Diverging trends in the APO seasonal cycle at northern high latitudes in the SIO Network

A tale of three sites

Cindy Nevison

University of Colorado

Ralph Keeling, Eric Morgan

Scripps Institution of Oceanography

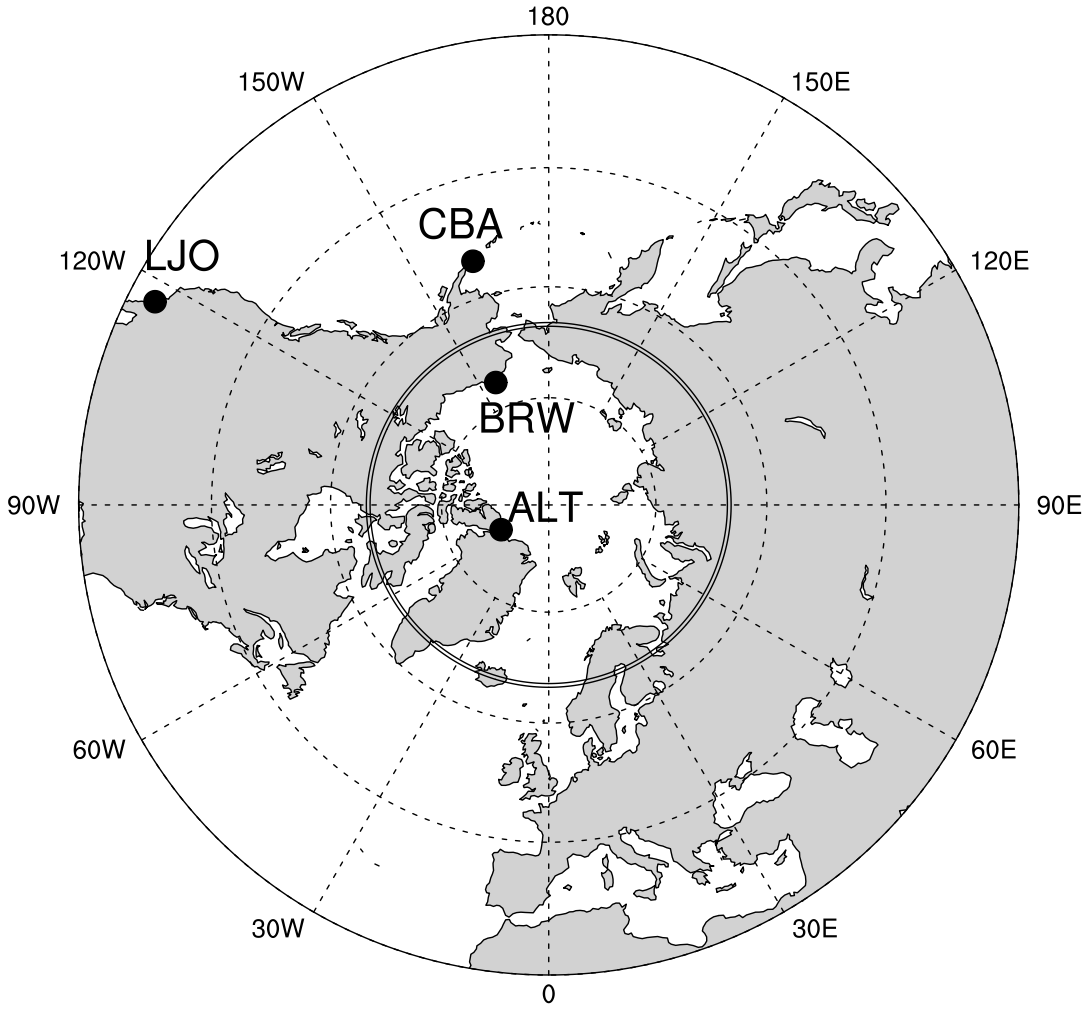
APO Meeting (WAO4)

Bowdoin College, Maine, Aug. 24, 2023

Acknowledgements: NSF Polar Programs

APO Monitoring Sites

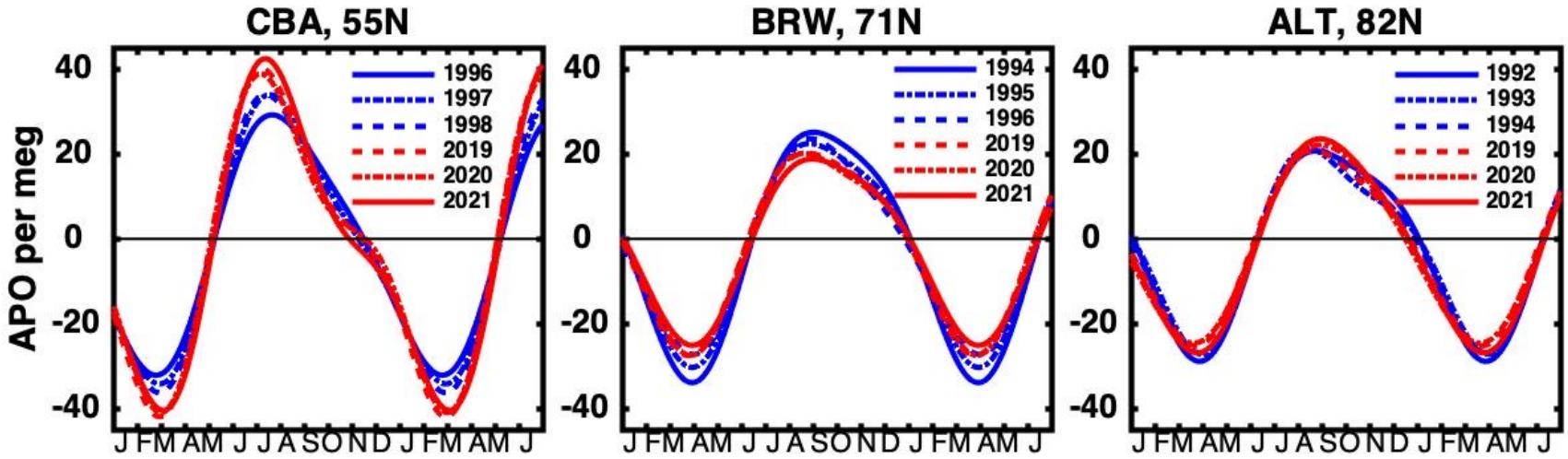
Scripps Institution of Oceanography (SIO)



