Meter-Scale Topography and Slopes of Candidate MSL Landing Sites from HiRISE Stereo

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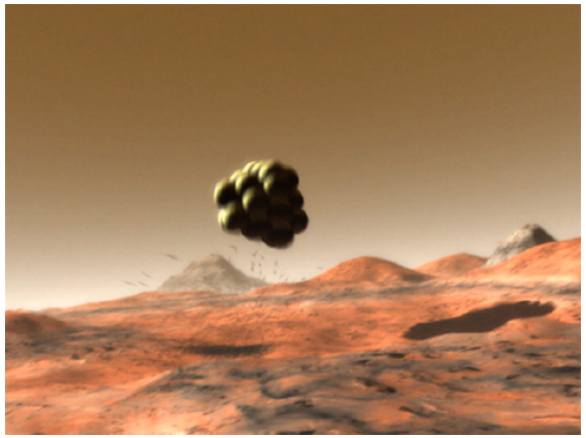
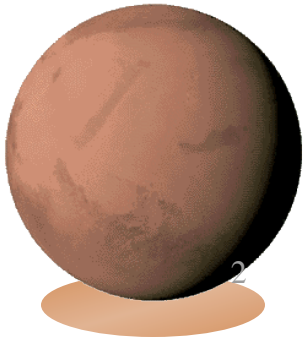
3rd MSL Landing Site Workshop

Pasadena, CA 15–17 September, 2008

Landing Site Selection Criteria

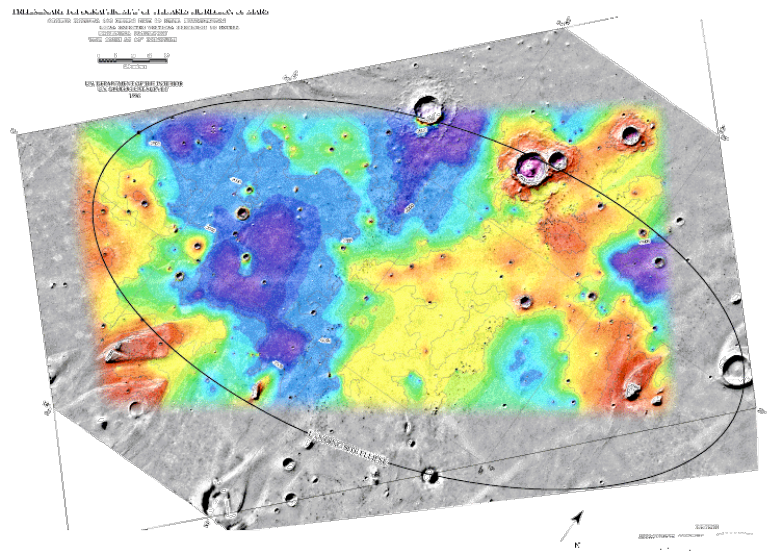


- Latitude
- Elevation
- Wind
- Slopes
  - Kilometer baselines
  - Hectometer baselines
  - 1-10 m baselines
- Rock abundance
- Dust abundance
- Temperatures
- *Science*



Landing Site Slope Criteria

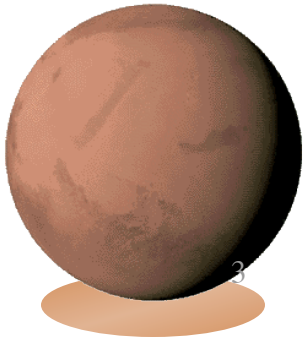
- ≥ 500 m: MOLA grid
- ≥ 300 m: MOLA profiles
- ~100 m: MOLA pulse width
- < 100 m: Images
  - 40–200 m Viking Orbiter
  - ~100 m THEMIS
  - 3–10 m MOC
  - 0.3–1 m HiRISE



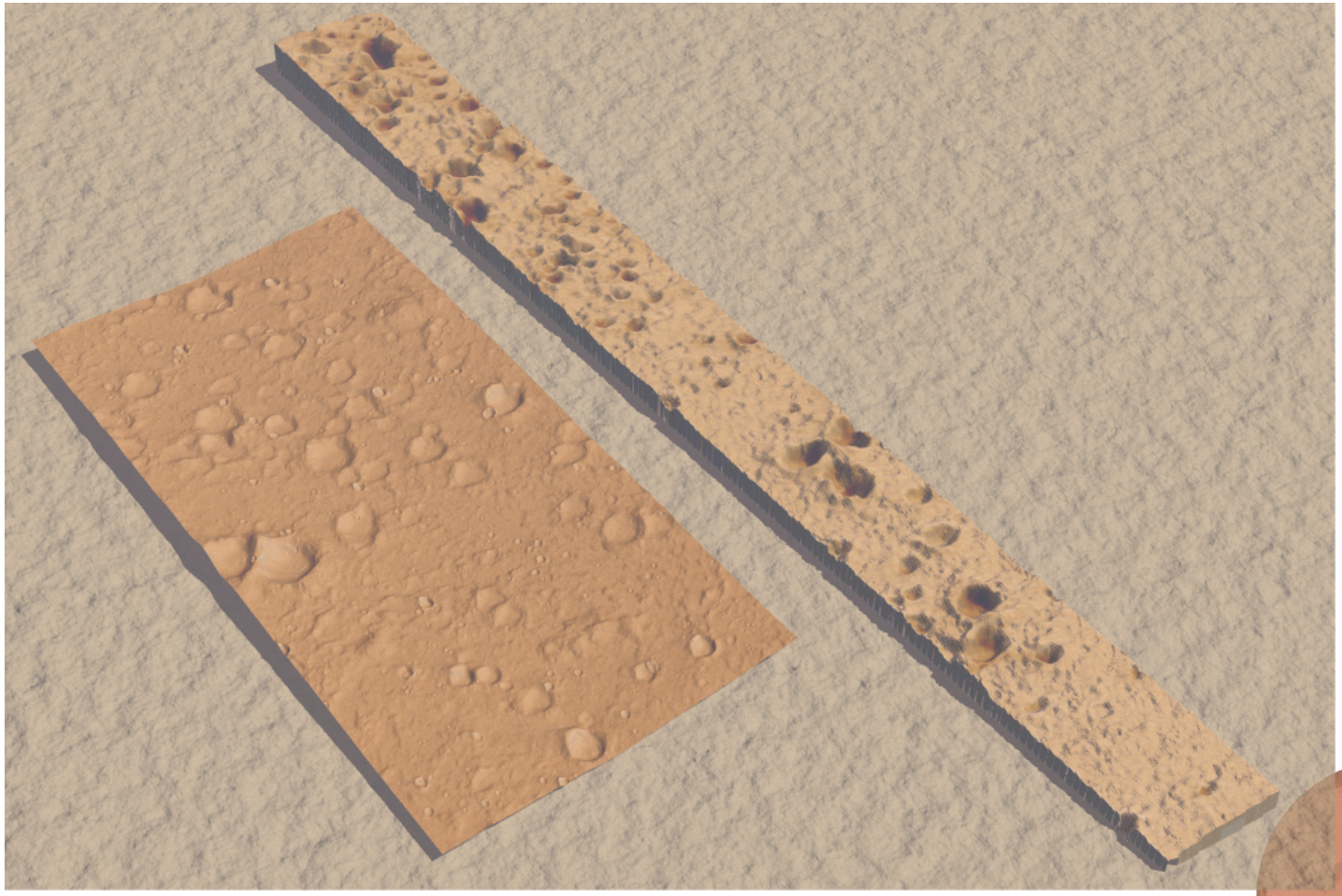
Mars Pathfinder Ares Tiu site
Viking Orbiter 40 m/pix stereo

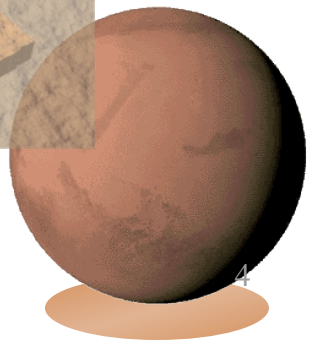
For MSL slope evaluation at 2-5 m baseline, choices are MOC (photoclinometry) or HiRISE (stereo)

- Other possibilities
  - 12–200 m HRSC
  - 6-20 m CTX
  - 3–10 m HRSC-SRC



Photoclinometry & Stereo





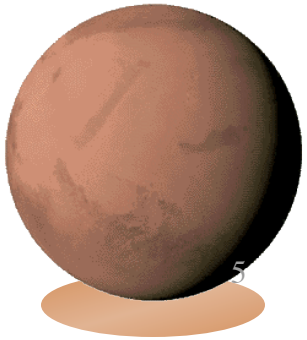
Methodologies Compared

Photoclinometry

- Single image
- Horizontal res 1 pixel
- Measure, $\int$ *slopes*
  - Neighbor hts to << 1 pix
  - Errors grow w/baseline
- Radiometric
  - Artifacts if albedo varies
  - Scale error if haze not calib. to stereo/MOLA
  - No absolute heights
- CPU & labor intensive

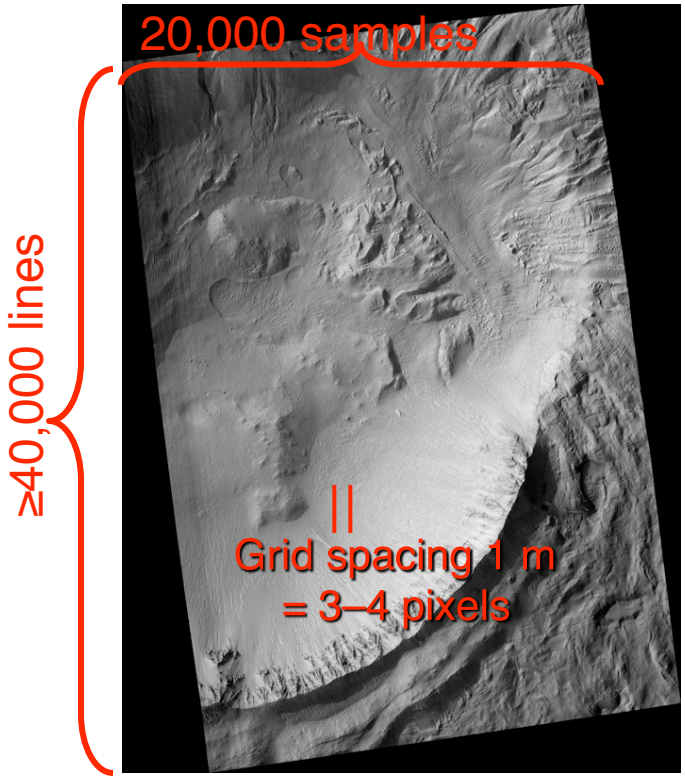
Stereo

- Two convergent images
- Horizontal res ≥3 pixels
- Vert res 0.2 pix / (b/h)
  - ~1 pix for MOC
  - Independent of baseline
- Geometric
  - Ignores albedo
  - Ignores atmosphere
  - Absolute heights require control (e.g. to MOLA)
- CPU & labor intensive



HiRISE Stereo: Data Volume Necessitates Digital Mapping

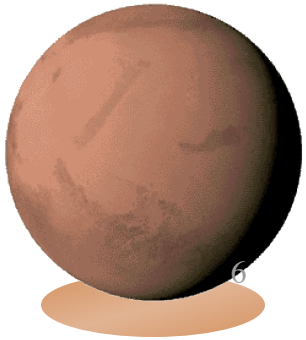
Typical HiRISE pair



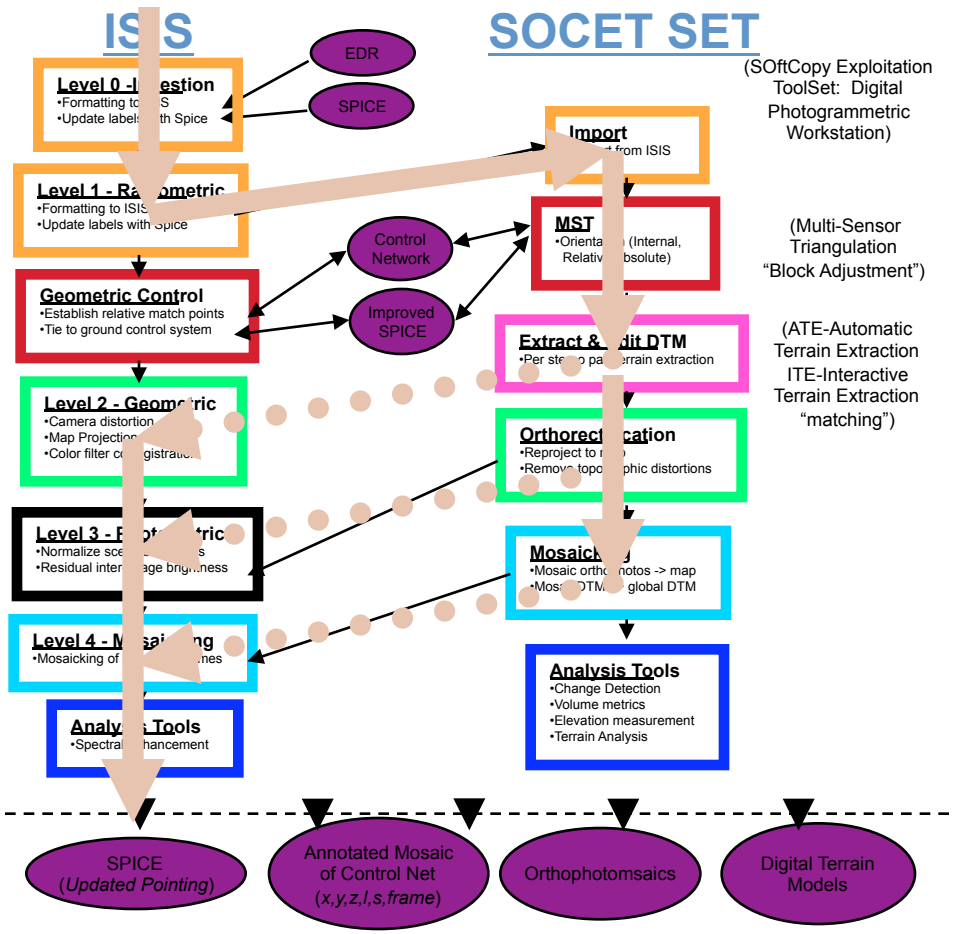
≥90 million posts
Control images, produce and edit DTM in a few work days by digital "softcopy"

