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Digital Elevation Models Derived from Small Format Lunar Images

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Outline

- Overview of Clementine Spacecraft
  - Image Sensors
  - Clementine Laser Altimeter
- Clementine Global Mosaic
- Collection of Digital Elevation Models

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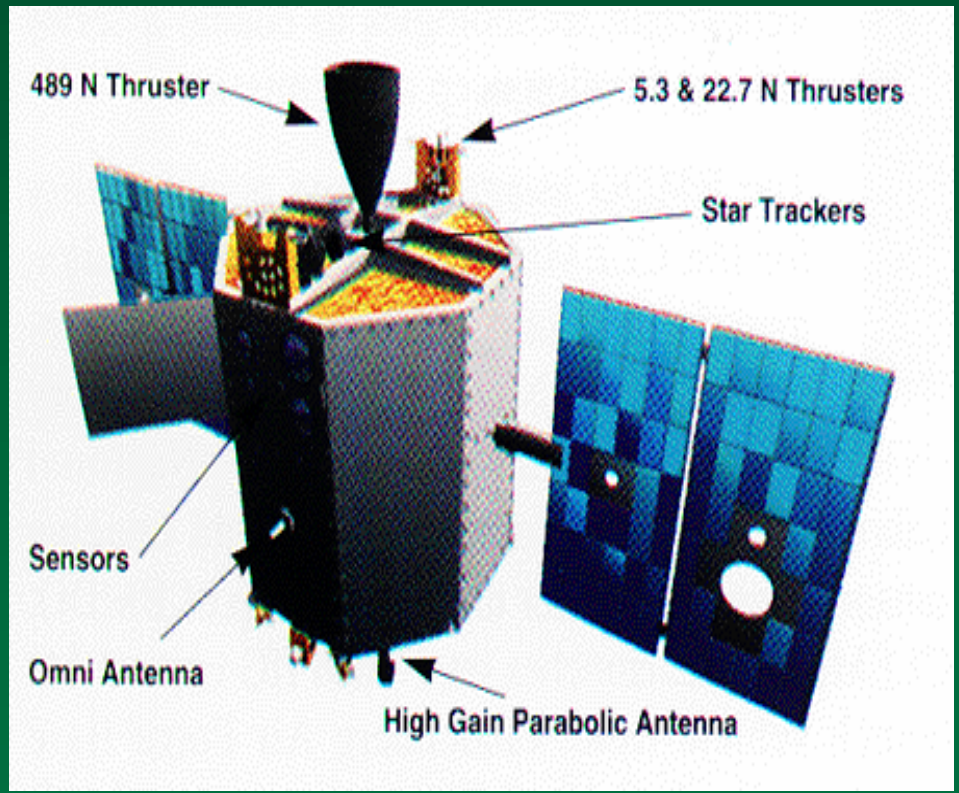
Clementine Mission to the Moon



- Launched 25 January 1994
- 3 – 19 February 1994 placed in lunar orbit
- 19 February – 3 May 1994 collected lunar data
- 7 May 1994 mission aborted

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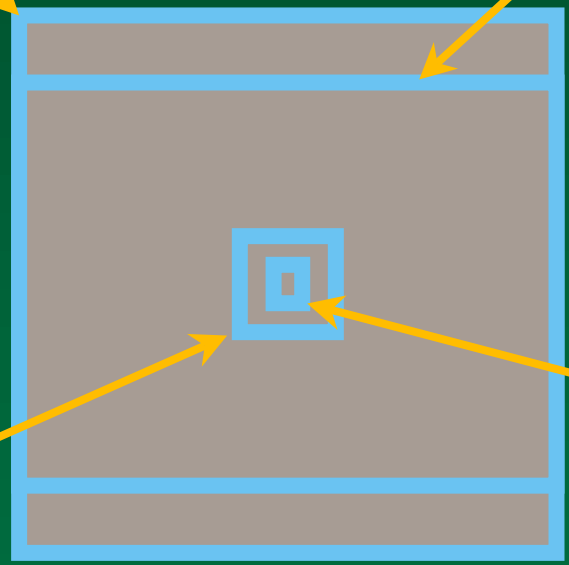
Sensor Overview

Footprint



Near-Infrared
5.6º by 5.6º
- 6 band pass filters

Ultraviolet-Visible
5.6º by 4.2º
- 6 band pass filters
- 750 m source

Long-Wave Infrared
1.0º by 1.0º
- 1 band pass filter

High-Resolution
0.4º by 0.3º
- 5 band pass filters
- LASER Altimeter

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Orbit Overview

- orbits 1-31 shakedown/ testing
- orbits 32-168, periselene in the southern hemisphere
- orbits 169-297, periselene in the northern hemisphere
- orbits 298-348, cover gaps in coverage, acquire observations of special targets

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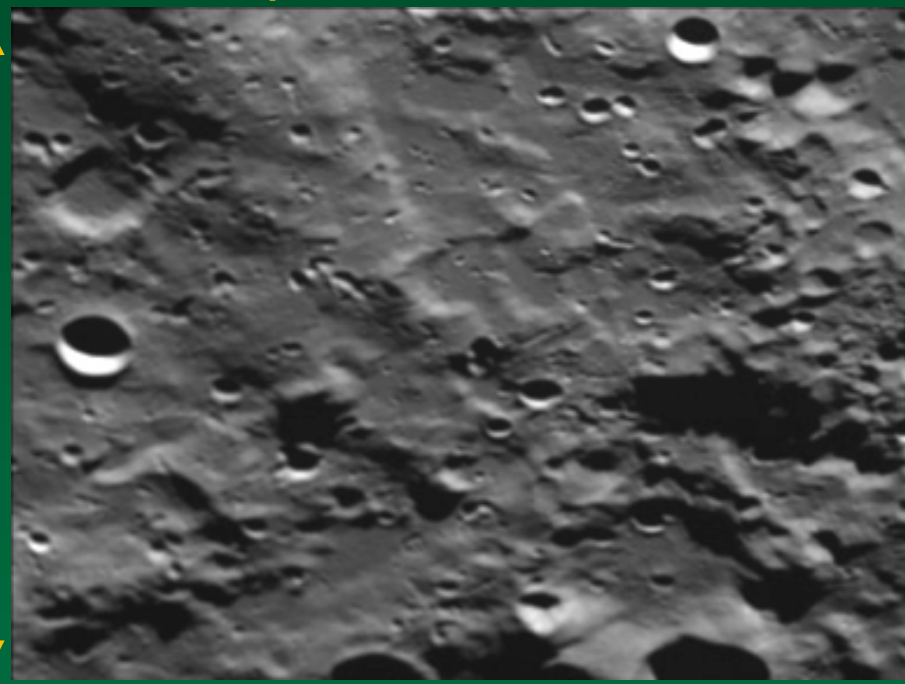
UVVIS Images

Nadir

Oblique



288

384 pixels

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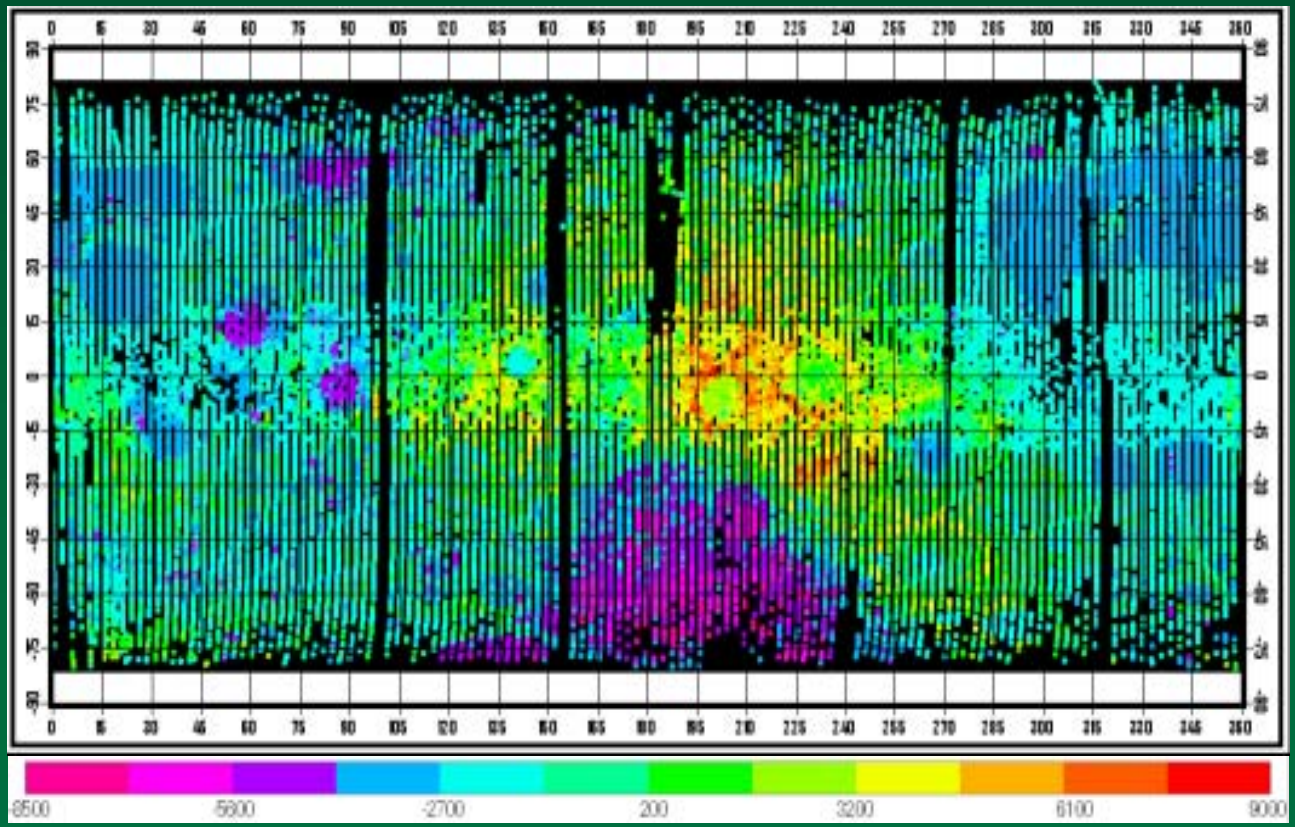
LASER Altimeter Points



