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Ammonia emissions, transport, and deposition downwind of agricultural areas at local to regional scales

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Ammonia (NH3) emissions from agricultural areas show extreme spatiotemporal variations, yet agricultural emissions dominate the global NH3 budget and ammoniated aerosols are a dominant component of unhealthy fine particulate matter. The emissions of NH3 and their deposition near and downwind of agricultural areas is complex. As part of a multi-year field intensive along the Colorado Front Range (including the NASA DISCOVER-AQ and NSF FRAPPE field experiments), we have examined temporal emissions of NH3 from feedlots, regional transport of ammonia and ammoniated aerosols from the plains to relatively pristine regions in Rocky Mountain National Park, and dry deposition and re-emission of grassland NH3 in the park. Eddy covariance measurements at feedlots and natural grasslands in the mountains were conducted with newly-developed open-path, eddy covariance laser-based sensors for NH3 (0.7 ng NH3/m2/s detection limit at 10 Hz). These measurements were coupled with other NH3/NHx measurements from mobile laboratories, aircraft, and satellite to examine the transport of NH3 from agricultural areas to cleaner regions downwind. At the farm level, eddy covariance NH3 fluxes showed a strong diurnal component correlated with temperature regardless of the season but with higher absolute emissions in summer than winter. While farm-to-farm variability (N=62 feedlots) was high, similar diurnal trends were observed at all sites regardless of individual farm type (dairy, beef, sheep, poultry, pig). Deposition at scales of several km showed relatively small deposition (10% loss) based upon NH3/CH4 tracer correlations, though the NH3 concentrations were so elevated (up to ppmv) that these losses should not be neglected when considering near-farm deposition. Ammonia was efficiently transported at least 150 km during upslope events to the Colorado Front Range (ele. 3000-4000 m) based upon aircraft, mobile laboratory, and model measurements. The gas phase lifetime of NH3 was estimated to be at least 12 hours. Eddy covariance measurements in the mountains showed deposition of 3.2 ng N/m2/s during upslope events from the agricultural areas. In contrast, during downslope events when clean, free tropospheric air was at the site, re-emission of NH3 to the atmosphere of a similar magnitude was observed. The strong correlations with wind direction, coupled to back trajectories and measurements, suggest that agricultural NH3 emissions are playing an important role in nitrogen deposition at Rocky Mountain National Park. These results will be compared to similar measurements by our group in the San Joaquin Valley in California and via TES/IASI satellite measurements elsewhere in the US.