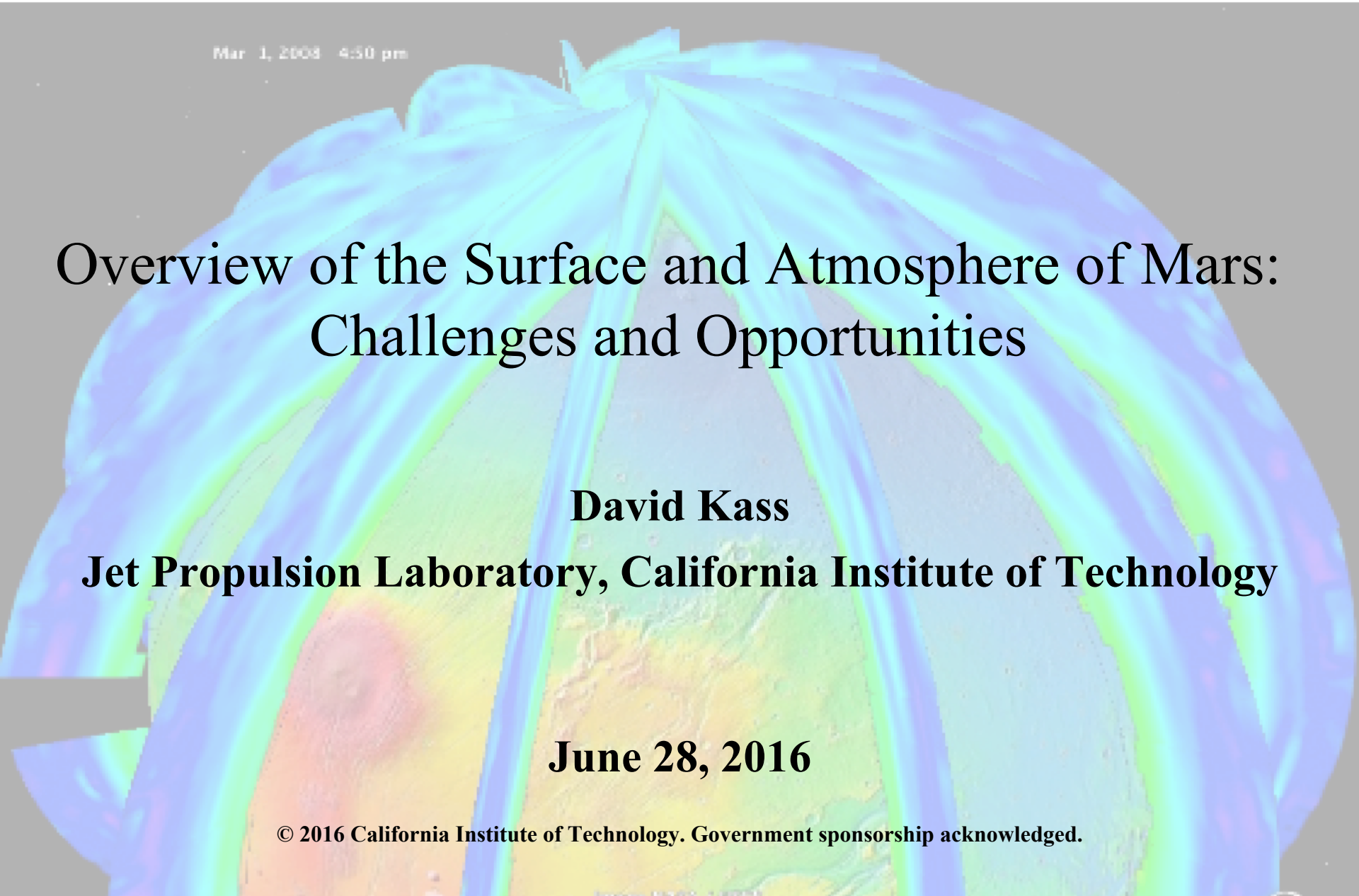

Overview of the Surface and Atmosphere of Mars: Challenges and Opportunities

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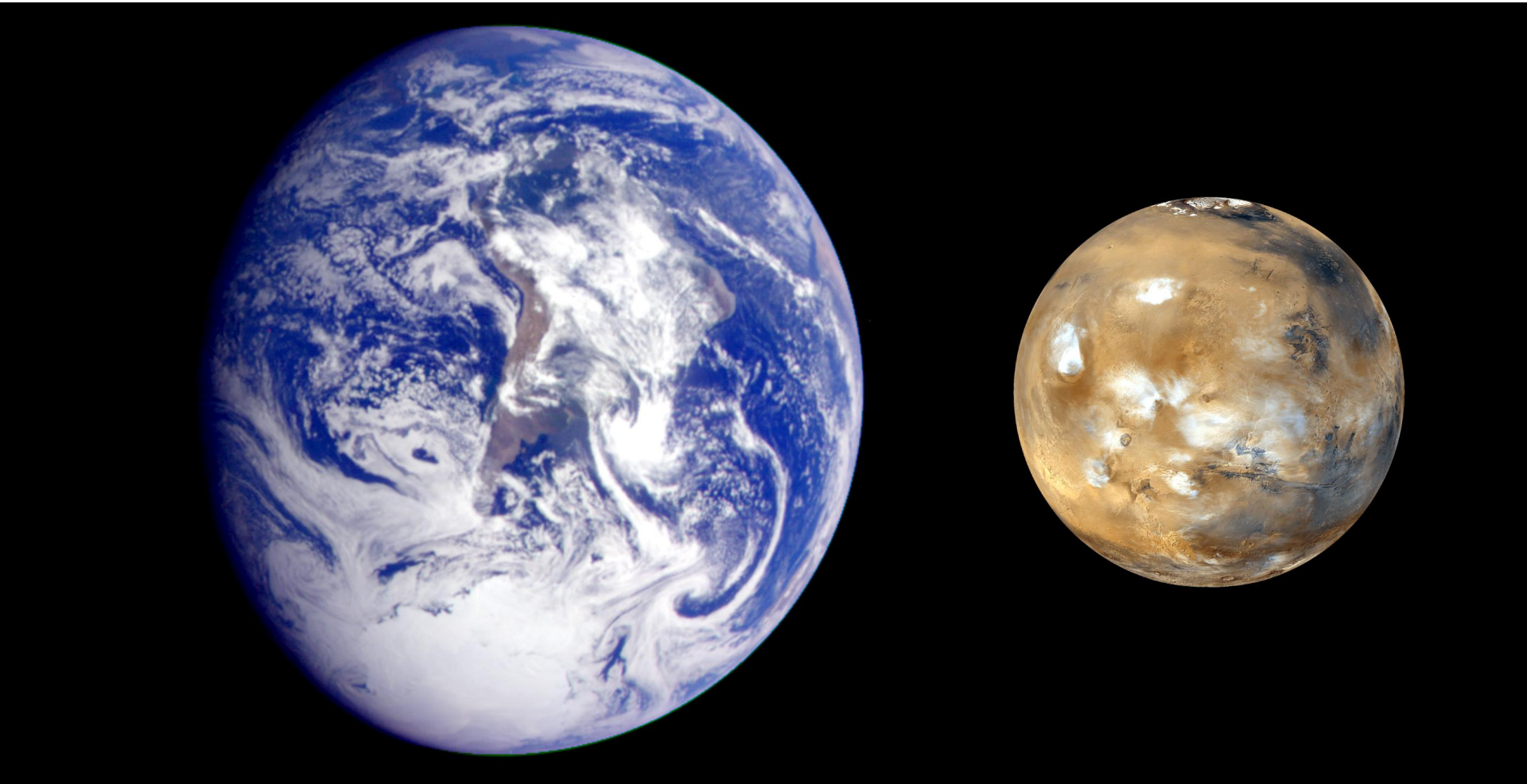
June 28, 2016

