Ph.D. Defense Announcement
Julieta Juncosa Calahorrano
Thursday, November 30, at 10:00 am

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Ph.D. Defense

November 30, 2023
10:00 am

Defense
ATS Large Classroom (101 ATS) or Teams

Post Defense Meeting
Riehl Room (211 ACRC)

Committee:
Emily Fischer (Advisor)
Jeffrey Collett, Jr.
Jeffrey Pierce
Shantanu Jathar (Mechanical Engineering)

Emissions, evolution, and transport of ammonia (NH_3) from large animal feeding operations: a summertime study in northeastern Colorado

The Transport and Transformation of Ammonia (TRANS2Am) airborne field campaign occurred over northeastern Colorado during the summers of 2021 and 2022. TRANS2Am measured ammonia (NH_3) emissions from cattle feedlots and dairies with the goal of describing the near-field evolution of the NH_3 emitted from animal feeding operations. Most of the animal husbandry facilities in Colorado are co-located within oil and gas development within the Denver-Julesburg basin, an important source of methane (CH_4) and ethane (C_2H_6) in the region. Leveraging TRANS2Am observations, this dissertation presents estimates of NH_3 emissions ratios with respect to CH_4 (NH_3 EmR), with and without correction of CH_4 from oil and gas, for 29 feedlots and dairies in the region. The data shows larger emissions ratios than previously reported in the literature with a large range of values (i.e., 0.1 - 2.6 ppbv $ppbv^{-1}$). Facilities housing cattle and dairy had a mean (std) of 1.20 (0.63) and 0.29 (0.08) ppbv $ppbv^{-1}$, respectively. NH_3 emissions have a strong dependency with time of day, with peak emissions around noon and lower emissions earlier in the morning and during the evening. Only 15% of the total ammonia (NH_x) is in the particle phase (i.e., NH_4^+) near major sources during the warm summer months. Finally, estimates of NH_3 emission rates from 4 optimally sampled facilities range from 4 - 29 g $NH_3 \cdot h^{-1} \cdot hd^{-1}$.

This work investigates the nearfield evolution of NH_3 in five plumes from large animal husbandry facilities observed during TRASN2Am using a mass balance approach with CH_4 as a conservative tracer in the timescales of plume transport. Since the plumes in TRASN2Am were not sampled in a pseudo-lagrangian manner, an empirical model is needed to correct for variations in summertime NH_3 emissions as a function of time of day ($CF = 1.87\ln(LT) - 3.95$). Results show that the average NH_3 lifetime against deposition in plumes from large animal feeding operations is between 1.5 and 3 hours. Within the first 10 km, deposition of NH_3 occurs with magnitudes ranging between 0.4 and 1.4 μg m^{-2} s^{-1}. After that, other small sources can contribute enough fresh NH_3 to change the direction of the flux to net emissions. Based on the calculated fluxes and observations of NH_3 in the atmosphere, the NH_3 compensation point (χ) decreases as a function of distance from the facilities from ~10 - 90 ppbv at 5 km to ~6 - 22 ppb at 25 km, a median percent decrease of ~50% between 5 and 25 km. The derived soil emission potential (Γ) ranges from ~650 - 5500, with plumes with higher NH3 mixing ratios exhibiting higher Γ. To our knowledge, this is the first study presenting NH3 evolution in the atmosphere using a conservative tracer and airborne measurements.

The second goal of TRASN2Am was to investigate easterly wind conditions capable of moving agricultural emissions of ammonia (NH3) through urban areas and into the Rocky Mountains. TRANS2Am captured 6 of these events, unveiling important commonalities. 1) NH3 enhancements are present over the mountains on summer afternoons when easterly winds are present in the foothills region. 2) The abundance of gas-phase NH3 is 1 and 2 orders of magnitude higher than particle-phase NH4+ over the mountains and major agricultural sources, respectively. 3) During thermally driven circulation periods, emissions from animal husbandry sources closer to the mountains likely contribute more to the NH3 observed over the mountains than sources located further east. 4) Transport of plumes from major animal husbandry sources in northeastern Colorado westward across the foothills requires ~5 hours. 5) Winds drive variability in the transport of NH3 into nearby mountain ecosystems, producing both direct plume transport and recirculation. A similar campaign in other seasons, including spring and autumn, when synoptic scale events can produce sustained upslope transport, would place these results in context.