Transient Processes and Environments on Present-Day Mars

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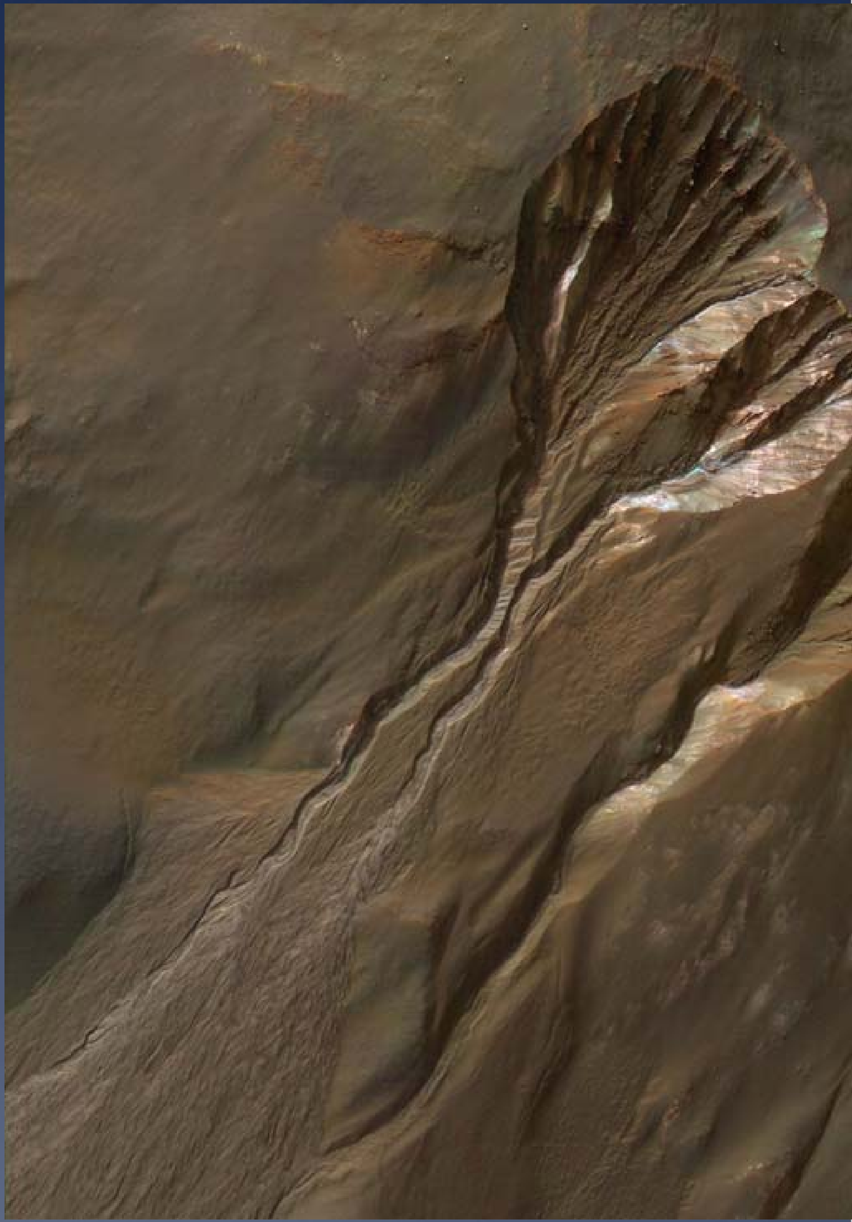
Mars Habitability Conference, Lisbon

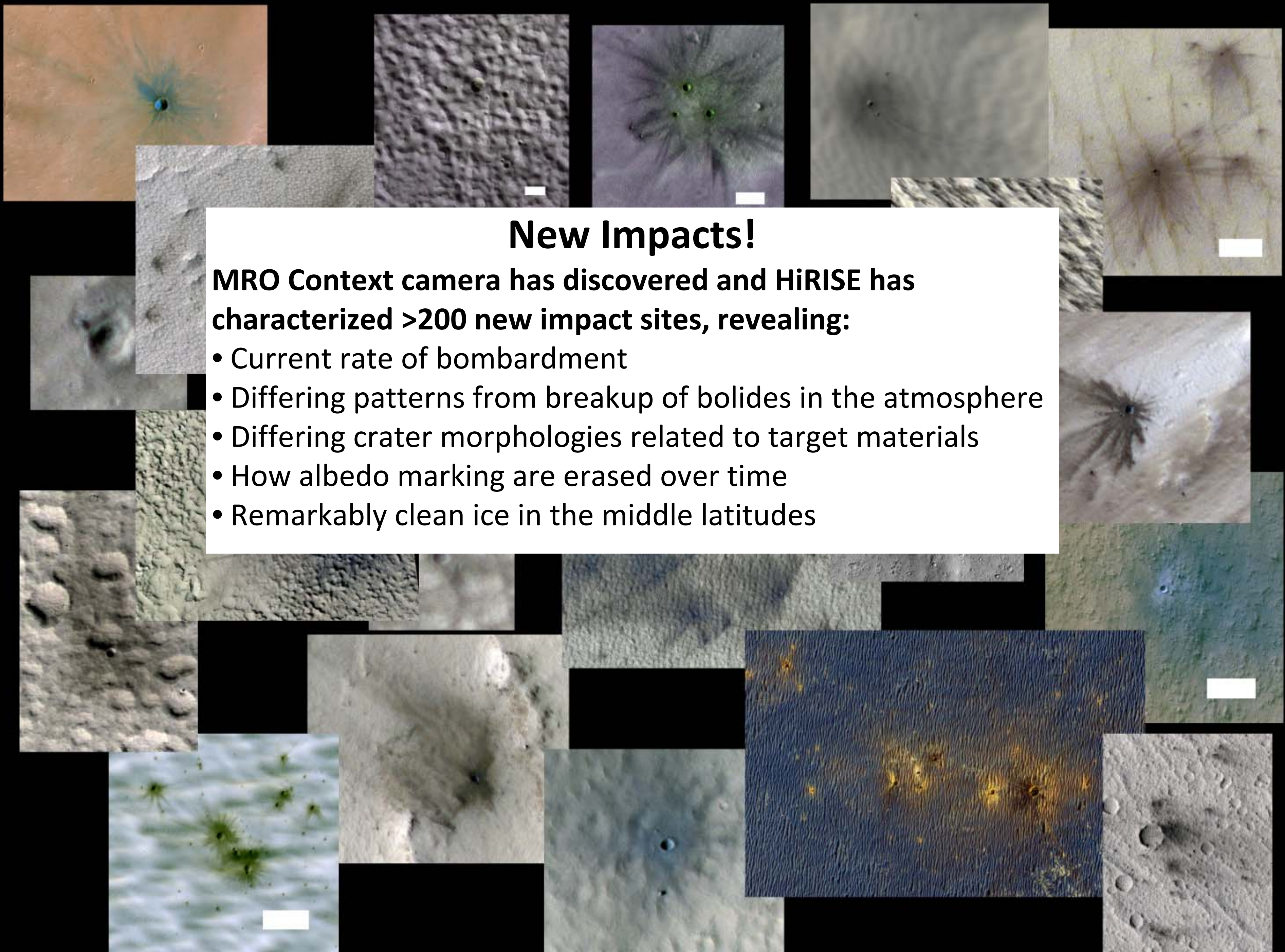
HiRISE ESP_014339_0930
South Pole residual CO_2 ice cap in mid-summer

Introduction

- Observed present-day surface activity on Mars:
  - Small Impacts
  - Eolian processes
  - Polar and seasonal processes
  - Slope processes (gullies, mass wasting, slope streaks, polar avalanches)
    - *Recurring Slope Lineae*
- Geologically recent processes, but not observed to be currently active:
  - Volcanism
  - Large impacts
  - Fluvial and Hydrothermal activity
  - Glacial flow
  - Water-carved gullies
- Observed activity will be summarized in this talk



Ravines (or big gullies) on Mars

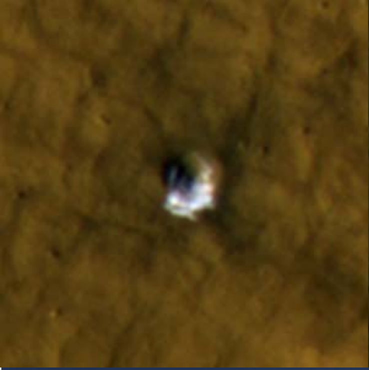


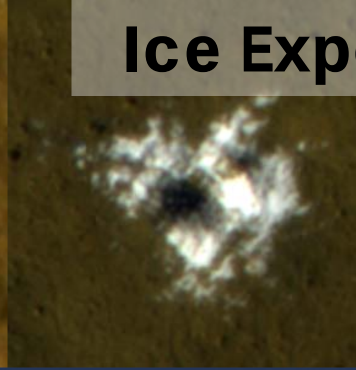
New Impacts!

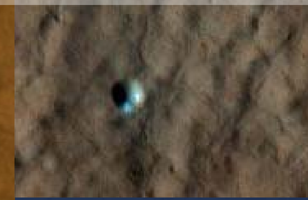
MRO Context camera has discovered and HiRISE has characterized >200 new impact sites, revealing:

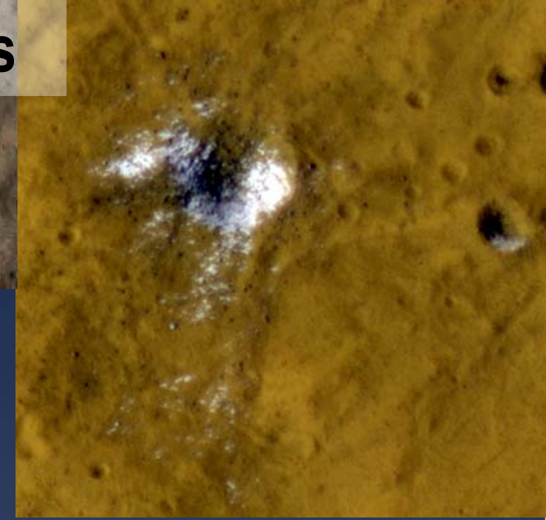
- Current rate of bombardment
- Differing patterns from breakup of bolides in the atmosphere
- Differing crater morphologies related to target materials
- How albedo marking are erased over time
- Remarkably clean ice in the middle latitudes

