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IMPACT OF TOPOGRAPHY ON VENUS' CLOUD TOP PROPERTIES AS OBSERVED BY HST.

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Introduction: Venus is permanently covered with ubiquitous $H_2SO_4 \cdot H_2O$ cloud and haze layers of temporally and vertically variant abundance and opacity[1-4]. Data obtained during the Akatsuki and Venus Express (VEx) missions are now revealing the interdependence of the cloud top properties on both Venus local solar time and topography [6-9]. In 2010/2011 Hubble Space Telescope Imaging Spectrograph (HST/STIS) was used to record the cloud top properties over Aphrodite Terra and a low elevation region downwind of Aphrodite. The Aphrodite data were obtained on two dates in January 2011 separated by 5 days at 200-600 nm, while the low-elevation plains regions data were obtained in December 2010 at 200-300 nm (Table 1); on each date two 0.1" wide maps of the cloud top radiance were obtained as function of latitude over local solar times extending from 7 to 11 hr. (Fig. 1)

Table I

Date	Number of maps	Phase Angle ǂ	Geo. Longitude (*LST, HH:MM*)	Terrain
December 28, 2010	2	97°	-5 to 45E; *(7:20 to 10:41)*	Plains
January 22, 2011	2	82°	70 to 125E *(7:20 to 10:54)*	Aphrodite Terra Mountains
January, 27, 2011	2	79°	85 to 140E *(7:20 to 10:52)*	Aphrodite Terra Mountains

ǂPhase angle is the sun-target-observer angle; VMC observations show that the cloud top albedo brightens as the phase angle increases [13]

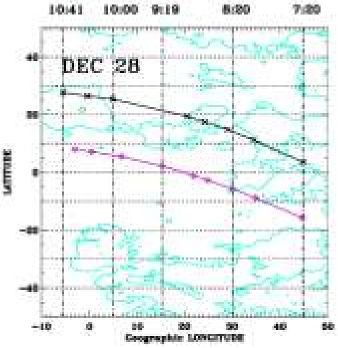

Fig. 1 Two distinct cloud top albedo maps (pink & black) are derived from the latitude x longitude swaths encountered within the 0.1″ HST/STIS slit on December 28, 2010, above regions with elevations < 1km (cyan) at LST ~ 7 to 11 hr (top axis). Similar cloud top albedo maps were obtained above Aphrodite (see Table 1).

Observed Trends and Lessons learned: Our analysis of these data shows distinct trends in Venus' cloud top properties (such as the albedo levels at 245 nm, 365 nm, and the overall cloud top SO_2 gas abundance) as function of terrain type (mountain/plains), latitude and LST as summarized in Figures 2-5 and Table 2.

Table 2

No.	Observed Trend	Implied Physics
1	The 245 nm albedo spatial variations replicate those observed at 365 nm (Fig. 3)	The species controlling the albedo at these wavelengths are linked [12,14]
2	Smooth increase in albedo with increasing latitude within longitude regions directly intersecting both the equatorial plains and Aphrodite Terra mountain range (Fig. 4)	Hadley cell Transport of absorbing materials [15]
3	Smooth & rapidly increasing albedo darkening (~20%) above the plains at LST between 10 and 11 hr (Fig. 5)	Manifestation of Shallow Cloud top Convective Cells (±2 hr of noon) [16,17]
4	Limited (~ 0-10%) darkening of the albedo at LST between 10 and 11 hr at longitudes intersecting Aphrodite Terra mountain range (Fig. 5)	Convective Cells formed near noon suppressed below cloud top altitudes; occurs when mixing rate or T in the stability layer is too high [18]
5	When visible, the degree of pre-noon darkening manifest at cloud tops above Aphrodite is smaller than the plains (Fig.5)	amount of darkening material and/or cloud top haze perturbation is lower over Aphrodite than over the plains
6	Smooth decrease in SO_2 abundance with increasing latitude away from equator over the plains (Fig. 2)	Hadley cell transport of SO_2
7	SO_2 gas latitude gradient above Aphrodite observed to reverse from increasing in latitude away from equator to decreasing with increasing latitude in a 5 day period—such that the SO_2 abundance at the equator was a minimum rather than a maximum (Fig.2)	Low vertical mixing rate within Hadley cell sufficient to allow photochemical destruction to minimize the equatorial SO_2 over 5-day period [14,15]
8	Although a reversal in the SO_2 gas latitude gradient was observed at longitude intersecting Aphrodite, no corresponding reversal in the cloud top albedo latitude gradient was observed [12]	Timescales of vertical and meridional transport and/or chemical loss of the species controlling the albedo are longer than the SO_2 photochemical loss timescale [12]
9	Equatorial SO_2 gas abundances of 200 ppb, 20 ppb and 10 ppb were retrieved from the HST data; the lowest equatorial abundances were observed over Aphrodite Terra (Fig. 2)	Equatorial SO_2 abundance depends on the vertical mixing in the upward branch of the Hadley cell –mixing rates over Aphrodite were suppressed relative to the plains; this impacts all species contributing to the cloud top albedo at Aphrodite [11,12]

