# Venus Global Ionosphere Thermosphere Model

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## Introduction

Aside from Earth, Venus is the most studied planet

- When learning about exoplanets, Venus is a more typical environment than Earth or Mars
- Believed to once have liquid water, but the runaway greenhouse effect dried up the planet

Models are excellent tools to perform simulations that help teach us more about how planets may have changed over time. **This project is presenting the introduction of a new Venus model** derived from an existing Earth-based ionosphere-thermosphere model called the Global Ionosphere Thermosphere Model (GITM).

## Model Description

GITM is a well-established, physics-based, 3D spherical code that couples the ionosphere and thermosphere of Earth [Ridley and Deng, 2006]. The dynamics and chemistry are solved for the neutrals, ions and electrons. Versions of GITM were developed for Mars, Earth and Titan.

Some unique characteristics of GITM:

- Uses an altitude grid instead of a pressure grid
- Does not assume hydrostatic equilibrium allowing for vertical velocities to be explicitly solved for
- Makes use of FISM fluxes

## Simulation Results

In this section, we describe a simulation that illustrates the current state of the Venus Global Ionosphere Thermosphere Model (V-GITM) and how well it computes the thermosphere and ionosphere during solar minimum conditions. (1) Density profiles, (2) winds in the meridional, zonal and vertical directions, (3) temperature profiles, (4) heating rates and (5) the resulting ionosphere are shown.

### 1.) Neutral Density Profile

The neutral densities are plotted for F10.7 = 80 conditions in Figure 1. The VTS3 model and Venus Express measurements are used as comparisons.

