Direct measurements of dry and wet deposition of black carbon over the Southern Great Plains site

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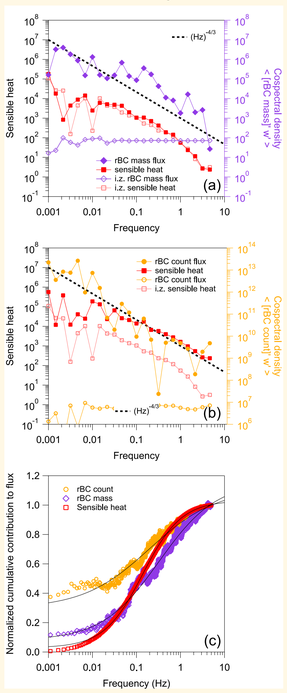
Summary

- Motivation: The atmospheric lifetime of black carbon (BC) is controlled by wet and dry deposition, which are poorly constrained by observations.
- Method: The single particle soot photometer (SP2) can measure surface-atmosphere exchange fluxes of refractory BC (rBC) particle mass and number by eddy covariance.
- Results: Field measurements of rBC dry and wet deposition rates during summer 2017 at the Southern Great Plains site in Oklahoma allow us to estimate dry deposition velocities (V_{dep}) of rBC mass (μ_g = 1.6; σ_g= 3.3 mm s^{-1}) and particle number (μ_g = 0.6; σ_g= 3.1 mm s^{-1}).
- Conclusion: We estimate a wet deposition flux of 2600 ng m^{-2} hr^{-1} over the 148.5 mm of rainfall observed. During the campaign, dry deposition constitutes 12% (σ_g= 2.6) of total deposition. These data indicate a rBC lifetime of 11 (σ_g = 3.3) days for dry deposition and 1-3 days for wet deposition at this site during this campaign.

SP2 for eddy covariance flux measurement



To demonstrate the ability of the SP2 to measure rBC mass and particle count fluxes, we use :

(1) spectral analysis to demonstrate that the SP2 meets the instrumental requirements for eddy covariance flux measurements (Fig.1, left);

(2) quantitative constraints on uncertainty and detection limits of the flux measurement:

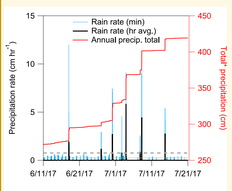
$$\overline{LOD}_{mass} = 0.04\ (ng\ m^{-2}s^{-1})$$
$$\overline{LOD}_{counts} = 3\ (\#\ cm^{-2}s^{-1})$$

(3) internal comparison of rBC mass and particle fluxes.

Figure 1: Cospectral density of (a) rBC mass fluxes, (b) rBC particle count fluxes, and (c) corresponding ogives. Data is shown in comparison to sensible heat for the same time period and an example instrument zero (i.z.). Datapoints shown represent the absolute value of averages of 25 logarithmically spaced bins. Ogives are normalized cumulative contributions to the flux based on integrated cospectral density. Points are medians of all quality controlled data for each frequency across the shown range. Curve fits are Hill Functions.

BCADS: Black Carbon Aerosol Deposition Study

BCADS 2017 took place at the Department of Energy Atmospheric Radiation Measurement Southern Great Plains (SGP) site in Lamont, Oklahoma, USA from 12 June to 23 July 2017.



BCADS measurements included: SP2 measurements of refractory Black Carbon (rBC); UHSAS (ultra high sensitivity aerosol spectrometer) measurements of aerosol size distribution; precipitation collection for off-line rBC measurements by SP2

Observations: SGP, Summer 2017

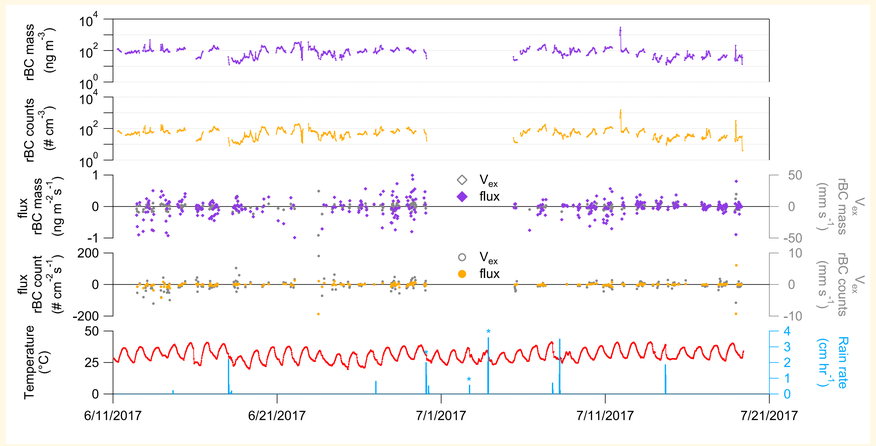


Figure 3: Campaign overview of rBC mass, particle counts, fluxes, vertical exchange, and meteorological parameters. We only show quality controlled data for fluxes and V_{ex}. rBC mass and particle counts represent 30-minute averages. Precipitation was collected during rain periods marked with an (*). Rain rates were measured using a weighing bucket precipitation gauge [ARM Climate Research Facility, Weighing Bucket Precipitation Gauge].

Figure 4: Diel profile of (a) rBC counts and (b) rBC mass, binned bi-hourly.

