Twilight on Kraken

Artwork: Michael Carroll

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A Brief History of TiME

- Liquid hydrocarbon lakes, then seas discovered 2006/7
- TiME proposed in 2007 to DSMCE call for PI-led missions enabled by ASRG Stirling Generator
- Concept refined during DSMCE study (arrival 2022); proposed to Discovery-12 opportunity in ~~2009~~ 2010. Draft AO stipulates launch NLT Dec 2016. (ASRG delivered NET March 2014)
- TiME Selected May 2011 for Phase A study (arrival 2023)

Demo engine by Rev. Dr. Stirling himself. in 1818. Photo R. Lorenz in the archives of the National Museum of Scotland, July 2013

In August 2012, NASA selected the Insight Mars seismology investigation as the next Discovery mission."ASRG development status did not affect selection"

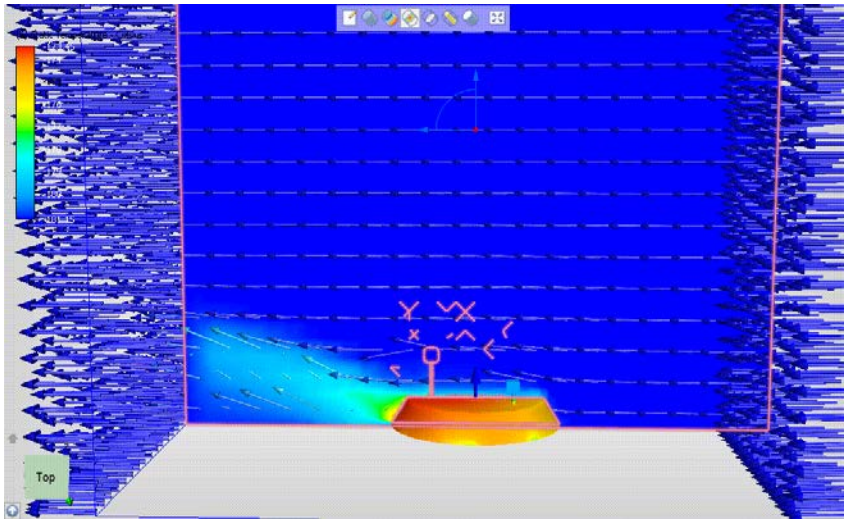
November 2012, "after restructuring of the management team" new ASRG schedule announced: 2 units *ready for fueling* *October 2016.*

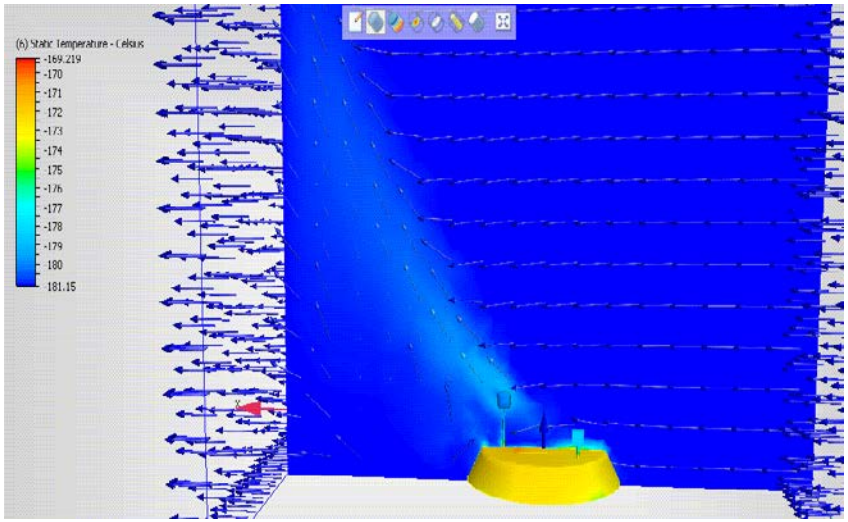
ASRG development cancelled November 2013.

Meteorological Measurements on a Radioisotope-Powered Capsule

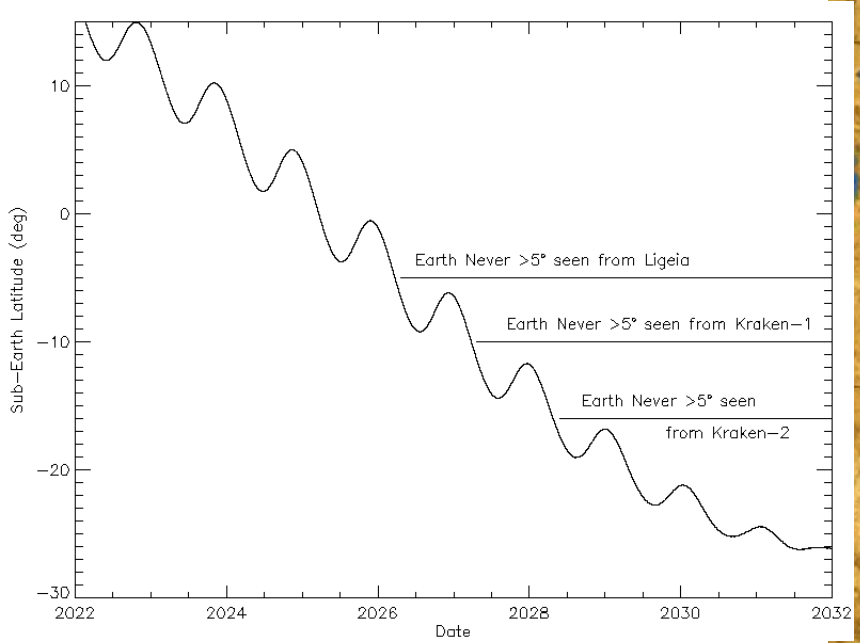
- ***To what extent would meteorological measurements be affected by thermal plume from capsule ? (an issue that confronts, less dramatically, Mars landers/rovers, and terrestrial oceanographic meteorology measurements).***

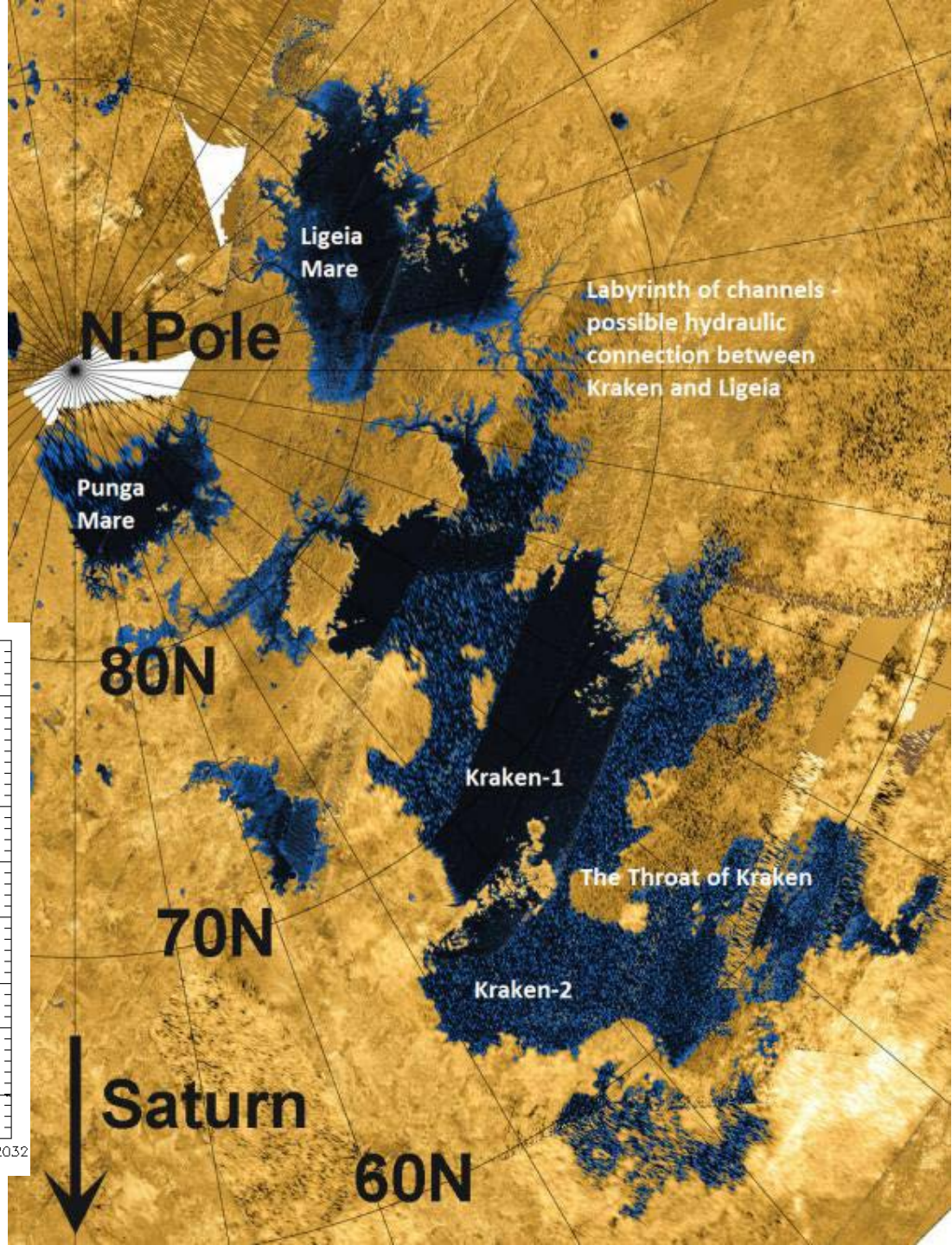
- ***Addressed by CFD simulations which showed that for most windspeeds, a 1m meteorological mast would keep sensors out of plume. (Lorenz and Sotzen, Planetary and Space Science, 2013)***

