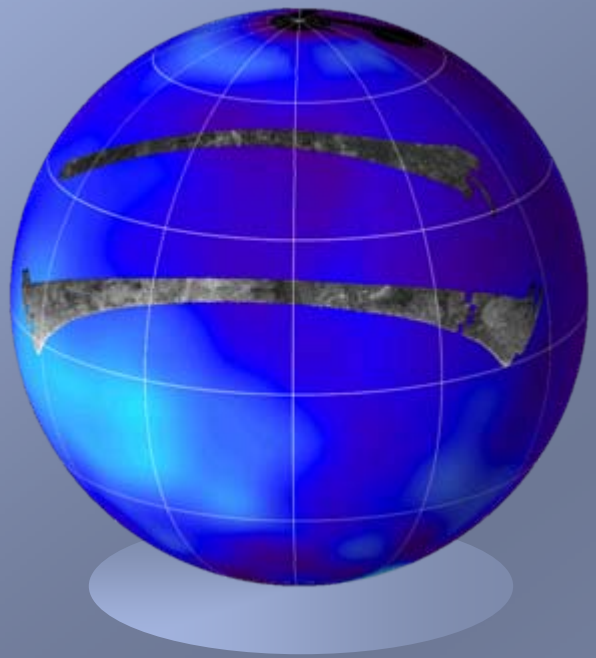
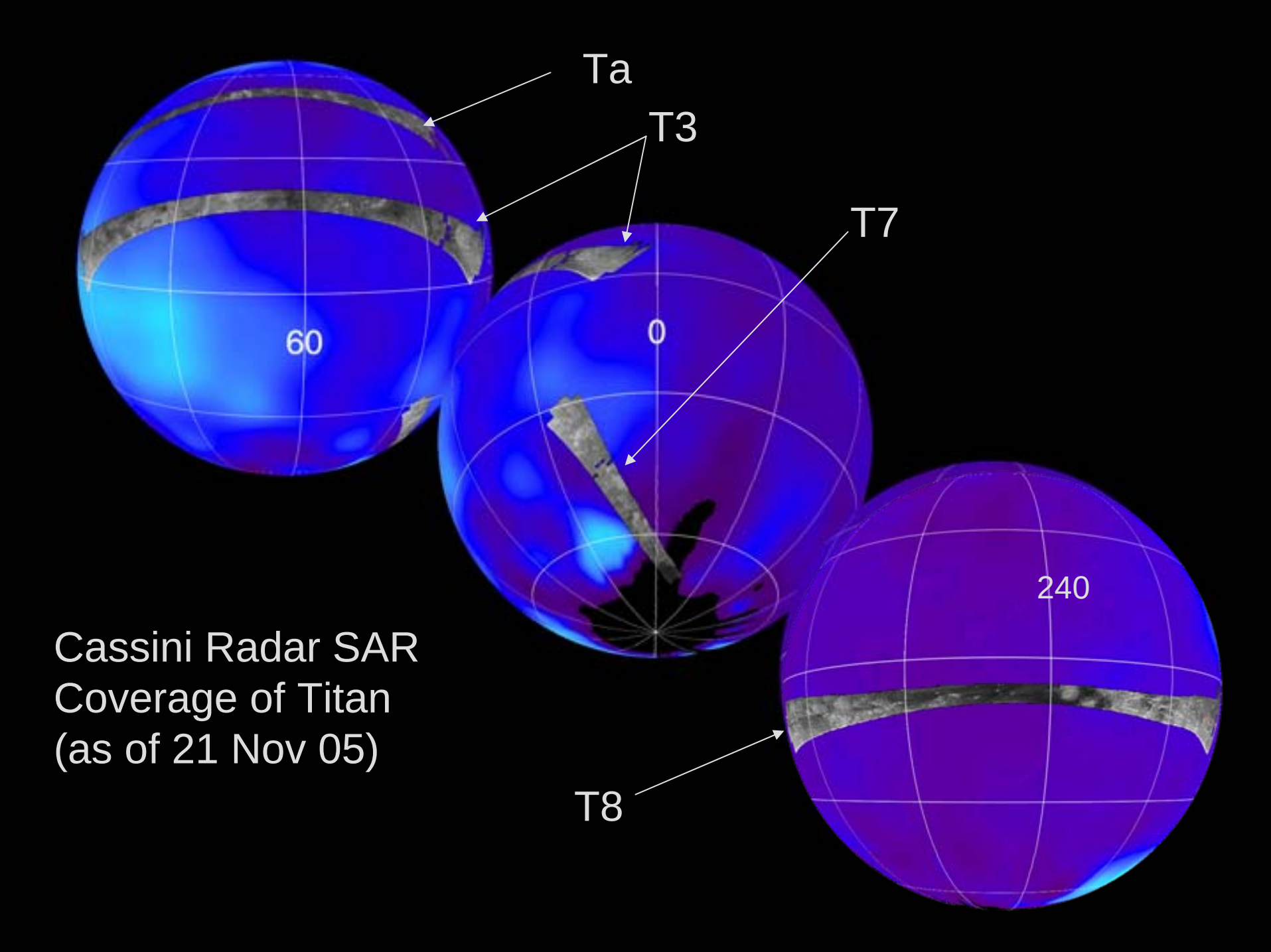
The Surface of Titan as seen by the Cassini Radar Mapper



R. Lopes and the Cassini RADAR Team

C. Elachi, M. D. Allison, Y. Anderson, R. Boehmer, P. Callahan, P. Encrenaz, E. Flamini, G. Francescetti, Y. Gim, G. Hamilton, S. Hensley, M. A. Janssen, W. T. K. Johnson, K. Kelleher, R. L. Kirk, R. D. Lorenz, J. I. Lunine, K.L. Mitchell, D. O. Muhleman, S. J. Ostro, F. Paganelli, G. Picardi, F. Posa, L. E. Roth, R. Seu, S. Shaffer, L. A. Soderblom, B. Stiles, E. Stofan, S. Vetrella, S.D. Wall, R. West, C. A. Wood, L. Wye, and H. A. Zebker



Cassini Radar SAR
Coverage of Titan
(as of 21 Nov 05)

Titan

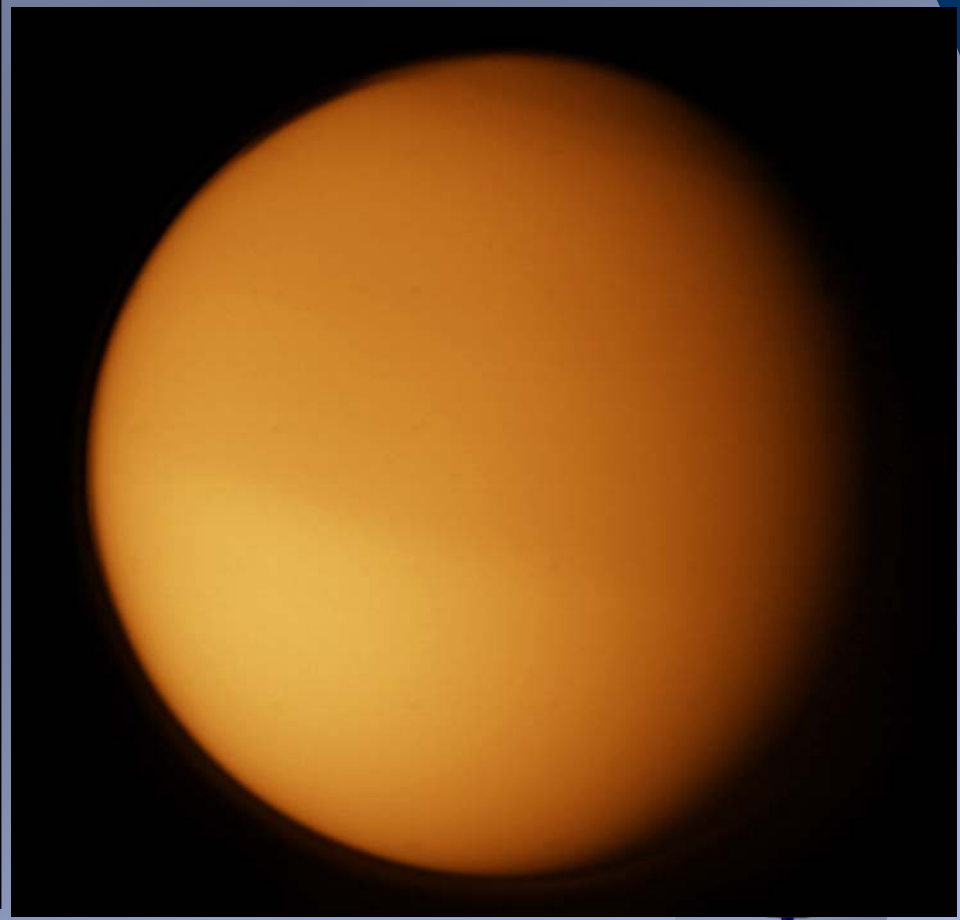
…is one of a triad of giant moons with bulk densities of 1.8 g/cm^3, and radii ~ 2500 km (Ganymede, Titan, and Callisto).

•…has the second-densest atmosphere of the solid bodies of the solar system—nitrogen-methane composition -- organic chemistry. Methane 2-10% near-surface, 2% in stratosphere.

• Surface P=1.5 bars, T=95K (-178 C, -288 F – “Lower than a lounge lizard’s moral character”, Space.com).

•Target of 45+ Cassini flybys plus Huygens probe descent

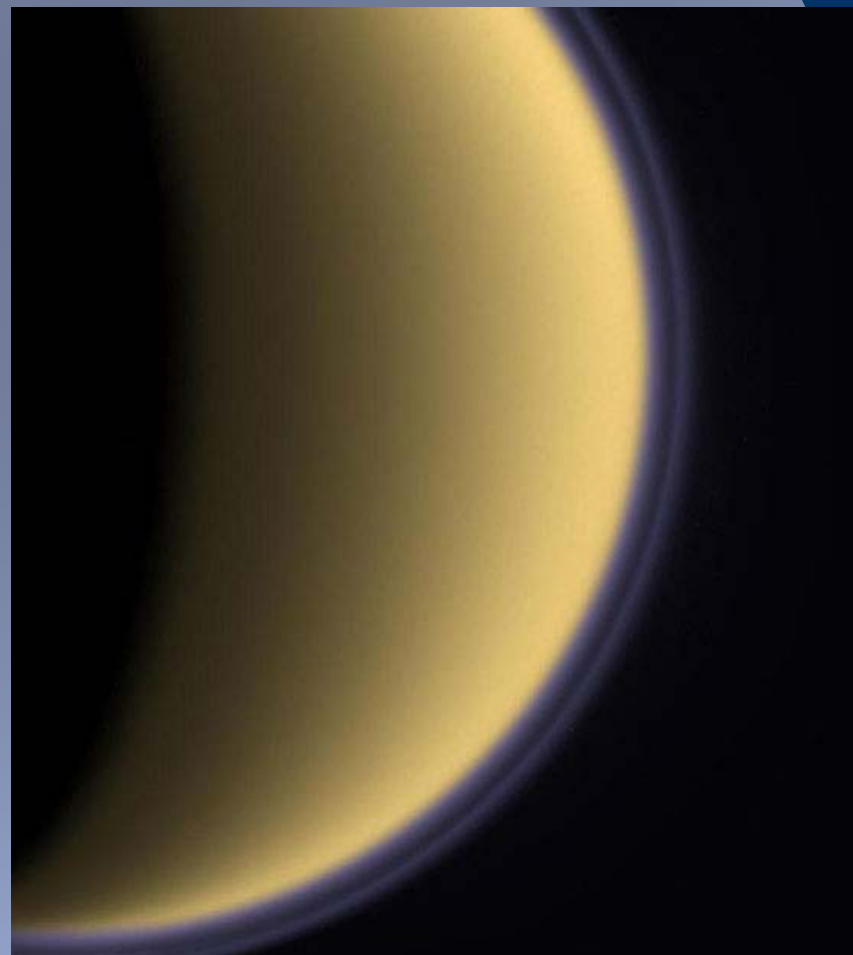
Titan from Voyager: haze obscured surface



Titan Characteristics

- **Dense atmosphere composed mostly of nitrogen with a few % methane. May be like Earth's before life evolved.**
- **UV image (colorized) taken on July 3, 2004, by Cassini's ISS shows atmospheric haze (purple)**
- **Titan's haze is formed by UV light breaking down methane and nitrogen molecules (at altitudes above 400 km)**
- **Products are thought to react to form more complex organic molecules containing carbon, hydrogen, nitrogen (can combine to form very small particles seen as haze)**
- **Image shows two haze layers. Outer layer is detached and is ~ 120 km thick**

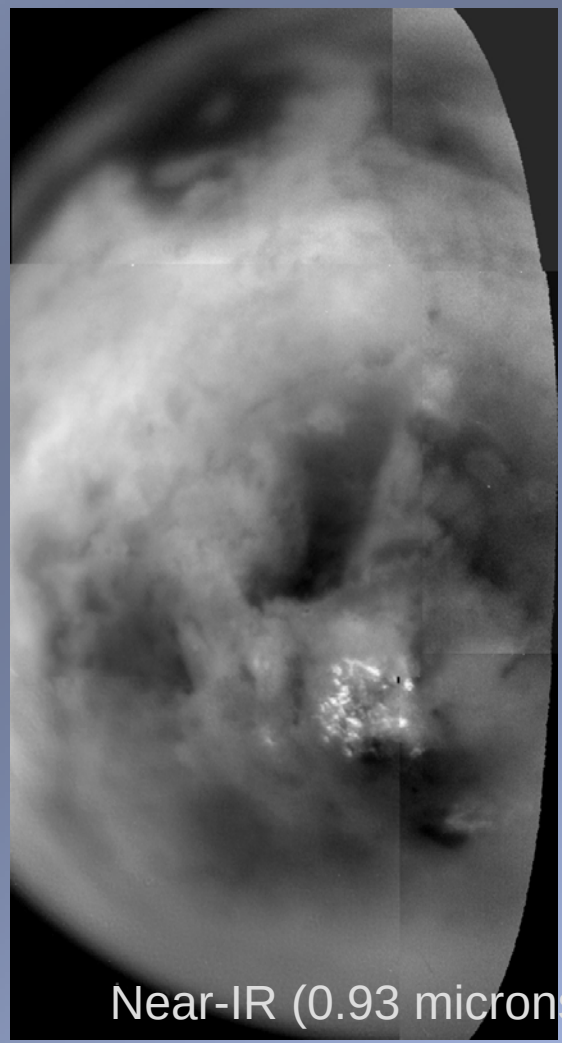
Image taken with filter centered at 338 nanometers (sensitive to UV light)



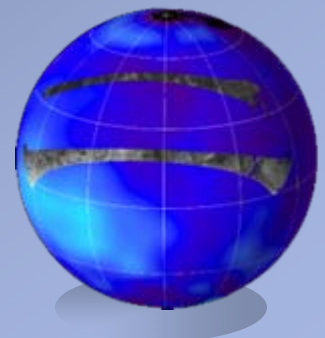
Why use RADAR?

ISS : high sensitivity but images of surface are affected by the haze extending from the high altitudes to the lowermost atmosphere

Optical



Near-IR (0.93 microns)



Credit: G. Nierenberg

Credit: C. J. Lunine

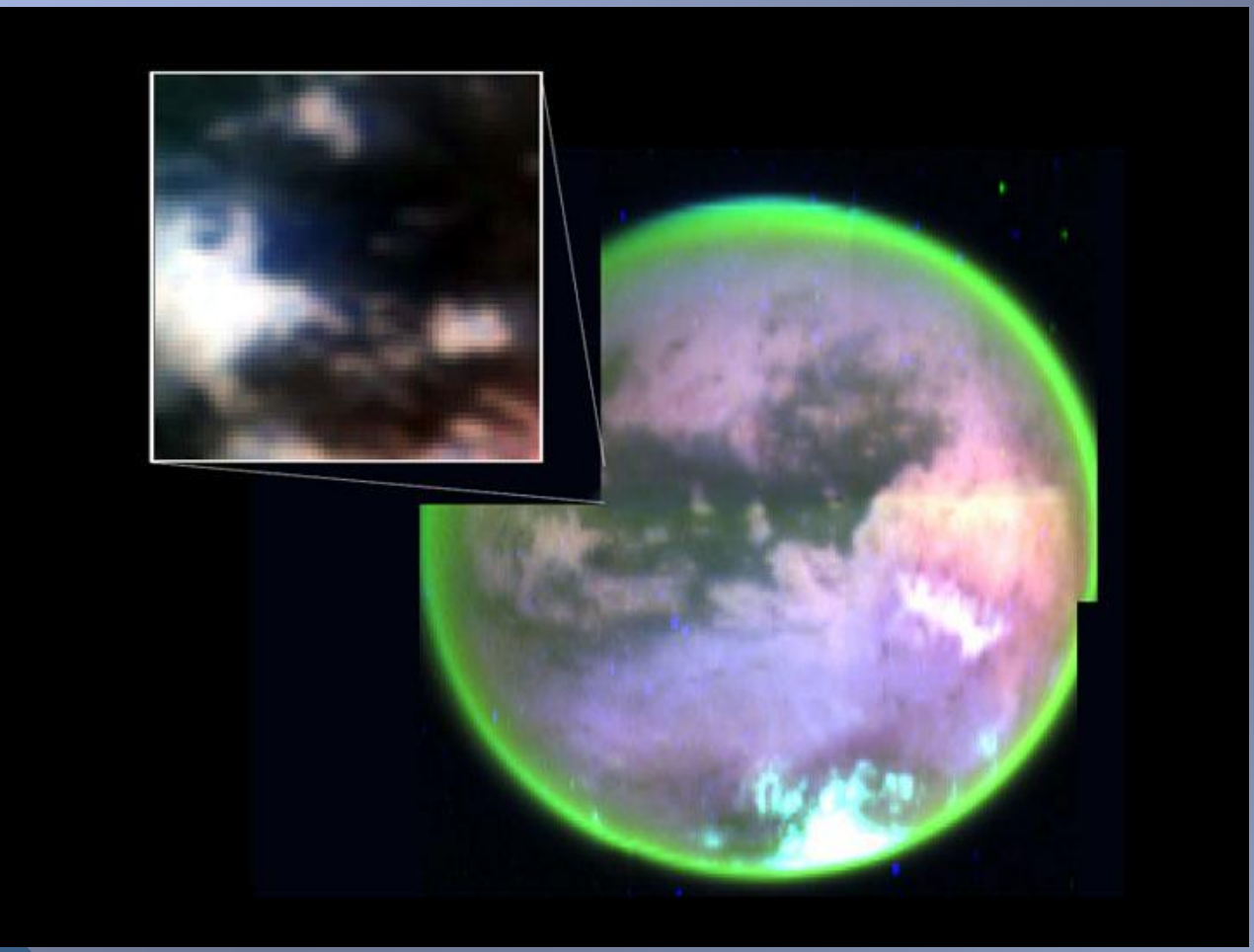
Haze scattering limits the information in an image (slide courtesy of J. Lunine)

Credit: G. Nierenberg

Credit: C. J. Lunine

Haze scattering limits the information in an image (slide courtesy of J. Lunine)

Titan in the IR (VIMS)

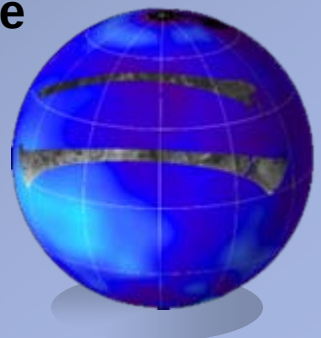


VIMS (Visible and IR spectrometer)

Composite of false color images taken at 2 microns (blue), 2.7 microns (red) and 5 microns (green).

