Martian Ice as a Resource for Exploration: Current Knowledge and Recent Results

Space Resources Roundtable

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Colin Dundas

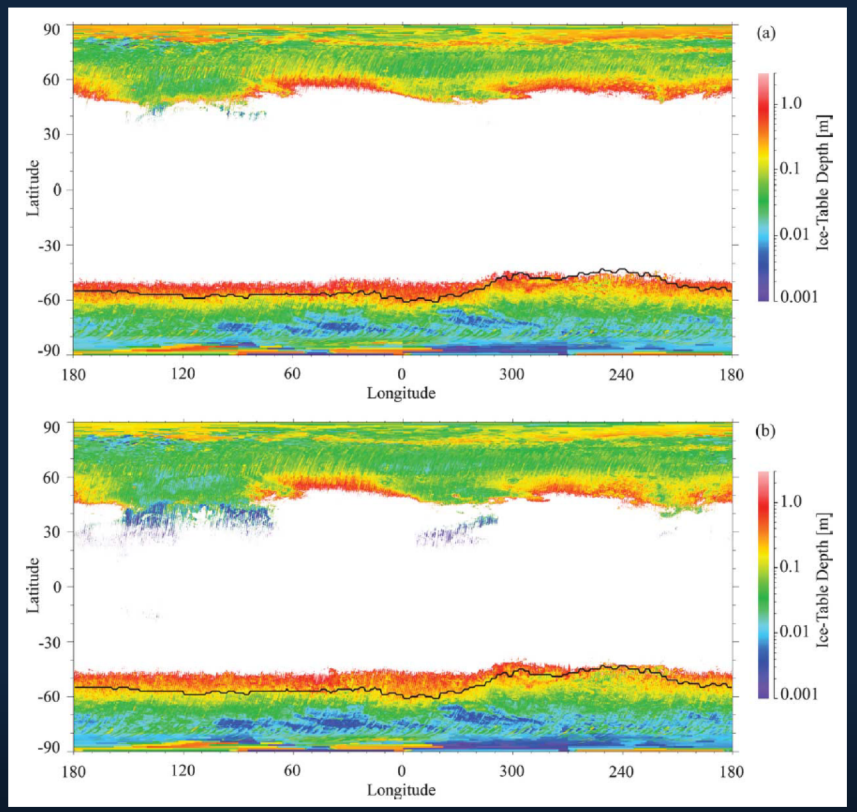
USGS
science for a changing world

Ice as a Resource: Needed Information

- Information needed to assess ice as a resource:
  - Spatial distribution at global and local scales.
  - Depth to ice.
  - Purity of ice (dust/regolith content, salts).
  - Mechanical properties (how hard to drill/extract?)
  - Accessibility (trafficability, etc.)
- This presentation is *not* a formal resource assessment; instead, it is a discussion of recent science related to these topics.

Ground Ice on Mars: Theory

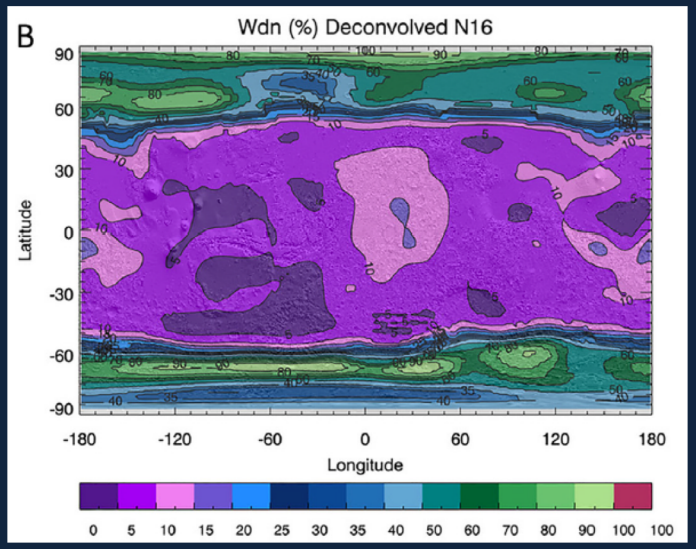
- Theoretical controls on stability of ground ice are well-understood at few-km scales.
  - Diffusive balance dependent on ice temperature and atmospheric water content.
- Several maps of depth to ice have been produced.
  - *E.g., Mellon et al. (2004), Schorghofer and Aharonson (2005), Chamberlain and Boynton (2007)*
- Major uncertainty in theory is near-surface humidity and its history.



(Mellon et al., 2004, Icarus; maps for 10 and 20 pr. μm H_2O)

Ground Ice on Mars: Observations

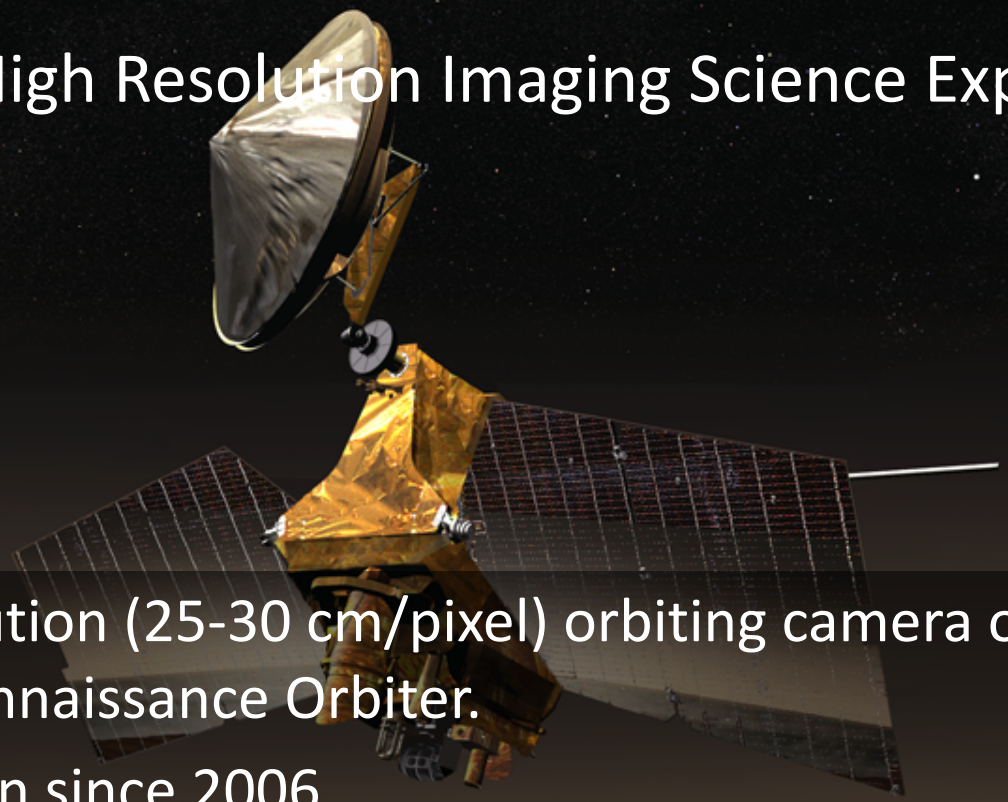
- GRS and radar data broadly consistent with theory.
- The vertical structure is not as well known.
  - Layering, variations between pore-filling and excess ice, depth to glaciers/massive ice.
- Radar indicates buried glaciers and ice sheets in several regions. *(Holt et al., 2008; Plaut et al., 2009; Bramson et al., 2015; Stuurman et al., 2016)*
- High-resolution orbital imaging offers us new insights into the nature of subsurface ice.



