Mars and the Science Programme
The case for Mars Polar Science

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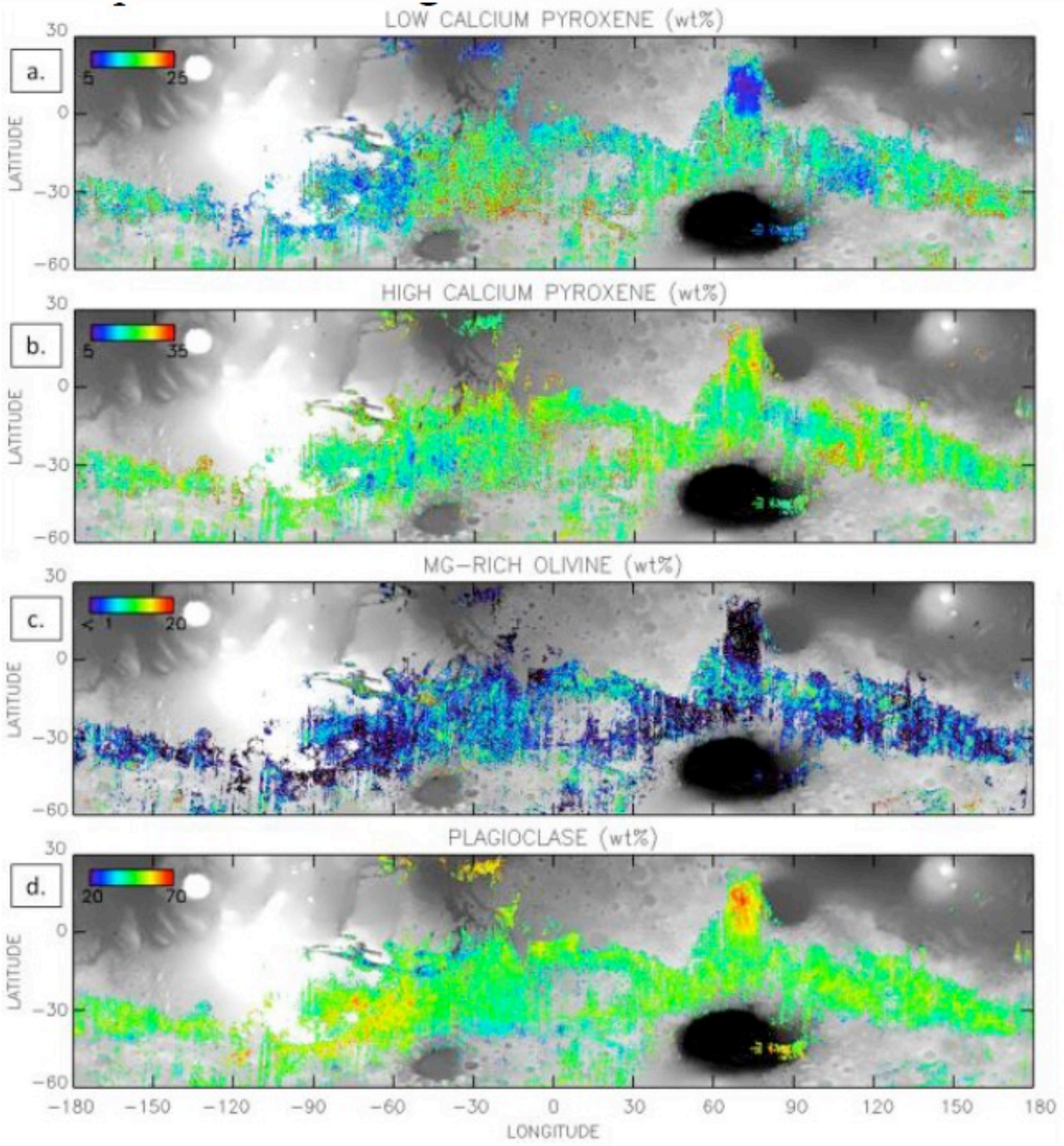
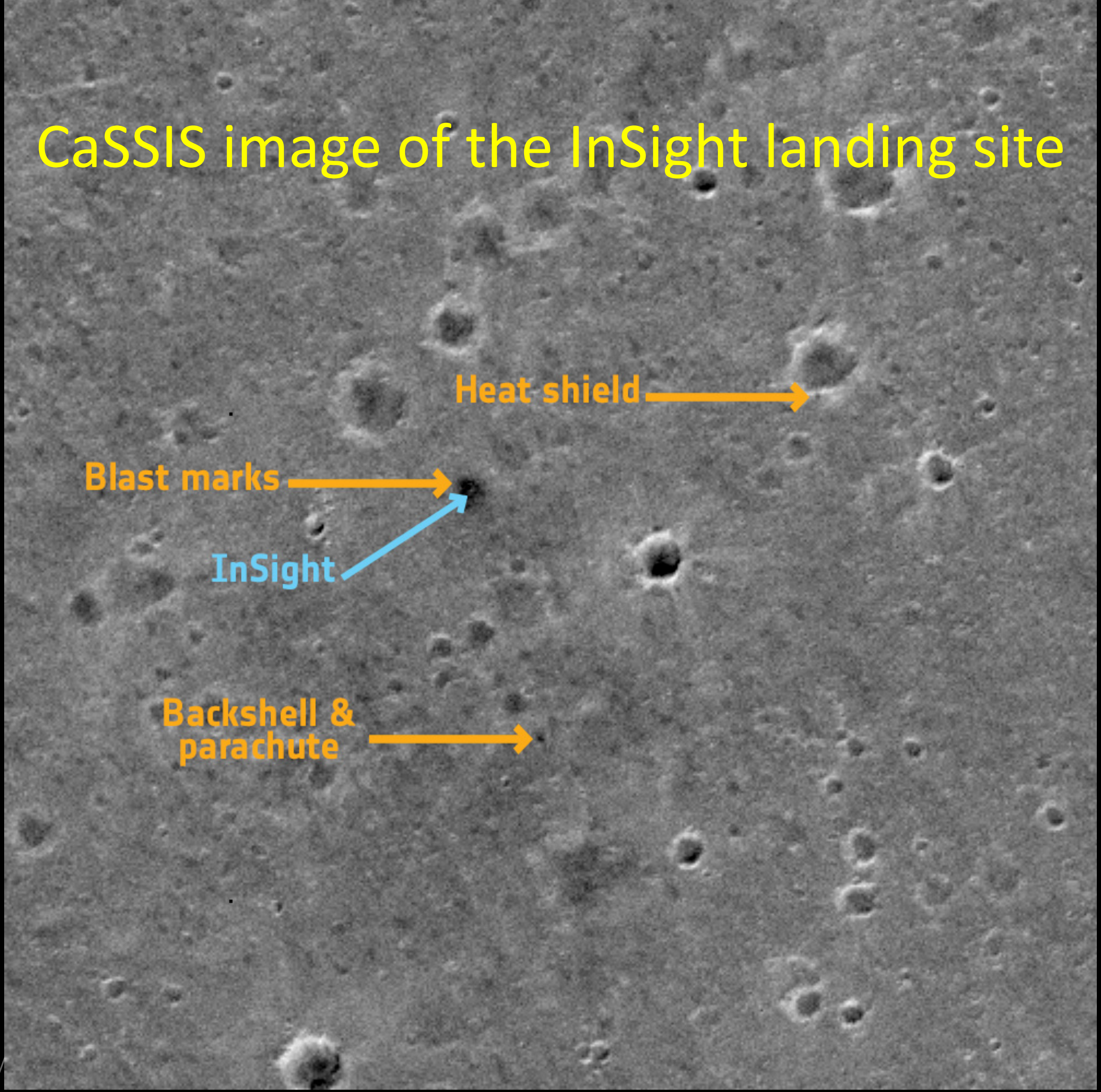


