iMars feedback

Introduction to HRSC 3D products

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iMars Feedback

- We ask you to complete a small questionnaire
  - It follows the agenda for clear orientation
  - There are four different sections
  - iMars would like to evaluate its results and assess additional needs

Part 1 - HRSC Introduction:

1) What is your professional background?

Geology, Geography, Geodesy, GIS, Planetology, Physics

2) Have you ever worked with planetary image data (of Mars before)?

Yes No

2.1) If "Yes" which:

Part 2 – ACRO and CASP-GO:

12) Do you imagine that you could run introduced software to produce co-registered and ortho-rectified images?

Part 3 – WebGIS:

15) Do you think that the WebGIS introduced provides added value to the planetary science community?

Yes No

15.1) If yes, what does it offer that other WebGIS systems do not offer?

Part 4 – Citizen Science:

17) Have you ever participated in a Citizen project on e.g. Zooniverse or other platforms?

Yes No

17.1) If yes, what caused you to participate?

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Introduction to HRSC 3D Products

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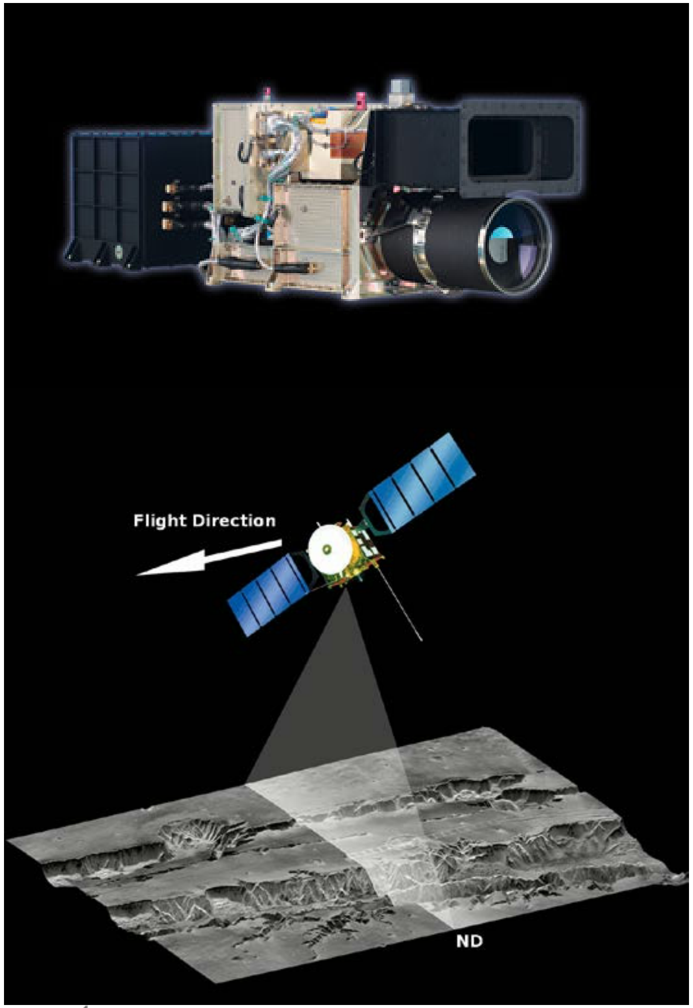
HRSC on Mars Express



- High Resolution Stereo Camera (HRSC) camera on Mars Express
- Mars Express is in Mars orbit since 2003
- Orbit is optimized to observe the Martian surface with pixel resolutions of better than 20 m

- HRSC has two sensors
  - Super Resolution Channel (SRC) – a 1K frame sensor with a focal length of 988 mm
  - HRSC – a nine channel line scanner with build-in stereo capabilities and a focal length of 175 mm

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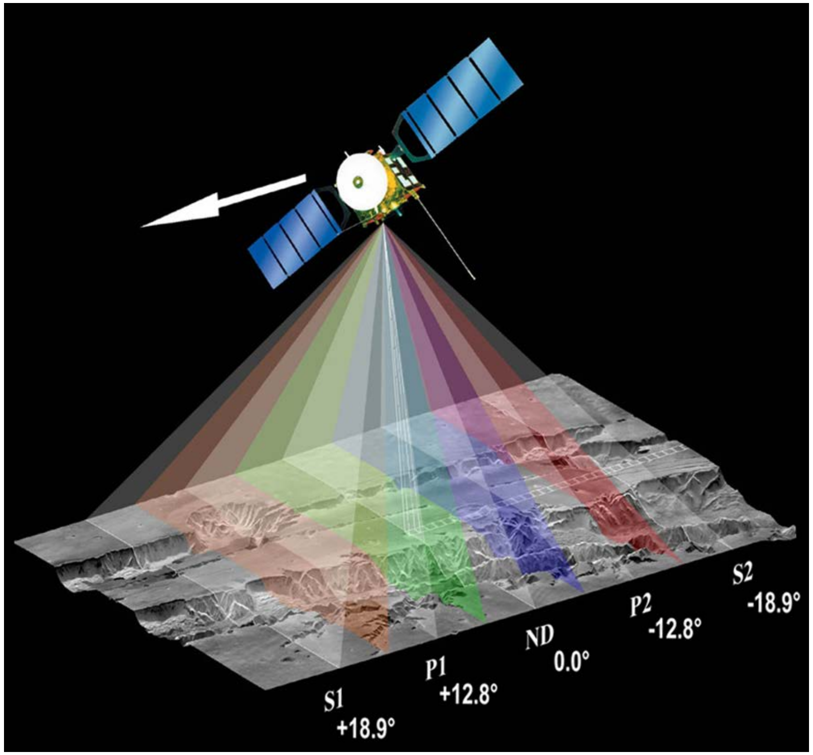
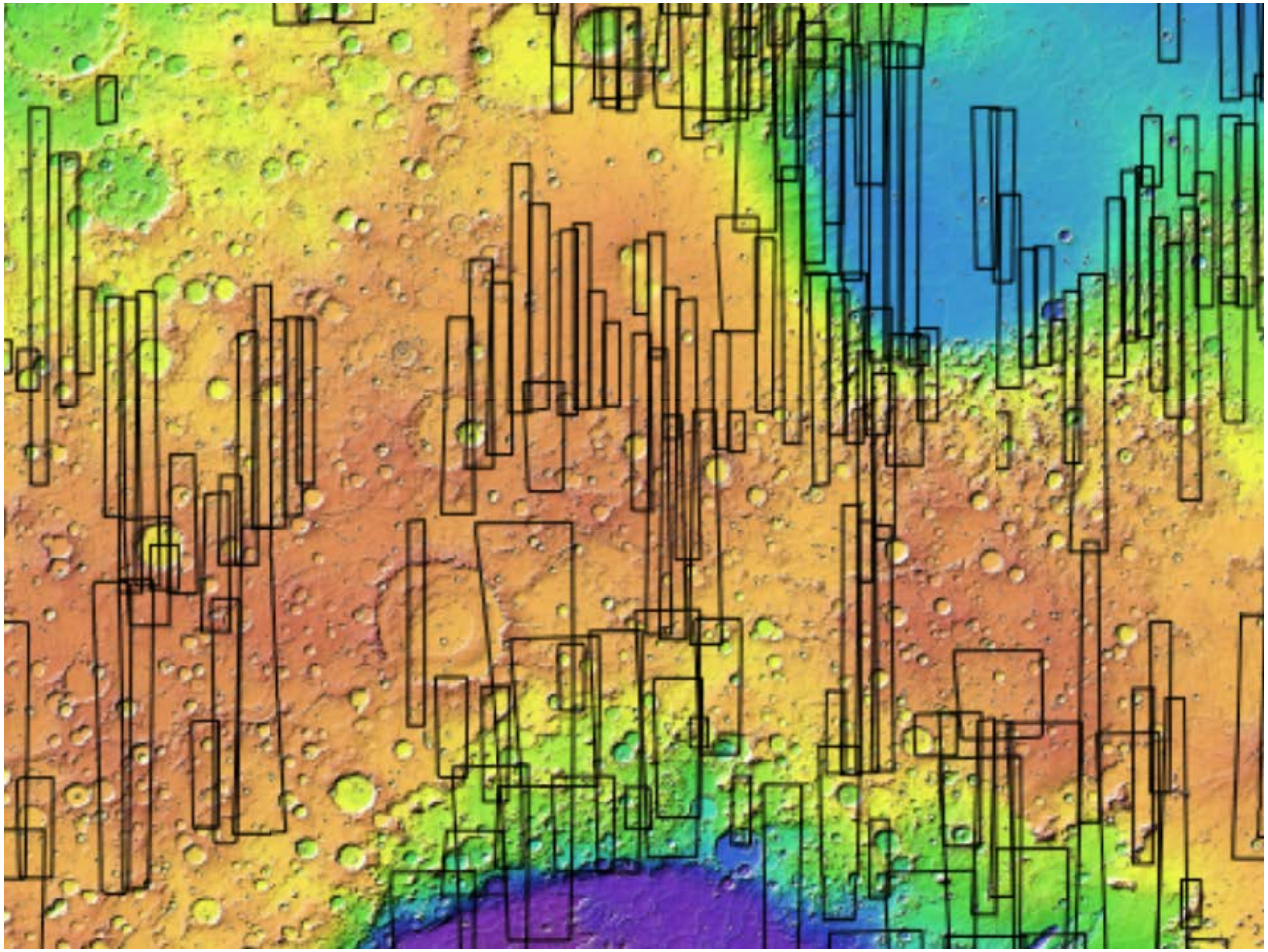
HRSC/SRC imaging principle and main characteristics



	HRSC	SRC
Electro-optical performance		
detector type	THX 7808B	Kodak KAI 1001
sensor pixel size	7 µm x 7 µm	9 µm x 9 µm
focal length	175 mm	985 mm
pixel size on ground	10 m x 10 m @250 km	2.3 m x 2.3 m @250 km
field of view per pixel	8.25 arcsec	2 arcsec
active pixels per sensor	9 sensors a 5184	1008 x 1018
image size on ground	52.2 km swath x [time] @250 km	2.35 km x 2.35 km @250 km
radiometric resolution	8 bit before compress.	14 bit or 8 bit selectable
sensor full well capacity	420.000 e^-	48.000 e^-
signal chain noise	< 42 e^- (rms)	< 42 e^- (rms)
gain attenuation range	3.5 – 2528 (10.5 -62 dB)	-
spectral filters	5 panchromatic, 4 color	panchromatic
nadir, 2 stereo, 2 photo.	675±90 nm	-
Blue,Green, Red, near infrared	440±40 nm, 540±45 nm 750±25 nm, 955±40 nm	-
Digital features		
on-line compression	DCT/table controlled JPEG	
compression rate	2-20; bypass possible	
max. output data rate	25 Mbit/s after compression	
Operations		
pixel exposure time	2.24 ms to 54.5 ms	0.5 to 516 msec*
pixel summation formats	1x1, 2x2, 4x4, 8x8	-
Compression rates	nominal: 5 to 10	not applied

* *longer exposure times technically feasible, but not realized due to dark current*

HRSC Observations



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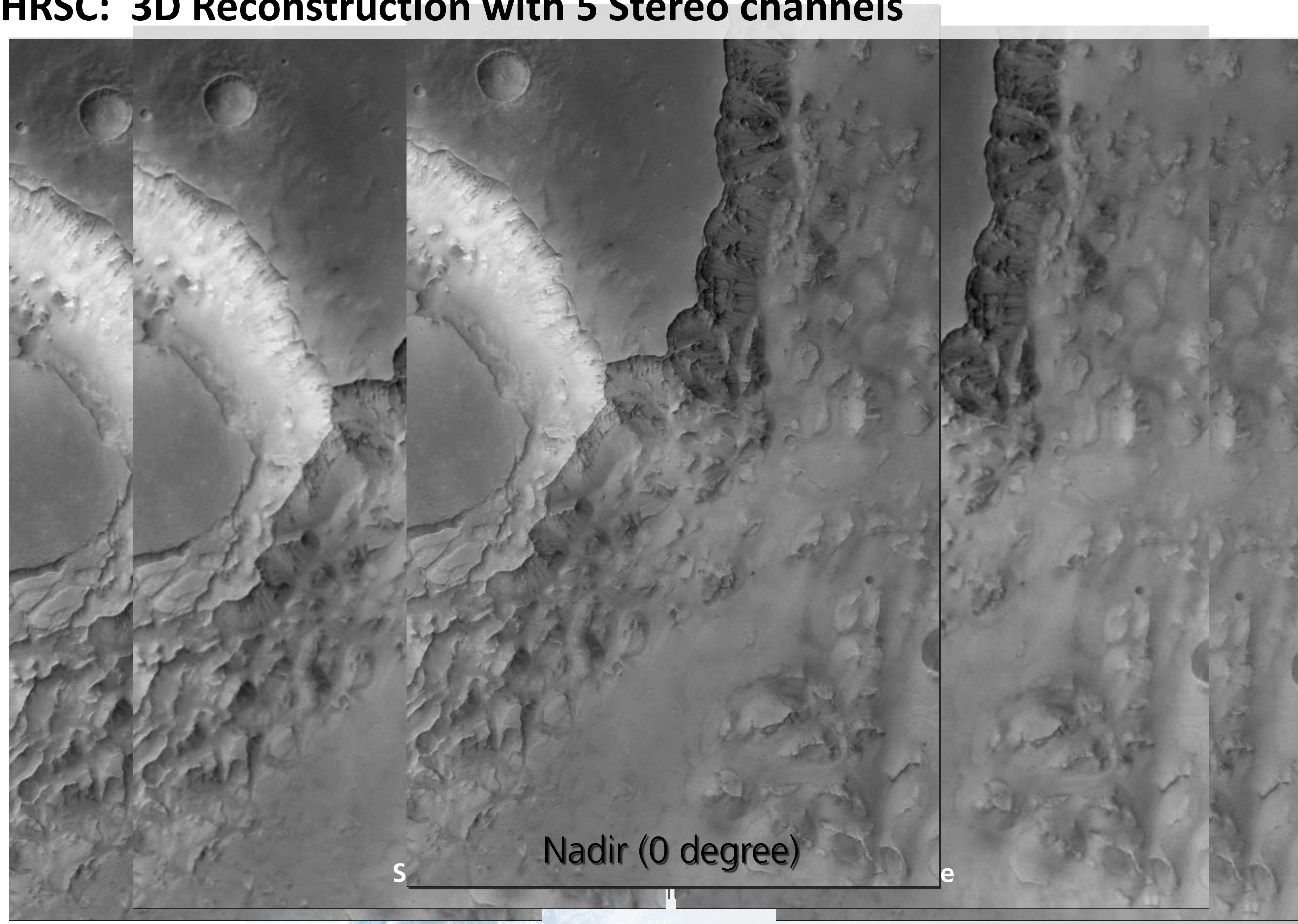
HRSC: 3D Reconstruction with 5 Stereo channels



