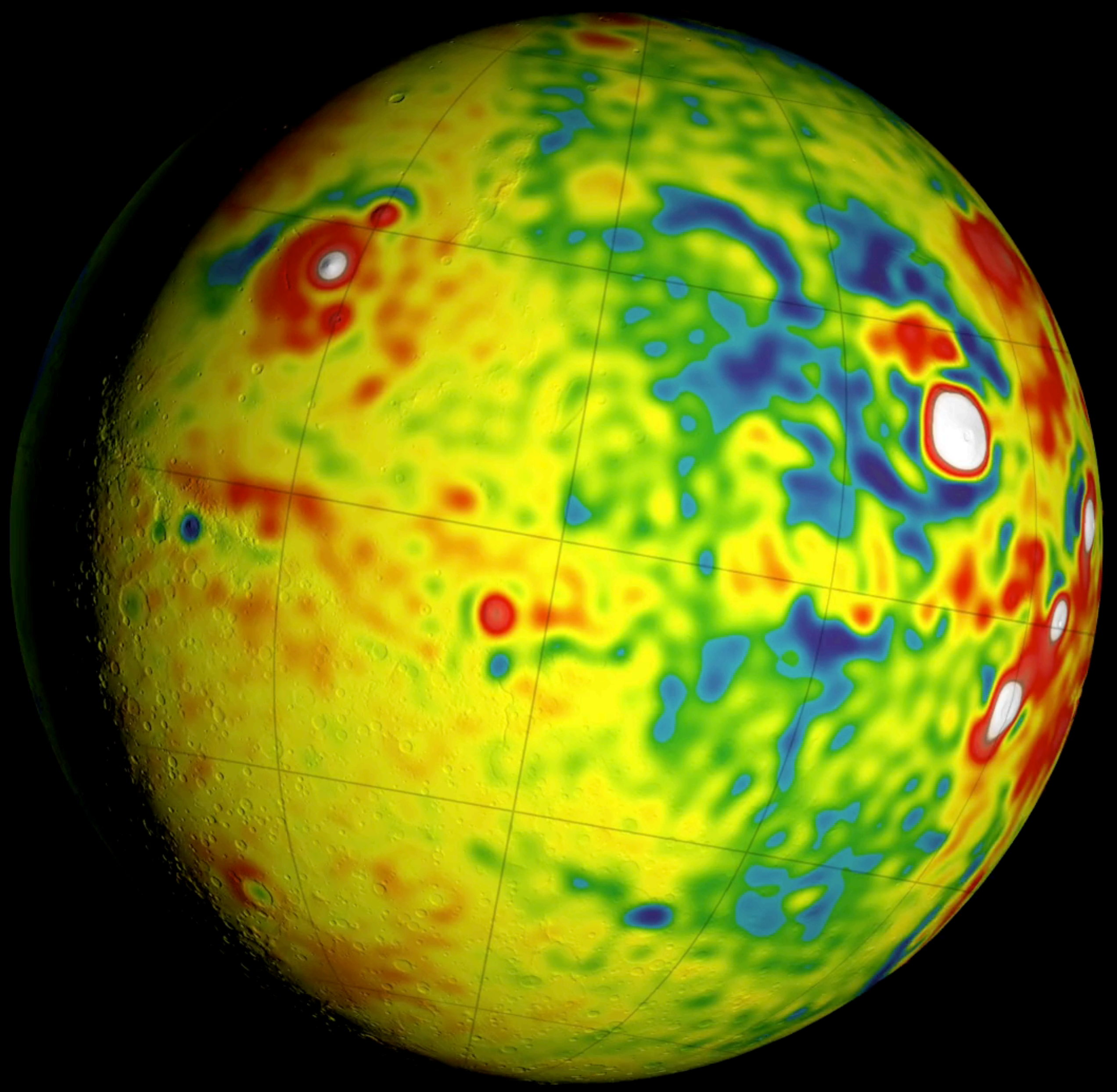
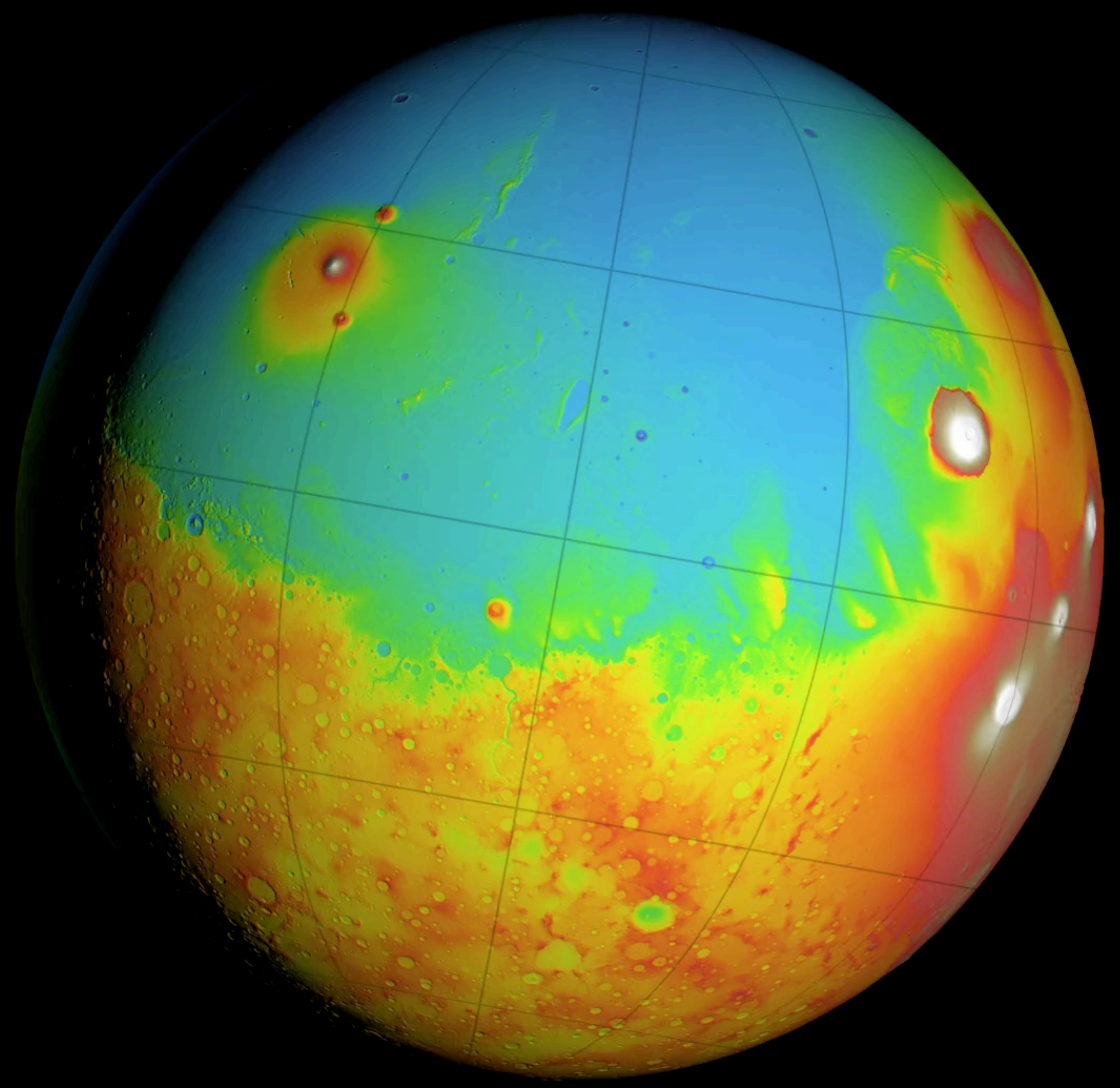
The lithosphere of Mars



Free-air gravity (GMM3)



Topography (MOLA)

InSight
UNIVERSITÉ CÔTE D'AZUR
LAGRANGE

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Observatoire de la Côte d'Azur, Nice, France
Geoazur, InSight @ School

No plate tectonics (stagnant lid)

No crustal recycling into the mantle

The geological & geodynamical history for the entire planetary evolution is recorded on the surface

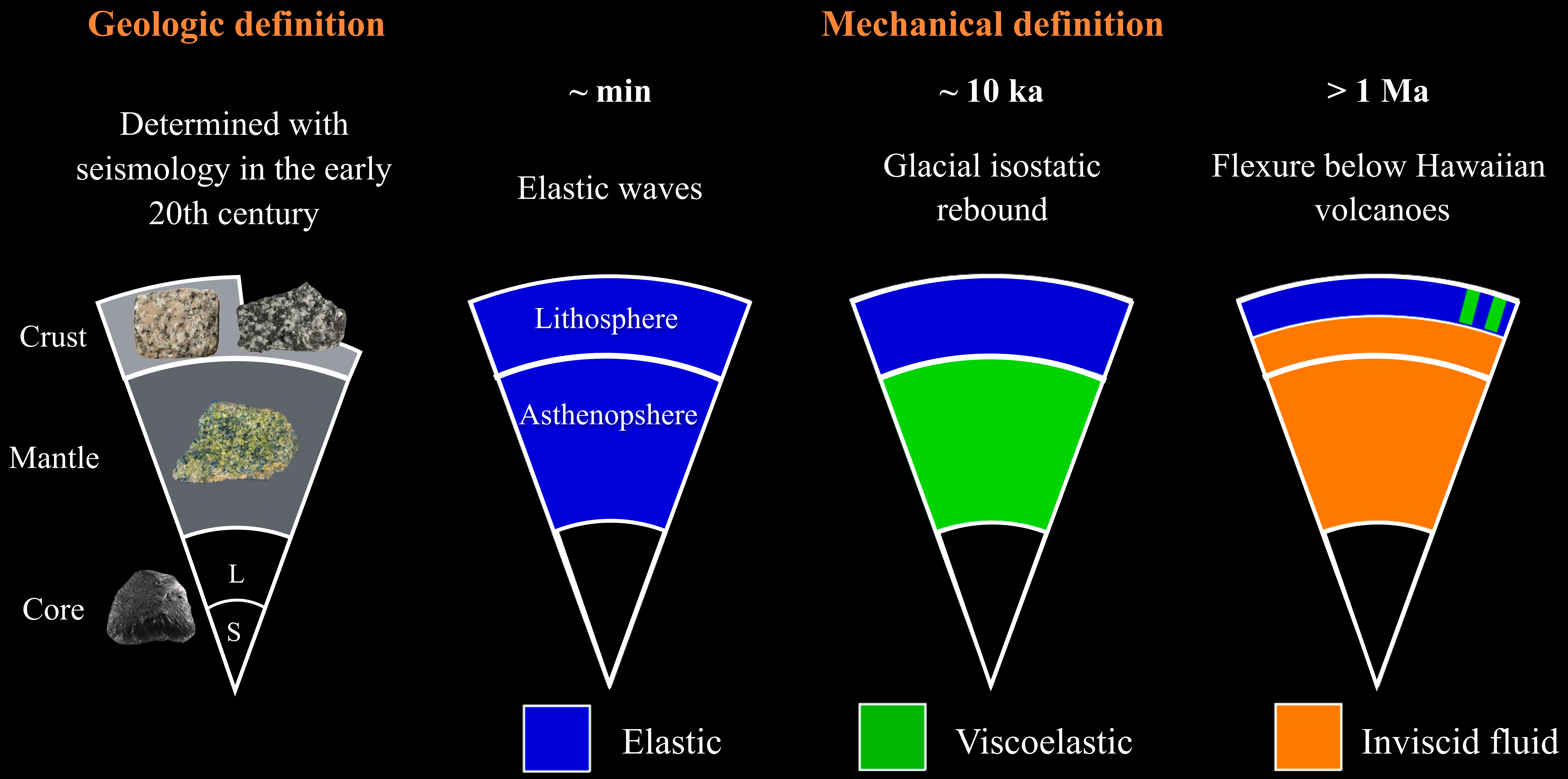
William Anders (Apollo 8 1968)

Outline

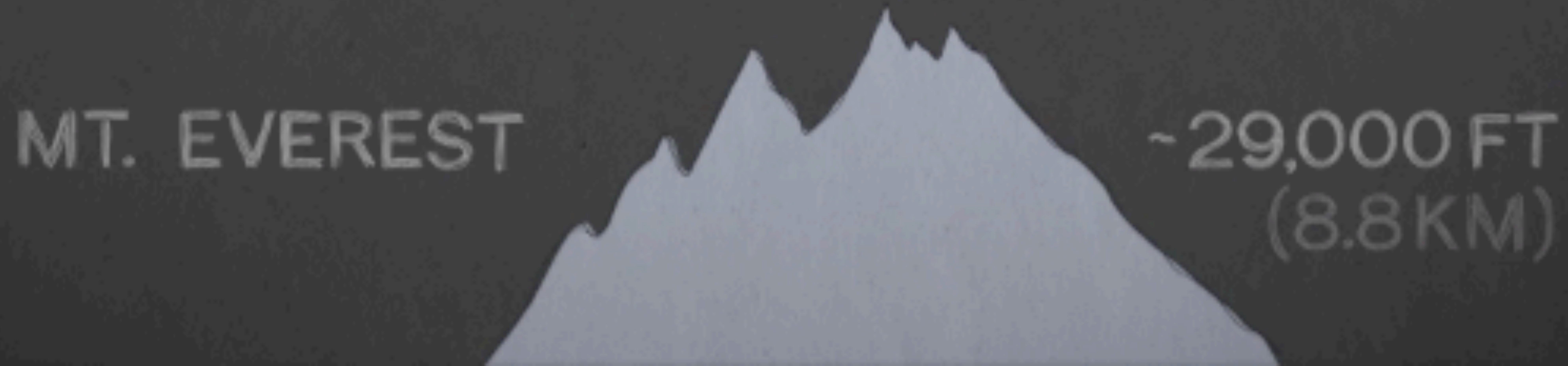
composition rigidity

The current view of Earth's interior

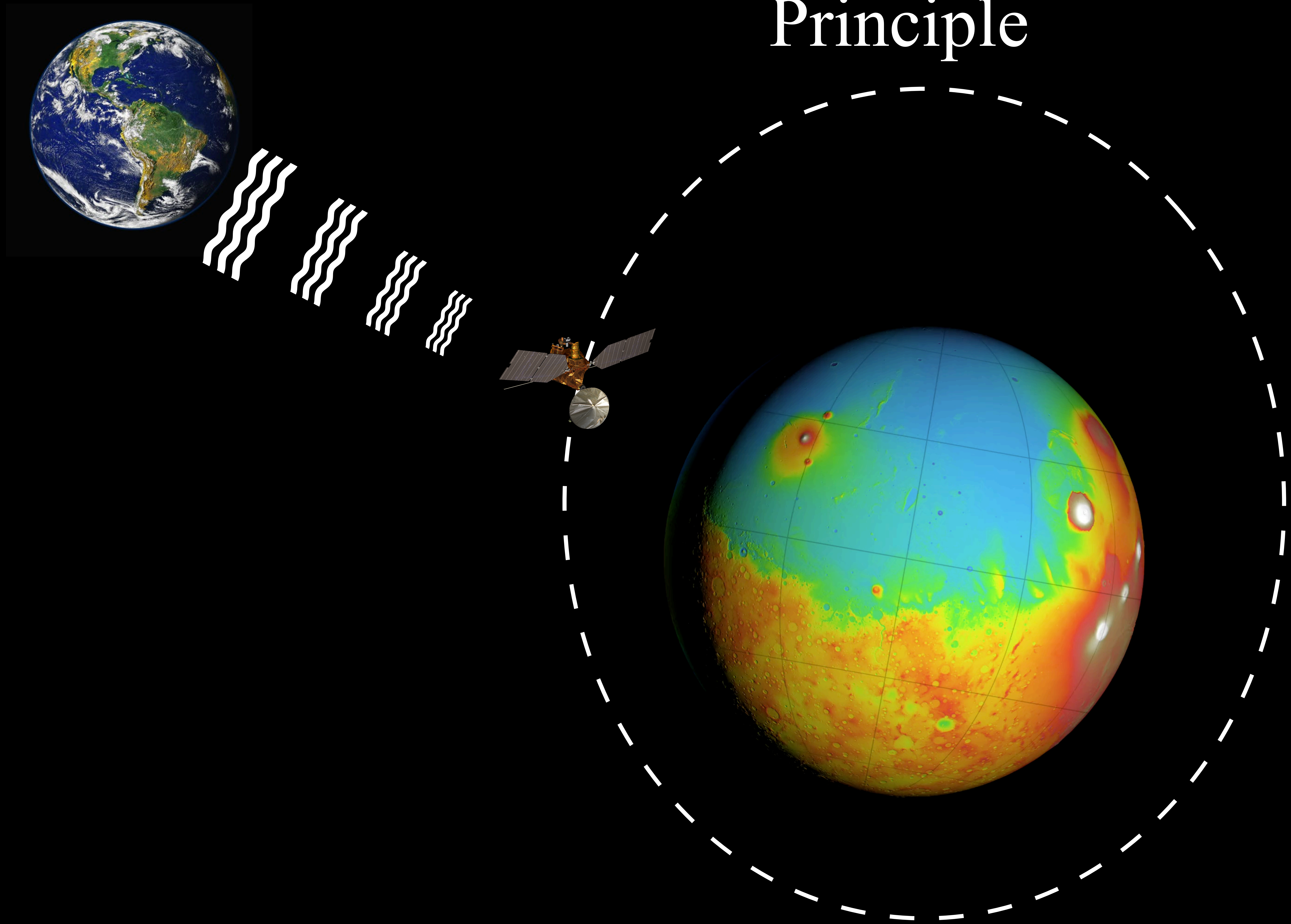
Timescale matters



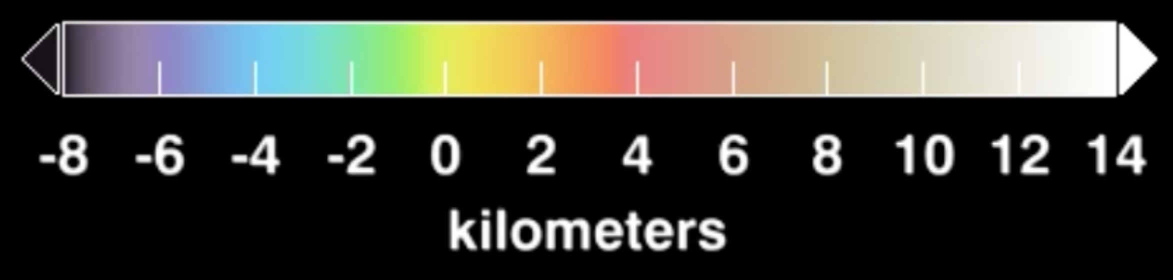
I. The gravitational signature of Martian volcanoes


