

A satellite with solar panels and a dish antenna is shown in orbit above the Venusian atmosphere. The planet's surface is visible through the hazy, orange-tinted clouds. The background is the blackness of space with some distant stars.

Modeling of Observations of the OH Nightglow in the Venusian Mesosphere

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Motivation

A satellite with solar panels and a dish antenna is shown in space, with the Earth's horizon and atmosphere visible in the background.

Airglow emissions, such as NO and O₂, have been observed on Venus

Airglow emissions provide insight into chemical and dynamical processes that control the composition and energy balance of the upper atmosphere

The first airglow emission had been observed previously only in the Earth's atmosphere

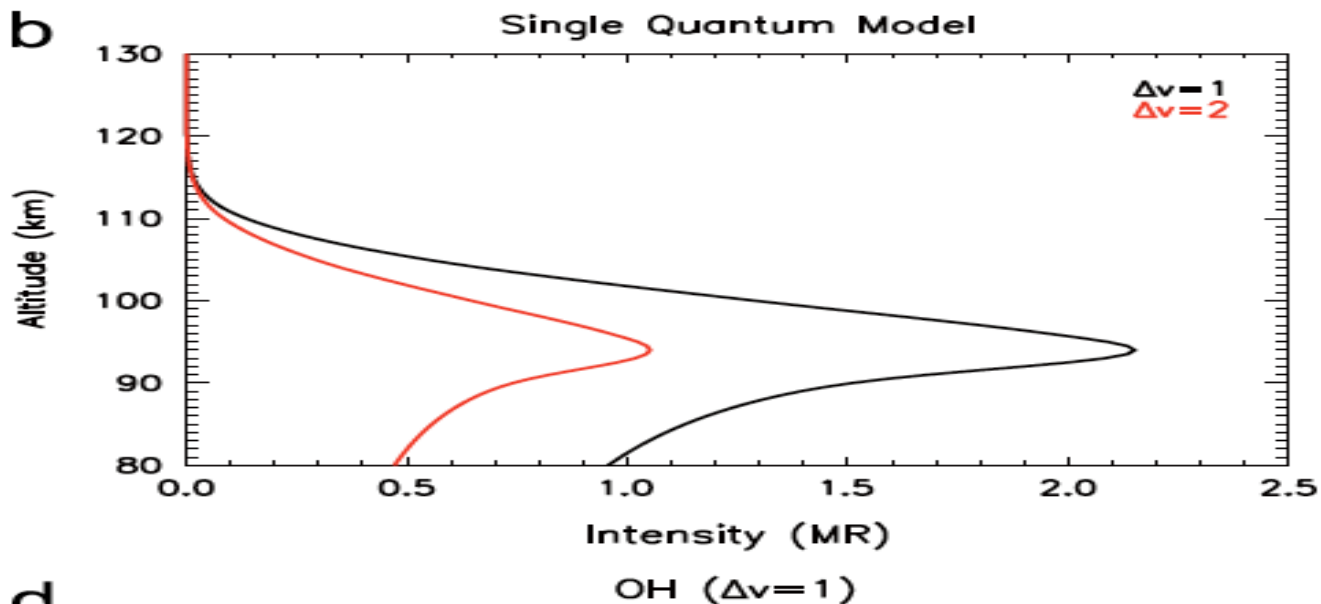
OH S:

OH airglow emissions have been detected in the wavelength regions of 1.40–1.46 and 2.6–3.1 μm during limb observations by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on the Venus Express spacecraft.

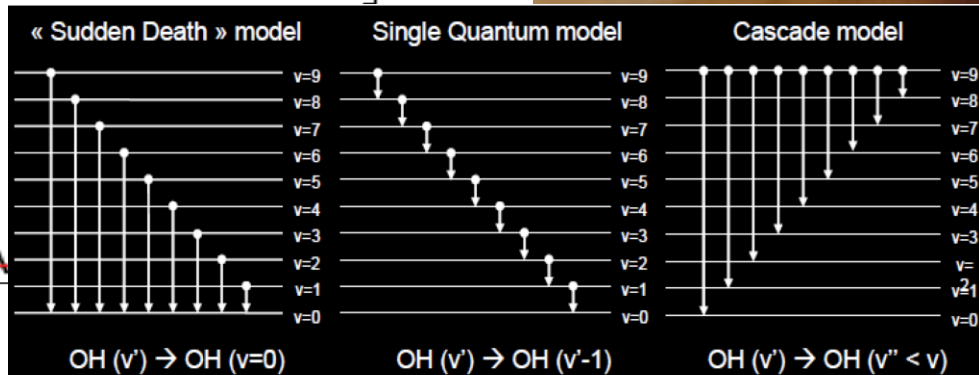
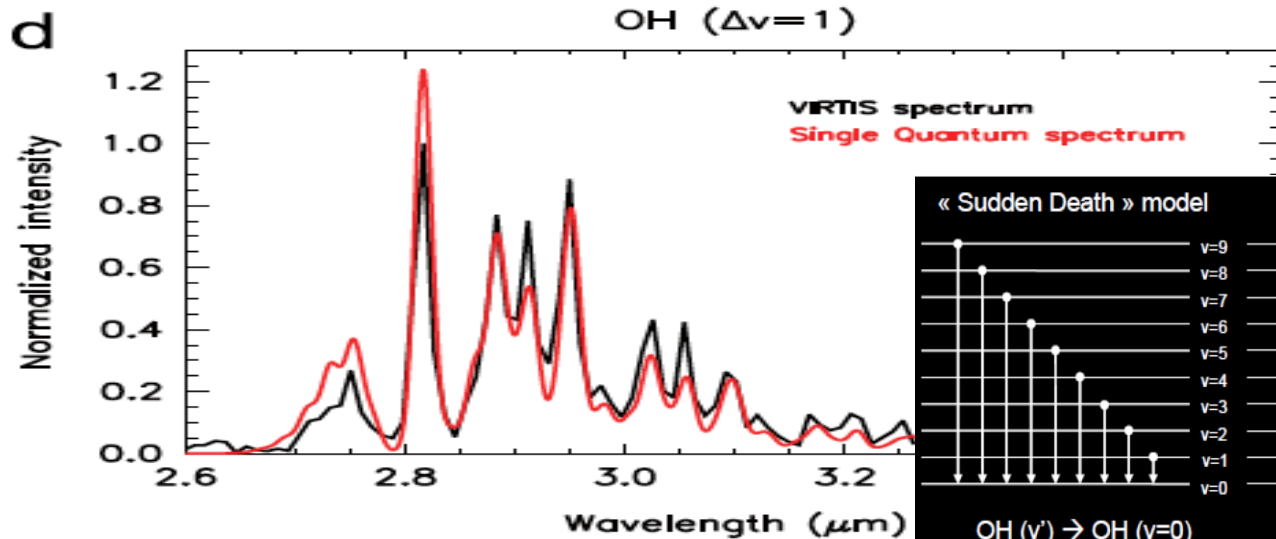
These emissions are attributed to the OH (2–0) and (1–0) Meinel band transitions (Piacentini et al., 2008).

