The Changing Carbon Cycle at Mauna Loa Observatory

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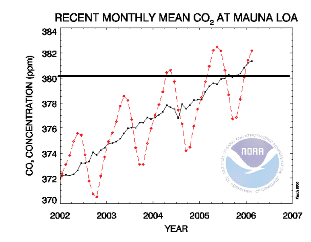
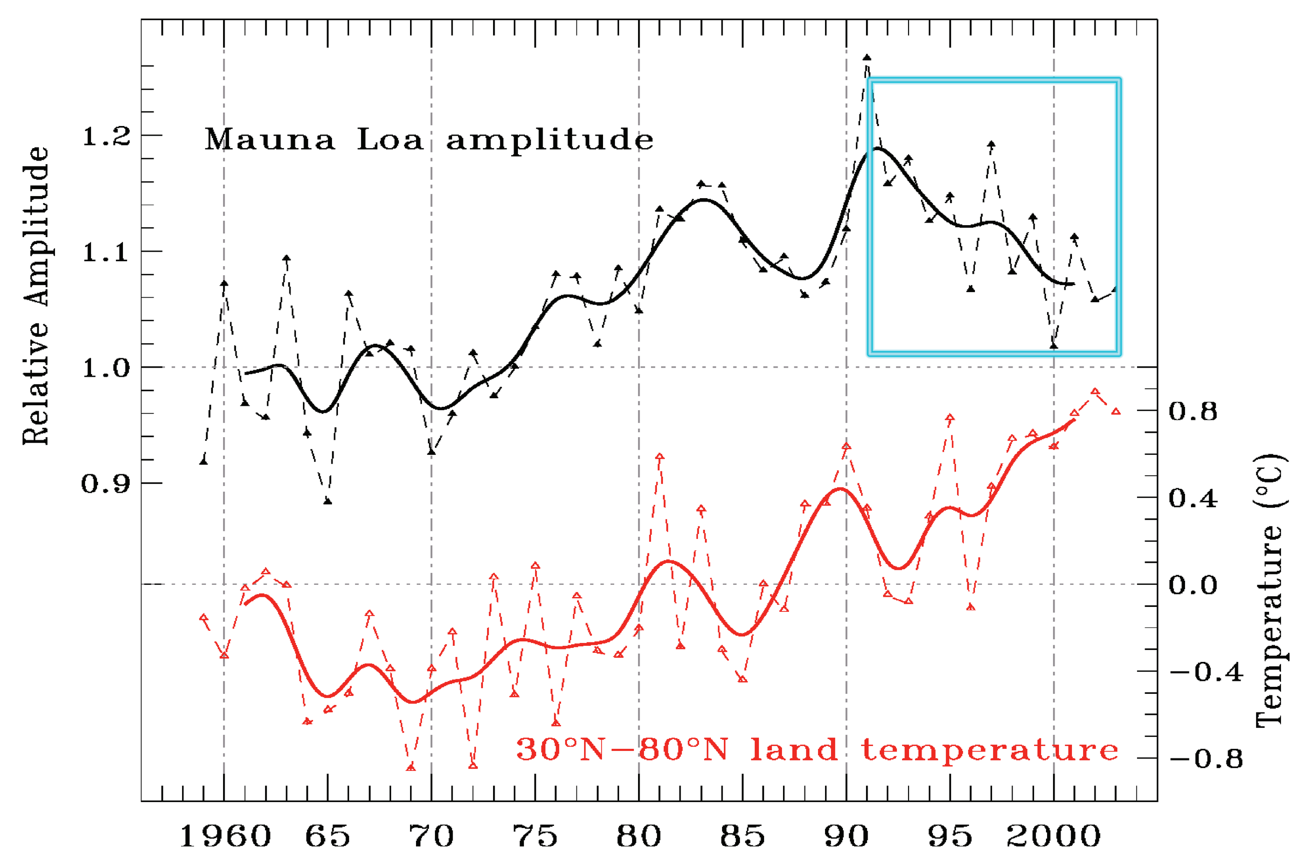
The MLO CO_2 Seasonal Cycle