MT. EVEREST
~29,000 FT
(8.8 KM)

Principle



$g\_mean \sim 3.72$ m s^{-2}
Internal mass structure

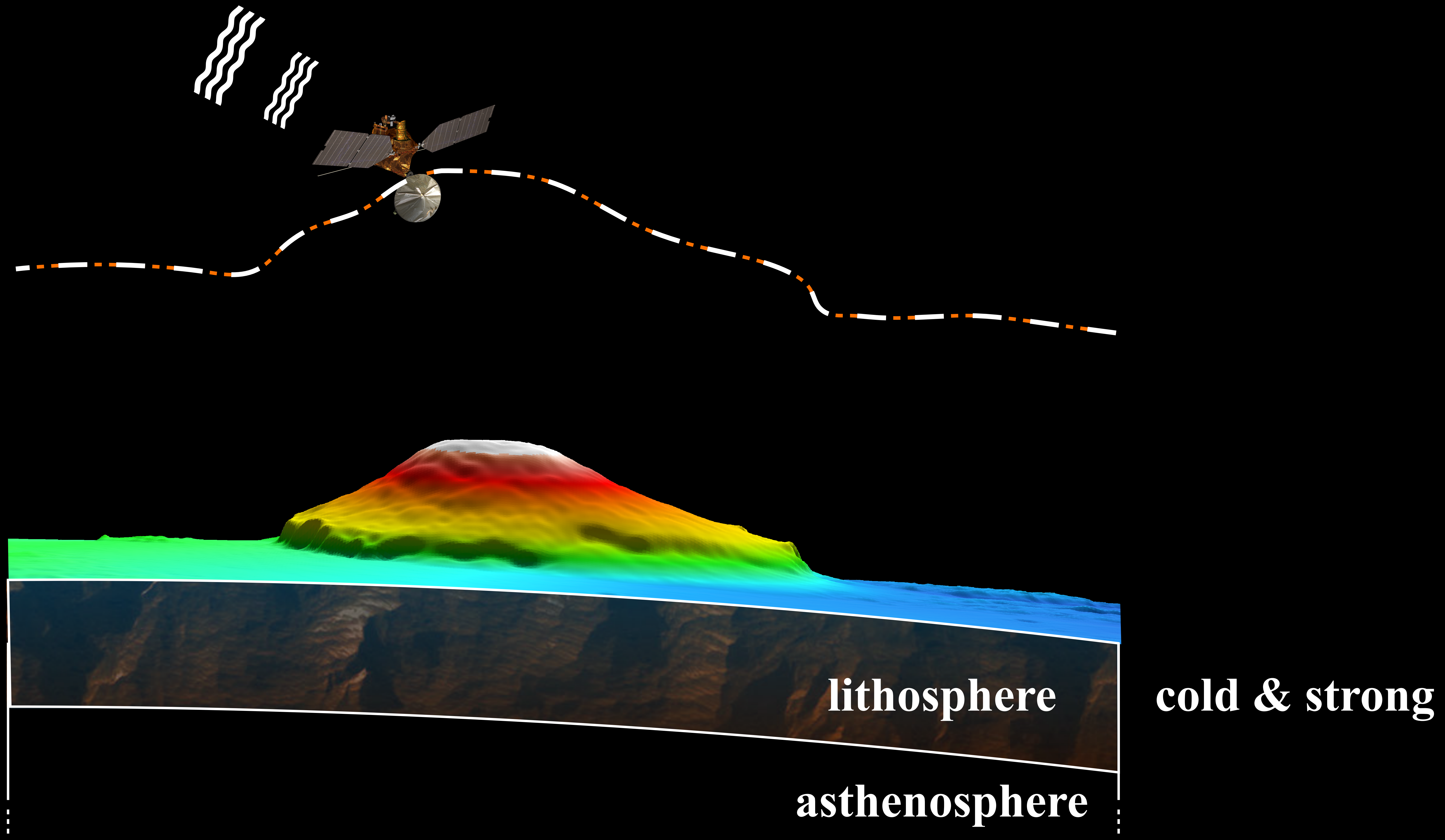


Principle

g_total

=

g_volcano (density)
~ 300 mgals (10^{-5} m s^{-2})



Principle

g_total

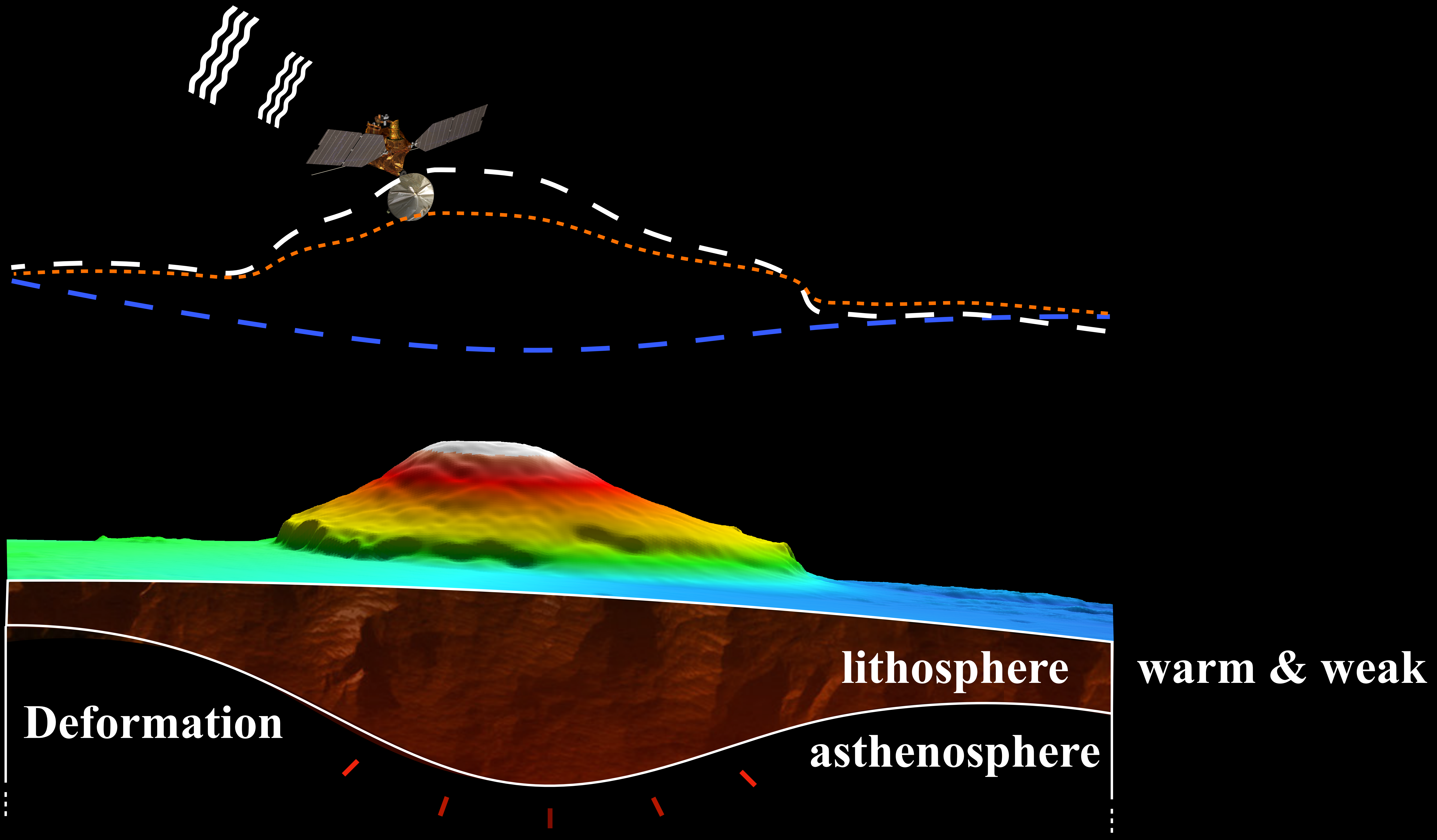
=

g_volcano (density)

~ 300 mgals (10^{-5} m s^{-2})

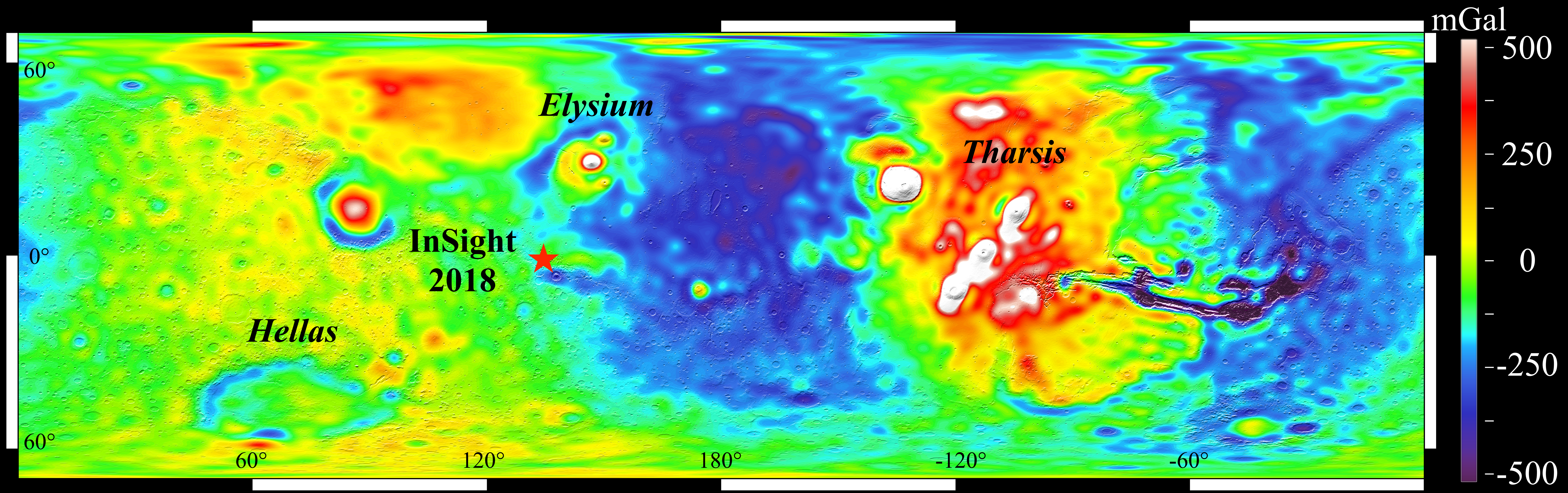
+

g_flexure (density, elastic strength of the lithosphere)

