Exploring Titan in 3D with Cassini RADAR

including evidence for (and against) ice volcanism

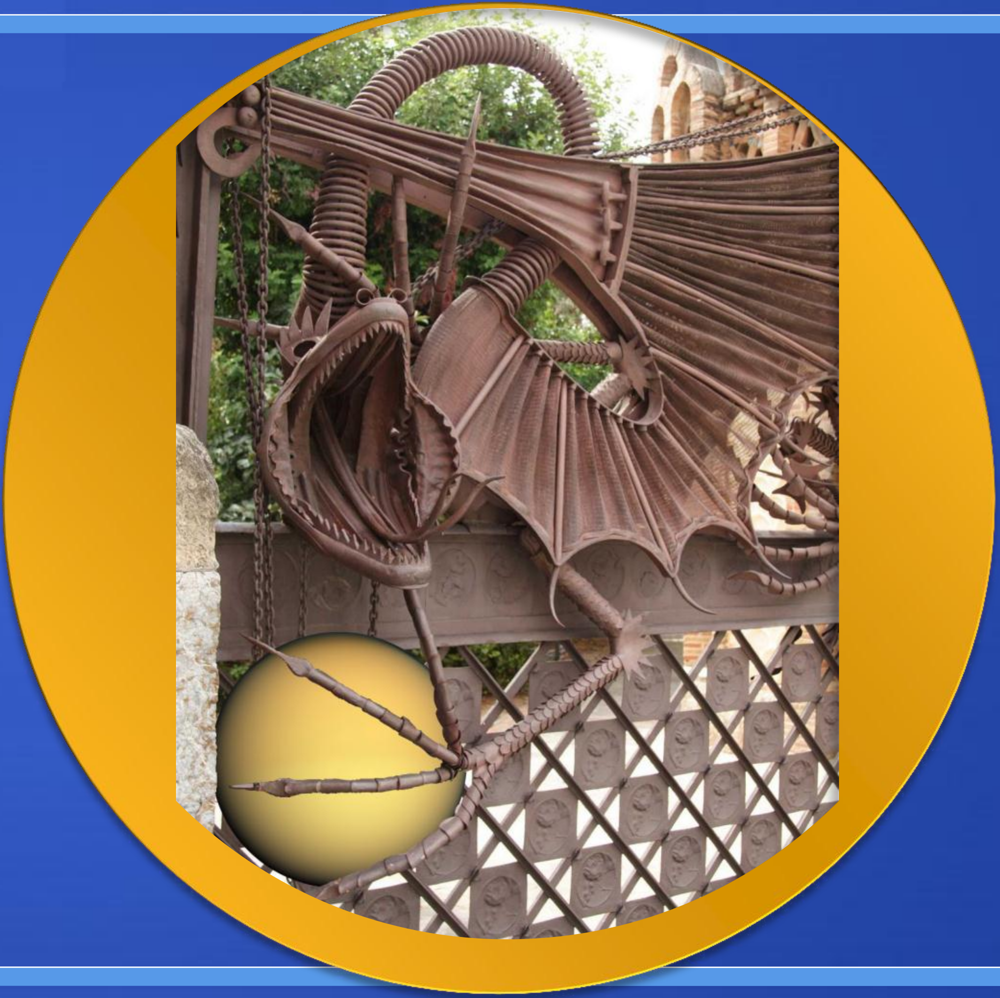
R. L. Kirk

Cassini RADAR / USGS

CHARM Telecon 2011 March 29

Outline

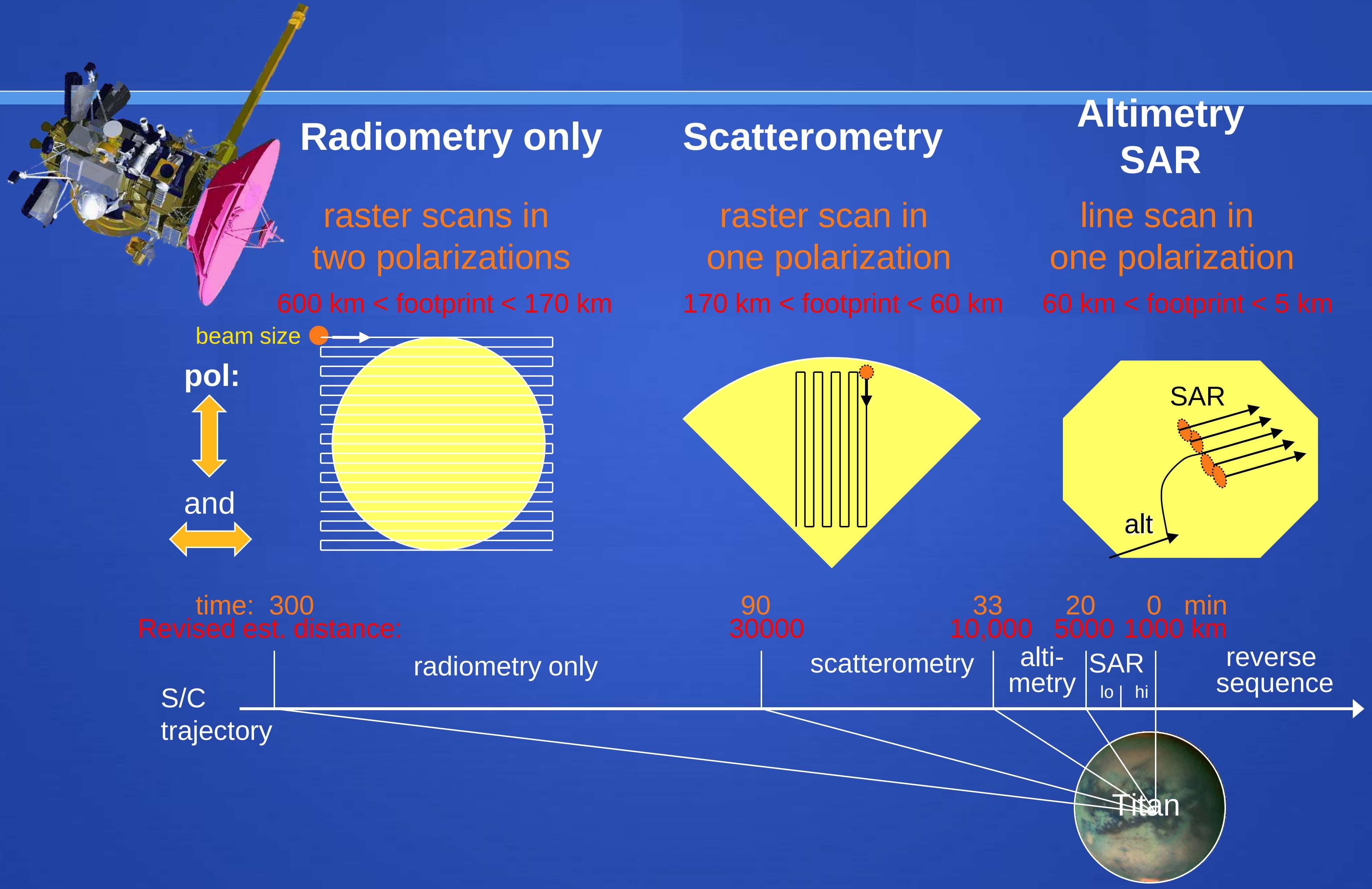
- Introduction
  - Cassini-Huygens
  - The RADAR Instrument
  - Titan
- Radargrammetry—what is it?
- Tour of Titan's surface features in 3D
- The case for ice volcanism



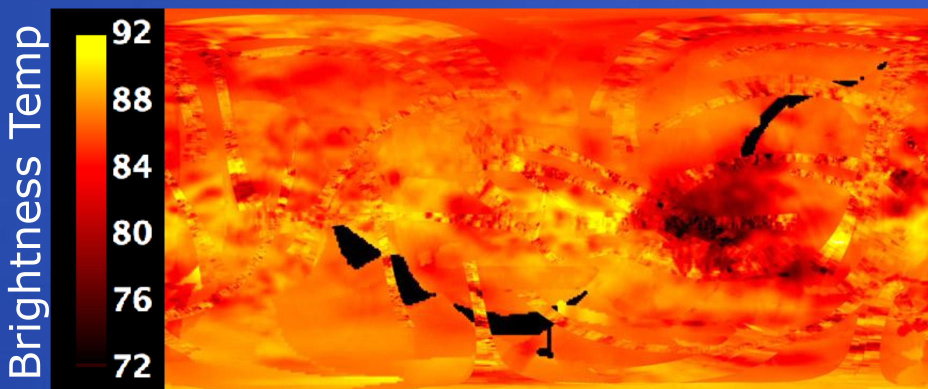
Cassini-Huygens Mission

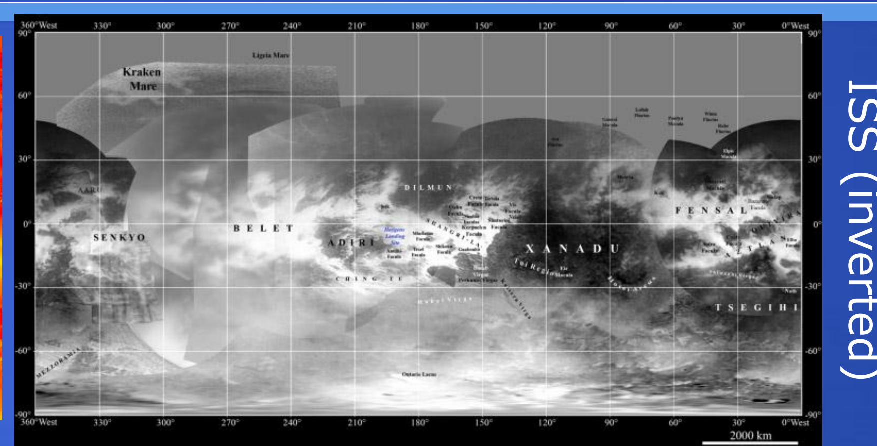
- Joint NASA-ESA mission
  - Cassini: Orbiting Saturn since 2004
  - Huygens: Landed on Titan in 2005
- Total of 18 instruments
- 2.2 cm RADAR for mapping Titan
  - 300-1400 m SAR images
  - 30-40 km altimetry
  - Scatterometry, radiometry
- Titan = Interesting
  - Size of Mercury
  - Dense atmosphere at -180 C
  - Organic chemistry…lots of it
  - Geologic processes similar to Earth but with different materials
    - H_2O is "rock"
    - CH_4 is "water"

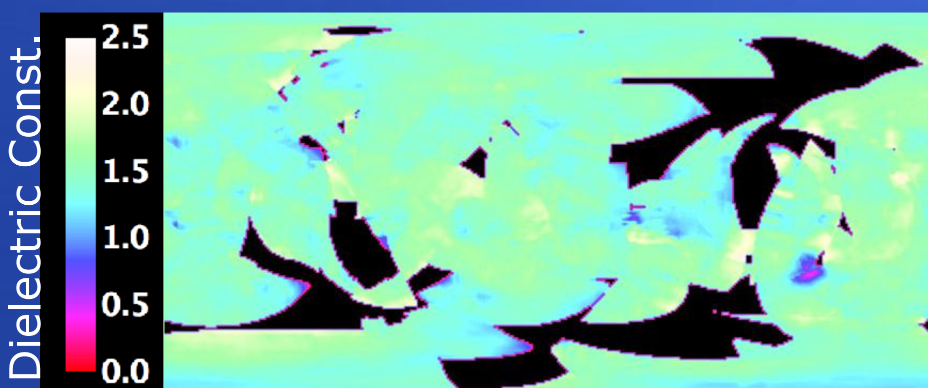
Cassini RADAR Observations

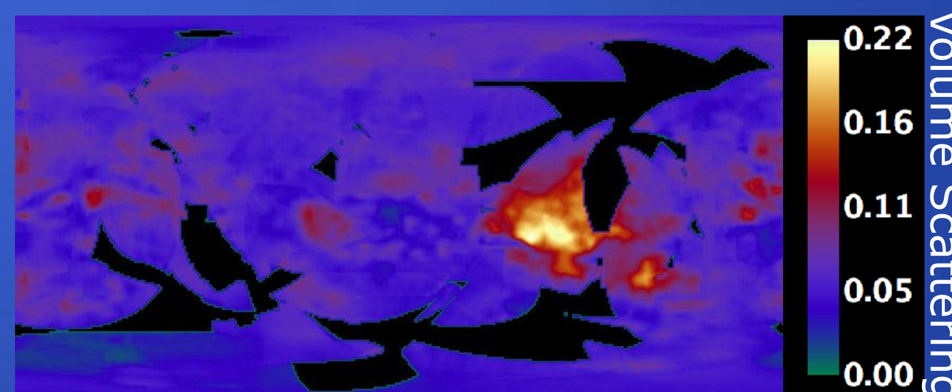


Global Radiometry

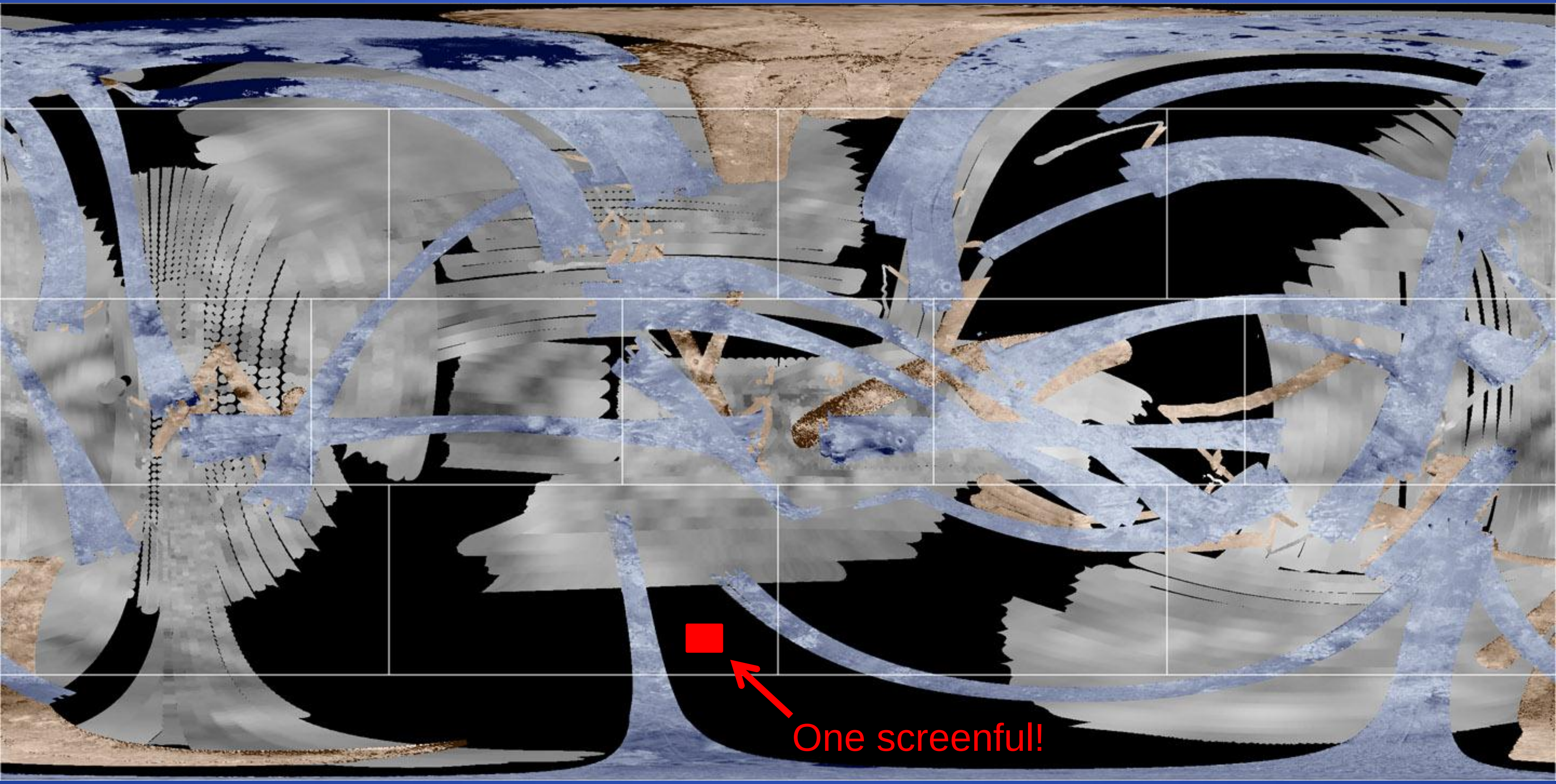






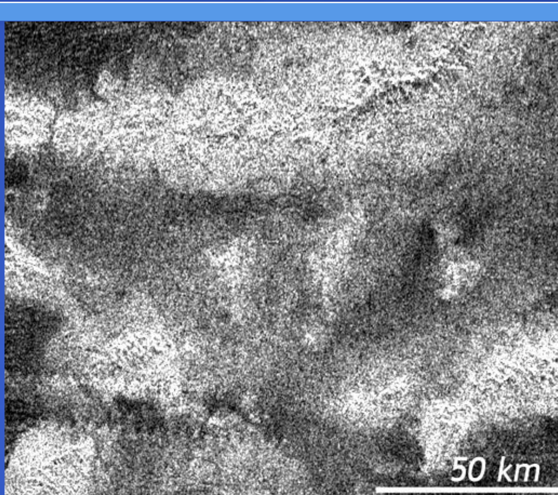


Scatterometry and SAR

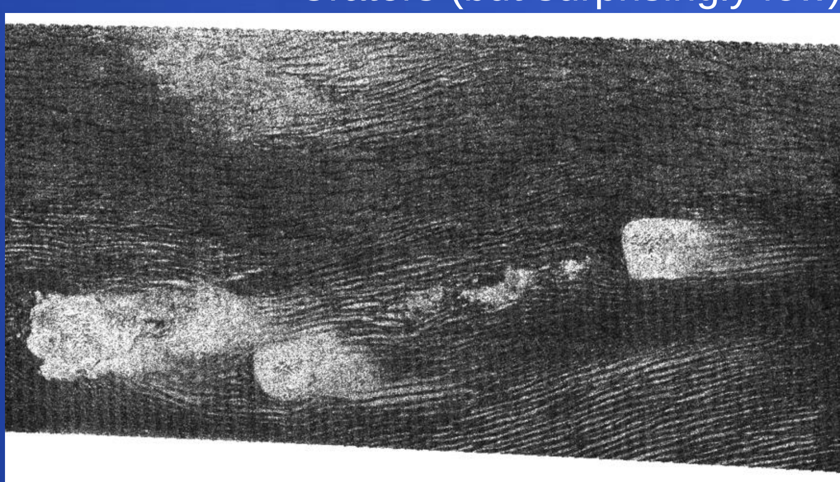


A Sampling of Titan's Geologic Features (1)

