Cassini CHARM Talk

27th February 2007

Dunes on Titan

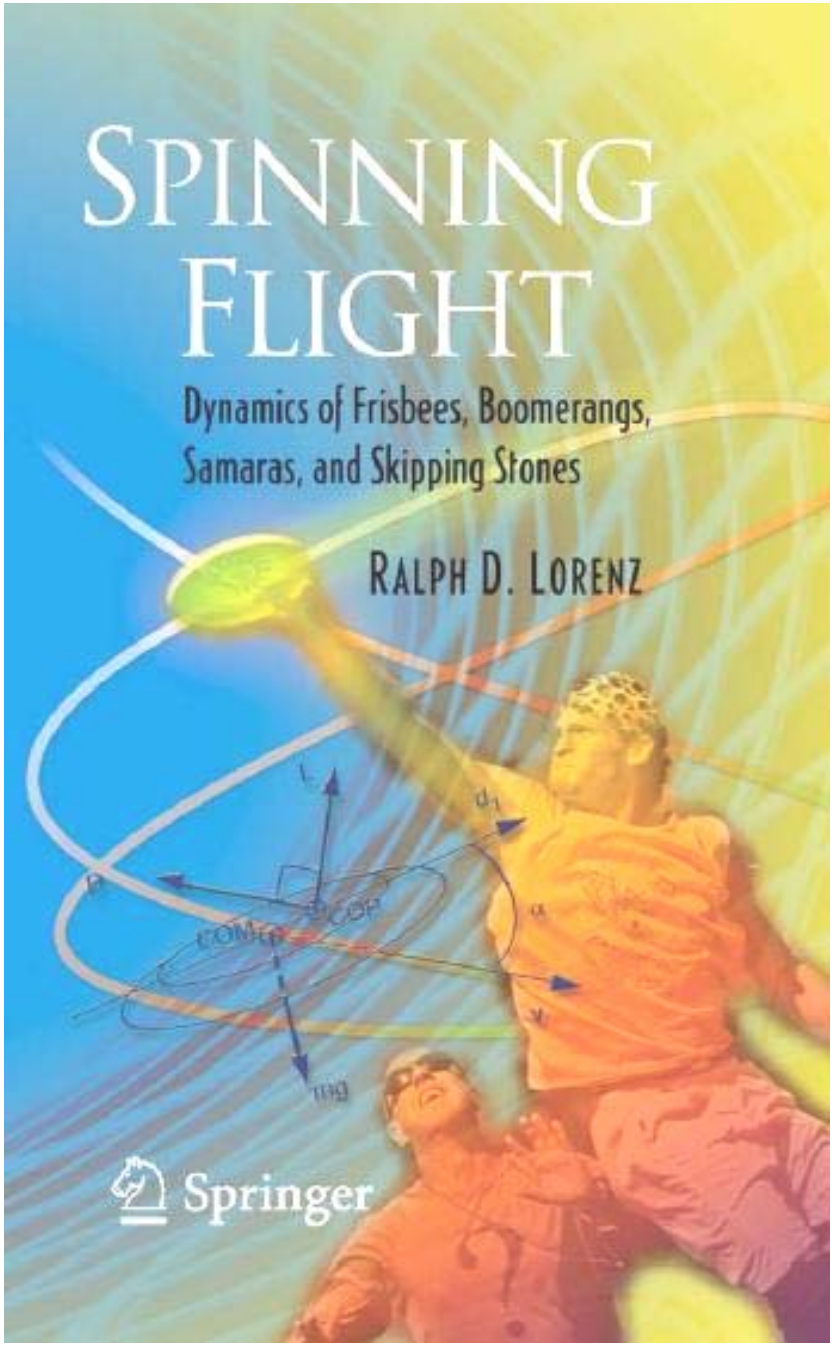
Ralph D Lorenz

Johns Hopkins University

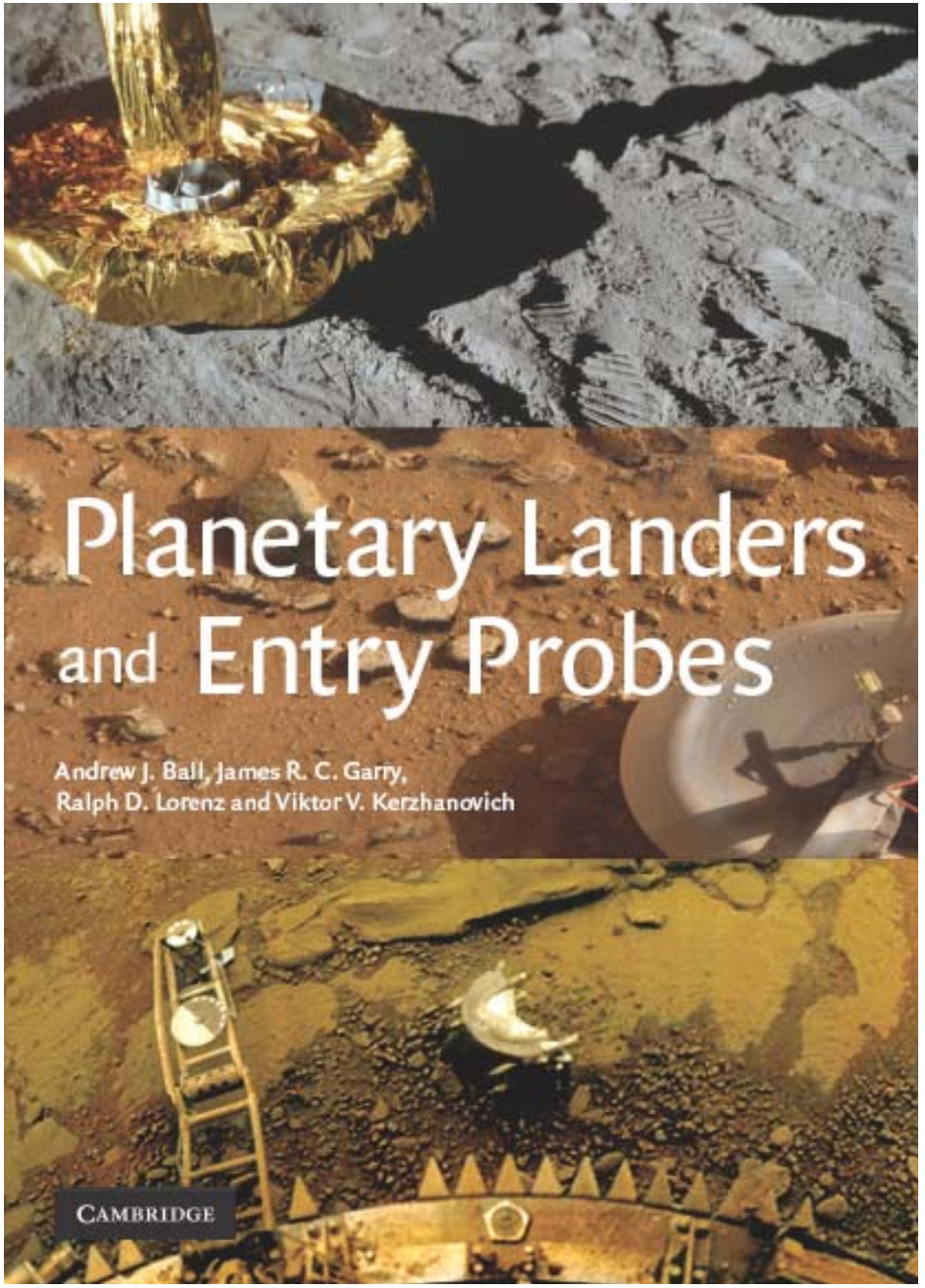
Applied Physics Laboratory

Laurel, MD

http://www.lpl.arizona.edu/~rlorenz



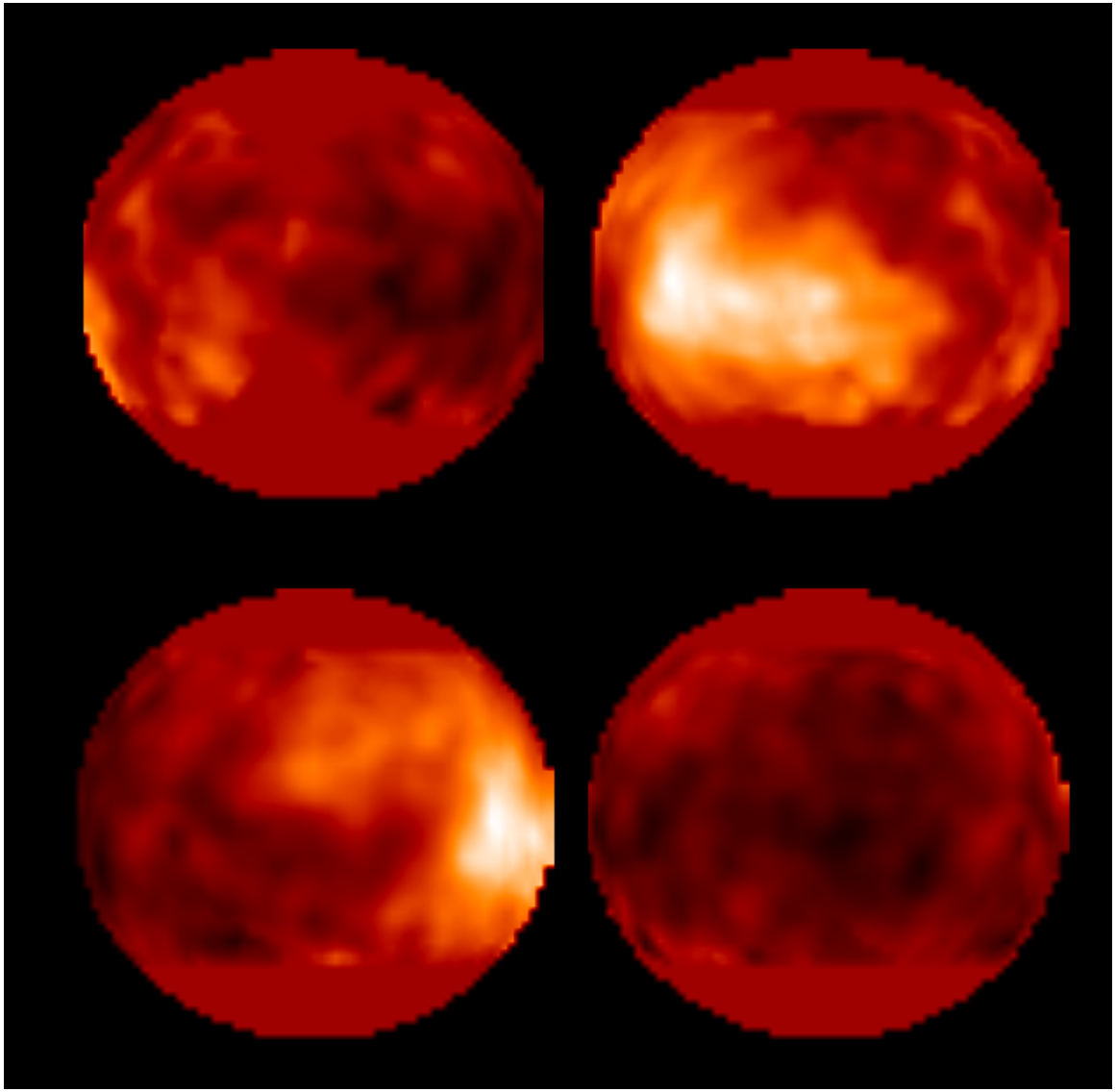
out now!