Changes in APO Seasonal Cycle

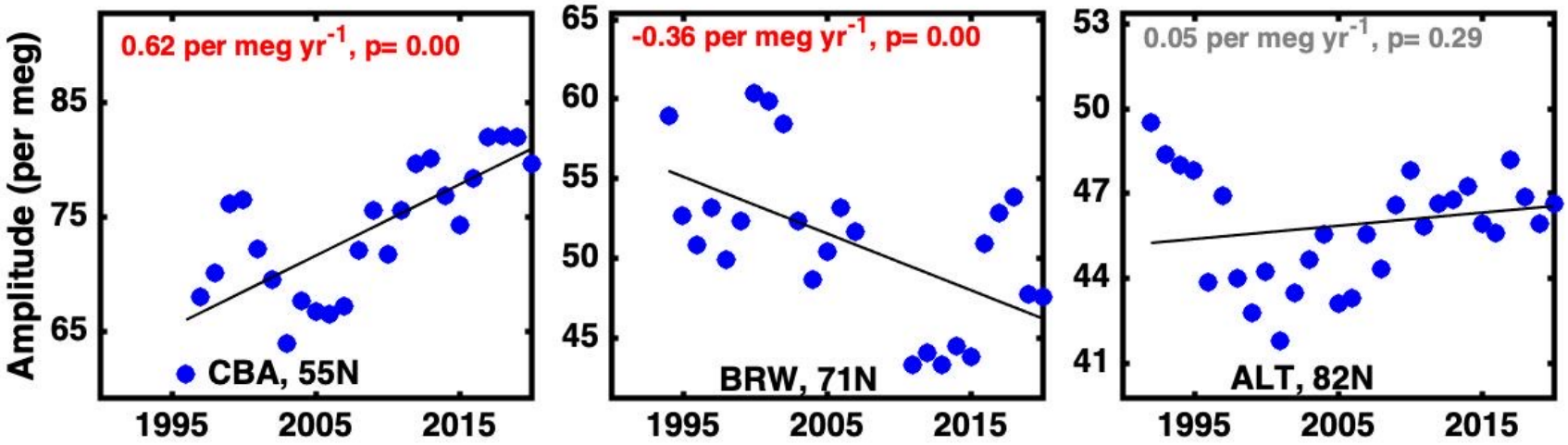
using Graven method:

harmonic fits to 3-year running time series segments



Changes in APO Seasonal Cycle

Method based on harmonic fits to 3-year running time series segments

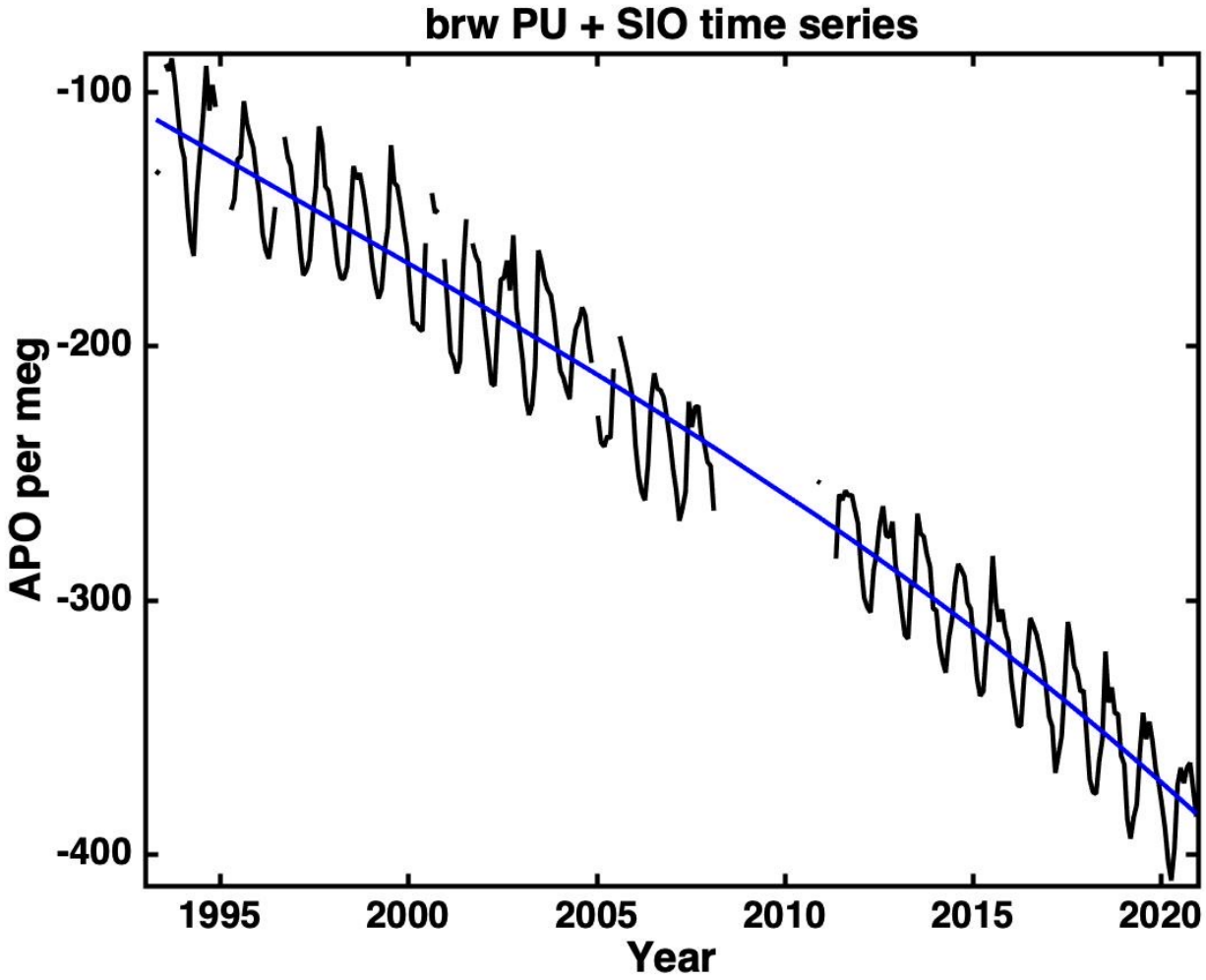


Observed Changes in APO Seasonal Cycle 1990s to 2023

Site	Amplitude (per meg/yr)	Positive Zero Crossing (days/yr)	Negative Zero Crossing (days/yr)
CBA (55°N)	**+ 0.62 ± 0.12**	**- 0.26 ± 0.08**	Not significant
BRW (71°N)	**- 0.36 ± 0.13**	Not significant	Not significant
ALT (82°N)	Not significant	Not significant	**- 0.48 ± 0.09**

