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Photometry of Venus upper clouds by Venus Monitoring Camera (VEx): spatial and temporal distributions of the retrieved aerosol parameters

O. S. Shalygina[1], E. V. Petrova[2], and W. J. Markiewicz[1]
[1]Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany (o.s.shalygina@gmail.com), [2]Space Research Institute, Russian Academy of Sciences, Moscow, Russia

1 Introduction

During 2 006 – 2 014 the Venus Monitoring Camera (VMC) onboard Venus Express (VEx) was imaging the Venus clouds in four narrow spectral channels that shared one CCD: UV (0.365 µm), VIS (0.513 µm), NIR1 (0.965 µm), and NIR2 (1.010 µm) [1]. Around 350 000 wide-angle images of the planet were obtained covering almost all the latitudes, which allowed the knowledge on morphology and dynamics of the cloud deck of Venus to be substantially extended [2].

The first images of a full glory in unpolarized light on the upper cloud deck of Venus were obtained with VMC [3] (see fig. 1). Glory is an optical phenomenon observed near opposition that poses constraints on the properties of cloud particles: they have to be spherical, and their size distribution has to be rather narrow. Observations of glory are of key importance for the phase function analysis of the Venus upper clouds, composed of H_2SO_4 droplets: the angular positions of maximum and minimum are determined by the size of particles, and the brightness of the first peak depends on their refractive index (especially in NIR, see fig. 2) [3, 4].

In this report we summarise our retrievals from the all VMC dataset [3–7]. From fitting the phase profiles with models, we have obtained the optical properties of the Venusian clouds (*i.e.* effective radius R_{eff} and variance ν_{eff} of particles' size distribution, refractive index m_r of aerosols, optical thickness of cloud layer τ and haze τ_h), and their spatial (in latitude) and temporal (in local time) variations.

2 VMC data and modelling

To estimate the properties of cloud particles, we modeled the phase dependence of brightness retrieved from the dayside images. We have analysed the whole set of the VMC data and separated them into two types: the data obtained in three channels (NIR1, UV ans VIS) in glory region, *i.e.* at small phase angles ($0° < \alpha < 60°$) [3–5, 7], and the data retrieved only in NIR1 channel at phase angle range $0° < \alpha < 140°$ for the local solar time (LST) interval of 6 – 18 h [6].

The model assumes plane-parallel atmosphere and consists of two layers: an optically thick cloud layer and a thin haze layer above it. For the main cloud layer two versions were considered: (1) only H_2SO_4 droplets of the 1-m mode are in the clouds, and (2) the clouds are composed of 1 micron H_2SO_4 droplets homogeneously mixed with small submicron particles of the same size as those in the above haze. This allowed us to distinguish the influence of the submicron mode, which is always present in the clouds, on the measured phase profile.

To find the intensity of light scattered by the cloud-haze system, the radiative-transfer code solving numerically the invariant embedding equation was used [8]. To calculate the single scattering phase functions of spherical particles in the clouds and the haze, the Mie theory was used, because the particles in Venus clouds are expected to be liquid (*i.e.*, spherical) and the smaller submicron particles presumably present in the haze and everywhere in the clouds are so small for the VMC wavelengths that can be also treated as spherical, even if they are solid. The total number of combinations in the values of varied parameters exceeded 1 500 [see 6]. The best fits were chosen

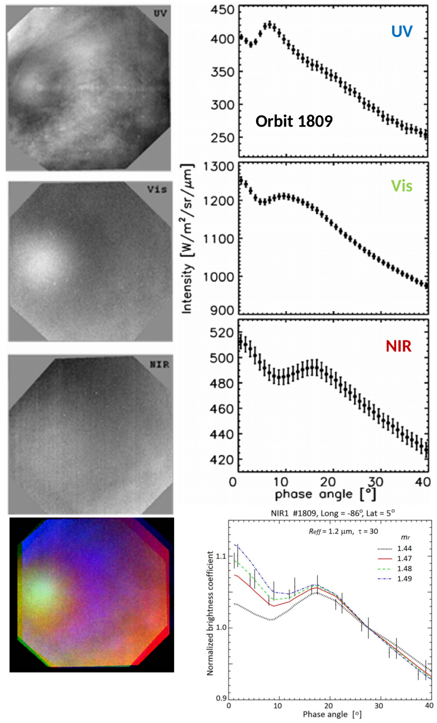

Figure 1: Venus glory as observed by VMC. Left: VMC images and a false-color composite of the glory. Right: the normalized measured values of NIR1 brightness (dots with error bars) as a function of α are compared to the cloud models [3].

automatically by the least square method.

3 Summary

Joint analysis of the whole VMC data set (the glory data obtained in three VMC channels and the full phase dependencies built for NIR1) yielded the maps of temporal (within a local day) and spatial variations in the retrieved parameters of the clouds, and allow us to conclude the following [3–7]:

- The decrease of the particle sizes at high latitudes down to 0.6 µm at 60°S is definitely seen.
- The cases with a relatively high real part of the refractive index (1.45 – 1.49 with sporadic spikes up to 1.52) are very often observed for the 1-micron cloud particles. An additional component (sulfur or ferric chloride) with a

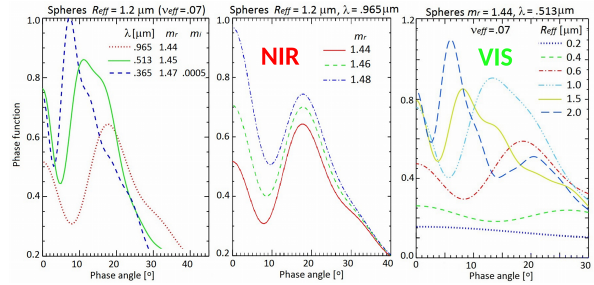

Figure 2: Examples of the single-scattering phase functions calculated for VMC wavelengths and different optical properties of particles.

high refractive index should be present in the cloud droplets.

- Small submicron particles ($R_{\text{eff}} = 0.23\,\mu\text{m}$) are detected mostly in the morning within the clouds and/or in the haze above the clouds.
- No clear long-term variations of the retrieved parameters were found.

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