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Changes in CO_2 Composition in the Air of the Los Angeles Megacity Coinciding with the Prolonged Drought

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Introduction

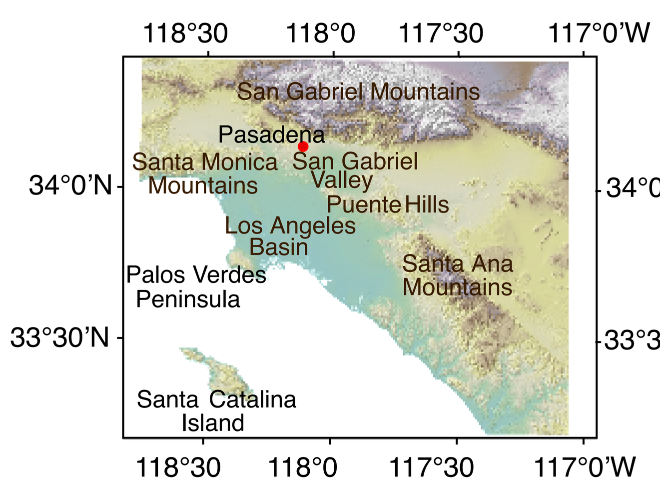

Figure 1. Map showing the location of the Pasadena site in the Los Angeles basin

California has been in a severe drought for five years affecting weather, vegetation, and policy. Unfortunately, the last year's strong El Nino conditions did not bring the expected extra rainfall relief to southern California, and we are just finishing a year of water rationing, concentrating on limiting irrigation of outdoor landscape. What changes in the atmospheric CO_2 composition in the Los Angeles, CA (LA) megacity have occurred during this period?

We investigate changes reflected in the radiocarbon ($\Delta^{14}C$) and stable carbon isotopic composition ($\delta^{13}C$) of the CO_2 in LA, using the long-term flask sample record at our Pasadena (18 years, 11 with $\Delta^{14}C$; samples collected on alternate afternoons at 14:00 PST) site (Fig. 1) to put the last five years in context. Pasadena is inland and a good receptor site for emissions in the LA basin for much of the year when the prevailing winds are from the ocean passing over LA. Radiocarbon measurements give information on the fossil fuel and biosphere components of the local emissions. $\delta^{13}C$ variations give information about the relative proportions of petroleum and natural gas combustion within the fossil fuel component. We have shown that the annual cycles of CO_2 from total fossil fuel (CO_2ff), petroleum (CO_2pet), and natural gas (CO_2ng) combustion are consistent with the annual cycle of wind directions in the LA basin (Newman et al., 2016). How do changes in seasonality between before and during the drought relate to meteorological changes? Are there changes in the seasonal cycles of source attribution signals?