red = positive trend
blue = negative trend

Gap in APO record at BRW

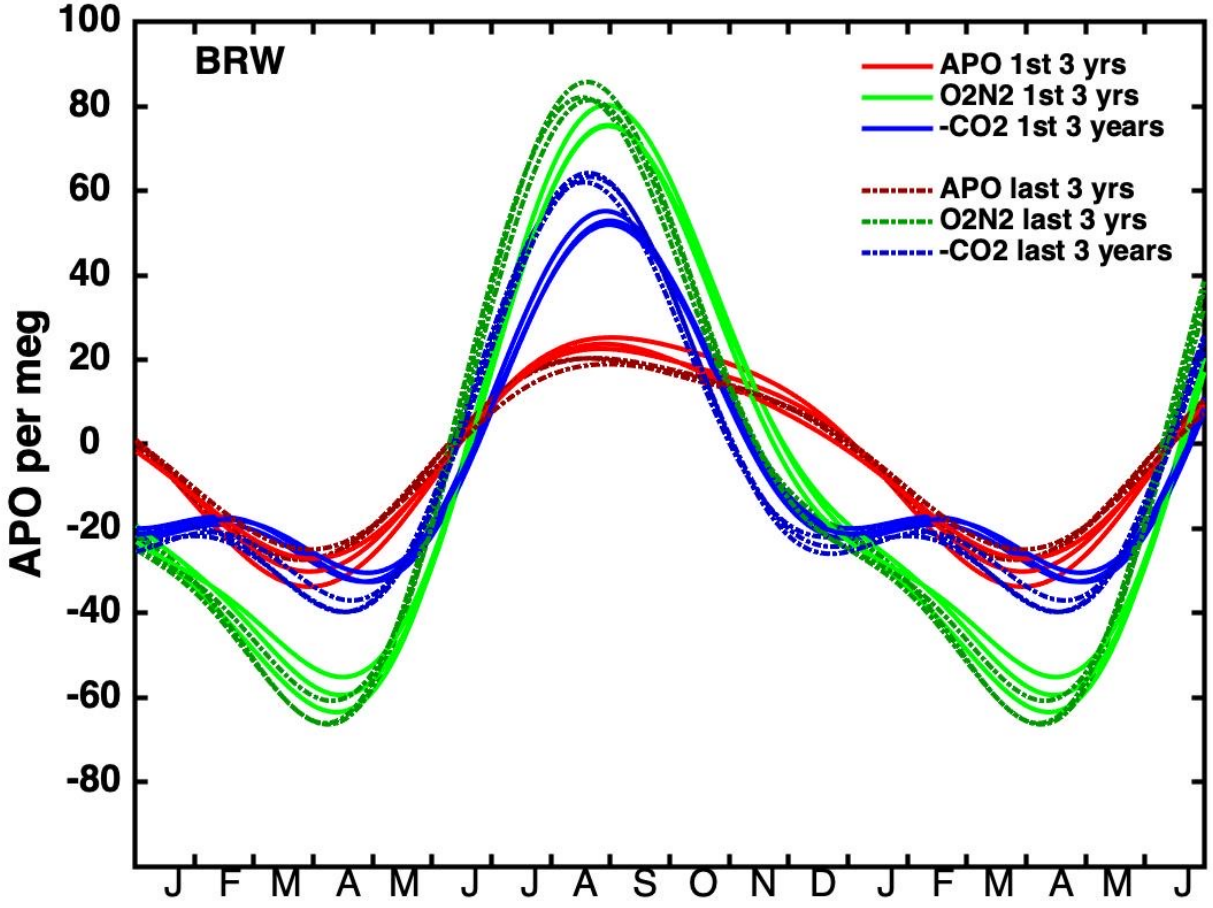


Components of APO seasonal cycle

$APO = O_2/N_2 + 1.1CO_2$

harmonic fits to 3-year running time series segments

Barrow, Alaska

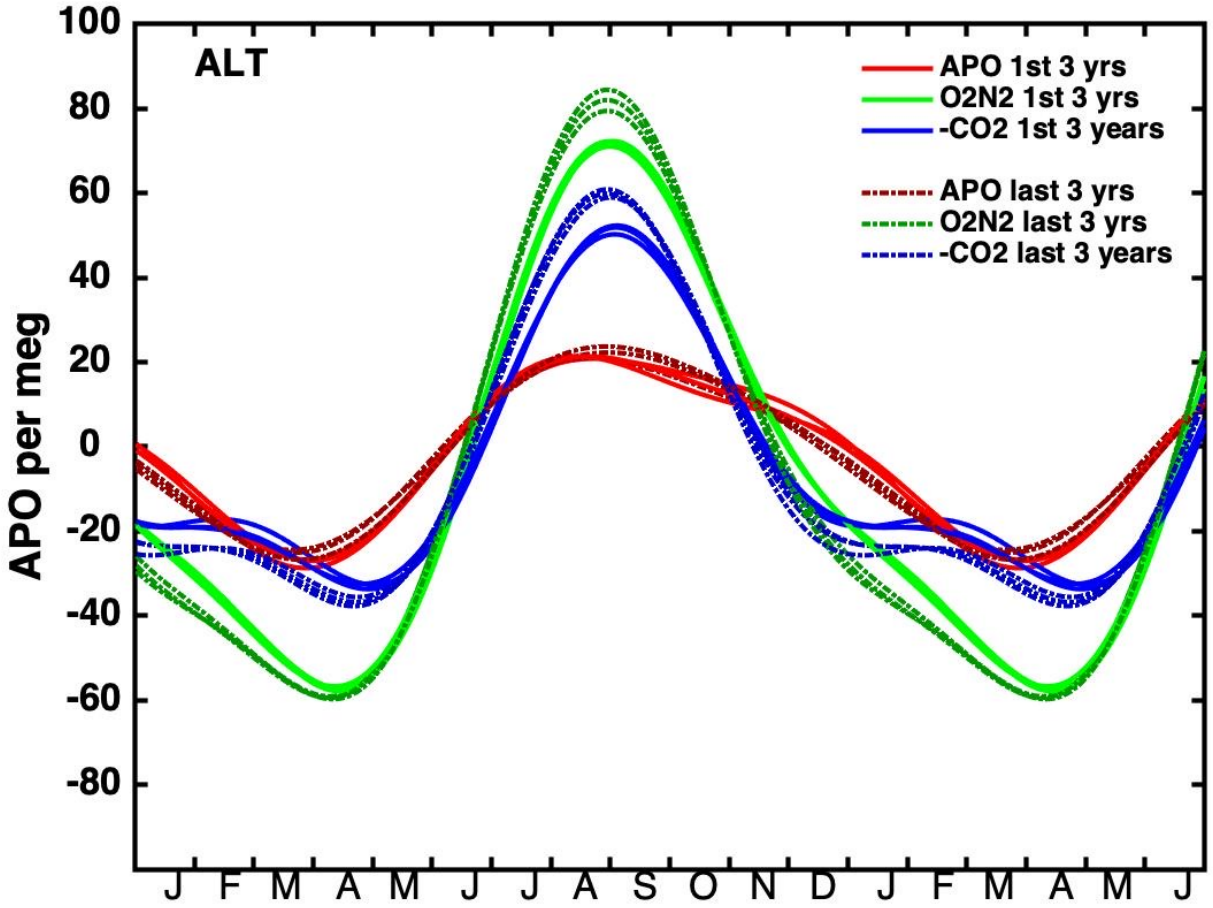


Components of APO seasonal cycle

$APO = O_2/N_2 + 1.1CO_2$

Method based on harmonic fits to 3-year running time series segments

Alert, Canada

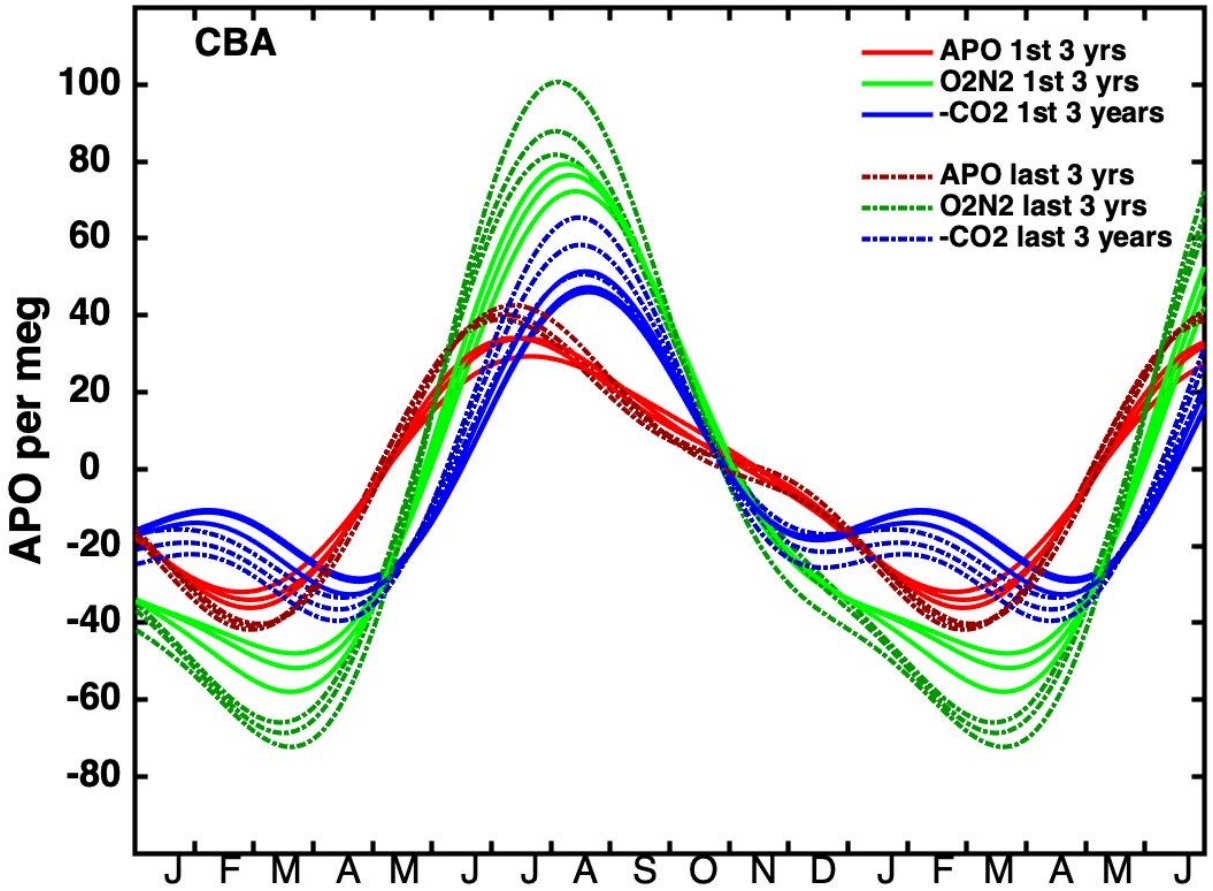


Components of APO seasonal cycle

$APO = O_2/N_2 + 1.1CO_2$

Method based on harmonic fits to 3-year running time series segments

Cold Bay, Alaska



