Unlocking the Mysteries of Venus' Atmosphere: *Investigating the Particle and Gas Density Distribution Relationships that Support the Formation of Venus' Dense Sulfuric Acid Clouds*

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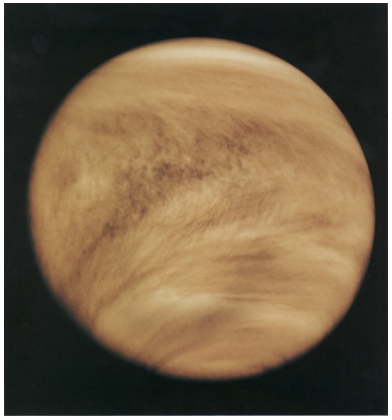
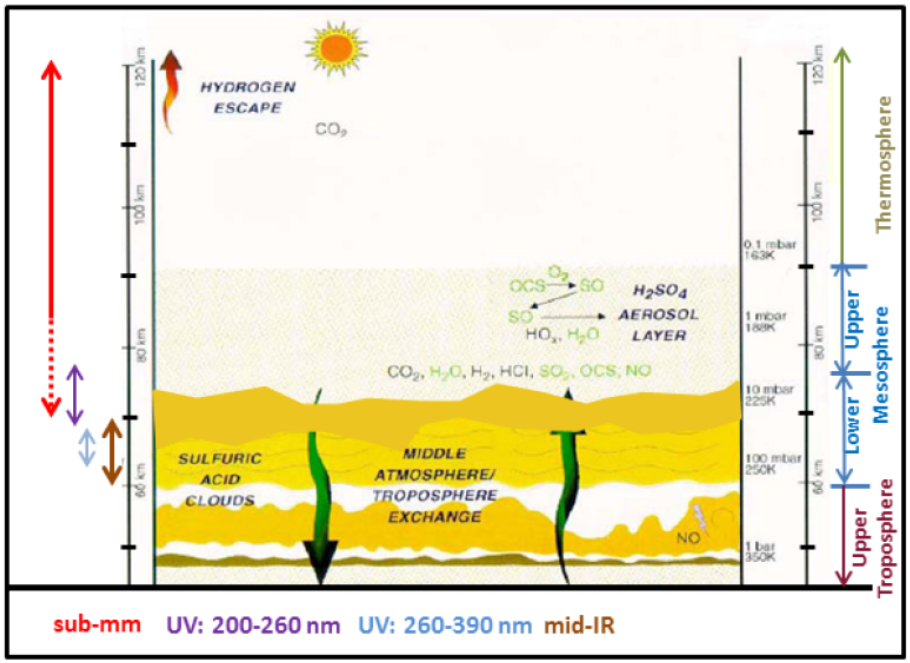
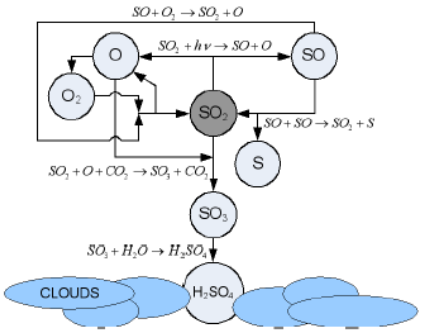
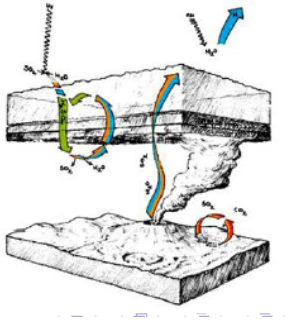


Basics of the Atmosphere

- CO_2 dominant
  - **96% (background gas)**
- Sulfuric Acid Clouds (H_2SO_4)
  - **Between 45 and 100 km**
  - **Acts like the green house glass**
  - **Trapping heat**
- Sulfur Cycle :
  - **Photolysis of SO_2 creates SO, S, and O**
  - **Kinetic reaction with creates O_2, SO_2, and SO_3**
  - **Kinetic reaction of H_2O and SO_3 creates H_2SO_4**





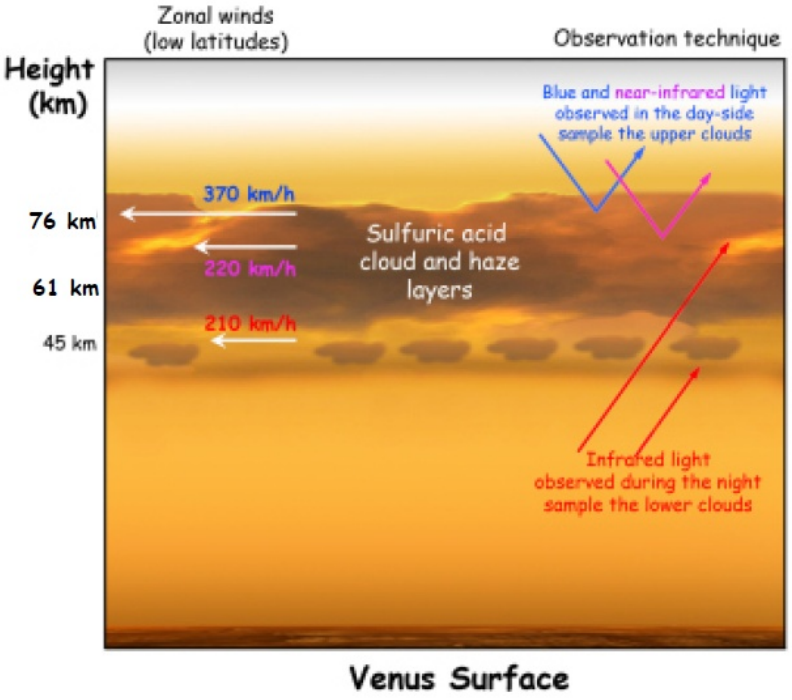


Why it is Important

- Sulfuric acid cloud formation rate
- Climate of Venus
- Global climate change
  - Abundance of SO_2 and SO – H_2SO_4

