HRSC 3D MAPPING PRODUCTS INCLUDING LARGE AREA MOSAICS

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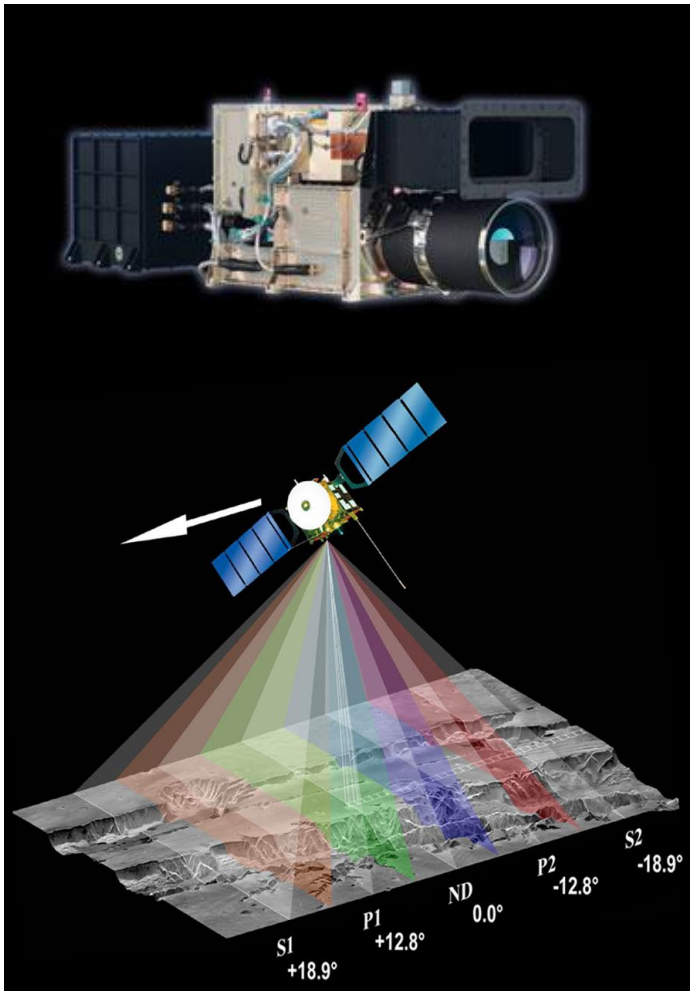
HRSC on Mars Express



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

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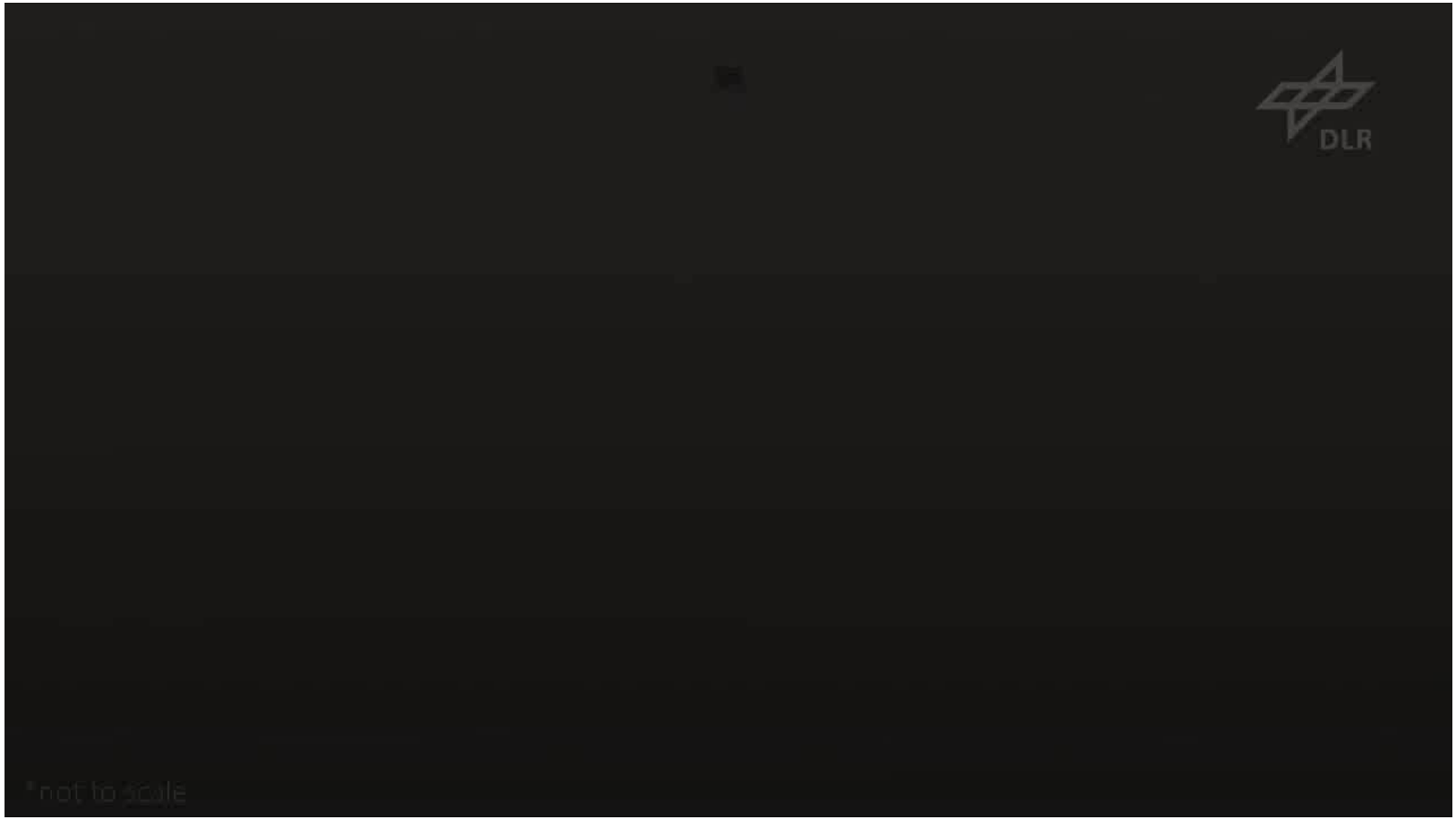
“How to map a planet?”