Methane cloud at the south pole

Inset shows the probe landing site



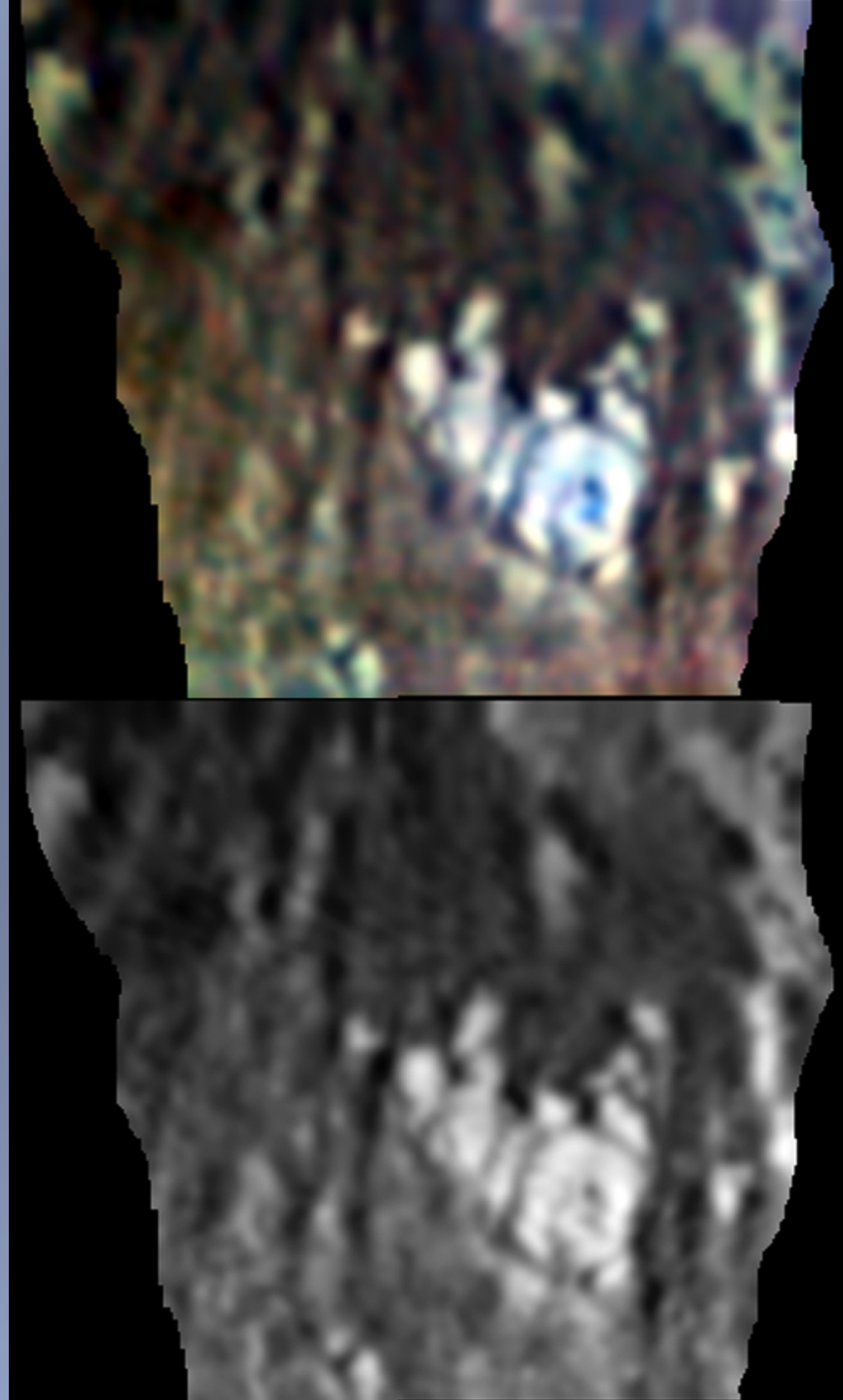
VIMS “Snail”

C. Sotin et al, Nature

Structure ~ 30 km diameter, so far unique in appearance – consistent with “pasty lava” structures

Cryovolcanic dome is preferred interpretation

RADAR has not yet imaged this area



2.03 μm

Huygens probe's view of Titan: Jan 14, 2005

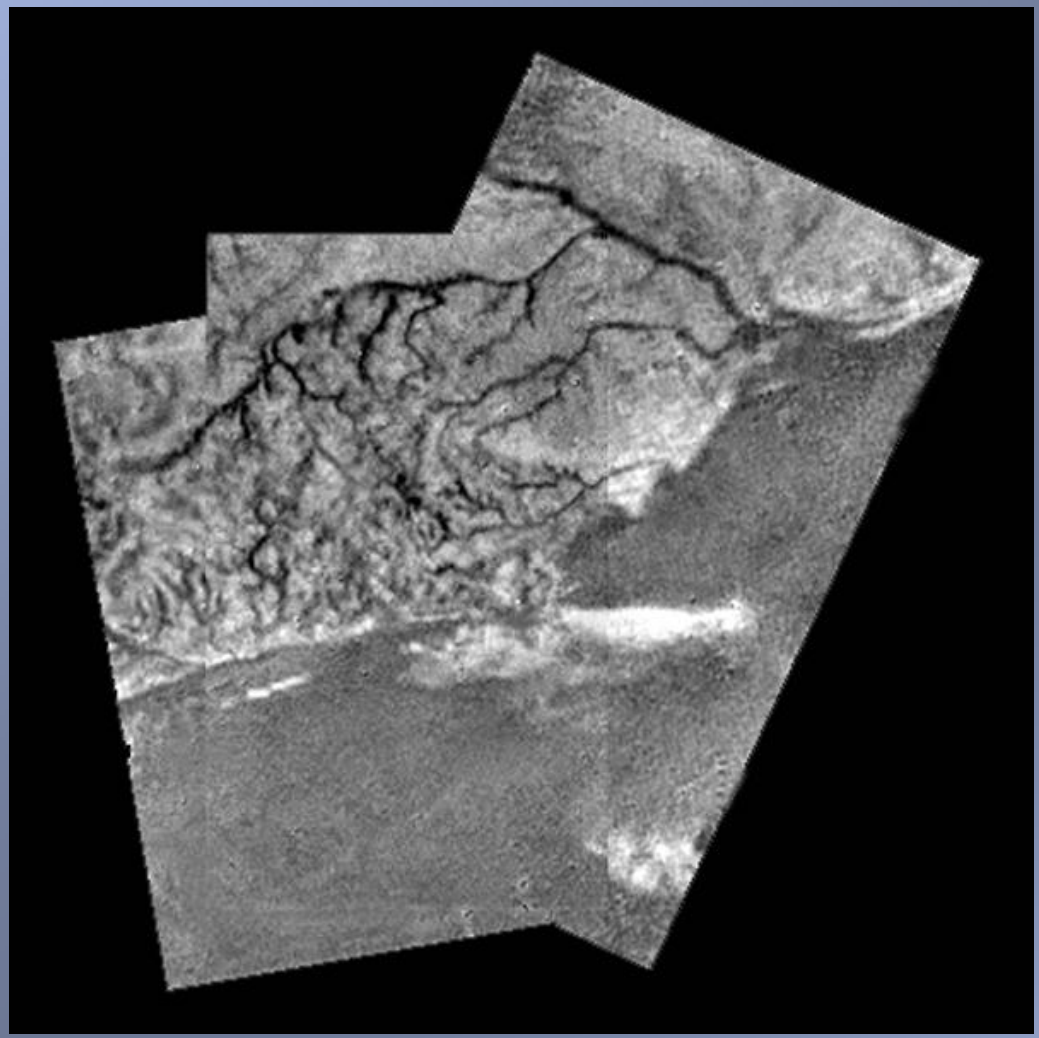
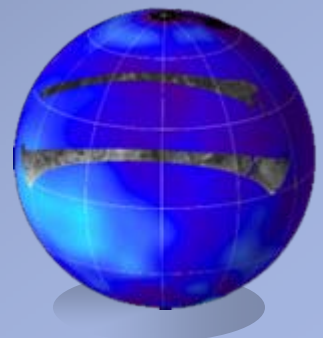


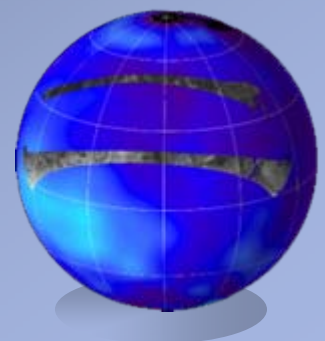
Image taken by DISR (Descent Imager/Spectral Radiometer)

RADAR imaged this area in T8

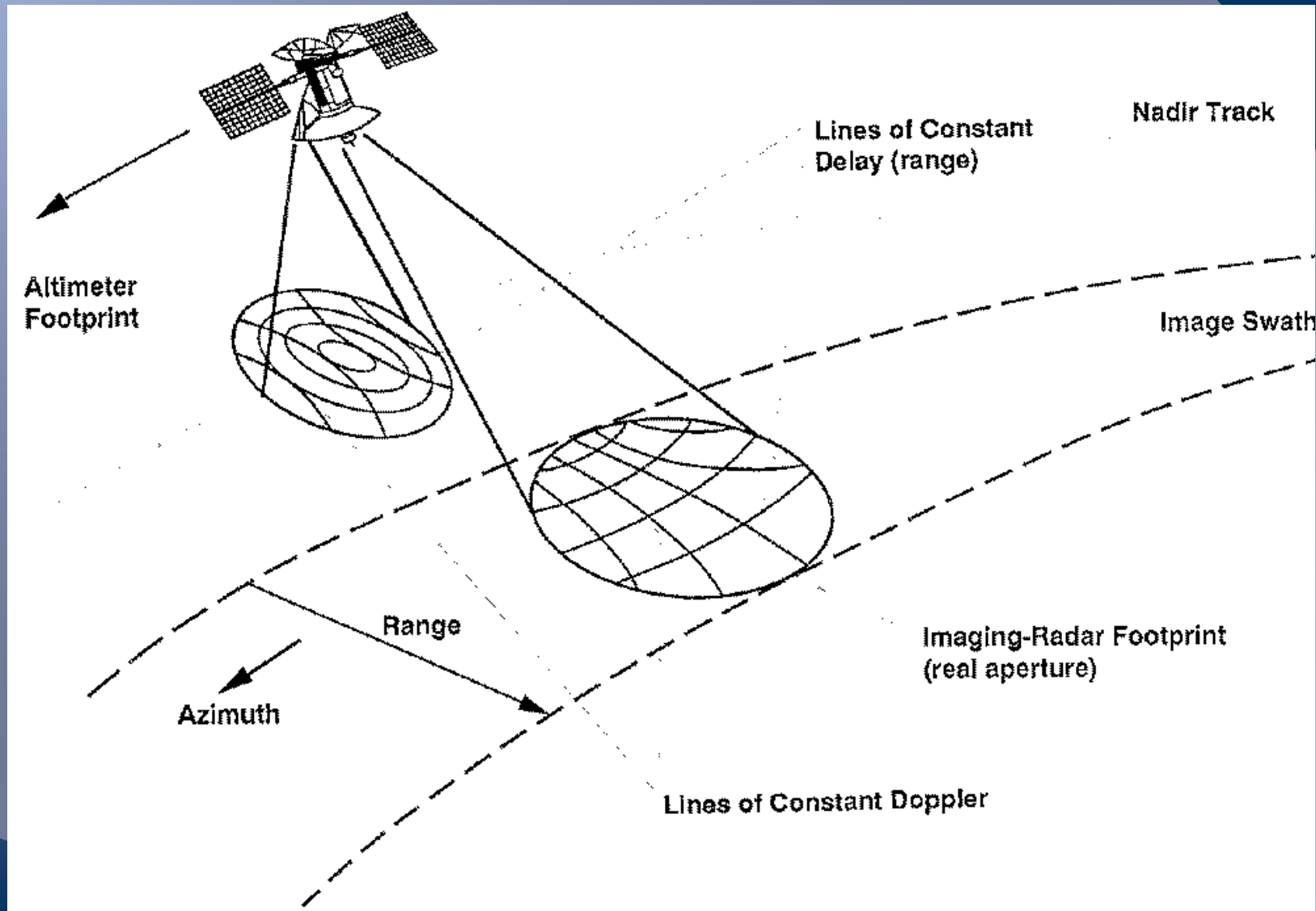


Cassini Radar

- Multimode Ku-band (13.78 GHz, λ=2.17 cm) radar instrument
- Four operating modes: scatterometry, radiometry, imaging and altimetry)
- SAR mode is used at altitudes below 4000 km, spatial resolution ~ 300 m to 1 km.
- Produces swath 120-450 km wide from 5 antenna beams.
- SAR coverage at Titan is dependent on spacecraft range and orbital geometry.

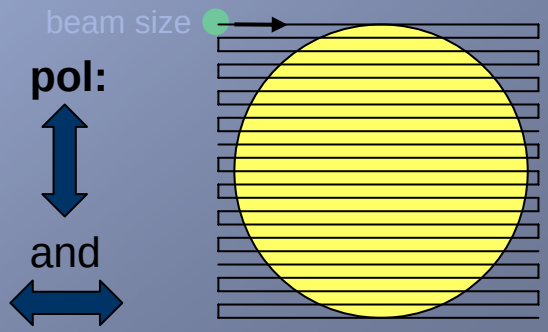


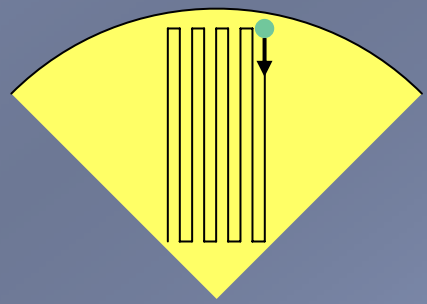
Cassini RADAR: uses the five-beam Ku-band (13.78 GHz) antenna feed associated with the Cassini high-gain antenna to direct radar pulses towards a target

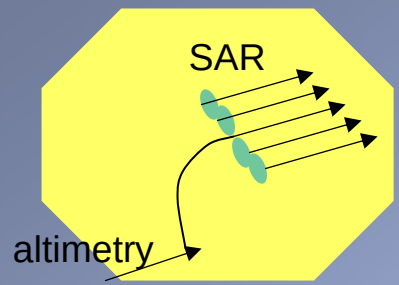


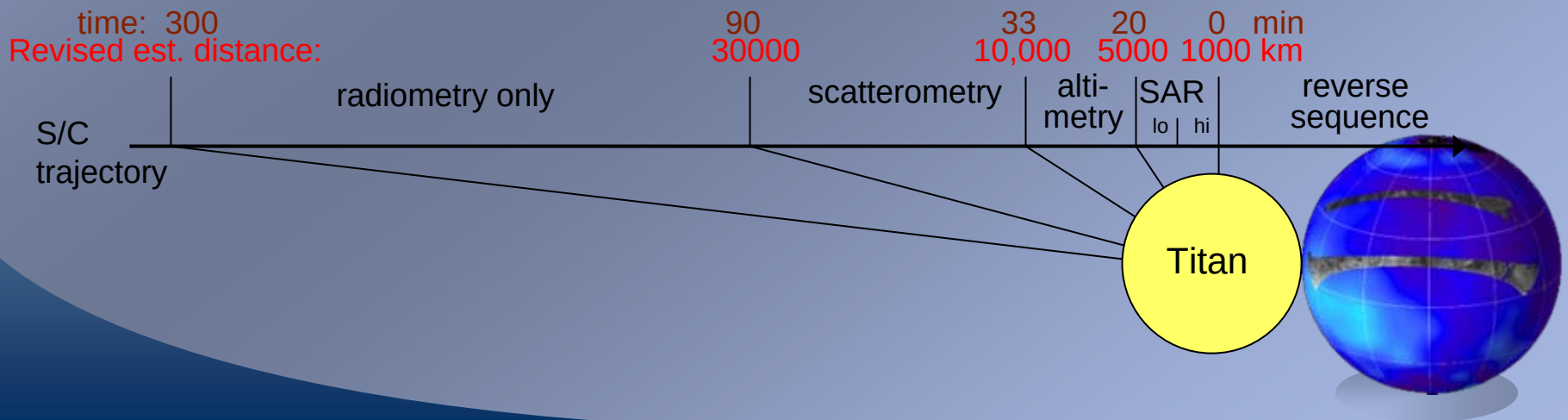
RADAR Observations

Radiometry only	Scatterometry	Altimetry SAR
raster scans in two polarizations	raster scan in one polarization	line scan in one polarization
600 km < footprint < 170 km	170 km < footprint < 60 km	60 km < footprint < 5 km

