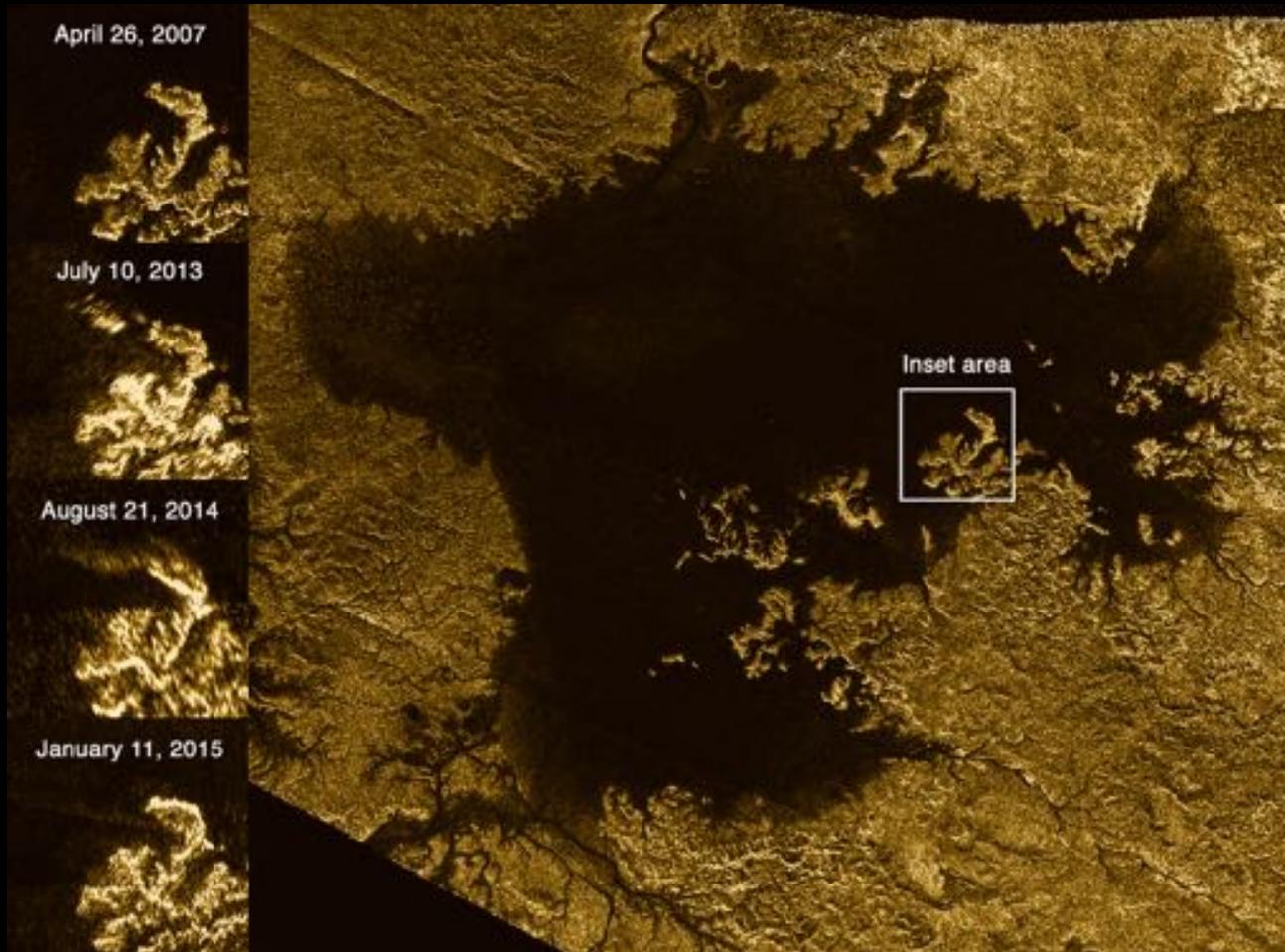


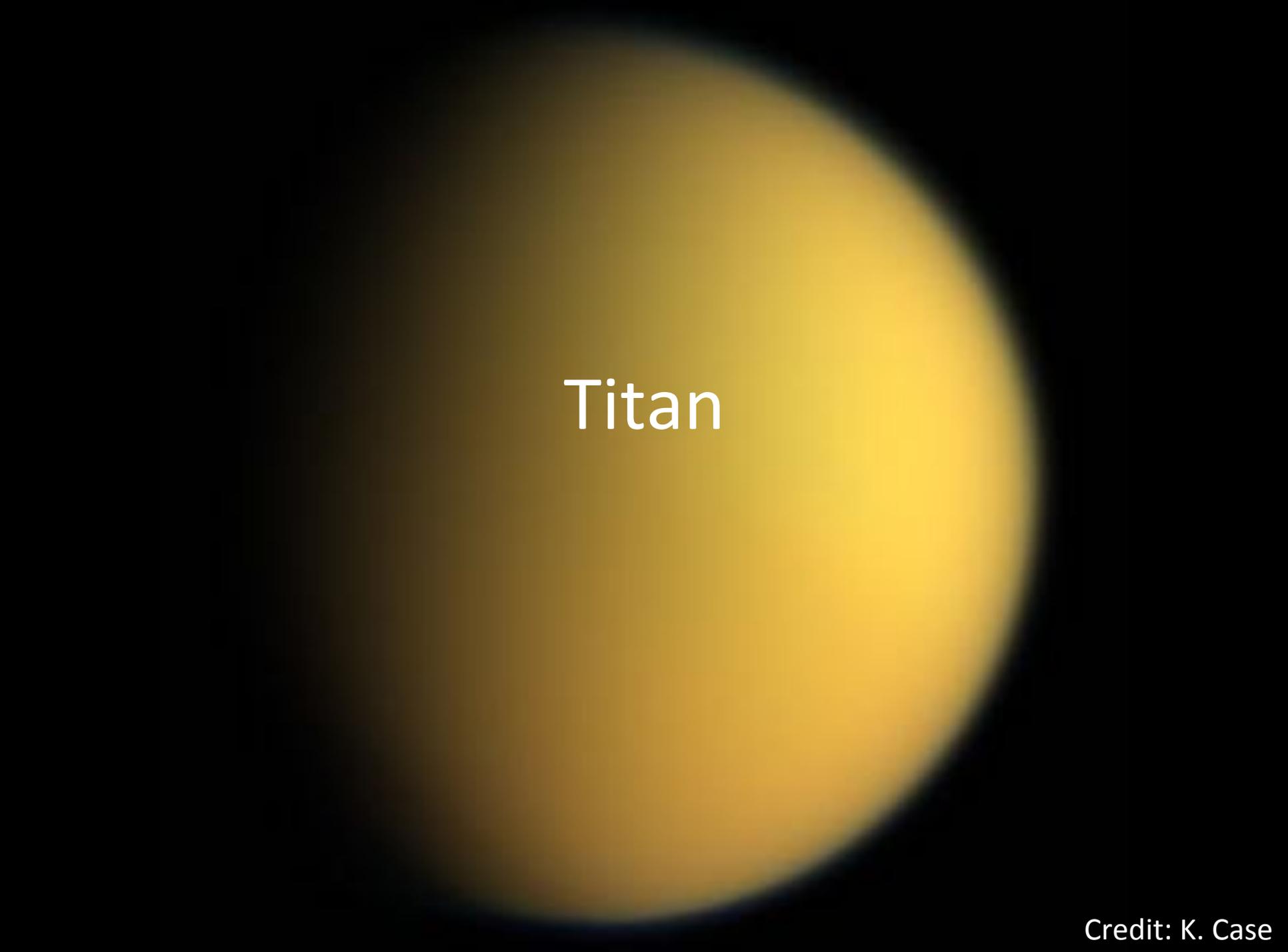
Titan's "Magic Islands": Transient Features in the Hydrocarbon Seas



Jason D. Hofgartner
Jet Propulsion Laboratory
CHARM, April 2016

Outline

- Titan's Surface Liquids and Hydrologic Cycle!
- Transient Features in Titan's Seas!
- Waves, floating/suspended solids, or bubbles!

A large, glowing yellow sphere representing Titan, set against a black background. The sphere has a soft, radial gradient, being brighter in the center and fading towards the edges. The word "Titan" is written in white, sans-serif font across the middle of the sphere.

Titan

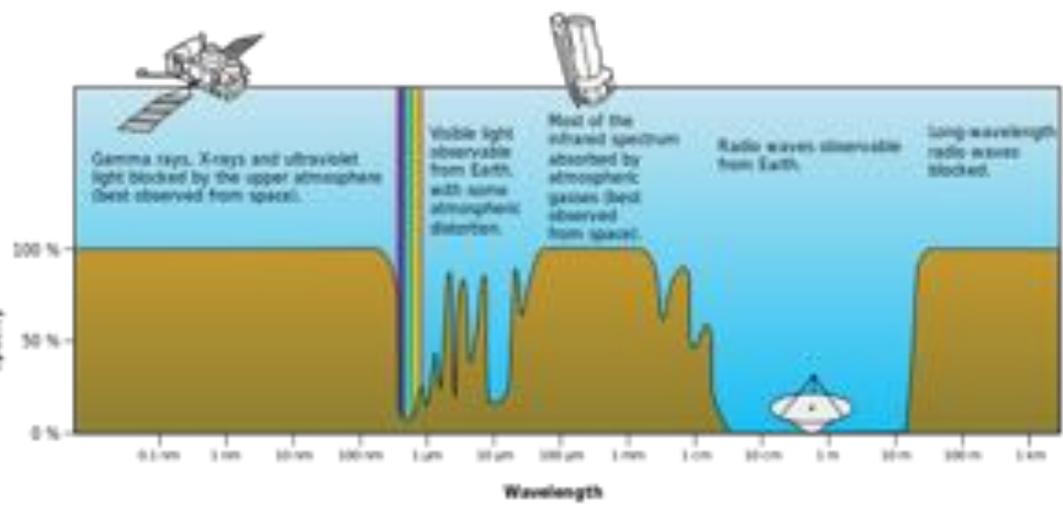
Atmosphere

- Titan is the only moon in the Solar System to have a significant atmosphere
- Pressure: ~ 1.5 times Earth's
- Temperature: ~ -300^o F
- Composition: ~95% nitrogen, ~5% methane
- Methane and ethane are stable liquids at Titan's surface!
- Titan's surface, however, is veiled by hazes

