

Spatial Variability in Measured Urban Fine Particles

Solomon T. Bairai

Tennessee Valley Authority, CEB 2A, P.O.B. 1010, Muscle Shoals, AL 35662
E-mail: stbairai@tva.gov; Telephone: (256)386-2298; Fax: (256)386-2499

Roger L. Tanner

Tennessee Valley Authority, CEB 2A, P.O.B. 1010, Muscle Shoals, AL 35662
E-mail: rltanner@tva.gov; Telephone: (256)386-2958; Fax: (256)386-2499

Menachem Luria

Environmental Sciences Division, Hebrew University, Givat Ram, Jerusalem, 91904, Israel
E-mail: luria@vms.huji.ac.il; Telephone: 972-2-636841; Fax: 972-2-637260

Robert E. Imhoff

MCNC, Environmental Programs, P.O. Box 12889, Research Triangle Park, NC 27709
E-mail: rimhoff@emc.mcnc.org; Telephone: (919) 248-9231; Fax: (919) 248-9245

Summary

The short-term spatial variability of fine particles has been little studied. During the 1999 SOS Nashville Air Quality Study, the Tennessee Valley Authority operated an instrumented helicopter on two days in and near Nashville, Tennessee. The instrument package included a laser particle size spectrometer (PSS) and a nephelometer (with spatial resolution of about 200 m) and filter samplers (spatial resolution of 40 km), as well as O₃, SO₂, NO_y, NO_y*, NO₂, and NO. PSS data were examined to determine horizontal and vertical scales of spatial variability for short-time-averaged particle volume and particle numbers in specific size bins during morning and afternoon flight segments.

A vertical profile was taken on the morning of July 8, 1999 starting at 8:10 AM from about 15 m above the surface at Cornelia Fort Airpark and ending at just over 1000 m above sea level. A plot of the temperature from near the surface to the top of the profile showed an adiabatic decrease with altitude to a height of about 350 m, then an increase (temperature inversion) to about 500 m. A second inversion is encountered between about 600 m and 700 m. Data above 400 m were examined for evidence of overnight transport to this location of point source plumes emitted the previous day. Plumes that have a high chemical age (fraction of secondary NO_y species) and exhibit SO₂/NO_y ratios similar to known power plants were used to trace this transport. The vertical profile identified multiple layers corresponding to discrete sources. One layer (A) extending from about 400 m to just over 600 m was enriched in SO₂ and NO_y but depleted in O₃ and particles. The layer (B) extending from 650 m to 750 m was enriched in SO₂, NO_y, O₃ and particles. There was another layer (C) extending from 750 m up to nearly 900 m which was enriched in SO₂ and particles, but not O₃ or NO_y. The pattern of light scattering followed that for particle volume. A plot of the altitude dependence of relative humidity (RH) showed a moist layer at 600 m capped by a dryer layer. The RH then increased with altitude because of the decreasing temperature. Examination of the particle size distribution showed strong dependence on RH. The smaller size particles in bins 1 to 4 (geometric mean diameter of 0.109 to 0.184 μm) decreased with increasing RH while those in bins 5 to 9 (GMD 0.224 to 0.592 μm) exhibited an increase in particle

numbers with increasing RH. This is attributable to smaller particles growing into the bigger size ranges. The decrease in the number of particles in the C1 to C4 bins is attributed to the growth of these particles into larger size range by water accretion. An examination of the vertical structure of chemical age (defined as NO_z/NO_y) showed values mostly greater than 0.75. This is usually regarded as a mature air mass. There was a trend toward increased chemical age with height (to near 0.9 at the top of the profile). This suggests that the air above the surface inversion in the urban area had been transported from other locations and had undergone photochemical processing en route.

The afternoon vertical profiling on the same location was characterized by growth of the mixed layer to greater than 1500 m (ASL), and by mixing of fresh emissions with a transported air mass in which the previous day's emission had been processed. There are no clearly distinguishable layers attributable to particular emission sources. High particle number counts on the smaller size bins (C1 to C5) and very few counts on the higher size bins ($>C9$) were observed. RH increased from 50 to 80% with increasing altitude up to the top of the boundary layer (1500 m) and decreased sharply above the boundary layer. A small decrease in particle numbers in bins C1 to C5 with increasing humidity is observed, but there was no detectable particle size growth with humidity. Above the boundary layer, a cleaner air mass with few particles in all bins was observed.

Another vertical profile study was done on the morning of July 14, 1999. An inversion at about 550 m created two distinct layers. The lower layer was characterized by low O_3 , SO_2 , NO_y , chemical age and high RH (90 to 94%). The second layer above 550 m had higher SO_2 , O_3 , but low NO_y . RH decreased to 80% and chemical age increased to 0.9 showing that this was a mature air mass. The particles in the smaller bins C1 to C4 increased from the surface up to 800 m while those in C5 to C7 were constant in the lower layer but increased in the higher layer. The particles in C9 decreased from the surface to 800 m. The effect of RH on particle size growth was not observed directly as on July 8, 1999, but the low number of particles on C1 to C4 (half as much as that of July 8) and the high number of particles on C5 to C9 (3 times that of July 8) suggests that the particles had already increased size due to high humidity.

Horizontal profiles on the mornings and afternoons of July 8 and 14, 1999 at 400 m aloft in Nashville showed strong correlation between fine particles and the photochemically produced ozone from urban plumes.