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Clouds and aerosols on Venus: an overview

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The past decade demonstrated significant progress in understanding of the Venus cloud system. Venus Express observations revealed significant latitudinal variations and temporal changes in the global cloud top morphology. The cloud top altitude varies from ~72 km in the low and middle latitudes to ~64 km in the polar region, correlated with decrease of the aerosol scale height from 4 ± 1.6 km to 1.7 ± 2.4 km marking a vast polar depression. The UV imaging shows the middle latitudes and polar regions in unprecedented detail. The eye of the Southern polar vortex was found to be a strongly variable feature with complex morphology and dynamics.

Solar and stellar occultations give access to a vertical profiling of the light absorption by the aerosols in the upper haze. The aerosol loading in the mesosphere of Venus investigated by SPICAV experiment onboard Venus Express between 2006 and 2010 was highly variable on both short and long time scales. The extinction at a given altitude can vary with a factor of 10 for occultations separated by a few Earth days. The extinction at a given altitude is also significantly lower towards the poles (by a factor 10 at least) compared to the values around the equator, while there is apparently no correlation between the extinction and the latitude in the region comprised between ±40° around the equator.

Based on the Mie theory and on the observed spectral dependence of light extinction in spectra recorded simultaneously in the UV (SPICAV-UV), in the near IR (SPICAV-IR), and in the short-and mid-wavelength IR (SPICAV-SOIR), the size distribution of aerosols in the upper haze of Venus was retrieved, assuming H_2SO_4/water composition of the droplets. The optical model includes H_2SO_4 concentrations from 60% to 85%. A number of results are strikingly new: (1) an increase of the H_2SO_4 concentration with a decreasing altitude (from 70-75% at about 90 km to 85% at 70 km of altitude) and (2) Many SOIR/SPICAV data cannot be fitted when using size distributions found in the literature, with an effective radius below 0.3 μm and a variance of about 2. The scale height of the upper haze is found to be 6.9 ± 5.1 km.

The lower and middle cloud layers – those at 48 – 60 km altitudes – are difficult to observe, as they are hidden by upper clouds. Nevertheless, both nightside near-IR sounding and radio occultation has provided valuable insight into cloud processes in this region. Near IR sounding reveals the morphology of the lower/middle clouds 'backlit' by thermally emitted photons from the lower atmosphere. The morphology of these clouds changes on timescales of order of 24 hours. The vertically integrated cloud optical depth is twice as great in the polar collar (at 75 degrees latitude) compared to low latitudes. Spectral band ratio analysis, if interpreted strictly in terms of Mode 1 / 2 / 2' / 3 particles of H_2SO_4:H_2O mixtures, suggests that the acidity of the cloud particles is higher near the polar collar and in regions of optically thick cloud. Particles in the centre of the polar vortex exhibit anomalously high band ratios so are significantly larger and/or of different composition than those at low latitudes.

Radio occultation from Venus Express confirms that the atmosphere is in convective equilibrium from 50-60 km. Sulphuric acid vapour profiles calculated from the absorption of the radio signals show an atmosphere saturated with sulphuric acid in the cloud layer. Both of these results are consistent with the understanding of convective condensational cloud at altitudes of 50-60 km.

Microphysical simulations of the aerosol populations in the atmosphere of Venus have received a boost from the recent exploration of particle properties carried out by various teams using Venus Express over the last decade or so. Numerous groups are applying separate models to the coupled problems of the Venus clouds. Quasi-periodic variability of aerosol population properties has been found in model simulations by several groups under both forced and unforced conditions. Since the clouds play such a significant role in the energy and momentum balance of the atmosphere of Venus – which then feed back into variations in the aerosols themselves – constraining the magnitude and timescales of these variations is a key to understanding the current, past, and future Venusian environment. This paper gives a summary of new observations and modelling efforts that will form the basis for a relevant chapter in the Venus III book.