(Pathare et al., 2018, Icarus)

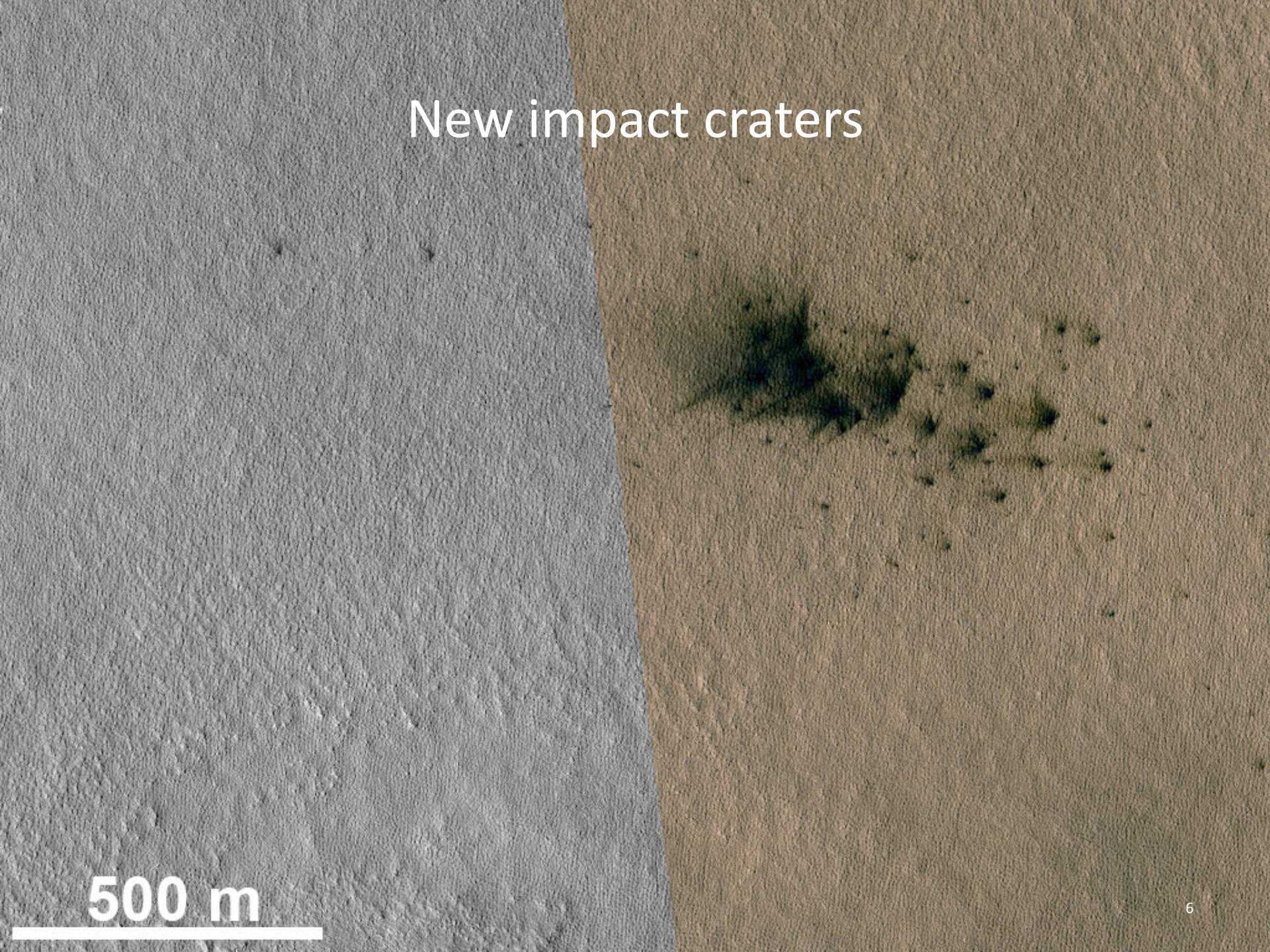
NASA PIA00161 (NASA/JPL/UA/TAMU)

HiRISE: The High Resolution Imaging Science Experiment

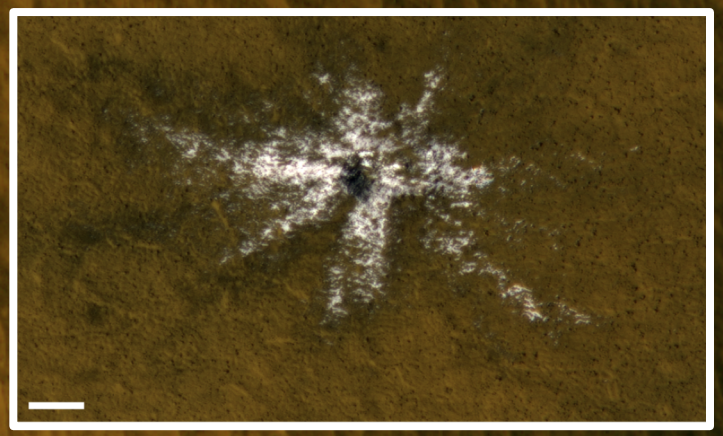


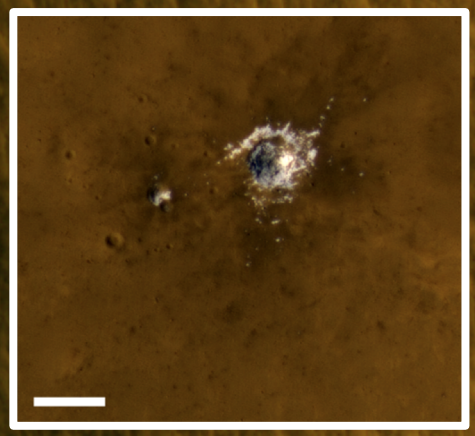
- High resolution (25-30 cm/pixel) orbiting camera on board Mars Reconnaissance Orbiter.
- In operation since 2006.
- Images include central swath in three color filters: near-IR, red, and blue-green.
- Two types of natural exposure: via impact craters and erosional scarps.

