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Preface

"Structure, composition, and dynamics of the middle atmosphere and lower ionosphere during a major meteor shower"

U.-P. Hoppe[1] **and M. Rapp**[2]

[1]University of Tromsø, Department of Physics and Technology, Tromsø, Norway
[2]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

Correspondence to: U.-P. Hoppe (ulf-peter.hoppe@ffi.no)

With this special issue we document our current understanding of the impact of a major meteor shower on the structure, composition and dynamics of the middle atmosphere and lower ionosphere. The results centre on, but are not limited to, a recent international campaign with sounding rockets, ground-based and satellite observations: the ECOMA 2010 Geminids campaign. This campaign was conducted in December 2010 from Andoya Rocket Range (69° N, 16° E). Three instrumented payloads were launched to investigate the evolution of meteoric smoke particles' distribution, properties and abundance as well as their effects on the middle atmosphere: one shortly before the onset of the shower, one at the peak of shower activity on 13 December, and one after shower activity had ceased. All scientific payloads included instruments to probe the neutral atmosphere (density, temperature, turbulence, trace species like meteor smoke, NO, O) and the lower ionosphere (electrons, positive ions, charged aerosols). In the same time period, many coordinated ground-based measurements were carried out. Among these were the new Middle Atmosphere ALOMAR Radar System (MAARSY), the ALOMAR RMR and Na-lidars, several specular meteor radars, photographic observations of meteors, the EISCAT VHF-radar, the PFISR, RISR and Arecibo incoherent scatter radars, and the Japanese MU-radar. Data from the Microwave Limb Sounder (MLS) on board NASA's Aura satellite was used to put some of the local observations into a global perspective. The results in this special issue show once again how much more valuable coordinated rocket- and ground-based measurements are than any of those methods alone. The results published in this special issue encompass the topics as follows.

The observations with rocket-borne instruments are consistent with the assumption that the meteoric smoke particles absorb free electrons under nighttime conditions. Thus, the smoke particles significantly change the usual balance between electrons and negative ions on the one hand, and positive ions on the other (Friedrich et al., 2012). Also, atomic oxygen destroys negative ions, but does not affect electrons attached to meteoric smoke particles.

Using the ECOMA program's main instrument, the ECOMA particle detector (PD), Rapp et al. (2012) have come to the following conclusions: sporadic meteors are much more important than shower meteors for the number density of meteoric smoke particles in the middle atmosphere. The strongly reduced photoelectron currents (which originate from active photoionization of the smoke particles by photons emitted by the Xenon-flash lamp of the PD) at the peak of the Geminids indicate that the smoke particles' chemical composition may be significantly different from an undisturbed situation when sporadic meteors are their sole source. The authors also tentatively conclude that smoke particles are larger at lower altitudes within the 80 to 95 km height range. From the first launch in December 2010 until the third one, both the uppermost and lowermost altitudes of particle detection decreased monotonically by several km, strongly pointing towards a systematic change of the smoke particle distribution. From their spectrally resolved photo electron measurements and quantum chemical calculations, the authors estimate the work function for smoke particles as 4–4.5 eV, pointing towards Fe and Mg clusters as their major constituent during this time period. We have become very interested in new measurements to corroborate or disprove the different composition of smoke from Geminid meteors compared to sporadic meteors. We recommend sampling experiments together with corresponding laboratory investigations, guided by the findings from this campaign.

The ECOMA instrument with its photoionization lamp also had an interesting and useful side effect: the Xe flashlamp not only charges meteoric smoke particles by ejecting electrons through the external photo effect (the intended effect), but also photoionizes some atmospheric trace molecules, i.e. primarily NO. Hedin et al. (2012) distinguished between the two effects during the ECOMA 7 flight and thus retrieved two atomic oxygen profiles and two NO profiles in the height region 85 to 106 km, one each from ascent and one from descent. For the purpose of studying the NO_2 continuum, these authors recommend using flash lamps with slightly shorter wavelengths in the future, in order to avoid auroral and chemiluminescent emissions as much as possible.

