



Space Research Institute Graz
Austrian Academy of Sciences



Exploring the Planets and Moons in our Solar System

Space Missions to the terrestrial planets

Helmut O. Rucker

CERN, Geneve, June 2006



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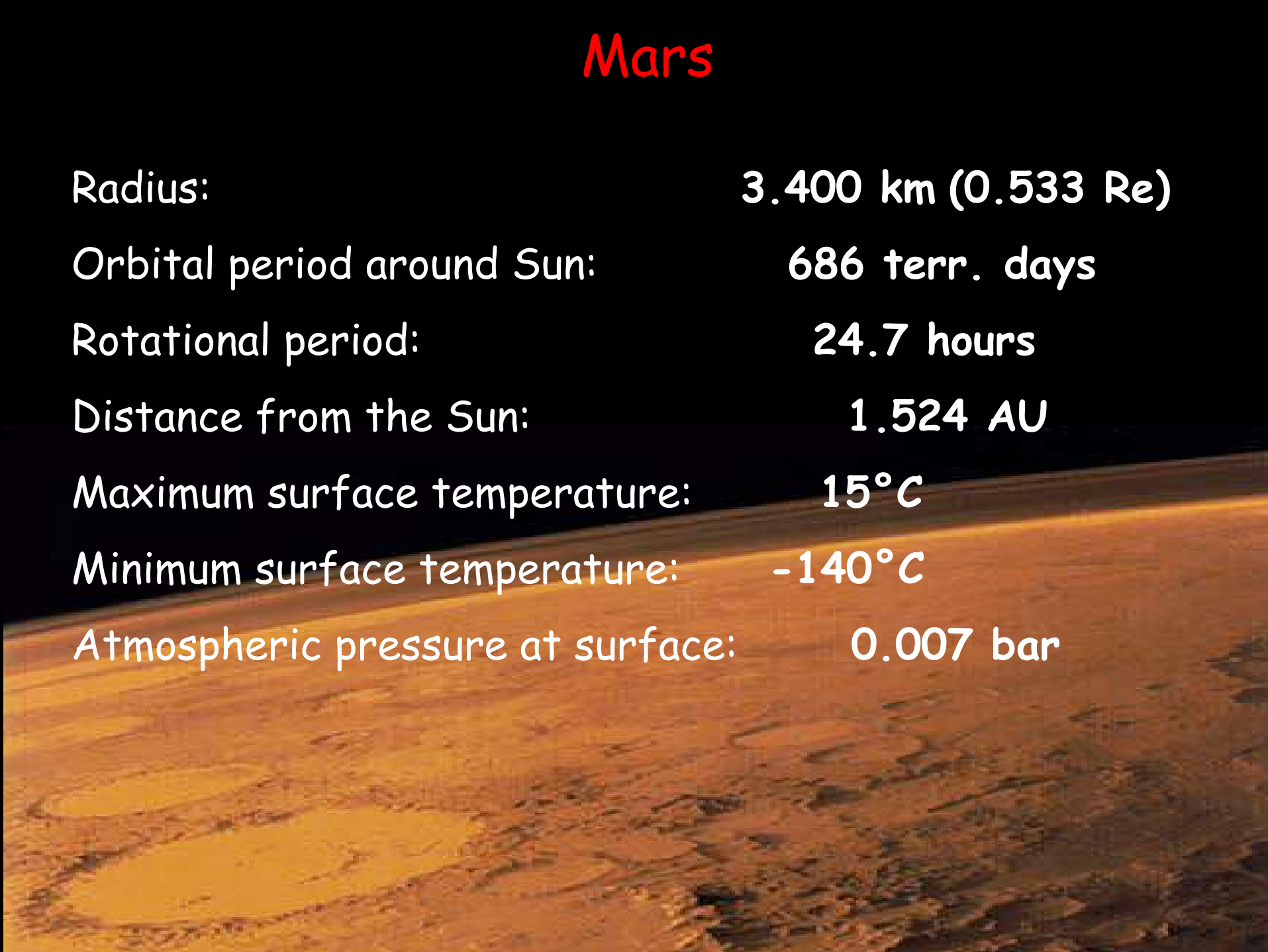


Exploring the Planets and Moons in our Solar System

Space Missions to the terrestrial planets

BEPICOLOMBO/
MERCURY MAGNETOSPHERIC ORBITER

Mars

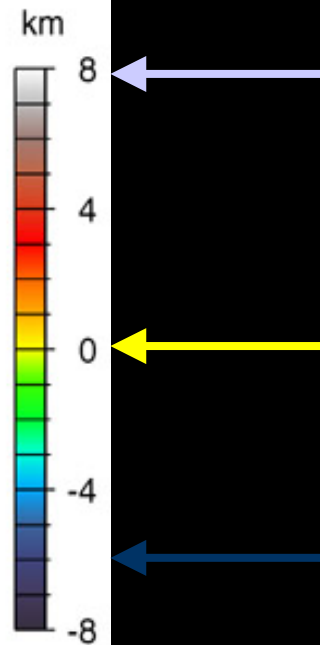
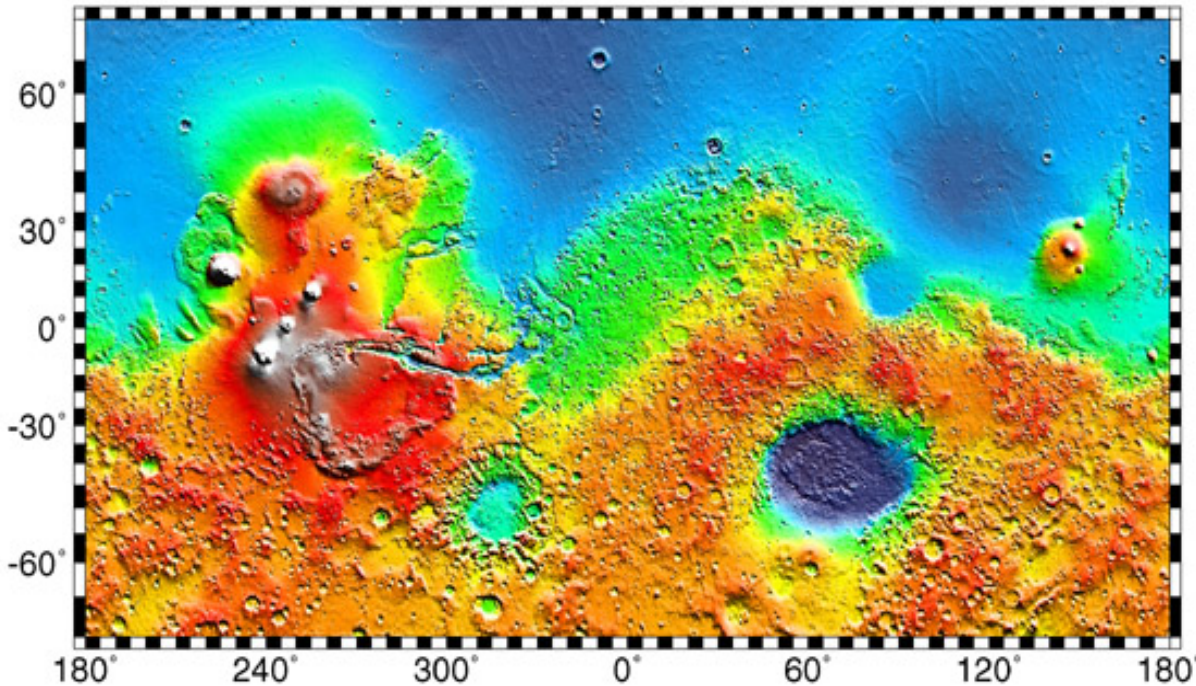
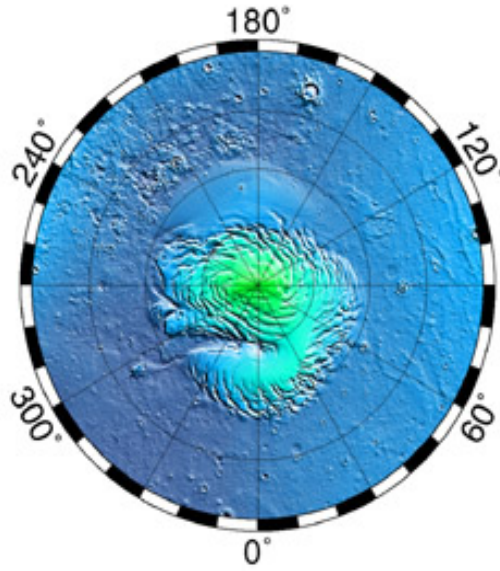
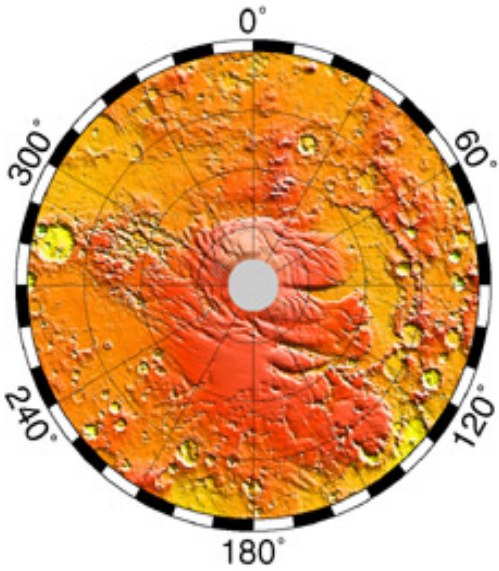


Radius:	3.400 km (0.533 Re)
Orbital period around Sun:	686 terr. days
Rotational period:	24.7 hours
Distance from the Sun:	1.524 AU
Maximum surface temperature:	15°C
Minimum surface temperature:	-140°C
Atmospheric pressure at surface:	0.007 bar

Southern pole

Northern pole

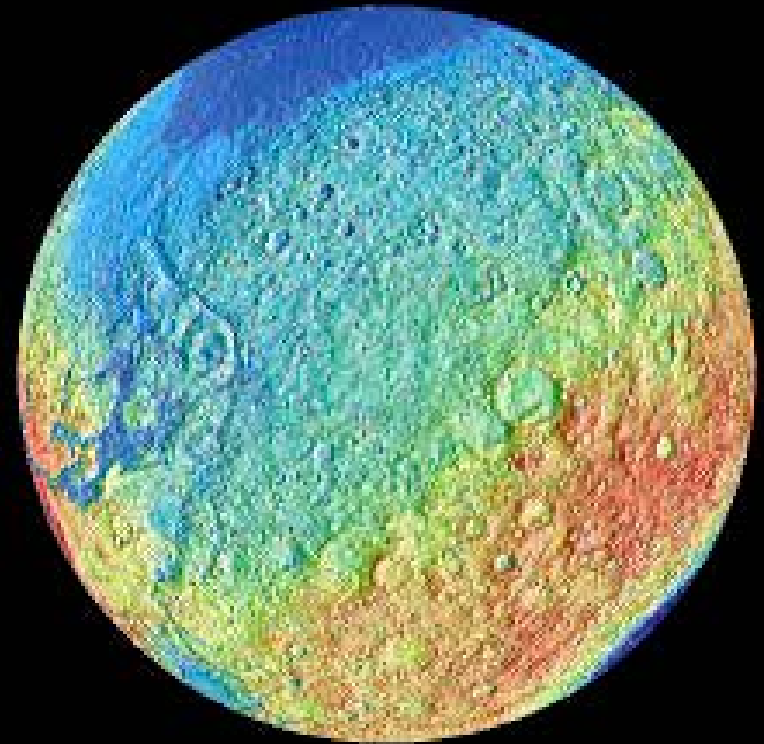
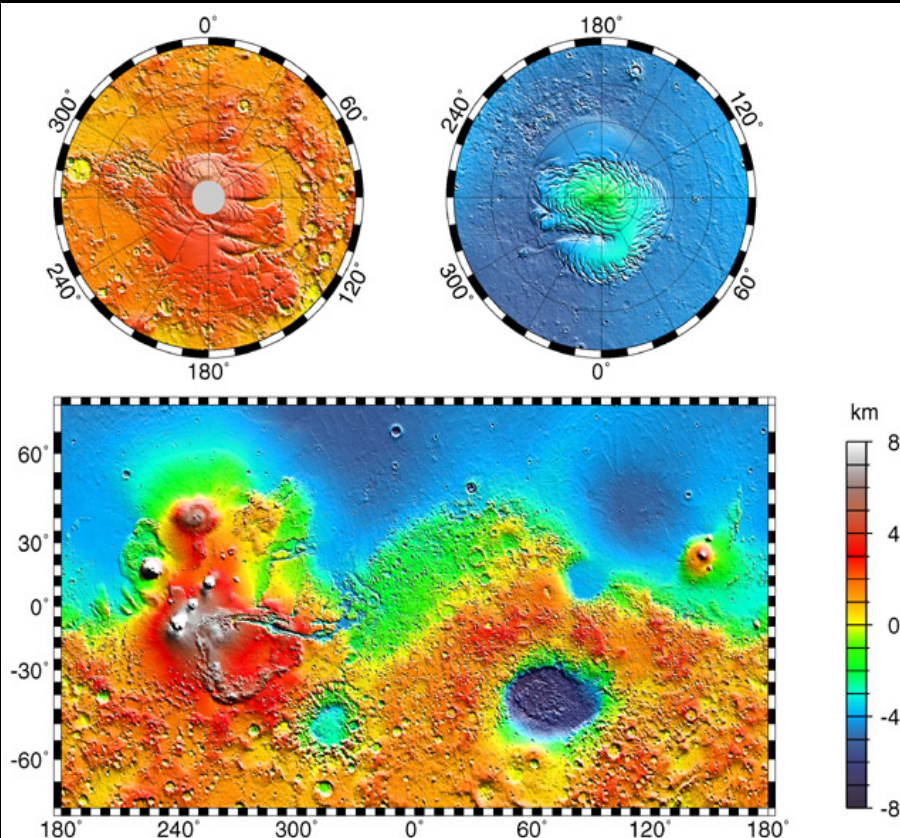
MARS TOPOGRAPHY

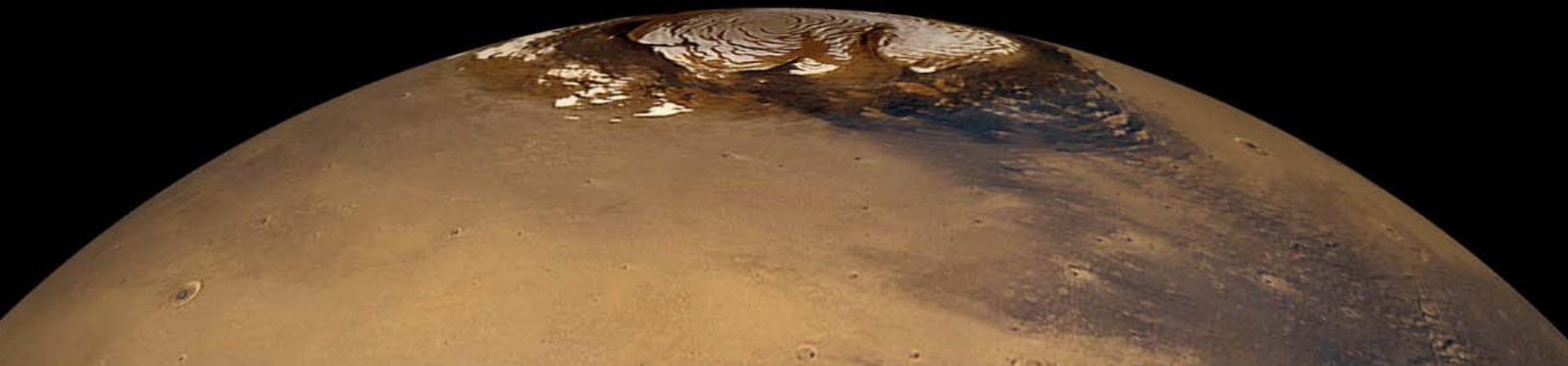
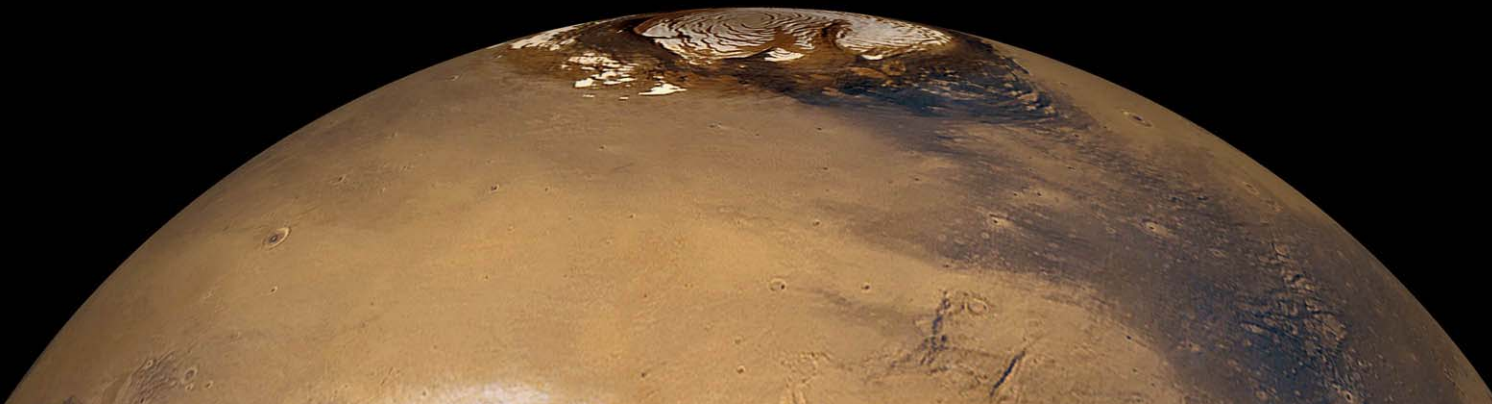
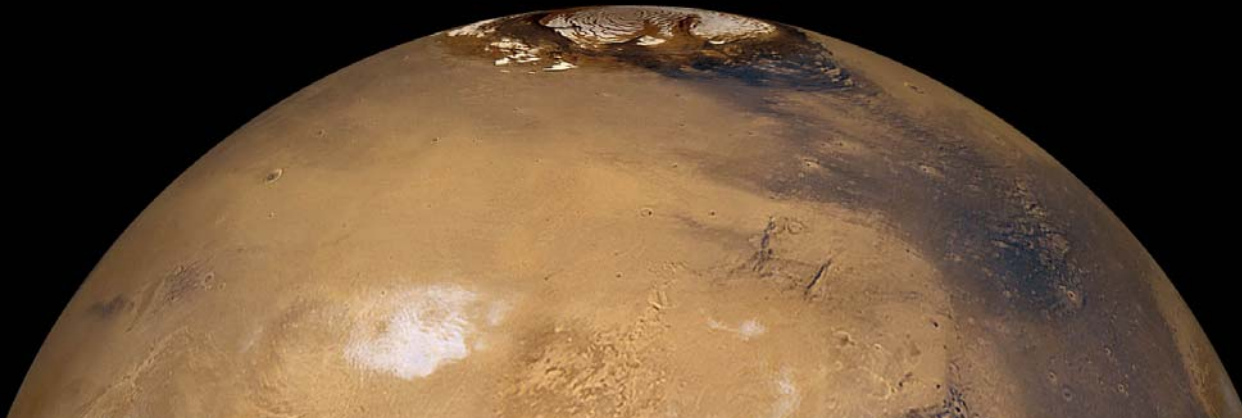