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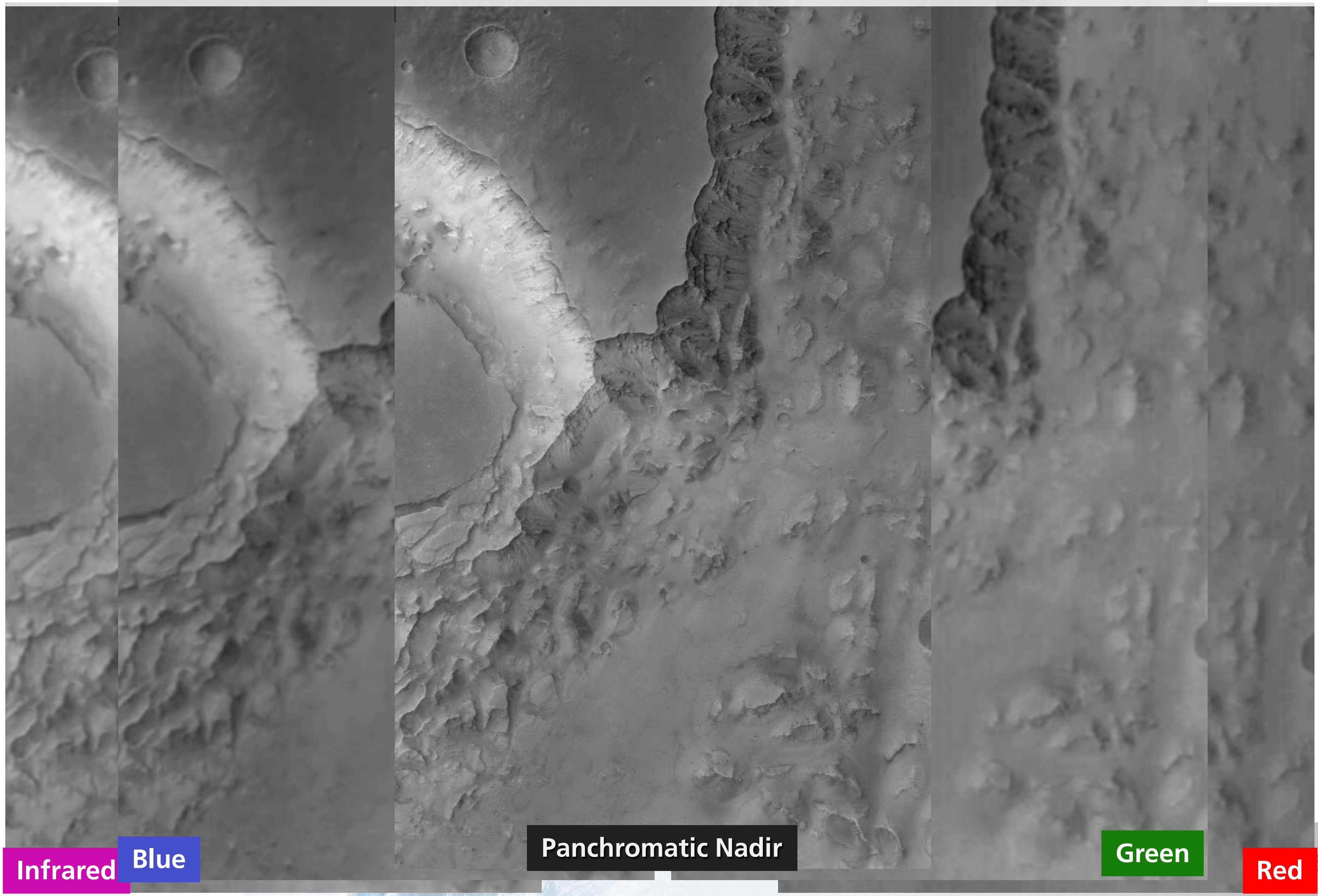
HRSC: Ortho- Rectification of the 4 colour and the Nadir channel



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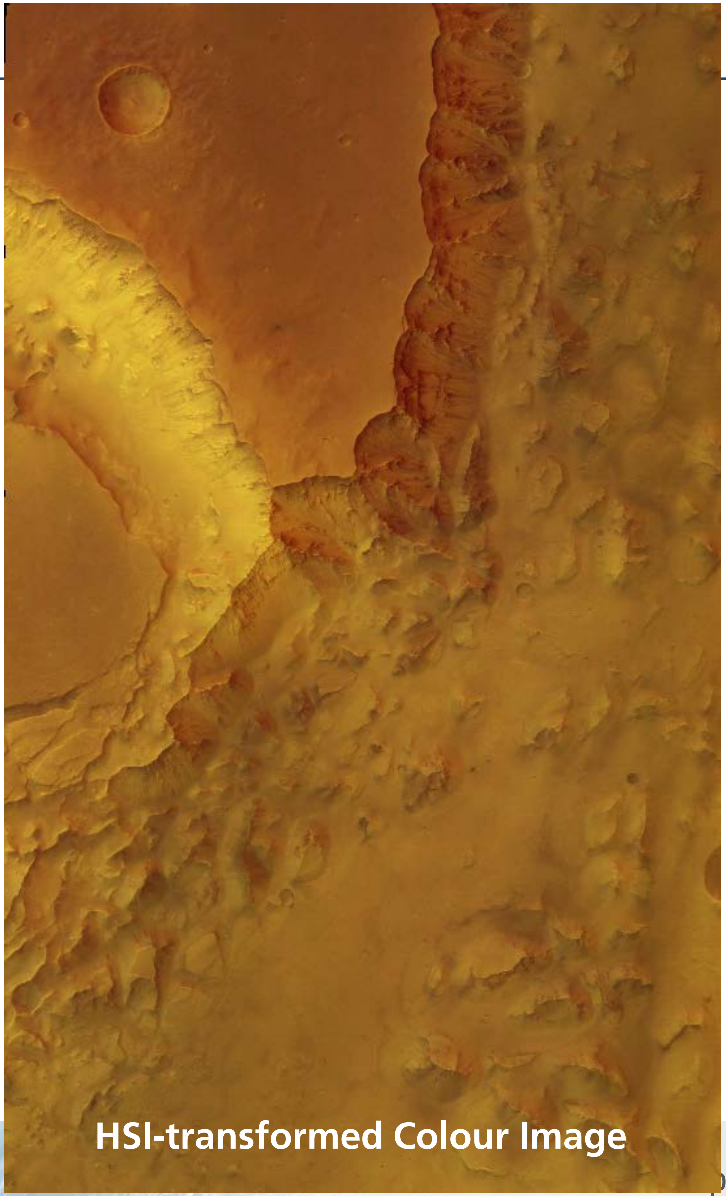
HRSC: Combination of the Colour- Orthoimages



HSI-transformed Colour Image

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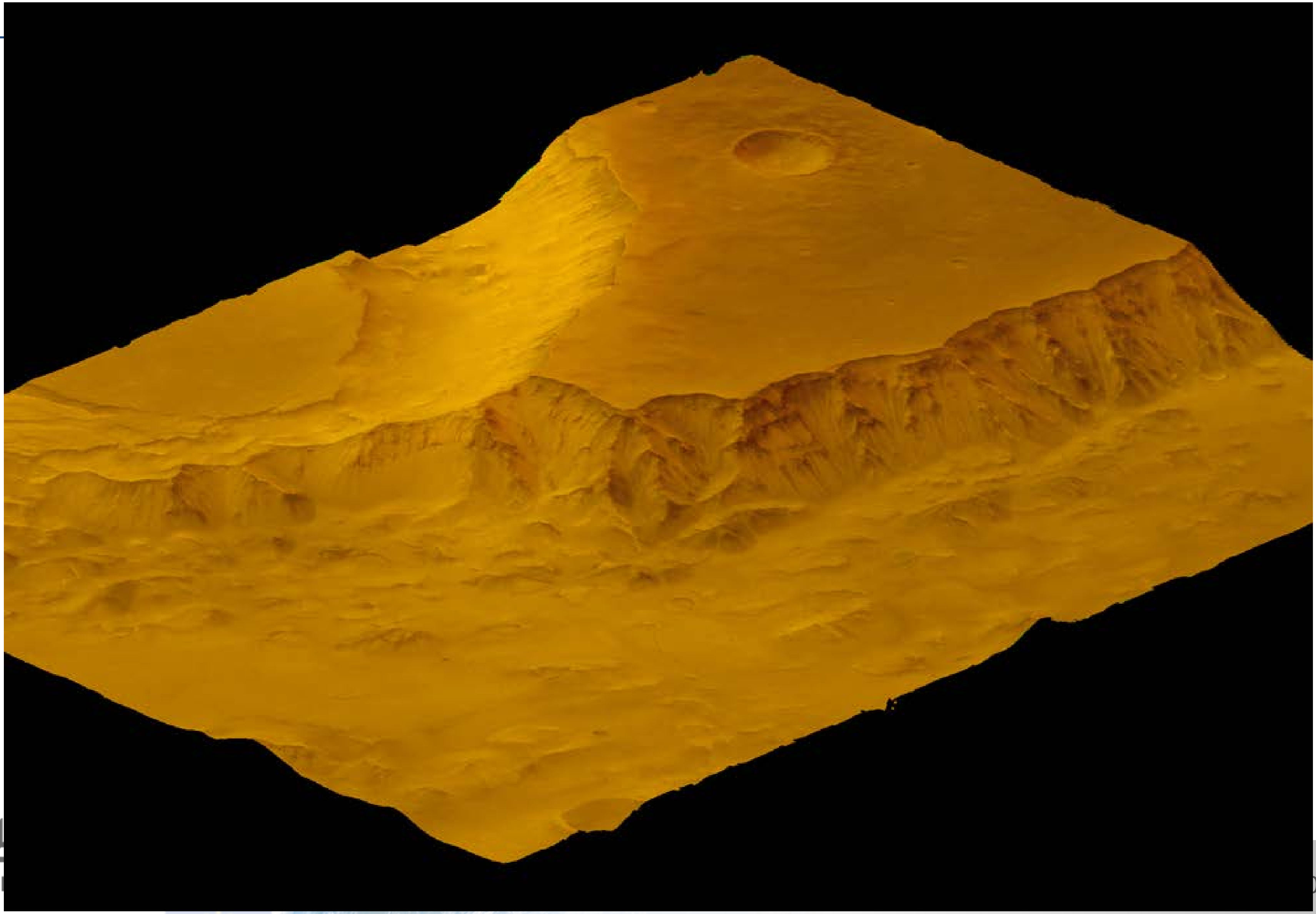
HRSC: Visualisierung der Farb- Orthobilder



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HRSC processing Levels

- In all processing Levels there is one file per sensor and image sequence
- First levels include raw images and calibration corrections
- First derived products at Level 3
  - Ortho-rectification (level-3 to level-5)
  - DTM generation (level-4 to level-5)
  - Mosaicking (level-5)

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Processing Levels

Level	Action taken	Data Products
Level 0	none	Original Data Stream
Level 1	De-compression of data stream	De-compressed uncalibrated images
Level 2	Radiometric correction based on calibration information (flat field and absolute flux)	Single strip calibrated image data
Level 3	Map projection onto MOLA DTM using standard map parameters	Single strip ortho-rectified images
Level 4	Adjustment of single strips and derivation of reconstructed surface	Single strip terrain models and single strip ortho-rectified images
Level 5	Adjustment and combination of adjacent image strips	Multi-orbit terrain model mosaics and ortho image mosaic

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Level 4 Data Products

- Single strip DTMs and ortho-images
  - Bundle and Sequential Photogrammetric Adjustment to improve forward ray intersection accuracies across one scene
  - Minimization of lateral and vertical differences to the MOLA DTM -> co-registration to a single reference

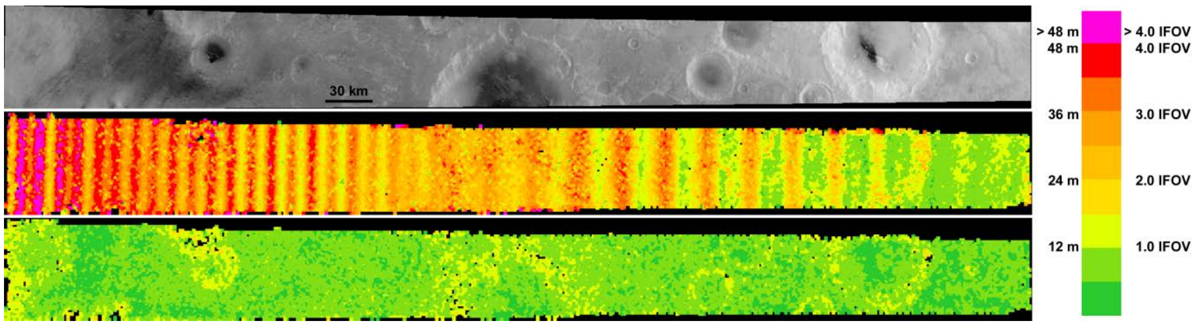
Overview of the main HRSC Level-4 data product specifications.