ESA's Science Programme was instrumental in placing Europe into the global Mars community through Mars Express

OMEGA-based maps of Mars showing distributions of minerals on the surface.
(Riu et al., 2018)

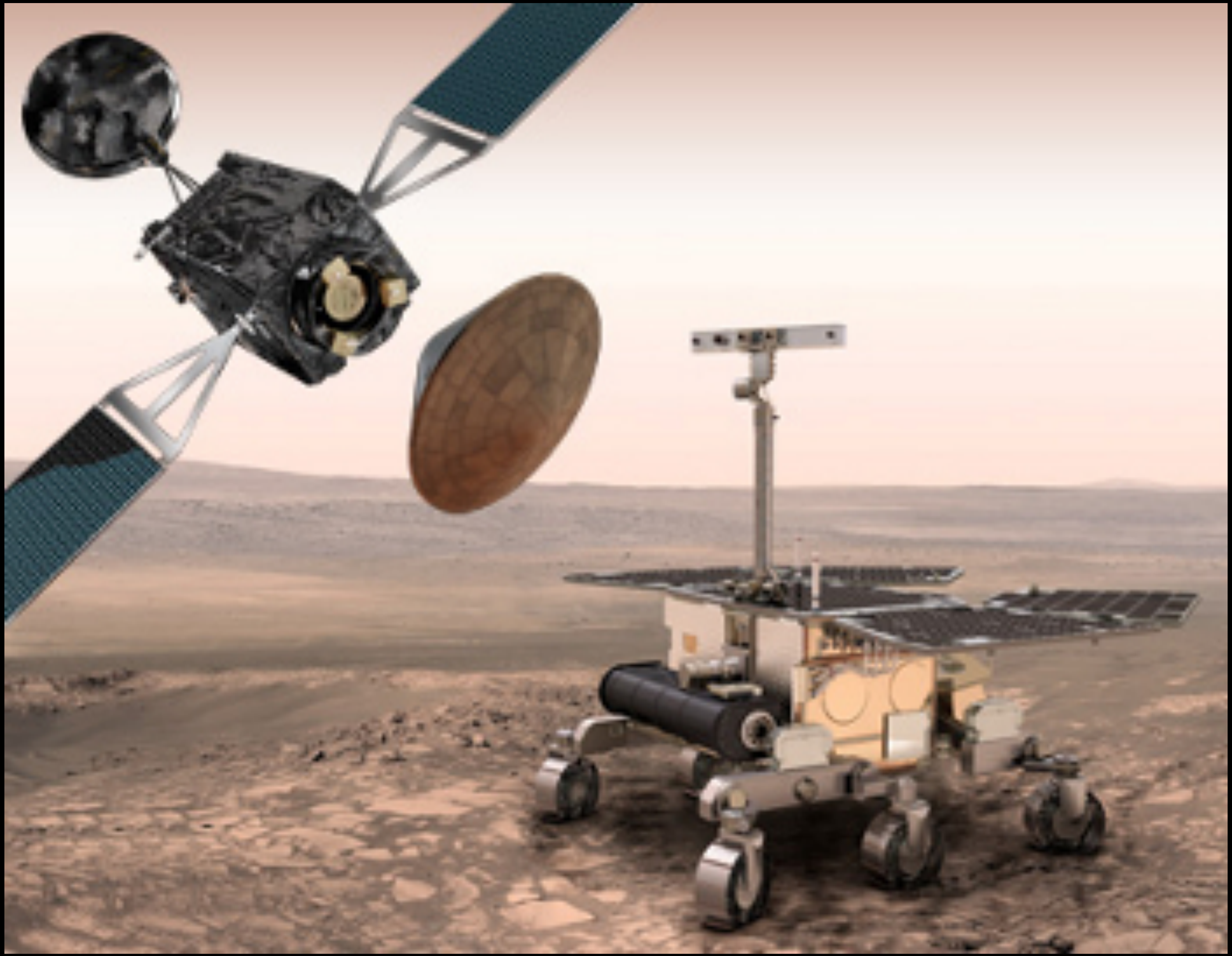
CaSSIS image of the InSight landing site



CaSSIS

Despite several proposals to the Science Programme for network science in the 1990s, eventually NASA attempted interior geophysics of Mars with a mostly European payload onboard InSight.

ExoMars is part of the HRE directorate and therefore in the optional programme



Beyond this is “Sample Return”

But note we already have Martian meteorites in our collections.

