Analysis of Observational Sampling and Geometry Effects on Dayside Measured Winds During Venus Express

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Motivation & Background

We investigate the effects observational and illumination geometries have on the superrotating zonal wind speeds on Venus. Venus's atmosphere superrotates ~50-60 times faster than the solid body (once every 4-5 days at ~65 km altitude). UV data returned by the Venus Express (VEX) Venus Monitoring Camera (VMC) showed a long-term zonal wind increase in mid- to low-latitudes during the VEX mission (2006-2013) with a magnitude of ~20 m/s [1-4].

We test the possibility that the observed ~20 m/s increase in Venus's superrotation may be due in part to changes in the sampling bias as well as observational and illumination geometries during the course of the Venus Express mission. Zonal wind varies by up to ~15-30 m/s across the dayside [1,3,5,6]. Across longitudes, zonal wind speed variations were found to be on the order of ~20 m/s [4,7]. Another source of apparent superrotation variability is vertical shear which would show up as a dependence on viewing geometry. If emission or incidence angle causes an apparent increase in the sensed altitude, then measurements will tend to detect winds in higher altitudes due to greater amounts of light scatter. For Venus, [8] showed the phase angle causes an apparent increase in the sensed altitude when observational geometry is favored by the scattering phase function. Vertical shear is ~1-4 m/s/km [3] in the cloud-top region of Venus; just a few km altitude difference could put such variations on the order of the change in superrotation during Venus Express.

The previously listed variables (local time, longitude, emission/incidence/phase angle) present zonal wind speed variability similar to the ~20 m/s change in the zonal wind speed across the Venus Express mission. Our preliminary results investigate the possibility that this apparent change in the measured wind speeds may be due to uneven sampling over local times, longitudes, or observational geometry (i.e. emission, incidence, phase angles).

Shown in this poster is the comparison between the zonal wind changes and the variability of emission and incidence angles.

Method

Wind vectors are measured by applying 2D Correlation Image Velocimetry (CIV) cloud-tracking analysis to mapped UV images.

