ASTR/GEOL-2040: Search for life in the Universe: Lecture 28

- Titan's haze
- Titan's interior
- Future missions

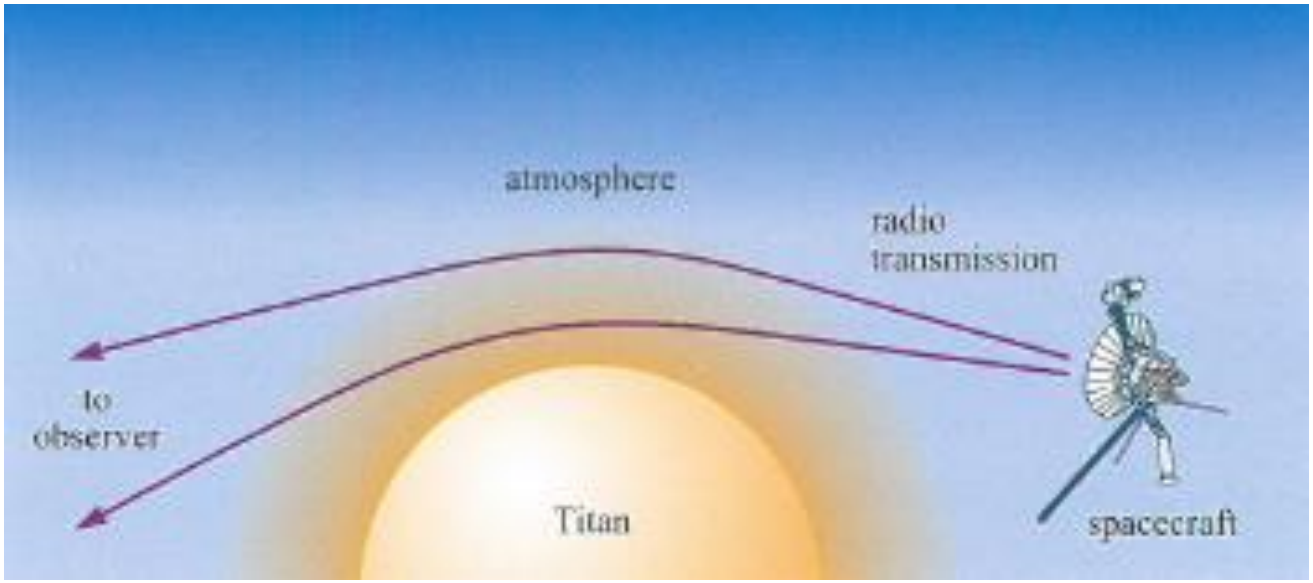
Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and Wednesdays 11-12 in D230)

Fiske, Quiz 2, & guest lecture

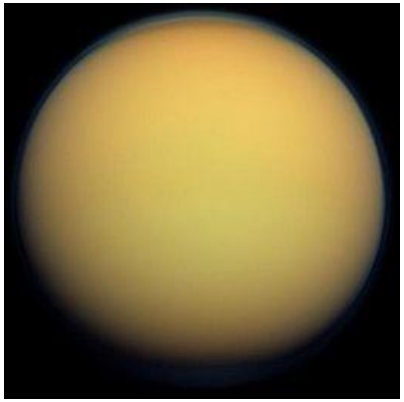
- Fiske, *next* Monday November 13
- Quiz #2, Wednesday November 15
  - Sample Quiz #2 is online!
- Guest lecture, Friday, Carol Cleland, Nov 17
  - Check out her work on Web of Science,
  - or ADS (see syllabus!)
- Fiske & Cleland lect included in final

Advantages of fly-bys…

- Measuring thickness of atmosphere
- 1.6 bar



Titan



- Titan's pressure of 1.6 bar
  - Bennett & Shostak, p. 319
  - "fairly comfortable even without space suit"
  - Why? What's the problem at low pressures?

A. Can't hear normally
B. Can't balance properly
C. Body tissue would burst
D. Water would boil

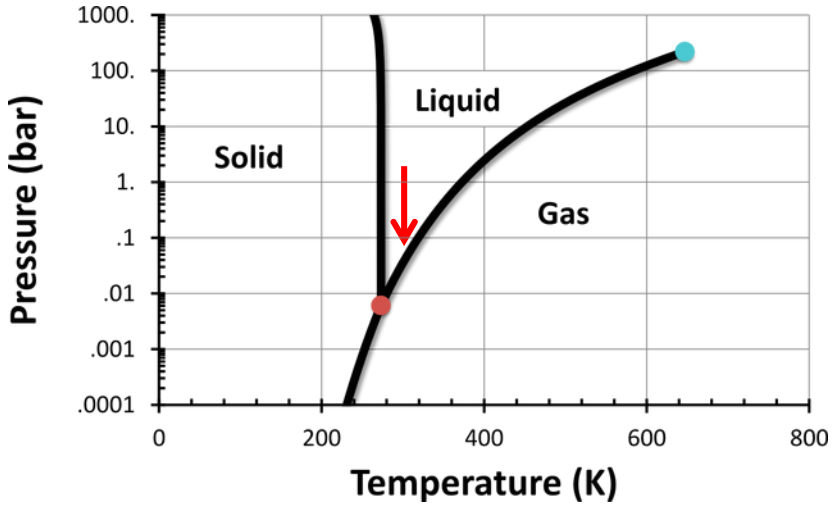
Neil Armstrong?

1930-2012

Armstrong limit

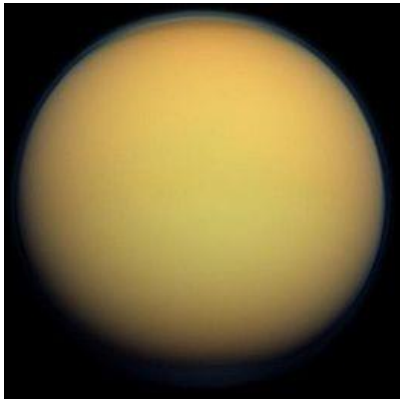
From Wikipedia, the free encyclopedia

The **Armstrong limit**, often called **Armstrong's line**, is the altitude that produces an atmospheric pressure so low (0.0618 atmosphere or 6.3 kPa (47 mmHg)) that water boils at the normal temperature of the human body: 37 °C (98.6 °F). It is named after Harry George Armstrong, who founded the U.S. Air Force's Department of Space Medicine in 1947 at Randolph Field, Texas.[Note 1] Armstrong was the first to recognize this phenomenon, which occurs at an altitude beyond which humans absolutely cannot survive in an unpressurized environment.[1] Above Earth, this begins at an altitude of approximately 18 km (60,000 ft)[2] to about 19 km (62,000 ft).[3]



If the cockpit lost pressure while the aircraft was above the Armstrong limit, even a positive pressure oxygen mask could not sustain pilot consciousness.

Titan



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Why is Titan so cold?

A. Because of the haze
B. Because of large albedo
C. Because of distance to the Sun
D. Because tidal heating inefficient
E. Radioactive heating inefficient

Why so cold?

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B. Because of large albedo
C. Because of distance to the Sun
D. Because tidal heating inefficient
E. Radioactive heating inefficient

→ Lecture 9 (Earth's temperature)

$$T_E = T_S \left(\frac{R_{Sun}}{2r} \right)^{1/2} (1-A)^{1/4} \leq 279\,\mathrm{K}$$

This was for r=1AU; for r=10AU →

A. 30% less
B. 3 times less
C. 6 times less

→ Lecture 9 (Earth's temperature)

$$T_E = T_S \left(\frac{R_{Sun}}{2r} \right)^{1/2} (1-A)^{1/4} \leq 279\,\mathrm{K}$$