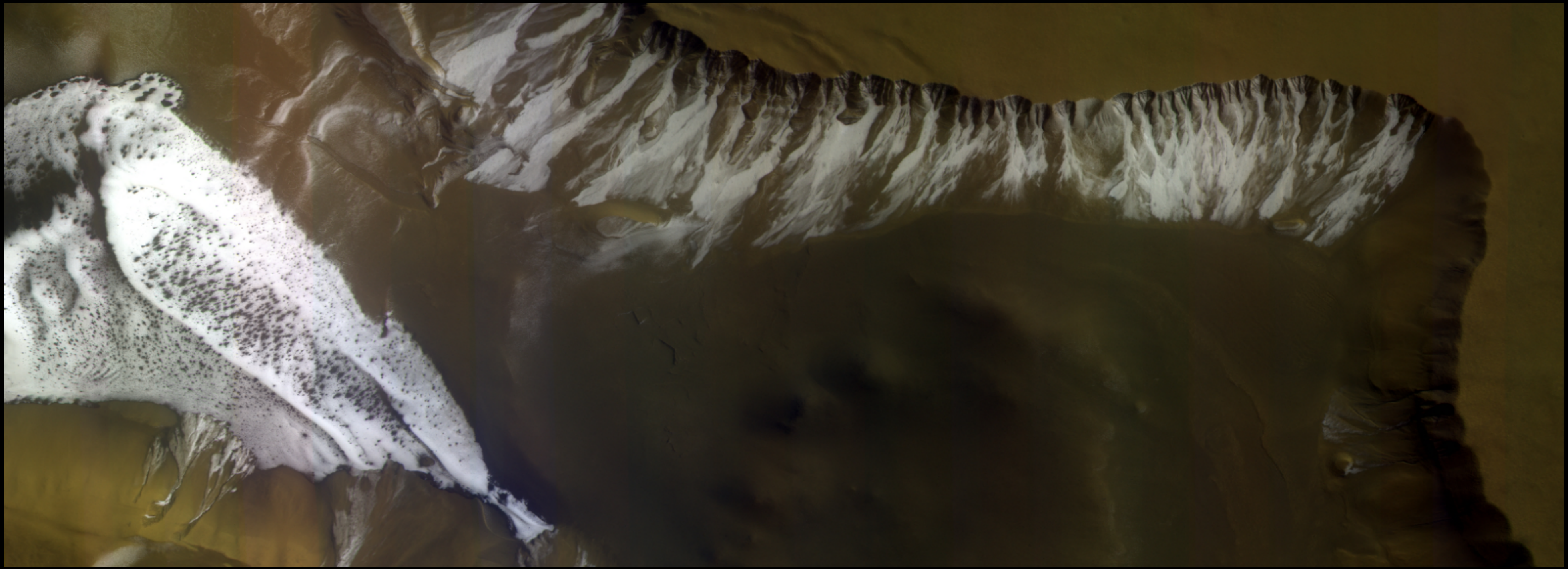
HRE’s web site says that

“NASA’s new Orion vehicle, with a European service module at its core, will build bridges to Moon and Mars by sending humans further into space than ever before.”

HRE’s activities will become “human focused” and that can mean scientifically interesting targets at Mars are likely to be secondary to this goal.

There are numerous targets and investigative goals at Mars that are of major scientific significance but are unlikely to be a goal of the HRE “human focused” programme.

I use Mars Polar Science here as an example

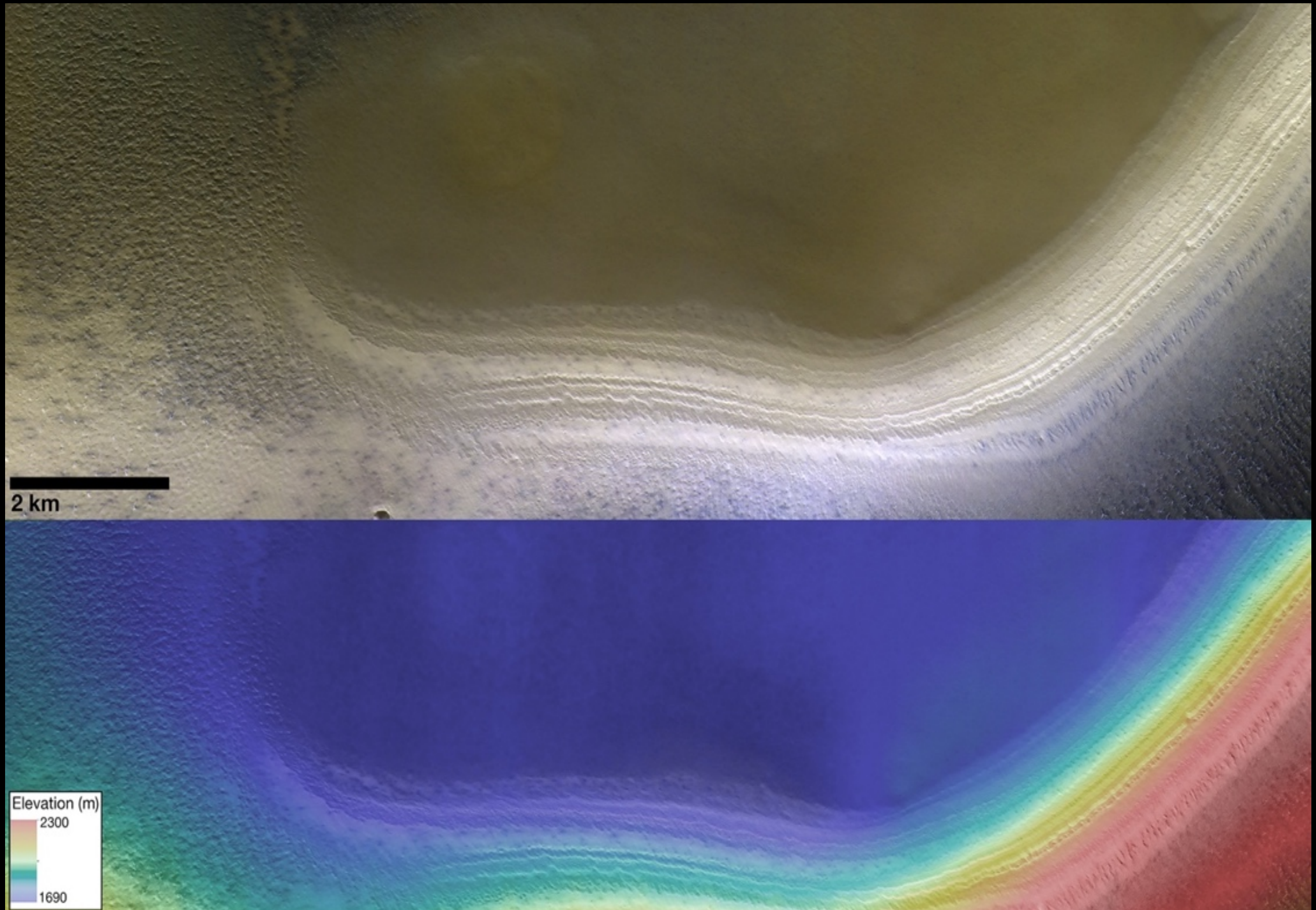


TGO CaSSIS image of melting seasonal CO_2 deposits.