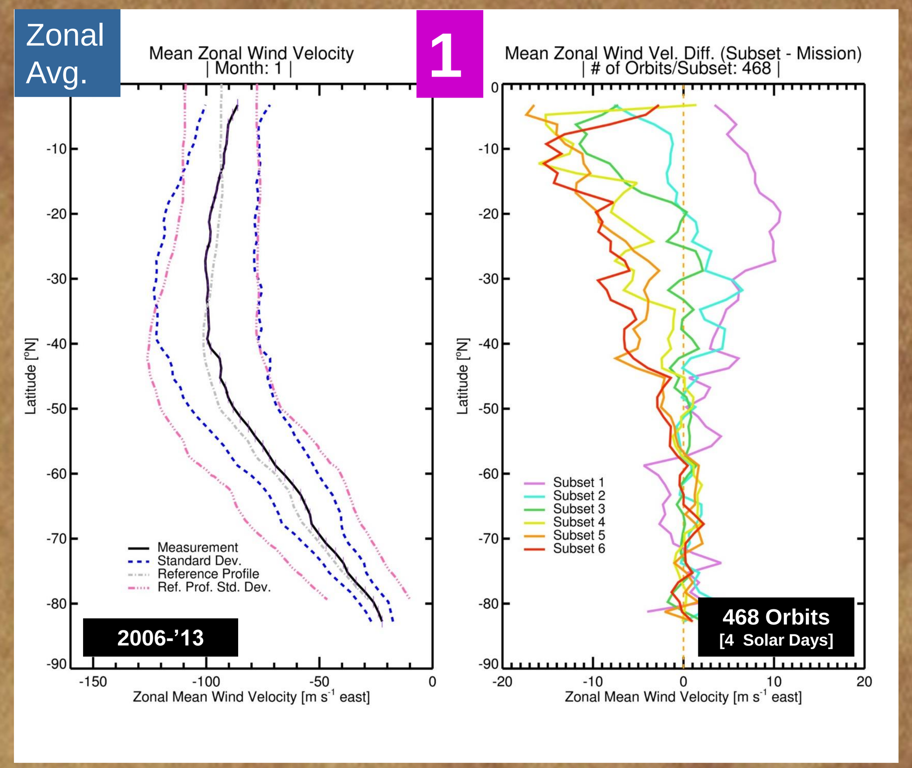
Data

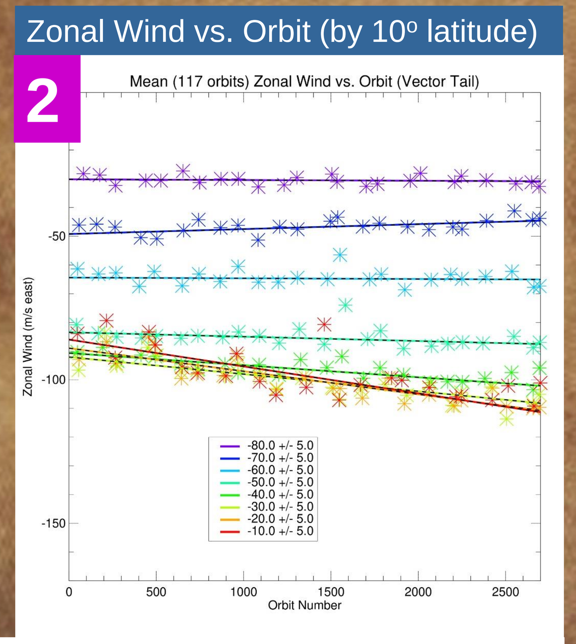
Venus Express Venus Monitoring Camera (VMC) UV images (~365 nm) [May 2006 – Sept. 2013]. This full mission characterization is possible thanks to the consistent distribution of UV observations during the mission [See Fig. 3]. From ~24,000 images [a], we have ~140,000 image pairs [b] from which we measured ~27 million wind vectors [c]. Latitude ranges from 5º-80º S [d], all longitudes are covered [e], dayside is covered as local time ranges from 6:30 - 17:30 [f]. Phase angles observed range between 60º – 115º [g], and emission and incidence angles range between 0º – 80º [h,i].

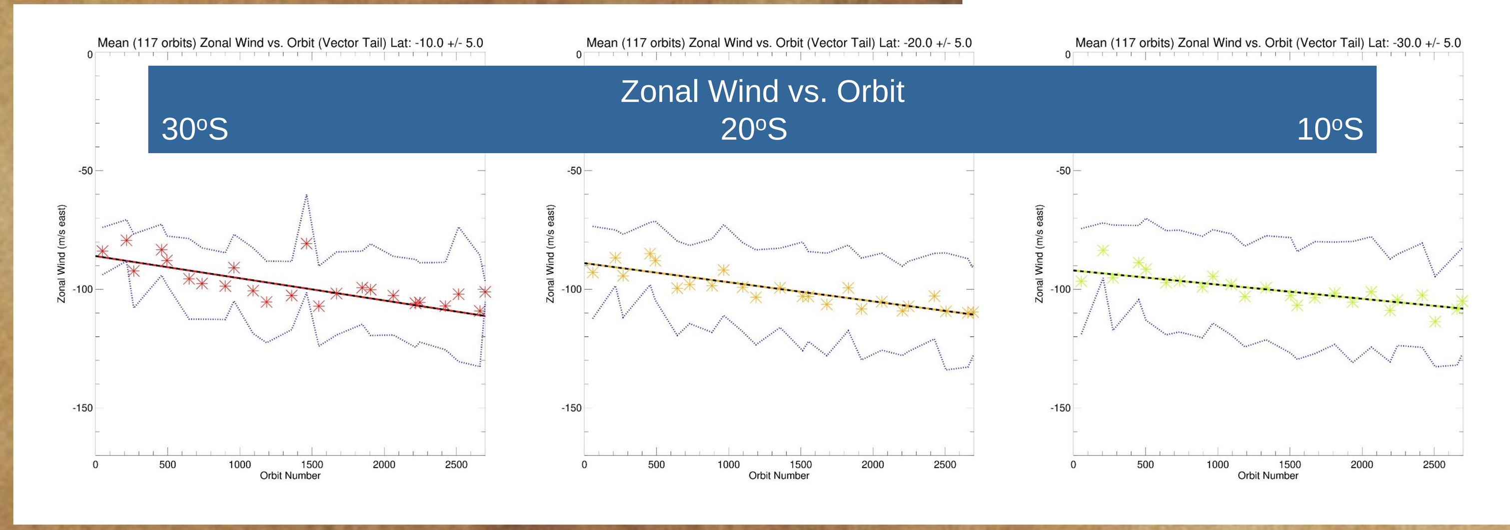
References

[1] Khatuntsev, et al. (2013) *Icarus, 226*, 140-158, [2] Kouyama, et al. (2013) *JGR: Planets, 118*, 37-46, [3] Hueso, et al. (2015) *P&SS, 113-114*, 78-99, [4] Patsaeva, et al. (2019) *JGR: Planets, 124(7)*, 1864-1879, [5] Horinouchi, et al. (2018) *EPS, 70(10)*, 1-19, [6] Patsaeva, et al. (2015) *P&SS, 113-114*, 100-108, [7] Bertaux, et al. (2016) *JGR: Planets, 121(6)*, 1087-1101, [8] Lee, et al. (2020) *JGR: Planets, 125(6)*, 1-17, [9] Lee, et al. (2019) *AJ, 158*, 126