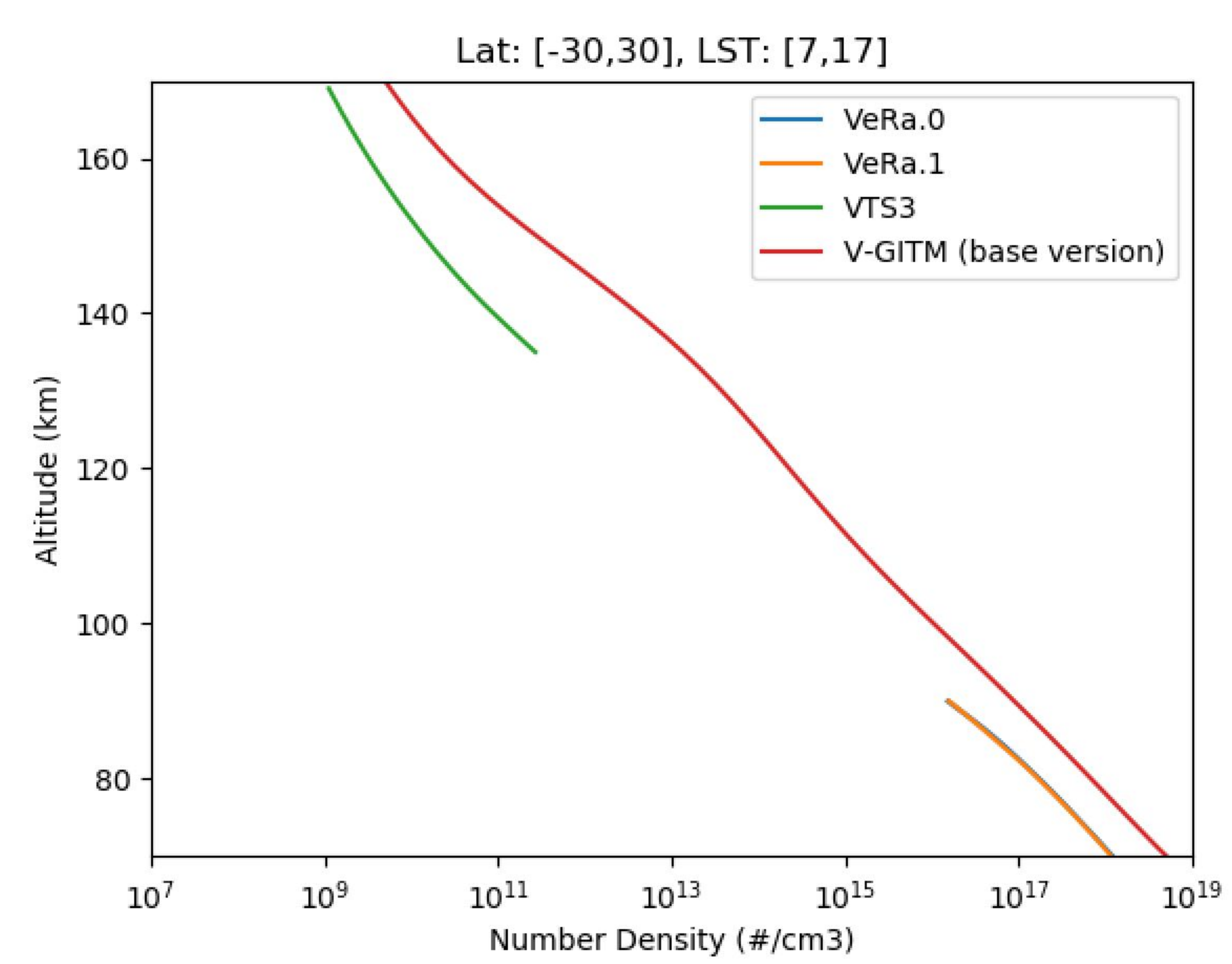


Figure 1: Total neutral density profiles for low solar activity conditions averaged from 30 S - 30 N and across 7-17 LST.

### 2.) Neutral Winds

Venus has two persistent wind patterns that are depicted in Figure 2.

- The retrograde superrotating zonal (RSZ) flow moves in the direction of the planet's rotation. The speed of the RSZ wind at the cloud tops (~70 km) is around 100 m/s
