Automated Co-Registration and Orthorectification and its uses in change detection using data mining

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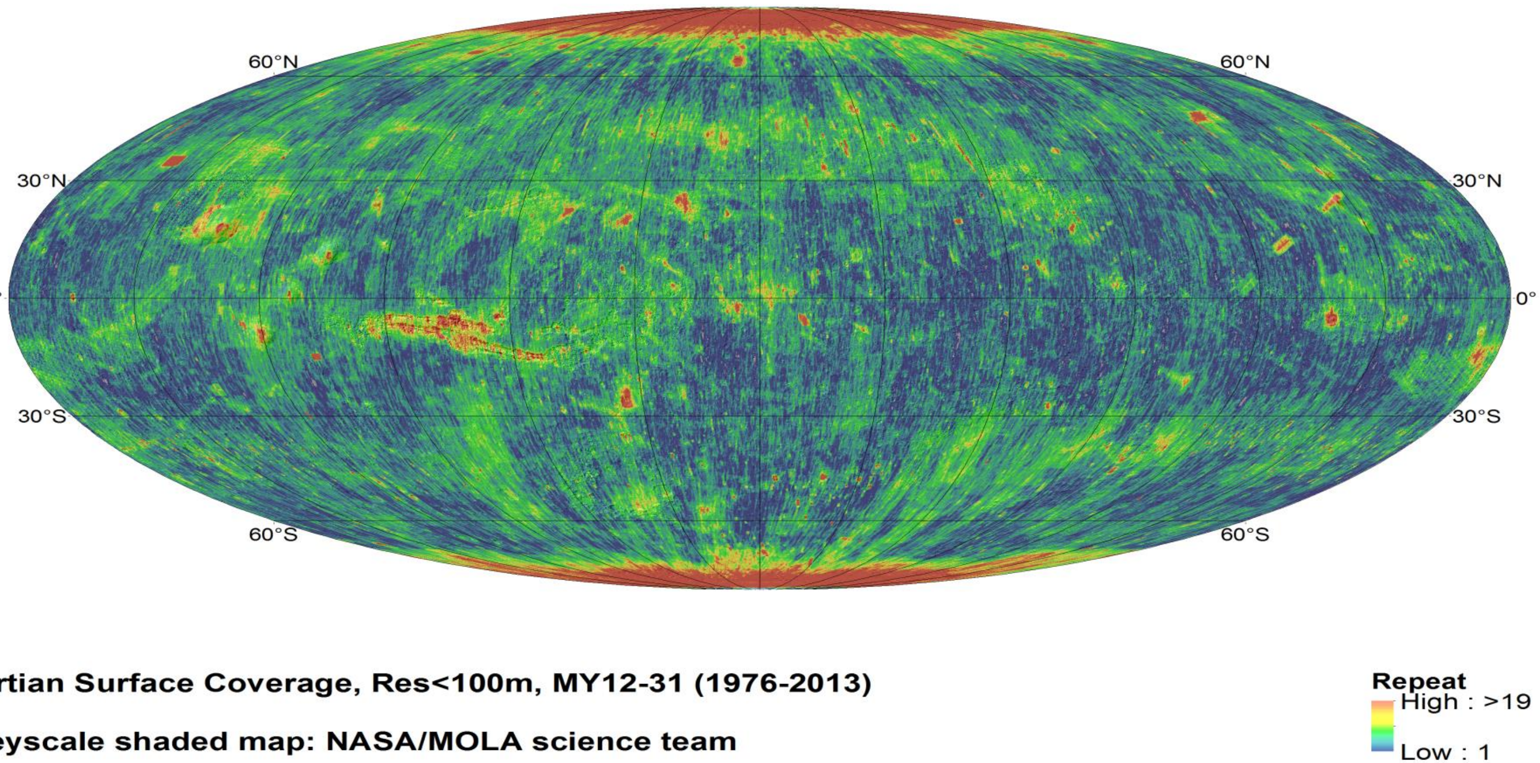
High-Resolution Mars Repeat Coverage



Martian Surface Coverage, Res<100m, MY12-31 (1976-2013)

Greyscale shaded map: NASA/MOLA science team

P. Sidiropoulos and J. P. Muller, Planetary Space Science, 2015.

Change detection potential

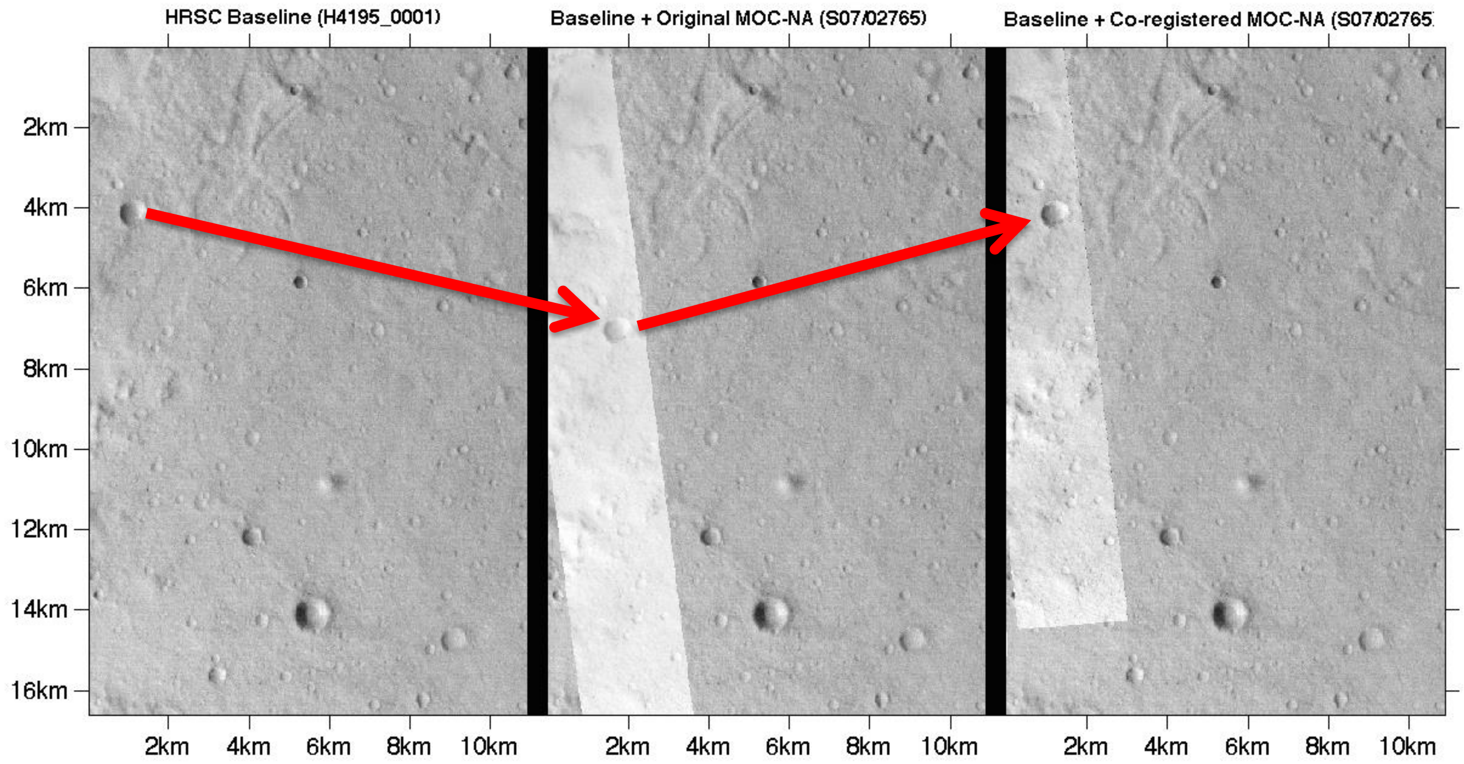
- Large areas of Mars have been mapped repeatedly
  - Even if the input images are constrained according to season
- Batch-mode automatic change detection is possible using the available data
- "Manual" change detection becomes gradually obsolete due to the increasingly large data volume
- iMars objective:

<u>automatically find multiple changes on the surface of Mars</u>

Season	Mapped twice or more (10^6 km^2)	Mapped thrice or more (10^6 km^2)
NH Spring	48.3	20.1
NH Summer	25.3	8.8
NH Autumn	18.8	6.2
NH Winter	26.7	9.9
All Seasons	121.3	89.0
Asia: 44.5 M km2, Africa: 30.2 M km^2, N. America: 24.7 M km^2, S. America: 17.8 M km^2, Antarctica: 14M km^2, Europe: 10.2 M km^2, Oceania: 8.5 M km^2		

The need for co-registration and orthorectification

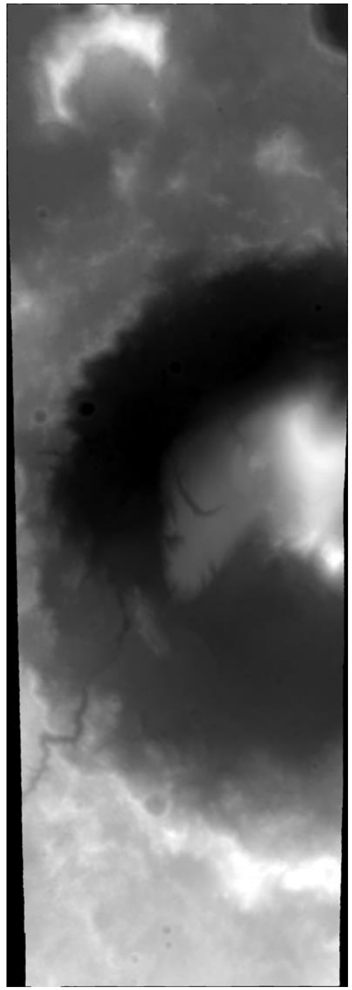
- Due to small position and orientation errors in the spacecraft location and pointing, each image is practically in its own coordinate system
  - Pixel-level comparisons are not feasible in these circumstances



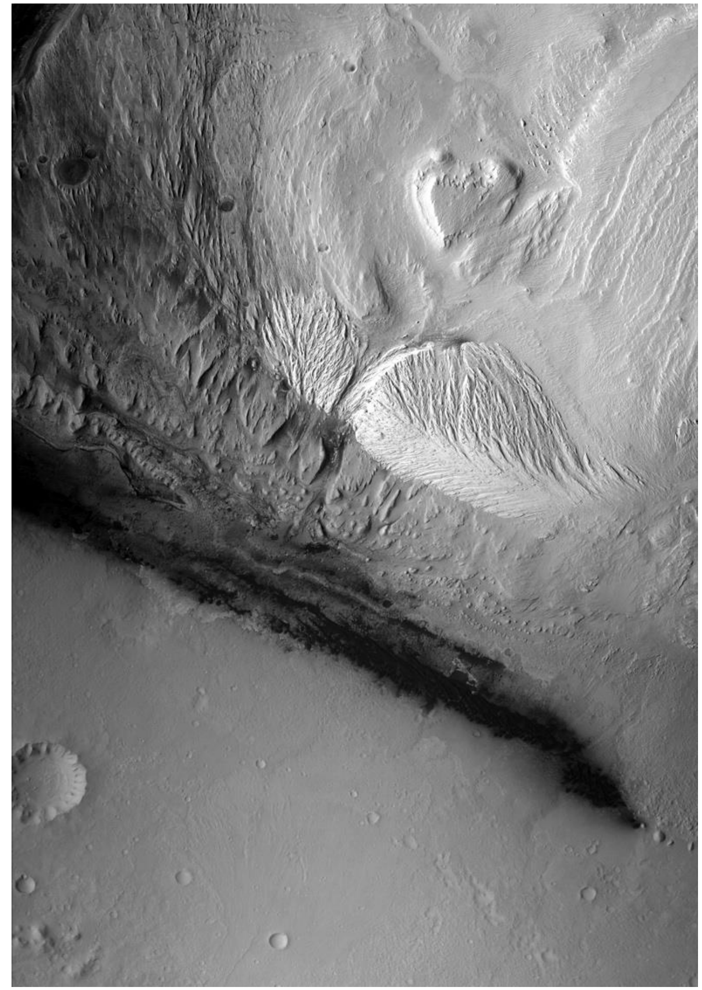
The original mislocation of the two images is more than 2km!