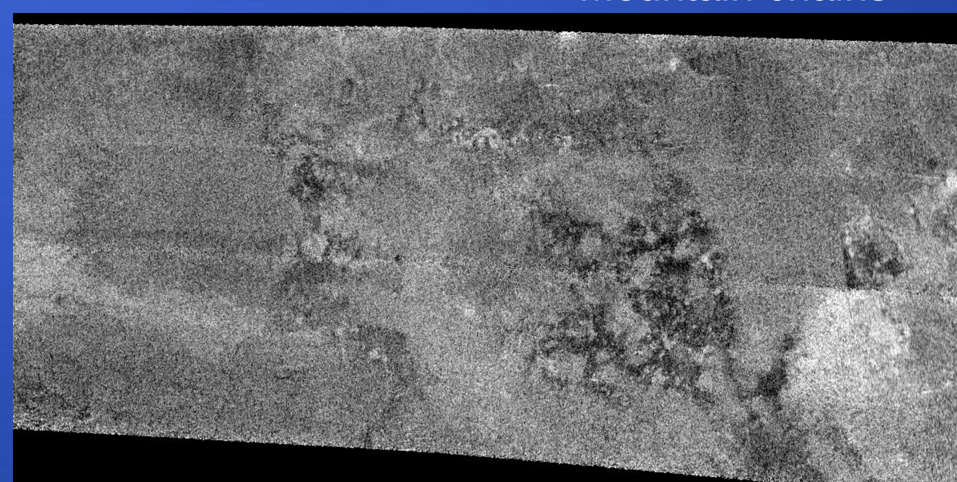
Craters (but surprisingly few)



Mountain chains

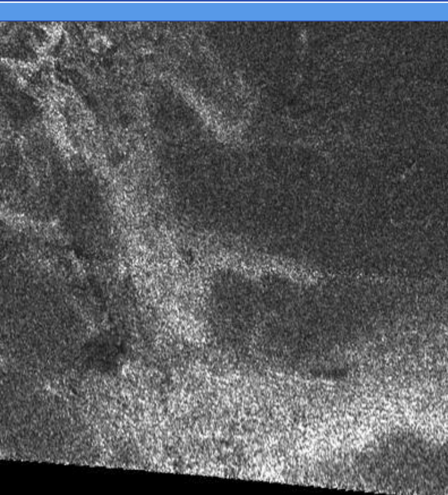


Lots of dunes (equatorial sand sea)

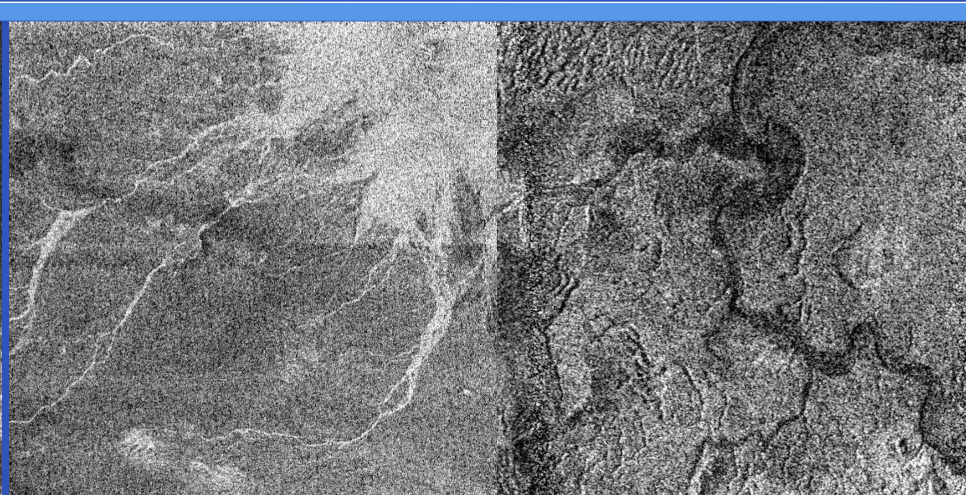


Enigmatic plains (mid latitudes)

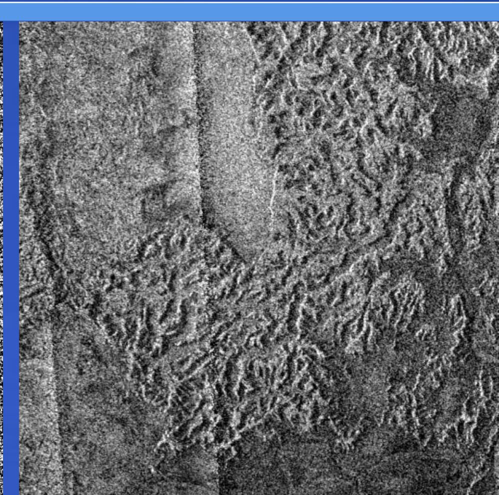
A Sampling of Titan's Geologic Features (2)



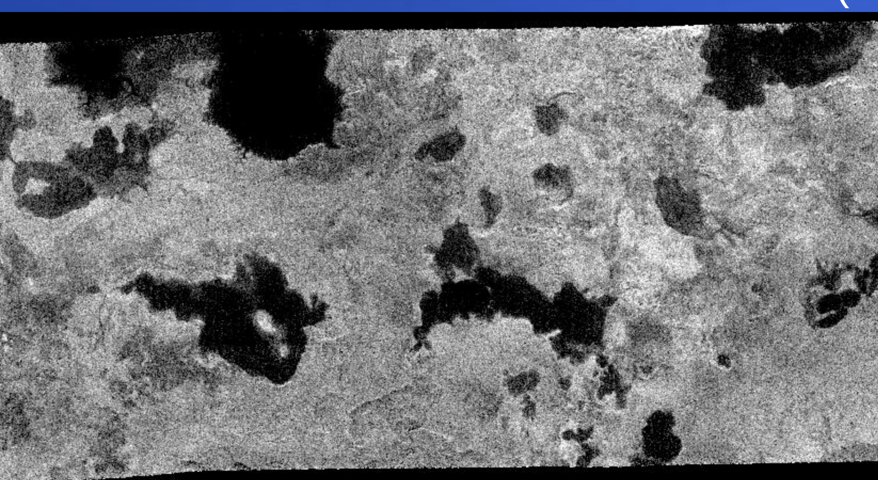
Flows?



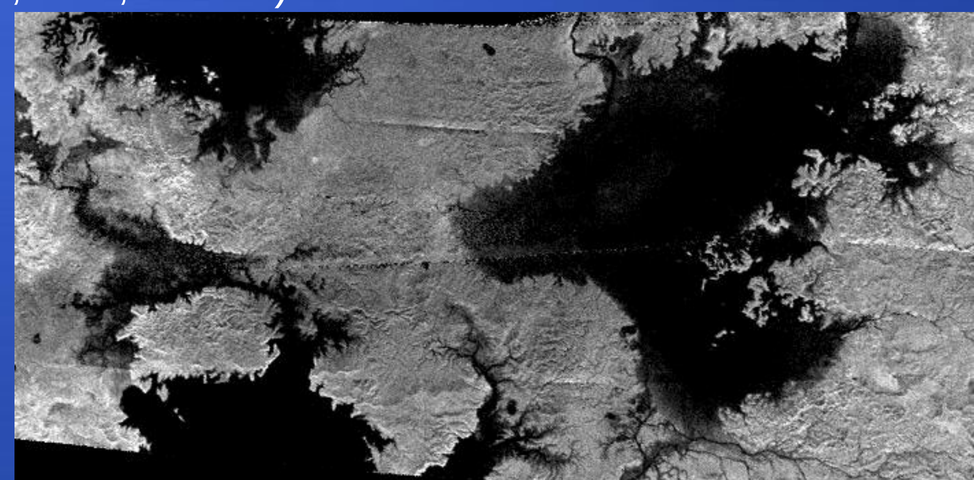
Channels (bright, dark, incised)



"Chaos" terrains



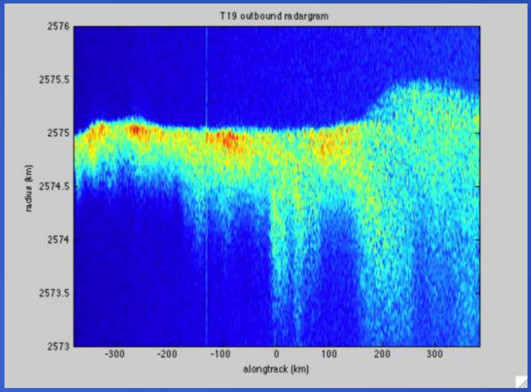
Polar lakes



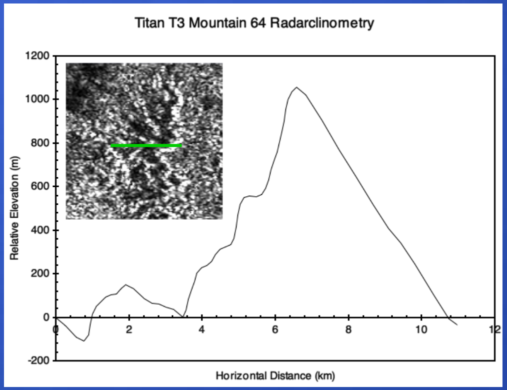
Polar seas

Titan's Topography Before RADAR Stereo

- Altimetry
  - Mostly short arcs (~400 km)
  - Flat (few 100 m) to very flat
- Radarclinometry/shape from shading
  - Applicable to limited areas
  - Mountains 300–2000 m
- "SAR topo"
  - Profiles along every image from height-dependent offset of beam pattern
  - Agrees nicely with altimetry
  - Shows surprisingly little large-scale relief over Ganesa, Menrva, Xanadu



1000 m

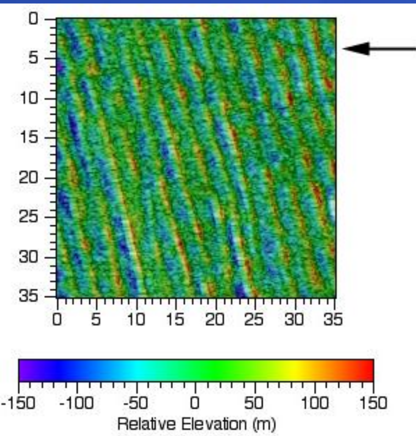


1000 m

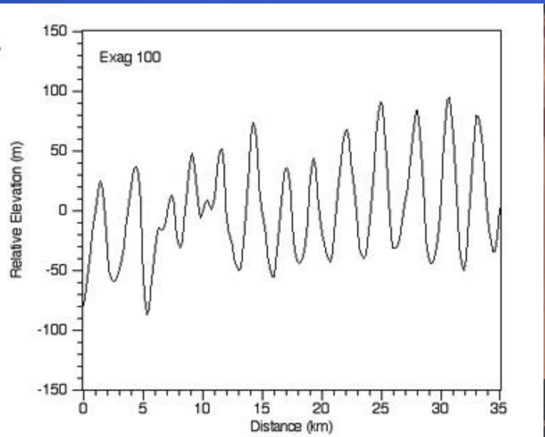
"Titan is flat…except where it isn't."

—R. Lorenz

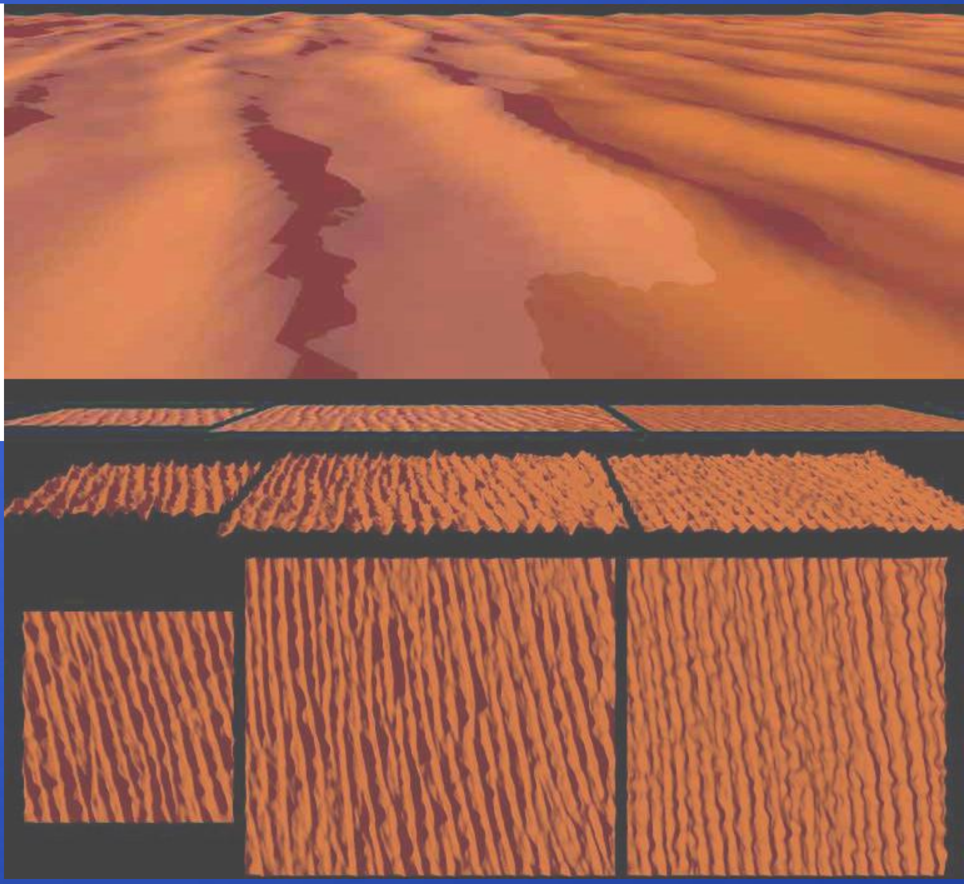
Dune Topography from Radar-clinometry (shape from shading)



