TiME : The Titan Mare Explorer Discovery Mission

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International Planetary Probe Workshop, IPPW9, Toulouse, June 2012

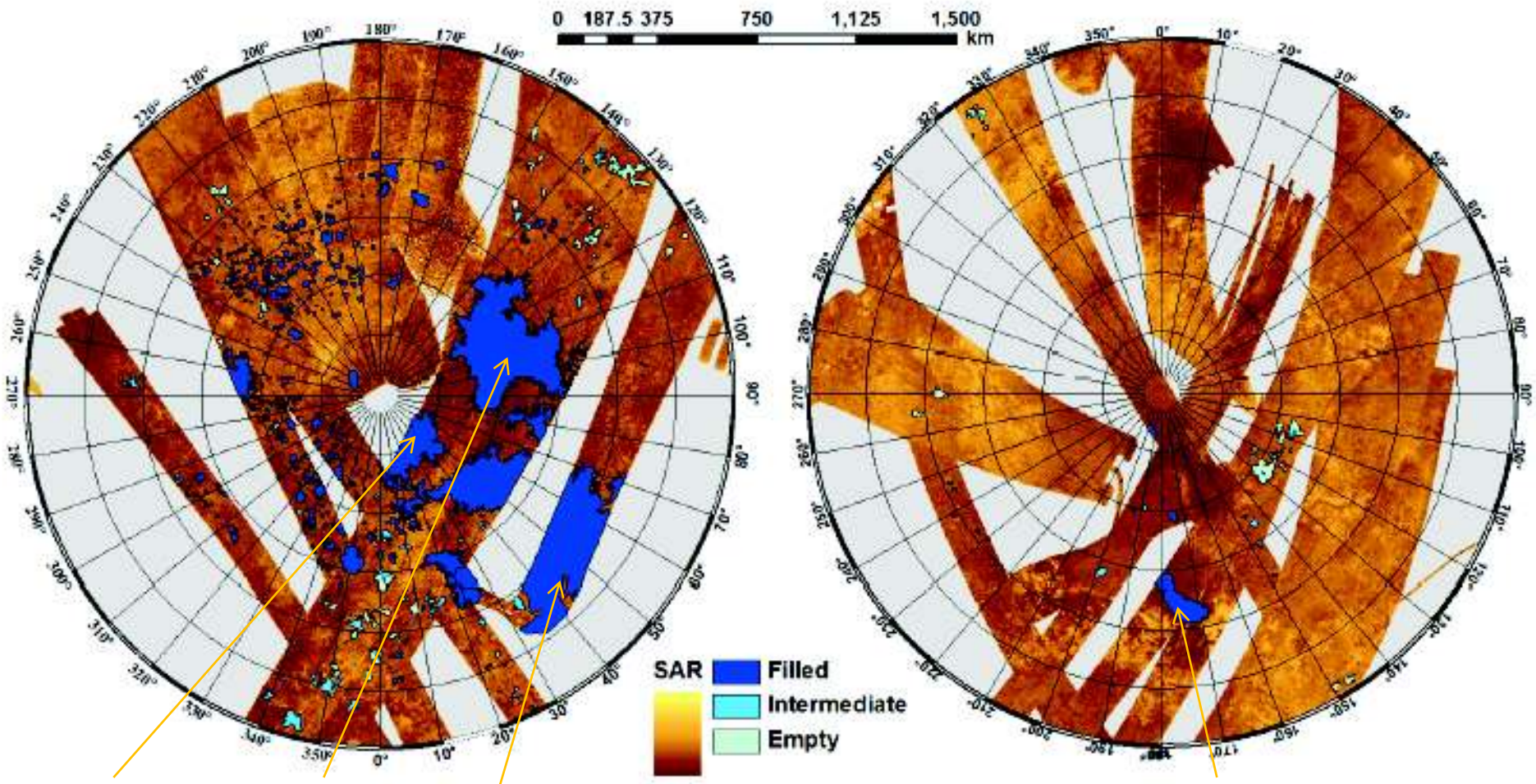
A Brief History of TiME

Proposed in 2007 to DSMCE call for PI-led missions enabled by ASRG Stirling Generator

Concept refined during DSMCE study; proposed to Discovery-12 opportunity in 2010

Selected May 2011 for Phase A study: under evaluation fo flight implementation with Phase B start July 2012

