ASTR/GEOL-2040: Search for life in the Universe: Lecture 27

- Titan
- Methan cycle
- How is it sustained?

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

Visitor today

- Emilie Royer (LASP, Laboratory for Atmospheric & Space Physics)
- Worked on upper atmospheres of most of the bodies of the solar system (Venus, Mars, Titan, Enceladus, and many more)

Moons of Jupiter & Saturn: a comparison

Jupiter	**orbit**	**Saturn**	**orbit**
Io	1.8 d	Enceladus	1.4 d
Europa	3.6 d		
Ganymede	7.2 d		
Callisto	17 d	Titan	16 d

Overview

- Saturn: 62 moons; Titan the only one with dense atmosphere
- Exotic environment, but no evidence for life (yet?)
- plays important role for our understanding
  - Photochemical processes important!
  - Wide range of organic molecules
  - A bit like early Earth?

Historical background

- Discovered by Huygens (1629 – 1695)
- Named in mid 1800 by John Herschel (son of William)
  - After Saturn's mythical brothers
- Limb darkening (Comas Sola, 1907) → atmosphere
- Gerard Kuiper (1940) with 82 inch (2m) McDonald Observatory: methane
- First "visited" by Pioneer 11 (Sept 1979): 363,000 km, Voyager 1 (Nov 1980): 4394 km

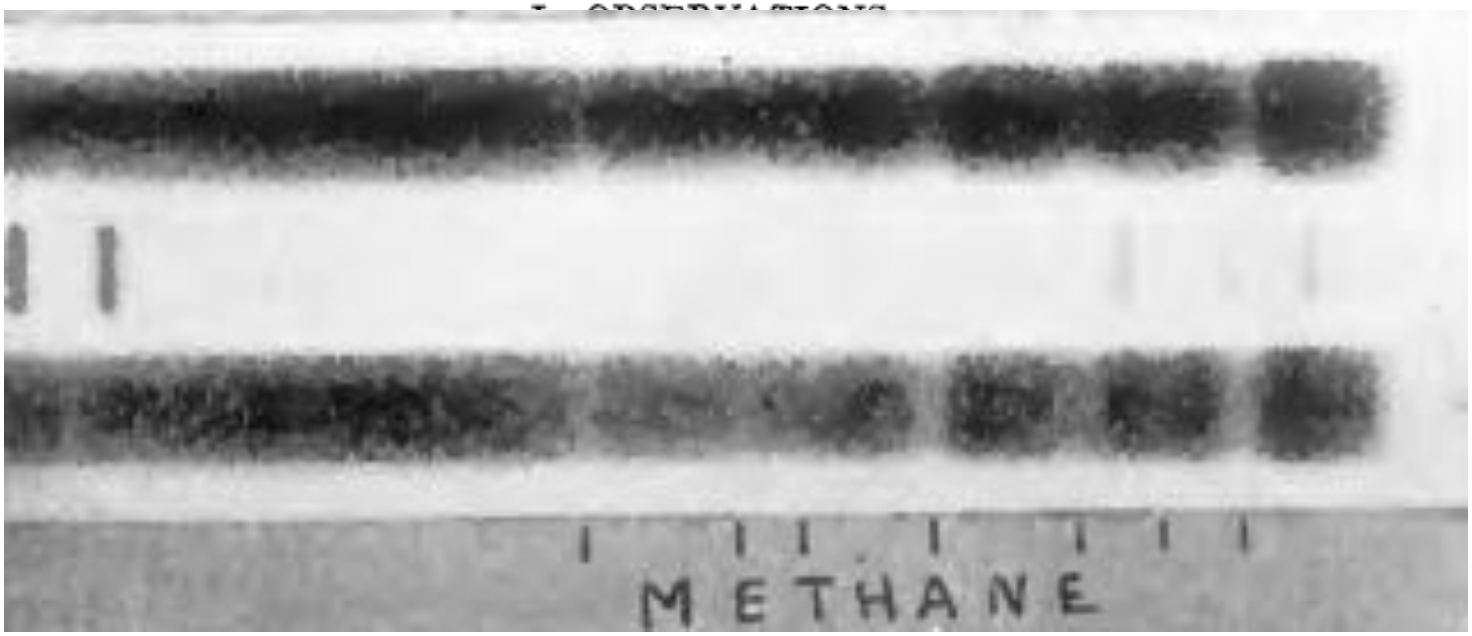
TITAN: A SATELLITE WITH AN ATMOSPHERE*

GERARD P. KUIPER[1]
McDonald and Yerkes Observatories
Received August 21, 1944

ABSTRACT

Recently the ten largest satellites in the solar system, as well as Pluto, were observed spectroscopically. Only Titan was found to have an atmosphere of sufficient prominence to be detected, but Triton and Pluto require further study. The composition of Titan's atmosphere is similar to that of Saturn, although the optical thickness is somewhat less.

The presence of gases rich in hydrogen atoms on a small body like Titan is surprising and indicates that the atmosphere was formed after Titan had cooled off. Similar arguments, though less compelling, may be advanced for analogous conclusions in regard to the formation of the atmospheres of Mars, Venus, and the earth.



Titan, before 2003

Voyager 1981

- Second-largest moon in SS
- Density ~1900 kg/m^3
- thick atmosphere! Sublimation
  - N_2 (96%), methane, ethane
  - ethane may condense
  - clouds, rain,oceans/lakes/ponds/erosion
- Geology was unknown due to thick atmosphere

