Multiple Peaks in SABER Mesospheric OH Emission Altitude Profiles

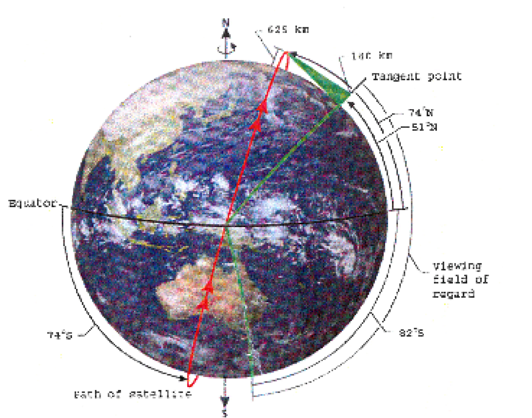
Jordan Rozum[1], Gene A. Ware[1], Doran J. Baker[1], Martin G. Mlynczak[2], James M. Russell[3]

[1]Utah State University, Logan, UT, United States.
[2]NASA Langley Research Center, Hampton, VA, United States.
[3]Hampton University, Hampton, VA, United States.

LaRC

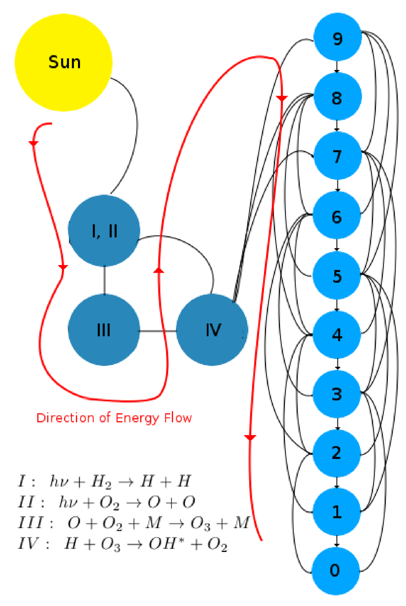
SABER Overview

One of the goals of the SABER mission is to provide long-term global measurements of hydroxyl airglow emissions in the Earth's mesosphere. The instrument does this by performing limb scans of the atmospheric emission spectra in the infrared, which are then processed off-site to generate altitude profiles. Over the past decade, SABER has scanned millions of airglow altitude distributions, such as depicted herein, which help provide insight into the Sun-Earth energy balance and atmospheric dynamics.



When SABER scans the atmosphere, it obtains integrated OH intensities along the line of sight; that is, it detects OH emissions from the airglow through the optically thin limb of the atmosphere. To obtain a vertical emission profile, a simple "onion skin" model is used: the radiance of higher layers is subtracted from lower layers. This technique is vulnerable to horizontal perturbations; the algorithm assumes homogeneity of each layer in the scan, which is not necessarily the case [2].

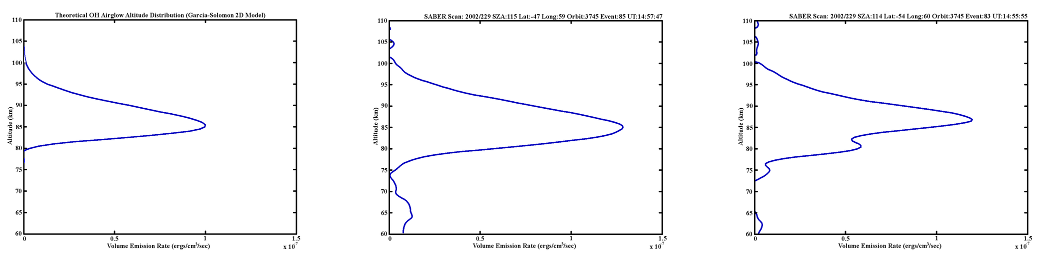
Hydroxyl Airglow Photochemistry



The mesospheric hydroxyl airglow is produced when ozone, formed by the reaction of molecular and atomic oxygen with a third molecule, interacts with hydrogen atoms to produce diatomic oxygen and vibrationally excited hydroxyl molecules. These excited OH molecules relax to lower energy levels, releasing photons. Examining the altitude and intensity of these emissions provides insight into ozone production and depletion rates in the mesosphere. Long term trends, such as the variations in the global 3-D airglow intensity over an entire solar cycle, provide clues to atmospheric energetics. This investigation is being pursued by the SABER mission.

