National Aeronautics and Space Administration

Enceladus Distributed Geophysical Experiment (EDGE)

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Program: Enceladus Surface Sample Acquisition for In Situ Measurements

Project Objective:

(1) Determine the 4D tidal response of Enceladus based on the final *Cassini* data set to predict deformation and seismic activity.
(2) Understand the provenance of sampled surface materials: Link ocean dynamics with the surface deposits and ice-ocean exchange to geological activity.
(3) Identify the best geophysical techniques for understanding the interior dynamics and properties. As a possible path forward, if seismology is determined to be the best way path to probing the interior two objectives are identified for FY20 and FY21:
(4) Develop the use of ambient seismic noise for Enceladus seismic imaging.
(5) Enable reduced data rate return of continuously updated subsurface images and located seismic activity using in-situ computing to process large volumes of network data.

FY18/19 Results:

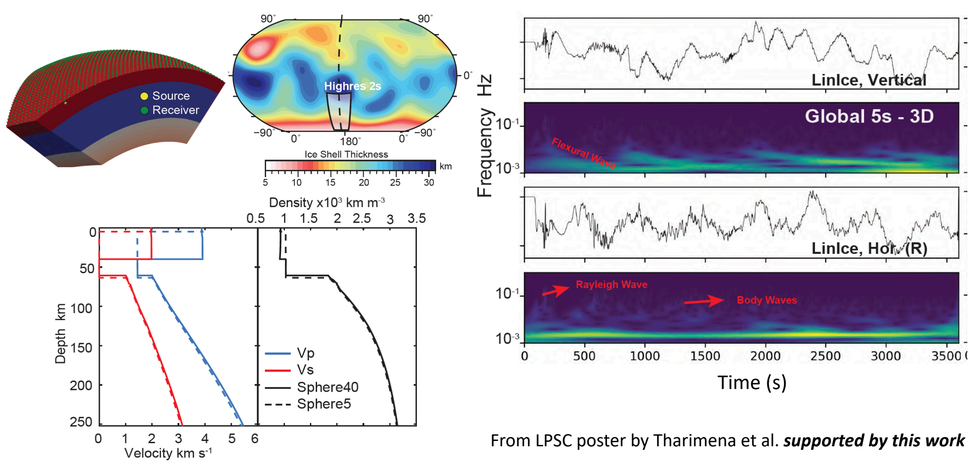
Assembled a team of experts to assess science questions and measurements needed for future geophysical exploration of Enceladus
Drafted a white paper and refined this draft into a two-page LPSC abstract
Model development:
3D finite element meshes associated with tidal dissipation and topography
Calculations of seismic waveform propagation
Chemical models for Enceladus formation and ocean composition
Density class model for overturning ocean circulation coupled to ice transport
Libration calculations
Plume mechanics coupled to seismic waves

Benefits to NASA and JPL

This work is evaluating the advantages of networked geophysical investigation on Enceladus as a complement to future searches for life. A thorough geophysical investigation is needed for characterizing the habitability of Enceladus, which is the context for any putative life discovery.

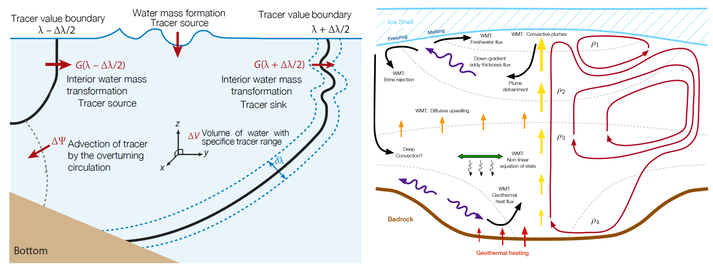
This work directly benefits studies of surface sampling by evaluating surface deposition of materials from below using more detailed thermodynamic modeling than has been available previously, coupled with rigorous geophysical modeling based on *Cassini* results.

The first 3D models of seismic propagation matched to topography and ice thickness. These will allow us to assess the feasibility of different instrument types, placement on spacecraft, number, and geographic location.



From LPSC poster by Tharimena et al. ***supported by this work***

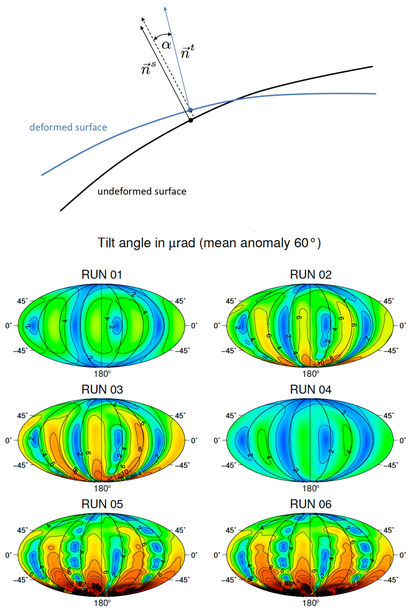
We are developing oceanographic models to explore how melting influences circulation and vice versa. This feeds into the nature of tidal dissipation, and possible magnetic induction signatures.



From SSW proposal submitted by A. Thompson
A. Lobo to present at AGU 2019

Computed surface tilt based on our structural models, using methods established by collaborators (Behounkova et al. 2017, Cadek et al. 2019).

The example shown here demonstrates the feasibility of using tilt to measure local tidal dissipation. Based on these results, such measurements would be possible only from the surface, not from orbit.



From LPSC abstract and poster by Vance et al.
supported by this work

We considered numerous measurement techniques for addressing science questions at Enceladus

Science questions	Science areas	Measurements
How and where is tidal dissipation distributed in Enceladus?	Ice crust, ocean, rocky core	Thermal, seismic, gravity, LiDAR, tilt
What characterizes the dichotomy between the North and South Polar terrains, and what is it caused by?	Ice crust, ocean, rocky core, active features	Gravity, stereo mapping, thermal mapping, seismic, ,
How prevalent is ongoing water-rock interaction, and where does it occur?	Ocean, rocky core, active features	Seismic, EM Sounding
What is the composition, structure and thermal state of Enceladus' rocky interior? How porous is it?	Rocky core	Seismic, gravity
What is the ocean's extent and composition? What are the ocean's dynamics and structure?	Ocean, active features, ice shell	Seismic, EM sounding
What are the physical conditions at the plumes? What is the thermal output and structure around the plume sources?	Active features, ice shell	Stereo mapping, thermal mapping, InSAR, LiDAR, seismic
What are the composition, extent, density, temperature , dynamics and structure of the ice shell?	Ice shell	Seismic

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Publications:

[1] Tharimena, S., M. P. Panning, S. D. Vance et al. (2019) Insights into the Seismic Structure of Icy Moons from Full Waveform Modeling. LPI Proceedings, Abstract 1606.

[2] Vance, S. D. et al. (2019) Enceladus Distributed Geophysical Exploration. LPI Proceedings, Abstract 1749.

[3] Lobo, A., A. Thompson, and S. Vance (2019) Overturning Ocean Circulations in Ocean Worlds. AGU Fall Meeting Abstract 572579.

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