SCIENTIFIC OBJECTIVES AND ENGINEERING CONSTRAINTS OF FUTURE TITAN LANDING SITES

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Titan

Huygens 1655
Ø: 5150 km
Period: 15.94 d
Distance: 1,221,850 km
Inclination: 0,33 °
Excentricity: 0.029
Surface Temperature: -180 ° C
Surface Composition: H_2O-Eis + organics
Gravity: ~1/7 g
Surface Pressure: 1,6 bar
Density: 1.88 g/cm³
Atmosphere: 90-97% N_2, 2-5% CH_4
900 km thick(!!)
Aerosol (C:N:H~10:10:1)

ISS, 0.338µm
Resolution:4.7 km/px

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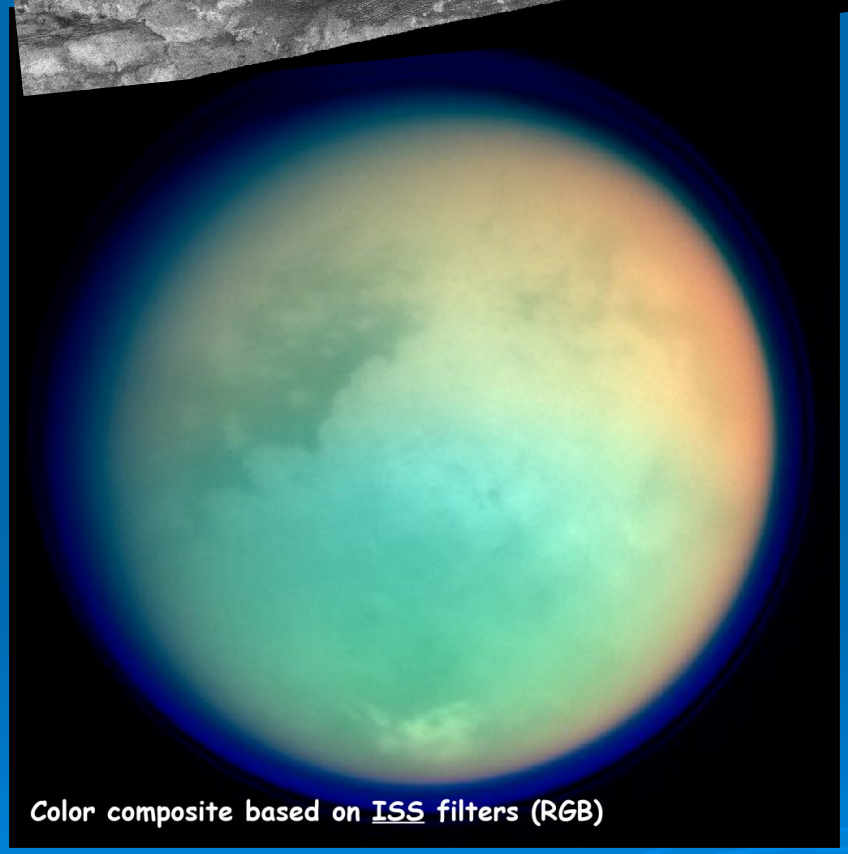
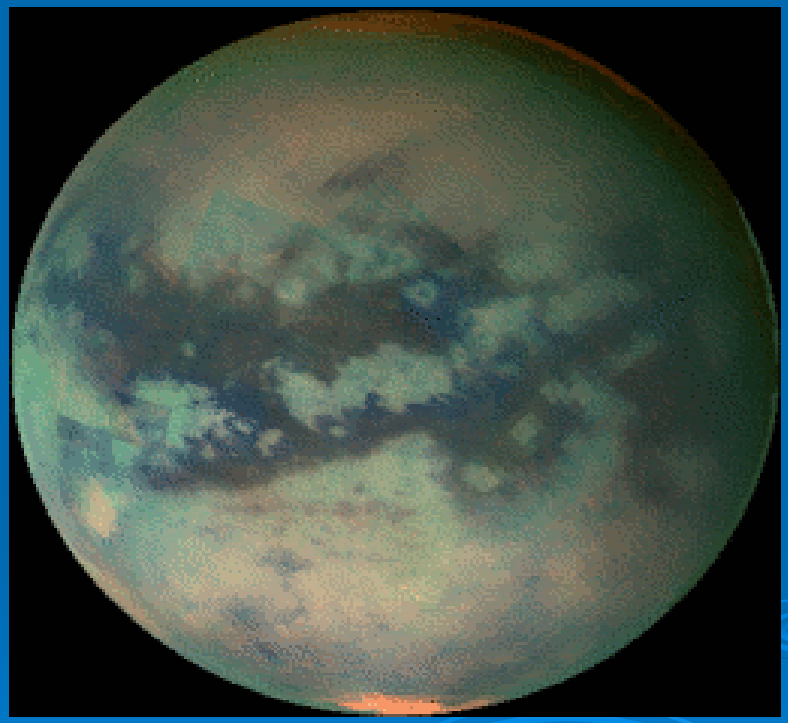
Titan



Color composite based on ISS filters (RGB)



Color composite based on VIMS channels

at 5, 2 and 1.3 µm

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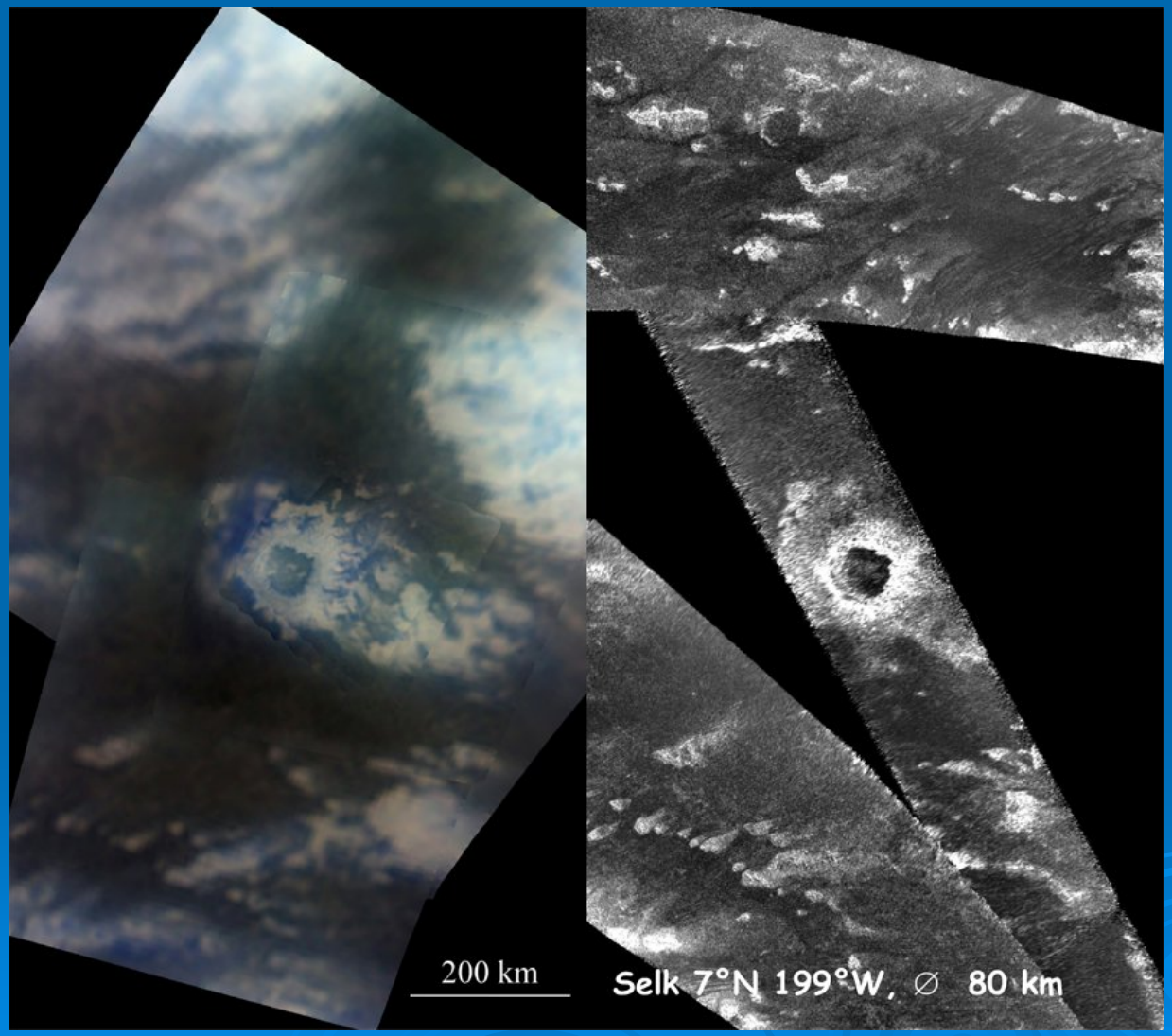

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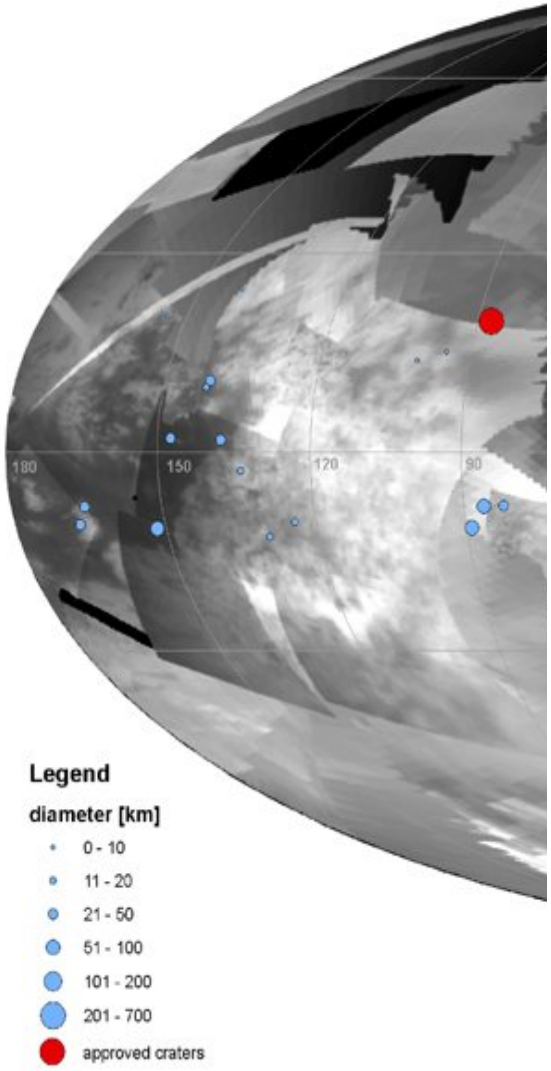
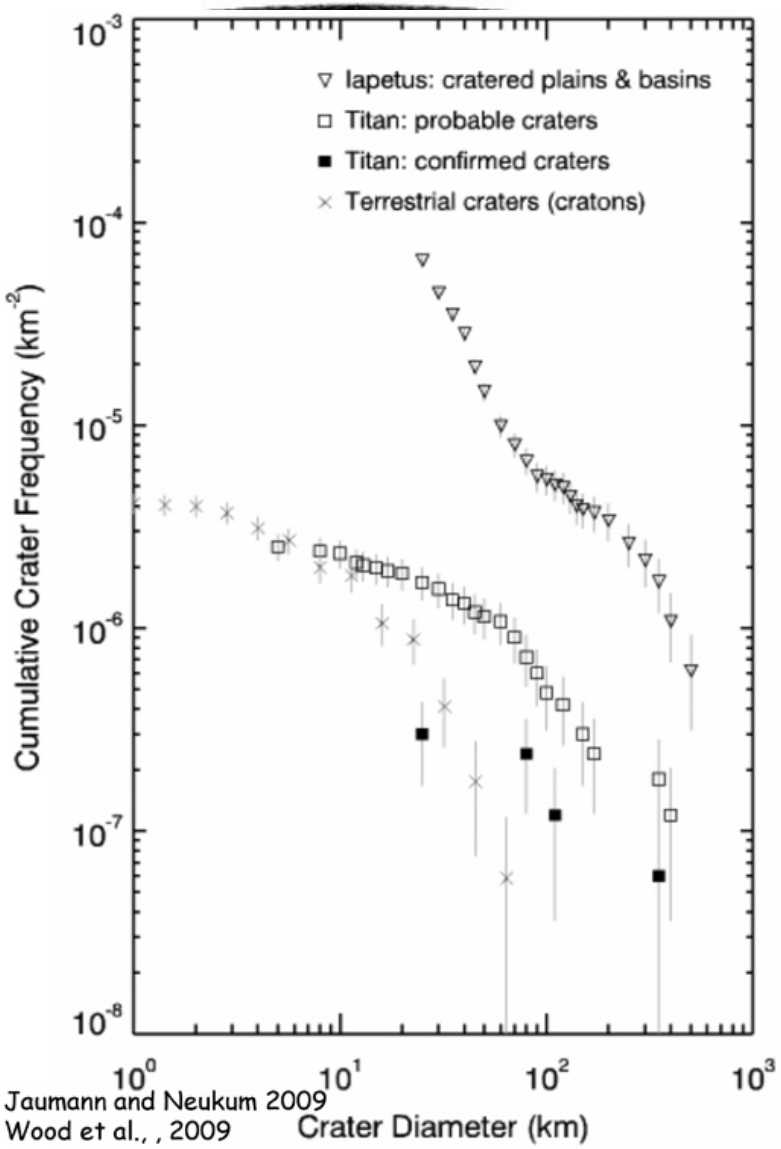
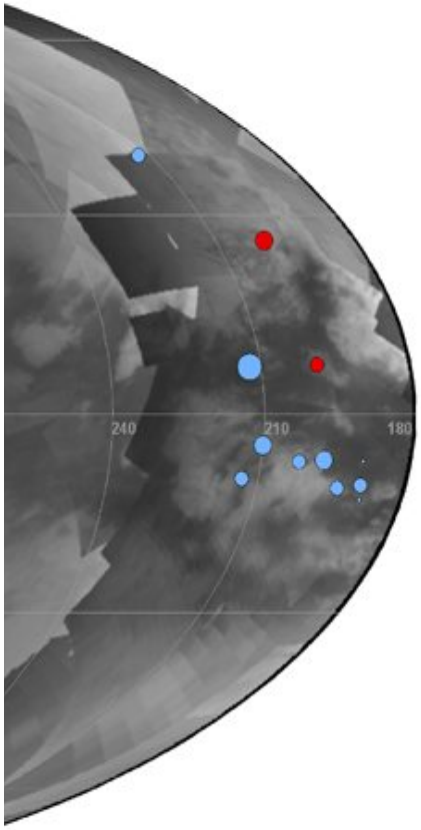




Jaumann and Neukum 2009
Wood et al., , 2009



Malaska, 2009
Jaumann and Neukum, 2009

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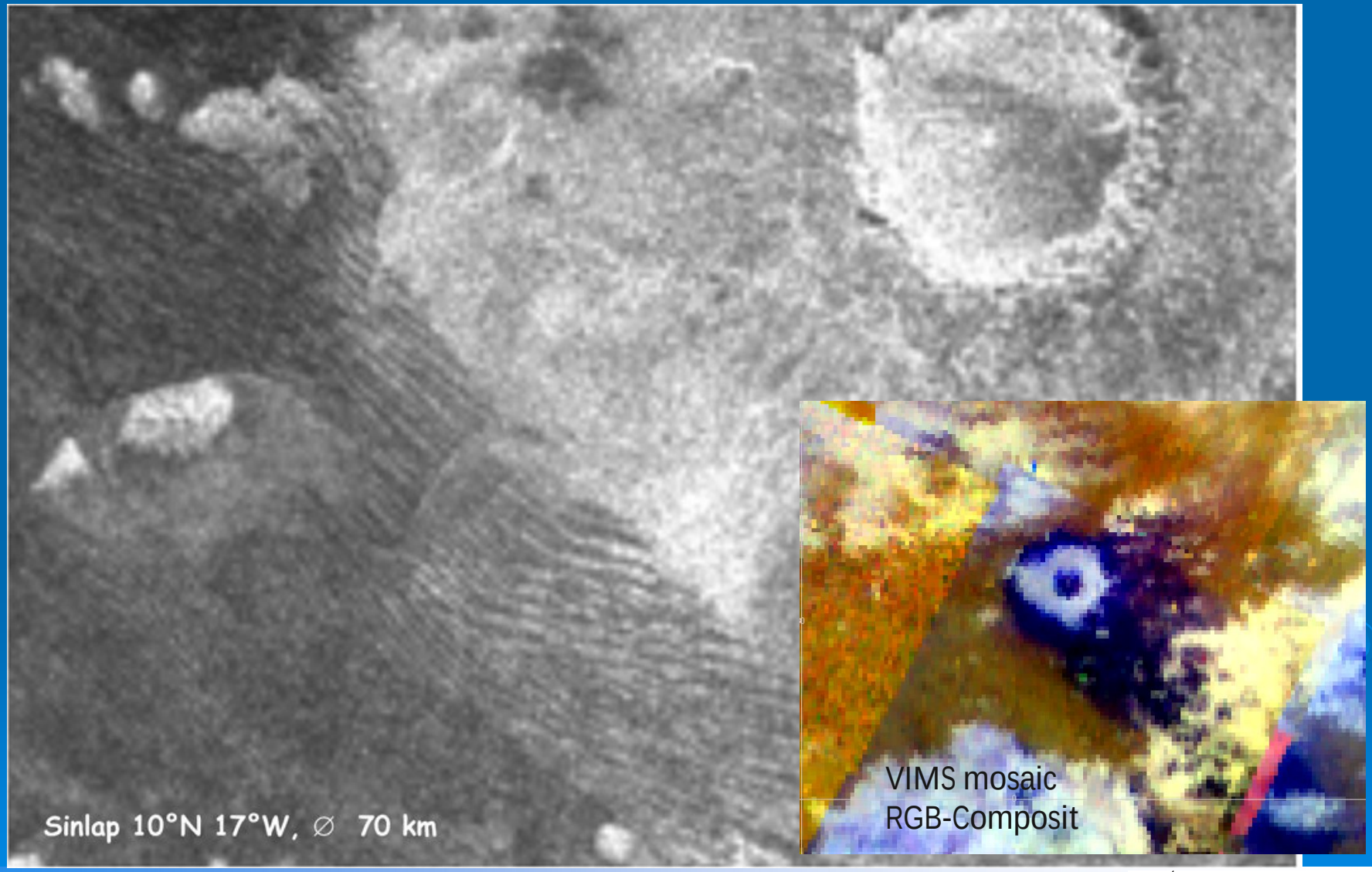