- There is a transition region between 70-120 km where the RSZ and subsolar-antisolar (SS-AS) flow superimpose
- Above 120 km, the SS-AS flow peaks out at 200-300 m/s [Bougher et al., 2006]

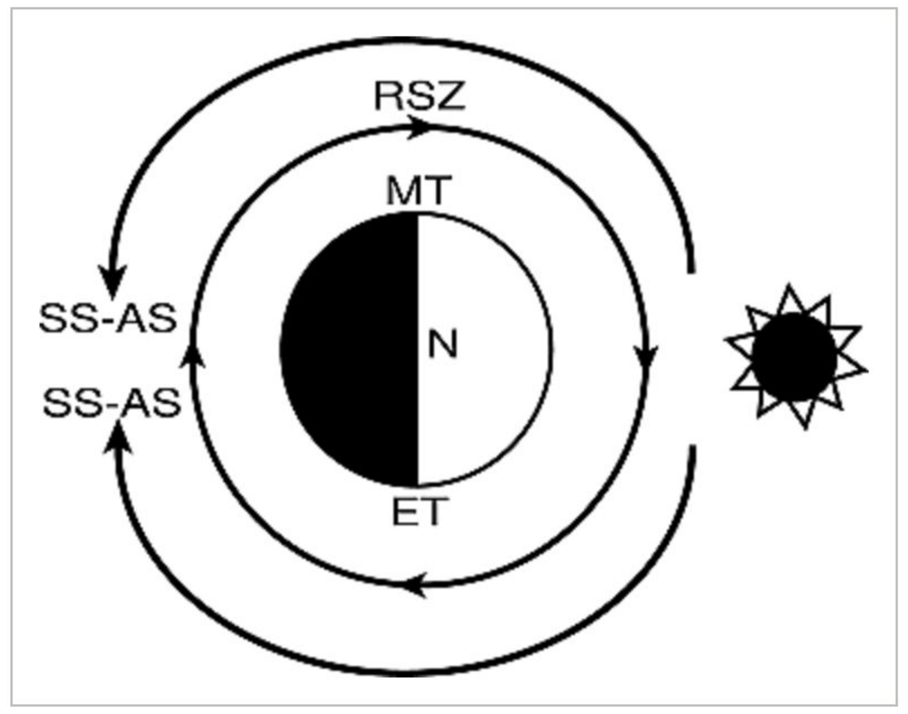


Figure 3: A north pole view of Venus' winds. MT is the morning terminator and ET is the evening terminator. Adopted from Schubert et al., 2007.

