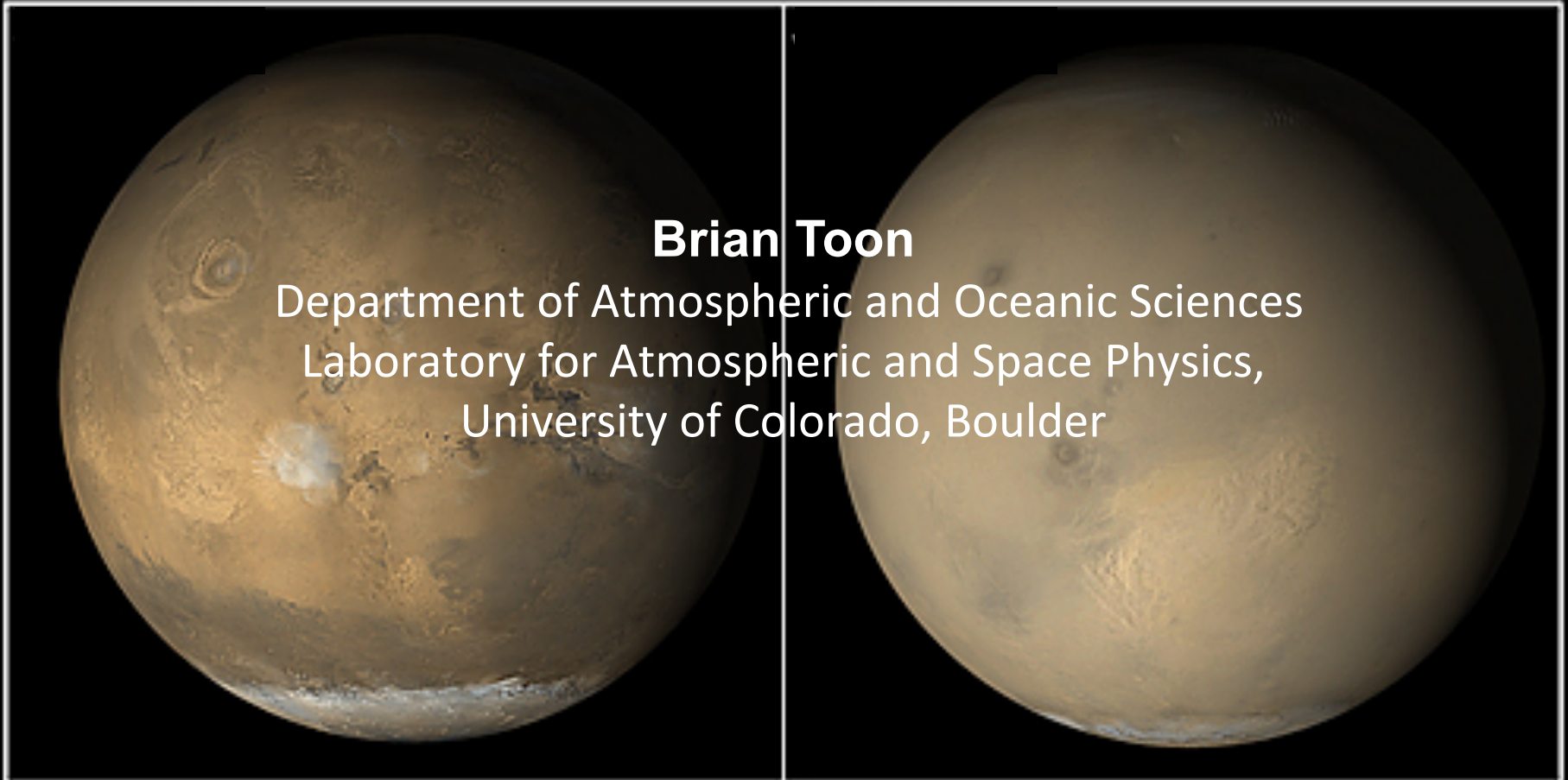


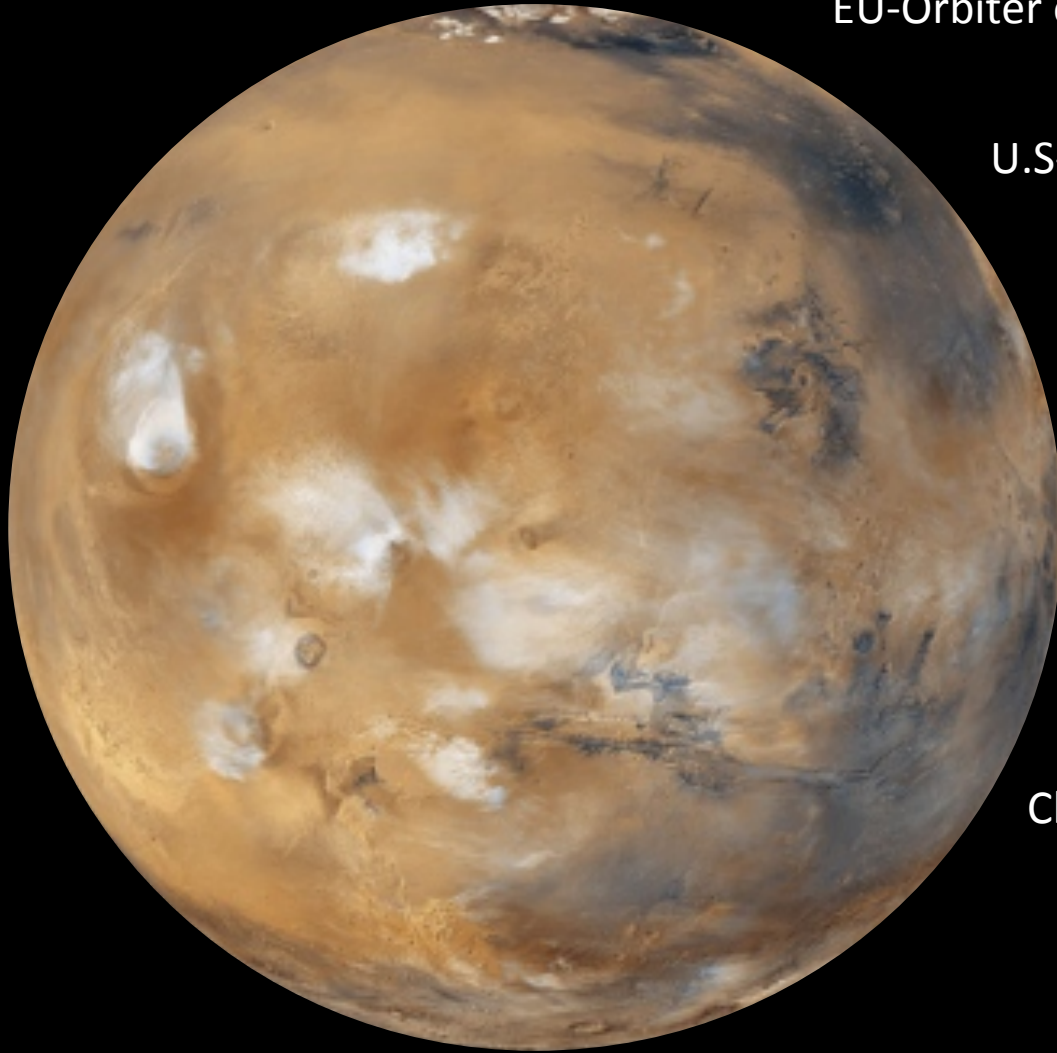
Clouds and aerosols on Mars and Earth: unsolved problems in Martian dust storms and Martian river valleys



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Mars is focus of human exploration



