Thermospheric Temperature Analysis Methods for the OPAL Mission

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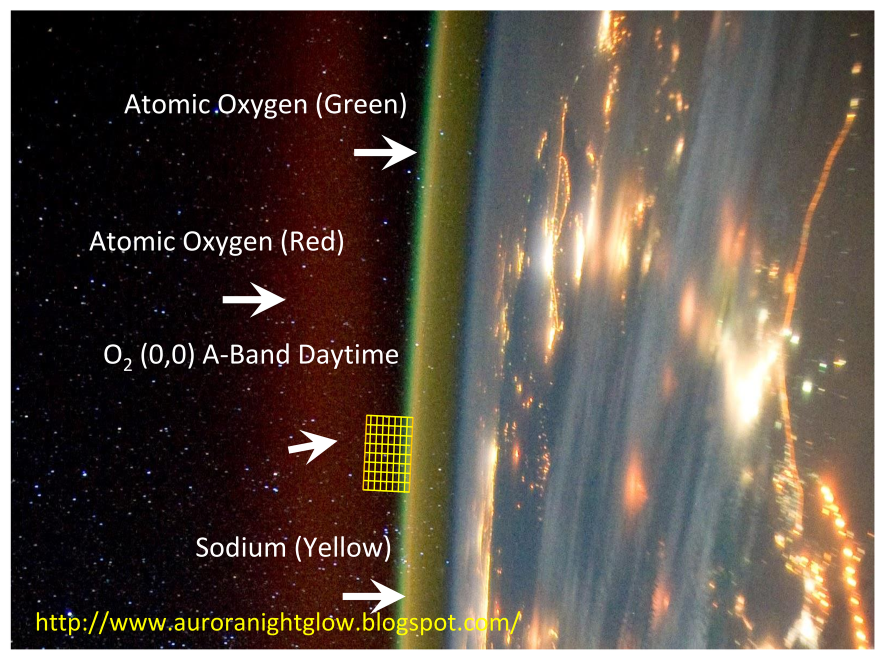
Optical Profiling of the Atmospheric Limb

Overview:

The Optical Profiling of the Atmospheric Limb (OPAL) mission is an NSF CubeSat which will measure the temperature in the lower thermosphere between 90 and 140 km via a tangential line-of-sight. Its instrument, a multi-slit imaging spectrometer, will allow the inference of temperatures in the transition region from the mesopause into the thermosphere and ionosphere.