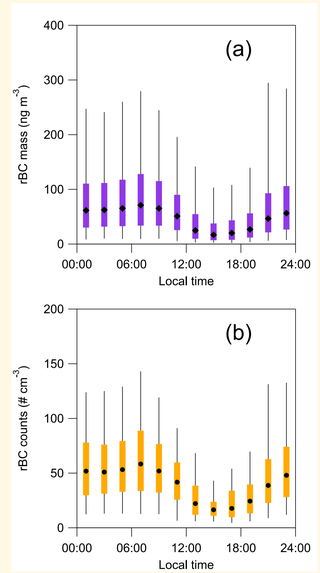
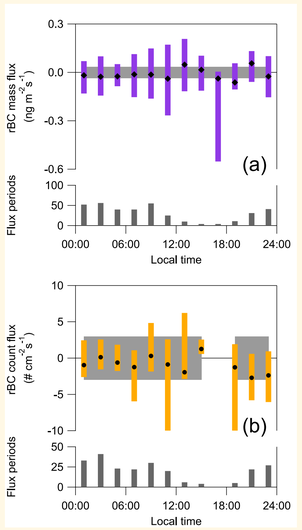


Figure 5: Bi-hourly binned fluxes of (a) rBC counts and (b) rBC mass. The shaded grey bar represents the LOD; bottom vertical bars show the # flux periods included in the analysis



Dry vs Wet Deposition as a sink of rBC

- Observed deposition velocities during BCADS (rBC mass 1.6 mm s^{-1}, σ_g= 3.3 and rBC particle number 0.6 mm s^{-1}; σ_g= 3.1) are consistent with current global model approaches and represent the first *in situ* measurements of rBC deposition velocities.
- Dry deposition represents 12% (σ_g = 2.6) of the total rBC mass deposition, within the typical 5-20% assumed in global climate models [*Koch et al.*, 2009]. However, this value is highly dependent on precipitation rates, and assumes that observed wet deposition at the site represents removal of the same air mass observed in dry deposition.
- Future Work will focus on the role of size and coatings in controlling deposition velocity, and the role of surface properties, precipitation and mass loading in controlling V_{dep}.

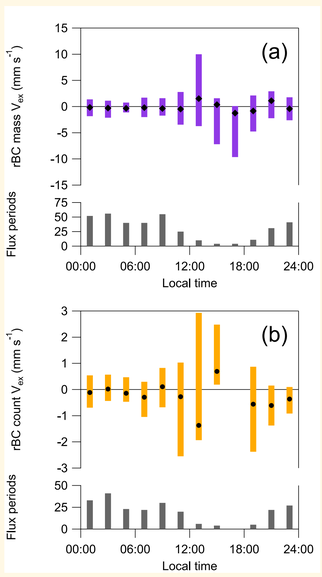


Figure 6: Diel profile of V_{ex} for rBC mass (a) and particle counts (b). Symbols are medians, boxes are 25th and 75th percentiles, number of points within each bin is shown in the bottom panel.

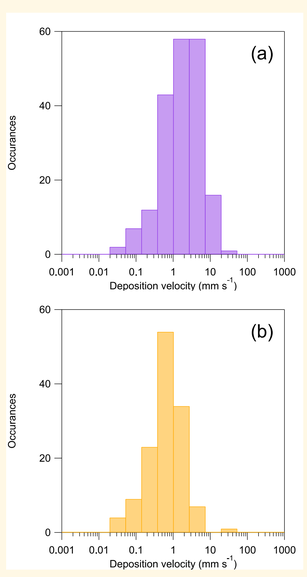


Figure 7: Logarithmically binned distributions of (a) rBC mass and (b) rBC counts deposition velocities. Data are from all times of day for quality controlled data as described in the methods section.

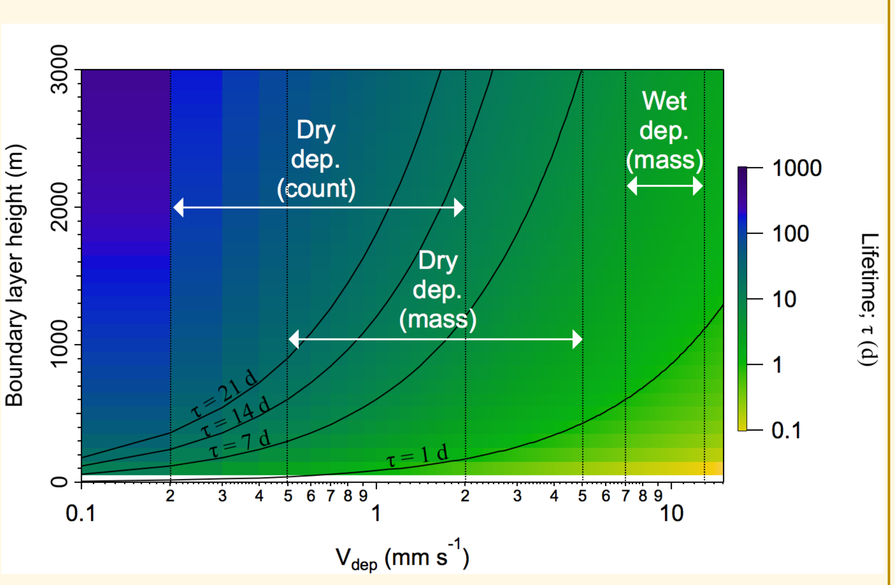


Figure 8: Comparison of rBC lifetimes for dry deposition (by mass and particle counts) and wet deposition as a function of boundary layer height and observed V_{dep}. We note that wet V_{dep} are not true velocities, but an expression of scavenging efficiency observed during BCADS. Boxes represent the 1σ range of deposition velocities. Black lines are lifetime isopleths.

Acknowledgements

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