Enhanced Seasonal Exchange of CO2 by Northern Ecosystems Since 1960

Graven, H.D. et al *Science* 6 September 2013: Vol. 341 no. 6150 pp. 1085-1089 DOI: 10.1126/science.1239207

Objectives:

- This study compares recent data (2009-2011) and earlier data (1958-1961) measuring seasonal variations in CO_2 in the Northern Hemisphere.
- In addition, results of the comparison were examined against historical simulations of terrestrial ecosystem models participating in the fifth phase of the Coupled Model Intercomparison Project (CMIP5), each of which incorporate potential mechanisms for changing Net Ecosystem Production (NEP) as critical factors.
- The recent observations of CO_2 cycles used were observed by the HIAPER Pole-to-Pole Observations (HIPPO) large scale aircraft campaign and by regular aircraft profiles over several fixed sites collected by the NOAA Carbon Cycle Group Aircraft Program in 2009-2011.
- The prior observations, made 50 years earlier in the International Geophysical Year (IGY), were obtained by 160 weather reconnaissance flights above the North Pacific and Arctic Oceans in 1958-1961.
- In both the recent (HIPPO and NOAA) and prior (IGY) time frames, data used for this study was obtained from the same regions and pressure surfaces.

New Science

- The data comparison reveals a striking large (~50%) seasonal amplitude increase north of 45° latitude.
- An approximately 50% increase in seasonal exchange of CO_2 by northern extratropical land ecosystems, focused on boreal forests, is implicated in this change.
- None of the CIMP5 models can account for the increase in CO_2 amplitude north of 45° between 1958-61 and 2009-11, and tend to underestimate both CO_2 amplitude change and NEP amplitude changes in northern ecosystems.
- The analysis suggests an additional 1.3 – 10_{15} g carbon (Pg C) is exchanged with the atmosphere seasonally by Arctic, boreal and temperate ecosystems combined in 2009-11 compared to 1958-63, an increase of 32 to 59%.
- It was also found that, counter to previous studies that invoke dormant or early growing season trends alone, that strong increases in CO_2 amplitude are unlikely to occur without enhanced uptake in the main growing season, because the intense fluxes in the main growing season make a much larger contribution to the seasonal CO_2 amplitude than either the dormant season or the shoulder seasons.

Significance

- The seasonal exchange represents the accumulation of carbon on land during the growing season (typically May-Aug.) and the release of carbon during the dormant season, after subtracting annual mean exchange.
- Ecological changes in boreal and temperate forests are driving additional increases in the summertime uptake of carbon.
- Such observations indicate large ecological changes in northern land ecosystems and a major shift in the global carbon cycle over the last 50 years.
- Observations of atmospheric CO_2 concentration from Mauna Loa, HI and Barrow, AK – the longest running Northern Hemispheric records – are in agreement with these findings, as they also show increasing trends in seasonal amplitude.
- The large changes in amplitude between 1958-61 and 2009-11 north of 45°N substantially exceed interannual variations at Barrow and in high-latitude NOAA aircraft data for recent years, indicating the observations represent a long-term change rather than a short-term fluctuation.
- There is no evidence that northern ecosystem trends are slowing down, since the largest CO_2 amplitudes at Barrow have been observed in the last few years.
- The inability of the CMIP5 models to account for the observed increase in the amplitude of atmospheric CO2 indicates that they underestimate the widespread ecological changes that occurred over the past 50 years and are likely to underpredict future changes.

