

Interactive comment on “Atmospheric ions and nucleation: a review of observations” by A. Hirsikko et al.

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We appreciate the comments by Dr. Adarsh Kamra, which certainly improved the manuscript considerably.

Regarding the following general comment:

Referee: “The discussion in this article is mainly centered around the properties of ions in the lower troposphere. Ions in the upper atmosphere are not covered. This, however, seems to be intentional and, I agree, is justifiably not within the scope of this article. However, it will be appropriate that such an intention is clearly mentioned in the beginning or at an appropriate place in the article”.

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Author Response: We took into account this comment, and added corresponding clarification in the manuscript when added the following corrections:

Specific comments:

1. Referee: “Production of small ions by point discharge from elevated sharp points on the ground is an important source of ions close to the ground surface. The generation and evolution of these ions need be discussed in the article”.

Author Response: The referee has a relevant point as the small ions are produced by point discharge in situations of enhanced atmospheric electric field e.g. during thunderstorms. However, the study of atmospheric point discharges is a specific research area. We feel that our paper is a review and we do not know publications, where the point discharge ions are discussed as connected with the aerosol nucleation problem. However, we modified a sentence in the introduction as follows: “Other known sources for small ions are traffic, corona dischargers (e.g. power lines, and point dischargers in the case of enhanced atmospheric electric field, like thunder storms) and splashing water (e.g. Eisele 1989a,b; Haverkamp et al., 2004; Tammet et al., 2009).” We also added remarks about ion sources and sinks due to comment 2.

2. Referee: “Authors should include a separate section on the discussion of the gaps in our present knowledge in this field. This will provide the motivation for future work and enhance the utility of this article”.

Author Response: We changed the last paragraph in the concluding remarks as follows: “This review concentrated on observations in the lower troposphere due to very limited number of observations in the upper troposphere. In future, we need to further improve our understanding of the evolution of small ions in the atmosphere to be able to evaluate the role of ions in particle formation. Therefore, developments are needed in the theoretical understanding of small ion balance in the atmosphere, as well as in the instrumentation used for detecting the size and mass spectra of especially neutral nanometer-sized particles and clusters (e.g. Iida et al., 2009; Lehtipalo

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et al., 2010b). The improvement of theoretical approaches requires comprehensive information of small ions in different environments, including their: 1) chemical composition (e.g. Eisele 1989a,b; Junninen et al., 2010; Ehn et al., 2010a,b), 2) vertical concentration profiles (e.g. Mirme et al., 2010; Laakso et al., 2007c), and 3) source and sink rates. This kind of information can be obtained for example via: 1) parallel measurements of ion size distribution, radon activity concentration and gamma radiation, 2) measurements in vicinity of local sources, e.g. corona dischargers and roads (e.g. Eisele, 1989a,b; Jayaratne et al., 2010), 3) parallel measurements of ions and neutral nano-particles, 4) laboratory studies (e.g. CLOUD experiment in CERN, Duplissy et al., 2010), and 5) airborne measurements from hot-air balloon and aeroplane." The authors of the present paper would be very thankful for the referee to list some of these gaps, what are the most relevant in his point of view.

3. From manuscript: "When using Eqs. (3) and (4) we assume equal concentrations of small positive and negative ions and symmetrical charging of aerosol particles." Referee: "Give the quantitative estimates of the errors caused due to these assumptions under different environmental conditions."

Author Response: We agree that these calculations are certainly needed in future to study the small ion balance in different environments. For example, the work by Tammet et al. (2006) and Hörrak et al. (2008) revealed that the underestimation of the ion sink in the measurements inside the forest canopy, neglecting the extra sink caused by dry deposition of small ions onto the needles of coniferous trees, could cause also underestimation of the ionization rate of the air by 20-40% assuming steady state situation of Eq. 3. However, the present paper is a review of observations. Thus the authors feel that complicated theoretical treatments does not fit the scope of the article. Therefore, only the simplest theoretical model is briefly included into the manuscript, and is sufficient to derive limited conclusions, necessary in following discussions. We included an explaining remark into Section 2.2 of revised paper.

