EPSC Abstracts,
Vol. 4, EPSC2009-622, 2009
European Planetary Science Congress,

Synthetic images of Venus surface based on VMC images

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Introduction

The Venus Monitoring Camera (VMC) is a part of the Venus Express payload. It takes images in four channels, one of which centered at 1.01 micron registers the night side thermal emission from the planet surface [1]. Venus Monitoring Camera performs wide-angle observations of Venus in four narrow band filters sharing one CCD [1]. On the night side VMC maps thermal emission of the surface in the $1.01\mu m$ spectral transparency "window". These measurements are at the limit of instrument capability. Faintness of the surface emission and low efficiency of the CCD detector ($\sim 2\%$) at $1.01\mu m$ result in that even at maximum exposure of $30s$ the measured signal does not exceed ~ 200 digital units (DNs) which is $\sim 3\%$ of the CCD full well. The second difficulty of the surface observations results from the solar stray light. In order to cope with this problem VMC observes the night side when the spacecraft is in eclipse. This limits the observations to low latitudes ($+/-$ 40 degrees).

Formal spatial resolution of these images taken from the working distances (2 000 – 8 000 km) is 1 to 5 km, but because the surface radiation on its way to the camera passes through the dense scattering atmosphere and cloud layer, the actual spatial resolution is about 50 km. The radiation intensity depends on the surface temperature thus giving a hope to register the ongoing volcanic eruptions. Also the radiation intensity depends on the emissivity of the surface material, which is a function of a number of parameters including surface texture in micron to millimeter scale and mineralogical composition. The latter is interesting for searching on Venus geological features and terrains whose chemical/mineralogical composition may be different from that of dominating basalts. On Venus with its very massive atmosphere, surface temperature has practically no diurnal, seasonal and latitudinal variations and is a function of surface altitude. So in search of volcanic eruptions and in attempts to find mineralogical differences, it is necessary to take into account the altitude of the given place and build model images showing altitude-dependent and emissivity-dependent thermal emission of the surface. Temporal variations in the cloud layer density also should be taken into account.

Modelling the night side $1\mu m$ emission

Meadows and Crisp [2] showed that the $1\mu m$ spectral "window" in the night side spectrum of Venus is free from atmospheric absorption. The dense atmosphere affects surface images in two ways. It strongly attenuates the emission and leads to degradation of spatial resolution, or blurring. Assuming that radiation field on the top of the atmosphere is orthotropic an image at the top of the atmosphere can be expressed by the formula:

$$I(x,y) = k \iint \frac{t\varepsilon(x,y)}{1-(r[1-\varepsilon(x,y)])} \cdot \cdot B[T_s(x',y')] \cdot F(x-x',y-y')dx'dy', \quad (1)$$

where x, y – coordinates of point on the surface, I – flux from point, r and t – reflectivity of atmosphere in back direction (to the surface) and transmittance of atmosphere, ε – emissivity of surface, T_s – temperature of surface, B – Planck function and k – norming coefficient. We applied the two-stream approximation to a whole (single layer in this case) atmosphere to account for attenuation and multiplied it by the blurring function responsible for smoothing contrasts. Assuming that both surface emissivity and atmospheric transmittance do not strongly vary within the scale of blurring function (~ 50 km), we can leave only $B \cdot F$ under integral in (1).

By dividing VMC image on model image with constant emissivity ε_0 we can obtain map of $\varepsilon/\varepsilon_0$. This map is correct, of course, only in area where atmospheric opacity variation are negligible.

The atmosphere blurring effect was modelled by the Monte-Carlo method [3] taking into account multiple scattering by aerosols and gases. We used the vertical structure of clouds and their optical properties from [5], Rayleigh scattering coefficient in the lower atmosphere from [4], and Henyey-Greenstein phase function with asymmetry parameter $g = 0.78$ and single scattering albedo $\omega_0 = 0.9995$. Thermal emission of the surface is the only source of radiation on the Venus night side. It is a product of the Plank function that strongly depends on surface temperature and, hence, on altitude and surface emissivity ε defined by mineralogical composition.

To calculate synthetic VMC images we used the Magellan topography derived from Magellan Radar Altimeter

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[6]. The topography data were converted into the maps of temperature assuming thermal equilibrium with the atmosphere, constant lapse rate of -8.1 K/km [7]. For ε calculations we assumed $\varepsilon_0 = 0.8$ for basaltic planes.

Here we present example image of ε calculated for VMC orbit-wise mosaic (orbit 470):

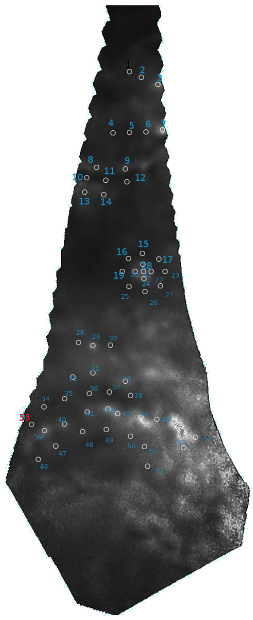

Figure 1: Relative emissivity for orbit 470

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