The integrated emission rates for the OH (2–0) and (1–0) bands were measured to be 440 ± 40 and 880 ± 90 kR respectively, both measured during the night at an altitude of 96 ± 2 km near sunset local time for the considered orbit.

VERTIS OH Airglow Observations et al. (2012) updated analysis



To fit observations, they must use single quantum cascade model with weighted coefficients for each transition and temperature of 180°K



A satellite is shown in orbit above the Earth's atmosphere. The satellite has a central body with a large parabolic dish antenna on the left and two large rectangular solar panel arrays extending to the right. The Earth's surface is visible in the background, showing a curved horizon and a blue and white atmosphere. The background is black with some stars.

Tale of Two Models

Most of talk devoted to discussion of
ports used to model VIRTIS
observations just discussed using

1-D Caltech/JPL model

Michigan VTGCM model

Key Reactions for

Channel	Reaction	Rate Coefficient	Reference	Heat of Reaction
(1)	$\text{H} + \text{O}_3 \rightarrow \text{OH}(v) + \text{O}_2$	$1.40\text{e-}10 \cdot \exp(-470/T)$	Sander et al 2002	27000 cm^{-1}
(2)	$\text{HO}_2 + \text{O} \rightarrow \text{OH}(v) + \text{O}_2$	$3.00\text{e-}11 \cdot \exp(200.0/T)$	Sander et al 2002	19000 cm^{-1}
(3)	$\text{Cl} + \text{HO}_2 \rightarrow \text{ClO} + \text{OH}$	$4.10\text{E-}11 \text{ EXP}(-450/T)$	Sander et al 2002	-500 cm^{-1}
(4)	$\text{SO} + \text{HO}_2 \rightarrow \text{SO}_2 + \text{OH}$	2.80E-11	Yung and DeMore 1982	23000 cm^{-1}

