# PyLap: An Open-Source Python Interface to the PHaRLAP Ionospheric Raytracing Toolkit

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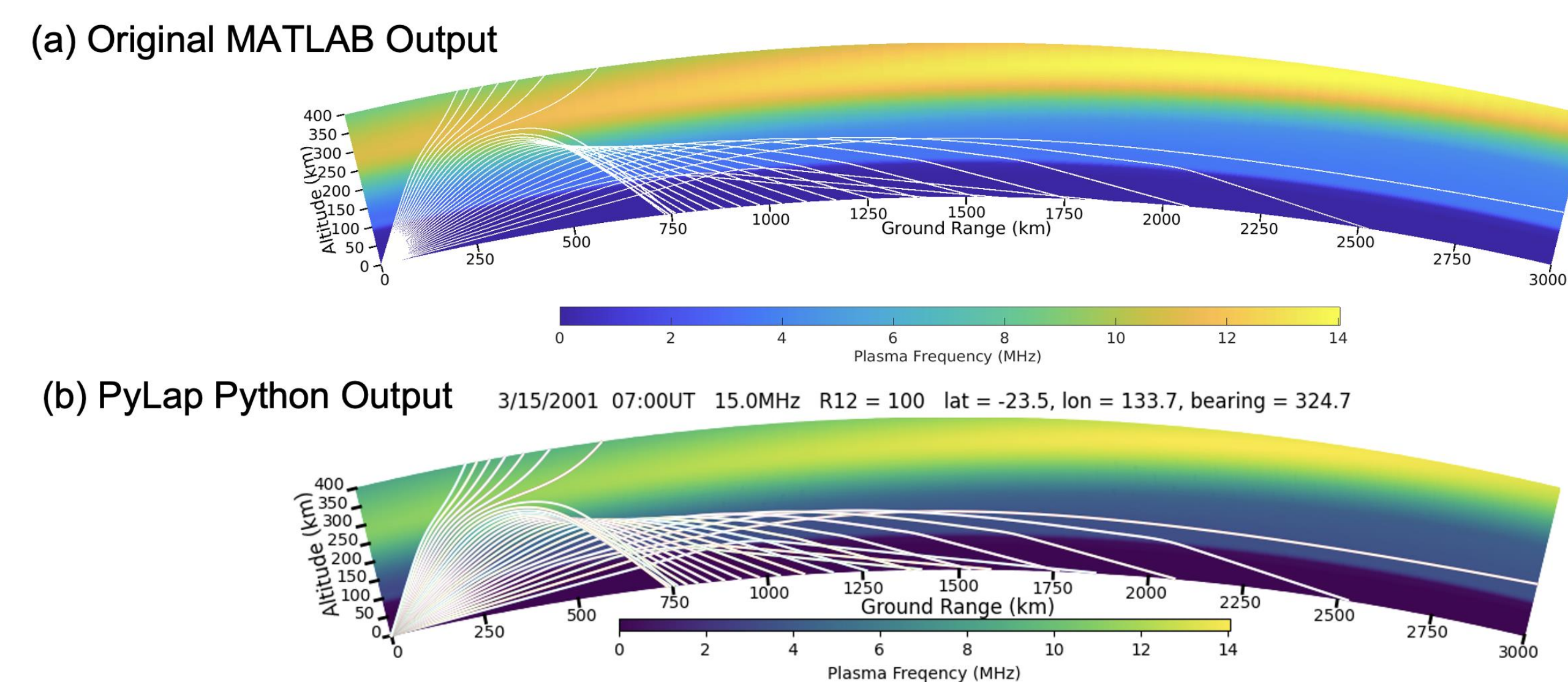[1]University of Scranton, [2]HamSCI Community, [3]Liles Innovations, LLC

## Abstract

PyLap is a Python interface to the ionospheric ray tracing toolkit PHaRLAP. The software allows users to generate accurate models of the ionosphere and ray tracing to make plots of radio propagation through the ionosphere. Not only does this software look, feel, and operate very similarly to how the MATLAB interface is currently used, it is also completely free alternative to the current MATLAB interface.

