National Aeronautics and Space Administration

Characterization of Safe Landing Sites on Venus Using Venera Panoramas and Magellan Radar Properties

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Objectives

During preparation of the JPL-led VISAGE proposal of a Venus lander in response to the New Frontiers-4 call, a new method for landing site safety evaluation was developed at JPL by PI Rabinovitch and Co-I Stack to determine "safe" and "unsafe" landing sites on the surface of Venus for a 3-legged lander. A peer-reviewed article was submitted to the journal *Icarus* describing this method. The first round of reviews, while generally positive, required some additional analysis to make the results and method more robust before the paper would be accepted for publication. The objective of the proposed work was to complete the analysis needed to make the safe landing site filter more robust and more reliable for future missions, and to deliver a peer-reviewed, published paper.

Background

- Robustly designing and successfully delivering a mission to the surface of a planetary body requires knowledge of the surface winds, local surface roughness, slope, and the size distribution of hazards at scales relevant to the size of the spacecraft itself.
- The relatively low spatial resolution and wavelength limitations of existing Venus image datasets largely preclude landing site assessment at the scales and quality developed for Mars surface missions. For the foreseeable future, potential Venus missions will have to rely on ~100 m/pixel radar data from the Magellan spacecraft to select and evaluate landing sites.
- Surface terrain assessment similar to those used to evaluate Mars landing sites is only possible for the four Venera landing sites where panorama photographs of the surrounding surface terrain permit measurements of rock distribution and slope on a scale relevant to a landed spacecraft.
- This study explores methods for identifying and characterizing sites on Venus where a lander could attain a high probability of safe landing through a synthesis of Venera surface panoramas, surface properties derived from Magellan radar data, and published global geological maps of Venus.

Publications

Jason Rabinovitch and Kathryn M. Stack, "Characterizing landing site safety on Venus using Venera panoramas and Magellan radar properties," *Icarus*, 363, https://doi.org/10.1016/j.icarus.2021.114429, 2021.

Significance/Benefits to JPL and NASA

This project resulted in the publication of a peer-reviewed paper that will be a citable reference for future JPL Venus mission proposals. Publishing this article will provide credibility to the approach developed, and will save space in future JPL proposals as the method used for landing site safety assessment will not have to be described in great detail in future proposals.

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Approach and Results

- This study explores an approach for identifying and characterizing sites on Venus where a future lander mission could attain a high probability of safe landing through a synthesis of Venera surface panoramas, Magellan radar properties, and existing global geological maps of the Venus surface. Surface panoramas from the Venera 9 and Venera 13 landers were used to define rock size distributions and to calculate the probability of a hazardous rock encounter for a reference Venus lander design at these specific landing sites.
- This surface analysis formed the basis and rationale for the development of a set of global filters seeking to identify "safe" 150-km-diameter landing ellipses with Magellan radiophysical properties including root mean square slope, radar backscatter coefficient, and emissivity values similar to the most benign regional plains unit (rp_2) mapped by Ivanov and Head [2011] within the Venera 13 landing site (Table 1).
- Using this method, 178 unique ellipses for which >95% of pixels exhibited rms slope and radar backscatter coefficient values similar to the Venera 13 rp_2 unit were identified across the Venus surface (Figure 1a). Of these ellipses, 36 also contained >95% of pixels with similar emissivity values as the Venera 13 rp_2 unit (Figure 1b). Emissivity is also known to be affected by the presence of low-density mantling deposits of variable thickness, so we considered the location of "safe" ellipses relative to modeled parabola on Venus thought to represent low-density impact ejecta (Figure 2). "Safe" ellipses identified by this method were predominantly composed of regional plains, shield plains, and smooth plains as defined in the Venus global geologic map of Ivanov and Head [2011] (Figure 3).
- Although the method developed in this study for identifying and characterizing safe landing sites on Venus requires several assumptions regarding the correlation of orbiter radar data to surface properties relevant to lander safety, this approach provides a best effort starting point integrating available data for the systematic, relatively objective, and automatic identification of safe landing sites on Venus.

Table 1. Comparison of Magellan radar data-derived surface properties for the Venera 9 and Venera 13 landing areas. From Rabinovitch and Stack (2021).

