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Variation and balance of positive air ion concentrations in a boreal forest

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Abstract. Air ions are characterized on the basis of measurements carried out in a boreal forest at the Hyytiälä SMEAR station, Finland, during the BIOFOR III campaign in spring 1999. The air ions were discriminated as small ions (charged molecular aggregates of the diameter of less than 2.5 nm), intermediate ions (charged aerosol particles of the diameter of 2.5–8 nm), and large ions (charged aerosol particles of the diameter of 8–20 nm). Statistical characteristics of the ion concentrations and the parameters of ion balance in the atmosphere are presented separately for the nucleation event days and non-event days. In the steady state, the ionization rate is balanced with the loss of small ions, which is expressed as the product of the small ion concentration and the ion sink rate. The widely known sinks of small ions are the recombination with small ions of opposite polarity and attachment to aerosol particles. The dependence of small ion concentration on the concentration of aerosol particles was investigated applying a model of the bipolar diffusion charging of particles by small ions. When the periods of relative humidity above 95% and wind speed less than 0.6 m s^{-1} were excluded, then the small ion concentration and the theoretically calculated small ion sink rate were closely negatively correlated (correlation coefficient −87%). However, an extra ion loss term of the same magnitude as the ion loss onto aerosol particles is needed for a quantitative explanation of the observations. This term is presumably due to the small ion deposition on coniferous forest. The hygroscopic growth correction of the measured aerosol particle size distributions was also found to be necessary for the proper estimation of the ion sink rate. In the case of nucleation burst events, the concentration of small positive ions followed the general balance equation, no extra ion loss in addition to the deposition on coniferous forest was detected, and the hypothesis of the conversion of ions into particles in the process of ion-induced nucleation was not proved. The estimated average ionization rate of the air at the Hyytiälä station in early spring, when the ground was partly covered with snow, was about 6 ion pairs cm^{-3} s^{-1}. The study of the charging state of nanometer aerosol particles (diameter 2.5–8 nm) in the atmosphere revealed a strong correlation (correlation coefficient 88%) between the concentrations of particles neutralized in the aerosol spectrometer and naturally positively charged particles (air ions) during nucleation bursts.

The charged fraction of particles varied from 3% to 6% in accordance with the hypothesis that the particles are quasi-steady state charged.

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