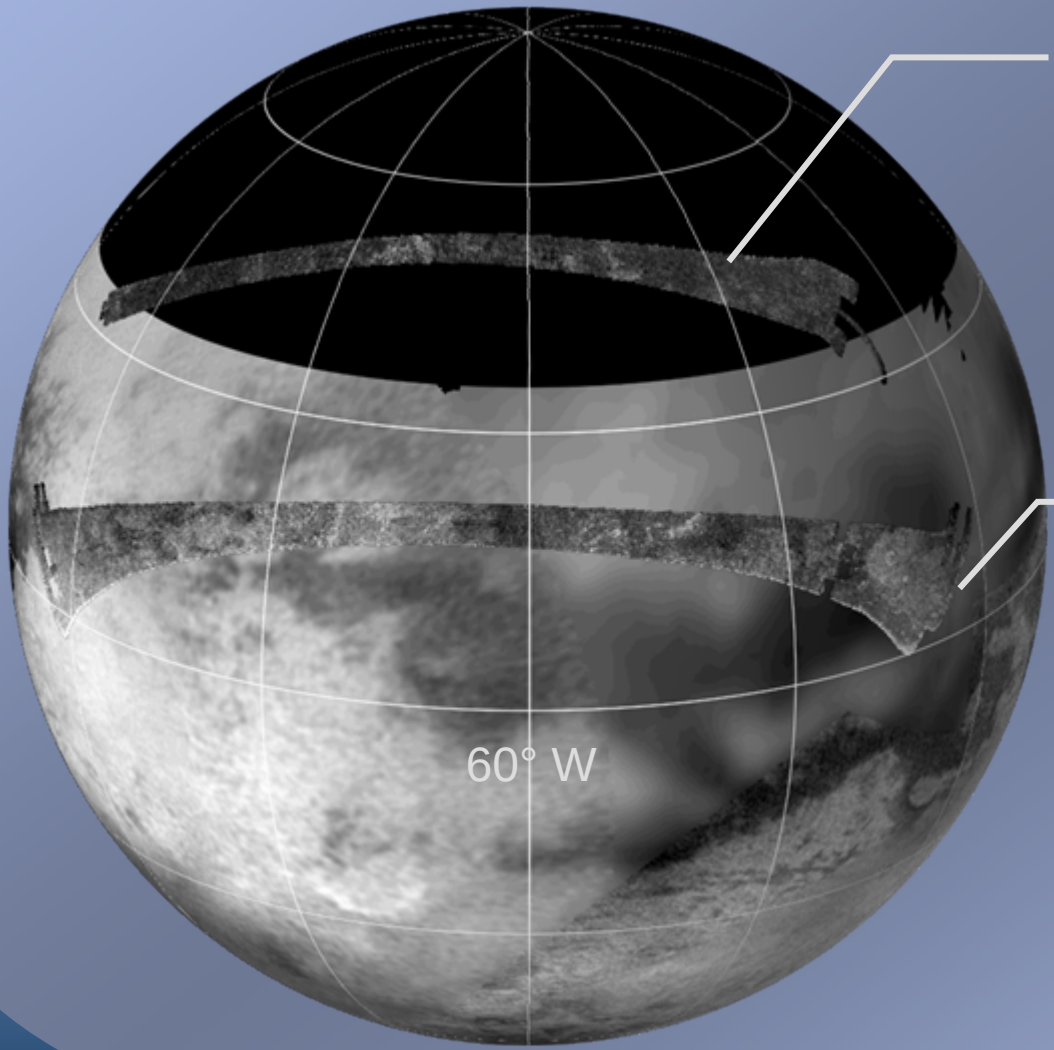






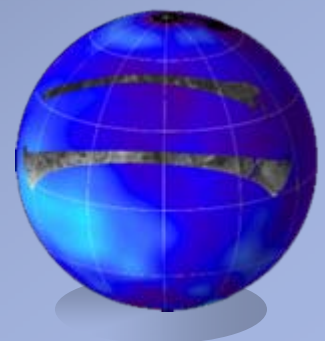


Initial Encounters

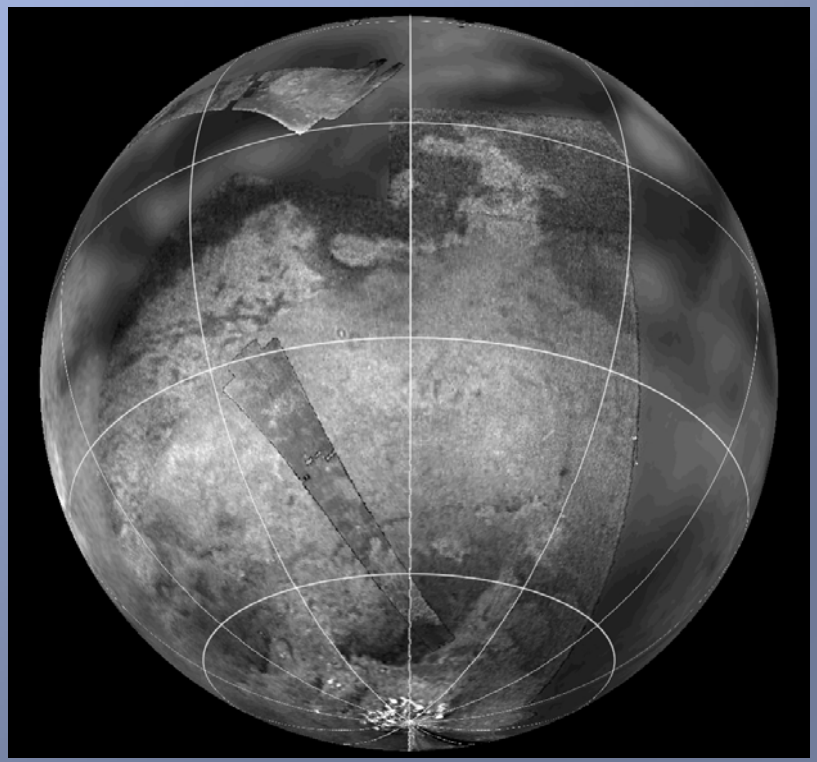


Ta—26 October 2004
- Scatterometry
- SAR (-5 to +15 m)
- Altimetry
- Scatterometry
- Radiometry (2 pol)

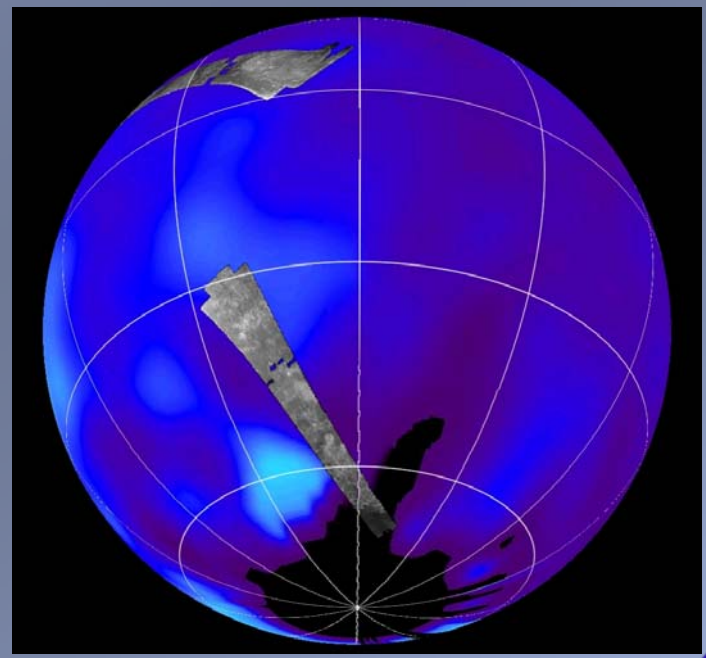
T3—15 February 2005
- Altimetry
- SAR (±20 m)
- Altimetry
- Scatterometry

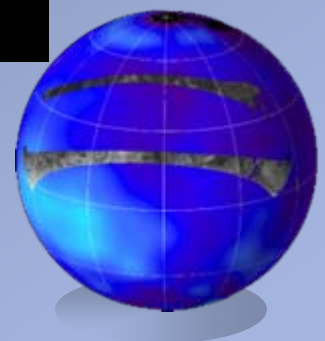


Recent encounter: T7 (9-7-05)

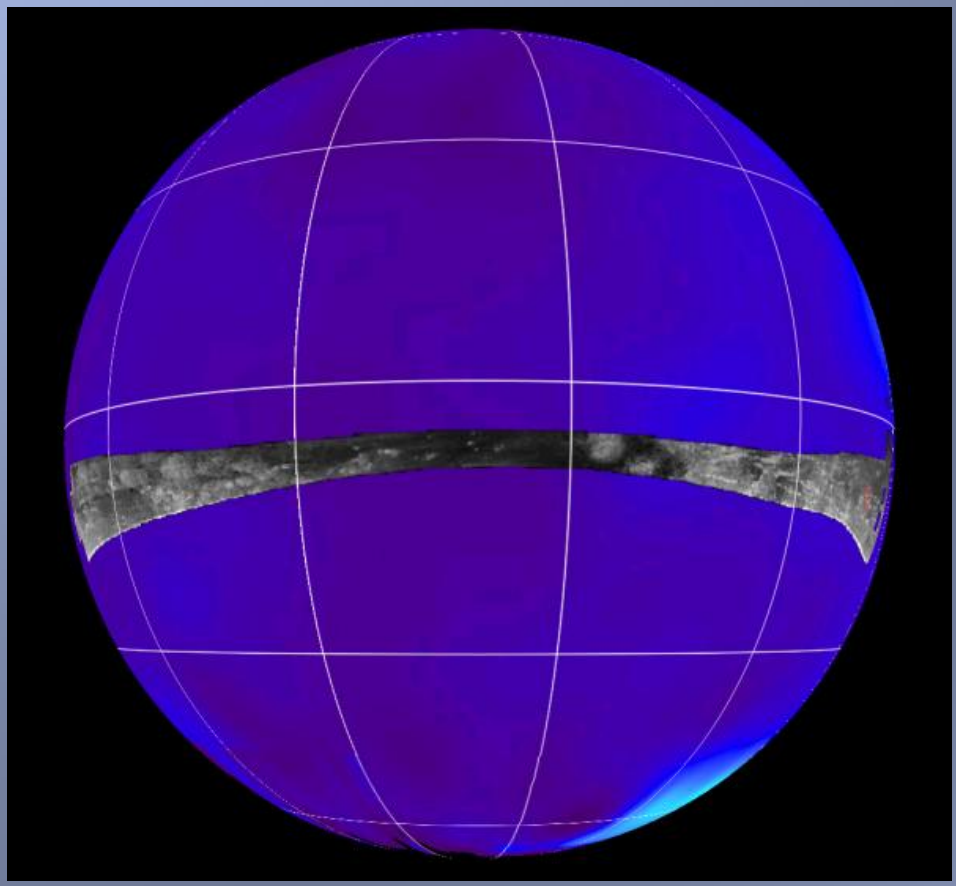


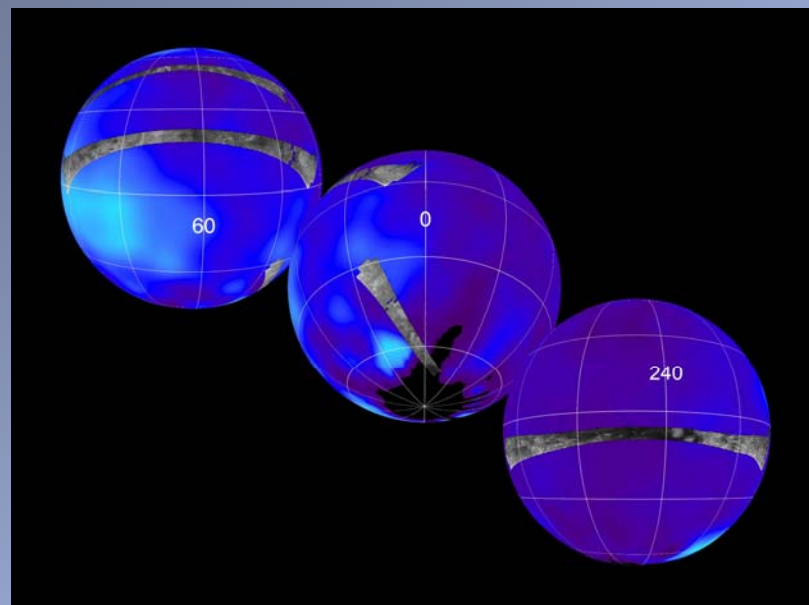
T7: 7 September 2005
SAR only (data loss)





Recent encounter: T8 (10-28-05)

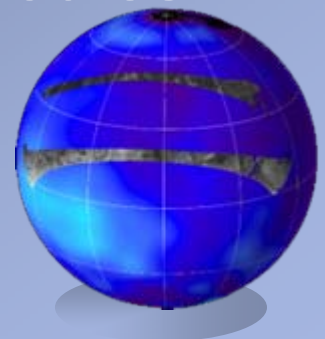




Titan SAR Images

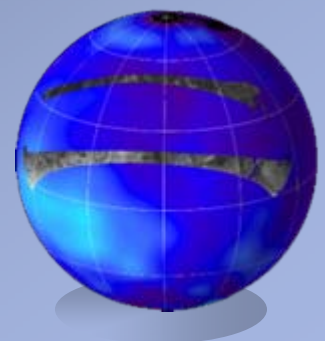
- SAR Radar backscatter variations generally interpreted in terms of variations in surface slope, surface roughness and surface dielectric properties.

- On Titan, the likely surface materials (ice, ammonia-water ice mixtures, hydrocarbons, tholins) are very different from those of bodies previously imaged with planetary radars: volume scattering may be significant.

