DETECTION OF ACTIVE VOLCANISM ON VENUS FROM ORBIT AND FROM BENEATH THE CLOUDS: J. A. Cutts[1], K. H. Baines[1], P. K. Byrne[2], A. B. Davis[1], L. Dorsky[1], J. S. Izraelevitz, M. T. Pauken[1], B. M. Sutin[1], [1]Jet Propulsion Laboratory, California Institute of Technology, MS 183-602, 4800 Oak Grove Drive, Pasadena, CA 91109, [2] Earth, Environmental, and Planetary Sciences, Washington University, St Louis, MO.

Introduction: Many lines of investigation now suggest that there is active volcanism on Venus, but the extent and nature of this activity remains unknown. Here we examine the potential for detecting volcanic activity both from orbit using a spectral region not previously contemplated for this purpose, and with a subcloud platform for characterizing thermal emission from active flows at much higher spatial resolution than is possible from orbit.

Orbital Detection: In 2001, Hashimoto and Imamura [1] examined the possibility of detecting active volcanism from Venus orbit using infrared night time imaging at 1.02 µm. They noted that the excess emission from the hot surface is blurred by multiple scattering in the optically thick clouds. Consequently, the radiant energy from a volcanic event when it emerges from the clouds has diffused over an area of about 10,000 km^2. Nevertheless, because the thermal emission from a volcanic event is so much greater than the ambient surface, these authors estimated that even modestly sized lava flows, ranging from 1 km^2 for a 1500-K basaltic lava lake to 50 km^2 for a 1000-K lava flow, could be detected from orbit.

Observational Results at 1.02 µm: Following this approach, Shalygin et al. [2] conducted a survey of transient volcanic phenomena using the 1.02-µm channel on the Venus Monitoring Camera (VMC) on Venus Express (VEx). They reported the occurrence of transient bright spots in the Ganiki Chasma region of Venus. However, because of the ambiguity in spatial scale from atmospheric scattering, these authors were not able to distinguish between small areas at very high temperatures versus larger areas at more modest temperatures. Subsequent efforts to search for active volcanism in the same window with the IR1 camera on Akatsuki were thwarted because light leaks in the camera precluded a statistically significant search [3].

Potential for detections at shorter wavelengths: Recent observations with the Wide Field Camera for Parker Solar Probe (WISPR), revealing a previously unrecognized spectral window through Venus' clouds, indicate that a search for active volcanism can be conducted at shorter wavelengths and achieve a lower detection threshold than with the 1.02-µm window. A comparison between the WISPR images (spectral range 0.4 to 0.8 µm: Figure 1, left) and radar-determined surface elevation (Figure 1, right) reveals a strong correlation. Since Venus surface temperature is determined primarily by elevation, this correlation is consistent with the premise that WISPR observed thermal radiation originating from the surface of Venus. This premise was confirmed by more detailed analysis and modeling of the spectral content of the radiation, which indicated that the signal contribution included both near-infrared and visible radiation [5]. We now consider how this new window might assist in the detection from orbit of active volcanism on Venus.

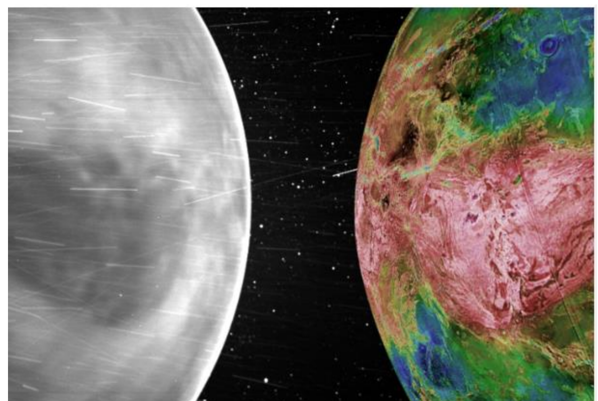

Figure 1. Nightside image of Venus on the left was acquired in the 0.4–0.8 µm band of the WISPR instrument. The mirror image on the right is based on radar altimetric data from Magellan. The bright limb of Venus in the left image results from airglow, which contributes a background to the surface emission elsewhere on the disc. Reproduced from [4].