Cassini-Huygens Unveils Titan's Surface

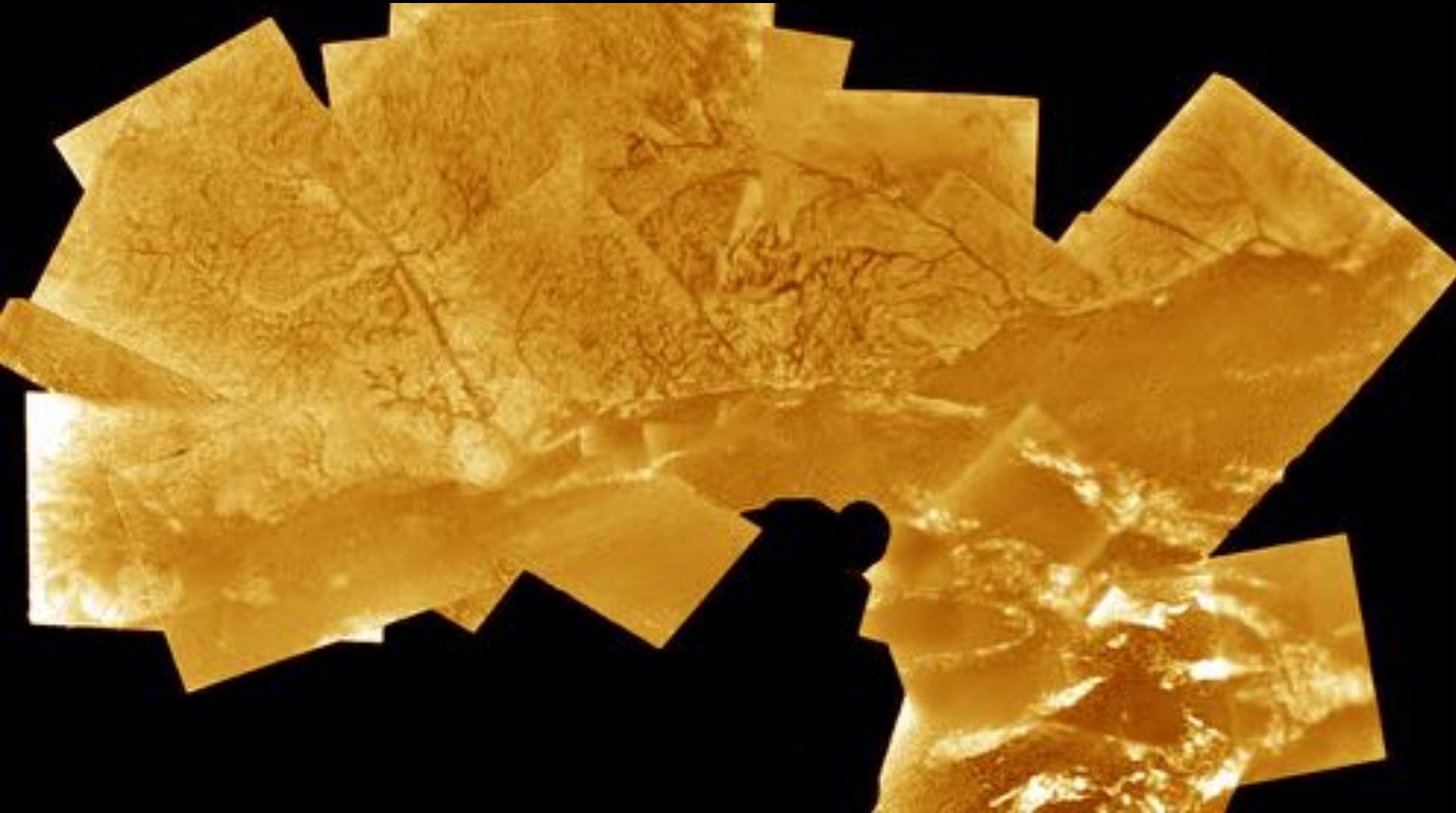
- Titan's surface can be observed in infrared and microwave "atmospheric windows"