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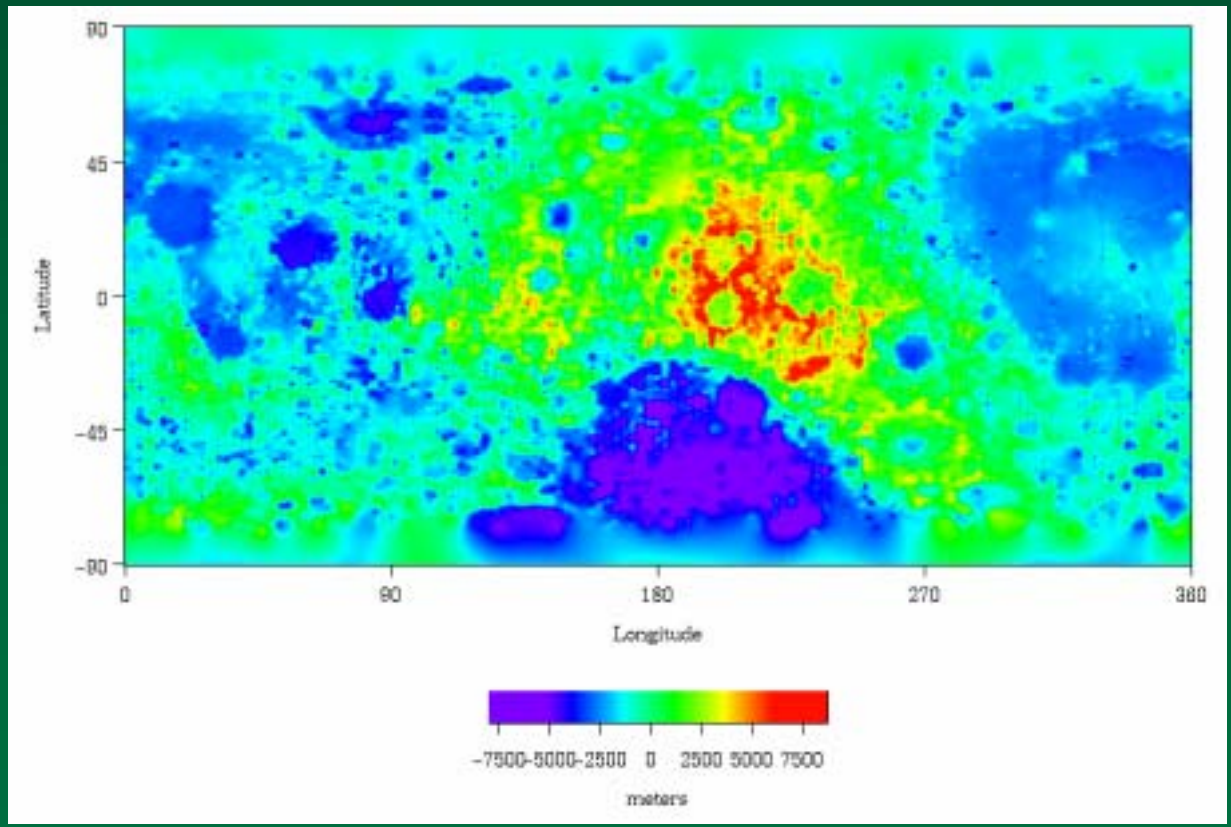
Interpolation of LASER Altimeter

A 720 line by 1440 sample image of topography (0.25 x 0.25 degree resolution)



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http://pds-geophys.wustl.edu/pds/clementine/images_revised/topogrd2.html

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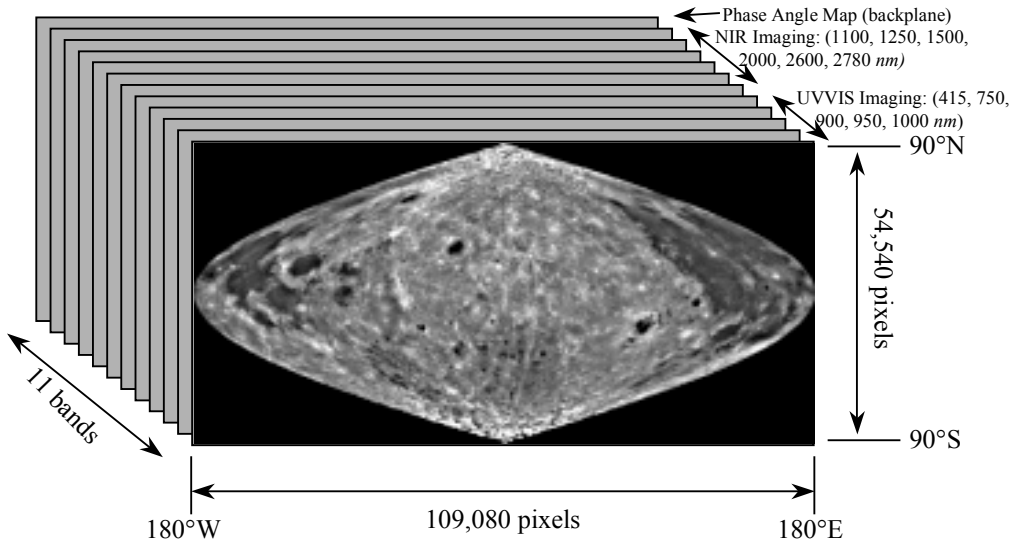
Clementine Global Mosaic

11 Bands – 100m/pixel

Figure 1 -- Schematic Diagram
Global Multispectral Image Mosaic of the Moon



Specifications
- Global Coverage (>98% surface)
- Sinusoidal Equal-Area Projection
- 100 *m/pixel* (or 303 *pixel/°*)
- 109,080(s) x 54,540(l) x 11(b)
- 43.6 giga-pixels (3.96 per band)
- Phase angle backplane

Geometry
- 0.5 *km* absolute positional accuracy for > 95% coverage
- <2 pixel matching neighbor frames (exclusive of oblique observations)

Radiometry
- UVVIS - 1% relative
- NIR - 5% relative

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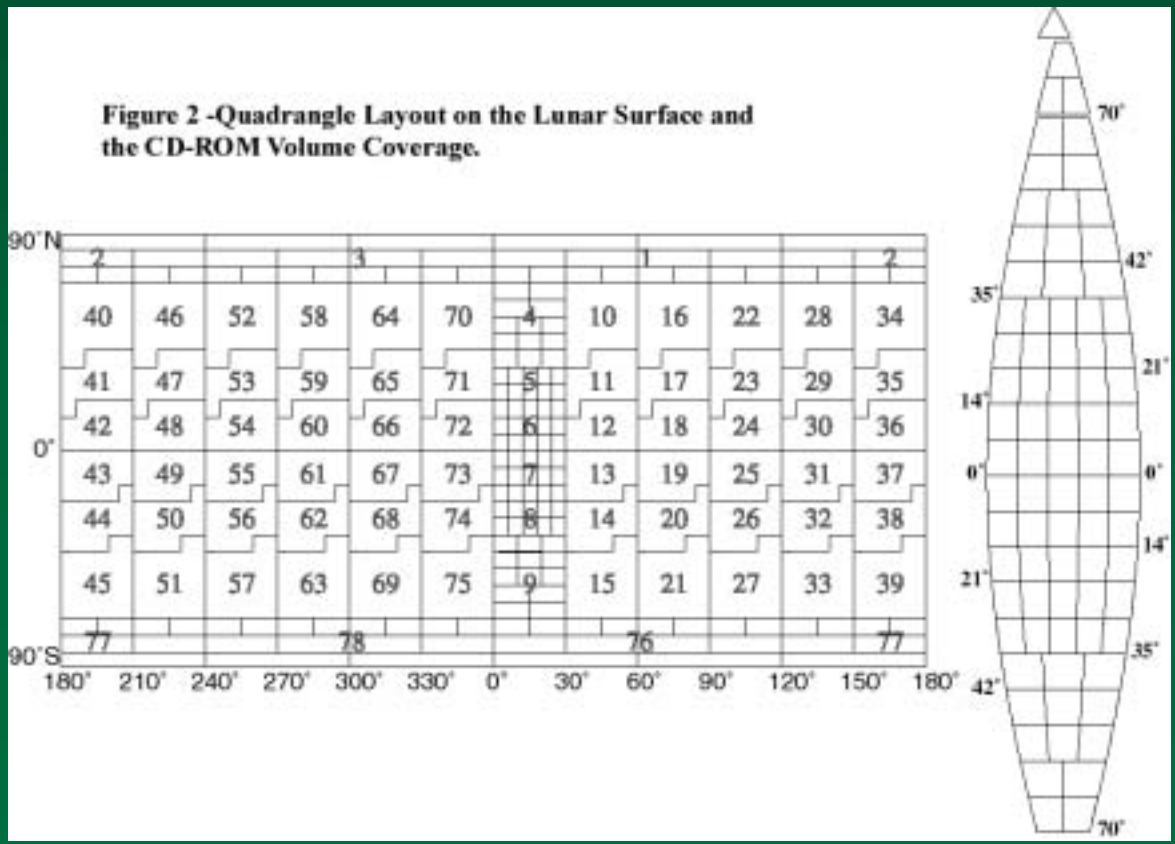
Mosaic Tile Scheme