Fly-bys

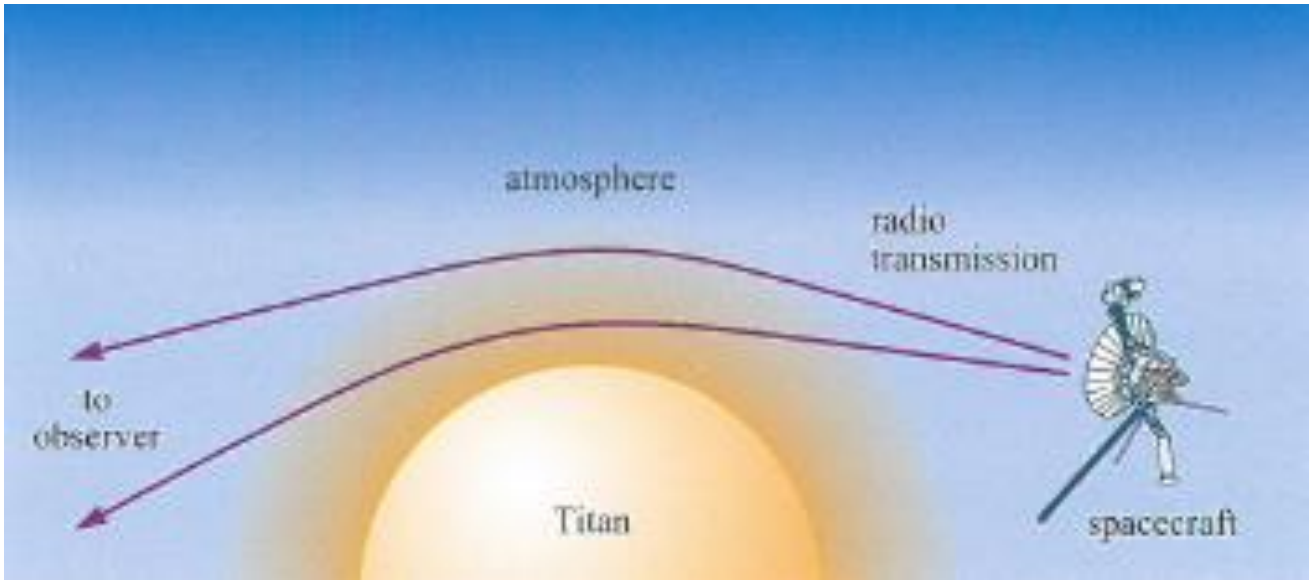
- Not limited by Earth atmosphere
- Infrared, ultraviolet
- Spatial resolution
- Higher intensity of radiation from object
- ……
- …

Voyager 1

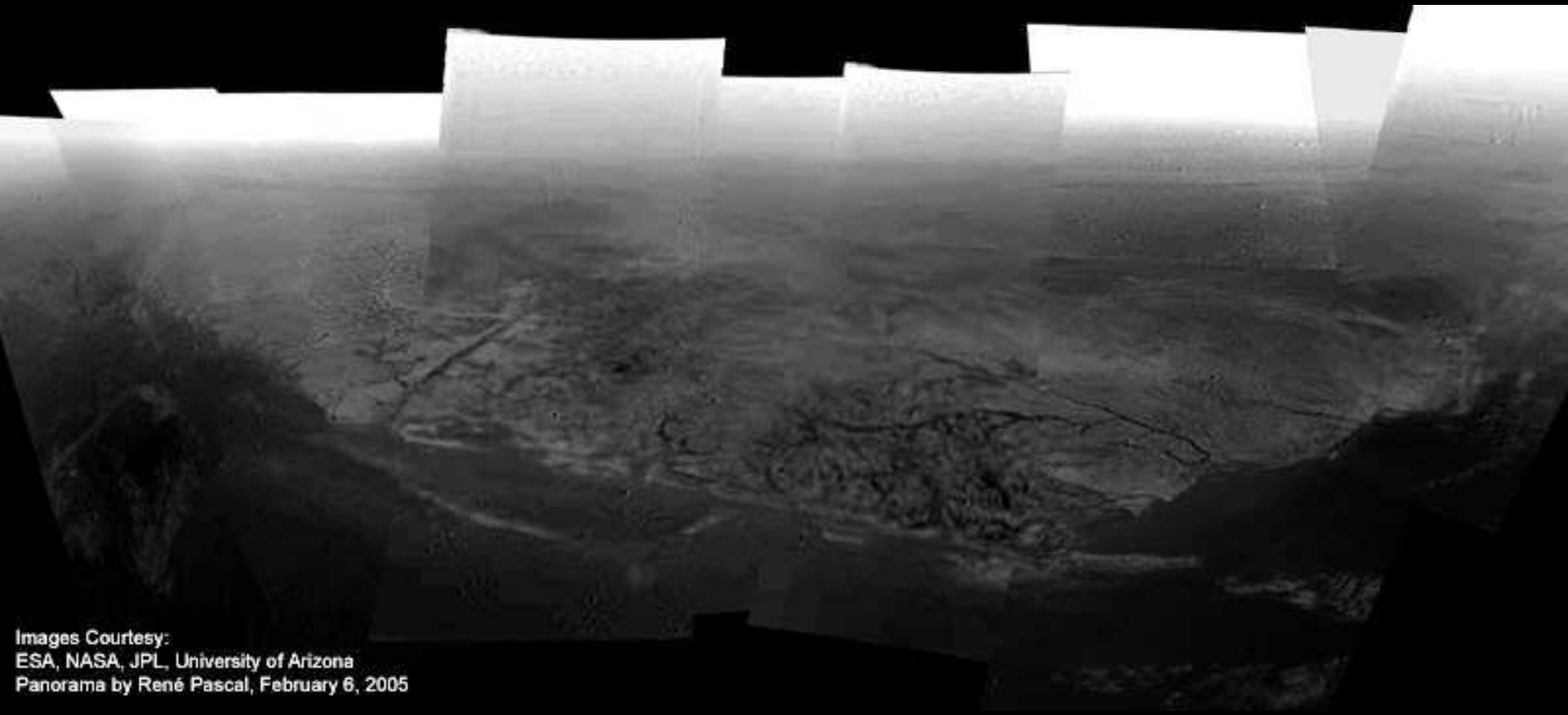
- Orange haze
  - But featureless
- Dark band near near north pole
  - Slight contrast between north/south
- No gaps in haze, no clouds
  - No wind velocity measurements
- Complex spectra