Co-registration and orthorectification input

H4235_0001_ND4
(HRSC nadir)



H4235_0001_DT4
(HRSC DTM)



P06_003453_1752_XI_04S222W
(CTX input)

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ACRO (Auto Co-Registration & Orthorectification) algorithm

1. Find corresponding points between the input and the baseline images
   - Baseline image is areo-referenced: we know its "real world" coordinates
   - DTM gives the height of each pixel
2. Using the areo-reference information and the DTM transform the correspondences from "image to image" to "image to real world"
3. Estimate a camera model that determines the image position in "real world" coordinates
4. Build the co-registered image one pixel at a time
5. Apply DTM to remove terrain relief effects

P. Sidiropoulos and J.-P. Muller, "Matching of large images through coupled decomposition", IEEE Transactions on Image Processing, Vol. 24, No. 7, pp. 2124-2139, 2015.

P. Sidiropoulos and J.-P. Muller, "A systematic solution to multi-instrument co-registration of high-resolution planetary images to an orthorectified baseline", IEEE Transactions on Geoscience and Remote Sensing (in review)

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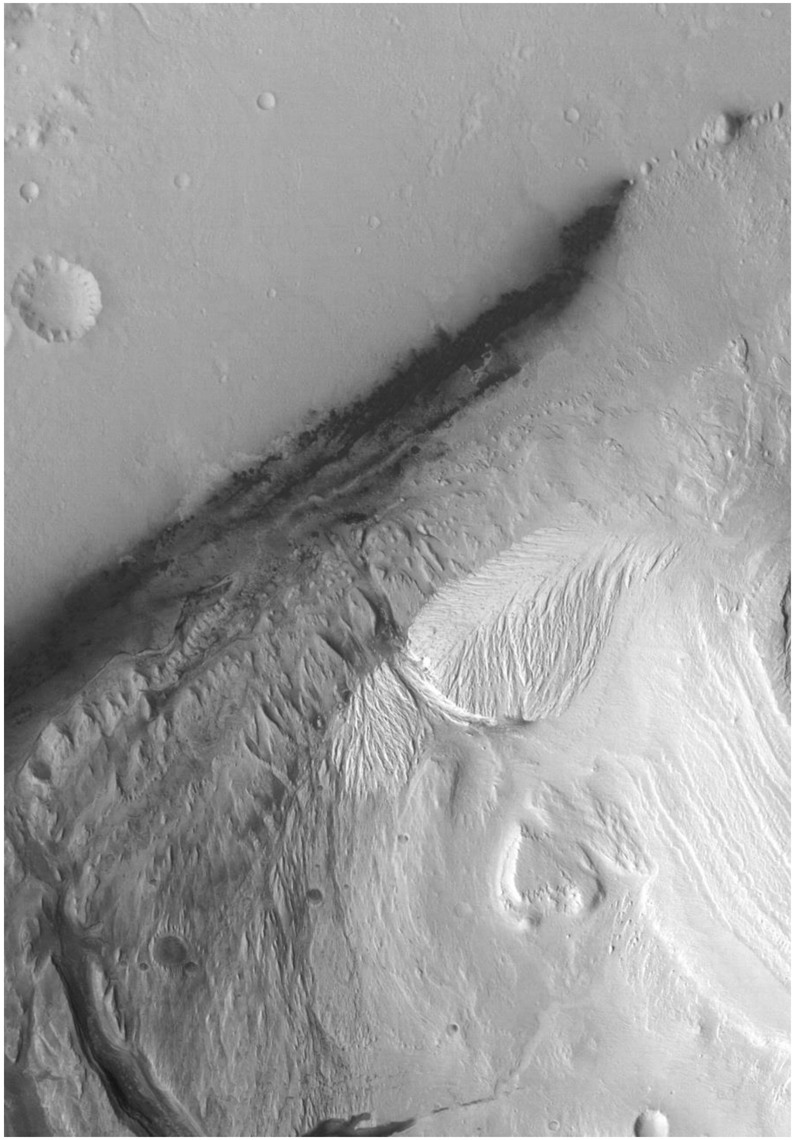
P06_003453_1752_XI_04S222W ACRO output

Corresponding h4235_0001_ND4 area



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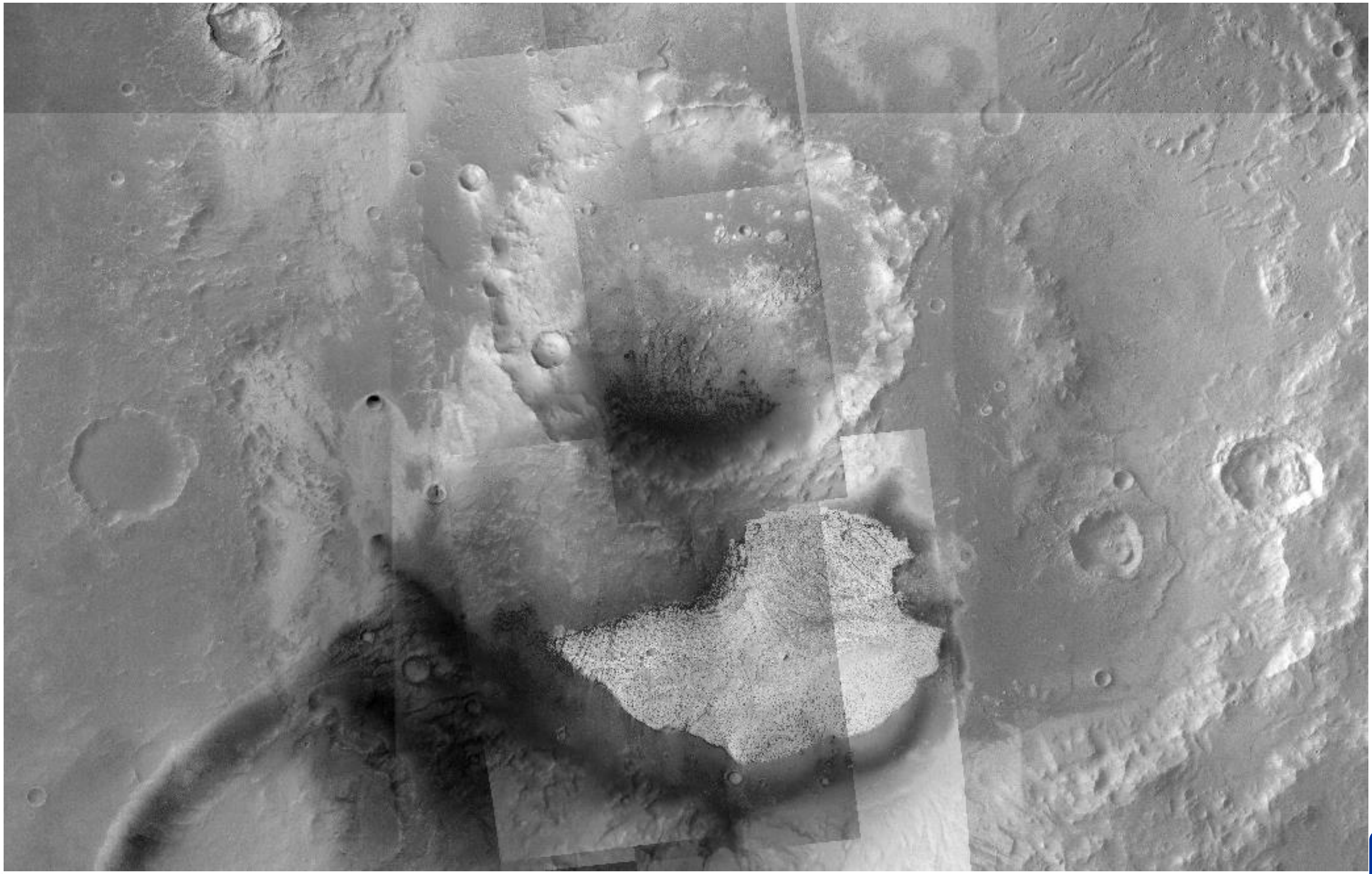
ACRO processing examples

