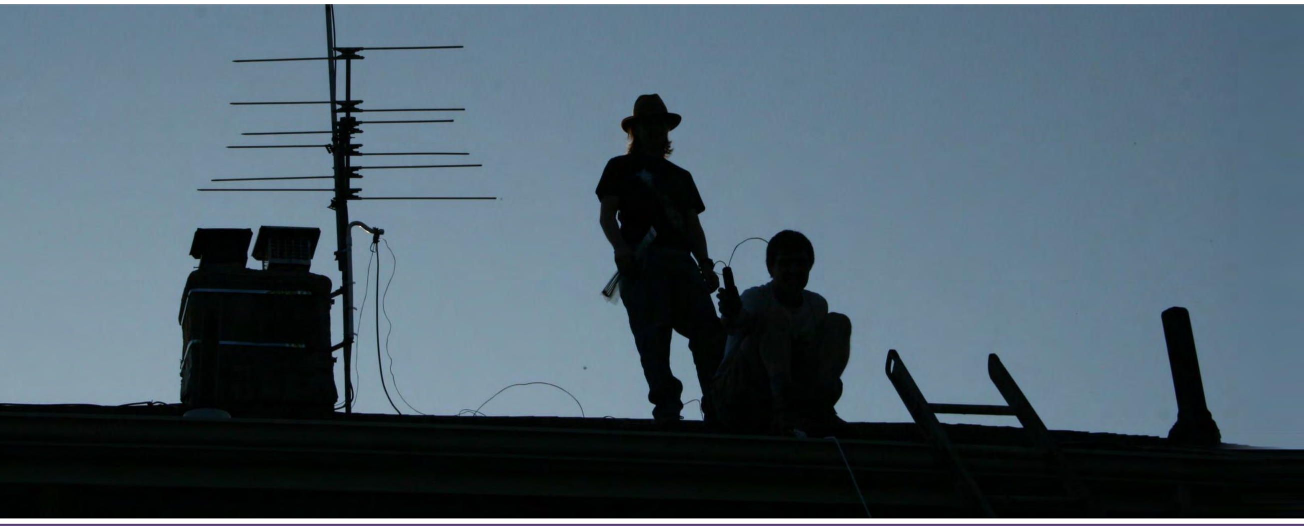

PyLAP/PHaRLAP HF Ray Tracing and SAMI3: Integration and Refactoring

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Abstract

PyLAP is a high frequency (HF) ray tracing toolkit that is used to model radio wave propagation through the ionosphere. Currently PyLAP uses the empirical International Reference Ionosphere (IRI) model. In an effort to use PyLAP to observe more discrete structures in ionosphere that are otherwise unobservable with IRI, PyLAP is being Integrated with the Physics-based SAMI3 Model of the ionosphere. Along with this there will be an effort to refactor some of the current PyLAP codebase so that it is more readable and usable for anyone using the current system including both professional and citizen scientists.

