Jet Propulsion Laboratory
California Institute of Technology

The Mars Reconnaissance Orbiter Mission:

2018 Status (IAC-18-A3.3A.4)

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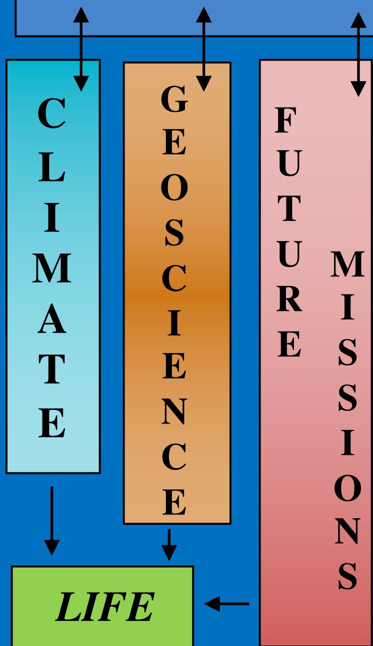
1 October 2018

MRO Mission Introduction

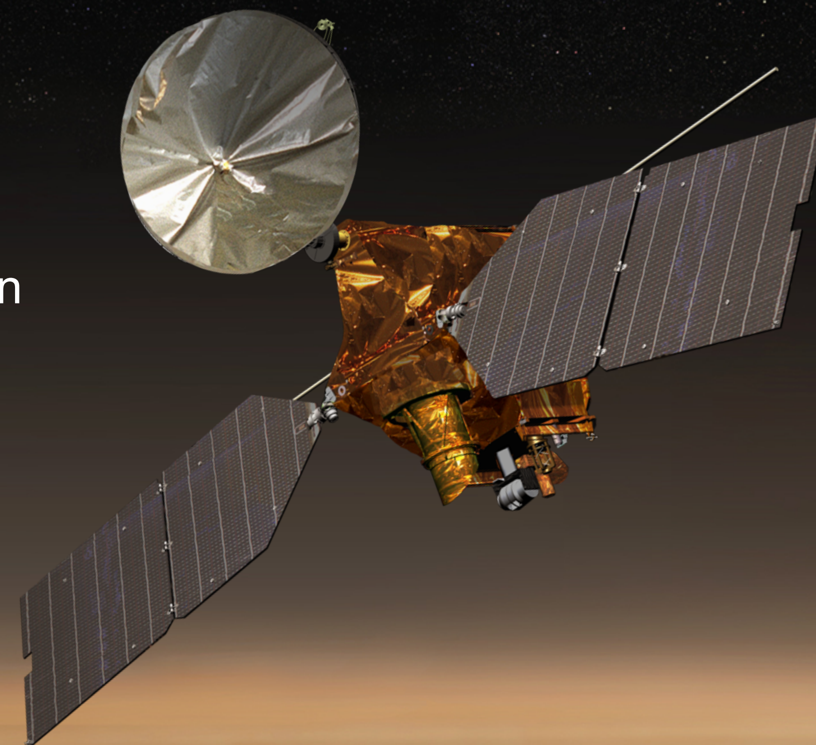
“Mars in Transition” Theme



- ***Weather and Climate Satellite***
  - Extends the record of the present climate, seasonally and year-to-year
  - Alerts Mars Exploration Rovers to evolving dust storm events
  - Monitors atmosphere for design and execution of landed mission entry
- ***Geological Explorer***
  - Identified water-related landforms and aqueous surface deposits
  - Identifying water-related (habitable) environments through time
  - Mapping subsurface ice and internal layering
  - Detecting surface change on a dynamic planet
- ***Site Reconnaissance***
  - Observed hundreds of sites at very high-resolution visual and spectral imagery to find the best places for future landed exploration
    - High potential for future scientific discovery in areas of acceptable landing/roving risk
    - Phoenix, MSL, InSight, Mars 20200, ExoMars Rover/Surface Platform (RSP)
  - Observed Phoenix and MSL on parachute during landing
- ***Communications Satellite***
  - Part of the Mars Relay Network providing relay for Phoenix (past), Mars Exploration Rovers, Mars Science Laboratory
  - Will support InSight, Mars 2020, and ExoMars RSP

MRO – MISSION Status

- Launched on August 12, 2005
- Inserted into Mars orbit March 10, 2006
- After aerobraking, achieved Science Orbit in November 2006
  - Low Altitude = 250 km (s. pole) x 320 km
  - Inclination = 92.7°
  - Sun-Sync at ~3:00 am/pm; certified LTST 2-4 pm
- Dual-mode mission now in 4th Extended Mission
- Scientific Objectives
  - Understand Environmental Transitions & Habitability of Ancient Mars
  - Understand Ices, Volcanism, & Climate of Amazonian Mars
  - Understand Surface Changes, Atmospheric, and Polar Processes for a Modern Dynamic Mars
- Programmatic Objectives
  - Provide relay and surface operations support to landed missions
  - Provide telecommunications coverage of Critical Events (EDL Events); image if possible
  - Identify sites with high potential for future scientific discovery
  - Collect data for landing site certification
  - Monitor/provide environmental (atmospheric) data for EDL/mission design

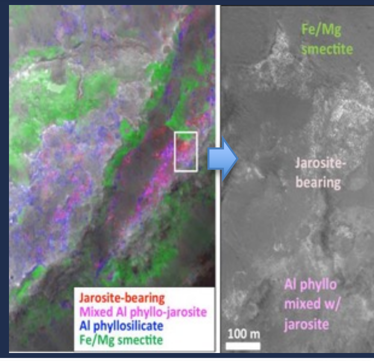


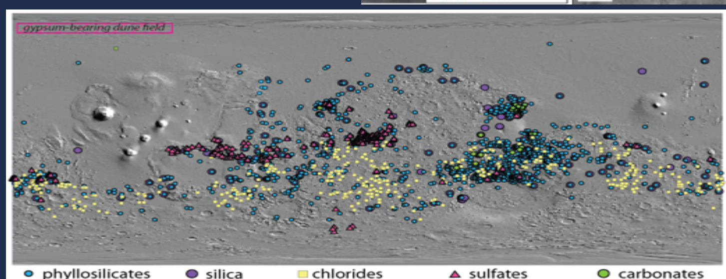
Mars Program direction is to keep the spacecraft operational for relay and critical event coverage until 2027

MRO: Four Scientific Goals in EM4 to Study *Mars in Transition*

1. Ancient Mars: Environmental Transitions and Habitability

Aqueous Minerals



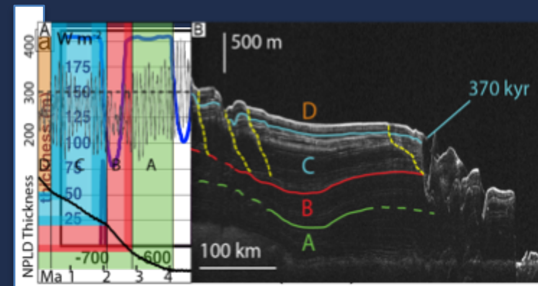


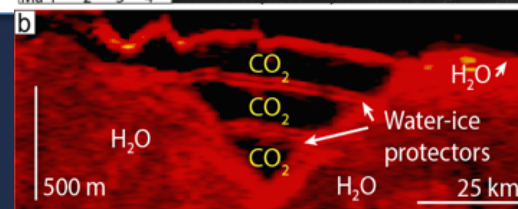
2. Amazonian Mars Climate: Ice and Volcanism