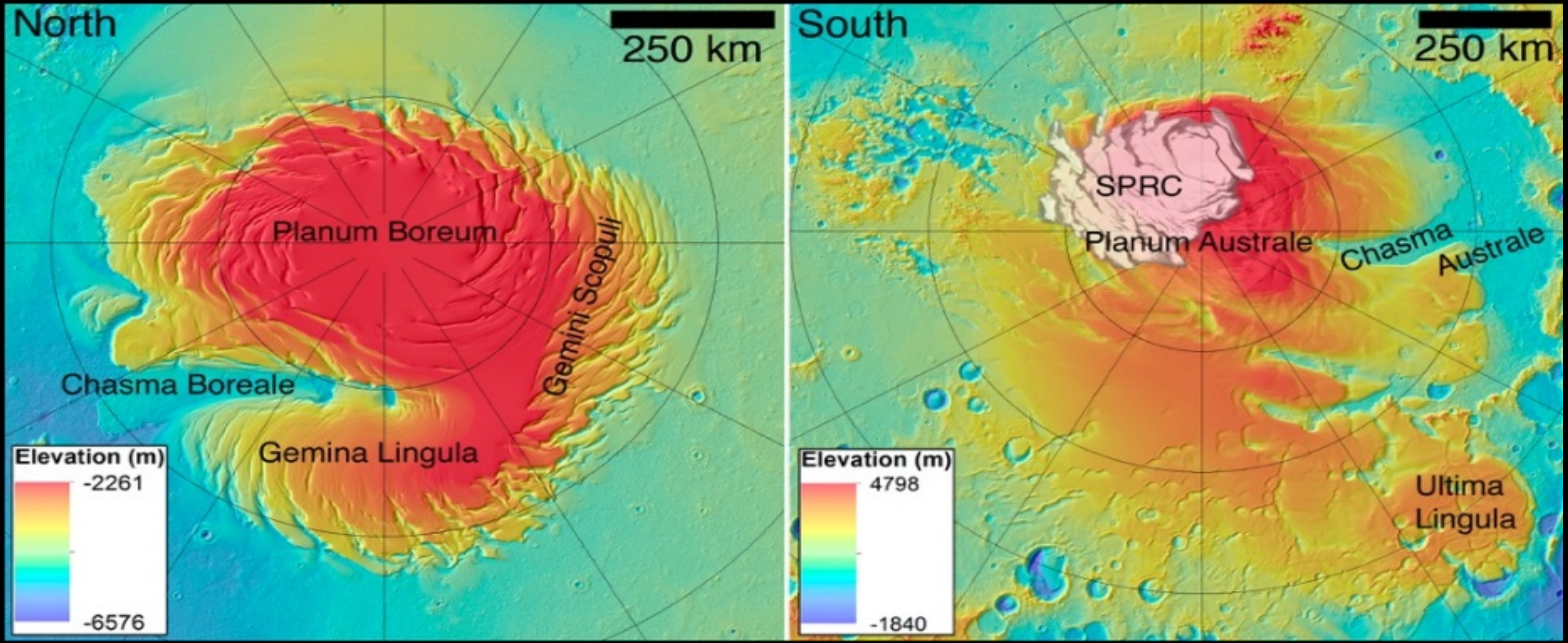
Motivation

- Understand the interactions of current climate with icy deposits.
- Understand the climate history of Mars during the Amazonian period.
- Understand climate variation generally on a simplified terrestrial planet.

Example: South polar layered deposits observed here with CaSSIS. Stacked sheets (layers) have been emplaced over the past 30-100 million years. (NPLD are younger ~ 5 My.) Sublimation lag deposits make this uncertain.



Polar caps of Mars



Mars Express/HRSC

Internal layers exposed by asymmetric spiral troughs
(initiated partway through the NPLD history)
Typically only a few 100m in relief
Gradients are not extreme (mean <5 degrees).

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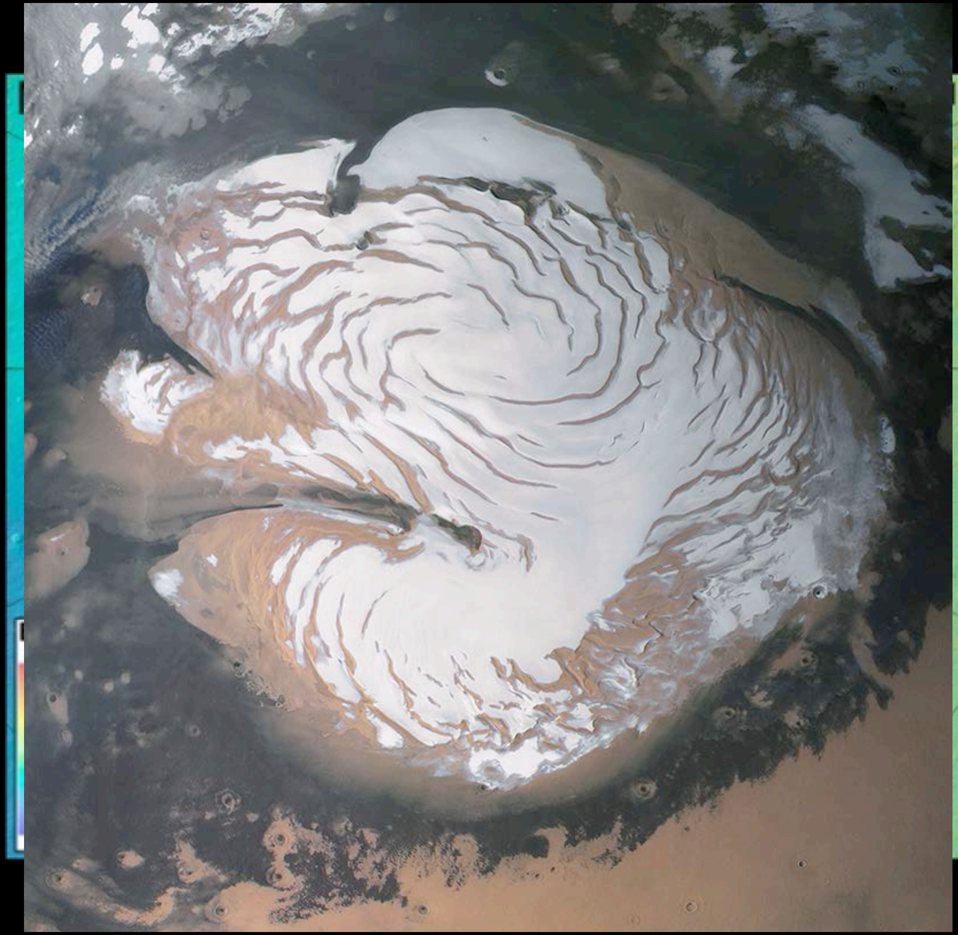

