Parameterizing Gravity Waves and Understanding their Impacts on Venus' Upper Atmosphere

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1. Introduction

The complexity of Venus' upper atmospheric circulation is still being investigated. Simulations of Venus' upper atmosphere largely depend on the utility of Rayleigh Friction (RF) as a driver and necessary process to reproduce observations (i.e. temperature, density, nightglow emission). Currently, there are additional observations which provide more constraints to help characterize the driver(s) of the circulation. This work will largely focus on the impact parameterized gravity waves have on Venus' upper atmosphere circulation within a three dimensional hydrodynamic model (Venus Thermospheric General Circulation Model).

2. Venus Thermospheric General Circulation Model (VTGCM)

The VTGCM's nominal set up utilizes two Rayleigh friction (RF) terms to help simulate mean thermosphere conditions observed by VEX (e.g. [2], [3]). One RF is symmetric about the sub-solar point with cos(latitude) variation which provide constant deceleration to the winds (RF-sym). The second RF is asymmetric about the sub-solar point with cos(latitude) variation in order to simulate the retrograde superrotation zonal wind (RSZ). The purpose of RF is to obtain first order approximation of the necessary wave momentum deposition to reproduce observations. Therefore, the RF provides guidelines for the implementation and adjustment of new wave momentum deposition parameterizations.

In the past, the VTGCM has been utilized to understand the impacts of gravity waves on the O_2 IR nightglow emission [10] and the zonal winds [9]. [10] had a shallower model but was able to show gravity wave deposition creating O_2 IR nightglow emission variations as observed. [9] demonstrated that gravity waves launched below 100km either broke below ~115 km or were reflected due to the internal reflection criteria of the deposition parameterization ([1]; [AD parameterization]). Overall, there was minimal impact on the circulation.

For this study, a different gravity wave momentum/energy deposition parameterization will be employed [8] within a more sophisticated VTGCM (compared to the version used in [10]) along with newly updated radiative processes (aerosol heating and 15 μm cooling parameterization). The radiative updates are important to properly simulate Venus' thermal structure which impacts the circulation and the behaviour of the gravity wave deposition parameterization.

2.1. Aerosol Heating

The VTGCM lower boundary is at ~70 km, which is near the cloud tops. Near this level, aerosols provide heat to the middle atmosphere. A parameterization guided by [7] has been incorporated and tested. The additional heating increases the scale heights in this altitude range (~75 – 90 km) and therefore augments density profiles (~100 – 130 km) and modifies wave propagation.

2.2. 15 μm Cooling Parameterization

We have adapted the updated simplified non-LTE formulation utilized within LMD-MGCM and LMD-VGCM ([6]; [5]). The non-LTE model uses five CO_2 levels and bands, instead of two molecular levels. It calculates the full exchange between atmospheric layers, instead of using the cool-to-space approximation which was the basis of the previous parameterization in the VTGCM ([4]; [2]). We expect to finid VTGCM temperatures warmer over ~80-110 km (day and night) and about the same (cool to space approximation is fine) in the Venus dayside and nightside thermosphere (above ~110-120 km).

2.3. Yiğit Gravity Wave Momentum Deposition Parameterization (GWMD-Y)

The GWMD-Y parameterization has been implemented into the VTGCM and testing has begun. It is a spectral non-linear parameterization [8]. It accounts for many wave dissipation processes that are important in the Venus upper atmosphere, including molecular diffusion and viscosity, plus radiative damping. The GWMD-Y parameterization is different from the AD parameterization because it allows waves to be saturated at multiple heights and the waves are not completely removed at a single breaking level. The computed momentum deposition ("drag") and heating/cooling rates are applied to the momentum and energy conservations equations, respectively. However, the GWMD-Y parameterization does not take into account total internal reflection as does the AD parameterization.

3. Discussion/Conclusion

The work to be presented will be the preliminary studies of the GWMD-Y parameterization incorporated into the VTGCM. The free parameters and their ranges for the parameterization will be discussed. Along with the impact the waves have on the thermal structure, wind structure, and O_2 IR nightglow emission.

4. References

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