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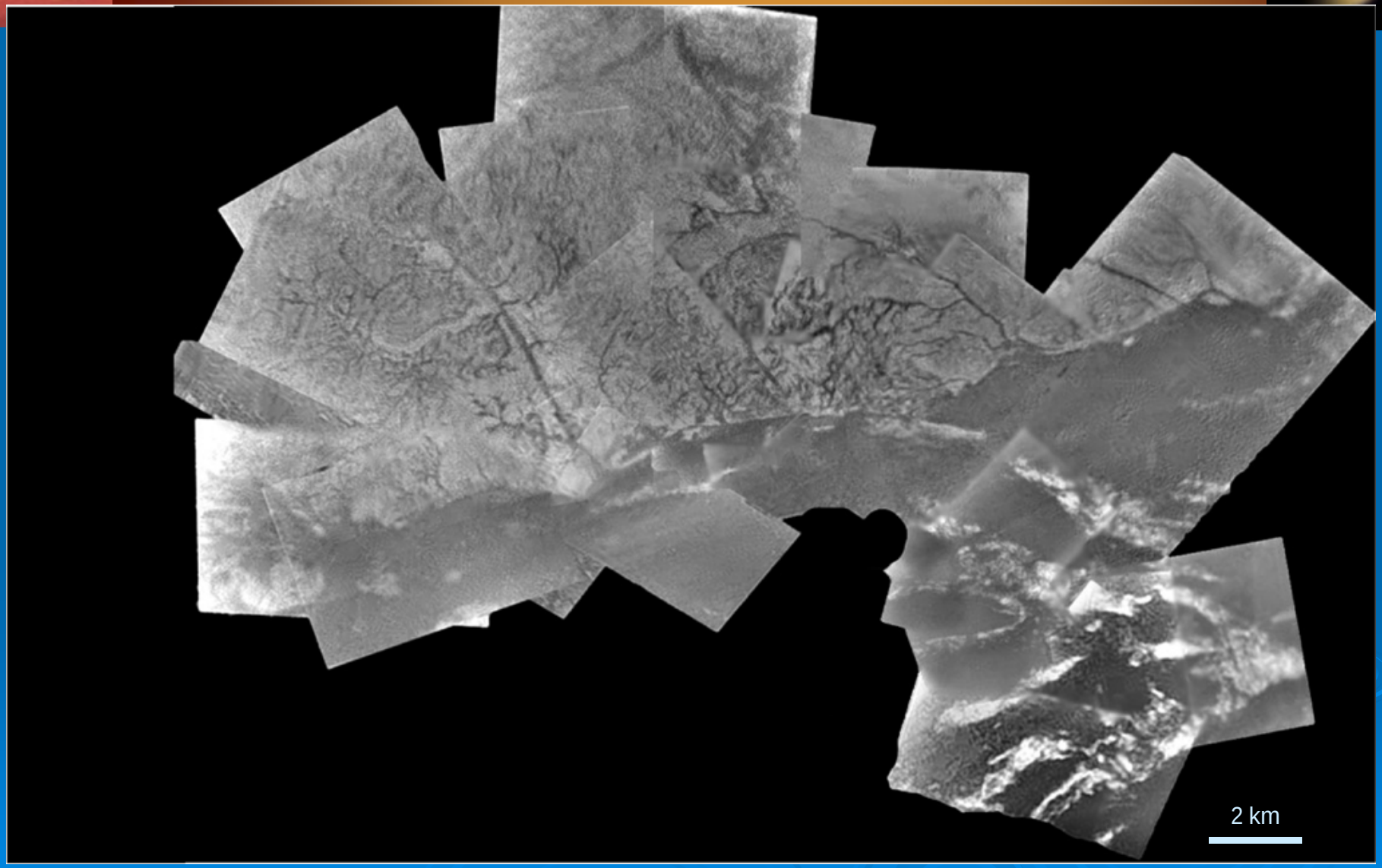

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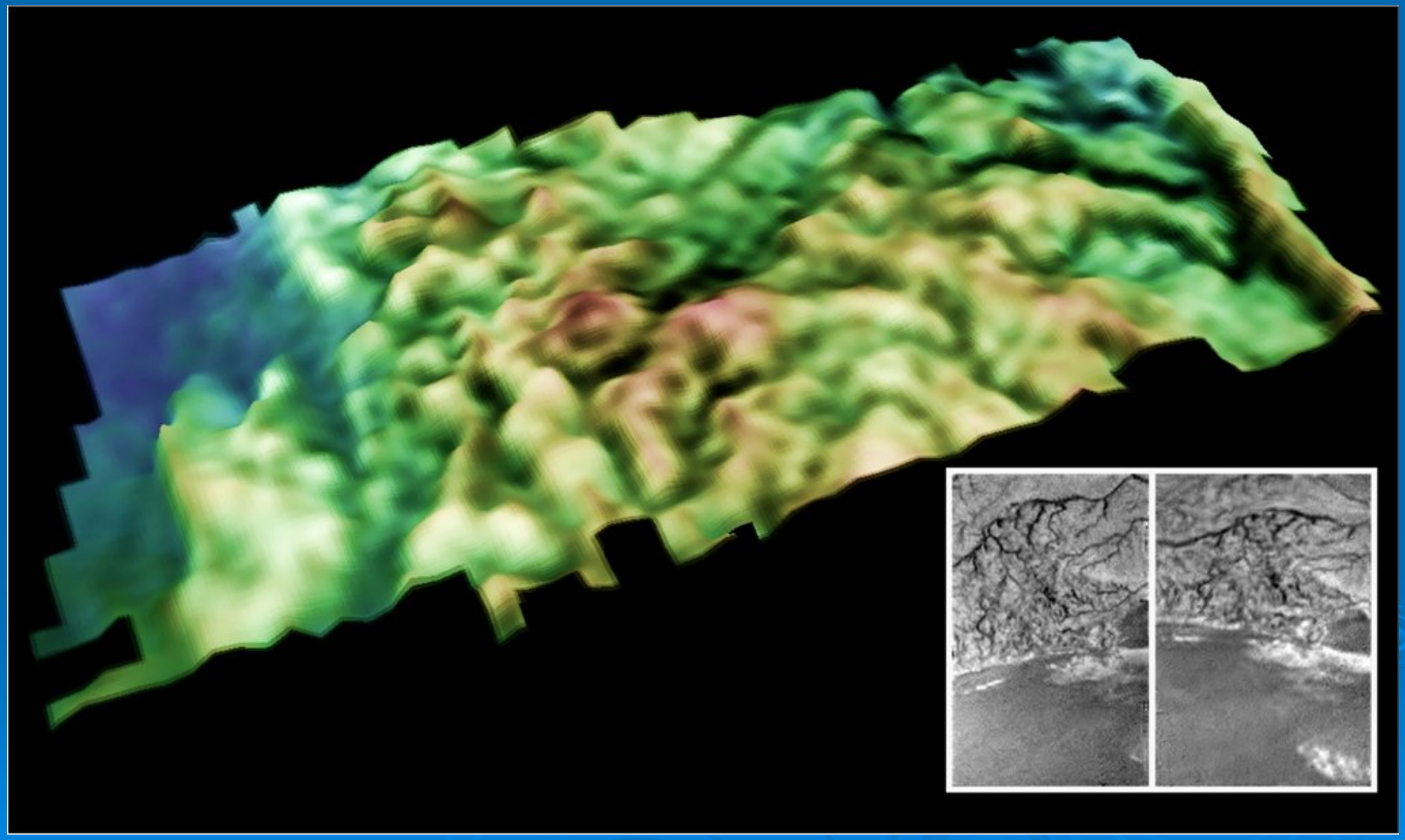

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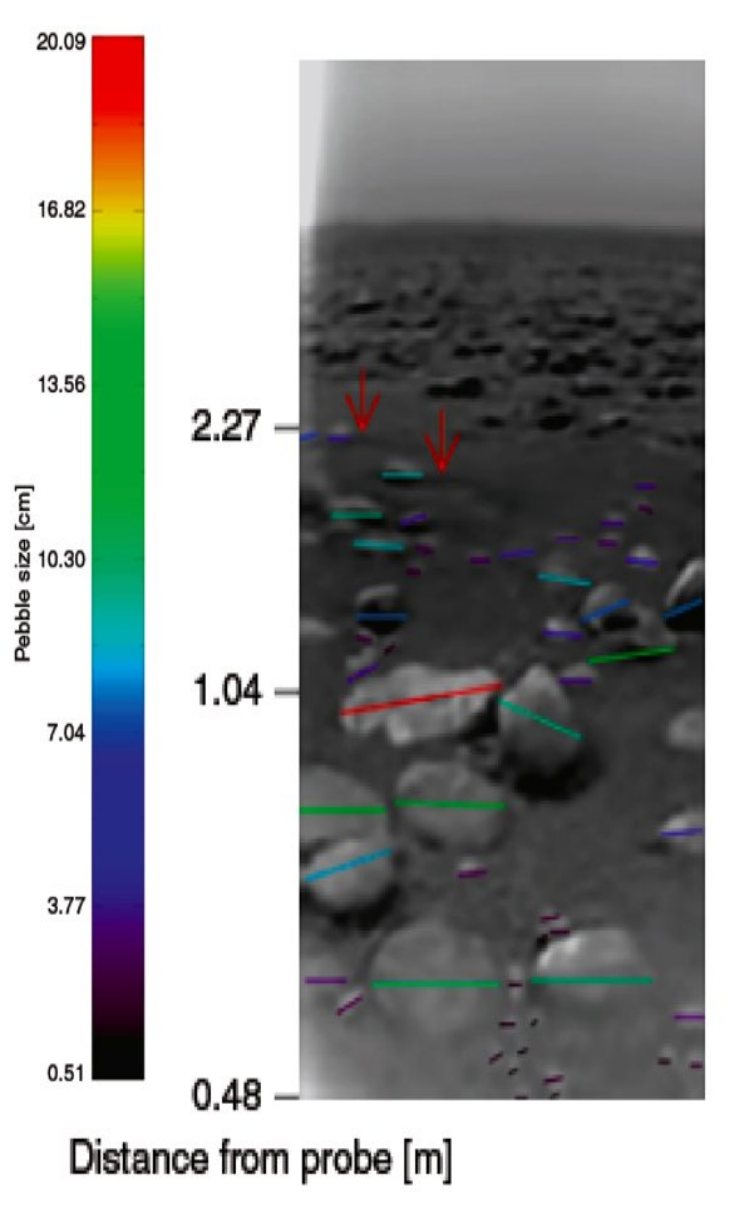

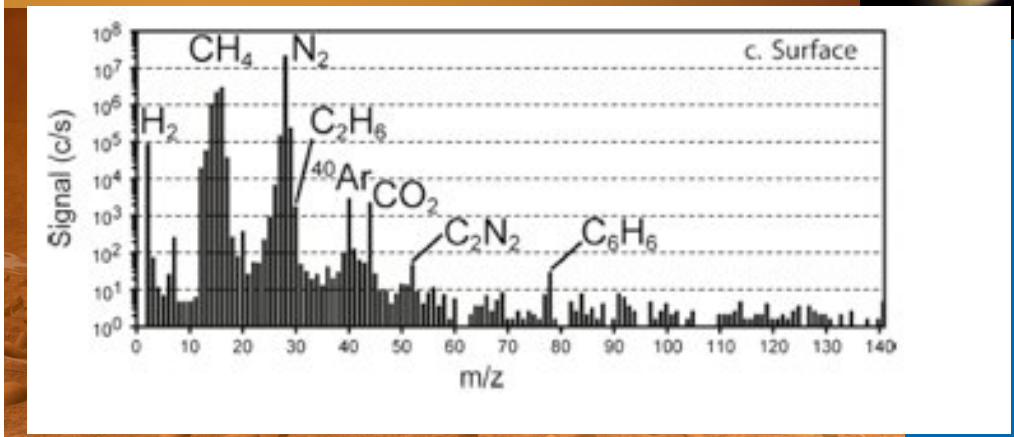

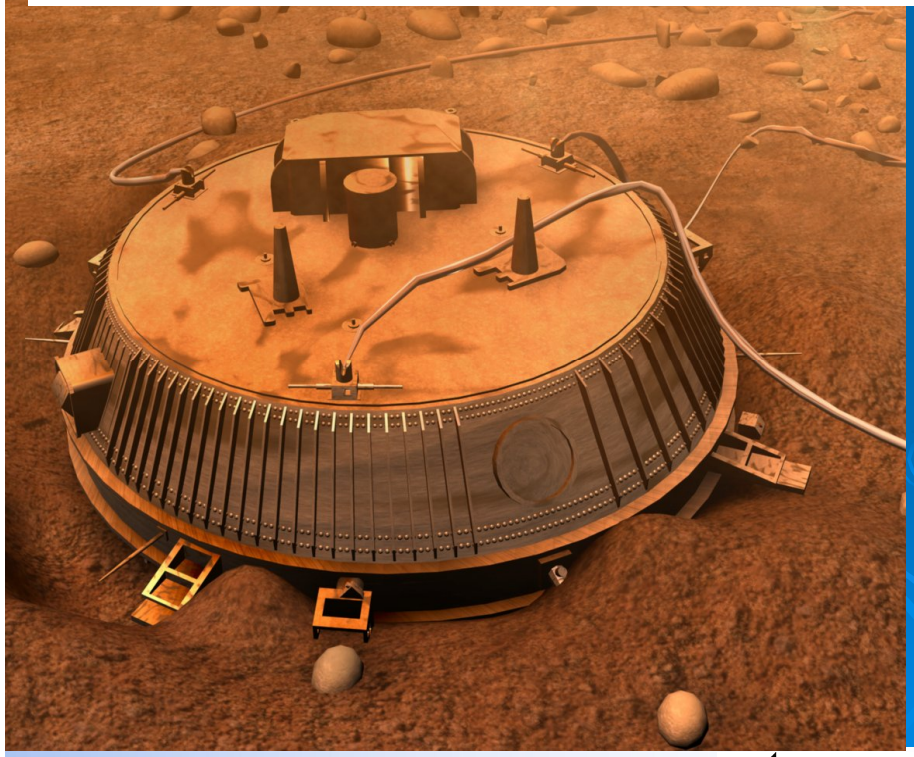

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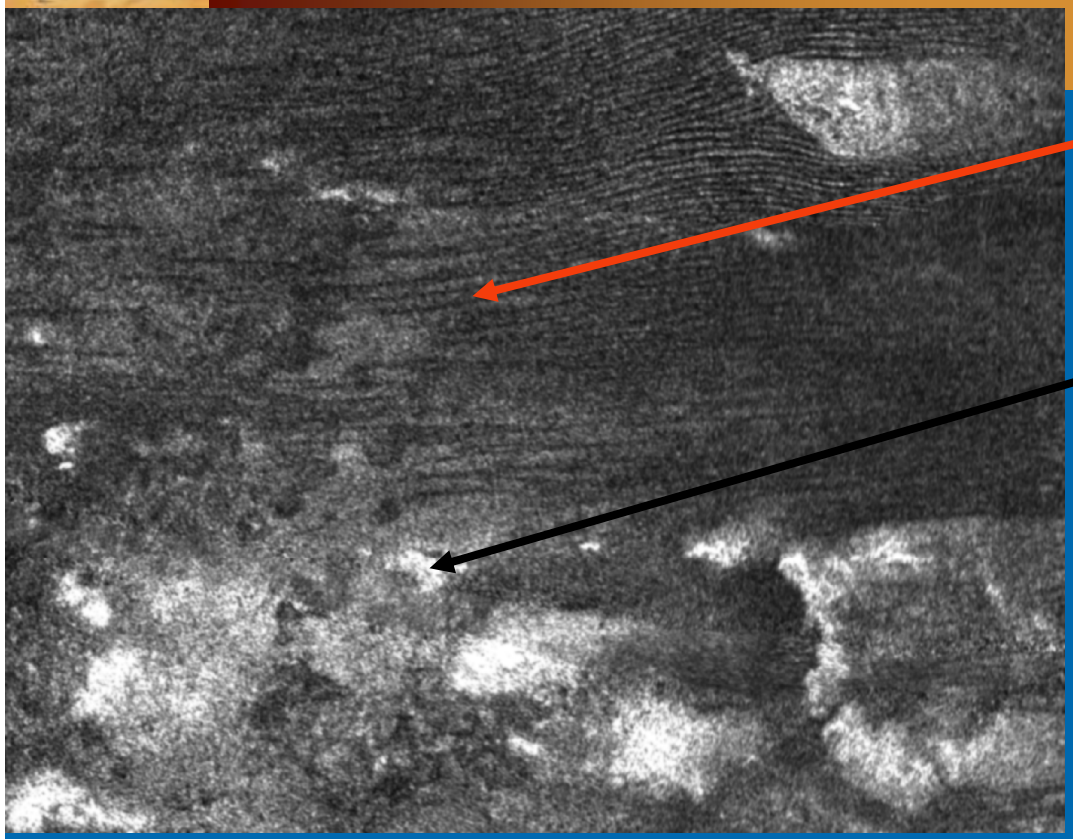

