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המכון למדעי כדור הארץ, האוניברסיטה העברית בירושלים

Earth Sciences Institute, The Hebrew University of Jerusalem.

Abstracts

Session I: Atmosphere I

HOW MUCH WATER CAN POLLUTION AEROSOLS HOLD IN THE CLOUDS BY SUPPRESSING WARM RAIN?

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Extensive aircraft measurements of vertical profiles of aerosols, cloud drop size distributions and hydrometeors were conducted in convective clouds all over the world, and recently in India and the adjacent seas, in the context of the Cloud Aerosol Interactions and Precipitation Enhancement Experiment (CAIPEEX) of summer 2009. It was found that air pollution aerosols dominated cloud microstructure and precipitation initiation by producing large concentrations of cloud condensation nuclei (CCN), which in turn produced large concentrations of cloud drops. It is found that the cloud depth for onset of warm rain was nearly linearly related to the number of CCN aerosols. Even during the most humid tropical atmosphere with low cloud base and zero isotherm level exceeding 5 km, commonly observed levels of air pollution was able to delay the onset of warm rain to above the freezing level. This resulted in lack of rain from clouds that do not reach the freezing level, and heavy rain and thunderstorms from the deeper clouds. Large and giant CCN occurred in some of the cases and were observed to moderate the effect of the small CCN. The aircraft measurements validated the satellite inferences that the onset of precipitation from convective clouds occurs when their particle effective radius (Re) exceeds the threshold of 14 micrometer. The application of the satellite observations of cloud top temperature (T) – Re relations worldwide reveals the vast extent of the microphysical impacts of air pollution aerosols on the cloud microstructure and precipitation forming processes. This has likely impacts on redistribution of the precipitation, latent heat release and hence affecting local and regional circulation systems in ways that are yet to be determined.

SYNOPTIC CLASSIFICATION OF MODIS AEROSOLS OVER ISRAEL

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The origins and variety of aerosols in Israel are strongly influenced by synoptic conditions as well as other variables. Days affected by a weak Persian trough system are characterized by coarse aerosols from North Africa, which contain mainly mineral dust aerosols, whereas days affected by the Red Sea trough with an eastern axis are characterized by fine aerosols from northern Europe. Some synoptic systems contain both groups of aerosols as well as mixed aerosols, e.g. the Red sea trough with a central axis. This study utilizes the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra Satellite to obtain a synoptic classification of aerosols over Israel for 6 years. MODIS synoptic classification revealed a number of different aerosol types.
For Weak Persian trough, a high-from-the-west and a medium Persian trough, the MODIS Terra Aerosol Optical Thickness (AOT) fine mode fractions are 0.51, 0.54 and 0.51, respectively. While for Red Sea trough with an eastern or central axis AOT fine mode fraction ('f') is higher and is equal to 0.63 and 0.59, respectively. This is the first study in the region that investigates average back trajectory with regards to both synoptic systems and aerosol type. Investigation of back trajectories for the Persian trough synoptic system indicates that days with low 'f' at 700 hPa are associated

with flows from North Africa, while days with high 'f' are linked to flow from Europe. Most of our findings are not unexpected, but provide the first 6 years quantified aerosol classification which is based on the synoptic systems.

MEASUREMENT OF IMMERSION FREEZING NUCLEI IN ANTARCTICA

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The effectiveness of aerosols as immersion freezing nuclei in the South Pole station was investigated during a campaign that took place in January 2009. Twelve samples were collected, nine from the rooftop and three from a balloon. The effectiveness of the sampled aerosols as immersion freezing was measured using drop freezing technique in the FRIDGE-TAU (FRankfurt Ice-nuclei Deposition freezinG Experiment, the Tel Aviv University version). The freezing nuclei (FN) were found to be effective from -12ºC down to -27ºC, with concentrations of 0.05 to 26.3 #/L, respectively. Higher concentrations of effective FN were found in the samples collected on the balloon as compared to those measured on the rooftop. During the first two campaign days the concentrations of FN were relatively high and decreased on the following days due to scavenging by precipitation in the form of small snow crystals and diamond dust. The best fit to the FN spectrum near the surface was:

$$N_{FN} = 3 \times 10^{-6} e^{0.59\Delta T}$$

Where: N_{FN} (#/L) is the total FN active at temperatures warmer than T. ΔT is the supercooling.
This spectrum shows that at T=-20 N_{FN} near the surface is about 0.4 #/L and is about 1 #/L at -22C. These concentrations are smaller than those reported by Bigg and Stevenson (1970) (~ 1 #/L at -20C) for higher latitudes.
50% of all the drops tested in these experiments froze at around -24C, much higher than the reports on the immersion freezing of bio-aerosols in the Polar Regions (Junge and Swanson, 2008).