78 CDs for UVVIS



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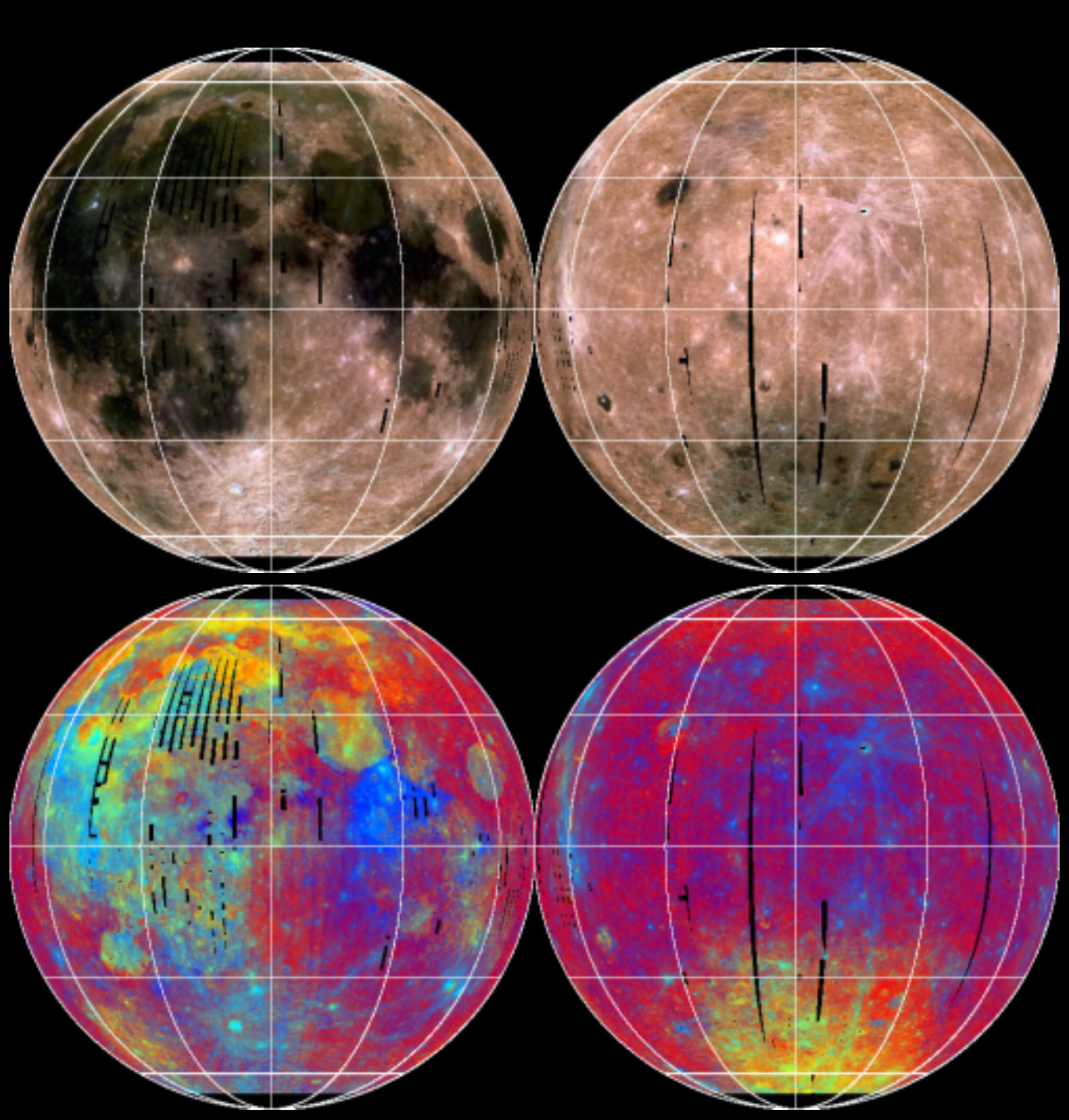
UVVIS 5-band global mosaic

Top images – enhanced false color composite of the lunar front side (left) and far side (right). 450 (blue), 750(green), and 1000 nm (red) spectral bands.

Bottom images – ratio using 415/750 nm (blue), 750/950 nm (green), and 750/415 (red). cancel the albedo component and enhance the color differences. Blue to red tones highlight titanium variations among mature maria and indicate maturity differences among the lunar highland soils. Yellow and orange colors indicate a greater abundance of iron and magnesium-rich materials in the lunar maria and cryptomaria.



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Production of Global Mosaic

- Select match points
  - Tie images from same orbit together
  - Tie images from adjacent orbits together
  - Tie images from different collection periods together
- Adjust camera pointing angles
  - Sphere of 1737.4 km

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Setting up SOCET SET

- Geodetic information
  - Lunar datum definition
  - Map projection for moon
  - UVVIS camera definition

- ISIS to SOCET SET
  - Raw to ISIS
  - Enhancements/Calibration
  - Earth Mean Equatorial Coordinates to planetographic coordinates (X, Y, Z, , ,)

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Setting up SOCET SET

match point information

- .gpf file – ground point file
  - Single file - add weights and type of point
- .ipf files – image point files
  - Single file to multiple files
  - Pixels to image coordinates

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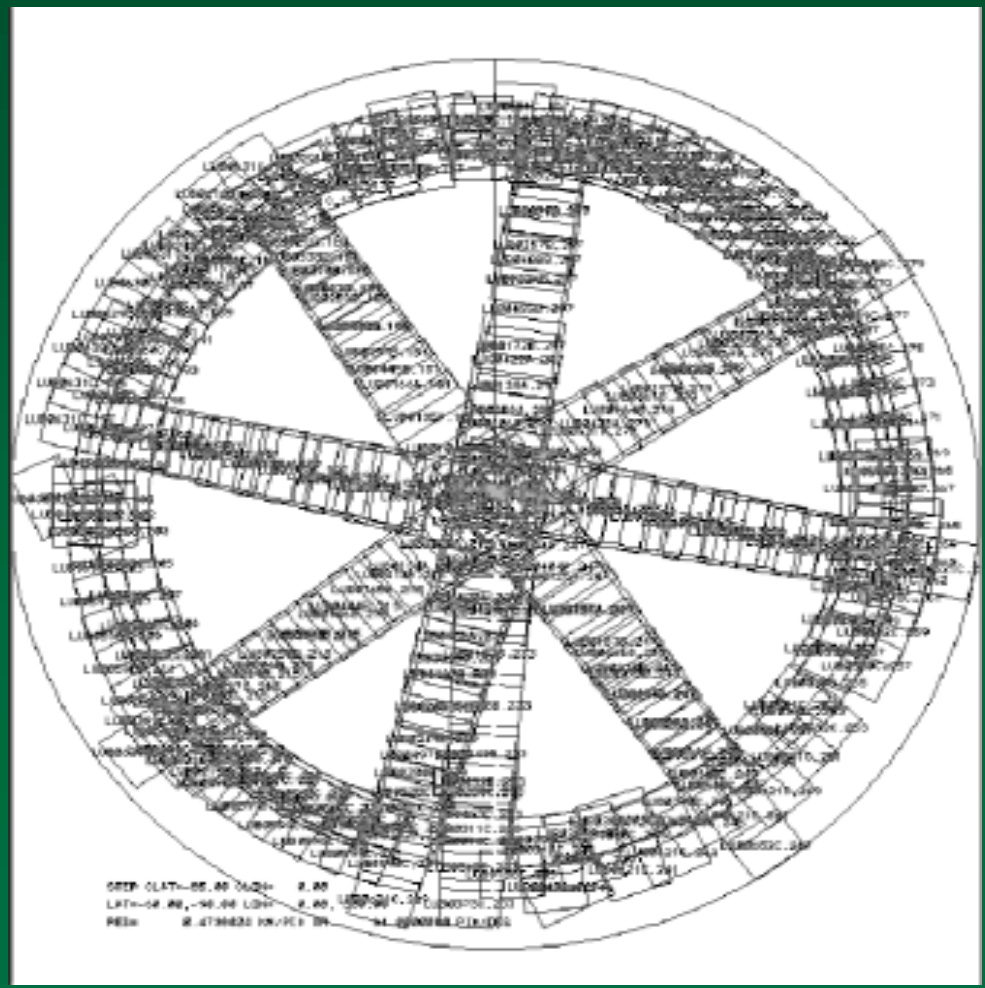
Triangulation

First Run

- 3,635 images
- 29,386 match points
- Blocks of images
- Avg RMS 0.3 pixel
- DEMs mismatch 2-3 km
  - 75% on two images
  - 15-24 points per image



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Triangulation

Second Run

- 978 images
- 1,265 match points use as control points weight 1,000 (xy) 5,000 or 10,000 (z)
- Added 1,200 tie points Weight 10,000 (xyz)