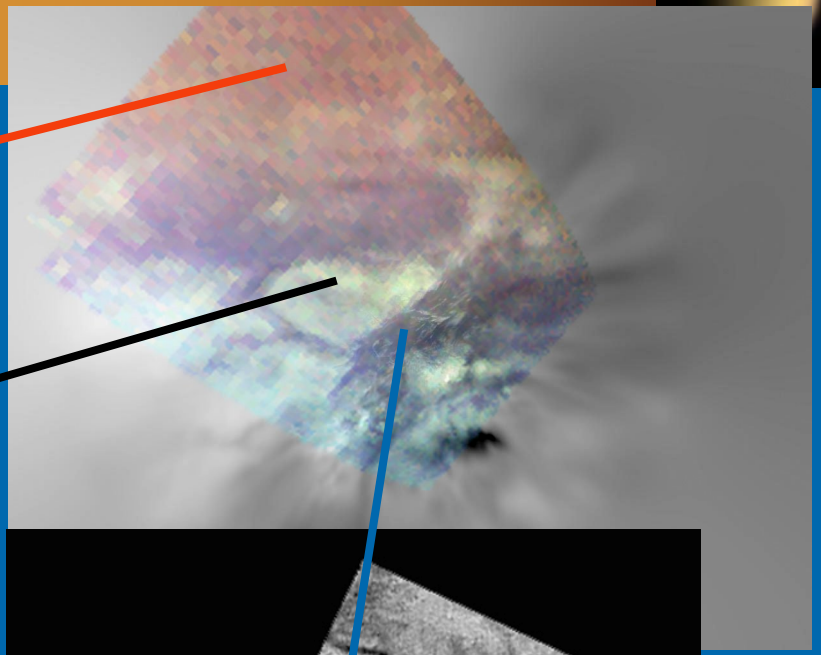

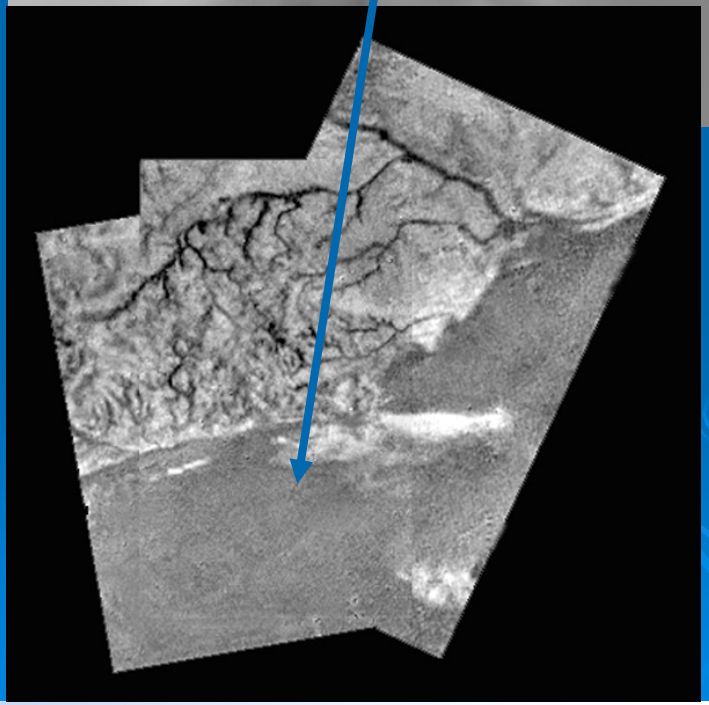

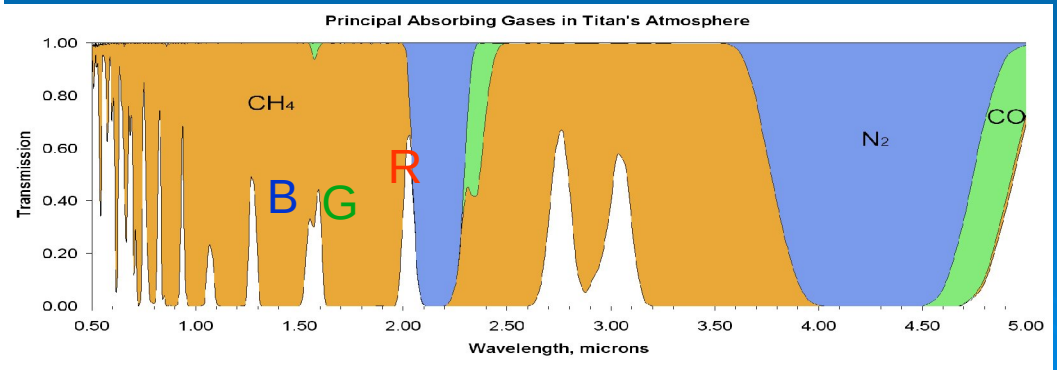

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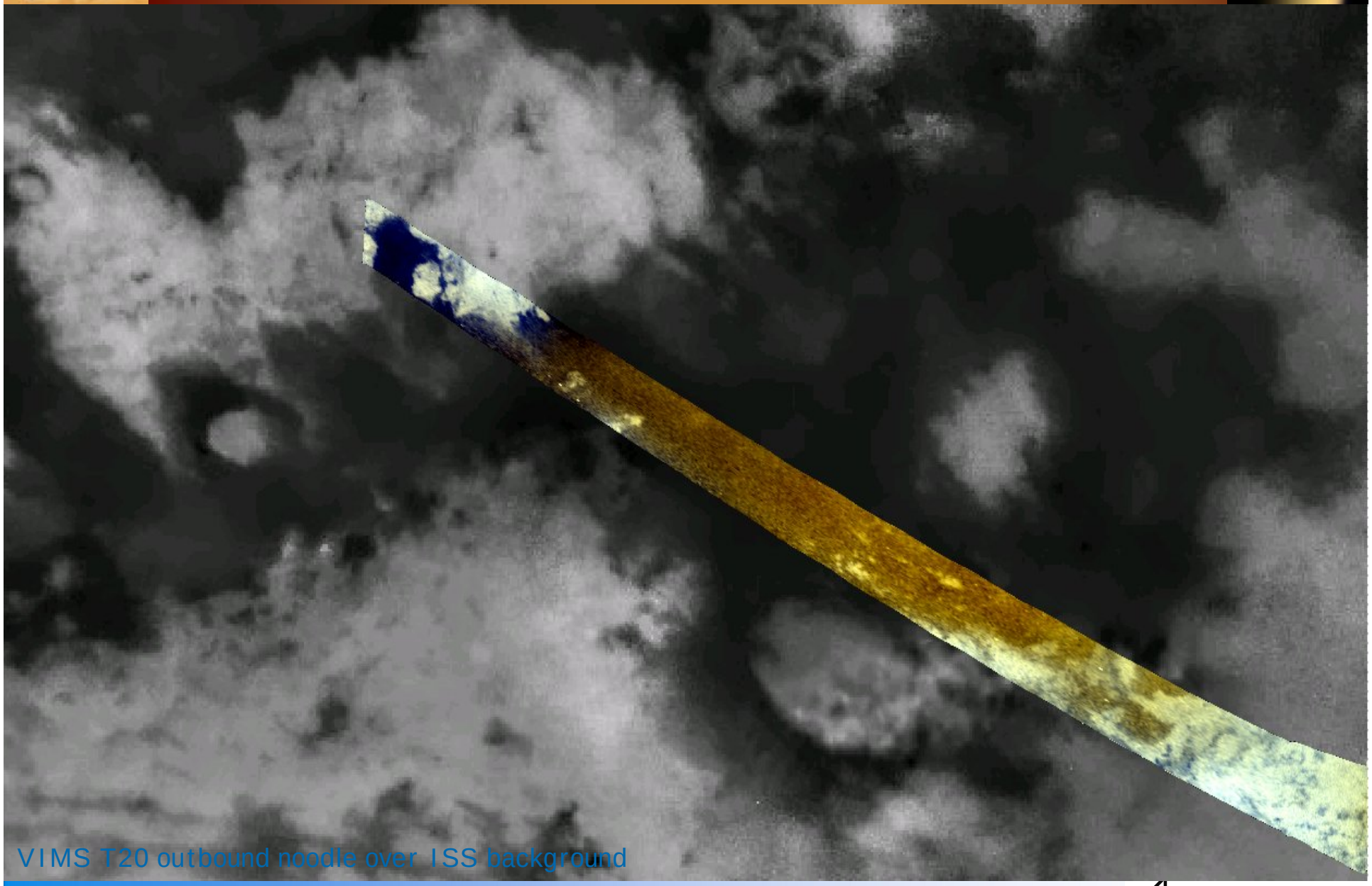

VIMS T20 outbound noodle over ISS background

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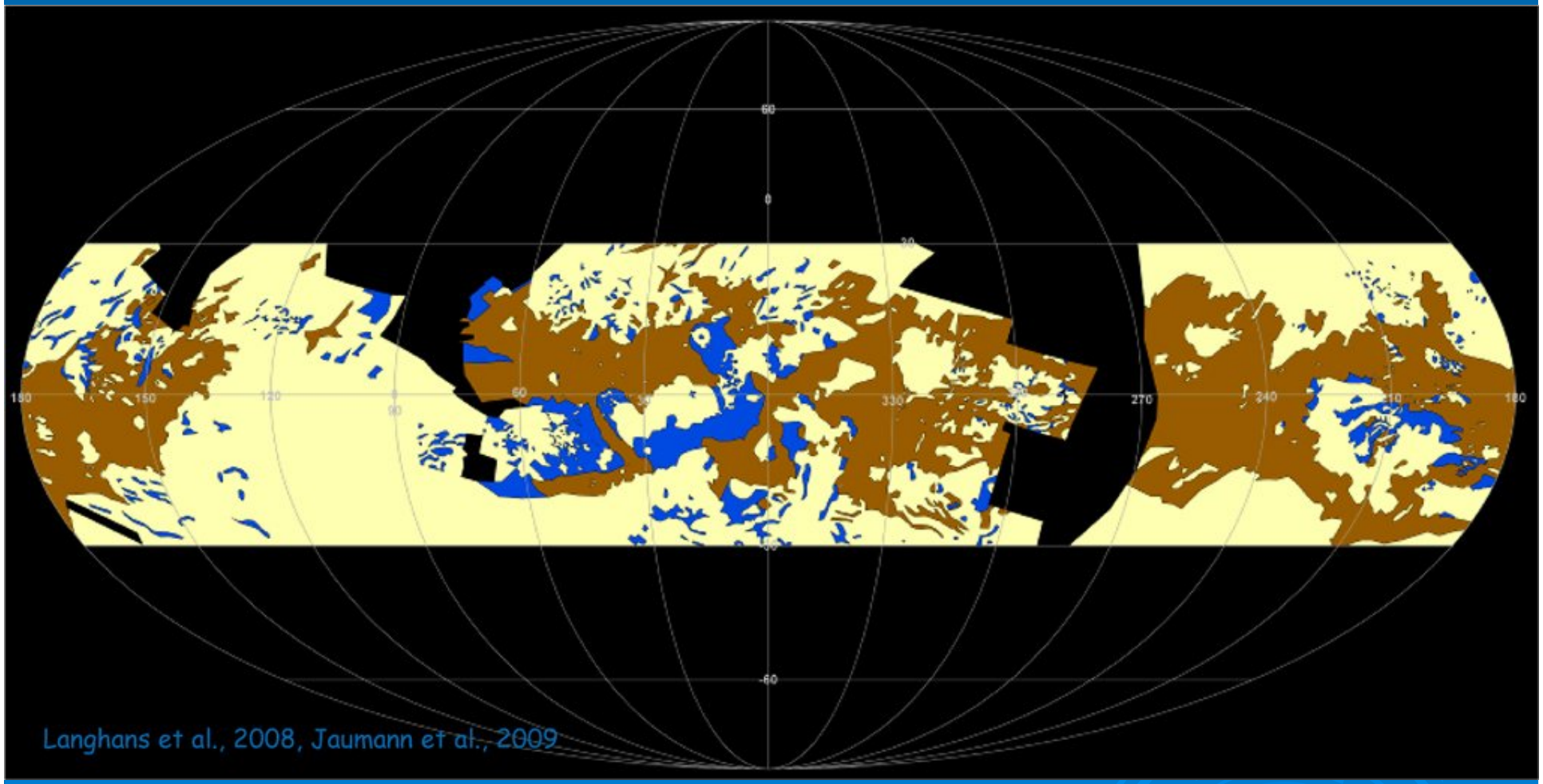

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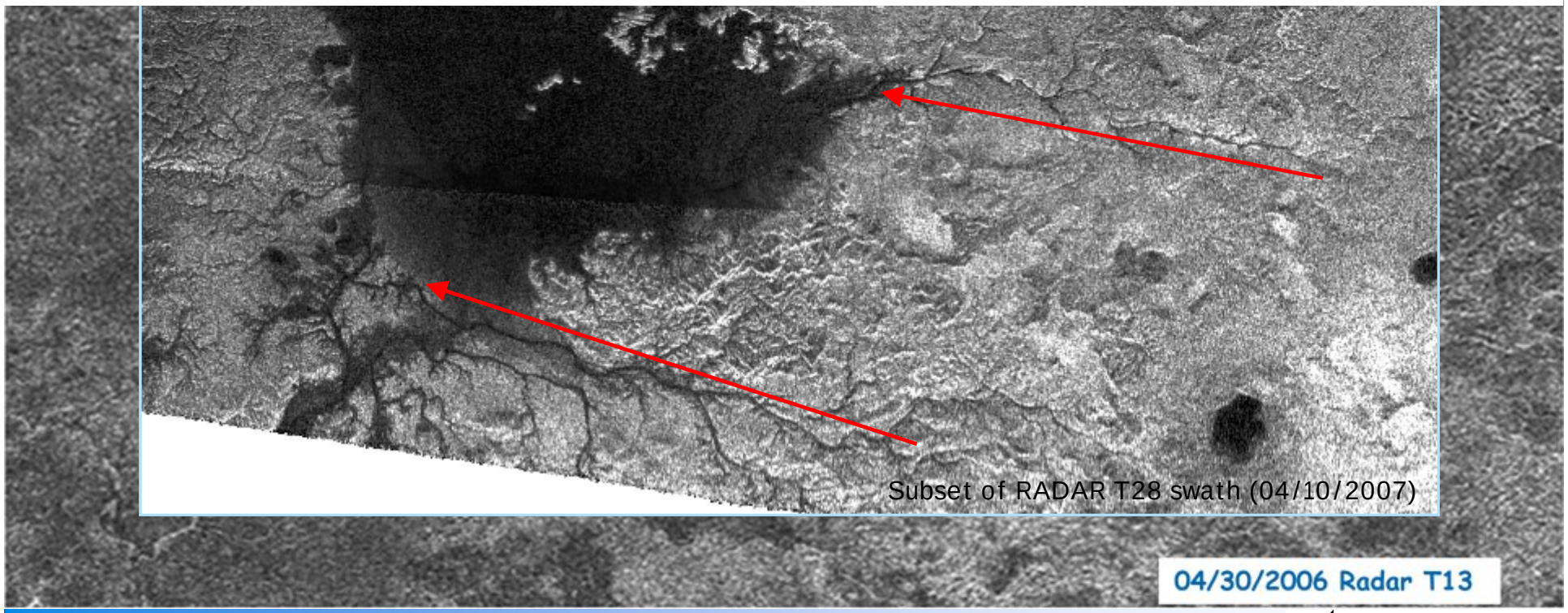
Titan

River systems: dendritic, meandering, branched networks;
radar bright: suggesting to be filled with boulders
radar dark: suggested to be filled with smooth deposits or liquid (e.g. Lorenz et al., 2006, Porco et al., 2005; Barnes et al., 2007: Lorenz et al., 2008;Jaumann et al., 2008,2009)



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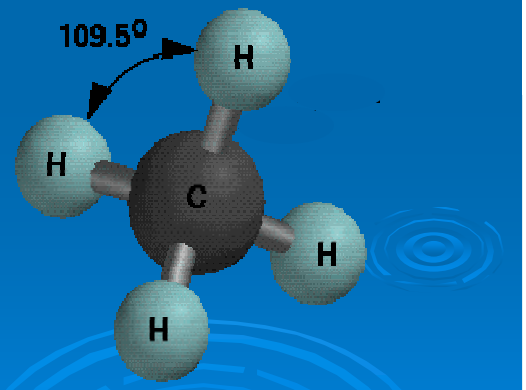
Titan

- Tripel point of methane at Titan's conditions 95K and 1.6 Bar atmospheric pressure
- Viscosity of methane (at 95K): 1.8x10-4 Pa s ~ 5 times lower than water on Earth
- Vapor pressure of methane is high enough to participate in a hydrological cycle on Titan
- Dendritic valley-system: up to 1200km lengths and discharge: 1600-18.270m³/s (1yr-1000yr recurrence)

Earth:
rivers (> 10m wide) 10 - 3 x $10^5 m^3/s$
outflow 10^5 - 10^7 m^3/s

Mars:
rivers (> 10m wide) 10 - 10^6 m^3/s
outflow 10^6 - 10^9 m^3/s



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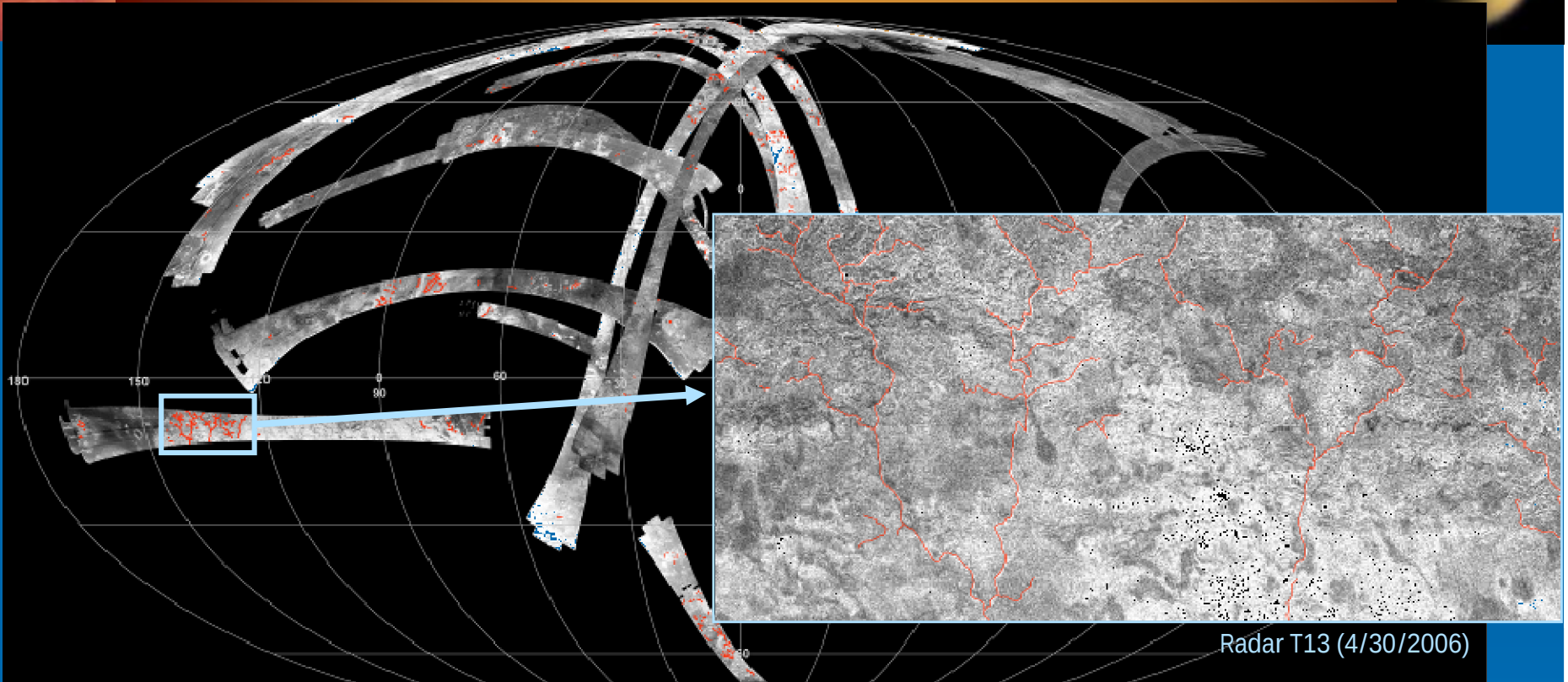

Global Radar-map of Titan. Mollweide projection. Fluvial channels are highlighted in red.

