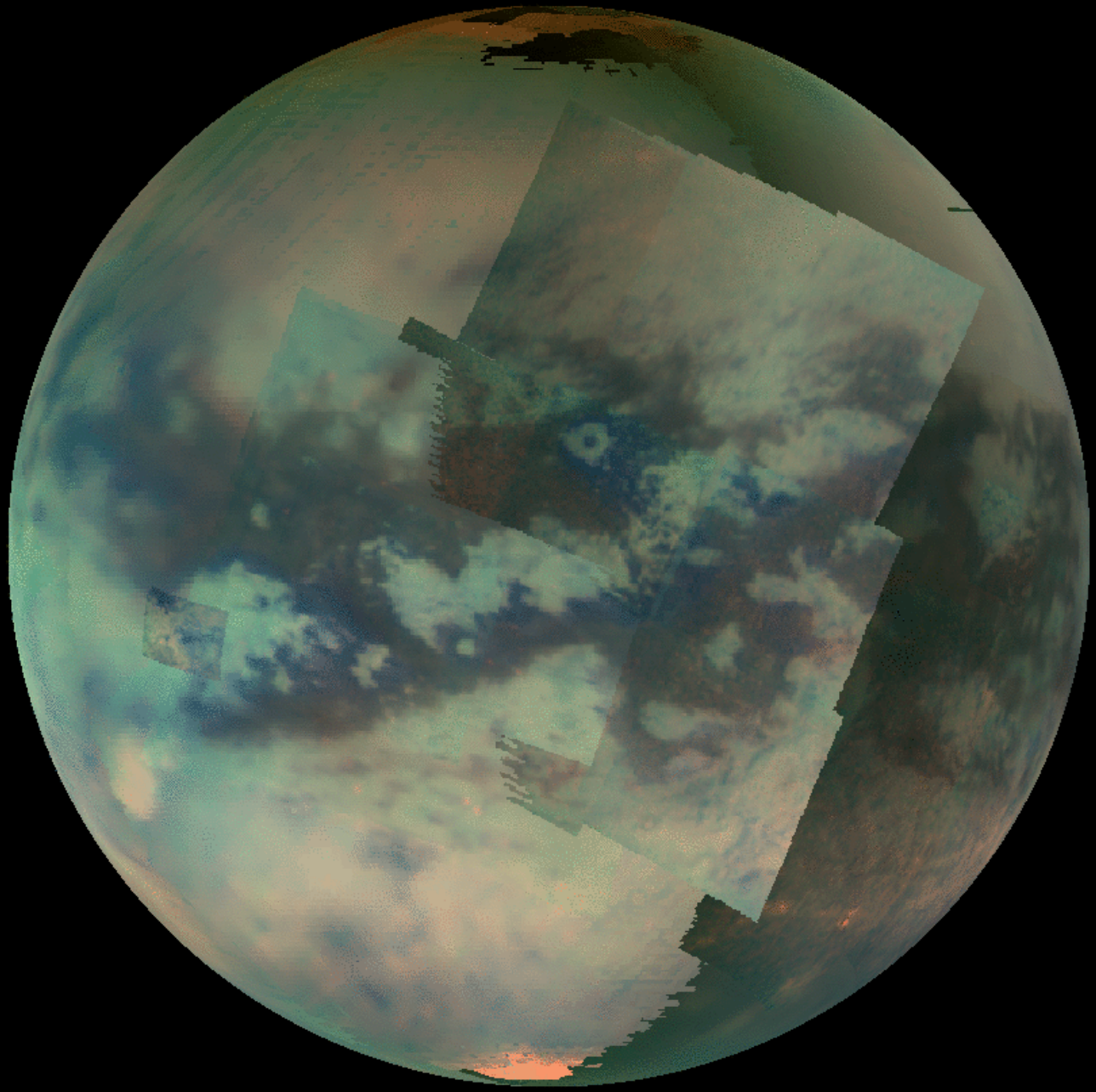
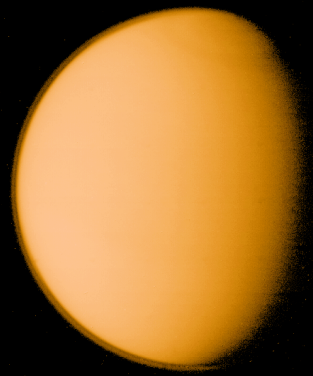
Titan's Sand Dunes: Window to a New World



Jason W. Barnes – NPP Postdoc – NASA Ames Research Center

Background on Titan



- Larger, but less massive, than Earth's moon – large water-ice component
- Thick atmosphere: 1.5 bars, mostly nitrogen, up to 5% methane
- Surface is obscured by scattering from haze in optical, atmospheric absorption in parts of the infrared
- Methane irreversibly converted to higher hydrocarbons – global ethane sea 300m thick predicted

Dunes on Earth

* Cover 5% of land surface

* Longitudinal dunes are the most common type

* Frequently made of SiO_2, but can be basalt, gypsum, seashells, olivene, coral, etc.

* Active dunes cluster around downwelling at 30N and 30S latitude

Dunes on Mars

* Not common

* Oftentimes found in craters, Vallis Marineris

* Mostly transverse, barchan, barchanoid, complex

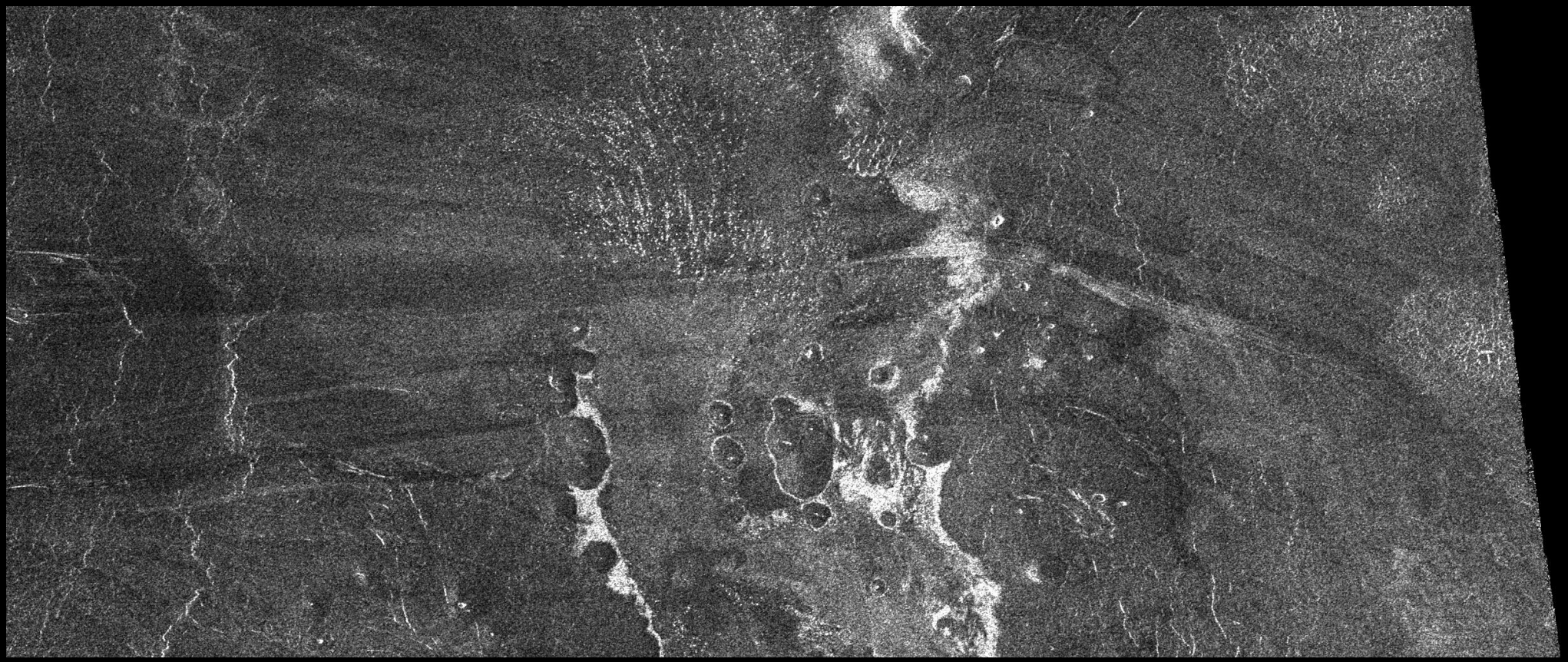
* Basaltic?

Dunes on Venus

* Rare

* Mostly found downwind of craters & obstacles

* Artifact of low spatial resolution?



Dunes on Titan – as predicted

* “on Titan there may exist seas or lakes of hydrocarbons. Particles that fall into these are likely to remain there”

* “Since the times to generate dunes of this size [500m] are improbably large, it is unlikely aeolian features will be detected with the radar.”

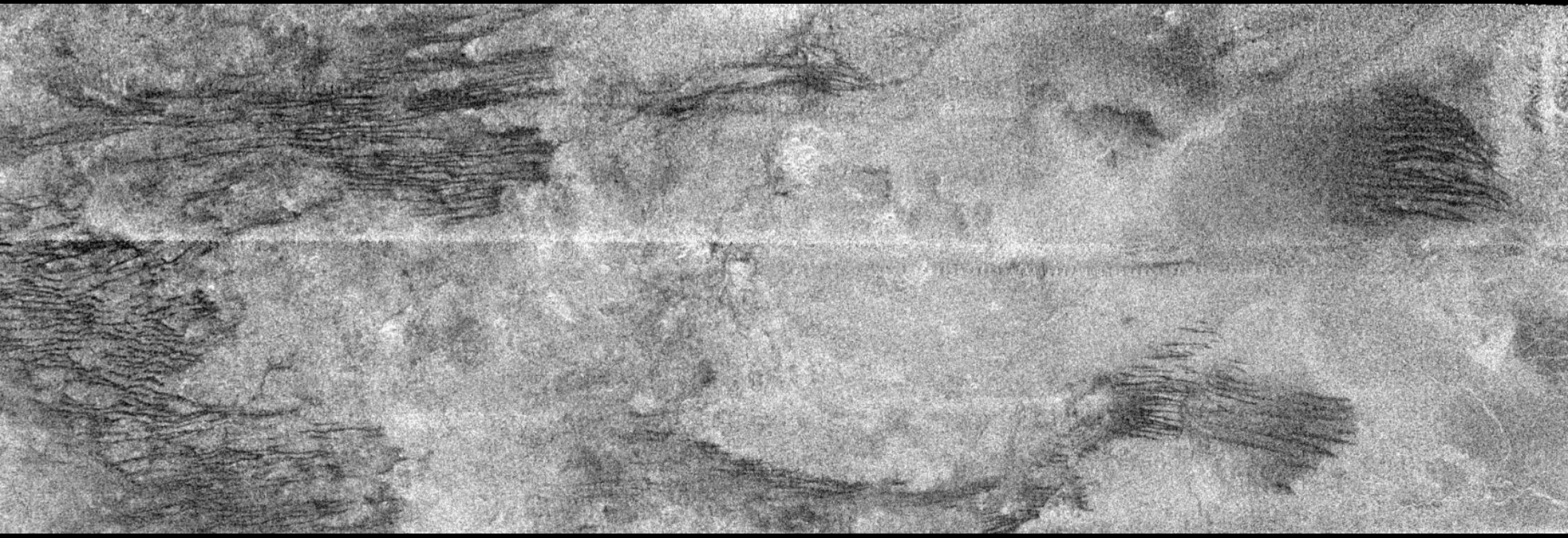
* “Present-day Titan is similar to Venus. Threshold speeds a factor of several above predicted friction speeds make saltation unlikely.”

* “Such small, sticky [atmospheric hydrocarbon] particles seem to be singularly unpromising candidates for aeolian transportation”

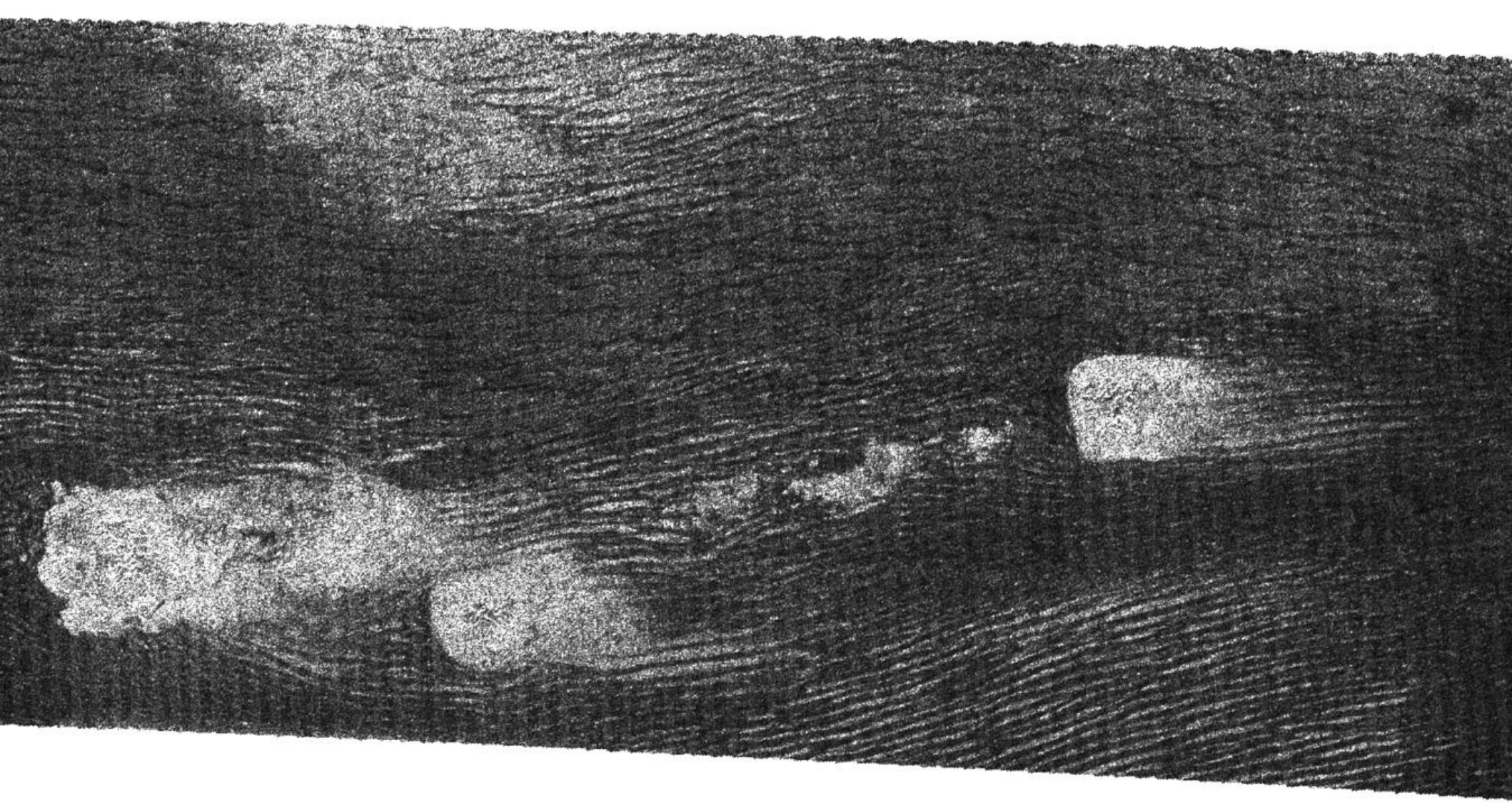
* “If anything dunelike occurs, it is probably localized and infrequent as on Venus.”

