

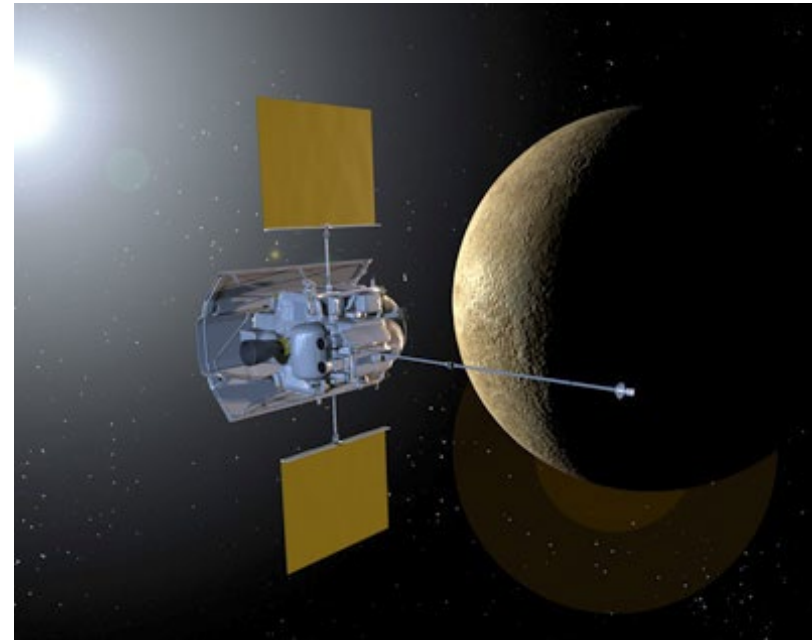
# High-resolution topography from MESSENGER orbital stereo imaging – The Southern hemisphere

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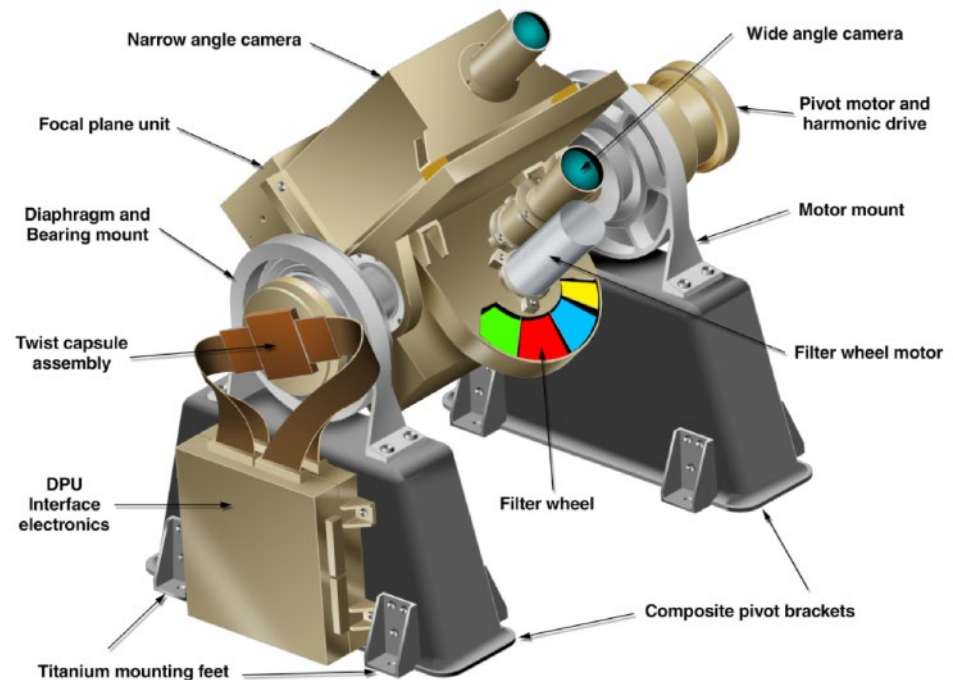
# MESSENGER Mission

- **M**ercury **S**urface, **S**pace **E**nvironment, **G**eochemistry, and **R**anging
  - Launch: 08/2004
  - Flybys: 01/2008, 10/2008 and 09/2009  
(Oberst et al., 2010; Preusker et al., 2011)
  - Orbit insertion: 03/2011
  - Almost 4 years of orbit operations
- One measurement goal of the mission: **global/topographic mapping**
- Main techniques: laser ranging and **stereo imaging**
- Due to MESSENGER's eccentric (polar) orbit, laser altimeter tracks are widely spaced near the equator and do not cover most of the southern hemisphere



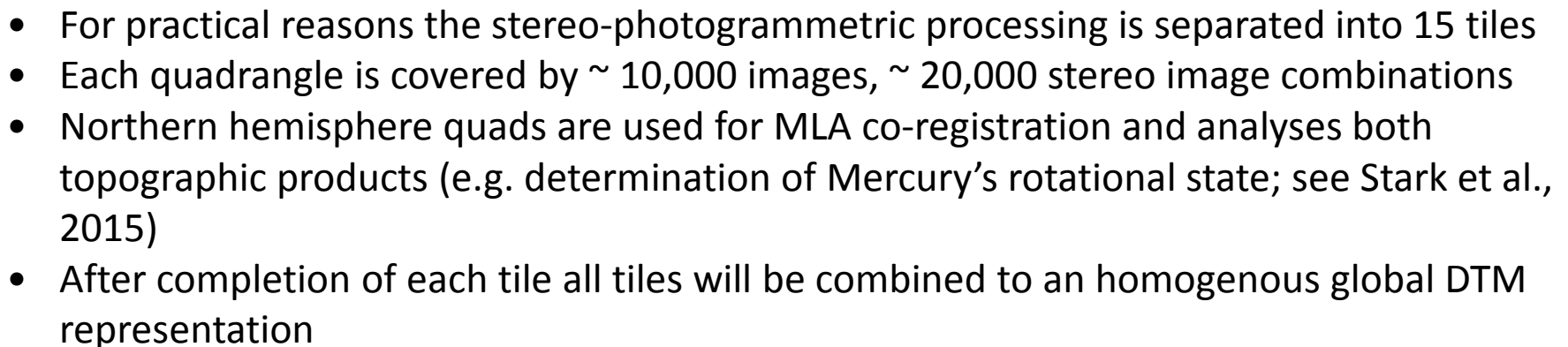
# MESSENGER Camera

- **Mercury Dual Imaging System (MDIS)** acquired more than 200,000 images
- Narrow Angle Camera (NAC) and Wide Angle Camera (WAC)
- Imaging by WAC or NAC is to optimize coverage vs. resolution from MESSENGER's elliptic orbit
- Global (stereo) coverage at resolution better than 250 m/pixel