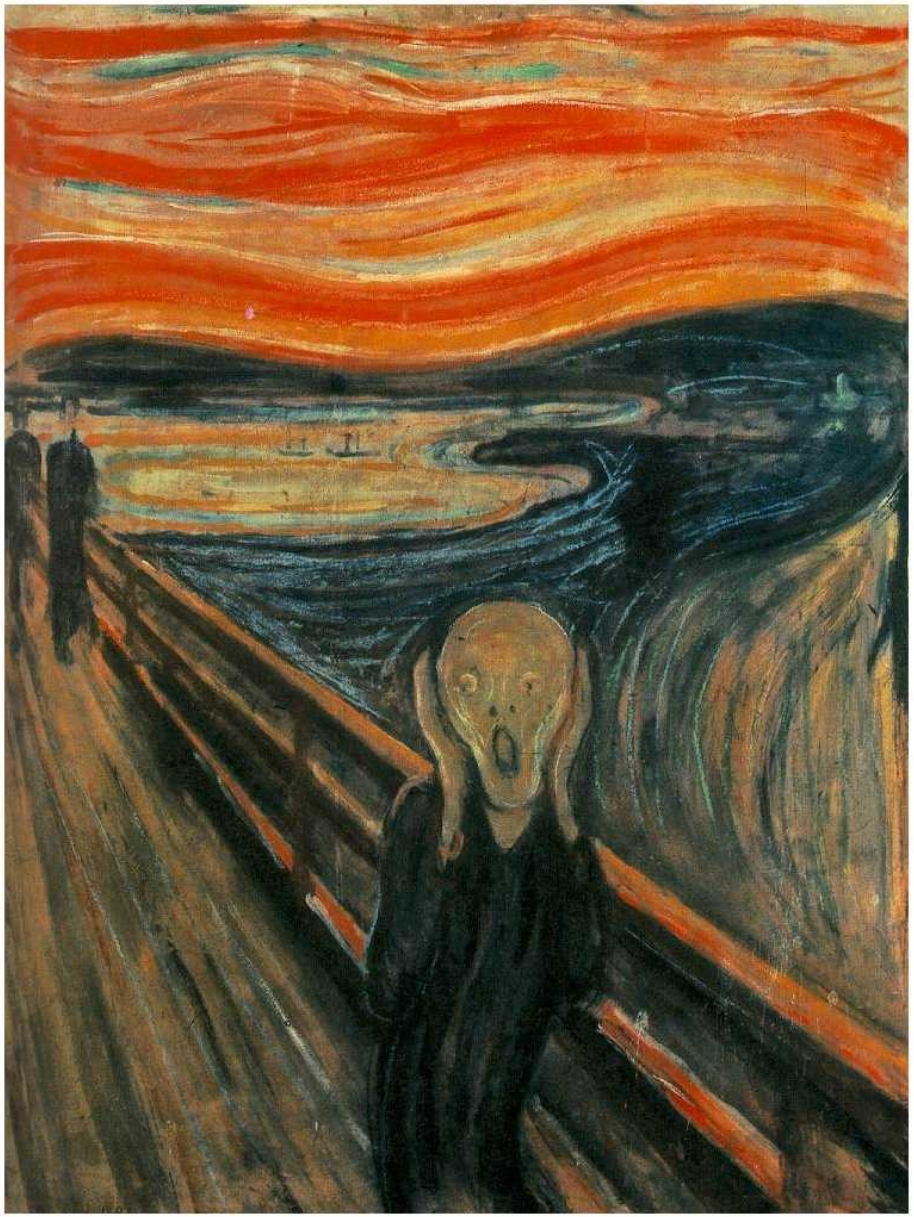




Cassini radar mapping in summer 2013 allowed safe landing zones in Kraken Mare – further south – to be identified. Bought a couple of years of time before direct-to-Earth comm (and sunshine!) lost….



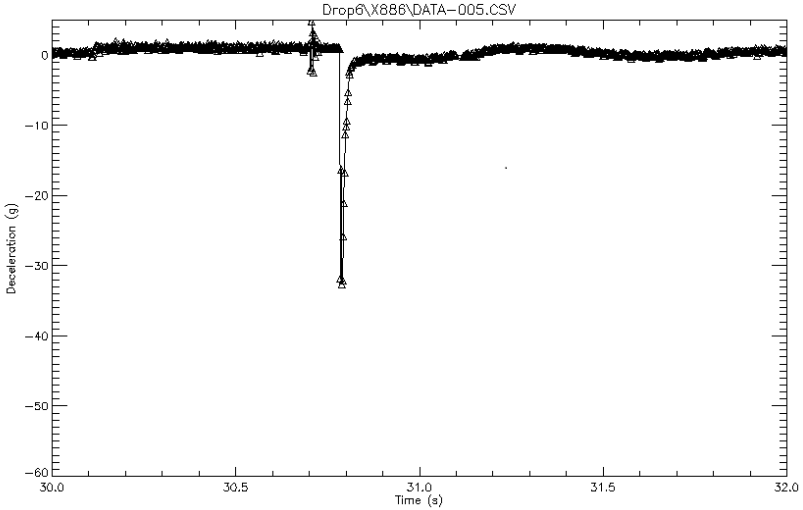




February 2014 Discovery notice :

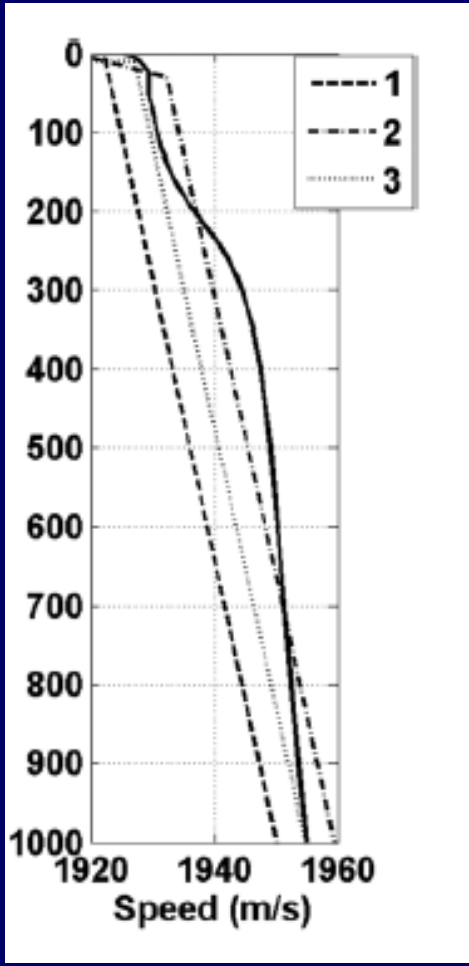
"The schedule for fueling of radioisotope power systems (RPSs) cannot be met in time for the expected launch window of Discovery 2014 investigations. Therefore, Discovery Program investigations may not propose the use of RPSs."