This was for r=1AU; for r=10AU → $1/\sqrt{10} \approx 1/3$

A. 30% less

B. 3 times less $\quad 279/3 = 93$

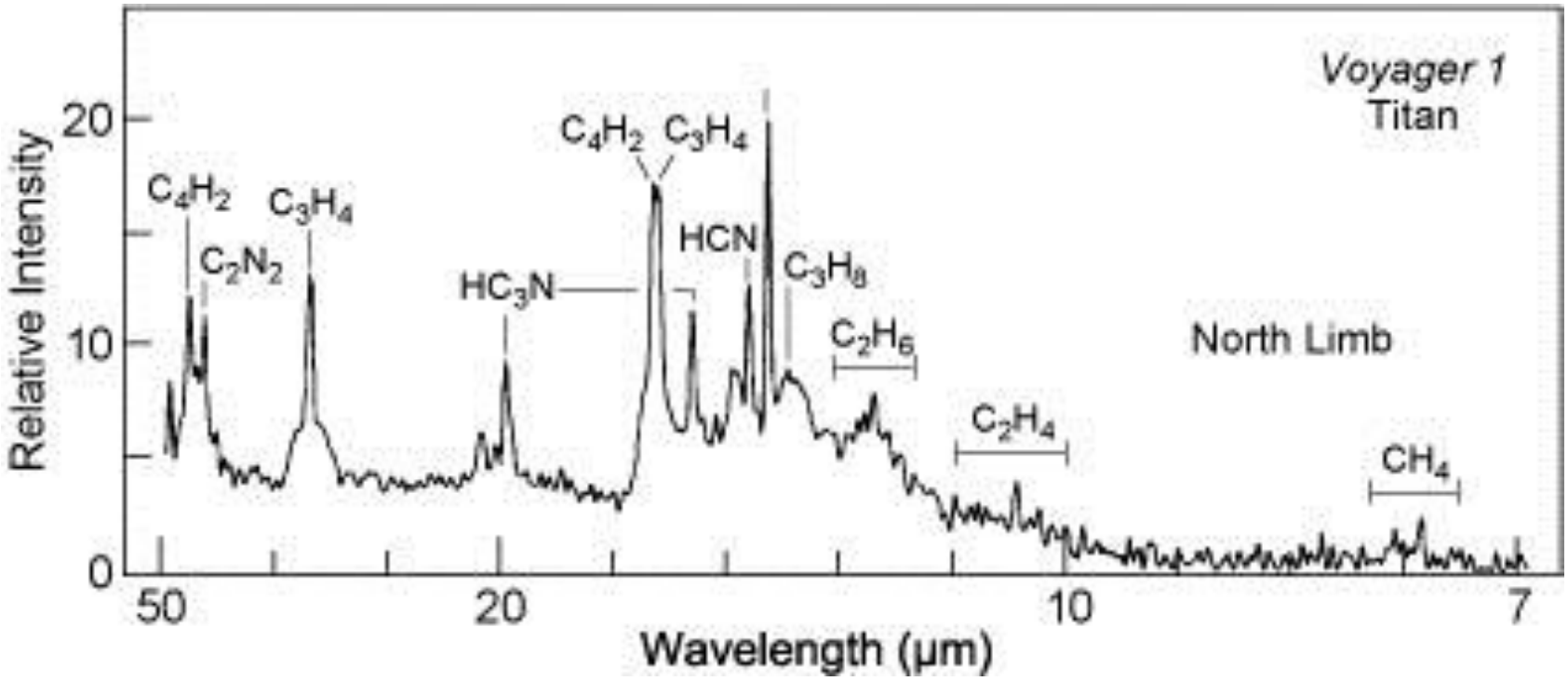
C. 6 times less

Today:

- Methanogenesis, cryovolcanism
- Haze photochemistry

- Longstaff: pp 297 – 303
- BS: 319 – 326
- RGS: 180 – 198

Titan's atmosphere



- Infrared spectrum from Voyager

Origin of N_2

Lect. 19, p.16
Bermuda triangle

- N_2 trapped in the ice (as clathrates)
- Lab experiments: N_2 and Ar trapped equally
- Original ratio: $Ar/N_2 \sim 0.06$

A. $Ar/N_2 \sim 0.6$

B. $Ar/N_2 \sim 0.06$

C. $Ar/N_2 \sim 0.006$

D. $Ar/N_2 << 0.0006$

Atmospheric composition

- N_2, CH_4, and H_2 most important

gas	concentration
N_2	0.97
CH_4	0.049
H_2	0.0011
CO	0.00006 (6e-5)
Ar	0.0000432
C_2H_6	0.000011 [ethane]
C_2H_2	0.000003 (3e-6) [ethyne]

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A. $Ar/N_2 \sim 0.6$
B. $Ar/N_2 \sim 0.06$
C. $Ar/N_2 \sim 0.006$
D. $Ar/N_2 << 0.0006$

Actually
0.00004
4e-5

2^{nd} model: $2NH_3 \rightarrow N_2 + 3H_2$

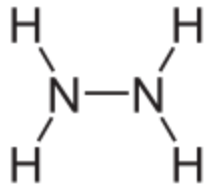
- Would be very slow at 94K
- if reaction in equilibrium!

Lect 4: Energy sources on Earth

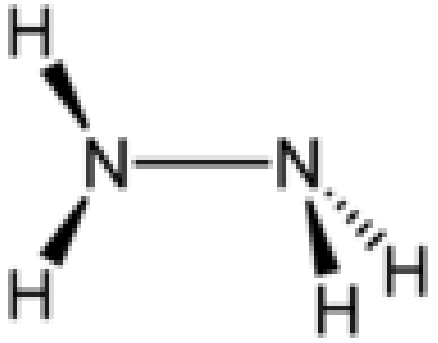
Source	Energy /J $m^{-2} yr^{-1}$
total radiation from the Sun	1 090 000.0
ultraviolet light	1 680.0
electric discharges (lightning)	1.68
cosmic rays	0.000 6
radioactivity (to 1 km depth)	0.33
volcanoes	0.05
shock waves (atmospheric entry)	0.46

$2NH_3 \rightarrow N_2 + 3H_2$ not directly

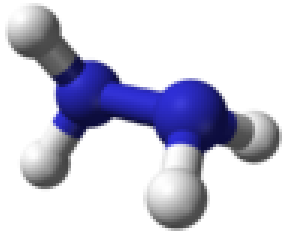
- $NH_3 \rightarrow NH_2 + H$
- $NH_2 + NH_2 \rightarrow N_2H_4$



Hydrazine (famable)



