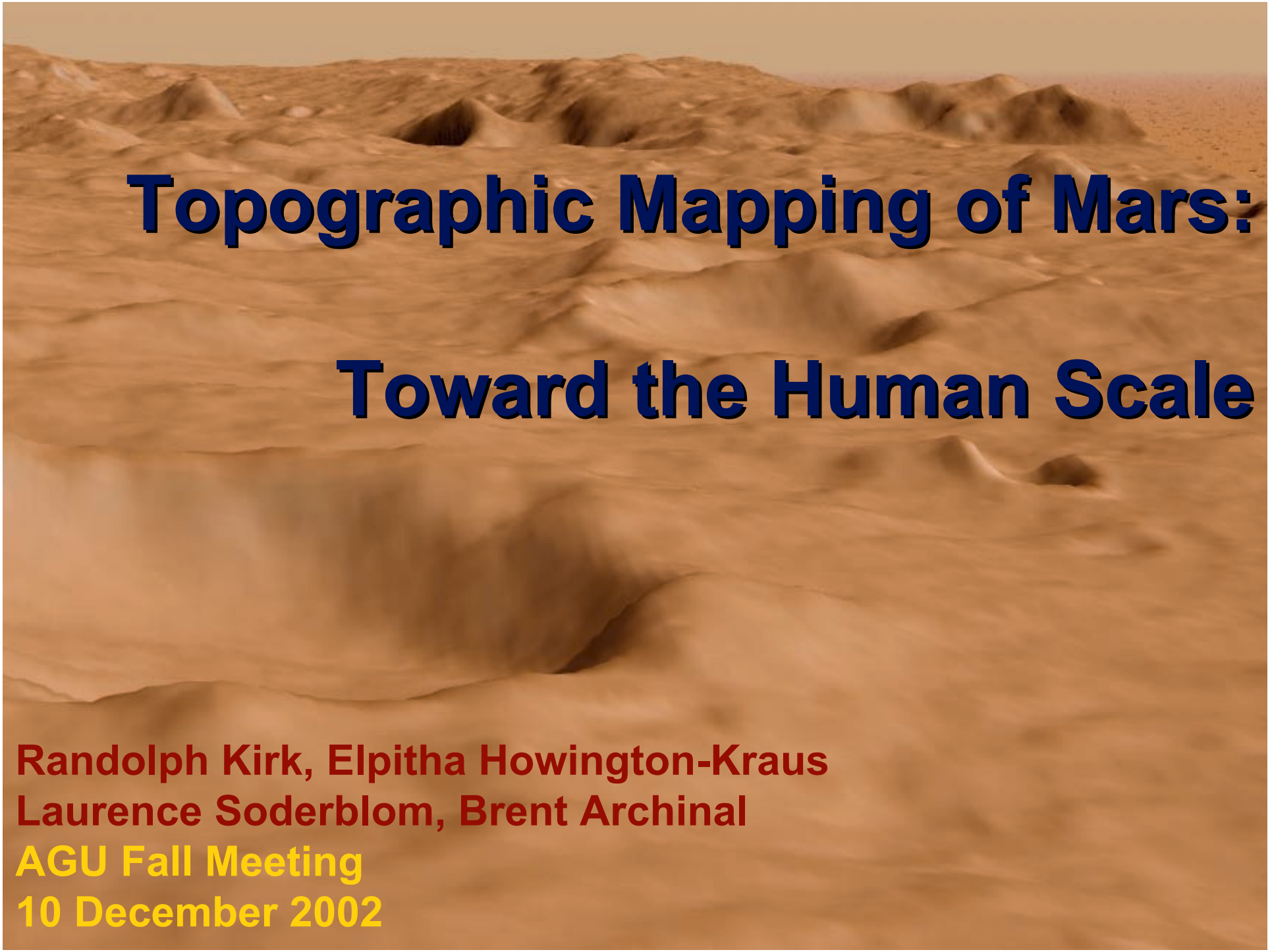


Topographic Mapping of Mars:

Toward the Human Scale

Randolph Kirk, Elpitha Howington-Kraus
Laurence Soderblom, Brent Archinal

AGU Fall Meeting
10 December 2002

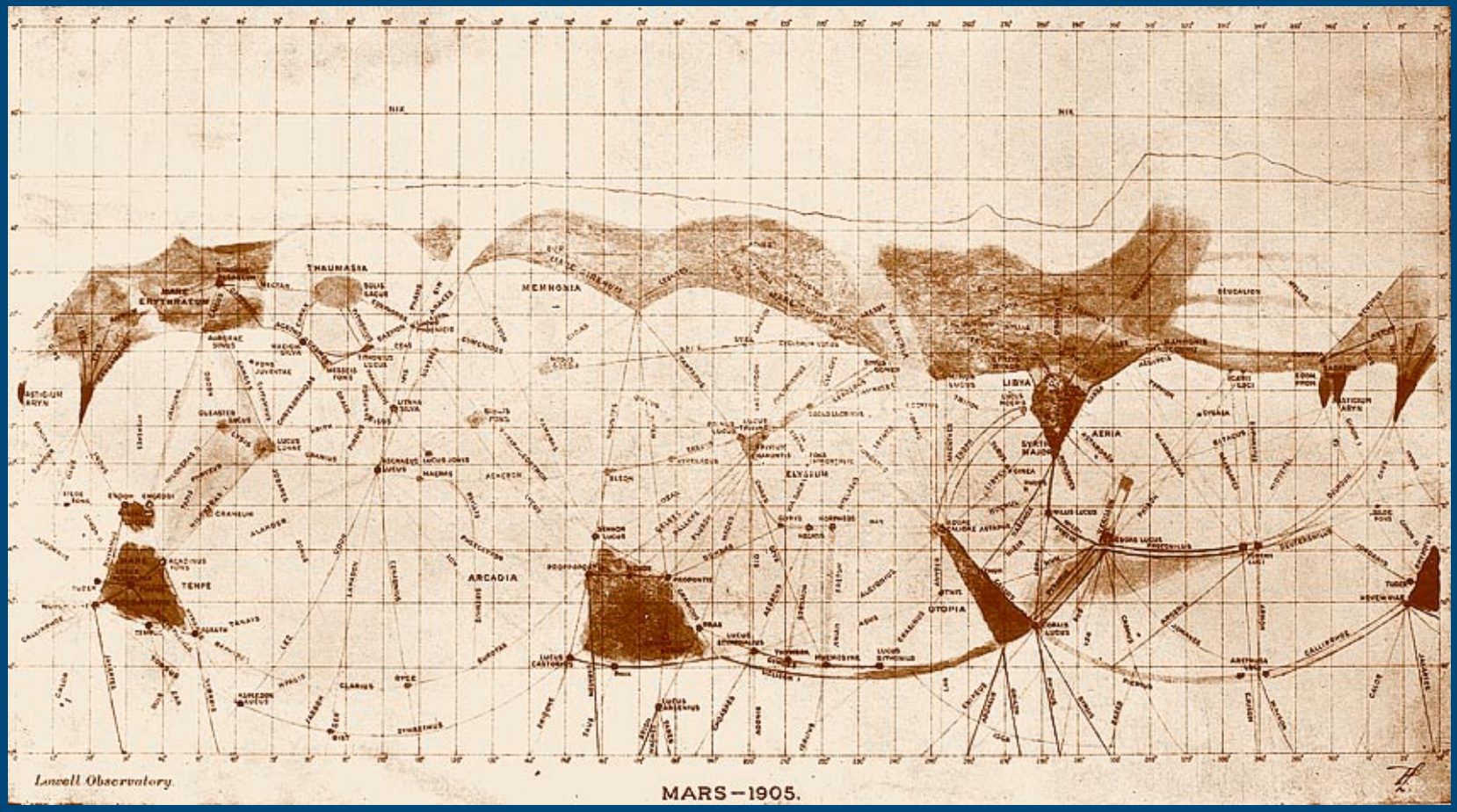
Outline

- Historical Background
- Stereomapping with MOC
- Photoclinometry
- Things to come

