Andrew Fleming

2024 NH Space Grant Summer Fellowship Final Report

Project Title: Development of Multi-Scale Hyperspectral Mapping Techniques to Identify Target Compounds within Hypersaline Terrestrial Analogs for Mars

The overall goal of this project is to develop multi-scale mapping techniques for terrestrial analogs. The work this summer prioritized mapping from a satellite scale. UAS and in-situ data was gathered during field seasons taking place in September 2023 and January 2024. UAS scale classification maps for the target salts were developed with calibration and validation using ground truth data. The beginning of the summer focused on wrapping up the UAS scale analysis and gaining a deeper understanding of the formulas used to classify the spectra.

Following the UAS analysis, satellite scale mapping techniques were developed. I received hyperspectral data from EnMAP (Environmental Mapping and Analysis Program). The EnMAP satellite is a German hyperspectral Earth observation mission designed to capture detailed spectral information about Earth's surface. Unlike traditional satellite sensors that capture images in a few broad spectral bands (multispectral), such as Landsat and Sentinel, EnMAP captures data in hundreds of narrow spectral bands covering the visible, near-infrared (NIR), and shortwave infrared (SWIR) portions of the electromagnetic spectrum. The acquired EnMAP imagery consists of 224 bands (218 – 2445nm) and a spatial resolution of 30m. This project focuses on the NIR and SWIR spectral ranges because these bands overlap with the UAS imagery captured during the fall 2023 field season.

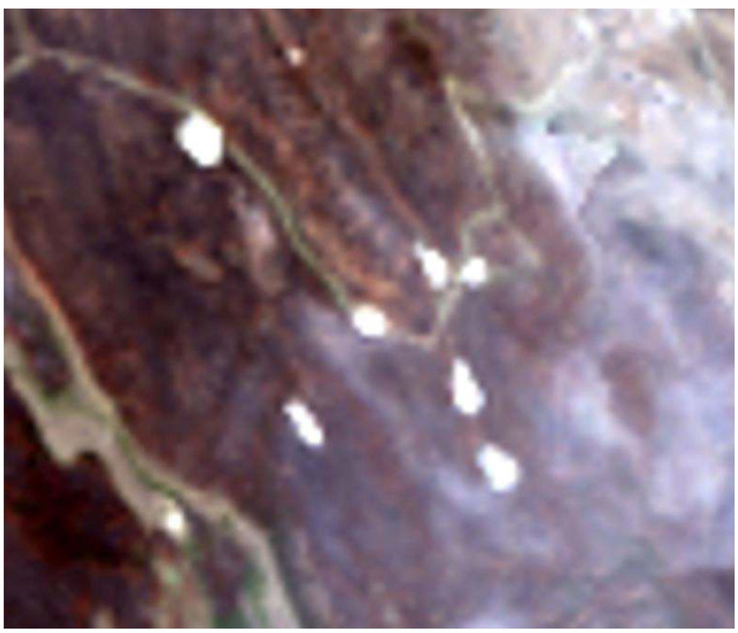

Figure 1: EnMAP Imagery of the Basque Lakes Located in the Caribou Plateau in British Columbia, Canada

Given the coarse nature of satellite imagery, the mapping methods implemented for the UAS data are not suitable. Instead, I employed spectral unmixing to detect spectral signatures embedded within the EnMAP data. With a pixel size of 30 m^2, it is less likely to encounter a pixel that can be sufficiently characterized by a single endmember. Instead, pixels contain a mixture of spectral signatures from target compounds, water, vegetation, etc. Linear Spectral unmixing is a process by which the abundance of each given endmember within the gathered spectra (in this case EnMAP data) is calculated. The reflectance values across the spectra are assumed to be a linear combination of the reflectance of each endmember at a given point along the spectrum. The calculated weight values of each endmember correspond directly to the percent abundance of the compound. This process assumes that the spectral signatures mix linearly, which in many systems (evidently including these lakes) does not hold true. Instead, the signatures mix nonlinearly and are affected by variables such as light refraction patterns and grain size. Developing accurate nonlinear mapping techniques requires well-tuned algorithms to consider the major variables at play, algorithms that reach beyond the scope of this project.

As an alternative a less precise mapping method is employed in which I manually compare absorption features within the spectra to known absorptions of hydrated minerals. This portion of the analysis is in progress. Since hydrated minerals contain many unique compounds and therefore unique absorptions, the compounds of interest in these systems are compiled within several categories including sulphates, silicates, chlorite Fe/Mg smectites, and Al-phyllosilicates. Identifying absorptions that indicate the presence of these hydrates can help to discern the endmembers expected within the scene and identify primary areas of interest. This method is not as powerful as classic spectral unmixing, but still provides insight into which areas could be of interest. Moving forward, the satellite-scale analysis will be completed, followed by the integration of mapping techniques across all three scales. This approach will enable a comparison of techniques, highlighting the strengths and weaknesses of each scale, ultimately aiding in the development of more robust mapping methods in the future. The summer concluded with a third field season in British Columbia, during which all lakes where UAV imagery was collected in 2023 were flown again. Data processing and analysis for this field season will begin shortly.

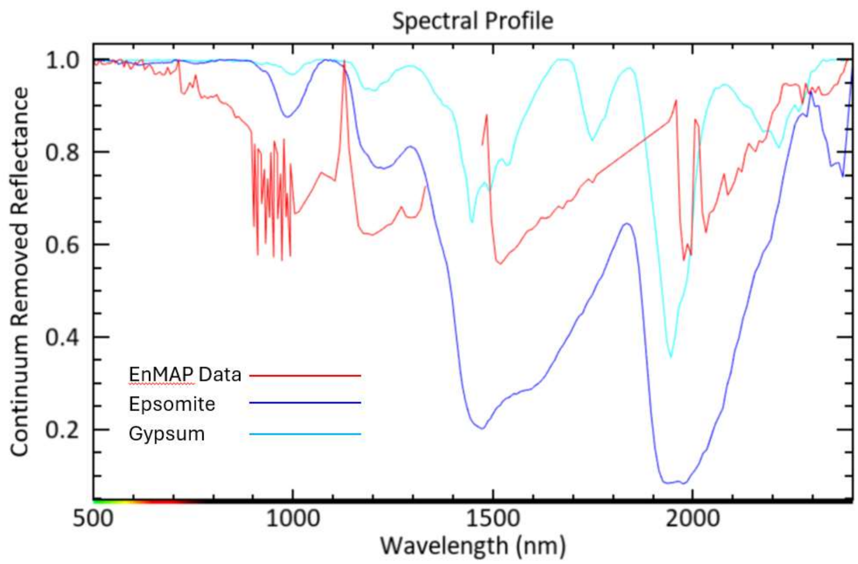

Figure 2: EnMAP Data vs. Spectra of Target Compounds

This work will be presented at the American Geophysical Union's Annual Meeting in December.

1. Fleming, A., J.M. Jacobs, J. Buffo, E. Hughes, and J. Johnston. Identifying Hydrated Compounds in Martian Analog Hypersaline Systems Using Hyperspectral Uncrewed Aerial Systems (UAS). AGU Fall Meeting, December 2024. Washington, DC.