THE ANOMALOUS DICHOTOMY IN THE 1.65 µm WATER ICE FEATURE BETWEEN EUROPA'S LEADING AND TRAILING HEMISPHERES.

Tanner W. Hayes and Shuai Li. University of Hawai'i at Manoa (twhayes@hawaii.edu)

Introduction: It is currently understood that Europa's surface is composed of water ice with several candidates for a non-ice component(s), such as sulfuric acid hydrate [1], chlorides [2], or other salts species (e.g. hydrated sulfates, [3]); and, that these non-ice components could be associated with processes on the surface and the interior ocean [4-6]. The presence of these non-ice components has been proposed to explain the asymmetric absorptions bands observed at 1.5 and 2.0 µm in reflectance spectra obtained by the Galileo Near Infrared Mapping Spectrometer (NIMS). However, another seemingly anomalously behaving feature that has not been investigated is the feature at 1.65 µm which corresponds to crystalline H_2O ice at cryogenic temperatures. It has been well-documented that this feature is to first order temperature-dependent [7-9], and to second order particle size dependent [9]. The absorption strength of this feature can be quantified by using the Hapke effective single particle absorption thickness (ESPAT) parameter [10]. The effects of multiple scattering, viewing geometry, and phase function are accommodated for in the ESPAT parameter, which is advantageous to the typical band depth parameter.

We derive the ESPAT values for the 1.65 µm feature from NIMS data and find that they are much higher than those calculated from laboratory-measured, pure H_2O ice at temperatures equal to Europa's surface (<130 K, **Figure 1**). Diurnal temperature variation cannot fully account for this increase, nor can particle size contributions [10]. Additionally, mixtures of H_2O ice with candidate non-ice materials results in the weakening or complete masking of the 1.65 µm feature, which can be seen in many of the spectral mixture analyses performed on NIMS data [11-14]. In cases where the 1.65 µm feature is fit well by modeled spectra, error increases at other wavelength ranges to compensate [11]. Irradiation of crystalline ice into amorphous ice produces a similar weakening/removal effect [9].

The 1.65 µm feature strength is difficult to explain based on our current understanding of Europa's surface. Not only are ESPAT values on Europa anomalously high, but also they are higher on the trailing than on the leading hemisphere (**Figure 2**). The trailing hemisphere is preferentially radiated by high energy particles carried by Jupiter's magnetic field [15]. This radiation should lead to an increase in non-ice component abundance on the trailing hemisphere [6, 16], and thus a decreased surface ESPAT value.

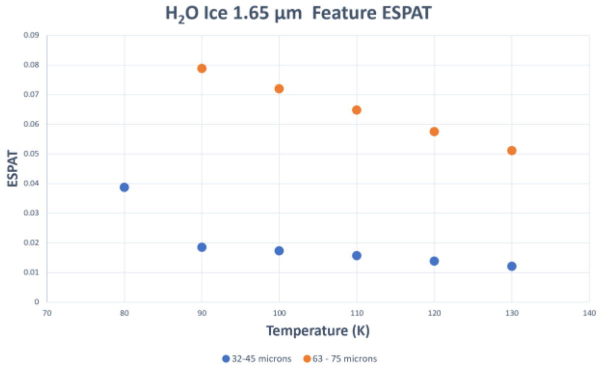


Figure 1: ESPAT values for H_2O ice at particle size groupings of 32 – 45 µm and 63 – 75 µm taken at various temperatures.

We propose several explanations for the high and anomalously distributed ESPAT values on Europa's surface. Current spectral libraries do not contain comprehensive spectra of candidate non-ice materials recorded at cryogenic temperatures at sufficient particle size groups. The 1.65 feature may be present in hydrated mineral species, which may affect or preserve the 1.65 µm feature's strength while depressing reflectance at other wavelengths. Alternatively, the effects of coating have not been fully explored; nanophase ice coating on Europa's surface particle grains may allow for a low-reflectance spectrum with a high 1.65 µm absorption due a high chance of scattering of light in the ice coating layer. Additional irradiation effects, other than the conversion of crystalline ice into amorphous ice, may also influence the 1.65 µm feature's strength.

Methods: Spectra of candidate species such as sulfuric acid hydrate, chlorides (e.g. NaCl and MgCl), and sulfate salts ($MgSO_4 \cdot nH_2O$) will be obtained at temperatures ranging from 80 – 130 K and at particles ranging from < 20 to 250 µm. This particle size range can be achieved through the use of a nebulizer which sprays directly into liquid nitrogen. Sieves will be used to create several particle size groupings. Cryogenic temperatures can be achieved by placing samples in a vacuum-sealed Linkam stage, which is capable of decreasing sample platform temperatures to as low as ~78 K, as well as removing ambient atmosphere to reduce contamination of atmospheric volatile condensation (e.g. H_2O, O_2) on the sample.

