SHELLS Model:
Specifying High-altitude Electrons using Low-altitude LEO Systems

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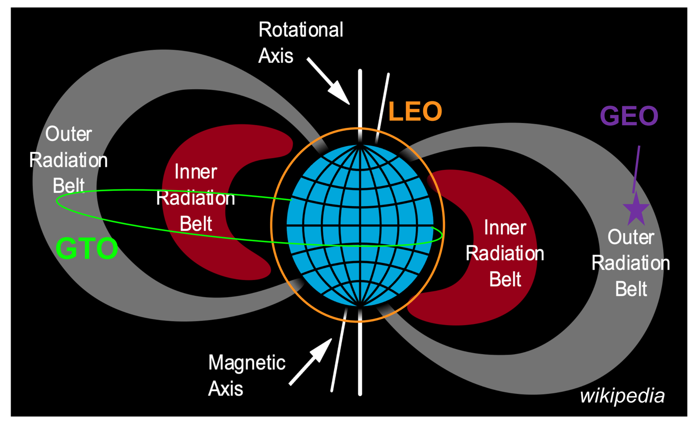
I. Motivation

- The Internal Charging hazard from energetic electrons is often difficult to specify for non-GEO orbits
- The goal is to develop a model that can connect measurements at LEO (POES) with energetic electron environment at higher orbits (i.e. Van Allen Probes). Once this model is trained, **it can specify the outer energetic electron environment for periods before and after the Van Allen Probes Era.**
- First Iteration of the SHELLS model (Claudepierre and O'Brien, 2020) used daily averaged fluxes, discrete energy, L-shells
- **Here, we used increased time resolution (1-minute), include L-shell, B-mirror dependence and output multiple quantiles for error estimation**

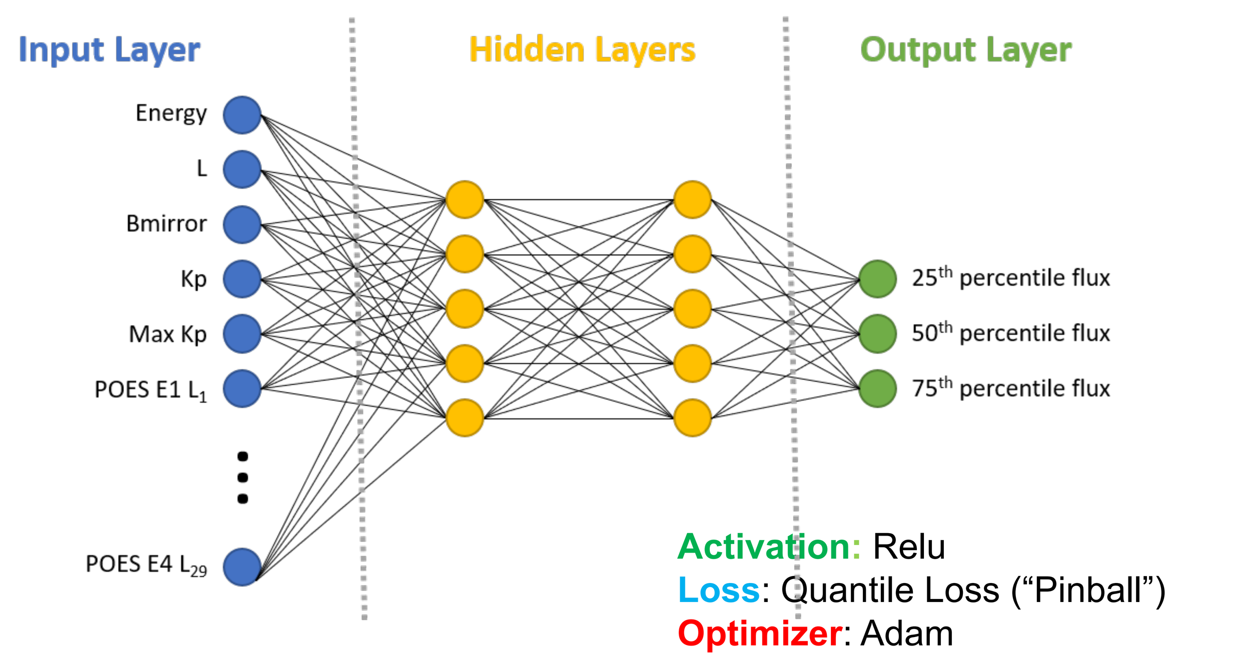


I. Model Summary

Model Inputs:
- Current Kp Index
- Maximum Kp from Last 3 days
- POES data at 4 energy channels: E1 (>40 keV), E2 (>130 keV), E3 (>400 keV), E4 (>700 keV) at 29 L bins (0.25 L-bins for L=1-8)