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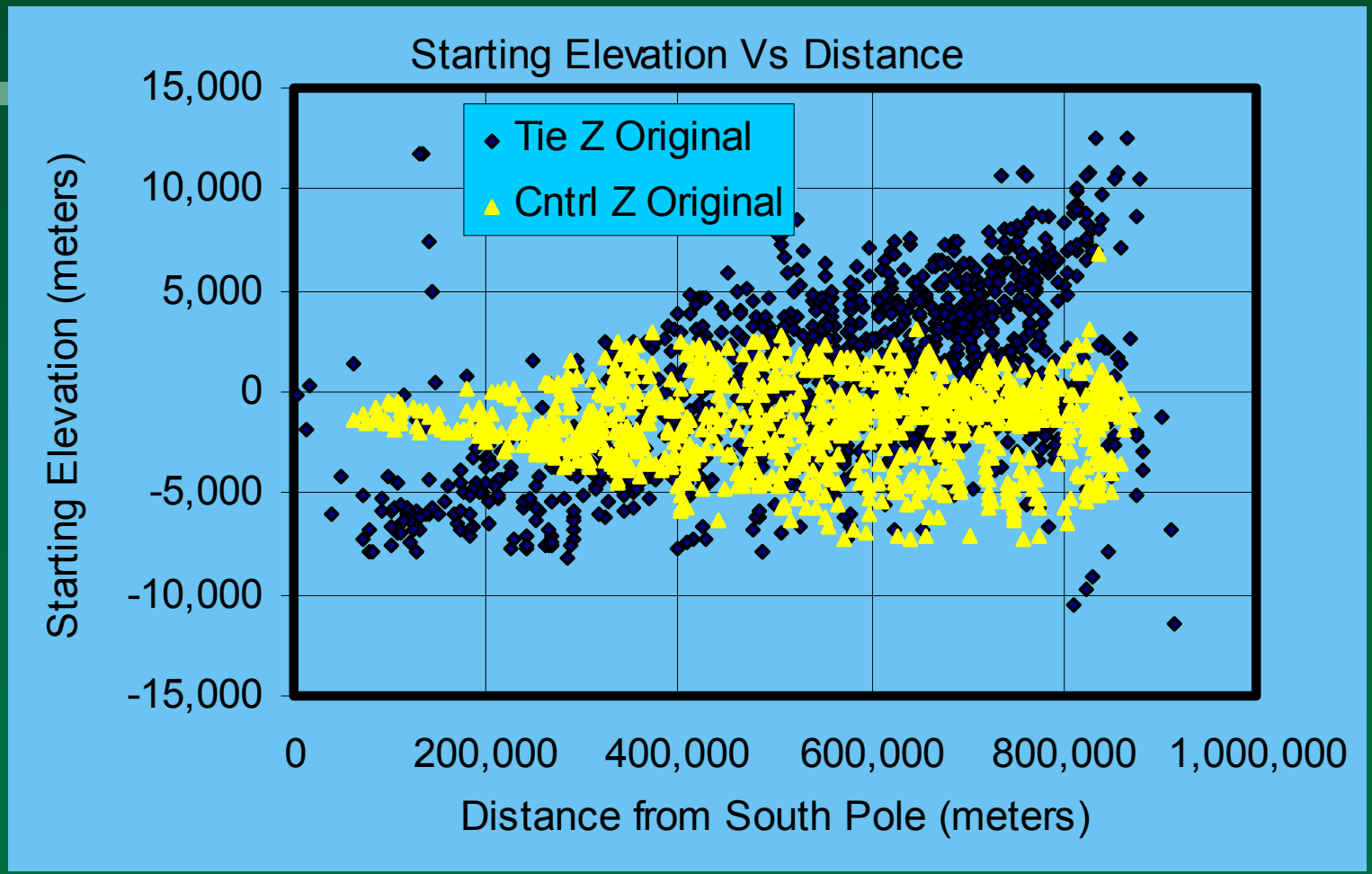
Triangulation

Second Run



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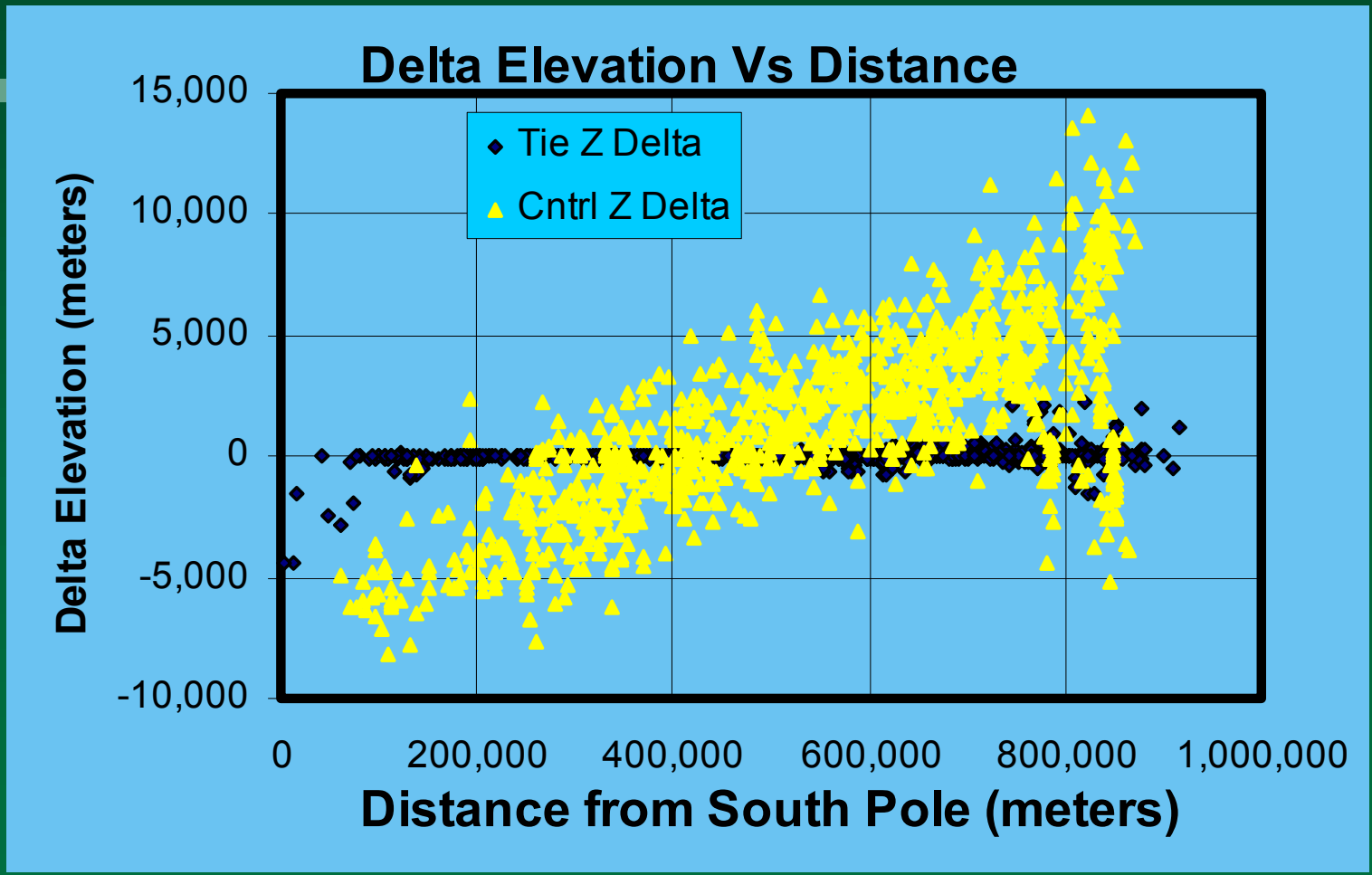
Triangulation

Second Run



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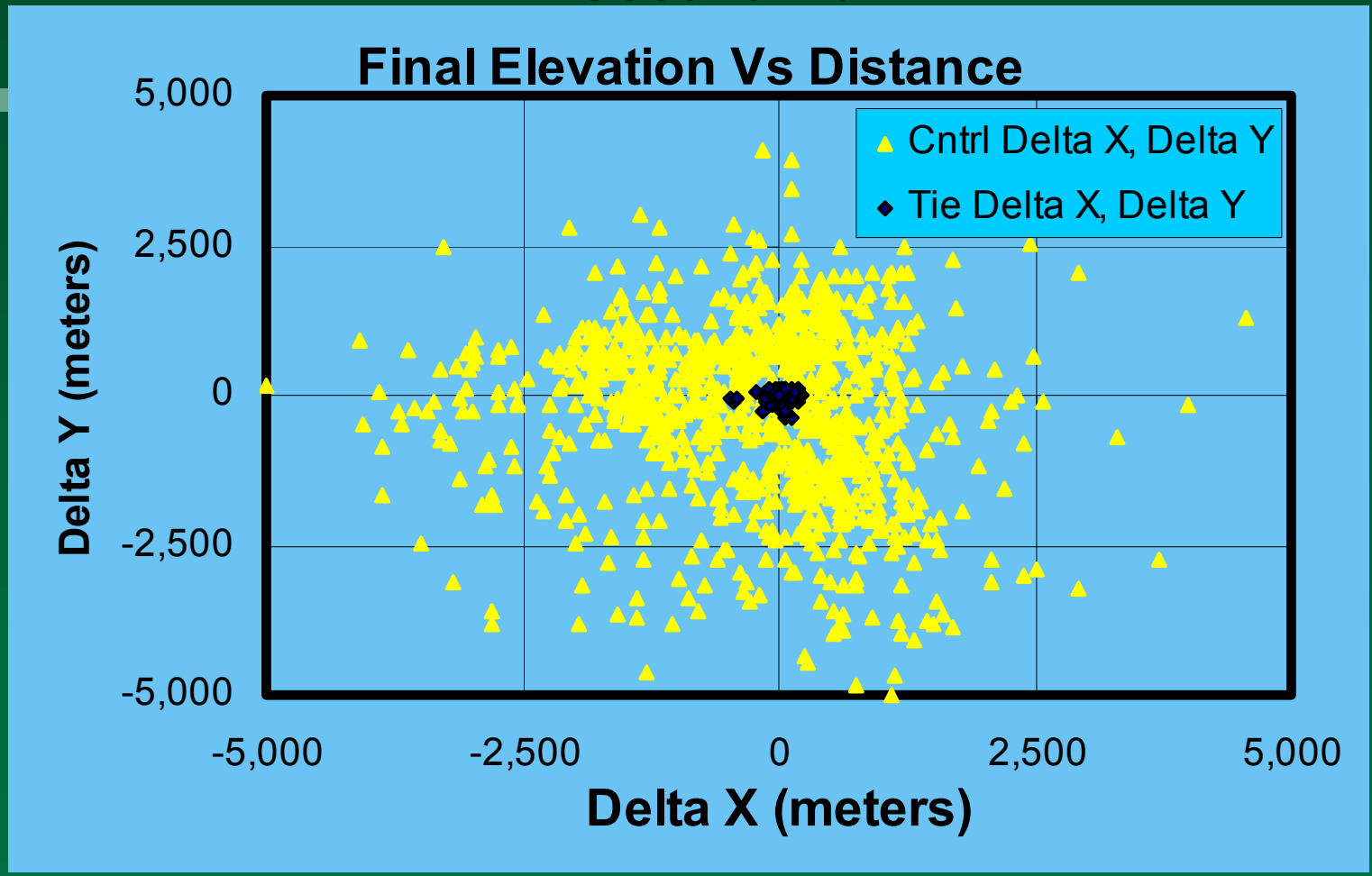
Triangulation