Web movie on how HRSC images and products are produced

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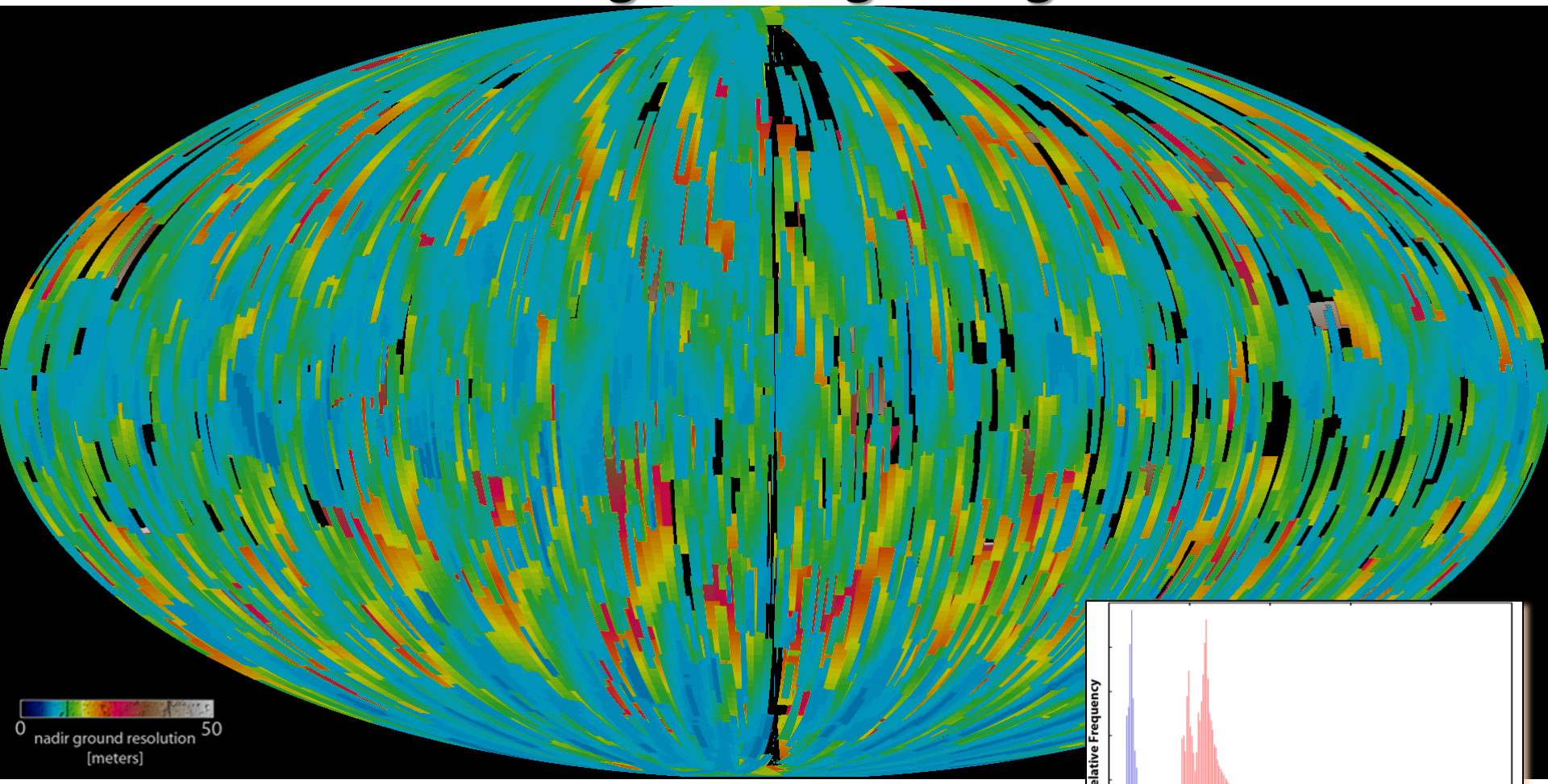
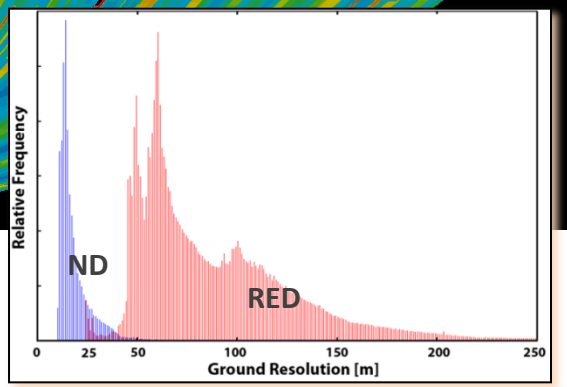
Global Mars HRSC image coverage and ground resolution





Mean ground res.: 18.3 m
up to orbit 12334

Coverage: 95.4% (99% < 54 m)

