Response to CC1: 'Atmospheric ion measurements: air conductivity versus ion counting', Karen Aplin, 27 Nov 2024

The paper esign and performance of the cluster ion counter (CIC) by Mirme et al describes the latest instrument in over fifty years of development of Estonian atmospheric ion spectrometers, begun by the late Prof Hannes Tammet. It seems another excellent instrument, which is well-characterised both theoretically and experimentally. This paper is a carefully and clearly written description that I hope could be further improved with some additions to the introductory material.

The Ebert ion counter and the Gerdien condenser are aspirated condensers, developed at around the same time at the start of the twentieth century (Flagan 1998). In the CIC paper's introduction, the different types of aspirated coaxial cylindrical condenser are listed all together, implying they are essentially identical. There are however some meaningful differences between them. An ion counter, such as that designed by Ebert, operates at a sufficiently high voltage for the electric field in the condenser to collect all the ions passing through the device. In contrast, a Gerdien-type instrument operates in a lower electric field regime, such that only a portion of the ions are collected, which measures atmospheric conductivity rather than counting ions directly (Chalmers 1967). The ion concentration can be estimated from the atmospheric conductivity if a suitable ion mobility can be assumed or separately determined. Understanding the distinctions between these types of instrument is important in interpreting their data.

We thank Professor Alpin for this valuable clarification. In the revised manuscript, we have removed the text that previously grouped all aspirated coaxial cylindrical condensers together, as it could misleadingly imply that these instruments are essentially identical.

The paper states that "one limitation of many devices" is their inability to measure bipolar ions, which the CIC avoids by simply having two sampling tubes biased at opposite polarities. The Gerdien condenser can also be operated, as the name suggests, as a capacitor, with a rate of voltage decay that is inversely proportional to the air conductivity. This "voltage decay mode" (Aplin and Harrison 2000) was commonly used in the first half of the twentieth century, and in many radiosonde ascents (Nicoll 2012), because measuring a voltage was simpler than measuring a small current. The voltage decay approach is less frequently used in modern devices but has been exploited in combination with the current measurement approach for self-calibration (Aplin and Harrison 2001). As the operating principle extends to other geometries, this type of instrument is also used in planetary atmospheric electricity, in which context it is known as a "relaxation probe" (Aplin 2013). In the voltage decay mode, a bias voltage is temporarily applied to charge the condenser. It is then released and the capacitor allowed to decay, with a time constant related to the air conductivity. Both positive and negative ions are involved in this process. The form of the decay also provides information on the ion mobility spectrum (Aplin 2005).

We thank Professor Aplin for highlighting the important historical and modern applications of the voltage decay mode in Gerdien condensers and related instruments. We acknowledge that this mode allows for the detection of both positive and negative ions, and we have updated the manuscript to reflect this point more accurately. However, as originally stated, our emphasis was on the limitation that many conventional instruments cannot simultaneously measure positive and negative ions. While the voltage decay mode allows bipolar ion detection over time, it does not provide simultaneous measurements of both polarities. We have revised the relevant section of the text to clarify this distinction.

Finally, it is worth noting that the total ionisation rate near the surface, combining both cosmic rays and natural radioactivity is 10 cm-3s-1, so C.T.R. Wilson was indeed within a factor of two of the modern average.

We corrected the text in the manuscript to reflect that 10 $cm^{-3}s^{-1}$ is the total ionisation rate near the surface, combining both cosmic rays and natural radioactivity.

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