EPSC Abstracts
Vol. 10, EPSC2015-856, 2015
European Planetary Science Congress 2015
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Venus atmosphere and extreme surface topography

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Abstract

The temperature fields at several levels in the Venus mesosphere (60-95 km) as well as the altitude of the upper boundary of clouds retrieved from Venera - 15 (FS-V15) [1], and the zonal wind fields and albedo of the upper clouds, measured by VMC Venus Express [2], and altitude of the upper boundary of clouds VIRTIS-M VEX [3] data are compared with the topographic map, obtained by Magellan [4] . The results show that the isotherms and the altitude isolines of the upper clouds boundary reproduce the extended surface features Ishtar and Atalanta Planitia. In turn, the shapes of wind isovelocities and albedo at the upper boundary of clouds (VMC) closely follow the details of relief of Terra Aphrodite as well the isolines of altitude of the cloud tops (VIRTIS). In all cases the isolines are shifted with respect to topography by about 30° in the direction of superrotation. Non-hydrostatic general circulation model of the Venus atmosphere [5] demonstrates that the major topographic features such as Maxwell Montes and Terra Aphrodite provide a prominent impact on the atmospheric dynamics at levels as high as 90-95 km.

1. Data sets and results

We study the traces of influence of the Venus' major topographic features like Ishtar and Aphrodite on the Venus atmosphere.

1. From FS-V15 data the 3-D temperature and clouds fields in mesosphere were retrieved [1]. Earlier it was found that distribution of temperature is described by the Fourier decomposition with 1, 1/2, 1/3, and 1/4 days and upper boundary of clouds (1, 1/2 days) harmonics in Solar-fixed coordinates. The amplitudes of the thermal tide harmonics with wavenumbers 1 and 2 reach 10 K. We found that in the Sun- fixed frame of reference, both maxima and minima are shifted from noon and from midnight to westwards. The temperature field at 65 km in latitude-longitude coordinates shows a good correspondence between topography (Ishtar and Atalanta Planitia) and temperature perturbations (coefficient of correlation CC>0.9). In Fig 1 we show the isotherms of temperature overlaid the Magellan topography map. We found a good correspondence also between altitude of clouds tops and relief (Fig.2). Based on FS-V15 data we cannot compare separately the solar and topographic longitudes, as we didn't observe Ishtar at different local time. Temperature and clouds maps in comparison of the map of Magellan topography show that the perturbations are shifted by ~30° in the direction of superrotation (Fig.1, Fig. 2).

2. The other set of data we consider is the wind speed estimates near the cloud tops, obtained from the UV VMC images [2]. It was found that zonal wind speed correlates with relief (CC > 0.9) in such a way that the extended spot of low wind speed in the region of Terra Aphrodite. A local decrease of the wind speed exceeds 20 m/s. (Fig.1.). The 'image' of the relief on the clouds tops is shifted by 30° to westward direction. Although the observations we used cover the dayside only, the measurements were averaged for many orbits, with local time varying over the day.

3. The altitude of upper boundary of clouds was retrieved from the depth of the CO_2 absorption band at 1.5 μm (VIRTIS-M) [3]. The cloud tops altitude isolines are given in Fig 2 with shift of 30 ° to topography. They also show a good correlation. In Fig. 2 we show the albedo map (VMC), also shifted.

2. GCM simulations

Non-hydrostatic general circulation model of the Venus atmosphere demonstrates that major topographic features such as Maxwell Montes and Terra Aphrodite provide prominent impact on the atmospheric dynamics as high as at 90-95 km[4]. This impact is revealed in the areas of enhanced downwelling airmass flow, shifted by 30-70 degrees in longitude relative to Venus' topography. This is consistent with the hypothesis of westward propagating gravity waves, whose amplitude increases in altitude, as the ambient air density drops. The wavelength and phase velocity is constrained by the waveguide dispersion properties, which in turn are determined by the vertical profile of static stability and zonal flow.

3. Conclusions

We study the different kinds of data, obtained at different time by different methods in the different experiments, with time gap of 30 years (Venera-15 and VEX).We found that Major topographic features as Ishtar and Terra Aphrodite perturb the atmosphere. At altitudes of the upper boundary of clouds the surface "image" is observed in the zonal wind, temperature, altitude of the cloud tops in TIR and NIR and albedo in UV shifted by 30° (this value, initially found for the wind, fits good the other maps). The upper boundary of the clouds may be of several kilometers higher above the mountings, the UV albedo is about 20 % higher above Aphrodite, but wind speed is of 20 m/s lower. (It is worth noting that the variation of thermal zonal wind found from FS-V15 caused by the thermal tides even exceeds this value).

Modeling with non-hydrostatic general circulation model of the Venus atmosphere supports the expected impacts of highlands of Venus surface on dynamic of Venus atmosphere at least up to 100 km altitude. A strong correlation with the relief features, and similar shifts enables to conclude that in all cases we deal with stationary waves, connected to thermal tides linked with the surface topography, non-migrating thermal tides, so common for Mars. The work is in progress now.

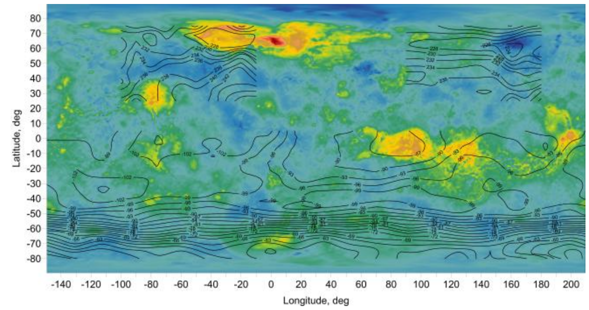

Fig.1. Isotherms at upper boundary of clouds (Venera-15) in the Northern hemisphere and isolines of the zonal wind speed in the Southern hemisphere (VMC) plotted on the Magellan topography map

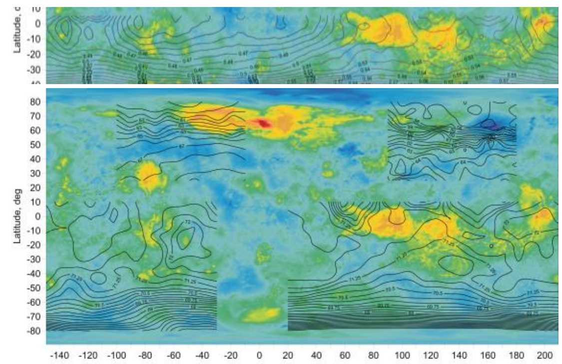

Fig 2. Upper: S-latitudes:Venus albedo in UV (VMC VEX). Low: N-latitudes - isolines of altitude of the upper boundary clouds, τ at 1218 cm-1; S-latitudes - altitude of upper boundary of clouds influence the atmosphere NIR spectral range overlaid the Magellan topography map.

Acknowledgements

L. Zasova, I. Khatuntsev, M. Patsaeva, N. Ignatiev and A. Turin were supported by the Program 9 of the RAS Presidium. The contriution of AR has been funded by the Russian Ministry of Educaton and Science grant #11.G34.31.0074. We thank Jean-Loup Bertaux for very fruitful discussions

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