Types of HRSC Map Products

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., 2016, PSS

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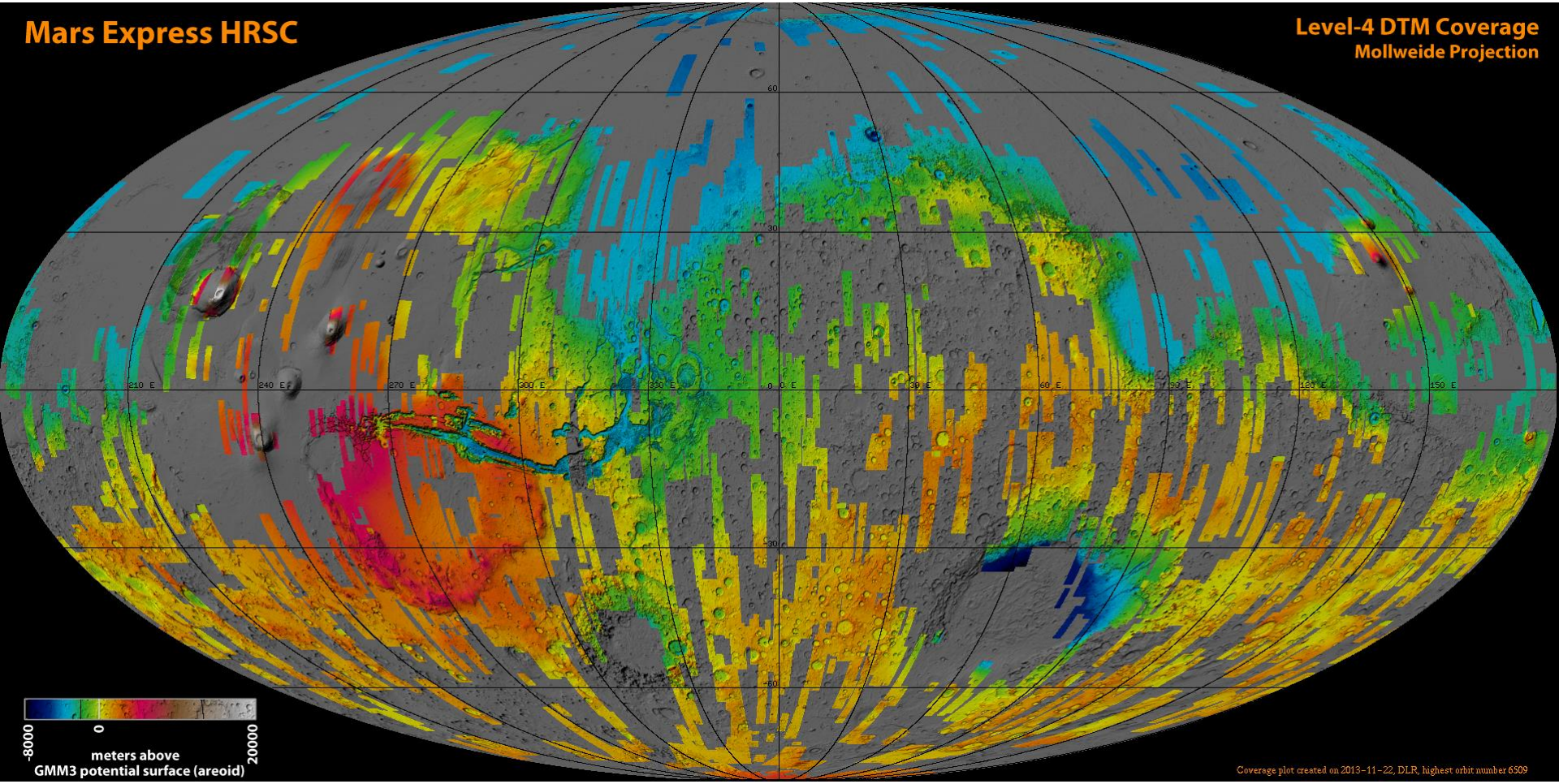
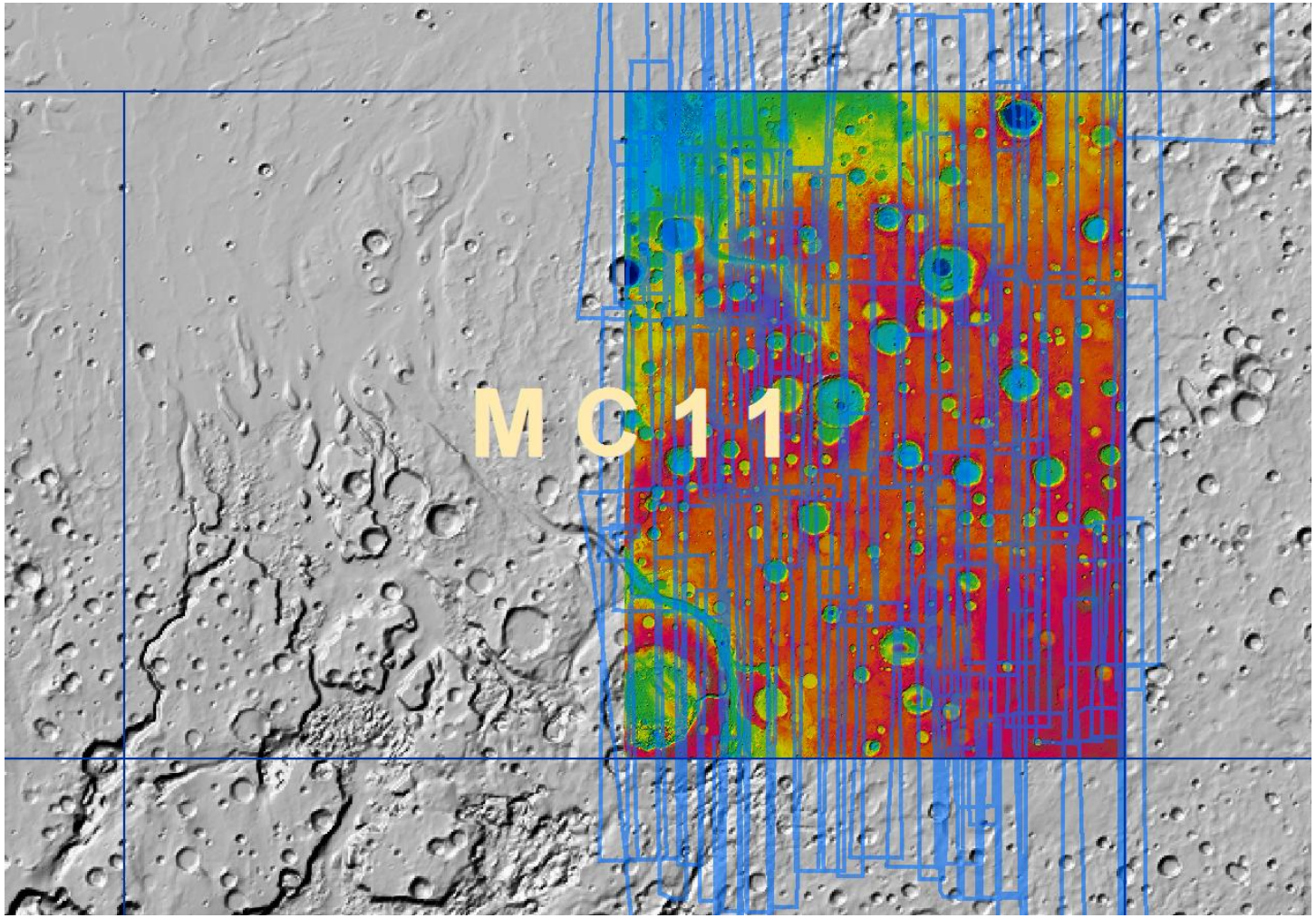
HRSC Level-4 DTM coverage up to orbit 6509