The results by Dunker et al. (2013) show in detail the surprising result mentioned above, that the steady decrease of sporadic meteors during November and December has more significant bearing on the amount of meteoric material in the upper mesosphere than the Geminids meteor shower. Comparing their own results with previously published results from the Geminids time period of previous years, these authors suggest that the amount of Na in shower meteors, or in sporadic meteors during this time period, may have decreased over the last four decades.

Friedrich et al. (2013) compare the results from different instruments on board the ECOMA payloads. The Faraday rotation method, also called the Radio Wave Experiment, appears to give the best absolute electron density results, even if at somewhat coarse height resolution. The multi-pin probe gives much better height resolution and the results are independent of any payload charging, but perhaps troubled by local ram and wake effects in electron density. When the pin material, geometry, and bias voltages are carefully chosen, the latter instrument also measures the payload potential during the flight, a valuable parameter for interpreting other onboard plasma measurements as well as measurements involving photoelectrons. We recommend flying these two instruments together on most ionosphere-related rocket payloads in the future. According to the results by these authors, the payloads ECOMA-7 to -9 have charged much more negatively than earlier flights of the identical and very similar payloads. Further research will be necessary to understand the reason for this.

The paper by Bekkeng et al. (2013) fully exploits the possibilities of the multi-needle probe for plasma density and payload potential studies. Here, the instrument and its data analysis is described in detail. These authors use a simple payload-charging model to show that the positive charging events on two of the three flights are today poorly understood.

Meteor showers are a global phenomenon, and observations were also performed during the 2010 Geminids meteor shower with the MU radar in Japan (Kero et al., 2013). These authors find a Geminid velocity before entering the atmosphere of $36.6\,\mathrm{km\,s^{-1}}$. The visual Geminid activity in 2010 peaked in the morning hours of 14 December, and the radar head echoes slightly sooner. Their observations are in agreement with earlier mass estimates of Geminid meteors of 10^{-9} kg to 0.5 kg. The observed Geminid observed cumulative flux at this location was $\sim 0.3\,\mathrm{h^{-1}\,km^{-2}}$.

Stober et al. (2013) did similar radar observations of Geminid and sporadic radar meteors very close to the rocket trajectory and with a standard meteor radar (using specular reflection) and with the new MAARSY (using meteor head echoes) at 69° N, as well as with another radar at 55° N. In agreement with the authors mentioned above, they found also at these locations that the most probable Geminid velocity in 2010 was approximately $35\,\mathrm{km\,s^{-1}}$. The portion of sporadic meteors (from other quadrants) observed during the time period of the Geminids was almost 50 % at 69° N and almost 44 % at 55° N. The reason for this difference is the different height of the Geminids quadrant at these two locations.

Finally, Szewzyk et al. (2013) took the opportunity to increase our understanding of Mesospheric temperature Inversion Layers (MIL) via rocket-borne measurements of density and temperature, in conjunction with ground-based lidar measurements of temperature, MF-radar wind measurements and satellite measurements of temperature with the MLS instrument onboard the Aura satellite. Their results from two such layers shows that heating by turbulence and downward transport of heat by tides at least contribute to MILs, or are even possibly the most important mechanism.

The results published in this Special Issue document results from the last campaign of the ECOMA programme, initiated by IAP and FFI in 2002. This programme has so far been the last one of a decades-long collaboration on mesosphere rocket campaigns and combined rocket/ground-based campaigns between Germany and Norway since the 1970s. The collaboration evolved from one between the University of Bonn and FFI to a collaboration between IAP in Germany and FFI in Norway in the 1990s. In 2012, FFI decided to cease engaging in this type of research, but it is envisaged that this highly successful collaboration will be continued involving new main partners. Many other science groups joined for longer or shorter periods. Many good scientists both contributed to and benefitted from this collaboration, too many to list here. However, we would like to use this opportunity to gratefully congratulate our earliest predecessors, Prof. Ulf von Zahn and Prof. Eivind Thrane. Without their pioneering spirit, creativity, advice, and perseverance, this fruitful international collaboration might not have come about.

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