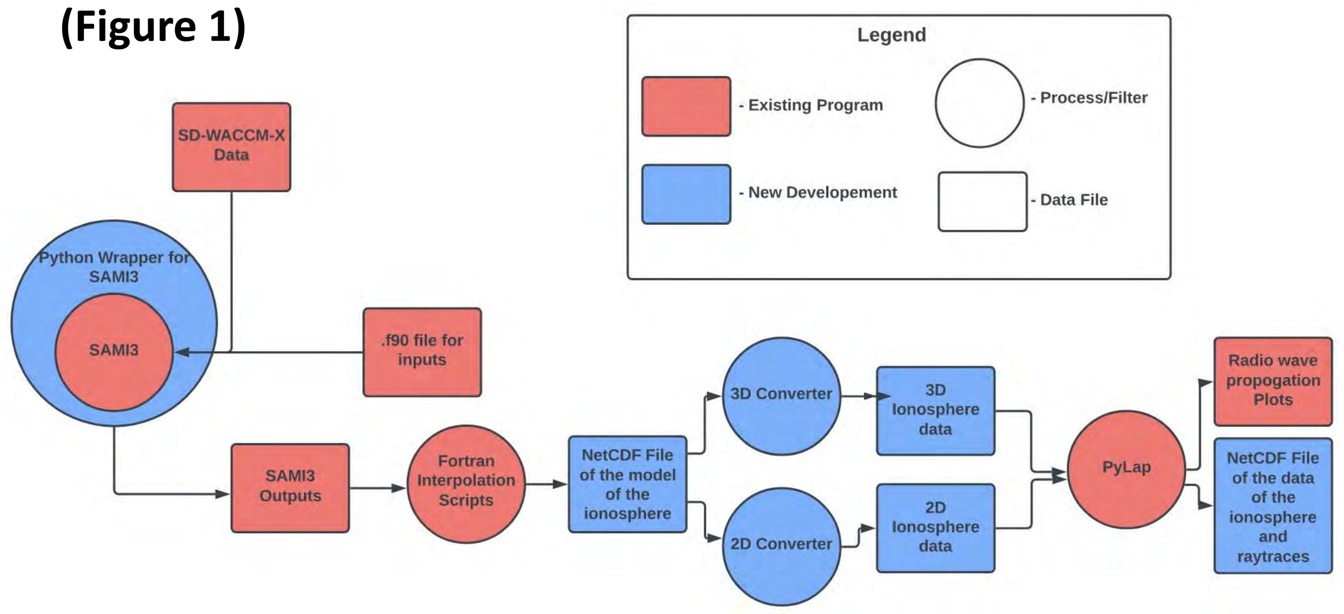
Introduction

Traveling Ionospheric Disturbances (TIDs) are space weather phenomenon caused by gravity waves or geomagnetic activity. These TIDs are disturbances in the electron density found within the ionosphere. Because of this, they also cause disturbances in HF radio communications and many other technologies that rely upon the ionosphere to work properly. In an effort to further study this phenomenon and others like it the SAMI3 Physics based model of the ionosphere along with PyLAP ionospheric raytracing toolkit are being integrated.

There are two main parts to this project, Refactoring the current code base so that it is usable and the actual integration itself. The current code base, being ported from MATLAB contains commented out code, methods that take way too many parameters, and methods with way too many lines of code. To remedy this before any development begins there will be an effort to fix some of these issue to make the code base more readable and usable for anyone who might be using it. The second part of the project, the integration will consist of the following. First, receiving a NetCDF file containing SAMI3 data in the form (latitude, longitude, altitude, time). Second transforming the SAMI3 data into a form that is usable by PyLAP for raytracing in both 3D and 2D. Lastly the production of NetCDF data files along the way to reproduce results or to use the data for other scientific applications.

Figure 1 proposed architecture for integration of SAMI3 and PyLAP.

(Figure 1)



