UTILISATION OF VIRTIS DATA FOR DETECTION OF POTENTIAL VENUSIAN ACTIVE VOLCANISM AND NOISE-REMOVAL ALGORITHMS FOR VIRTIS USING MACHINE LEARNING.

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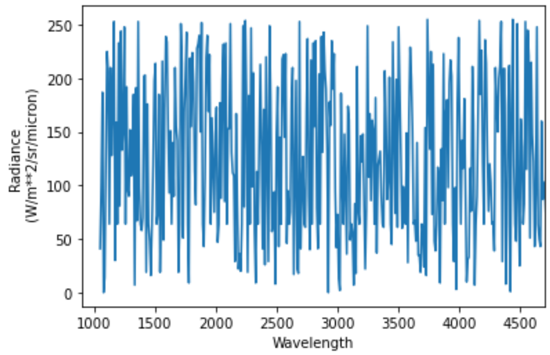
Venus has always been an attractive target for comparative planetology and understanding the history of Earth. Several missions have been sent by the USA, Soviet Union, and recently, Europe to explore Venus. One of the major scientific questions includes the status of active volcanism on Venus. It is believed that the Altian period volcanism may continue to present. The Venusian atmosphere consists of CO_2 (96.5%), and N_2 (3.5%), with few to a few hundred parts per million (ppm) of sulfur-bearing trace gasses, chlorine and carbon compounds and water vapour. Any active volcanoes would cause an anomaly in the atmospheric concentration of volatile components due to outgassing. We aim to analyze the spectral characteristics of volatiles present in the Venusian atmosphere at specific locations to detect their concentration anomalies indicating active volcanism. The Pioneer mission observed a decline in the sulfur dioxide abundance in cloud tops and the amount of haze above clouds for five years. On an encounter, a decline (by more than a factor of 10) in sulfur dioxide abundance at the cloud tops and in the amount of submicron haze above the clouds was recorded [1]. These spectral and temporal variations can be further analyzed for potential active volcanism [2].

Analyzing the entire Venusian atmosphere at different scales would be highly unfeasible. Based on a geological map by [3], specific sites can be selected to narrow the regions of the Altian Period's youngest units of volcanic origin such as lobate plains, smooth plains, and shield clusters. Venus Monitoring Camera (VMC) Infrared-2 (IR2) channel (at 1.01 μm) aboard Venus Express gives night-side thermal emission which can be analyzed to find sites of relative brightness. The brightness excess can yield temperature excess which when associated with topographic data from the Magellan mission gives potential sites for active volcanism [4].

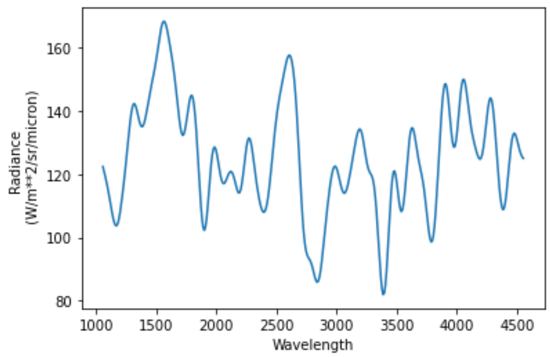
Since Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) data has a high signal-to-noise ratio (SNR), several noise removal algorithms like PCA, Laplacian Filters, Butterworth filters etc. [5] are applied to enhance the features. These algorithms are limited to mathematical concepts of various filters while machine learning has a dynamic nature. Certain signal processing algorithms used in other disciplines of science are proven to remove large amounts of noise from distorted signals. A Generative Adversarial Network (GAN) based algorithm developed for the removal of Electroencephalogram (EEG) signals by [6], has proven to remove the noise by more than 90%. GAN and Autoencoder-based algorithms can reconstruct the signals using concepts of encoders and decoders. ANN/DNN-based approaches have a great potential to identify the features from the noisy spectra. Since the availability of pure spectra from the VIRTIS datasets is limited, a transfer learning-based approach can be utilized. The detection of specific features from the EEG signals is analogous to mineral identification using absorption features in hyperspectral imagery.

Thus, the weights and biases of preliminary layers where low-level features such as peaks and dips are being identified or extracted from the pre-trained models from spectral/signal-based data where a large amount of training dataset is available can be transferred to the preliminary layers of the noise removal VIRTIS data-based neural networks. Further, the architecture can have data-specific minerals of interest in the subsequent layers from VIRTIS. Once the noise is removed, ANN-based architectures can be automated to perform per-pixel-based classification. Further, a comparative study of traditional noise removal techniques with advanced techniques such as Autoencoder-based algorithms can be performed for an effective algorithm selection. A traditional moving average-based noise removal performed on the pixel of the VIRTIS dataset for two locations is shown below.

The spectral signatures of VIRTIS data for two locations on Venus were compared. Location 1 (68.14°S, 22.79°W) in the Bell formation constitutes lobate plains which are occasionally disturbed smooth surfaces from the Altian period. These are some of the youngest surfaces on the planet therefore, they could be volcanically active. Location 2 (60.78°S, 45.67°W) lies in the Fortuna formation including tesserae structures which are the most tectonically deformed structures with a high radar backscatter. They are the oldest units on the surface of Venus and therefore assumed to be volcanically dead. The absorption bands of carbon dioxide at 2 μm, 2.7 μm and 4.3 μm while sulfur dioxide at 4 μm are studied. On comparing the band depth of spectra for both locations, it is found that sulfur dioxide absorption (4 μm) is significantly varying. At location 1 (Bell fm), a decline in the sulfur dioxide is registered which may be indicative of active volcanism. On the other hand, location 2 has a relative abundance of sulfur dioxide. The nature of carbon dioxide absorption is also varying in both locations and can be further studied.

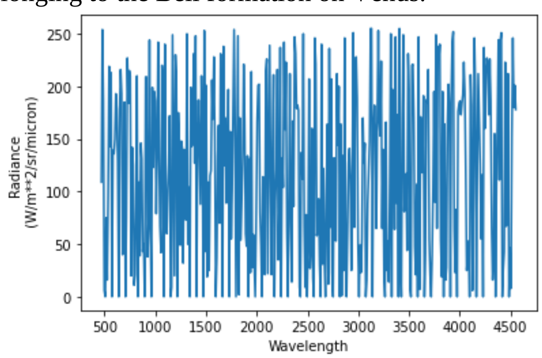


(1)

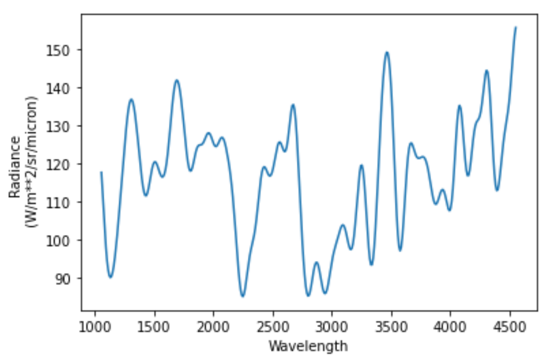


(2)

Fig. 1 and 2 show the noisy and smoothened spectra from VIRTIS of location 1 (68.14°S, 22.79°W) belonging to the Bell formation on Venus.



(3)



(4)

Fig. 3 and 4 show the noisy and smoothened spectra from VIRTIS of location 2 (60.78°S, 45.67°W) belonging to the Fortuna formation on Venus.

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