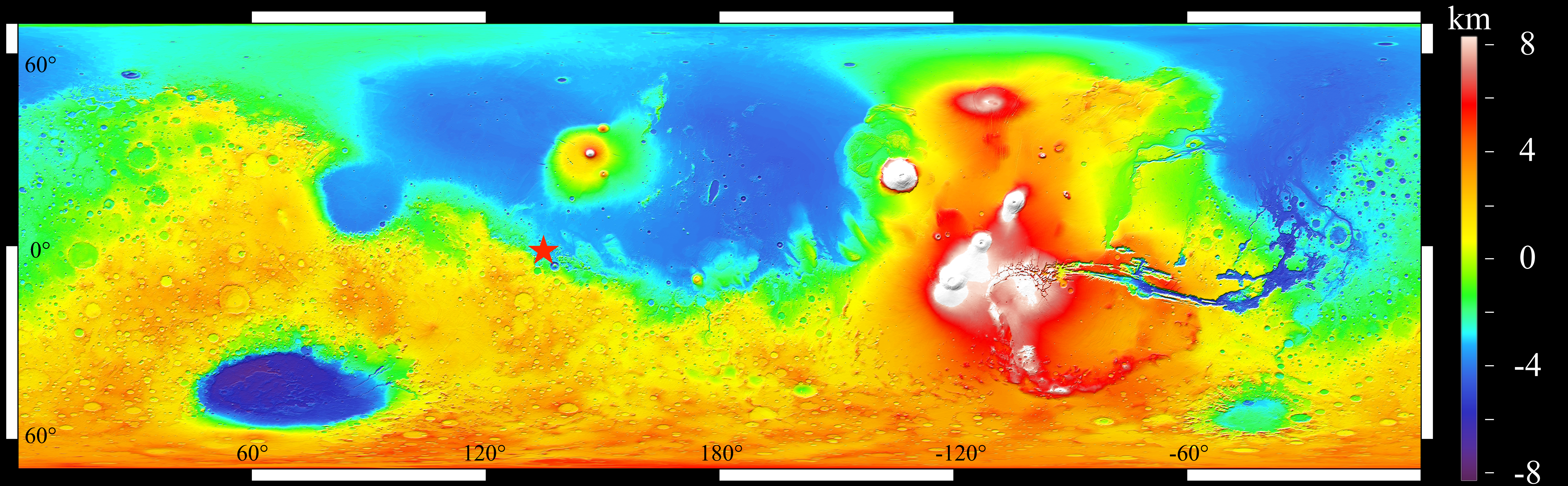


Gravity and topography

Gravity anomaly
Sp. resolution ~ 89 km



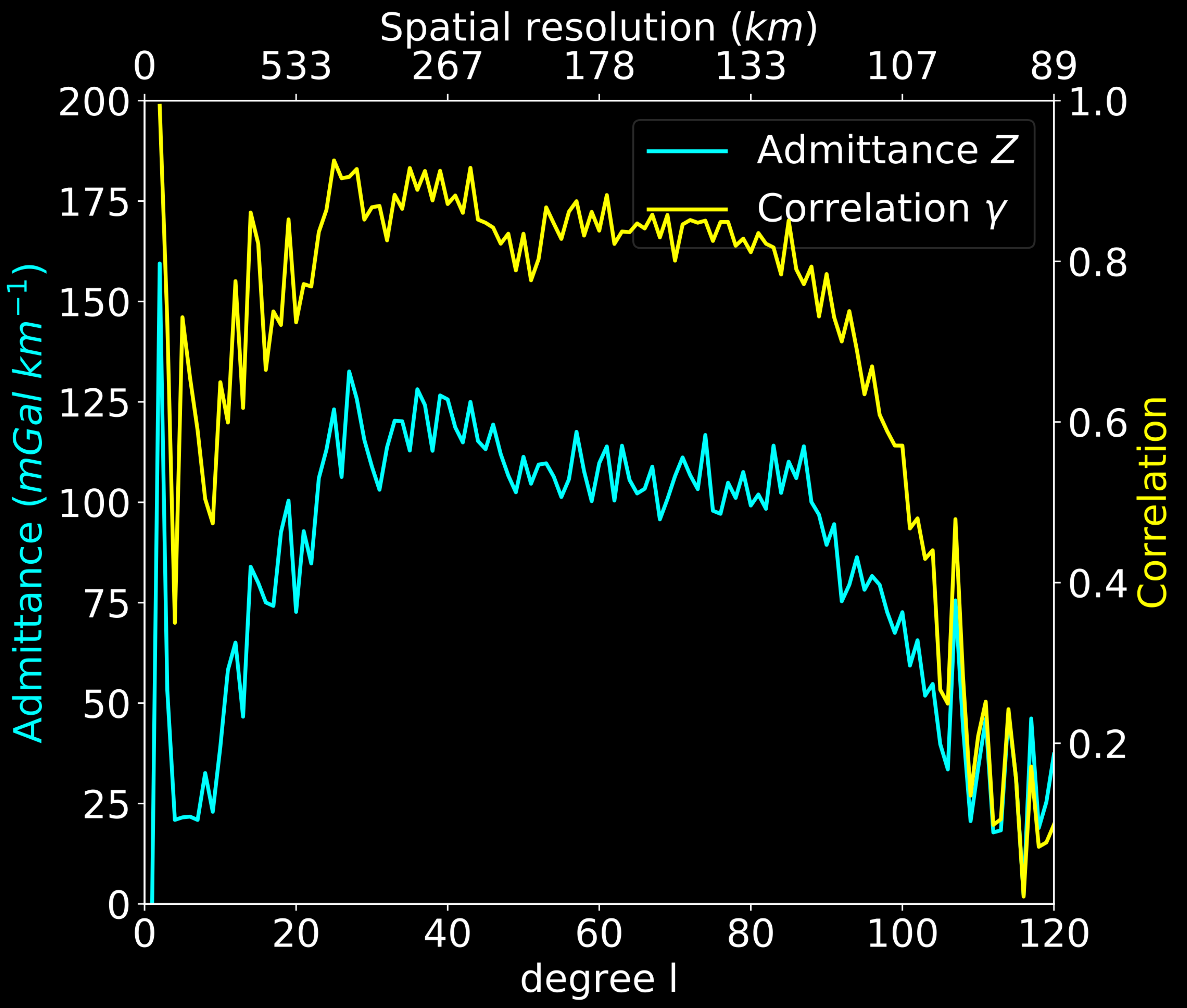
Topography
Sp. resolution ~ 168 m



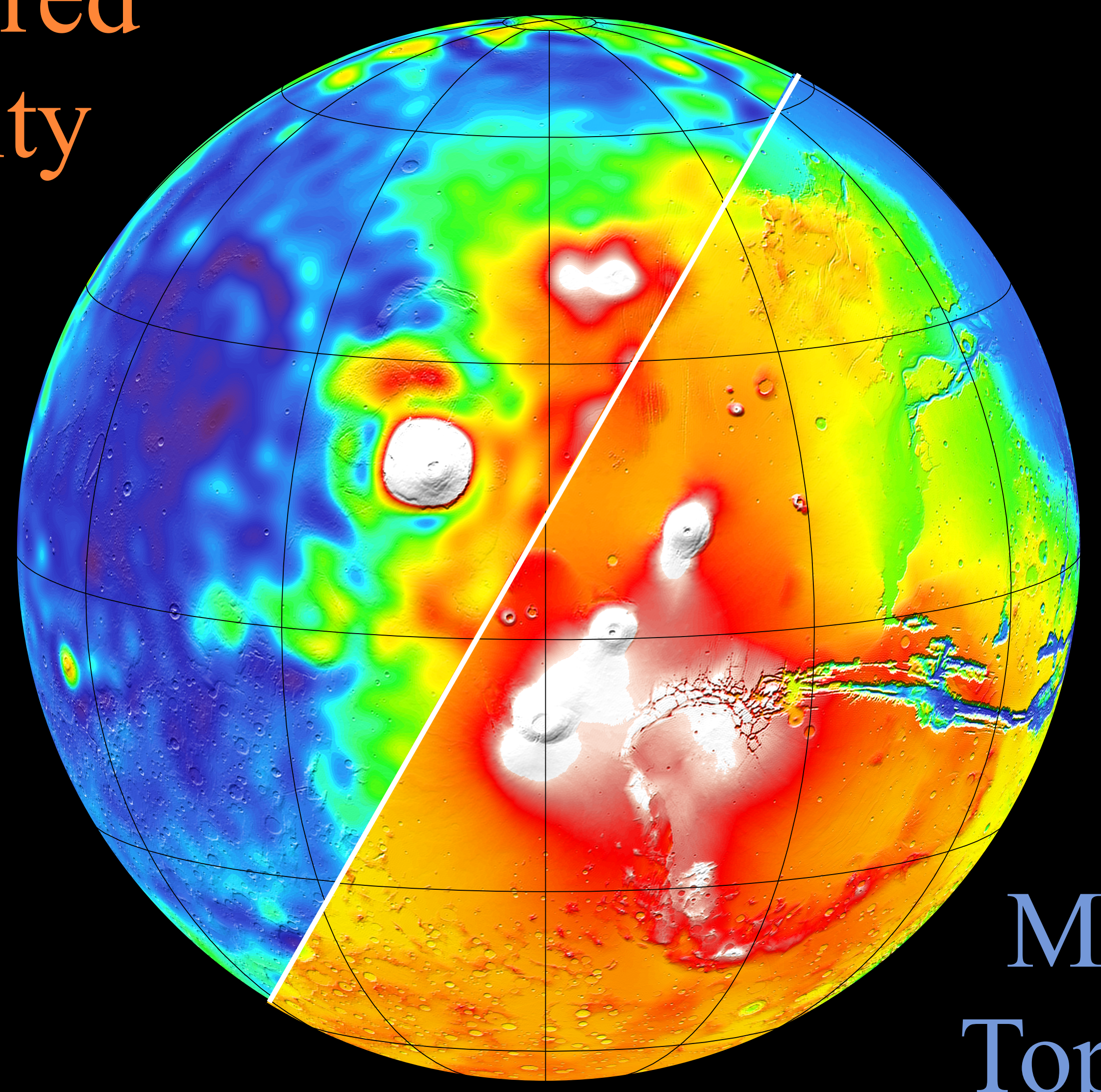
Admittance & Correlation

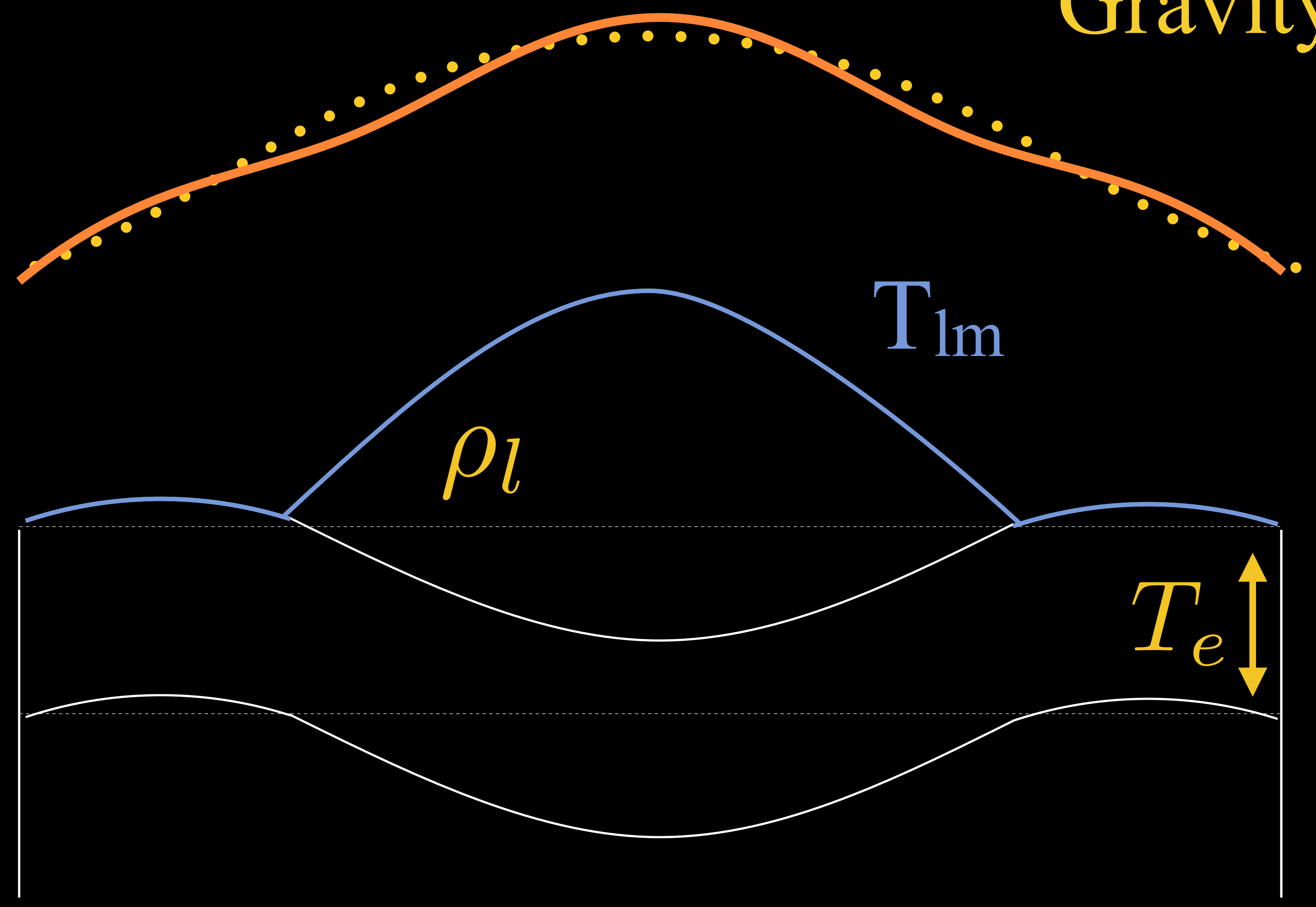
Admittance: Gravity to topography **amplitude ratio** – How much gravity do I have for each wavelength?

Correlation: Gravity to topography **phase relationship** – Can I fully express the gravity field with respect to topography using a linear transfer function?



A simple forward model



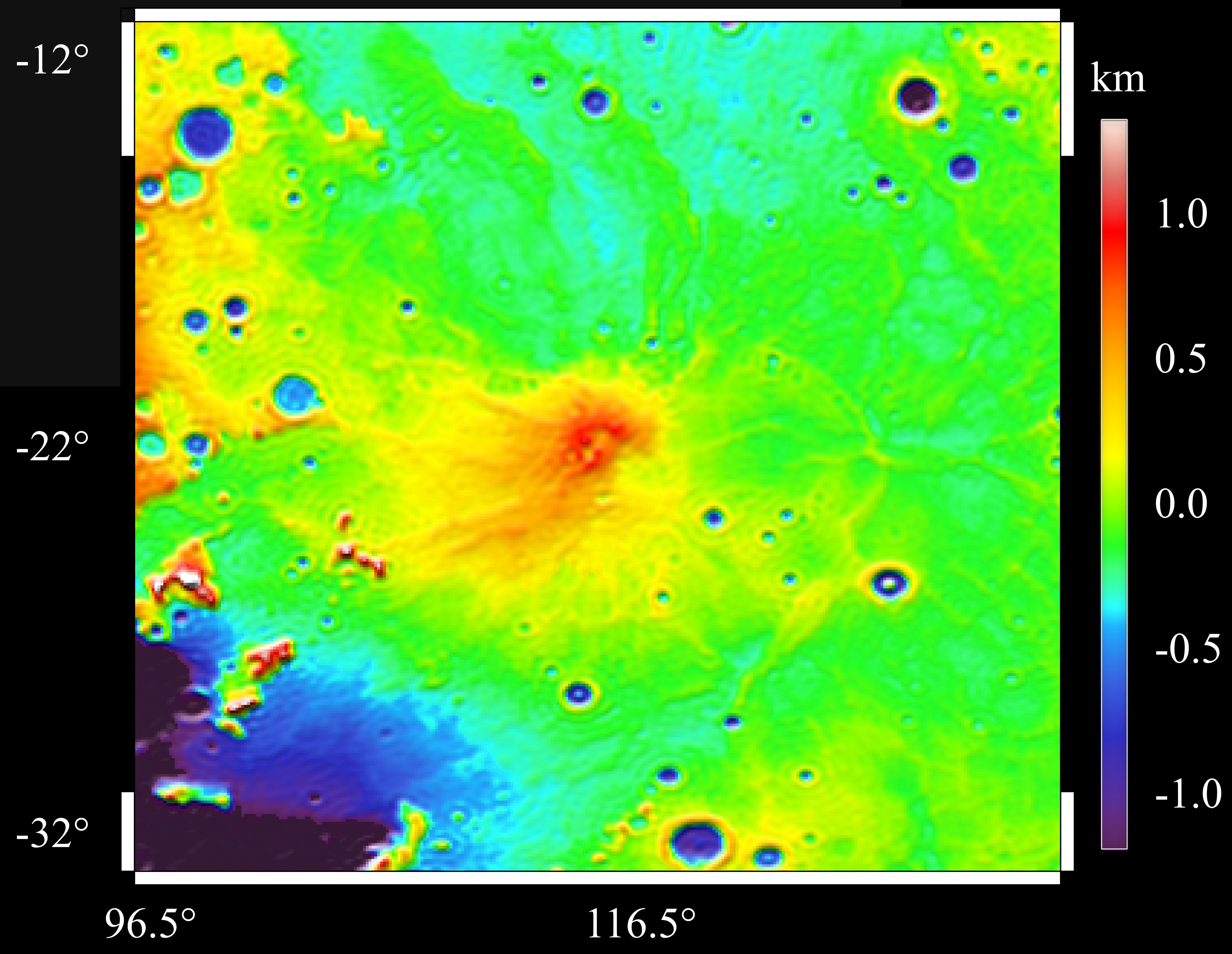


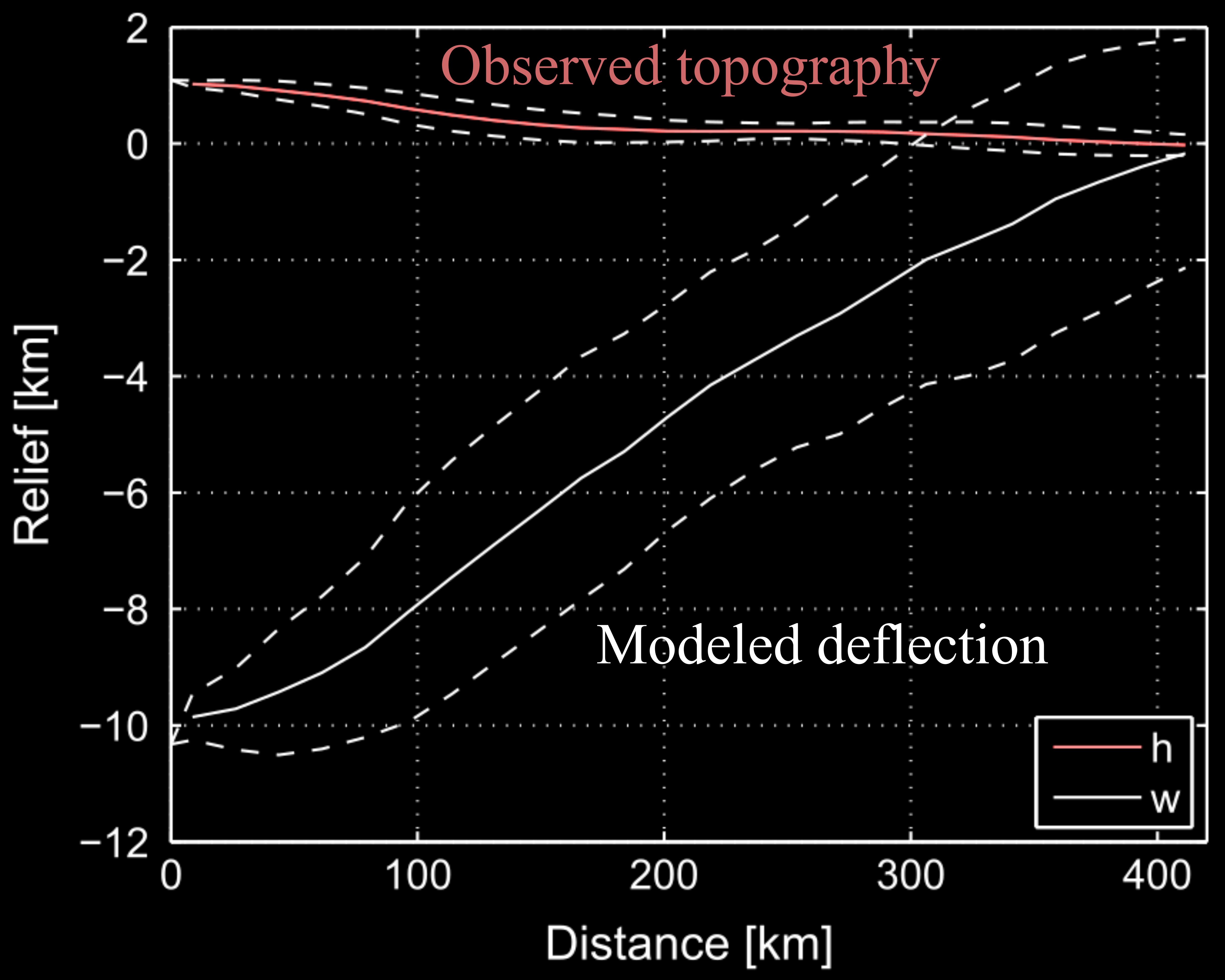
$$G_{lm} = \text{model}(\rho_l, T_e)\, T_{lm}$$

