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Zonal Wind Velocity in the Venusian Atmosphere from the Akatsuki and Venus Express Temperature Fields

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Background

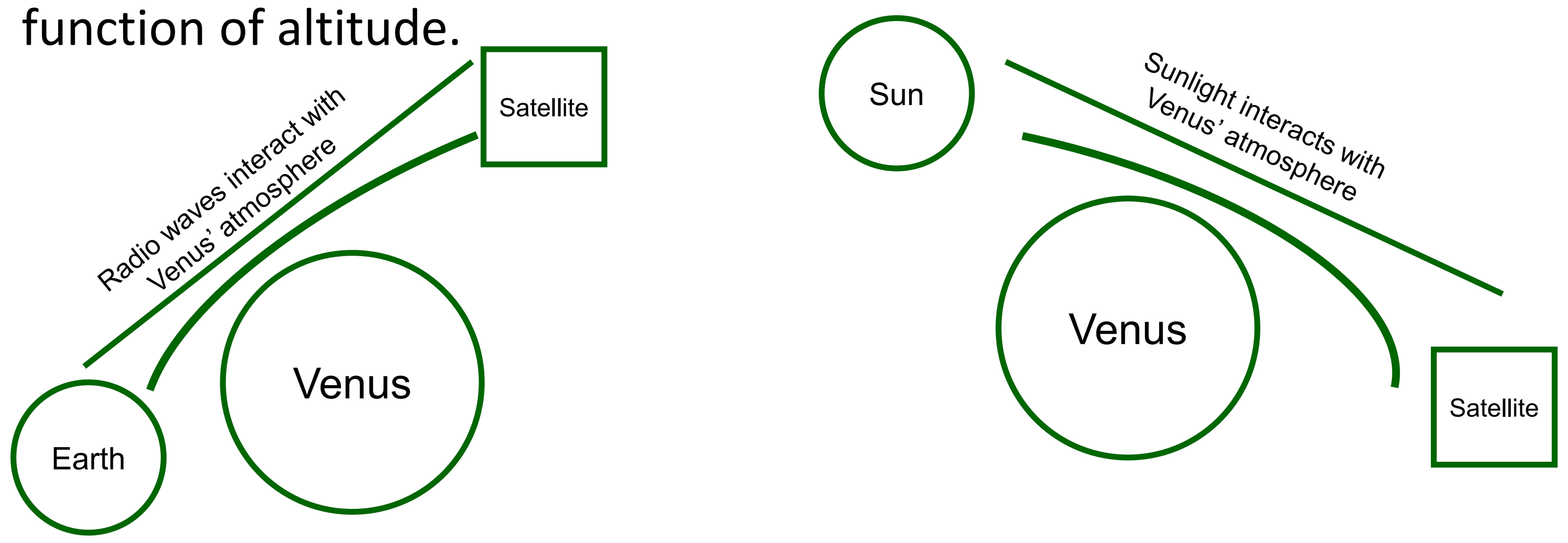
The Venusian mesosphere (55 — 100 km) is in a state of superrotation, with a slowly rotating planet and a rapidly rotating atmosphere. Although the overall behavior of the winds is known, directed measurements of wind velocities are limited. Zonal winds are calculated using:

- Temperature fields of the Venusian atmosphere
- Cloud-tracked wind velocities
- Thermal wind relation and cyclostrophic approximation

Venus' slow rotation means that the Coriolis force is small enough to be neglected in comparison with the pressure gradient and centrifugal forces. The pressure gradient force is balanced by the centrifugal force in the cyclostrophic approximation.

Methods

The Venus Express (VEx) and Akatsuki satellites provide measurements of atmospheric temperature and information on cloud-tracked winds. The VEx Solar Occultation in the Infrared (SOIR) instrument uses solar occultations, and the Akatsuki RS instrument uses radio occultations to provide atmospheric temperature as a function of altitude.



