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# On the Decadal Variation of Sulphur Dioxide at the Cloud Top of Venus

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## Abstract

Venus atmosphere is a natural laboratory of sulphur chemistry. As one of the parent species of sulphur, sulphur dioxide ($SO_2$) is generated in the lower atmosphere and transported upward to the middle atmosphere, where it is further oxidized and eventually produces sulphuric acid cloud. The 30-year observations from the Pioneer Venus (Esposito et al., 1988) to the Venus Express (Marcq et al., 2012) show a decadal variation of total column abundance of $SO_2$ above the cloud top. The amplitude varies in orders of magnitude and therefore poses a question on what causes such a dramatic change on the sulphur budget. Previous interpretations include episodic volcanic eruption (Esposito 1984) and long-time dynamical oscillation (Marcq et al., 2012) that is supported by a recent general circulation model on Venus (Parish et al., 2011), but no chemical modelling work has yet investigated those mechanisms. Here I use a time-evolving photochemistry-diffusion model (Zhang et al., 2010; 2012) to understand the decadal variation. Specifically for this study, I perturb the mean steady state of the middle atmosphere of Venus by adding forcing in the upper cloud layer (58-70 km). Important parameters such as the amplitude and timescale of the forcing are constrained by the observed secular patterns. Possible consequences are discussed and the variations for other species are predicted to guide the future observations.

## 1. Model and Results

I used a one-dimensional photochemistry-diffusion model which includes ~50 species and ~350 reactions (see details in Zhang et al., 2010; 2012). In this work I updated the model by solving the water vapour together with other chemical species. I performed non-equilibrium runs to study the time evolution of the chemical species at the upper cloud top (~70 km), especially focusing on the decadal timescale. Two types of forcing are considered here: (1) the volcanic eruption is simulated by a mass flux injected from the bottom layers; and (2) a non-steady eddy diffusion profile to approximate the decadal dynamical perturbations. Figure 1 illustrates the time evolution of sulphur dioxides from the two cases, in comparison with the observations. The simulations successfully capture the observed secular patterns. Other chemical species also show long-term evolution patterns in my model, such as water and carbon monoxide. The strength of the possible volcanic plume or dynamical disturbance can be constrained by the model. The total $SO_2$ flux erupted from the volcano might be large compared with a typical Earth counterpart. The timescale of the dynamical perturbation is about 14 years, consistent with the recent general circulation model results (Parish et al, 2011). The differences between the two forcing cases are discussed.

## 2. Figures

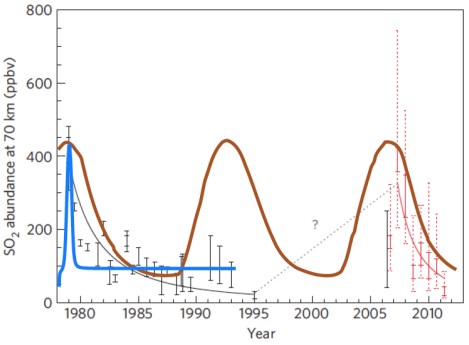


Figure 1: Simulated $SO_2$ volume mixing ratio at Venus's cloud top (adapted based on Fig. 1 in Marcq et al., 2012). The volcanic plume case is in blue and the dynamical perturbation case is in brown. Black and red data points stand for observations in the previous thirty years, with black and red lines fitted by Marcq et al. (2012).

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