EU-Orbiter operational; Orbiter, Lander en route

U.S-3 Orbiters and 3 Landers operational

India-Orbiter operational

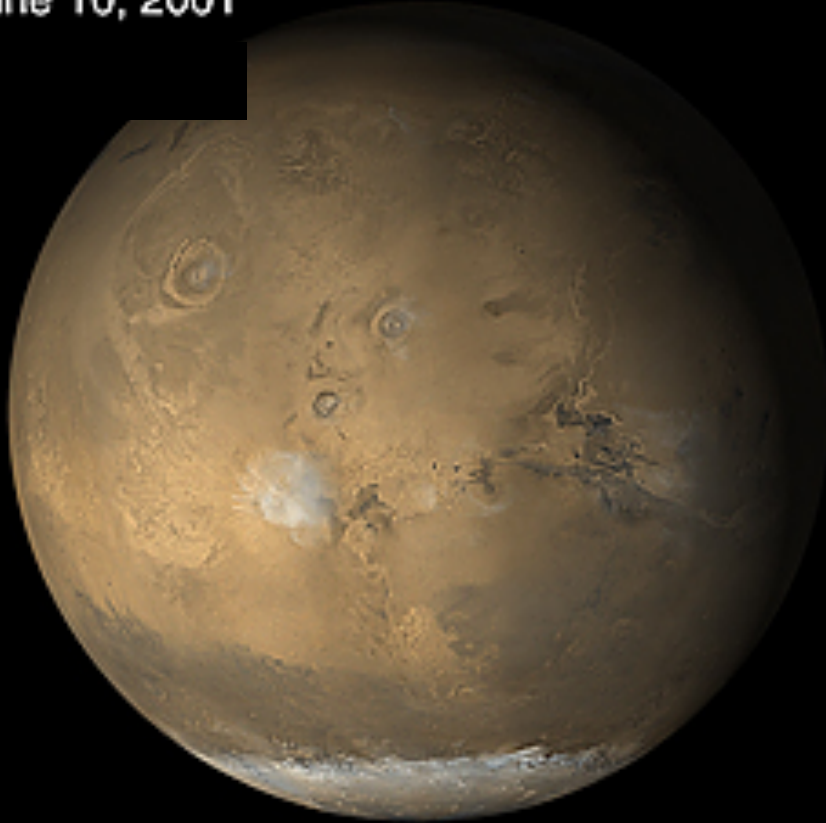
Russia-partner with ESA

UAE-Orbiter - 2020 launch

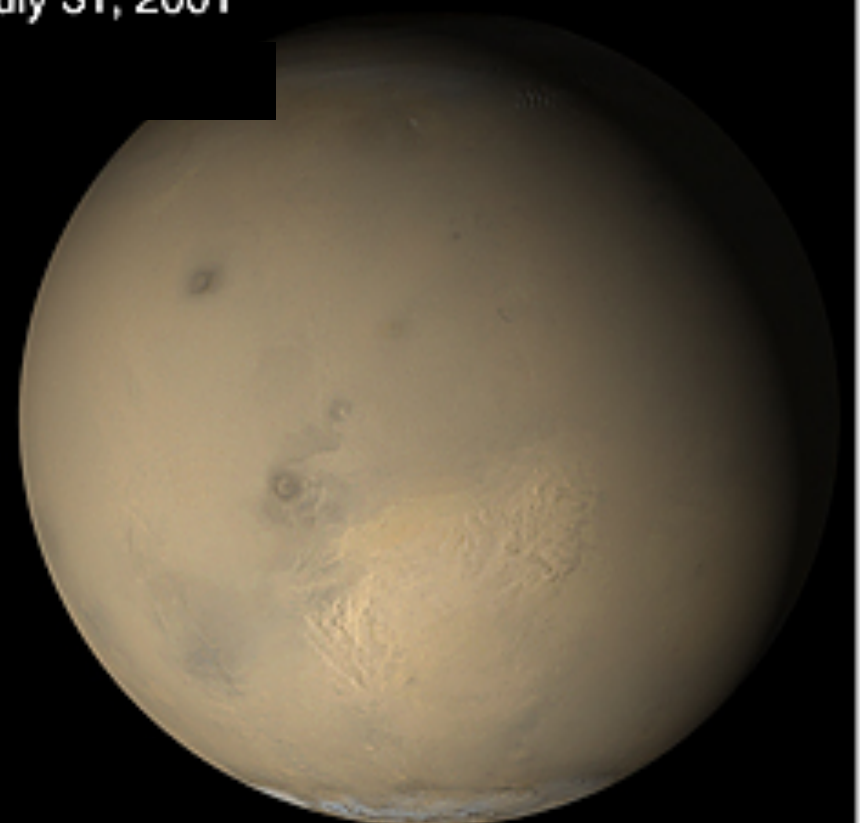
China-Orbiter. Lander, rover 2020 launch