- Becquerel crater (22.1N, 352E), 7 CTX co-registered to HRSC mosaic



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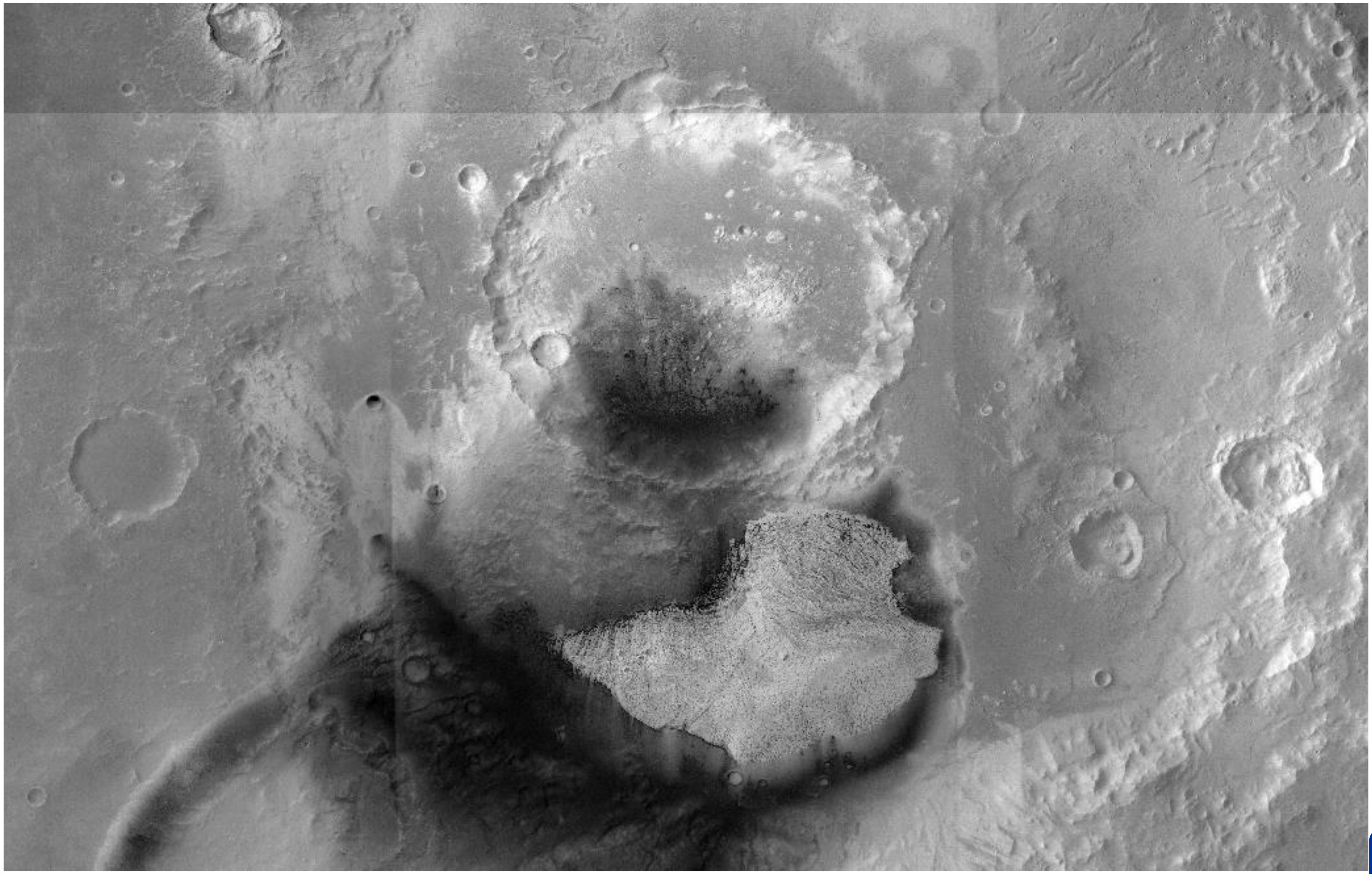
ACRO v1.0 processing examples

- Becquerel crater (22.1N, 352E), HRSC baseline



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Co-registration processing within iMars

- Batch-mode co-registration of thousands of images from CTX, THEMIS-VIS, MOC-NA, VO to HRSC baseline
  - All NASA images in MC11-E half-quadrangle
  - All NASA images in MC11-W half-quadrangle
  - 4,400 images in ROIs (selected according to the literature)
  - 1,200 images in SPRC (South Pole)
- MC11-E CTX mosaic using CTX co-registered images
- MC11-W CTX mosaic using CTX co-reregistered images
- Cloud computing grant from Microsoft Azure to process the rest of the planet over the next year

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Change detection inputs

- A pair of co-registered images from ACRO pipelines
- The corresponding HRSC DTM

<u>Algorithm</u>

1. Find pixel-level changes
2. Aggregate them into larger sets of “changed regions”
   - Discard spurious “changes” that appear as isolated pixel-level changes
3. Discard changes that are caused by illumination effects
   - E.g. Shadows
4. Load all remaining candidate changes into 4 classifier modules, each focusing on certain type of changes
5. Merge partial results using a second-layer classifier and declare changes

