**INTEGRATED STUDY OF THE VENUS SURFACE WITH MAGELLAN DATA: AN OPPORTUNITY TO SEARCH FOR SURFICIAL DEPOSITS AND WARM LAVA FLOWS.** N. V. Bondarenko, Institute of Radiophysics and Electronics, NAS of Ukraine, 12 Ak.Proskury, Kharkov, 61085, Ukraine; Earth and Planetary Sciences, University of California - Santa Cruz, 1156 High Street, Santa Cruz, CA, 95064, USA; nbondar@ucsc.edu.

**Introduction:** Earth-based radar studies of Venus surface have shown that some volcanic features in plains region (including fields of shield volcanoes and lava flow complexes) and extended crater-related deposits (known as radar dark diffuse features, DDFs) return radar echo with significant linearly polarized component, when illuminated by circularly polarized probing signal [1]. This can occur only when target surfaces are very smooth and rather transparent for radio waves, so the waves scattered at internal interfaces or inclusions can reach the observer.

In the case of volcanic flows, the flow transparency significantly increases the chance to observe thermal effect of recent volcanic eruptions on Venus through observations of surface thermal emission, because in this case the thermal emission is formed at some depth, where thermal effect of recent eruptions lasts orders of magnitude longer than at the surface.

The typical state of DDF-forming mantles near craters of different ages seems to be characterized by a rather smooth mantle–atmosphere interface at scales in a wide range from ~ 13 cm to decameters [2]. DDF mantles appear to preserve their smoothness for a geologically long time. Observations of emissivity features associated with DDFs [3] and interpretation of Earth-based polarimetric radar observations [1] indicate that the extended crater-related deposits are significantly wider than it is apparent from the DDFs alone in the Magellan SAR mosaics.

In the present work an approach to the search of possible extension of crater-related deposits and to the warm flow detection using results of Magellan radiometry and altimetry experiments (the GREDR, GEDR, ARCDR and SCVDR data sets) is discussed. SAR images were used also for the morphological analysis.

**Source data and approach:** Values of surface emissivity (at the wavelength of 12.6 cm) have been obtained in the Magellan radiometry experiment [4]. Spatial resolution of Magellan emissivity data is rather poor, about 20 km × 30 km at low latitudes. Local variations of emissivity are measured with accuracy better than 1%.

According to Kirchhoff law [5], the emissivity of the surface observed from a given direction, $e = 1 - R^*$, where $R^*$ is the hemispheric reflectivity of the surface illuminated from the same direction. The radiothermal emission of the surface covered by a mantle can be defined through the surface reflectivity as stated by Kirchhoff law [5] as $e = 1 - R_i - R_s$, where $R_i$ is the scattering coefficient at the upper mantle interface, and $R_s$ describers a positive contribution of internal scattering into integral scattered fluxes over all scattering directions. Thus, emissivity of the surface covered by rather transparent mantle has to be lower then $(1- R_i)$. If we consider that the upper mantle interface is smooth, $R_i$ can be calculated with the Fresnel equations. In this case, $R_i$ depends only on dielectric permittivity of the mantle material and on the incidence angle.

Magellan data allow independent estimates of surface dielectric permittivity through the so called "Fresnel reflectivity" $R_0$ obtained in radar altimetry experiment. $R_0$ is surface reflection coefficient at normal incidence derived using the approximation of received echo sequence by Hagfors law [6]. Spatial resolution for these data was about 15 km × 10 km at low latitudes but their accuracy is not high, the errors of individual measurements can reach ~30% [6].

Nevertheless, we can estimate the difference between emissivity measured during Magellan radiometric observations and one calculated using surface dielectric permittivity derived from $R_0$. In the case of rough surface covered by a mantle with a smooth upper interface under thermodynamic equilibrium, the observed emissivity has to be lower then one predicted with Fresnel formula. The apparent decrease of emissivity depends on properties of underlying surface and the mantle. In particular, thick mantle can cause strong absorption of radiation which causes $R_s \approx 0$.

An apparent enhancement of emissivity in comparison with one expected from reflectivity-derived dielectric permittivity of volcanic flow with smooth upper interface can be considered to occur due to increased temperature in the shallow subsurface. It can be true only for smooth terrains because rough upper flow interface easily leads to higher emissivity values in comparison to those predicted with Fresnel formula.

**Warm lava flow?:** The approach discussed above was applied to a radar dark lava flow located at about 28°E, 39°N in Bereghinia Planitia. This flow is recognized in the map obtained during earth-based radar polarimetric observations ($\lambda$ = 12.6 cm) [1] and exhibits enhanced linear polarization (up to 12%).

The flow is darker in comparison with surrounding surface as seen in Magellan 1st (Fig.1a) and 2nd cycle SAR image. This flow is also distinctly dark in the earth-based radar map published in [1].