Mars

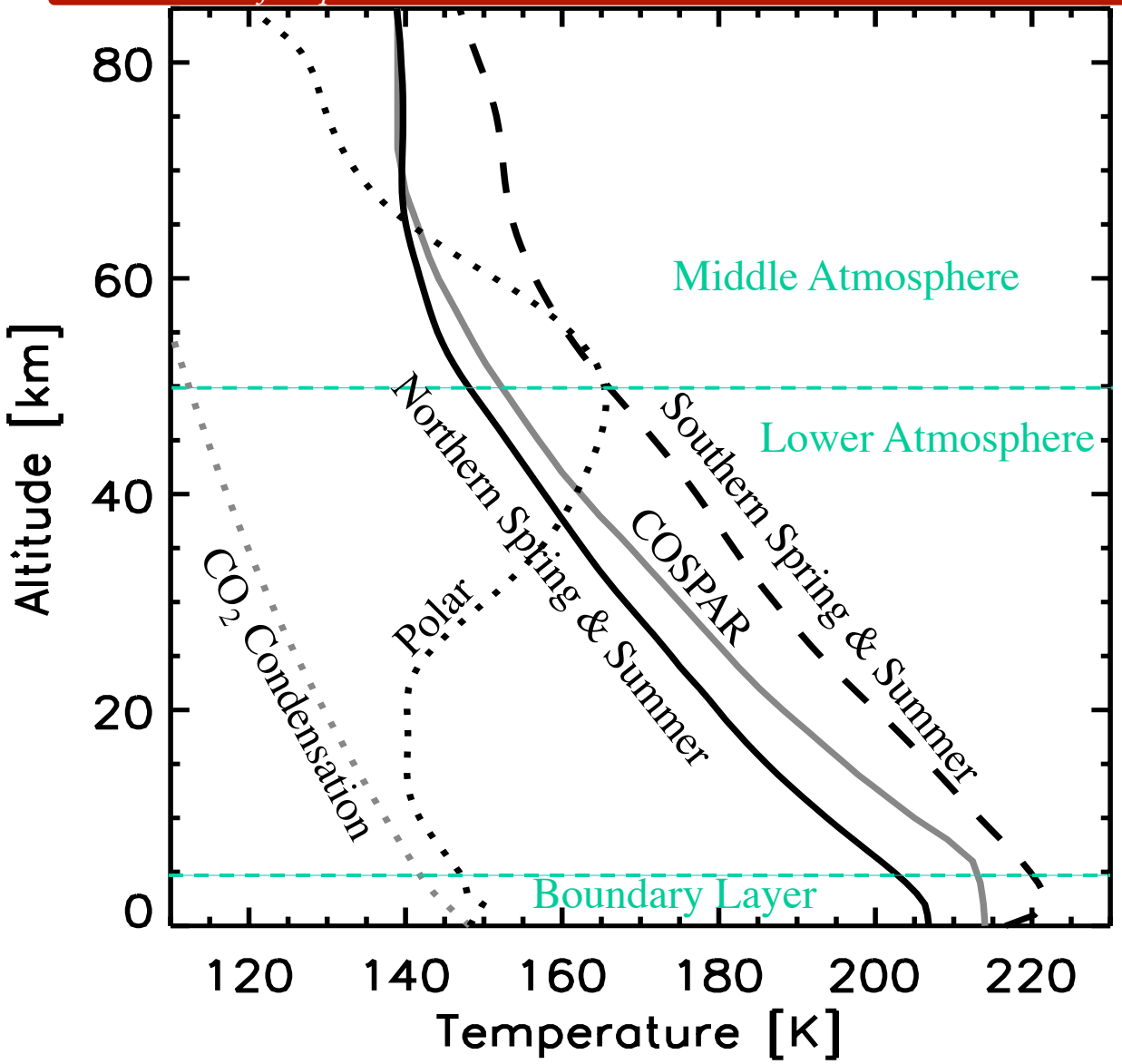
- Mars is a terrestrial planet with a thin atmosphere
  - This is the same "general" classification as the Earth.
  - There are both similarities and differences



Mars' Seasons

- Mars Years (MY)
  - Mars years last 668.6 sols (sol = Mars day = 24.62 hours)
- Mars' orbit is significantly more elliptical than the earth (e = 0.09)
  - Insolation changes by 45% over the Mars year
  - Use Ls (Heliocentric Longitude) to designate season during the year
- Mars has axial tilt of 25.19°
  - Very similar to the terrestrial tilt (23.4°)
- Mars has four seasons
  - Northern Spring (starts at Ls = 0°)
    - Start of Mars Year (MY)
    - Generally relatively little dust => cold and cloudy during the season
  - Northern Summer (starts at Ls = 90°)
    - Remains cold and cloudy
    - Relatively little dust, but it starts to increase towards the end of the season
  - Southern Spring (or Northern Autumn, starts at Ls = 180°)
    - General increase in the amount of dust in the atmosphere
    - Warmer atmosphere and continued warming during the season
    - Perihelion near end of season (Ls 251°)
  - Southern Summer (or Northern Winter, starts at Ls = 270°)
    - Continued significant amounts of dust and a generally warm atmosphere