We use a geophysical admittance model to compute deflection & gravitational potential of all interfaces

Chronology: (1) volcano erupts and forms quickly (2) the lithosphere elastically bends (3) the flexural signal freezes as the planet cools

Tyrrhena Patera (-21.36°, 106.53°)





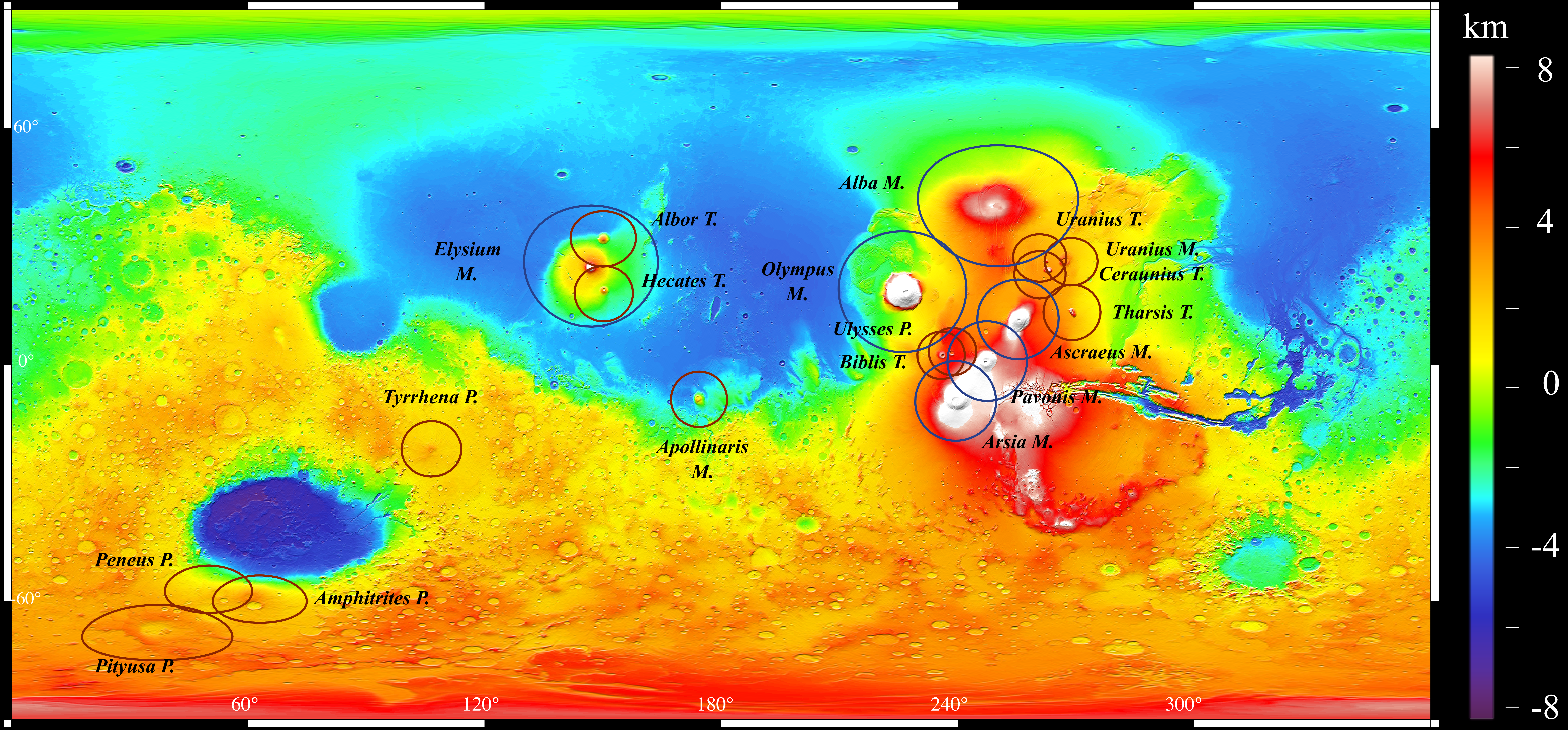
Localized spectral analysis

Because the lithospheric properties are spatially variable, we perform localized spectral analyses

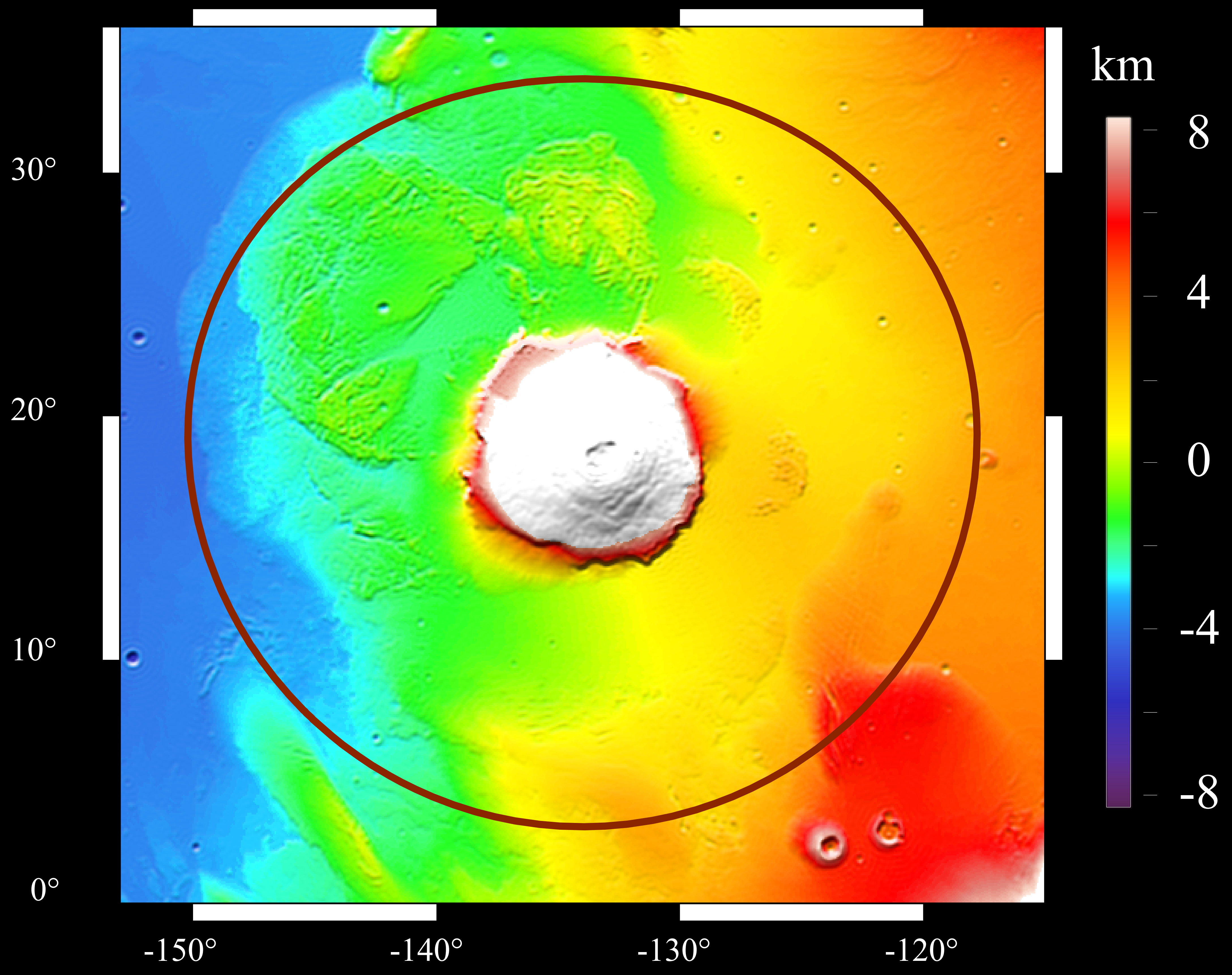
6 Large volcanoes:
Young: < 3.0 Ga
Size >800 km

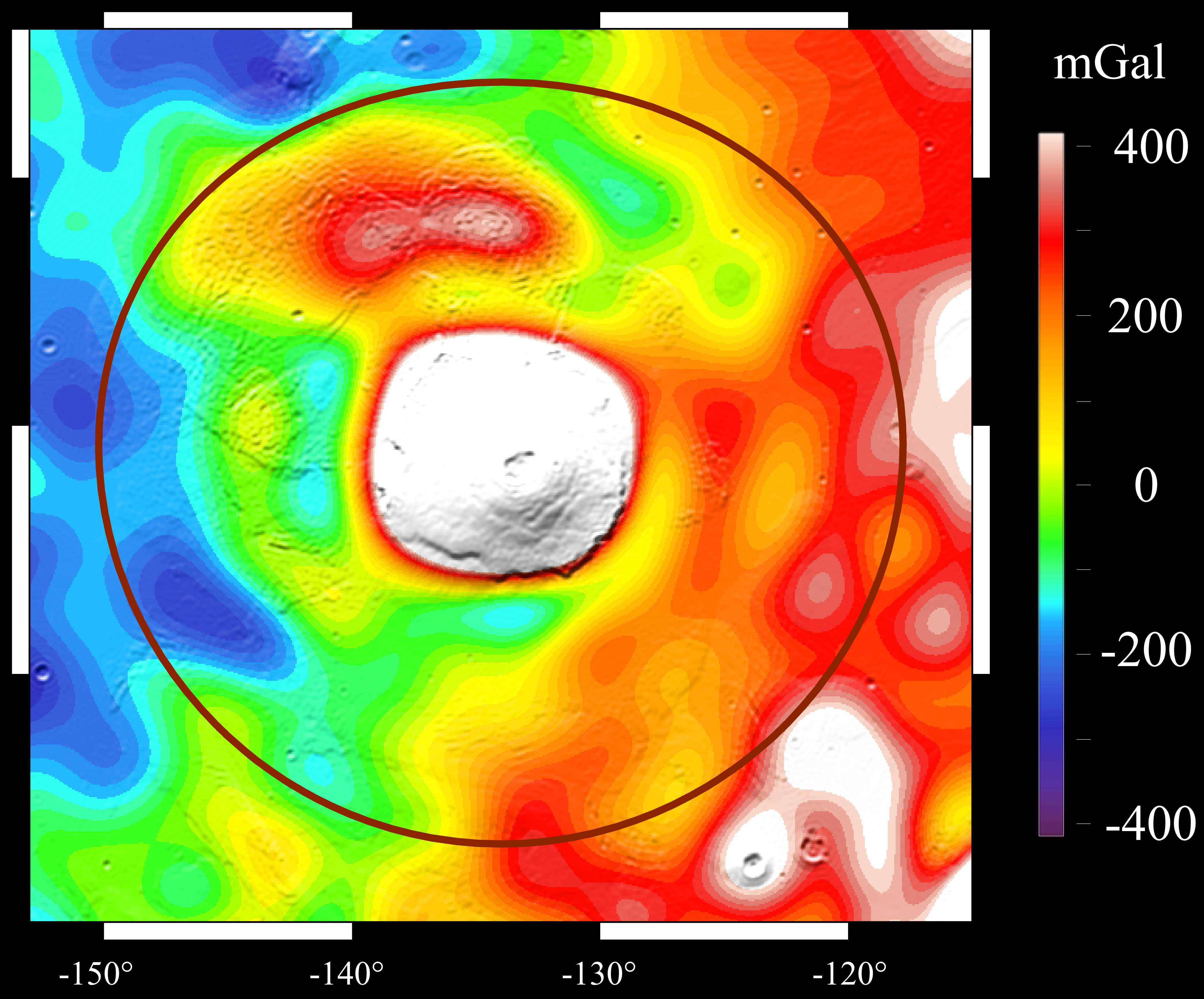
13 Small volcanoes:
Old: 3.8 - 3.4 Ga
Size 400 - 800 km

Ages from Robins *et al.* (2012)



Case study: Olympus Mons (Tharsis)





