Assessing terrestrial ecosystem responses to climate change from analysis of the shape and amplitude of the atmospheric CO$_2$ seasonal cycle

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Barrow, Alaska CO₂: Detrend with polynomial
BRW Mean CO$_2$ Seasonal Cycle
BRW: Apply Filter to Deseasonalized Residuals
High Frequency Residuals
significantly correlated among Arctic stations
R=0.54 (brw v. mbc); R=0.44 (brw v. alt); R=0.49 (alt v. mbc)
Sort High Frequency Residuals by Month
BRW: Summary of Monthly CO$_2$ Trends
BRW Changing Shape of Seasonal Cycle
BRW Change in Amplitude
Slope of Cmax-Cmin Residuals v. Year

brw Change in CO2 Amplitude

\[ R = 0.56 \]
\[ b = 0.068 \text{ ppmv/yr} \]
Monthly CO₂ Trends at 4 Arctic Stations
Arctic 5-Station Composite
Niwot Ridge: Trends in CO$_2$ Seasonal Cycle
North Pacific Islands 5-Station Composite
Correlation between composite N Pacific and Arctic high frequency residuals

Arctic5 v N Pacific 5 residuals: $R = 0.32$ $p = 0.000$
Source regions from Transcom basis functions
Barrow, Alaska (BRW): 71.3N, -156.6W, 11m
Source regions from Transcom basis functions

Mauna Loa (MLO): 19.53N, -155.58W, 3397m
MATCH Transport Runs with NEE from Two Terrestrial Ecosystem Models
MATCH: CLM-CN and CASA’ Transport Runs

High frequency residuals from both ecosystem models correlated to obs

IAV in transport & biology

IAV in transport only
CASA’-MATCH Arctic Composite
High Frequency Residuals: Intra-annual correlations of June v. other months
(each square represents one year from 1982-2004)
Obs Arctic June High Frequency Residuals plotted vs. all other months
Niwot Ridge June High Frequency Residuals plotted vs. all other months
Conclusions

1. Significant increases in amplitude at 5 Arctic stations ~ 10% over 25 years

2. Most likely reflects a terrestrial ecosystem response, although transport may also contribute

3. CASA’ and CLM-CN Ecosystem models in part reproduce these trends, although not necessarily for the right reasons.
CO₂ Seasonal Amplitude Trends at 4 Arctic Stations

mbc 1980 to 1997

\[ R = 0.54 \quad \text{0.123 ppm yr}^{-1} \]

brw 1971 to 2006

\[ R = 0.57 \quad \text{0.067 ppm yr}^{-1} \]

stm 1981 to 2006

\[ R = 0.49 \quad \text{0.057 ppm yr}^{-1} \]

cba 1978 to 2006

\[ R = 0.24 \quad \text{0.041 ppm yr}^{-1} \]
Monthly Trends at 4 NH Midlatitude Stations

- **uum 1992 to 2006**
- **nwr 1968 to 2006**
- **uta 1993 to 2006**
- **azr 1979 to 2006**
Arctic 8-Station Composite
Niwot Ridge CO$_2$: 40.0N, -105.6W, 3523m
Niwot Ridge: Trends in CO$_2$ Seasonal Cycle

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**Graph 1:**
- **Title:** nwr Change in CO2 Amplitude
- **Legend:**
  - R = 0.42
  - $b = -0.064$ ppmv/yr
- **Axes:**
  - x-axis: 1970 to 2005
  - y-axis: max-min CO2 ppmv

**Graph 2:**
- **Title:** nwr Slope of Residual v. Year
- **Legend:**
  - Statistically Significant
- **Axes:**
  - x-axis: month (1 to 12)
  - y-axis: slope ppmv/yr
- **Annotations:**
  - Cmax
  - Cmin
Source regions from Transcom basis functions

Carr (CO): 40.90N, -104.8W, 3000m
(using as analog for Niwot Ridge (CO): 40.0N, -105.6W, 3523m)
MATCH Fossil Fuel Simulation
high frequency residuals not correlated to observations