Topo on Image

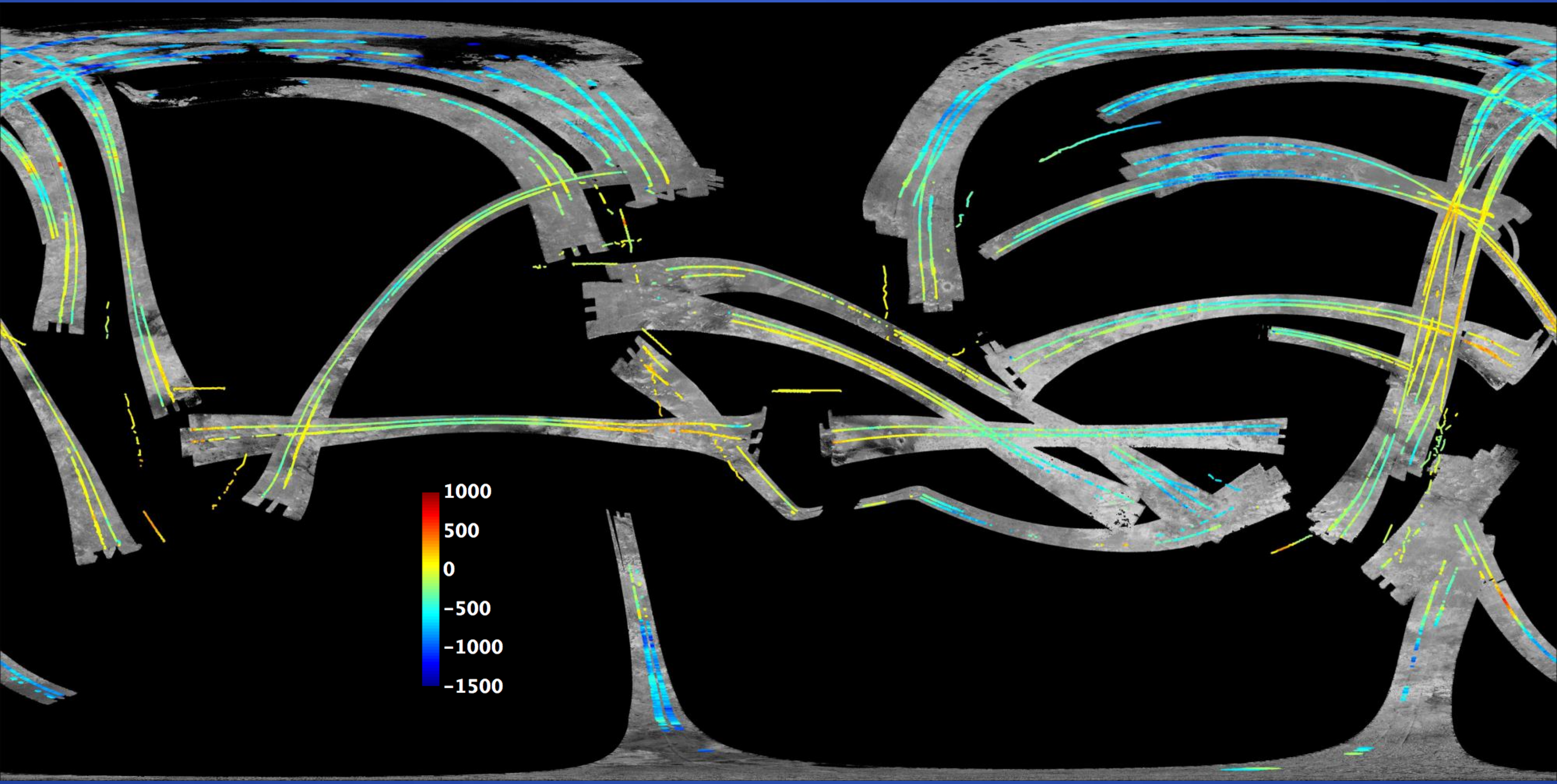


Topo Profile

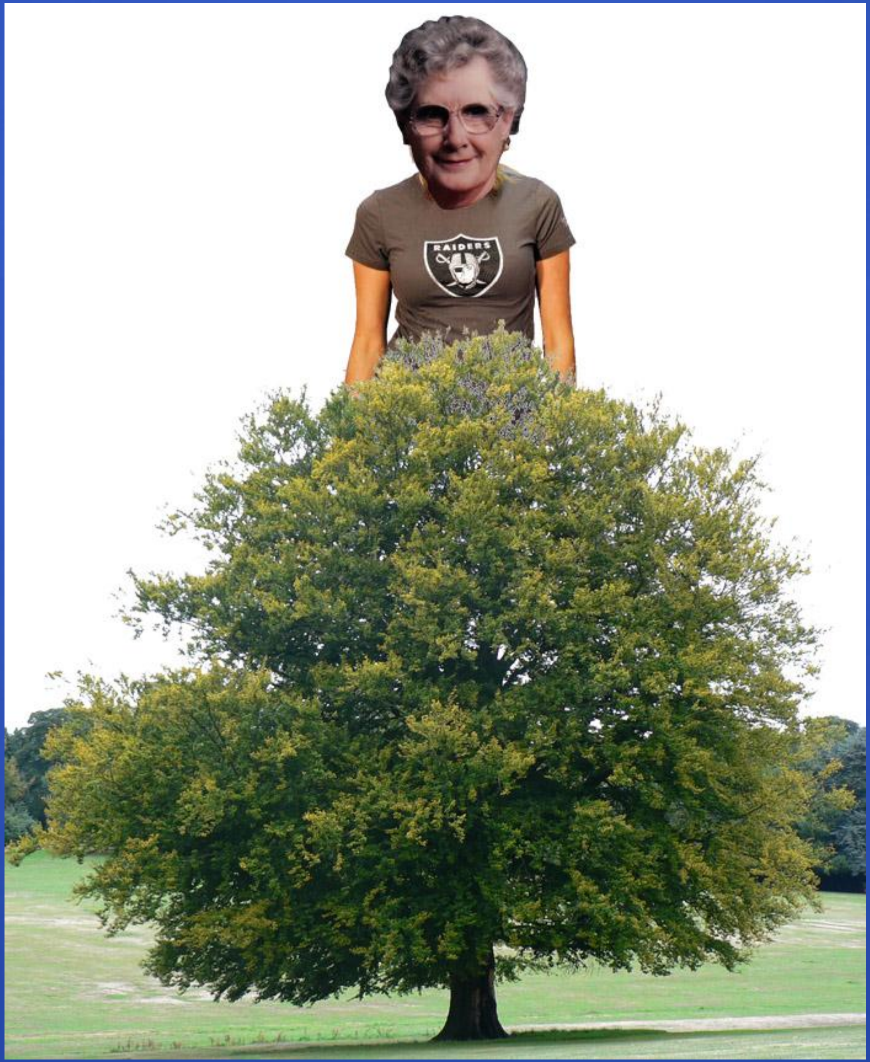


Visualizations

Global Topography Altimetry + SARTopo

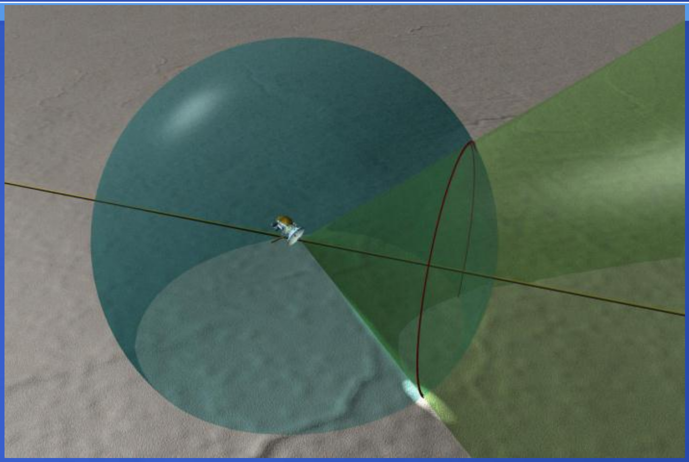


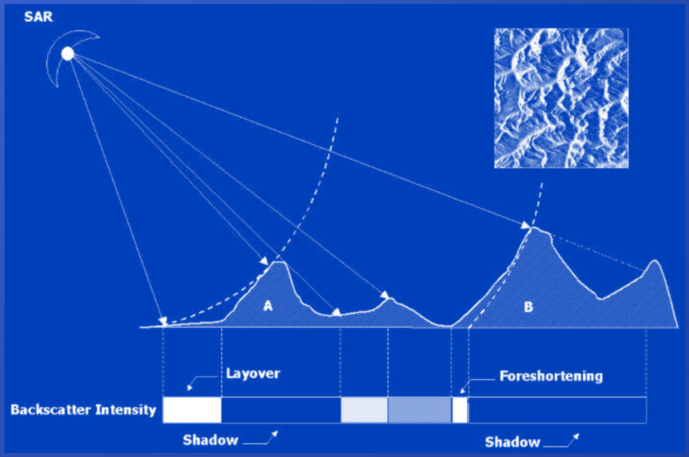
Raider Gramma Tree?



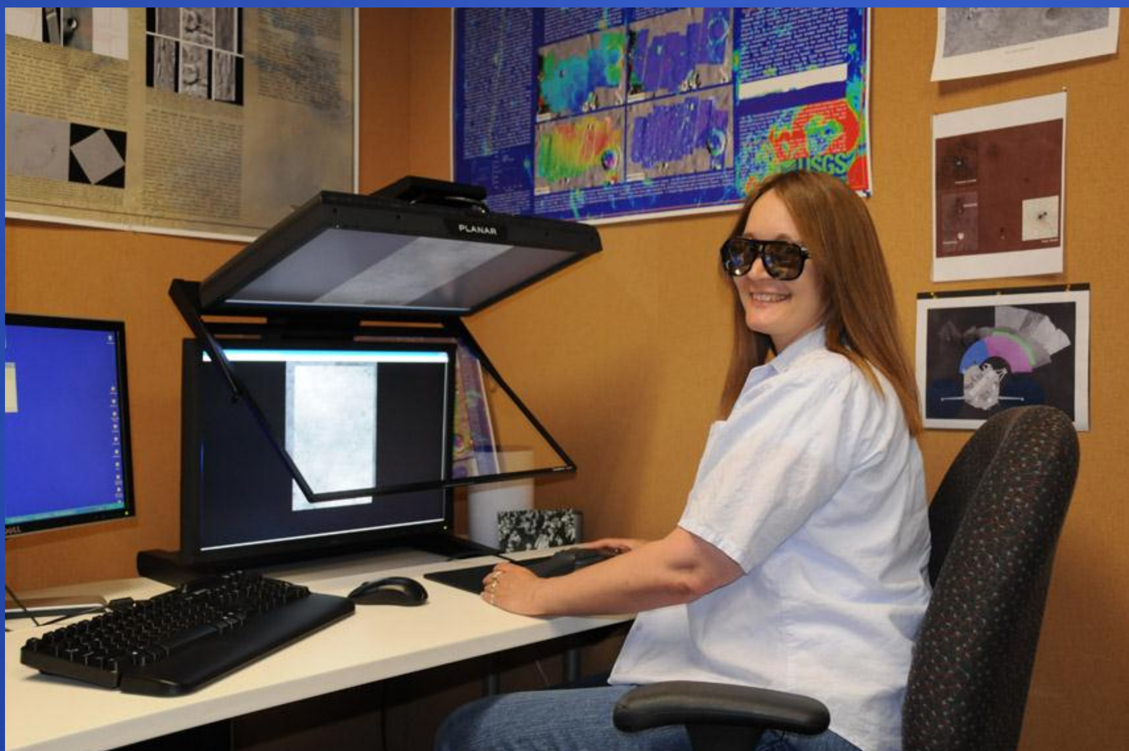
Radargrammetry Concepts

- Raw radar "images" (echos) are formed in terms of
  - Range (sphere)
  - Doppler shift (cone)
- To combine multiple echos, convert to common coordinates
  - Time at closest approach (Doppler=0)
  - Range at closest approach (within a plane perpendicular to flight line)
- From here, conversion to map coordinates depends on height
  - Images contain height parallax
- Radar provides its own illumination
  - More parallax –> more change in illumination





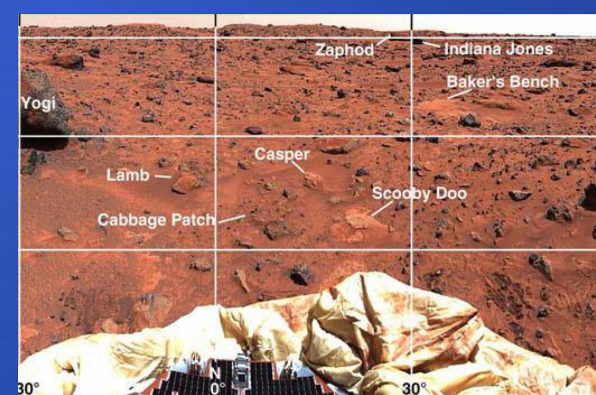
Astrogeology SOCET DPWS:
Dr. Jones, Henry Jr., Hen3ry,Temple, Grail*



Elpitha (Annie) Howington-Kraus with our 4th generation SOCET Set workstation "Temple (of Doom)"

*Assisted by Sallah and Shorty

Indiana Jones on Earth
"I have a lot of good memories of that dog"



Indiana Jones on Mars

SOCET Set Stereo Capabilites

Provided by system:

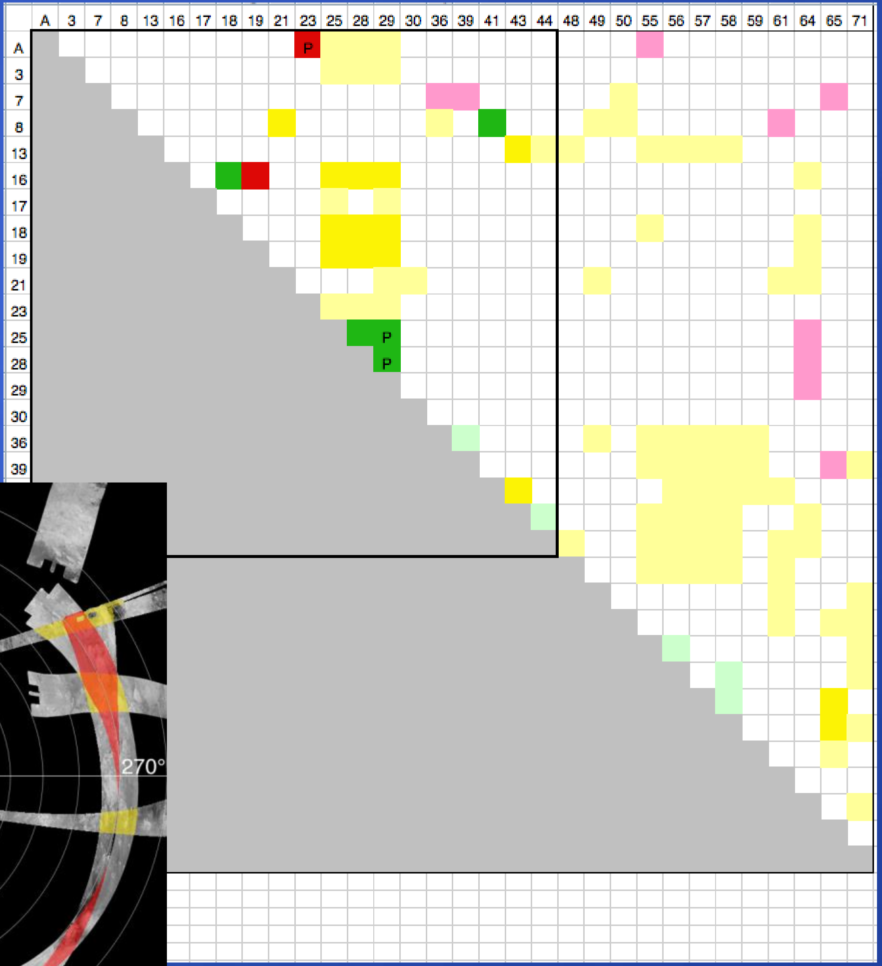
- View images in stereo
- Overlay 3D data (e.g. alt, SAR topo profiles, DTMs)
- Adjust image control
- Automatic image matching to collect DTM
- Manual editing of DTM on stereo display
- Collection of 3D feature data (e.g., shorelines)

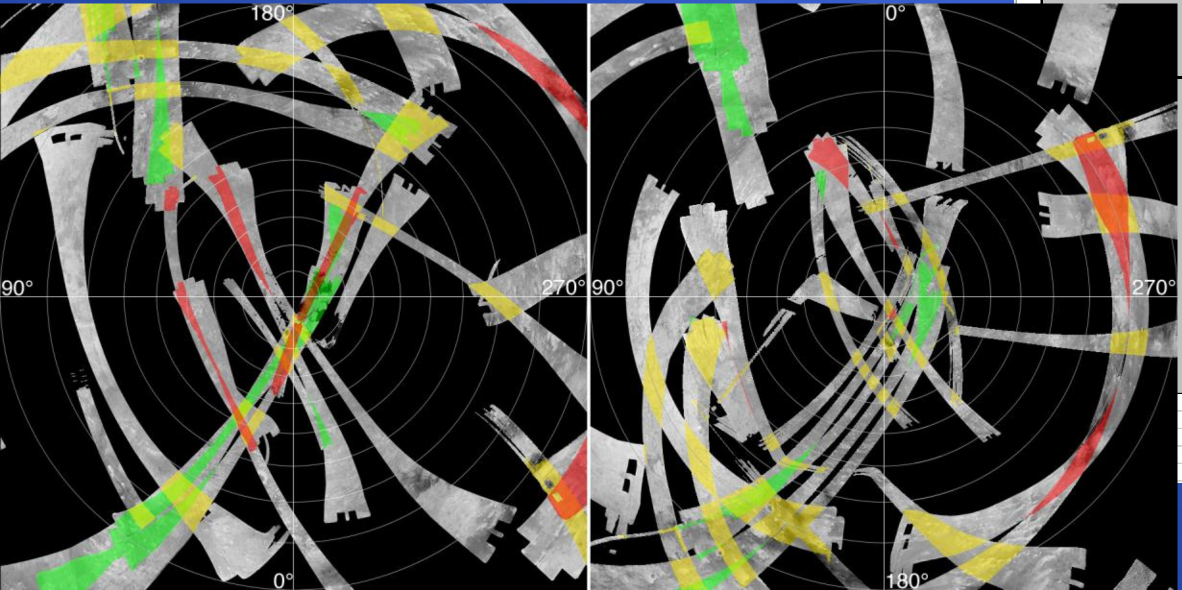
We must provide:

- Import image
- Import geometric info
- *Sensor model* computes tranformation from pixels to lat, lon, z
- Export results to planetary (ISIS) format