Traveling Ionospheric Disturbance Modeling

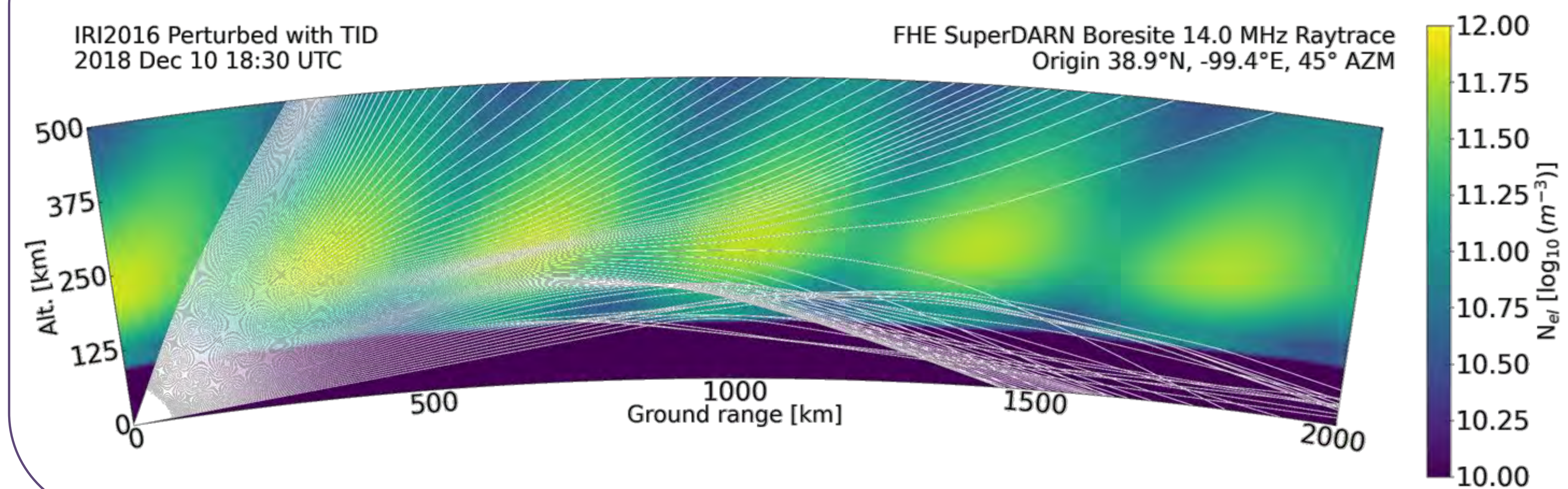
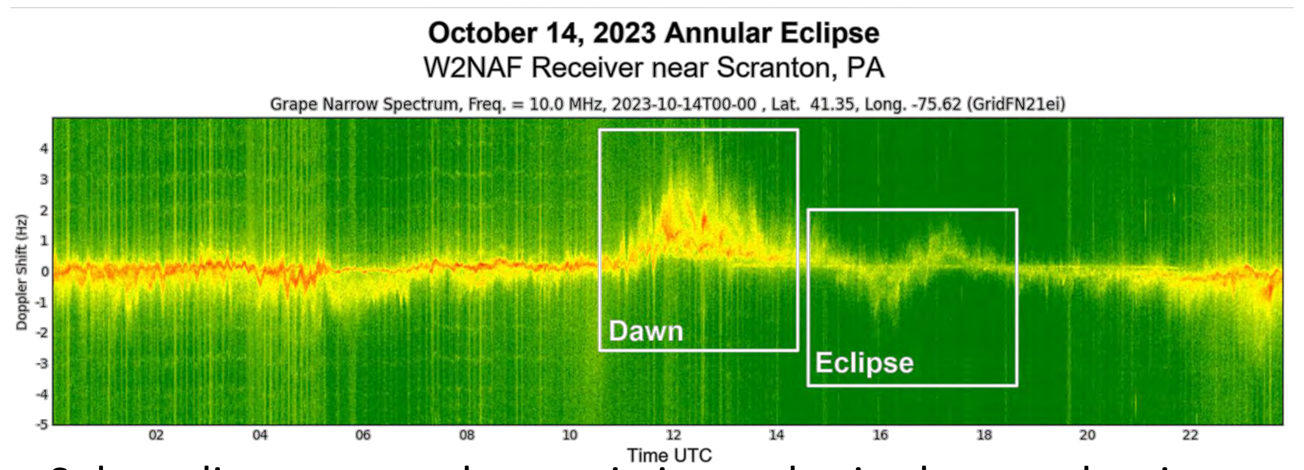


Figure 2 shows how SuperDARN radars and HF amateur radio communications sense TIDs. Colors indicate IRI electron densities artificially perturbed with a sinusoidal MSTID ($\lambda_h = 300$ km); white lines show ray traced 14 MHz radio waves. Electron density gradients created by the TID focus signals hitting the ground, creating regions of strong radar backscatter and good radio communications known as the skip focusing distance. The skip focusing distance moves in time as the TID passes overhead.