Global Temperature Structure



96% CO_2

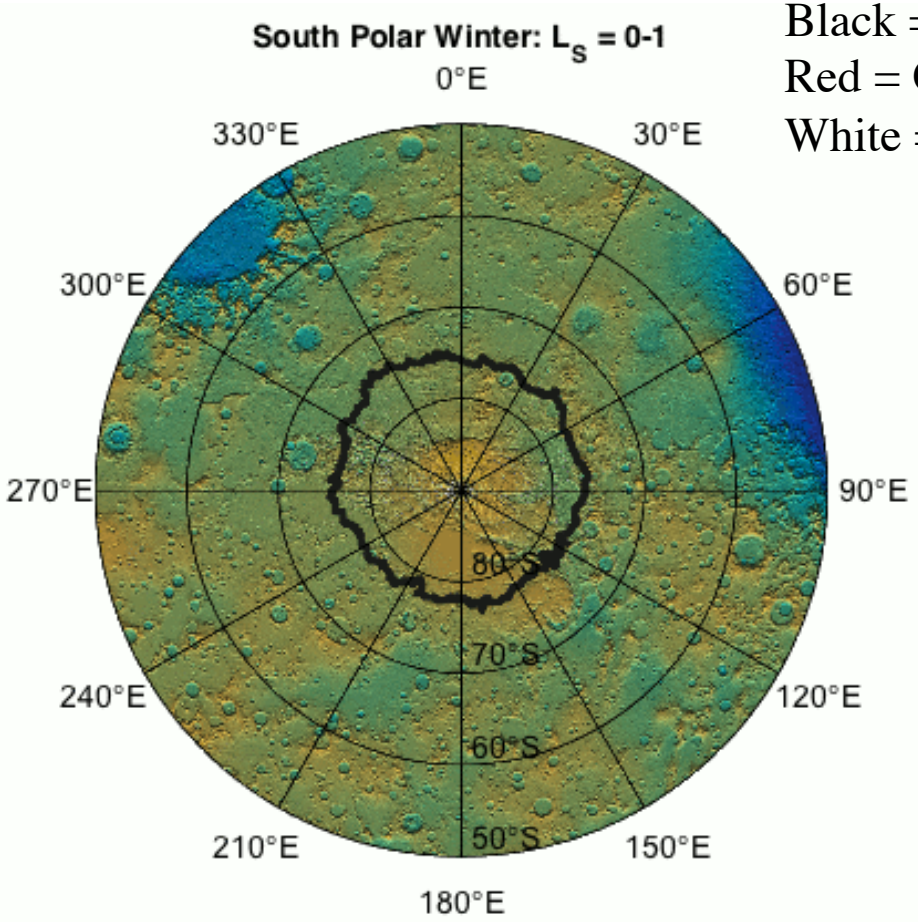
P_{surf} ~ 610 Pa

~ 0.6% terrestrial

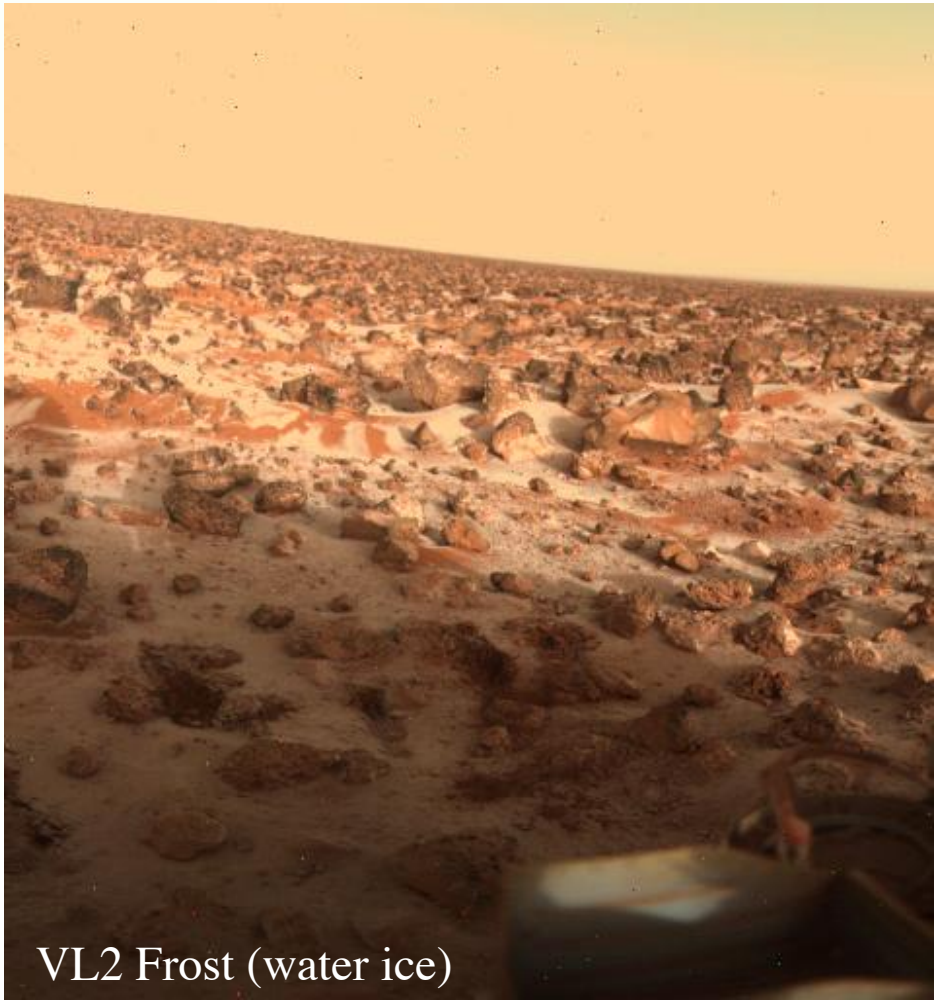
Boundary Layer

- Deeper and stronger than on Earth
- Day: convective ~10 km deep
- Night: surface inversion ~2 km deep

Polar Caps and Frost



Black = edge of CO_2 polar cap
Red = CO_2 snowfall
White = CO_2 snow drifts

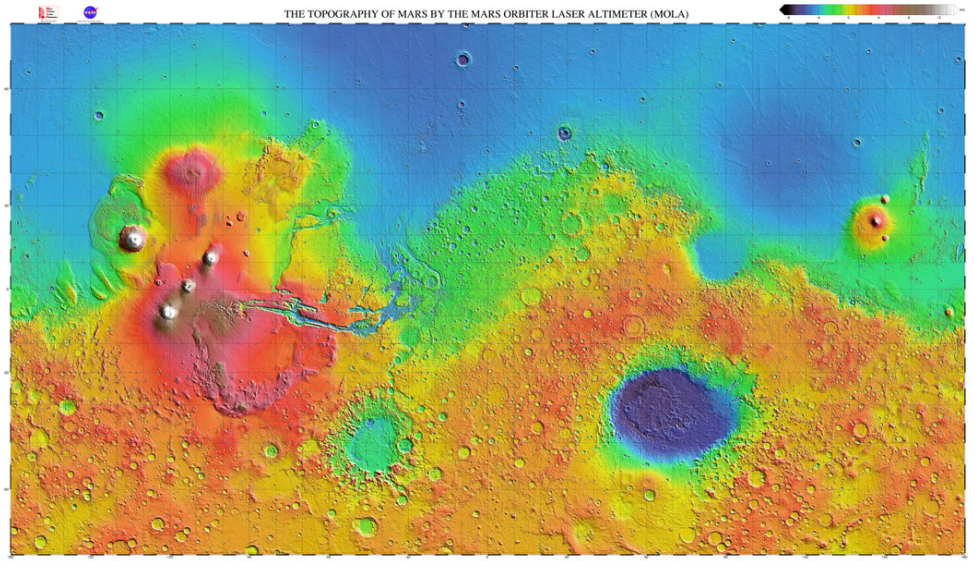

VL2 Frost (water ice)

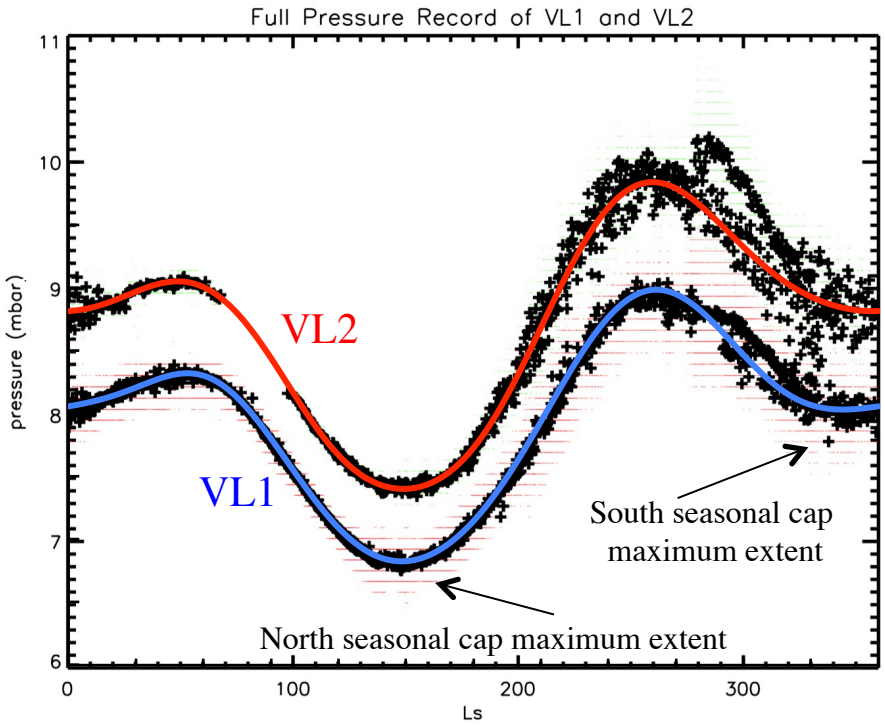
CO_2 frost also detected at night in the tropics