Lorenz, Lunine, Grier, & Fisher (1995)

Cassini RADAR “Cat Scratches”



Cassini RADAR Dunes – T8



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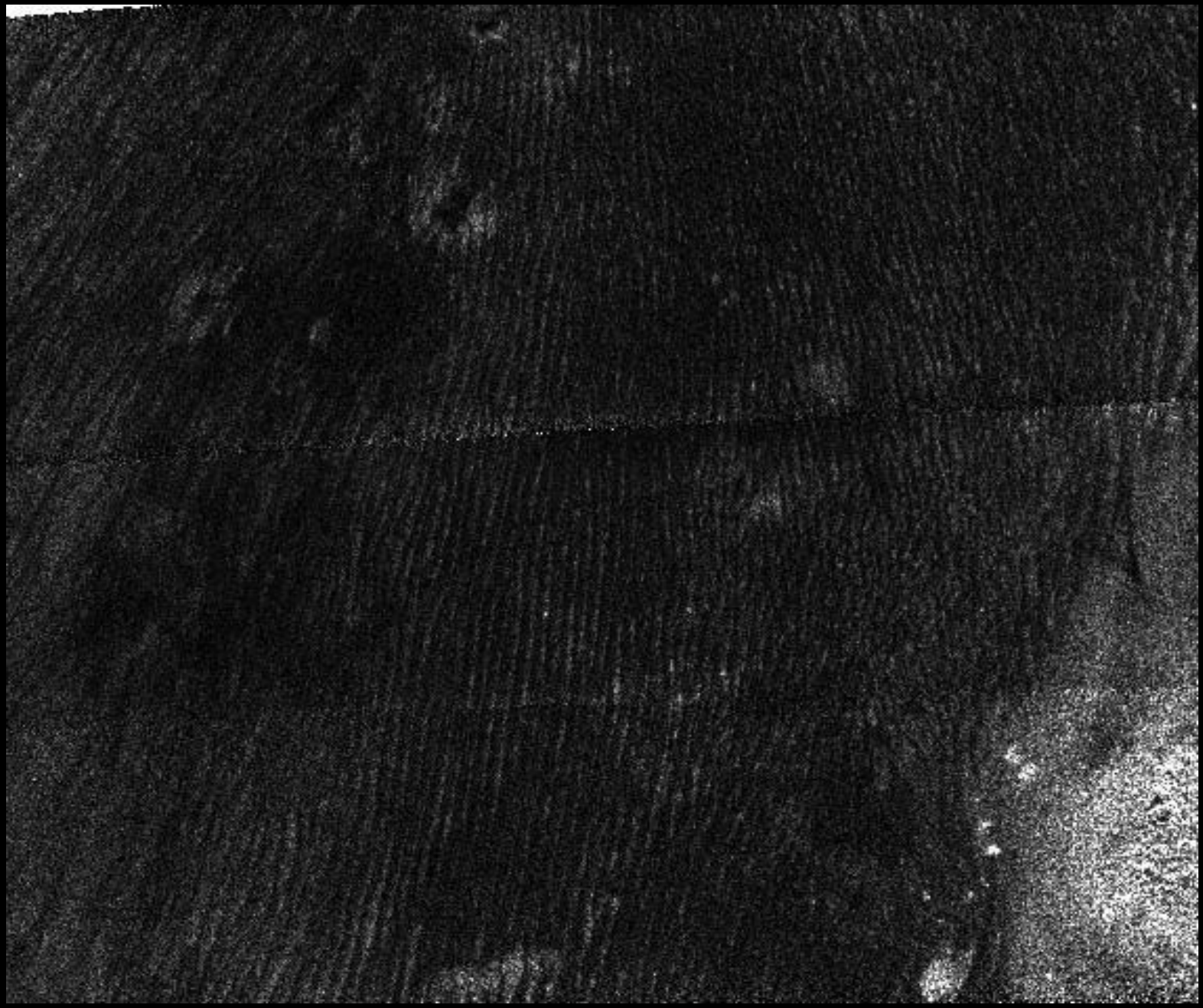
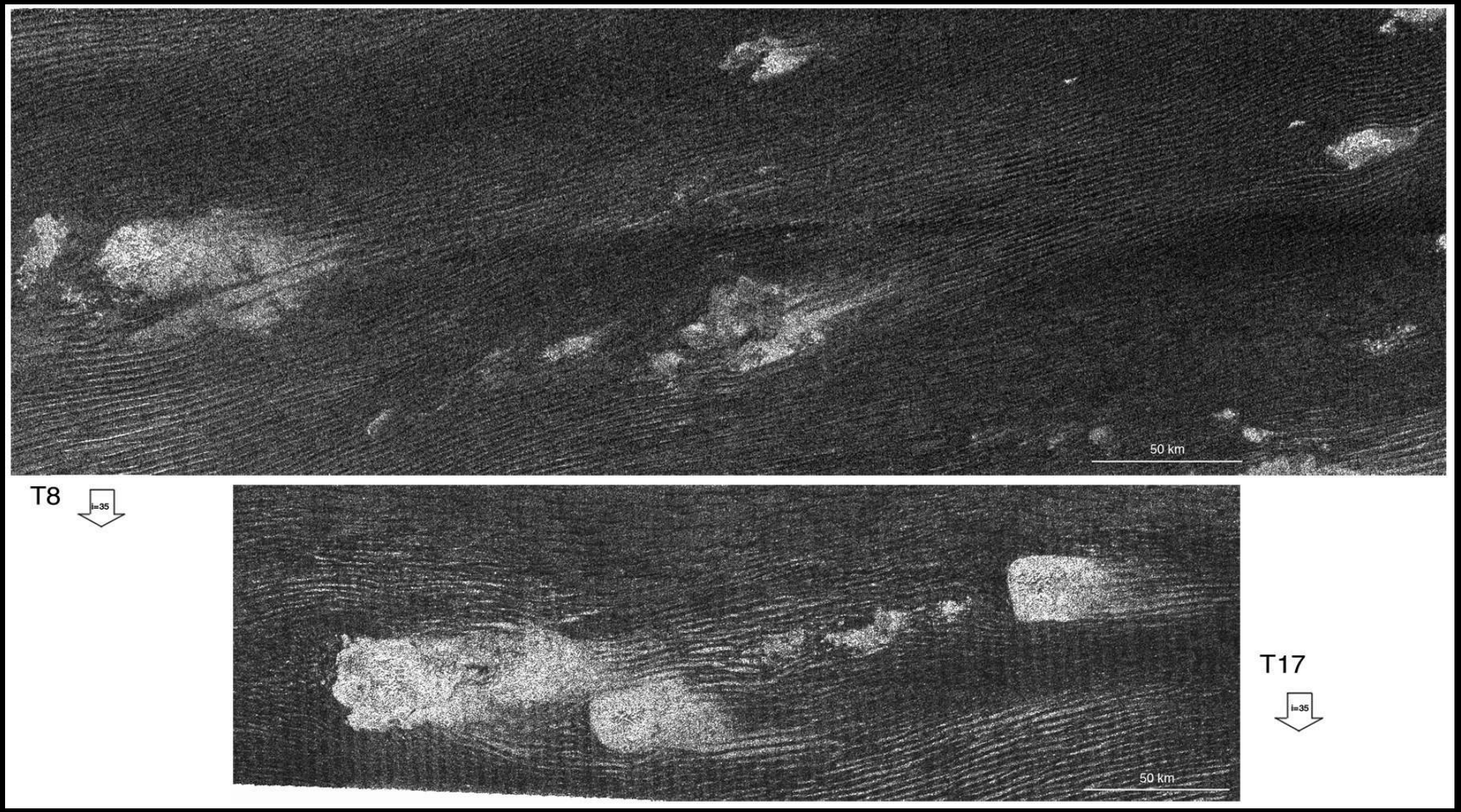


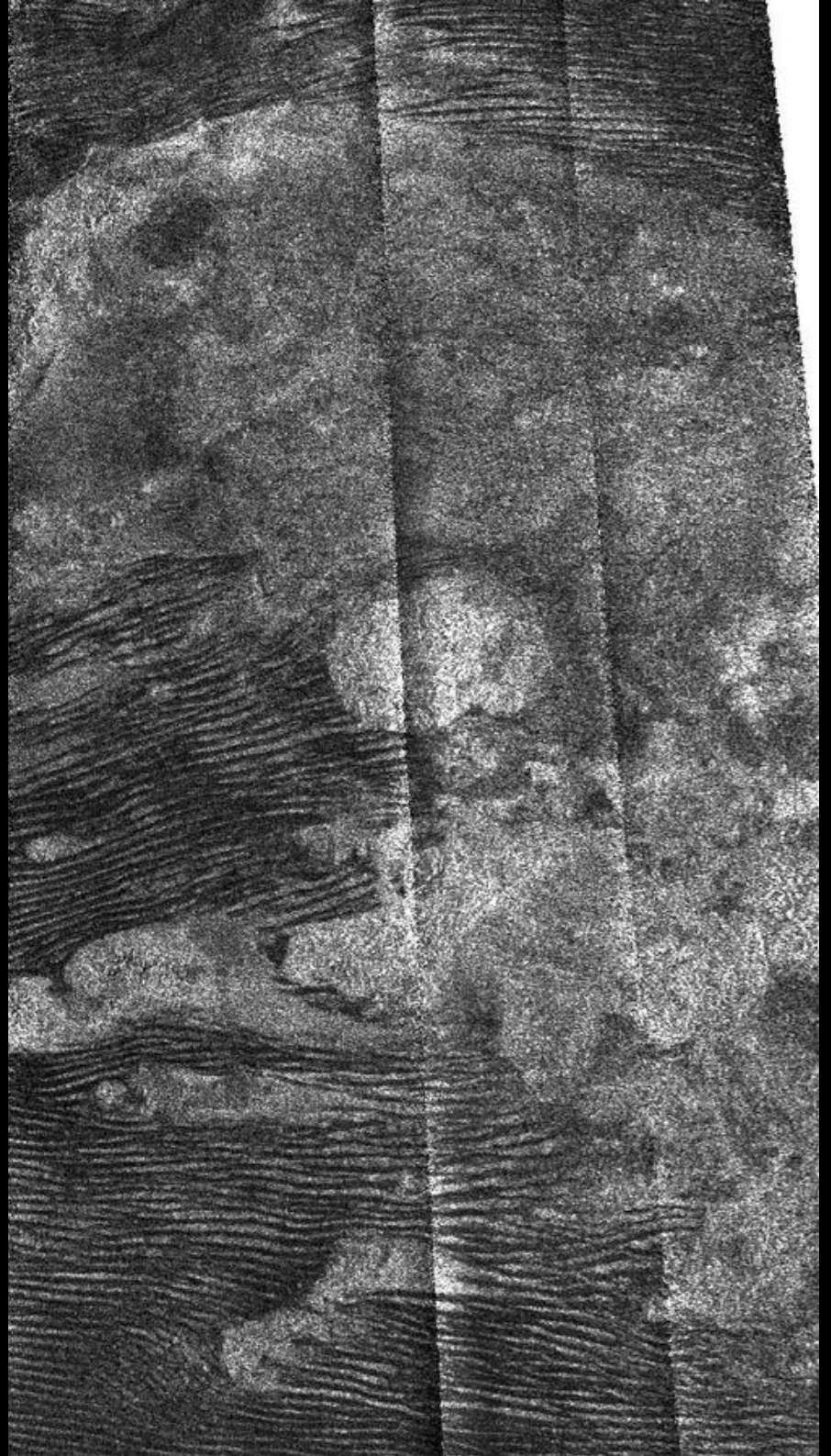
Cassini RADAR Dunes



Radebaugh et al., in revision Icarus

Cassini RADAR Dunes Interaction with Surrounding Features

Lorenz et al. (2006)



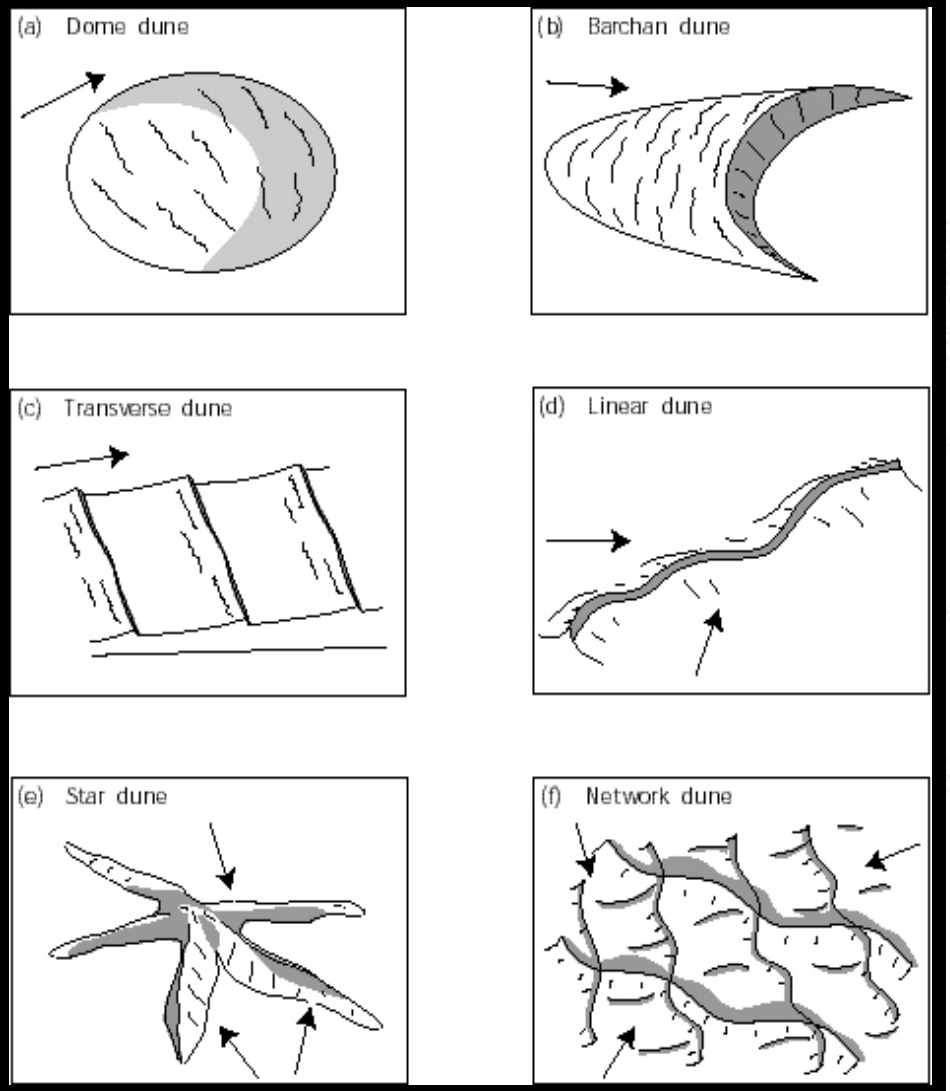
Evidence Supoprting Longitudinal Dune Identifiation

