Study of the Venusian cloud formation and distribution in low- and mid-latitudes using a GCM: Effects of atmospheric chemistry and circulation

Kazunari Ito[1], *Takeshi Kuroda[1], Yasumasa Kasaba[1], Naoki Terada[1], Kohei Ikeda[2], Masaaki Takahashi[3]

1.Department of Geophysics, Tohoku University, 2.National Institute for Environmental Studies, 3.Atmosphere and Ocean Research Institute, The University of Tokyo

Sulfuric acid clouds cover the Venusian atmosphere in 48-70 km, and are important in the Venusian climate through their radiative processes. The clouds are the main objective of the JAXA Akatsuki orbiter for the investigations of atmospheric dynamics, so the modeling study of the formation and advection of them using a Venusian General Circulation Model (VGCM) is of significance also for the help of the mission. We have implemented the sulfuric acid cloud formations and related chemical processes into a VGCM, and investigated their distribution and the formation systems.
We used the VGCM modified from the CCSR/NIES/FRCGC AGCM [Ikeda, 2011], with the horizontal resolution of T21 (longitude and latitude grids of about 5.6 degrees) and 52 levels in vertical with the sigma (equivalent to the pressure) coordinate (the top altitude of ~95 km). For the cloud condensation and evaporation processes, the effects of supersaturation are not considered and the radius of cloud aerosol is artificially distributed into 4 modes by ratios based on the vertical profiles shown by Haus and Arnold [2010]. Note that our model at the moment does not include the growth or reduce of the particle size, and only traces the advection of produced clouds. Also note that the cloud distributions should modulate the thermal distributions through radiative effects, but the current model still assumes constant heat input profile (as well as the former code by Ikeda [2011]).
Our model includes the chemical processes related to the production and loss of H_2SO_4 vapor (SO_3, SO_2 and H_2O) in order to reproduce the realistic maintenance processes of cloud distributions. In the model with those chemical processes (hereafter WC model), the simulated latitudinal distributions of the optical thickness of clouds agree with the observational results by the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS) onboard Venus Express (VEX), and also the simulated vertical profiles of H_2SO_4 vapor agree with the Magellan radio occultation data, in low- and mid-latitudes (0-70^{o} N). On the other hand, in the model without the chemical processes (hereafter NC model), the cloud opacity distributions become less than half of the observed ones, and also the abundance of H_2SO_4 vapor around 48 km becomes less than half in comparison with the WC model. Clouds are formed above ~50 km in both models, but the abundances in the WC model are larger than those in the NC model. The difference of the WC model is caused by the production of H_2SO_4 vapor due to the chemical processes and the condensation of it into the clouds in the upper cloud region (60-80 km). We conclude that our VGCM reproduces the observed features with a good reliability in low- and mid-latitudes with chemical processes.
With this VGCM, we investigated the maintenance and circulation processes of the sulfuric acid clouds and vapor in low- and mid-latitudes. Our model indicated that, in the upper cloud region, the clouds are produced centered at ~65 km altitude, and flow upward and poleward by the meridional circulation and vertical diffusion. Meanwhile, in the lower cloud region (50-60 km), H_2SO_4 vapor transported by the upward advection and vertical diffusion condenses into the cloud in the equatorial region at the altitude of 50-54 km, and the formed clouds are transported poleward along the meridional circulation. These cycles are consistent with those simulated in a 2-D latitude-altitude cloud formation model by Imamura and Hashimoto [1998] with a given meridional circulation, and we first reproduced the cycle in a VGCM. Using this new VGCM, we showed that the diurnal tide mainly contributed to drive the meridional circulation through the wave-zonal mean

flow interaction in low- and mid- latitudes.

Keywords: Venus, Sulfuric acid clouds, Atmospheric chemistry, General circulation model, Akatsuki

