Temporal variations of $\delta(O_2/N_2)$ and Atmospheric Potential Oxygen (APO) observed at Syowa Station, Antarctica.

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Outline

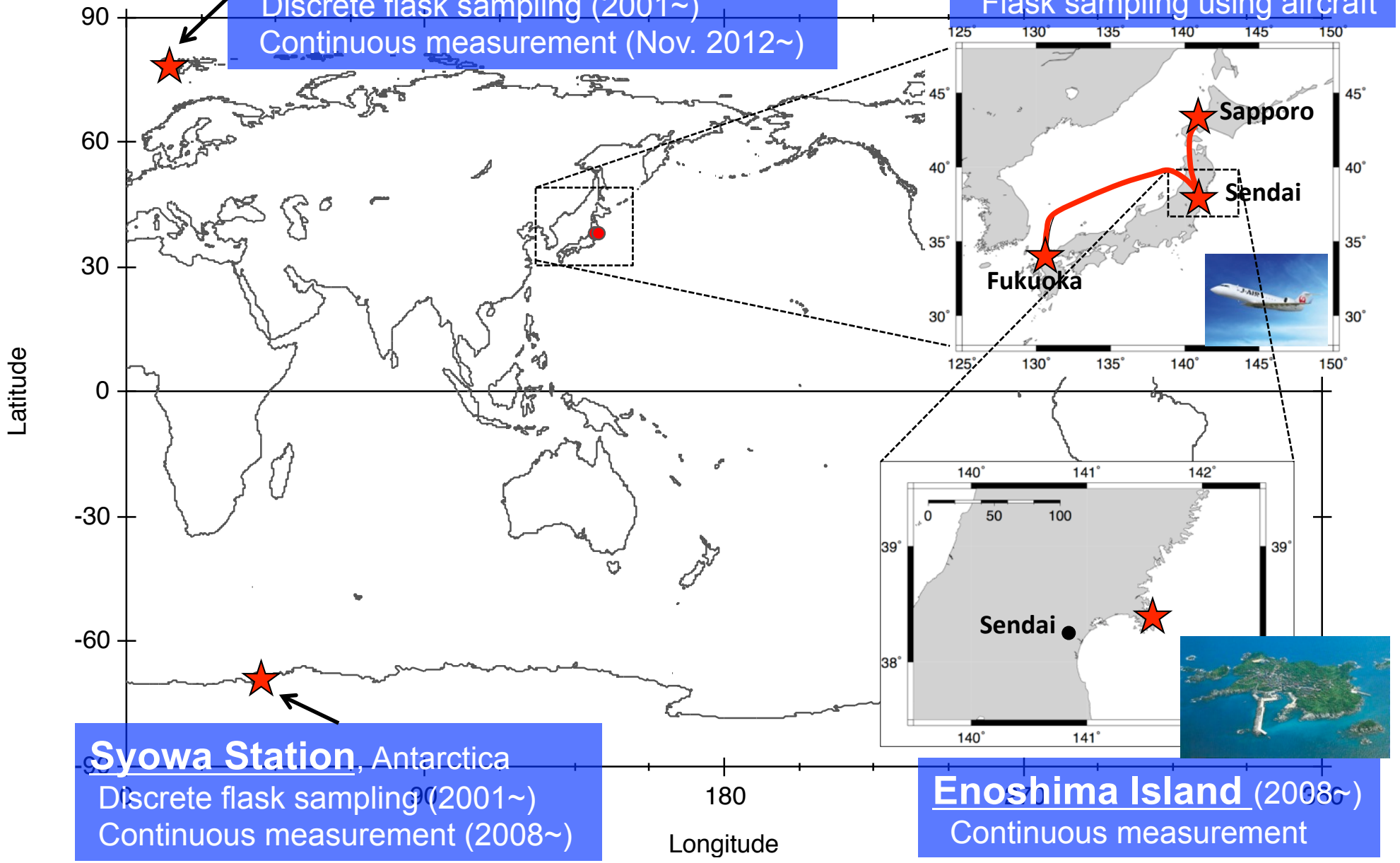
- Measurement sites by Tohoku U. and NIPR
- Continuous measurement system of $\delta(O_2/N_2)$

- Seasonal variations of APO at Syowa Station
- Synoptic scale variations of $\delta(O_2/N_2)$ and CO_2

O_2 observation sites of TU & NIPR

Ny-Ålesund, Svalbard
Discrete flask sampling (2001~)
Continuous measurement (Nov. 2012~)

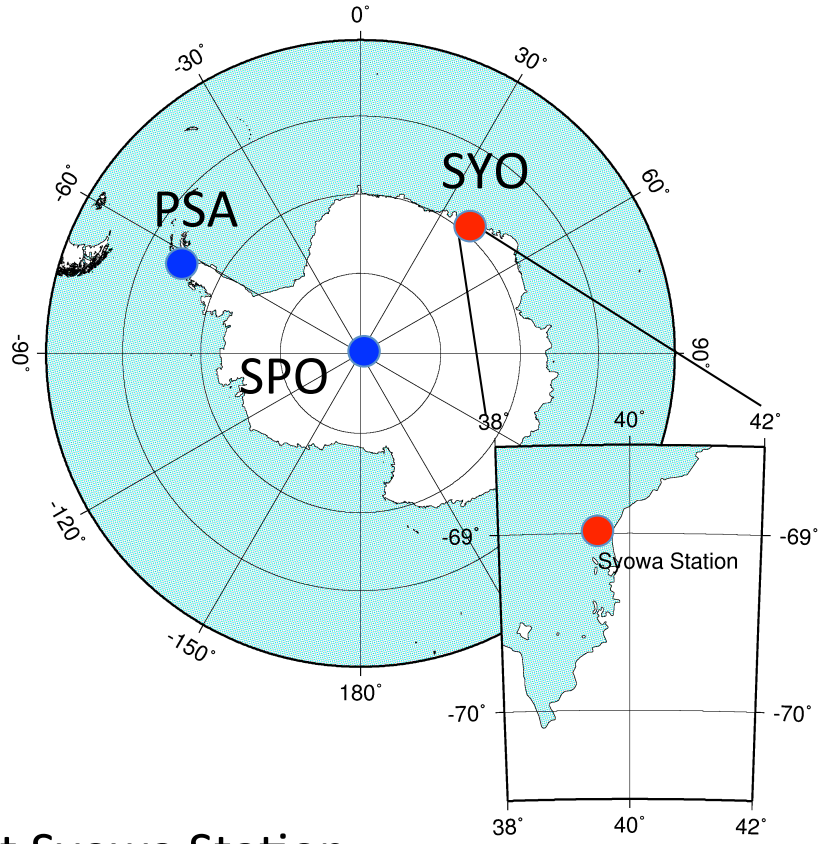
Over Japan (1999~)
Flask sampling using aircraft