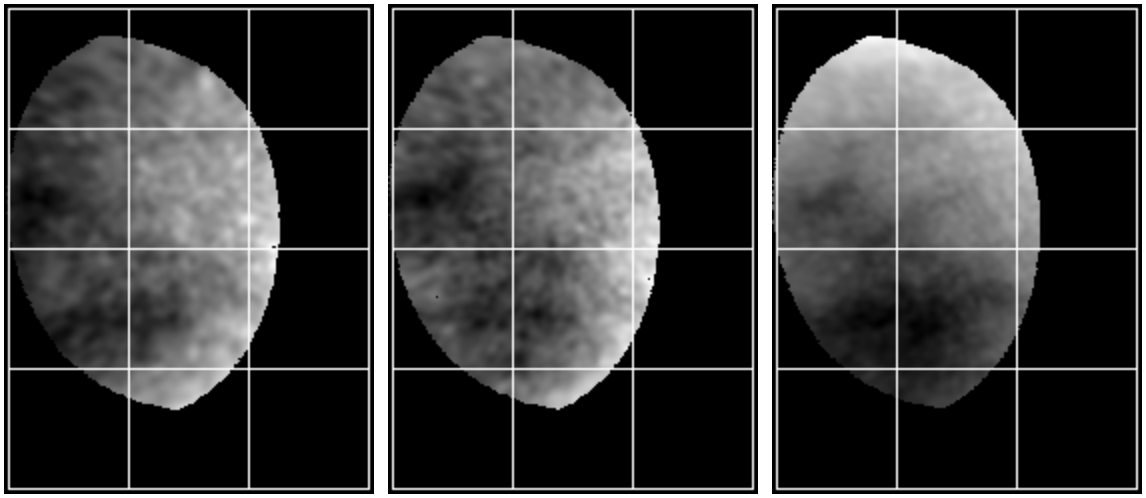
coming soon – end March 2007

HST 940nm Map (Smith et al., 1996) projected onto a Globe, viewed from 4 longitudes (0,90, 180, 270)

What makes dark areas dark ?

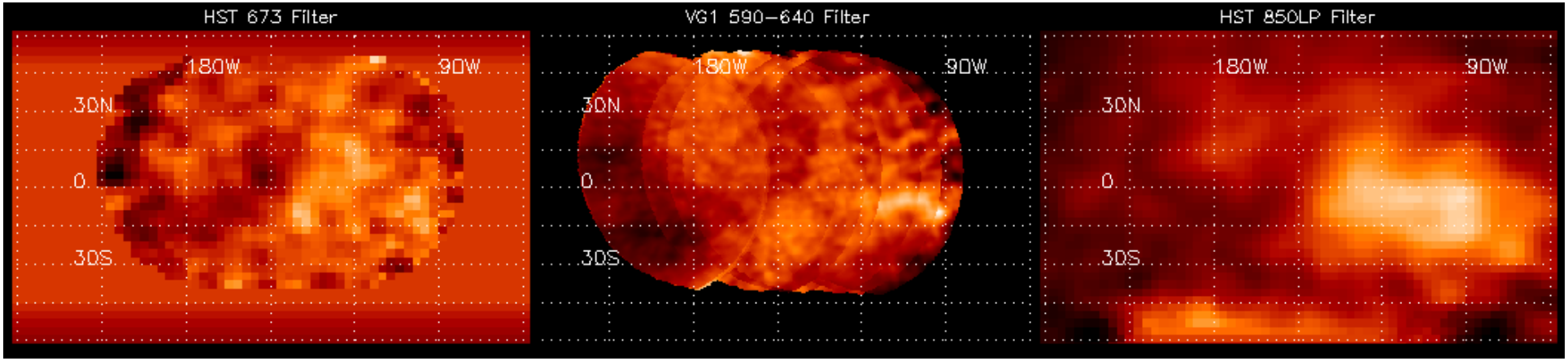


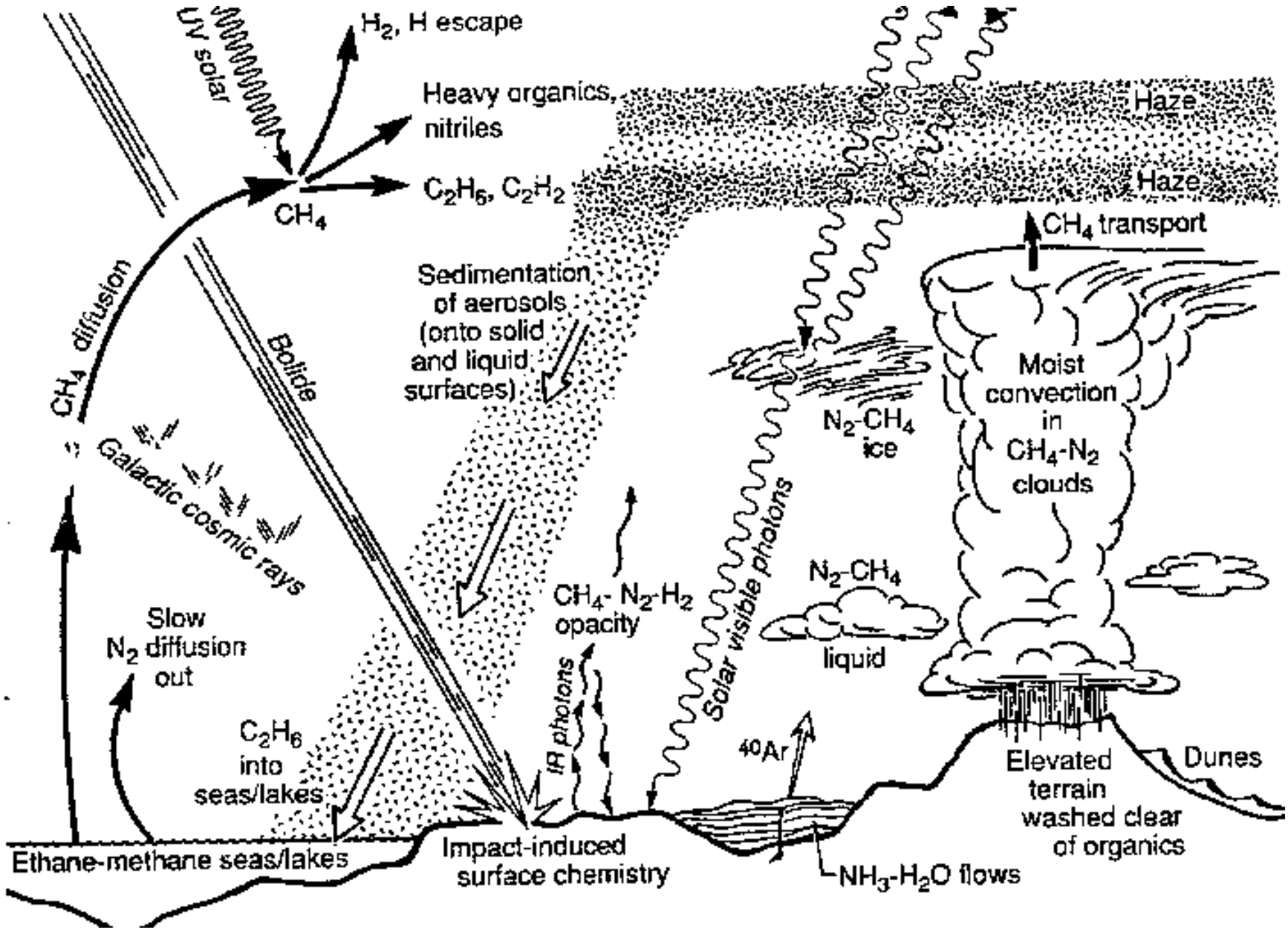
Re-analysis of Voyager orange filter images shows weak (~5%) but consistent contrasts



(Richardson et al., 2004)