Amplitude Trends in APO and its components 1990s to 2023

Site	**APO (per meg/yr)**	**O_2/N_2 (per meg/yr)**	**1.1 CO_2 (per meg/yr)**
CBA (55°N)	**+ 0.62 ± 0.12**	**+ 0.69 ± 0.29**	Not significant
BRW (71°N)	**- 0.36 ± 0.13**	**+ 0.48 ± 0.11**	**+ 0.76 ± 0.08**
ALT (82°N)	Not significant	**+ 0.67 ± 0.08**	**+ 0.59 ± 0.06**

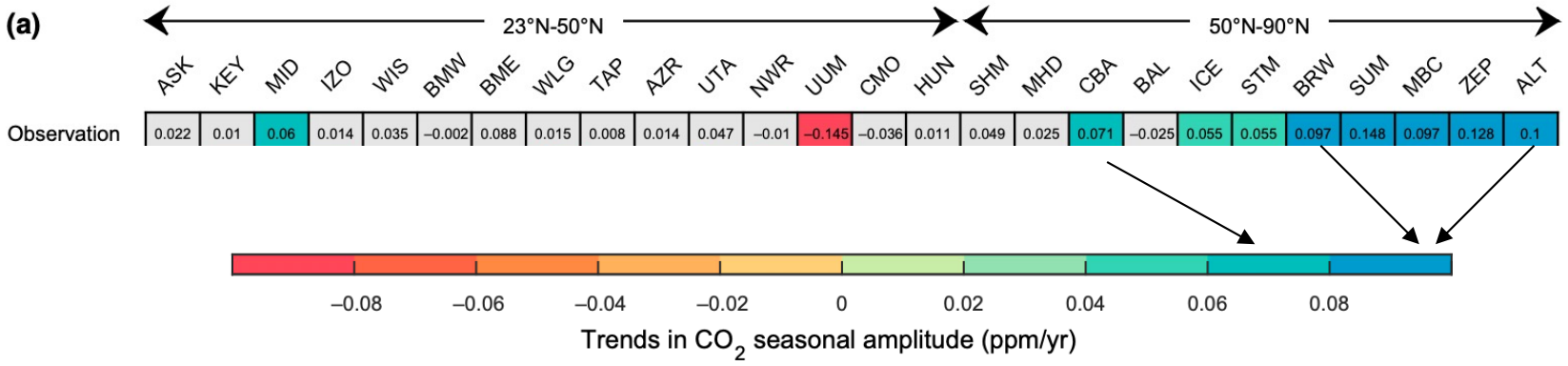
Amplitude Trends in CO_2 1990s to 2023

Site	**$CO_{2,\,pm}$ (ppm/yr)**	**1.1 CO_2 (per meg/yr)**	**$CO_{2,\,pm}/O_2N_2$ mean ratio**
CBA (55°N)	Not significant	Not significant	0.59 ± 0.05
BRW (71°N)	**+ 0.14 ± 0.015**	**+ 0.76 ± 0.08**	0.66 ± 0.04
ALT (82°N)	**+ 0.11 ± 0.01**	**+ 0.59 ± 0.06**	0.67 ± 0.01

