THE EARTH-BASED RADAR SEARCH FOR VOLCANIC ACTIVITY ON VENUS. B. A. Campbell[1] and D. B. Campbell[2], [1]Smithsonian Institution Center for Earth and Planetary Studies, MRC 315, PO Box 37012, Washington, DC 20013-7012, campbellb@si.edu; [2]Cornell University, Ithaca, NY 14853.

Introduction: Venus is widely expected to have ongoing volcanic activity based on its similar size to Earth and likely heat budget. How lithospheric thickness and volcanic activity have varied over the history of the planet remains uncertain. While tessera highlands locally represent a period of thinner lithosphere and strong deformation, there is no current means to determine whether they formed synchronously on hemispheric scales. Understanding the degree to which mantle plumes currently thin and uplift the crust to create deformation and effusive eruptions will better inform our understanding of the "global" versus "localized" timing of heat transport. Ground-based radar mapping of one hemisphere of Venus over the past 32 years offers the opportunity to search for surface changes due to volcanic eruptions.

Radar Data. The Arecibo Observatory S-band (12.6-cm wavelength) radar system has been used to make 1-2 km resolution maps of the hemisphere of Venus visible at inferior conjunction since 1988 [1]. Subsequent observing campaigns provide coverage at similar resolution and number of looks for 2012, 2015, 2017, and 2020. The signal-to-noise ratio (SNR) is markedly higher in 2015 and 2017 than in the other years, making the darker same-sense circular (SC) echoes more useful for polarimetric analysis (Fig. 1) [2].

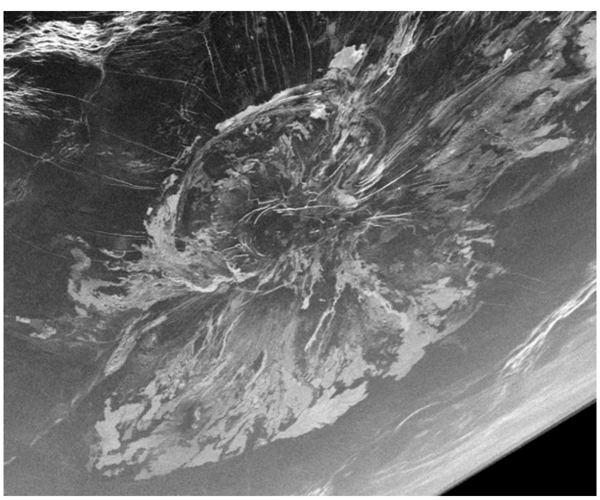

Fig. 1. 2017 same-sense circular (SC) image of lava flows surrounding Quetzalpetlatl Corona in Lada Terra.

All of the minimally-processed data for the runs through 2017 are available on the NASA Planetary Data System [3]. The major difference in observation geometry comes from shifts in the latitude of the sub-radar point, which spans the range from about 8° S (2017) to 8° N (2015). Observations in 1988, 2012, and 2020 share a similar sub-radar point latitude of ~3° S. Coverage of higher northern and southern latitudes may be obtained during favorable conjunctions (Fig. 1), but the shift in incidence angle must be recognized in analysis of surface features over time. The 2012 data were collected in an Arecibo-GBT bistatic geometry that led to poorer isolation between the hemispheres.

Searching for Change. Ideally, surface change detection could be achieved by co-registering and differencing any pair of radar maps. Several factors make this work more challenging. First, the 1988 data have lower SNR since they were collected prior to the Arecibo transmitter upgrade. Second, the radar incidence angle, ϕ, may be different between observations in different years, which can strongly bias the relative brightness of features in the opposite-sense circular (OC) polarization, especially when a feature occurs at low incidence angle in one of the two images. Third, the raw delay-Doppler data are collected separately for the northern and southern hemispheres by offsetting the pointing of the radar beam, but a significant amount of power still illuminates the undesired hemisphere (e.g., Maxwell Montes appears in the south and Alpha Regio appears in the north) (Fig. 2).

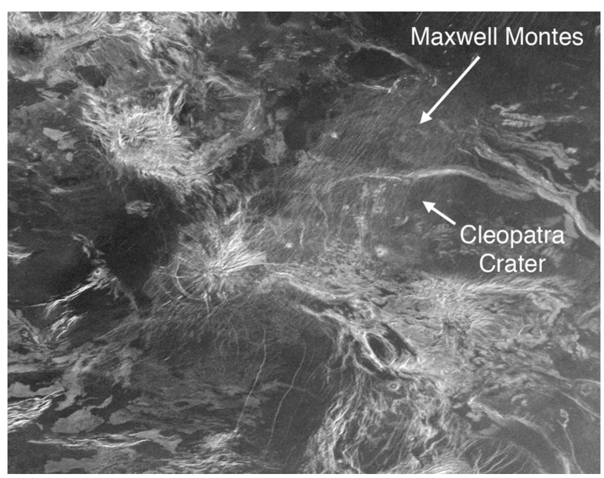

Fig. 2. Multi-look radar map of region NE of Lada Terra in the southern hemisphere, with blurred image of Maxwell Montes from the northern hemisphere.