- $N_2H_4 \rightarrow N_2+2H_2$



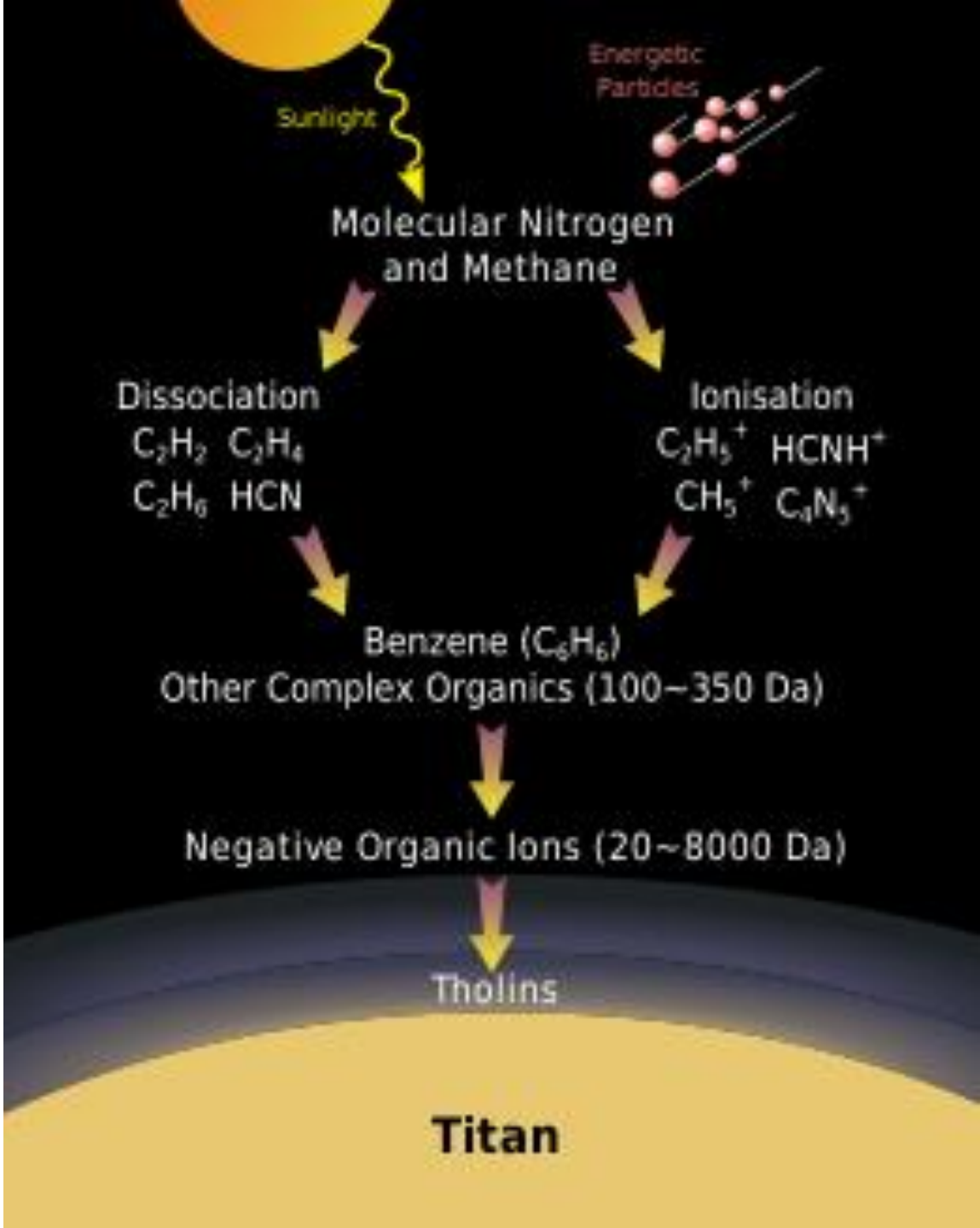
Methane: similar story

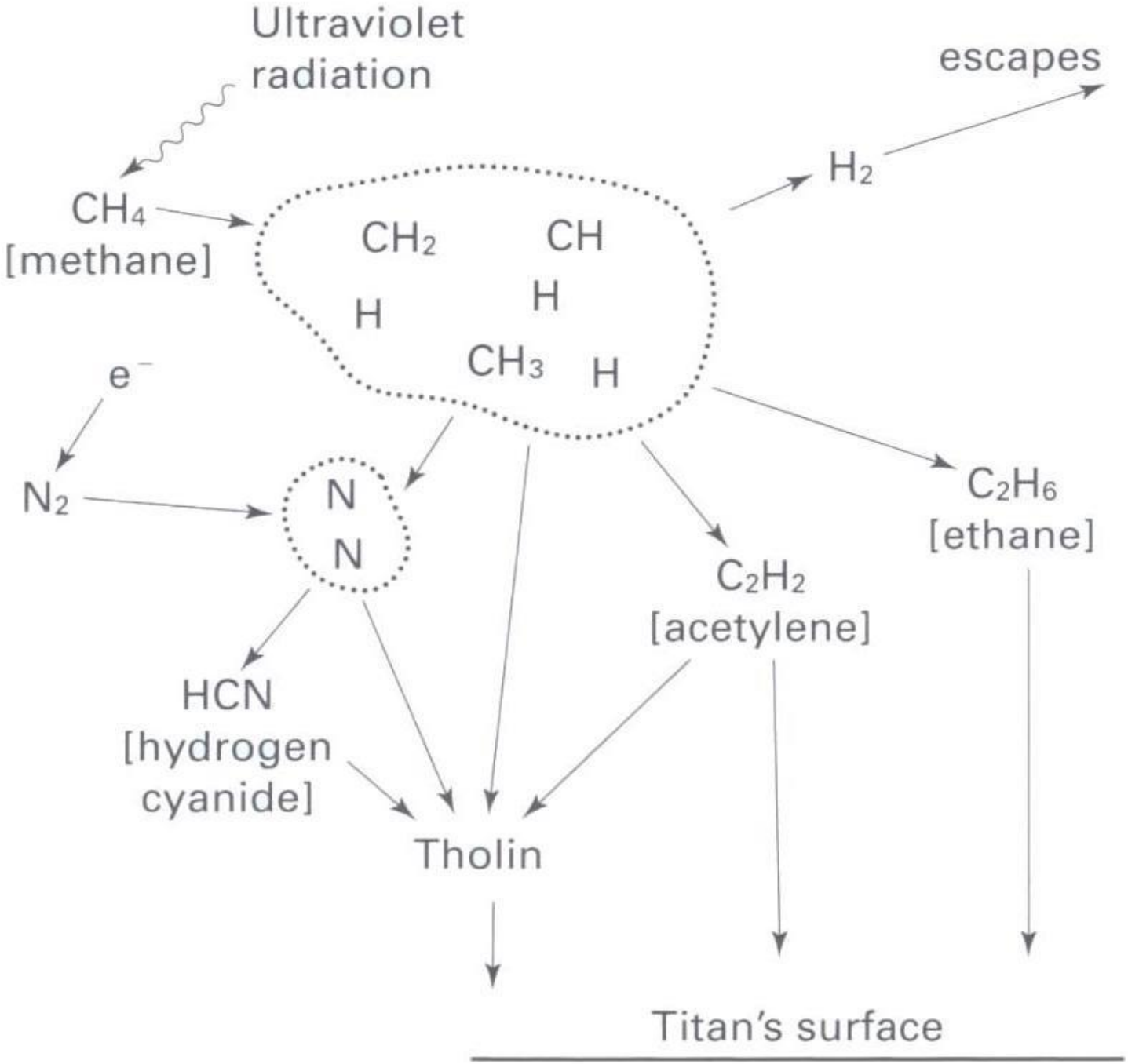
- $CH_4 \rightarrow CH_3 + H$ (methyl molecule)
  - has an unpaired electron → highly reactive
  - chemists call this a "radical"
- $CH_3 + CH_3 \rightarrow C_2H_6$ (ethane)
  - Readily absorbs ultraviolet
  - $C_2H_6 \rightarrow C_2H_2 + 2H_2$ (C_2H_2 ethyne)

C_2H_2

Continue losing H

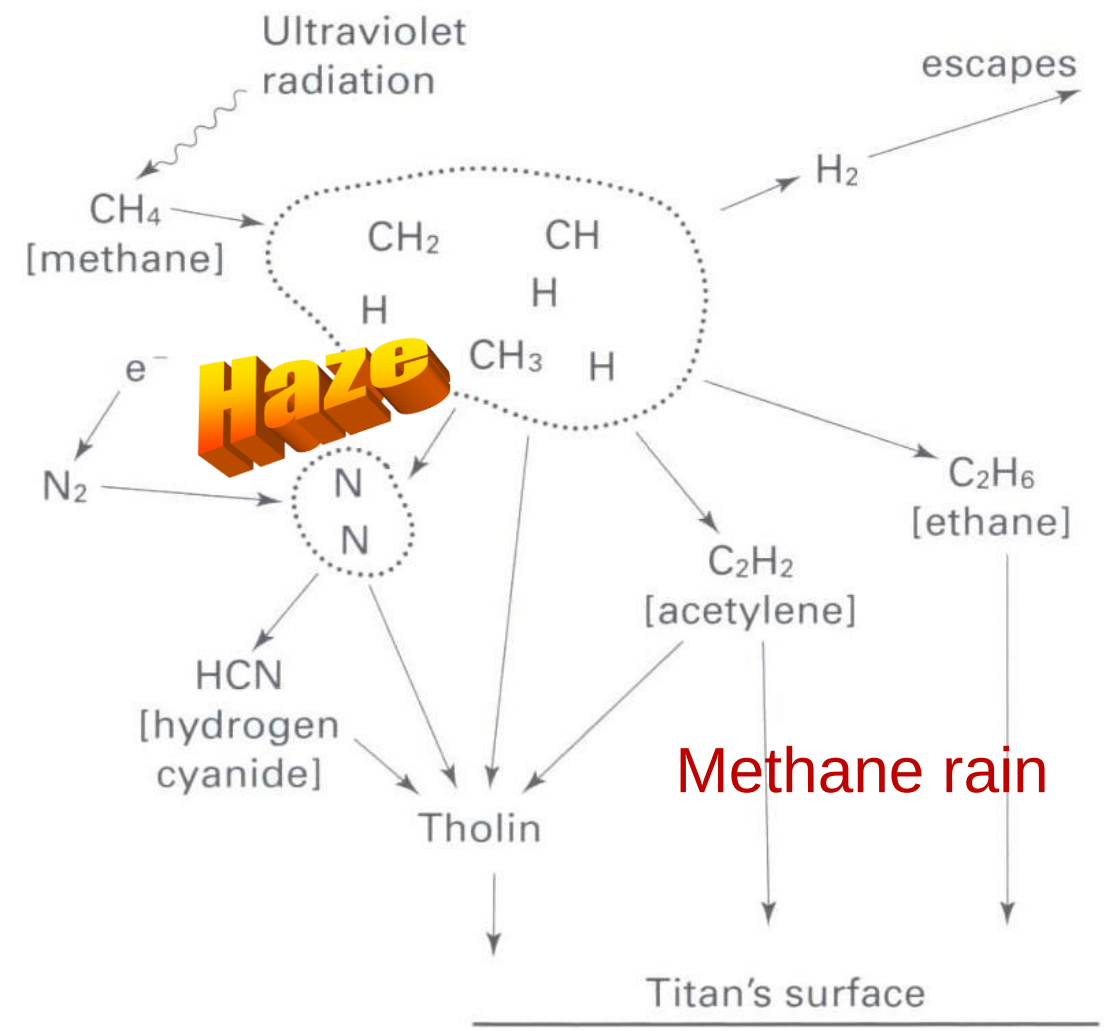
- Longer carbon chains
- HCC + HCCH → HCCCCH+H
- Never regain any methane
  - irreversible