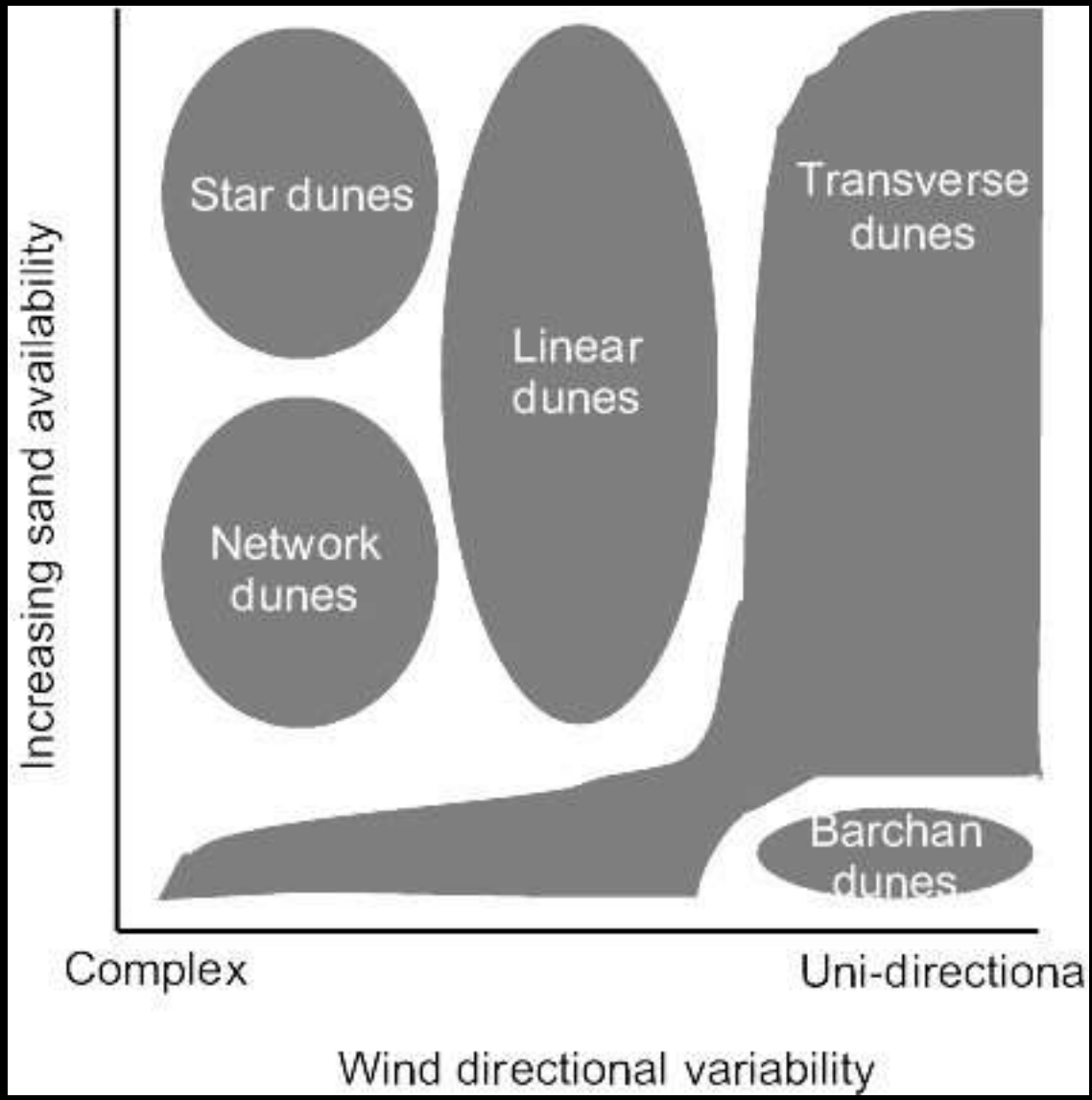
- Longitudinal symmetry
- Superposition
- Tuning fork junctions
- Diversion and recombination around obstacles

Lorenz et al. 2006 Science

Longitudinal Dunes in Arizona

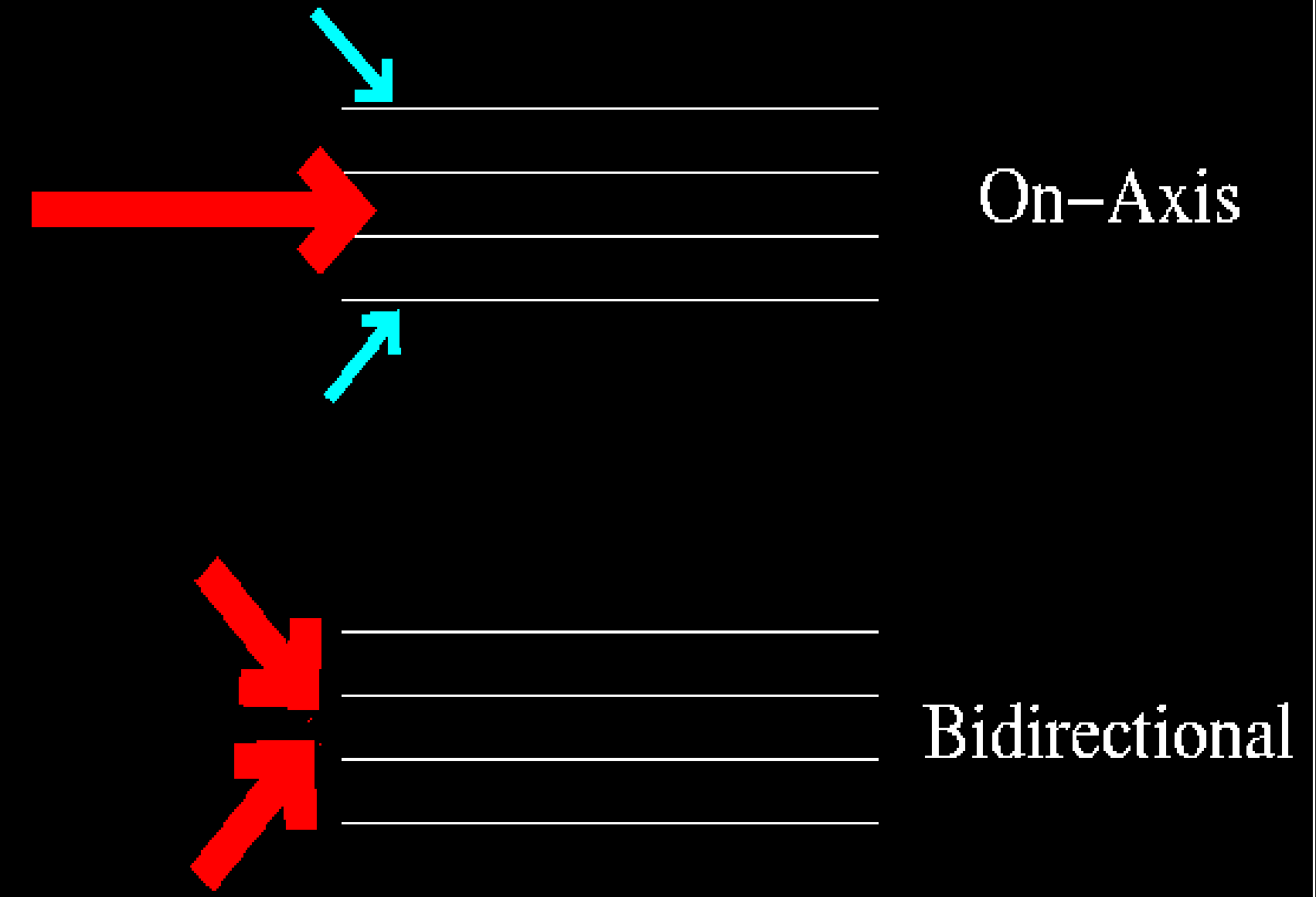
Under What Conditions are Longitudinal Dunes Produced?



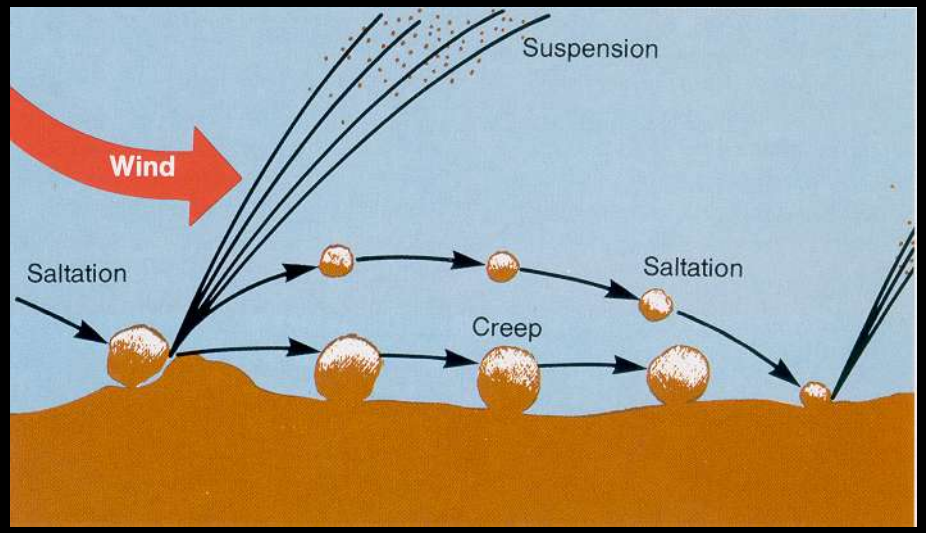


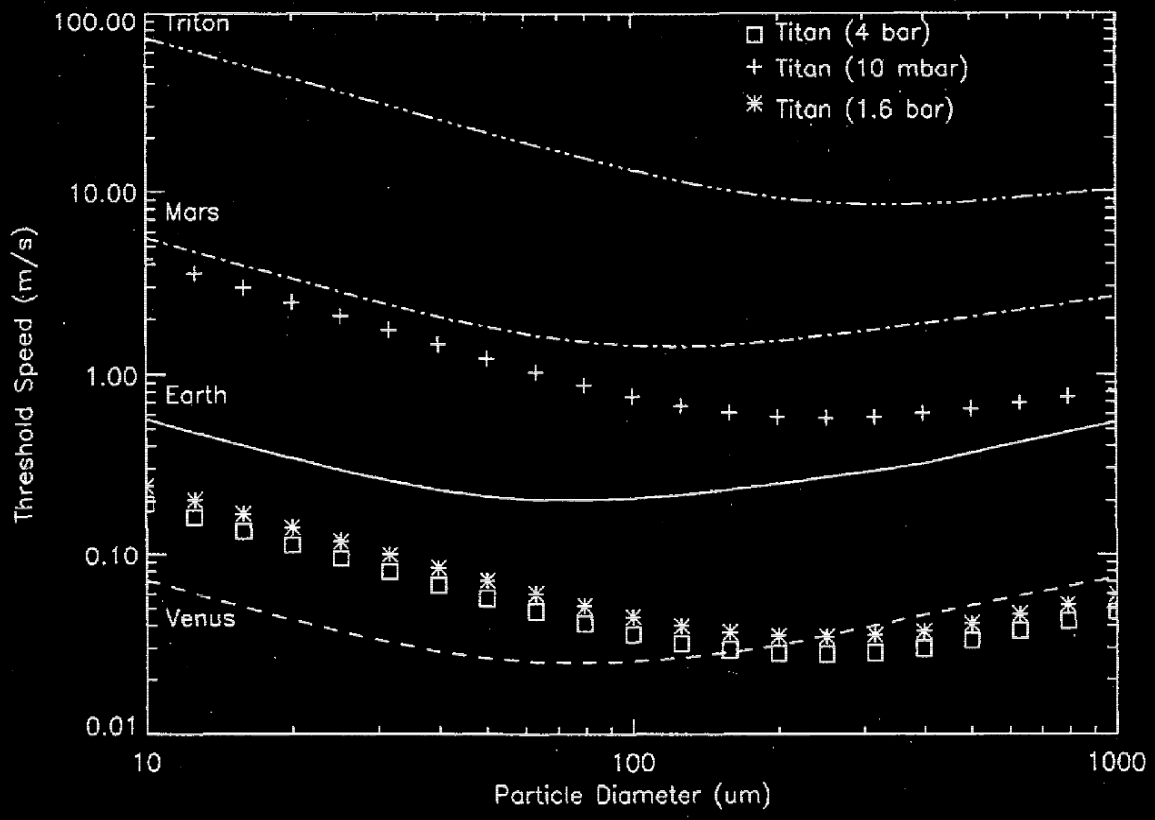
http://www.geog.ucl.ac.uk/~hmomiji/

What is the Longituninal Dune Wind Regime?