Multiple Peaks in the OH Airglow

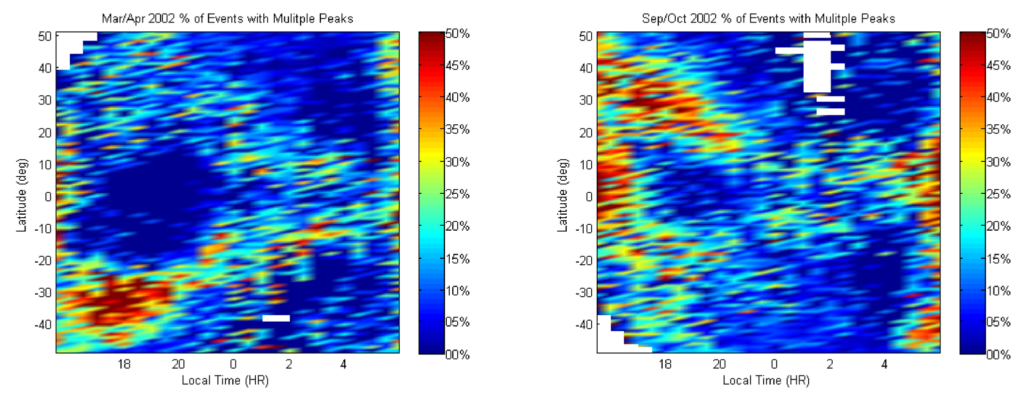
A significant portion of the SABER OH altitude profiles show evidence of multiple. While two apparent layers are most common, examples exist of profiles with additional maxima. These peaks are generally attributed to photochemical and dynamical effects in the mesosphere, but could result from limb geometry, particularly in twilight regions [4]. Shown for reference alongside the bifurcated profile is a theoretical distribution and a typical non-bifurcated profile.



From left to right: a theoretical airglow intensity altitude profile obtained via the Garcia-Solomon 2-D Model, a typical SABER derived profile, and a representative profile with dual maxima.

Global and Temporal Distributions

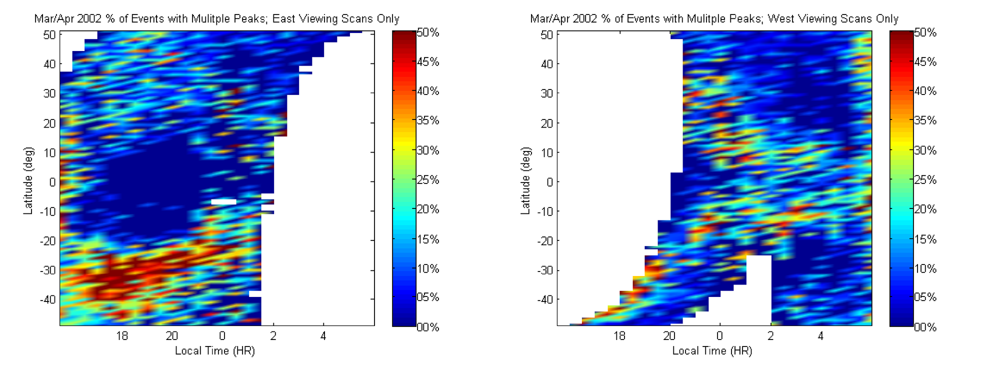
SABER multiple-peak OH events are most common at mid-latitudes and in the winter hemisphere. During the night, the relative number of multi-peak events tends to reach its maximum near 18:00 Local Time (LT), a result consistent with Melo, Lowe, and Russel [3], and Liu and Shepherd [2], who performed a similar analysis using the WINDII data. The observation of a strong dependence upon satellite orientation prompted the separate examination of alternate yaw cycles. These differences are likely sampling artifacts coupled to the orbit of the TIMED satellite. When the line of sight of the SABER instrument is oriented eastward, the mid-latitudes are observed around 18:00 LT, and there are more events with multiple maxima. There is a much larger number of multi-peak events during the day, though there is reason to suspect that the false-positive rate is high.



