GEOLOGIC ANALYSIS OF THE SURFACE THERMAL EMISSION IMAGES TAKEN BY THE VENUS MONITORING CAMERA, VENUS EXPRESS: INITIAL RESULTS.
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Introduction. One of the channels of the Venus Monitoring Camera (VMC) onboard of Venus Express (VEX) spacecraft is centered at 1.01 µm. When the camera looks at the night side of Venus in eclipse, the channel registers thermal emission from the planet surface in the mid-southern to mid-northern latutudes [1]. Due to scattering in the atmosphere and the cloud layer, the effective resolution of the surface images is ~50 km. VMC takes sequences of images, which are mosaiced by orbits and by regions of study. Here we report the results of preliminary analysis of the images taken at the first three seasons of observations which cover Beta and Phoebe Regio, Hinemoa and Gunda Planitia with latitude range of 35°S to 40°N and longitudes from 230° to 315°E. First results of the VMC data analysis are given in [2]. Complementary to VMC, observations of thermal emmision from the Venus surface are being done by the VEX imaging spectrometer VIRTIS [3].

Intensity of the surface thermal emission at 1 µm depends strongly on its temperature thus giving a hope to register ongoing volcanic eruptions, and on the emissivity of the surface material which is a function of a number of parameters including surface texture and mineralogy. The latter gives a principal possibility for search for terrains which composition is different from basalts that dominate the Venus' surface. Essential component of our study are comparisons of the VMC images and model images constructed from the distribution of surface temperature which in turn is a function of surface elevation.

Modelling surface black body emission at the top of the atmosphere. The 1 µm spectral "window" is free from the atmospheric absorption bands [4]. Multiple scattering on clouds particles and atmospheric gases attenuates the emissions and produces blurring. We use Monte-Carlo-based code to model light scattering in plane-parallel multi-layer atmosphere. The vertical structure of clouds as well as their optical properties have been taken from [5] and Rayleigh scattering coefficient of the lower gaseous atmosphere from [6]. We assume that such thick atmosphere (together with not very oblong phase function) will give us orthotropic radiation field on the top of the atmosphere. That is why we can obtain point spread function of atmosphere and use it to blur surface images in azimuthal (orthographic) projection. Such modelling gave us point spread functions with half-width of ~50 km, which is in agreement with the acquired VMC data.

We used topographic maps (GTDR data set) derived from Magellan Radar Altimeter [7] to convert them into temperature distribution maps assuming constant temperature gradient (-8.1 K/km) and then into images of black body emission (to compare them with the VMC images) by calculating values of the Plank function at 1.01 µm wavelength in each surface point. The surface emissivity of 1.0 was assumed. As the final step these images were blurred with the mentioned point spread function.

Geologic analysis. As it was mentioned above, the VMC image analysis can potentially progress in two directions: 1) to search for the ongoing or very recent lava flows and 2) to look for areas whose emissivity at 1 µm differs from surroundings. Strategy for the first direction is to search for anomalous brightening at areas of geologically young rifts and volcanoes by comparing the VMC images with the model images of black body emission of the same areas. Now we are in a process of such search in the young rifts and volcanoes of the study region.

Strategy for the second direction of the analysis is to pay special attention to the terrains, whose mineralogical composition could differ from that of basalts. First type of such targets is represented by massifs of tessera terrain. Nikolaeva et al. [8] compiled several pieces of evidence that tessera might be composed of the material geochemically more differentiated than basalts, e.g. rocks such as rhyolites and andesites, or analogs of lunar highland materials, such as anorthosites, whose mineralogies and thus 1 µm emissivity can be different from those of basalts.