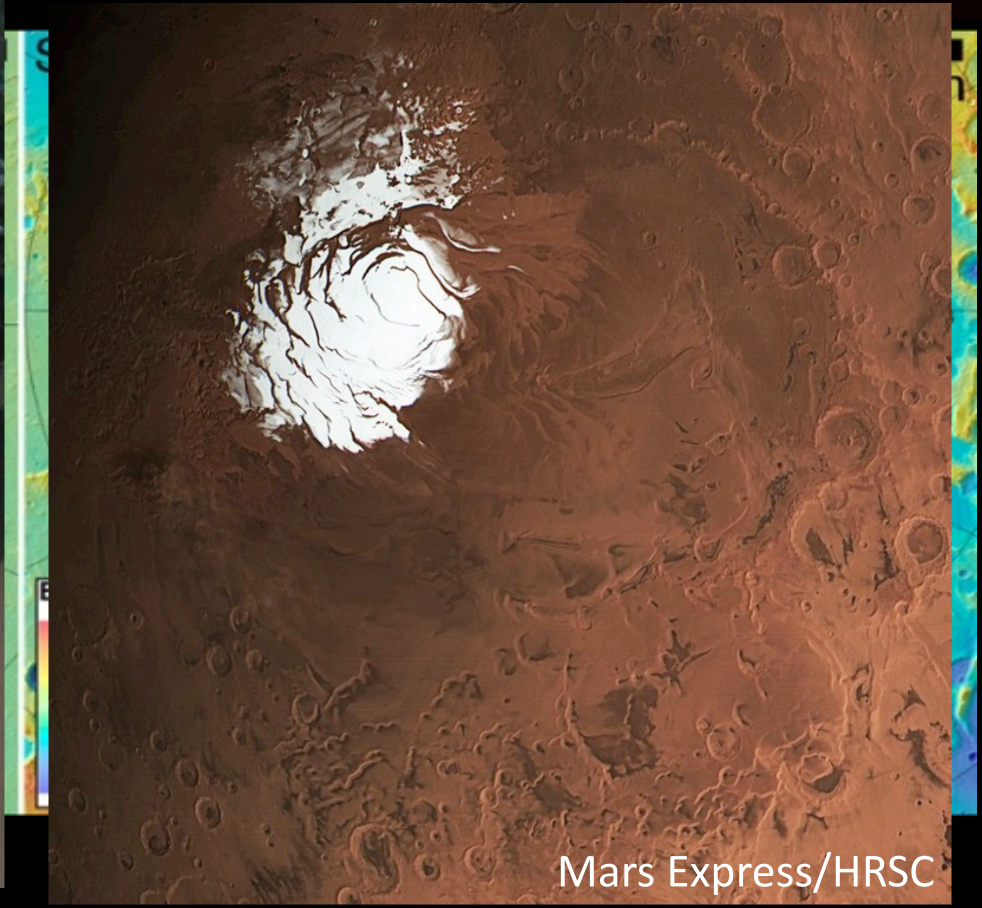

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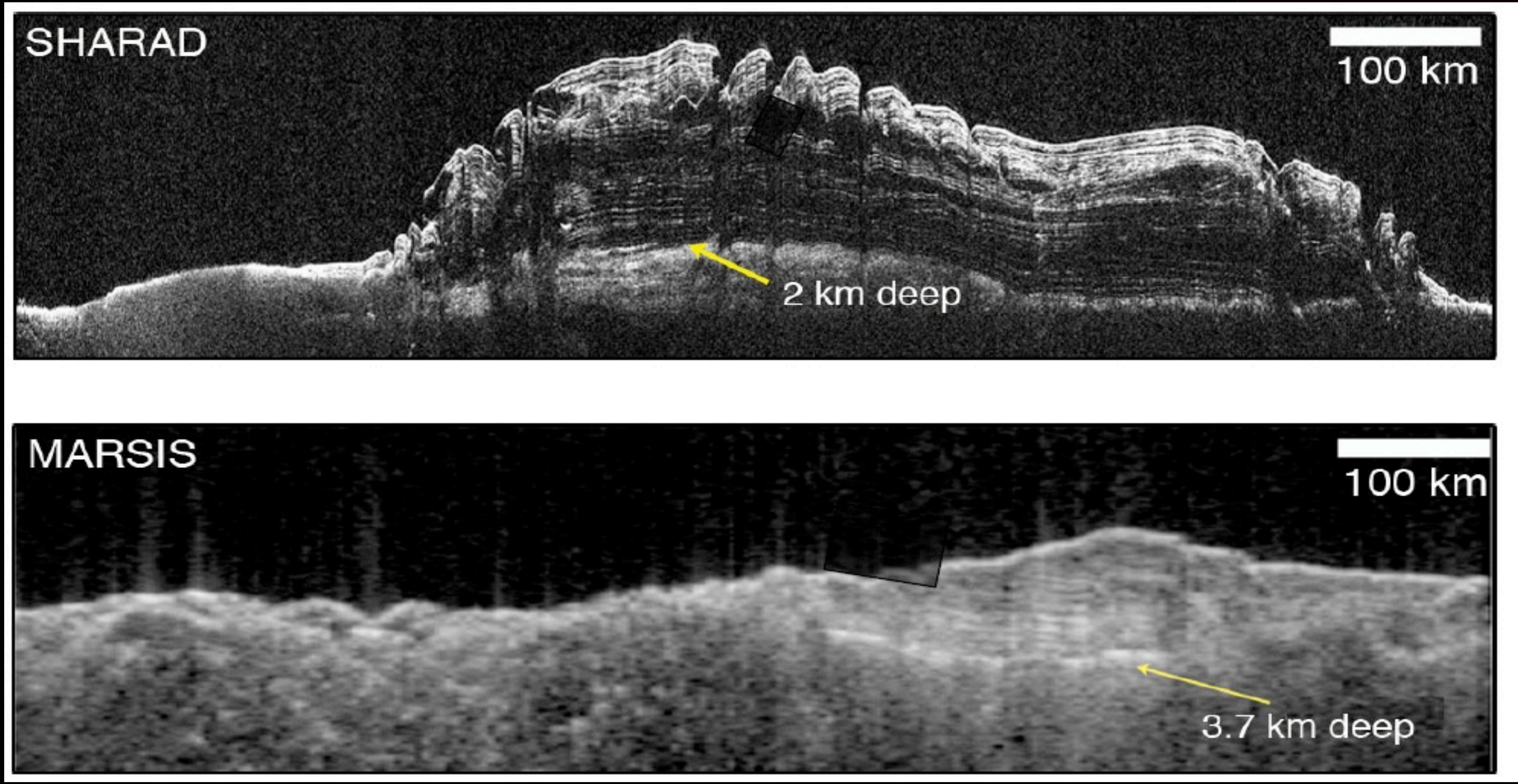
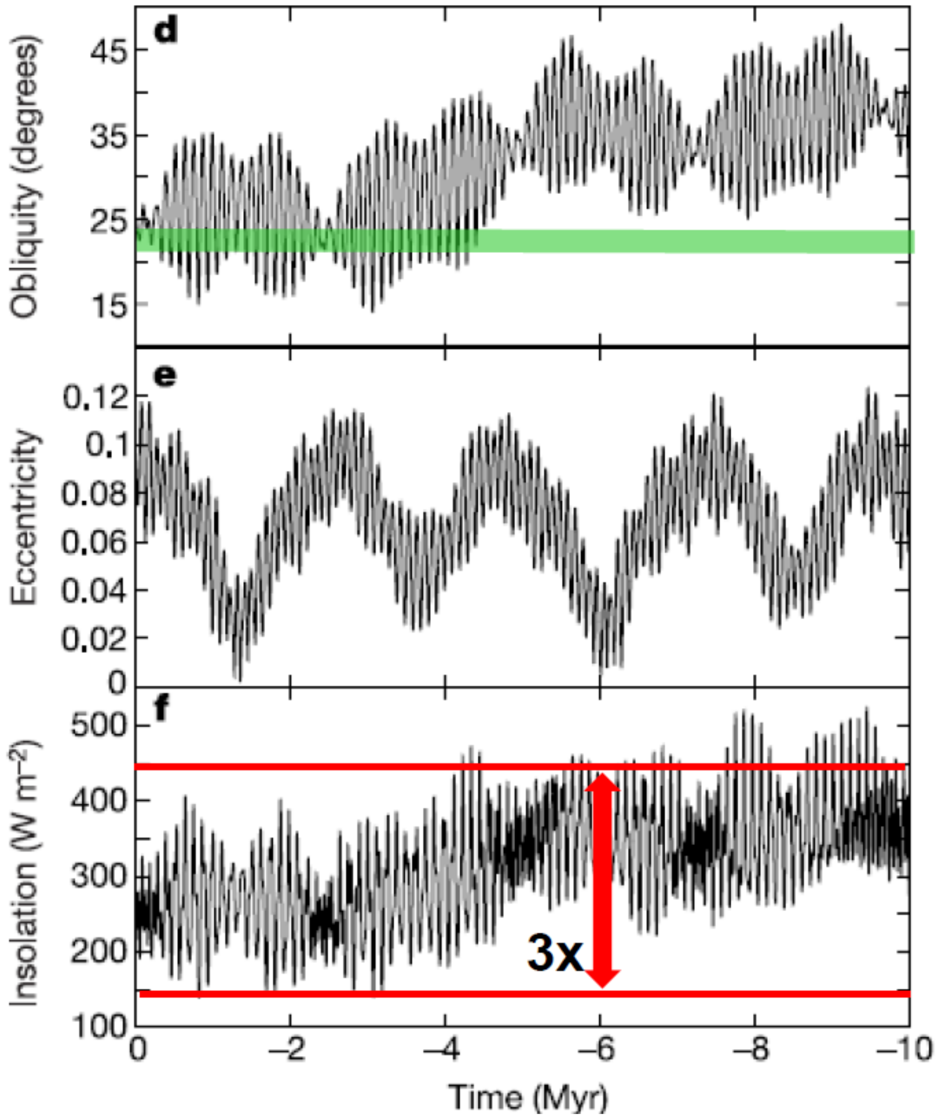
Radar observations of layering



