

## Response to Editor

Thank you for completing the public discussion. Both reviewers raised valid concerns. The editor shares the concern about dayglow removal at multiple stages of the processing chain, and some replies are confusing in that regard. The paper claims a new technique for aurora dayglow removal, but the reply claims that the problem was solved in a previous paper. Such replies are not adequate.

- **We appreciate the feedback and suggestions we have received from the reviewers and the editor. This feedback has caused us to realize that several of our statements were somewhat ambiguous, which understandably led to confusion.**

**We wish to be clear that we are *not* creating a new dayglow removal method and we are *not* claiming that this is a solved problem. Dayglow removal will always result in some kind of error. The sole purpose of the technique that we present is to isolate the auroral signal from the dayglow-corrected data.**

**The issues regarding the explanations of the isolation technique have been addressed in the revised manuscript. We hope the editor and referees will agree that all instances of ambiguous language have been removed from the title, abstract, and main text of the revised manuscript. The response to the reviewers has also been updated with more precise language.**

A similar concern is related to the title, which is indeed confusing because it is imprecise.

- **The title has been altered to be more precise, with respect to both our focus on seasonal effects (during northward IMF) and our technique for isolating the auroral contribution in UV images.**

The simple statement that the southward IMF will be part of a separate publication seems not to be adequate either. Please include and describe why only northward IMF conditions are considered.

- **Our focus is on the seasonal differences during different IMF By conditions. We chose to look at these effects during northward IMF to avoid contamination from periods of elevated geomagnetic activity. We thank the editor and reviewers for bringing to our attention that this was not clear in our original submission.**

This list is not complete, and all concerns raised during the review should be addressed.

- **The rest of the questions and suggestions are addressed below.**

## Response to Reviewer #1

Hessen et al.

This paper develops a new technique to separate contributions to auroral images from the auroras and dayglow. The technique is applied to images from the DMSP/SSUSI instrument. The technique assumes that the distributions of luminosity contributions from the two sources are different, and uses a probabilistic approach to separate the two. The technique cannot be applied to individual images, but to the sum of multiple images collected over several months. Hence seasonal variations in the locations of the auroras are studied. The paper concludes that dawn-dusk asymmetries in the location of the auroral oval associated with IMF  $B_y$  dominate in some seasons and not others. In principle the paper is of interest, but it has some major shortcomings which require major corrections to address. These issues are outlined below, in no particular order.

The paper studies dawn-dusk asymmetries in the location of the auroras during northward IMF. It is not stated in the title that the study relates to northward IMF, it is only alluded to a few times within the paper, and it is never (to my knowledge) explained why the authors ignore southward IMF. The rationale for studying northward rather than southward IMF should be clearly articulated and should be clear in the title.

- **This is a good point, thank you for bringing this to our attention. The reason for our focus on northward IMF is that we are primarily concerned with seasonal differences in this study. We have chosen to limit observations to those occurring during stable northward IMF to reduce contamination from periods of elevated geomagnetic activity. We now make a statement along these lines in the fourth paragraph of Section 2 of the revised manuscript.**

**We have also modified the abstract and title to reflect our focus on northward IMF. The title of the revised manuscript is “New technique for isolating the auroral contribution in UV imagery: IMF  $B_y$  dependence of seasonal differences in auroral oval location during positive IMF  $B_z$ ”. This new title also serves to emphasise that our technique is centered on isolating the auroral contribution in UV images, rather than dayglow removal.**

A major issue appears to be with the dataset used itself. The DMSP/SSUSI images have already had a dayglow removal algorithm applied to them (which introduces serious artefacts into them – see below). This paper then tries to separate a dayglow contribution, which has supposedly already been removed, from the auroral contribution. It would seem to make more sense to use the original images, without dayglow removal, and develop a new technique that does the removal better. One of the coauthors is from the DMSP/SSUSI team – is the original data available?

- **This comment consists of a suggestion and a question.**
- **Regarding the suggestion to use the original, uncorrected images: We realize that in our original submission, we did not make clear enough that our goal is simply to isolate the auroral contribution in UV images that have *already* been subjected to dayglow removal. We do not present a new method for dayglow removal, as that is not our aim. Rather, we begin with dayglow-subtracted UV images that contain a relatively predictable error related to the imperfection of the dayglow removal algorithm.**

**We have strived to make this point much clearer in the revised manuscript, in which we**

have removed all ambiguous language that could be interpreted as suggesting that we perform the dayglow removal ourselves. We refer instead to our new technique as an “isolation technique” that assumes the observed distribution of intensities consists of separate contributions from dayglow and aurora, and that the dayglow subtraction process is imperfect and leaves a residual error.

- Regarding the suggestion to develop a new dayglow removal technique: Our team’s experience with dayglow removal for both SSUSI and other imagers has shown that it is far from trivial, and we do not necessarily share the reviewer’s view that it would make more sense to attempt to develop a new dayglow removal technique with the original data. The problem of dayglow removal from SSUSI images has been addressed by one of us as recently as 2022 (Zhang et al, [doi: 10.1016/j.jastp.2022.105833](https://doi.org/10.1016/j.jastp.2022.105833)), as indicated in the original manuscript.

Perhaps most importantly, even if we did develop a more accurate dayglow removal method there would still be residual errors associated with counting statistics as well as processes not captured by the existing dayglow removal procedure, which is based on solar zenith angle and look angle. In other words, we would still be in a situation where the dayglow-corrected data have an associated bias and error. We therefore respectfully submit that the cost of developing a new dayglow removal procedure would far outweigh the benefit – hence our focus on isolating the auroral contribution instead of improving or replacing the methodology for dayglow removal.