Topography

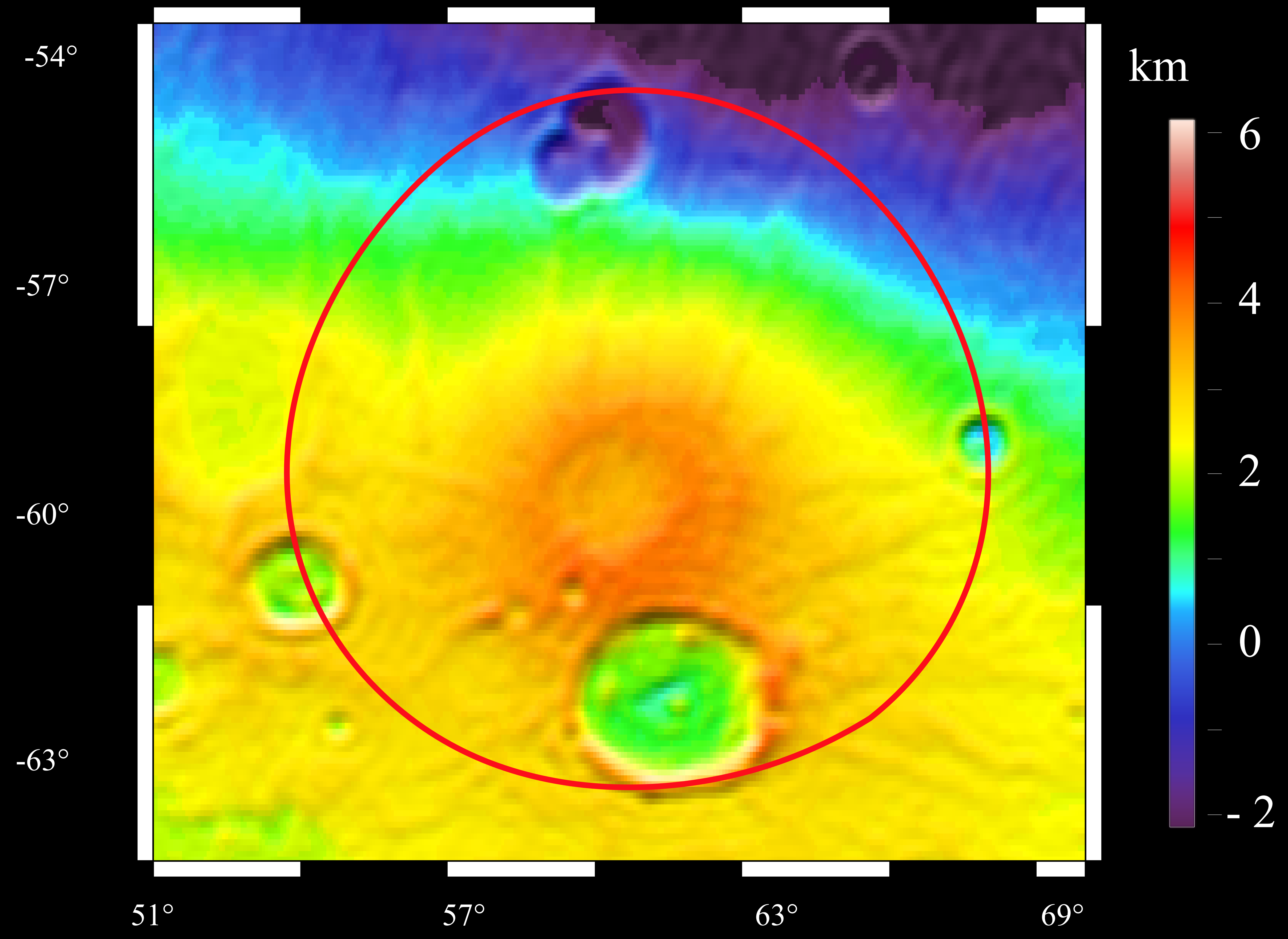
Localization window
diameter ~1800 km

Gravity

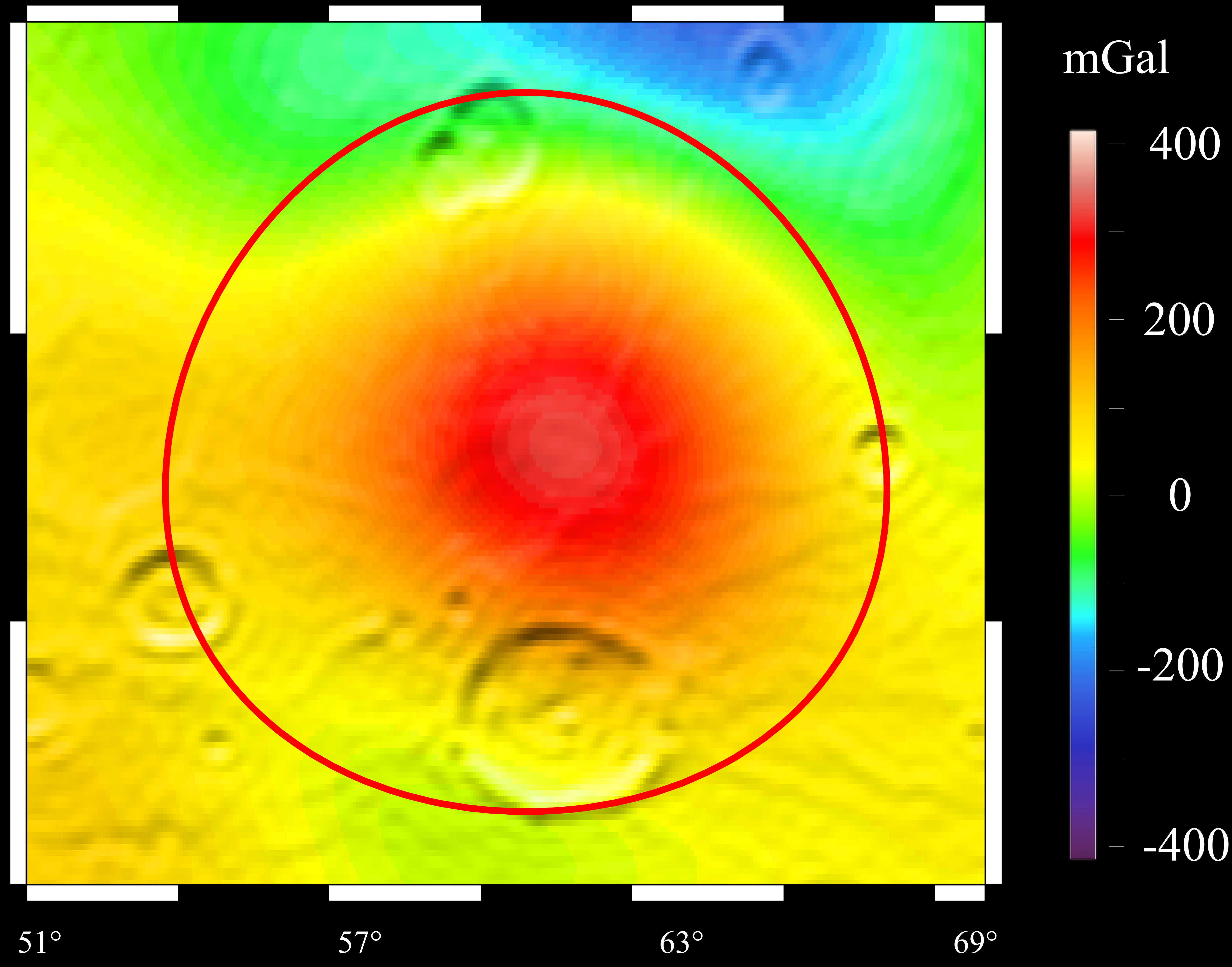
Case study: Olympus Mons (Tharsis)

The density is large ~ 3100 kg m-3, T_e is about 50 km

Case study: Amphitrites Patera (Southern rim of Hellas)



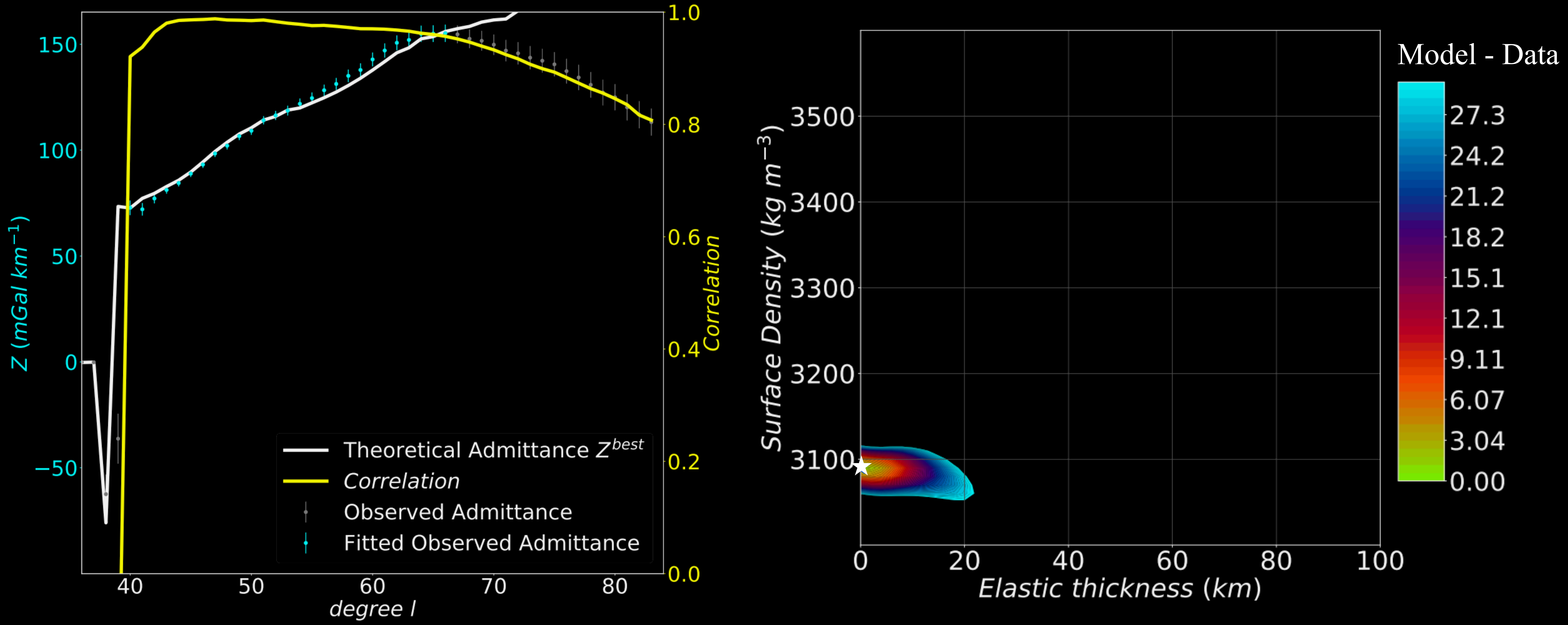
Topography



Gravity

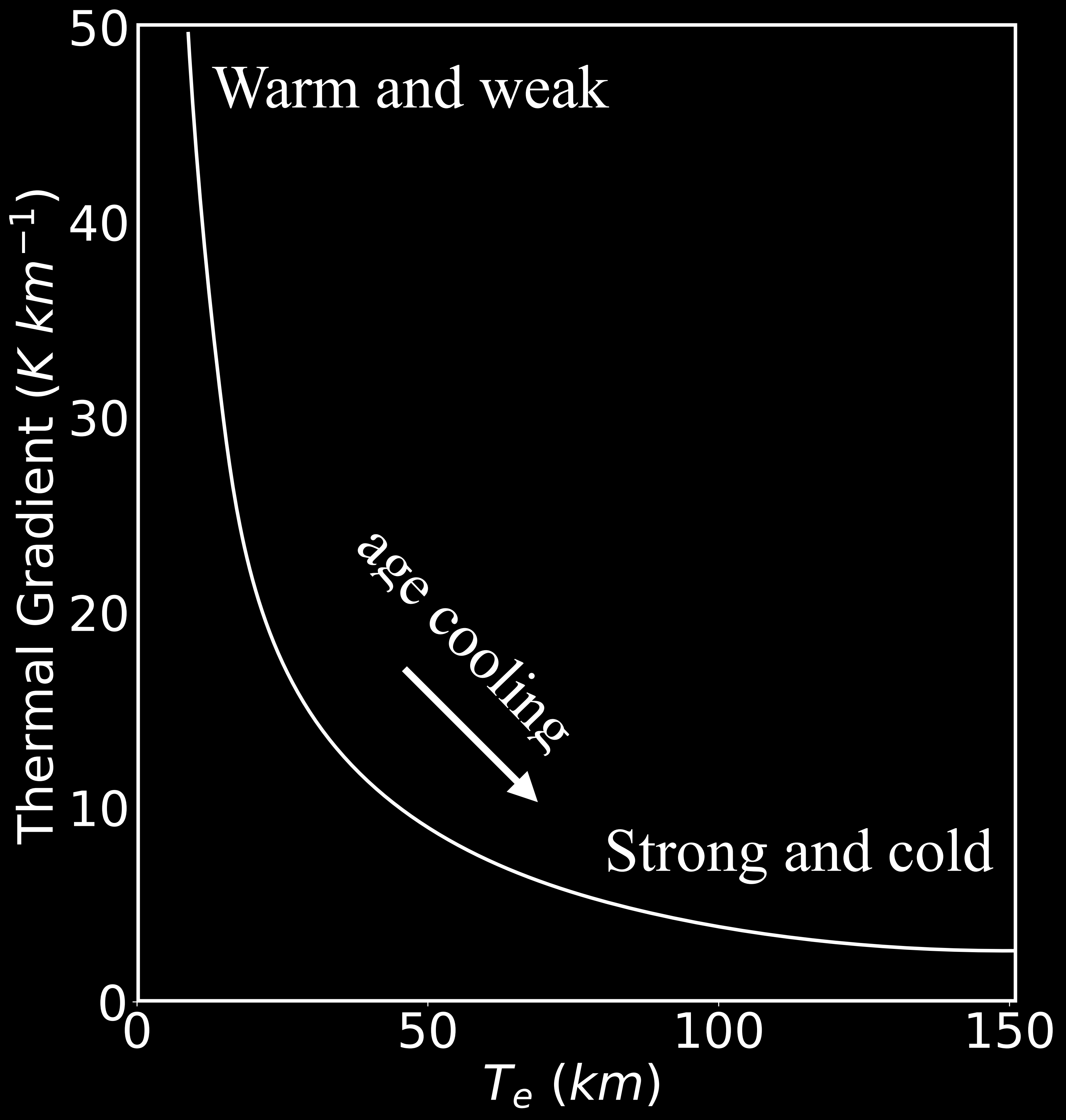
Localization window diameter ~800 km

Case study: Amphitrites Patera (Southern rim of Hellas)