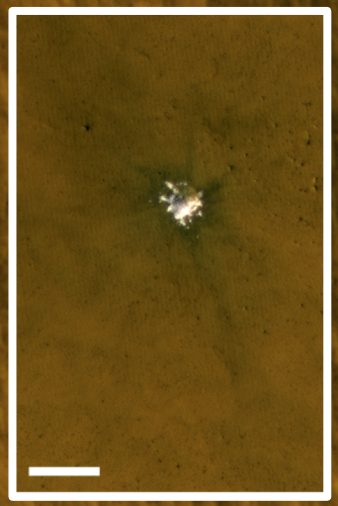
New impact craters

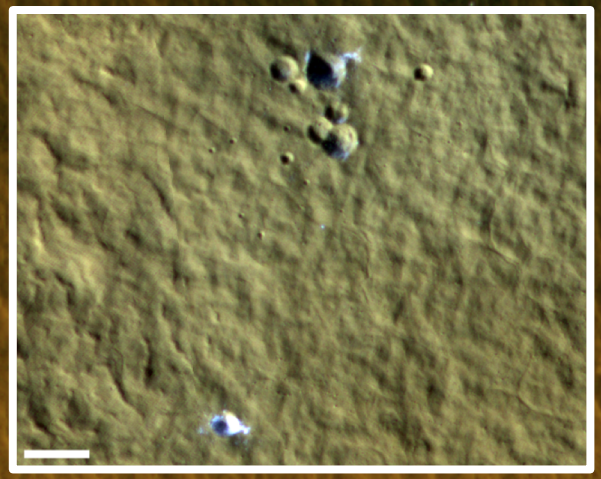


Mid-Latitude Craters





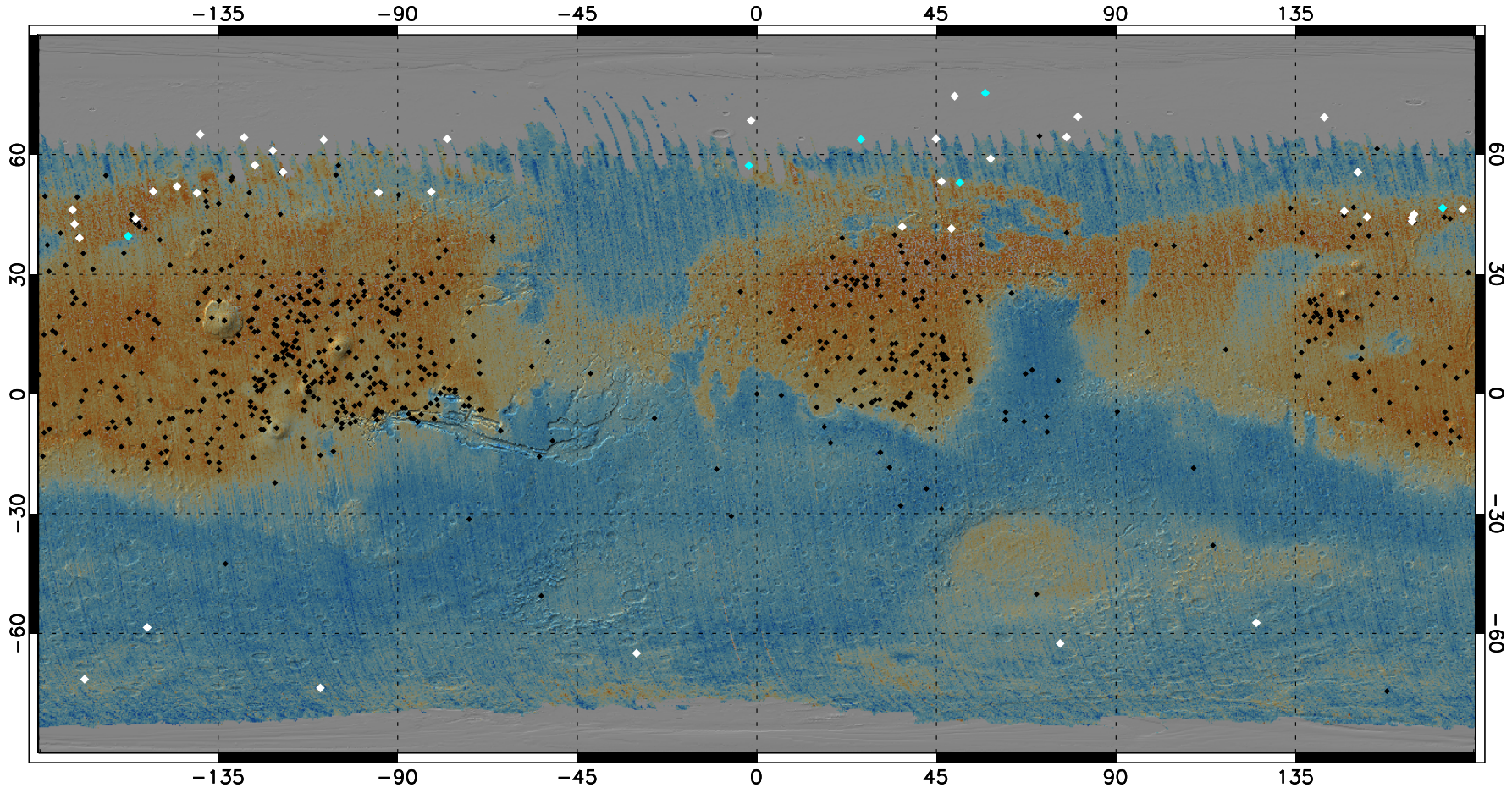




(Scale bars 20 m)

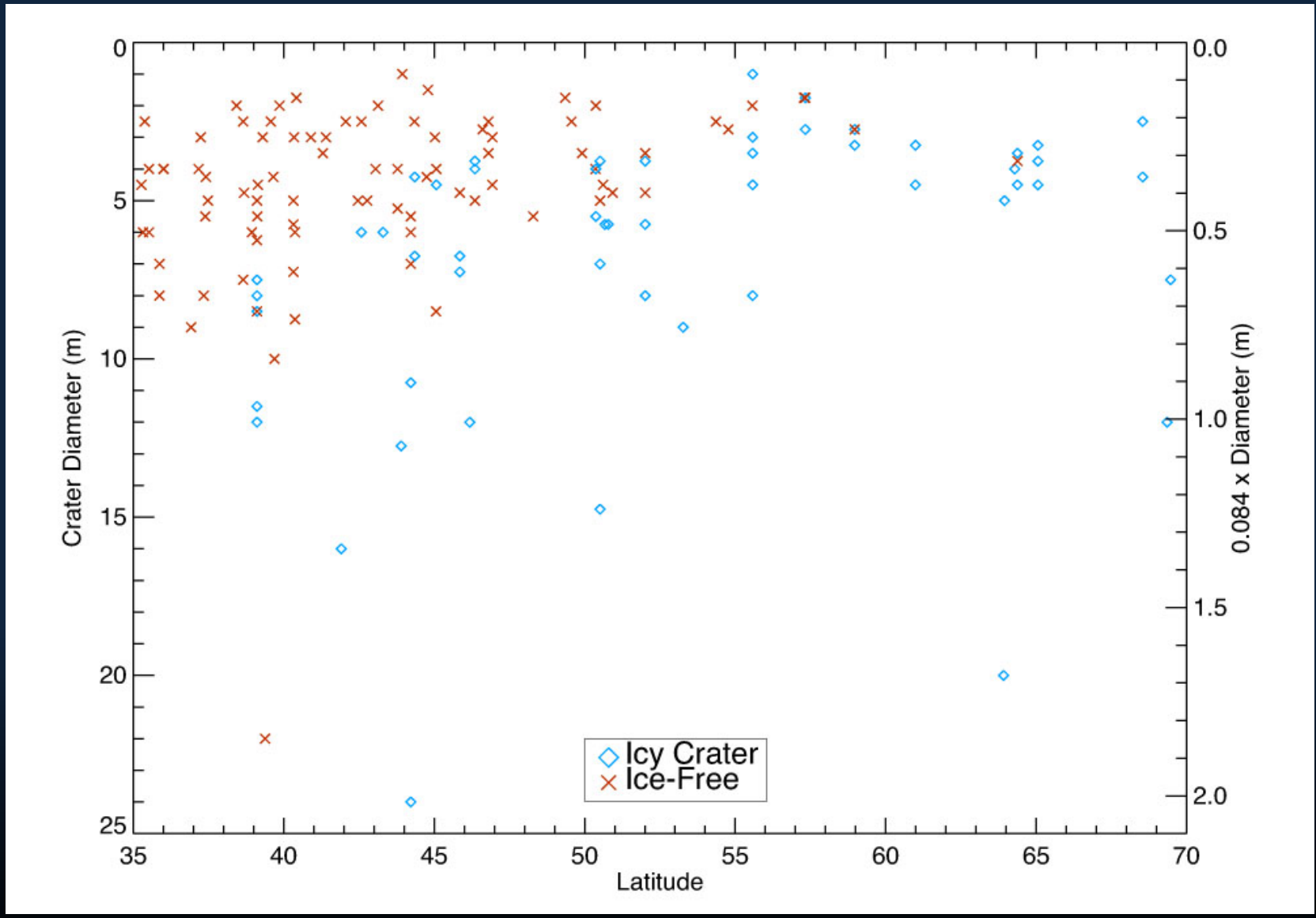
100 m

Ice-Exposing Crater Map



(Background: Dust Cover Index (Ruff and Christensen, 2002, JGR))

