VENUS’ WINDBLOWN EJECTA DEPOSITS MAY NOT ALIGN WITH PRESENTLY OBSERVED WINDS. T. J. Austin¹, J. G. O’Rourke¹, N. Izenberg², ¹Arizona State University, Tempe, AZ. ²The Johns Hopkins University Applied Physics Laboratory, Laurel, MD. *t.austin@asu.edu

Background: The superrotating atmosphere of Venus creates unique features surrounding its impact craters: Parabola-shaped ejecta deposits hundreds of kilometers across. Initial surveys observed ~60 of these ‘parabolas’ [1,2] but all craters >8 km diameter may have originally had them [3]. Thus, what few parabolas remain may be among the youngest surface deposits, and the deposition/gradation of parabolas may be the dominant sedimentary process on Venus.

Parabolas are thought to form as follows [3,4]: Impacts with sufficient energy create large vapor plumes that propel fine ejecta up out of the atmosphere. This ejecta spreads out on suborbital trajectories, re-enters the atmosphere, and rains back onto the surface over the course of several hours. Thus, the shape and (largely West-facing) orientation of the deposits is a product of strong East-to-West winds in Venus’ superrotating middle atmosphere (~60–100 km altitude).

Many parabolas are not oriented directly West. Past work mentioned that 7 parabolas point West-Northwest [1] and has recorded some non-Westward orientations for parabolas’ airfall windstreaks [5]. We wish to test whether North/South deflection of parabolas is consistent with observations of winds in the parabola-forming middle atmosphere. If there is an inconsistency, that would suggest that the accepted parabola formation model is incomplete OR that the dynamic character of Venus’ atmosphere has changed over time due to processes like obliquity cycles or true polar wander.

Meridional winds in the middle atmosphere are prevailing, oriented poleward, and are generally <10° the velocity of the zonal winds [6]. Corresponding equatorward winds of roughly the same magnitude may exist lower in the atmosphere, but these have not been confirmed by observation. Thus, the expectation is that parabolas will either be oriented within a few degrees of West or deflect <10° poleward at most.

Methods: We measure the orientation of parabolas on Magellan SAR and emissivity mosaics using two types of features: Symmetrical axes and windstreaks. Parabolas are oriented about a symmetrical axis that passes through the upwind margin, central impact crater, and the poorly defined downwind margin. Identifying the symmetrical axis may not be straightforward if the parabola overlaps other radar-dark deposits (including other parabolas) or rough terrain. Thus, we also measure windstreaks wherever present on parabolas. These parallel windstreaks can extend for hundreds of kilometers and are thought to represent airfall deposits, rather than post-deposition gradation, because they do not change orientation in response to topography [6]. Further, these streaks occur at consistent locations on the parabolas – radiating out from the crater, along the central axis, and at the downwind margin of the parabola – this would not be expected of gradational features, which should be found everywhere. Where symmetrical axes and windstreaks are measured together, their orientations match to within a few degrees, strengthening the notion that both features record wind direction at time of deposition.

Results: We measured the orientation of 56 parabolas (Examples: Fig 1), and an additional 12 narrow windblown ejecta deposits that are similar to parabolas [1]. We identified a further 67 candidate parabolas, but many of these are low-confidence and we could not make accurate orientation measurements.

Figure 1: (Top left) Slight equatorward deflection at Stuart crater’s parabola, East of Alpha Regio; (Top right) Two parabolas in close proximity, but with dramatically different poleward deflection angles; (Bottom left) Equatorward deflection at Phyllis crater’s parabola; (Bottom right) Equatorward deflection at the narrow windblown ejecta surrounding Unay crater.

Only 32 of the 68 measured features are consistent with the expected orientations. 9 parabolas are oriented >15° North/South of West. Further, parabolas do not display consistent poleward or equatorward orientations (Fig 2), which is incongruous with perturbation by prevailing meridional winds.
Discussion: Windblown ejecta deposits display orientations that are not compatible with existing models of parabola formation that predict subtle, systematic deflection from middle atmosphere winds. We suggest three possibilities to explain this discrepancy:

1) Our understanding of the deposition of parabolas is somehow incomplete. For instance, the orientation of parabolas may partially be set by lower atmosphere winds, of which less is known. Low-level winds’ orientation/speed may vary significantly in response to regional topography, causing some parabolas to be askew. Alternatively, ejecta vapor plumes might form with natural asymmetries, perhaps due to shallow impact angles. Both of these scenarios would seem to predict that parabolas deflected substantially North/South of West would also be noticeably asymmetric, which we have not observed.

2) The dynamic character of Venus’ middle atmosphere changes over time. The dynamics of Venus’ atmosphere, including how it maintains superrotation, are not well understood. It could be reasonable to suggest that zonal/meridional winds fluctuate in intensity over time. Atmospheric rotation is currently co-axial with the slow-rotating surface, but perhaps this changes as Venus changes its obliquity.

3) The rotational axis of Venus has changed recently due to true polar wander. If one assumes that the existing models of parabola formation are broadly correct, that the dynamics of superrotation have not changed substantially over the age of the parabolas, and that atmospheric motion is coupled to surface rotation, the simplest remaining explanation for the parabolas’ orientation discrepancy is true polar wander in the recent geologic past. Venus’ slow surface rotation means that modest redistributions of mass (relative to Earth) can produce dramatic shifts in the polar axis [7]. The implication that the Venusian lithosphere is active at a rate comparable to Earth is extremely consequential, thus caution should be exercised if invoking this explanation without firmer understanding of parabola formation and Venus’ atmospheric dynamics. Nevertheless, polar wander originating from a paleopole ~15–30° off the present rotational axis could be consistent with the parabola orientations we observe.

The orientation of parabolas is not nearly as straightforward (or rather, straight-westward) as has been assumed, raising many questions. Answering these questions will require more mature models of parabola deposition and better understanding of their gradation.


Figure 2: Many windblown ejecta features are perturbed farther North/South than can be explained by observed middle atmosphere meridional winds. There is no consistent global trend of equatorward/poleward orientations.