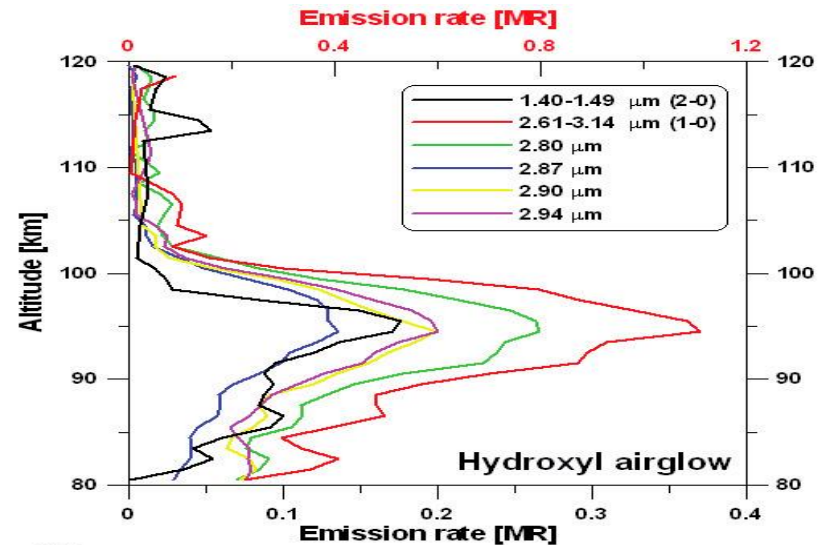
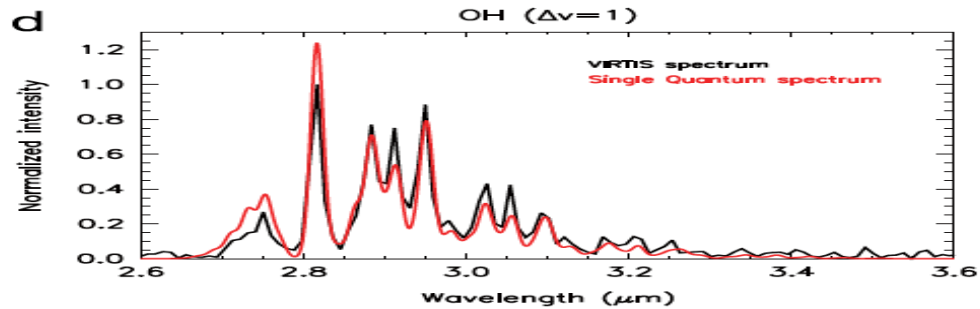
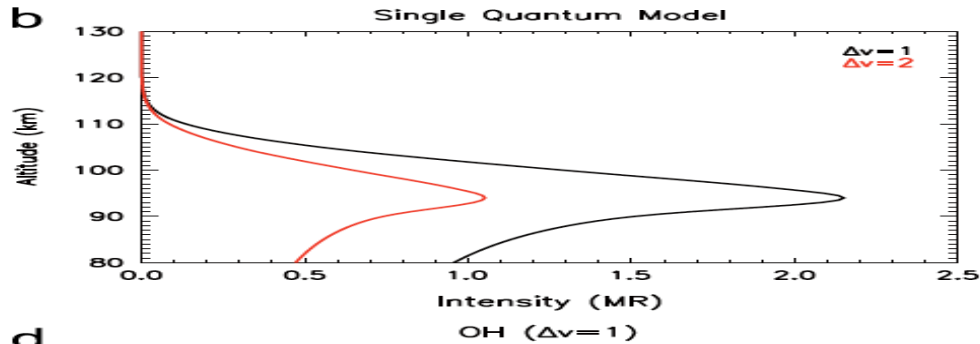
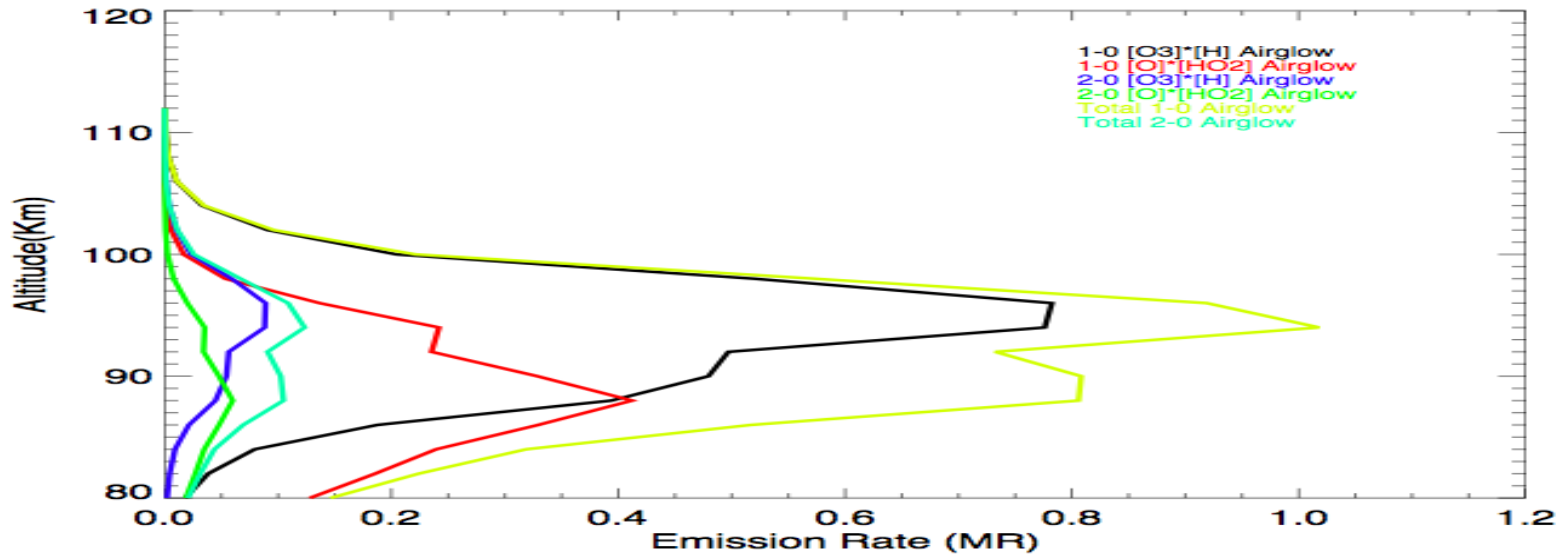
Exothermicities of these reactions: Channel (2) has the highest exothermicity and can excite OH(v) levels up to v=6. Channel (1) up to levels v=6.

Due to exothermicity arguments, channel (3) does NOT contribute to OH(v). We are investigating channel (4)

Vertical distributions of CO_2 measured via channels (1) and (2)

Reaction	ν	f_ν (Adler-Golden, 1997) Caltech/JPL 1-D Kinetics Model	f_ν (García Muñoz et al., 2005)	f_ν (Krasnopolsky, 2010)
(1)	9	0.47	0.35	
(1)	8	0.34	0.29	
(1)	7	0.15	0.19	
(1)	6	0.03	0.07	
(1)	5	0.01	0.05	
(1)	4	0	0.05	
(1)	≤ 3	0	0	
(2)	6	0.47		0
(2)	5	0.34		0
(2)	4	0.15		0
(2)	3	0.03		0.3
(2)	2	0.01		0.3
(2)	1	0		0.3
(2)	0	0		0.1

1-D modeled and normalized OH Airglow



GCM modeling results

A satellite is shown in orbit above Earth's atmosphere. The satellite has a central body with various instruments and two large solar panel arrays extending outwards. The Earth's surface is visible below, showing a mix of land and clouds. The background is the dark void of space with some distant stars.