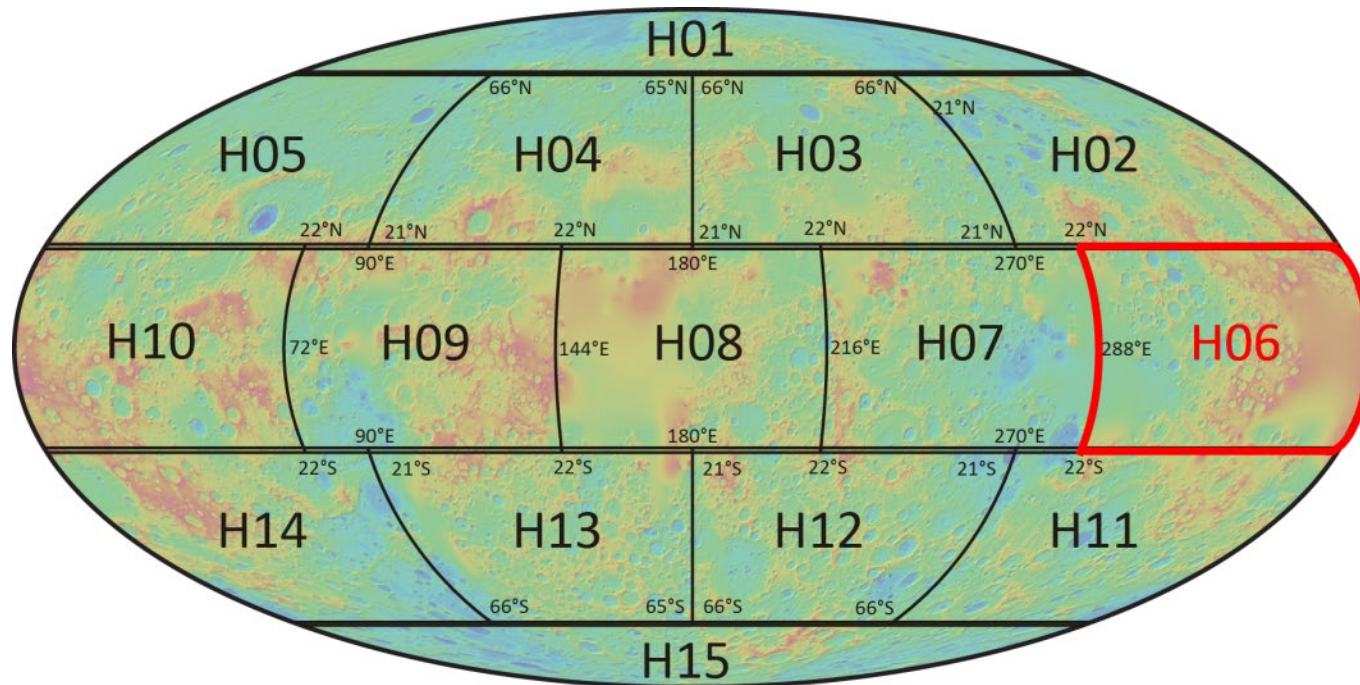


# Motivation

- Global high-res topographic base map for Mercury
  - Complementary to MLA in the northern hemisphere
  - Quantitative geomorphologic analysis (impact basin morphology, tectonic etc.)
  - for precise ortho-image registration, mosaicking, and map generation of monochrome/color MDIS images (or other instruments, e.g. MASCS)
  - Preparation for ESA mission BepiColombo



# Processing Strategy



- H6 was chosen as “Prototype” for quadrangle processing
- Delivered to PDS in 2016 (see [https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-dem-elevation-v1.0/MESSDEM\\_1001/DEM/QUAD/IMG/](https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-dem-elevation-v1.0/MESSDEM_1001/DEM/QUAD/IMG/))
- Published this year (Preusker et al., Toward high-resolution global topography of Mercury from MESSENGER orbital stereo imaging: A prototype model for the H6 (Kuiper) quadrangle, Planetary and Space Science, Volume 142, p. 26-37, 2017.)



- **Identification of suitable stereo image data set**
- Sparse multi-image matching
- Bundle block adjustments
- High-density multi-image matching
- Generation of surface points
- Interpolation of surface points for gridded DTMs

From H6 Kuiper (Preusker et al., 2017):

- ~10,500 NAC and WAC images;  
average resolution: 150 m/pixel
- ~21,100 stereo image combinations,  
at least three images each.

| Parameter                   |           |
|-----------------------------|-----------|
| Differences in illumination | < 10°     |
| Stereo angle                | 15° - 55° |
| Incidence angle             | 5° - 85°  |
| Emission angle              | 0° - 55°  |
| Phase angle                 | 5° - 160° |

- Identification of suitable stereo image data set
- **Sparse multi-image matching**
- Bundle block adjustments
- High-density multi-image matching
- Generation of surface points
- Interpolation of surface points for gridded DTMs

From H6 Kuiper (Preusker et al., 2017):

- ~250,000 tie-points between more than 3 images, respectively, representing ~50,000 surface points



- Identification of suitable stereo image data set
- Sparse multi-image matching
- **Bundle block adjustments**
- High-density multi-image matching
- Generation of surface points
- Interpolation of surface points for gridded DTMs

From H6 Kuiper (Preusker et al., 2017):

- Improve nominal s/c position and pointing data for each image
- Improved accuracy of the surface point positions from ~850 m to ~55 m.