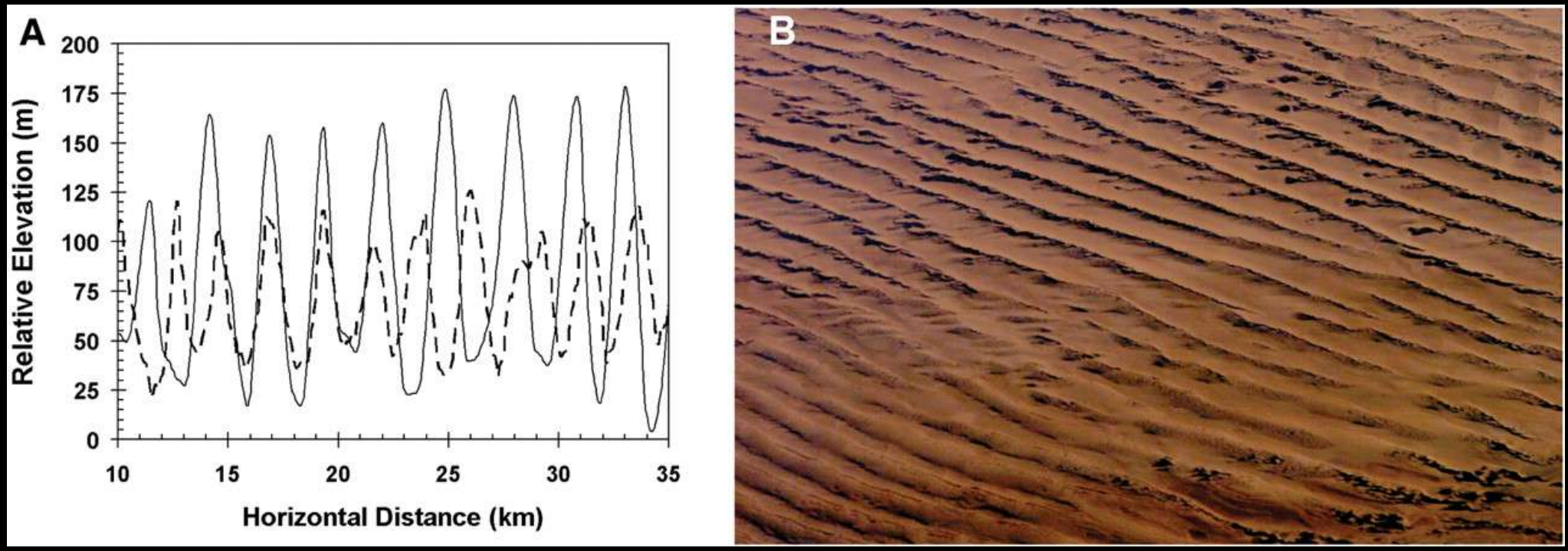
Particle size





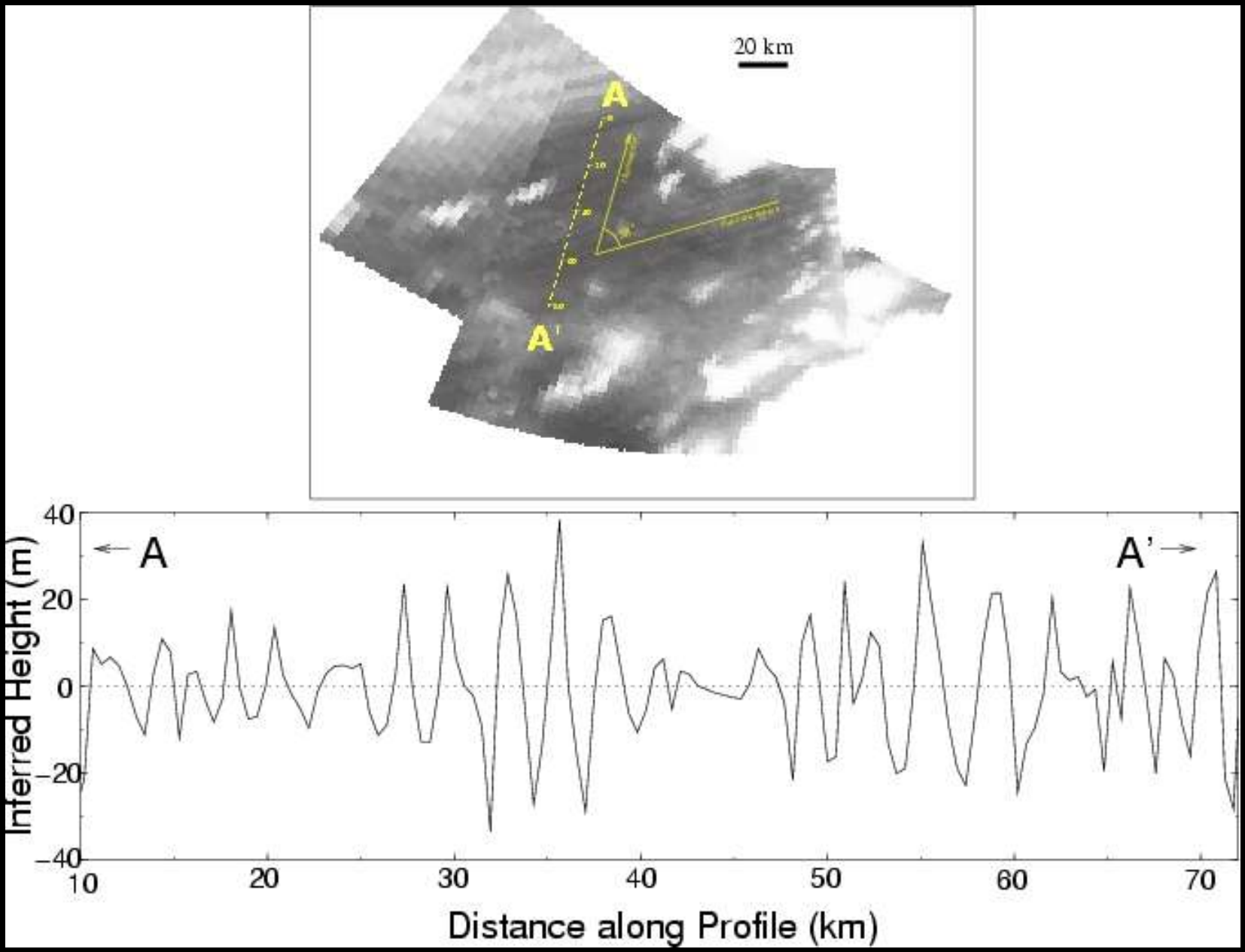
Sand: defined by geologists as a particle between 0.0625 and 2 mm in diameter (Wentworth 1922 Journal of Geology)

