EPSC Abstracts
Vol. 11, EPSC2017-652, 2017
European Planetary Science Congress 2017

How does the latitudinal dependency of the cloud structure change Venus' atmosphere's general circulation?

I. Garate-Lopez and S. Lebonnois
Laboratoire de Météorologie Dynamique (LMD/IPSL), Sorbonne Universités, UPMC Univ Paris 06, Paris, France
(itziar.garate@lmd.jussieu.fr / Fax: +33 (0)1 44 27 62 72)

Abstract

Differently to the previous simulation of the LMD/IPSL Venus GCM [5], we now take into account the latitudinal variation of the clouds' structure described by [2], and we analyze its impacts on the general circulation of Venus atmosphere. Both solar heating rates and the infrared net-exchange rate matrix used in the radiative transfer code have been modified in that sense. Additional tuning below the clouds has also been performed.

The current results show a better agreement with observations in both mean zonal wind and average temperature fields. Moreover, taking into account the latitudinal variation of the clouds has brought along with it the formation of a well defined cold collar poleward of 60º at cloud level.

Besides, we have reanalyzed the wave activity present in Venus atmosphere and found new baroclinic mid-latitude waves. However, we do not obtain the gravity waves present in the deep atmosphere in the previous model [5].

1.Introduction

The model used here is based on that presented in [5]. This previous simulation reproduced Venus' atmosphere's superrotation and obtained mid-latitude and equatorial zonal wind jets. However, the vertical shear of the zonal wind below the clouds was not completely consistent with the measurements performed by different probes, and the modeled equatorial jet was too intense comparing with the mid-latitude jets.

The average temperature structure obtained with the previous simulation was also good, since it was quite close to the reference VIRA model [6] and it showed a wide cold polar region with some inner structure. Nevertheless, the modeled temperatures were warmer than the VIRA values above the clouds and colder below the clouds, and the obtained cold polar region was located higher than the observed cold collar.

In the previous model, polar barotropic and mid- to high-latitude baroclinic waves were present in the cloud region, while in the middle cloud a Kelvin type and a Rossby-gravity type waves were obtained.

2.Modifications to the model

In Venus, the cloud top altitude decreases and the particles' size increases towards the poles [2]. In the present simulation, we take into account these latitudinal variations of the cloud structure when using look-up tables of the solar heating rates based on [3] and when computing the infrared net-exchange rate matrix [1] used in the radiative transfer code.

Moreover, in order to better fit the vertical profile of the modeled mean temperature to the VIRA reference profile [6], we multiply by a factor of 3 the solar heating rates of [3] between 30 and 48 km where the lower haze is observed. We also consider an additional extinction below the clouds by adding a continuum in the IR spectra used for the computation of the cooling rates. This additional continuum is divided in two; a value of 1.3×10^{-6} cm^{-1} $amagat^{-2}$ at 30 - 48 km altitude and a value of 4×10^{-7} cm^{-1} $amagat^{-2}$ at 16 - 30 km where the transition between stability and instability against convection is observed. This additional continuum plays a key role in the windows present between 3 and 7 μm, but has no influence in the rest of the spectrum.

3.Results

The present vertical profiles of the mean zonal wind are more consistent with the probes' measurements between 40 and 60 km altitude (see Figure 1), probably due to a new baroclinic wave activity found at low and mid latitudes at these altitude range. However, below 40km the present zonal winds are slower than the previous ones, which were more consistent with the vertical profiles obtained by the Venera and Pioneer Venus probes. The gravity waves present in the deep atmosphere in the previous model [5] are no longer seen, which might be the reason why the deep zonal winds decreased speed, as they played a significant role in angular momentum transport.