Layering is not local. Layers can be traced from one side of the cap to the other.
(E.g. Fishbaugh and Hvidberg, 2006; Fishbaugh et al., 2010; Whitten and Campbell, 2018).



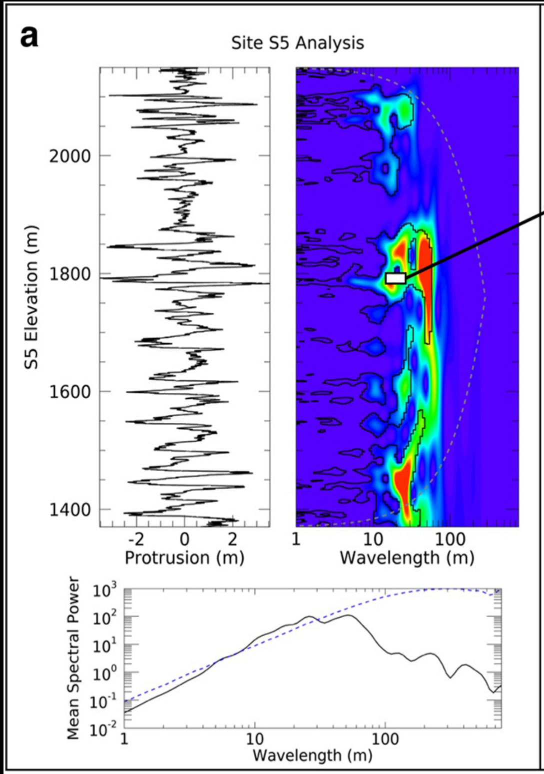
Orbit calculations indicate periodicities in the changing obliquity and eccentricity of the planet and resultant changes in the polar insolation over the past 20 million years.

These changes influence the transport of water vapour and the polar deposition rates and this is recorded in the layering. Periods of sublimation are self-limiting in that ablation of ice builds up dust lags and dust is very insulating. (It is also the most difficult to model.)

Laskar, J., Levrard, B. & Mustard, J. F.
Orbital forcing of the martian polar layered deposits. Nature 419, 375–377, 2002

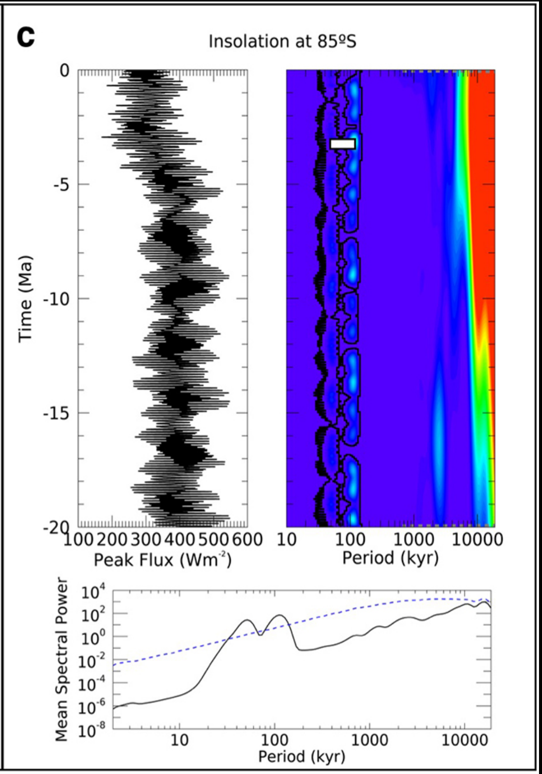
Analysis of Climate Change

- The elevations and colour of the layers have been used in wavelet analyses to compare with the frequencies evident in the orbital evolution models.



b

Protrusion Profile	Long Wavelength: Wavelength (m)	Long Wavelength: Error (m)	Short wavelength: Wavelength (m)	Short wavelength: Error (m)	Ratio: Ratio	Ratio: Propagated Error
S2	39	7	12	2	3.25	0.80
S5	26	3	11	2	2.36	0.51
S6	13	4	8	2	1.63	0.64
S8	26	4	17	3	1.53	0.36
S9	19	3	10	1	1.90	0.36
S11	37	6	20	4	1.85	0.48
S12	34	4	18	3	1.89	0.39
S13	45	7	20	3	2.25	0.49
S15	35	9	13	9	2.69	1.99
Total Mean ± Prop. Err.	**31**	**2**	**15**	**2**	**2.07**	**0.31**
Std. Deviation	**11**		**5**			
AM Mean ± Prop. Err.	**37**	**6**	**20**	**4**	**1.85**	**0.48**
AS Mean + Prop. Err.	**16**	**3**	**9**	**1**	**1.78**	**0.35**
Std. Deviation	**5**		**2**			
PL Mean ± Prop. Err.	**26**	**3**	**11**	**2**	**2.36**	**0.51**
UL Mean + Prop. Err.	**36**	**3**	**16**	**3**	**2.25**	**0.46**
Std. Deviation	**7**		**4**			
PUL Mean + Prop. Err.	**35**	**3**	**16**	**2**	**2.19**	**0.33**
Std. Deviation	**8**		**4**			



NPLD: Becerra et al. GRL (2017) SPLD: Becerra et al. GRL (2019)

However .....