Advantages:

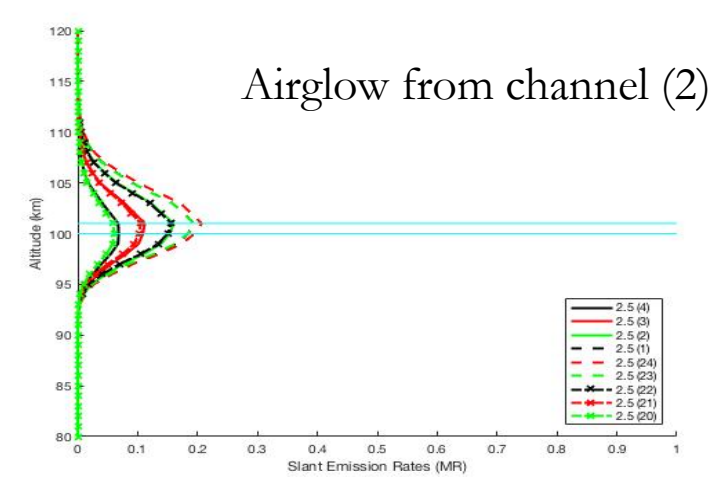
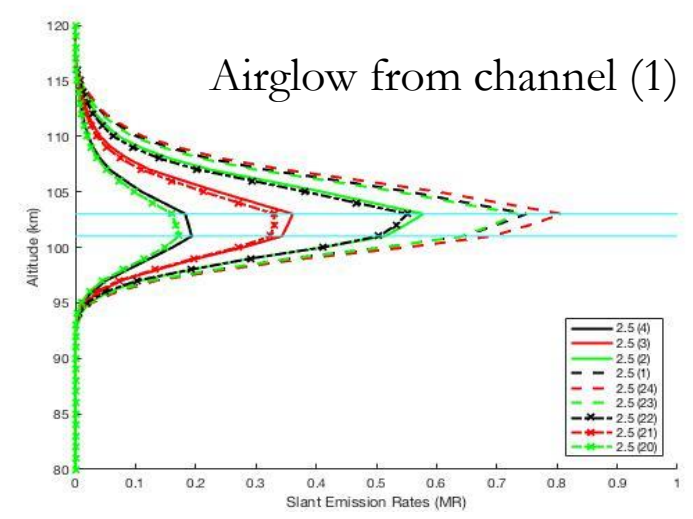
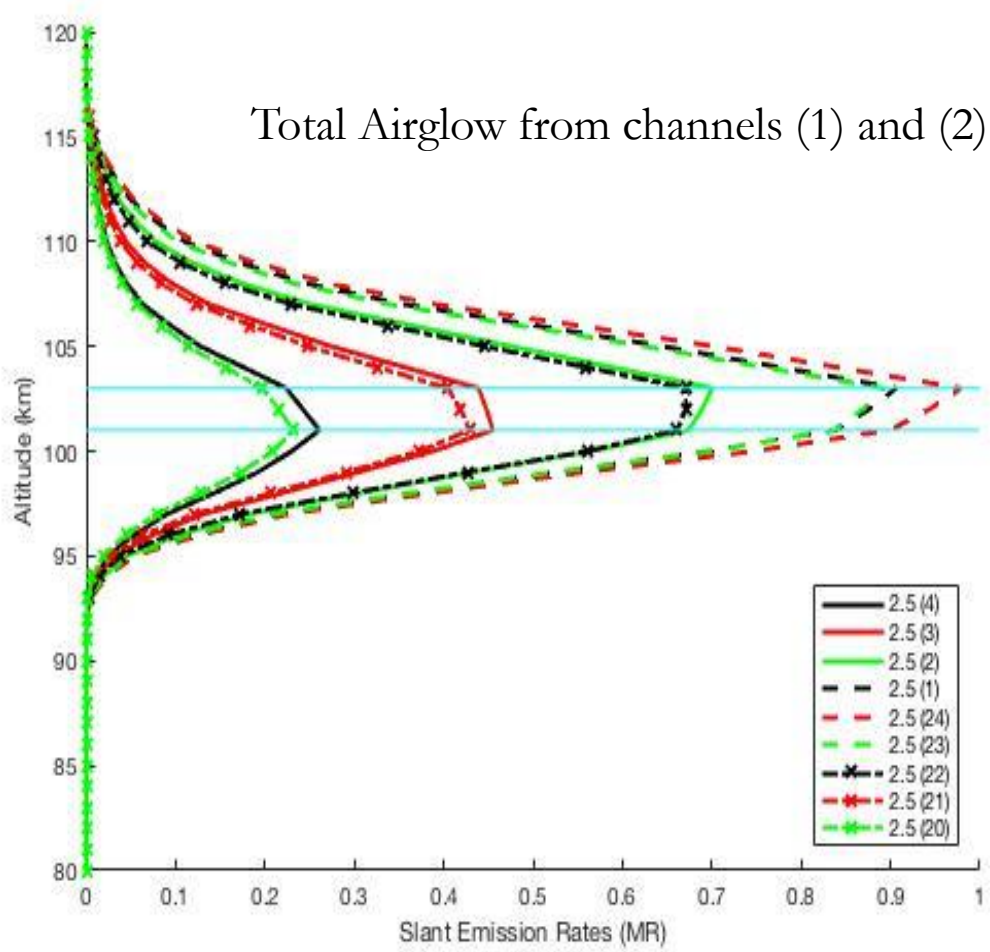
Heating and cooling terms included

Allows for variable temperature profile

Adds latitudinal and longitudinal variation in
number density (and hence airglow) of OH
rotational species