Diameter (Depth) Profile

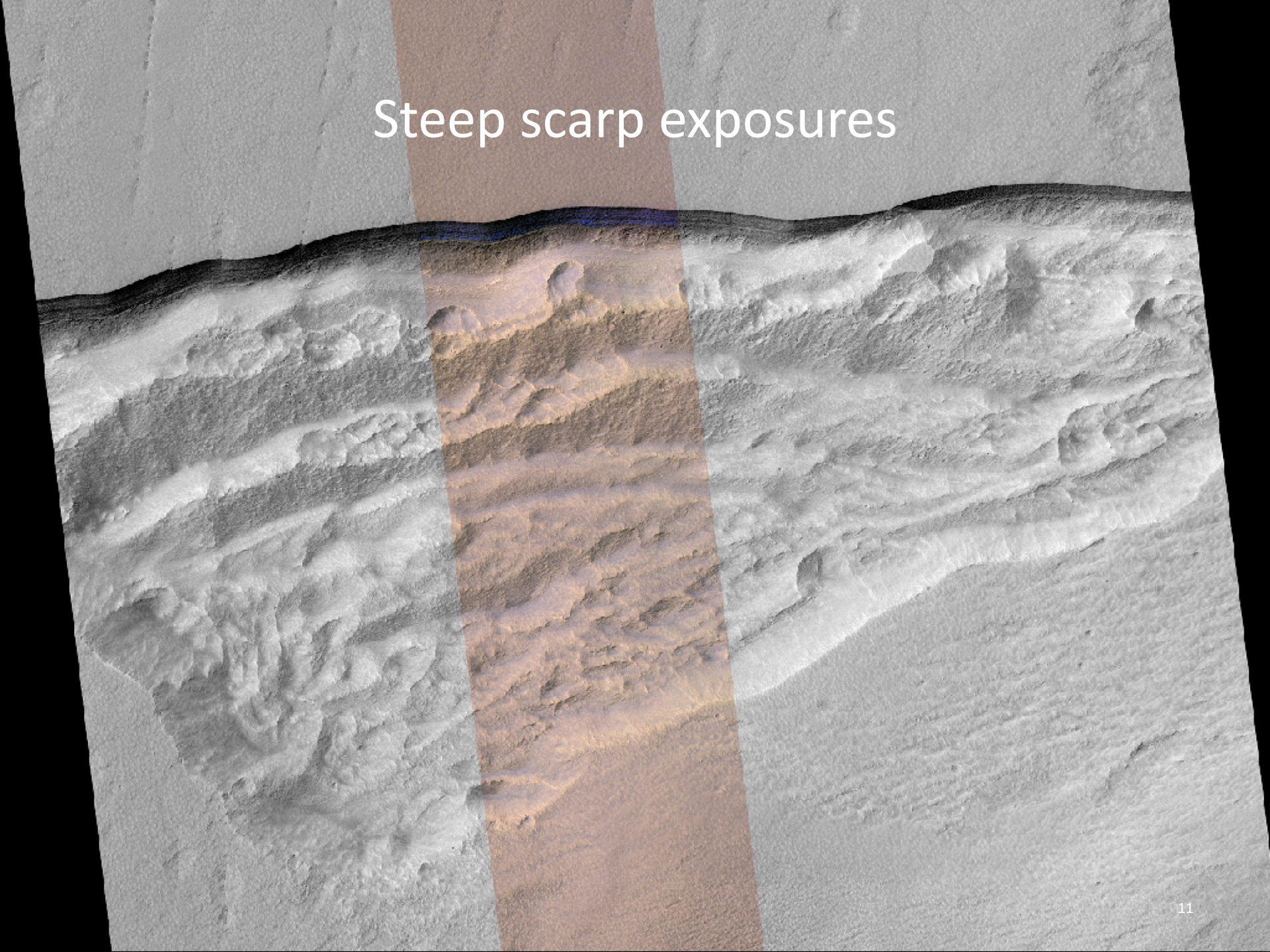


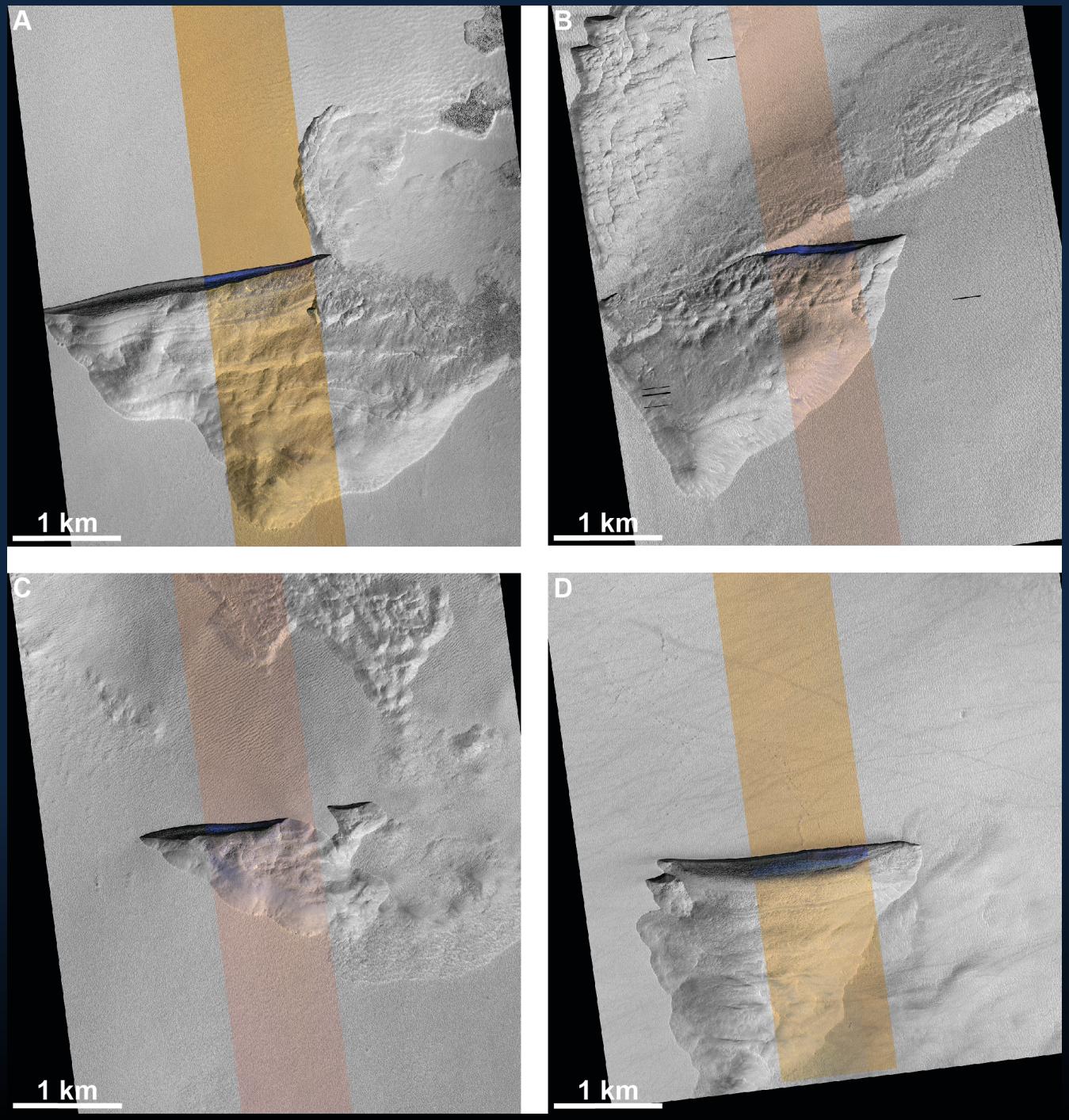
Ice-exposing craters: Summary

- New craters expose ice at latitudes above 39˚N and also mid/high southern latitudes.
- Depth profiles resemble expectations from theory with near-surface humidity modestly higher than present.
- Ice can remain bright for months or years, indicating that it contains little dust.
    - Some clean ice may be due to melting/refreezing, not original.