## Introduction

PHaRLAP is a radio ray tracing toolkit that makes use of ray tracing to accurately model the propagation of radio waves through the ionosphere. PHaRLAP is Written in Fortran and has been compiled against MathWorks mex libraries so that the MATLAB programming language can be used to call the routines. MATLAB is incredibly useful for graphing the ray tracing models but is expensive to use and introduces financial difficulty for many scientist or hobbyist trying to use the software.
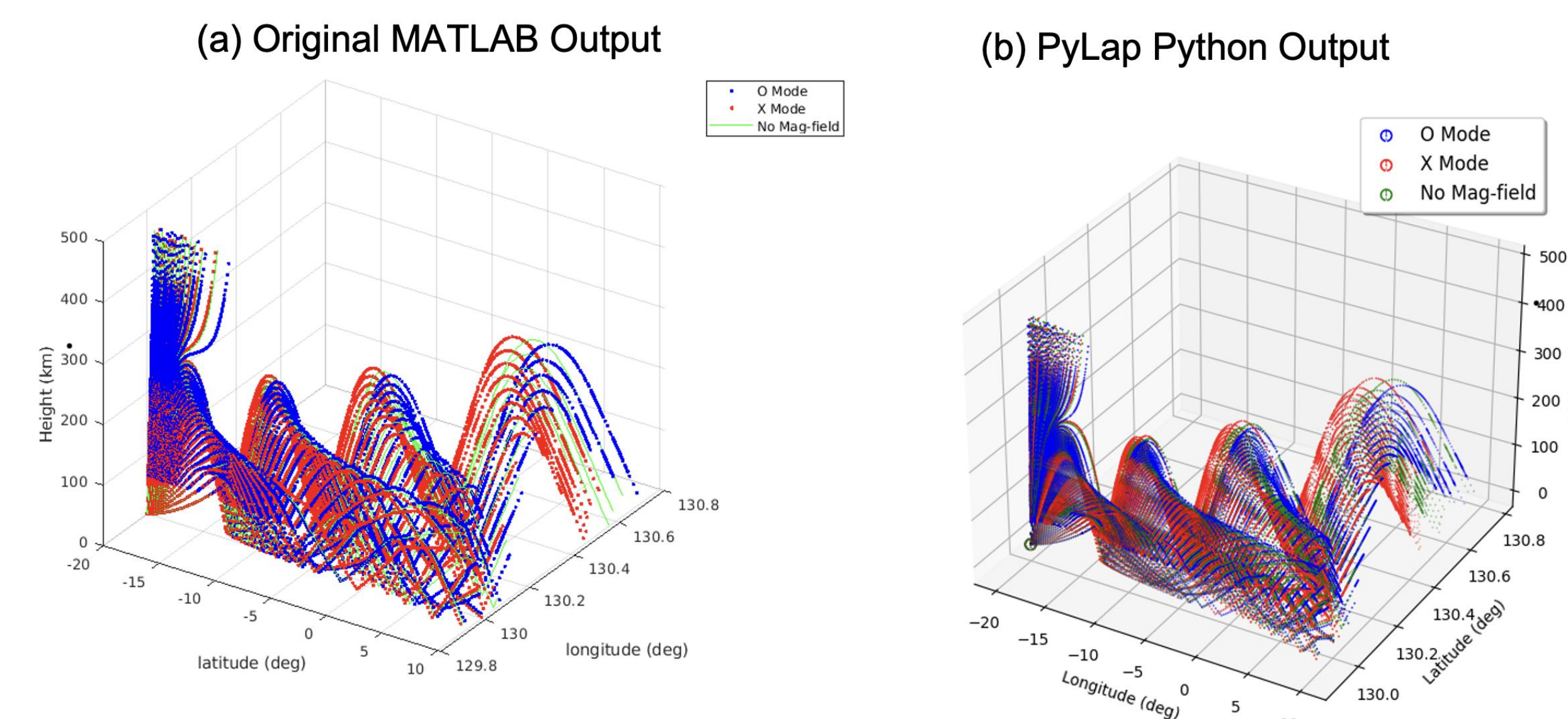
PyLap is a completely open-source interface for PHaRLAP which eliminates PHaRLAP's dependency on MATLAB. PyLap includes all of the core functionalities of PHaRLAP including Generating an ionosphere, ray tracing through the ionosphere, and plotting the ionosphere and ray traces. PyLap was developed in Python and C as an easy-to-use interface that is also opensource. Python was chosen in order to take advantage of many of its useful packages(NumPy and Matplotlib).

**(Figure 1)**



(a) Original MATLAB Output

(b) PyLap Python Output     3/15/2001  07:00UT  15.0MHz  R12 = 100  lat = -23.5, lon = 133.7, bearing = 324.7

**(Figure 1, Figure 2)** Both show a comparison between the original MATLAB output and the PyLap output for a 2D Raytrace, and 3D Raytrace respectively to depict the level of similarity between the two implementations.