In Figure 4, the computed winds are plotted. There is clear divergence of flow right where the solar EUV is being deposited.

- The meridional winds diverge toward the poles on the dayside. At the terminator they peak 300-400 m/s
- The zonal winds divert east and west on the dayside
- In the vertical direction, the dayside has outflow to higher altitudes

The sources and losses for the winds are primarily from the gradient pressure and viscosity. There are minor contributions from the coriolis force and the spherical geometry.

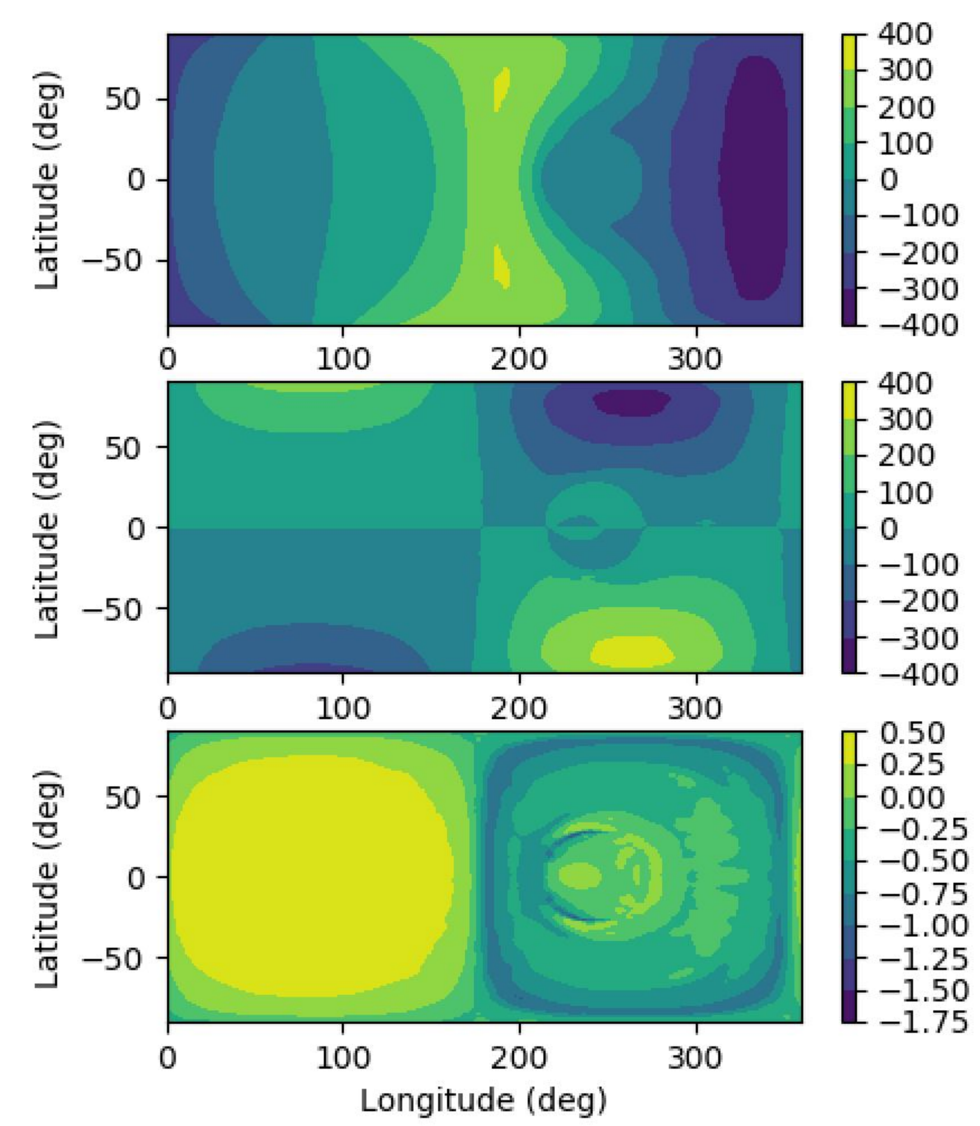


Figure 3: The wind profiles in each direction at 160 km produced by V-GITM.

### 2.) Temperature Profile

With a lower boundary condition of 228 K and a top of atmosphere boundary setting gradient T to be zero, the temperature of V-GITM is shown in Figure 4.

- Nightside temperature bottoms out around 100-110 K.
- The dayside heating peak (160 - 170 km) is 275 - 300 K. This is ~ 50 K warmer than comparable model results for solar minimum conditions.
- Around 110-115 km, there is a local temperature maximum due to the solar near IR.

The major source and loss terms in the temperature equation is solar EUV heating (5% heating efficiency), IR heating, exothermic reactions, thermal conduction, and CO2 radiative cooling.

In Figure 5, there is a comparison of the V-GITM profile with many other sources of in-situ measurements or model results.