- *More info: Dundas et al. (2014, J. Geophys. Res. 119)*

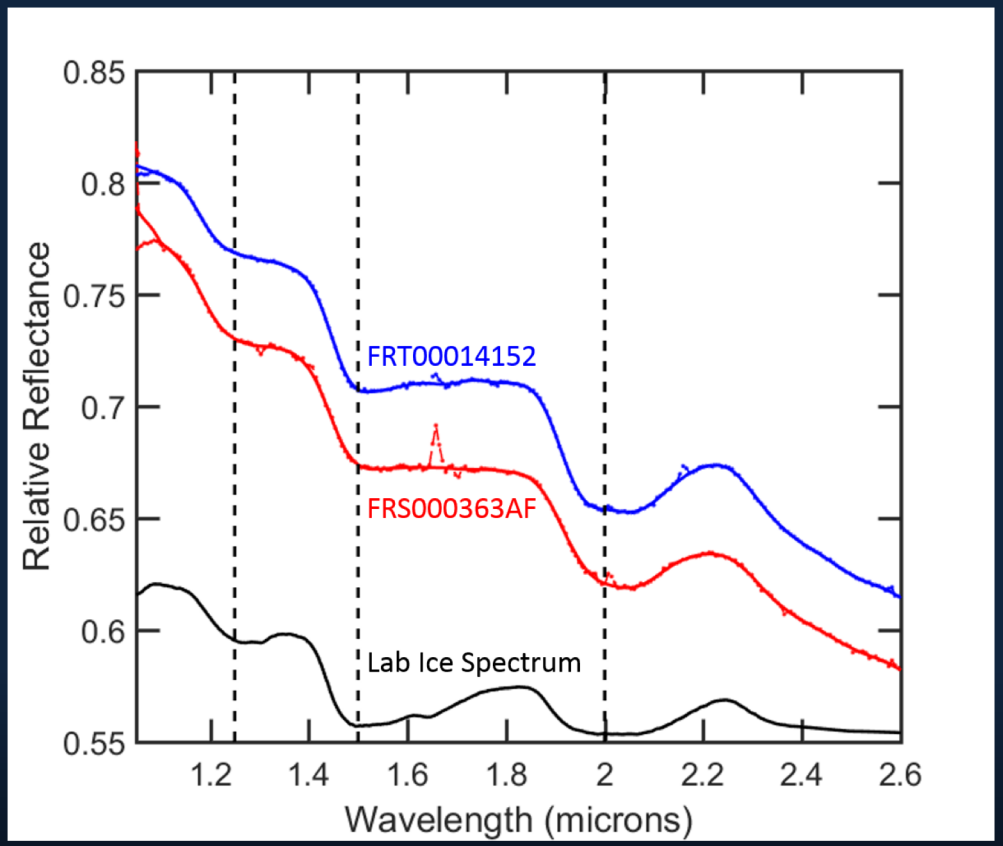
Steep scarp exposures

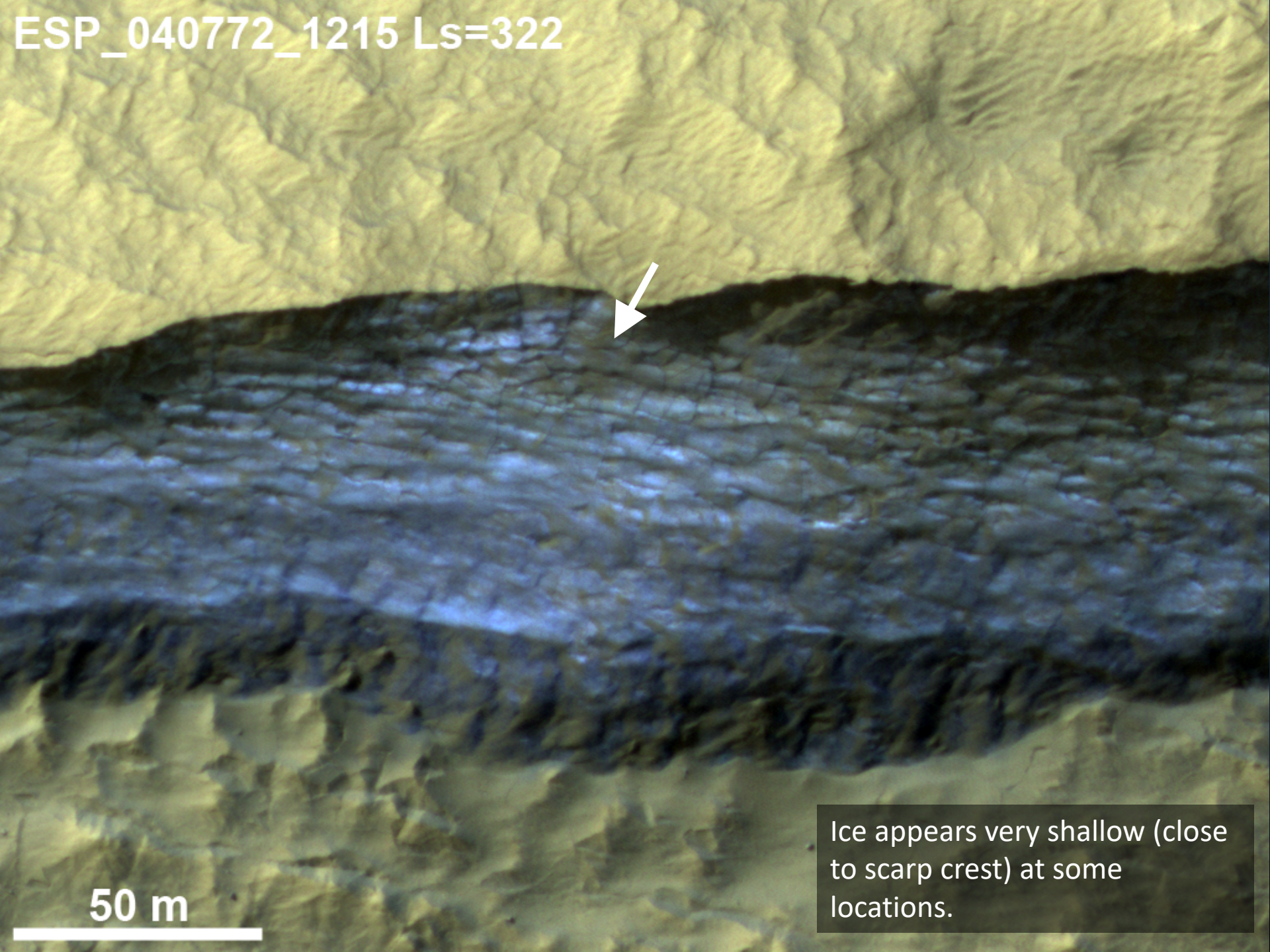


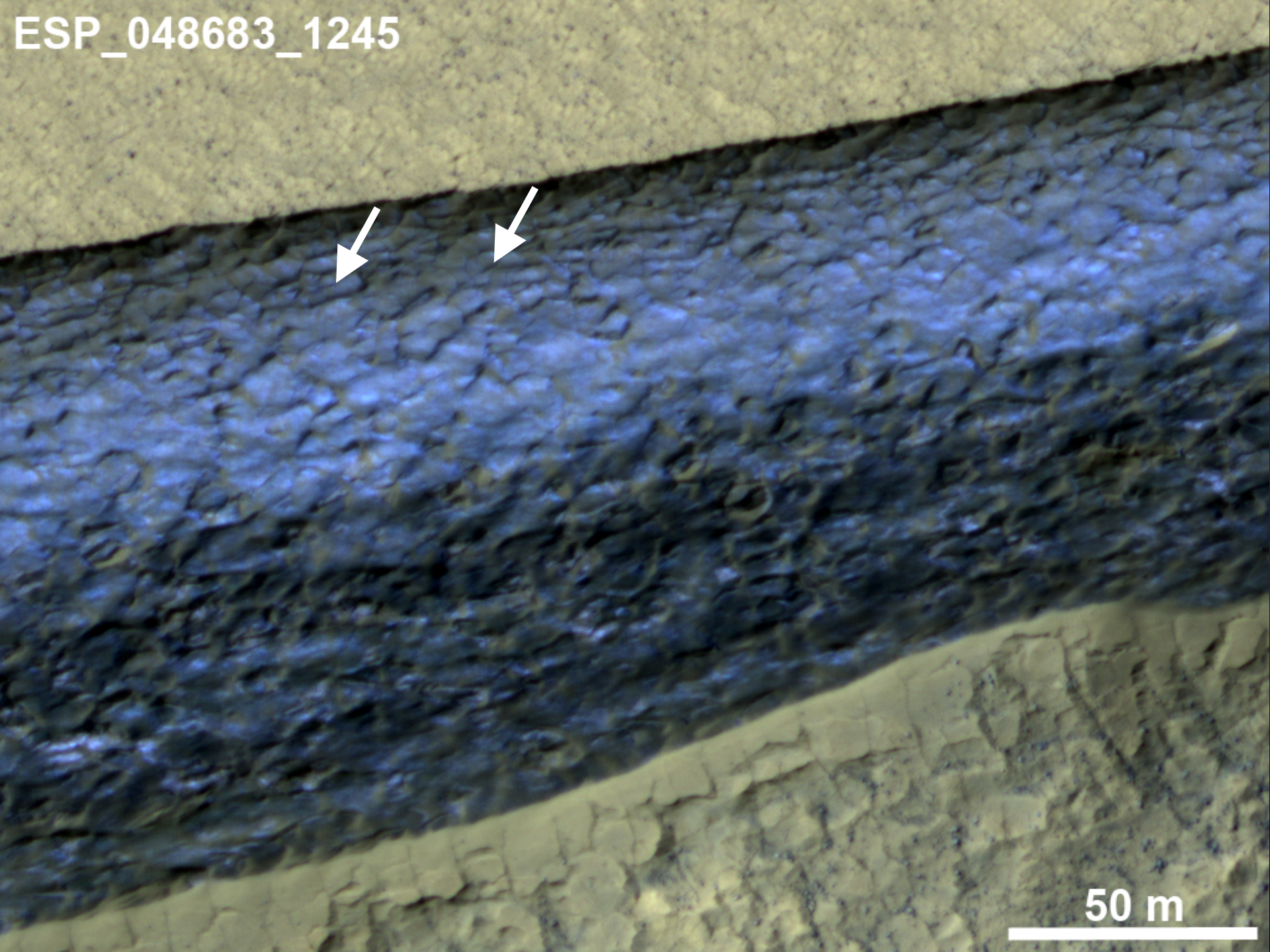

A
1 km
B
1 km
C
1 km
D
1 km

