Nov. 10, 2017

- Titan introduction
- Will discuss exam results Monday (and student presentations)
  - Notes on how to read Birch et al paper
- Habitable Worlds 2017 conference next week
  - https://www.hou.usra.edu/meetings/habitableworlds2017/
- Today:
  - Decide what part of Mars to cover
  - Introduction to Titan
    - Review of Owen and Lunine & Lorenz papers

Titan Introduction

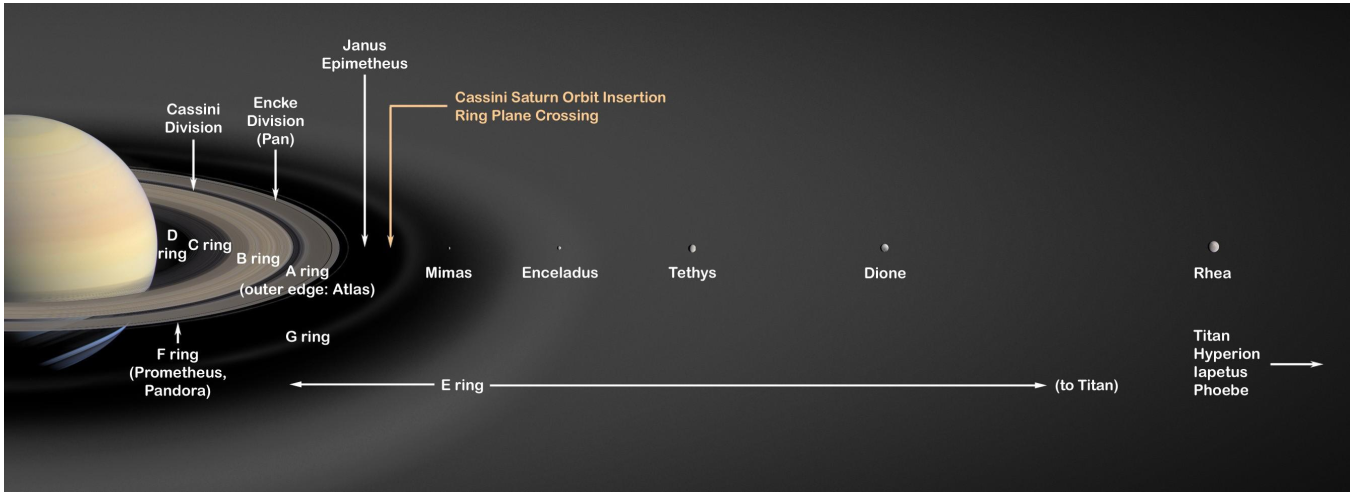
For Friday Nov. 10 read:

Owen 2005 Huygens rediscovers Titan

Lunine and Lorenz 209 "Rivers, Lakes, Dunes, and Rain: Crustal Processes in Titan's Methane Cycle

with links to the above on the Class Reading List web page.

Saturn System



Sat.	Orbit (Rs)	Radiu (km)
Mimas	3.08	197
Enceladus	3.95	251
Tethys	4.88	530
Rhea	8.7	765
Dione	6.26	560
Titan	20.3	2575
Hyperion	24.6	205
		x130
		x110
Iapetus	59	730
Phoebe	215	110

2nd Gas Giant (after Jupiter)

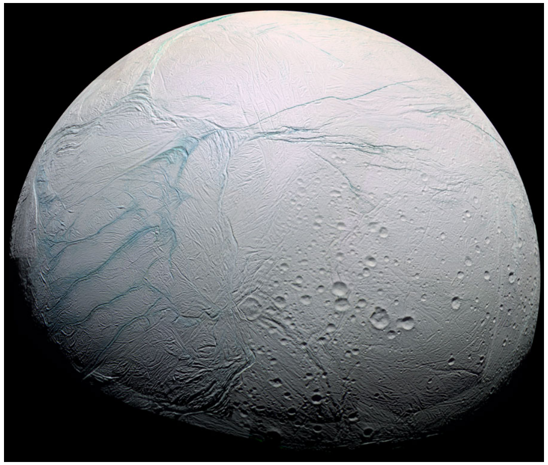
5 large icy moons, Titan (similar size to Mercury), dozens of smaller moons

Inner main rings (A,B,C,D)

Outer E ring of material from Enceladus

Resonances and tital heating important in system

- Gaps in main rings
- Activity on Enceladus



Early Observations

Largest of Saturn's moons

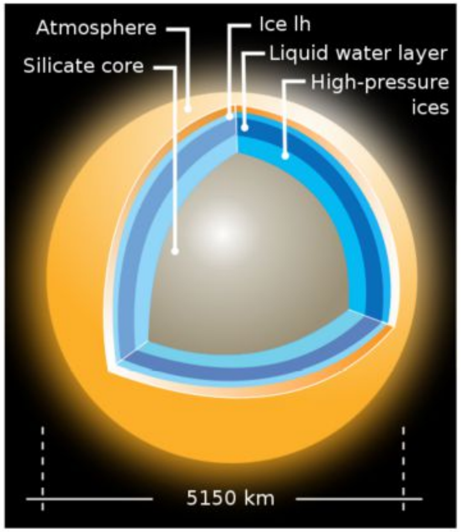
- Radius = 2575 km (Earth's moon = 1737)
- P = 1.88 gm cm^{-3} implies ice + rock mix

Atmosphere discovered in late 1940's

- Thick haze opaque in the visible, partially transparent in the near IR

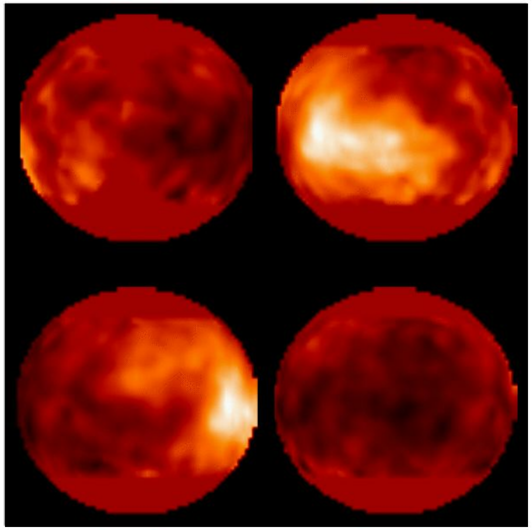
Flyby's: Voyager 1 Nov. 1980 & Voyager 2 Aug. 1981