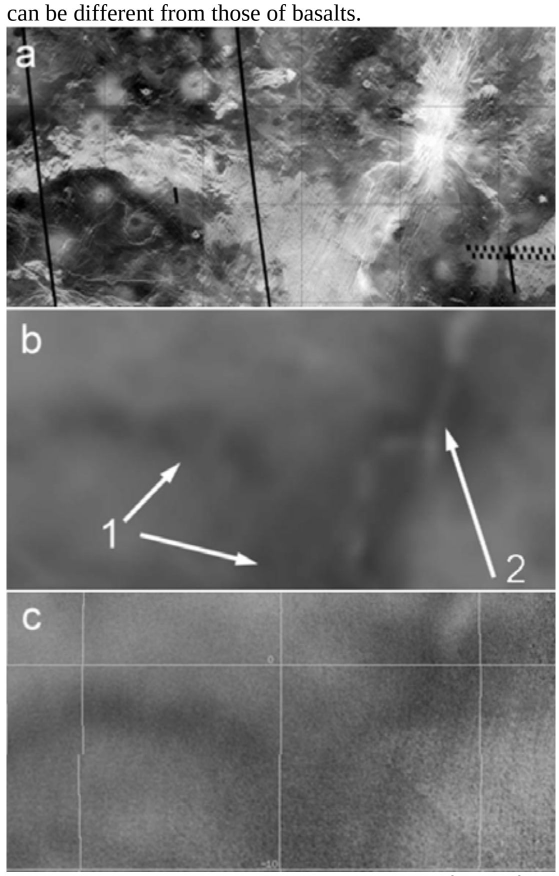

Figure 1. 1400 x 2800 km area centered at 4°N 280°E, 1 – tesserae, 2 – rifts. a) Magellan SAR image, b) model black body emission, c) VMC.

Within the study region there are several massifs of tessera terrain elevated above the surrounding plains. We see them in VMC images as darker areas which look rather similar to those seen in the images of model blackbody emissions (Figure 1). This means that the elevation effect dominates here and further quantitative analysis of the VMC data and modeling results is needed.

The second type of mineralogical targets are mountain tops which show anomalously low microwave emissivity interpreted to be due to presence of conductive, semiconductive, ferroelectric or ferromagnetic materials such as hematite, magnetite or pyrite formed due to elevation-specific weathering and/or deposition from the atmosphere [e.g., 9-13]. Some of these phases have 1 μm emissivity different from that of basalts. In the study area these are tops of Theya Mons and Rhea Mons where the anomalous areas are rather extensive. In VMC images these high-standing areas show low brightness closely resembling what is seen in the images of model blackbody emission. Hence, the potential effect of difference in 1 μm emissivity, if exists, is masked by the elevation effect and, again, further quantitative analysis of the VMC measurements is needed.

The third type of mineralogical targets could be mid- and low-elevation areas (plains level) whose surface materials may locally be different in the weathering state. Physico-chemical calculations [e.g., 9, 13-15] suggest that at the plains level the expected weathering mineral assemblages can be different from primary ones. The major expected difference is presence of anhydrite ($CaSO_4$) formed due to sulfurization of diopside ($CaMgSi_2O_6$). Less weathered materials are expected to be present in the areas of the most recent volcanism: (not enough time for weathering).

The fourth type of targets of this sort are regional volcanic plains which are ubiquitous on Venus surface. They represent a kind of reference surface for the analysis of the VMC night-side images. Typical for them is the presence of rather large radar-bright flows on the moderately dark background. The flows and the background around them are typically on the same elevation. Higher radar brightness of these flows is usually considered as a result of their higher surface centimeter- to meter-scale roughness, but some difference in mineralogy can not be excluded and this possibility should be studied.

For mineralogical analysis it is important to know the 1 μm emissivity of the abovementioned candidates of rocks and minerals. From the John Hopkins University Mineral Library (http://speclib.jpl.nasa.gov/ Search.htm) and Brown University Keck/NASA Relab Spectra Catalog (http://lf314-rlds.geo.brown.edu) we have acquired the 1 μm reflectivities (*R*) for typical basalts, andesites, rhyolites, anorthite, anhydrite, magnetite and pyrite (Table 1, 20^{o}C) and transformed them into emissivities ($E = 1 - R$). We acquired values for fine-grain powders because the *in-situ* TV observations on Venus surface [16-17] and some analyses of Magellan data [18] suggest that surface materials on this planet are generally fine-grained. From the terrestrial geology experience we also know that mineral assemblages resulted from surface weathering are typically fine-grained.