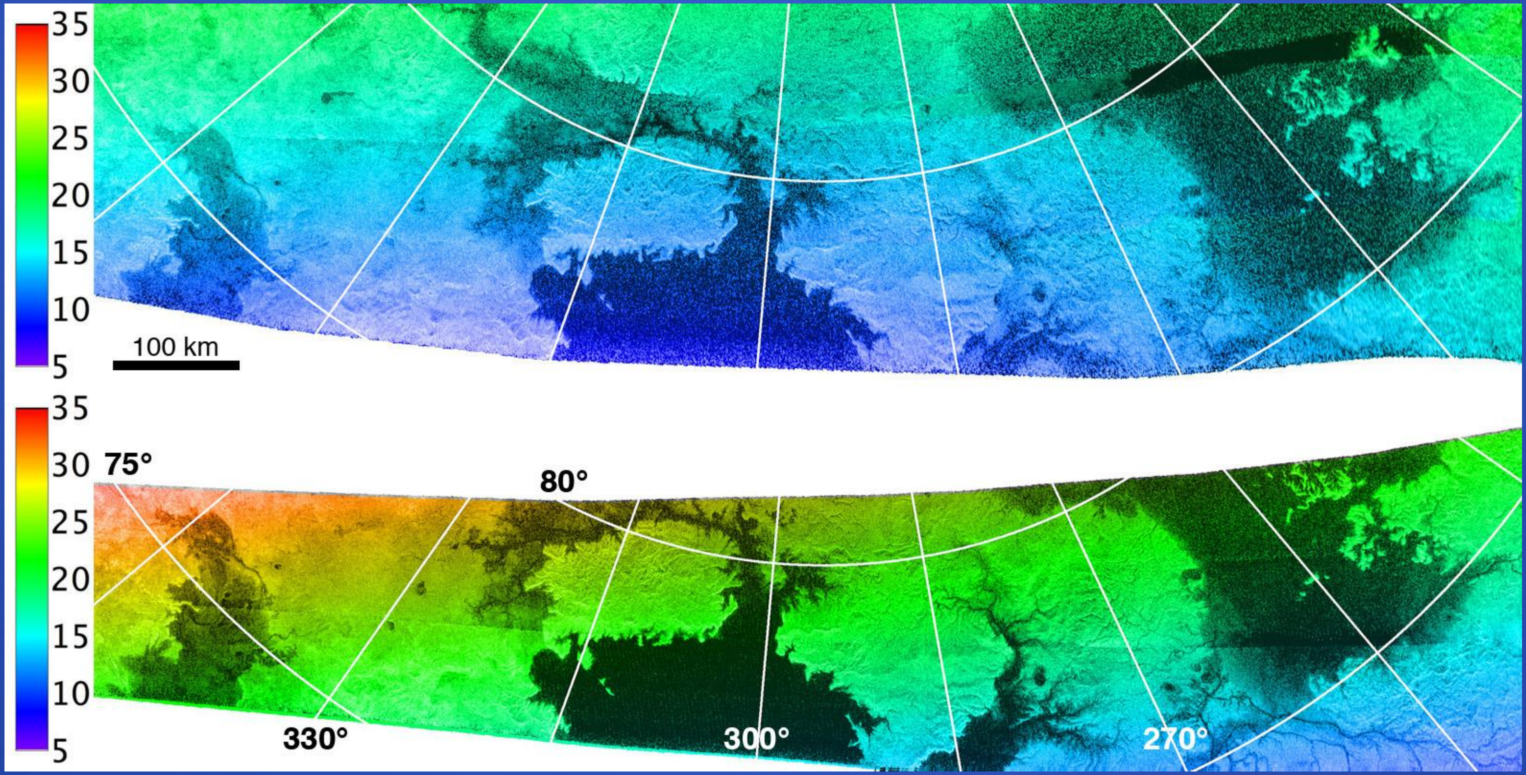
Current Stereo Coverage

- Prime Mission:
  - 38 pairs
  - 19 DTMs
- To T71:
  - 108 pairs
  - 21 DTMs



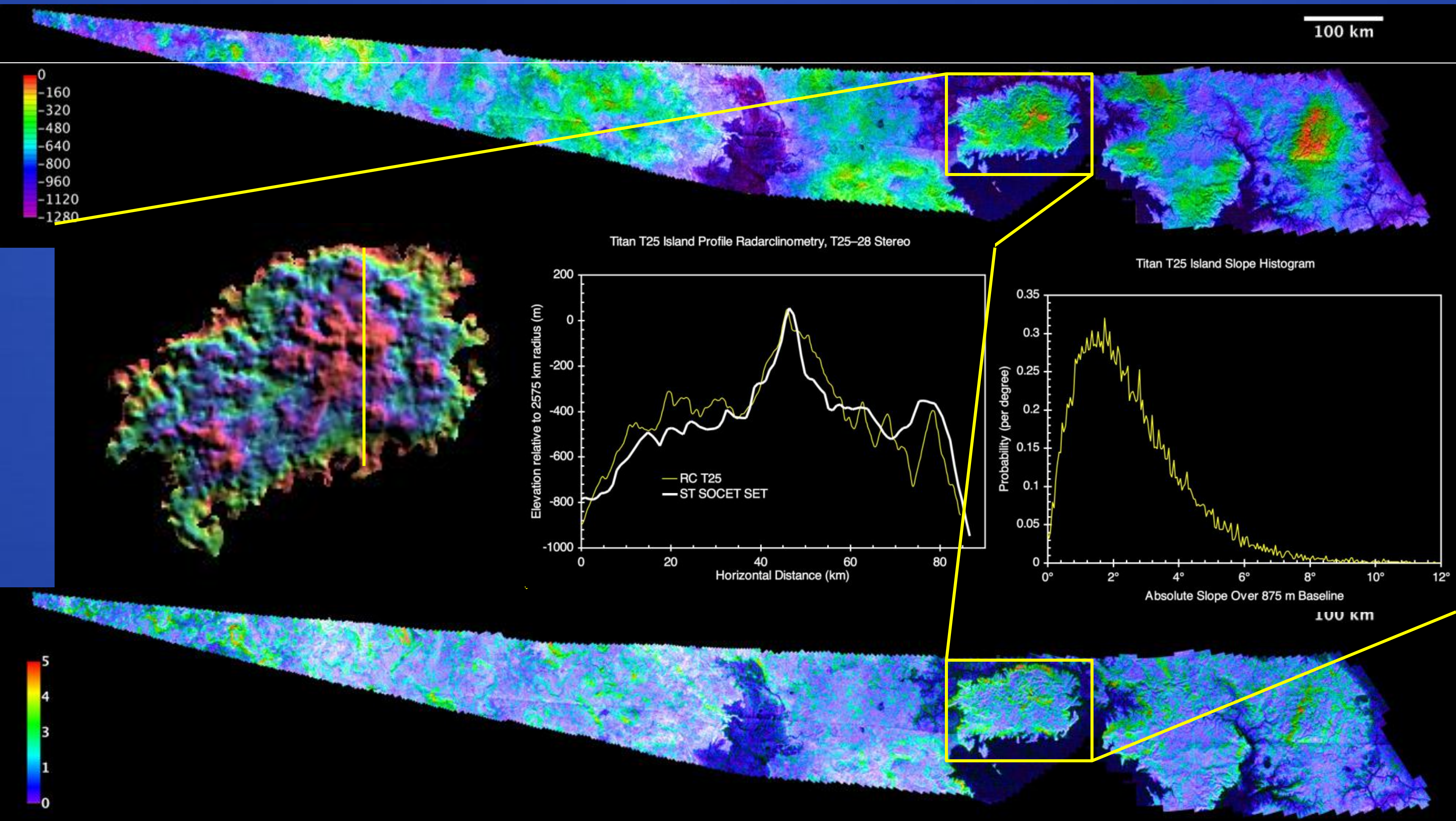


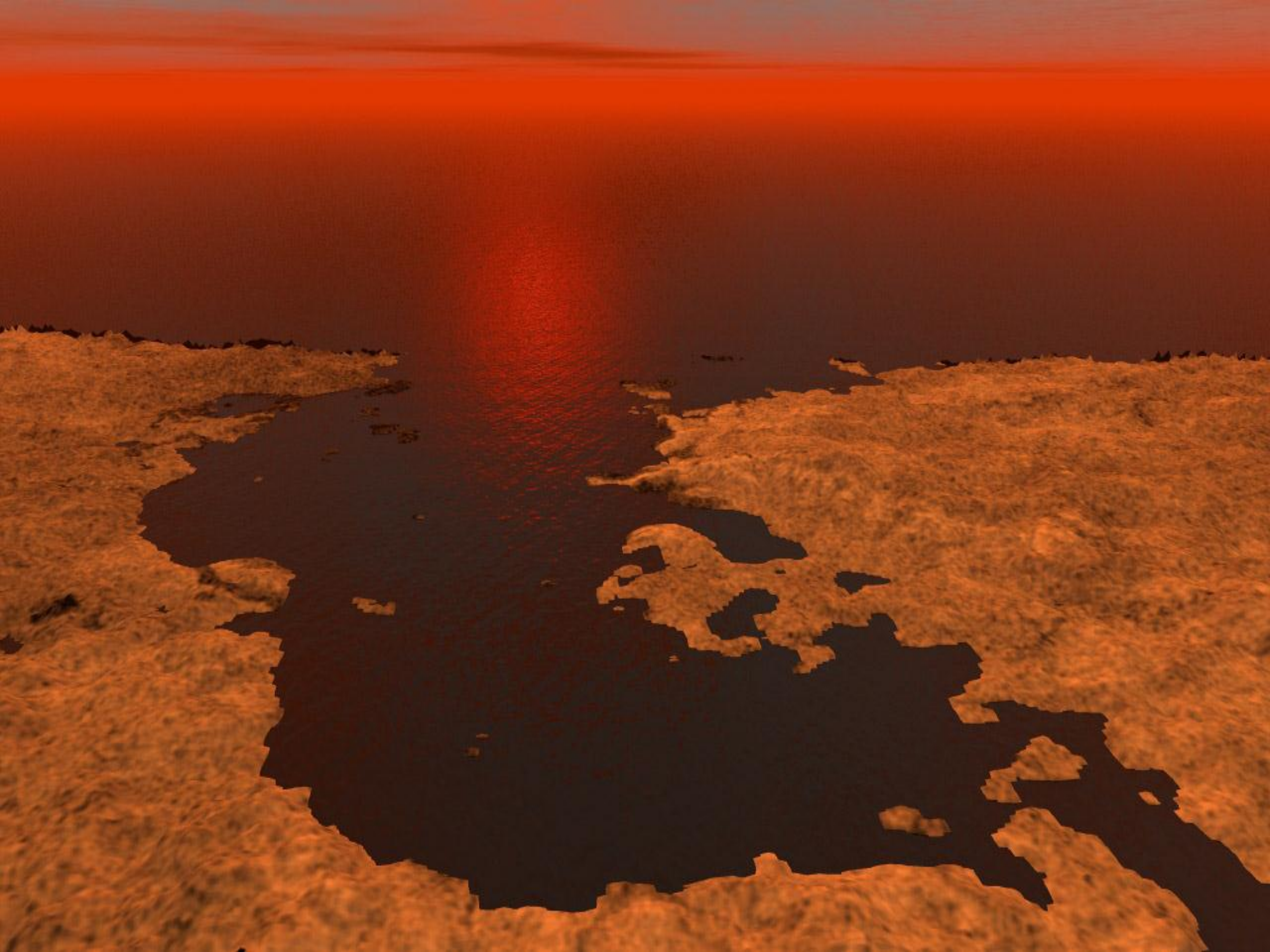
T25-T28 Northern Overlap



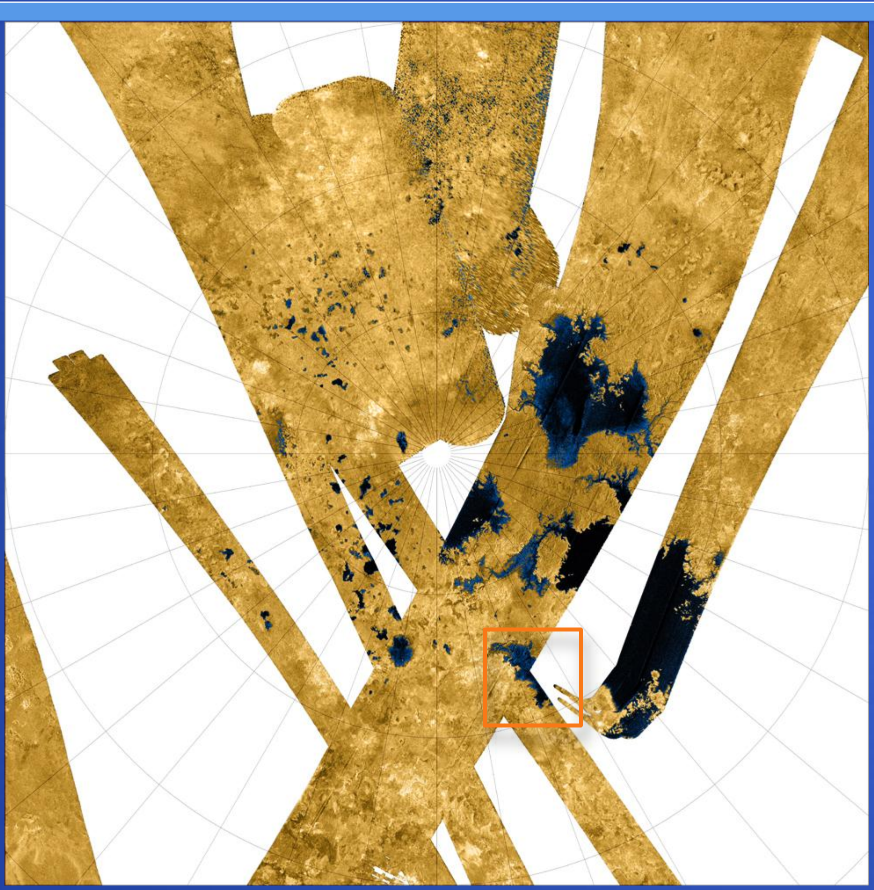
Incidence Angles

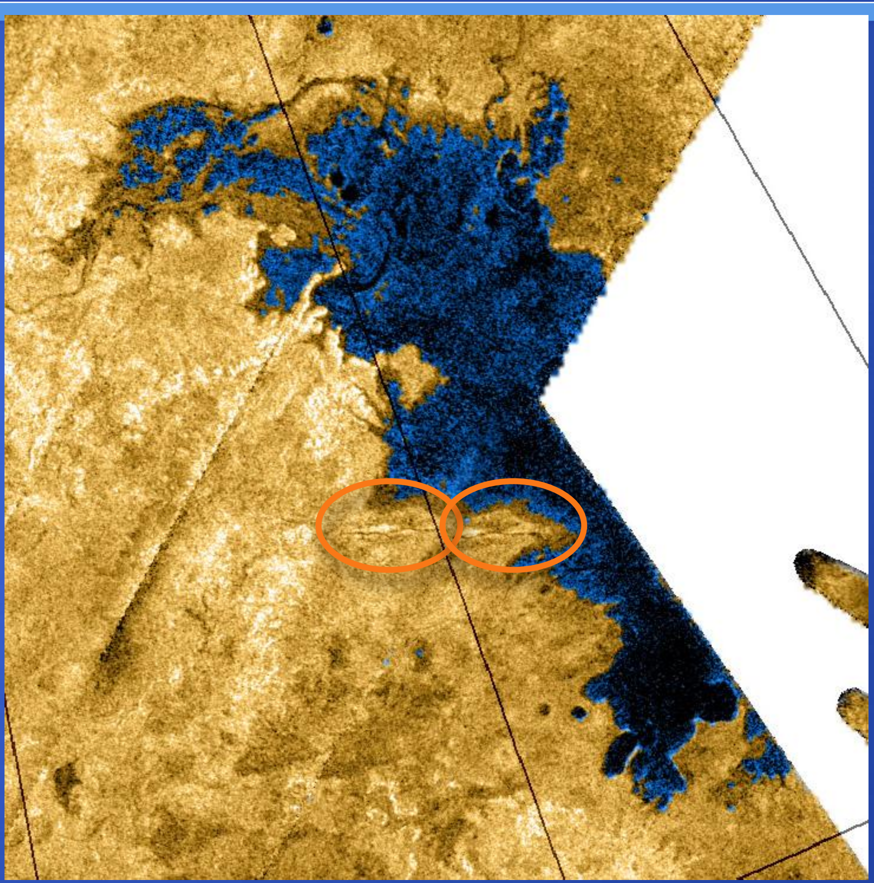
First DTM: Kraken and Ligeia Maria, T25-28