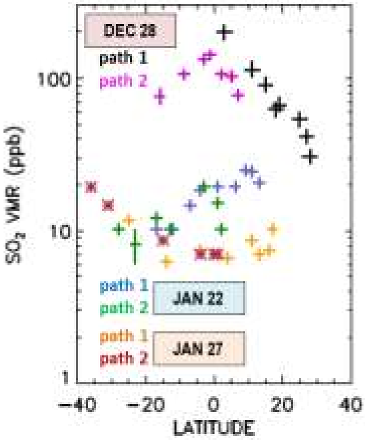

Fig. 2 SO_2 gas abundance retrieved from the 2010/2011 HST data; two paths or maps were observed on each date as indicated by the color legend

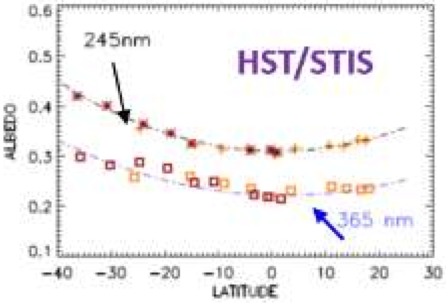

Fig. 3 The 245 nm and 365 nm cloud top albedo observed above Aphrodite show the same rate of change with increasing latitude

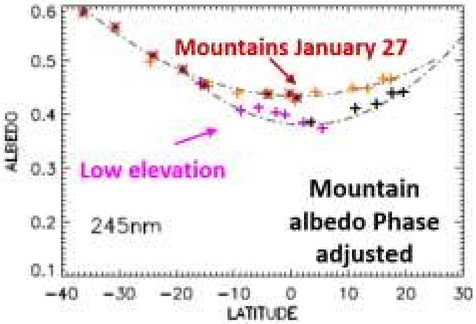

Fig. 4 Smooth increases in the cloud top 245 nm albedo with increasing latitude were observed over the plains and over Aphrodite Terra. The 20˚ higher phase angle value associated with the December 2010 observations produces a ~ 20% brightening in the cloud top albedo in December 2010 relative to the January 2011 dates. Therefore, to make a legitimate comparison of the albedo levels between the two terrain types we apply this brightening scale factor to the January albedo data.

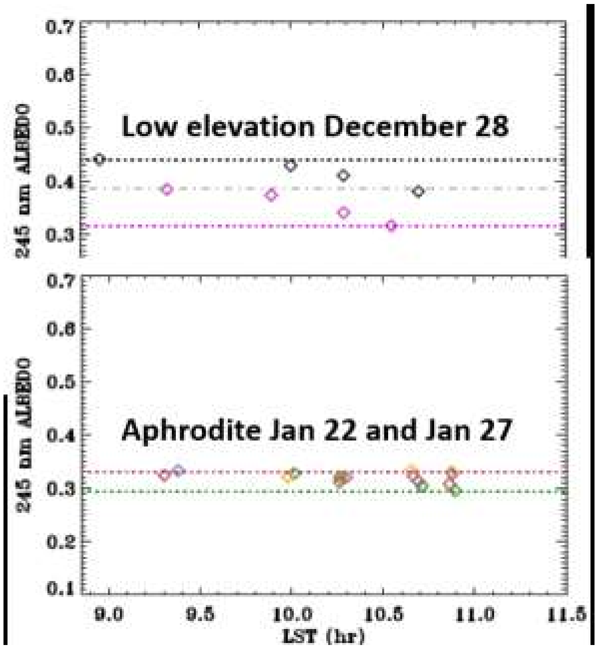

Fig. 5 Changes in the cloud top albedo as a function of LST between 10 and 11 hr is shown for the plains and Aphrodite; rapid and smooth darkening is more prominent over the plains

Conclusions: We find that both the observed SO_2 behavior and the observed albedo behaviors implies that large and small scale equatorial vertical motions (and winds) are compressed (suppressed) over Aphrodite, and that this compression (suppression) impacts the abundance of SO_2 gas at the cloud tops the, the cloud top albedo, and the manifestation of sub-solar convective cell activity at the cloud tops.

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