Mars is a dusty place

June 10, 2001

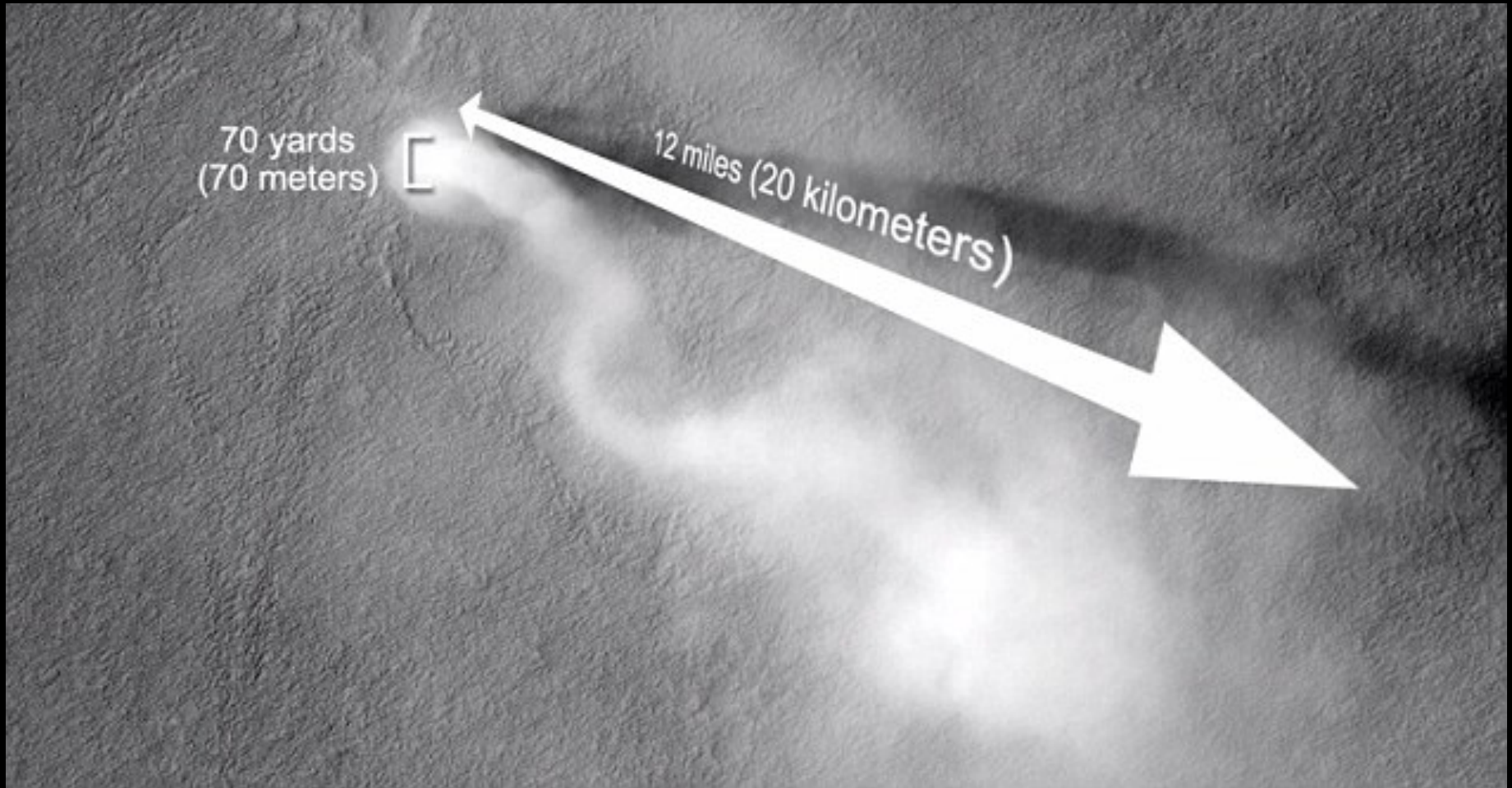


July 31, 2001



Hubble image

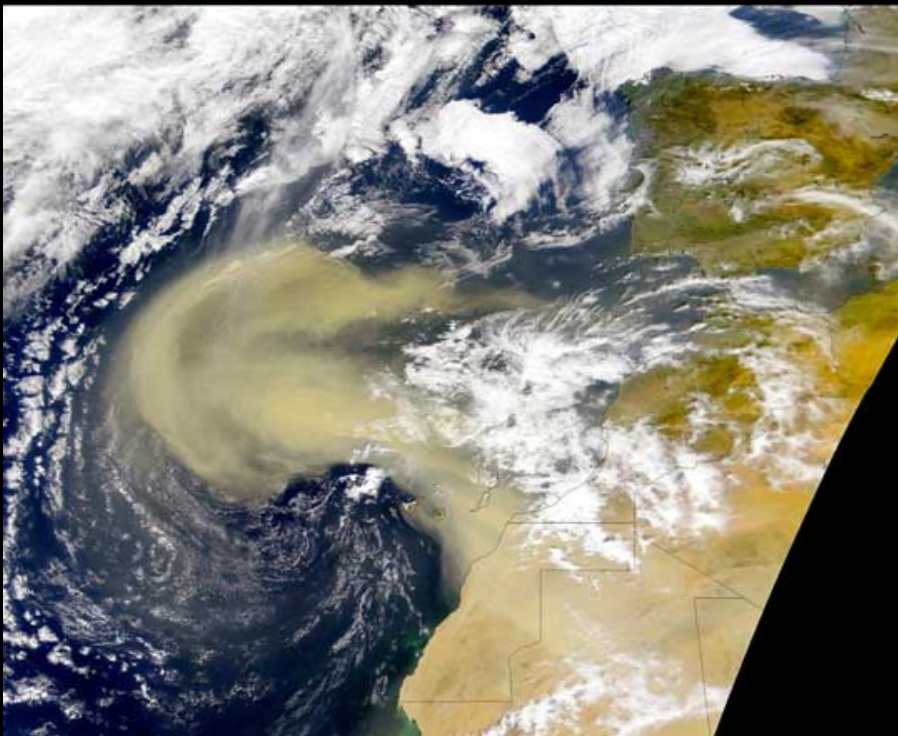
Huge dust devils are common on Mars





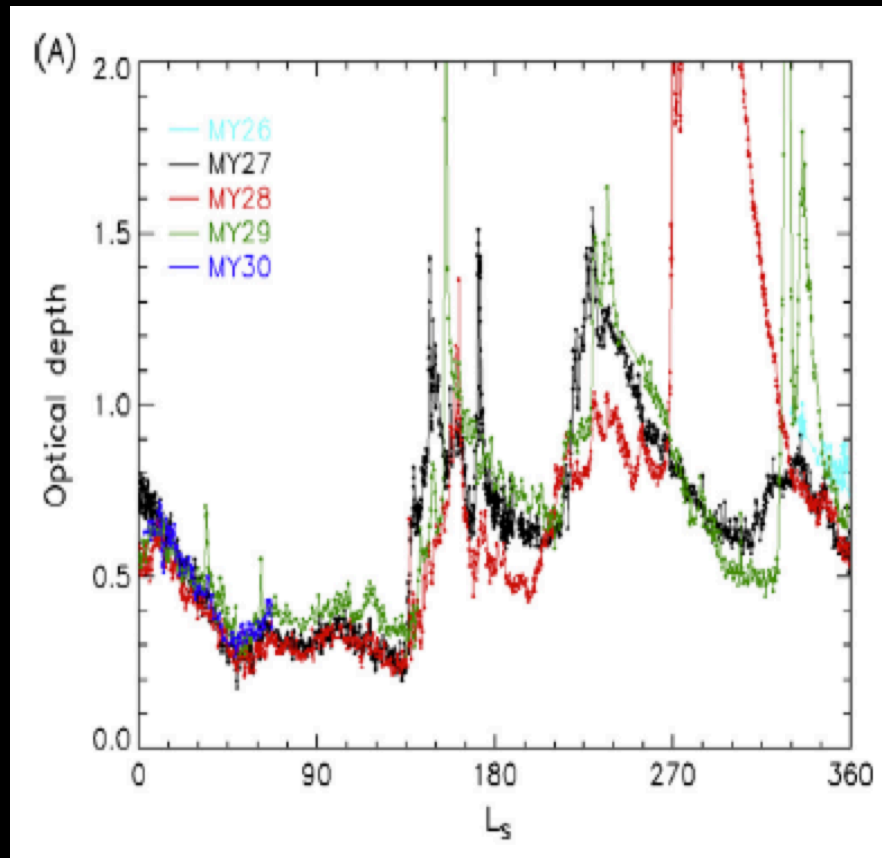
Mars polar cap dust storm

**Most large Martian
dust storms look
similar to terrestrial
ones**

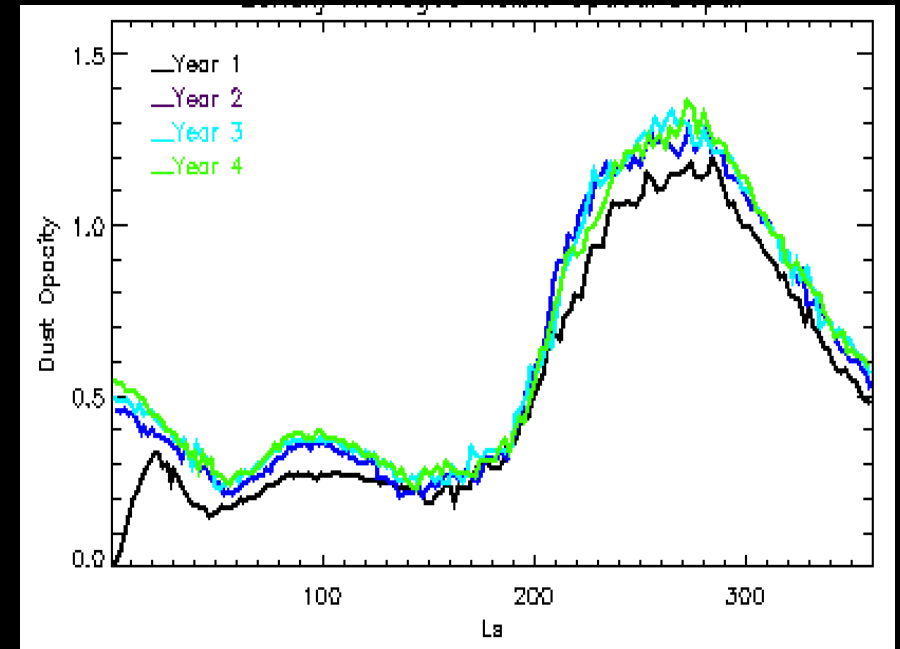


Saharan dust storm

Seasonal dust storm activity on Mars not understood

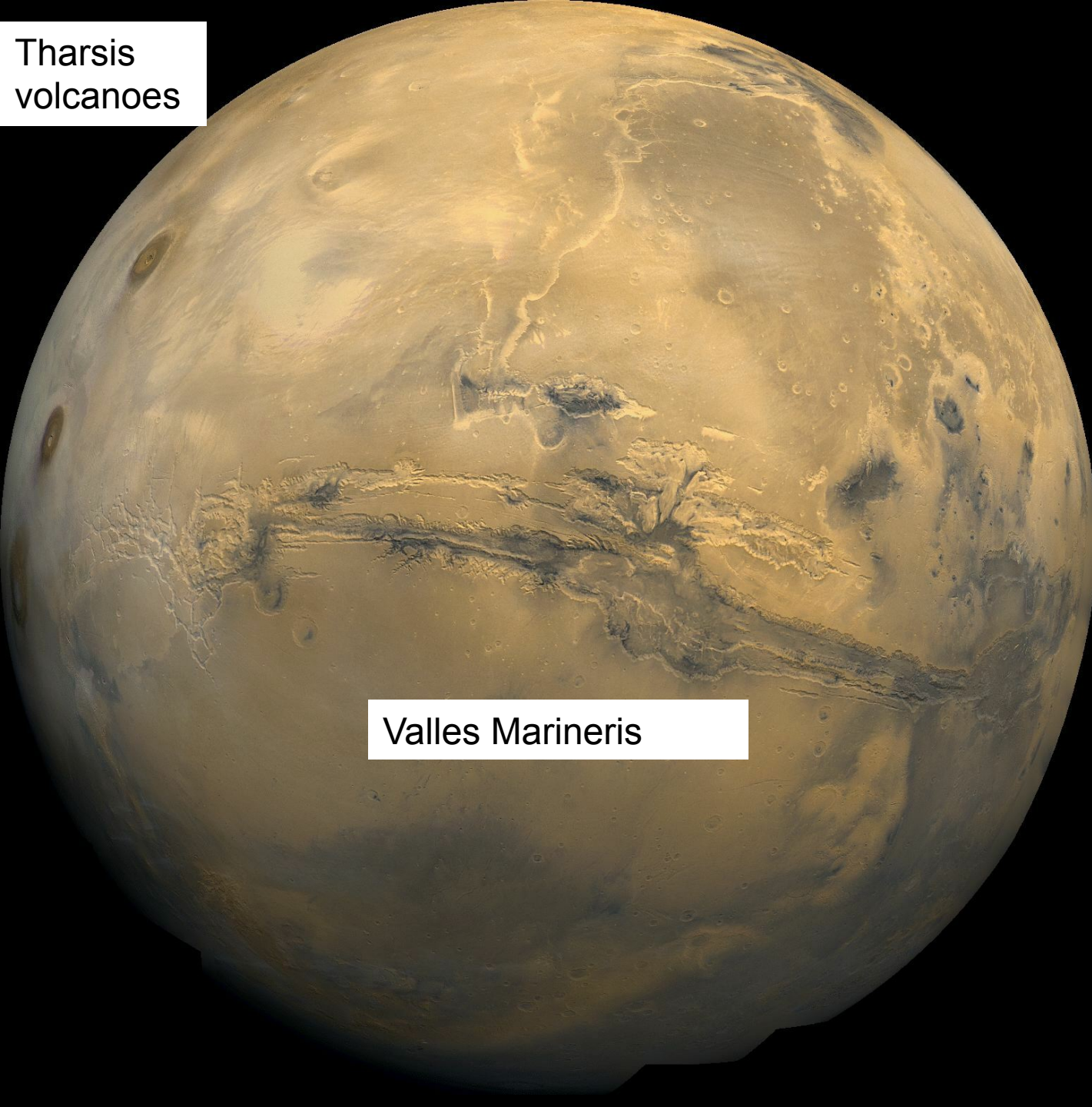


*Observed dust optical depths
(Lemmon et al., 2014)*



*Simulated optical depths
(Hartwick).*

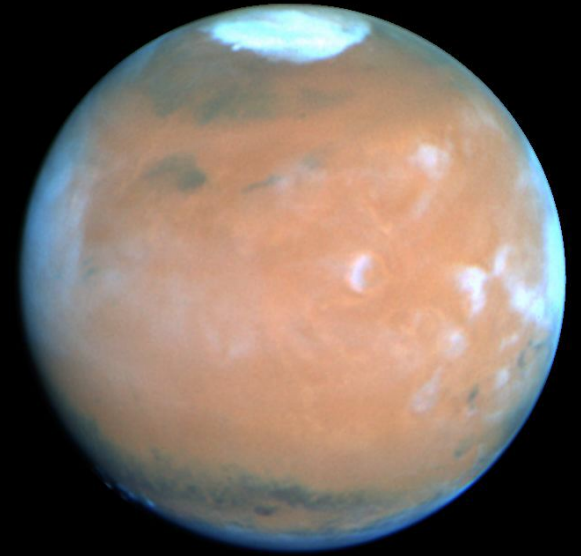
Tharsis
volcanoes



Valles Marineris

Mars is a cold (~210K), dry (~5 pr μm) place today. The pressure (~6 hPa) is so low that liquid water will boil.

