is the best way to use these data and calculated fluxes?
- Atmospheric transport models – how simple/complex do they need to be to aid in interpretation of air-sea fluxes?

Other thoughts or suggestions?

SOCCOM   **Moving forward…**