Changes in CO_2 Seasonal Cycle Amplitude

Piao et al., 2017

used 9 terrestrial models, NOAA data from 1980 to 2012

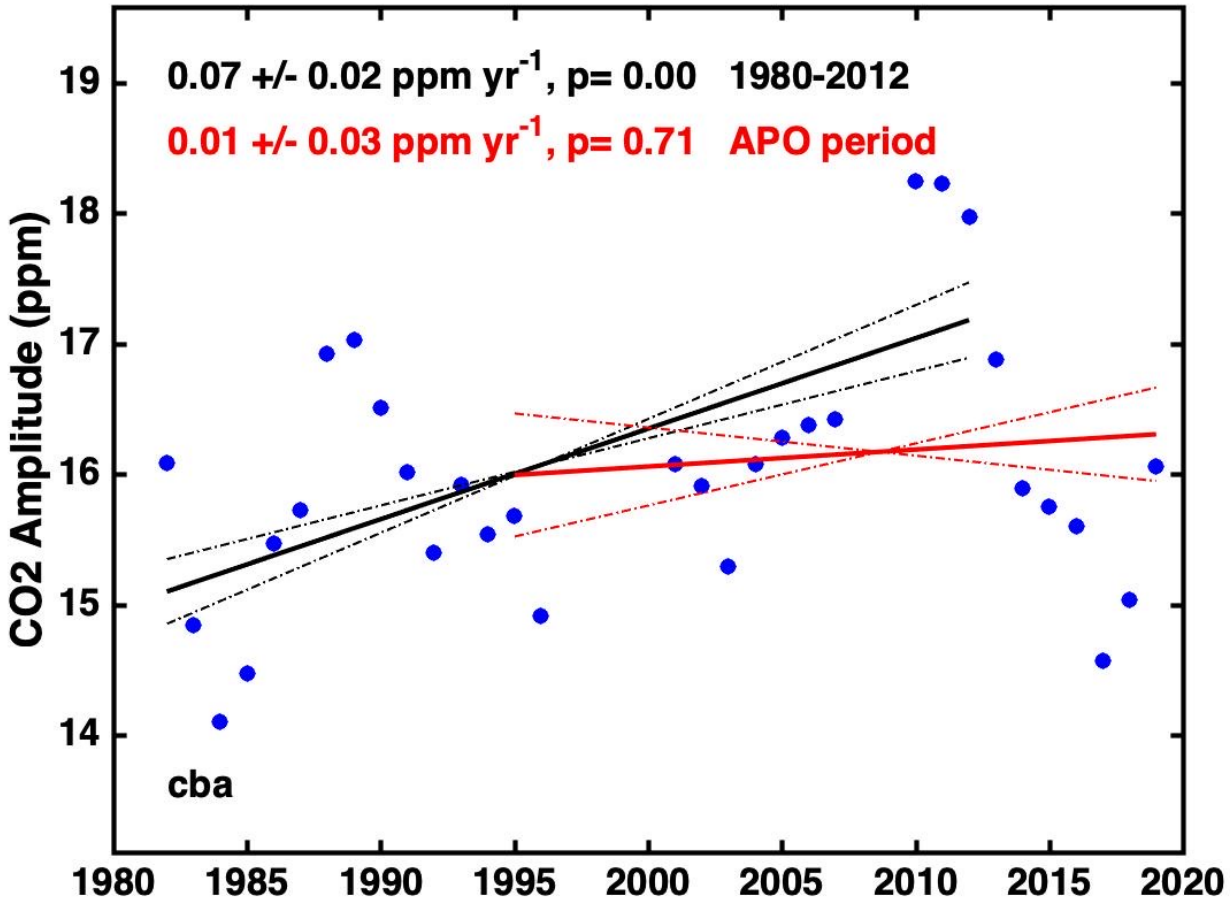


"The multi-model ensemble mean (of 9 terrestrial ecosystem models) shows that the **response of ecosystem carbon cycling to rising CO_2 concentration and climate change** are dominant drivers …"