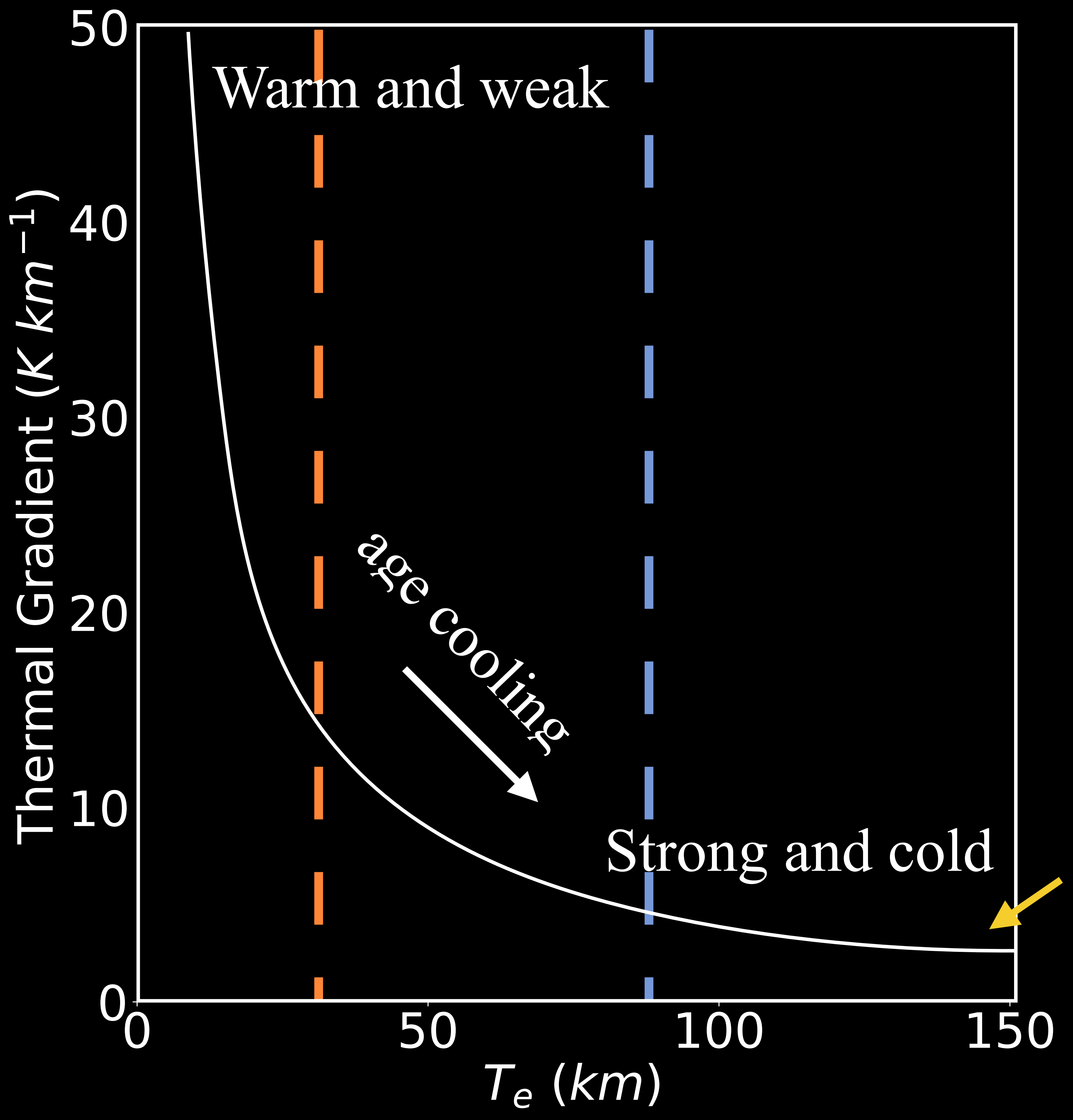


The density is similar to that of Olympus Mons, but T_e is smaller

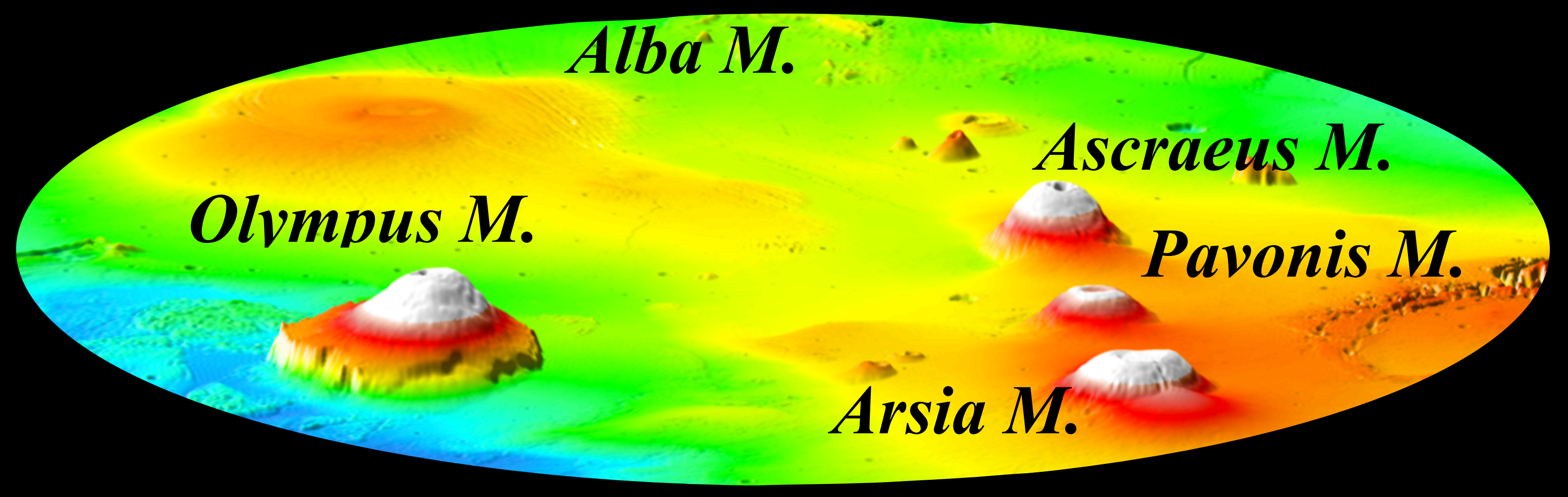
Elastic to thermal state of the lithosphere



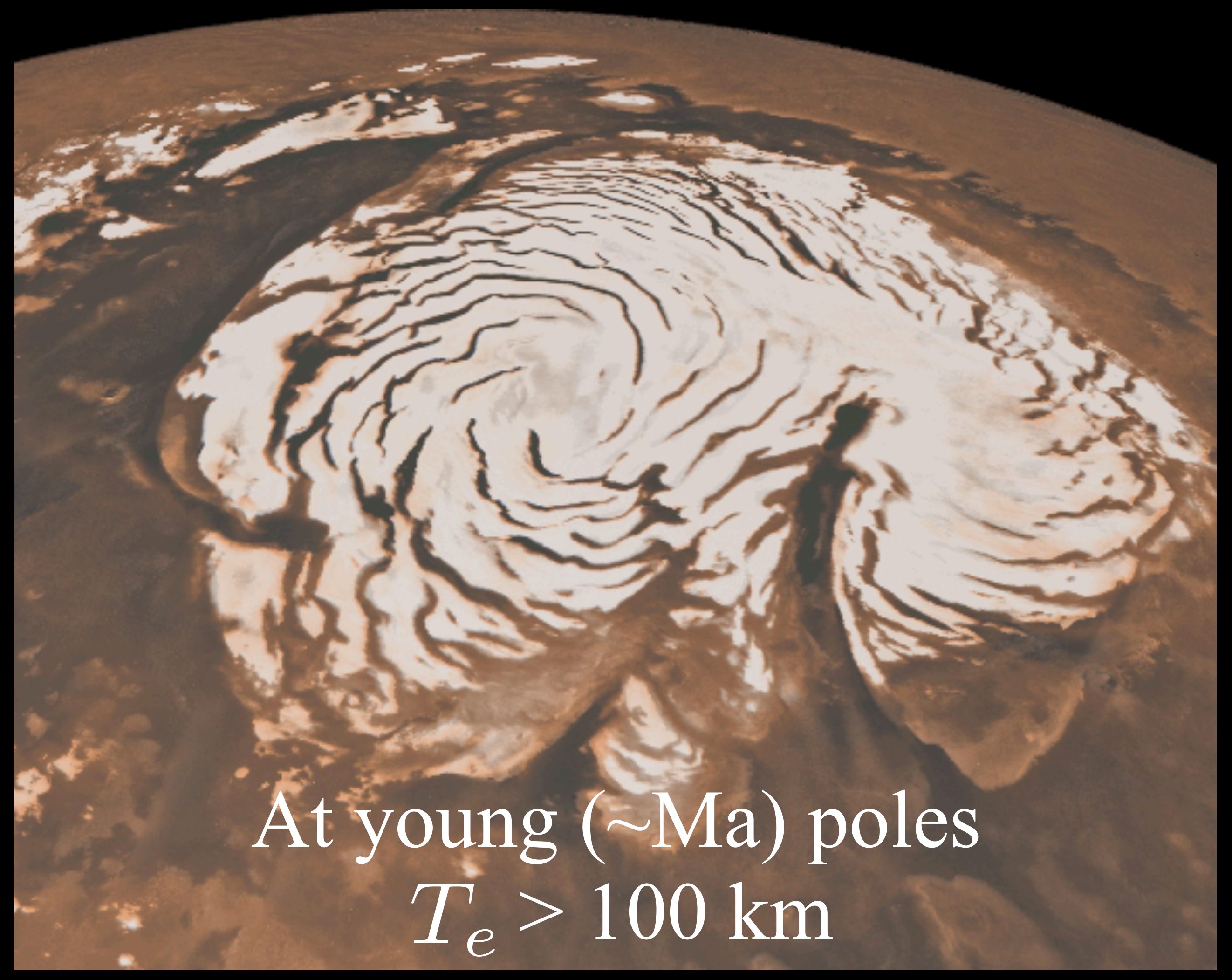
Elastic to thermal state of the lithosphere



Polar caps & HP[3] future constraint?



Old (Ga) volcanoes T_e< 100 km



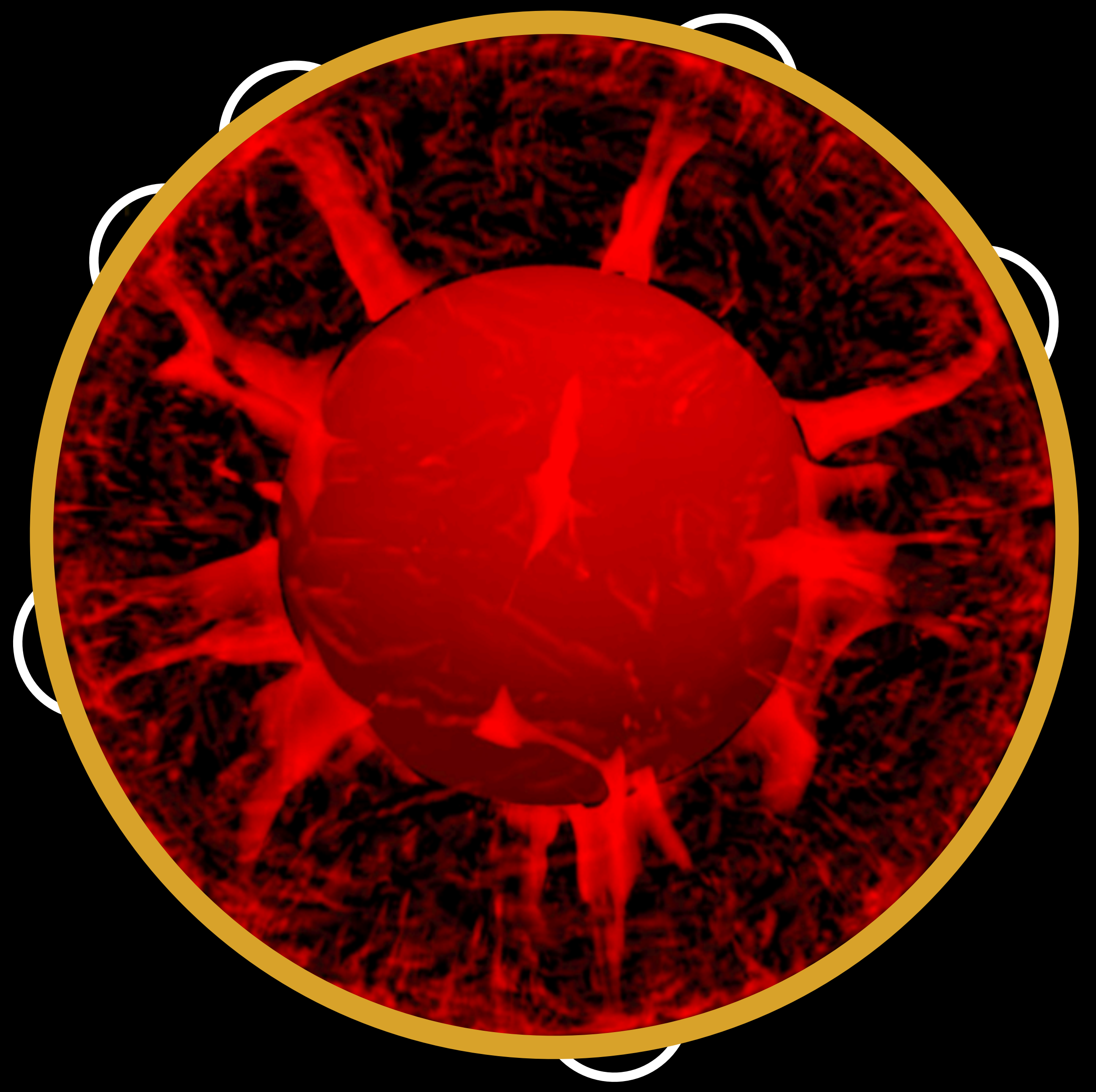
Small volcanoes appeared/froze early, when the lithosphere was hot and thin

Large volcanoes appeared/froze after, when the lithosphere was cold and thick

Evolution of the volcanism on Mars

4.5 to ~2 Ga

Lithosphere thickness



The volcanism was sparse and weak, leading to the formation of scattered small volcanoes

Evolution of the volcanism on Mars

Lithosphere thickness

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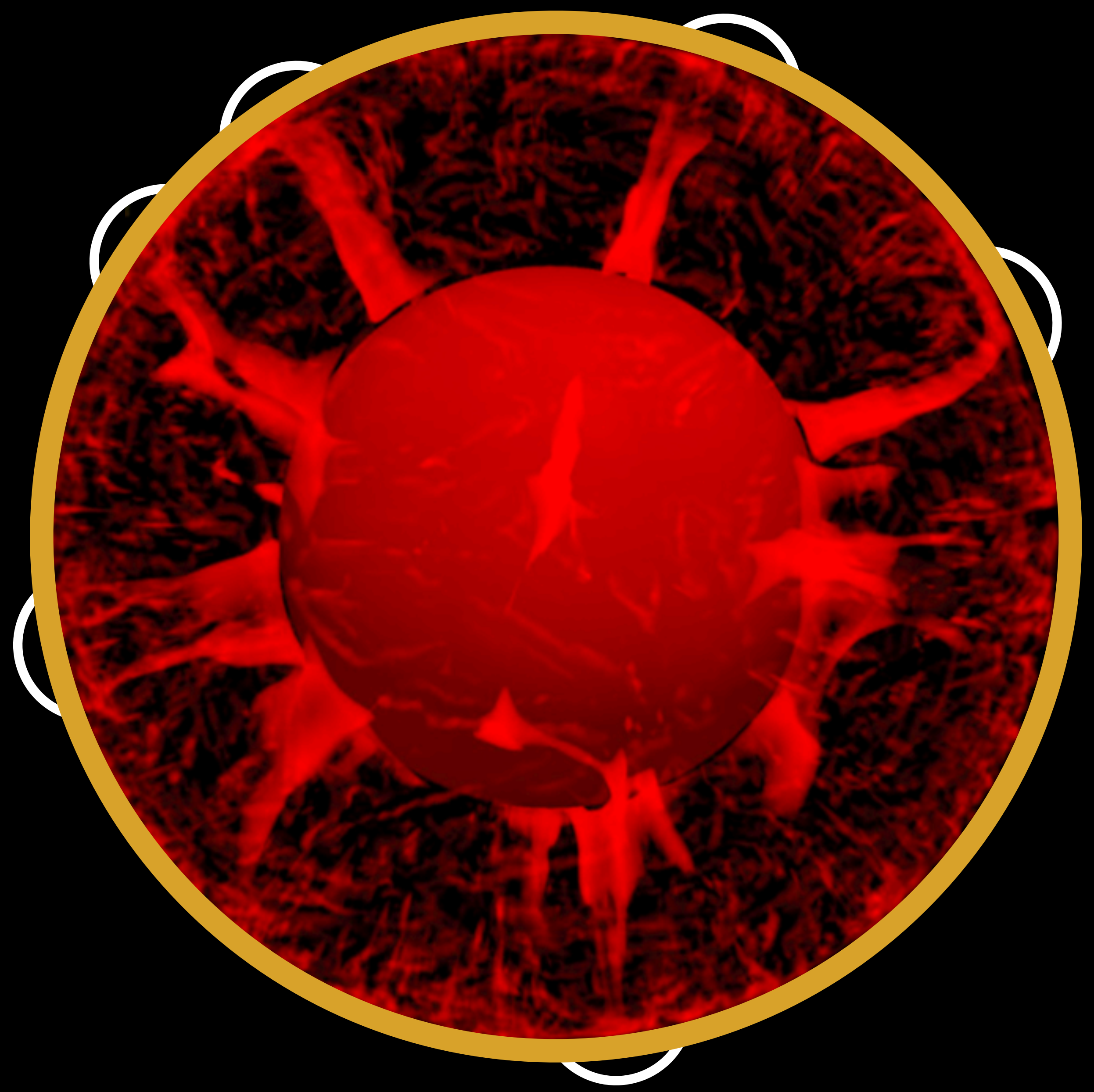
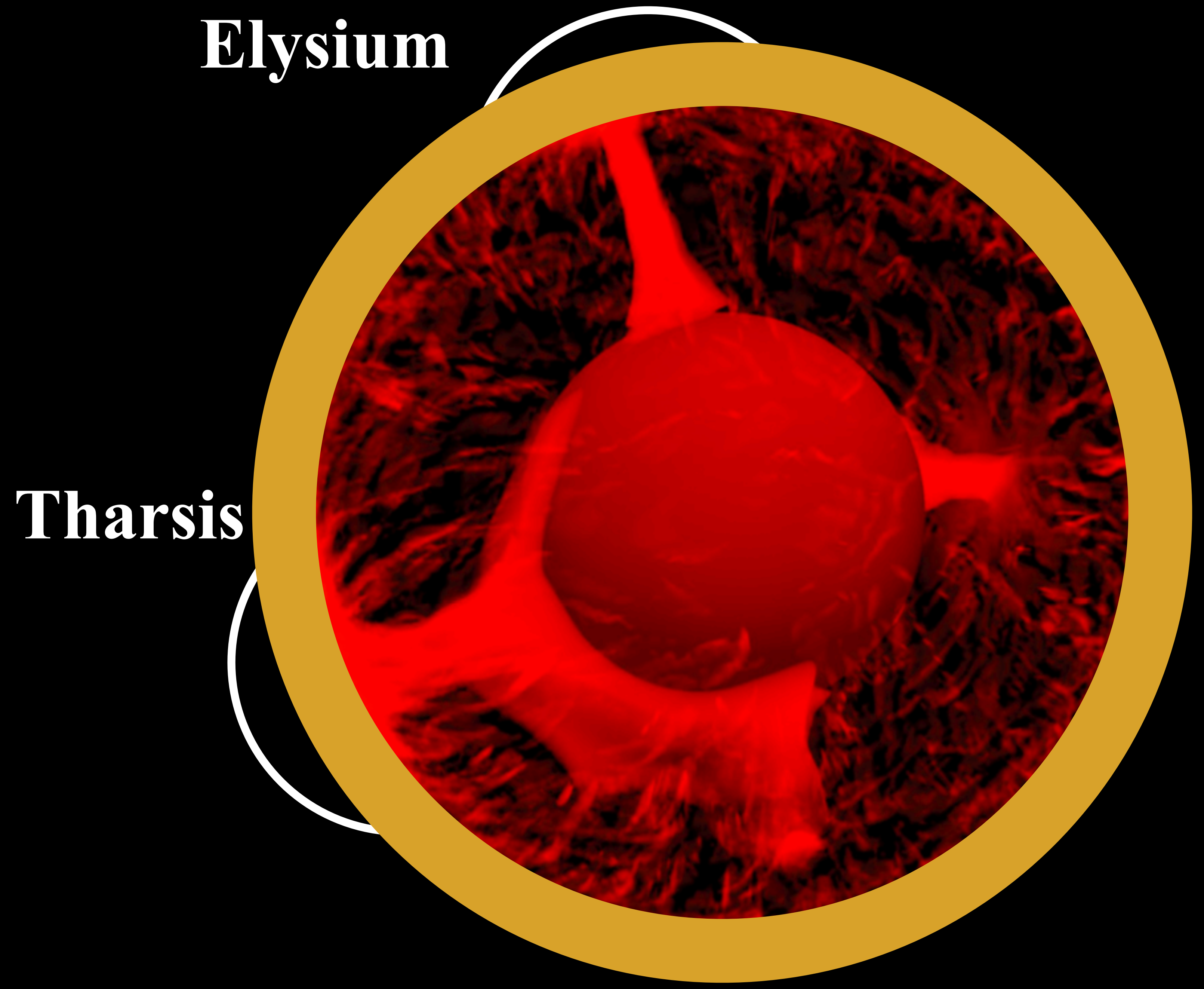


