

QUANTIFICATION METHODOLOGY FOR IDENTIFYING MARTIAN FROST USING HIRISE IMAGERY. V. M. Karnes¹, J. R. Sandtorf-McDonald¹, R. A. Slank¹, and V. F. Chevrier¹. ¹ University of Arkansas, Fayetteville, AR, 72701; vmkarnes@uark.edu

Introduction: The identification of frost on Mars in 1979 by the Viking 2 lander was the beginning of a multitude in depth studies in the 1970s and 1980s to determine the implications of its presence [1, 2, 3]. Most notably, the identification of frost has implications for water relative humidity and temperature, which remain important discoveries for use in Global Circulation Models (GCMs), overall climate, and localized weather. Technology has come a long way since Viking 2, however, which allows frost to be detected in finite detail within small areas. One of the instruments that allows such fine detail is the Mars Reconnaissance Orbiter (MRO) HiRISE camera. This camera provides a more recent dataset with high seasonal coverage RGB image products at a 1-meter resolution, which allow for high resolution identification and mapping.

We have focused our research on the Northern hemisphere of Mars to determine frost presence and dynamics over the course of the martian seasons.

In this abstract we detail our current method of quantification of frost and our proposed method for removal of the red band.

Initial case studies: Two initial case studies were performed to identify frost on Mars: one on a dune field located at the Mars northern latitude (80°N, 122.5°E) and one in the Windy City polar erg (73°N, 355°E). These locations were analyzed and assigned a qualitative scale (1-5), which is shown in Figure 1 using example imagery.

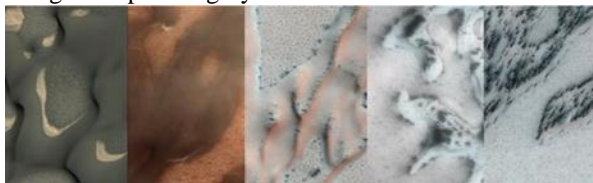


Figure 1: Example of the Qualitative Frost Scale. This frost scale, from left to right, was assigned the following values and identification: 1. visible but minimal frost, 2. small but consistent frost, 3. ubiquitous frost with moderate ground coloring (translucent frost), 4. ubiquitous frost with minimal ground coloring (opaque frost), and 5. maximum or complete frost coverage with no ground coloring.

While this scale provided an initial method for identifying seasonal and perennial trends in frost on Mars, it was not able to provide us with a quantifiable value for frost that could be used in further research or methodologies and thus why new possible frost quantification methods using HiRISE imagery and GIS software were considered.

Threshold analysis: To identify and quantify the frost in the northern hemisphere of Mars, the first iteration of study was to choose a value within each of the three bands where all pixels above the value counted as frost and all pixels below the value did not. These were considered frost thresholds. Once these thresholds were determined, they were compared to our initial estimates from the qualitative method, shown in Figure 2.

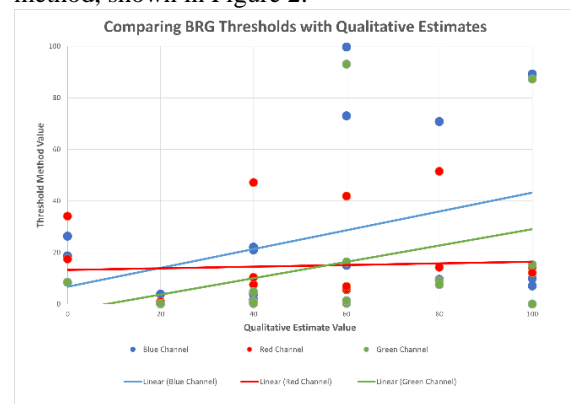


Figure 2: Surface coverage of frost using the threshold method in the red, green, and blue bands (colored lines) versus qualitative estimates (dots).

This method was not accurate enough for frost identification, however, as it does not include some images that are partially covered by frost. For example, an image with 25% frost coverage may not be concluded as having frost in this method. In the frost identification. However, it also showed that the red band differed from the green and blue band, indicating that the red band is not as useful for identifying frost as the green and blue bands, as changing the threshold value resulted in a scattered range of values for frost coverage that show no discernable pattern.