Data

CO_2

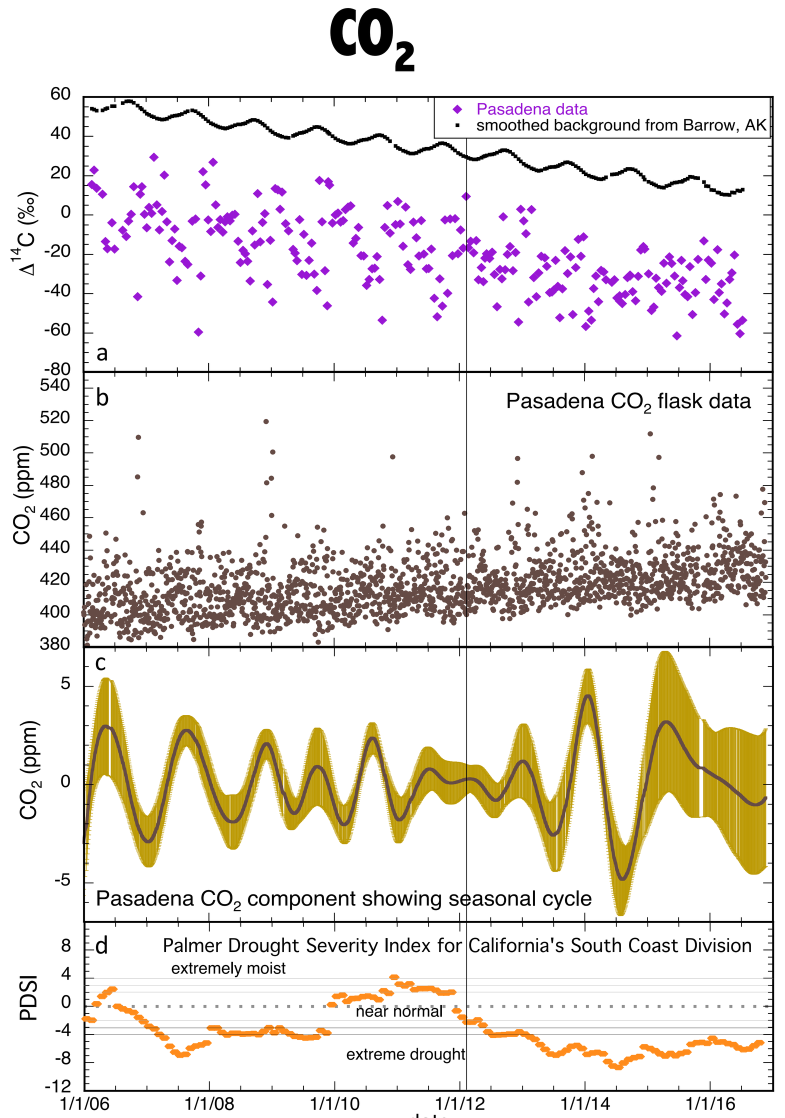

Figure 2. Our radiocarbon time series (a) from flask samples shows a change in seasonality beginning with the beginning of the drought in 2012, according to the Palmer Drought Severity Index (d; vertical line in a-e; http://www.cgd.ucar.edu/cas/catalog/climind/pdsi.html). The CO_2 mixing ratio time series (b) does not show any obvious change at this time. However, when the high frequency variations are removed, using Ensemble Empirical Mode Decomposition (EEMD; Huang et al., 1998; Wu and Huang, 2009), we can extract the seasonal component of the signal (c). This component shows a change in the seasonality, again at the time of the beginning of the drought (d).

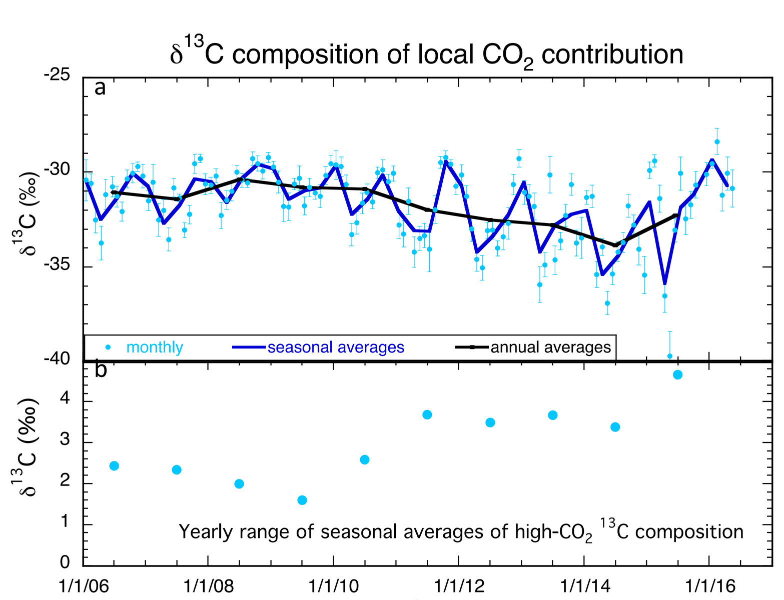

Figure 3. The stable carbon isotopic composition ($\delta^{13}C$) time series (not shown) shows similar short-term variability to the CO_2 mixing ratio record. When the isotopic compositions of the high-CO_2 end member of each month are plotted (a), we see a different kind of change with the onset of the drought. The range of the seasonal cycle of the high-CO_2 end member increases at the time of the shift to the prolonged drought (b). The increase in the value of the $\delta^{13}C$ in the last year is consistent with values that might be expected if drought-resistant C4 plants were becoming more abundant relative to C3 plants, whose respiration results in greater fractionation of the stable carbon isotopes and lower values. We had mandatory water rationing during the last year.