Second Run



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Triangulation

Third Run

- 978 images
- Use two passes - low Z weights on first pass
- Use sensor information before global mosaic adjustment
- 1,265 match points use as control points weight 1,000 (xy)
  - first pass 20 or 10,000 then 750 or 10,000 (z)
- 1,200 tie points - Weight 10,000 (xyz)

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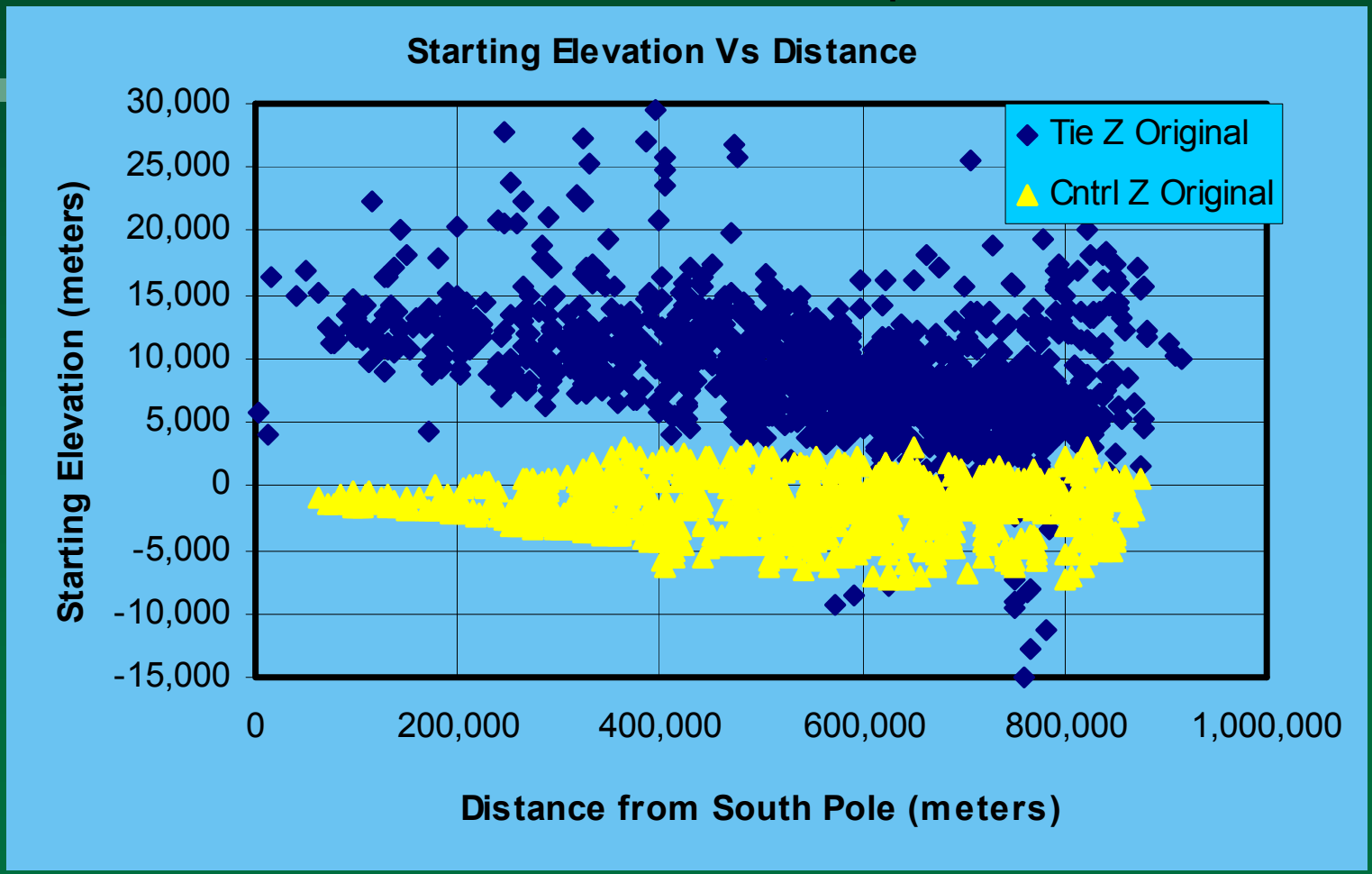
Triangulation

Third Run – first pass



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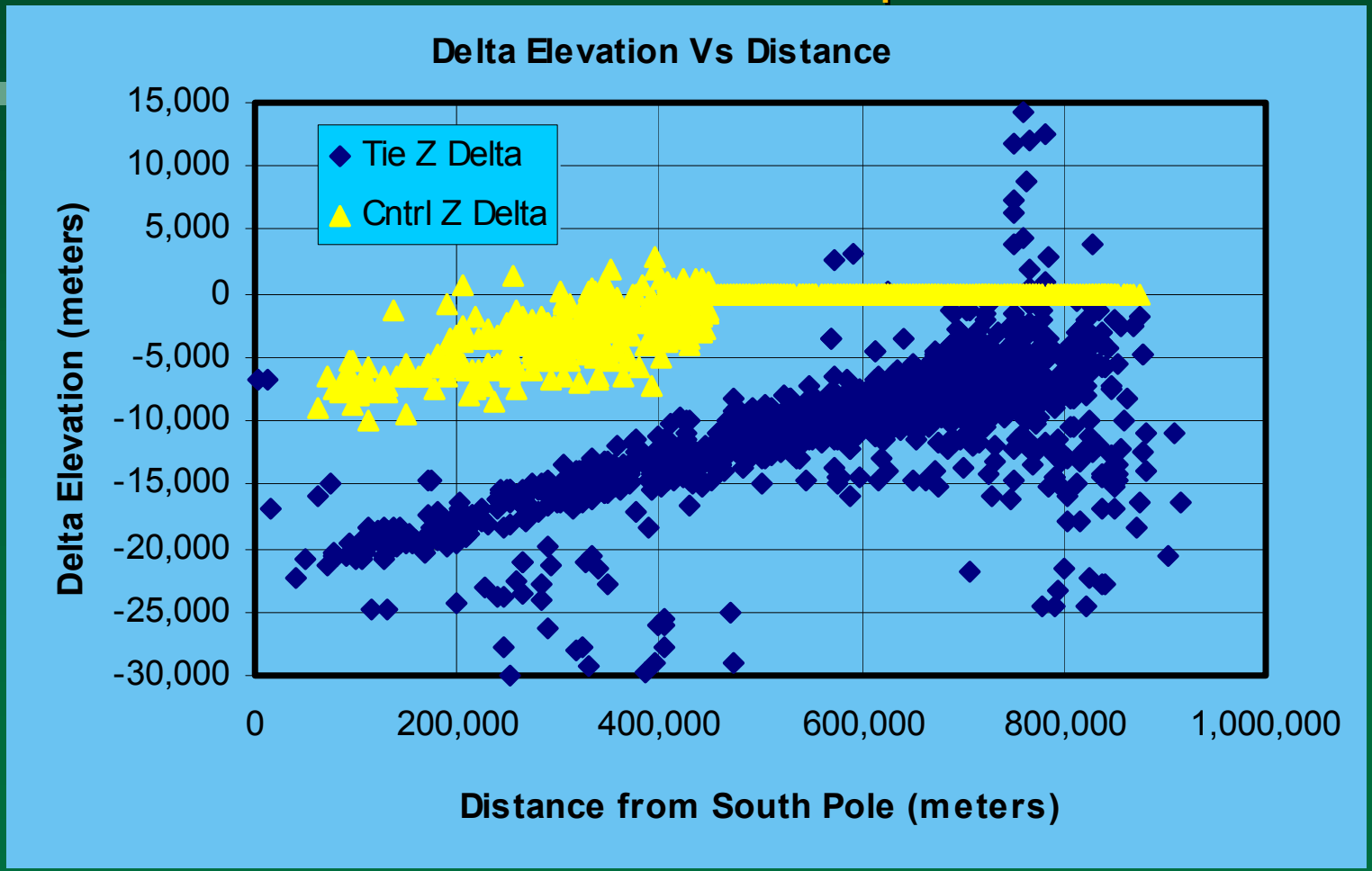
Triangulation