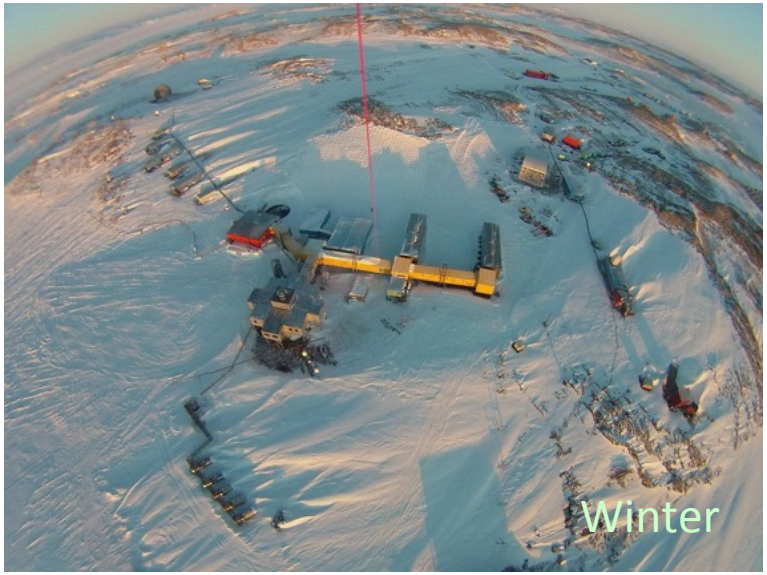
Syowa Station, Antarctica
Discrete flask sampling (2001~)
Continuous measurement (2008~)

Enoshima Island (2008~)
Continuous measurement

Syowa Station (SYO), Antarctica (69°S, 39.6°E)







<u>At Syowa Station</u>

Air sampling for TU, NOAA, PU

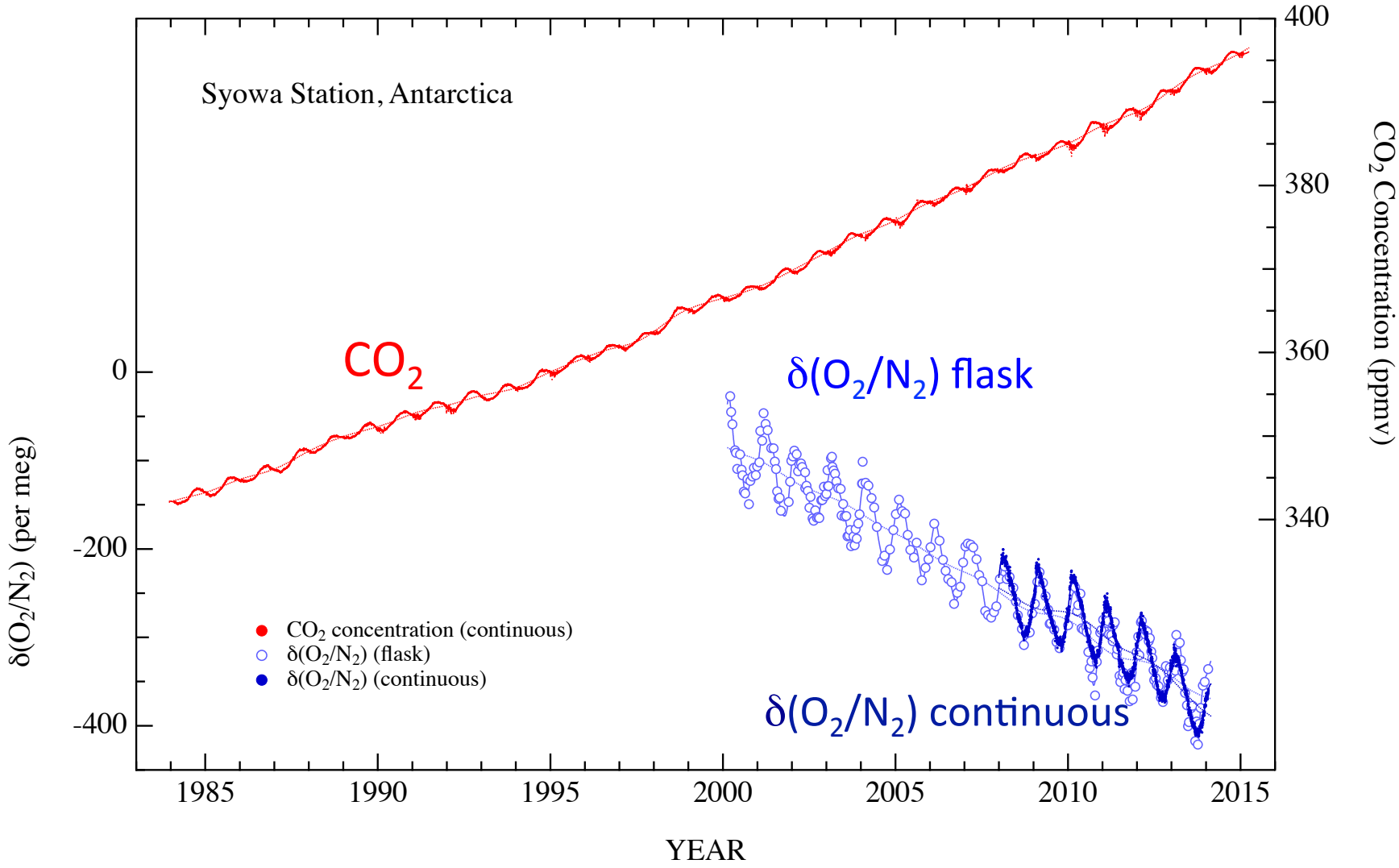
CO_2 continuous (1984 -)

CH_4 continuous (1988 -)

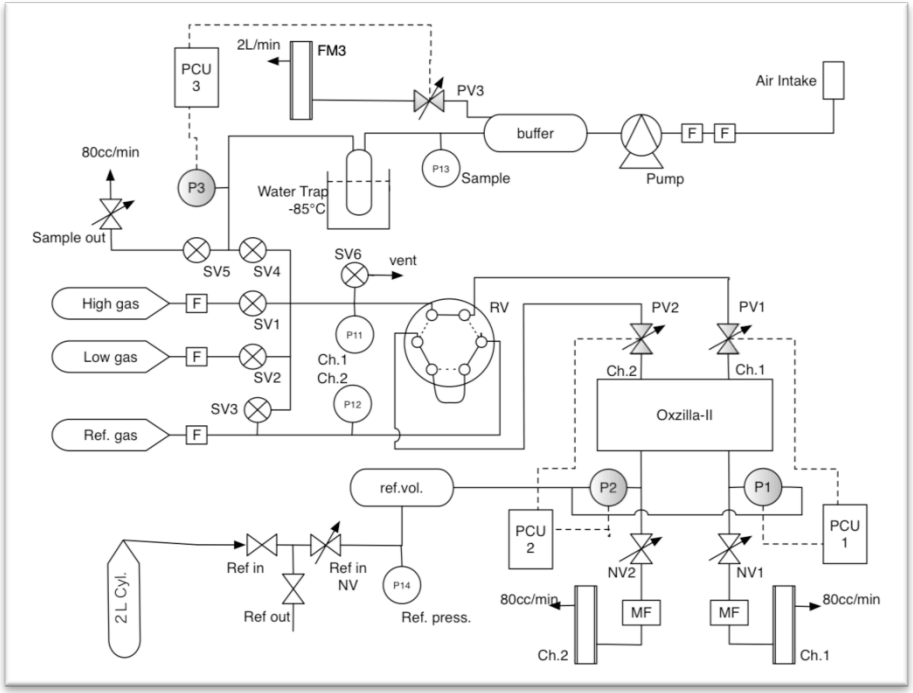
CO continuous (2000 -)