Meteorology

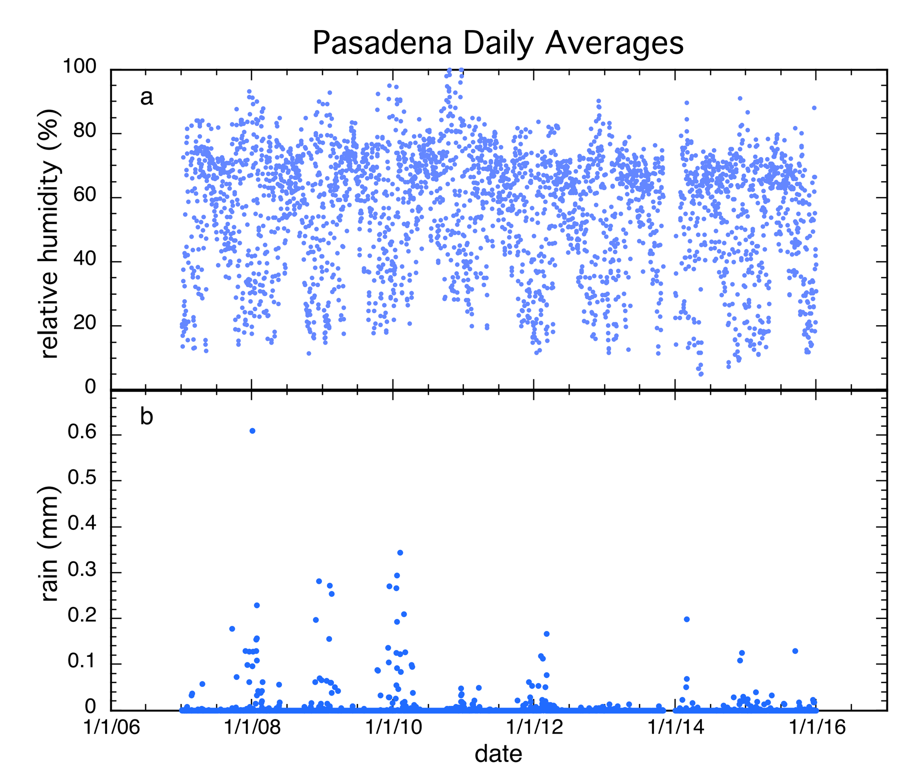

Figure 4. Our Pasadena weather station shows the drought as decreases in both relative humidity (a) and rain fall (b).

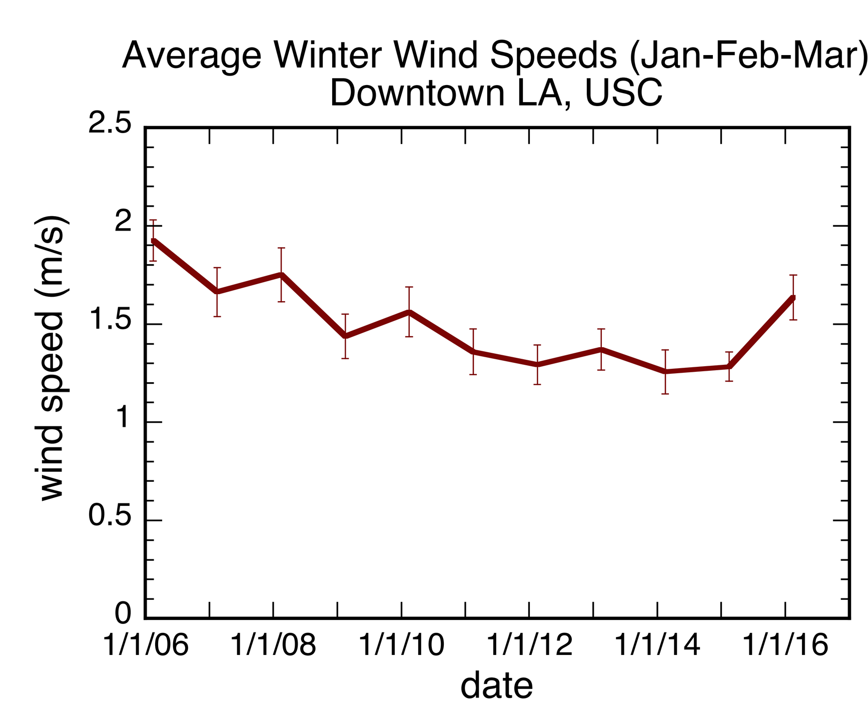

Figure 5. The average winter winds at USC, show a change in wind speed at the beginning of the drought. Wind speeds are lower during the drought than before. Wei et al. (2016) concluded that atmospheric circulation in the eastern north Pacific is the most important factor in understanding the precipitation in California. Atmospheric modeling, such as using WRF-VPRM/Chem, must be done to confirm that this is the mechanism causing the changes in seasonality of CO_2 observed in Pasadena.

Drought affects source attribution?