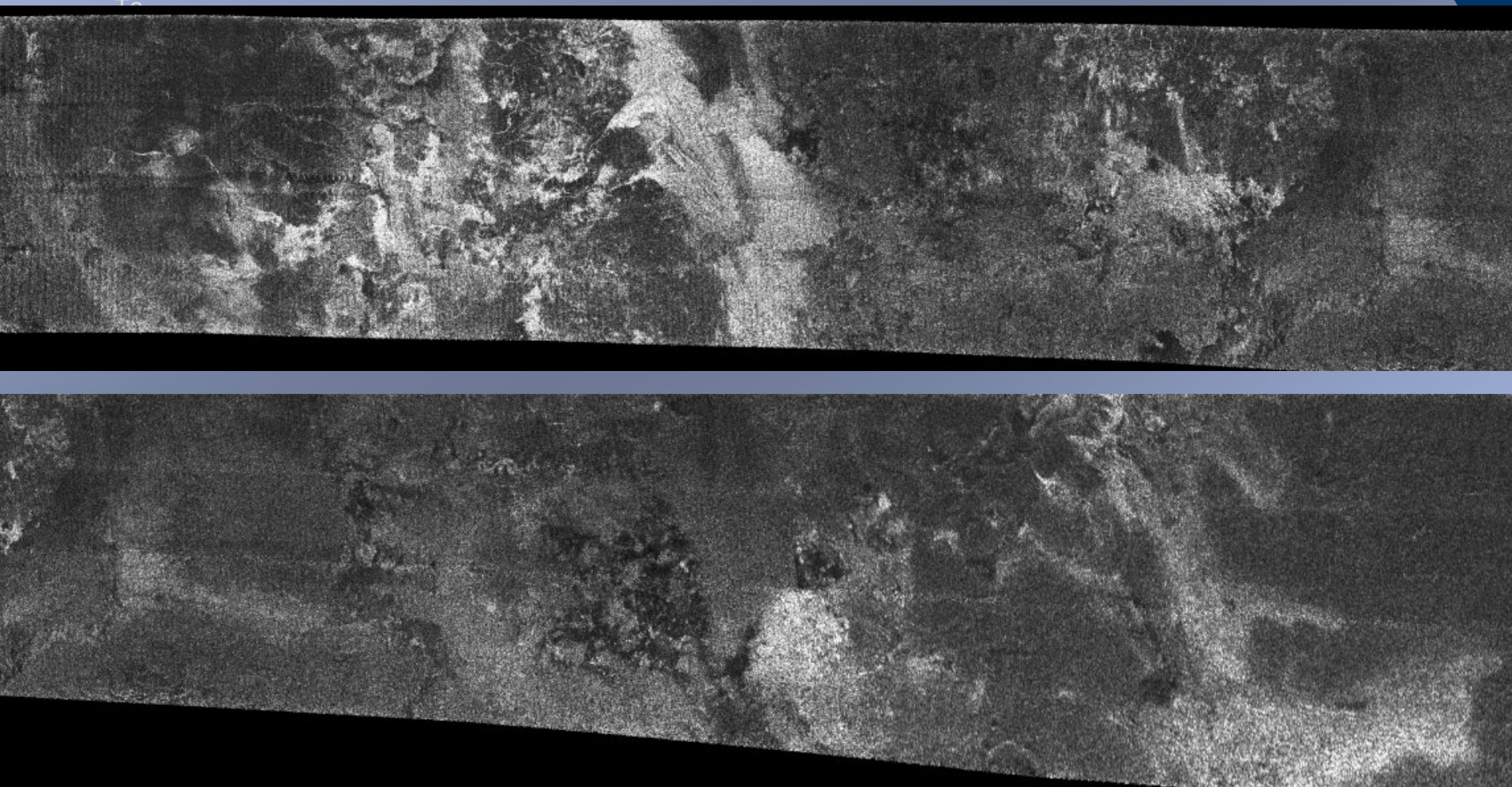


Initial Identification of Geologic Units

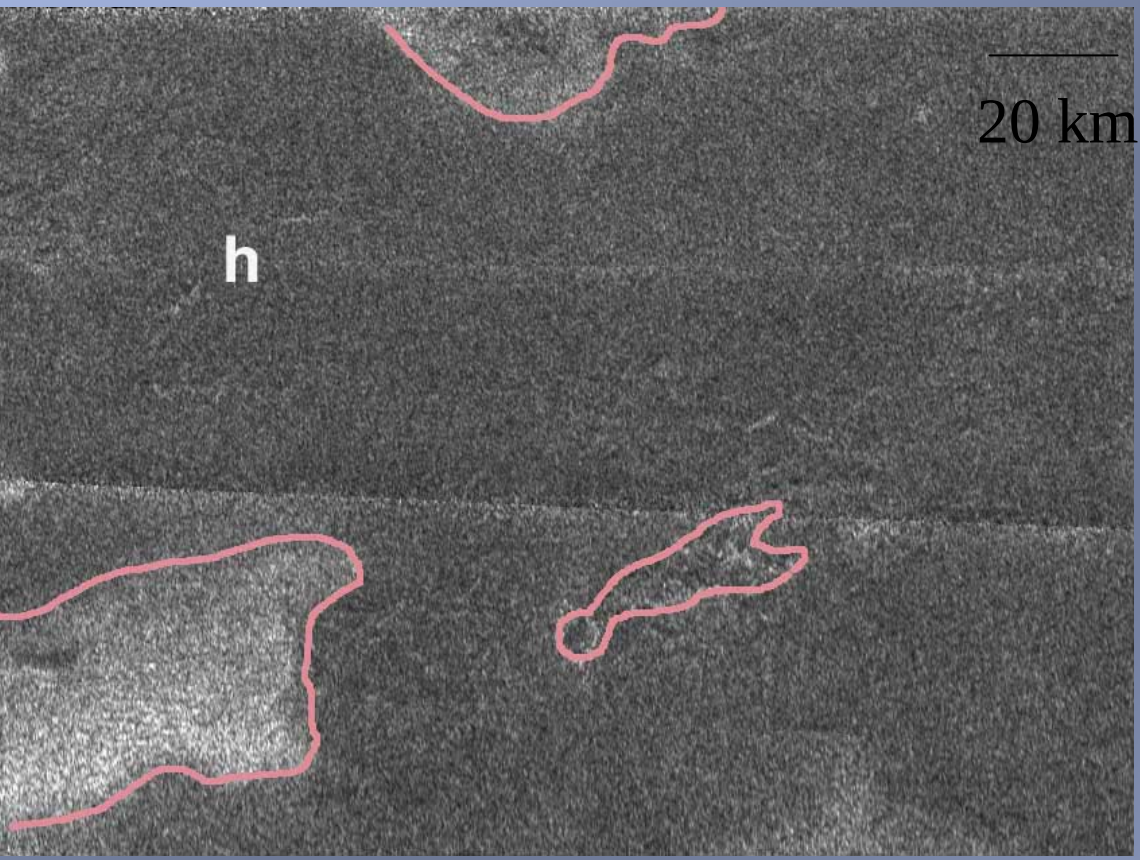
- 8 units in Ta and T3 swath (<3% of planet). Most units occur in both swaths, though differ in significance.
- Units identification in T7 and T8 swaths still ongoing
- Units based on radar brightness variations, general planform shape and texture.
- These units are not yet classified as rock (ice) stratigraphic units, as we do not fully understand the causes of the variations in radar brightness (i.e., composition, volume scattering effects, roughness).
- Cryovolcanic features in Ta swath, possibly T3 and T8
- Sinuous features and fan-shaped units in all swaths
- “Coastline” in T7, candidate for liquids
- Two impact craters seen in T3
- “Cat scratches” (dunes) in T3 and T8
- Possibly tectonic features in T8



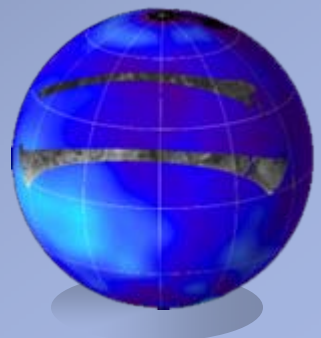
Ta SAR showed a remarkable diversity of features, including flow-like features.



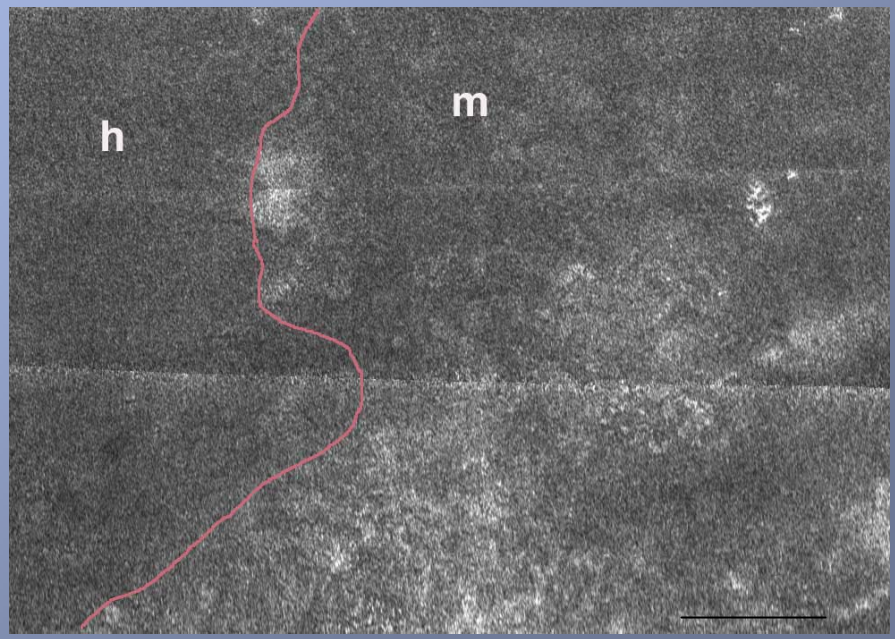
Homogeneous Unit

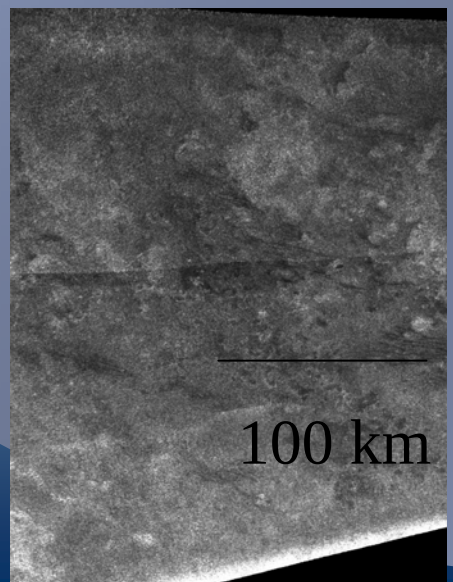


- Most extensive unit in Ta swath (50-60%)
- Relatively low backscatter
- Less common, less extensive and less dark patches in T3 swath
- Ice ‘plains’?



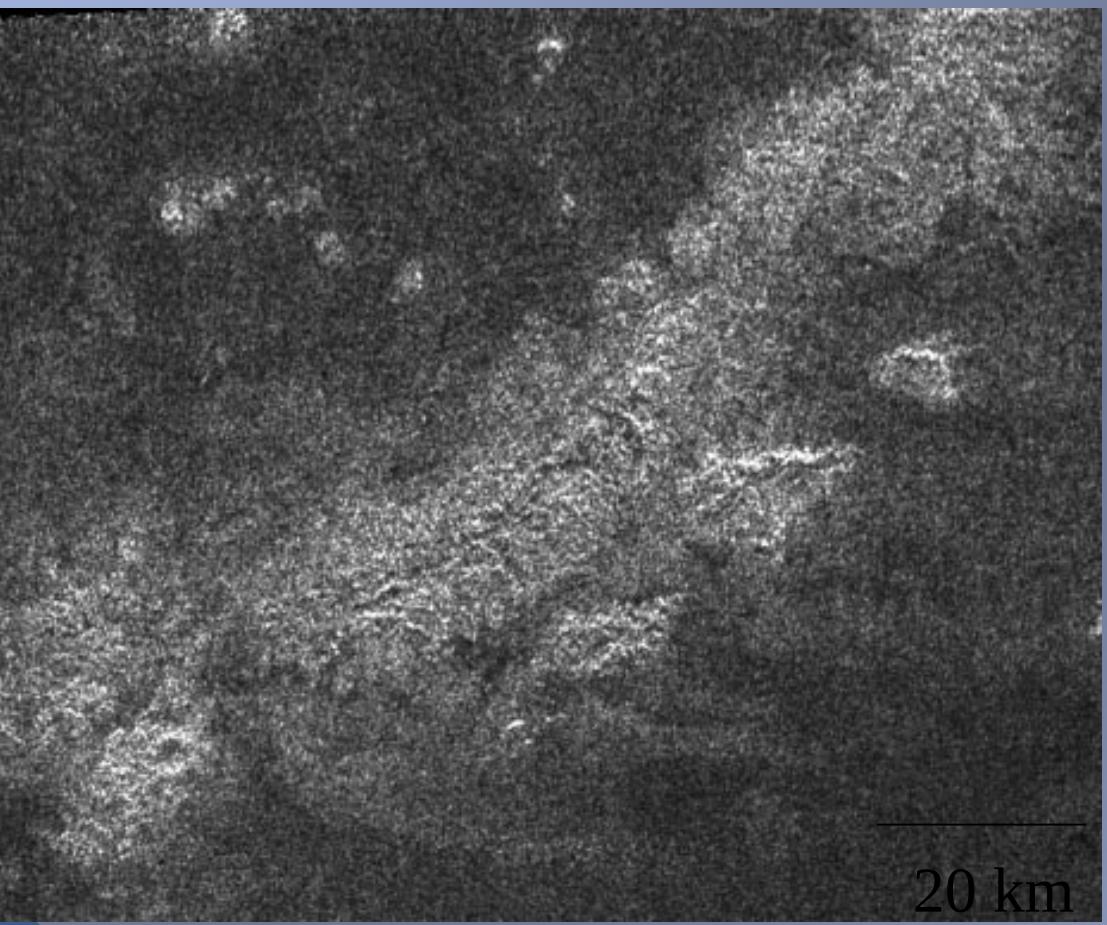
Mottled Unit



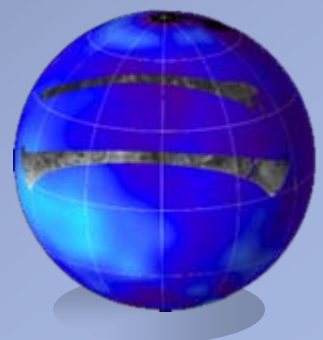


- Second most extensive unit
- Moderate to bright backscatter
- Gradational boundaries
- In Ta swath, in patches 100’s kms across, sometimes smaller
- Ice unit, volume scattering?
- Mottled unit in T3 swath is brighter, more extensive

Hummocky unit



- Textured terrain with positive topography
- Appears to be embayed by surrounding plains
- Tends to occur as small isolated ‘hills’
- Occurs in both Ta and T3

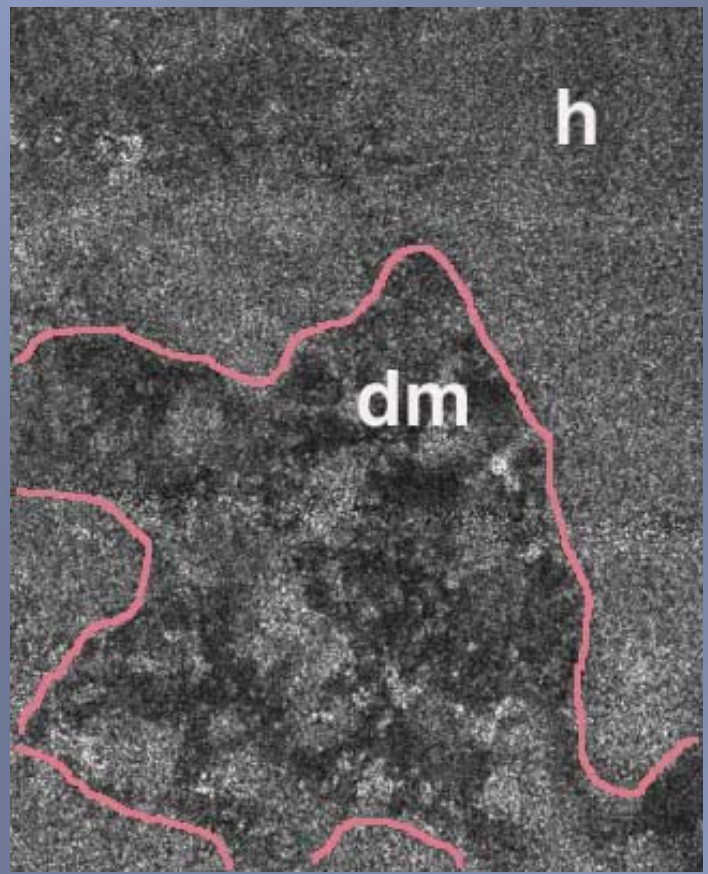


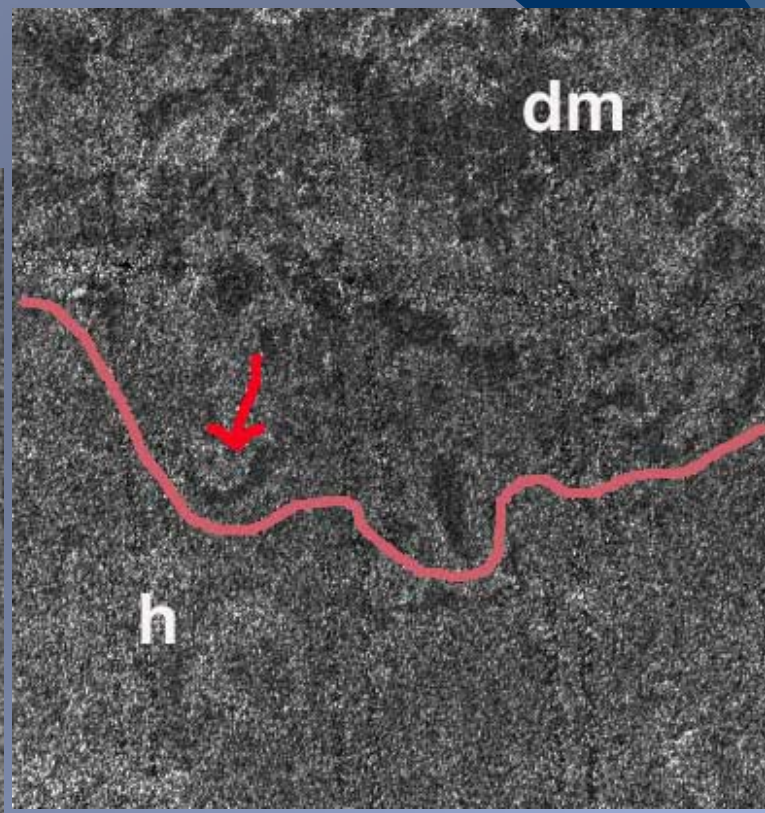
Dark Mottled Unit

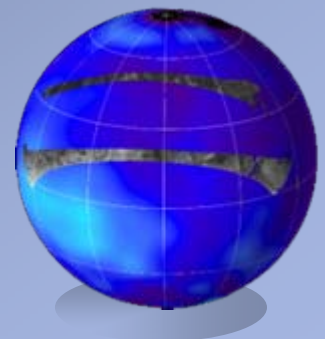
Patchy unit, 10s-100s kms across

- Oxbow shapes
- Ponds?