Third Run – first pass



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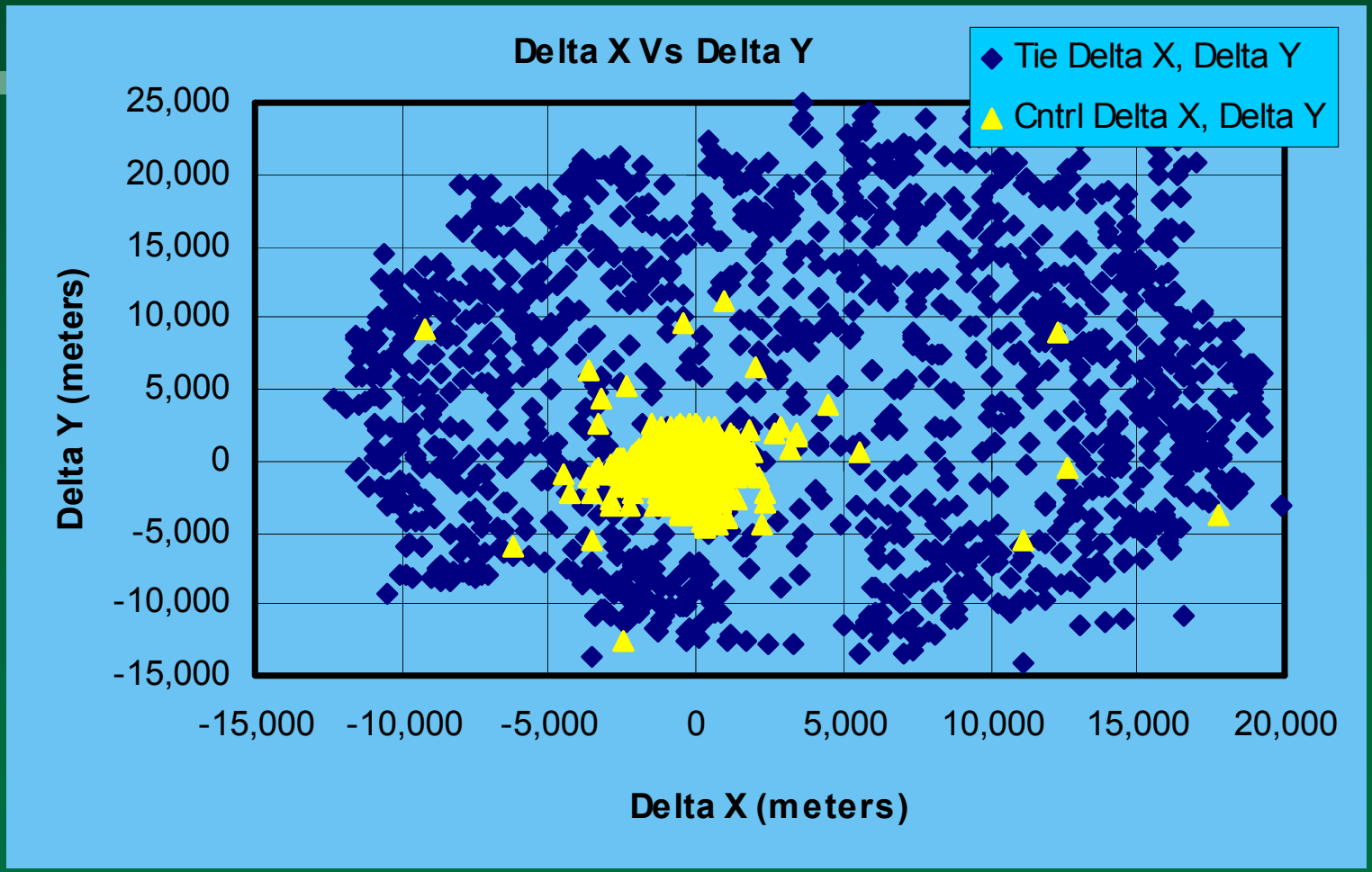
Triangulation

Third Run – first pass



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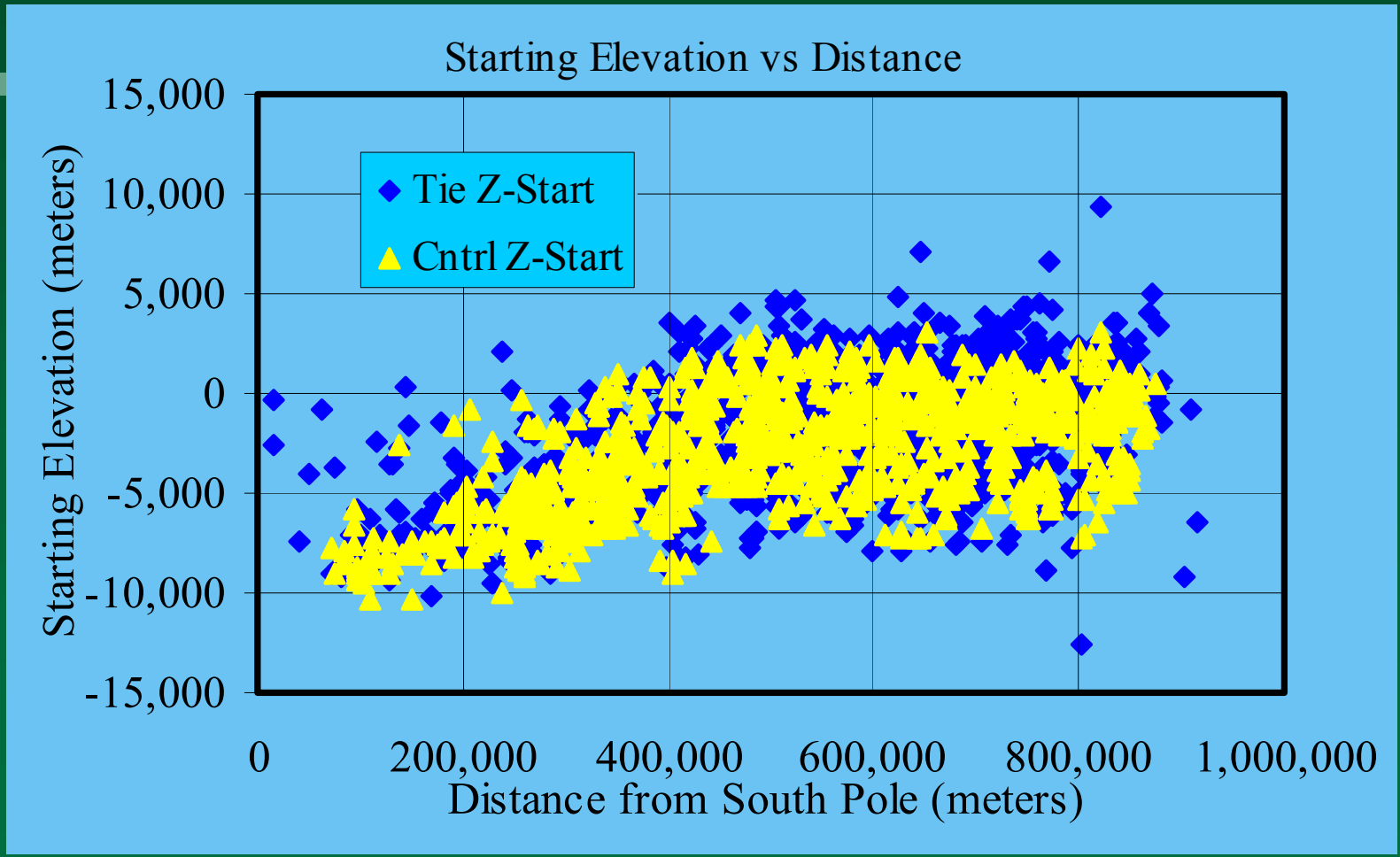
Triangulation

Third Run – second pass



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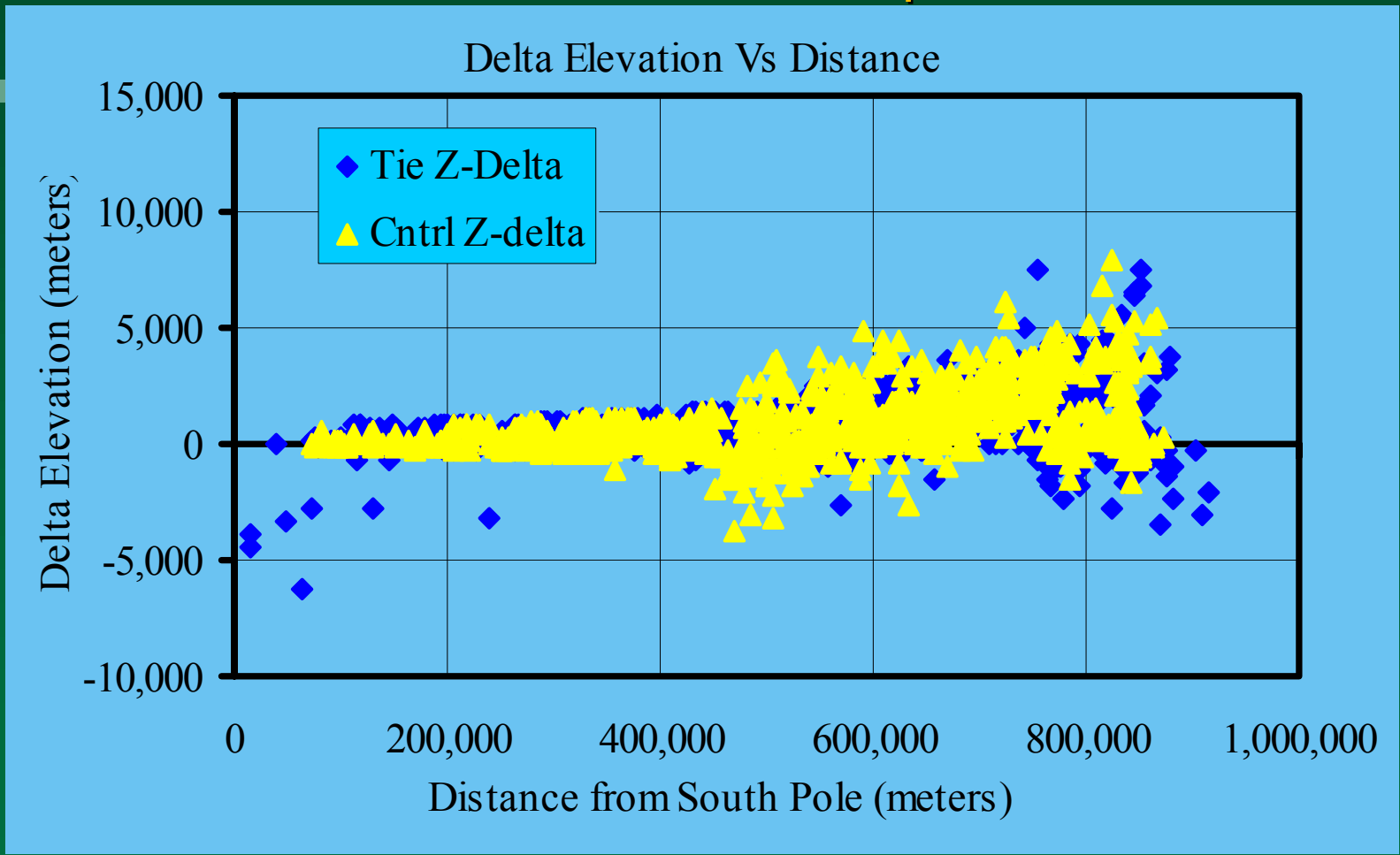
Triangulation

