SPW, thereby weakening laser–SPW coupling[13]. The two surface waves can be launched by employing the attenuated total reflection configuration[16], in which the electromagnetic wave is launched onto the prism–metal interface at an angle such that the component of propagation constant of the electromagnetic wave in the glass along the interface equals the propagation constant of the metal.

The process could go over to a parametric one[13], where initially a weak SPW is excited by surface roughness induced scattering from the incident field; the spatial modulation of the optical intensity resulting from the interference between the incident wave and the SPW can provide the growth of a periodic structure which increases the scattering into the SPW. Coupling to SPWs has shown to result in substantial field enhancement in the vicinity of a metal/dielectric interface. This could also serve as a diagnostic tool for various linear and nonlinear optical spectroscopic studies of the interface[12,17].

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Field measurements of sub-micron aerosol concentration during cold season in India

D. M. Chate[1,]* and T. S. Pranesha[2]

[1]Indian Institute of Tropical Meteorology, Pune 411 008, India
[2]Department of Physics, BMS College of Engineering, P. B. No. 1908, Bangalore 560 019, India

Sub-micron particle size distribution and temperature were measured at six levels immediately above the ground surface during 8–16 December 1997 and 24–28 December 1998. Diurnal observations were made at every three-hour interval at all the levels. Continuous measurements of aerosol concentration were made from 0300 to 1000 h at 1 m level. During this period, particle concentration decreases from 0300 h, attains a minimum value between 0600 and 0700 h, and then maximum at 0900 h. Particles ≥ 0.075 μm show systematic variation in concentration, whereas particles < 0.075 μm show large fluctuations with time during 0300 to 1000 h. Concentration of particles of sizes 0.075–0.75 μm shows a minimum at 15-cm level where the temperature is maximum. However, particles of size 0.013 μm undergo Brownian diffusion and thus do not show any trend with temperature. The phenomena of thermophoresis and fog scavenging are discussed in terms of these results.

THERMOPHORESIS is the motion of particles caused by a kind of thermally induced force, which arises from the non-uniform heating of particles due to temperature gradients in the suspending gas. Consider a particle suspended in the fluid with the temperature gradient. It is well known that gas molecules in a high temperature area have higher

*For correspondence. (e-mail: chate@tropmet.res.in)

energies and higher momentum than those in a colder gas. Therefore, molecules colliding with this particle from the hot side of the particle will exert a greater force than those on the cold side. As a result of these forces, we expect the particle to move away from the higher temperature area and flow towards colder gas temperatures. This simplified description of thermophoresis is directly applicable to small aerosol particles. For larger particles, the particle surface and layer around it will develop temperature gradients. This leads to gas motion from the colder to the warmer regions along the surface of the particle, resulting in a force in the cold direction. Pruppacher and Klett[1] discuss the phenomenon of thermo- and diffusiophoresis in detail. Quantitative studies using various experimental techniques have also been carried out[2–4]. Theoretical aspects of these mechanisms have also been discussed in detail[5–8].

To our knowledge, study of the phenomenon of thermophoresis with field observations is lacking in the literature. Directly measured vertical profiles of temperature and aerosol distribution are expected to give a better understanding of thermophoresis. Atmanathan Ramdas discovered a curious atmospheric phenomenon and observed a temperature minimum some 20–50 cm above the bare soil on calm, clear nights during the cold season in India (Pune) and the dynamics of this layer has been discussed[9]. During calm, clear nights aerosols are expected to be transported under the influence of thermophoretic forces due to the existence of a temperature gradient.