Trends in NOAA CO_2 seasonal cycle amplitude

Method based on harmonic fits to 3-year running time series segments

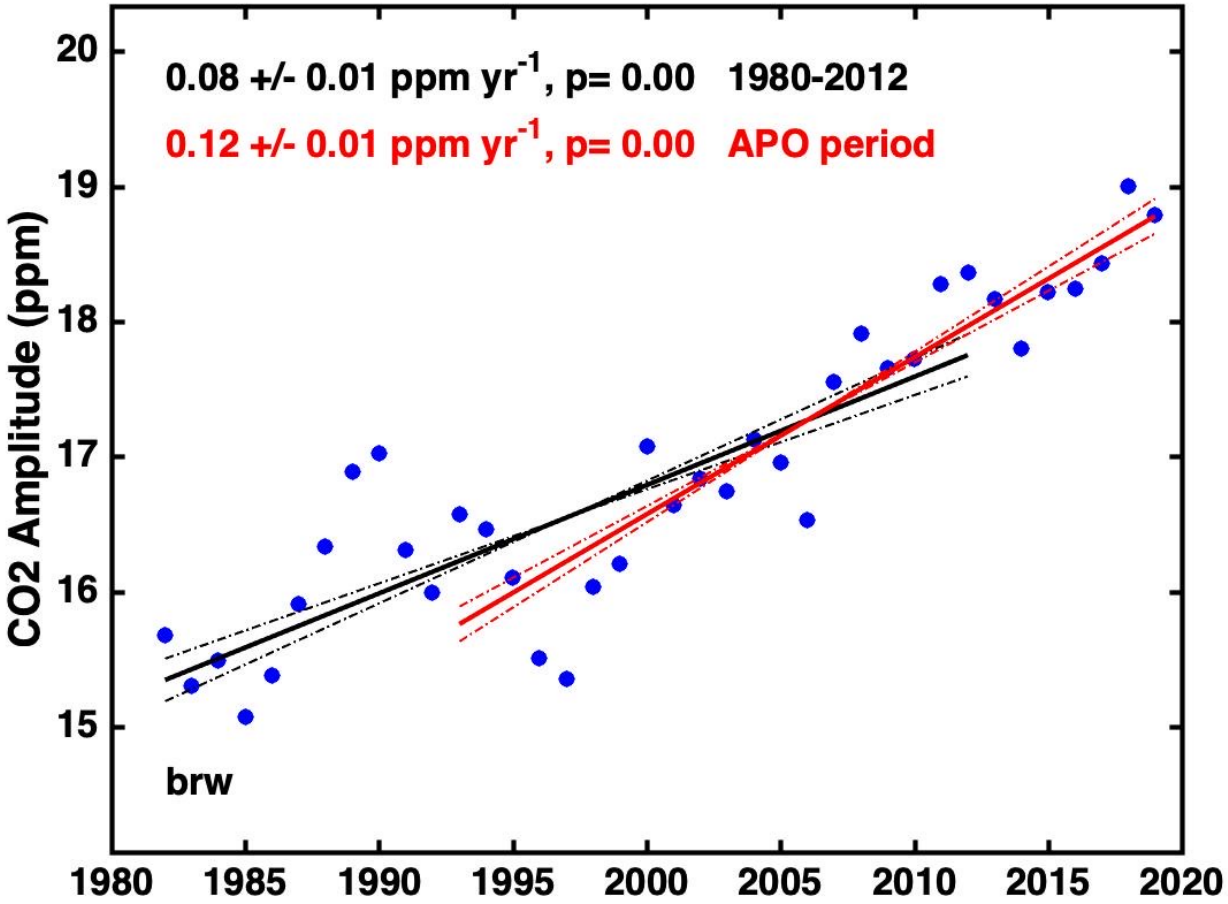
Cold Bay, Alaska



Trends in NOAA CO_2 seasonal cycle amplitude

Method based on harmonic fits to 3-year running time series segments

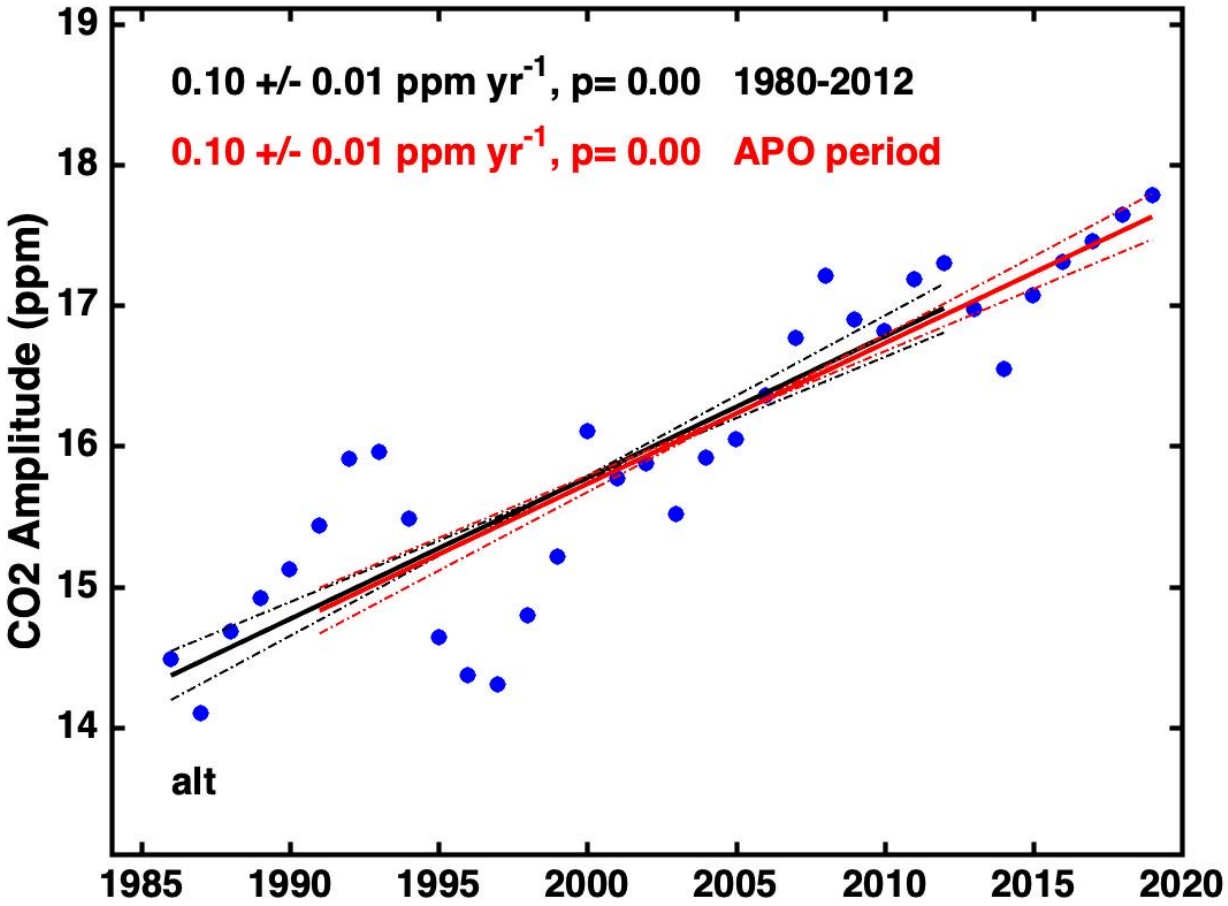
Barrow, Alaska



Trends in NOAA CO_2 seasonal cycle amplitude

Method based on harmonic fits to 3-year running time series segments

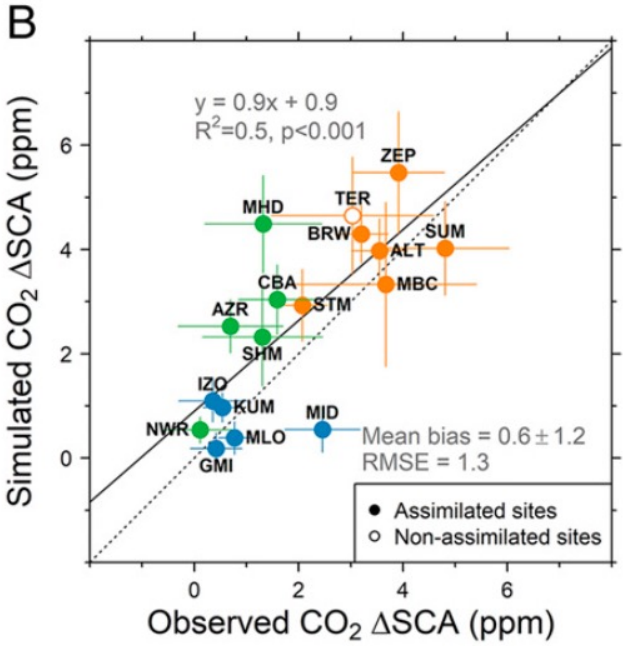
Alert, Canada

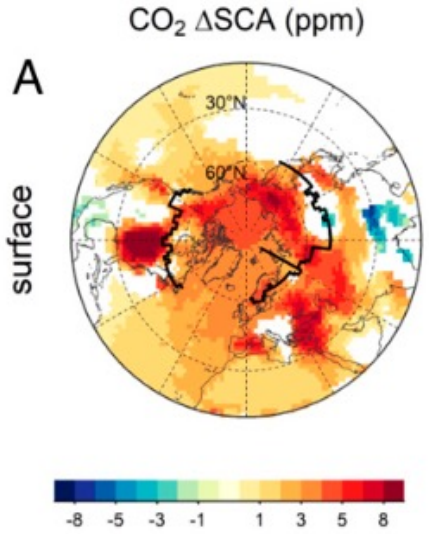


Changes in CO_2 Seasonal Cycle Amplitude

Lin, Keppel-Aleks et al., 2020

used GEOS-Chem w/ tagged CO_2 tracers, NOAA data 1980 to 2017



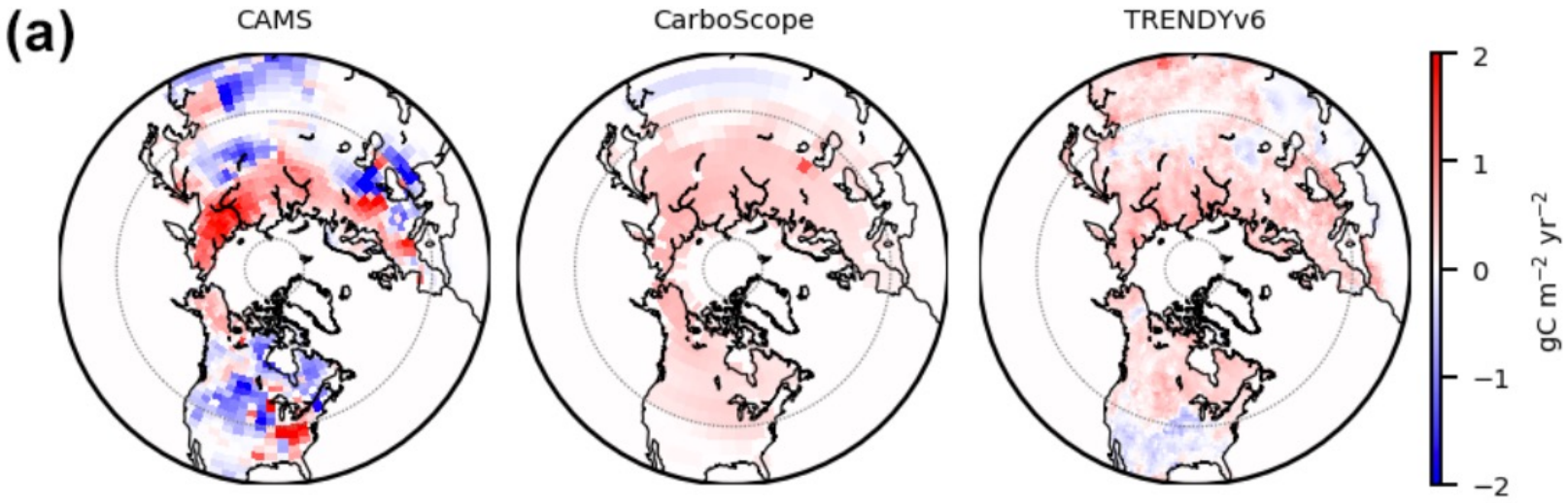


"… **enhanced seasonal carbon exchange in Siberia is the dominant contributor** (followed by temperate ecosystems). Arctic-boreal North America shows much smaller changes in flux seasonality … These continental contrasts …. corroborate heterogeneous vegetation greening and browning trends from field and remote-sensing observations"

Changes in CO_2 Seasonal Cycle Amplitude

Bastos et al., 2019

used TRENDY and 2 inversion fluxes, NOAA data 1980 to 2015



… the most likely explanation of the seasonal cycle of atmospheric CO_2 at high latitudes is the **CO_2 fertilization of photosynthesis** in unmanaged high-latitude ecosystems, **especially in the Eurasian boreal forests**.”

