Exploring Saturn's Moon Titan, An Earth-like Alien

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United States Geological Survey

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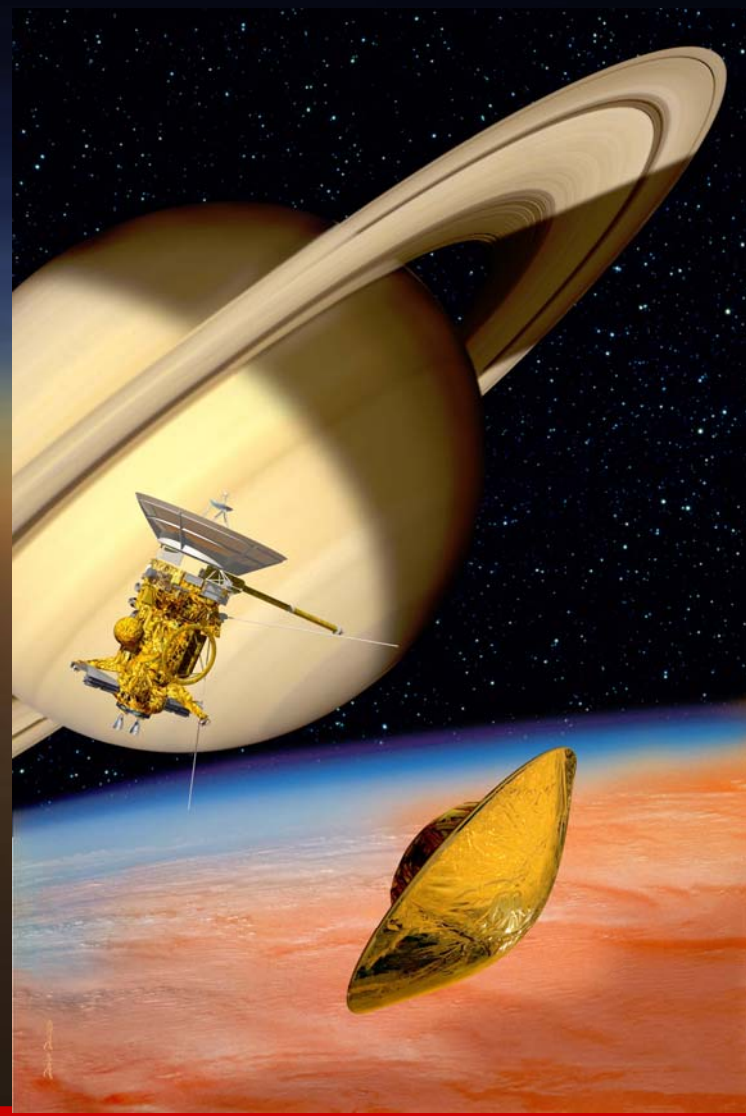
Huygens and Cassini
The Scientists and the Machines

Christiaan Huygens

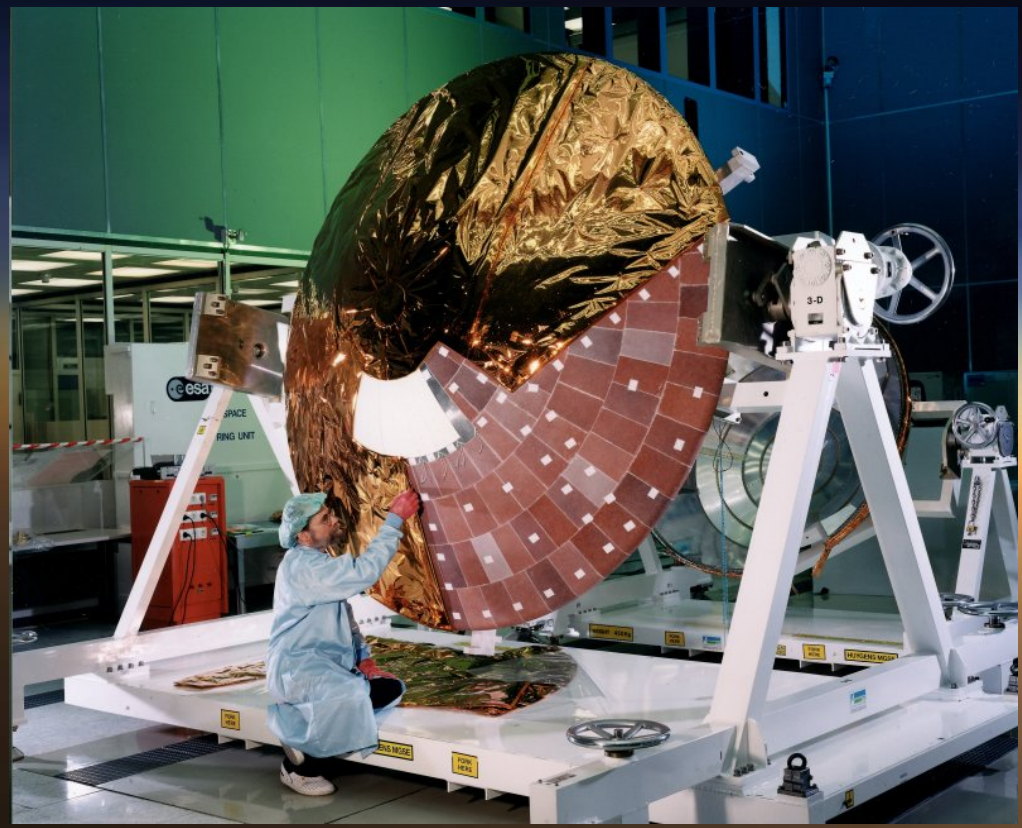
Giovanni Domenico Cassini

Christiaan Huygens (1629-1695) Dutch scientist, who discovered the true nature of Saturn's rings, and in 1655, Titan

Giovanni Domenico Cassini (1625-1712), Italo-French astronomer, who discovered several of Saturn's satellites: Iapetus, Rhea, Tethys and Dione. In 1675, he discovered what is today called "Cassini Division" the gap in-between the two main rings of Saturn



NASA Cassini Orbiter and European Space Agency (ESA) Huygens Probe



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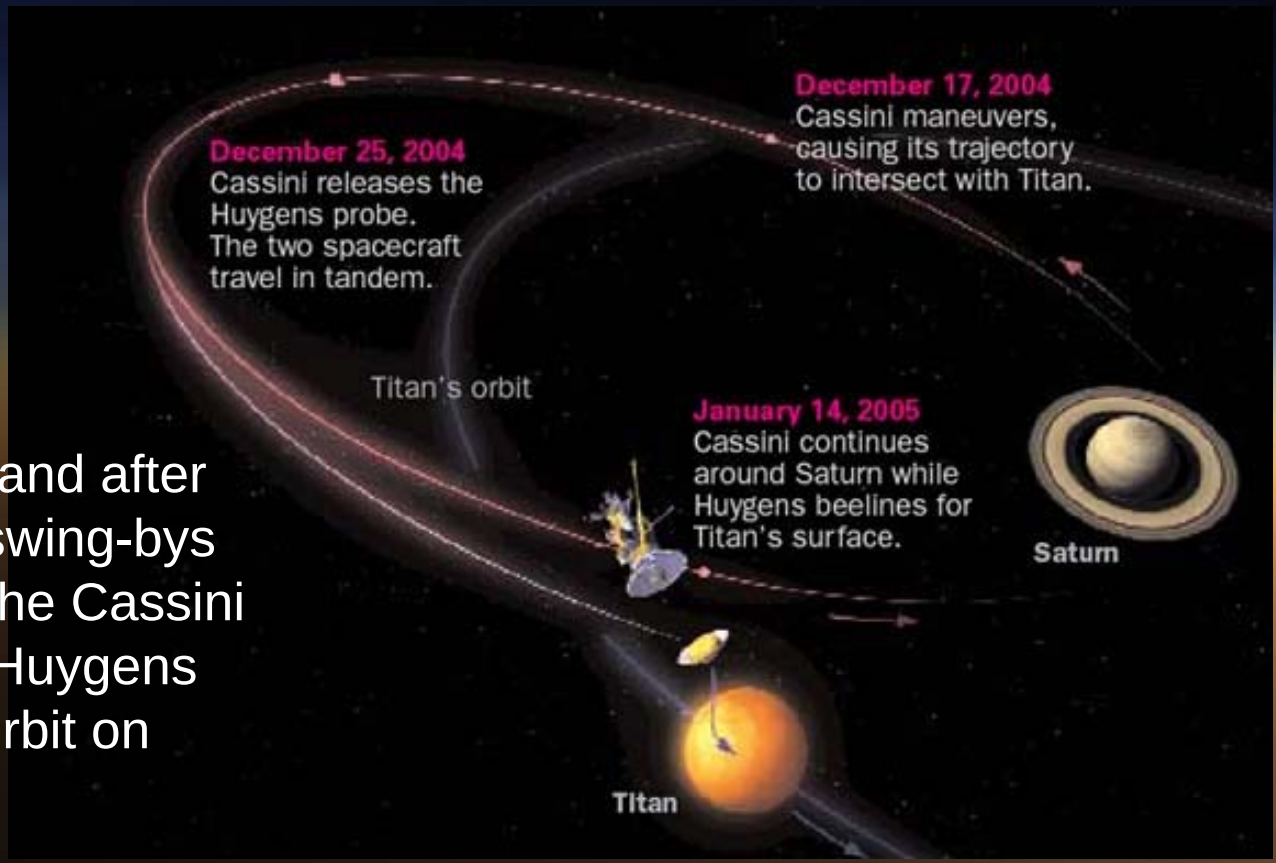
Cassini-Huygens Trip to Titan

Launched in 1997, and after two Venus gravity swing-bys and one at Earth, the Cassini Orbiter carried the Huygens Probe into Saturn orbit on July 1, 2004.



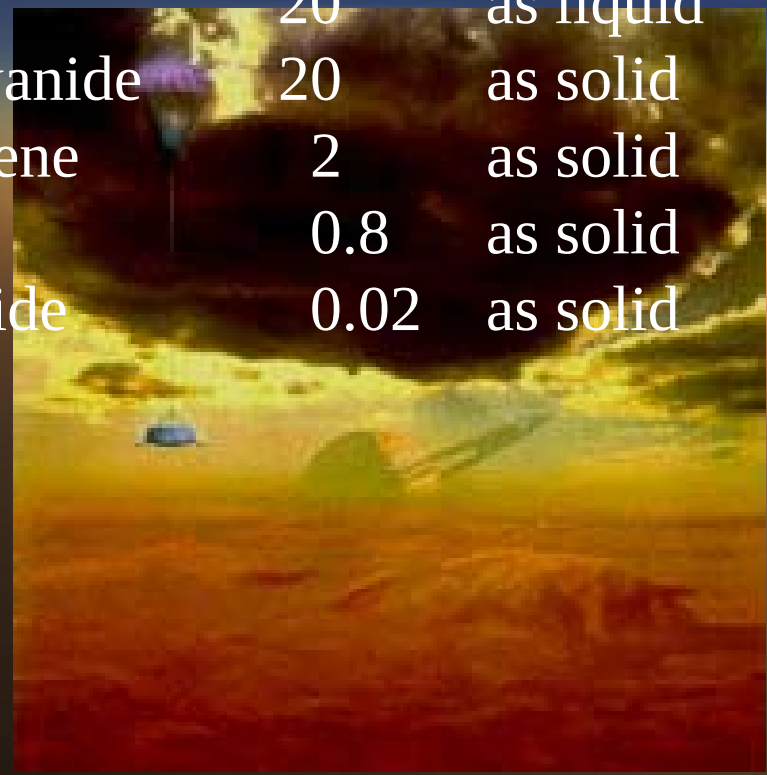
Titan's Surface Environment

- Larger than Mercury, Titan holds an atmosphere
- Like Earth it has a dominantly nitrogen atmosphere
  - Its atmosphere is very thick and extremely cold
  - Surface pressure - 1.5 x Earth
  - Surface temperature - 94 K (-179 Celsius, -290 Fahrenheit)
- Titan's atmosphere is rich in hydrocarbons
  - About 5% methane
  - Methane is to Titan as water is to Earth, existing as gas and liquid
  - We anticipated finding clouds, rain, rivers, lakes
- Sunlight converts methane into
  - Ethane, acetelyene, propane, and higher-order H-C-N compounds
  - Smog-like haze of tholin 'snows' down onto the surface
  - Sludges, black, brown, to bright orange may coat the surface
- Titan holds clues to the Solar System's early chemistry, to the raw ingredients that ultimately led to life

Lots of hydrocarbons and nitriles would collect on Titan's surface in 4.5 billion years

There could be a km-thick organic layer on surface consisting of liquids and solids

	Global Averge Depth (meters)	
ethane	300-600	as liquid
acetylene	100	as solid
propane	20	as liquid
hydrogen cyanide	20	as solid
cyanoacetylene	2	as solid
cyanogen	0.8	as solid
carbon dioxide	0.02	as solid



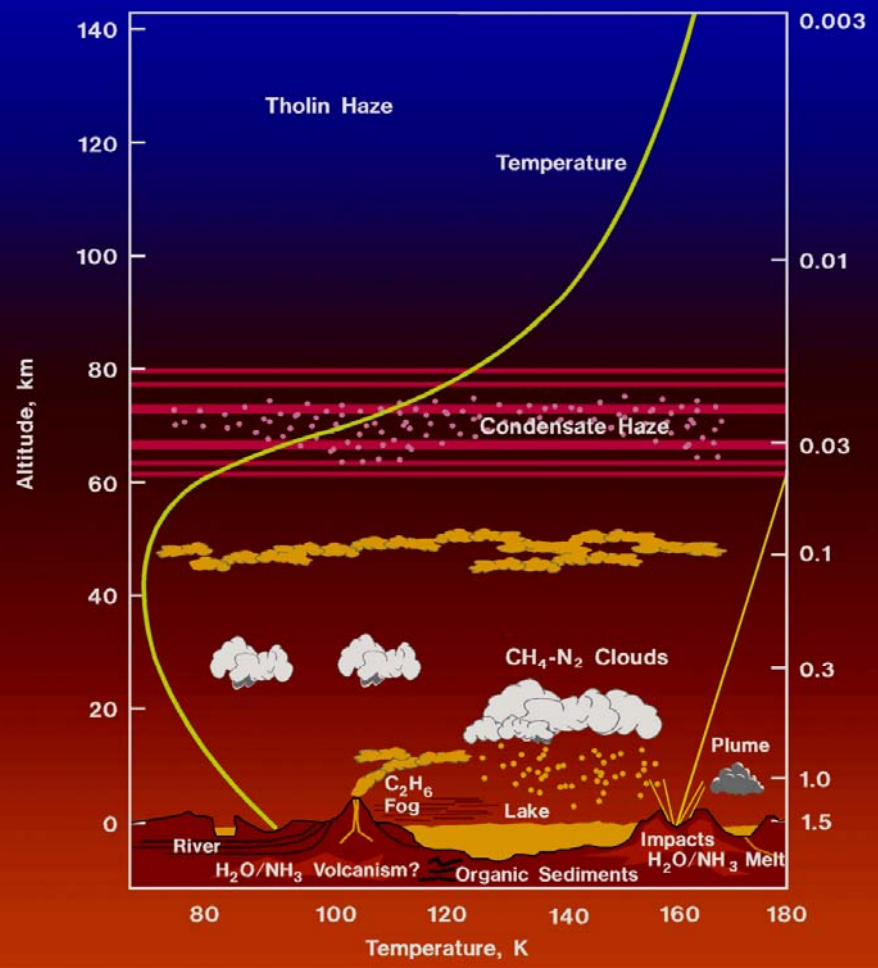
The Challenges of Exploring Titan

- Titan's thickly absorbing and hazy atmosphere is very difficult to see through---

  So Cassini carried

  – An imaging RADAR
  – A near-infrared spectrometer
  – A very sensitive camera that can image out to ~1 μm

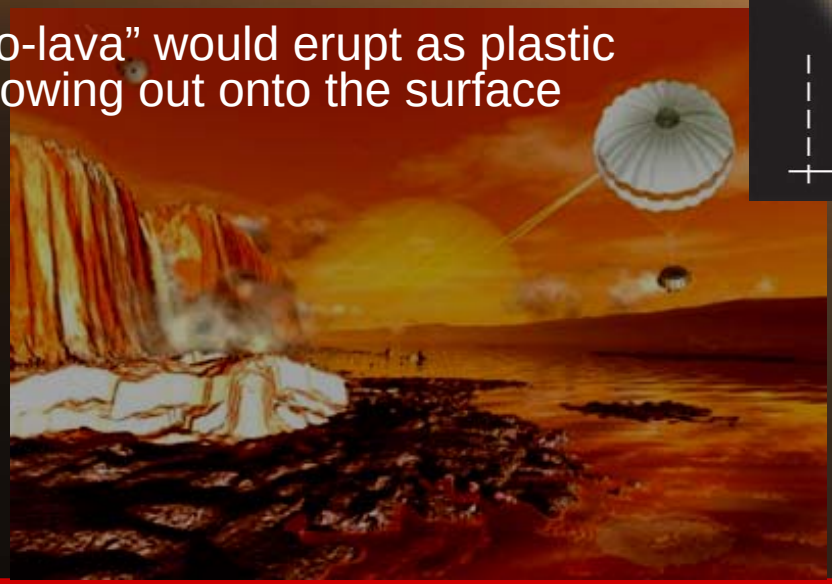
- Titan's thick atmosphere also makes it ideal for exploration by parachute
  – Huygens Probe floated down to the surface in about 2 hours
  – Carried a suite of cameras and spectrometers to the surface