Dune Heights from T8 RADAR: 150m



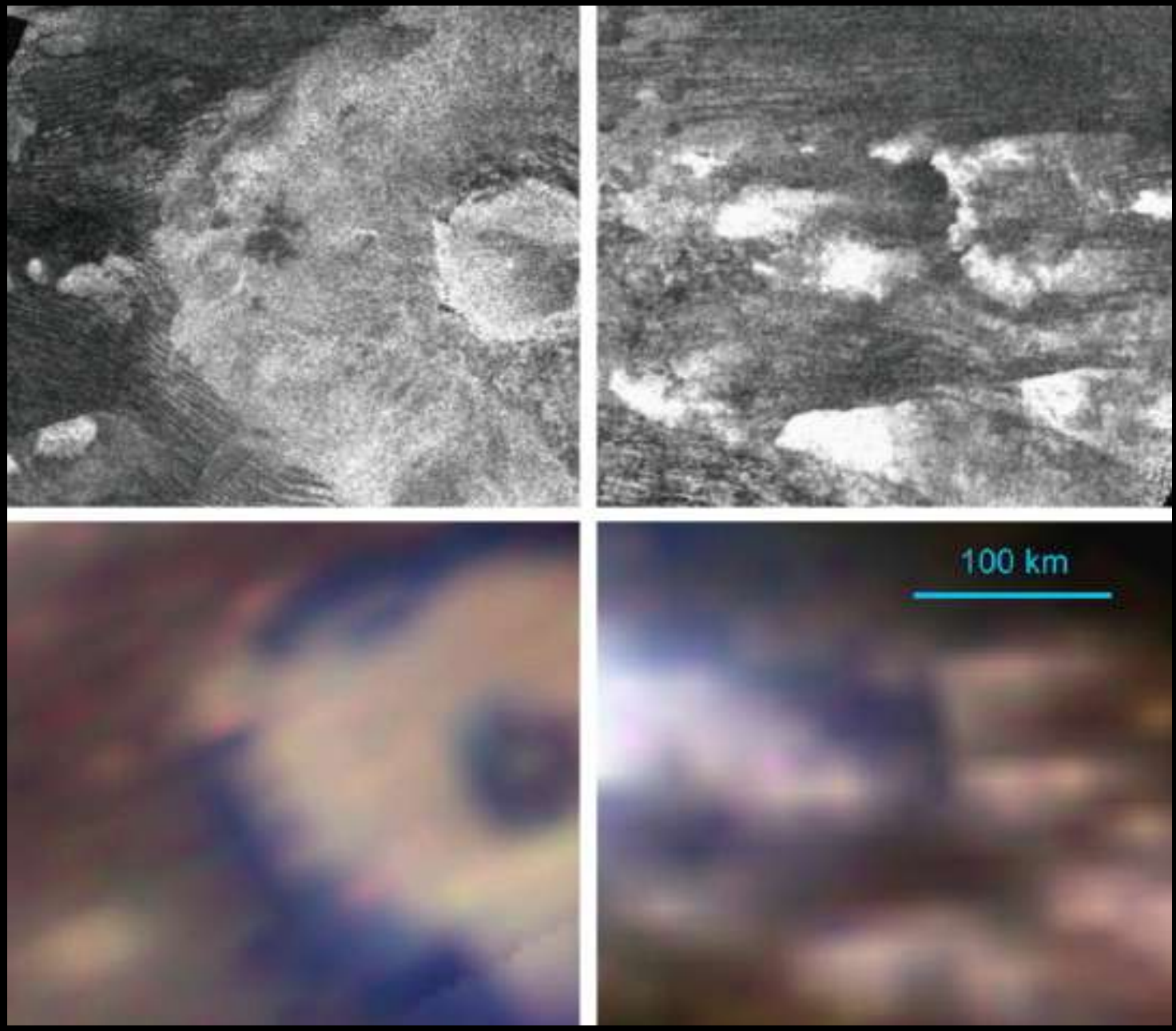
Lorenz et al. 2006 Science

Dune Heights from T4 VIMS: 30-70m



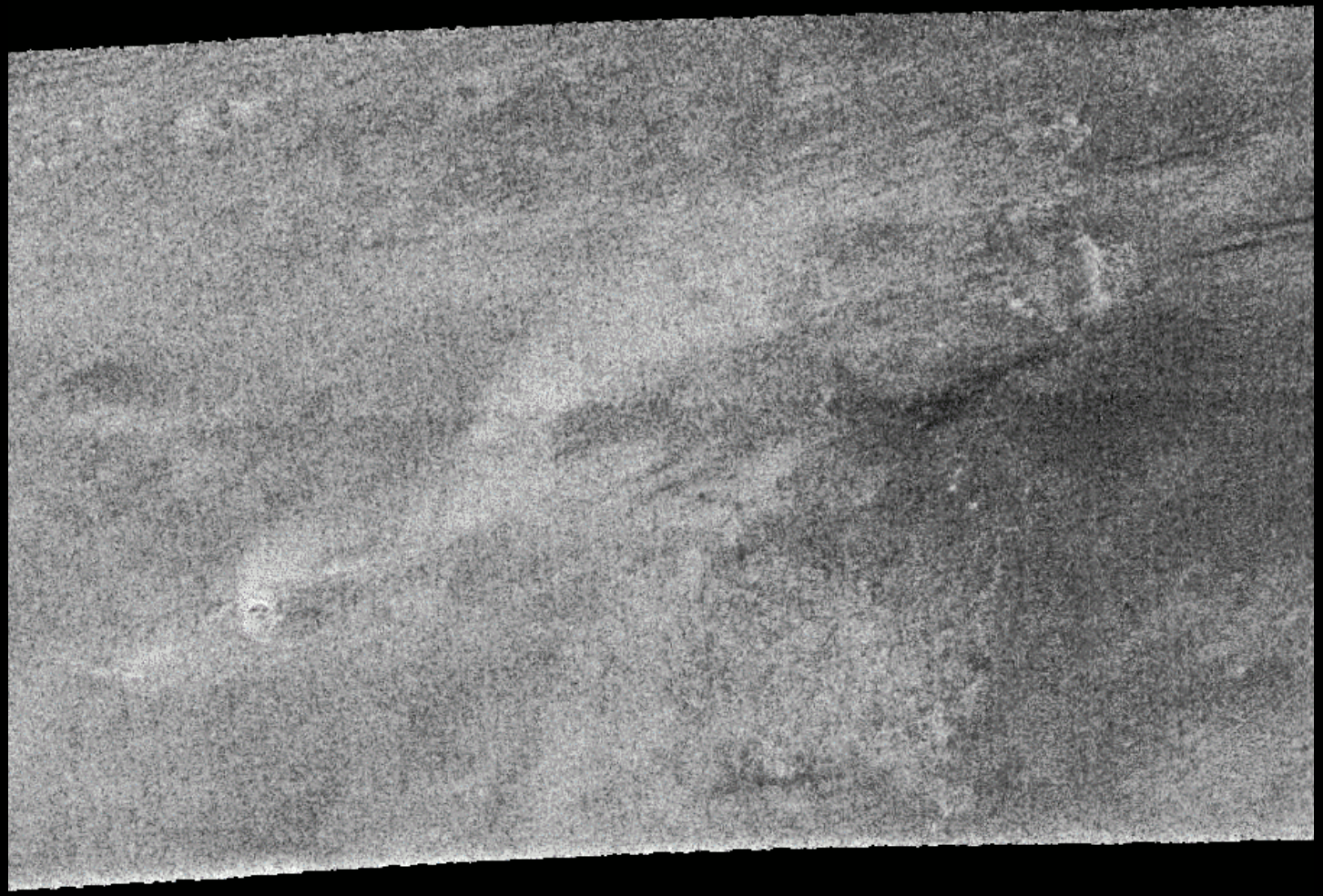
Barnes et al. Icarus, submitted

RADAR Dunes / VIMS Dark Brown Correlation



Soderblom et al., in press P&SS

RADAR Dunes / VIMS Dark Brown Correlation



Barnes et al. 2007 Icarus

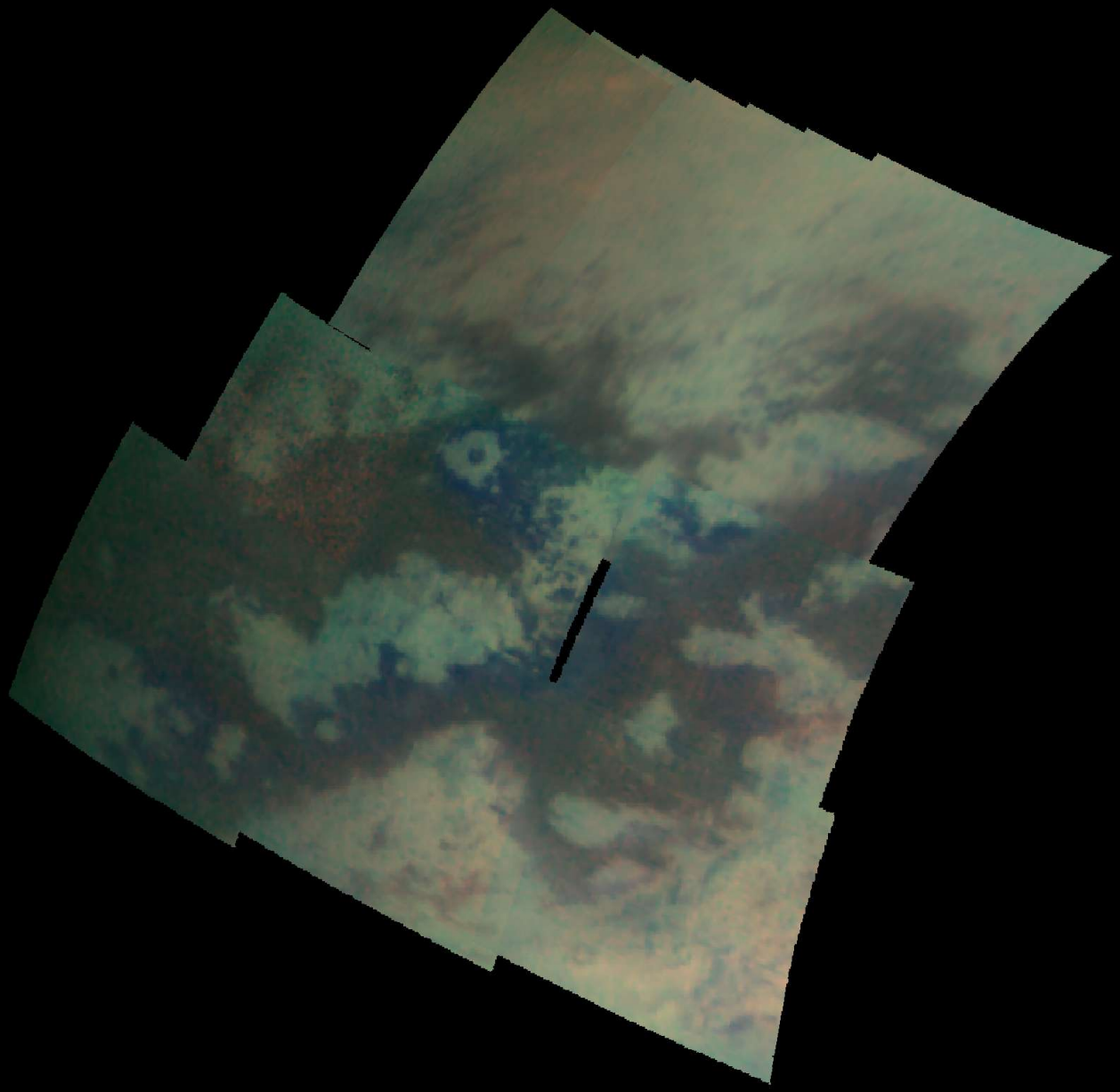
VIMS
T33

