

First direct observations on sub-3 nm molecular clusters in lower atmosphere using airborne measurements

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The first observations of newly formed sub-3 nanometer aerosol clusters have been made now via airborne measurements in the lower atmosphere. Flights were done close to Hyytiälä SMEAR II field station, in Southern Finland. The aim of this work is to investigate where, when and how the new particle formation (NPF) occurs in the atmosphere. Specifically we aim to answer: What is the contribution of charged clusters, and ion-induced particle formation as a function of altitude, and what are the vertical and horizontal scales of NPF event?

Earlier studies at Hyytiälä have suggested that new particle formation events are occurring throughout the boundary layer (Schobesberger *et al.* 2012). Direct observations on the first steps of NPF from the sizes of molecular clusters to nucleated particles have been made at ground-based measurements (Kulmala *et al.* 2013), and here we report a success to observe those newly-formed clusters as well inside the mixed planetary boundary layer. In addition to the activation of sub-3 nm clusters, the atmospheric small ions may be used as an indicator for NPF events (Leino *et al.* 2016).

The airborne cluster measurements were done during two measuring campaigns: autumn 2014 and spring 2015. As measurement platform we used a small Cessna 172 one-engine aircraft with slow air velocity (~130 km/h, for details see Schobesberger *et al.* 2012). The total particle concentration was measured with an Airmodus Particle Size Magnifier (PSM, Kangasluoma *et al.* 2015) model A10 with a particle counter (TSI 3010). The vertical number size distribution of atmospheric ions was measured with a Neutral cluster and Air Ion Spectrometer (NAIS, see Wagner *et al.* 2016). The cut-off size of the PSM was ~1.5 nm for neutral and charged particles, and the cut-off size of the NAIS is ~0.8 nm for ions only.

An example vertical profile of ions is shown in Fig. 1. The cluster ion band was visible all the way from the boundary layer up to the lower troposphere. The pressure in y-axis indicates the altitude so that ~790 hPa is the air pressure in the layer of 2 km from ground and 900 hPa in the one kilometre. Typical lower edge of the Aitken mode charged particles was seen inside the mixed boundary layer up to ~1 km. The cluster ion mode was seen at free troposphere, whereas the Aitken mode background particles were limited to boundary layer.

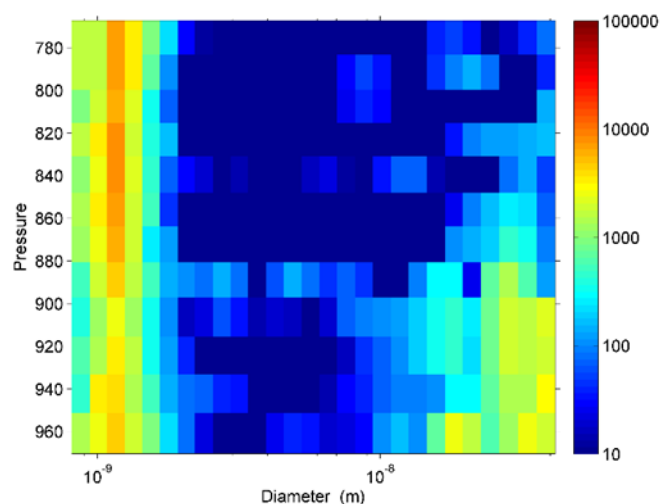


Figure 1. Median number size distribution of negative air ions as a function of altitude measured with a Neutral cluster and Air Ion Spectrometer (NAIS) in southern Finland at 16th Sept 2014 in the morning. The colour indicates the concentration of negative ions (dN/dlogDp).

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