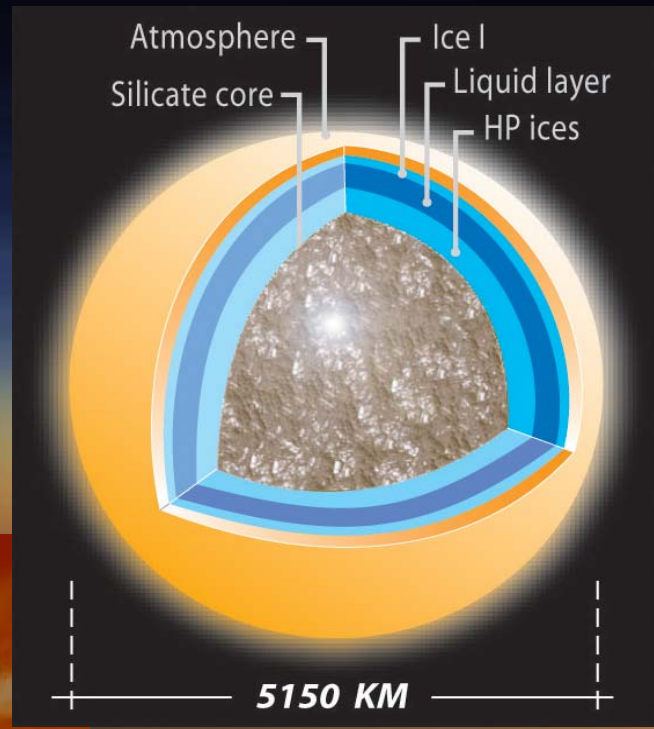


Possibilities for Titan Geology: What's 'Cryo-volcanism'

Titan's Interior is thought to contain-

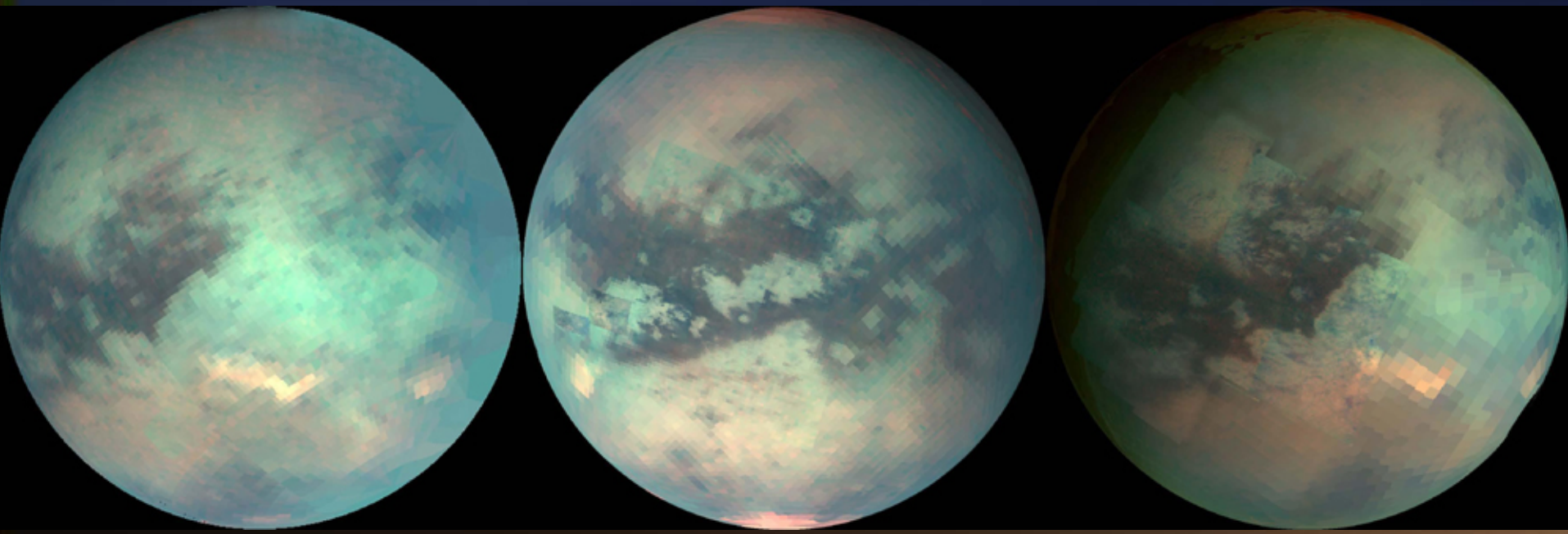
- A large rocky core surrounded by layers of liquid and ice (mostly water)
- Abundant ammonia (NH_3) lowering the melting point of water ice by ~100 C producing a liquid zone
- Tectonism could breach the crust allowing this fluid to reach the surface
- Ammonia-water "cryo-lava" would erupt as plastic gelatinous masses flowing out onto the surface



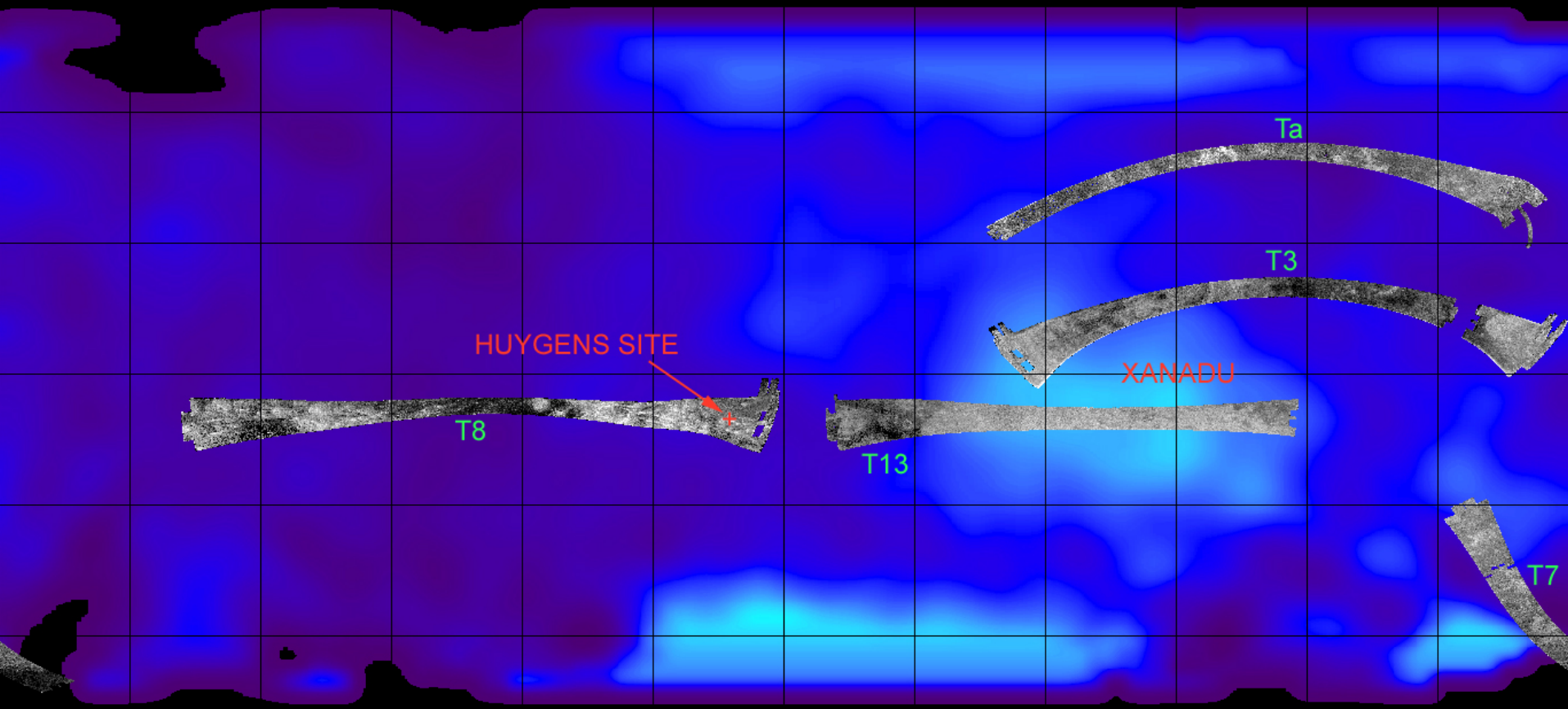


A Model of Titan's Interior

Global Views by VIMS (Visible and Infrared Mapping Spectrometer, RGB=5.0, 2.0,1.6μm)



Cassini Radar Coverage Ta-T13



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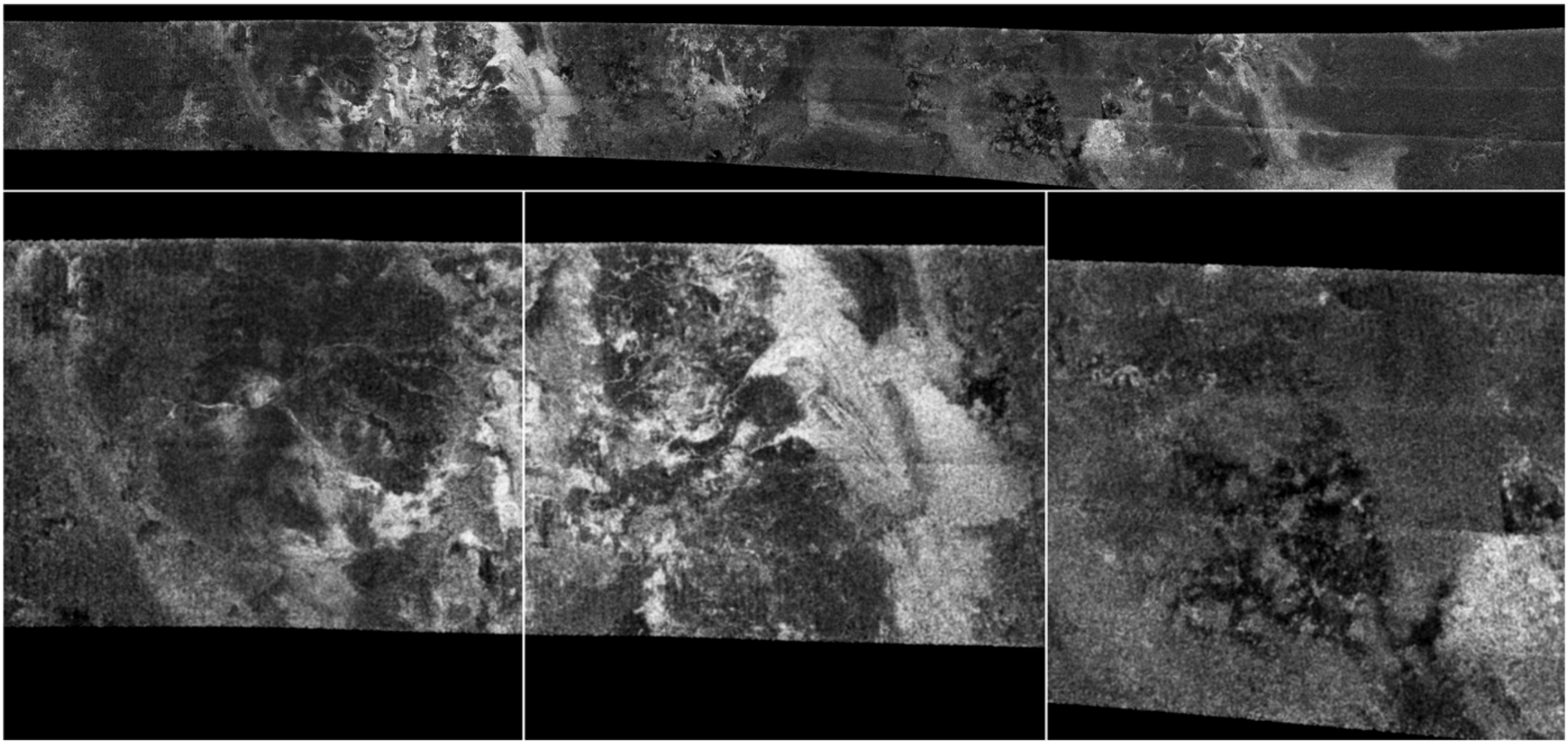
Ta - First Radar Pass – Volcanism and Tectonism



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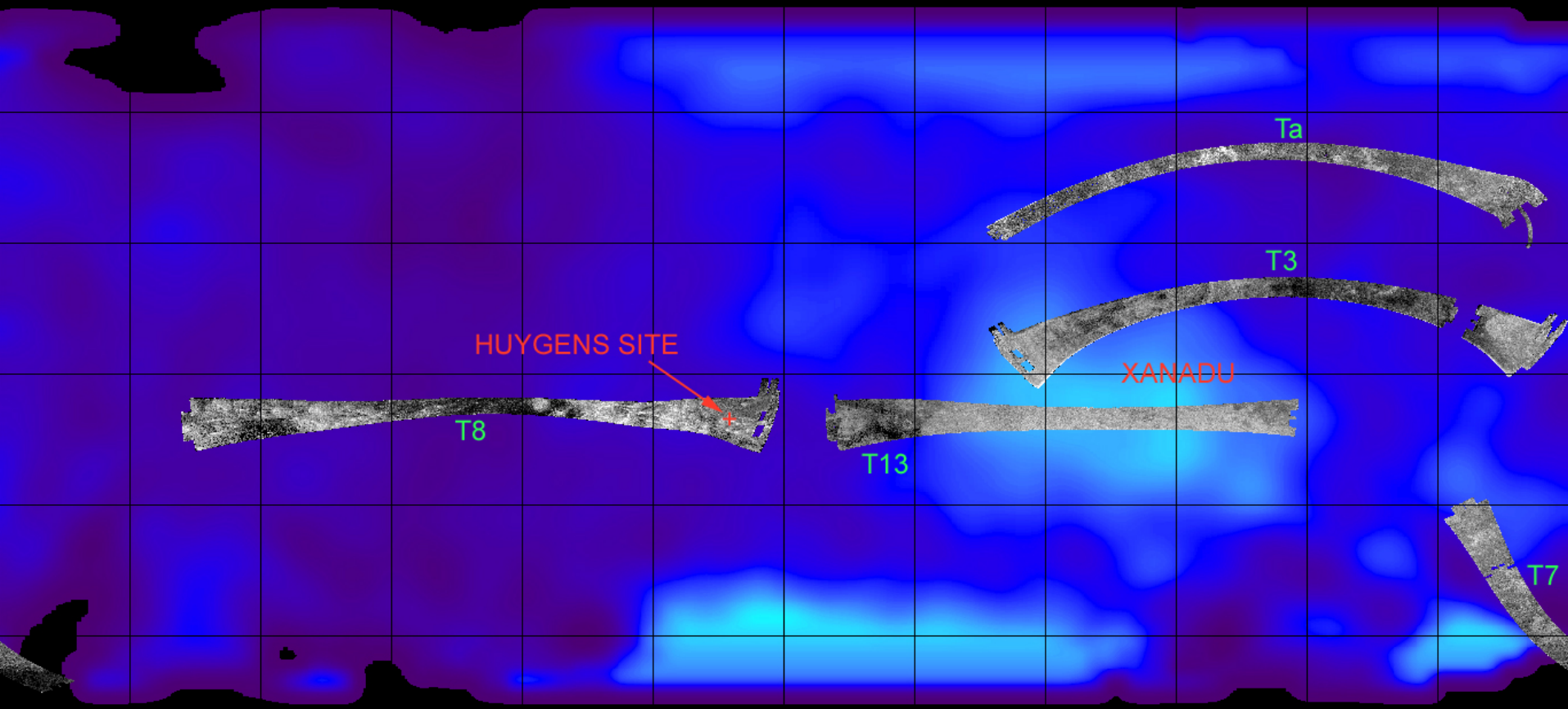
Cassini Radar Coverage Ta-T13