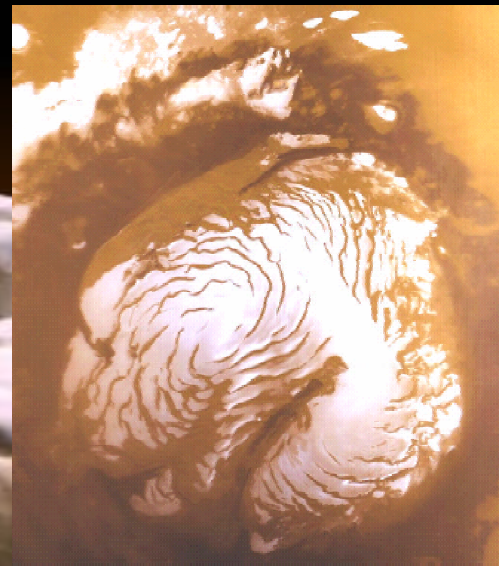
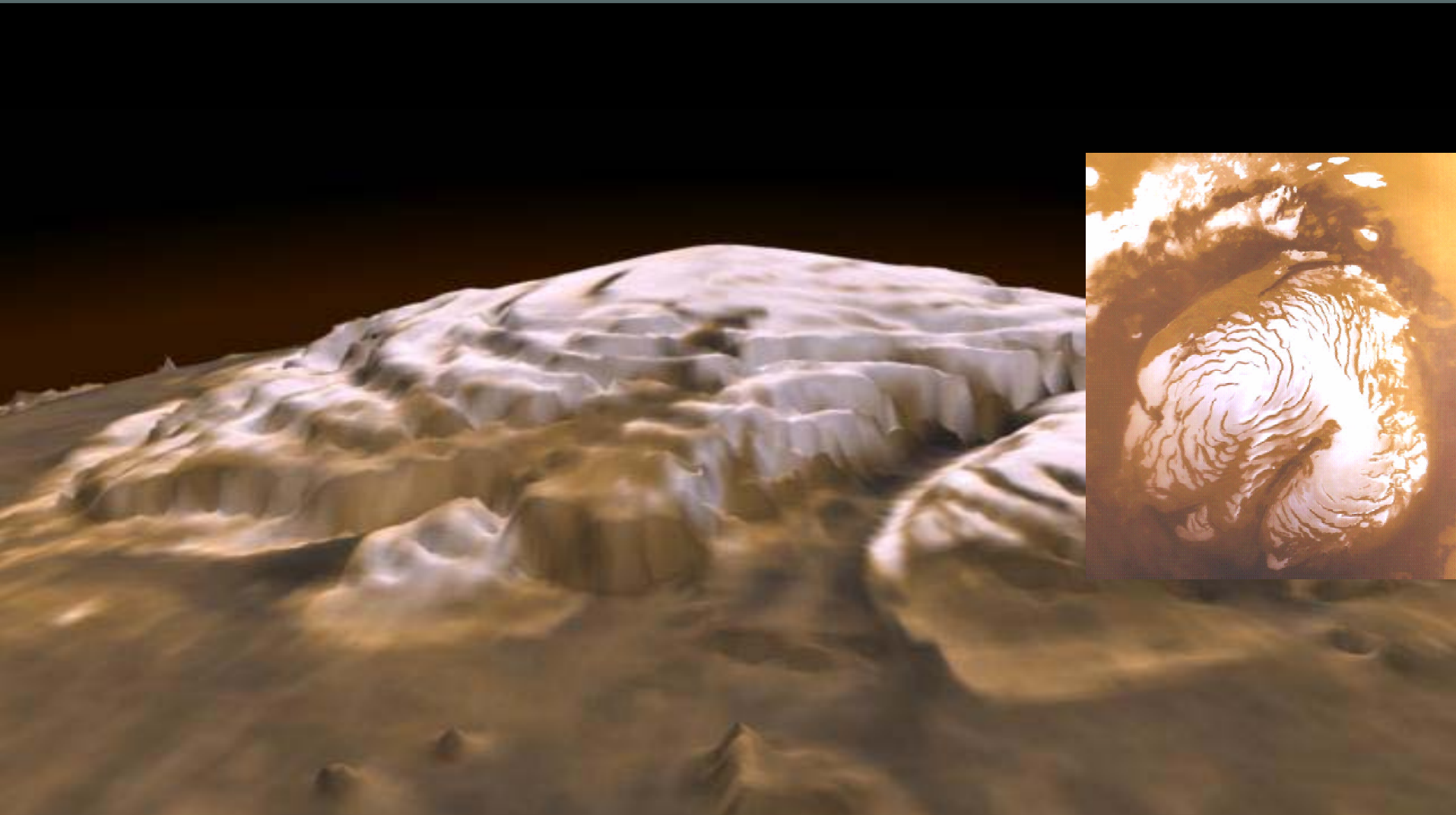
MARS TOPOGRAPHY

Southern pole

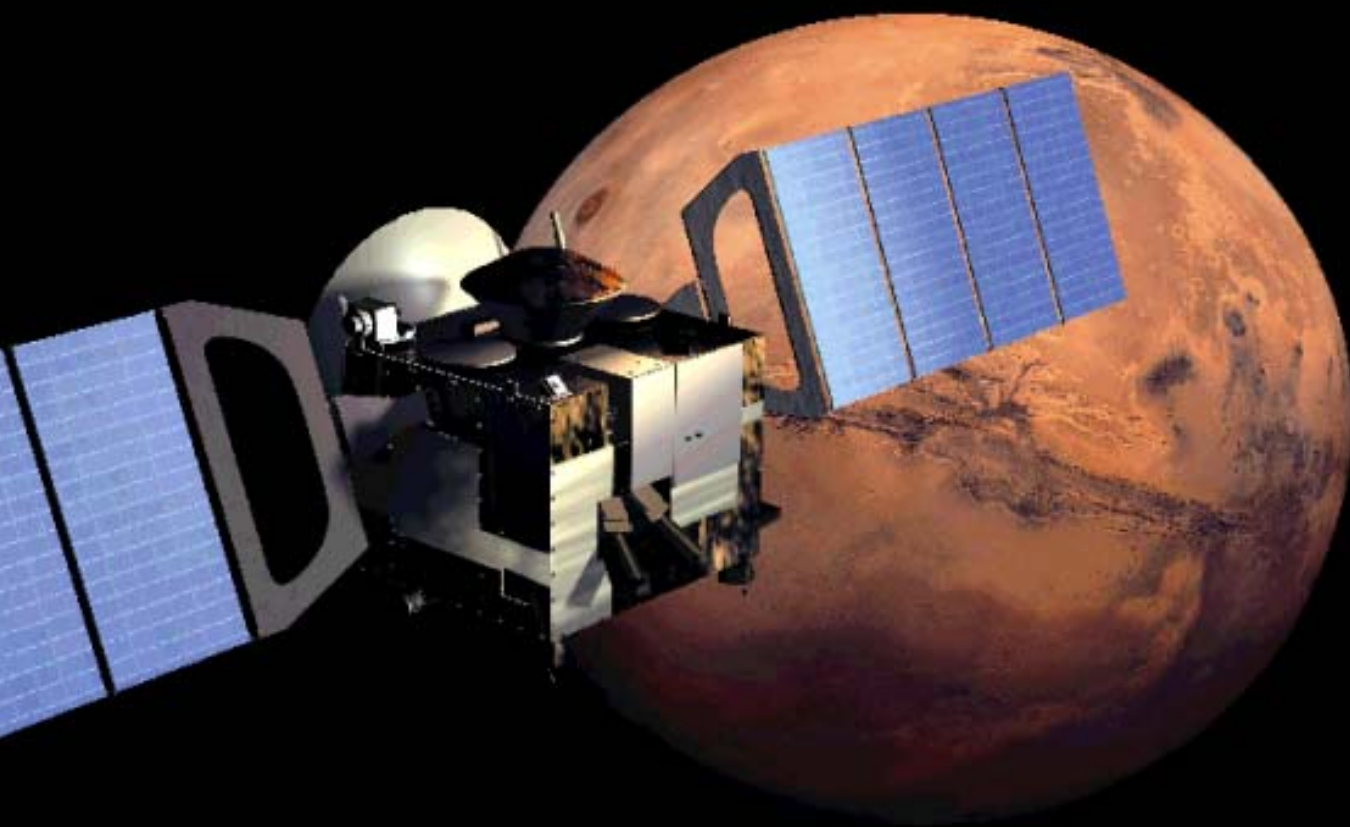
Northern pole



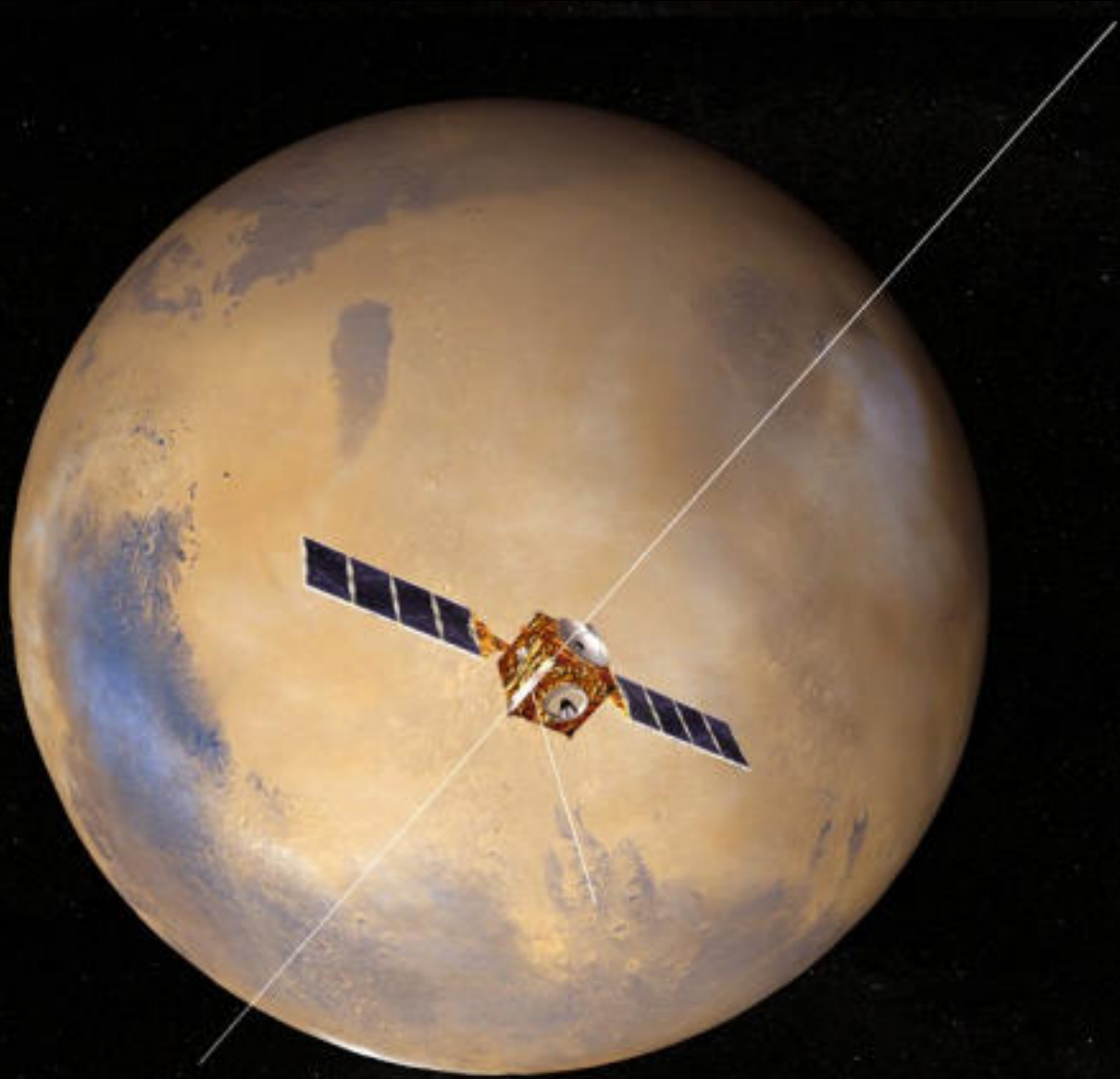




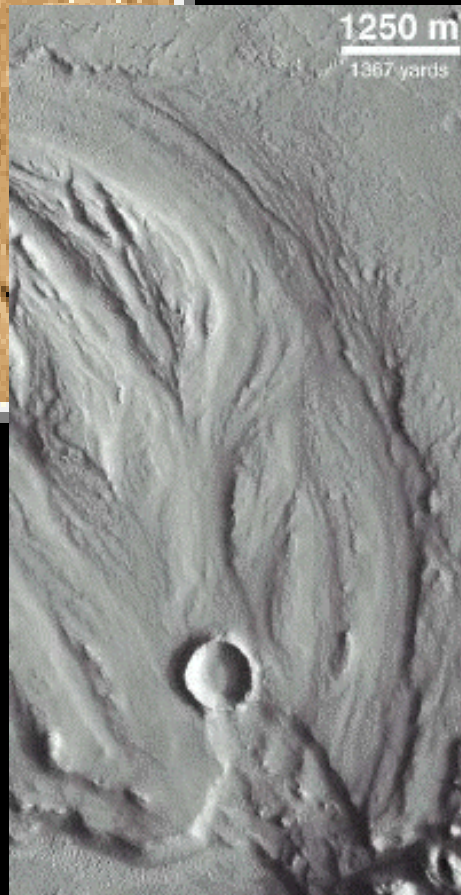
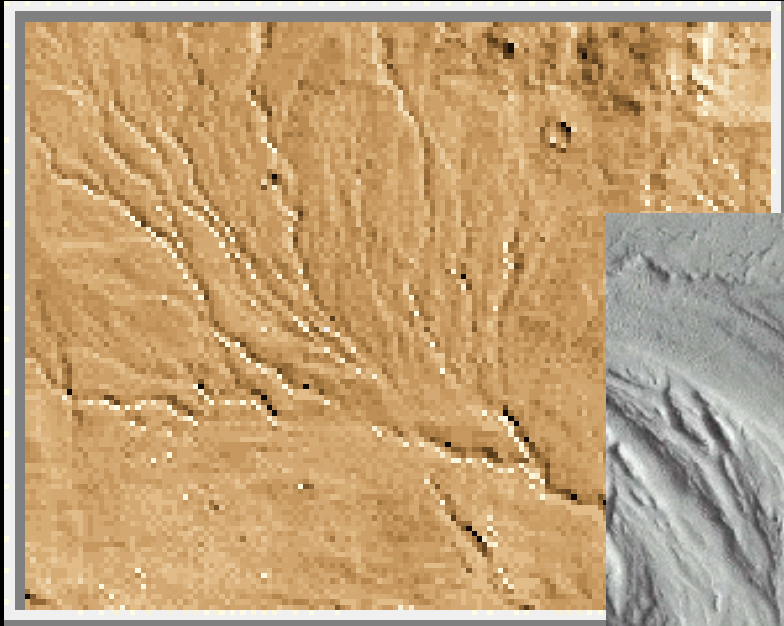
Mars Express

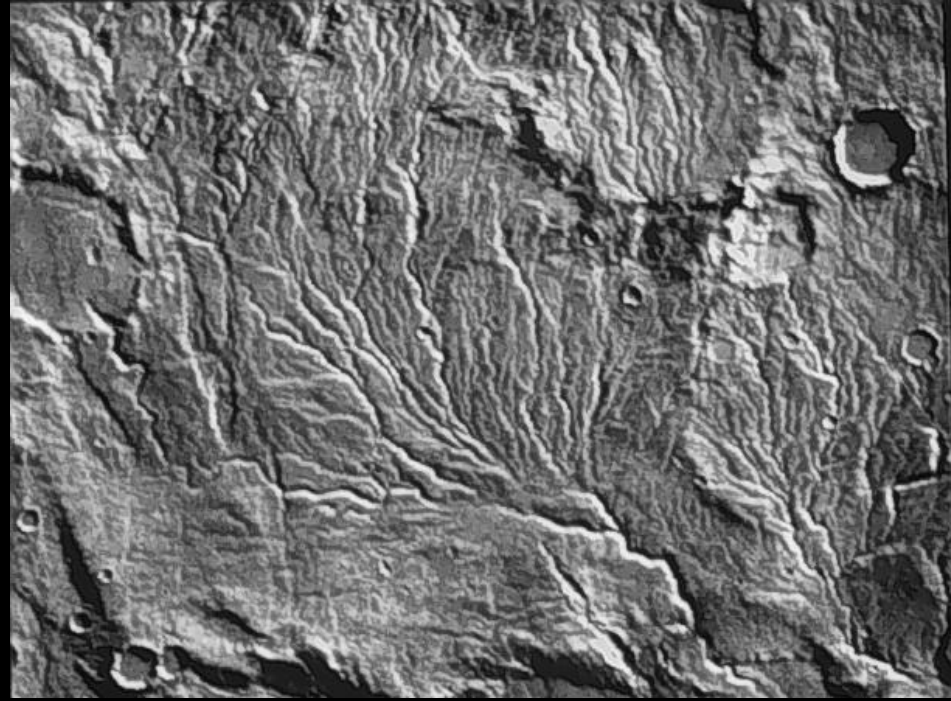


Mars Express: The search for water



Mars Express: The search for water





river
systems



MAP

40/80NM

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MARSIS

Radar Experiment
on

Mars Express

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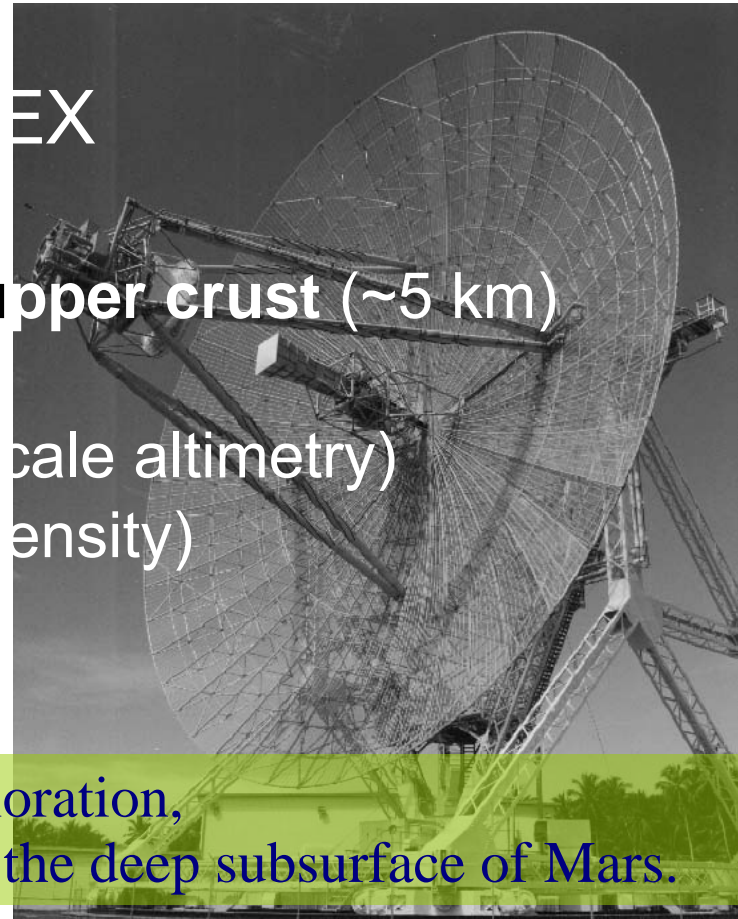
3

6

What is MARSIS ?