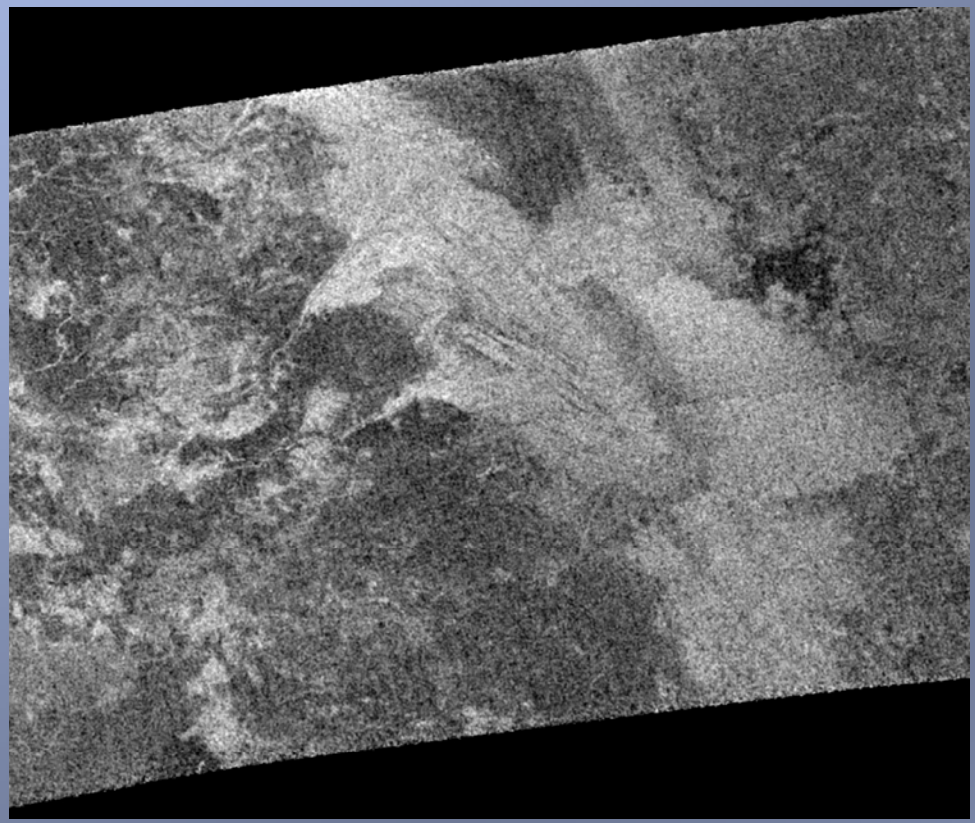
Titan's atmospheric methane abundance suggests the likelihood of a surface reservoir of methane and a surface sink for its photochemical products, which might be predominantly liquid







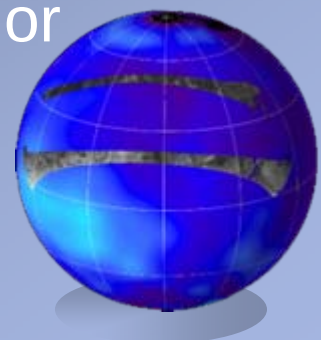
Fans/deltas (Ta)



Fan-like features seem to open at a possible change in topography
Image height ~ 200 km

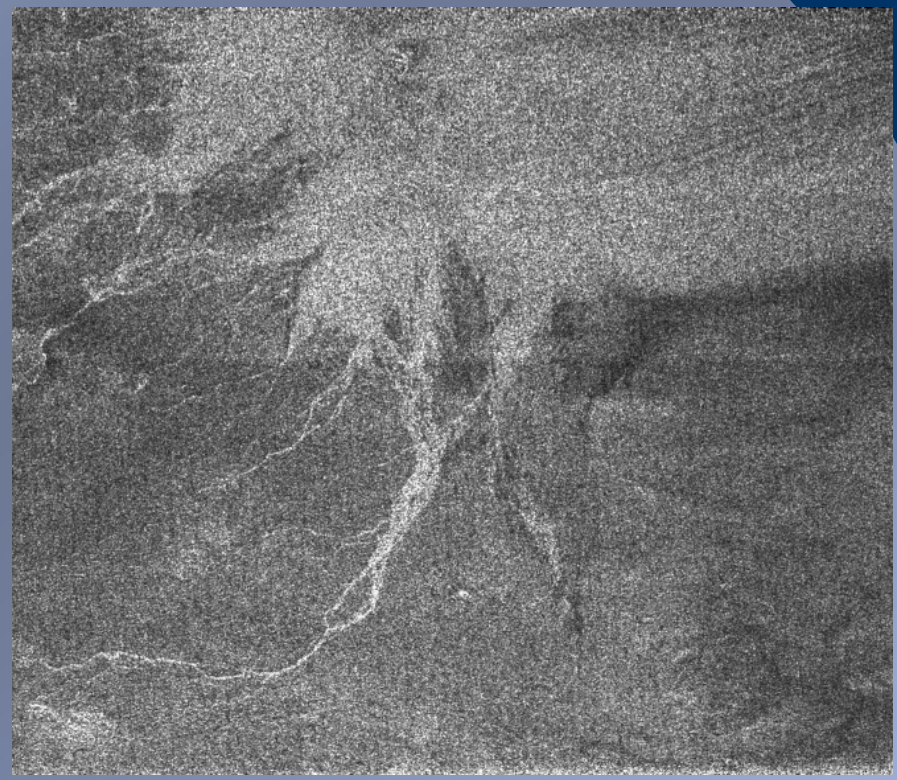
Fan-shaped units with sinuous features

- Most larger in scale than Huygens ‘channels’
- 500m – 1km across and extend for tens of km
- Indicative of transport and deposition of materials, and topography
- Possible transport mechanisms include slope-related processes, cryovolcanism, or hydrocarbon fluid flow

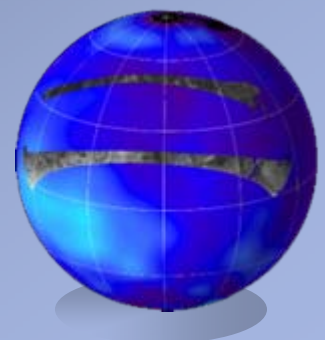


Alluvial deposits (T3)

- Presence of channels
- Channels draining into a depositional area
- Dendritic, braided, and meandering bright channels
- Characteristic tortuosities of channels - thin channels split and re-group
- No lobate deposit



Lorenz et al., paper in preparation



T7: “Coastline”

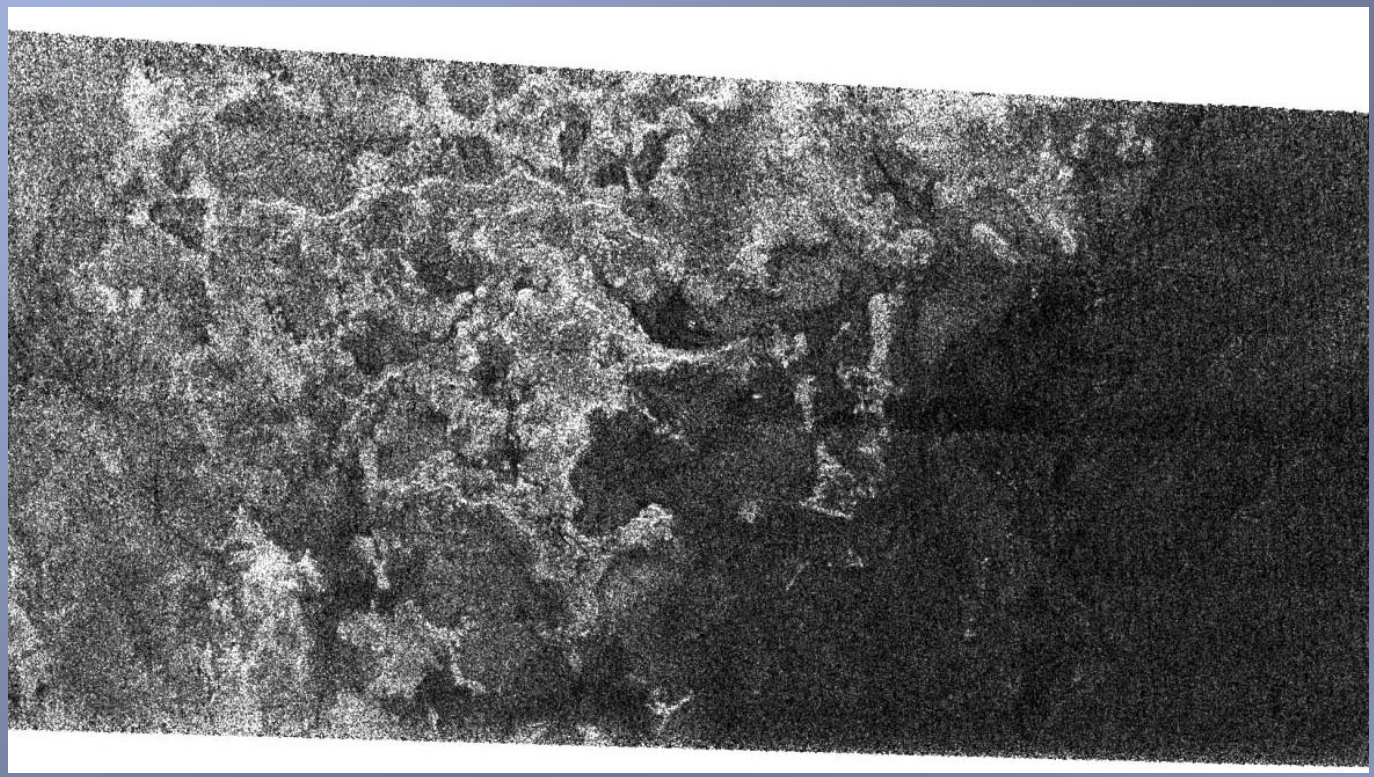
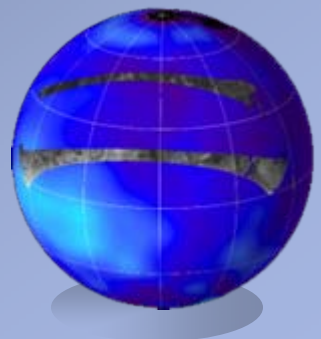
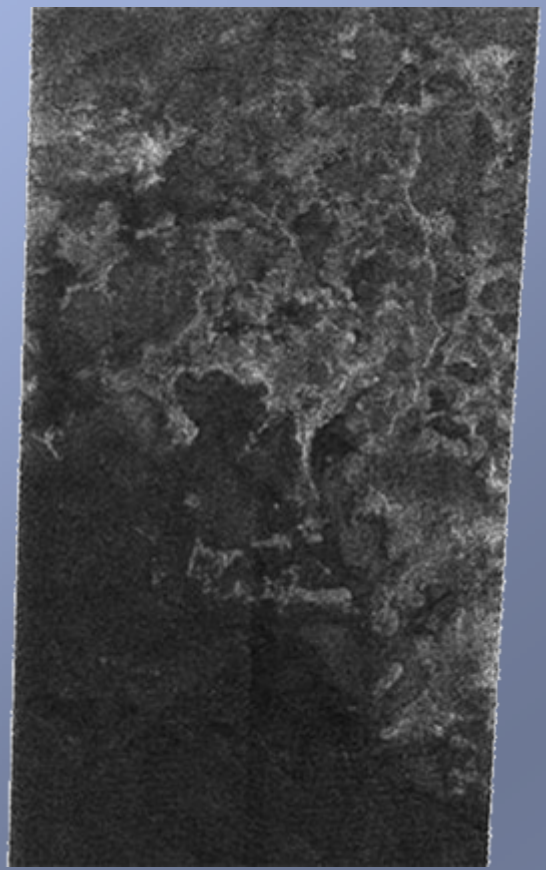


Image height
~ 200km

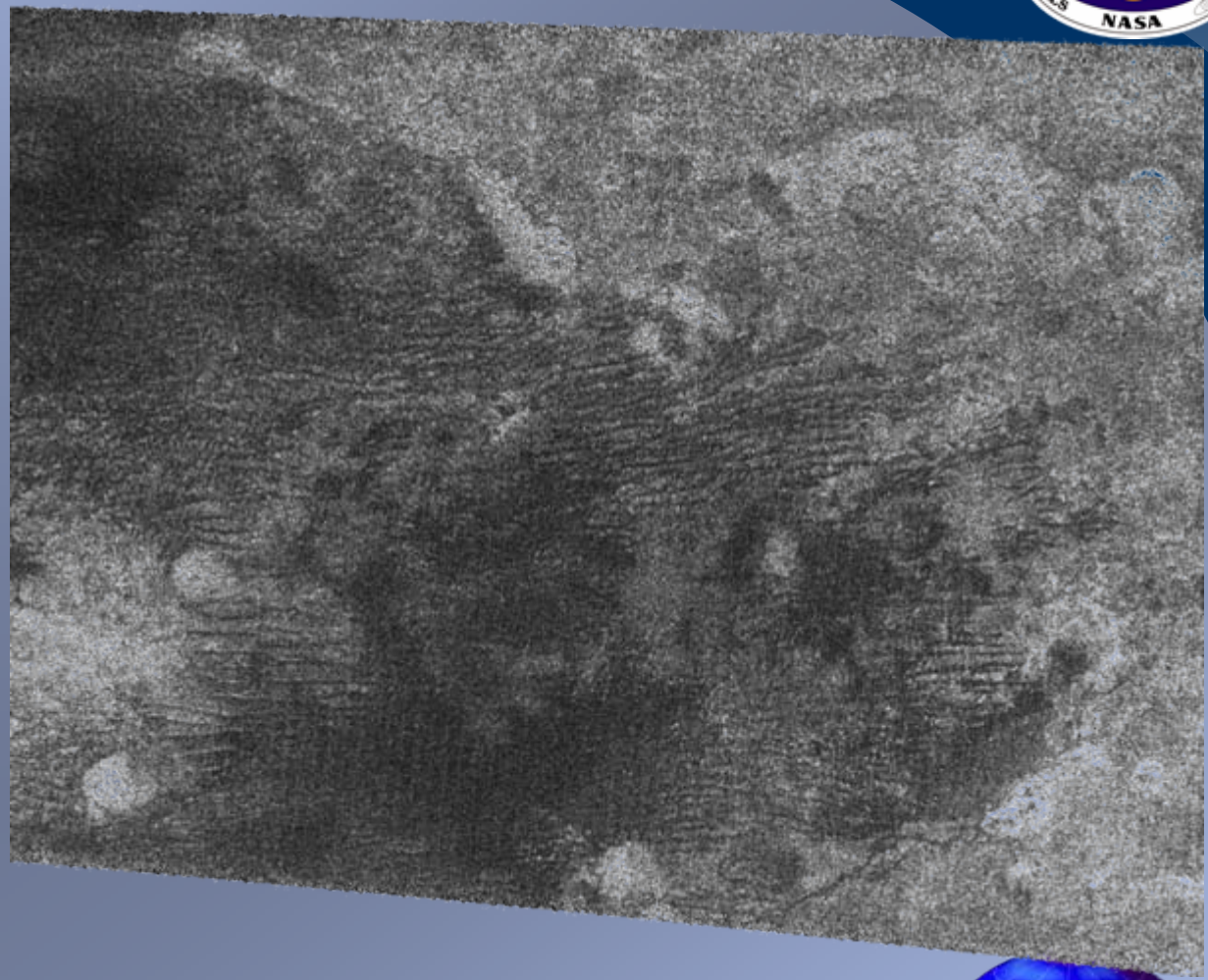
Bright, rough region appears be topographically high terrain, cut by channels and bays.
Is boundary a shoreline? Patterns in the dark (smooth) region indicate that once it may have been flooded.



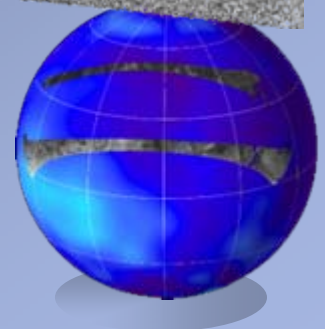
Coastlines?