USGS science for a changing world

AGU

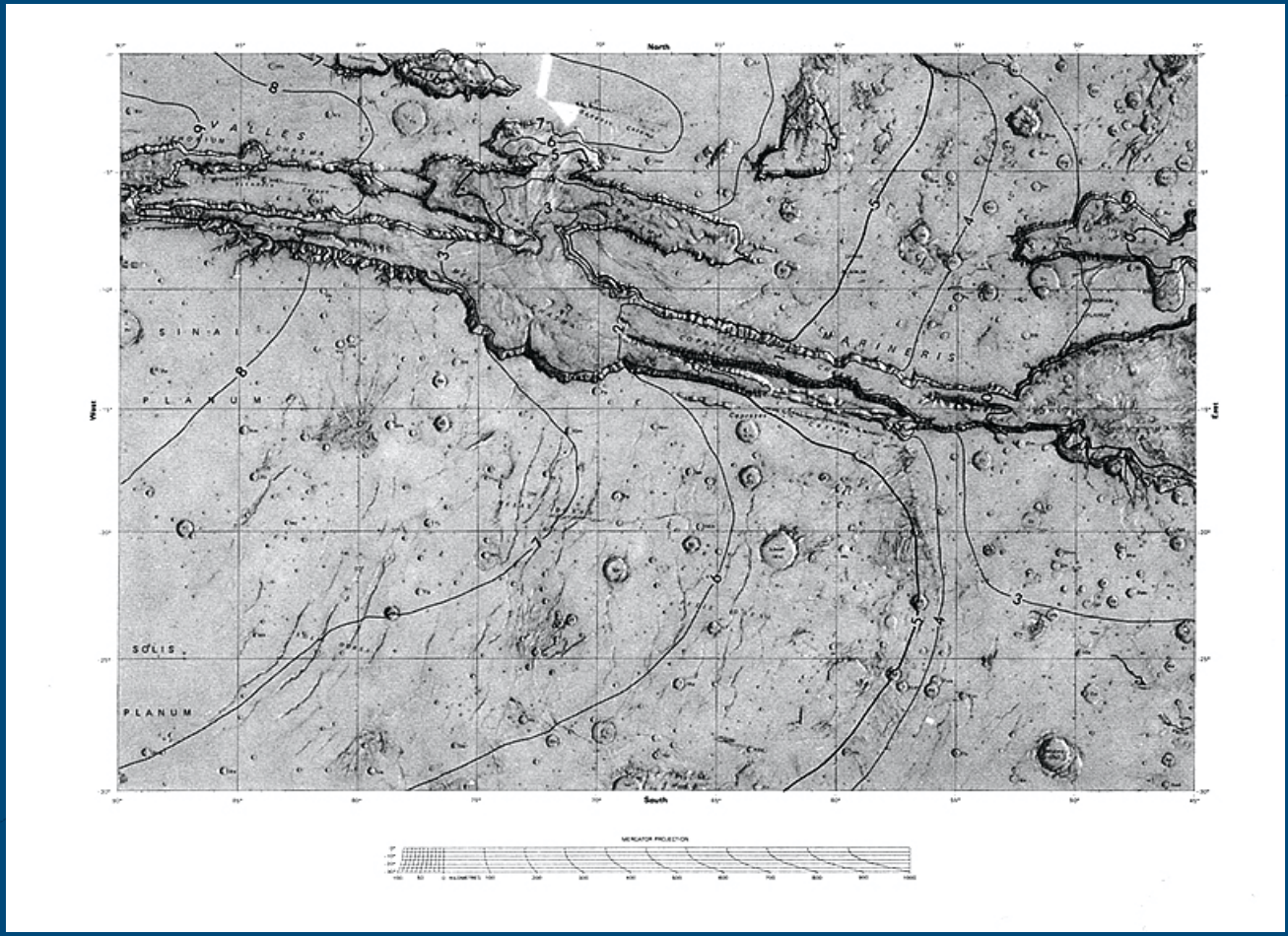
100 Years Ago



USGS science for a changing world

AGU

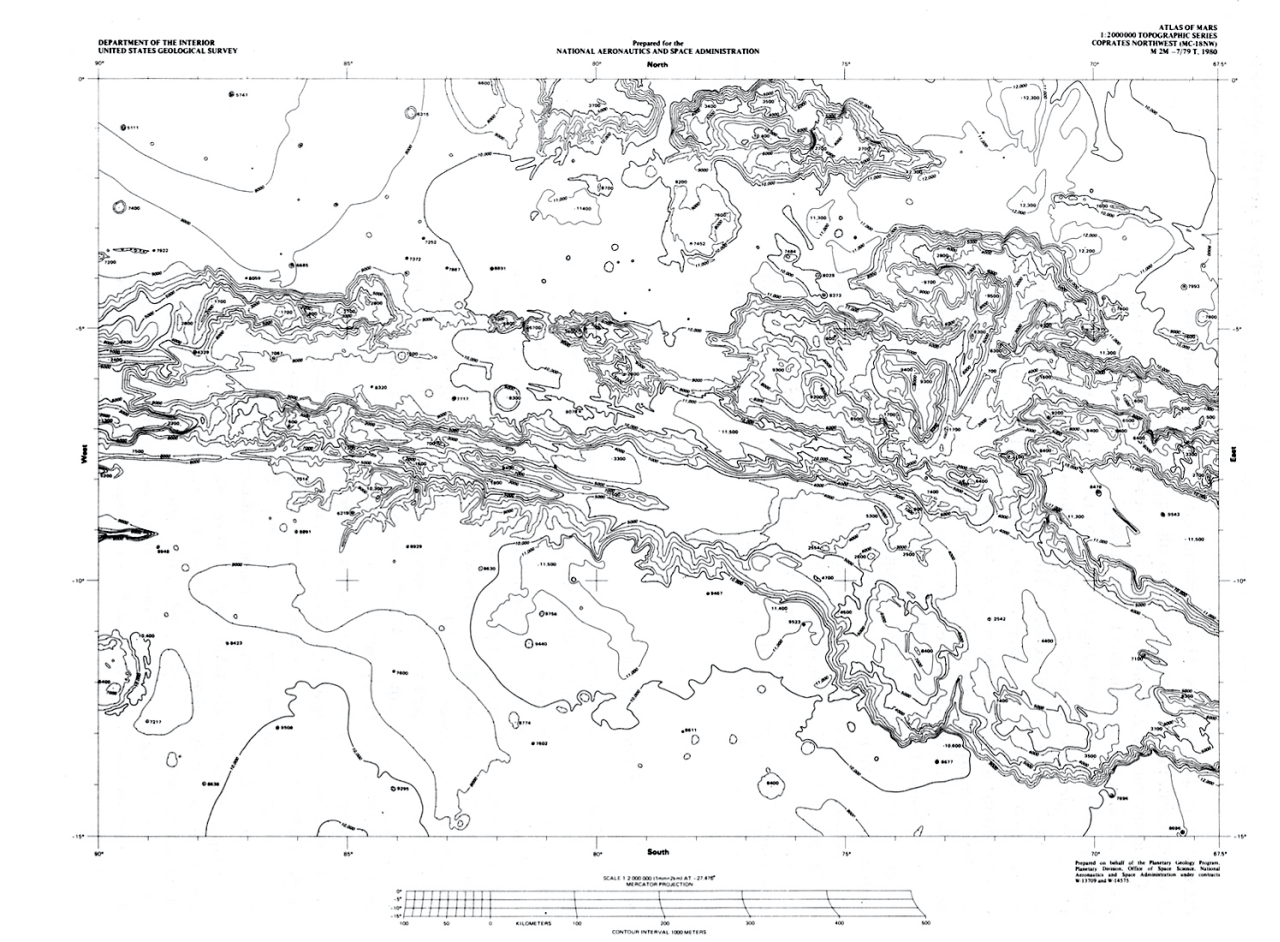
Mariner 9 Topography



USGS science for a changing world

AGU

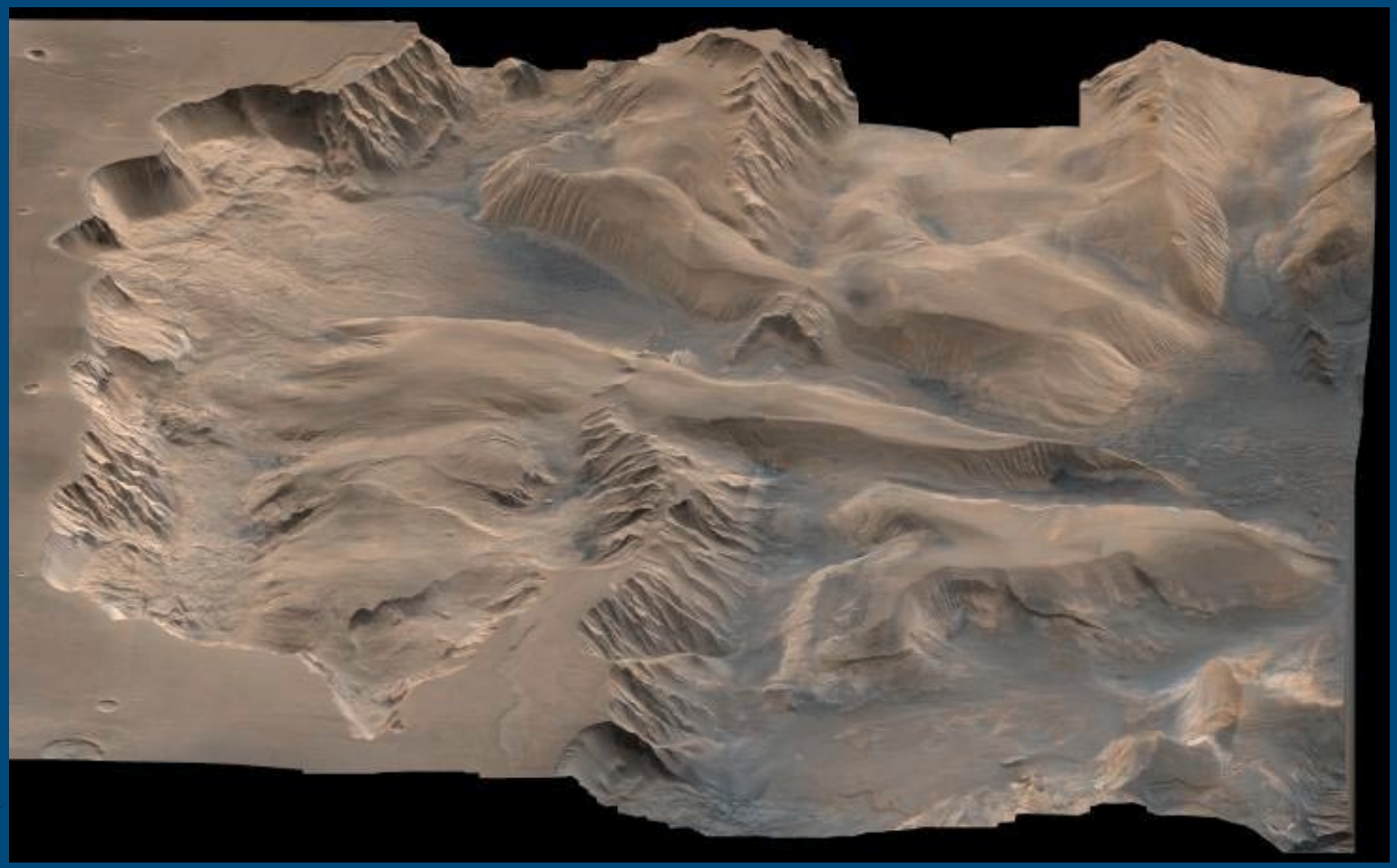
Viking Stereotopographic Maps



USGS science for a changing world

AGU

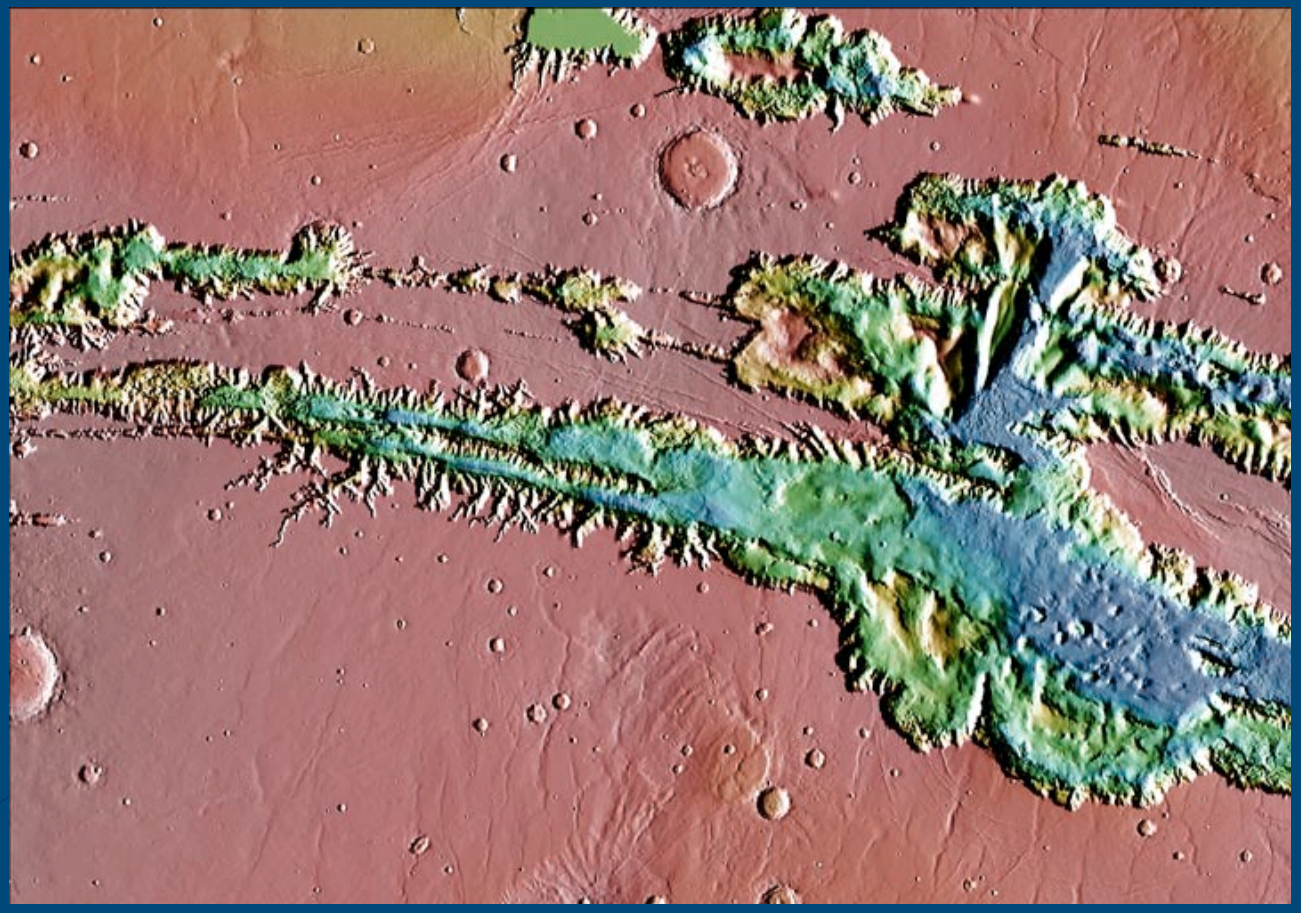
Viking Stereotopographic Maps



USGS science for a changing world

AGU

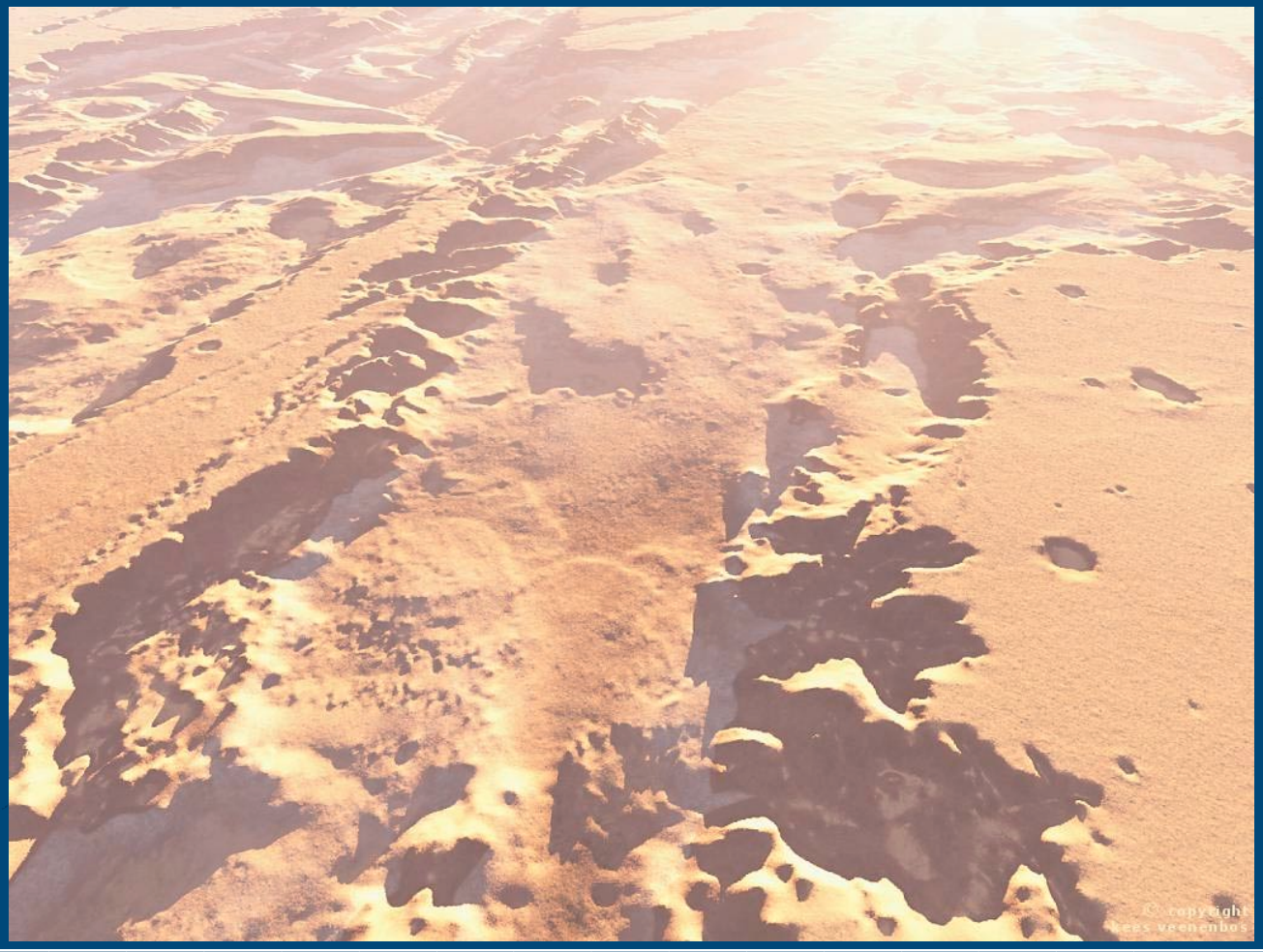
Mars Orbiter Laser Altimeter (MOLA) …The End of Photogrammetry?



