PRINCIPAL COMPONENT ANALYSIS OF MAGELLAN RADAR ALTIMETER DATA: EVIDENCE FOR SURFACE PROPERTIES VARIABILITY ON VENUS. N. V. Bondarenko[1, 2] and M. A. Kreslavsky[1], [1]Earth and Planetary Sciences, University of California - Santa Cruz, 1156 High Street, Santa Cruz, CA, 95064, USA (nbondar@ucsc.edu), [2]IRE, NAS of Ukraine, 12 Ak. Proskury, Kharkov, 61085, Ukraine.

Introduction: Results of the Magellan radar altimeter (RA) experiment have been widely used in the Venus surface studies. Such results included model-dependent estimates of surface normal reflectivity and large-scale roughness calculated on the basis of Hagfors scattering law [1]. Measured Doppler centroid values have allowed studies of surface structure anisotropy in S-N direction [2, 3], in particular, surface aeolian deposits. Shape of the backscattering function [2] have been used for the search of best-fit surface scattering law [4] and analysis of surface roughness [5].

In the present work we continue analysis of surface properties variability [5, 6] on the basis of RA-derived backscattering function.

Source data and approach: As source data, we used the backscattering function solution [2] of Magellan RA data archived in the PDS as a part of SCVDR data set. Each data point had been obtained from analysis of 5 consecutive radar bursts and consists of backscattering cross-section for several reference incidence angles with 0.5° step; the data points are arranged along the Magellan orbits.

We studied Venus surface in the 75°N-55°S latitude zone, where the source data quality was adequate. The effective spatial resolution of the source data is lower at high-latitude parts of the studied zone due to higher elevation of the Magellan elliptical orbit. The backscattering function solutions in 0.25° - 4.75° incidence angle range were used.

We assume that the surface backscattering cross-section r can be presented as $r(\theta) = r_0 \cdot F(\theta)$, where θ is the incidence angle, r_0 is the reflectance coefficient at normal incidence, which depends mainly on the dielectric permittivity of surface material, and $F(\theta)$ is a scattering function, which depends on structural properties of the surface.

We calculated logarithm of every backscattering solution from SCVDR to make the r_0 factor additive. Then we applied the principal component (PC) analysis technique to the result.

Results and discussion: Ten reference angles (0.25° – 4.75°) of the backscattering function allow ten formal principal components. The first 3 PCs for the studied surface area contain 72.4%, 13.6%, and 7.1% of the total backscattering function logarithm variability, respectively. Other PCs seem to contain only noise and should be discarded. Noise level extrapolated on the base of PC4-PC10 eigenvalues lead to signal-to-noise ratios for the first 3 PCs of 12.3, 3.0, and 2.1, respectively.

The first component PC1, which is related to r_0, is dominant in the near-nadir backscattering. This component has a good correlation [6] with model-dependent Fresnel reflectivity retrievals R_0 calculated on the basis of Hagfors scattering law [1]. Here we further analyze PC2 and PC3, the component that describe $F(\theta)$ variability. Although separation of $F(\theta)$ variability into two factors PC2 and PC3 is formal, analysis of the loading coefficients shows that PC2 mostly controlled by the ratio of near-nadir backscattering cross-section (θ = 0.25°) to typical cross-sections at greater incidence angles; low PC2 values mean relatively sharper near-nadir backscattering peak.

PC2-PC3 color composite image is shown in Fig.1a accompanied with global SAR mosaic (Fig. 1b) of the Venus surface. The yellow color intensity codes PC2 values, while blue channel intensity codes PC3. “Blue” areas in Fig. 1a mean that PC3 values are high and PC2 values are low. “Yellow” areas are related to lower PC3 and high PC2 vales, “gray” areas are a combination of intermediate PC3 and moderately high PC2.

Not surprisingly, many “blue” areas coincide with some prominent radar-dark diffuse features (D, Fig. 1). They have been interpreted as mantles of granulate material ejected by large impacts with very flat and smooth surface, which is consistent with prominent nadir backscattering peak and low PC2. More surprising is that deep canyons in eastern Aphrodite Terra, including Artemis Chasma (A in Fig. 1) and in Atla-Beta-Themis region are also blue in Fig. 1a and therefore have some proportion of smooth horizontal surfaces, while heavily tectonized terrains around the canyons have high PC2. Significant areas of tessera terrain (T) and some groove belts (G) have intermediate PC2 values (grayish in Fig. 1a).

Mean vales of the PCs calculated over the mentioned geologic units (according to the geologic map [7]) and radar-dark (SAR cross-section is lower than -4 dB) surfaces in the plain areas are shown in Tab. 1. Additionally, Tab. 1 includes Maxwell Montes area, the microdune field near crater Stowe, dark parabola of crater Carson, and three areas showing a high linear polarization coefficient observed in radar probing from the Earth [8]. The latter means that in these areas the radar echo is forming by refraction at the smooth flat surface and subsurface scattering. These areas near craters Anya, Barton and Aurelia do not have as low PC2 as the typical "blue" dark diffuse features, which is consistent with the radar-transparent mantle and subsurface scattering. These areas are characterized by high PC3 values. A similar combination of moderate PC2 and high PC3 is typical for tesserae, which might indicate a role of subsurface scattering there.

