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Atmospheric ions, boreal forests and impacts on climate

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Aerosol particles play an important role in the Earth's atmosphere and in the climate system: They scatter and absorb solar radiation, facilitate chemical processes, and serve as seeds for cloud formation. The aerosol particles have direct cooling and warming effects on climate (IPCC, 2007). Secondary new particle formation (NPF) is a globally important source of aerosol particles (Kulmala and Kerminen, 2008). Currently, the mechanisms of particle formation and the vapors participating in this process are, however, not truly understood. Several formation and growth mechanisms have been proposed for the very first steps of the process: homogeneous, heterogeneous, ion-induced and kinetic nucleation and activation type cluster growth.

Small ions are part of the atmospheric aerosol spectrum, and in atmospheric sciences study of ion-aerosol interactions is essential. Small ions are small molecular clusters carrying a net electric charge. They are produced by ionisation of molecules in the air. Typically the small ion concentrations vary in the range of 100-2000 cm-3 in both polarities (Hirsikko et al., 2011). Ion-induced NPF is limited by the ion production rate, which typically is around 10 ion pairs cm-3s-1 in the boundary layer over the ground. The ion production rate has strong spatial and temporal dependence. The ionisation mechanisms change with altitude: radon and gamma radiation from the ground and galactic cosmic rays dominate close to the Earth's surface, while higher in the free troposphere cosmic rays become the main driving factor.

In order to fully explain atmospheric NPF and subsequent growth, we need to measure directly the very initial steps of the formation processes. Air ion spectrometers measure the mobility distributions of charged aerosol particles in the mobility diameter range of 0.8–42 nm (Mirme et al., 2007; Tammet et al., 2011). Neutral cluster and air ion spectrometers measure additionally the mobility distribution of neutral particles larger than 2 nm in diameter by charging the aerosol sample with unipolar corona chargers (Manninen et al., 2009). According to earlier studies, the atmospheric nucleation and cluster activation take place at the mobility diameter range of 1.5–2 nm. Therefore, the ion spectrometers allow direct measurements at exactly the size where atmospheric nucleation takes place. The results indicate that the ion-induced nucleation contributes $\sim$1-30% to the NPF events in most atmospheric conditions (Manninen et al., 2010). In other words, neutral particle formation seems to dominate over ion-mediated mechanisms, at least in the boreal forest conditions.

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