Impact of the new spectral window on detection threshold: This new spectral window has the potential to substantially reduce the required detection threshold for active volcanic eruptions on Venus. This threshold is controlled by the ratio of the radiance per unit area of the hot flow to that of the surrounding ambient terrain. It is a characteristic of the Planck function in the spectral region of interest that this ratio is higher at shorter wavelengths and when the temperature difference between the flow and the ambient background is higher. The utility of this new spectral window on detection threshold is illustrated in Figure 2, where the minimum detectable lava surface area is plotted against temperatures for observations between 0.5 and 1.2 µm. The results at 1.00 µm are similar to those found by Hashimoto and Imamura for the 1.02 µm window. For flows that are several hundred degrees hotter than their surroundings, the detectable size of the flow should be an order of magnitude smaller for similar assumptions than at 1 µm. One limiting factor is the airglow in the spectral region shortward of 0.8 µm, which is apparent at the limb of the left image of Figure 1 and constitutes a background that is at shorter wavelengths than the surface emission. We posit that there is an optimal wavelength between 0.7 and 0.8 µm, a hypothesis that requires further analysis to test.

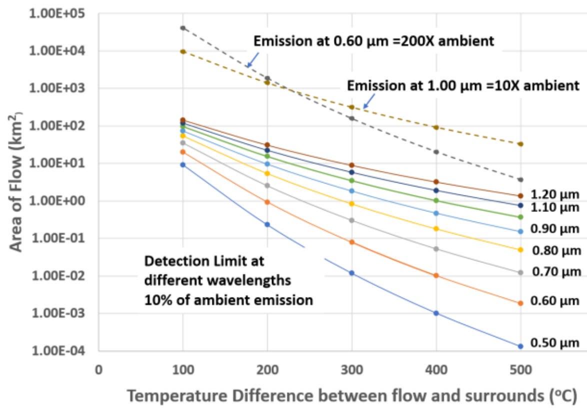

Figure 2. Solid lines show the minimum lava flow area detectable from orbit as a function of temperature. Shorter wavelengths enable smaller flows to be detected, with the gain increasing with the flow temperatures. The dashed curves represent notional measurements at 0.6 and 1.0 µm, which can resolve the ambiguity between temperature and flow area.

Effect on resolving area-temperature ambiguity: Where there is a positive detection at the single wavelength of 1.02 µm, there remains ambiguity in lava flow area and temperature. Making a detection in two or more wavelengths simultaneously offers the potential for resolving this ambiguity. This approach is illustrated in Figure 2, where the temperature and area of the flow are established by the intersection of the two dashed curves representing notional, concurrent measurements at 0.6 and 1.0 µm. Of course, the model underlying Figure 2 has only two components: the ambient background and a flow of uniform temperature. Observational at additional wavelengths would help to further characterize the flow temperature variability and even spatial extent.

Subcloud Imaging of Lava Flows: Observations from a platform below the Venus clouds [6] would enable a definitive measurement of the areal extent and morphology of lava flows. Some indication of the type of imaging that could be acquired with this modality are shown in Figure 3: a nighttime image of Holuhroun volcano in Iceland. For observations below the clouds at ≤1 µm, the dominant source of image degradation is Rayleigh scattering. For hot lava sources, the analysis of Davis et al. [7] can be applied to show that 23% of the emitted radiation will reach the sensor with the remainder diffused across the entire scene. As for eruptive detection from orbit, observations made from below the global cloud deck at several wavelengths (e.g., between 0.8 and 1.0) µm would allow a more complete characterization of the temperature distribution and morphology of lava flows on Venus.

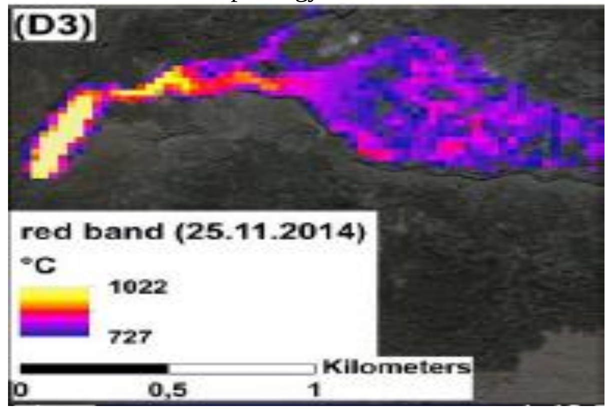

Figure 3. Image from Landsat 8 of a flow during a 2014 eruption at Holuhraun Volcano, Iceland observed in the red band (0.62–0.67 µm) from an altitude of 705 km. Subcloud imaging will be at much lower altitude (~47 km).

Conclusions: The threshold for orbital detection of active volcanism on Venus can be reduced by using observations in the spectral window between 0.4 and 0.8 µm, as established by the Parker Solar Probe mission. A high-altitude, near-equatorial orbiter would be best suited to this task. The EnVision and VERITAS missions are neither equipped with suitable sensors nor in an appropriate orbit for providing synoptic global observations at a suitable cadence. In-situ, high-resolution imaging from beneath the clouds would complement orbital observations by determining the morphology and, by proxy of eruptive temperature, the composition of detected lava flows, and by relating those observations to flow details discerned in high-resolution orbital radar images.

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