Ice Exposed by New Impacts

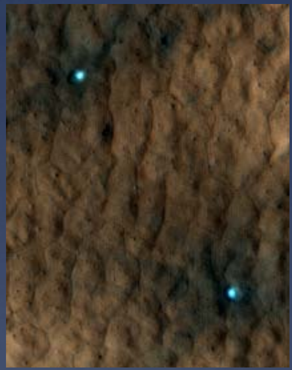


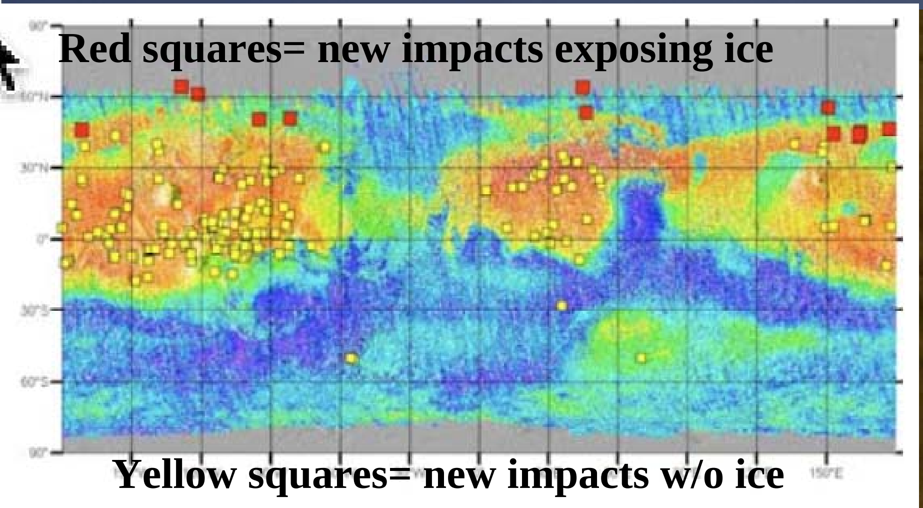


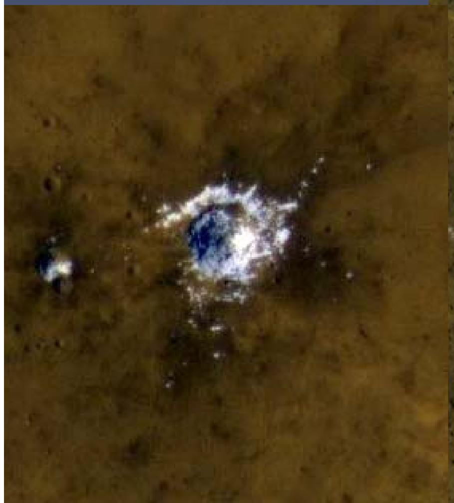




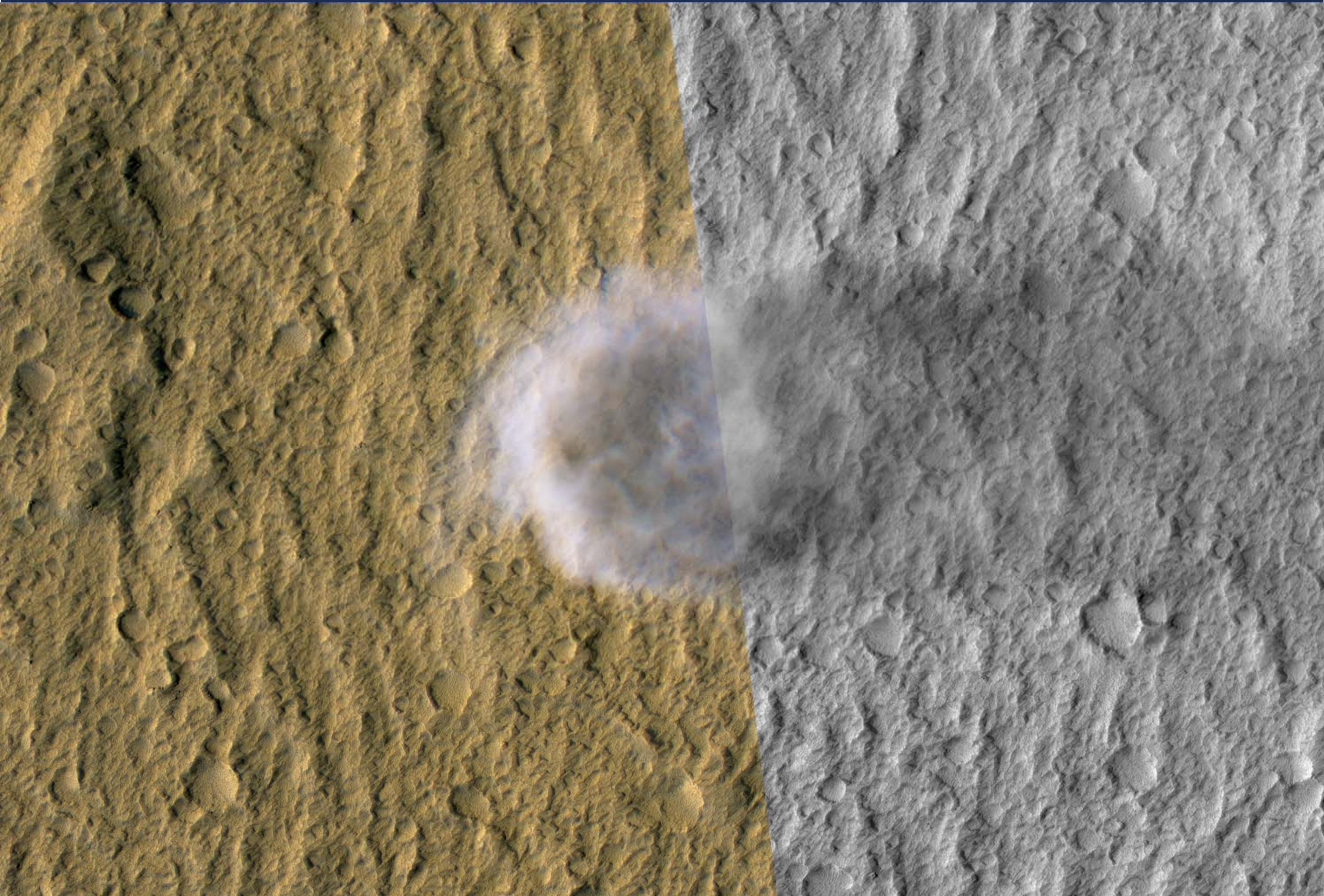
- 13 New impacts north of ~35 N have distinct ice patches.
- Distribution and depth of ice is consistent with model calculations for an atmosphere slightly more humid than present.
- Image sequences show some ice fading over time.
- Sublimation modeling indicate that mm of ice sublimate before it fades, indicating clean (>99%) ice.
  - Melting unlikely from small impacts.
  - Snowfall layer unlikely--covered by boulders
  - Migration of thin films of briny water may work