O_2/N_2 continuous (2008 -)

CO_2 and $\delta(O_2/N_2)$ variations observed at Syowa



$\delta(O_2/N_2)$ measurement system at Syowa Station

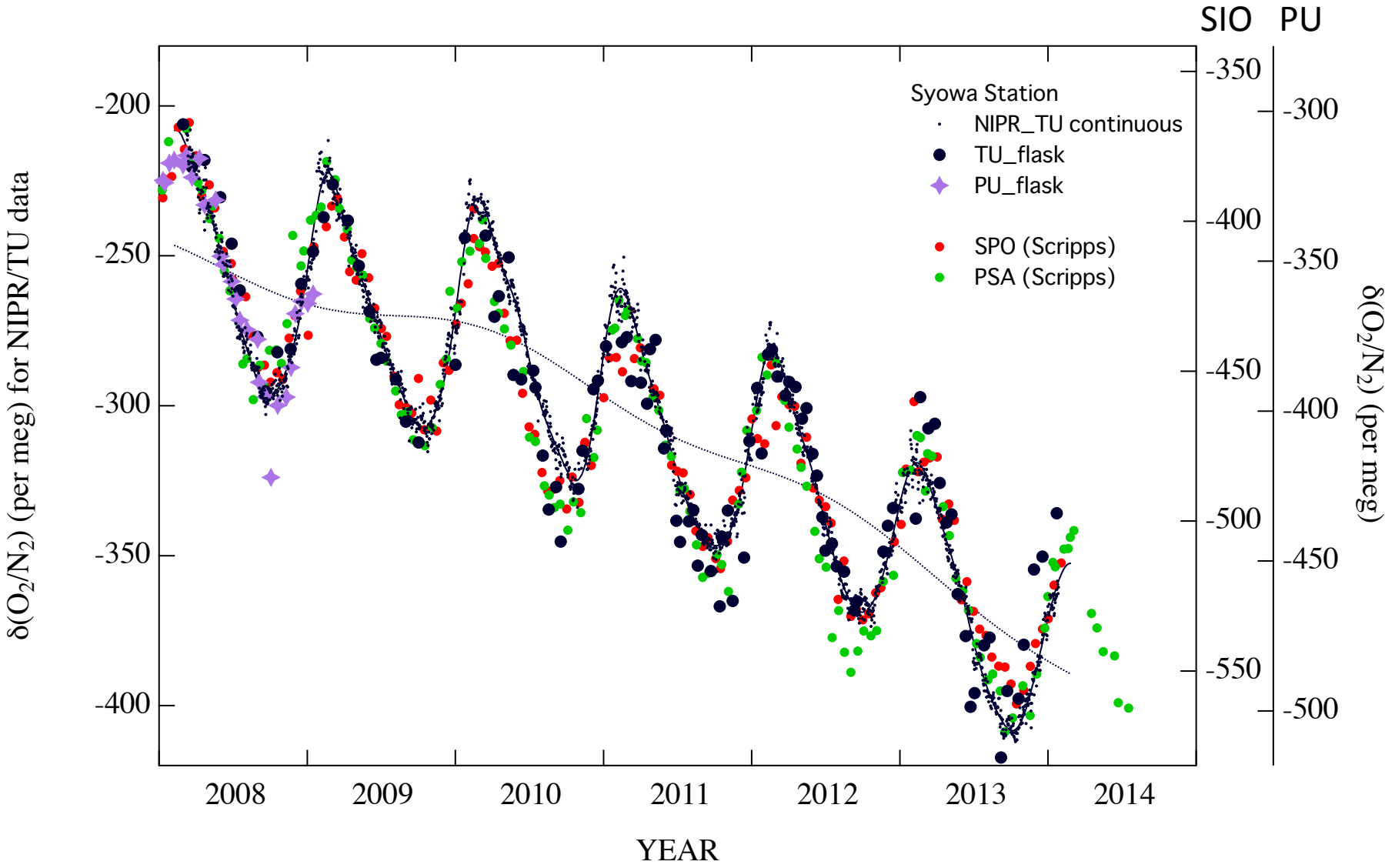






Analyzer	Oxizilla-II (Fuel Cell)
Calibration	TU scale (Ishidoya et al., 2003)
Reproducibility	2.5 per meg (1 sigma)