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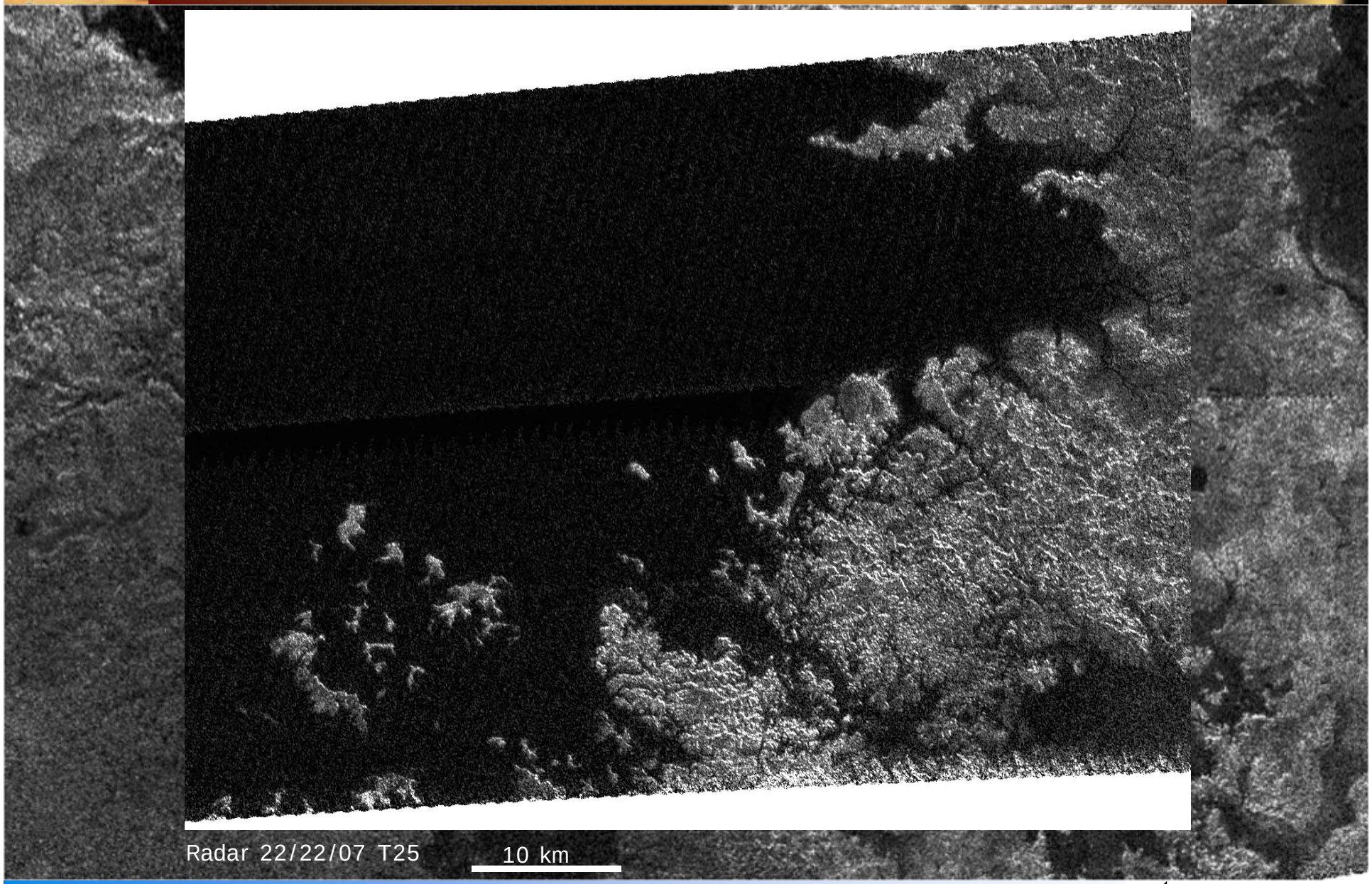
Titan



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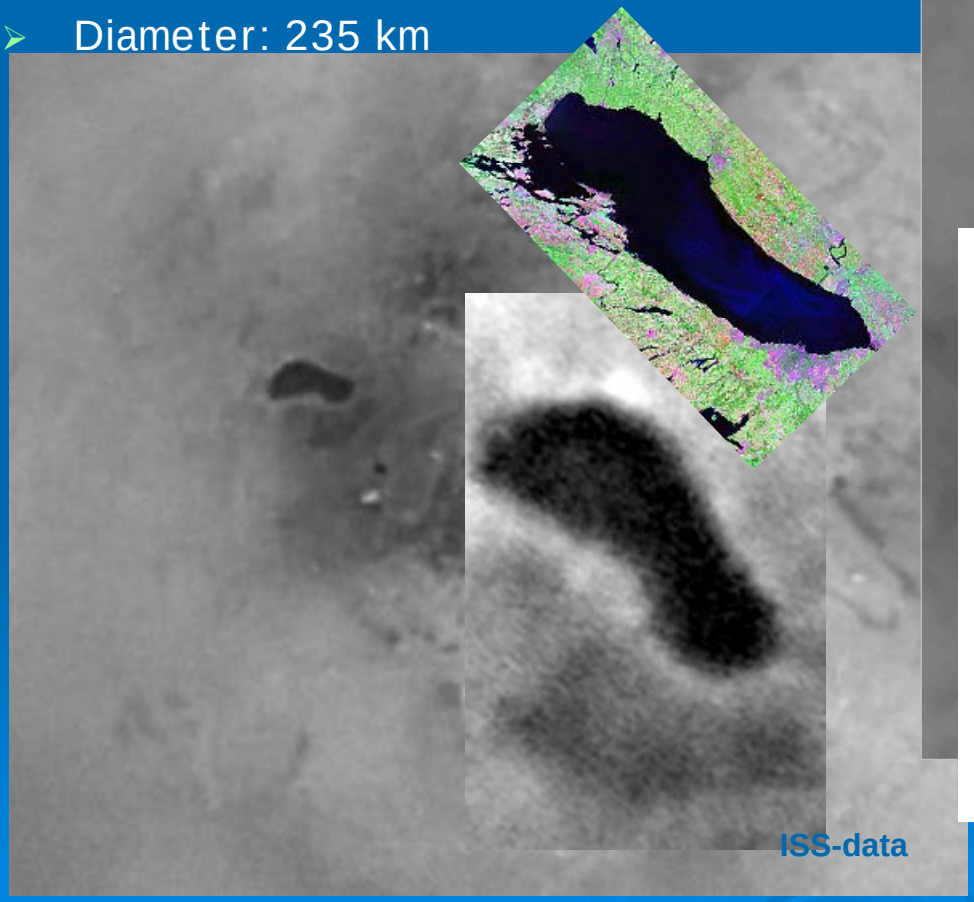
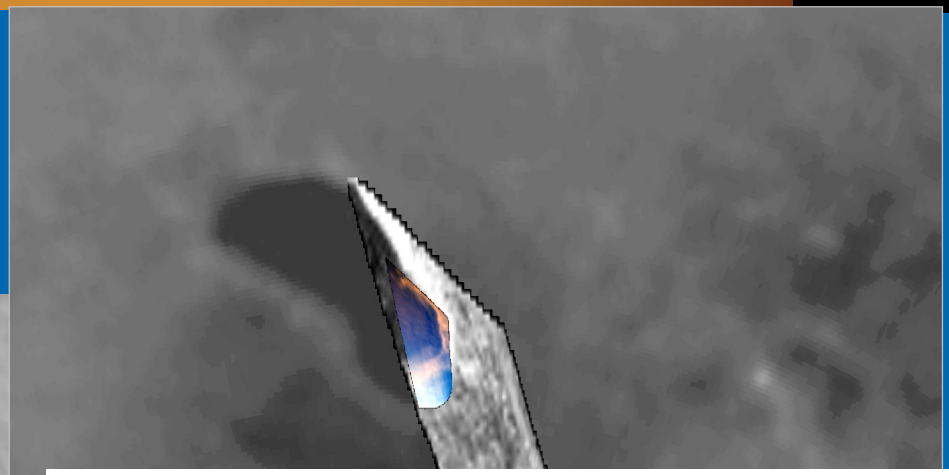
Titan

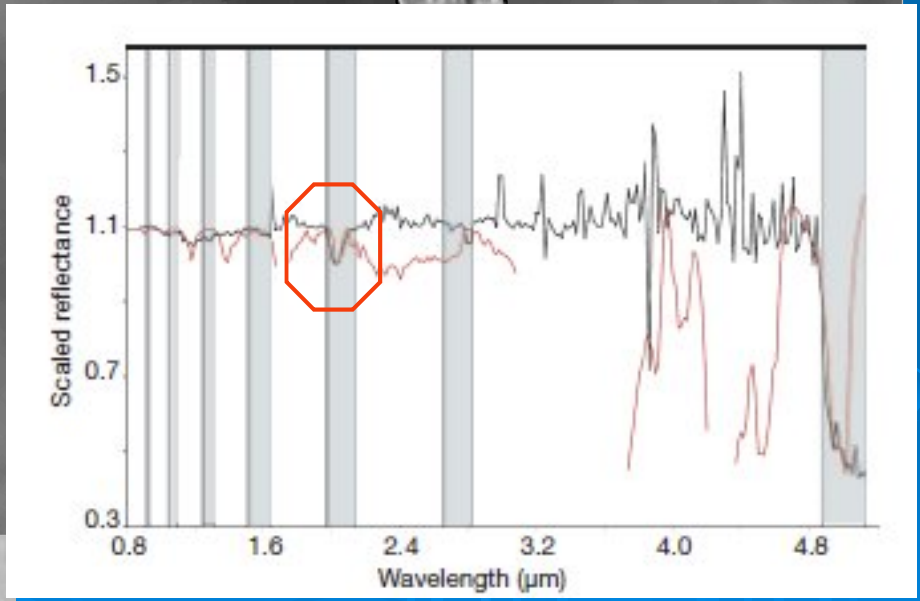
Lakes on Titan:

Ontario Lacus

- Coordinates: 72 ° S 183 ° W
- Area: 20.000 km^2
- Diameter: 235 km







(Brown, Jaumann et al., 2008)

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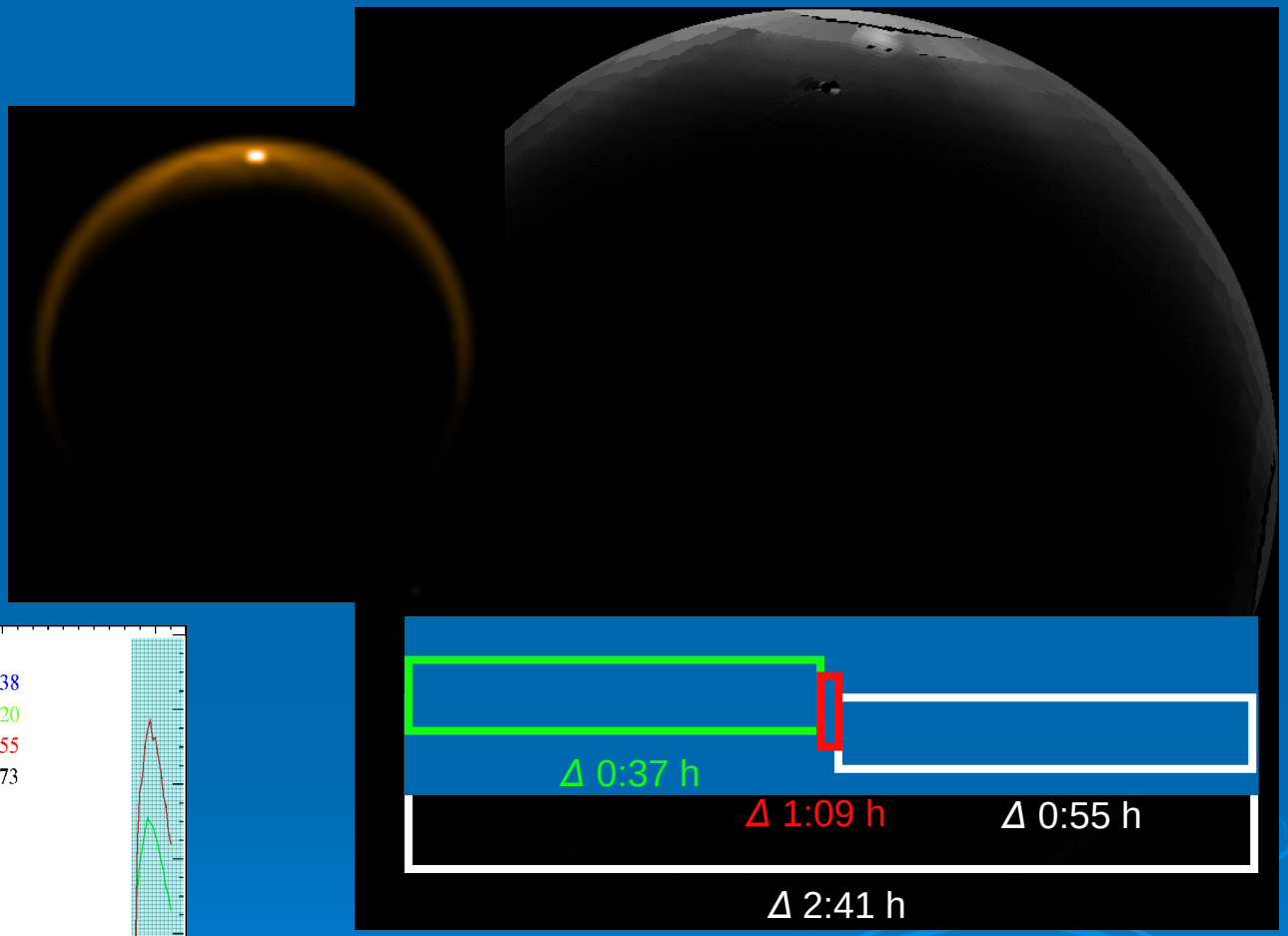
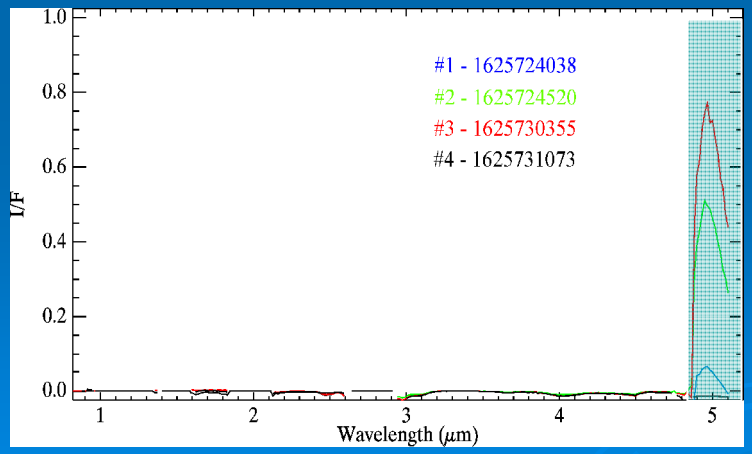
Titan
T58 Observations

VIMS observations from July 8th, 2009 show a spatial very limited (1-2 VIMS pixel) strong reflection at 5µm in Titan's northern polar region

(Stephan et al., 2010)