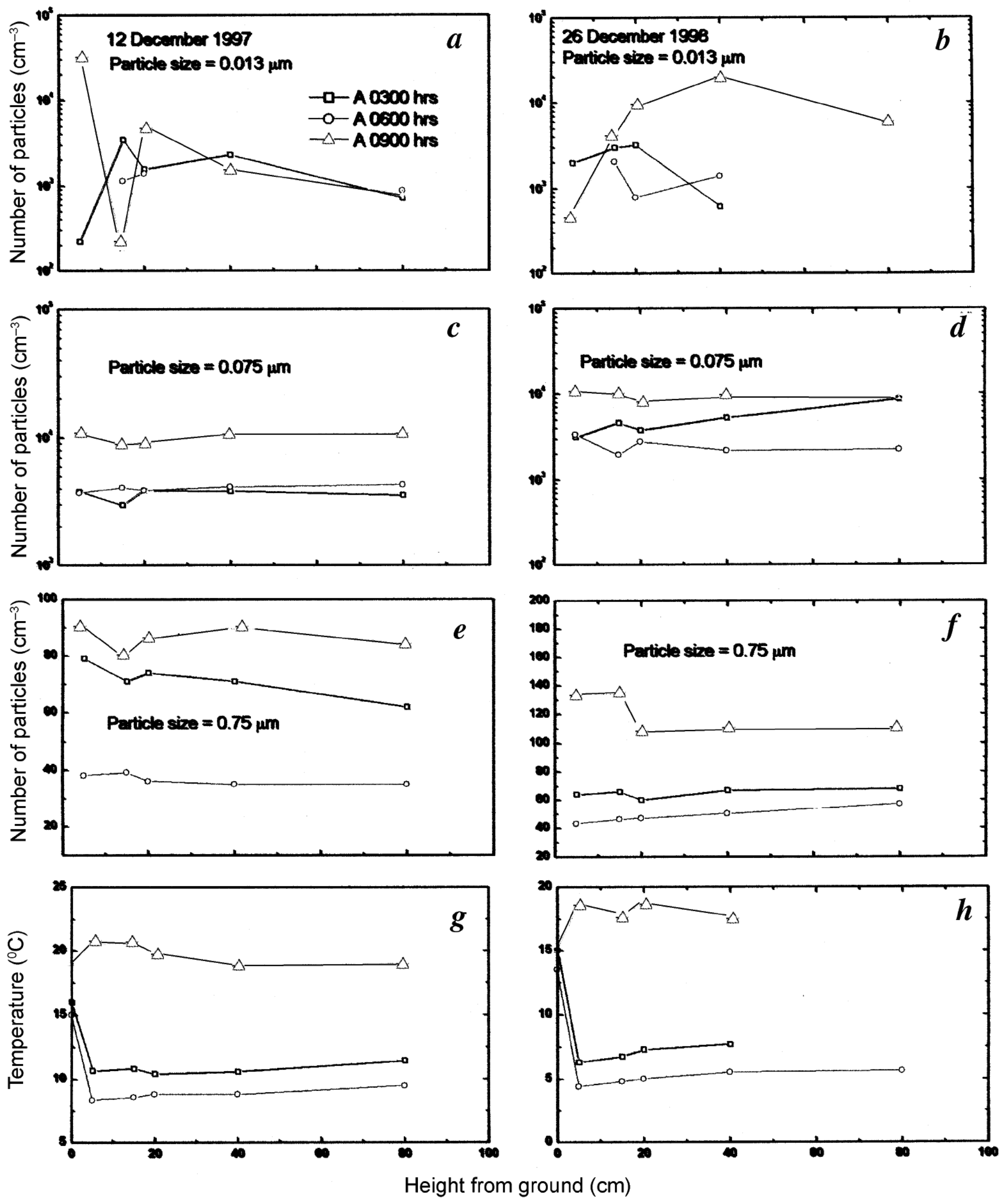

Figure 1. Vertical profiles of temperature and aerosol number concentration.

Evolution of the roles played by Brownian diffusion, thermophoresis and diffusiophoresis in precipitation scavenging is available in the literature, either on the basis of theoretical models based on certain assumptions or laboratory experiments under controlled conditions. Results obtained in both the cases may not be realistic.

Here, an attempt has been made to study the phenomenon of Brownian diffusion, thermophoresis and fog scavenging with field measurements for a better understanding of these removal processes. The present result would be ideal to obtain evolution of particle size distribution due to the removal of sub-micron particles with thermo-diffusiophoresis processes and fog scavenging, and may be useful in air quality models due to their realistic magnitudes.

Measurement of sub-micron aerosol size distribution and atmospheric temperature in the lowest 1-m of the atmosphere was made during 8–16 December 1997 and 24–28 December 1998 at Pune. Aerosol particle concentration and atmospheric temperature were measured at every three-hour interval at six different levels of 5, 15, 20, 40, 80 and 100 cm above the ground surface. One set of measurements of aerosol concentration at all the six levels is obtained within 2 min. Continuous measurements of particle distribution were made from 0300 to 1000 h at 1-m level. Particle concentration was measured using Electrical Aerosol Analyzer (EAA, TSI-Model 3030) system and temperature was measured with linearized thermistors. The EAA system is based on the 'diffusion charging – mobility analysis' principle of Whitby and Clark[10]. It consists of the aerosol charger, the particle precipitator and the electrometer sensor together with associated electronics and flow controls. The sample ambient air is first sucked in the diffusion charger and the aerosols are exposed to unipolar gaseous ions. Then the aerosol particle mobility is measured with a mobility analyser. Aerosol size distribution is then derived from the measured mobility distribution. A complete description about the EAA system, such as accuracy of measurements for each size distribution, calibration, etc. is provided elsewhere[11]. Wind speed, and dry and wet bulb temperatures were recorded during the observation period. Measurements were conducted mostly during calm, clear nights, so that changes in particle distribution at layers immediately above the earth surface due to temperature gradients are measured. Observed wind speeds were very low during night hours and remained almost zero during morning hours (0300–0900 h). As a result, aerosol particles were moving mainly under the influence of temperature gradients during these hours. In the present study, only those observations are considered when the observed wind speed was zero and temperature gradient existed at the lowest levels of the atmosphere. The sampling site at Pune (18°32′N, 73°51′E, 559 m asl) is an open field, approximately 500 m away from the Indian Institute of Tropical Meteorology (IITM) and local residential build-