1/2 scale model of Cassini spacecraft

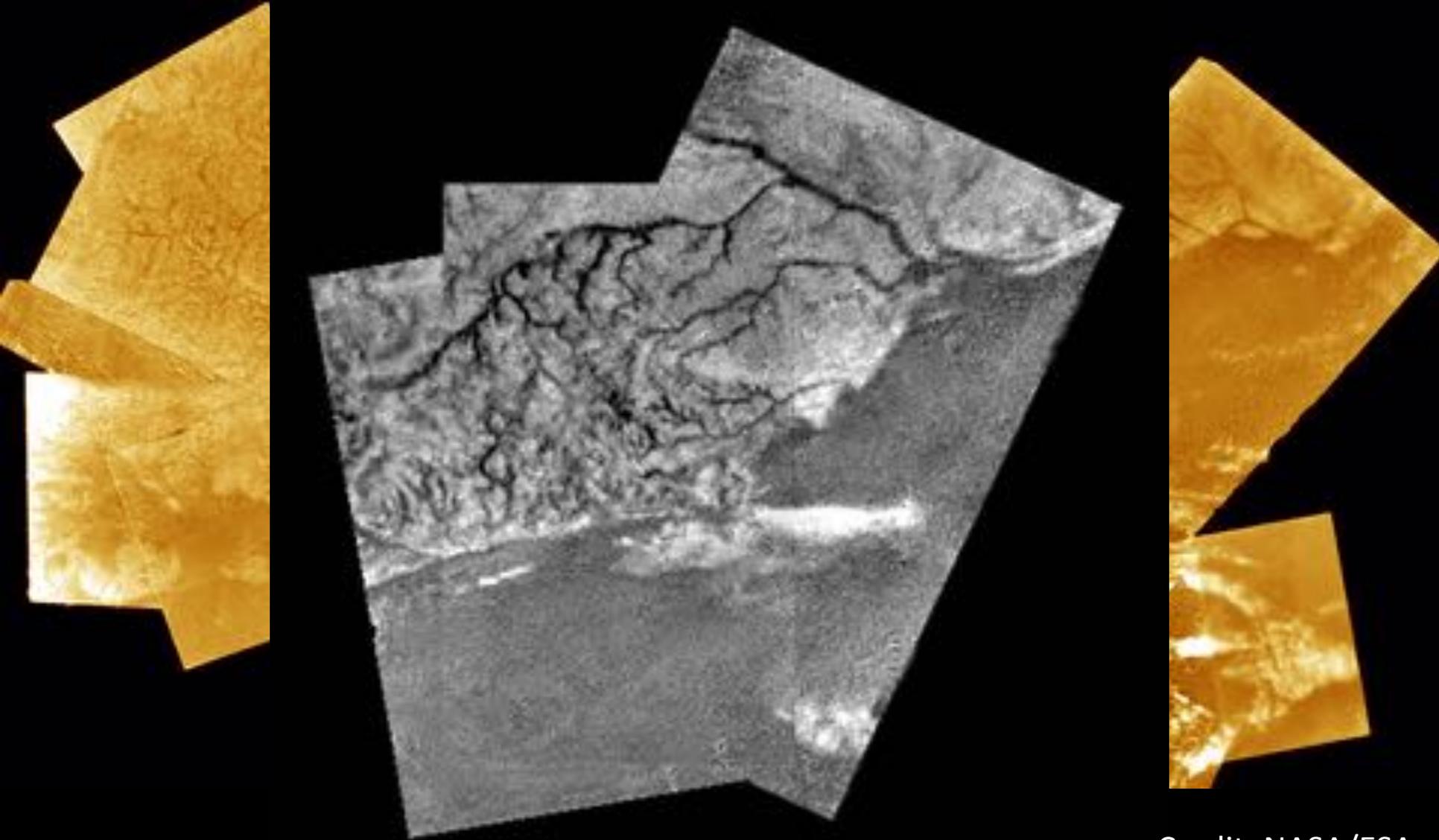


Earth's atmospheric windows

Huygens Landing – Evidence of Liquids

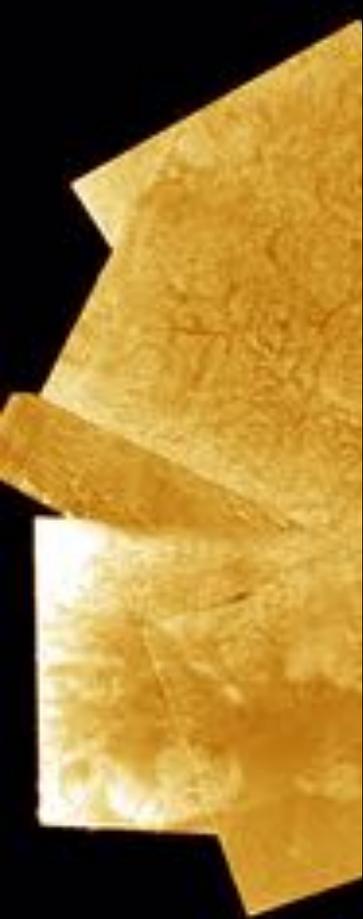


Huygens Landing – Evidence of Liquids



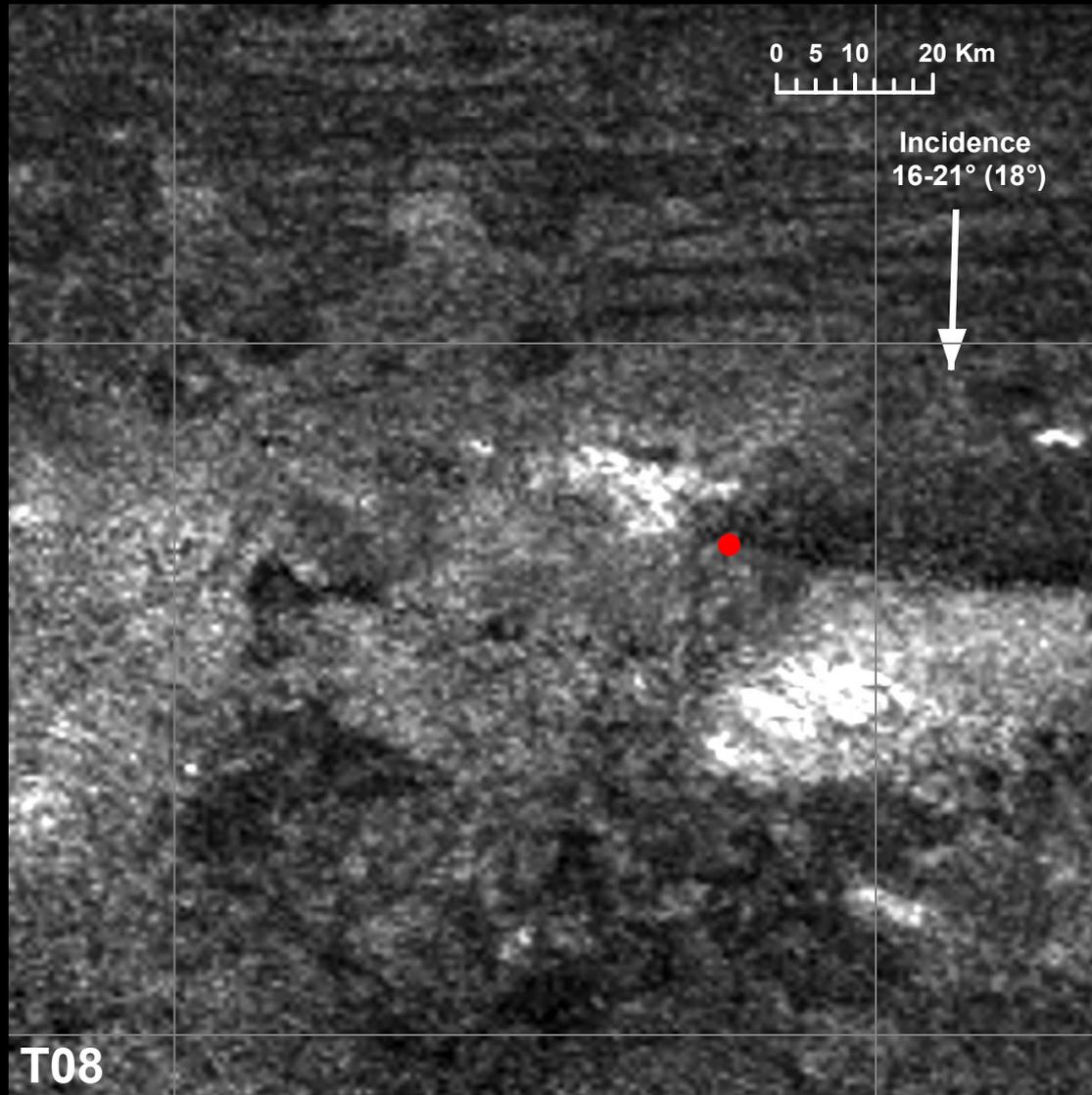
Credit: NASA/ESA

Huygens Landing – Evidence of Liquids



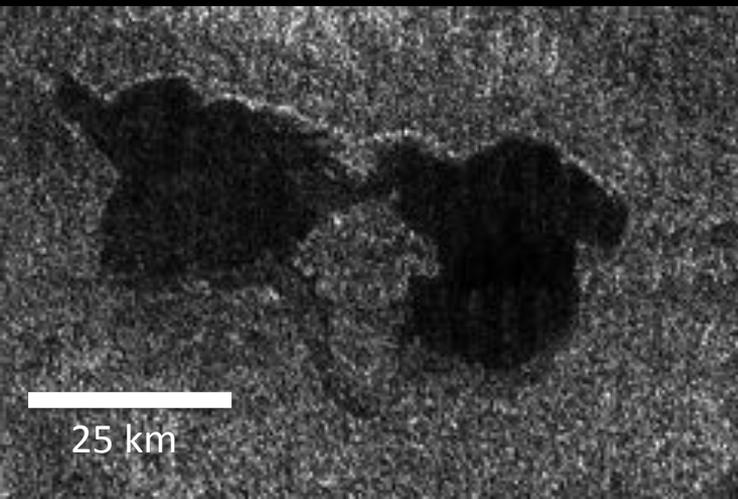
Credit: NASA/ESA

Huygens Landing at 300 m Resolution

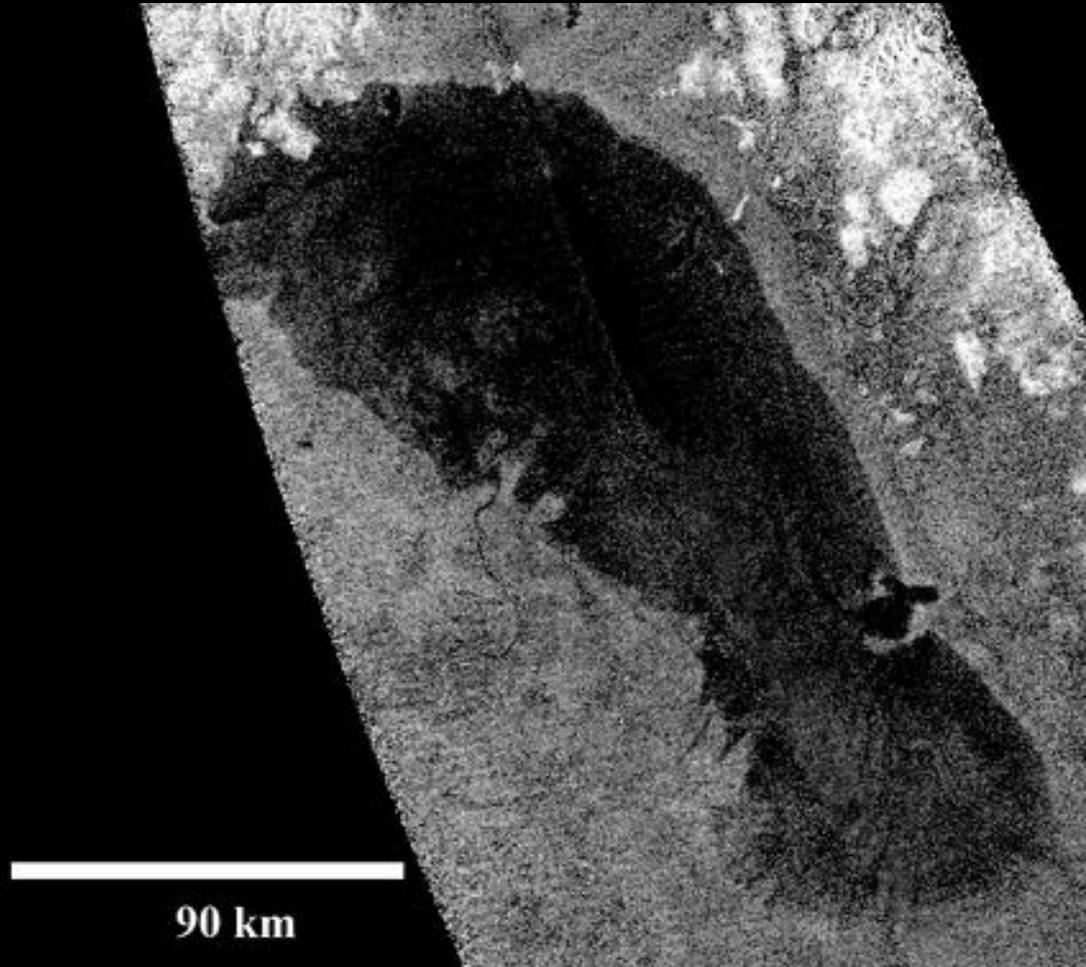


Lakes

- Only instance of current, stable, surface liquids in the Solar System aside from water on Earth



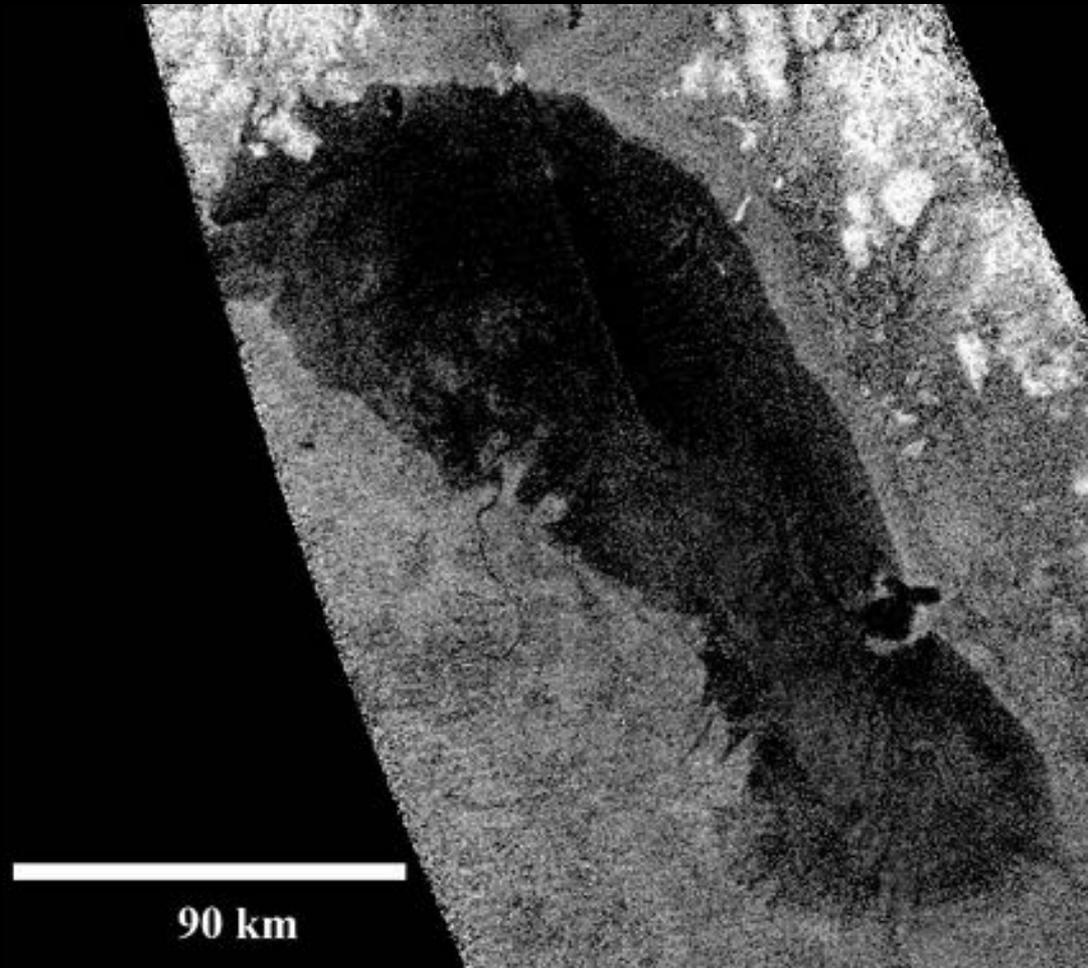
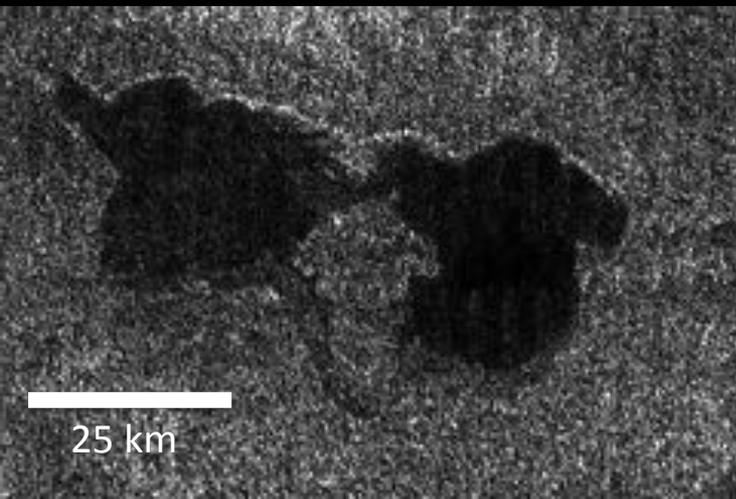
Abaya Lacus