HST imaging in near infrared



Model

Voyager visible image



HST 0.9 μm images

Cassini-Huygens Mission

1997 Oct. 15 Launch

2004 Jun. 30 Saturn Orbit insertion

2004 Dec. 24 Huygens probe release

2005 Jan. 14 Huygens Titan landing

Cassini orbiter mission continues –

- Multiply flybys of Saturn's moons
- Observations of Saturn itself, and magnetosphere

Titan Atmosphere

Primarily N_2

1.6% CH_4

^{40}Ar 43 ppm less ^{36}Ar

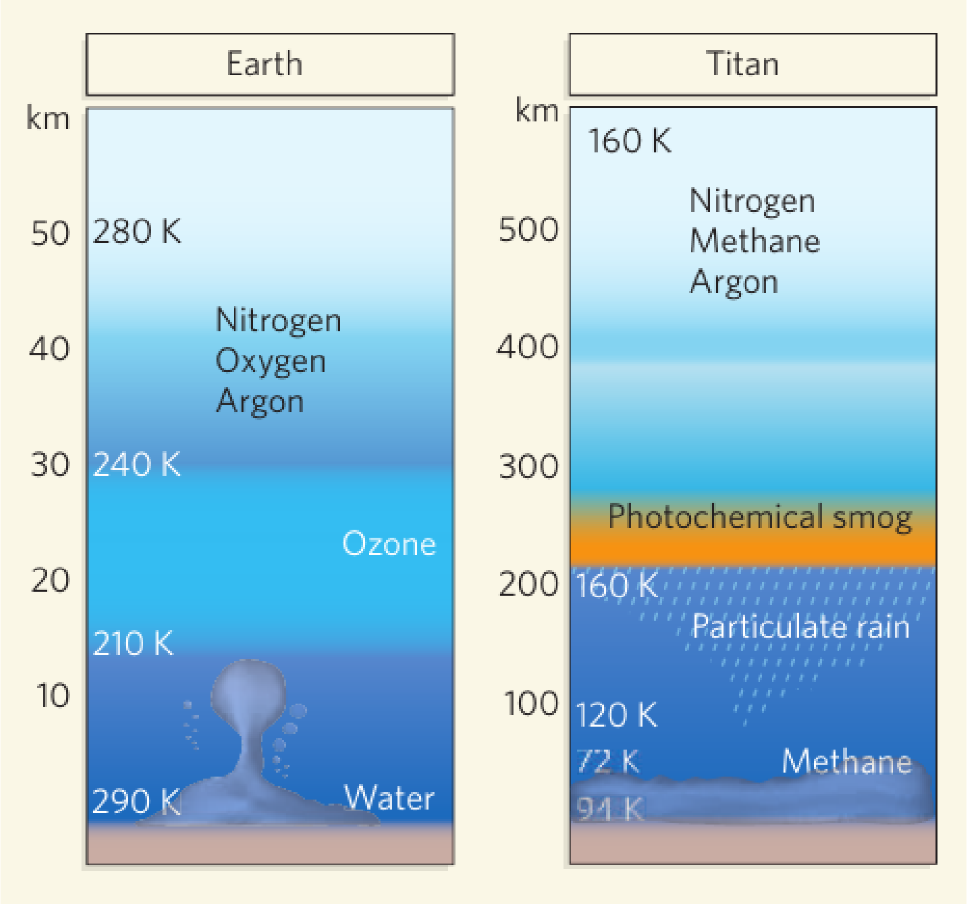
P ~ 1.5 bars

- Note P = force/area = weight / area = mass * g / area
- To get mass of atmosphere per unit area just divide by g
- For Earth ~1 bar = 10^5 Pascals = 10^5 nt/m^2
  implies 10^5 nt/m^2 / 9.8 m s^{-2} = 10^4 km/m^2 = 1 kg/cm
- For Titan with g ~1/7 earth and Po ~ 1.5 bars so ~10^5 kg/m^2

$T_{surface}$ ~ 94 K

Winds high in upper atmosphere, very low at surface

CH4 in atmosphere can reach saturation and begin to rain out



Atmospheric History

UV breaks apart CH4 in upper atmosphere, producing smog and ethane

Rate at which CH4 is destroyed implies there must be reservoir (other than atmosphere) to replenish it over the age of the solar system