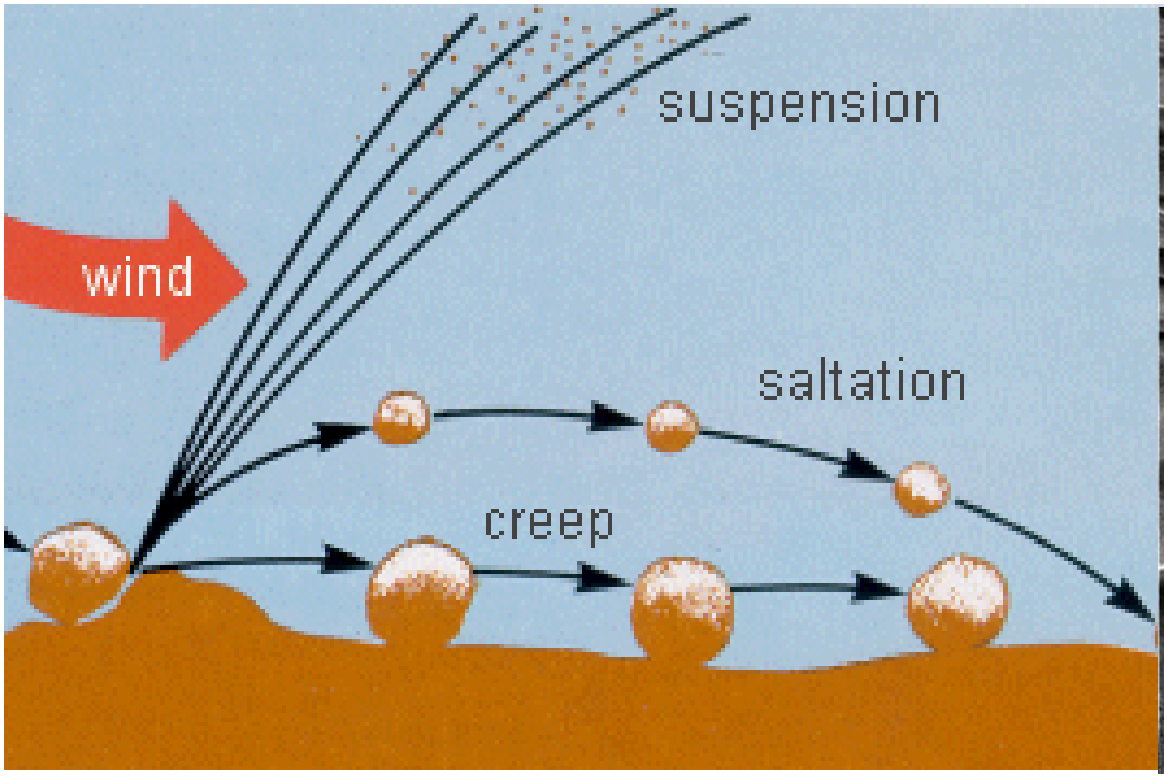
Resultant map compares well with HST and other near-IR maps. Human with red (ideally polarizing) glasses could see Titan's surface

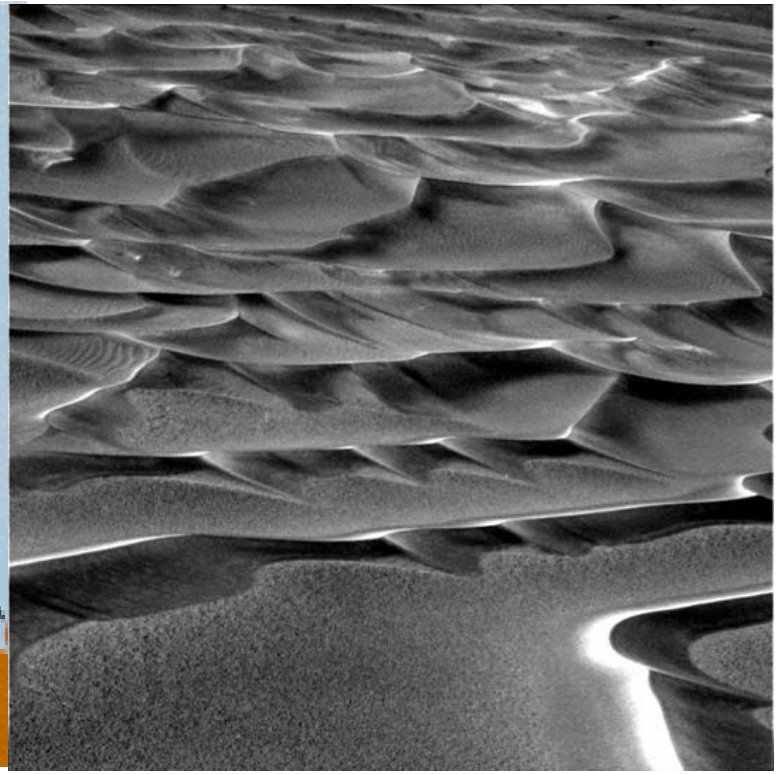



UV solar
H_2, H escape
Heavy organics, nitriles
C_2H_6, C_2H_2
CH_4
Haze
Haze
CH_4 transport
CH_4 diffusion
Sedimentation of aerosols (onto solid and liquid surfaces)
Bolide
Moist convection in CH_4-N_2 clouds
N_2-CH_4 ice
Galactic cosmic rays
CH_4-N_2-H_2 opacity
Solar visible photons
N_2-CH_4 liquid
Slow N_2 diffusion out
IR photons
^{40}Ar
C_2H_6 into seas/lakes
Elevated terrain washed clear of organics
Dunes
Ethane-methane seas/lakes
Impact-induced surface chemistry
NH_3-H_2O flows

Dunes form by process called ‘saltation’ - particles jump/bounce along the ground driven by the wind.

Wind is compressed by topography - as dune grows, aerodynamic stress on crest of dune removes material faster than it is supplied : reach an equilibrium state with dune slowly moving forwards





