Observations of sunlit N2+ aurora at high altitudes during the RENU2 flight
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MS No.: angeo-2020-50

The paper is a study of near coincident data from meridian scanning photometers (MSP) and instruments on board the RENU2 rocket. The time of flight around 07:30 UT over the Svalbard region meant that the rocket passed through the daytime auroral region when the higher regions of the atmosphere were still sunlit. The role of the sunlit ionosphere under auroral conditions is indeed an important topic, and the effect of the resonance scattered emissions must be accounted for, especially when N2+ measurements are used for estimating fluxes and energies of the precipitation. However, the paper as presented does not add significant results to the subject, and some of the methods used and conclusions reached require more rigorous examination.

The MSP scans intercepted several poleward moving arcs during the time around and during the rocket flight. The instruments on RENU2 include a photometer measuring the N2+ emission at 391.4 nm and an electron plasma sensor (EPLAS). The paper uses results from the rocket data, which include modelling of the emissions, and also the ground measured emissions from three MSP channels. The latter include the N2+ emission at 427.8 nm. Both 391.4 nm and 427.8 nm emissions are from the First Negative bands of N2+ and are the result of excitation which occurs simultaneously with ionization on particle impact. However, the First Negative bands of N2+ are also excited by solar photons. This is a two-stage process in which the N2+ ions are produced by electron impact and by photoionization. Ground state nitrogen ions then act as very efficient resonant and fluorescent scatterers of sunlight, producing radiation at 391.4 nm and 427.8 nm. The paper is an exploration of this now established physics of the auroral sunlit atmosphere. There are several strands to the work, which do not add together very coherently as presently written.

It is stated (line 30) that one focus is to study the link between sunlit aurora and upwelling. Apart from establishing that sunlit aurora was present and hence an extra source of N2 was needed at high altitudes, the assumptions made in the correlation analysis of MSP data are dependent on many uncertainties, which are not quantified. Another stated focus is to study how different processes contribute to N2+ emissions. In this regard, the final sentence of the abstract is misleading unless I have misunderstood. Does it refer to the figure of 40% derived in Section 4.1.3? This rough estimate of the ionisation rates from both photoionization and electron impact confirms the known fact that their ionization efficiencies are very similar and therefore very hard to distinguish. It is not clear what this calculation adds to the study. However, the statement in the abstract claims that sunlit aurora was a major part (40%) of the observed 427.8 nm emission. Indeed such estimates have been made before by several researchers from Svalbard observations. But the separation of the ionization sources is not the same thing.

Figure 4 shows the data from the EPLAS; these raise some questions when comparing them with the ground photometers and the all-sky camera images that are included as supplementary data. The characteristic energies are very small (~100 eV), but with quite large fluxes of electrons during short bursts. Such electron data are not directly comparable with what is observed from the ground along the magnetic meridian. So how does the rocket trajectory coincide with the all-sky images? Although the all-sky camera data are very integrated in time, could an image or two be used to clarify where the rocket's footprint is, and what it may be measuring in relation to the optical aurora during the times of interest?

The aurora seen at 07:40 is bright and structured, to the south of KHO, and moves rapidly northward, seeming to be overhead at KHO at 07:42:22. Cloud is then an issue but it looks like a very narrow arc is overhead at KHO at 07:44:50. Then another bright arc forms south of KHO. The rest of the interval seems cloudy and with much less structure in the aurora, although it may be obscured. The MSP 5577 has 4 kR brightness in the arc to the south of zenith and from the auroral images of this active rayed arc it is clear that the energies must be far greater than the peaks of 200 eV measured on the rocket. No mention of this discrepancy is made. An obvious question that arises is how closely does the aurora seen from KHO relate to the EPLAS measurements?

The next part of the study (4.1.5) is a comparison between the rocket measured 391.4 nm emission, and a modelled estimate, in order to demonstrate that the emission measured by the rocket is from the resonance scattered component of the emission. It is essential to describe in detail the procedure and assumptions required to produce figure 6, rather than rely on the Hecht et al 2019 paper. Many questions arise about the photometer field of view, the model spectra used and what exactly is included in the output model curve. How are photoelectrons included as an input source in the model? Is the model result shown purely 391.4 nm emission? The caption states it is dayglow plus emission due to auroral precipitation, but the axis label is 391.4 nm brightness. At these heights and at such low energies there will be minimal contribution from other emissions, but some discussion of these important factors is needed.

It is stated (line 194) that the resonance scattered contribution to the emission vastly exceeds that from direct excitation. Although this statement is not surprising, where is the evidence? Is it the result of modelling? The scattered contribution is dependent on shadow height, height of observation and energy of precipitation. How all of these factors affect the statement is important to know. At line 198 is it stated 'there are clear increases that correspond to model predictions ...' ; however, these correspondences are not clear, so more direct evidence is needed of these instances.

It is claimed (line 200) that the most noticeable aspect of the data is the increase in emissions after 500 seconds, which is **not** reflected in the model. If there is indeed a clear difference between the data and model during this time it needs to be presented more clearly so that the obvious nature of the feature is evident. At this time there is a large increase in the flux of low energy electrons, so an increase in brightness of emissions which result from low energies might be expected at these heights. If there is indeed no increase in 630.0 nm emission at this time, how is this explained? A breakdown of the model results is of importance for any conclusions that are drawn. On reading Hecht et al 2019, there appears to be some increase in both 630.0 nm and 557.7 nm emission from the model at this time, so the authors need to provide more details in the present paper. However, given the height and position of the rocket, the most likely emission would indeed be the resonant scattered 391.4 nm.

The correlation analysis of MSP data is discussed in terms of issues with geometry, which are indeed significant. But it is not obvious exactly **how** all these very serious matters have been taken into account. Where is the crucial information about the analysis of the raw photometer data? How have the profiles of the scans been integrated? How has a background been subtracted? Looking at individual scans, is the scattered contribution visible as an increase in brightness above the shadow line at any time, especially when scanning through an arc? Interpreting such data, however, would be complicated by the occurrence of more than one arc in each scan. And if there are several auroral features within each scan how is the brightness measurement interpreted? The only angle where the true comparison can be made about the relative brightnesses at any time is in the zenith. Since this is not the case here, more justification for the method in the light of the inherent uncertainties is needed.

The main conclusion drawn from this analysis appears to be the seeming delay between different correlations, and the interpretation of this delay as an upflow of ions. The authors also claim that the correlation analysis shows that the height of the 427.8 nm emission is the same as the 630.0 nm emission. The data do not justify such conclusions without much more rigorous analysis and interpretation of the events at the times when the correlation 'switch' is observed. The uncertainties in the correlations need to be assessed quantitatively.

A tantalising reference is made in the final section to RENU2 measurements of 427.8 nm emission and a reference to a paper unavailable (Godbole et al, under review).

Minor points

64 Poleward

71 this emission isn't relevant

103 reference to the figure isn't needed here

104 are available

125 missing stop

147 clarify, what ionisation rates? Confusing since the aim is to find the ionisation rate

166 sentence not clear. Removing the first 'as' would help

Same paragraph - it is not clear what the point of the last two sentences is here.

172 Not included in what?

187 'somewhat' needs enlarging

191 - and produced by solar photons?

198 'could affect' - explain more