National Aeronautics and Space Administration

FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

Origins of phosphine in the Venus aerosol layer: modeling and simulations of the interaction between the lower aerosol layer and the upper layer of the deep atmosphere

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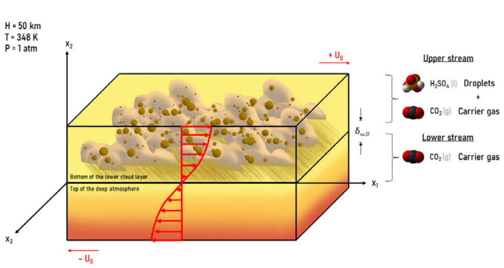
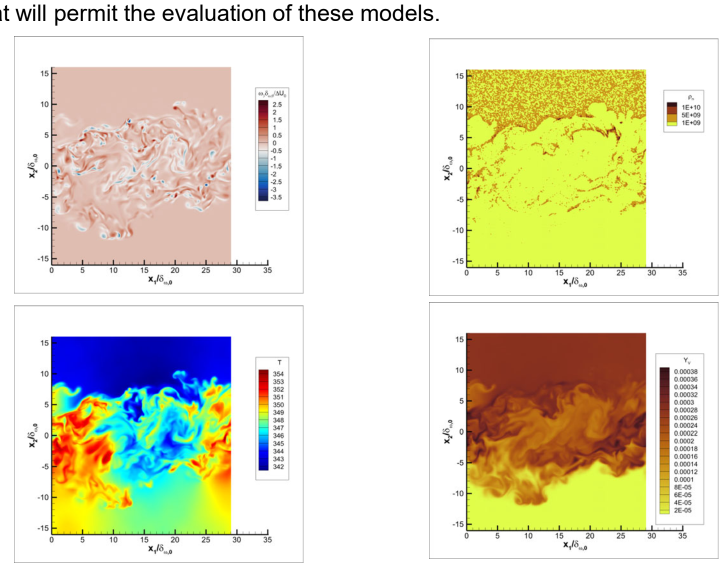
Objectives: Prompted by the discovery of phosphine in the Venus aerosol layer and the hypothesis that it may be of biotic origin, the objective was to investigate whether the biotic origin is the only one tenable. As an alternative it was recently proposed that phosphine in the Venus cloud layer could instead result from phosphide in the upper deep atmosphere entering the aerosol layer and reacting with sulfuric acid from the lower cloud layer rather than being of biotic origin. The biotic versus non-biotic aspect of the cloud layer was the underlying motivation of this study.

Background: The idea that the Venus clouds could harbor biotic processes has been promoted for years. The recently reported phosphine observation in the aerosol layer reinforced this hypothesis. However, the measurement was more recently scrutinized, and phosphine appeared to be a fraction of that initially reported, or nonexistent. Others have hypothesized that phosphine is produced by phosphide produced by volcanoes that mixes and reacts with sulfuric acid in the lower aerosol atmosphere. (produced in the upper atmosphere by the Sun's photochemical action on CO_2, SO_2, and H_2O vapor). This study was initiated around this hypothesis. However, upon consultation with chemists, it appears that this proposed reaction is presently unknown and moreover could possibly only occur in the liquid phase and would be very complex. Other studies alternately promoted the importance of sulfuric acid drops, known to exist in the aerosol layer, as the source of sulfuric acid vapor that would provide an environment for biotic processes. Since this study was initiated as a scientific inquiry based on known physical/chemical/ thermodynamic principles to investigate a possible biotic promoting environment in the Venus clouds, it was natural to turn to the investigation of sulfuric acid instead of phosphine.

Approach and Results: The modeling approach for the sulfuric acid cloud follows the goal of initiating the study of the microphysics of the lower aerosol layer. The sketch of the configuration (left most figure) shows a stream laden with drops representing the lower aerosol layer of the cloud layer, and a stream devoid of drops representing the upper layer of the deep atmosphere in contact with lower aerosol layer as described in the literature. The drops are smaller than the smallest length scale of the flow, portraying the aerosol in a turbulent flow. The relatively small domain in which the equations are solved, consistent with the study of microphysics, allows the utilization of a methodology whereby all length scales of the gas are computed, thereby imparting high accuracy to the results. The domain boundary conditions are such that the flow to and from inside the domain freely communicates with the outside of the domain. The figures show the non-dimensional vorticity (top left), drop number density in m^{-3} (top right), temperature in degrees Kelvin (bottom left) and sulfuric acid vapor mass fraction (bottom right) in the middle spanwise plane of the domain.

Significance/Benefits to JPL and NASA: The significance of the results is multiple. First, it is shown that the microphysics of the Venus aerosol layer can be modeled, numerically simulated and understood; the predictions will improve with additional information obtained from observational data. Second, it appears that sulfuric acid drop evaporation produces an environment that is not inconsistent with biotic processes. Third, the model/code only establish the basis of the complex microphysics of the clouds; additional phenomena such as photochemical effects, nucleation and coagulation. Fourth, the predictions obtained from models established on firm physical grounds could lead to instruments on forthcoming missions that will permit the evaluation of these models.





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