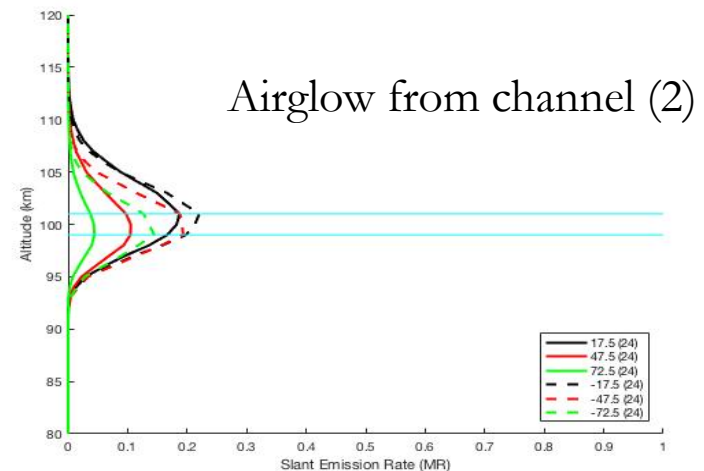
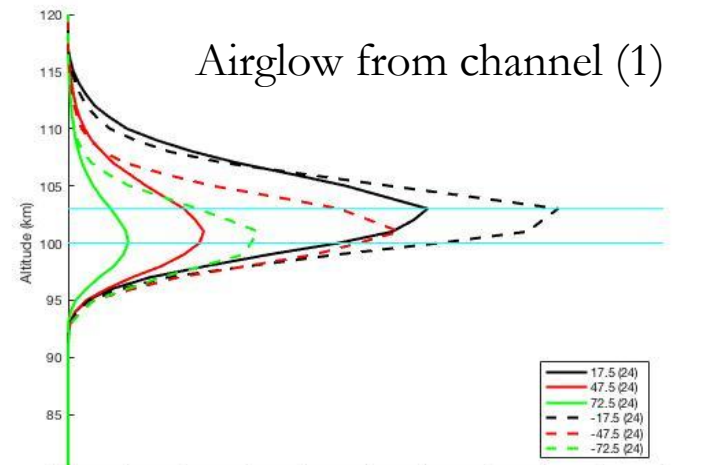
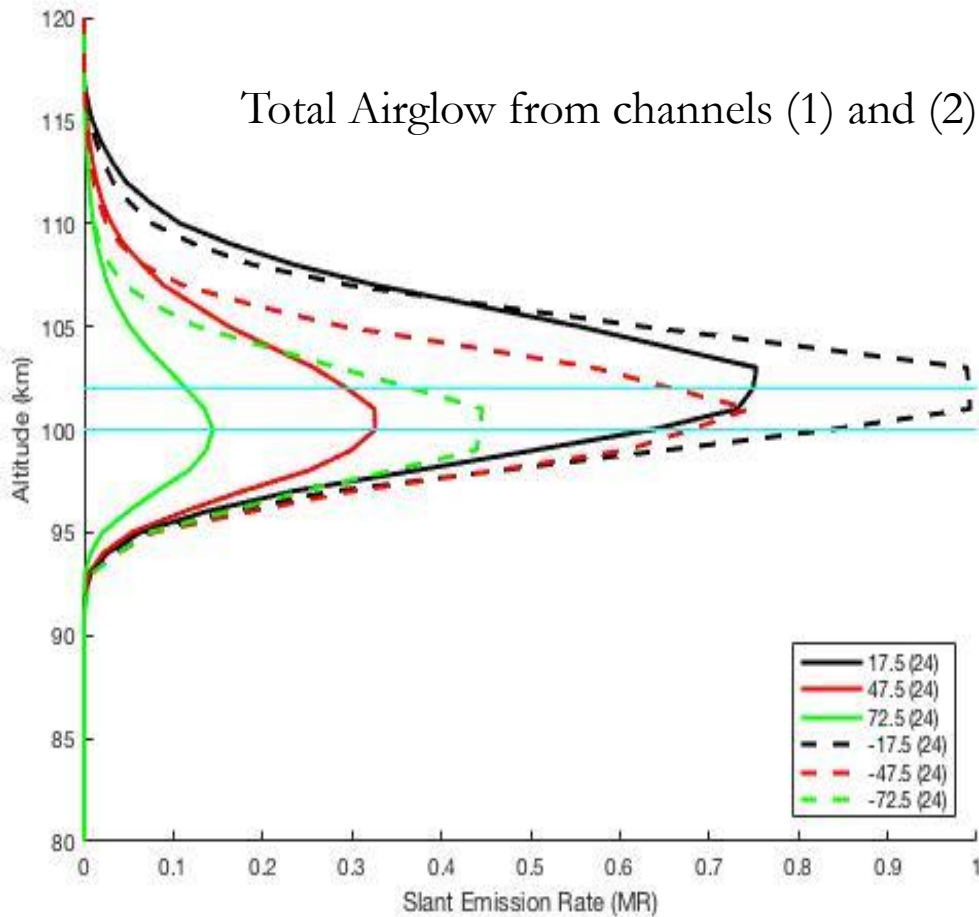
Total Airglow, varying latitude

band system slant path emission rates corresponding to profiles for 2.5 N LAT (LT = midnight +1, +/-2, +/-3, +/-4) are consistent with the O₂ airglow