Area	Emissivity range	Emissivity mean	Rms slope range	Rms slope mean	Backscatter coefficient (dB) range	Backscatter coefficient (dB) mean
V13 (rp_2)	0.80–0.83	0.81	1.3–4.7	2.7	-0.14-0.29	-0.0034
V13 (not rp_2)	0.81–0.84	0.82	1.2–6.2	2.8	-0.10-0.32	0.043
V9	0.84–0.89	0.86	1.1–12	4.1	-0.41-0.35	0.075

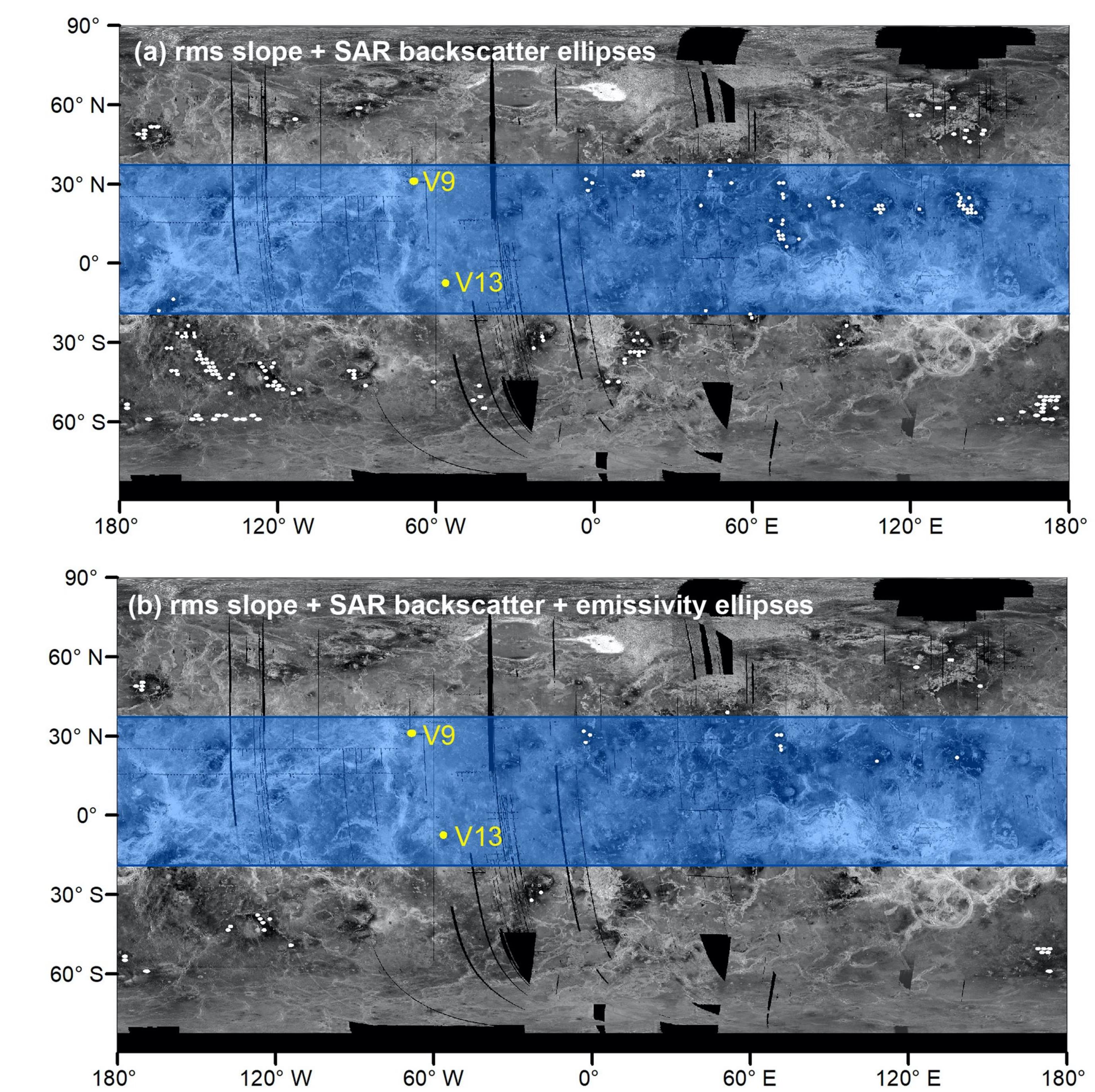

Figure 1. (a) 150-km-diameter ellipses containing at least 95% of pixels within rms slope and SAR backscatter coefficient filter. (b) ellipses containing at least 95% of pixels satisfying rms slope, SAR backscatter coefficient, and emissivity filter. Area highlight in blue is the latitude range within which ellipse look angle is +/- 5º of the look angle for the Venera 13 ellipse. From Rabinovitch and Stack (2021).