The Seas of Titan



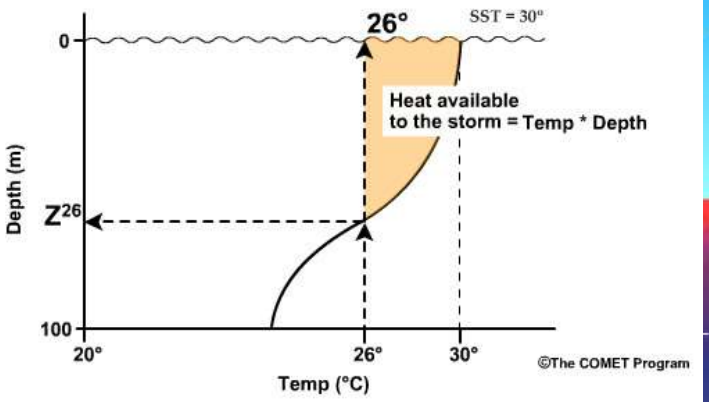
Punga Mare, Ligeia Mare, Kraken Mare

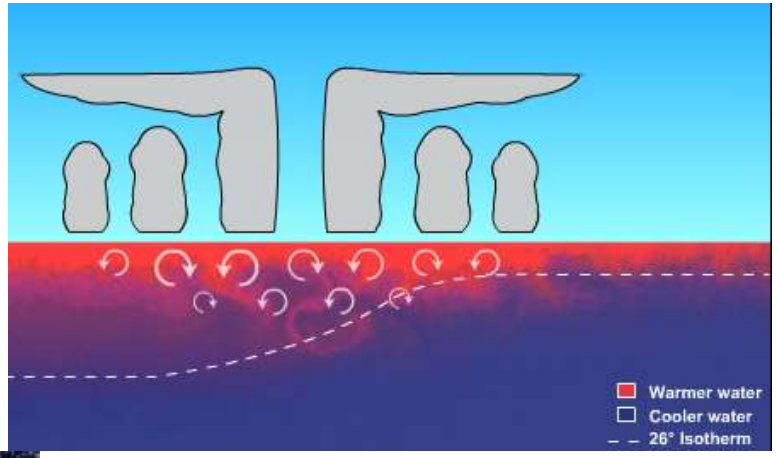
Ontario Lacus

Ligeia Mare – best-mapped of Titan's Seas

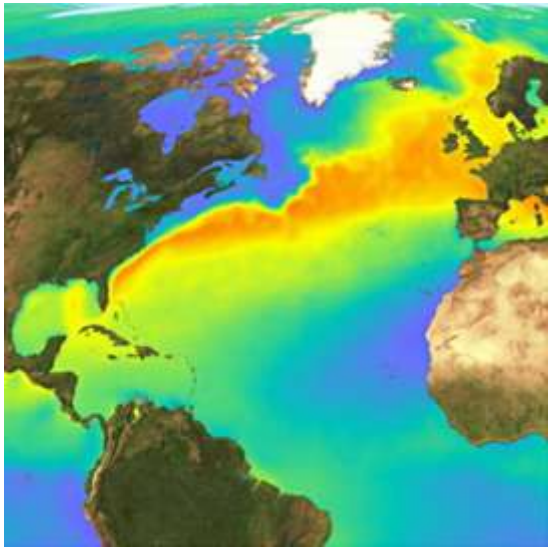
Flooded valleys indicate sea level rise

Air: Sea Exchange is of considerable importance on Earth





El Niño is defined by SST



Ocean surface layer is the fuel behind the hurricane heat engine. Downward mixing of warm water by hurricanes drives the buoyant push behind thermohaline circulation

TiME Science Objectives

- **Constrain sea composition**
  - Determine the chemistry of seas to constrain Titan's methane cycle, look for patterns in the abundance of constituents in the liquids and analyze noble gases. ***Instruments:*** Mass Spectrometer (MS), Meteorology and Physical Properties Package (MP3).
- **Constrain sea depth**
  - Determine the depth of the Titan sea to determine sea volumes, and thus, organic inventory. ***Instrument:*** MP3 (Sonar).
- **Measure sea surface properties**
  - Characterize physical properties of sea liquids and how they vary with depth. ***Instrument:*** MP3.
  - Determine how the local meteorology over the seas ties to the global cycling of methane on seasonal and longer timescales. ***Instrument:*** MP3
  - Analyze the nature of the sea surface (waves, foam) and the state of the atmosphere above the sea. ***Instrument:*** Descent and Surface Imagers (DI, SI).