Ultraviolet radiation
escapes
H_2
CH_4 [methane]
CH_2
CH
H
H
CH_3
H
e^-
N_2
N
N
C_2H_6 [ethane]
C_2H_2 [acetylene]
HCN [hydrogen cyanide]
Tholin
Titan's surface

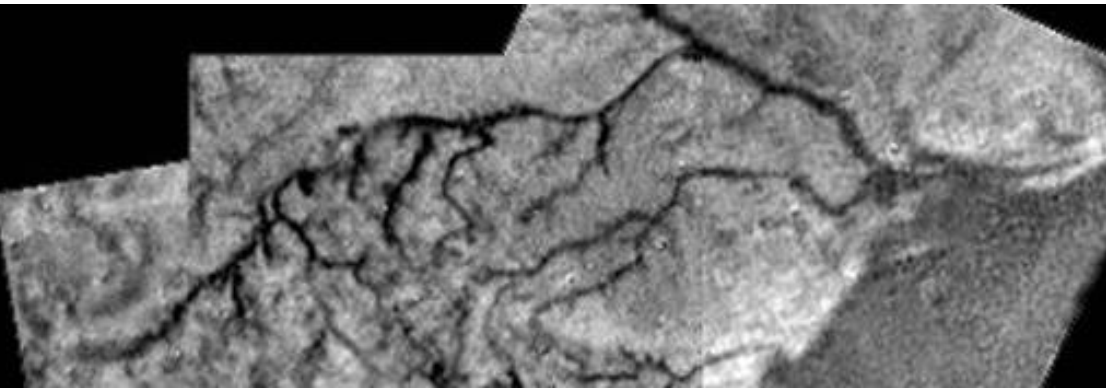
Haze = Smog

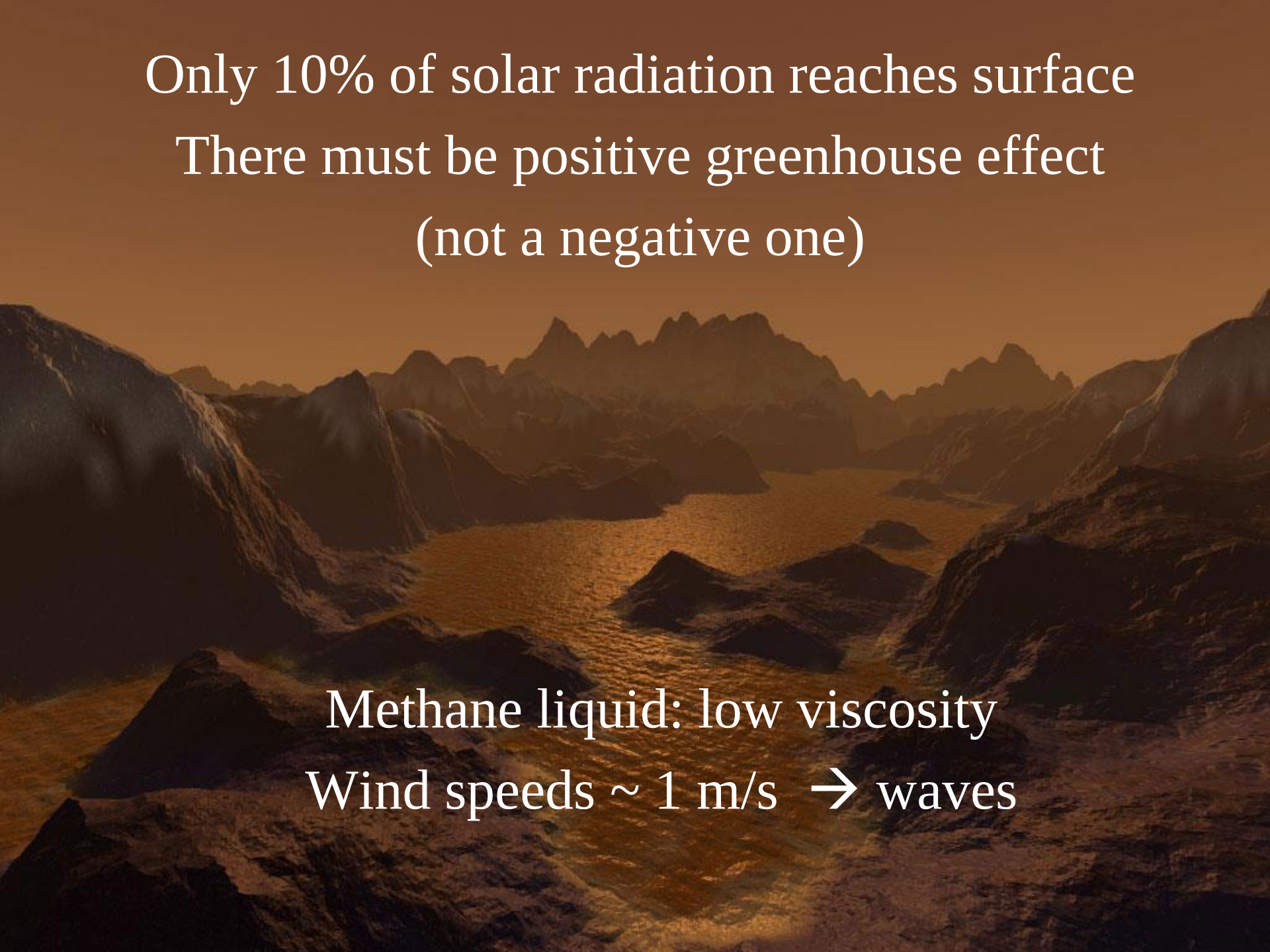
- Aerosols
- Wet haze
- Photochemical smog/haze



Titan has a "hydrological cycle" like Earth but with methane instead of water!

Methane rain




Only 10% of solar radiation reaches surface
There must be positive greenhouse effect
(not a negative one)
Methane liquid: low viscosity
Wind speeds ~ 1 m/s → waves

