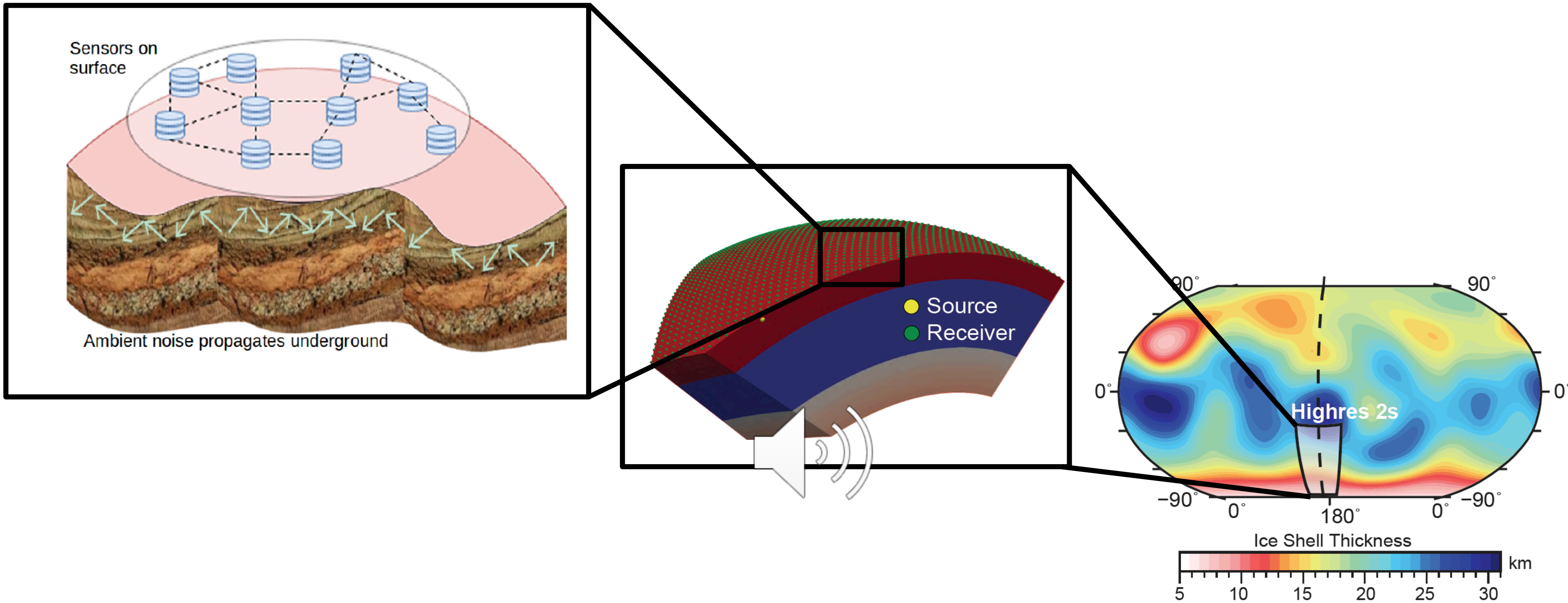

Virtual Research Presentation Conference

Enceladus Distributed Geophysical Experiment (EDGE)

Principal Investigator: Steven Vance (322)
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Program: Strategic Initiative

RPC-081

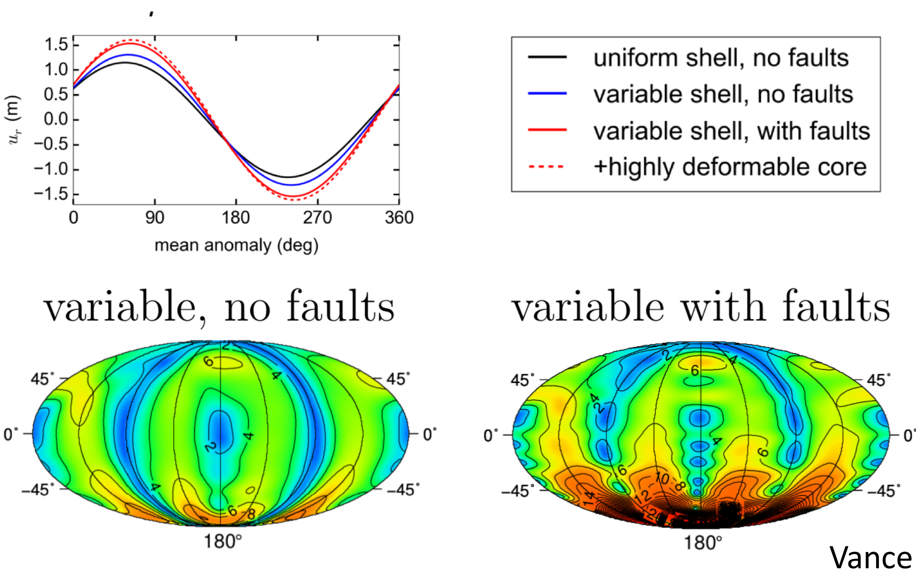
Jet Propulsion Laboratory
California Institute of Technology