- Identification of suitable stereo image data set
- Sparse multi-image matching
- Bundle block adjustments
- **High-density multi-image matching**
- Generation of surface points
- Interpolation of surface points for gridded DTMs

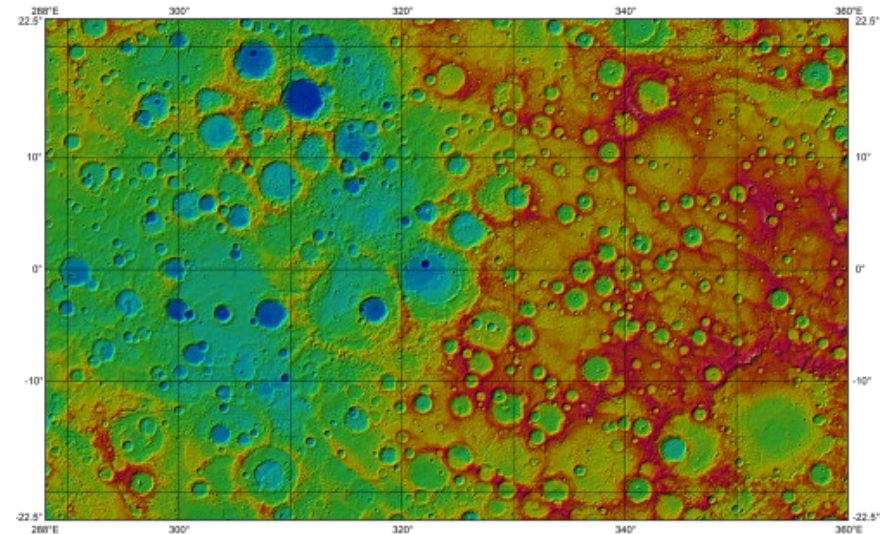
From H6 Kuiper (Preusker et al., 2017):

- High-density (pixel-by-pixel) multi-image matching: ~45 billion tie-points, representing ~6.3 billion surface points

- Identification of suitable stereo image data set
- Sparse multi-image matching
- Bundle block adjustments
- High-density multi-image matching
- **Generation of surface points**
- **Interpolation of surface points for gridded DTMs**

Data for H06 Kuiper (Preusker et al., 2017):

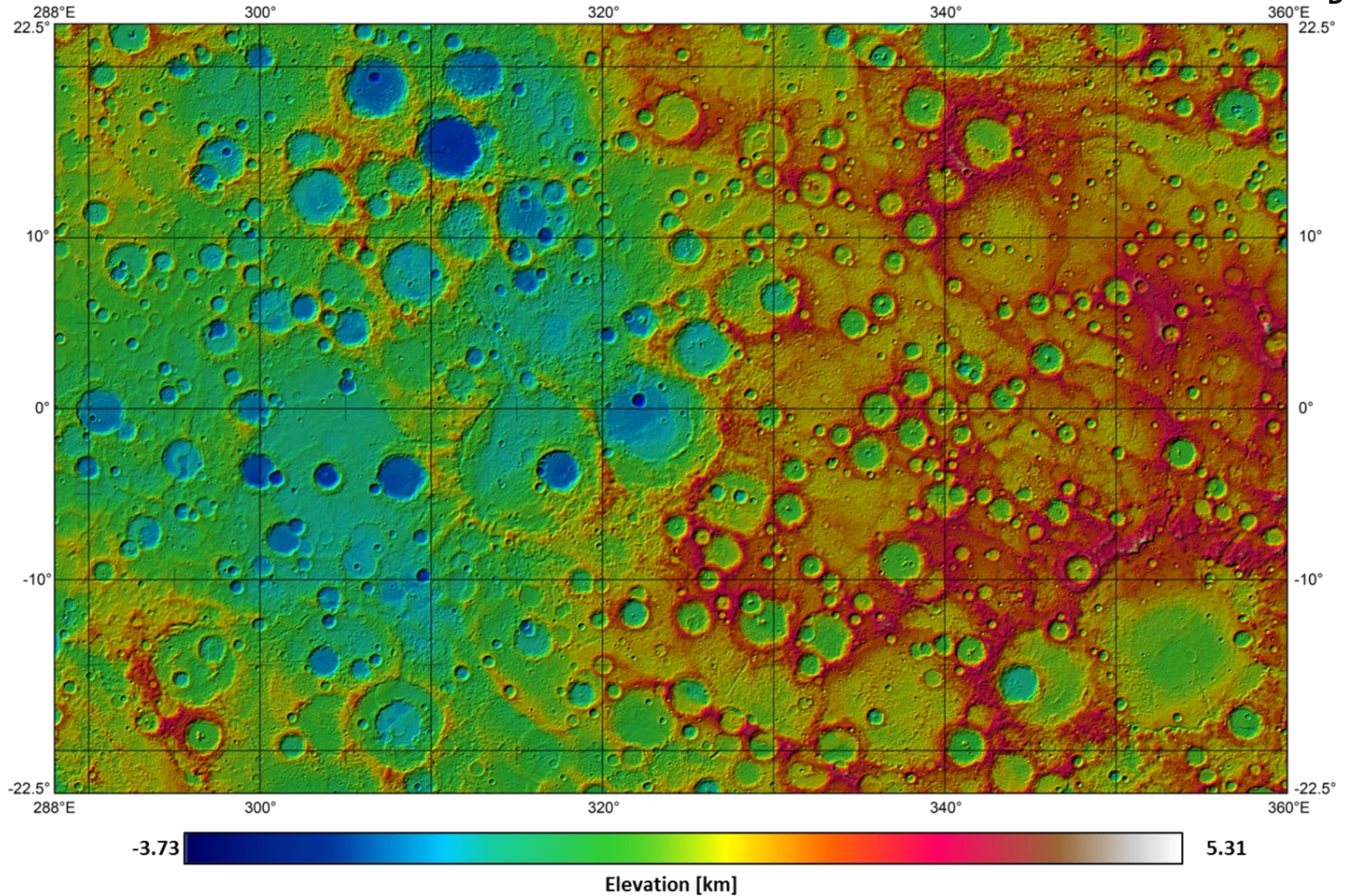
- In total ~6.3 billion surface points generated
- DTM lateral spacing of 221.7 m/pixel (192 pixels per degree) and a vertical accuracy of about 30 m



**Preusker et al.**, Toward high-resolution global topography of Mercury from MESSENGER orbital stereo imaging: A prototype model for the H6 (Kuiper) quadrangle, **Planetary and Space Science**, Volume 142, p. 26-37, **2017**.