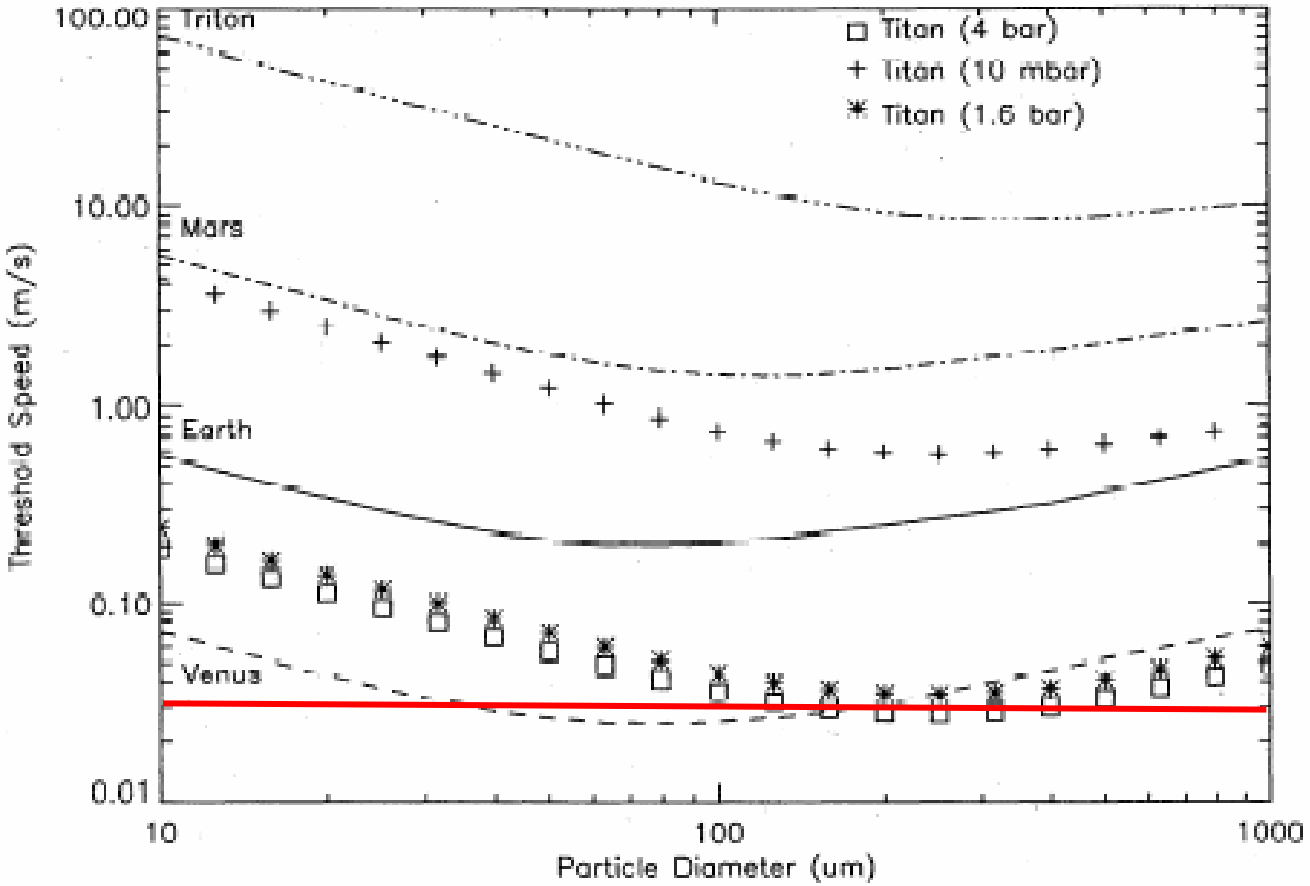


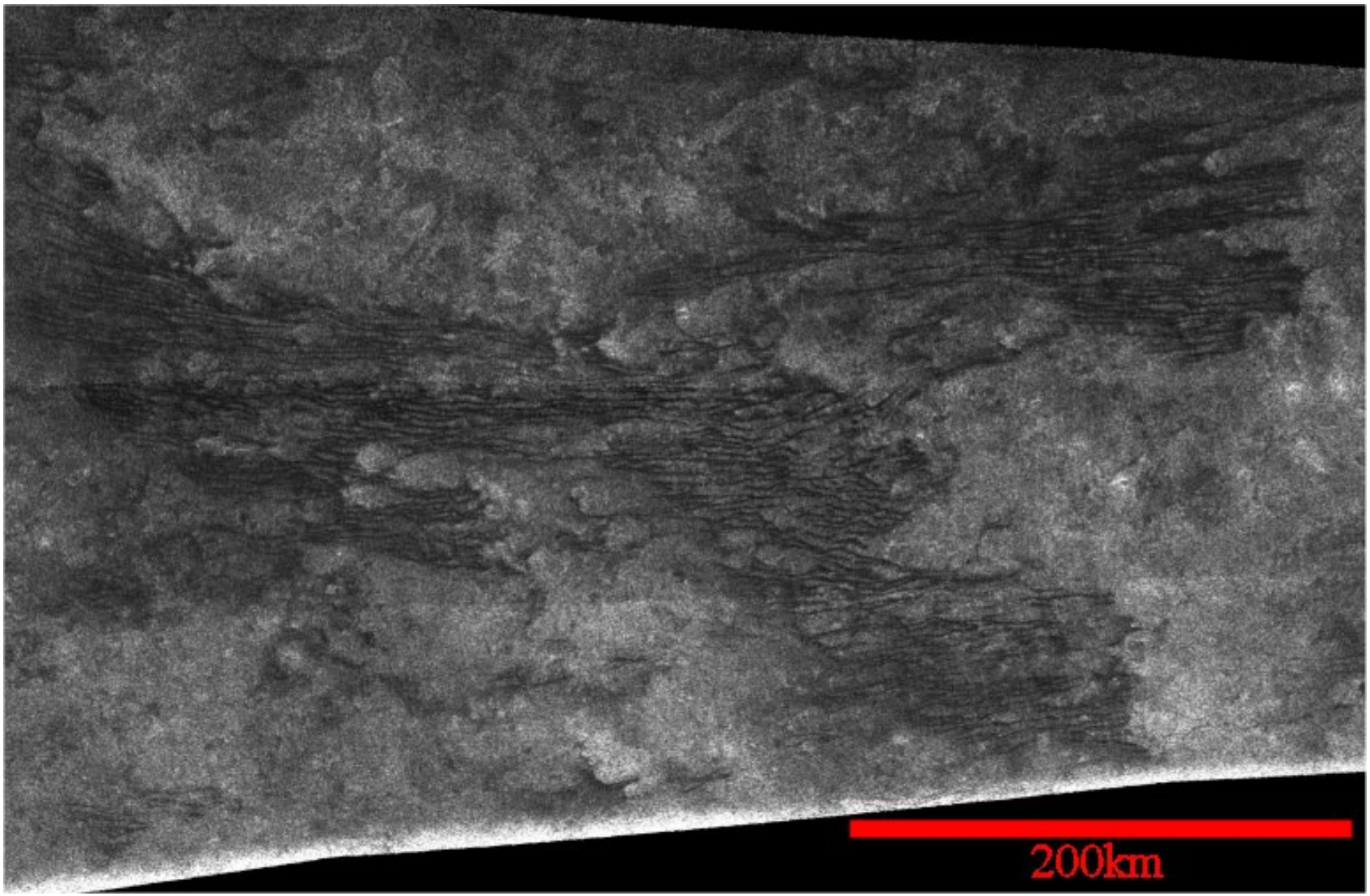
Figure 2. Threshold friction speeds for different planets, assuming the same interparticle cohesion as on Earth. In the absence of cohesion, the graphs would be straight lines, asymptotic to the curves shown at the large particle side of the curves (i.e., running bottom-left to top-right). In the presence of small cohesive forces, the curves would have minima further to the bottom-left, but would be again asymptotic to the curves shown at the large-particle side.

Calculations showed only weak winds ($U^* \sim UC_d^{0.5} \sim 0.03$ m/s) needed to lift particles in Titan's thick atmosphere, low gravity environment.

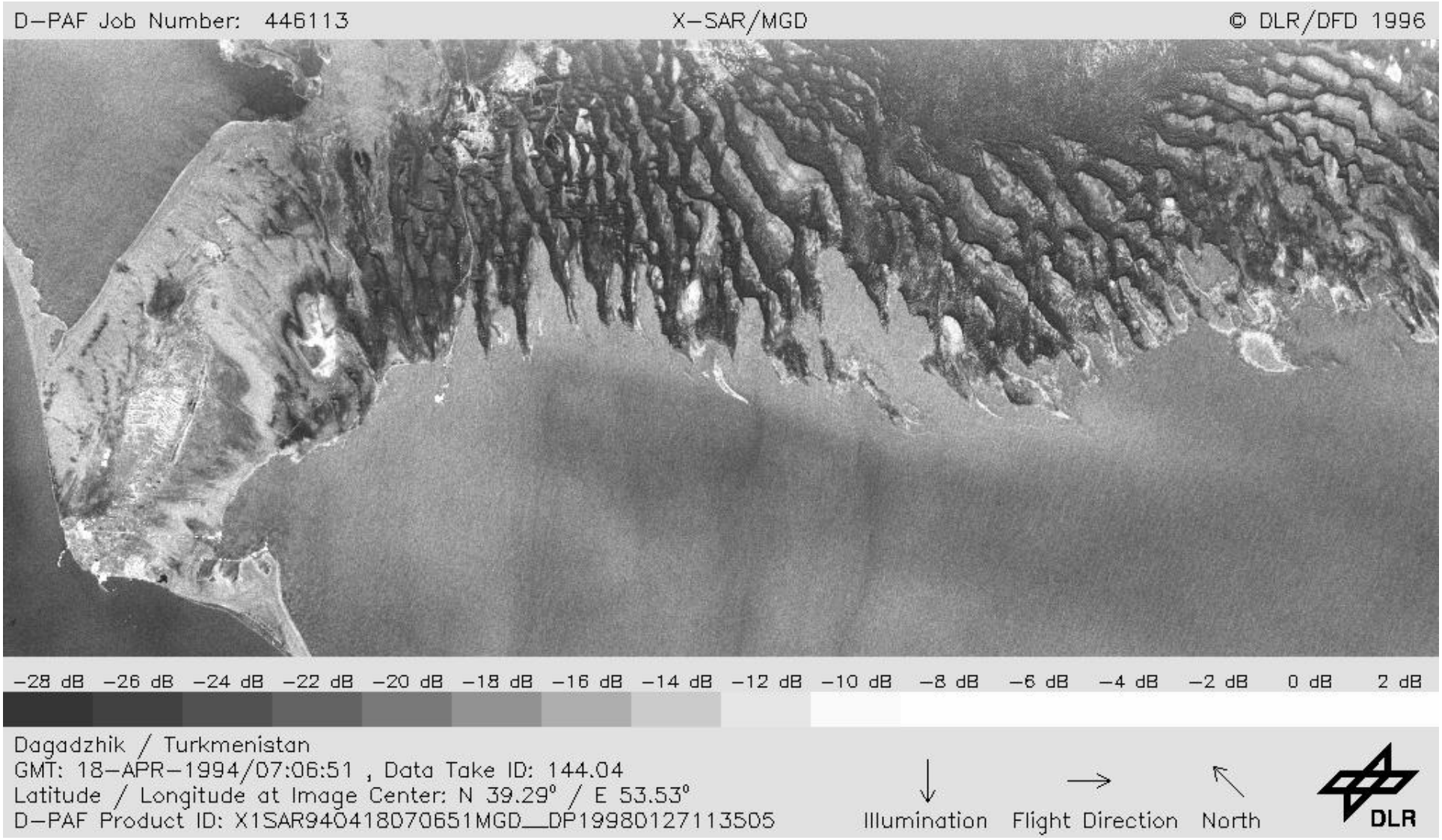
But also showed (Lorenz et al., JGR, 1995) that thermally-driven winds are low anyway, so saltation seemed marginal. (Only the fastest winds drive saltation.Weibull distribution)

T3 ‘cat scratches’

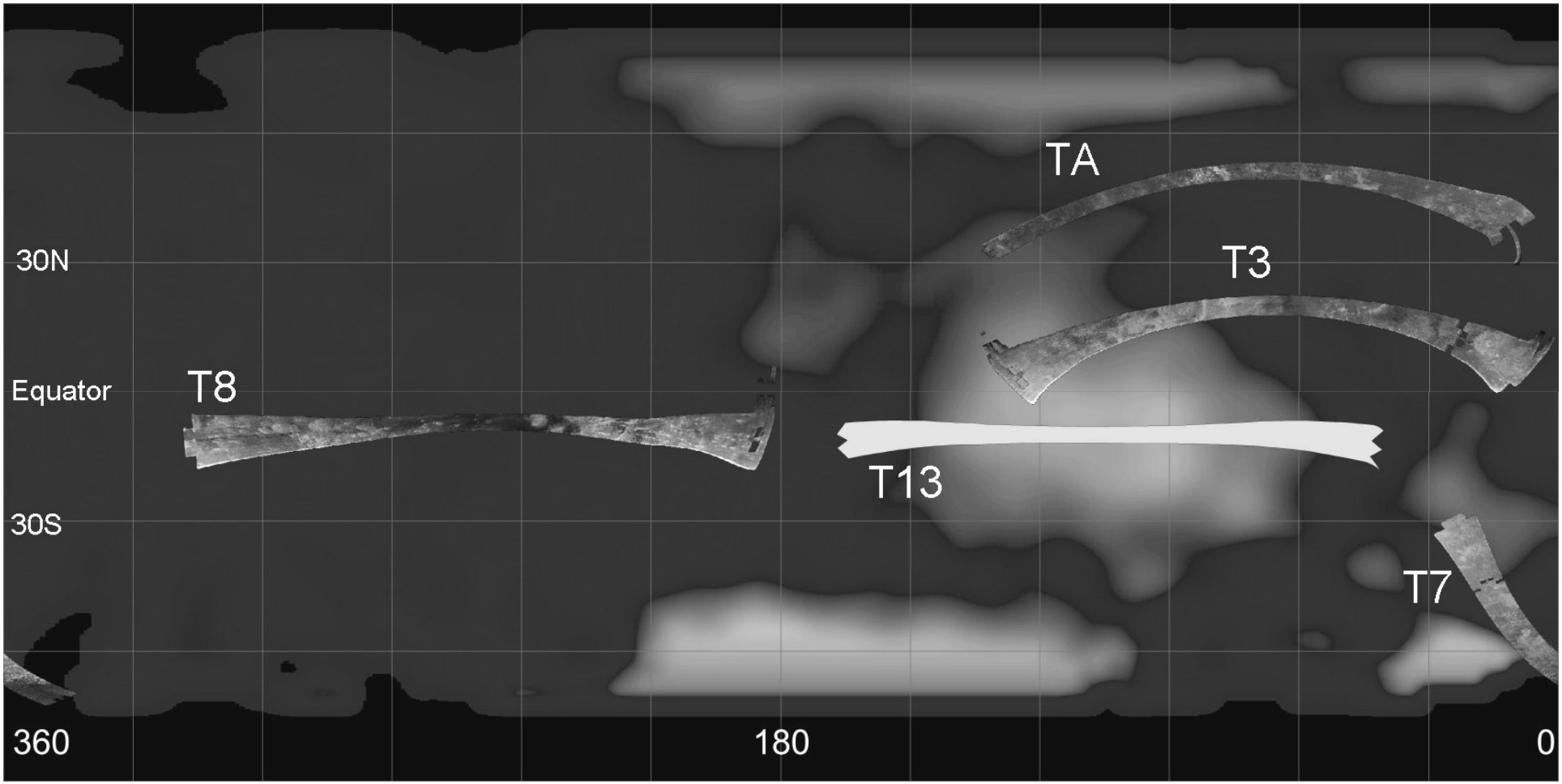
- Dark subparallel (E-W) streaks observed, apparent indicators of flow of something. No topographic signature.

