INVESTIGATIONS BELOW THE CLOUDS OF VENUS WITH THE IPSL VENUS GCM. S. Lebonnois[1], G. Schubert[2], F. Forget[1], I. Garate-Lopez[1,3], A. LeSaux[1], T. Navarro[2], A. Spiga[1], [1] LMD/IPSL, Sorbonne Université, Campus P&M Curie, CNRS, Paris, France (sebastien.lebonnois@lmd.jussieu.fr), [2] Department of Earth, Planet. and Space Sci., UCLA, Los Angeles, CA, USA, [3] Universidad del País Vasco/Euskal Herriko Unibertsitatea (UPV/EHU), Bilbao, Spain.

Introduction: Thanks to the various space missions that investigated Venus's atmosphere since the 70's, and in particular the recent Venus-Express (Europe, 2006-2014) and Akatsuki (Japan, 2015-) missions, the atmosphere of Venus above roughly 45 km altitude including the clouds (~48-70 km) has been thoroughly investigated. This vast amount of data helps to understand how this complex atmospheric system works, in particular with the help of advanced Global Climate Models (GCMs). However, data from below the clouds are sparse, despite the importance of the deep atmosphere in the global behavior of Venus's atmospheric system: peak of angular momentum content, interactions between surface and atmosphere (including angular momentum exchange, volcanism, weathering). A better knowledge of the region is also needed for specific mission planning purposes, such as aerial platforms or landers.

Investigations with the IPSL Venus GCM: To investigate this region while planning new missions, GCMs are valuable tools and we review here all the studies conducted on this region with the IPSL Venus GCM developed in Paris [1,2].

Radiative transfer improvements. To model the temperature profile in the deep atmosphere, it is crucial to investigate the radiative transfer and the opacity sources below the clouds. [3] studied how the solar energy absorbed below the cloud may be balanced with infrared energy heating the base of the cloud, convecting up to the middle cloud to escape finally to space mostly in the 20-30 micron region. Using recent solar flux calculations [4] and up-to-date datasets for IR gaseous opacities and collision-induced absorptions, the temperature profile in our GCM is tuned through assumptions on the haze below the cloud to fit the observed temperature profile between the cloud base and the surface.

Wave activity near and below the cloud-base. Though we obtain realistic superrotation in the upper cloud, the vertical profile of zonal wind observed below 60 km is not fully understood. Around the cloud base (40-60 km), wave activity obtained in our most recent simulations contributes to angular momentum convergence in the equatorial region [2]. In previous simulations [1], large-scale gravity waves were transporting angular momentum equatorward and downward, improving the distribution of zonal wind below 40 km. As both wave activities are not obtained in the same simulations, we are investigating the conditions for the development of each of these wave groups.

Planetary Boundary Layer. Near the surface, the IPSL Venus GCM was also used to investigate the behavior of the Planetary Boundary Layer (PBL), in particular diurnal convective activity [5]. The deepest 10 km above the surface are neutrally stable in our simulations, a peculiar environment for the diurnal cycle of the PBL. A nocturnal stable layer is obtained due to cooling of the surface during nighttime. In daylight hours, convection develops in mid- to low-latitude regions, with a maximum around noon and a convective layer mostly limited to just over 1 km thickness. Strong slope winds are obtained in the simulations, with a diurnal cycle: downslope katabatic winds at night, upslope anabatic winds during daytime. The convergence of anabatic winds at noon over the western slopes of topographic features induces a large increase in the vertical extension of the convective activity, reaching higher than 5 km thickness in some of these regions.

Topographic waves. The interactions between the near-surface flow and the topography are also explored with the IPSL Venus GCM [6]. A parameterisation of the drag due to orographic gravity waves generated by topographic features is now implemented and can help interpret the stationary bow-shape waves observed at cloud-top by the Akatsuki spacecraft [7].

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