Ice Ages

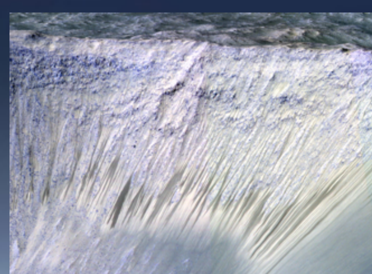
Volatile Reservoirs

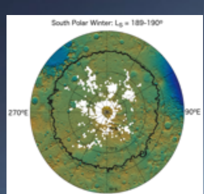
Climate Change





3. Modern Mars: Surface Changes and Implications

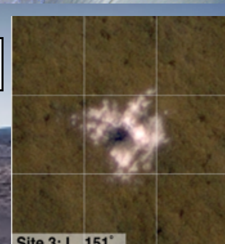




Volatiles

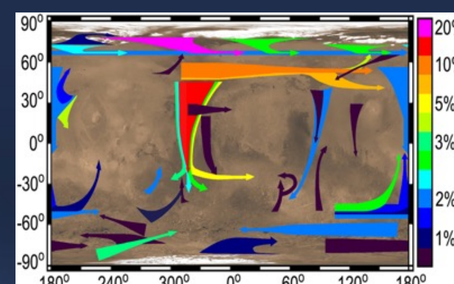
Water Environments?

New Impacts



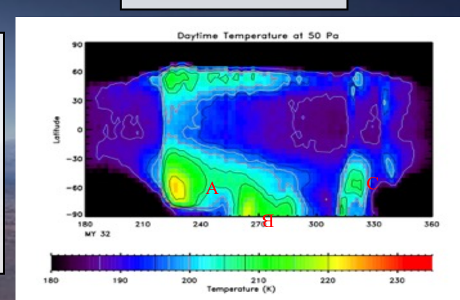
4. Modern Mars: Atmospheric and Polar Processes

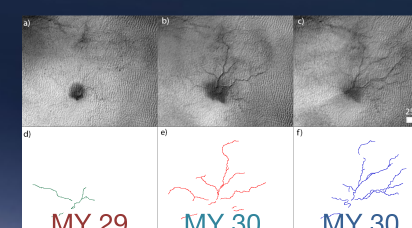
Storm Tracks



Dust Storms

Temperatures





Polar Changes

2018a Dust Storm: Overview

May 30: MRO MARCI spots a local dust storm, one of many in the polar jet stream at high northern latitudes

June 1: The local storm moves down the Acidalia storm track; MER alerted

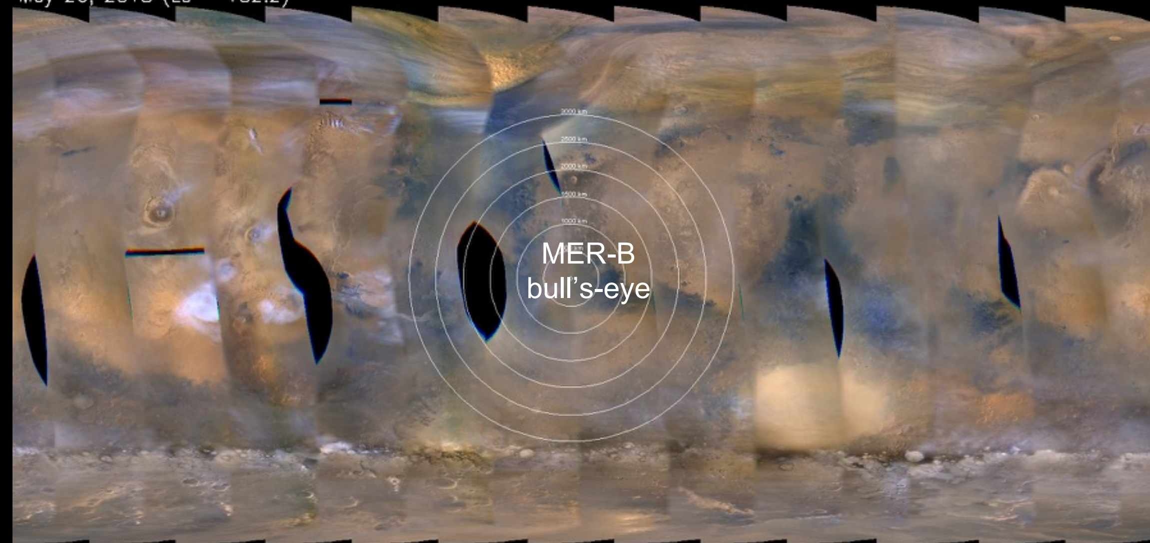
June 2-present: Local dust storm stalls over Meridiani and expands to the east

June 9: Regional storm merges with southern hemisphere local storms to cover most of eastern hemisphere

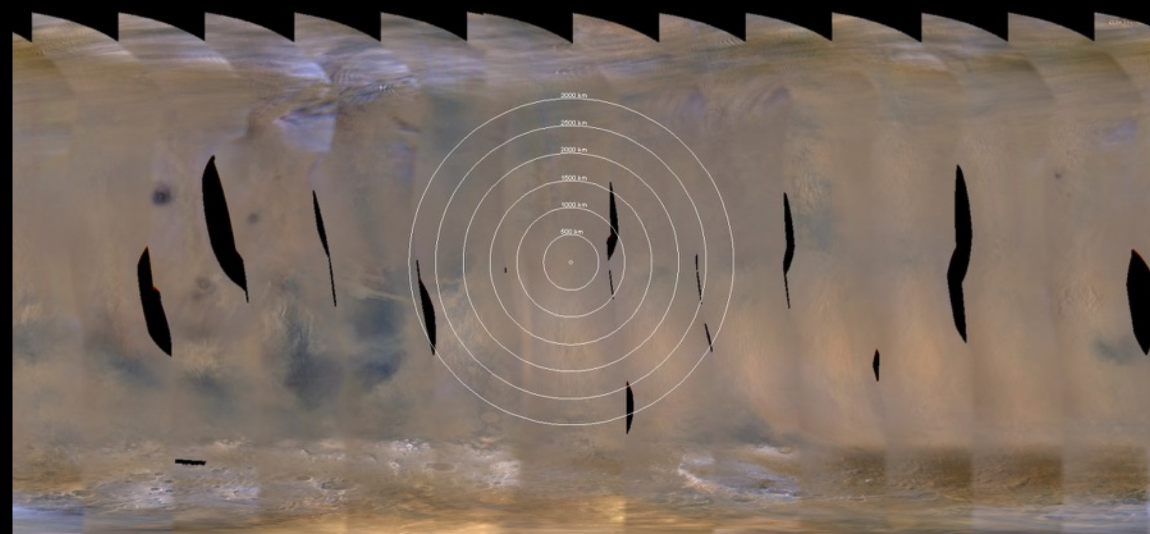
June 19: New activity in Solis-Sinai Planum pushes storm into the rare category of a Planet-Encircling Dust Event (PEDE 2018a)

Today: Dust-raising activity back to seasonal local storms; dust haze gradually clearing; *Opportunity* site still obscured

May 26, 2018 (Ls = 182.2)