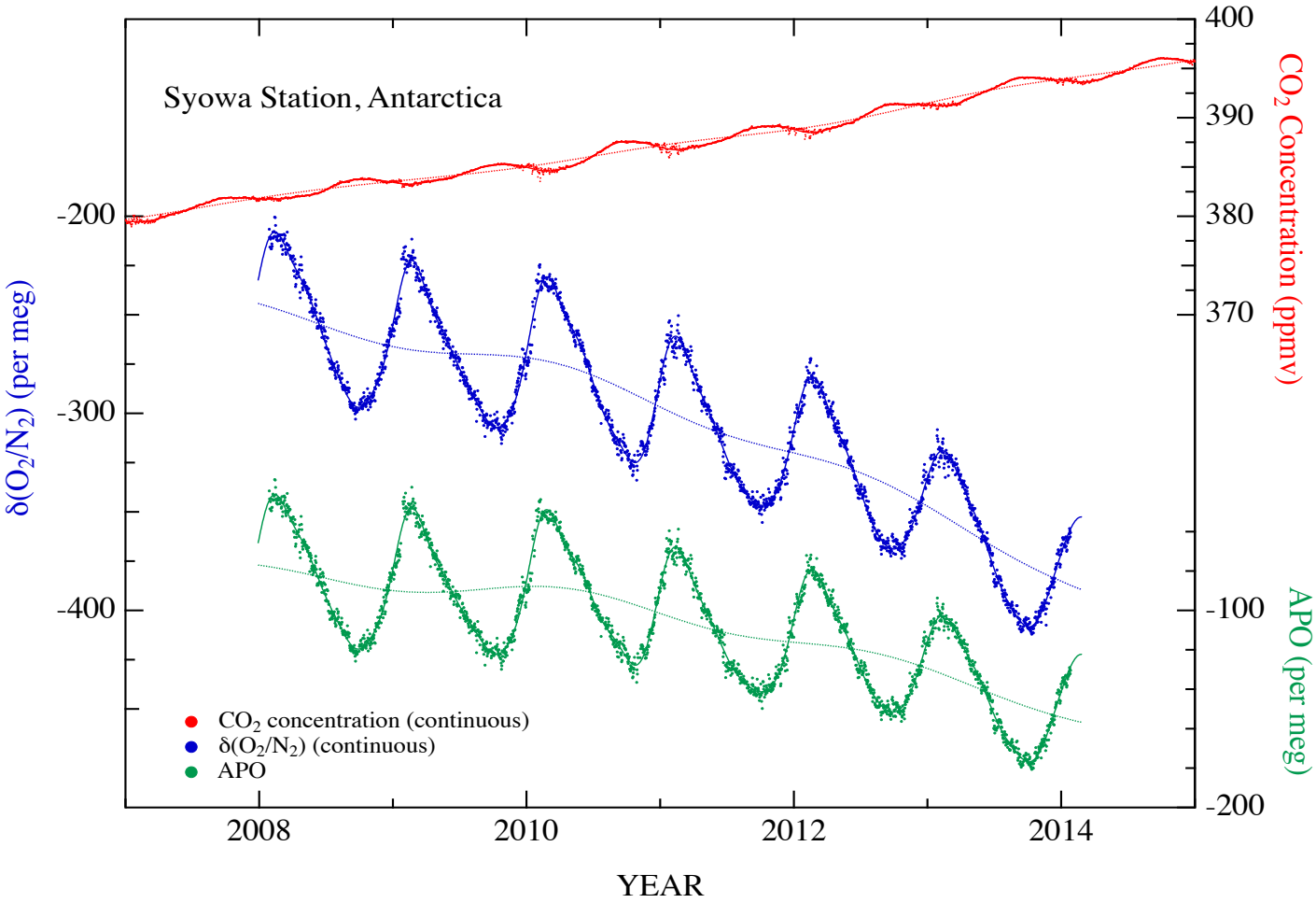
Comparison with Princeton and SIO data



Princeton data were provided by N. Cassar

Scripps data were downloaded from the SIO website (Aug.,2015)

Temporal variations of CO_2, $\delta(O_2/N_2)$ and APO



Trend (2008-2013)
- 1.98 ppm/yr
- -22.2 per meg/yr
- -11.7 per meg/yr

Seasonal amplitude (peak-to-peak; 2008-2013 average)
- 1.35 ppm
- 71.9 per meg
- 65.3 per meg

daily standard dev.

CO_2	0.00 – 0.24 ppm	average 0.05 ppm
$\delta(O_2/N_2)$	1.1 – 17.7 per meg	average 3.7 per meg

Simulation of APO and $\delta(O_2/N_2)$ by ACTM

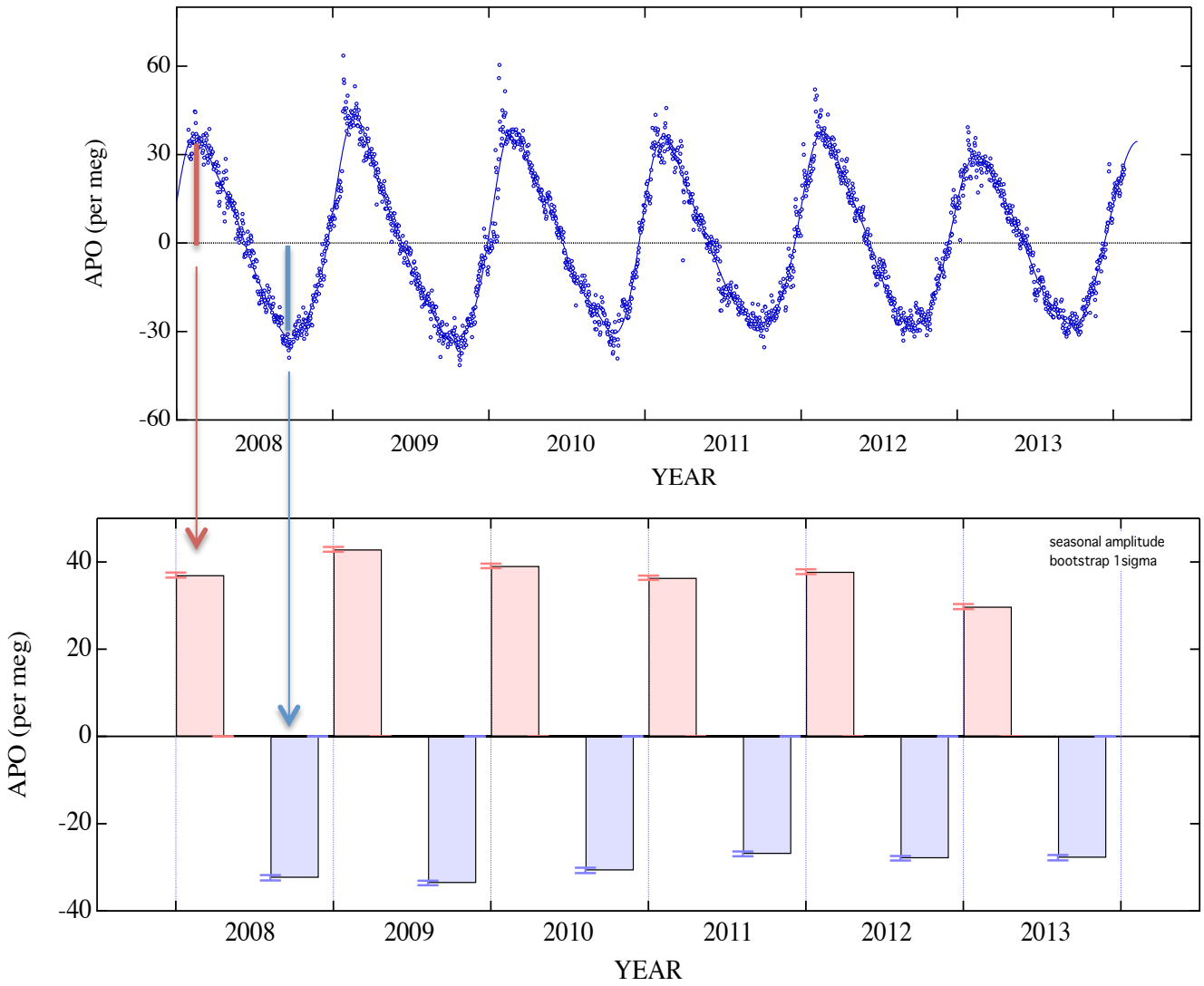
(Atmospheric General Circulation Model-based Chemistry Transport Model) (Patra et al., 2009)