Annual Pressure Cycle

Mean surface pressure: ~ 610 Pa
- No sea level to use as reference
  - Use mean equatorial surface

Extreme topography on Mars
- ~28 km total elevation variation
- Scale height ~11 km
- Surface pressure varies by factor of ~ 13 due to altitude





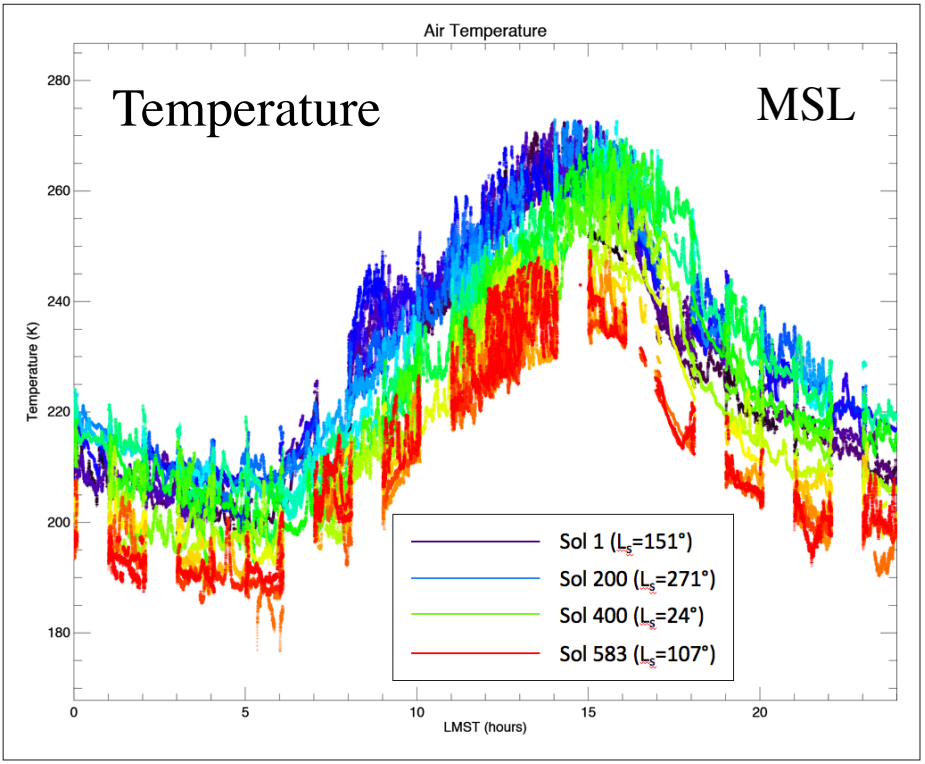
Surface pressure varies seasonally
- Growth & retreat of seasonal CO_2 polar caps
- Two annual minima
  - One for each polar cap

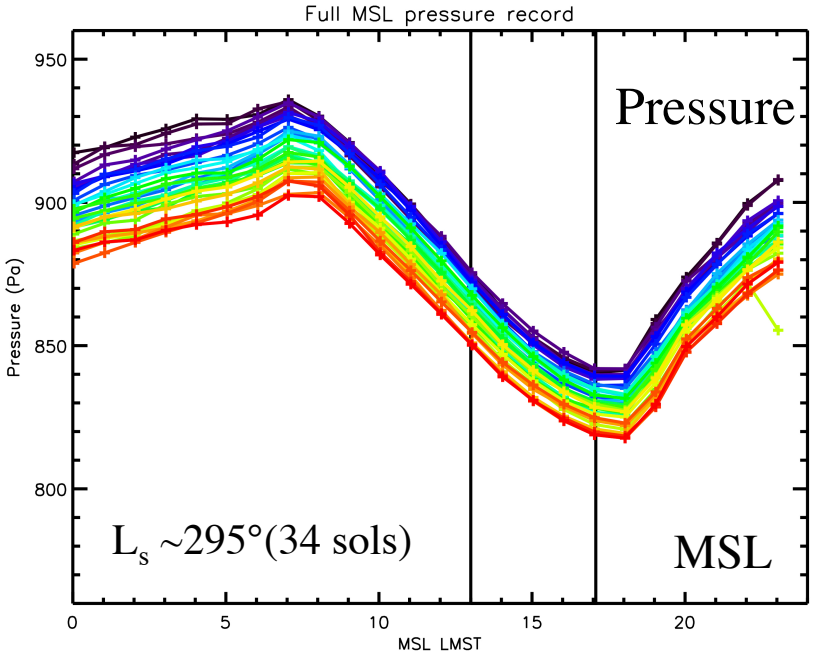
Strong dust storm influence
- Mean pressure variations
- Diurnal pressure variations

Near Surface Diurnal Cycle

Martian near-surface atmosphere undergoes large diurnal cycles

- Variations of surface pressure ~10%
- Variations in surface temperature ~ 100 K
- Strong location and seasonal dependence





Local and regional topography has major role in near-surface and boundary layer

- Thin atmosphere + strong surface heating
- Deep and vigorous convective layer
- Very strong katabatic flows
  - Affect winds and temperatures
- Modulates global thermal tides
- Significant variations in surface pressure

Atmospheric Composition

Gaseous Species	Average Abundance
CO_2	0.960
Ar	0.0193
N_2	0.0189
O_2	0.0014
CO	800 ppm
H_2O	15–1500 ppm
H_2	15 ppm
Ne	2.5 ppm
Kr	0.3 ppm
Xe	0.08 ppm
O_3	10–350 ppb
H_2O_2	10–40 ppb
CH_4	0.7–7 ppb

Isotope Ratio	Value with respect to terrestrial value
$^{13}C/^{12}C$	1.046 ± 0.004
$^{17}O/^{16}O$	1.024 ± 0.005
$^{18}O/^{16}O$	1.048 ± 0.005
$^{15}N/^{14}N$	1.6 ± 0.2
$^{38}Ar/^{36}Ar$	1.26 ± 0.03
$^{40}Ar/^{36}Ar$	6.4 ± 1.0
$^{129}Xe/^{132}Xe$	~2.5
D/H	5.5 ± 1.0

Water vapor is highly variable with season and location

CO_2 varies with season due to polar cap condensation

Dust

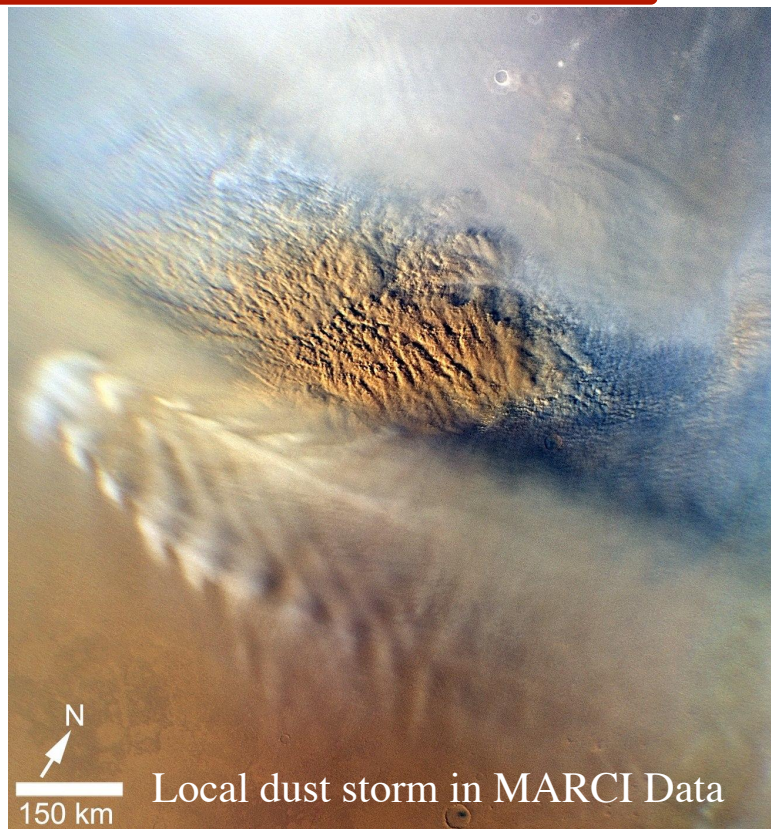
- Dust and dust storms are key drivers of Martian weather and climate
  - Dust in atmosphere absorbs sunlight and heats it
    - Very efficient at heating the atmosphere
  - There can be positive feedback cycles with the dust
    - Atmospheric heating increases the wind speed
    - Higher wind speeds increase amount of dust lifted
- Dust is a fine grained, light toned component of the soil
  - Composition similar to basaltic Martian soil, but enriched in S, Cl and Fe
  - Effective radius is ~1.5 μm
  - Modified gamma distribution