Advantages of fly-bys…

- Measuring thickness of atmosphere
- 1.6 bar

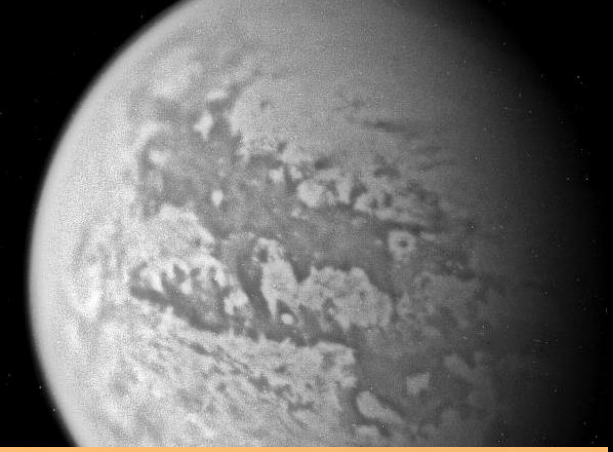


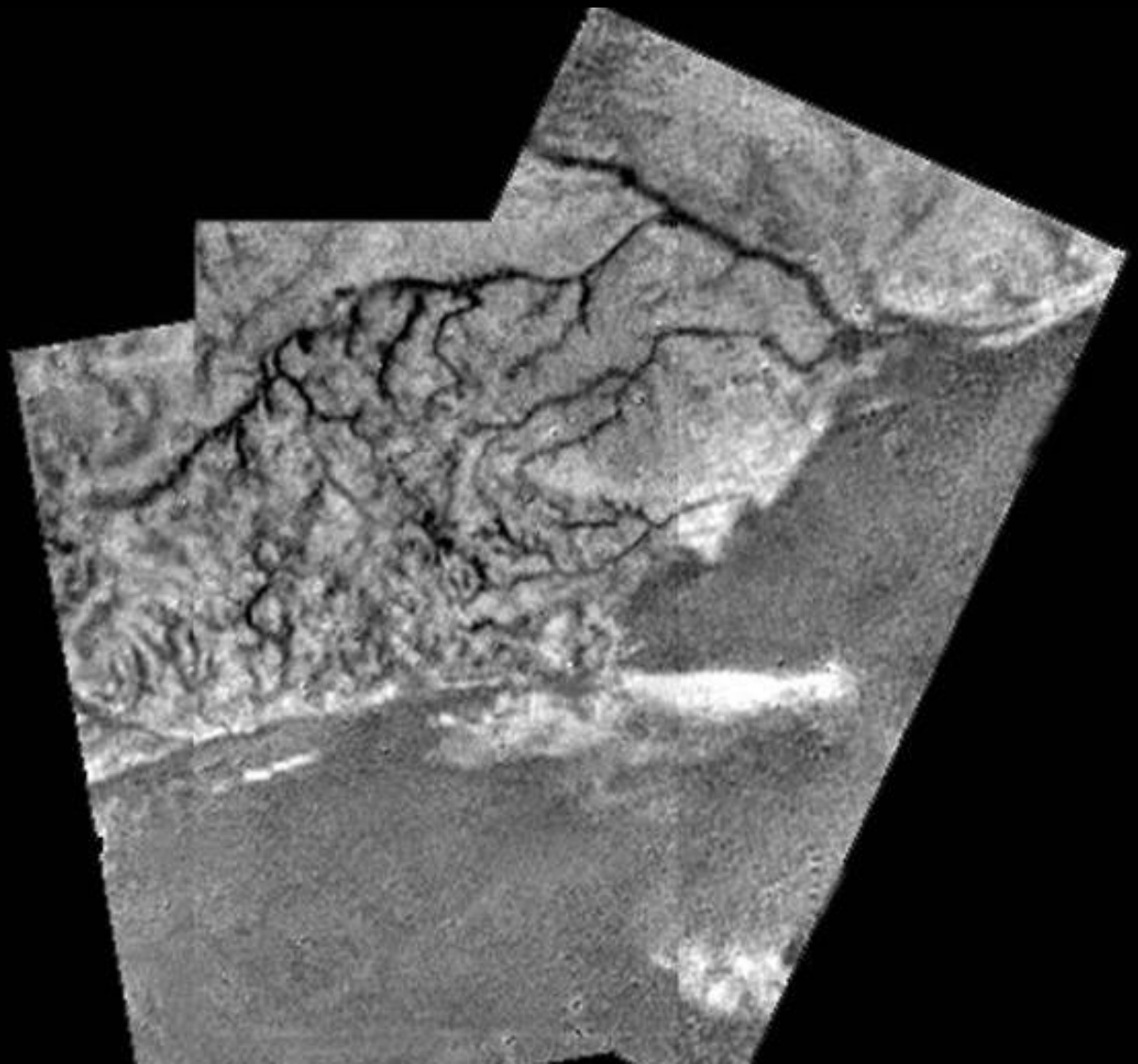
Huygens descent, Jan 14, 2015

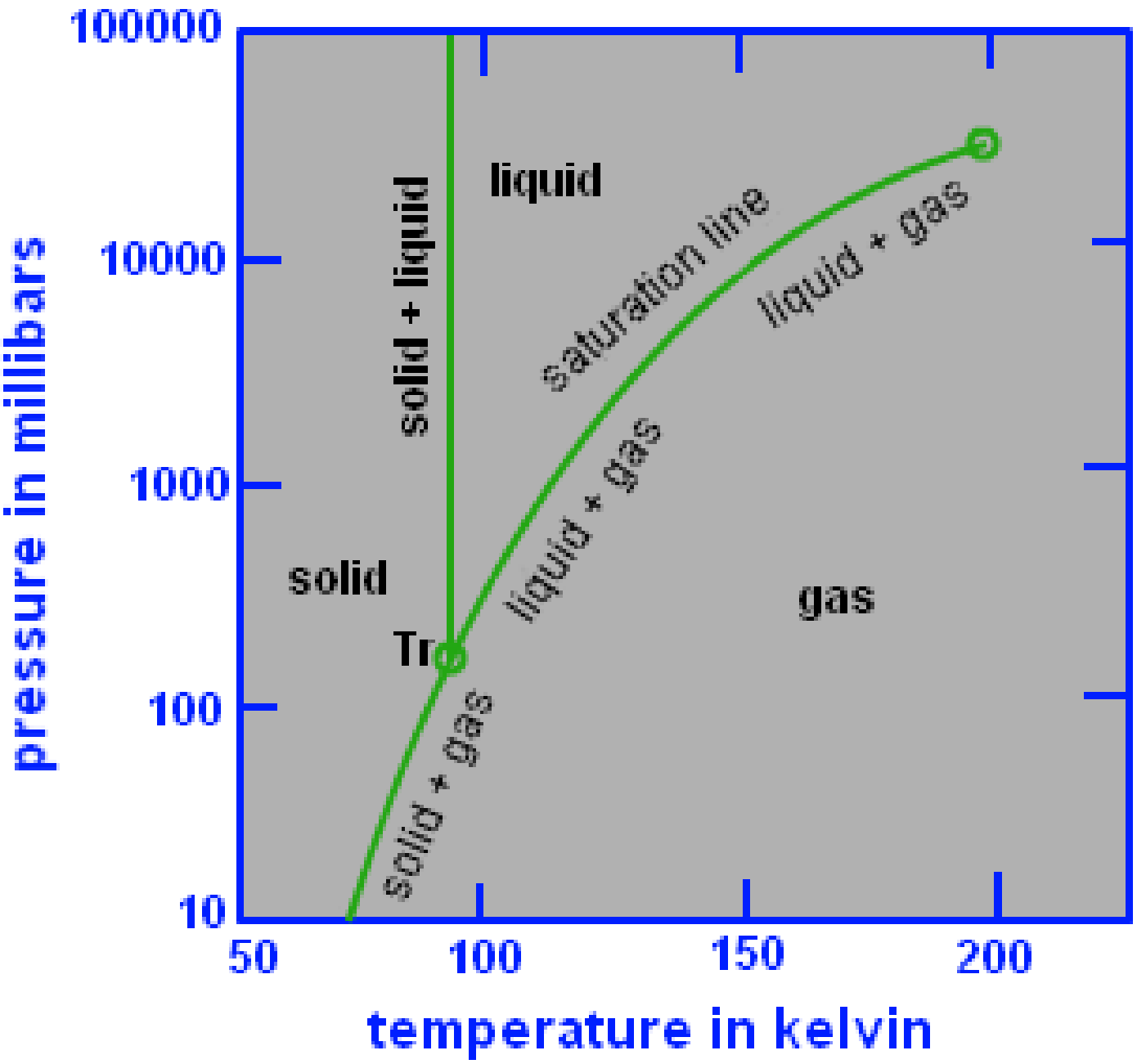


Images Courtesy:
ESA, NASA, JPL, University of Arizona
Panorama by René Pascal, February 6, 2005

Lakes, rivers, riverbeds



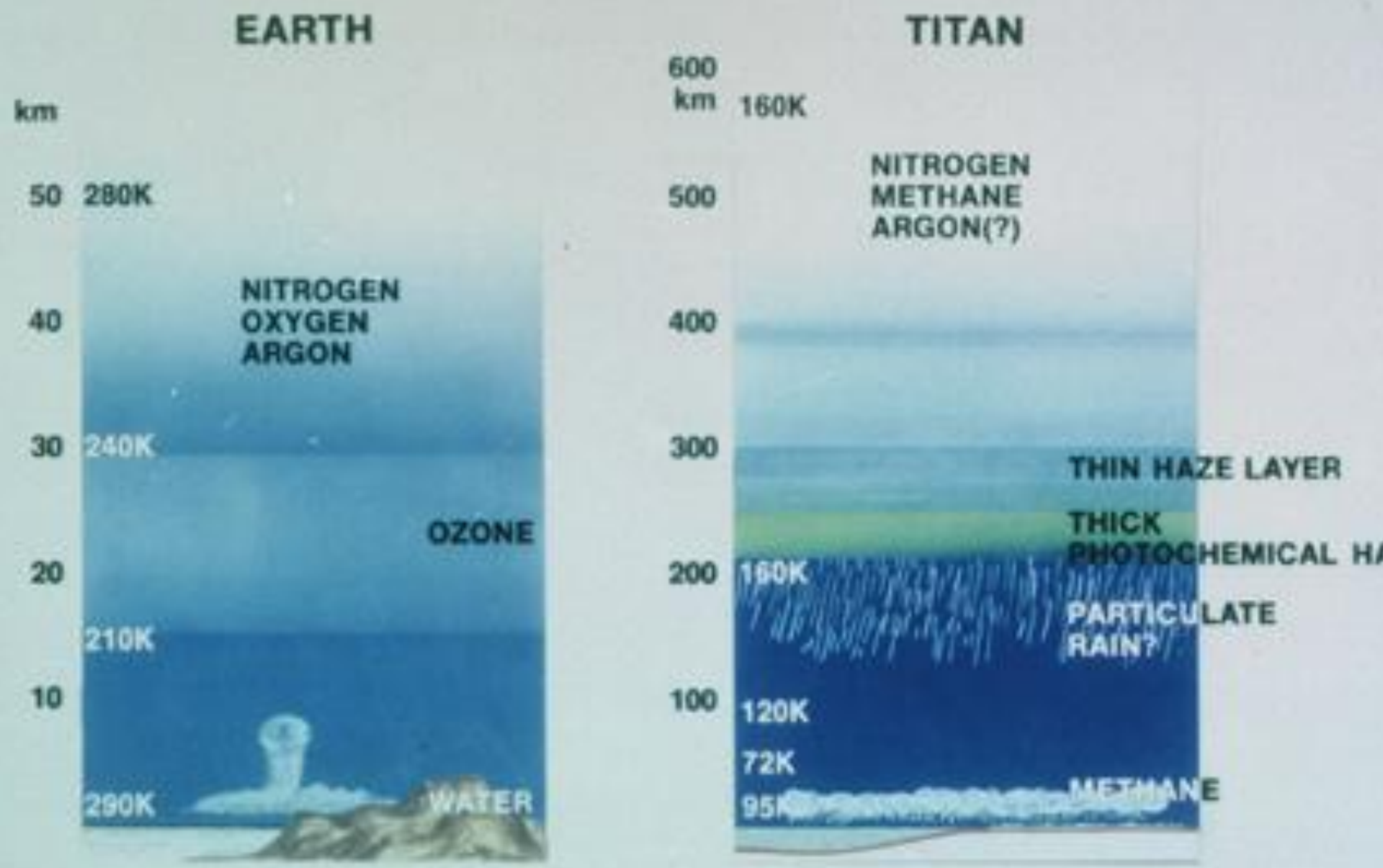




Methane phase diagram

- At triple point of methane
- What does this imply?