## Method and Data Analysis

**(Figure 2)**



(a) Original MATLAB Output

(b) PyLap Python Output

**(Figure 3)** shows the Overall Architecture of the software with PyLap consisting of the user facing Python Code and the C Source files. Since PyLap is only an interface to PHaRLAP  the C Files are used to call both the Fortran numerical engine and the Fortran Peripheral calls to the International Reference Ionosphere(IRI) ionospheric model to retrieve the data needed to create plots to model radio wave propagation.
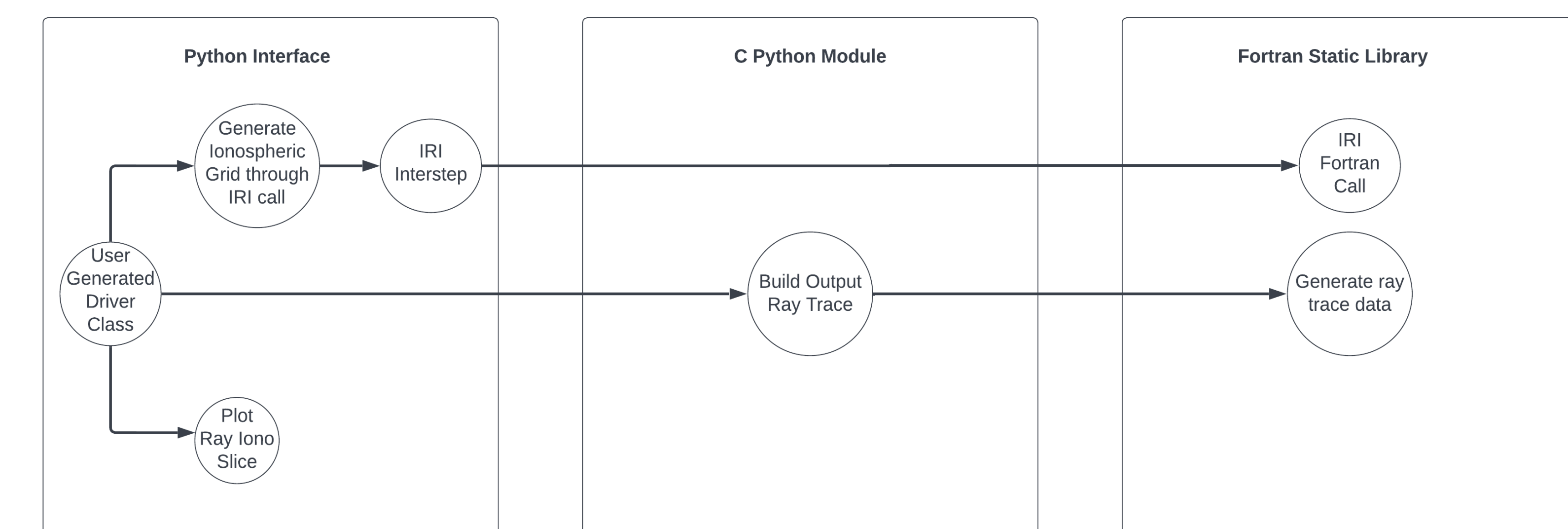
Work has also been done to further validate PyLap through testing and Porting over more example files from the MATLAB implementation to the Python implementation. This work to port over more example files has expanded the code base and also helped to find and fix other issues within the PyLap codebase. Along with this a shell script has been made to make the installation process for Linux easier. PyLap is also now available to the public on the HamSCI GitHub at **https://github.com/HamSCI**

**(Figure 3)**



## Conclusion

Given the comparisons that have been made and the data validation that has been done it can be seen that PyLap performs with a level of accuracy that is acceptable and also provides an open–source alternative to using PHaRLAP. This will impact the science community greatly bringing PHaRLAP to a much wider audience.

## Future Work

In the future PyLap will be made to work with the Sami3 model of the ionosphere instead of the Default IRI model. PyLap also still needs to be packaged so that I can be downloaded to run on both Windows and MacOS, right now it is only available on Linux.

## Acknowledgements

## References

Calderon, A. (2022). *Ray Tracing in Python Utilizing the PHaRLAP Engine*. Masters Thesis, The University of Scranton. https://digitalservices.scranton.edu/digital/collection/p15111coll1/id/1335/rec/3

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