Corresponding VIMS spectra with the peak at ~5µm

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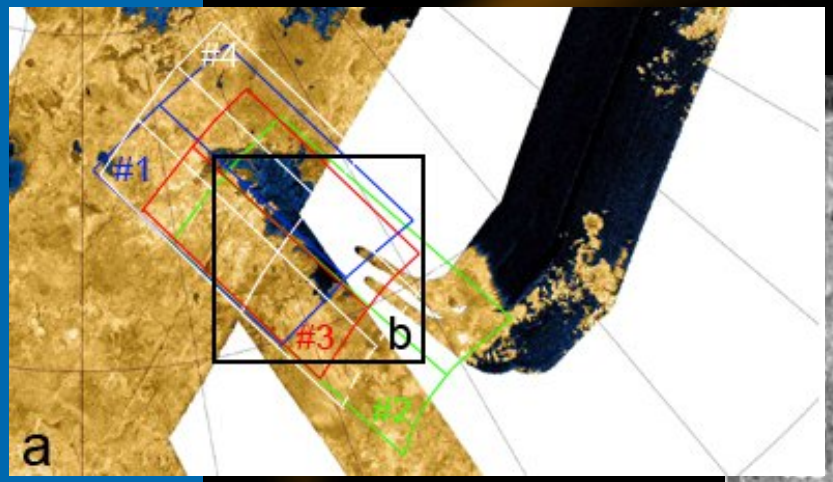
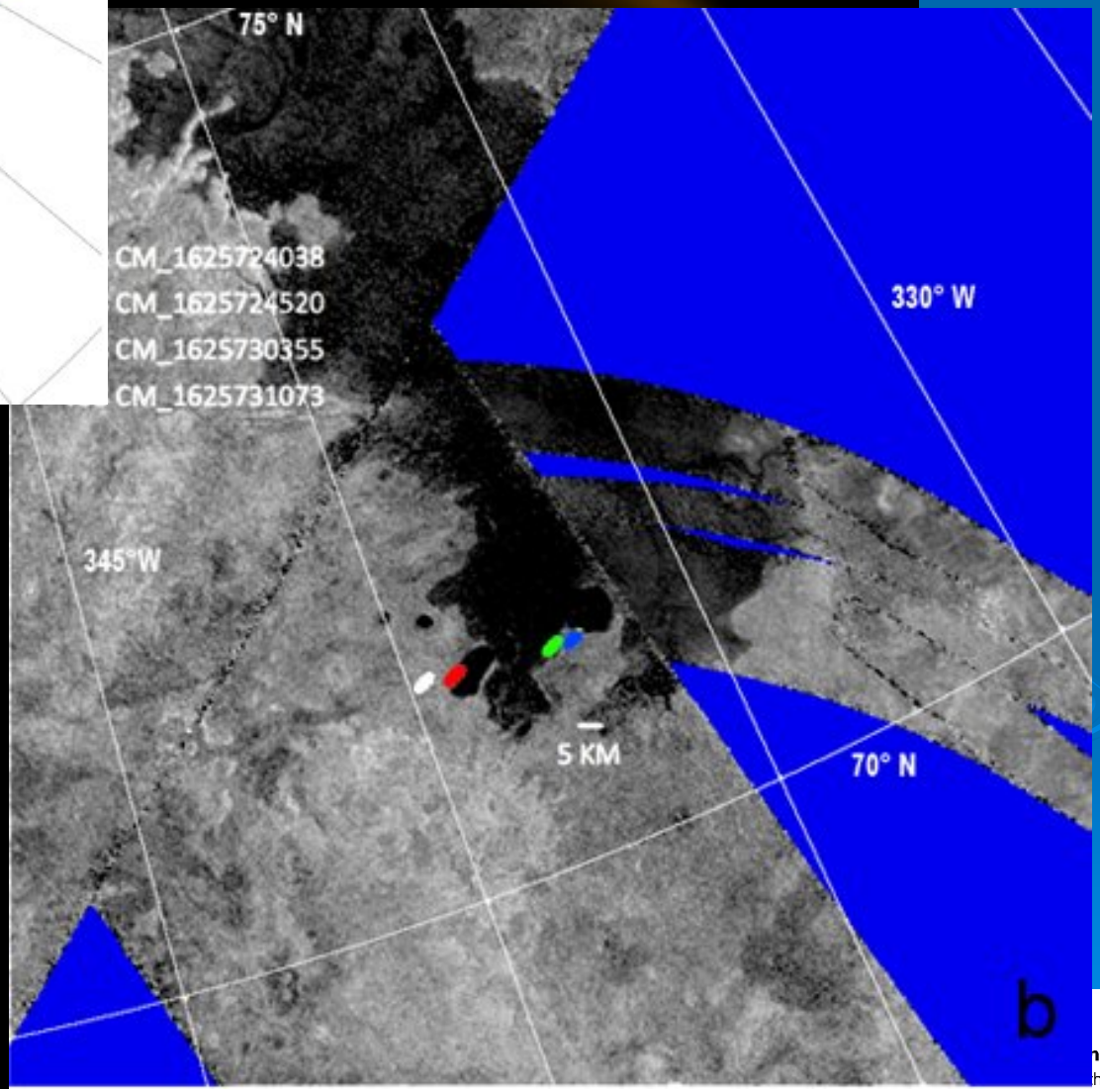
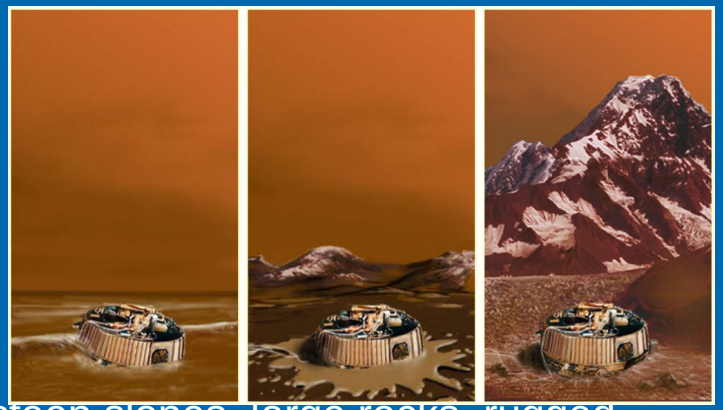


Expected size of the Sun‘s image in the Western part of Kraken Mare:
~4.4 by 1.3 km



Titan

Engineering Constraints to potential Landing Sites on Titan



Mission Success comes first => Safety is the highest order criterion over any other scientific
or engineering constraint

Terrain relief/slopes:
'free' area over size of landing ellipse (~1000km needed, no steep slopes, large rocks, rugged surface (canyons, craters, channels, etc.)
Uniformity in major surface features, i.e. no change between solid and liquid surface on smaller scales than size of landing ellipse;
Assumption: a Doppler velocimeter/altimeter on the carrier module will be used (e.g. to control time of airbag inflation): These systems will measure the distance to the surface and the descent velocity (both vertical and horizontal components). Although not all of the landing ellipse must meet all of the slope requirements, the more area that exceeds them, the less likely the site would meet all the safety criteria thereby increasing the chances for failure.

Latitude and elevation:
Elevation plays a role w.r.t. the EDLS design. In Titan's thick atmosphere a system approach will favour a soft landing using parachutes rather than an active landing system.

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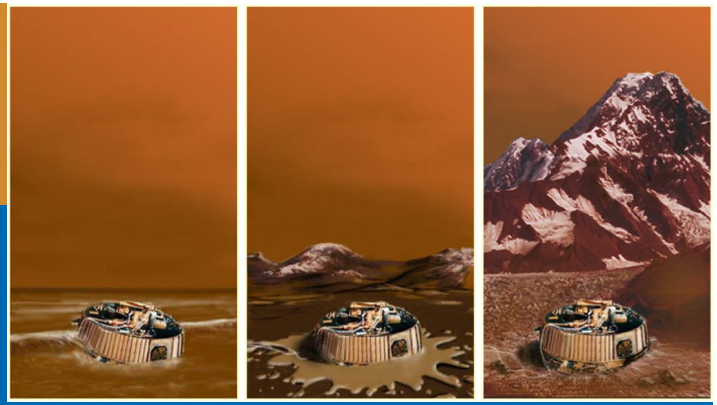

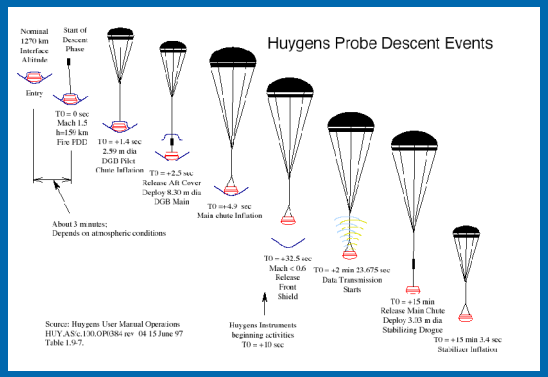

Engineering Constraints to potential Landing Sites on Titan

Landing Ellipse/Warning track:
~1000 km (preliminary estimation), dispersion from winds during parachute descent needs to be considered.

Atmospheric Parameters:
due to Titan's dense atmosphere no difficulties with EDL are expected.

Surface Parameters:
The surface material at the landing site must: i) be radar reflective (sufficient radar backscatter cross-section) to enable measurement of altitude and velocity during descent, ii) bear the load of the lander at landing, iii) experience a range of temperatures within the limits of the lander design.

Illumination:
Variation of illumination geometry is maximum at low altitudes (e.g. for phase function studies).
Illumination is strong (high light level, but small shadows) in polar summer
(=South, late 2020s/early 2030s)
Illumination weak is (scattered light plus Saturn shine) in polar winter
(=North, late 2020s/early 2030s).

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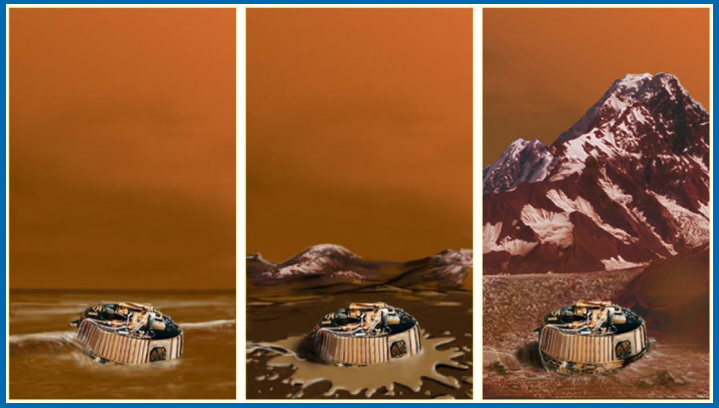
Engineering Constraints to potential Landing Sites on Titan



Power:
The negligible available solar power on Titan's surface requires implementation of radioisotopic devices for electrical power generation

Communication/tracking:
Low-latitude landing sites will 'see' Earth and Sun ~1/3 of the time – elevation changes continuously. High latitude (summer) landing site will see Earth and Sun 50-100% of the time, with rather constant (but low) elevation.

Delivery:
Trade/off: soft landing do not have to withstand high deceleration impacts, but are more restrictive in landing locations. Delivery accuracy will depend on entry angle. Allowable entry angles will depend on entry speed (from Titan orbit? From Saturn orbit? From arrival hyperbola?)

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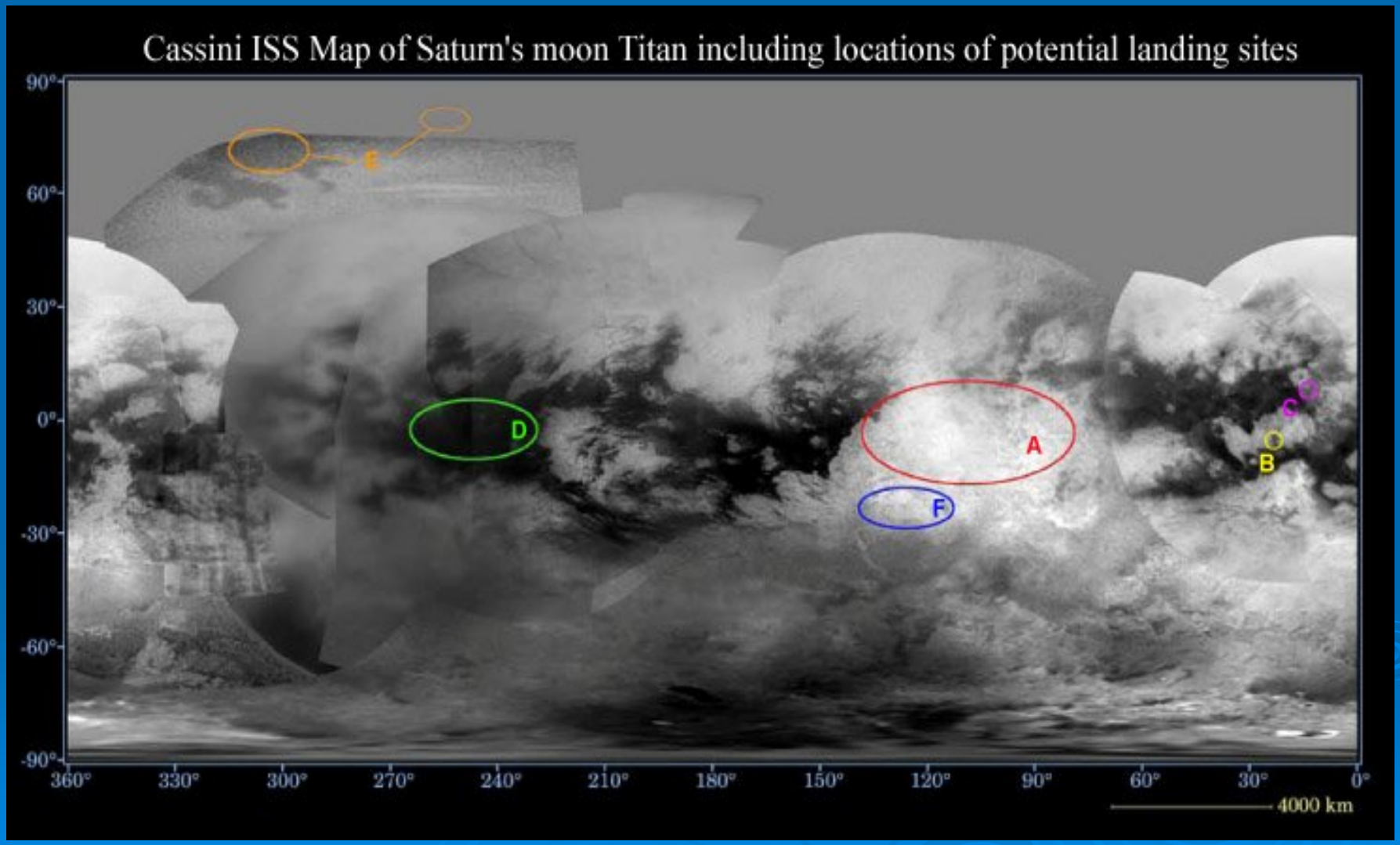

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Titan

ISS-data ~2km/pixel, Orbit Ta+Tb)

(A) Xanadu broadly defined as 'bright terrain' (can be hit by a 45x30 (2000x1300km) landing ellipse).
Coordinates: 110 ° W 12 ° S (center of ellipse)

Complex albedo pattern in the western Xanadu may be due to tectonics.
The boundary between Xanadu and Shangri-la, a dark region to the west suggests that dark (spectraly bluish) material embays the bright terrain.
Radar images revealed dunes, hills, rivers and valleys present on Xanadu.

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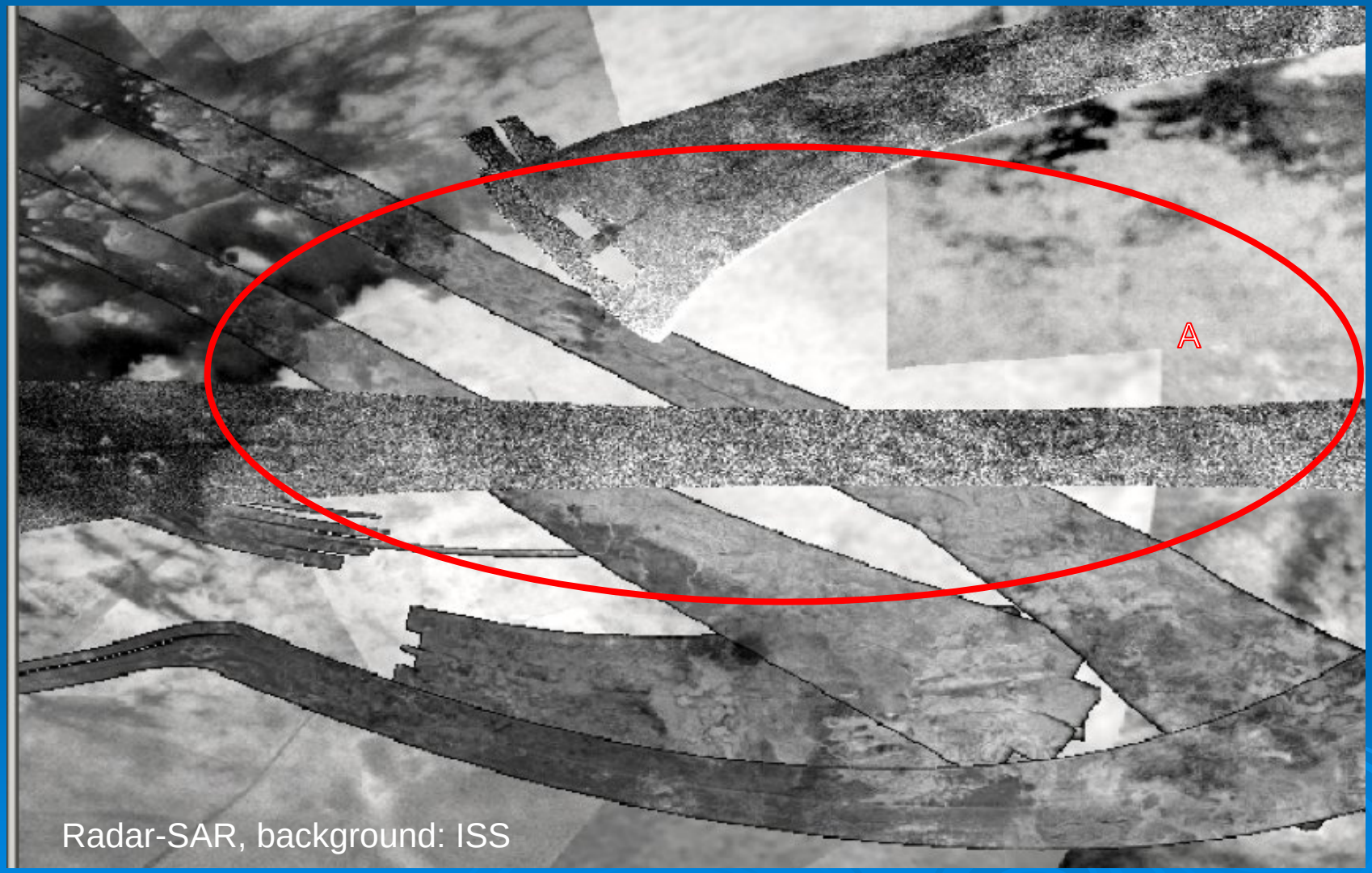

Radar-SAR, background: ISS

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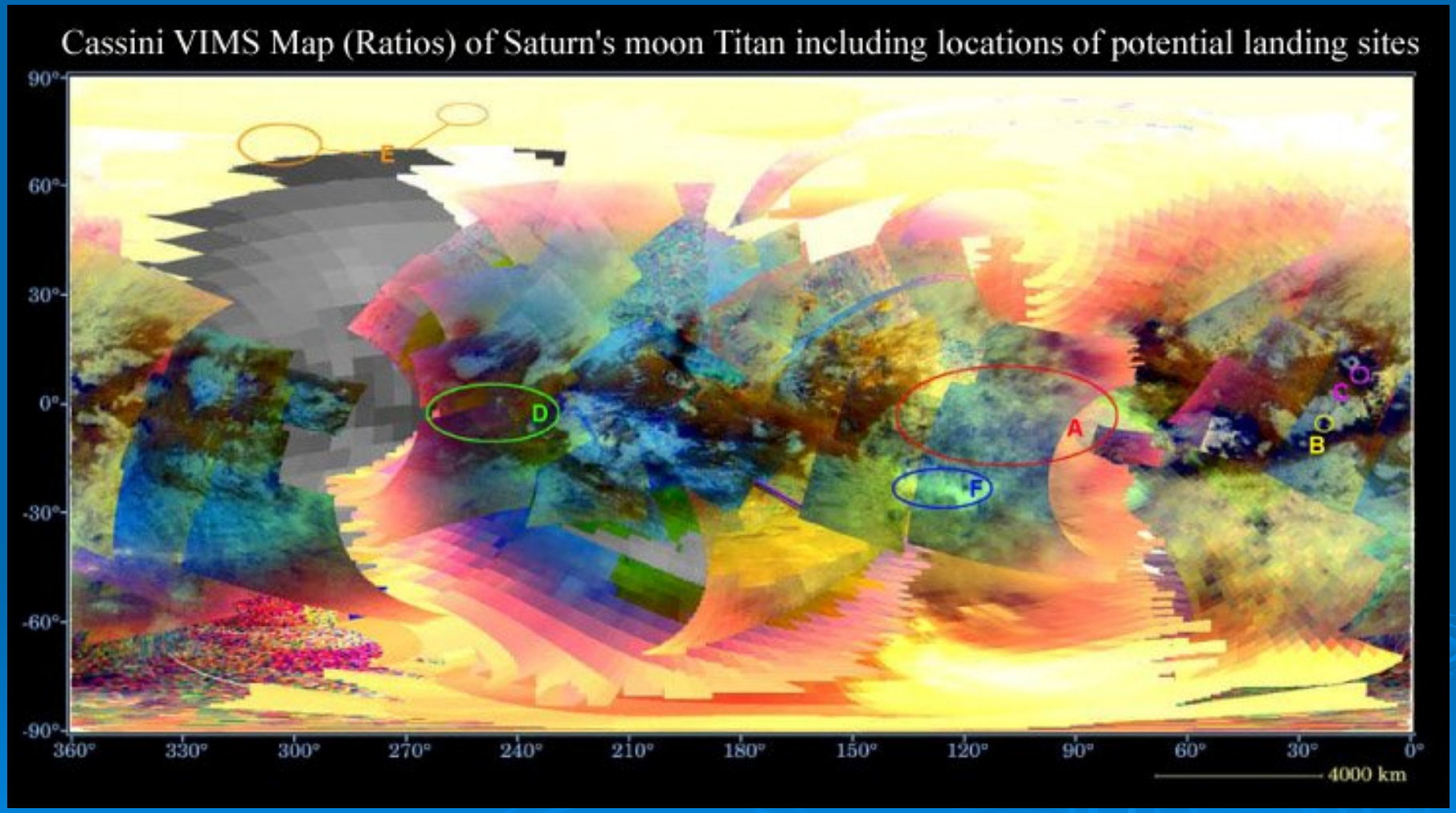

