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OPAL CubeSat Data Analysis Model

Kenneth Zia
Utah State University

Ludger Scherliess
Utah State University

Michael J. Taylor
Utah State University

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Kenneth Zia, Ludger Scherliess, Michael Taylor, and the OPAL team
USU Department of Physics & Center for Atmospheric and Space Science
Phone: (435) 797-2857, E-mail:kennethzia@gmail.com

Optical Profiling of the Atmospheric Limb

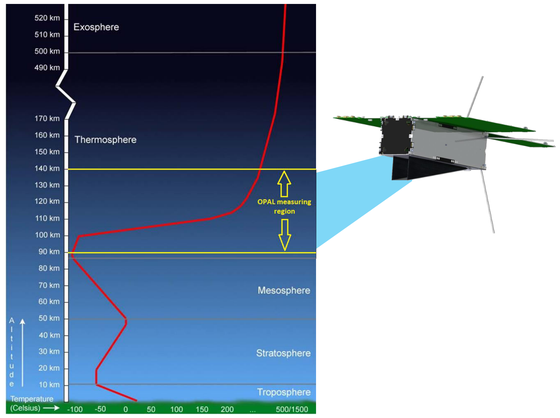
Abstract

Understanding the Earth's lower thermosphere (altitude range 90km-140km) is of growing interest for many areas of research within the space weather community. The NSF sponsored OPAL (Optical Profiling of the Atmospheric Limb) mission is designed to measure temperature profile by observing the integrated line of sight of the day-time O_2 A-band (~760nm) emissions on the limb. The OPAL instrument has an altitude resolution of 1.03km from 80-160km flown on a 3U CubeSat, and is expected to be launched from the ISS (International Space Station) (~400km altitude). We have developed a model of OPAL's position and attitude of its optical system to investigate the instrument's ability to detect space weather signatures (i.e. solar storms and gravity waves) in the lower thermosphere temperature data. Models of the flight, line-of-sight, and atmospheric O_2 A-band emission are used to simulate the expected output of the OPAL instrument. The simulated emission will be used in an inversion method to obtain the altitudinal temperature profile in the lower thermosphere to test our ability to resolve the input parameters of the lower thermospheric model.

Mission Overview

OPAL is a 3U (10X10X30cm) CubeSat measuring the daytime thermosphere temperatures.

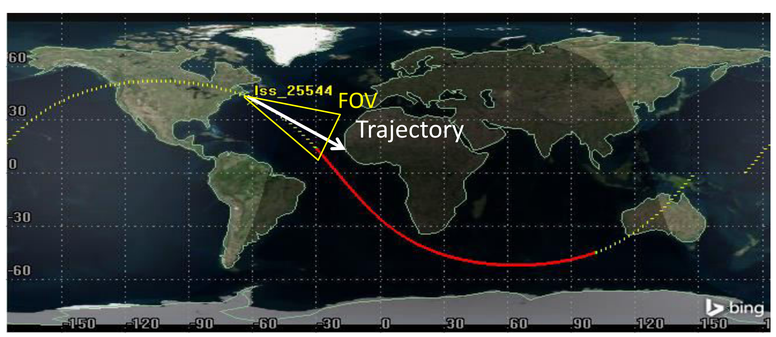
OPAL will observe the temperature from 90-140km altitude through observing day-time emissions of O_2 A-band (~760nm) emissions.



Plot of temperature vs. altitude with labeled atmospheric layers. Also shown is the OPAL observing region .

Flight Modeling

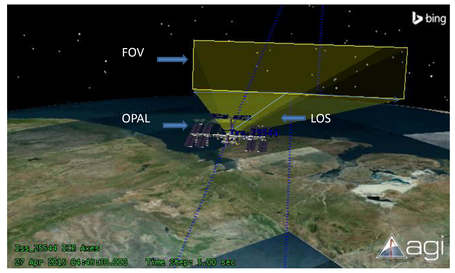
Using Matlab and Analysis Graphics Inc. (AGI) Systems Took Kit (STK), we model the OPAL position and velocity. The expected launch for OPAL is Spring 2018 from the International Space Station (ISS), and is modeled with an orbit at ~400km altitude. The OPAL instrument's field of view (FOV): width 11 deg height 2.5 deg.



2-D map of the OPAL model with Yellow representing sunlit regions, and red in the umbra regions.

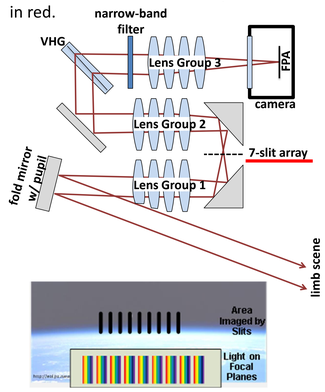
Instrument Field of View

The FOV is rectangular due to the geometry of the aperture. This horizontal FOV is broken into seven smaller fields by the slit array in the OPAL instrument.



Model of the OPAL (3D-modeled with the ISS) orbit (blue), FOV (yellow), and light blue line denoting tangential line of sight (LOS).