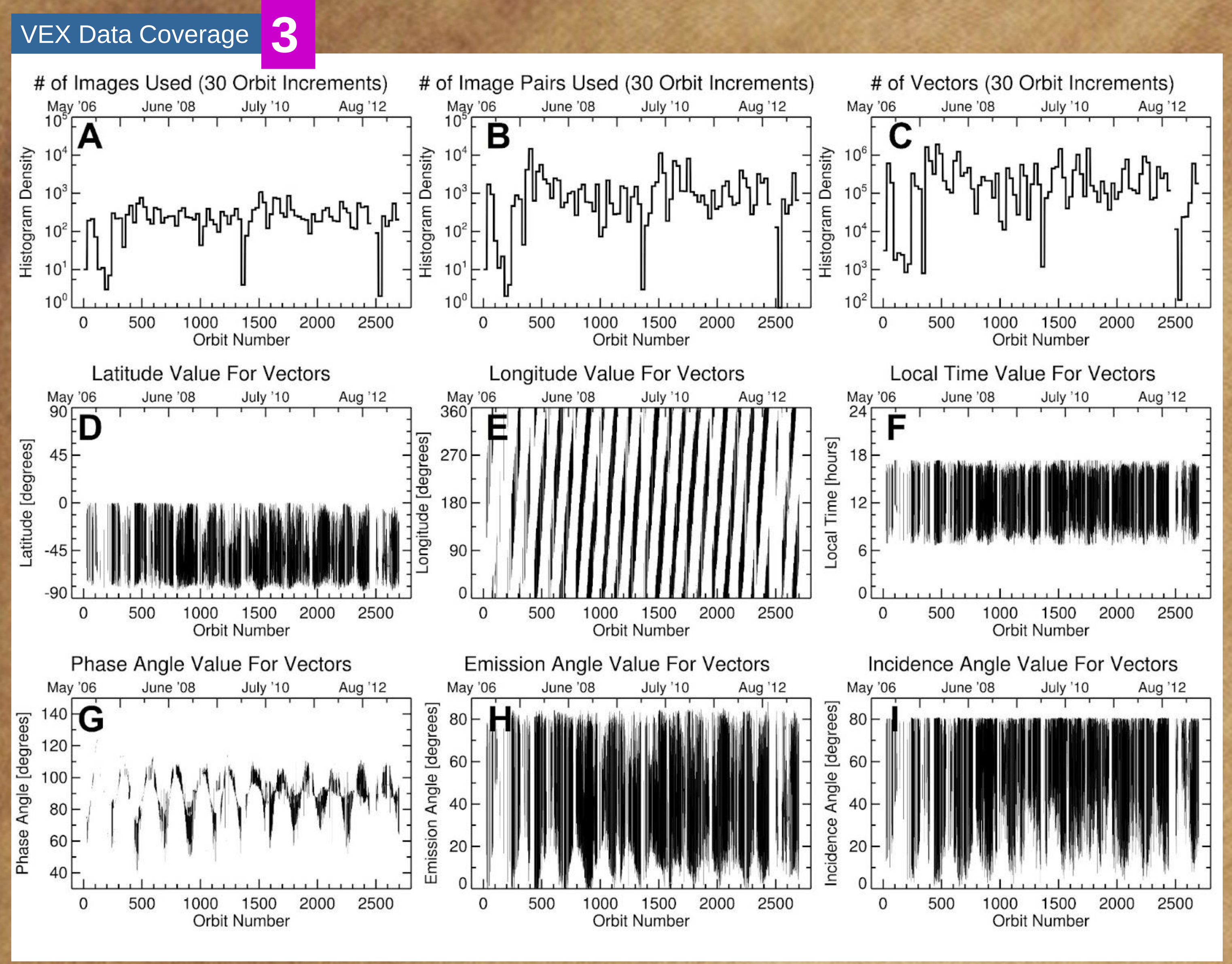
Trend of Zonal Mean Winds



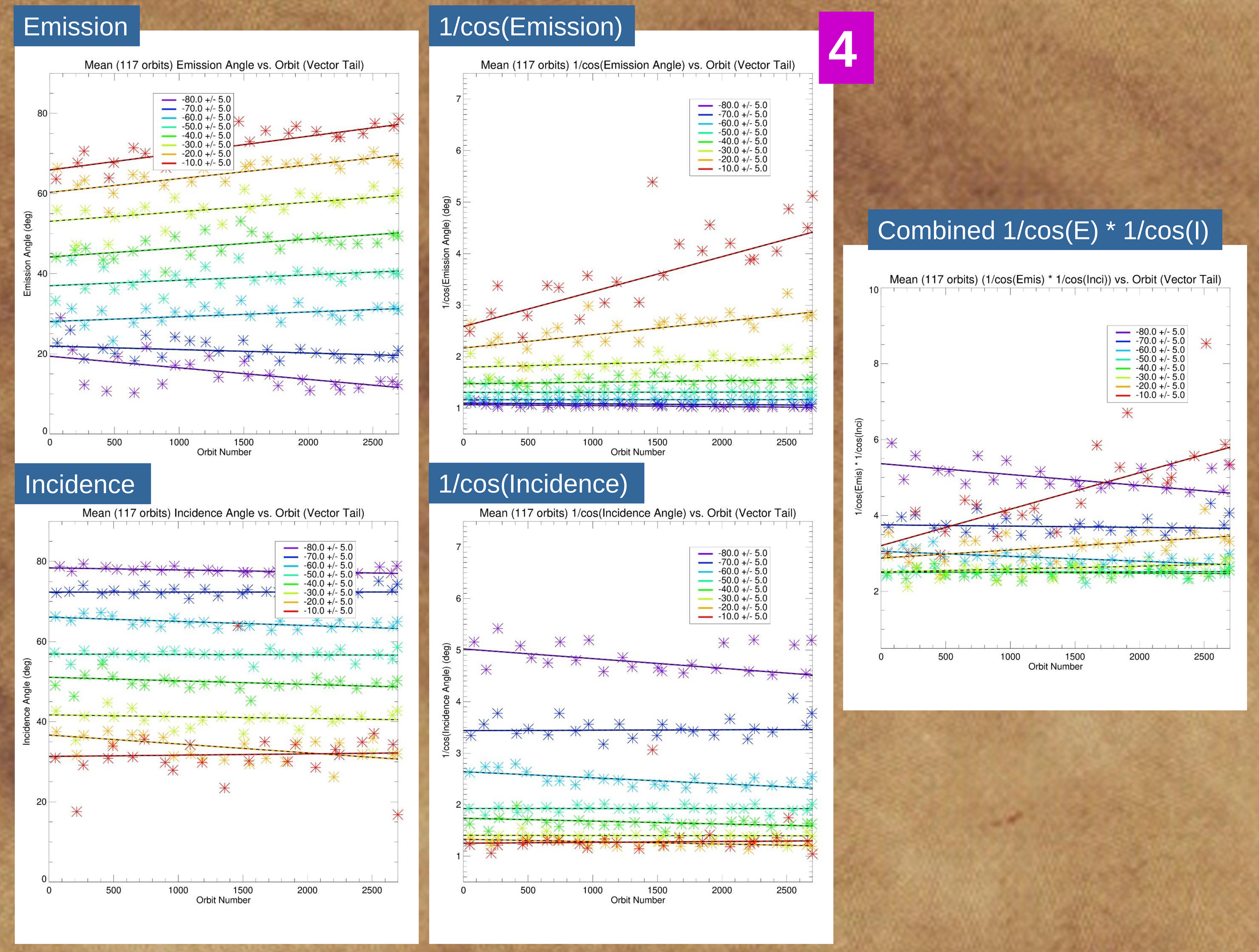


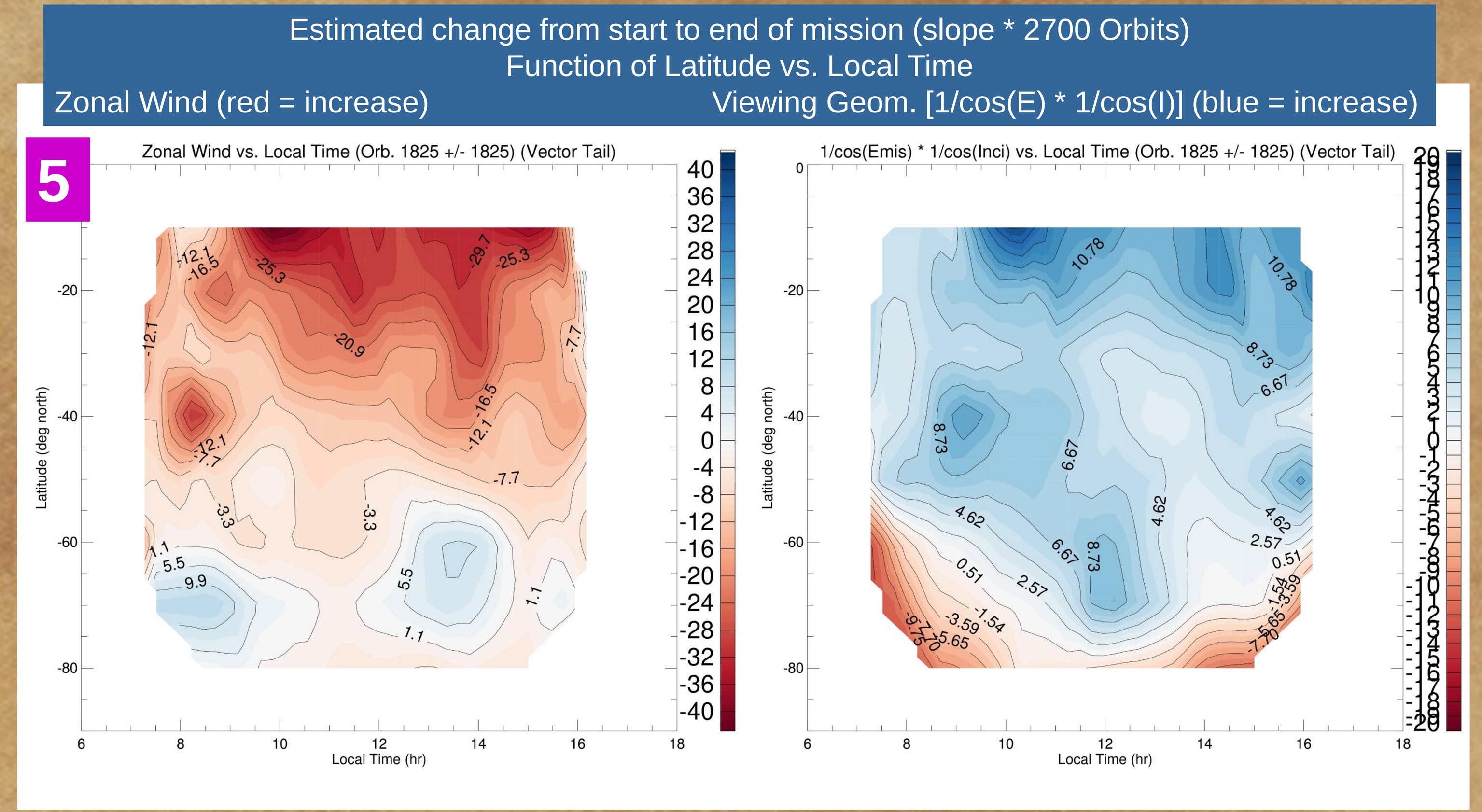


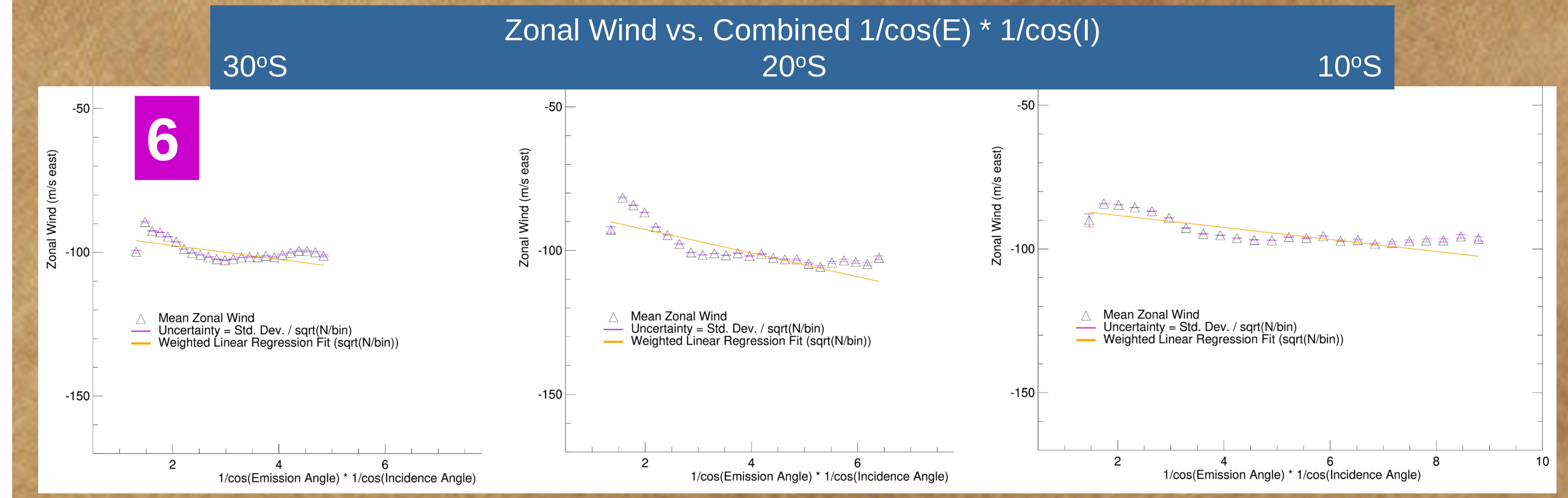
Data Availability / Coverage



Observational Geometry Variability & Zonal Wind Dependence







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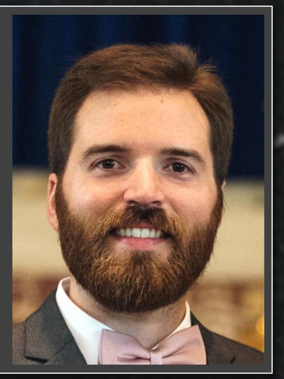

Discussion

Our measured wind vectors reliably reproduces the VEX zonal wind profile as found in past works [Fig. 1 left] as well as the noted trend of increasing winds at mid- to low-latitudes of ~20 m/s [Fig. 1 right]. To further clearly illustrate the increase in wind speed **(more negative eastward is stronger/increasing westward motion)**, Fig. 2 (top) provides a latitudinal breakdown with the Fig. 2 (bottom) displaying the overall trend for 30ºS – 10ºS.