Airglow: An Introduction

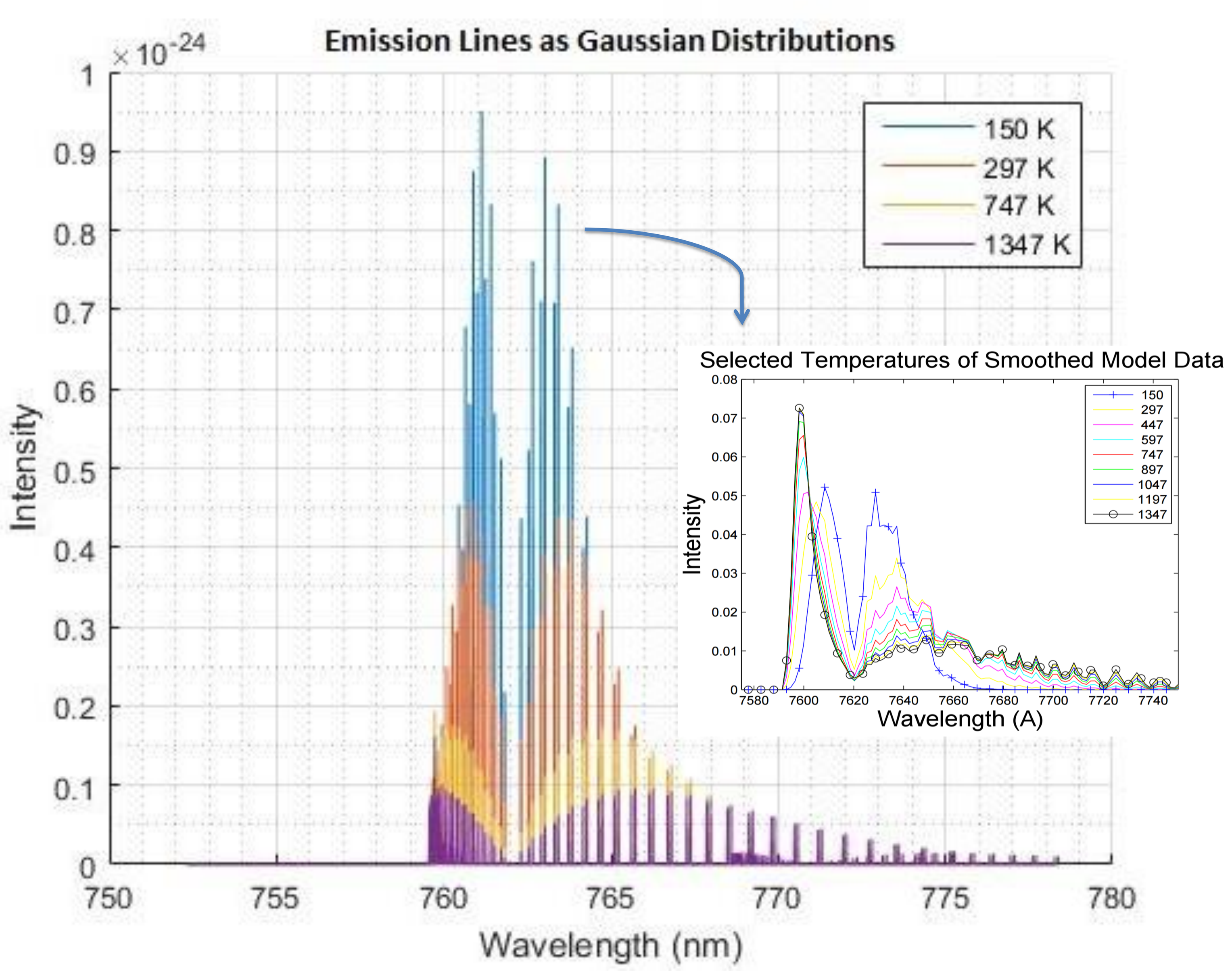
Airglow is a natural phenomena generated by excited gasses in the upper atmosphere. It originates in several different emission layers , being generated from various species. OPAL will study the O_2 A-band, to infer temperatures of the lower thermosphere. This region is highlighted by the yellow grid in the figure below.



The A-band lies just outside of visible, centered around 762 nm it consists of two bands and a series of rotational lines which give it fine structure. This structure is characteristic of the temperature of the 0_2 which emits it, allowing OPAL to make remote measurements of this transition region

Temperature Dependent Spectra

OPAL will measure the 0_2 A-band to determine neutral temperature. The strength of each rotational mode of the electronic transition is highly temperature dependent. By comparing a measured spectrum to the modeled A-band the atmospheric temperature can be determined. [Sullivan,2013]

