

Surface science with VIRTIS on VEX

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The Magellan images have shown that Venus has been among the most geologically active planets in the Solar System. Volcanism and tectonics strongly shaped the surface [Solomon et al., 1992]. Large lowlands cover about 80% of the surface and highly deformed plateau (tesserae) form the highlands. Although there is evidence that majority of the observed tectonic and volcanic features of Venus formed in a short period of time close to 500 my ago, other volcanic and tectonic features appear to be formed in very recent time suggesting that the internal activity of the planet may be ongoing.

Regional and global stratigraphy studies based on Magellan images pointed out that volcanic activity has shaped the surface in different geological epoch and may be active since recent time [Basilevsky and Head 1997, 2002; Guest and Stofan, 1999]. Dating of the recent resurfacing activity on Venus based on impact crater density, confirmed that some of the volcanic units are among the youngest geological features [Strom et al., 1994; Price et al., 1996; Basilevsky and Head, 2002].

Regarding the mineralogical composition of the surface of Venus, we actually know quite reliably that plains, that are 75-80% of the surface, are basaltic. However, this knowledge is very general. We do not know, in most cases, what types of basalts what the composition of tesserae, steep-sided domes, etc. is. Moreover, the observation on Magellan images of sinuous and long *canali-type* channels suggests unusual lava process occurring on Venus at places and involving very low-viscosity lavas [Baker et al., 1992; Komatsu et al., 1993] which are rare on Earth.

The M channel of VIRTIS will allow the first systematic mapping of the surface and of the near-surface atmosphere of Venus in the near infrared wavelengths range. This will be done using the atmospheric windows located at 1.10, 1.18 μm and if possible additionally using the window at 1.02 μm (Wattson and Rothman 1986, Kamp et al. 1988, Moroz 2002). The latter is unfortunately right at the low end of the wavelength range of the IR channel and at the upper end of the VIS channel. Therefore, the usability of this window is unclear until first data from Venus are obtained. The atmospheric windows will allow measuring the thermal emission of the surface as was demonstrated by Galileo/NIMS (Carlson et al. 1991) and Cassini/VIMS (Baines et al. 2000). Based on these data three main science tasks for the surface analysis will be pursued: Classification of the surface composition, study the interaction between low atmosphere and surface, and mapping of the variability of the surface temperature.

To first order, the surface temperature on Venus is only a function of altitude with a temperature lapse rate of 8K/km (Seiff et al. 1985, Meadows and Crisp 1996). Therefore, the thermal emission from the surface measured in the NIR atmospheric windows is a function of the topography. This was nicely shown by the comparison of Galileo/NIMS observations and Pioneer Venus altimetry (Carlson et al. 1991). For the first phase of the mission, surface temperature will be predicted using the temperature lapse rate of 8K/km and the Magellan topography. These temperatures and especially the spatial distribution can be compared to the surface emission measured by VIRTIS in the atmospheric windows. In a later stage of the mission the

temperature lapse and the near surface atmospheric temperature will be derived from the VIRTIS measurements itself and also from the PFS measurements. This will increase the quality of the surface temperature prediction. Based on the thermal emission measured in the atmospheric windows and the estimate for the surface temperature the emissivity of the surface can be derived for each of the wavelengths. While these windows have a relatively high transmittance of 40-95%, the observations are still complicated by the cloud deck. Multiple reflections between the surface and the clouds tend to wash out essentially the contrast between high albedo and low albedo parts of the spectrum. This puts constraints on the achievable contrast for the surface emissivity as discussed by Baines et al. (2000). However Hashimoto et al. (2004) have put forward an improved method to deal with these effects and have applied it successfully to the Galileo/NIMS observations. The estimations show an achievable emissivity contrast of at least $(\epsilon_2 - \epsilon_1) / \epsilon_1 = 0.17$ (Hashimoto et al. 2003). A similar correction approach is planned for the processing of VIRTIS data. Based on the derived surface emissivities a classification map of surface types can be produced. The achievable spectral contrast would allow identifying variation in the FeO content from the 1.10 and 1.18 μm windows. From this it will be possible to map the distribution of mafic and felsic material on the surface (Rogers and Hawkesworth 2000). The classification map derived from the VIRTIS measurements will complement the radar reflectivity and radiothermal emissivity derived from Magellan and Pioneer datasets. A comparison of the different datasets could provide crucial information on the surface composition and especially the spatial variation.

