EVE Rocket Analysis

A New Method to Analyze EVE Rocket Data

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EVE Science Meeting, 2023
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

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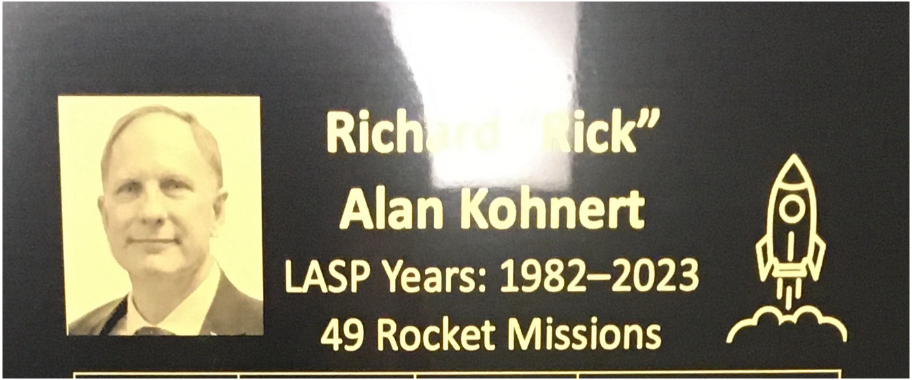
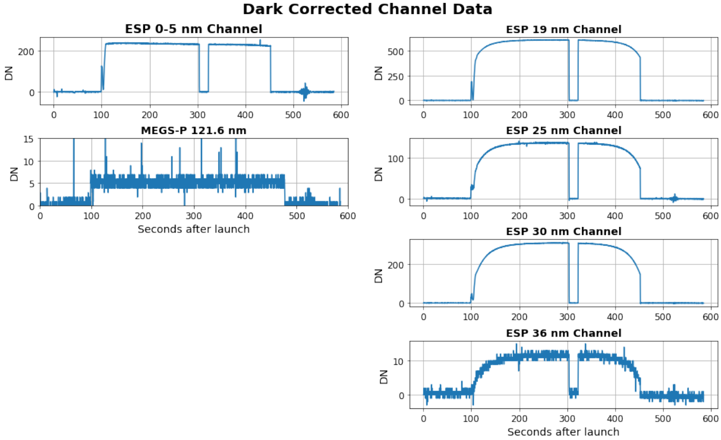
Remembering Rick Kohnert



EVE Diodes: (ESP, MEGS-P) 0.25 s Flight Data



ESP and MEGS-P data. “Outage” at $\sim$300 s is a stray-light check in ESP using a FS filter, it is ignored in the analysis. Soft X-ray and Lyman-α channels don’t show atmospheric

Old Method

- Isolate data close to apogee ($\sim \pm 40$ s).
- Average apogee data.
- Use NRL-MSIS to calculate residual atmospheric absorption.
- Calculate Air Mass Zero (AM0) response.
- Compare Rocket-EVE AM0 measurement with SDO-EVE measurement.

New Method

- Parabolic fit to WSMR radar altitude vs. time.
- Match radar altitude data to EVE data.
- Fit data vs. Altitude and to extrapolate to air mass zero (AM0).
- Compare Rocket-EVE AM0 measurement with SDO-EVE measurement.
- This method also provides the residual atmospheric absorption:

$$ABS_{ch} = DN_{ch}(AM0) - DN_{ch}(apogee)$$

- I developed this using data from the 36.353 (9 Sept. 2021) flight.
- I have working radar data readers for all flights.
- I have not looked carefully at the data except for the 36.353, and 36.389 flights.
- I have problems reading data for a couple of early flights (36.258, 36.240).

