Generation of Altitude Profiles of the Hydroxyl Airglow

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ABSTRACT

Research was done to generate altitude profiles of various bands using real data from SABER. The main purpose is to design a theoretical spectrometer based on the results obtained using the spectrometer aboard SABER. [3]

The main approach is to generate a theoretical model which uses the limb scan profile obtained from SABER and generates the profiles. This model will then be integrated into the larger framework to essentially find the radiance at a point given the temperature.

I. INTRODUCTION

SABER is one of the four instruments on NASA’s TIMED (Thermosphere Ionosphere Mesosphere Energetic Dynamics) mission. The instrument was launched into space by a Delta II rocket on December 7, 2001 from the Western Test Range. More information on the SABER instrument can be found at [3].

The presence of hydroxyl ions in the upper atmosphere gives rise to intense radiation in the wavelengths from 2.6 to 4.4 μm. The modeling of such radiation is very important. The height distribution of the OH radiation is of importance in interpretation of its production mechanisms.

The model which uses the approach being described will itself be used as a sub system in a larger framework which is devised to generate radiance plots at various temperatures in the atmosphere.

II. APPROACH

The main approach here was based on the requirement that given a band and a resolution level, an OH altitude profile had to be generated. Various parameters come into play when this process is done. The model that is being generated uses the data from the SABER instrument and then we generate the altitude profiles using the approach described in this paper. Now since we use the data from a rocket/satellite we have to consider certain parameters in the model. These are tabulated in Table 1. [2]

Table 1. Factors to be considered in rocket and satellite measurements of OH airglow properties.

<table>
<thead>
<tr>
<th>Field of View</th>
<th>Aspect Geometry</th>
<th>Spin and Precession</th>
<th>Ascent Velocity</th>
<th>Overlapping Spectra</th>
<th>Continuum Airglow</th>
<th>Starlight</th>
<th>Differentiation</th>
<th>Distributed Nature of Light itself</th>
</tr>
</thead>
</table>

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These parameters are to be considered to generate an accurate model of hydroxyl emissions. The main approach that's taken in this paper is to generate a basic model then modifying the model to consider each of the above said parameters. The main reason behind this method is that the basic model needs most of the design and implementation.

The approach in this model is to generate a volume matrix and then use matrix operations to determine the altitude profiles. The volume matrix is characterized by some properties which are listed below:

1. The size of the matrix is determined by the resolution level chosen at the beginning.
2. The matrix in case of a pencil beam approach which is described in this paper will be an upper triangular matrix regardless of the resolution or the altitude.

Taking this into nature, volume matrices were generated for various possible resolutions and stored and then accessed as and when required. It should be noted here that the generation of the volume matrix changes with each new approach. This matrix is essentially generated by using a series of trigonometric identities and applying them to spatial nodes that are generated.

The main principle in all these methods that are going to be adopted is outlined below.

A volume matrix is generated which basically contains volume areas in each of the atmospheric cells that have been generated. Let us call it “A”. Now from the data coming from the SABER instrument we can generate a limb scan profile containing the data for the given distance domain. Let us call this “L”. Now let “P” be a row vector having the radiance values at the distances required (based on the resolution given).

Then we can conclude that

\[ P \times A = L \]  \hspace{1cm} (1)

And hence

\[ P = L \times A^{-1} \]  \hspace{1cm} (2)

The above result holds well only if A satisfies the regular matrix inverse conditions. The matrix inverse algorithms were verified using two modeling software’s namely MATLAB 6.0 and Mathematica 4.1.

III PENCIL BEAM

The first approach that was done was the “Pencil Beam” approach. This method was basically implemented to test the design method that was thought of earlier. The main assumption in this approach is the atmosphere is considered to be optically thin.

The entire atmosphere is divided into shells as shown in figure (1)

![Figure 1](image)

As shown the atmosphere is divided into shells with the spacing between the shells equal to the resolution that was needed.
The SABER instrument performs multiple scans during its movement. Each scan is treated as a pencil beam and the scan passes through each shell and reaches the tangent point altitude shown in the figure as tpalt. Data obtained from each of the SABER scan is actually the total sum of the radiation in that directions of the pencil beam. The total radiance value is due to the cumulative effect of each of the small volume areas as shown in figure (2).

Each single scan passes through a certain da in each atmospheric layer.

Each of these areas contributes to the total radiance seen by SABER.

Figure 2

Now considering each volume area separately and generating a matrix for each shell we obtain the volume matrix A. Essentially what this shows is that the radiation $L$ for that scan is

$L = A_{11} \times \text{radiance per unit area}$ where $A_{11}$ indicates the volume area of the first layer.

Now from the limb scan profiles we use cubic interpolation to determine the radiance at the specific tangent point altitudes as shown in figure (3) which can be represented as

$L = [L_1, L_2, ..., L_N]$

Figure 2

The volume areas are calculated using trigonometric identities. So finally, in matrix form we have

$$[L_1, L_2, ..., L_N] = [P_1, P_2, ..., P_N] \cdot [A_{11}, A_{12}, ..., A_{1N}]$$
$$[A_{21}, A_{22}, ..., A_{2N}]$$
$$[... ... ...]$$
$$[A_{N1}, A_{N2}, ..., A_{NN}]$$

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Where $N$, is the number of shells that are generated and $P_1, \ldots, P_N$ are the radiance values at the respective tangent point altitudes. $N = \text{Total Range} / \text{Resolution}$

The total range used in this model is $60 - 130 \text{ km}$.

From the above matrix operation we can hence generate $[P_1, P_2, ..., P_N]$ through a process of matrix inversion as

$$[P_1, P_2, ..., P_N] = [L_1, L_2, ..., L_N] \cdot A^{-1}$$

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The main underlying fact here in the whole process is that the tangent point altitudes are in fact some altitudes above the surface of the earth and hence can be used as a reference themselves. The altitude profiles were generated with 5 different resolution levels of 1 km, 0.5 km, 0.2 km and 0.1 km. These are shown in figures (3-6).
Resolution – 1 km
Figure 3

Resolution – 0.5 km
Figure 4

Resolution – 0.2 km
Figure 5

Resolution – 0.1 km
Figure 6

The above simulation results are generated using the following limb scan profile

Date: year 2002 day 110
(April 20 2002) Time: 1:38:00
Tangent Point Latitude, Longitude: 21.4°, 292.3°

With the above said approach we can see that the maximum radiation occurs at a distance of about 85.5 km.

IV. 2-D APPROACH

The pencil beam approach is now modified to include the field of view of the SABER instrument. The field of view is modeled using a Gaussian curve as of now. They will later on be replaced by the actual calibration curves obtained from the SABER ground calibration report [4]. This approach also involves using a cone instead of a pencil beam. The computations done are similar to the earlier case i.e. to develop a volume matrix and then find the radiance at each of the tangent point altitudes.

V. CONCLUSION

The altitudes profiles generate do match the actual profiles described in
[1]. But considering the various factors affecting rocket borne measurements we have to develop the model accordingly. The 2-D approach will be modified to include the atmospheric attenuation. Also the model will be included in the main framework to generate temperature profiles of the hydroxyl emission.

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REFERENCES


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