Atmospheric Dry Deposition of Gaseous and Particulate Nitrogen to Urban-Influenced Sonoran Desert Sites

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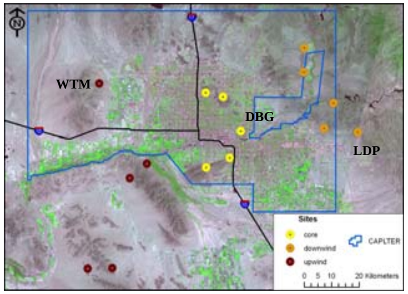
Introduction

Atmospheric deposition is an important vector for the transfer of anthropogenic nutrients to terrestrial ecosystems. In arid regions, such as the western United States, dry deposition is the dominant mechanism for pollutant deposition. Urbanization in this region magnifies the impact of atmosphere-land exchange by increasing the emissions of nitrogen pollutants. This additional atmospheric N is eventually deposited to the biosphere where it may affect receptor ecosystems.

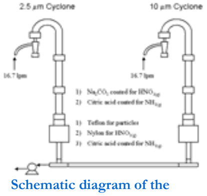
Experimental Methods

Dry deposition fluxes of gaseous and particulate nitrogen were measured in the Phoenix, Arizona, metropolitan area, an arid region with significant atmospheric pollution, in order to examine patterns of nitrogen deposition at urban-influenced Sonoran desert sites. Gas and particle concentrations were measured using a denuder and filter sampler system at three intensive measurement sites located upwind, within, and downwind of the Phoenix urban core. Micrometeorological measurements were made at one site to estimate deposition velocities from meteorological data collected at the intensive measurement sites. These sites were located at the White Tanks Regional Park (WTM), Desert Botanical Garden (DBG), and Lost Dutchman State Park (LDP).



Map of the measurement sites along the air-flow gradient through the CAP LTER study area. Gas and particulate nitrogen concentrations and meteorological variables were measured at three intensive measurement sites.

Denuder and filter samplers (DFS) were used to measure the concentration of gas (ammonia and nitric acid) and particle phase nitrogen (ammonium-nitrate) without introducing sampling artifacts (Hering and Cass, 1999). The DFS consists of two sampling trains to measure concentrations of particulate matter smaller than 2.5 µm ($PM_{2.5}$), particulate matter smaller than 10 µm (PM_{10}), and gas phase acids and bases.

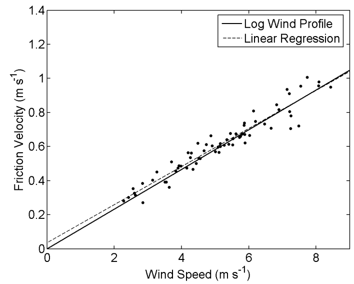


Schematic diagram of the denuder and filter sampler.

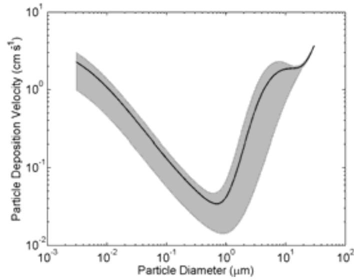
Weather towers were used to measure wind speed, wind direction, air temperature, relative humidity, incoming solar radiation, and precipitation at the DBG and LDP sites. The same data were obtained from the Waddell, Arizona meteorological station, approximately 4 km northeast of the WTM site. Eddy correlation measurements were made at the LDP site in order to characterize surface exchange for the Sonoran desert landscapes. The LDP site was used as a representative site since the terrain and vegetation were similar at all three sites.

Results

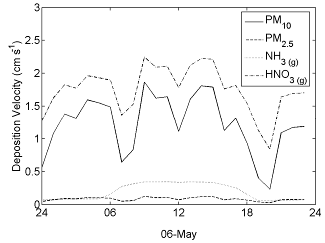
Atmospheric boundary layer parameters necessary for calculation of gas and particle deposition velocities were directly measured from micrometeorological measurements at the LDP site. The measurements were then used to predict the aerodynamic roughness, z_o, and parameterize friction velocity, u_*, from the meteorological measurements all three Sonoran desert sites. These were then used to predict hourly gas and particle deposition velocities.



Friction velocity and wind speed measurements under near-neutral conditions at the Lost Dutchman State Park (LDP) site. The log-wind profile was used to predict z_o = 0.27 m and u_* = 0.12U for the Sonoran desert sites.