Radar Data

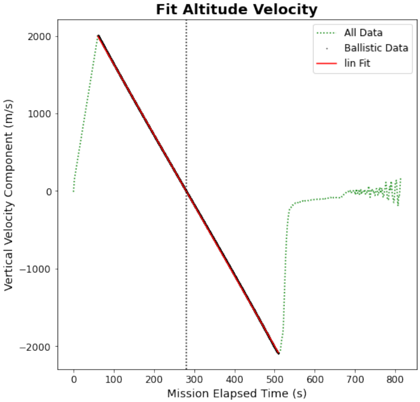
The radar data file often arrives in different formats, but for this analysis, I am only using three fields:

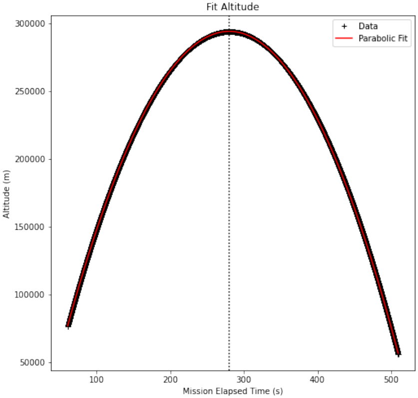
TIME: The time after launch in seconds.

ALT: The altitude above sea level in meters.

ALT VEL: The vertical component of the velocity in m/s. I use this to determine when the rocket is in ballistic flight, It is sometimes not included, in which case I calculate it.

Radar Plots and fits





Vertical Velocity (m/s) vs. M.E.T (s)

Fit: altitude vs. M.E.T.
Apogee Altitude: 293.982 km

Fit Function

When the signal (DN_{ch}) shows atmospheric absorption during the flight I fit:

$$DN_{ch} = DN_{AM0} \times (1 - e^{-\frac{(z-z_0)}{H}})$$

DN_{AM0} is the extrapolated AM0 signal

z is the altitude in km

z_0 is the extinction altitude in km

H is the scale height in km

If there is not enough extinction to fit the 1-$e^{-\frac{z}{H}}$ then a simple linear fit to the profile is used. In these cases extinction is not significant, so we are directly measuring the AM0.

Fit Function Details

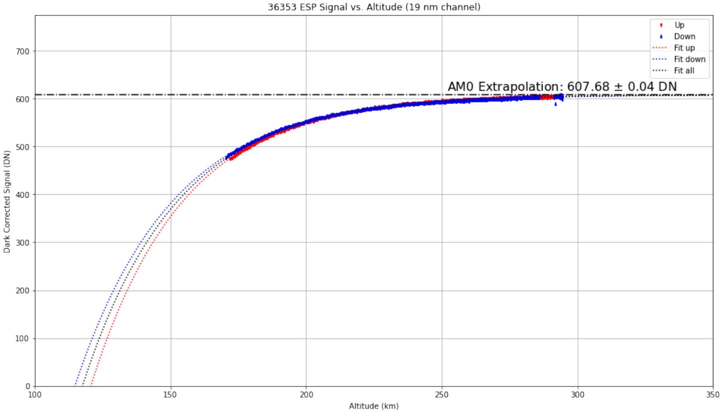
- I used the SciPy fit function, which defaults to the Levenberg–Marquardt method. After trying to do the fit to altitude in meters (read directly from the radar data file) the fitter was very sensitive to the initial parameters, I changed to using km for the altitude, and the fitting performed much better.

```
def EXP_fit_fn(z, am0, h, z0):
    return am0*(1.0 - numpy.exp(-(z-z0)/h))
```

```
tparams, tdcv = scipy.optimize.curve_fit(EXP_fit_fn, z/1000.0, dn, [p0])
```

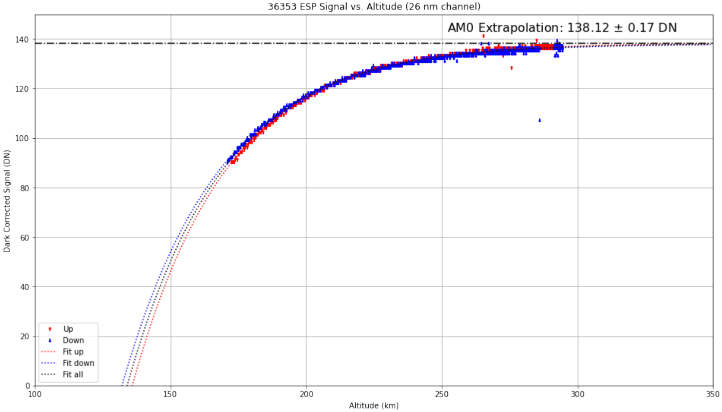
- I fit the whole mission data as well as the up and down-legs individually.
- I use the diagonal of the covariance matrix (tdcv) to calculate the fit error.

