LANDSAT ~~AND ASTER THERMAL~~MULTISPECTRAL IMAGE~~RY~~ ANALYSIS OF HIAWATHA CRATER, GREENLAND

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***Abstract*— Faculty and students at Elizabeth City State University have investigated the distal ejecta associated with a possibly fragmented, asteroid or comet that may have impacted the Laurentide ice sheet, contributing to a millennium long climatic cooling known as the Younger Dryas climate change. A large, apparently young crater recently discovered beneath Hiawatha Glacier in northwest Greenland might be associated with this event. Some evidence of a thermal anomaly beneath the ice has been reported. Moulin 'chimneys' have been observed near the Glacier's margin but none yet through the thicker ice covering the crater's center. A warm plume of air, evidence of a thermal anomaly may survive the ≈900-meter ascent to the surface through a yet to be detected moulin. However, a search using historic Landsat imagery for evidence of a moulin in the glacier's central area overlying the crater found no evidence of their existence and no surface expression of a warm plume of escaping to the surface. An examination of the Glacier's margin spanning a period of three decades also yielded no evidence of significant changes suggesting some stability has been achieved between ice loss and glacial advance.**

Keywords*— *Multispectral imaging, climate change, Hiawatha crater, Greenland, MultiSpec, ENVI

I. INTRODUCTION

Faculty and students at Elizabeth City State University's Center of Excellence for Remote Sensing Education and Research (CERSER) have been involved in investigating a hypothesis that a major cosmic impact event occurred 12,800 Years Before Present (YBP)1,2. This impact has been proposed as contributing to the abrupt climate change known as the Younger Dryas cooling episode, the extinction of mega fauna, and major cultural modifications observed in paleo human cultures in North America. A major problem with the decade- old hypothesis is the absence of one or more appropriately large, recent craters. To date, the only evidence discovered to support the hypothesis are wide spread fields of distal ejecta impact proxies. This is similar to the circumstances that attended the discovery of the Paleogene-Triassic (K-Pg) impact that is claimed to be responsible for the demise of the dinosaurs 65 million years ago. The decade long search for a correspondingly large crater also kept the K-Pg impact hypothesis in doubt for a decade.

In November of 2018, a Danish-led international team announced the discovery of an apparently young, large, 31 km diameter crater in Northwestern Greenland (see Figure 1). The crater was discovered lying beneath 900 meters of ice during aerial radar mapping of the bedrock covered by the Hiawatha Glacier. Interpretation of radar data suggests much of the overlying ice is relatively young, no older than the end of the Younger Dryas at about 11,500 YBP and younger. The exact formation date of the crater itself remains uncertain and is estimated to range from the very early Pleistocene to the early Holocene. Thus, no convincing association of this crater to the Younger Dryas Start or Boundary (YDB) can presently be made.

However, the radar returns from the ice immediately above the crater floor appear to be disturbed in a manner that may indicate a hydrothermal anomaly. Hydrothermal activity might be expected to persist, if produced by an impact occurring as recently as the time of the Pleistocene-Holocene transition (the YDB).

Any residual thermal energy release would likely be continuing to melt overlying ice as the glacier's basal surface advances across the crater floor.

Landsat 7 & 8 visible images of the surface of Hiawatha Glacier reveal the existence of numerous large pools of melt water, created by solar heating of surface ice during the height of the summer season, the largest of these pools are located directly over and near the center of the sub-glacial depression. However, it appears that most if not all of the water in these pools drains to the margin of the ice flow along surface channels. A large amount of melt water is also drained through a river channel issuing from beneath the center of the glacier's leading edge. (see figure 2.) To date, no surface expression of an existing thermal anomaly has been reported.

Nevertheless, it may be worthwhile examining data acquired by thermal sensing instrumentation aboard orbiting platforms such as Landsat, for the possibility of detecting any heat that might be escaping via an as yet undetected moulin "vent" or "chimney. (Figure 3)." A moulin is created by ponded solar-melted surface ice flowing into cracks caused by the strain of a glacier's slow movement across the underlying terrain. Moulins can become conduits for water to reach the ground lying under as much as a kilometer of ice. Moulins are reported1 near the edge of the Hiawatha Glacier where the ice is relatively thin (<500 m).

It would not be surprising to discover moulins through the deep ice overlying the crater's center. A plume of warm air rising from below might even facilitate its growth.

If such a deep Moulin exists, it may provide a nearly vertical channel, a literal chimney or vent, to allow a warm plume of air to escape from the floor of the crater to the surface of the glacier and into the atmosphere. A warm plume would certainly cool during its ascent to the surface through the moulin to the surface. A vanishingly small temperature differential between an emergent plume and the surrounding ambient surface air might render it undetectable. Assuming a temperature differential is detectable, such venting might be transitory or episodic so multiple image data sets, collected over time, should and will be examined. Alternatively, heat might be escaping from the moulin vents located near the crater's leading edge. Although, such a thermal anomaly would undoubtedly be small and may even be beyond the spatial and radiometric capabilities of current orbiting sensors, the effort represents an excellent educational opportunity for students at ECSU's CERSER laboratory to tackle a real geophysical remote sensing problem as an exercise.