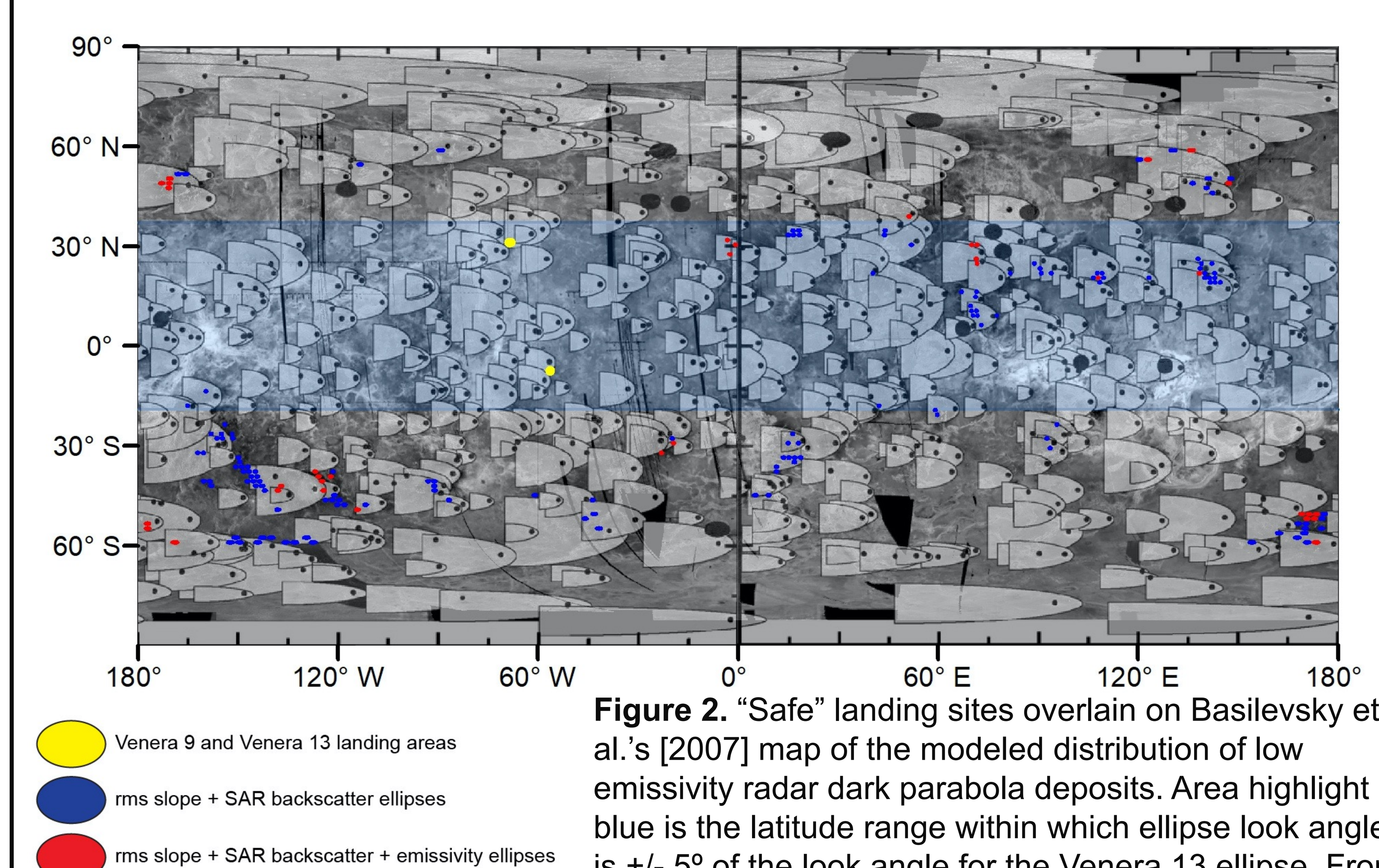

Figure 2. "Safe" landing sites overlain on Basilevsky et al.'s [2007] map of the modeled distribution of low emissivity radar dark parabola deposits. Area highlight in blue is the latitude range within which ellipse look angle is +/- 5º of the look angle for the Venera 13 ellipse. From Rabinovitch and Stack (2021).