User Specified
- L-shell
- Energy (keV)
- B-mirror value (nT)

Model Outputs:
- 25th, 50th, 75th percentile Van Allen Probes/MagEIS flux



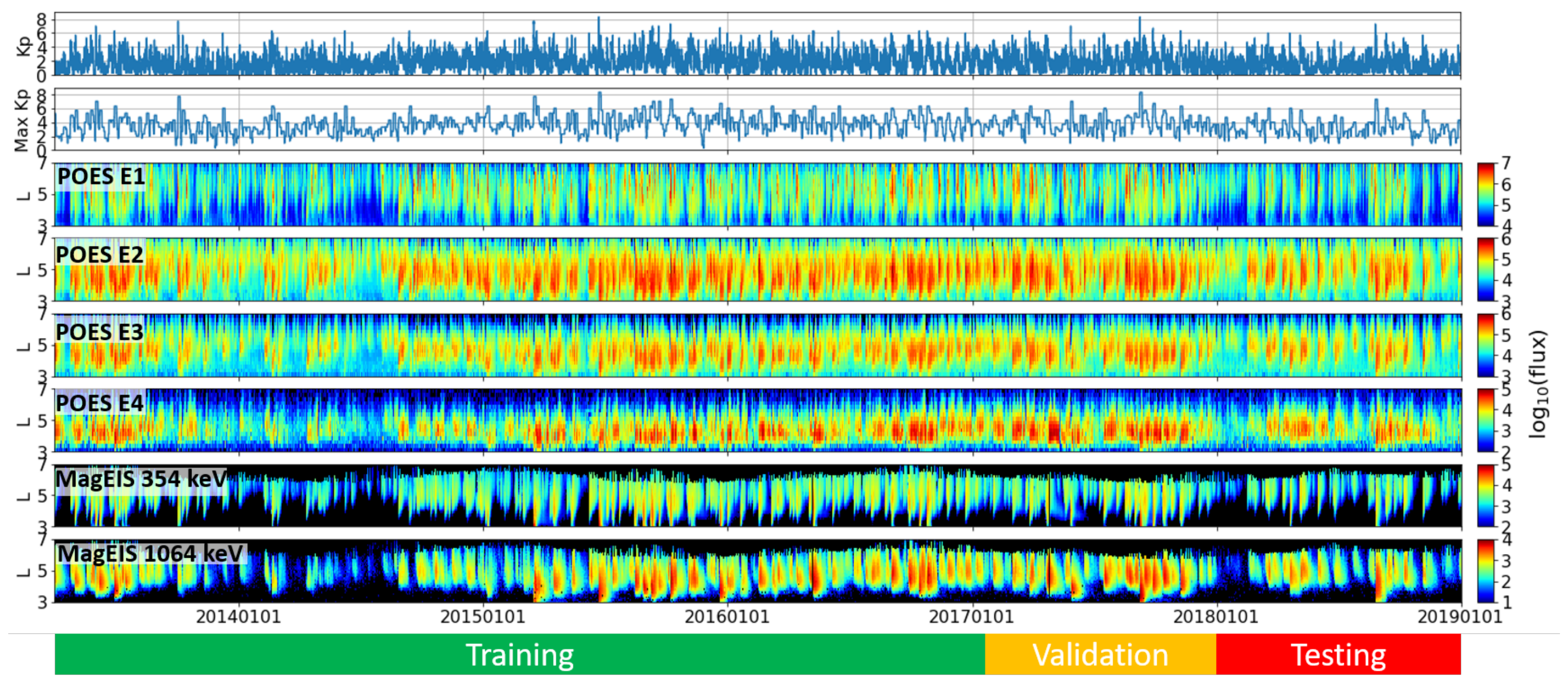
Model Architecture
- The model is constructed using Keras as a feed forward neural network with an input layer and 2 hidden layers (20/10 nodes).
- Use pinball loss function to get quantile outputs:

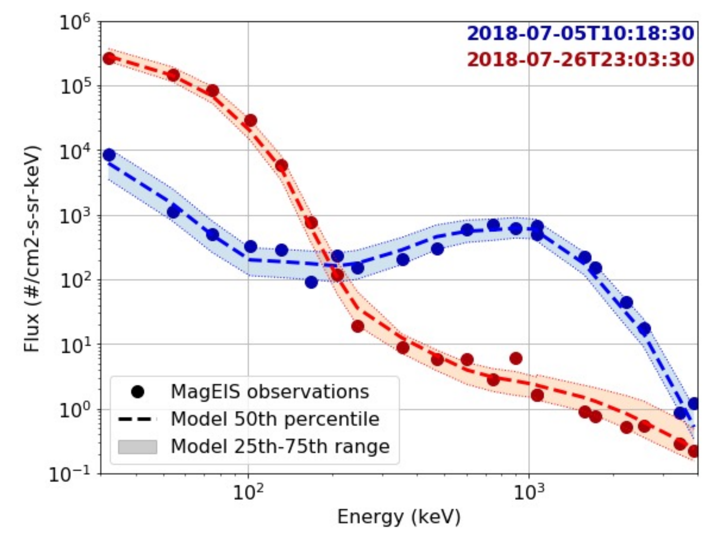
$$L_q = \begin{cases} (y-z)q & \text{if } y \geq z \\ (z-y)(1-q) & \text{if } z > y \end{cases}$$

Where y is the true value, z is the predicted value and q is the quantile value (0 to 1)
- Inputs are scaled to have 0 mean and unit variance

III. Results

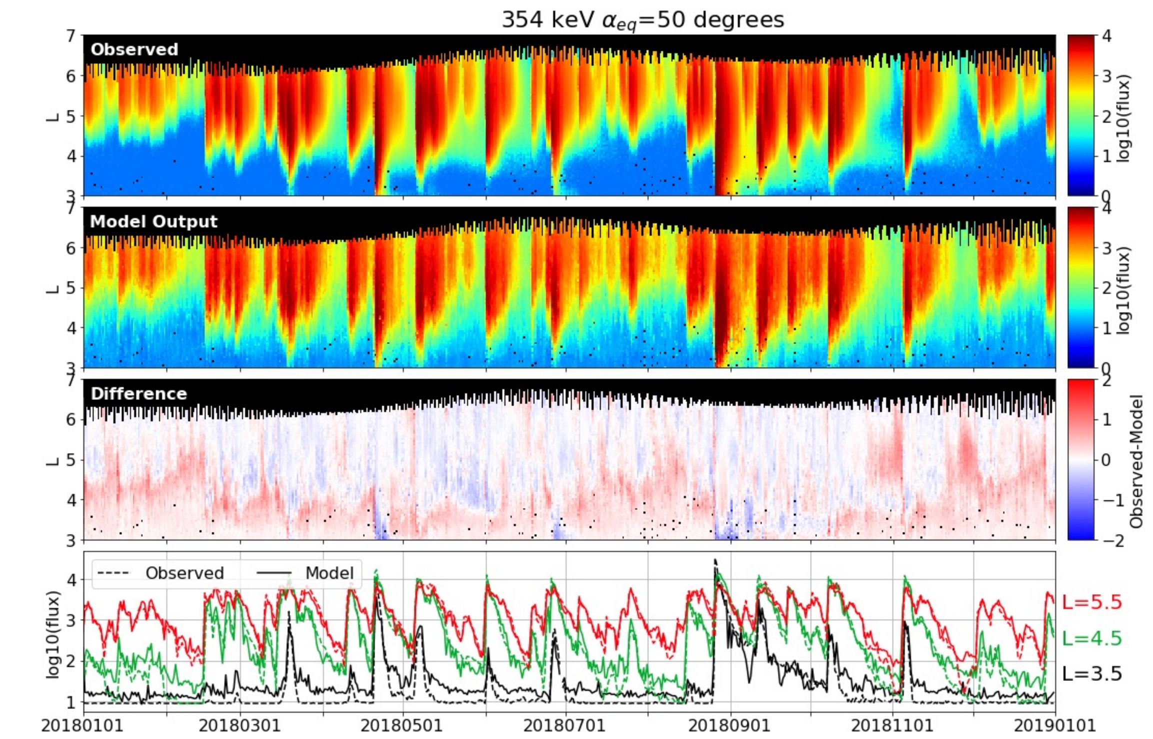
↓ Overview of Training and Validation datasets. We utilize a 70/15/15 training/validation/test split