Change detection output

- ROIs determined by change detection are extracted and stored as two areo-referenced images
  - Fixed size: 512x512
  - Resolution equal to the resolution of the coarsest image
- These ROIs are also the input in the crowdsourcing experiment
- Metadata stored
  1. Lat/Lon coordinates of the change
  2. Pixel coordinates of the change
  3. Date of the before/after images
  4. Names of before/after images

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Change detection processing and results

- Initial results: 868 changes (Europlanet Workshop)
- Current results:
  - 3,365 changes (for the Mars in Motion website)
  - Also, 465 non-changes as the control group
  - Change detection results in MC11-E and MC11-W half-quadrangles
  - Change detection results in ROIs

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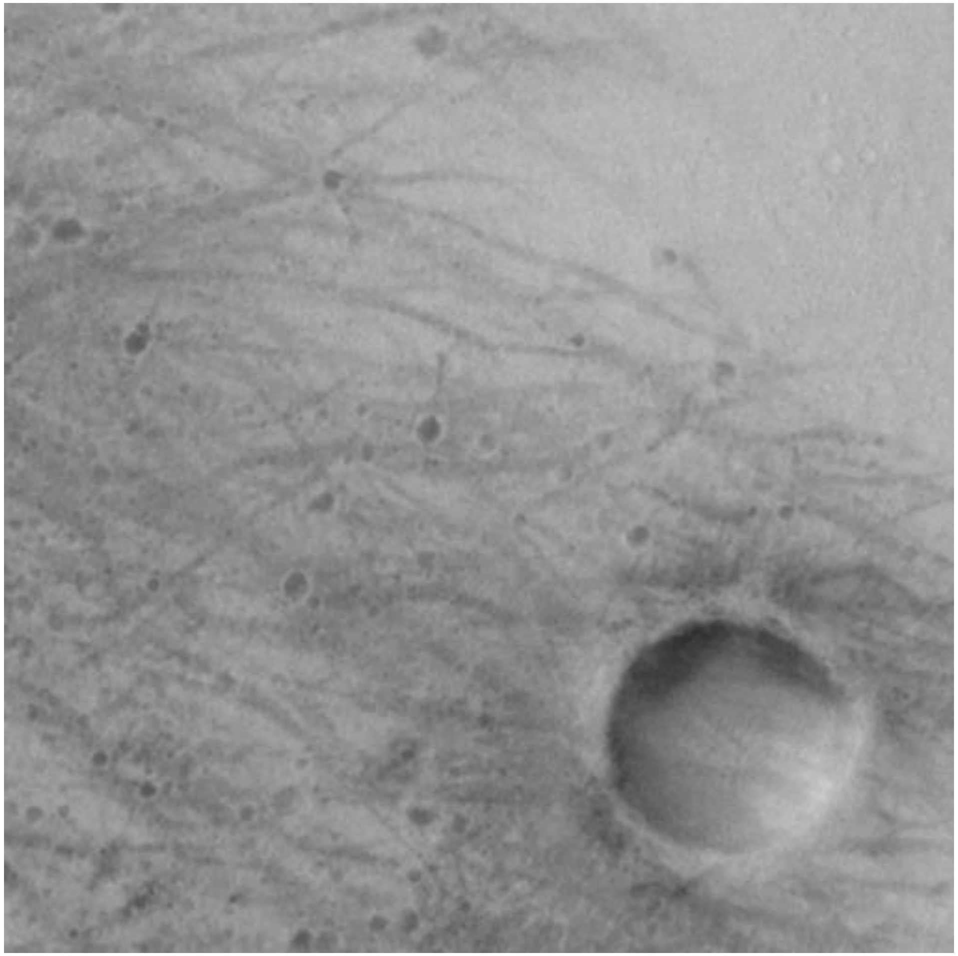
Automatically detected changes

- Dust devil tracks: the most common change
  - Hundreds of dust devil tracks changes have been found



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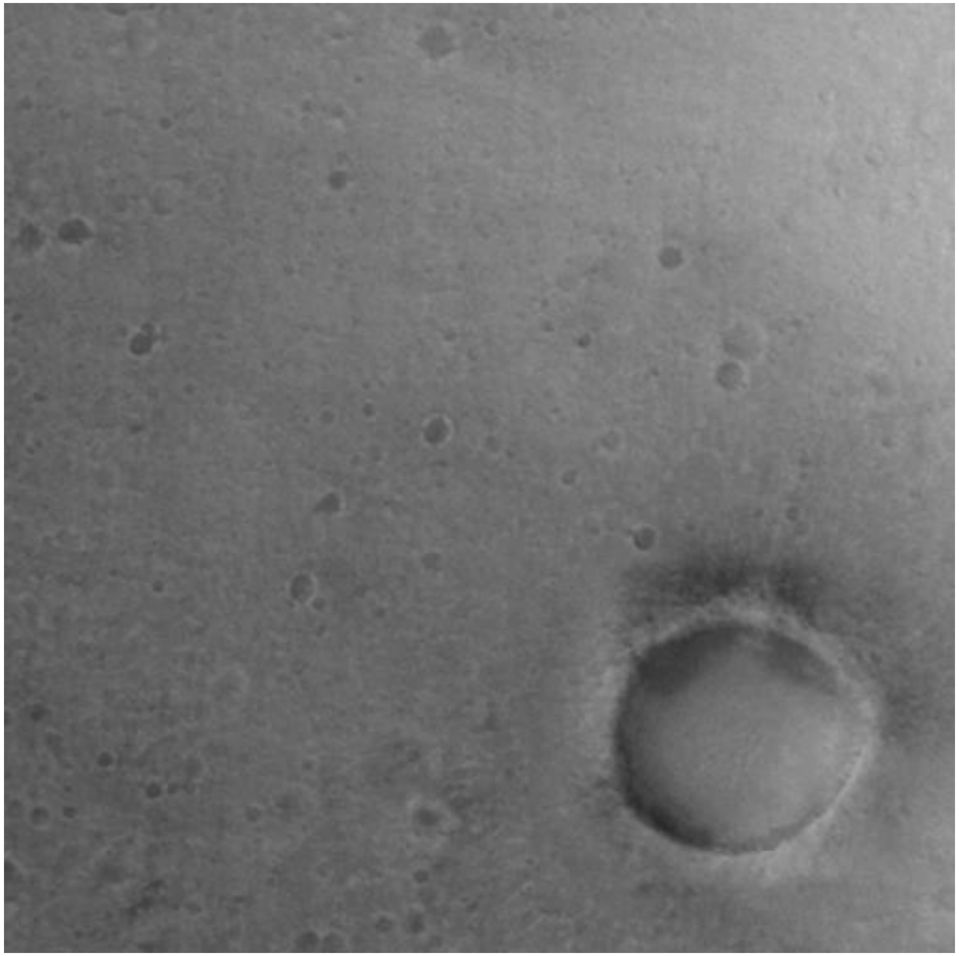

