Investigating the OPAL Cubesat's Ability to Measure Thermospheric Gravity Waves

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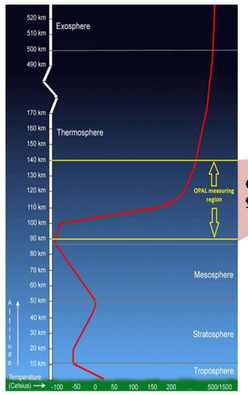
Optical Profiling of the Atmospheric Limb

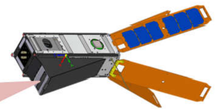
Introduction

Understanding the Earth's lower thermosphere is of high interest to the space science community because of competing forcing due to solar heating above and episodic wave forcing from below. The NSF sponsored OPAL cubesat is designed to measure the temperature profile in this region by observing day-time O2 A-band (~760nm) emission on the limb and is expected to be launched from the ISS (International Space Station). To investigate the instrument's ability to detect space weather signatures (i.e. solar storms and gravity waves) we have developed a suite of models that simulate the flight track of the satellite, the attitude of its optical systems, as well as the expected atmospheric O2 A-band observations that will be seen by the instrument. These models combine in a virtual CCD image that is used to develop and test different OPAL running modes for gravity wave detection.

OPAL Region of Interest



OPAL is expected to be launched from the ISS in Spring 2019.



OPAL is a 3U cubesat that will measure the daytime O_2 A-band (~760nm) emissions to derive thermosphere temperatures.

Hyperspectral Imager

OPAL uses a hyperspectral imager with a rectangular Field of View (FOV). The FOV is broken into seven smaller fields by the slit array.

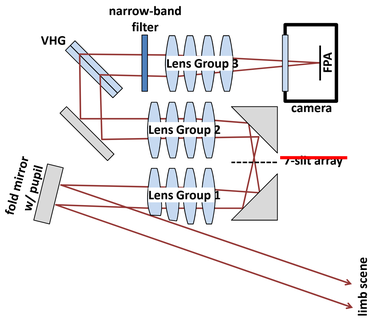
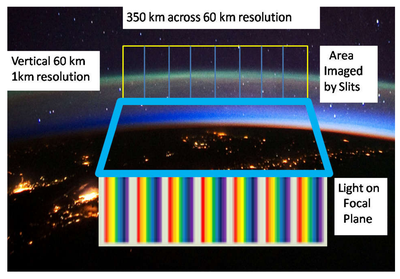


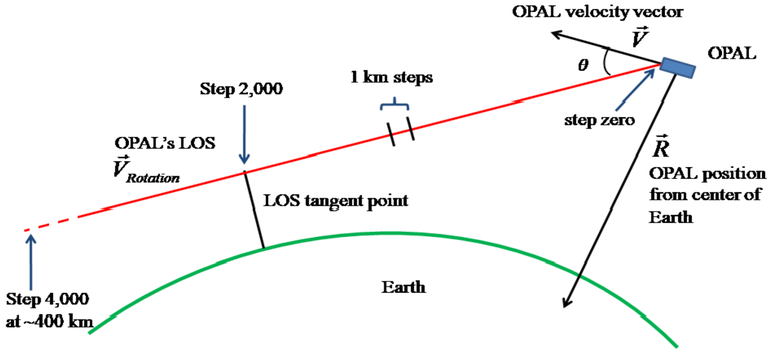
Diagram of OPAL instrument [Marchant et al .2014].



OPAL total FOV and slit FOV with depiction of spectral analysis on CCD

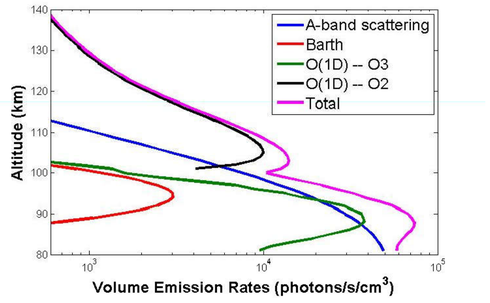
Flight Modeling

Modeled after the ISS flight path, OPAL points forward through the atmospheric limb to image the A-band emissions.



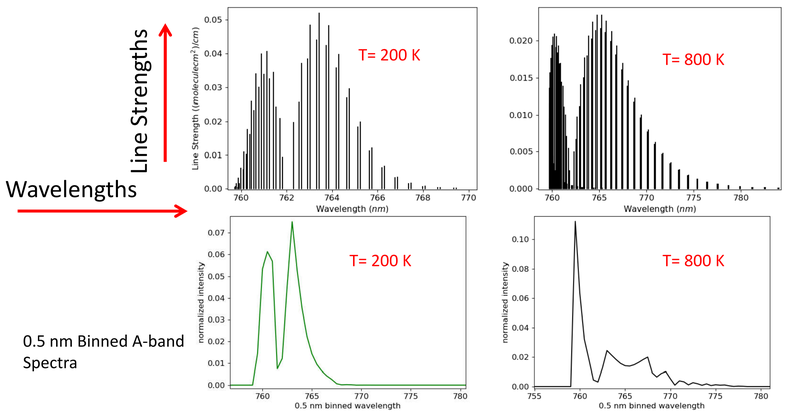
Atmospheric Model for A-Band Emissions

The intensity of the A-band volume emission rate varies with solar radiation, densities of several atmospheric molecules, and the temperature