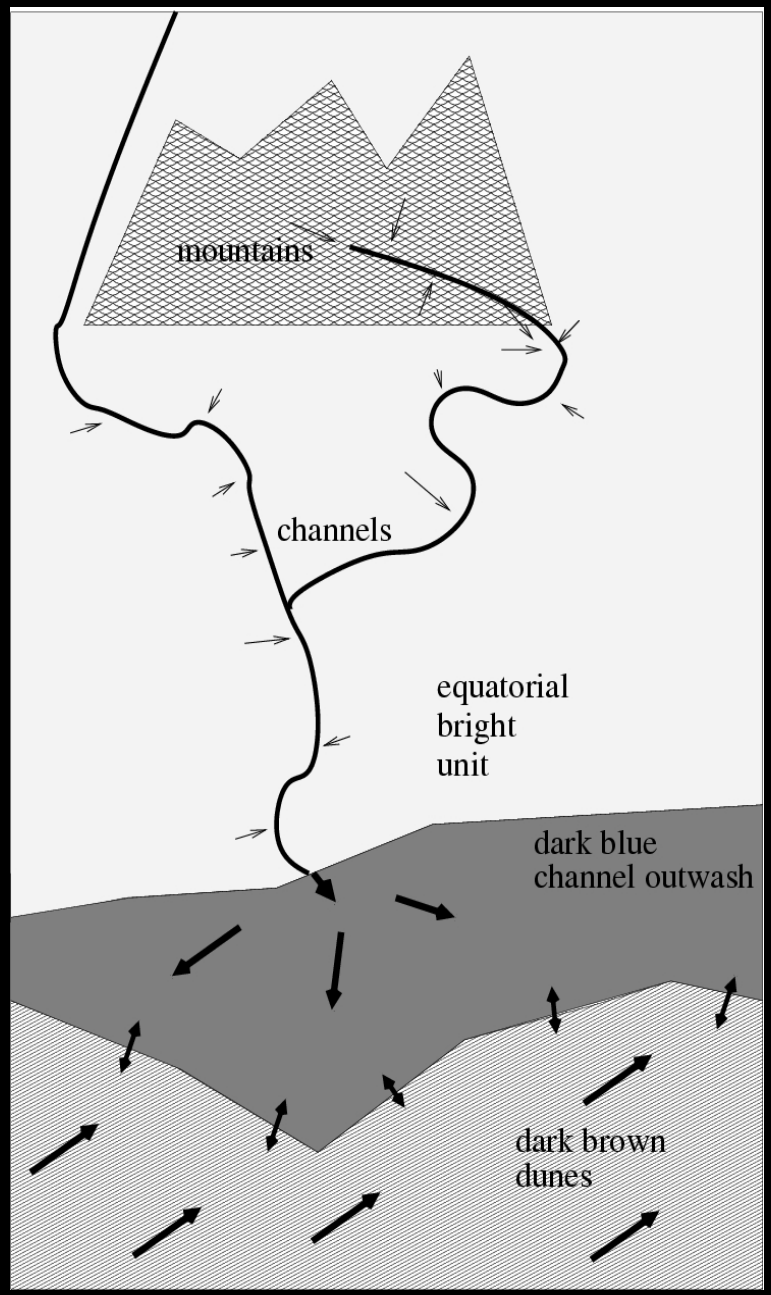
Faculae Orientations Suggest E-W Flow

ISS
T30

Perry et al. 2007 LPSC abstract

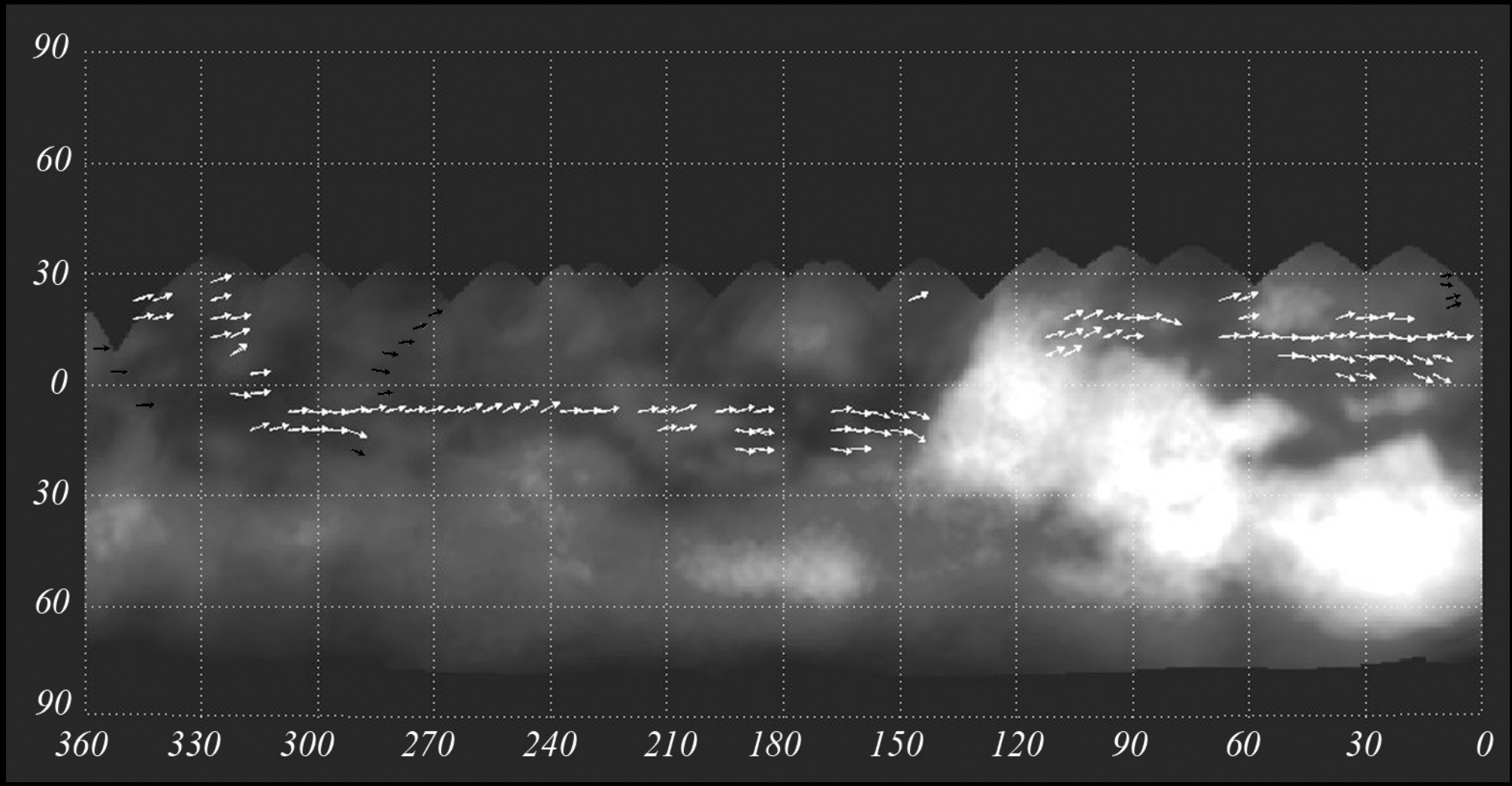
Dunes on West Side of Equatorial Bright





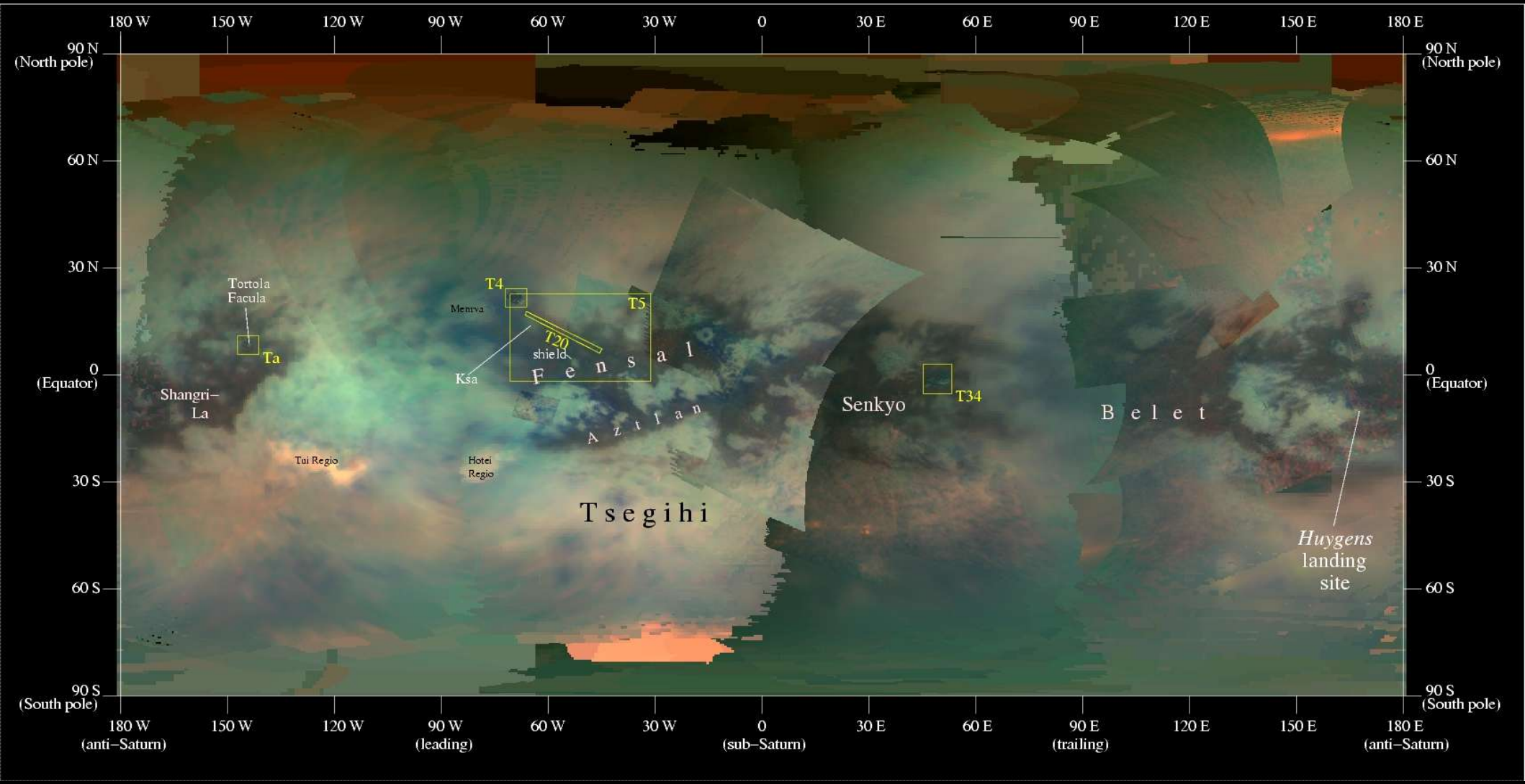
Barnes et al. JGR-P in press

RADAR Dune Orientations



Radebaugh et al. Icarus in revision

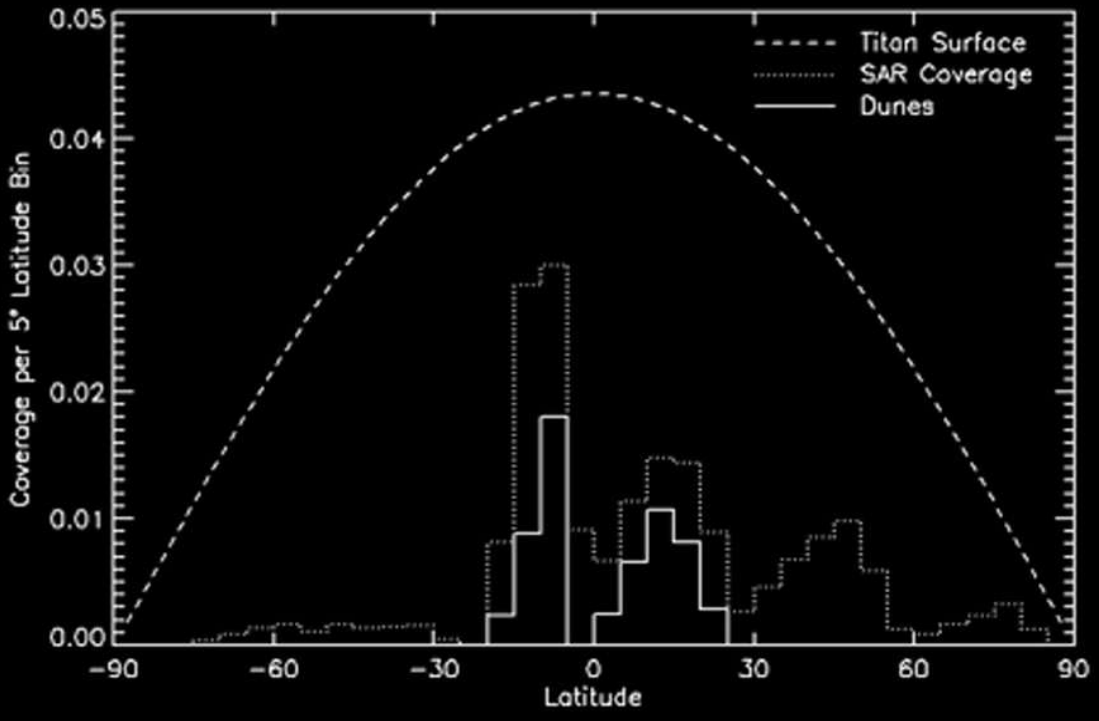
Latest Cassini Visual and Infrared Spectrometer (VIMS) Titan Map