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CLAY MINERAL SIGNATURES IN SAHARAN DUST IN THE EASTERN MEDITERRANEAN

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This research summarizes mineralogical analysis of heavy dust storms in Israel from 1958 to 2009. Samples from 60 Dust Storms were analysed. Only settled dust was collected to provide the large amounts needed for mineralogical analysis. The source of the storms was deduced with Back Trajectories from the 3-D HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model made available by the U. S. National Oceanic and Atmospheric Administration (NOAA), and additional information from the TAU-dust model, and satellite images from TOMS and MODIS.
We found clear distinctions in the Smectite and Illite content of dust between sources. Most (70%) dust storm cases are from the sector to the west of Israel from sources in North Africa.
Most (60%) of the DS from this sector are in the range of Smectite and Illite together making up 40-60% of the clay minerals. The range of Smectite and Illite for all cases from this sector is 0-87% of total clay minerals.
For DS from the North-East sector Smectite and Illite make up 0-16%. For DS from the Eastern sector Smectite and Illite give 30-69%, and for DS from the Central African source the range is 10-44%.
Therefore, sources from the East and sources from the North-East are completely separated by the criterion of Smectite and Illite. Sources from Central Africa seem to fall in the range between the North-East and the Eastern sources (but there are only 3 cases).
In addition only in DS from the eastern sector do we find paligorskite.

EVALUATION OF SEA-SALT AEROSOL FORECASTS IN THE OPEN SEA

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Acting as efficient cloud condensation nuclei, sea-salt aerosols (SSA) could affect cloud formation. In the open sea, where SSA are mainly produced, their effects on climate are maximal. Model performance over the open sea has been verified in this study by comparing modeled SSA concentrations with observed wave height on a daily basis. Two buoys, located in the Eastern Mediterranean near Haifa and Ashdod, provided us with information about wave height during the three-year period, from 2006 - 2008. In the winter months, when local sea-breezes were insignificant, the two buoys measured sea-waves created by synoptic-scale westerlies associated with the transit of cyclones across the Mediterranean: these conditions were similar to the conditions in the open sea. The comparison showed that a high correlation between observed wind speed and wave height was accompanied by a high correlation between wave height and modeled SSA concentrations. This indicates that the model is capable of producing realistic variations of SSA concentrations over the open sea, in line with observed wind speed and wave height.

SYNOPTIC ANALYSIS OF A RARE EVENT OF SAHARAN DUST REACHING THE ARCTIC REGION.

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A rare event of Saharan dust cloud in the sub arctic region north of the Scandinavian Peninsula was discovered by the LIDAR of the Arctic LIDAR Observatory (ALOMAR) on the 7th August 2007 and identified by Rodriguez et al (2008). The origin of this cloud was from the permanent dust reservoir which exists in the atmosphere above the Sahara and not necessarily a result of a single dust storm.

The wind flow and the geopotential height at 700 hPa in the area bounded by 0°N-80°N and 100°W-40°E were examined for the days 1-4 of August. Additionally, the 6 to 7 days forward trajectories from the location 28°N-0°E were computed for the same time.

It was found, that during 1-2 August a strong southwesterly flow was formed in northern Africa and Western Europe, between a trough along the Atlantic coast of Southern Europe and Northern Africa and the eastern branch of the subtropical high. This synoptic situation was suitable to long range transportation of the dust from the Sahara to the Arctic.

APPLICATION OF RegCM3 FOR REGIONAL CLIMATE STUDIES

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The ICTP regional climate model (RegCM3) is coupled with a simplified anthropogenic aerosol and desert dust aerosol model for use in climate studies. The model includes desert dust, sea salt, sulphur dioxide, sulphate, hydrophobic and hydrophilic black carbon (BC) and organic carbon (OC). The model captures the basic observed climatology over most of the world's regions. The spatial and temporal variations of near surface concentration, mass load, optical depth and emission of anthropogenic aerosols, sea salt and dust aerosols from the main source regions are reproduced by model. Results of the model applications over different regions of the world indicate that effects of aerosols should be included in the assessment of climate.