soid, liquid, gas can all exist

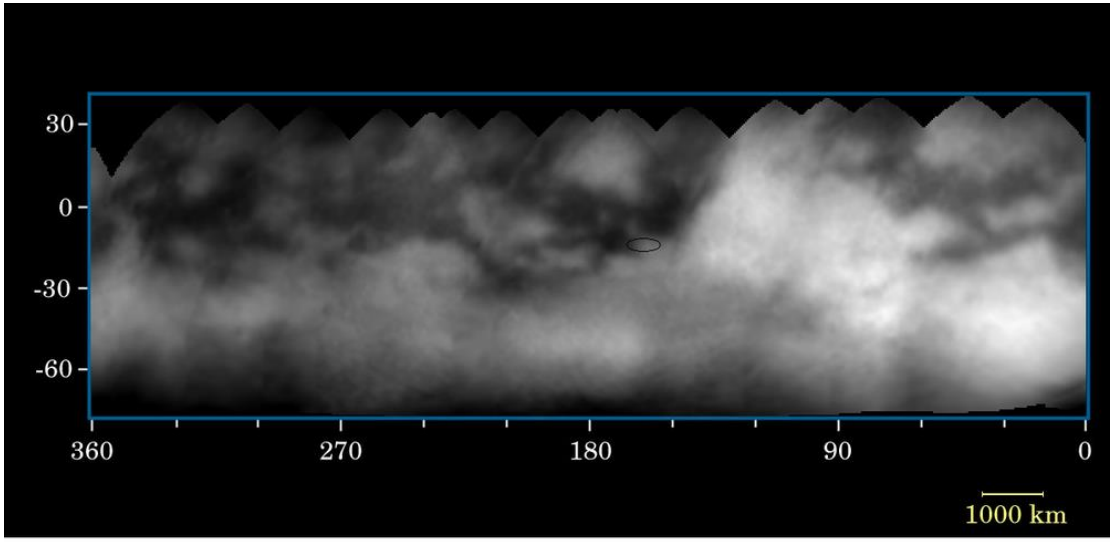

EARTH
km
50
280K
NITROGEN
OXYGEN
ARGON
40
30
240K
OZONE
20
210K
10
290K
WATER
TITAN
600
km
160K
500
NITROGEN
METHANE
ARGON(?)
400
300
THIN HAZE LAYER
THICK
PHOTOCHEMICAL HA
200
160K
PARTICULATE
RAIN?
100
120K
72K
95K
METHANE

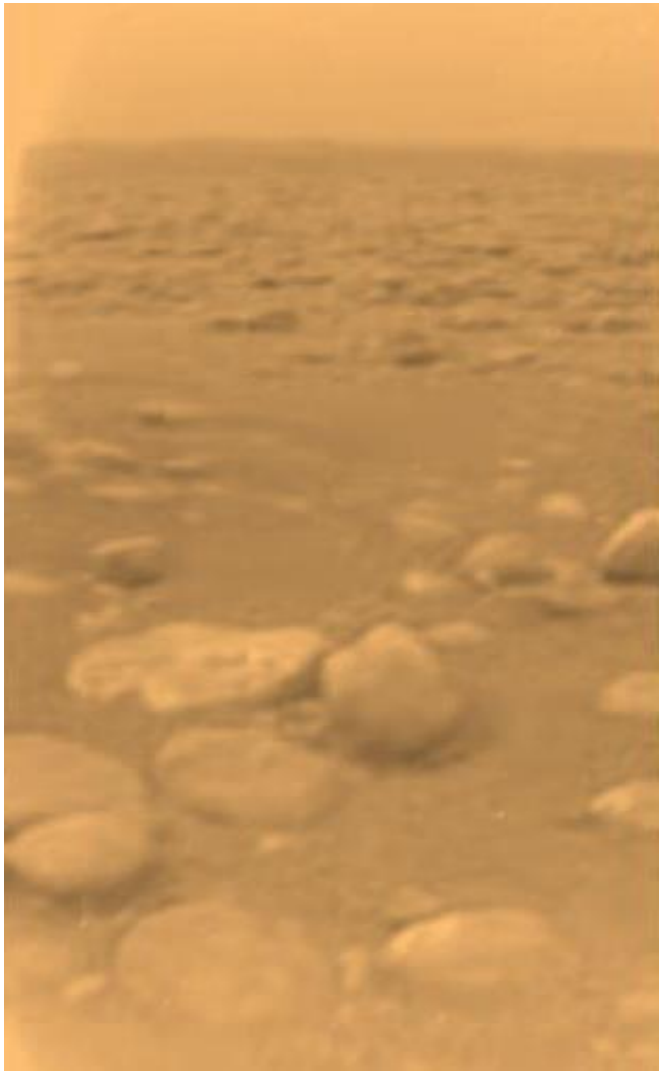
Ice versus terrestrial

	Rocky planet	**Icy body**
Core	Iron	Rock
Mantle	Silicate rocky shell	Liquid water
Crust	Rock	Water ice
Outgassing	CO_2	CH_4
Eruption of …	Lava	Slush
Aerosols	Dust	Haze
Dunes	Sand	Organics
Cycles	Water	Methane

Surface topography

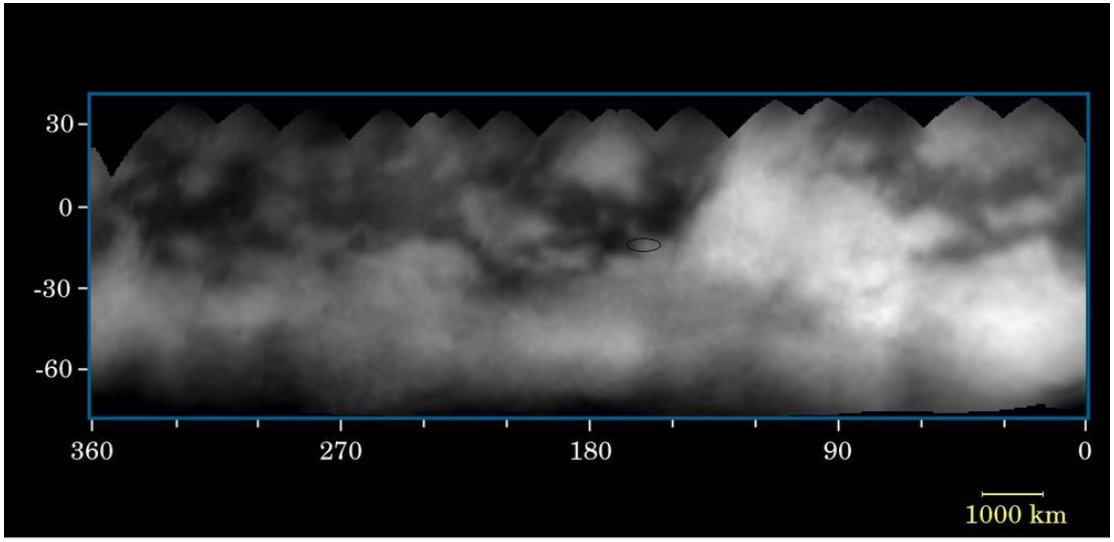
- Rivers from bright highlands
- To dark/flat lowlands
- Coast lines
- Pebbles: round (why?)