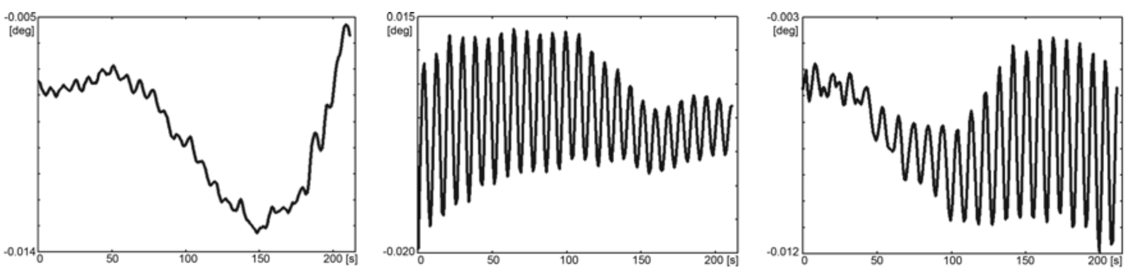
	DTM	Orthoimage
Product subtypes	Spheroid DTM Areoid DTM	Panchromatic (nadir), red, green, blue and near-infrared channel orthoimages
Data format	16 bit, numeric height resolution 1 m	8 bit
Spatial resolution	50 m/75 m/100 m/... depending on quality of image and orientation data	12.5 m/25 m/50 m... depending on ground resolution
Reference bodies for height	Spheroid $r=3396$ km and GMM3-derived equipotential surface (areoid DTM)	n/a
Ref. body for map projection	Spheroid $r=3396$ km	Spheroid $r=3396$ km
Map projection	Sinusoidal ($\pm 85°$ latitude) Polar-Stereographic (polar areas)	Sinusoidal ($\pm 85°$ latitude) Polar-Stereographic (polar areas)

Gwinner et al., EPSL, 2010

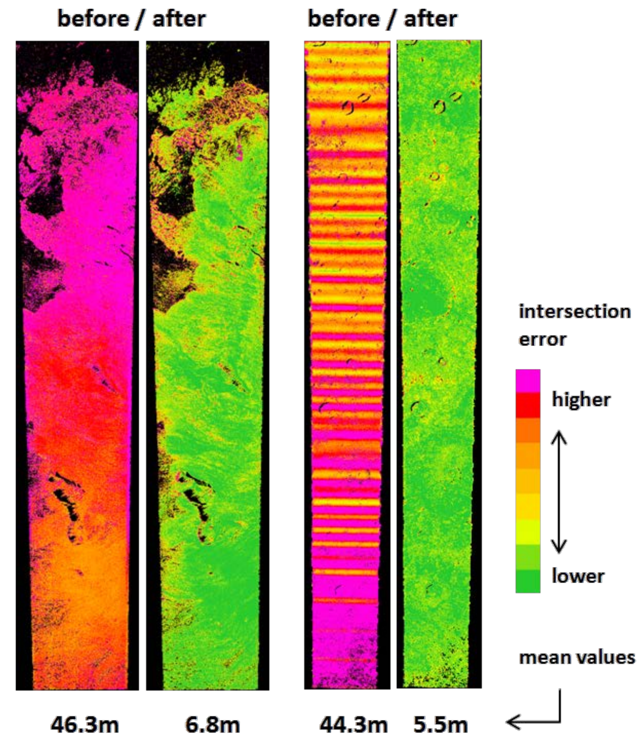
Photogrammetric adjustment of HRSC sensor orientation (single-strip case)

SPA Results
(Gwinner et al., EPSL, 2010)





BA Results
(Bostelmann et al., ISPRS, 2012)



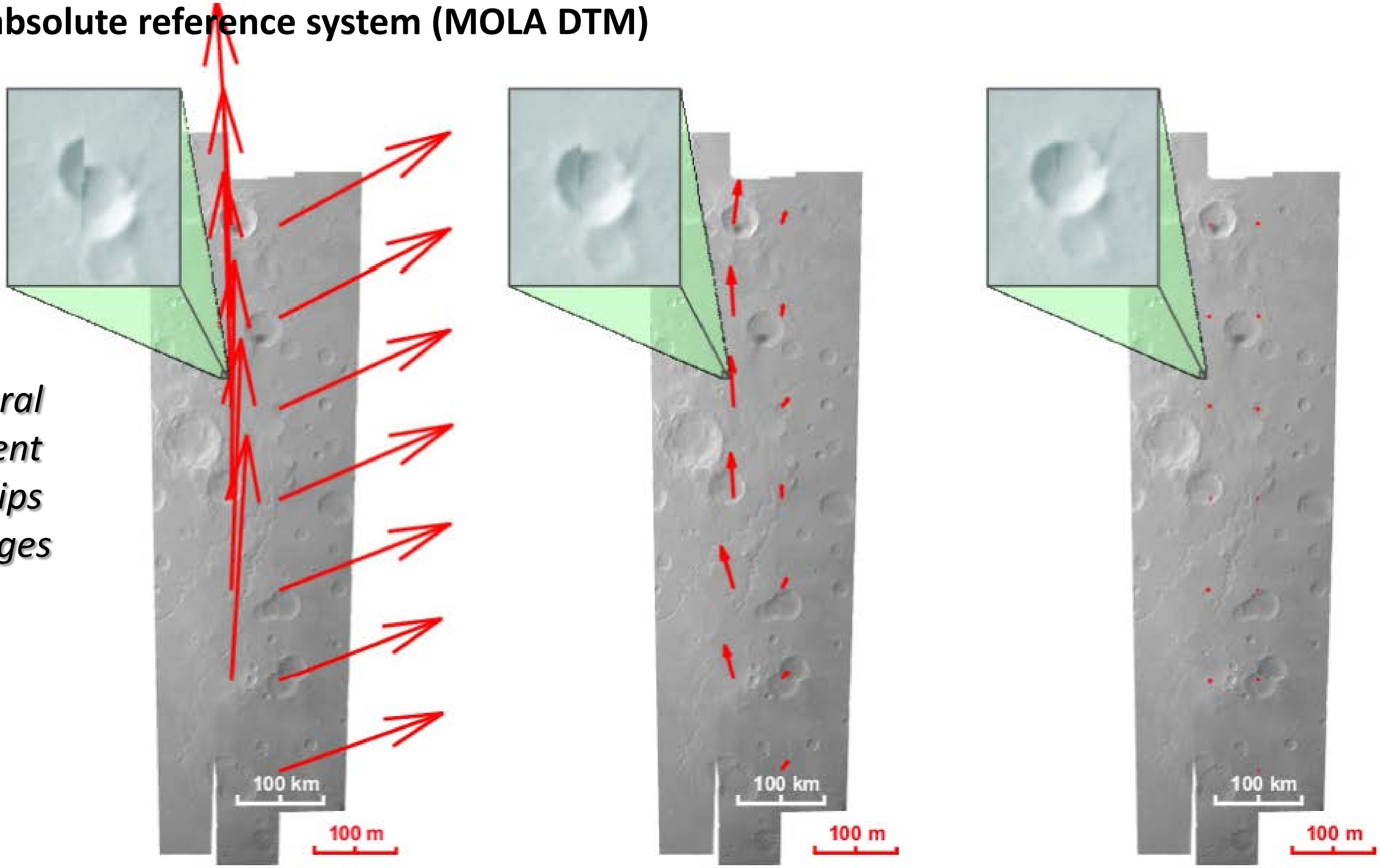
Improvement of intersection error by photogrammetric adjustment: time-dependent corrections to orientation angles pitch, roll and yaw.

⇒ Time variation of orientation angles on the order of up to 0.1 Hz occuring, sampling must be on the scale of seconds

Bundle block adjustment

- Use homologous image points to improve the exterior orientation data of a single strip (up to 5 images) or a block (2 or more strips)
- Reconstruct geometric consistency
  - relative to other images (of strip or block)
  - relative to absolute reference system (MOLA DTM)

***Arrows:** lateral displacement between strips in ortho images*



before adjustment ***adjusted as strips*** ***adjusted as a block***

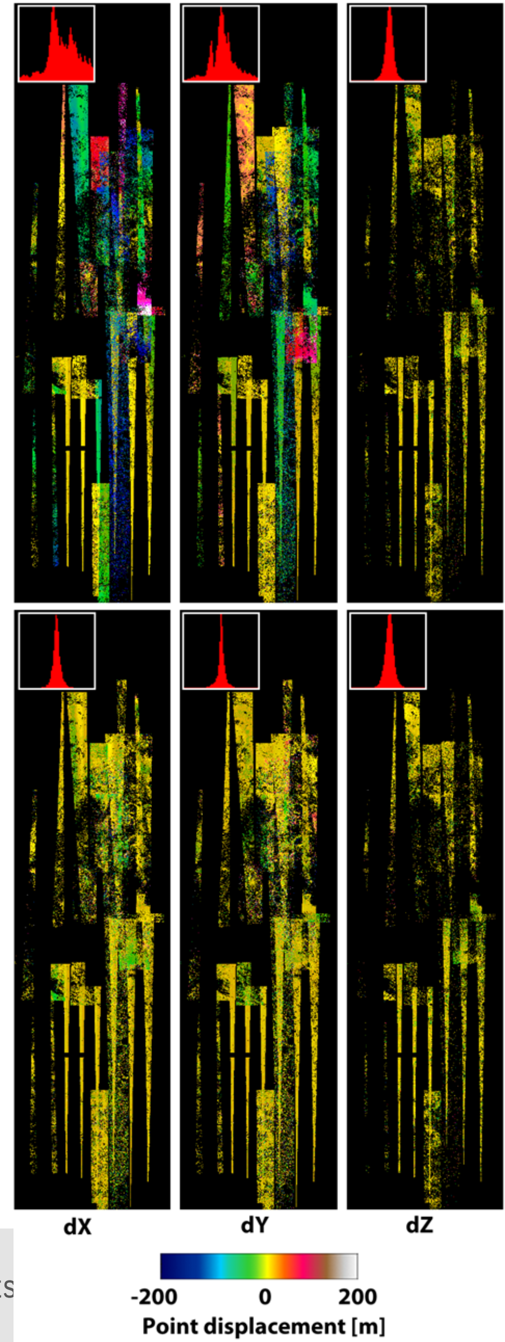
Analysis of internal co-registration of image blocks: single-strip vs. block adjustment

	Single-strip adjustment (SSA)	Block adjustment (BBA)
RMS of mean strip-to-strip point displacements dX / dY /dZ	90.5 / 65.4 / 9.3 m *2.36 / 1.69 / 0.27 pixels[1]*	18.2 / 20.1 / 8.6 m *0.49 / 0.53 / 0.26 pixels[1]*
Mean relative strip offsets 1D dX / dY / dZ	64.0 / 46.2 / 6.6 m *1.67 / 1.19 / 0.19 pixels[1]*	12.9 / 14.2 / 6.1 m *0.35 / 0.38 / 0.18 pixels[1]*
Mean relative strip offsets 2D / 3D dXY / dXYZ	78.9 / 79.2 m *2.05 / 2.06 pixels[1]*	19.2 / 20.1 m *0.52 / 0.55 pixels[1]*

[1] fraction of the mean stereo pixel size

Quality of **height adjustment** by the two methods can be considered as equivalent

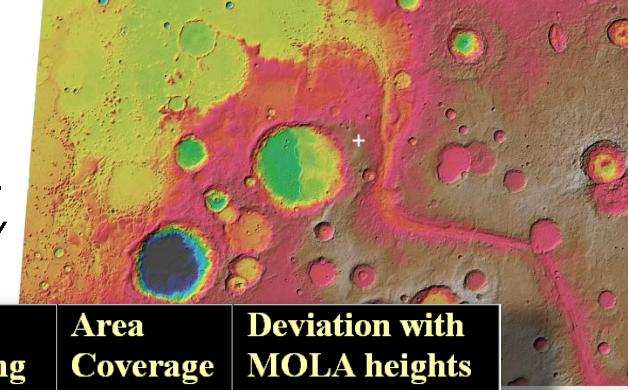
For horizontal position, precision at scale of one pixel at full resolution is only achieved using bundle block adjustment



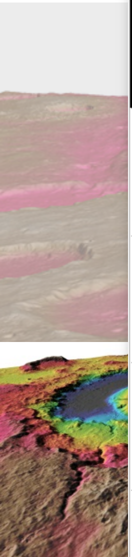
Residual x, y, z displacements on overlaps after adjustment