Third Run – second pass



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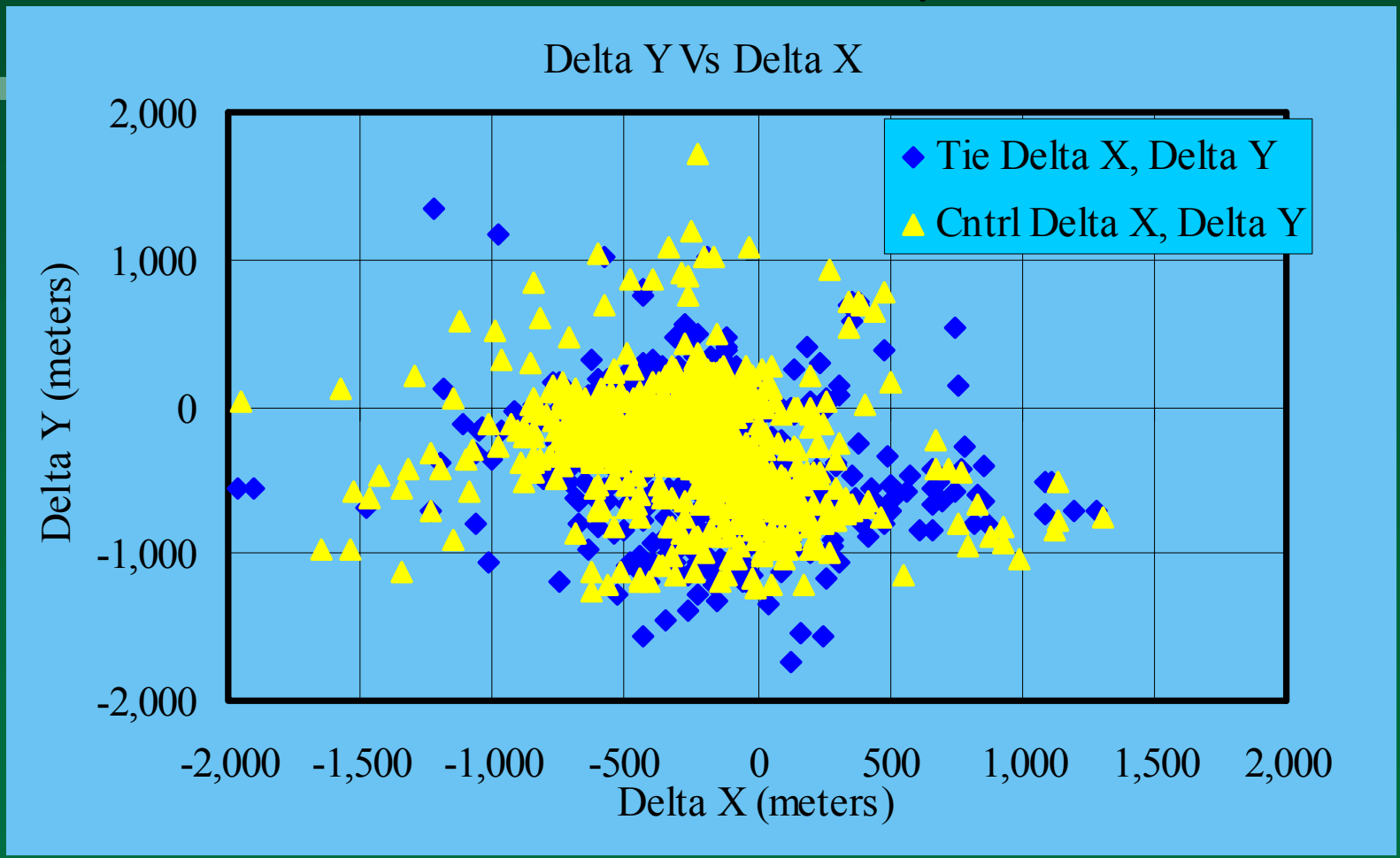
Triangulation

Third Run – second pass



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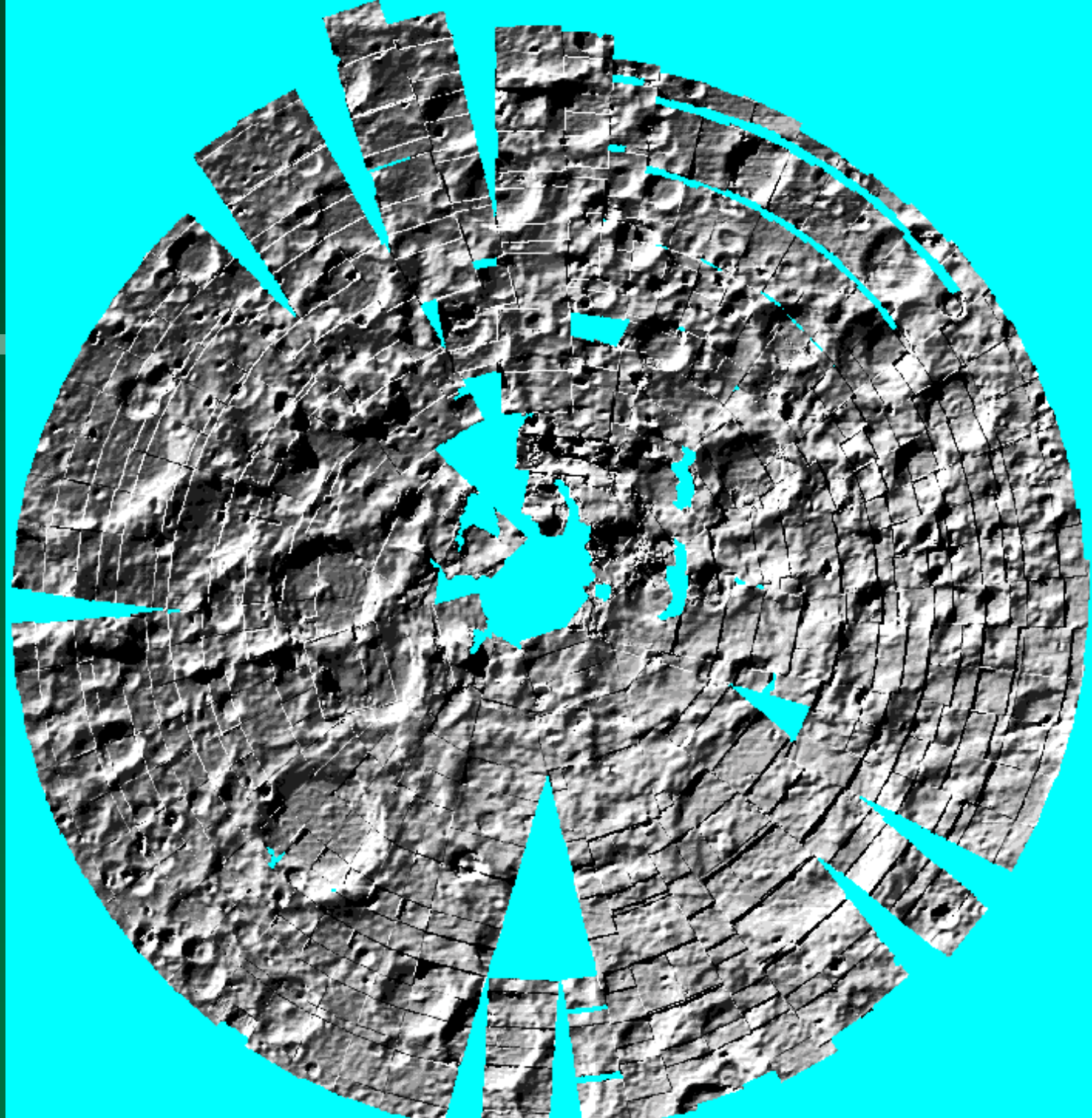
Initial DEM



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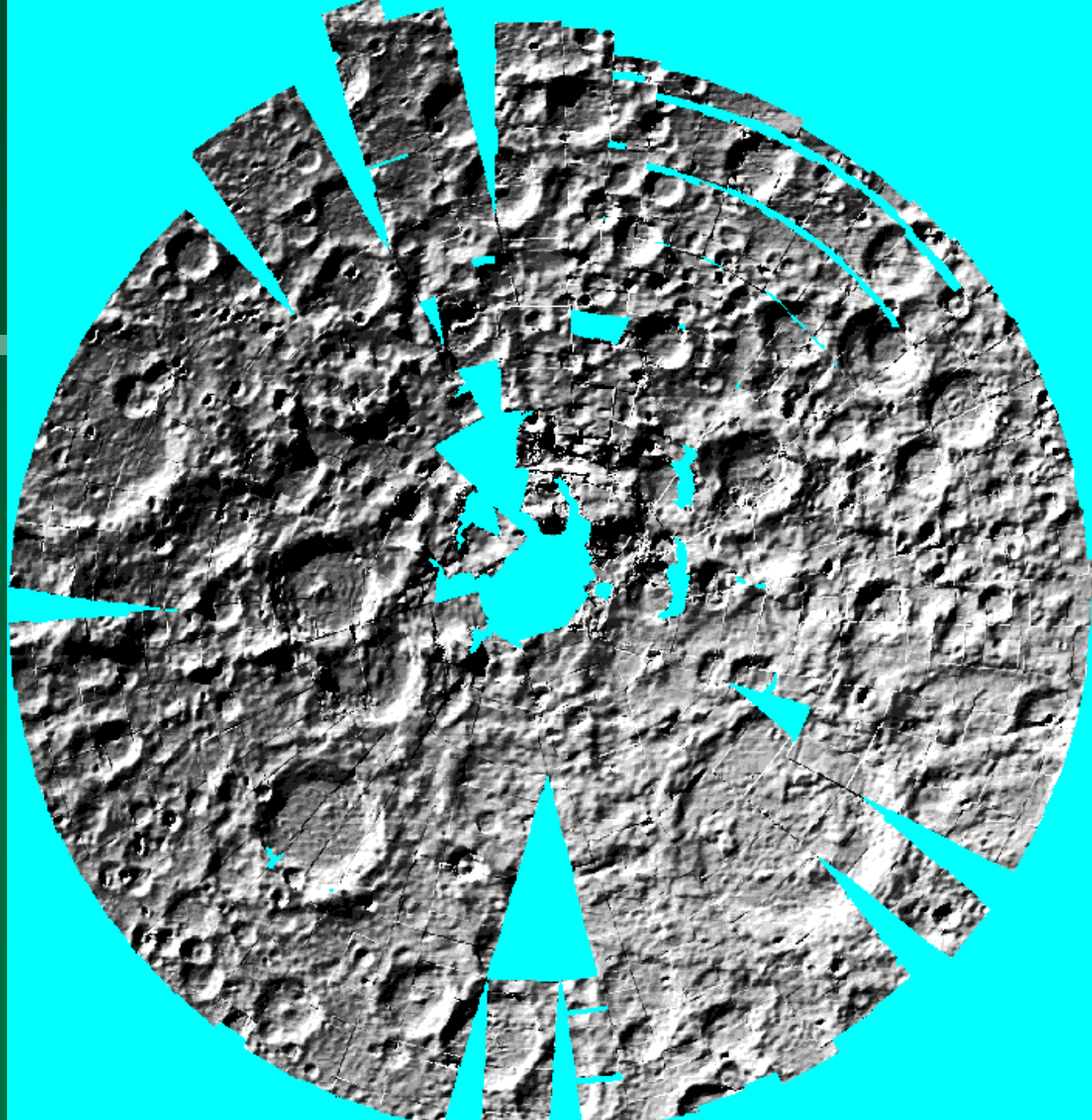
Equalized DEM



