ENABLING EUROPA SCIENCE THROUGH ONBOARD FEATURE DETECTION IN HYPER-SPECTRAL IMAGES. M. Bunte[1,2], D. R. Thompson[3], R. Castaño[3], S. Chien[3], R. Greeley[1], [1]School of Earth and Space Exploration, Arizona State University, [2]mbunte@asu.edu, [3]Jet Propulsion Laboratory, California Institute of Technology.

Summary: We applied an automatic endmember detection algorithm to the Galileo NIMS catalog using the method of Thompson et al. [1]. Tests were run for automatic onboard detection of spectral anomalies. The endmember detection algorithm accurately retrieved spectra for features and anomalies that were not anticipated in advance of spacecraft observation. This method identifies regions of interest over both icy plains and dark linear features, the two major morphological feature types for Europa. Spectra retrieved for these regions capture the full range of diversity and at least one subtle anomaly reported in the literature.

Background: Future outer planets missions are limited in downlink bandwidth; under these circumstances, hyperspectral image data volumes limit their achievable coverage and science return over the mission lifespan. This is a particular concern for a future mission to Europa. Hyperspectral images might reveal novel spectra associated with fresh upwellings, surface material from eruptions, or other transient phenomena such as plumes or thermal anomalies. However, such features might be missed during standard mapping campaigns that accumulate coverage slowly and rarely target the same location twice.

Automated processing allows many images to be acquired and then analyzed onboard, thus increasing the opportunity to capture transient events and identify features associated with endmember materials. These key spectra could be downlinked *in lieu* of the image to characterize full spectral diversity at minimal additional bandwidth cost. In case of a significant anomaly, ground operators can downlink the entire image or schedule followup observations.

Approach: The harsh Jupiter radiation environment complicates automated analysis by constraining available computing power and limiting algorithm options. Additionally, it causes high levels of instrument noise that human analysts typically address by averaging spectra over surface features. This work favored a spatial averaging method that mimics such an approach and is computationally feasible for onboard use. Specifically, we used the superpixel endmember detection algorithm [1] to identify salient surface features. A superpixel segmentation over-segmented the images into homogeneous connected regions. Thereafter, the images were represented using the mean spectra of their superpixels. Spatial averaging alleviated mitigateed noise and reduced the number of spectra by one or more orders of magnitude, easing computational burdens for subsequent processing.

Evaluation: We applied superpixel endmember detection to the catalog of Galileo NIMS images of Europa. We included all images greater than 30 sample lines having a spatial resolution better than one degree of planetary latitude or longitude per pixel. This study was limited to the visible near-infrared region and only considered the spectral window between 0.7 and 2.5 microns. We combated detector saturation by extrapolating with a constant value from left to right across gap regions. We further preprocessed the image with a median filter of one-pixel diameter which also helped to reduce pervasive shot noise. After this initial processing, we employed superpixel endmember detection to produce a rank-ordered list of the most salient regions as in [1]. We evaluated detection performance by identifying key spectral features in previously published studies of NIMS data for comparison with salient spectra and by assessing the correlation between endmembers and surface morphology.

Results: A total of 30 images were analyzed by the endmember detection method; 17 were determined to produce viable spectral results. The average number of endmembers detected for each image was 8.5; the number ranged from 3 to 30 and was correlated with the quality and resolution of the original images. From the 17 viable images, 120 regions of interest were determined. Comparison with SSI images revealed a strong correlation between autonomously detected regions of interest and surface morphology (Fig.1).

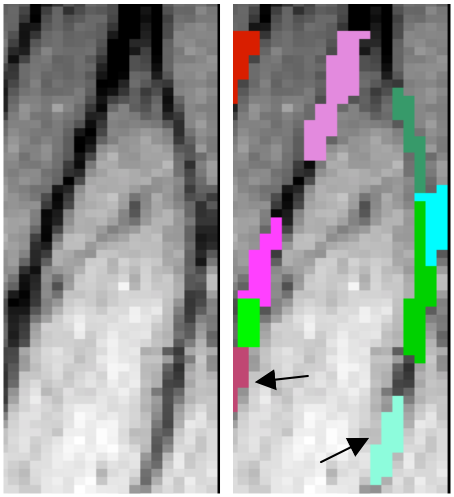

Figure 1. *Galileo NIMS 11ENCYCLOD01A. Each color represents a region of interest selected autonomously. These 9 regions coincide with dark linear features and are ranked in the top 20 of the 30 regions for this image. Spectra for two regions (arrows) in Fig. 2.*

Each image and its endmember regions of interest were examined by hand to assess the correlation with surface morphology and to evaluate the endmember priority ranking with respect to surface feature. 35% of the regions of interest are preferentially associated with dark linear features (i.e., fractures, ridges, or flexūs) while 65% correspond to the surrounding icy plains or mottled terrain. Evaluating only the top 3- or top 10-ranked endmembers reveals a consistent distribution; this suggests that linea are overrepresented relative to their fractional coverage of the surface. The distribution may be influenced by the selection of NIMS targets but reflects attention to both large-scale and outlier features.