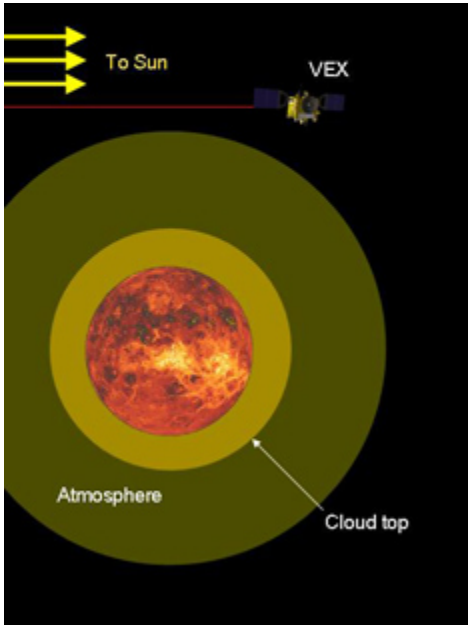
How to Study - Hubble

- Hubble (HST)
- Sunlight backscattered from the upper cloud deck
- Integrated column density from top of atmosphere down to 76 +/- 3 km
  - **Used to reproduce the SO_2 and SO gas absorption in reflectance spectrum**
- I/F spectrum – ratio of solar light scattered from Venus cloud tops/incoming solar light
- UV wavelengths – only SO_2 gas present in the upper regions of clouds is measured
  - **Below these altitudes, the atmosphere becomes opaque**
  - **Best fit by model that defined tau = 1 altitude at ~ 76 km**
- Column densities used to predict the SO_2 number density at each altitude between 50 – 100 km assuming the atmosphere exponentially decays with altitude
- 3 days – December 2010, January 2011



How to Study - VEx

- 9 years, launched in 2005
- SOIR – Solar occultations
  - **Detect the sunlight that is transmitted through the atmosphere at different latitudes**
  - **Data tangent to a latitude**
- Simultaneous HST and SOIR observations confirm that SO_2 number density fit matched SOIR observations made at the same altitudes
  - **Important to know how often HST and SOIR saw similar SO_2 number densities**
- Also looked at:
  - **Local time**
  - **Latitude**
  - **Altitude**
  - **Temperature, distribution of water molecules, and density of aerosols**



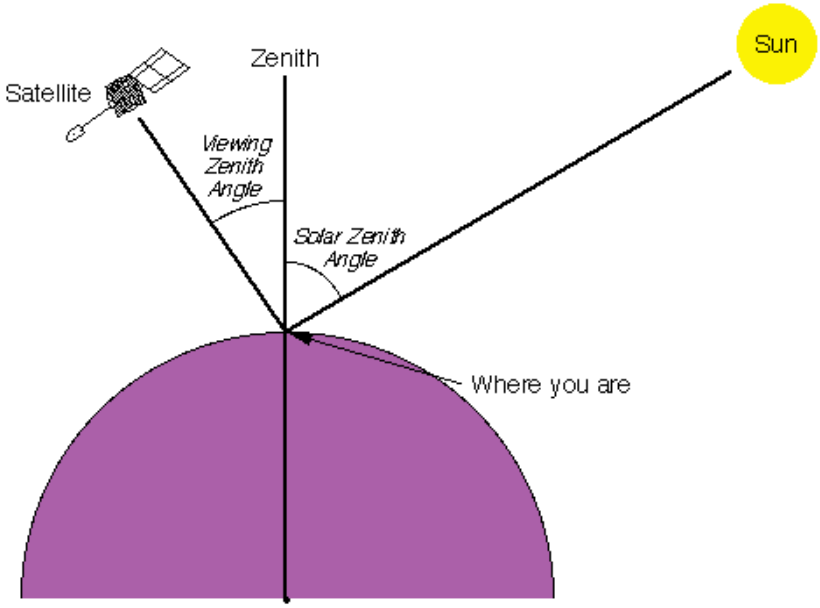
http://venus.aeronomie.be/en/soir/solaroccultation.htm

Goals

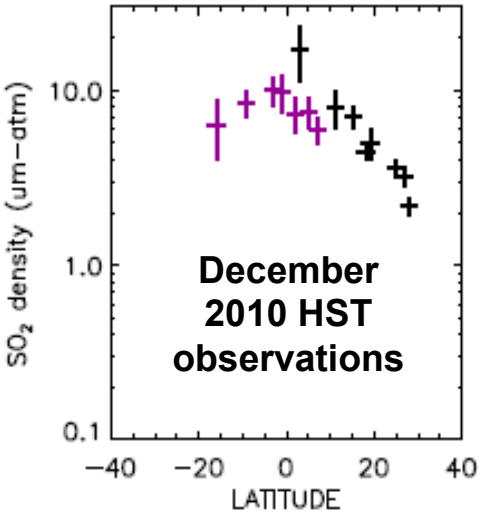
- Combined HST and SOIR dataset allows us to:
  - Look for trends that might reveal links between SO_2 variability and atmospheric conditions
  - Catalog plausible atmospheric conditions relative to SO_2 variability, so that photochemical and cloud formation models that track chemistry, vertical transport and winds can be better constrained