USGS science for a changing world

AGU

Mars Orbiter Laser Altimeter (MOLA) …The End of Photogrammetry?



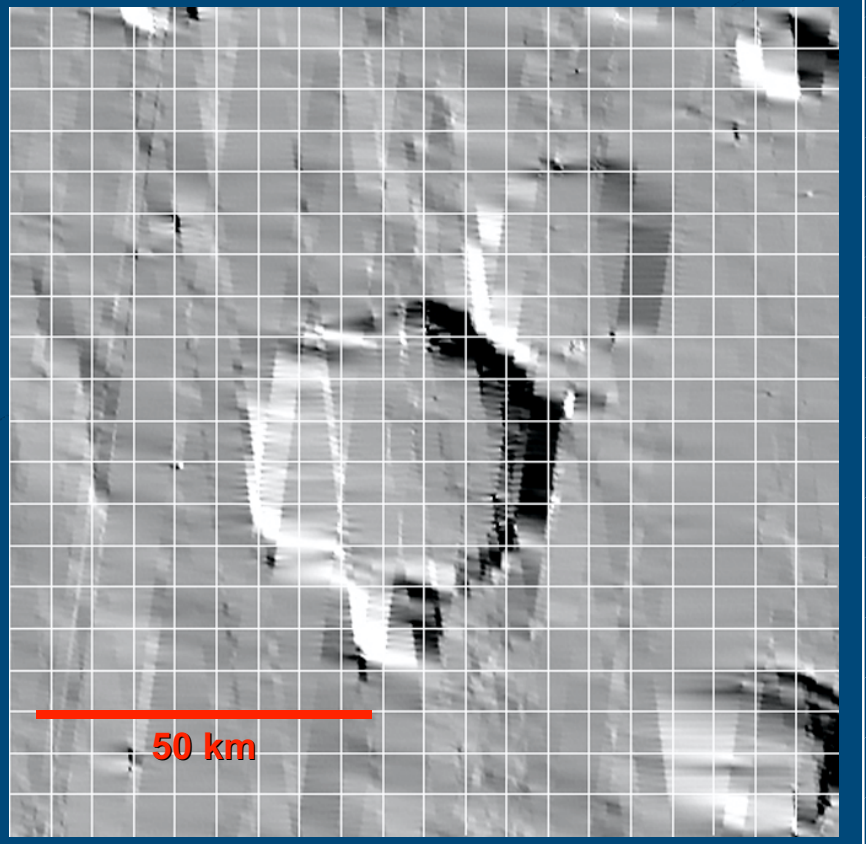
USGS science for a changing world

AGU

MOLA Statistics

600 Million Shots

- <1 m vertical precision
- ~10 m vertical accuracy
- 160 m spot diameter
- 300 m along-track spacing
- 1–5 km gaps between tracks



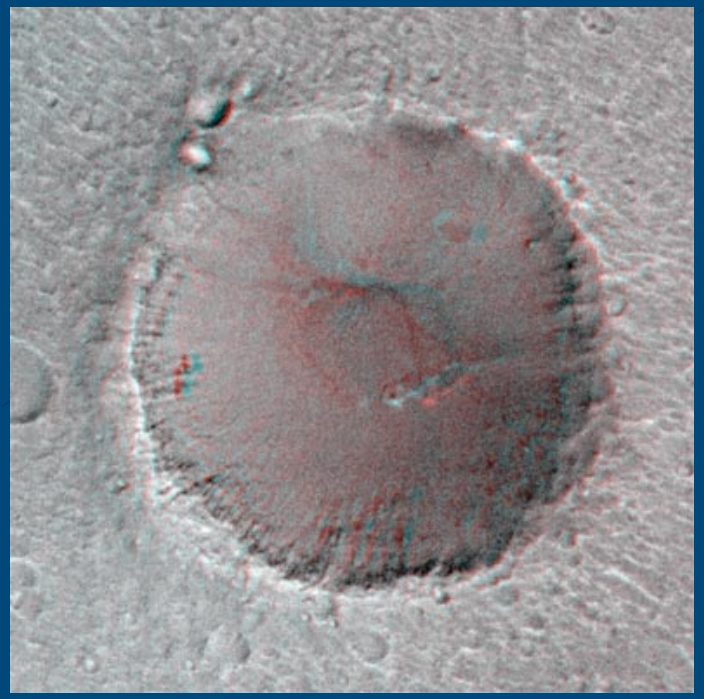
USGS science for a changing world

AGU

MOC-NA Stereo

>150 Stereopairs

- Out of >30,000 images
- ~10^{-5} of Mars by area
- ≥1.5 m/pixel (3 m typical)
- DEM horizontal resolution ~3 pixels (10 m typical)
- 2 m vertical precision typical
  EP = 0.2 pixel / (base/ht)
- Accuracy depends on ties to MOLA

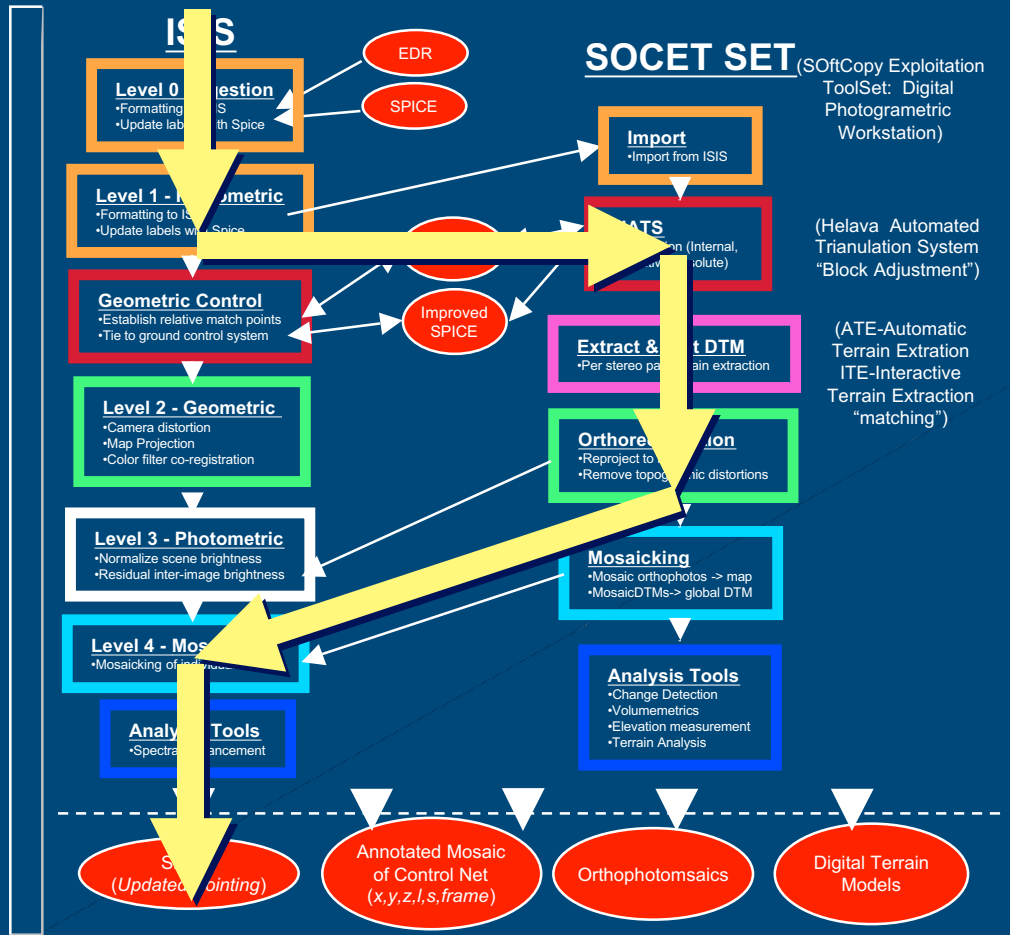


"Big Crater" (1.5 km diam)
Ares Vallis, S of Pathfinder site,
5 m/pixel

USGS science for a changing world

AGU

Stereo Process Flow
ISIS & SOCET SET



ISIS: Integrated Software for Imagers & Spectrometers

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

SOCET SET: SOftCopy Exploitation ToolSET

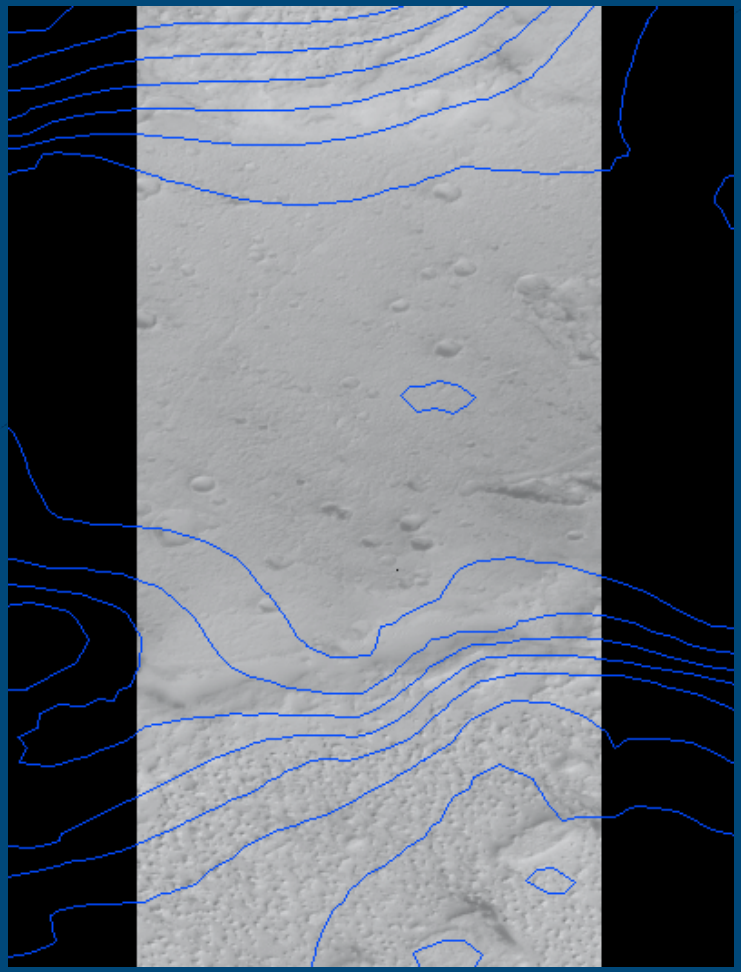
- LH Systems commercial s/w
- Strengths:
  - Stereo display/input
  - Bundle-block adjustment
  - Automatic DTM matching
- Use for 3D processing
- Write new sensor models

USGS science for a changing world

AGU

MOC Stereomapping Approach

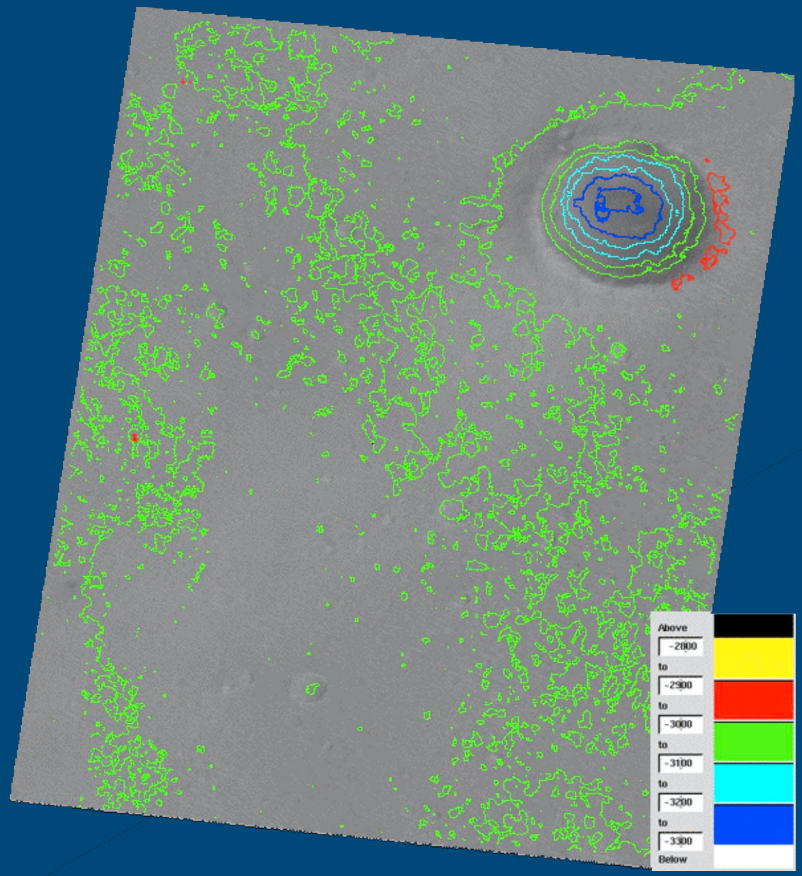
- Geometric calibration of NA, alignment of NA, WA to MOLA using preflight, inflight data
- Decompression, QC, and radiometric calibration with ISIS
- ISIS program to translate metadata from NAIF SPICE Kernels to SOCET support file
- SOCET “Generic Pushbroom” sensor model (physically rigorous but simple)
- Control images to high resolution MOLA DEM produced in ArcView
- Collect & edit DEM as usual
- Analyze w ArcView, custom s/w