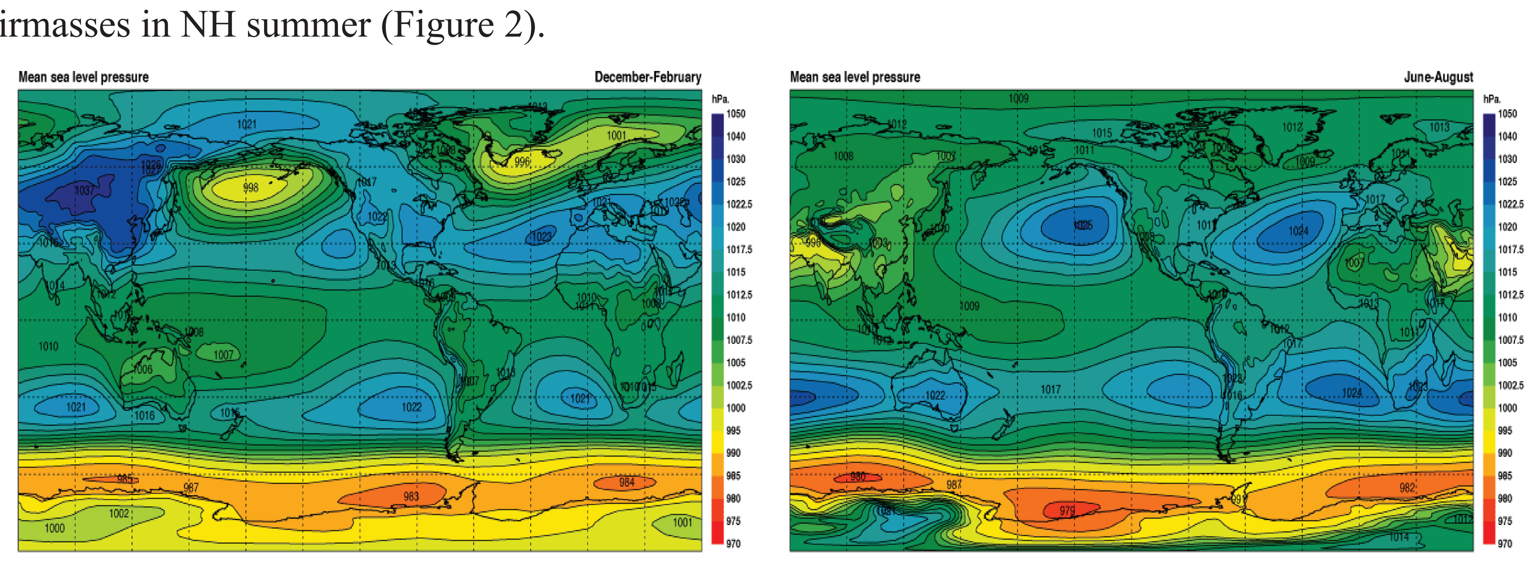
The CO2 seasonal cycle at the Mauna Loa Observatory (MLO) captures the photosynthetic uptake and respiration release of CO2 by terrestrial ecosystems in the northern hemisphere. The peak-to-trough amplitude averages ~6 ppmv, and increased by ~10% from the early 1970s to the early 1990s. The increase has been attributed to increased activity of the biosphere as a result of warming (Keeling et al. 1996). Since the 1990's the amplitude has decreased despite continued warming over northern continents.

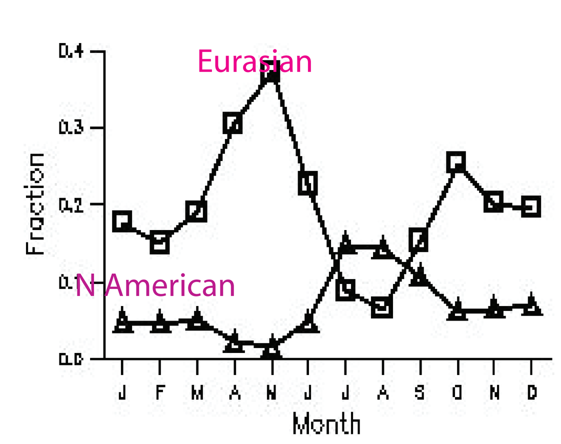




MLO and Atmospheric Circulation

Because of its location relative to the large-scale atmospheric circulation, MLO receives mainly Eurasian airmasses in the Northern Hemisphere (NH) winter but relatively more North American airmasses in NH summer (Figure 2).