Data Description and Analysis Method

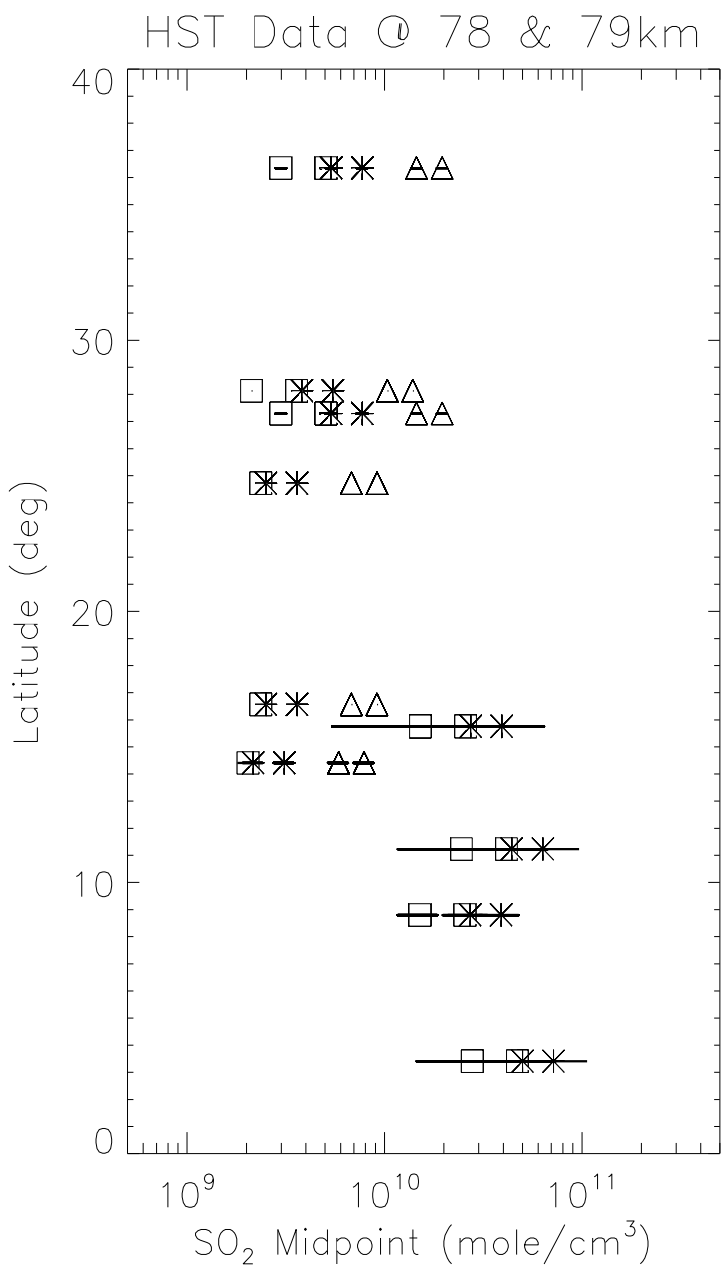
- Ultimate Goal
- Vertical Resolutions
  - **+/- 1, 3, 5, and 7 km**
- HST – 0.2 km grid
  - **4 different vertical sampling grids**
- SOIR – 1km grid
  - **Average SO_2 density profiles interpolated**
- SOIR – solar zenith angle greater than 80 degrees
- HST – solar zenith angle greater than 59 degrees