Images in infrared: CO_2 etc

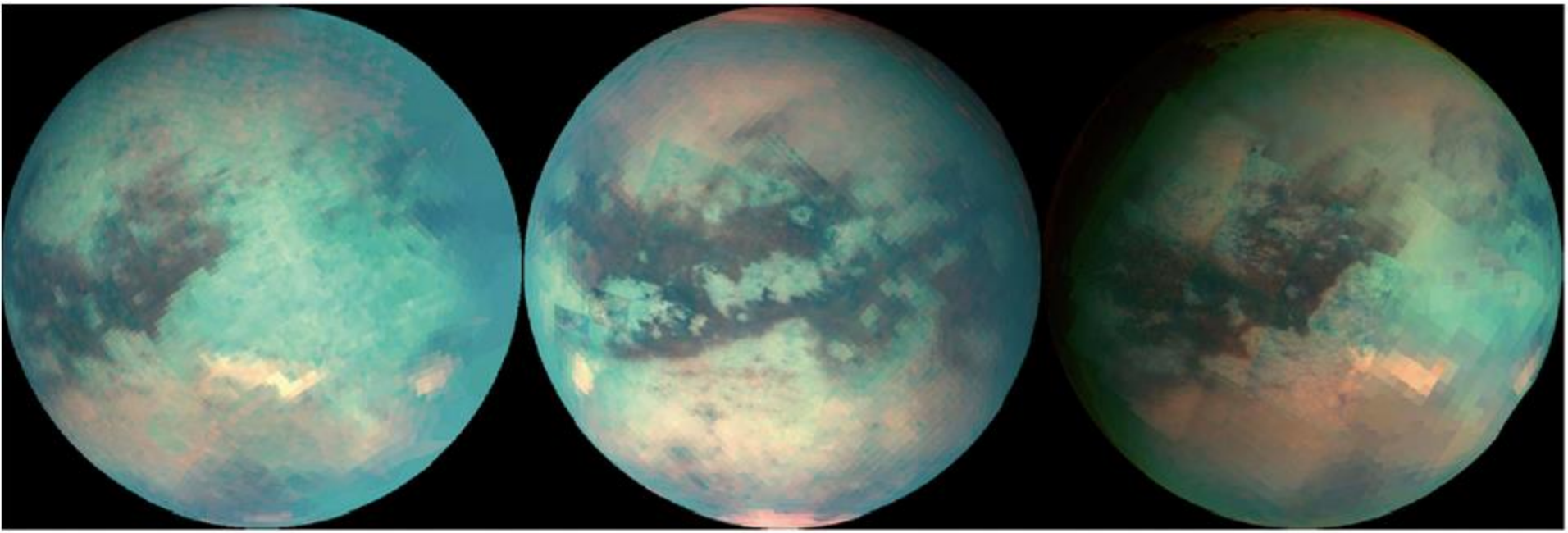
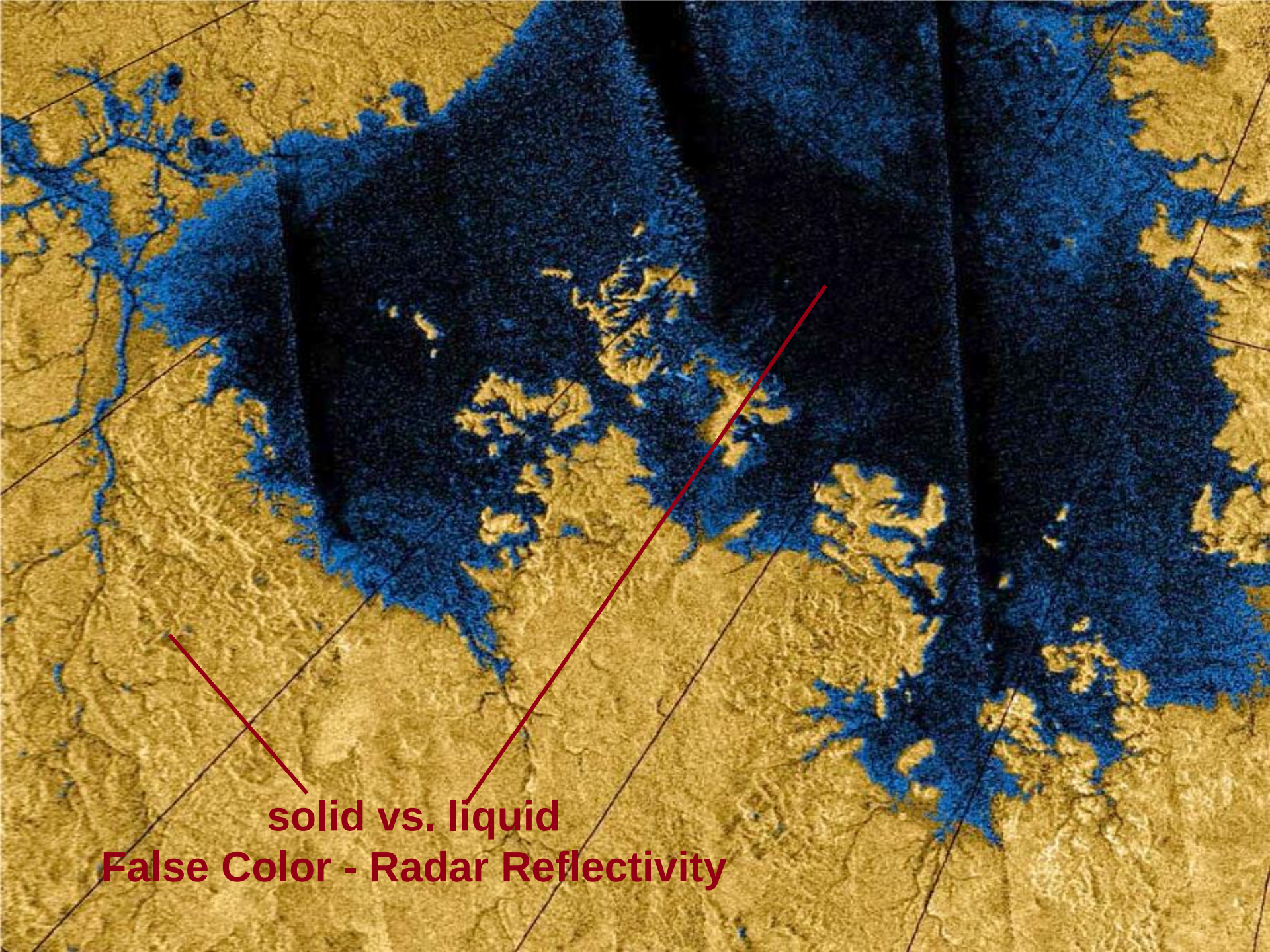
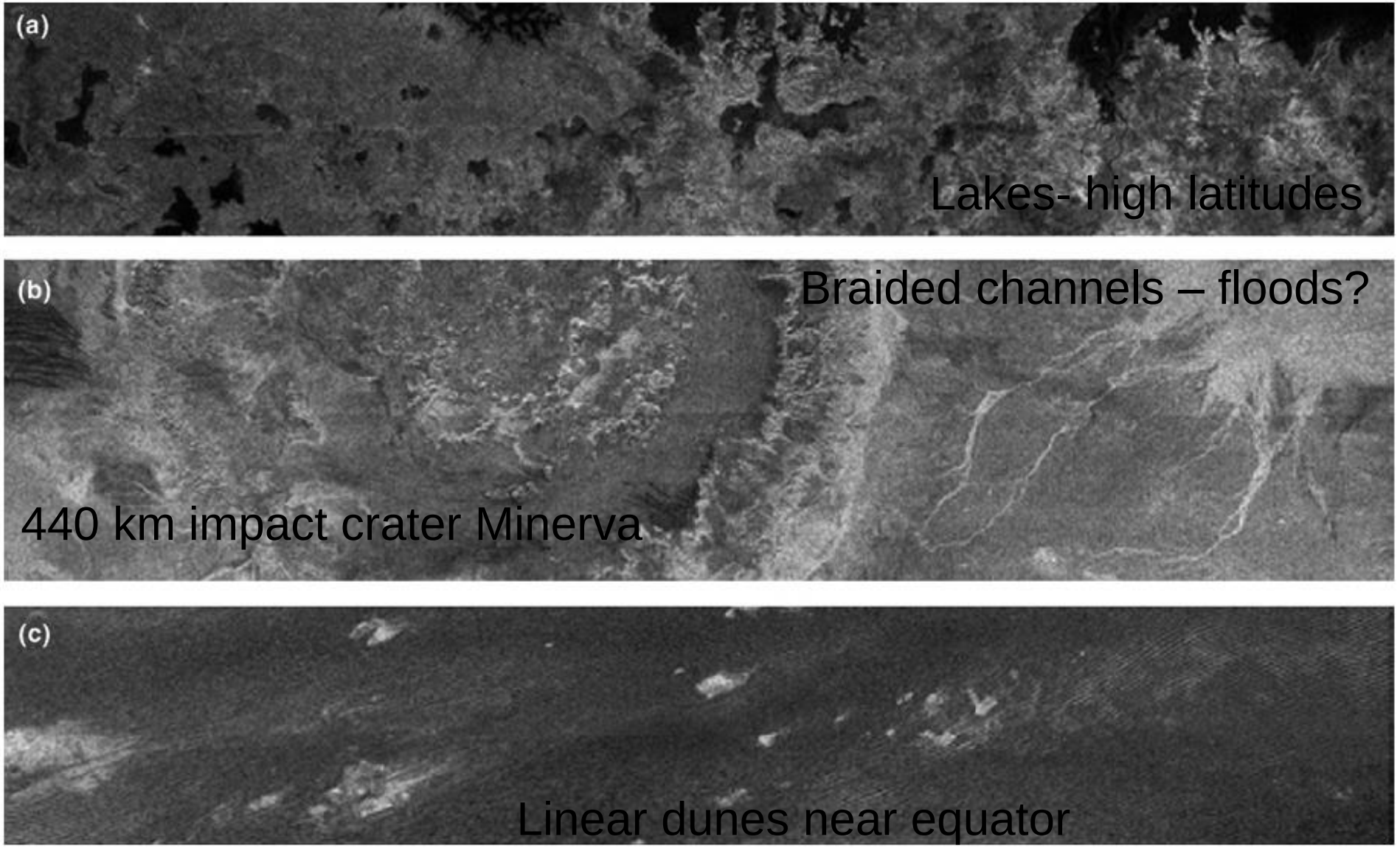
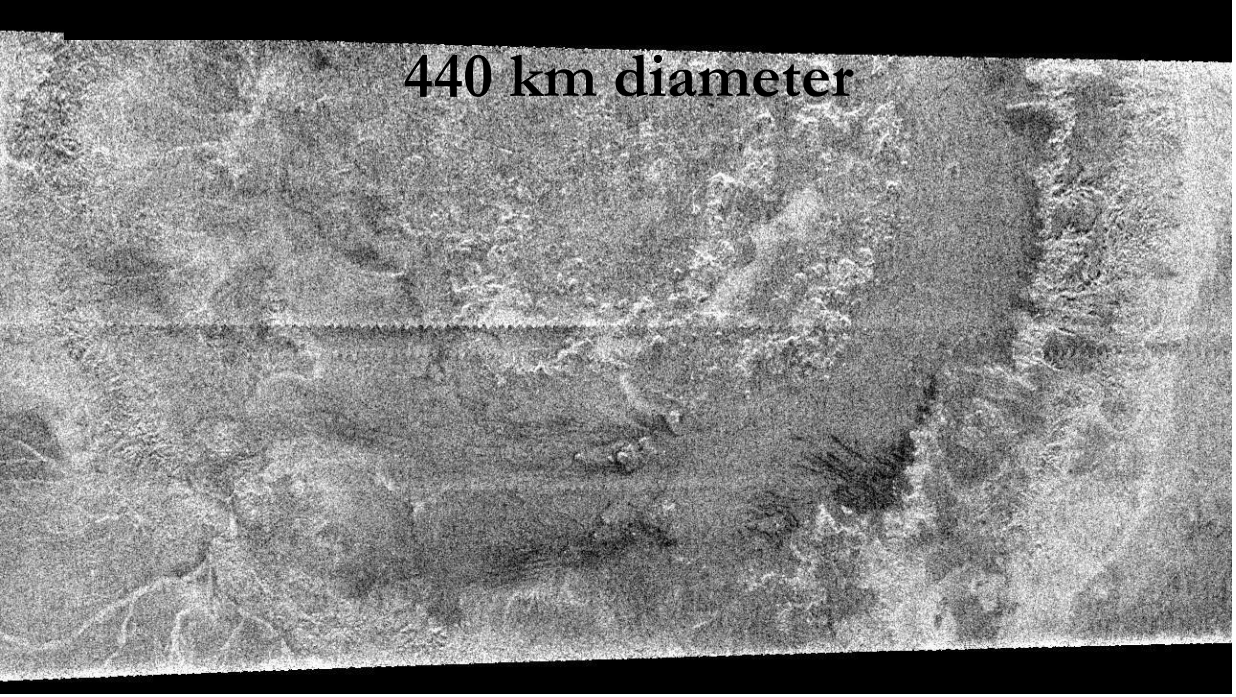