Session II: Health

ASSESSING CONTRIBUTION OF AIR POLLUTANTS FROM LOCAL URBAN SOURCES DURING THE DAY OF ATONEMENT

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Measurements of atmospheric pollutant (e.g., NOx, particulate matter) in three urban centers in Israel before, during, and after the Day of Atonement allow us to investigate the significance of local versus long range sources of pollution and probe the effect of meteorological conditions (synoptic systems, ventilation rates, height of surface boundary layer, and wind speed) on level of pollution. During the Day of Atonement all traffic and most of the industrial activities cease in the Jewish populated parts of the country. We observed that in spite of this, concentrations of particulate matter (PM2.5 and PM10) are very similar in all three urban centers during the Day of Atonement to the days before and after. Moreover, PM levels during the Day of Atonement are generally higher during Red Sea trough synoptic conditions which carry air from the Saudi and Jordanian deserts in the east and southeast relative to Persian Trough synoptic conditions which bring air from the eastern Mediterranean and the Black Sea region in the north-west. This suggests that long-range sources determine the concentrations of PM in the atmosphere of Israel as expected from their long residence time. On the other hand, NOx levels during the Day of Atonement are significantly lower than the days before and after, reflecting NOx short residence time in the atmosphere. Furthermore, the difference in concentrations of NOx cannot be accounted for by different synoptic conditions but can be accounted for by variations in ventilation rates, height of surface boundary layer, and wind speed, however, in a complicated fashion which depends on the proximity of pollution sources and the local emissions before and after the Day of Atonement.

INTEGRATION OF SATELLITE OBSERVATIONS AND GROUND MONITORING AND ITS APPLICATION FOR ASSESSING EXPOSURE TO PM IN ISRAEL

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Particulate matter air pollution (PM) is derived from diverse sources - natural and anthropogenic. PM is usually characterized by its size and chemical composition, which may affect its diverse health effects. Recent studies revealed significant associations between fine particles (diameter<2.5□m) and human health, based on standard ground monitoring data. A global observation from space can give an answer to some ground monitoring limitations, since satellite imagery allows environmental mapping at a large spatial scale. Following a careful literature review on the use of satellite data for air quality management, we have started to study whether it is possible to utilize satellite observations for assessing exposure to fine particles in Israel in areas where ground monitoring does not exist or is too sparse. In particular, we will study how satellite AOT observations can be used for gaining better understanding of regional air quality for deriving reliable human health risk metrics. The work consists of retrieval of data from different sources and platforms, including a new spatial resolution product (3x3km2) from NASA, and the development of methods for linking, integrating, and assimilating these databases. The work has merit not only from a scientific standpoint, as the results are expected to present additional tools for policy makers for introducing appropriate guidelines and regulations.

3RD HAND SMOKING; HETEROGENEOUS OXIDATION OF NICOTINE AND SECONDARY AEROSOL FORMATION IN THE INDOOR ENVIRONMENT

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Tobacco smoking is well known as a significant source of primary indoor air pollutants. However, only recently has it been recognized that the impact of Tobacco smoking may continue even after the cigarette has been extinguished (i.e., third hand smoke) due to the effect of indoor surfaces. These surfaces may affect the fate of tobacco smoke in the form of secondary reactions and pollutants, including secondary organic aerosol (SOA) formation.

Fourier Transform Infrared spectrometry with Attenuated Total Reflection (FTIR-ATR) in tandem with a Scanning Mobility Particle Sizing (SMPS) system was used to monitor the ozonation of cellulose sorbed nicotine and resulting SOA formation. SOA formation began at onset of ozone introduction ($[O_3]$ = 60 ± 5 ppb) with a size distribution of $d_p \leq 25$ nm, and was determined to be a result of heterogeneous reaction (opposed to homogeneous). SOA yield from reacted surface nicotine was on the order of 10%.

Simultaneous to SOA monitoring, FTIR-ATR spectra showed surface changes in the nicotine film as the reaction progressed, revealing a pseudo first-order surface reaction rate of 0.0026 ± 0.0008 min^{-1}. Identified surface oxidation products included: cotinine, myosmine, methylnicotinamide and nicotyrine. Surface reaction rate was found to be partially inhibited at high relative humidity.

Given the toxicity of some of the identified products (e.g., cotinine has shown potential mutagenicity and teratogenicity) and that small particles may contribute to adverse health effects, the present study indicates that exposure to 3^{rd} hand smoke ozonation products may pose additional health risks.