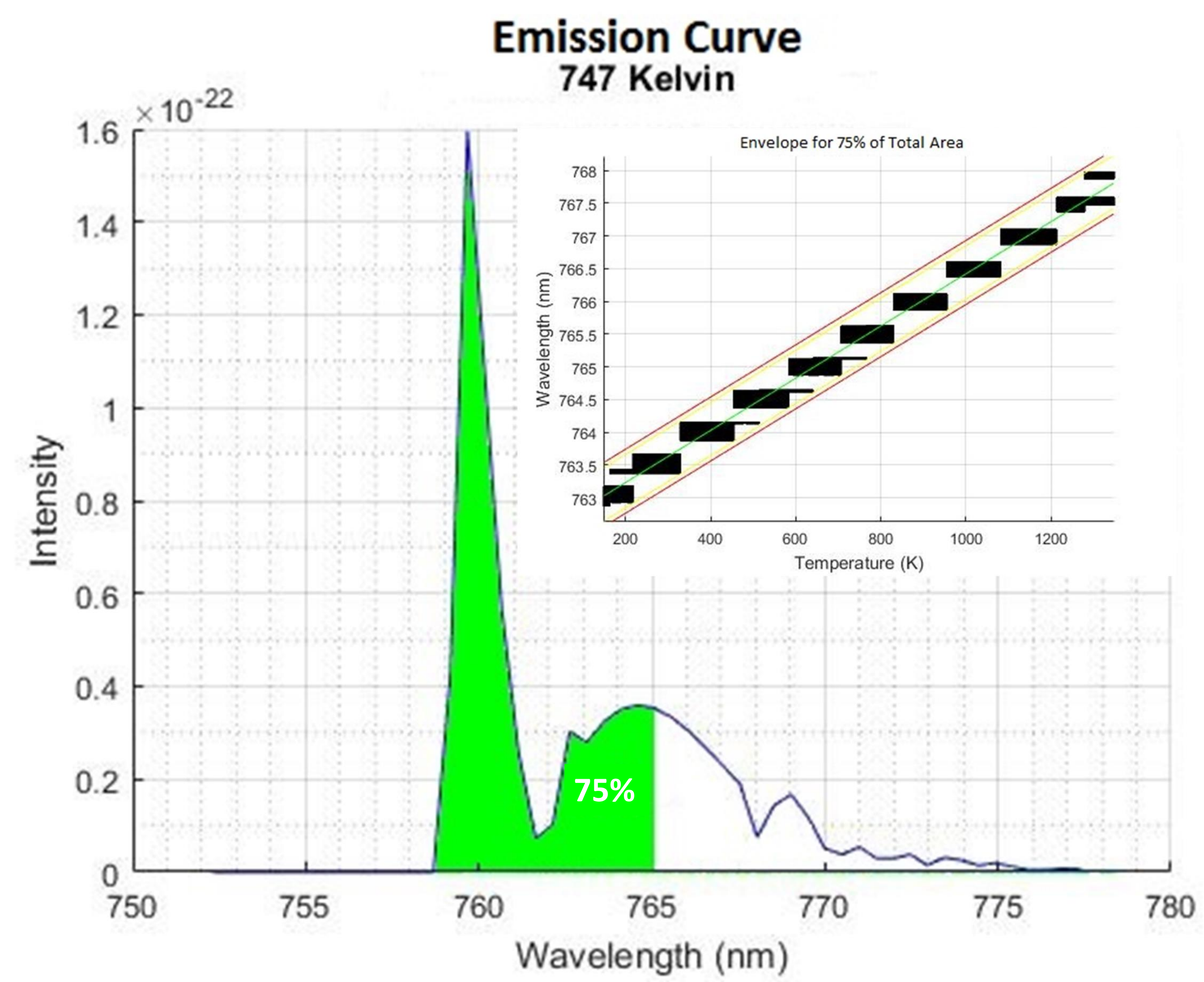


The OPAL instrument is binned to a spectral resolution of 0.5 nm. The fine structure of the spectrum is smoothed by instrument resolution. However, the spectrum shape is still characteristic of temperature..

Recognizing Emission Curves:

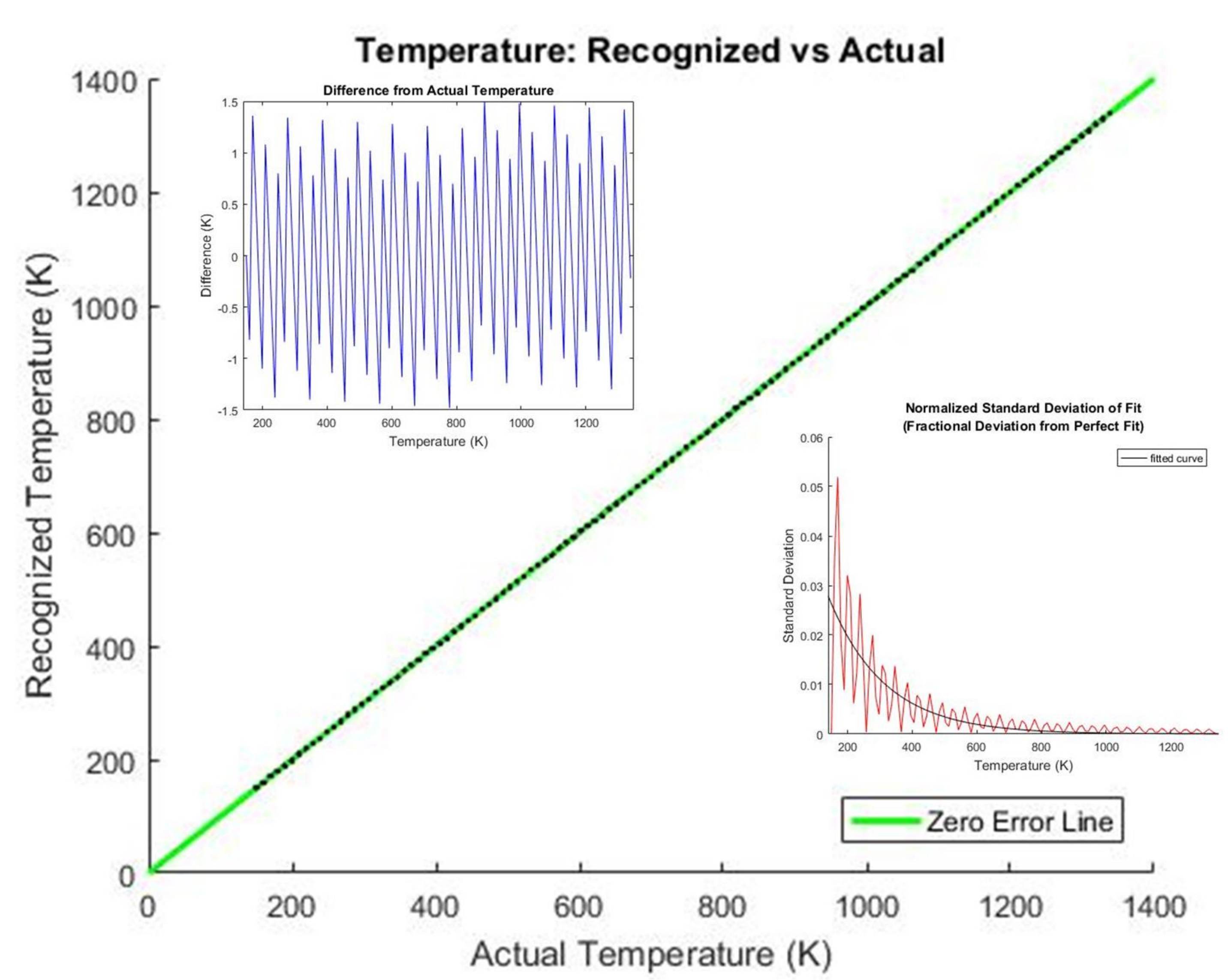
Absolute strength of emission lines are not necessary to obtain temperatures, and therefore onboard calibration is not required. The temperature recognition software first narrows down the possible temperature by locating the wavelength at which the integral of the spectrum is equal to 0.75 of the integral of the entire spectrum. This gives a narrow band in which to make a point by point comparison of full spectra

Narrowing Down: Percent of Integral approach



Finding the point at which the integral is 0 75% of the whole, allows one of the black boxes in the inset to be selected for further analysis.