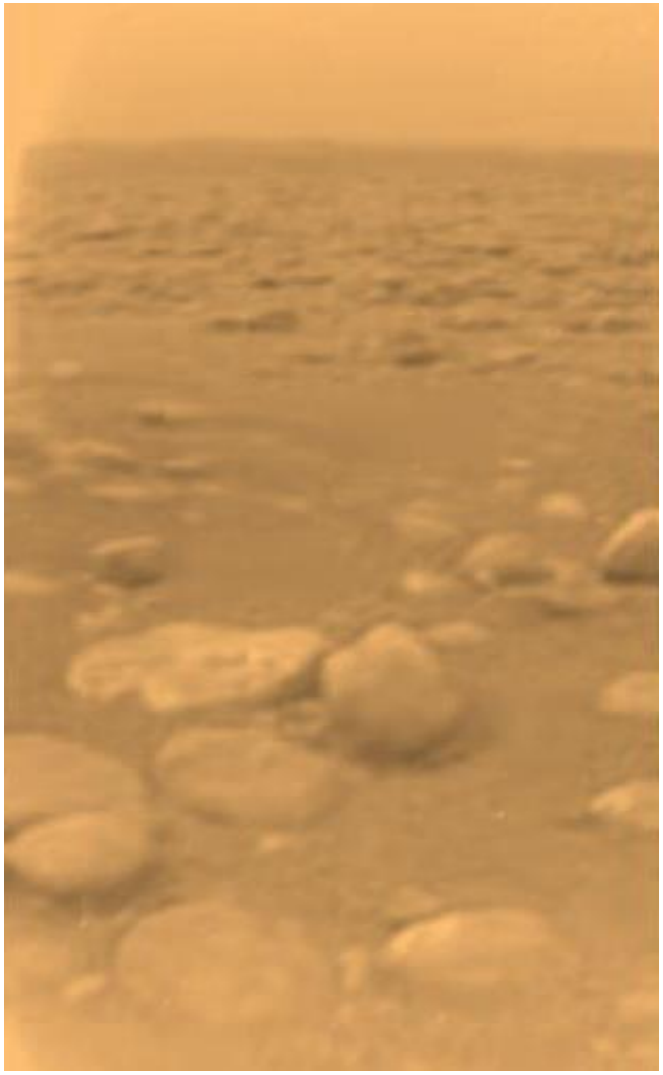




Stones made of water ice!

- Ice balls deposited by powerful currents
- Liquid methane obvious possibility





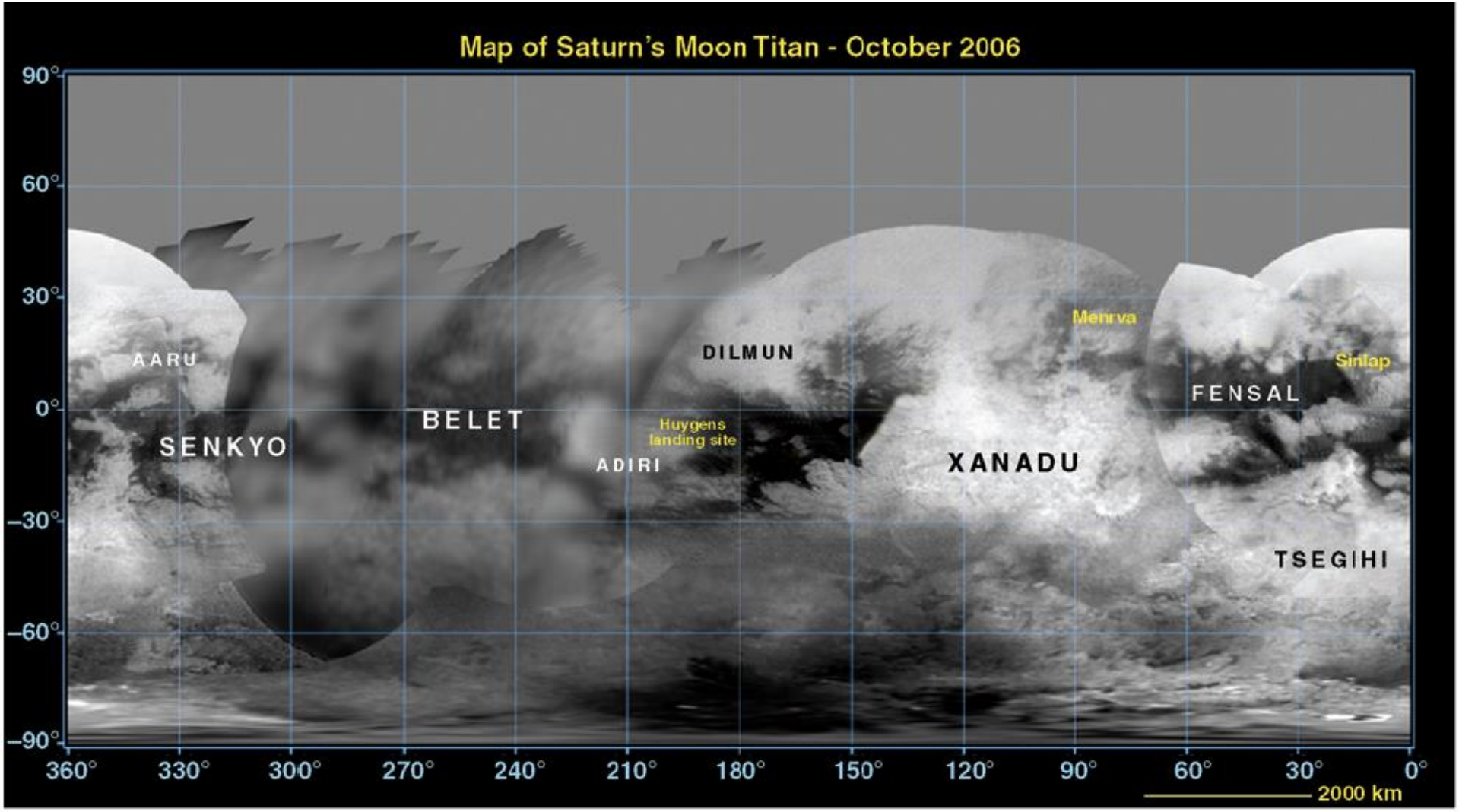


Figure 3. A map of Titan from Cassini ISS images at 940 nm, with names indicated for major regions (names are selected by a committee of the IAU). Some areas are mapped at rather higher resolution than others; latitudes 50°N and higher are insufficiently illuminated in the season shown to map. (Image courtesy of NASA/JPL/Ciclops.)