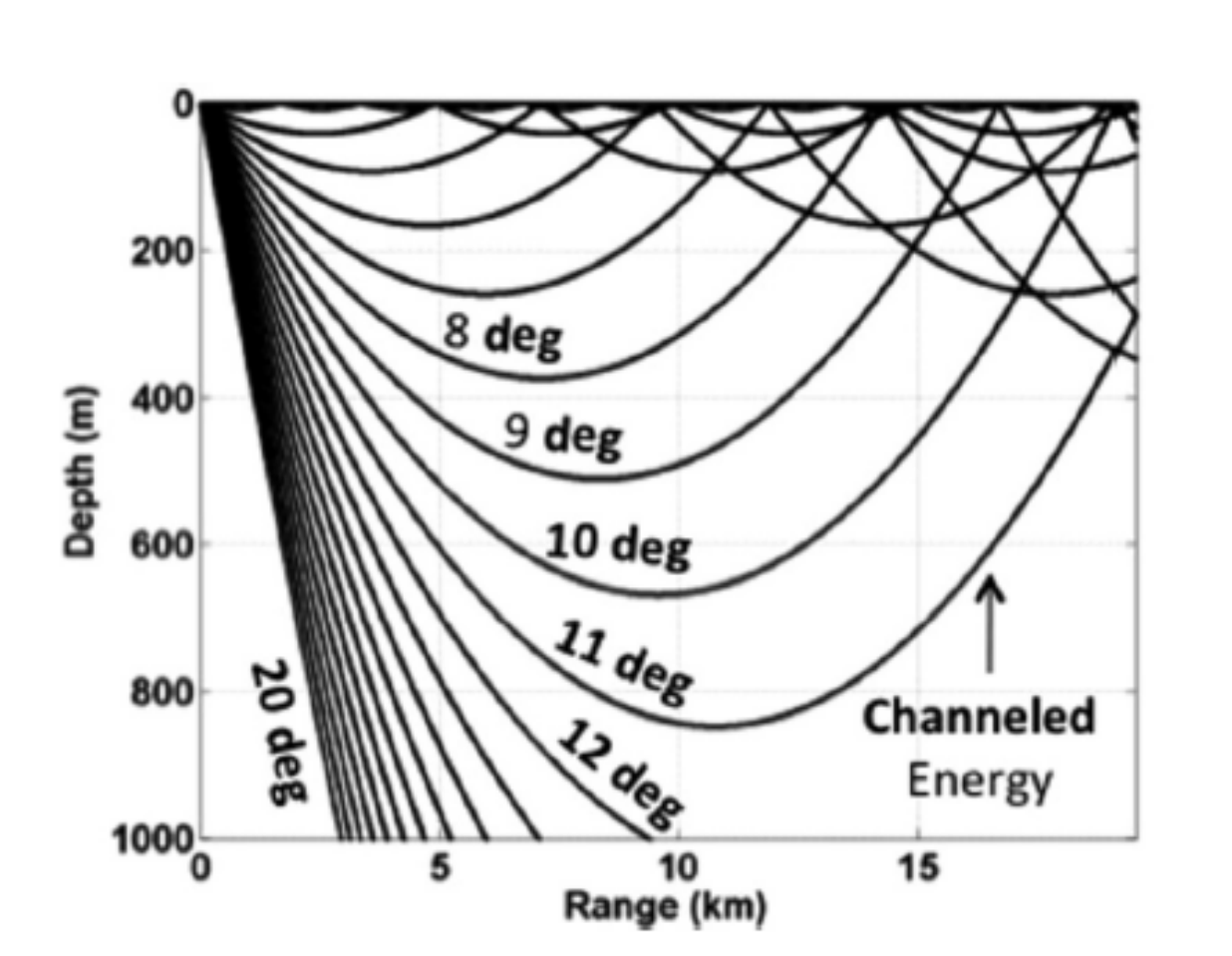
Splashdown Test Campaign



Scale model tests at Penn State (ARL) were instrumental in validating splashdown load predictions (scaled to Titan conditions). Over 250 tests performed.

(results under review)

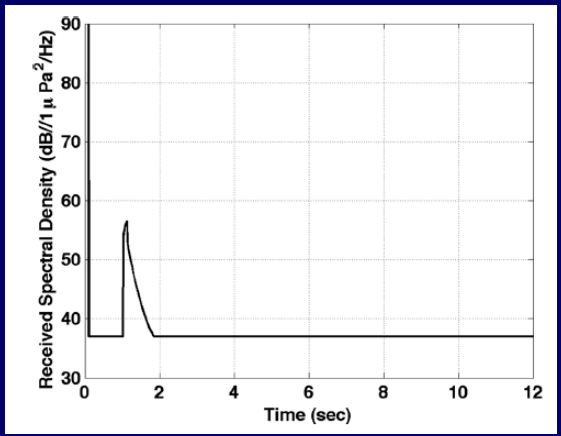




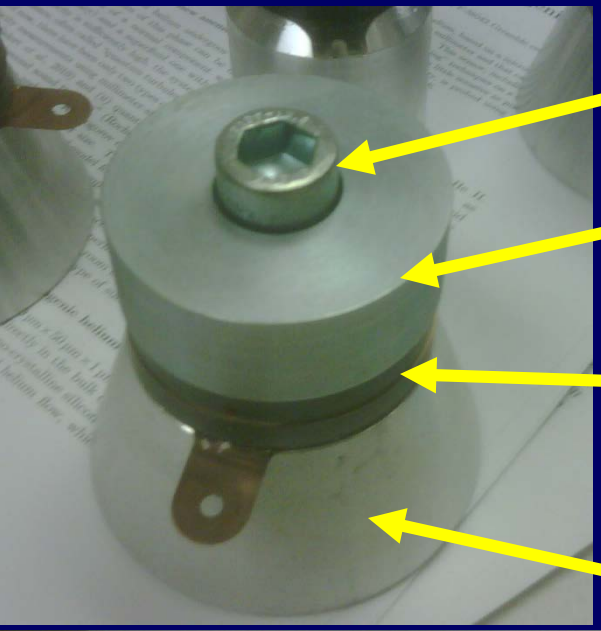
Plumbing the depths of Ligeia: Considerations for depth sounding in Titan's hydrocarbon seas

Juan Arvelo[a)] and Ralph Lorenz
The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland 20723

