EPSC Abstracts
Vol. 13, EPSC-DPS2019-866-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Surface Water Ice Crystallinity of Europa's Leading Hemisphere on a Regional Scale

Jodi R. Berdis (1), Nancy J. Chanover (1), Jim R. Murphy (1), Murthy S. Gudipati (2)
(1) Astronomy Department, New Mexico State University, New Mexico, USA.
(2) Jet Propulsion Laboratory, California Institute of Technology, California, USA.

Abstract

Physical surface processing by charged particle bombardment, thermal relaxation, and cryovolcanic activity can alter the percentage of crystalline water ice compared to that of amorphous water ice (the "crystallinity") of Europa's surface. The surface water ice on Europa's leading hemisphere is ~45−60% crystalline according to ground-based observations [1, 2], however, temperature and radiation modeling suggest an expected ~85% crystallinity [2]. In order to probe the source of this discrepancy, we analyze the crystallinity of specific regions (such as lineae, pits and domes, and chaos terrain) on Europa's leading hemisphere and contextualize their surface placement into our understanding of Europa's full-disk leading hemisphere crystallinity.

Introduction

Europa's young, predominantly water ice surface is only ~10^7−10^8 years old due to resurfacing by geophysical processes and effects of its sub-surface liquid water ocean [3, 4]. The timescales over which amorphous water ice is thermally transformed to crystalline water ice at Europan surface temperatures (80−130 K) suggests that the Europan water ice should be primarily in the crystalline form, where amorphous water ice at T ~ 90 K, for example, will relax into crystalline water ice after 10^5 years [5, 6]. However, charged particle bombardment and vapor-deposited water ice from plumes can produce partial amorphous water ice surface deposits, decreasing the overall surface fraction of crystalline water ice compared to amorphous water ice, i.e., the crystallinity. The type and magnitude of physical processes at play, such as charged particle bombardment due to Jupiter's magnetic field, and vapor-deposited plume material could likely be deduced by determination of the crystallinity.

Several water ice absorption bands in the near-infrared can be useful tools in quantifying the crystallinity of an ice sample or icy surface. Water ice absorption features at 1.5, 1.65, 2.0, and 3.1 µm increase in depth and shift to longer wavelengths as the crystallinity increases [7, 8, 9]. The absorbance band areas of the 1.5 and 1.65 µm bands increase linearly as the crystallinity percentage increases [6, 8]. Comparison of spacecraft or ground-based spectra to laboratory spectra of pure crystalline and amorphous water ice can aid in determining the crystallinity of a surface. In order to approximate the crystallinity of surface features on Europa, end-member spectra indicative of pure crystalline and amorphous water ice may also be identified in regions near the surface features for which we seek to determine the crystallinity [e.g. 10, 11].

The surface water ice crystallinity of Europa's leading hemisphere as deduced from comparison of ground-based spectral observations to laboratory spectral experiments is ~45−60% [1, 2]. However, the crystallinity we expect to see based on temperature modeling and radiation flux is closer to ~85% [2]. In order to elucidate a possible reason for this discrepancy, we approximate the crystallinities of several regions of Europa's leading hemisphere on a more local scale and analyze our results within the context of the calculated and modeled global crystallinities.

Methods

The Near-Infrared Imaging Spectrometer (NIMS) instrument onboard the Galileo spacecraft acquired spectral image cubes of Europa's surface over the wavelength range 0.7−5.3 µm at spatial resolutions down to <3 km. We are employing the USGS Integrated Software for Imagers and Spectrometers (ISIS3) software to process these image cubes and locate surface features of interest. We are specifically targeting features such as lineae, pits and domes, and chaos terrain on the leading hemisphere at which high resolution NIMS spectra are available. We employ an approach similar to that of Hansen & McCord [10] by identifying crystalline and amorphous end-member spectra that are spatially close to surface features of interest. We then calculate the band areas of the 1.5 and 1.65 μm spectral regions of the targeted surface feature spectra and compare them to a linear sum of the end-member amorphous and crystalline band areas by assuming:

$$BA_{NIMS} = (xtal \times BA_{cryst}) + (1 - xtal) \times BA_{amor} \quad (1)$$

In Eqn. 1, BA_{NIMS} represents the band area of the 1.5 μm and 1.65 μm regions, BA_{cryst} is the band area for the end-member crystalline spectra, BA_{amor} is the band area for the end-member amorphous spectra, and *xtal* is the crystallinity of the surface feature spectra for which we are solving.

Once approximate crystallinities are calculated for these leading hemisphere spatially resolved regions, we evaluate possible origins and histories that may have led to their crystallinities. We employ the Incipient Code for Investigating the Crystallinity of the Leading-hemisphere of Europa (ICICLE), which generates simulated surface temperature cycles on Europa and calculates crystallinities based on the thermal relaxation of amorphous water ice to crystalline water ice, and the transformation of crystalline water ice to amorphous water ice via ion bombardment [2]. Using ICICLE, we identify if the crystallinities we calculate from the NIMS spectral observations are expected based on the thermal history and radiation flux at the locations of these features of interest. Additionally, we implement a simple extrapolation of the regional crystallinities to a global crystallinity and compare with results from Berdis et al. [2]. Discrepancies between the regional and global crystallinities can elucidate the spatial extent of physical processes impacting Europa's surface.

Summary and Conclusions

We present preliminary results of determining the approximate crystallinities of localized regions of interest such as lineae, pits and domes, and chaos terrain on Europa's leading hemisphere. We speculate upon the origin of these features based on their crystallinities, and evaluate their surface emplacement into our understanding of Europa's leading hemisphere surface history and crystallinity based on results from Berdis et al. [2].

Acknowledgements

This study was funded by NASA under Grant 80NSSC17K0408 issued through the NASA Education Minority University Research Education Project as a NASA Harriett G. Jenkins Graduate Fellowship. A part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA. Funds were provided through NASA Solar System Workings Program.

References

[1] Ligier, N. et al. (2016), *AJ*, 151, 163.

[2] Berdis, J. et al (2019, in prep), *Icarus*.

[3] Zahnle, K. et al. (1998), *Icarus*, 136, 202.

[4] Pappalardo, R. et al. (1999), *JGR*, 104, 24015.

[5] Kouchi, A. et al. (1994), A&A, 290, 1009.

[6] Mastrapa, R. et al. (2013), *The Science of Solar System Ices*, 371.

[7] Schmitt, B. et al. (1998), *Solar System Ices*, 199.

[8] Mastrapa, R. et al. (2008), *Icarus*, 197, 307.

[9] Mastrapa, R. et al (2009), *ApJ*, 701, 1347.

[10] Hansen, G. & McCord T. (2004), *JGR Planets*, 109, E01012.

[11] Dalle Ore, C. et al. (2015), *Icarus*, 261, 80.