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

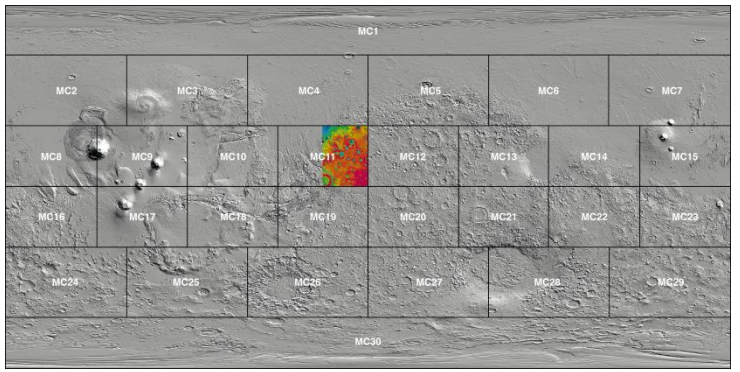
Regional data products from continuous HRSC Coverage

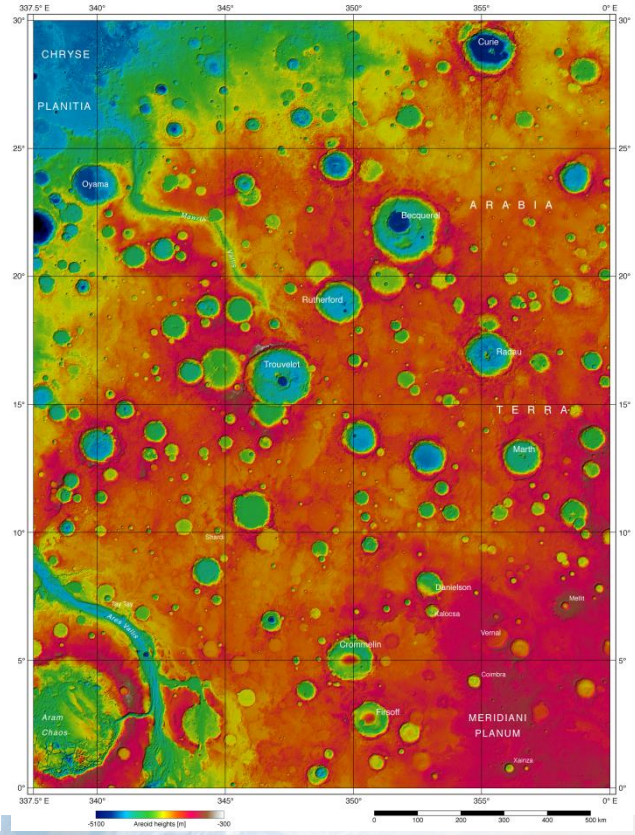


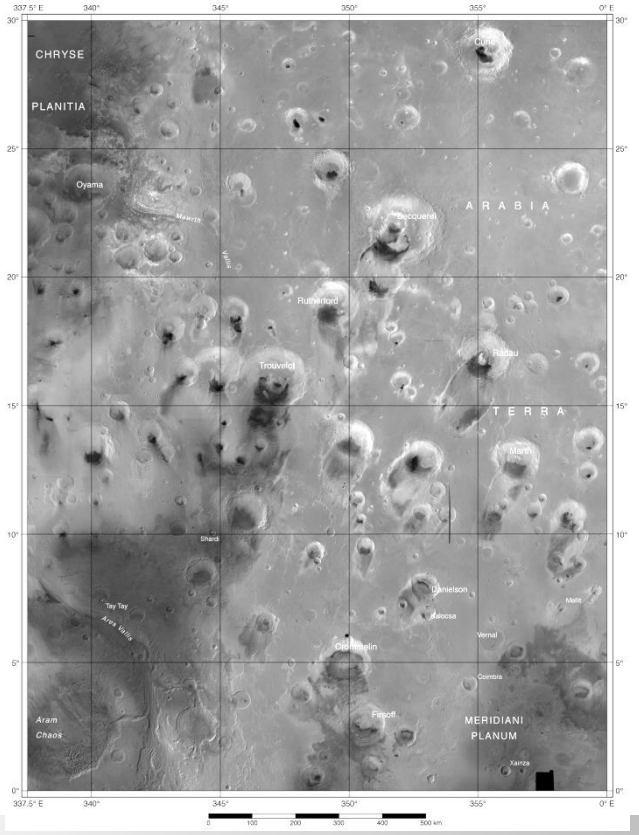
Coverage of MC11-E by HRSC image strips (89 orbits)