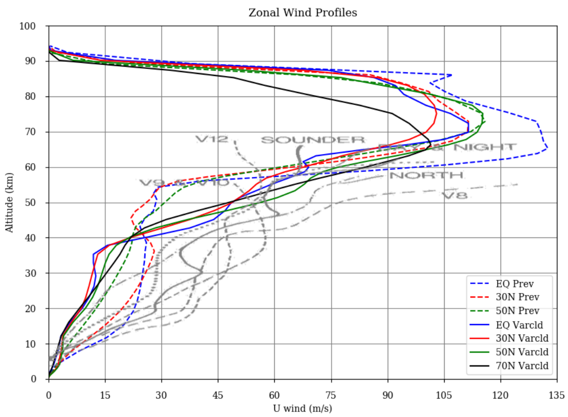

Figure 1: vertical profiles of the mean zonal winds for the previous (dashed line) and new (continuous line) IPSL VGCM models. Different probes' measurements are added in grey.

The equatorial jet is less intense that in the previous model while the mid-latitude jets have increased velocity, being the present latitudinal profile of the wind more consistent with observations [4]. This improvement is mainly related to the meridional transport of angular momentum by the intense wave activity present in the atmosphere. The different types of waves obtained by the present IPSL VGCM model are: diurnal and semi-diurnal tides, barotropic and baroclinic waves, and low-latitude Rossby-type and equatorial Kelvin-type waves.

The present zonally averaged temperature structure is also more consistent with observations than in the previous model. The temperature values above the cloud have decreased and the values below the clouds have increased due to the modifications in the solar heating and IR cooling rates, so the mean vertical profiles fits better now the VIRA profile.

Moreover, the zonally and temporally averaged temperature field (altitude vs. latitude cross section) obtained from the present model shows a cold feature at ~62km altitude and poleward of 60º that resembles the observed cold collar [2] (see Figure 2).

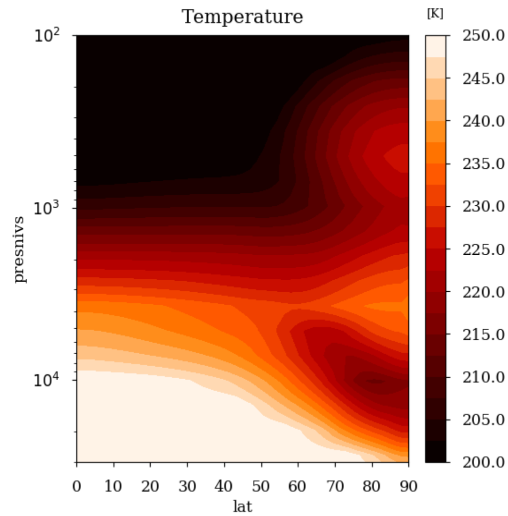

Figure 2: zonally and temporally averaged temperature field of the new IPSL VGCM model.

References

[1] Eymet, V., Fournier, R., Dufresne, J.-L., et al.: Net-exchange parameterization of the thermal infrared radiative transfer in Venus' atmosphere, J. Geophys. Res, Vol. 114, E11008, 2009.

[2] Haus, R., Kappel, D., Arnold, G.: Atmospheric thermal structure and cloud features in the southern hemisphere of Venus as retrieved from VIRTIS/VEX radiation measurements, Icarus, Vol. 232, pp. 232–248, 2014.

[3] Haus, R., Kappel, D., and Arnold, G.: Radiative heating and cooling in the middle and lower atmosphere of Venus and responses to atmospheric and spectroscopic parameter variations, Planet. Space Sci., Vol. 117, pp. 262–294, 2015.

[4] Hueso, R., Peralta, J., Garate-Lopez, I., et al.: Six years of Venus winds at the upper cloud level from UV, visible and near infrared observations from VIRTIS on Venus express, Planet. Space Sci., Vol. 113–114, pp. 78–99, 2015.

[5] Lebonnois, S., Sugimoto, N., and Gilli, G.: Wave analysis in the atmosphere of Venus below 100-km altitude, simulated by the LMD Venus GCM, Icarus, Vol. 278, pp. 38–51, 2016.

[6] Seiff, A., Schofield, J.T., Kliore, A.J., et al.: Model of the structure of the atmosphere of Venus from surface to 100km altitude, Adv. Space Res., Vol. 5, pp. 3-58, 1985.