Gwinner et al., PSS, 2016

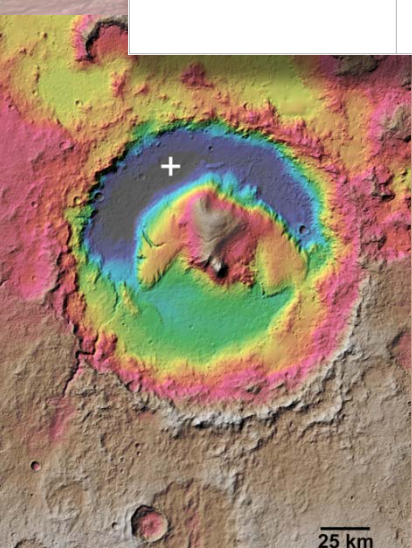
Regional HRSC DTMs of the MSL landing site candidates



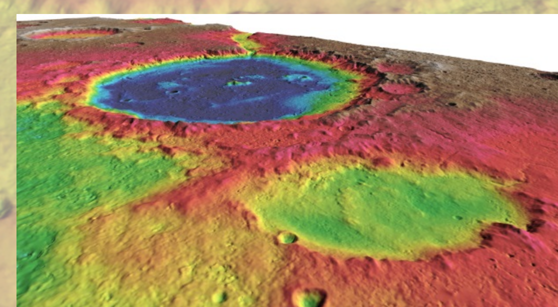
Mawrth Vallis
Lat/Lon ranges: 19.8° N - 28.7° N / 334.6° E - 346.5° E

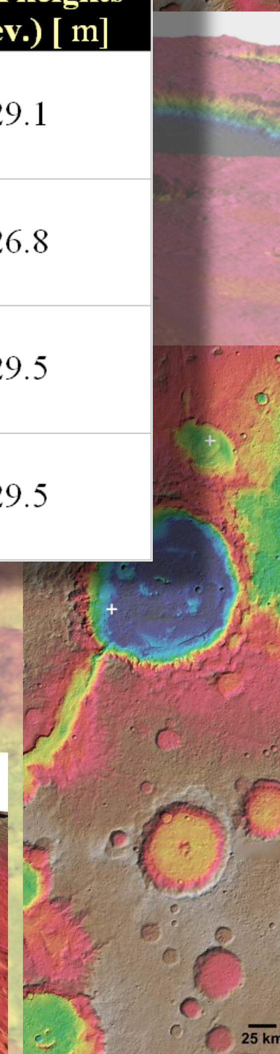


Site Name	Site Coordinates Lat / Lon	Approx. Lat. Range	Approx. Long. Range	Elevation Range [m]	Grid Spacing [m]	Area Coverage [km]	Deviation with MOLA heights (Std.dev.) [m]
Gale Crater	4.49°S / 137.42°E	3.2°S 7.8°S	135.0°E 139.5°E	-4680 1460	50	275 x 205	29.1
Mawrth Vallis	24.01°N / 341.03°E	19.8°N 28.7°N	334.6°E 346.5°E	-5190 840	50	530 x 650	26.8
Holden Crater	26.37°S / 325.10°E	22.5°S 32.9°S	323.7°E 328.1°E	-3140 1880	50	625 x 235	29.5
Ebersw. Crater	26.37°S / 325.10°E	22.5°S 32.9°S	323.7°E 328.1°E	-3140 1880	50	625 x 235	29.5



Holden and Eberswalde Craters
Lat./Lon. ranges: 22.5° S - 32.9° S / 323,7° E - 328.1° E





Gale Crater
Lat./Lon ranges: 3.2° S - 7.8° S / 135.0° E – 139.5° E

Gwinner et al. (2010), #2727, LPSC 41

MULTI-STRIP ADJUSTMENT & MOSAICKING EFFORT

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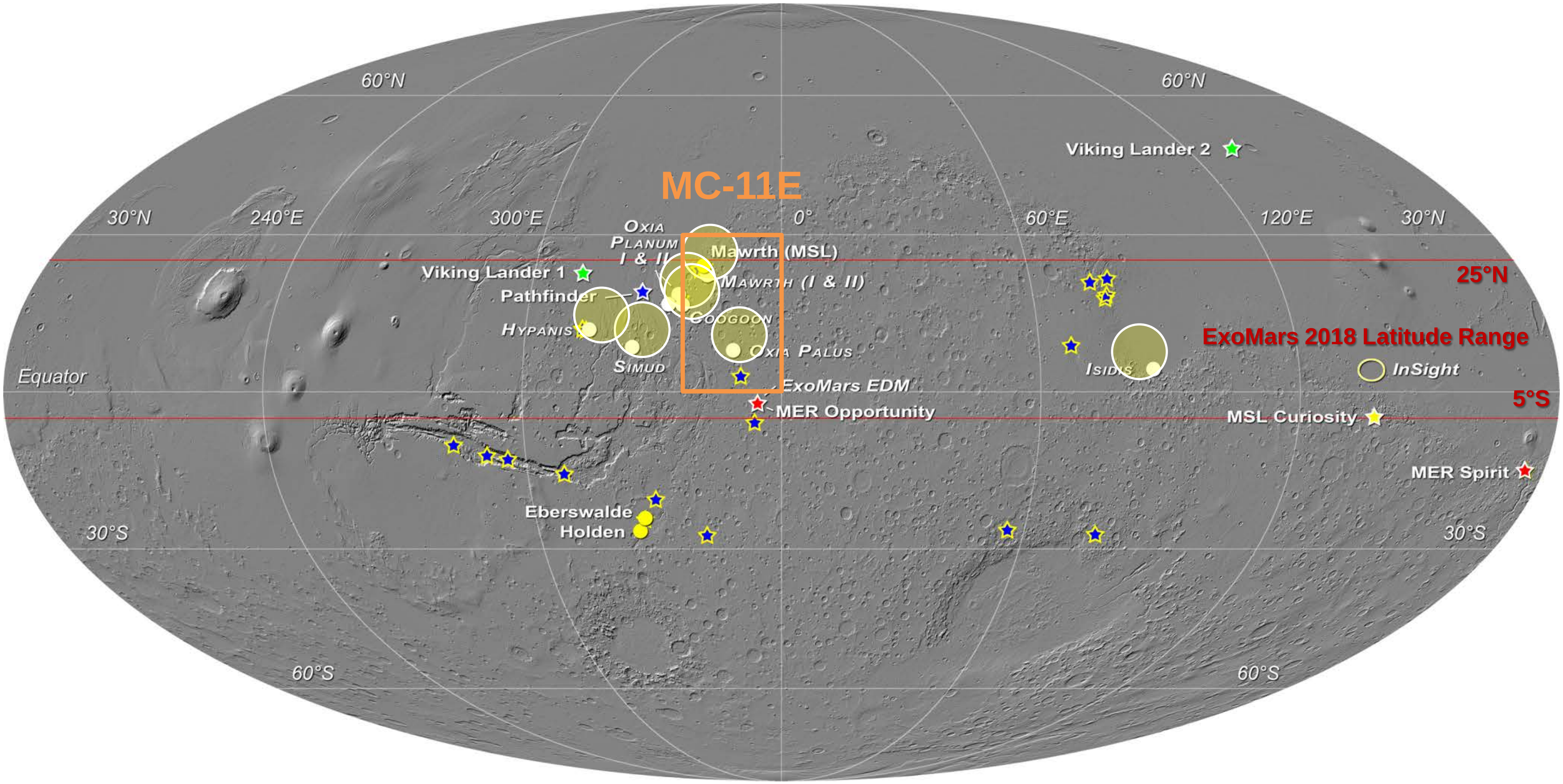
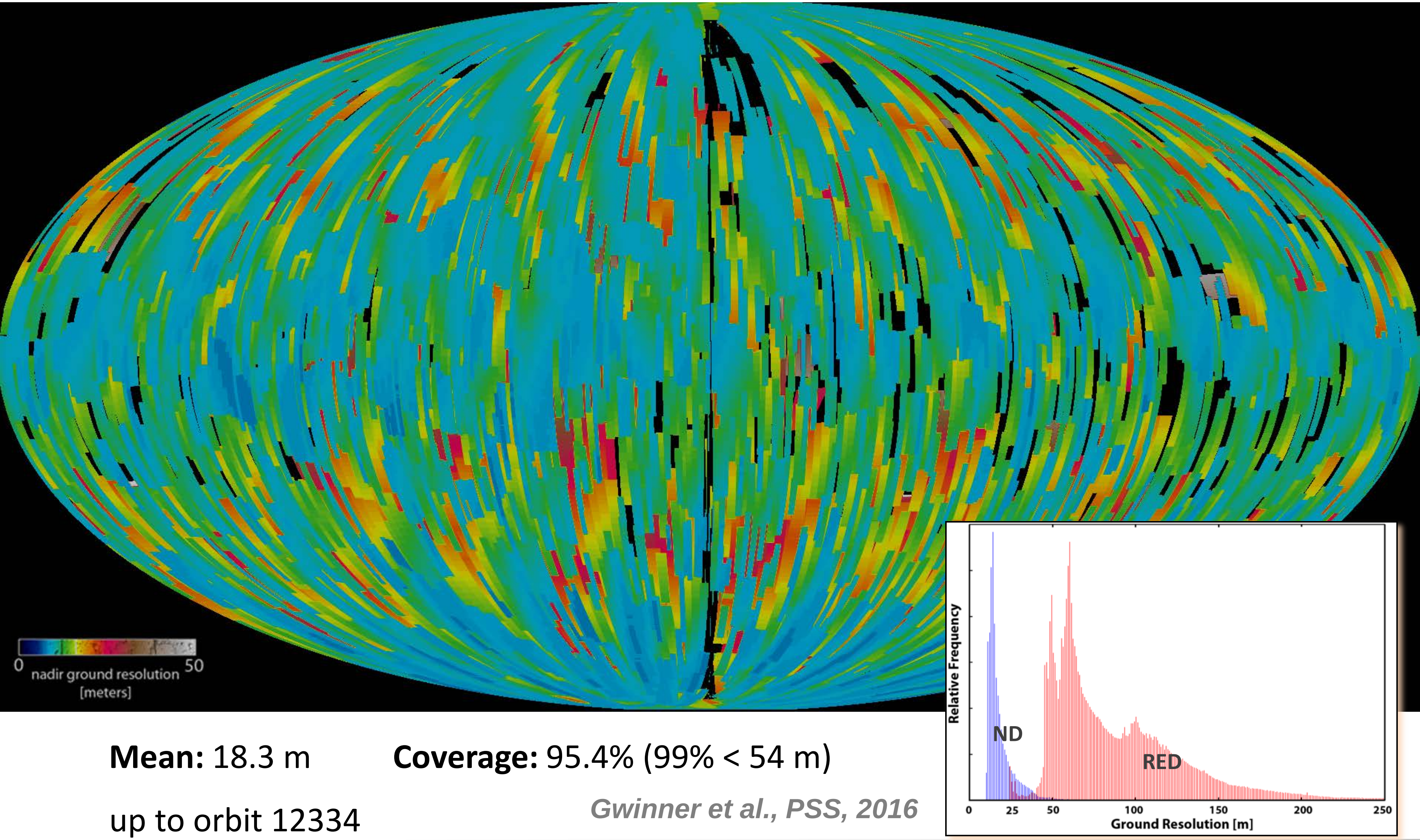
Mars landing sites and landing site proposals



Best local HRSC Nadir-channel ground resolution



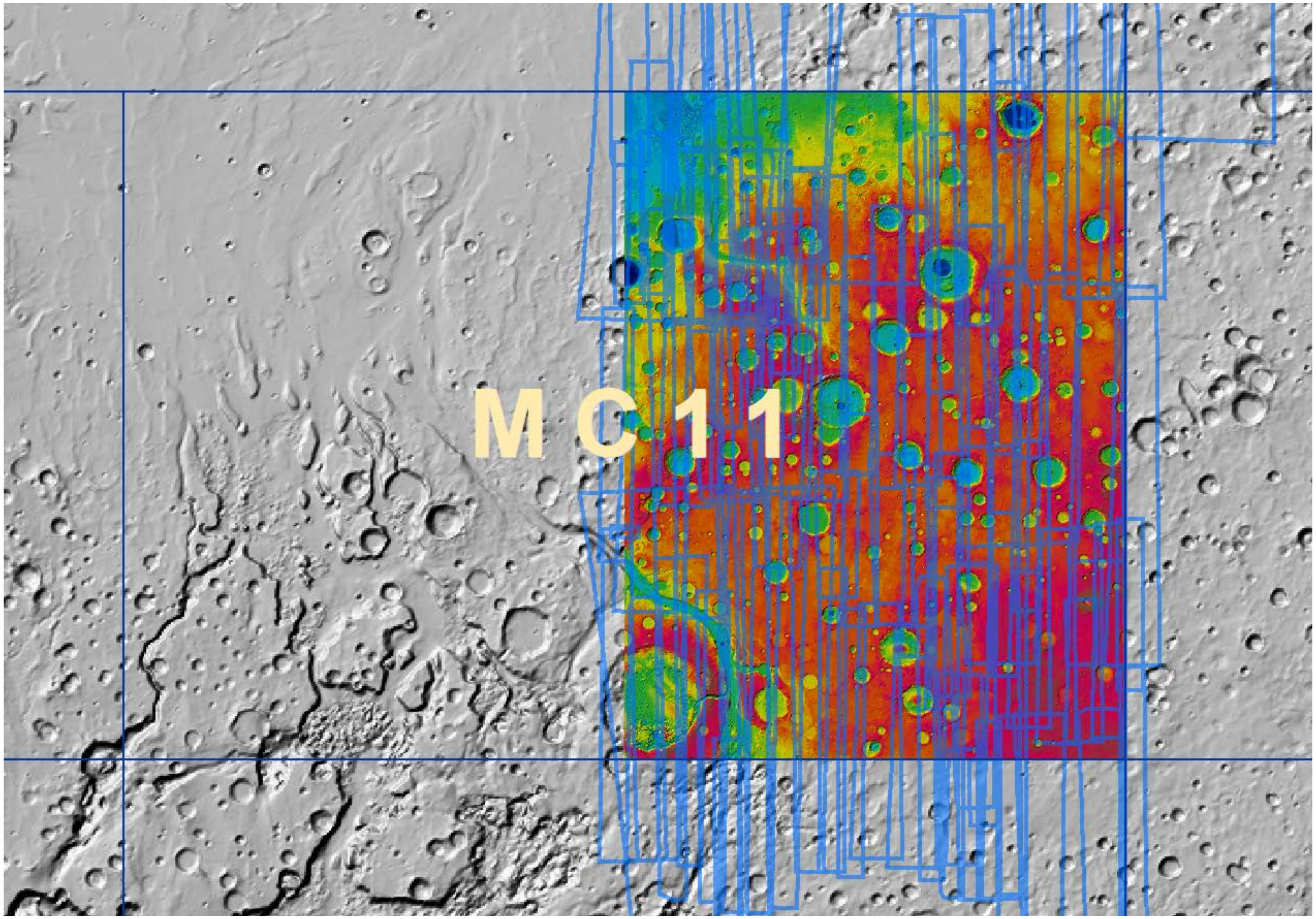
Mean: 18.3 m

Coverage: 95.4% (99% < 54 m)