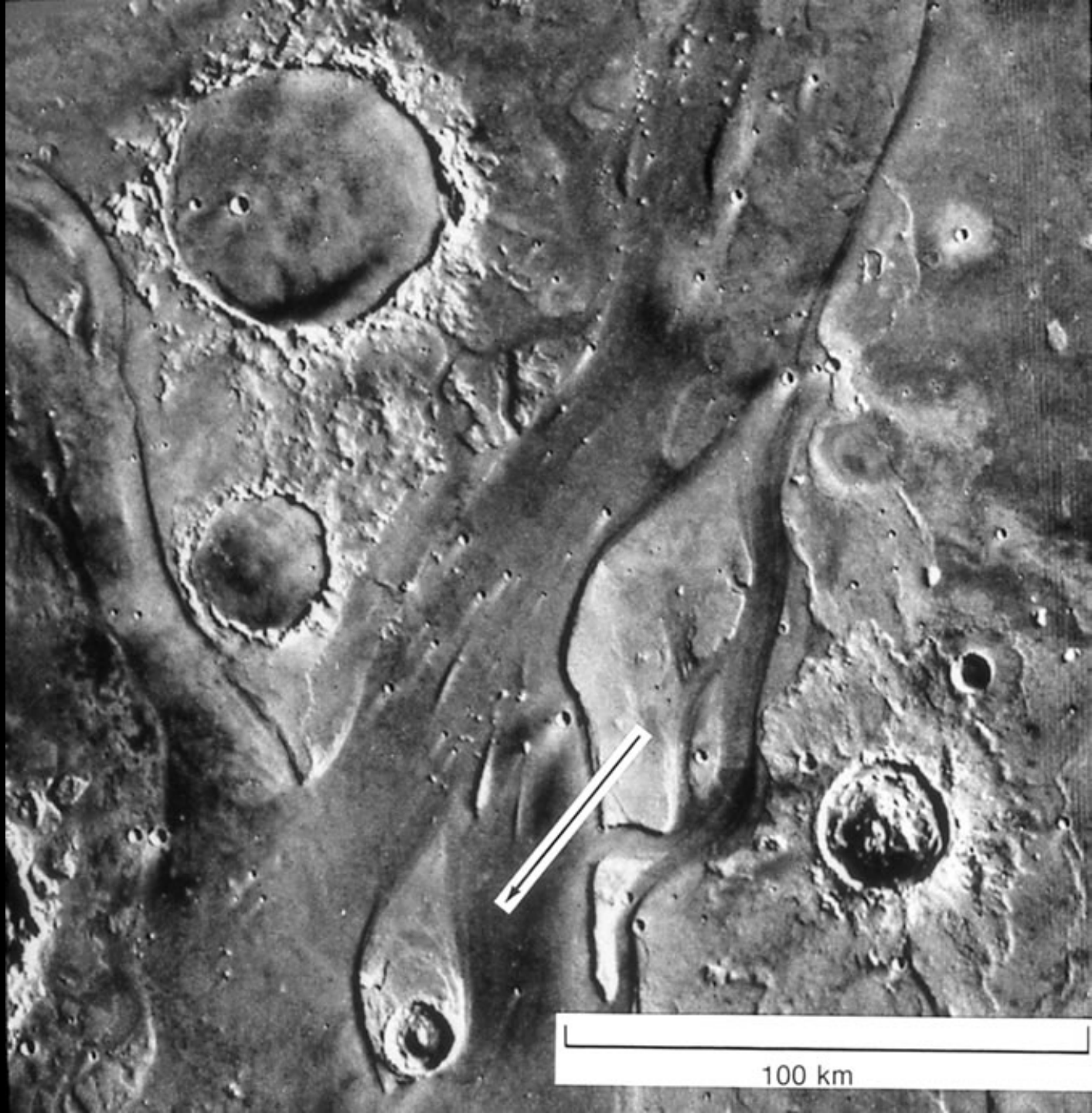
While liquid water is not stable, abundant water is present as ice



Hubble images

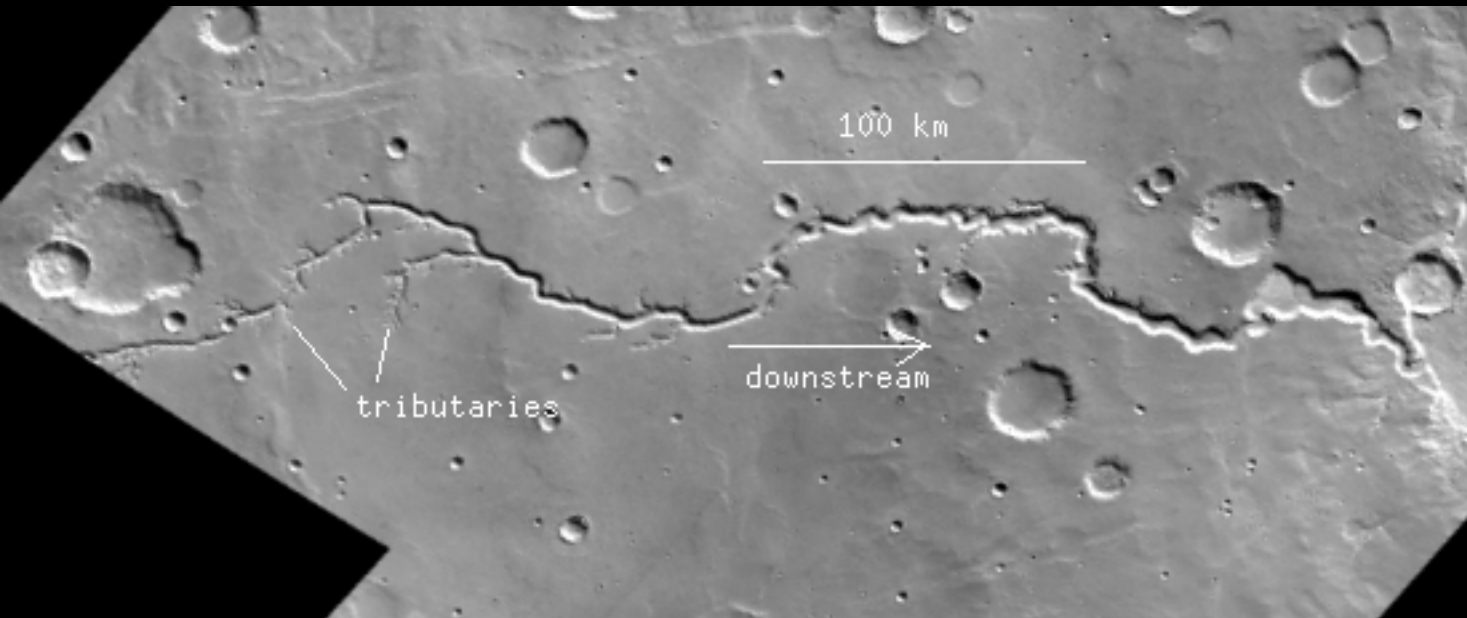
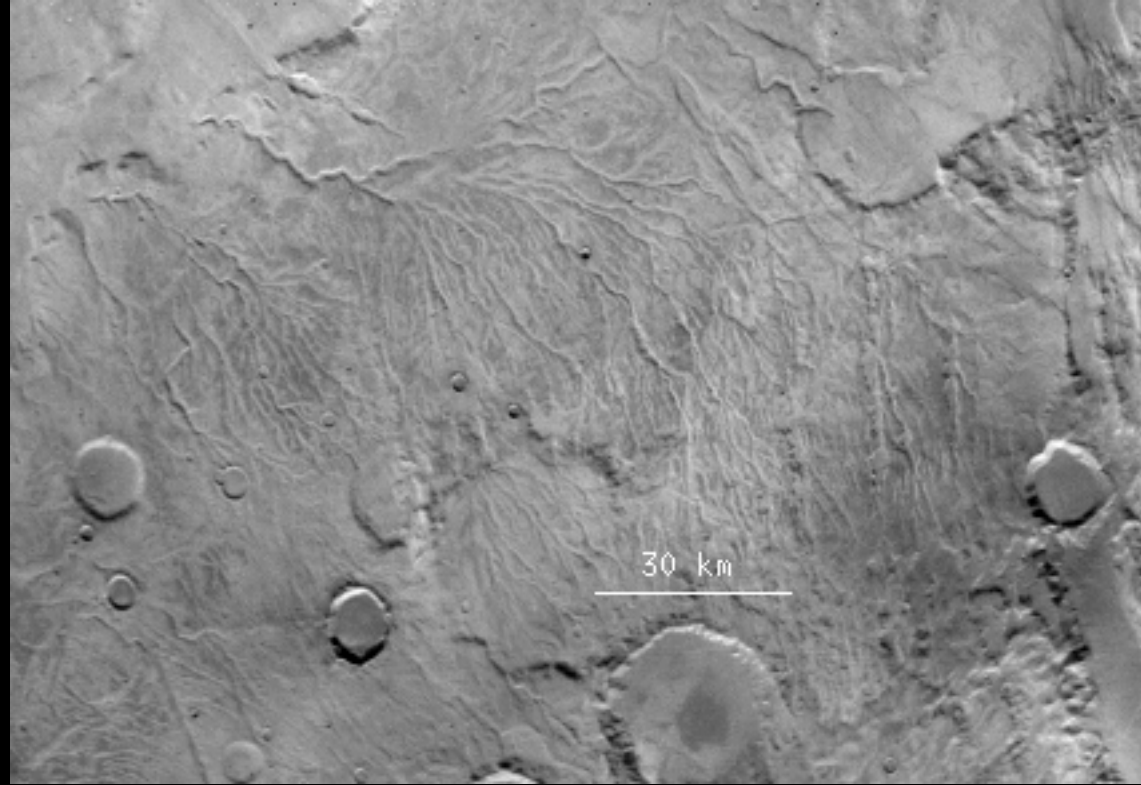
Martian river
Valleys
were
discovered
by Mariner 9
in 1971-2