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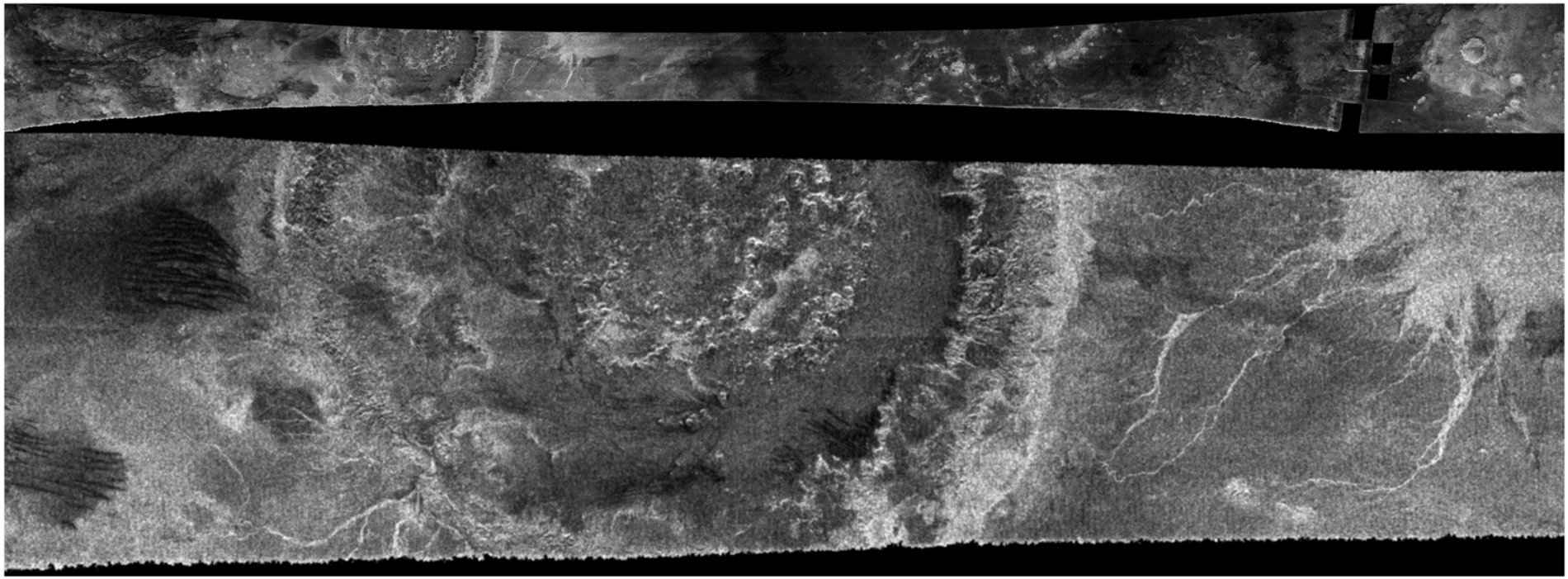
T3 – 2nd Radar Pass – Impact, Dunes, Drainage Networks



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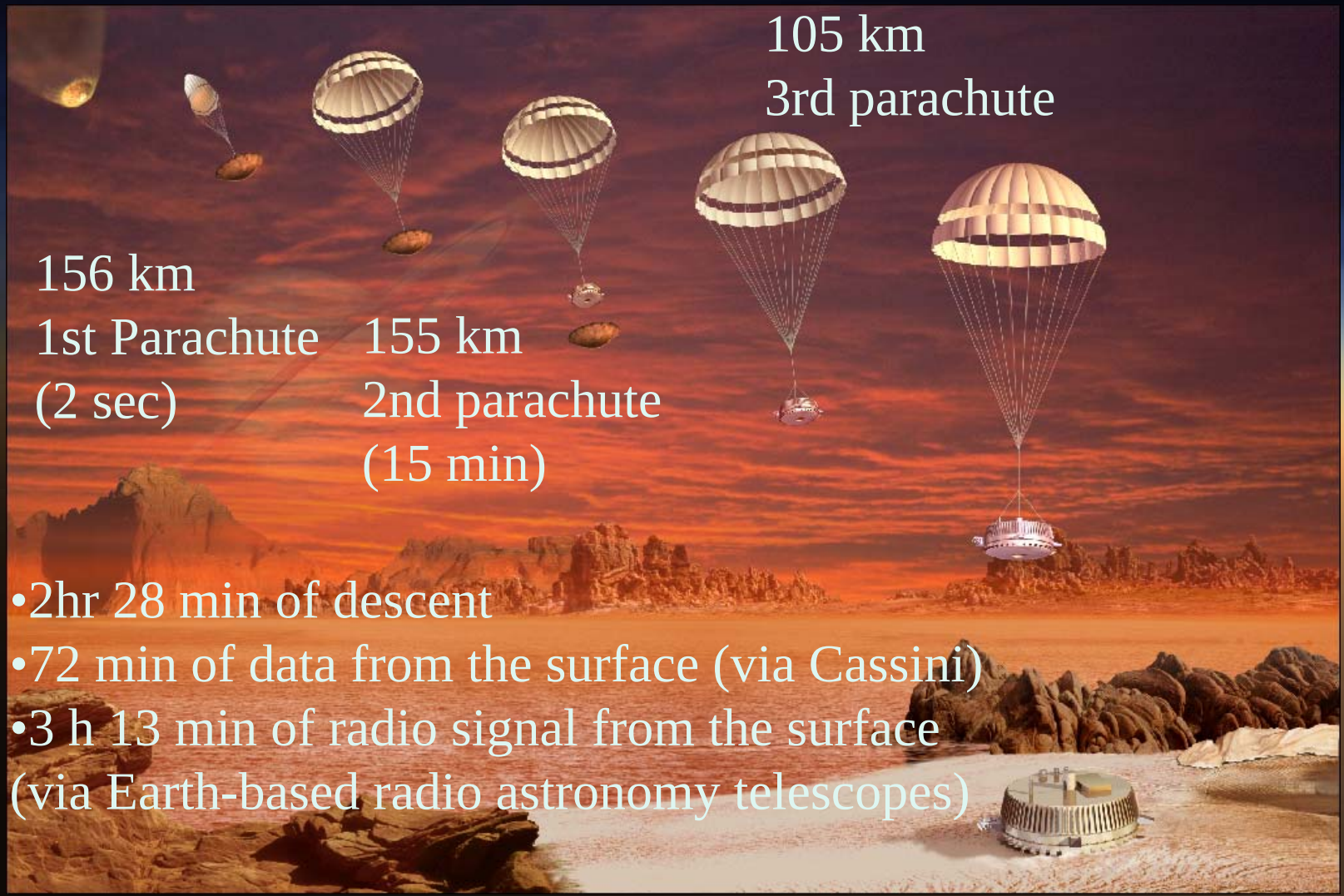
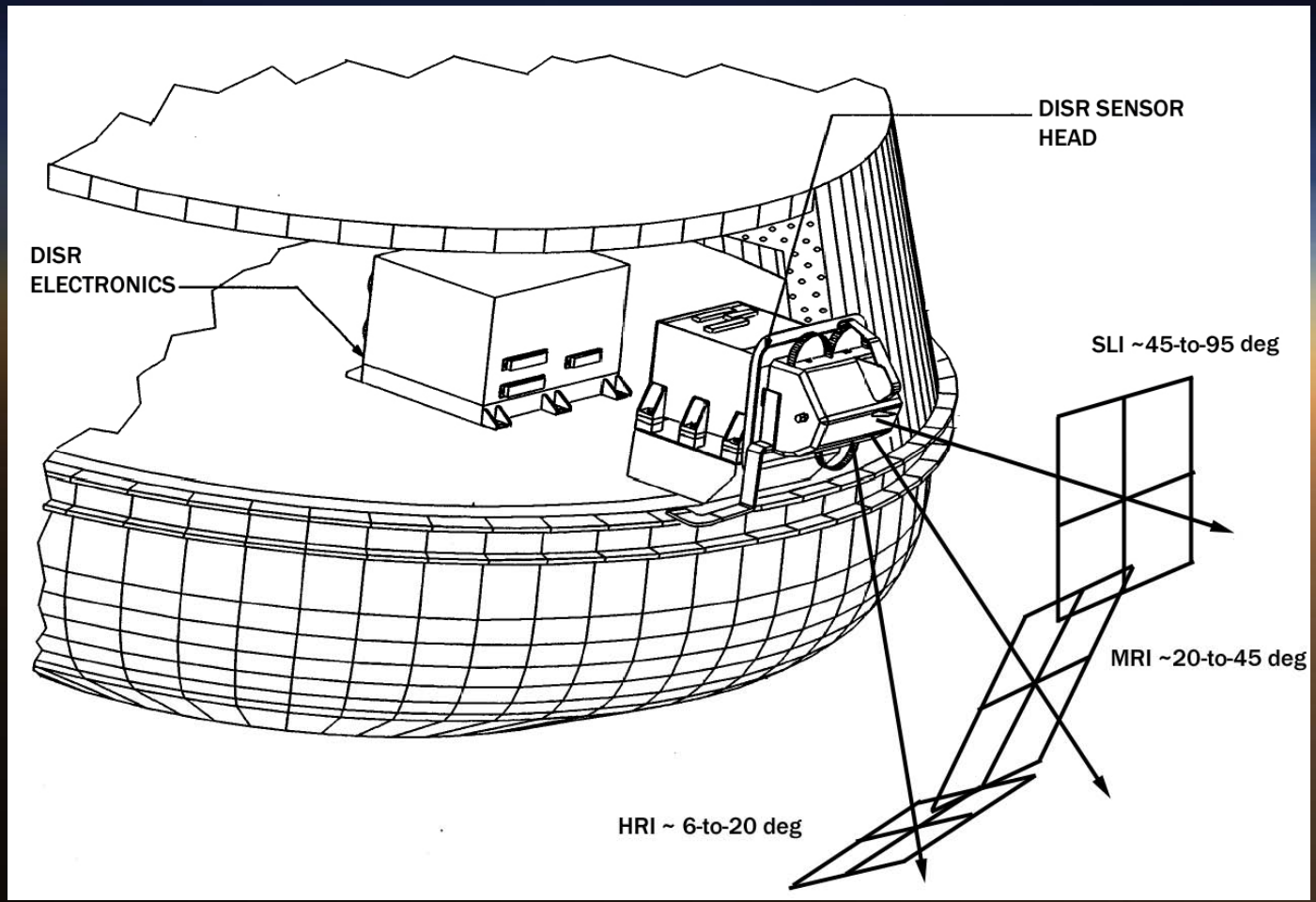
Onto the Surface of Titan!
Huygens Separation and Entry

Entry, Descent, and Landing



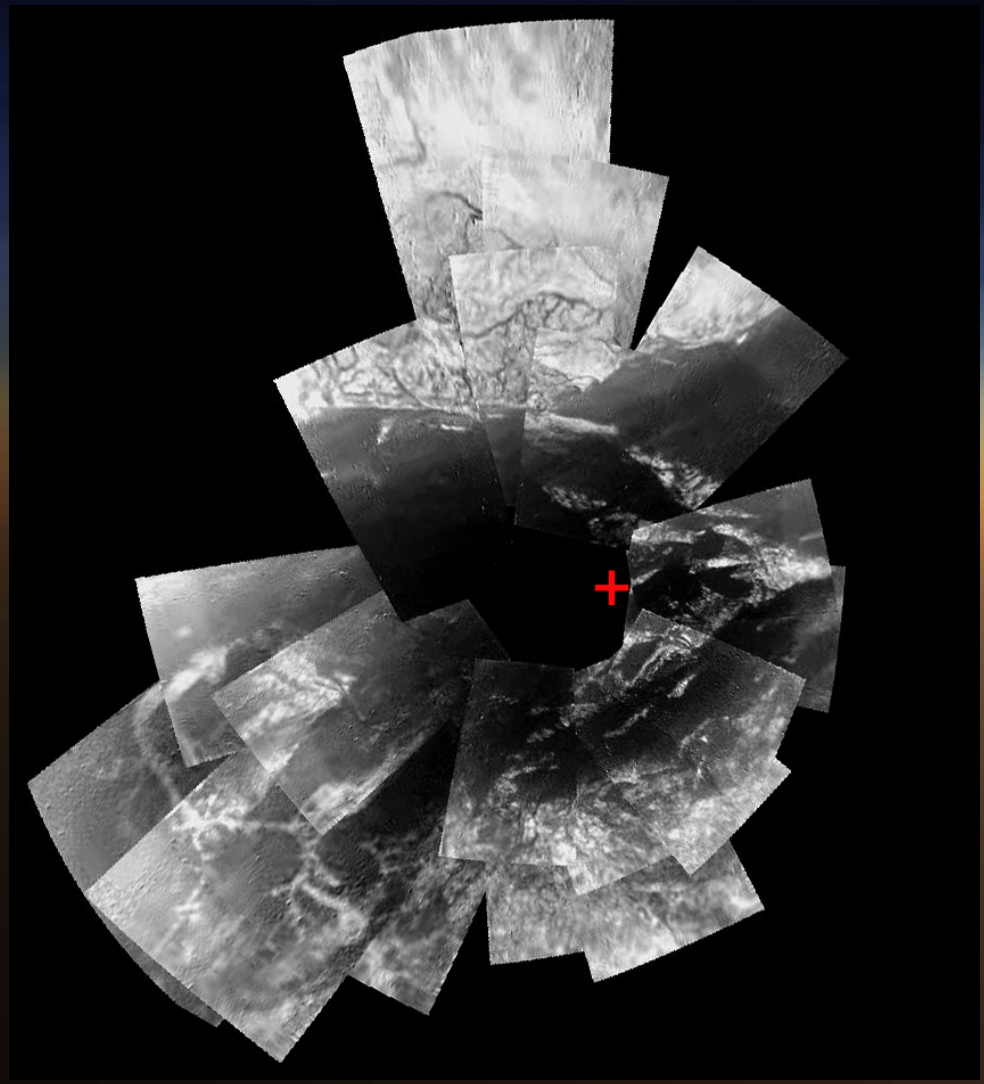
The Huygens Probe cameras: the Descent Imager Spectral Radiometer was supplied by the University of Arizona



The Descent was Unexpectedly Chaotic

- The direction of parachute rotation changed randomly
- The DISR instrument system lost track of the Sun
- Wind speeds were way below expected
- Wind direction changed randomly and reversed
- Parachute experienced chaotic tip and tilt
- To start the analysis, about all we had was altitude

As the wind speeds were low, the descent was nearly vertical and images repeatedly covered the same region.



