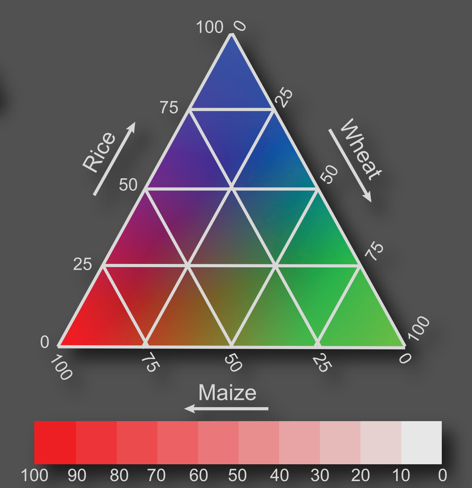
Direct human influence on atmospheric CO_2 seasonality from increased crop productivity

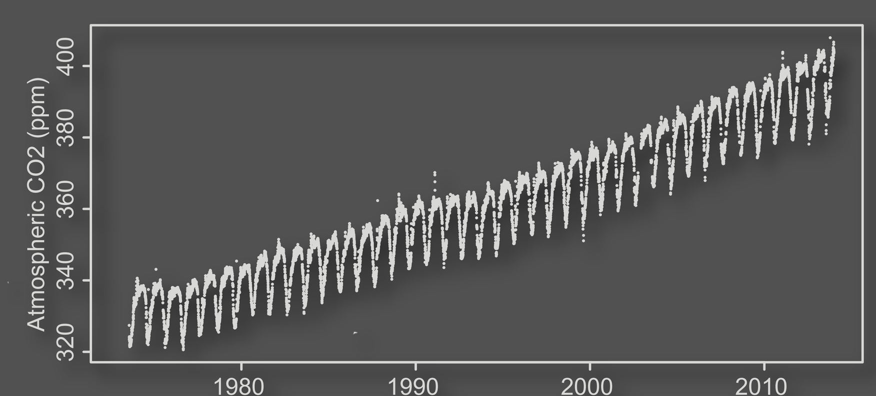
Josh Gray, Steve Frolking, Eric Kort, Deepak Ray, Christopher Kucharik, Navin Ramankutty, and Mark Friedl

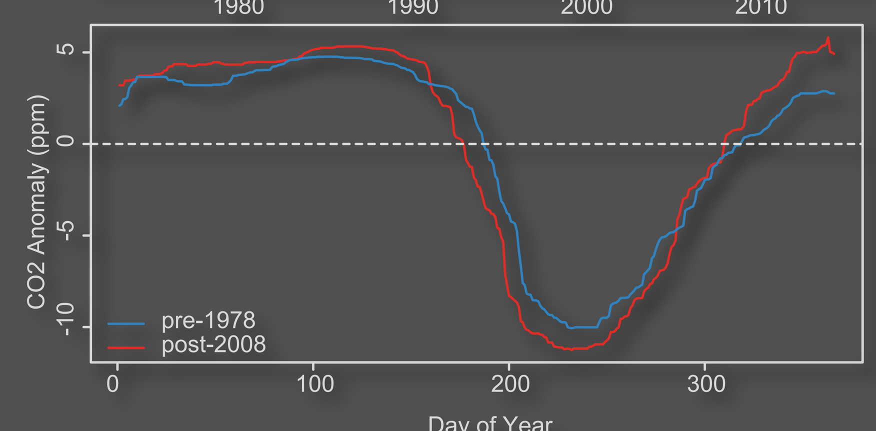


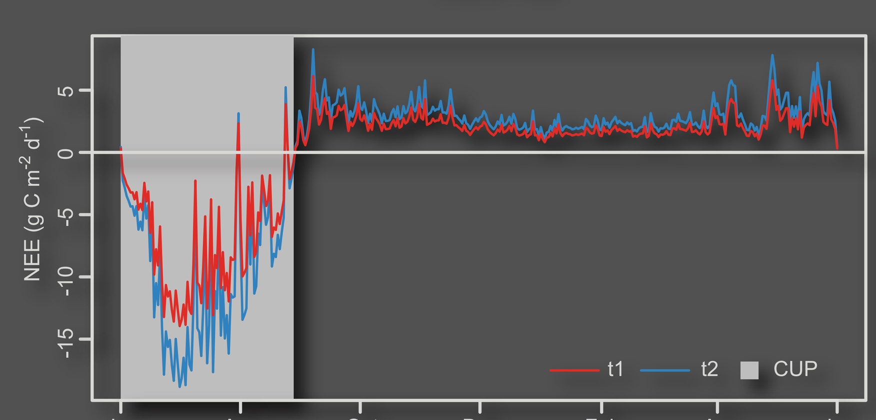
Fraction of maize, wheat, and rice 1961-2008 production increases accounted for by each crop (ternary color legend), and the percentile of increases across the globe (lower alpha-scale shown for 100% maize)

