EPSC Abstracts
Vol. 5, EPSC2010-564, 2010
European Planetary Science Congress 2010

Space weathering perspectives on Europa amidst the tempest of the Jupiter magnetospheric system

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Abstract

Europa resides within a "perfect storm" tempest of extreme external field, plasma, and energetic particle interactions with the magnetospheric system of Jupiter. Missions to Europa must survive, functionally operate, make useful measurements, and return critical science data, while also providing full context on this ocean moon's response to the extreme environment. Related general perspectives on space weathering in the solar system are applied to mission and instrument science requirements for Europa.

1. Introduction

The compositional and energetic interaction relations of Europa to Io and the Jupiter magnetosphere are writ large on this ocean moon through the apparent deposition of sulfur, at least partly from iogenic plasma interaction [1], onto the trailing hemisphere and by radiolytic generation of the thin oxygen atmosphere mainly [2] in regions of purer water ice. Crustal resurfacing processes may both carry these surficial species deep into the interior, e.g. forming mix-gas clathrates potentially altering thermal conductivity and thickness of the ice crust [3], and convey oceanic chemistry to the sensible surface. The extreme plasma and energetic particle radiation environment [4,5] presents both a challenge and a boon, since surface materials brought up from below have short lifetimes at highest dosage and oxidation rates, but surface and atmospheric sputtering processes make such materials more immediately accessible to orbiters. But the central problem common to space weathering situations [6] is how to distinguish the thin outer patina of mostly iogenic species from those intrinsic to the body interior and necessary for understanding of oceanic evolution. The most sensitive technique for sounding of a modern Europa ocean, generation of induced magnetic fields from jovian magnetospheric field interaction, is also potentially obscured by external currents arising from the magnetospheric plasma interaction. Thus we must sense the tell-tale oceanic heart of Europa, including its chemistry and magnetodynamics, and any subtle biochemical signatures of potential or actual habitability, through a plasma & field "perfect storm" tempest of origin ultimately from Io volcanism, jovian magnetospheric dynamics, and moon surface & atmospheric interactions.

2. Recommended Approach

The multi-platform approach of the planned international Europa Jupiter System Mission is clearly needed to unravel these complex relationships and allow definitive understanding of Europa chemical evolution and present morphology in the context of interconnections to the Jupiter system. Each platform must carry the appropriate science payload to assure safe and reliable operations with maximal data return for the measurements most critical to questions of origin, evolution, and present state for Europa and Galileo's other moons. For the Jupiter Europa Orbiter there must be the right mix of magnetic field, plasma, energetic particle, and neutral gas instrumentation to fully characterize both the upstream magnetospheric environment and the near-surface environment where products of the extreme moon-magnetosphere interaction are manifested and detectible. Of particular importance from the space weathering perspective [6] is the full specification of elemental & molecular composition across the full periodic table, including major isotopes, for both the iogenic source of magnetospheric plasma versus what may be found of intrinsic origin from the moon surface and atmosphere. If we are to later send landers to search for chemical anomalies potentially related to oceanic and any associated biology activity, past and present, the full characterization of the background compositional environment, iogenic and intrinsic, is essential. A vigorous international effort on laboratory measurements of candidate surface material evolution with respect to space weathering effects is an absolute necessity. Also operationally, we need realistic computational and laboratory simulation facilities to plan mission and instrument operations for full specification, mitigation, and even exploitation of extreme environment effects to achieve mission science goals. Finally, there must be sustained efforts to integrate evolving physical models of the moon-magnetosphere interactions [7] into mission data analysis plans so that complete views of these variable interactions and effects are visible through open data environments to knowledgeable teams of researchers and with more educational views for the general public. Such virtual observatory facilities are rapidly evolving within the U.S. and international heliophysics community [6] and can be very usefully applied to Europa and other planetary interaction environments.

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