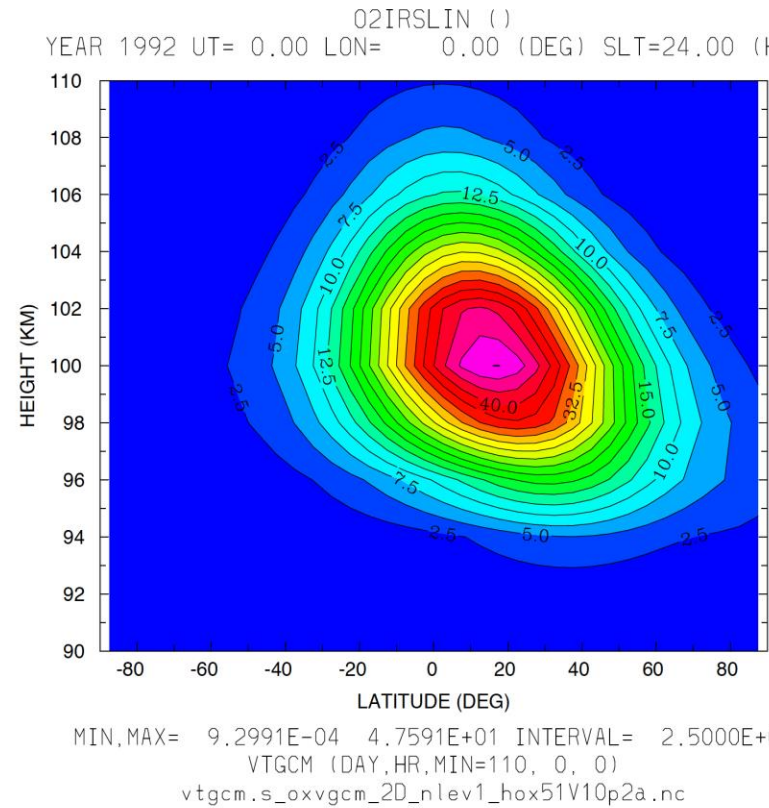
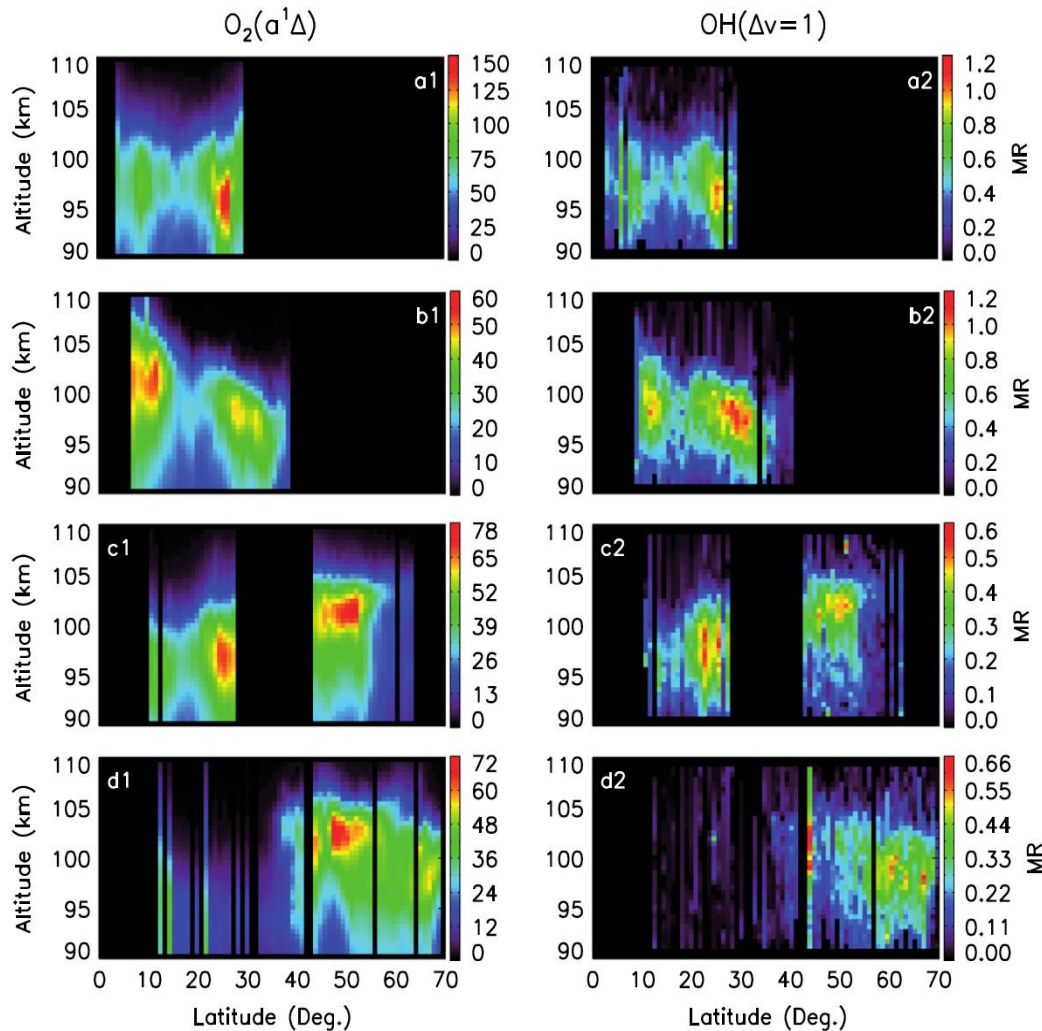
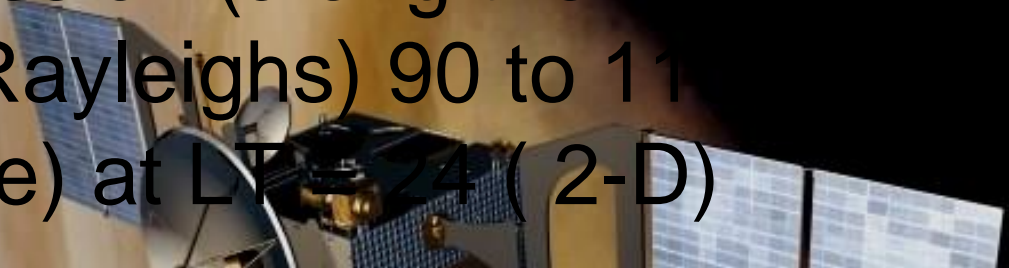