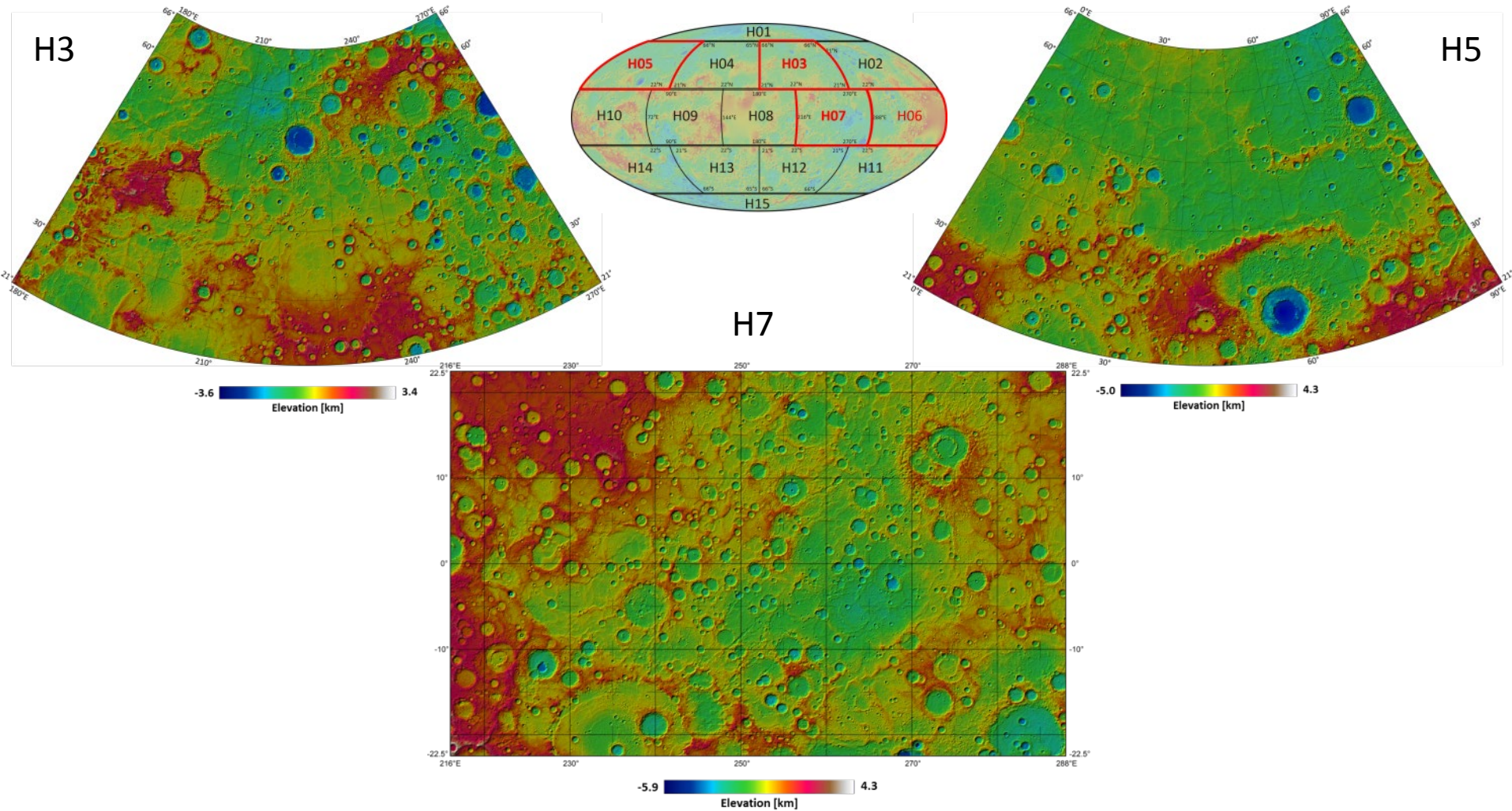


# H06 (“Kuiper”)



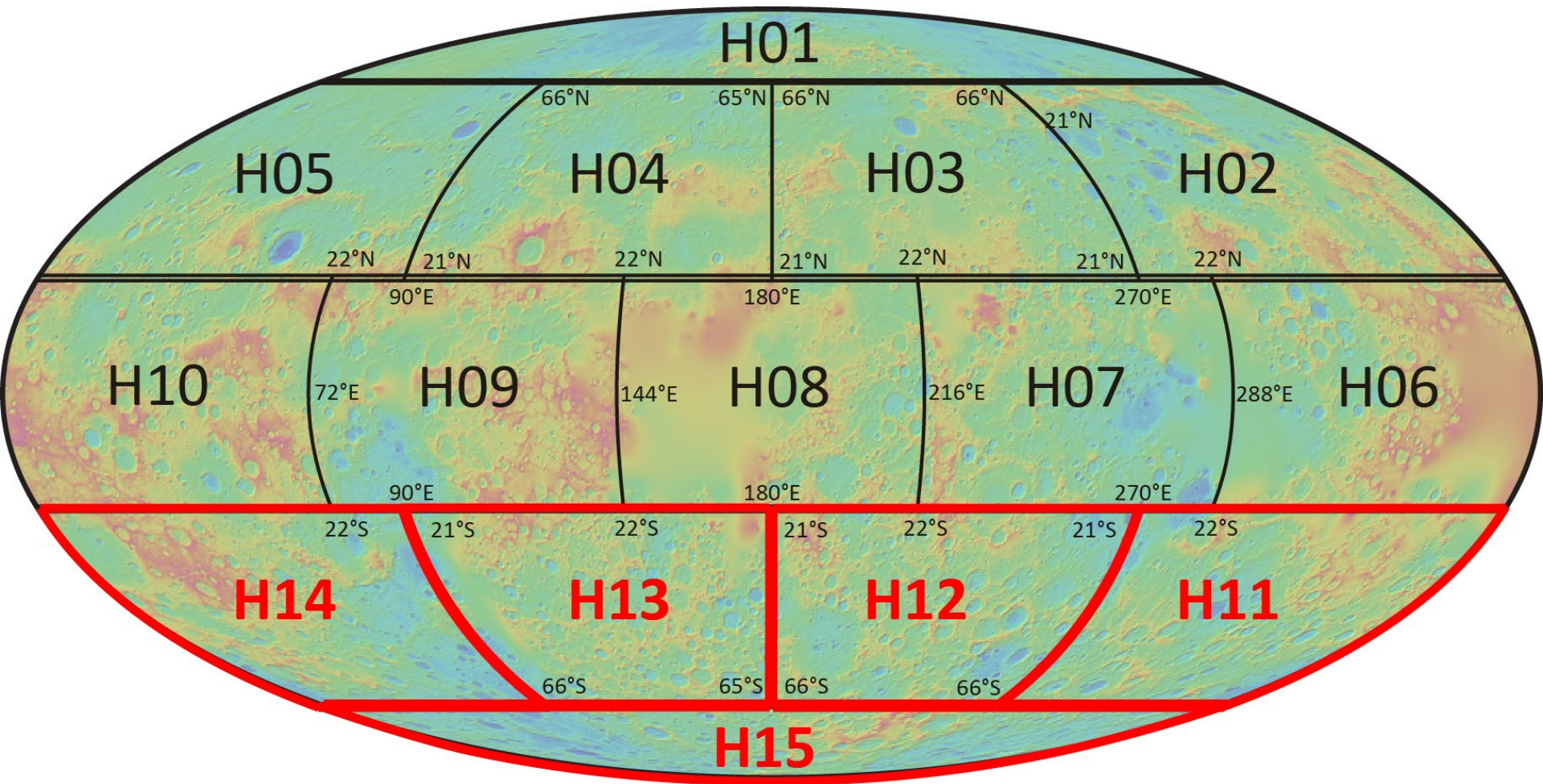


# Other Quadrangle delivered



- We now processed quadrangles H3 “Shakespeare”, H5 “Hokusai”, and H7 “Beethoven”, delivered to PDS in March 2017
- [https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-dem-elevation-v1.0/MESSDEM\\_1001/DEM/QUAD/IMG/](https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-dem-elevation-v1.0/MESSDEM_1001/DEM/QUAD/IMG/)

# Status of Southern hemisphere quadrangles

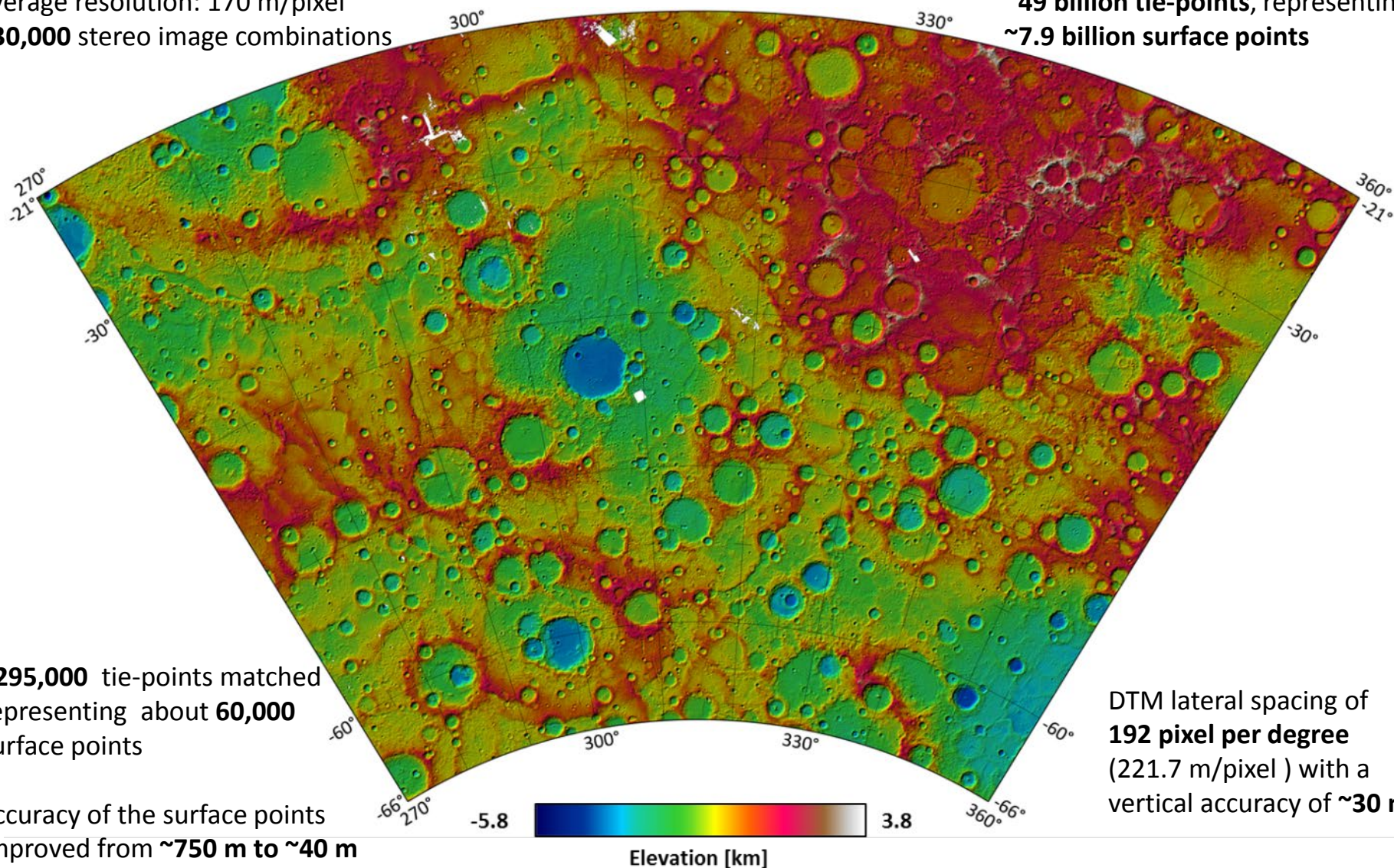




# H11 (“Discovery”)

~**6000 NAC** images and ~**70 WAC** images used with  
average resolution: 170 m/pixel  
~**30,000** stereo image combinations