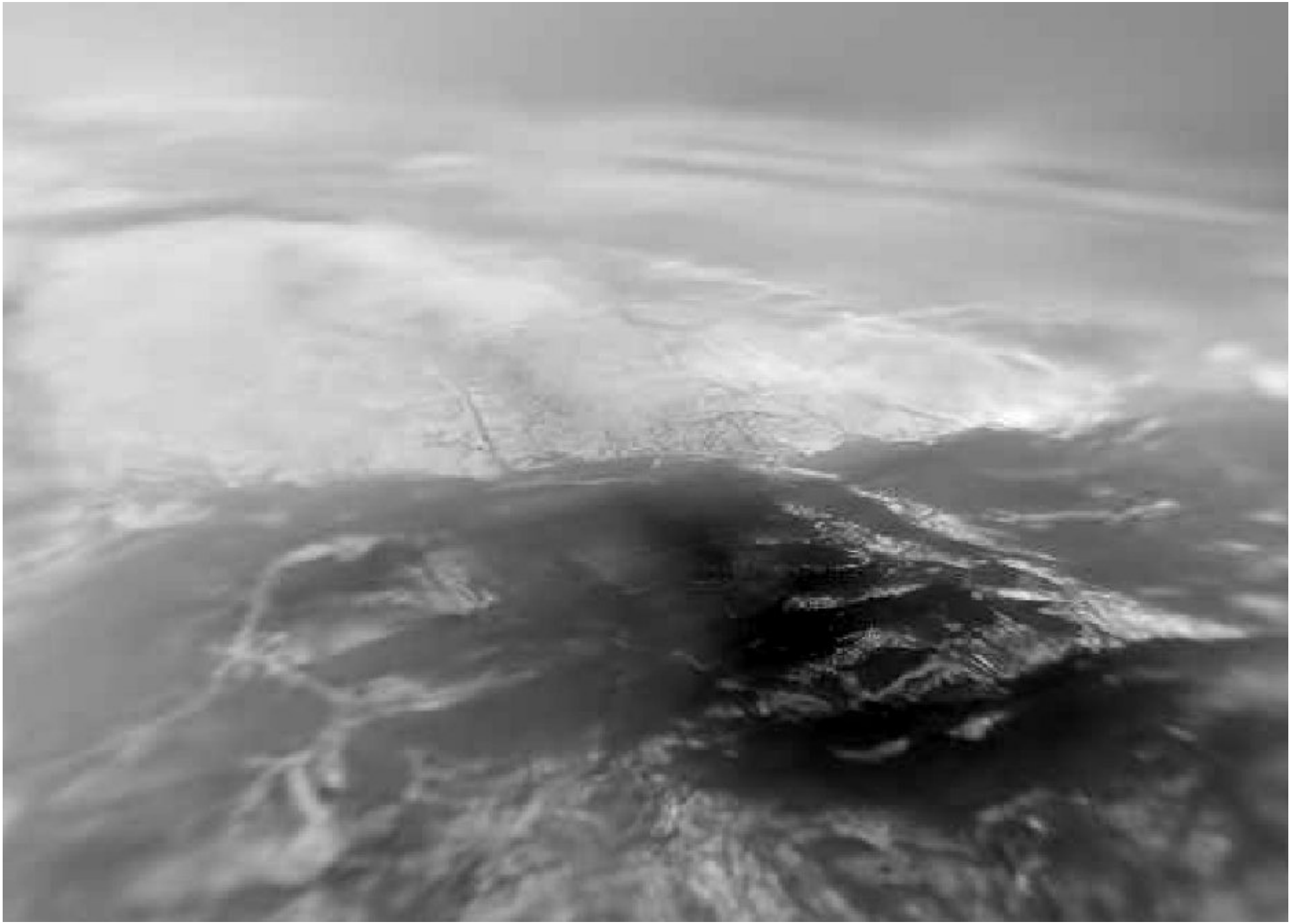


Aeolian features, like this terrestrial analog ? But could cat-scratches just be some sort of liquid seeps?