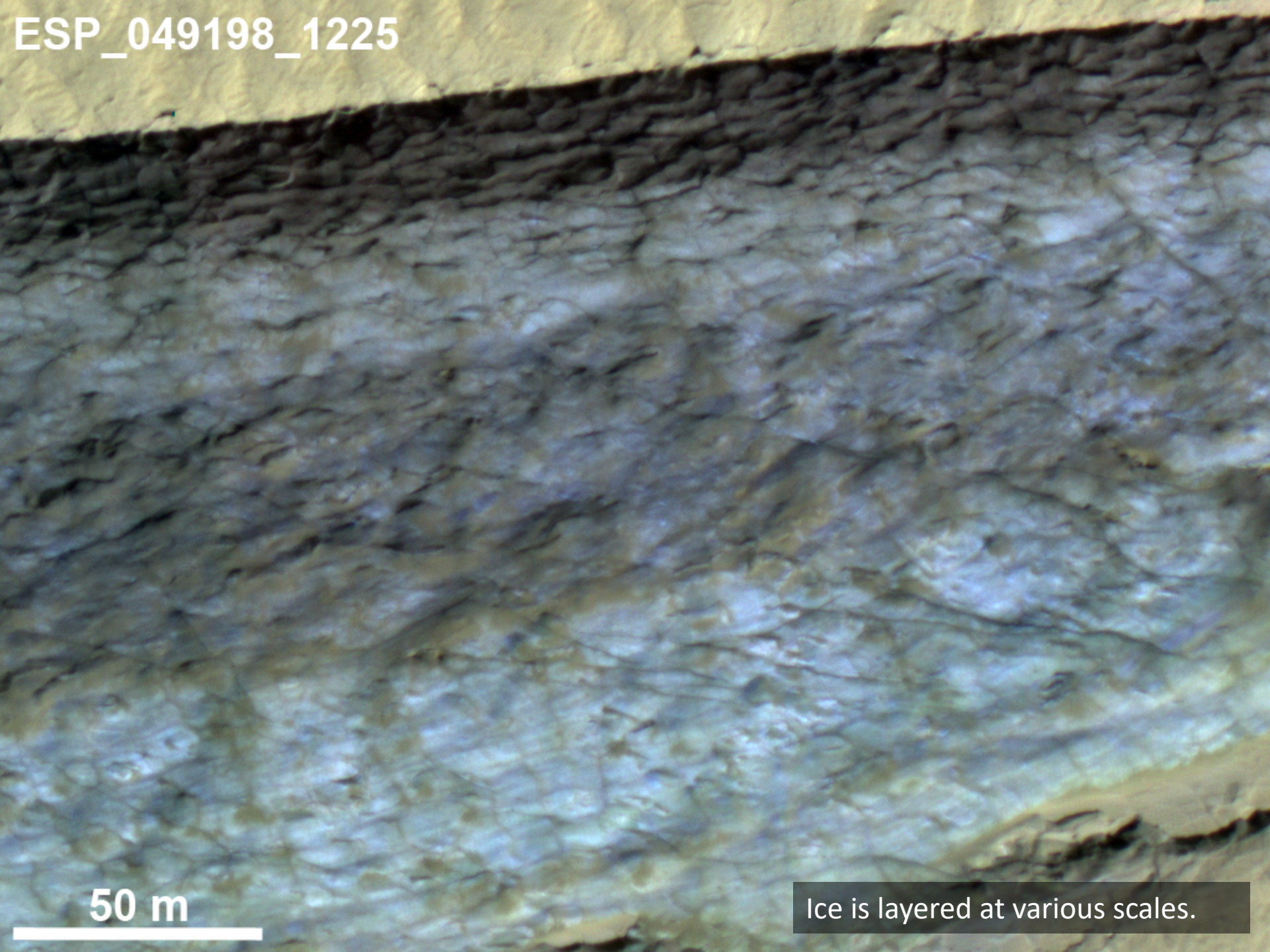
Composition

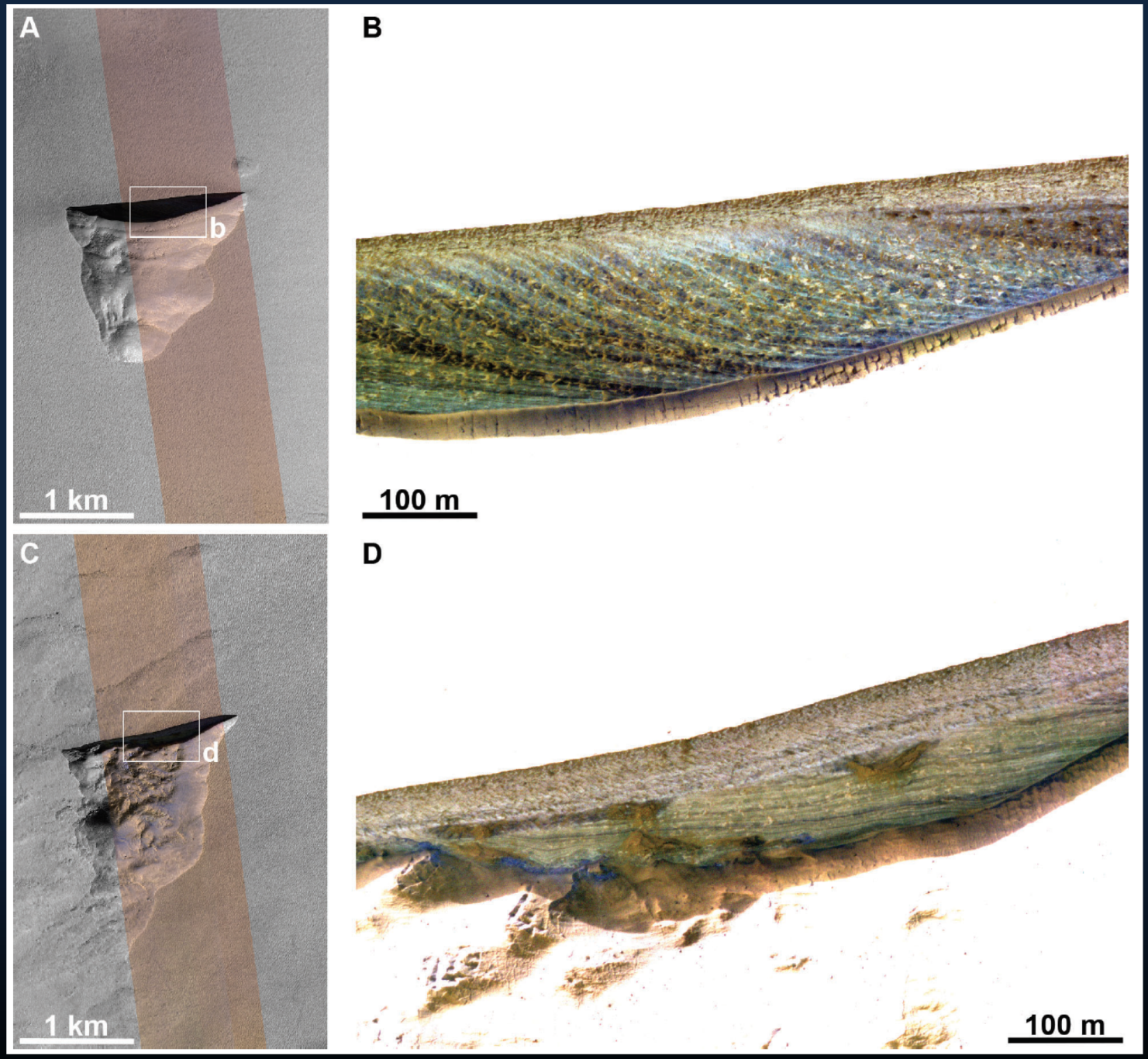
- Water ice (CRISM).
- Scarps remain relatively-blue in late summer.
- Frost on pole-facing slopes in and around gullies is gone much earlier.
  - Not seasonal frost.