How does uncertainty in the O_2:CO_2 ratio (α_B) affect APO trends at the NH sites?

Atmospheric O2 and CO2 observations ... sampling well mixed tropospheric air have consistently found

–O_2:CO_2 ratios to be within 1.10 ± 0.05,

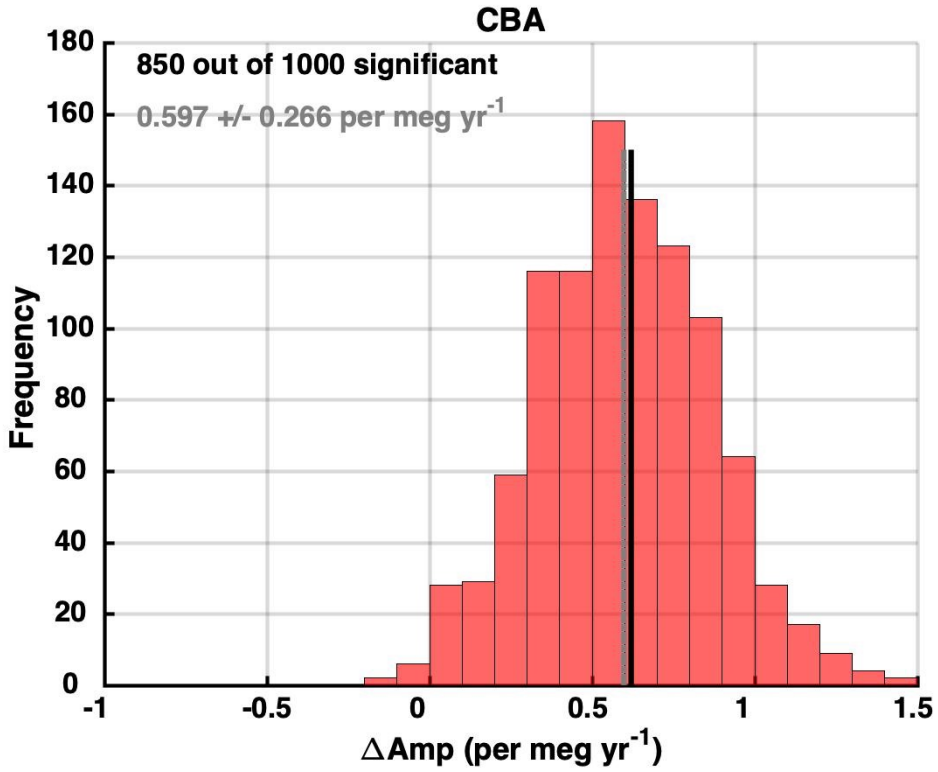
with very little temporal or spatial variability observed.

