

## ***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**

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### **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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## 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. 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.

For nucleation processes, given the high temperatures of about 260-280 K and the low ion production rates of  $2.6\text{-}4.5$  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. 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.

## Technical corrections

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

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minimum values). And highlight the significant features in the text.

3. Page 3951, line 1-3. “Measurements in marine environment ”, 1994).” should be moved to the end of first paragraph of page 3950.
4. Section 2.4 and 2.5 should better be reversed.
5. Many sentences in Abstract and Conclusion are identical or repetitive.
6. Redraw Fig. 1. as a straightforward schematic diagram.
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 “ $\text{cm}^{-3}\text{s}^{-1}$ ”. Other minor corrects follow.

#### Page 3949

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

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

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

Line 13, change to “ ”, can be found in Israel (1970, 1973) and in Chalmers (1967). ”

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.”

Line 16-19, change to “ ”, 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 ”, ”.

Line 22, remove “ (many times) ”.

Line 24, change to “ ”, 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 ”, ”.

#### Page 3950

Line 2, change to “ionization source”.

Line 7, change to “Reports of recent measurements of ion production rate can be found elsewhere (Dharnorkar ”, ”.

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

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

Page 3951

Line 2, change to “,,, within different latitudes ,,, ”.

Page 3952

Line 1, change to “The BSMS manufactured by ,,, ”.

Line 20, change to “,,, and the other between 10 to 500 nm.”

Line 24, define “CPC”.

Page 3953

Line 14, change to “,,, (APS) (model TSI 3320) ,,, ”

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

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

Page 3954

Last line, change to “,,, is increased),  $GF$ , due to the absorption ,,, ”.

Page 3956

Line 3, define “BIOFOR”.

Line 10, change to “,,, (HTDMA) (e.g., Hämeri et al. ,,, ”.

Line 11, change to “,,, for monodisperse aerosol samples ,,, ”.

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

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.”

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. ”

Page 3959

Line 18, change to “ „, only when RH >98 %”

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

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