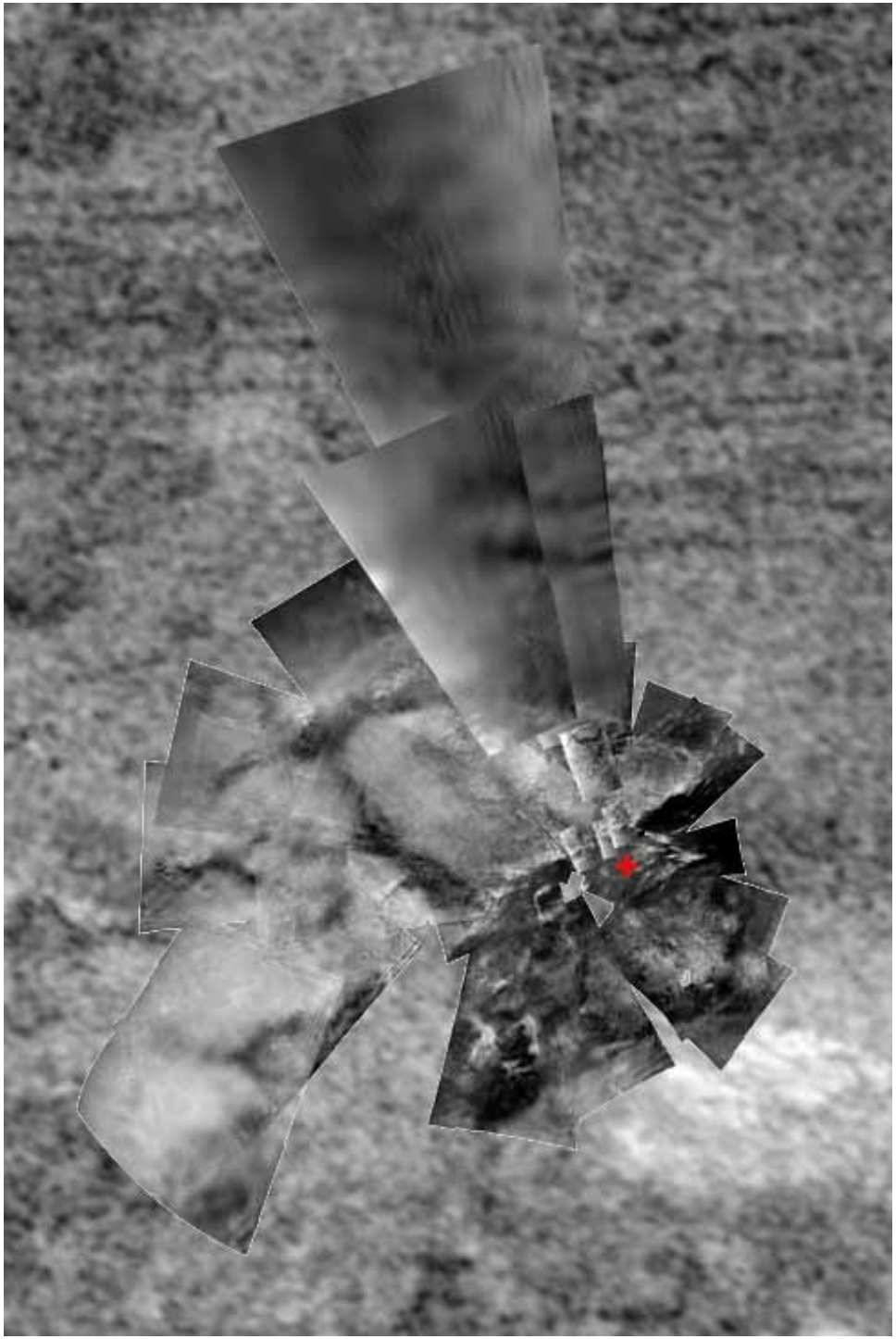


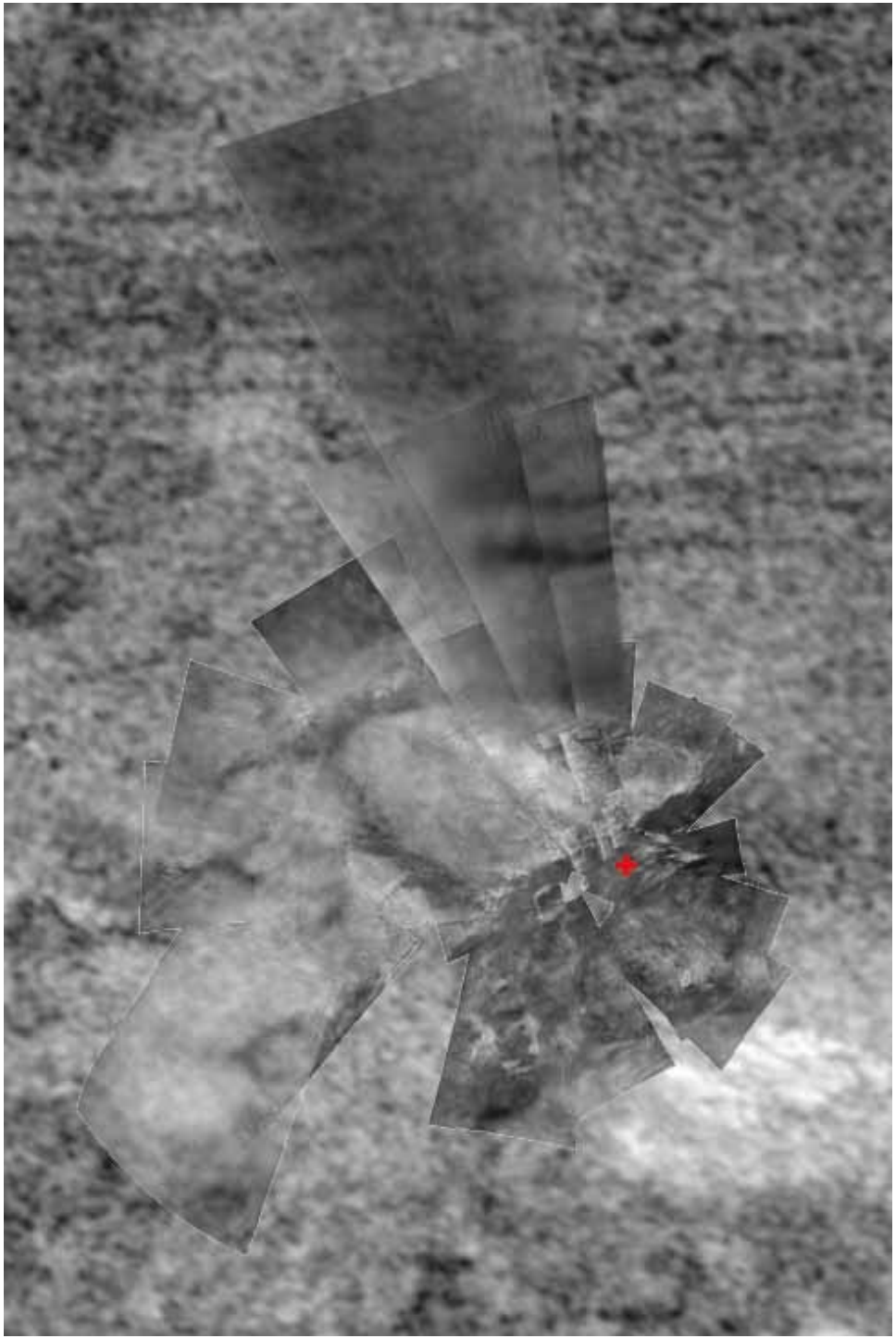
Correlation of ‘lobster’ cat-scratch region and optically-dark region (individual scratches not resolved in ISS) was noted after T3. This suggested that the optically-dark area Belet would be observed with T8 SAR

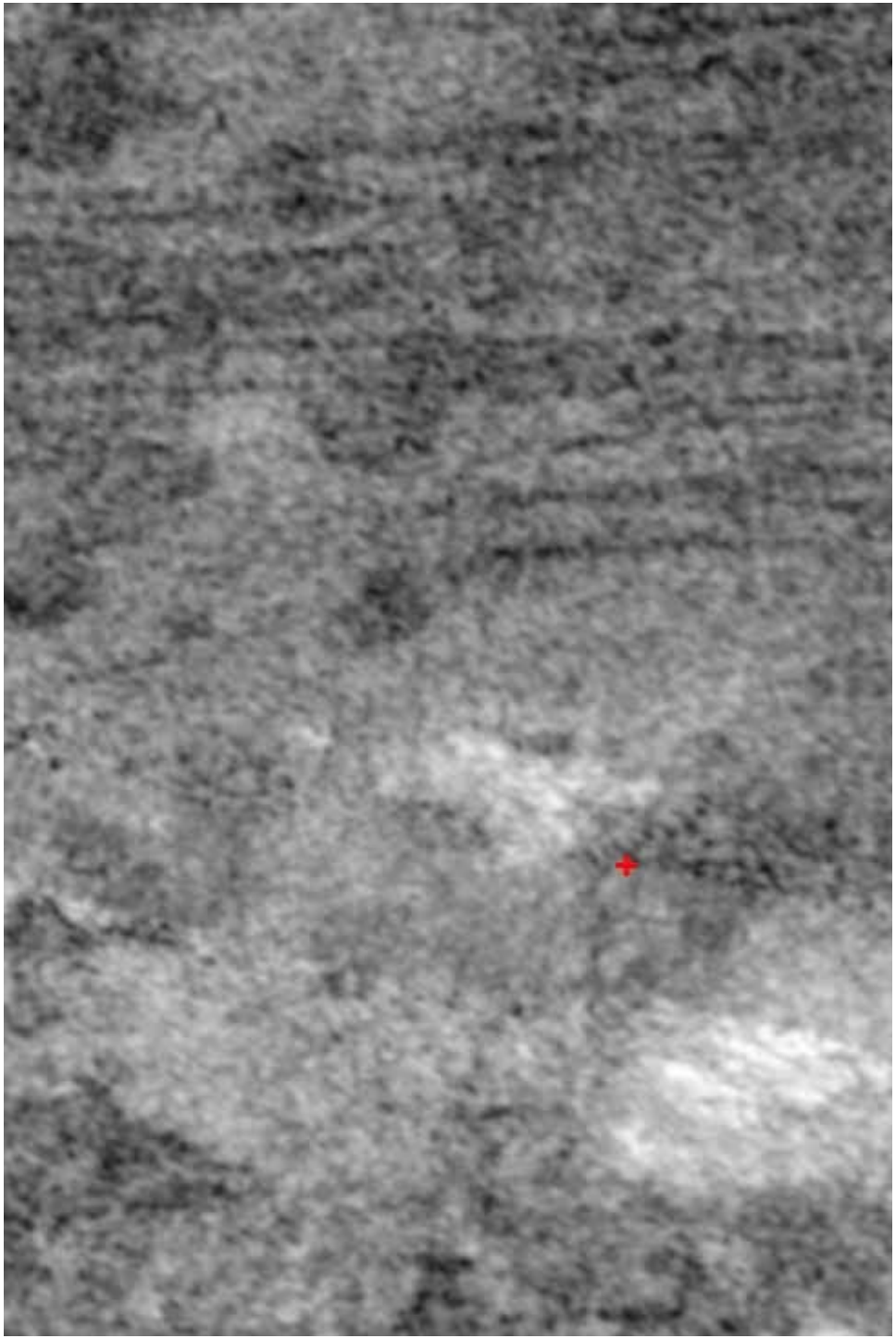




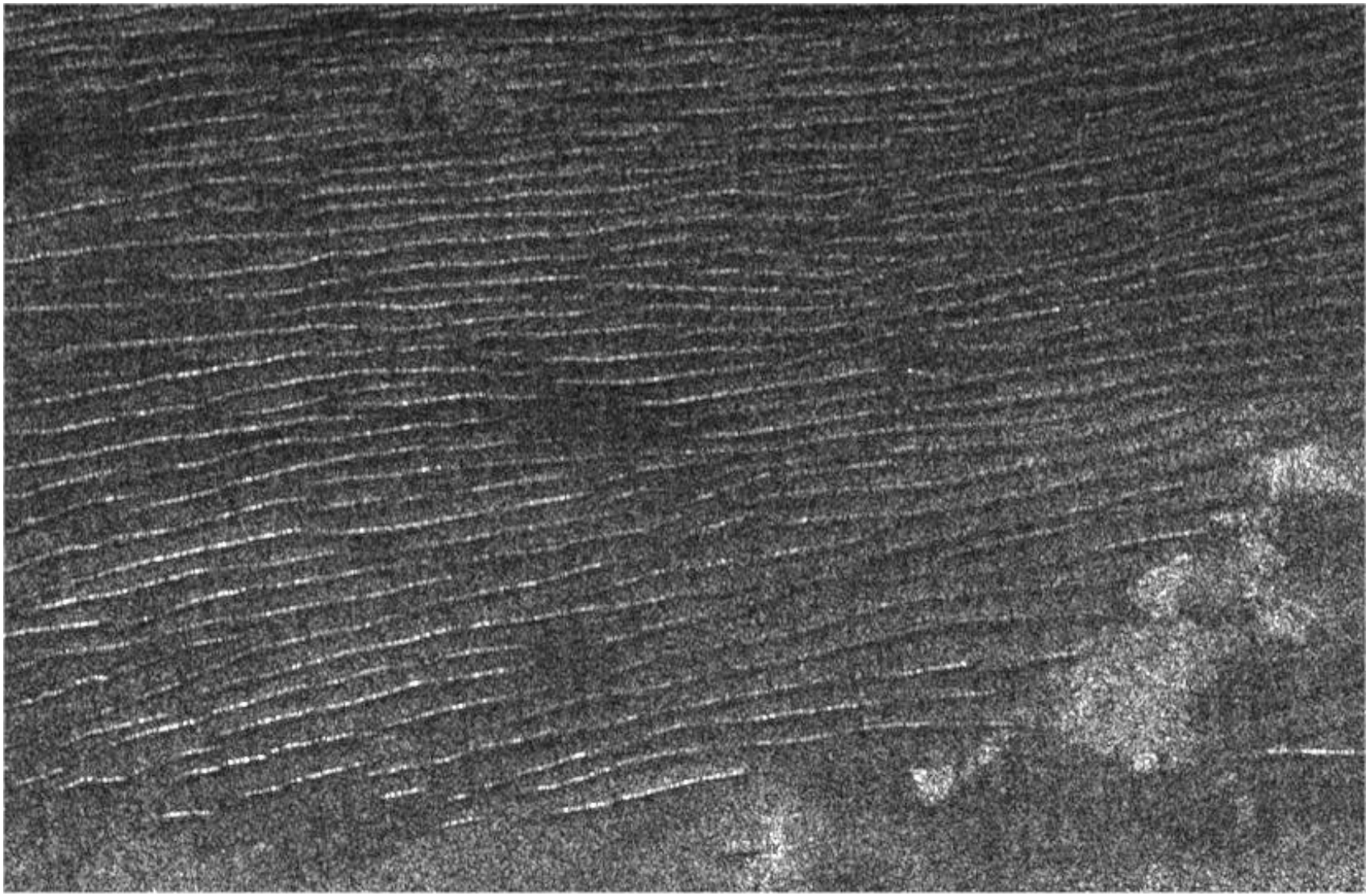
Reprojected DISR mosaic by E. Karkoschka, LPL, UA