It is also known that the 1 micron reflectivity of basaltic and other materials may be significantly affected by the temperature-dependent changes in the Fe^{2+} absorption band. Experimental studies of this dependence are very scarce, but nevertheless some very preliminary estimates can be done. We did it based on measurements of [19] for the -193^{o}C to 127^{o}C temperature range and extrapolating the change to 500^{o}C. As a result, as a very rough hypothesis we suggest that for the basaltic and other materials containing Fe^{2+}, the temperature increase from room temperature to the Venus surface temperature could lead to the decrease of 1 μm reflectance by 25-30%. For materials having small or negligible amounts of iron, this effect might be much smaller or even absent. Results of such estimates are given in Table 1 (T = 500^{o}C). Of course, direct measurements of the 1 micron reflectivity / emissivity of the candidate materials is the best solution of this problem and some plans to do this have recently been published [3].

Table 1. Estimates of 1 micron reflectivity / emissivity of some candidates of Venus surface materials (%)

T^oC	Basalt	Andesite	Rhyolite	Anorthite	Anhydrite	Magnetite	Pyrite
20	20/80	30/70	50/50	70/30	70/30	5/95	12/88
500	15/85	20/80	50/50	70/30	70/30	4/96	8/92

As it is seen from Table 1 if tessera terrain is composed of materials resembling rhyolites, andesites or anorthosites their 1 micron emissivities differ significantly from those typical for basalts thus increasing chances to test this hypothesis using the VMC data. It is also seen from the Table 1 that chances to identify phases responsible for the low microwave emissivity of the mountain tops are much lower. We are now working on these targets, on targets related to different state of surface weathering at the plains level as well as on differences in radar brightness of some flows being part of regional plains. In two subareas already studied, the brighter flows did not show any difference which could be interpreted as the difference in 1 micron emissivity.

References: [1] Markiewicz W. et al. (2006) *Bull. Amer. Astronom. Soc.*, *38*, 511. [2] Basilevsky et al. (2007) *Vernadsky-Brown Microsymposium 46*, abs. M46_6. [3] Helbert J. et al. (2007) *ibid*, abs. M46_25. [4] Meadows, V. & Crisp, D. (1996) *JGR*, *101*, 4595-4622. [5] Tomasko M. et al. (1985) *Adv. Spece Res.*, 5, 71-79. [6] Moroz V. (2002), *PSS*, *50*, 287. [7] Ford P. & Pettengill G. (1992) *JGR*, *97*, 13091-13102. [8] Nikolaeva O.V. et al. (1992) in *Venus Geology, Geochemistry and Geophysics.* Univ. Ariz. Press, 129-139. [9] Klose K. et al. (1992) *JGR*, *97*, 16,353-16,369. [10] Pettengill G. et al. (1997) in *Venus II*. Univ. Ariz. Press, 527-546. [11] Shepard M. et al. (1994) *GRL* , *21*, 469-472. [12] Starukhina L. & Kreslavsky M. (2002) *LPSC-33*, #1559. [13] Wood J. (1987) in *Venus II*. Univ. Arizona Press, 637-664. [14] Fegley B. (2003) in *Treatise on Geochemistry*, 487–507. [15] Zolotov, M.Yu. (2007) in *Treatise on Geophysics*, 333-444. [16] Florensky C.P. et al. (1977) *Geol. Soc. Amer. Bull*., *88*, 1537-1545. [17] Florensky C.P. et al. (1983) *Science*, *221*, 57-59. [18] Basilevsky A.T. et al. (2004) *JGR*, *109*, doi:10.1029/ 2004JE002307. [19] Hinrichs J.L. & Lucey P.G. (2002) *Icarus*, 155, 169-180.