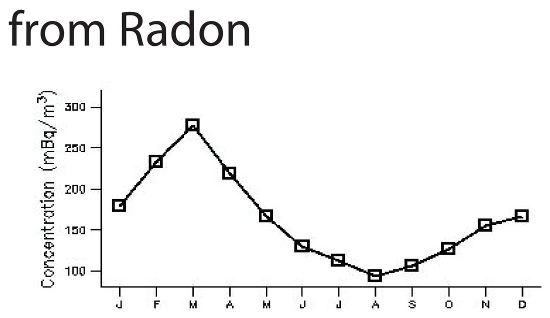




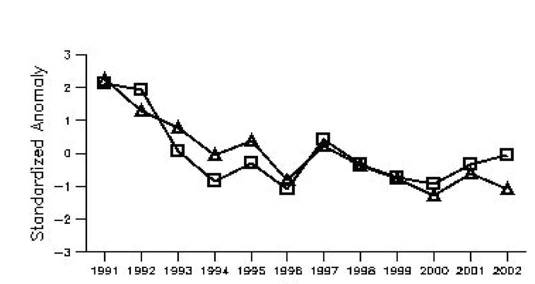
Using a Lagrangian back-trajectory model, we tagged the ***origins of airmasses arriving at MLO*** from Eurasia (0-150E, 20-70N) and from N America (130-60W, 20-70N). The relative abundance (Figure 3) hows the dominance of Eurasian air in NH cold season and a slight dominance of N American air in NH warm season (Lintner et al. 2006).

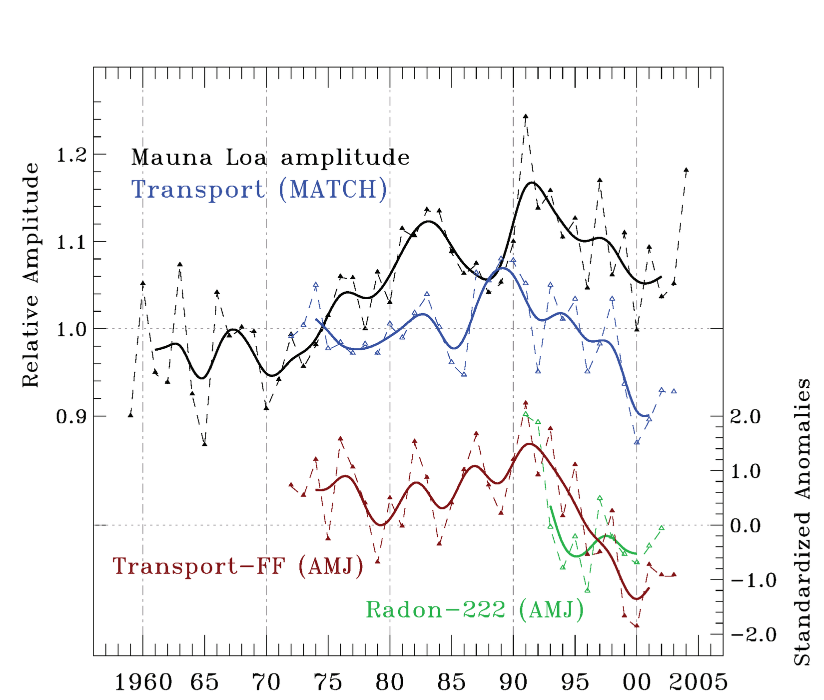
Cold Season Changes: Clues from Radon

Radon is a tracer of continental air masses, and has a half-life of 3.8 days. The ***mean radon seasonal cycle*** (1991-2002) measured at MLO (Figure 4) shows a maximum in NH winter and a minimum NH summer, consistent with direct transport (faster than its half-life) from Eurasia in NH winter. Transport path from N America is comparatively more circuitous (not shown).