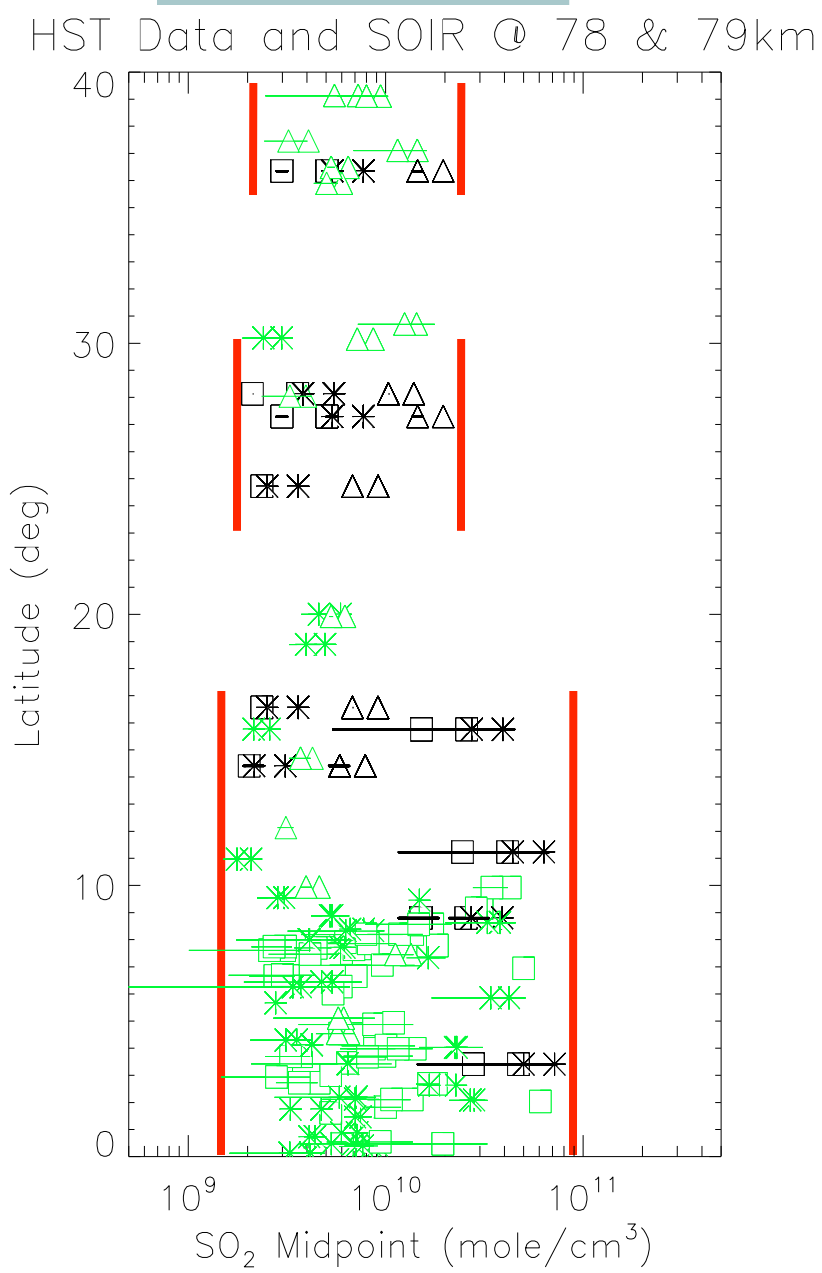


SO_2 Variability



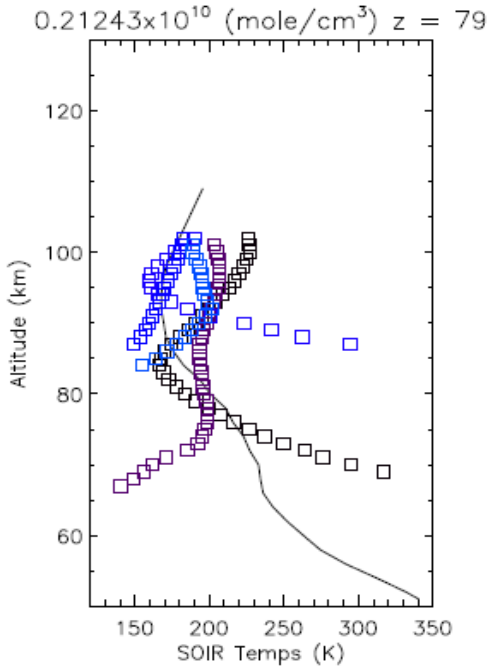
- VEx orbited every day – tracked by orbit number
- Venus is highly variable
- Broad range of densities observed by HST and SOIR
- 110/131 matched orbits between 0 and 40 degrees latitude (same range as HST)
- Relationship between detected SO_2 density profiles and latitude?

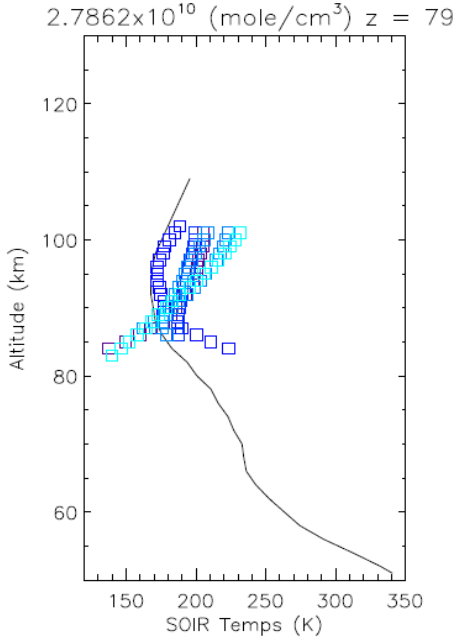

HST Data @ 78 & 79km
Latitude (deg)
40
30
20
10
0
10^9
10^{10}
10^{11}
SO_2 Midpoint (mole/cm^3)


HST Data and SOIR @ 78 & 79km
Latitude (deg)
40
30
20
10
0
10^9
10^{10}
10^{11}
SO_2 Midpoint (mole/cm^3)

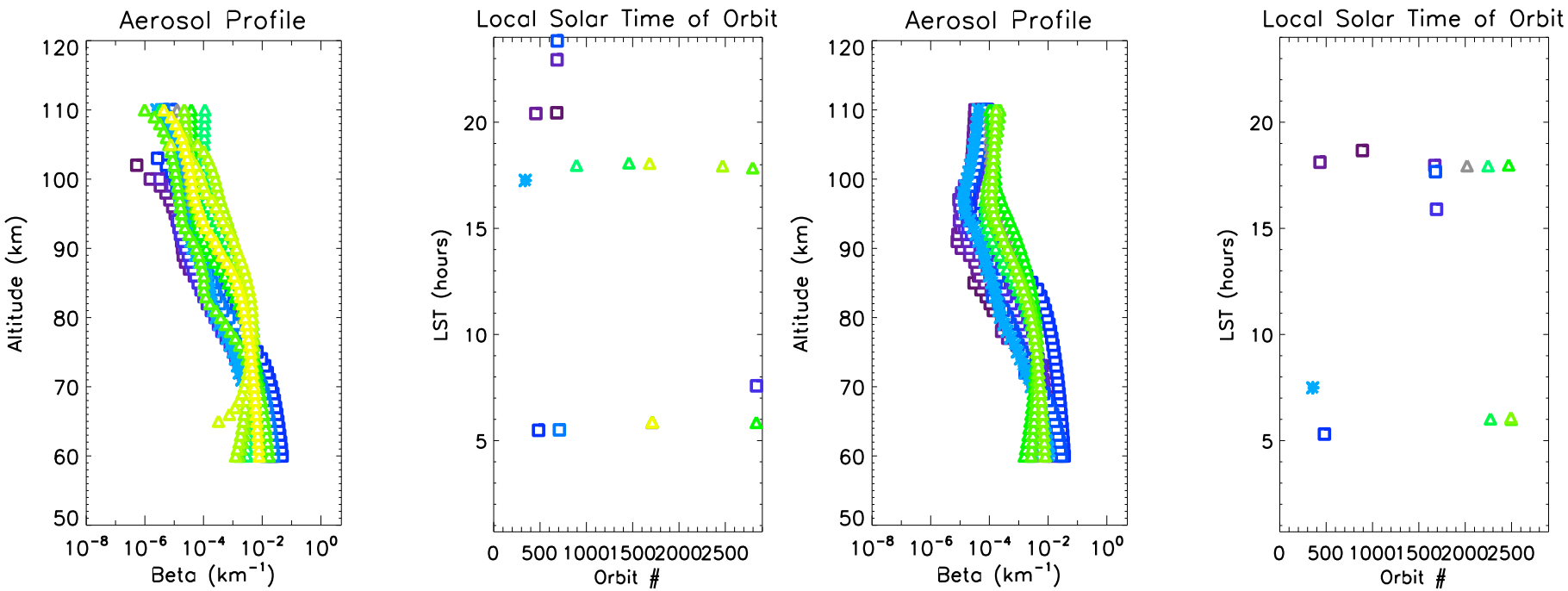
Variation in Atmospheric Conditions Relative to Observed SO_2 Density