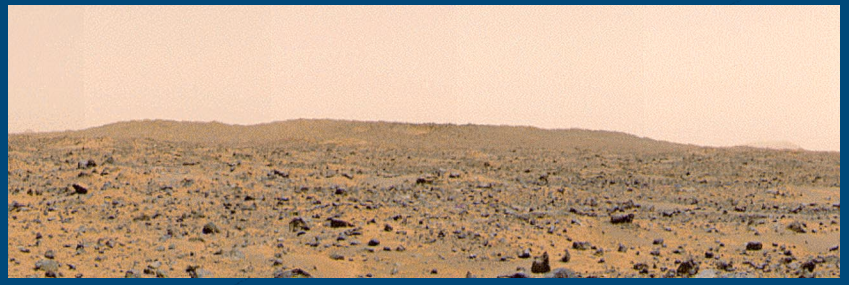


USGS science for a changing world

AGU

First MOC DEM: "Big Crater"

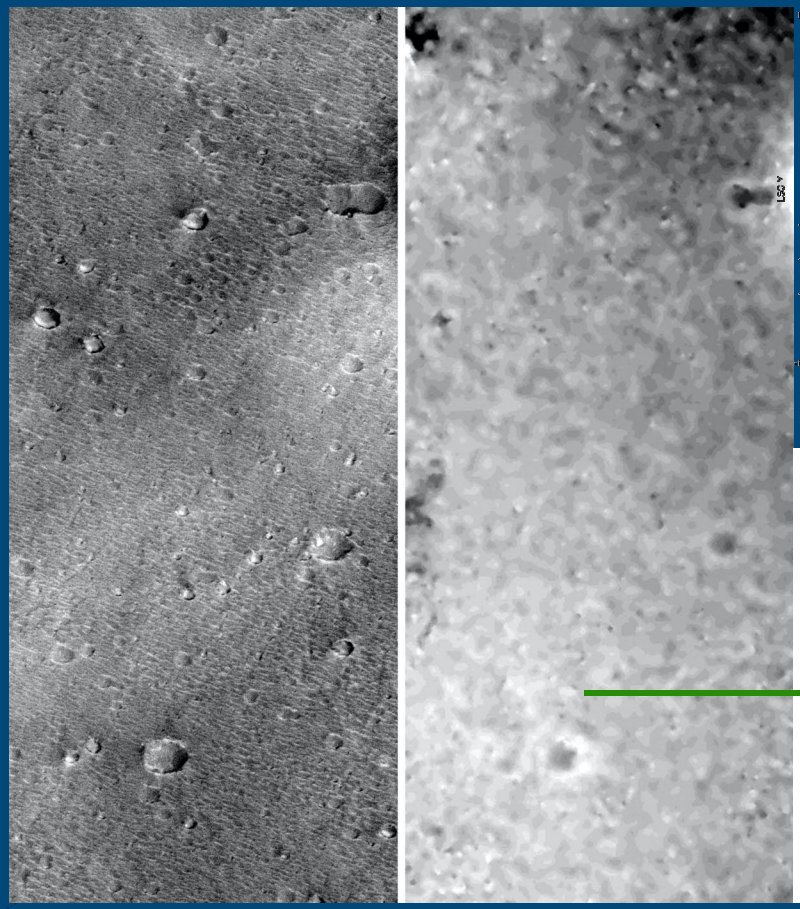


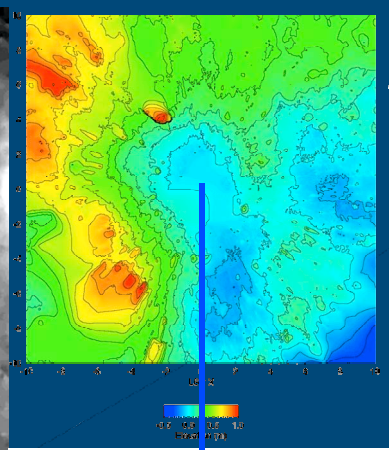


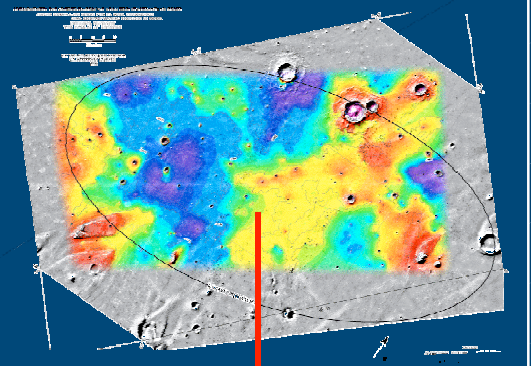
USGS science for a changing world

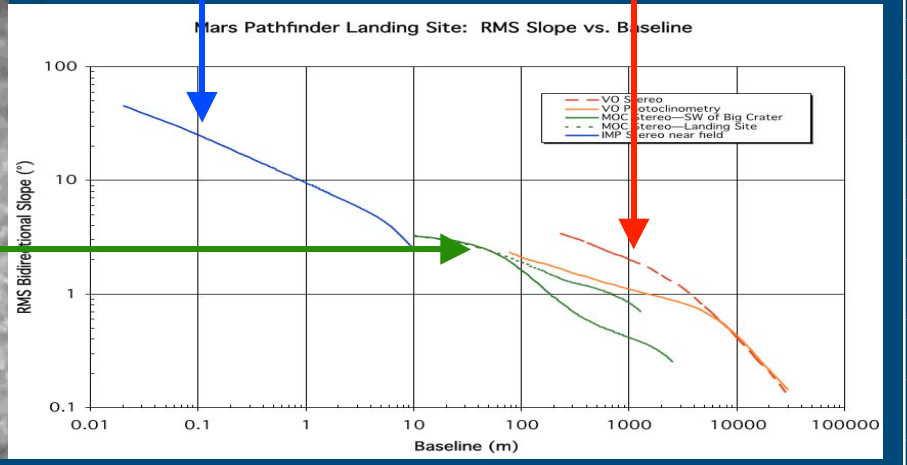
AGU

Pathfinder Site: "Ground Truth" Comparison of Slope v. Baseline





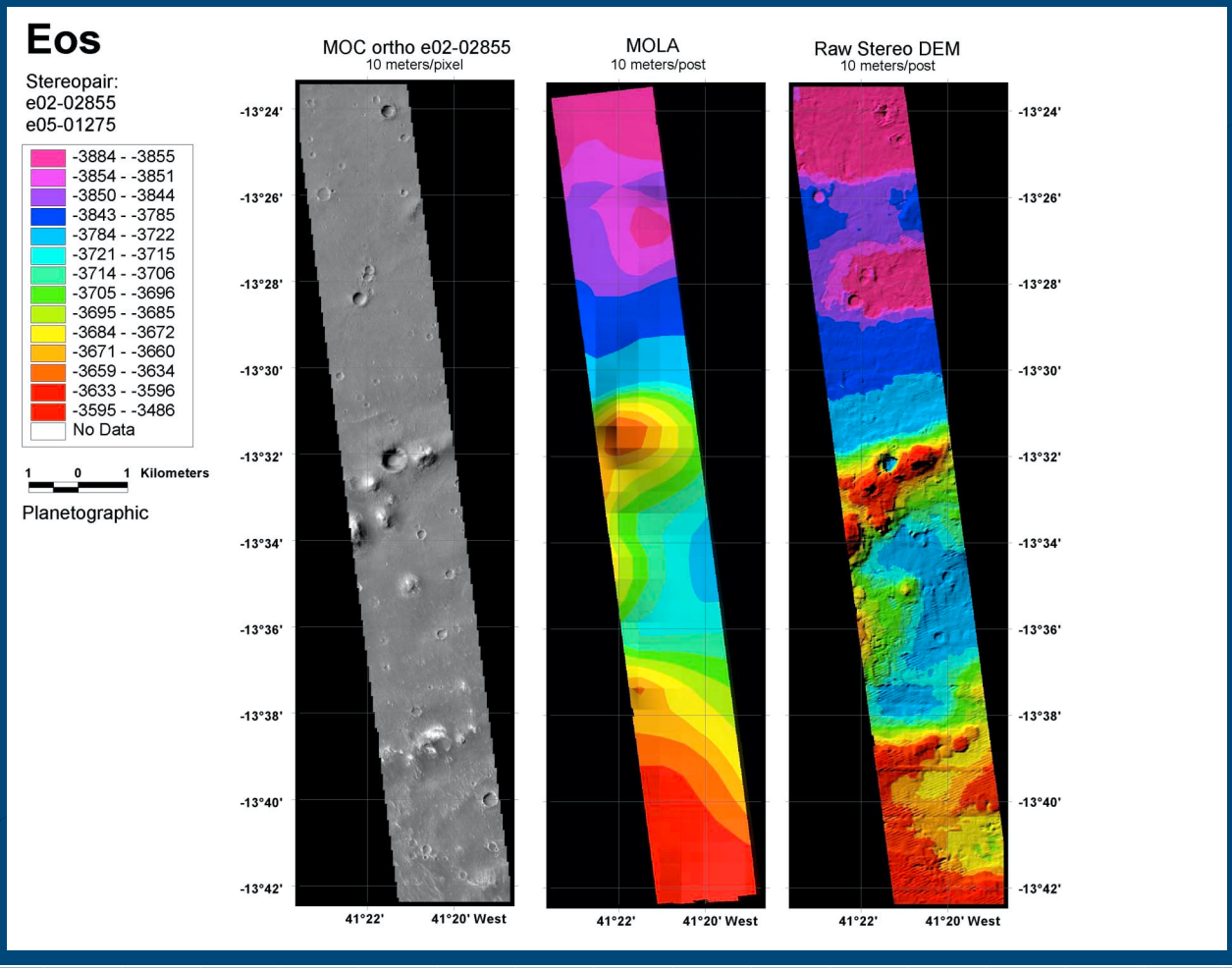




USGS science for a changing world

AGU

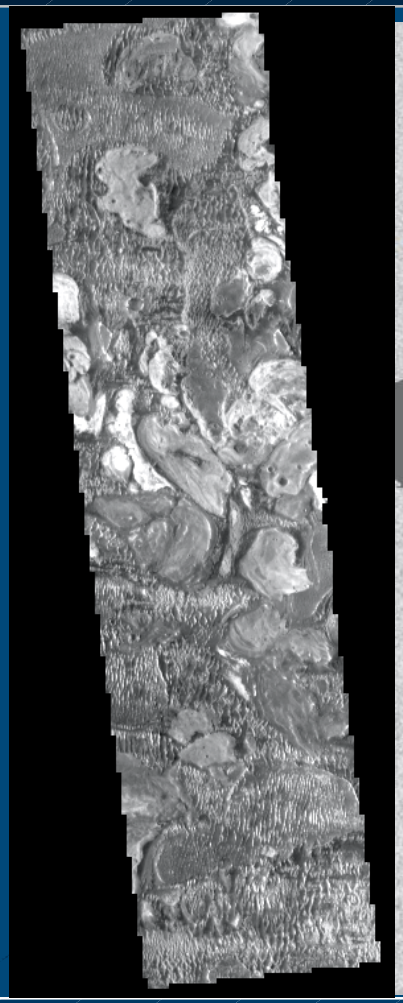
Eos Chasma: E02-02855/E04-01275

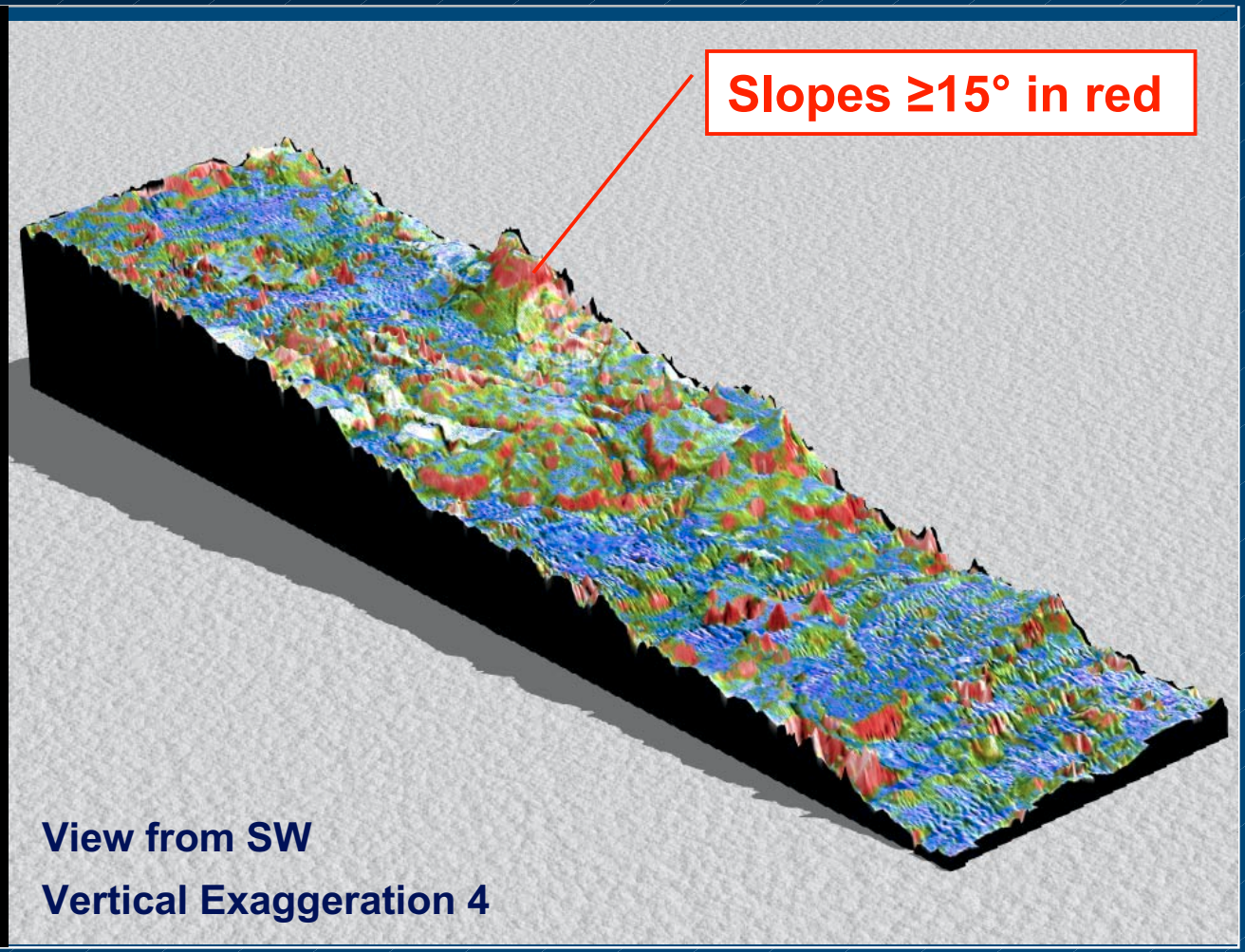


USGS science for a changing world

AGU

Melas Chasma Visualized





USGS science for a changing world

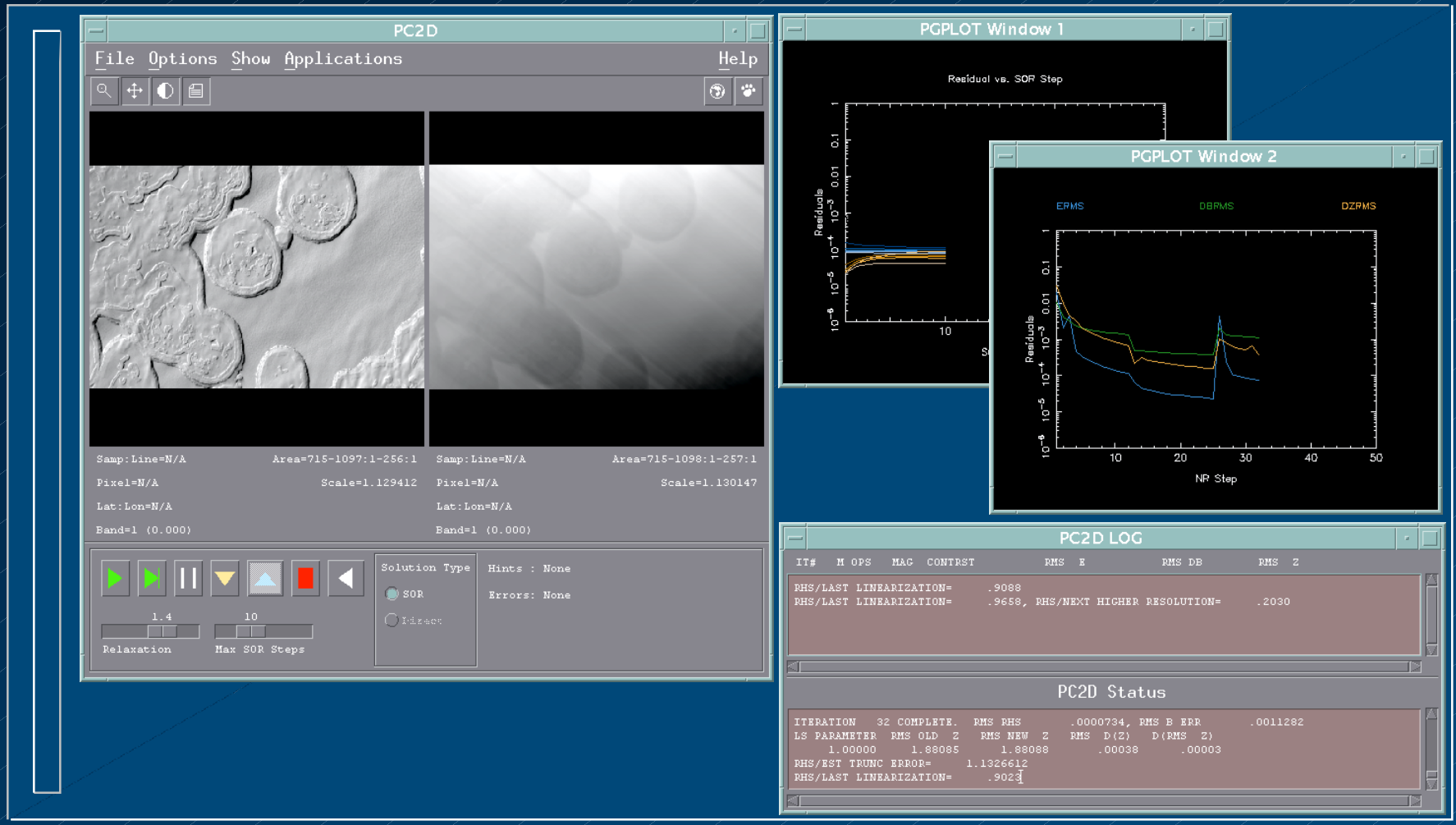
AGU

Photoclinometry: Shape from Shading

Inference of topo from brightness information in image

- Highly complementary to stereo
- Brightness <–> slope; must integrate to get heights
  - Most accurate for short baselines, down to 1 pixel
- Can be formulated various ways
  - 1 D (profile): must make assumptions about slope direction
  - 2 D (DEM): use implicit or explicit continuity of surface
    - Think of it as a nonlinear PDE with image as driver
    - Think of it as the inverse problem to hillshading
    - Think of it as nonlinear lsq fitting of model image to real image
- 2D solution is iterative, delicate, CPU+labor intensive
- Results depend on validity of photometric model used
  - Surface reflectivity variations –> artifacts
  - Surface photometric function
  - Atmospheric scattering: amount and directionality