Ares Vallis



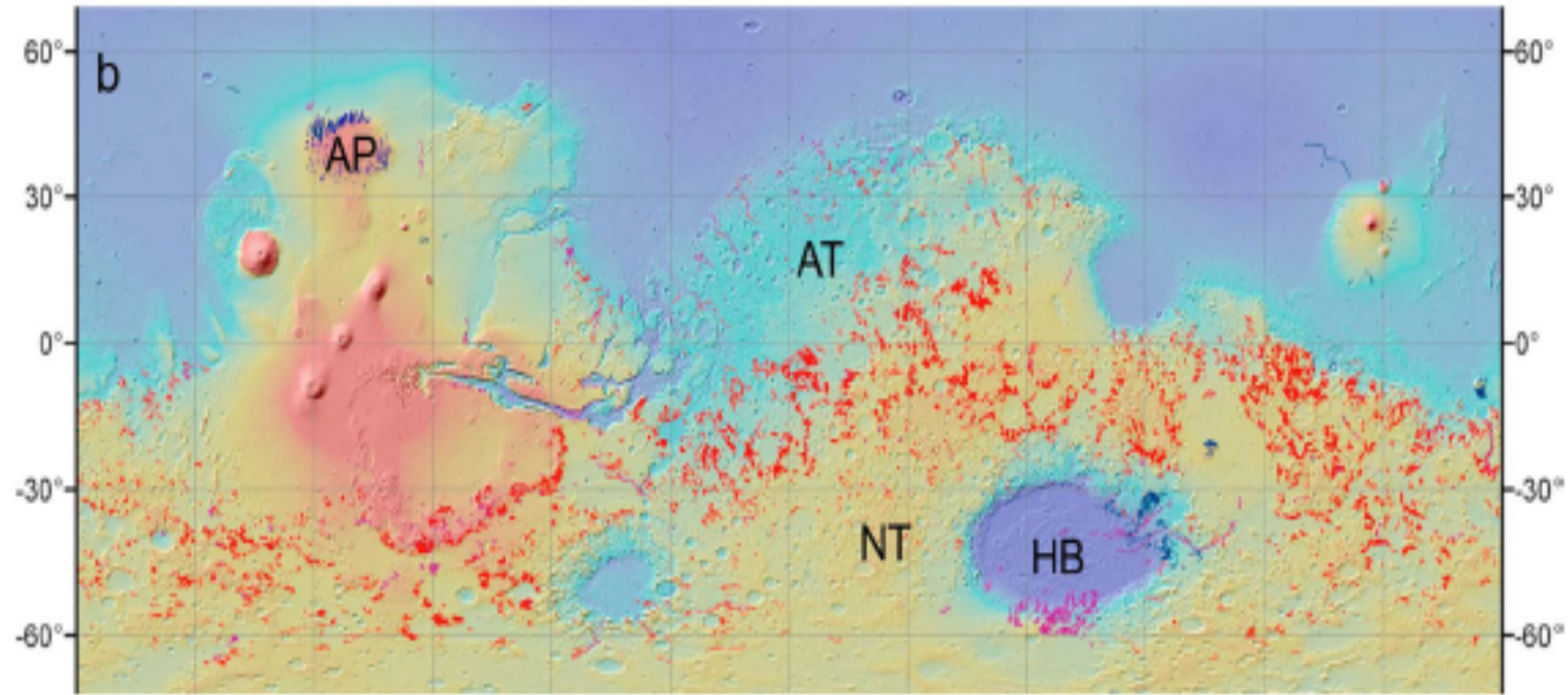
Valley networks appear to have been created by rainfall

Network in the Thaumaisa region
42S, 93W



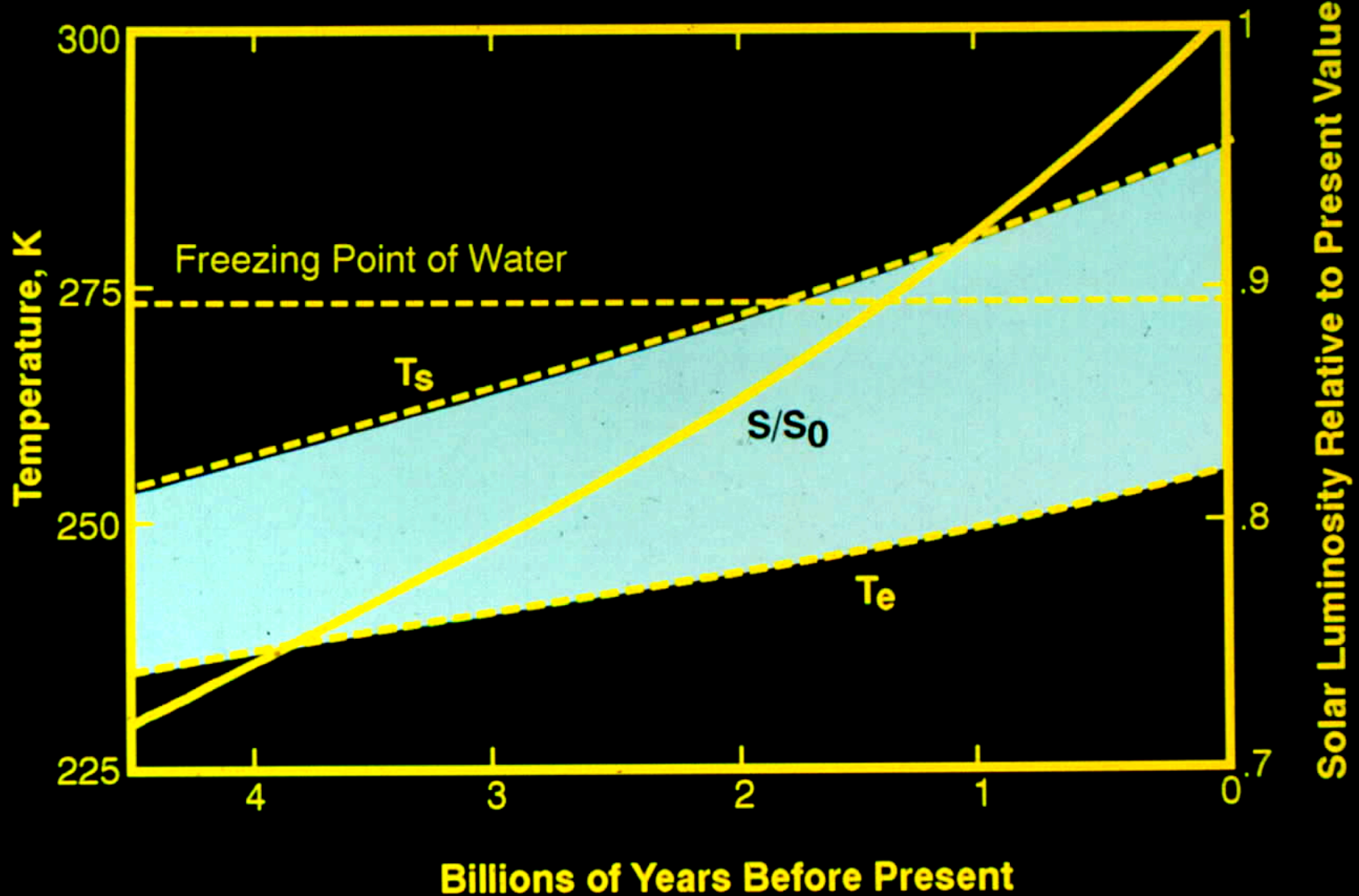
Nirgal Vallis

Valleys mostly 3.8 Ga old, where did they come from?



River line colors=Noachian, Hesperian, Amazonian
Topographic shading= red high, blue low

The Faint Young Sun Problem



Kasting, Toon and Pollack., *Scientific American* (1988)

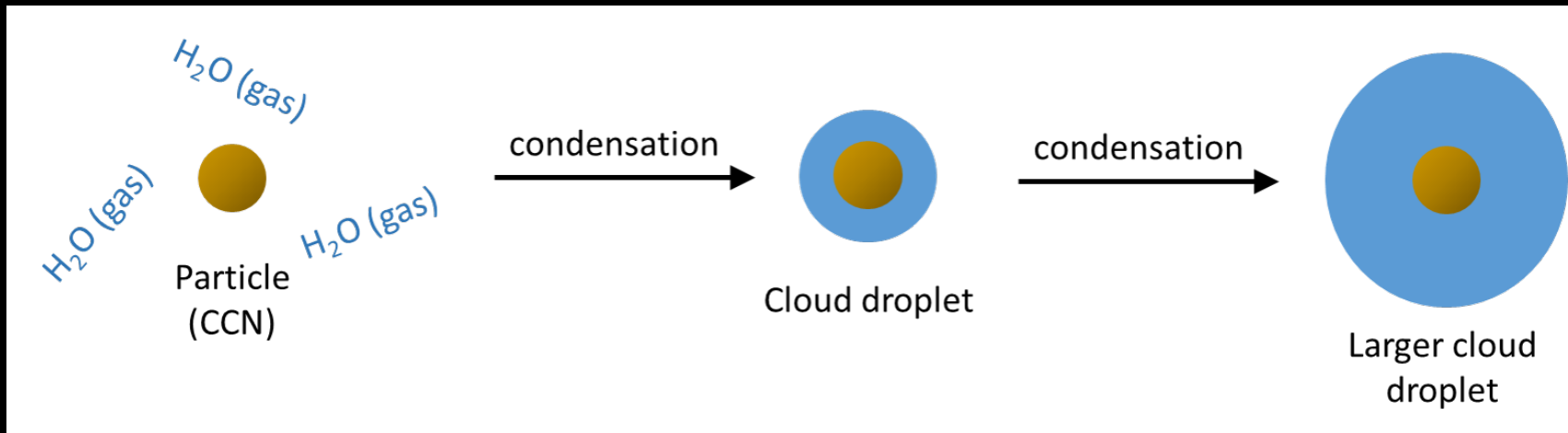
We tried greenhouse gases, which may have been important in the long term evolution of Earth