Using this spectral library, we will follow the intimate mixture model described in [17] to deconvolve NIMS reflectance spectra into compositional endmembers and estimate their abundances. Temperature values derived from NIMS reflectance spectra following [18] will further constrain the spectral inputs in the intimate mixture model.

Preliminary Results and Discussion:

Spectral Library Creation

Currently, we have created samples of sulfuric acid octahydrate with particles ranging from 45 - 106 µm. Our spectra exhibit a high near-visible reflectance and low NIR reflectance, with a very minor absorption at 1.65 µm across all particle sizes that remains constant at temperatures between 80 K to 130 K.

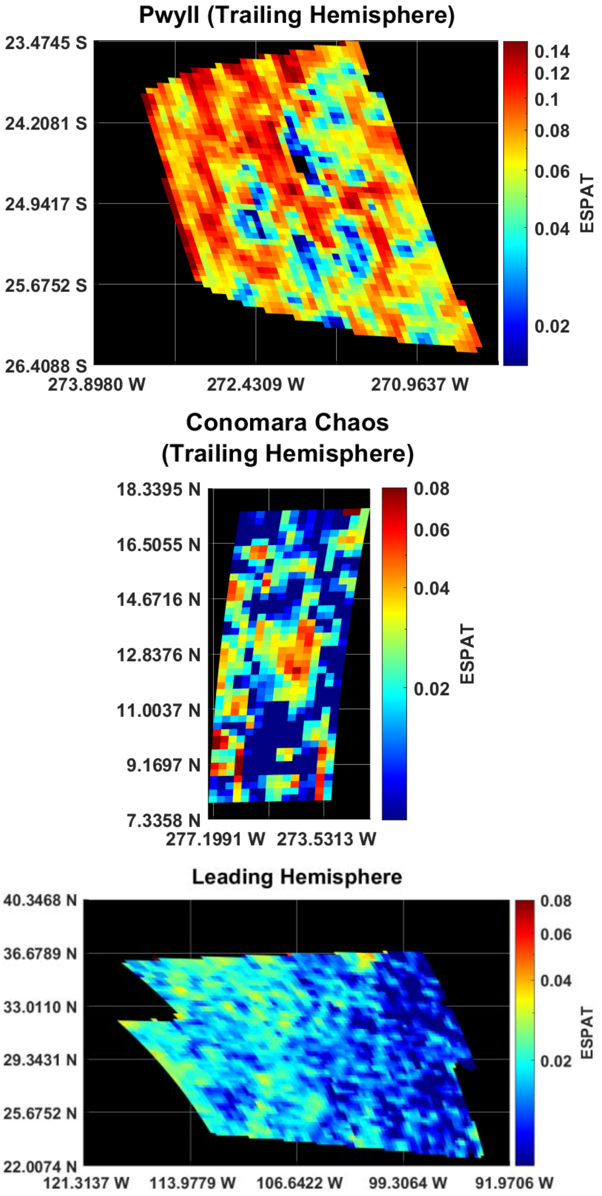
ESPAT Distribution

Figure 2 shows ESPAT maps for three regions on Europa: Pwyll, a region slightly west of Conomara Chaos, and a section of the leading hemisphere. Both trailing hemisphere maps have ESPAT values higher than pure H_2O ice at equivalent temperatures. Moreover, Pwyll's ESPAT values are much higher than other trailing hemisphere regions. As a relatively young crater, Pwyll has not bathed in Jupiter's radiation environment as long as the Conomara Chaos, but this does not explain the enhancement of ESPAT relative to pure H_2O ice.

Future Work: Sulfuric acid hydrate measurements will be continued for the full desired particle size range. Chlorides and hydrated sulfates need to be produced at measured at all desired particle size groups and temperatures. As we obtain the optical constants for our spectral endmembers, we can begin to explore the effects of nanophase coating.

Surface temperatures of Europa will be derived using longer wavelength sections (4 - 5 µm) of NIMS spectra following [18] to directly compare the 1.65 µm ESPAT of a pixel with its temperature.

Current ESPAT maps only use datasets for which all 360 NIMS bands have values. There are several high resolution datasets that do not have data in all 360 bands but do have data in the 1.65 µm wavelength range that we have not yet used to produce maps.


Pwyll (Trailing Hemisphere)

Conomara Chaos (Trailing Hemisphere)

Leading Hemisphere

Figure 2: ESPAT values calculated from NIMS cubes 12e001ci (Pwyll), 14e005ci (Conomara Chaos), and 15e016ci (Leading Hemisphere). The image of Pwyll is scaled separately from the other images.

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