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Variations in Venus' Cloud Top SO_2 and SO Gas Density with Latitude and Time of Day

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Abstract

1. Introduction: Motivation

Venus' upper atmospheric H_2SO_4 clouds are formed from SO_2 gas via the sulfur-oxidation cycle, beginning with SO_2 photolysis; followed by the formation of SO_3 via photochemical SO_2 oxidation, which then reacts with H_2O forming H_2SO_4. Thus, photochemical processing of SO_2 is intimately linked to the global-scale cloud and haze layers, which are composed primarily of concentrated sulfuric acid. At the same time, detailed thermochemical modeling of Venus' key atmospheric species suggests that the sulfur dioxide in Venus' atmosphere most likely originates from volcanic outgassing [1], though volcanic activity has yet to be directly observed. The exchange of SO_2 from below the cloud deck to above the clouds is not fully understood, but undoubtedly involves convection transport [2, 3] and may also include direct volcanic injection of the SO_2 gas [4]. Consequently, observations of sulfur oxides (SO_2, SO, OCS, and H_2SO_4) in Venus' mesosphere are of great interest because they provide important insight into the ongoing chemical evolution of Venus' atmosphere, atmospheric dynamics, and possible volcanism.

2. Data description

In order to establish patterns in the sulfur-oxide photochemical behavior as a function of latitude and time of day 200-300 nm HST/STIS observations were obtained on Dec 28, 2010, Jan 22, 2011 and Jan 27, 2011 that recorded Venus' cloud top (65-75 km) SO_2 and SO gas absorption signatures at 0.3 nm spectral resolution [5]. Using the HST/STIS long slit at 0.1" spatial resolution limb-to-limb coverage of Venus was possible, however on each date only 12-18" of daylight was observable on Venus (Fig 1). For our analysis we binned the data spatially along the slit every 6 pixels, so that a total of 56 spectra were produced per exposure providing continuous limb-to terminator data on Venus at ~ 150 km resolution. These observations provide a distinct record of the density and spatial distribution of SO and SO_2 gas as a function of latitude, longitude, and time of day.

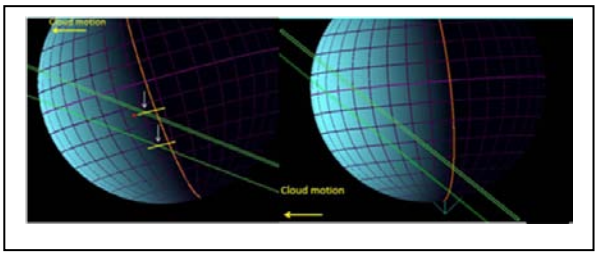

Figure 1: HST/STIS observation geometry on Dec. 28, 2010 (left) and January 22+27, 2011 (right), The 0.1" slit coverage is indicated in green.

3. Modelling Techniques

Analysis of the HST data is completed using a modification of the radiative transfer model originally developed by [6]. This model relies on the pseudo-spherical SPS-DISORT code to calculate the transfer of radiation through a non-isothermal atmosphere as a function of the optical depth as a function of wavelength, altitude and solar zenith angle. For the analysis of the HST data we have updated the [6] model to include the temperature-dependence of the SO_2 absorption cross-section based on the most recent and best available high-spectral resolution cross-section data [7-10], and the best available SO cross-section data.

The modified RT model replicates the 200-300 nm HST Venus spectra based on the definition of 6 key elements: the atmospheric pressure and temperature profiles; the Rayleigh cross-sections of key gas constituents including: N_2 and CO_2; the gas absorption cross-section of the key gas absorbers in

the atmosphere including CO_2, SO, and SO_2; the bimodal aerosol size distribution in the atmsophere; the vertical profile of the aerosols, and the aerosol scattering extinction coefficients assuming Mie Theory. We constrain the specific SO and SO_2 mixing ratios per observed latitude and longitude by modifying the vertical SO and SO_2 gas density profiles and the aerosol profile.

4. Results Summary

Our analysis indicates that:

i) an SO_2 abundance of ~ 10-350 ppb was retrieved, consistent with previous Venus Express SPICAV observations made at ±25° latitude [6,11]
ii) similar to the SPICAV observations, the observed SO_2 gas density decreased as the latitude increased from 20 S towards 20 N.
iii) the observed SO_2 gas density decreased with local time from the morning terminator towards noon, as expected for a gas density controlled by photochemical destruction;
iv) variation in the observed SO gas density per latitude paralleled that of the SO_2 gas. This indicates that the latitudinal distribution of the SO gas density was *not solely* controlled by SO_2 photolysis, since the opposite trend would be expected.

These results lend credence to recent speculations by [2-3,11-12] that the gas density variability and distribution is determined by a balance of the temperature driven convection at low latitudes, the depletion of SO_2 gas at high latitudes due to advection powered by Hadley cell circulation, and the relative strength of SO_2 photolysis as a function of time of day and latitude. Validation of these speculations, requires on-going systematic quantification of changes in the SO_2, SO, aerosol, convective flux as a function of latitude and time of day coordinated and co-located with measurements of the cloud properties (including altitude and wind speed), on a day to day basis.

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