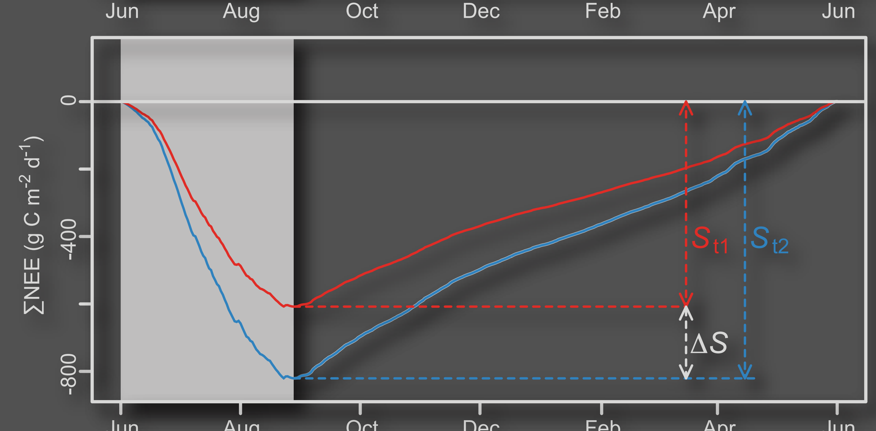
What is atmospheric CO_2 seasonality?

Atmospheric CO_2 concentrations rise and fall annually as carbon is removed from the atmosphere by photosynthesis, temporarily stored as biomass, and then returned to the atmosphere by decomposition. The difference between annual maxima and minima, the depth of the biosphere's annual "breath", is known as atmospheric CO_2 seasonality. This seasonality is clear in daily in-situ measurements from Point Barrow, AK (below, top), as is the increase in this quantity over the past 50 years (below, bottom).