^{14}N / heavier N is less than on Earth or in chondrites

- Assuming thermal escape – implies original atmosphere was 5 times present one

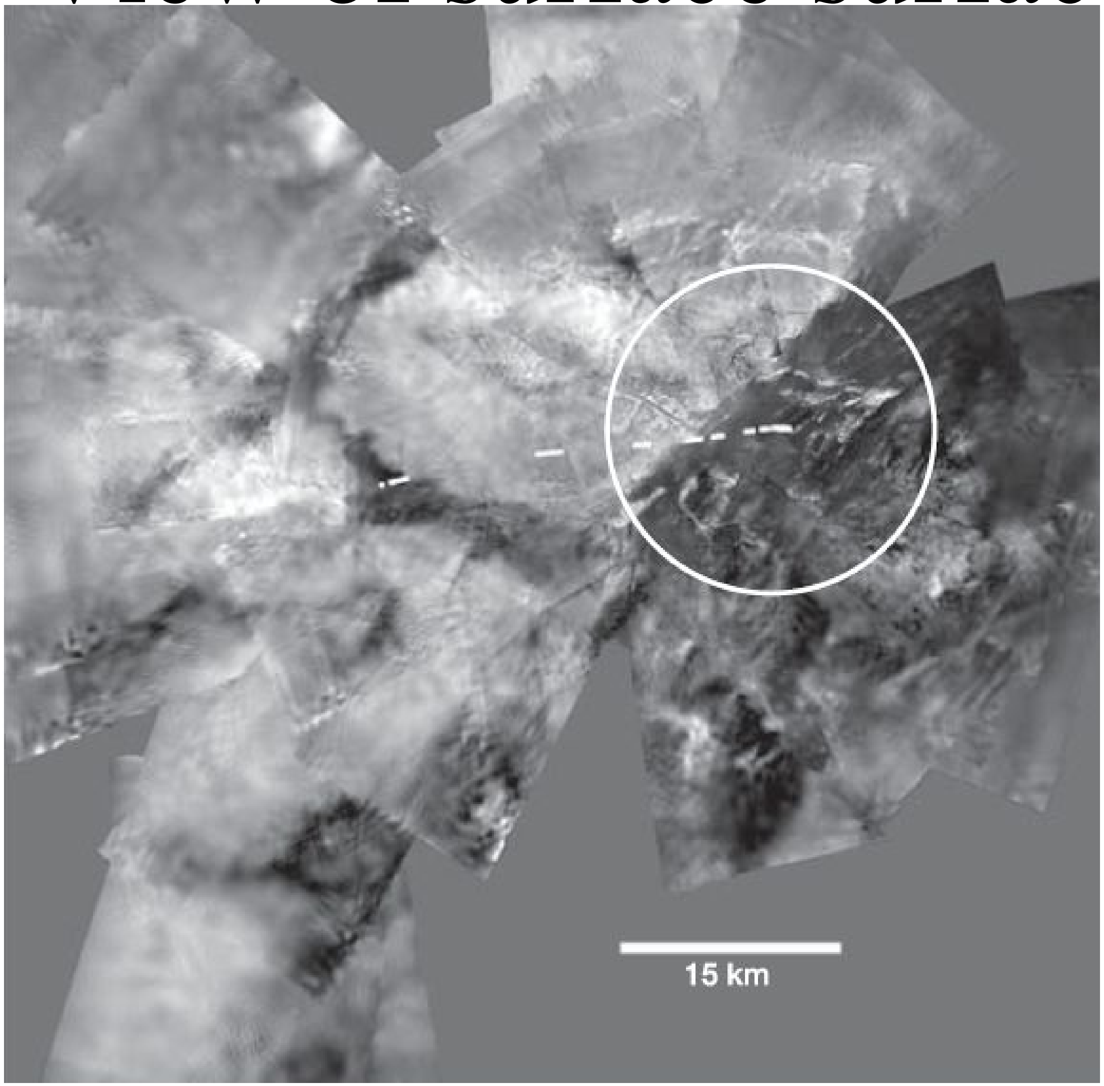
Small abundance of ^{36}Ar implies little of primordial atmosphere is left

Higher abundance of ^{40}Ar (from 40K decay) implies outgassing from planet

Source of N_2? If it were cold enough to trap N_2 then it would also trap lots of ^{36}Ar
The N_2 must have been trapped in some other form (NH_3?) then converted to N2

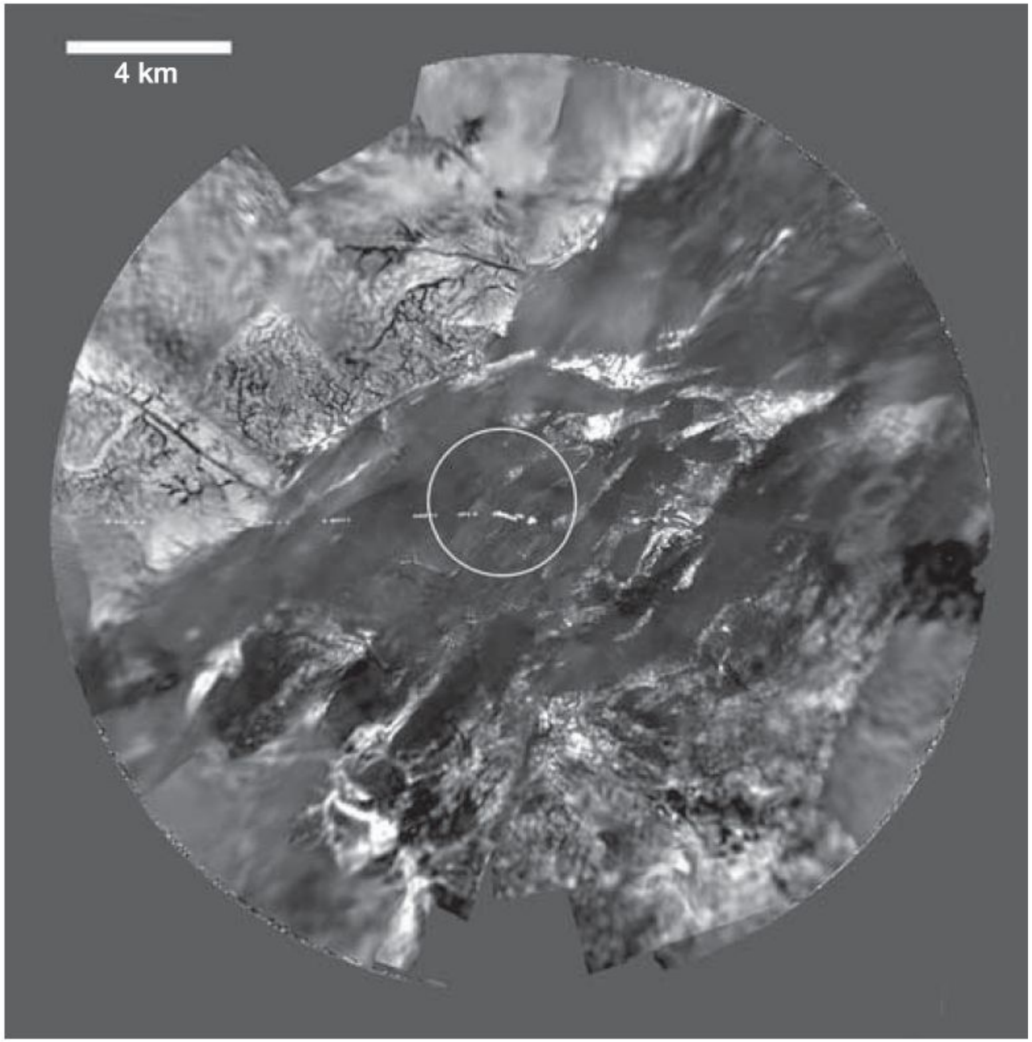
CH_4 clathrates (methane hydrates) can exist in interior and even on the surface