INDUCED PARTICLE GROUPING AND COAGULATION IN DIESEL EXHAUST

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Grouping is the attachment of particles as a result of fluctuation in the carrying-fluid's velocity field. This is described by a mathematical model. Following this model, a Diesel-engine emission tube has been modified to achieve such flow conditions that induce particle grouping as they travel in the tube.

Particle size distributions were compared against a regular emission tube under different working conditions. Results show grouping in every engine operating conditions such that we can say that the modified emission tube works well.

The grouping phenomenon leads to particle coagulation, which shifts particle size and reduces the health risk associated with PM emission from Diesel engines.

DYNAMICS OF EXHALED AEROSOL

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The recent H1N1 Epidemic (swine flu) brought attention to the importance of aerosols exhaled from the respiratory tract. Aerosols are emitted from the respiratory tract during various activities such as coughing, speaking or sneezing. These aerosols play an important role in the transmission of airborne diseases such as influenza, tuberculosis and others. After evaporation droplets can form droplet nuclei which, in turn, can remain suspended for prolonged periods and constitute a health hazard. A mathematical model was constructed to describe the dynamics of a single droplet. Simulations were conducted in order to evaluate the effect of various factors, include environmental conditions and flow and droplet characteristics, on the evaporation and motion of the droplet. The results of these simulations can assist in estimating the risk imposed by exhaled droplets and in designing solutions to minimize this risk in controlled environments.

Session III: Theory and modeling I

SIMULTANEOUS RETRIEVAL OF THE COMPLEX REFRACTIVE INDICES OF THE CORE AND SHELL OF COATED AEROSOL PARTICLES FROM EXTINCTION MEASUREMENTS USING SIMULATED ANNEALING

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Retrieving the complex refractive index of homogeneous aerosol particles given the measured extinction efficiency as a function of particle size can be achieved to good precision with almost any minimization algorithm. This is because, given the proper range of sizes and number of sizes in the aerosol size distribution, the measured extinction minus the calculated extinction has an easily distinguished minimum. Simultaneously retrieving the complex refractive index of the core and shell of coated aerosol particles given the measured extinction efficiency as a function of particle size is much more difficult, however. Not only must the minimization be performed over a four-parameter space, requiring more computational resources, but in addition, the measured extinction minus the calculated extinction does not have an easily distinguished global minimum. Rather, there are numerous local minima (other physical solutions leading to approximately the same extinction) to which almost all conventional retrieval algorithms rapidly converge. In this work, preliminary results using two new retrieval algorithms, one that employs a simple random search technique rather than a usual iterative technique, and second that employs the simulated annealing technique, will be shown. Both of these techniques are especially designed to converge on the global minimum when local minima are present. The results of these new retrieval algorithms will be discussed.

COMPLEX-VALUED VARIABLE AND SOLUTIONS FOR BOUNDARY LAYERS WITH DROPLETS/PARTICLES

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Aerosol concentrations in a boundary layer with downstream velocity variation reveal a bifurcational behavior. The solution of both the flow and concentration fields involves the use of similarity transformations. The similarity solution of the flow field has 3 bifurcating branches: for accelerating flow, for decelerating flow, and a previously unexplored solution for high-rate deceleration which involves complex values of the similarity solution. Although the latter solution involves complex values of the similarity variable, it still leads to an acceptable solution in the physical variables. The bifurcation in the downstream distribution of the aerosol concentration stems from the bifurcation characteristics of the flow, with a further third branch stemming from downstream behavior outside the boundary layer. These results have ramifications to aerosol dynamics (transport, deposition) in boundary layers developed in industrial facilities and sizing instrumentation, over airfoil, as well as in the human respiratory system. Effect on captured particles and the forces acting on it are also addressed.