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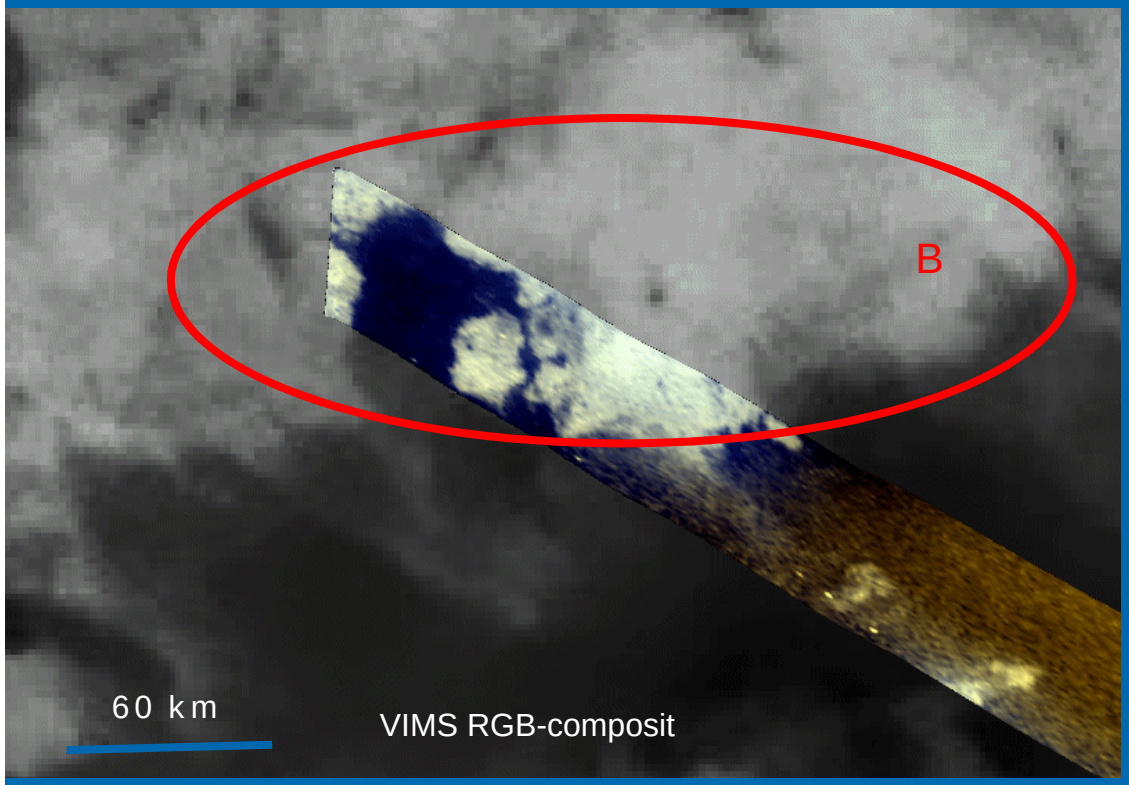

(B) Distinct blue alluvial units,
e.g **Chusuk Planitia** (landing ellipse
of about 200x100km requires
delivery accuracy of 100km or better?)
Coordinates: 30 ° W 7 ° S center of ellipse

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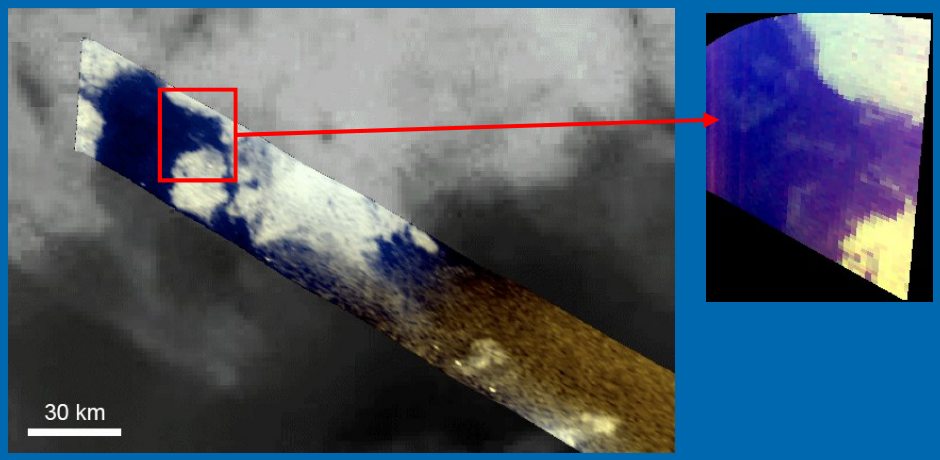
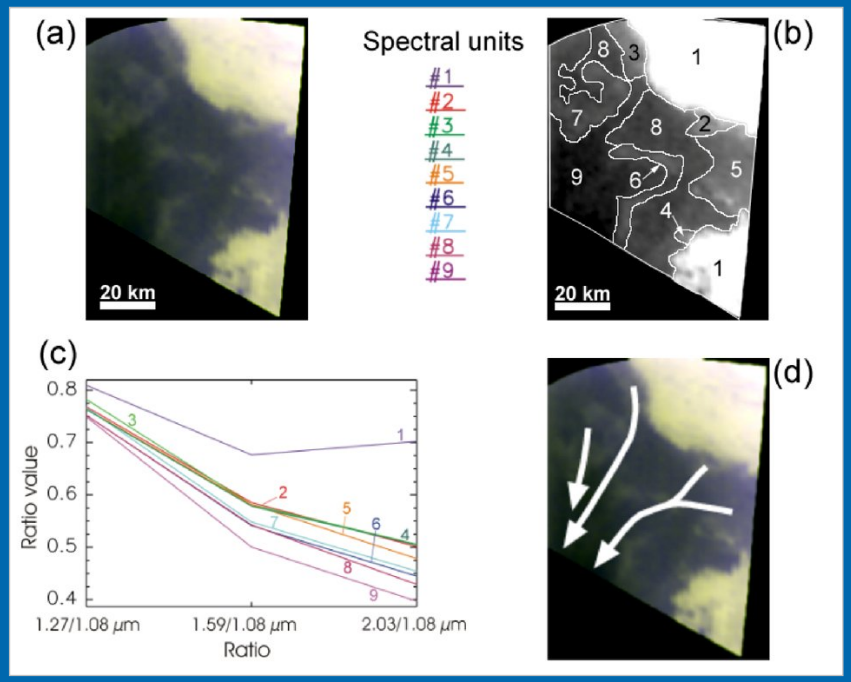
Spectral variations at Chusuk Pl. T20





Spectral differences systematically change throughout the plain area

Spectral differences are due to chemical and /or physical changes within the materials

-> systematic trend within the area due to compositional and/or particle size variations

Units
1: bright high standing terrain;
2,3,4: bright outwash where possible channels terminate;
5: similar to 2-4 but larger extend possible outwash plain;
6,7: bright v-shaped deposits
8,9: dark bluish material

(Jaumann et al., 2008)

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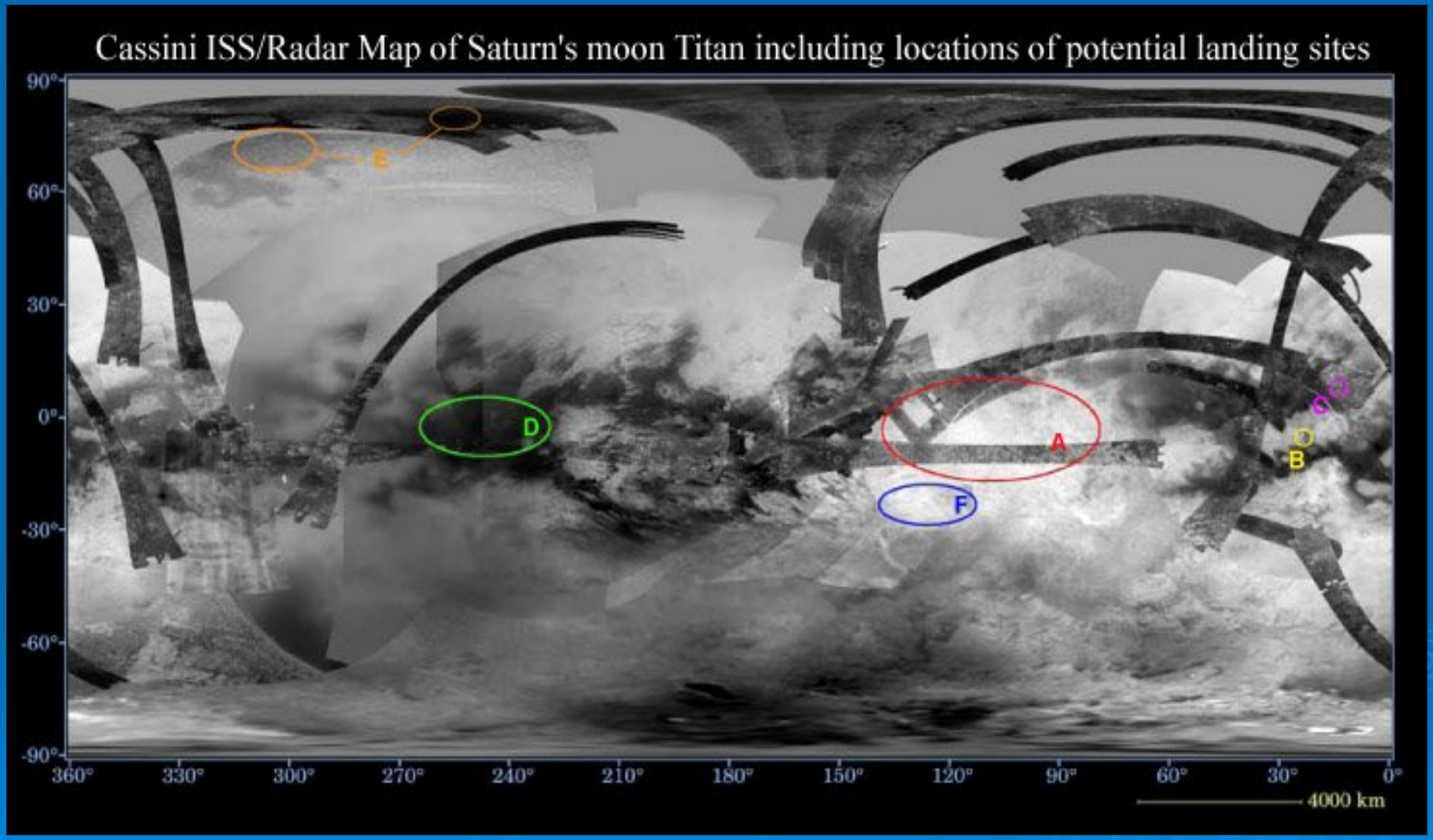
Titan



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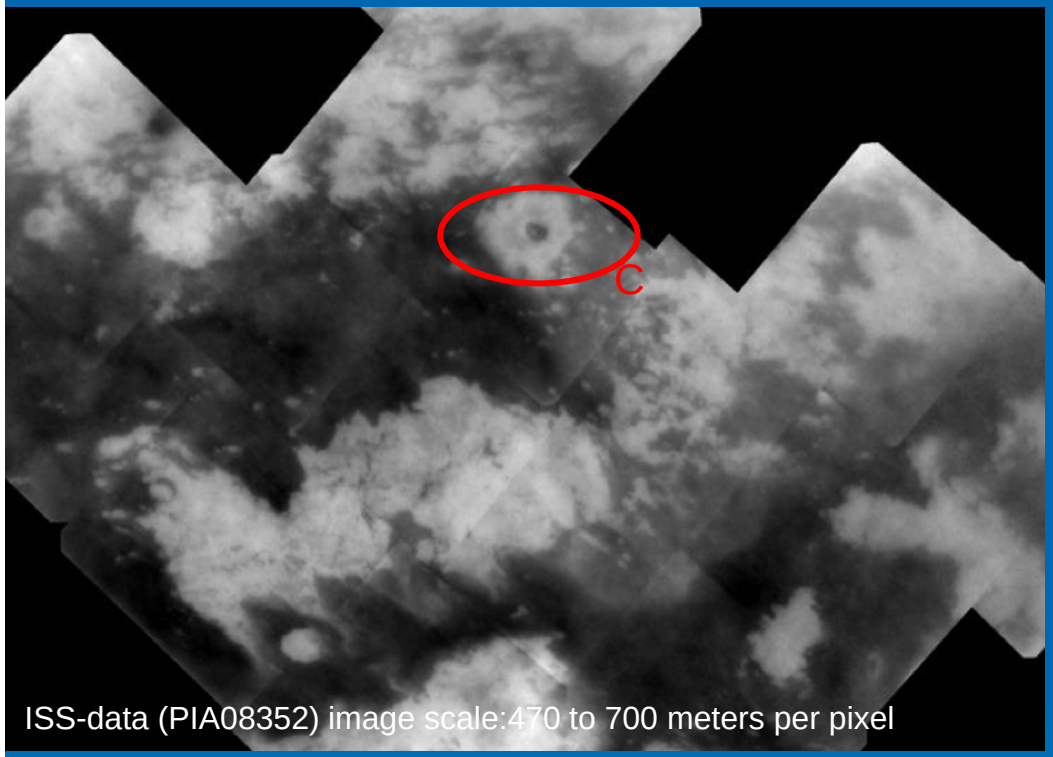
Titan



ISS-data (PIA08352) image scale:470 to 700 meters per pixel

(C) Distinct crater surrounding unit, e.g **Sinlap** (landing of ellipse about 100x100km; requires delivery accuracy <100km).
Coordinates: 14 ° W 7 ° N (center of ellipse)

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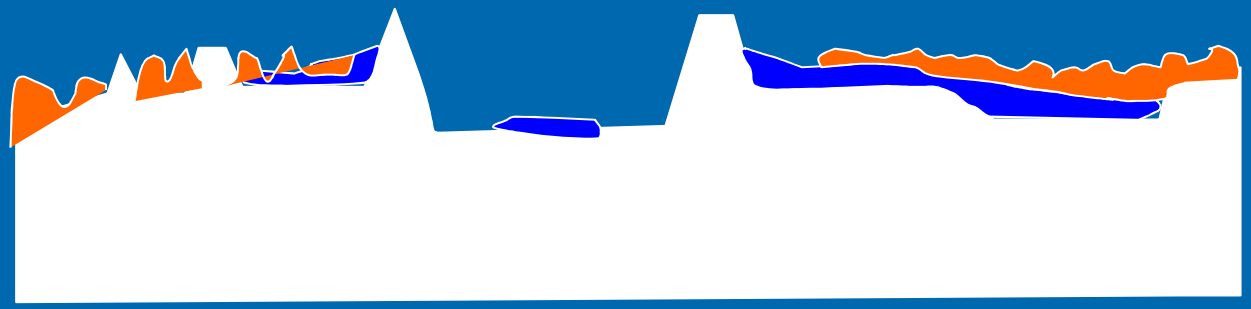
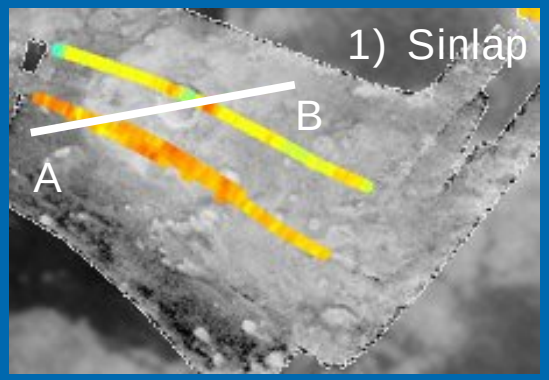
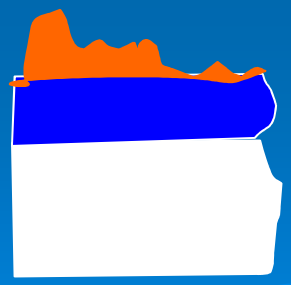
Stratigraphic Relations on Titan