Ontario Lacus

Lakes

- Only instance of current, stable, surface liquids in the Solar System aside from water on Earth

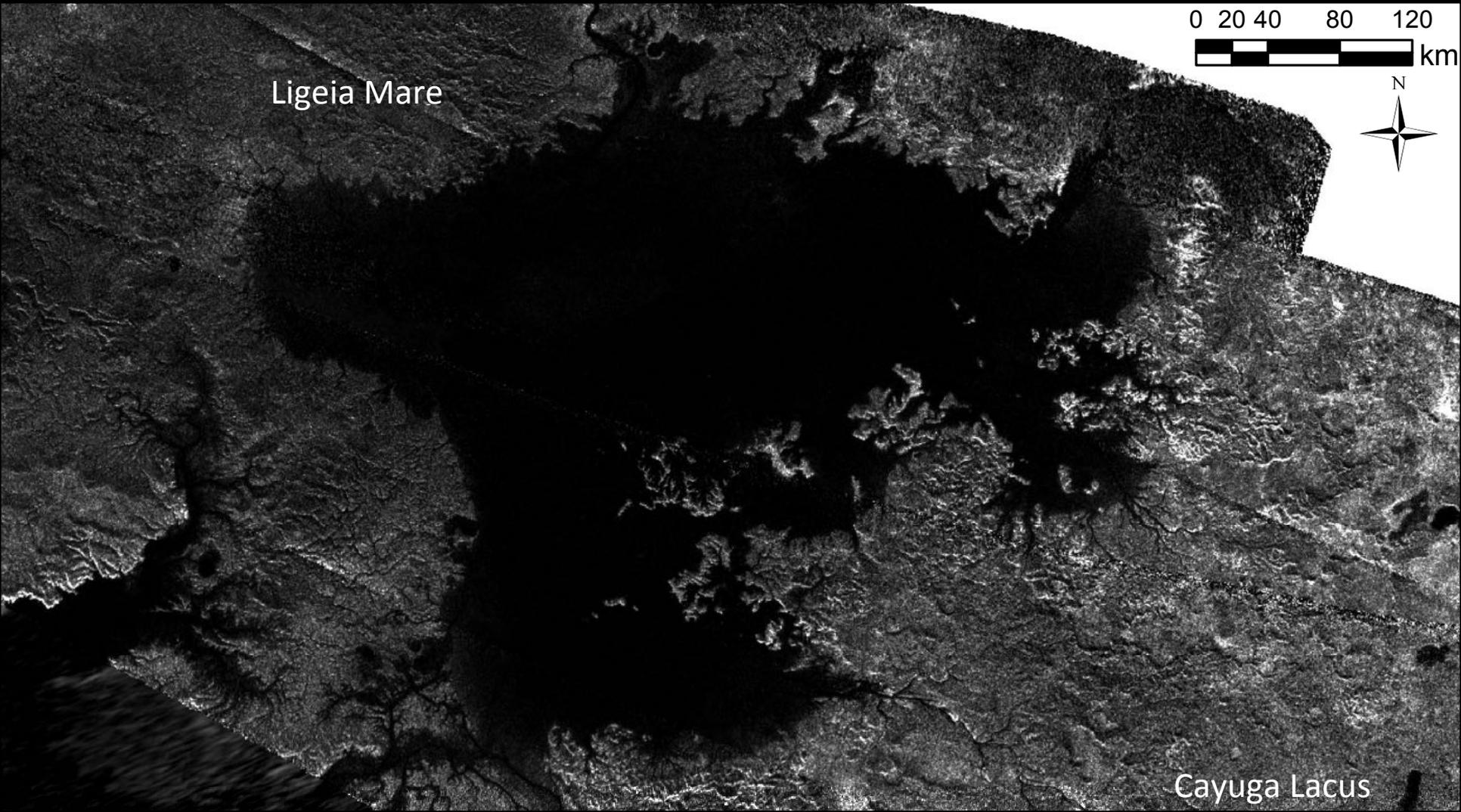


Ontario Lacus

Abaya Lacus
Kissing Lakes

Seas

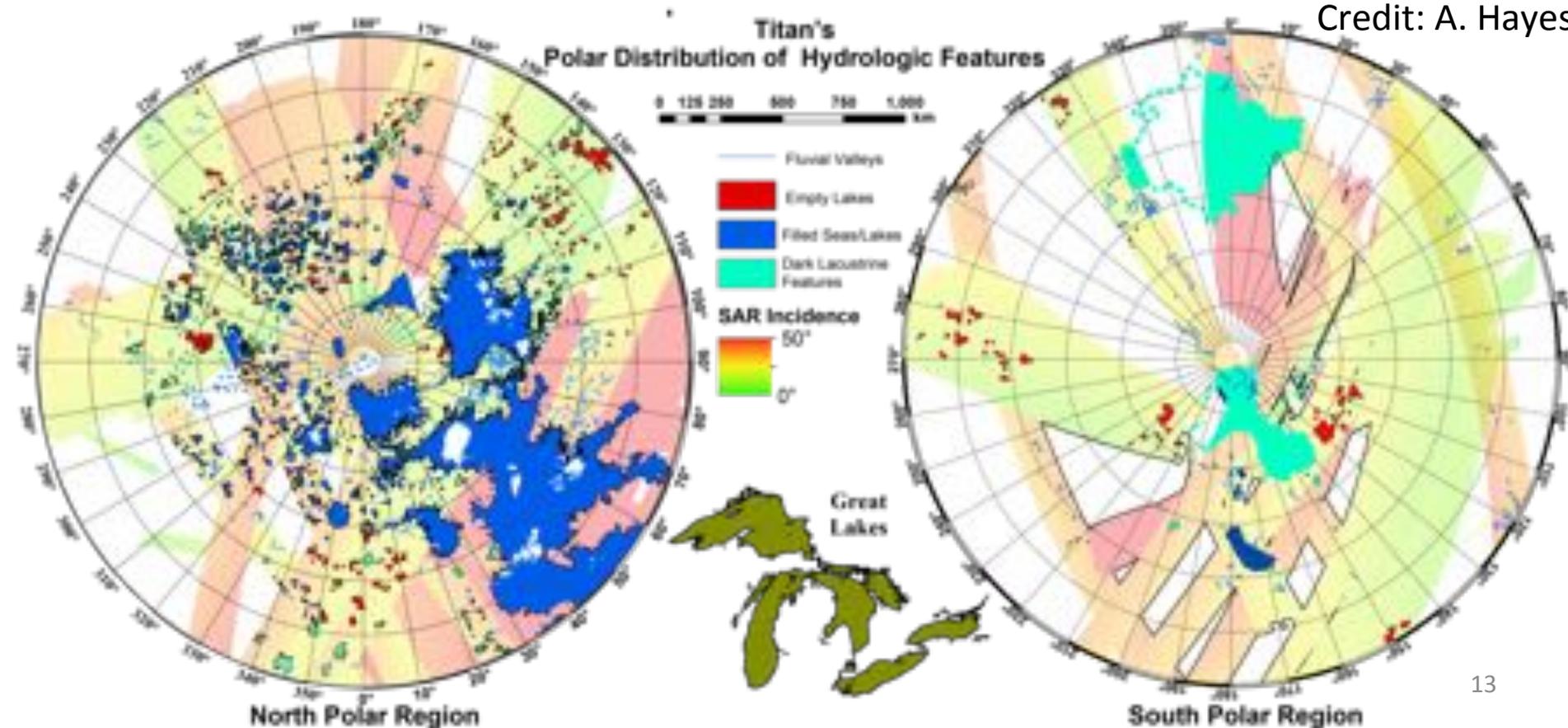
- Similar in size to the Great Lakes on Earth