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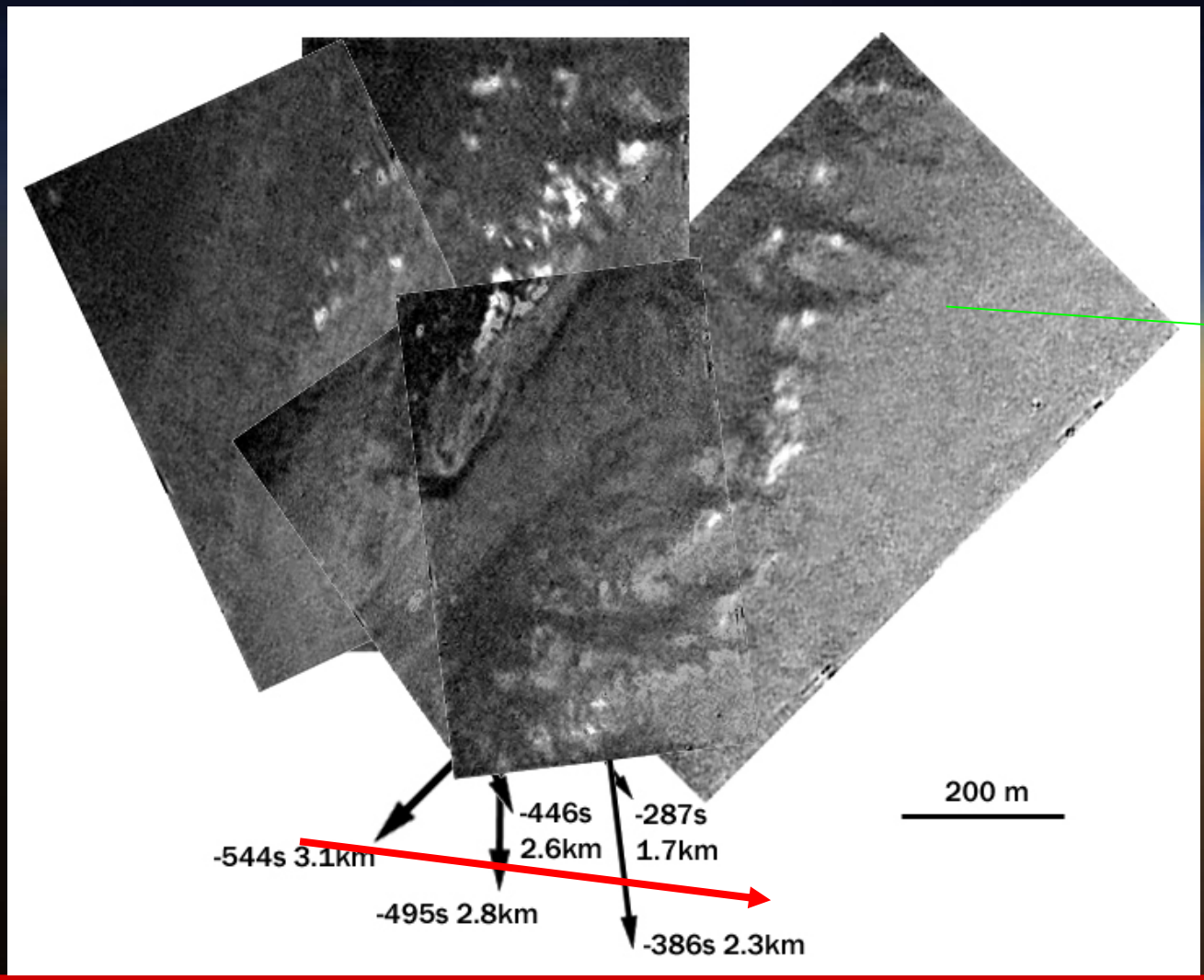
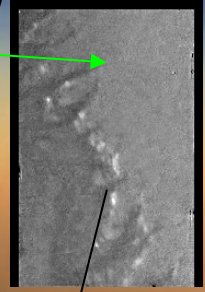
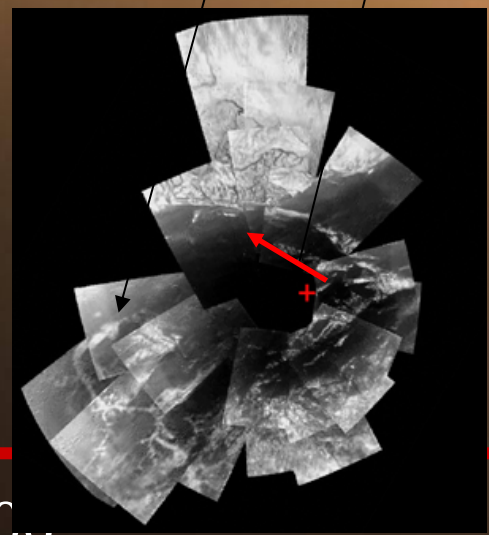
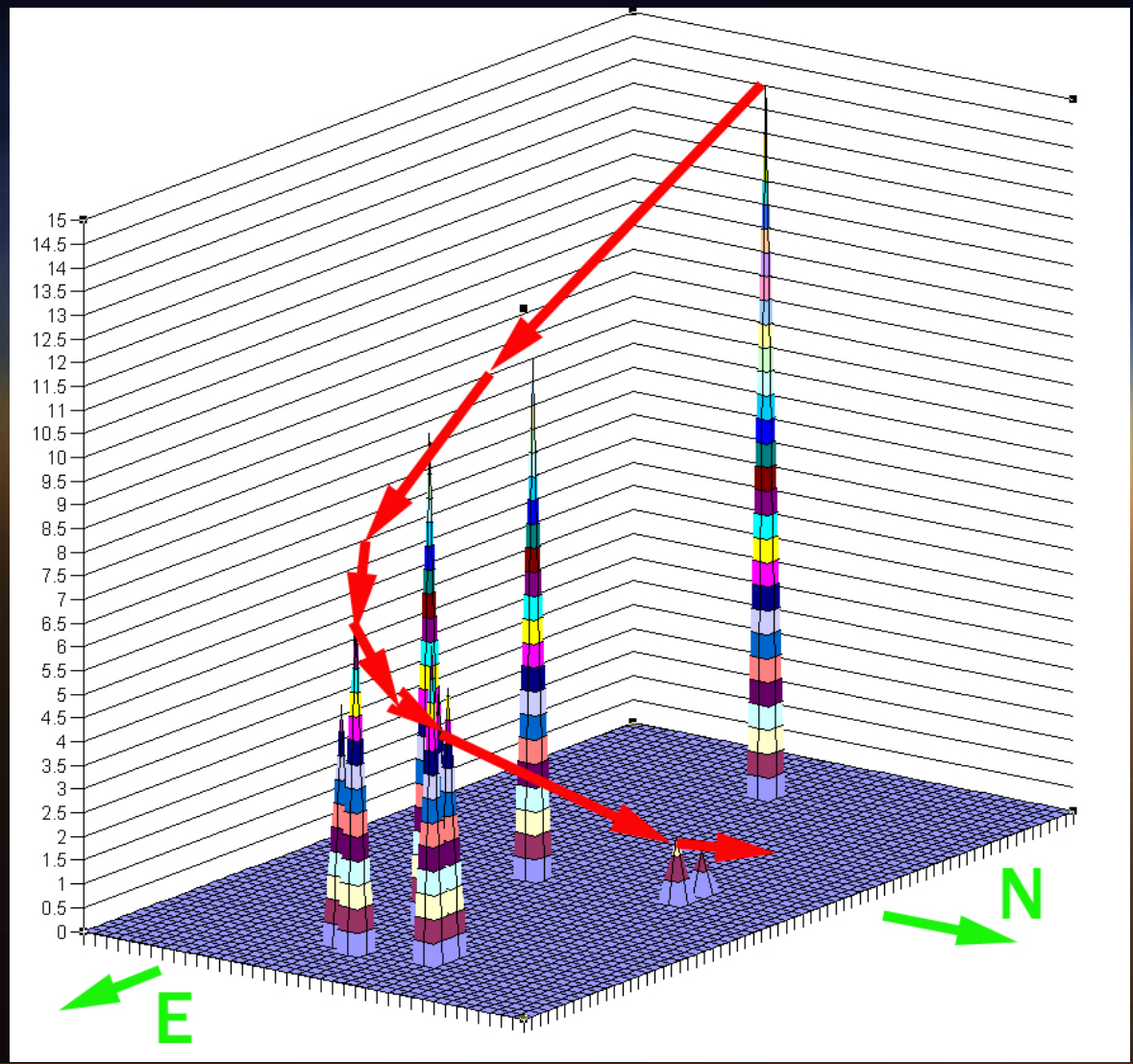
Reconstructing the flight path: recovering the changing flight direction & probe orientation from image overlap







Model of the complex descent path of the Probe caused by changing winds



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The View from Huygens on January 14, 2005

A Simulation Made Possible by the **D**escent **I**mager / **S**pectral **R**adiometer

Erich Karkoschka, the DISR Team, NASA, ESA

Version 2

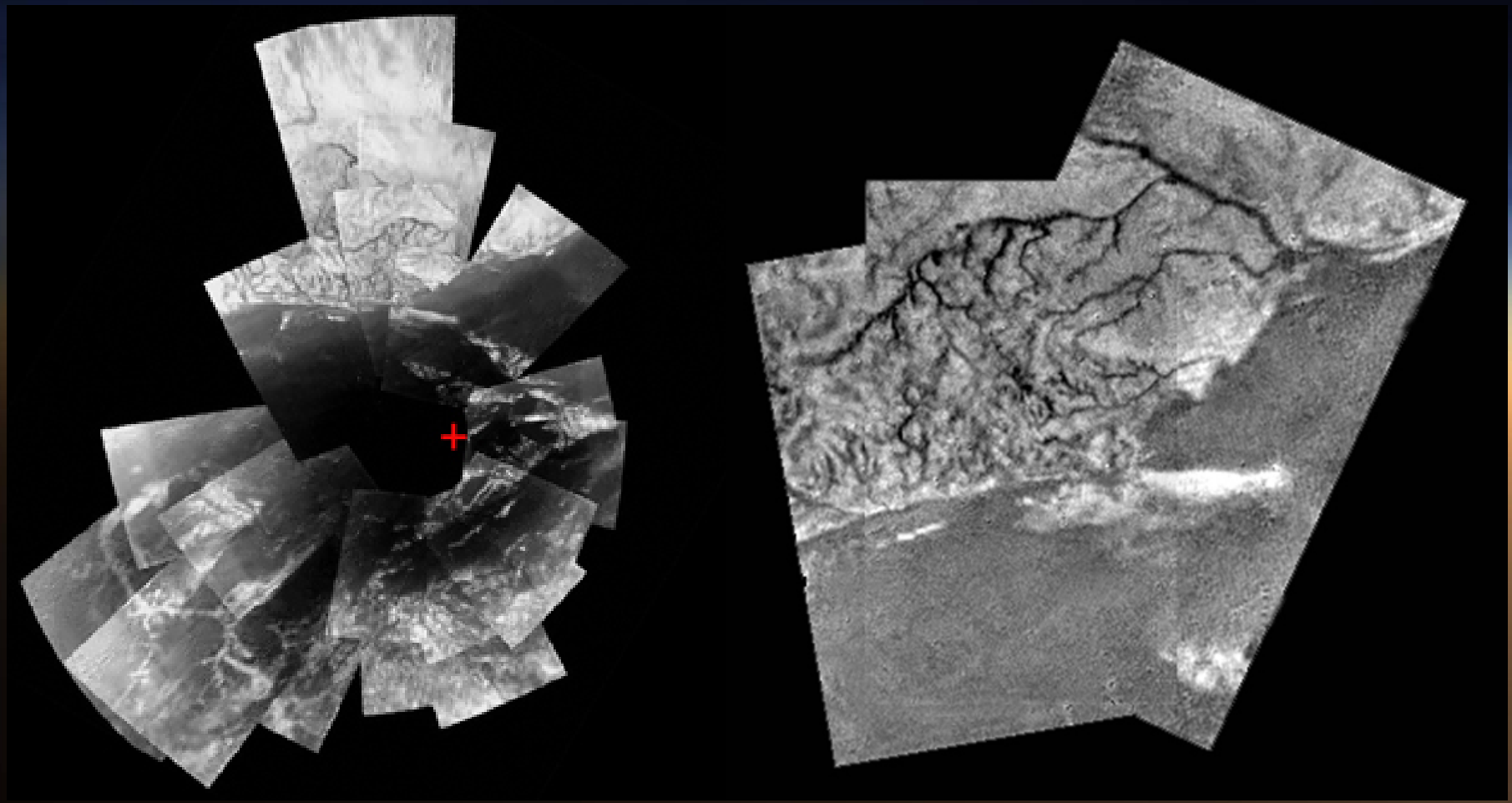
http://saturn.jpl.nasa.gov/multimedia/videos/video-details.cfm?videoID=117

The Descent Imager / Spectral Radiometer During the Descent of Huygens onto Titan on January 14, 2005

Erich Karkoschka, University of Arizona,
the DISR Team, NASA, ESA

http://saturn.jpl.nasa.gov/multimedia/videos/video-details.cfm?videoID=116

Dendritic drainage patterns. Due to methane rain? Dark channel floors full of organic sludge eroded from brighter highland? Do liquid pools exist locally? Probe GCMS showed methane humidity ~50%. Steadily rose.



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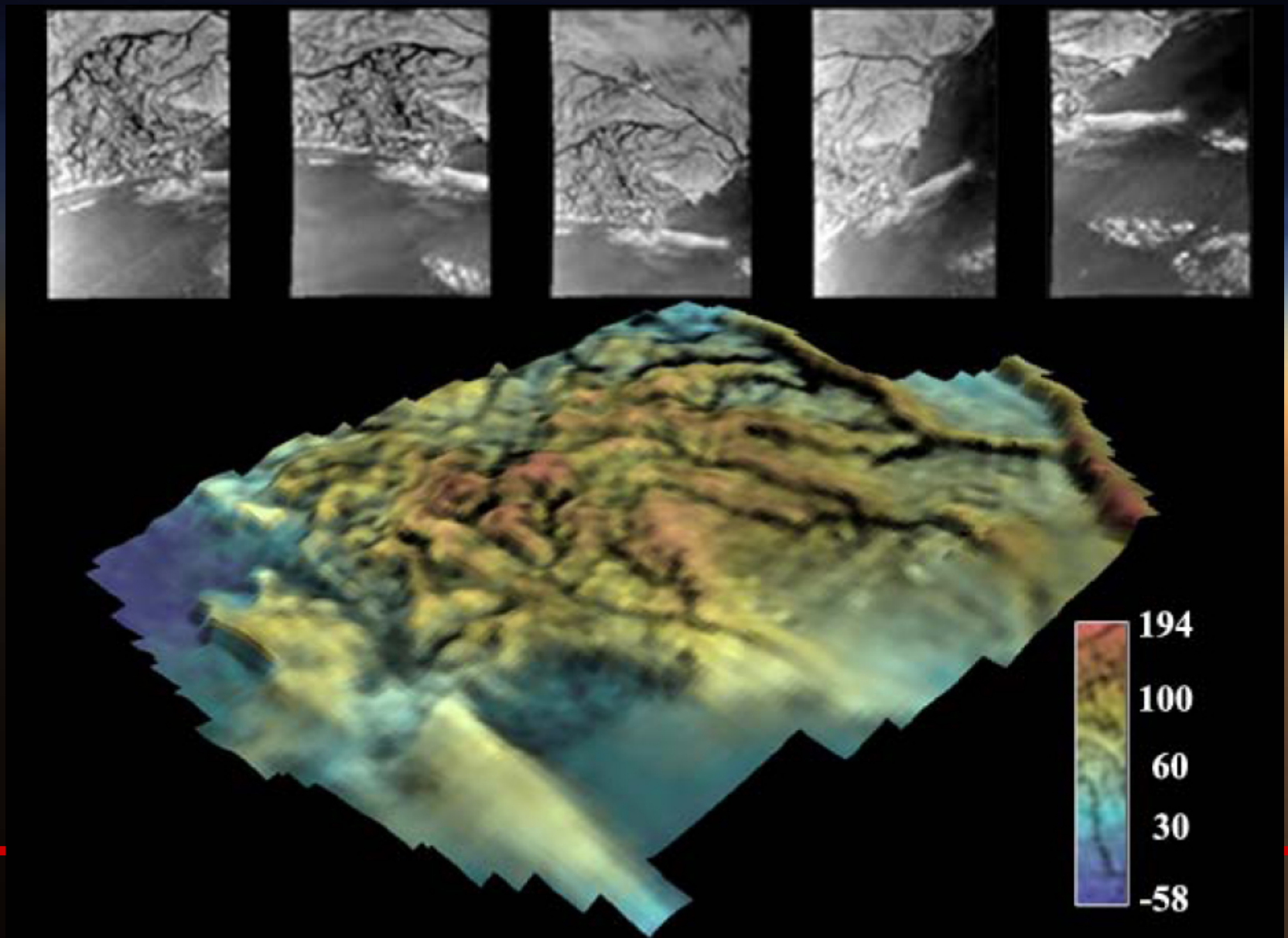
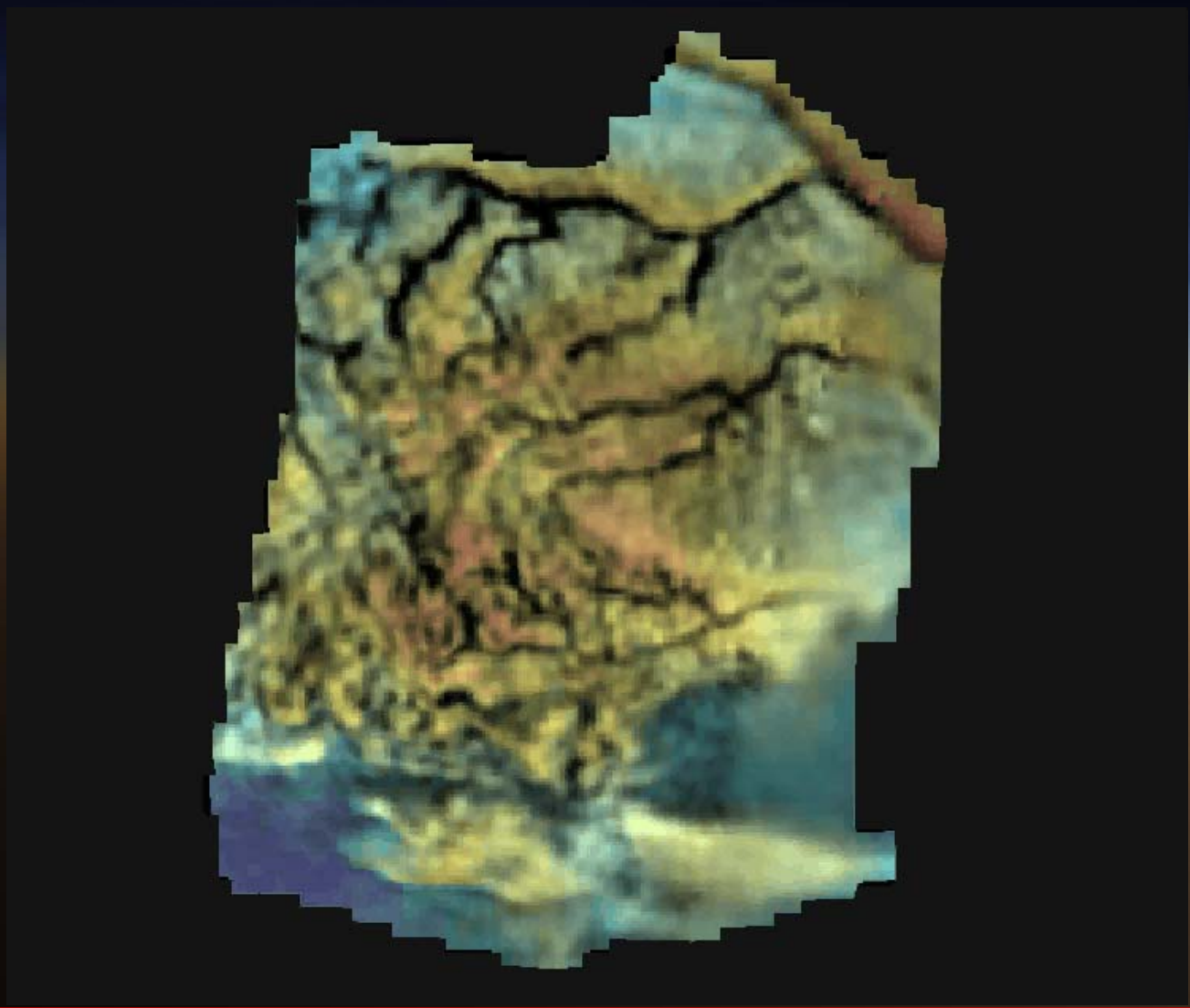
Stereo Model Using 5 DISR Frames