2 D Photoclinometry
ISIS Graphical User Interface



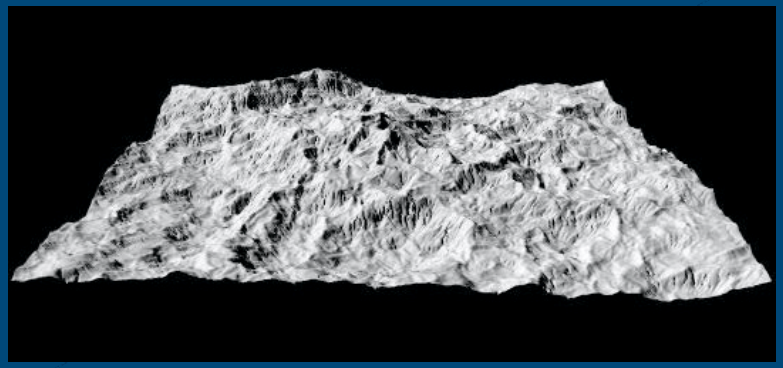
USGS science for a changing world

AGU

Effect of Haze and Albedo

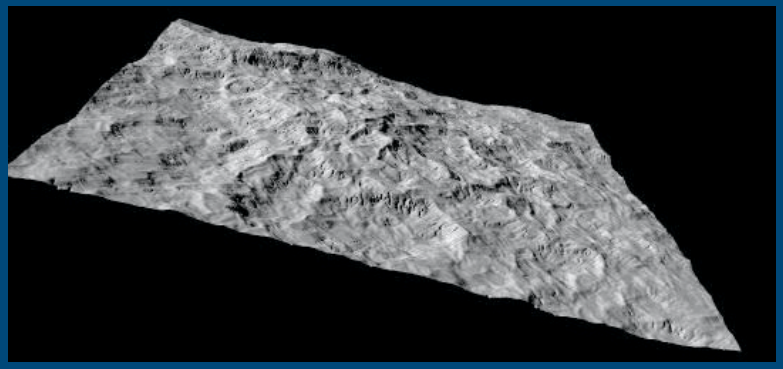
Sun is from upper left in all examples

Correct Haze and Albedo



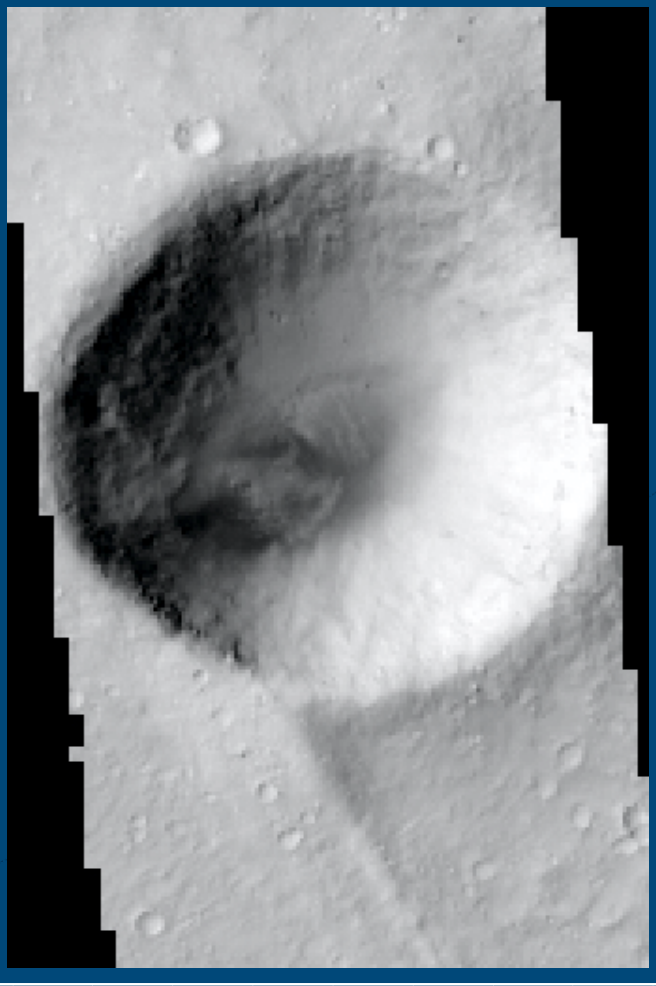
Too much Haze subtracted

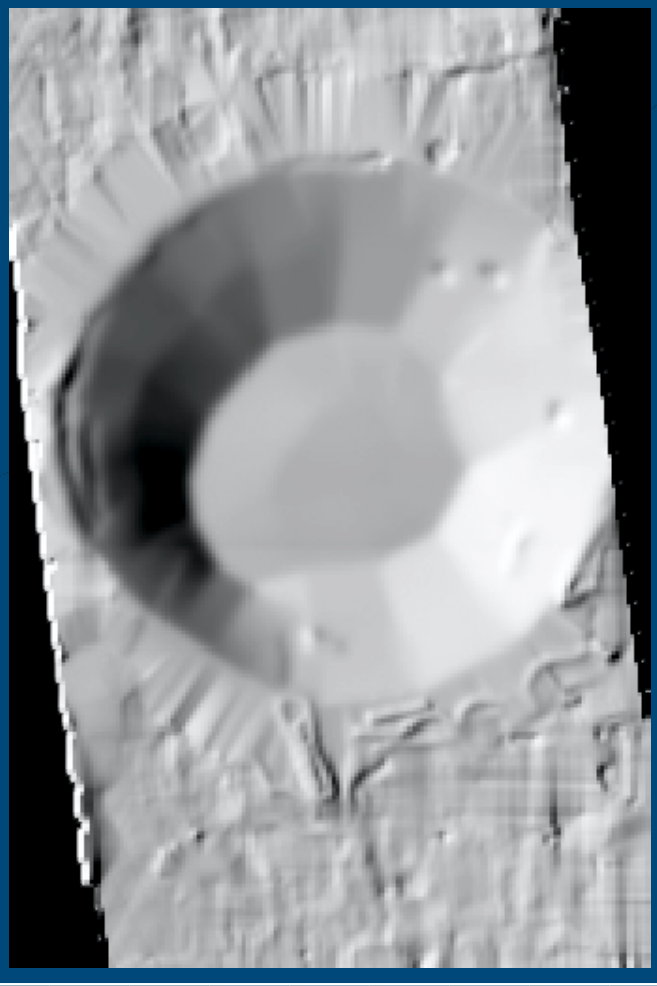
Albedo underestimated



Albedo overestimated

Forward Fitting for Haze: Simulate Image from DEM