Introduction

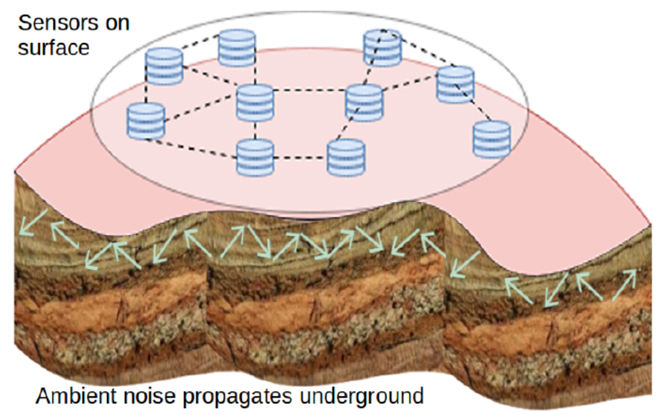
Abstract

The goal of the three-year strategic task is to **demonstrate the advantages of networked geophysical investigation on Enceladus.** In addition to documenting the enhanced science return associated with the objectives of a future Enceladus lander mission, we hope to demonstrate that a networked approach reduces risks associated with data volume transmitted to Earth by enabling on board processing.

As part of this work, we are also examining the science return of different types of geophysical measurements



Vance et al. 2020a



Wang et al. 2020

Problem Description

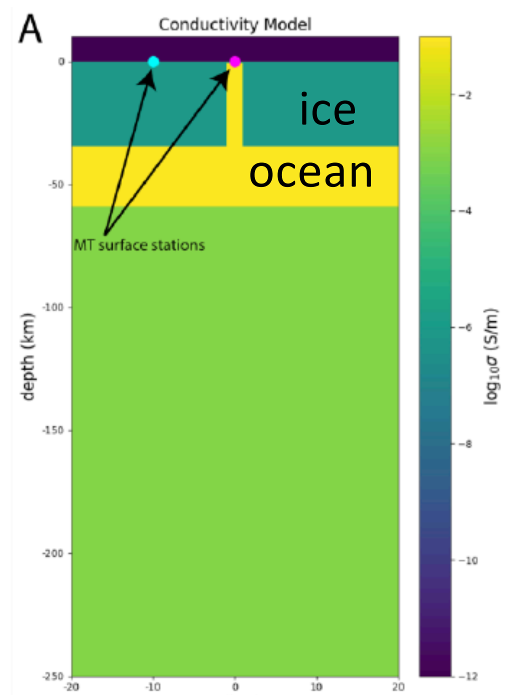
a) A future in-situ mission to the surface of Enceladus could be the lowest cost mission to determine if life exists beyond Earth, since material from the subsurface ocean, where the presence of hydrothermal activity has been demonstrated by the Cassini mission, is available on its surface after being ejected by plumes and then settling on the surface.

b) JPL is a leader in ocean world seismology and thus on the placement of seismometers on Enceladus. Co-I Song at UG Athens contributes ambient noise imaging and time reversal and migration techniques for seismic networks.

c) This study also considers active electromagnetic experiments that might resolve the near surface structure of fluid pockets in the ice, and passive ones that might constrain the ocean's structure and salinity. Co-I Schmidt at Georgia Tech contributes astrobiological expertise, and modeling work on active EM sounding.

d) We are collaborating with groups in France and the Czech Republic to examine gravity and geodetic methods to understand the tidal dynamics of Enceladus.

e) This activity will influence the Planetary Science Decadal Survey with publications on planetary network optimization, demonstrating their feasibility relative to cost and risk, and strengthening JPL's leadership in both planetary seismology, EM sounding, and Enceladus mission architecture.



Schematic for EM study

Methodology

a) Model the interior structure of Enceladus using *Cassini* results and detailed chemical/physical data (Vance et al. 2018)

