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VENUS NEAR SURFACE TEMPERATURE

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Abstract

In this work we show that the thermal emission observed by VIRTIS on Venus Express indicates lateral and temporal variations of surface temperature, which is coupled to atmospheric temperature. These variations are similar to self-consistent temperatures predicted by a General Circulation Model (GCM).

1. Introduction

The current temperature at and near the surface of Venus is relevant for many open questions regarding its evolution as an Earth like planet. In situ data is scarce, especially close to the surface. They cannot provide the global picture, and the sparse data leave unsolved questions. The Venus International Reference Atmosphere (VIRA) [1] provides laterally and temporally averaged temperature for the lowest atmosphere, with a vertical temperature profile extrapolated from Pioneer Venus and Venera measurements higher up. Yet the only high-resolution descent profile from the VeGa-2 lander [2] shows an apparently dynamically unstable lapse rate, which led [3] to hypothesize that the supercritical CO_2 causes a density driven compositional gradient. Remote observations of thermal emission through the near infrared atmospheric windows are sensitive to surface temperature, which is closely coupled to atmospheric temperature.

2. VIRTIS Observations

We correct the VIRTIS data for detector non-linearities and instrumental straylight following the approach of [4]. To invert the data to emissivity we use the radiative transfer model (NEMESIS) developed for Venus by [5] to model the radiances of the near infrared atmospheric windows between 1000 and 1400 nm. The atmospheric temperature and pressure profile is based on [1] as in previous studies of deep atmosphere and surface emissions [6, 7].

The result is a map of surface emissivity in three bands at approximately 1020, 1100 and 1180 nm, all showing some residual trend with topography. Such trends of emissivity have been reported by other studies with the same assumptions on surface temperature [6, 7]. The new observation here is that the trend varies with location and local time. The trend can be interpreted as deviation of Venus surface temperature from the VIRA profile assumed for the radiative transfer modeling. The absolute deviation is not well constrained, but relative differences are.

3. General Circulation Model

We use results of a GCM developed for Venus by [8]. The model is based on an Earth GCM with several modifications. The main modification is the radiative transfer model, developed specifically for Venus, allowing the GCM to provide self-consistent temperatures. There are two GCM runs, one with constant abundance of N_2 (as in VIRA) and one with an artificially imposed gradient of N_2 between approximately 0 and 6 km altitude as proposed by [3] to explain the VeGa-2 profile. At lower altitudes, N_2 is completely absent and lapse rates between the model runs are almost identical.

4. Results

Fig. 1 shows the VIRTIS derived temperature deviation from the VIRA profile for two regions at the same latitude of 58°S to 42°S, and different longitudes -41°E to -4°E (Themis Regio), -105°E to -68°E (Lavinia Planitia), and the GCM surface temperatures of these two regions.

Temperature lapse rate in both model and observations are most consistent with the VIRA profile near 1km elevation, but indicate a lower lapse rate at lower elevations, which make up the bulk of VIRTIS data.

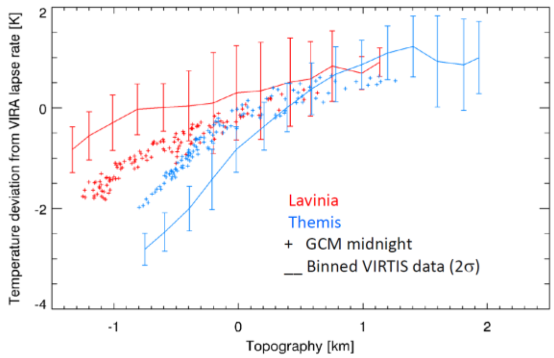

Figure 1: Observed and modeled surface temperatures relative to the VIRA profile for two regions in the same latitude band

The lowlands in Lavinia and Themis show distinct temperature lapse rates both in data and model, although the difference is more pronounced in the data.

The VIRTIS data has to be averaged over many observations to yield reasonable signal to noise. We separate the nightside data set in two wide local time intervals, before and after local midnight. The resulting VIRTIS maps are more noise but still show a similar cooling rate over the course of the Venus night as the GCM in both regions.

Fig. 2 shows all of the VIRTIS data, which is limited to southern latitudes, and the global GCM results for the two model runs.

5. Discussion and Conclusions

The potential impact of these observations is clear. The GCM predictions testable by remote observation were previously limited to the upper boundary winds and atmospheric temperature fields above roughly 40 km altitude [9]. Near infrared data provides constraints for the planetary boundary layer. On the other hand, the GCM model temperatures differing from the VIRA temperatures provide a physical meaning to the empirical corrections of emissivity trends that were necessary in previous work [6, 7].

At present we cannot show whether a gradient in N_2 provides a better fit to the VIRTIS data due to the limited altitude range covered in the data.

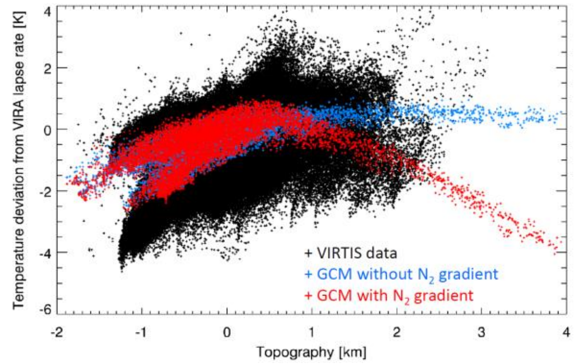

Figure 2: VIRTIS data of the southern hemisphere and global GCM results

Future observations could provide a better temporal resolution, a wider range of observed surface elevations, and a much better SNR, and more reliable altimetry of highlands, each of which will significantly improve the interpretability of the data.

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