Methane Clathrate Effects on Seismic Propagation within Titan

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1. Introduction

Titan is the target of the upcoming New Frontiers mission, Dragonfly. As part of the payload, Dragonfly will carry a seismic package[1]. Here, we investigate how a 10 km methane clathrate lid could alter the thermal and seismic profile, and the seismic response (ground motion) compared to a pure water ice model.

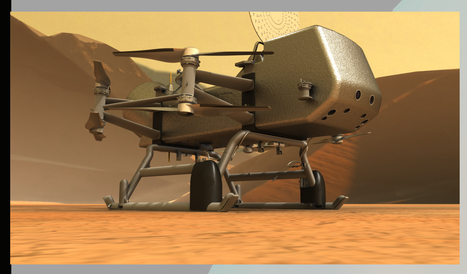
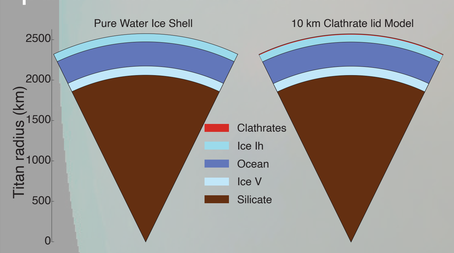


Image credit: JHU APL

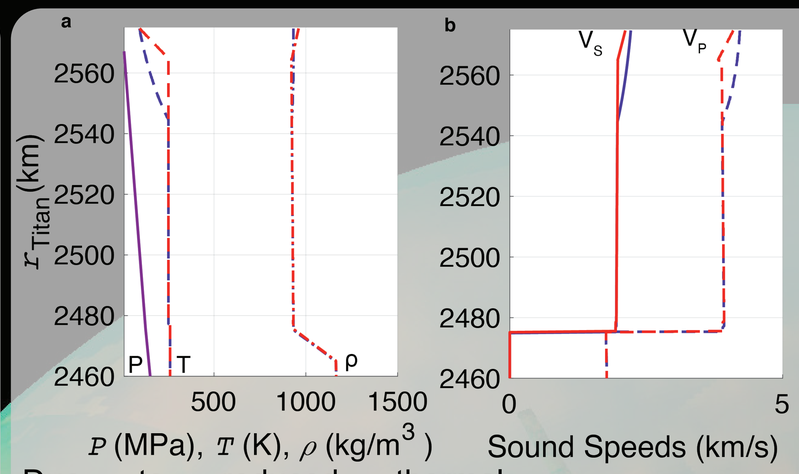
2. Methods

We create interior models using PlanetProfile[2]. The models have identical interiors, except one has a 100 km thick pure water ice Ih shell, and the other has a 10 km clathrate lid over a 90 km pure water ice Ih shell.

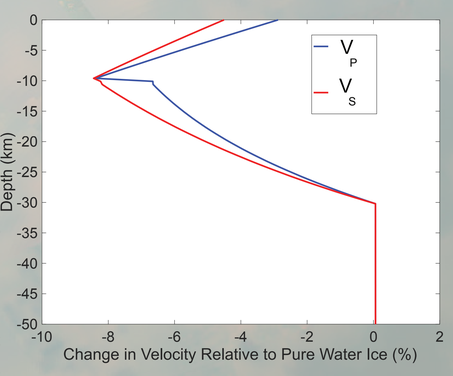


To calculate the seismic velocities we use the SeaFreeze[3] library for ice Ih and published laboratory results for clathrates[4,5]. Clathrates have similar bulk properties to ice, but have much smaller thermal conductivities.