Background amount of dust varies over the MY

- Affects the overall temperature structure
  - More dust -> warmer atmosphere
- Depth of background dust haze varies seasonally and regionally
  - Up to ~40 km around perihelion
  - Frequently see dust layers at 20 km to 30 km

Dust Storms

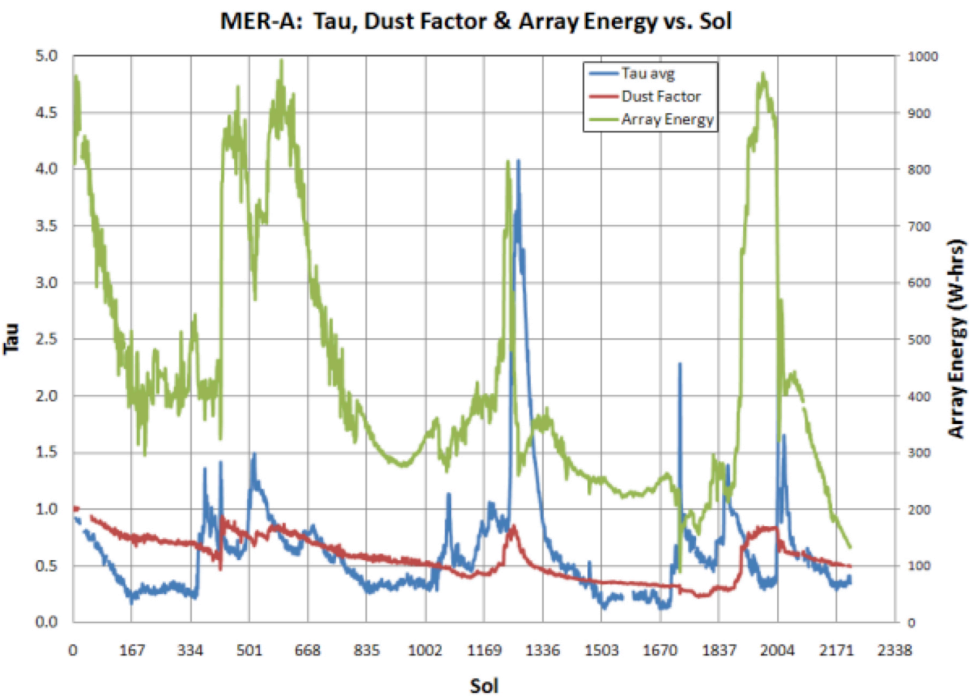
- Dust storms range from local to global
  - Local: last 1 to 3 sols
    - Large effect on atmosphere in lowest ~10 km
  - Regional: 3 sols to few weeks
    - Can leave dust hazes persisting for several weeks
  - Large Regional/Planet Encircling:
    - Affect hemisphere for ~1 month
    - Thermal effects in regions with little or no dust
  - Global:
    - Affect entire atmosphere for 1 to 3 months
    - Large & global changes in the thermal state
    - Density changes can exceed ×20 in places



Local dust storm in MARCI Data

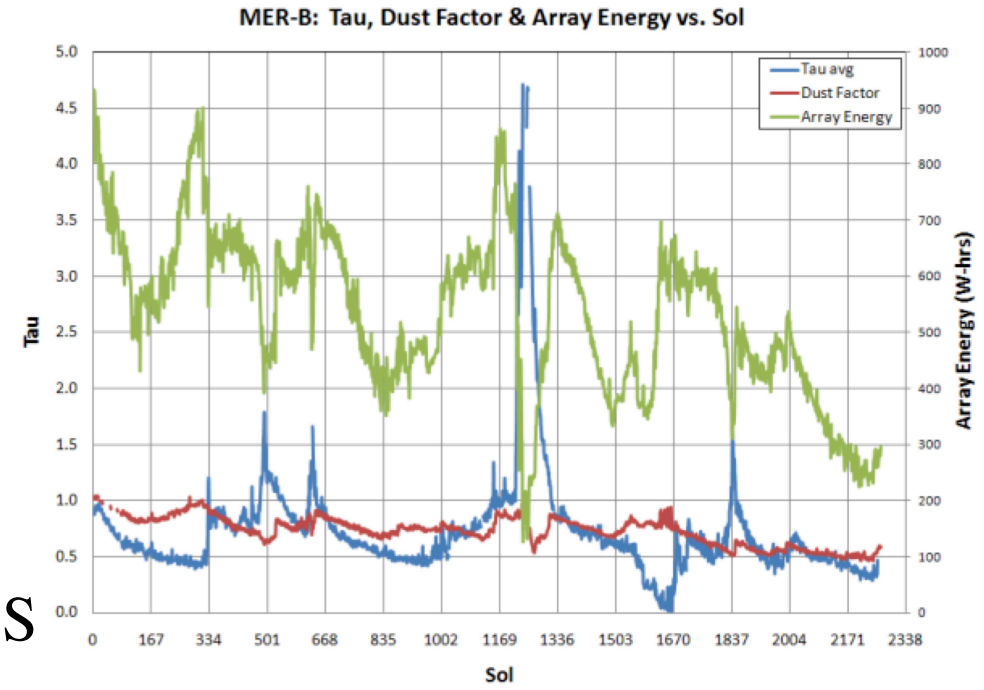
- Dust storms are a regular occurrence
  - Occur in all seasons
  - Largest storms usually during southern spring and summer
  - Local and regional storms have "storm" tracks they follow
    - ➢ Probability of local & regional storms varies strongly with location
  - Storms (esp. large ones) also perturb the surface pressure