	Data set used in this model simulation
Transport Model	CCSR/NIES/FRCGC AGCM5.7b
Ocean fluxes O_2 & N_2 CO_2	 Garcia & Keeling, 2001; Blaine, Ph. D. Thesis Inversion ACTM (Patra et al., 2011)
Terrestrial fluxes O_2 CO_2	 [Terrestrial CO_2] * (-1.1) Inversion ACTM (Patra et al., 2011)
Fossil fuel fluxes	EDGAR 4.2, scaled to CDIAC global totals

Transport : variable

Fluxes : monthly, cyclic (no interannual variations)

Seasonal variations of APO

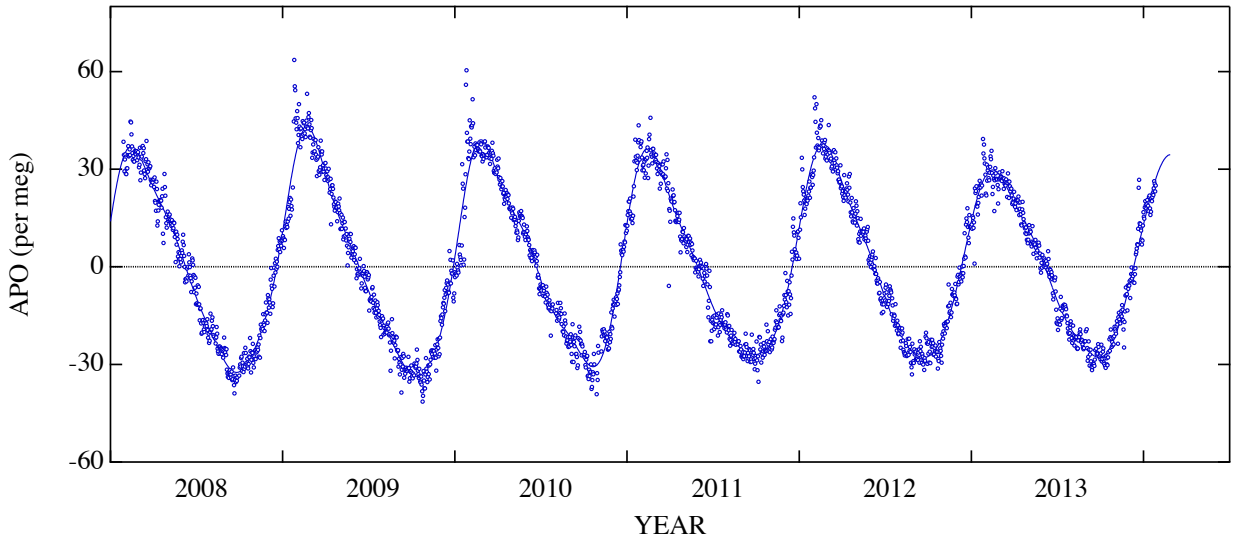


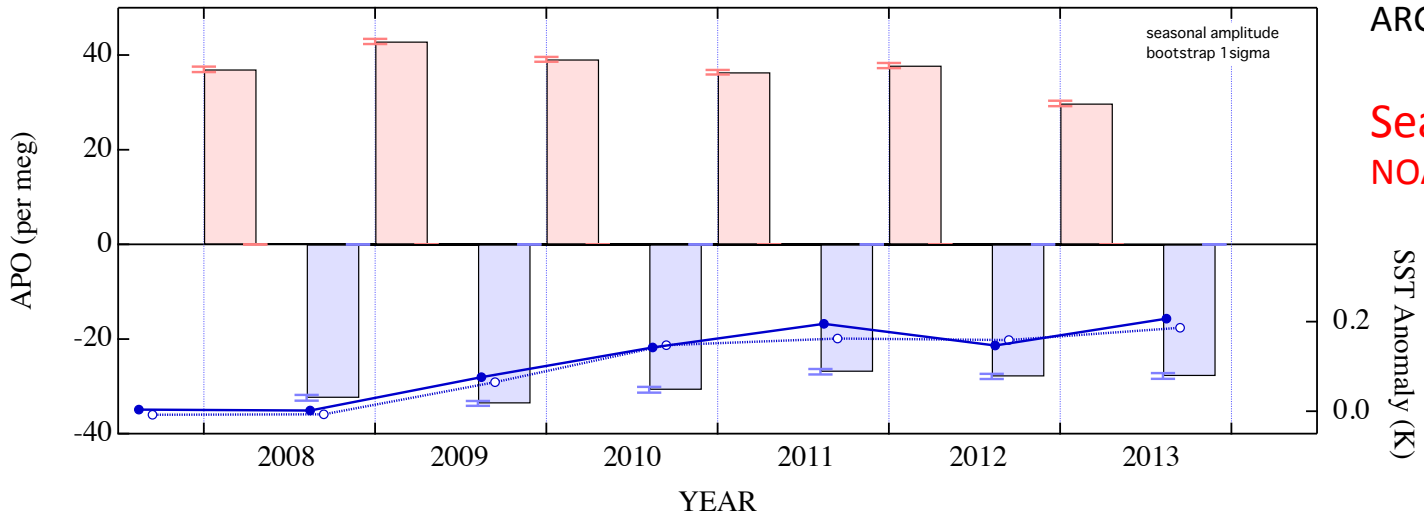
Degree of fluctuation
for p-p amplitude
(maximum)

Observation 9.6%
ACTM 2.7%

Degree of fluctuation ={ (each year's amplitude) – (average) } / (average)

Seasonal variations of APO





Comparison with:

Oceanic NPP

http://www.science.oregonstate.edu/ocean.productivity/

Wind Speed

NCEP/DOE reanalysis2 data

Sea Ice area

SSM/I and SSMIS compiled by JMA

Ocean Mixed Layer Depth

ARGO buoy data -- too sparse

Sea Surface Temperature

NOAA/NCDC ERSSTv.4

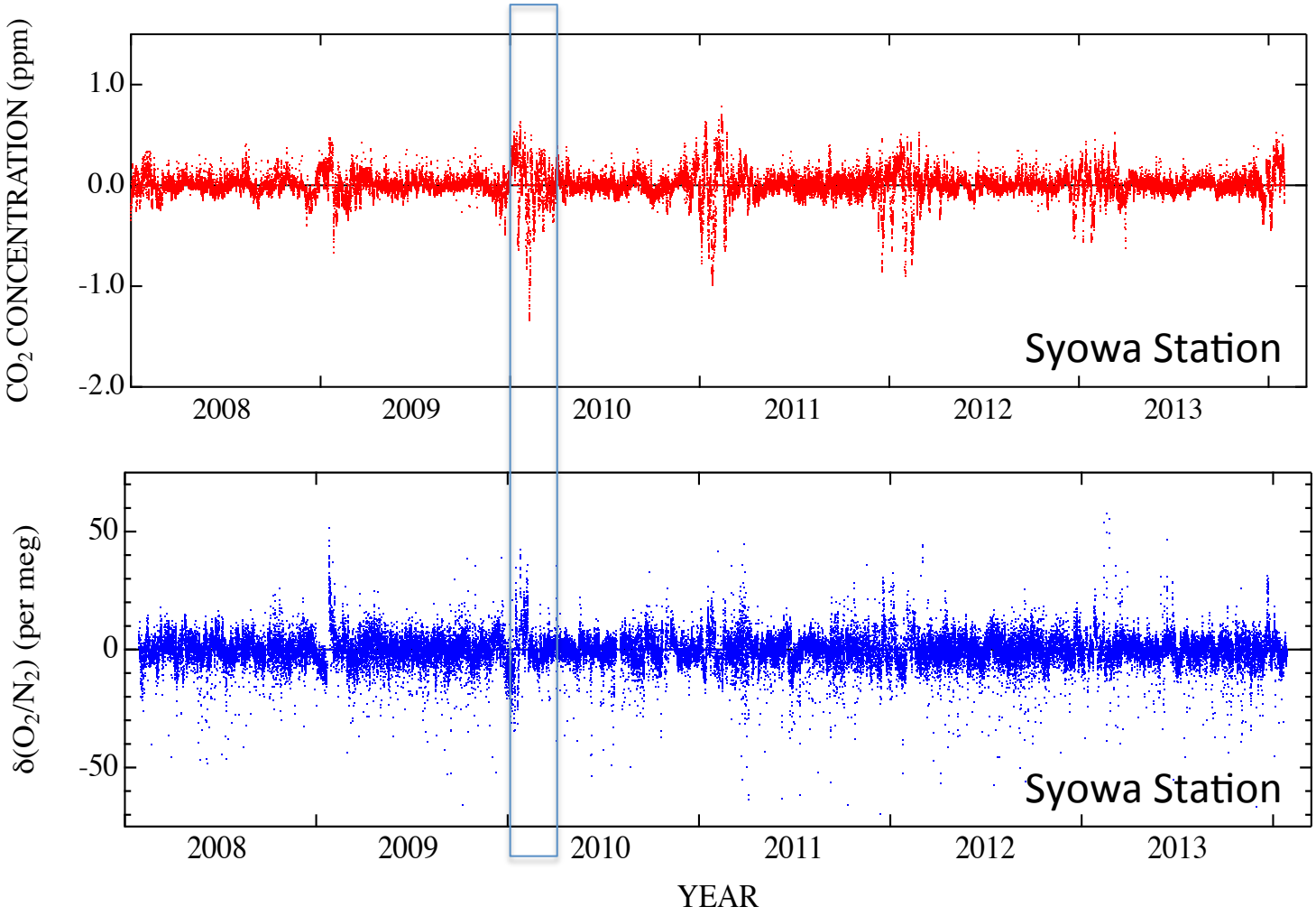
Anomaly from 1970-2000 average

30S – 60S May-Nov.

30S – 60S Jul.-Nov.

Synoptic scale variations of CO_2 and $\delta(O_2/N_2)$

= (hourly mean data) – (best fit curve)

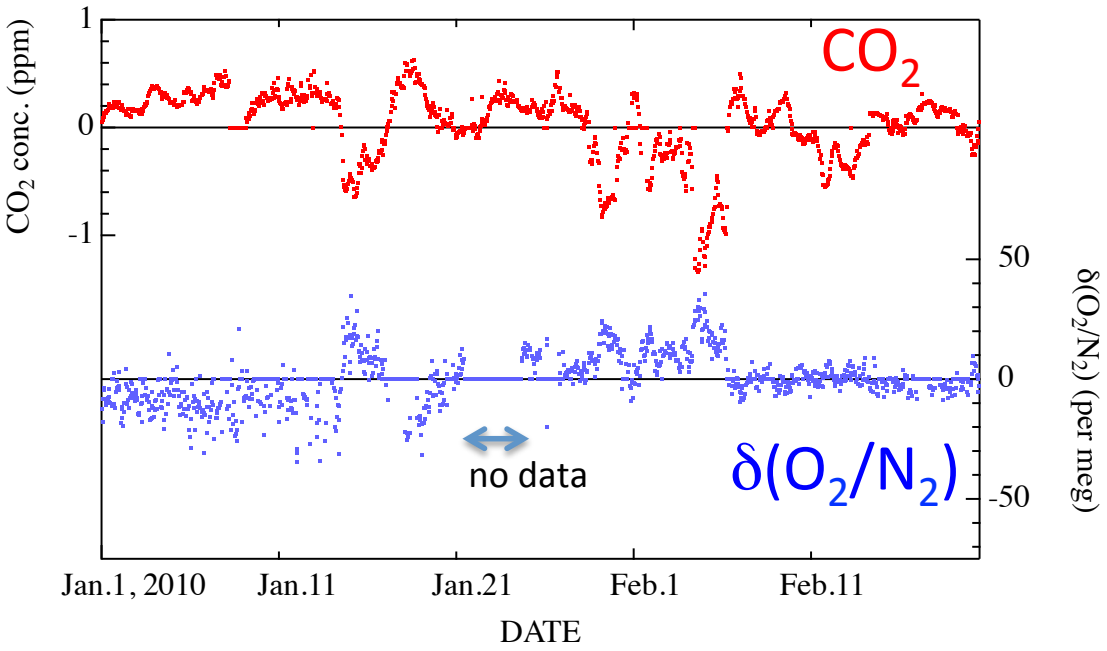


CO_2

$\delta(O_2/N_2)$

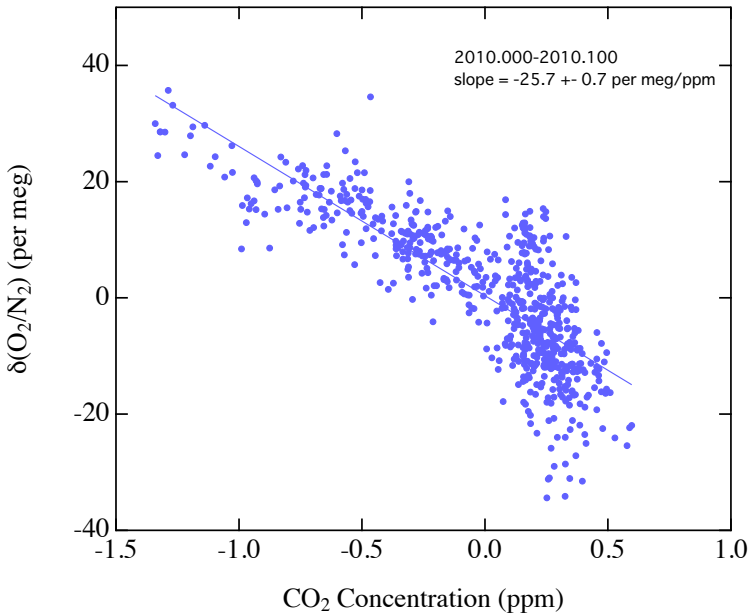
Remarkable short-term variations were observed in austral summer.