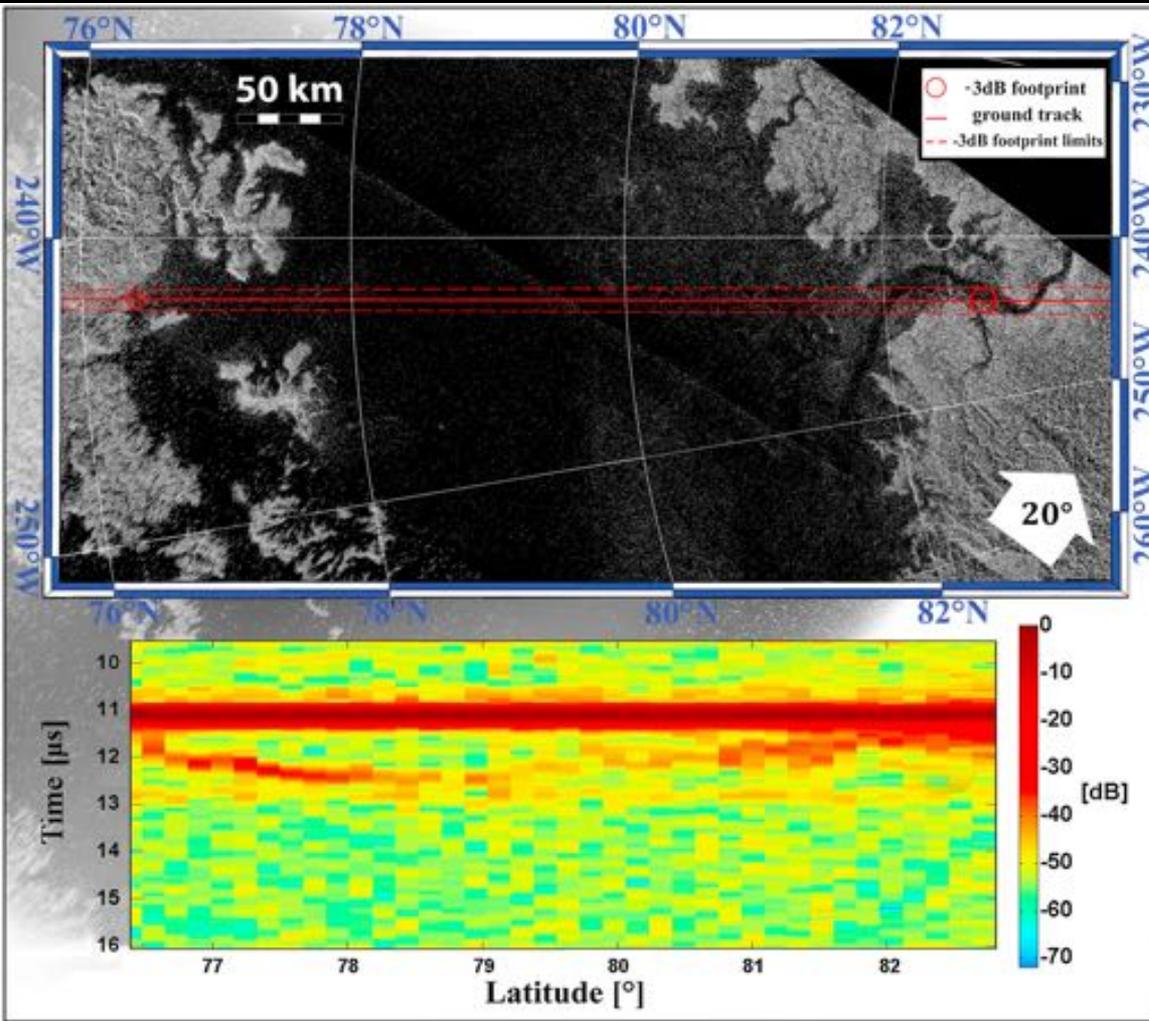
Distribution of Lakes and Seas

- All of the lakes and seas are poleward of 55°
- More than 99% of the liquid is in the north

Credit: A. Hayes



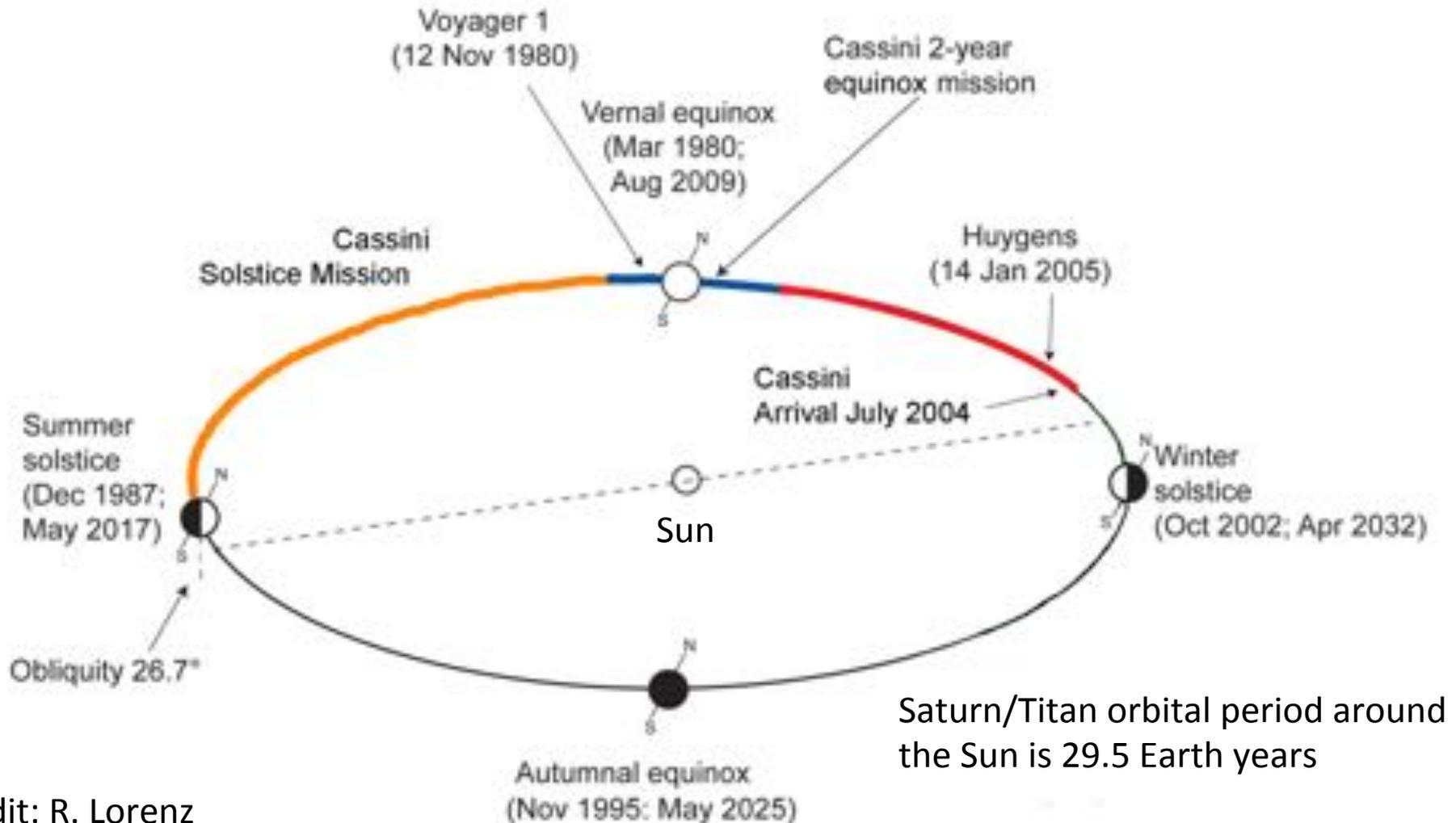
Depth and Composition



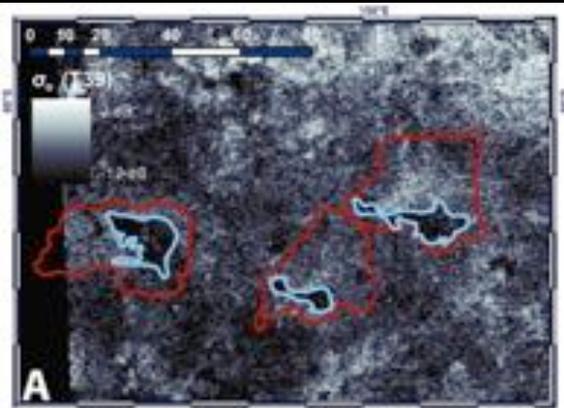
- Ligeia Mare is 600 feet deep and mostly methane
- A single sea has more hydrocarbons than all of the proven fossil fuel reserves on Earth

Seasons on Titan

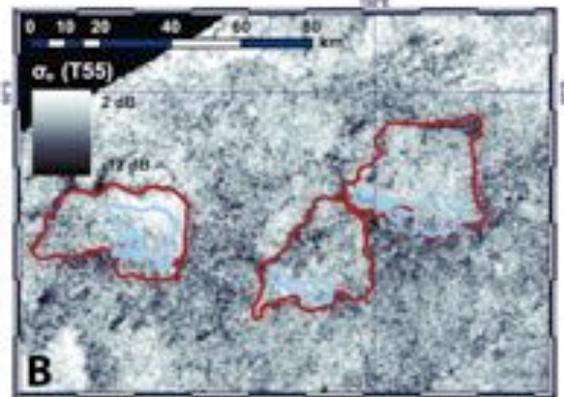
- Seasons are due to obliquity not eccentricity!



