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## *Preface*

# ECOMA/MASS: aerosol particles near the polar summer mesopause

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The polar summer mesopause region (75–95 km) is one of the most intriguing parts of the Earth's atmosphere. Its unique thermal structure and the presence of aerosol species gives rise to fascinating phenomena like polar mesosphere summer echoes (PMSE) and noctilucent clouds (NLC) that are called polar mesospheric clouds (PMC) when observed from space. Owing to the gravity wave driven global circulation from the summer to the winter pole the air rises and cools adiabatically above the summer pole. Consequently, the lowest temperatures in the entire atmosphere are reached with minimum values of about 110 K. In this extreme thermal environment, the tiny amount of water vapor (typical volume mixing ratios are in the low ppm-range) is supersaturated so that ice particles may form and grow to "visible" sizes of a few tens of nanometers. In addition, the majority of meteoroids ablate in the same altitude range and it has long been suggested that this ablated material should re-condense to form meteor smoke particles (MSPs). These, in turn, have long been suspected to serve as the condensation nuclei for the mesospheric ice particles. In recent years, the interest in mesospheric ice clouds and corresponding microphysical processes has considerably intensified, in part because it was suggested that they could be extremely sensitive indicators of long term mesospheric trends which in turn could be useful to identify climate change. In recognition of the need for more comprehensive data sets, NASA has sponsored the Aeronomy of Ice in the Mesosphere (AIM) satellite which is exploring NLC/PMC to find out why they form and why they are changing.



Considering the goal to use observations of mesospheric ice clouds as indicators for climate change, it is evident that a quantitative understanding of all forcing variables is required including all aspects of the cloud microphysics. Regarding the latter, however, it is surprising how many fundamental properties of the clouds are still unknown. To mention just a few examples, it is still not known whether mesospheric ice clouds do nucleate on MSPs or other mesospheric constituents such as proton hydrate clusters or sulfate aerosols. It is further unclear what fraction of the particles are charged and whether or not the charge significantly affects the threshold for nucleation. And finally, the data for the size distribution of particles has been limited to the largest particles, tens of nanometers in radius that are visible to lidar.

In order to address several of the above mentioned questions, the joint ECOMA/MASS sounding rocket campaign was conducted in August 2007 from the North-Norwegian Andoya Rocket Range. The primarily German and Norwegian-funded ECOMA (Existence and Charge state Of meteor smoke particles in the Middle Atmosphere)-program aims at characterizing meteor smoke particles in the middle atmosphere including properties like their concentration and size, their charge state, and their role in the formation of mesospheric ice particles. The ECOMA-payload consists of detectors to measure charged and neutral aerosol particles including optical aerosol signatures, instruments to measure electron and ion concentrations, and detectors to characterize the neutral background atmosphere including fluctuations at the smallest scale.

The NASA-funded MASS (Mesospheric Aerosol Sampling Spectrometer) sounding rocket combines a mass analyzer for both positively and negatively charged smoke and ice particles up to $10^6$ amu in mass, with instruments for

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electric fields, electron densities, and particle detection by photometry.

In the course of the joint ECOMA/MASS-campaign one ECOMA and two MASS-sounding rockets were launched into polar mesosphere summer echoes and noctilucent clouds as indicated by the ground based radar and lidar systems located at the Andoya Rocket Range. The first MASS-payload was launched in close proximity to an overflight of the AIM-satellite.

The current special issue consists of a total of eight papers and gives an initial overview of the results obtained by all these instruments. The papers deal with a wealth of topics ranging from the global morphology of the studied ice cloud to the detailed size and charge distribution of the aerosols during the rocket launches. Some of the noteworthy findings from these papers are highlighted below:

To set the stage, Baumgarten et al. describe the mesospheric ice cloud morphology on global to local scales using a unique set of measurements from the AIM and ENVISAT satellites, ground based cameras, and ground based lidars at three different locations. While satellite observations show a planetary wave 2-structure, the cloud morphology on local scales is clearly dominated by small scale gravity wave structures which can have large effects on time scales as short as ∼100 s. Several of the rocket borne measurements show a highly inhomogeneous and structured cloud as seen in large differences from rocket upleg – to downleg – measurements on distances of ∼50 km (Robertson et al.; Rapp et al.) and even on much smaller spatial scales (several 100 m) as seen in photometer data (Megner et al.). These measurements show the extremely dynamic character of the summer mesopause region which in turn leads to immense detail in the corresponding ice clouds.

Coming to the microphysical aspects, Robertson et al. report about the first mass and charge analysis of mesospheric aerosol particles. Interestingly, they find compelling evidence for the co-existence of negative and positive particles in any given size range hence questioning the validity of instruments where net charge only is measured. Furthermore, they find a predominant occurrence of positive particle charges at the smallest particle sizes (0.5–1 nm) whereas the largest detected particles ($>$3 nm) were predominantly negative. In consequence, they propose that ice particle nucleation occurs on positive ice nuclei after which the particles collect more negative charge as they continue to grow. The evidence for positive particle charge at the smallest particle sizes is supported by the model results of Brattli et al. who analyzed the charge balance based on ECOMA-particle, electron and positive ion measurements. They find that charge neutrality requires a population of positively charged particles smaller than ∼2 nm which cannot be detected by the ECOMA instrument which is sensitive to particles with radii in excess of 2 nm only.

Rapp et al. present measurements of charged aerosol particles larger than 2 nm. Comparing profiles of charged particles, electron number densities from Friedrich et al., and the small scale features of charged particles and neutral density from Strelnikov et al. with the simultaneously measured PMSE, they conclude that the presence of charged particles and corresponding small scale fluctuations is a necessary but not sufficient condition for the presence of the radar echoes. They argue that also the electron number density needs to be sufficiently large, i.e., in excess of $\sim$100/cm$^3$. In addition, Rapp et al. introduce a new detection method to directly obtain ice volume density based on the active photo-ionization of aerosol particles and subsequent detection of photoelectrons. Derived altitude profiles are in full qualitative agreement with concurrent photometer observations of the ice particles on the same rockets proving the validity of this new technique. Resulting ice volume densities fall into the range of values previously reported from satellite and lidar observations and are the first such estimates with the unique spatial resolution of an in situ measurement.

An analysis of small scale features in electric fields, charged particles and in neutral density is presented in Shimogawa and Holzworth and in Strelnikov et al., respectively. While Shimogawa and Holzworth can exclude the presence of any strong large scale DC-electric field and hence call into question corresponding PMSE-theories, they find that small scale field fluctuations resemble the structure of simultaneously observed PMSE both along the direction of the rocket axis as well as perpendicular to it. In addition, Strelnikov et al. compare small scale irregularities in charged particles and neutrals and derive Schmidt-numbers, i.e., the diffusivity of the particles vs. the kinematic viscosity, of up to several thousands. Such large Schmidt-numbers are required to explain PMSE at the largest frequencies around 1 GHz.

Finally, Friedrich et al. conclude that electron density depletions (bite-outs) are more likely to occur when the electron density is initially low, whereas at times of large ionisation the balance between production and attachment to aerosol particles is more shifted towards free electrons.

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