Mars Advanced Radar for Subsurface and Ionosphere Sounding

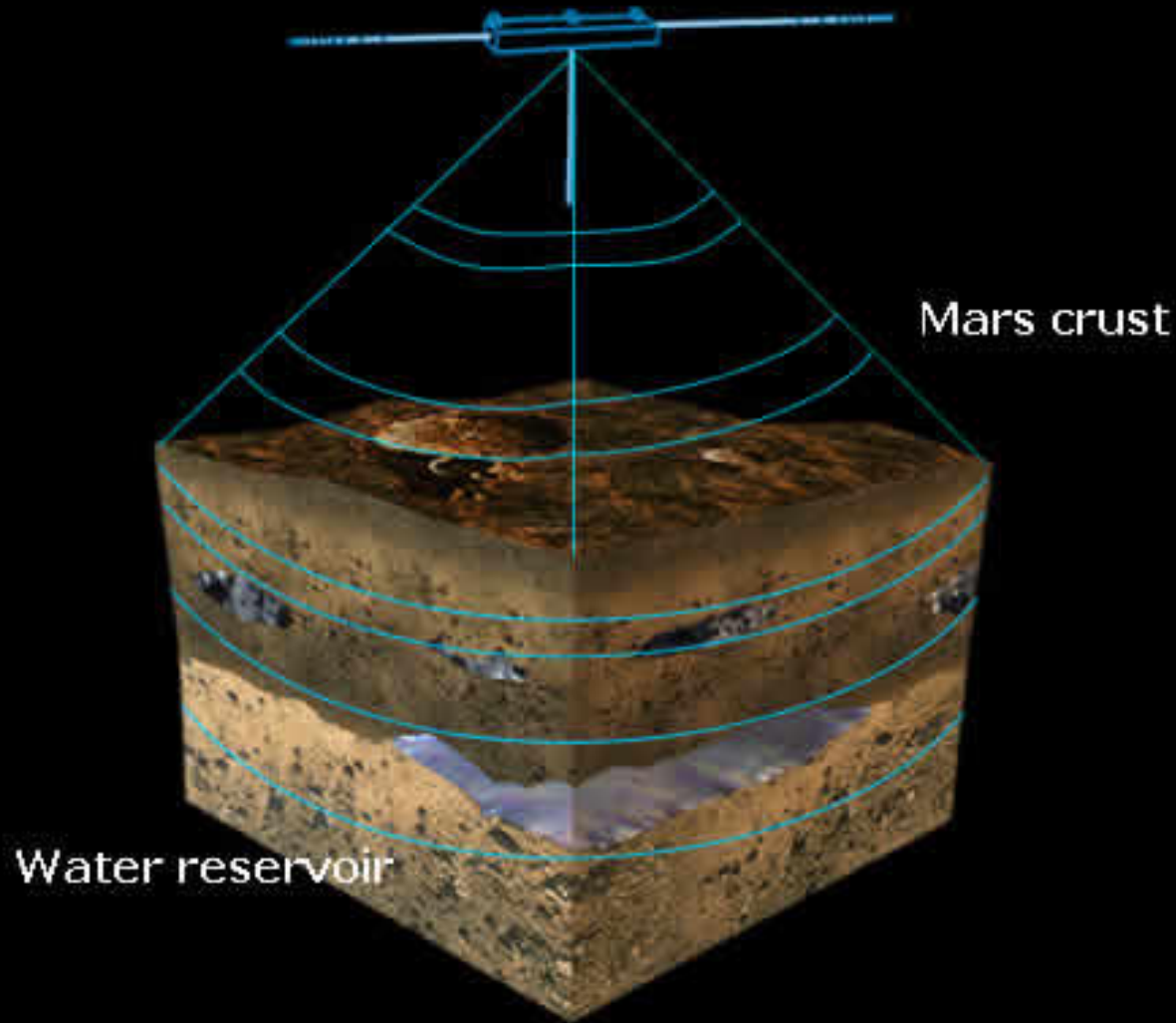
- **Subsurface radar sounder**
- One of seven instruments of MEX
- **Scientific objectives**
 - Map the distribution of water in **upper crust** (~5 km)
 - **Subsurface** geologic probing
 - **Surface** characterization (large scale altimetry)
 - **Ionosphere** sounding (electron density)



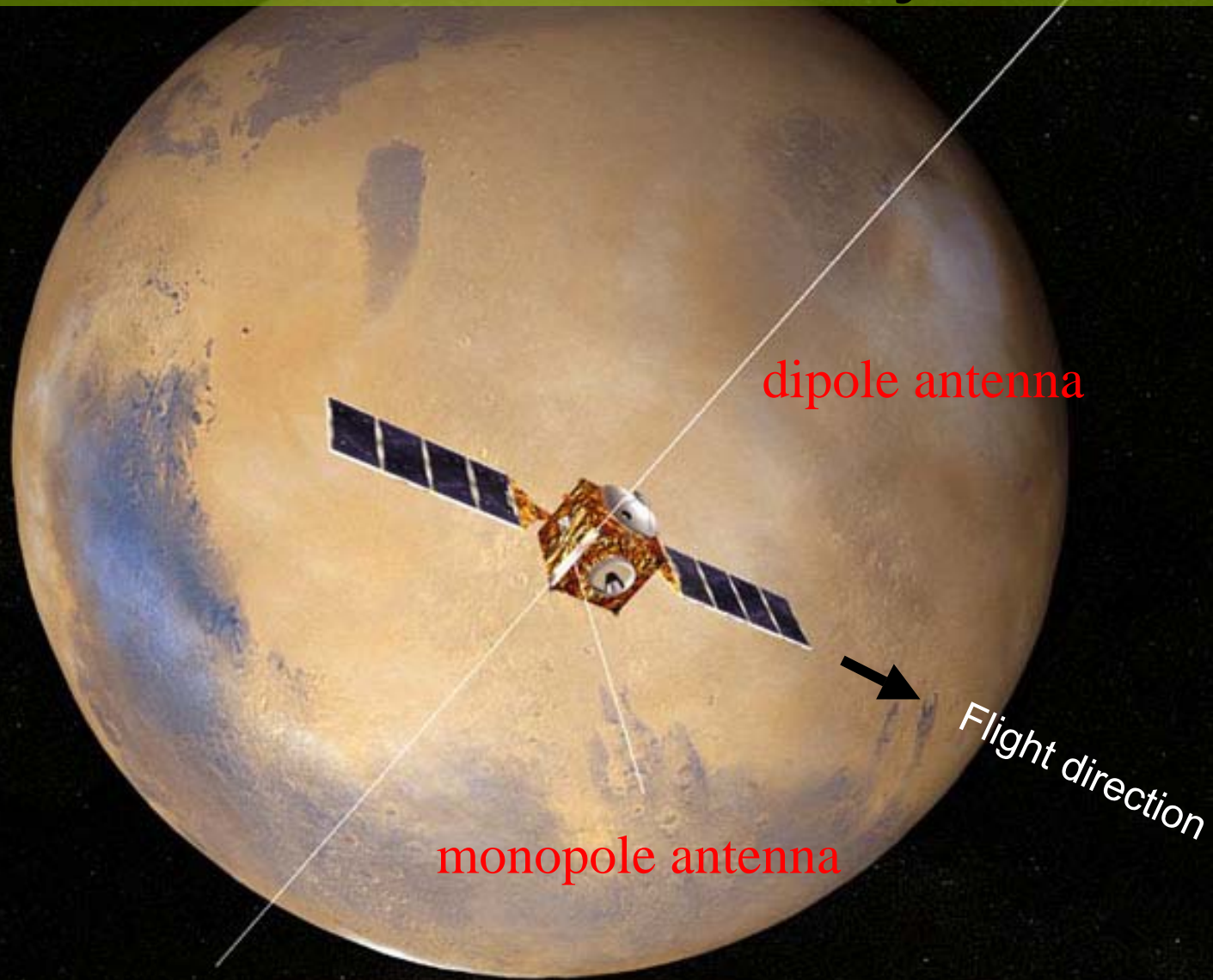
For the first time in the history of planetary exploration, MARSIS has provided direct information about the deep subsurface of Mars.

Mars Express: The search for water

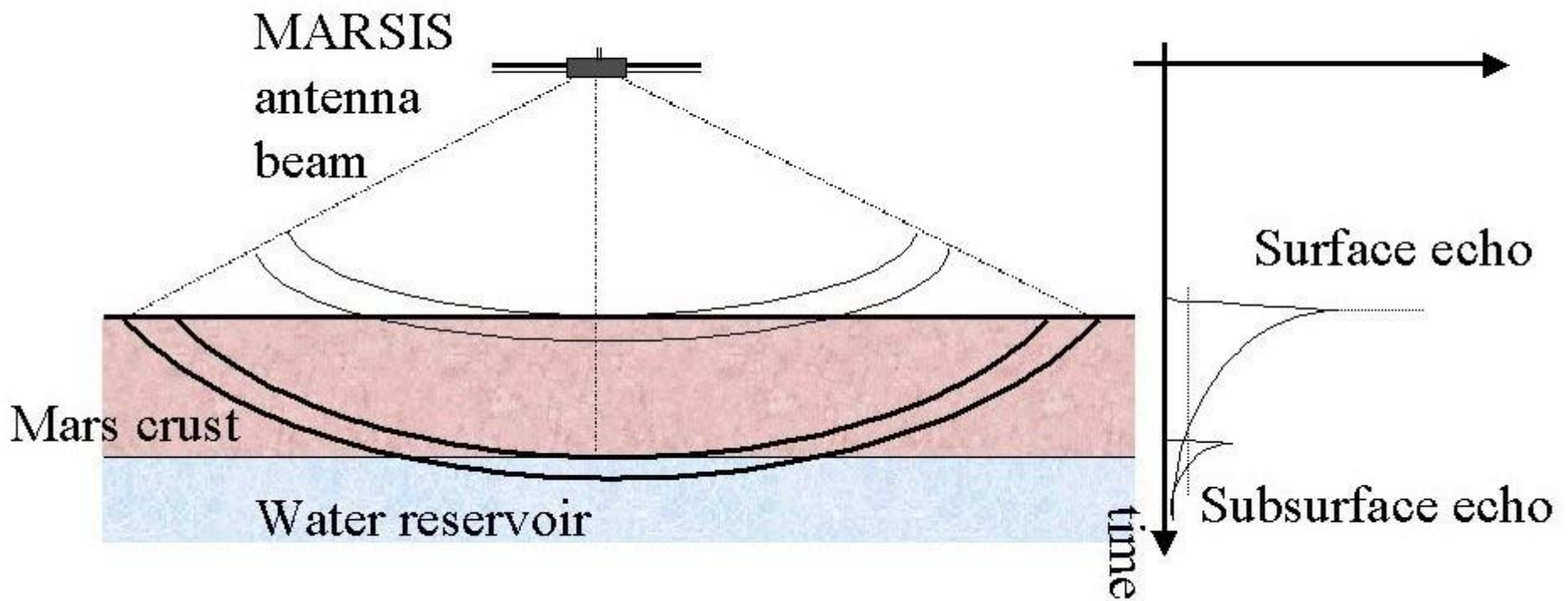
MARSIS antenna beam



MARSIS antenna system

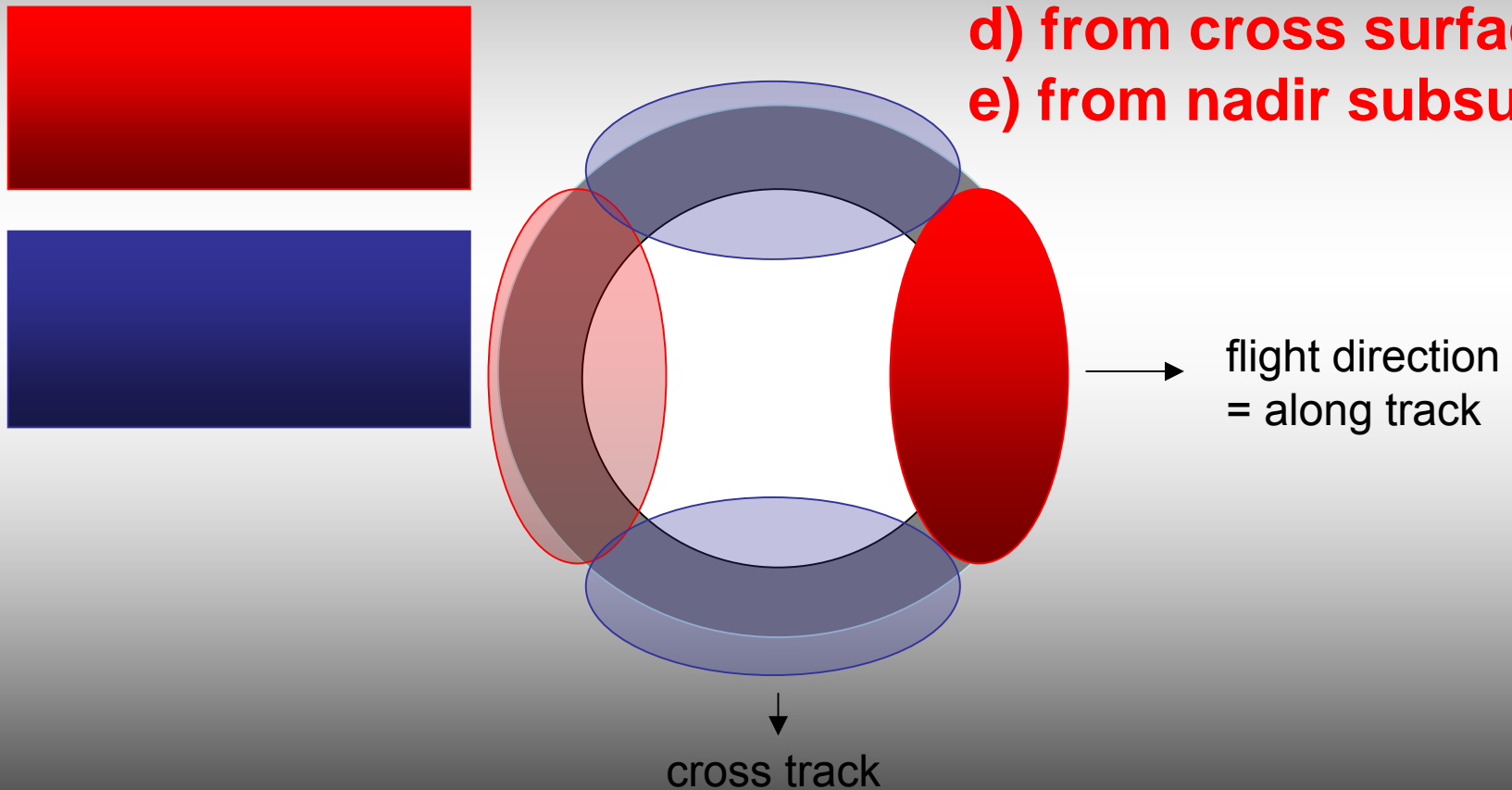


Sounding the subsurface



Discrimination between various return pulses:

- a) from nadir surface
- b) from ahead surface
- c) from behind surface
- d) from cross surface
- e) from nadir subsurface



sounding mode characteristics

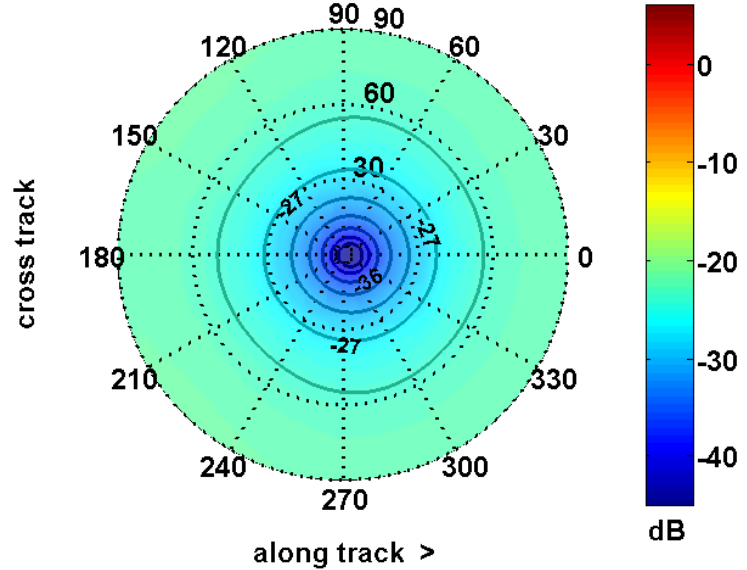
MARSIS subsurface sounding mode characteristics

Centre frequency (MHz)	1.8	3.0	4.0	5.0
Bandwidth (MHz)	1.0	1.0	1.0	1.0
Radiated power (W)	1.5	5.0	5.0	5.0
Transmit pulse width (μS)	250 or 30			
Pulse repetition rate (s^{-1})	130			
Minimum science data rate (kbps)	18			
Maximum science data rate (kbps)	75			

MARSIS ionosphere sounding mode characteristics

Start frequency (kHz)	100
End frequency (MHz)	5.4
Number of frequencies	160
Transmit pulse length (μS)	91.43
Frequency step (kHz)	10.937
Pulse repetition rate (s^{-1})	130
Sweep duration (s)	7.38

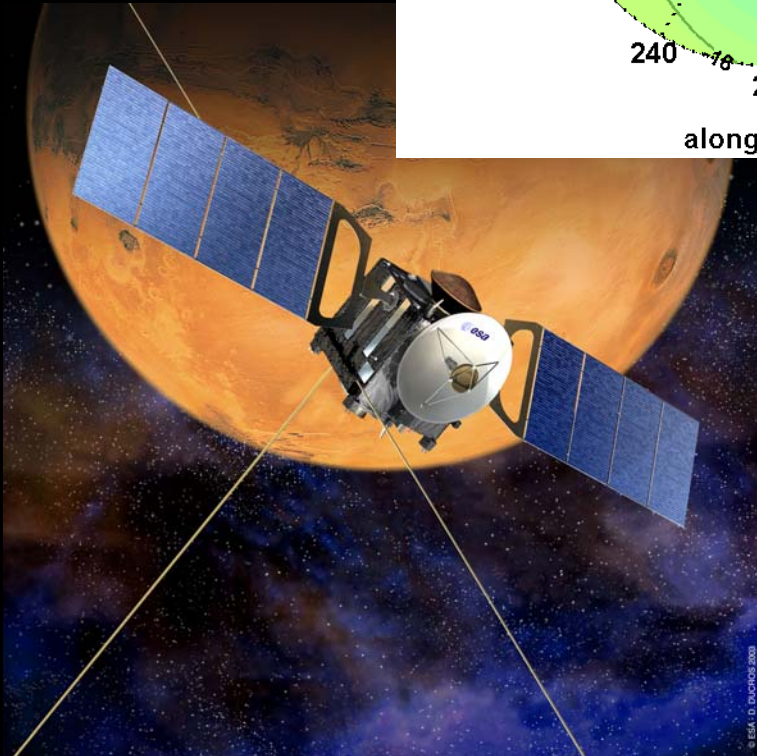
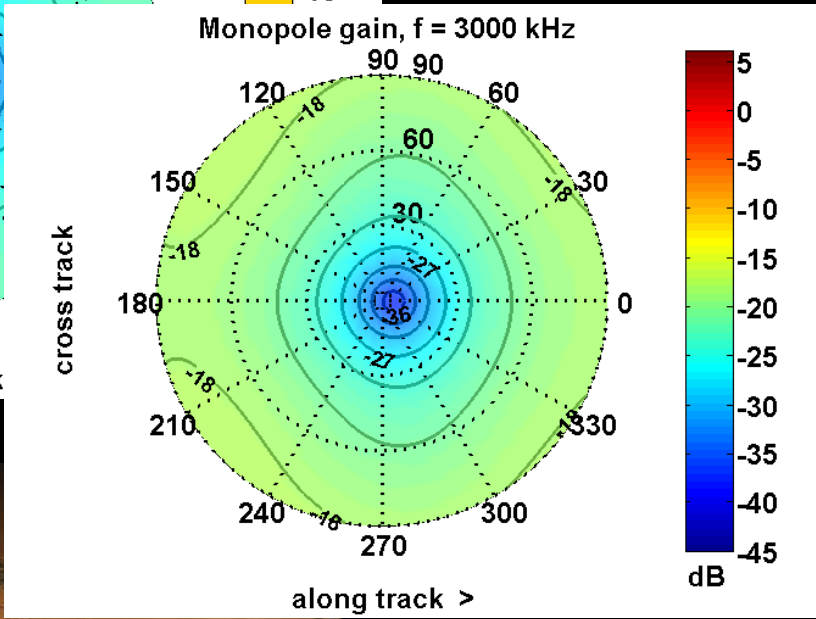
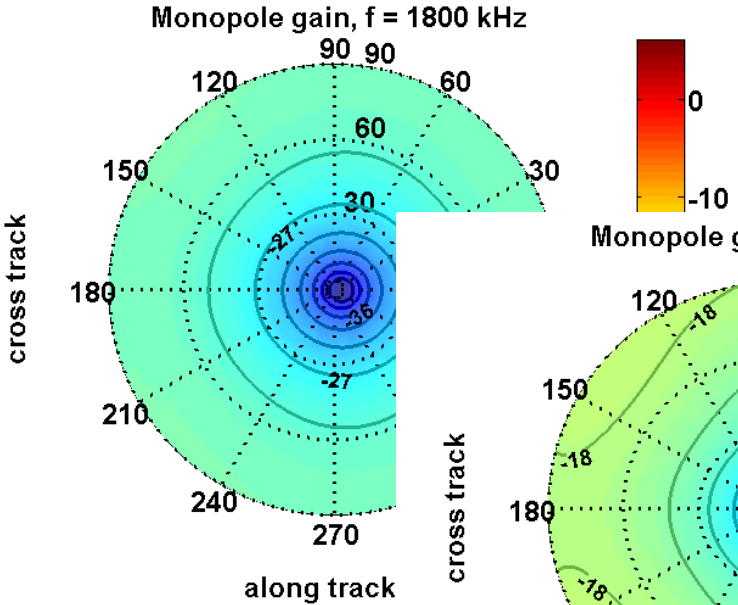
Monopole gain, $f = 1800$ kHz