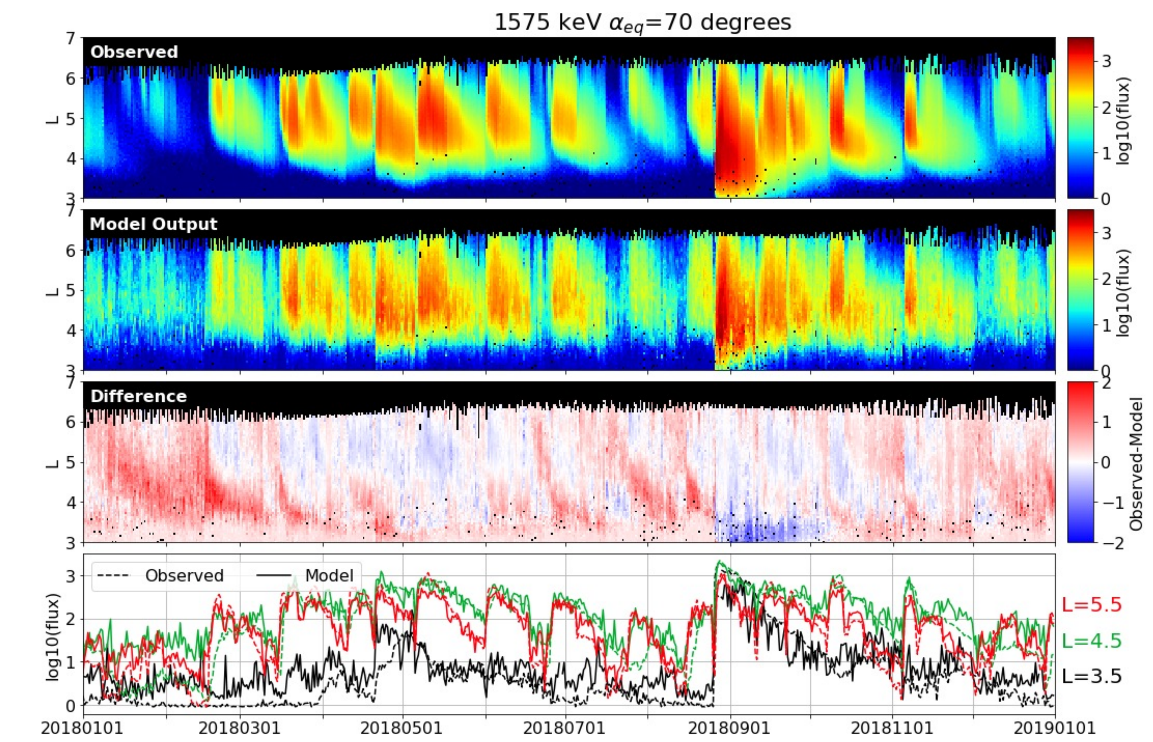


← Comparison of energy spectra at 2 different L-shells. The model is generally able to produce reasonable spectra even at energies in between the training set values.
The shaded region shows the 25-75th percentile range output by the model

Here we show comparisons of the trained model output to out-of-sample MagEIS observations from 2018.



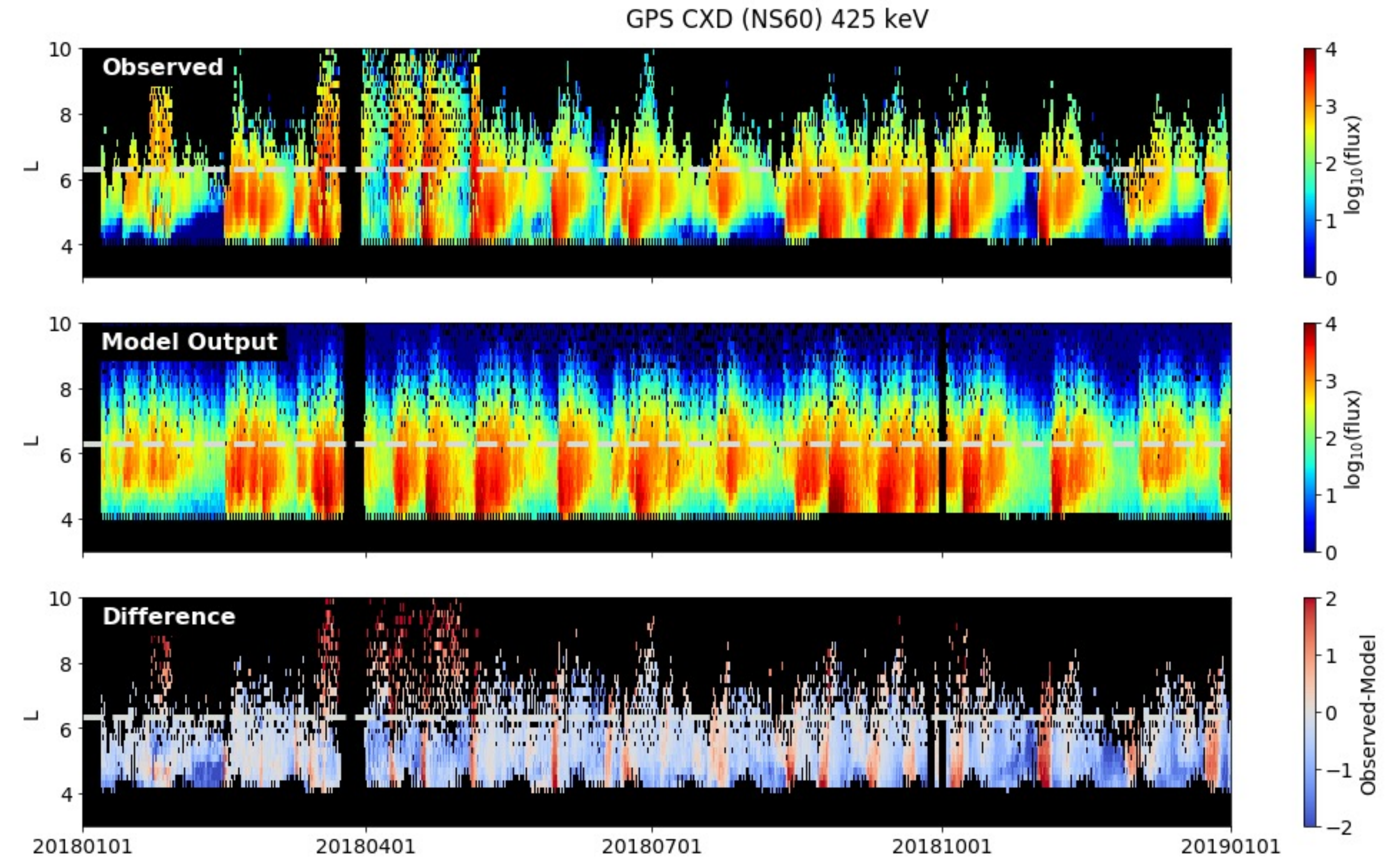
← Comparison at 354 keV at equatorial pitch angle of 50 degrees
For clarity, the 50th percentile results are shown for fixed equatorial pitch angle rather than B_{mirror}
Model generally matches the observations very well.
Overall, the model is more accurate at this lower energy.