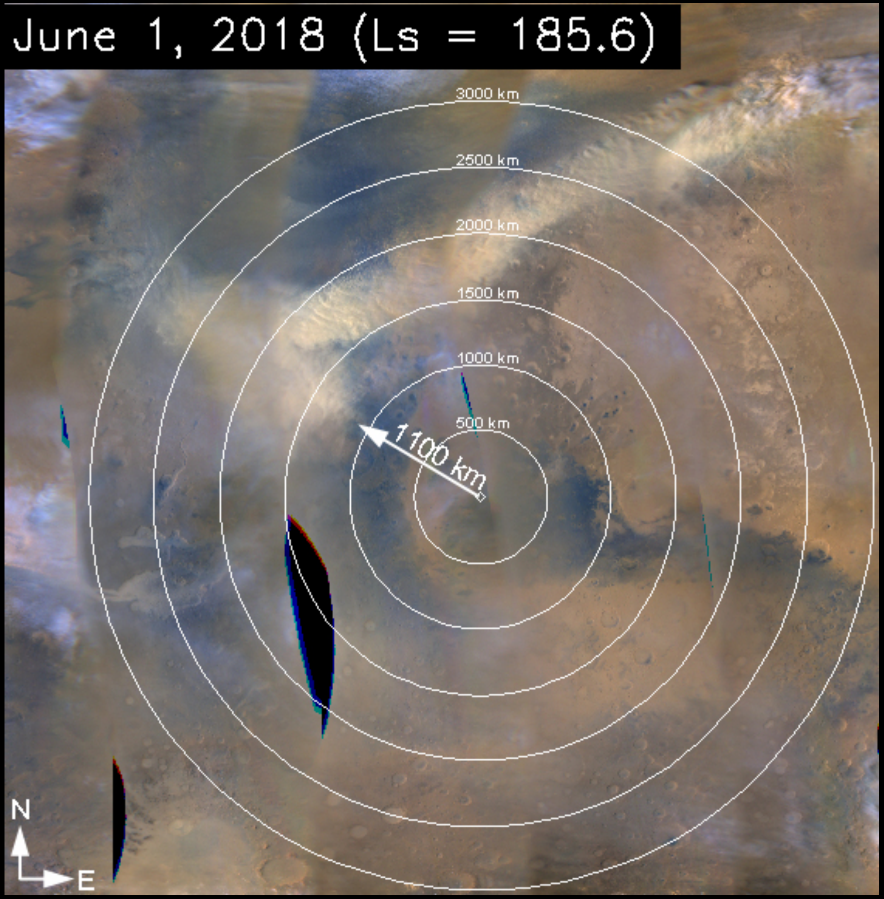


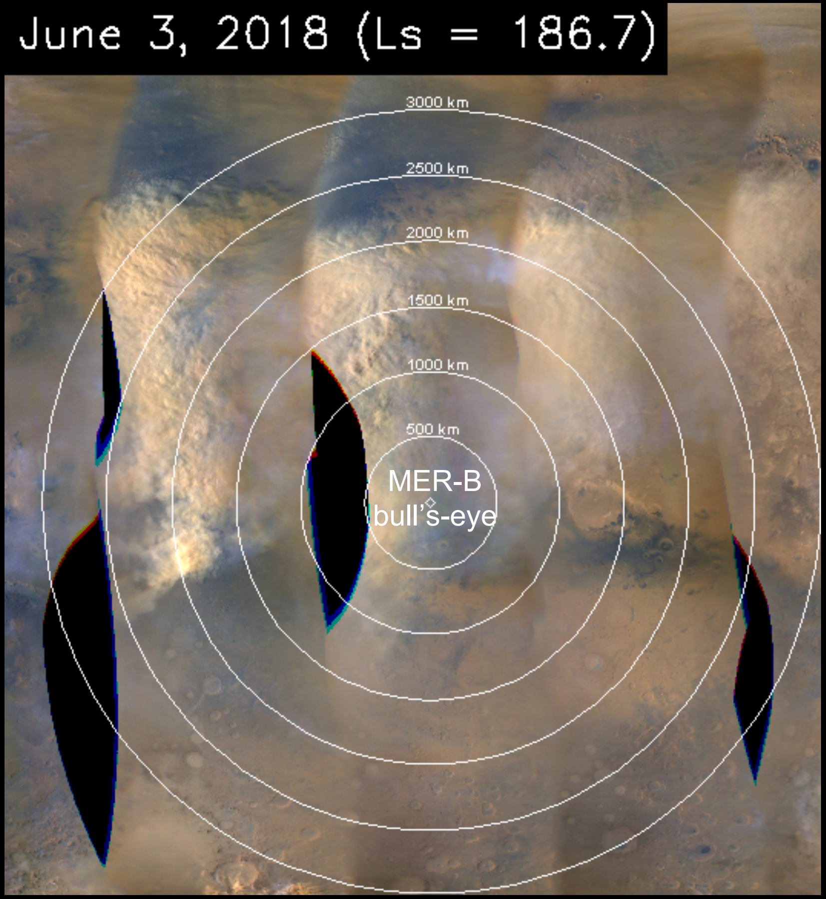
June 19, 2018 (Ls = 196.0)



MRO MARCI (*Daily global maps provided by B. Cantor, MSSS/JPL/NASA*)

2018a Dust Storm: Early Development





Early Development of the 2018a Planet-Encircling Dust Event

Left: Dust front of a local storm moves down the Acidalia Storm Track

Right: Local dust storm stalls over Meridiani and MER-B, expands to the east

MRO MARCI / MSSS / JPL / NASA ***Provided by B. Cantor (MSSS)***

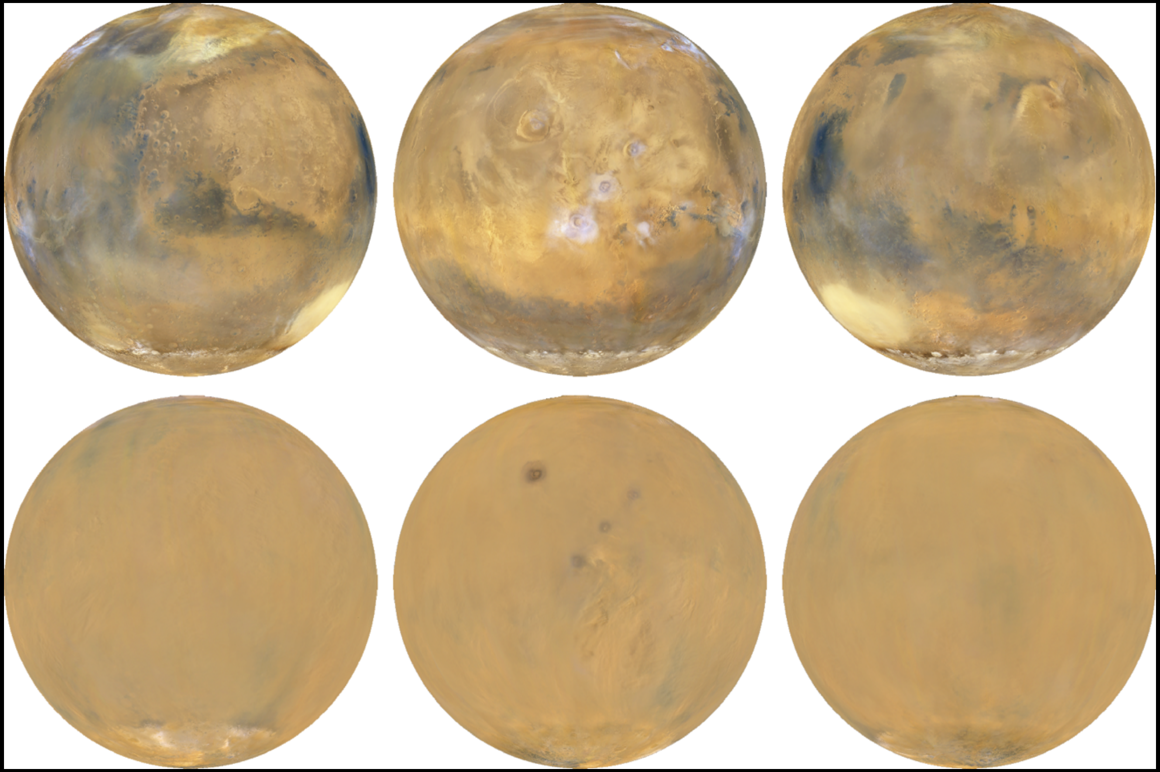
MARCI Observations of Mars Before and During the 2018a PEDE

