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Ground-based mapping of SO_2 and HDO on Venus in the thermal infrared

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Abstract

Since January 2012 we have been monitoring the behavior of sulfur dioxide and water on Venus, using the Texas Echelon Cross-Echelle Spectrograph (TEXES) imaging spectrometer at the NASA InfraRed Telescope Facility (IRTF, Mauna Kea Observatory). Data were recorded around 1345 cm^{-1} (7.4 μm) and 530 cm^{-1} (19 μm). The molecules SO_2, CO_2, and HDO (used as a proxy for H_2O) were observed at the cloudtop of Venus at 7.4 μm, and a few km below at 19 μm. The volume mixing ratio of SO_2 was estimated using the SO_2/CO_2 line depth ratios of weak transitions; the H_2O volume mixing ratio was derived from the HDO/CO_2 line depth ratio, assuming a D/H ratio of 200 times the terrestrial value (VSMOW). The SO_2 mixing ratio shows strong variations with time and over the disk, showing evidence for the formation of SO_2 plumes with a lifetime of a few hours; in contrast, the H_2O abundance is remarkably uniform over the disk and shows moderate variations as a function of time. We performed a statistical analysis of the behavior of the SO_2 plumes, using all TEXES data at 7.4 μm between 2012 and 2018. The plumes appear mostly located around the equator. Their distribution as a function of local time seems to show a depletion around noon, which remains to be confirmed. There is a good agreement between the TEXES results and those obtained in the UV range (SPICAV/Venus Express and UVI/Akatsuki) at a slightly higher altitude. A comparison of TEXES data at 7.4 and 19 μm can be used to retrieve information about the vertical distribution of SO_2, which shows a depletion above the cloudtop [1-4].

1. Short-term variations of SO_2

Figure 1 shows examples of SO_2 and HDO maps recorded with TEXES. The two pairs of SO_2 maps, separated by 2 hours, were taken on two consecutive days. It can be seen that the SO_2 distribution is very patchy; the SO_2 plumes sometimes follow the 4-day rotation of Venus at the cloudtop over a timescale of 2 hours, but disappear within 24 hours. In contrast, the HDO distribution is very uniform over the disk.

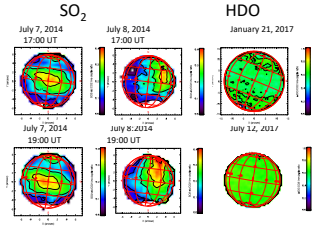


Figure 1: Examples of TEXES maps of SO_2 (left and middle) and HDO (right)

2. Long-term variations of SO_2 and H_2O

Figure 2 shows the variations of the disk-integrated mixing ratios of H_2O and SO_2 between January 2012 and September 2018. While the H_2O abundance shows a slow decrease by a factor of about 2 (from about 1 ppmv to 0.5 ppmv) between 2016 and 2018, the SO_2 abundance exhibits changes by as much as a factor 20, with a minimum of 30 ppbv in February 2014 and a maximum of 600 ppbv in July 2018.

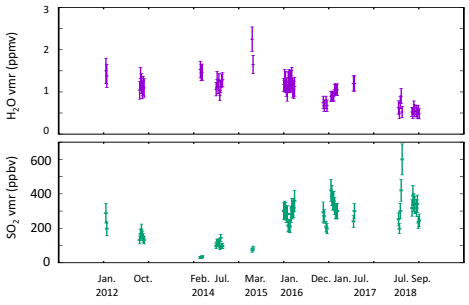


Figure 2: Long-term variations of the disk-integrated mixing ratios of H_2O (top) and SO_2 (bottom) measured by TEXES between 2012 and 2018.

3. Statistical analysis of the SO_2 plumes: comparison with space data

We have analyzed the behavior of the SO_2 plumes as a function of latitude, longitude and local time. This study has shown that they are mostly located around the equator, with a depletion around noon and two possible maxima around the terminators. More data will be needed to confirm the existence of a semi-diurnal wave. The depletion around noon is also observed in the SO_2 distribution retrieved in the UV by SPICAV/VEx [5] (Fig. 3); a very good agreement is also observed between the SO_2 measurements recorded by TEXES and the ones obtained in the UV by UVI/Akatsuki (Fig. 4). This comparison shows that the SO_2 measurements obtained in the thermal infrared can be used to complement, in the night side, the space data recorded in the UV on the dayside.

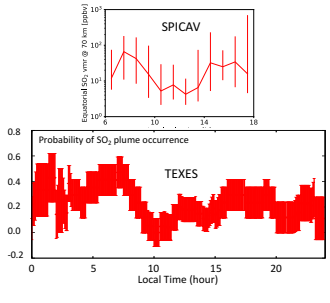


Figure 3: The SO_2 abundance recorded by SPICAV (top) and the probability of the SO_2 plume occurrence as measured by TEXES (bottom) as a function of local time.

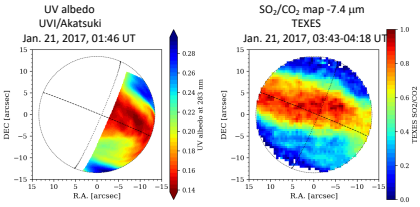


Figure 4: The SO_2 abundance measured in the UV by UVI/Akatsuki (left) and in the IR by TEXES (right)

4. Vertical distribution of SO_2

Simultaneous observations of TEXES at 7.4 µm and 19 µm have allowed us to probe SO_2 at two different levels, at the cloudtop and a few kilometers below within the clouds. In addition, the widths of the SO_2 lines, broader than the CO_2 lines, have allowed us to constrain the SO_2 vertical profile which shows a clear depletion above the cloudtop [2]. By combining the use of weak and strong CO_2 lines, we have shown that, in the polar collars, the morning terminator is colder than the evening one, showing evidence for a cold diurnal longitudinal wave [2]. In a forthcoming study, we are going to analyze the whole TEXES dataset at 7.4 and 19 µm to refine the vertical distribution of SO_2 as a function of latitude and local time.

Acknowledgements

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