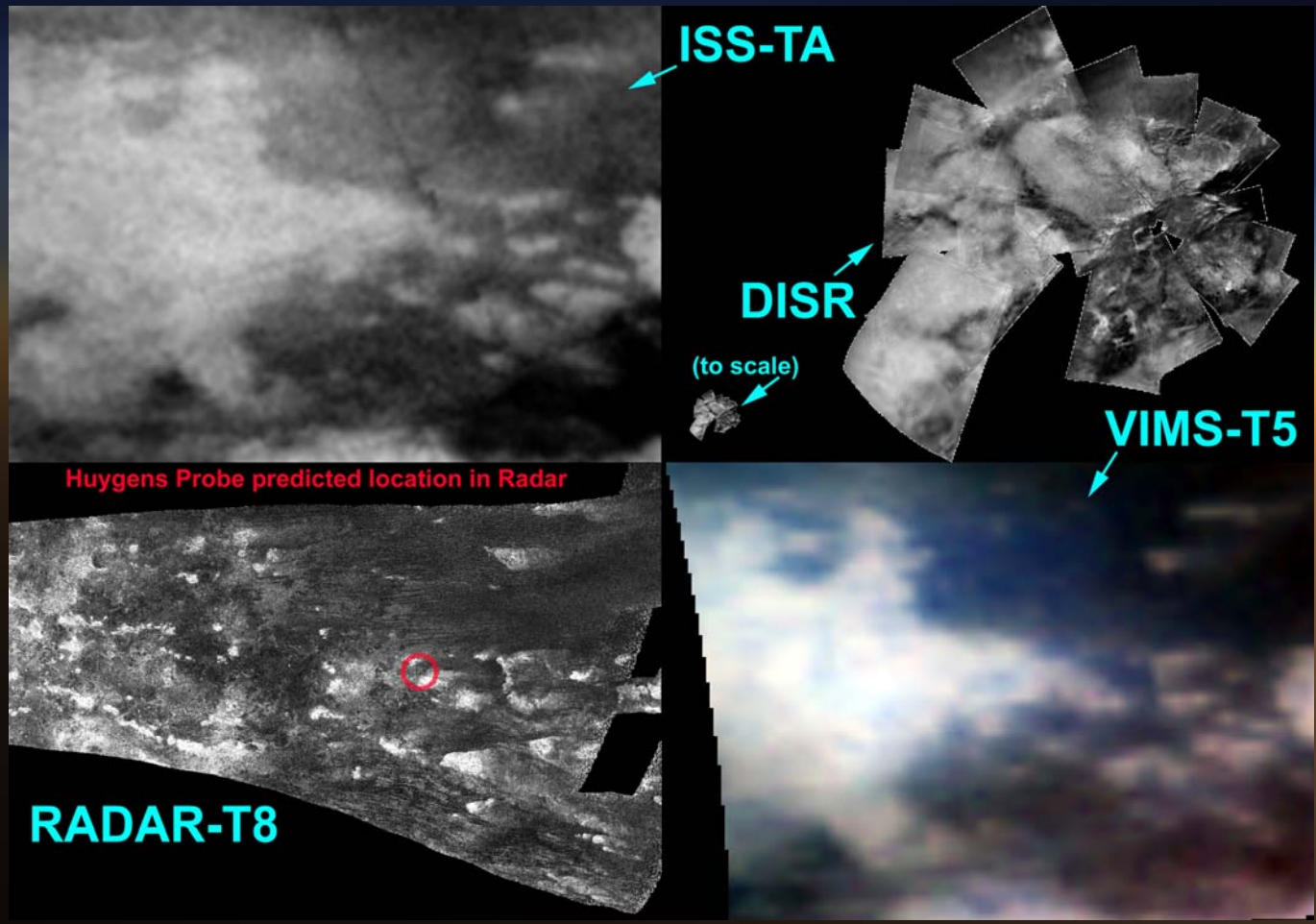


Vertical exaggeration 1:1 – area ~3×5 km



Confusion in Locating the Huygens Landing Site

As seen from Cassini, what terrain did Huygens Land on?



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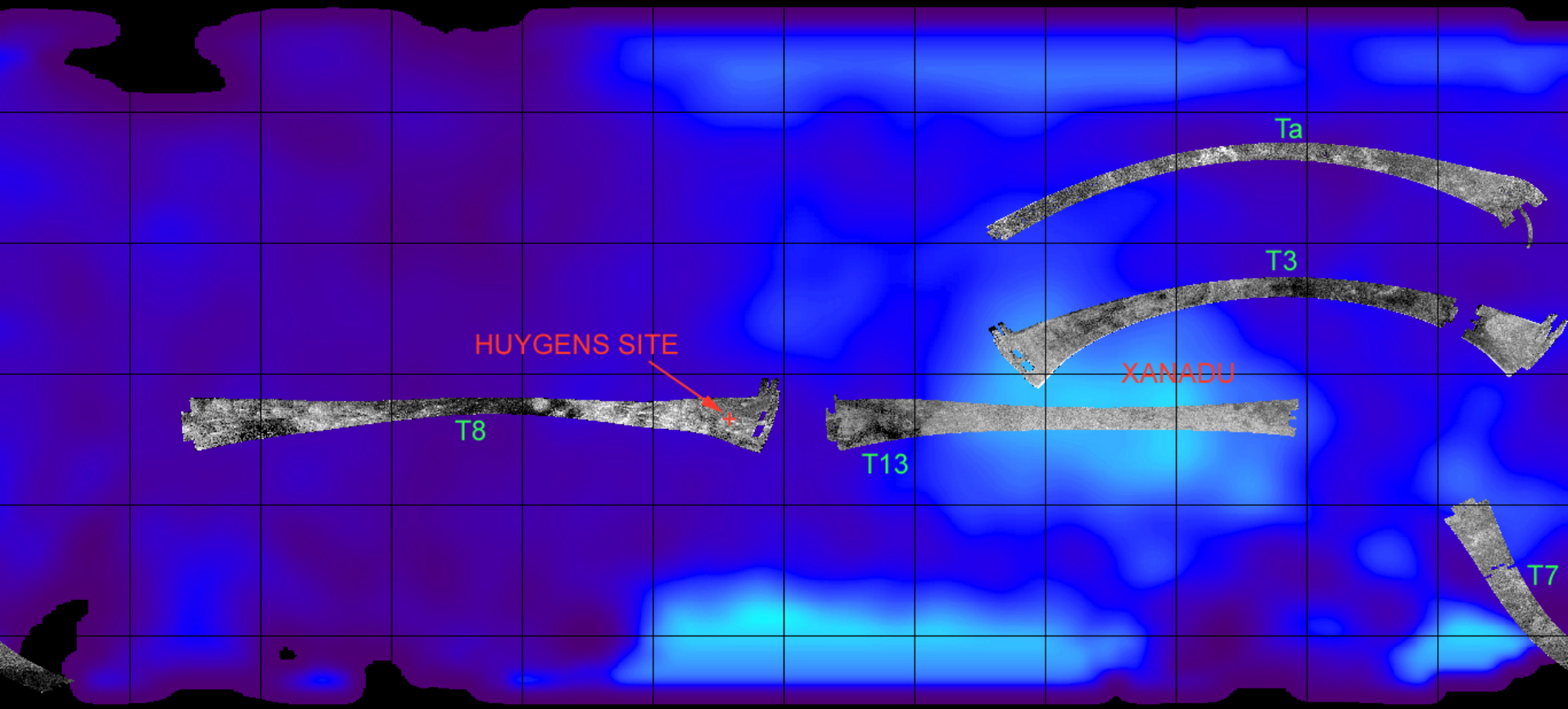

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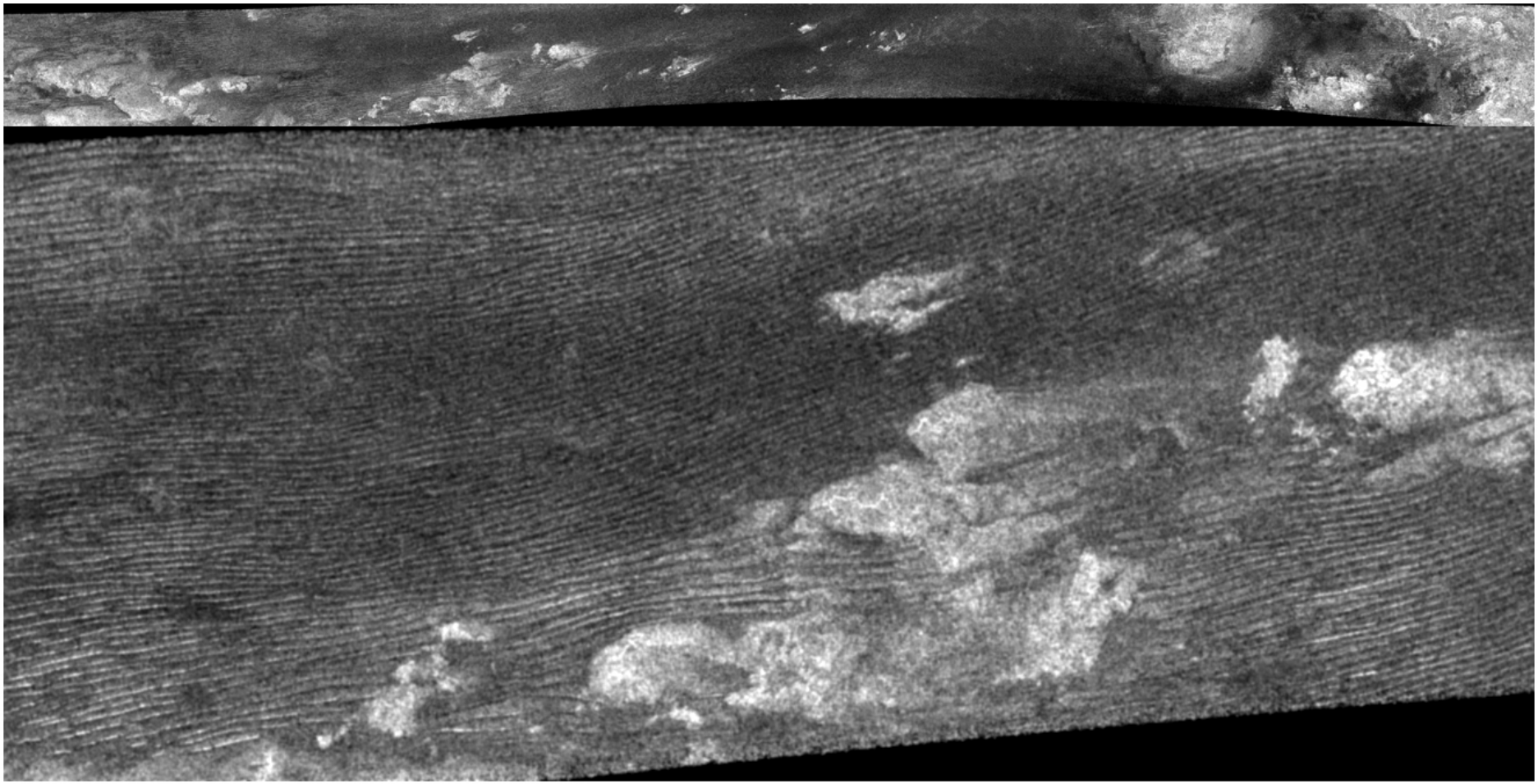
T8 Radar Swath – Expansive Dune Fields



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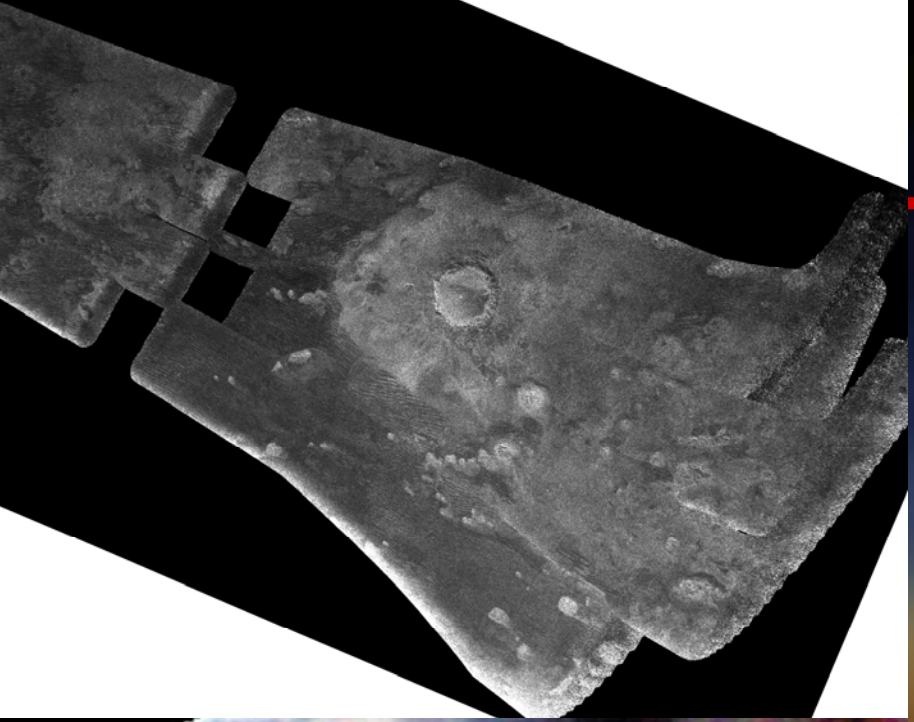

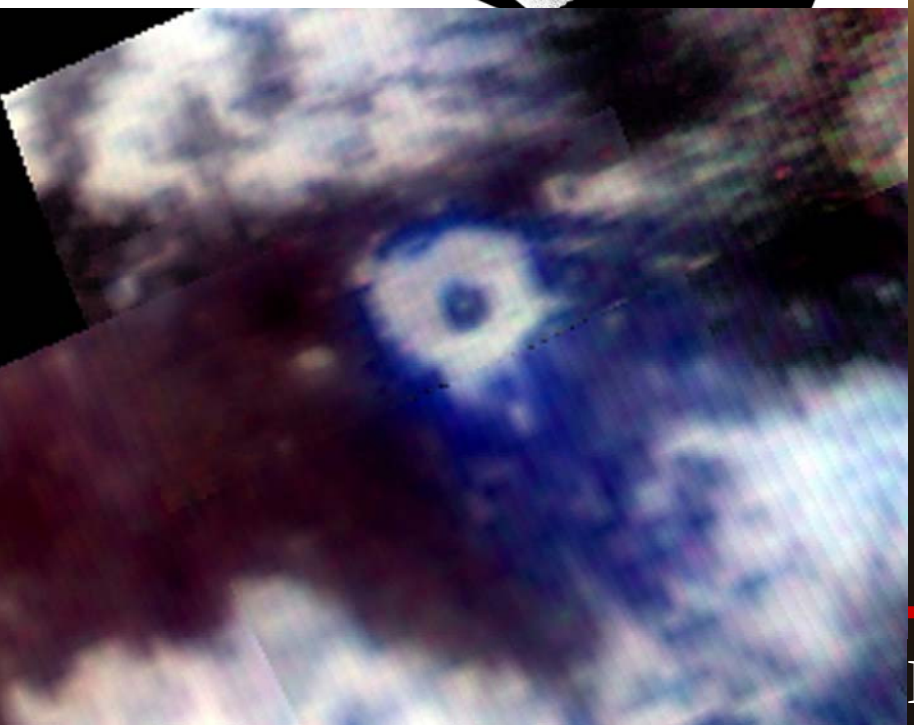

Correlation between optical and radar properties: the region of Sinlap crater

T3 Radar swath

vs

T5 VIMS

(Visible-Infrared Mapping Spectrometer)