- Temperature Profiles

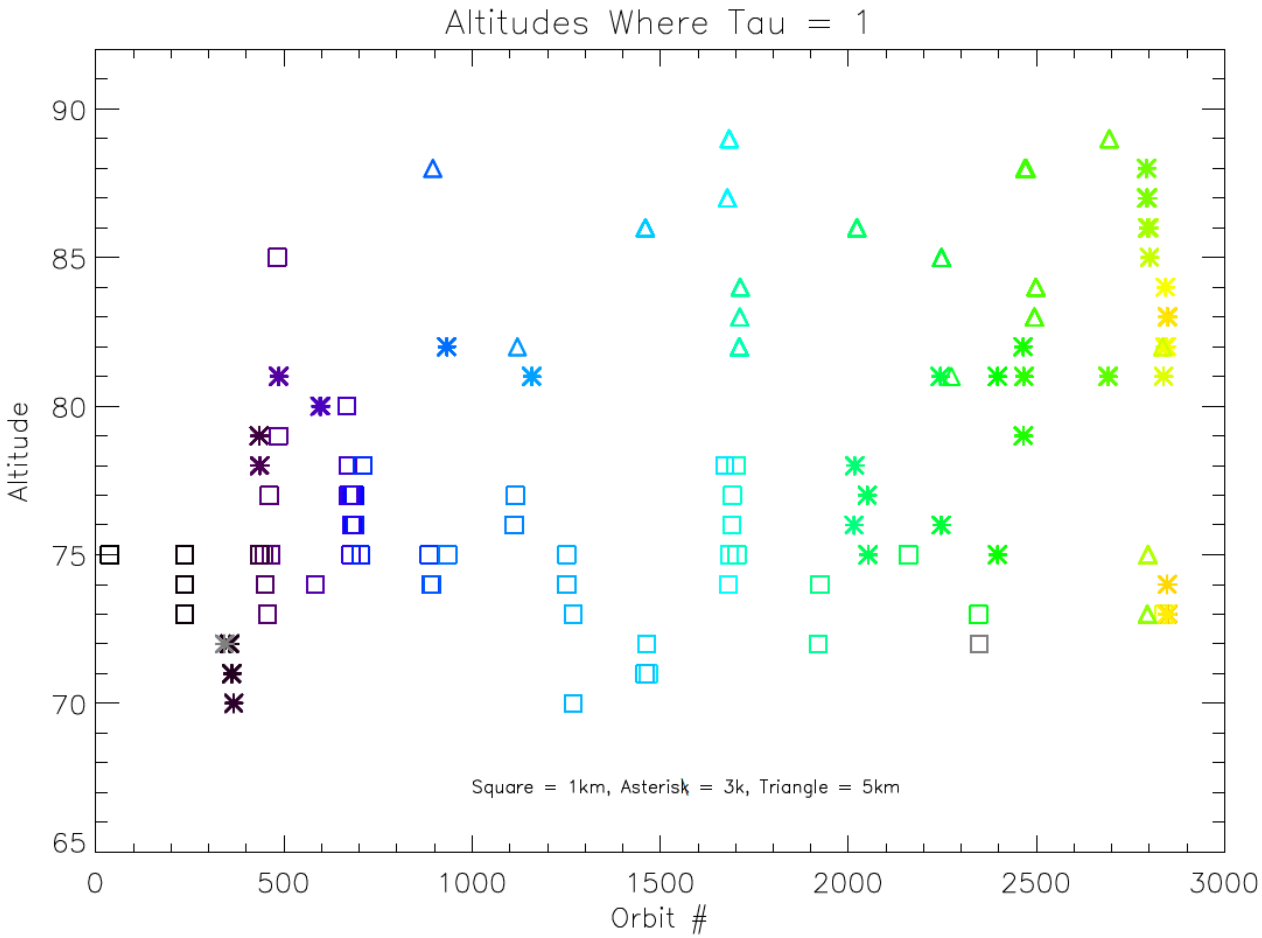




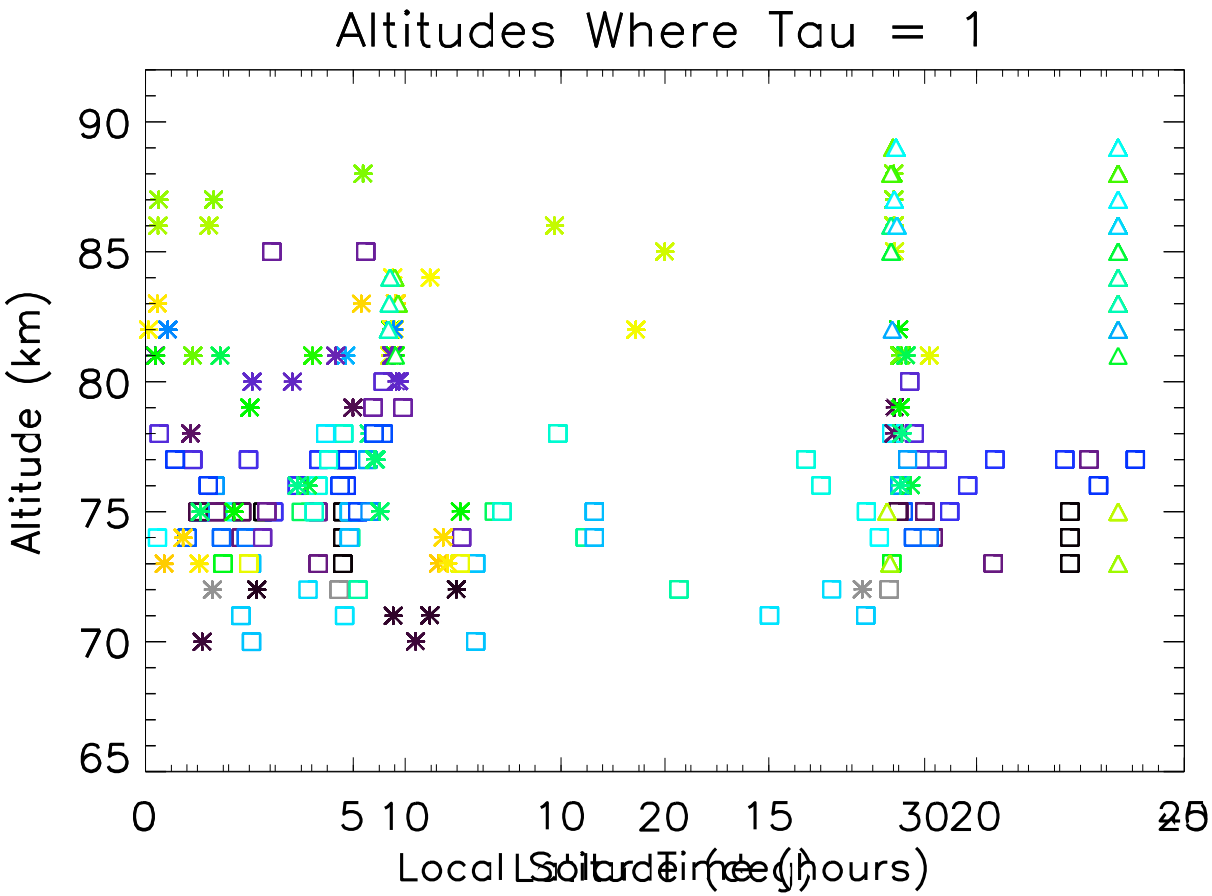
Aerosol Behavior



Cloud Height Variability

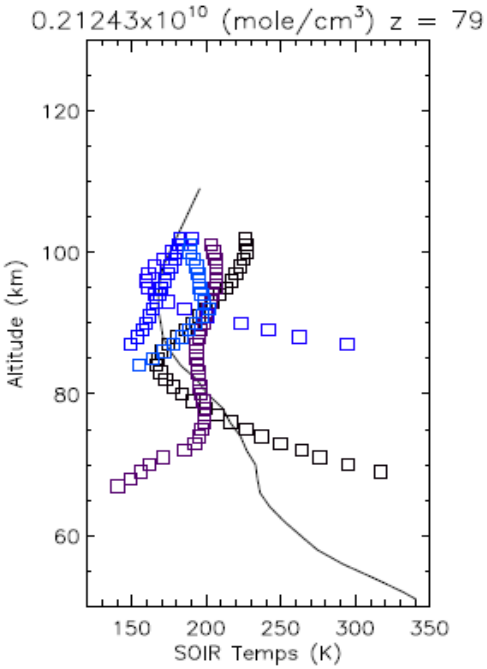


Cloud Height Variability (cont'd)

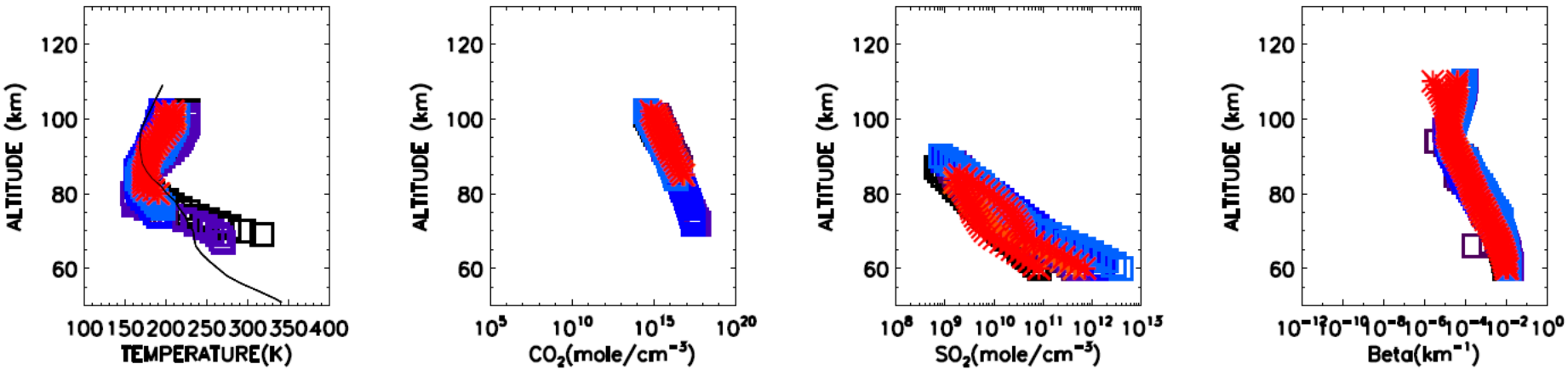


Temperature Trends

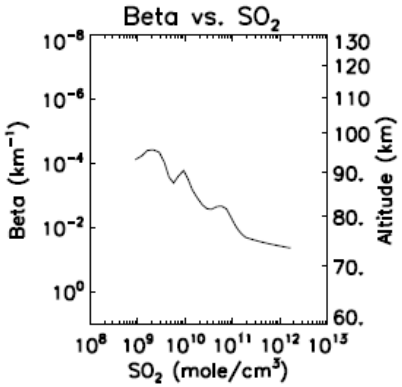
- Inverts at 85 km and has warming below
- Is very cold between 100 and 80 km
- Goes from warming to cooling at 75 km



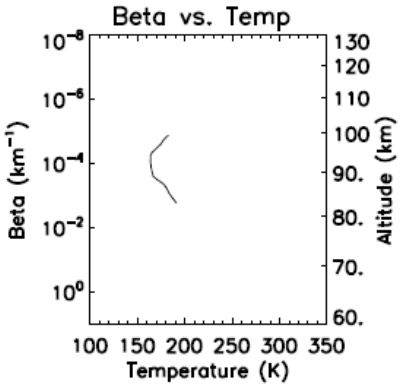
Atmospheric Conditions Relative to Temperature Trends