Regarding the question about the availability of the original data: they can be found on CDAWeb: <https://cdaweb.gsfc.nasa.gov/pub/data/dmsp/>. We have included this information in the data availability statement of the revised manuscript.

Artefacts in the data include a bias towards negative luminosities (even when the positive auroral contributions are included!) and spikes in the distributions at particular luminosity values. At the very least there should be a discussion in the paper about how the original dayglow removal is done, and why it leads to these artefacts. Otherwise the results from this paper are of little use. Currently, most of the paper is discussing the fact that there are these artefacts, without describing why they arise. The paper would be much better focussed if the original data was used (see previous comment).

- The reviewer is correct that the dayglow-corrected dataset exhibits an overall negative bias. The distribution of counts in bins outside the auroral oval is fairly consistent, with a mostly symmetric distribution and mean values that vary between -250R and -50R in the summer. In contrast, the mean is almost never negative in bins where the aurora is present.

There are some outliers, like extreme negative values, and the spike around -60R to -40R.

The negative values are caused by data processing: removing scatters from bright emissions (H121.6nm, O130.4nm and O135.6 nm) into the LBH bands and counting errors. Isolated spikes are due to glints and MeV particle noises.

**However, the contributions from these are insignificant when the technique is applied. This can be seen when we truncate the window to -2000R to 5000R.**

I'm not sure that I understand Figures 6 and 7. Three distributions are shown: blue is aurora and yellow is DG-residual. My understanding is that green is the sum of these two distributions, but this is clearly not the case. For instance, if green is the sum then the two bottom distributions should be bimodal. Please explain these figures better.

- **The “sum” curve is fitted to the sum of two randomly distributed values ( $Z = X + Y$ ). The probability distribution function (pdf) of this sum is the *convolution* of the pdfs of the two random variables, and not the *sum* of their pdfs.**

**We have made this point clearer in the revised manuscript by rewriting the relevant portion of the caption of Figure 5 in the revised manuscript (formerly Figure 6) so that it reads, “The ‘sum’ curve represents the convoluted distribution given by Equation 5.”**

I think Figures 4 and 8 are the same, but one has more labelling. Just use the second figure.

- **Thank you for pointing this out, Figure 4 has been dropped in the revised manuscript.**

## Response to Referee #2

The article touches an important topic of observing aurora under dayglow conditions. The authors introduce an algorithm for cleaning the widely-used DMSP SSUSI dataset of auroral emissions. They suggest this new algorithm as an addition, or as an alternative, to the standard cleaning algorithm developed at the John Hopkins APL. It appears that the article is based on the master thesis of the primary author (Hessen, 2023). The proposed cleaning algorithm and its validation is interesting. My key concern is that the article is describing technical developments (details of the cleaning algorithm) and thus it does not fit the scope of *Annales Geophysicae* as a geophysical journal. I would recommend that the authors select a more relevant journal for this article, e.g., *Atmospheric Measurement Techniques*. I included some specific comments below, especially regarding the choice of IMF conditions for the validation.

- **We wish to thank the reviewer for their feedback and suggestions for improving the manuscript. We have strived to bring the revised manuscript in line with the reviewer's comments.**

**From this and the reviewer's last comment, we gather that the reviewer is under the impression that this study presents a new cleaning algorithm. We wish to clarify that the technique we present is not intended as an additional or alternative cleaning algorithm for SSUSI data. Rather, our technique aims to isolate the auroral contribution from the dayglow-corrected SSUSI data, which in each bin is a convolved distribution consisting of separate contributions from dayglow *error* (*not* the dayglow itself!) and the aurora. This technique allows us to obtain a better statistical estimate of the location and brightness of the auroral oval.**

**The actual physical result we have highlighted is that the auroral oval boundaries shift in response to IMF By. We believe this result makes the manuscript a clear candidate for *Annales*, instead of a journal focused solely on methodology.**

Line 2: It is stated here and throughout the article that northward IMF conditions are considered, but there is no clear explanation of why southward IMF conditions are excluded. IMF By should also be a controlling factor for dawn-dusk asymmetries under southward IMF, so southward IMF cases should be also considered.

- **We agree that this choice was not clearly motivated, thank you for bringing it to our attention.**

**We made the choice to screen for northward IMF since this study focuses on seasonal effects, rather than effects related to geomagnetic activity (which are generally associated with southward IMF). We do however point out in the conclusions that investigation of the role of IMF By during southward IMF conditions would likely be enlightening, and reserve this as a topic for future work.**

17: The statement that "the seasonal dependence of polar cap location has not been previously reported" is confusing. I would recommend the authors to remove this strong statement and summarize the actual results of their study instead, or at least to make the statement more specific.

- **We thank the reviewer for catching this. We agree that the sentence in question is unnecessary, and we have removed it from the revised manuscript.**

70-74: Here I have a question about the methodology. The authors mention correctly that the dayglow removal routines have been already applied to the SSUSI dataset. Do they apply their new cleaning algorithms to the SSUSI dataset that has already been cleaned? If so, they should explain the rationale, because the original dayglow cleaning routines may have introduced certain biases. Perhaps, it would be preferable to apply the new dayglow cleaning algorithm to the lower-level, uncleaned SSUSI data?

- **We thank the reviewer for helping us to understand that this aspect was unclear. We will modify the description on these lines and elsewhere to clarify that we use “dayglow-corrected SSUSI irradiance data”.**

**In response to the reviewer’s question about our “new cleaning algorithm”: we emphasize that our technique does not constitute a cleaning algorithm, as we point out in our response to the reviewer’s first comment. Rather, the technique we present is intended to isolate the auroral contribution to the dayglow-corrected SSUSI irradiance measurements. Our technique assumes that dayglow has already been removed, and that what remains is both the auroral contribution and a statistical bias or offset (the “dayglow error”).**