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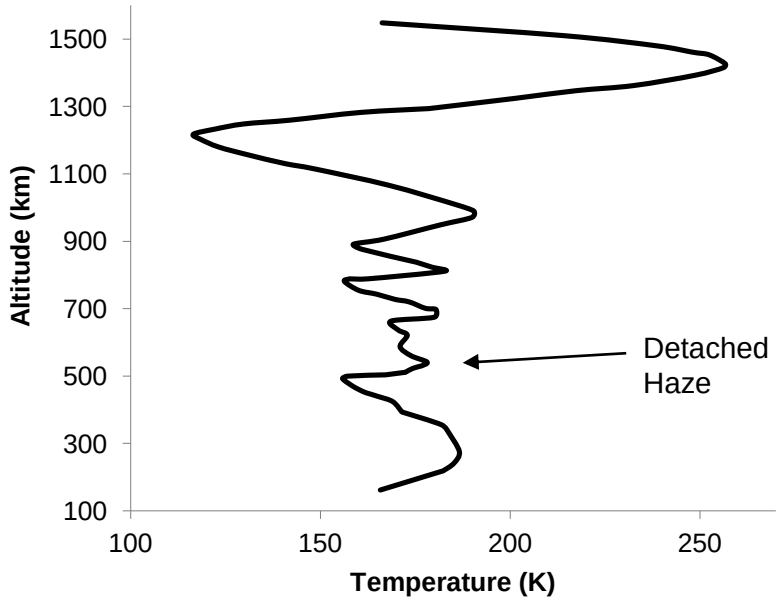
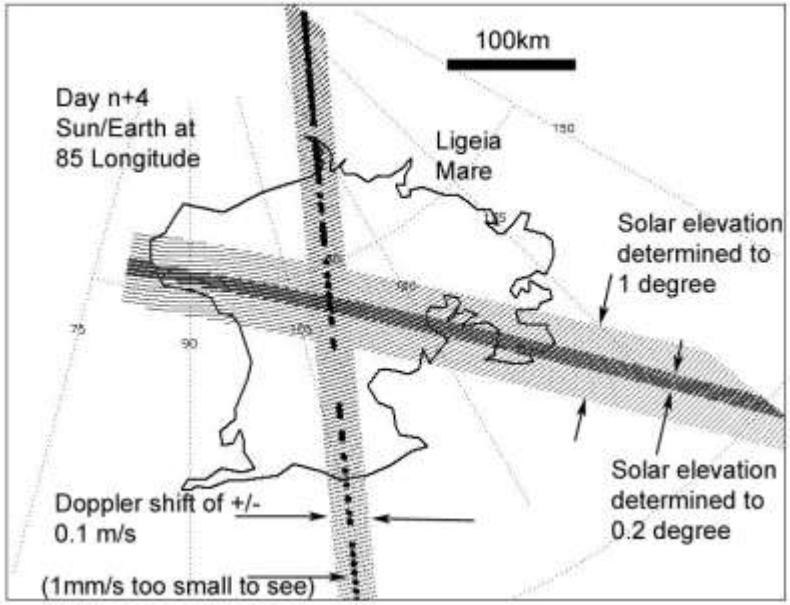
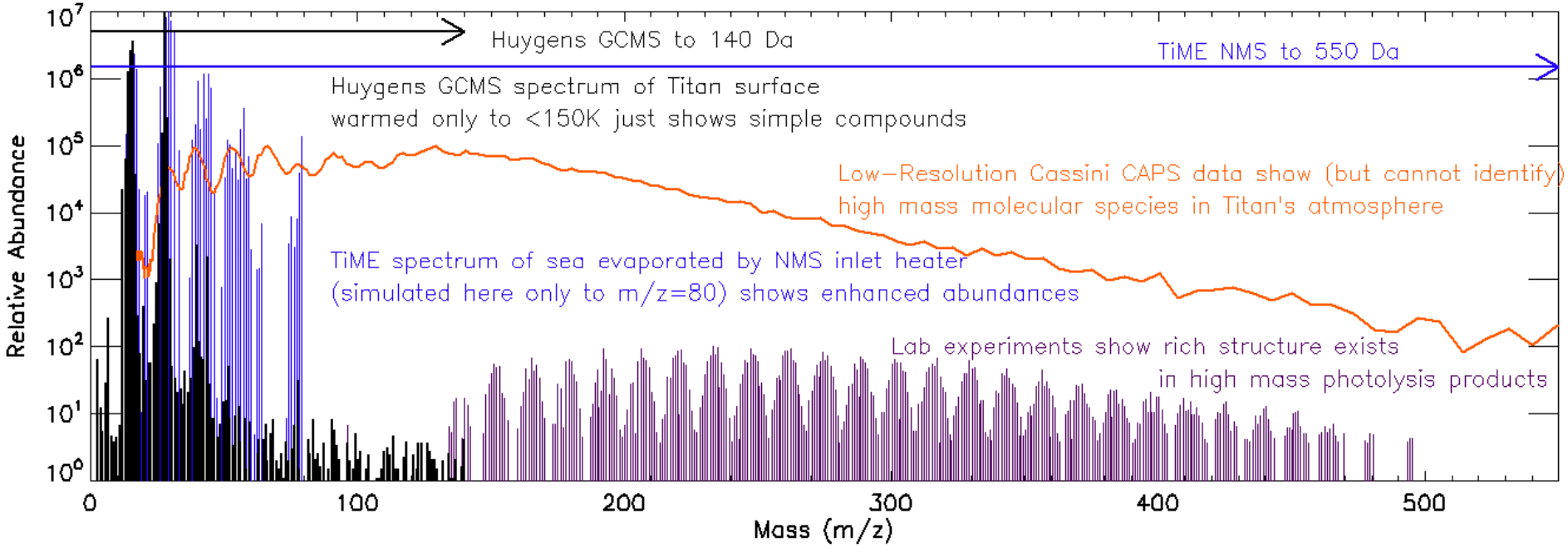
Engineering Systems Add Science Value

IMU yields entry density profile, wave motions on surface.
Radio link provides location (drift) information, short-period dynamics, propagation studies.
Off-the-shelf IMU and Radio performance meets science needs.



