Modelling Venus reflectivity in the visual range

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1 Introduction

The atmosphere of Venus has a thick stratified cloud deck covering the planet's surface. It is mainly composed by spherical droplets of sulphuric acid mixed with an ultraviolet absorber of unknown nature. The Venus Express mission of the European Space Agency is orbiting around the planet since April 2006, being one of its main tasks the analysis of the atmosphere and clouds [1]. In this work we present a theoretical study of the spectral reflectivity of the atmosphere in the visible range for several geometric configurations, using a radiative transfer code which includes absorption and scattering by gas and particles in the atmosphere. Such a model will be used in the analysis of the image qubes taken with the instrument VIRTIS onboard Venus Express [2].

2 The atmosphere of Venus

The atmosphere of Venus is basically composed of CO_2 (more than 96%) and N_2, although it is possible to find other species with strong absorption bands in the visible and near ultraviolet and infrared spectral ranges, such as SO_2 and H_2O. The mean molecular weight is 43.45 and surface gravity is about 887 cm/s^2 (see for example [3]). Our interests are centred in the region below 90 km: the stratosphere and troposphere of Venus. Thick H_2SO_4 clouds are distributed between about 70km and 50 km. Below and above it less dense hazes can also be found [4].

3 The radiative transfer code

Our radiative transfer code is based in the doubling-adding technique. It has been applied previously to the giant planets Jupiter and Saturn ([5],[6],[7]),

Table 1. Short description of cloud layers, taken from [4]. See fig. 1

Layer	**Optical thickness** τ	**Particles radii** $r(\mu m)$
Upper Haze	0.2–1.0	0.4
Upper Cloud	6.0–8.0	0.4 & 2.0
Middle Cloud	8.0–10.0	0.3 & 2.5 & 7.0
Lower Cloud	6.0–12.0	0.4 & 2.0 & 8.0
Lower Haze	0.1–0.2	0.2

and now it is adapted for Venus. It includes the following contributions for the outcoming radiation:

- Gas scattering (Rayleigh scattering) by the mix of CO_2 and N_2
- Gas absorption (SO_2, CO_2 and H_2O) by species of variable (vertically and horizontally) abundance.
- Particle scattering by clouds and hazes, including phase functions and size distributions characteristic of the atmosphere of Venus

Our model reproduces the observed reflectivity I/F of the planet (in terms of the incoming solar radiation) for a given geometrical configuration and wavelength. Wisely using the different viewing and illumination geometries and spectral range it is possible to constrain the atmospheric properties, such as the particle phase function (hence their size and refractive indexes) and the location (height and optical thickness) of clouds and hazes.

4 First results

Using a standard atmospheric model as the one in Sec. 2 [4], it is possible to find the atmospheric reflectivity in various wavelengths, taking into account the contributions aforementioned. We calculate the reflectivity function, i.e. the way the reflectivity varies as a function of the cosine of illumination (μ_0) and observation (μ) angles.

From the reflectivity matrix it is possible to find the reflectivity of the atmosphere under any geometrical condition. This is shown in the figure 2, where the reflectivity at 600 nm has been calculated and compared to one of the VIRTIS qubes obtained during the Venus Express Orbital insertion, on April 2006. The agreeement is noteworthy, although there are are deviations at extreme viewing angles. In such a way it is possible to find the vertical cloud structure that best reproduces observations.