Figure 6. A mosaic of VIMS data showing the spectral diversity of Titan's surface. The bright orange areas, notably Tui Regio and inside Hotei Arcus, are particularly reflective at 5 μm, perhaps indicating CO_2-rich deposits that might be associated with cryovolcanism. In this mosaic, bright clouds are present around the south pole. (Image courtesy of NASA/JPL/University of Arizona.)

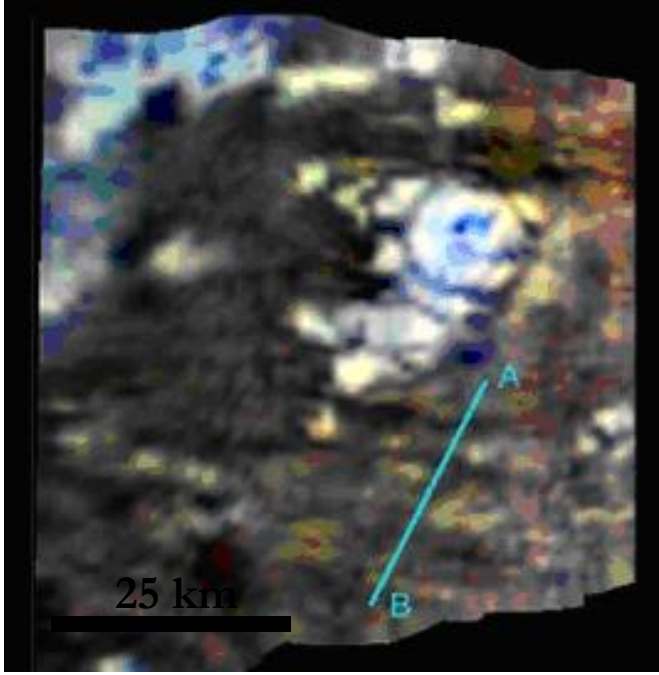

solid vs. liquid
False Color - Radar Reflectivity

Cassini Radar images



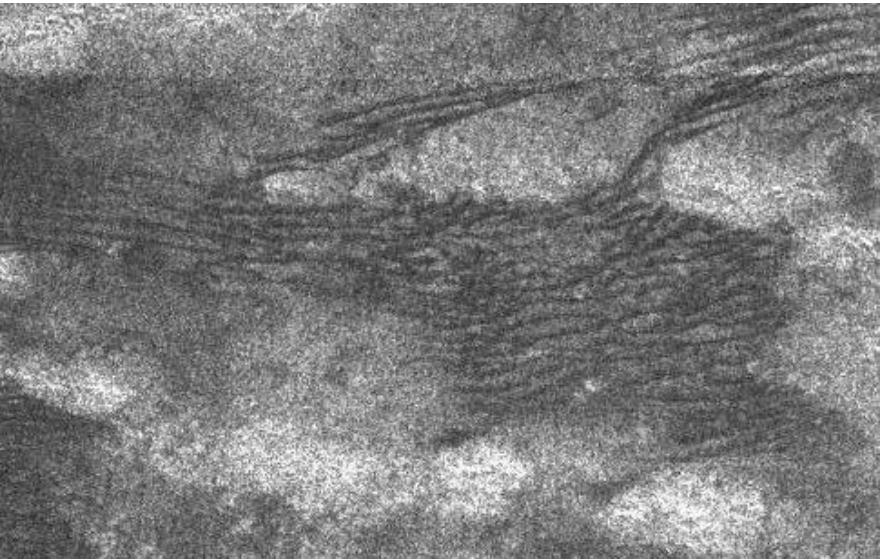


Impact Crater



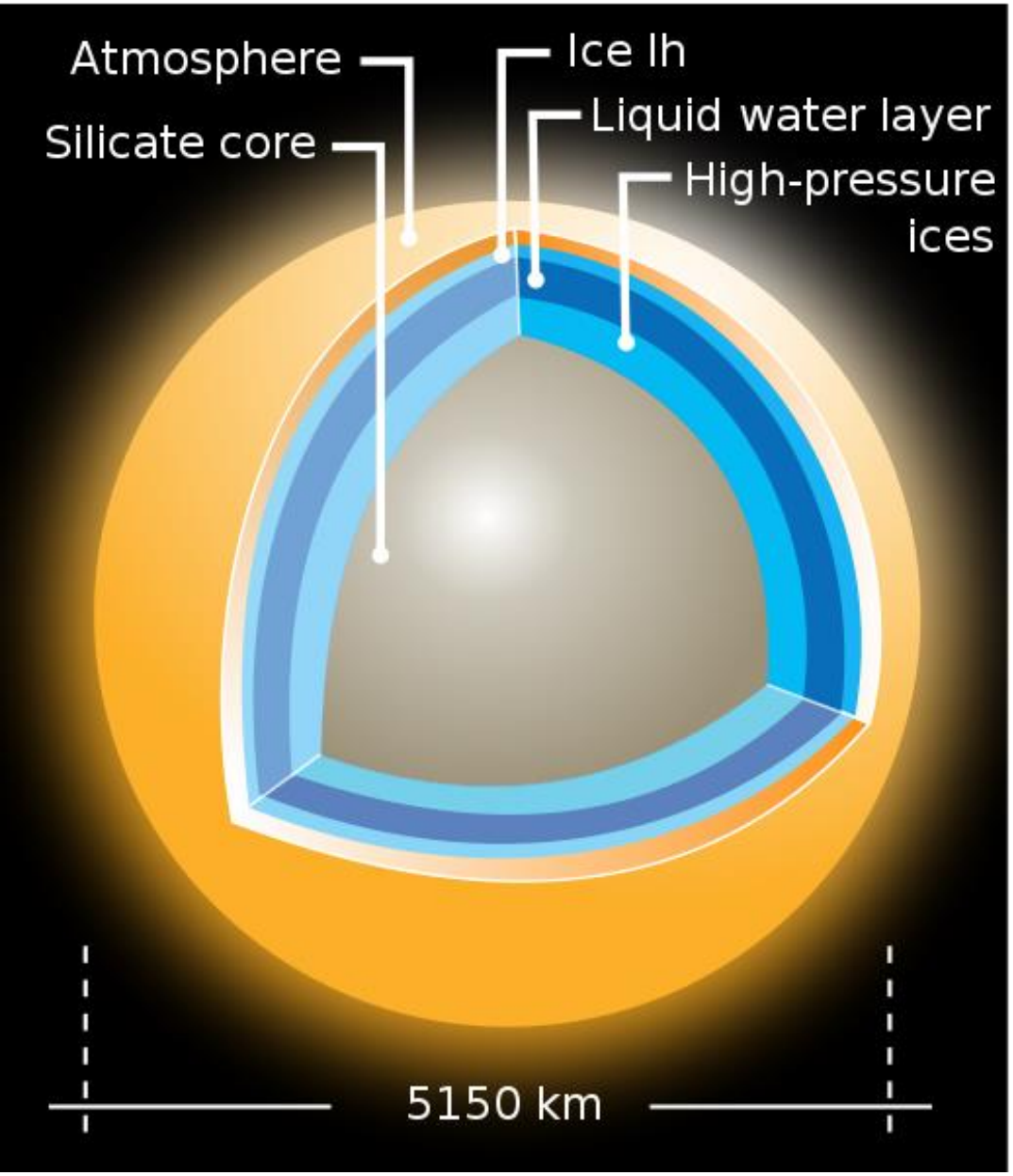
Cryovolcanic Extrusion ?