Active dust devil

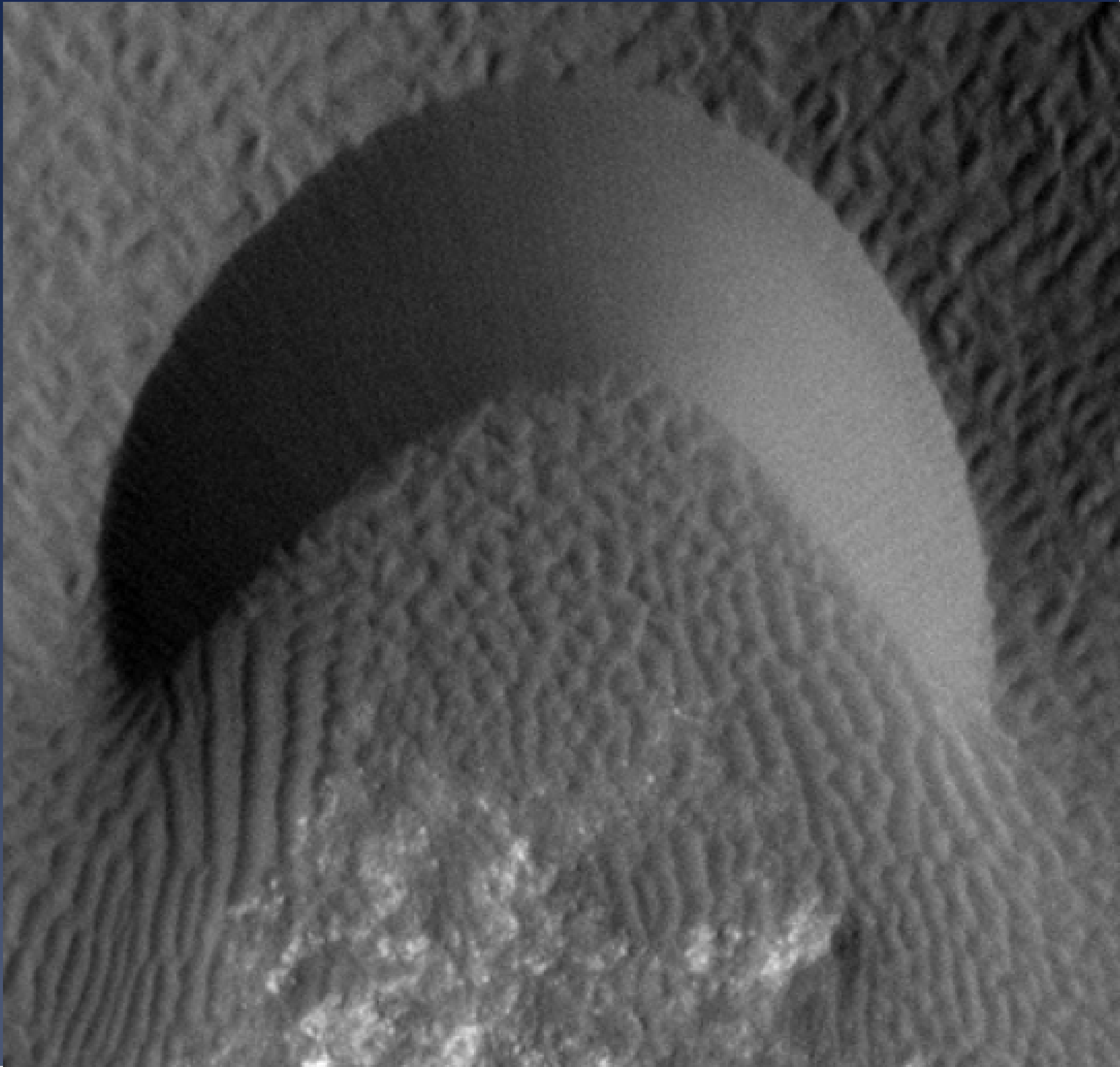


MER and HiRISE have shown than many sand bodies are active

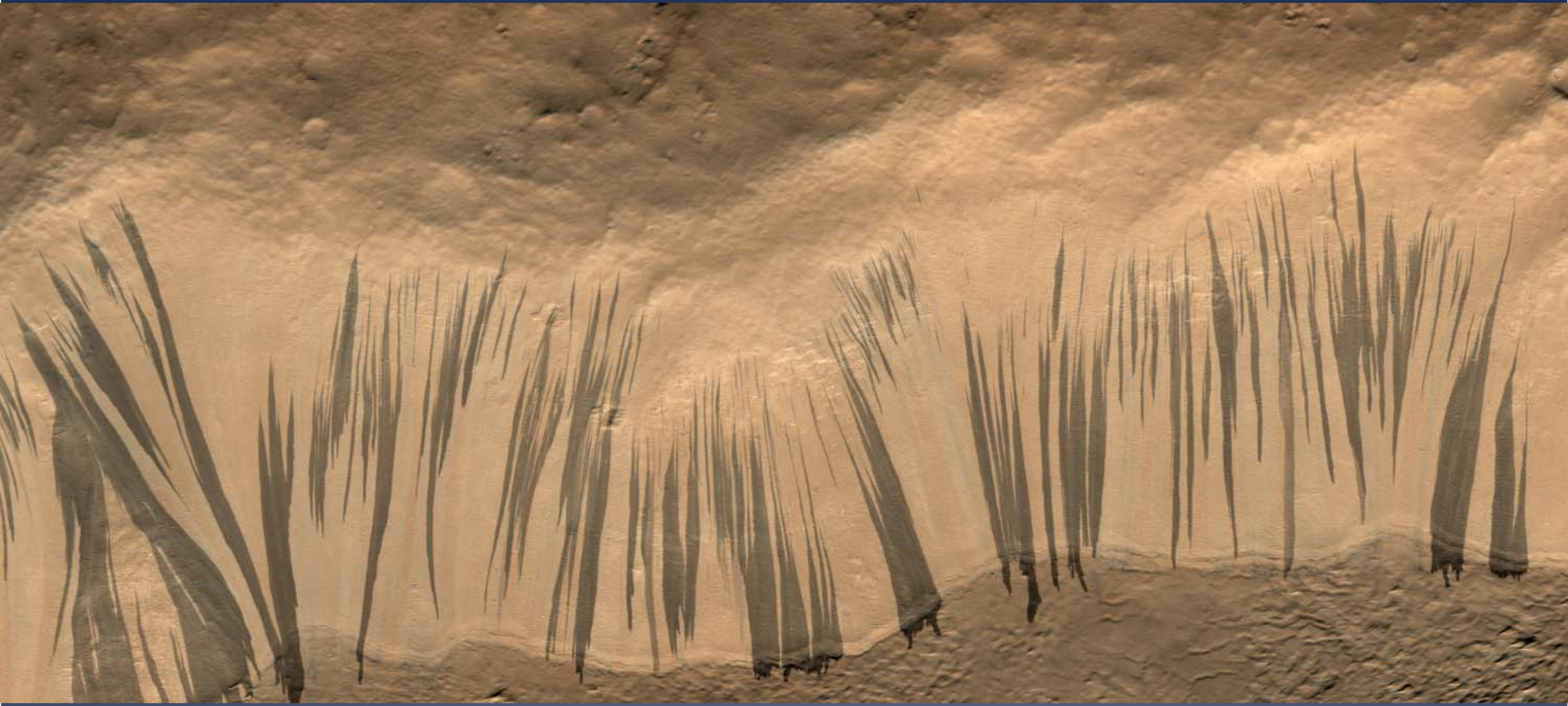
Herschel Crater Dunes

PSP_002860_1650

ESP_020384_1650

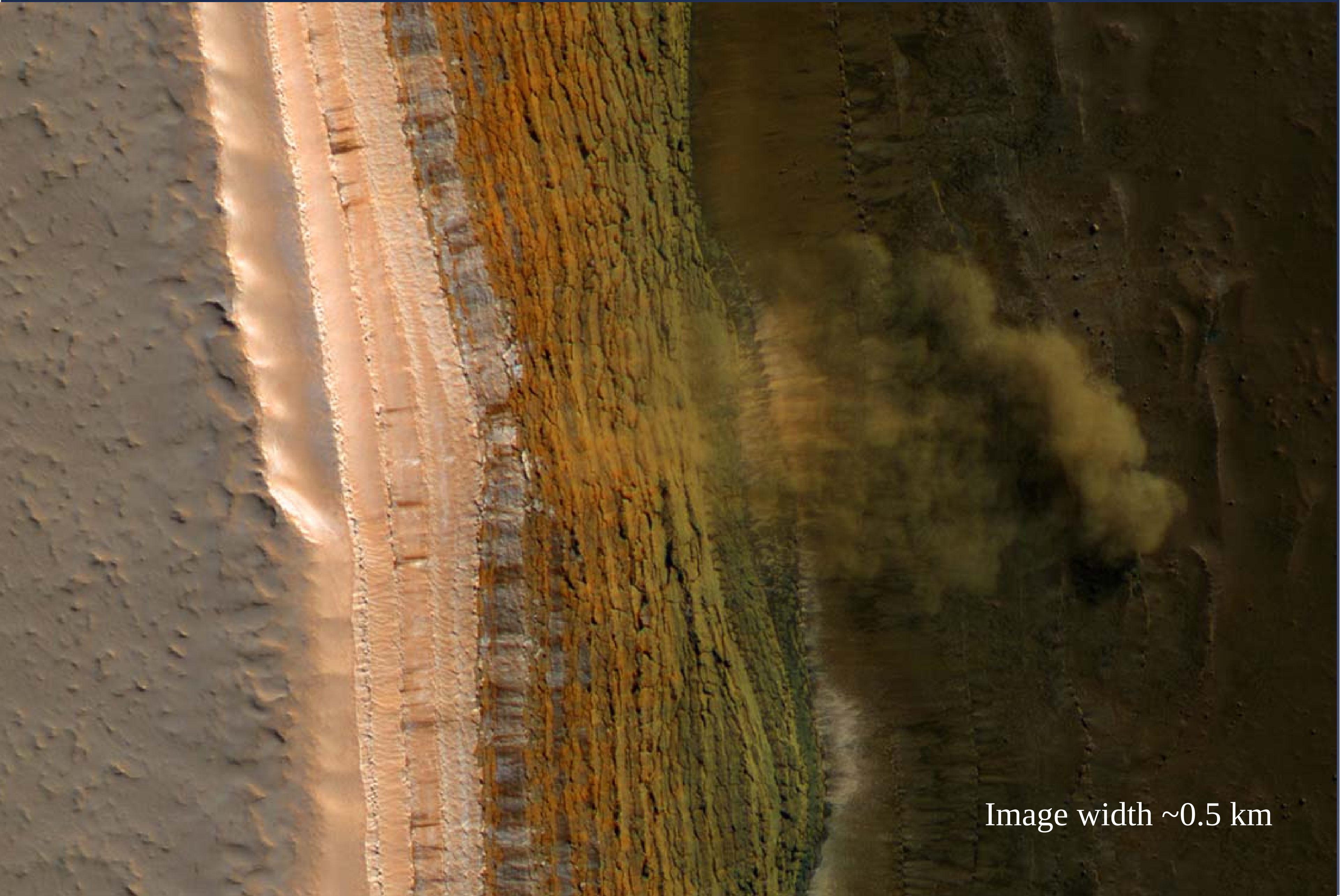


Thousands of new slope streaks form every year on dust-mantled slopes

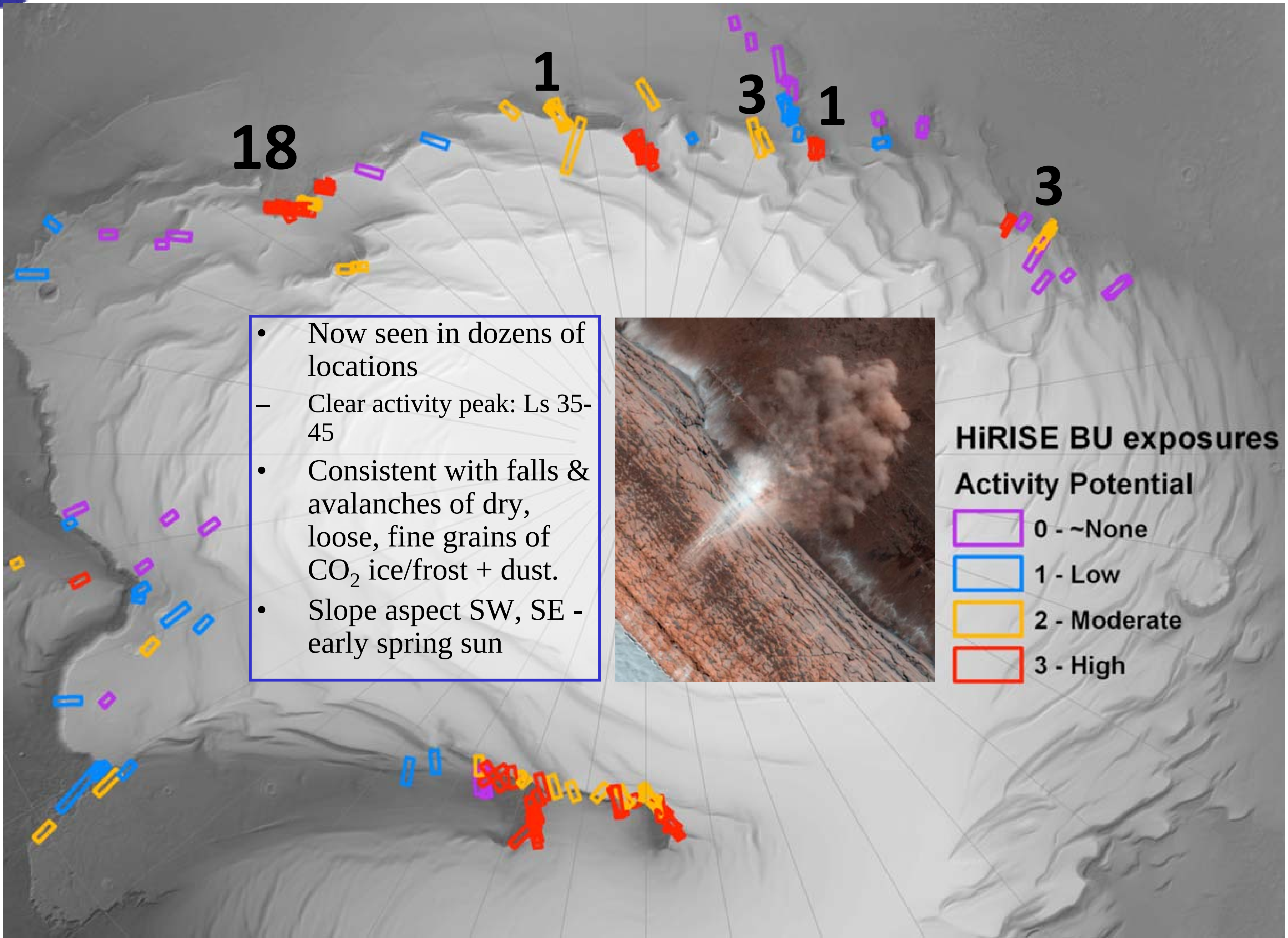


Lack of seasonality suggests that volatiles do not play a role in slope streak activity.

Polar avalanche--dust hasn't settled yet!



Distribution of early spring avalanches around N Polar scarps



- Now seen in dozens of locations
  - Clear activity peak: Ls 35-45
- Consistent with falls & avalanches of dry, loose, fine grains of CO_2 ice/frost + dust.
- Slope aspect SW, SE - early spring sun

Migrating ripples and changing ice blocks and slope deposits in the North Polar layers

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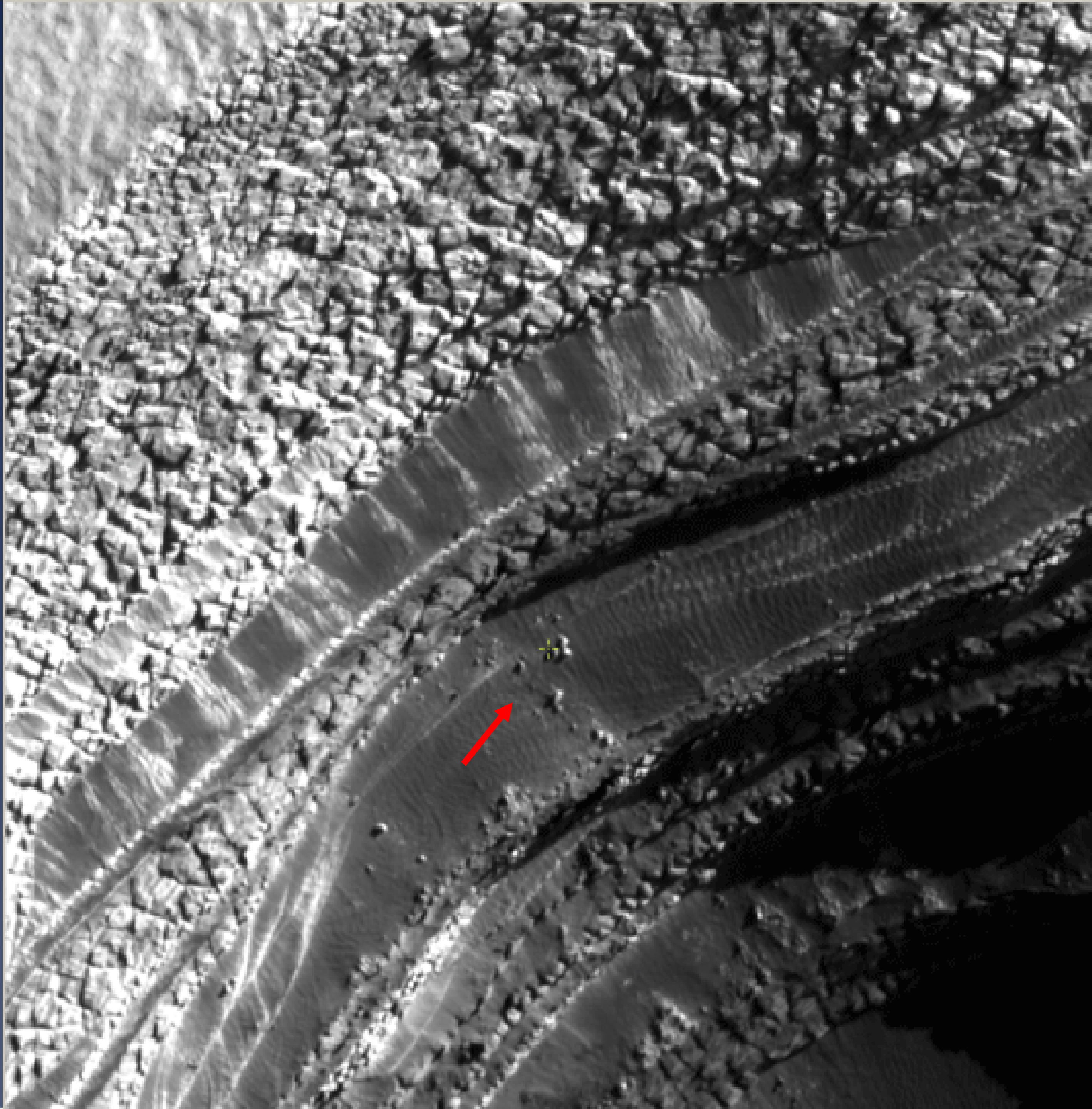
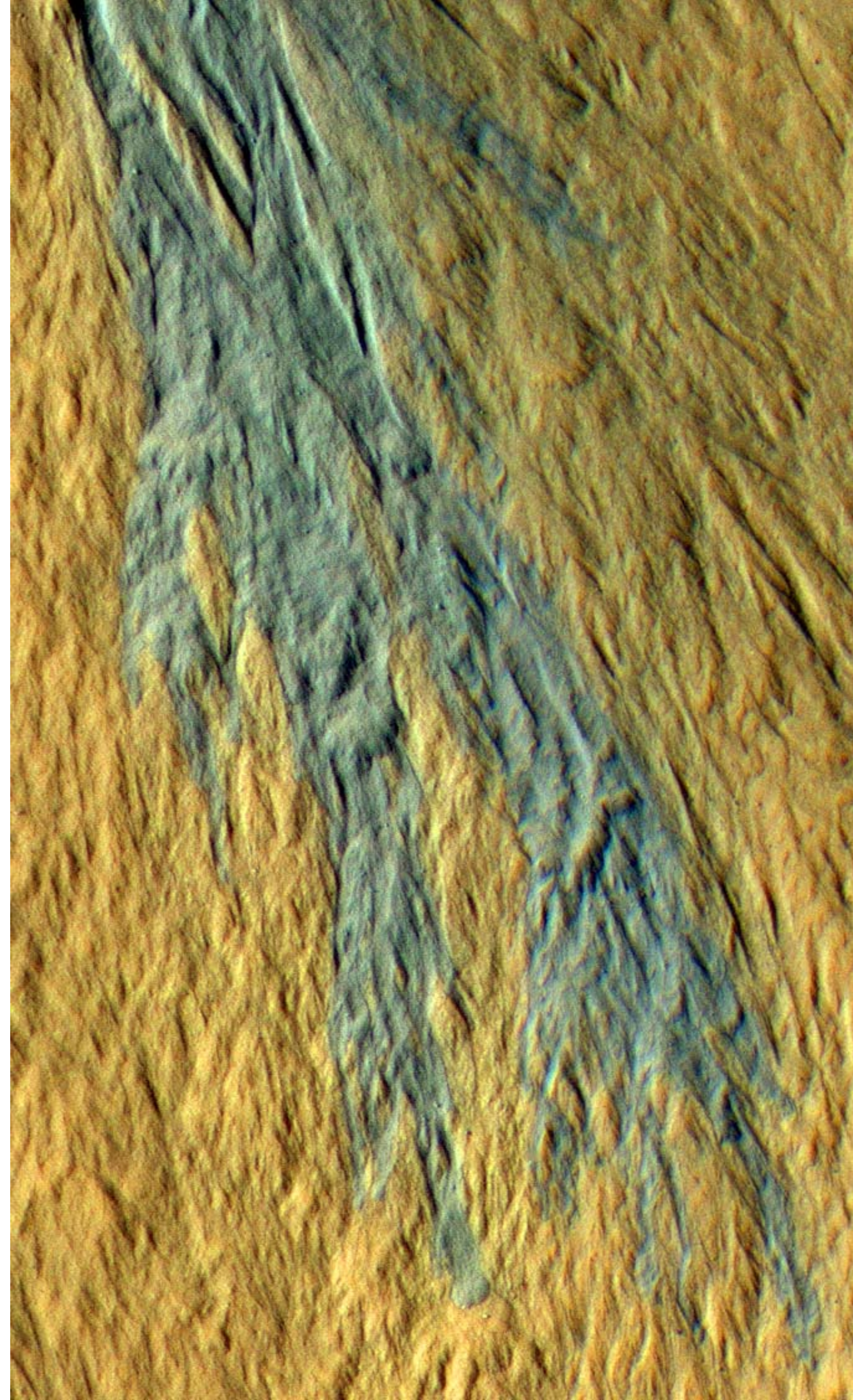
ESP_018832_2645