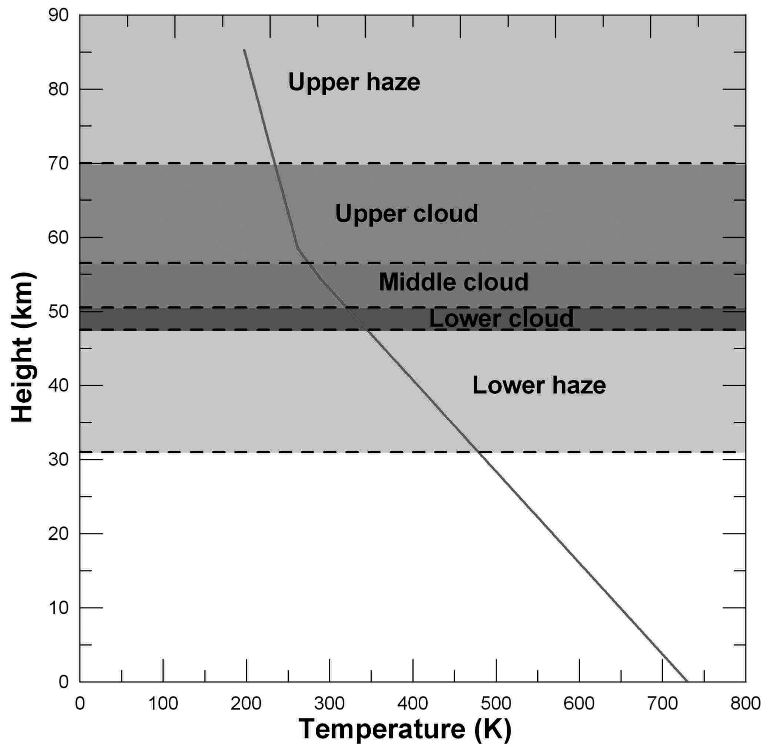

Fig. 1. Vertical distribution of clouds and hazes in the atmosphere of Venus. The red line marks the variation of the temperature with height.

5 Future work

VIRTIS is a spectrograph onboard Venus Express able to take images from the near UV to the IR. In this spectral range, we will be able to reproduce the mean observed reflectivity $I/F(\lambda, \mu, \mu_0, \Delta\phi)$ (i.e., the reflectivity as a function of wavelength and scattering angles) using a standard vertical cloud structure model. But, more importantly, we will also describe the variation (temporal and horizontal) of the mean reflectivity $\delta I/F(\lambda, \mu, \mu_0, \Delta\phi)$ in terms of aerosol concentration, vertical distribution, or size and phase function changes.

The code also allows to find the internal radiation fields (both upward and downward fluxes and intensities), similarly as in [8]. This will be compared with data obtained with previous spacecrafts, see for example [9]. Our goal is thus to study the vertical and horizontal distribution of aerosols, mainly in the upper haze and cloud.

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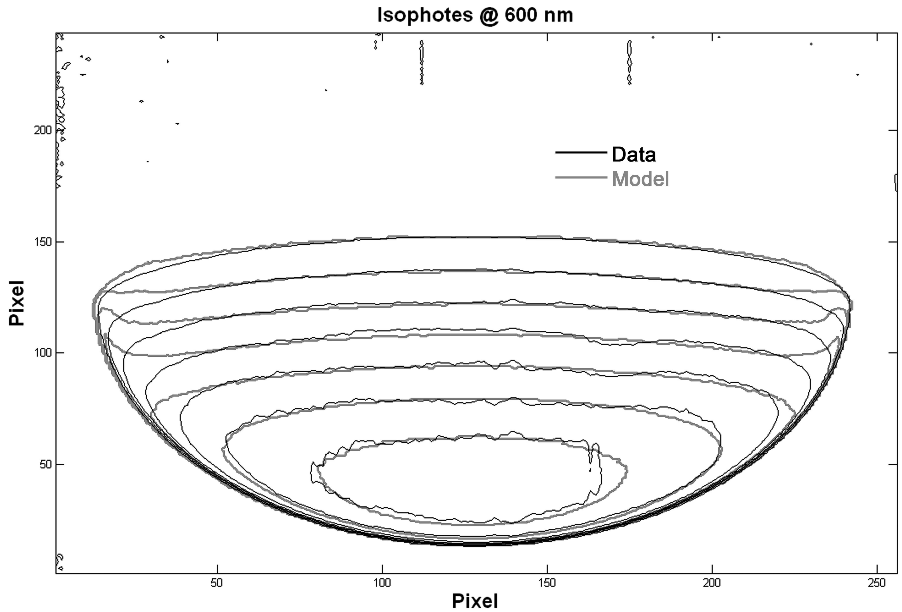

Fig. 2. Reflectivity data at 650 nm (black lines) and modelled results (gray line) as viewed during the Venus Express orbital insertion.

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