Stratigraphic Relation

dune/sediment mixing







Dunes

Sediment, ejecta

Basement

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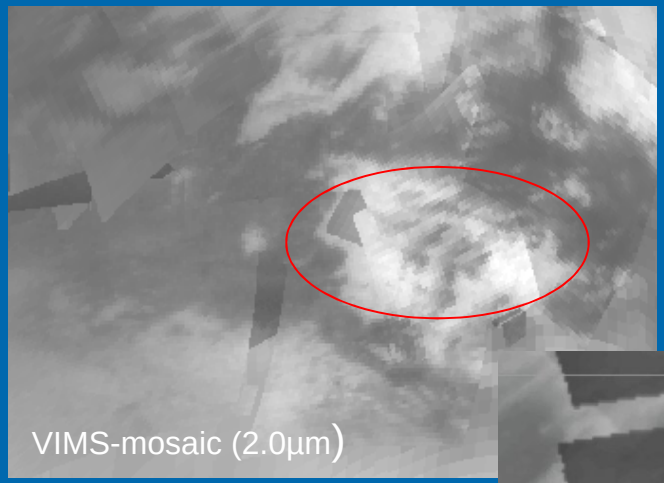
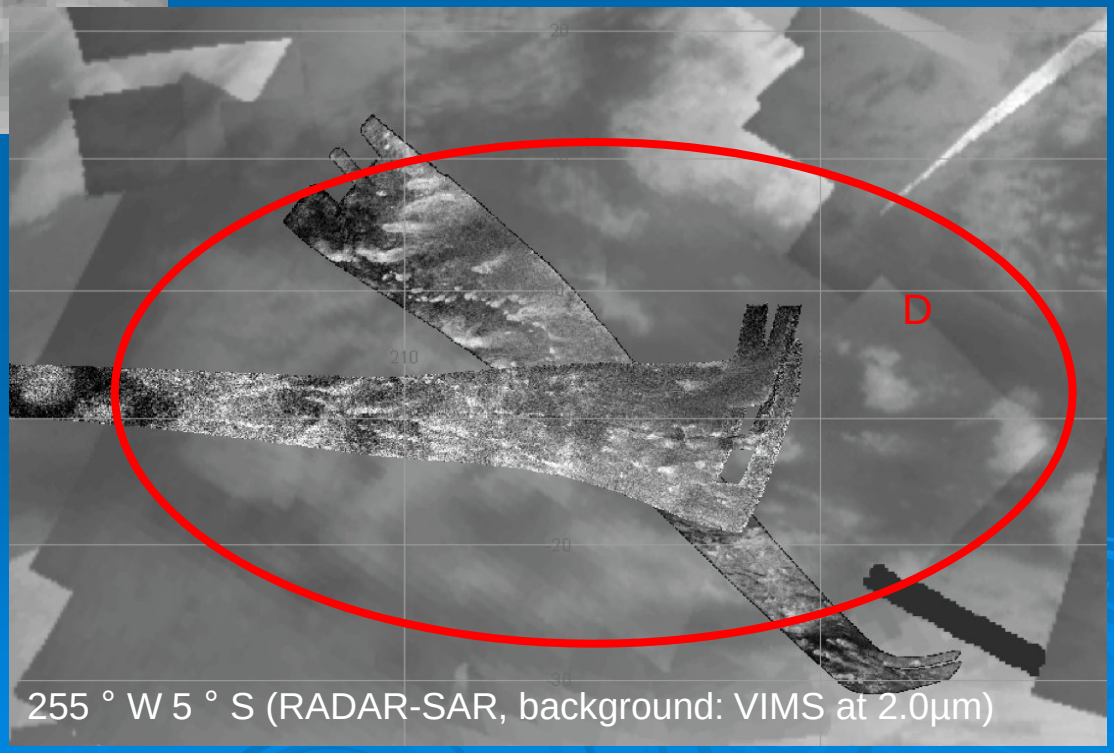


(D) Brownish dune units e.g. **Belet** dunefield (can be hit by a 15x40 ° (600x1600km) landing ellipse).
Coordinates: 255 ° W 5 ° S (center of ellipse);



255 ° W 5 ° S (RADAR-SAR, background: VIMS at 2.0µm)

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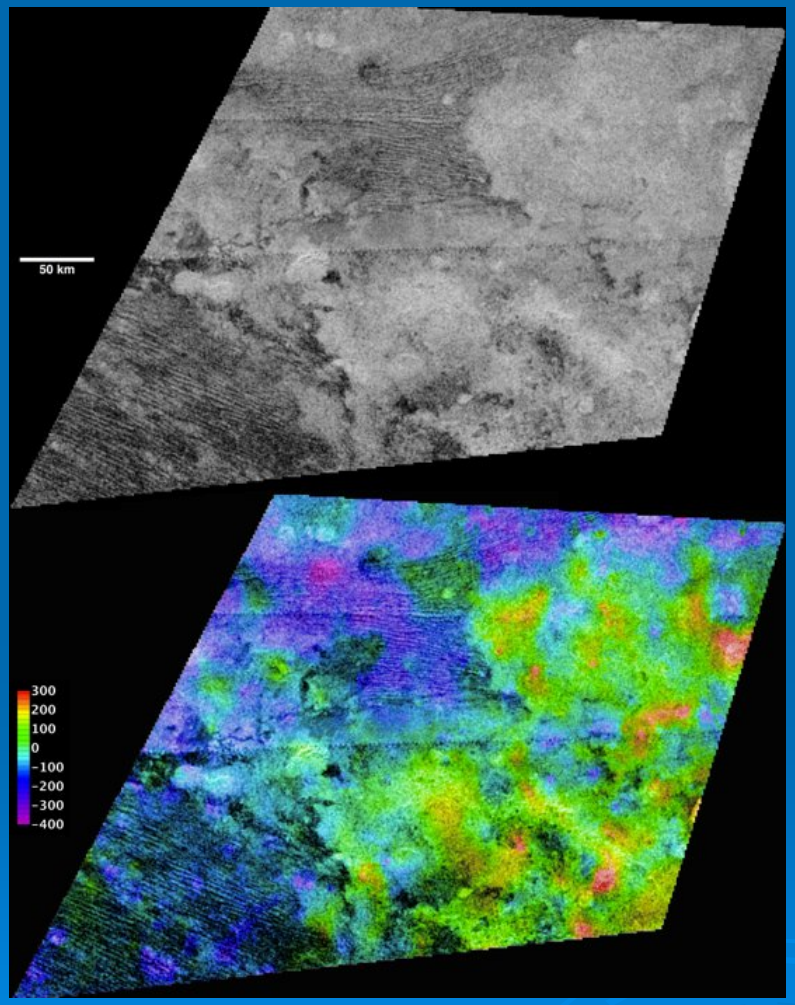

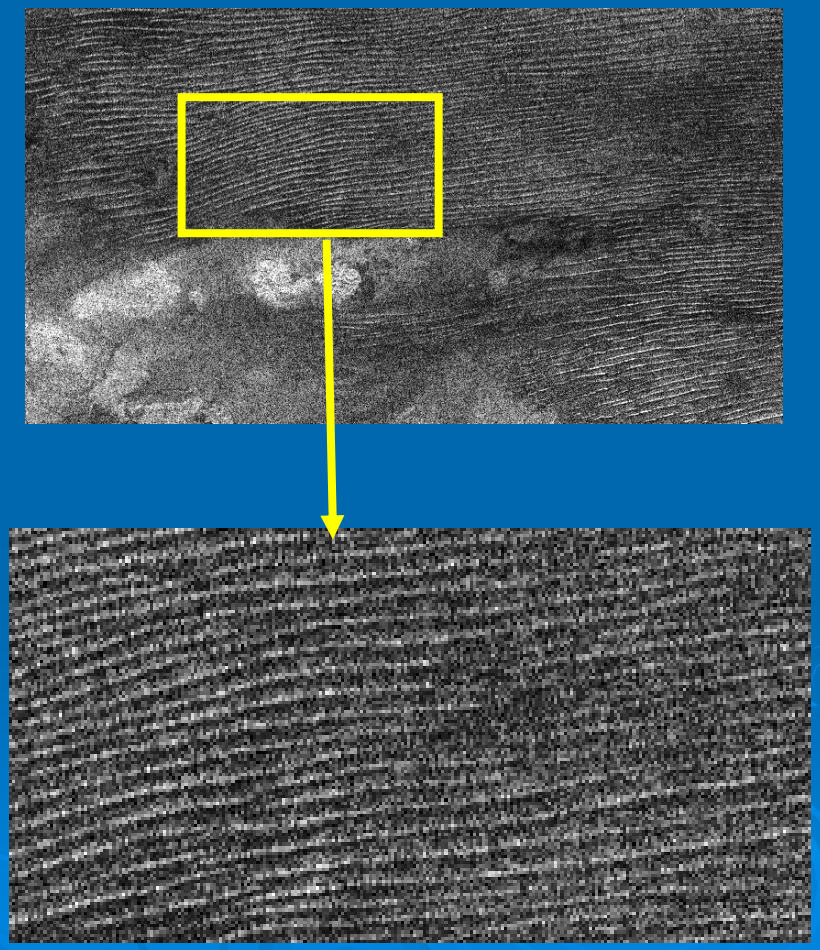

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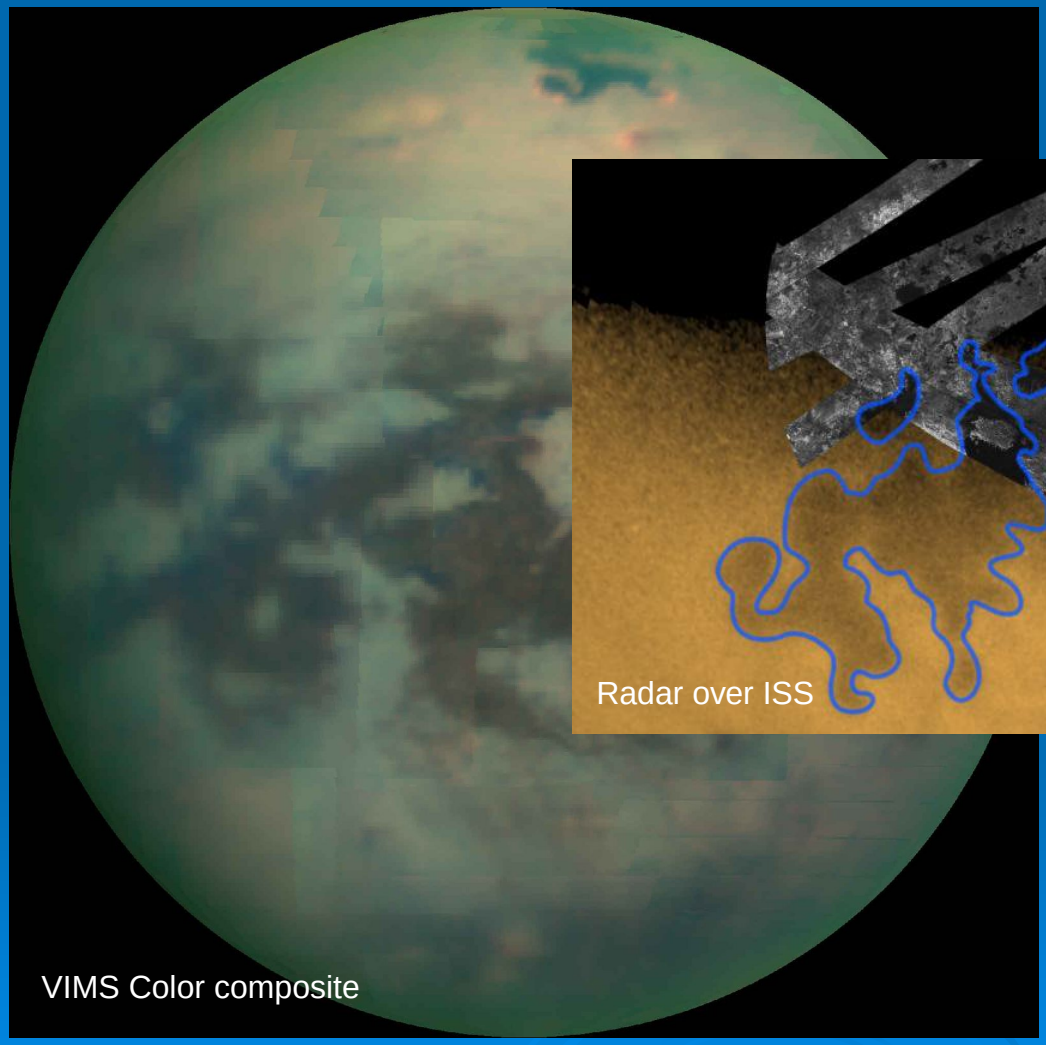
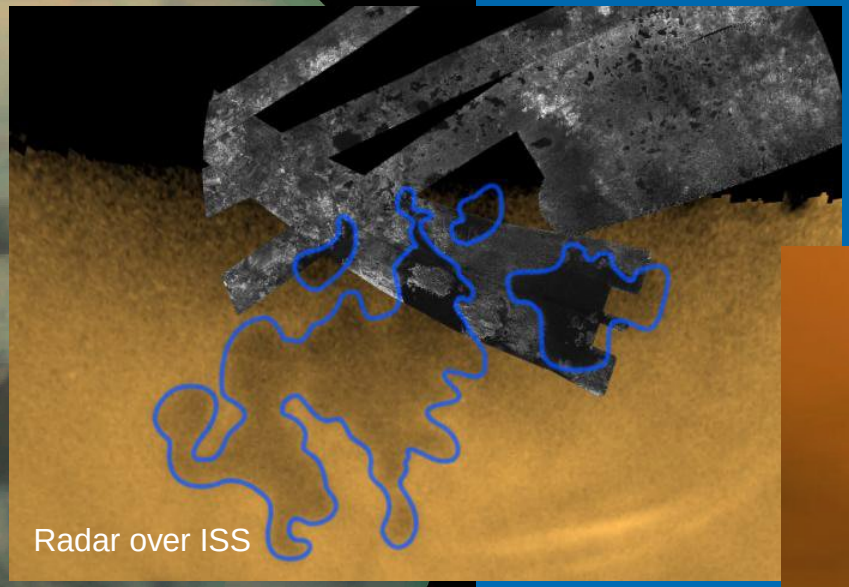
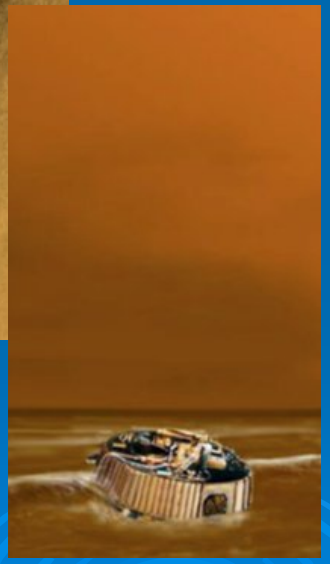
Lakes







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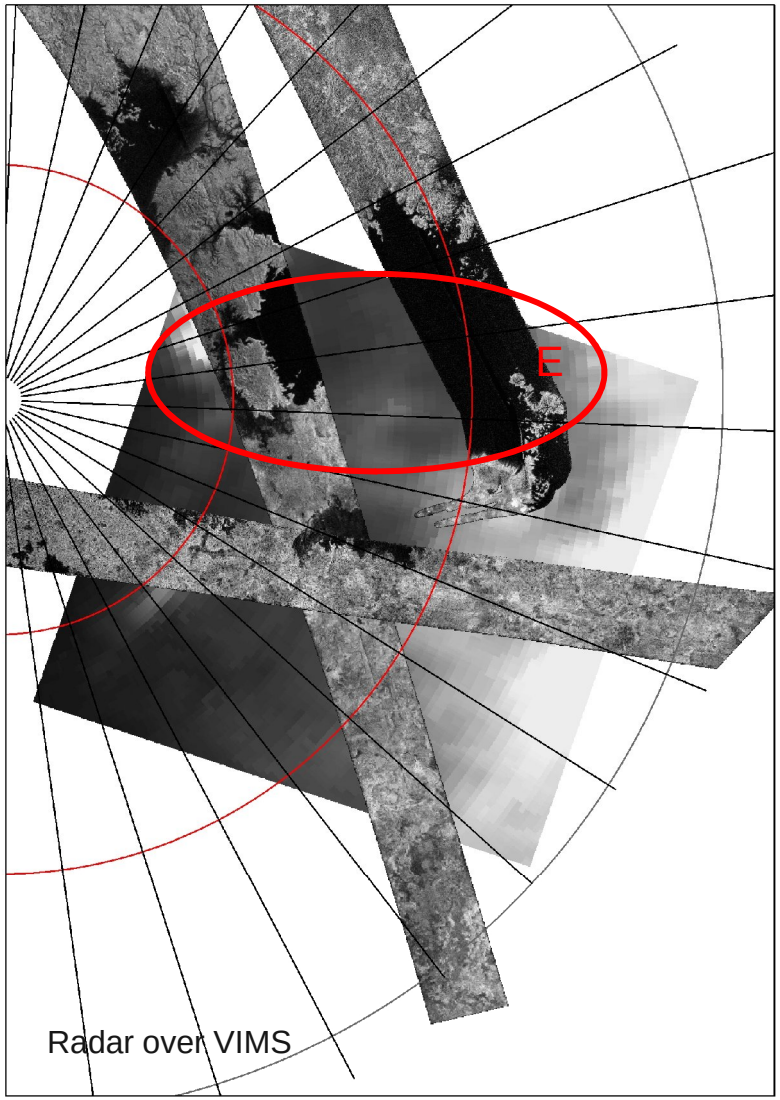
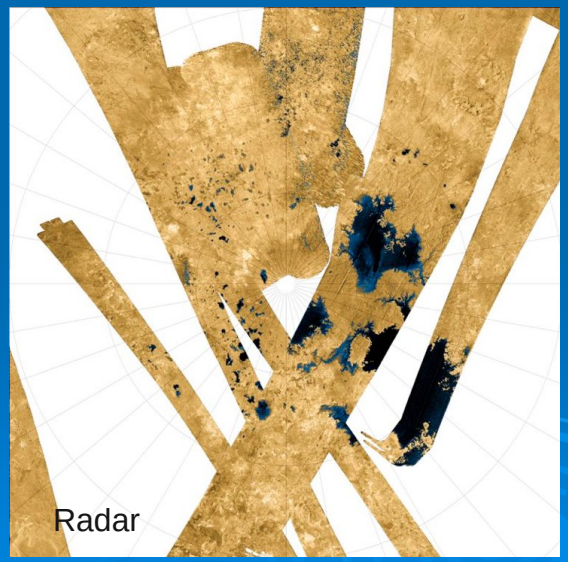


(E) **North Polar Lakes** above >72 ° N
(200km circular delivery error can be accommodated in Ligeia Mare;
Kraken Mare can probably accommodate ~400km circular delivery zone)
coordinates: > 72 ° ;