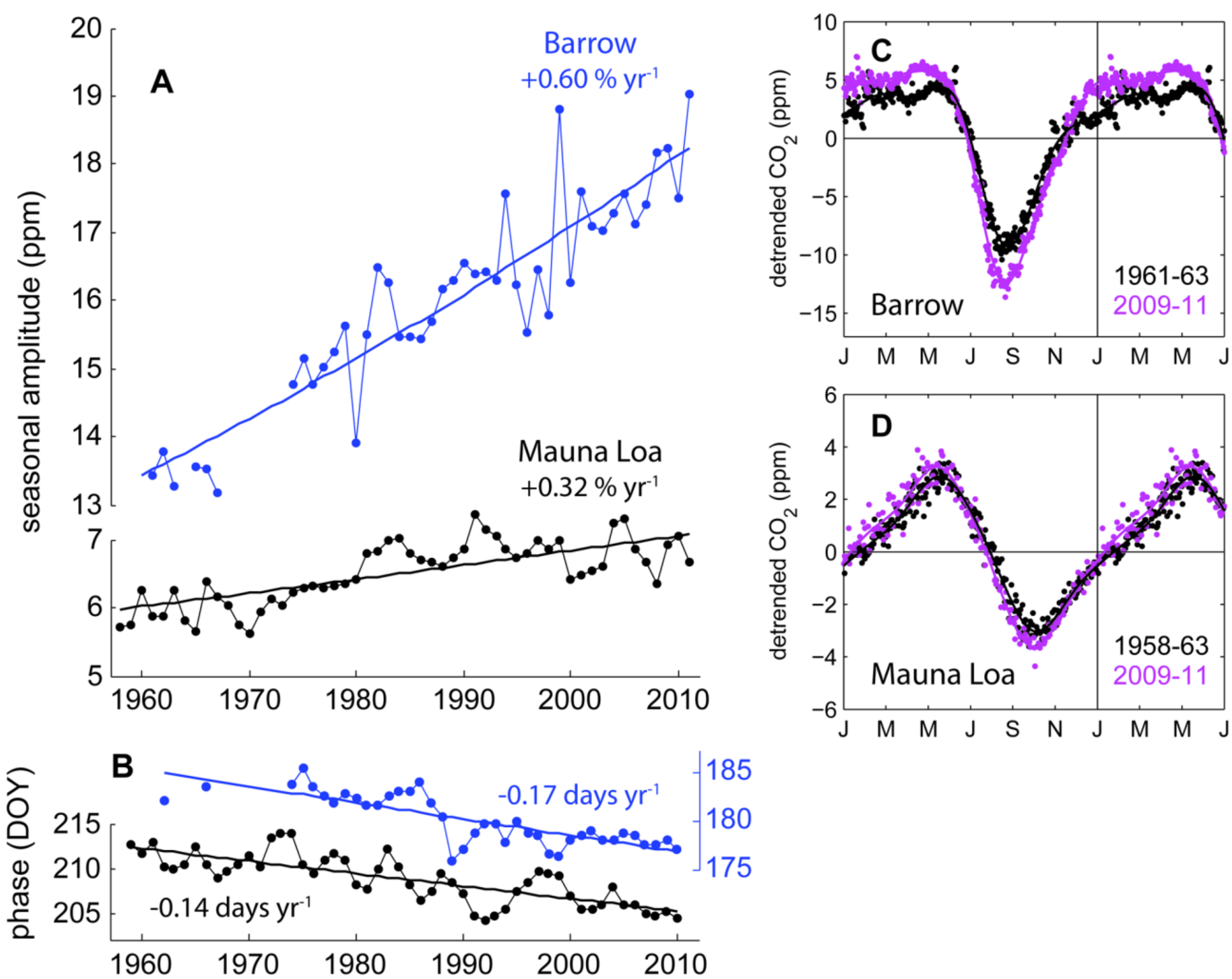

Fig. 1. Observed peak-to-trough seasonal amplitude (**A**) and phase (**B**), given by the day of year of downward zero crossing, of CO_2 concentration at Barrow (71°N, blue) and Mauna Loa (20°N, black) measured by the Scripps CO_2 Program (*7*, *8*) and the NOAA Global Monitoring Division (*9*). Growth rate of amplitude is given in percent change per year, with one-sigma uncertainty of ±0.05-0.07% $year^{-1}$. Seasonal CO_2 cycles observed at Barrow (**C**) and Mauna Loa (**D**) for the 1961-63 or 1958-63 and 2009-11 time periods. The first six months of the year are repeated.