One way to improve our threshold analysis could be to use histograms to determine if improvements to our thresholds could be made. Further study will be done into the possibility of threshold improvement using histograms.

Quantification of frost using categories: The identification and quantification of frost on Mars was first established as a rudimentary process using QGIS, which has been further developed and analyzed to include a percentage of coverage.

This process starts by downloading, exporting, and projecting the HiRISE imagery into a usable format for

the study. The images used are RGB color non-map projected JPEG images readily available through the University of Arizona Lunar and Planetary Laboratory, which are easily manipulated in the QGIS platform.

Once exported and projected, the imagery is polygonised into separate vector files for each individual band. This allows for frost detection by the pixel values in all three bands separately and combined to determine if they were viable for identifying frost. An example image of the results from this process are shown in Figure 3.



Figure 3: An original JPEG HiRISE image with a high frost coverage (top) compared to the brighter polygonised versions created in the quantification process (bottom). Using prior findings of the similarities between the band values and their frost identification potential, value boundaries were then chosen for all bands to create five categories based on pixel color value (0-70, 71-86, 87-103, 104-120, 120+). These categories were then assigned their respective frost percentages (0%, 25%, 50%, 75%, and 100% respectively), the number of pixels in each category counted, and the final percentage of frost within the image was calculated. This was done to each of the three color bands and was then rerun ten times, increasing the category pixel values by 5 each time to determine the most accurate pixel value categories for frost identification. An example of this process of pixel counting within the chosen categories is shown in Figure 4.

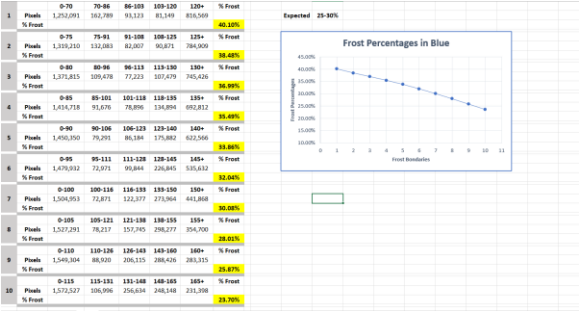


Figure 4: An example of the categorical process using the image in Figure 3, which also shows the ten tests and their respective values.

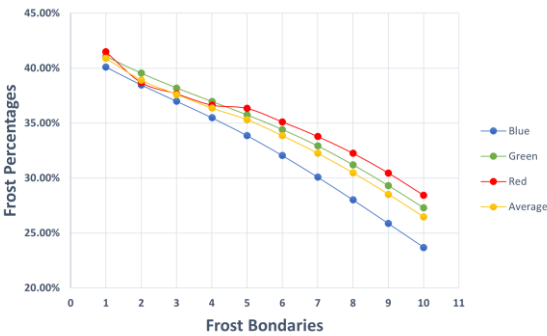


Figure 5: Frost surface coverage as a function of percent coverage for the ten tests in all three bands.

For the test image in figure 3, we determined the likely frost coverage would be between 25% and 30%. This puts our findings for accurate frost detection categories to be between the ninth and tenth tests as shown in Figure 4 and Figure 5.

However, when these values are analyzed, the red band seems to veer in the beginning tests when compared to the blue and green bands. This leads to the conclusion that the red band might not be as accurate for identifying frost as the blue and green bands, which may be due to its sensitivity to the red dust on Mars. When taking this into consideration, it opens the eighth test as a viable frost detection category, as well.

Conclusion: Initial evaluations in the martian northern hemisphere indicated that frost was identifiable in HiRISE imagery using RGB image products, which can be used to identify seasonal and yearly trends. A process has also been developed and expanded to quantify frost coverage using QGIS, which is assessed using the blue filter within the program. Preliminary investigations have also begun to determine the validity of the red band in frost identification and quantification. Further automation of this process, specifically the categorical approach shown in Figure 5 with increased sensitivity to frost, will allow for continued research in the presence of frost in Mars' northern hemisphere and the subsequent changes over time.

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References: [1] Hart, H. M., & Jakosky, B. M. (1985). *Icarus*, 66, 134-142. [2] Higuchi, K. (2001). *Icarus*, 154(1), 181-182. [3] Smith, P. H., et al. (2009). *Science*, 325(5936), 58-61.