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Atmospheric Measurement Techniques Discussions

Interactive comment on "Use of O_2 airglow for calibrating direct atomic oxygen measurements from sounding rockets" *by* J. Hedin et al.

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Dear Editor and Referees,

We thank the reviewers for their efforts in the thorough investigation of our paper and for the very helpful and constructive comments and suggestions. All suggestions and comments have been considered carefully. Responses to the reviewers are included below and appropriate changes to the paper have been made.

Best regards, Jonas Hedin

Response to Anonymous Referee #1

All minor comments and suggestions on style and language have been implemented

in the manuscript. The more major comments are addressed below.

* The second paragraph in the introduction about the dominant measurement techniques and the variability in the measurements has been rewritten. And yes, we agree that the Offermann et al 1981 reference is unsuitable to support the view that the variability is of instrumental nature. This has been changed. We now discuss the instrumental variability mainly in terms of resonance fluorescence as the technique most commonly used for O measurements.

* The description of the Rayleigh unit has been removed from the text. However, since the Editor asked for an explanation of the unit, it is now included in the figure caption of figure 6.

* The sentence about atomic species being particularly suitable for optical measurement techniques has been removed.

* A sentence about the cryo-cooled mass spectrometer not being affected by aerodynamics has been added in the aerodynamics section. Indeed, we regard this particular mass spectrometer technique as the most accurate in situ method for O measurements. Unfortunately, it is very expensive and no longer in use.

* Figure 7 and 9 have been changed only showing the curve where quenching is ignored, since omission of quenching has little effect. This is also explained in the text.

* The structure in the red and black profiles in figure 9 (now only the black profile is shown) below $\sim$100 km are mainly due to that the Atmospheric band emission profile measured during NLTE-1 was more structured than that measured during NLTE-2. Also, as stated in the section about the oxygen retrieval, at higher altitudes (above $\sim$100-105 km) the possible errors in the measured Atmospheric band emission rates are large due to the low signal-to-noise ratio and the retrieval procedure becomes less reliable. Another thing that influences the oxygen retrieval for NLTE-1, but to a lesser extent, is that the measured temperature profile used in the oxygen retrieval has much

more structure than the MSIS temperature profile used for NLTE-2.

* Additional discussion has been added on the large spread of the O profiles obtained by the resonance fluorescence as compared to the small spread in the O profiles retrieved from the airglow measurements. We discuss this in terms of the instrumental variability of the fluorescence measurements.

* The Mlynczak et al., 2001 paper is now used as a reference to support the view about using the Infrared Atmospheric band during daytime measurements.

* A section has been added about the attempts to use ground-based airglow measurements to retrieve atomic oxygen density profiles.

Response to Anonymous Referee #2

The major purpose of the paper was neither a review of direct oxygen measurements nor a summary of the NLTE rocket campaign, but to present the new technique to use airglow measurements to calibrate the direct measurements. Over 50 resonance fluorescence measurements have been made in the past and in this paper we only look at the very few that also included a simultaneous measurement of an O related airglow emission. A more general review paper about direct atomic oxygen measurements is in preparation. All comments are addressed below starting with the major comments first.

Major comments:

Points 1 and 2.: While the airglow measurement provides a reliable absolute peak density, the resonance fluorescence measurement provides the very high sensitivity needed to study the detailed structure of the atomic oxygen profile over the entire measured altitude range including the very low values below 80-85 km and at the apogee above 130 km. The sampling rates of the resonance fluorescence measurement (150 Hz) and airglow measurements (100 Hz) are similar. This results in a data point every 6 m for the resonance fluorescence and 9 m for the airglow measurements at the O

peak. However, to get satisfactory results from the differentiation and oxygen retrieval, the airglow column emission profile has to be smoothed, or interval averaged, to a vertical resolution of about 1 km in the case of the Atmospheric band and 2 km in the case of the Chamberlain band. Figures 4 and 6 have been changed and now include some error estimates. This is also included in the text. The two NLTE payloads are essentially identical so the difference between them demonstrates the problems with the resonance fluorescence technique described in the paper. Especially the lamp output (line shapes) is a major uncertainty. Differences can also be expected in the aerodynamic behaviour as the two flights experienced different angle of attack.

Point 3.: As stated in the paper the airglow inversions presented are based on nightglow rate coefficients from the ETON database. There are to our knowledge no better rocket-borne O measurements that were carried out together with comprehensive airglow photometry. If the relevant rate coefficients are changed as a result of future investigations, using a more accurate direct technique of some kind together with simultaneous photometric airglow measurements, a re-calibration of O profiles will be straight-forward for retrievals that are based on airglow photometry. It would indeed be desirable to have simultaneous cryo-cooled mass spectrometer measurements of atomic oxygen and airglow measurements, but to our knowledge this technique is no longer in use.

Minor comments:

Point 1: The Shepherd et al., 2005 reference is now replaced by Liu et al., 2008.

Point 2: This section has been rewritten.

Point 3: The sentence has been rephrased. Since the rocket was launched in the late evening at 69°N, in the auroral region, the O(1S) emission of 120-250 R indicates that there was low and no auroral activity during the first and second launch of the NLTE payloads, respectively.

Point 4 & 5: We would like to keep these two more general sections where they are. While section 1 is a general introduction to the scientific questions, section 2 provides a broad introduction about the measurement techniques. Also a clarification is made in the text that the description of the rocket photometer is a general description of a rocket photometer.

Point 6: The neutral density and temperature was measured by the CONE instrument. This is now mentioned and a reference to the Lübken et al., 1999 paper describing this measurement is given.

Interactive comment on Atmos. Meas. Tech. Discuss., 2, 1419, 2009.