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Remote Sensing Investigation of Recent Volcanic Activity on Reykjanes Peninsula, Iceland, as an Analog for Venus

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Abstract: Venus and Earth share key similarities yet differ fundamentally. It is uncertain how Venus's evolution diverged from Earth's and if its past was significantly different from its present state. Despite the interest in Venus since the dawn of planetary missions, orbiters could only use radar waves to observe the surface due to its dense and opaque atmosphere. Subsequent research revealed that Venus's atmosphere permits the transmission of electromagnetic waves emitted from its hot surface through six spectral bands centered at 0.86 µm, 0.91 µm, 0.99 µm, 1.02 µm, 1.11 µm and 1.18 µm within five atmospheric windows [1]. Advances in near-infrared imagers and laboratory measurements of the emissivity of rocks have spurred a new era of Venus exploration. In June 2021, two orbiters were announced as part of a fleet of Venus missions: NASA's VERITAS and ESA's EnVision. Both orbiters will be equipped with emissivity mappers designed and built by the German Aerospace Center (DLR) and aim to use these six bands to map the surface globally: Venus Emissivity Mapper (VEM) and VenSpec-M, respectively. [2, 3].

Here, we inquire into the potential of near-infrared remote sensing observations to investigate recent or active volcanic activity by employing machine learning methods for classifying surface units and change detection in preparation for future Venus missions.

Iceland serves as a primary analog for Venus in addressing the research questions of this study. This is because Iceland has a young, mostly vegetation-free surface that is formed by ongoing volcanic activity. Reykjanes Peninsula has been experiencing frequent fissure eruptions for the last 4 years. Two of these eruptions, known as the 2021 and 2022 Fagradalsfjall eruptions, resulted in the formation of a 5.01 km^2 flow field called Fagradalshraun [4, 5, 6]. The study investigated the Reykjanes Peninsula, focusing on Fagradalshraun, using near-infrared bands in the spectral range of VEM of pre- and post-eruption Sentinel-2A datasets. The imagery dataset was selected based on three essential criteria that were satisfied by ESA's Sentinel-2 constellation: Open public access, spectral bands within the range of VEM, and temporal coverage of the eruptions.

Supervised classification with the Support Vector Machines method and unsupervised classification with the K-means clustering method were performed to distinguish between geological units based on their age differences. In addition, the contributions of the Texture Analysis and the Principal Components Analysis methods for improving the classification results were tested. Then, the Normalized Difference of Time Series method was used for change detection. The results showed that despite employing a limited number of spectral bands as VEM and VenSpec-M will provide, both

classification methods could distinguish between fresh basalt, weathered basalt, and aeolian cover. The accuracy of the classification methods improved with the inclusion of texture measures. Additionally, it was observed that the highest accuracy in unsupervised classification was achieved through the utilization of Principal Component Analysis. Finally, it was seen that the Normalized Difference of Time Series method detected the Fagradalshraun with an accuracy of 95%.

The results presented here underscore the capability of VEM and VenSpec-M, especially in detecting potentially active or recently active volcanism on Venus. In addition, they emphasize the contribution of studying the terrestrial analogs to enhancing the science return from future Venus missions.

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