USGS Viking Orbiter Global DTM

170 million posts
>99% interpolated from contours
Team of 5-6 people working for a decade by analog stereo



ISIS/SOCET SET Workflow

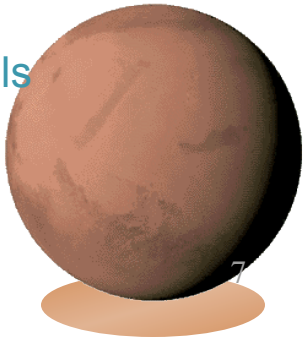


ISIS: Integrated Software for Imagers & Spectrometers

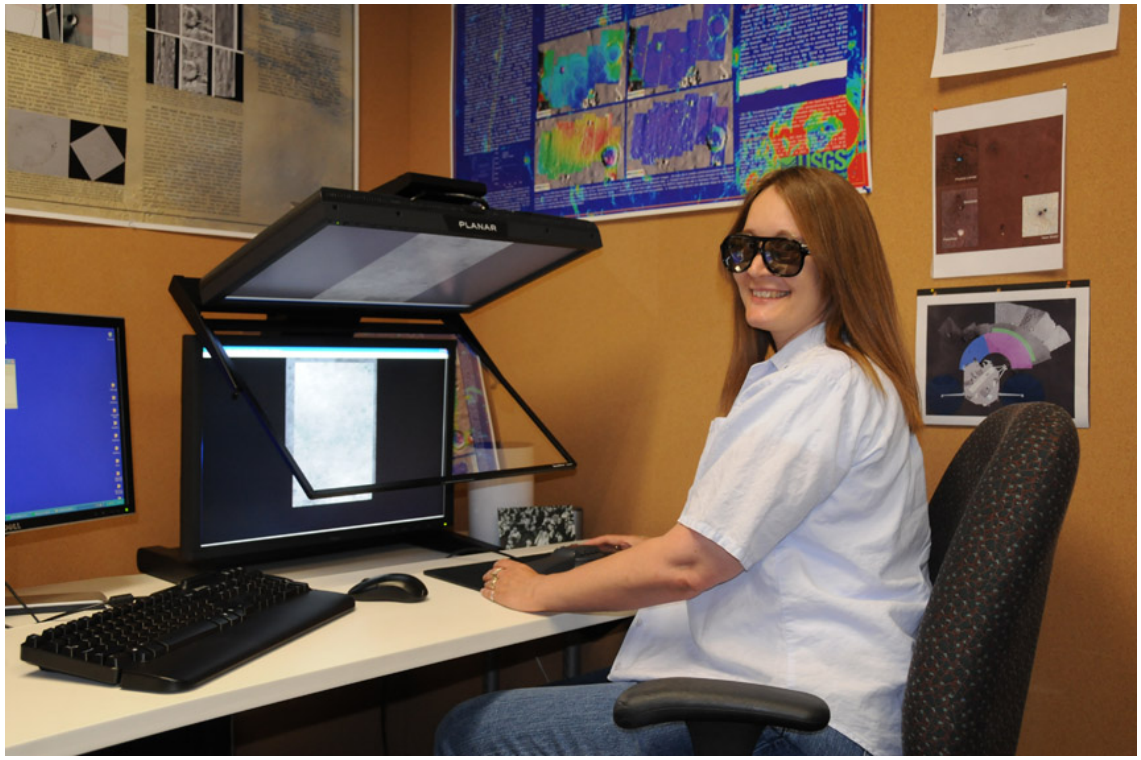
- USGS in house s/w
- Strengths:
  - Ingestion/calibration
  - Planimetric mosaicking
  - Quantitative analysis including photoclinometry
- Use for calibration, 2D proc.

SOCET SET: SOftCopy Exploitation ToolSET

- BAE Systems commercial s/w
- Strengths:
  - Stereo display/input
  - Bundle-block adjustment
  - Automatic DTM matching
- Use for 3D processing
- Write new sensor models

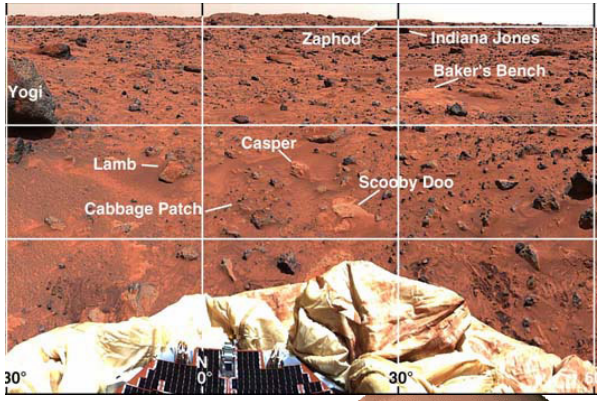


Astrogeology SOCET DPWS: Dr. Jones, Henry Jr., Hen3ry, Temple, Grail*



Elpitha (Annie) Howington-Kraus with our 4th generation SOCET Set workstation "Temple (of Doom)"

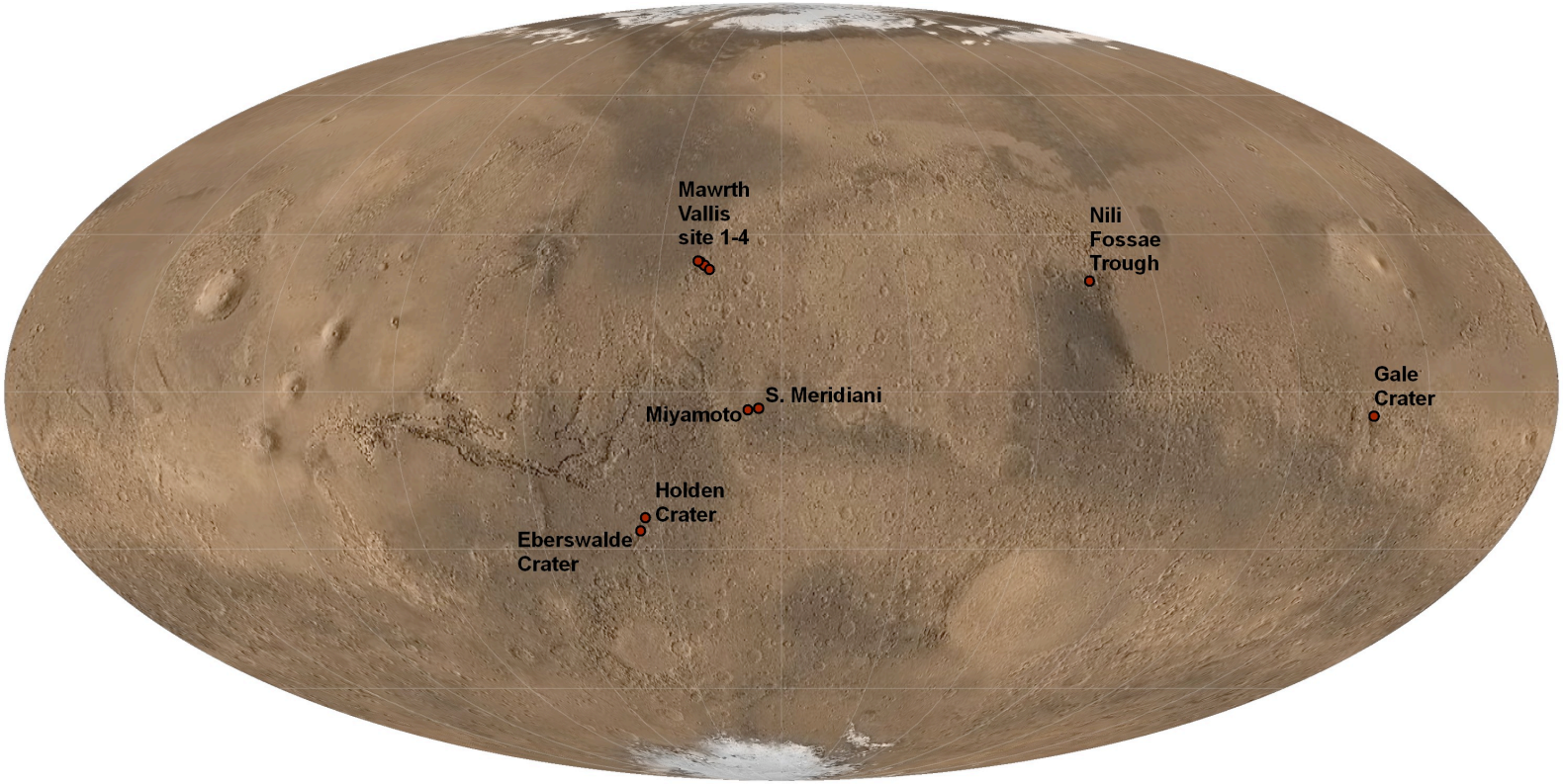
Indiana Jones on Earth
"I have a lot of good memories of that dog"

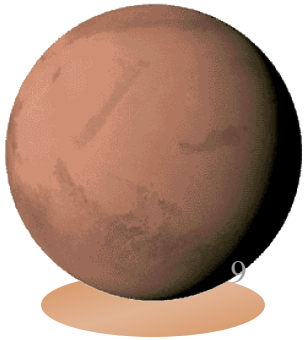


Indiana Jones on Mars

*Assisted by Sallah and Shorty

MSL Candidate Sites



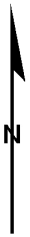


Holden

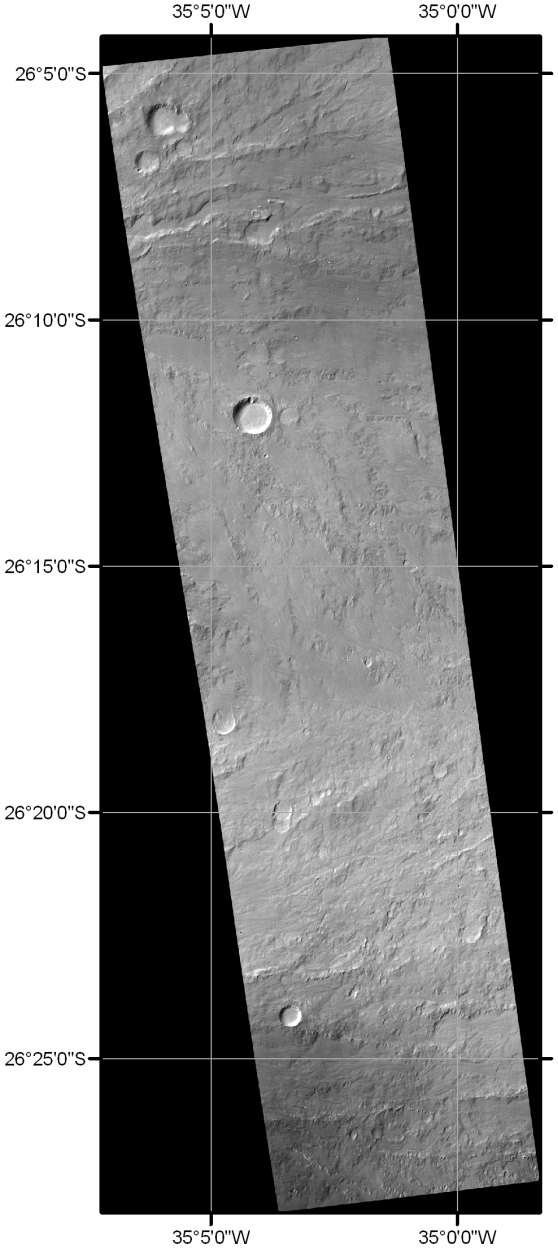
Stereopair:
PSP_007191_1535
PSP_007903_1535