up to orbit 12334

Gwinner et al., PSS, 2016

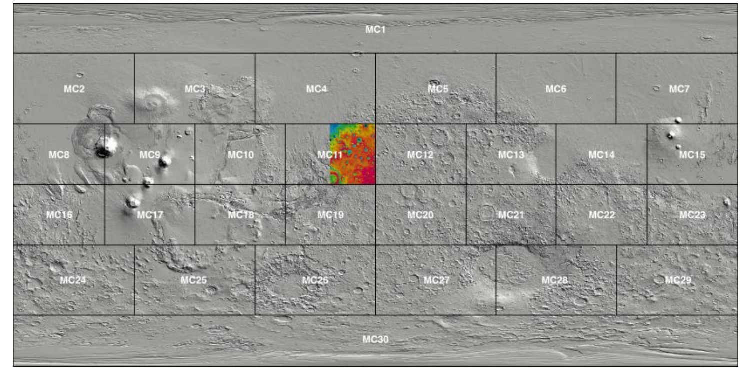
Continuous HRSC Coverage in MC-30 East Half-Tile

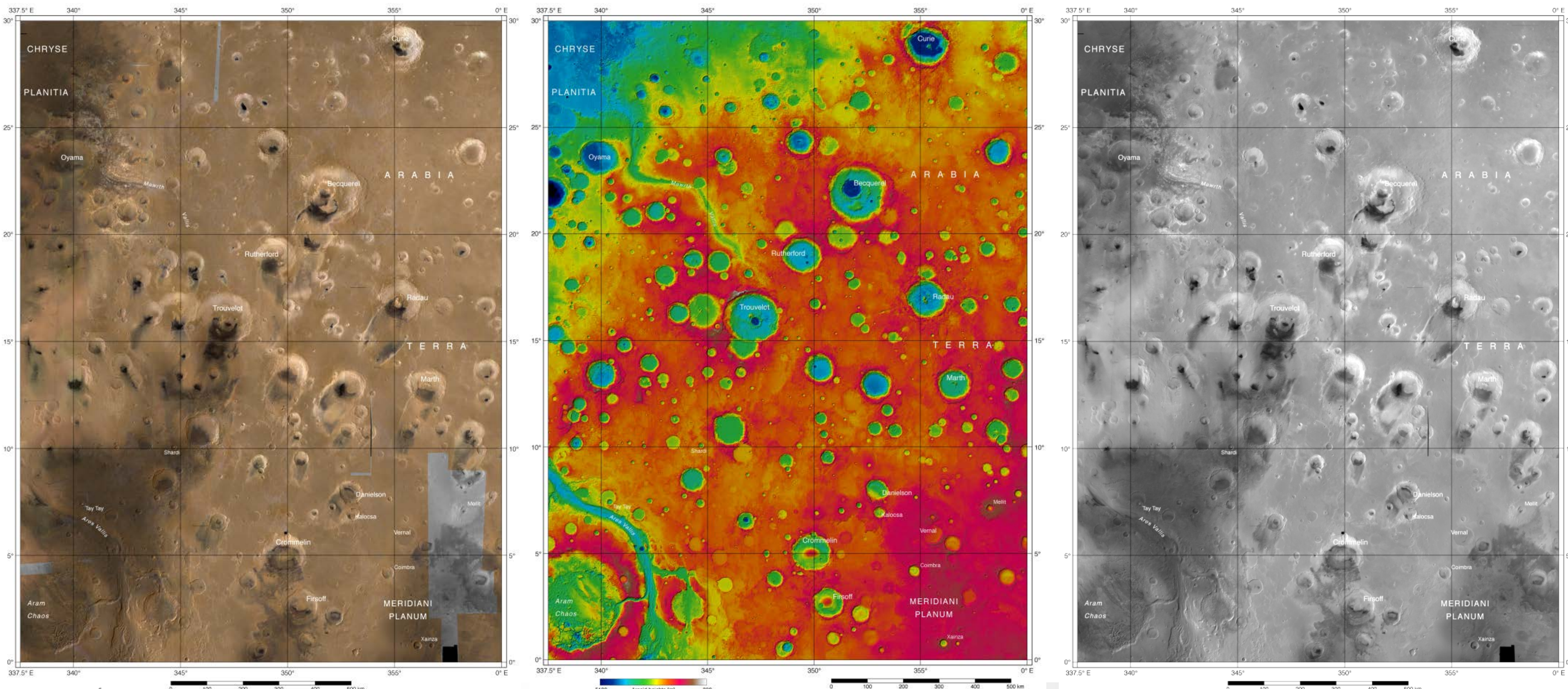


Coverage of MC11-E by HRSC image strips (89 orbits)

HRSC Multi-orbit data products for MC-11 East (Oxia Palus East)

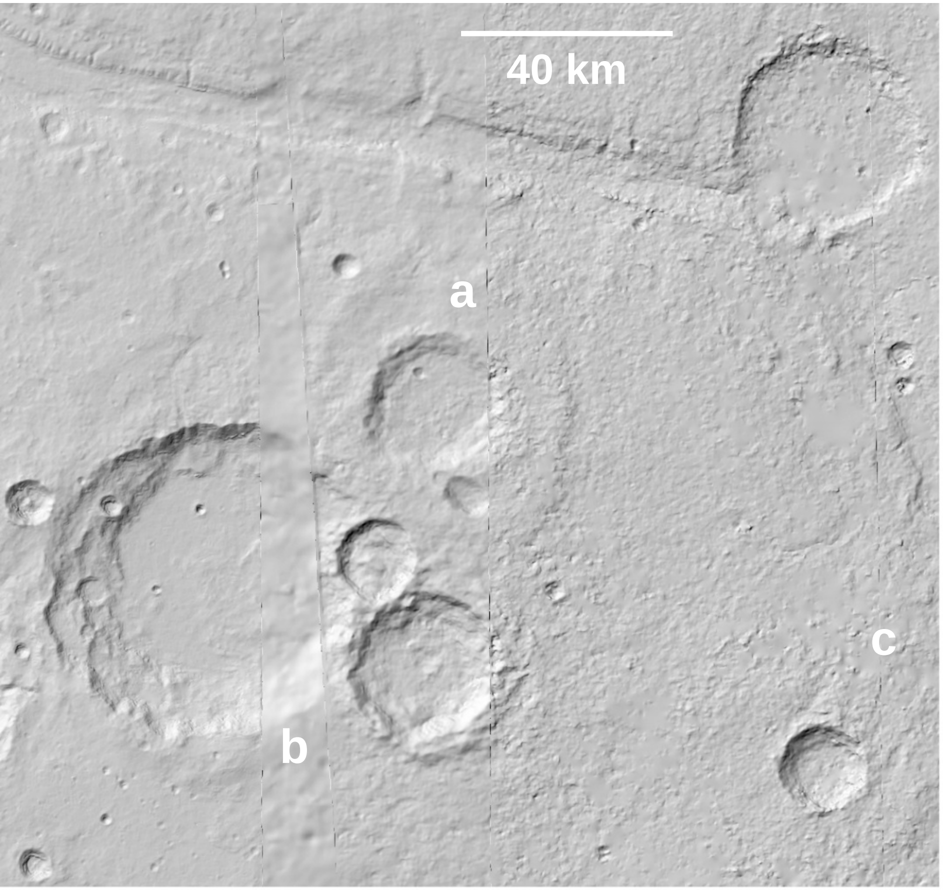
- Coordinated mapping effort of the Global Topography and Mosaic Generation Task Group in the HRSC Team
- MC30 half-tiles as basic subdivision
- Equidistant Cylindical projection (Stereographic in polar areas)
- Grid spacing 50 m (DTM and color), 12.5 m (panchrom.)





Gwinner et al., PSS, 2016

Multi-orbit DTM versus mosaic of single-strip DTMs



Mosaic of single-strip Level-4 DTMs

Multi-orbit DTM

Joint interpolation of overlapping 3D point sets

(a) *avoids edge artefacts, related to weakly constrained interpolation close to the strip border*

(b) *avoids masking of higher resolution datasets by lower resolution datasets*

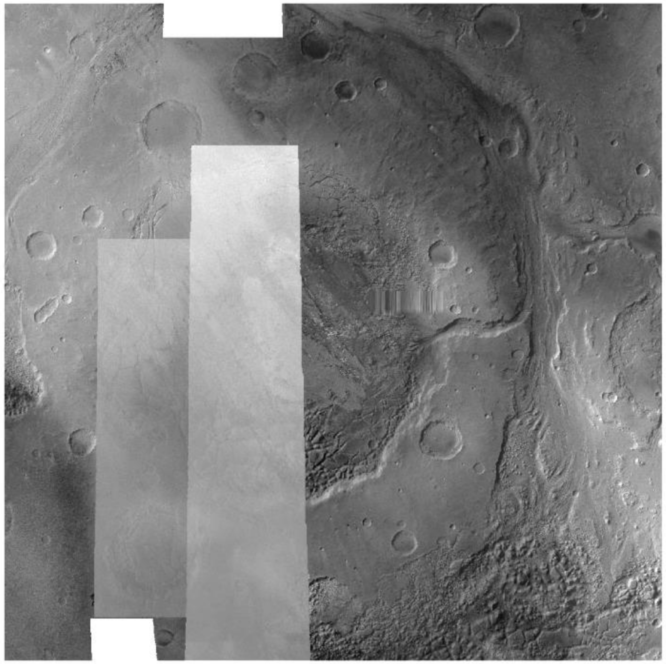
(c) *increases coverage through filling of data gaps present in one of the datasets*

Gwinner et al., PSS, 2016

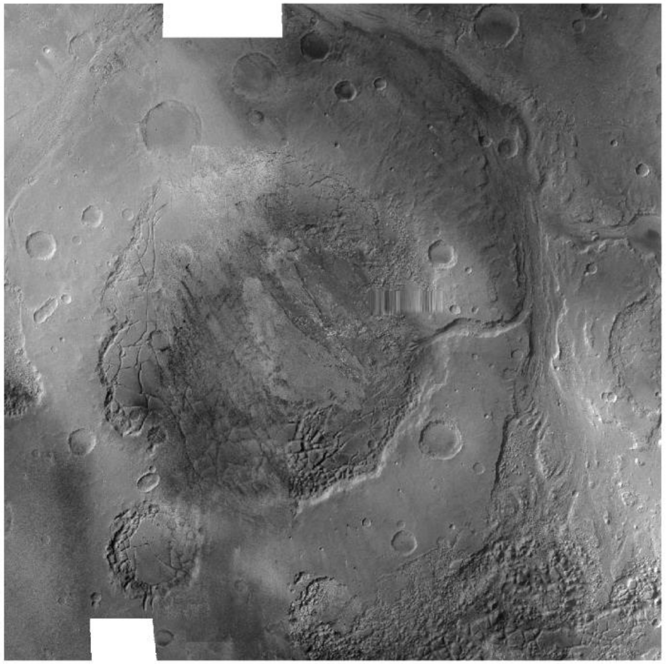
Main characteristics of existing HRSC DTMs and comparison with results for MC11-E

Site Name	Latitude Range	Lon. Range	Elevation Range [m]	Grid Spacing [m]	Area Coverage [km]	Mean 3D Intersection Error [m]	Deviation with MOLA heights (Std.dev.) [m]
Gale Crater	3.2°S 7.8°S	135.0°E 139.5°E	-4680 1460	50	275 x 205	11.6	29.1
Mawrth Vallis	19.8°N 28.7°N	334.6°E 346.5°E	-5190 840	50	530 x 650	9.7	26.8
Holden and Eberswalde Craters	22.5°S 32.9°S	323.7°E 328.1°E	-3140 1880	50	625 x 235	12.9	29.5
Aeolis Mensae Insight LS Area	-2.5°N 5.5°N	133.5°E 141.0°E	-4400 -400	100	444 x 474	13.1	26.6
MC-11E	0°N 30°N	337.5°E. 0°E	-5060 -420	50	1780 x 1330	8.9	34.9
PDS single-strip DTMs (up to h2217)	global	global	--	50-175	--	12.9	34.5