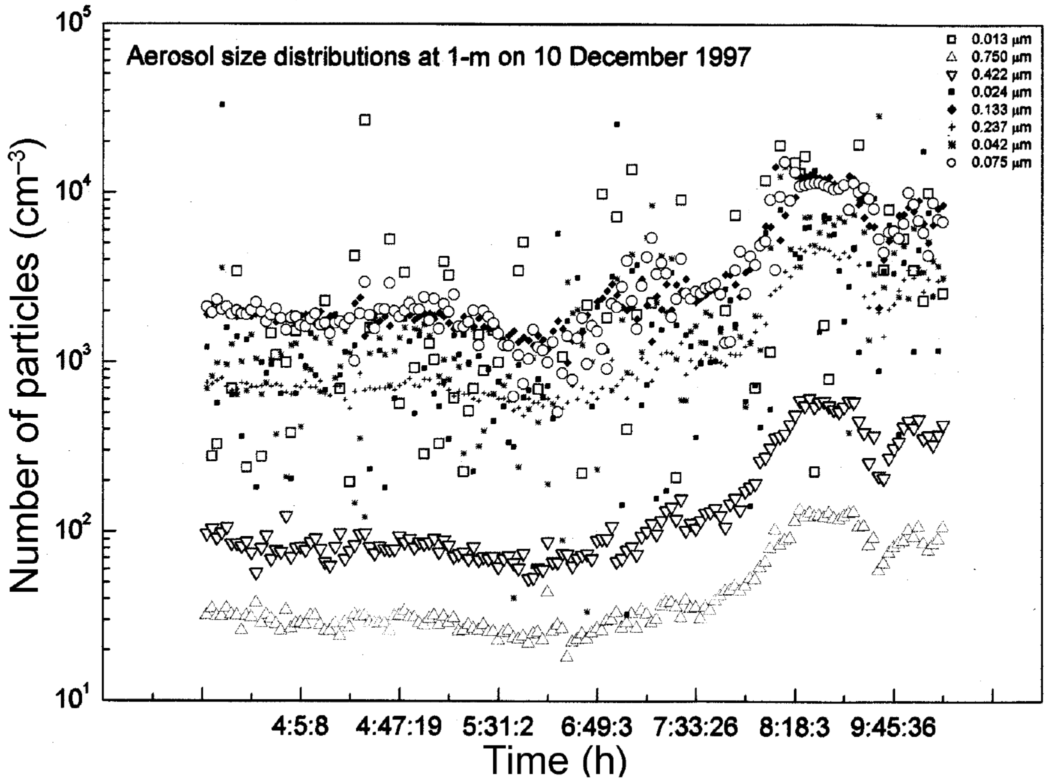

Figure 2. Aerosol concentration as a function of time.

ings. It is about 100 km inland from the west coast of India, located on the lee of the Western Ghats (range of hills).

At 15–20 cm level, the temperature profiles measured on 12 December 1997 and 26 December 1998 show a small maximum at 0300 h, a slightly increasing trend but no maximum at 0600 h and then a distinct maximum at 0900 h (Figure 1 *g* and *h*). Concentration of particles of 0.075 and 0.75 μm shows a minimum at 15–20 cm level, where the temperature is maximum (Figure 1 *c–f*). This minimum in concentration of particles is attributed to thermophoresis forces which drive these particles away from hotter layers. However, particles of size 0.013 μm undergo Brownian diffusion and thus do not show any trend with temperature (Figure 1 *a* and *b*).

Particle distribution measured continuously from 0300 to 1000 h at 1 m level on 10 December 1997 is plotted as a function of the time in Figure 2. During this period, particle concentration decreases from 0300 h, attains a minimum value between 0600 to 0700 h and then increases. The minimum concentration of particles around 0600 to 0700 h may be due to removal of these particles when they served as nuclei for the condensation of atmospheric water to form fog-droplets. Particles which are incorporated in the process of fog formation start evaporating after sunrise and subsequently get released into the atmosphere; so a higher value of particle number density is observed at 0900 h. Particles of size < 0.075 μm show large fluctuations in concentration with time, whereas particles of size ≥ 0.075 μm show systematic trends (Figure 2).

The effect of relative humidity (RH) on size distribution and scavenging coefficient in case of hygroscopic particles of NaCl and $(NH_4)_2SO_4$ has been studied by Chate *et al.*[12]. Thus, RH is strongly dependent on the aerosol chemical composition[13]. However, at RH   70% the hygroscopic particles may behave almost like solid particles[14]. Davenport and Peter[15] measured aerosol concentration before and after rain and found that RH does not affect the results obtained in their field measurements. Chate and Pranesha[16] measured aerosol concentration before and after thunderstorm rain events with the EAA system and found that the effect of RH in such field experiments may be neglected.

We have presented here the preliminary results obtained during the coldest days in 1997–1998 to demonstrate the effect of thermophoretic forces on sub-micron aerosols, when the other forces are ineffective. Thermophoretic forces are found to be dominant for the particles residing in the size range of 0.075–0.75 μm. However, for particle size < 0.075 μm, Brownian diffusion may be effective due to least inertia.

Minimum concentration of particles (0.075–0.75 μm) is observed during 0600–0700 h mainly due to the participation of these particles in the formation of fog. However, it must be cautioned that preliminary results presented here may not be adequate. Further investigations and field observations are warranted to study thermo- and diffusiophoresis, and fog-scavenging.

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