CHARACTERIZATION OF A SULFUR-RICH ICY ECOSYSTEM BY REMOTE SENSING OBSERVATIONS D. F. Gleeson[1,2], R. T. Pappalardo[1,2], S. E. Grasby[3], A. S. Templeton[1] and J. R. Spear[4], [1]Laboratory for Atmospheric and Space Physics and NASA Astrobiology Institute, University of Colorado, Boulder, CO 80309-0392, [2]Planetary Science & Life Detection Section, Jet Propulsion Laboratory, Pasadena, CA 91109,[3]Geological Survey of Canada, 3303 33rd St. NW, Calgary, Alberta, T2L 2A7, [4]Department of Geological Sciences, University of Colorado, Boulder, CO 80309-0392, [5]Division of Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401.

Introduction: Over several years, sulfur-rich springs and associated deposits of elemental sulfur, gypsum and calcite have been observed discharging onto a glacier at an isolated field site at Borup Fiord Pass (81°N, 81°W) on Ellesmere Island in the Canadian High Arctic (Figure 1). The spectral signatures of these sulfur-rich materials may be analogous to those of materials on the surface of Europa. Biological mediation of the local geochemistry of the site seems likely and abundant microbial communities have been encountered in the deposits [1].

Figure 1 – Sulfur-rich deposits obsewrvedduring the 2006 field season

A field expedition to Borup Fiord Pass was undertaken during June and July of 2006 to further explore the complex biogeochemistry of the site, and to provide ground truth for spectroscopic analyses of hyperspectral satellite imagery of the area. Geochemical measurements of spring waters were obtained in-situ, while samples of waters and associated deposits were collected for compositional, isotopic and microbiological laboratory analysis. Field spectra of the deposits were obtained using a ASD FieldSpecPro spectrometer on the ground and from helicopter. Hyperspectral imagery of the site was obtained from the Hyperion instrument aboard EO1 in a similar timeframe to the fieldwork.

Early results from DNA analyses and cultures of returned samples from our 2006 field season suggest the presence of sulfur-oxidizing and reducing bacteria which are contributing to the presence of elemental sulfur on the ice, as will be reported in future work.

The goals of this study are firstly, to understand the processes which have led to the deposition of these sulfur-rich materials on the ice, and secondly, to investigate how well these materials can be characterized and mapped by use of remote sensing techniques. It is the second aspect of this work which we report on here and which is of particular interest from a Europa perspective. The juxtaposition of sulfur chemistry and ice in a terrestrial setting provides a valuable opportunity to evaluate and enhance our ability to identify and map the distribution of sulfur minerals on ice by reference to ground truth. Future orbiters and early landers will aim to identify the non-ice materials on the surface of Europa, and to understand their origin. Borup Fiord Pass allows us to test remote sensing and in-situ techniques for application to Europa.

Spectroscopic analyses:

Spectral identifications. The main spectral signatures emerging from the hyperspectral imagery of the area of interest are those of the of ice and sulfur, the latter indicated by the rapid fall off in reflectance in the wavelength range of 0.4 - 0.5 µm. This drop can be seen in the Hyperion spectrum shown in Figure 2 and many of the field spectra shown in Figure 3. There may also be evidence for the bound water contained within gypsum in certain of the field spectra, indicated by the slight offset and distortion of some of the water bands normally located at 1.4 and 1.9 µm. Interpretation of the field spectra is aided by high resolution laboratory spectra of samples returned from the field.

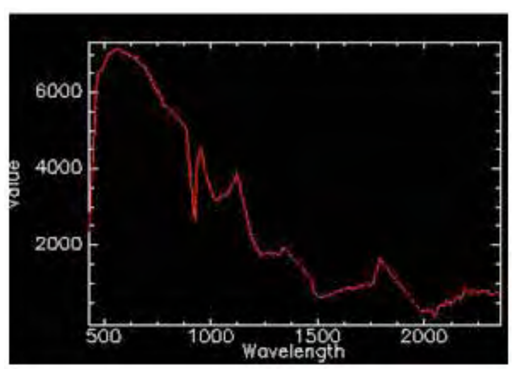

Figure 2 – Spectrally pure sulfur-rich pixel from Hyperion obtained July 16th 2006.

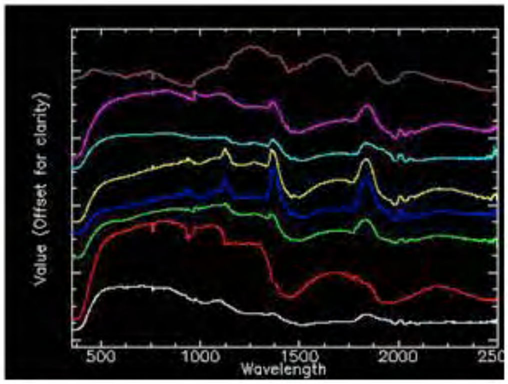

Figure 3 – Field-derived endmember spectra, see text.