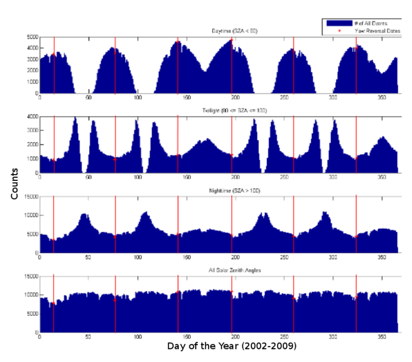
Also of note is a seasonal dependence for multiple-peak profile location and time of occurrence.

Orbital Considerations

Since the SABER instrument is maintained on the anti-sun side of the TIMED satellite to help keep the cryogenic systems cool, there is a sampling bias relating to satellite scan direction, as shown below:

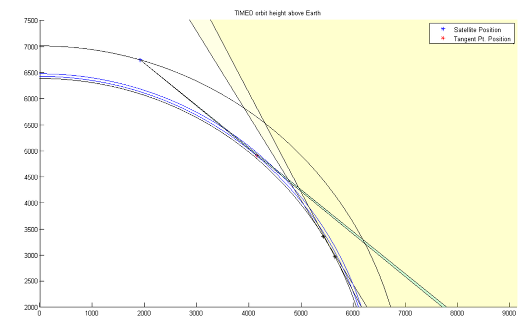


From the above figures, it is apparent that when SABER scans during the evening, it is facing eastward, and faces westward when it scans during the morning hours.

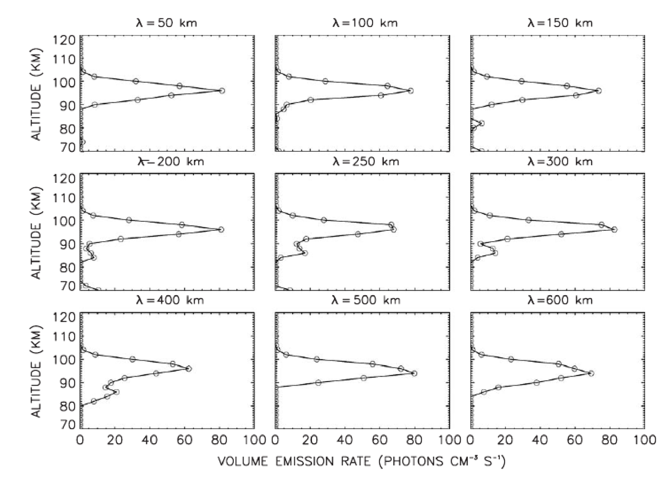


Seasonal variations must be carefully considered in the context of SABER viewing geometry and sampling frequency. As the figure at right shows, the satellite scans more often during the day when it is in one phase of its yaw cycle, and more often at night during the other phase.