Dune Field



Geology

- Cryovolcanism
- Impact cratering
- Dune field formation



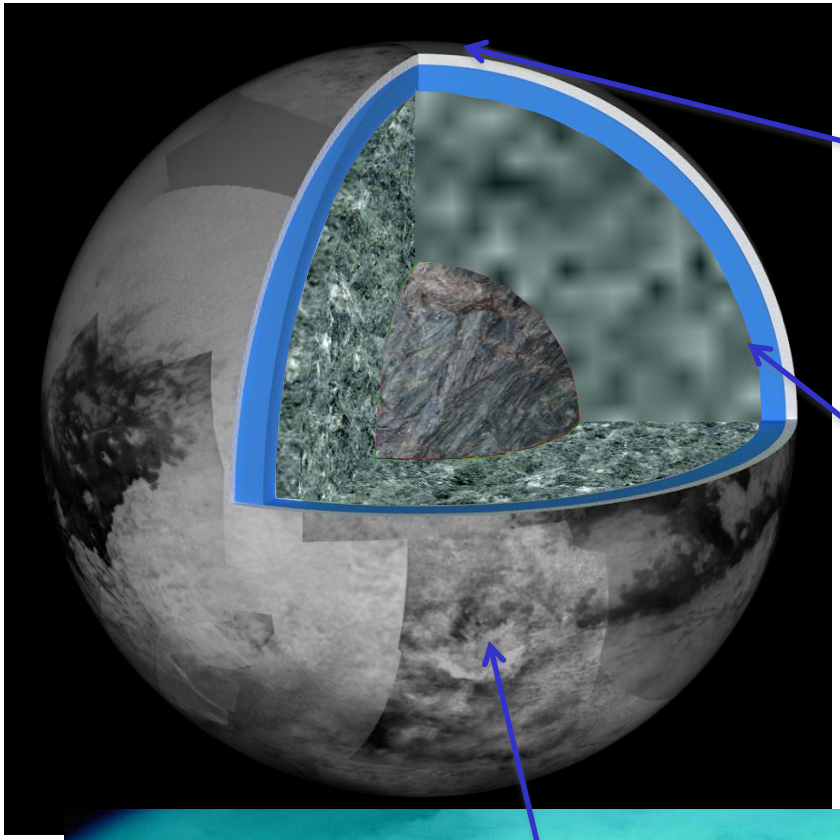
Subsurface water ocean

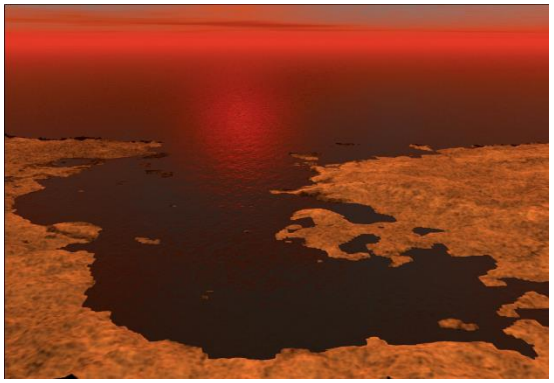
Typical of other icy worlds

Evidence:

1. Land marks shifted 30 km
2. Resonant radio waves
3. Heat flux 4-7 mW/m2
   → ice layer 50-150 km

Titan is differentiated: Core mantle of ice and water, icy crust covered in organics



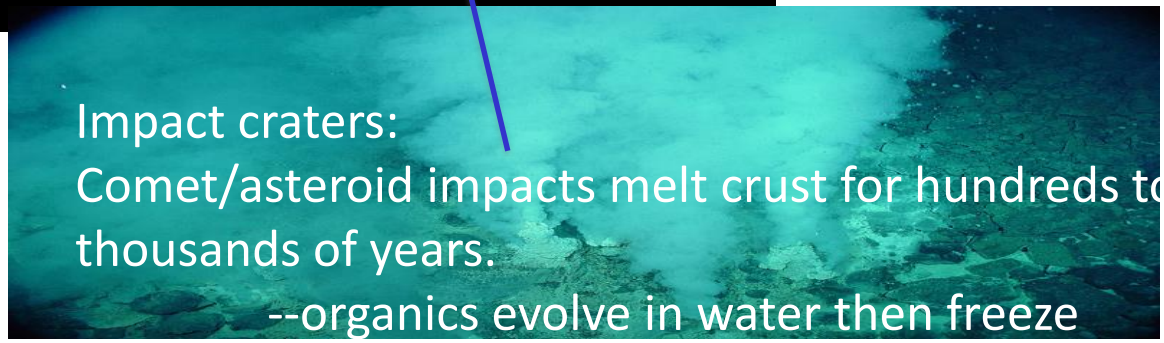


Life in the methane-ethane lakes and seas of Titan:

--totally alien biology

--does not violate physics

--strict test of life's cosmic commonality



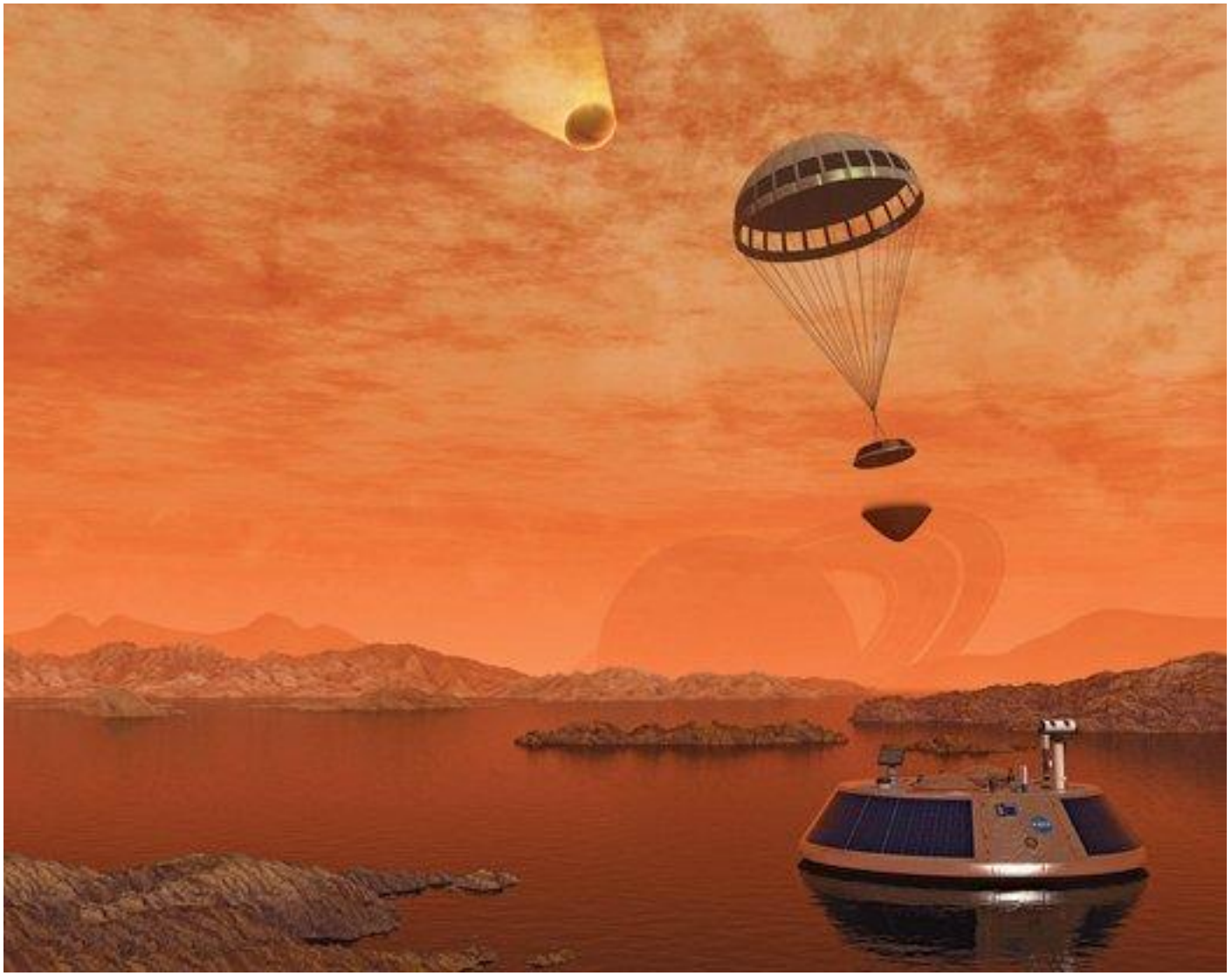
Base of the liquid water ocean:
life as we know it in hydrothermal vents?