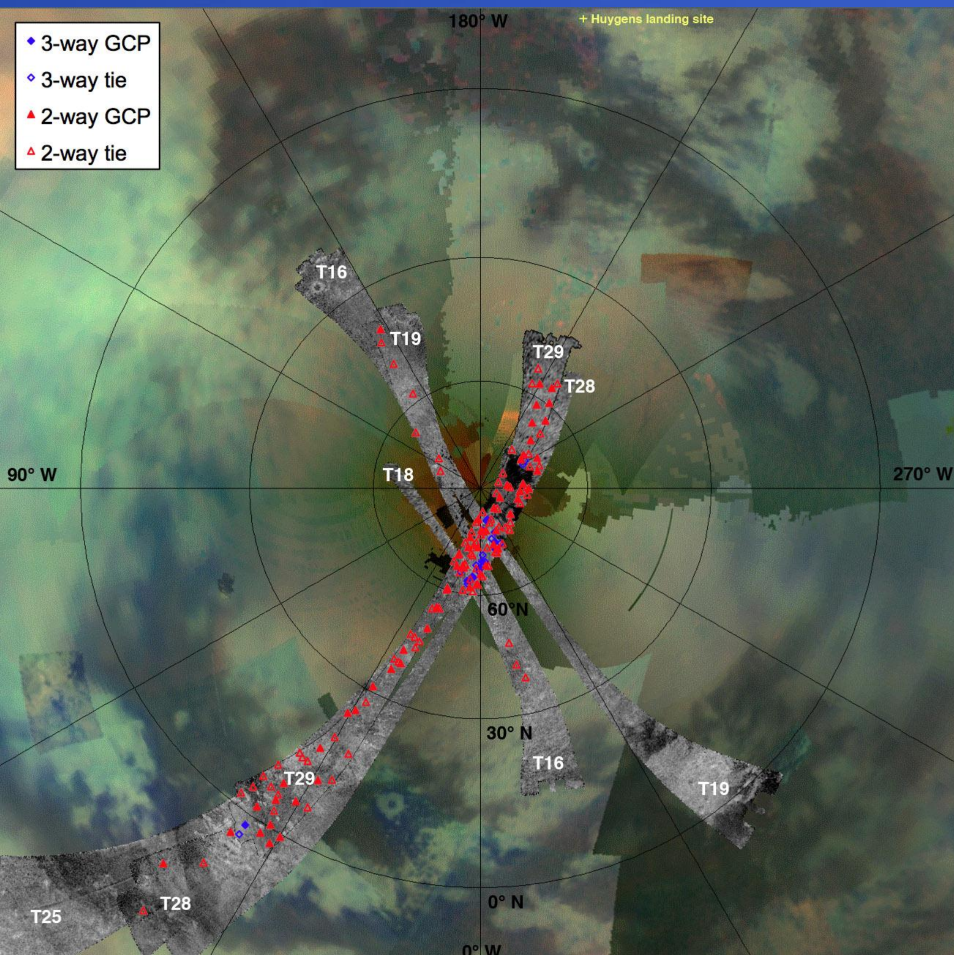
Effect of Unexpected Titan Spin

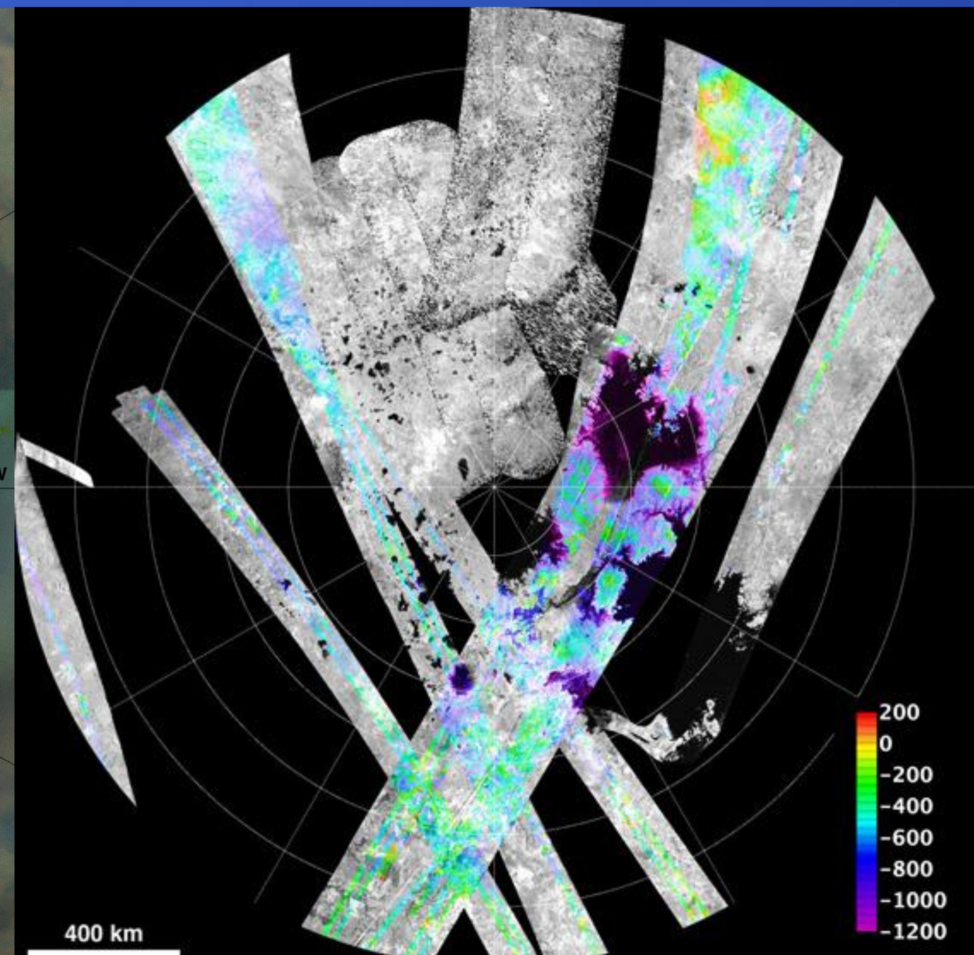




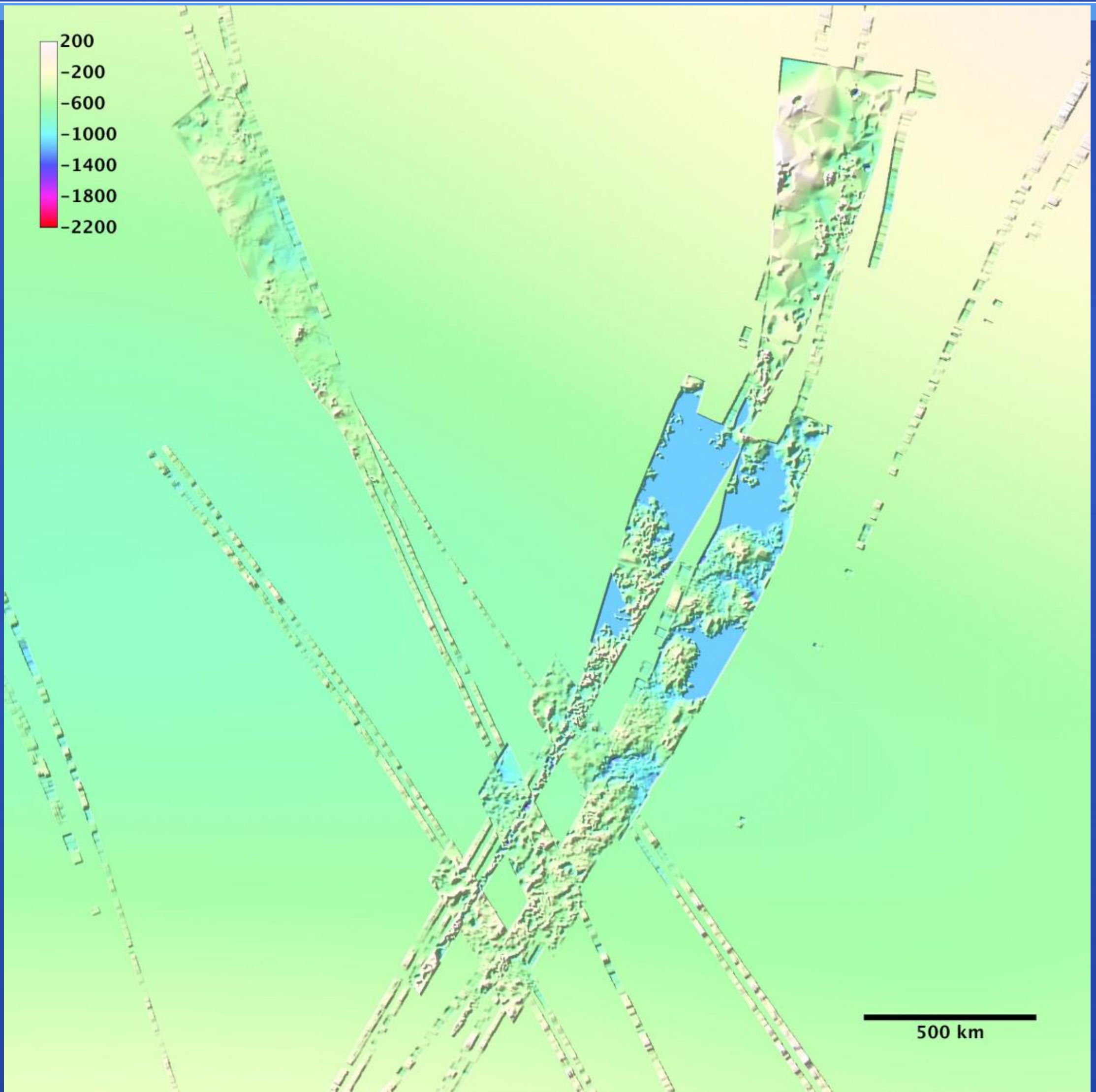
Uh oh!

Controlled North Polar DTM: 6 Images, 14 Overlaps

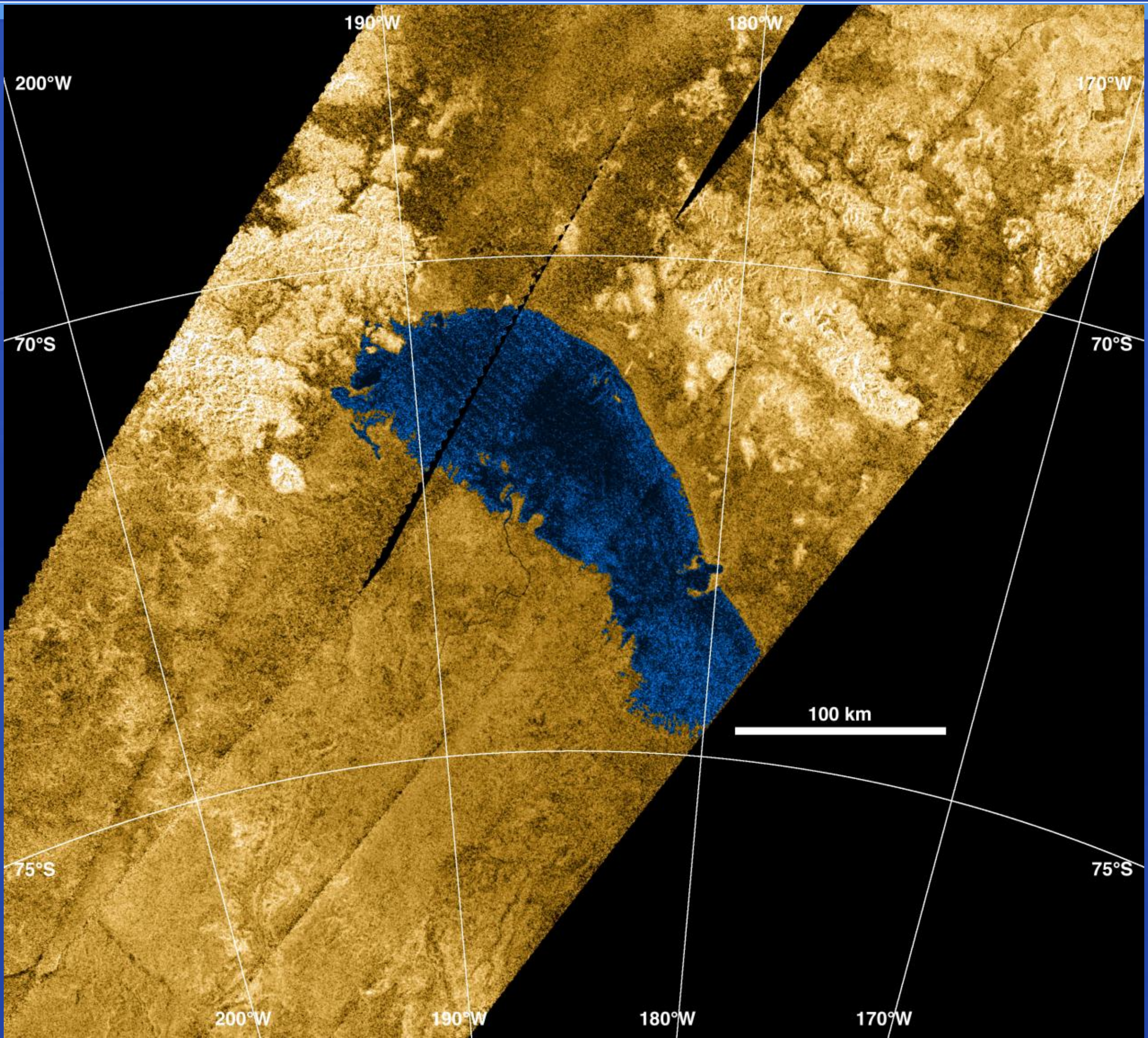




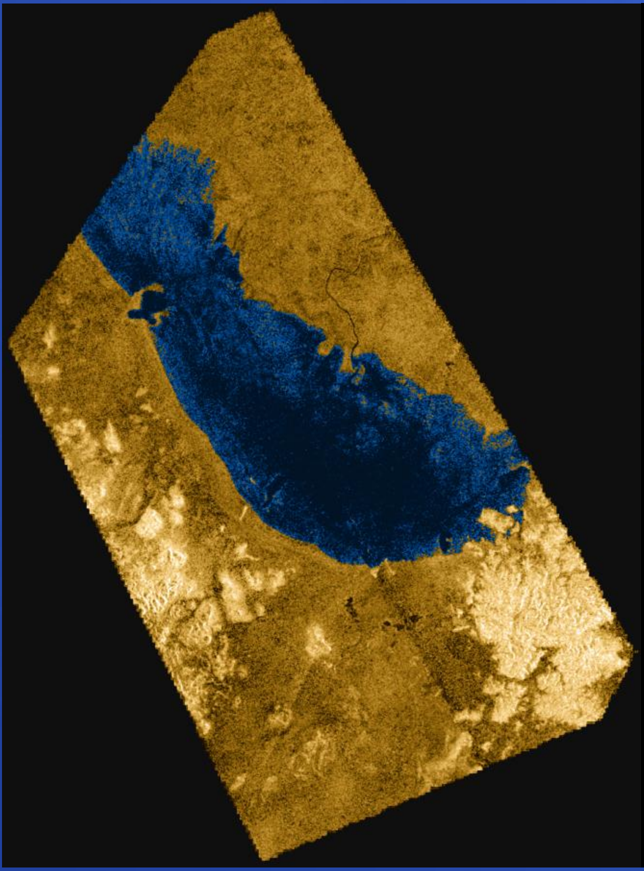
Combined DTM of North Pole –> JPL Tactile Model



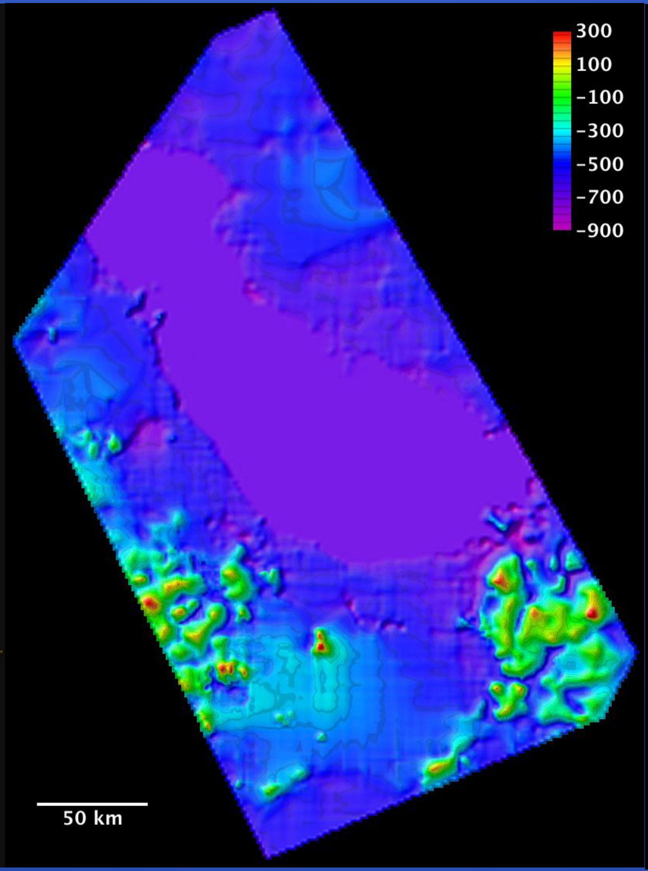
Ontario Lacus (Southern Hem.)