ESP 19 nm Channel



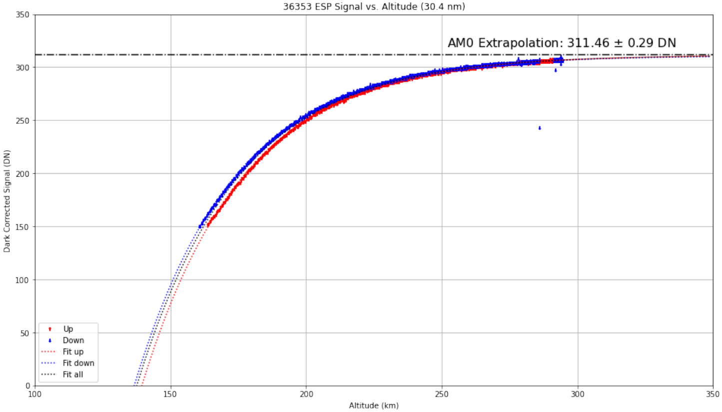
ESP 19 nm channel fits. I fitted the up-leg, down-leg, and all data separately, and used the difference between the fits to calculate the uncertainty.

ESP 26 nm Channel



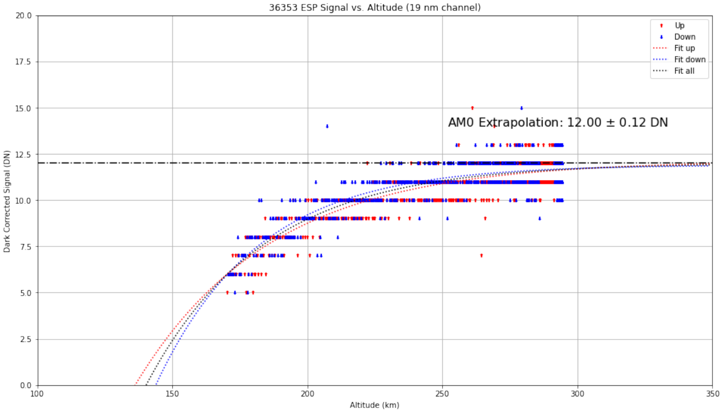
ESP 26 nm channel fits.

ESP 30 nm Channel



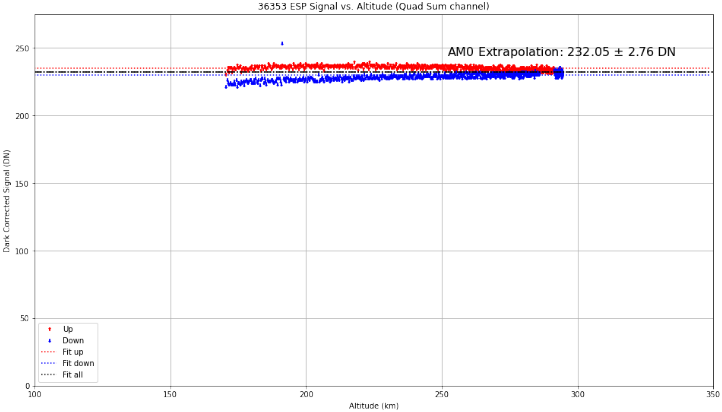
ESP 30 nm channel fits.