Total Airglow, varying latitudes

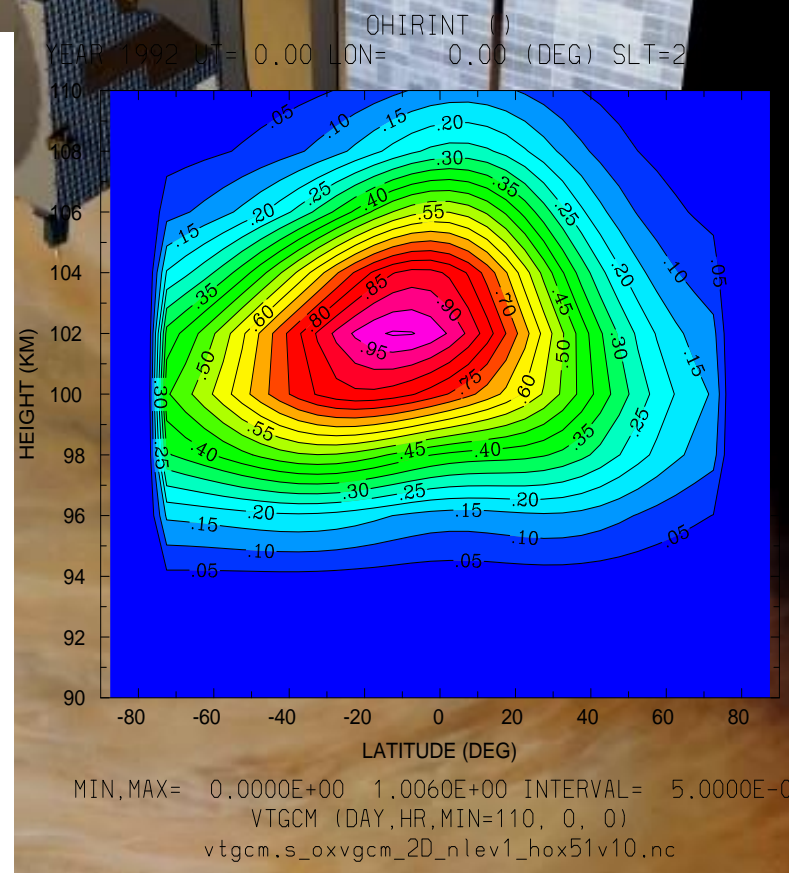
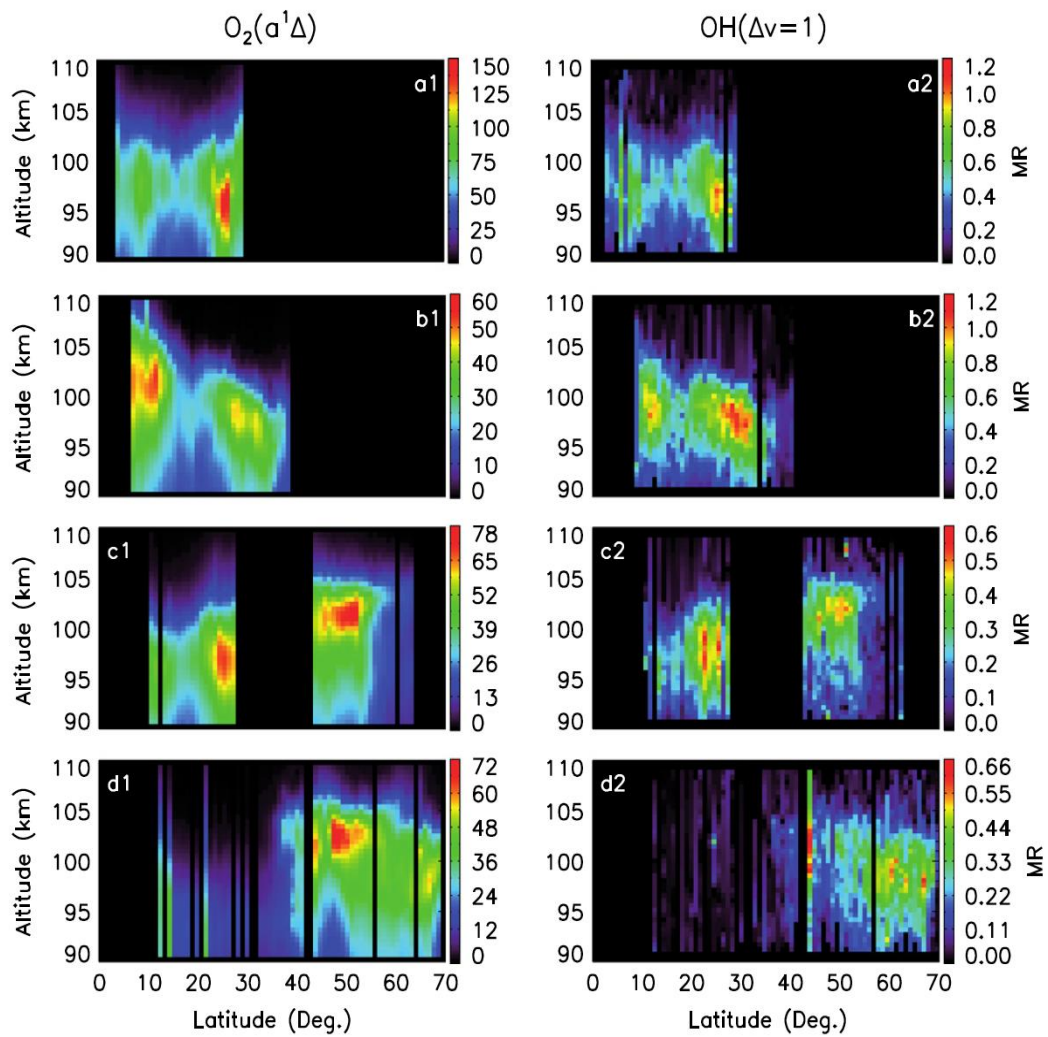
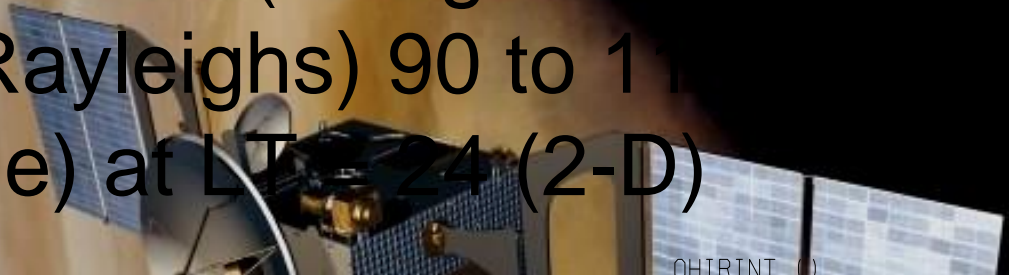
... system slant path emission rates corresponding to positive latitudes (2.5N, 17.5N, 47.5N, 72.5N, 72.5S, 47.5S, 2.5S) ...
... asymmetric due to the lower boundary specified ... we ...
... quantify a little better to understand it.