The Goldilocks
Problem

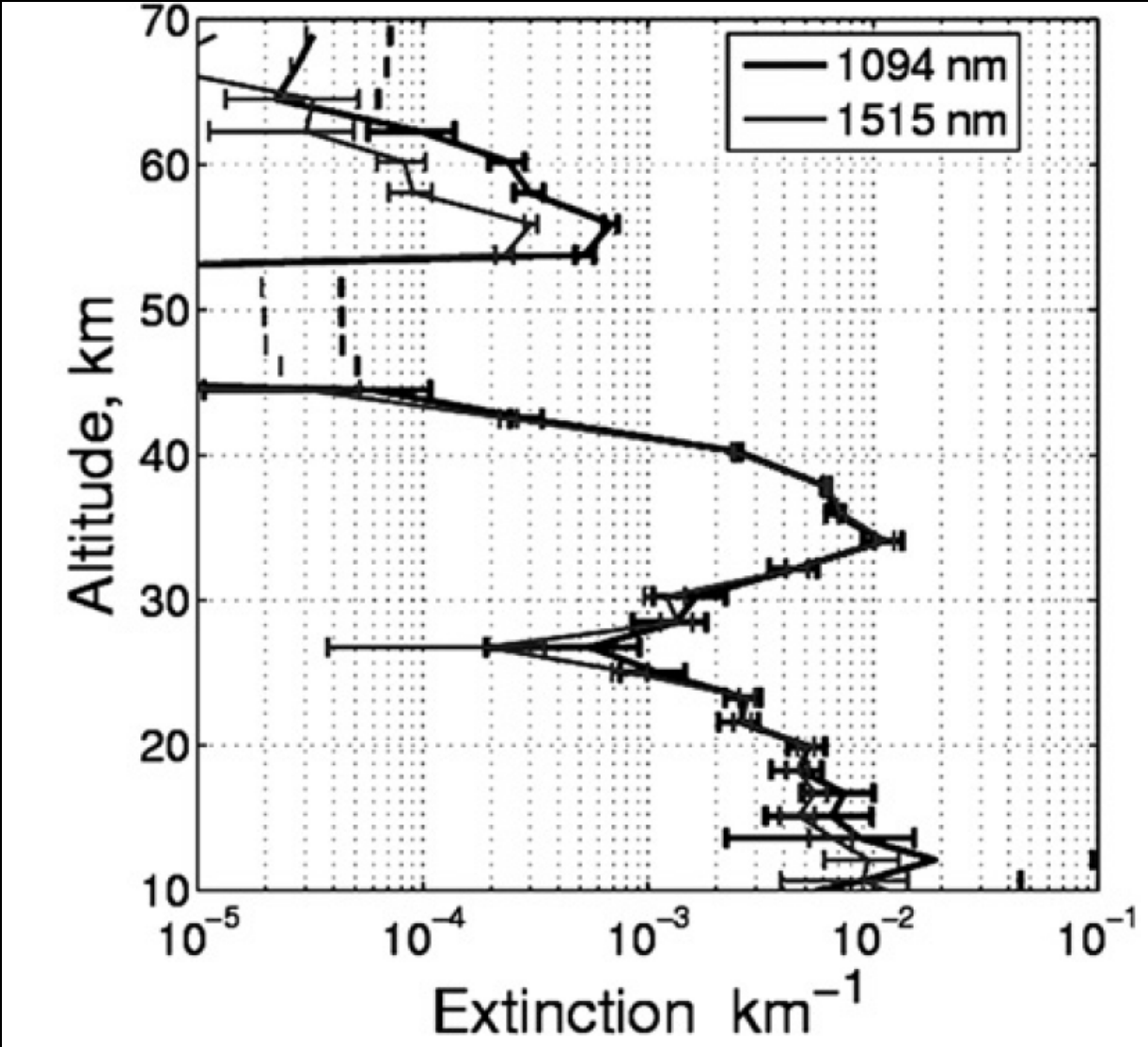
Clouds and aerosols may solve the Mars climate problem

Can clouds create a greenhouse?

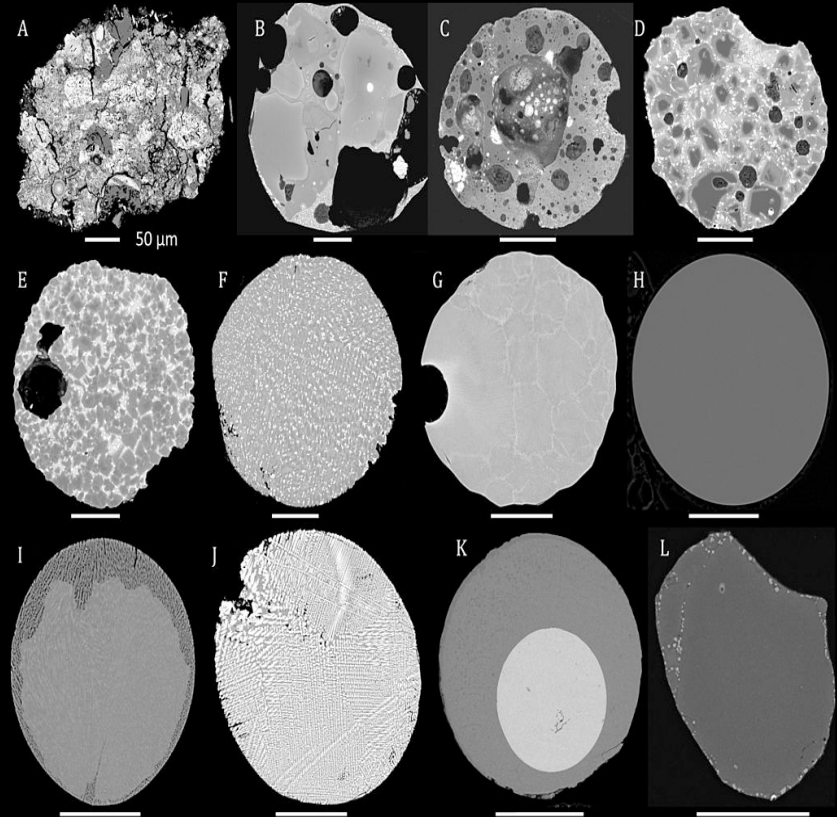
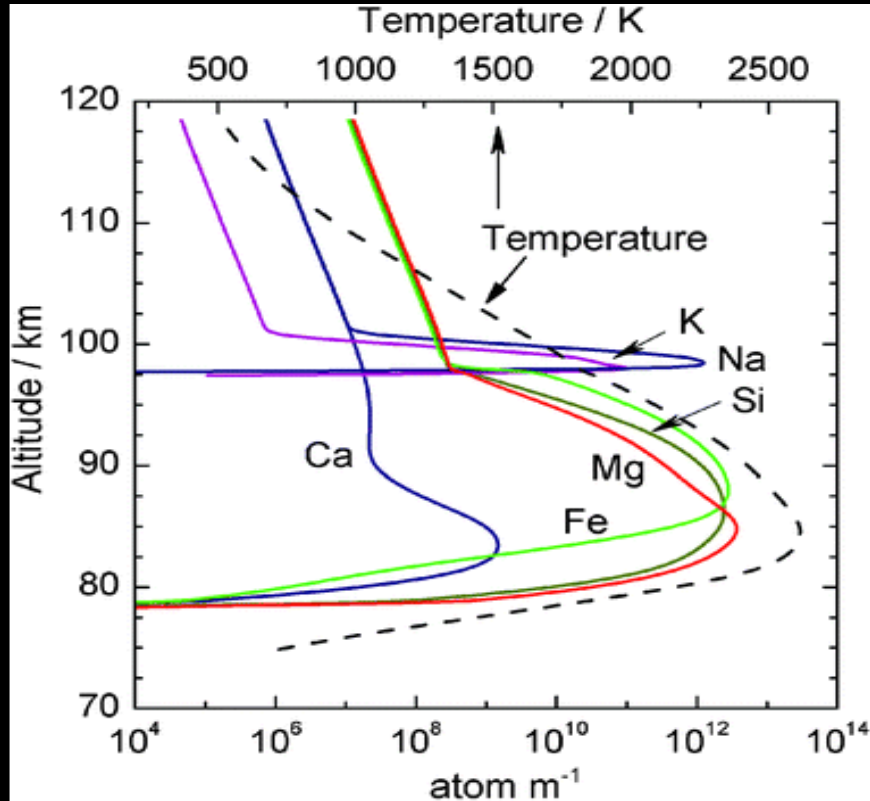