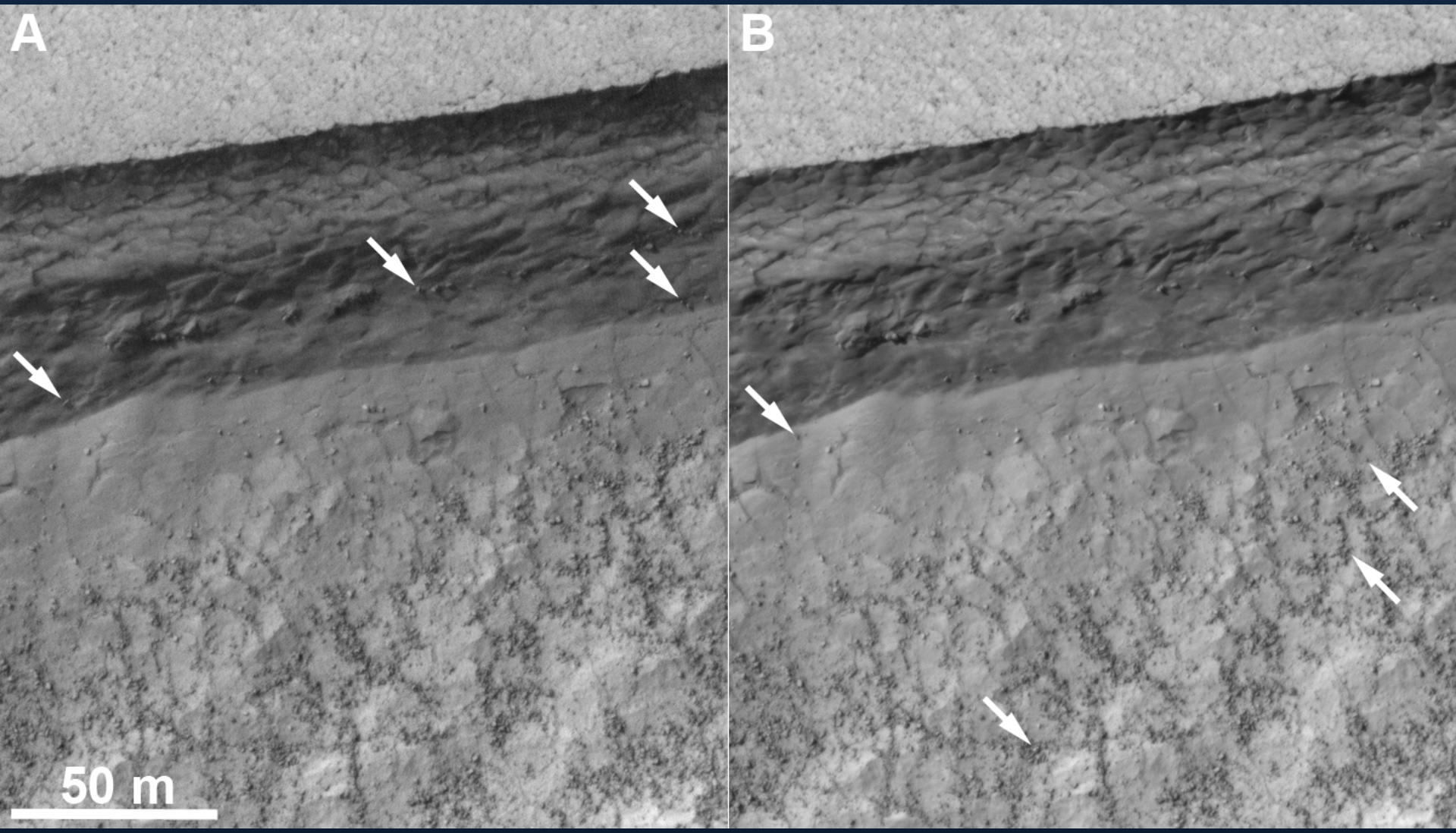



ESP_040772_1215 Ls=322
50 m
Ice appears very shallow (close to scarp crest) at some locations.

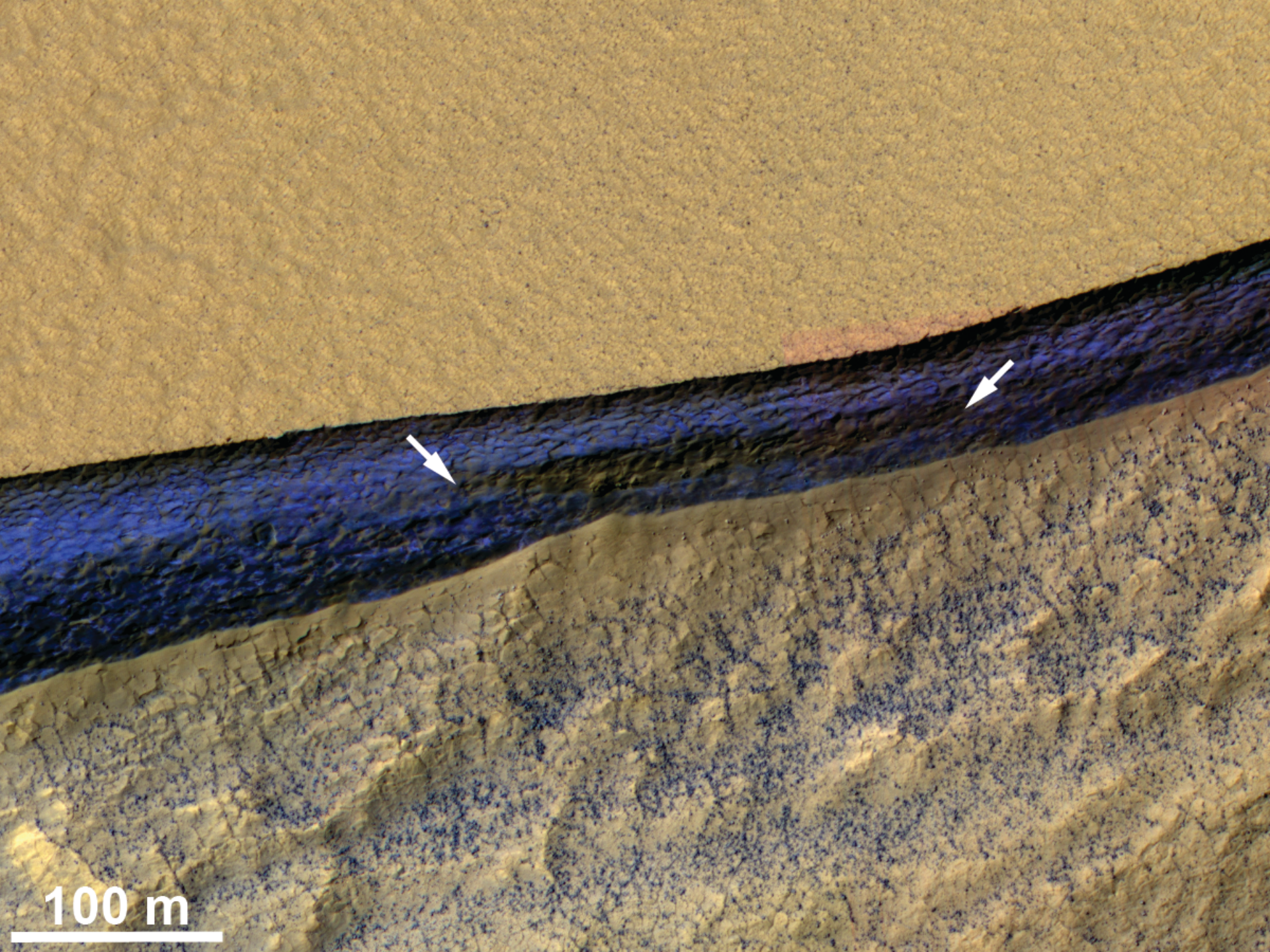

ESP_048683_1245
50 m

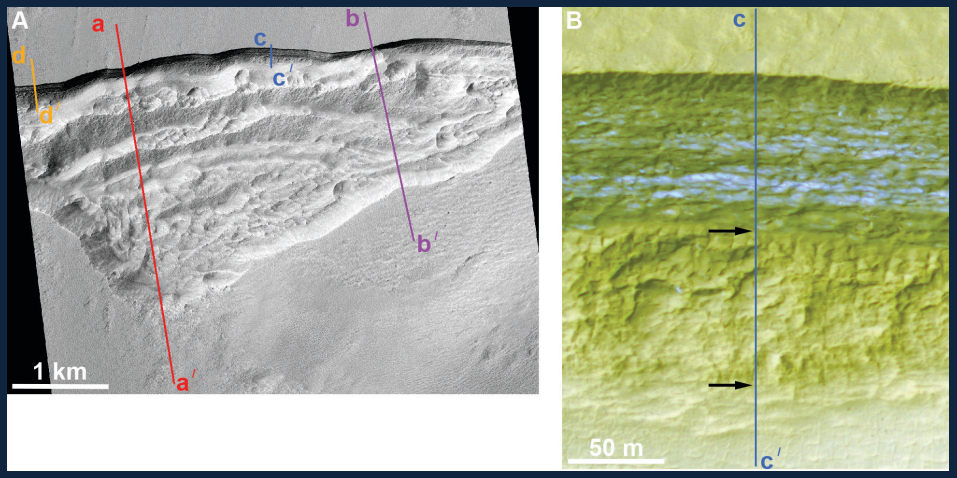

ESP_049198_1225
50 m
Ice is layered at various scales.