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

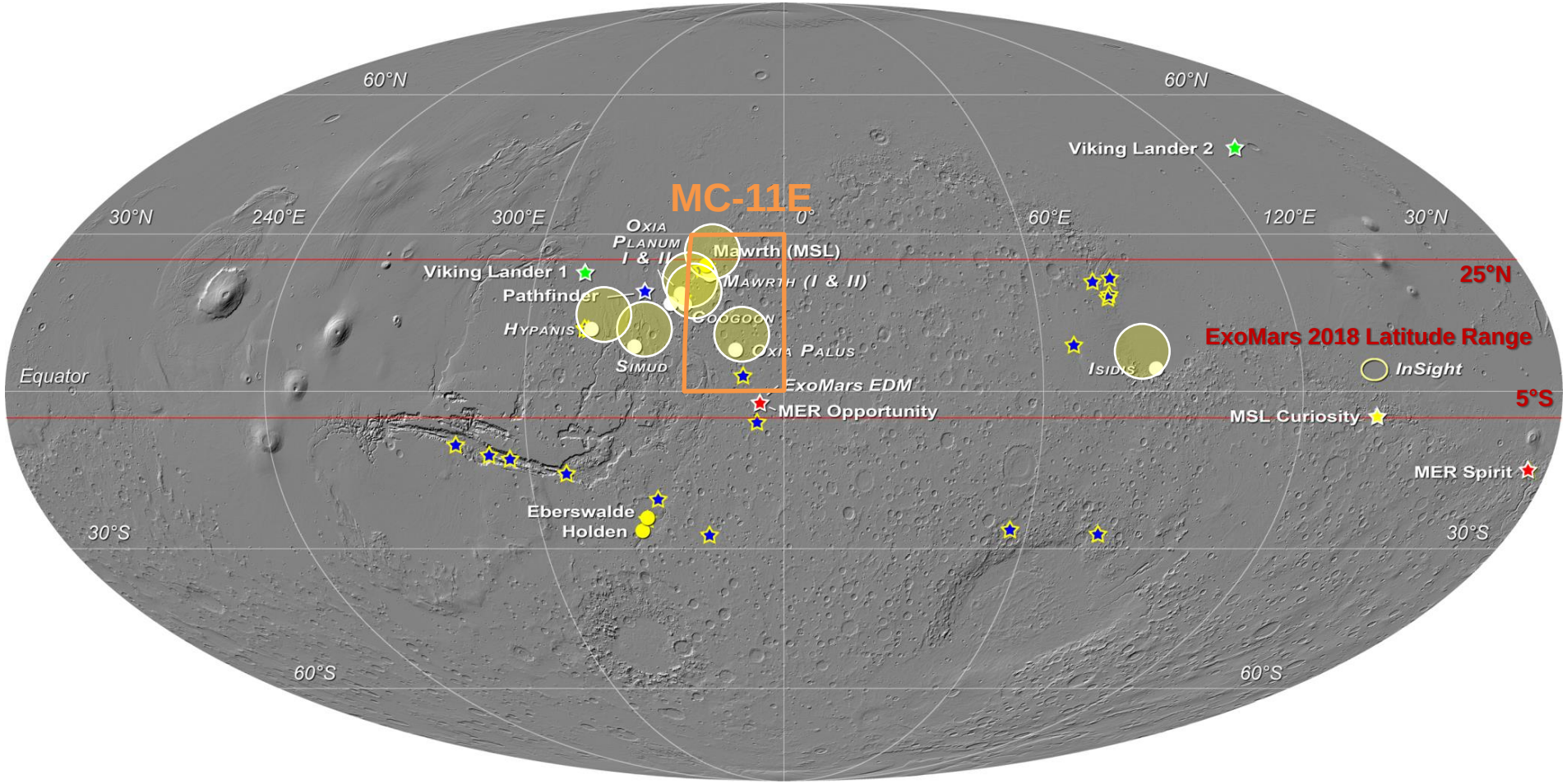
- Coordinated mapping effort of the Global Topography and Mosaics Task Group of the HRSC Science Team
- MC30 half-tiles as basic subdivision
- Equidistant Cylindical projection (Stereographic in polar areas)
- Grid spacing 50 m (DTM and color), 12.5 m (panchrom.)