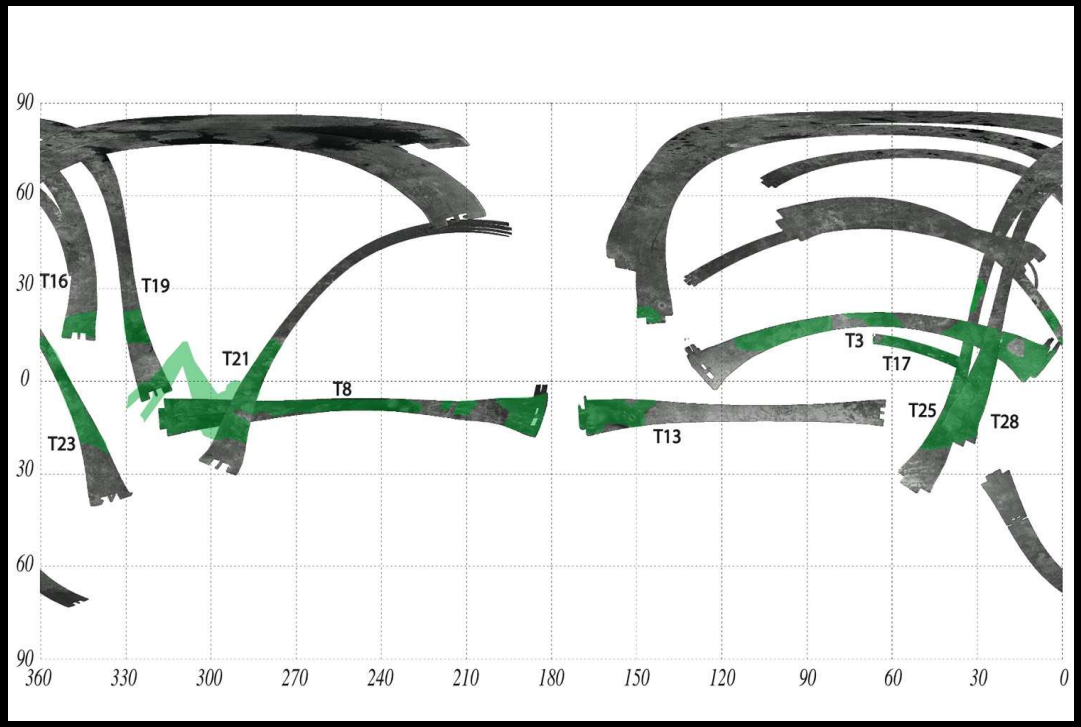


B = 1.28 microns, G = 2.0 microns, R = 5 microns

Barnes et al. Icarus submitted

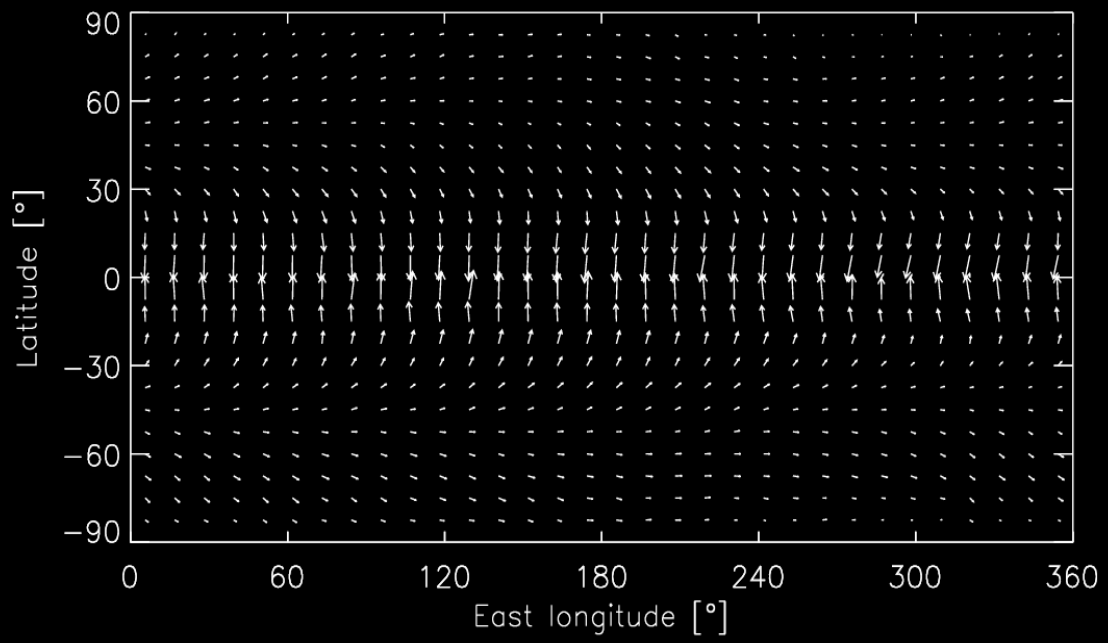
Distribution of RADAR-Detected Dunes



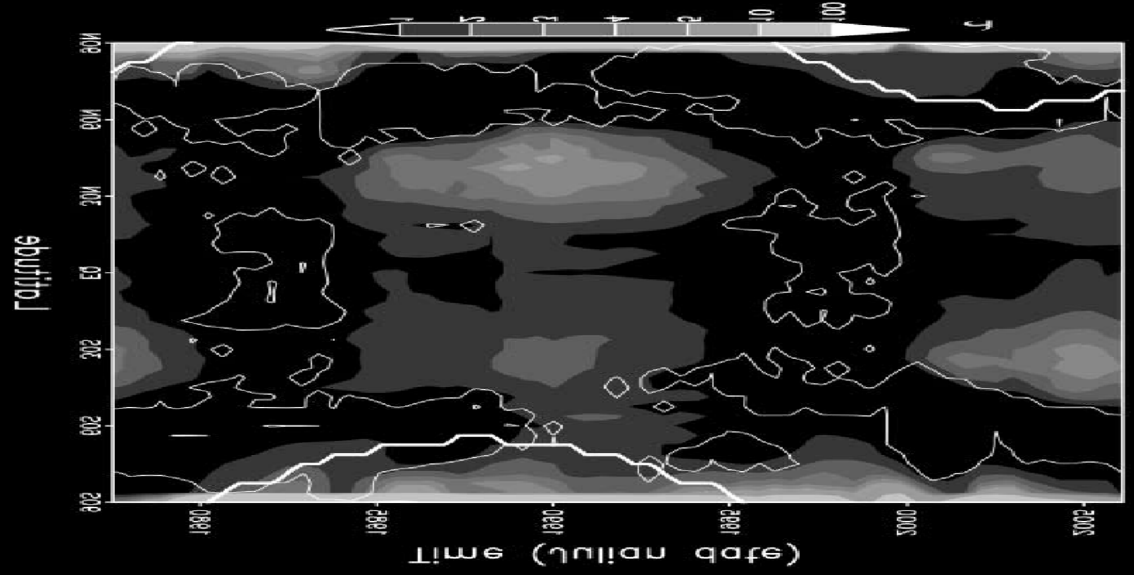


Radebaugh et al.
Icarus
in revision

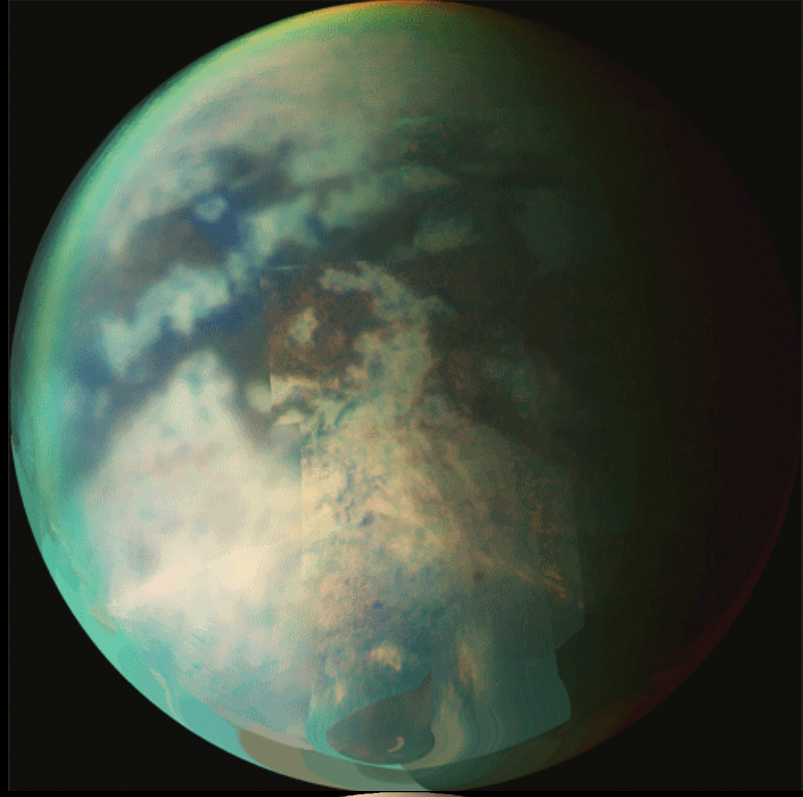
Titan Global Circulation

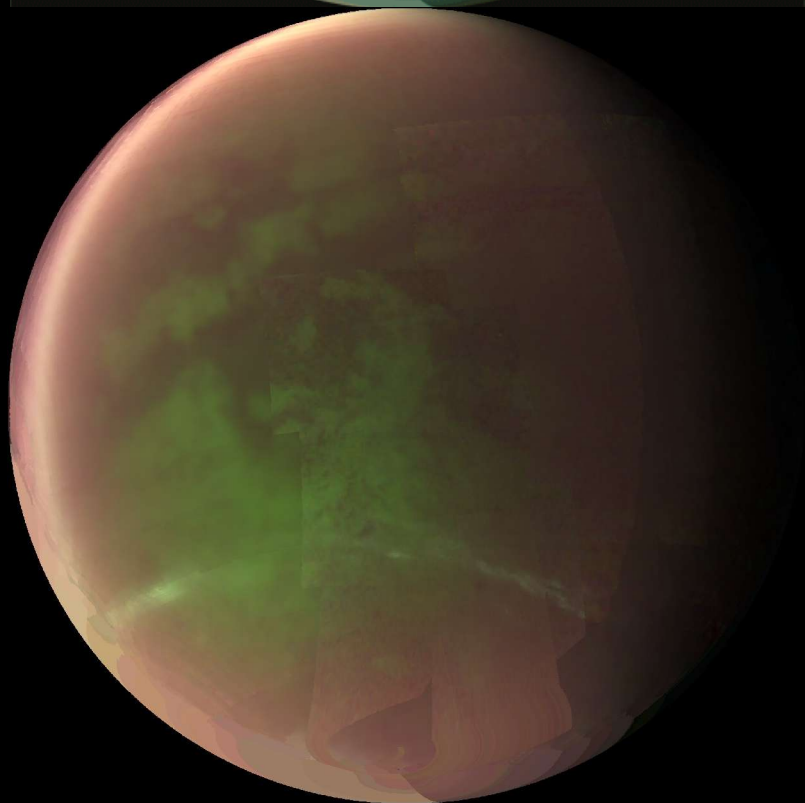


Tokano & Neubauer, 2002 Icarus

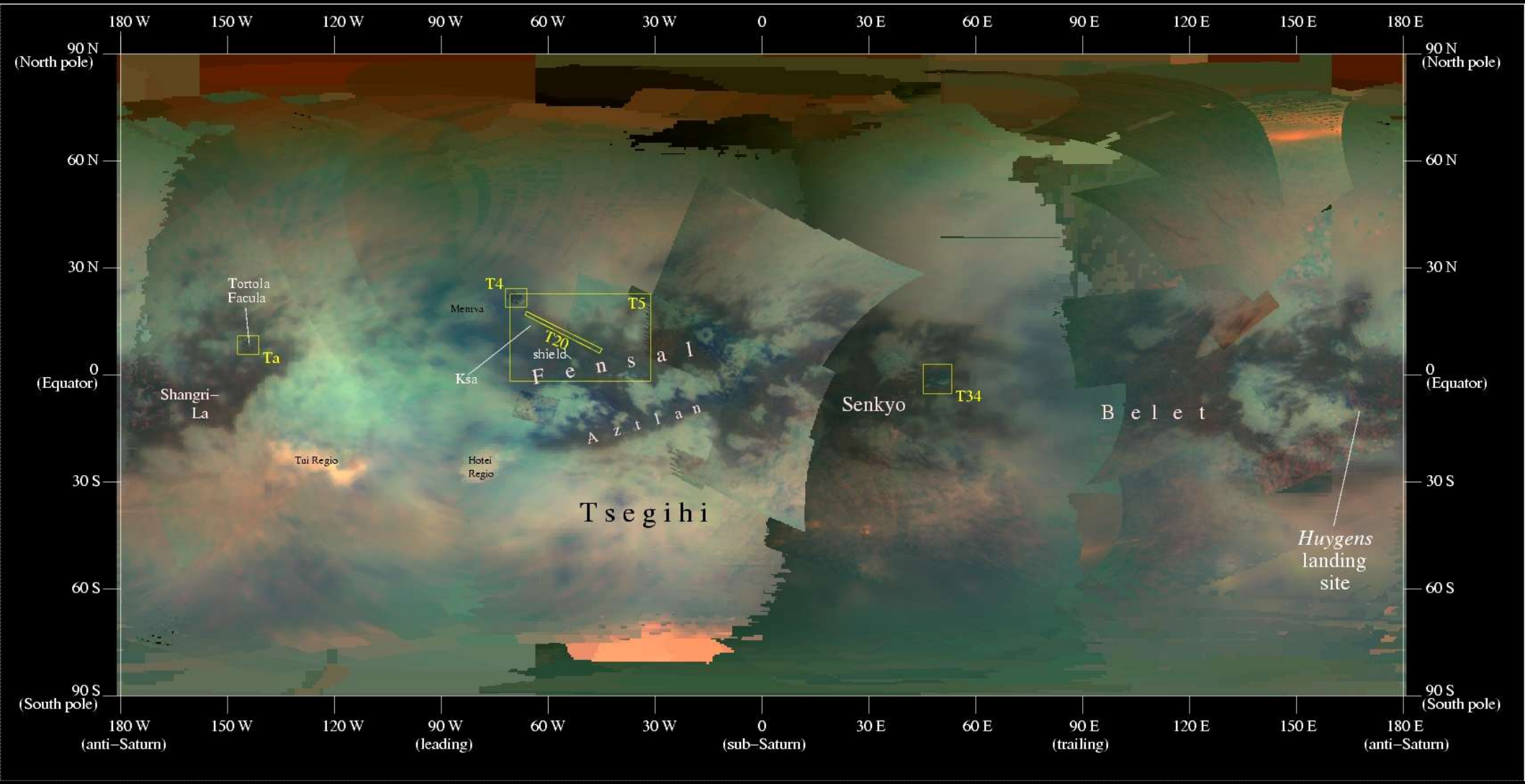


Rannou et al., 2006 Science





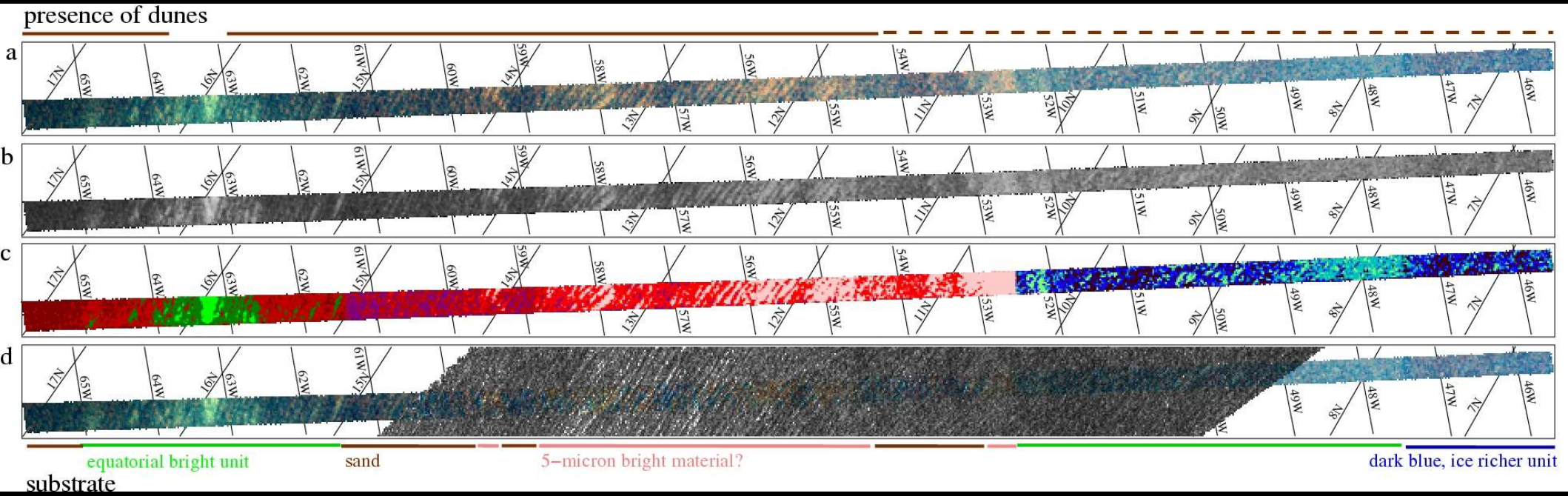
Location of T20 VIMS Swath



B = 1.28 microns, G = 2.0 microns, R = 5 microns

Barnes et al. Icarus submitted

Spectral Mapping from T20



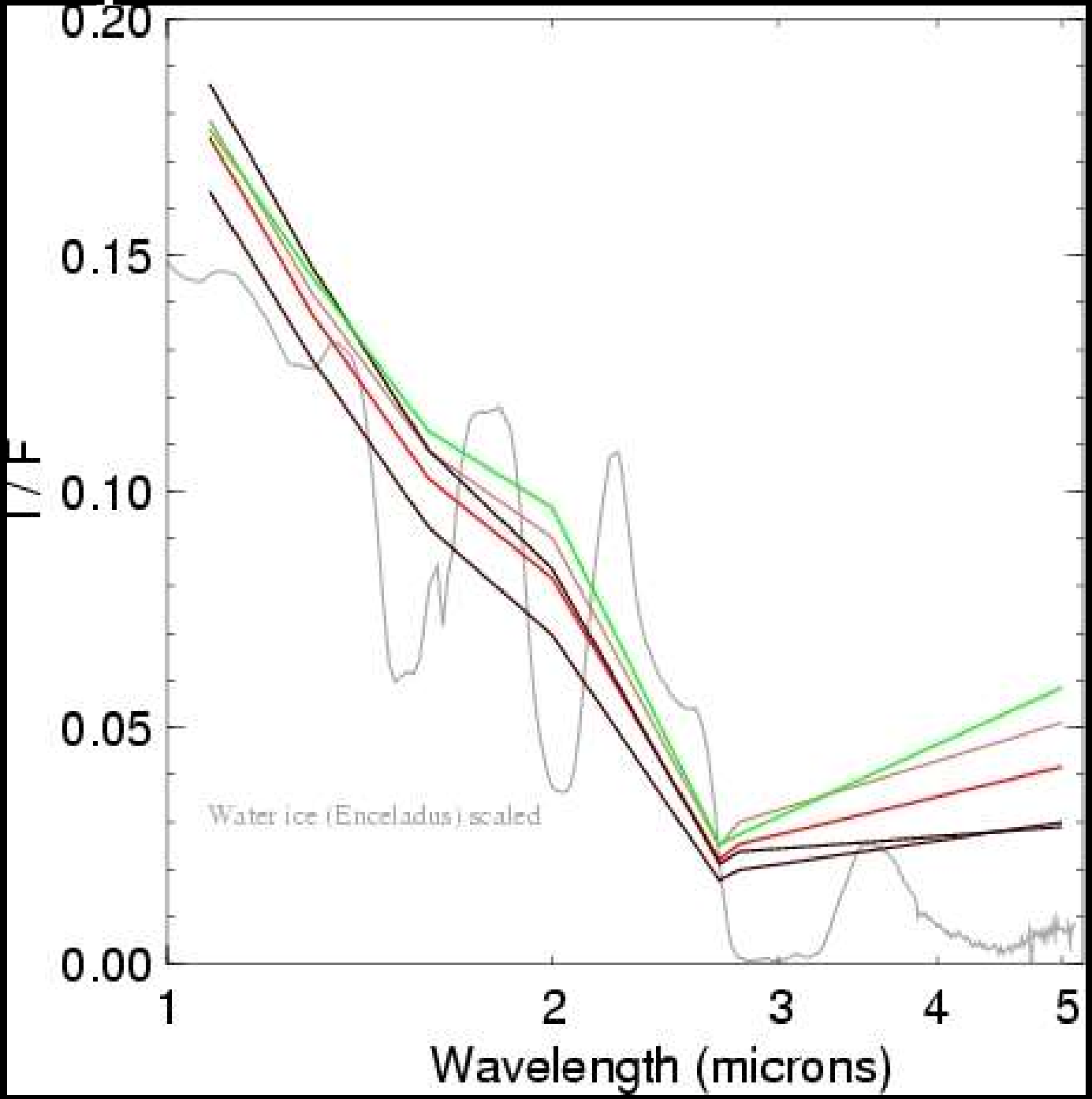
- Dunes resolved
- Sand is not continuous: some areas have sand-free interdunes
- Interdunes vary in spectrum – they represent the substrate underlying the dunes