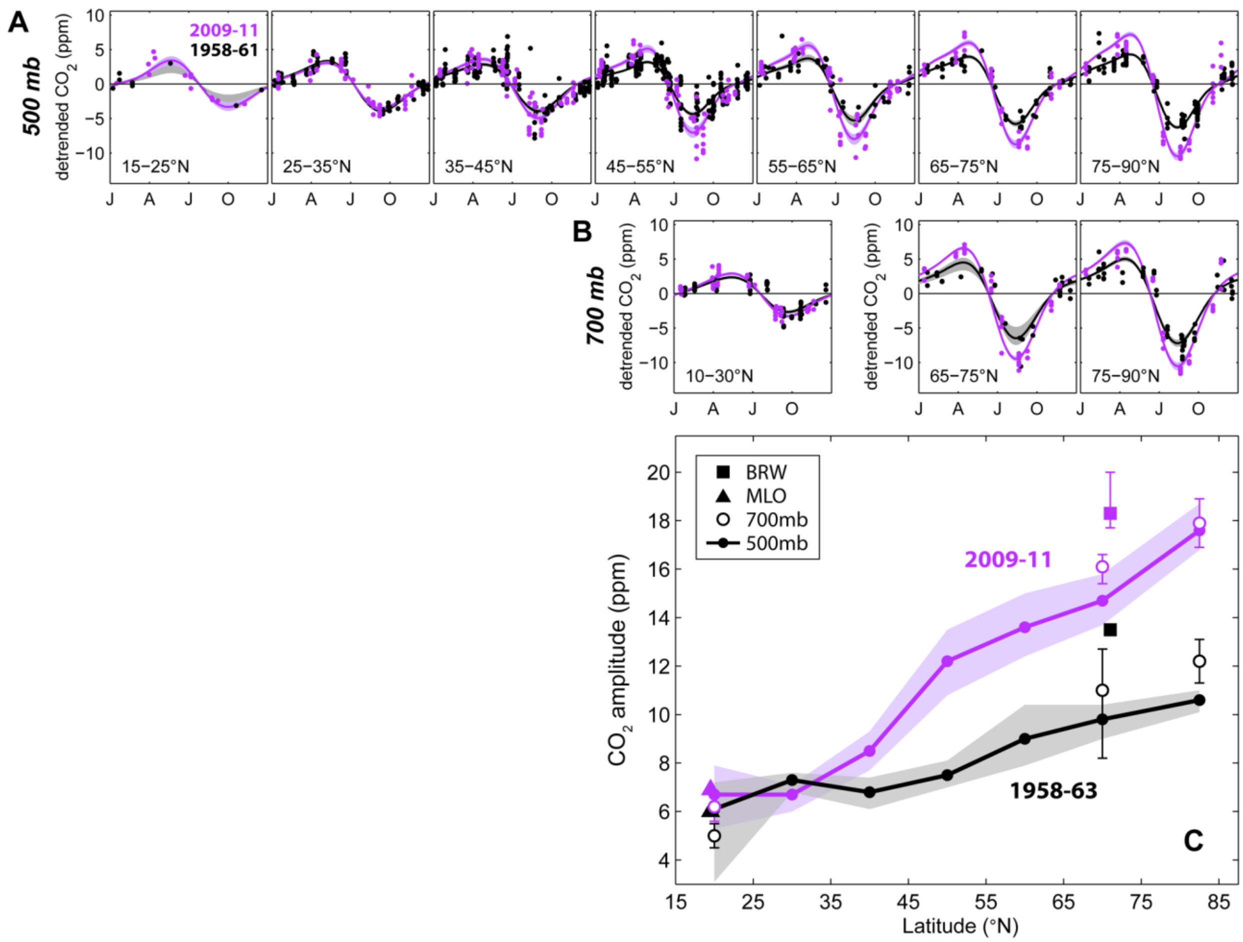

Fig. 2. Seasonal cycles of CO_2 at 500 mb in the top row (**A**) and 700 mb in the middle row (**B**) for each latitude band with aircraft data in both periods. Curves show the seasonal cycles fit to the data, with uncertainties indicated by shaded areas. Amplitudes of the seasonal cycle of CO_2 for all locations with data available in both periods (**C**). The IGY aircraft data cover the period 1958-61; the early BRW and MLO data cover 1961-63 and 1958-63. Uncertainties (*15*) are shown by the shaded areas for 500 mb data and by error bars for 700 mb and BRW in 2009-11. Uncertainties for BRW in 1961-63 and MLO in both periods are smaller than the symbol sizes.