Should Venus still have active volcanism at the surface this would lead to a localized excess of thermal radiation on the surface. Based on the instrument performance an increase by 10% in the thermal radiation from the surface should be clearly identified. Following the estimates by Hashimoto et al. (2001) VIRTIS should be able to detect lava flows with a surface temperature of at least 1000K if they cover an area larger than approx. 20km². This flow dimensions are well in the lower range of lava flows observed by synthetic aperture radar (SAR) images obtained by Pioneer Venus and Magellan spacecrafts. Typical dimensions are several tens of kilometers in length and several kilometers in width (Zimbelman 1998). Small lava lakes covering an area of less than 1km² are detectable if the surface temperature exceeds 1200K. Assuming that the eruption temperature of the magma is approximately, the liquidus temperature for basalt temperature up to 1500K can be expected. Estimates on the lava cooling rate by Head and Wilson (1986) indicate that an eruption would be undetectable after one Earth day. This implies that the chance of detecting volcanism increases if the time between surface observations of the same location is small. Of special interest are here the maps obtained from the apocenter mosaic observations. While each of the maps can be analyzed separately for excess radiation indicating volcanic activity, analyzing the differences between successive maps might be an even more sensitive tool. Unfortunately, the results obtainable will not be unambiguous because of variations within the cloud structure. Therefore, a careful correlation of possible eruption events with surface morphology is necessary. Further confirmation can be derived from an analysis of the near surface atmosphere composition. Volcanic activity should produce a localized increase of volcanic gas emission (CO₂, CO, SO₂, HF, CH₄).

The chemical composition of the lower atmosphere, in particular the CO/CO₂ and COS mixing ratio, is crucial to understand the effects of chemical weathering on the

surface of Venus. Dramatic changes in radar emissivity values have been observed by Magellan above high relief (> 5000m above MPR) and have been interpreted as due to chemical weathering of the surface basalt operated by the atmosphere at high altitudes (Pettengill et al., 1992). The mineral responsible for low emissivity on mountain tops and volcano edifices appears to be the electrical semiconductor pyrite whereas magnetite is thought to characterize the lower altitude (Klose et al., 1992). In addition, available data suggest that magnetite and hematite may both be stable on the surface probably in solid solution with other oxide minerals.

Interestingly, Maat Mons volcano, which reaches ~ 6000 m of height, does not show this low emissivity at the summit. This has been interpreted as possible evidence for recent volcanic activity, which prevented the weathering effect at high altitude [Klose et al., 1992; Robinson et al., 1995].

The altitudes at which the magnetite/pyrite phase boundary is encountered vary with the redox state (CO/CO₂ ratio) of the troposphere, which is still poorly known (Fegley et al., 1997; Wood, 1997). Radar data cannot provide final clues on the mineral stability under the corrosive condition, but spectral mapping of VIRTIS of the near-surface can help in defining the redox state of the atmosphere and, thus, to identify the surface minerals in equilibrium with the atmosphere. In combination with the surface classification, this might help to distinguish for example surface material flowing out of the volcano compared to the weathered material that is being covered up.

Observations for the surface studies will be obtained mainly on the nightside of the planet. During dayside observations, the contribution of the thermal emission from the surface will most likely be washed out by the thermal emission from the atmosphere and the cloud particles. As discussed by Moroz (2002) this will make measurements of emissivity variations on the surface rather difficult. For the surface analysis, it is planned to perform targeted observations during the descending branch of the orbit and mapping observations during the apocenter mosaic mode. Given the orbital velocity of the spacecraft VIRTIS-M can obtain multispectra images using the pushbroom mode only for altitudes large than approx. 10000 km. Below this altitude there will be gaps between the individual stripes. The best obtainable spatial resolution from an altitude of 10000km will be approx. 16km, while during the pericenter pass the spatial resolution would be better than 1km. This is however an unrealistic value, because any photon being emitted from the surface will encounter multiple scattering at particles in the clouds. This will result in a blurring of the images and limits the spatial resolution to 50-100km (Moroz 2002). The limitation on achievable spatial resolution and latitudinal coverage put some constrain on the selection of targets. The current list of potential surface targets used for observation planning is limited to features with a diameter larger than 150km. Figure 1 shows as an example for targeted observations by VIRTIS of Quetzalpetlatl Corona with a diameter of 780km. This feature can be covered for the first time in orbit 60-70. The example shows the FOV of VIRTIS. For Quetzalpetlatl Corona this would cover also part of the surrounding plains. It is interesting to note that for this example within the FOV there is an altitude difference of more than 2km. Assuming the temperature lapse rate of 8K/km one would expect a significant difference in the thermal emission of the corona top and the low lying base material. Comparing the derived emissivity of the corona material with the surrounding area will allow searching for possible compositional difference. The fact that VIRTIS covers both areas within the same FOV will reduce possible cross calibration effects.