Generation of seamless image mosaics

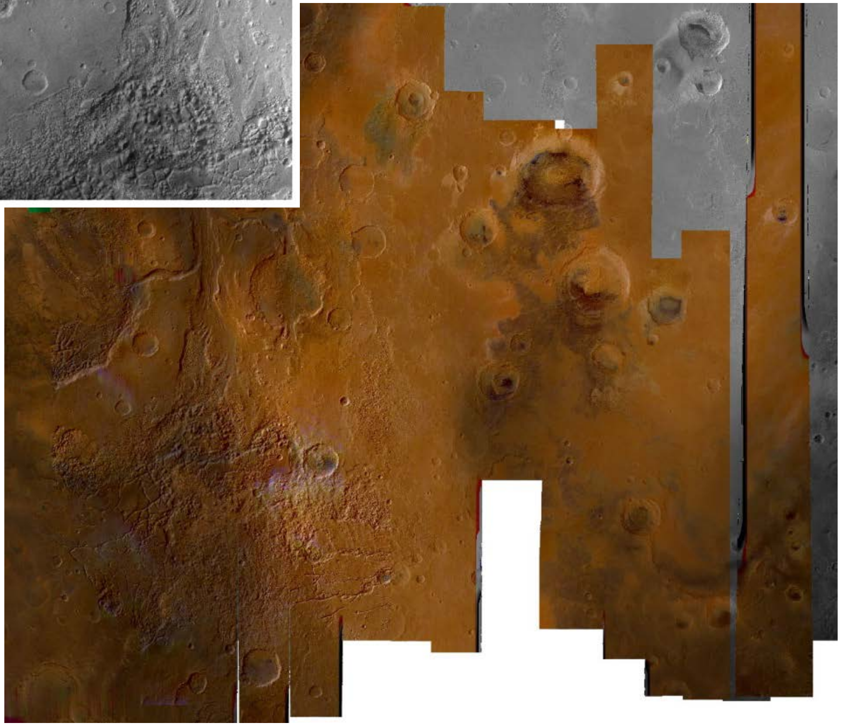


Mosaic with overlaid very low contrast images



Contrast adjusted

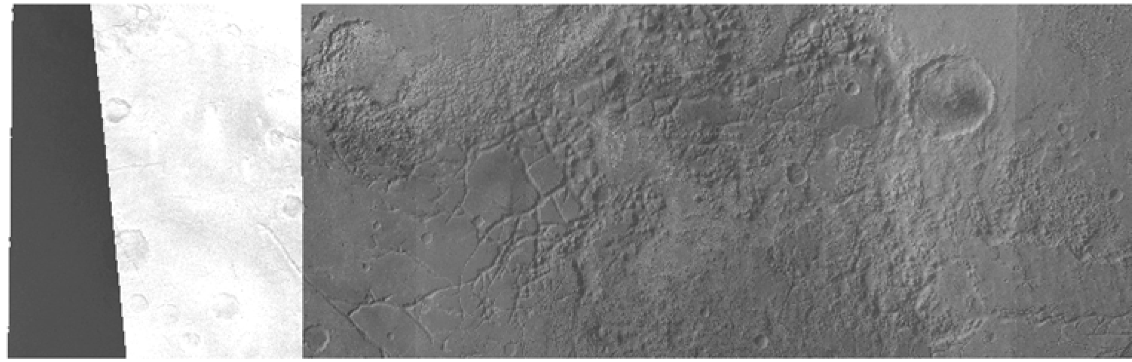
Normalized color image mosaic



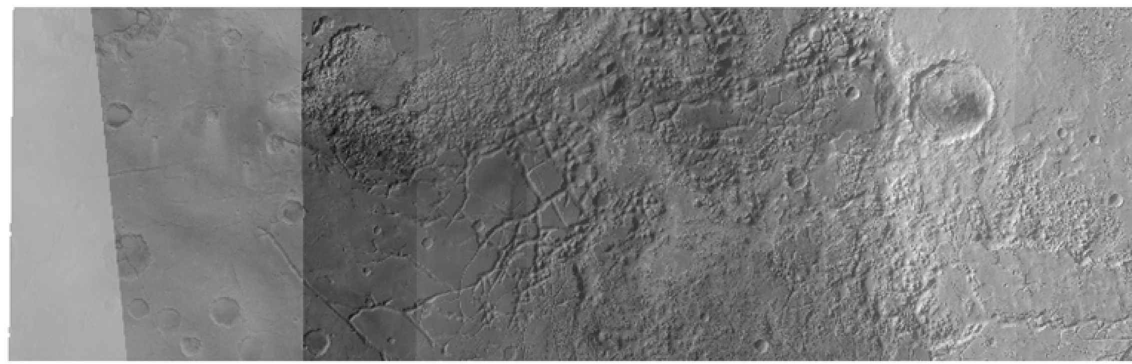
Contrast adjustment method of Michael et al., 2015

Processing steps for radiometric processing

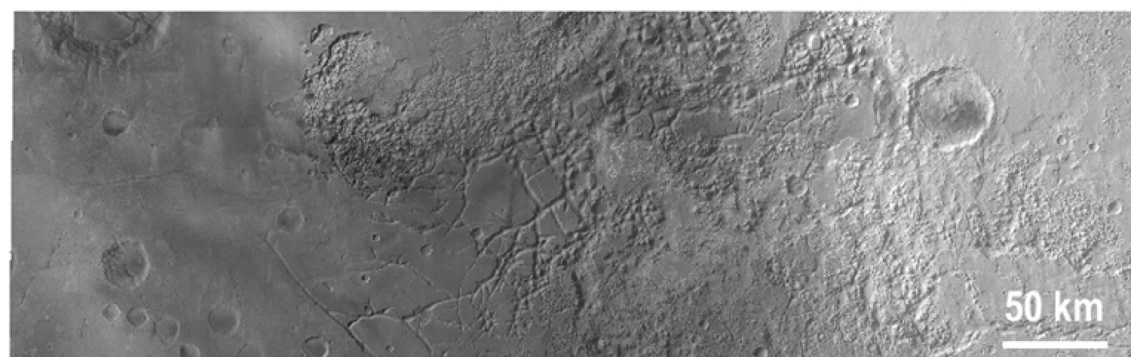
Calibrated orthoimage:
grey values scaled to
Physical units (radiance)



Lambert normalization:
simple physics-based
image modelling



Adjustment to external brightness standard and elimination of edges:
physical units are lost
in favour of consistent
visual appearence



Gwinner et al., PSS, 2016

HRSC Map Product Types included in the PSA/PDS

Product classification	Level-3	Level-4	Level-5
Product type	single-strip	single-strip	multi-orbit
Exterior orientation data	nominal	strip-adjusted or block-adjusted	block-adjusted
Digital terrain model	none	Single-strip HRSC DTM	Multi-orbit HRSC DTM
Image products	Orthorectification using MOLA DTM	Orthorectification using single-strip HRSC DTM	Orthorectification using multi-orbit HRSC DTM
Image grey value interpretation	Calibrated radiance	Calibrated radiance	Brightness-adjusted image mosaic
Typical applications	HRSC image analysis when no HRSC DTM information is available	Co-registration, Spectral /radiometric analysis, Multi-temporal analysis	Regional mapping and analysis, Co-registration, Visualization

Gwinner et al., PSS, 2016

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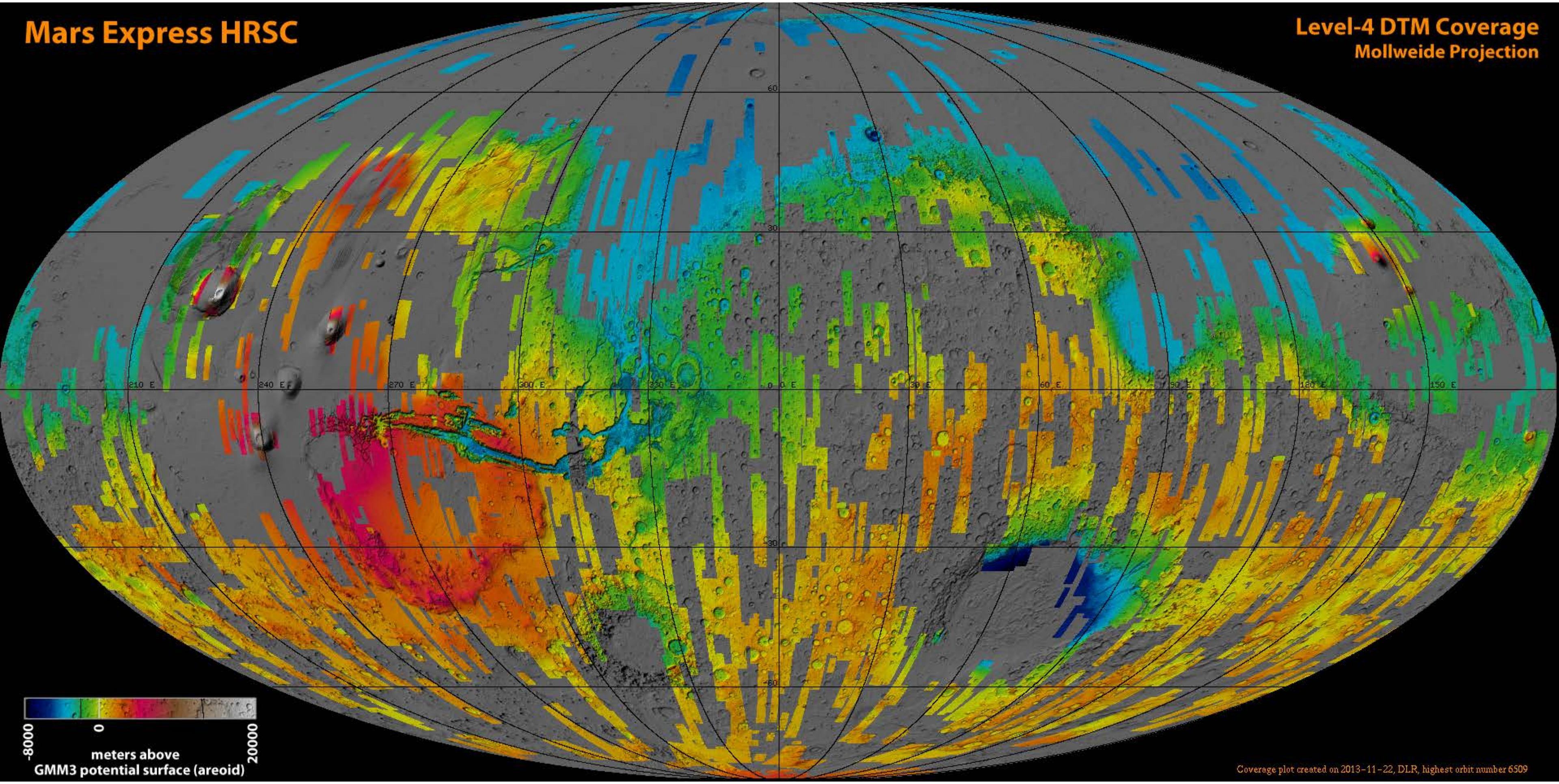
HRSC L4 DTM coverage up to orbit 6509



- 1359 datasets with single-orbit L4 DTM result
- 39.9 percent of Mars surface

Comparison to other Data Sets

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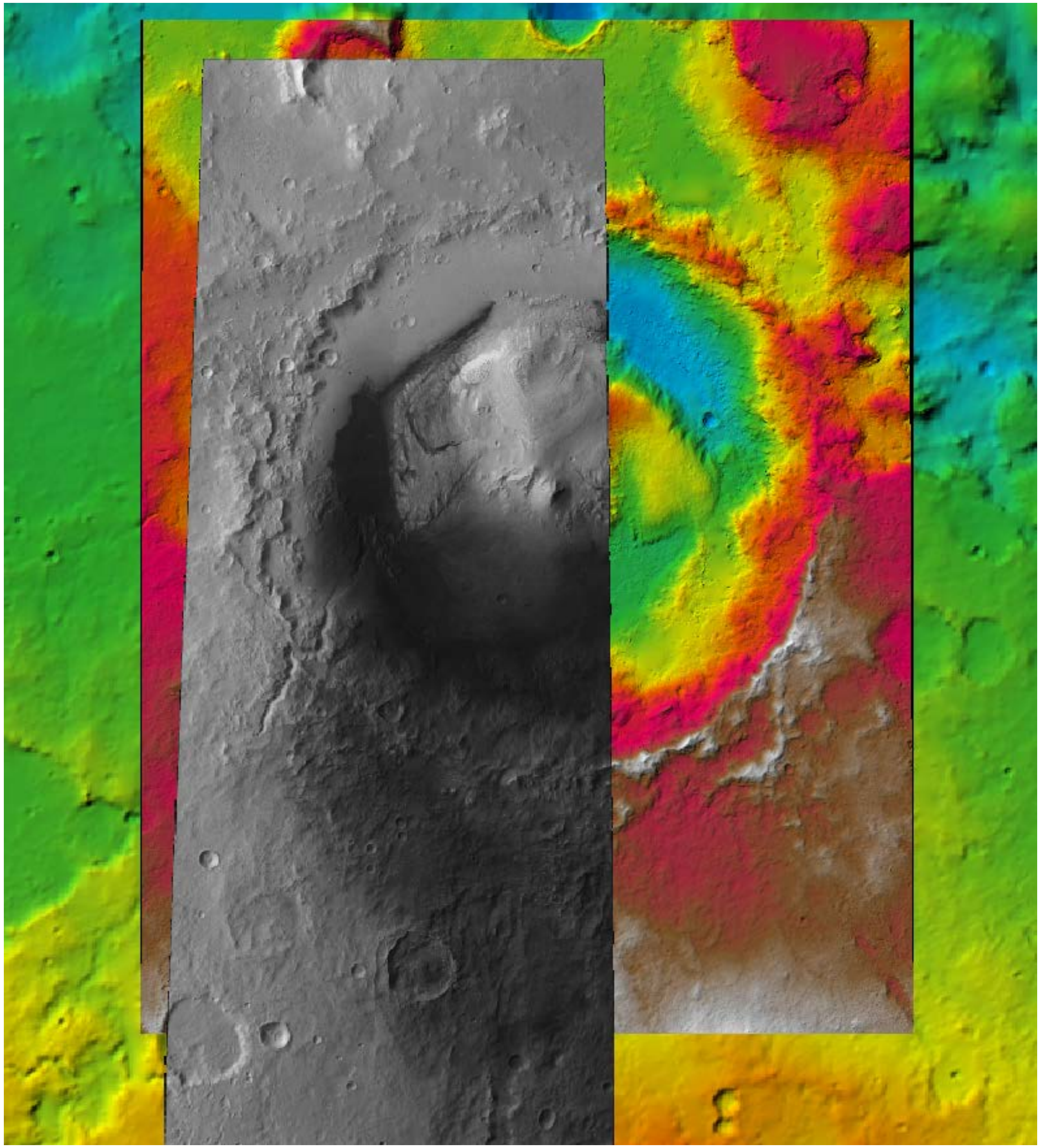
HRSC nadir
25 m/pixel