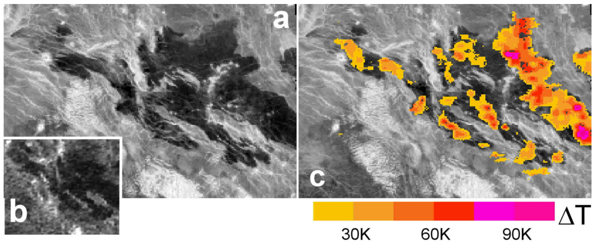


**Fig. 1**

Thus the flow is expected to be smooth at spatial scales, which control oblique backscattering at 12.6 cm wavelength. The flow is also very smooth at larger spatial scales, as seen from Magellan altimetry experiment results. The Hagfors' roughness parameter map (GSDR data set) for the area under study is shown in Fig. 1b. The flow roughness is very low, ~0.4° (dark shades in Fig. 1b).

An apparent thermal enhancement of the flow in comparison with the mean surface calculated based on an apparent enhancement of emissivity is presented in Fig. 1c. These data correspond to the lower limit for the flow thermal enhancement because of unaccounted scattering from the lower surface-flow interface.

The results presented in Fig. 1c raise the question, if the sample flow is really hot? Morphological analysis of this area using high resolution SAR mosaics (F-maps) showed that this radar-dark flow is younger in comparison with surrounding radar-brighter surface. The dark material clearly embays large wrinkle ridges, truncates narrow radar-bright lineaments and is free of any superposed tectonic structures.

The flow has to be older than 15 years because it is recognized in SAR map obtained in Pioneer-Venus mission in 1978. Theoretical estimates show that it takes ~ 100 years for a 20-m thick slab of lava emplaced over "normal"-temperature surface to cool down to 50 K temperature excess. For thicker flows the thermal effect may last significantly longer.

Properties of the dark flow in Bereghinia Planitia are consistent with presently existing temperature excess at shallow depth and hence very recent flow emplacement.

**DDF mantles:** On the basis of approach discussed above, low resolution (0.25°×0.25°) maps of differences between two emissivity values: observed (SCVDR data set) and calculated (using $R_0$ from GREDR data set) were obtained for three cycles of Magellan observations. The comparison of overlapping areas in these maps showed high qualitative similarity in the pattern of emissivity variations.

In general, the apparent decrease of emissivity is rather weak; it is very sensitive to accuracy of Magellan radiometry and altimetry experiments. In terms of local accuracy of emissivity estimates $\sigma_E$ (as reported in SCVDR data set), the total surface area with the apparent decrease of emissivity in ranges of [0, $-\sigma_E$] and [$-\sigma_E$, $-2\sigma_E$] is about 72% and 5% of the whole surface observed during 1st Magellan cycle, respectively. Thus, for the most part of Venus surface the data inaccuracy could account for the observed difference.

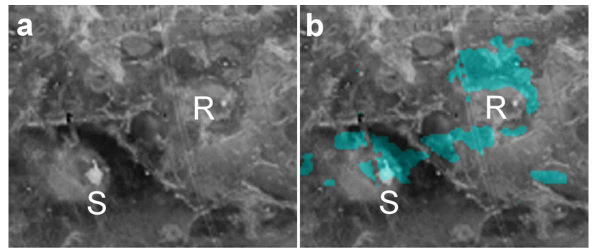


**Fig. 2**

But some crater-related deposits can be distinguished in the map. Example of such kind for crater Roze (35.2S, 248.2E, 14.7 km; marked as R) is shown in Fig. 2. (Crater Stowe is marked as S). Surface areas having the apparent emissivity decrease lower then $-\sigma_E$ is marked by blue colour in Fig. 2b. These areas seem to be not very dark in SAR image (Fig. 2a) supporting rather thin mantles in these parts of DDFs.

**Discussion and conclusions:** The results obtained show that the proposed approach can be useful for the search and study of surficial deposits on Venus having different origin including mantling during impacts, redistributed loose material due to winds, and, possibly, some lava flows, if they are rather transparent for microwaves and have smooth upper interfaces.

At the current state of knowledge, however, it is impossible to completely exclude the chance that these estimates are affected by strong systematic errors in the Magellan emissivity and Fresnel reflectivity data.

Nevertheless combination of microwave radiometry and scatterometry in future missions can give interesting interpretable results, if accuracy and resolution surpass those of Magellan's.

**References:**

[1] Carter L. M. et al. (2006) *JGR, 111*, doi:10.1029/2005JE002519. [2] Bondarenko N. V., and Head J. W. (2009) *JGR, 114*, doi: 10.1029/2008JE003163. [3] Bondarenko N. V., and Head J. W. (2004) *JGR, 109*, doi: 10.1029/2004JE002256. [4] Pettengill G. H. et al., (1992) *JGR*, *109*, 13091-13102. [5] Ulaby F. T. et al. (1986) *Microwave Remote sensing: Active and Passive*. [6] Ford P. G. and Pettengill G. H. (1992) *JGR, 97*, 13103-13115.