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Variability of SO_2 at Venus' cloud top during the July 2009 brightening event as seen by SPICAV-UV

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Abstract

This paper applies the methods used by Marcq et al. [5] to derive observable SO_2 column densities using SPICAV-UV in nadir mode on *Venus Express* to newer data immediately before and after the brightening event seen from Earth from 2009/07/19 to 2009/07/26 in the visible range. This event appears to have been followed by a global depletion in visible SO_2 content lasting at last 6 Earth months. Various explanations are proposed to explain the observations, stressing the need for simultaneous measurements of other minor species in order to discriminate between competing hypotheses.

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 [1]. 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 [4]. 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 [5] on an extended spatial and temporal coverage. A correlation with IR cloud top altitude derived from simultaneous SPICAV-IR measurement indicate that SO_2 mixing ratio is now controlled dynamically through upwelling in the Hadley cell circulation.

2 SO_2 variability

2.1 Latitudinal variability

Before and up to *Venus Express* orbit #1175, the latitudinal variability is unchanged compared to Marcq et al. and Belyaev et al. [5, 4], with more SO_2 at lower latitudes. The typical mixing ratios are also in the usual range of variation observed from 2006 onwards, as well as the spotted correlation with IR cloud top altitude. Observations after orbit #1379 also present the same characteristics (see Fig. 1).

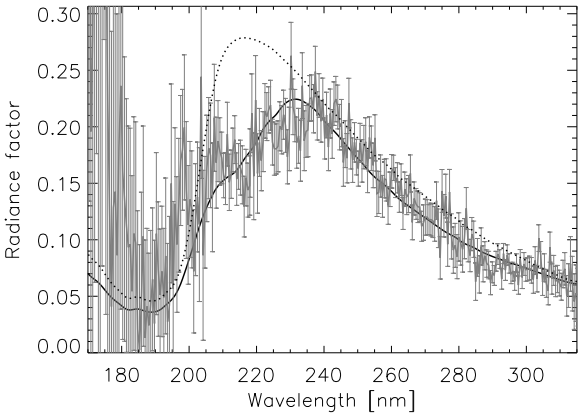

Figure 1: Spectral fit obtained during orbit #1379 at $4°N$ with $N_{SO_2} = 11 \pm 2\,\mu\mathrm{m} - \mathrm{atm}$.

2.2 Temporal variability

Nevertheless, orbits recorded after the brightening event and until about 6 terrestrial months after (between #1281 and #1338) seem to depart from the established pattern. Low, if any SO_2 content is observed at any latitudes, with no correlation to the IR cloud top altitude (see Fig. 2). Also, mean UV albedo during this orbit is around 20% lower than the mean value, but the magnitude of this darkening does not lie out of

the usual variability range observed prior to the 2009 brightening event.

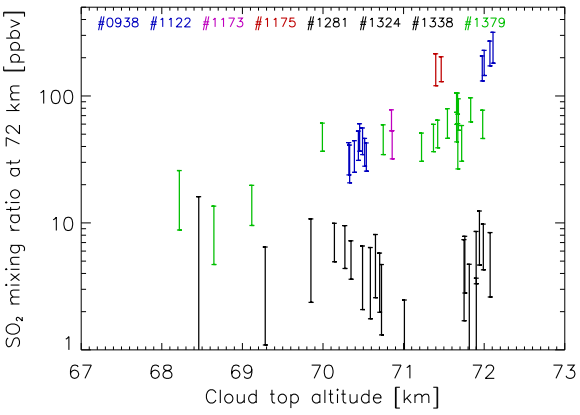

Figure 2: SO_2 mixing ratio at 72 km vs. IR cloud top altitude. Depleted orbits away from the usual correlation are shown in black.

3 Interpretation

There are two interpretation frameworks accounting for the observed trends which will be discussed. Note that these frameworks are not mutally exclusive, so that it is rather a matter or relative importance of the two phenomena.

3.1 Enhanced destruction of SO_2

Observing less SO_2 may imply that there is genuinely less SO_2 to detect. The order of extra depletion rate needed to lower SO_2 content above the clouds by an order of magnitude for a week-long brightening event is around 10^{13} molecules per cm^2 per s, which is not unrealistic. The observed darkening points to a conversion of SO_2 into a sulphur based UV absorber, probably the same as in the main cloud decks. Such a conversion probably involved heterogenous chemistry on the aerosol particles brought during the brightening event and may imply correlated variations in HCl, HF and water vapour content. Measurements of other minor species are therefore needed to confirm this hypothesis.

3.2 Transient high-altitude aerosol layer

The other class of interpretation assumes that SO_2 is merely hidden below a UV-thick aerosol layer rather than destroyed. The fact that IR cloud top seem unchanged during these orbits implies that this aerosol layer must be optically thin in the IR range, thus consisting in very small particles. These particles may also be responsible for the observed UV darkening provided they contain some UV absorber. These detached layers, maybe similar to the ones seen by Wilquet et al. ([6]), may originate from the bright spot of July 2009.

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