T7

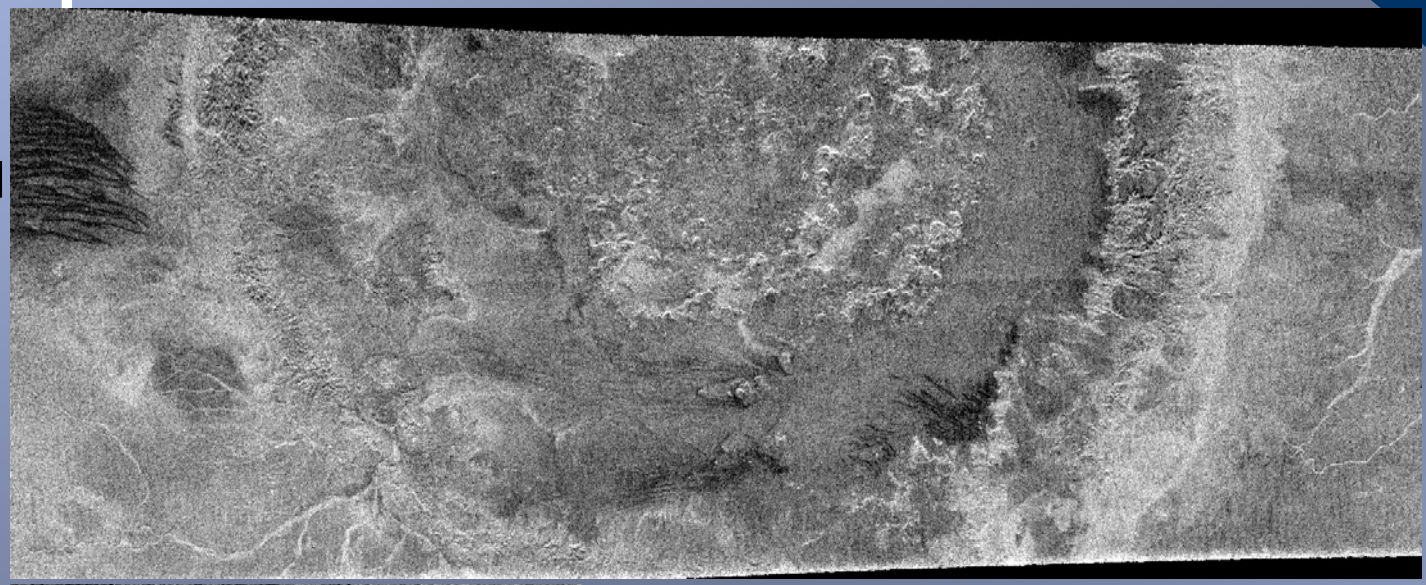


T8



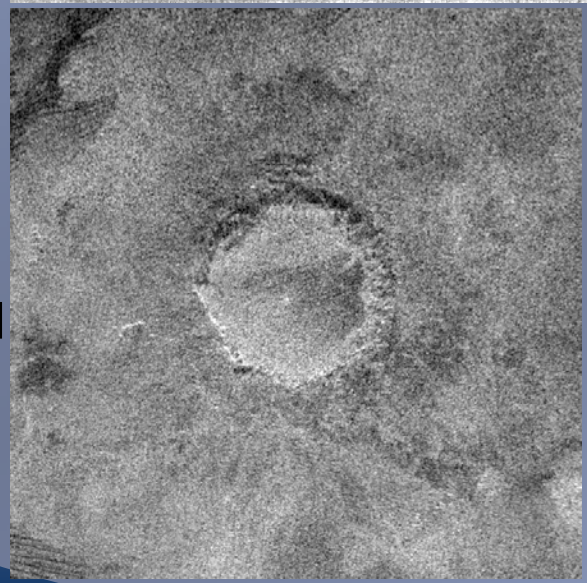
T3 Impact Craters

450 km
87°W 20°N



100 km

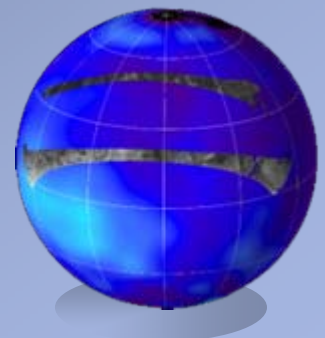
Mernva



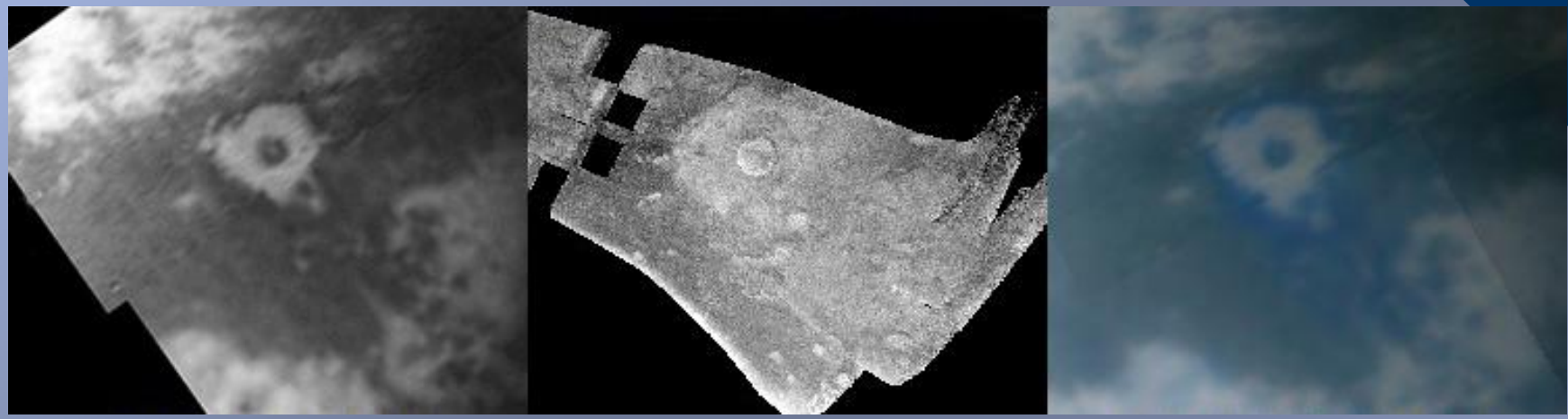
80 km
16°W 11°N

Atmospheric shielding means impactors need be > 2 km, ~ 20 km diam crater

Sinlap

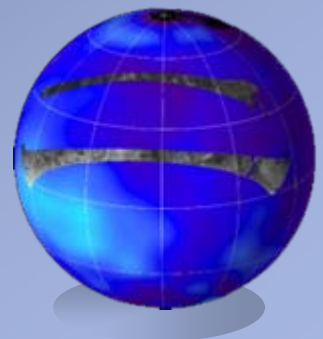


Radar/VIMS comparison of 80km diameter crater (Sinlap)

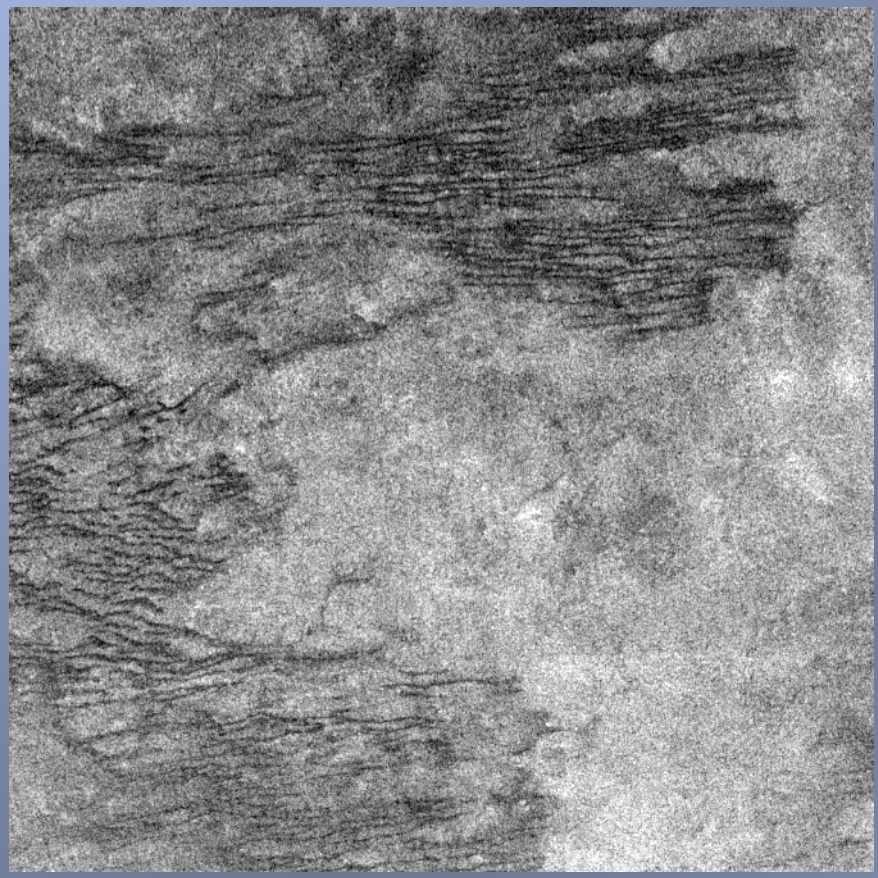


VIMS 2.03 µm | T3 SAR | VIMS false color

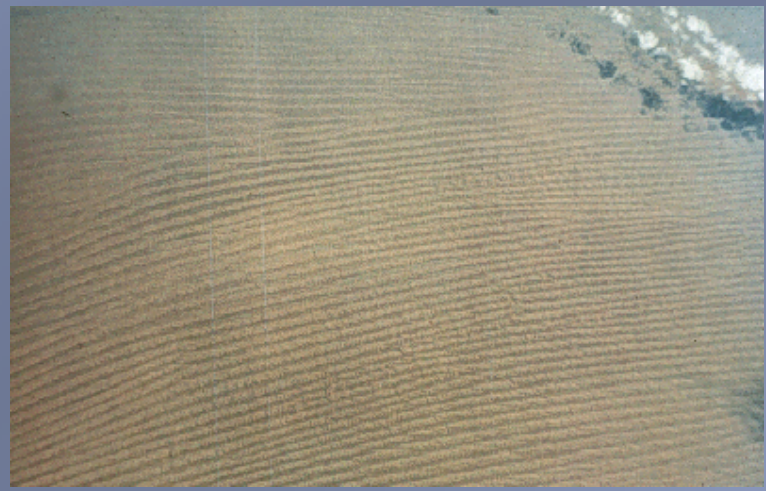
VIMS shows ejecta has a faint halo that is bluer than the central bright material, implying different composition. Titan's upper crust may have different composition layers that were excavated by the impact



“Cat Scratches” = Dunes?

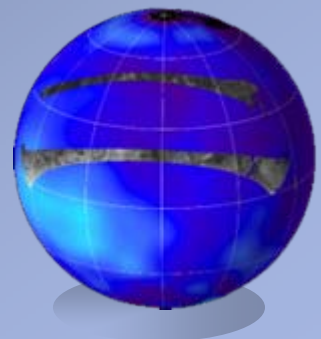


100 km



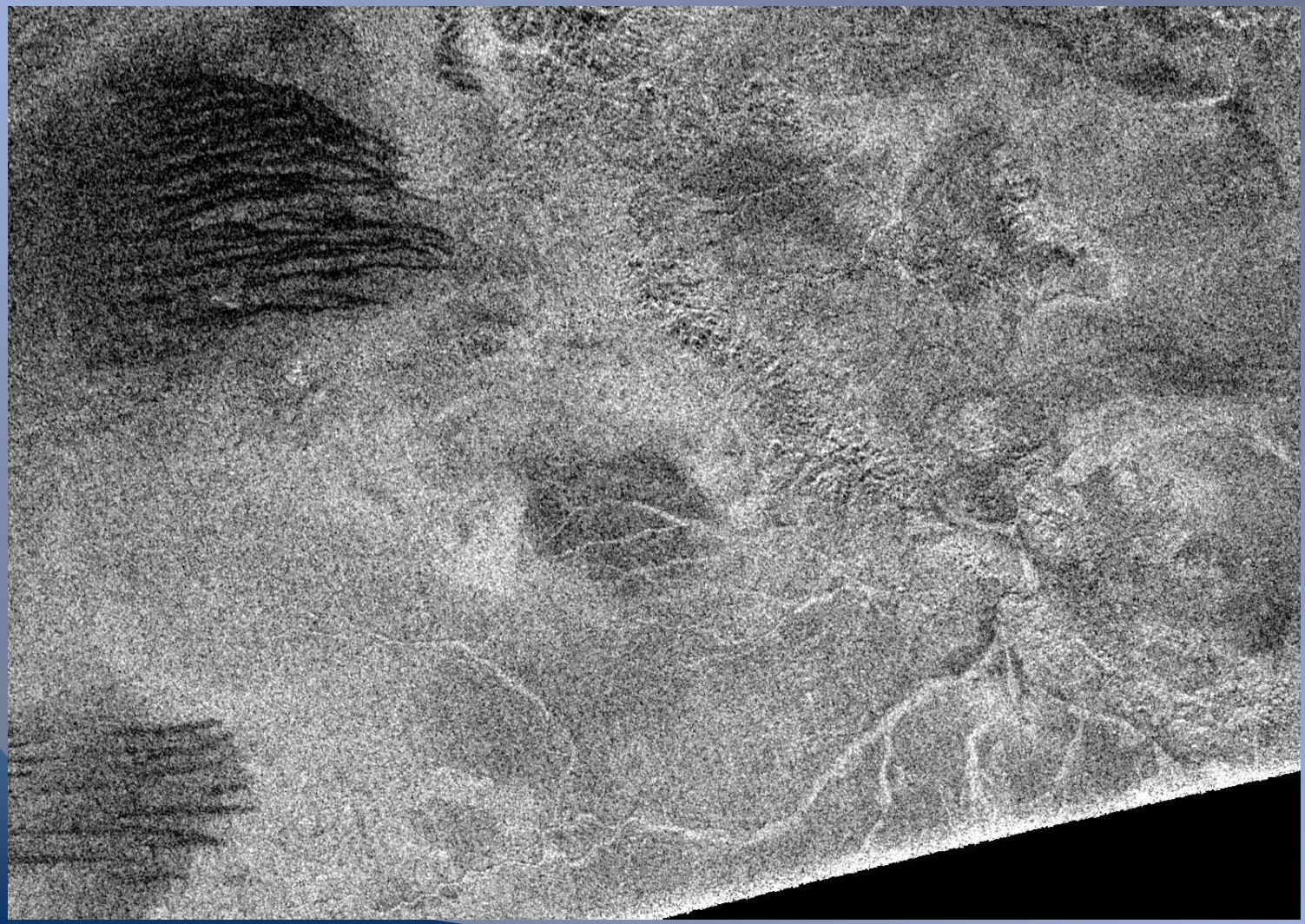
Longitudinal Dunes
Arabian Peninsula

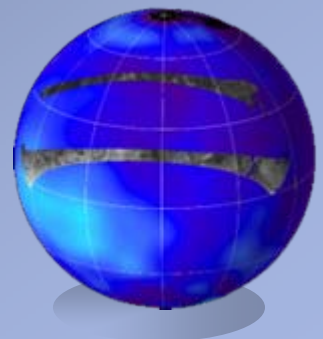
Here, near 104°W 13°N
Ubiquitous in T3, possibly in Ta



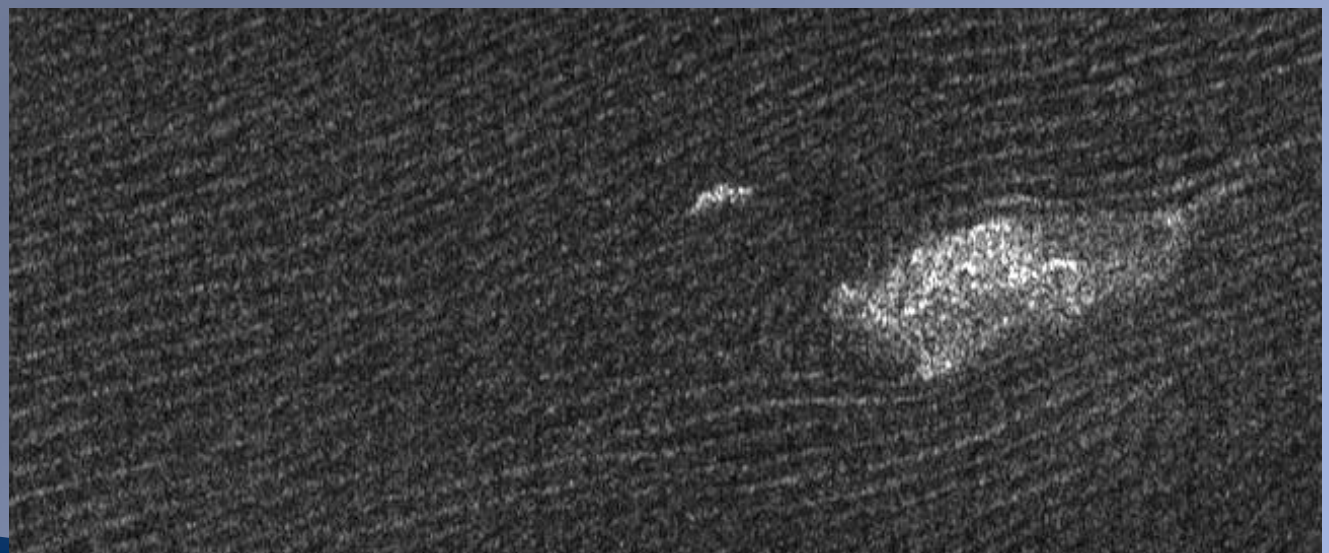
T3: cat scratches and drainage patterns

Channels 1-2 km wide, up to 200 km long





T8: Catscratches in Context



T8: Tectonics?