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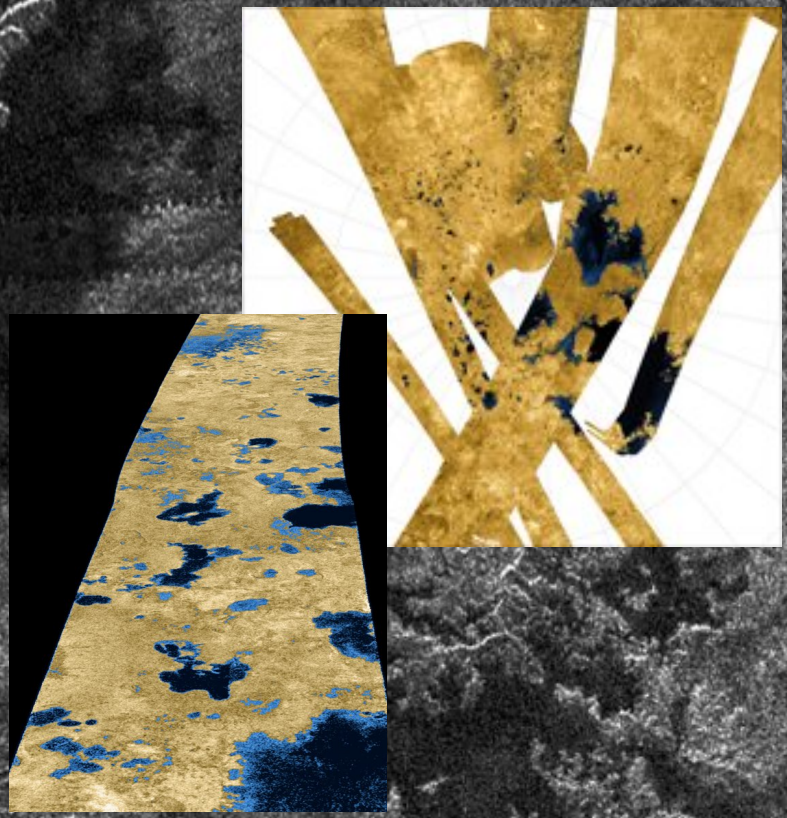
Lakes are exposed in polar regions > 70 ° ; with sizes < 10 km^2 to greater than 100,000 km^2 with circular to complex estuary/fjord-like shorelines and islands; either dry or filled with liquid) (e.g. Stofan et al. 2007, 2008; Brown et al., 2008)

Lakes are either open systems or isolated indicating drainage or seepage processes and may Originate from impact cratering, volcanism or karstic processes (e.g. Stofan et al. 2007, 2008)



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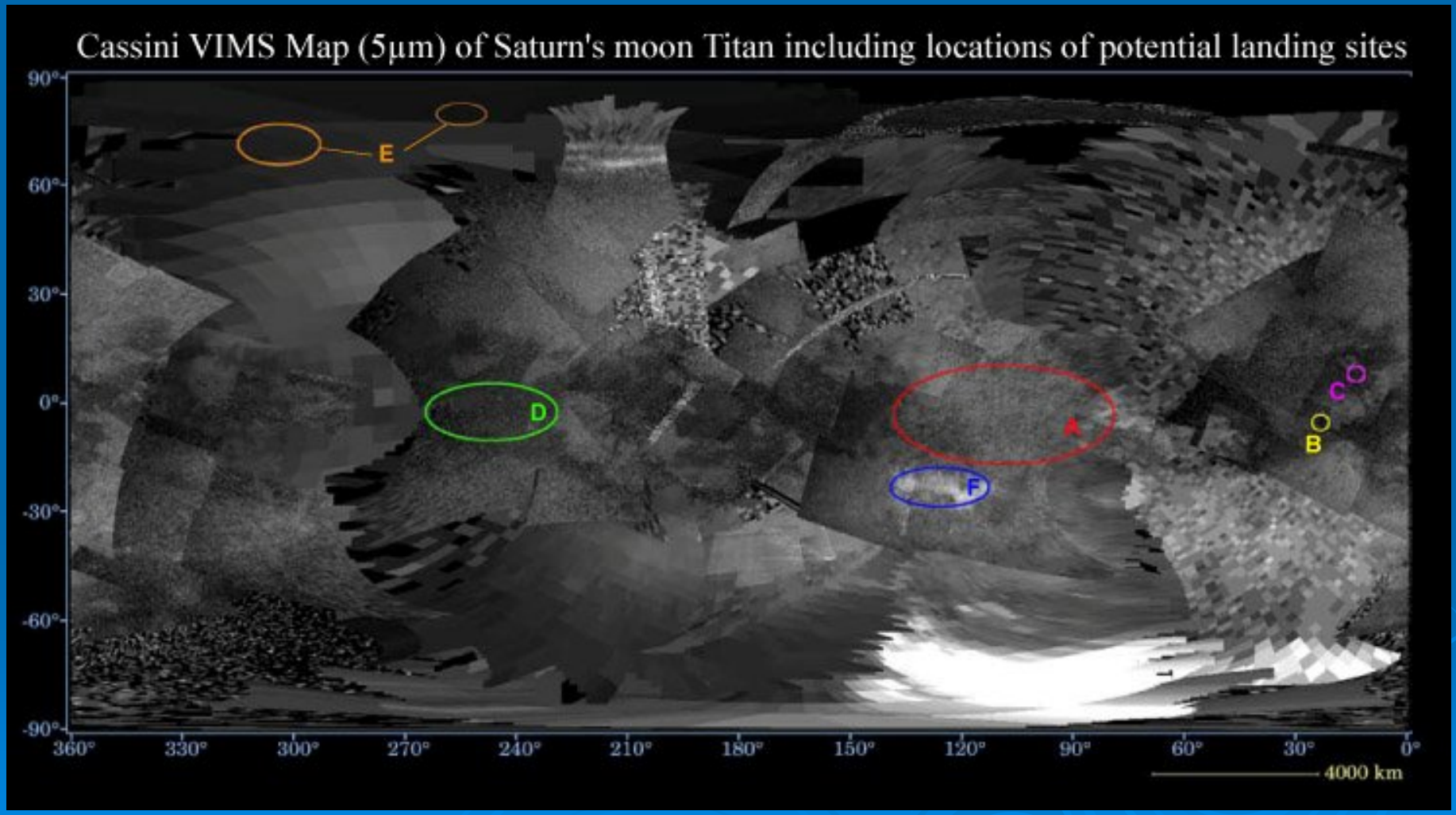

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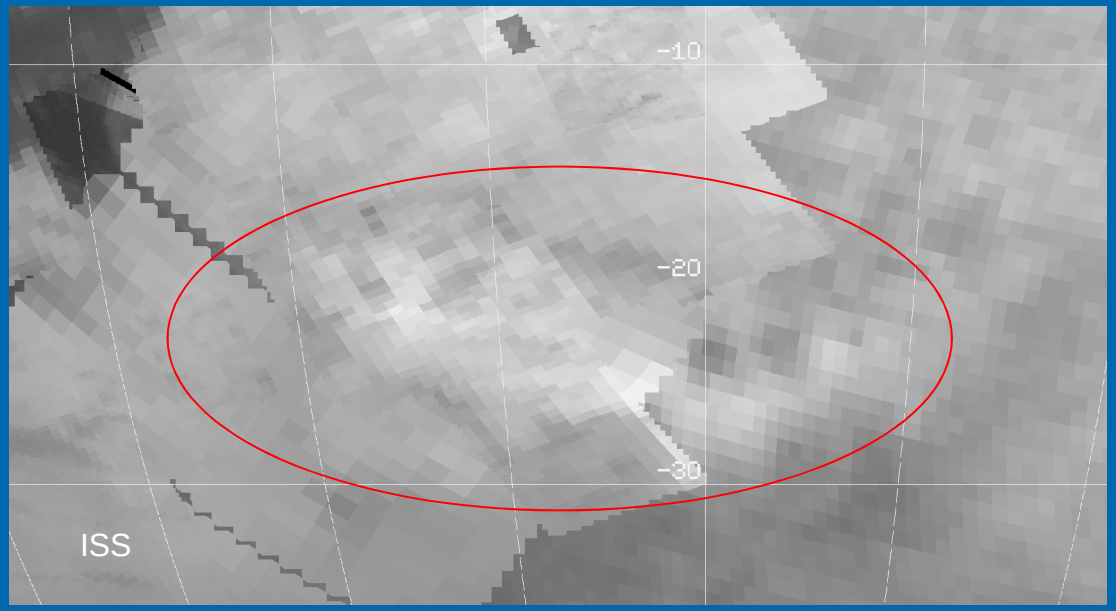

(F) Anomalous spectral region e.g. **Hotei/Tui Re**gio (~80% fit by 7x18 ° landing ellipse (300x800km) ~100% fit by 5x12 ° ellipse (200x500km)). Coordinates: 130 ° W 20 ° S (center of ellipse)

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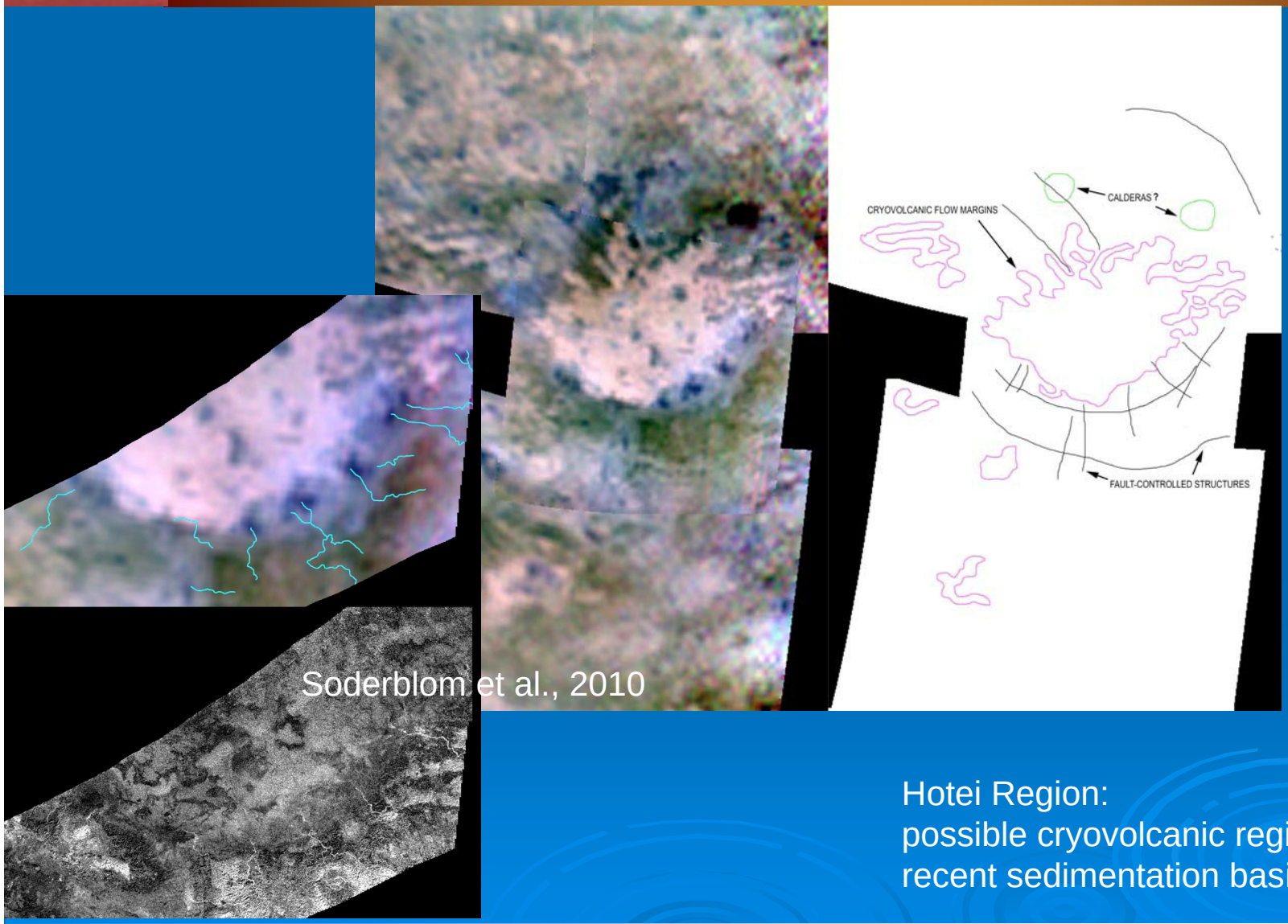

Soderblom et al., 2010

Hotei Region:
possible cryovolcanic region ???? or
recent sedimentation basins

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Titan Landing Sites
Conclusions

Titan is geologically very diverse

the composition of surface units is not yet fully identified

candidate landing sites are

- Bright old (?) terrain

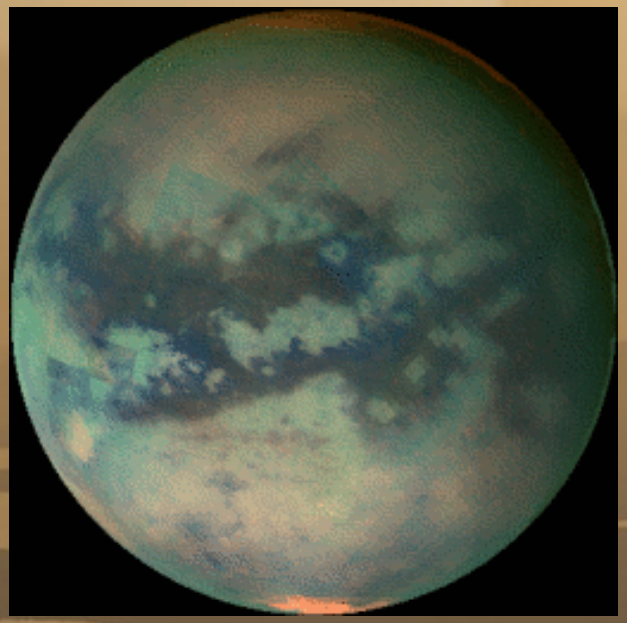
- Plains of fluvial origin (Huygens)

- Impact crater (access to subsurface material)

- Dunes

- Lakes (easy access to organics) and recent sedimentation activity (rivers and deposits)

- Cryovolcanic regions



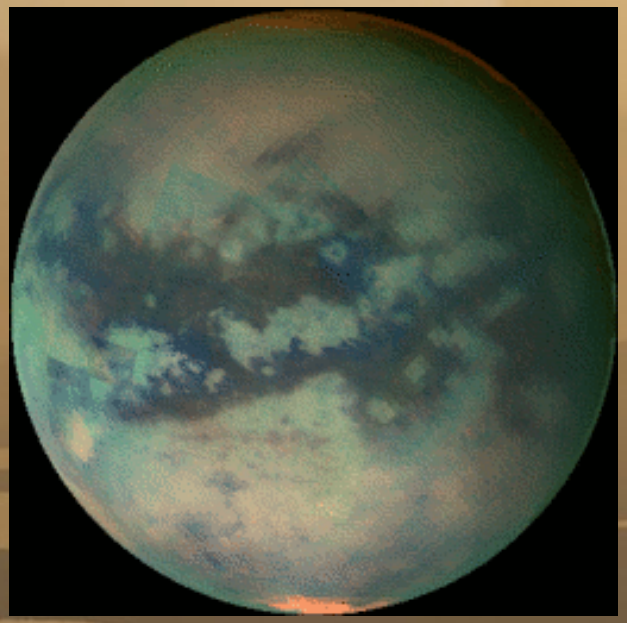
Titan Landing Sites
Conclusions

however:

Most interesting targets like
lakes,
rough terrain and
erosional surfaces

need precise landing
(landing ellipse <<1000 km)
requesting more and higher resolved
surface information or a robust landing
technology

… seems feasible because Huygens landed on
erosional surface



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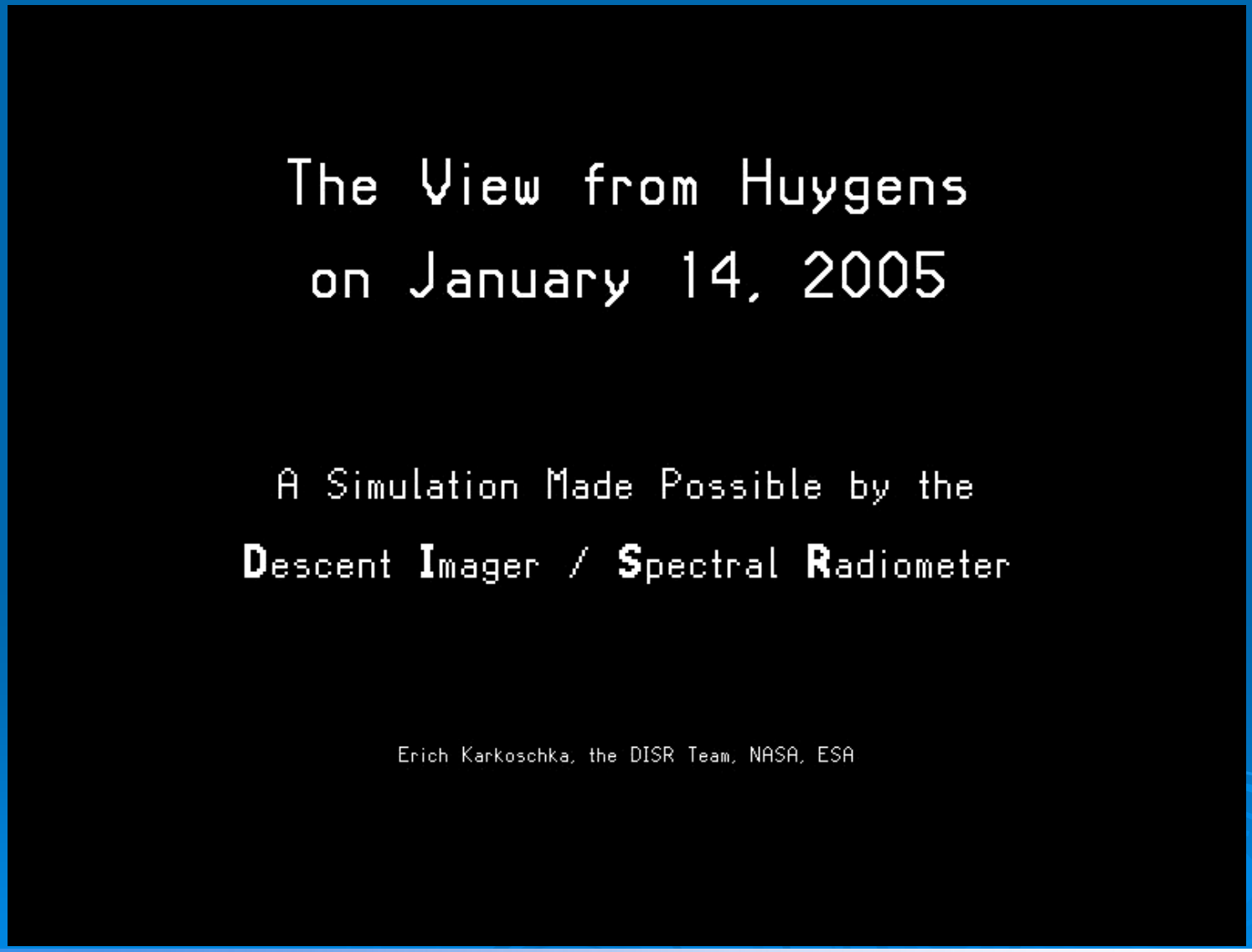

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