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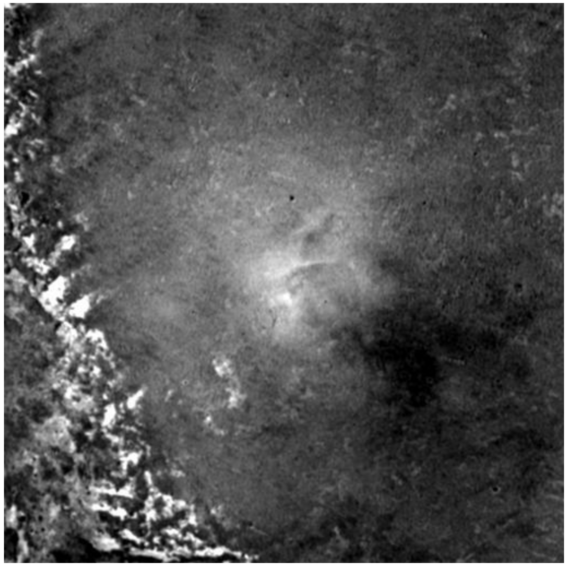
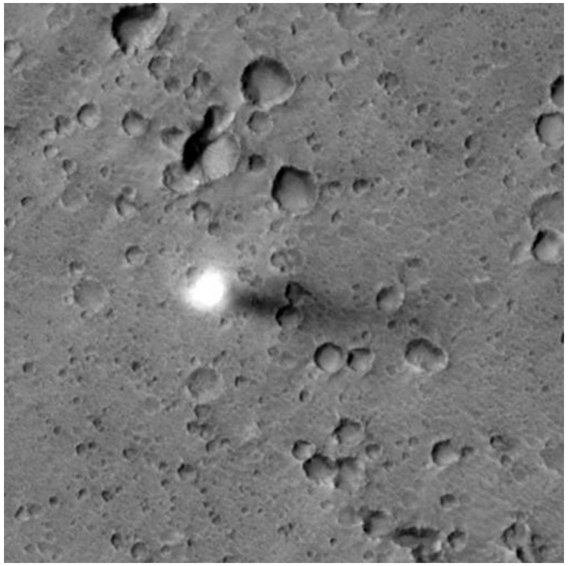
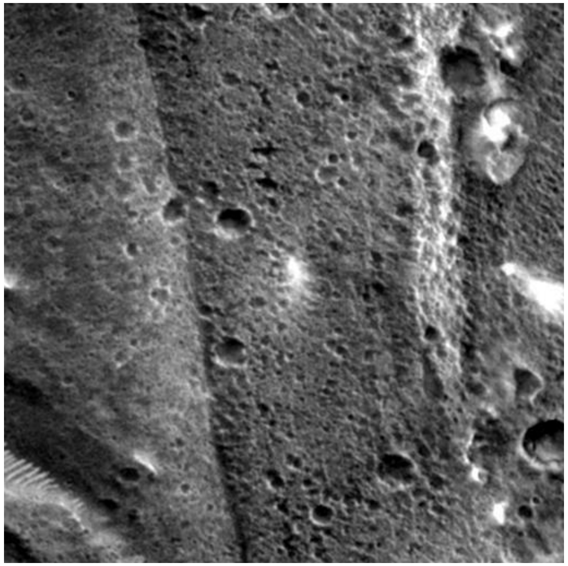
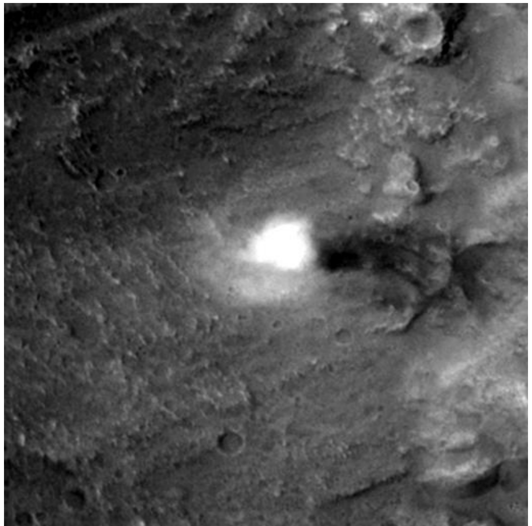
Automatically detected changes

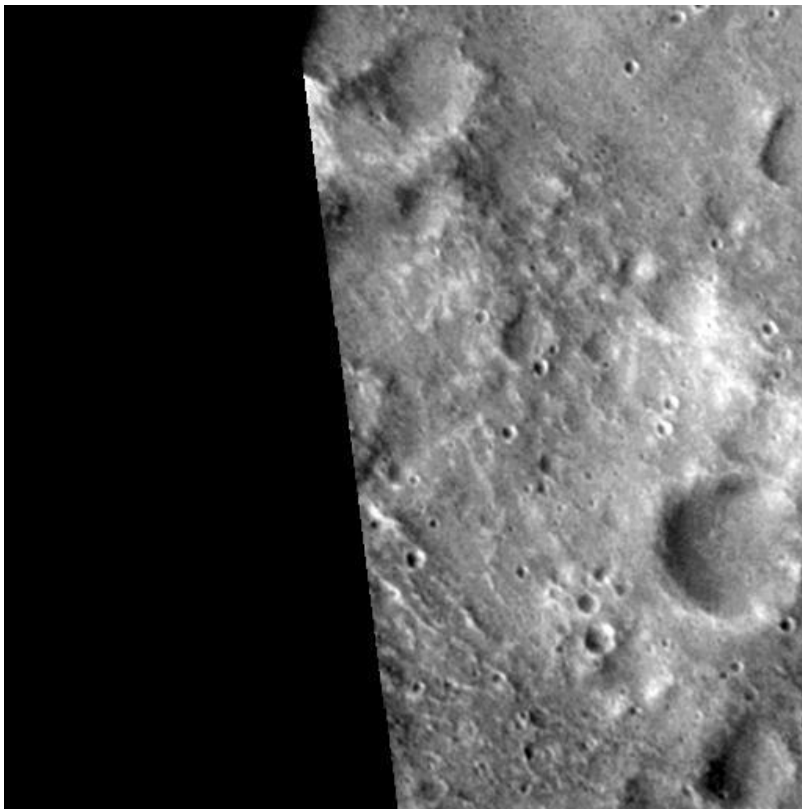
- Dust devils in action (more than 10 found to date)