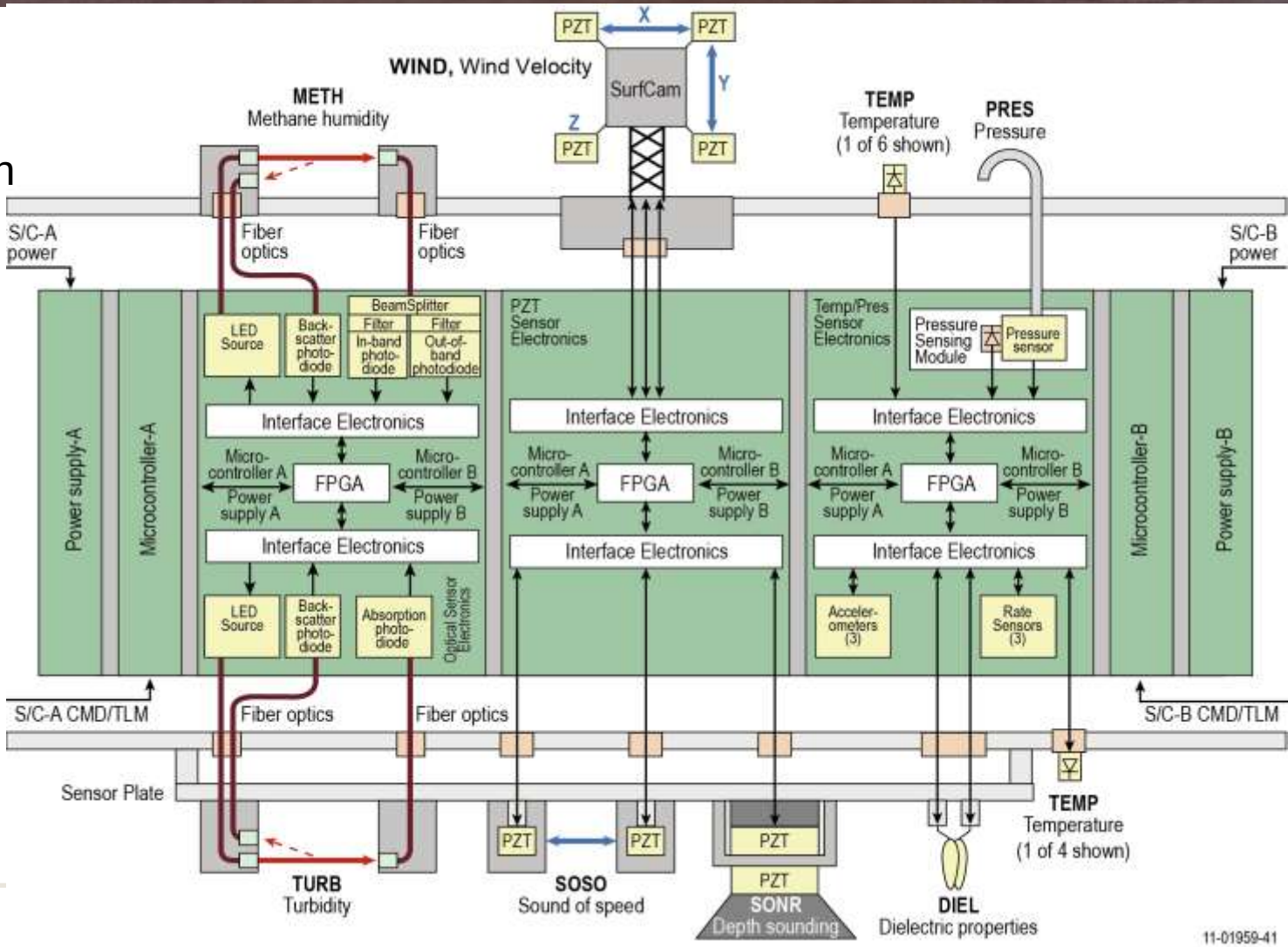


Capable Mass Spectrometer promises new insights on sea chemistry

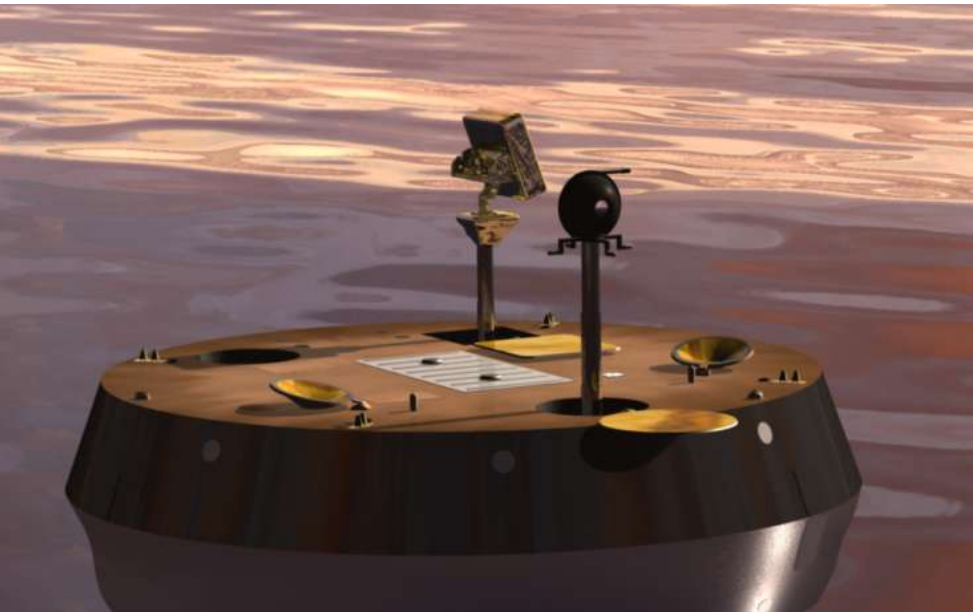


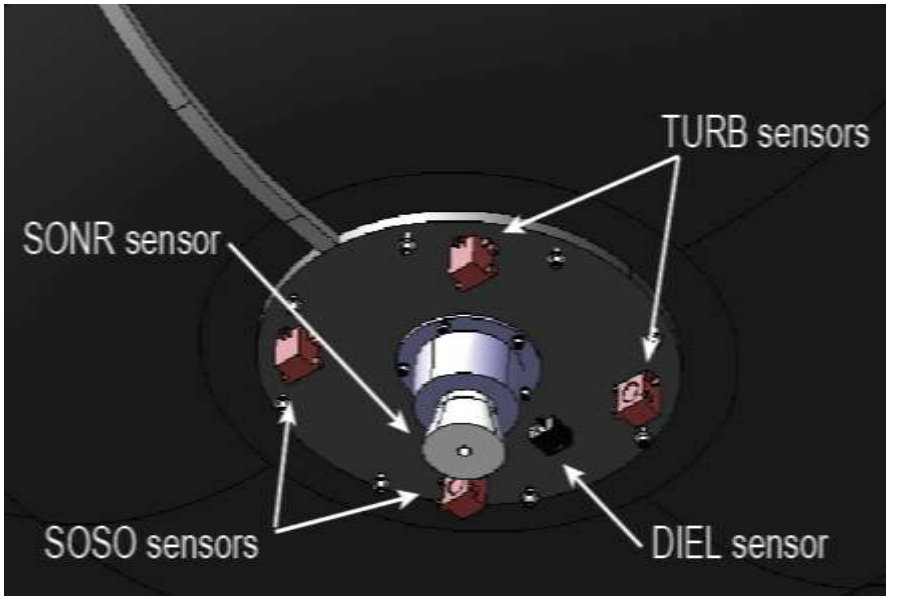
MP3 Instrument Architecture

APL MP3 instrument has a modular layout, with redundant processors and power supplies, with 3 signal processing cards (drawing on heritage from Juno and other missions), handling the optical, piezoelectric and other sensors respectively. This architecture is readily-adapted to other missions.