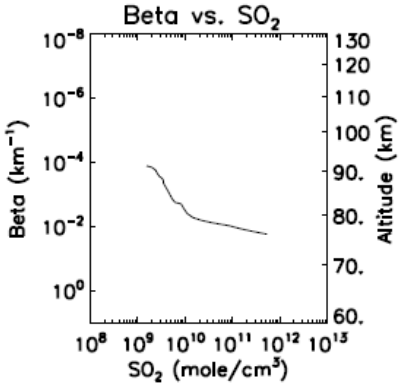


Orbit Numbers: 235.100 2347.10 2345.20 2838.10 1691.10 356.100 361.100 341.100



Orbit # 2838.1





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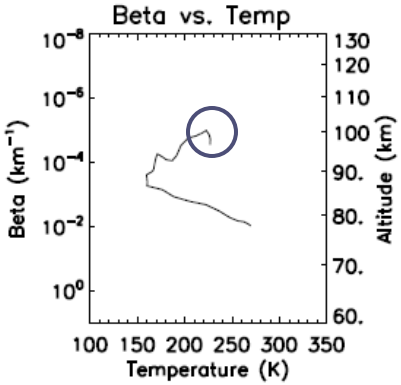
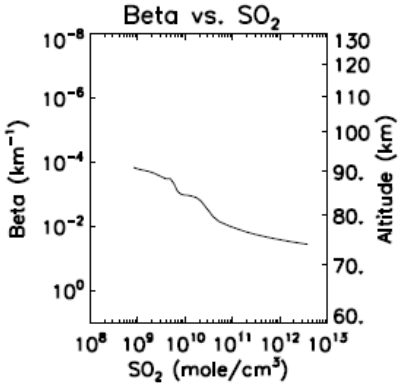
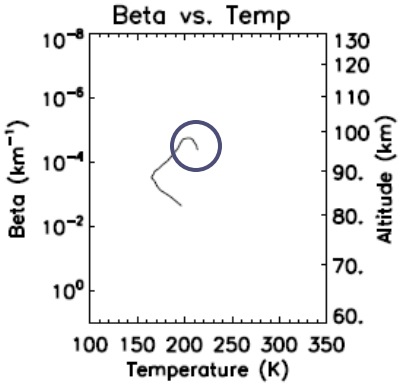
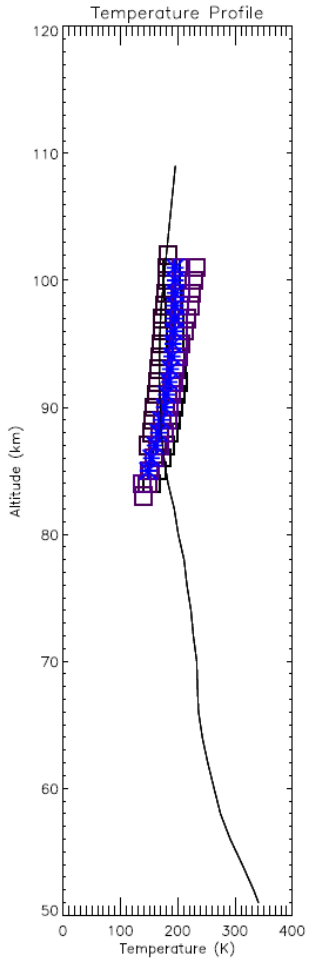


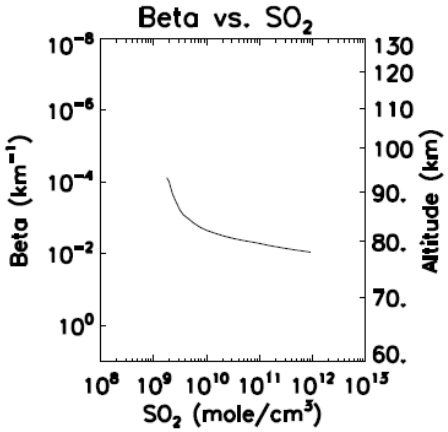


Orbit # 1691.1



Other Trends?





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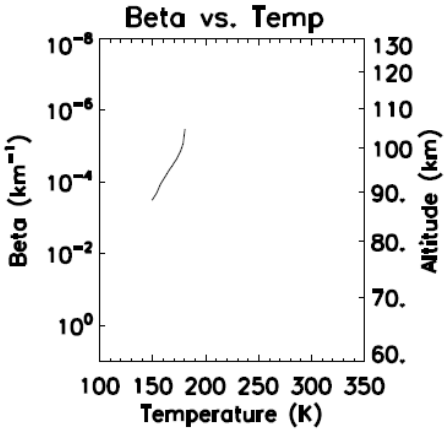
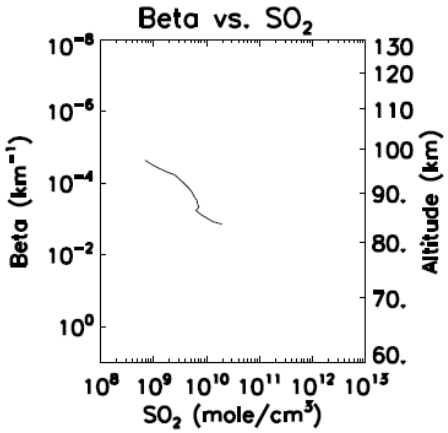
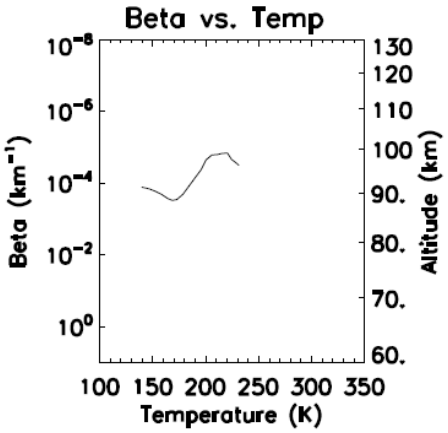
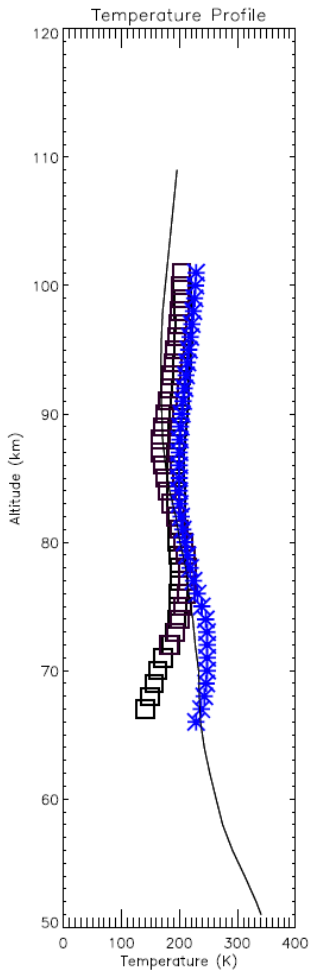