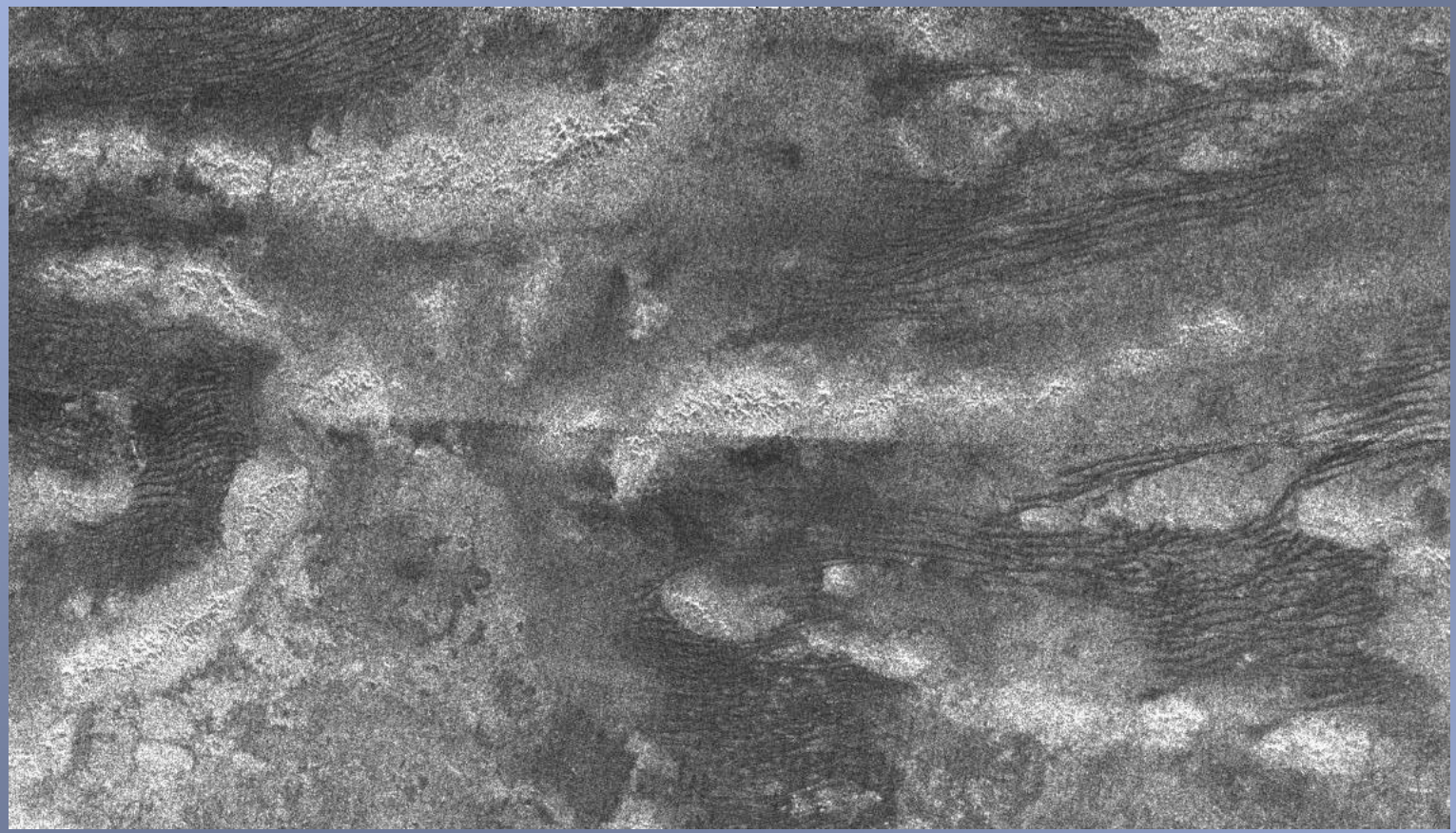
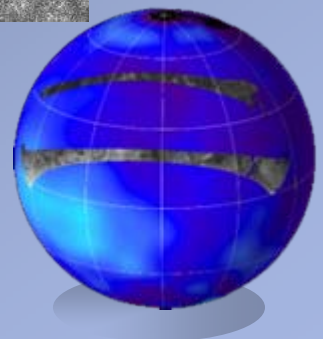
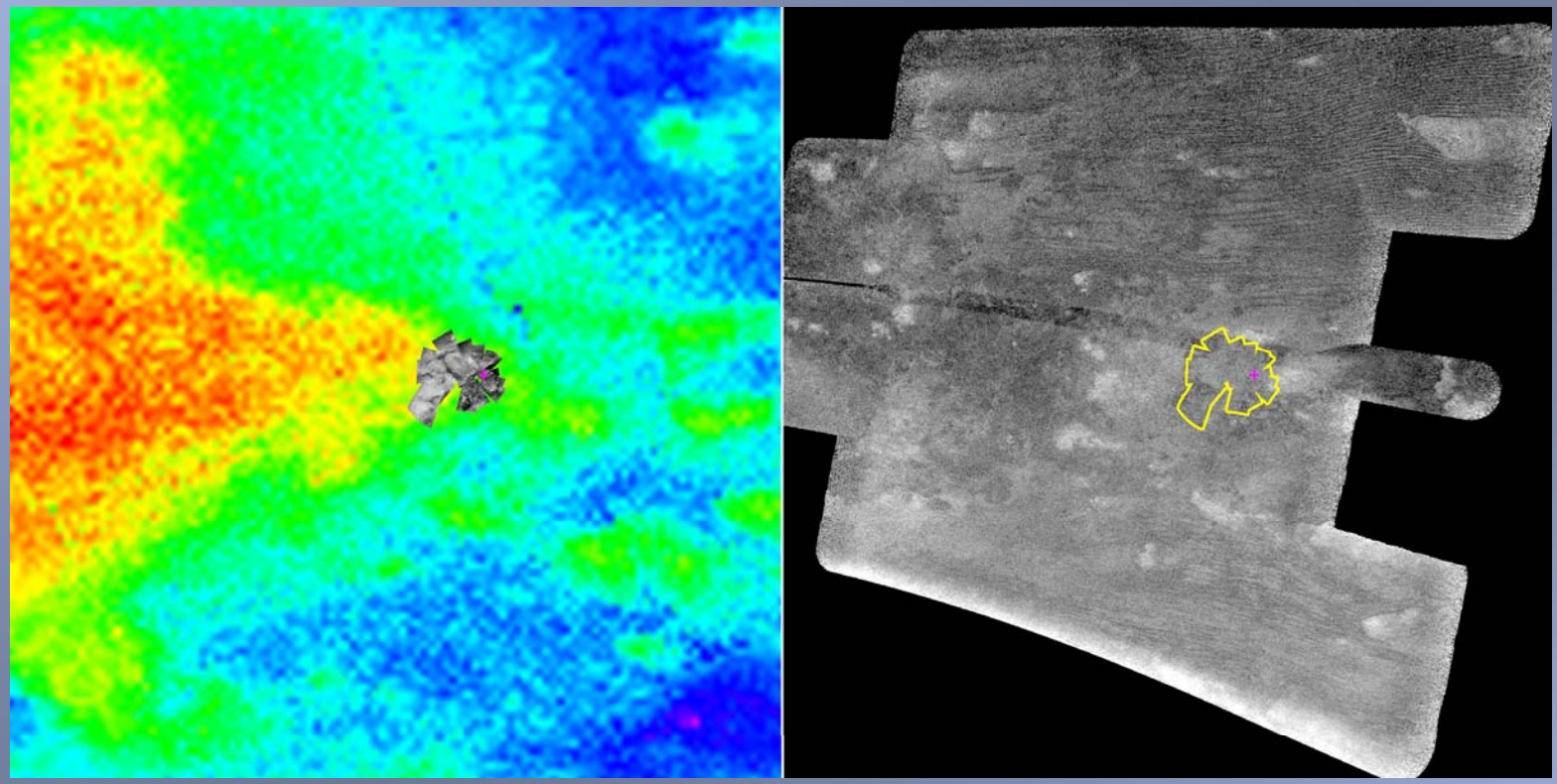


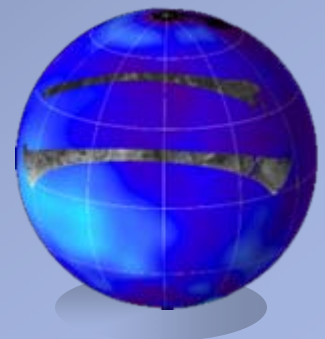
Image is 400 kilometers (250 miles) across



T8: RADAR observes Huygens landing site

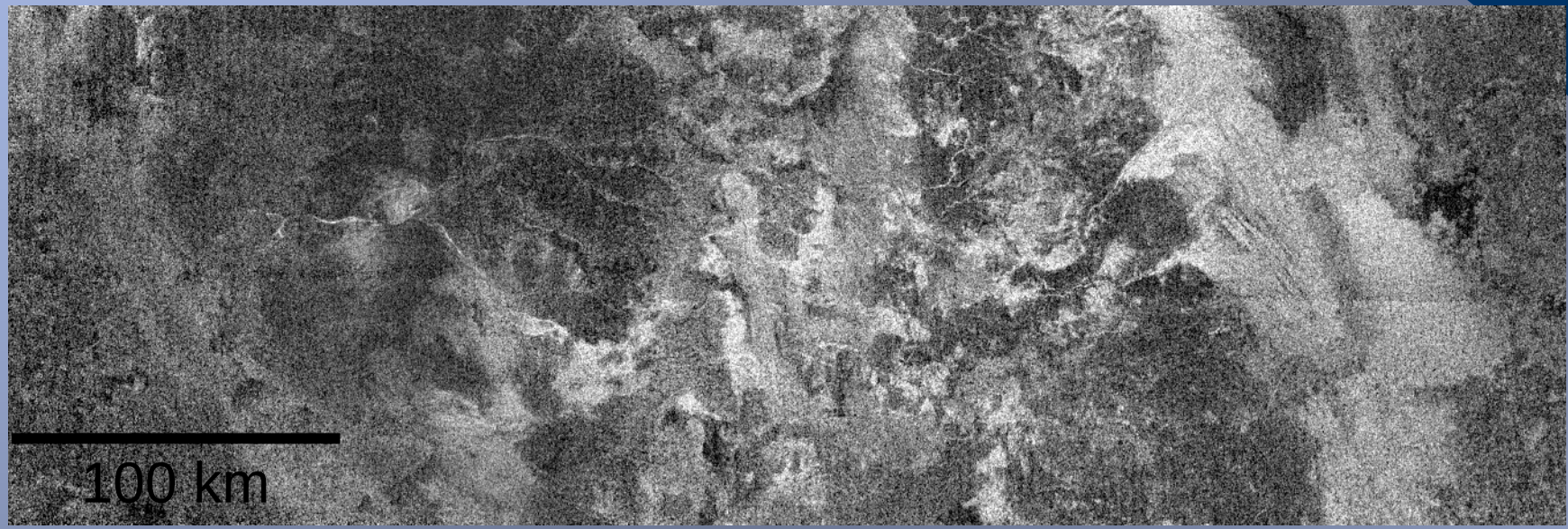


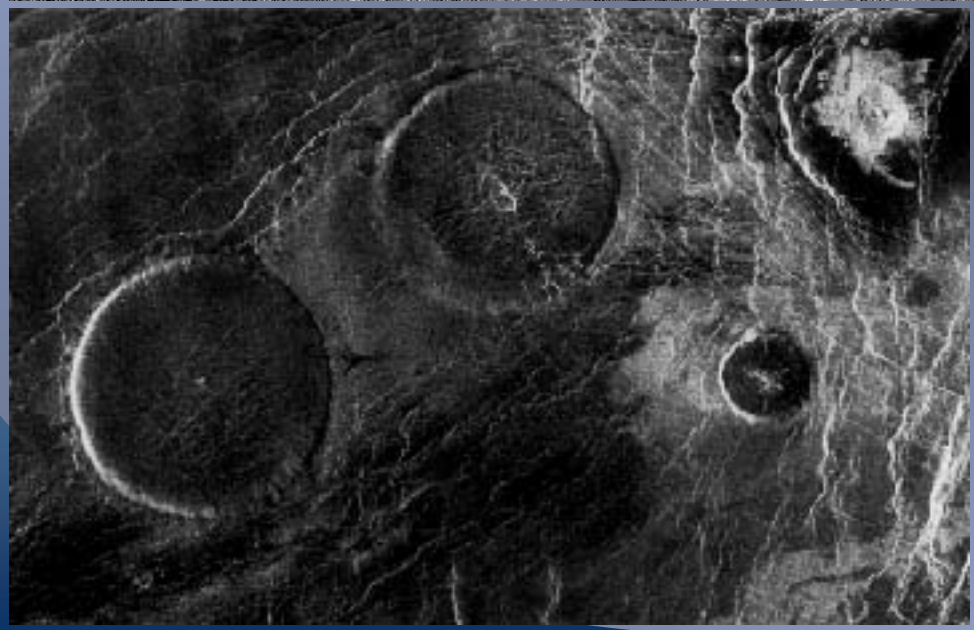
Look for press release Nov. 30

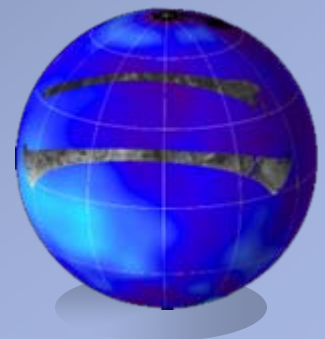


Ganesa Macula

180 km
87°W 50°N

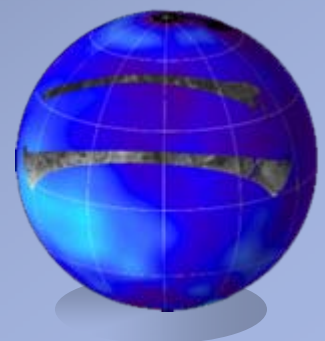


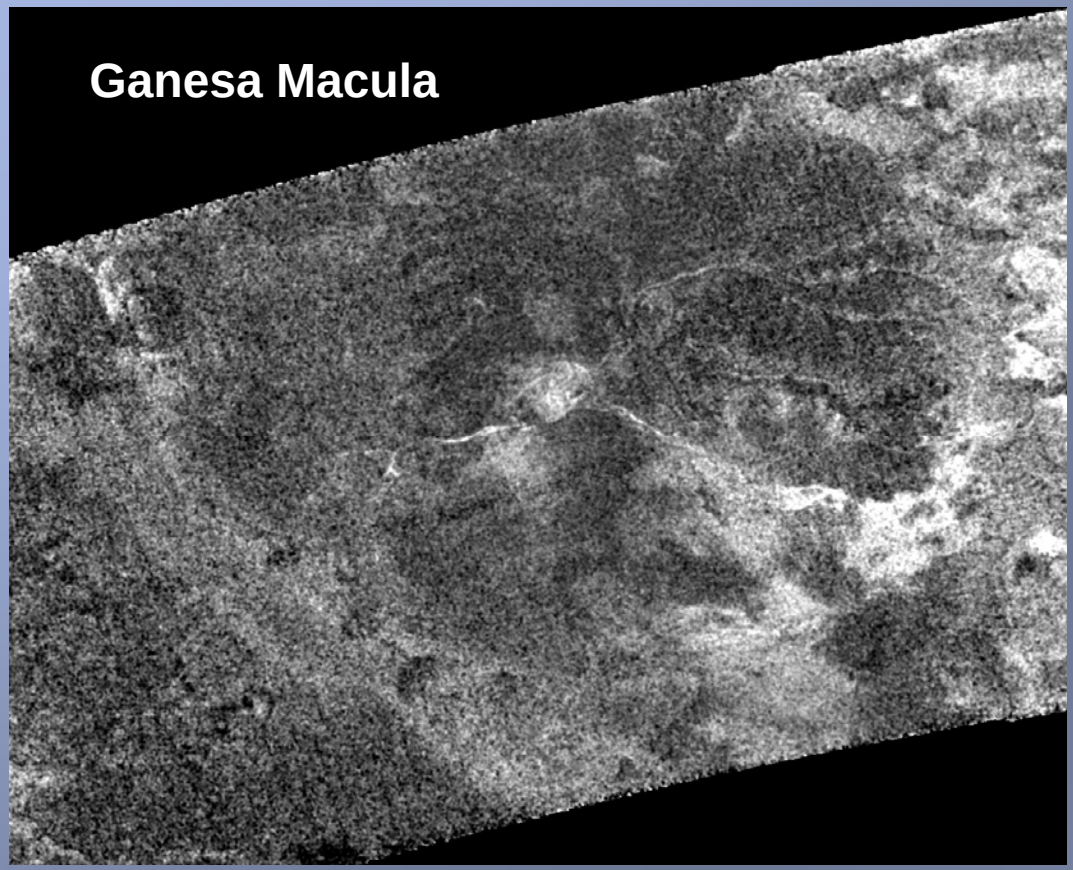


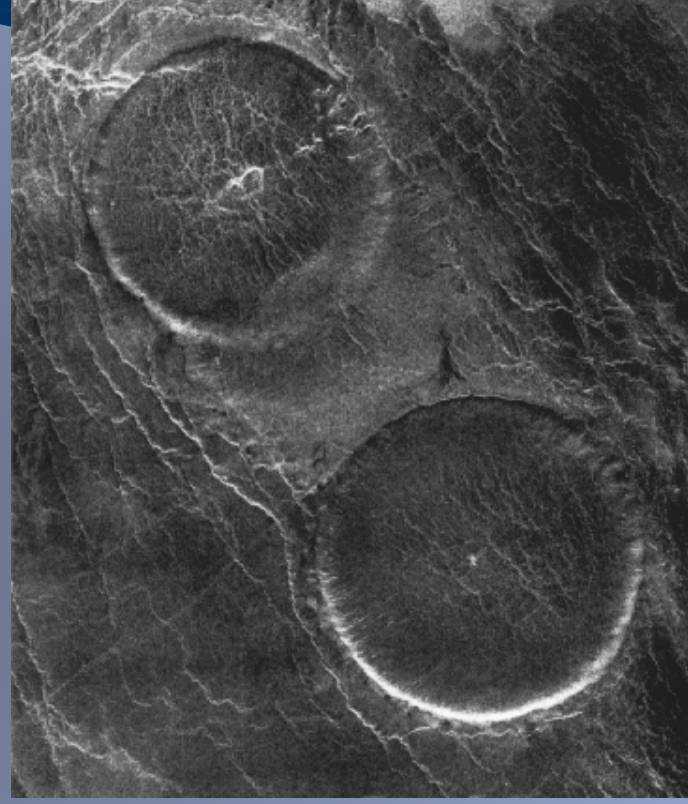


Predictions for Titan's geology (pre-Cassini) included cryovolcanism

- Water or water/ammonia or other
- Ammonia-water mixtures would be consistent with compositional models, and ammonia would lower the melting point, density and mobility of liquid water
- Ammonia-water mixtures on Titan would produce surface features similar to those of silicate volcanism (e.g. Kargel 1992, 1995)
- Water-ammonia cryomagmas probably have < 1% of methane as volatile – not enough at Titan's atmospheric pressure to produce explosive eruptions (e.g. Lorenz, 1996)
- Pancake domes predicted as perhaps most likely volcanic landform for Titan (e.g. Lorenz & Mitton 2002)