Clouds form when atmospheric water vapor condenses on a suspended aerosol = dust

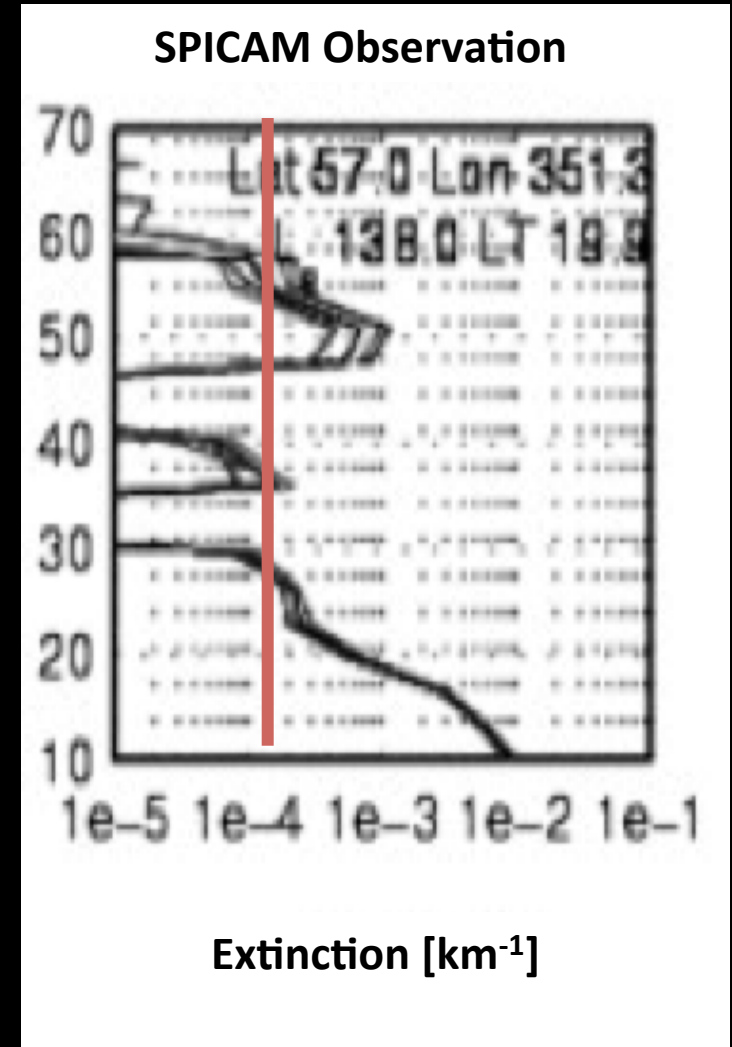
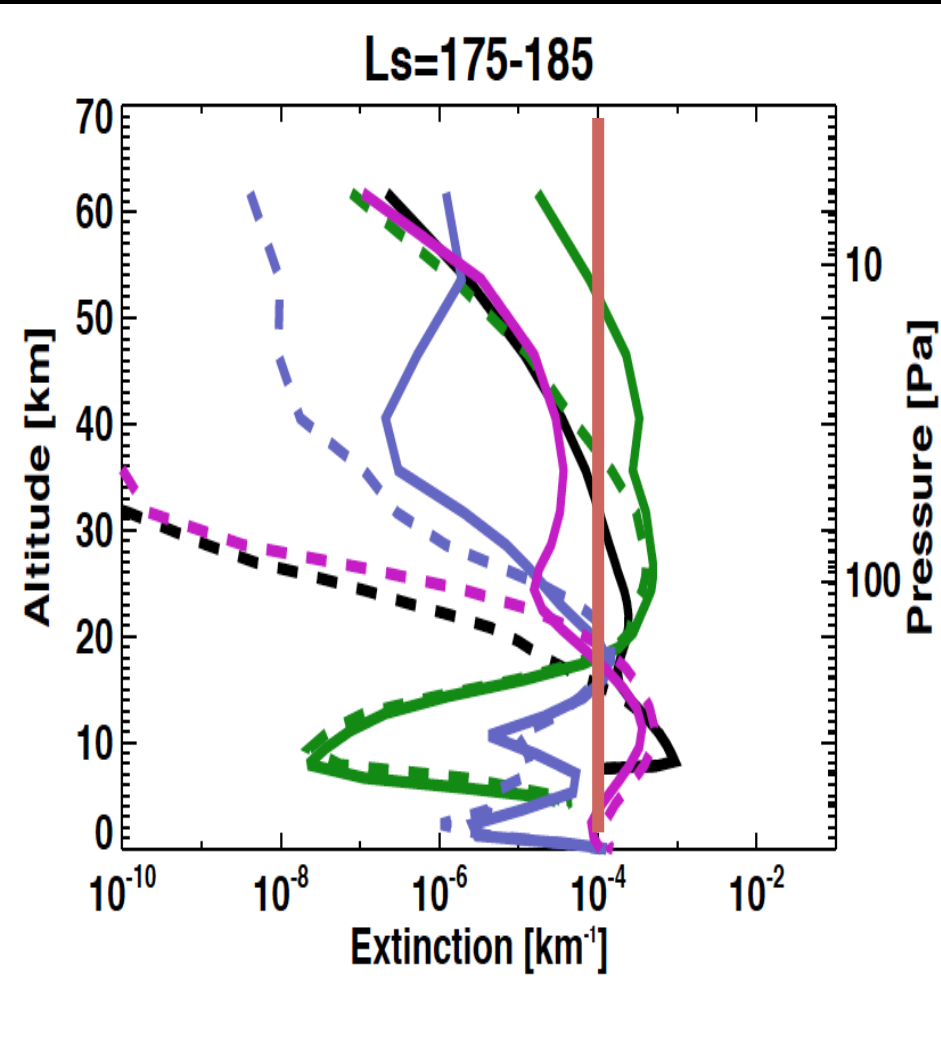
High Altitude Ice Clouds Are Commonly Observed, but models can't make clouds above 20 km



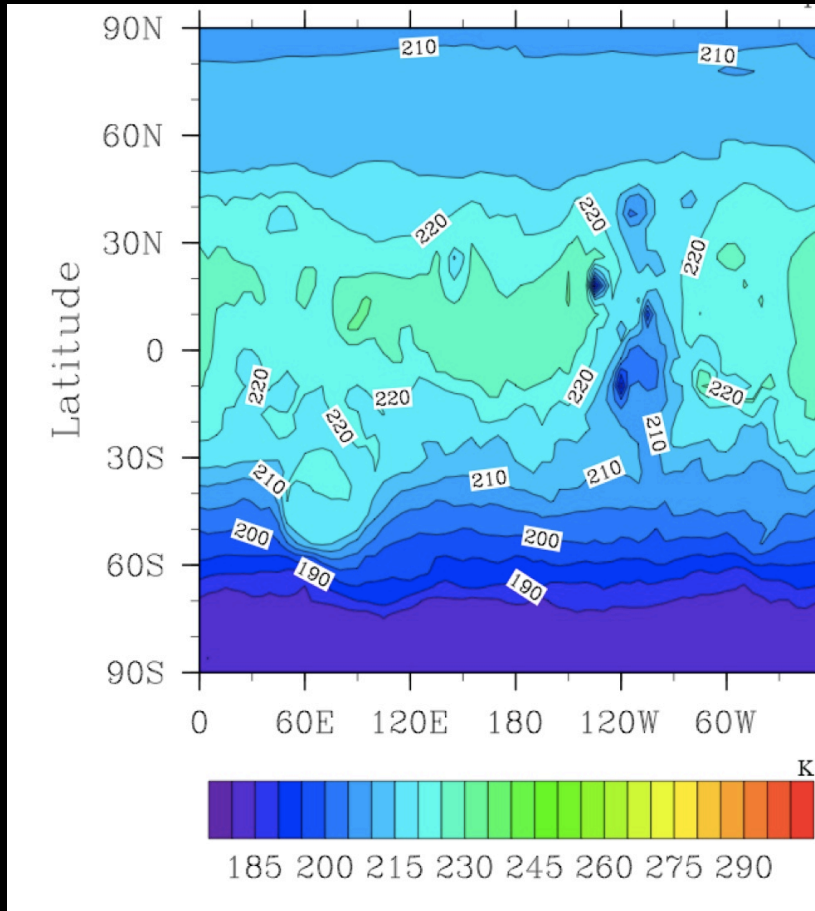
On Earth micrometeorites are an important source of ice nuclei for noctilucent clouds



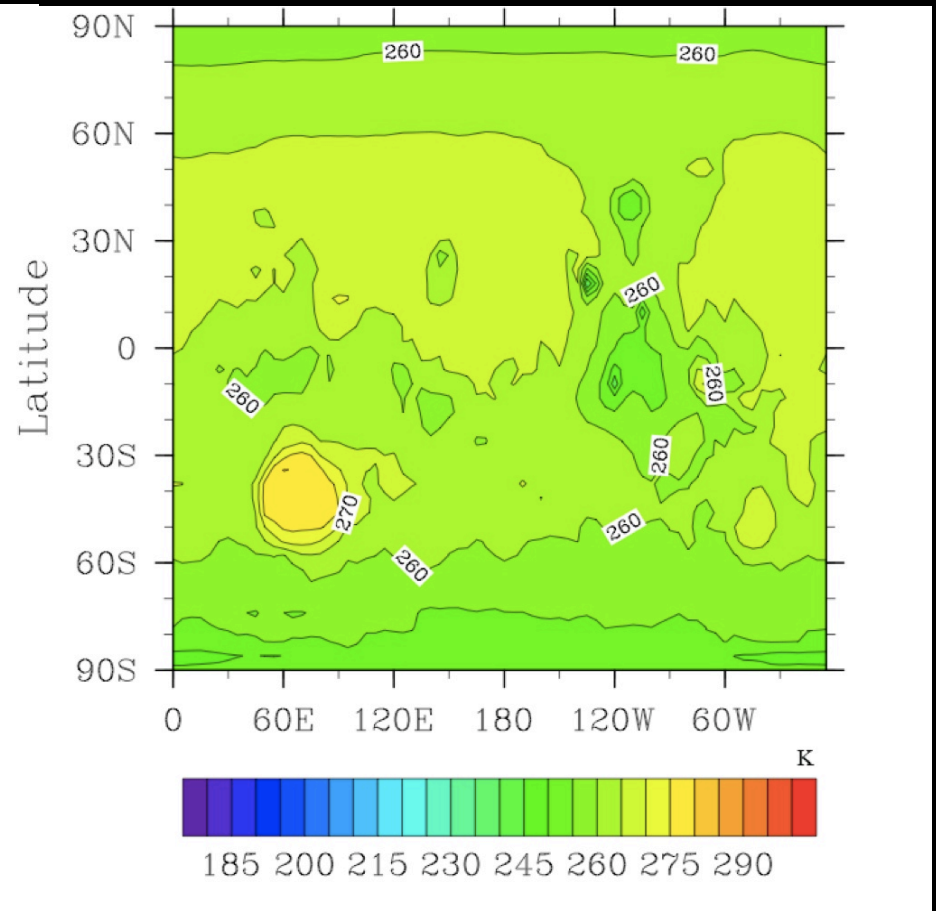
Micrometeorites enhance cloud extinction