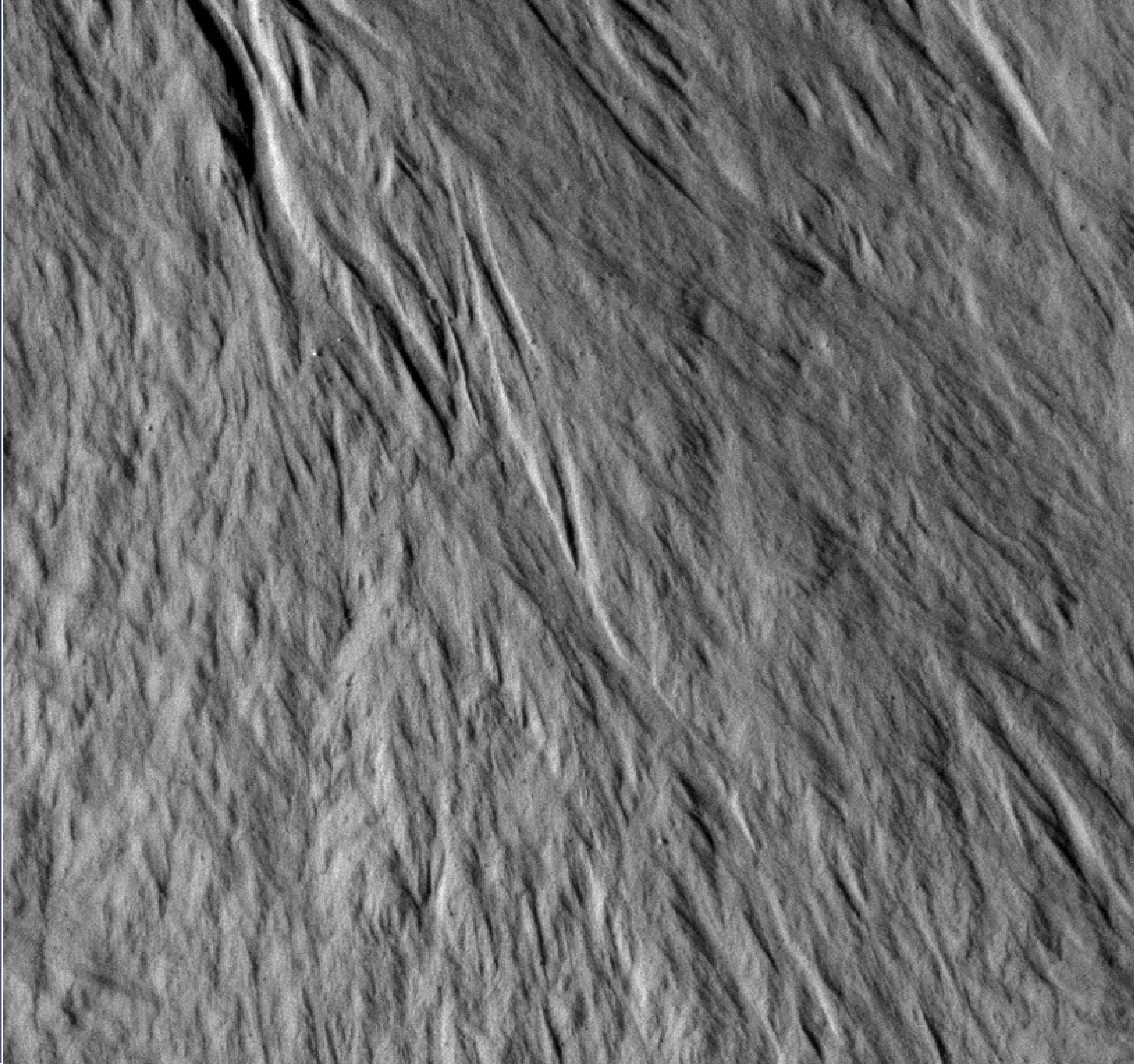


Active Gullies



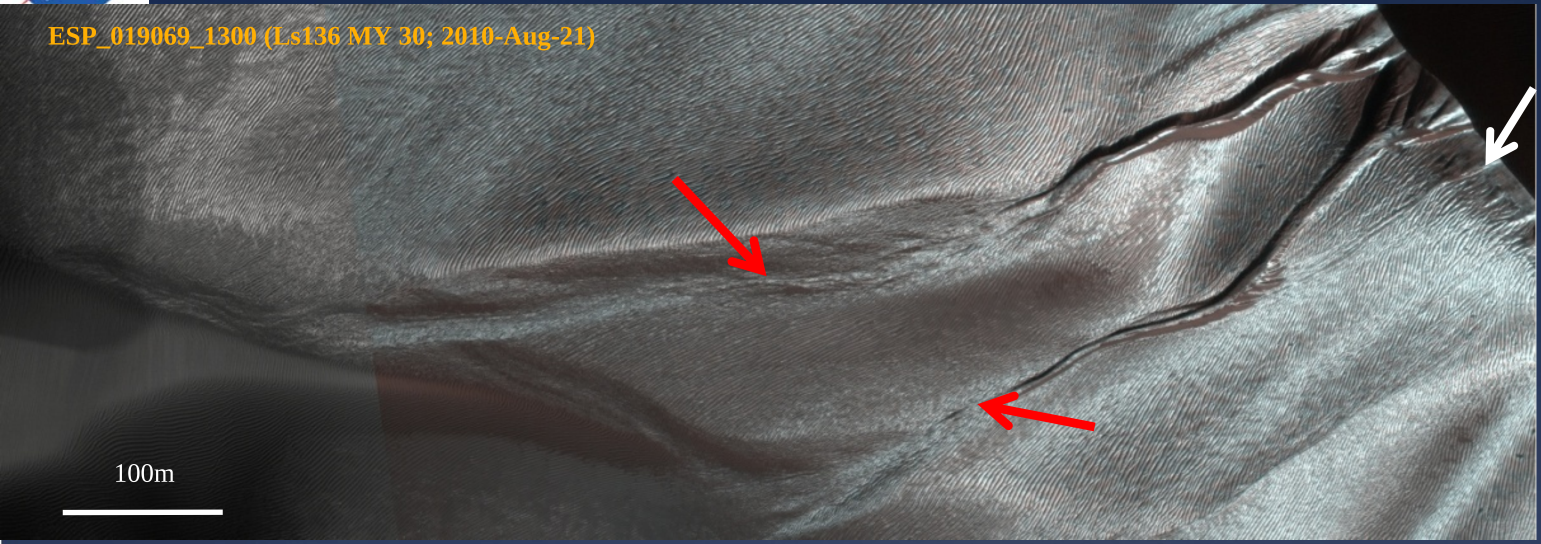
New debris lobes on a gully fan in Gasa crater

(2nd image 1 Mars year later)



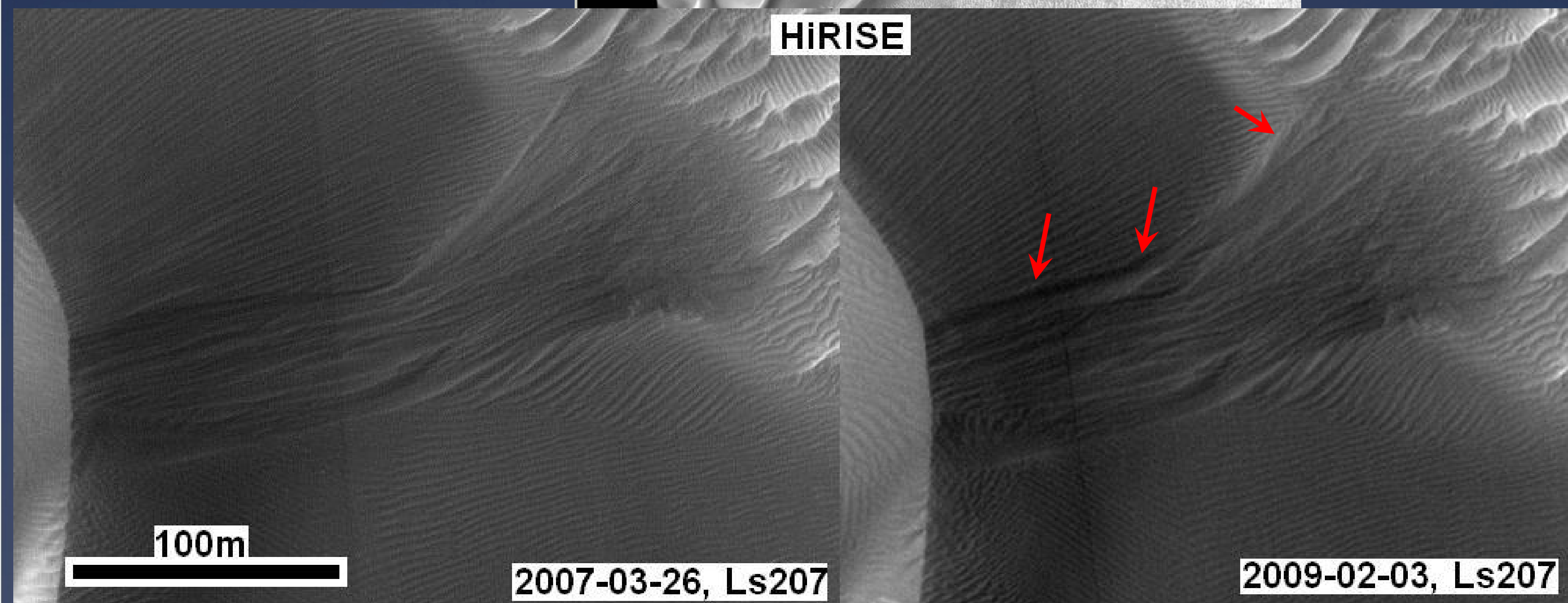
Dark material flowing down channel in springtime.
Bright areas covered by CO_2 frost.