Thermal imagery of the Hiawatha Glacier surface overlying the crater and terrain immediately surrounding the crater rim will therefore be examined and analyzed for evidence of any expression of a persistent, transitory or episodic thermal anomaly. The results of this ongoing study will be reported.

II. Methodology

The project was initiated by obtaining and training to use two specific software packages for the analysis of the area encompassing the Hiawatha Crater as well as its surroundings. The first software package being utilized was MultiSpec, the second being ENVI, both providing analysis tools for multispectral images.

MultiSpec is a software produced by David Landgrebe and Larry Biehl for the purpose of examining hyperspectral and multispectral images [4]. It is free to download for Mac operating systems as well as Windows operating systems [4]. The MultiSpec software package is free to download from the MultiSpec website [4]. MultiSpec is still being updated both in the software itself as well as the documentation that is associated with said software package [4].

ENVI is commercial software from Harris Geospatial Solutions for examining images that can be utilized through mobile electronics, desktops and the cloud [5]. ENVI provides instruments that can provide support for alterations of the software package to better adapt to the necessities of various endeavors [5]. Examples of said adaptability include "[allowing the addition of] proprietary algorithms, [extending] existing tools and models, automate high-frequency tasks, and [stringing] together multiple tools" [5] to buttress the skills and knowledge of the users. More can be read on the ENVI website: https://www.harrisgeospatial.com/Software-Technology/ENVI [5].

MultiSpec was originally being used for examining multispectral images for the beginning of this research endeavor for training purposes. MultiSpec used mathematical functions to reconstruct the view of the image being opened through MultiSpec such as linear and gradient with other options for best accommodating for the peculiars of the data for the user's necessities. After specifying the parameters for loading the data the new rendering would be loaded with the processes of MultiSpec's software already applied. Colors differentiate the classification of values that appear in the newly developed MultiSpec rendering. The spectrum of colors to differentiate data can be expanded to allow for examination of minute details. The issue with using MultiSpec is whether a shorter or wider spectrum is necessary to view relevant details of a MultiSpec rendering. If the spectrum of colors is too short, details in the rendering may merge with the general landscape or surrounding visual noise. If the spectrum of colors is too wide, an enormous amount of visual noise can be rendered leaving other details obscured. Often the number of display levels, which determines the size of the spectrum, used was 32. There were other considerations, but 32 display levels was a suitable baseline unless there was a particular region of the rendering that prompted the use of more display levels for a more intense examination.

When using MultiSpec, there would typically be instances where colors in close proximity were too close in hue and tint to differentiate from one another easily. For such instances, the mapping of colors in the 1-Channel Thematic Map could be altered to allow for more contrast between data values in that particular region. There were five other color mappings that proved useful in providing contrast of colors within the rendering. While gray scale was an option of color mapping for the initial rendering, doing so would not allow access to the remainder of the color mapping options as provided in the 1-Channel Thematic Map. After finding the right color mapping and display levels for a feature of the rendering, the goal was to either determine what that feature was and if it was relevant to the research goals of the project.

ENVI was acquired in the latter portion of the research endeavor with MultiSpec providing a background in multispectral images until ENVI was acquired. ENVI provided a much more fluid usage of instruments for examining various renderings loaded into the ENVI software. ENVI allowed arithmetic operations of different images for a single rendering, linking images to one another, and the use of different mathematical functions to enhance images.

III. Changing Image Set #1

The images collected display changes over time to a particular area. The images are taken from 1987, 1999, 2018 and display the same feature, possibly a nunatak, an exposed, rocky element of a ridge, mountain, or peak not covered with ice or snow within (or at the edge of) an ice field or glacier.

Figure 1: Aerial view of the feature of interest from the year 1987.

Figure 3: Aerial view of the feature of interest from the year 2018

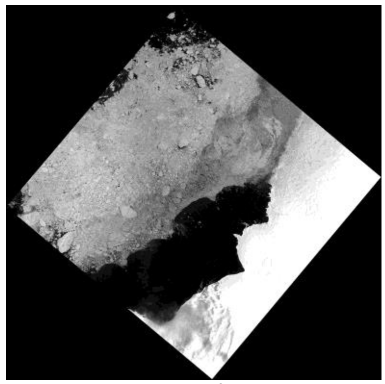

Figure 4: Full aerial view of Hiawatha crater and surrounding area. Was the original image used to generate Figure 1.