Synoptic scale variations of CO_2 and $\delta(O_2/N_2)$



CO_2-depleted and O_2-rich air-mass came from eastern ocean of South America

$\delta(O_2/N_2)$

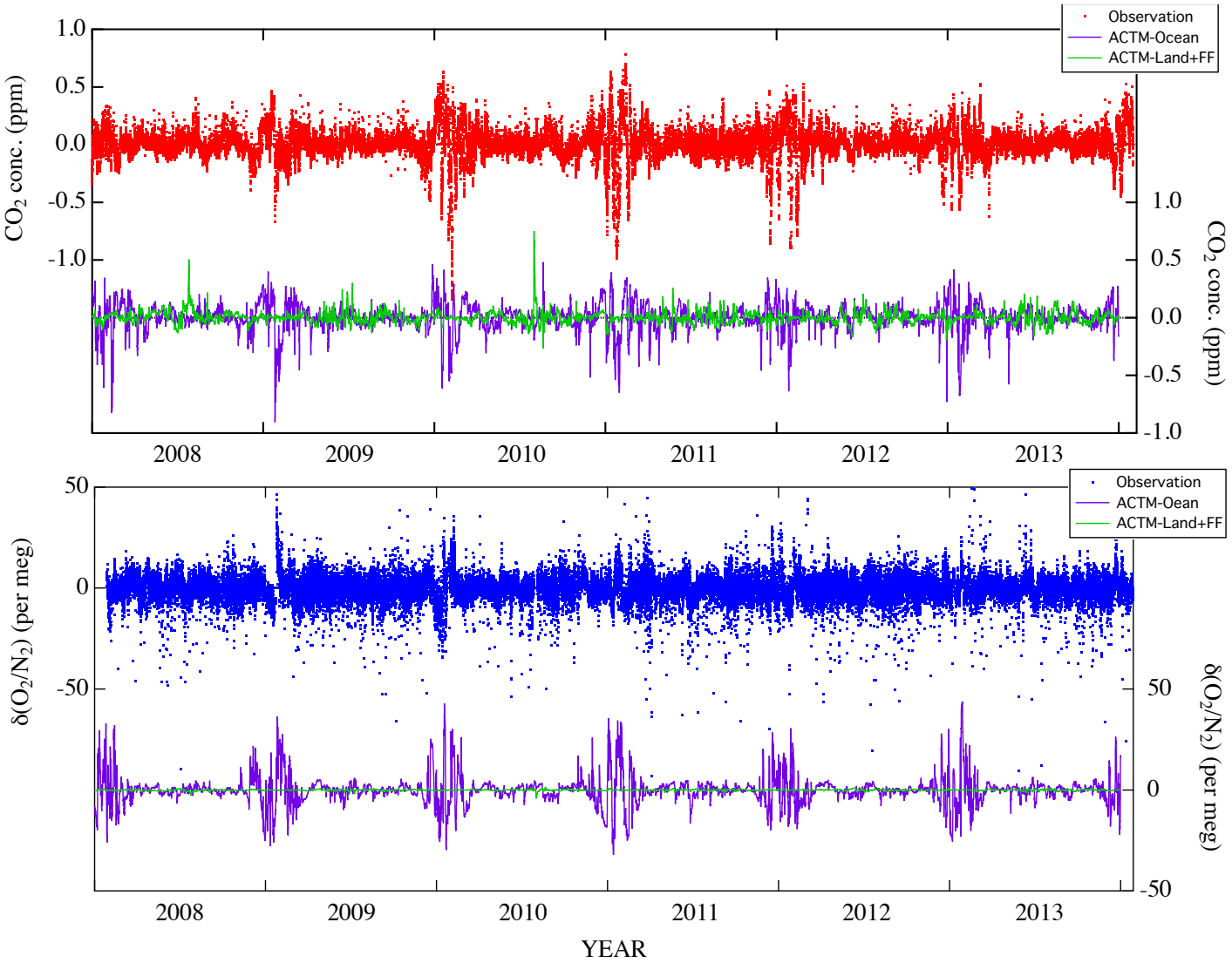


CO_2

Slope of the regression line
= 5.4 ppm/ppm > 1.1

The CO_2 and O_2 variations reflected oceanic fluxes.