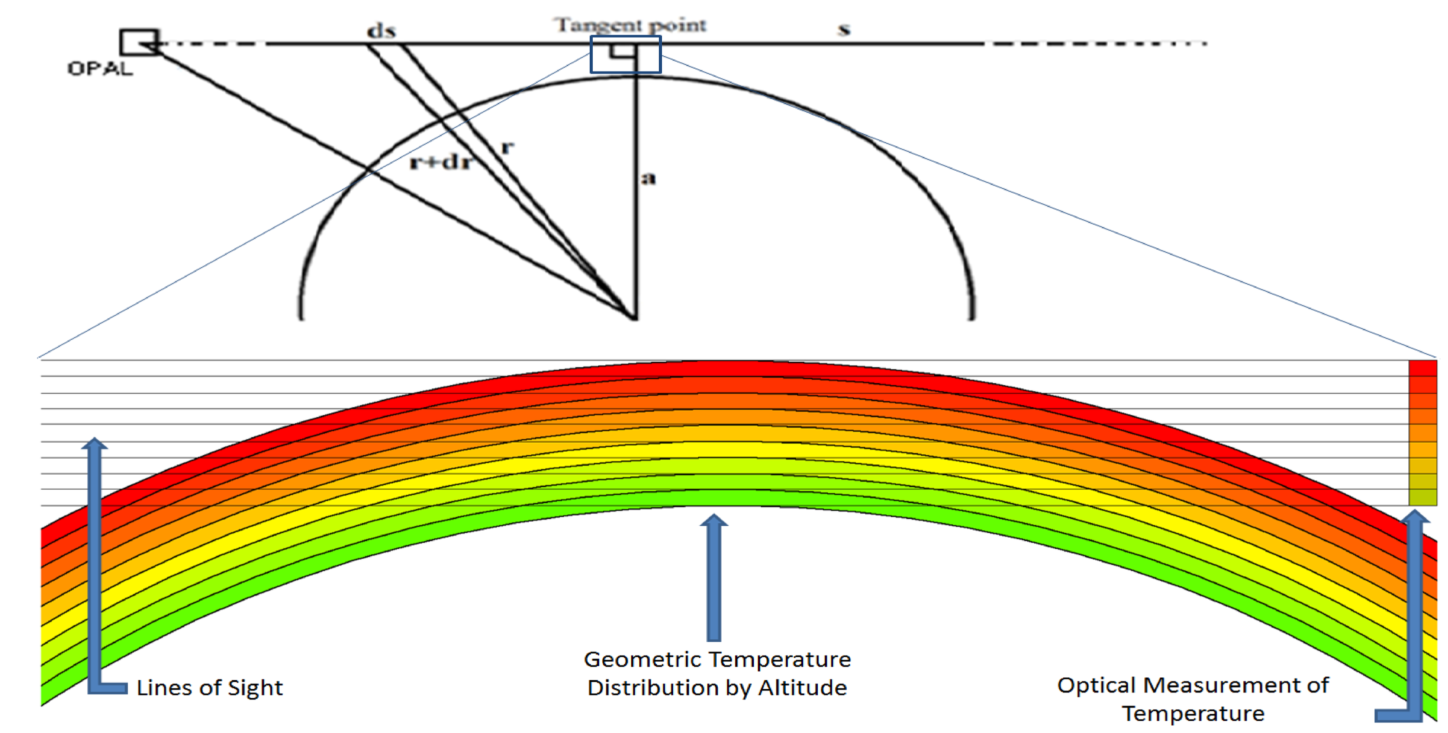
Pinpointing: Point-to-Point Model Comparison



This figure shows the success of the temperature recognition software, having error of <1.5 K..

Inversion of Line of Sight measurements:

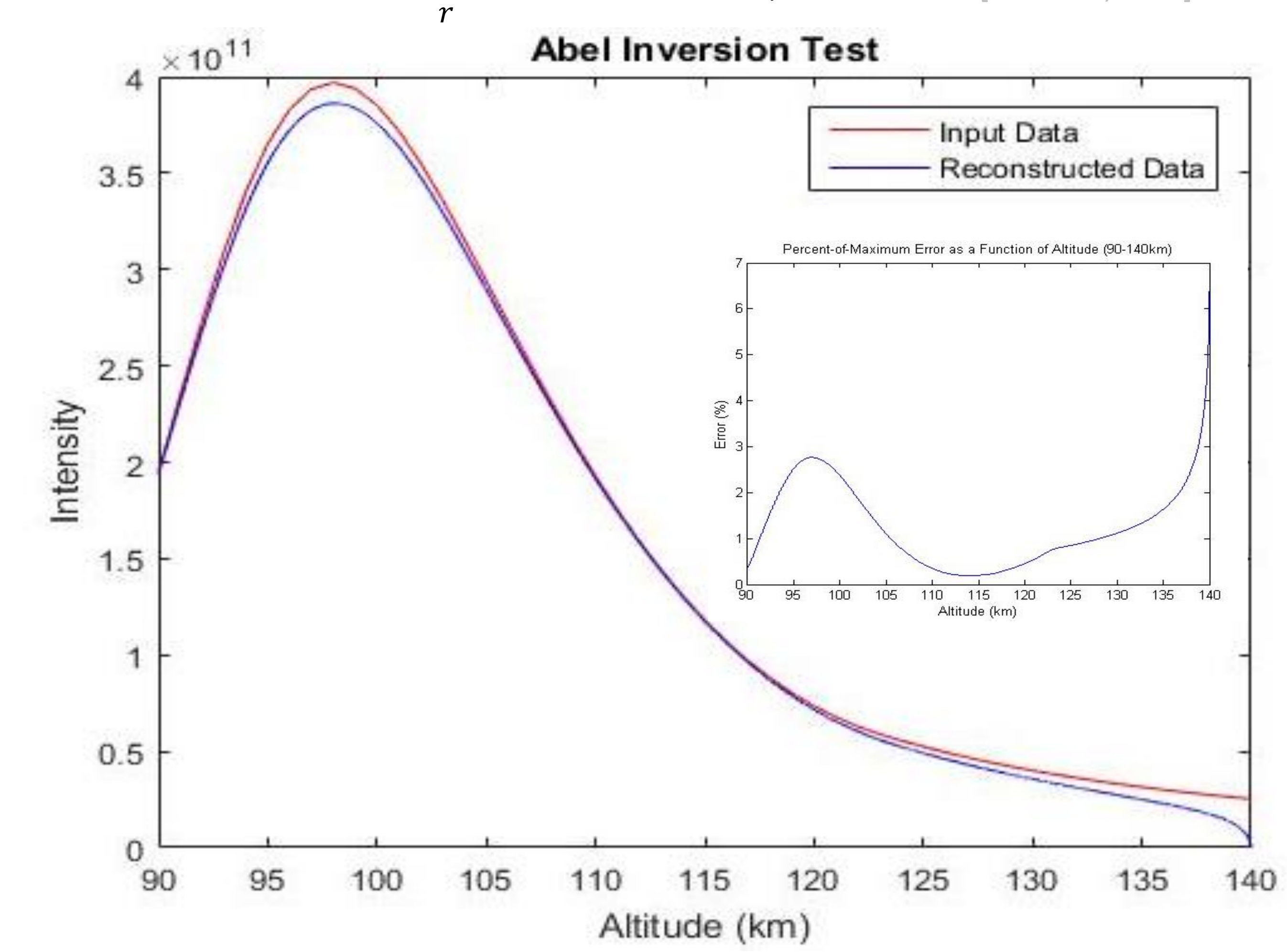
An Abel inversion technique, borrowed from radio occultation methods, allows a line of sight integrated measurement to be reassembled into 3 dimensional sampling



Visualization of the difficulties of Line-of-Sight (LOS) measurements

$$I_\lambda(r) = \frac{-1}{\pi}\int_r^{r_{OPAL}} \frac{d}{da}\left(S_{LOS}(a)\right)\frac{da}{\sqrt{a^2 - r^2}}$$

Adapted from [Lomidze,2015]



A test of the Abel inversion shows that it is able to reconstruct the data quite well, with the percent error as a function of altitude shown on the inset graph

Conclusion:

- The ability to determine temperatures with less than 1.5 K uncertainty is demonstrated
- The process of deconvolution of the profile data from a line-of-sight measurement is demonstrated
- Future work will combine these processes to describe a final uncertainty in the measurement of temperature for the OPAL mission

References:

Levan Lomidze, "The Role of Thermospheric Neutral Winds in the Mid-latitude Ionospheric Evening Anomalies," Doctoral Dissertation, Utah State University (2015).

Stephanie Whalen Sullivan, "Optical sensors for mapping temperature and winds in the thermosphere from a CubeSat platform," Master Thesis, Utah State University (2013).