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Sulfur Dioxide variability in the Venus Atmosphere

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Abstract

Recent observations of sulfur oxides (SO_2, SO, OCS, and H_2SO_4) in Venus' mesosphere have generated controversy and great interest in the scientific community. These observations revealed unexpected spatial patterns and spatial/temporal variability that have not been satisfactorily explained by models. Particularly intriguing are the layer of enhanced gas-phase SO_2 and SO in the upper mesosphere, and variability in the maximum observed SO_2 abundance and the equator-to-pole SO_2 abundance gradient, seemingly on multi-year cycles, that is not uniquely linked to local time variations. Sulfur oxide chemistry on Venus is closely linked to the global-scale cloud and haze layers, which are composed primarily of concentrated sulfuric acid. Consequently, sulfur oxide observations provide important insight into the ongoing chemical evolution of Venus' atmosphere, atmospheric dynamics, and possible volcanism.

Existing observations have been obtained using multiple platforms, observing techniques, and wavelengths. Each has its own unique strengths and limitations. Although there is strong agreement on some features, there are significant unresolved apparent disagreements among current observations and between observations and models. These apparent disagreements need to be analyzed and assessed carefully to synthesize a clear understanding of sulfur oxide chemistry on Venus. These investigations have been performed via 1) the comparison and validation of observations, from past missions, Venus Express, Earth-based telescopes, and the Earth-orbiting Hubble Space Telescope; and 2) modelling of the SO_2 and sulfur-oxide family photochemistry. The current study has been carried out within the frame of the ISSI International Team entitled 'SO_2 variability in the Venus atmosphere'.

1. Introduction

SO_2 is strongly related to the formation of the clouds and haze on Venus, which are composed of sulfuric acid combined to water complexes. Presence and variations of SO_2 could be the proof of a possible volcanism on Venus. The most intriguing are discrepancies among different observations, and the suspected long-term variations of the SO_2 abundance observed on the scales of several years, in particular during Pioneer Venus Orbiter and Venus Express missions. Similar trends are also observed in the super-rotation period and circulation patterns, which suggest that these aspects may be more strongly coupled than expected.

2. Data sets

In this study, we tried to reconcile the following different observations: previous measurements performed by the Venera probes and Pioneer Venus, as well as more recent observations carried out from Earth or from space-borne instruments, either those on board Venus Express (SPICAV, SOIR, and VIRTIS) or being part of the Hubble Space Telescope suite of instruments.

A first step was the direct comparison of SO_2 abundances obtained by these various instruments. This led to a better understanding of the limitations of each technique used to determine the SO_2 abundance, either at localized altitudes, as profiles or as integrated column values. In a next step, the SO_2 abundance was investigated in terms of spatial and temporal variability, on small/short and large/long scales, as well as relative to local time.

For example, the dayside the gas abundance detected in the 60-100 km altitude range was observed to vary by a factor of 2-5 as a function of local time; similarly, one-to-one comparison of observations made in the 60-100 km altitude range at specific latitudes and local times indicates that the SO_2 gas abundance varied by a factor of 2-10 on the time scale of a few Earth days.

At the cloud tops the long-term average of the SPICAV data shows that during the VEx campaign the 70-80 km dayside SO_2 gas abundance was typically highest in the equatorial region and decreased with increasing latitude. At the same time, both the SPICAV and HST observations indicate that the latitudinal SO_2 gradient in the 70-80 km altitude region was variable, and that the variation in the latitudinal gradient was dependent on the overall abundance of the SO_2 gas.

Photochemical and dynamical modelling schemes investigating the observed vertical and horizontal (both latitudinal and local time) gas density distributions are underway and we will present a summary of the most recent findings.

4. Summary and Conclusions

An ISSI international team has been built in view of considering different aspects of sulfur chemistry on Venus. This includes comparison and validation of observations, from past missions, from Venus Express, from the Earth, and from Hubble Space Telescope, modelling of photochemistry and of other dynamical processes in which the sulfur family is involved. We will consider not only SO_2, but also SO and other constituents involved in its cycle. Reference density and Volume Mixing Ratio (VMR) fields will be constructed from the detailed analysis and comparison of data. These will be included into the next generation of the VIRA references atmosphere.

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