May 28, 2018

T ~ 0.5

July 1, 2018

T >> 5



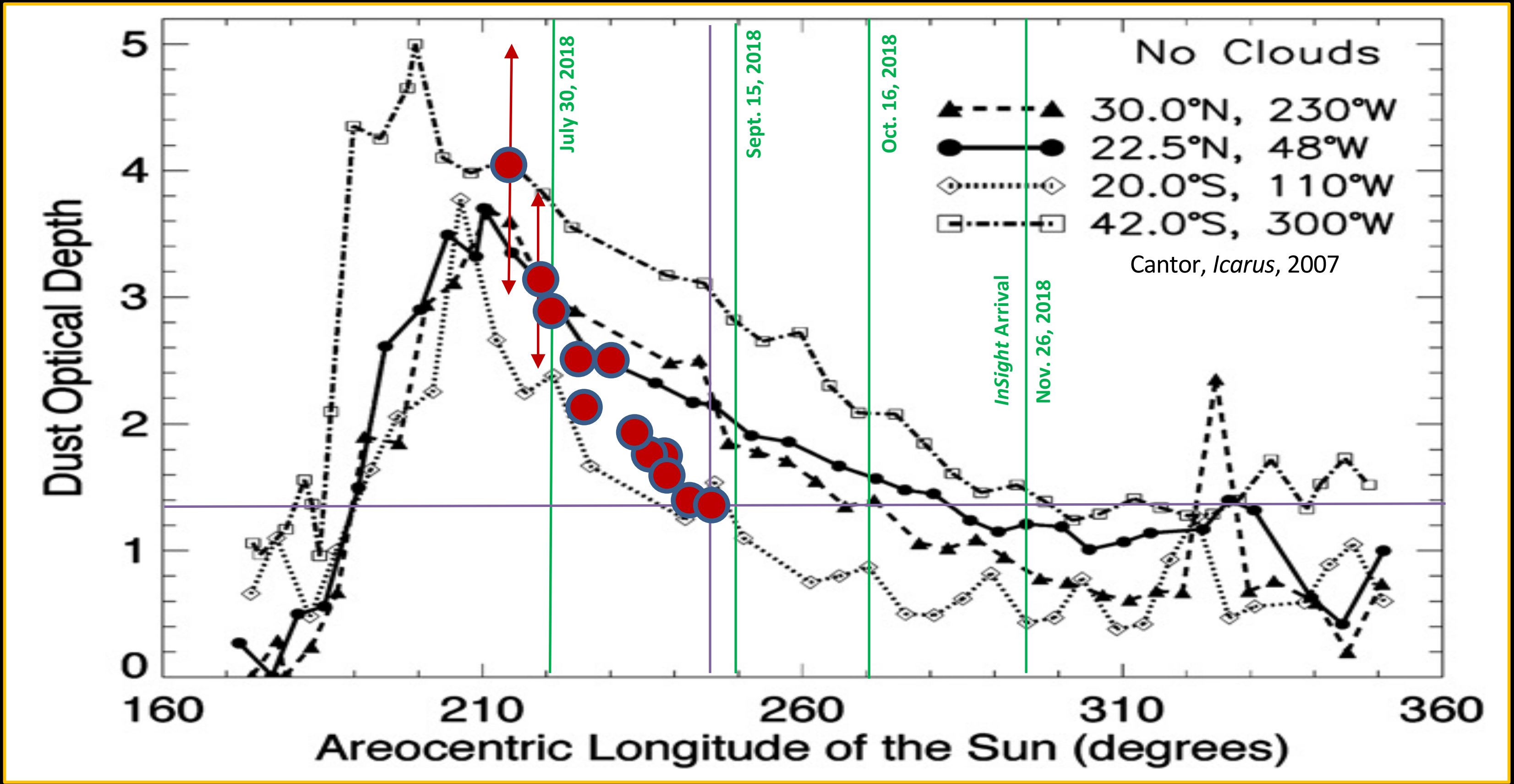
Images courtesy of B. Cantor & M. Malin

MRO MARCI / MSSS / JPL/NASA

Three sides of Mars viewed before and near the peak of the 2018 Planetary Encircling Dust Event.

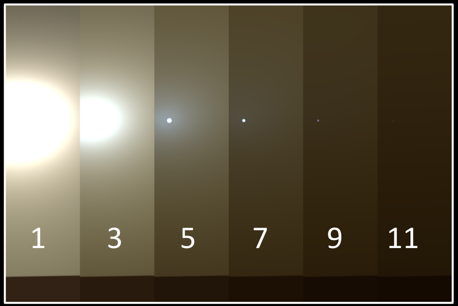
- **Each column shows MARCI data projected onto a sphere centered at 0˚(left), 120˚W (center), & 240˚W (right).**
- **The top row shows the planet on May 28, 2018; the bottom is for July 1, near the peak of the event.**
- **Daily global maps are mosaicked and interpolated from the 13 daily MARCI swaths generated by imaging cross-track limb-to-limb as MRO flies across Mars at a local time ~3 p.m.**

Using the 2001 PEDE to Predict 2018a Dust Clearing



Mars Seasonal Date: Southern Spring and Summer

Tau (Opacity)



Estimates of opacity above *Opportunity* (Cantor, MRO MARCI / MSSS / JPL / NASA)

Seasonal Flows on Warm Martian Slopes

(A. McEwen et al., Science, 14 July 2011)

∗ Recurring Slope Lineae (RSL) are narrow (0.5-5 m), dark markings on steep slopes (>25°)

∗ Form and incrementally grow in warm seasons (late spring to summer), then fade or disappear in cold seasons.

∗ Reform at nearly same locations in multiple Mars years.

∗ Extend downslope from bedrock outcrops or rocky areas; often associated with small channels.

∗ Question: Is liquid water involved?