← Comparison at 1575 keV at equatorial pitch angle of 70 degrees
Overall, Model generally matches the observations very well, but not as well as at lower energy.

IV. Validation

Once the network is trained, it can be used to output fluxes at any given energy, L, and B_{mirror}. Here, we compare the model output to electron observations from CXD instruments on GPS [Morley et al. (2017)].



Overall, the comparison at 425 keV is very good at L ≤ 5. The model is able to capture the overall dynamics and accurately model the peak fluxes during enhancements.

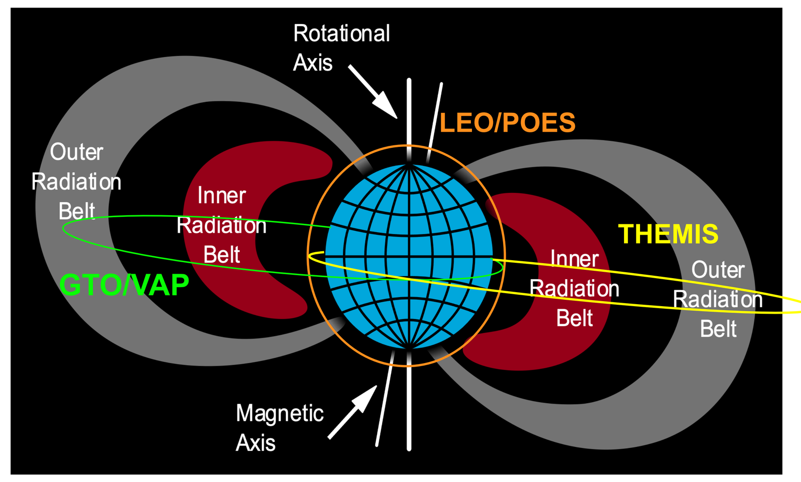
At higher L shells, the model performs poorly. This is expected, given that the training data is limited to the Van Allen Probes L range (L < 6.5; shown with gray dashed line). To improve this performance, we're working on adding in datasets at larger L values.

V. Conclusions

- Current version of the model from the Space Hazards Applications website (http://spacehaz.com/shells.html)
- Working on producing a standard long-term reference dataset for use in data-assimilation models

- Paper describing the model recently submitted to Space Weather

SHELLS model development is ongoing
- Currently working on integrating THEMIS/SST and MMS/FEEPS data in addition to Van Allen Probes to cover larger L-range (at GEO and beyond)
- Comparison to similar models (Pre-MeV (Chen et al., 2019), MERLIN (Smirnov et al., 2020)
- Future work include integrating high inclination data and developing a forecast model



References

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