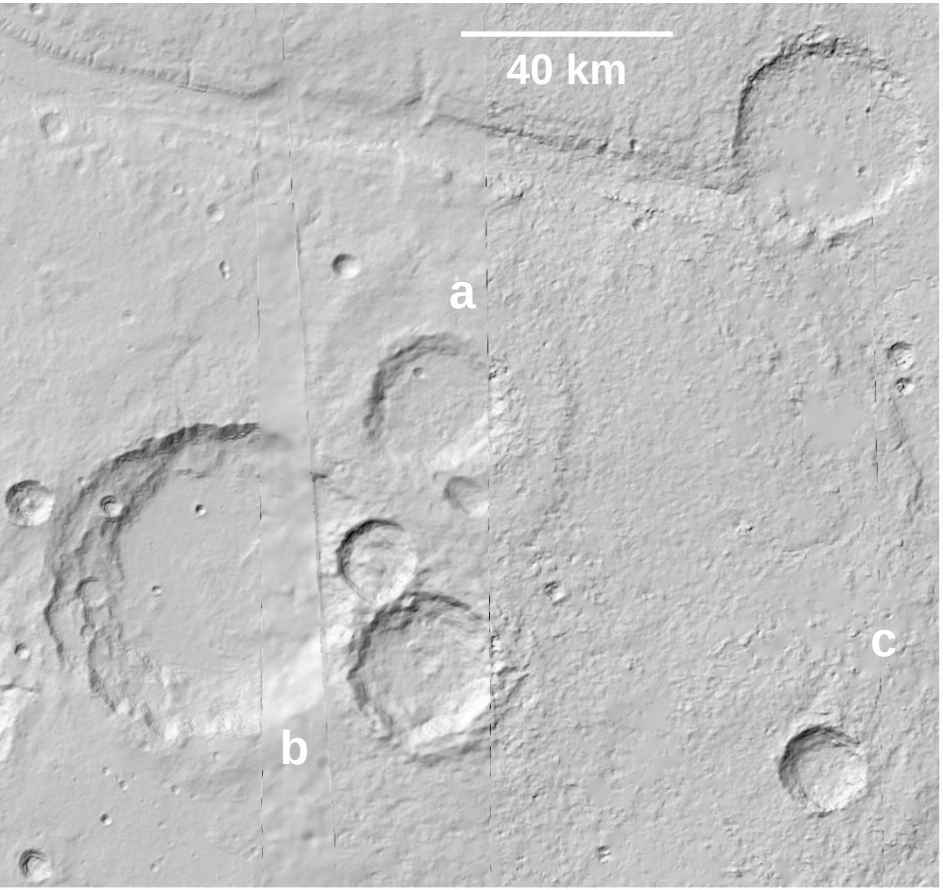




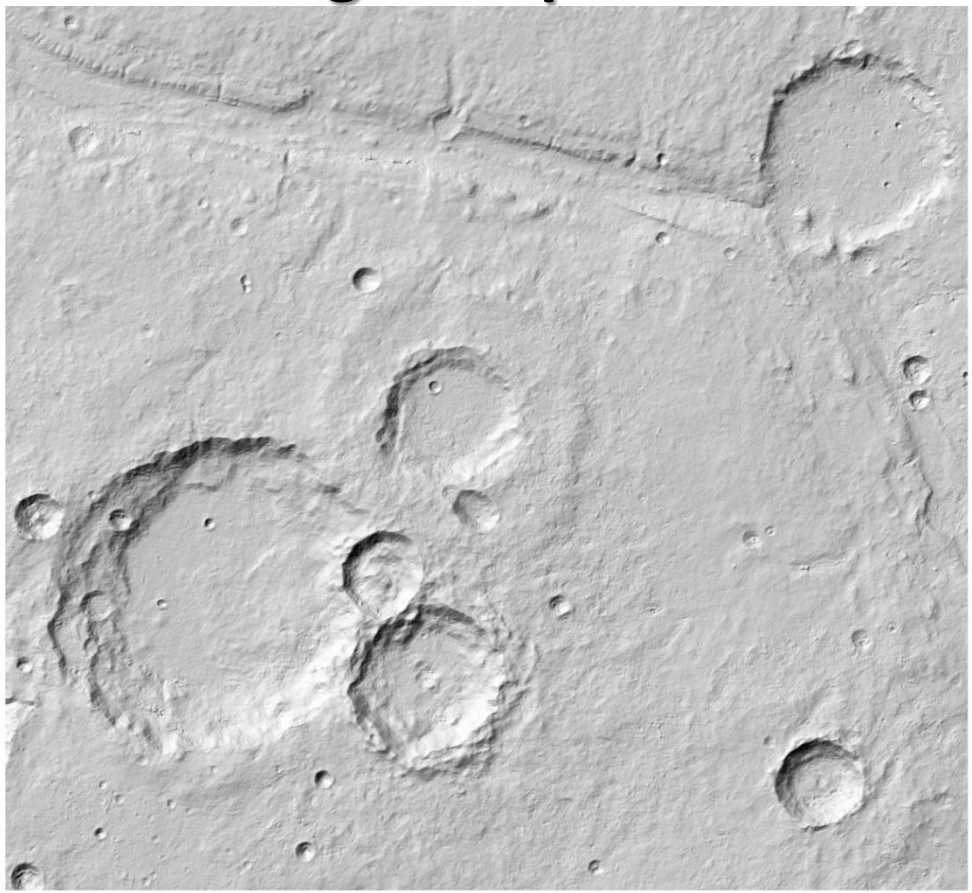
Mars landing sites and landing site proposals



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*

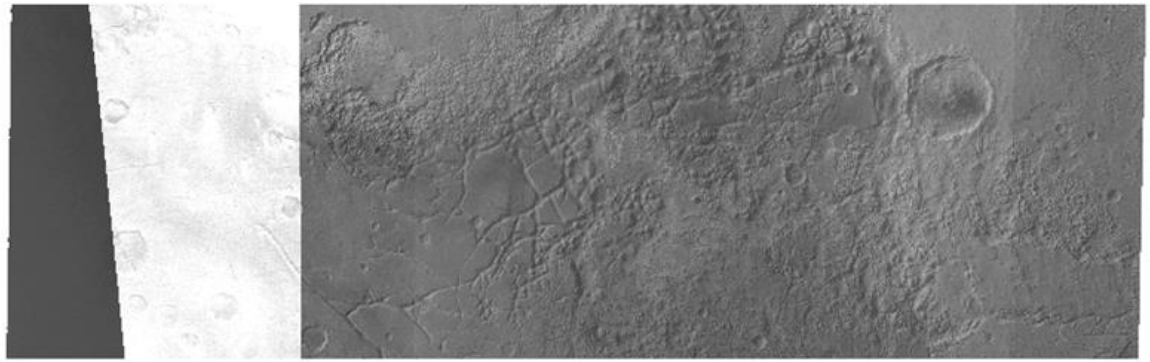
(b) *avoids masking of higher resolution datasets by lower resolution datasets*

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

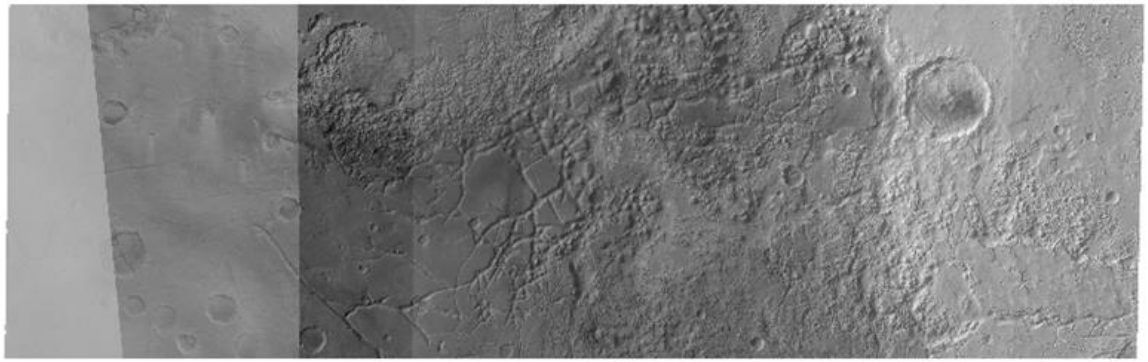
Gwinner et al., 2016, PSS

Processing steps for radiometric adjustment

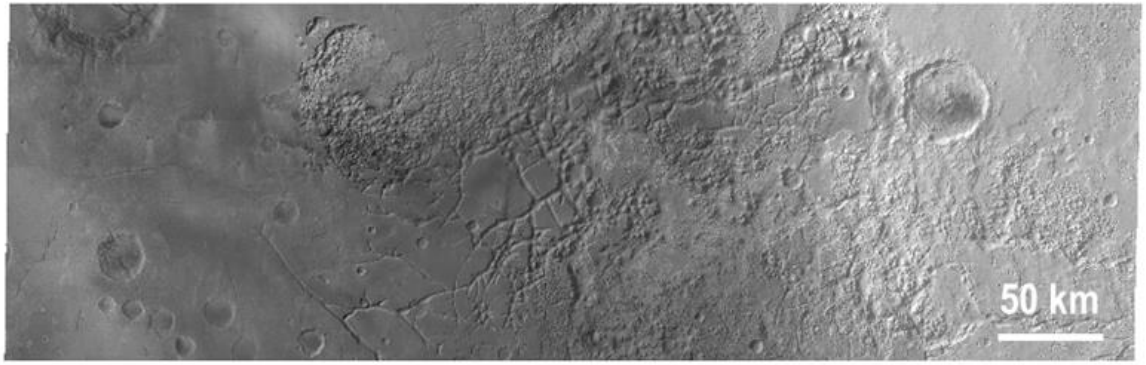
Calibrated orthoimage:
grey values scaled to
Physical units (radiance)



