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Discussions

Interactive comment on "Auroral ionospheric E region parameters obtained from satellite-based far ultraviolet and ground-based ionosonde observations: Effects of proton precipitation" *by* Harold K. Knight

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Reviewer comment:

This article, however, is hard to follow its logic.

HK reply:

I am sorry that you have this impression of the paper. The paper is considerably shorter than my previous paper on FUV-ionosonde comparisons, Knight et al. (2018), so I was

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hoping that readers would find it less challenging.

I was also first author on a related paper, Knight et al. (2012), “An empirical determination of proton auroral far ultraviolet emission efficiencies using a new non-climatological proton flux extrapolation method”. In my opinion, Knight et al. (2012) was considerably more challenging for readers than the current paper.

I am willing to make limited changes to the current paper to clarify the specific issues you have raised.

Reviewer comment:

One of the conclusions is summarized at lines 224-227 (at the top of Section 4.1). Based on results shown in Figure 1a, these sentences state that "it is expected that FUV-derived auroral NmE (i.e., derived under the assumption of pure electron aurora) will be too high for pure proton aurora by a factor of ∼1.22". This is the case for kappa = 3.1, and for the other two cases kappa = 6.2 and 100, this conclusion cannot meet individual results because the estimated values are in a same level as the estimated for the pure electron case. The article should explain the reason to focus on the case of kappa = 3.1 alone in more detailed.

HK reply:

The factor of 1.22 is explained in section 3 at lines 148-151. The factor of 1.22 is obtained as the square root of 1.5, where 1.5 is obtained as the factor resulting from LBHL values being ∼50% higher for electron spectra than for proton spectra for the same precipitating energy flux. Note that 50% is equivalent to a factor of 1.5 and that this is where the factor of 1.5 comes from. I can add a statement to this paragraph to clarify this particular logical connection.

In lines 151-153, it mentions that the situation is more complicated for kappa=3.1 but that there will still be an algorithm bias of 1.22 for kappa=3.1. In other words, the factor of 1.22 applies to all kappa values. You concluded that the factor of 1.22 was specific to kappa=3.1, but it was actually explained in the lines 148-151 that the factor of 1.22 applies to the other proton spectral shapes as well.

When you write “This is the case for kappa = 3.1, and for the other two cases kappa = 6.2 and 100, this conclusion cannot meet individual results because the estimated values are in a same level as the estimated for the pure electron case”, this reflects a misperception on your part. You are basing this statement on Figure 1a, but actually the factor of 1.22 is explained at lines 148-153, as just described.

Reviewer comment:

Furthermore, it is unclear for me why NmE is the appropriate parameter to evaluate the proton/electron contributions. The article should mention this point clearly.

HK reply:

The main motivation for the paper is that a bias in FUV-derived NmE (meaning NmE predicted by auroral FUV remote sensing algorithms) is expected in the presence of proton precipitation. As explained at lines 213-218, if proton aurora is a factor of 2 more efficient in producing LBH than electron aurora (as predicted by previous papers), then it is expected that FUV-derived NmE will be too high by a factor of 1.73. This means that it is expected that auroral FUV remote sensing algorithms will report NmE values that are too high by a factor of ∼1.7 for proton aurora.

There are several different effects involved here, including emission efficiencies, model-predicted NmE values, and the way auroral FUV remote sensing algorithms work. I think that there is enough information in the paper to allow readers to understand the issues, but in order to help readers, I could add a parenthetical statement after line 218 to remind readers of why LBH biases imply NmE biases in auroral FUV remote sensing algorithms. It has to do with NmE being approximately proportional to the square root of Q.

Reviewer comment:

Line 148 tells that "... LBHL values are ∼50% higher than for electron spectra with the same precipitating energy flux and LBHS/LBHL values." According to Figure 1c, this is the case for LBHS/LBHL from about 0.5-0.8. For the LBHS/LBHL outside of this range, this is not the case or even LBHL intensity for the pure electron case can be higher than that for the proton cases. Discussion written at Lines 215-216 has been developed taking into account "50% higher" case alone, and there is no consideration on ambiguities of the ratio of the proton case to the electron. Since a part of conclusions in this study has been made by discussion at Lines 215-216, that no consideration is serious lack for making the conclusion.

HK reply:

First of all, one cannot tell directly from Figure 1c what the expected bias is based on the observed LBHS/LBHL ratio for any particular example. The purple curve in Figure 1c is for pure electron aurora, and blue, green and orange curves are for pure proton aurora. There are no LBHS/LBHL ratios outside of ∼0.4 to ∼0.9 (according to the model) for pure proton aurora. Suppose that for a particular example of observed LBHS and LBHL there is a mix of electron and proton aurora, with the portion of LBH due to electron precipitation having an LBHS/LBHL ratio of 0.2 and the portion due to proton precipitation having an LBHS/LBHL ratio of 0.6. Depending on the relative energy fluxes of electron and proton aurora, the observed LBHS/LBHL ratio (setting aside observation error) could be anywhere between 0.2 and 0.6. Suppose that the observed LBHS/LBHL ratio is 0.4, near where the orange curve crosses the purple curve. This does not mean that the precipitating proton and electron spectra have the same LBHL yields. The proton LBHL yield is likely to be around 270-300 R/(ergs/cmˆ2/s), while the electron LBHL yield will be around 140 R/(ergs/cmˆ2/s) (based on the assumed LBHS/LBHL ratios mentioned above for this particular example).

Having said that, there is still an underlying issue of the variation of LBHL yields with precipitating particle and spectra types and whether the predicted biases in auroral FUV remote sensing algorithms are realistic given the aforementioned variation. The main way I have addressed this in the paper is by giving results of a simulation in the appendix. The simulation is based on an entire year of TED and MEPED observations of precipitating electron and proton fluxes. The observations were filtered (in the simulation) in such a way as to give spectra that would be representative of the spectra occurring in the actual coincident FUV-ionosonde observations.

To further address the issue of variation of spectral types, I could add a statement such as the following to the main text: “Based on an examination of in situ particle flux data, we have seen that in cases where proton Q is comparable to or greater than electron Q, proton aurora typically has a ∼50% greater model-predicted yield than electron aurora. Details of such analysis are omitted, but the results of related analysis based on in situ electron and proton flux observations are given in the appendix.”

Thank you for your comments.

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