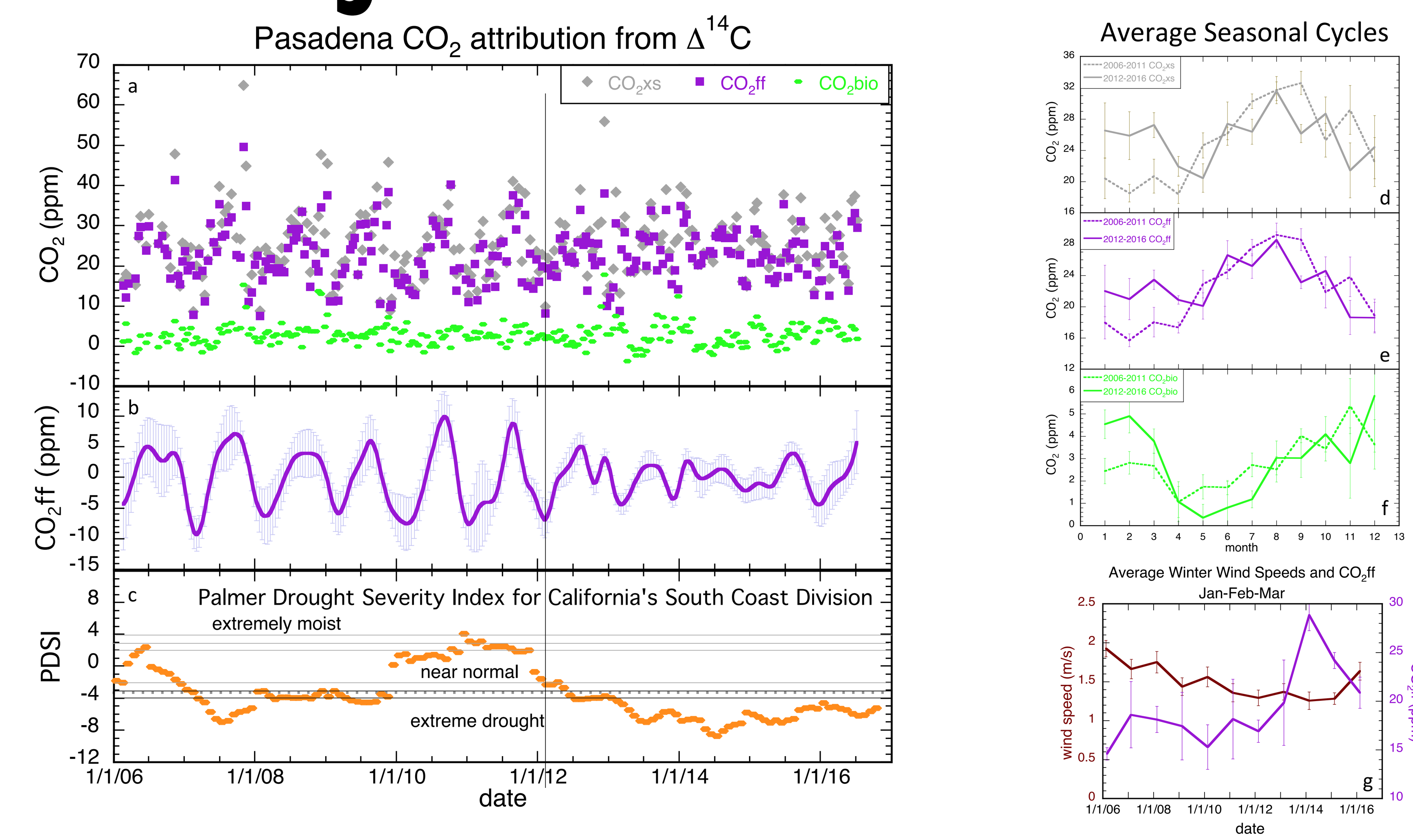

Figure 6. We observe a change in the calculated seasonality of both CO_2 excess over background (using La Jolla data as background for CO_2 mixing ratios) and CO_2ff (CO_2 from fossil fuel combustion, using Pt. Barrow data as background for $\Delta^{14}C$) (a) at the onset of the drought (c). The seasonality of CO_2ff is shown in the seasonal component extracted by EEMD (b) and highlighted in the average seasonal patterns for CO_2xs (d), CO_2ff (e), and CO_2bio (f) for the time periods before (dashed curves) and during (solid curves) the drought. CO_2xs, CO_2ff, and CO_2bio during the late winter months have been higher during the drought than beforehand, perhaps due to stagnant air masses as suggested by lower wind speeds, seen in panel (g) for CO_2ff and wind speed at USC.