The volcanism was sparse and weak, leading to the formation of scattered small volcanoes

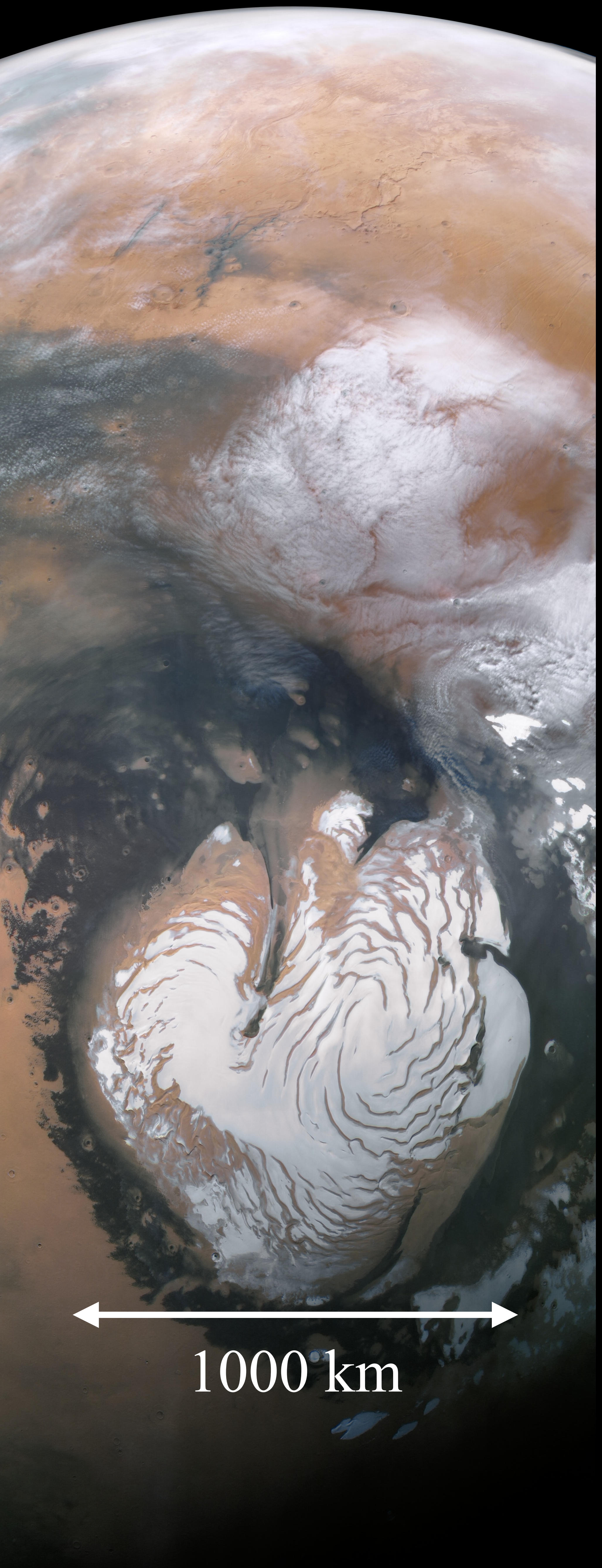
~2 Ga to present



The volcanism evolved towards a steady state with at least 2 active mantle plumes to form the clustered large volcanoes

II. Flexure of the lithosphere beneath the polar caps of Mars

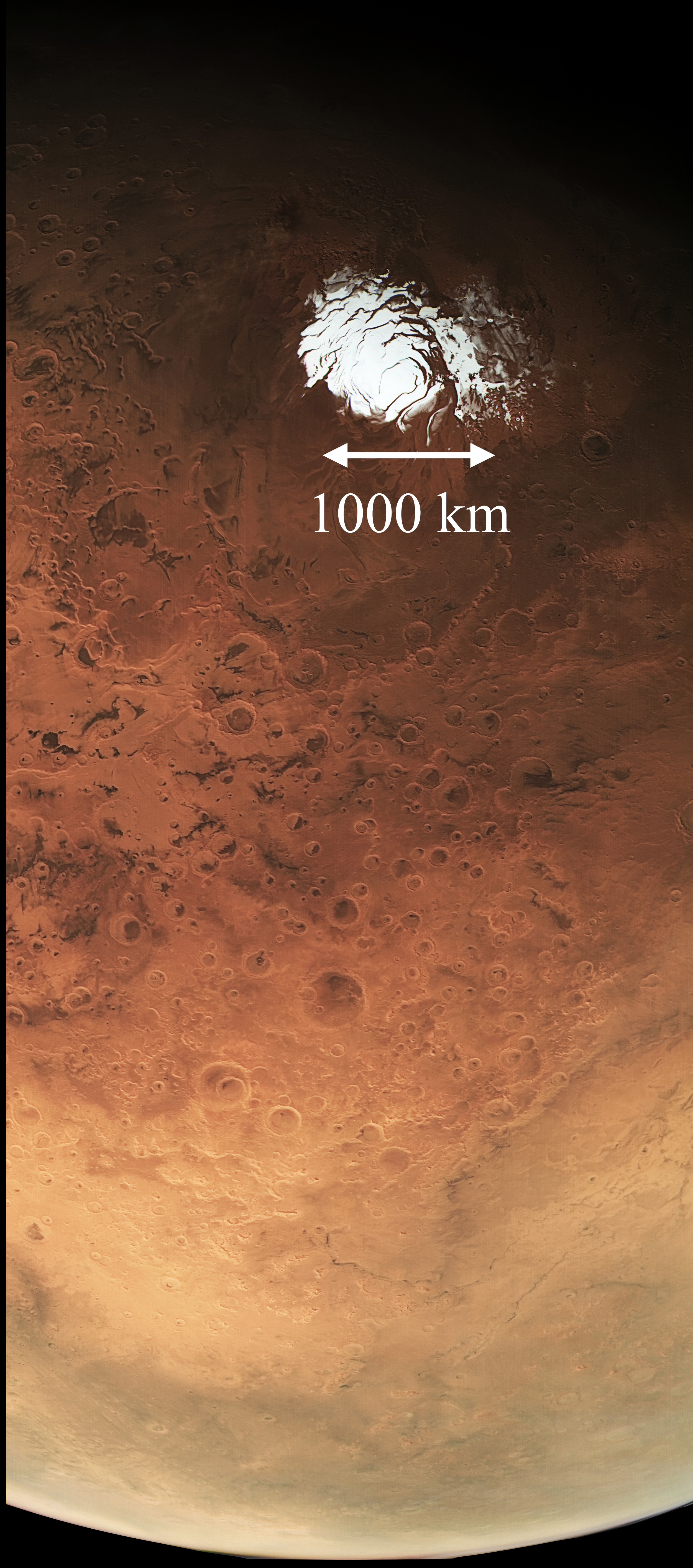
Motivation



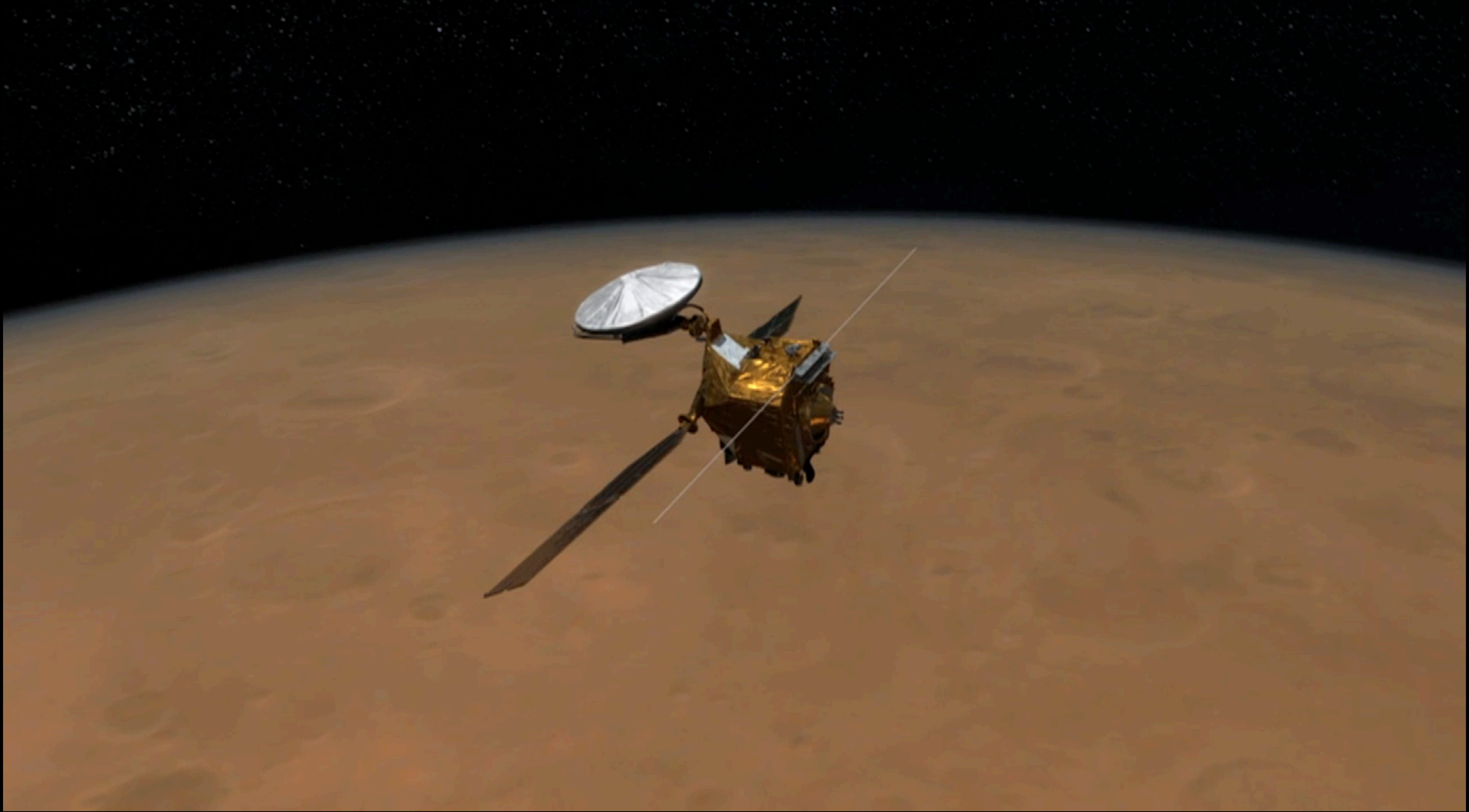
The polar terrains are amongst the youngest surface feature on Mars (< 10 Ma). No crater at the north pole, a few at the south.

They act as large scale loads that are "transparent" to radar giving a unique insight into the shape of the load/crust interface. Investigating the lithospheric flexure underneath the deposits allows us to place constraints on the present-day thermal state of Mars.

They may preserve a stratigraphic record of climate change modulated by the planet orbit and obliquity. Knowing their composition, the partition of dust and ice is critical for understanding how Mars evolved.