Blue= 1.3 μm

Green= 1.6 μm

Red= 2.0 μm

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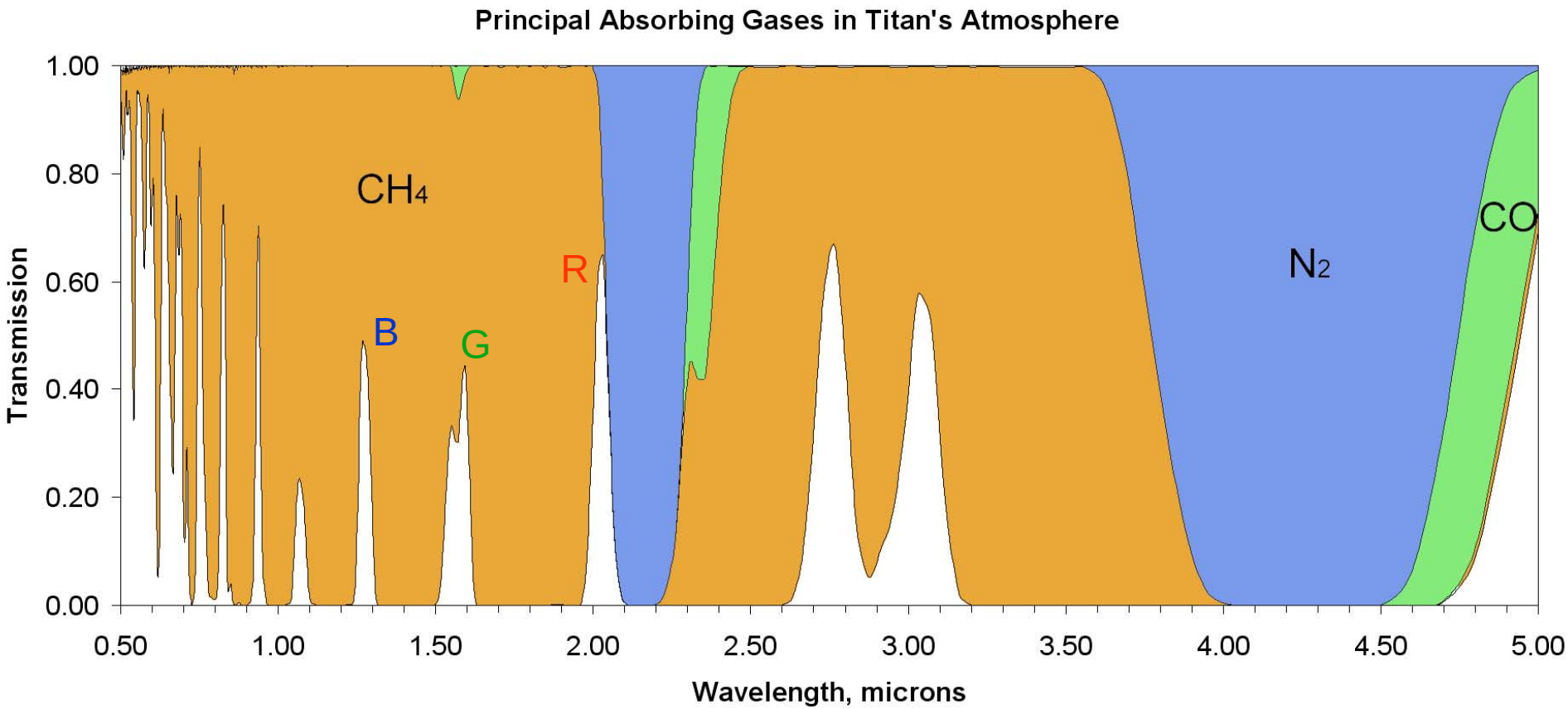
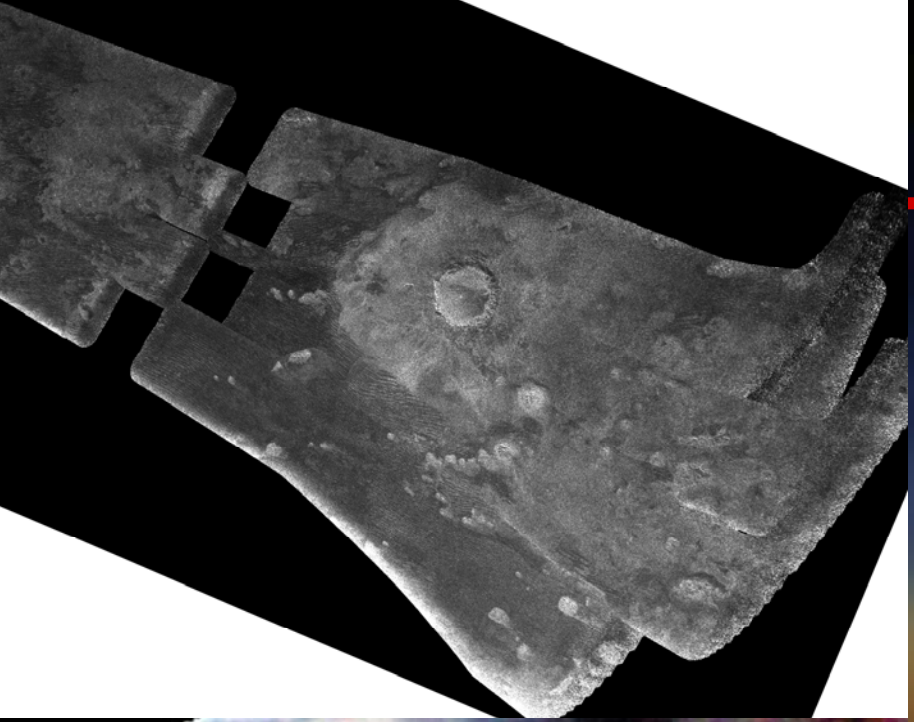
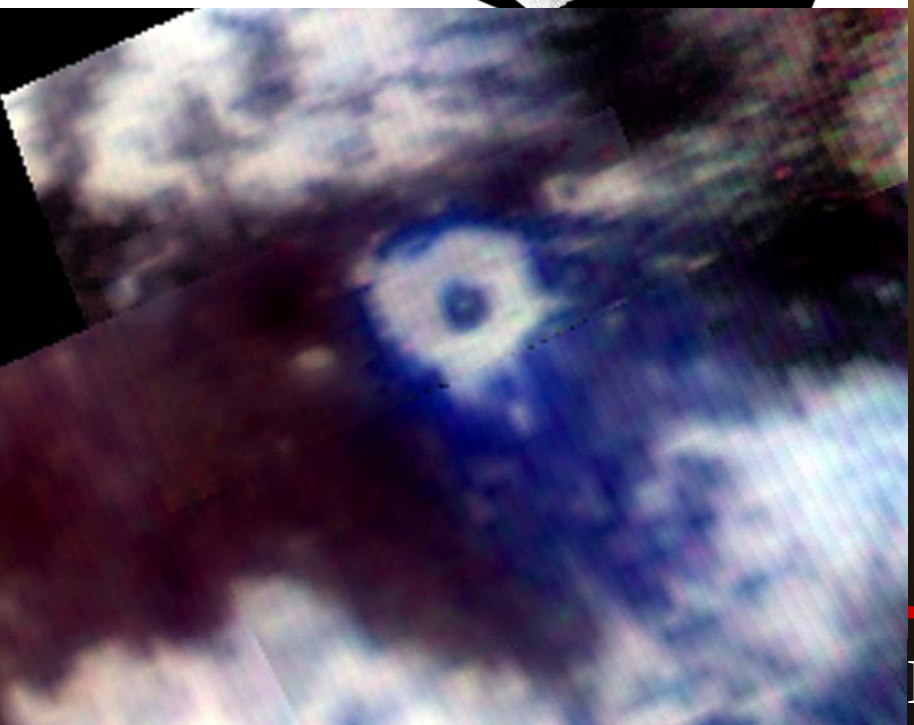
Atmospheric Windows in VIMS spectral region







Correlation between optical and radar properties: the region of Sinlap crater

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(Visible-Infrared Mapping Spectrometer)

Blue= 1.3 μm

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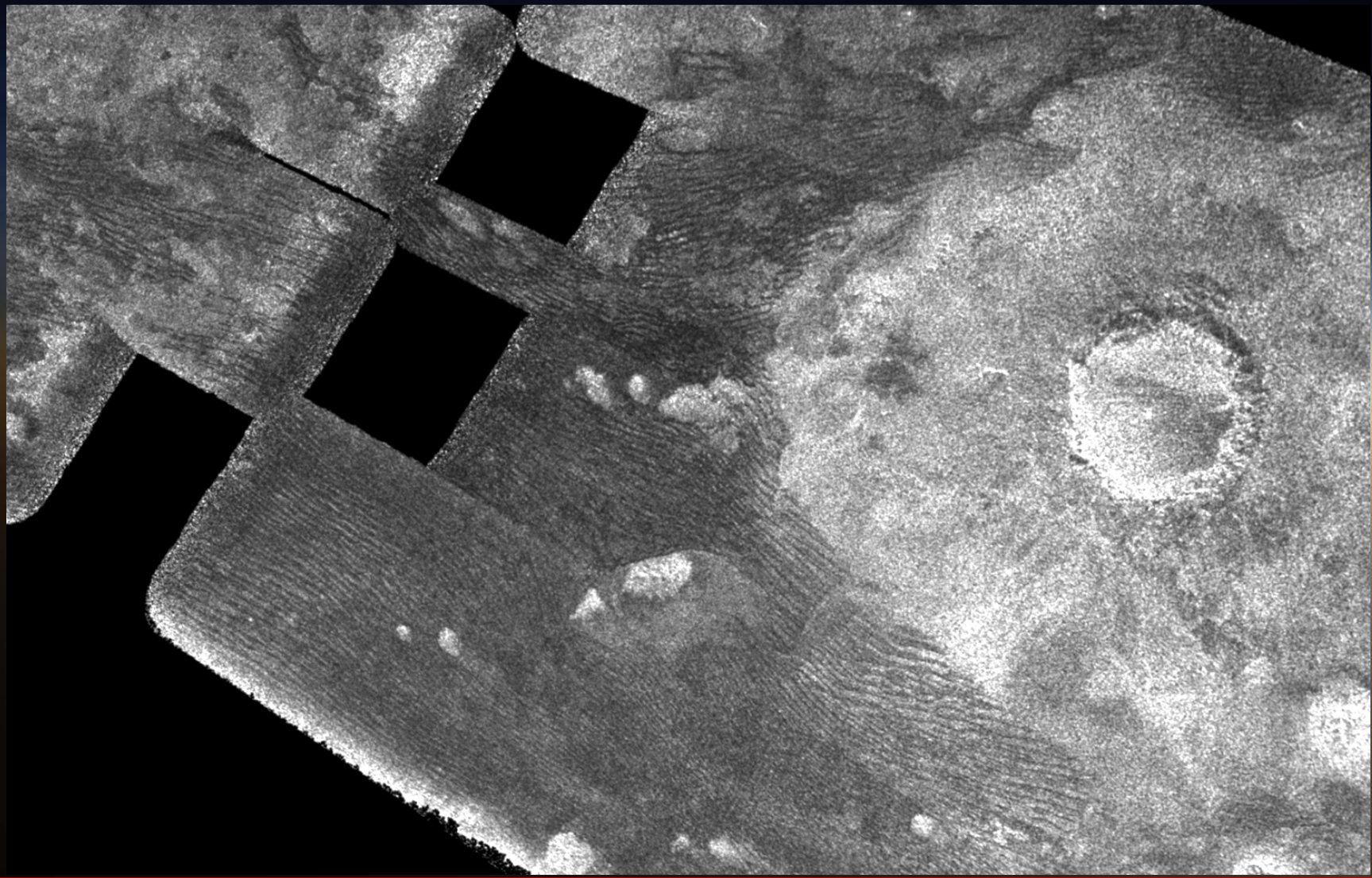
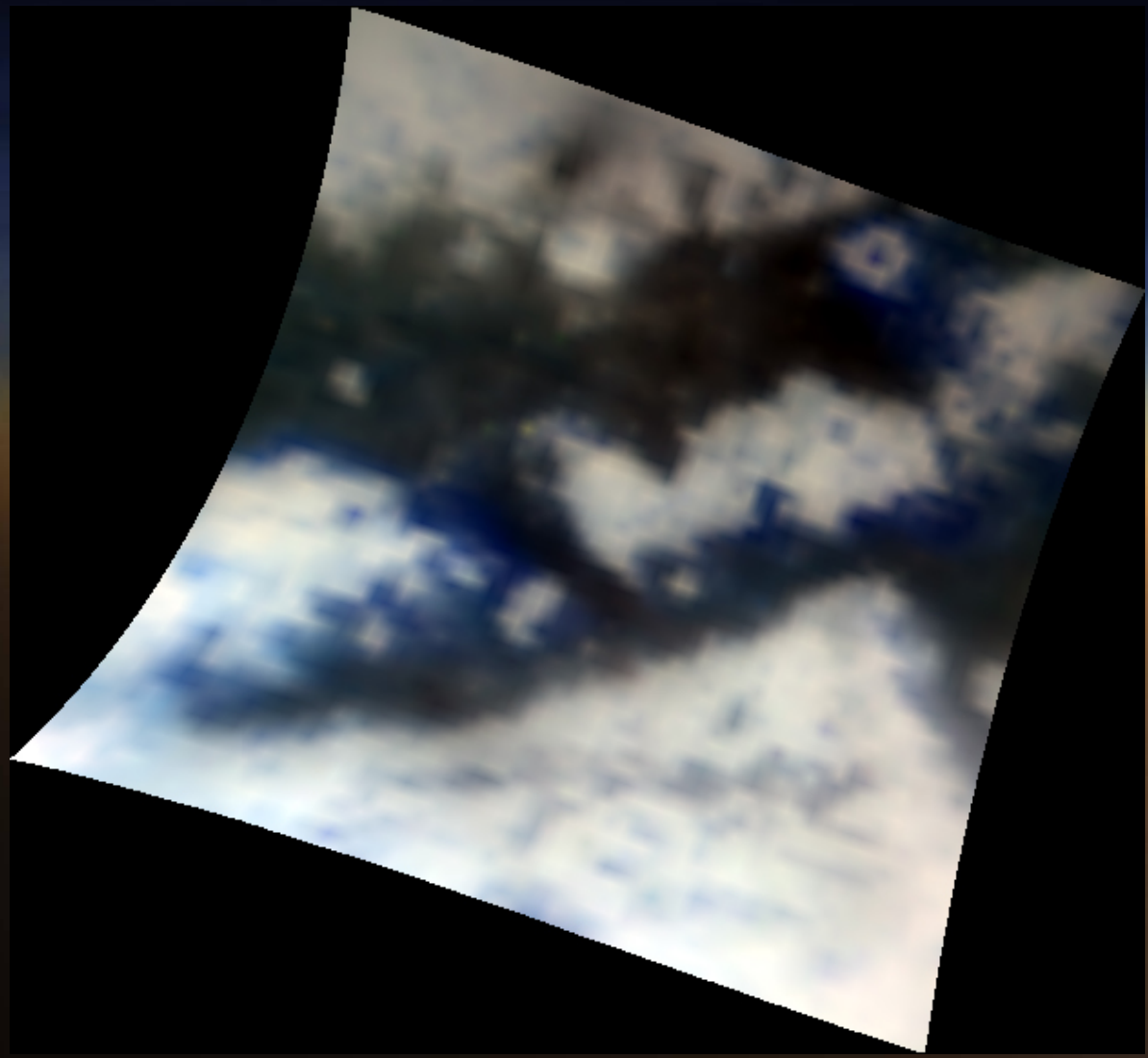
VIMS dark brownish unit strongly correlated with Radar dunes -
VIMS bright and dark bluish units show no correlation with Radar



A larger region - Sinlap and NE Xanadu - Both Bright and Dark Units show blue-brown variations