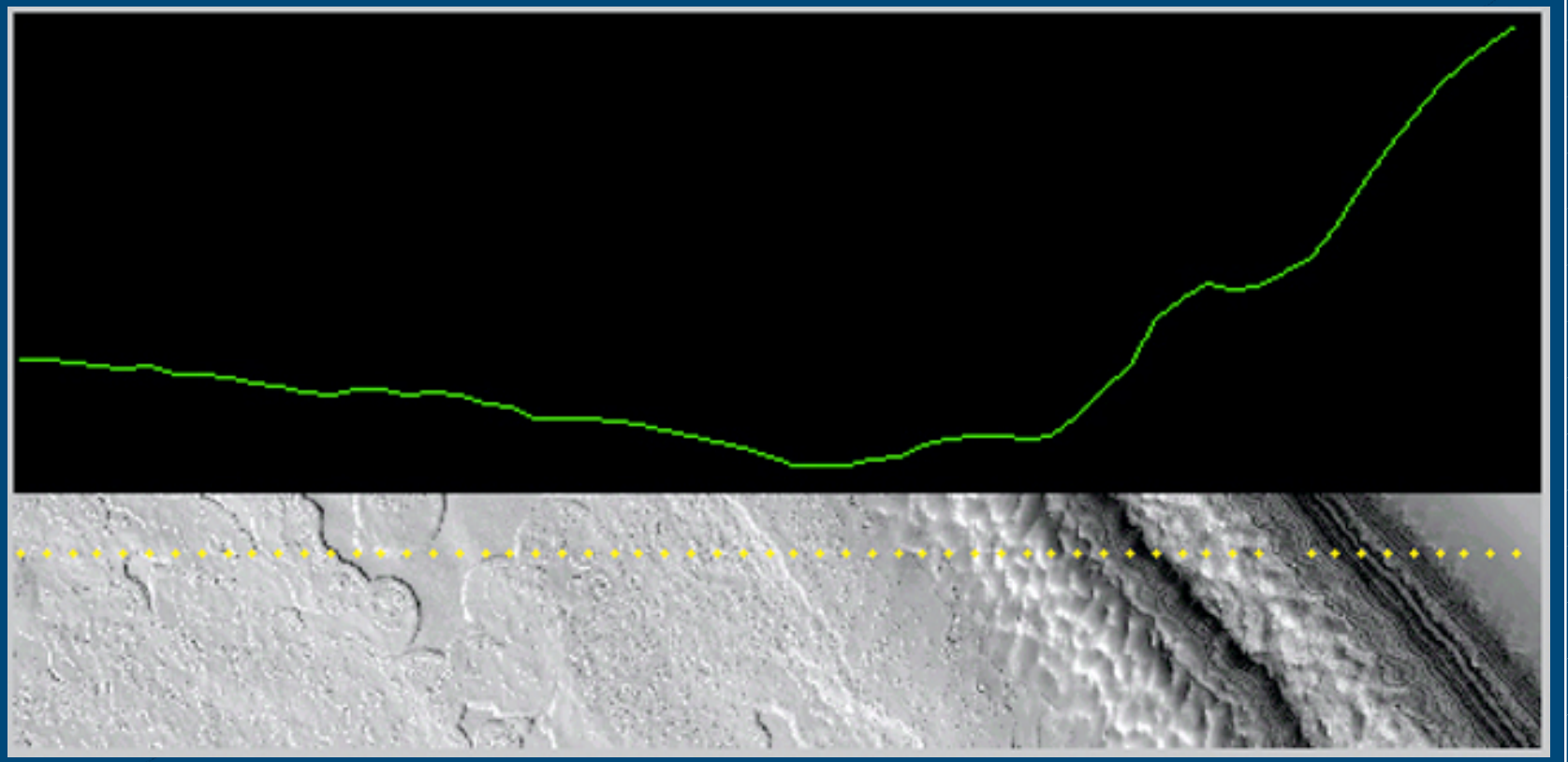




USGS science for a changing world

AGU

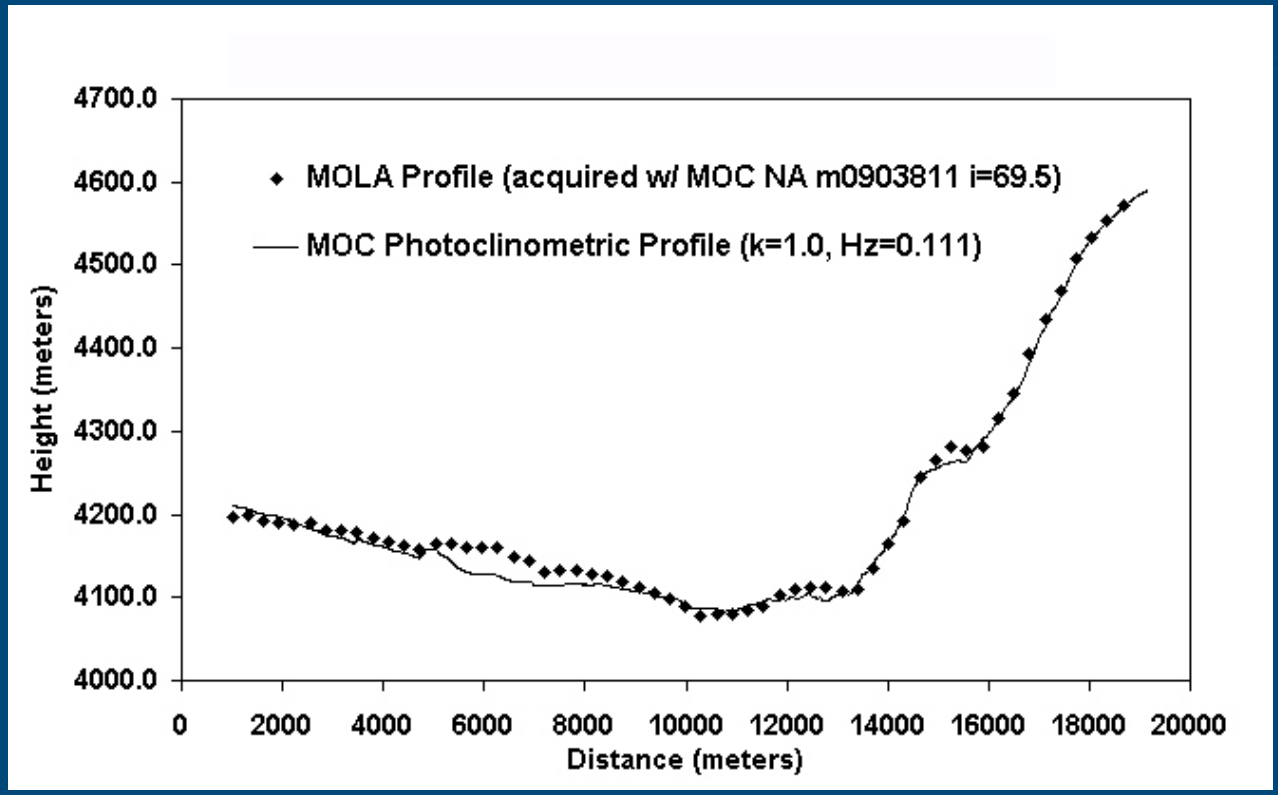
Inverse Fitting for Haze: Tweak Photoclinometry to Match DEM



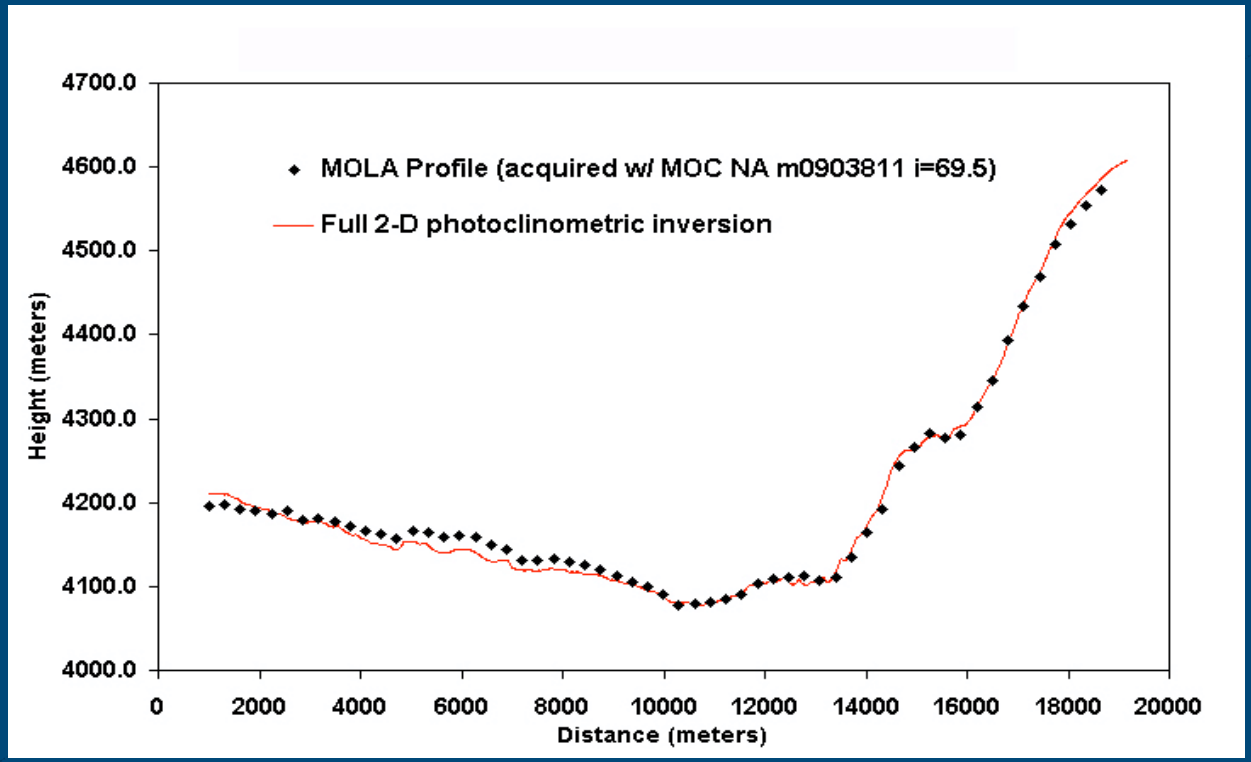
USGS science for a changing world

AGU

Inverse Fitting for Haze: Tweak Photoclinometry to Match DEM



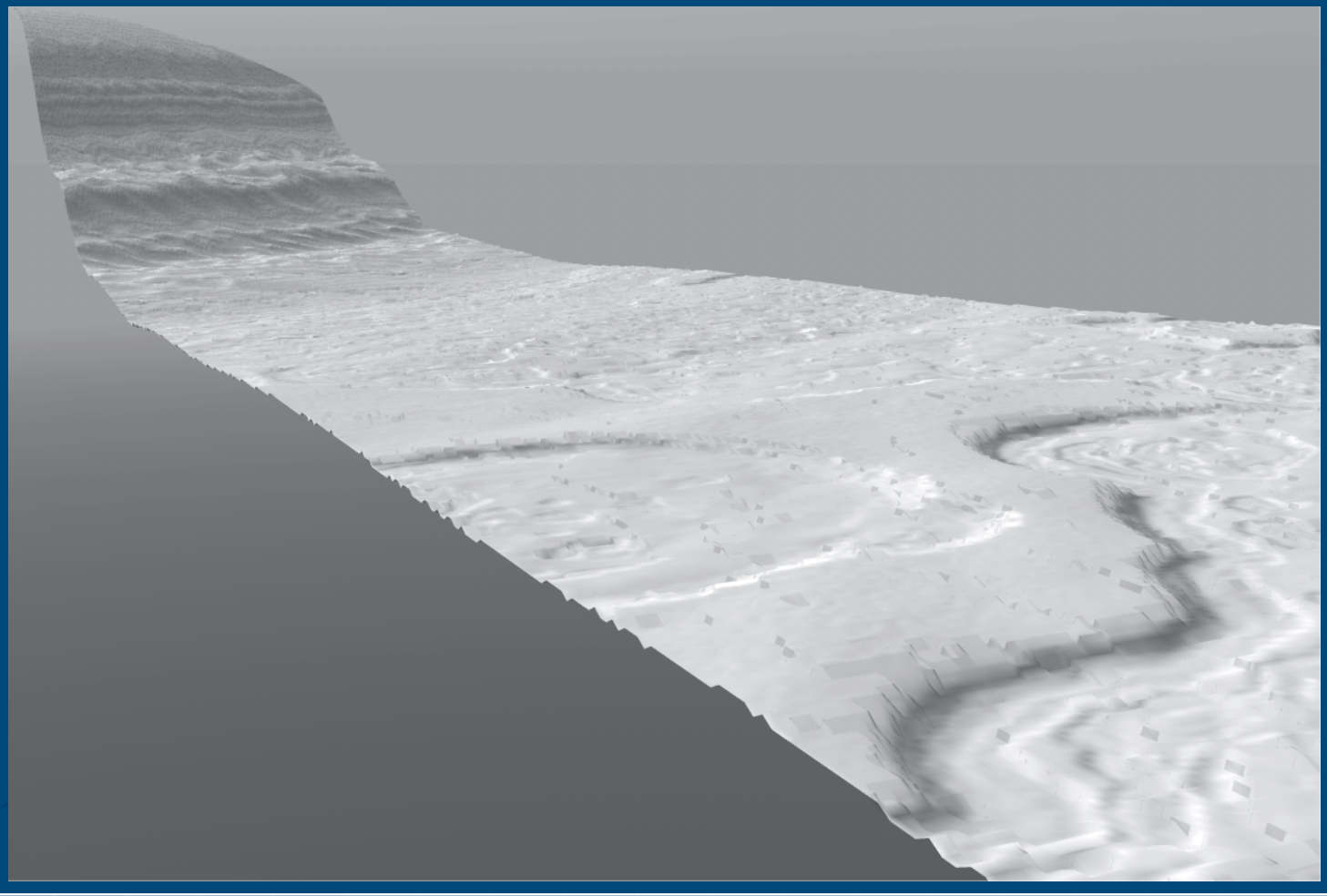
Inverse Fitting for Haze: Tweak Photoclinometry to Match DEM