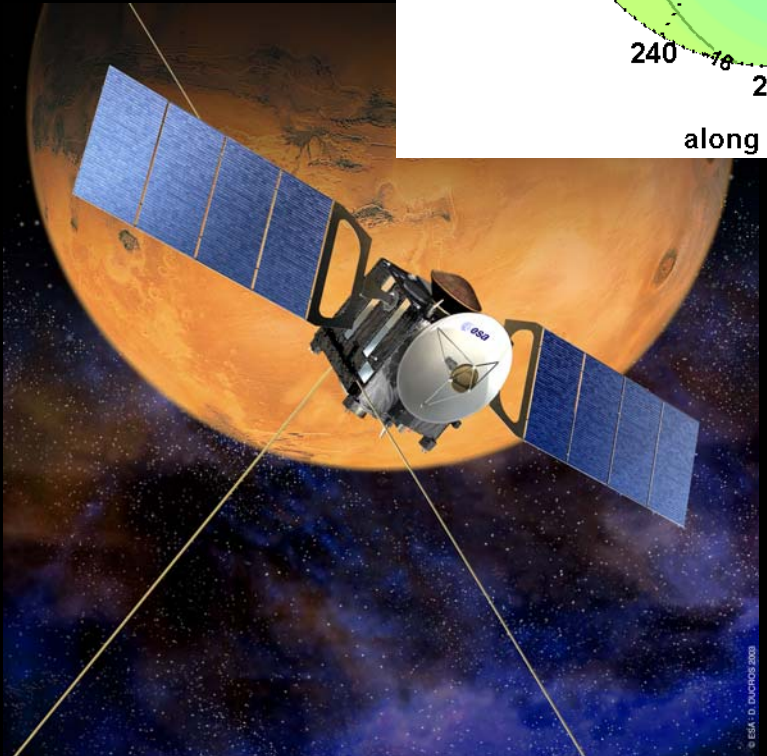
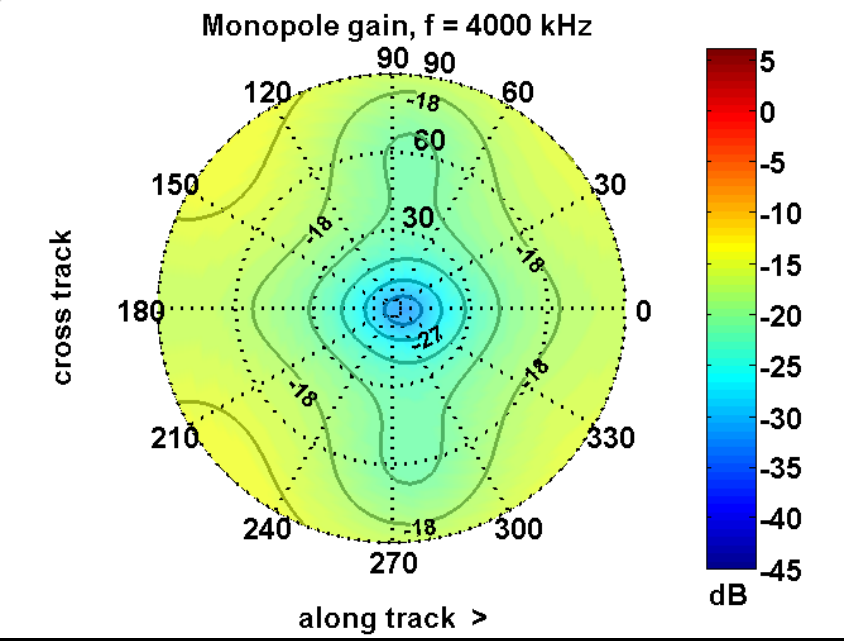
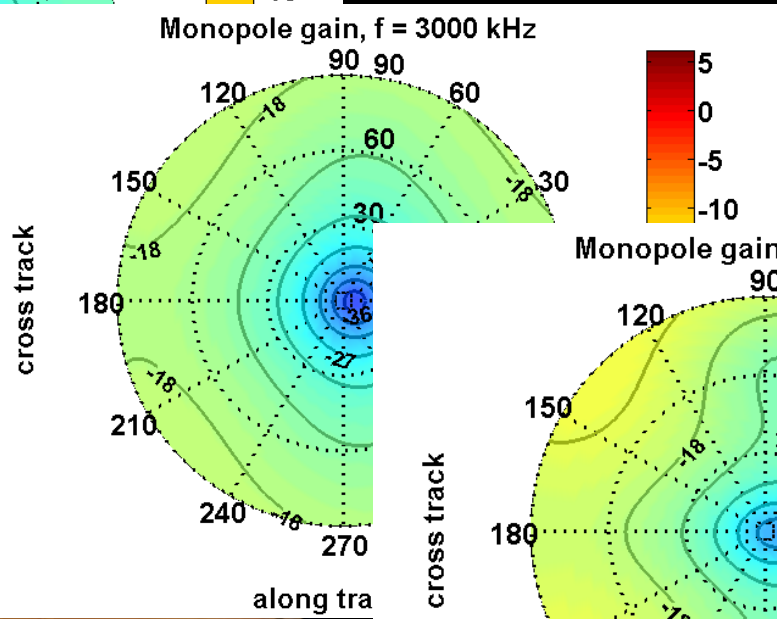
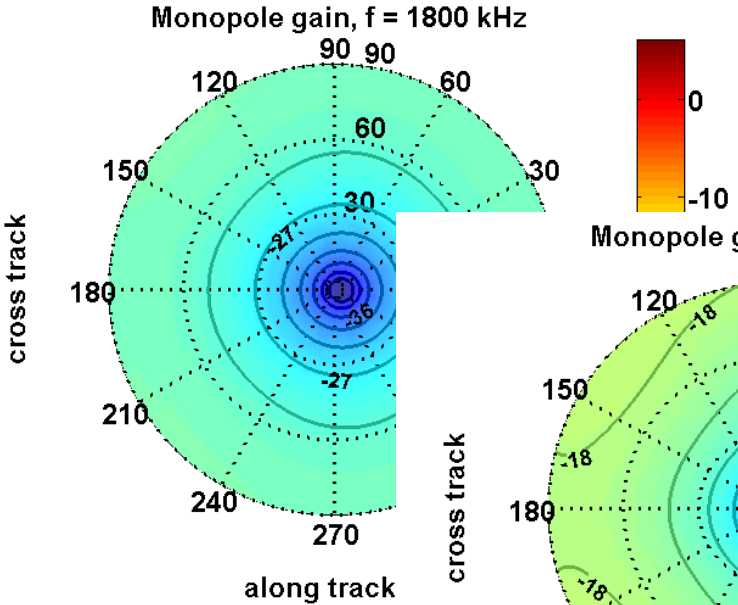


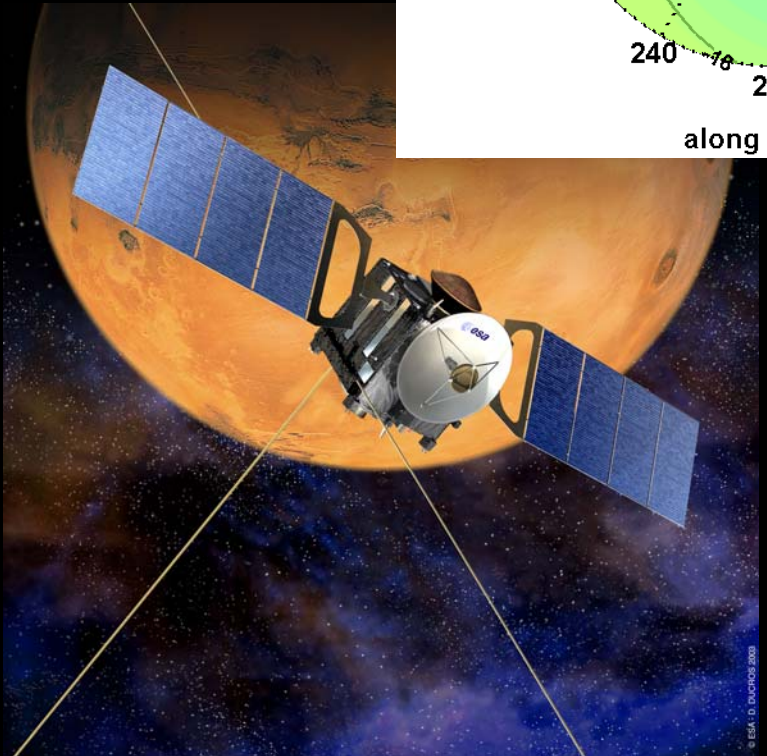
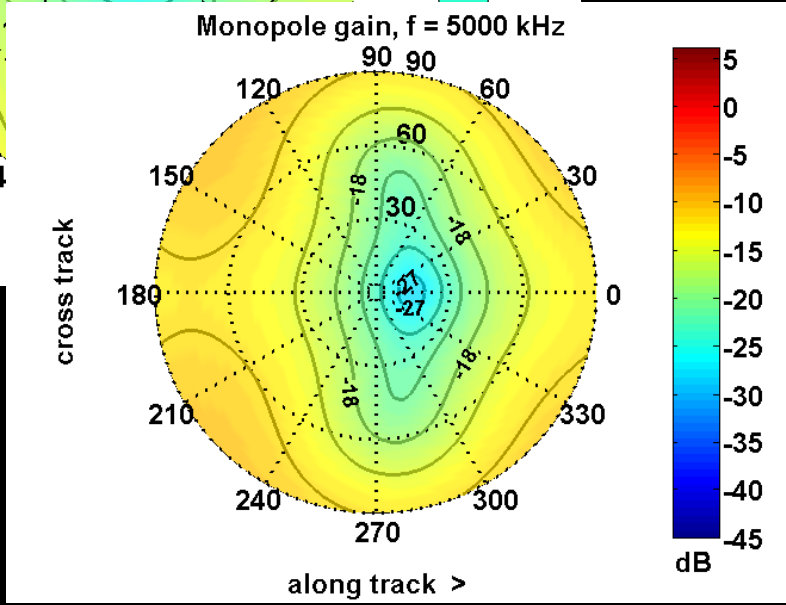
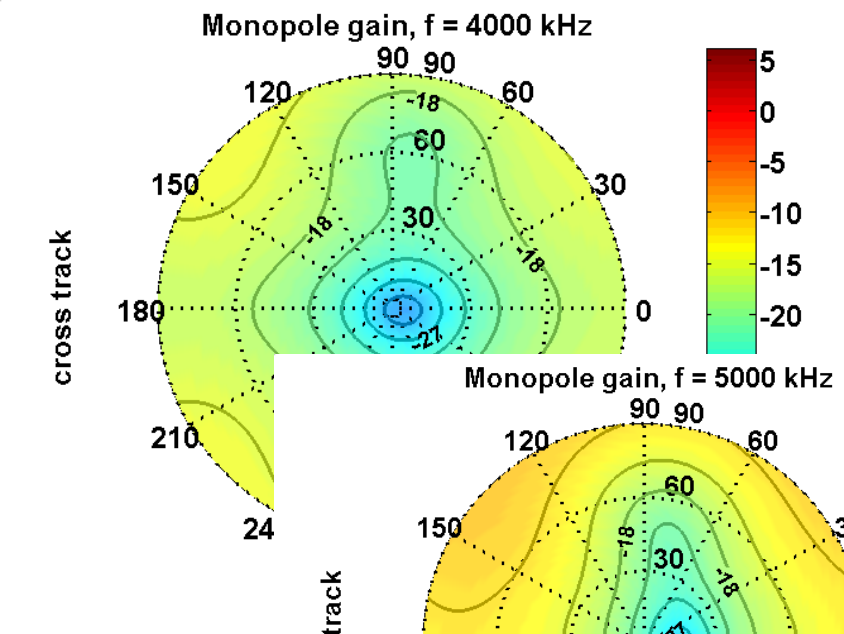
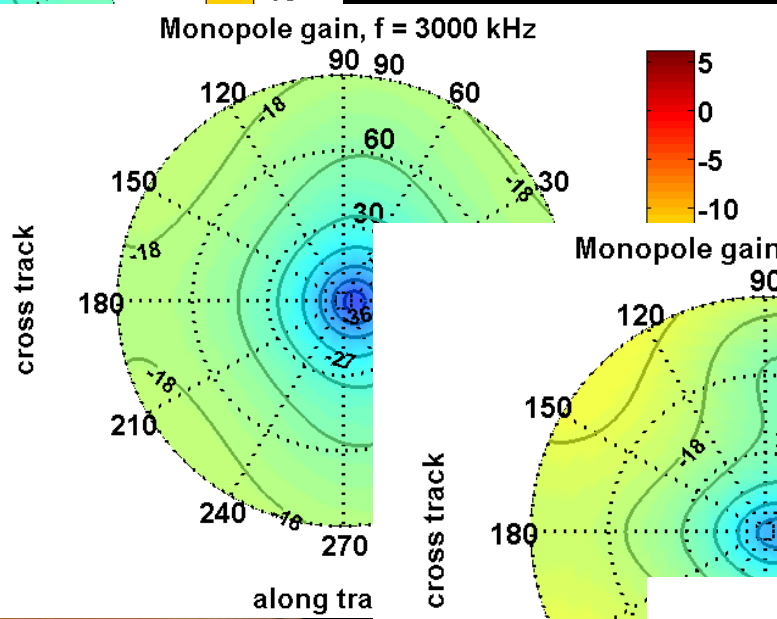
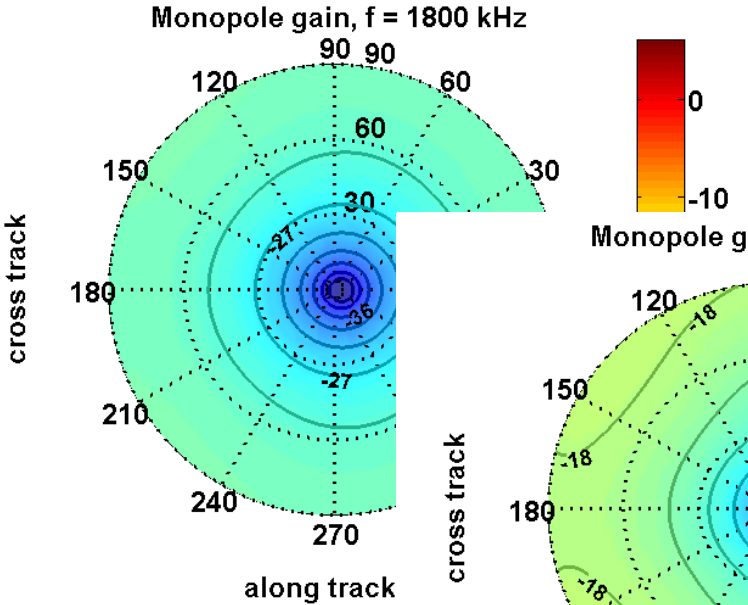
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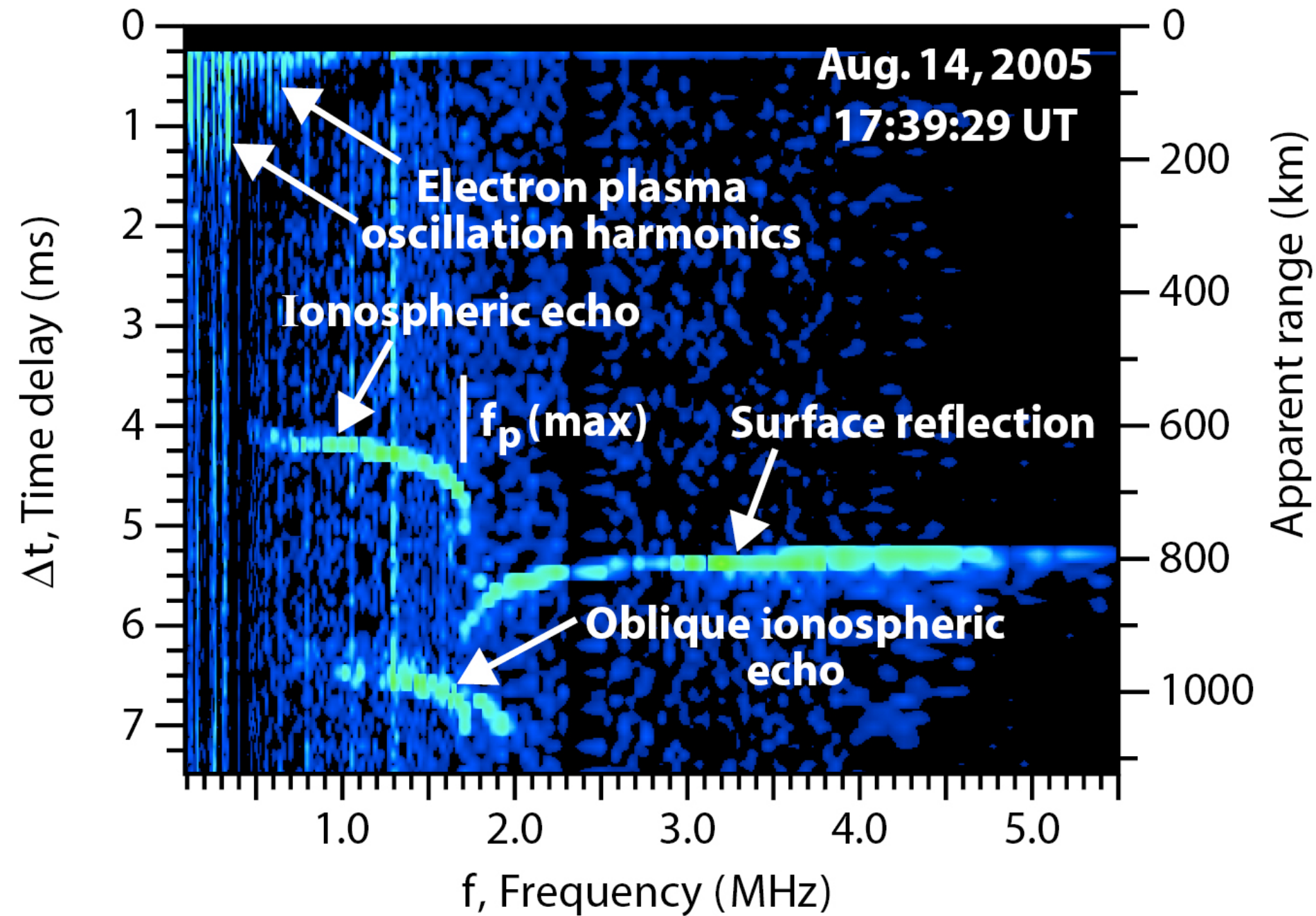