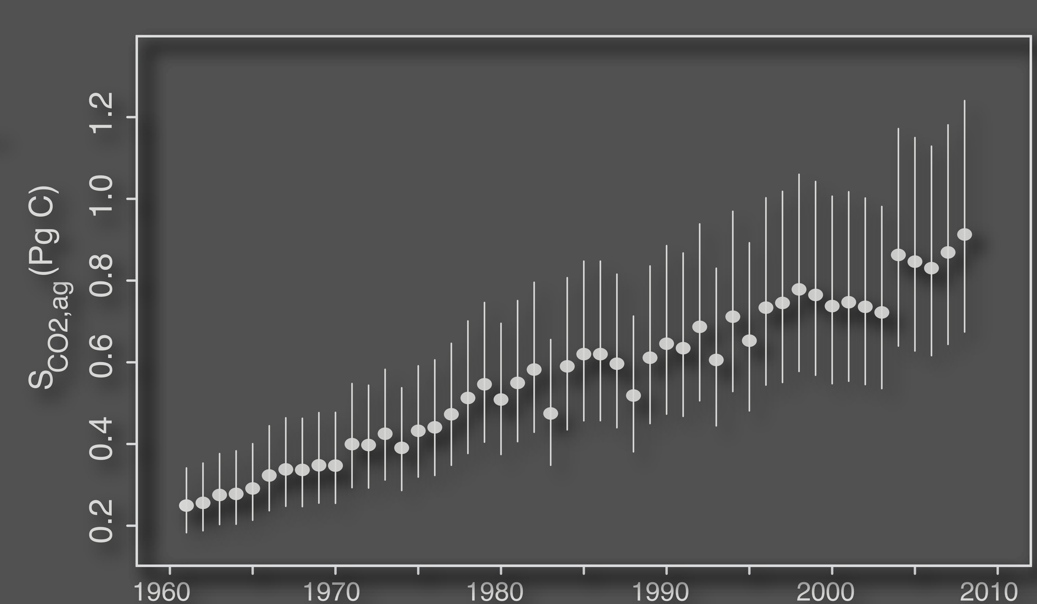


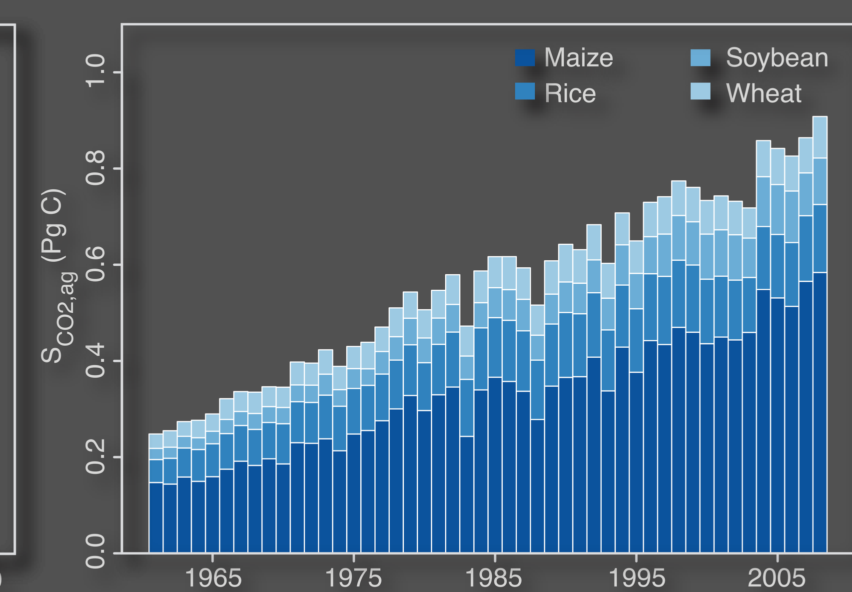


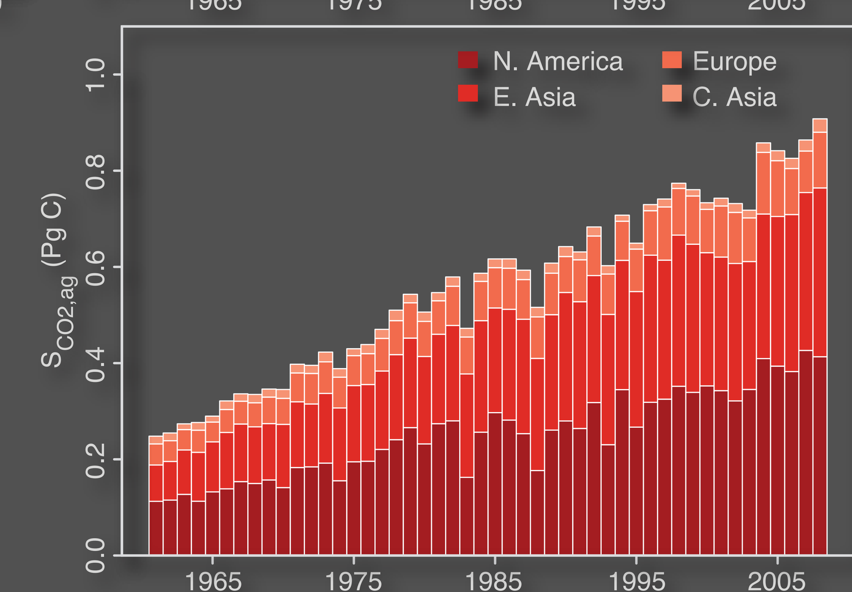
Calculating CO_2 Seasonality: NEE for a baseline condition (*t1*), and where NEE is enhanced 35% (*t2*; top). The accumulated NEE (bottom) shows the resulting increase in CO2 seasonality (ΔS).

Could increased crop production influence CO_2 Seasonality?

The seasonal amplitude of atmospheric CO_2 concentrations has increased over the past 50 years, particularly in the Northern Hemisphere's high latitudes, but for reasons that have remained unclear. We used gridded production statistics and a carbon accounting model to quantify what role increased extratropical production of maize, wheat, rice, and soybeans (MWRS) has played in this increase. Our results indicate that 17-25% of the increased extratropical carbon exchange since 1960 is due to increased production of MWRS, with maize grown in China and the midwestern United States accounting for the largest proportion.