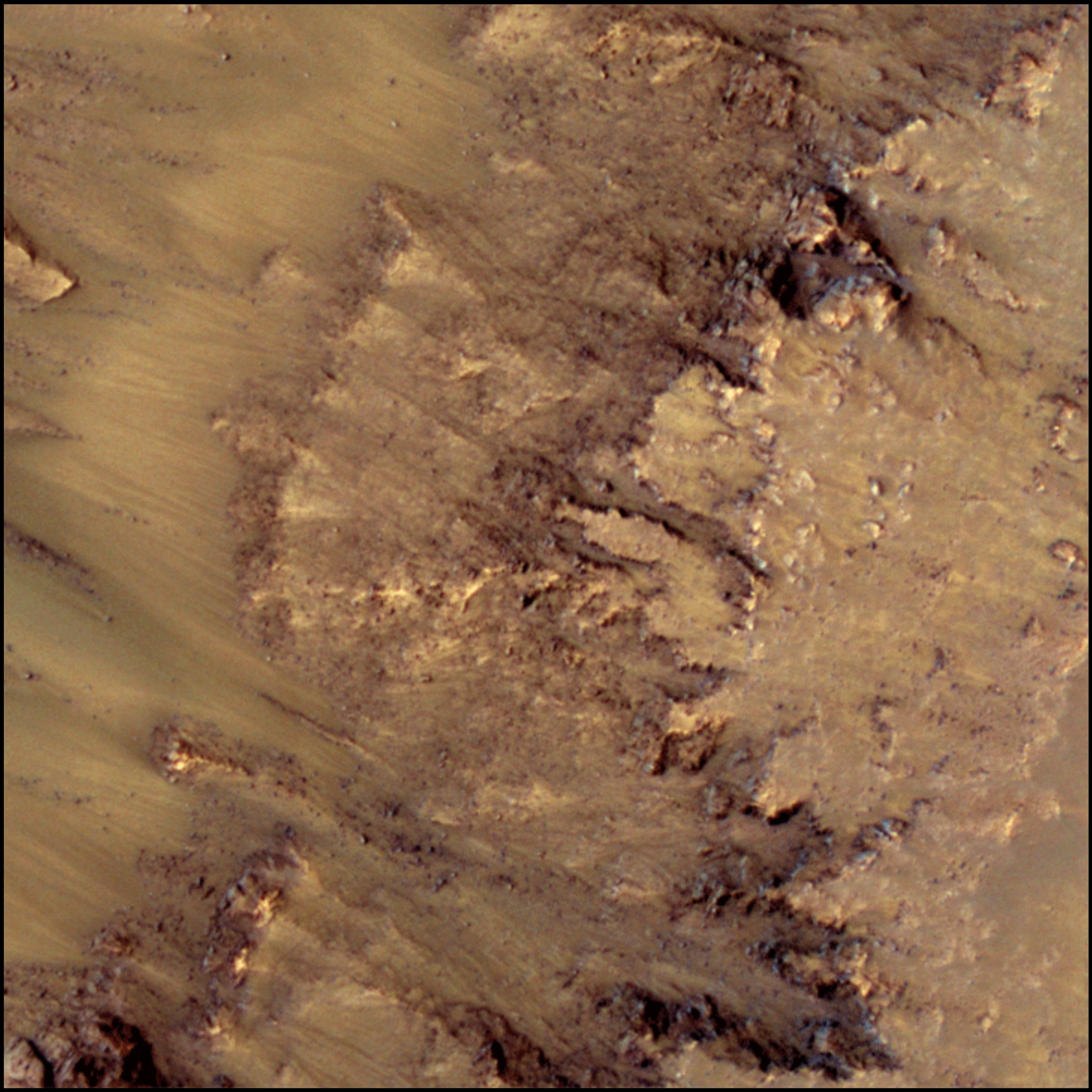
Yes:

- Temperature dependence
- Evidence of hydrated salts

No:

- No effect on surface temp.
- Slopes at angle-of-repose

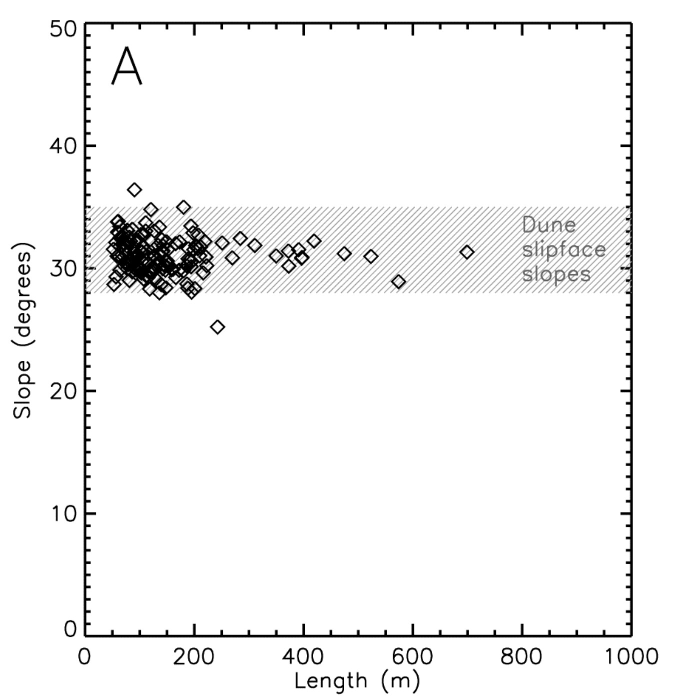
HiRISE / U. Arizona / JPL / NASA



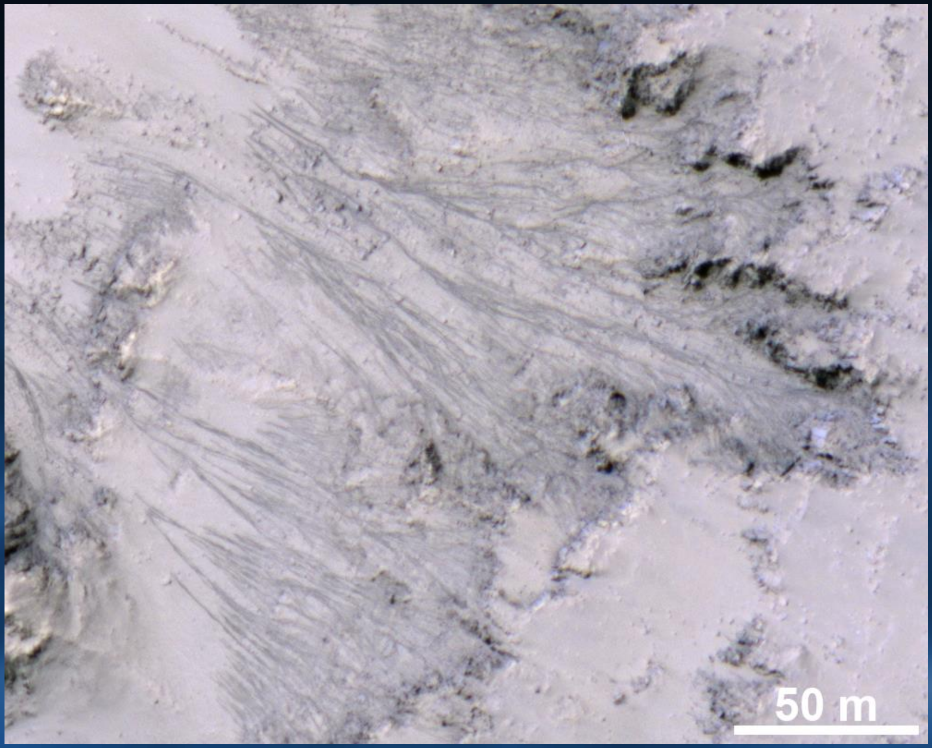
Evidence for Granular Flows at RSL sites on Mars

Recurring Slope Lineae (RSL) are flows that recur annually in summer, grow incrementally, and then fade again in winter.

New observations show that RSL terminate on slopes that match the angle of repose for dry sand. This strongly suggests that they are granular flows.



Terminal slopes for RSL compared with Martian sand dune avalanche slopes



RSL in Palikir crater

The triggering mechanism of the granular flows remains uncertain and could be connected to previously detected hydrated salts and/or deliquesced water. However, this new work suggests that RSL likely involve little or no liquid flow.

Dundas, C. M., et al., 2017. Nature Geosci., 10, 903-908.