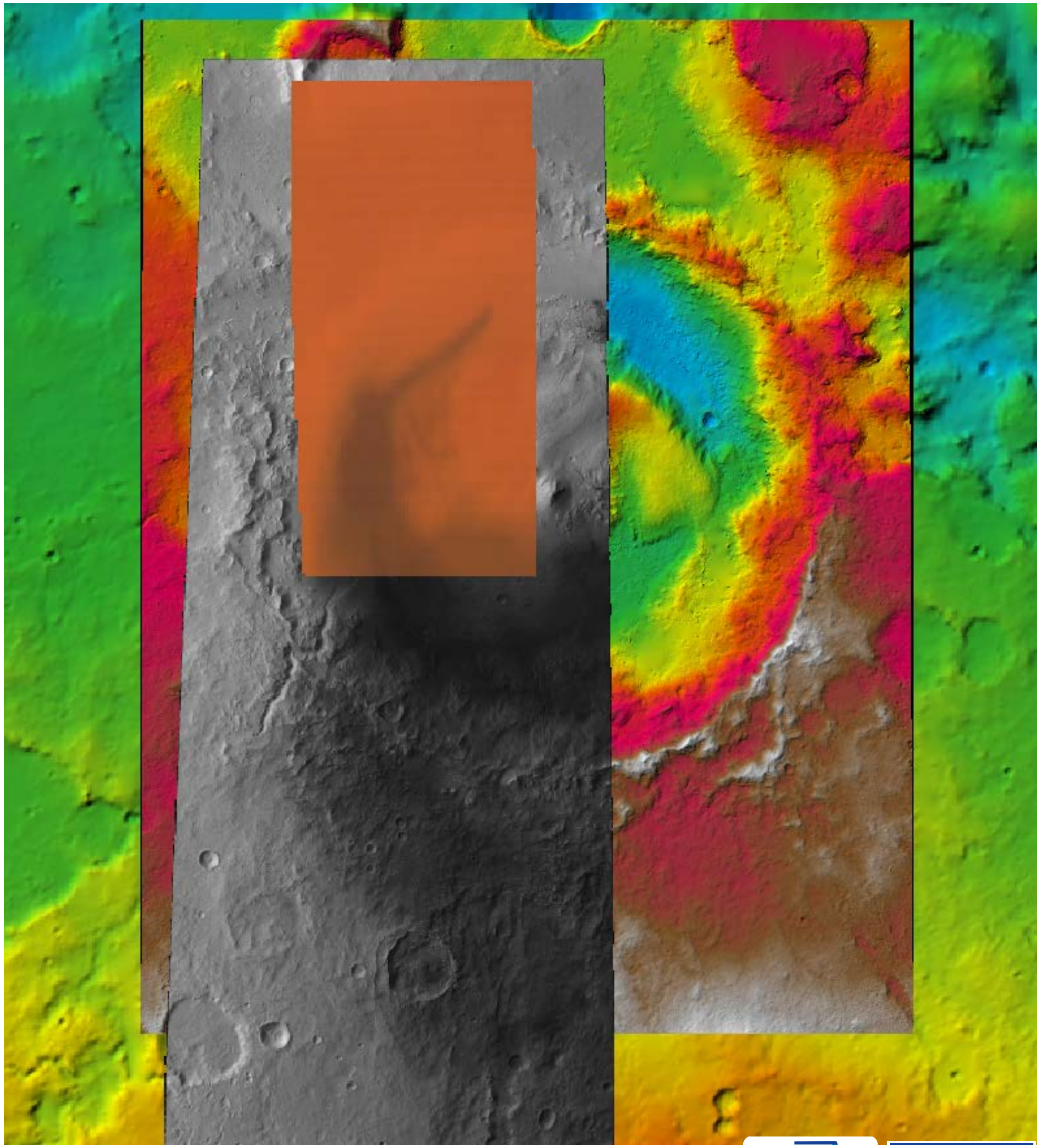
-6000 1000 m (HRSC DTM)
6000 m (MOLA DTM)
Height above Areoid

50 km

Mars image datasets for CROSS-DRIVE Use Case 1

HRSC nadir
25 m/pixel

OMEGA bands 38,25,6
1,85 km/pixel



-6000 1000 m (HRSC DTM)
6000 m (MOLA DTM)
Height above Areoid

50 km

Mars image datasets for CROSS-DRIVE Use Case 1

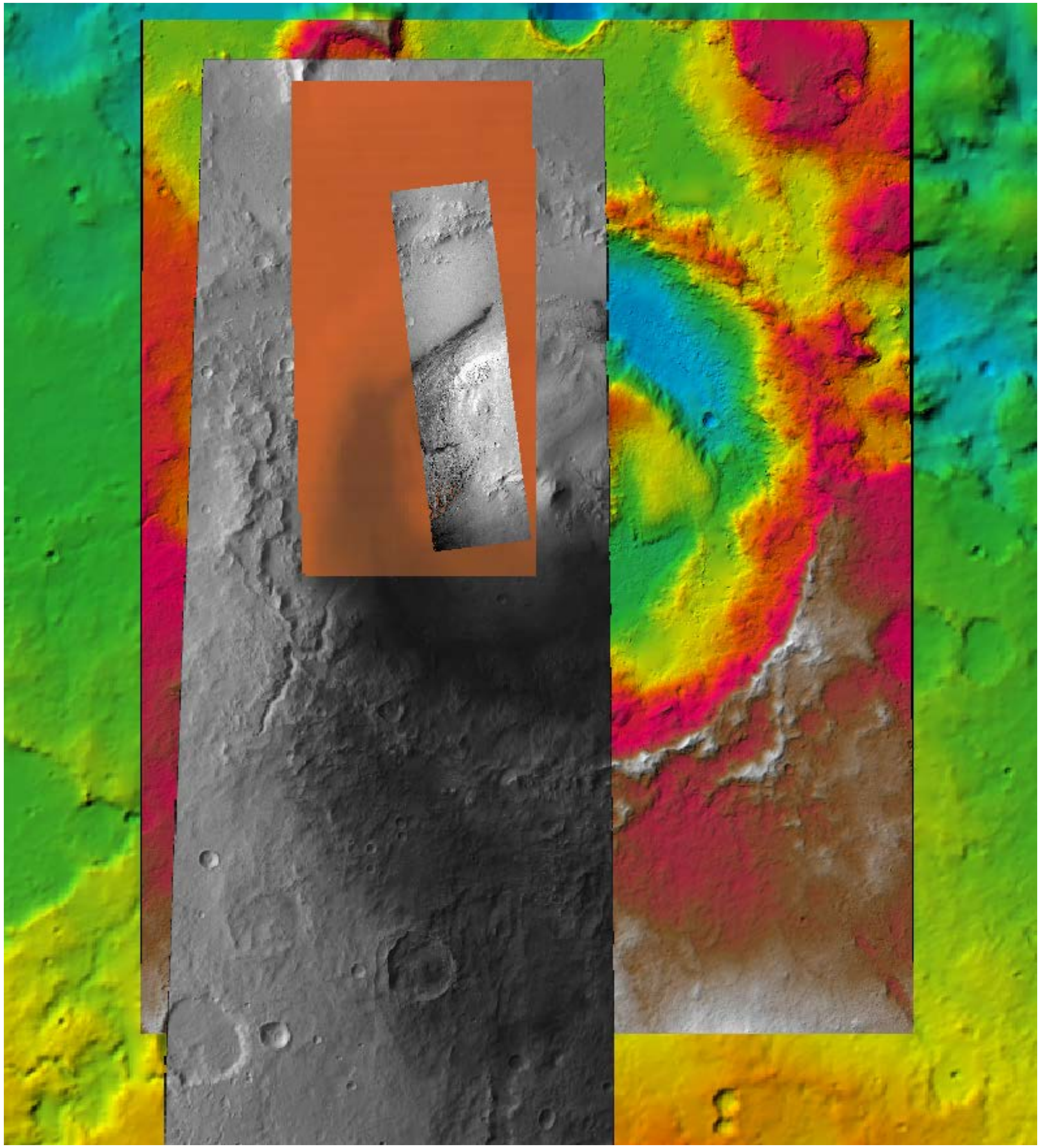
HRSC nadir
25 m/pixel

OMEGA bands 38,25,6
1,85 km/pixel

CTX
5,5 m/pixel

-6000 1000 m (HRSC DTM)
6000 m (MOLA DTM)
Height above Areoid

50 km



Mars image datasets for CROSS-DRIVE Use Case 1

HRSC nadir
25 m/pixel

OMEGA bands 38,25,6
1,85 km/pixel

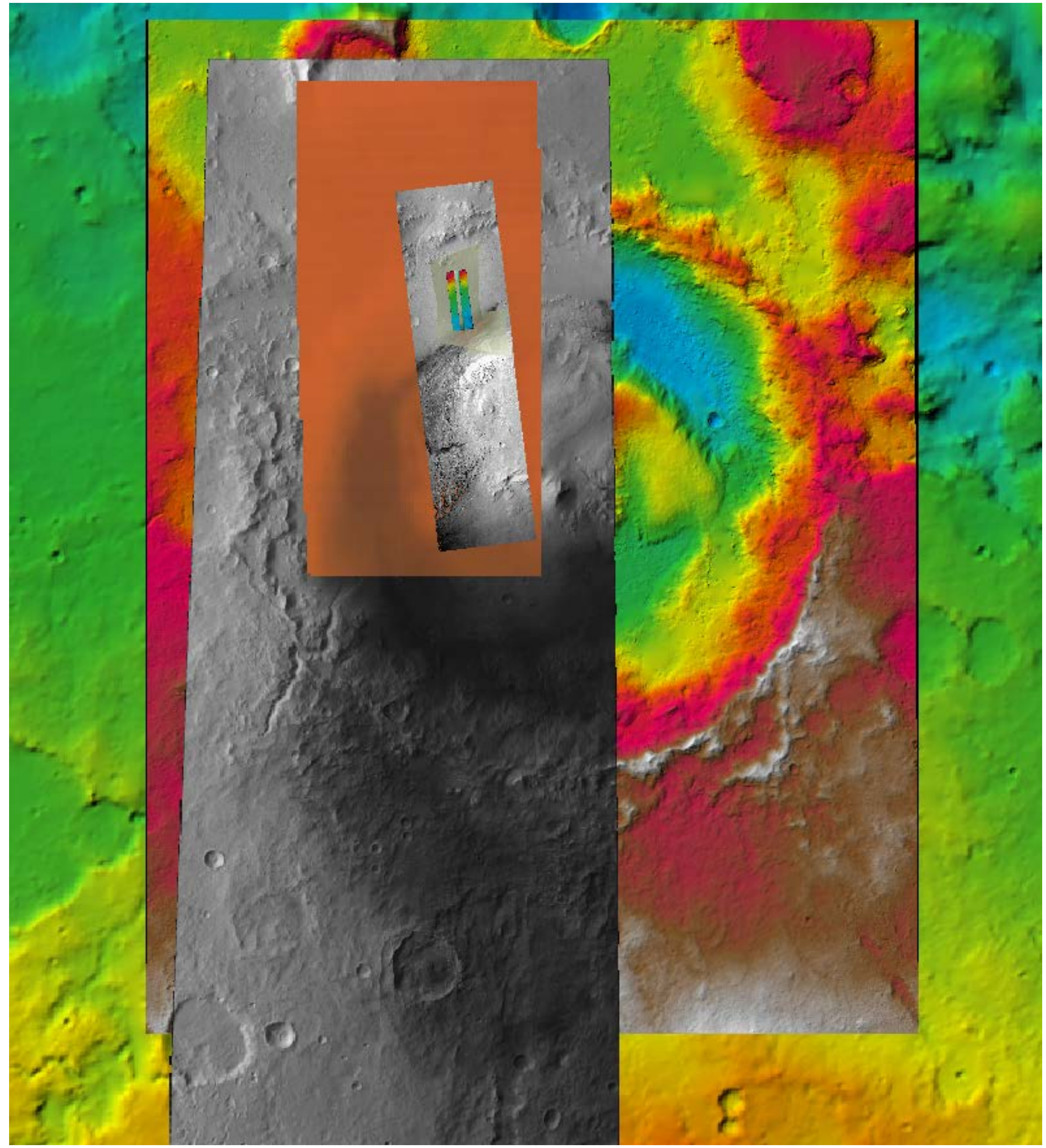
CTX
5,5 m/pixel

CRISM bands 60,40,15
16 m/pixel

HiRISE
0,25 m/pixel
HiRISE DTM 1 m grid

-6000 1000 m (HRSC DTM)
6000 m (MOLA DTM)
Height above Areoid

50 km



Mars image datasets for CROSS-DRIVE Use Case 1

Availability of HRSC Products

- Main distribution channels are the
  - European Planetary Science Archive – **PSA**
  - NASAs Planetary Data System – **PDS**
- These are FTP folder structured archives for planetary science data
- Level 4 products can be identified by the filename