- This simple picture is probably naive.
- There are inconsistencies between this interpretation and the cratering records on the PLDs.
- And there are also numerous processes of considerable interest active today.

Russell et al. GRL (2008)
HiRISE image ESP_016423_2640 showing an avalanche from a scarp that cuts into the margins of the topographical dome of Planum Boreum in the north polar region of Mars (~83˚ N).

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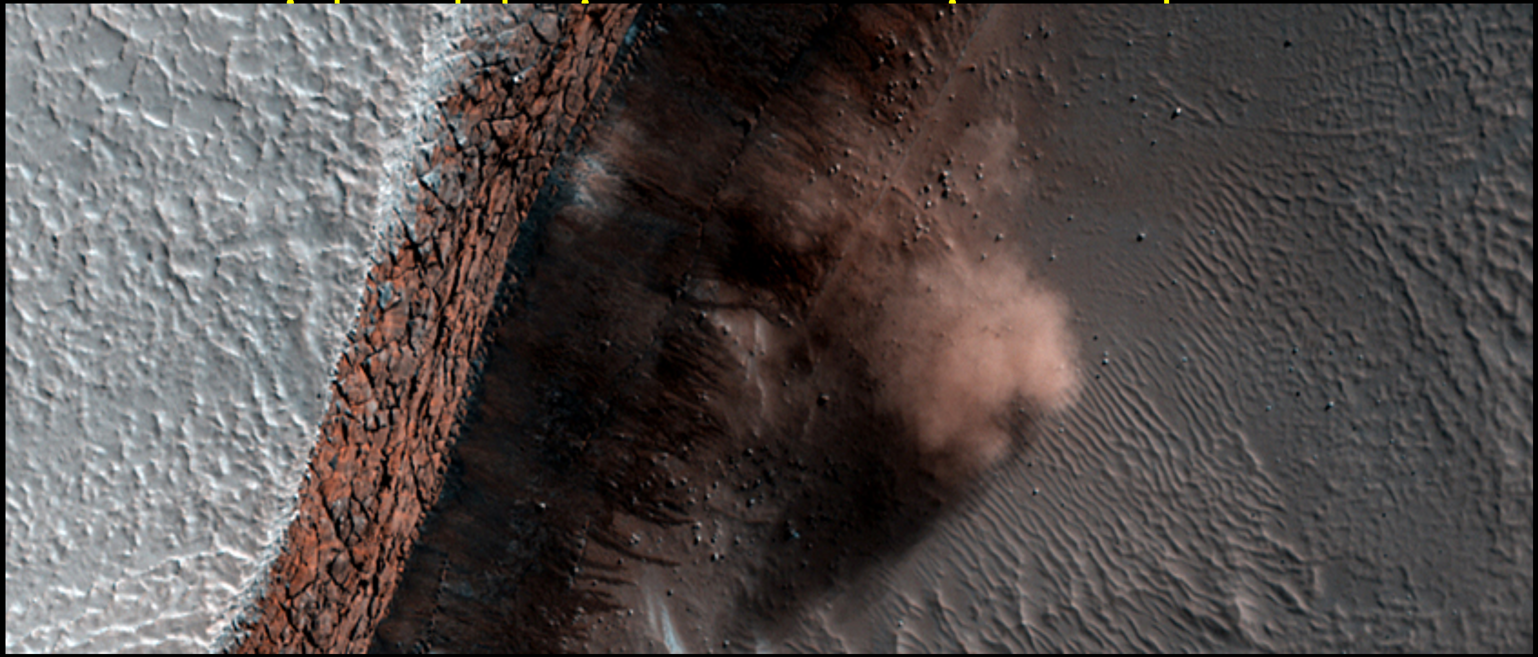

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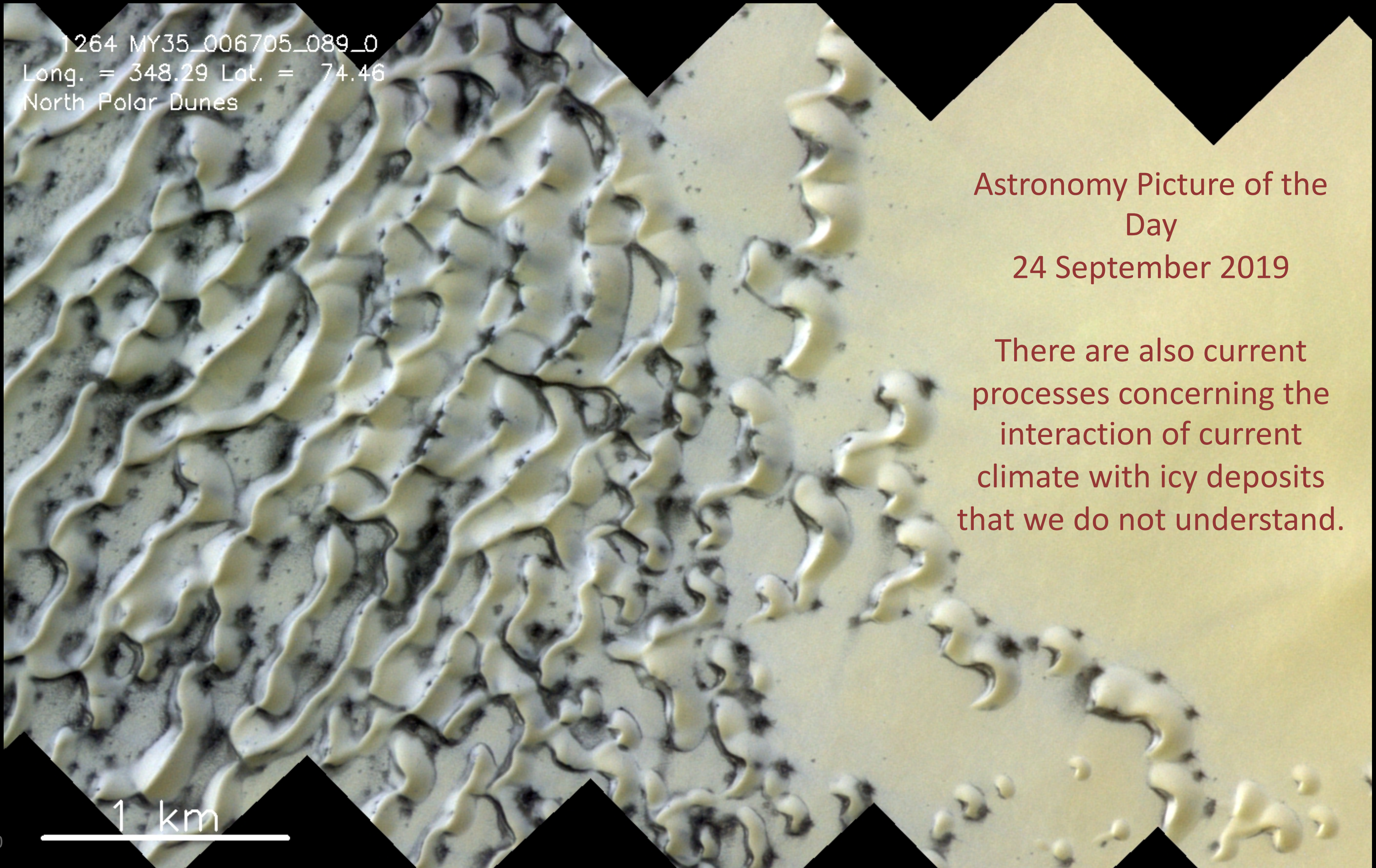
North Polar Dunes