1 0 1
Km

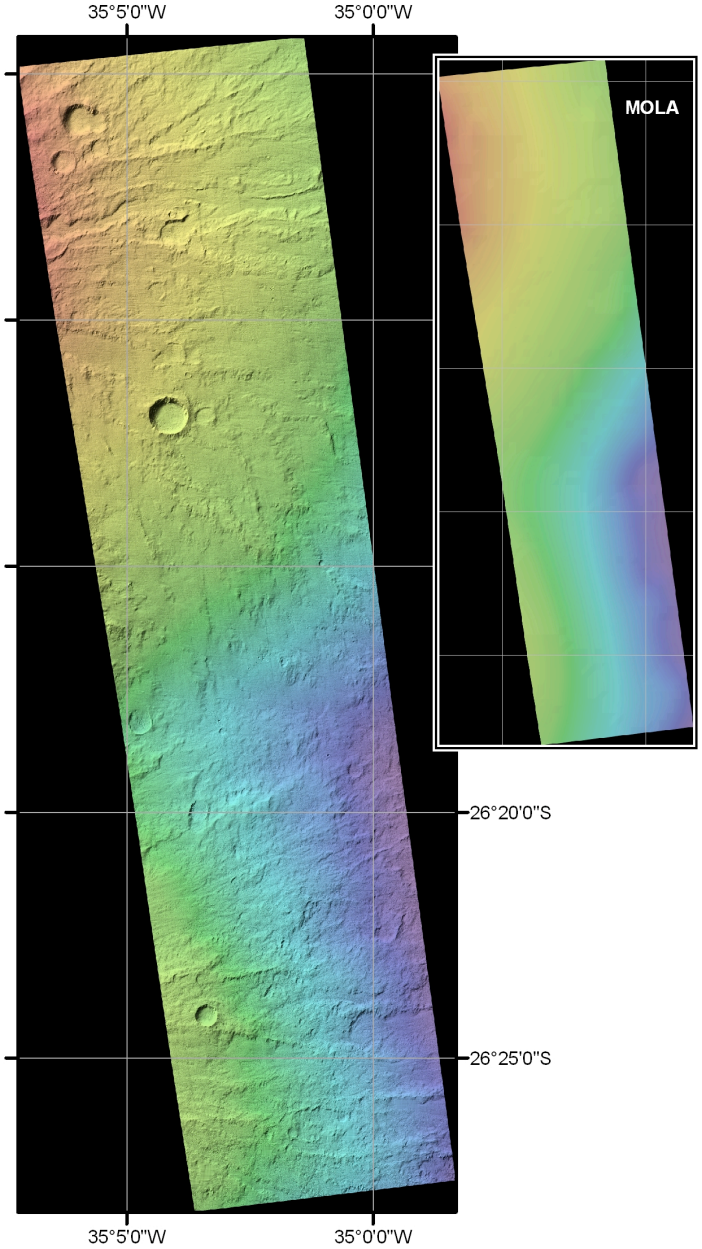
Planetocentric



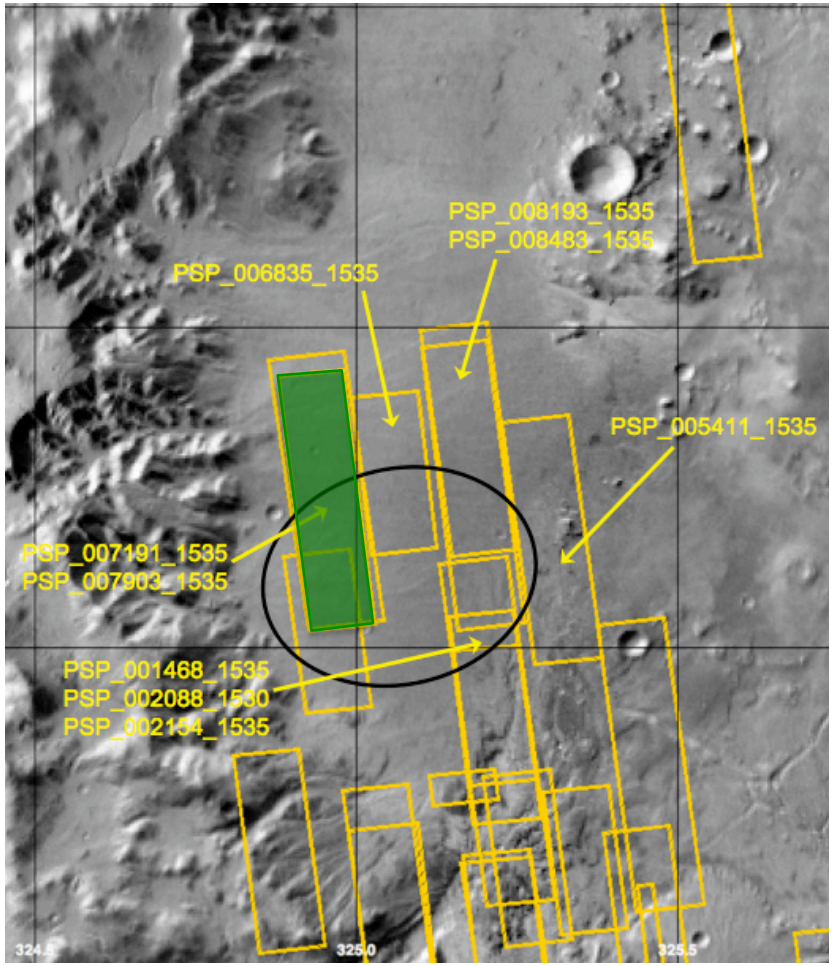
HiRISE Ortho PSP_007191_1535
1 meter/pixel

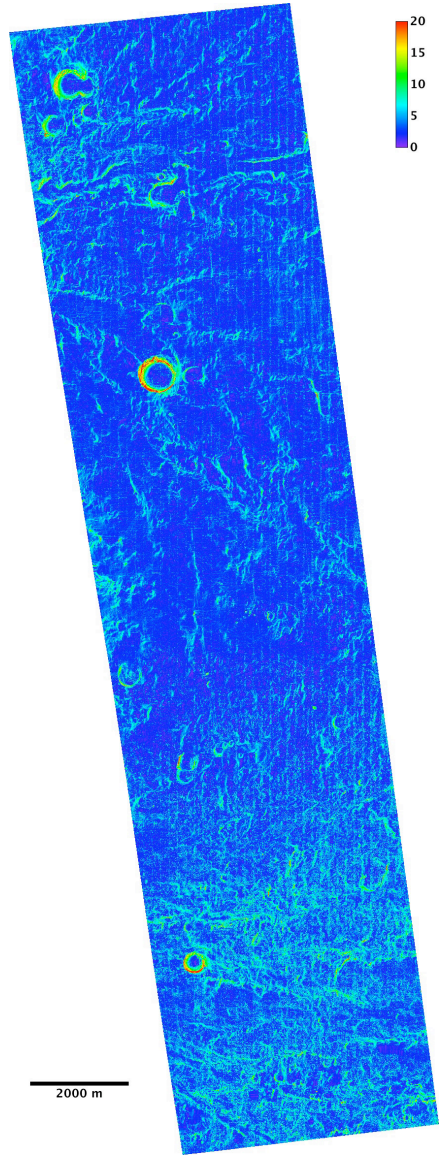


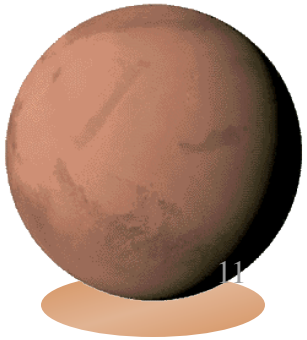
Stereo DEM
1 meter/pixel



Holden Crater Context & Slopes

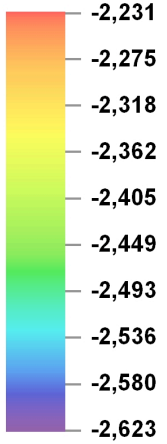


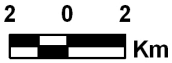




Mawrth2

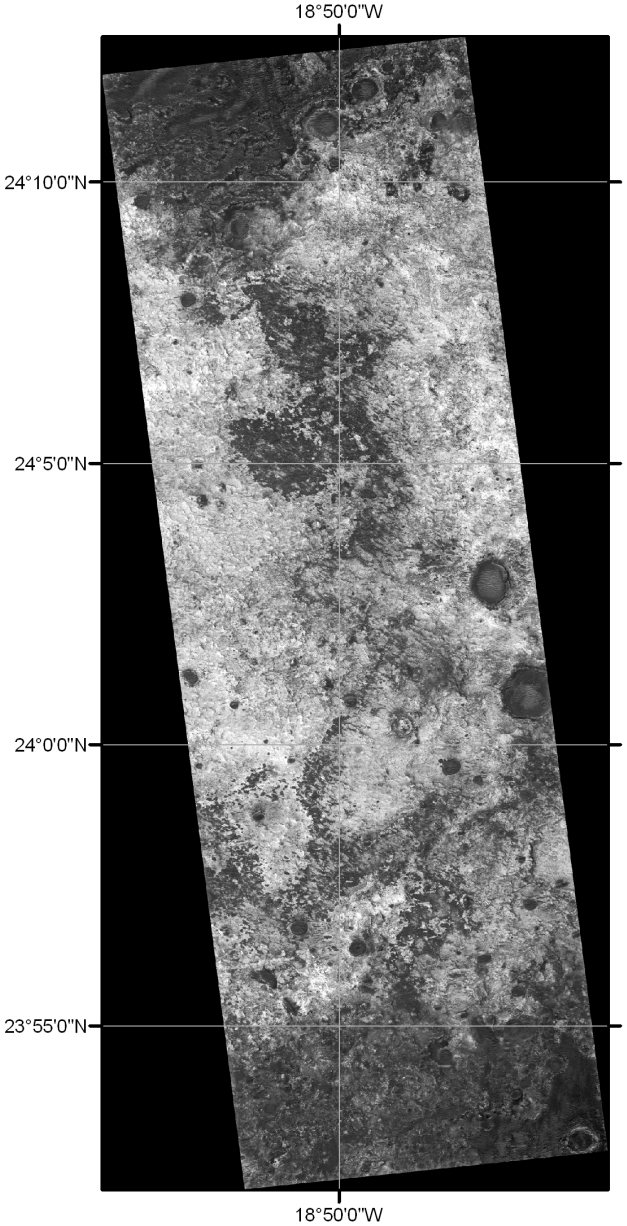
Stereopair:
PSP_006676_2045
PSP_007612_2045



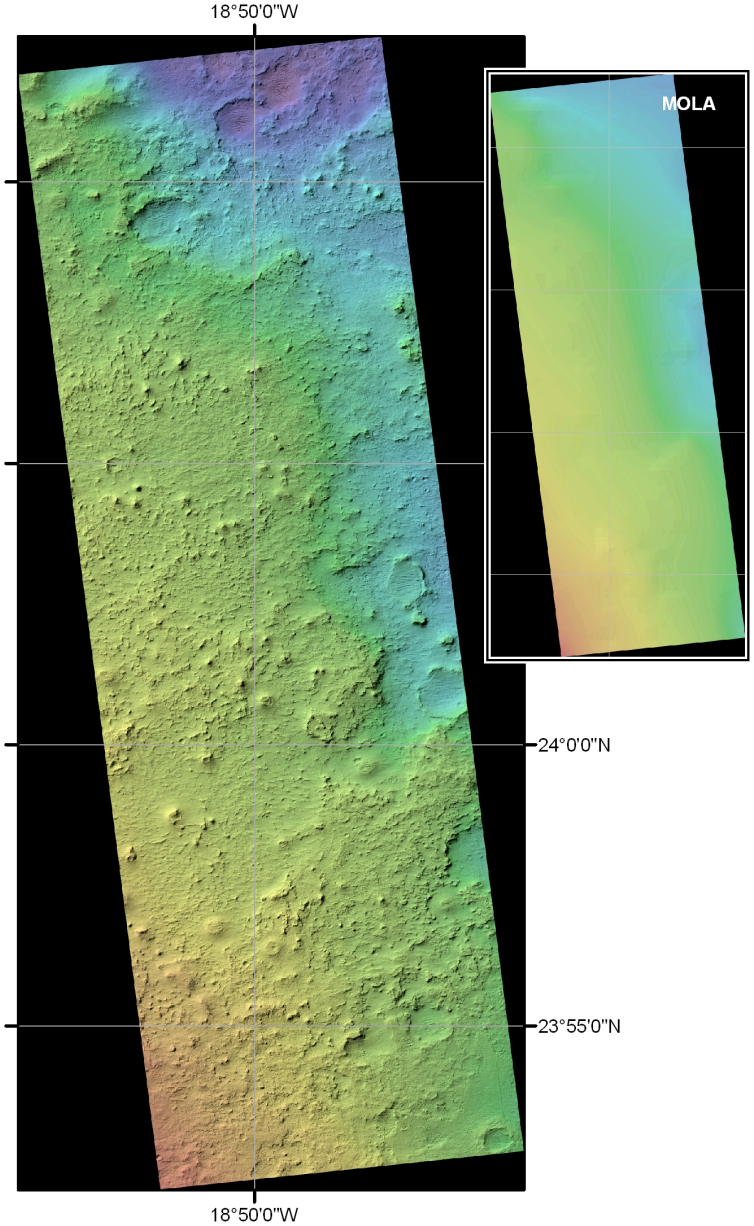


Planetocentric

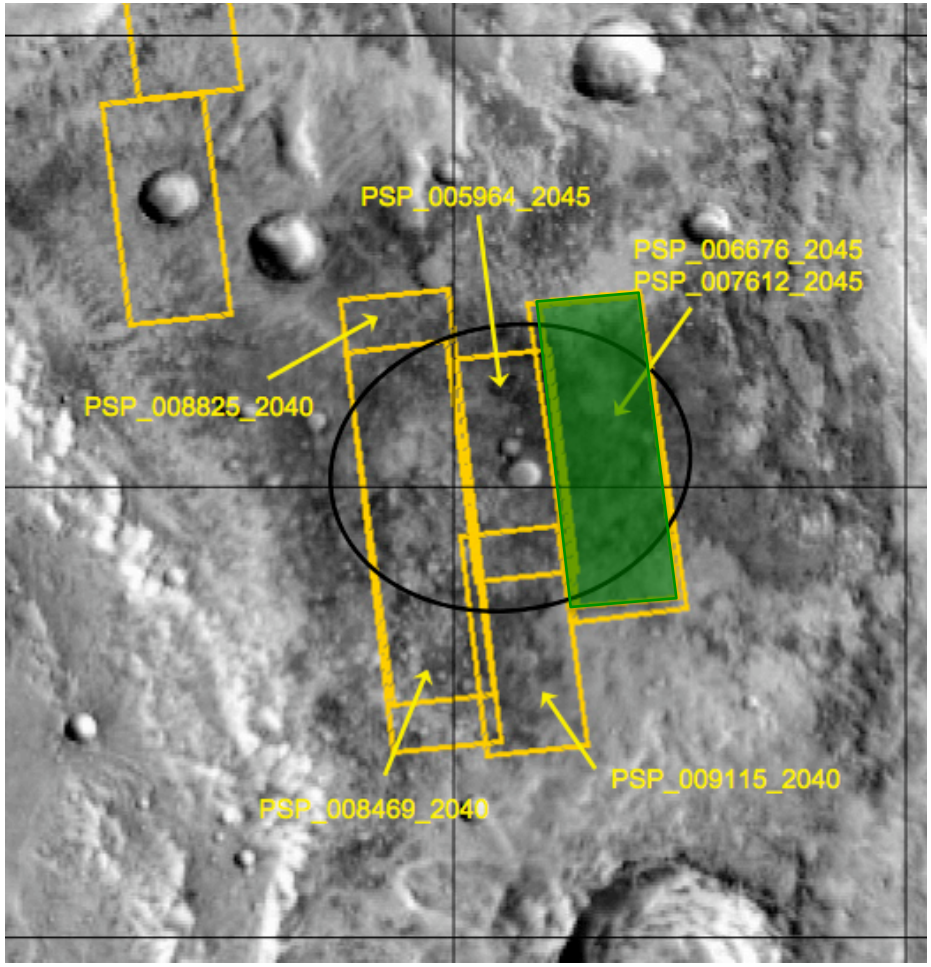
HiRISE Ortho PSP_006676_2045
1 meter/pixel