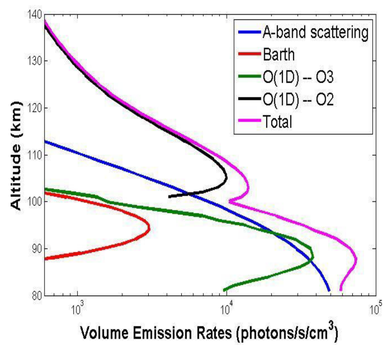
The OPAL instruments optical path with the placement of the slit array underlined in red.



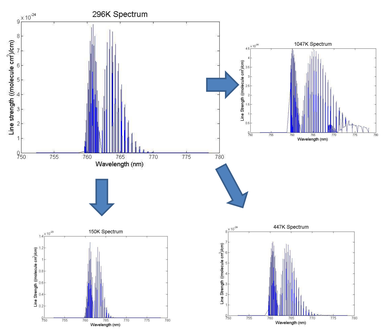
The limb source with the slit array superimposed with its imaging.

Atmospheric Model for A-Band Volume Emission Rates

The intensity of the A-band volume emission rate varies with solar radiation, densities of several atmospheric molecules, and the temperature (all of which have spatial and temporal dependencies). The figure to the right shows and 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.



Spectral Model for A-Band Emissions



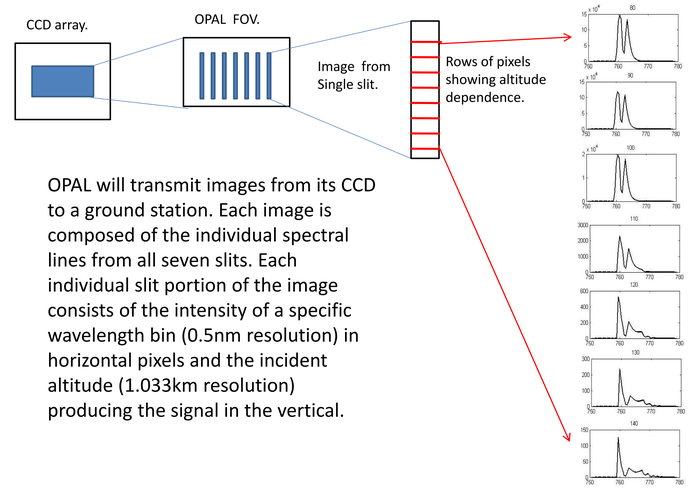
Atmospheric A-band spectral lines at standard temperature (top left), at T=150K (bottom left), T=447K (bottom right), and T=1047K (top right).

The A-band ranges from about 750nm to 770nm. Within that range the spectral shape has a distinct temperature dependence that is characterized by : [2]

$$S_\lambda(T) = \frac{S_\lambda(T_s)T_s}{T}\exp\left(\frac{1.439E''_\lambda\,(T-T_s)}{TT_s}\right)$$

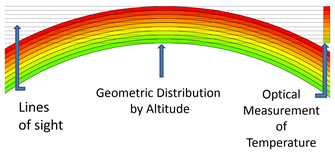
Where the S_λ is the emission/ absorption line strength at wavelength,λ, and temperature, T. T_S is the standard temperature (~296 K), making $S_\lambda(T_S)$ the line strength at standard temperature, and E''_λ is the energy of the lower state of the transition. All aforementioned variables are given by HITRAN.

OPAL output



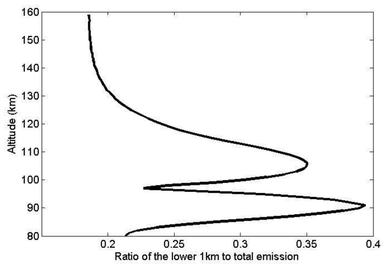
OPAL will transmit images from its CCD to a ground station. Each image is composed of the individual spectral lines from all seven slits. Each individual slit portion of the image consists of the intensity of a specific wavelength bin (0.5nm resolution) in horizontal pixels and the incident altitude (1.033km resolution) producing the signal in the vertical.

Analysis/Future Work



Each OPAL spectrum is an integrated observation along the line of sight.

The figure to the right shows the percentage of each line of sight emission that comes from its lowest 1km in altitude.
The figure shows that a significant portion of these emissions originate from altitudes higher than 1km above the tangent point.



In order to obtain the altitude profile of the temperature the convoluted line of sight observations need to be inverted.

Useful References & Acknowledgements

[1] Christensen, A. B., J.-H. Yee, R. L. Bishop, S. A. Budzien, J. H. Hecht, G. Sivjee, and A. W. Stephan (2012), Observations of molecular oxygen Atmospheric band emission in the thermosphere using the near infrared spectrometer on the ISS/RAIDS experiment, J. Geophys. Res., 117, A04315, doi:10.1029/2011JA016838.
[2] Sheese, Patrick. Mesospheric ozone densities retieved from OSIRIS observations of the oxygen A-band dayglow. Doctoral Dissertation, York University, 2009.

The OPAL team consists of students at Utah State University and University of Maryland Eastern Shore University, as well as professional scientists and engineers from the USU/Space Dynamics Laboratory, Hawk Institute, and Dixie State University.