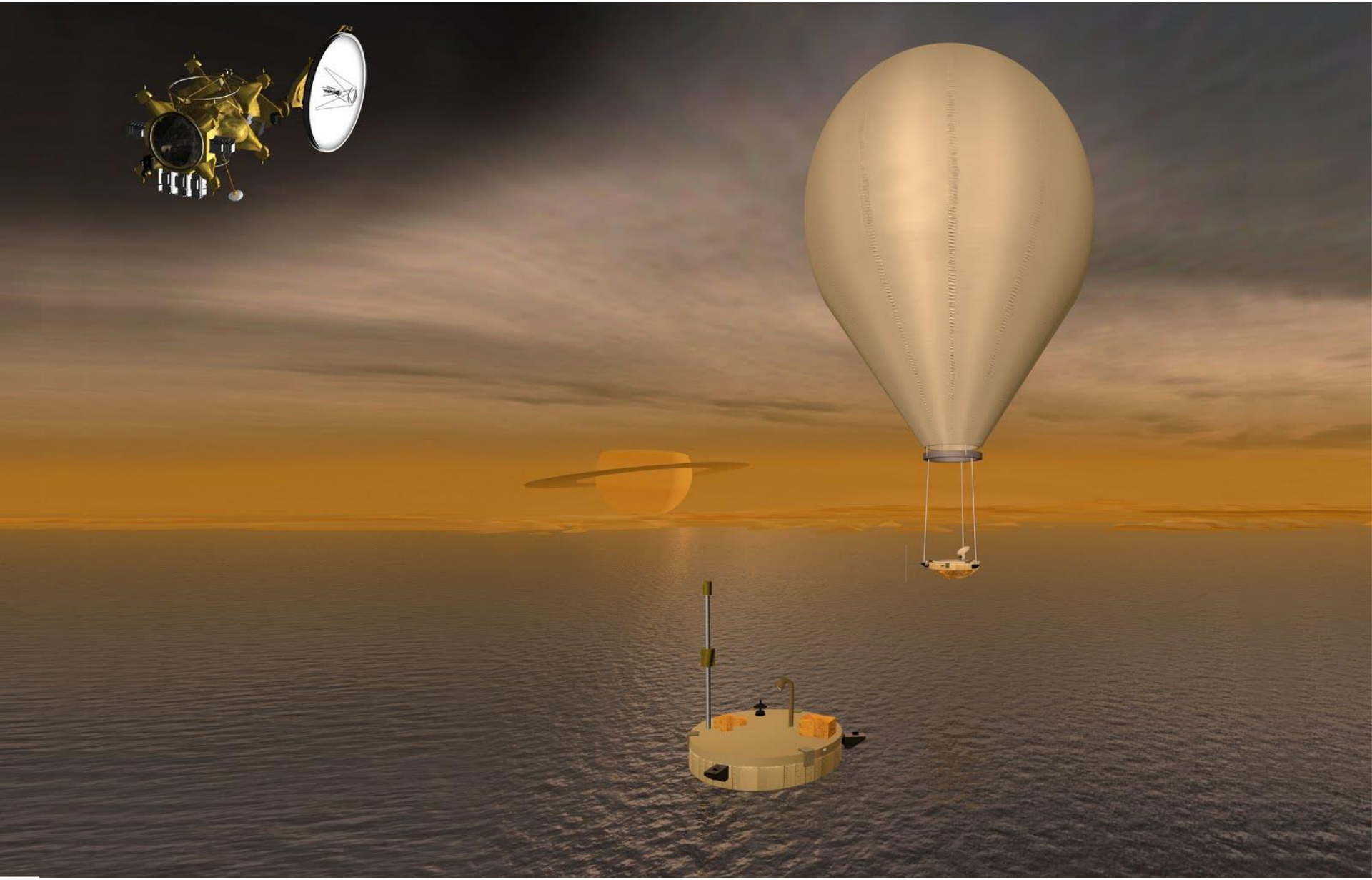
Titan Mare Explorer (TIME)

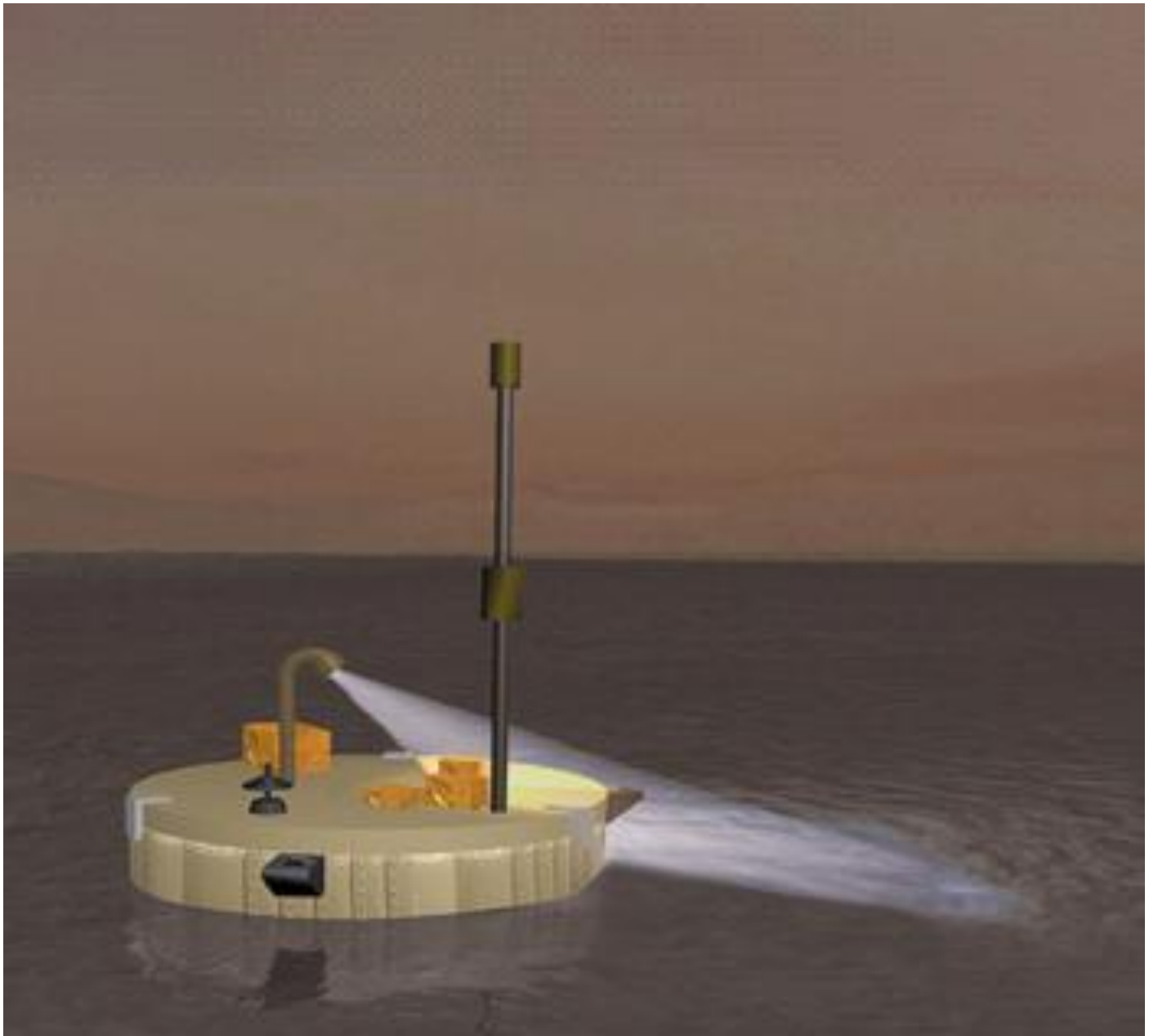
- Was proposed to NASA, but not selected for flight
- TiME is a relatively low-cost, outer-planet mission designed to measure:
- organic constituents on Titan
- and would have performed the first nautical exploration of an extraterrestrial sea,
- analyzed its nature and,
- possibly, observed its shoreline.

Comparing Titan and Earth lakes

Titan Mare Explorer (TiME)







Next time

- Outer solar system's bodies
- More on icy bodies
- Pluto
- Organics on/in comets

- Longstaff: pp 297 – 303
- BS: 319 – 326