

## ***Interactive comment on “Ion production rate in a boreal forest based on ion, particle and radiation measurements” by L. Laakso et al.***

**L. Laakso et al.**

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Interactive comment on “Ion production rate in a boreal forest based on ion, particle and radiation measurements” by L. Laakso et al. Anonymous Referee #2 Received and published: 6 August 2004

General comments In this paper, the authors present interesting results of air ion production measurements made in a boreal forest. The authors examine the differences resulting from two independent methods, one with direct measurements of radon/external radiation and the other with charge balance calculations using ion cluster/particle measurements. Measuring atmospheric ion production rates is essential to better understand how ions contribute to particle nucleation processes. The subject is appropriate to ACP. But the language needs to be more precise and concise. I recommend the publication in ACP after revision.

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Comment: The language is now checked and revised.

Specific comments It seems that the two methods used in this study to estimate ion production rates provide similar results at night, but show larger discrepancies during daytime. The authors speculate several potential factors, such as fog, unmeasured TSC or aerosol smaller than 3 nm, hygroscopic growth, ion-ion recombination, uptake by forest canopy, and nucleation processes, to explain the differences. Fog should present both during day and night if relative humidities are high enough, and relative humidities are usually higher at night than daytime. So it may be difficult to explain with fog.

Comment: In accordance with referee's suggestion we have removed this sentence from the text.

For the TSC that may be higher during daytime than nighttime, it would be interesting to see the time variation of TSC values. Although the authors conclude that the measurement heights have little effects on different ion production rates, height seems an important parameter to determine ion productions, especially when close to the ground.

Comment: Of course the measuring height of is an important parameter which determines the ion production rate, especially when measuring close to the ground. Text changed so that this comment is taken into account.

For nucleation processes, given the high temperatures of about 260-280 K and the low ion production rates of 2.6-4.5 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  provided in this paper, it is very unlikely that ion-induced nucleation plays a substantial role compared to other nucleation processes.

Comment: This is in principle true. However, we found in our measurements that particles are sometimes overcharged during the nucleation bursts which indicates the effect of ion-induced nucleation in the particle formation. At the present moment, we

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are pin-pointing this effect quantitatively.

Forest is a source of ammonia, and in this circumstance, ternary homogeneous nucleation involving ammonia or organics will probably be more important than ion-induced nucleation. If this is correct, aerosol particles will only act as a sink of air ions.

Comment: We made an order of magnitude analysis on the sink caused by neutral clusters or TSC's during the nucleation bursts and found it to be approximately 1 ion pairs/cc/s. This is also given in "results"-section.

Technical corrections 1. The terms of "first/second methods" should be consistent in Abstract, in para 3, page 3951, and in Conclusion.

Comment: done

2. From para 3, Page 3949 to para, 1 3951. Description of the previous measurements of ionization rates can be brief, for example, by summarizing them in a table including different authors, locations, heights, and ionization rates (mean, maximum, and S1475 minimum values). And highlight the significant features in the text.

Comment: The locations and measurement methods are so different that we suppose it is better to explain the measurements more in detail since comparisons from the table would be misleading. However, this part of the article is improved.

3. Page 3951, line 1-3. "Measurements in marine environment D, 1994)." should be moved to the end of first paragraph of page 3950.

Comment: done

4. Section 2.4 and 2.5 should better be reversed.

Comment: Done

5. Many sentences in Abstract and Conclusion are identical or repetitive.

Comment: Improved

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6. Redraw Fig. 1. as a straightforward schematic diagram.

Comment: Done

7. The authors should choose either the present or past tense throughout the manuscript. Unit of ionization rate should be in either “ion pairs  $\text{cm}^{-3}\text{s}^{-1}$ ” or “ $\text{cm}^{-3}\text{s}^{-1}$ ”.

Comment: Done

Other minor corrects follow.

Page 3949 Line 1, change “active” to “effective”.

Comment: Done

Line 3-4, change to “For ion-induced nucleation, ion production rate is one of the factors that govern nucleation rates”.

Comment: Done

Line 4, change “condensation” to “coagulation”.

Comment: Condensation is here the correct process.

Line 13, change to “ $\check{D}$ , can be found in Israel (1970, 1973) and in Chalmers (1967).”

Comment: Done

Line 13, change to “The average ionization rate of 10 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  is considered as a standard at the height of 1 m from the ground in continental areas.”

Comment: Done

Line 16-19, change to “ $\check{D}$ , the ionization rate is about 4.6 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$ , 4 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  in air (radon and radiative aerosol), 1.5-1.8 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  by cosmic radiation (Israel  $\check{D}$ , ”.

Comment: Done

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Line 22, remove “ (many times) ”.

Comment: Done

Line 24, change to “  $\check{D}$ , 1-2 km, and increases with altitude with the maximum of about 50 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  near 15 km (Hoppel  $\check{D}$ , ”.

Comment: Done

Page 3950 Line 2, change to “ionization source”.

Comment: Done

Line 7, change to “Reports of recent measurements of ion production rate can be found elsewhere (Dharnorkar  $\check{D}$ , ”.

Comment: Done

Line 12-14, change to “The two-day measurements showed the diurnal variation of the ionization rate with the minimum of 2.75 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  at noon and the maximum of 117 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  in the early morning. ”

Comment: Done

Line 25-26, change to “  $\check{D}$ , at 1 m has the minimum of 6 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  at noon and the maximum of 13 ion pairs  $\text{cm}^{-3}\text{s}^{-1}$  during nighttime. ”

Comment: Done

Page 3951 Line 2, change to “  $\check{D}$ , within different latitudes  $\check{D}$ , ”.

Comment: Done

Page 3952 Line 1, change to “The BSMS manufactured by  $\check{D}$ , ”.

Comment: Done

Line 20, change to “  $\check{D}$ , and the other between 10 to 500 nm.”

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Comment: Done

Line 24, define “CPC”.

Comment: Done

Page 3953 Line 14, change to “ $\check{D}$ , (APS) (model TSI 3320)  $\check{D}$ , ”

Comment: Done

Line 19, change “best consistency” to “a good agreement”.

Comment: Done

Last line, change to “Measurements of airborne radon-222 have been made since March 2000.”

Comment: Done

Page 3954 Last line, change to “ $\check{D}$ , is increased), GF, due to the absorption  $\check{D}$ , ”.

Comment: Done

Page 3956 Line 3, define “BIOFOR”.

Comment: Done

Line 10, change to “ $\check{D}$ , (HTDMA) (e.g., Hämeri et al.  $\check{D}$ , ”.

Comment: Done

Line 11, change to “ $\check{D}$ , for monodisperse aerosol samples  $\check{D}$ , ”.

Comment: Done

Line 26, change to “Based on Eq. (3), measured dry size spectra are converted to wet size spectra at ambient relative humidities. ”

Comment: Done

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Page 3957 Line 17-19, change to “In the case of direct measurements, the external radiation was mostly responsible for ion production; the contribution from radon was about 10 %, with the maximum of about 36 % recorded on 26 March, 1999, in Hyhtiälä.”

Comment: Done

Page 3958 Line 6, change to “The both measurements showed a similar feature, with the highest ion production rates in the middle of the measurement period. ”

Comment: Done

Page 3959 Line 18, change to “ $\checkmark$ , only when  $RH > 98\%$ ”

Comment: Done

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Interactive comment on Atmos. Chem. Phys. Discuss., 4, 3947, 2004.

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