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Thermal structure of Venus upper atmosphere by a ground-to-thermosphere GCM: a preliminary study.

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Abstract

We present here preliminary results of the thermal structure of the upper atmosphere of Venus simulated by a ground-to thermosphere General Circulation Model (GCM). The GCM developed at the *Laboratoire de Meteorologie Dynamique* (LMD) [1] has been recently improved and extended vertically from 100 to 150 km, with the inclusion of the physical processes which mostly contribute to the thermal balance in the mesosphere/thermosphere of Venus (i.e near IR heating by CO_2, 15 μm thermal cooling, extreme UV heating, thermal conduction). We also focus on recent Venus Express and ground-based temperature measurements above 100 km, both at daytime and night-time, and we interpret the observed main features with the help of model simulations. This ongoing study may indicate that both radiative and dynamical effects play a crucial role in determining the thermal structure of those upper layers of Venus atmosphere.

1. Introduction

The interest of the scientific community in the upper atmosphere of Venus has noticeably increased in the last decade. First of all it is characterized by a complex dynamic: the layers between 90 and 140 km constitute a transition region between the zonal super rotation (stronger around 70 km) and the sub-solar to anti-solar (SS-AS) circulation of the thermosphere (above 120 km). Secondly, the low density layers of planetary atmospheres are typically difficult to observe and usually poorly constrained. Recent measurements by the instruments on board Venus Express (VEx) and by ground-based observations have considerably improved our knowledge of those upper layers. However, specific processes remain unresolved and synergies between model predictions and observations are fundamental to interpret those results and to give answers to specific questions (e.g. role of thermal tides and gravity waves in the superrotation, latitudinal temperature variability, etc). In this study we will focus only on the temperature structure of Venus upper atmosphere, to understand and characterize it with the help of a GCM model.

2. Model improvements

The Venus GCM [1] developed at LMD has been used to compute consistent temperature fields from the surface up to 100 km and to interpret VEx observed thermal structure [2]. It has been recently extended up to 150 km, and improved with the implementation of a full radiative transfer scheme for the solar radiation, as it was previously done in the thermal range with a pre-computed net exchange matrix.
The vertical extension requires to take into account for physical processes specific for these altitudes. At the very low gas densities typical of those upper layers, the thermal balance of the upper mesosphere/lower thermosphere is controlled by non Local Thermal Equilibrium (non-LTE) radiative transfer processes (i.e near-IR heating by solar absorption in CO_2 bands and 15 μm cooling). Those situations are described and interpreted by a non-LTE model for Venus [3]. A comprehensive on-line implementation into a GCM of a complex non-LTE model is very expensive computationally, and proper simplifications are required. Above 125 km, the thermal structure is mainly controlled by the absorption of extreme UV heating and thermal conduction. Molecular viscosity and molecular diffusion also have impact on the winds and on the composition of the atmosphere, respectively. Our strategy was to follow the parameterization already developed for the LMD Mars GCM, which is computational compatible with 3D GCM simulations [4, 5], and adapted those routines directly to the Venus GCM (also thanks to the fact that their atmospheres are mainly composed of CO_2). Sensitivity studies to evaluate the impact of the non-LTE parameterization on the thermal structure will be presented.

3. Temperature measurements in the upper atmosphere

The upper atmosphere is currently observed with unprecedented sensitivity and vertical resolution by SPICAV [6] and SOIR [7] spectrometers on-board VEx, during stellar and solar occultation, providing nighttime and terminator temperatures, respectively. SPICAV measurements cover both the south and north hemisphere, from 90 to 140 km, and observe a significant temporal and latitudinal variability. SOIR profiles cover altitudes range from 70-170 km, and latitudes from the equator to north pole: the general trend is a strong minimum around 125 km and a weaker temperature maximum over 100-115 km. Latitudinal variations are found, but not strong differences between morning and evening terminator. Daytime temperatures have been retrieved by VIRTIS/VEx measurements at northern hemisphere latitudes, from 100 to 150 km [8]. They also indicate an apparent warmer layer between 110 and 120 km, near the terminator at equatorial regions, but not at noon, where instead temperatures are lower than expected. Ground-based observations are also providing complementary information to probe the mesosphere of Venus [9]. Those observations correspond to 110 km ($\pm$ 10 km) and exhibit large latitudinal variations, with changes up to 100 K between high and low latitudes. All those results show that the thermal state of the upper atmosphere is far more complex than expected and the variability observed is a combination of radiative and dynamical processes, which complete analysis and understanding are still under investigation. We will present here comparisons between our new GCM simulations and available observations to analyse how well features may be modeled and intepreted at current stage of developement.

4. Summary and future work

The LMD Venus GCM has been recently improved and extended vertically up to 150 km: the simulated thermal structure will be compared with recent temperature observations by VEx and ground-based telescope. Our goal is to understand and interpret the main features observed in the thermal structure of Venus atmosphere above 90-100 km. This is an on-going study and a more comprehensive comparison will be done after coupling the actual extended GCM with a 3D photochemical model [10] and a new parameterized cloud model [11], which are both in progress.

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