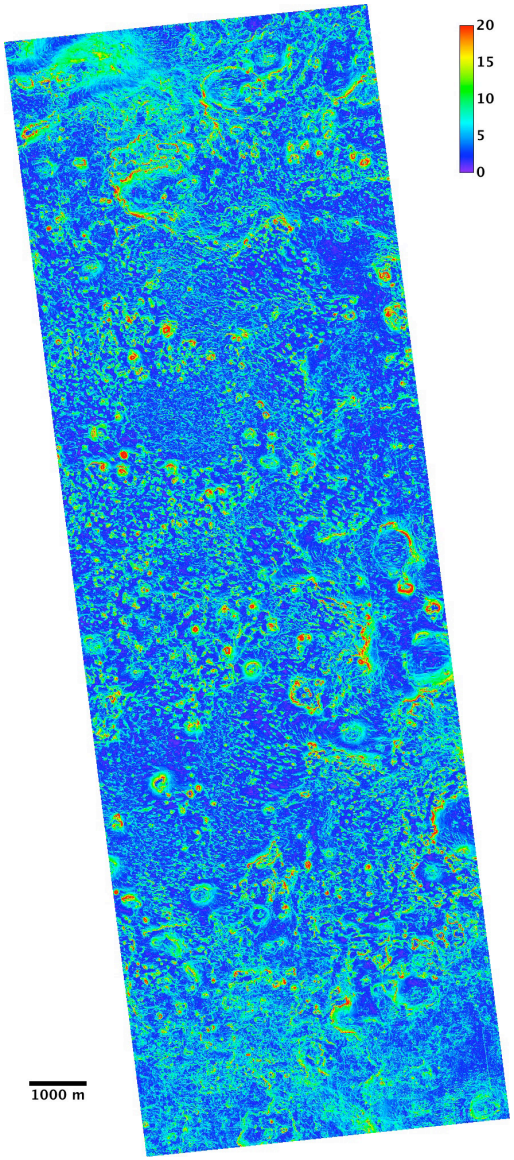


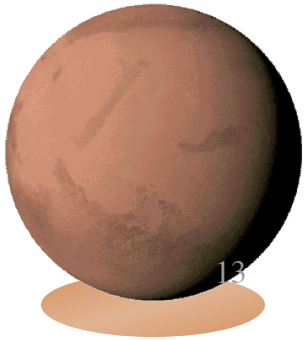
Stereo DEM
1 meter/pixel



Mawrth 2 Context & Slopes

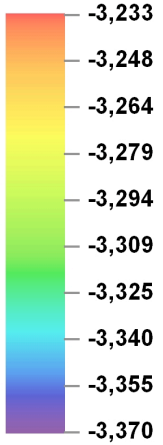






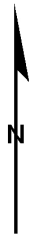
Mawrth4

Stereopair:
PSP_006887_2050
PSP_007823_2050

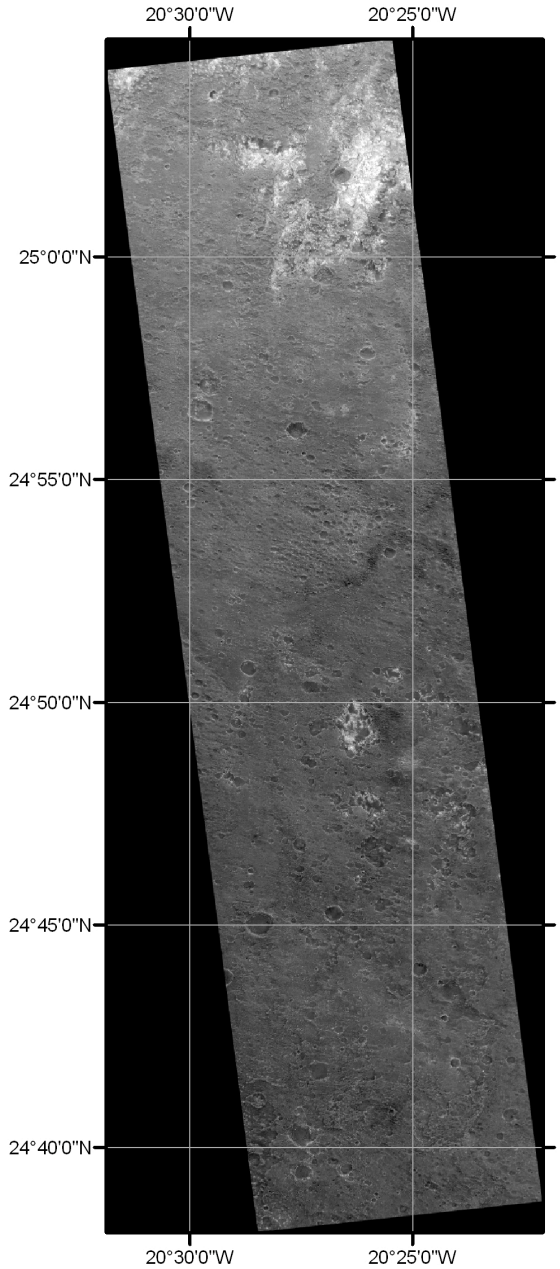


0 2 4
Km

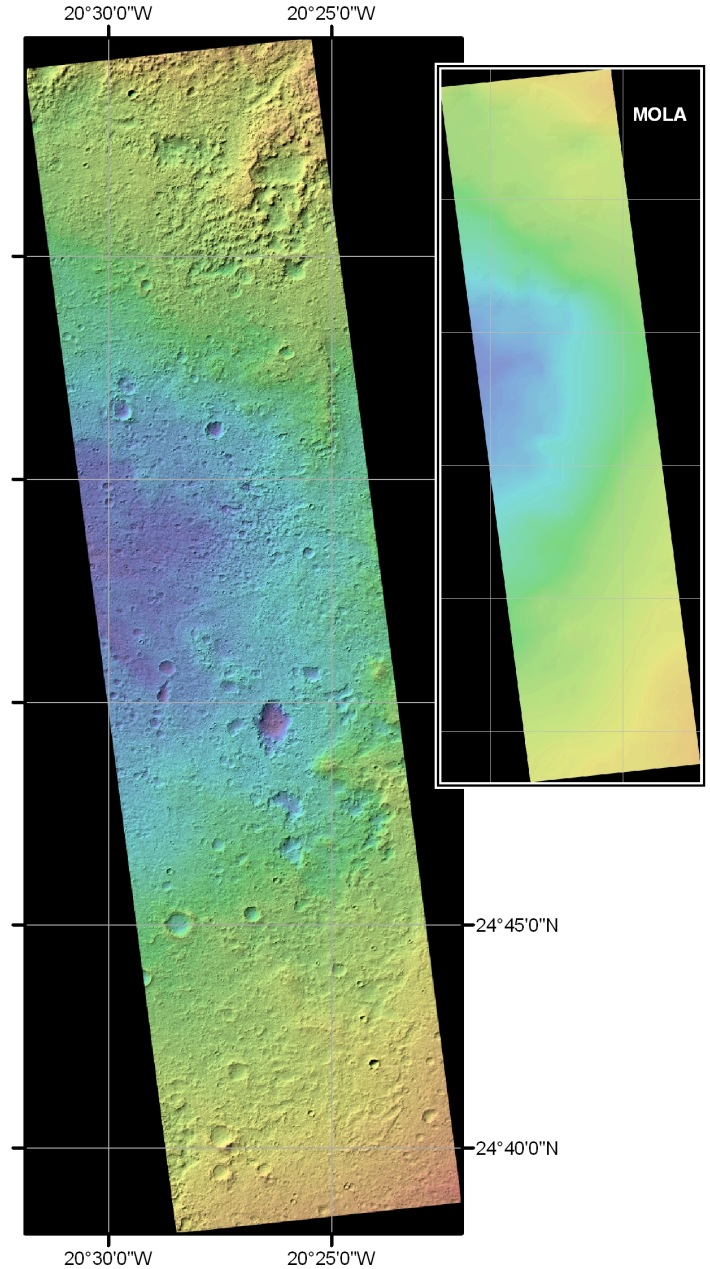
Planetocentric



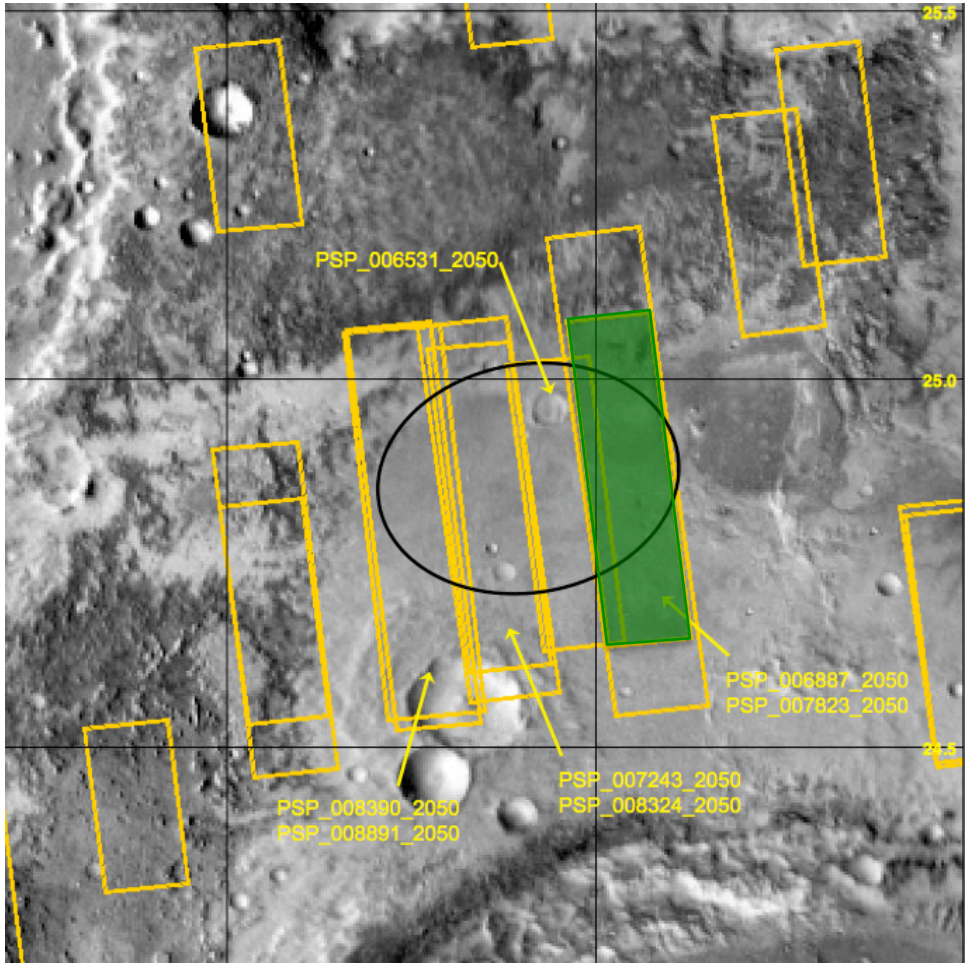
HiRISE Ortho PSP_006887_2050
1 meter/pixel