View of surface surface: Distant



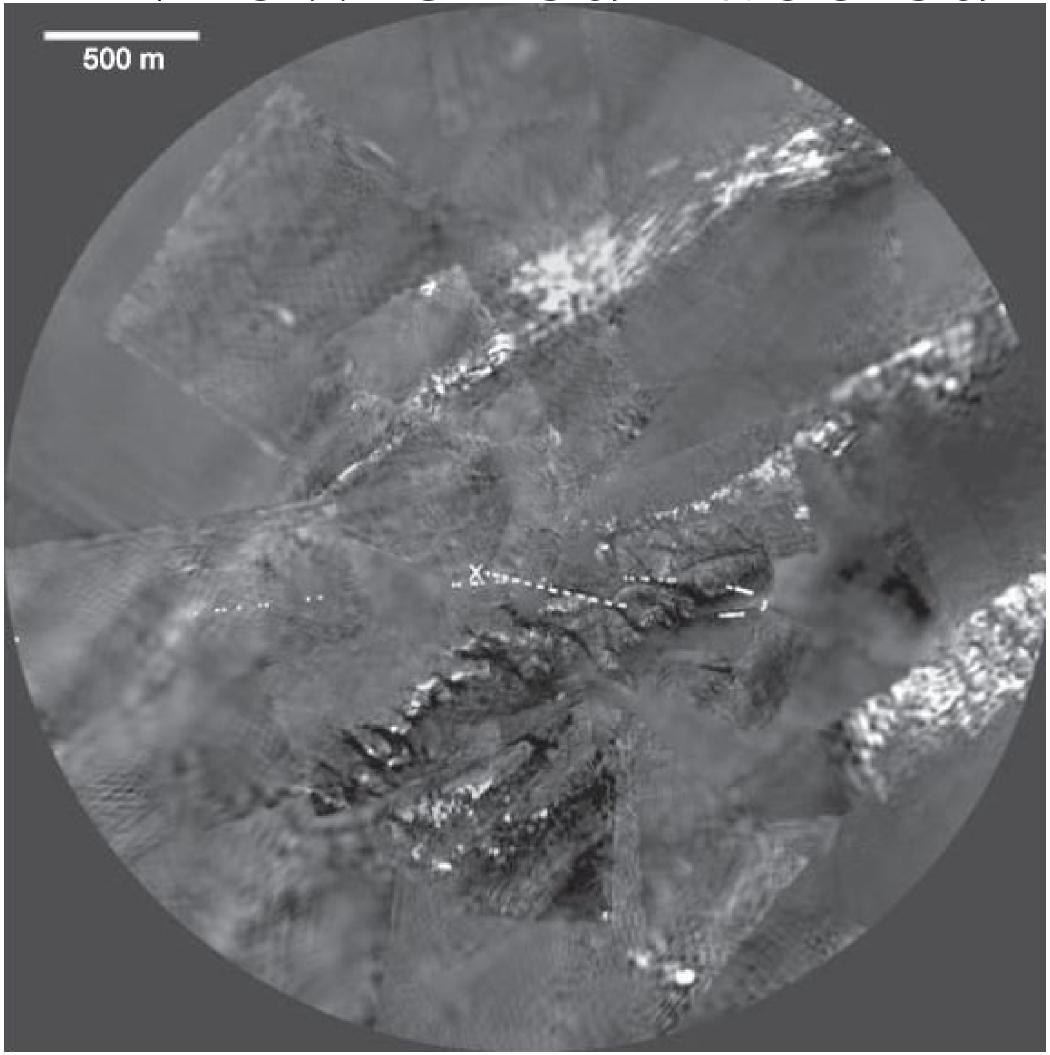
From descending Hyugens probe Distant view