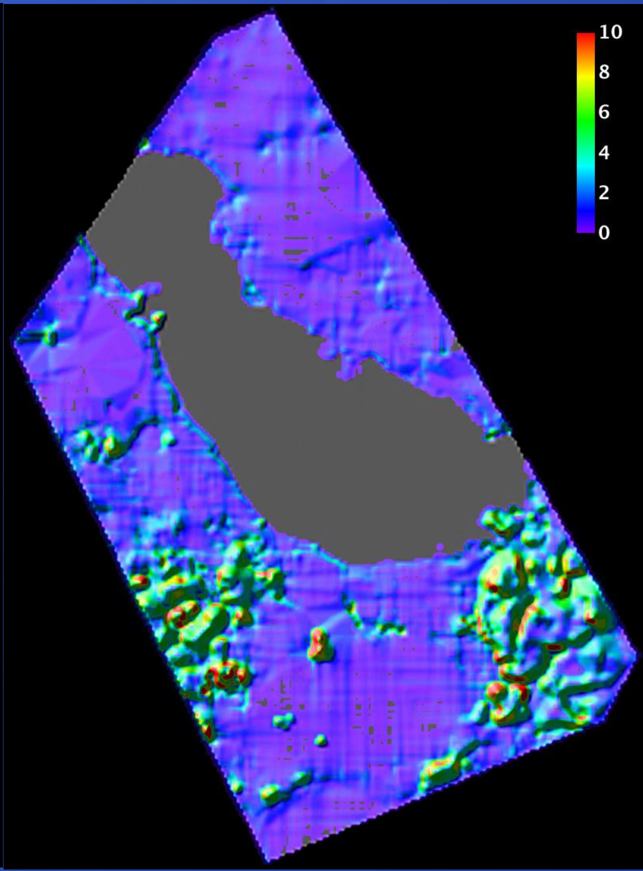
Ontario DTM



Combined and
colored orthoimages

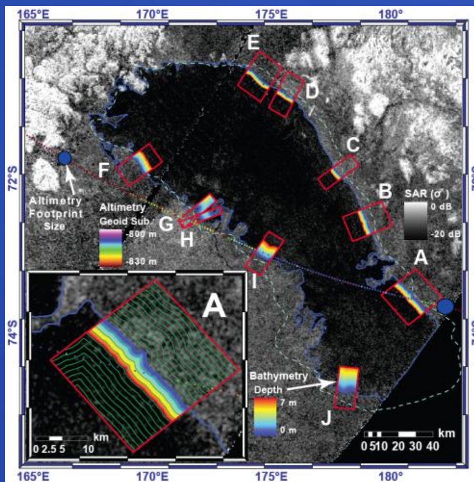


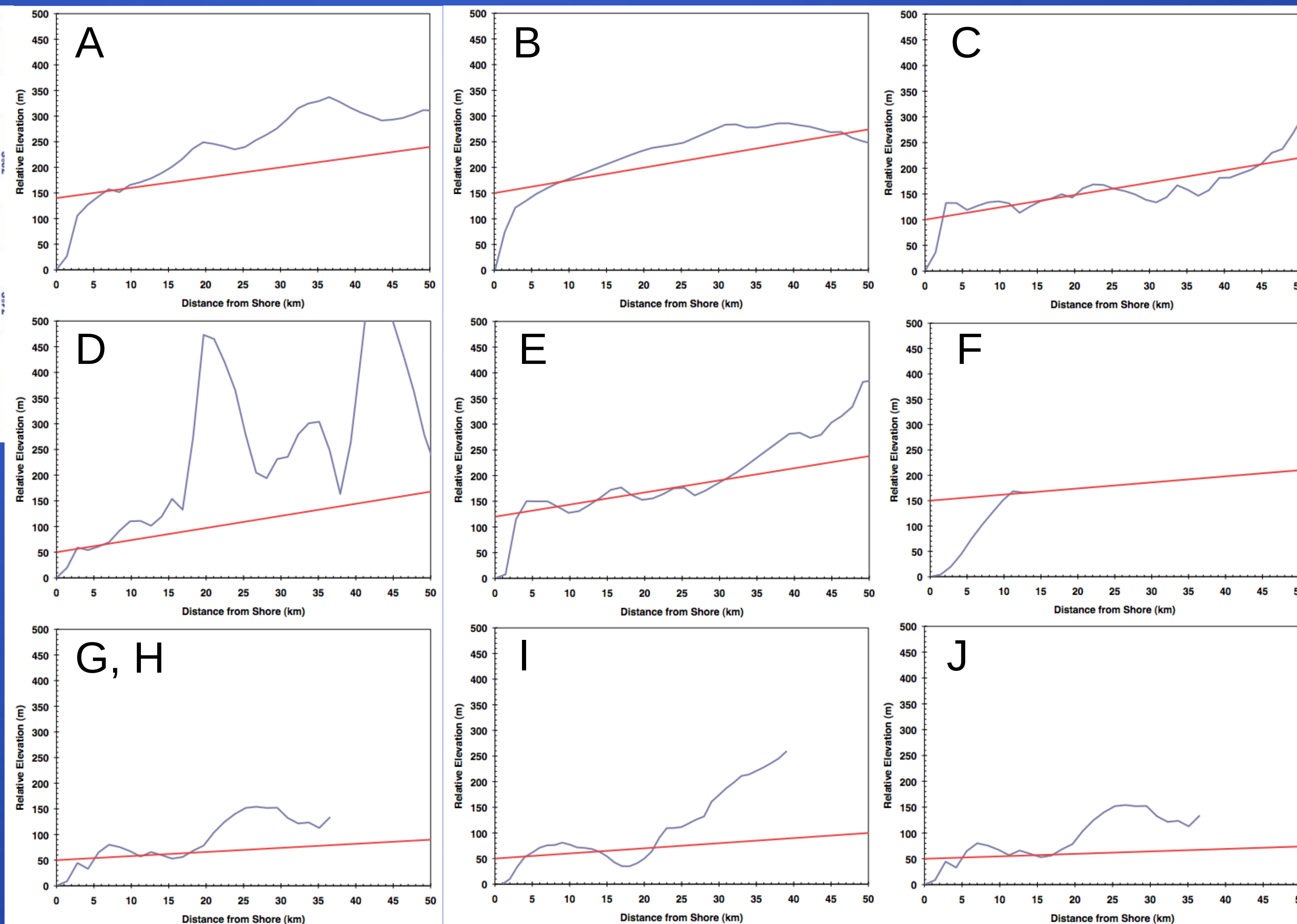
Shaded relief and
color coded elevation



Shaded relief and
color coded slopes

DTM Slopes Compared to Inferred Bathymetry



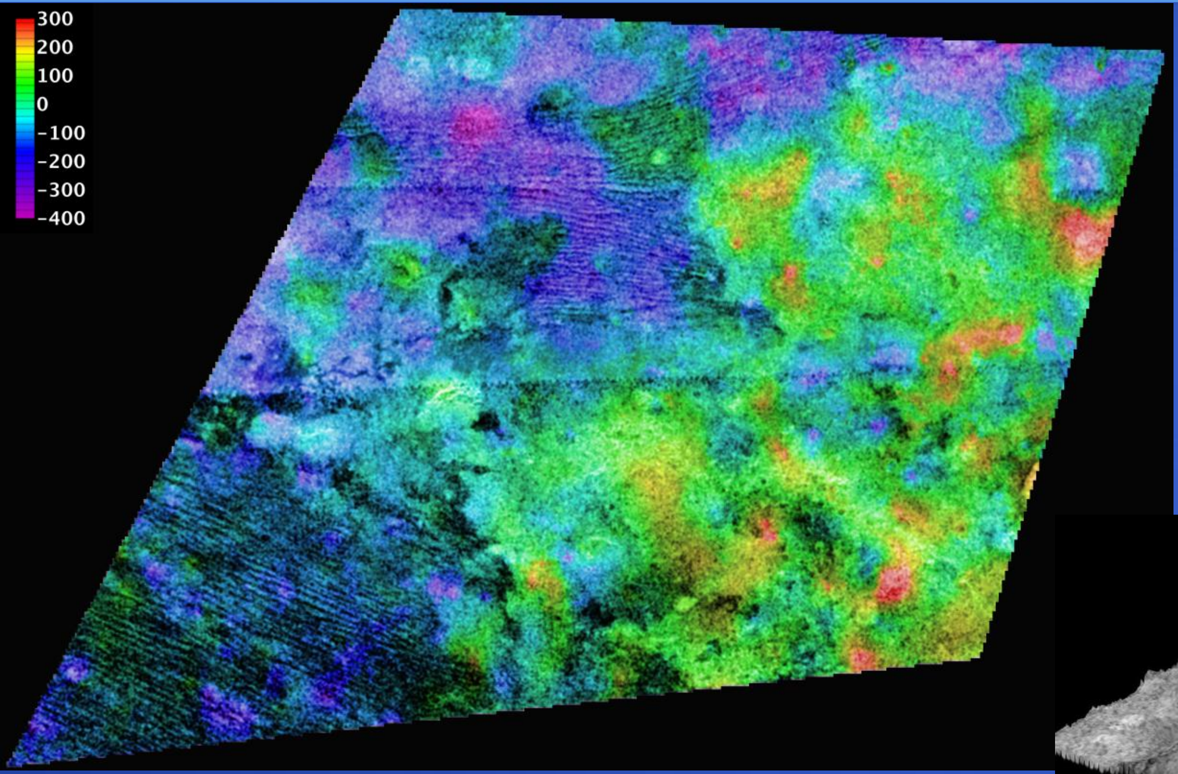


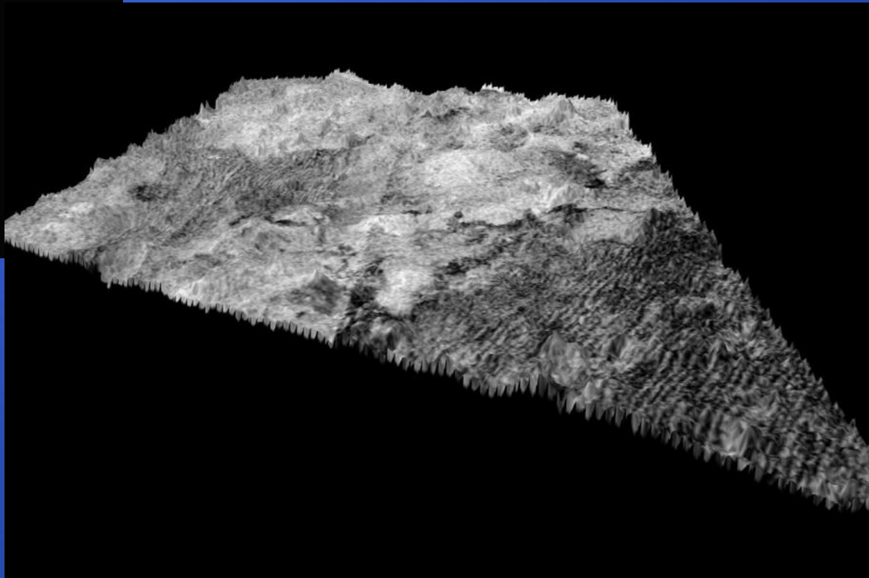
— Stereo DTM

— Bathymetry (Alex Hayes)

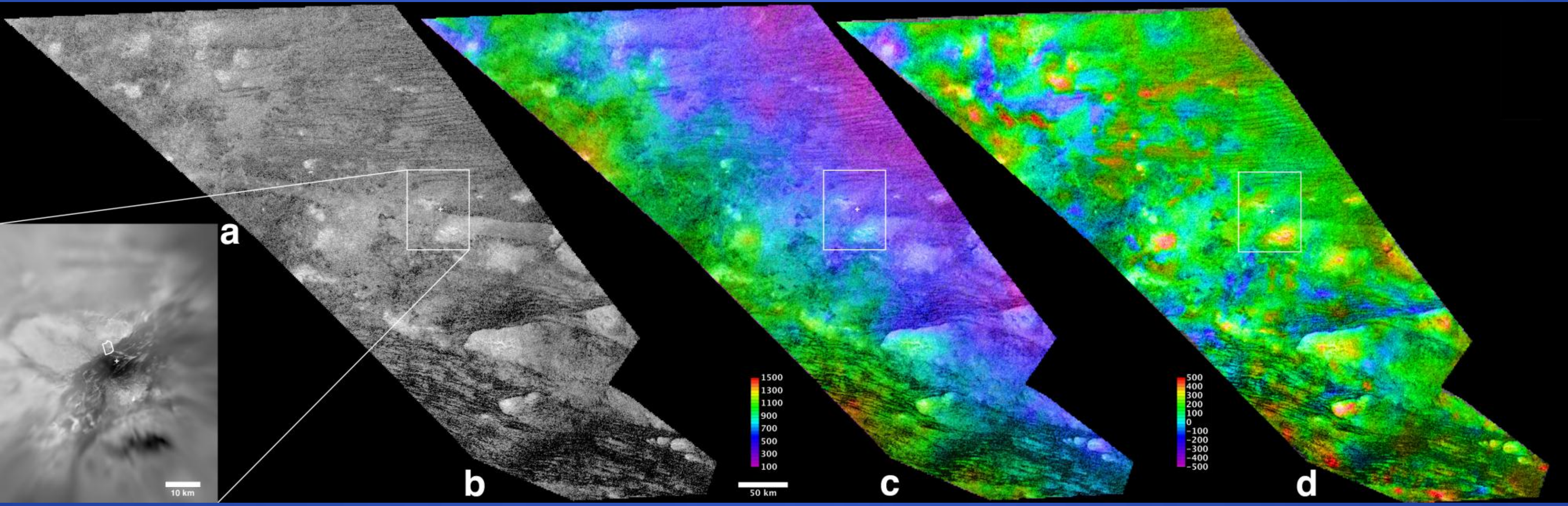
Ontario Flyover

Typical Dune-Free Area in Equatorial Sand Sea (Belet)

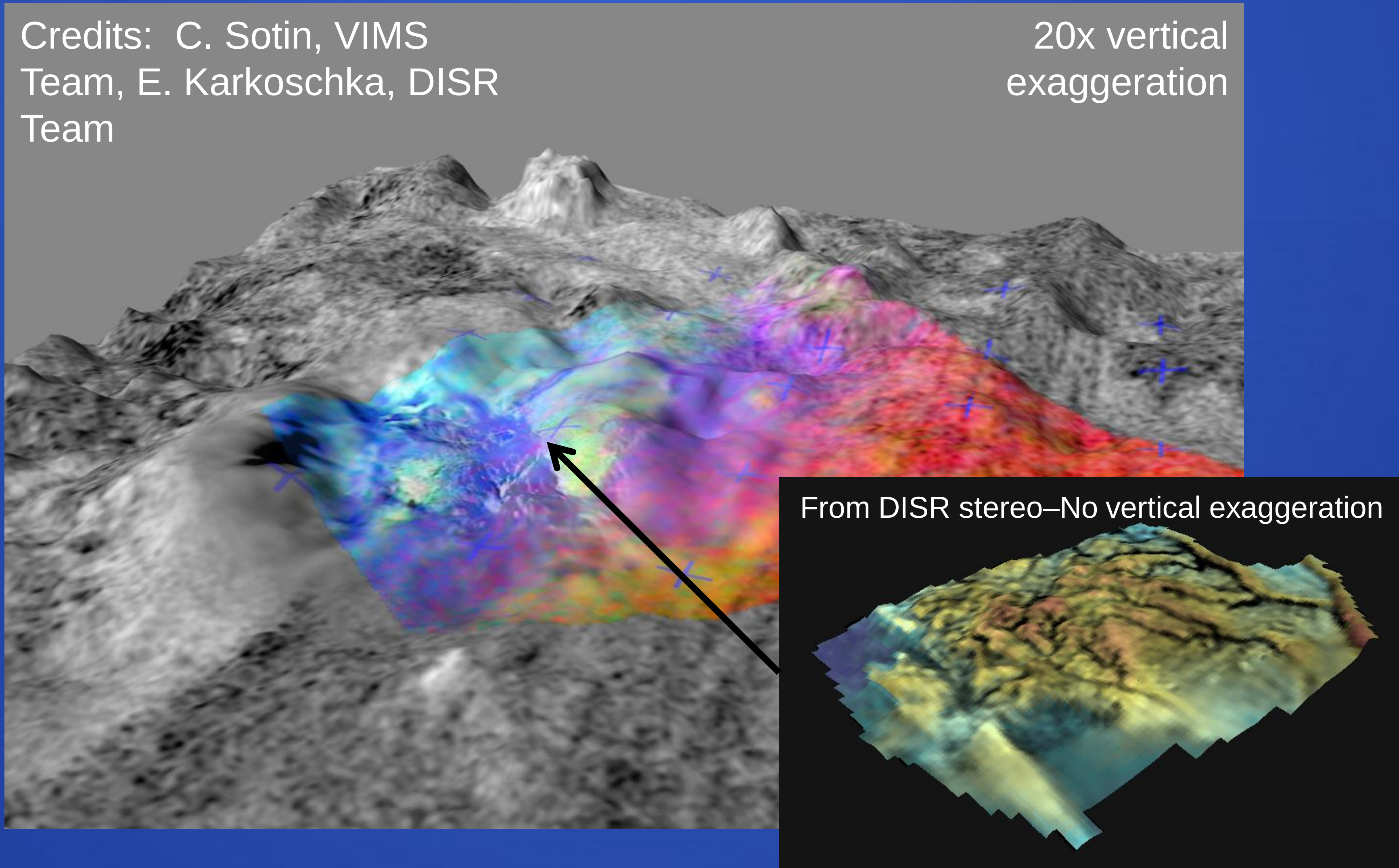




T08-T41 Huygens Landing Site



Huygens Site Perspective with RADAR+VIMS+DISR



Cryovolcanoes on Titan

- What are they?
  - Volcano = bulk material of a planet or moon melts and erupts
  - Cryovolcano = same thing, where the moon is made of icy materials
- Do they exist?
  - Curiosity: "How planets work"
  - Possible role in carbon cycle
- How do we find them?
  - Thermal emission
  - Change detection
  - Morphology
- Problems with morphology
  - What to look for?
  - Limited resolution
- Checking the interpretation
  - Higher resolution imaging
  - Topography
- Case studies
  - Value of topography
  - Sotra Facula—the best candidate yet

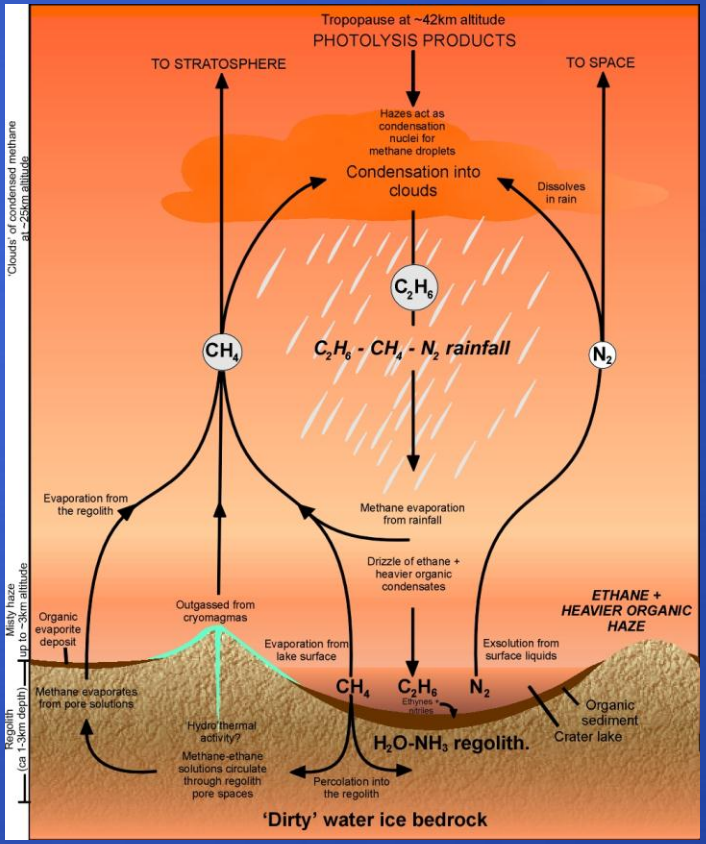
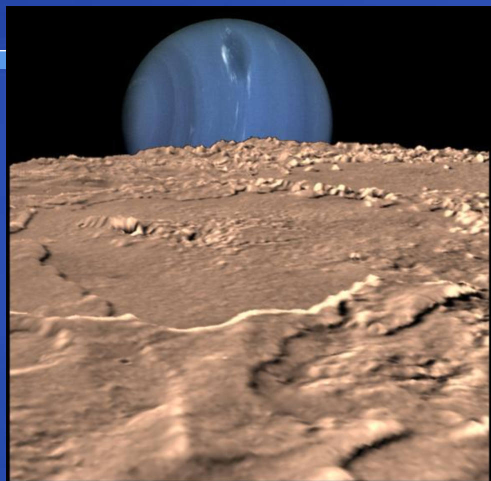
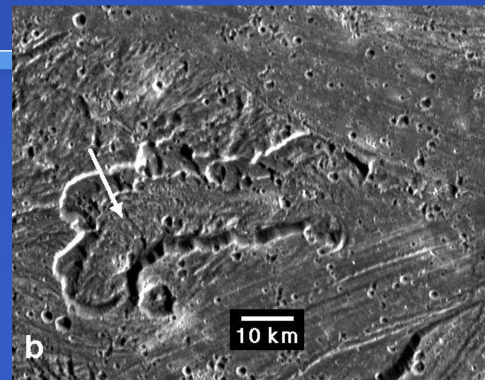


Figure credit: Andrew Fortes

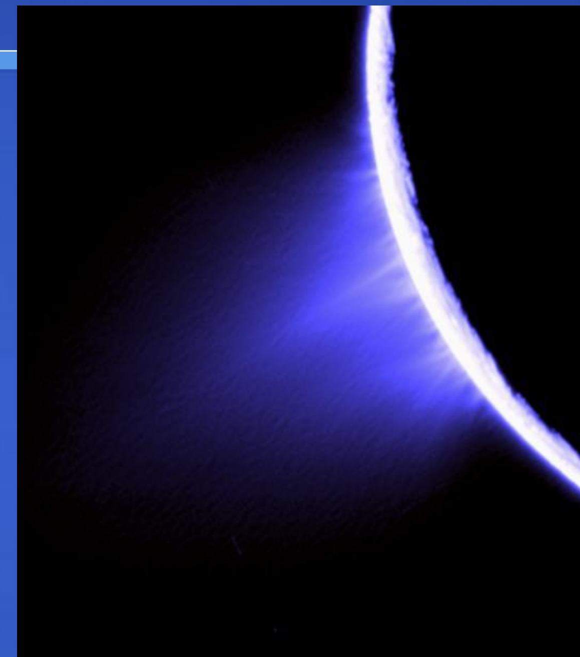
What would a cryovolcano look like?



Caldera? Titan

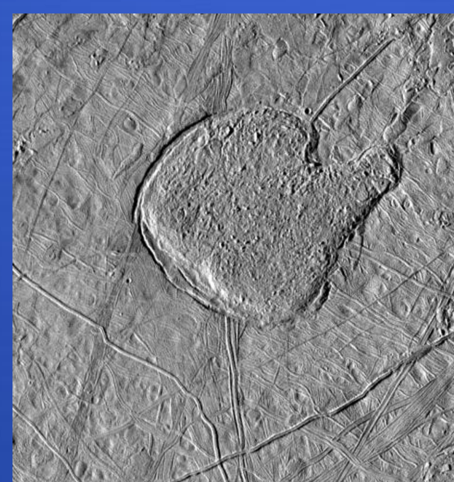


Caldera and flow? Ganymede

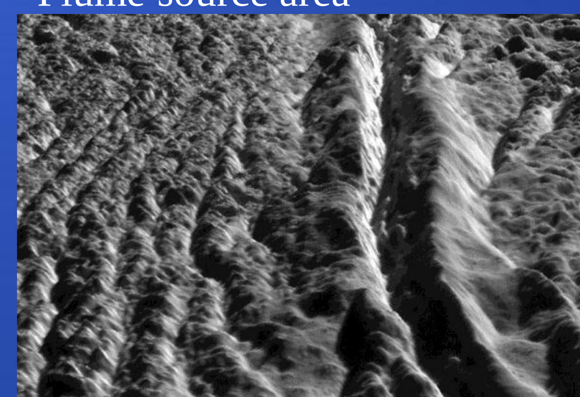


Valley fill, Ariel

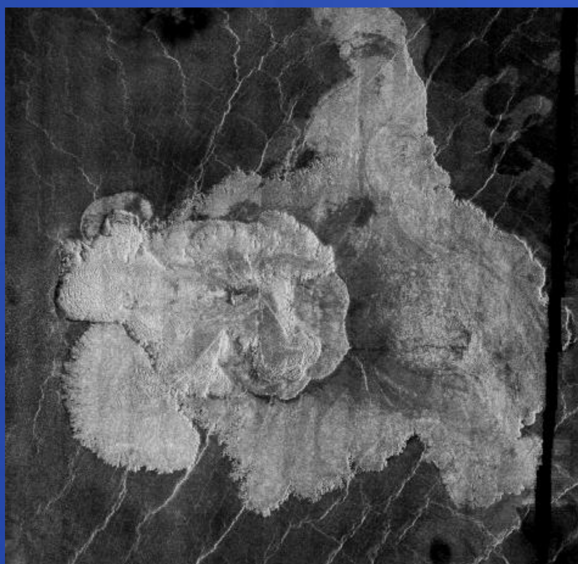
“Mitten,” Europa



Plume source area



Morphologic evidence from VIMS: Tortola Facula—The “Snail”