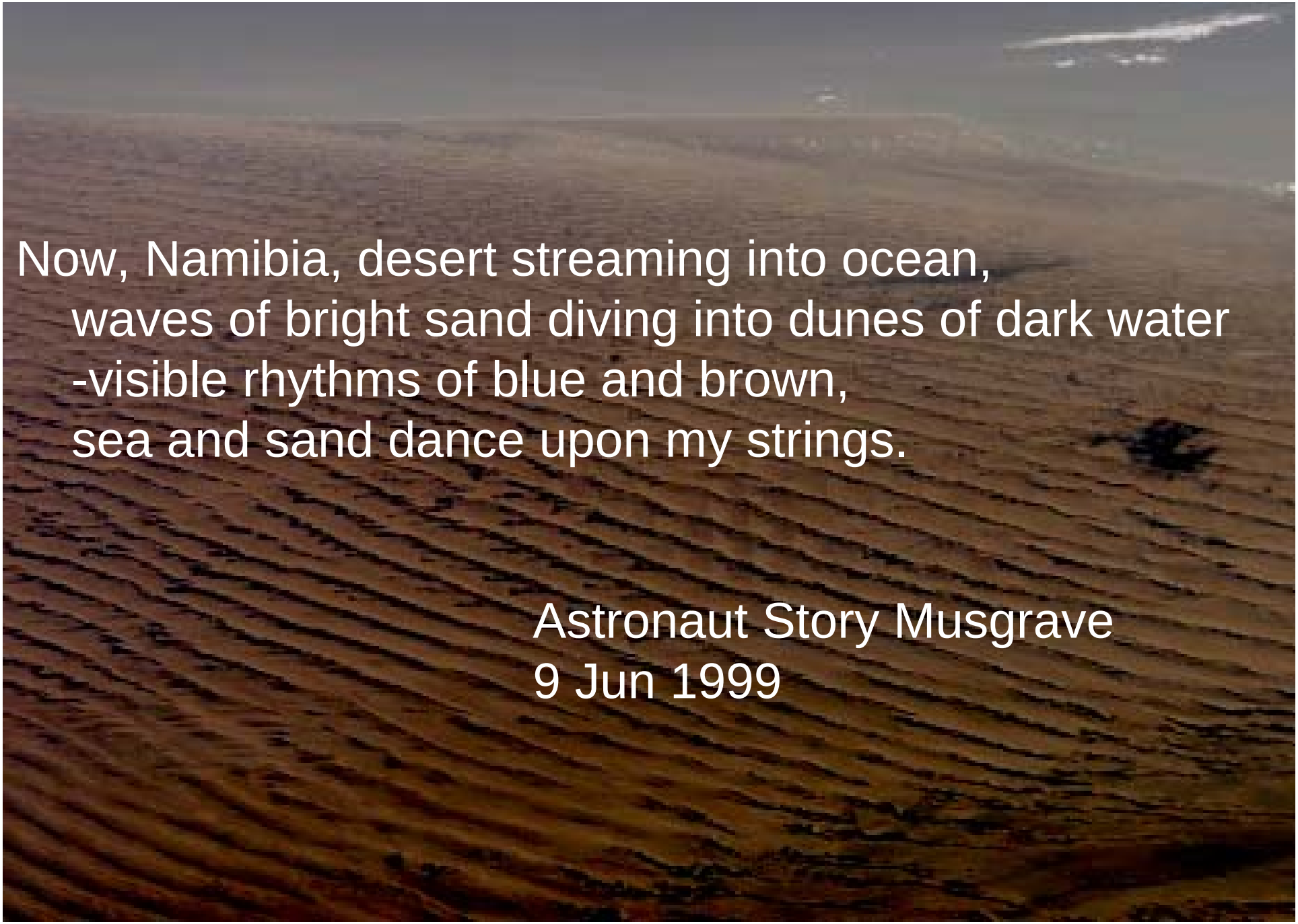
T8 SAR : not just dark streaks, but bright uprange edges indicating slopes

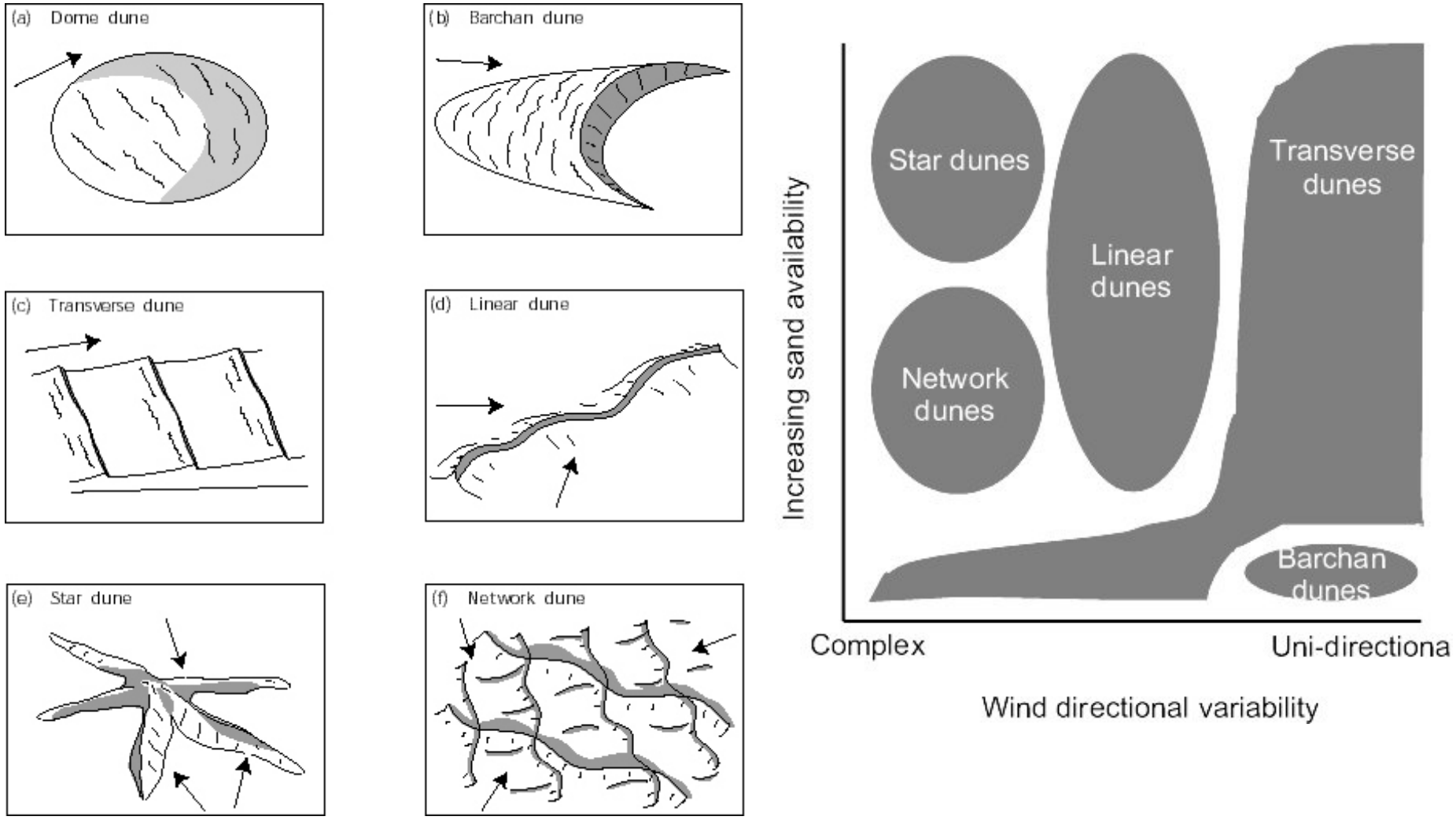


150x100km

Linear dunes in the Namib Desert

Shuttle handheld digital camera STS107


Now, Namibia, desert streaming into ocean,
waves of bright sand diving into dunes of dark water
-visible rhythms of blue and brown,
sea and sand dance upon my strings.
Astronaut Story Musgrave
9 Jun 1999