3. Thermal & Seismic Profiles



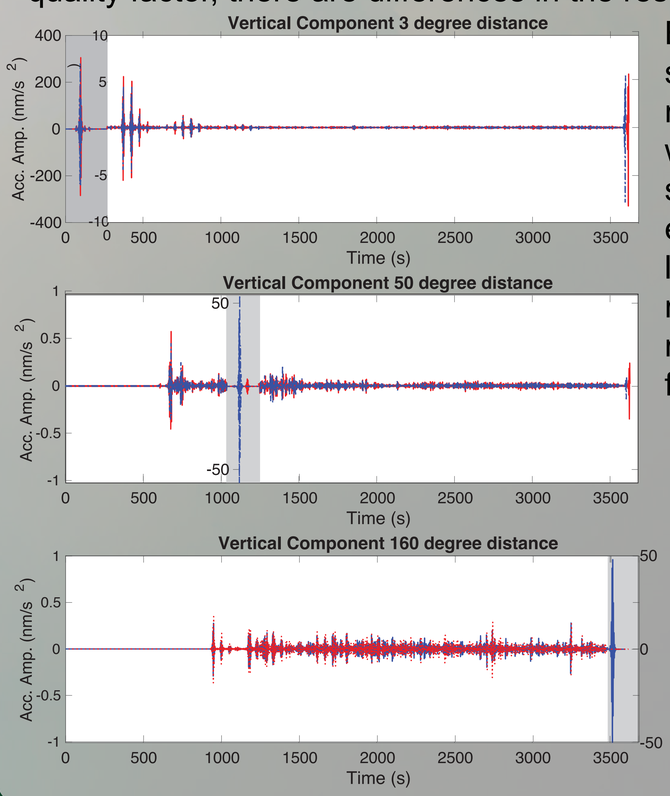
Due to reduced thermal conductivity, clathrates will act as insulators and decrease the conductive lid thickness relative to a pure water ice shell. The reduction in conductive lid allows warmer, more ductile, ice to exist closer to the surface. There will be differences in thermal profiles (a), creating changes in seismic profiles (b) and seismic quality factors (c).



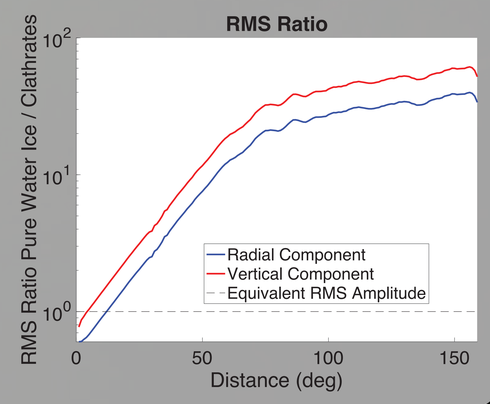
The change in seismic velocities maximizes at a depth of about 10 km. The difference is up to 8.5 %, which could be detectable.

4. Ground Motion Effects

We use Instaseis[6] and AxiSEM[7] to generate ground motion from a Mw 3.1 quake occurring at a depth of 3 km. Due primarily to the differences in seismic quality factor, there are differences in the resulting waveforms.

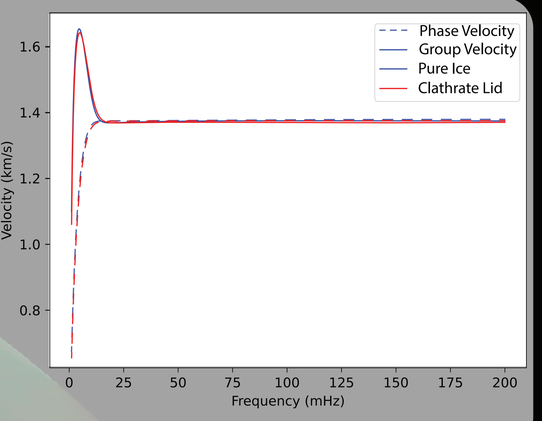


Because the clathrate lid suppresses surface waves the root mean square (RMS) of the waveform will also be much smaller. We compare the RMS of each waveform from the clathrate lid model to the pure water ice model. The clathrate model reduces RMS values by up to a factor of 75.



5. Surface Wave Dispersions

We use Mineos[8] to model the dispersion curves of surface waves. The group (solid) and phase (dashed) for both models are nearly identical. The velocities differ by less than 2% between the models.



6. Summary

- The clathrate lid will reduce the conductive lid thickness of the ice shell.
- The change in conductive lid thickness results in differences in the thermal profile.
- The change in thermal profile results in changes in seismic velocity profile (up to ~9%).
- The change in thermal profile also affects the seismic quality factor (Q_S).
- Reduced Q_S suppresses the surface waves in the clathrate lid model, reducing the ground motion.
- There are small (<2%) differences in the surface wave dispersion curves.

7. Acknowledgements

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8. References

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