© ESA, D. DUCROS 2008

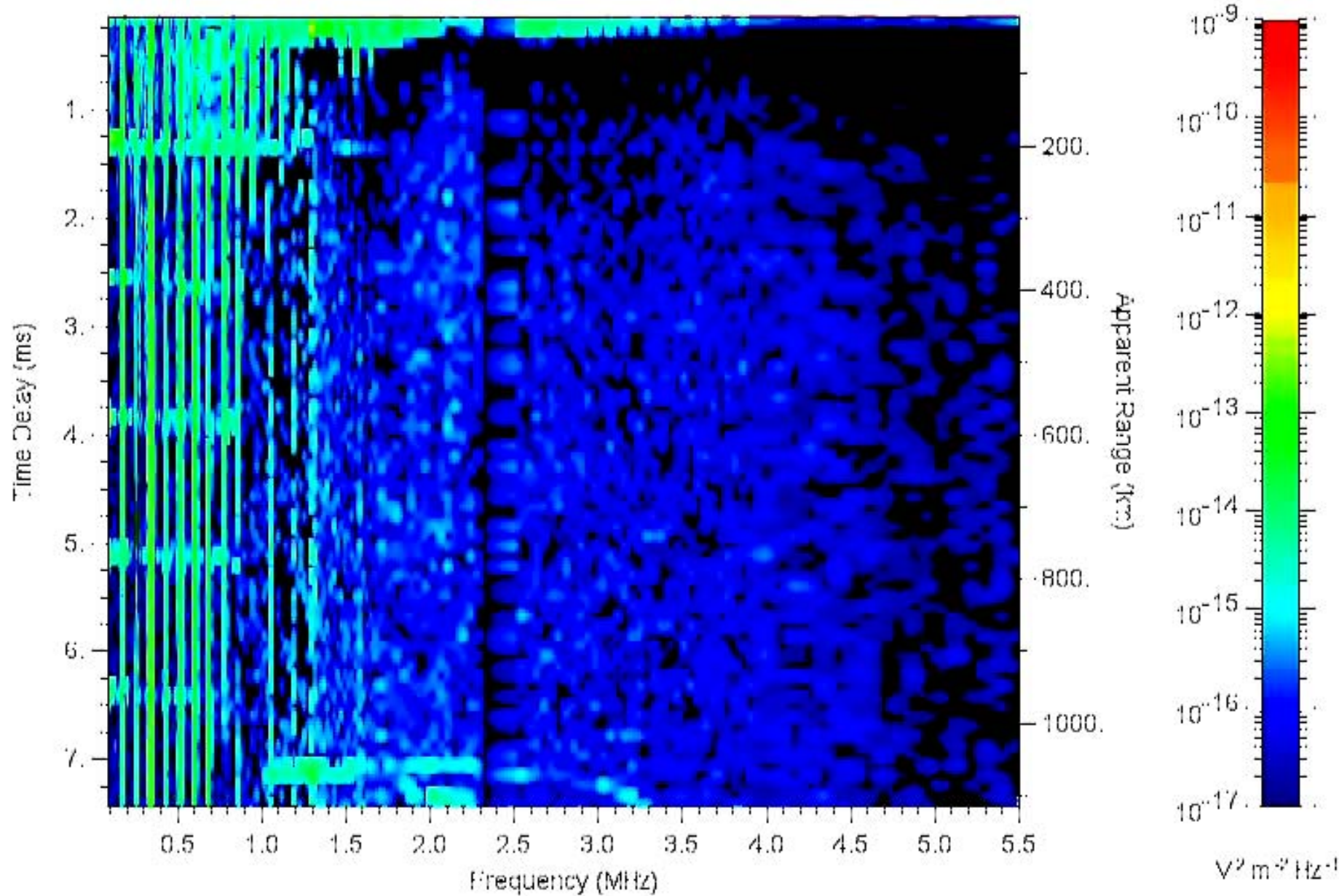






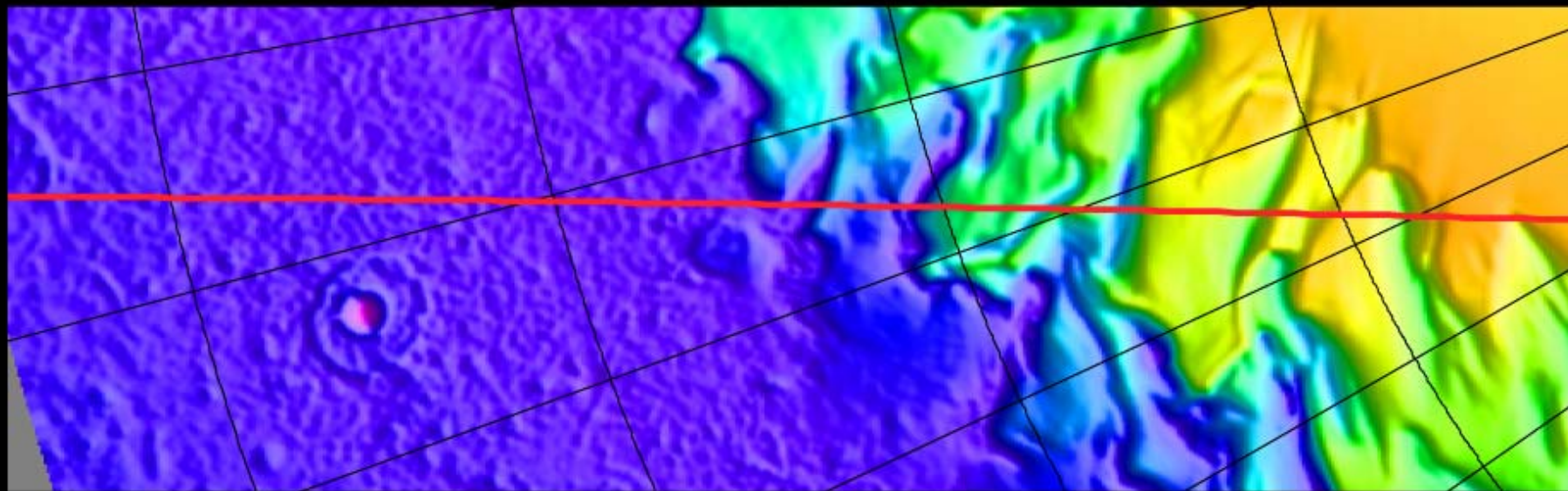


Orbit: 2018 2005-08-10T19:05:17.442 SZA: 48.59 Altitude: 1164 Lat: -57.66 Long: 166.69



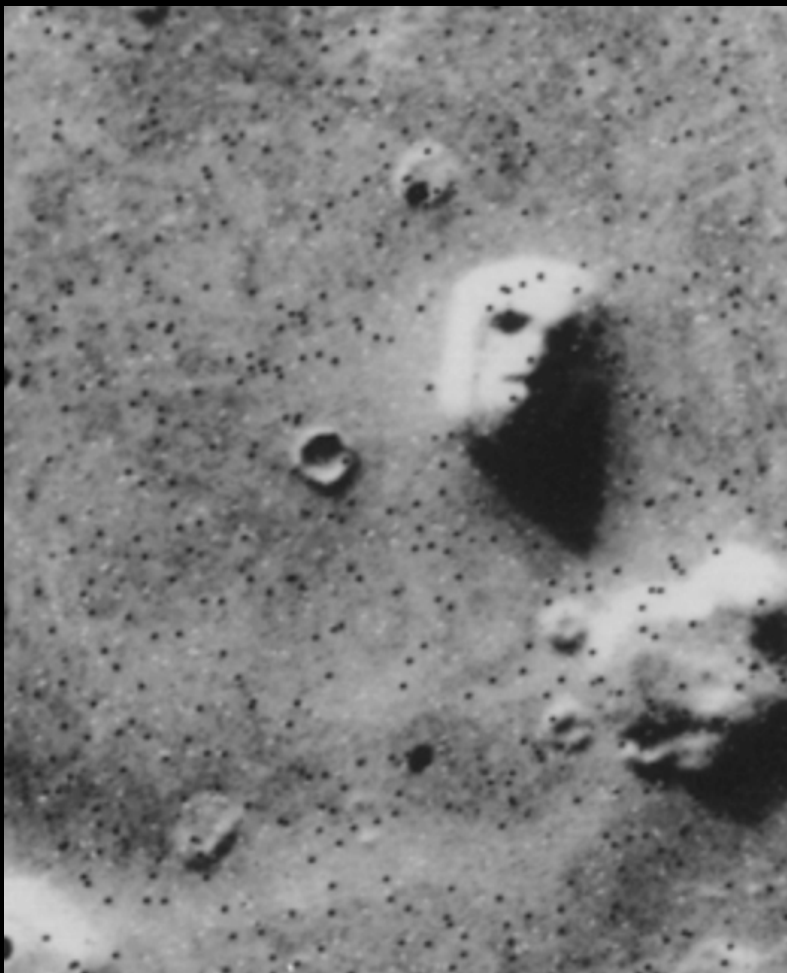
northern pole: pure water ice

1,8 – 2,0 km



458 km

Life on Mars?



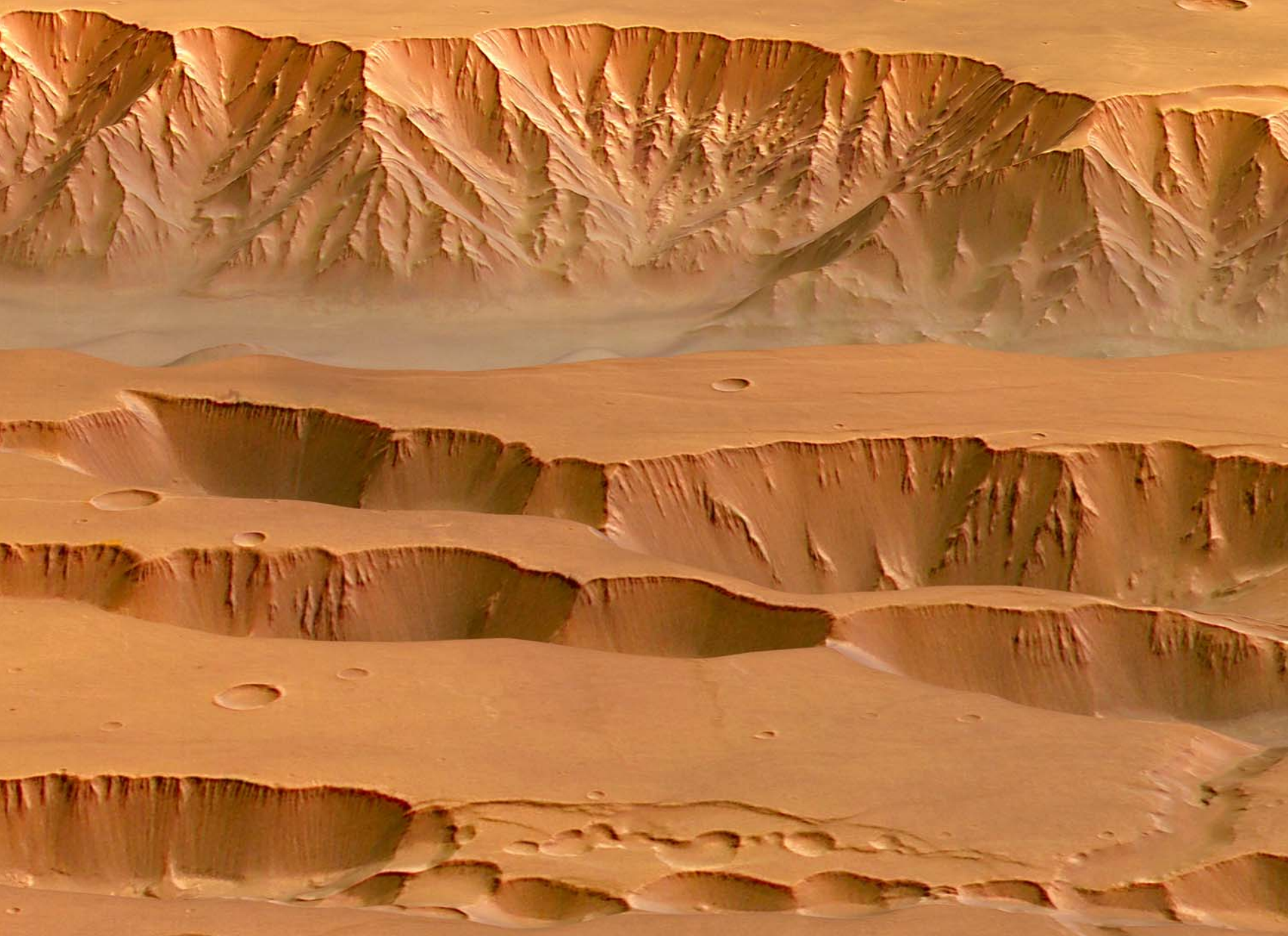
The atmosphere of Mars

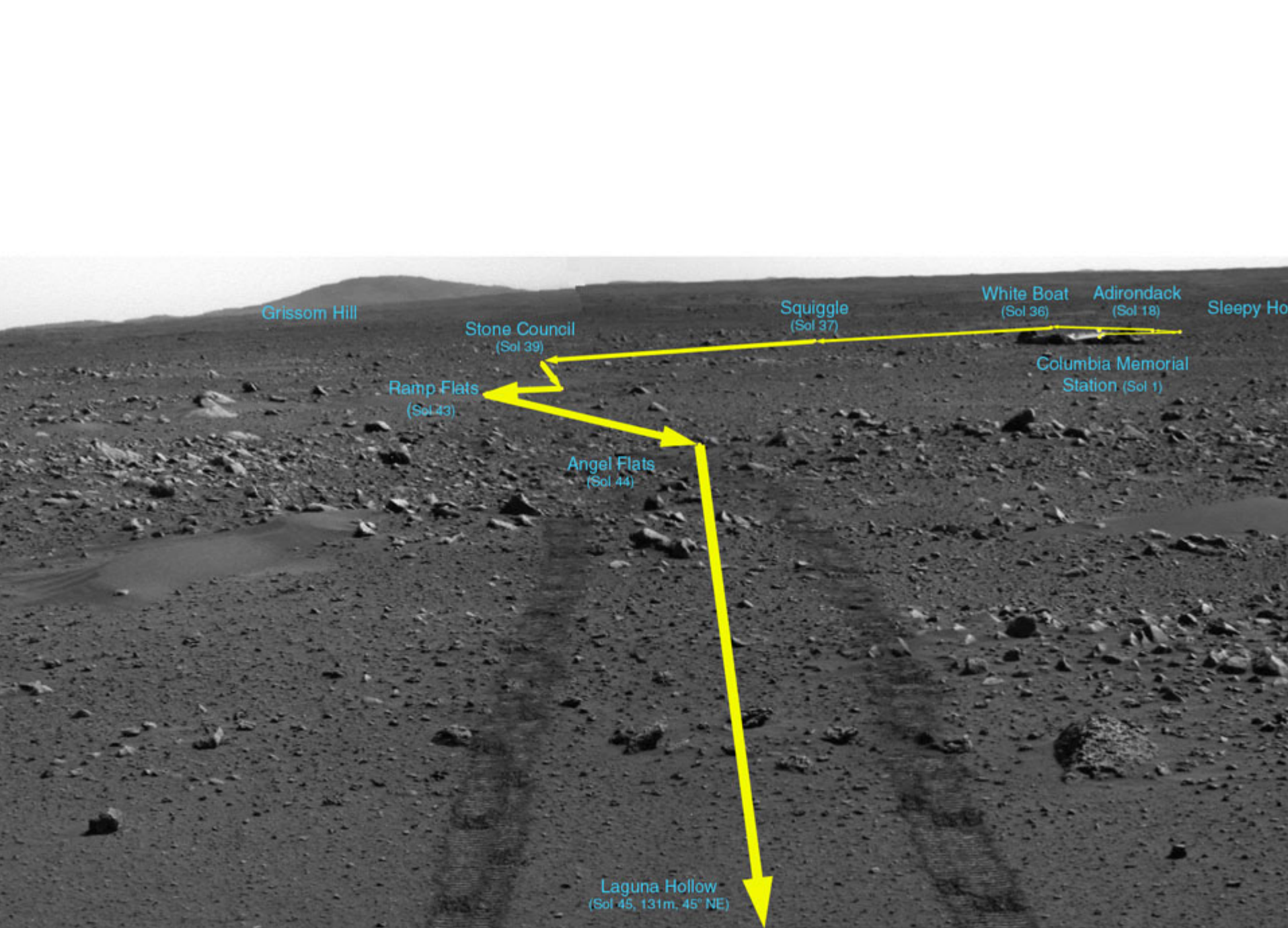


June 26, 2001



September 4, 2001





Grissom Hill

Stone Council
(Sol 39)

Squiggle
(Sol 37)

White Boat
(Sol 36)

Adirondack
(Sol 18)