View of surface surface: Middle



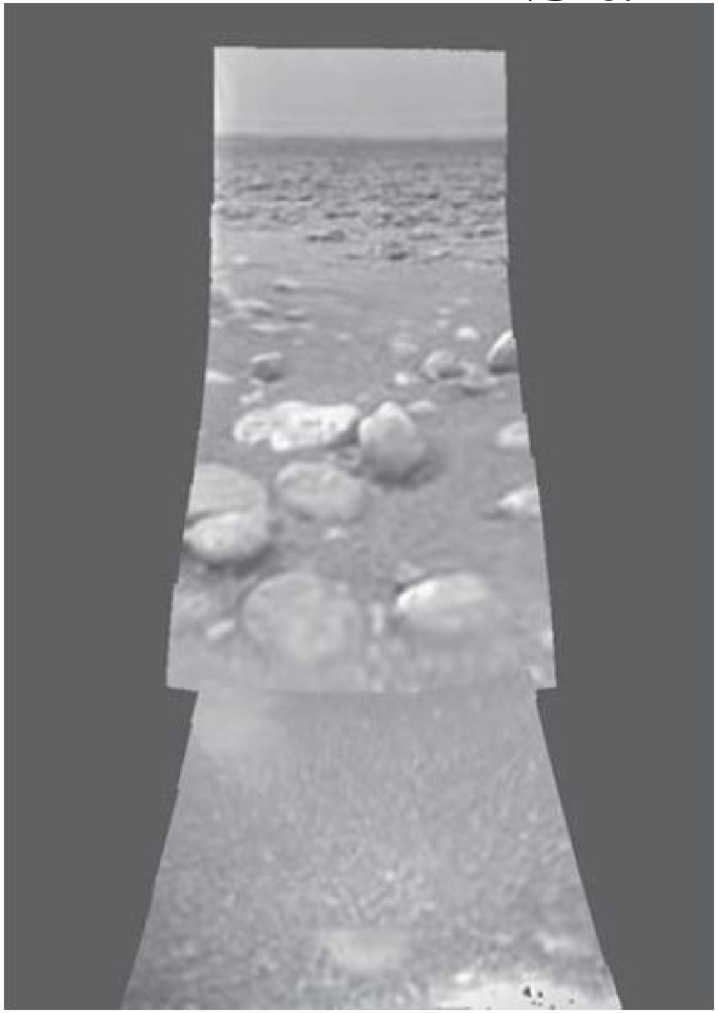
From descending Hyugens probe

View of surface surface: Close



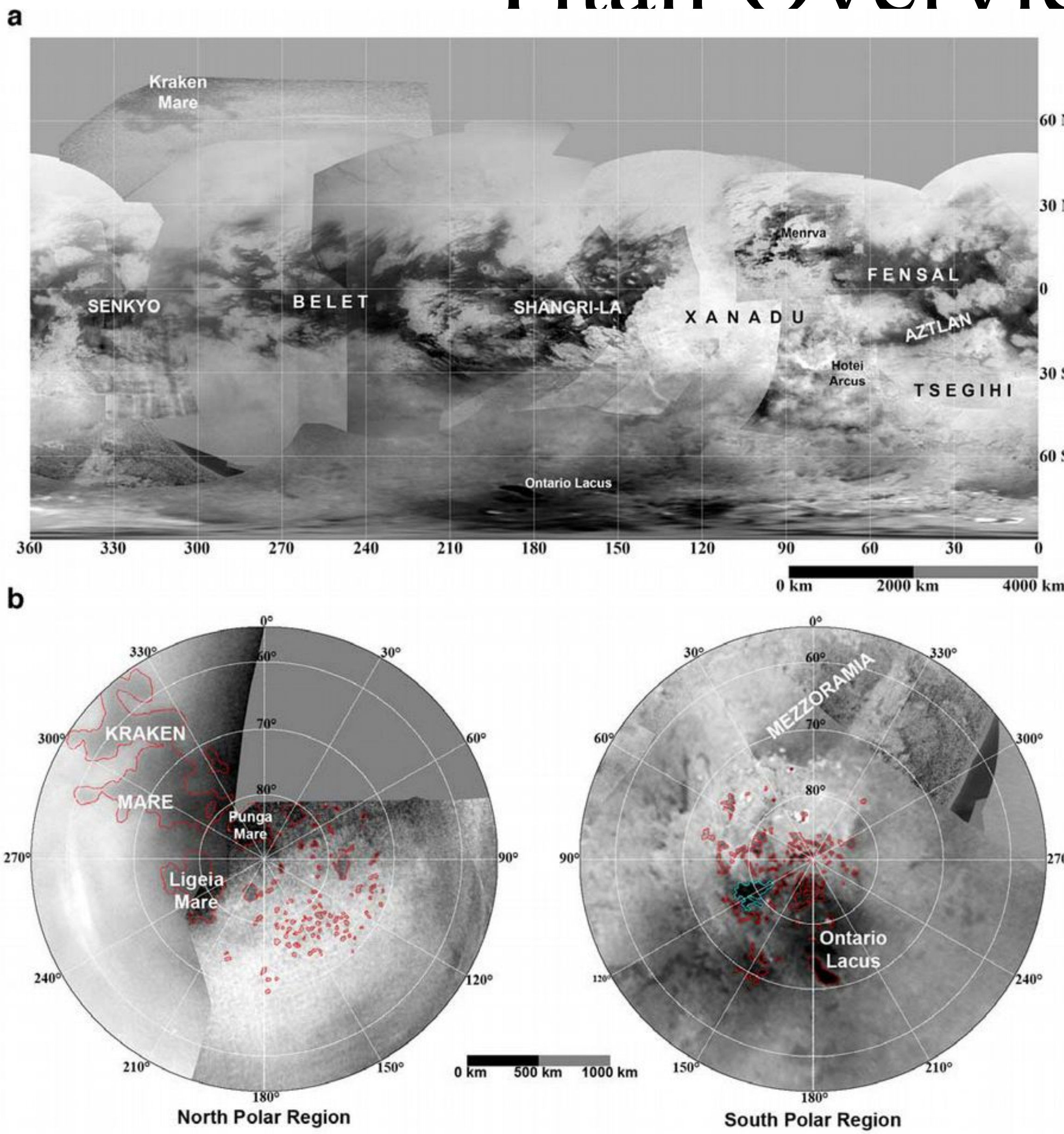
From descending Hyugens probe

Surface



From Hyugens probe. Note “ice” boulders and fine grain sediment

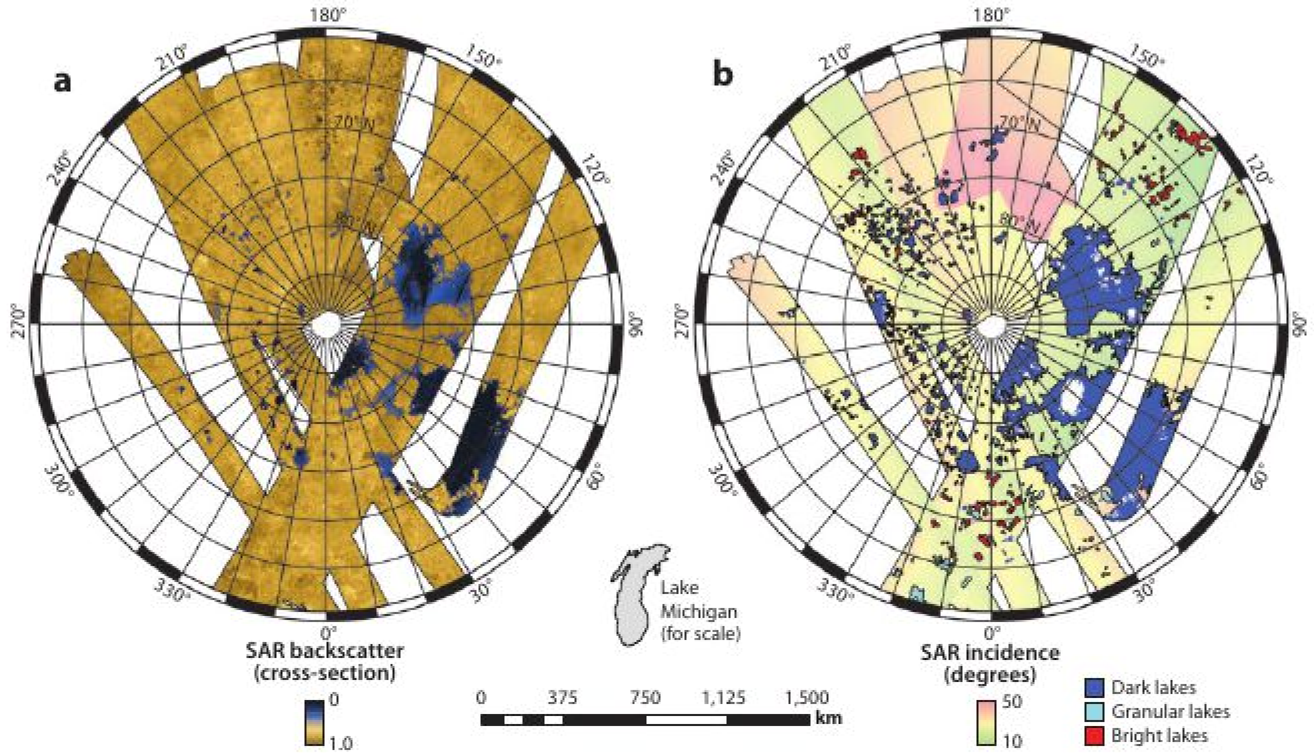