Hoooo_nnnn.DDL.IMG

L = 4
DD = dt, da

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Archives and Search Portals

- http://www.rssd.esa.int/index.php?project=PSA
  - Need to navigate to appropriate data set and FTP listing

Index von ftp://psa.esac.esa.int/pub/mirror/MARS-EXPRESS/HRSC/MEX-M-HRSC-5-REFDR-DTM-V1.0/DATA/

In den übergeordneten Ordner wechseln

Name	Größe	Zuletzt verändert
0010		13.08.2013 00:00:00
0016		13.08.2013 00:00:00
0018		13.08.2013 00:00:00
0022		13.08.2013 00:00:00
0024		13.08.2013 00:00:00
0032		13.08.2013 00:00:00

- http://pds-imaging.jpl.nasa.gov/volumes/mex.html
  - Need to navigate to appropriate FTP folder to download data

PDS Imaging Node

Jet Propulsion Laboratory U.S. Geological Survey

PDS Imaging Node: Data Archive

Name	Last modified	Size	Description
Parent Directory		-	
0010/	20-Aug-2012 08:33	-	
0016/	20-Aug-2012 08:35	-	
0018/	20-Aug-2012 08:41	-	
0022/	20-Aug-2012 08:50	-	

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Data Search Portals

- http://maps.planet.fu-berlin.de/
  - WebGIS locating the footprints of the Level4 Products in the global context
- http://ode.rsl.wustl.edu/mars/
  - Searchtool to locate Mars data of different missions based on a e.g. a bounding box, rover location and other criteria

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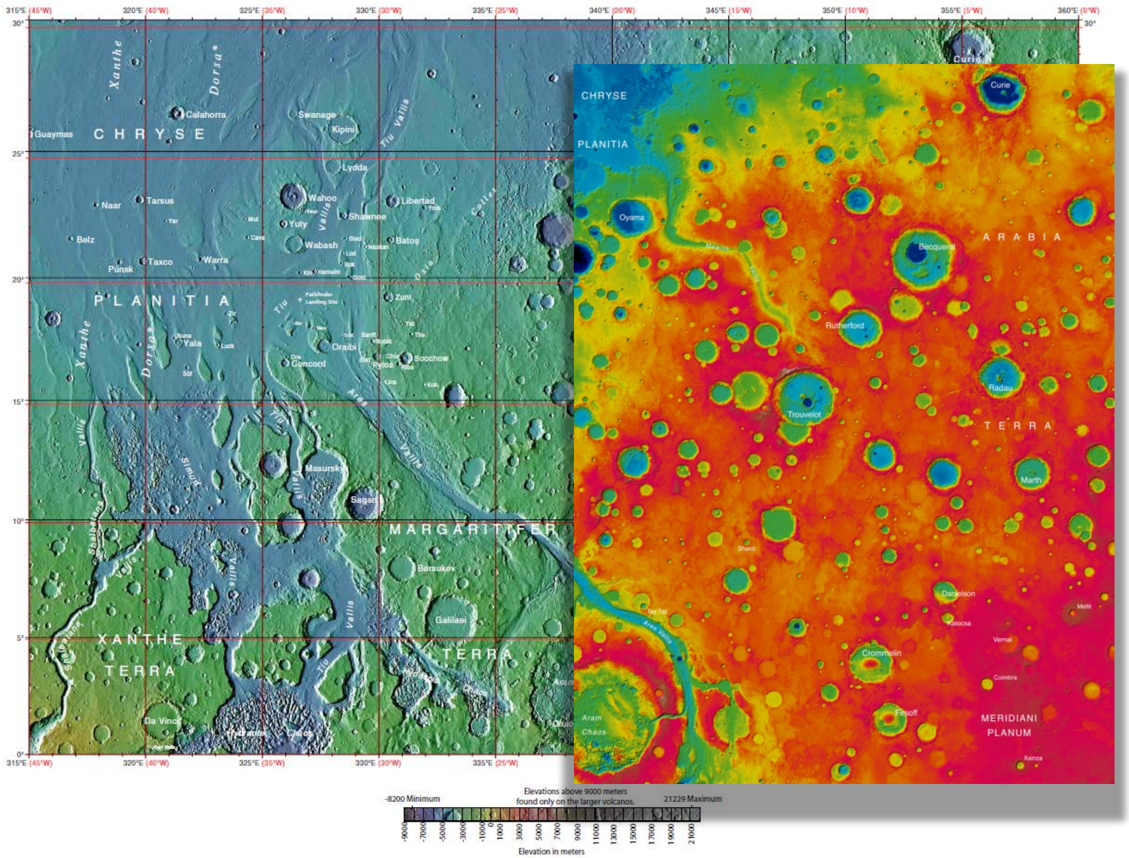
Other known issues …

Comparison of MOLA megt44n270 and MC11E-DTMs with ISIS tools shows apparent offsets (1 pixel sample direction, 3 pixels line direction)



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Reference systems in planetary image maps: PDS/Vicar and ISIS/GDAL definitions

PDS Definition of Line_Projection_Offset and Sample_Projection_Offset:

The line_projection_offset element provides the line offset value of the map projection origin position from the line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array). Note: that the positive direction is to the right and down.
Sources:
http://pds.nasa.gov/tools/ddlookup/data_dictionary_detail.cfm?ResultsSelBox=line_projection_offset
http://pds.nasa.gov/documents/psdd/PSDDmain_1r71.pdf [Page 94]

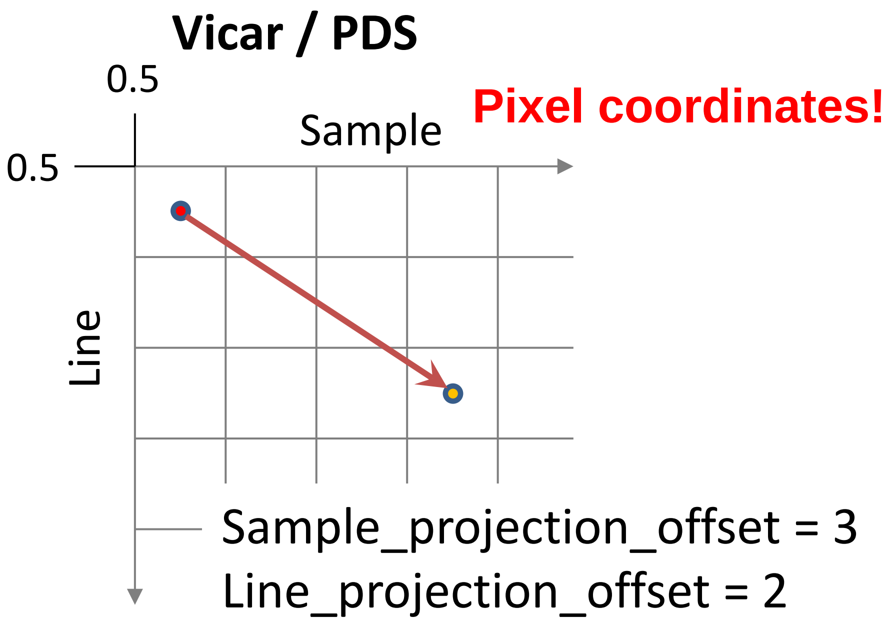
Note that integral values of line and sample correspond to center of a pixel. Lat and lon are the latitude and longitude of a given spot on the surface.
Source:
http://pds.nasa.gov/documents/sr/stdref3.7/StdRef_20060320.v3.7.pdf [Page B-23]

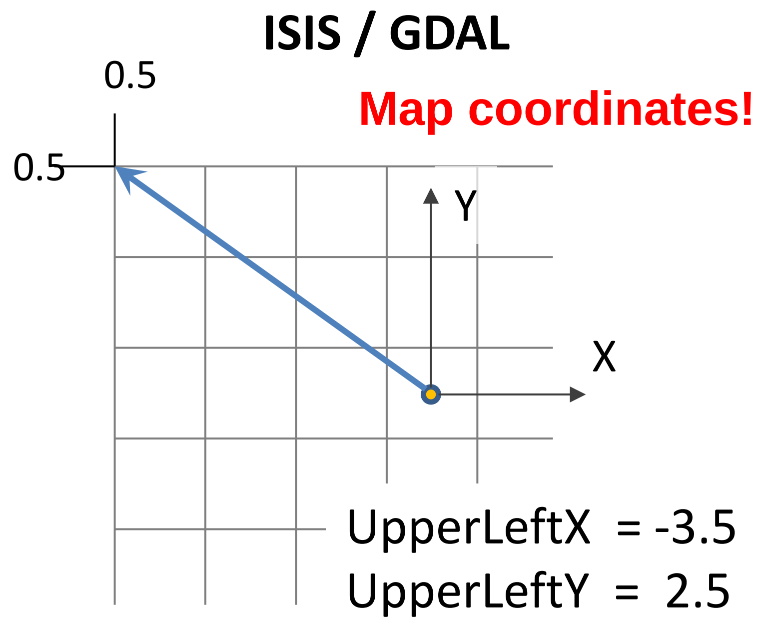
ISIS DEFINITION OF ULX and ULY:

These values indicate the projection X/Y in meters at sample 0.5, line 0.5.
Projection X
Projection X is the x-coordinate (Easting) for a point on a geographic Cartesian coordinate system
Projection Y
Projection Y is the y-coordinate (Northing) for a point on a geographic Cartesian coordinate system
Sources: http://isis.astrogeology.usgs.gov/documents/Glossary/Glossary.html#ProjectionX ;
http://isis.astrogeology.usgs.gov/documents/LabelDictionary/LabelDictionary.html

NOTE that when selecting a SAMPLE and LINE for referencing known coordinates to a pixel, pixel coordinate (0.5, 0.5) is the top-left corner of the top-left pixel in the cube. By extension, (1.0, 1.0) is the center of the top-left pixel, and (1.5, 1.5) is the lower-right corner of the top-left pixel.

Source: http://isis.astrogeology.usgs.gov/Application/presentation/Tabbed/maplab/maplab.html





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Specifications for HRSC single-strip and multi-orbit data products

	Single-strip DTM	Single strip Orthoimage	Multi-orbit DTMs	Orthoimage mosaics
Product Subtypes	Spheroid DTM Areoid DTM	Panchromatic (Nadir), Red, Green, Blue and Near-Infrared Channel Orthoimages	Spheroid DTM Areoid DTM	Panchromatic nadir mosaic Pan-sharpened color mosaic
Data Format	16 bit, numeric height resolution 1 m	8 bit	16 bit, numeric height resolution 1 m	16 bit
Spatial Resolution	50 / 75 / 100 m … depending on quality of image and orientation data	12.5 / 25 / 50 m … depending on ground resolution	50-100 m	depending on subtype 12.5 m (pan) max 50 m (col)
Reference Bodies for Height	Spheroid r = 3396 km and GMM3-derived equipotential surface (Areoid DTM)	n/a	Spheroid r=3396 km and GMM3-derived equipotential surface (Areoid DTM)	n/a
Reference Body for Map Projection	Spheroid r = 3396 km	Spheroid r = 3396 km	Spheroid r = 3396 km	Spheroid r = 3396 km
Map Projection	Sinusoidal (±85° latitude) Polar-Stereographic (polar areas)	Sinusoidal (±85° latitude) Polar-Stereographic (polar areas)	Equidistant Cylindrical (±57° latitude) Polar Stereographic (polar areas)	Equidistant Cylindrical (±57° latitude) Polar Stereographic (polar areas)

Gwinner et al., PSS, 2016

Publications

- Bostelmann J., Heipke C., 2014. Analysing blocks of HRSC strips for a simultaneous bundle adjustment. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2(4), 15-20.
- Gwinner, K., R. Jaumann, J. Bostelmann, A. Dumke, S. Elgner, C. Heipke, E. Kersten, G. Michael, F. Preusker, T. Roatsch, R. Schmidt, F. Scholten, M. Spiegel, S. van Gasselt, S.H.G. Walter, HRSC Global Topography and Mosaic Generation Task Group, 2015. The first Quadrangle of the Mars Express HRSC Multi Orbit Data Products (MC-11-E). EPSC 2015.
- Gwinner, K. and 34 co-authors, The High Resolution Stereo Camera (HRSC) of Mars Express and its Approach to Science Analysis and Mapping for Mars and its Satellites. Planetary and Space Science 126, 2016, 93-138. http://dx.doi.org/10.1016/j.pss.2016.02.014
- Michael, G., Walter, S., McGuire, P., Kneissl, T., van Gasselt, S., Gross, C. , Schreiner, B. , Zuschneid, W., 2015. Systematic procesing of Mars Express HRSC image mosaic quadrangles. Lunar Planet. Sci. XXXVI, #2387.
- Walter, S.H.G., Michael, G., van Gasselt, S., Kneissl, T., 2015. Photometric Lambert correction for global mosaicking of HRSC image data. Lunar Planet. Sci. XXXVI, #1434.