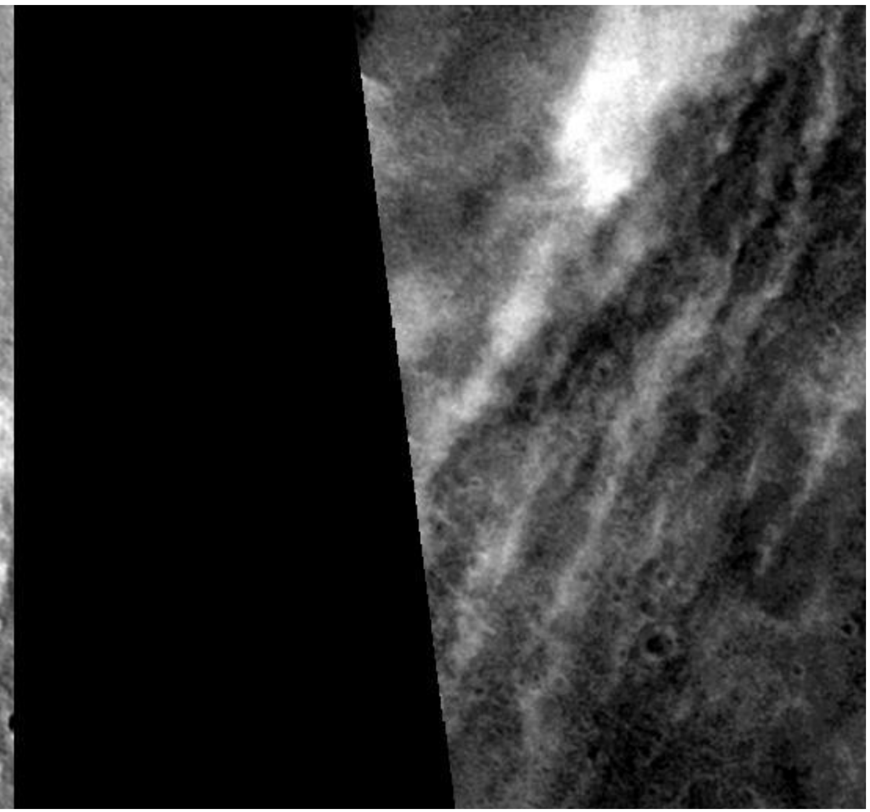


Automatically detected changes

- Clouds



CTX/2007



CTX/2009

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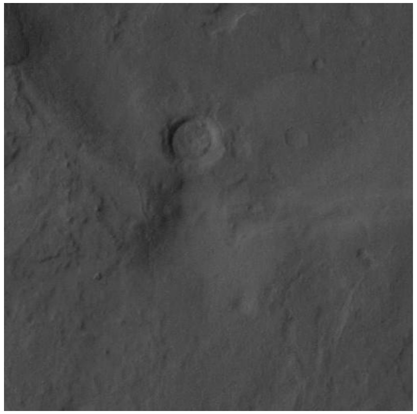
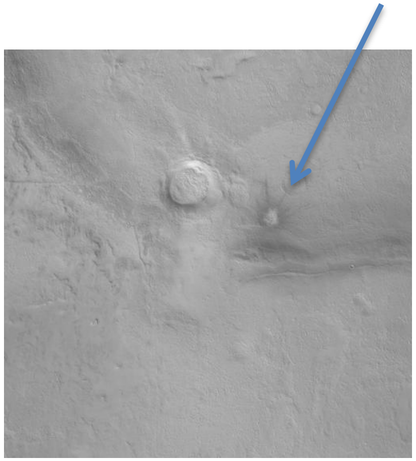
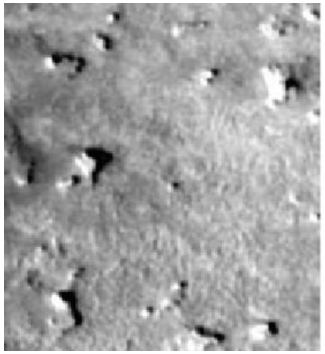
Automatically detected changes

- New impact craters (2 found in MC11, not reported in literature)

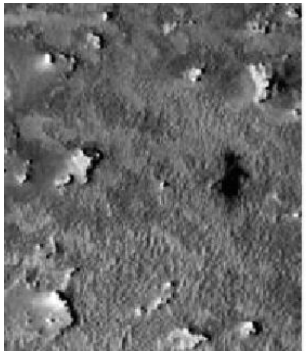




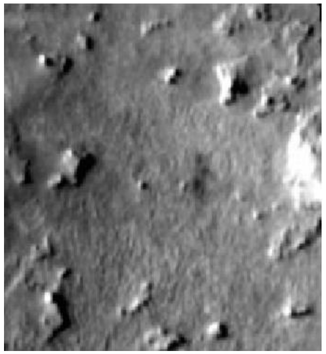
New impact crater in MC11-E, not reported in literature