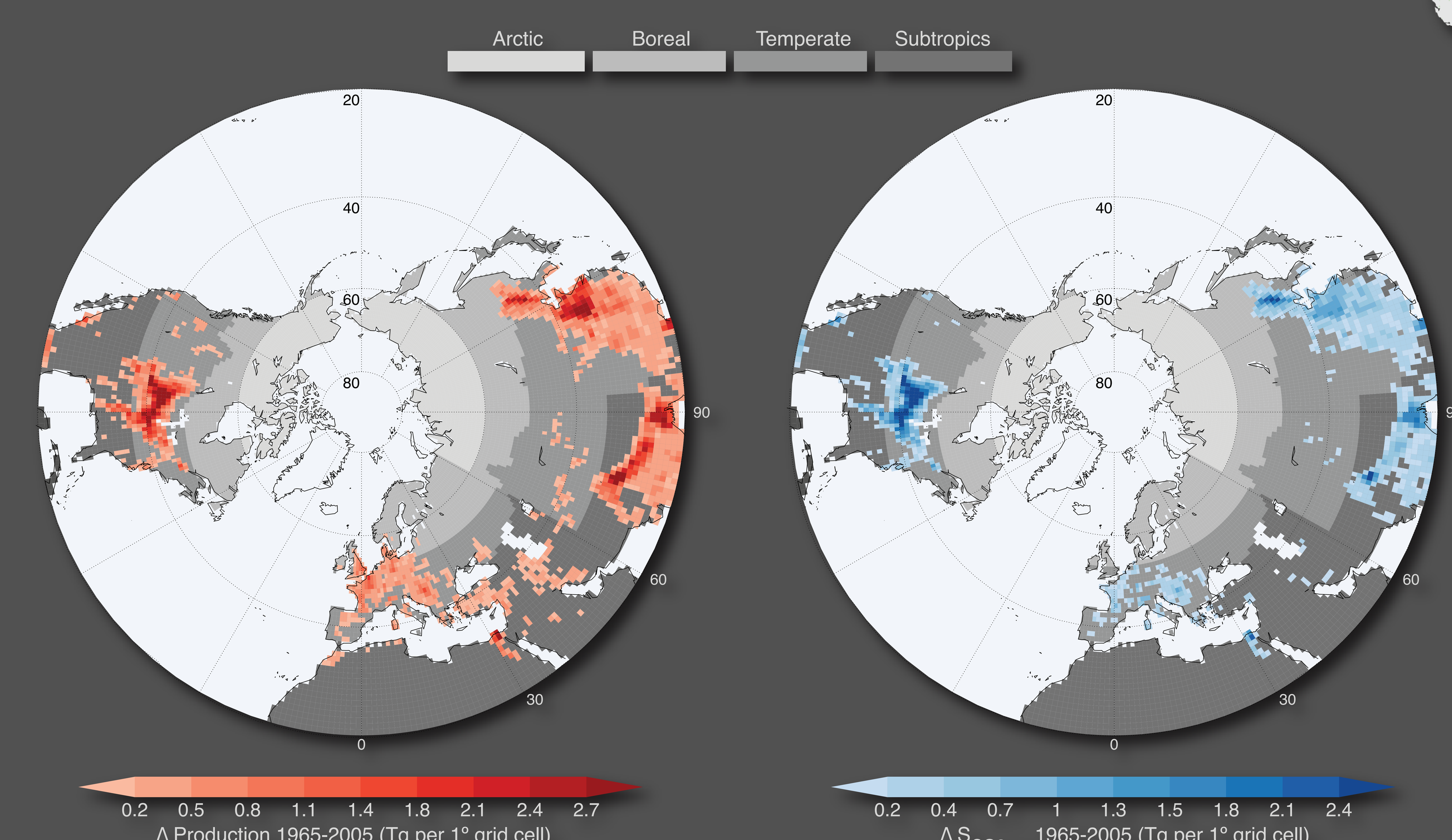


Attributing the increased CO_2 Seasonality: Extratropical production of MWRS has increased 240% since 1960, increasing the forcing on atmospheric CO_2 seasonality by about 0.66 Pg C (top, with 95% confidence intervals from one million Monte Carlo parameter realizations). Maize alone accounts for nearly two-thirds of the increased atmospheric CO_2 seasonality attributable to increased MWRS production (right, top). Moreover, nearly 90% of this change comes from production increases in N. America (primarily the midwestern United States) and East Asia (mostly in China; right, top). Though extratropical wheat production has increased a similar amount as maize, temporal patterns of assimilation/respiration mean it has a less pronounced effect on atmospheric CO_2 seasonality.

Read the full letter in *Nature*:

Key Findings:

- Despite occupying only 6% of extratropical vegetated area, MWRS production increases are responsible for up to 25% of increased biosphere-atmosphere carbon exchange.
- Maize accounts for 66% of the increased seasonality due to MWRS production; 90% of this comes from China and the U.S.
- Increased CO_2 seasonality is a poor indicator of future source-sink dynamics



Increased production and seasonality: Geographic patterns of increases in Northern Hemisphere extratropical MWRS production from 1961–2008 (left), and the resulting increase in forcing to atmospheric CO_2 seasonality (right). Values are shown as sums within 1° x 1° grid cells for illustration, but analyses were conducted at 0.05° x 0.05° grid resolution. Cells with values <0.1 Tg C are not shown.