Solar Array Performance



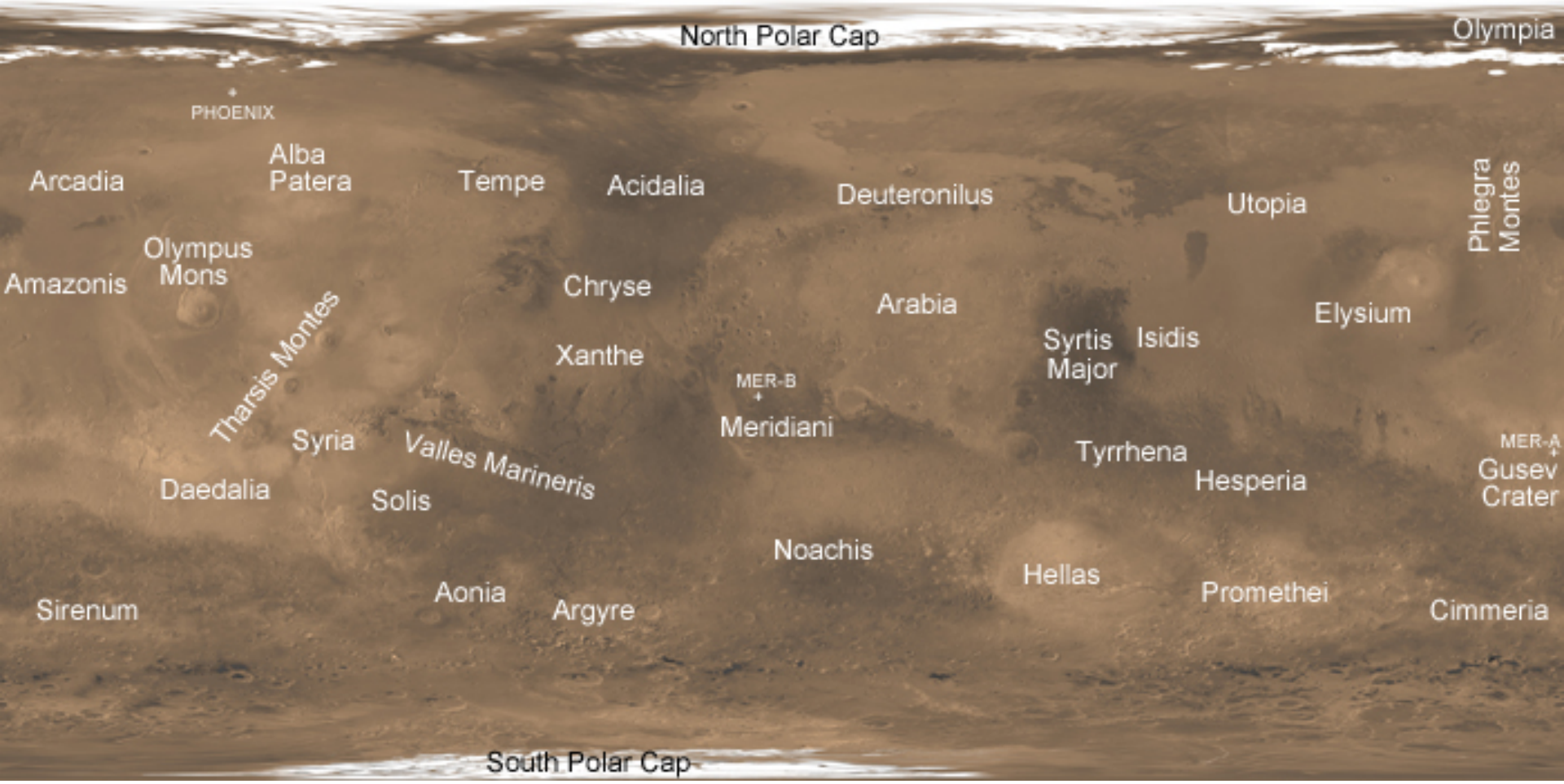
3 1/3 Mars years of MER solar array performance