Exposed Mid-Latitude Ice Sheets on Mars

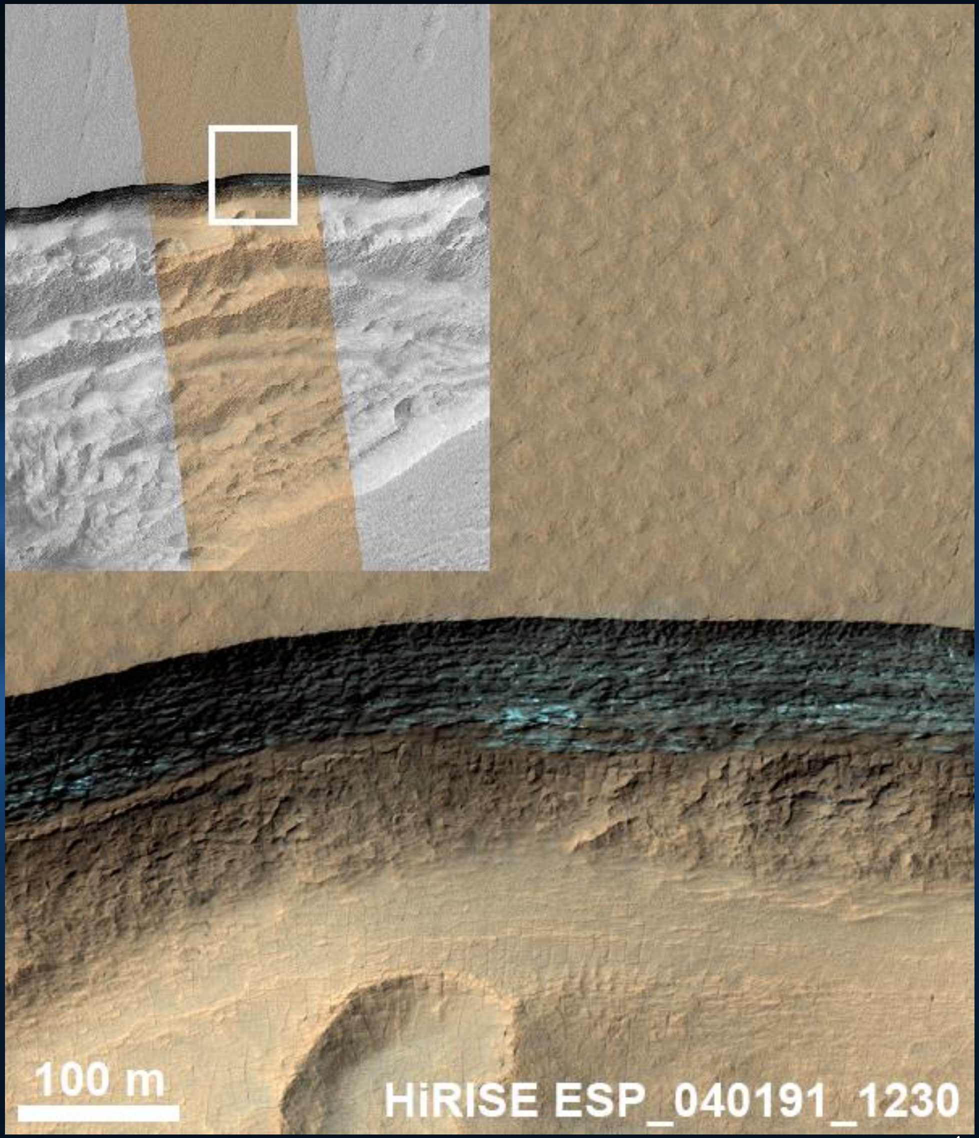
Data from HiRISE, CRISM, SHARAD (MRO), and THEMIS (Odyssey) demonstrate that erosional scarps expose hundred-meter-thick sections of water ice at the Martian mid-latitudes in both northern and southern hemispheres.

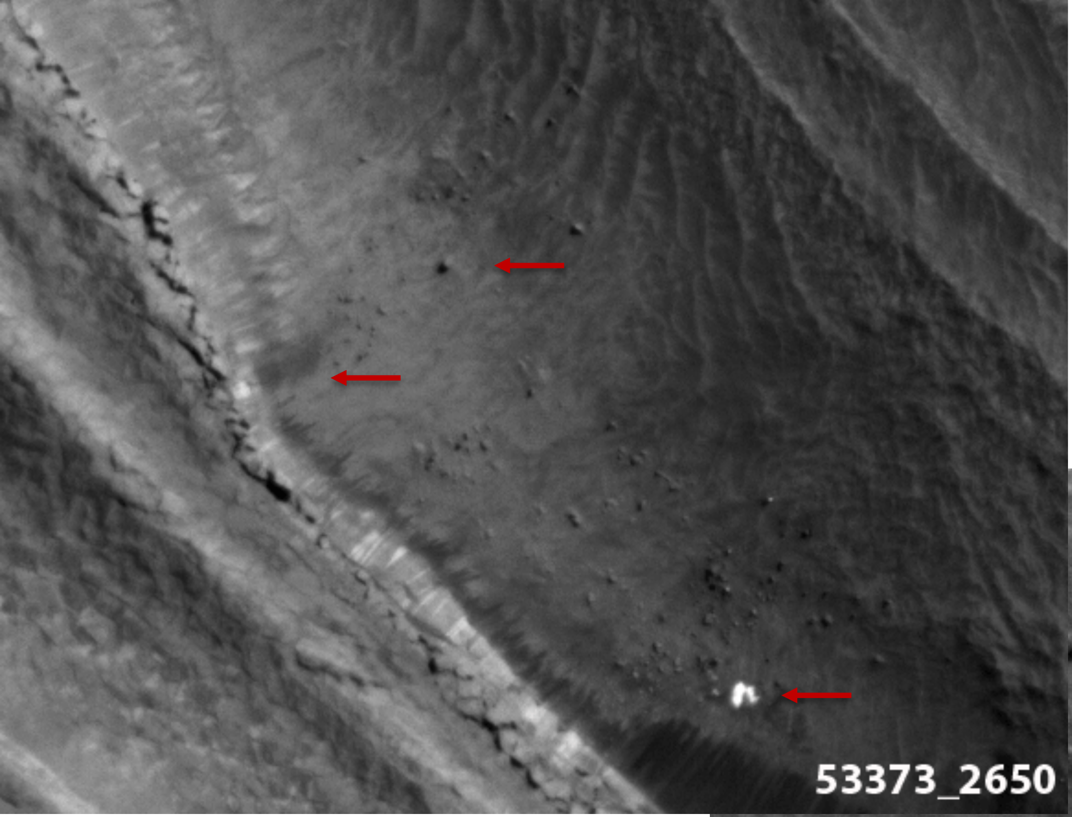
The ice is interpreted as geologically recent remnant deposits, likely laid down when Mars was at high obliquity, and may preserve an accessible record of climate variations.

The ice can be layered or massive, but has a low lithic (rock or soil) content and is covered by only a thin (<1-2 m) layer of dust and regolith.

Ice was detected by CRISM using both near-IR and VNIR-only data. This supports previous SHARAD evidence for thick regional ice sheets elsewhere on Mars and suggests that they may be more widespread than previously thought.