Precipitation in the Summer

A. More precipitation
B. Less precipitation
C. No difference

Precipitation in the Summer

A. More precipitation

B. Less precipitation

C. No difference

Evaporation from tropics!

autumn. There is evidence for rainfall at high latitudes in summer. It seems that methane evaporates from the warm tropics over summer and is transported toward the poles where it falls as rain. This recharges the lakes but leaves the tropics a dry desert

Longstaff, p.293

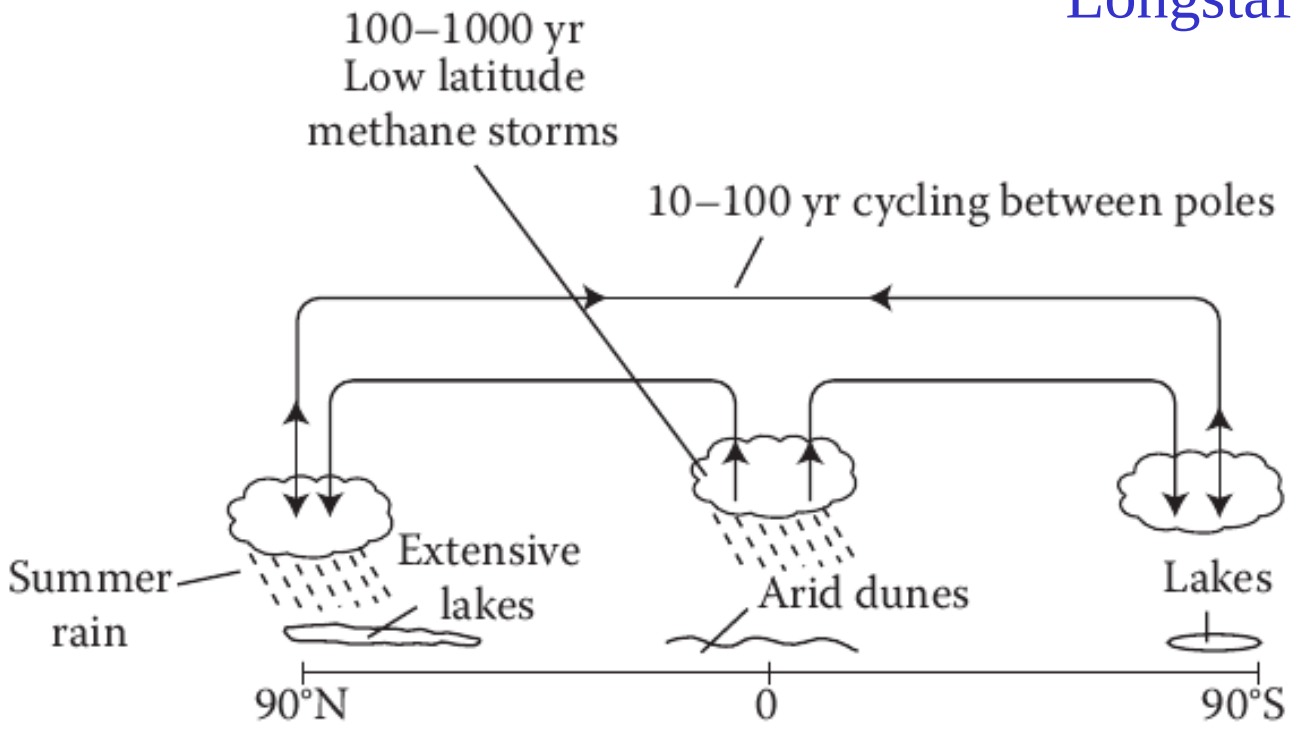
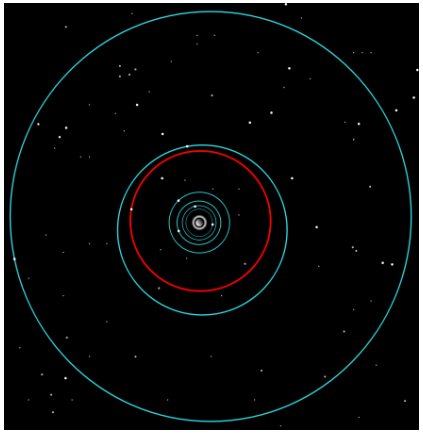
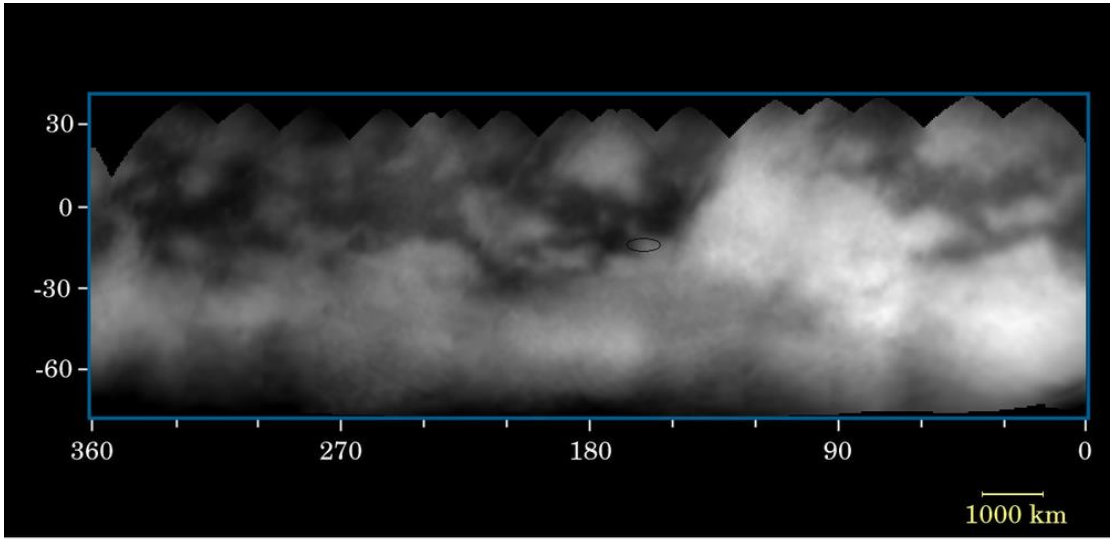


FIGURE 11.2 The methane cycle on Titan evaporates methane in equatorial regions in summer and transports it to polar regions where it rains.