Session IV: Atmosphere II

Effect of Rain Scavenging on Altitudinal Distribution of Soluble Gaseous Pollutants in the Atmosphere

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Wet deposition, including below-cloud scavenging by rains, is one of the most important removal mechanisms that control the distribution, concentration and life-time of many gaseous species in the atmosphere. In the present investigation we developed a model for predicting scavenging of soluble gaseous pollutants from the atmosphere by the rain. The developed model is valid for arbitrary gradients of soluble gaseous pollutants in a gaseous phase and is suitable for predicting scavenging of moderately soluble gases, e.g., sulfur dioxide (SO_2), carbon dioxide (CO_2) and ammonia (NH_3) from the atmosphere. Using the equation of mass balance for soluble gaseous species in gaseous and liquid phases we derived a nonstationary convective-diffusion equation for evaluating the amount of precipitation required for scavenging of various soluble gaseous pollutants from the atmosphere and determined transient altitude distribution of these gases in the atmosphere during rain fall. Numerical solution of the derived equation with the appropriate initial and boundary conditions showed that soluble gas in the atmosphere is washed down by precipitation and is smeared by diffusion. Using the suggested model we analyzed the temporal evolution of the vertical profiles of ammonia and sulfur dioxide in the atmosphere caused by their washout. We calculated also scavenging coefficient. It was showed that the magnitude of scavenging coefficient varies with time and altitude and depends on the vertical distribution of soluble gaseous pollutants in the atmosphere and on the rain intensity. The predictions of the developed model were compared with the available experimental data.

Keywords: gaseous pollutant, gas absorption, precipitation scavenging, convective diffusion.

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TURBULENT EFFECTS ON CLOUD MICROSTRUCTURE AND PRECIPITATION OF DEEP CONVECTIVE CLOUDS AS SEEN FROM SIMULATIONS WITH A 2-D SPECTRAL MICROPHYSICS CLOUD MODEL

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Effects of turbulence on evolution of deep convective clouds and on precipitation are investigated using the spectral bin microphysics Hebrew University Cloud Model with the spatial resolution of 50 m. Turbulent collision kernels between drops are calculated at each time step and at each grid point. The turbulence-induced collision rate enhancement is determined by means of lookup tables calculated in the recent studies for different values of turbulent dissipation rate and the Taylor microscale Reynolds numbers.

Deep convective clouds observed during the LBA-SMOCC campaign (Brazil) were simulated under a wide range of aerosol concentrations. It is shown that the intensity of turbulence is highly spatially inhomogeneous. Clouds consist of multiple bubbles, the turbulence intensity reaching its maximum at the edges of these bubbles. As a result, the zones of enhanced turbulence are elongated and form "large scale" turbulent intermittency. It is shown that polluted clouds are more turbulent than those developing in the clean atmosphere. A good agreement of the calculated droplet size distributions with those measured in-situ is demonstrated. It is shown that under polluted conditions the effect of turbulence on drop collisions leads to a faster formation of raindrops and to a dramatic acceleration of warm rain rate at the surface. At the same time, turbulence-induced collision enhancement lessens the amount of supercooled drops and leads to a decrease in the rain forming by melting of ice.

EFFECTS OF STRATOCUMULUS CLOUDS ON AEROSOLS IN THE MARITIME BOUNDARY LAYER

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Evolution of the aerosol size distribution and the rate of aerosol scavenging in drizzling maritime stratocumulus clouds are analyzed using a Lagrangian model of a cloud topped boundary layer in which 1344 adjacent Lagrangian parcels move within a turbulent like flow with statistical parameters derived from observations made in the research flight RF07 during DYCOMS-II field experiment.

The effect of cloud microphysical processes on the evolution of aerosol size distribution is investigated. A significant difference between AP sizes and salinity within droplets in cloud updrafts and in downdrafts was found and analyzed. Drizzle-cloud droplet collisions lead to formation of large AP with radii up to 3.3 μm, which is 2 μm larger than the maximum aerosol radius in the initial aerosol spectrum. However, the concentration of such large AP is very low, so that it is concluded that stratocumulus clouds with a comparatively weak drizzle fluxes cannot be a source of giant cloud condensation nuclei. The dependence of the amount of large aerosols on the precipitation rate is investigated.

THE POSSIBLE ROLE OF SMALL AEROSOLS IN THE MICROPHYSICS AND LIGHTNING OF DEEP MARITIME CLOUDS

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According to the state-of-the art concept, the charge separation takes place within cloud zones where graupel and ice crystals collide in the presence of a significant amount of supercooled water. In maritime clouds most of droplets formed at the cloud base fall out not reaching the freezing level. Nevertheless, lightning takes place sometimes in eye walls of hurricanes, where clouds are, supposedly, the most maritime in the word. In this study we address the following question: "Why does lightning can take place in deep maritime convective clouds in the Intertropical Convergence zone and in the hurricane eyewalls at all?"

