Using the development process of the Venus Global Ionosphere-Thermosphere Model to understand the importance of planetary attributes on Earth's atmosphere

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Abstract

The Global Ionosphere-Thermosphere Model (GITM) has been used to model the atmosphere of Earth, with various versions for studies of Mars, Jupiter, and Titan. Currently, a version for Venus is under development. During this process, we will conduct systematic studies of how the Earth's atmosphere would change when given certain characteristics of Venus. The Venus model (V-GITM) development includes systematic parameter variances of certain key planetary attributes such as distance from the Sun, planetary axis tilt, and rotation and revolution rates. The lack of an intrinsic magnetic field will also be implemented, along with an atmospheric composition of high carbon dioxide levels and different ratios of minor species. This methodical approach to creating an atmospheric model of Venus will allow for a closer look at the importance of planetary characteristics on Earth's atmosphere.

In this poster, two planetary attributes will be discussed. Simulations have been conducted on planetary axis tilt and rotation rate, highlighting the differences between Earth and Venus.

Motivation

Goals:
- ✧ Develop a version of GITM for Venus
- ✧ Investigate how varied planetary attributes affect the atmosphere

Objectives:
- ✧ Examine how varying planetary axis tilt affects the atmosphere
- ✧ Explore how varying planetary rotation rate affects the atmosphere

Development Process

Simulation Setup
- ✧ Created GITM development version
- ✧ Modified the model to include an option for Venus

Axial Tilt Test Parameters
- ✧ Planetary characteristics
  - ✧ Venusian rotation period: 5832.6 hours, counterclockwise
  - ✧ Venusian days per Earth year: 1.503
  - ✧ Venusian axial tilt: 2.64 degrees
- ✧ Simulation timeframe
  - ✧ 20 June 2008 through 23 June 2008
  - ✧ Solstice timeframe allowed maximum tilt effect

Simulation Initial Parameters
- ✧ GITM parameters
  - ✧ Resolution: 10 degrees latitude by 20 degrees longitude
  - ✧ No tidal influence
  - ✧ No dynamo influence
  - ✧ Flat boundary conditions
- ✧ Earth planetary characteristics
  - ✧ Rotation period: 24.0 hours
  - ✧ Days per year: 365.25
  - ✧ Axial tilt: 23.5 degrees
- ✧ General simulation timeframe
  - ✧ 20 March 2008 through 21 March 2008
  - ✧ Midway between solar maximum and solar minimum to use average solar conditions

Rotation Period Test Parameters
- ✧ Planetary characteristics
  - ✧ Rotation period: 6–1000 hours
  - ✧ Days per year: 0.36–1461
  - ✧ Venusian axial tilt: 2.64 degrees
- ✧ General simulation timeframe
  - ✧ 20 March 2008 through 21 March 2008
  - ✧ Equinox timeframe negated tilt effect during rotation rate tests
- ✧ Special cases
  - ✧ Certain tests were run for an extended timeframe, especially the more extreme cases
  - ✧ 20 March 2008 through 23 March 2008
  - ✧ Tests 7, 9, 10, and 11 and control

Table 1: Rotation Period Test Parameters

Test Number	Ratio to Earth	Rotation Period (hours)	Days per Year
1	1	24	365.25
2	2	48	182.625
3	4	96	91.31
4	10	240	36.525
5	100	2400	3.65
6	200	4800	1.826
7	243.025	5832.6	1.503
8	400	9600	0.913
9	1000	24,000	0.36525
10	0.25	6	1461
11	0.5	12	730.5