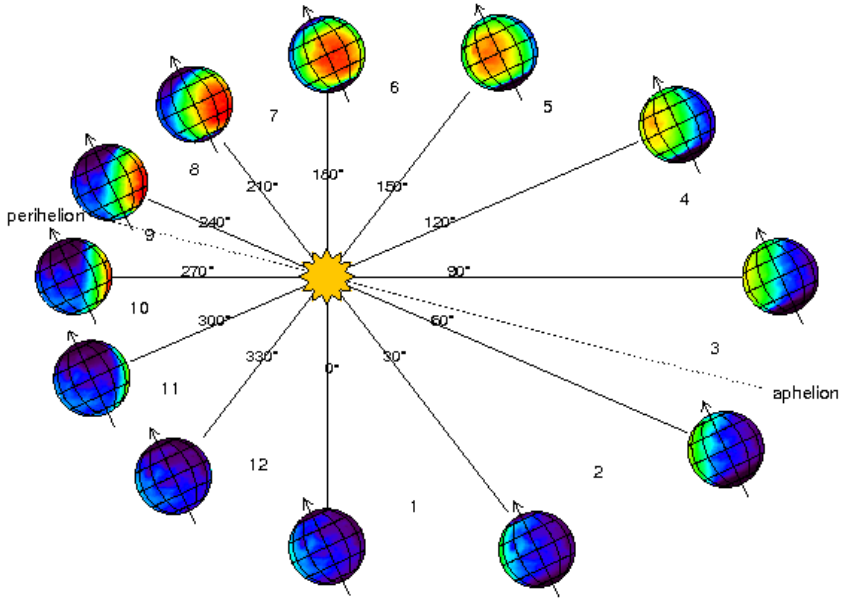
Northern summer stronger

- Because of eccentricity
- Longer rainy season than in the south
- More lakes in the north



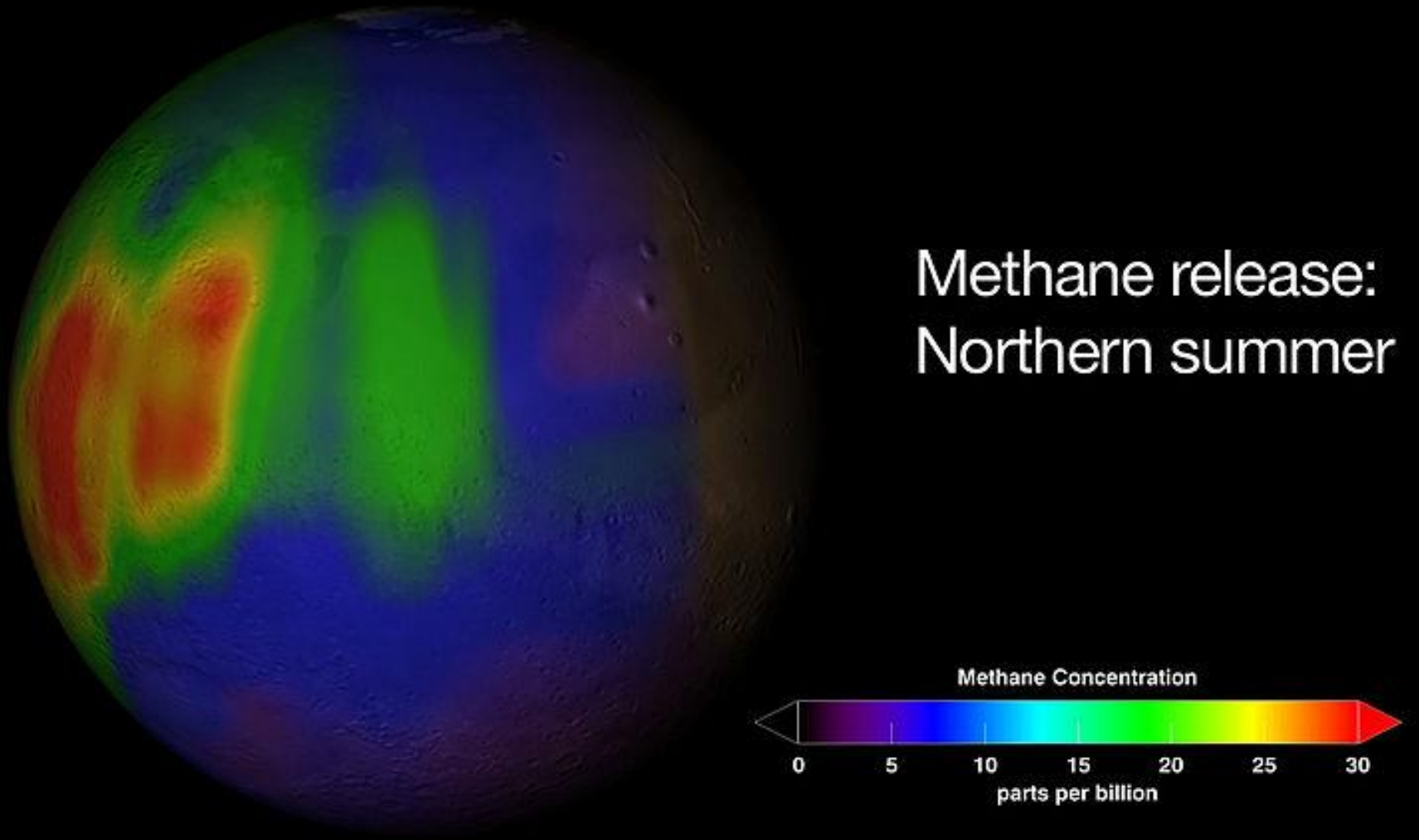


Similar to Martian seasons



	Summer	Winter
North	Cooler	wamer
	longer	shorter
	caps sublimate less	Caps freeze less
South	hotter	cooler
	shorter	longer
	caps sublimate more	freeze more

Comparison with Mars: constant loss of methane



Lake reservoir sufficient?

- Loss ~ 100 kg/s
  - Exercise 5.4 in RGS, p.195
- If 10% of surface methane lakes
  - 400 m deep on average
  - Total 1.5×10^{18} kg
- Time: 1.5×10^{18} kg / (100 kg/s)
  - 1.5×10^{16} s = 0.5 Gyr

Main results so far

- Titan is the size of a planet, and resembles the Earth, with a thick, organic-rich and complex atmosphere
- Methane-ethane lakes resupply the methane in the atmosphere, which is continuously released from Titan's interior by volcanoes
- Titan shows pre-biotic chemistry, like on Earth before life arose
- Life using methane as a solvent or eating acetylene are possible

Life on Titan?

- If not, it resembles Earth before life: plenty of organics and chemical reactions: Can organisms eat these?
- After giant impacts? ‘Titan Spring’
- Hot springs?
- At great depths: warm pond or deep-sea vent?
- Methane-based or acetylene eating life?

Next time

- Titan's subsurface ocean habitable?
- Methanogenesis, cryovolcanism
- Haze photochemistry

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