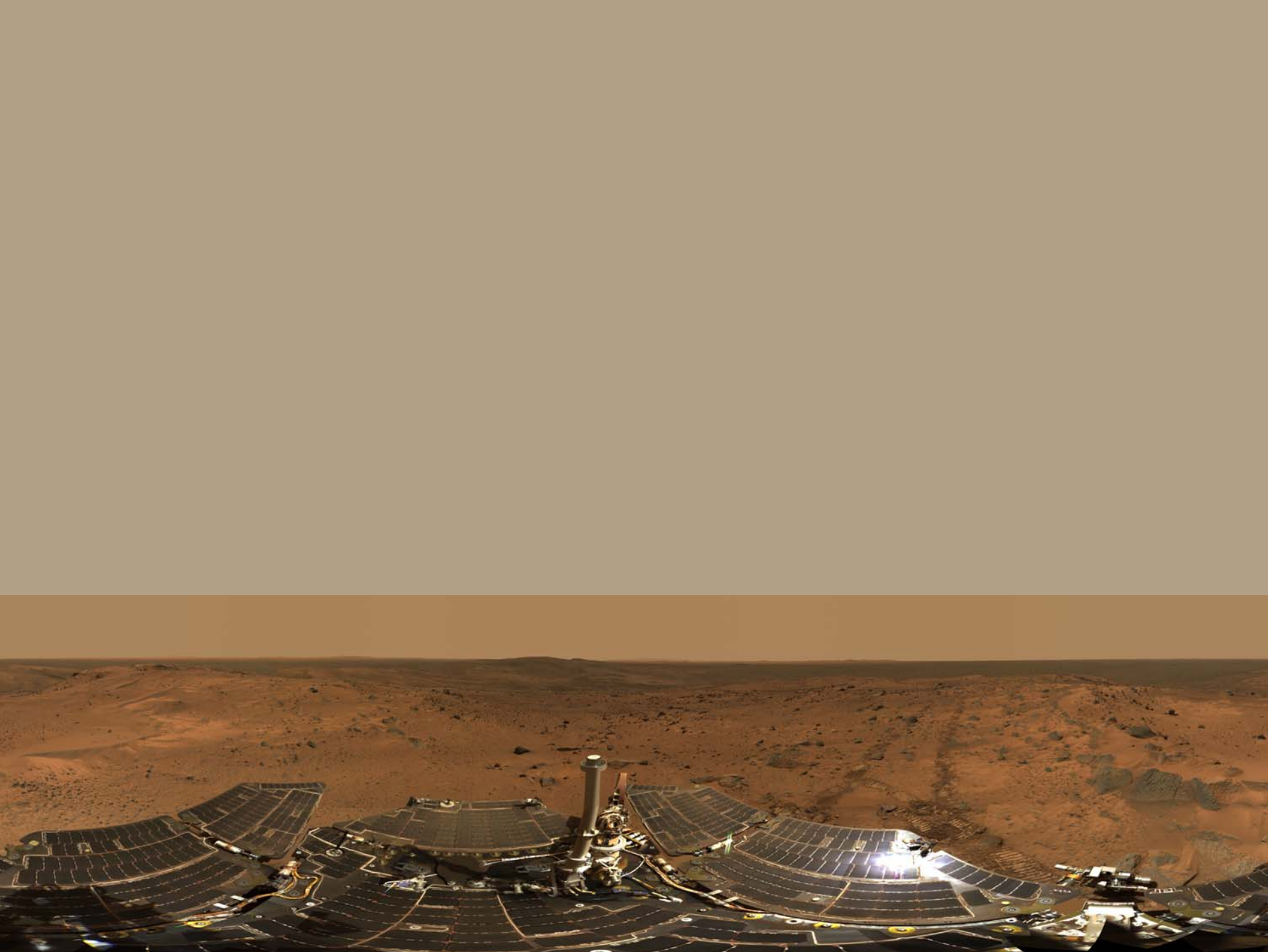
Sleepy Ho

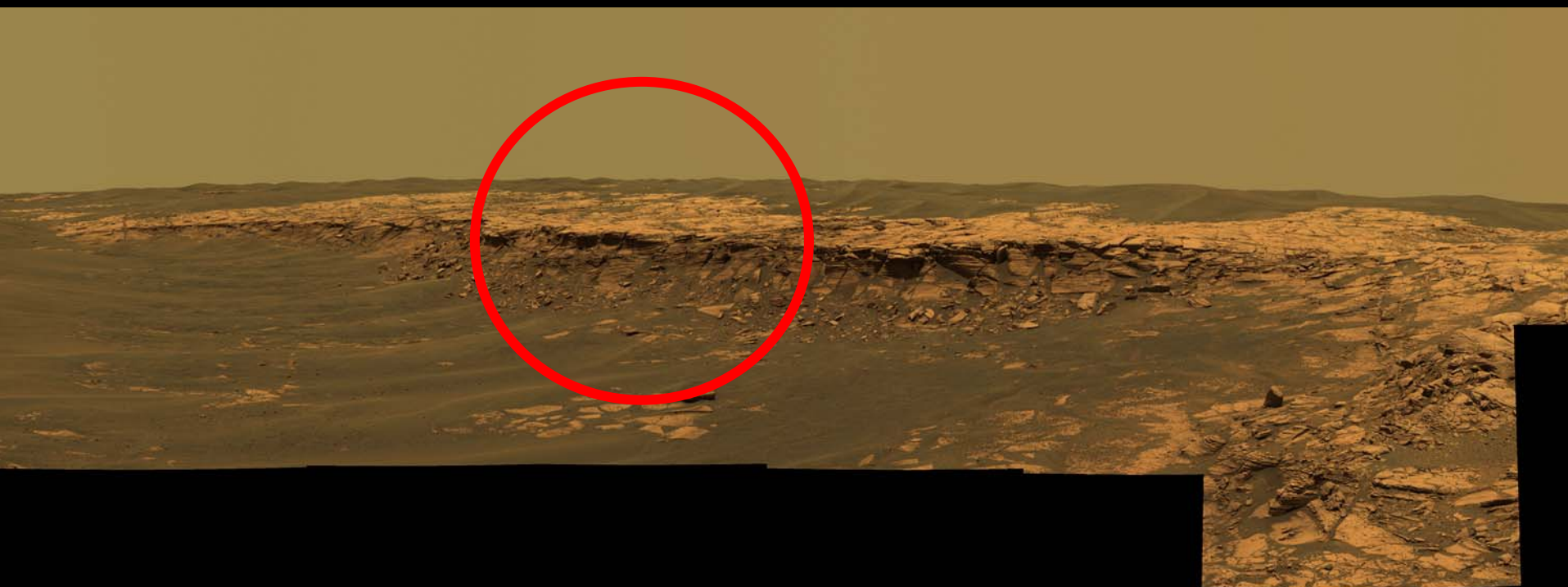
Ramp Flats
(Sol 43)

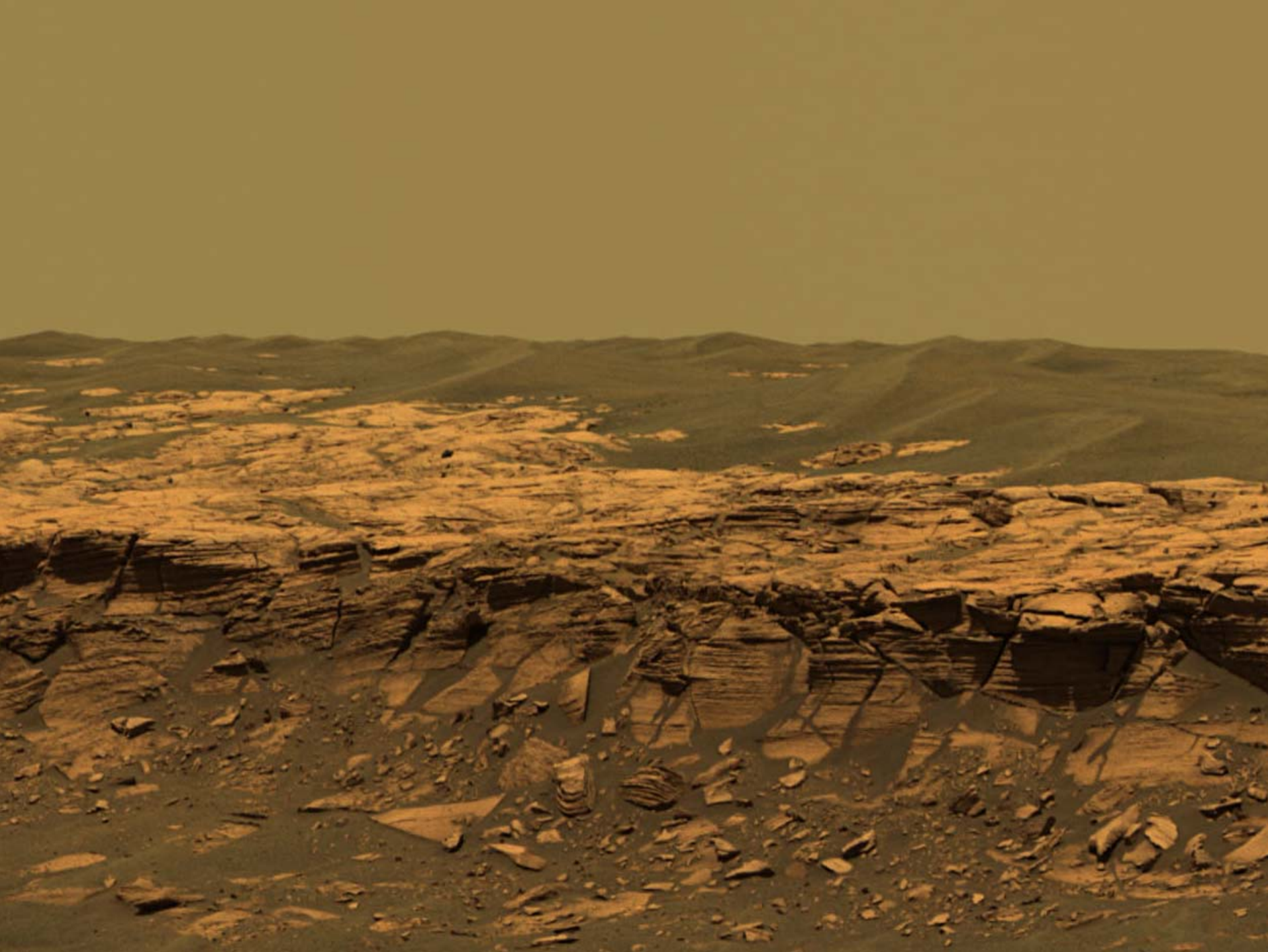
Columbia Memorial
Station (Sol 1)

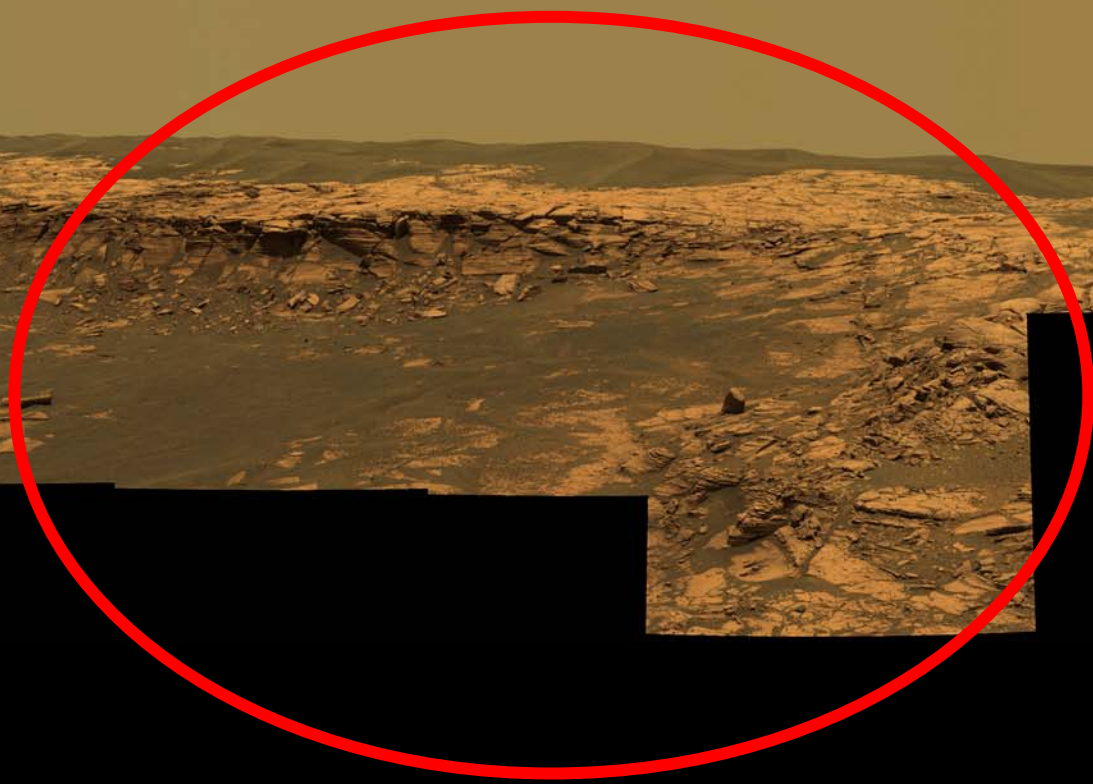
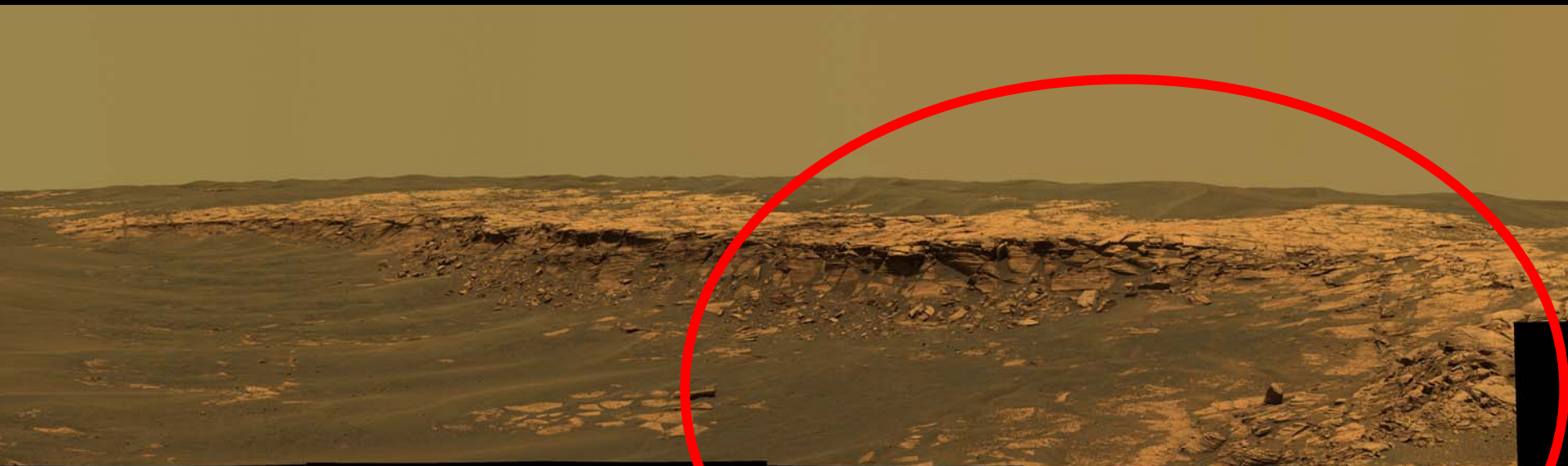
Angel Flats
(Sol 44)

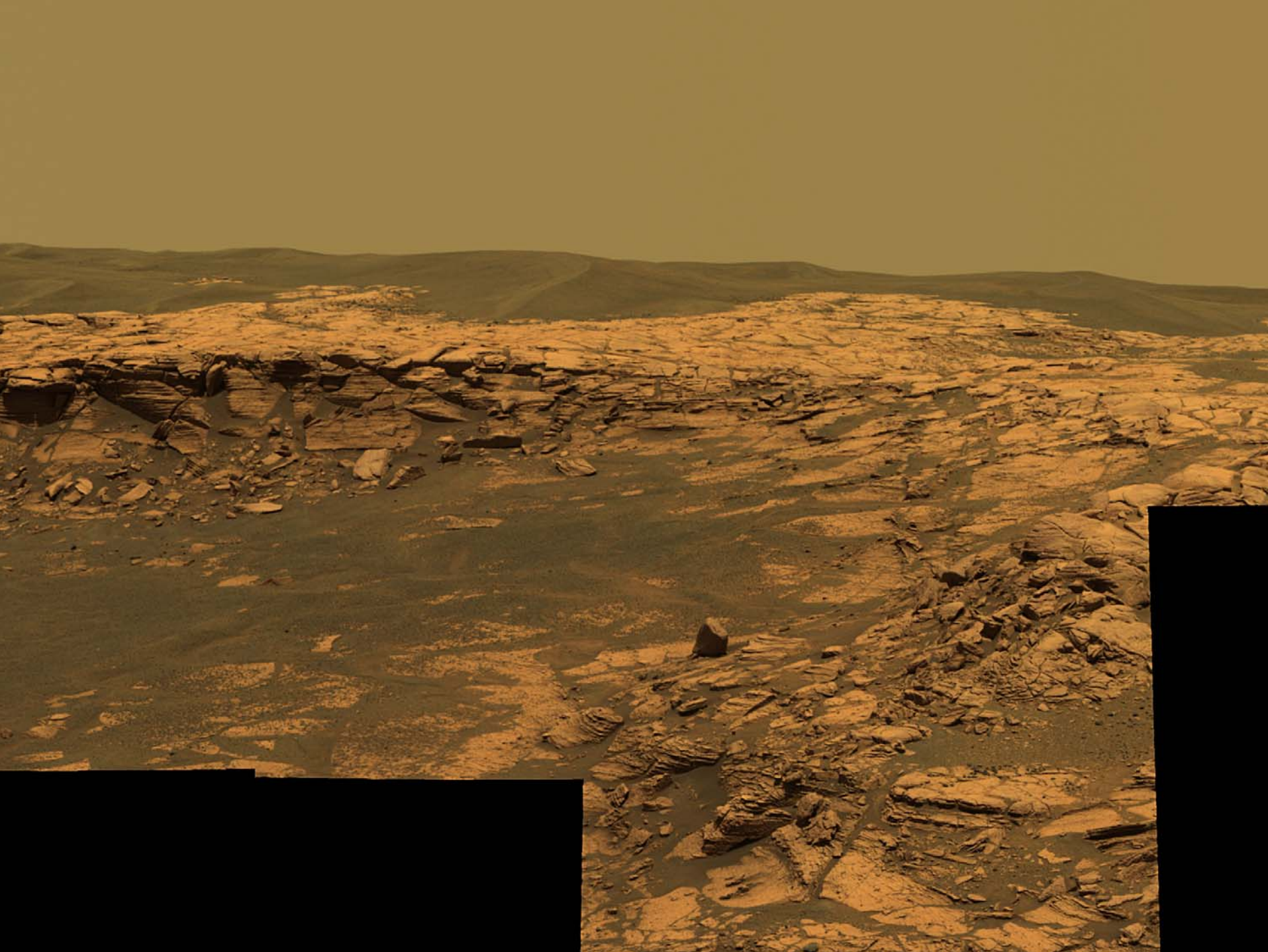
Laguna Hollow
(Sol 45, 131m, 45° NE)





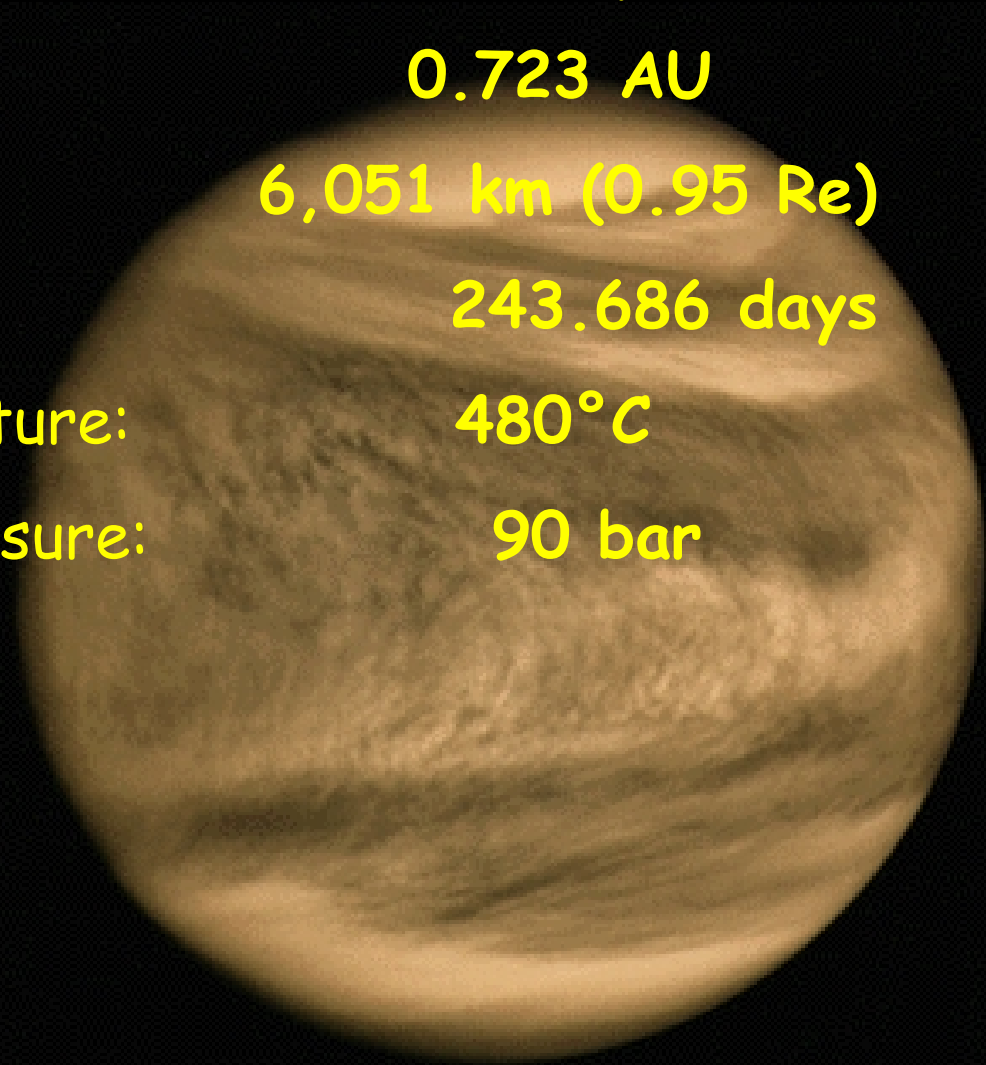






Venus

Orbital period around Sun:	224.5 days
Distance from Sun:	0.723 AU
Planetary radius:	6,051 km (0.95 Re)
Planetary rotation period:	243.686 days
Average surface temperature:	480°C
Surface atmospheric pressure:	90 bar