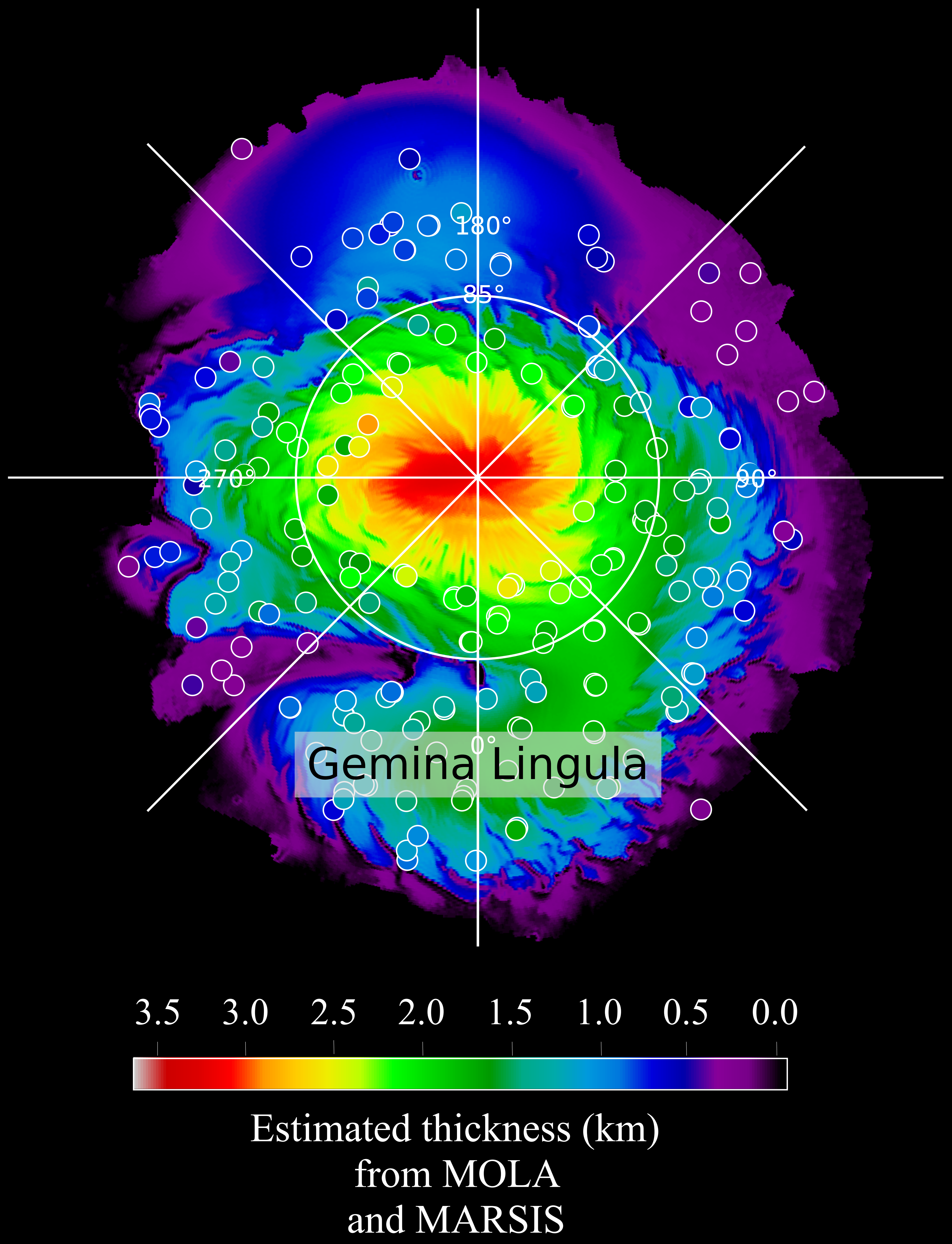


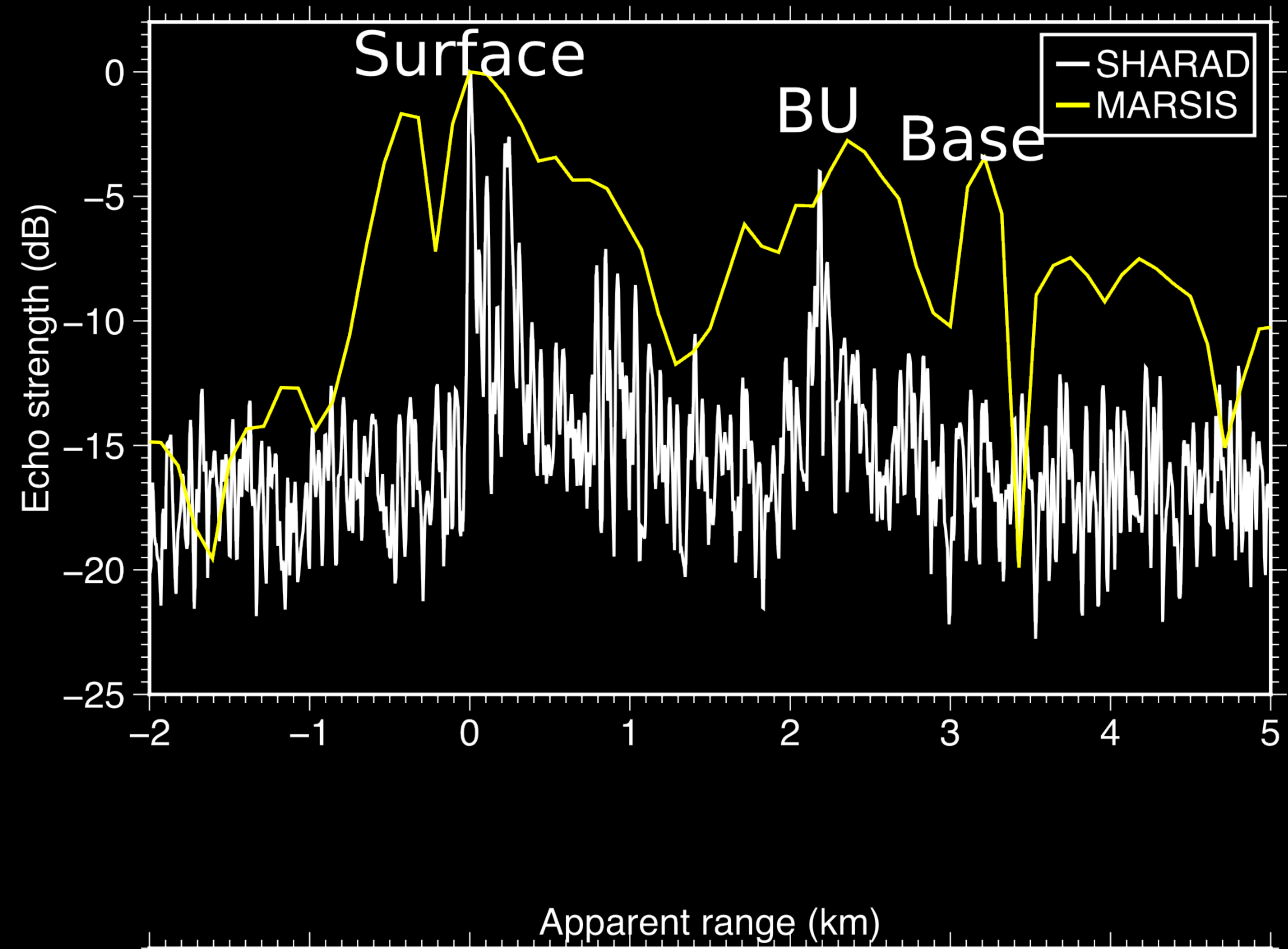
The Radar Era: SHARAD

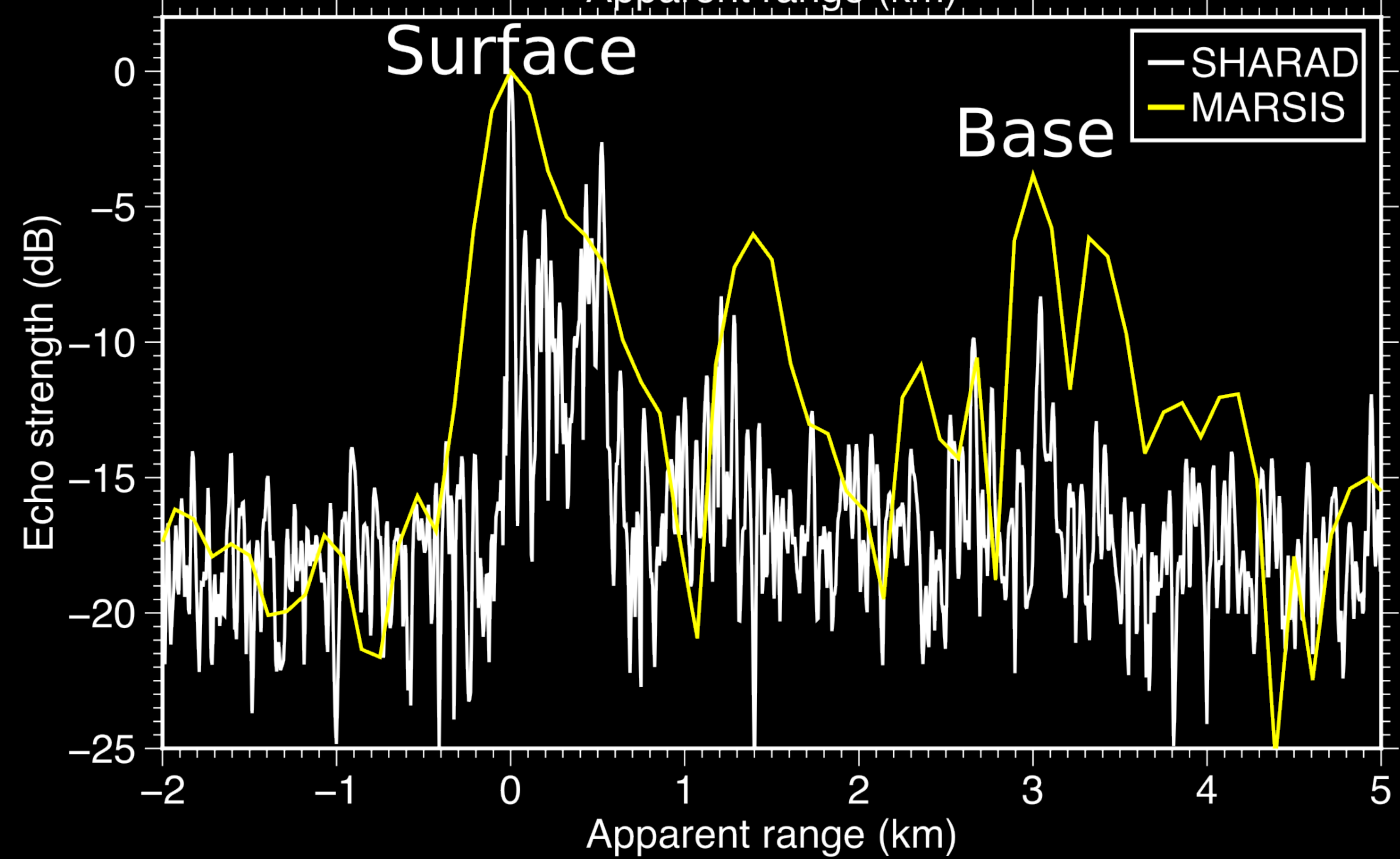


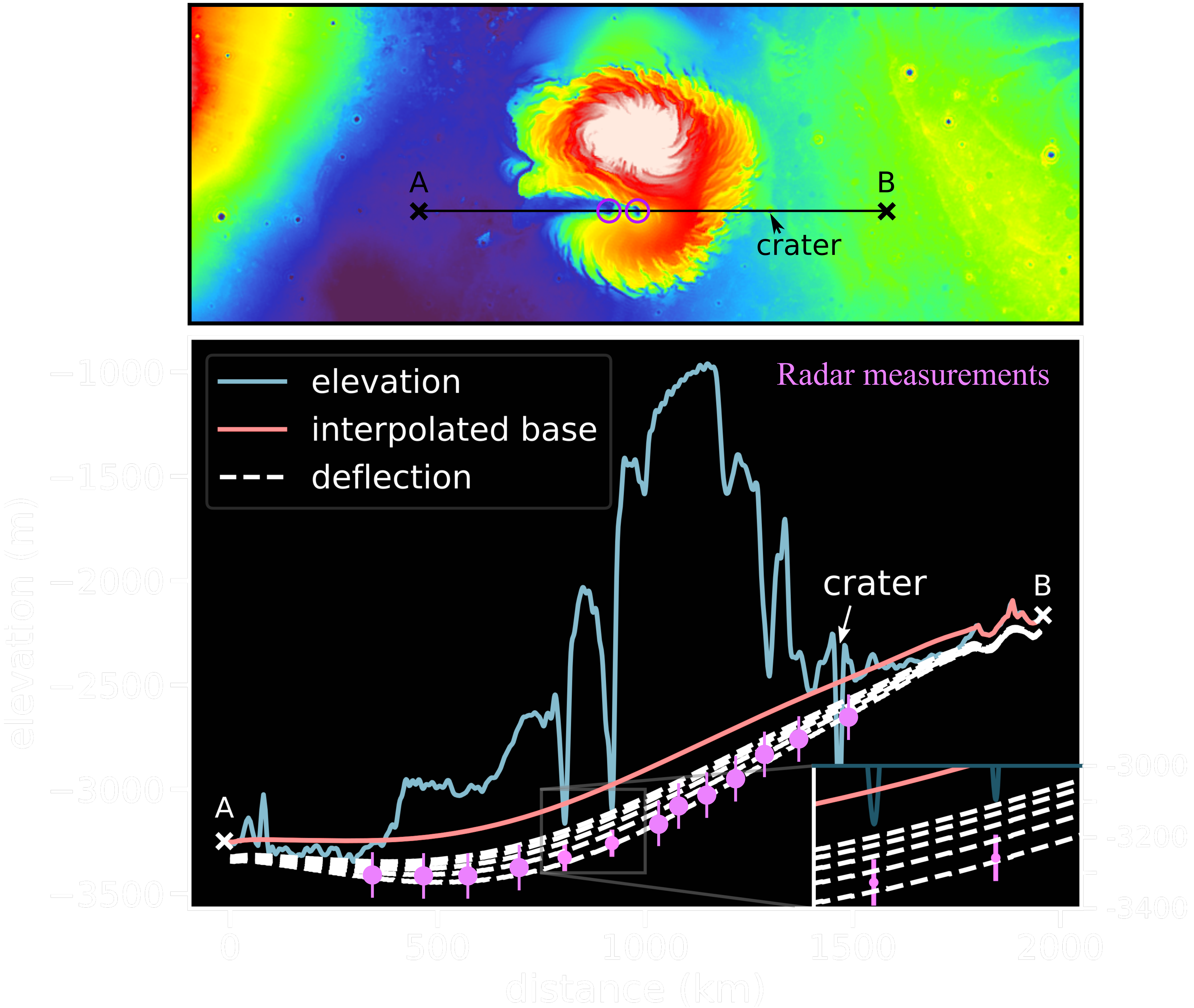
The north polar cap

MARSIS & SHARAD





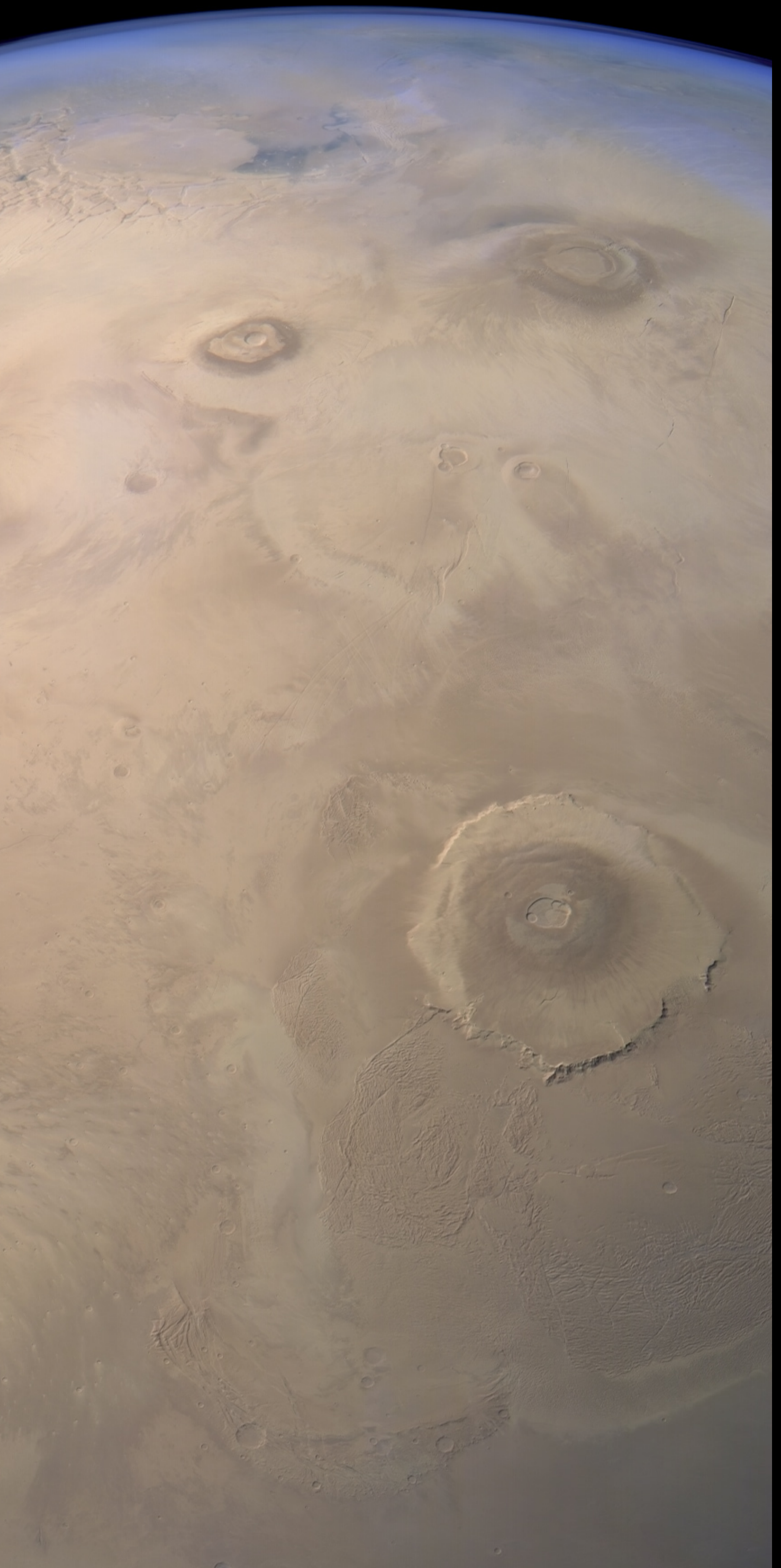




is large (> 330 km), implying a present-day heat flow of 16 mW m^{-2}

water ice (~ 80%), with some dust and CO_2 ice

Conclusion



Investigating response of a planetary surface when subject to loading is a powerful tool to determine the structure and composition of the lithosphere.

As a function of the load scale and expected signal, several orbital datasets can be used. The low resolution Martian gravity data allows to study large scale structures such as volcanoes. If the expected flexure signal is small, then radar data can be used.

We have determined that the composition of volcanoes to be iron-rich basalts similar to Martian meteorites collected on Earth. The lithospheric thickness increased with time as the planet cooled.

We have constrained the composition of the northern polar cap of Mars, found some CO_2, and observed that it is supported by a thick elastic lithosphere.