From Fig. 4 (left), we found that as the mission progressed, the average observed emission angle increases for most latitudes and less so for incidence angle. Of note, the emission angle is generally larger for low latitudes (**red**/**orange**) while incidence angle is larger for higher latitudes (**blue**/**purple**). To get a better idea of the geometrical contribution these observation angles have, we can look at 1/cos(angle) [Fig. 4 middle]. At lower latitudes, 1/cos(emission) still increases during the mission while 1/cos(incidence) does not. We can illustrate the total contribution from the two by multiplying them together (Fig. 4 right). Again, we see large changes at lower latitudes.

Larger values of 1/cos(emission) * 1/cos(incidence) represent longer pathlengths for the light to travel to reach the same altitude as lower values (such as zenith/nadir). This would result in higher altitudes being sensed by VMC. At this altitude range, vertical shear is positive at ~1-4 m/s/km. Therefore it's possible that if we have an increase in observational geometry, then we may be sensing higher altitudes and thus faster winds.

To illustrate the correlation of the increase in zonal winds to the increase in observational geometry, see Fig. 5. We present an estimated total mission change (2700 orbits * linear regression slope) for each the zonal wind (Fig. 5 left, **red** = faster winds) and the observational geometry (Fig. 5 right, **blue** = increased, color bar range = 20 to -20) as a function of latitude and local time. We see at mid- to low- latitudes the increase in zonal winds seemingly aligning with the increase in observational geometry.

This possible dependence of zonal wind speed on observational geometry is shown for 30ºS – 10ºS in Fig. 6. While not exactly linear, we can see an increasing westward wind slope as we increase in observational geometry. When considering the range for each latitude, winds vary on the order of 10-20 m/s. This level of dependence is similar to the magnitude of change in zonal wind observed during VEX and work is ongoing to better understand this connection.

Ongoing / Future Work

Ongoing work is looking at the shorter periods of time to investigate the robustness of this correlation between zonal wind and observational geometry, and what that may mean for the observed zonal wind trend and vertical shear. We are also considering the noted change in albedo during the VEX mission [9] as a possible indication of observational geometry's effect on measured wind speeds.

In addition to observational geometries, we are investigating how observed wind speeds vary with regards to observational biases from thermal tides and topography.

Acknowledgements

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