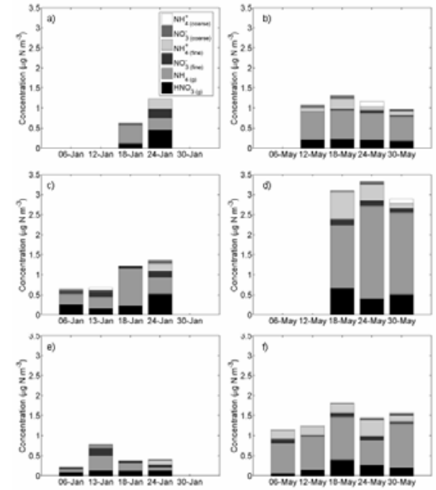
Deposition velocities calculated for particles at the Lost Dutchman State Park (LDP) site on 6 May 2007. The gray region represents the range of modeled deposition velocities for 24 hours calculated from parameterizations of hourly meteorological measurements. The line represents the mean of the predicted range.



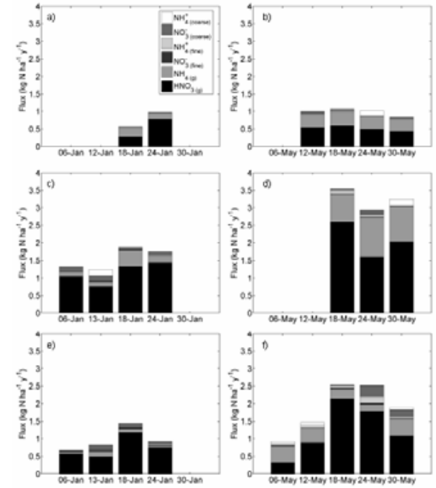
Deposition velocities predicted for coarse and fine particles, NH_3, and HNO_3 on 6 May 2007 at the Lost Dutchman State Park (LDP) site.

Results

Atmospheric nitrogen concentrations were measured at the WTM, DBG, and LDP sites in January and May 2007. Fluxes were then calculated by multiplying the concentrations by the deposition velocities for each nitrogen component.



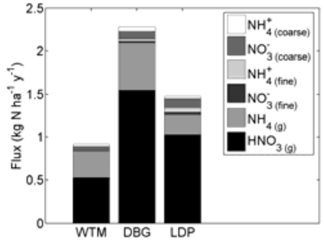
Atmospheric concentrations during January (left column) and May (right column) 2007 using denuder and filter samplers: a,b) White Tank Mountain (WTM); c,d) Desert Botanical Garden (DBG); and e,f) Lost Dutchman State Park (LDP) sites.



Inferred nitrogen fluxes during January (left column) and May (right column) 2007 using denuder and filter samplers: a,b) White Tank Mountain (WTM); c,d) Desert Botanical Garden (DBG); and e,f) Lost Dutchman State Park (LDP) sites.

Discussion

Annual nitrogen fluxes were calculated from the mean of the monthly mean deposition estimates. Total nitrogen fluxes were 0.92, 2.28, and 1.47 kg N (ha y)$^{-1}$ at the WTM, DBG, and LDP sites, respectively. Mean annual nitrogen (HNO_3, NO_3^-, and NH_4^+) deposition has been estimated to be 0.7-1.1 kg N (ha y)$^{-1}$ at a desert site with no urban influence (Baumgardner et al., 2002), similar to the annual deposition at the WTM site. Using air quality models of high pollution events, Fenn et al. (2003) estimated nitrogen dry deposition of 7.5 kg N (ha y)$^{-1}$ for the upwind desert, 13.5 kg N (ha y)$^{-1}$ for the urban core, and 15 kg N (ha y)$^{-1}$ for the downwind desert. The ratio of deposition at the DBG site to that at the WTM site was 2.5, similar to the core to upwind ratio of 1.8 predicted by Fenn et al. (2003). Deposition measured at the LDP site was elevated compared to the WTM site but lower than the DBG site. This suggests that nitrogen pollutants were transported from the urban core and deposited in the downwind desert.



Annual nitrogen deposition to Sonoran desert sites in the Phoenix area.

Conclusions

- Atmosphere-surface exchange parameters were measured at a representative Sonoran desert site.
- Deposition velocities were predicted from parameterizations of meteorological measurements at three Sonoran desert sites.
- Atmospheric concentrations of gas and particulate nitrogen were measured using denuder and filter samplers.
- Characteristic inferred nitrogen deposition fluxes were 0.92, 2.28, and 1.47 kg N (ha y)$^{-1}$ at the upwind, core, and downwind sites, respectively.
- The main contributor to nitrogen flux was nitric acid.
- Total deposition was an order of magnitude lower than previous estimates based on air quality modeling of high pollution episodes.

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