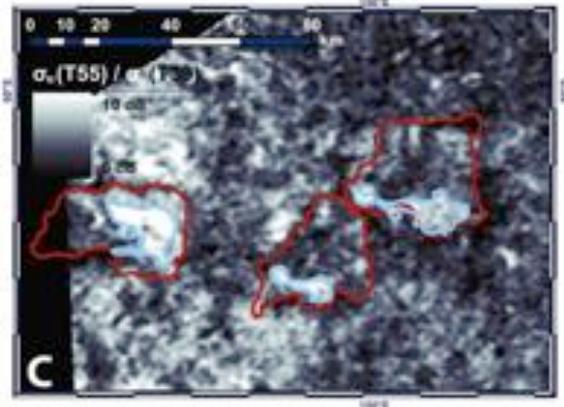
Seasonal Hydrologic Cycle



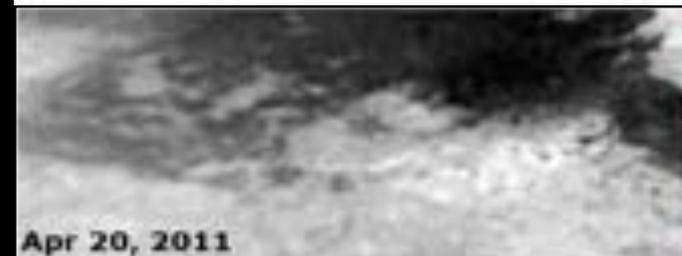
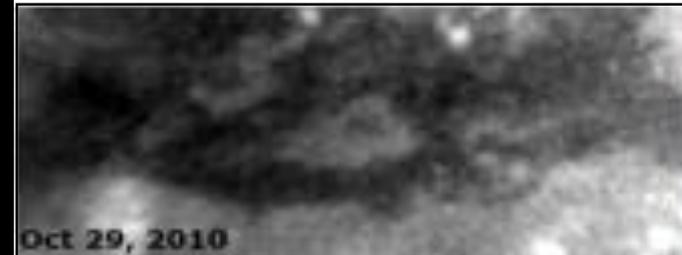
Southern Summer:
Retreat of southern lakes
due to evaporation and/
or infiltration
Hayes et al., 2011



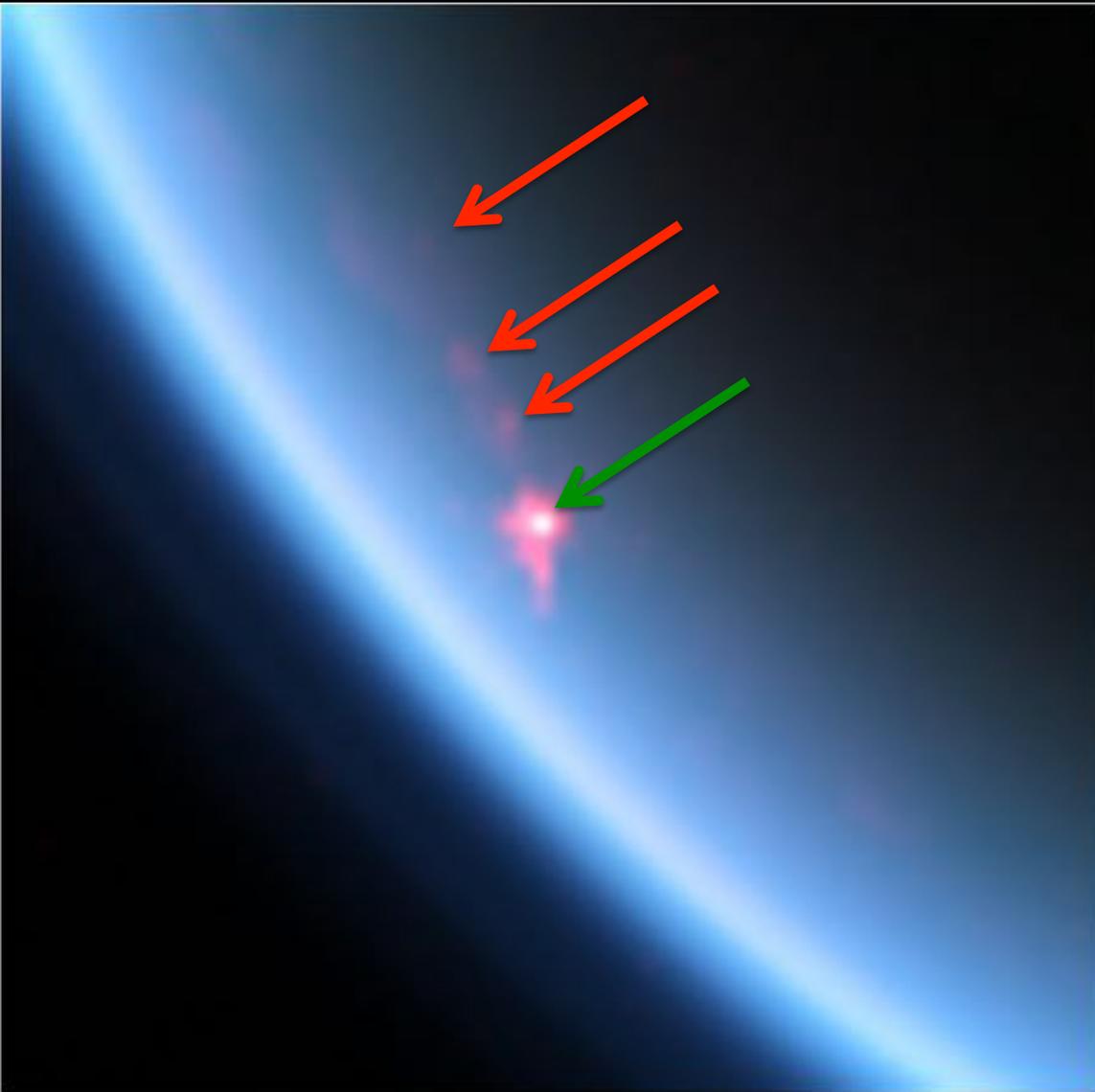
Vernal Equinox:
Equatorial precipitation
Turtle et al., 2011



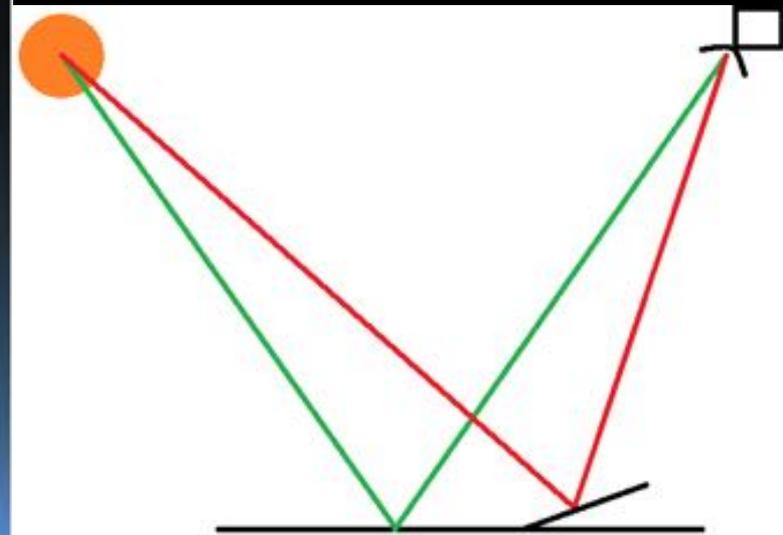
Sep 27, 2010; Large Cloud to the West

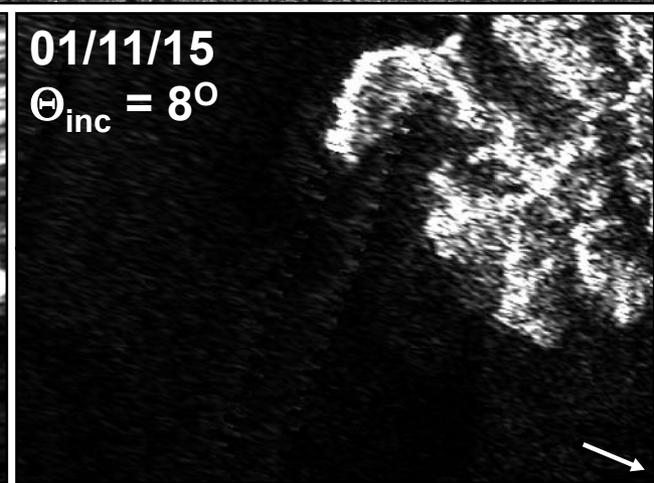
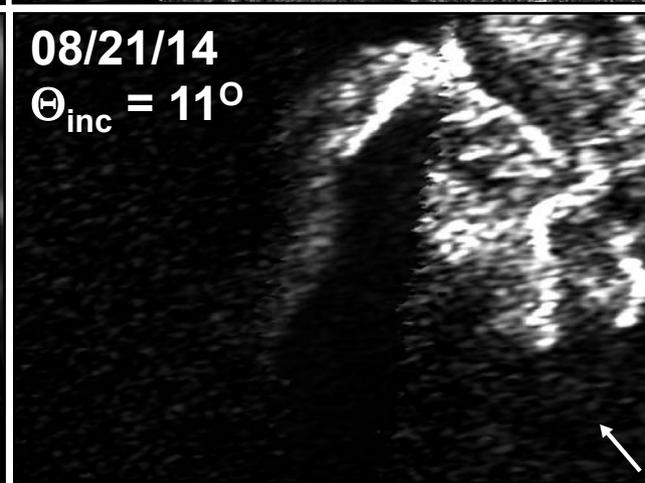
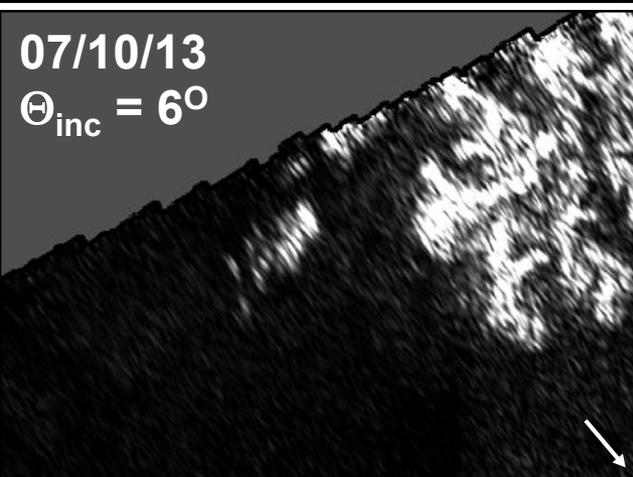
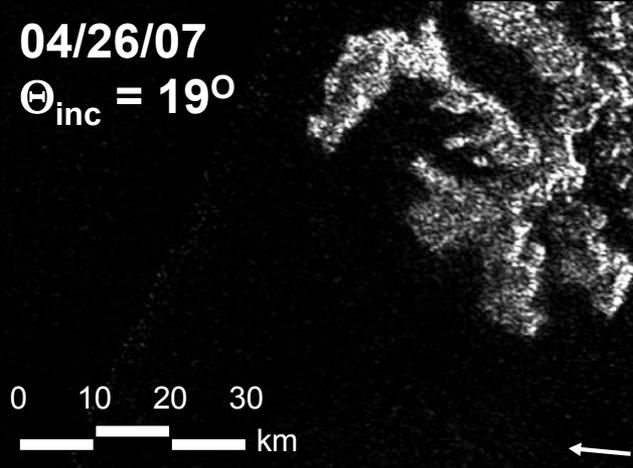