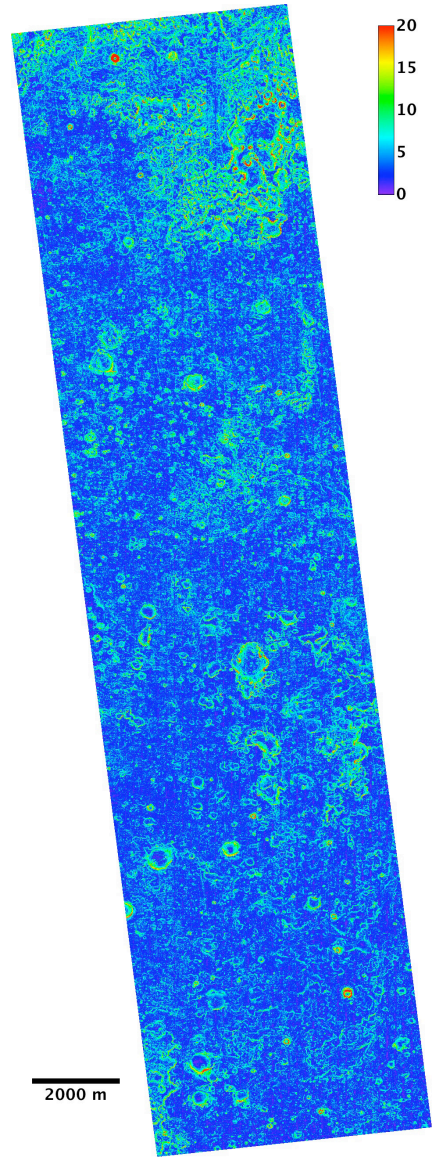


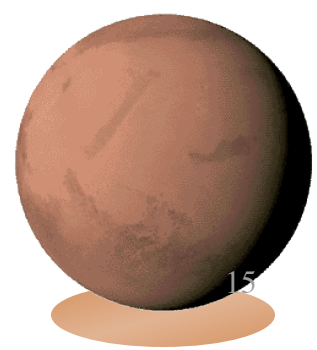
Stereo DEM
1 meter/pixel



Mawrth 4 Context & Slopes

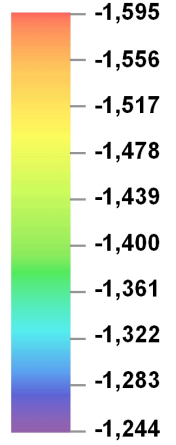






Eberswalde

Stereopair:
PSP_008272_1560
PSP_007481_1560

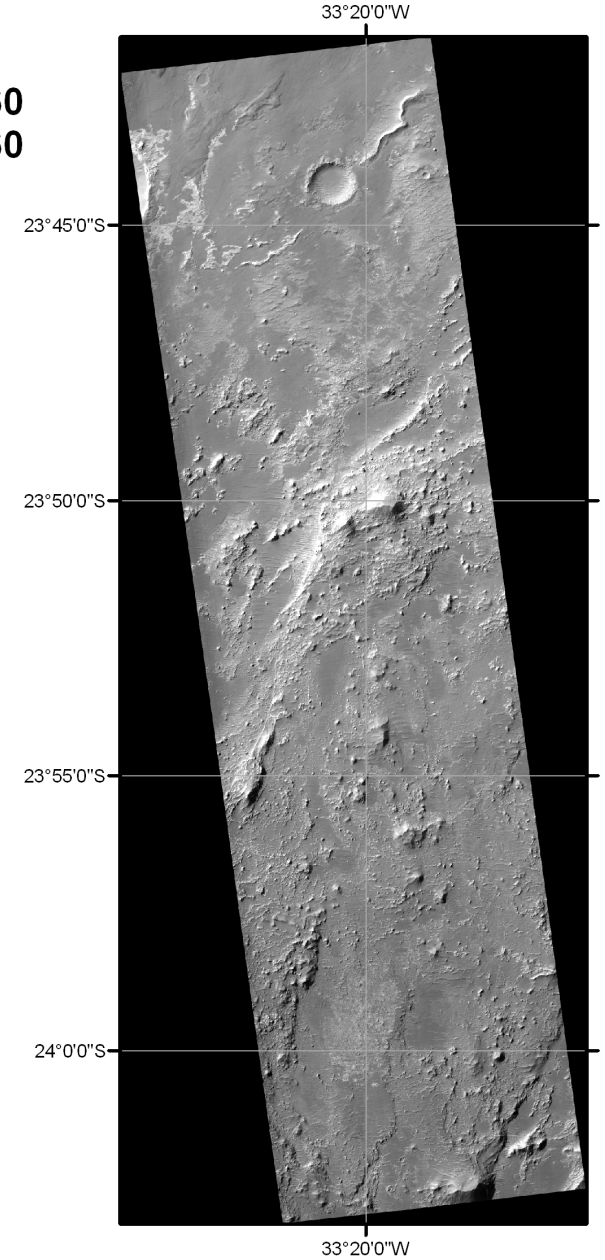


2 0 2
Km

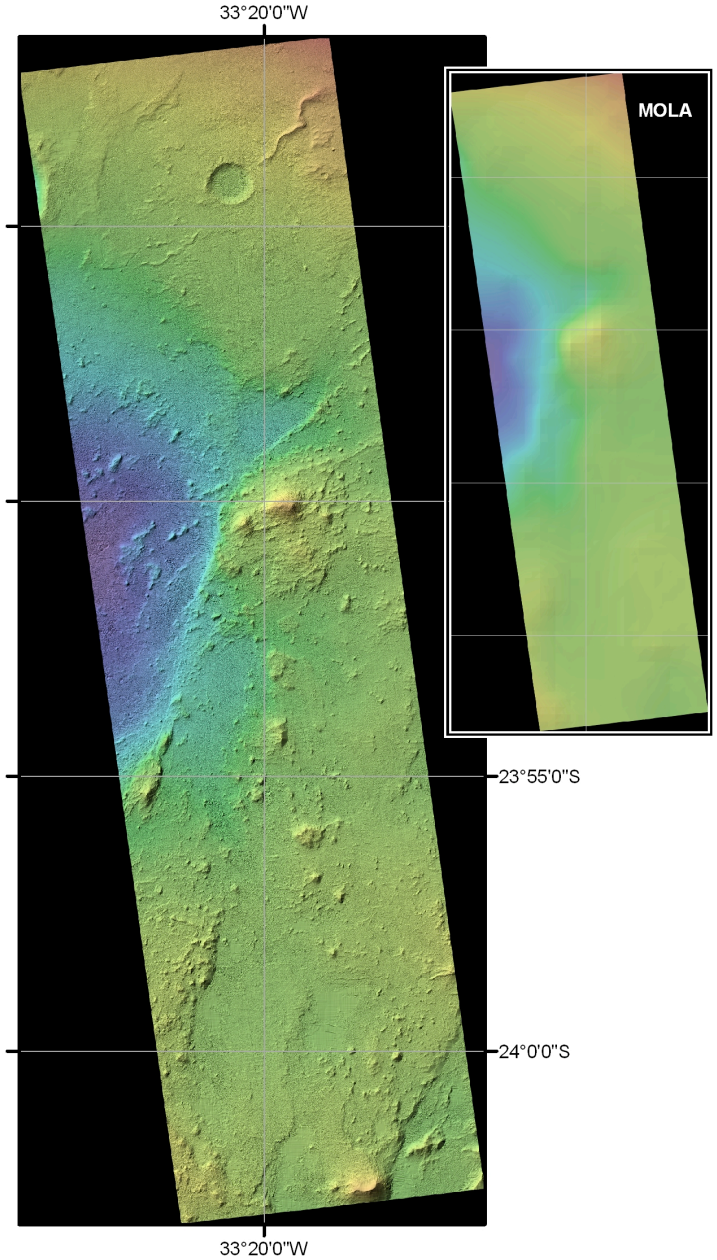
Planetocentric

N

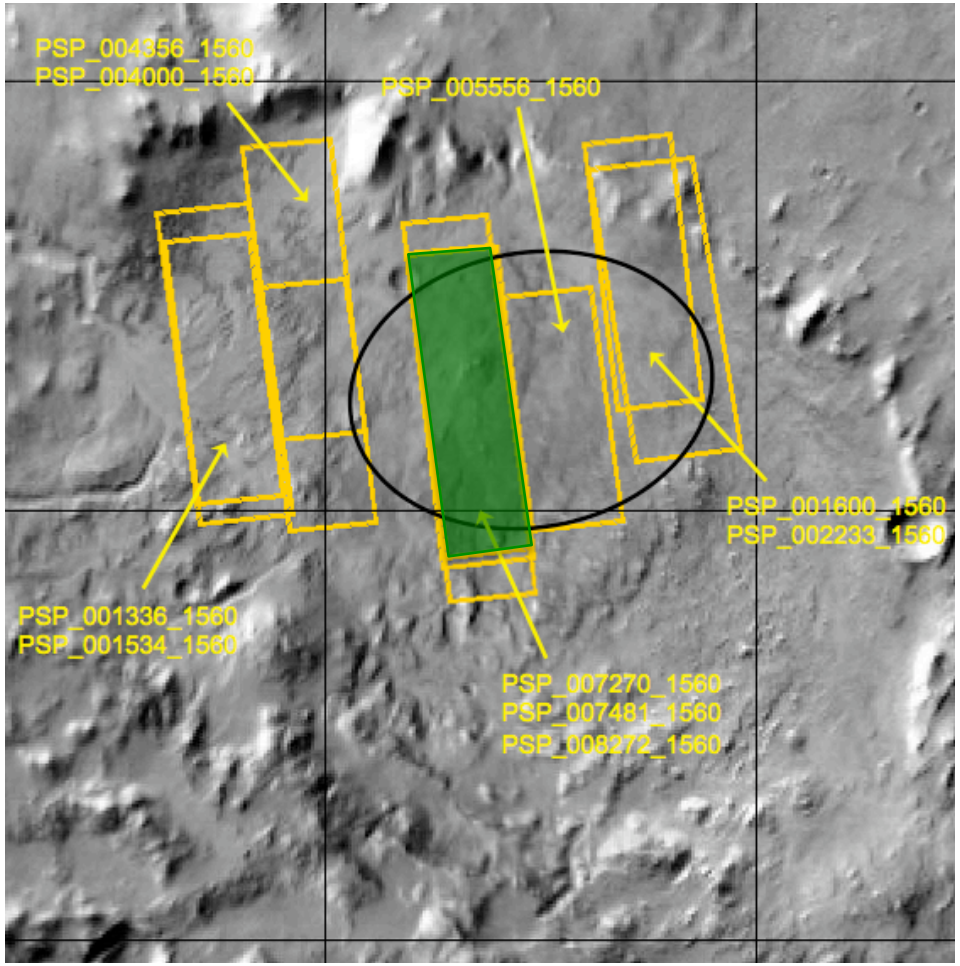
HiRISE Ortho PSP_008272_1560
1 meter/pixel

