EPSC Abstracts
Vol. 10, EPSC2015-634, 2015
European Planetary Science Congress 2015

VenLA: The LATMOS Venus cloud model

A. Määttänen, S. Guilbon, A. Stolzenbach, S. Bekki, F. Montmessin
Université Versailles Saint-Quentin; Sorbonne Universités, UPMC Univ. Paris 06; CNRS/INSU, LATMOS-IPSL, 11 boulevard d'Alembert, 78280 Guyancourt, France

Abstract

The LATMOS Venus cloud model VenLA (Venus Liquid Aerosols) is based on a terrestrial Polar Stratospheric Cloud (PSC) model [7]. VenLA models the formation, growth and decay of sulfuric acid - water droplets. The model has undergone several updates. We will present results of reference runs and sensitivity tests based on input profiles from VIRA [5] for temperature and pressure and from occultation data concerning the vapors, as in [8]. We compare the results to the available observations on cloud particle number densities and sizes, and to other modeling studies. The VenLA model will define the baseline for a parallel project on development of a moment method scheme to be used in a global climate model (see abstract Guilbon et al., this conference [2]).

1. Introduction

The clouds of Venus and the aerosols in the Earth's stratosphere are close relatives: they are mainly composed of sulphuric acid droplets. The Venus clouds are an important climatic element. The clouds are optically thick and absorb most of the insolation arriving at Venus, letting only few percent of sunlight reach the surface. The clouds on Venus are divided in three layers of differing properties (particle size distributions, number density). Even though the upper clouds can be directly studied with satellite instruments, only a handful of observations have acquired information on the conditions and properties inside the clouds (in particular [6] on cloud properties) and thus the study of the lower and middle cloud layers relies largely on modeling.

2. Methods

The PSC model [7] is a sectional microphysical model that can describe a multimodal particle size distribution discretized with tens or hundreds of radius bins. In its original configuration is is able to model all of the microphysical processes relevant to the PSCs including the multiple phase transitions related to the particle types including liquid and solid phases of water, sulfuric acid, nitric acid and their mixtures. The PSC model required several modifications when becoming VenLA. The major modifications include: removal of nitrous species and related cloud particle types from the model, addition of homogeneous and heterogeneous nucleation parameterizations, inclusion of the condensation nucleus particle type, addition of coagulation accounting for both single-type and multi-type particle coagulation, and parametrization of vertical mixing via eddy diffusion. Because of the extreme dryness of the Venus atmosphere, we also needed to add iteration in the calculation of the weight fraction of sulfuric acid in the droplet in order to correctly account for the change in total water content.

VenLA receives as input atmospheric profiles of temperature, pressure, vapor concentrations and condensation nucleus properties (a lognormal size distribution defined in a given altitude range [3]). The vapors are consumed during nucleation and condensation and replenished when the droplets evaporate or when mixing brings in vapor-rich air. In these simulations the temperature and pressure profiles are not changed and thus the simulated clouds are considered as formed in average conditions and do not reflect effects of large-scale dynamics. In principle the model can also be used with varying input profiles, but here we focus on using time-independent VIRA profiles [5] only.

Homogeneous nucleation is described with the parameterization of [14] and heterogeneous nucleation with a simple parameterization as in [3]. Condensation/evaporation is treated in two steps: simple (fast) equilibration whenever a droplet experiences a change in environmental conditions (temperature, partial pressure of water vapor) causing a change in the equilibrium composition, and (slow) condensation/evaporation during which the droplet grows/shrinks conserving the equilibrium composition [9]. We account for Brownian and gravitational coagulation (coalescence) and we use the numerical method of [4]. The coagulation kernels are calculated as in [1, 12] and the sum of the Brownian and gravitational kernels is corrected as in [10, 11]. Vertical transport (sedimentation and eddy diffusion) is treated following the method of [13] and settling velocity is calculated using [9, 1] and corrected to account for mixing.

3. Results

We will focus on reproducing the [6] in-situ observations of the cloud properties. We will also probe the variations of the clouds by using the VIRA profiles from different latitudes. One of the main sensitivity tests will be the effect of CN on the cloud properties. The nucleation pathway may prove significant in the simulations since it defines the number of formed particles. This regulates the particle size for a constant condensible mass. In our preliminary test runs, when using only the homogeneous nucleation parameterization, the we reach the observed condensed mass load, but the droplet number concentrations are too low and consequently the droplets are too large. Using heterogeneous CN activation it is much easier to attain observed number concentrations and sizes, however, the used initial CN concentration profile plays a role in the development of the cloud. We will initialize our CN profiles following previous studies to enable a direct comparison.

4. Summary and Conclusions

The VenLA cloud model and reference and sensitivity run results will be presented. The results will be compared with published modeling studies and observations. The role of CN will be put in particular focus.

Acknowledgements

We acknowledge the support of the French Planetology program (Programme National de Planétologie, ATMARVEN project).

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