Sensor Accommodation



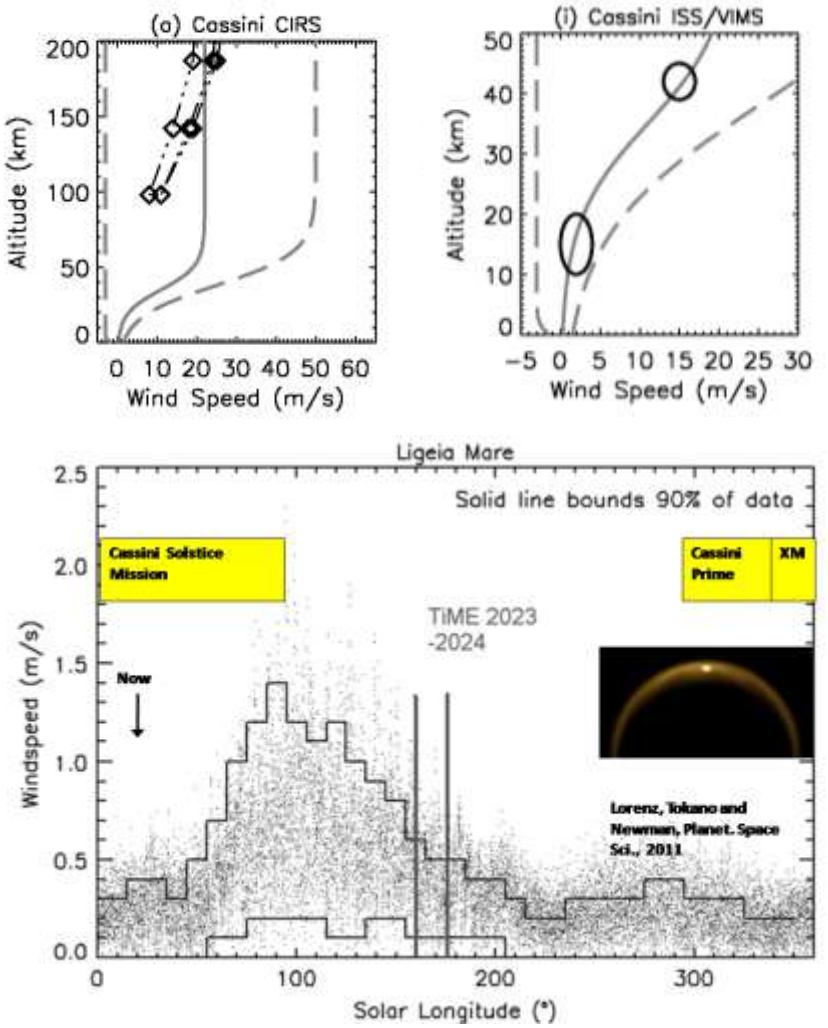


Methane humidity optical apertures on the topside are protected by covers that open during descent. Ultrasonic anemometer is mounted on surface camera mast. Temperature sensors are accommodated at a range of locations

Sensors to measure sea properties (speed of sound, dielectric constant, and turbidity), as well as depth sounder, are mounted on a common plate at the base of the vehicle. Temperature sensors at different depths are mounted on a conduit attached to the plate.

Descent Winds Defined with large Margins

- Stratospheric winds decline with latitude (except winter polar jet). Polar summer has gentle descent winds (weaker than Huygens by factor of 3 or more). Conservative descent wind model formulated, peer reviewed.
- Cassini observations of south pole in 2004-2009 mirror TiME season in north 2018-2024
- Surface winds higher in polar summer (to be observed by Cassini) : Ligeia L_s~160º arrival is well after peak winds. Assessed with 4 independent GCMs.