Titan Overview



Cassini ISS
0.938 µm images from
Turtle et al. 2009

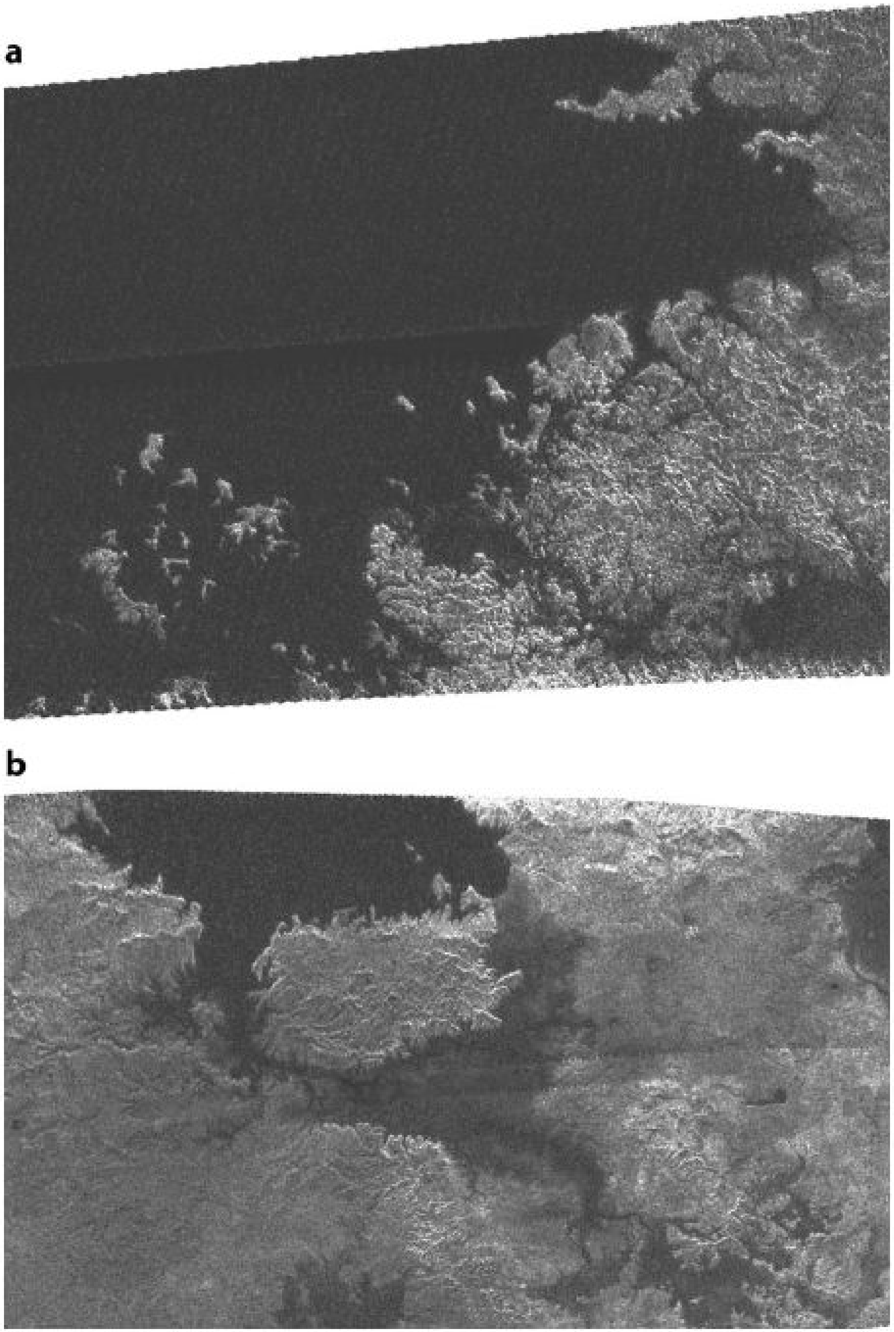
Colored lines are possible shorelines of seas or laks.
Blue ones have shown changes with time.

Titan Lakes (and Radar notes)



- Rough: Radar bright
- Dark: Radar dark
- Lakes: Methane (volatile) + Ethane (less volatile) + some N_2