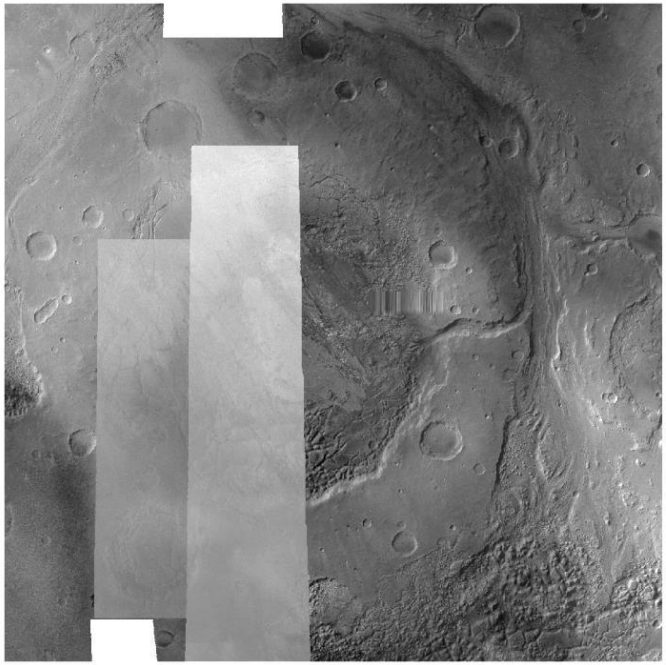
Lambert normalization:
simple physics-based
image modelling



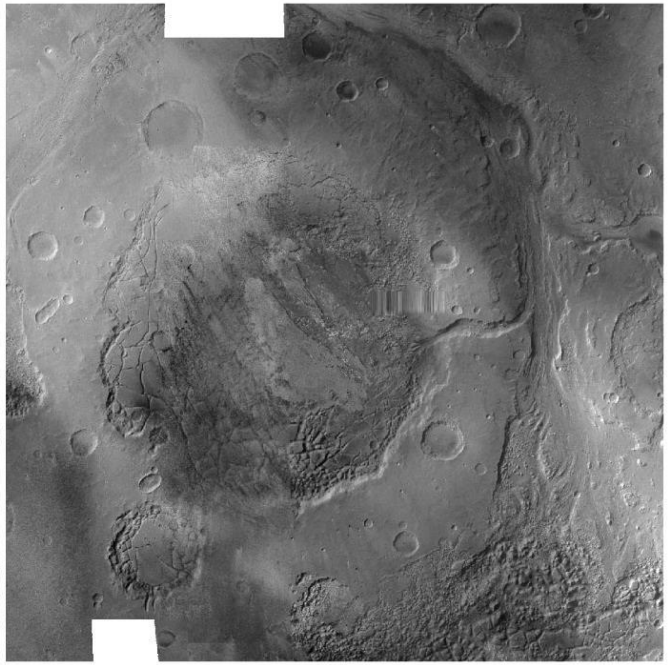
Adjustment to external brightness standard and elimination of edges:
physical units are lost
in favour of consistent
visual appearence