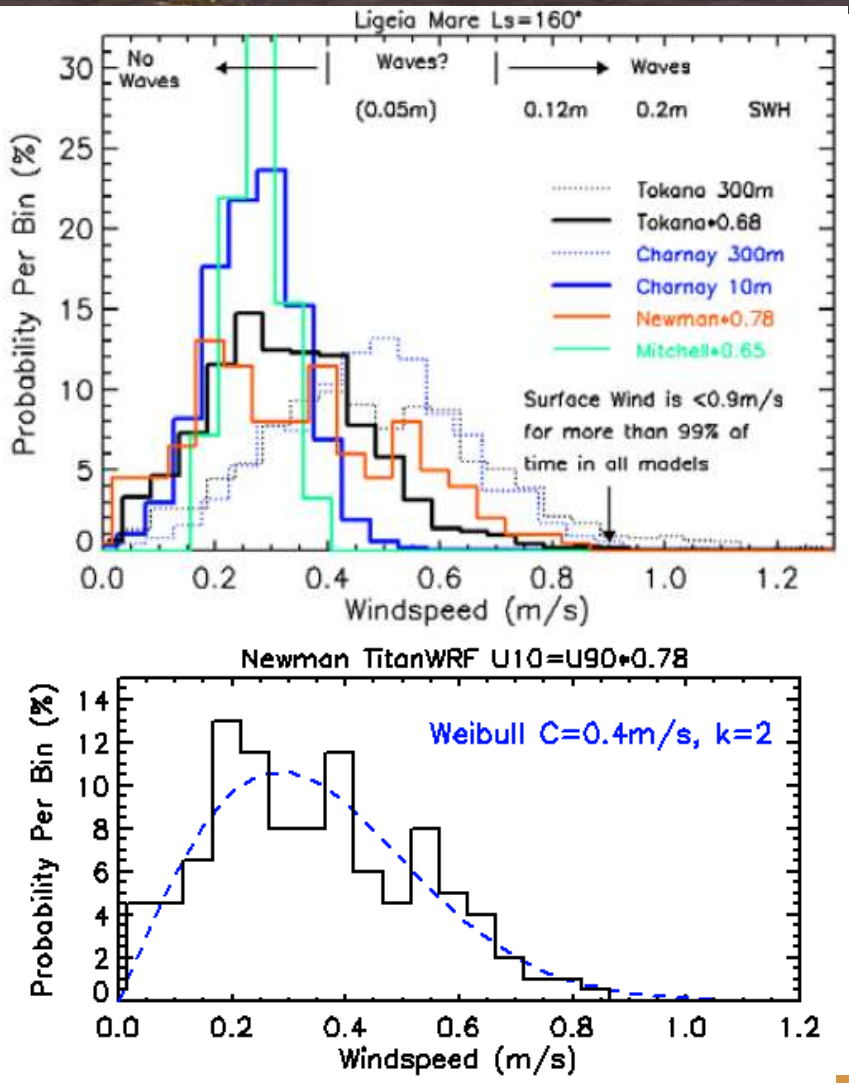
Surface Winds are Gentle

4 independent GCMs, corrected for boundary layer effects, confirm wind U_{10}<0.9m/s >99% of the time at Ligeia during mission.

Relevant for splashdown conditions, waves, meteorology package design, heat transfer, etc.

(Huygens Doppler winds ~0.25m/s in lowest 250m)

Wind model defined in Lorenz et al., Planetary and Space Science, 2012



Liquid Properties Defined and Familiar

Expected liquid composition is principally ethane-methane (cf Liquefied Natural Gas, methane-ethane, routinely handled on Earth at Titan temperatures). Physical properties are well-known in petrochemical industry.

Density range drives capsule float level
Viscosity is unimportant for capsule dynamics

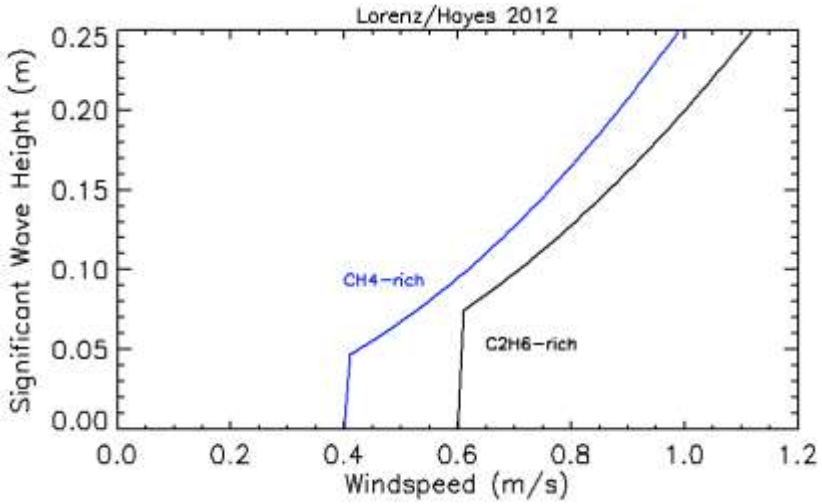
Property	Values
Liquid temperature (K)	92 (90–96)
Density (kg/m^3)	660 (520–670)
Sound speed (m/s)	2000 (1250–2100)
Acoustic loss (dB/km) @10 kHz	0.03 (0.01–1)
Viscosity (μPa-s)	1500 (150–4000)
Thermal conductivity (W/mK)	0.24 (0.18–0.3)
Specific heat capacity (kJ/kgK)	2.4 (2.3–3.3)
Surface tension (N/m)	0.02 (0.018–0.03)
Real dielectric constant	2.0 (1.6–2.2)
Loss tangent	1E-3 (1E-4–1E-2)

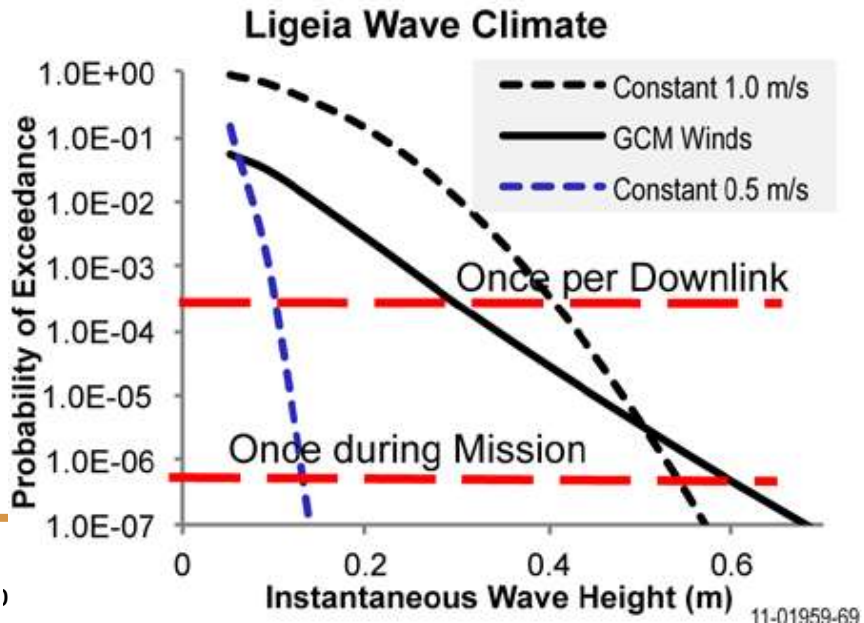
Wave Statistics Robustly Defined

Phase A work refined wave model to fully account for fluid viscosity and atmospheric density to relate signficant wave height to windspeed and fetch (peer reviewed, published) as well as gravity, fluid density in step 1 model (Ghafoor et al., 2000).