These results were generated by perturbing the IRI with a synthetic sinusoidal TID and passing that output to PyLAP/PHaRLAP.

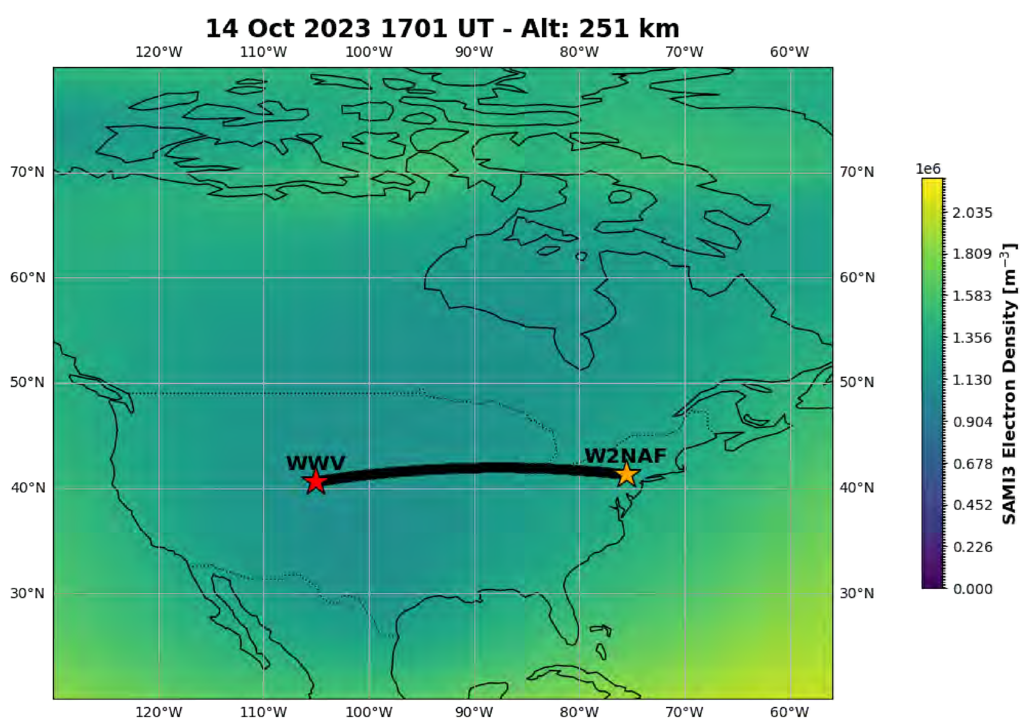
Modeling of Solar Eclipse Ionospheric and HF Propagation Effects



Solar eclipses cause changes in ionospheric electron density and to HF radio propagation. This can be seen in **Figure 3 (above)**, which shows HF Doppler Shifts of the 10 MHz WWV signal transmitted from Ft. Collins, CO received by the HamSCI Grape Personal Space Weather Station Receiver near Scranton, PA.

We will be modeling the solar eclipse HF propagation effects by using an eclipsed version of the SAMI3 physics-based ionospheric model and passing those results into PyLAP.

Figure 3 (right) shows the SAMI3 electron densities at 250 km altitude at 1701 UTC during the 14 October 2023 annular eclipse. The electron density clearly dips in the middle of the plot and follows the path of the solar eclipse. Work is underway to use these results in PyLAP.



Conclusion

SAMI3 will be integrated into PyLAP so that the community can make use of a physics-based model of the ionosphere. Currently the largest portion of work lies in getting the SAMI3 outputs to match what PyLAP expects for the data format of the ionosphere.

Future Work

In the near future ray tracing will be completed using SAMI3 outputs for the Ionosphere to produce plots in a similar fashion to how PyLAP does with IRI currently. There will also be work done to add regression testing. Beyond the scope of this thesis project there are also plans to improve the install process.

Acknowledgements

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