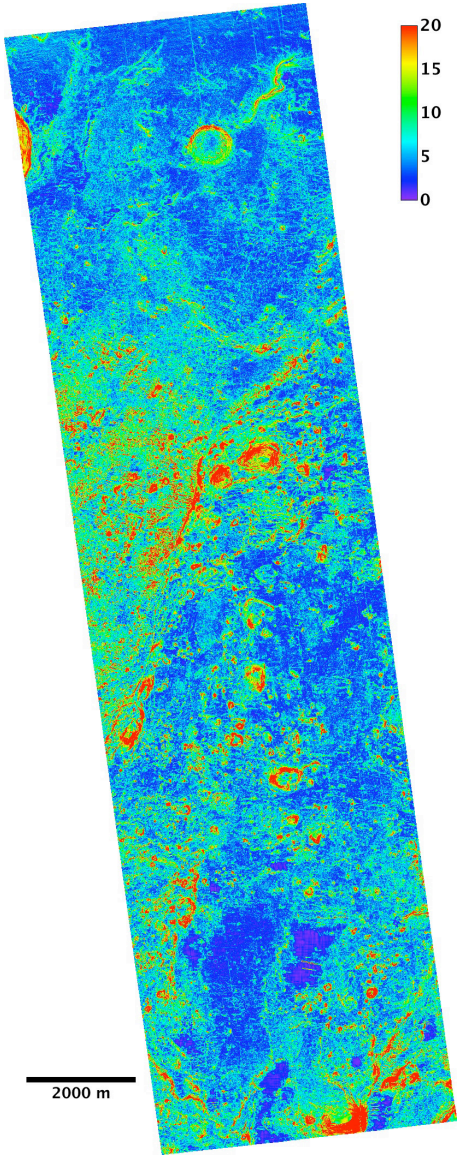


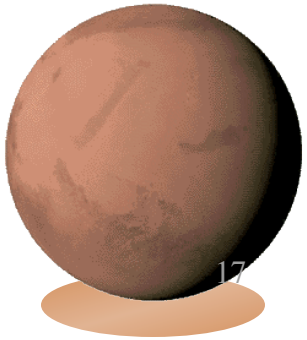
Stereo DEM
1 meter/pixel



Eberswalde Context & Slopes

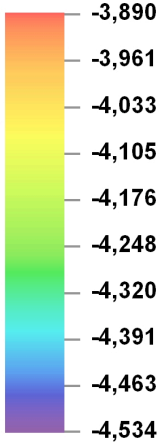






Gale

Stereopair:
PSP_009505_1755
PSP_009571_1755

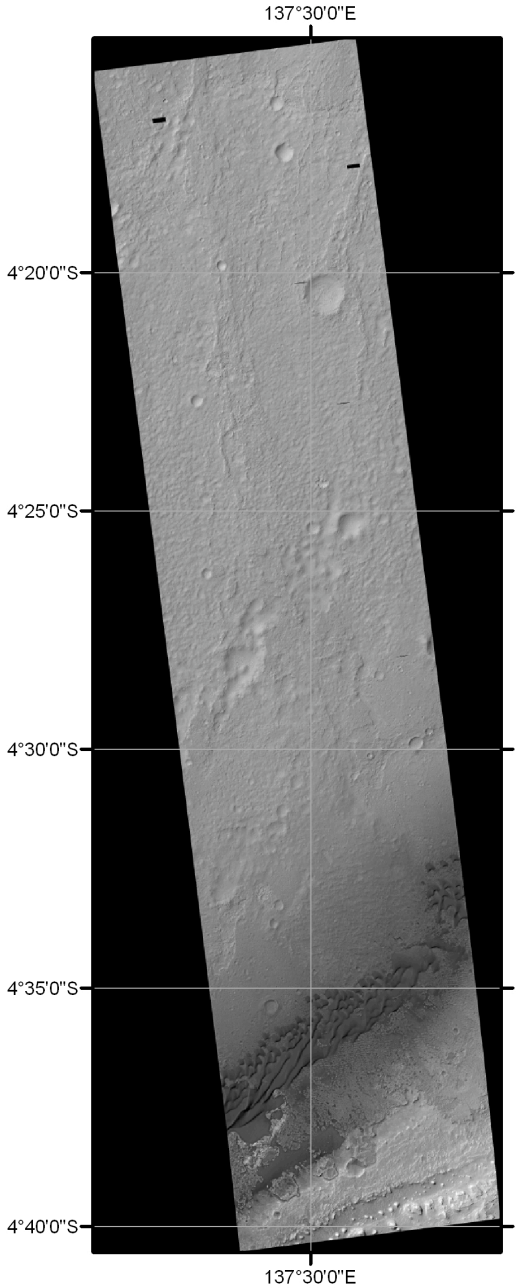


1 0 1
Km

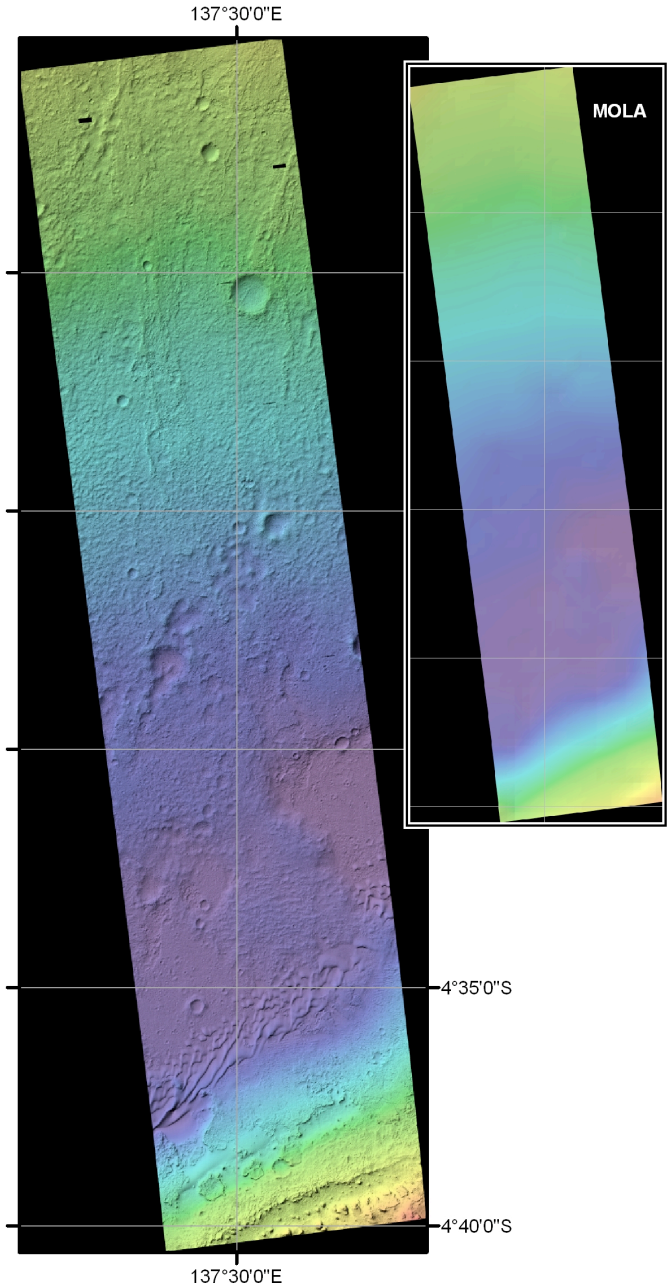
Planetocentric

N

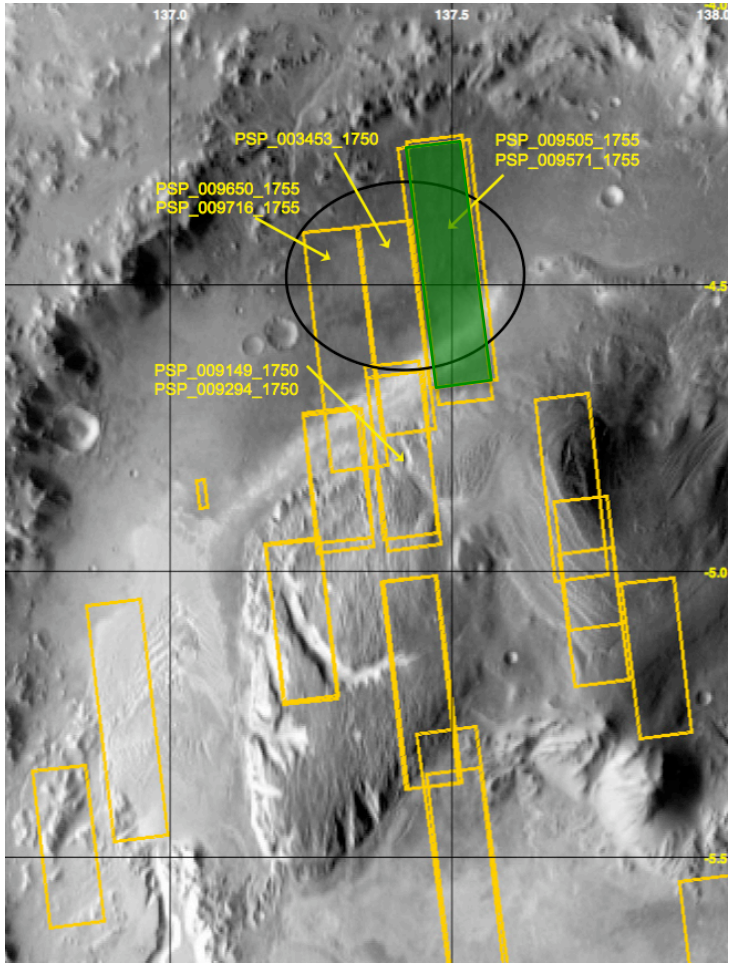
HiRISE Ortho PSP_009505_1755
1 meter/pixel

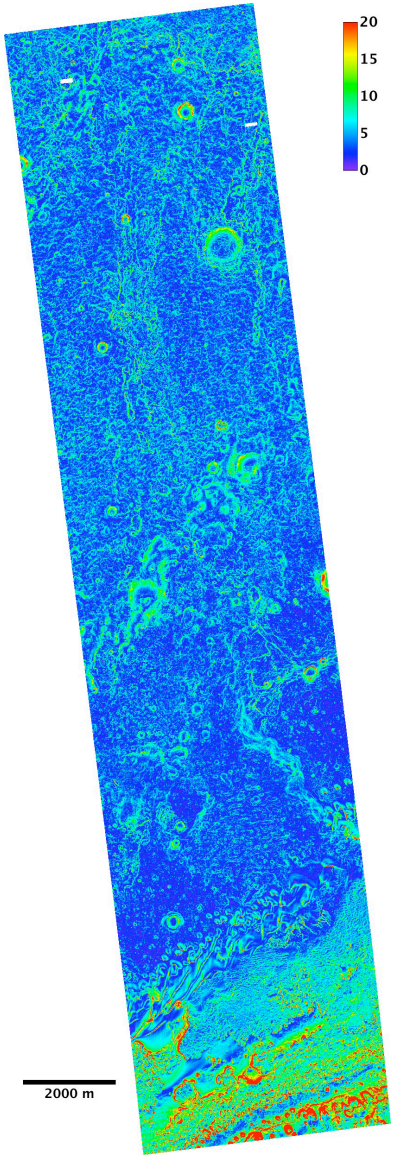


Stereo DEM
1 meter/pixel

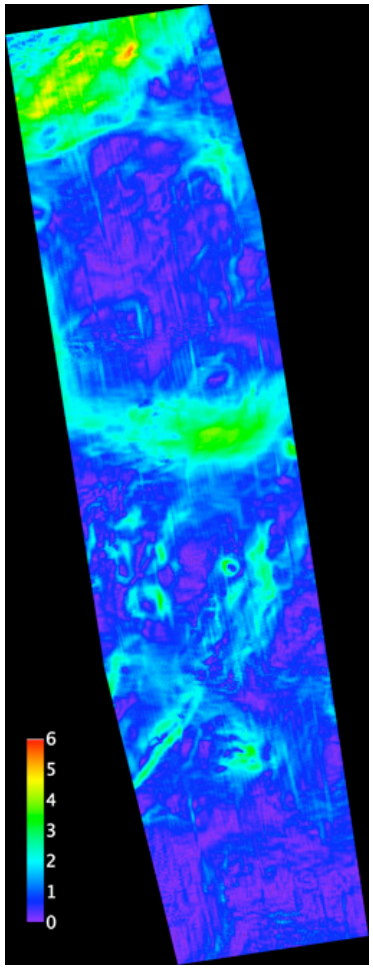


Gale Crater Context & Slopes

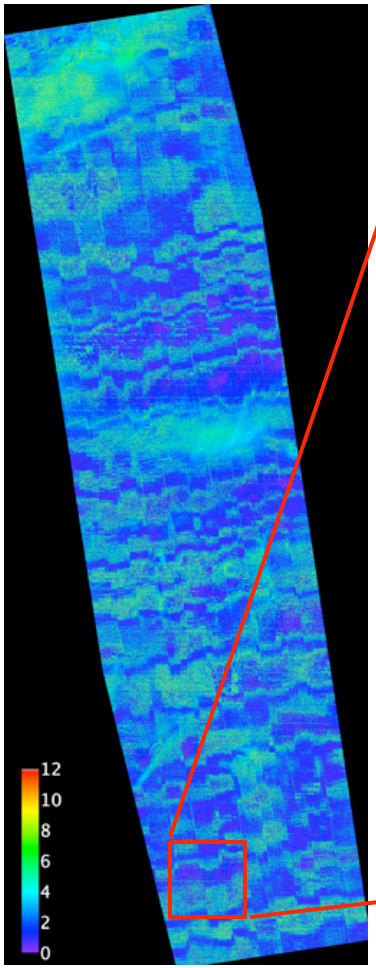




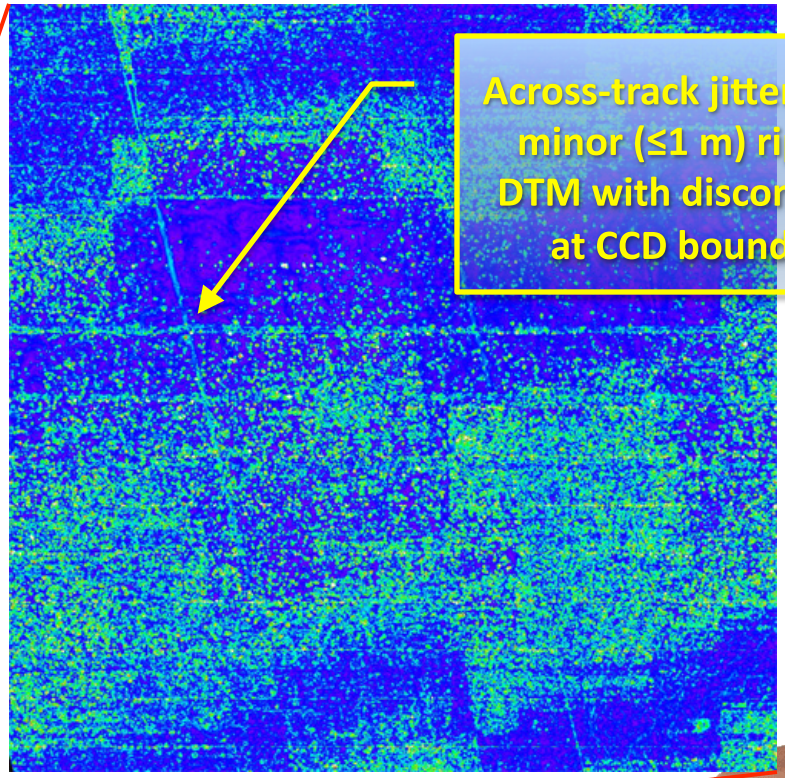
Remaining sites are on hold because of "jitter," which degrades DTMs as shown here at PHX site



