Long-term observations of atmospheric ions and their role in particle formation

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The effect of ions on new particle formation (NPF) in the planetary boundary layer has been focus of active research in recent years. Some studies suggest a dominant role of ion-induced nucleation while others show a minor contribution from ions to particle formation (see Hirsikko et al. 2011 for a review). We have studied atmospheric ions, their connection to NPF and ultimately global climate based on long-term measurements. Results of the trend analysis of the cluster and intermediate ion concentrations as well as their correlation with ionization rate, air pollution and other environmental factors will be presented.

Number concentration size distributions of 0.8–40 nm air ions have been measured continuously at the University of Helsinki research station in Hyytiälä, Finland since 2003 together with extensive meteorological, aerosol and trace gas concentration measurements. Ion instruments include the Balanced Scanning Mobility Analyzer (BSMA; Tammet, 2006) and the Neutral cluster and Air Ion Spectrometer (NAIS; Mirme and Mirme, 2013). Until the last years, ion spectrometers have been the only source of information on sub-3 nm (and especially sub-2 nm) clusters and particles, the sizes where atmospheric nucleation occurs (Kulmala et al., 2013). Two distinct size regimes in the ion spectra are the cluster ions below 2 nm and intermediate ions between 2–7 nm in diameter. The cluster ions are always present in the ambient air as a result of primary ionization by galactic cosmic rays, gamma radiation and decay of radon emitted from the soil. The cluster ion concentrations in Hyytiälä vary between 600–800 cm^{-3} per polarity on NPF event days, and 450–650 cm^{-3} per polarity on days with no particle formation. Seasonally cluster ion concentrations are lowest in winter and highest in summer, but no clear inter-annual trends have been observed in Hyytiälä.

Typically in Hyytiälä ion-induced contribution to NPF is 10% or less, proceeding mainly via the negative ions. This is indicated by higher concentrations of negative than positive intermediate ions during NPF and points to the crucial role of sulphuric acid, which is a strong acid and can take up the negative charge. Sulphuric acid containing clusters have also been identified in the high-resolution ion spectra during particle formation in Hyytiälä (Ehn et al., 2010). Intermediate ion concentrations have a slightly increasing trend during the observation period, coinciding with an increase in cosmic-ray induced ionization starting from 2003 (Kulmala et al., 2010).

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