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Mid-infrared sensing of atmospheric ammonia: linking farms, cities, and ecosystems

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Atmospheric ammonia - the most important base in the atmosphere - degrades the environment through the formation of unhealthy particulate, nitrogen deposition in sensitive ecosystems, and scattering of visible light for climate and visibility impacts. Despite its global importance, ammonia is a challenging measurement to make. Ammonia readily sticks to instrument surfaces such as inlets or sample cells, its atmospheric mole fraction is low (parts per trillion to parts per billion by volume), and it can readily partition between gas phase ammonia and particulate phase ammonium. I will discuss field measurements with open-path, quantum cascade laser-based sensors that have been deployed in field campaigns across the world to understand the spatiotemporal variabilities of its atmosphere-surface fluxes. The open-path configuration - where the sampled air is passively sampled between mirrors of a Herriott cell without actively going through tubing, inlets, or sample manifolds - allows for fast (25 Hz), sensitive (30 pptv), and accurate (20%) measurements to deduce rapid changes in fluxes on platforms such as mobile laboratories, tall towers, and aircraft. The sensor consumers 45 W of power for ease of deployment in power-constrained environments such as in remote settings of agricultural fields or natural ecosystems. Vehicle emissions of ammonia from real-world driving measurements across 5 cities in the United States are twice as high as the EPA National Emissions Inventory, suggesting an important urban emission source that is co-located with emissions of nitrogen and sulfur oxides. Agricultural sources in both Colorado and California show large spatiotemporal variabilities including diurnal, seasonal, and farm-to-farm differences. Agricultural emissions, when combined with new satellite ammonia measurements, in-situ measurements, and ecosystem flux measurements, show significant effects on downstream air quality in cities and nitrogen deposition in remote ecosystems.

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