From: Christine Gabrielse
To: Shumko, Mike
Cc: Turner, Drew L.; Cohen, Ian J.; Mykhaylo Shumko
Subject: [EXT] RE: ASI ELFIN Project
Date: Monday, August 11, 2025 7:55:23 PM
Attachments: ASIdataCSV100.zip

Hi Mike,

Here are the files for the original (actual) ELFIN longitude (ASIdata0..txt) through a 10 degrees longitude difference at 0.5 deg increments. Remember not to use times when elevation angle is below 10 deg. Note that as longitude changed, “ELFIN” mapped to higher elevation angles so you will end up with more data points for each subsequent file.

Let me know if you have questions! The columns are labeled, but note that there are 3 new columns listing the ELFIN longitude, GILL longitude, and PINA longitude of closest approach.

Christine

From: Christine Gabrielse
Sent: Monday, August 11, 2025 2:18 PM
To: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>; Mykhaylo Shumko <msshumko@gmail.com>
Subject: RE: ASI ELFIN Project

Thanks! I found it on my other computer.

From: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Sent: Monday, August 11, 2025 2:05 PM
To: Christine Gabrielse <christine.gabrielse@aero.org>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>; Mykhaylo Shumko <msshumko@gmail.com>
Subject: RE: ASI ELFIN Project

Hi Christine,

Originally I thought about tabling this analysis, since we already have a nice result I want to do this sensitivity study soon.

I just sent you your original email for your reference, and in this email I attached the data file that you produced. I hope that you can use the filename and/or column names to find your code!

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From: Christine Gabrielse <christine.gabrielse@aero.org>
Sent: Monday, August 11, 2025 4:54 PM
To: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>; Mykhaylo Shumko <msshumko@gmail.com>
Subject: [EXT] RE: ASI ELFIN Project

Hi Mike,

Can you remind me, did I already give you results for this event or had you asked me to table the work to focus on the other papers? I'm trying to find code I already wrote but maybe it doesn't exist yet.

Christine

From: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Sent: Tuesday, August 5, 2025 2:45 PM
To: Christine Gabrielse <christine.gabrielse@aero.org>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>; Mykhaylo Shumko <msshumko@gmail.com>
Subject: RE: ASI ELFIN Project

Hi Christine,

I'm glad to hear that it will be fairly straight-forward to run! To confirm that I found the correct document regarding line-of-sight errors, are you referring to the discussion in your SI section titled: "S2.2.2 Note on Elongation of Off-Zenith Arc in ASI Images" in your paper? I really like how clearly you explain how a tall arc is projected across an extended elevation angle.

I wasn't sure where Jun got 90 km from, but I think that he was fiddling around with the altitude assumption to make the poleward arc appear continuous across the ASI FOV boundaries. I tired that as well, and I found that I needed to use both the 90- and 110-km altitude assumptions to make the arc line up for the entire substorm expansion phase. The emission height must have changed throughout the substorm.

But let's not worry about the emission height for now!

I attached the 110-km ELFIN-A footprint file. Are you missing additional files, or is this enough for your analysis? The longitude shifts, say in 0.5 [deg] increments, should be easy to do with this file.

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From: Christine Gabrielse <christine.gabrielse@aero.org>
Sent: Tuesday, August 5, 2025 4:40 PM
To: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>; Mykhaylo Shumko <msshumko@gmail.com>
Subject: [EXT] RE: ASI ELFIN Project

Hi Mike,

That shouldn't be a problem.

In either case, there is more error on the edges because the ASI is not looking up the actual field line. A purist won't accept the results regardless. (I work alongside one such person, haha, and only got him to be a co-author so long as I included plenty of caveats in my paper…) As you likely know, it's because only at the zenith is the ASI looking straight up, so all precipitating electrons at that location are observed. At the edges, you are observing the line of sight so you get what is deposited there but not what is deposited at higher altitudes. There's an appendix/SI in my 2025 paper showing the possible extent of the error. Anyways, the workaround we usually employ is that this is the best we've got, and the error is usually within such and such percentage.

Why is he assuming a 90km emission instead of 110? The average energy is putting the peak emission at 90km?

Feel free to send me the files to run!

Christine

From: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Sent: Tuesday, August 5, 2025 1:01 PM
To: Christine Gabrielse <christine.gabrielse@aero.org>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>; Mykhaylo Shumko <msshumko@gmail.com>
Subject: RE: ASI ELFIN Project

Hi Christine,

I have an analysis request before this result is buried in my other projects!

At GEM, Jun expressed skepticism in our ELFIN-ASI energy flux comparison methodology because ELFIN passed through the Eastern edge of the ASI FOV. His point was if you assume a 90-km altitude auroral emission, ELFIN flew just outside of the FOV. Therefore, our method is not appliable in that case.

Channeling my inner Paul O'Brien, one way to put at least some naysayers at ease is to do a sensitivity study. I think that the simplest way to do one is to shift ELFIN's orbit track westward in pre-defined longitude steps (i.e., ELFIN_lon(t), ELFIN_lon(t)-0.5 [deg], ELFIN_lon(t)-1.0 [deg],… ELFIN_lon(t)-10 [deg]), and resample your inversion maps along the shifted ELFIN trajectories. A maximum westward shift of 10 degrees is sufficiently small that you only need to use pixels from GILL & PINA.

Is your code straight-forward to run a bunch of times? Please let me know if that is not the case, and I can think of a different approach. You can use the same file format and add the longitude shift in the filename.