30 km

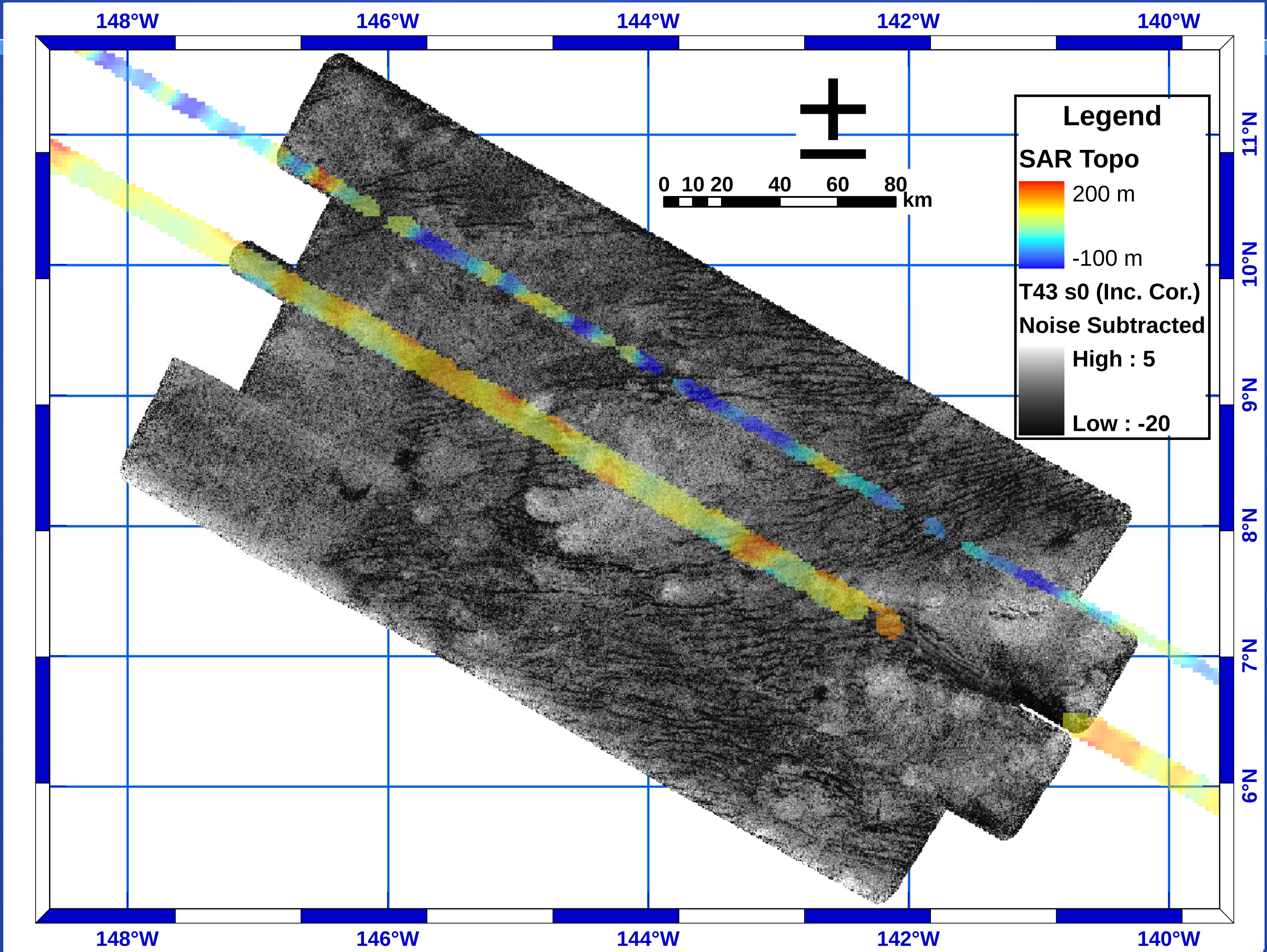
Magellan “Unusual Volcano”, between Artemis Chasma and Imdr Regio , Venus
(P-39916 MGN-93)

Tortola Facula
(Sotin, 2005)

30 km

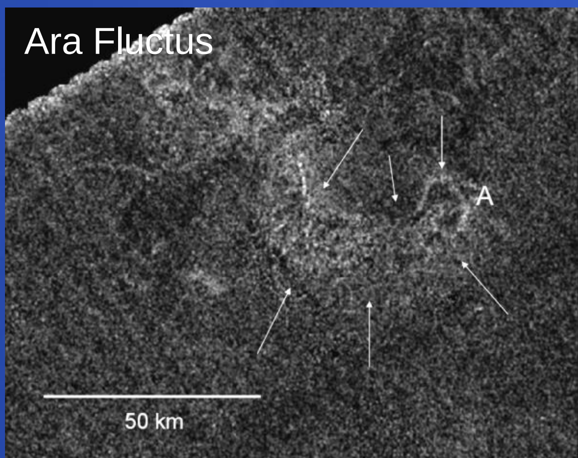
Chao coulèe, Volcano World, Chile

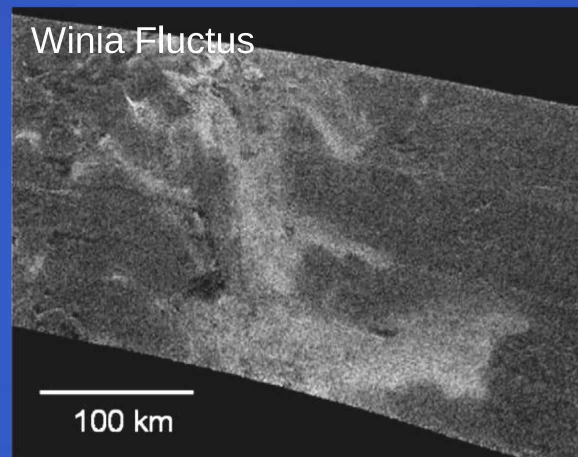
RADAR looks at Tortola

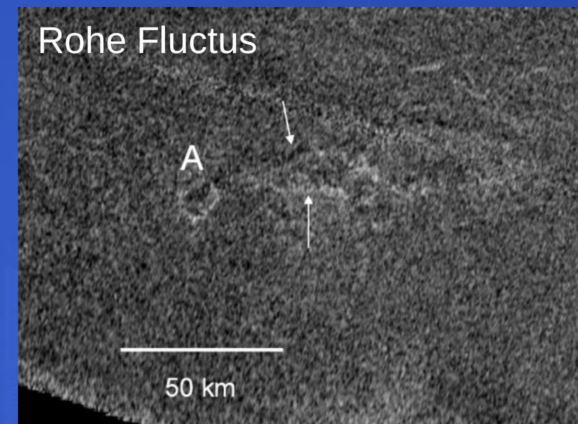


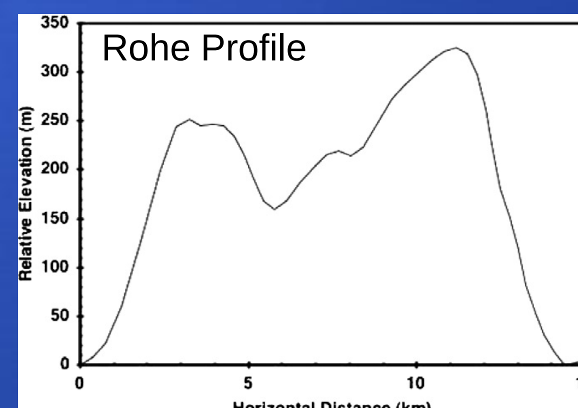
Morphologic evidence from RADAR

Lopes et al. (2007) Icarus 186

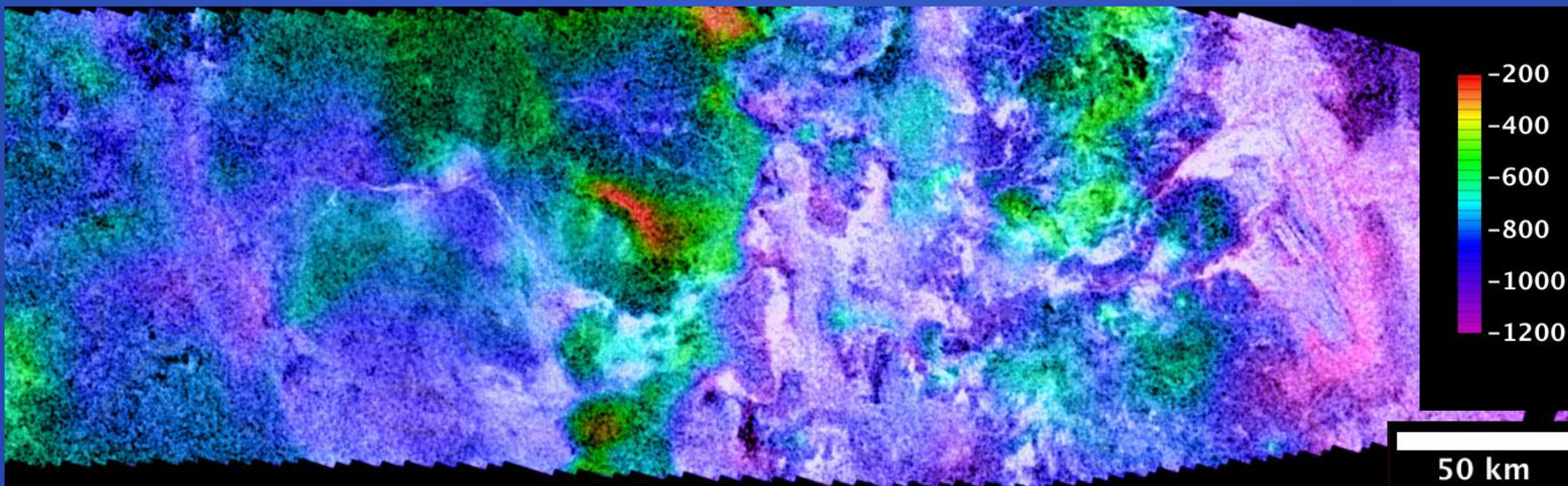


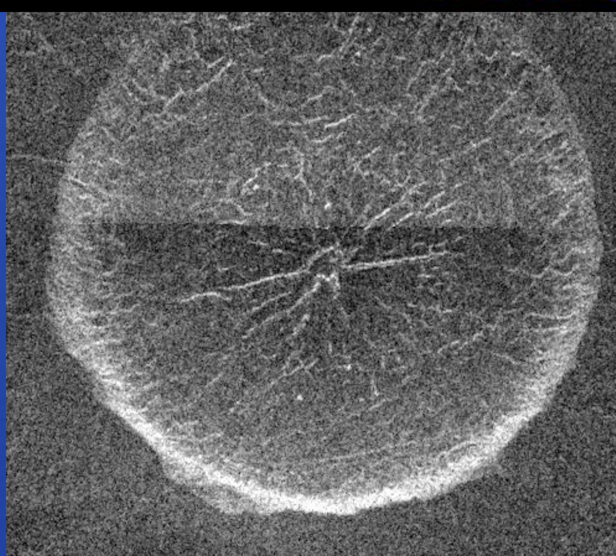






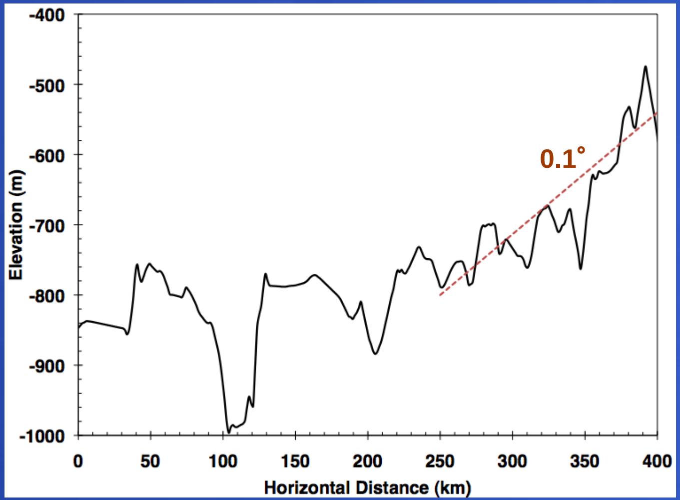
Ganesa Macula:
A steep-sided dome… NOT!

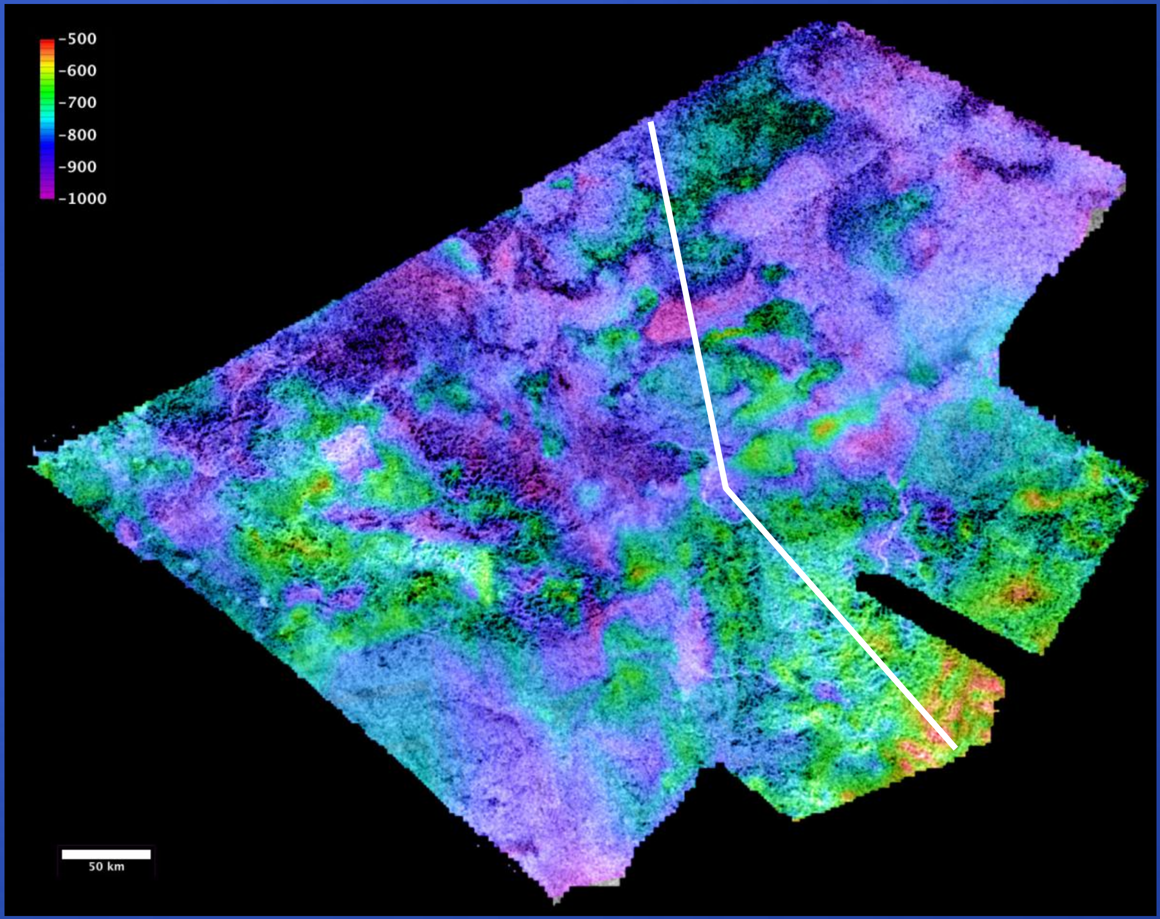


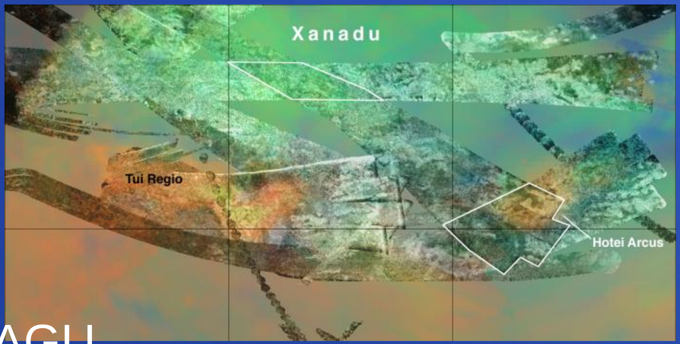


AGU
Fall 2008

Hotei Regio:
Thick flows, but are they volcanic?