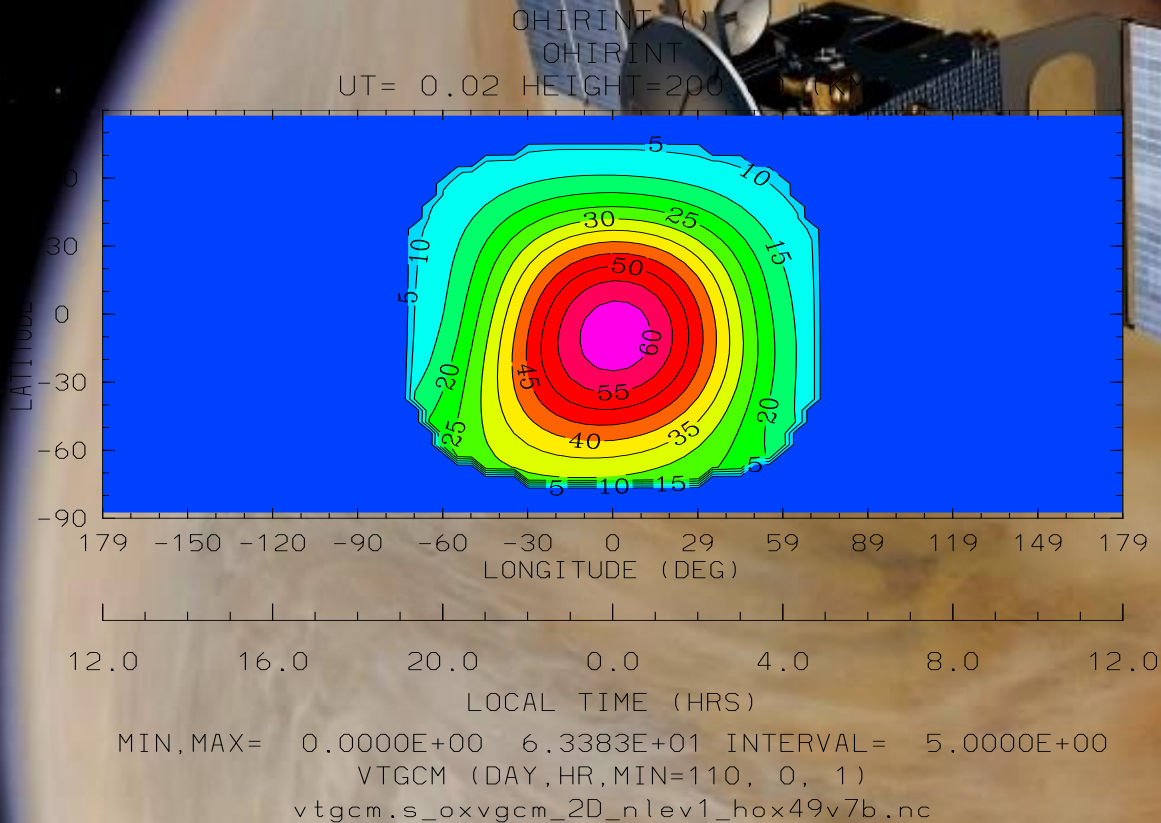
OH emission (along the equator) (MegaRayleighs) 90 to 110 km (pole to pole) at LT=04 (2-D)



OH emission (along the
 (MegaRayleighs) 90 to 110
 pole to pole) at LT = 24 (2-D)



Integrated Intensity: Both O



Integrated vertical intensity (kR units)

that the integrated vertical intensity shows
near midnight and just South of the equator

A satellite is shown in orbit above the Earth's atmosphere. The satellite has a central body with various instruments and two large solar panel arrays extending outwards. The Earth's surface is visible below, showing a grid of latitude and longitude lines. The background is the blackness of space with some stars.

Verification of VTGCM results

Longitudinal differences are clearly seen between the N. hemisphere and S. hemisphere

The magnitude of this emission (both integrated slant path intensity and volume emission rate) are consistent with VEx VIRTIS slant path observations

Interpretation of VTGCM results

Key features seen here:

Peak altitude of emission decreases
with latitude

$O_3 + OH$ (channel 1) consistently peaks
at higher altitude than $O + HO_2$ (channel

Differences in latitudinal variations of O_2
and OH emission layers is interesting
and puzzling!



Conclusions and Future Work

VTGCM models successfully model observed
O₂, and OH airglow in a self-consistent
manner

Our OH airglow results (normalized by peak)
match well with observed OH airglow
missions (KINETICS and VTGCM modeling)

Quantifying airglow variations in the North
and South hemispheres needed