J. Acoust. Soc. Am. **134** (6), December 2013



Tonpilz Sonar Transducer : Cryogenic Tests

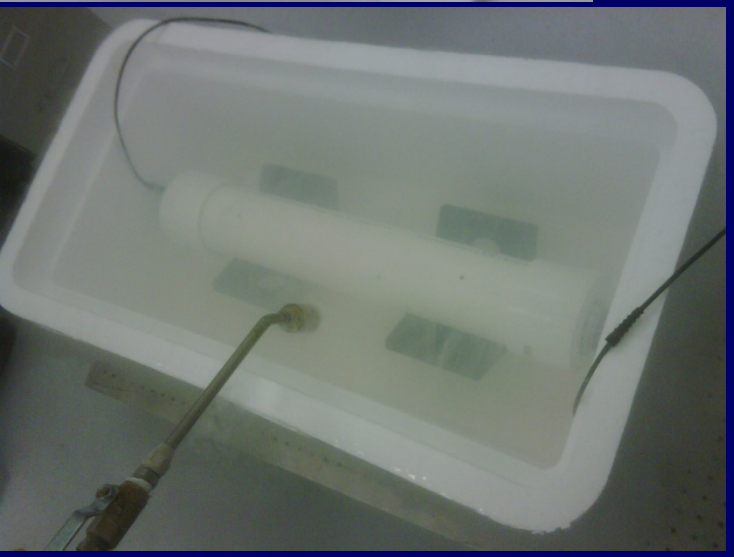


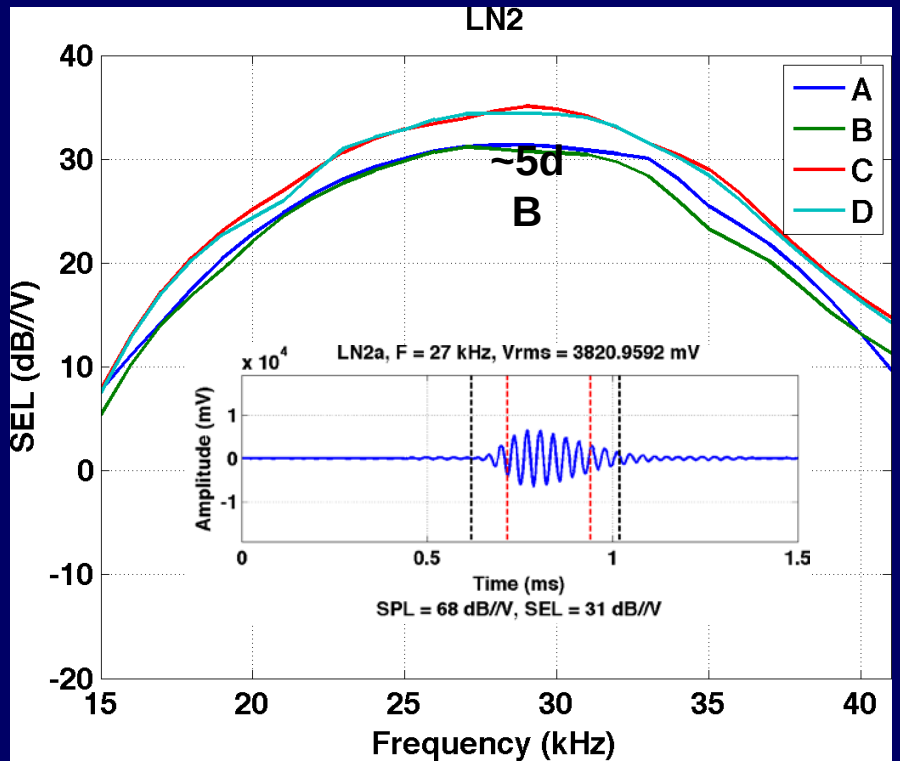
Stainless Steel Bolt

Stainless Steel Tailmass

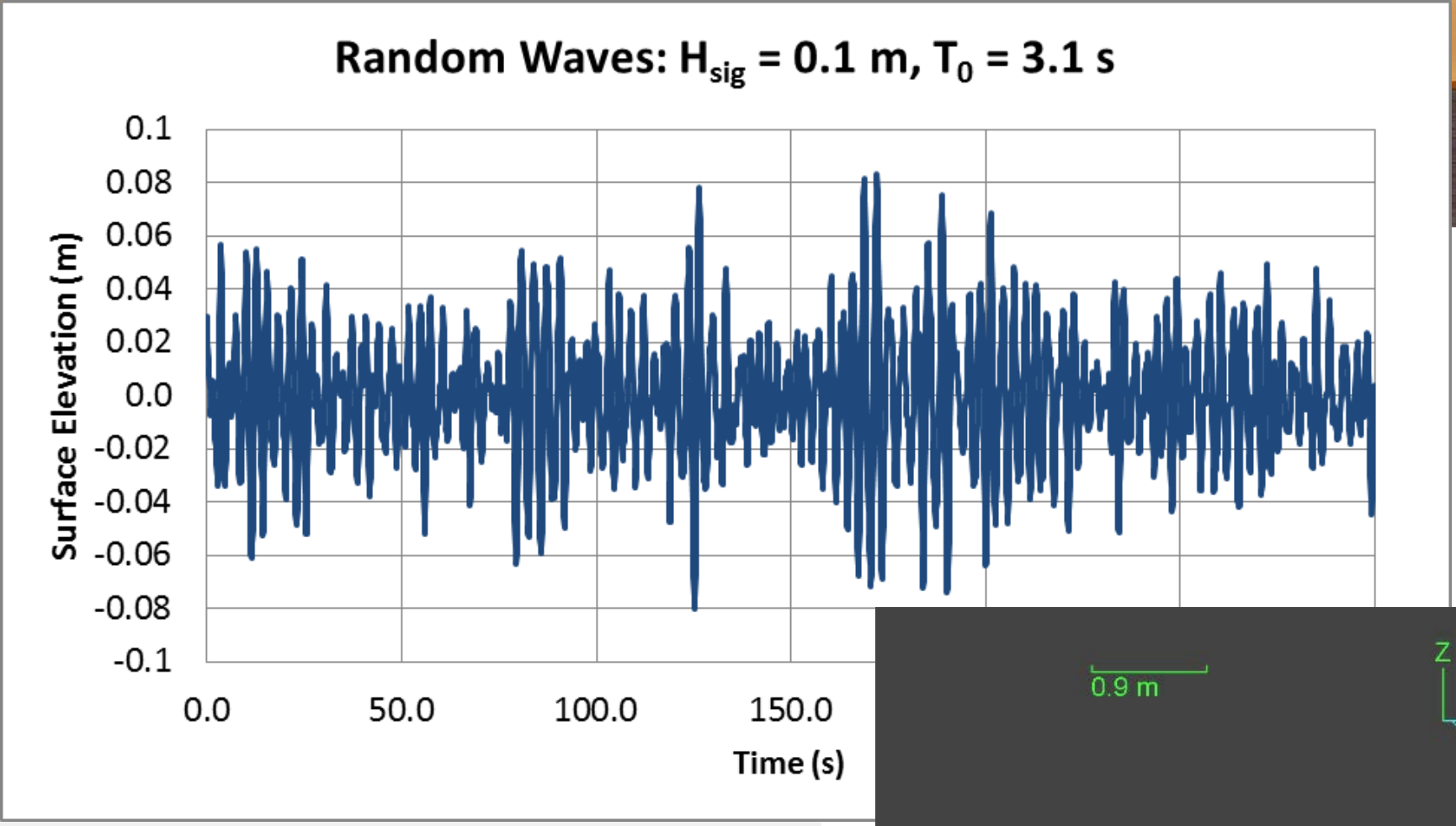
PZT-4 Piezoceramic Disks

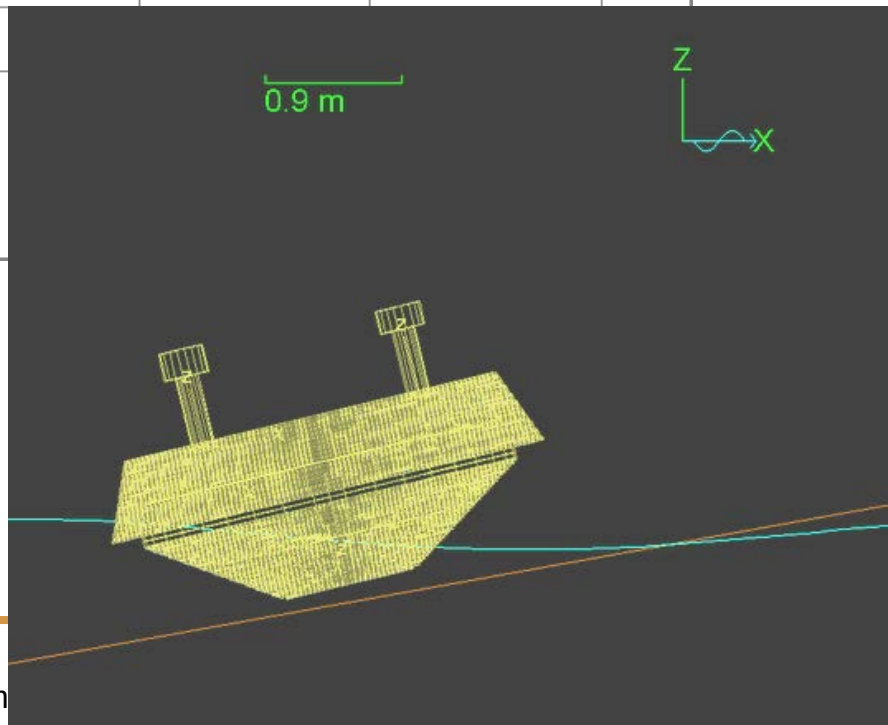
Aluminum Headmass





Generated Single-Cycle Waveform @ 20 Vpp
Same Drive Voltage Applied For H2O & LN2
All Transducers Were Unaltered