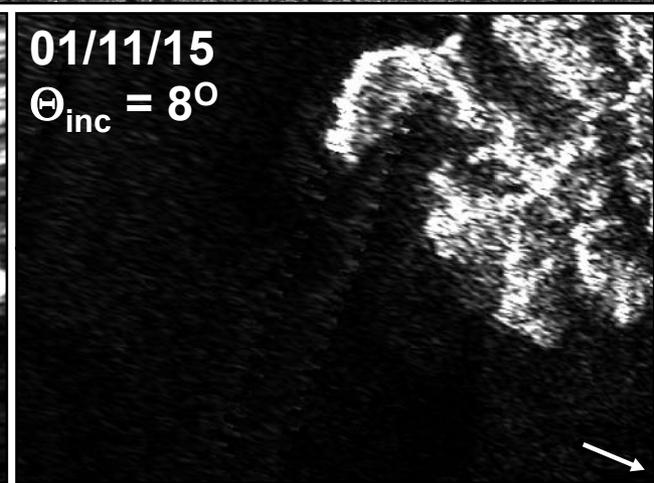
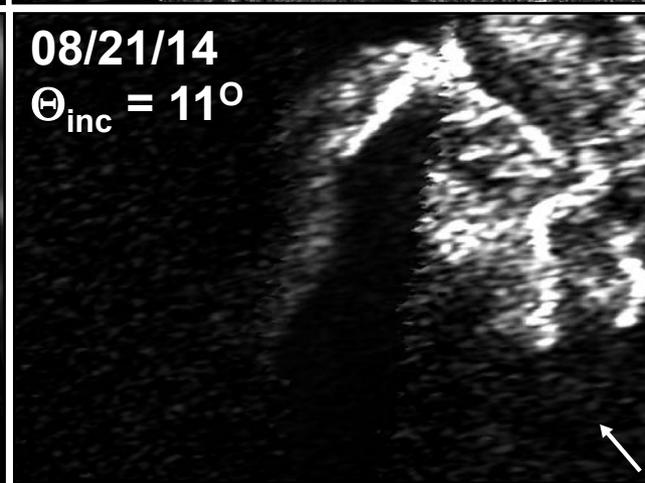
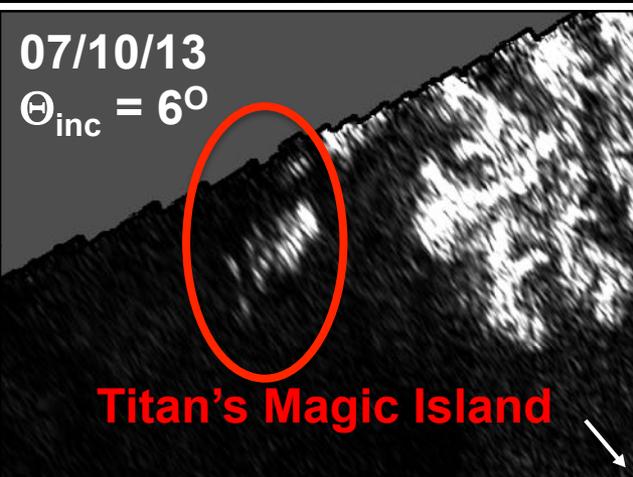
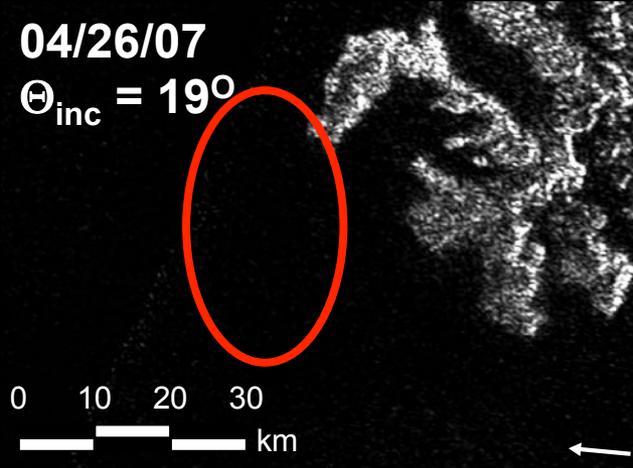
Northern Spring

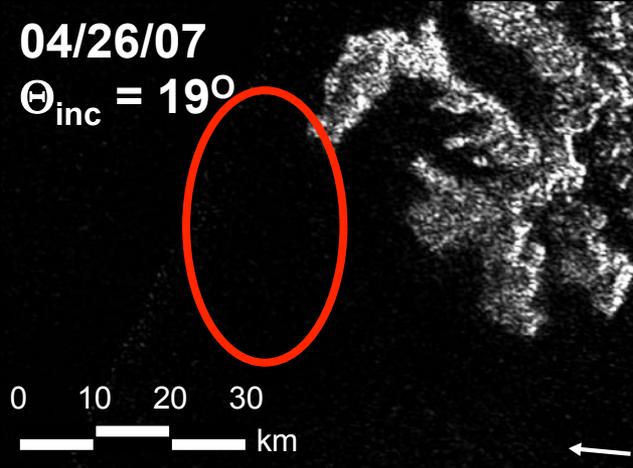


High-phase specular reflections are isolated patches of Punga Mare: **mudflats or waves**

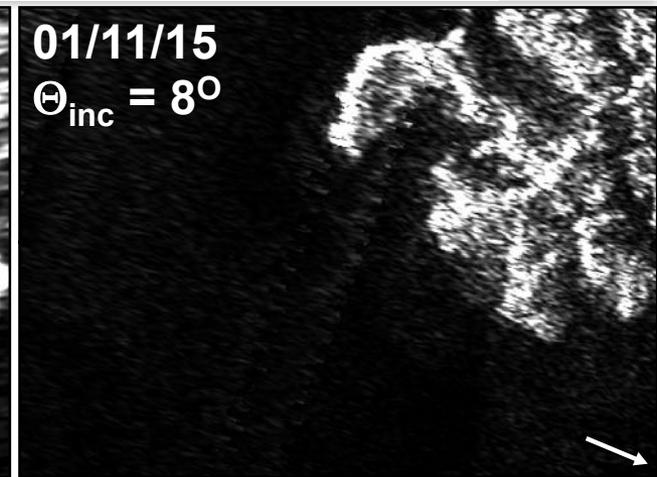
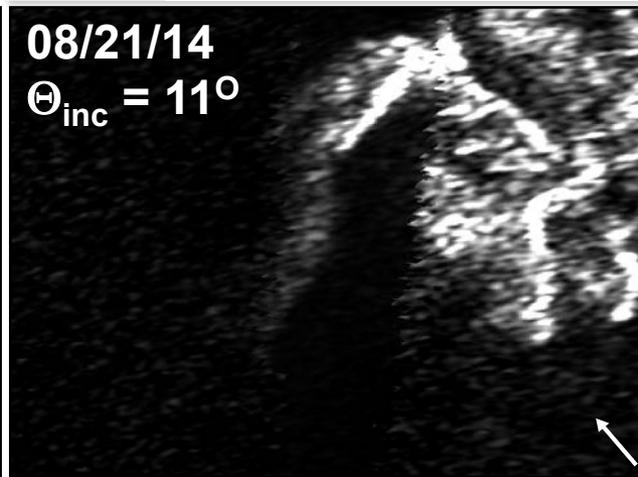
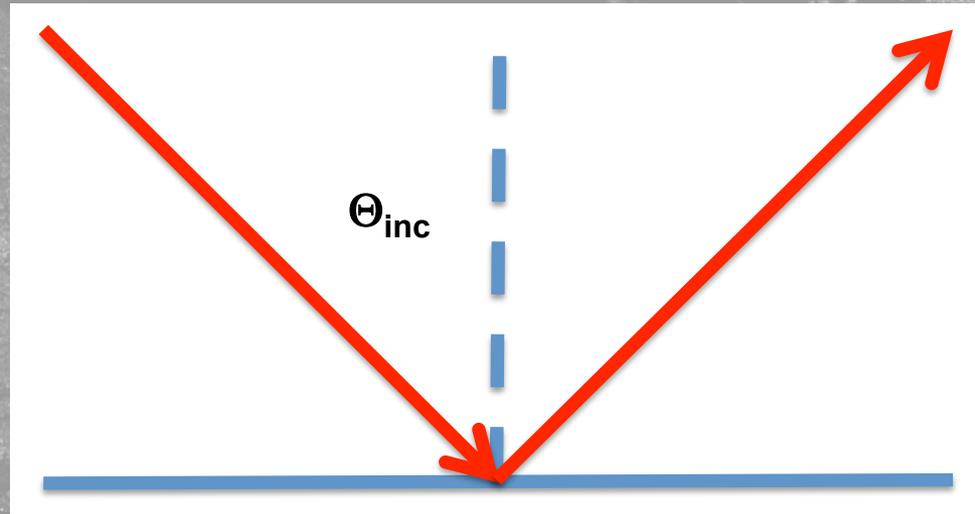








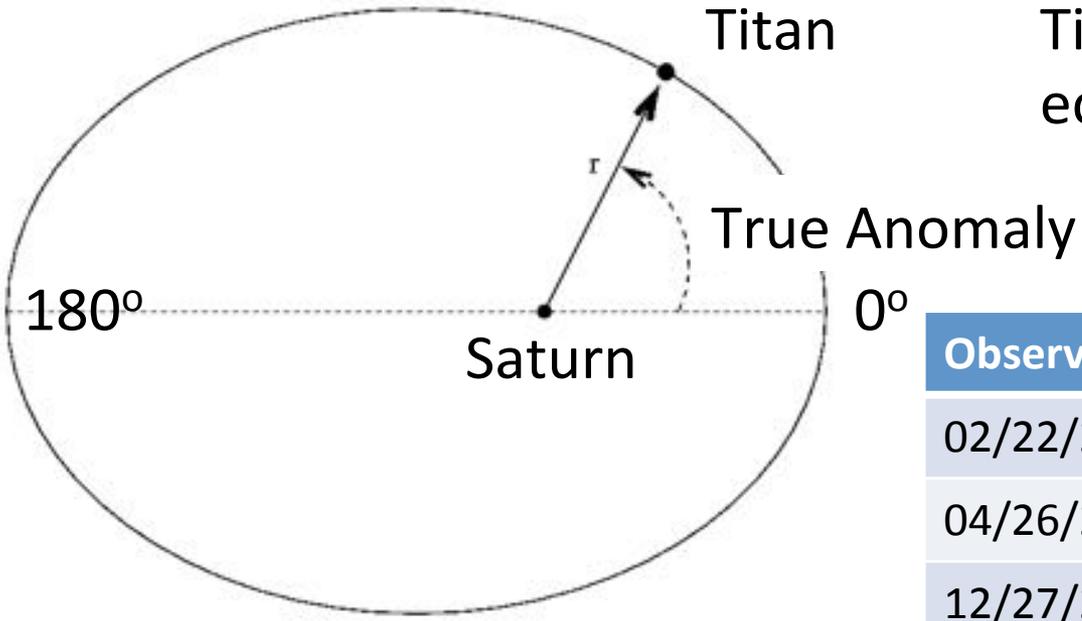
- Not an artifact
- Not a permanent geophysical structure
- A transient feature



