Modeling Temporal and Spatial Characteristics of Nitrogen dry Deposition in the Phoenix Metropolitan Area

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Introduction

1. Air quality models offer the opportunity of simulating dry deposition fluxes in urban areas with a relatively high spatial resolution, but usually only over a few day period. Dry deposition fluxes can also be calculated by means of diagnostic models which use measured pollutant concentrations and meteorological data at a reference height in the atmosphere as input data. Data are often available on a continuous basis over extended time periods and from sites within urban core areas. However, the low density of monitoring stations makes it difficult to assess the degree of spatial variation in dry deposition.
2. A diagnostic model was developed in order to determine nitrogen dry deposition fluxes in the Phoenix metropolitan area. The model includes equations describing the surface energy balance and the ability of the surface to take up matter.
3. A Models-3/CMAQ simulation combined with meteorological modeling for 22-23 July, 1996 was used to predict spatial patterns of NO_x-derived and nitric acid dry deposition in the study area.

Materials and Methods

1. Diagnostic model description: The vertical dry deposition flux was modeled by means of the deposition velocity and the measured pollutant local mean concentrations at a reference height in the atmosphere. The surface resistance was calculated according to Walmsley and Wesely (1995). The temperature response function of canopy stomatal resistance was replaced with the response function suggested by Jarvis (1976) allowing for the parameterization of the temperature response for trees and shrubs in semiarid regions (Larcher 1994). The aerodynamic resistance was calculated according to Hanna & Chang (1992) where the sensible heat flux is a function of a moisture availability factor which depends on the land cover fraction of irrigated vegetation (Oke 2001, personal communication). Input data for the model were measured atmospheric state variables and pollutant concentrations as well as surface characteristics - albedo, emissivity, roughness length. The simulated deposition fluxes were assumed to be representative for an area of about 2 km x 2 km around the air quality monitoring stations.
2. Models-3/CMAQ simulation: US EPA's photochemical model, Models-3/CMAQ was employed to simulate spatial variation of NO_x and HNO_3 deposition fluxes. The computational domain spanned 120 km in east-west direction and 80 km in south-north direction. The spatially and temporally allocated emission data were provided by the Arizona Department of Environmental Quality. Meteorological data were simulated by means of the atmospheric model MM5 (Penn State/NCAR) using nested simulations of four domains. The output of the MM5 innermost domain (2 km x 2 km) was used for the Models-3/CMAQ computations starting at 04:00 July 22 1996 and ending at 00:00 LST July 24 1996. USGS land use data with 30 second resolution were used in both, the MM5 and Models-3/CMAQ simulations (cp. Poster B22B-0756 Hope *et al.*).

Central Phoenix Monitoring Site

Figure 2. Daily average NO_x concentrations & daily NO_x deposition, Phoenix Supersite 1998

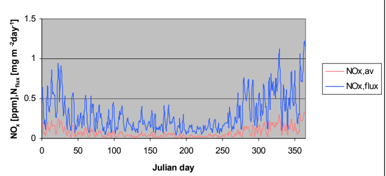


Figure 1

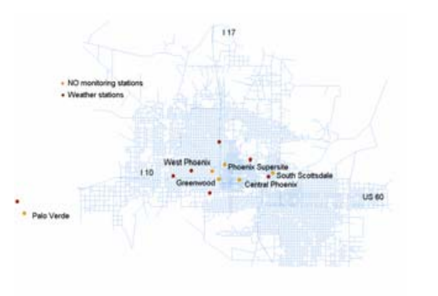


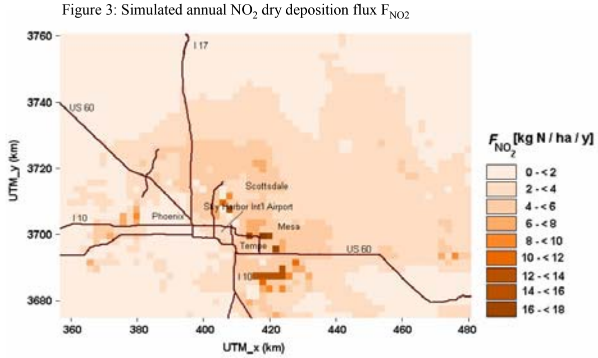
Table 1:

Annual deposition	NO	NO_2	NO_x [kg ha^{-1} year^{-1}]
Phoenix Greenwood	0.1	6.0	17.9
Central Phoenix	0.05	5.2	11.7
West Phoenix	0.06	4.3	10.6
Phoenix Super Site	0.05	4.6	11.0
South Scottsdale	0.03	3.7	7.4
Palo Verde	0.001	0.3	0.4

West Phoenix Air Monitoring Site

3. Monitored data: Hourly data on ambient concentrations of NO, NO_2 and NO_x were obtained from 6 air quality monitoring stations operated by the Arizona Department of Environmental Quality and Maricopa County Air Quality Division (Figure 1). Five sites were located within the urban core area and one site in the surrounding desert. Hourly air temperature, dew point temperature, relative humidity, solar radiation and wind speed at 10 m) were obtained from the NWS and PRISMS stations.

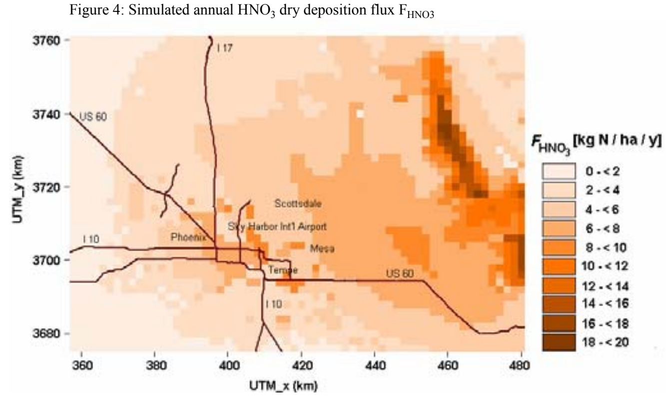
Figure 3: Simulated annual NO_2 dry deposition flux F_{NO2}



Results and Conclusions

1. Annual fluxes: The simulated annual NO_x dry deposition fluxes for the year 1998 (Table 1) show that N deposition in the urban core area was significantly elevated above deposition at the non-urban Palo Verde site. Since the land use characteristics around the urban stations are similar we conclude that differences in the simulated deposition fluxes were caused mainly by differences in the measured pollutant concentrations. The Greenwood station is close to a major highway and therefore characterized by very high deposition rates, which are not representative for a larger area. The simulations showed a marked seasonal pattern for the NO_x dry deposition fluxes, peaking over the winter months and declining during the summer (Figure 2).
2. Spatial Variation: The simulated spatial distribution of NO_2 deposition fluxes (extrapolated to annual fluxes) showed the highest deposition fluxes in the urban area and the eastern part of the modeling domain (Figure 3). The highest HNO_3 deposition fluxes (Figure 4) were simulated in the foothills of the eastern mountainous area, i.e. downstream of the daytime urban plume.
3. Future work: Update land use data in Models-3/CMAQ, improve the physical description of the exchange of energy, matter and momentum between urban surfaces and the atmosphere in meso-scale atmospheric models. Determine seasonal and annual average dry deposition fluxes based on typical weather conditions and seasonal emission inventories.

Figure 4: Simulated annual HNO_3 dry deposition flux F_{HNO3}



Acknowledgements

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References

Hanna SR, Chang JC. 1992. Boundary-layer parameterizations for applied dispersion modeling over urban areas. Boundary Layer Meteorology **58**: 229-259.

Jarvis PG. 1976. The interpretation of the variations in leaf water potential and stomatal conductance found in canopies in the field. Phil. Trans. R. Soc. London B **273**: 593-610.

Larcher W. 1994. Photosynthesis as a tool for indicating temperature stress events. In: Ecophysiology of photosynthesis. Schulze ED, Caldwell MM (eds.) Springer Verlag Berlin Heidelberg, Germany. p. 264.

Walmsley JL, Wesely ML. 1996. Modification of coded parameterizations of surface resistances to gaseous dry deposition. Atmospheric Environment **30**: 1181-1188.