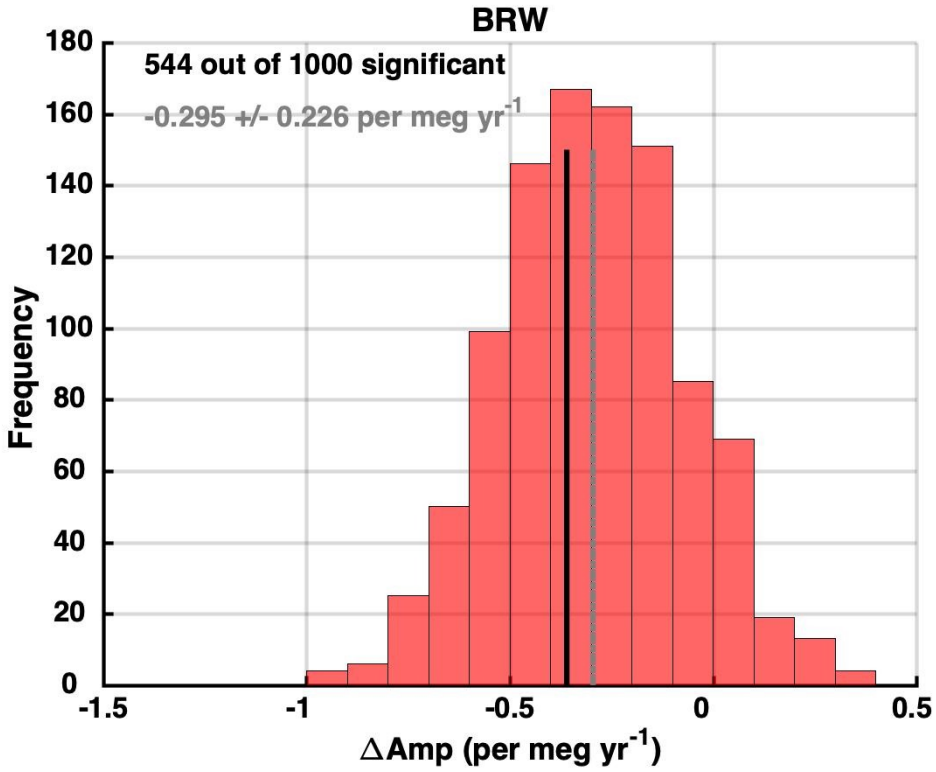
Pickers et al., 2022

–O_2:CO_2 biospheric for UK = 1.07 ± 0.04

Chernow et al., 2023

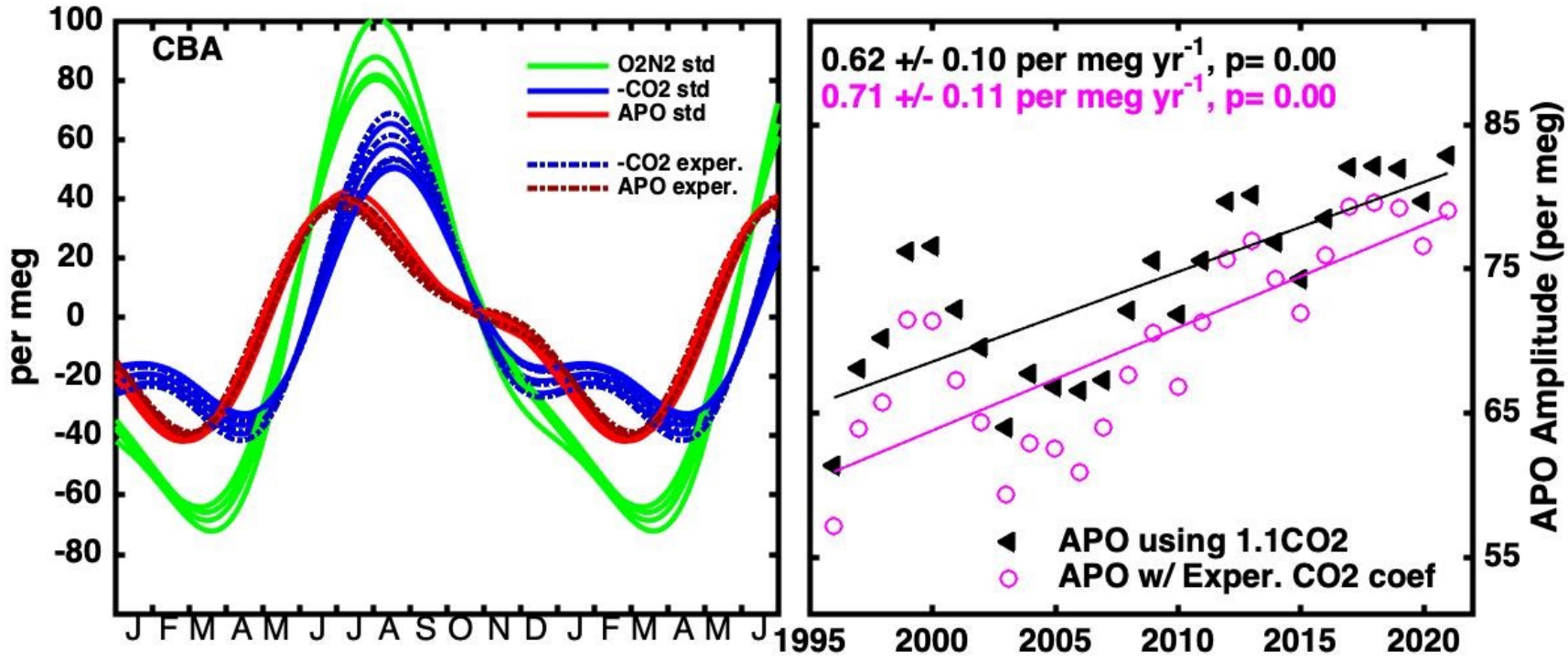
1000 applications of Graven method
α_B varies randomly 1.10 ± 0.01 for each data point



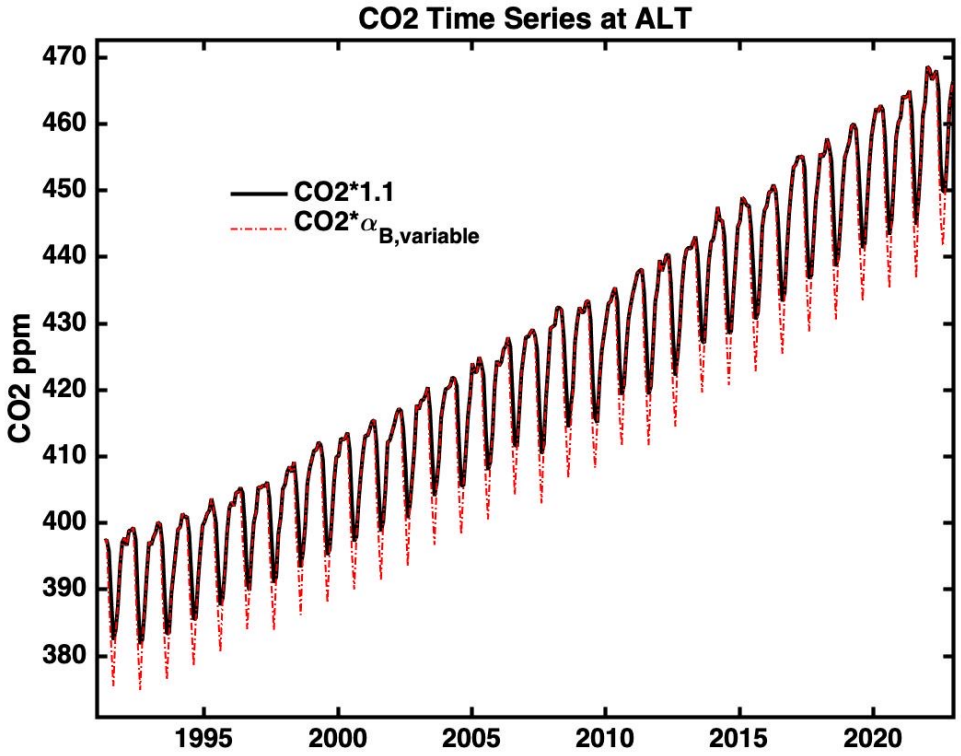


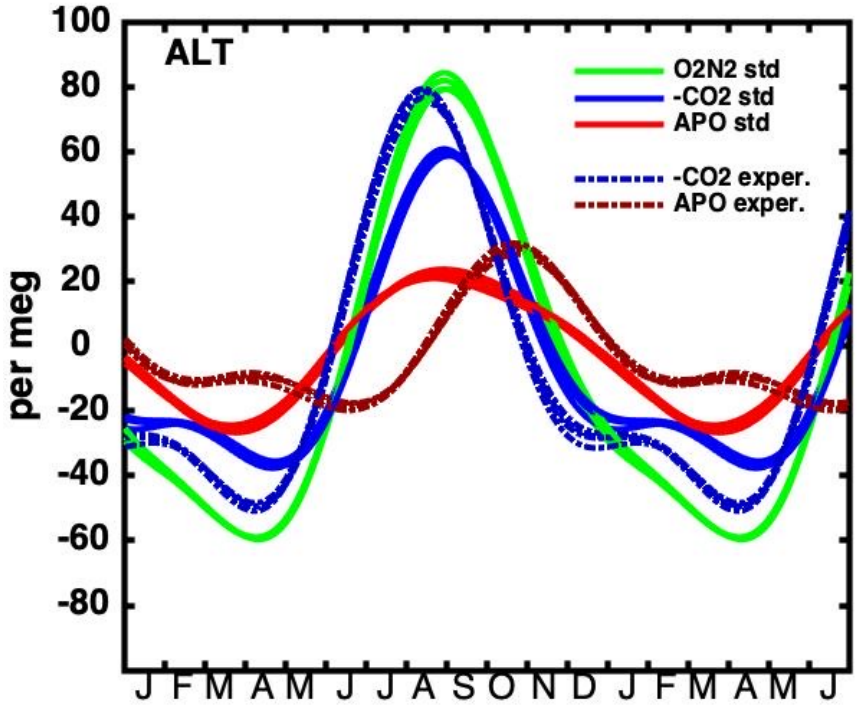
Black vertical line is slope with constant α_B =1.1

Linear decrease in α_B to 1.10 to 1.05 over 30 year time series



Decrease α_B to 1.08 in June-August, otherwise 1.1





Summary and Conclusions

- 3 long-term NH sites in SIO network all show contrasting amplitude trends.

- The increasing amplitude trend at Barrow, AK is sensitive to uncertainty in the O_2:CO_2 biospheric exchange ratio used to compute APO and may be an artefact of the dramatic change in the CO_2 amplitude at BRW.

- The increasing amplitude trend at Cold Bay, AK is more robust with respect to uncertainty in O_2:CO_2 and is more likely to be a true oceanic signal.