The atmosphere of Venus

Glass house effect: $\sim 500^{\circ}\text{C}$

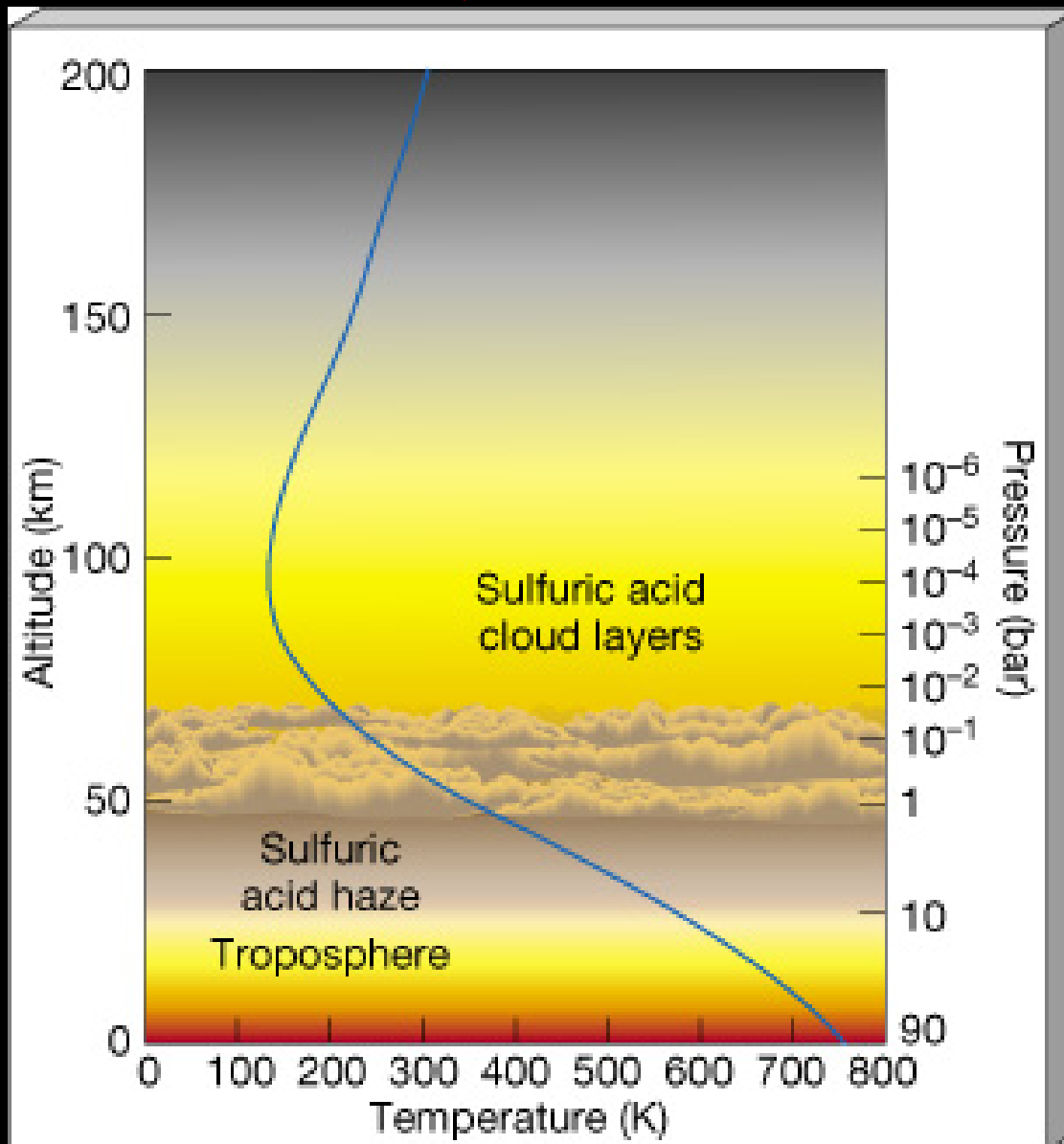
Glass house effect: $\sim 30^{\circ}\text{C}$

Gas	Venus	Earth
CO ₂	96%	0.03%
N ₂	3.5%	78.1%
Ar	0.006%	0.93%
O ₂	0.003%	21.0%
Ne	0.001%	0.002%

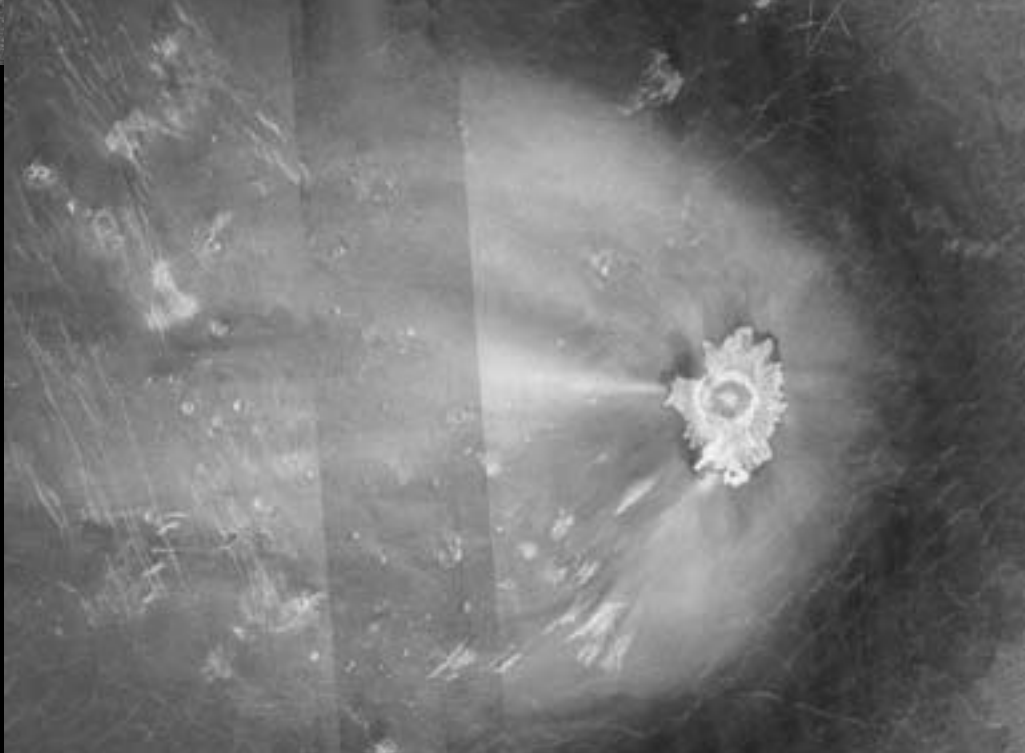
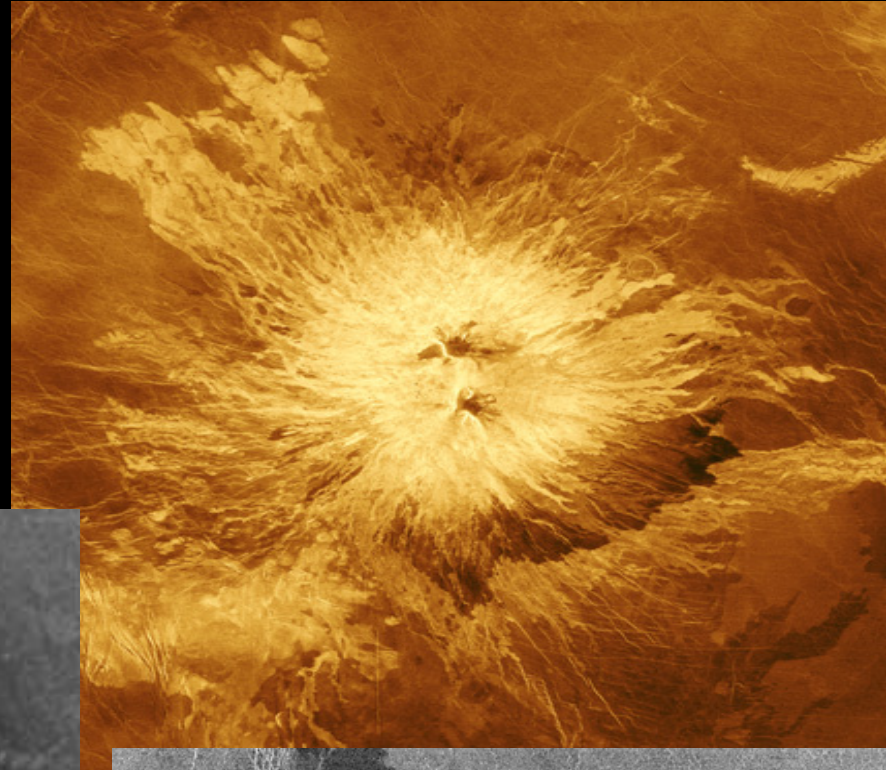
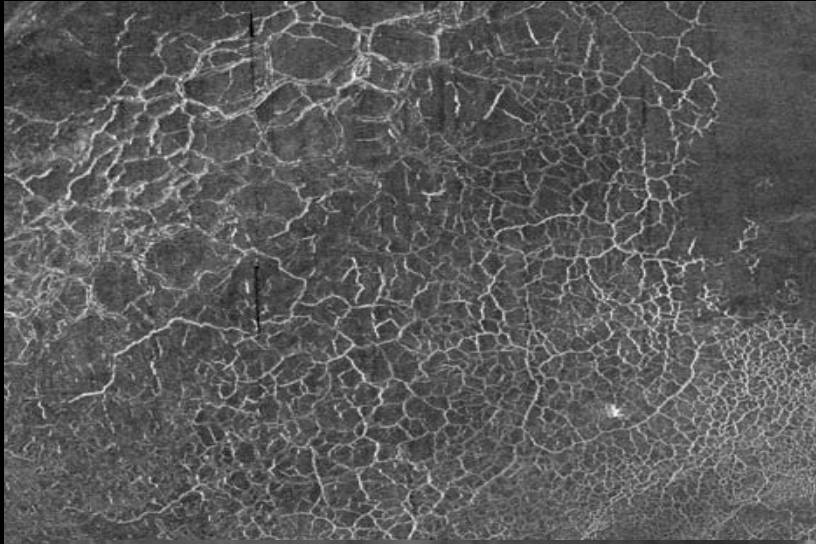
Water always in gaseous phase, thus CO₂ concentration in atmosphere could increase.

CO₂ is washed out by rain.

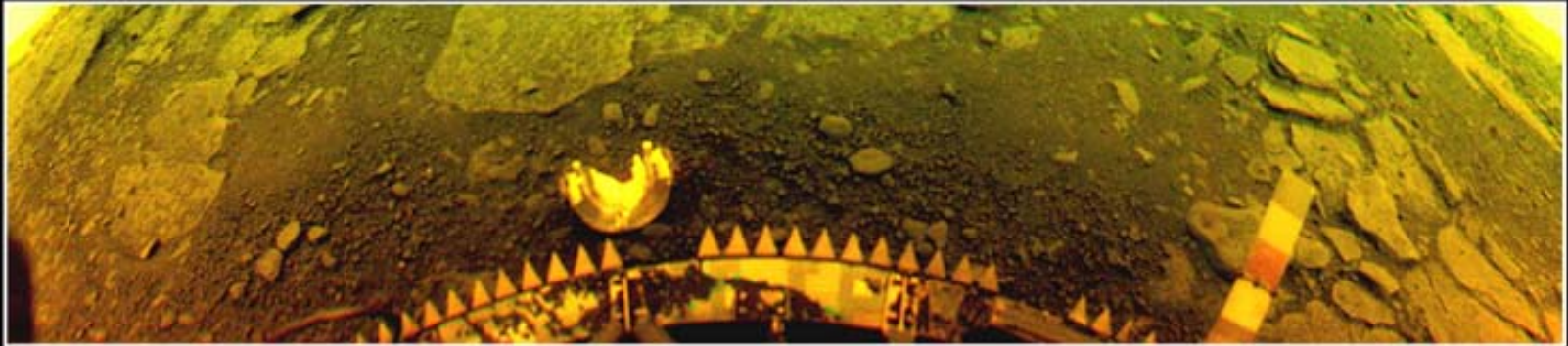
The atmosphere of Venus



Volcanism on Venus



Impression on the surface of Venus



Color as seen on the surface of Venus

Venera 13

Color with atmospheric effects removed



ВЕНЕРА-9 22.10.1975

ОБРАБОТКА ИППИ АН СССР 28.2.1976

Impact crater on Venus



Venus Express

Launch vehicle: Soyuz-Fregat
since 1963 1700 launches
success rate: 98 %

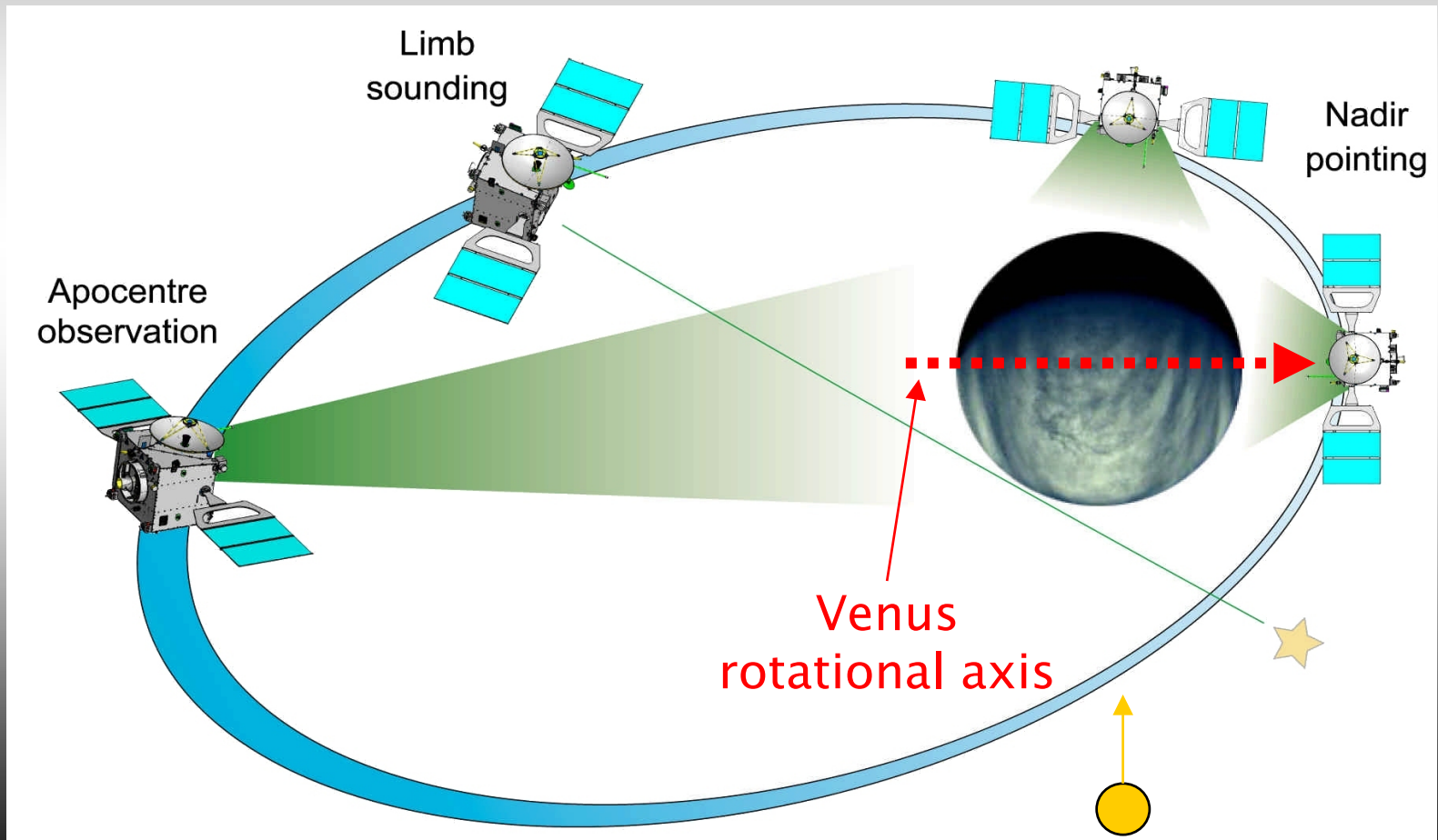


Venus Orbit Insertion (VOI) April 11, 2006

VEX periapsis ~ 250 km (close to pole)

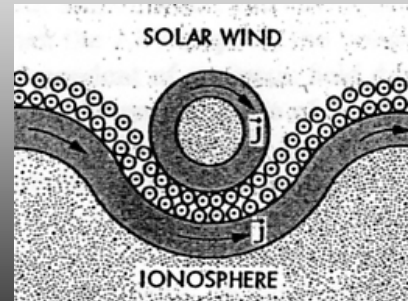
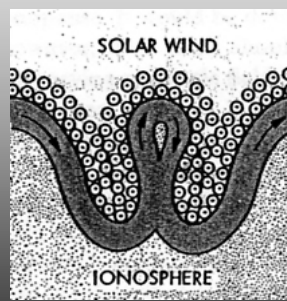
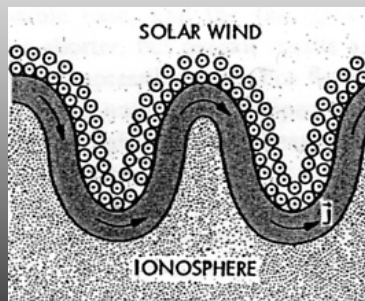
VEX apoapsis ~ 66,000 km;