A schematic of radio occultation (left), used to collect the Akatsuki data, and solar occultation (right), used to collect the VEx data. Radio occultation operates by measuring the propagation of a radio wave through the Venusian atmosphere. Solar occultation operates by using the propagation of sunlight through the Venusian atmosphere to determine the spectra of the atmosphere.

We use the following steps to calculate zonal wind velocities:

- Interpolate temperature onto pressure grid
- Bin temperature measurements into 1° latitude bins; include all longitudes and local times
- Fit a polynomial to temperature as a function of latitude
- Determine temperature gradient with respect to latitude

Then the cyclostrophic thermal wind equation (below) is applied.

$$\frac{\partial(u^2)}{\partial\zeta} = -\frac{R}{\tan(\varphi)}\left(\frac{\partial T}{\partial\varphi}\right)_p, \zeta = -ln(p/p_0)$$

Methods and Results

Upward and downward integrations of the **cyclostrophic thermal wind equation** with multiple **boundary conditions** help characterize zonal winds in the Venusian atmosphere.

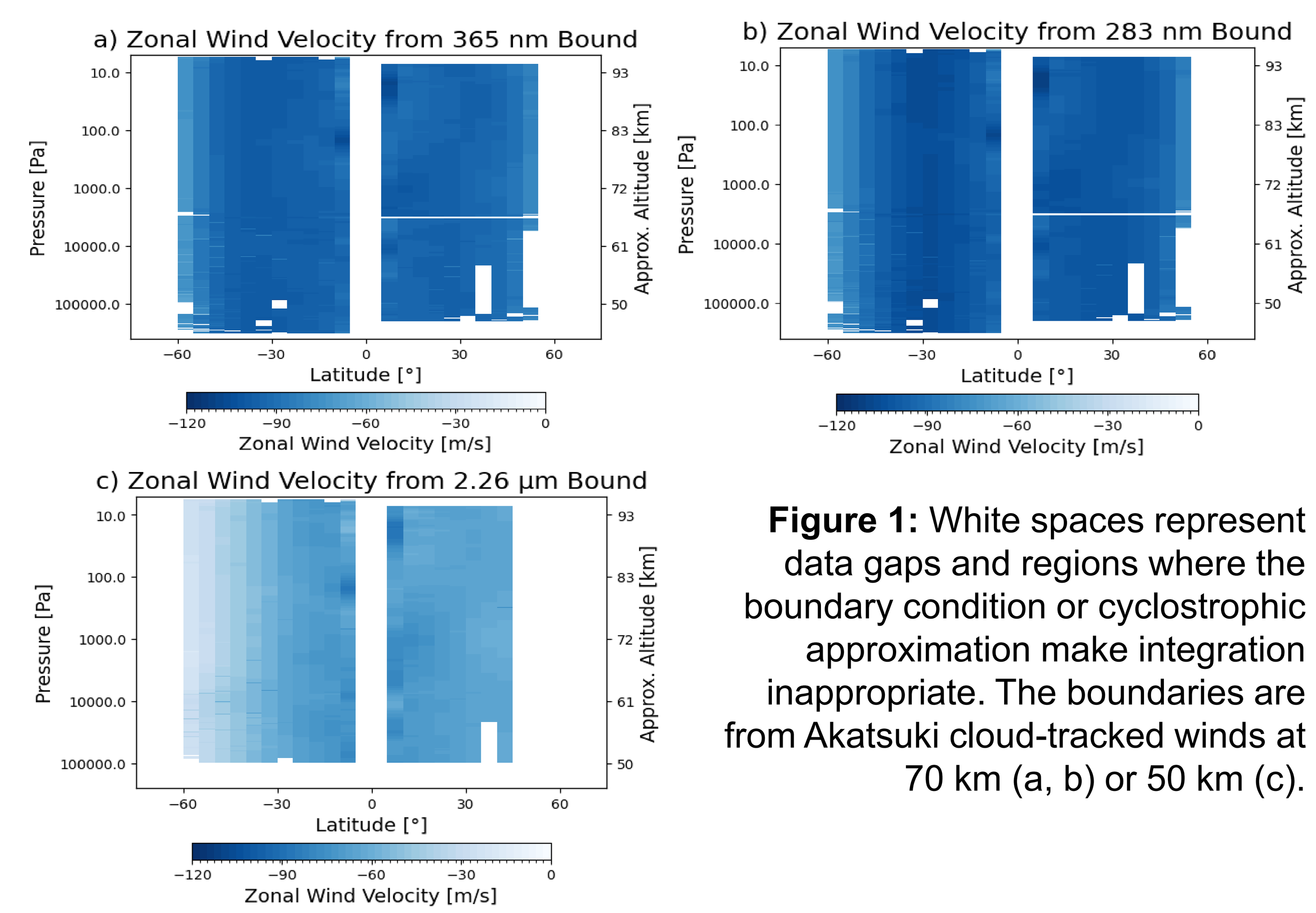


Figure 1: White spaces represent data gaps and regions where the boundary condition or cyclostrophic approximation make integration inappropriate. The boundaries are from Akatsuki cloud-tracked winds at 70 km (a, b) or 50 km (c).

Due to a lack of data on cloud-tracked wind speeds from VEx, the known behavior of zonal winds at 70 km in combination with the equation below provides a lower boundary condition.

$$u = (a \times \operatorname{sech}(\frac{\varphi - b}{c}) + d) \times \cos(\varphi) + e$$

Hemispherical symmetry is assumed for the lower boundary, but differences in data coverage between the northern and southern hemispheres force zonal wind velocities to be calculated separately for each hemisphere when using the VEx data.

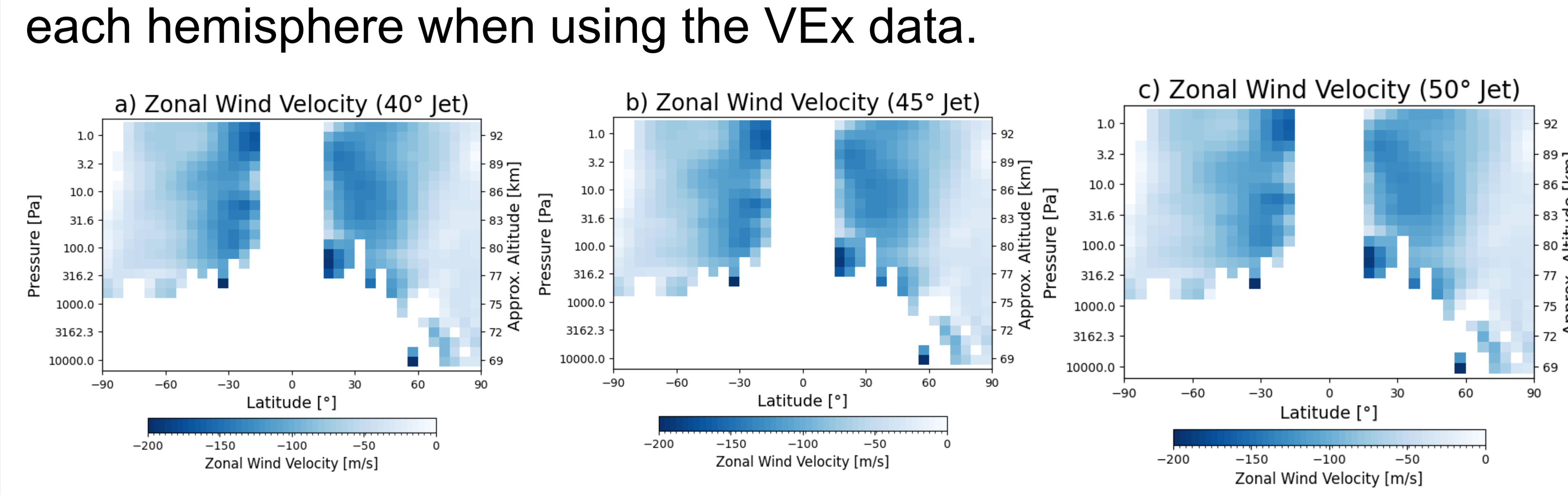


Figure 2: White spaces represent data gaps and regions where the cyclostrophic approximation made integration inappropriate. Three boundary conditions are used with the expected mid-latitudinal jet shifts between 40—50° in each hemisphere.