Comparisons between satellite and in-situ measurements. Hundreds of spectra were obtained from the ground across a grid corresponding to 2x2 Hyperion pixels in size (1200m^2) across the sulfur-rich area of the glacial outwash plain seen in Figure 1. All of these spectra were averaged (shown in Figure 4, bottom) for the purposes of comparisons with the Hyperion spectra taken over the same area (Figure 4, top).

Using the averaged grid spectrum it is then possible to evaluate how well the corrected satellite data matches reflectances measured on the ground.

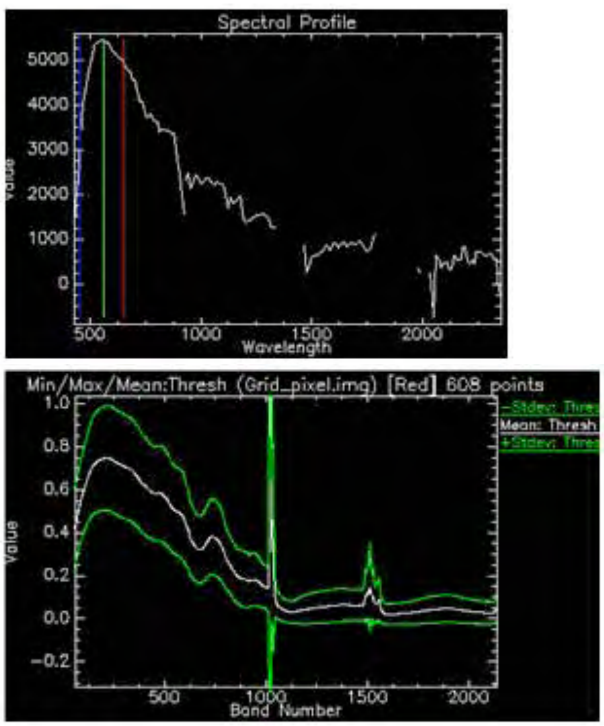

Figure 4 – Hyperion spectrum (top) vs. in-situ spectral measurements (bottom) across the sulfur-rich outwash plain

Mapping the deposit distributions. Using a sulfur-rich spectrally pure pixel (shown in Figure 2) as the endmember spectrum, sub-pixel analysis of Hyperion imagery was carried out based on the concept that each pixel spectrum is made up of a linear combination of endmember spectra with contributions owing to their areal coverage within the pixel. Mixture-tuned matched filtering (MTMF) refers to a partial unmixing where an endmember spectrum is compared to each pixel in the scene and a score returned for each one. Figure 5 below illustrates the results of the MTMF using the sulfur-rich endmember, where the pixels shown in red had a high matched spectrum filter score and a low infeasibility score, which reduces the risk of false positives while allowing pixels containing even low amounts of sulfur-rich coverage to be identified.

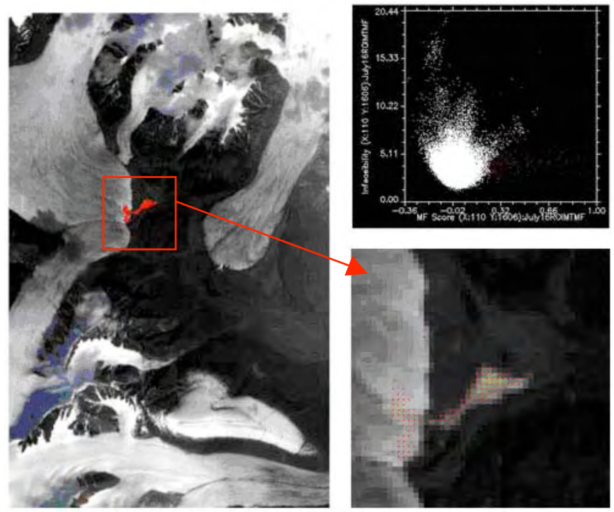

Figure 5 – Sulfur-rich deposits are mapped in red, with zoom window on bottom right. Top right is a scatterplot of matched spectrum filter score as a function of infeasibility score.

Limitations: Low solar incidence angle at high polar latitudes leads to reduced light intensity and consequent lower signal-to-noise ratios for much of the data. Other issues with the data include a slight artifact at about 0.9 µm in both Hyperion and field spectra where the two spectrometers overlap, and some overcorrection for water absorptions in the field spectra leading to peaks at major water absorption features. This results from rapid changes in moisture content in the air over the course of taking measurements.

Next steps for the project: Work is continuing to refine our spectral identifications and mapping of the spring deposits. Further spectroscopy will be carried out on materials produced by means of laboratory microbiological culturing experiments. It will also be of interest to investigate the effect of radiation on these samples. Low temperature spectra may be obtained of materials inferred to be present at the site based on spectral or geochemical analyses, to closer approximate the environment existing at Europa.

References: [1] Grasby, S.E. et al., *Astobiology*, 3, 583-596, 2003.