VEX orbital periode = 24 hrs



Solar wind interaction

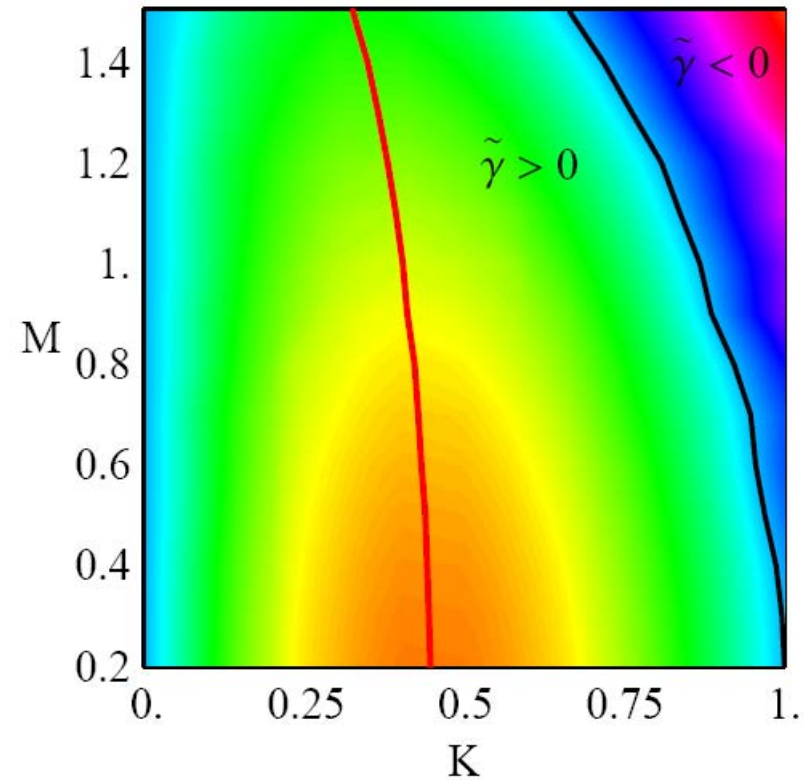
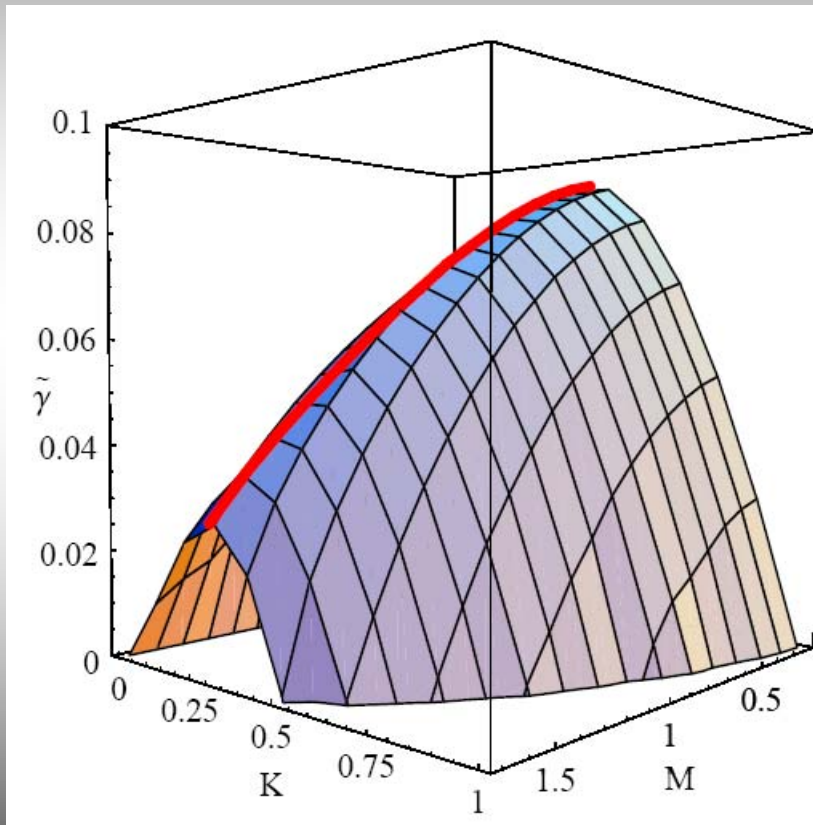
- Non-magnetized planets: solar wind streams tangential to ionosphere
 - relative velocity → Kelvin-Helmholtz instability
 - waves possibly break → plasma clouds?



Wolff et al., 1980



Kelvin Helmholtz instability growth rate versus normalized wave number K and Mach number M



$$M = \frac{v^*}{\sqrt{v_s^2 + v_A^2}}$$

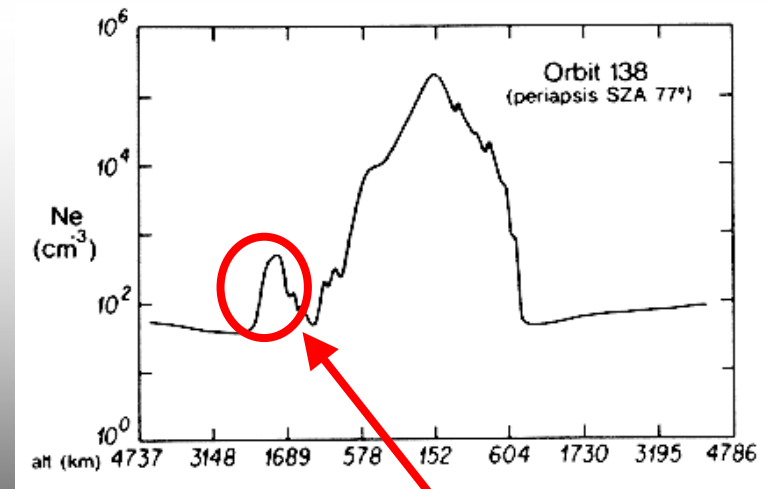
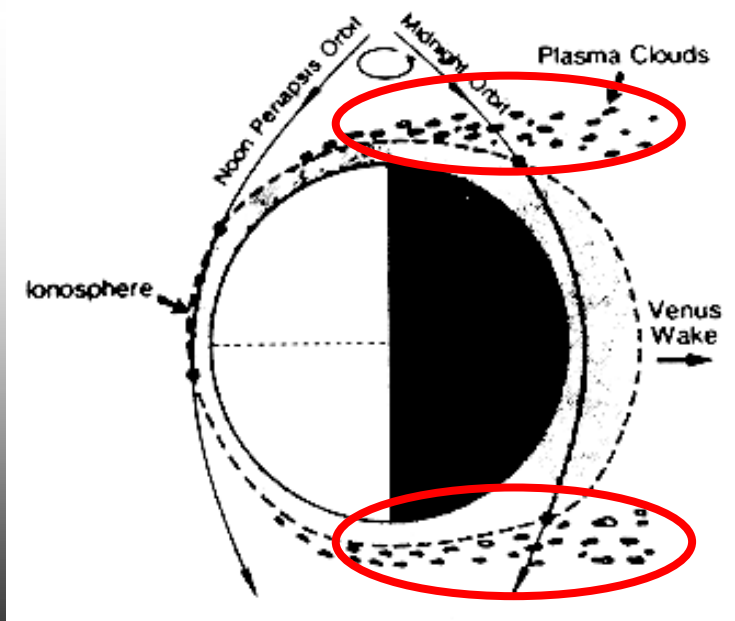


Venus PVO observations



- Brace et al., 1982:
 - Pioneer Venus Orbiter observations
 - 10^{26} ions s^{-1} could be able to escape due to plasma clouds

Comparison with
data of VEX:
ASPERA-4
VEXMAG



detached plasma cloud

Mercury

Orbital period around Sun: 88 terr. days

Distance from the Sun: 0.387 AU

Mercury



Radius: 2,440 km (0.383 Re)

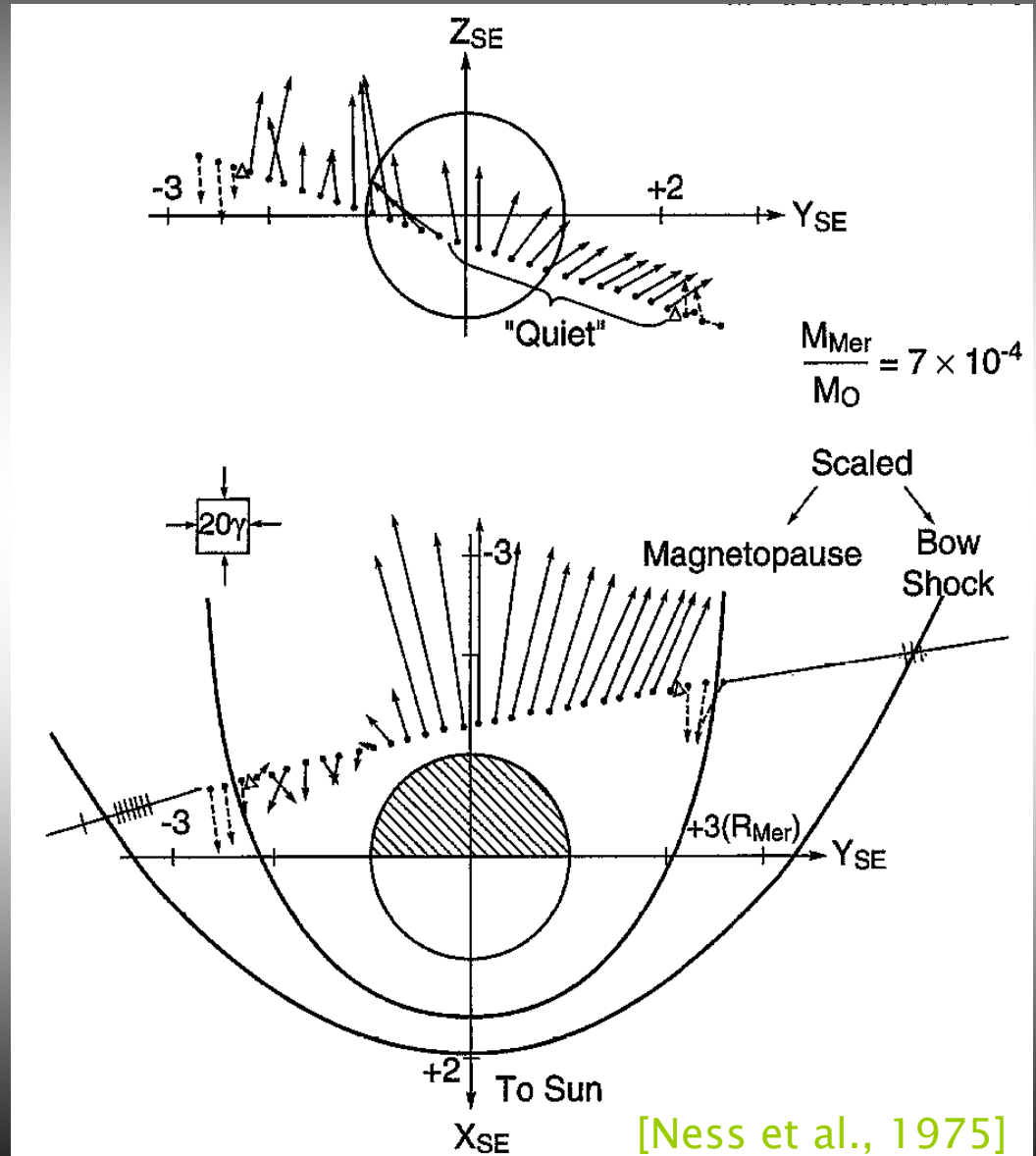
Rotational period: 58.65 terr. days

Average daytime temperature at equator: 430°C

Average night time temperature: -170°C

Mercury

- Only 3 Mariner flyby
- limited amount of data,
- only ~25 genuine publications



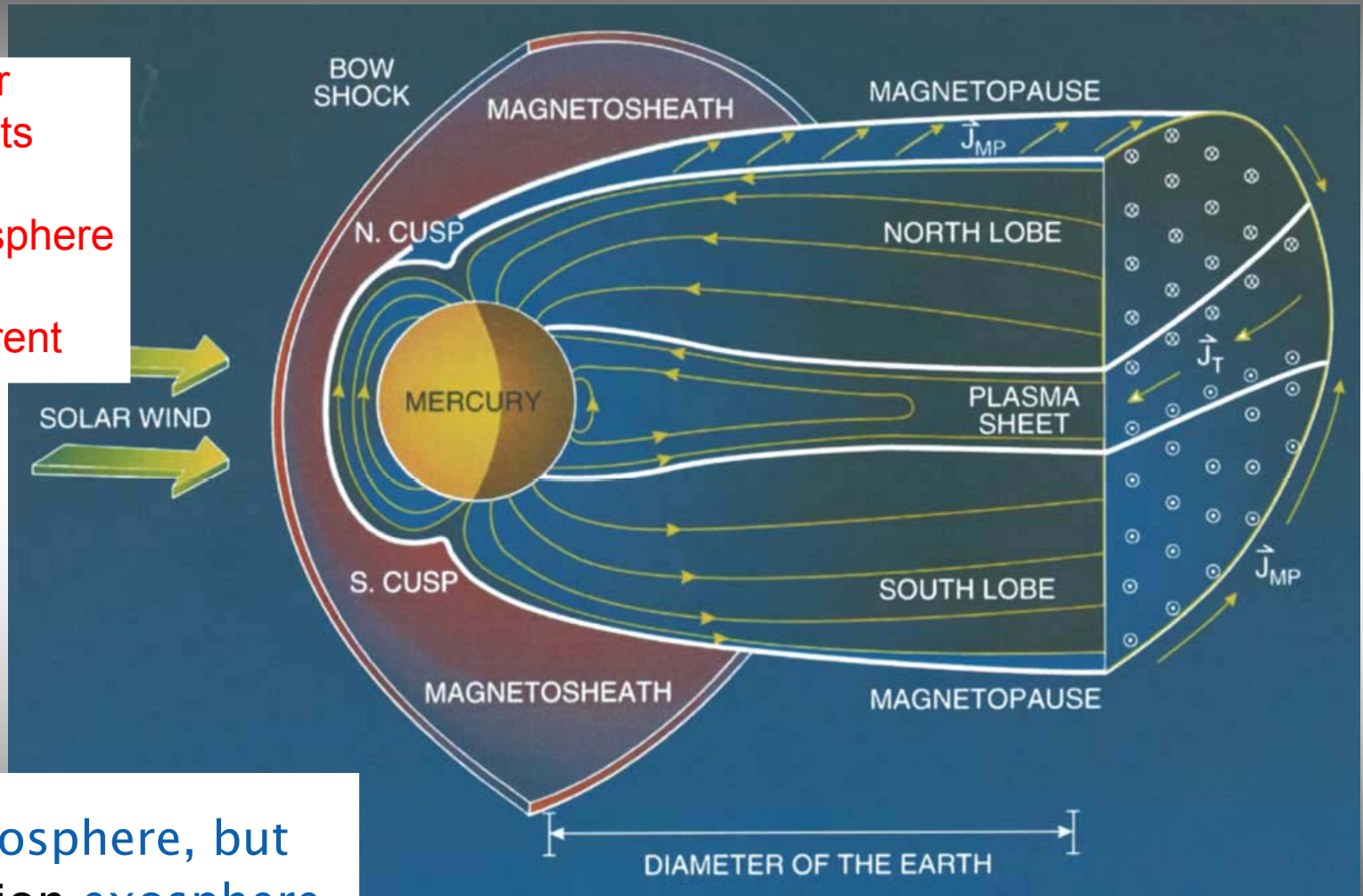
(Courtesy Baumjohann)

Mercury

No place for
particle orbits

No plasmasphere

No ring current



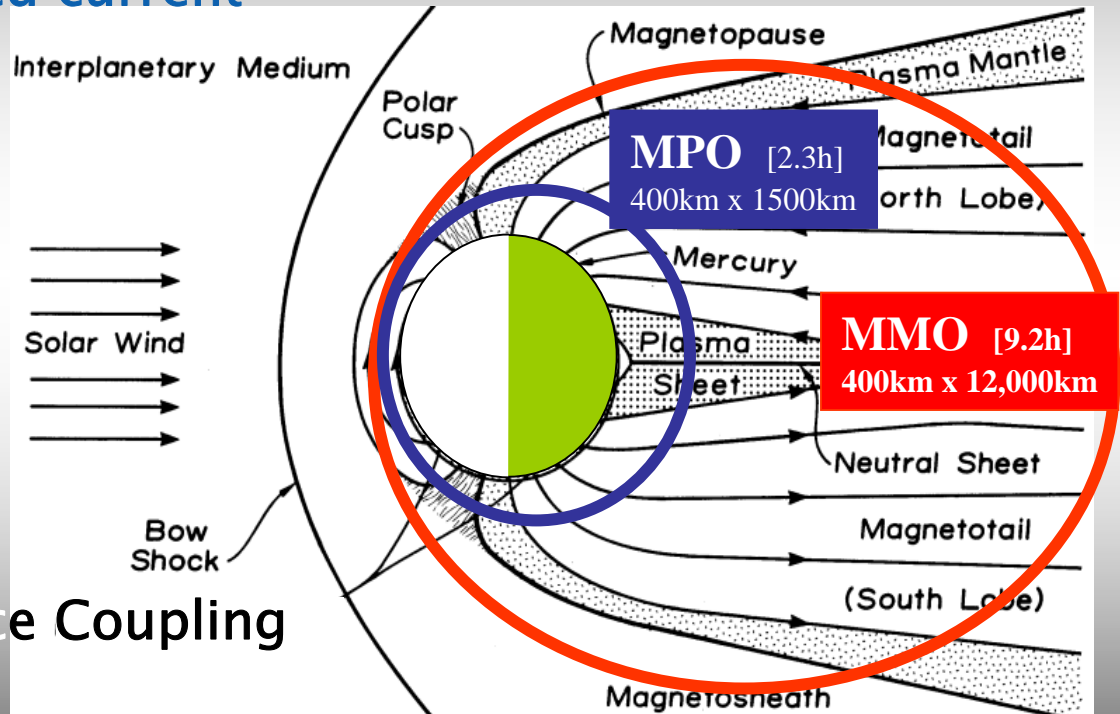
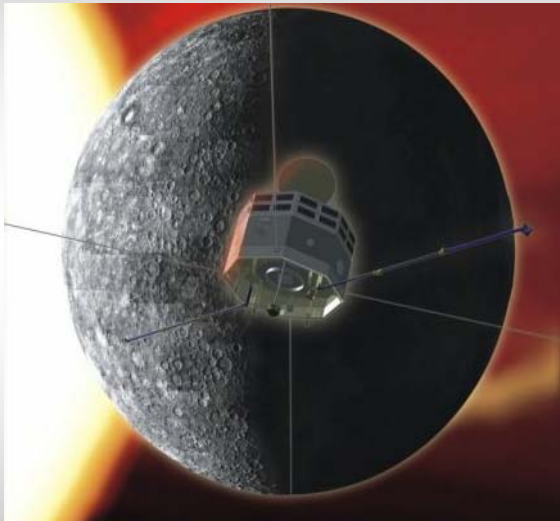
No ionosphere, but
heavy ion exosphere

[Slavin, 2004]

(Courtesy Baumjohann)

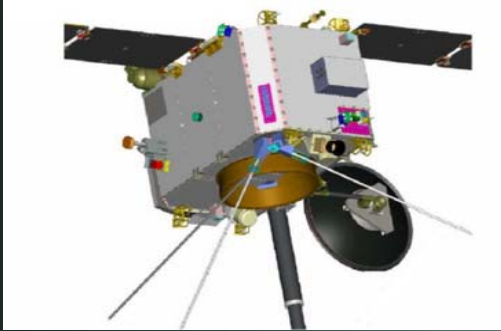
Multi-Point Measurements at Mercury Mission BepiColombo

- Magnetic field: Coordinated measurements
 - Identification of internal, external, induced fields
 - Closure of field-aligned current



- Magnetosphere–Surface Coupling
 - Space weathering
 - Production of exosphere
 - Feedback from/to the Magnetosphere
- (Courtesy Baumjohann)

Explorations running and in preparation



Sun:

STEREO

Solar B

Solar ORBITER

Mercury:

BepiColombo

Venus:

Venus Express

Mars:

Mars Express

Jupiter:

Juno

Europa Mission

Saturn:

Cassini

Uranus: --

Neptune: --

Pluto:

NH Pluto Express

Comets:

Rosetta

Exoplanets: COROT (only remote sensing)