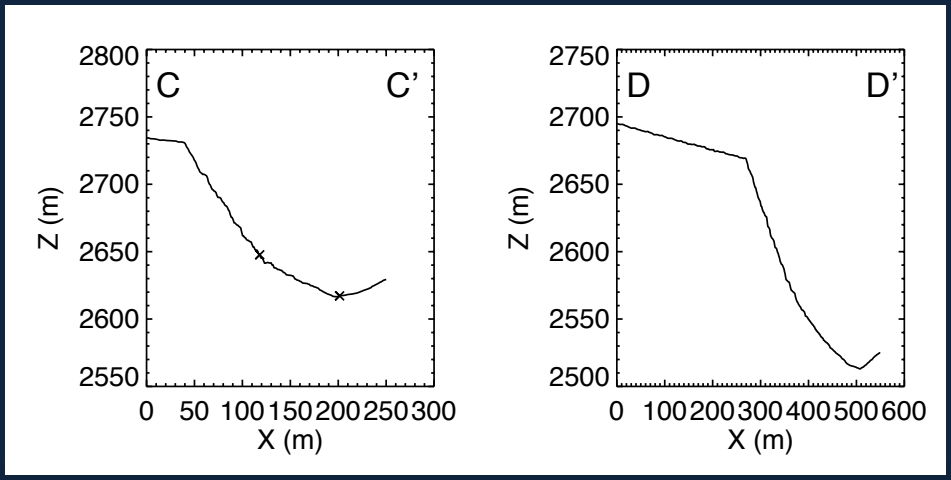

A
b
1 km
B
100 m
C
d
1 km
D
100 m

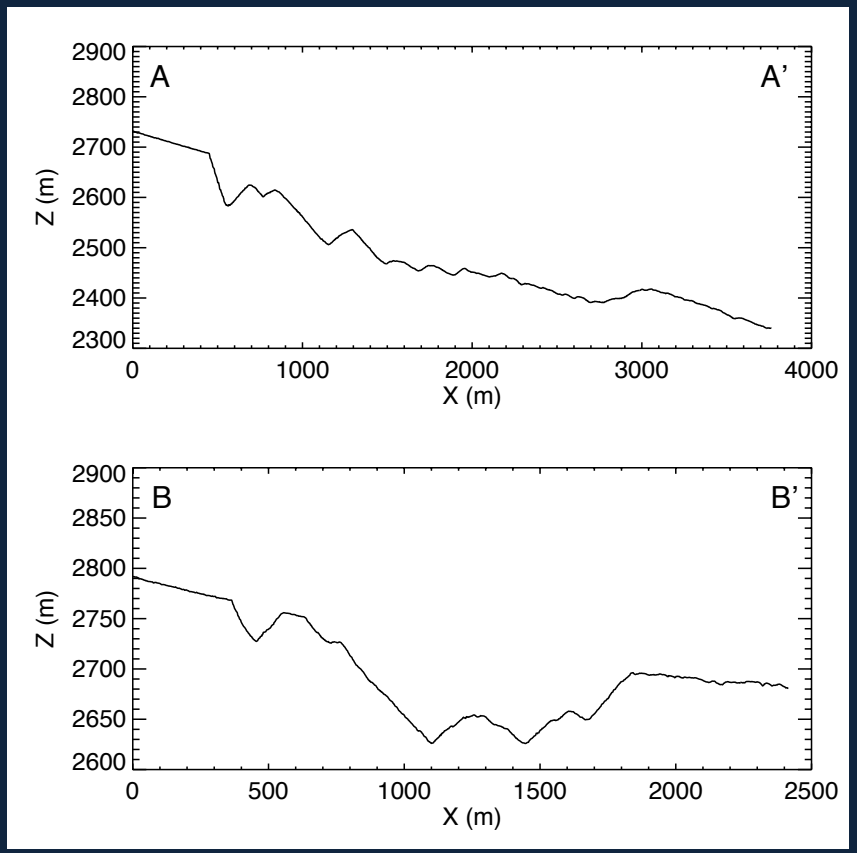


Rocks observed to fall from one scarp—active sublimation, slope retreat.


100 m







Scarps occur in broad pits with >100 m of relief.

Not fault scarps—no offset of “island” within pit.

Total ice thickness >130 m.

Schematic cross-section

- Thick ice sheets are exposed in cross section.
- Ice begins at shallow depths (< 1 m), and can be >100 m thick at these locations.
- Possible thin covering layer of ice-cemented material.

Ice-exposing scarps: Summary

- Scarps expose massive ground ice with low regolith content at multiple locations near 55˚N and S.
- Provide a high-resolution cross-section through the ice.
  - Some vertical and horizontal variations and layering.
  - Overall, consistent with simple structure: thin lag over massive ice.
- Ice was likely deposited as snow in the geologically recent past and now locally exposed by sublimation-thermokarst processes.

- *More info: Dundas et al. (2018, Science 359, 199-201).*

Planetary Protection

- Any possibility of using Martian ice as a resource requires attention to Planetary Protection.
- Martian ice, in itself, is not necessarily a Special Region as defined by COSPAR ($T>255$ K, $a_w>0.6$) since ice is found in cold places.
- However, extracting ice is likely to create induced Special Regions, and ice has been considered a possible habitat.
- Further study is needed *(see Rummel et al. (2014))*.

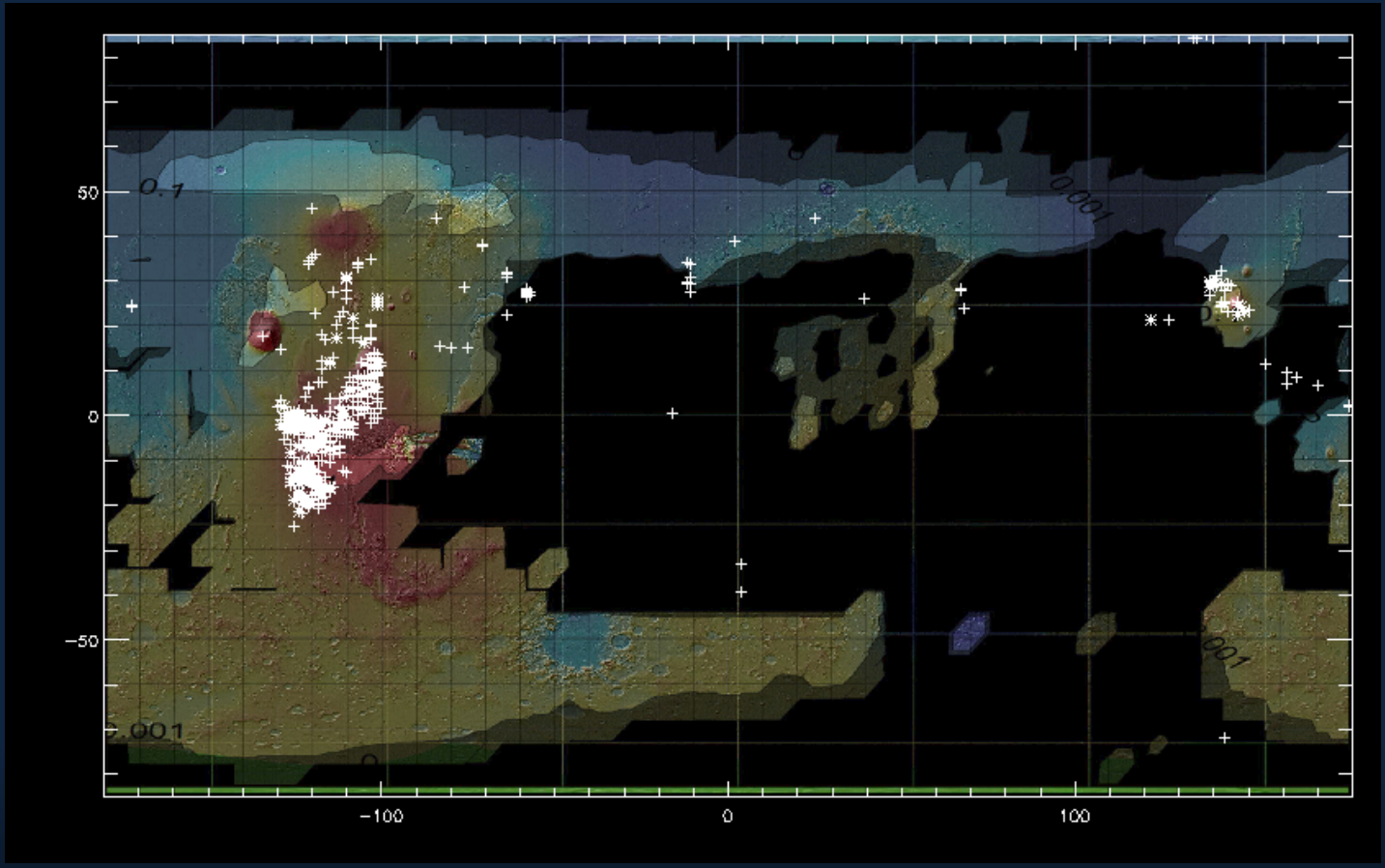
Conclusions

- Not a formal resource assessment, but science relevant to understanding the possibility.
- New craters expose shallow ice at latitudes as low as 39˚N and also mid/high southern latitudes.
- Scarps expose massive ground ice with low regolith content at multiple locations near 55˚N and S.
- Ice on Mars is variable—no single cross-section, latitudinal boundary, or depth to ice is universal.
- But there is substantial evidence for large volumes of relatively-clean ice starting at shallow depths in some locations.
- Accessing and utilizing such ice requires attention to Planetary Protection.

- Questions?

Extra slides

Ice caves?



Ice caves may exist locally (Williams et al., 2010); existence not yet demonstrated but likely caves exist (Cushing et al., 2015).