Ls=30.2°



Astronomy Picture of the Day
24 September 2019

There are also current processes concerning the interaction of current climate with icy deposits that we do not understand.

Possible Top Level Objectives

- What are present and past fluxes of volatiles, dust, and other refractory materials into and out of the polar regions?
- How does orbital forcing and exchange with other reservoirs, affect those fluxes?
- What chemical and physical processes form and modify layers?
- What is the timespan, completeness, and temporal resolution recorded in the PLD?

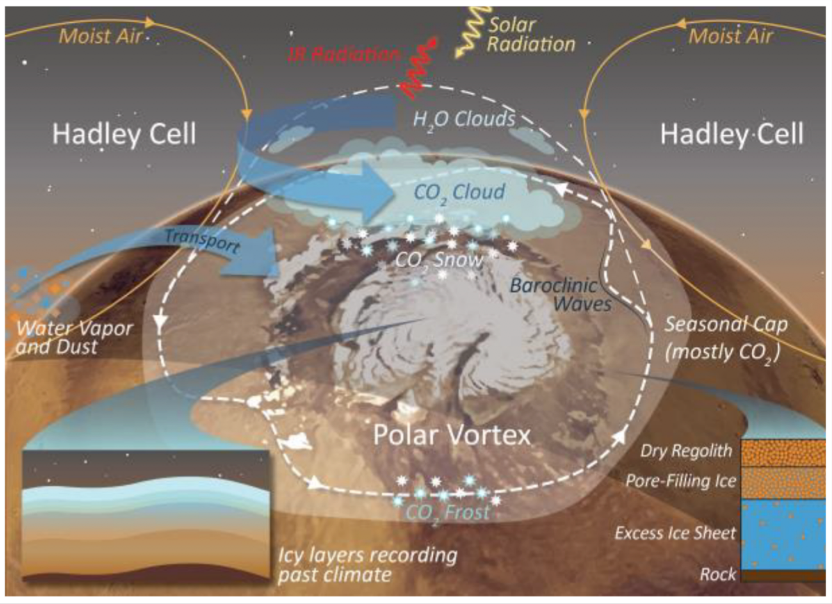
Smith et al., 2019, submitted
“Unlocking the Martian climate record”
Reproduced in the White Paper

Other objectives of note

- Why is there a difference in composition between the two residual caps?
- What are the processes involved in the emplacement and removal of CO_2 ice on the caps?

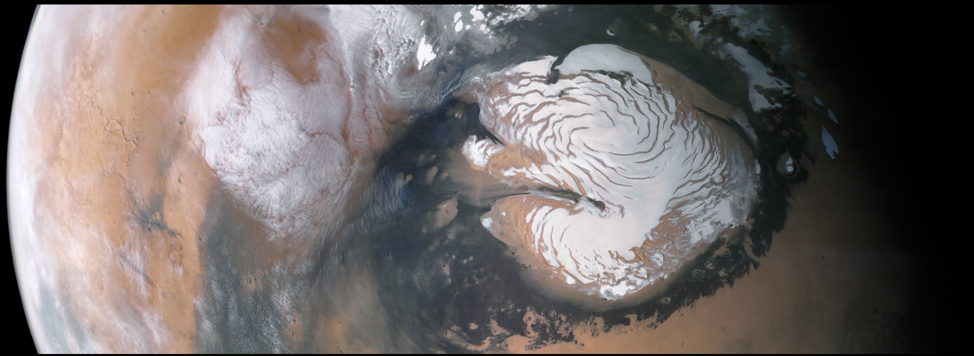
So what could we do?

- Orbit studies with
  - high frequency radar, (better res. on layers)
  - high precision gravity field measurements (better knowledge of current mass transfer)
  - high spatial resolution spectrometers (better knowledge of cap composition from orbit).



COMPASS

Climate Orbiter for Mars Polar Atmospheric and Subsurface Science



U. Arizona proposal to NASA's Discovery programme. Direct product of a CalTech study.

http://kiss.caltech.edu/workshops/polar/polar.html

Drills, rovers, and drones

- Discovery is constraining, but …..
  - Multiple static landers
    - To measure atmospheric properties and fluxes (condensation/sublimation/dust) over the cap(s).
  - Melting/drilling through the uppermost layers to get recent records with a large lander.
    - Mars Mini-Cryobot to melt through the top 80 m of ice proposed in 2007. NASA has been conducting tests in Antarctica with similar systems (SPINDLE).
    - Ice coring systems have been studied by Honeybee Robotics (cf. Rosetta?)
  - Driving up the layered terrains (slopes are not steep in places) and sampling layers.
  - Flying up layered terrains to investigate specific layers at key times in recent Martian history (cf. Dragonfly).

CaSSIS

Stone Aerospace concept from 2015

JPL's Mars Helicopter Scout

Summary

- There are science objectives at Mars that are clearly within the remit of the Science Programme and should be stated as such.

- There is a strong case for investigations of the polar caps to look at the recent history of the Martian climate.

- The interest on both sides of the Atlantic suggests that joint missions/programmes (e.g. within New Frontiers, if approved in next Decadel) are conceivable to maximize the science return.

- There are numerous items to be studied; melting probes, drones in Martian conditions, low temperature long timescale survival, etc.