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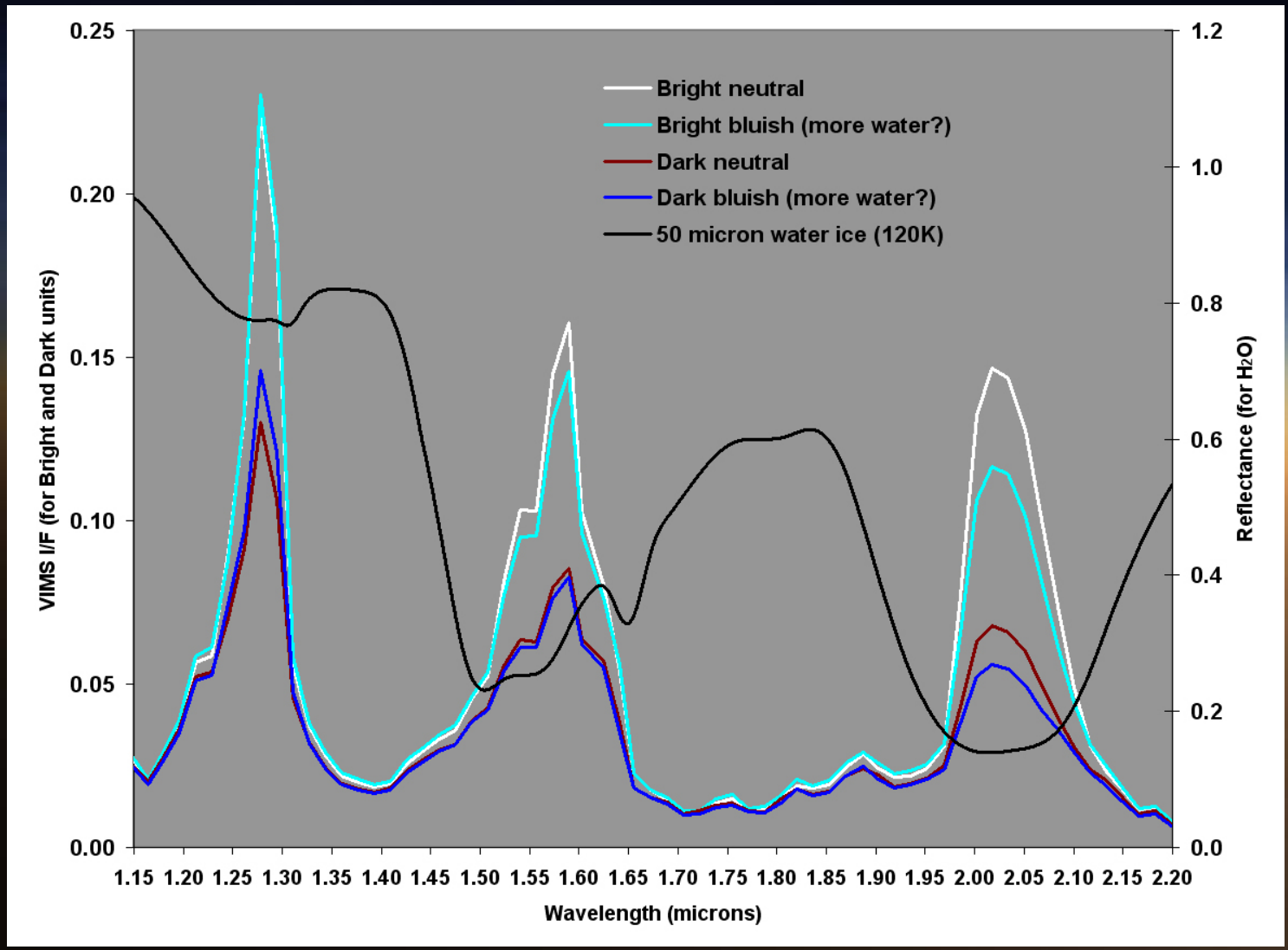
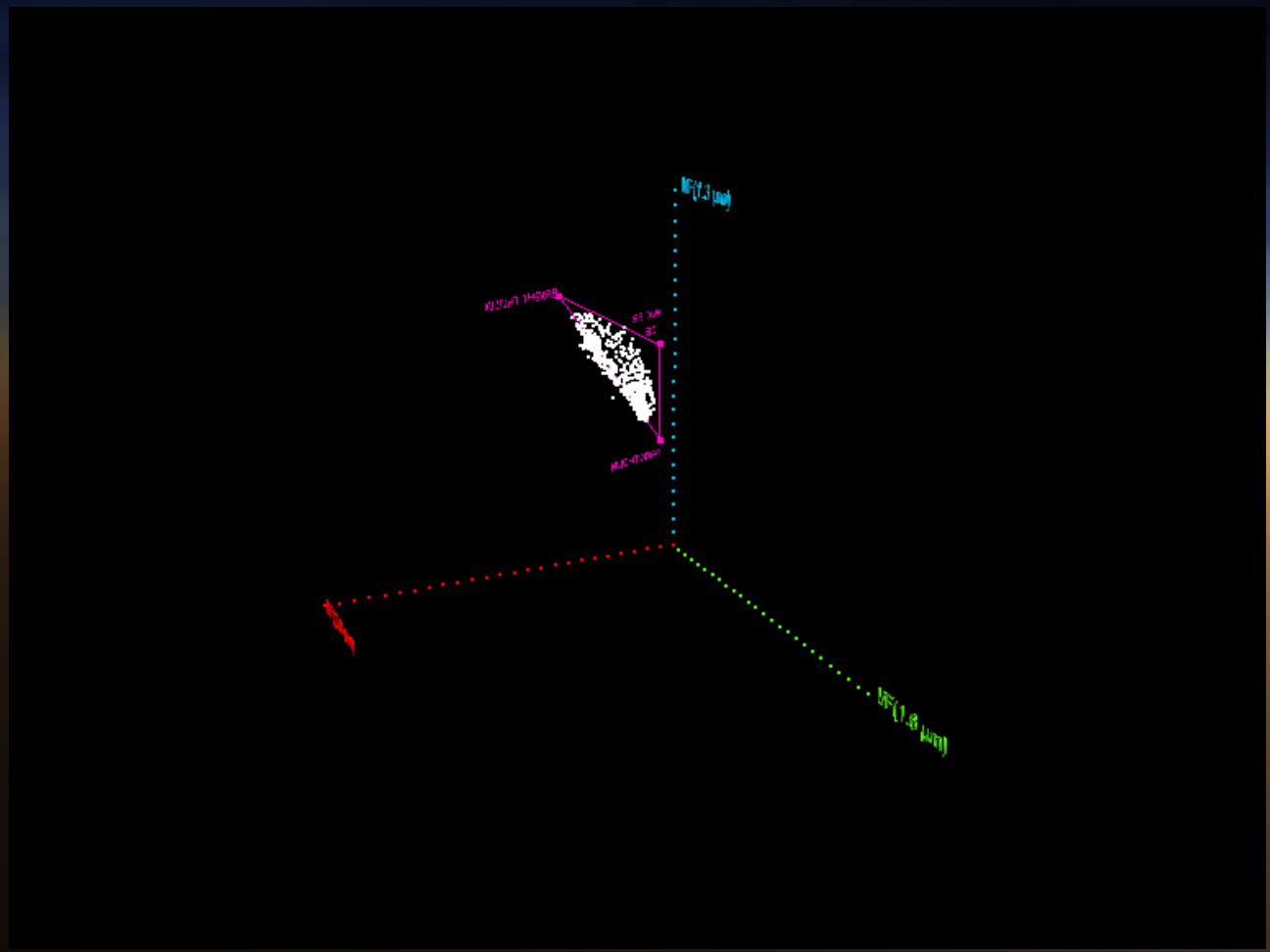
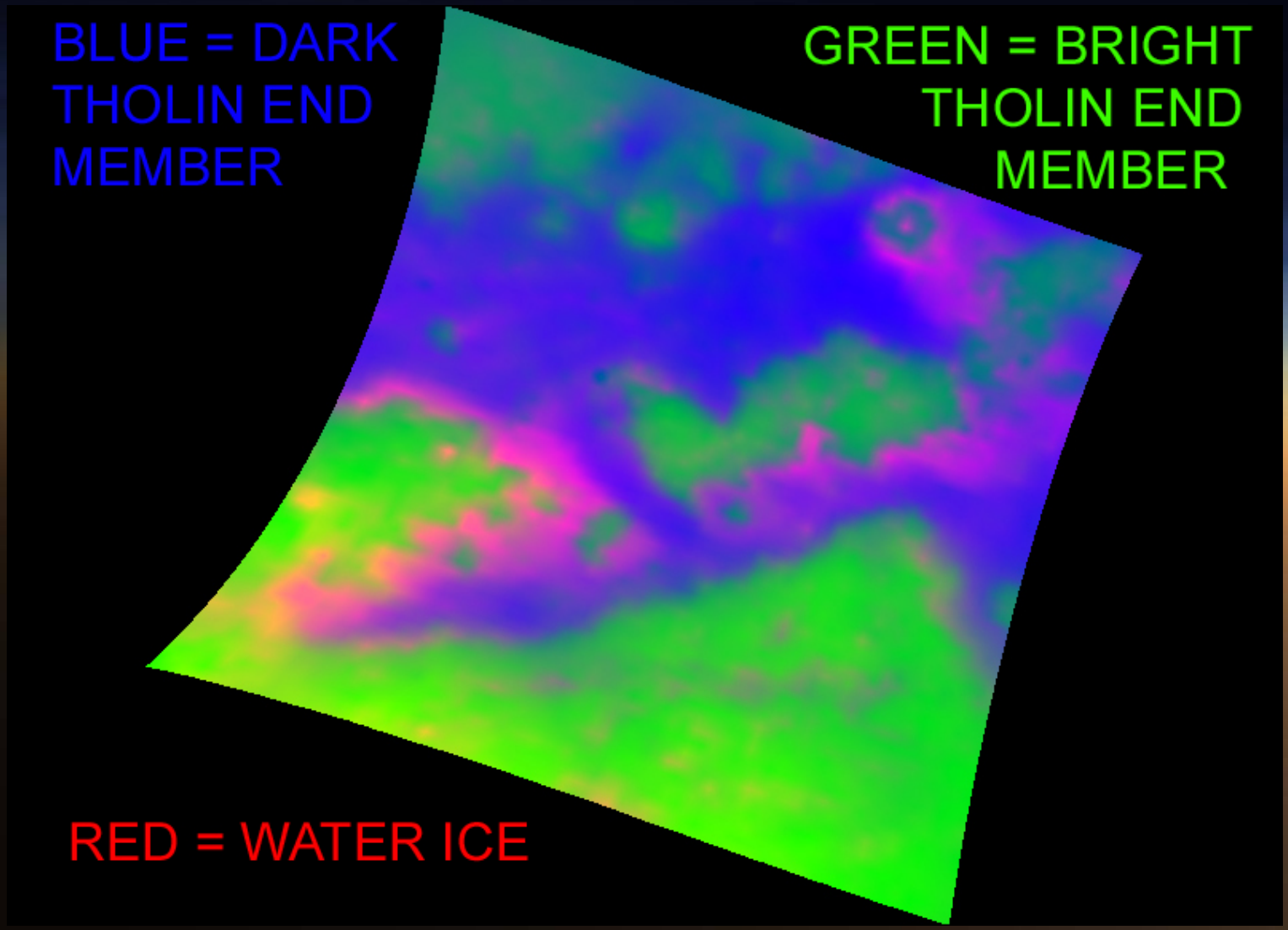
Probably variations in H_2O ice



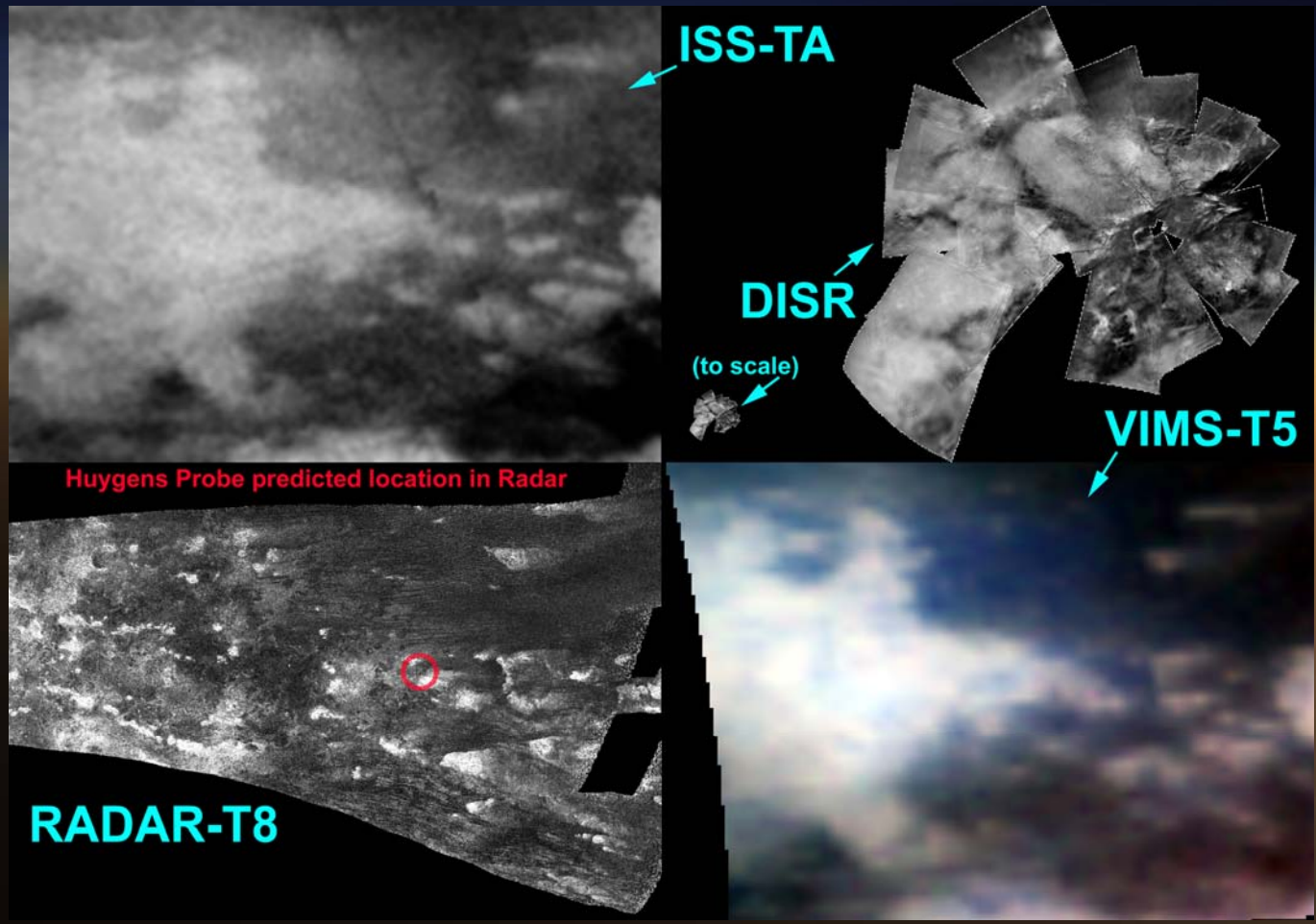
Mapping a VIMS cluster to a 3-component system



Interpretive map of tholins and H_2O ice



Returning to Locating the Huygens Landing Site



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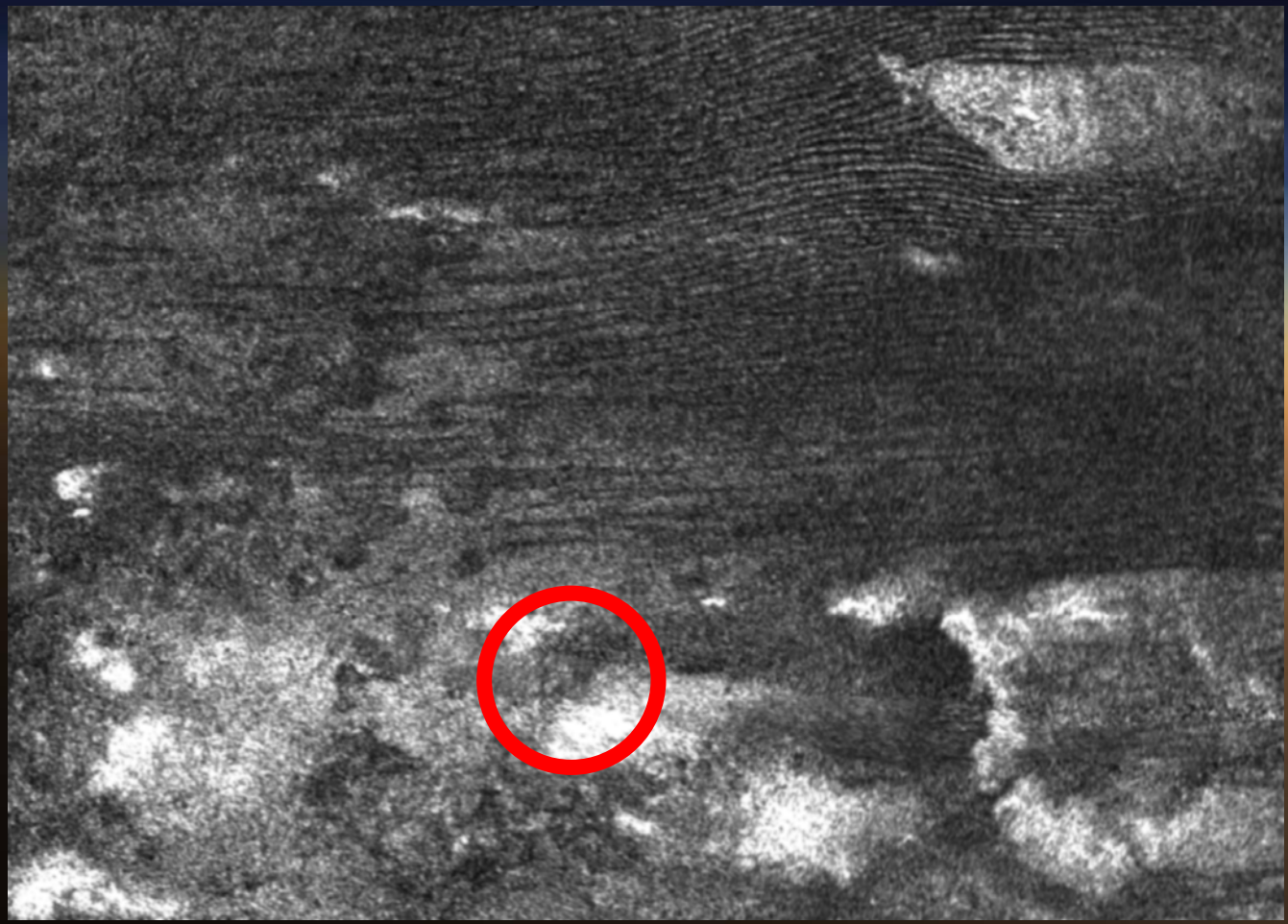
DISR should see the closest dark dune fields - ~30km North of the Huygens Landing Site