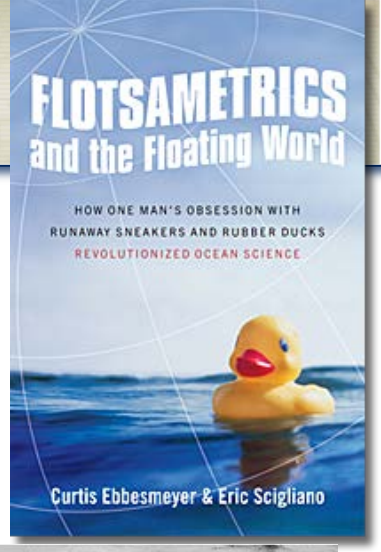




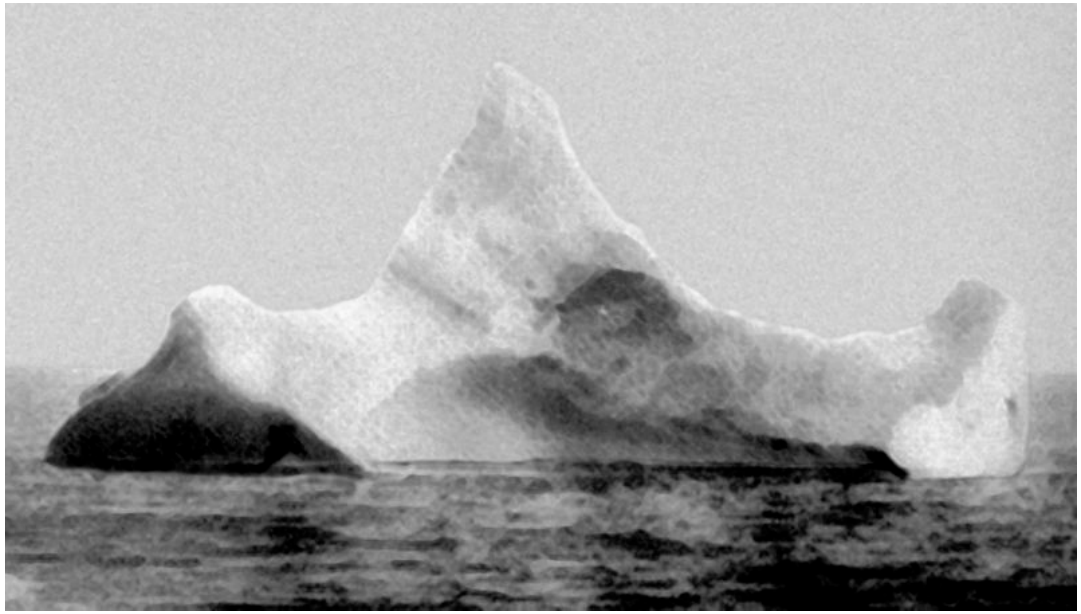
Random wave series generated from a JONSWAP spectrum with a significant wave height of 10 cm and a dominant wave period of 3.1 seconds. Dynamics and Bottom interaction simulated in Orcaflex