Thanks for running your model and I look forward to seeing your results!

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From: Christine Gabrielse <christine.gabrielse@aero.org>
Sent: Wednesday, April 23, 2025 3:46 PM
To: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>
Subject: [EXT] RE: ASI ELFIN Project

Hi Mike,

That direction sounds more promising! I recommend doing a lit search for EISCAT results that look into energy deposition. A quick search found this study: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JA025636 I didn't read the paper but skimmed through figures and found they plot energy flux spectrograms for energies from 1->64 keV over time in Figures 7 and 8. EISCAT studies may be a good place to find what questions have already been answered, what are open questions, etc. EISCAT of course looks up from one location, whereas you have 2D ASI data and a 1-D track from ELFIN over time and space.

Christine

From: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Sent: Wednesday, April 23, 2025 12:22 PM
To: Christine Gabrielse <christine.gabrielse@aero.org>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>
Subject: RE: ASI ELFIN Project

Hi Christine,

That does make sense. I'm thinking of this in two ways:

1. We can ask a broader question: what is the total energy input into the high-latitude atmosphere (ionosphere included) from electron precipitation? To answer this question we would combine the energy fluxes from the THEMIS ASI inversion and ELFIN, and it should be our first estimate of the total energy input due to electron precipitation (excluding the 30-50 keV component of the spectrum), or alternatively
2. We can ask a more specific question: What is the relative energy input into the high-latitude D- and E-layer ionosphere and mesosphere from electron precipitation? To answer this question, the THEMIS (and TREx) ASI inversion calculation tells us about energy input into the E-layer ionosphere, while the ELFIN energy flux calculation tells us about the energy input into the D-layer ionosphere and mesosphere.

And thanks for providing nuance to the energy flux vs average energy. I needed a reminder about their red-line estimate.

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JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

From: Christine Gabrielse <christine.gabrielse@aero.org>
Sent: Wednesday, April 23, 2025 2:09 PM
To: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>
Subject: [EXT] RE: ASI ELFIN Project

Hi Mike,

Thanks for sending the figures! Very interesting! One big point to note: The auroral energy flux is only composed of particle energies that contribute to the visible light, so, up to ~30 keV. Larger energies (>50 keV) do not contribute to the aurora. So you would not say that the >50 keV populations contribute to the auroral energy flux, but rather that their energy fluxes are roughly equal to the population that composes the aurora. Make sense?

As I might have mentioned before, I would trust the TREx-ATM version of energy flux since they are using a blue ASI (and energy flux is almost completely a function of the blue line). But I would trust the mean energy less than the white light inversion for cases when there are localized aurora (since they define the red line as whatever the red spectrograph sees at one line of longitude, assuming everywhere along the same latitude line has the same red light intensity).

Christine

From: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Sent: Wednesday, April 23, 2025 10:59 AM
To: Christine Gabrielse <christine.gabrielse@aero.org>
Cc: Turner, Drew L. <Drew.Turner@jhuapl.edu>; Cohen, Ian J. <Ian.Cohen@jhuapl.edu>
Subject: [EXTERNAL] RE: ASI ELFIN Project

Hi Christine,

Thank you for the data! Indeed it was a very exciting morning playing with your data. I've CCd Drew and Ian, as they would be very interested in this result.

As the attached figure and Jupyter notebook show, the auroral and energetic fluxes are remarkably consistent and similar considering the uncertainties that you described (and the projection effect from ELFIN's low elevation in the ASI FOVs).

I have two takeaways from the bottom panel of the figure:

1. Typically the energetic (>50 keV) electron fluxes make up a small portion of the total energy flux (4% median and 9% mean), and
2. Occasionally the energetic electron fluxes contribute as much as 68% of the total energy flux.

Others can chime in here, but I think that this is the first such comparison? While I suppose that this is not a groundbreaking result, I do think that we have a publishable result here.

I will soon poke the Calgary folks to have an independent comparison with their TREx-ATM model.

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From: Christine Gabrielse <christine.gabrielse@aero.org>
Sent: Tuesday, April 22, 2025 8:41 PM
To: Shumko, Mike <Mike.Shumko@jhuapl.edu>
Subject: [EXT] ASI ELFIN Project

Hi Mike,

I did a simplistic gathering of the mean energy and energy flux values for your ELFIN footpoints as they traversed GILL and PINA. They are attached. Please do not use values when the elevation angle is below 10 deg. They are only included because I didn't want to take the time to write them out.

The reason I say I did a "simplistic" gathering is that I used the relationships between green, red, and blue light (with white light) that I built for the 2013-03-17 storm, since your event was embedded in activity. I did not calibrate the white light to MSP data for your event, because there were no more MSPs from the NORSTAR data set for this date. We could consider pursuing a calibration for this date, which would require me to use the TREx spectrometers and learn how to use those data, which would take longer.

I did do a background subtraction. I didn't grid the data so that I could keep it the highest resolution possible, so I selected to use GILL vs. PINA based on which was closer to ELFIN unless they both had data close to ELFIN, then I used the one with a higher elevation angle.

It's interesting that the numbers are kind of low. Highest energy flux is around 30 ergs/cm^2/s, and highest mean energy is ~4 keV. I should probably do some additional double checks of the white light values and such, but the checks I did by printing the geographic latitudes of ELFIN and that of the ground stations match well.

Anyways, I wanted to get something to you to play with. Let me know if you have questions!

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