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Implementation of sulfuric acid cloud into a Venus GCM

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Venus has global sulfuric acid (H_2SO_4) cloud deck in the altitude of 50-70 km. Past reproductions of cloud distributions in numerical models have been tried using VGCMs (Venusian General Circulation Models) with cloud parameterization (condensation / evaporation and sedimentation processes) in Lee et al. [2010] and our group (e.g. Kato et al. [2014]). However, they did not include chemical processes, and did not reproduce the cloud cycle based on realistic processes.

We have tried to implement the chemical processes related to H_2SO_4 clouds into our VGCM and to reproduce the realistic production and extinction of clouds. As Kato et al. [2014], we used a VGCM based on the CCSR/NIES/FRCGC AGCM [Ikeda, 2011]. Horizontal resolution is T21 (longitude and latitude grid : about 5.6 degree). In vertical, the model has 52 levels (the top altitude: about 95 km). For cloud condensation/evaporation processes, we assumed that if the mixing ratio of H_2SO_4(sum of vapor and cloud) is larger than the calculated saturated level, i.e., the supersaturated H_2SO_4 concentrates as an aerosol, and if not the H_2SO_4 aerosol all evaporates. The radius of cloud aerozol is distributed into 4 modes by ratios based on Haus and Arnold[2010]. It means that our model at the moment does not include the growth of particle size, and only traces the advection of produced clouds. We also note that the produced cloud distributions should modulate the thermal distributions through radiative effects but current our model assumes constant heat input profile (as well as the former code).

In this study, we implement following chemical reactions (1) – (4) into the VGCM.

$SO_2 + O + M \longrightarrow SO_3 + M$, (1)
$SO_3 + H_2O + H_2O \longrightarrow H_2SO_4 + H_2O$, (2)
$H_2SO_4 + H_2O \longrightarrow SO_3 + H_2O + H_2O$, (3)
$SO_3 + CO \longrightarrow SO_2 + CO_2$, (4)

After 15 Venus days, the cloud distribution in this model reaches equilibrium status. In this model, we succeeded to reproduce the cloud cycle, i.e., the formation of H_2SO_4 cloud particles in the upper cloud region (about 67-75 km altitude) and the formation of SO_2 and its extinction in the lower cloud region (about 50km altitude). This is consistent with the formation / extinction processes suggested by a two-dimensional model [Imamura and Hashimoto, 1998]. This model could also qualitatively reproduce the cloud top altitude with latitude. However, optical thickness in polar region (more than75 degree) was smaller than Venus Express observations [Haus et al., 2014]. Another problem is that the mixing ratios of H_2O and SO_2 were larger than those in a chemical model [Krasnopolsky, 2012]. We are now trying to solve these problems.

As the next step, we will implement the radiative effects of H_2SO_4 clouds into the VGCM, and enable to produce more realistic thermal structure. We will apply this model for studying qualitatively and quantitatively clouds global distributions and their variation which will be observed by Akatsuki mission from 2016.

Keywords: Venus, sulfuric acid cloud, General Circulation Model