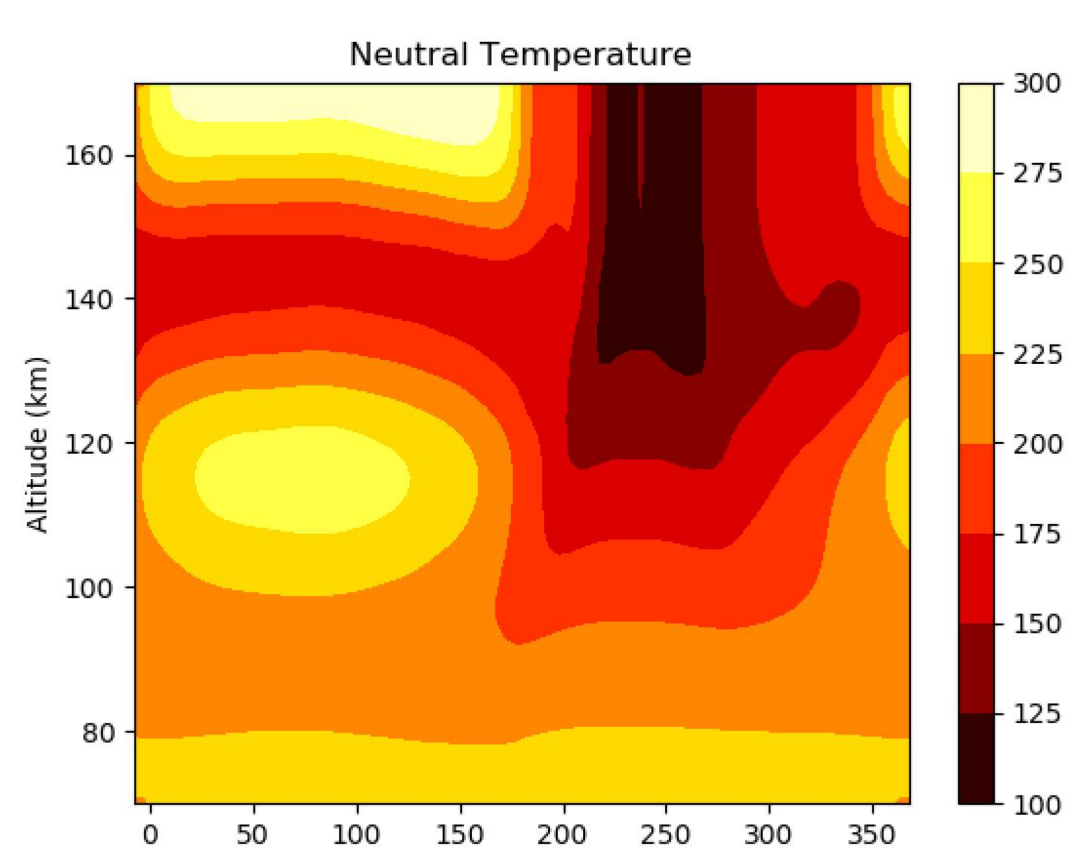


Figure 4: V-GITM temperatures (K) produced at 5 deg N latitude.

The lower atmosphere temperatures are strongly dictated by balance of the IR heating and CO2 15 micron cooling.

Gilli et al., 2021 has an updated parameterization for the IR heating that should be used.

The radiative cooling code originates from the Laboratoire de Meteorologie Dynamique (LMD) group. This cooling was developed for Mars originally and so additional calibration for adopting to Venus may be needed.

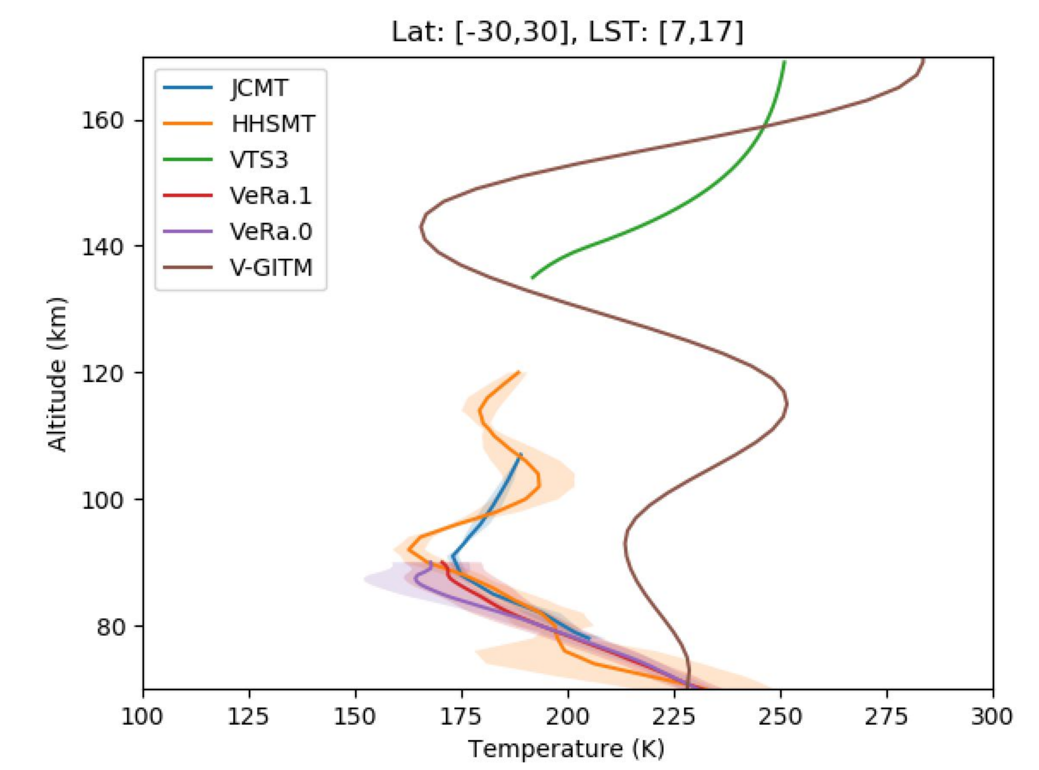


Figure 5: A data-model comparison of the averaged dayside temperatures from 30 S - 30 N and from 7-17 LST.