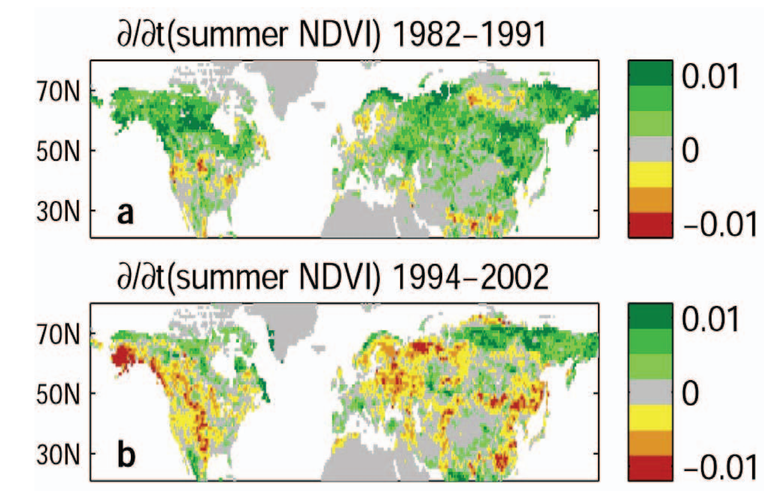
Standardized anomalies of ***April-May-June Radon and CO2 at MLO*** at significantly correlated (r=0.86) and show a downward trend (Figure 5), suggesting a change in atmospheric circulation and a decrease in Eurasian airmasses (with high CO2 abundance) arriving at MLO in the winter .





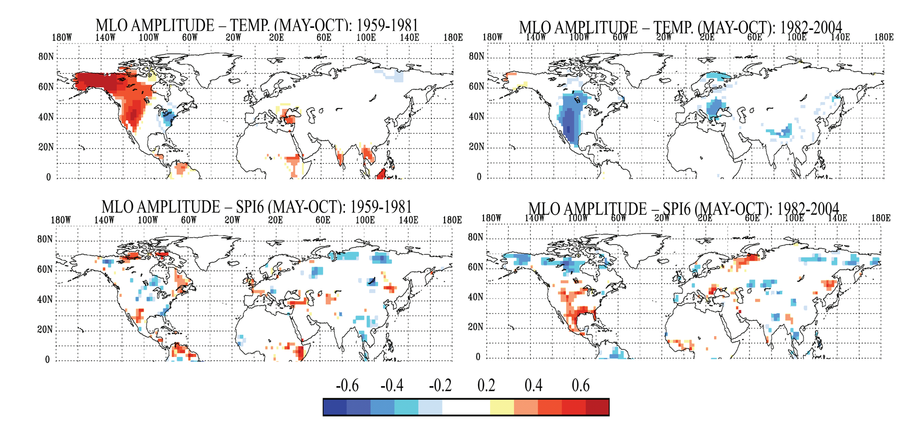
To estimate the effect of changing atmospheric circulation on the global CO2 distribution, Dargaville et al. (2001) specified a time-invariant fossil fuel source as a forcing to a global 3D atmospheric transport model (MATCH) with time-varying circulation from NCEP reanalysis. The results (Figure 6) show that April-May-June decrease in the modeled FF CO2 is similar to the observed AMJ radon concentration, and suggest that reduced arrival of Eurasian airmasses with high CO2, espcially in the cold season, could be a contributor to the decreasing trend in MLO CO2 amplitude.

Warm Season Changes:

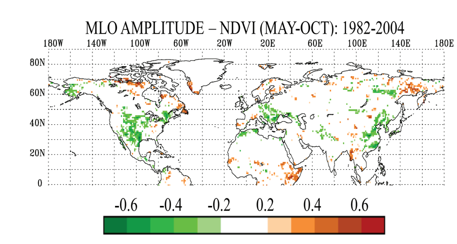


The first 1.5 decades of the NDVI, a satellite photosynthesis index, show a greening trend. In the recent decade, however, the greening trend in the summer has halted, with the severe heat waves and droughts of 2000-2003 (Angert et al. 2004).

The ***correlation coefficients between the MLO CO2 ampltiude and N American warm-season temperature anomalies*** switch from from positive to negative between an early 23 years and a recent 23 years. (Figure 8). Consistent with the circulation, there is no significant correlations with summer temperature anomalies in Eurasia.