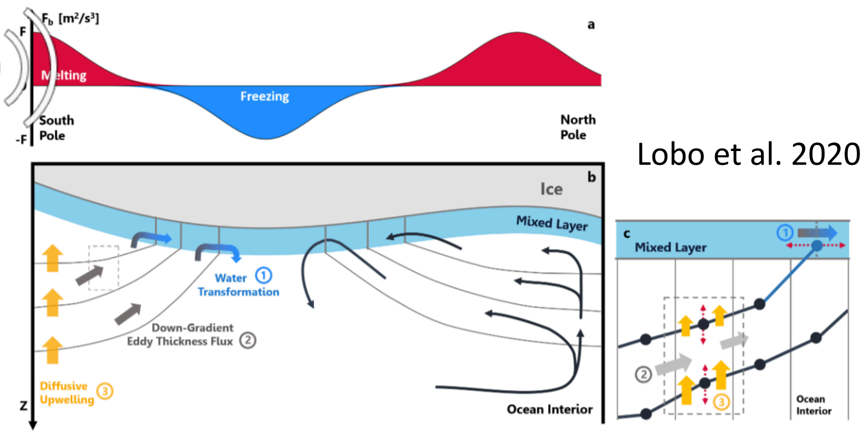
b) Compute the associated tidal dissipation and surface tilt based on radial structure models (a)

c) Evaluate oceanic flows in relation to the structure of the ice (Fig: below left)

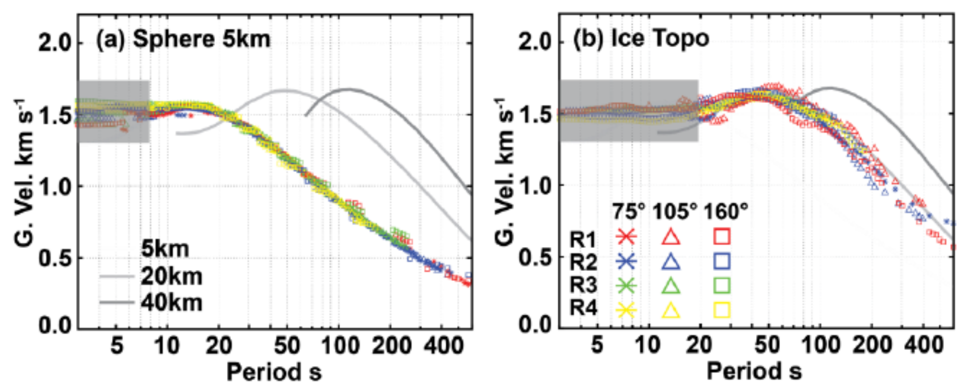
d) Develop 3D seismic forward modeling of Enceladus using the new software package Salvus (Fig: below right)

e) Develop Ambient Noise Seismic Imaging (ANSI) for use in future landed seismic networks

f) Develop active and passive electromagnetic sounding to determine the near and deep structure of Enceladus



Lobo et al. 2020



Tharimena et al. in prep

Results

a) Accomplishments versus **goals**

- a) **We submitted two white papers (Vance et al. 2020a,b) and contributed to a third for an Enceladus Flagship study (MacKenzie et al. 2020)**
- b) Under revision:
  - a) paper on flow dynamics in the ocean of Enceladus driven by melting and freezing at the ice interface (Lobo et al. 2020)
  - b) Also presented at the AGU Fall meeting 2019
- c) Published: paper on Ambient Noise Seismic Imaging (Wang et al. 2020)
- d) Presented: initial results for 3D models of Enceladus demonstrating the effects of non-uniform ice thickness on wave propagation
- e) With additional support from 4x, we conducted an A-Team study of geodesy at Enceladus
- f) We demonstrated the potential for sounding the structure of Enceladus using electromagnetic methods

b) Significance

- a) These results can be essential parts of a future mission to Enceladus
- b) Overall, we made good progress in arguing to the outer planets community that any future mission should include geophysical experiments sufficient evaluate the habitability context for any discovered biosignatures

c) Next steps

- a) In FY21 we will work to publish our remaining work:
  - a) Finish revisions to Lobo et al 2020
  - b) Investigate Time Reversal and Migration Imaging to further enhance the science return of seismic networks
  - c) Publish work on 3D wave propagation in Enceladus

Publications and References

Lobo, A., et al. (2019). Overturning Ocean Circulations in Ocean Worlds. Oral presentation at the Fall AGU Meeting P52B-07.

Lobo, A. et al. (2020) A pole-to-equator ocean overturning circulation on Enceladus. Nature Geoscience, under revision.

MacKenzie et al. (2020) Enceladus Orbilander, A Flagship Mission Concept Study for Astrobiology. A white paper submitted to the 2023 NRC Planetary Science Decadal Survey

Vance et al. (2020a) Distributed Geophysical Exploration of Enceladus and Other Ocean Worlds. A white paper submitted to the 2023 NRC Planetary Science Decadal Survey

Vance et al. (2020b) Planetary Seismology: the Solar System's Ocean Worlds. A white paper submitted to the 2023 NRC Planetary Science Decadal Survey

Wang, S., Li, F., Panning, M., Tharimena, S., Vance, S., and Song, W. (2020). Ambient Noise Tomography with Common Receiver Clusters in Distributed Sensor Networks. IEEE TRANSACTIONS ON SIGNAL AND INFORMATION PROCESSING OVER NETWORKS