DOWN AND DIRTY: USING A CONTINENTAL, NOT-SO-TALL TOWER TO STUDY TRENDS IN LOCAL, REGIONAL, AND GLOBAL ATMOSPHERIC CO_2 CONCENTRATIONS

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ABSTRACT:
Precise CO_2 concentration measurements at marine stations and tall towers are crucial for quantifying global trends in atmospheric CO_2 concentrations. We propose that measurements in the continental planetary boundary layer—the poor cousin of the clean background stations—can be used to understand trends in, and controls, of atmospheric CO_2 concentrations at local and regional scales as well as global scales. The key is choosing appropriate time scales of integration for the data. In the US Southern Great Plains, we are measuring precise CO_2 concentrations continuously at 2–60 m and weekly at 300 and 3300 m above ground level (agl). CO_2 flux is measured in individual crop fields and pastures (4 m towers) and at 60 m. The precise CO_2 concentrations show strong continental influence in both diurnal and seasonal cycles. In continental regions, atmospheric CO_2 profiles are strongly influenced by atmospheric dynamics as well as ecosystem and anthropogenic fluxes. Relating site level measurements or atmospheric profiles to regional CO_2 budgets requires methods to represent or evaluate these influences. We observe inter-annual differences in the climatology of diurnal cycles (seasonal average diurnal cycles). Using the several years' data for boundary layer concentrations, the annual trend in CO_2 growth nearly matches the value estimated by National Oceanic and Atmospheric Administration (NOAA) Climate Monitoring Diagnostic Laboratory for our latitude band.

METHODS:
We are working in the Southern Great Plains (SGP) testbed, a 300×300 km area of Oklahoma and Kansas supported by the U.S. Department of Energy Atmospheric Radiation Measurement Program (ARM). Most of our carbon measurements are collected at the 60 m tower of the ARM Central Facility, including precise CO_2 concentration profiles; NOAA flasks in the mixed layer and free troposphere (by aircraft); and diurnal profiles of ^{13}C and ^{18}O in CO_2. We are making measurements of carbon fluxes at the scale of individual fields and integrated over a larger heterogeneous area. We make flux measurements at 60 m, and from a permanent AmeriFlux tower and two portable towers (each 4 m) to document spatial and inter-annual variability in CO_2 exchange for fields containing winter wheat, summer crops, and pasture.

To summarize the diurnal CO_2 cycle observations, we averaged each hour over a season (for example, all 10–11 am measurements) and express as a diurnal cycle climatology (Fig. 1). To characterize the diurnal cycles, we made a simple box model with three well mixed compartments for the surface layer, boundary layer, and free troposphere.

By comparing airborne and tower data, we have found that the 60 m tower is tall enough to sample well-mixed boundary layer air during the afternoon, when convective mixing is active. As a result, the data can be used to estimate regional atmospheric CO_2 concentrations.

RESULTS:
On still nights, atmospheric CO_2 concentrations can be elevated over mid-day values by more than 200 ppm. Even the season-averaged diurnal cycle has an amplitude of more than 70 ppm (Fig. 1). The simple box model shows that the diurnal cycle in continental regions has three phases, distinguished by different

atmospheric and biotic processes: CO_2 buildup in the evening follows cessation of photosynthesis and increasing atmospheric stability; rapid decrease in concentration after sunrise driven by atmospheric mixing; and gradual draw-down of concentrations mid-day by net ecosystem uptake and the growing boundary layer. We observe inter-annual differences in the diurnal cycles (seasonal average diurnal cycles). According to a (back trajectory) footprint analysis, these seasonal and inter-annual differences could be attributed to differences in regional climate patterns, which affected both productivity and respiration, and the footprint influence function, i.e., what land surface was influencing the concentrations at the tower.

For the annual trend in data, the daily CO_2 concentrations measured between 2 and 5 PM, show an annual increase over three years that was more than 2 ppm yr^{-1} (data not shown). The trend nearly matches the global background trend (2.3 ppm y^{-1}) reported by NOAA at Mauna Loa.

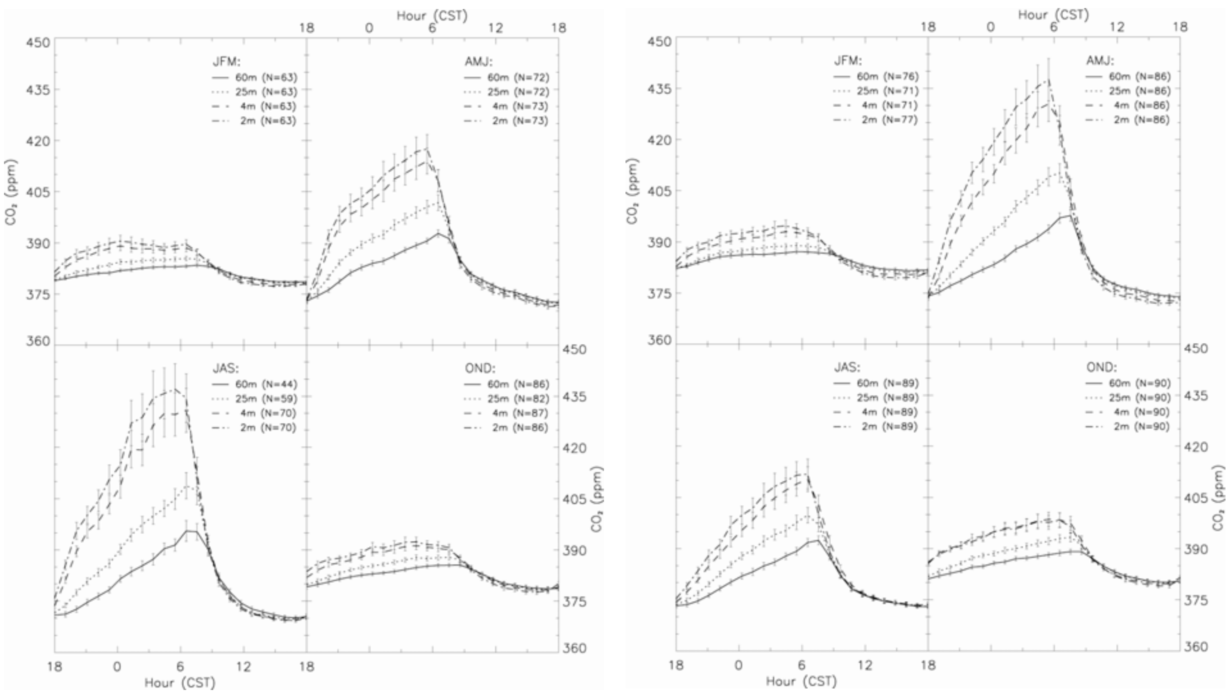

Fig 1. Diurnal cycle of CO_2 concentrations at 4 heights by season for years 2002 (left panel) and 2003 (right panel).