Com

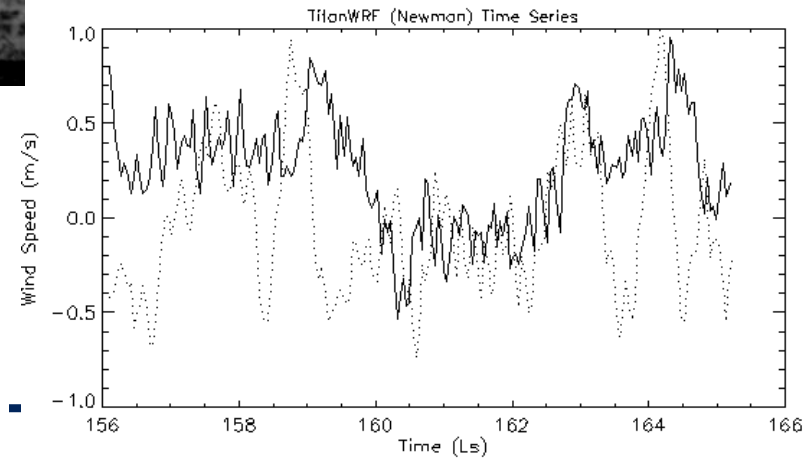
Wind-driven Drift

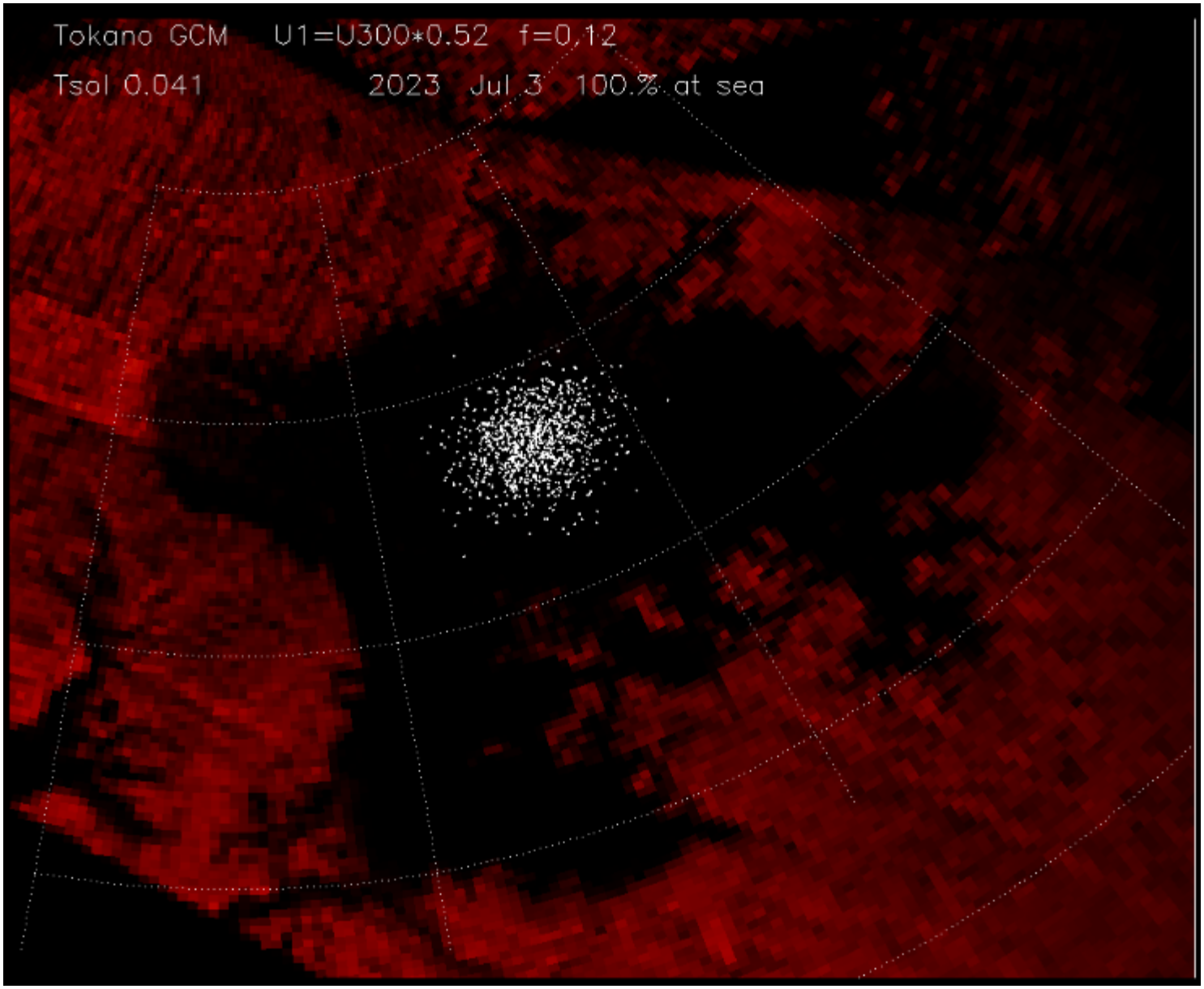


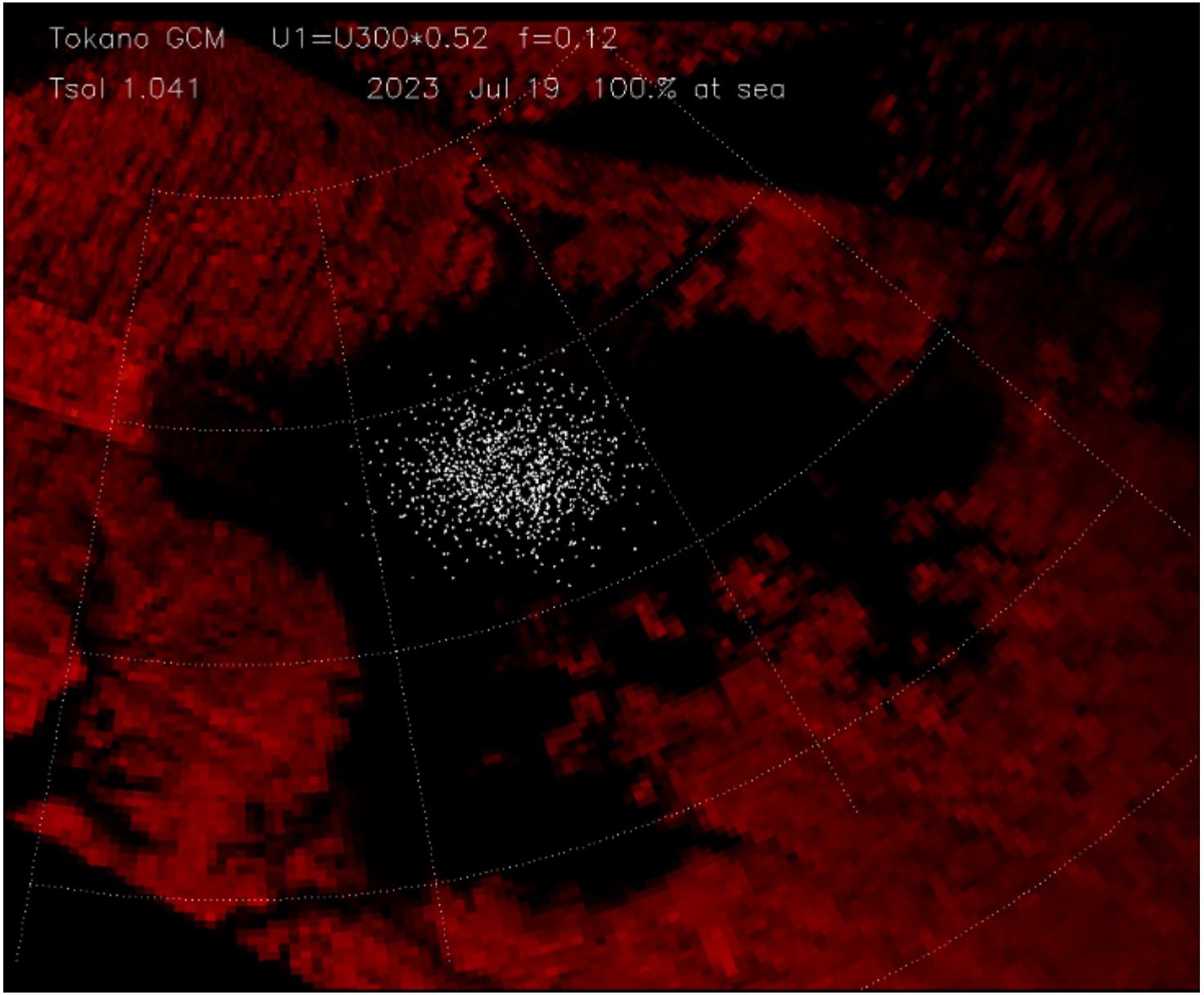
E. Halley - 'The Manner of Computing the Weight or Force of the Winds..', read to the Royal Society on 18th November 1691 - balance between the force of wind on the sails and the 'force of a stream equal in swiftness to the way of the ship'