Titan Lakes



Titan Sand Dunes

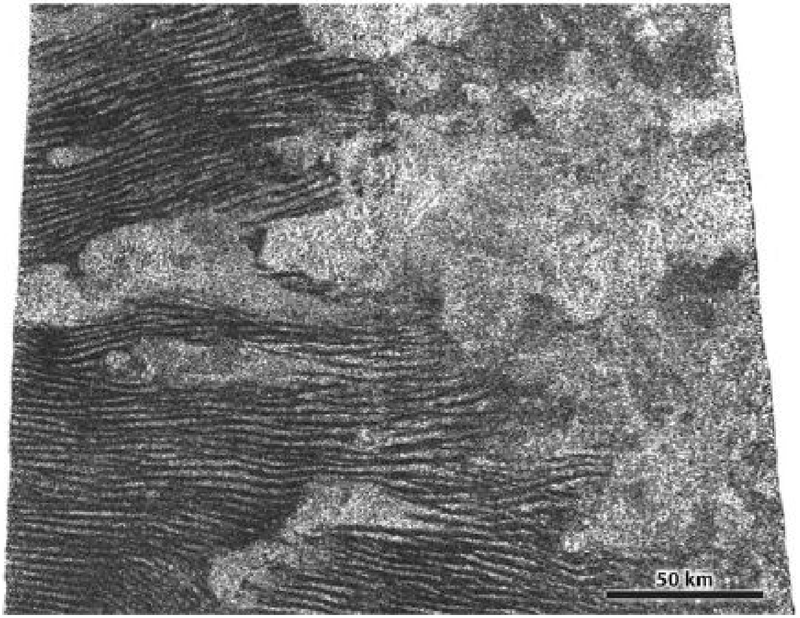
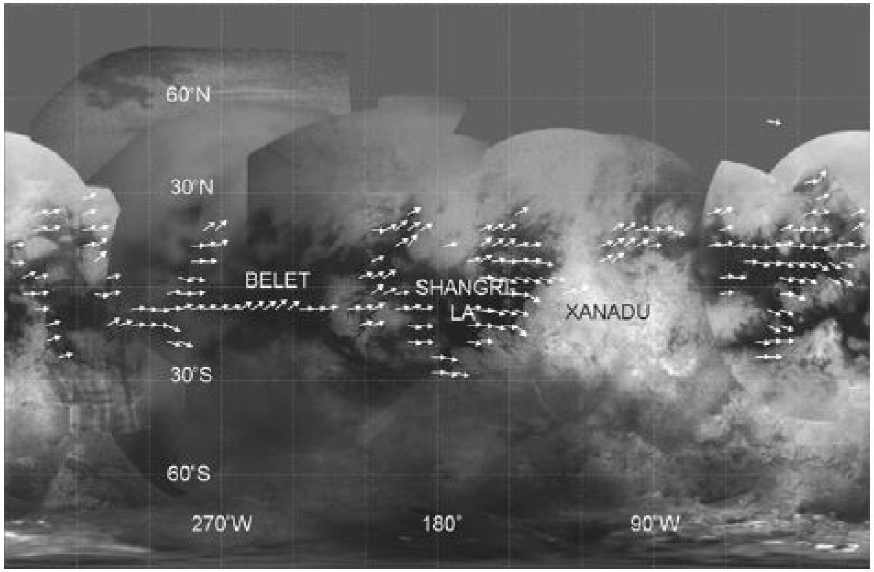


Figure 7

A segment (North up) of the T25 radar swath, showing dunes in Aztlan. The bright interdune areas can be seen, as well as a few uprange glints on the dunes at upper left. Note the abrupt termination of dunes when they reach the western edge of topographic obstacles.



Titan Seasonal Change

(Blackboard diagram)

Titan and Saturn axes aligned so they have same seasons:

- 29.5 yr period.
- 26° obliquity (tilt)
- Long Milankovitch cycles too

Cassini arrived in N Winter, S Summer

- In 2010 sun moved from S to N hemisphere – "Northern Spring Equinox"
- Lighting (imaging) patterns changing – N pole now visible in reflected light. (Older data all radar)

Weather patterns also now changing. Equatorial storms seen starting ~2010/2011

Cyrovolcanism Debate

Major debate about whether cryovolcanism has been seen:

- Lopes and others believe they have seen features which show morphology of flows
- Nelson and others think they have seen albedo (cloud) pattern changes due to venting of CH_4 from interior
- Moore and others believe all the features claimed to be volcanic are more likely fluvial.