Martian Dune Gullies Active in Winter

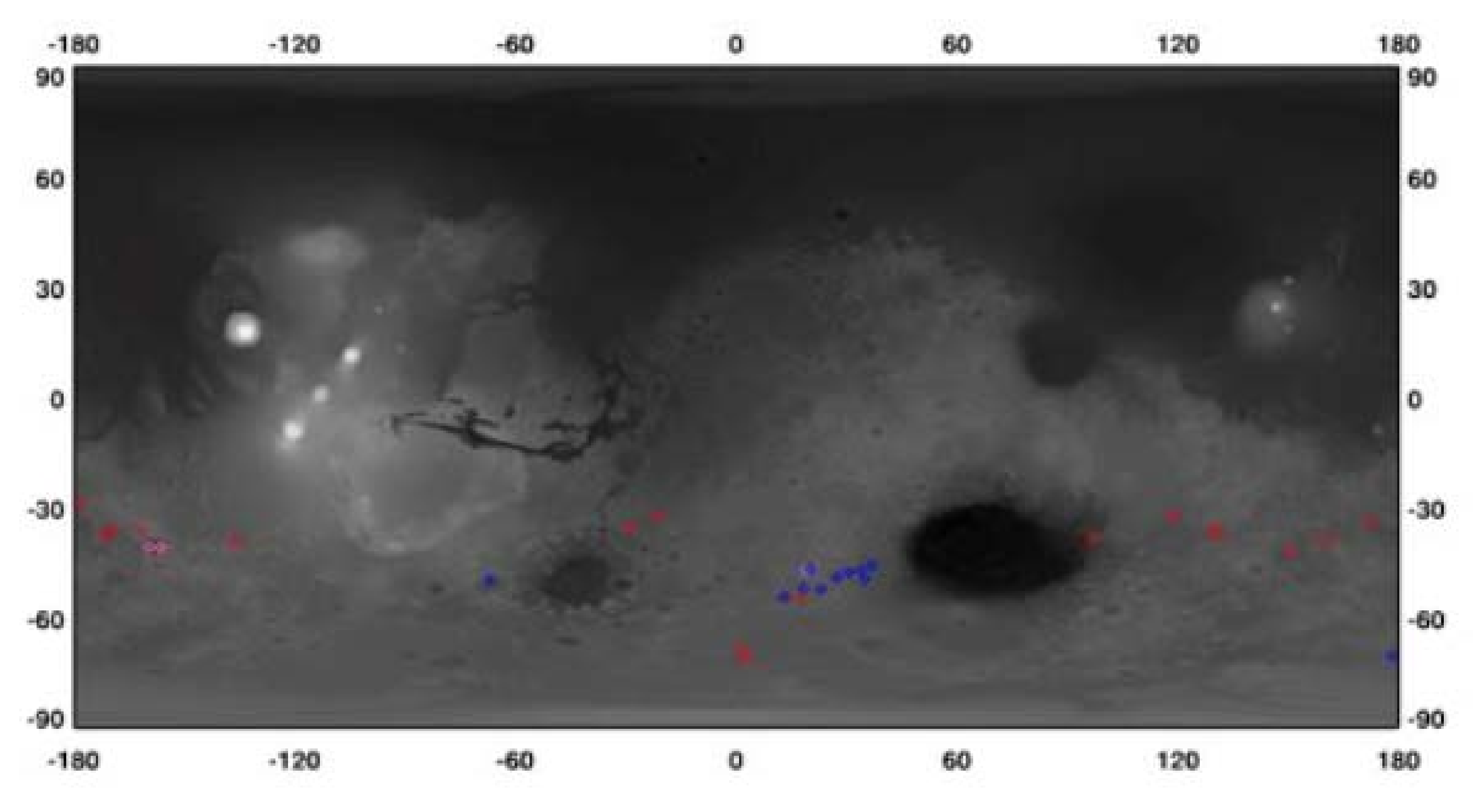


Dune gully in Matara Crater (50°S). During the latest Mars southern winter, a new alcove and channel (white arrows) eroded during late winter, sending material downslope through the existing channel and out onto the fan (new deposits are the darker material on the dune surface). In both larger gullies, the existing channel was incised further into the apron (red arrows). Frost coats the dune surface in both images, but defrosting has begun in the bottom one.

New channel 5 m wide!

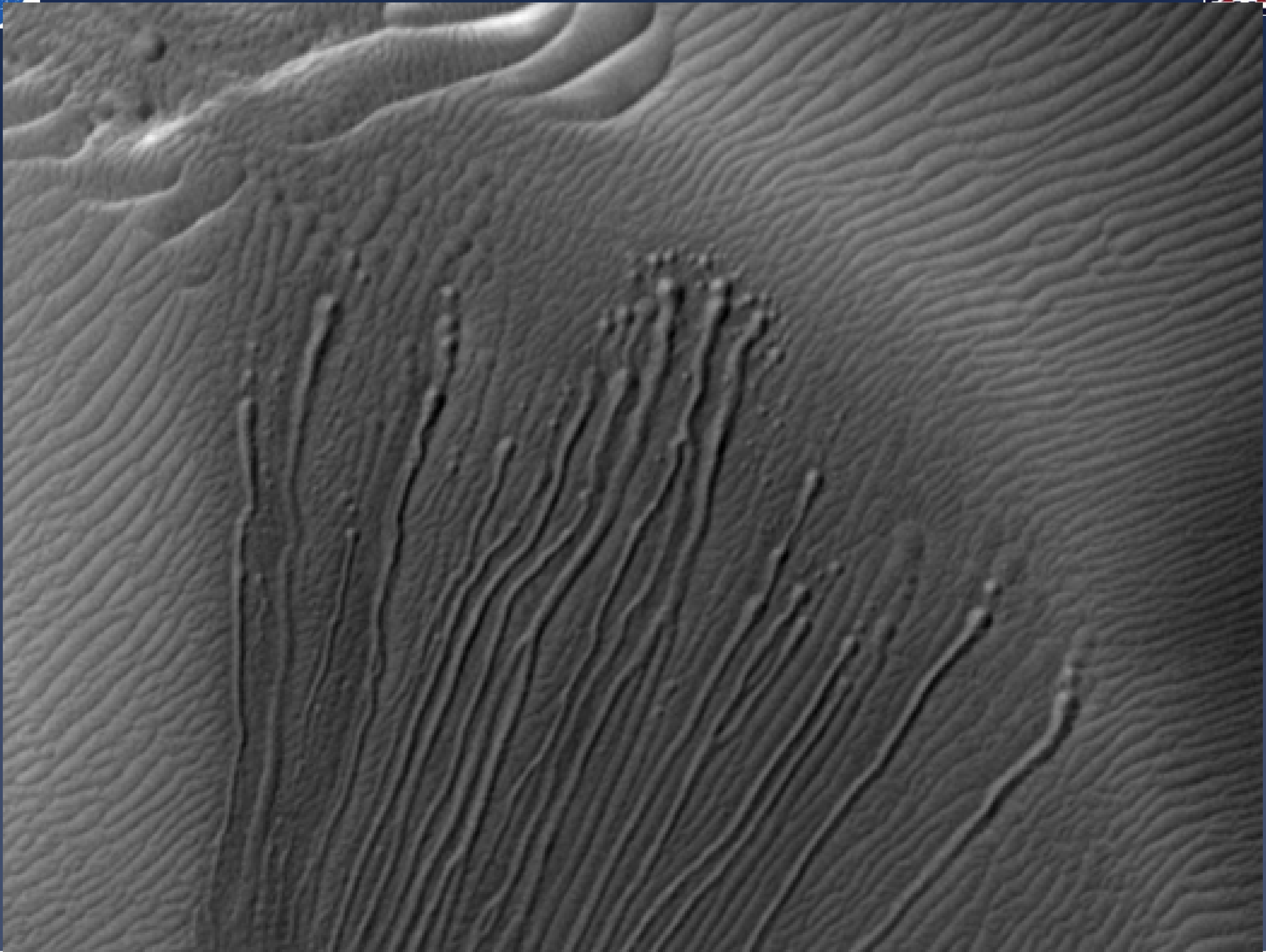


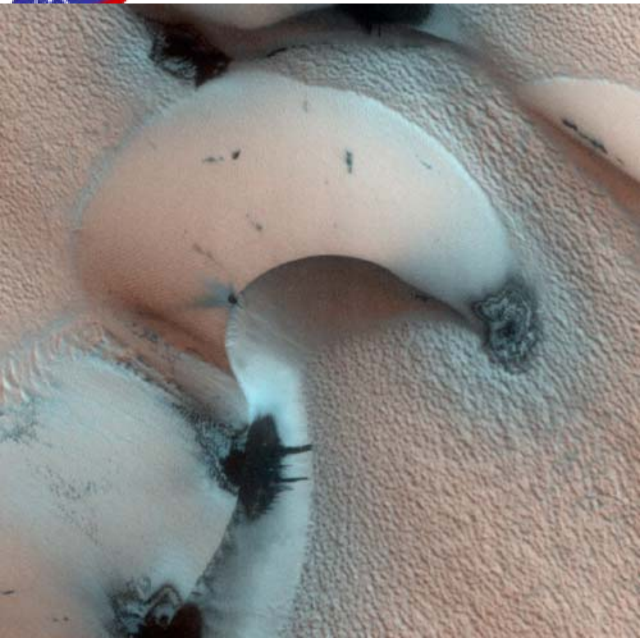
Proctor crater (47.5S, 30.6E)



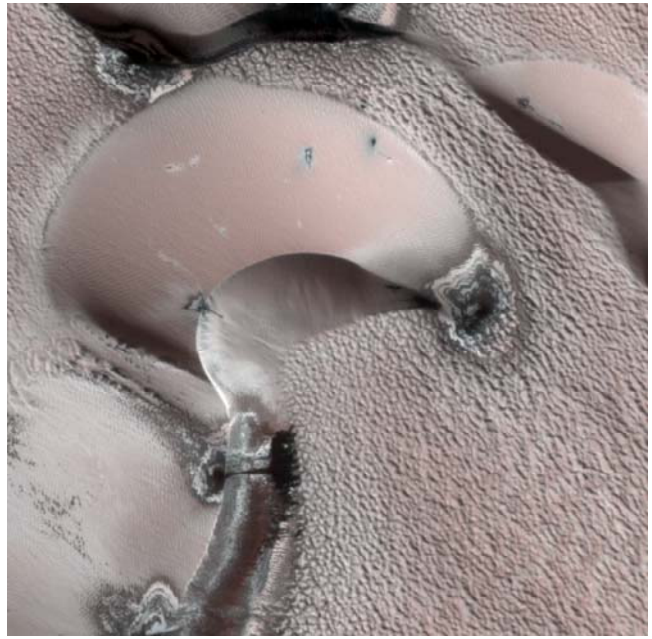
Distribution of known active gullies in S. hemisphere. Red diamonds indicate typical gullies with known changes, red Xs indicate albedo changes seen in winter shadows, purple diamonds indicate dune-gully-like features on sandy crater walls, and blue diamonds indicate dune gullies. Background is MOLA topography.