High-density multi-image matching:  
~**49 billion tie-points**, representing  
~**7.9 billion surface points**

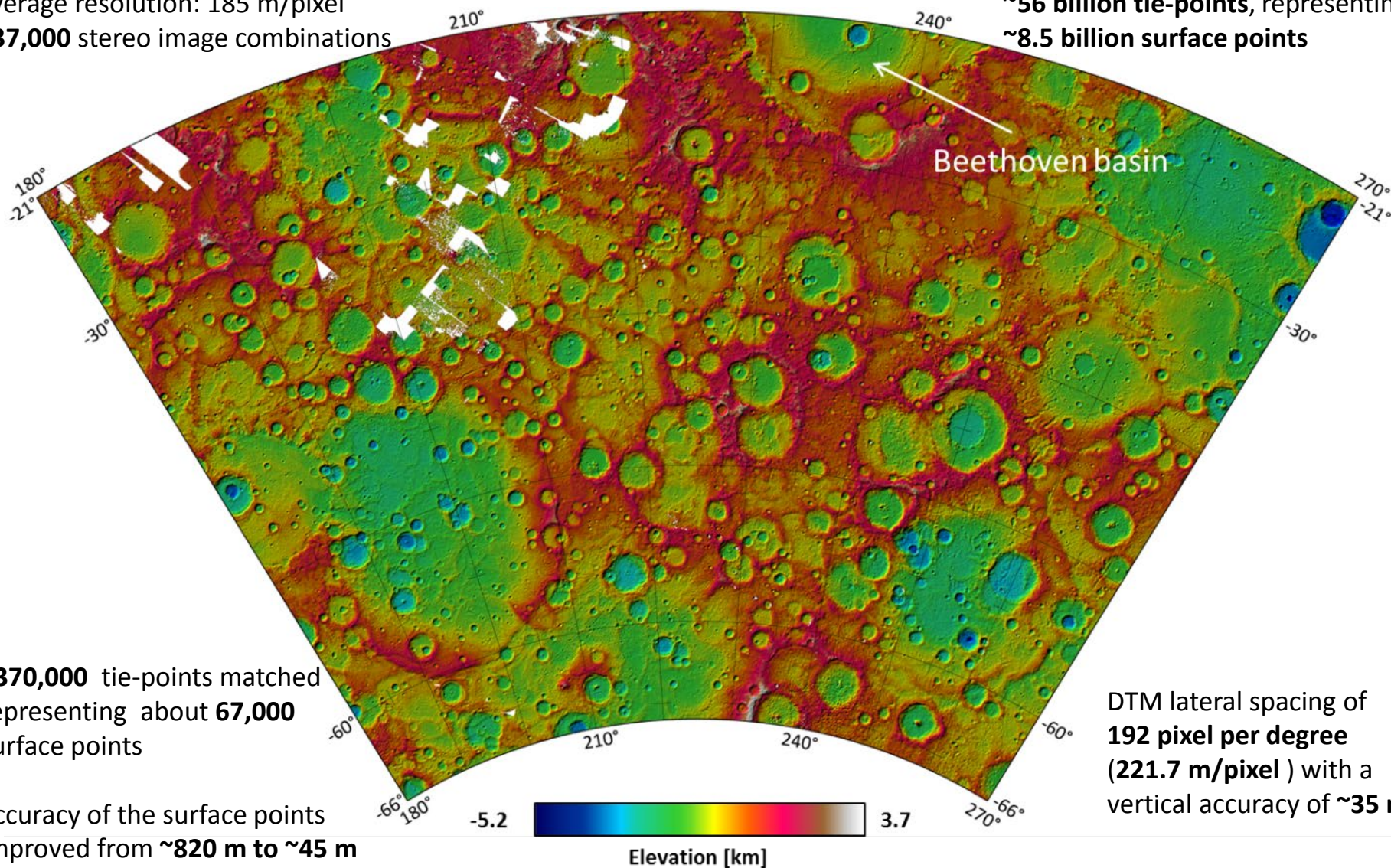




# H12 (“Michelangelo”)

~**5300 NAC** images and ~**80 WAC** images used with  
average resolution: 185 m/pixel  
~**37,000** stereo image combinations

High-density multi-image matching:  
~**56 billion tie-points**, representing  
~**8.5 billion surface points**