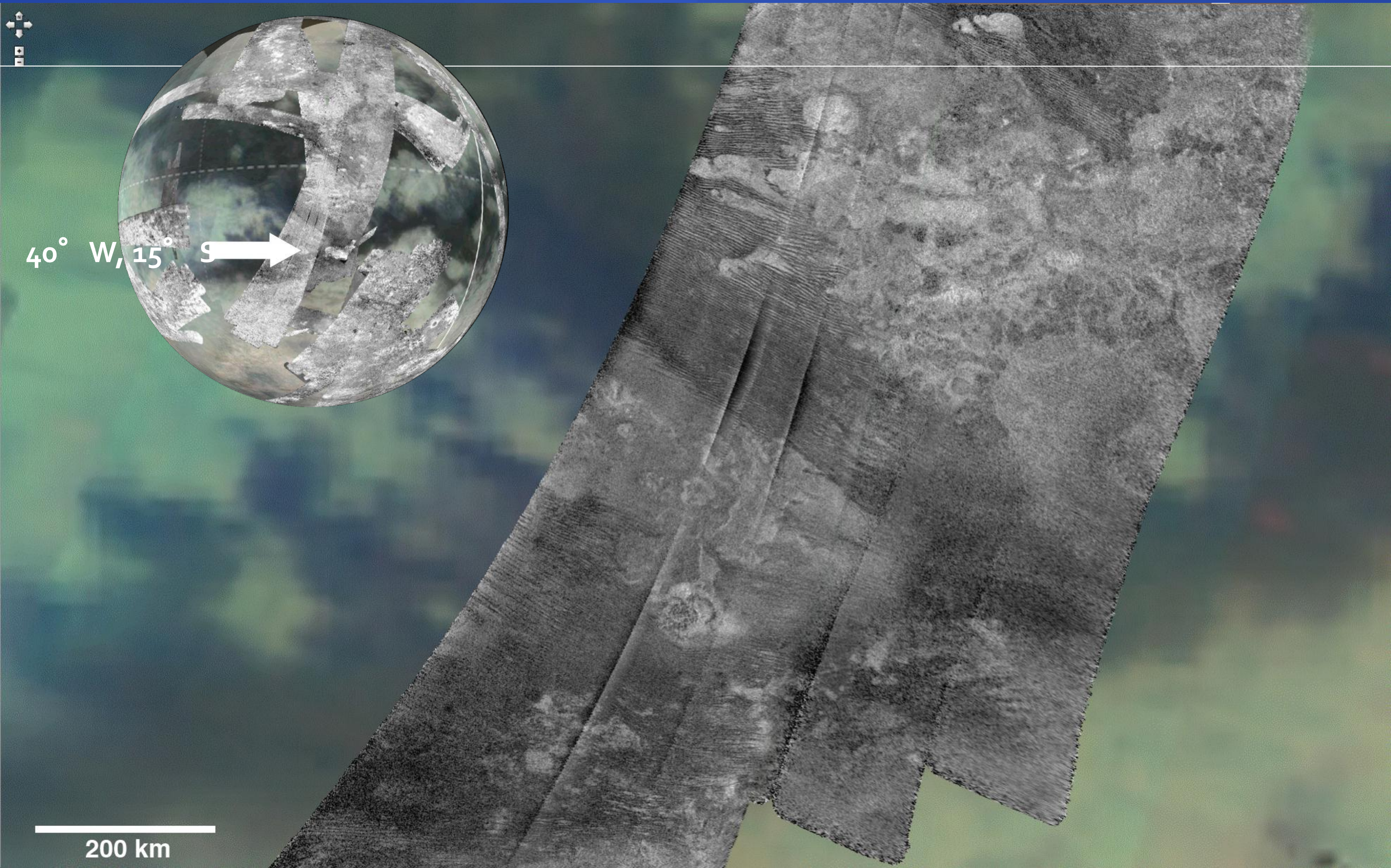




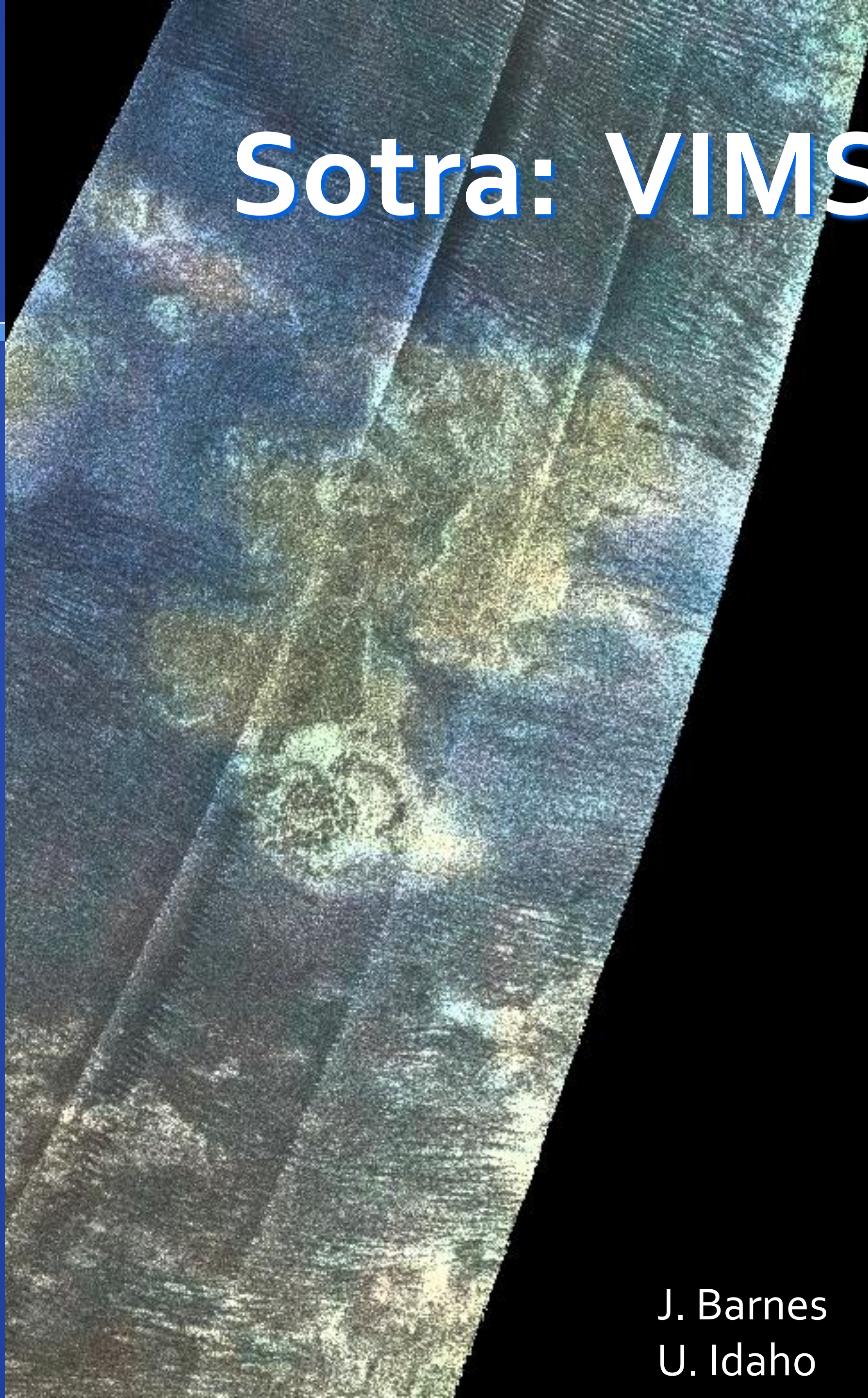


AGU
Fall 2008

Sotra Facula



Sotra: VIMS and RADAR



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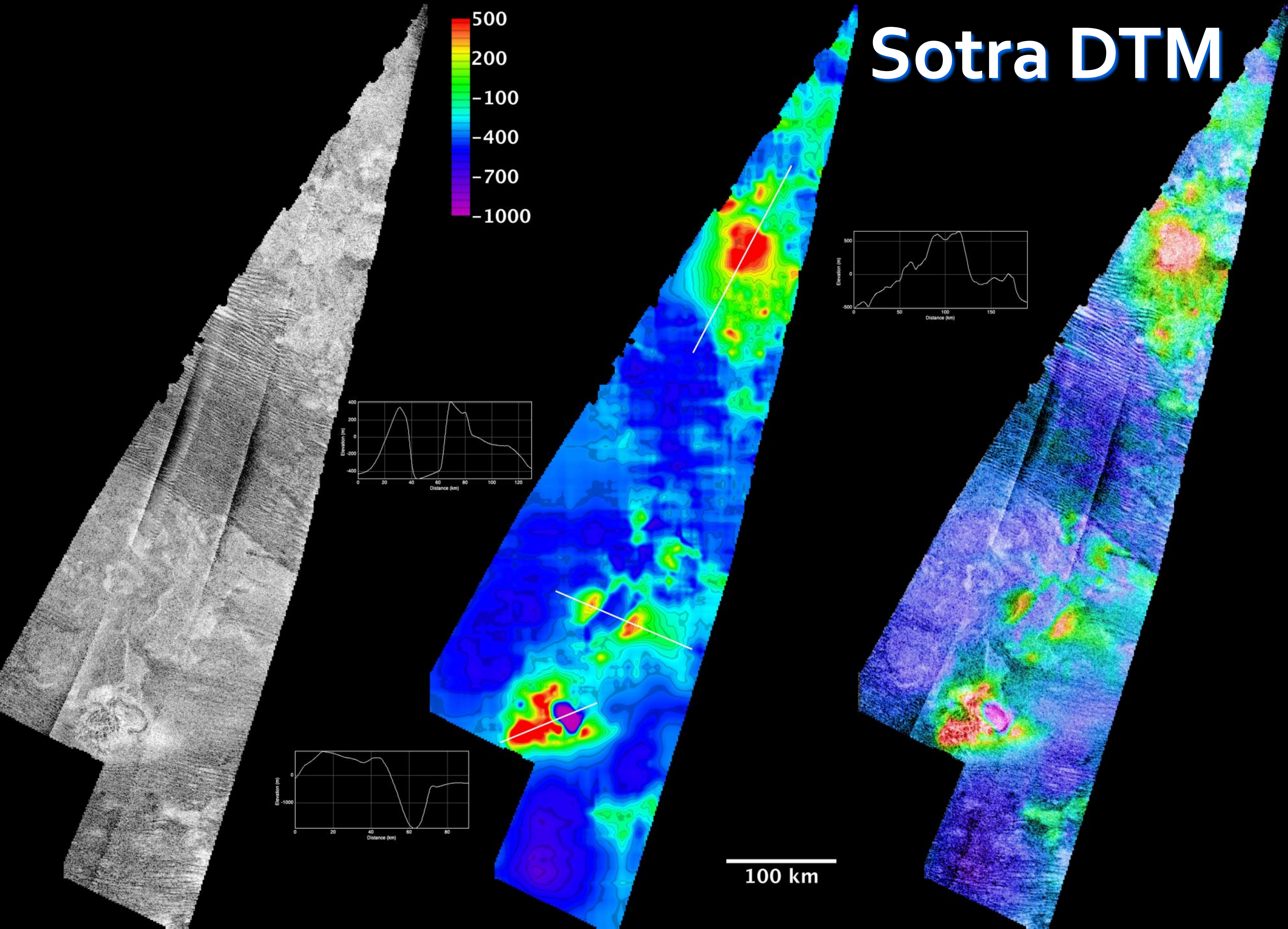
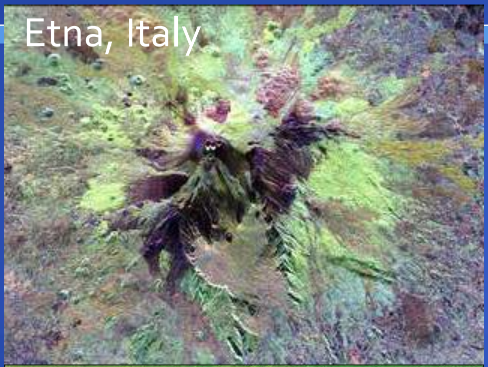
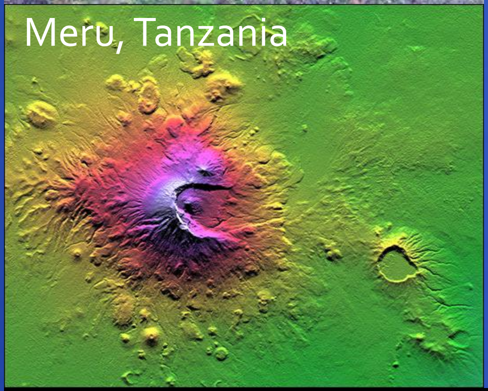


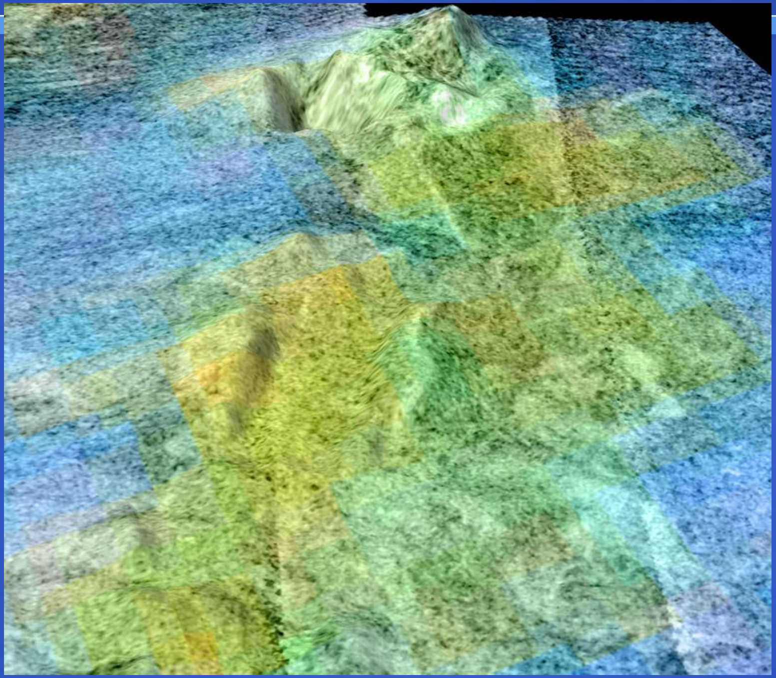
An “earthlike” volcano revealed

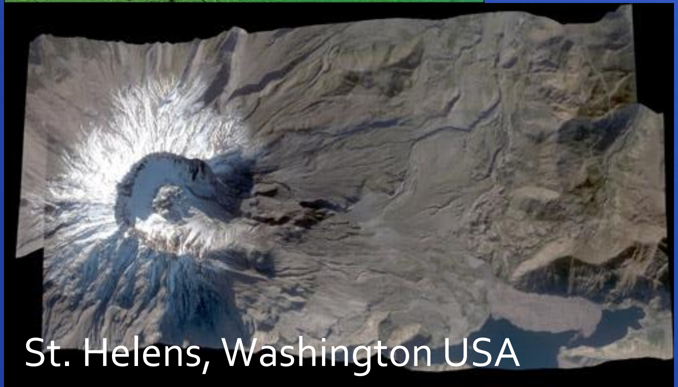
Possible analogs for Sotra

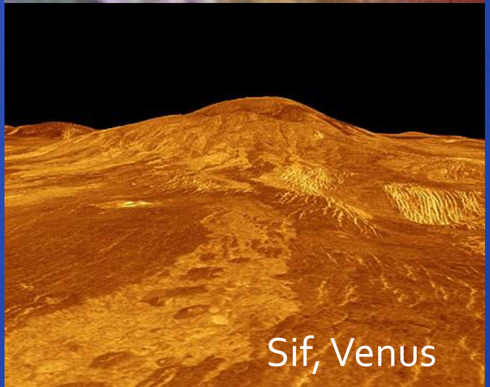




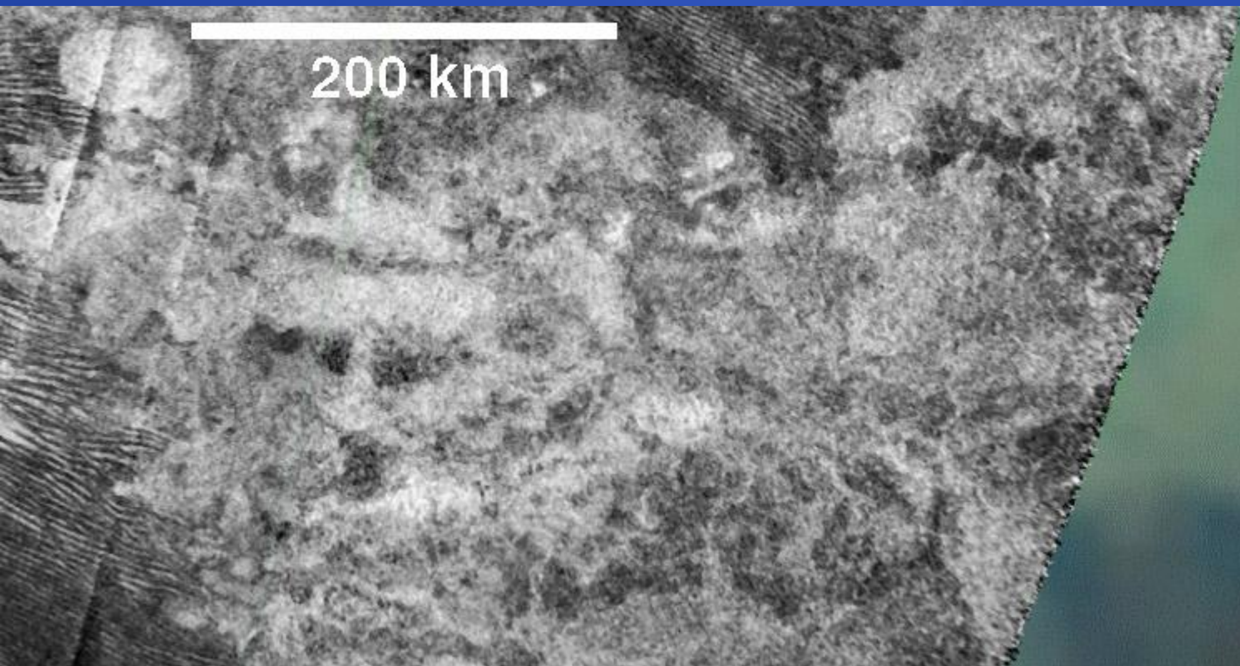
Sotra Facula, Titan

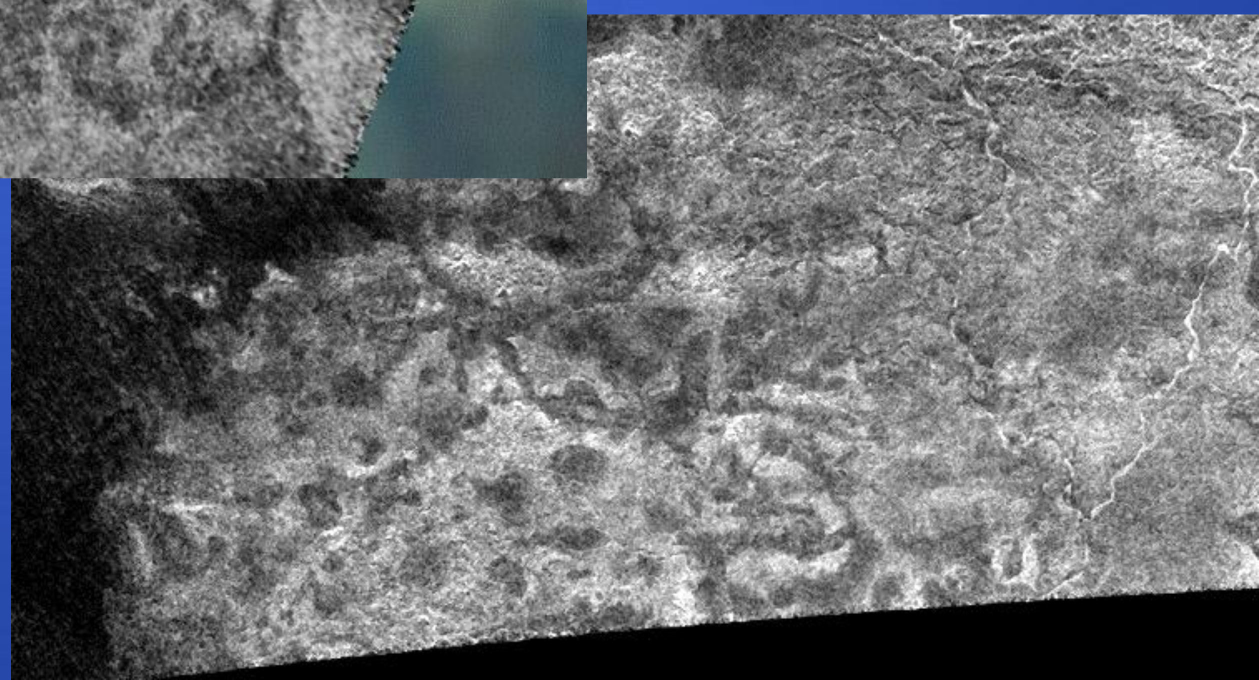






“Sotra North” and West Xanadu





Conclusions

- Titan is an exceptionally fascinating world
  - Nearly as diverse geologic processes as Earth
  - Familiar roles are played by different substances
  - Really challenges our understanding of planets/satellites
- Topography helps us interpret the images to look for volcanoes and to study all sorts of features
- 3D visualization is especially helpful
  - Requires area coverage (topo maps, not profiles)
- Sotra is the strongest candidate volcano on Titan so far: “Titan’s Mount Doom”
- The Cassini mission will continue to 2017 and we have lots and lots more stereo pairs from which to make topo maps