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Evidence for Long-term Variability at Venus' Clouds Top

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Abstract

The ESA mission *Venus Express* has been operating since 2006 around Venus, thus providing a dataset spanning more than six years of observations. Following the methods used by Marcq et al. [1], we have thus derived (i) SO_2 column densities above cloud top and (ii) mean UV brightness in the $200-320$ nm range between 2006/04/14 and 2012/02/18. Very strong temporal and spatial variability is found for both observable parameters, but a mean decrease is found for SO_2 (5 to 10-fold) and mean UV brightness (about $40\,\%$) between 2007 and 2012. The latitudinal pattern is also subject to changes, with decreasing SO_2 with increasing latitude prevalent during SO_2-rich periods and no noticeable (or even reversed) latitudinal gradient during SO_2-poor episods. This evolution is highly reminiscent of the situation observed by *Pioneer Venus* and *Venera-15* [2, 3]. Possible causes for these long-term trends are difficult to assess at the present stage of our study. Fluctuation on a decadal timescale of the intensity of the advection from the deep, SO_2-enriched atmosphere is the most likely candidate according to simple modeling, but it does not preclude possible fluctuations in the volume of volcanic outgassing rich in SO_2.

1 Context

Sulphur dioxide (SO_2), an important tracer for dynamics, chemistry and geological activity on Venus, has been measured at cloud top level in the UV since the early 1970s [4]. Until the mid-1990s, a decreasing trend was observed [2], as well as a latitudinal gradient increasing from equator to pole that has been interpreted in terms of photochemical control of SO_2 mixing ratio [3].

Measurements of SO_2 have only resumed recently thanks to the *Venus Express* mission, especially using the SPICAV and SOIR instruments. Using the latter, Belyaev et al. found better constraints on the scale height of SO_2, quite high mixing ratios compared to the 1990s and a reversed latitudinal gradient (increasing SO_2 with decreasing latitude) [5]. More recently, Marcq et al. used SPICAV-UV nadir data and confirmed these trends for SO_2 column density N_{SO_2} above the unity optical depth [1] on an extended spatial and temporal coverage (2006-2007). A correlation with IR cloud top altitude derived from simultaneous SPICAV-IR measurement indicate that SO_2 mixing ratio was then controlled dynamically through upwelling in the Hadley cell circulation.

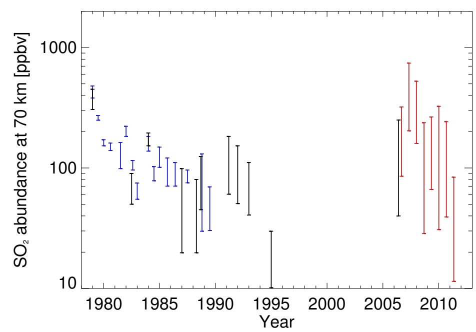

Figure 1: Long term evolution of SO_2 mixing ratio at cloud top. Red stands for our SPICAV-UV retrievals (between latitudes of $\pm 25°$), blue for *Pioneer Venus* retrievals. A constant, typical conversion factor of 10 ppb per 1 μm-atm was assumed for comparison, consistent with the modeled vertical profiles of SO_2 above the clouds.

2 Long-term variations

2.1 SO_2 column densities

SO_2 column densities increase in average before 2007, and decrease afterwards as shown on Fig. 1. The magnitude and speed of this decrease are comparable to the decrase observed during the 1980s, suggesting a similar origin, perhaps hinting to a periodicity of roughly 25 Earth years of the Venusian atmosphere, a suprising result for a planet without any seasonal forcing.

Latitudinal profiles of SO_2 (shown on Fig. 2) also show an interesting dichotomy between SO_2-rich profiles (prevalent before 2008, see also [1, 5]) and SO_2 poor-profiles for which the gradient seems cancelled or even reversed. This is indicative of temporal variations of the sources and sinks for SO_2. Preliminary simple modeling suggests that during SO_2-rich periods, advection of SO_2 originating from the deep atmosphere is efficient enough to counter-balance photochemical destruction of SO_2, at least in the lower latitudes where upwelling is commonplace. This would not be the case during SO_2-poor epochs, at least in average.

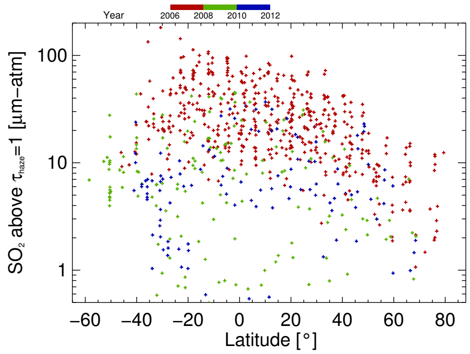

Figure 2: Latitudinal variations of SO_2 column densities. Color codes for the year of observation.

2.2 UV brightness

A steady decrease of the mean UV brightness occurs starting from 2007, when SO_2 also starts to decrease. Such a correlation between these evolutions adds credence to a causal link between SO_2 and the yet unknown UV absorber, which may contribute to the UV opacity in the $200-320$ nm range although its absorption peaks at longer wavelengths. Our study then favors a sulphur-containing UV absorber that some[6] already advocated.

Acknowledgements

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References

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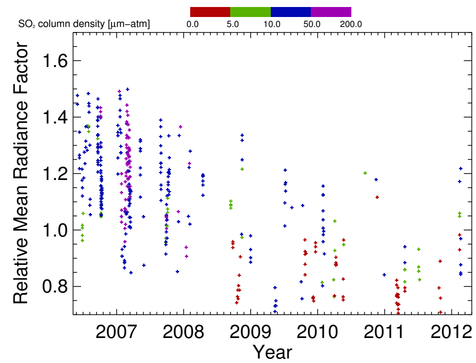

Figure 3: Long term evolution of mean UV brightness for latitudes between $\pm 25°$. Color codes for observable SO_2 column densities.

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