Numerical simulations using the spectral microphysics Hebrew University cloud model show that the formation of lightning requires the existence of small aerosols with the radii of about 0.01 μm in the CCN size spectra. Both factors are the necessary components of the lightning formation. The absence of small aerosols prevents in-cloud nucleation of small drops at high distances above the cloud base. The lack of high updrafts prevents in-cloud nucleation and the formation of supercooled water at high levels. Small aerosols form over the ocean, supposedly, due to chemical reactions following by particle collisions to create the aerosol accumulation mode. We also speculate that small aerosols can be of continental nature and penetrate the ocean like African dust. The latter can explain the existence of intense lightning in the ITCZ over the ocean near the African coast. The potential importance of small CCN in microphysics of deep tropical convection is discussed.

Session V: Theory and modeling II

CHARACTERIZATION OF SOOT AGGLOMERATES BY MOBILITY, VACUUM AERODYNAMIC DIAMETER AND MASS

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A method of particle characterization by measuring their mobility d_m, mass, m and vacuum aerodynamic diameter d_a^{vac} is proposed and tested for diesel- and flame soot agglomerates having mobility sizes 300 – 768 nm. The method involves no assumptions other than the knowledge of the particle inherent density. Experiments were performed to establish mass-mobility relationship. The agglomerates' mass mobility fractal dimension was found to be 2.314 and 1.984 for diesel-soot and flame-soot particles, respectively. The agglomerates' dynamic shape factors (DSF) in vacuum and at atmospheric pressure were deduced from the data measured in the range from 2 to 5 for diesel-soot and from 2.7 to 4.3 for flame-soot particles, respectively. The vacuum DSFs are significantly higher than those measured at atmospheric pressure.

Independently, from the measured agglomerates' vacuum aerodynamic diameter d_a^{vac} and mass m we evaluated their vacuum mobility diameters d_m^{vac} and the concomitant vacuum fractal dimension D_{pr}, relating m

and d_m^{vac} : $m = k_{pr}(d_m^{vac} / d_p)^{D_{pr}}$ and governing also the agglomerates' projected properties. We obtained that despite the clear difference in the values fractal dimension D_{fm}, determined from the mass-mobility relationship, both soot particles have close vacuum properties D_{pr}, k_{pr}, reflecting the screening effect by monomer primary particles, composing the agglomerates. A method is proposed to determine the average primary particles diameter d_p from the measured agglomerates m- d_a^{vac} power dependence.

The model of Vainshtein and Shapiro (2005) for agglomerates' drag in rarefied gases, is used to rationalize and correlate the measured experimental results. We found that the agglomerates' DSFs are very sensitive with respect to the their structure, as expressed in the intrinsic (or geometric) fractal dimension D_f, defined via radius of gyration. Therefore we proposed a method of retrieving the agglomerates' geometric fractal dimension from the DSFs measured in the transition regime, on the basis of an appropriate theoretical model for agglomerates' drag.

TANGLING CLUSTERING OF INERTIAL PARTICLES IN STABLY STRATIFIED TURBULENCE

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We have predicted theoretically and detected in laboratory experiments a new type of particle clustering (namely, tangling clustering of inertial particles) in a stably stratified turbulence with imposed mean vertical temperature gradient. In this stratified turbulence a spatial distribution of the mean particle number density is nonuniform due to the phenomenon of turbulent thermal diffusion, i.e., the inertial particles are accumulated in the vicinity of the minimum of the mean temperature of the surrounding fluid, and a non-zero gradient of the mean particle number density is formed. It causes generation of fluctuations of the particle number density by tangling of the large-scale gradient by velocity fluctuations. In addition, the mean temperature gradient produces the temperature fluctuations by tangling of the large-scale gradient by velocity fluctuations. The anisotropic temperature fluctuations contribute to the two-point correlation function of the divergence of the particle velocity field, i.e., they increase the rate of formation of the particle clusters in small scales. We have demonstrated that in the laboratory stratified turbulence this tangling clustering is much more effective than a pure inertial clustering (preferential concentration) that has been observed in isothermal turbulence. In particular, in our experiments in oscillating grid isothermal turbulence in air without imposed mean temperature gradient, the inertial clustering is very weak for solid particles with the diameter of the order of 10 microns, and Reynolds numbers based on turbulent length scale and root-mean-square velocity, Re=250. In the experiments the correlation function for the inertial clustering in isothermal turbulence is much smaller than that for the tangling clustering in non-isothermal turbulence. The size of the tangling clusters is of the order of several Kolmogorov length scales. Our theoretical predictions are in a good agreement with the obtained experimental results.