Possible Materials for Cryovolcanism: H_2O and NH_3

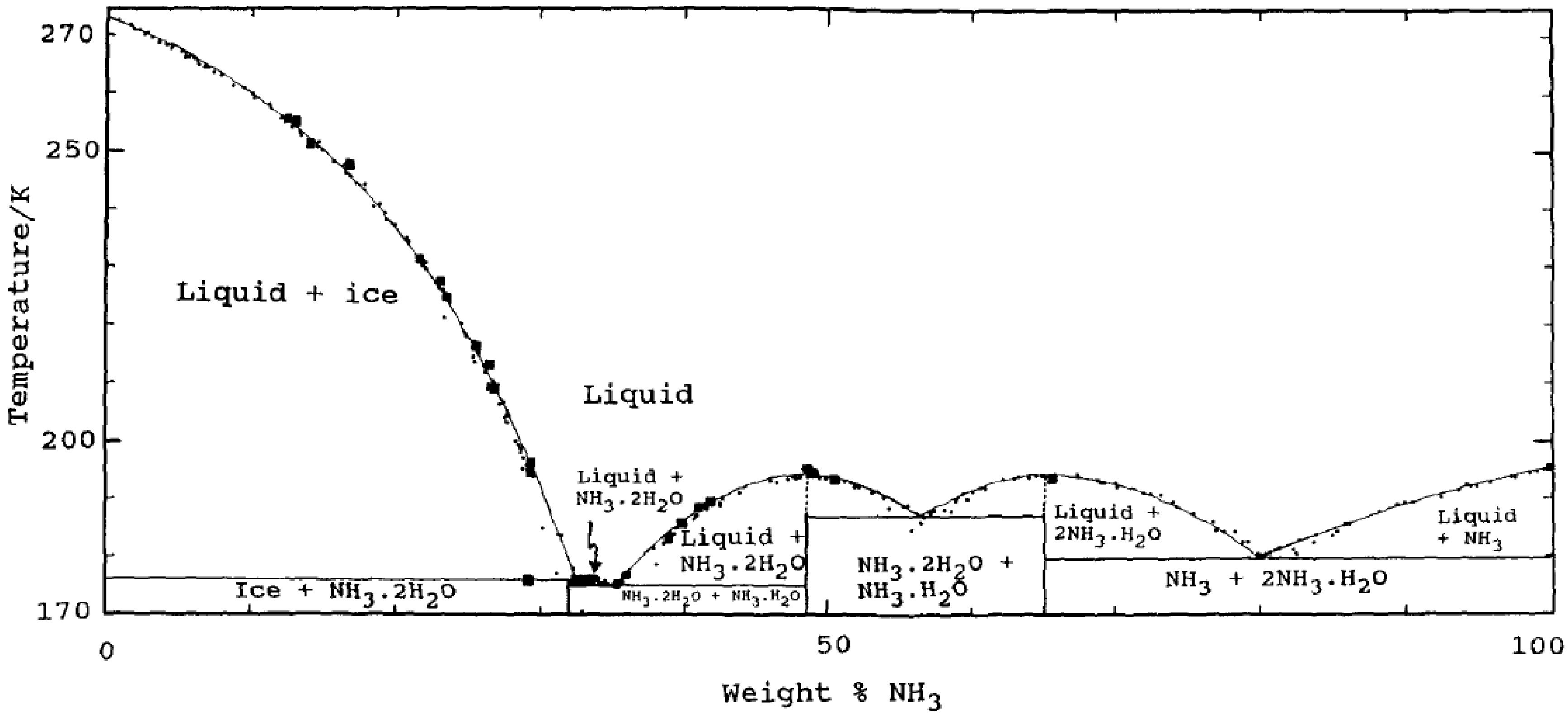


FIG. 1. *System H_2O–NH_3* at 1 atm pressure. Sources: Kargel (1990) (solid squares) and literature (dots), including Pickering (1893), Rupert (1909, 1910), Smits and Postma (1910), Postma (1920), Elliot (1924), Rollet and Vuillard (1956), and Van Kasteren 1973. Data of Mironov (1954) not included due to large systematic deviations from other data sets.

Phase diagrams from Kargel et al. 1992

Possible Materials for Cryovolcanism: H_2O and CH_3OH

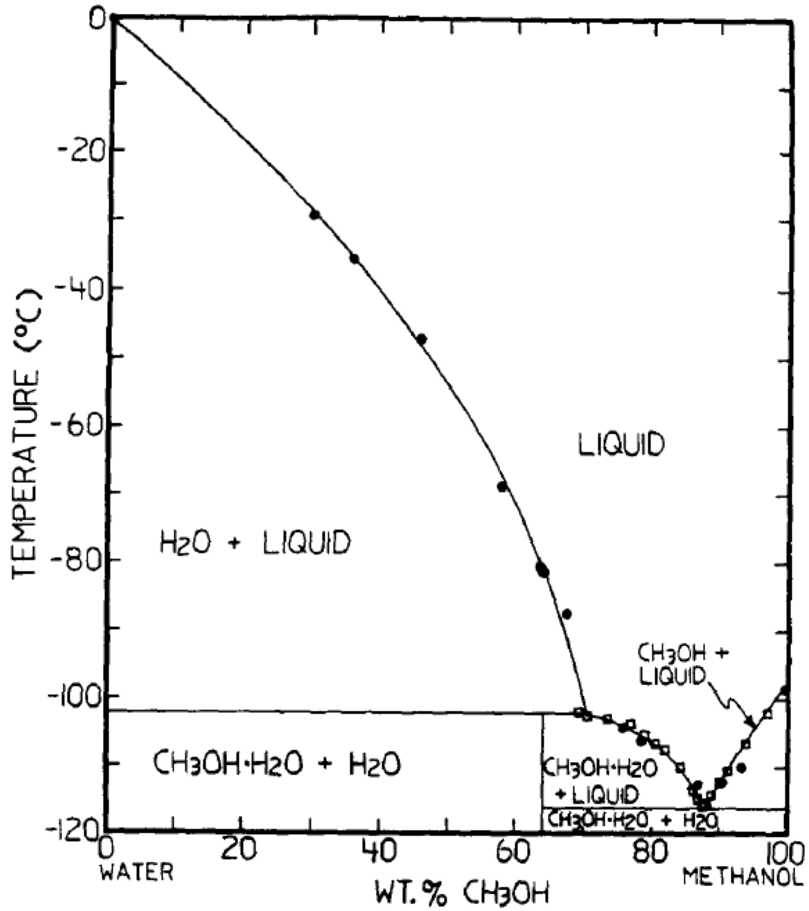


FIG. 7. System H_2O–CH_3OH. Sources: Solid circles, Vuillard and Sanchez (1961); open squares, Miller and Carpenter (1964).

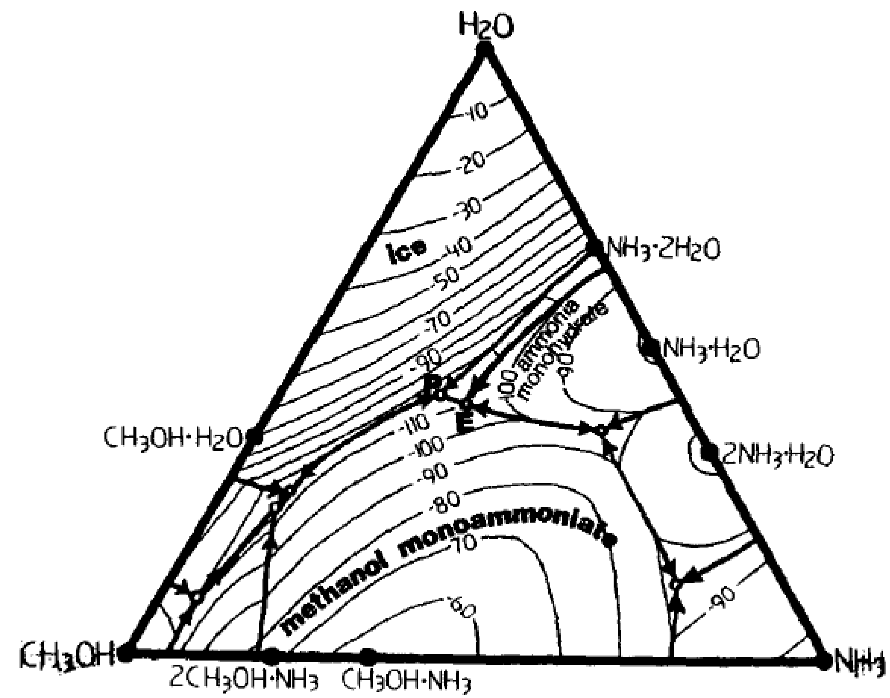


FIG. 9. System H_2O–NH_3–CH_3OH. Source: Kargel (1990).

Phase diagrams from Kargel et al. 1992