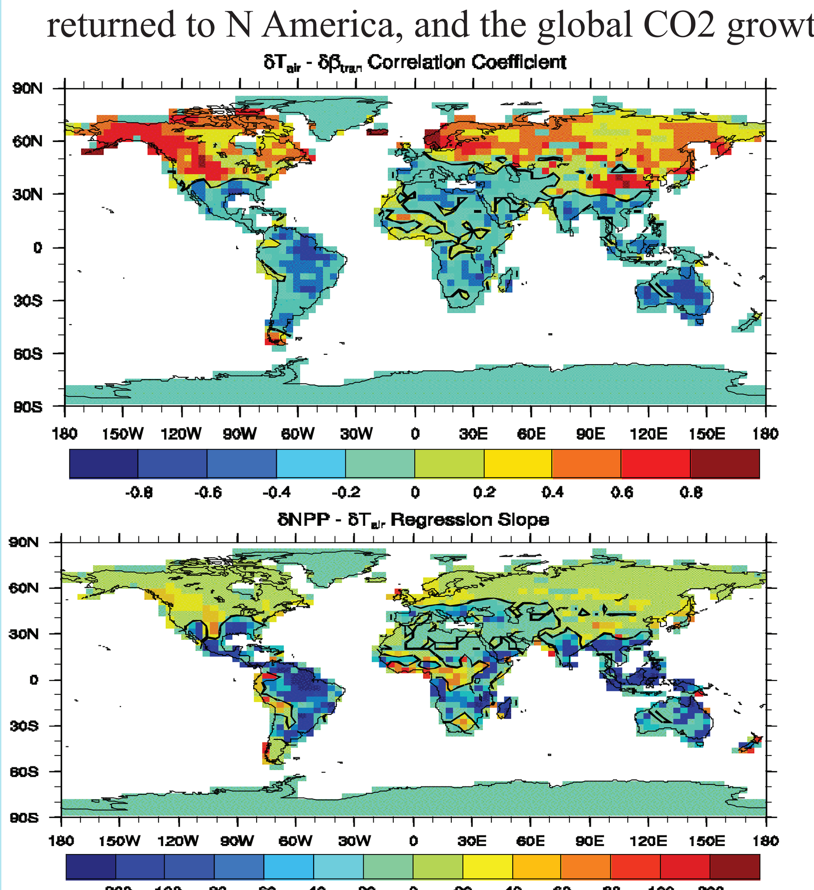


Over the satellite NDVI period, year-to-year variations in MLO CO2 amplitude are significantly and negatively correlated with variations in the ***warm (growing) season NDVI***, mainly in N America, confirming that MLO CO2 amplitude is a record of NH biospheric activity (Figure 9). The NDVI (i.e. photosynthesis) increased in the 1980's and early 1990's, as did atmospheric CO2 drawdown and MLO CO2 amplitude. The reverse happened during the droughts of 2000-2003, and MLO CO2 amplitude decreased (Buermann et al. 2007).



Discussion

The CO2 seasonal amplitude at MLO documents the response of the carbon cycle to climate change. In the recent period, the negative response of photosynthesis to droughts and heat waves overwhelmed the positive response to warming and increased CO2. Not only did the MLO seasonal amplitude decrease, the annually and globally averaged CO2 growth rate increased dramatically to ~2.8 ppmv/yr. In 2004, MLO CO2 amplitude increased when the rains returned to N America, and the global CO2 growth rate returned to ~1.5 ppmv/yr.



Global climate models predict greater frequency of droughts for hte 21st century. Even though there remains considerable uncertainty in projections of precipitation, evaporation will increase with warming, especially in warm places (i.e. tropics, mid-latitude summers), leading to ***drier soils with global warming*** (upper panel) and less enhancement of net primary photosynthesis (NPP), especially in the tropics (Figure 9).

Feedbacks between the terrestrial carbon cycle and the climate change would act to decrease photosynthesis, increase airborne fraction, and accelerate global warming (Fung et al. 2005).

Summary

The time series of MLO amplitude shows behavior and controls in the last two decades that are very different from those of the earlier two decades. Our analysis suggests that throughout the last two decades, the MLO CO2 seasonal amplitude

The unique location of MLO in the context of seasonally varying atmospheric circulation allows the separate identificaiton of the variations in North American versus Eurasian carbon sources and sinks. This work suggests that long time-series measurements of atmospheric CO2 at remote sites can continue to play an important role in documenting changes in continental CO2 sources and sinks as well as in atmospheric transport.

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