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Temperature retrieval for the Venusian atmosphere by a scattered thermal radiation model

I. Garate-Lopez (1), A. García Muñoz (2), R. Hueso (1), A. Sánchez-Lavega (1)

(1) Departamento de Física Aplicada I, ETS Ingeniería de Bilbao, UPV/EHU, Alda. Urquijo s/n, 48013, Bilbao, Spain.
(2) ESA Fellow, ESA/RSSD, ESTEC, 2200 AG Noordwijk, The Netherlands
(itziar.garate@ehu.es / Fax: 00 34 94 601 4178)

Abstract

Venus' thermal radiation spectrum is punctuated by CO_2 bands of various strengths probing into different atmospheric depths. It is thus possible to invert measured spectra of thermal radiation to infer atmospheric temperature profiles. In practice, the retrieval becomes complicated by the fact that the outgoing radiation is multiply scattered by the ubiquitous aerosol particles before leaving the atmosphere.

We numerically investigated the radiative transfer problem of thermal radiation from the Venus night side between 3 and 5 µm with a purpose-built model of the mesosphere [1]. We are now developing a temperature retrieval algorithm based on the comparison of the modeled radiances with the measurements obtained by the VIRTIS-M instrument onboard Venus Express.

VIRTIS permits simultaneous determinations of the temperature profile and the velocity field, which are essential to infer the atmospheric potential vorticity (PV). Recent work [2] has shown that the long-lived vortex at the southern pole of Venus is more chaotic and unpredictable than initially thought. So the ultimate goal of this project is to infer the PV field in the southern polar region so as to understand the high variability of the vortex and its role in the general circulation of the Venusian atmosphere.

1. Effects of clouds on the forward model

Visual and Infrared Thermal Imaging Spectrometer (VIRTIS-M) observations of Venus in the 3-5 µm region allow us to study the night time thermal structure of the planet's upper troposphere and lower mesosphere from 50 to 105 km [3, 4]. However, there are significant cloud layers in that altitude range whose spatial structure mixes with the thermal structure of the atmosphere.

Building a forward radiative transfer model that solves the radiative transfer equation for the atmosphere on a line-by-line basis, we confirmed that aerosol scattering must be taken into account in the temperature retrieval [1]. We also studied the impact of factors such as cloud opacity, and the size, composition and vertical distribution of aerosols, on the outgoing radiance at the top of the atmosphere [1].

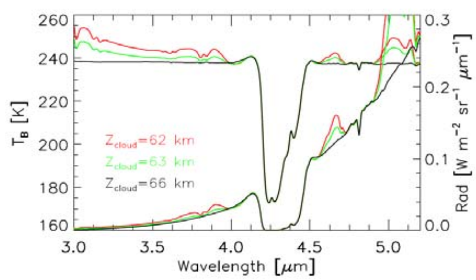

Figure 1: Synthetic spectra and brightness temperatures for a thermal profile representative of 75º latitude, standard aerosol composition and size, multiple scattering, and various cloud top altitudes. The narrow feature at 4.6µm is indicative of low Z_{cloud} values.

The cloud top altitude, Z_{cloud}, and aerosol scale height, H, have a notable impact on the spectrum. Their weighting function matrices (the $\partial T_B/\partial H_{aer}$ and $\partial T_B/\partial Z_{cloud}$ derivatives) have similar structures, what may contribute to the degeneracy of the temperature retrieval algorithm [4].

2. Temperature retrieval algorithm

The temperatures in the lower mesosphere (60-90km altitude range) are of particular interest for dynamical studies of the Venus atmosphere 2]. So far, our code is focused on the strong 4.3μm CO_2 band, which enables the determination of the thermal profile above the cloud top.

In our initial approach to the problem, we use the algorithm proposed by Grassi et al. (2008) to obtain the temperature update between two consecutive iterative cycles:

$$T_l^{i+1} = T_l^i \frac{\sum_{ch=1}^{m} \frac{TB_{ch}\left(I_{obs,ch}\right)}{TB_{ch}\left(I_{expected,ch}^i\right)} W_{ch,l}}{\sum_{ch=1}^{m} W_{ch,l}}$$

where *i*, *ch*, and *l* are the indices for the iteration cycle, the sampling channel and the pressure level, respectively. $TB(I_{obs})$ represents the brightness temperature derived from the radiances observed by VIRTIS and $TB(I_{expected})$ the brightness temperature estimated from the modelled radiances according to the current temperature profile T(p). The weighting functions are given by:

$$W_{ch,l} = -\left.\frac{\partial T_{ch}}{\partial \log_{10} p}\right]_{p=p_l}$$

These weighting functions are exact for the non-scattering problem, but they also provide an acceptable approximation to the derivatives in the multiple-scattering problem. This class of relaxation methods try to find a perfect match between the observed and modelled spectrum, correcting empirically a first guess temperature profile.

3. Future Work

Our immediate purpose is to study the thermal structure and the cloud morphology in deeper levels of the Venusian atmosphere. For that purpose, we need to take into account the cloud parameters. Considering the full 3.8-5.1μm range, where radiances are dominated by clouds and CO_2 (but excluding the spectral region dominated by CO [5]), adds potential difficulties to the inversion problem and raises the computational burden of the retrieval.

In the longer run, this work aims to achieve moderate spatial resolution temperature maps of the South Polar Vortex of Venus. Combining these maps with the measured velocity field from the same VIRTIS-M infrared images [2], we will be able to infer the PV distribution in the south polar region. PV is an important magnitude in the study of a fluid's dynamical behavior, and PV maps for different vortex configurations will be very helpful to understand its unpredictable character and its role in the general atmospheric circulation.

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References

[1] García Muñoz, A., et al. (2013). A model of scattered thermal radiation for Venus from 3 to 5 μm. *Planetary and Space Science* (in press).

[2] Garate-Lopez, I., et al. (2013). A chaotic long-lived vortex at the southern pole of Venus. *Nature Geoscience* **6**, 254-257.

[3] Roos-Serote, M., et al. (1995). The thermal structure and dynamics of the atmosphere of Venus between 70 and 90 km from the Galileo-NIMS spectra. *Icarus* **114**, 300-309.

[4] Grassi, D., et al. (2008). Retrieval of air temperature profiles in the Venusian mesosphere from VIRTIS-M data: Description and validation of algorithms. *Journal of Geophysical Research (Planets)* **113**, E00B09.

[5] Irwin, P. G. J., et al. (2008). Spatial variability of carbon monoxide in Venus' mesosphere from Venus Express/Visible and Infrared Thermal Imaging Spectrometer measurements. *Journal of Geophysical Research (Planets)* **113**, E00B01.