The Importance of Dry Deposition to the Nitrogen Mass Balance of an Arid Urban Ecosystem

D. Hope[1], S. Grossman-Clarke[2], S. M. Lee[3]., H.J.S. Fernando[2], P. G. Hyde[4], W. L. Stefanov[5] and N.B. Grimm[6]

[1] Center for Environmental Studies, Arizona State University, Tempe AZ 85287; [2]Department of Mechanical and Aerospace Engineering, ASU; [3] Department of Civil and Environmental Engineering, ASU; [4]Arizona Department of Environmental Quality, 3033 N. Central Ave., Phoenix AZ 85012; [5]Department of Geological Sciences, ASU; [6]Department of Biology, ASU. Contact email for author: di.hope@asu.edu

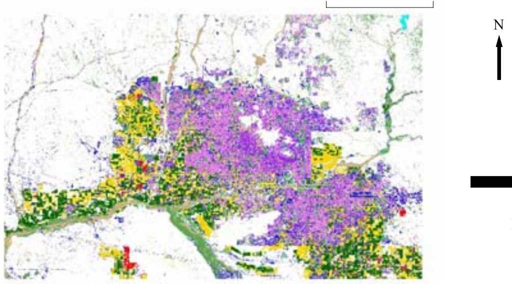
Introduction and Aims

1. Anthropogenic emission of oxidized nitrogen species in urban areas are typically high. Negative effects of such enrichment include eutrophication of water bodies, degradation of water quality, plant and microbial community changes, altered nutrient cycling, and reduced forest sustainablity. Human populations in the western U.S. are rapidly increasing, causing NO_x emission to rise. However Ndry deposition inputs are not well characterized (Fenn *et al*. submitted), particularly for urban areas where a significant proportion of NO_x emissions can be deposited in dry form (Russell et al. 1993). In the Central Arizona-Phoenix (CAP) region such deposition may represent a significant input to the annual N mass balance (Baker et al. 2001).
2. The aim of our study is to determine the magnitude of NO_x-derived dry deposition inputs to the N mass balance of the CAP ecosystem, to adapt and refine existing modeling approaches to the urban environment, and to utilize the large amounts of available monitoring data both on air quality and land cover information available for metropolitan Phoenix.

Methodology

1. *Modeling approach:* is described on the adjacent poster by Grossman-Clarke *et al*.
2. *Land cover*: The heterogeneity of urban land cover has been a major problem for urban air quality modeling to date. We refined existing CMAQ/Models3 land cover for Phoenix using a digitized land use classification derived from LANDSAT TM images with a resolution of 30m x 30m (Stefanov *et al.* 2001). Land use categories were grouped into 6 major land cover types which are distinct for the process of atmospheric dry deposition: urban (asphalt, concrete etc.), agricultural crops, bare soil, xeric vegetation, irrigated vegetation and water.
3. *Ground survey data:* The detailed surface cover for each land cover type was characterized using data from a ground survey carried out at 204 sites across the entire CAP study area (Hope *et al*. submitted).
4. *Model input*:The proportion of each main surface cover type in every 2 km x 2 km model grid cell was determined using GIS/ArcInfo, including those cells within which continuous air quality monitors were located (Table 1).

Figure 1. Land cover from Landsat TM image classification by Stefanov et al (2001).



Key: dark green – cultivated vegetation (active agriculture); dark yellow – compacted soil (prior agricultural use); red – compacted soil; pale yellow – asphalt & concrete; mid purple – mesic residential; light purple – xeric residential; pale green – vegetation (riparian); white – undisturbed; grey – fluvial and lacustrine; dark purple/blue – commercial/industrial; aqua – water.

Land cover classes are condensed into major cover types for the atmospheric model

Effect of Different Urban Land Cover Types

Table 1. Composition of Stefanov et al (2001) land cover classes as determined by field survey at 204 sites across the CAP study area (Hope *et al*. submitted), used as input in the deposition model.

Model land cover classes	**Land cover classes as defined by Stefanov et al (2001)**								
	Cultivated vegetation (active)	**Compacted soil**	**Cultivated grass**	**Disturbed (commercial / industrial)**	**Disturbed (asphalt / concrete)**	**Undisturbed (native vegetation)**	**Mesic residential**	**Xeric residential**	**Vegetation**
Irrigated vegetation	**100**		**100**	**18**			**38**	**3**	**100**
Xeric vegetation						**38**		**22**	
Urban surfaces (asphalt, concrete,				**79**	**100**		**60**	**73**	
Bare soil		**100**		**3**		**62**	**2**	**2**	

NO_x deposition is strongly influenced by the nature of the urban surfac. Figure 2 shows the fraction of the total annual NO_2 dry deposition flux apportioned to different surfaces in the 2 km x 2 km grid cell in which the Phoenix Supersite is located. The percent surface cover is 50% urban, 25% irrigated vegetation, 25% xeric vegetation and 10% bare soil – figures which are typical for most model grid cells in the urban core (see Table 2).