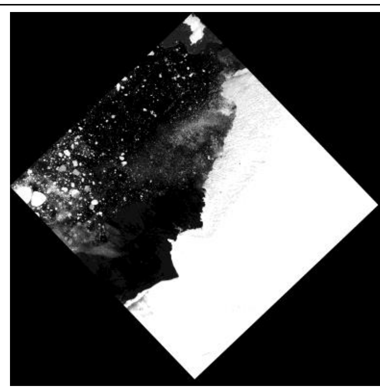

Figure 5: Aerial view of the Hiawatha crater and surrounding area. Was the original image used to generate Figure 2.

spectrum, which in turn emphasizes different details within each image.

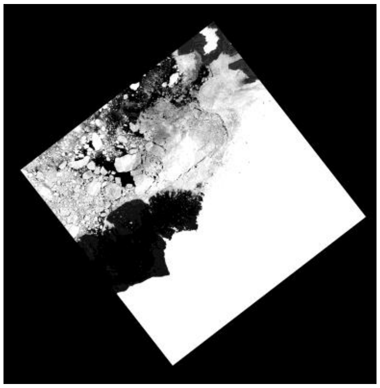

Figure 6: Aerial view of the Hiawatha crater and surrounding area. Was the original image used to generate Figure 3.

The feature has a shifting amount of snow/ice that is present throughout three different time periods. From 1987 to 1999, the shift in the amount of ice and snow is minor. The 1987 image displays the feature seemingly retracting from the landscape to the right of the feature. The 1997 image (Show images) either shows such retraction halting or continuing at an incredibly slow pacing. The 1997 image also portrays the feature's lower half seemingly attaching to the portion of landscape to the left of it. The 1987 and 1997 images display more characteristics in common with one another versus the 2018 image, which has significant details that are absent in the former two images. The third image has displayed the ice and snow feature apparently having joined the landscape present to the left and almost separated completely from the landscape on the right side. This would suggest that there was cooling in the area enclosing the feature between the 1999 and the 2018 images. If such is the case, it may suggest that other phenomena may be occurring elsewhere in the proximity of the Hiawatha Crater. The alterations of this feature would need to be analyzed over time along with other features to determine if the Hiawatha Crater is currently in equilibrium, is receding or is expanding.

IV. Data

Data for this research originates from datasets that were being hosted on the Earth Explorer website from satellites Landsat 5, 7, and 8. The datasets were collected in1987, 1990, and 2018. The URL for the Earth Explorer website is: https://earthexplorer.usgs.gov/. The Earth Explorer website hosts a plethora of GIS data accumulated by satellites and aerial technology that allow for research of the geographic and climate related phenomena that is captured within the collected datasets. The images of each dataset can contain a variety of Bands that emphasize various portions of the electromagnetic spectrum, which in turn emphasizes different details within each image.

V. Future Work

Given that any assertion on climate change affecting the Hiawatha glacier and the surrounding landscape cannot be confirmed with the amount of data that has been examined within this research endeavor, the main objective for any future work would be to prioritize the collection and examination of a significant amount of data. This data would be displaying multispectral images of the data across years, seasons, and multiple bands to observe the differences that occur that show pertinent variation of features over the long term. To accomplish such, a long-term strategy should be implemented to facilitate the training of MultiSpec and ENVI for future teams so that succeeding teams can successfully continue the research. This would include reinforced practice of such techniques as cropping, warping, and linking images. There would also need to be a section of training dedicated to identifying features that could be the result of or caused in part by climate change regarding the Hiawatha crater. The Hiawatha crater area and the surrounding landscape would remain the area of focus for future research. More subsections of images would have to be collected and compared to determine if the there is a viable argument that climate change has affected the Hiawatha crater and the surrounding landscape.

Another possibility in continuing the research is developing algorithms that allow for more detailed image analysis to observe changes in the Hiawatha crater over time through the utilization of computing resources. The key idea would be to develop a way to display the differences of features appearing in subsets across multiple images. This can be observed through generating an output file that consists of a shape around an area that displays features with significant changes to coloring of features in the image that vary. Considering that the images of the dataset can be of varying sizes, encompass different features based on what region is emphasized, the varying representation of the area due to the band, time of day, and season.

Another long-term goal to assist with research would be the design of machine learning algorithms that could identify significant differences between collected multispectral images of the dataset. Conception, design, and implementation of the suggested machine learning algorithms would take an extensive amount of time and would likely not be timely to attempt within one, two, or three research semesters given the amount of preparation, knowledge, skills involved with the machine learning field. Considerations must also be made for the amount time and computing resources that would be used regarding the training, testing and usage of these machine learning algorithms. A prerequisite to the usage of the machine learning algorithms are teams of students well-versed in the necessary knowledge and skills for collecting and examining the images for the analysis of any variations of the Hiawatha crater and the surrounding area and the accumulation of an immense of amount of data to generate viable machine learning models for implementation.

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