Comparison of the salient spectra to previously published studies [2] confirmed that the autonomously retrieved spectra showed similar features such as the water of hydration absorption features at 1.5 and 1.9µm. Several of the salient spectra included the absorption feature at 2.05µm that was attributed by [2] to amide peptides (Fig. 2). Figure 2 illustrates the similarities between the autonomous and manually extracted spectra. The diversity in the near 2.0µm absorption feature as explored by [4-6] showed a correlation with surface features; spectra from dark linea have a narrower absorption feature than the spectra from icy plains regions (Fig. 3).

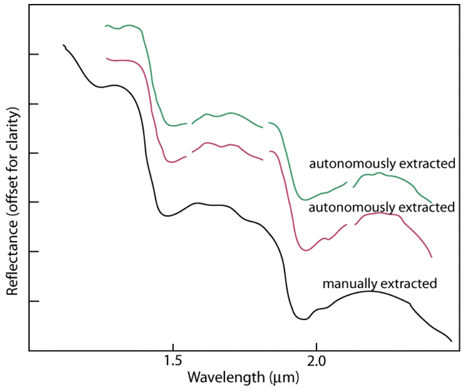

Figure 2. *Spectra for regions of interest selected autonomously (top pair) compared to manually extracted spectra of Europa (bottom, after [3]). Autonomously extracted spectra from regions selected by endmember detection method (colors match Fig. 1). Both exhibit absorption features at 2.05µm (see [2]). Breaks in spectral lines are due to removal of overlapping data. Black line: manually extracted average spectrum of Europa's dark terrain.*

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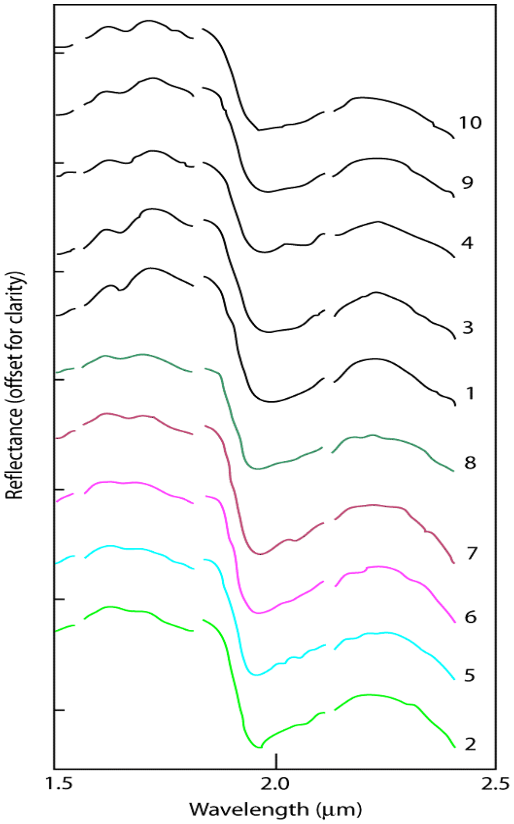

Figure 3. *Spectra for the top 10 endmembers selected autonomously; full spectral diversity is captured in these endmembers. The variation in the absorption feature at 2µm illustrates that autonomous extraction captures the key water absorption distortion in dark linea noted by [4-6]. Colors match regions of interest shown in Figure 1 for dark linea; black are icy plains. Spectra from dark linea have a narrower absorption feature than the spectra from icy plains regions.*

Conclusion: We have demonstrated the autonomous selection of regions of interest for each image of Europa in the Galileo NIMS catalog and confirmed that regions from both types of surface features are selected. We showed that an endmember detection algorithm can accurately retrieve spectra for features and anomalies. Numerical endmember detection does not require prior input from a spectral library or assumptions of surface composition and automatically identifies most spectral features reported in published analyses of the NIMS Europa data.

References: [1] D. R. Thompson, L. Mandrake, M. Gilmore, R. Castaño, (2011) Trans. Geosci. Remote Sensing, Nov. 2010. [2] J. Dalton (2003), Astrobiology 3:3. [3] J. Dalton (2010) Space Sci. Rev. 153, 219. [4] T. B. McCord and colleagues (1998) JGR 103, 8603. [5] T. B. McCord and colleagues (1999) JGR 104, 11827. [6] T. B. McCord, G. B. Hansen, J. P. Combe, P. Hayne (2010) Icarus 209, 639.