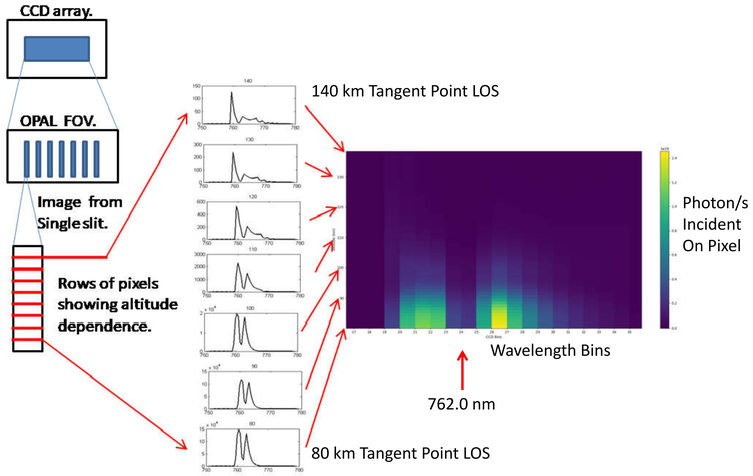
Example of the main contributors to the volume emission as a function of altitude. The neutral densities and temperature were taken from MSIS-E 90.

The A-band spectrum has a strong temperature dependence.

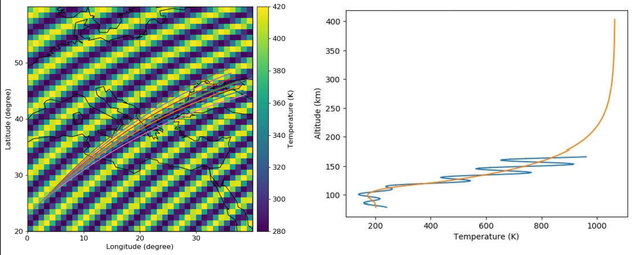


OPAL Virtual CCD Image

Virtual hyperspectral CCD construction using instrument parameters.



Simple Gravity Wave Model

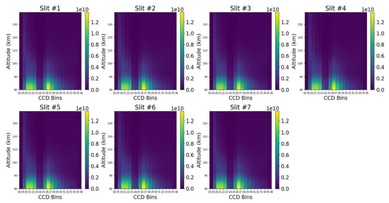


A simple model for a gravity wave with a vertical (15 km) and horizontal (400 km) wavelength was used to perturb the neutral temperature by 20%.

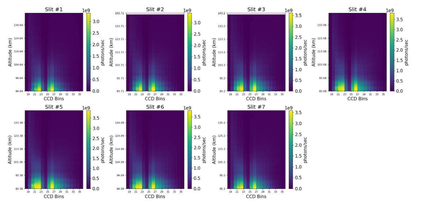
Virtual CCD Wave Analysis

To analyze the effects of the gravity wave on the OPAL virtual images, they were contrasted with those corresponding to background conditions.

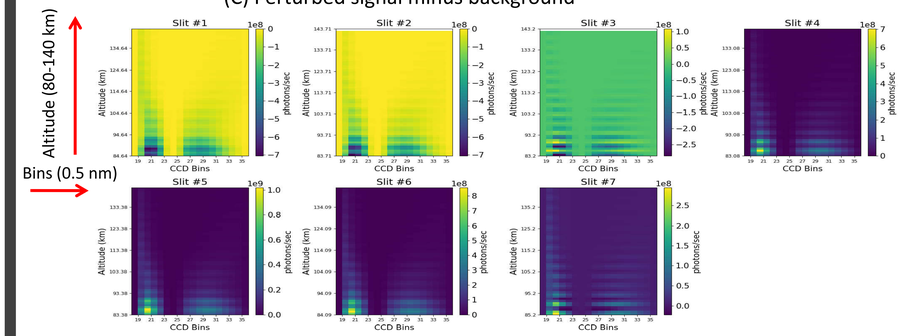
(A) Unperturbed/background image.



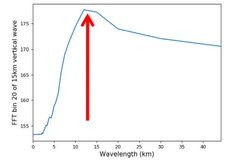
(B) Perturbed signal from simple GW model.



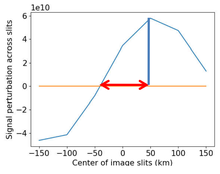
(C) Perturbed signal minus background



(E) FFT of bin 20 from either slit image.



(D) Plot of total signal in each slit.



Results

Using a careful selection of the CCD bins for analysis, our results indicate that OPAL will be able to observe gravity waves.