NEAR-GROUND HYPERSPECTRAL IMAGING FOR URBAN SCALE REMOTE SENSING OF AEROSOLS, DURING NIGHTTIME

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Keywords: remote sensing, urban pollution, fine particles, aerosol measurement, hyperspectral imaging

Spatiotemporal variations in size attributes of ambient aerosols, in particular fine PM, are important estimates for public health risk assessment. Both satellite and ground remote sensing (RS) are applied for characterizing atmospheric aerosols by analyzing the aerosol interactions with electromagnetic radiation in different visible-NIR wavelengths or multiple angles. Relying on solar radiation, these methods are limited by the sun elevation angle and the cloud cover, and also by the revisit periods for satellite-borne sensors.

Current RS procedures can provide estimates of bi-modal size distributions in vertical atmospheric columns (Wang *et al.*, 1996). However, the correlation between the vertical aerosol profiles and ground-level particulate matter (PM) distribution at the urban-scale resolution is highly influenced by the geo-site specific seasonality and the corresponding mixing layer height (Schäfer *et al.*, 2008). Standard ground-level stations that monitor ambient PM provide only integrated

concentrations in discrete and sparse locations. Consequently, their data is susceptible to sporadic readings.
A ground hyperspectral camera (VDS Vosskühler Cool-1300Q), originally used for biomedical applications, has been adapted for ground environmental remote sensing. The camera acquires signals in the visible-NIR range (λ=400-1100nm, 160 channels), thus having a prospective aptitude to trace spectral signatures of urban PM in the accumulation mode (Kuzmanoski *et al*., 2007). The aim of this study was to examine the feasibility of extracting concentrations of such PM from signals acquired by hyperspectral imaging through horizontal open paths of 1-4km between the camera and the imaged targets. The study focused on implementing an innovative night-time imaging procedure by using remote street lights as spectral emission sources. This procedure offers a new concept for simultaneous measurements of aerosols in multiple ambient air columns when solar radiation cannot be used.
A laboratory scale feasibility study as well as field sessions have been conducted, which demonstrated stable and linear response of the hyperspectral CCD, This allows for straight forward conversion into spectral radiance. Detection limits of current system were assessed with regards to aerosol optical thickness.
In the laboratory phase spectral imaging was experimented with a halogen source which emits radiation in the range of λ=500-900nm. Aerosol optical thicknesses (AOT) in between 0.02-0.5 was emulated by flowing controlled concentrations of PSL spheres into a dedicated optic chamber, Spectral imaging The optical thickness derived from the hyperspectral sensor response in the laboratory experiments was comparable to Mie calculations of spectral extinction based on simultaneous size measurement by scanning mobility particle sizer (TSI, SMPS™ 3936). Periodical field imaging of remote street lights was performed next. Significant changes in the hyperspectral signature were acquired during dust storm events.

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THE ORIENTATIONS OF PROLATE ELLIPSOIDS IN LINEAR SHEAR FLOWS

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Collisions of small ice crystals in mixed-phase and ice clouds determine snow (aggregate) formation which determine precipitation from cold stratiform clouds and dramatically affect precipitation in mixed-phase clouds. At the same time the rate of collisions of ice crystals is not known. The non-spherical shape of ice crystals makes their motion very complex even in still air. In cloud such collisions take place in turbulent environment which makes the problem more difficult. This study represents the first step toward understanding of motion and collisions between small non-spherical crystals in turbulent flows.

The most widespread shapes of ice crystals is clouds are prolate and oblate ellipsoids. In this study the dynamics of the orientations of small prolate ellipsoids in general linear shear flow is considered. The orientations of a single ellipsoid are studied via the solution of "Jeffery Equation". The attractors of the equation are found. It is shown that the equation may have either a stable fixed point or a stable limit cycle or periodic solutions - "Jeffery Orbits".
Characteristic time scales for convergence to the stable solutions are found. It is shown that convergence may not be monotonic due to non-normal growth, thus resulting in long convergence times compared to the characteristic time scale of the shear. The probability distribution function of the orientations of an ensemble of particles is calculated via the solution of the Fokker-Planck equation. As with the case of a single particle, the convergence of the p.d.f. may be non-monotonic. Possible implications to the collision rate of non-spherical particles in turbulent flows are discussed.