Slopes over
100 m baseline



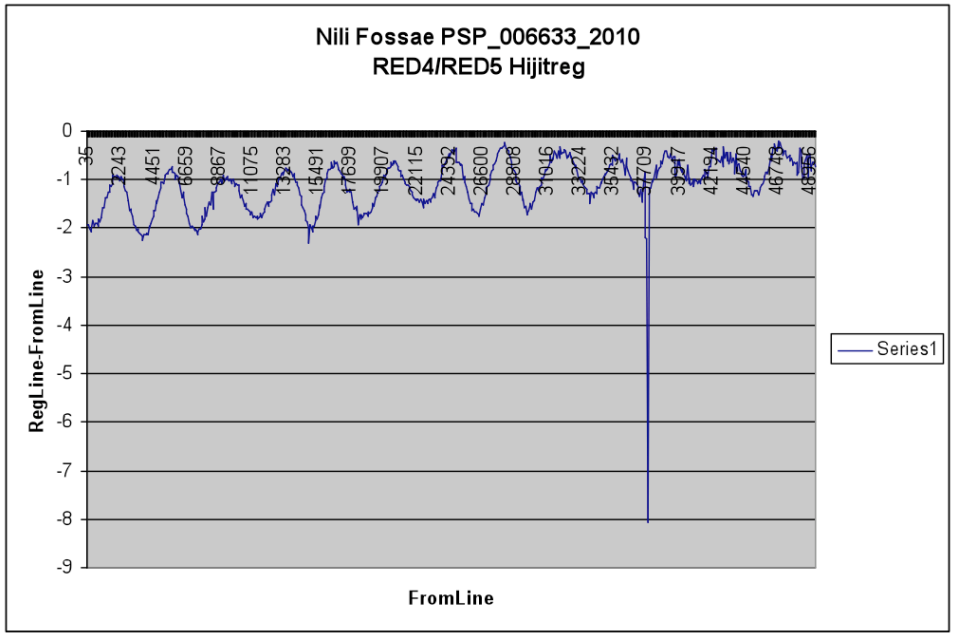
Slopes over
2 m baseline

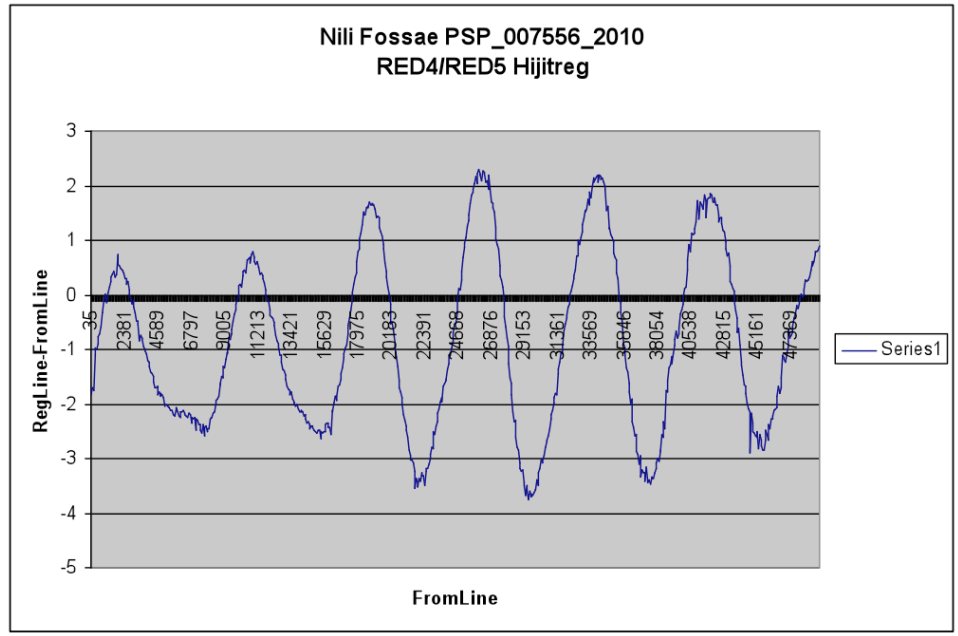


Across-track jitter leads to minor (≤1 m) ripples in DTM with discontinuities at CCD boundaries

Stereo matching becomes "noisy" where images are out of alignment along-track because of jitter
Problem for ≥2 pixels jitter, severe if >3

Example Good and Bad Jitter Cases





Nili Fossae Image 1, line component ~1 pixel oscillations—no problem (Ignore the spike, it's a bad feature match)

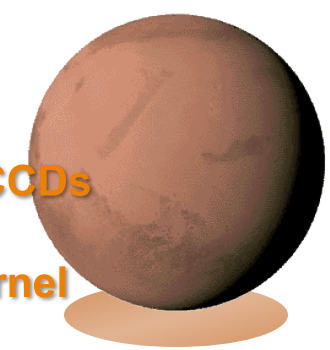
Nili Fossae Image 2, line component 4-6 pixel oscillations—BIG problem

USGS approach:

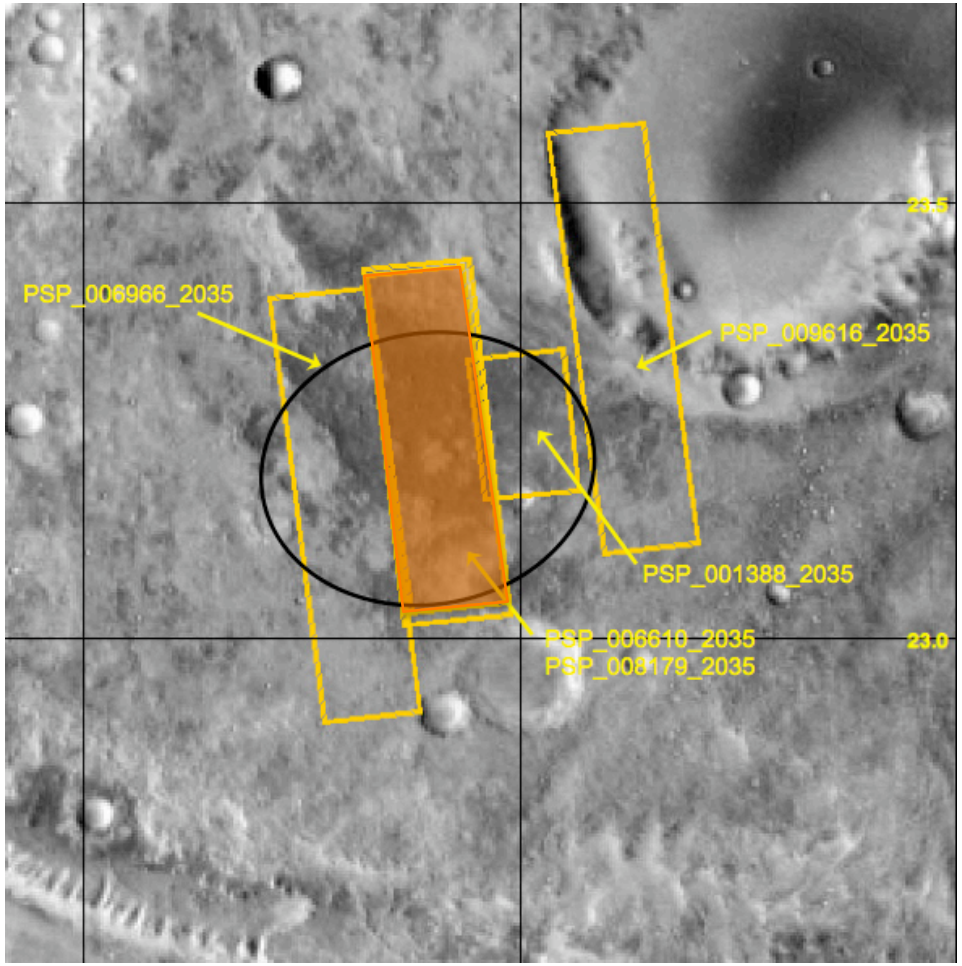
- Incorporate polynomial for motion in jigsaw (bundle adjustment)
- Practical limit 20th degree handles 6–7 "wiggles" per image

U of A approach:

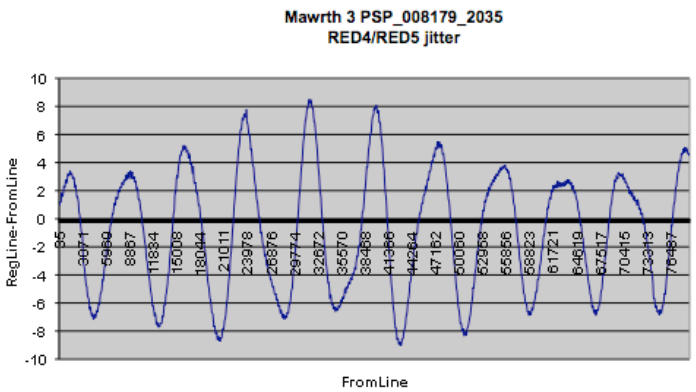
- Fourier series for offsets -> Fourier series for net motion of features in the focal plane
- Each CCD pair is "blind" to certain frequencies of jitter but 3 CCDs give a full solution
- USGS converts model of feature motions to new SPICE CK kernel



