Large-scale increase in the seasonal cycle of CO_2 in the Northern Hemisphere since 1960

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As part of the measurement program of the International Geophysical Year (IGY), airborne observations of CO_2 concentration were conducted over the North Pacific and Arctic Oceans during 1958-61. Samples were collected at 700 and 500 mb (approx. 3 and 6 km altitude) and provide good spatial and seasonal coverage, particularly at 500 mb. With the HIAPER Pole-to-Pole Observations (HIPPO) campaign sampling similar regions of the Northern troposphere during 2009-11, direct comparison of the two datasets provides a measure of the change in the seasonal cycle of CO2 between the 1950s-60s and the 2000s. We have shown that the seasonal amplitude at 500 mb has increased by 40-60% at latitudes north of 45°N, while amplitude changes south of 45°N are smaller than 25% (Graven et al., 2013). This pattern is similar to long-term ground-based CO_2 measurements at Alert, Barrow and Mauna Loa over the past 25 years (Figure 1). The atmospheric observations demonstrate that large-scale changes in the seasonal flux of CO_2 from Northern ecosystems have occurred over the last 50 years. Our analysis suggests that the changes in net ecosystem production (NEP) required to produce the observed growth in CO_2 amplitude are not captured by the terrestrial models participating in the IPCC CMIP5. Further study towards detecting ecological changes that occurred over the past 50 years should be conducted for better prediction of future changes.

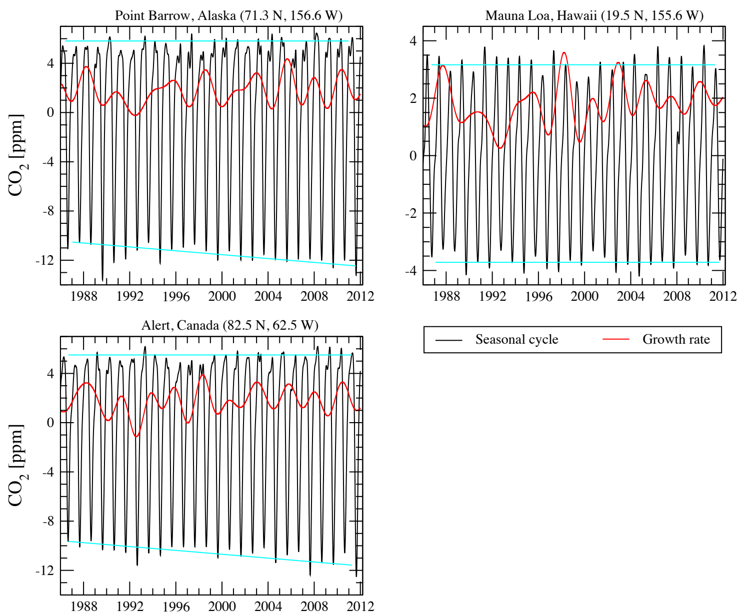

Figure 1. Example of CO_2 seasonal cycle change (black line) and growth rate variations (red line) at Alert, Point Barrow, Mauna Loa during the period of 1986-2011, as measured by NOAA/GMD (www.esrl.noaa.gov/gmd/ccgg). For calculating seasonal cycle and growth rate, the measured time series is decomposed in to longterm trend, best-fit curve and short-term variation (Nakazawa et al., 1997). The time derivative of the longterm trend, and the fitted curve - longterm trend are is shown as the growth rate and seasonal cycle, respectively. Approximate trends in seasonal cycle minima are depicted by the straight lines (cyan). The anomalously low growth rates during 1992-1993 are caused due to enhanced uptake and reduced respiration by the terestrial biosphere following the Mt. Pinatubo eruption, and the extremely high growth rates in 1997-1998 and 2002-2003 are caused by the tropical CO_2 release during El Nino and forest fires in boreal northern lands (e.g., Patra et al., 2005).

References

Graven, H. D., R. F. Keeling, S. C. Piper, P. K. Patra, B. B. Stephens, S. C. Wofsy, L. R. Welp, C. Sweeney, P. P. Tans, J. J. Kelley, B. C. Daube, E. A. Kort, G. W. Santoni and J. D. Bent, Enhanced seasonal exchange of CO_2 by northern ecosystems since 1960, Science, 341, 1085-1089, 2013.

Nakazawa, T., Ishizawa, M., Higuchi, K., and Trivett, N. B. A.: Two curve fitting methods applied to CO_2 flask data, Environmetrics, 8, 197–218, 1997.

Patra, P. K., S. Maksyutov and T. Nakazawa, Analysis of atmospheric CO_2 growth rates at Mauna Loa using inverse model derived CO2 fluxes, Tellus, 57B, 357-365, 2005.