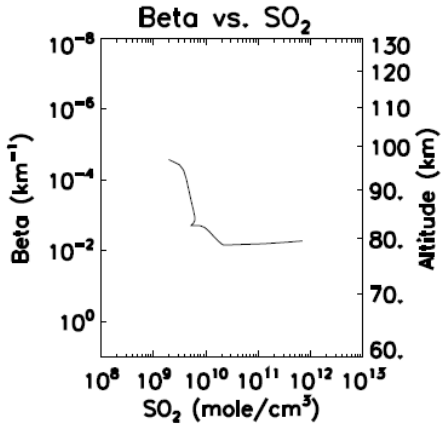


Orbit #1680.1



Other Trends?





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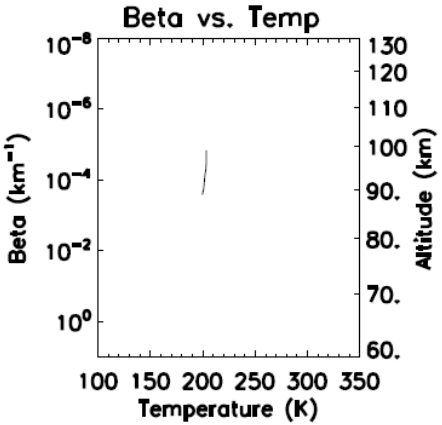

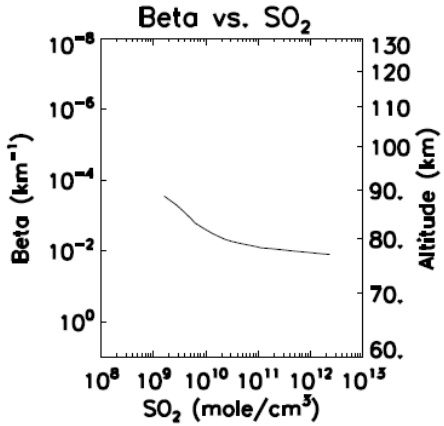

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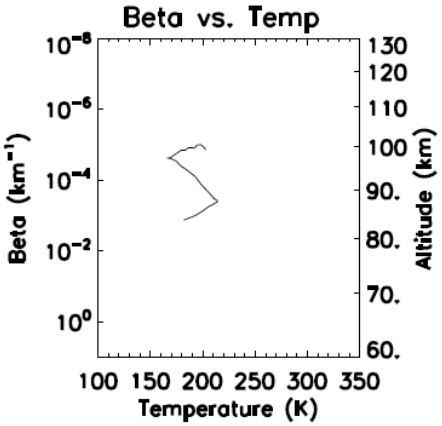
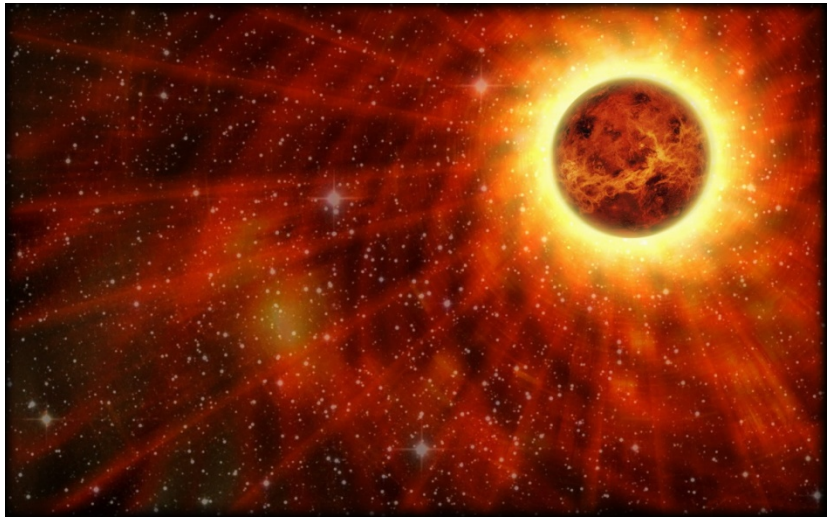


Next Steps

- H_2O
  - Temperature and aerosol extinction
  - More information on the formation of the sulfuric acid clouds



Conclusions

Questions?

- Successfully catalogued the SOIR and HST data
- Confirmed that:
  - 76 +/- 3km SO_2 number densities inferred from HST data at high SZA are consistent with values typically observed by SOIR at those altitudes at high SZA
  - No dependence on latitude in regards to SO_2 or temperature
  - Variation on the shape of the aerosol profiles were not uniquely linked to one time of day