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Triangulation

Fourth Run

- 978 images
- Use three passes - increase weights
- Adjust sensor position
- Use sensor information before global mosaic adjustment
- Initialize Z using equalized DEM

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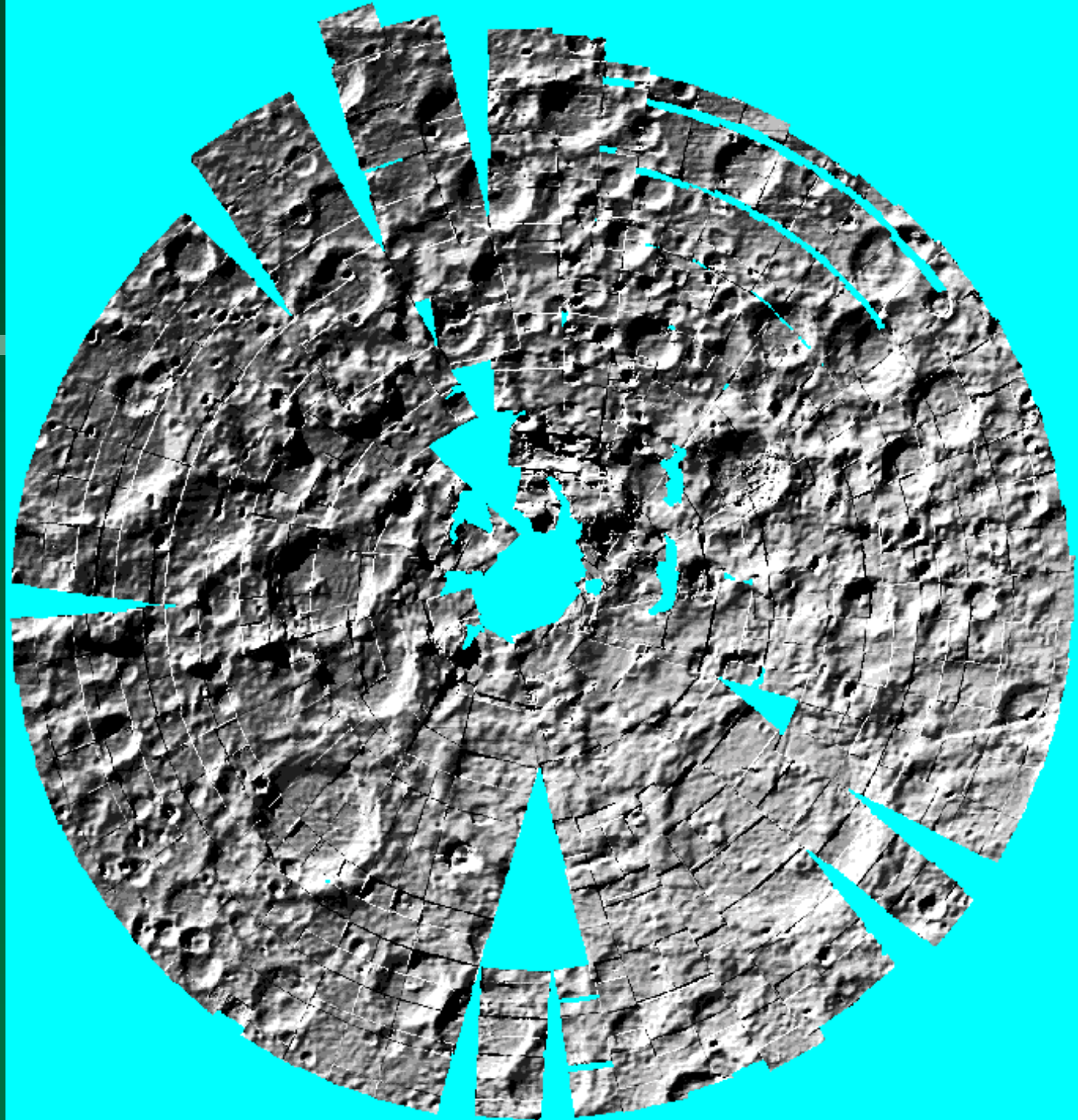
Fourth Run DEM before equalizer



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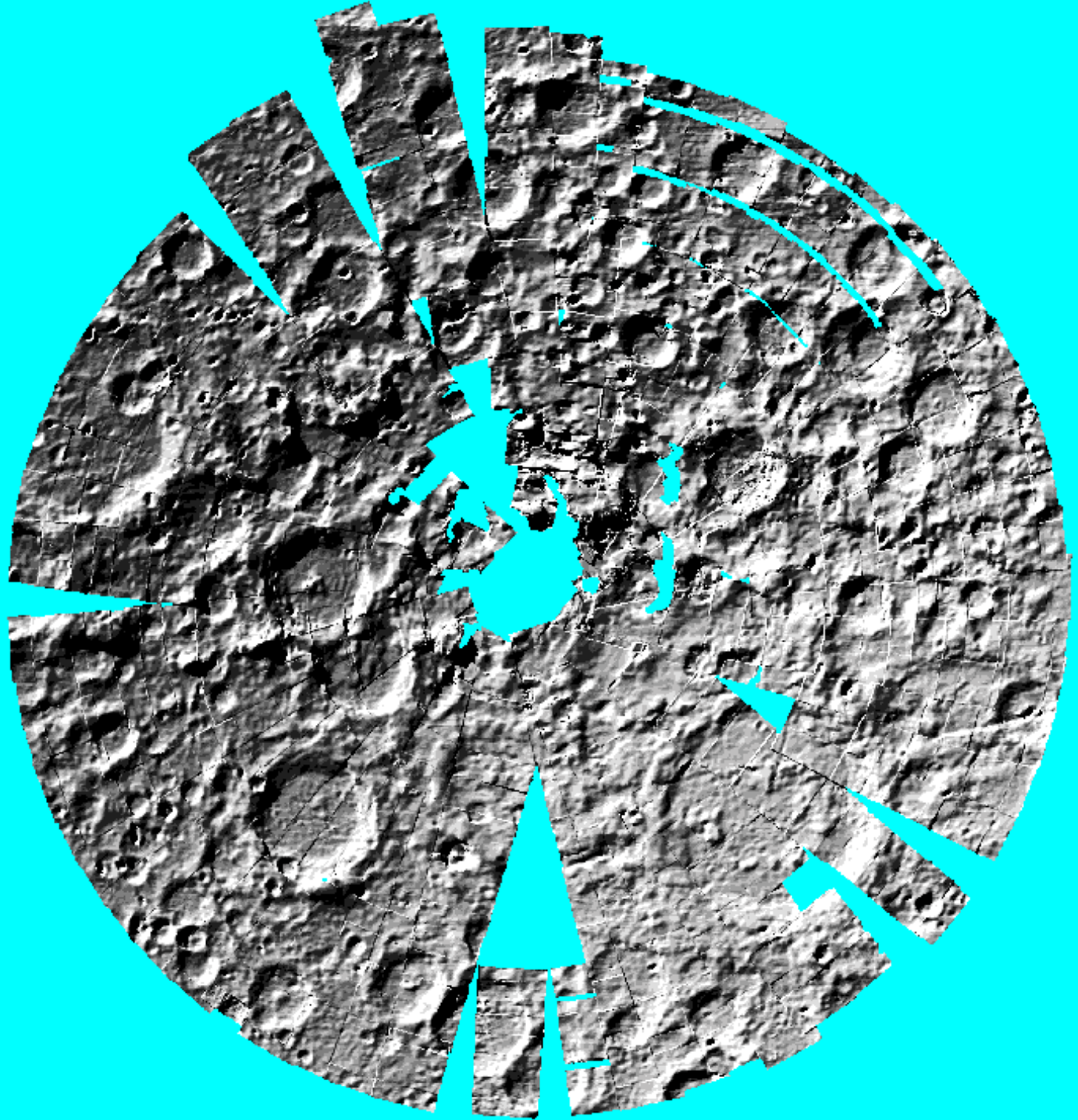
Fourth Run DEM After Equalizer No feathering



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Conclusions

- Topography data was collected at 1 km spacing
  - Clementine Altimeter 20 km spacing, voids at poles
- Photogrammetric topography
  - Systematic bias
    - Orbital errors ?
    - Oblique/nadir stereopairs ?
    - Geometry ?
    - Control point distribution ?

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Conclusions

- Modify procedures for lunar north pole collection
  - Increase number of match point (~4000 points)
  - Use higher resolution UVVIS imagery to tie images
  - Hand transfer points
- Final data products will be distributed on line