Linear channels with terminal pits on dunes





PSP_007043_2650, Ls = 23.4



PSP_007676_2650, Ls = 45.8

PSP_007887_2650, Ls = 53.1

Lat = 84.7
Lon = 0.7

PSP_008032_2650, Ls = 58.1

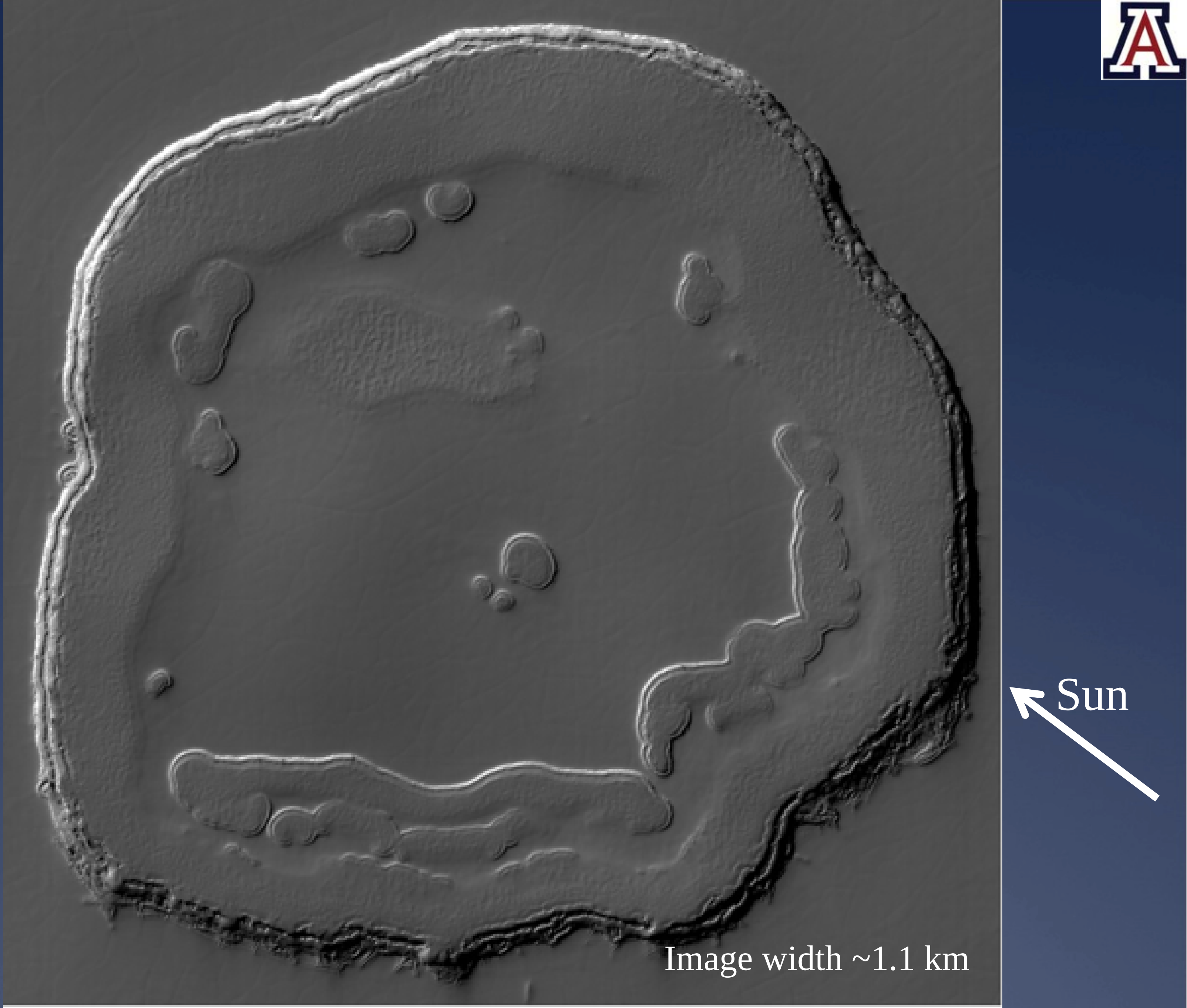
PSP_008230_2650, Ls = 64.9

CO_2 (dry ice) Sublimation Process

Dunes Defrosting
Time-lapse Sequence

Northern Hemisphere

Growth of pits in South Polar residual CO_2 cap (the happy face)



PSP_004000_0945, June 4 2007

Recurring Slope Lineae (RSL): Possible Summertime Briny Flows on Mars (see poster at this conference)

Rare meter-scale slope features on Mars that reform every year in the warmest seasons and fade in cold seasons might be explained by briny water mobilizing flows.

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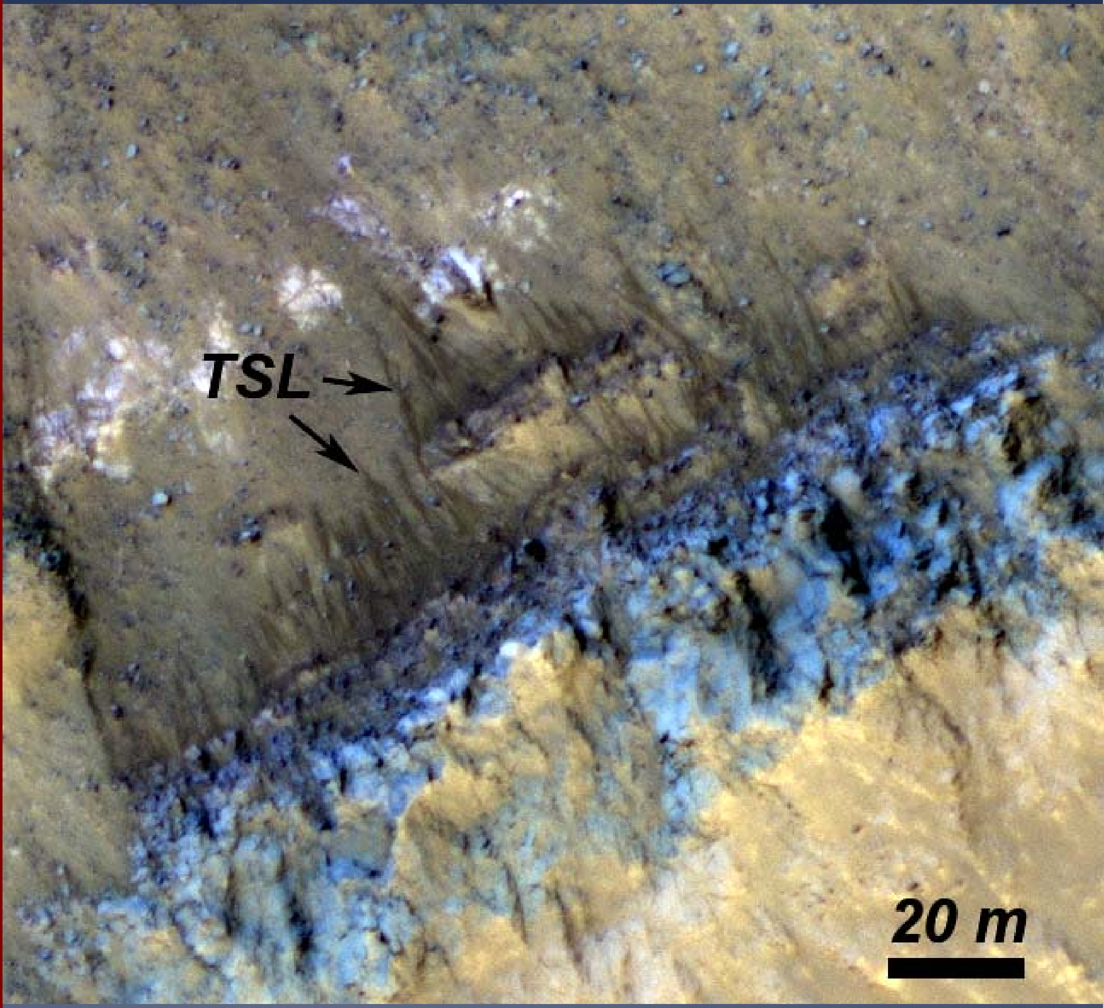
Recurring Slope Lineae (RSL)

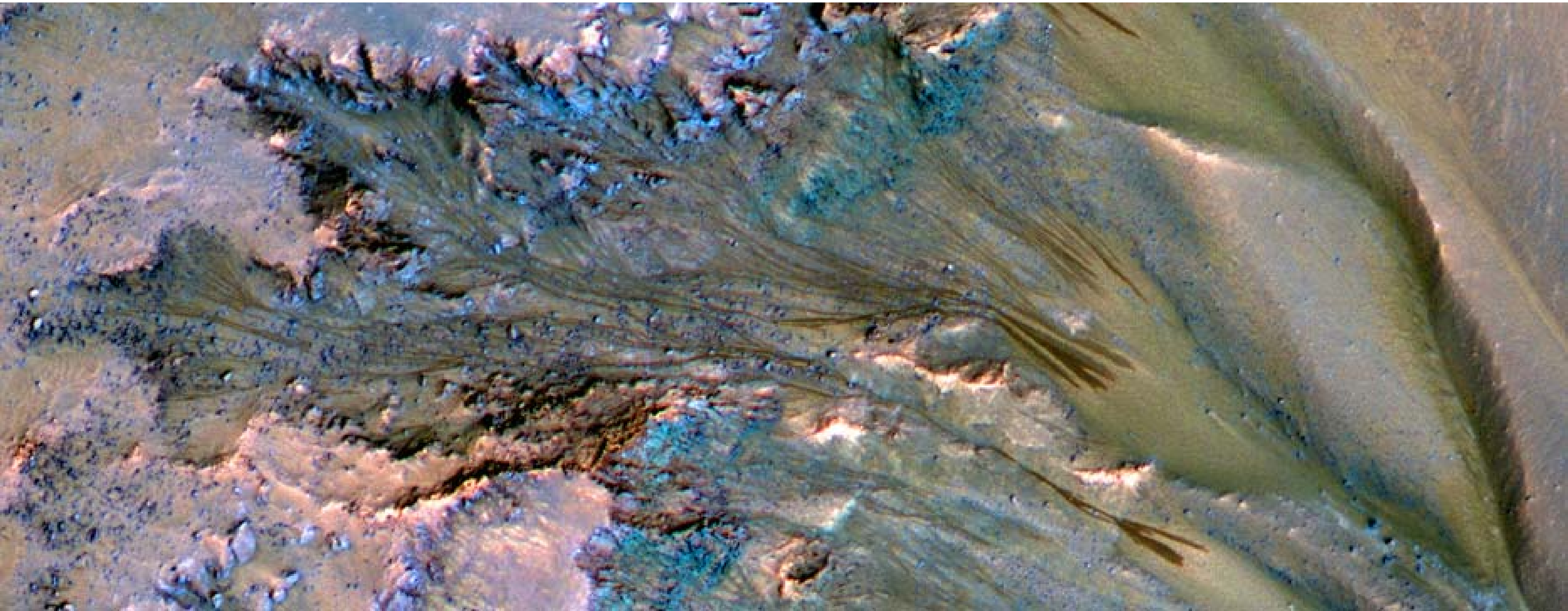
(Initially called Transient Slope Lineae or TSL)

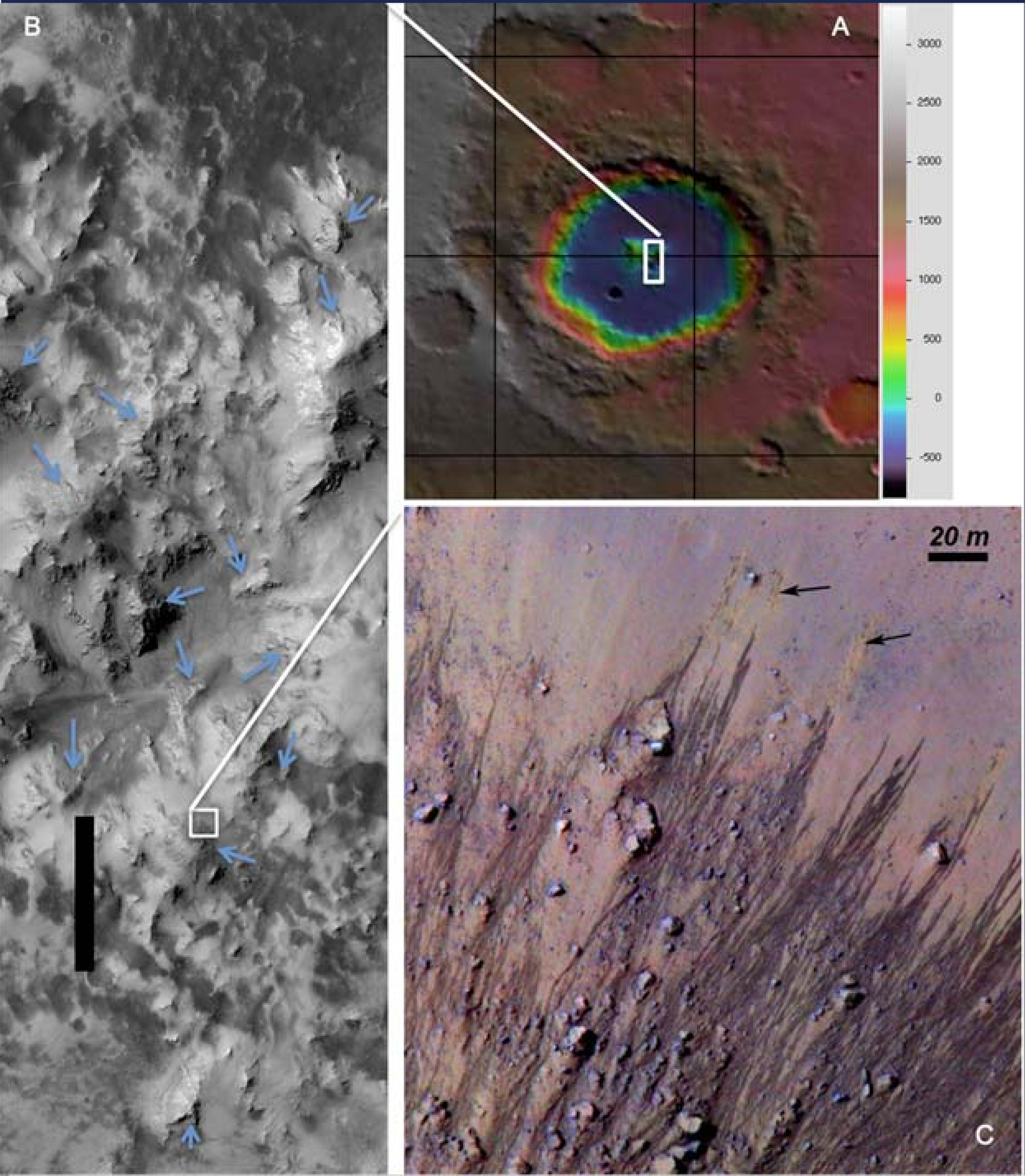
* RSL are narrow (0.5-5 m), dark markings (up to ~40% darker than background) on steep slopes (>25°)
* They form and grow from late southern spring to early fall (L_s from ~260-20) and to fade or disappear in other seasons (L_s 20-260).
* They reform in multiple years.
* They extend downslope from bedrock outcrops or rocky areas, and are often associated with small channels.
* RSL have lengths up to hundreds of meters, and hundreds of them may be present on a slope.
* Concentrated in southern hemisphere (32°S to 48°S), favoring equator-facing slopes.
* Growth is incremental.