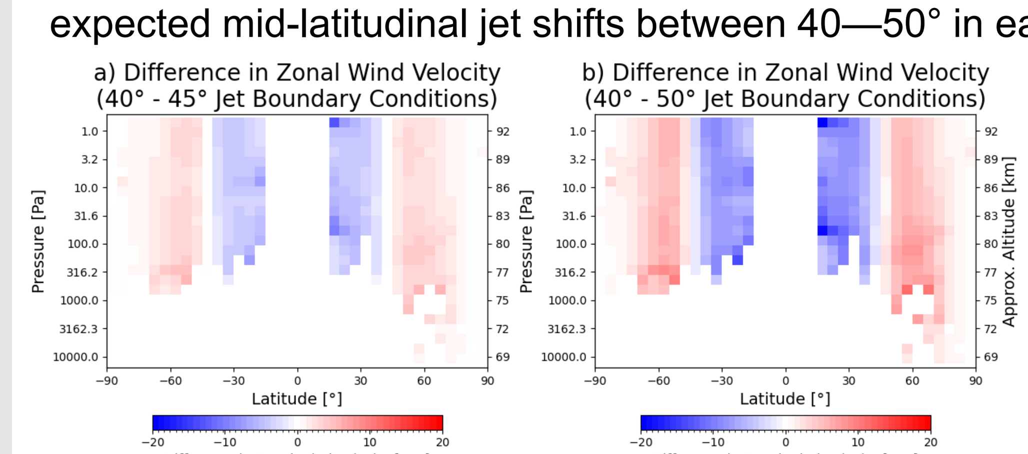


Figure 3: White spaces represent data gaps and regions where the cyclostrophic approximation is inappropriate. The zonal wind velocities produced by the 45° and 50° jets are subtracted from those produced by the 40° jet.

Conclusions and Future Work

The **main purpose** of the study is to calculate zonal wind velocities in the Venusian atmosphere for future studies, which have not been previously derived using data from the Akatsuki mission or the VEx SOIR instrument.

Main findings:

- Significant impact of boundary condition; differences reach a maximum of 60 m/s.
- Wind speeds do not decrease with altitude at all latitudes, as previous studies suggest.
- There is no strong indication of a jet between 40—50° latitude in either hemisphere.
  - There are increases in wind speed at certain altitudes
  - Could be a result of the altitudes included in the study; the jet appears between 60—70 km, which is excluded from the VEx data and used as a boundary condition for VEx.
- Wind speed increases at latitudes around 30 ° N at altitudes between ~85—90 km
  - Based on VEx data

Future Work:

- Use calculated zonal winds to study wave-induced effects in the Venusian atmosphere

Major Citations

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2. João M. Mendonça, Peter L. Read, Colin F. Wilson, Stephen R. Lewis, *Zonal winds at high latitudes on Venus: An improved application of cyclostrophic balance to Venus Express observations*, Icarus, Volume 217, Issue 2, 2012, Pages 629-639, ISSN 0019-1035, https://doi.org/10.1016/j.icarus.2011.07.010.

3. A. Piccialli, S. Tellmann, D.V. Titov, S.S. Limaye, I.V. Khatuntsev, M. Pätzold, B. Häusler, *Dynamical properties of the Venus mesosphere from the radio-occultation experiment VeRa onboard Venus Express*, Icarus, Volume 217, Issue 2, 2012, Pages 669-681, ISSN 0019-1035, https://doi.org/10.1016/j.icarus.2011.07.016.

Acknowledgements

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