4. Referee: "P. 24254 –I.4-5 – First sentence may be deleted or at least corrected."

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Author Response: We took this into account and removed the first sentence.

5. Referee: "P. 24275 – I.23 –These opposite observations were reported in wind speeds of $<10 \text{ m sec}^{-1}$, this needs to be clarified here."

Author Response: Thank you for pointing this out. We made changes accordingly.

6. Referee: "Fig. 7 and 9 are not necessary and may be deleted."

Author Response: We think that it is better to include the data from Fig. 7 into the Fig. 8, and the data from Fig. 9 into the Fig. 10.

Technical comments:

1. Referee: "P. 24247 I.29 –Change nn to nm".

Author Response: We agree and made corrections.

2. Referee: "P. 24248 I.28 –Reference to Lida et al. (2006) is missing".

Author Response: The correct reference is "Lida et al. (2006)", and this is included in references.

3. Referee: "P.24253 1.6 – Change 'have observed' to 'have been observed'".

Author Response: We agree and made corrections.

4. Referee: "P. 24254 I.21 – Change 'electric' to 'dielectric'".

Author Response: We prefer to use term "electric constant", because the permittivity of air is $\epsilon \approx \epsilon_0$, and the term ϵ_0 is called "electric constant" in modern usage. ISO 31-5 prefers using of term "electric constant", but allows also using of the terms "permittivity of free space" and "dielectric constant of vacuum". International standards organizations CODATA and NIST use the term "electric constant" (see <http://physics.nist.gov/cuu/constants>, category "Universal"). The term "dielectric constant" for the constant ϵ_0 is considered absolute nowadays, and it typically refers exclusively to a static relative permittivity (ϵ/ϵ_0) in modern usage.

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5. Referee: "P. 24260 I.5 – 'result' not 'results'".

Author Response: We agree and made correction.

6. Referee: "P. 24261 I.4 – Include 'in' between available and publications".

Author Response: We agree and made correction.

7. Referee: "P. 24264 I. 20 – Change 'the atmosphere the heights up to 5nm' to 'the atmosphere upto the height of 5 nm'".

Author Response: We agree and made the following correction "the atmosphere up to the height of 5 km".

8. Referee: "P. 24267 I. 27- Correct the sentence".

Author Response: We have corrected the sentence "In Tumbarumba, Australia ion production rates via radon decay were high, with also maxima early in the morning (Suni et al., 2008, Table S2)" as follows: "In Tumbarumba, Australia, the ion production rate caused by radon decay was high, with maxima recorded in the early morning (Suni et al., 2008, Table S2)".

9. Referee: "P. 24268 I.28 – Change 'Dahnorkar' to 'Dhanorkar'".

Author Response: We agree and made correction.

10. Referee: ". . . I.21 &22 – Change 'done' to 'made'".

Author Response: We agree and made correction.

11. Referee: "P. 24275 I.1 – Change 'similarly' to 'similar'".

Author Response: We agree and made correction, and also changed the end of the sentence as follows: "the concentrations of positive and negative small ions began rapidly to increase from the background of about 300 cm⁻³ and reached maximum 800 cm⁻³ on May 1, 1986, afterwards slowly decaying during a month back to a value of about 400 cm⁻³".

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12. Referee: "P. 24278 I.25 – Delete 'a with'".

Author Response: We agree and made correction.

14. Referee: "P. 24290 I.20 – Change 'Chalmer' to 'Chalmers'".

Author Response: We agree and made correction.

15. Referee: "P. 24295 I.15 – Change 'spactru' to 'spectra'".

Author Response: The correct reference is: Dhanorkar, S. and Kamra, A.K. (1993a) Diurnal variations of the mobility spectrum of ions and size distribution of fine aerosols in the atmosphere. J. Geophys. Res. 98, 2639-2650. www.agu.org/journals/ABS/1993/92JD02545.shtml

15. Referee: "P. 24308 I.5 – Year of publication missing".

Regarding the publication by Richmann, it was published in 1751.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 24245, 2010.

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