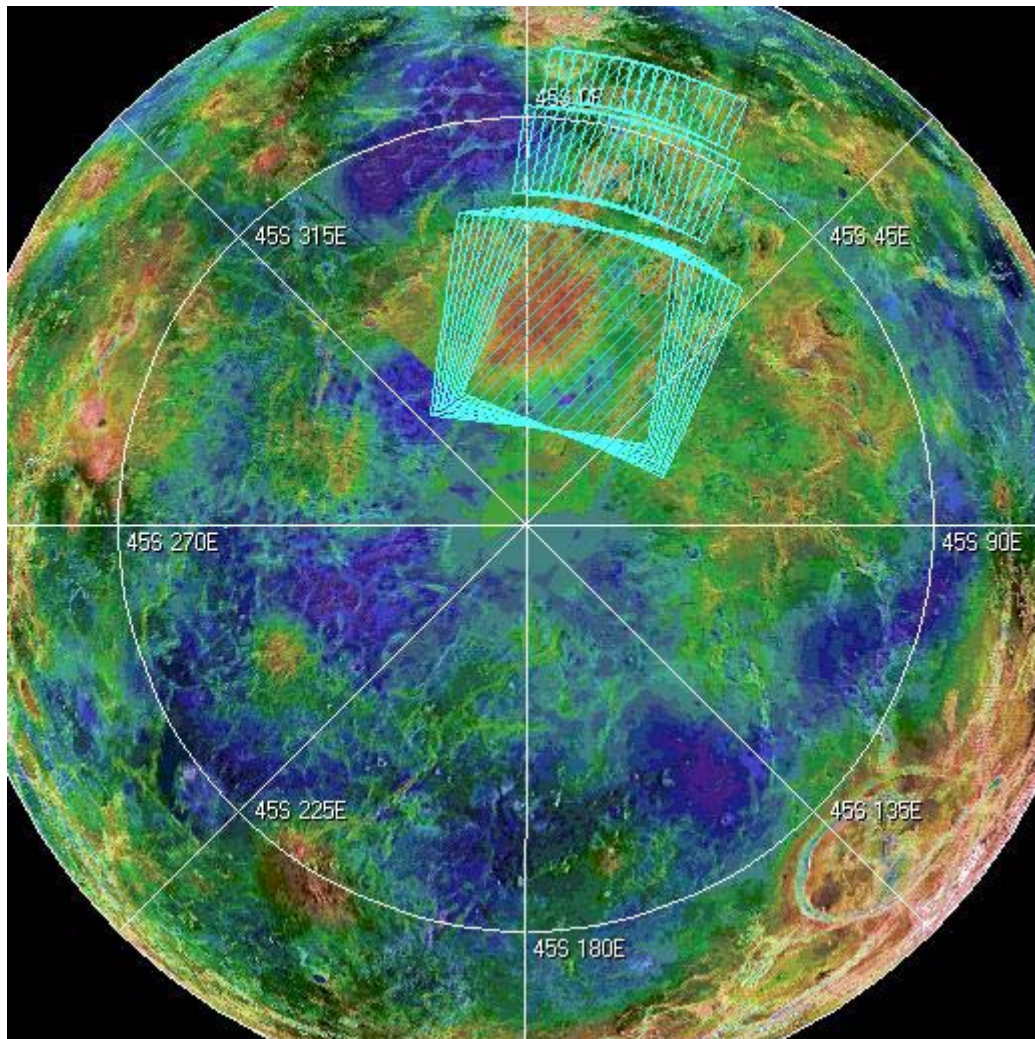


Figure 1 FOV of VIRTIS-M covering Quetzalpetlatl Corona in orbit 60-70 - images produced using the VEX MAPPS software

In the apocenter mosaic mode, maps of the southern hemisphere are obtained at regular time intervals. While the spatial resolution is less than for the targeted observations at lower altitudes this observations have a high scientific value. As discussed before the repetition of this observation mode over the whole mission lifetime will allow searching for time variability of the surface emissivity. Furthermore, by stacking large numbers of observations the effect of the variation in optical thickness of the clouds can be decrease.

The data VIRTIS can provide on the surface of Venus has never been obtained before in a systematic way. While the flybys of Galileo and Cassini have shown that the principle of using atmospheric windows to study surface variations is sound, VIRTIS will for the first time do a systematic surface surveyor of the whole southern hemisphere of Venus. This dataset will be highly complementary to the existing data from surface investigation using radar and from the in-situ measurements at the landing sites. An integration of these datasets will significantly improve our understanding of the evolution of the surface of Venus. VIRTIS will also be the first instrument to routinely monitor the Venusian surface for volcanic activity.

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