Four RSL Categories

RSL Type	Description and Seasonal Behaviors	Number of Sites	Latitude Range	Number of Lineae per Site
Confirmed RSL	Observed to recur in multiple warm seasons and fade in cold seasons	7	48°S to 32°S	10^2-10^3
Likely RSL	Evidence for fading in cold seasons, but not yet observed to recur in multiple years	12	47°S to 34°S	10-10^3
Candidate equatorial RSL	Morphology and geologic setting of RSL, changes observed, but seasonality unclear	8	18°S to 19°N	10-10^2
Candidate RSL poleward of 30° S	Morphology and geologic setting of RSL, but no repeat imaging	12	52°S to 31°S	10-10^3





Horowitz Crater

(named for Norman Horowitz, Viking Lander biologist)

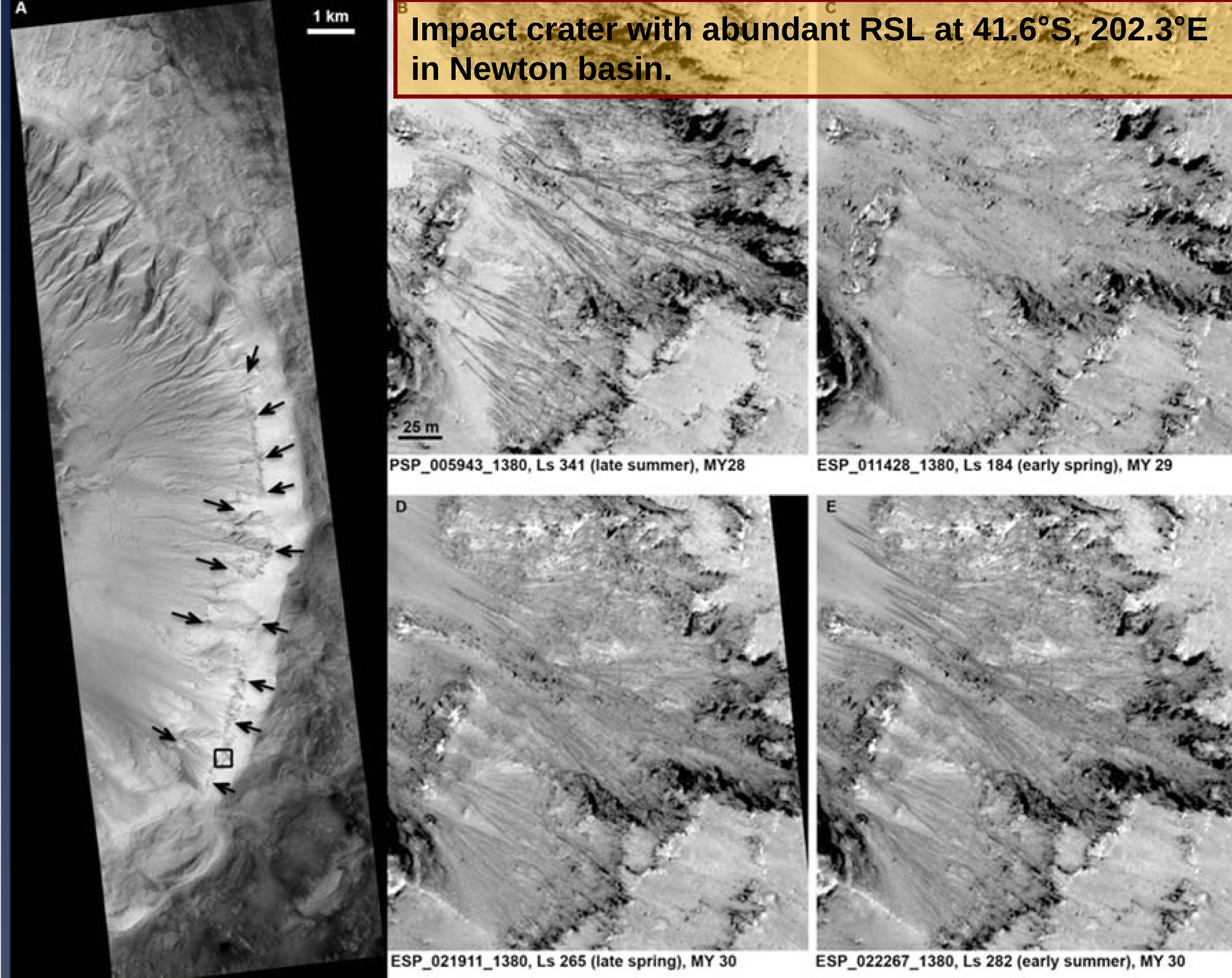
RSL on central structure of Horowitz crater (32°S, 140.8°E), PSP_005787_1475 (Ls 334—late summer).

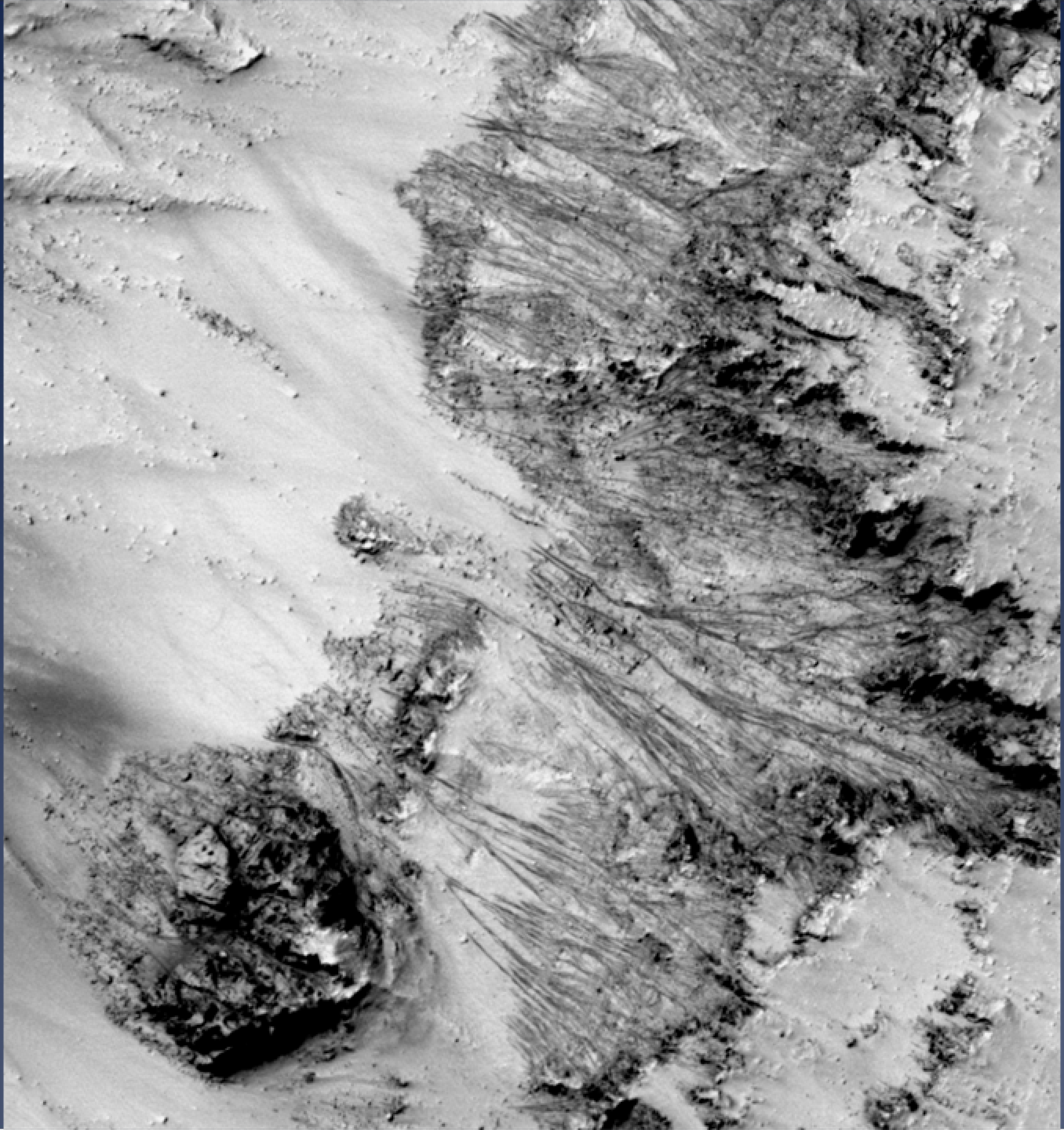
Altimetry map (A) locates the full 5.1-km wide HiRISE image (B), with white box indicating the color enlargement (C).