Figure 2: Contribution of individual land cover types to the estimated annual NO_x dry deposition at Phoenix Supersite

Table 2: Fraction of land cover for the 2 km x 2 km grid cells around the 6 sites where NO_x concentrations were continuously monitored.

Site	Urban	Irrigated veg.	Bare soil	Xeric veg.
Phoenix Greenwood	0.63	0.21	0.06	0.10
Central Phoenix	0.58	0.19	0.09	0.14
West Phoenix	0.63	0.13	0.10	0.14
Phoenix Super Site	**0.59**	**0.21**	**0.08**	**0.12**
South Scottsdale	0.61	0.17	0.07	0.14
Palo Verde (desert)	0.00	0.00	0.62	0.38

Note very little difference in surface cover among urban core sites

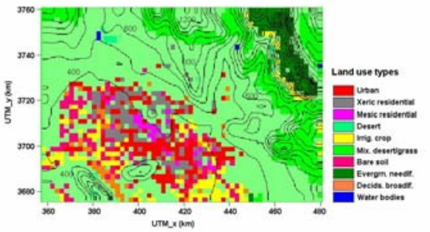
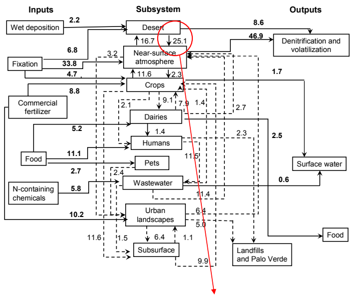


Figure 3. Major land cover types for each 2 km x 2 km grid cell in the atmospheric model domain

Role of NO_x Dry Deposition in N Balance

Figure 4. Summary of the N balance for the CAP Ecosystem. From left to right: inputs (bold), internal transfers (dashed lines) and outputs (bold). All values are given in Gg N y^{-1}. Red highlights dry deposition.



Results from model predictions: Annual NO_x-derived N dry deposition fluxes were found to be approx. 9 kg N ha^{-1} y^{-1} in the urban core area, 1.5 kg N ha^{-1} y^{-1} in upwind desert and 10 kg N ha^{-1} y^{-1} downwind of the urban core. Total N dry deposition was estimated at 13.4 Gg N y^{-1}, which represents 20% of total annual N inputs and hence a significant term in the N balance.

Summary and Conclusions

1. *Is there urban enhancement of N deposition?*: Yes - deposition of direct reaction products such as NO_2 are increased by up to one order of magnitude close to the urban core areas where they are produced.
2. *Annual fluxes*: Our model results indicate that NO_x-derived dry deposition IS a significant term in the ecosystem N balance, comprising 20% of the total annual N inputs to the CAP study area.
3. *Sensitivity analysis*: The most important determinants of NO_x-derived N deposition flux are ***ambient concentrations of NO_x species*** in the atmosphere and the ***amount of vegetated surface cover*** *(*Figure 2). For more accurate simulation of N dry deposition rates it is essential to obtain good representation of the amount and type of vegetated surface when applying 3-D Eulerian air quality models.
4. *Implications*: Elevated N deposition on non-reactive urban surfaces, can lead to high concentrations of nutrients on these surfaces and in the first-flush runoff during rainfall events. Amounts of inorganic N on asphalt parking lot surfaces across the Phoenix metro area averaged 40.2 mg m^{-2} for NH_4-N and 151.1 mg m^{-2} for NO_3-N, values that were 13 - 91 times higher than measured in surface samples of undeveloped desert soils outside the city (Hope *et al.* submitted b).

Acknowledgements

We thank Sandra Wardwell, Arizona Department of Environmental Quality, and Ben Davis, Maricopa Association of Governments, for providing us with data from the air quality monitoring network. We are grateful for the support of our work by Nancy Selover, Department of Geography at ASU, who provided data from NWS and PRISMS weather stations. We acknowledge the help of Jamie Harris, Department of Geological Sciences at ASU, and Matt Luck, Department of Life Sciences at ASU, with processing the land use data by means of GIS/Arc View. The project was supported by NSF grant DEB 9714833 and SCERP grant XAJ 9981.

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