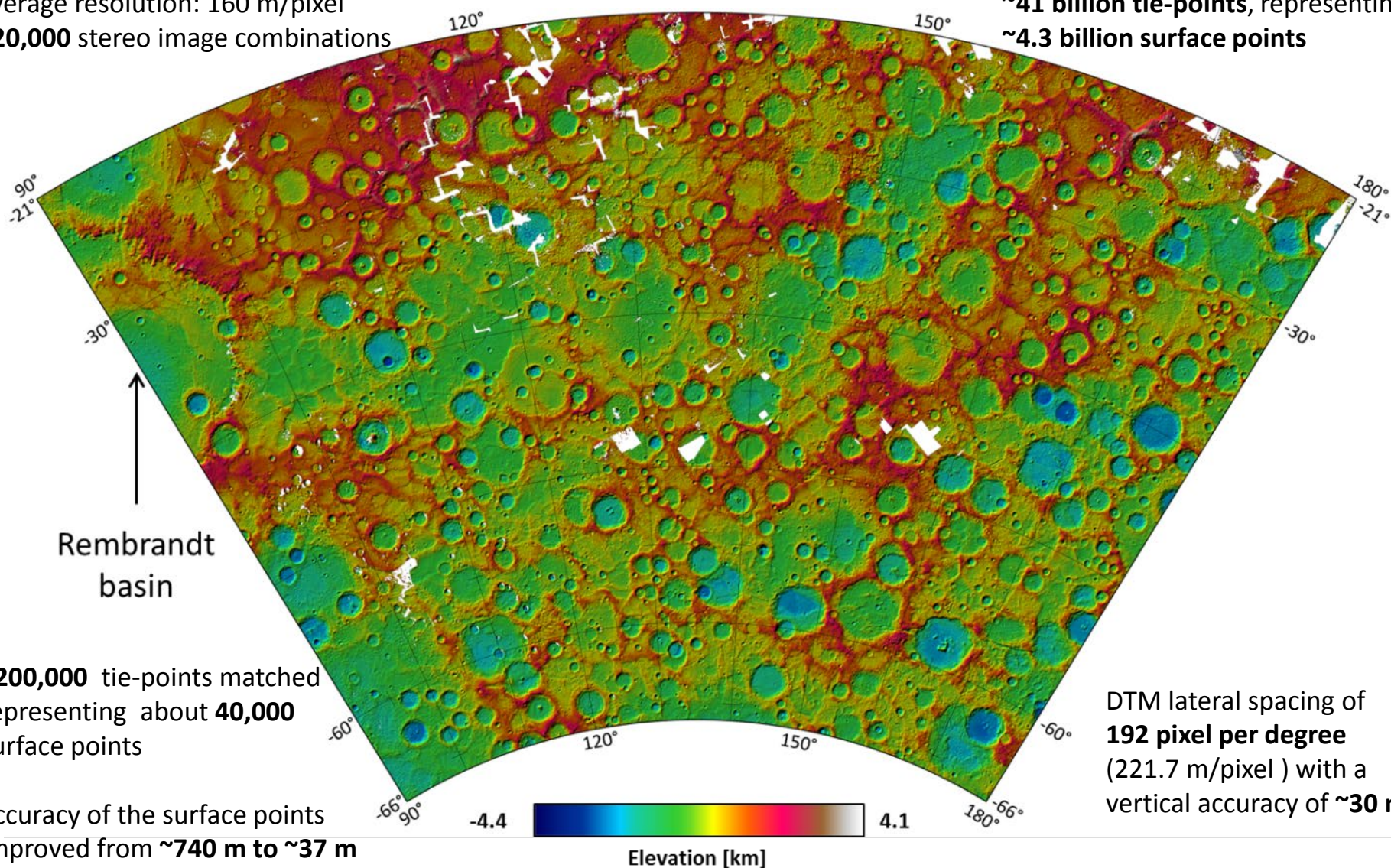




# H13 (“Neruda”)

~**6700 NAC** images and ~**15 WAC** images used with  
average resolution: 160 m/pixel  
~**20,000** stereo image combinations

High-density multi-image matching:  
~**41 billion tie-points**, representing  
~**4.3 billion surface points**