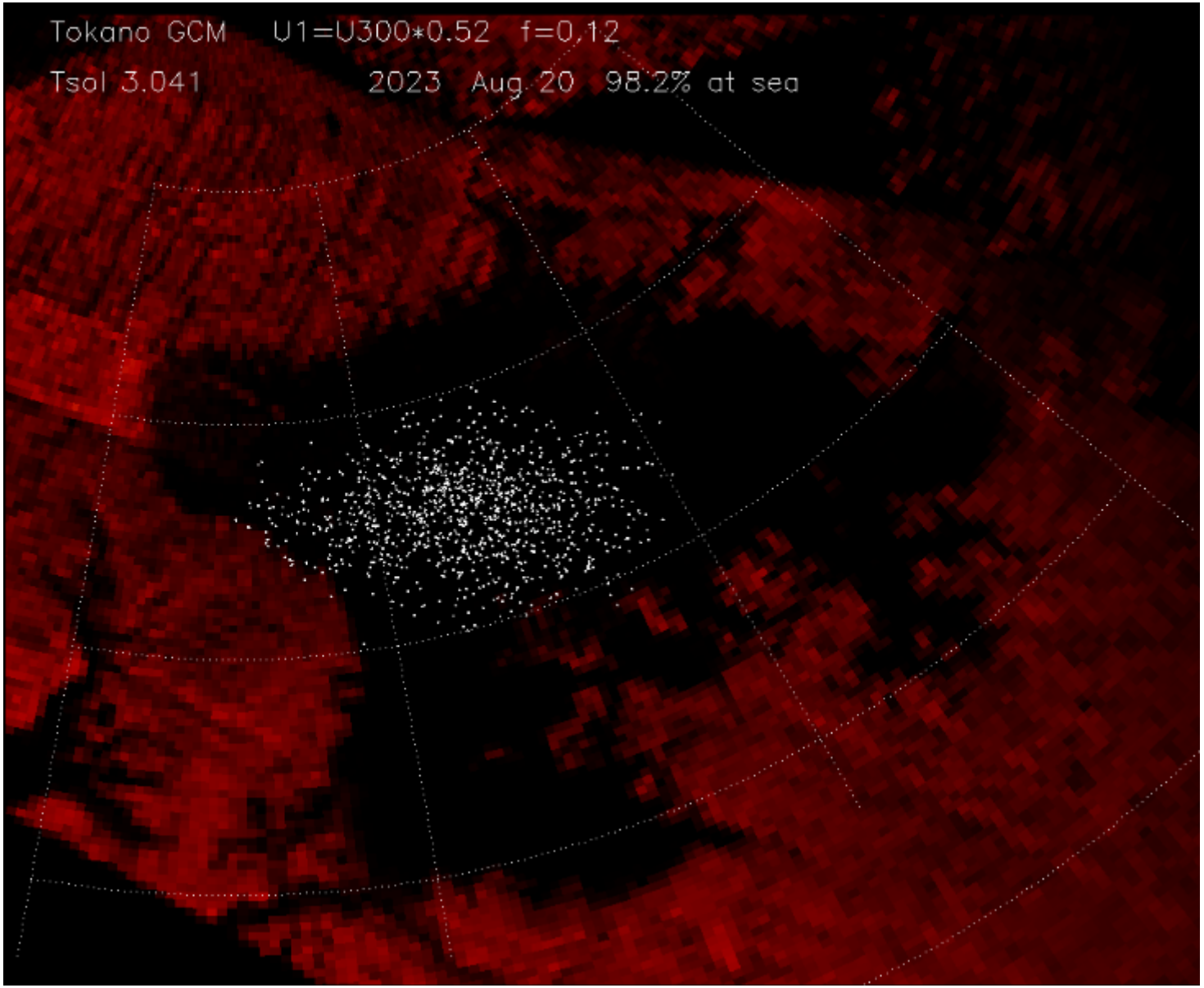


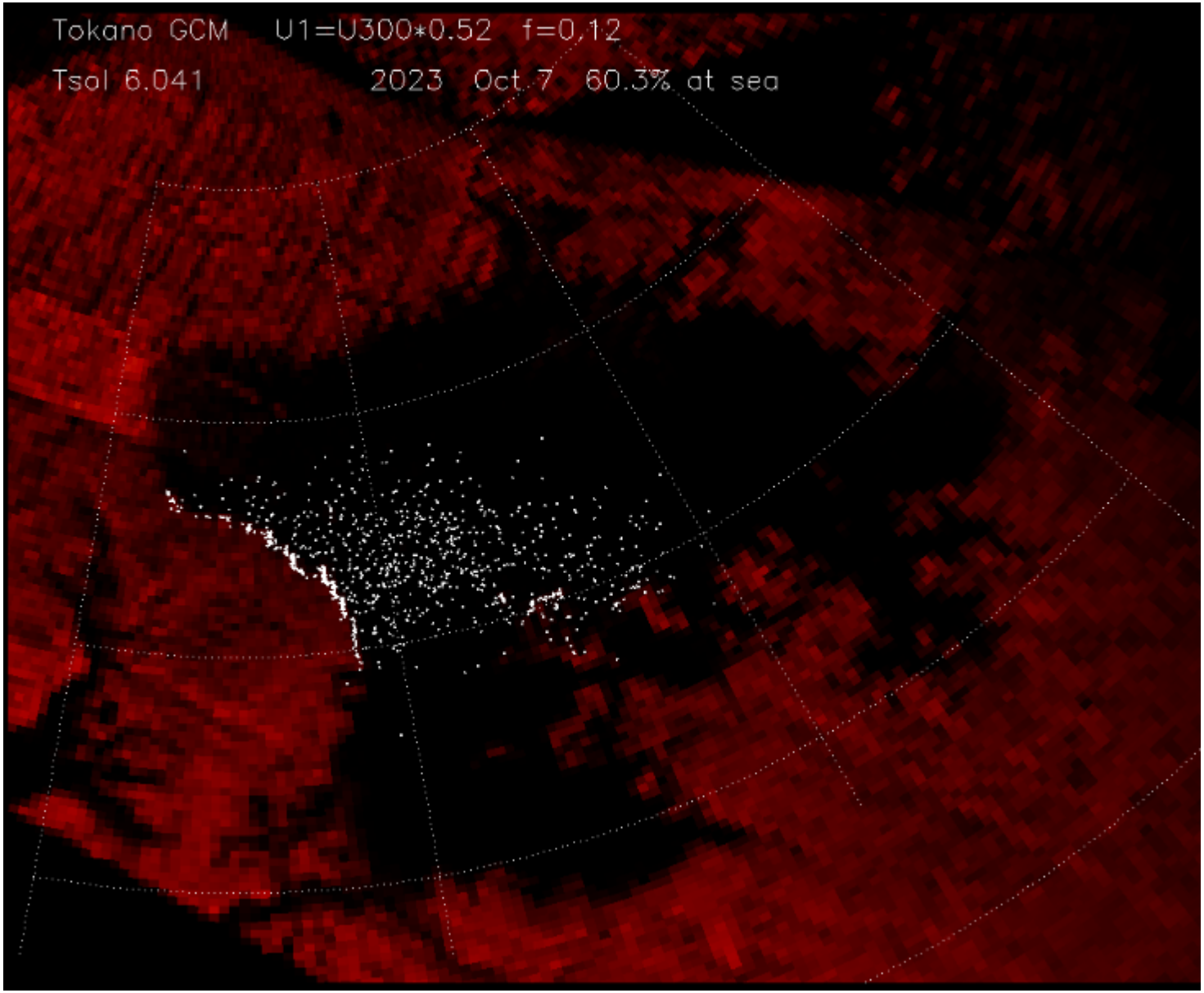
Monte-Carlo drift calculations across Ligeia Mare starting from splashdown ellipse. Drift estimates informed by work on icebergs, spilled cargo (wind drag plus wave forces). Persistence in wind direction turns out to be important (different GCMs yield very different trajectories)