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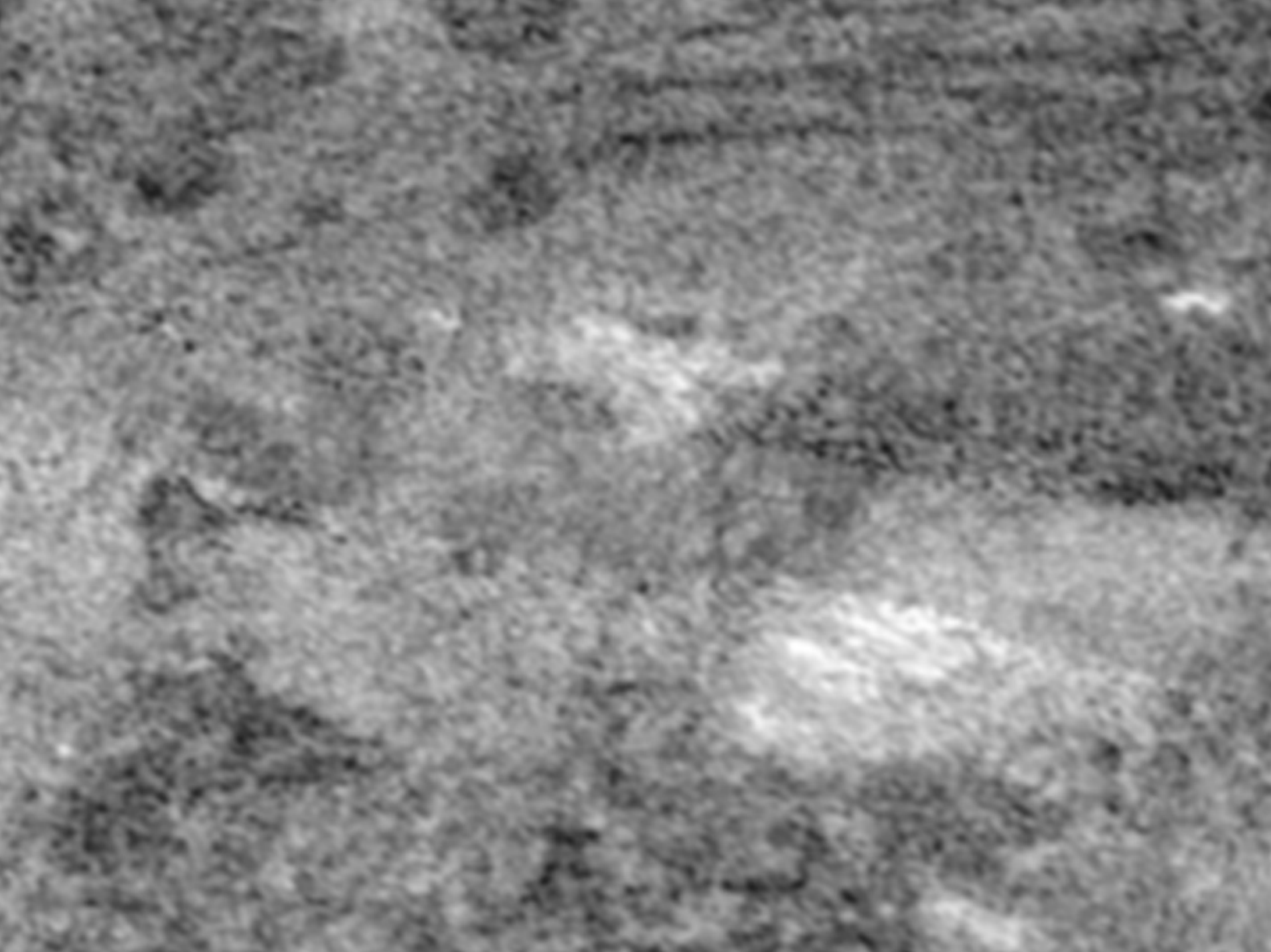

Summary VIMS-RADAR Correlations

- The seas of dark longitudinal dunes identified in SAR images correlate with the dark brown unit
- Huygens landed in the a region of bright and dark blue unit about ~30 km south of a dark brown units of sparse longitudinal dunes
- Presuming water ice absorbs in the dark blue unit at 1.6 μm and 2.0 μm (relative to 1.3 μm), the dark brown unit is lowest in water ice content suggesting the dunes contain dry grains of hydrocarbon and/or nitrile compounds

Summarizing Titan's Geology

Ample evidence for ---

- Impact cratering
- Wind or eolian transport and deposition
- River channels (carved by methane?)
- Volcanic domes and volcanic flows
- Faulting and tectonism
- Coastlines and lake-like features
- Radar and VIMS consistent with hydrocarbons, ammonia, water ice

But…until recently there remained little evidence of bodies of liquid currently standing on the surface

Cassini ISS image of the south polar region: Dark kidney-shaped feature interpreted as a possible lake

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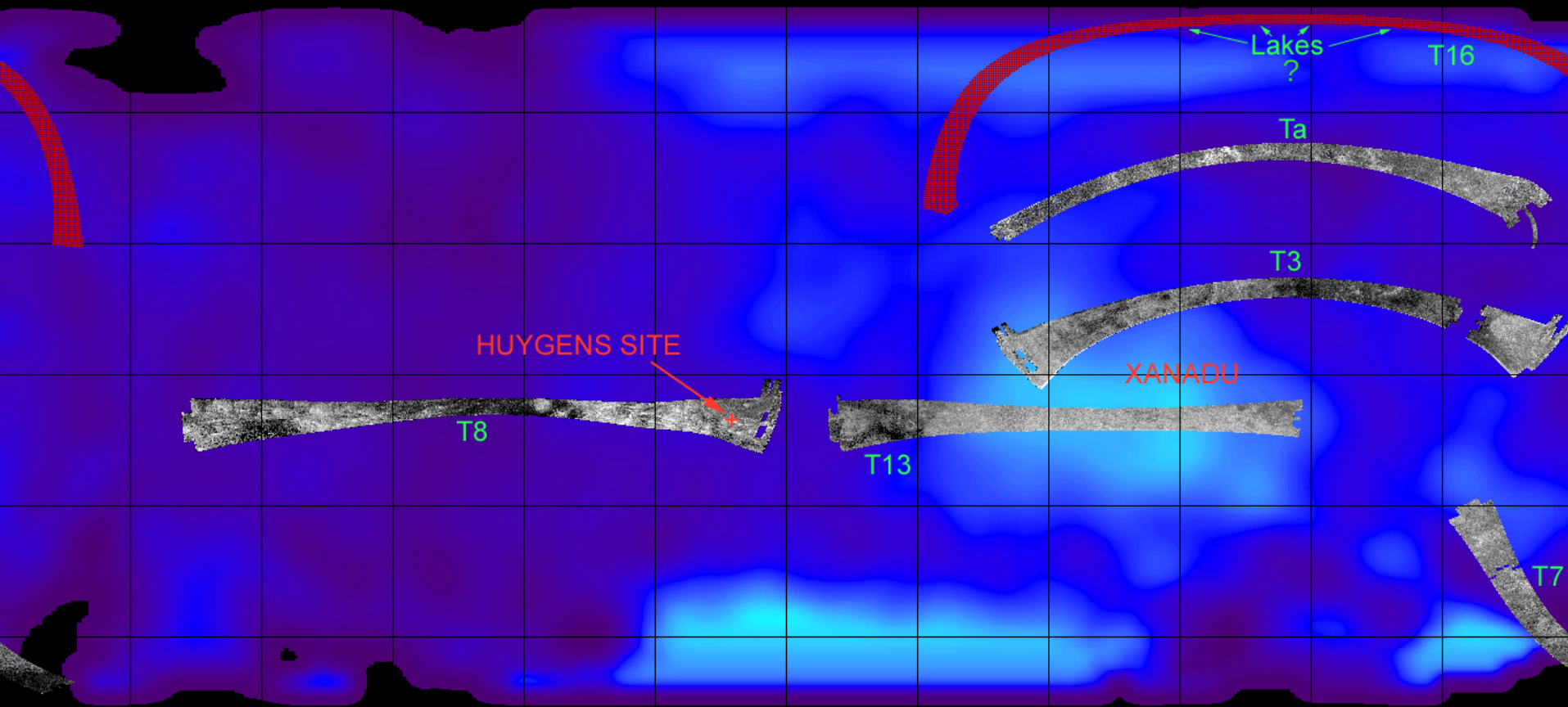
Radar Pass T16 that just occurred on July 22 --- methane/ethane lakes at last???



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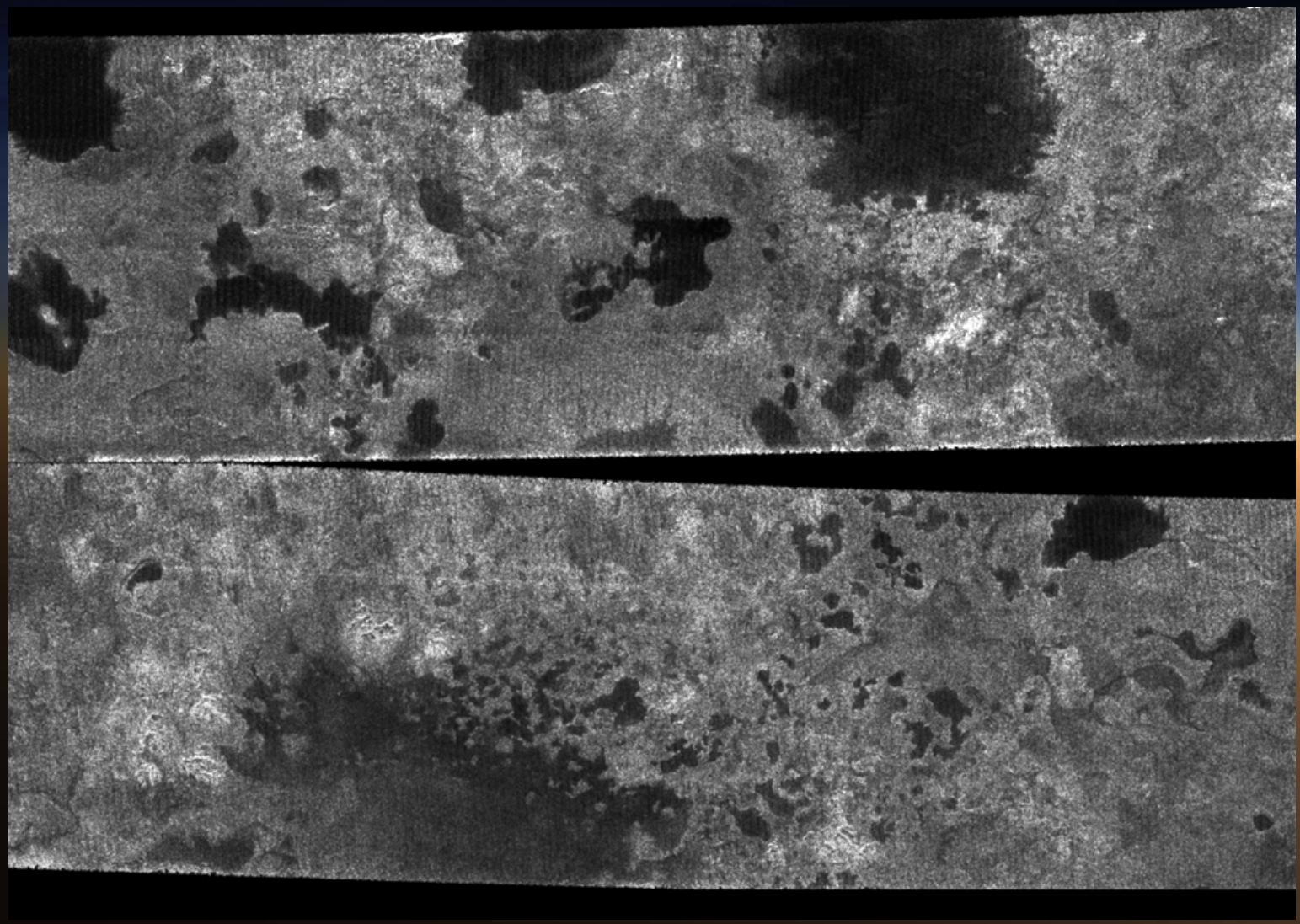
Radar imaged numerous very lake-like features – the darkest seen on Titan to date occur north of 75° N



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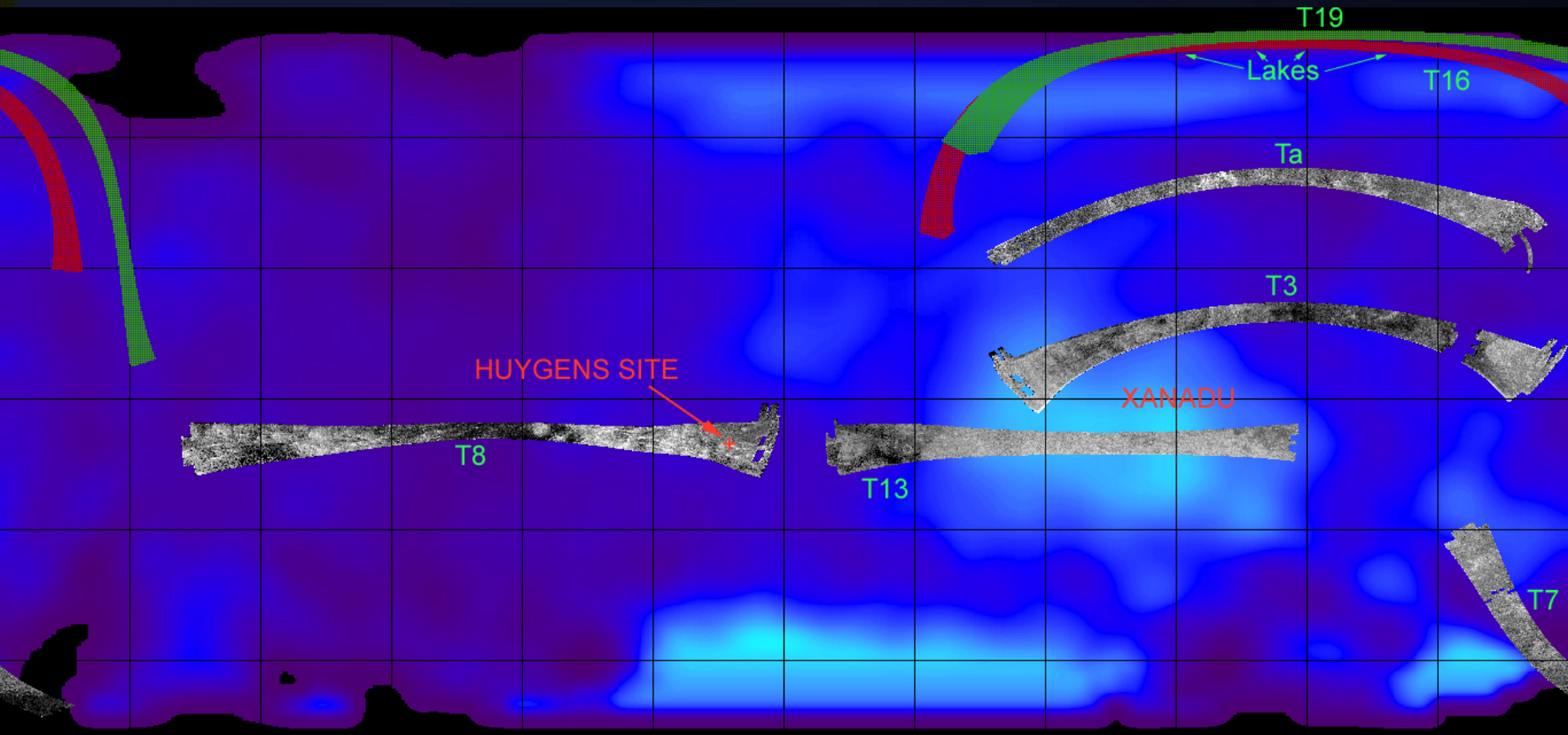
In early October 2006 the Radar on T19 will explore the "lakes region" even farther to the north - Stay Tuned!!



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Titan's emerging picture and puzzles

- We expected the most bizarre planetary landscape so far visited --- superficially it resembles the Earth more than any other
- Titan exhibits a plethora of geologic processes reading like a textbooks in structural geology and geomorphology from pluvial to volcanic to tectonic
- Are the north-polar features truly hydrocarbon lakes?
- Does it rain frequently? or is spring sapping dominant?
- How young is the surface? The rarity of fresh craters with diameters >20km suggests < 100 million years (maybe its far, far younger)