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HDO and SO_2 thermal mapping on Venus

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Abstract

We report on ground-based thermal observations of Venus using the TEXES imaging spectrometer at IRTF (Mauna Kea, Hawaii) in October 2012. High-resolution data were obtained at 7 µm and 19 µm, probing slightly different layers atop and within the cloud, and were compared with the results of our previous campaign (January 2012, [1]). Three main conclusions can be drawn: (1) An isothermal/ inversion layer appears at high latitudes in the October data but not in the January data; (2) The spatial distribution of SO_2 seems to show variations within a very short timescale, less than an hour; in contrast, the HDO distribution over the Venus disk shows no noticeable spatial nor temporal variation; (3) The SO_2 vertical distribution is strongly depleted a few kilometers above the cloudtop. The high variability of SO_2 is probably the result of its very short photodissociation lifetime.

1. Introduction

Water vapor and sulfur dioxide are known to play a key role in the atmospheric chemistry of Venus [2]. Their mixing ratios (typically 30 and 100-150 ppm below the clouds) are depleted down to about 1 ppm and 1 -0.1 ppm respectively above the clouds, as a result of photodissociation and condensation/ evaporation processes. As a complement to Venus Express data, ground-based imaging spectroscopy offers the possibility of recording quasi-instantaneous maps of minor species abundances. In January 2012, using the TEXES (Texas Echelon Cross Echelle Spectrograph) at the Infrared Telescope Facility (IRTF), we recorded maps of HDO and SO_2 on Venus in the 7 µm-spectral range. While the HDO maps were globally flat and constant with time, the SO_2 maps showed high spatial and temporal variability on a timescale of a day [1]. A second observing run took place in October 2012. Observations were performed at 7 µm, probing again the cloud top, but also at 19 µm, where the radiation comes from slightly deeper levels within the cloud. The spatial resolution of the maps was about 1.5 arcsec, and the spectral resolving power was 8 10^4 and 6 10^4 at 7 and 19 µm respectively. Maps were recorded by moving the slit (aligned along the N-S celestial axis) from West to East. A full map was recorded in about 50 minutes at 7 µm and 30 minutes at 19 µm.

2. Data analysis and results

2.1 Thermal structure

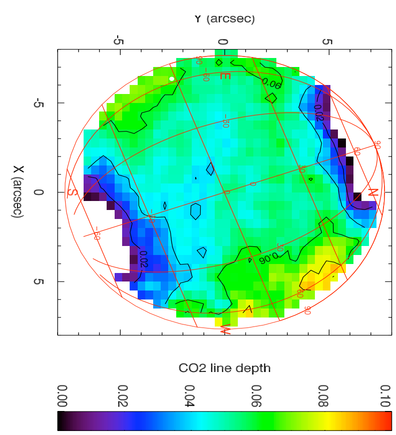

Figure 1: Map of the CO_2 line depth at 1345.2 cm^{-1}.

Figure 1 shows the map of a weak CO_2 line depth at 7 µm. In contrast with the map achieved in January 2012, the CO_2 line disappears at latitudes higher than 60 °, indicating the presence of an isothermal/ inversion layer. This signature of the polar collar was not observed in January [1]. A possible explanation of this difference is the fact that January observations were probing the evening terminator, while the morning terminator was visible in October. The observed maps are consistent with the interpretation of the polar collar as a cold, diurnal or semi-diurnal cold longitudinal wave [3, 4].

2.2 HDO and SO_2

The HDO map recorded in October 2012 is very similar to the January maps, with a mean mixing ratio of about 1 ppm (assuming a D/H ratio equal to 200 times the terrestrial value [5]) and a globally constant spatial distribution. In contrast, the 7-μm SO_2 maps show, as in the case of the January data, a high local variability. In addition, they show temporal variations on a very short time scale, less than an hour. An example of such a map is shown in Figure 2.

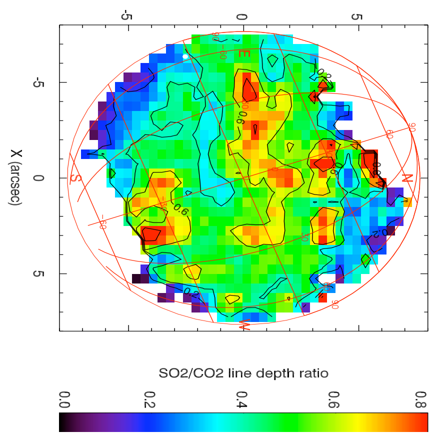

Figure 2: Map of the SO_2/CO_2 line depth ratio (SO_2 at 1345.12 cm^{-1}., CO_2 at 1345.27 cm^{-1})

Figure 3 shows a spectral fit of SO_2 and CO_2 lines in the 19 μm region. The spectrum is taken in a region corresponding to a local SO_2 maximum. It can be seen that the best fit is achieved for a SO_2 mixing ratio of 180 ppb within the cloud, with a cutoff at 67 km, few kilometers above the cloudtop. It also illustrates that a constant SO_2 mixing ratio gives a poor fit of the SO_2 doublet. The depleted vertical distribution of SO_2 also gives a good fit of the 7-μm SO_2 doublet (Fig. 4). This depletion was not noticed in [1] because the fit of the SO_2 single lines, used in our previous analysis, is less sensitive to the effect.

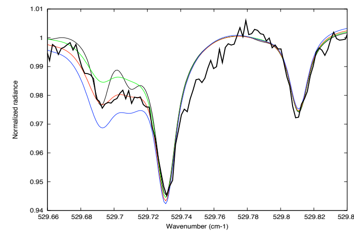

Figure 3: Spectral fit of the SO_2 doublet observed at 529.7 cm^{-1}. Thick black line: TEXES spectrum in a region of maximum SO_2 abundance. Models with a cutoff at 67 km: SO_2 = 120 ppb (green), 180 ppb (red, best fit), and 250 ppb (blue). Model with no cutoff: SO_2 = 50 ppb (black). The models include a level of infinite opacity at 241 K (P = 250 mbars).

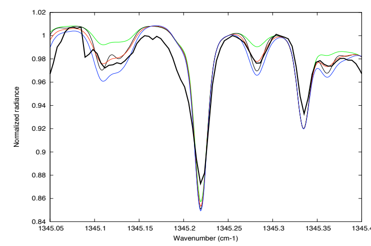

Figure 4: Spectral fit of the SO_2 doublet observed at 1345.12 cm^{-1}. Thick black line: TEXES spectrum (integrated disk). Models with cutoff at 67 km: SO_2 = 50 ppb (green), 100 ppb (red, best fit), and 150 ppb (blue). Model with no cutoff: SO_2 = 35 ppb (black). The models include a level of infinite opacity at 231 K (P = 100 mbars).

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References: [1] Encrenaz T et al A&A 2012; [2] Zhang et al, Nature Geosc. Letters 3, 834-837, 2012; [3] Migliorini et al. Icarus 217, 640, 2012; [4] Yamamoto M and Takahashi M, Icarus 217, 702, 2012; [5] Fedorova A et al, J. Geophys. Res. 113, E00B01, dii: 10.1029/2008JE003093, 2008