MER A (Spirit) 14.6° S

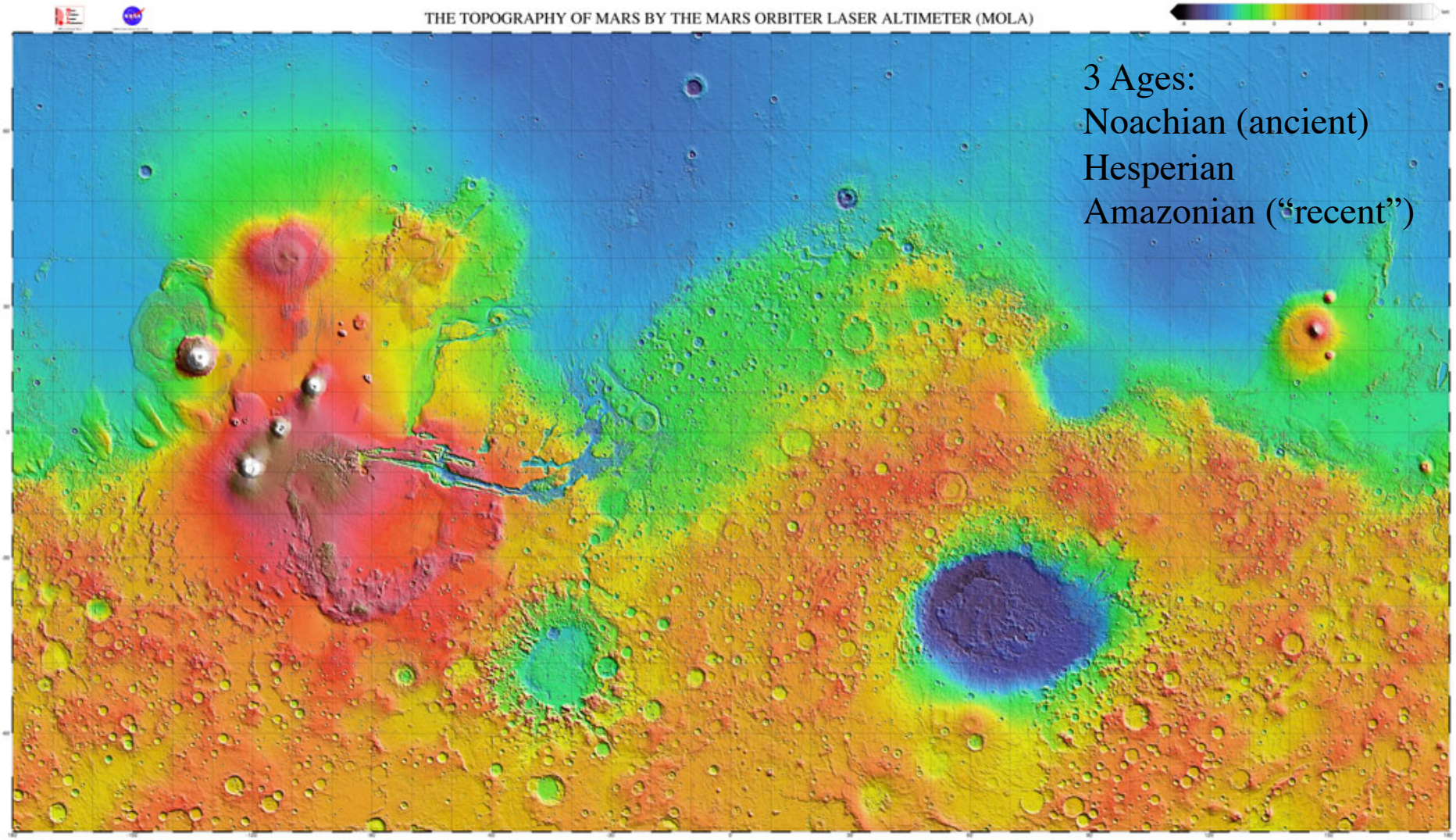


MER B (Opportunity) 2° S

Locations on Mars

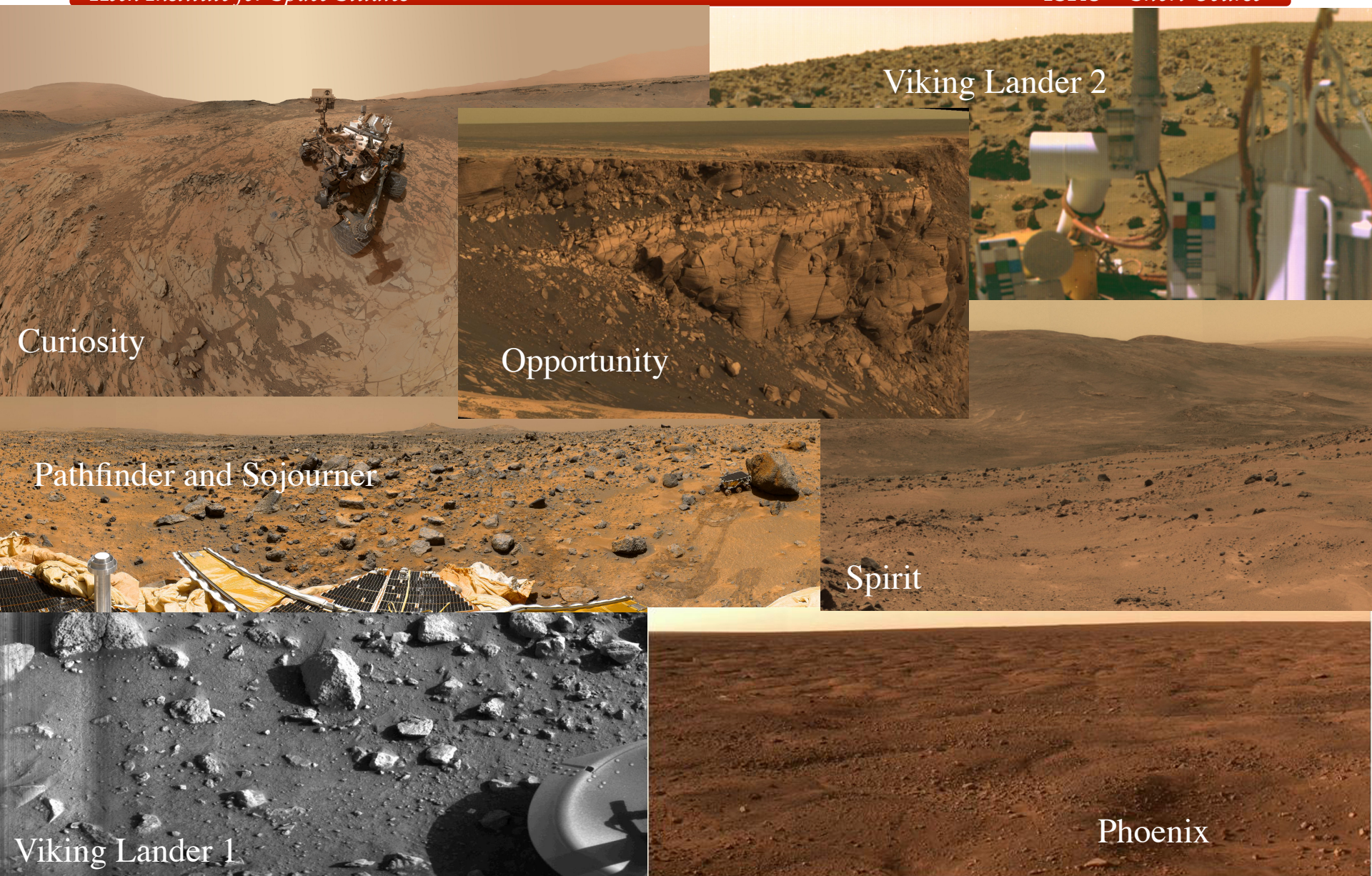


Topography and Terrain

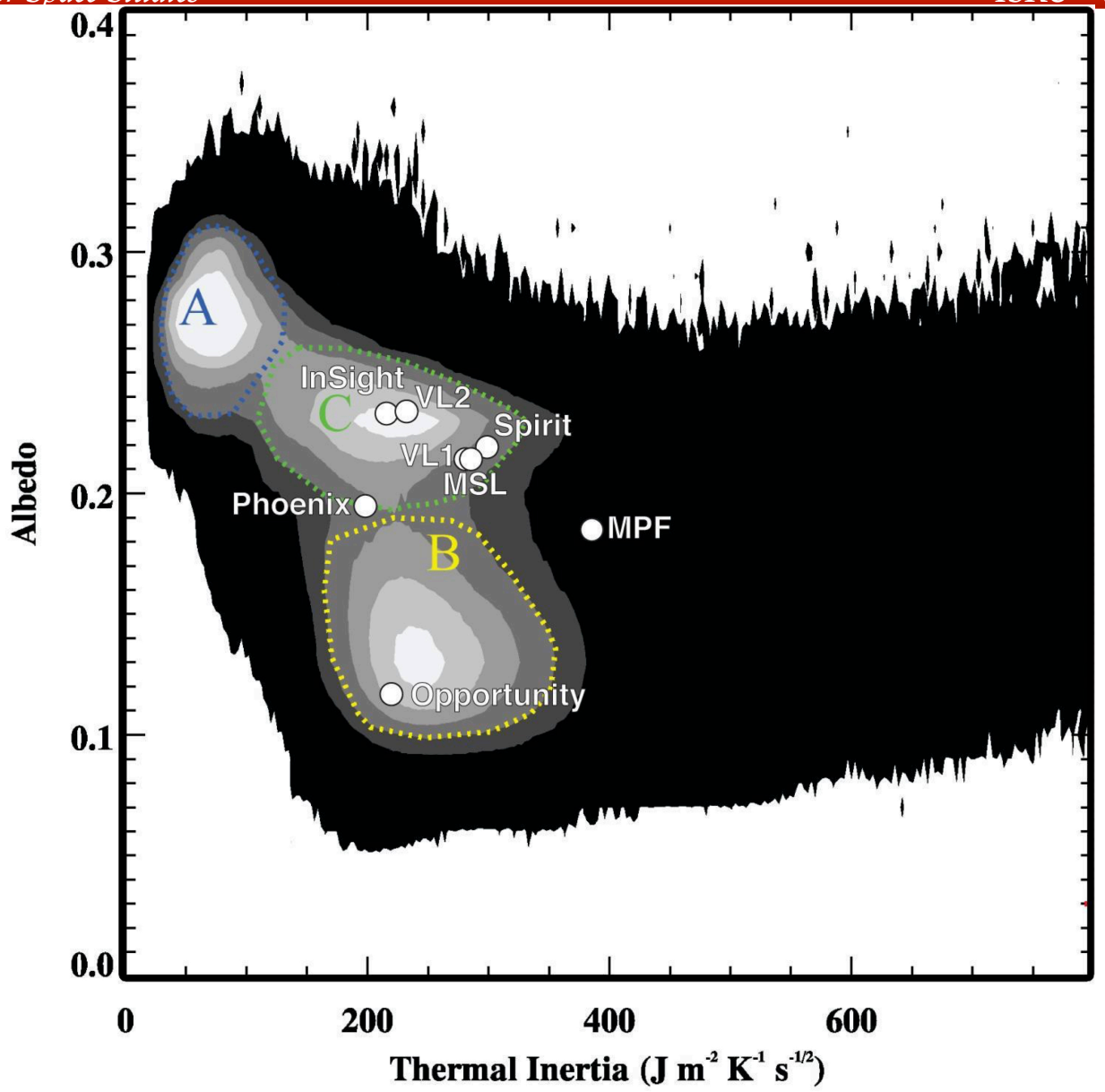


Surface composition is dominated by weathered basalt, when not covered in dust