Transient Hypotheses

- A new island is unlikely
 - Change in morphology
 - Not observed in most recent observation
- Sea level change that reduces absorption is unlikely
 - Ligeia Mare is nearly transparent to the radar; Mastrogiuseppe et al., 2014
 - Requires changes of > 60 m
- Sea level change that causes surface exposure is unlikely
 - Requires exposure of $> 60\%$ of the area
- Seafloor change is unlikely
 - Requires $\epsilon_{\text{seafloor}} > 2.7$ and then reversion to ~ 2

Tides do not explain the Transient Features



Tides on Titan are due to its eccentric orbit around Saturn

Tides should cause consistent presence/absence with true anomaly

Observation	True Anomaly	Transient?
02/22/2007	16	X
04/26/2007	15	X
12/27/2009	71	X
05/23/2013	68	X
07/10/2013	68	✓
10/14/2013	68	X
08/21/2014	246	✓
01/11/2015	245	X

Bubbles are a Plausible Hypothesis

- Terrestrial Analog: La Brea Tar Pits



~ inch sized methane bubbles in tar
Credit: tarpits.org



~10 inch sized methane bubble plume in water
Credit: Feldfrei Blog

Floating or Suspended Solids are Plausible Hypotheses

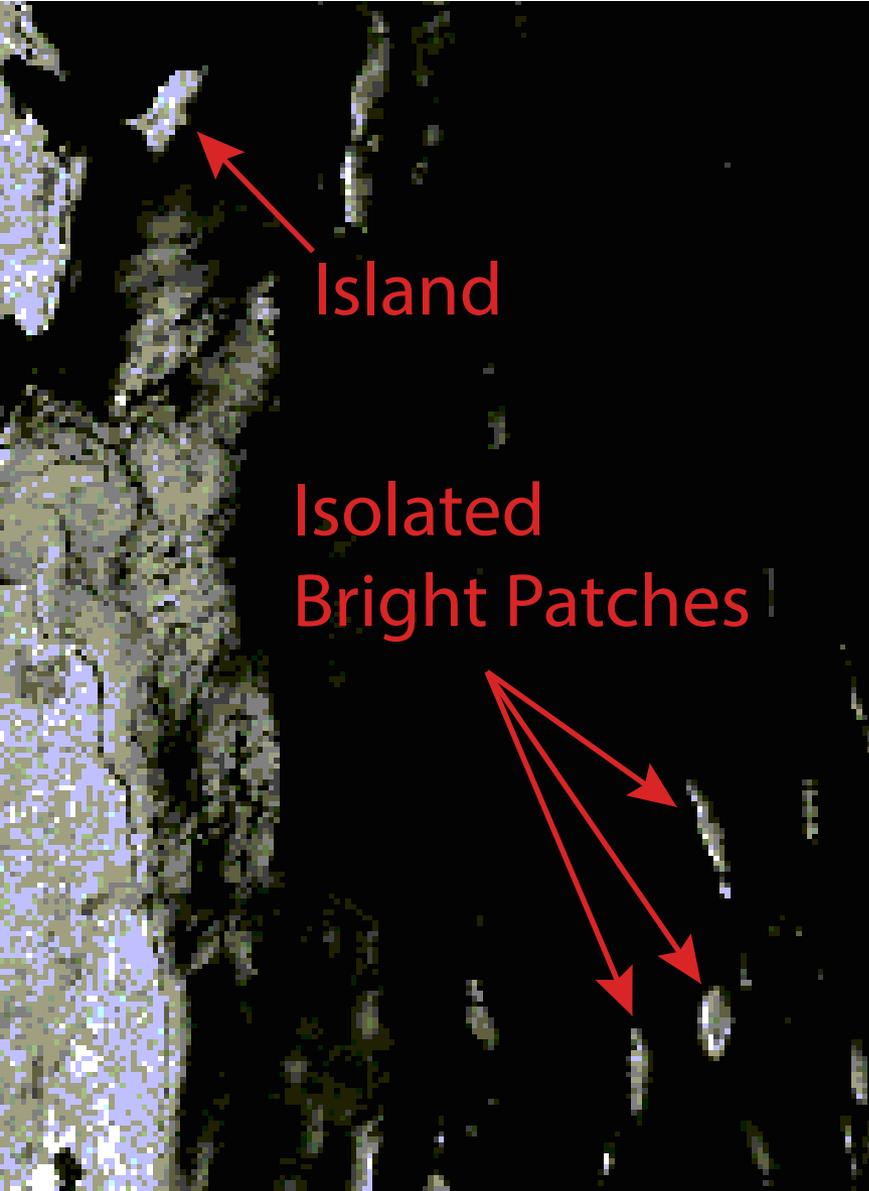
Credit: Randy Kirk



Floating or Suspended Solids are Plausible Hypotheses



Waves are the *Preferred* Hypothesis



Terrestrial Analog

ERS-1 radar image of Lake Ladoga, Russia

70 by 50 km

Ivanov et al., 1997

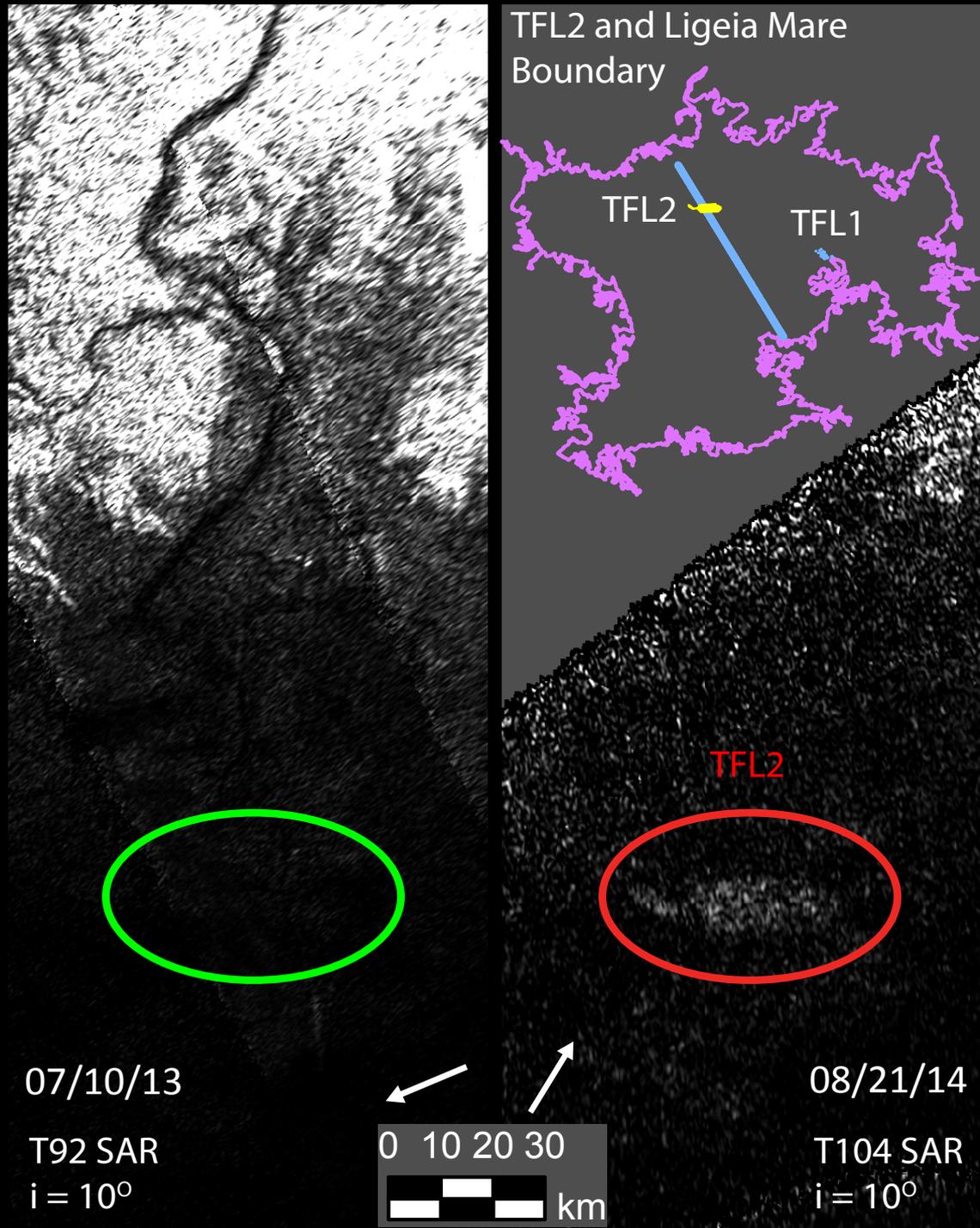
Illustration of Waves on Titan

Credit: NASA



“Magic Island” #2

- Similar to “Magic Island” #1 on 08/21/14
- Also a transient feature that is most consistent with waves, floating or suspended solids, and bubbles





Future Observations and Exploration

Conclusions

- Titan's Surface Liquids and Hydrologic Cycle!
- Transient features discovered and confirmed in Titan's hydrocarbon sea, Ligeia Mare!
 - Most consistent with waves, floating or suspended solids, and bubbles
- Waves are favored as the most probable explanation because of their higher frequency in analogous terrestrial environments