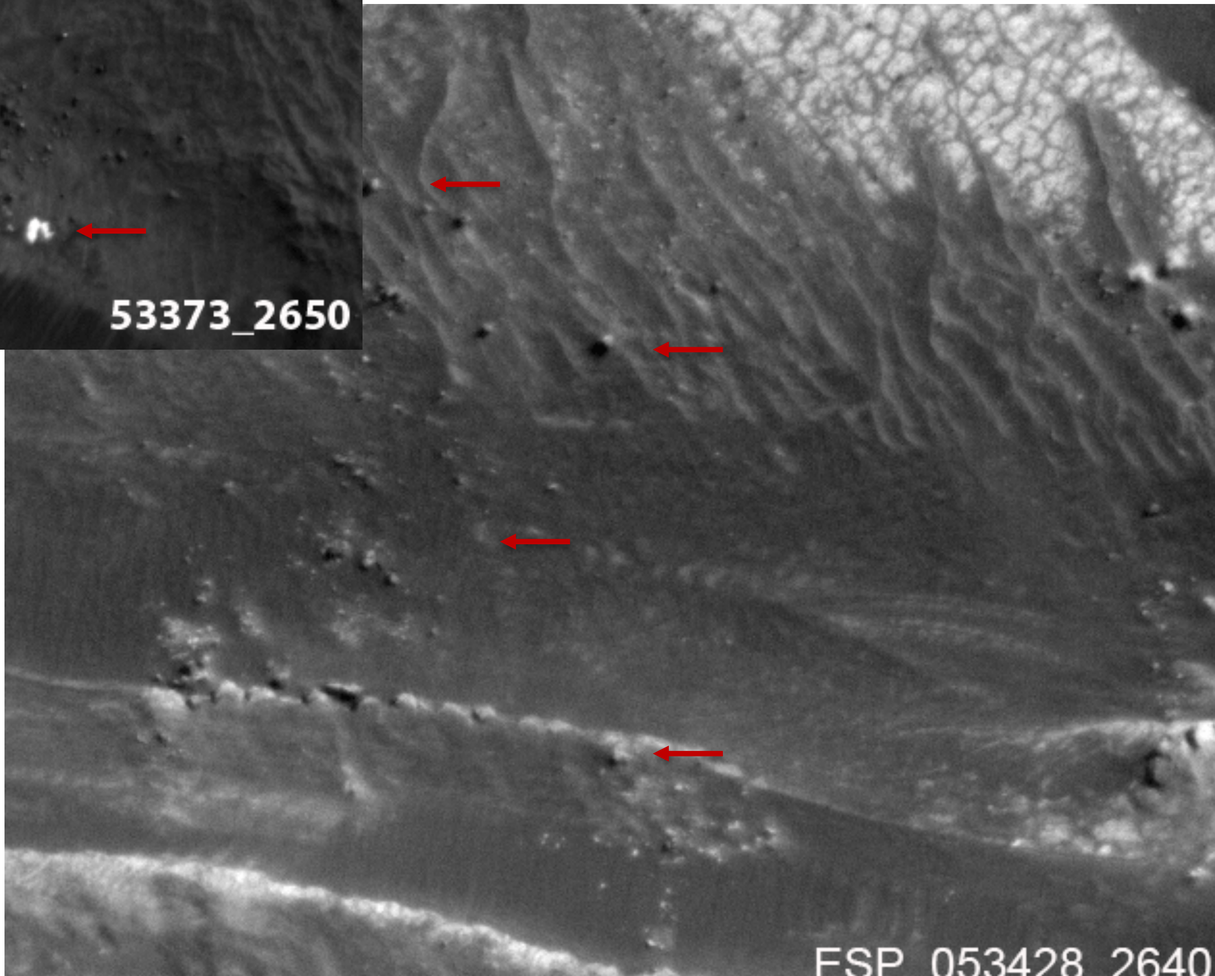
These scarps and the associated ice sheets represent both a potential target and a possible resource for exploration, important to NASA strategic goals for Mars exploration.





North Polar Cap Edge Cliffs

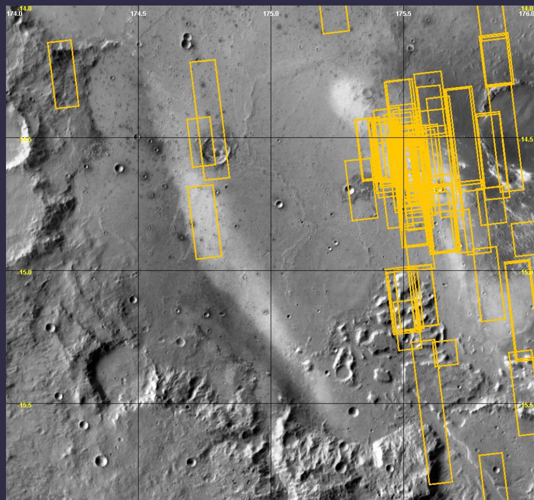
HiRISE / LPL / U. Arizona / JPL / NASA



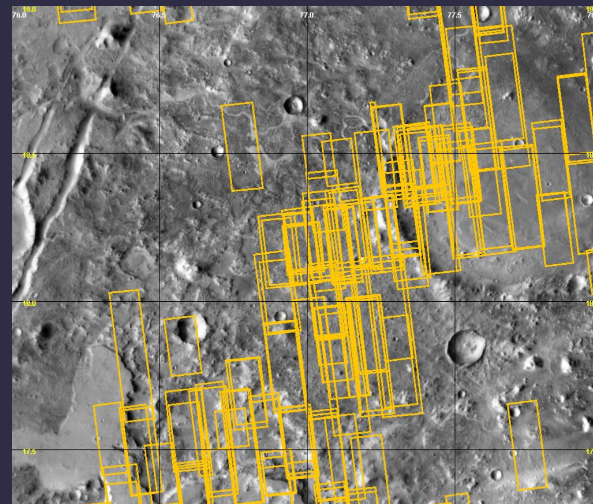
Change Detection Campaign Continues – Looking for:

- Ice-block falls and sublimation (see images above and to right; arrows identify some prominent changes)
- Ice slab avalanches
- Mass wasting in craters and canyons
- Sand Dune movement

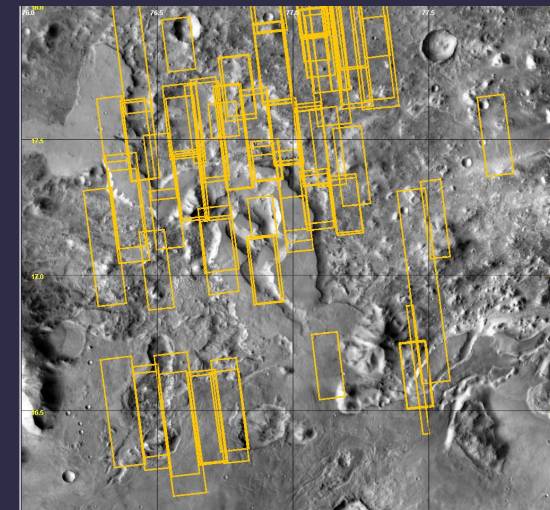
HiRISE Coverage of the Final Mars 2020 Sites:



