Onset of new particle formation in boundary layer

H. E. Manninen[1,2], S. Mirme[2], M. Ehn[1,3], K. Leino[1], S. Schobesberger[1], H. Junninen[1], E. Järvinen[1], J. Kangasluoma[1], T. Nieminen[1,4], R. Tillmann[3], F. Angelini[5], G. P. Gobbi[5], A. Mirme[2], S. Decesari[6], A. Wahner[3], T. Petäjä[1], D. R. Worsnop[1,7], F. Rohrer[3], T. F. Mentel[3] and M. Kulmala[1]

[1]Department of Physics, University of Helsinki, P.O. Box 64, 00014, Helsinki, Finland
[2]Institute of Physics, University of Tartu, Ülikooli 18, 50090, Tartu, Estonia
[3]Institute for Energy and Climate Research (IEK-8), Forschungszentrum Jülich, 52425 Jülich, Germany
[4]Helsinki Institute of Physics, P.O. Box 64, 00014 University of Helsinki, Finland
[5]Institute of Atmospheric Sciences and Climate, ISAC-CNR,
Via Fosso del Cavaliere 100, 00133, Rome, Italy
[6]Institute for Atmospheric Sciences and Climat, ISAC-CNR,
via Gobetti 101, 40129 Bologna, Italy
[7]Aerodyne Research Inc, Billerica, MA 01821, USA
Keywords: atmospheric aerosols, new particle formation, boundary layer, PEGASOS project.
Presenting author email: hanna.manninen@helsinki.fi

The planetary boundary layer (PBL) is chemically and physically the most dynamic part of the atmosphere as it has high loading of aerosol particles and their gaseous precursors. Secondary formation of atmospheric aerosol particles, so-called new particle formation (NPF), is believed to be the dominant source of aerosol particles in the atmosphere. Nucleation is a process of gas-to-particle conversion, beginning with a few gas molecules colliding to form a cluster of 1-2 nm in diameter (Kulmala et al. 2013). This first step of NPF is followed by the growth of the newly formed particles.

At this moment, the mechanisms of particle formation and the vapors participating in this process are not truly understood. Especially, in which part of the atmosphere the NPF takes place, is still an open question. To detect directly the very first steps of NPF in the atmosphere, we measured these chemical and physical processes within the PBL (altitudes up to 1 km). We used airborne Zeppelin measurements and ground based in-situ measurements. Using Zeppelin, we focused on the time of the development of the PBL from sunrise until noon to measure vertical profiles of aerosol particles and chemical compounds.

We have measured the vertical and the horizontal extension for NPF events using an instrumented airship, Zeppelin. The vertical profile measurements represent the particle and gas concentrations in the lower parts of the atmoshere: the residual layer, the nocturnal boundary layer, and the PBL. At the same time, the ground based measurements records present conditions in the surface layer. Horizontal, almost Lagrangian, experiments are possible as the airship drifts with the air mass.

The key instruments to measure the onset of NPF were Atmospheric Pressure interface Time-Of-Flight mass spectrometer (APi-TOF, Junninen et al. 2010), a Particle Size Magnifier (PSM, Vanhanen et al. 2011), and a Neutral cluster and Air Ion Spectrometer (NAIS, Mirme and Mirme, 2011). These instruments are able to measure particles at the size range ~1-2 nm where atmospheric nucleation and cluster activation takes place (Kulmala et al. 2013). The high time resolution of the instruments allowed us to observe the starting time of the NPF events. In addition, particle number size distributions from 1 nm to 1 µm, and concentration of NO, NO_x, O_3, CO, OH, HO_2, and lifetime of OH were measured, as well as meteorological parameters.

On June 2012, Zeppelin was measuring nucleation occuring in the Po Valley area, Nothern Italy, especially over the San Pietro Capofiume (SPC) field site. The newly formed particles were observed some hours after sunrise at ground level in SPC. The onset of NPF was usually observed onboard Zeppelin when it was measuring inside the rising mixed layer which is connected to the surface layer by effective vertical mixing. This observation suggests that the onset of NPF starts in the surface layer, and not in nocturnal boundary layer nor inside the residual layer. The newly formed, subsequently growing, particles were observed to be homogeneously distributed inside the mixed layer.

These measurements are part of the PEGASOS project which aims to quantify the magnitude of regional to global feedbacks between the atmospheric chemistry and physics, and thus quantify the changing climate. The Zeppelin flights are observing radicals, trace gases, and aerosols inside the lower troposphere over Europe. The main nucleation campaigns were performed in Po Valley (summer 2012), and Hyytiälä, Southern Finland (spring 2013). The results will support the numerical air-quality and climate modelling.

This research is supported by European Commission under the Framework Programme 7 (FP7-ENV-2010-265148), the Academy of Finland Centre of Excellence program (project no. 1118615) and the Finnish Cultural Foundation. The Zeppelin is accompanied by an international team of scientists and technicians who are all acknowledged.

Junninen H. et al. (2010) *Atmos. Meas. Tech.* **3**, 1039–1053.

Kulmala M. et al. (2013) *Science* **339**, 943–946.

Mirme S. and Mirme A. (2011) *Atmos. Meas. Tech. Discuss.*, **4**, 7405-7434.

Vanhanen J. et al. (2011) *Aerosol Sci. Tech.* **45**, 533–542.