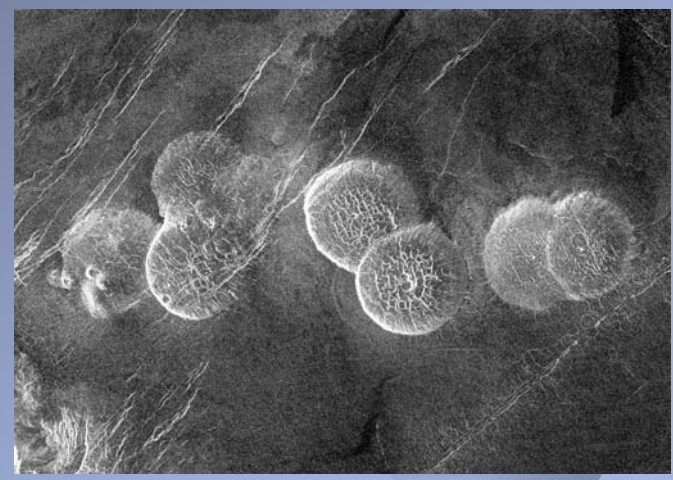




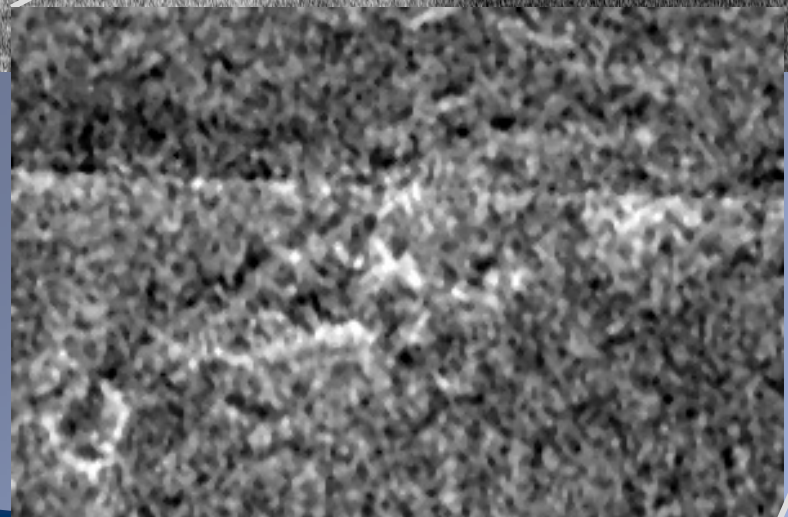


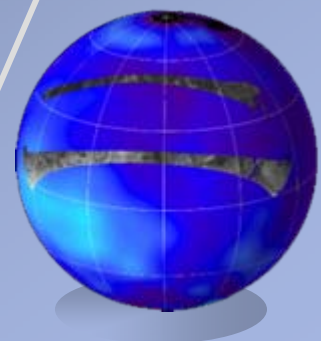
Similar morphology to Venusian pancake domes

- cracks due to cooling
- channels may be cryolava channels or fluvial

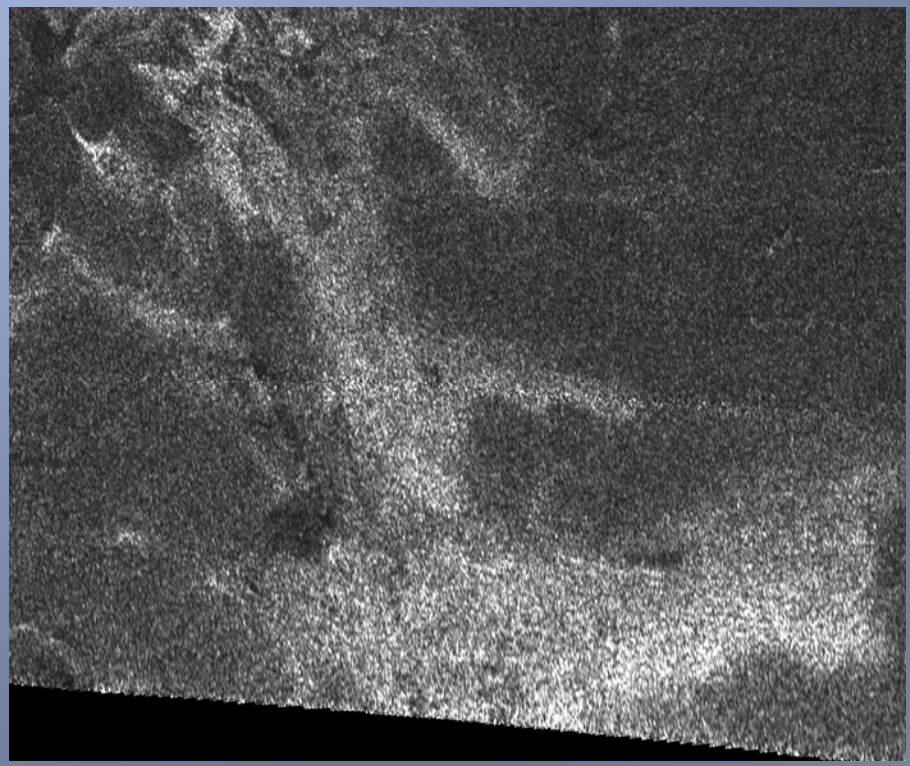


Ta: Cryovolcanic Flows?





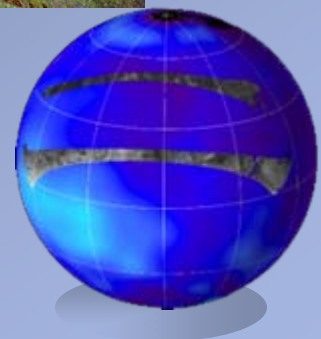
Ta: Cryovolcanic flows?



Lobate shape and possibly very high thickness consistent with volcanic flows

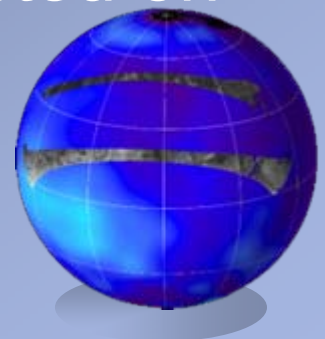
Very large area ~ 24,000 km^2

Mauna Loa from SIR-C



Cryovolcanic features

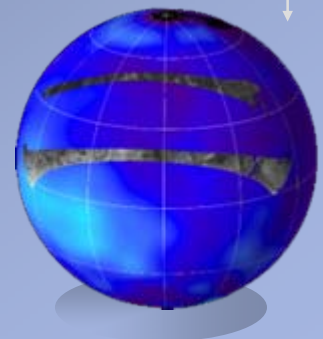
- Association with a vent (crater, caldera or fissure)
- Form constructs such as domes and shields
- Flows form lobate deposits
- Cryolavas are erupted at much lower temperatures than silicate lavas, but they can sculpt landscapes and resurface vast areas.
- Composition of cryolavas can have large effect on viscosity.
- Ammonia-water lavas have rheological properties similar to silicate lavas: this would be reflected on flow thickness (expect well-defined, thick margins) and final morphology of deposit



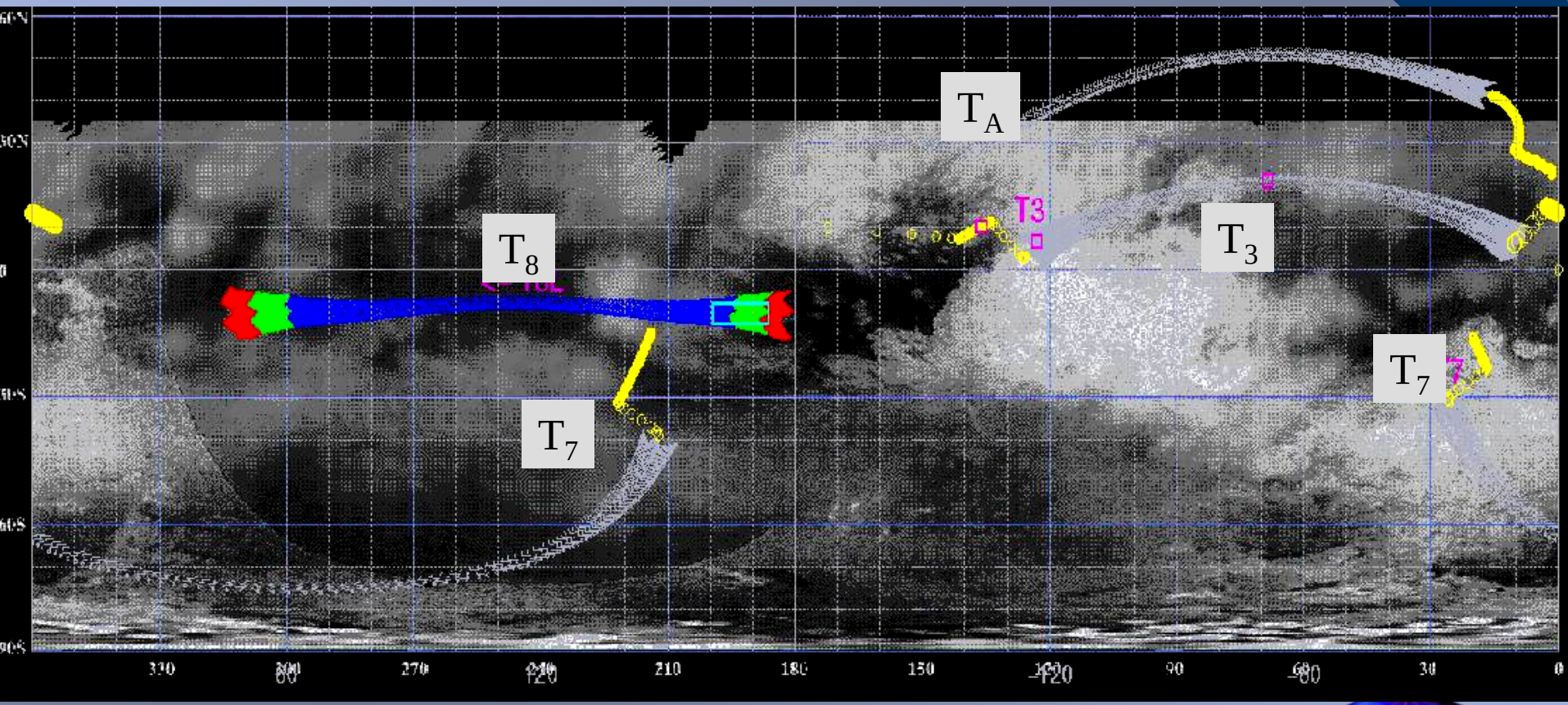
T3 fly-by: weak evidence for cryovolcanic flows

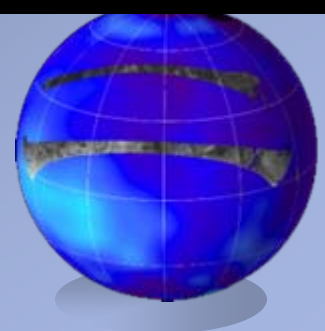
~ 300 km

T7: no evidence for cryovolcanism
T8: still under discussion!

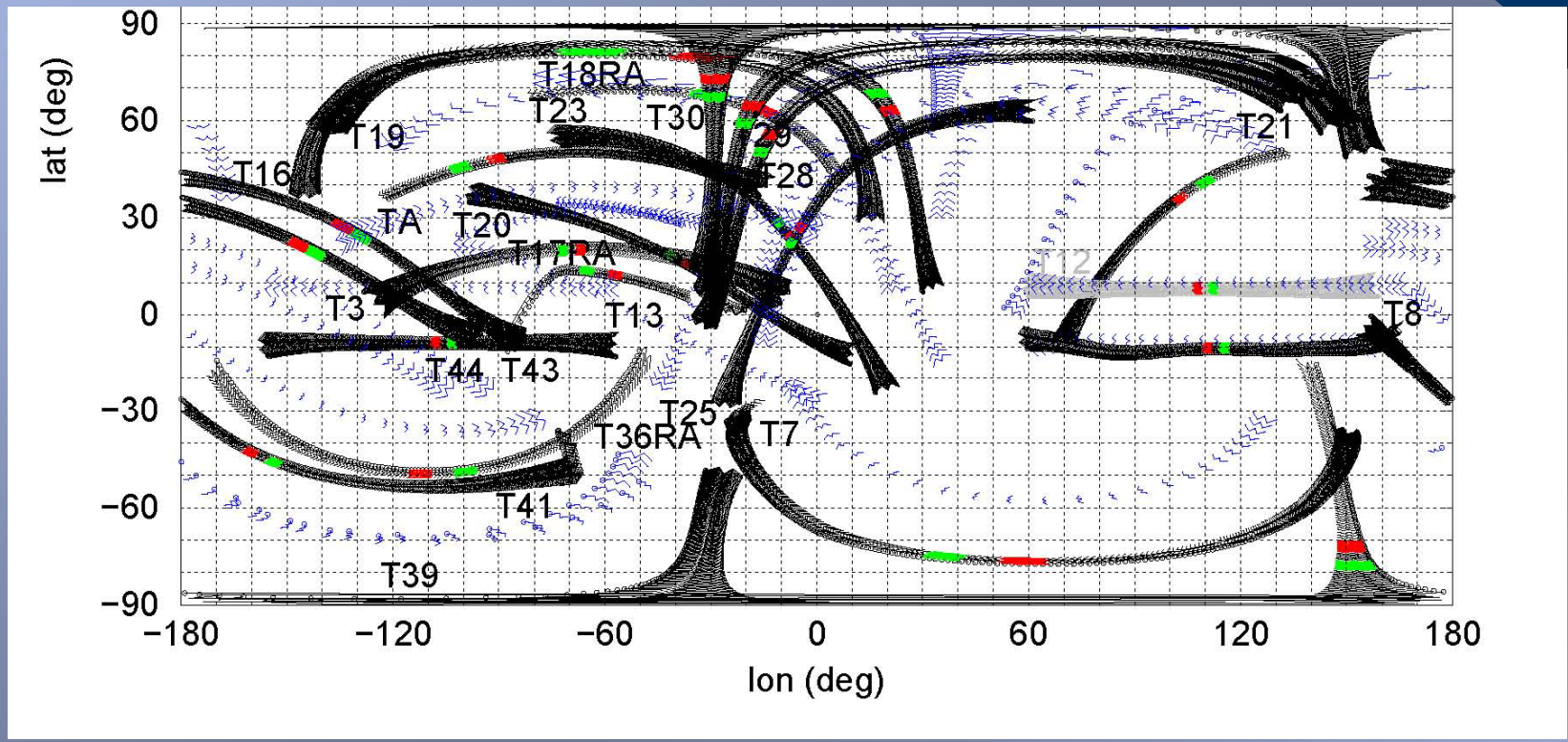


Location Map for Recent and Upcoming Titan SAR Coverage

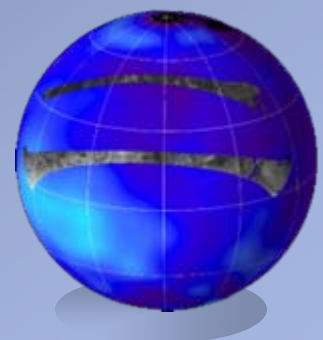


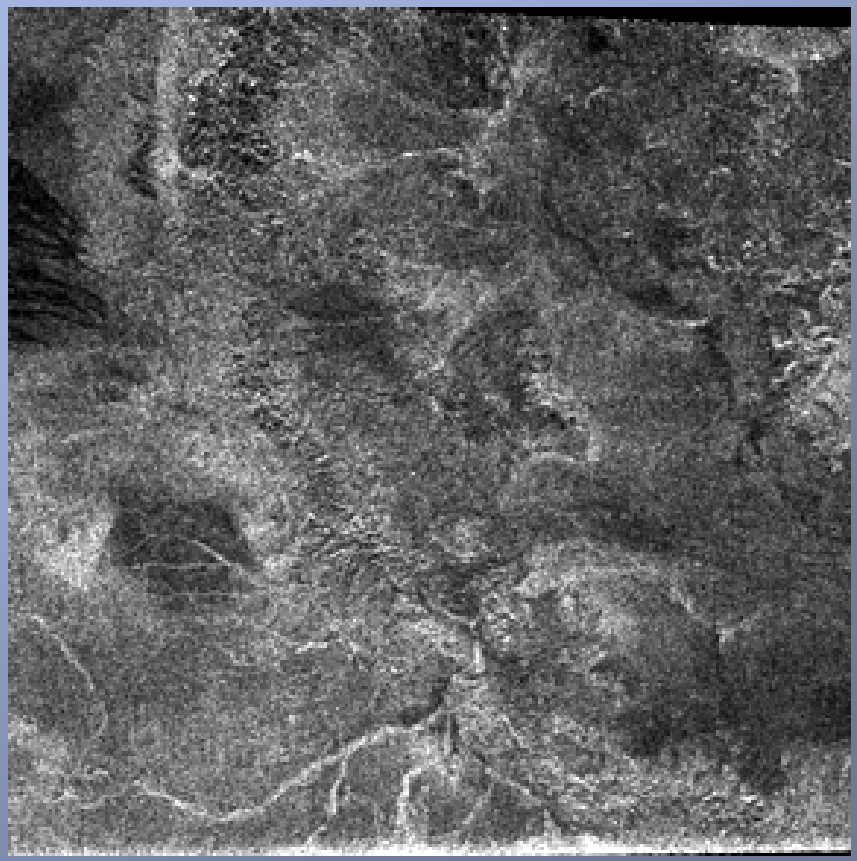


SAR Planned coverage during mission



SAR coverage in black (blue show ‘alternatives’ where we change the look direction from right to left or vice versa)





Conclusions

- Surface is surprisingly young (seen ~ 3%), dynamic
- Some smooth areas which may be liquids (but no clearly identifiable liquids yet)
- Geologic processes:
  - Cryovolcanism
  - Fluid flow (erosion/deposition)
  - Impact craters
  - Aeolian processes
  - Tectonics