Generation of seamless image mosaics

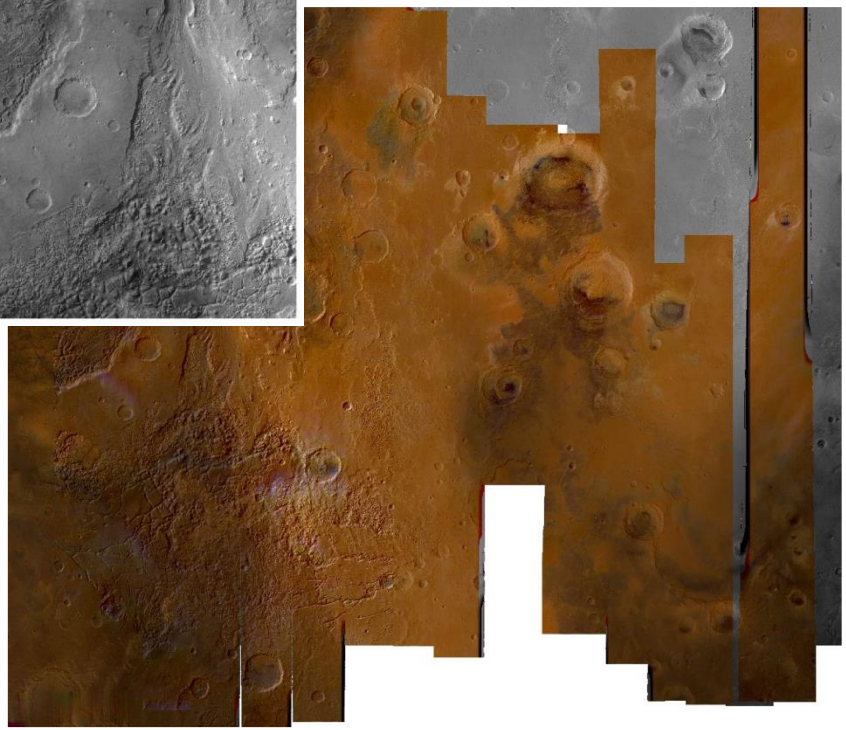


Mosaic with overlaid very low contrast images



Contrast adjusted

Normalized color image mosaic



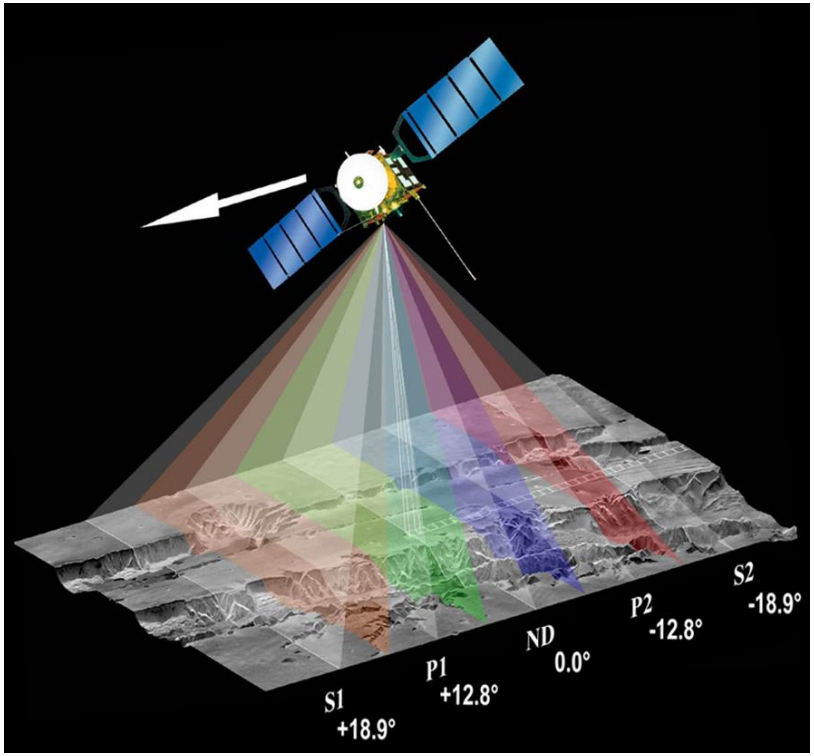
Contrast adjustment method of Michael et al., 2015

Main characteristics of existing HRSC DTMs

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

Backup
Background Info

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

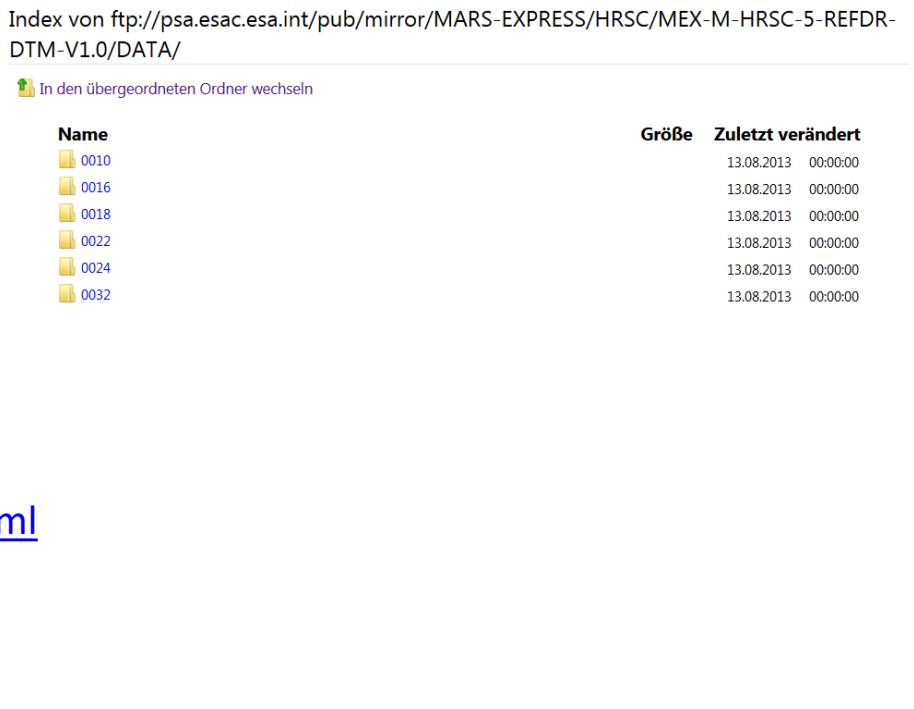
** longer exposure times technically feasible, but not realized due to dark current*

Specifications for HRSC single-strip and multi-orbit data

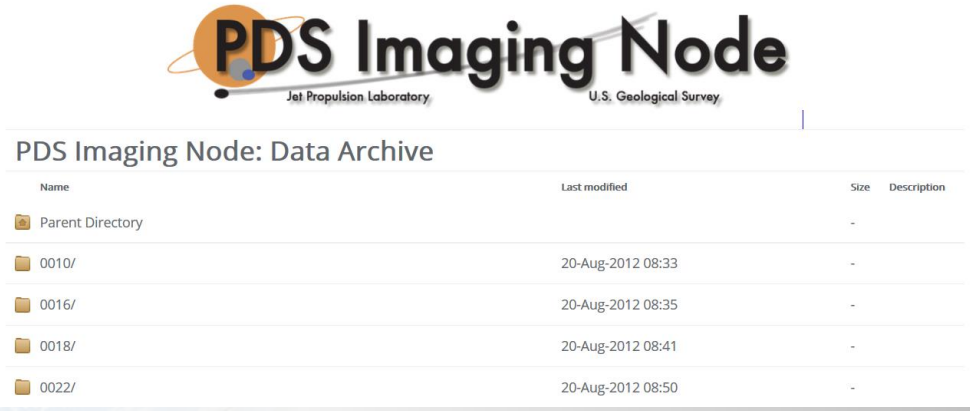
	Single-strip DTM	Single strip Orthoimage	Multi-orbit DTMs	Orthoimage mosaics
Product Subtypes	Spheroid DTM Areoid DTM	Panchromatic (Nadir), Red, Green, Blue and Near-Infrared Channel Orthoimages	Spheroid DTM Areoid DTM	Panchromatic nadir mosaic Pan-sharpened color mosaic
Data Format	16 bit, numeric height 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)

Archives and Search Portals

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



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



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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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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, 2016. 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.