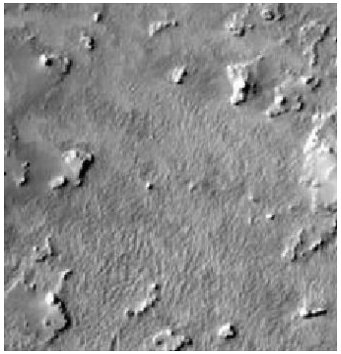
THEMIS/2005



CTX/2007



THEMIS/2008



CTX/2014

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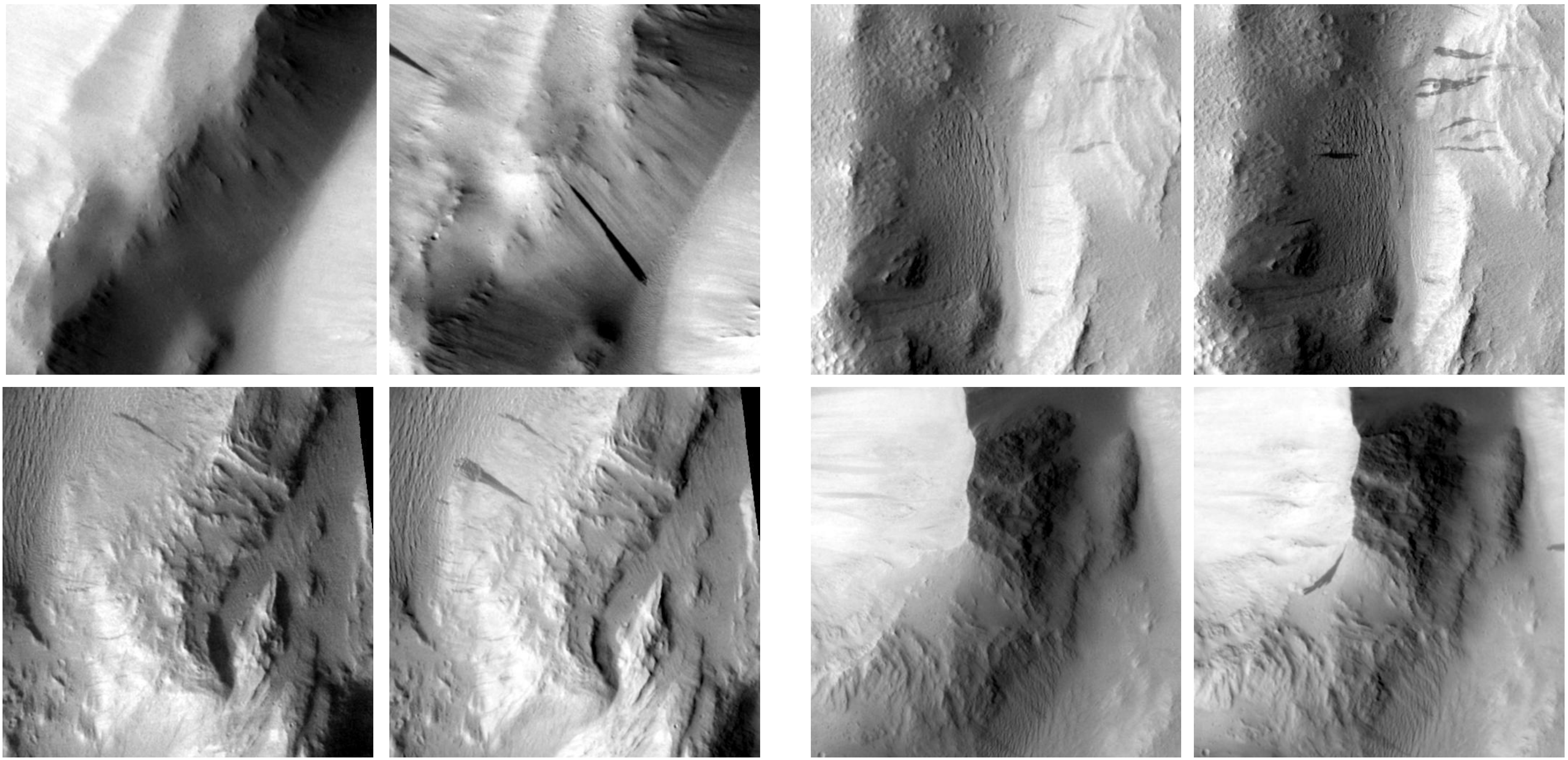
Automatically detected changes

Slope streaks: Several instances found in areas with plenty already reported



Top Row: Nicholson Crater
Bottom Row: Olympus Mons Aureole

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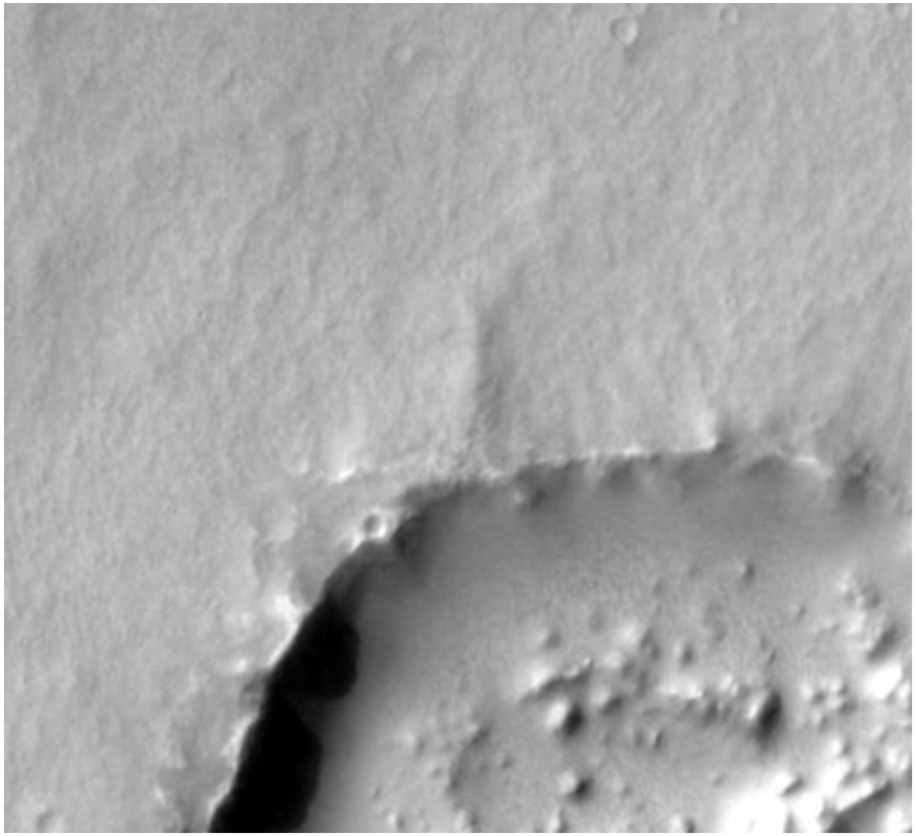
Automatically detected changes

- The problem with active gullies, RSLs (and unreported slope streaks): We can't declare them without first having the support of a planetary scientist
  - "changes" found on slopes – are these due to changes in resolution, atmospheric transparency and/or solar angle effects?



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