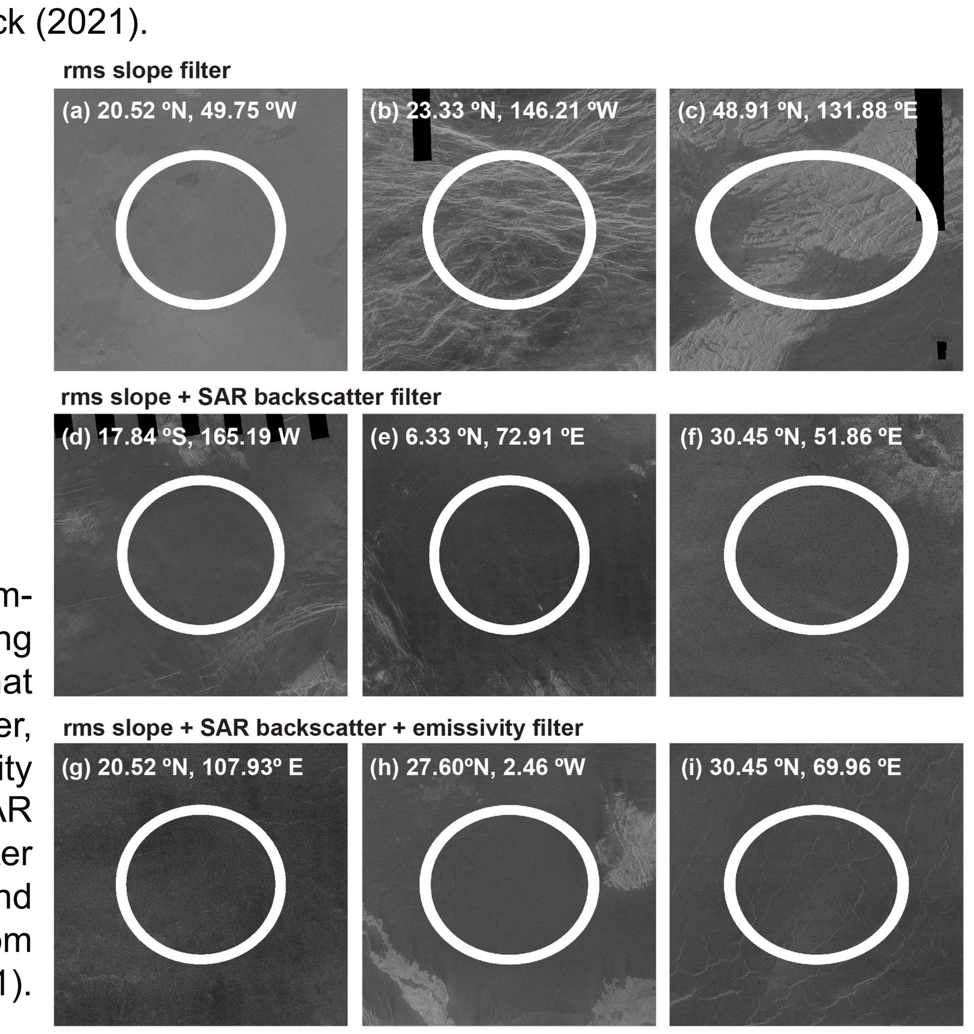

Figure 3. Example 150-km-diameter candidate landing ellipses (outlined in white) that passed the (a-c) rms slope filter, but not the SAR or emissivity filters. (d-f) rms slope and SAR filters, but not the emissivity filter and (g-h) rms slope, SAR, and emissivity filters. From Rabinovitch and Stack (2021).

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