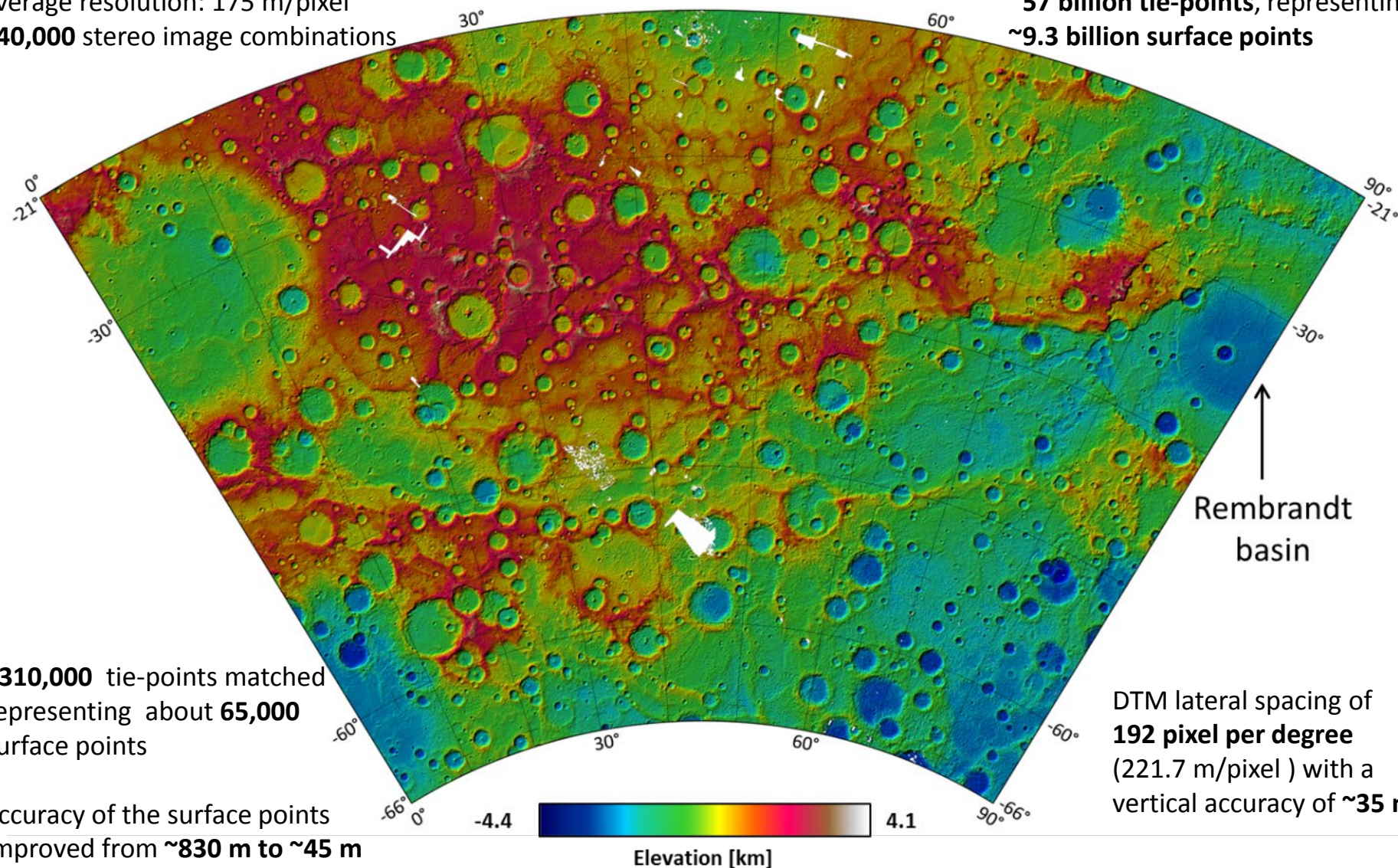




# H14 (“Derain”)

~**6200 NAC** images and ~**80 WAC** images used with  
average resolution: 175 m/pixel  
~**40,000** stereo image combinations

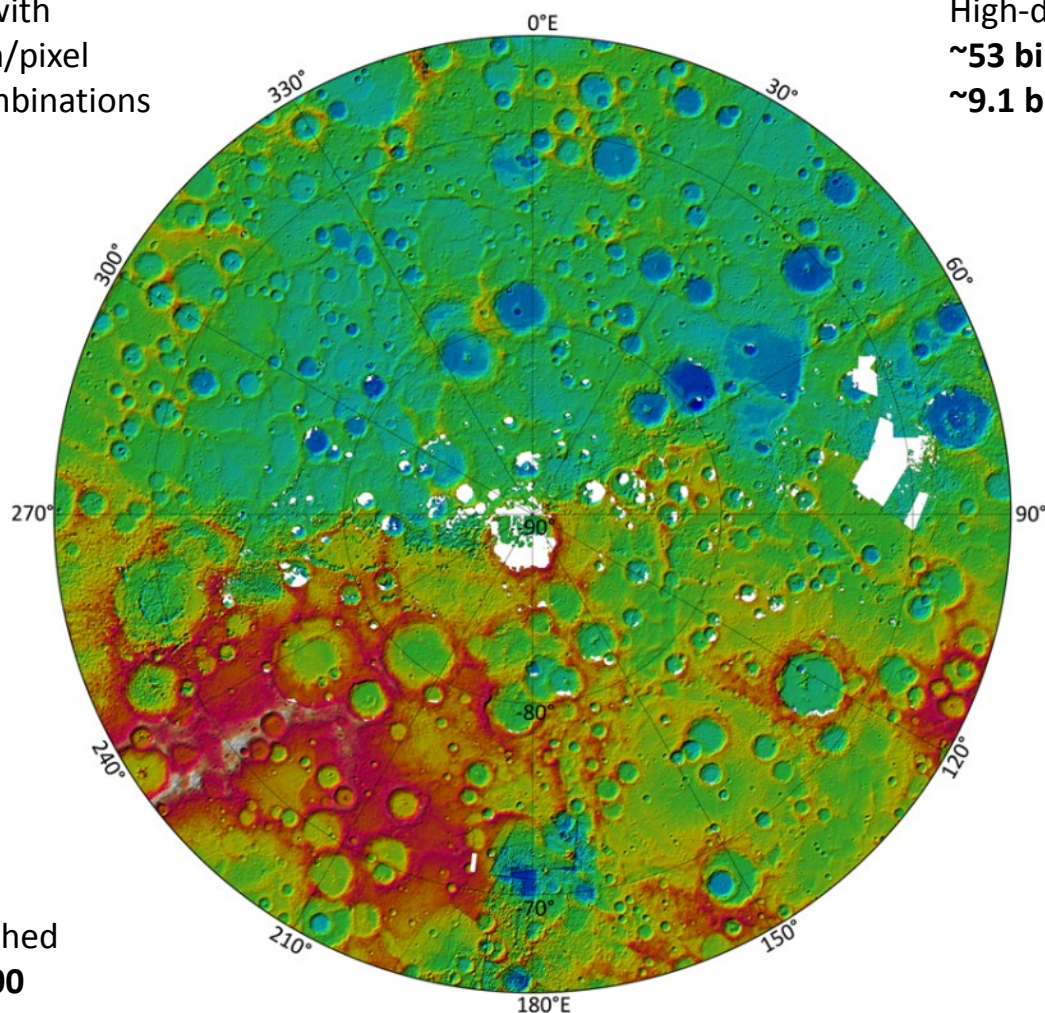
High-density multi-image matching:  
~**57 billion tie-points**, representing  
~**9.3 billion surface points**



# H15 (“Bach”)

~**3400 NAC** images used with  
average resolution: 185 m/pixel  
~**28,000** stereo image combinations

High-density multi-image matching:  
~**53 billion tie-points**, representing  
~**9.1 billion surface points**



~**300,000** tie-points matched  
representing about **50,000**  
surface points

accuracy of the surface points  
improved from ~**750 m** to ~**30 m**

DTM lateral spacing of  
**192 pixel per degree**  
(221.7 m/pixel ) with a  
vertical accuracy of ~**25 m**



# Conclusion & Outlook

- H3, H5, H6 and H7 quadrangle DEM were successfully delivered to PDS  
[https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-dem-elevation-v1.0/MESSDEM\\_1001/DEM/QUAD/IMG/](https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-dem-elevation-v1.0/MESSDEM_1001/DEM/QUAD/IMG/)
- Southern hemisphere quadrangle DEMs H11 – H15 will be finalized until end of this year and delivered promptly
- Remaining equatorial quadrangle H8-H10 are planned to ready until summer 2018
- Merging all southern hemisphere quads H6-15 to produce high-res topographic map until end of 2018
- The global high-res topographic base map for Mercury is targeted for end of 2019