How does ionising radiation contribute to air ion formation in the lower atmosphere?

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Ionising radiation provides the energy for the ionisation of air molecules in the lower atmosphere to produce electric charges. The potential production rate of electric charges by ionising radiation is termed as the ionising capacity. The initially formed electric charges are known as primary ions, which may either end up in the recombination and other sink processes or undergo clustering, coagulation and condensational growth, and eventually become detectable air ions. The connection of air ion formation to ionising radiation is self-evident. However, although there exist a few attempts (Laakso et al., 2004; Hirsikko et al., 2007), the underlying processes influencing the relationship between air ion formation and ionising radiation in the lower atmosphere remain unrevealed. The aim of this study is to analyse the relation of observed air ions to ionising radiation, based on ambient measurements deployed at Hyytiälä SMEAR II station (Hari and Kulmala, 2005) in a boreal forest in southern Finland, to assist a better understanding on air ion formation and atmospheric clustering processes.

A radon monitor and a total gamma detector are used to measure ionising radiation at the SMEAR II station. The total ionising energy was first calculated from the measured quantities of ionising radiation. With the assumption that 34 eV is needed for the production of an ion pair, the total ionising energy was converted into the ionising capacity in per cubic centimetre per second, which was then analysed in comparison with air ion concentrations measured by a Balanced Scanning Mobility Analyser (BSMA (Tammet, 2006)). To assist the investigation, recorded meteorological data from the mast measurement, particle data, snow depth data and soil data collected at the site were also employed in this work. Besides, mixing layer height (MLH) estimates retrieved from the European Centre for Medium-Range Weather Forecasts (ECMWF), and trajectory data calculated from the FLEXible TRAjectories (FLEXTRA) model were analysed in this work together with the measured data.

The seasonality in the ionising capacity came from both the radon and gamma components, whereas the diurnal feature resulted primarily from the dynamical response of radon to the mixing layer evolution (Chen et al., 2016). The radon ionising capacity accounted for 10-20% of the total ionising capacity. The 0.8-1 nm ion concentration showed in general a clear linkage to the ionising capacity (only summer shown in Figure 1). A similar relationship between the cluster (0.8-1.7 nm) ion concentration and the ionising capacity was also identified by setting constraints on key parameters relevant for air ion formation. In order to obtain insights into atmospheric aerosol formation processes, the link between the ionising radiation and air ion formation in the lower atmosphere needs to be understood. This knowledge would further be beneficial in finding solutions to air-quality- and climate-related problems. Further investigation to understand the transformation process from primary ions to cluster and larger ions is under progress.

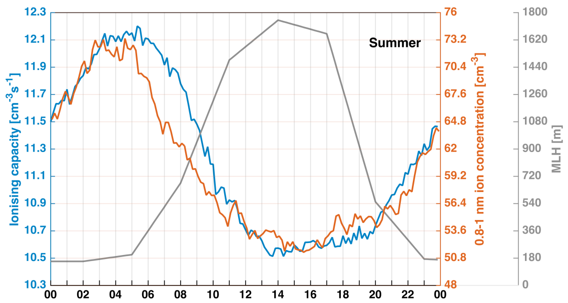

Figure 1. Median diurnal patterns in 0.8-1 nm negative ion concentrations, ionising capacities, and modelled mixing layer heights (MLH) in summer for 2003-2006.

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