Table 1.

Unit	PC1	PC2	PC3
D	0.91	-0.09	0.37
Tessera	-1.43	-0.50	0.23
Artemis Chasma	-2.04	-0.84	0.25
Groove belts	-0.49	-0.10	0.01
Anya	0.61	0.03	0.46
Barton	0.57	0.40	0.13
Aurelia	0.36	-0.37	0.94
Carson	0.86	0.11	0.07
Stowe μ-dune	0.62	0.39	-1.01
Maxwell	-1.07	-0.37	-0.54

The microdune field near crater Stowe has a high PC2, which is consistent with the absence of vast flat surfaces. It is interesting that the dark parabola associated with Stowe (S, Fig. 1) outside the microdune fields is also "yellow" in Fig. 1a; it has a high PC2, which indicates the presence of microdunes not recognized with SAR image. The radar-dark parabola associated with crater Carson has a high PC2 and is similar to Stowe and dissimilar to the typical D. It is likely that the mantle in the Carson parabola also produced microdunes.

Conclusion: Considered examples illustrate the usefulness of backscattering function shape for characterization of small-scale surface structure. Collection of such information in future radar probing experiments would be beneficial.

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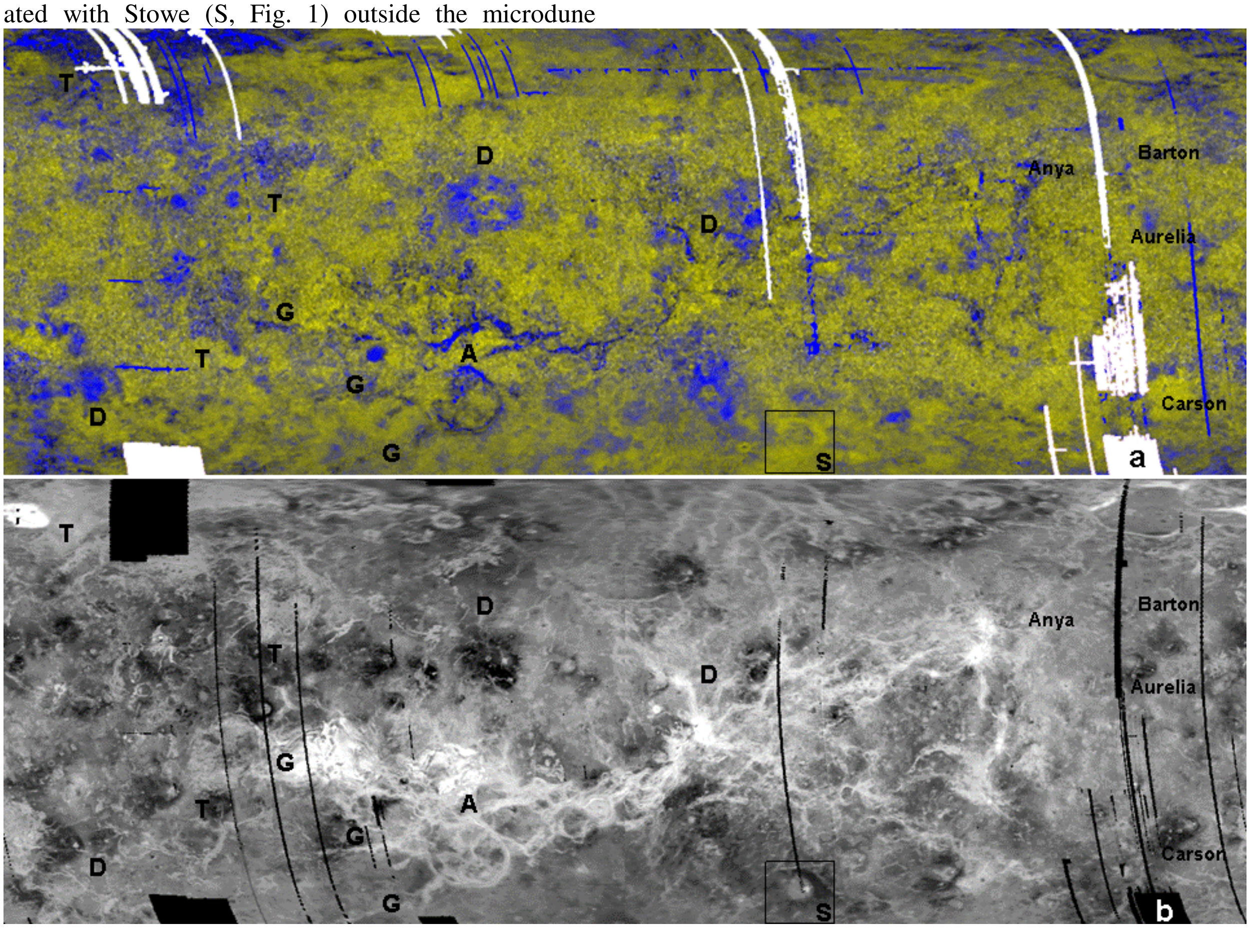

Fig. 1. Maps of 75°N-55°S latitude zone in the simple cylindrical projection. **a**, Yellow – Blue color composite of PC2 and PC3. **b**, SAR mosaic.