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Surficial deposits on Venus: Integrated study with Magellan data

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Introduction

Earth-based radar studies of Venus surface [1] have shown that a number of radar dark diffuse features (DDFs) associated with craters return radar echo with significant linearly polarized component, when illuminated by circularly polarized probing signal. This can occur only when target surfaces are very smooth and rather transparent for radio waves, so that the waves scattered at internal interfaces or inclusions can reach the observer. DDFs have been interpreted as deposits (mantles) of loose material ejected and lifted by the impact.

The Magellan mission results showed that the typical state of DDF mantles near craters of different ages seems to be characterized by a rather smooth mantle–atmosphere interface at scales of ~ 13 cm (wavelength of observation) along with decameter scale [2]. DDF mantles appear to preserve their smoothness for a geologically long time.

Emissivity features associated with DDFs are usually much wider than the corresponding radar-dark parabolas, indicating that the crater-related deposits are significantly wider than is apparent from the DDFs alone in SAR mosaics [3]. A similar conclusion was reached in [1] from interpretation of Earth-based polarimetric radar observations.

In the present work an approach to trace possible extension of crater-related deposits using results of Magellan radiometry and altimetry experiments is discuss.

Source data and approach

This study was based on the use of Magellan mission data, in particular, emissivity and Fresnel reflectivity, archived in the GVDR data set. SAR images were used also for the morphological analysis.

The values of surface emissivity (at the wavelength of λ = 12.6 cm) has been calculated in the Magellan radiometry experiment through a several steps procedure [4]. It included: converting the registered thermal emission flux power into the apparent surface brightness temperature, correction for absorption and emission by the Venus atmosphere as well as for partial reflection of the thermal emission from the sky by the surface, and, finally, the calculation of the surface emissivity using following equation shown in [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. In an ideal case of a dielectric half-space with a flat interface, R_* is equal to Fresnel reflection coefficient at the interface. This is not the case for a real surface with any degree of surface roughness or subsurface heterogeneity.

For example, radiothermal emission of the surface covered by mantle with smooth upper interface 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 reflection coefficient at the smooth upper surface, and R_s describers a positive contribution of internal scattering into integral scattered fluxes over all scattering directions. Since the upper mantle interface is smooth, R_i can be calculated with the Fresnel equations. Thus, emissivity of the surface covered by smooth and rather transparent for radio waves mantle has to be

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lower then (1- R_i). R_i of the smooth interface depends only on dielectric permittivity of the mantle material and on the incidence angle.

Magellan data set allows independent estimation of surface dielectric permittivity through so-called "Fresnel reflectivity" R_0 obtained in the radar altimetry experiment. R_0 is the 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].

Thus we can estimate the difference between emissivity measured during Magellan observations and one calculated with Fresnel equations using surface dielectric permittivity derived through the "Fresnel reflectivity". In the case of rough surface covered by mantle with smooth upper interface observed emissivity has to be lower then one predicted with Fresnel formula. The apparent decrease of emissivity depends on properties of underlying surface.

Such approach can be used for smooth terrains because rough upper mantle/surface interface easily leads to higher emissivity values in comparison to those predicted with Fresnel formula.

Processing procedure and results

Using GVDR data set maps of emissivity and "Fresnel reflectivity" (derived through the Hagfors law approximation) were obtained for three cycles of Magellan observations. The resolution of maps was chosen to be 0.25°×0.25° to increase the map accuracy. Based on approach discussed above maps of differences between two emissivity values: observed and calculated (taking into account actual emissivity observational angles) were obtained.

Though maps constrained do not cover the whole Venus surface, the comparison of overlapping areas showed high qualitative similarity in emissivity difference behaviour.

The lower measured emissivity in comparison with the one predicted with Fresnel equation does exist on Venus surface. The total surface area with lower measured emissivity occupies about 70% of the whole surface observed during 1st Magellan cycle. Such surfaces are observed mainly in regional plains but also seen in other areas including tessera.

Many crater-related deposits are clearly distinguished in the map. They usually exhibit higher values of the apparent deficiency of emissivity in comparison with surrounding surface.

The result obtained shows that the proposed approach is promising for the 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 radio waves and have smooth upper interfaces.

References

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