Limb Scan Artifacts



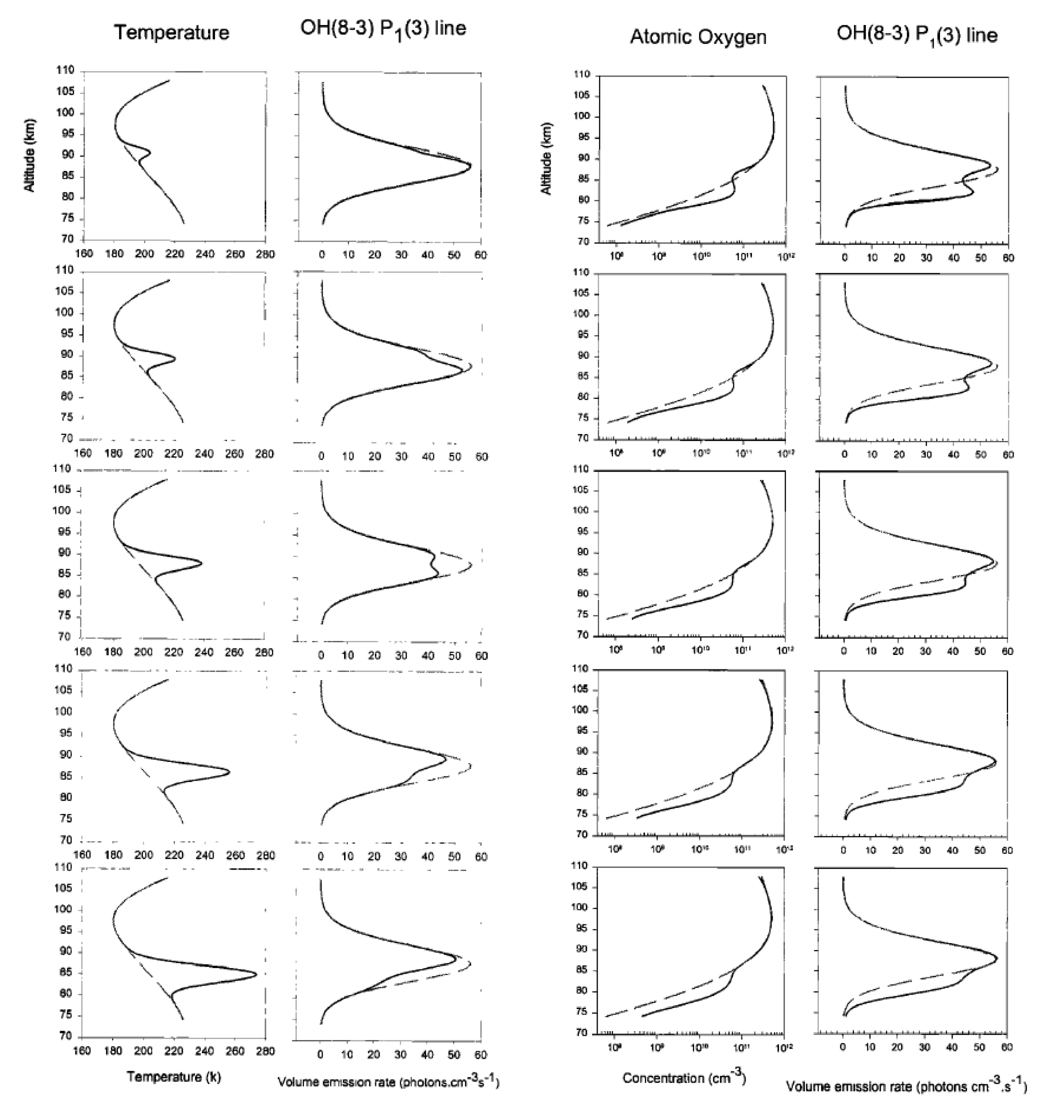
Limb scan geometry is vulnerable to horizontal inhomogeneities, which can alter the shape of the derived profile. Liu and Shepherd [2] showed, using data from the WINDII instrument, that limb scan geometry can introduce errors that replicate the appearance of multiple peaks:



Replication of this analysis using SABER geometry is underway. However, it is reasonable to suspect similar results due to the similarity of the SABER instrument's scanning geometry and inversion process.

Dynamical Effects

Investigation of multiple-peak profiles using data from the WINDII instrument aboard UARS has revealed possible dynamical explanations for multiple-peak phenomena [3]. The simulations used in this investigation are presented here as a possible source of SABER multiple-peak profiles:



Melo *et al.* [3], as shown above, demonstrate that temperature inversions and local O mixing effects can, in theory, produce the observed altitude distributions.

Conclusions

The SABER instrument measures limb radiances in the infrared and from these measurements, volume emission rate altitude profiles are derived. Profiles with multiple maxima have been presented, and seasonal and diurnal trends have been plotted. The results herein are consistent with results obtained using the WINDII instrument. Plausible geometrical, as well as dynamical, causes for these multiple maxima are given, with plans to extend previous investigations to more current data and instrumentation.

References

[1] Baker, D.J. and Stair, A.T. "Rocket Measurements of the Altitude Distributions of the Hydroxyl Airglow." 6th International Symposium on Solar Terrestrial Physics (1988).

[2] Liu, G. and Shepherd, G.G. "Perturbed Profiles of Oxygen Nightglow Emissions as Observed by WINDII on UARS." *Journal of Atmospheric and Solar-Terrestrial Physics.* 68 (2006)

[3] Melo, S.M.L., Lowe, R.P., and Russell, J.P. "Double-peaked hydroxyl airglow profiles observed from WINDII/UARS." *Journal of Geophysical Research.* 105 (2000)

[4] Winick, J.R. *et al.* "Global Statistics of OH Layer Heights and Double Layers from SABER Limb Measurements of OH Meinel Emission at 1.6 and 2.0 Microns." AGU Fall Meeting, San Francisco, CA. Dec. 08 2005.

Acknowledgements

SABER Data Processing by GATS Inc. Special Thanks to Jeremy Winick, Mike Taylor, Robert Lowe, and Connor George.