USGS science for a changing world

AGU

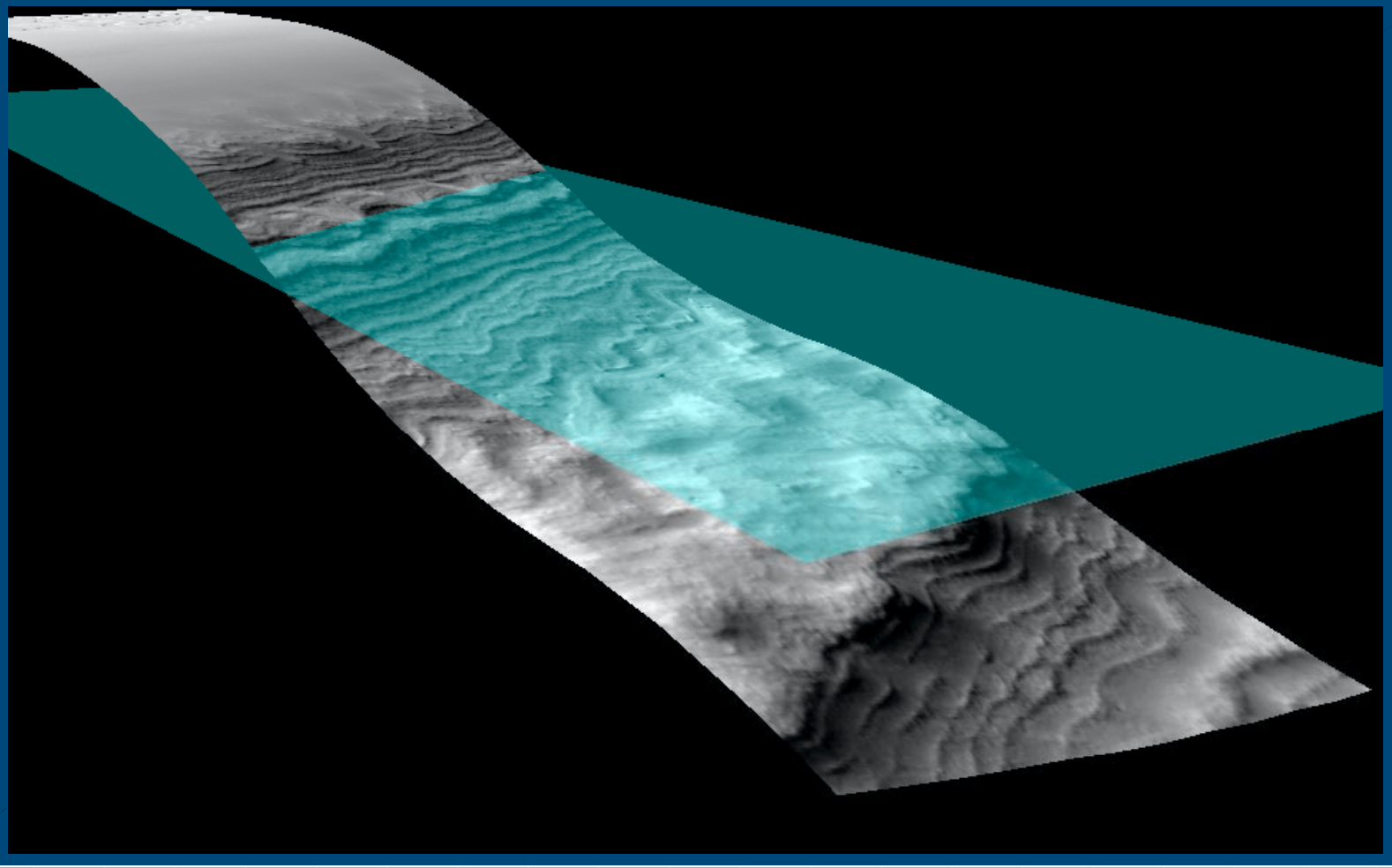
Perspective Views of Polar Layered Terrain



USGS science for a changing world

AGU

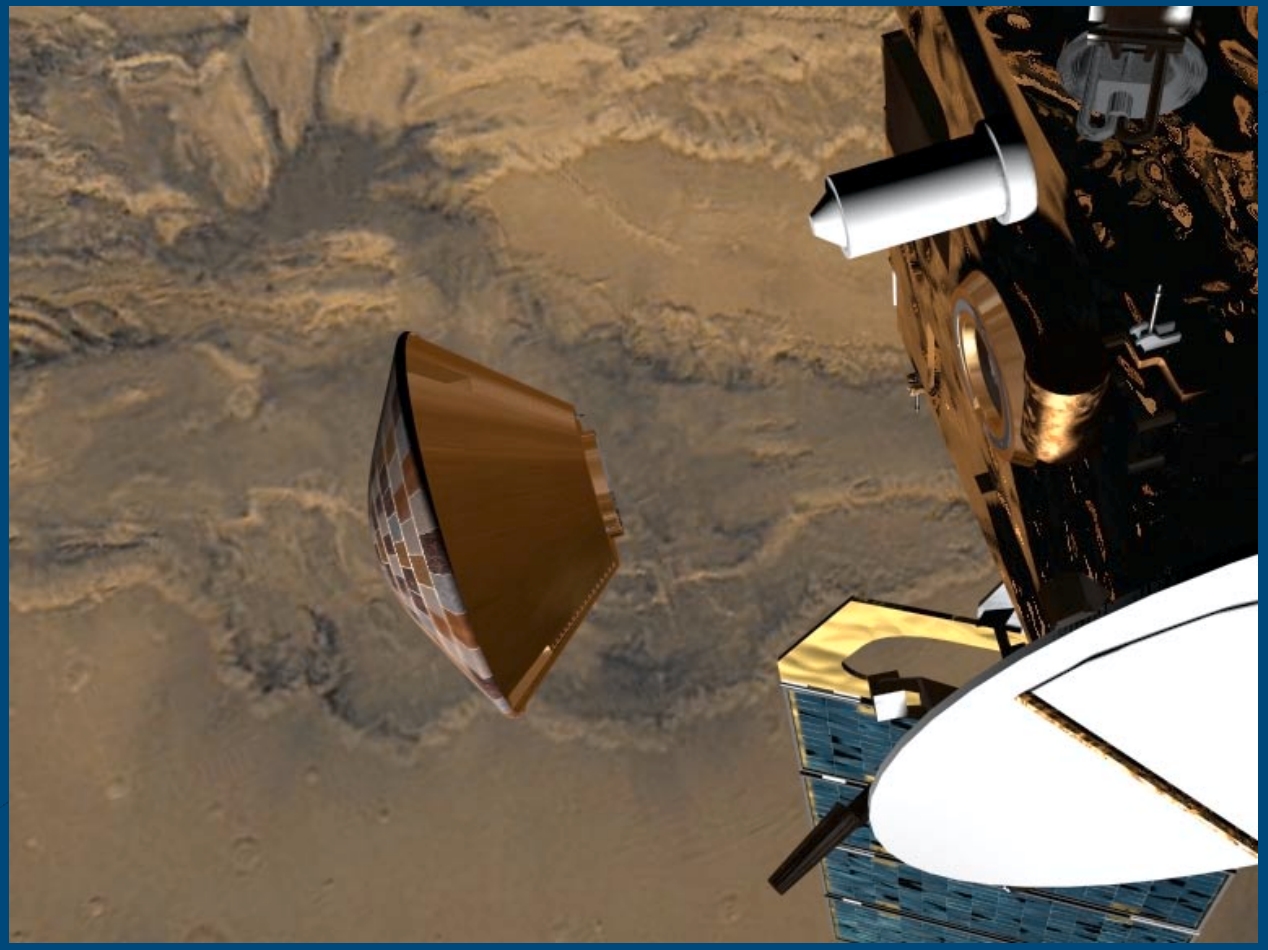
Perspective Views of Polar Layered Terrain



USGS science for a changing world

AGU

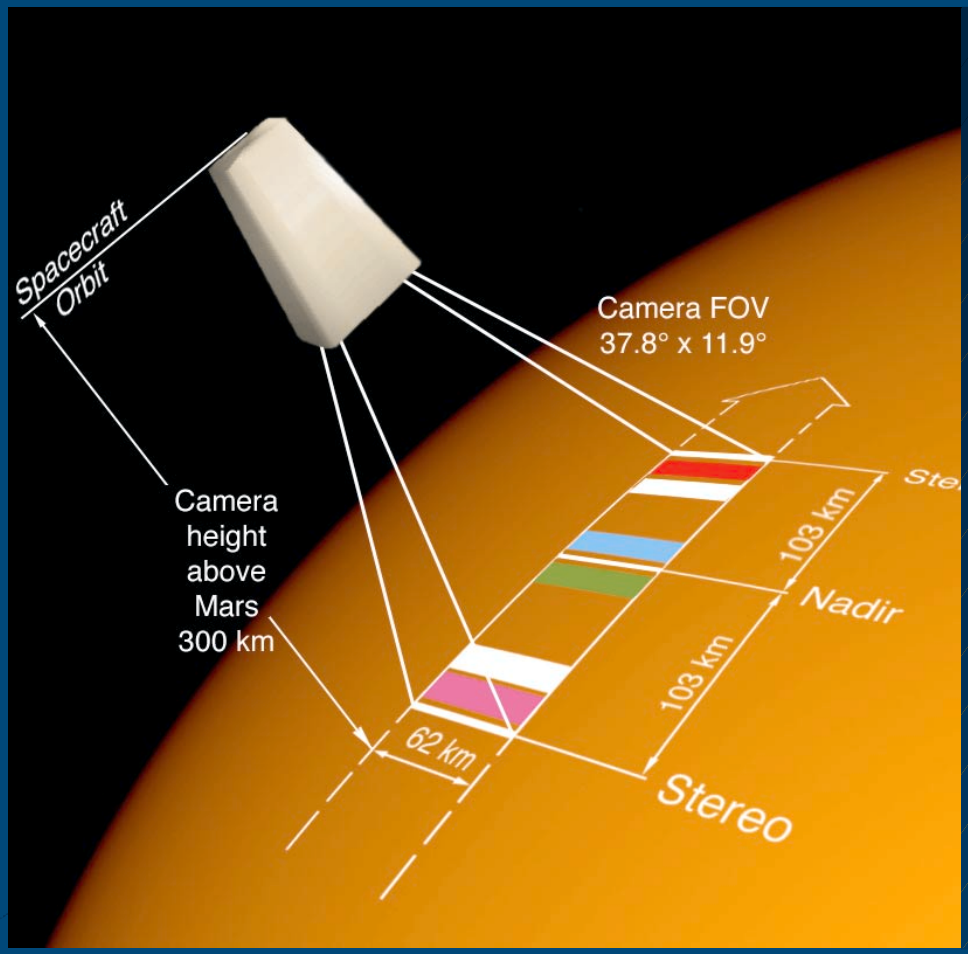
Mars Express HRSC (2003)



USGS science for a changing world

AGU

Mars Express HRSC (2003)