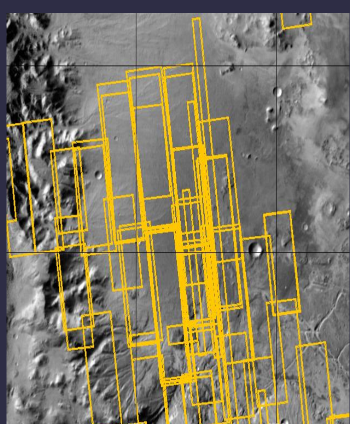
Columbia Hills



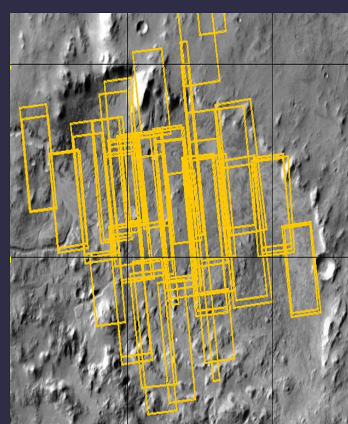
Jezero & Midway



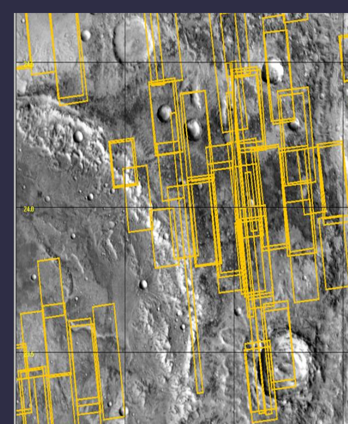
NE Syrtis



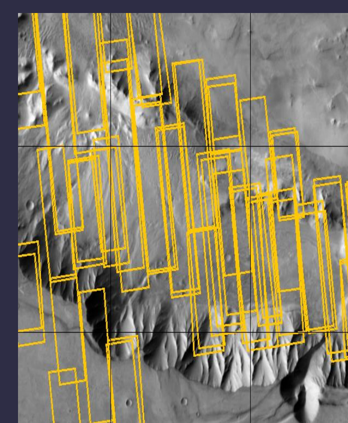
Holden



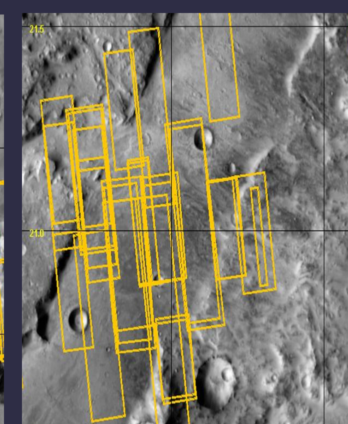
Eberswalde



Mawrth



SW Melas



Nili Fossae

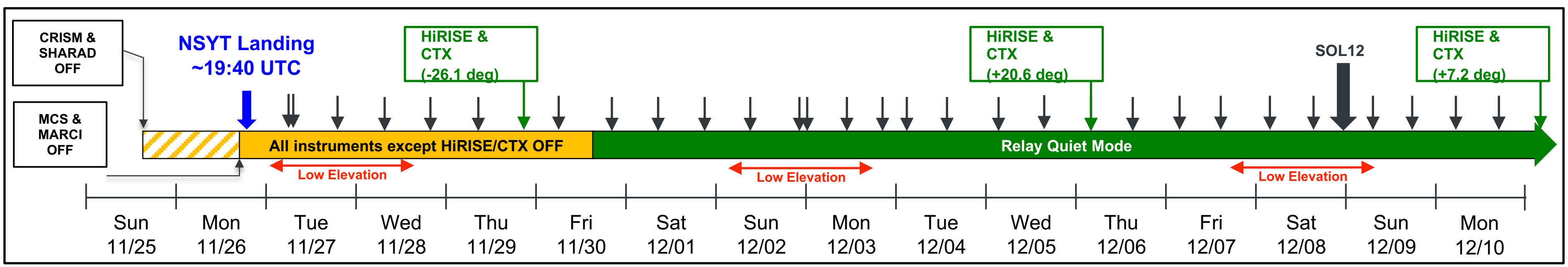
InSight Critical Event Coverage

EDL & Initial Surface Relay Support Plan Similar to MSL

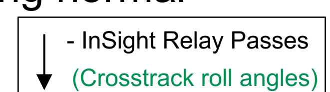
- Primary objective is to capture an open loop recording of the InSight radio signal during EDL using the Electra UHF radio [from InSight cruise stage separation to landing + 5 min]
- Navigation Strategy: Perform two in-plane phasing maneuvers to properly position MRO for InSight arrival – Third contingency maneuver available, if needed
- Special EDL Sequence: Spacecraft will slew such that the Electra antenna will “track” InSight during its EDL phase [slew strategy will maintain the Electra antenna boresight within a 30° half-cone angle of InSight] - Slew strategy compatible for HiRISE imaging
- Payload Configuration --- Instruments off to minimize EMI effects on the UHF radio link

  ON: Electra (open loop record), HiRISE (parachute image attempt), CTX

  OFF: CRISM (18-hr before EDL), SHARAD (18-hr before EDL), MARCI (6-hr before EDL), MCS (2-hr before EDL)



- Post-landing, MRO will provide 4 sols of primary relay support before resuming normal operations in “relay quiet mode”
  - All instruments except HiRISE and CTX will remain off (to minimize EMI)
    - MCS powered on to capture post-EDL atmospheric conditions and then powered off prior to 1st relay pass



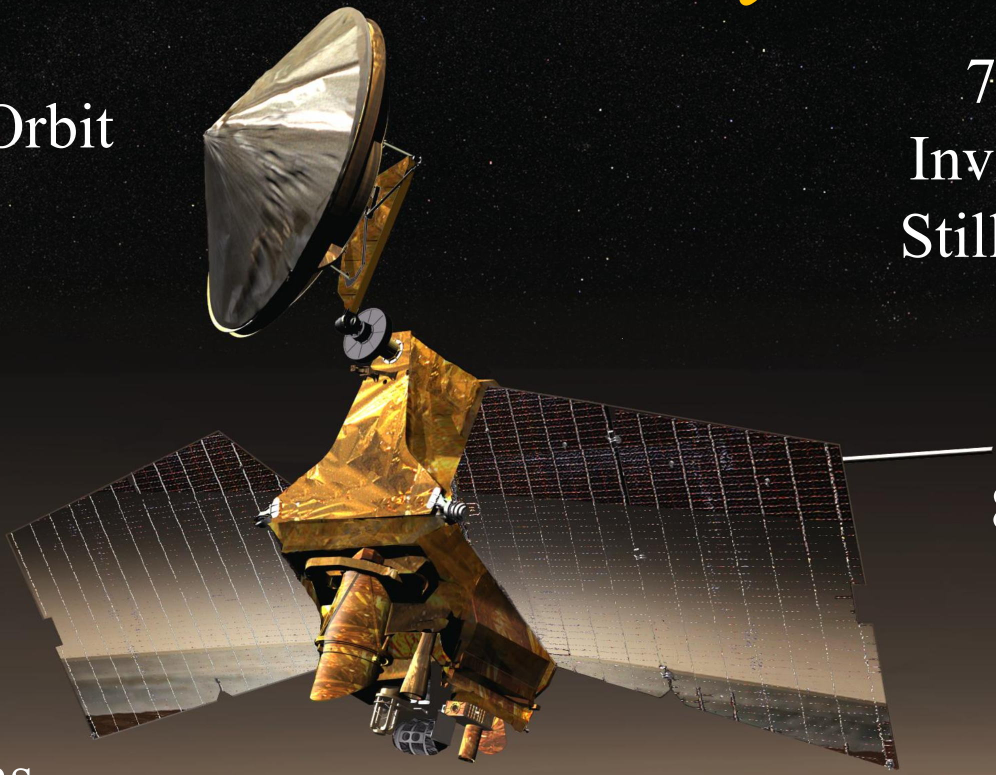
Flight System Status and Challenges - 2018

- Consumables Status - Component Lifetime
  - Large fuel reserves => ~199 kg of propellant
  - Nearly all subsystem redundancy remains
- Operating using All-Stellar (AS) Attitude Determination (AD) mode
  - Transitioned to all-stellar on 3/19; IMUs powered OFF
  - Spacecraft ACS continues to function well with the AS algorithm
- Spacecraft Power Management / Battery Reconditioning
- Experienced another occurrence of the C&DH Side-Swap Anomaly (Aug 2018)
- Payload Status
  - HiRISE Image Blur—mitigated by enabling HiRISE heaters during imaging
  - CRISM Infrared Capability –Remaining Cryo Cooler not able to hold temperature for IR measurements; visible spectrometer continues to operate nominally

Mission Summary

12 Years in Mars Orbit
(MY 28-34)
~55,000 orbits

7 Science Investigations Still Returning Data



340 Tbits of Science Data Returned

895 Gbits of Relay Data Returned

~1200 Publications in peer-reviewed Journals

Mars Reconnaissance Orbiter

Over 4700 Relay Passes

More to Come!

~3% of the planet imaged at 30 cm/pixel (high resolution)
99.6% of the planet imaged at 6 m/pixel
75% of all Curiosity's data returned through MRO

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