THE ANALOGS FOR VENUS' GEOLOGICALLY RECENT SURFACES (AVENGERS) INITIATIVE: UPDATES AND NEW TARGET AREAS.

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Introduction: Several missions to Venus have been recently selected for launch [1-4], opening a new era for the exploration of the planet. One of the key questions that future missions need to address is the rate and style of present-day volcanic activity on Venus. To this regard, an important target on Venus is certainly represented by the young topographic rises [5], which can be interpreted as the surface expression of underlying mantle plumes [6]. These areas can be considered as the geologically youngest regions of Venus, being characterized by recent volcanic and tectonic activity. Studying areas of active volcanism and tectonism on Venus is crucial as it can reveal clues to the geologic past of the planet, as well as provide information about the volatile content of its interior and about the formation of its dense atmosphere. The "Analogs for VENus' GEologically Recent Surfaces" (AVENGERS) initiative [7] aims to select and analyze a number of terrestrial analog sites for the comparative study of recent and possibly ongoing volcanic activity on Venus. In addition to its scientific importance, the AVENGERS initiative acts as a bridge for international scientific collaboration, including selected mission teams.

Main objectives: The objectives of the AVENGERS initiative are: (1) Comparative study through SAR image analysis, geologic mapping and stratigraphic reconstruction at regional level of the selected volcanic structures; (2) Age estimate of Venusian volcanic activity by determining the alteration rates of lava flow samples retrieved from terrestrial analog sites; (3) Radiometric properties and interferometry (change detection) analysis on active volcanoes on Earth and on Venus; (4) Comparative analysis of the crustal thickness between volcanic structures on Venus and Terrestrial analogs.

Criteria of selection: We use the following criteria for the selection of the terrestrial analogs: (1) *Sites of ongoing volcanic and tectonic activity on Earth*. Areas of ongoing volcanic activity on Earth will be a priority target in this project; (2) *Ease of access*. Ease of access primarily allows performing in-situ geologic field trips with the possibility of retrieving lava flow samples for laboratory analyses and drilling operations as test for future landing missions; (3) *Similarities in lava composition*. It is important to analyze volcanic areas on Earth that are geochemically comparable with Venusian counterparts, based on the data of surface geochemistry provided by the Soviet Venera and Vega missions.

Currently selected analog sites: Based on the main objectives and criteria of selection of the AVENGERS initiative — after Mount Etna [7] — we have currently selected the following analog sites on Earth.

Kīlauea (19°N, 155°W) located in Hawai'i, USA, is an active shield volcano, and it is a good example for terrestrial hotspot volcanism, which has been frequently used to describe volcanism on Venus. For this reason, active hotspot volcanoes such as Kīlauea can be used as a suitable Terrestrial analog for identifying active volcanism on Venus. Moreover, Kīlauea is also easily accessible and has basaltic lavas similar to the rocks analyzed by Venera 14 and Vega 2 [8]. As an example, we show in Figure 1 the qualitative analysis of the radar polarization properties of Kīlauea lava flows using the high-resolution fully polarimetric C-band (5.6 cm wavelength) SAR data of a part of this region obtained by RISAT-1A instrument on board EOS-4 mission [9] by the Indian Space Research Organization (ISRO). Comparable polarimetric products will be also provided by the Shukrayaan-1 mission to Venus [4]. Polarimetric SAR images allow better analysis of texture and relative age of the lava flows.

Another suitable area is represented by the *East African Rift System (EARS)* (10°N, 40°E), an active rift zone located in East Africa with multiple volcanoes with diverse compositions that could be potential analogues. Given its structural frame, the EARS can help us to better study the mechanism behind the formation of the volcano-rift systems such as the Olapa Chasma-Idunn Mons system on Venus (45°S, 215°E), which can be considered among the most recently active areas on Venus.

Mount Merapi (7°S; 110°E) in Indonesia is another Terrestrial analog site that we plan to investigate. It is the most active stratovolcano of Indonesia, and it is the youngest of a group of volcanoes situated in southern Java. It is located at the "subduction zone" where the Indo-Australian plate is subducting under the Sunda plate [10]. Despite the fact that Venus appears not showing Earth-like plate tectonics, some spatially limited plume-induced crustal recycling activity cannot be excluded [11]. For this reason, it is also important to analyze a very active subduction zone volcano on Earth like Mount Merapi, as the spectral signatures of its volcanic products can be analyzed in the laboratory and provide us important data for future comparison with spectral data from the surface of Venus. It can also help distinguish pyroclastic deposits, an issue for Venus.

Besides Mount Merapi, another suitable endmember for crustal recycling is given by the *volcanoes of Kamchatka*, a group of very active volcanoes located in the Peninsula of Kamchatka (56°N; 158°E) in Russia. Being very active, these volcanoes may be used for change detection analysis as well as for drilling operations to test the functionalities of the future Venus landers.

Iceland is another excellent analog, currently being investigated by another team [12].

Other suitable analogs may be represented by *Bolivian volcanoes*. Because of their explosive nature, these volcanoes may be related to the possible occurrence of pyroclastic and tephra events on Venus [i.e., 13].

Conclusions: As the launch of the future missions gets closer, it is important to collect and analyze data from volcano-tectonically active areas on Earth. These areas will be used for analog studies to detect ongoing volcanic activity on Venus. As no perfect analog exists, it will be important to analyze several suitable analogs as each analog can indeed provide useful information, both in terms of potential similarities and differences with active and recent volcanic structures on Venus. As more and more Terrestrial exoplanets are being investigated [14], the currently available data seem to show how several of them may be characterized by very dense likely CO_2-dominated atmospheres. Hence, one possibility is that many terrestrial planets may evolve toward Venus-like conditions at some point in their geologic history. In this regard, studying the interior, surface, and atmosphere of Venus opens a broader perspective for a better understanding of Earth-like exoplanets.

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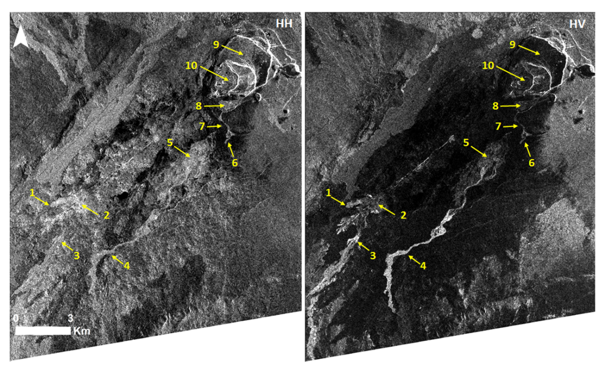

Figure 1: RISAT-1A C-band SAR data of Kīlauea volcano and lava flows shown here in left: HH and right: HV polarization at 7 m/pixel resolution. Arrows highlight the extents and boundaries of historical and recent lava flows that have a suite of textures (ʻaʻā to pāhoehoe). Compared to the HH-pol image, the rough a'a flows are radar bright, and are distinctly highlighted in the HV-pol image on the right. Labels for the numbered sites are taken from Campbell et al. 1993 and the index is 1: Mauna Iki ʻaʻā 2: 1920 Mauna Iki pāhoehoe, 3: 1920 Mauna Iki ʻaʻā, 4: December 1974 ʻaʻā, 5: December 1974 pāhoehoe, 6: 1982 ʻaʻā, 7: 1982 pāhoehoe, 8: 1982 Smooth pāhoehoe, 9: Kīlauea Caldera pāhoehoe, 10: Pit crater Ponded pāhoehoe.