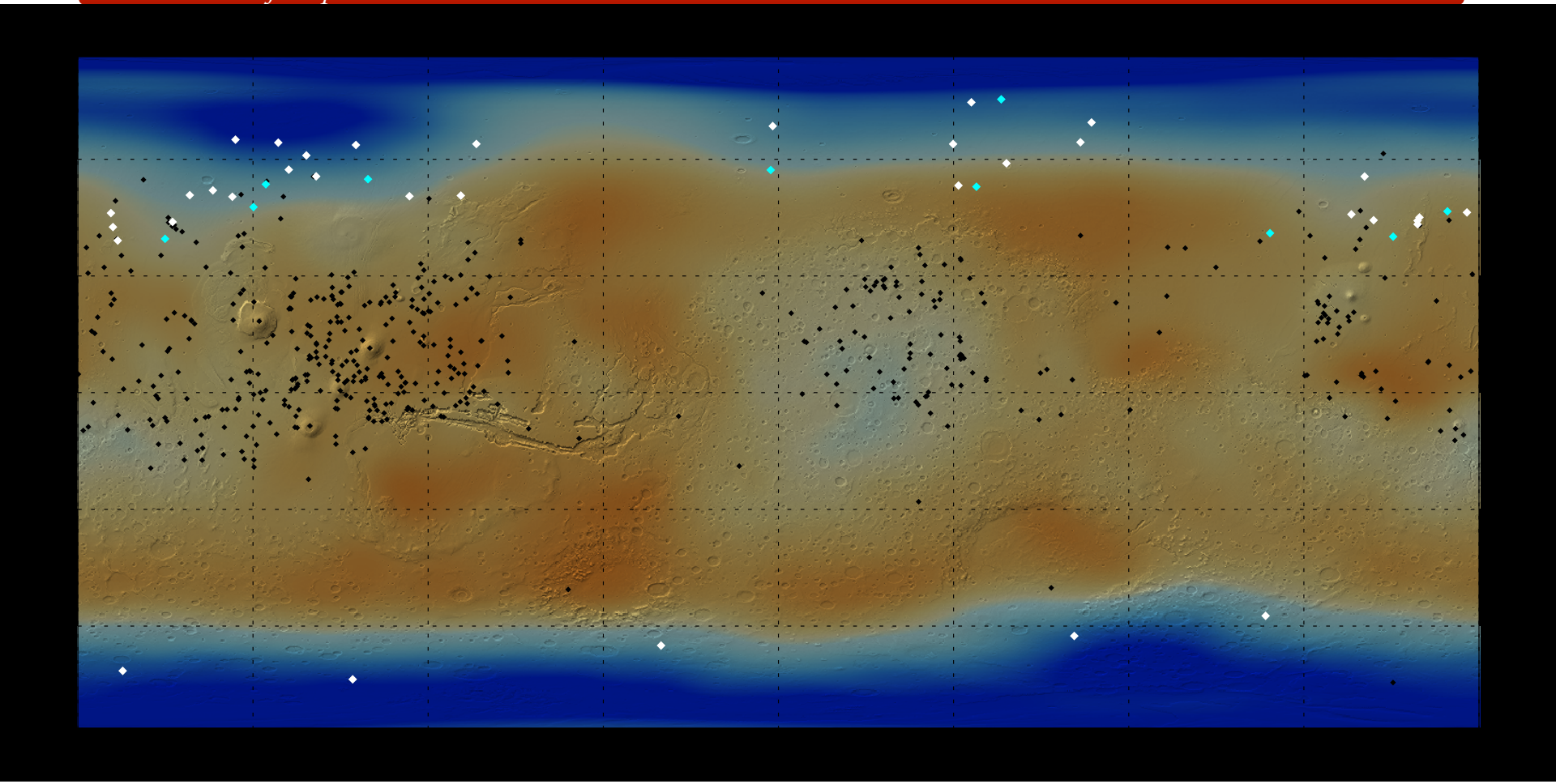
Views of the Surface of Mars



Global Surface Properties

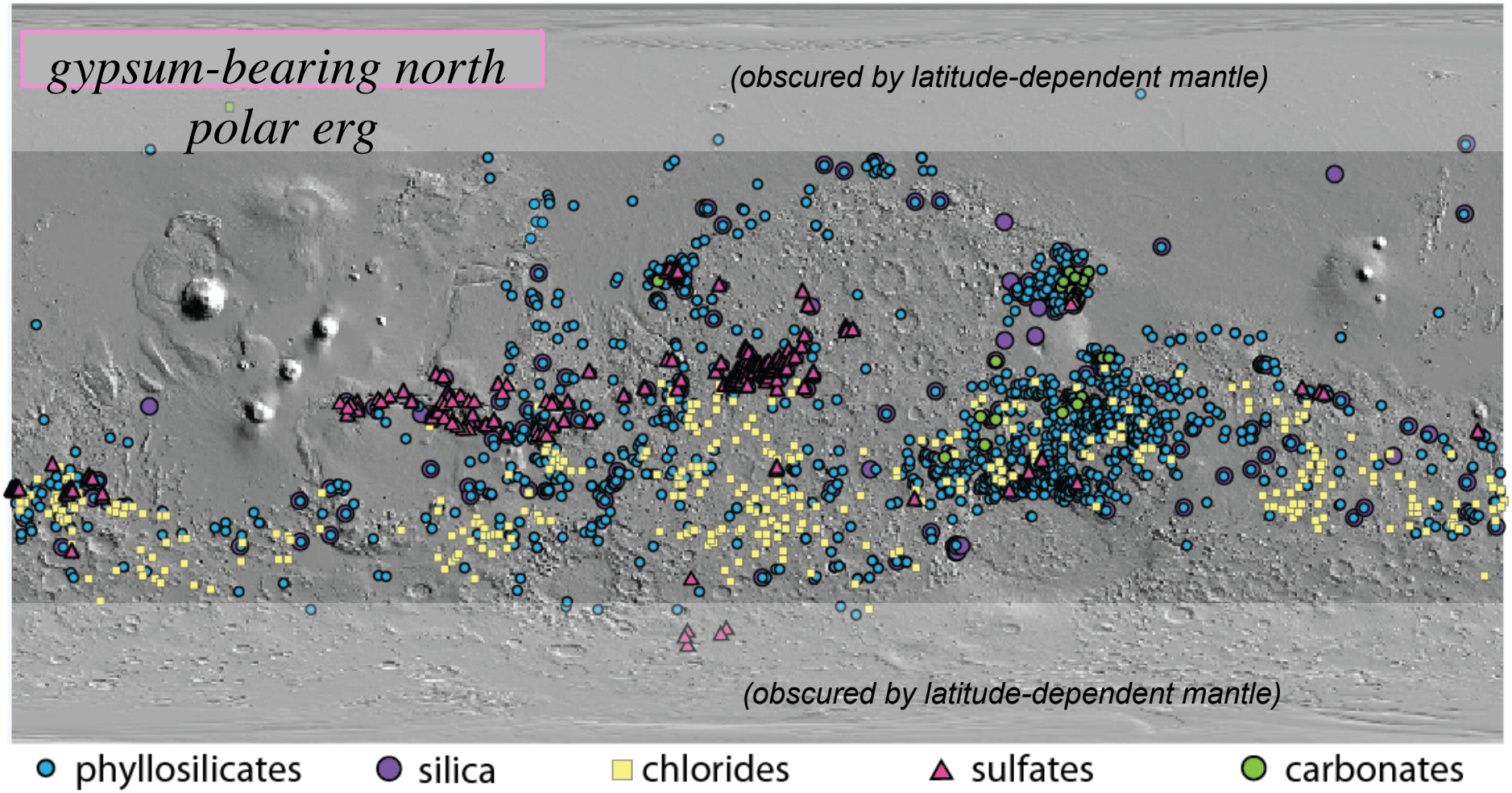


Sub-Surface Water Ice



GRS Hydrogen detection (color map)—blue: high; red: none
Craters: white: icy; black: non-icy; cyan: possible

Summary of Aqueous Mineral Distribution



Mars

Questions?