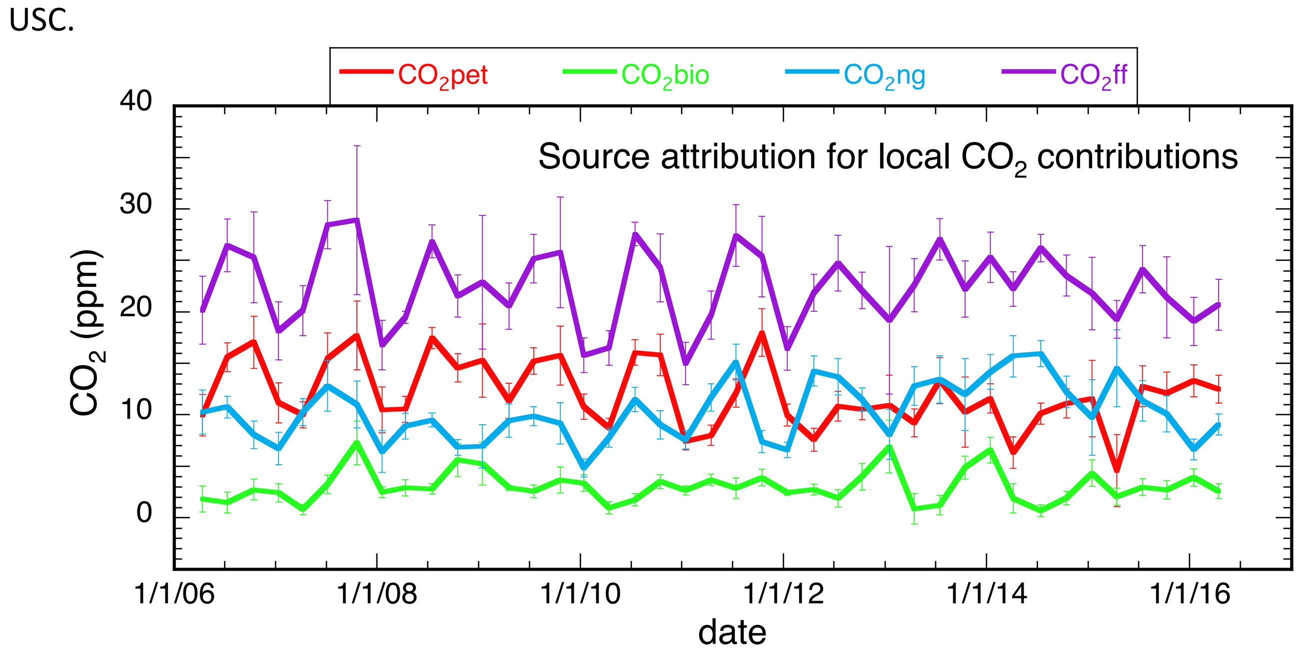

Figure 7. Seasonal attribution of the local sources of CO_2 observed in Pasadena is shown among CO_2ff (total from fossil fuels), CO_2bio (from the biosphere), and between natural gas (CO_2ng) and petroleum (CO_2pet) combustion within the fossil component. We have previously concluded that the seasonality of CO_2ng and CO_2pet was due to seasonal variations in wind direction, for the period 2006-2013 (Newman et al., 2016). The change in seasonality coinciding with the start of the drought is seen in CO_2ff and CO_2pet, but is not seen convincingly in CO_2ng or CO_2bio. We are looking into explanations for these trends.

Conclusion

- Used the Regional Palmer Drought Severity Index to identify the start of the current drought
- Local meteorology - decrease in relative humidity, rain fall, and winter wind speeds
- CO_2, $\Delta^{14}C$, $\delta^{13}C$, CO_2ff, and CO_2pet - changes in seasonal cycles with the start of the current drought, but not in CO_2ng
- Need to use atmospheric transport model such as WRF-VPRM/Chem to confirm causal relationship between drought conditions and CO_2 observations

References:

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Newman, S., X. Xu, K. R. Gurney, et al., 2016, Atmos. Chem. Phys., 16, no. 6, 3843–3863, doi:10.5194/acp-16-3843-2016.

Wei, J., Q. Jin, Z. L. Yang, and P. A. Dirmeyer, 2016, Geophys. Res. Lett., 43, 6554-6562,doi:10.1002/(ISSN)1944-8007.

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