Comparison with numerical experiments by ACTM



CO_2

Observation

ACTM ocean only

ACTM terrestrial only

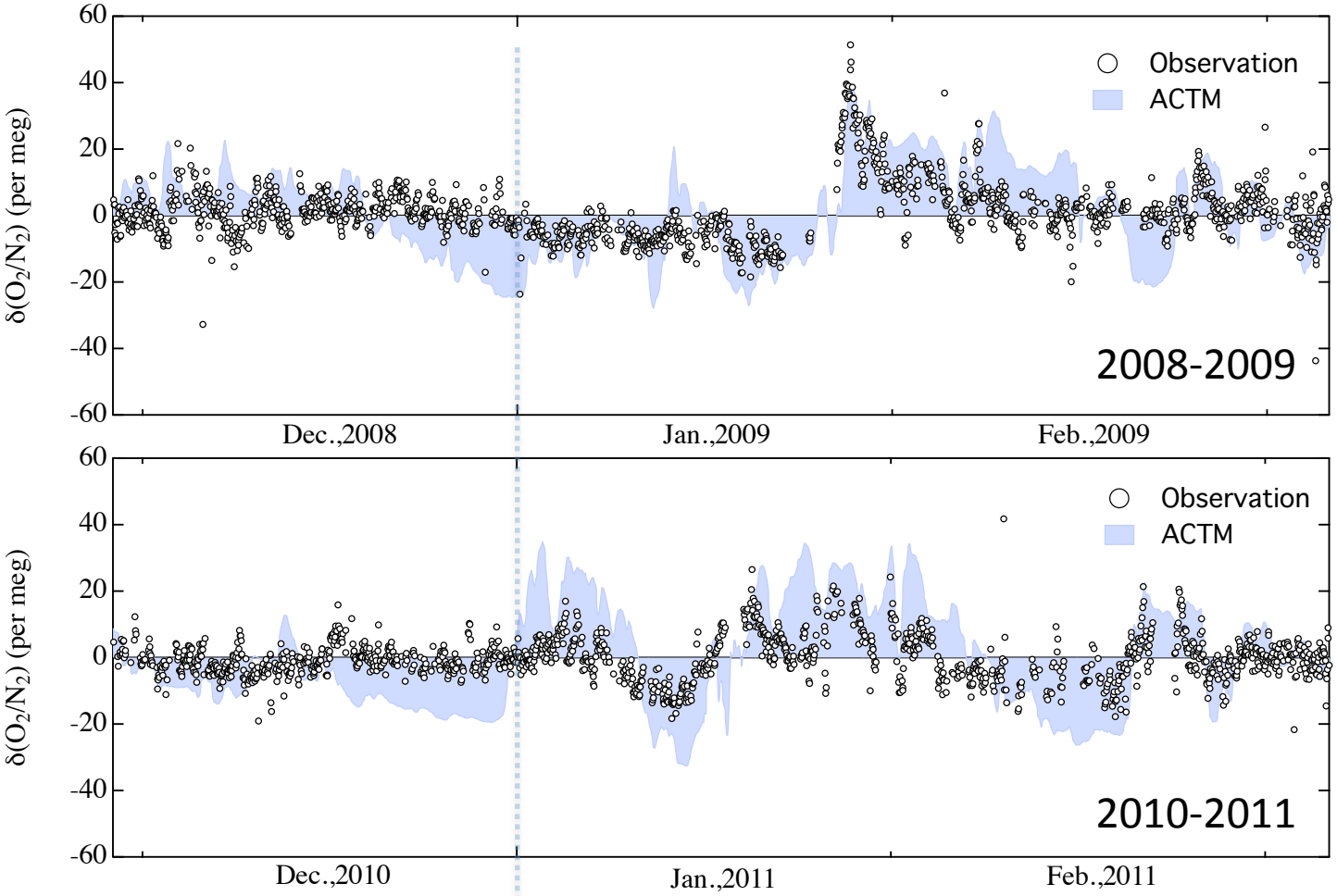
$\delta(O_2/N_2)$

Observation

ACTM ocean only

ACTM terrestrial only

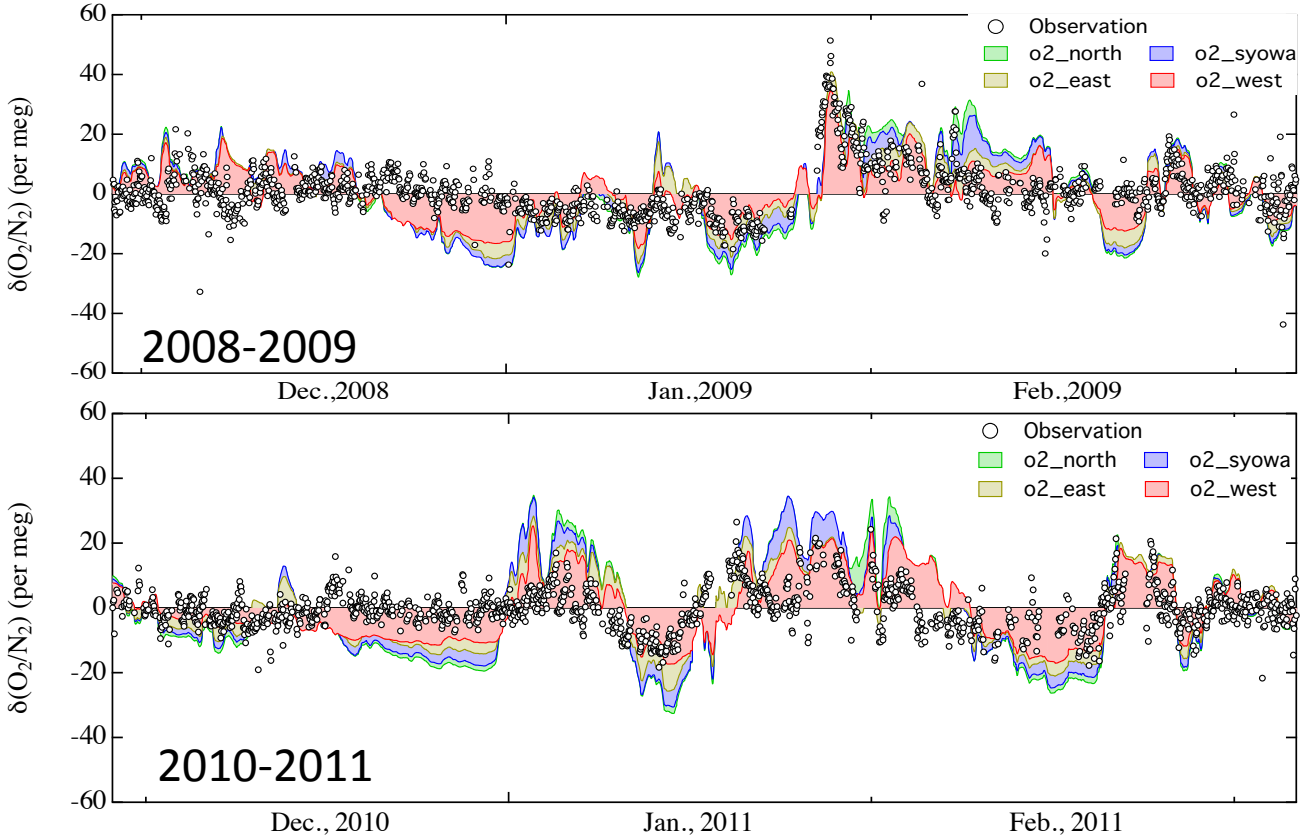
Comparison with ACTM simulations with oceanic O_2 and N_2 fluxes



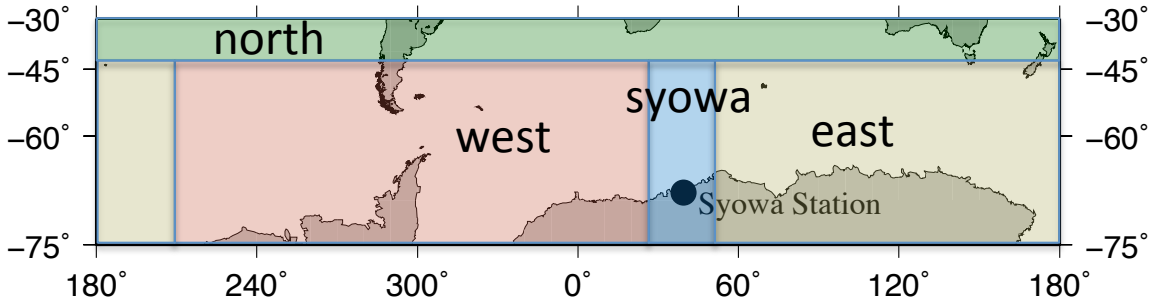
larger sink than obs. in late Dec.

well reproduced in 2009
larger fluctuations than obs. in 2011

Comparison with ACTM simulations with oceanic O_2 and N_2 fluxes (tagged tracer experiment)



short term variation at Syowa largely reflects oceanic signal at the 'west' region



Summary

- Continuous $\delta(O_2/N_2)$ measurement at Syowa Station well captures seasonal and shorter time scale variations.
- Year-to-year variations of seasonal APO cycles were observed. At this stage, correlation with sea surface temperature was found.
- Synoptic scale variations in CO_2 and $\delta(O_2/N_2)$ were observed in austral summer. They could be produced by oceanic fluxes.
- ACTM simulation well reproduced the synoptic $\delta(O_2/N_2)$ variation using climatological O_2 and N_2 fluxes. The synoptic variation at Syowa Station can detect interannual variations of oceanic fluxes in the 'western' part of the Southern Ocean.