ESP 36 nm Channel



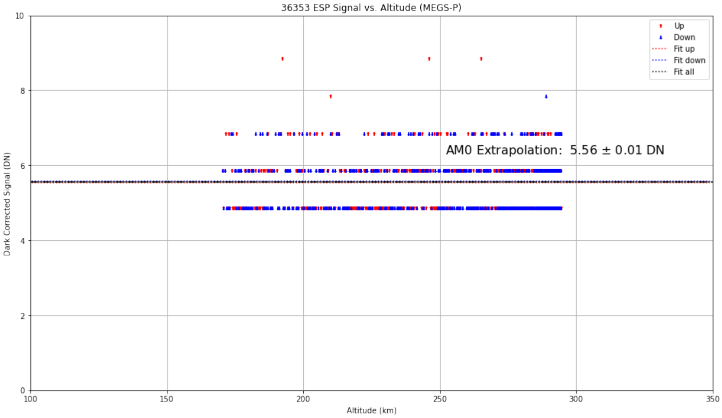
ESP 36 nm channel fits.

ESP Quad Sum (Linear Fit)



ESP Quad Sum linear fits

MEGS-P (Lyman-α) (Linear Fit)



ESP Quad Sum linear fits

ESP 36.353 (2021-09-09 17:25:00) Rocket Results Summary

Channel	AM0 Counts (DN/.25s)	Fit Errors[1] (%)	Apogee Counts (DN/.25s)	Absorption (%)
E19	606.83	0.05	603.05	0.62
E26	137.99	0.06	136.52	1.06
E30	310.59	0.06	306.24	1.40
E36	11.94	0.83	11.58	3.07
QS[2]	231.53	0.05		
MEGS-P[2]	6.32	1.22		

[1] These are calculated as the 1σ errors of the fit covariance AM0 element

[2] There is not enough absorption to make an air-mass fit, so I use linear fit

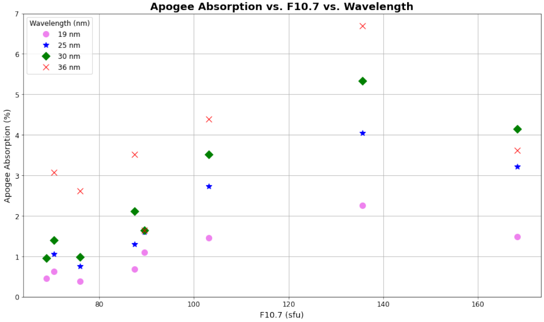
ESP 36.389 (2023-06-06 18:30:00) Rocket Results Summary

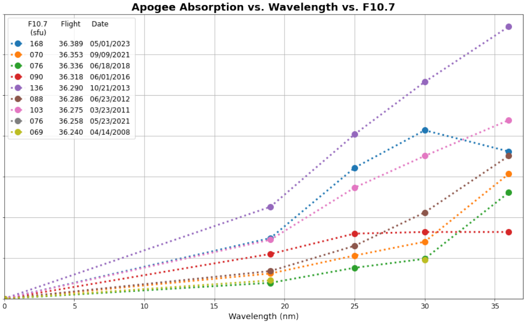
Channel	AM0 Counts (DN/.25s)	Fit Errors[3] (%)	Apogee Counts (DN/.25s)	Absorption (%)
E19	1038.46	0.03	1022.98	1.49
E26	277.48	0.04	268.54	3.22
E30	478.22	0.03	458.41	4.14
E36	20.19	0.71	19.46	3.62
QS[4]	775.84	0.08		
MEGS-P[2]	12.48	0.49		

[3]These are calculated as the 1σ errors of the fit covariance AM0 element

[4]There is not enough absorption to make an air-mass fit, so I use linear fit

ESP Rockets Apogee Absorption





Apogee Absorption vs. $F_{10.7}$ Apogee Absorption vs. Wavelength

Data from flights: 36.389, 36.353, 36.336, 36.318, 36.290, 36.286, 36.275, 36.240

Still working on: 36.258, 36.240. 36.300 was lost

Conclusions

Advantages:

- The method seems to work well.
- It uses all [good] data.
- Averages over solar activity changes, and local air mass variations.
- Doesn't rely on external models e.g. NRL-MSIS to calculate AM0 results.
- Determined absorption could be used to 'correct' NRL-MSIS.