Barnes et al. Icarus submitted

Interdune from Death Valley

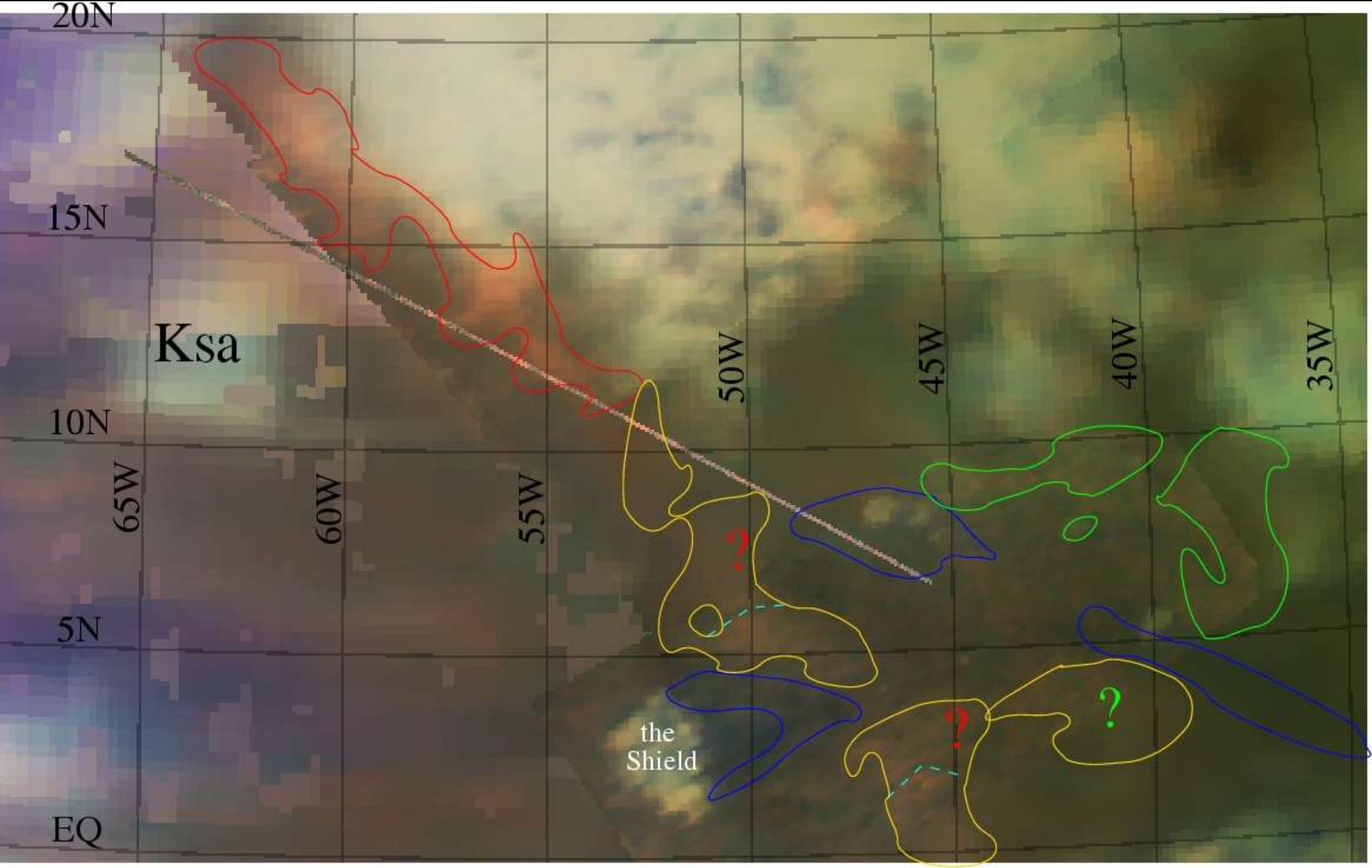
Barnes et al. Icarus submitted

Spectra of T20 Classes



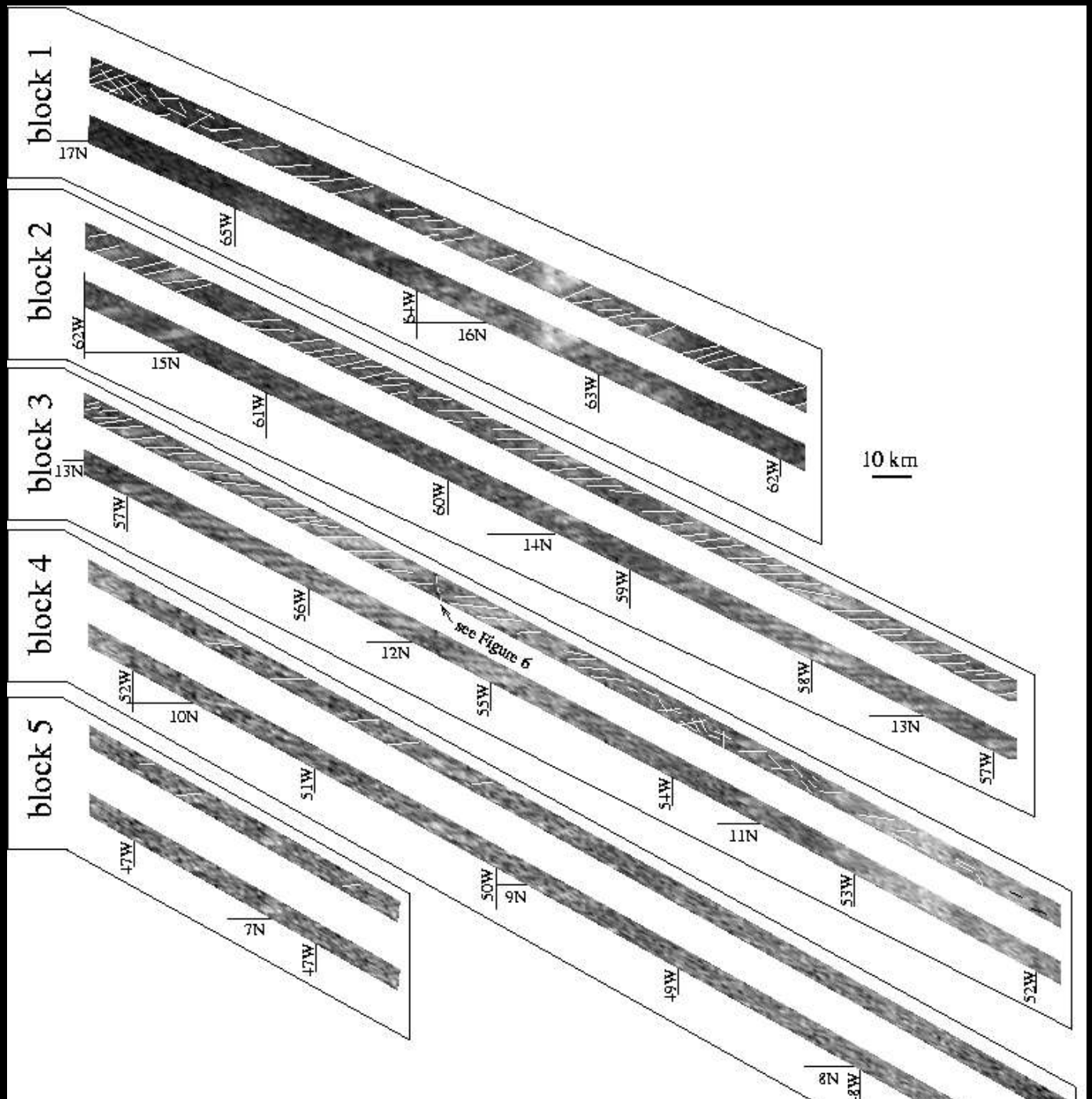
Barnes et al. Icarus submitted

Context for T20 from T5



Barnes et al. Icarus submitted

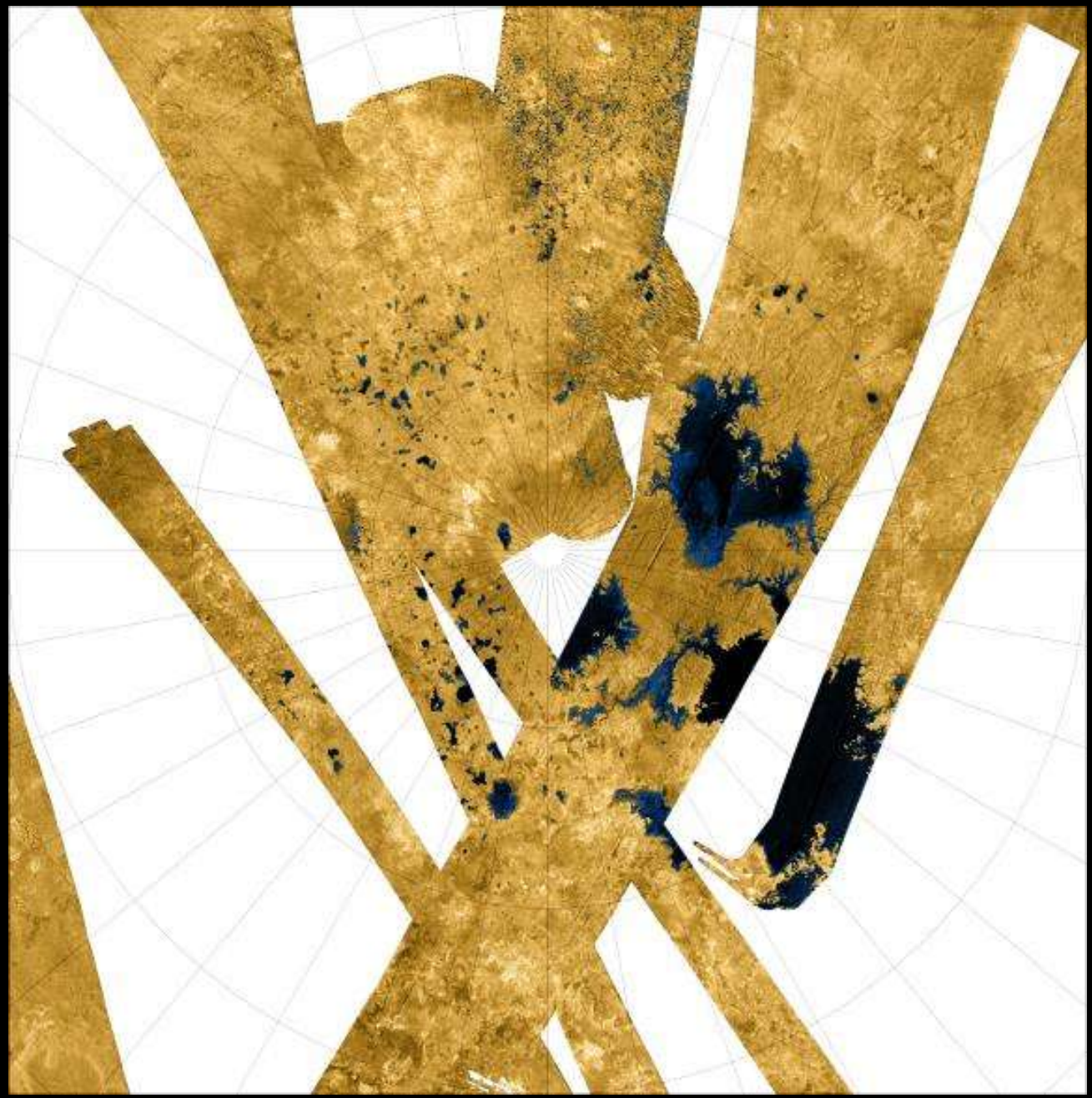
Dune Spacing and Orientation



Review of Predictions

Prediction	Possible Resolution
• Sand lost to liquid	• Liquids cover only 2% of surface; at high latitudes far removed from dunes
• Long timescales needed to create 500m dune forms	• Titan's dunes seem to be stable features that may have lasted for hundreds of millions of years
• Threshold speeds far above friction speeds	• Thermal winds only assumed, no tidal or latent-heat driven winds (?)
• Hydrocarbon haze particles make poor saltators	• Unresolved; haze must either build up to sand size or erode to sand size from a lithic reservoir. Also, hydrocarbons behave strangely at 94K
• Impacts generate only small amounts of fragments, so no sand source	• Though the sand source remains indeterminate, ubiquitous channels allow for erosion to create particles
• No sand sink	• Unresolved; do buried dunes lithify into hydrocarbon sandstone?

Possible RADAR Lakes at North Pole



Cassini RADAR Team

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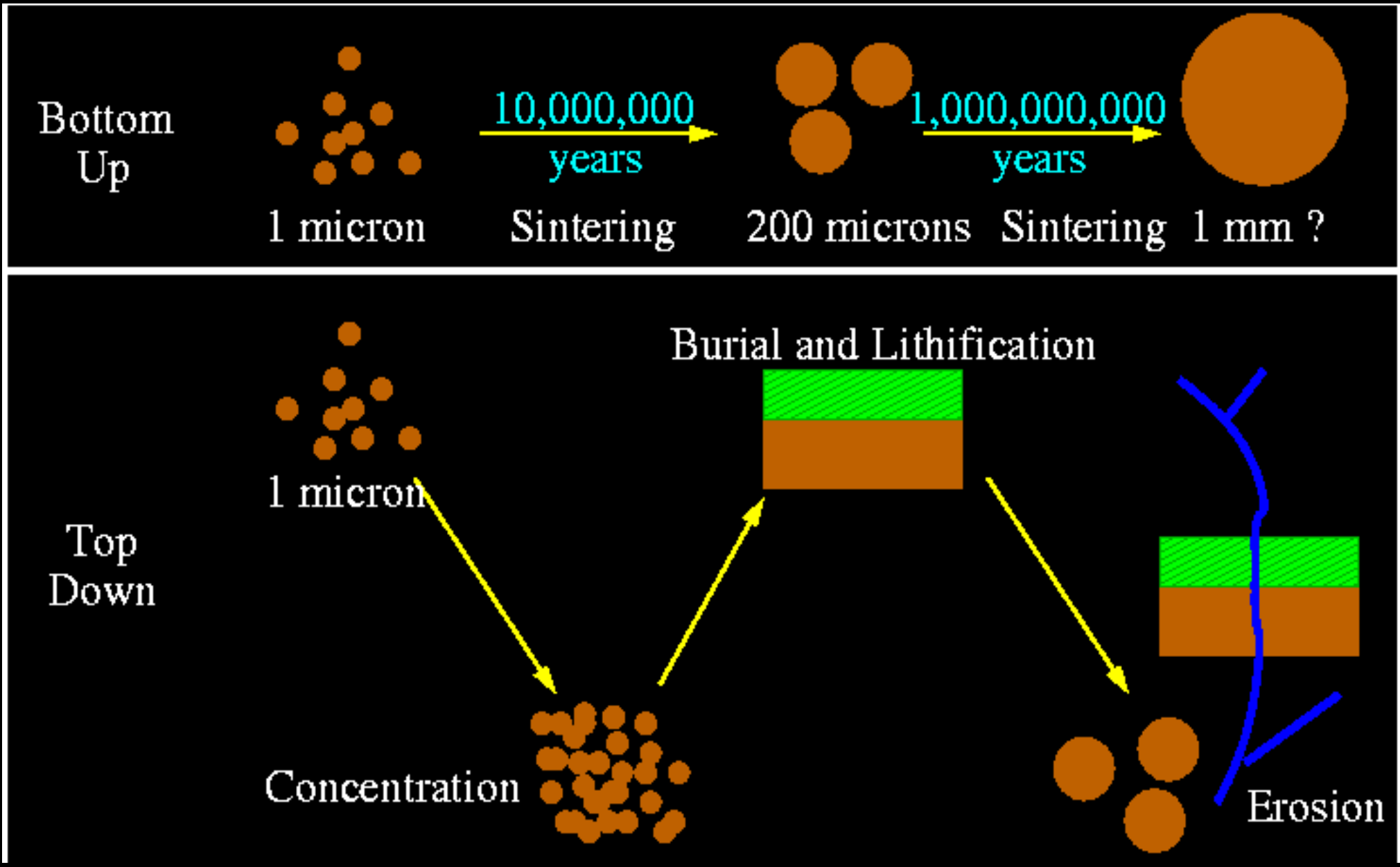
Where do sand-sized particles come from?



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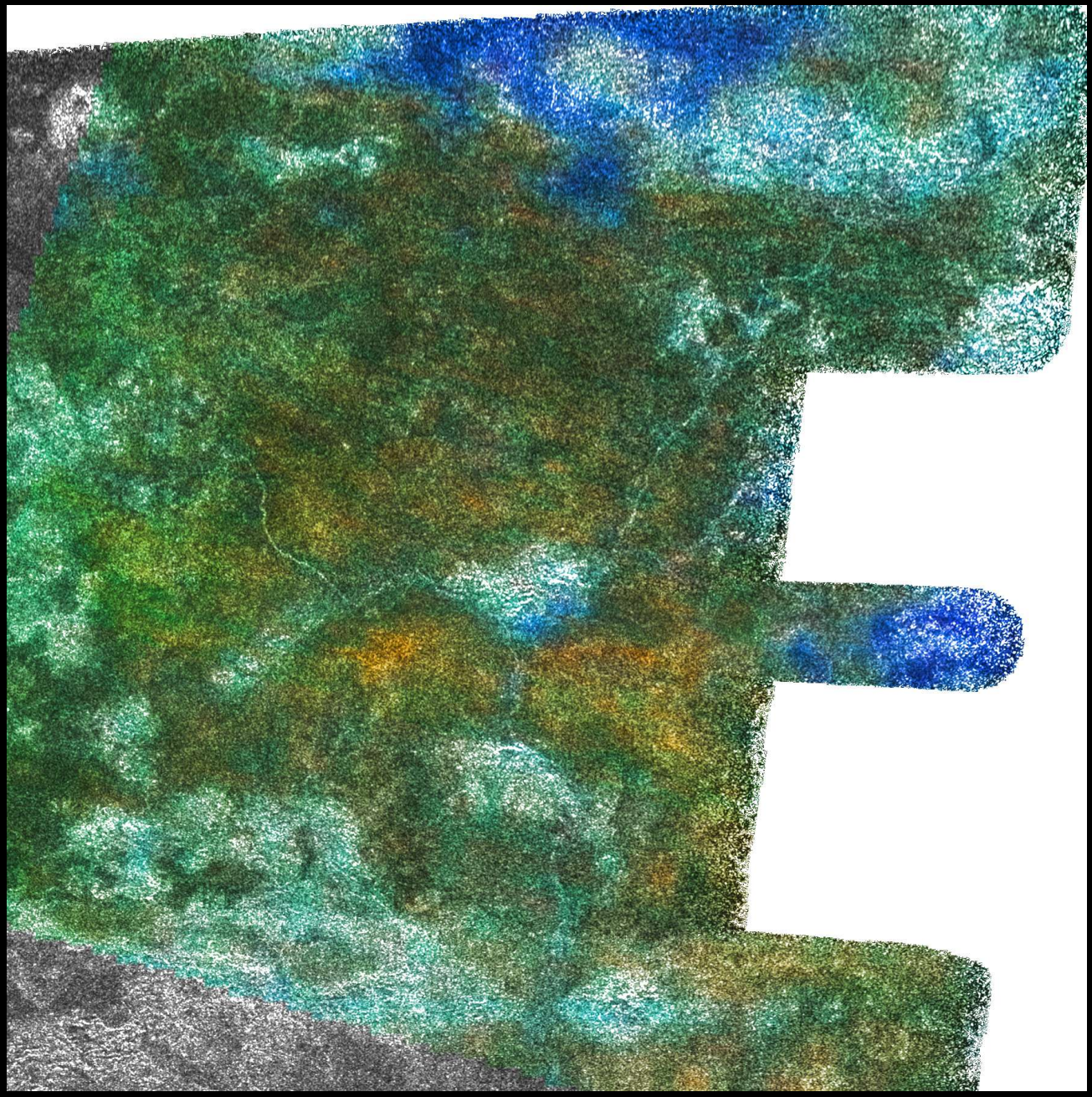
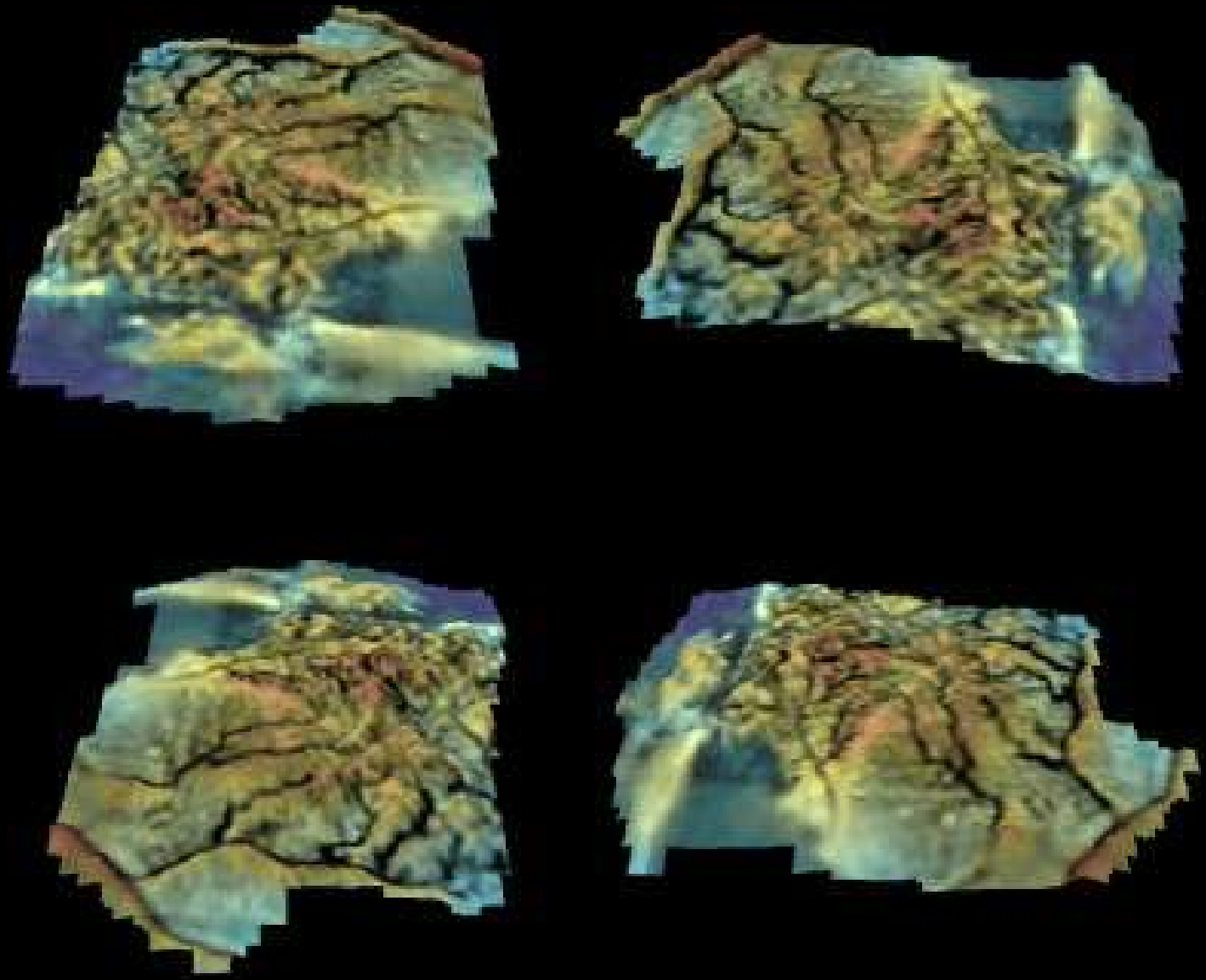
VIMS & RADAR Channels



Barnes et al., in press JGR-P

Huygens Channels (DISR)



Soderblom et al., in press P&SS (2)

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Summary

- All studied bodies with both solid surfaces and thick atmosphere now known to exhibit sand dunes (what about Triton and Pluto?)
- Titan's dunes cover ~20% of the surface, all within 35 degrees of the equator
- Dunes are longitudinal; presumably old like longitudinal dunefields on Earth
- Particles calculated to be of sand size (180-250 microns)
- Spacing 1-3 km, heights 30-150m
- Not made of ice grains – hydrocarbons consistent
- Interdunes show substrate; dunes seem to cover a variety of terrains

Newly Relevant Questions

- What is the wind regime that produces longitudinal dunes on Titan?
- Are the dunes confined to equatorial regions due to climate or wind circulation?
- What precisely is the sand that makes up the dunes composed of? Is the composition uniform across the globe, or is it regionally variable?
- How are sand-sized particles formed, and maintained? Is the computed particle size correct?
- Are Titan's dunes active today? If so, how can they stay active given continuous drizzle (Tokano et al., Adamkovics et al.)?
- Why don't the dunes penetrate into Xanadu?
- What causes variations in sand coverage and dune height?
- Are there particle sources and sinks?
- What science could a lander in the dunes do?