In any single look, features appear sharp regardless of their location on the planet, but mapping to cartographic coordinates causes the opposite-hemisphere features to gradually drift through the multi-look mosaic. Rather than sharp images of the features, the final maps have arcuate streaks or blobs that may be difficult to discriminate as erroneous (Fig. 2). Some success has been achieved in masking strong ambiguity features in single looks to form a clean area of the multi-look image, but as yet this cannot be done in a quantitative method.

Figure 3 shows an OCP image pair from 1988 and 2017 for the large shield volcano Sif Mons. The significant difference in SNR comes from the intervening upgrade to the S-band radar system. An initial comparison of these two images shows no apparent change on scales greater than at least 10 km by 10 km. This lower limit is of the same order as the 144 km^2 area (4.4 km^3 of lava) covered in 35 years by the Pu'u O'o eruption of Kilauea. While these results cannot establish limits on eruption rates or periods of quiescence, detection of an eruption of these scales would certainly suggest locales for orbital and landed investigations. Future orbital missions like VERITAS or EnVision could extend the time since Magellan imaging and lower the threshold of detection for flow extent to perhaps the few-km scale (given the 150-m Magellan resolution).

Acknowledgments: The Venus mapping data represent the collective effort of many people over the past 30 years. Special thanks are due to the staff of the Arecibo Observatory and Green Bank Telescope.

References: [1] Campbell, D.B., et al. (1989), *Science, 246*, 373-377. [2] Campbell, B.A., et al. (2018) *JGR-Planets, 122, 1580-1596*. [3] Campbell, B.A., Earth-Based Radar Observations of Venus, ARCB/NRAO-V-RTLS/GBT-3-DELAYDOPPLER-V1.0, NASA Planetary Data System, 2016.

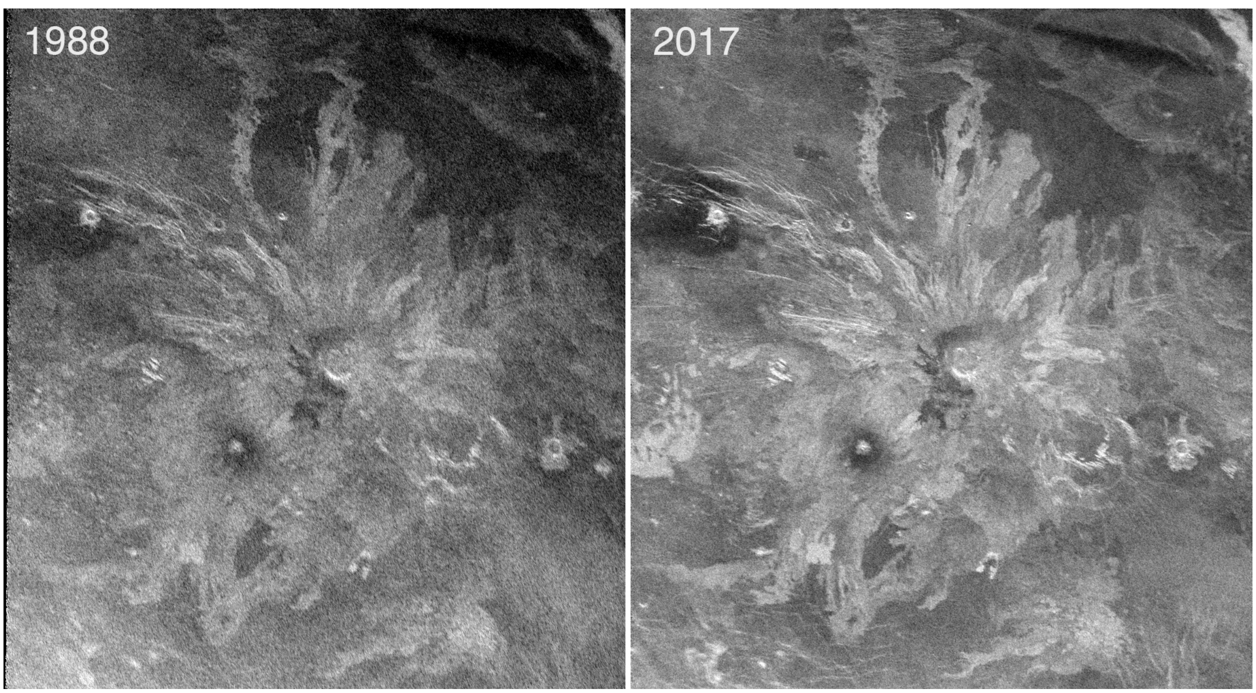

Fig. 3. Arecibo 1988 and 2017 radar images in OC polarization for Sif Mons on Venus. The improvement in SNR between the two years reflects the upgraded Arecibo transmitter.