Assessing Terrestrial Ecosystem Responses to Climate Change from Analysis of the Shape and Amplitude of the Seasonal Cycle of Atmospheric CO_2

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We analyzed changes in the shape of the seasonal cycle in atmospheric CO_2 to assess large-scale changes in terrestrial ecosystem function. Monthly mean data from the NOAA ESRL global cooperative air sampling network first were filtered to remove the long term secular trend. Rates of change were then calculated for each month based on linear regressions of monthly residuals versus year. Linear rates of change provide a measure of how the shape of the seasonal cycle has changed through time, with positive rates indicating an increase in monthly CO_2 concentrations and negative rates indicating a decrease. The emphasis on seasonal shape provides a different perspective from methods that focus on the overall amplitude of the seasonal cycle, for which the current method detects changes only when there is a significant trend in the difference between months of maximum and minimum CO_2 concentration. Most stations north of 55º N displayed significantly decreasing summer minima and increasing fall and winter maxima (Figure 1). In contrast, several stations at northern midlatitudes showed the opposite pattern, with shallower summer minima, although these trends were only marginally significant. In an effort to identify the cause of the above changes, we compared observations with climate and soil freeze-thaw anomalies. We also made comparisons with MATCH atmospheric transport model runs forced with historical NCEP meteorology and interannually varying CO_2 fluxes from the CASA and CLM-CN terrestrial ecosystem models.

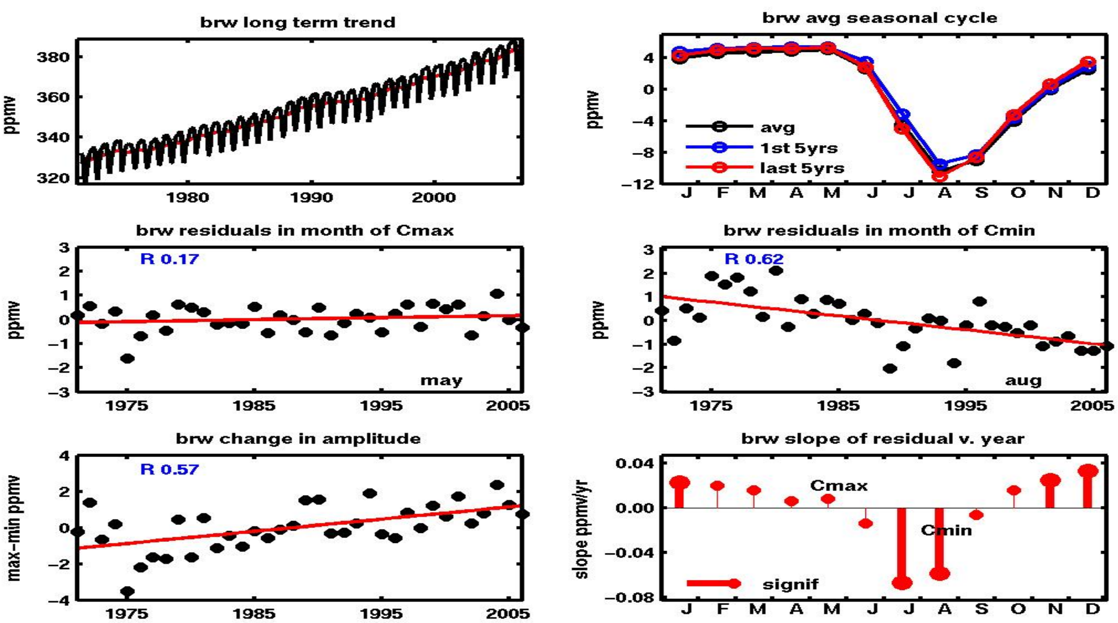

Figure 1. Earth System Research Laboratory atmospheric CO_2 data from Barrow, Alaska (71º N). Upper left panel shows ESRL data and fitted secular trend. Upper right panel shows the average seasonal cycle over the entire record and the first and last five years, calculated from monthly averages of the detrended data. Middle panels show linear regressions on monthly residuals in May (month of Cmax) and August (month of Cmin). Bottom left panel shows linear regression on the difference between the May and August residuals, which is used to estimate the change in amplitude in ppmv/yr. Lower right panel shows the linear slopes in ppmv/yr calculated from residuals for each month. Thick bars indicate slopes significant at the 5% level or better.