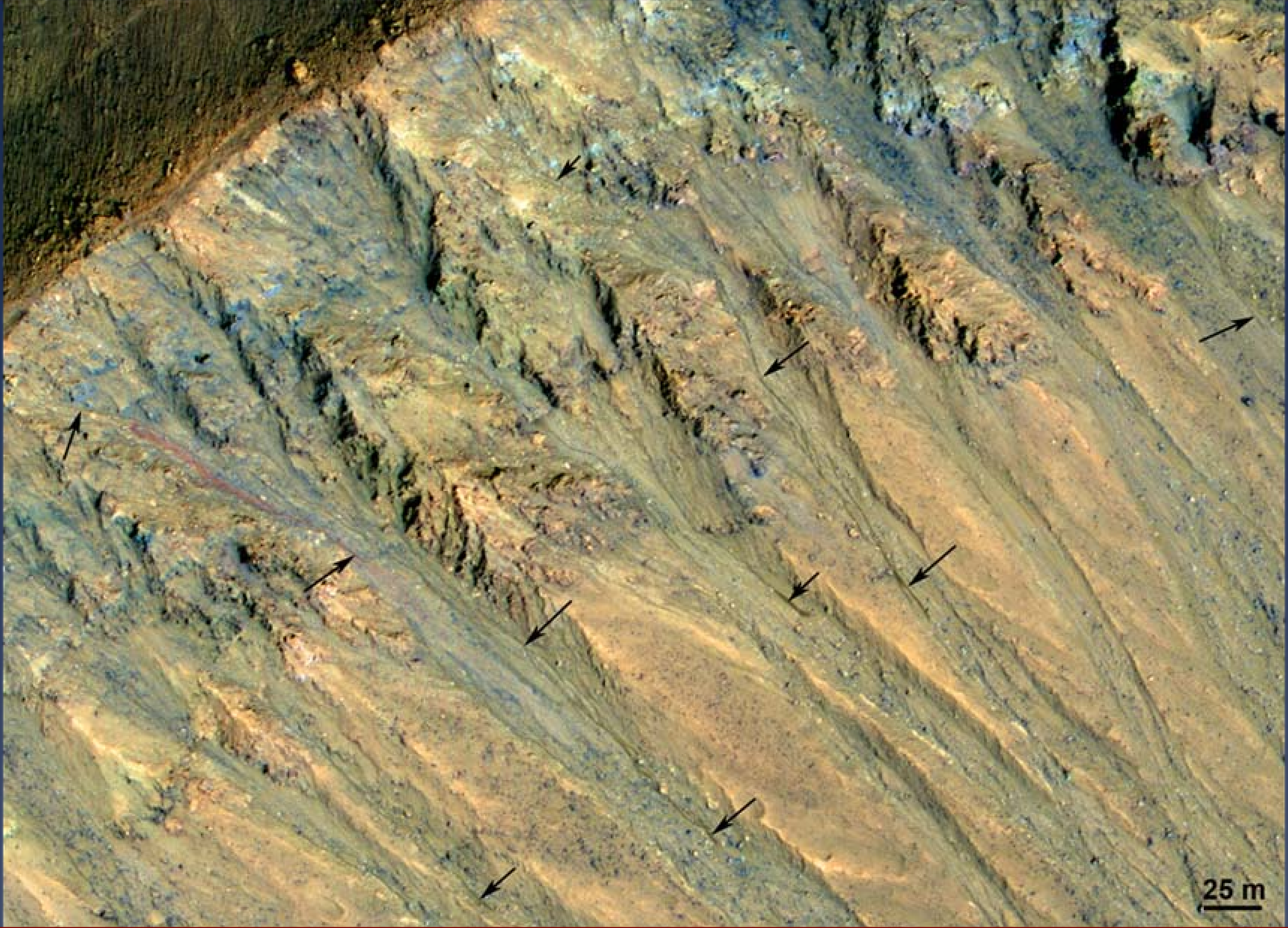
Blue arrows on B show some concentrations of RSL within the central peaks and pits.

Colors in C have been strongly enhanced to show the subtle differences, including light orange streaks (black arrows) in upper right that may mark faded RSL.

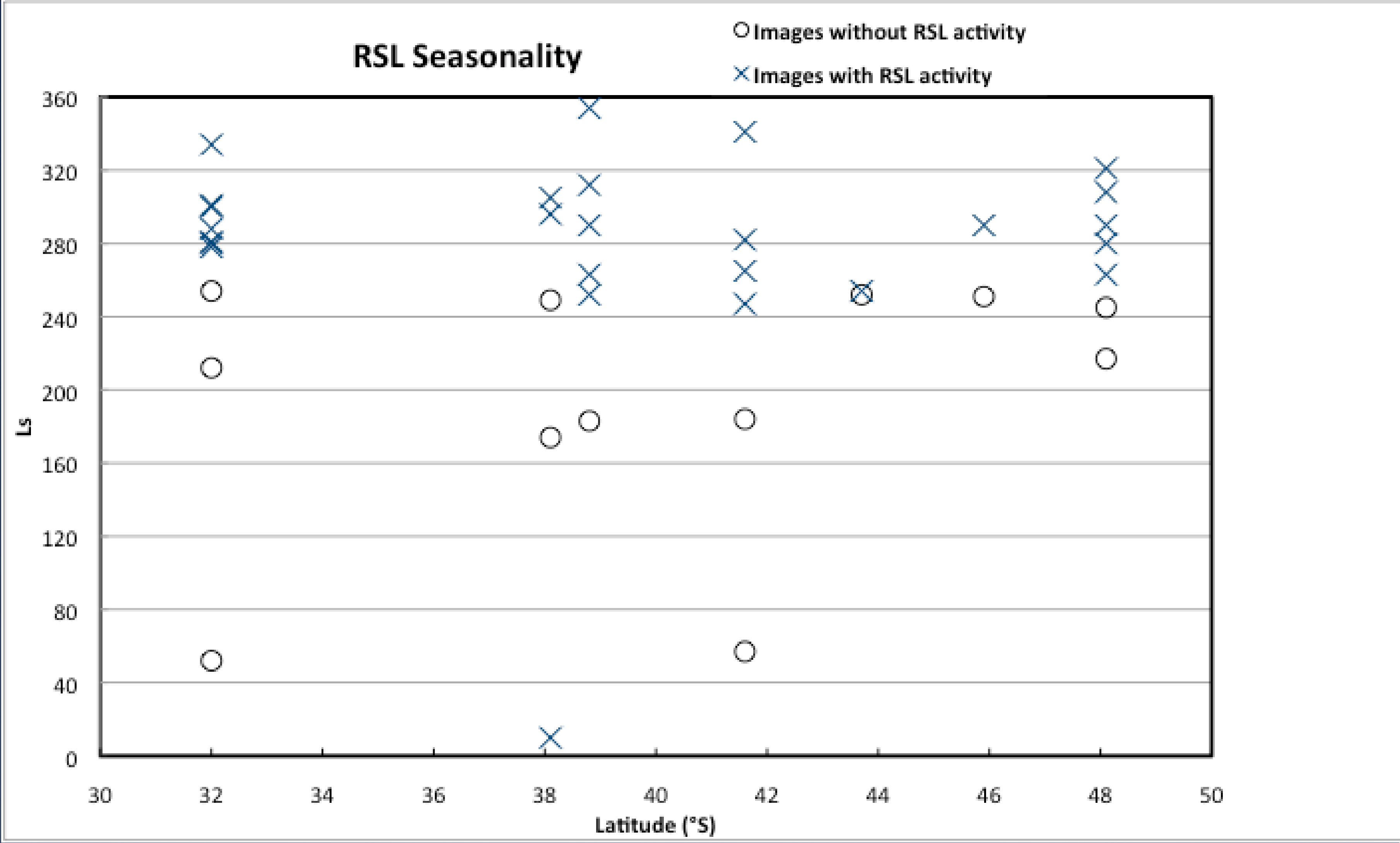
Impact crater with abundant RSL at 41.6°S, 202.3°E in Newton basin.







Although there are diverse color units in the bedrock and colluvium, the RSL show little color contrast, appearing relatively red over relatively red surfaces, etc. ESP_022437_1315; enhanced color; north is approximately down.



For the seven confirmed RSL sites, images with and without distinct RSL are plotted as a function of season (L_s). All images acquired from L_s 260 to 10 show distinct RSL; all images acquired from L_s 40 to 240 do not show distinct RSL.

(lack of) Compositional Data

- RSL occur in the classical dark regions of Mars, which have moderate thermal inertias (~200-340 $Jm^{-2}s^{-1/2}K^{-1}$).
- Determining the composition of RSL from orbit is challenging, as they are much smaller than the pixel scale of CRISM.
- RSL cover a substantial fraction of resolvable slopes in some areas, but no distinctive spectral features have been identified.
  - Small quantities of water produce strong absorption bands
- Hydrated minerals are associated with bedrock at several RSL sites.
- CRISM will use super-resolution mode on RSL; attempt to observe before/after to isolate RSL signature.

RSL are not like slope streaks on dust-mantled slopes!

Slope Streaks vs. RSL

Attribute	Slope streaks	RSL
Slope albedo	High (>0.25)	Low (<0.2)
Contrast	~10% darker	Up to 40% darker
Dust index*	High (e<0.95)	Low (e>0.96)
Thermal inertia	Low (<100)	180-340
Width	Up to 200 m	Up to 5 m
Slope aspect preferences	Varies with regional wind flow *(15)*	Equator-facing in middle latitudes
Latitudes; Longitudes	Corresponds to dust distribution	32°S to 48°S; all longitudes
Formation L_s	All seasons *(31)*	L_s 240-20
Fading timescale	Years to decades	Months
Associated with rocks	No	Yes
Associated with channels	No	Yes
Abundance on a slope	Up to tens	Up to thousands
Regional mineralogy	Mars dust	Variable
Formation events	1 event per streak or streaks	Incremental growth of each feature
Yearly recurrence	No	Yes

* 1350-1400 cm^{-1} emissivity

RSL Formation Requires Warm Temperatures (250-300 K at surface)

- The seasonal, latitudinal, and slope aspect distributions suggest that RSL require relatively warm temperatures.
- Summertime afternoon brightness temperatures measured on RSL-covered slopes in the middle to late afternoon range from 250-300 K from THEMIS 9-micron data
  - Assume optical depth 0 and emissivity 1, so minimum Ts
    - Mini-TES temperatures (below atmosphere) higher than THEMIS
  - Peak daily temperatures likely at 1-3 PM rather than 3-5 PM of THEMIS, so again these are minimum Ts
- Moderate thermal inertias, so temperatures conduct to greater depth than over dusty low-TI slopes
- The Spirit landing site in Gusev crater (14.6°S) reaches temperatures similar to the RSL slopes; the subsurface temperature at the hottest times should exceed 250 K to ~2 cm *(Ulrich et al. 2010).*
- Chloride and Fe-sulfate brines, expected to be common on Mars, have eutectic temperatures below 250 K.

Non-Brine RSL-Formation Hypotheses

- Thermal expansion might trigger rock falls and dry granular flows
  - Difficult to explain hundreds of flows or their likely concurrent incremental growth.
- Adsorbed water, which makes grains sticky, could be released in the summer, allowing dry mass wasting
  - Association with bedrock and rocky slopes is left unexplained, or why they don't occur on all steep slopes
- Triggering by seasonally high winds or dust devils is possible
  - Doesn't explain the absence of RSL in the northern hemisphere or the orientation preference.
- All of these hypotheses require that entire slopes be simultaneously on the brink of failure due to very minor disturbances, and none of them explain why RSL fade in cold seasons.
- **All hypotheses deserve further consideration.**

Are RSL Brine Seeps or Flows?

- To produce brine seeps there must be sufficient liquid to fill the pore space between particles and create a hydraulic gradient.
- If these are thin debris flows, sufficient water to fill pore space is also needed to reduce grain-to-grain friction.
- A difficulty with this model is the source of water for brines.
  - The RSL-bearing slopes are too warm to preserve shallow ground ice in equilibrium with the atmosphere.
  - Deliquescent salts could trap atmospheric water vapor at night, but it isn't clear that enough water can accumulate to cause flow.
  - Disequilibrium ice bodies at depth could supply water vapor, but at a slow rate
- RSL are rare features so they might be driven by unusual sources of water
  - Images with gullies are ~100x more common than images with RSL

RSL Suitability Matrix: Model (top) vs. Observation (left).

Y (green) indicates consistency between observation and model; N (red) indicates lack of consistency.

Model: **Observation:**	**Wet debris flow**	**Dry dust avalanche or grain flow**	**Brine flow in shallow subsurface**	**Briny surface flow**
Follow steep downhill gradient	Y	Y	Y	Y
Darken surface	Y	Y	Y	Y
No strong color contrast with background slopes	N	N	Y	Y
Formation and growth when surface temperature 250°-300° C	Y	?	Y	Y
Known source of sufficient water	N	Y (no water needed)	N	N
Fading (and sometimes brightening) in cold seasons	?	?	?	?
Lack of water bands in CRISM	Y	Y	Y	?
Lack of strong spectral signature of salts in CRISM	Y	Y	Y	?
Episodic, incremental growth	?	N	Y	Y
Lack of resolved topography	N	N	Y	Y
Concentrated in Latitude 32-48 S	Y	N	Y	Y
$10^3 – 10^4$ lineae within a HiRISE image	?	N	Y	Y
Associated with rocky slopes	Y	?	Y	Y
Yearly recurrence at same locations	N	N	Y	Y
Flow around obstacles like boulders; no uphill or downhill deposits.	N	N	Y	Y

Potential Habitability Associated with Present-Day Activity

- Bolides hit Mars >100 times per year--unlikely to cause significant melting, but **expose clean ice that may implicate thin films of water**
- Sand ripples are on the move over many regions across Mars--dry process (but may expose ice)
- Much activity in regions covered by CO_2
  - Surface and atmospheric temperatures are buffered to CO_2 frost (~140 K)
- Steep slopes are active:
  - Dry processes like slope streaks
  - Currently active gullies occur when there is CO_2 frost on the ground (~140 K)
  - **Recurring Slope Lineae *might* be explained by briny water, and *might* implicate habitability**

Thank you!
Questions?