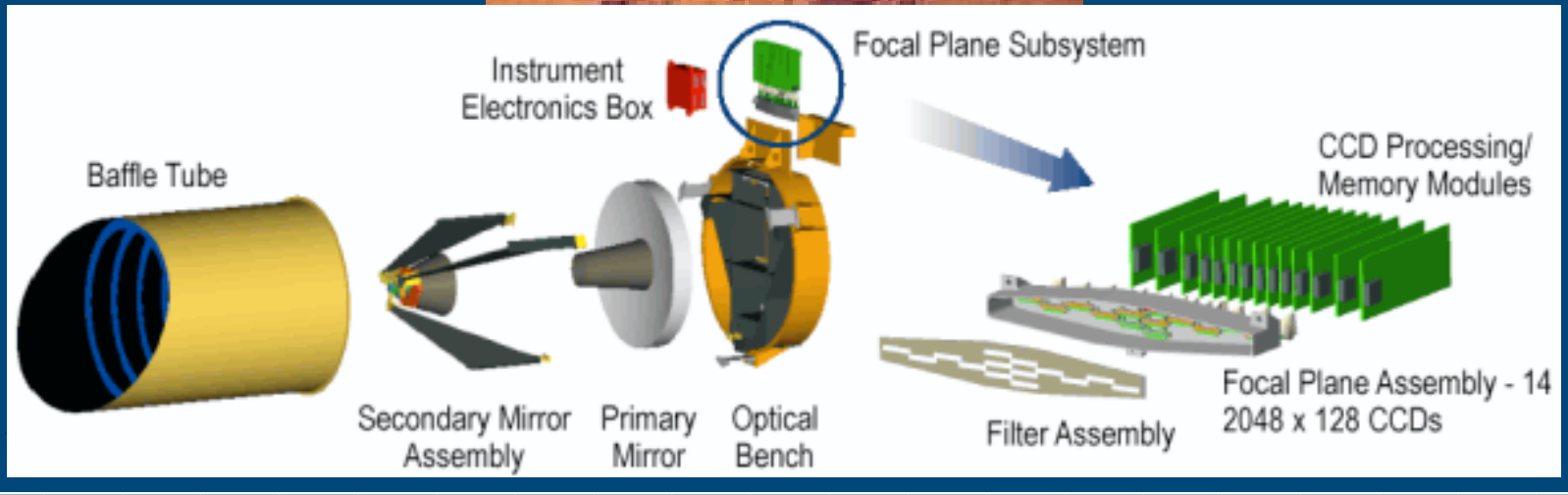
First Dedicated Stereo Camera at Mars

- 9 pushbroom lines
- 3 stereo lines+color
- 5000 pixel swath
- 10 m/pixel at periapse
- *Many* % of Mars with
  - ≤50 m DEM spacing
  - ≤10 m vertical prec
- Plus larger areas at poorer resolutions

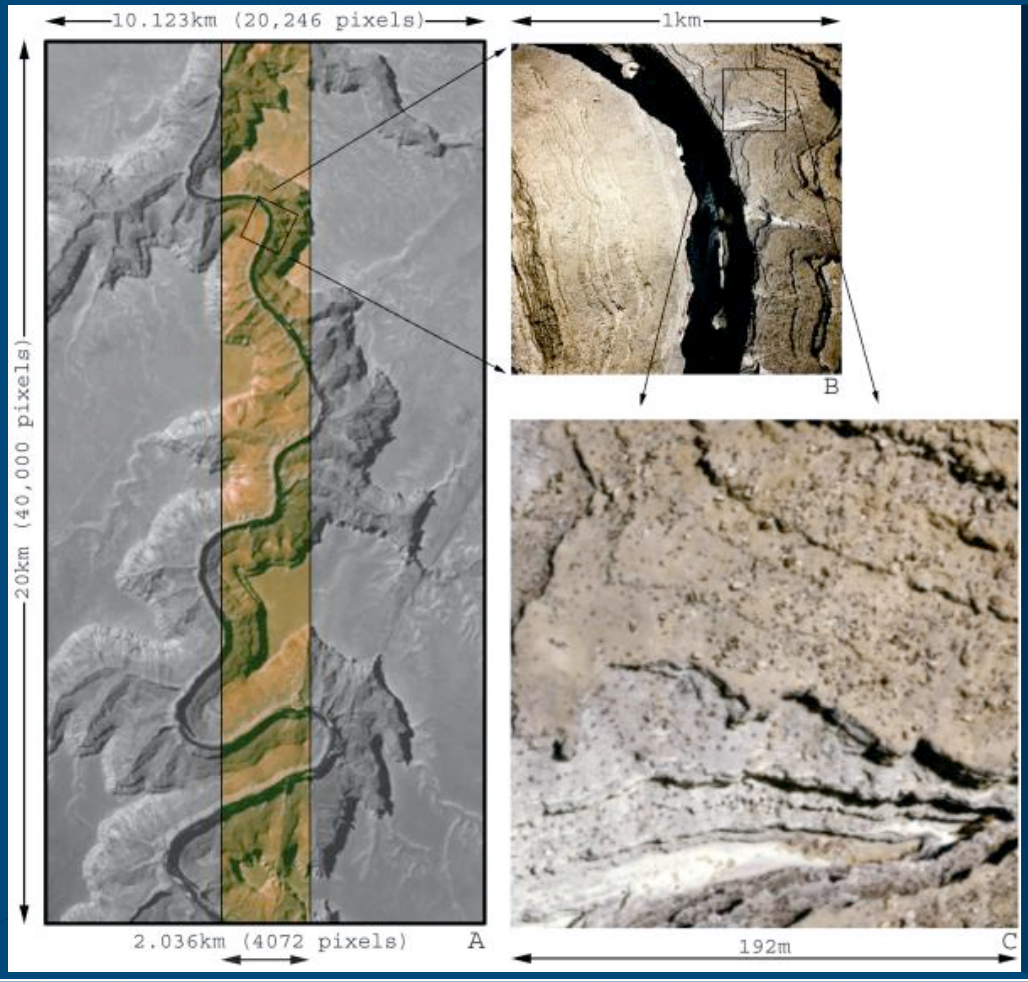
USGS science for a changing world

AGU

MRO—HiRISE (2005)



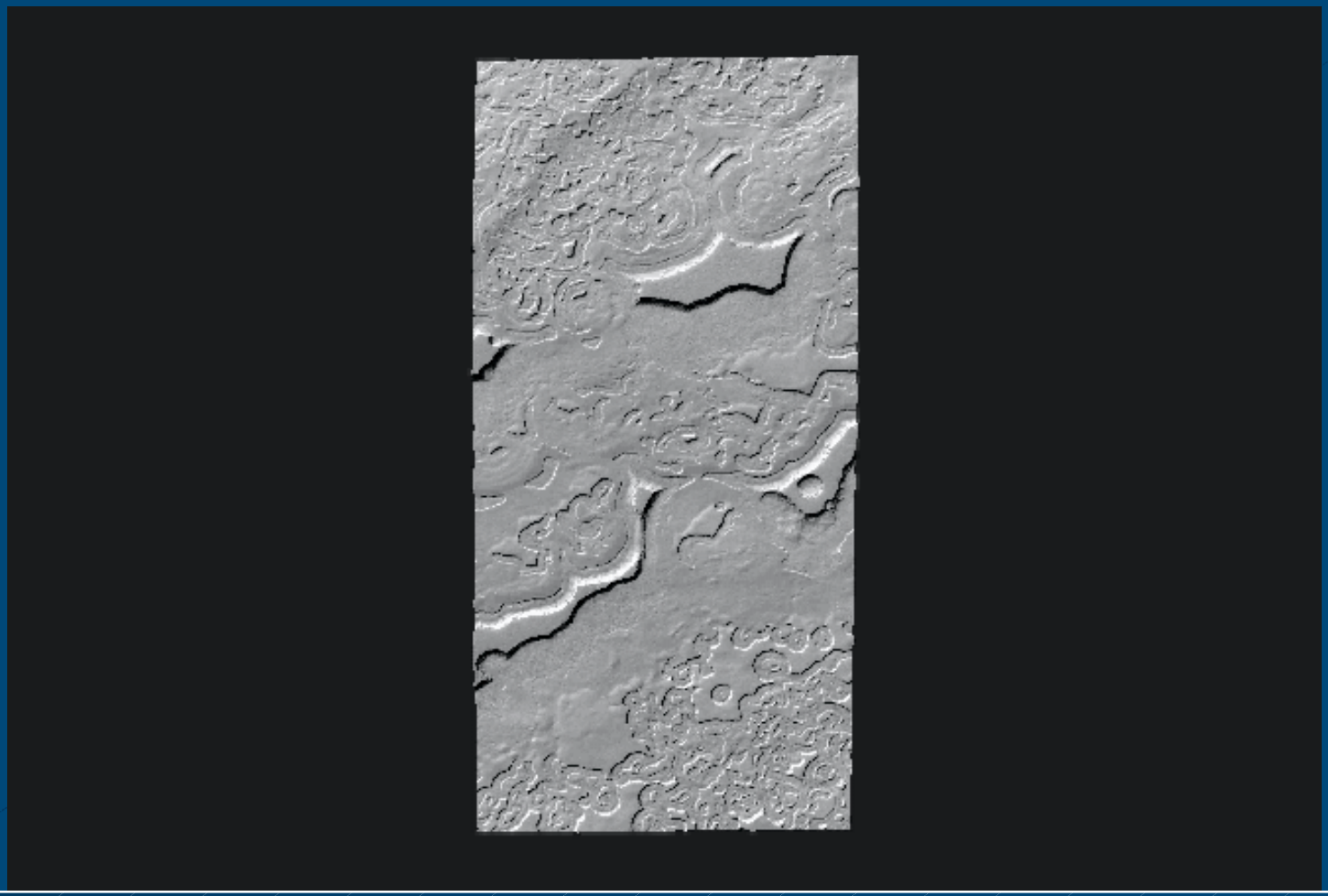
MRO—HiRISE (2005)

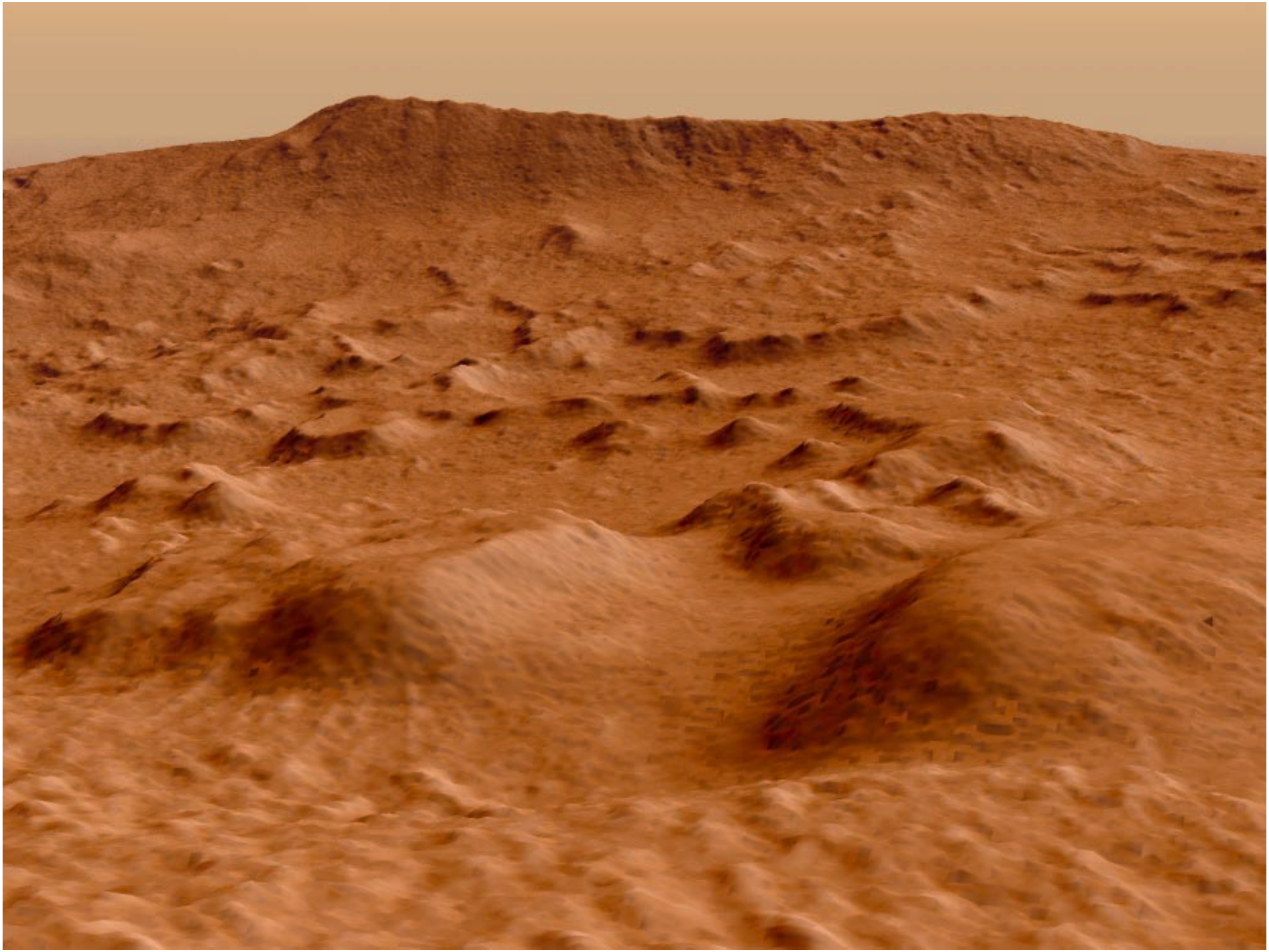


Ultrahigh Resolution

- 20,000 pixel swath
- 4000 pixels in color
- 30 cm/pixel
- 1 m DEM spacing
- 20 cm vertical prec
- Stereo a priority: ~1000 pairs
- ~10^{-3} of Mars in stereo

“Flyover” of Polar Layered Terrain



USGS science for a changing world

AGU