Disadvantages:

- Need to wait for WSMR Radar data (But NRL-MSIS needs average $F_{10.7}$).
- Probably can't use for all MEGS data.

To Do

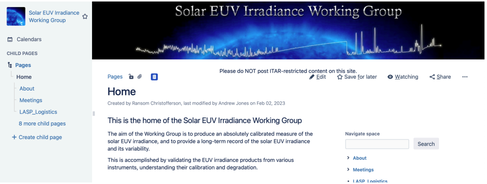
I am not sure how easy it will be to apply to MEGS-A/B data at 40× slower cadence but Don has some promising results.

However, this method can be compared to the MEGS results, or used to scale the NRL-MSIS model.

The next step in this work are:

- Proceduralize the fit and plot routines.
  - Unfortunately, every flight has some slight differences in file formats, etc. so I need to hard-code some specifics for each flight.
  - Check data for all flights.
- Understand the $F_{10.7}$ results.
  - Calculate absorption to a standard altitude, not Apogee?
- Finish paper detailing this work.

Shameless Advertisement

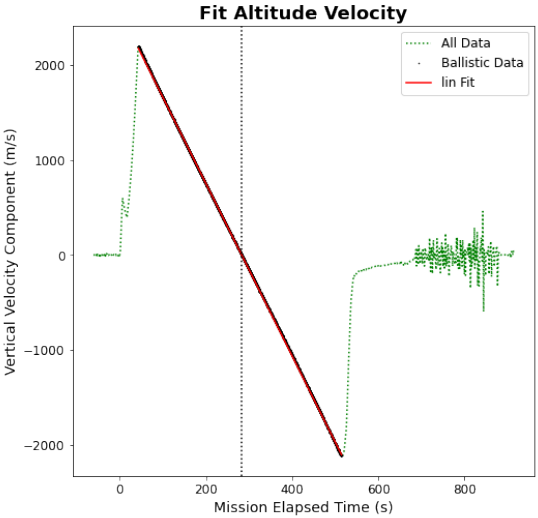


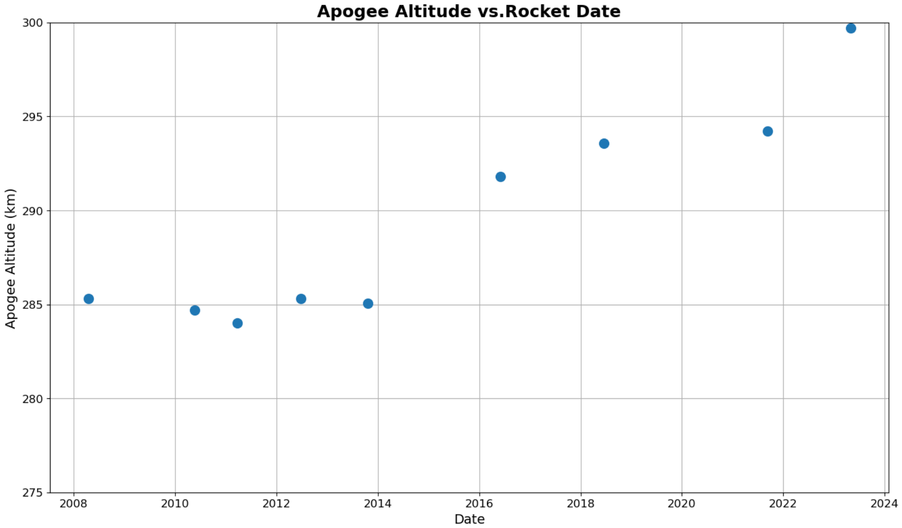
SEIWG is a community resource for sharing information on things like instrument degradation, rocket data, analysis techniques, etc.: Solar EUV Irradiance Working Group (SEIWG).

For deeper data access and posting you need a login, please let me know if you want access Andrew Jones and I will try and arrange it.

Backup Plots

Radar Detail





Apogee Altitude vs.Rocket Date
Apogee Altitude (km)
300
295
290
285
280
275
2008
2010
2012
2014
2016
2018
2020
2022
2024
Date