Testing

Test 0: Control

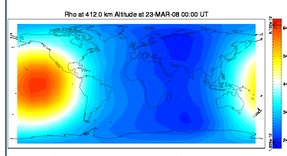

Figure 1: Density at 412 km

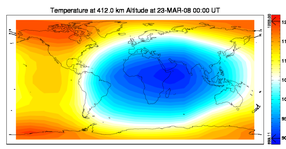

Figure 2: Temperature at 412 km

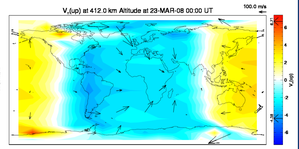

Figure 3: Neutral Winds (up) at 412 km

Test 11: Rotation Rate 6.0 hours, Spring Equinox

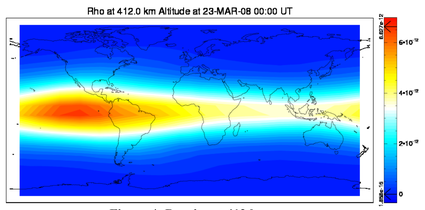

Figure 4: Density at 412 km

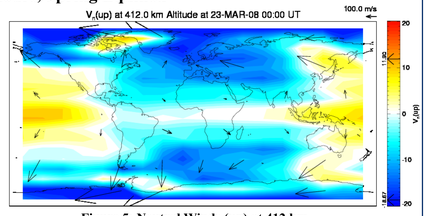

Figure 5: Neutral Winds (up) at 412 km

Test 9: Rotation Rate 24,000 hours, Spring Equinox

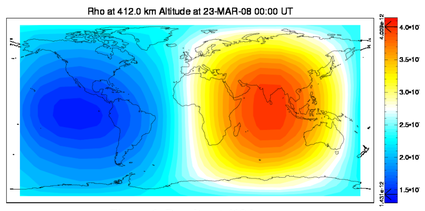

Figure 6: Density at 412 km

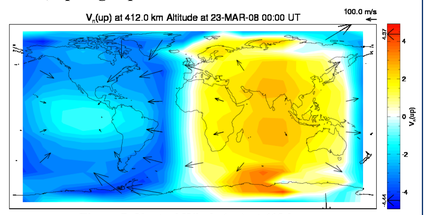

Figure 7: Neutral Winds (up) at 412 km

Test 7: Rotation Rate 5832.6 hours (Venusian rate)

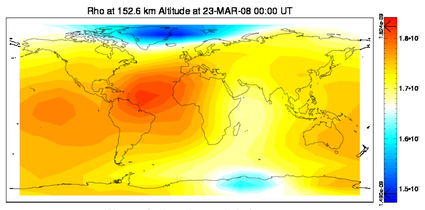

Figure 8: Density at 152.6 km

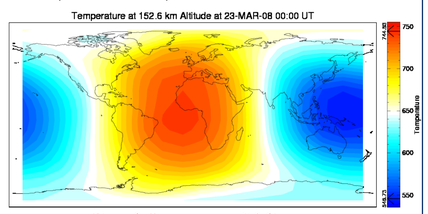

Figure 9: Temperature at 152.6 km

Test 13: Rotation Rate 5832.6 hours, Summer Solstice with Axial Tilt 2.64 degrees (Venusian tilt)

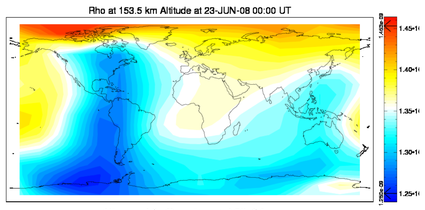

Figure 10: Density at 152.6 km

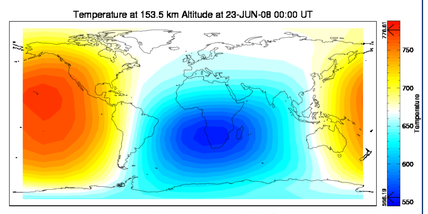

Figure 11: Temperature at 152.6 km

Conclusions

Results at 412 km Altitude
- ✧ Faster rotation rates
  - ✧ Density is not as dependent on time of day, instead it forms a band of higher density near the equator
  - ✧ Temperature is still somewhat dependent on time of day, and cooler temperatures are still found at the poles
  - ✧ Neutral winds going up are nearly 0 m/s
- ✧ Slower rotation rates
  - ✧ Density is dependent on time of day and is higher on the Eastern hemisphere
  - ✧ Temperature is dependent on time of day and is higher on the Eastern hemisphere
  - ✧ Neutral winds going up are slightly higher on the Eastern hemisphere

Results at 153 km Altitude
- ✧ Venusian rotation rates
  - ✧ Density is lower near the poles
  - ✧ Temperature is dependent on time of day and is unexpectedly higher at night
- ✧ Venusian rotation rate and axial tilt on summer solstice
  - ✧ Density is lower at the poles
  - ✧ Temperature is dependent on time of day and is lower at night

Future Work

More Detailed Simulations on Effects of Rotation Rate and Axial Tilt
- ✧ Run simulations for longer time periods
- ✧ Allow for clockwise planetary rotation
- ✧ Test additional axial tilts in between Earth and Venus
- ✧ Increase simulation resolution

Next Steps in Creating V-GITM
- ✧ Change additional planetary parameters
  - ✧ Gravity force
  - ✧ Planetary radius
  - ✧ Magnetic field (or lack thereof)
  - ✧ Planetary orbital characteristics
- ✧ Change atmospheric chemistry to reflect that of Venus
  - ✧ Will use equations from the Venus Thermospheric General Circulation Model
- ✧ Test effects of running simulations at solar maximum and solar minimum

References

- ✧ Ridley, A. J., Deng, Y., and Tóth, G., "The Global Ionosphere-Thermosphere Model," Journal of Atmospheric and Solar-Terrestrial Physics, Vol. 68, No. 8, 2006, pp.839-864. doi: 10.1016/j.jastp.2006.01.008
- ✧ Williams, D., "Venus Fact Sheet," [online], https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html [retrieved June 2017].
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