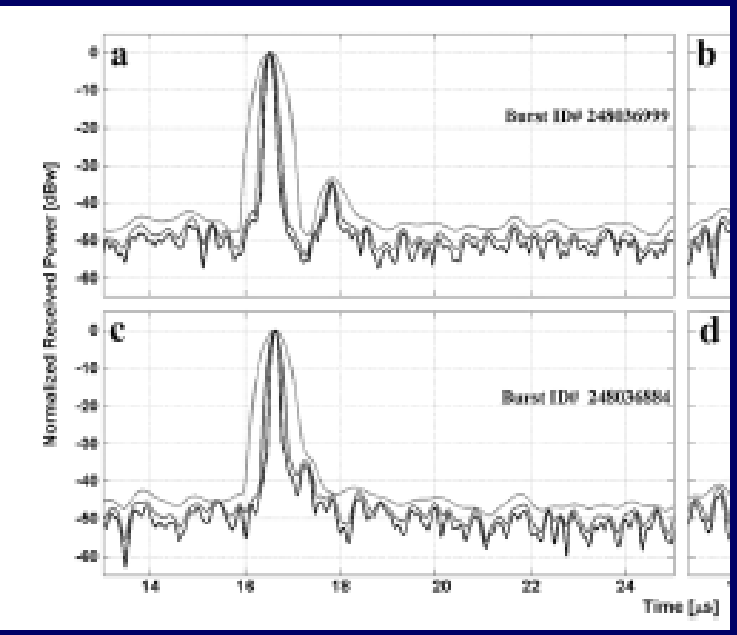

Tokano GCM U1=U300*0.52 f=0.12
Tsol 0.041 2023 Jul 3 100.% at sea

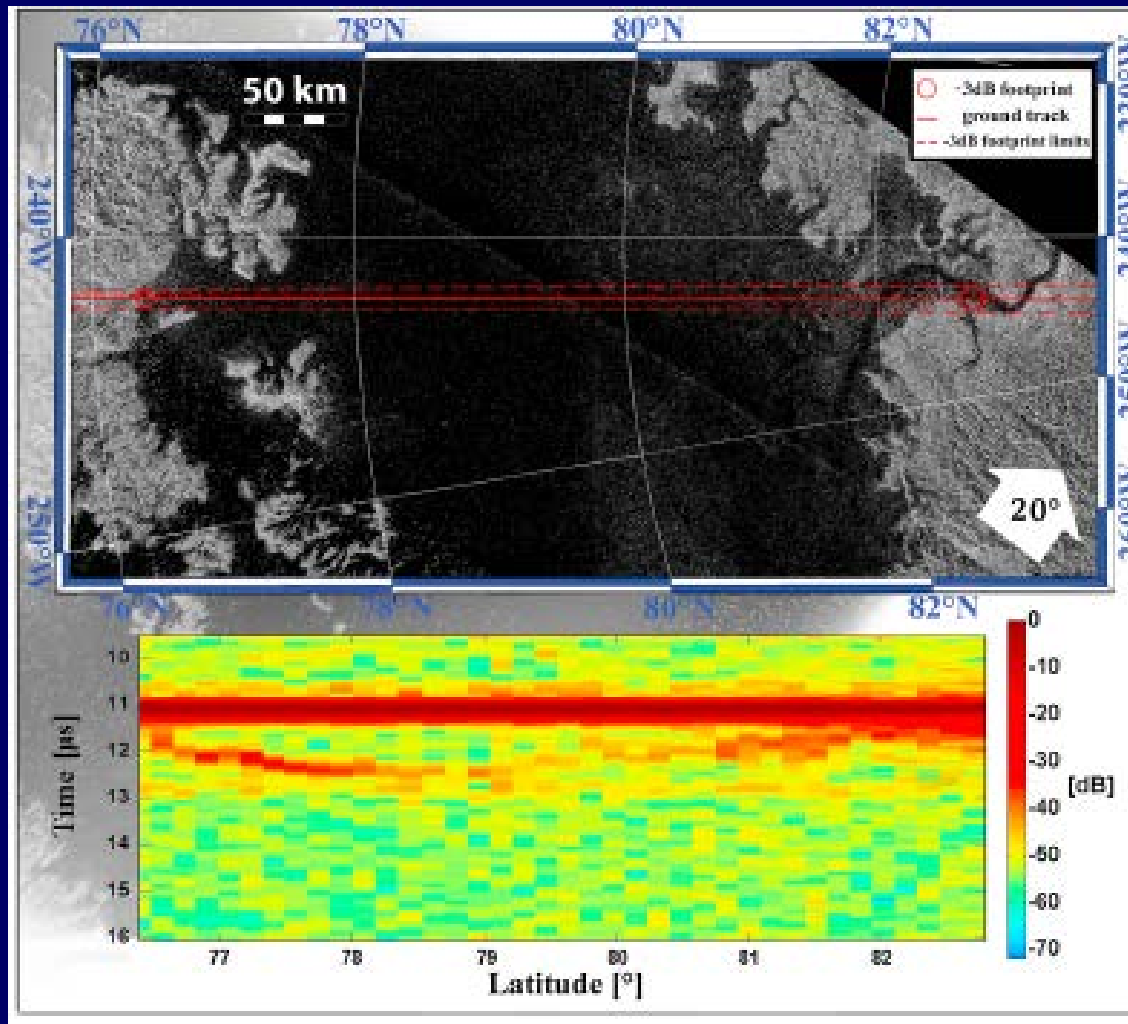

Tokano GCM U1=U300*0.52 f=0,12
Tsol 1.041 2023 Jul 19 100% at sea


Tokano GCM U1=U300*0.52 f=0,12
Tsol 3.041 2023 Aug 20 98.2% at sea


Tokano GCM U1=U300*0.52 f=0,12
Tsol 6.041 2023 Oct 7 60.3% at sea

Recently, Mastrogiuseppe et al (GRL, 2014) reported a distinct second echo from altimetry over Ligeia Mare on T91 (May 2013). Such an echo (from a depth of up to ~160m) requires the sea to be exceptionally radar-transparent (consistent with lab measurements of methane-rich composition with very low solute levels)

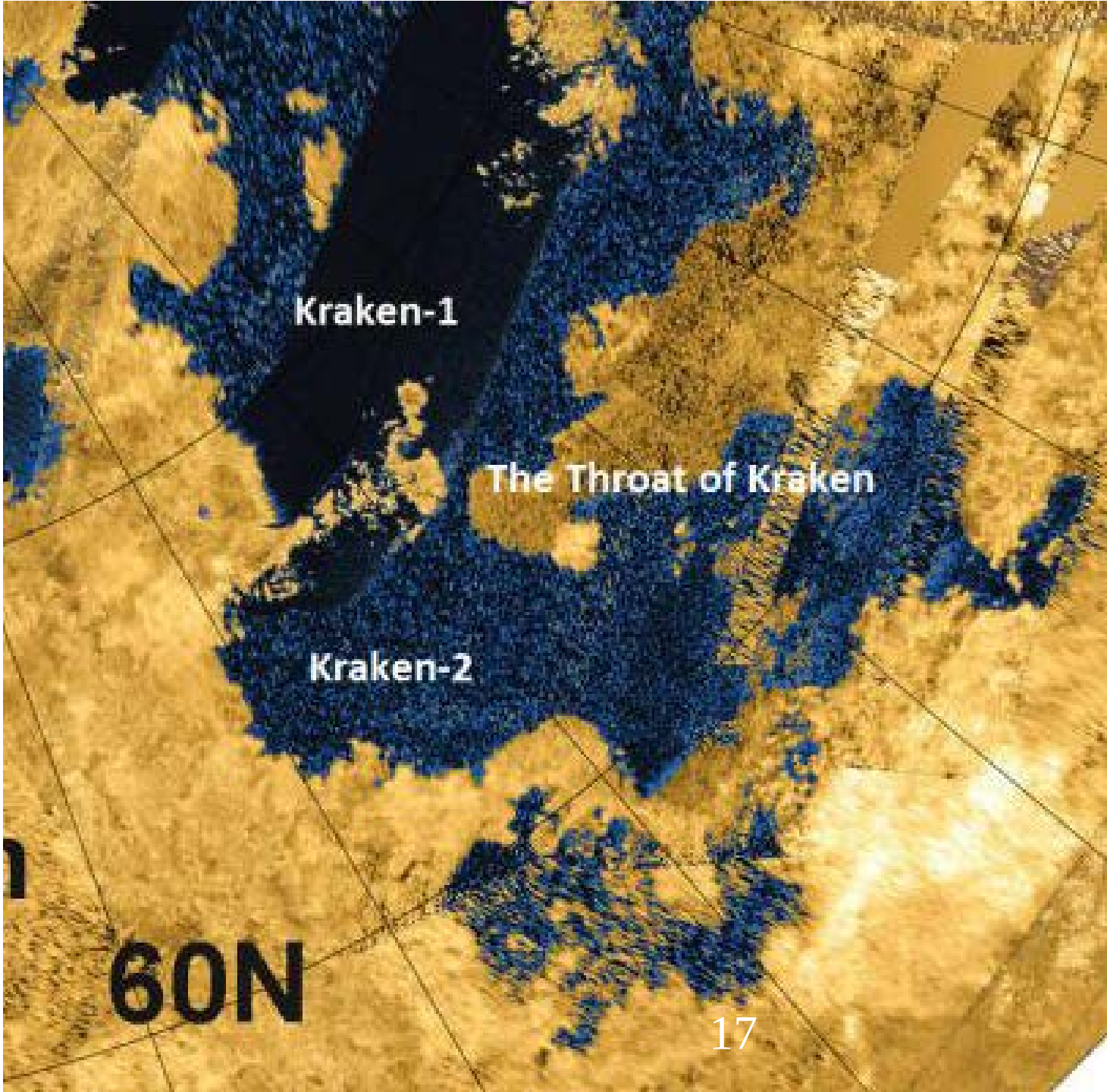




Microwave radiometry also favors methane-rich composition (Zebker et al., GRL 2014)

Tidal (and wind-driven) mixing is throttled by constriction between main basins.

Since precipitation is fn(latitude) this means there will be significant compositional gradients : measuring one spot at one time will not be fully representative of the overall inventory.



Christiaan Huygens 'The Celestial Worlds Discover'd' (1698)

"this Water of ours, in Jupiter or Saturn, would be frozen up inftantly by reafon of the vaft diftance of the Sun. Every Planet therefore muft have its Waters of fuch a temper, as to be proportioned to its Heat : Jupiter's and Saturns muft be of fuch a Nature as not to be liable to Froft…."

"The Air I confefs may be much thicker and heavier than ours, and fo, without any Difadvantage to its Tranfparency, be fitter for the volatile Animals. There may alfo be many forts of Fluids ranged over one another in Rows as it were. The Sea perhaps may have fuch a fluid lying on it, which tho' ten times lighter than Water, may be a hundred Time heavier than Air"

:"If their Globe is divided like ours, into Sea and Land….we have great Reafon to allow them the Art of Navigation…… If they have Ships, they muft have Sails and Anchors, Ropes, Pullies, and Rudders, which are of particular Ufe in directing a Ship's Courfe againft the Wind, and in failing different Ways with the fame Gale"

Sailing Titan's Seas

Titan's polar lakes and seas are important reservoirs in that world's climate system, entailing changes on seasonal, astronomical and geological timescales.

In-situ exploration of an extraterrestrial sea offers public and scientific appeal far beyond the traditional bounds of planetary science. But bottleneck in encapsulation of Pu-238 precludes sailing missions this AO. Now too late to perform mission at Ligeia (possible until ~2024) or Kraken (until ~2026) : lose DTE/tracking and sunlight.

Single battery-powered capsule not scientifically strong (especially after recent Cassini findings). Ontario Lacus too small for unguided landing (muddy too?).

Titan's seas will re-emerge from darkness in ~2040.