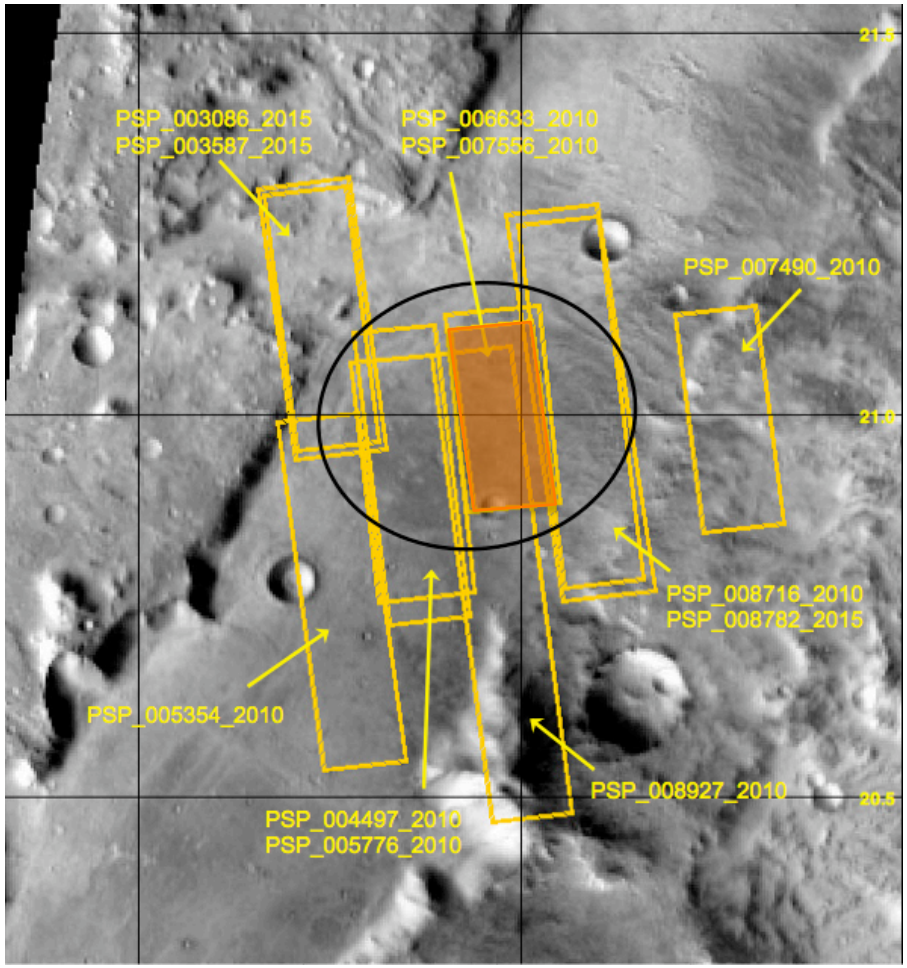
Mawrth 3



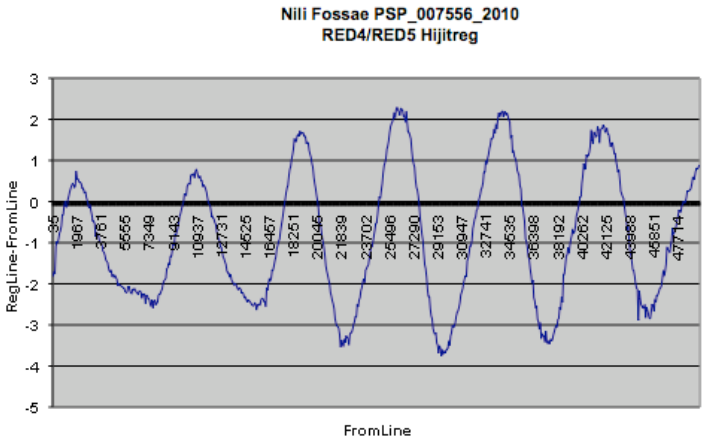
2nd half has jitter, awaiting fix



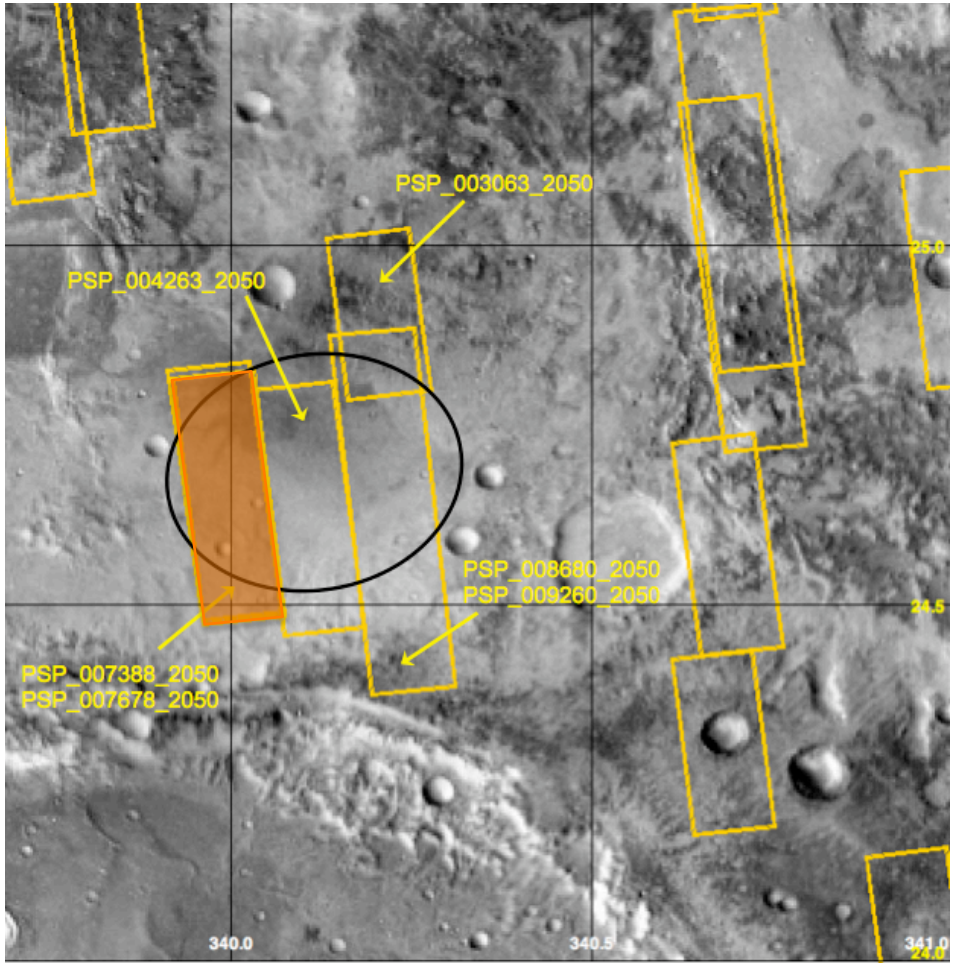
Nili Fossae



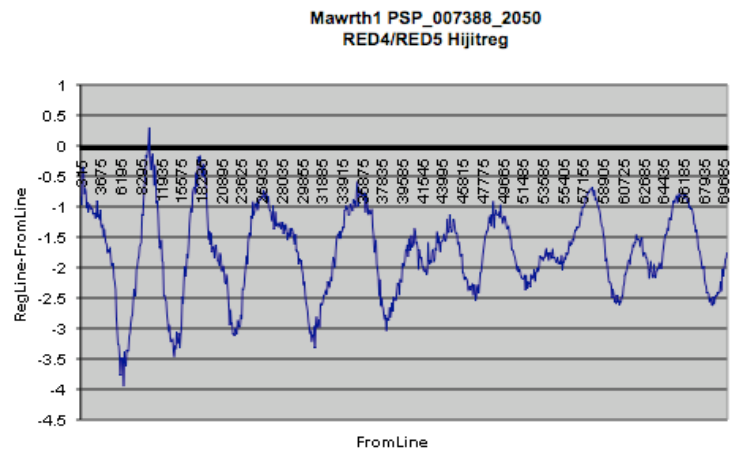
2nd half has jitter, awaiting fix

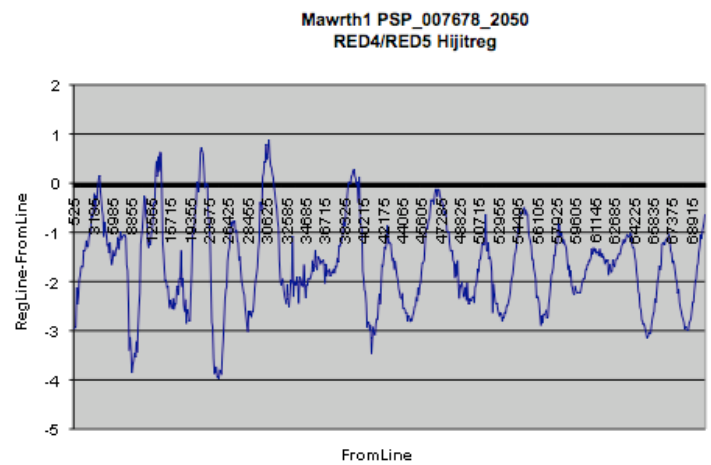


Mawrth 1

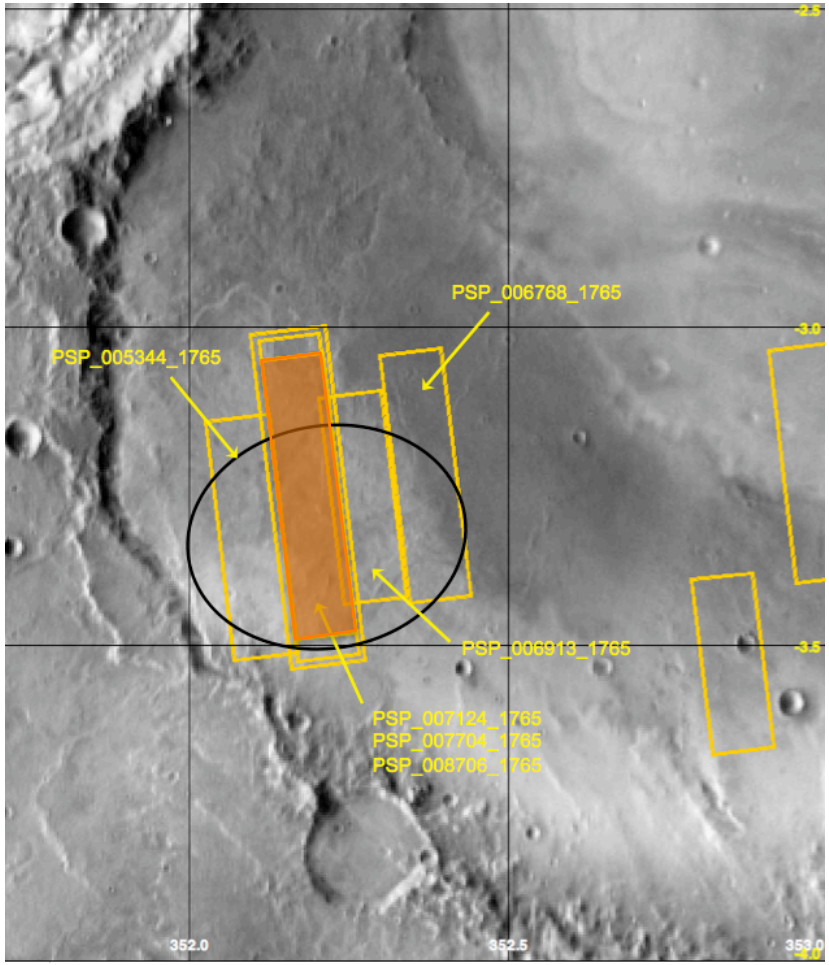


Both have jitter, awaiting fix

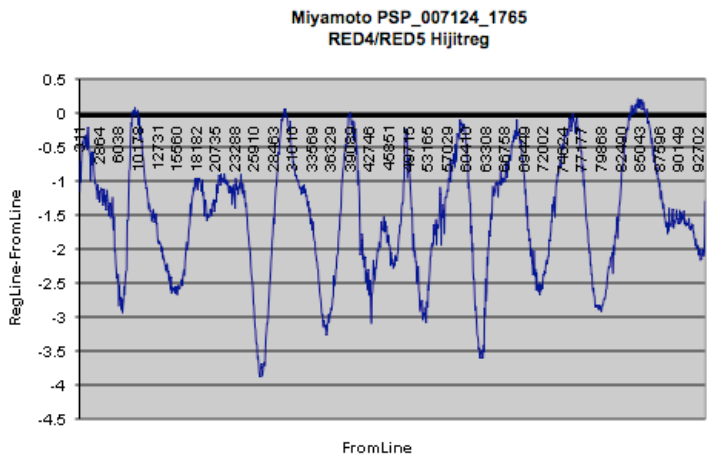


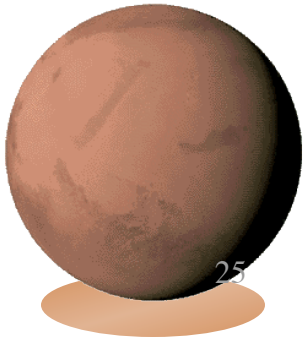


Miyamoto Crater

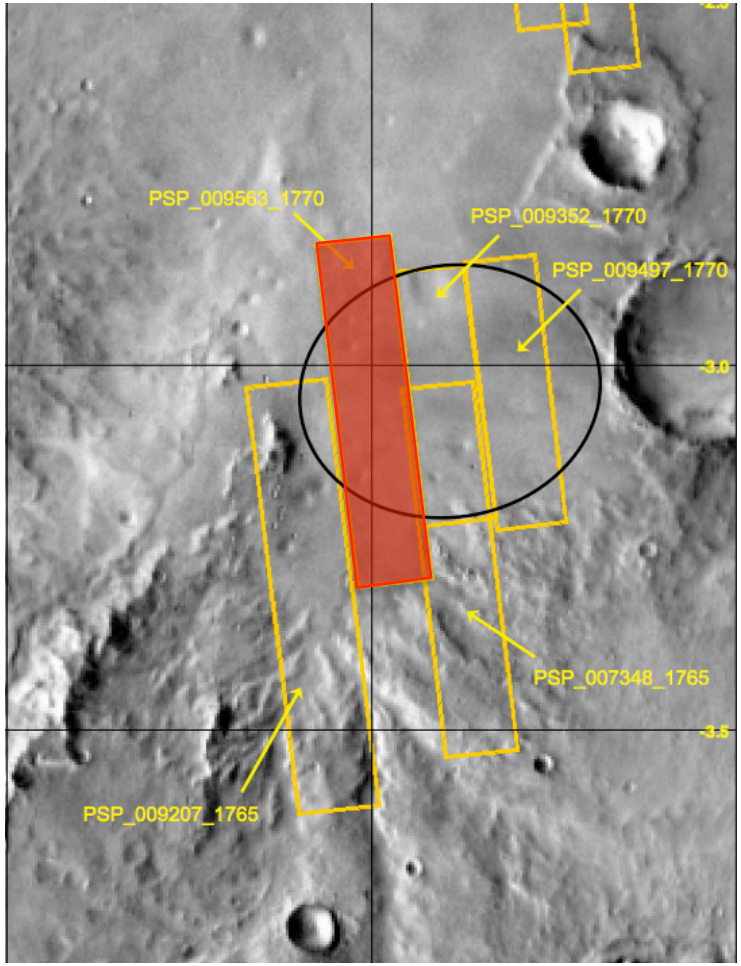


1st half has jitter, awaiting fix

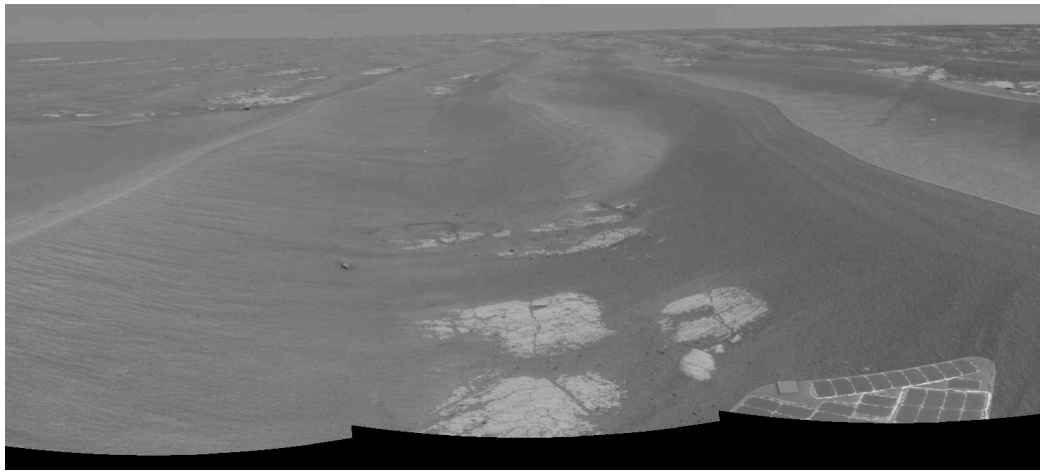


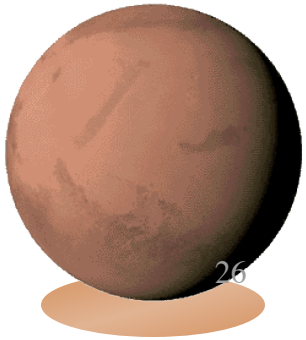


South Meridiani

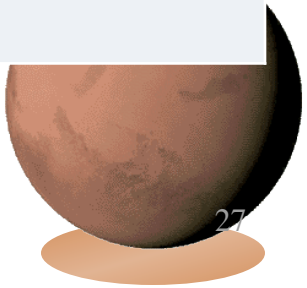


Lowest priority





Slopes Summary

Site	RMS Slope (°) at 2m	% 15° Slopes at 2m	RMS Slope (°) at 5m	% 15° Slopes at 5m
Holden Crater	4.41	0.59	3.85	0.25
Mawrth 2	6.73	3.30	6.30	2.60
Mawrth 4	5.47	1.52	4.87	0.98
Eberswalde*	10.89	13.90	9.22	9.43
Gale Crater	6.66	2.98	6.19	2.47
Mawrth 3				
Nili Fossae				
Mawrth 1				
Miyamoto				
S. Meridiani				

*Contains both real features with steep slopes and extremely bland areas in which matching fails, leading to high apparent slopes at short distances