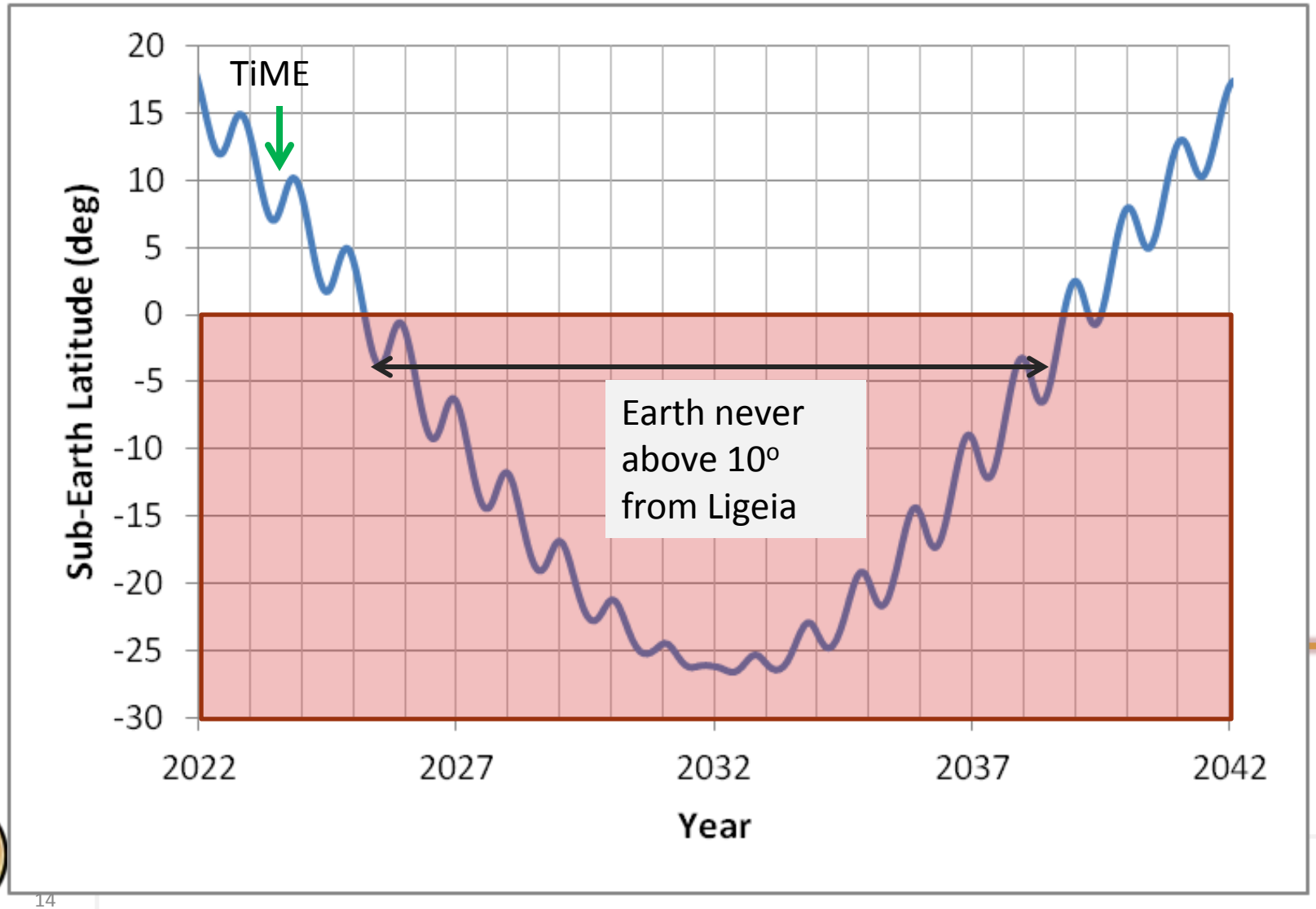
Statistical (Rayleigh) models of individual wave heights developed and applied. NB waves are actually likely not present at all most of the time.

Lorenz and Hayes, icarus, 2012





Mission with DTE from Ligeia not feasible again until ~2040



There is a tide in the affairs of men.
Which, taken at the flood, leads on to fortune;
Omitted, all the voyage of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat,
And we must take the current when it serves,
Or lose our ventures.

William Shakespeare
Julius Caesar
Act 4, scene 3, 218–224