Clouds at high altitude can warm ancient Mars even with a faint sun



Mars is cold with 500 mb of CO₂



Mars is warm when clouds

Mars Clouds Victoria Hartwick

victoria.hartwick@gmail.com



Summary

Current Mars has global dust storms

- *We don't know why they don't occur every year

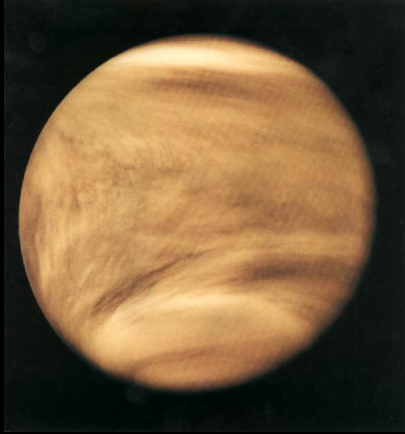
Ancient Mars had rivers.

- *We don't know why Mars was warmer 3.8 Ga, it should have been colder.

- *We don't know if the warm temperatures lasted long enough for life to arise as it did on Earth at this time.

Many planets have aerosols and clouds

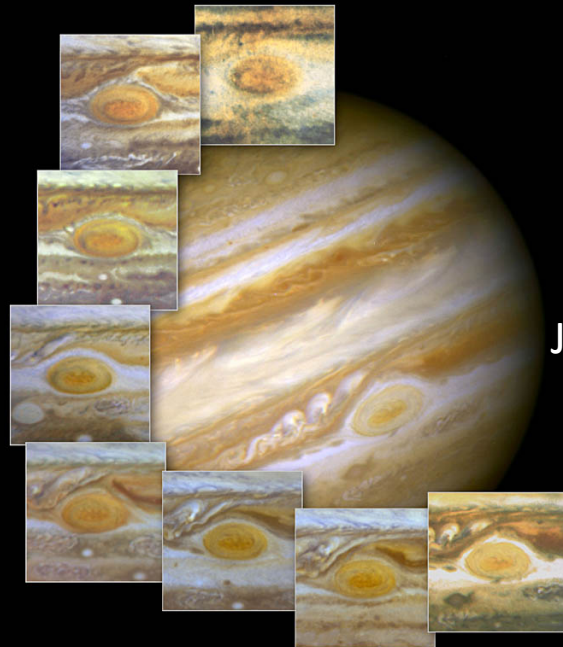
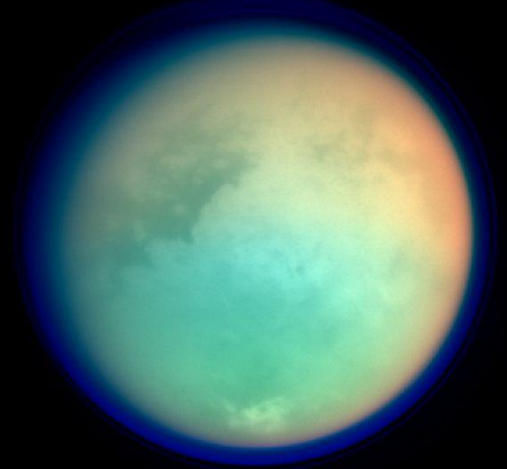
Venus, uv, H₂SO₄ clouds



Titan, visible, organic haze



Titan, ir, organic haze



Jupiter, visible, CH₄, NH₃ clouds

What can you do?

Many countries and private companies are involved in planetary exploration

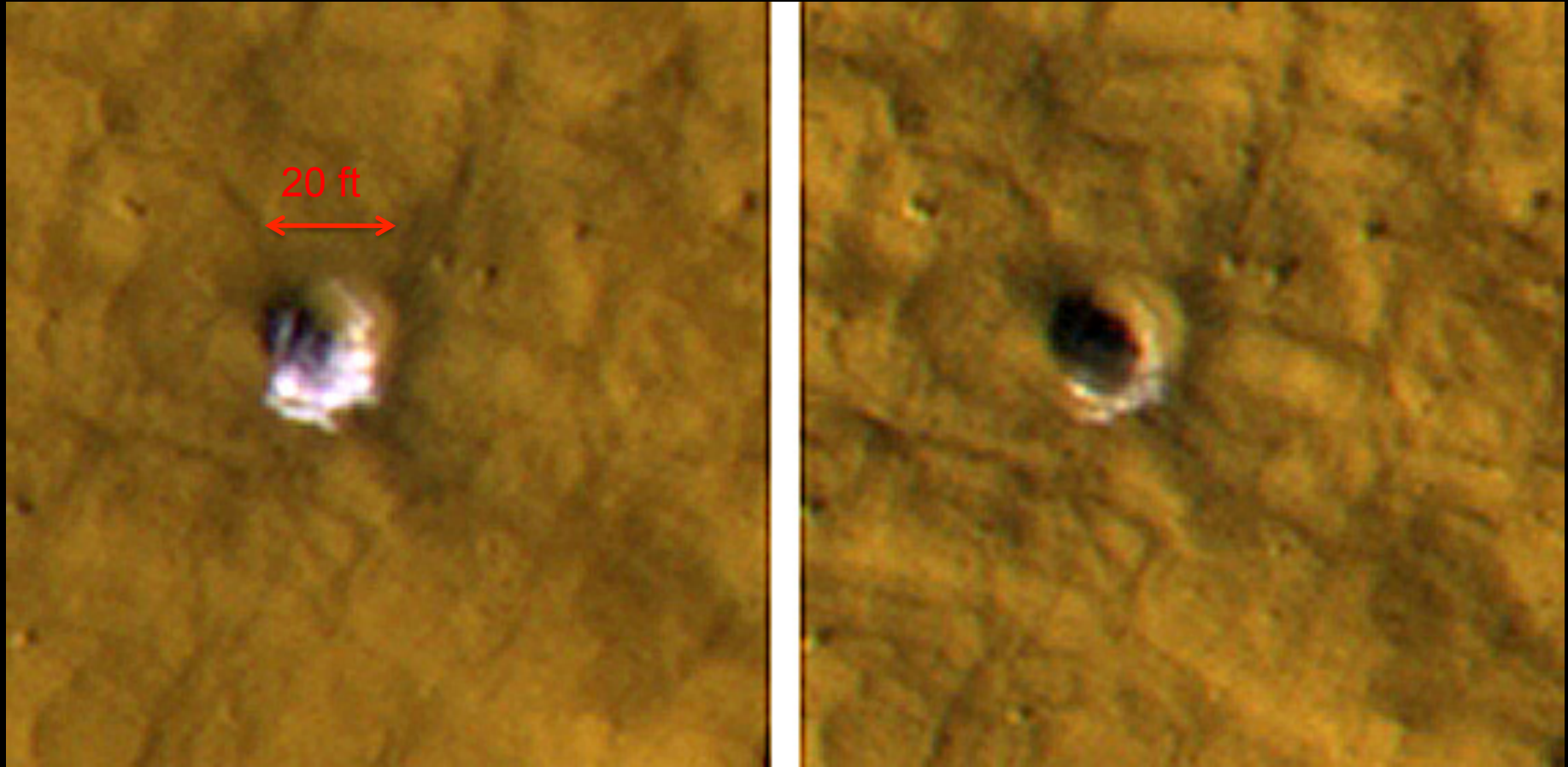
China, EU, Japan, India, Russia, US, UAE, Space-X

There are large numbers of unsolved aerosol and cloud problems on almost every solar system object.

Global dust storms are rare

Global Dust Storm Emergence Date		Duration (days)	Longitude at start	
			L_s	η
1909	June 3	119	207°	2°
1924	December 9	68	311°	°
1956	August 19	73	249°	4°
1971	September 22	161	260°	5°
1973	October 13	91	300°	°
1975	July 14	100	270°	5°
1977	February 15	60	204°	9°
1977	May 27	158	268°	3°
1982	October 14	110	208°	3°
2001	June 26	159	185°	0°
2007	June 24	~70	264°	349°

Mars Reconnaissance Orbiter discovers water just below the surface at 43°N latitude



Oct 18, 2008

Jan 14, 2009

Young gullies on an ancient river valley suggest water can still flow on Mars