### 3.) Ionosphere

V-GITM only has two ions (CO2 and O2) currently calculated due to a simplified set of chemistry applied in the model. Atomic oxygen, NO, and carbon monoxide ions will be added in the future.

- Ionization due to the solar radiation is the primary driver of the ion density.
- Charge exchange has a lower impact on the ion population.
- The densities and ion peak altitudes are reasonable compared to Fox and Sung, 2001 results.

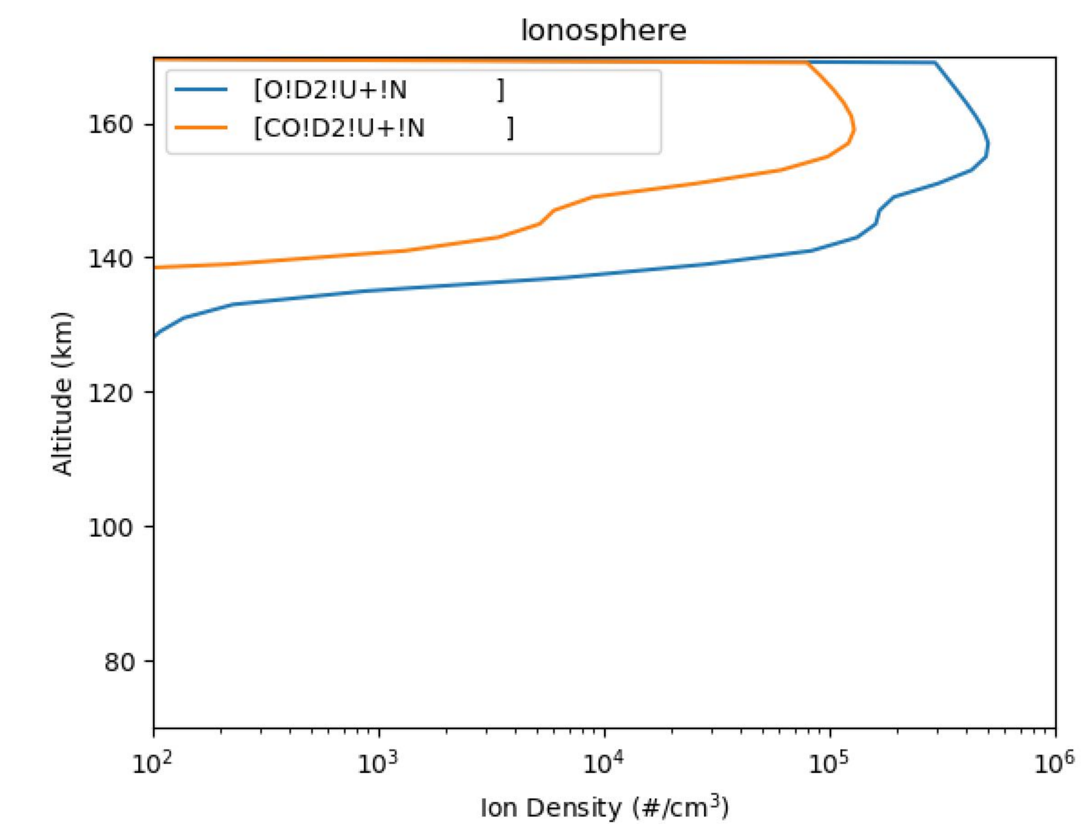


Figure 6: Dayside, equator O2 and CO2 ion densities currently implemented in V-GITM.

## Next Steps

Once density, winds and temperature structure in V-GITM are closer to satellite measurements, this model can be useful in answering some outstanding questions in the Venus community.

Science questions to answer:

- Does solving for the winds explicitly change day-night structure?
- Are gravity waves & their breaking responsible for the asymmetries in the temperature and night glow?
- With such a slow planet rotation rate, how is the nightside ionosphere sustained?

## References

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