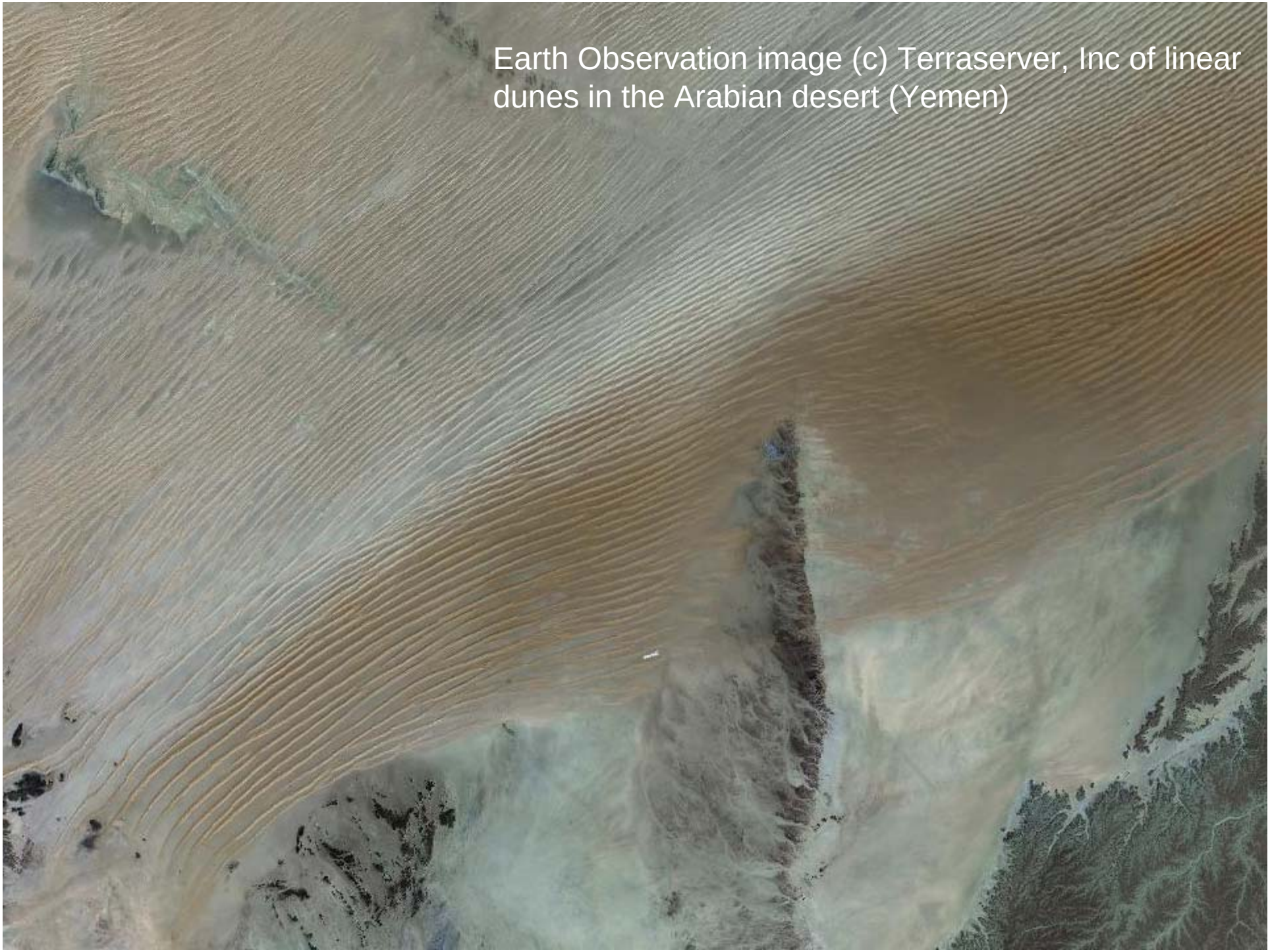


Dune morphology is a function of variability in wind direction, and availability of sand. Linear dunes require modest variability (often bidirectional)

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

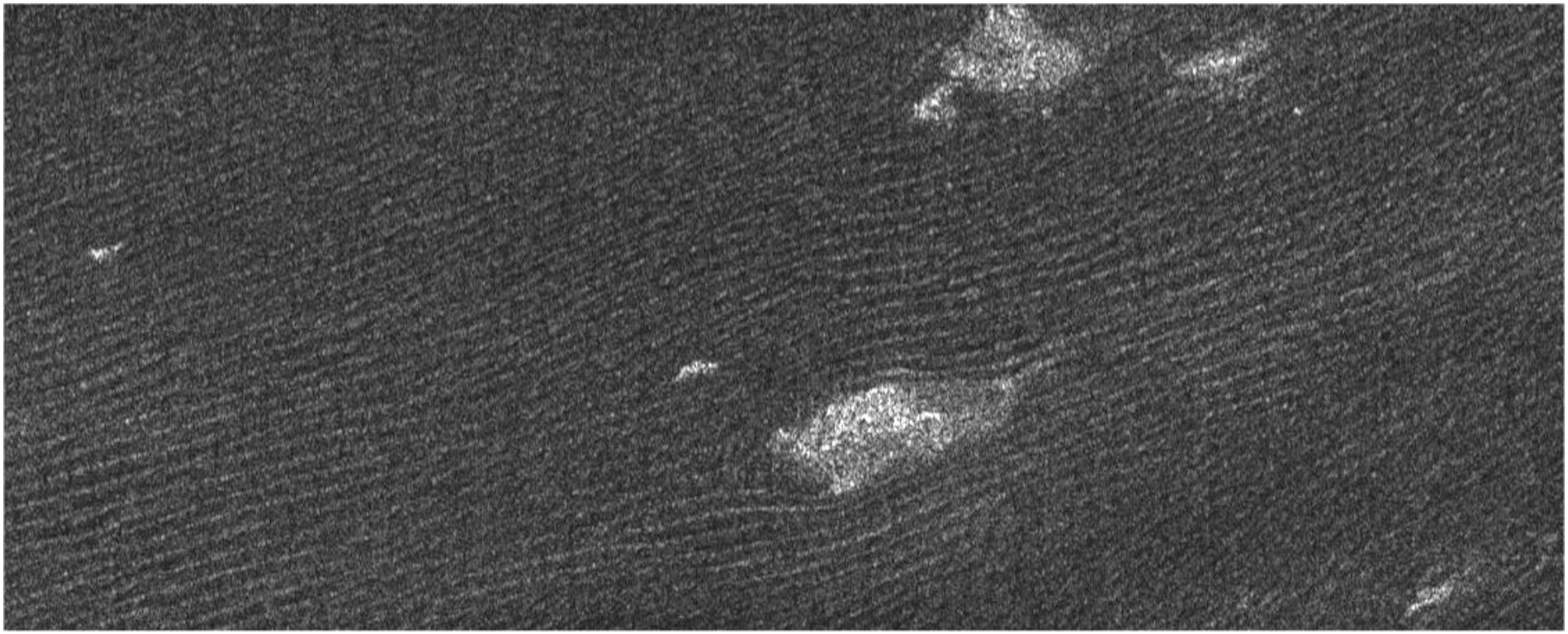
Linear dunes not common in the Americas, but dominant type globally (esp. Simpson, Arabian, Sahara, Namib..)

Moenkopi Plateau, N. Arizona


Earth Observation image (c) Terraserver, Inc of linear dunes in the Arabian desert (Yemen)

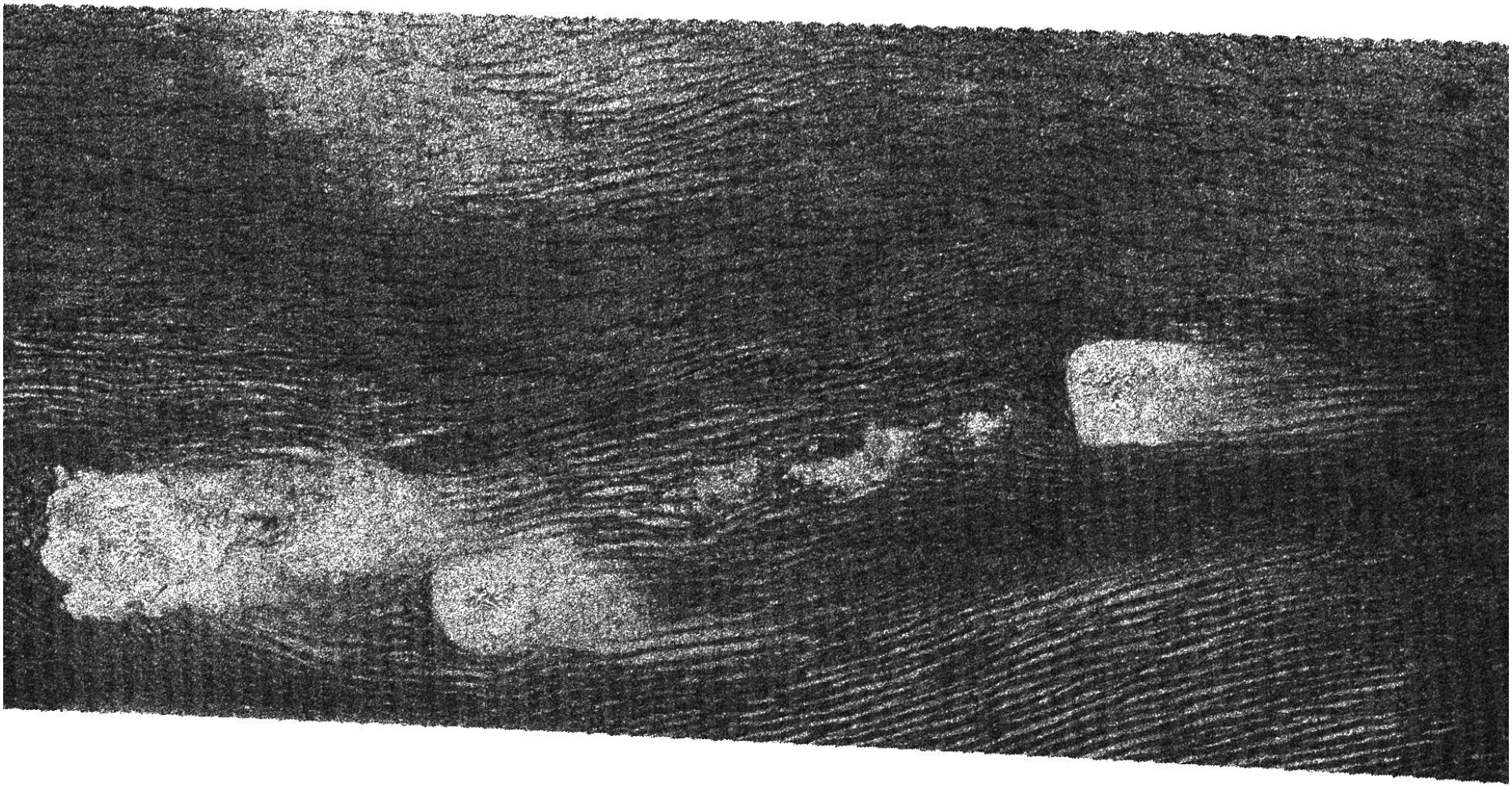
Dunes ‘flow’ around hills (no ‘wake’)

- depostional, longitudinal (linear) dunes

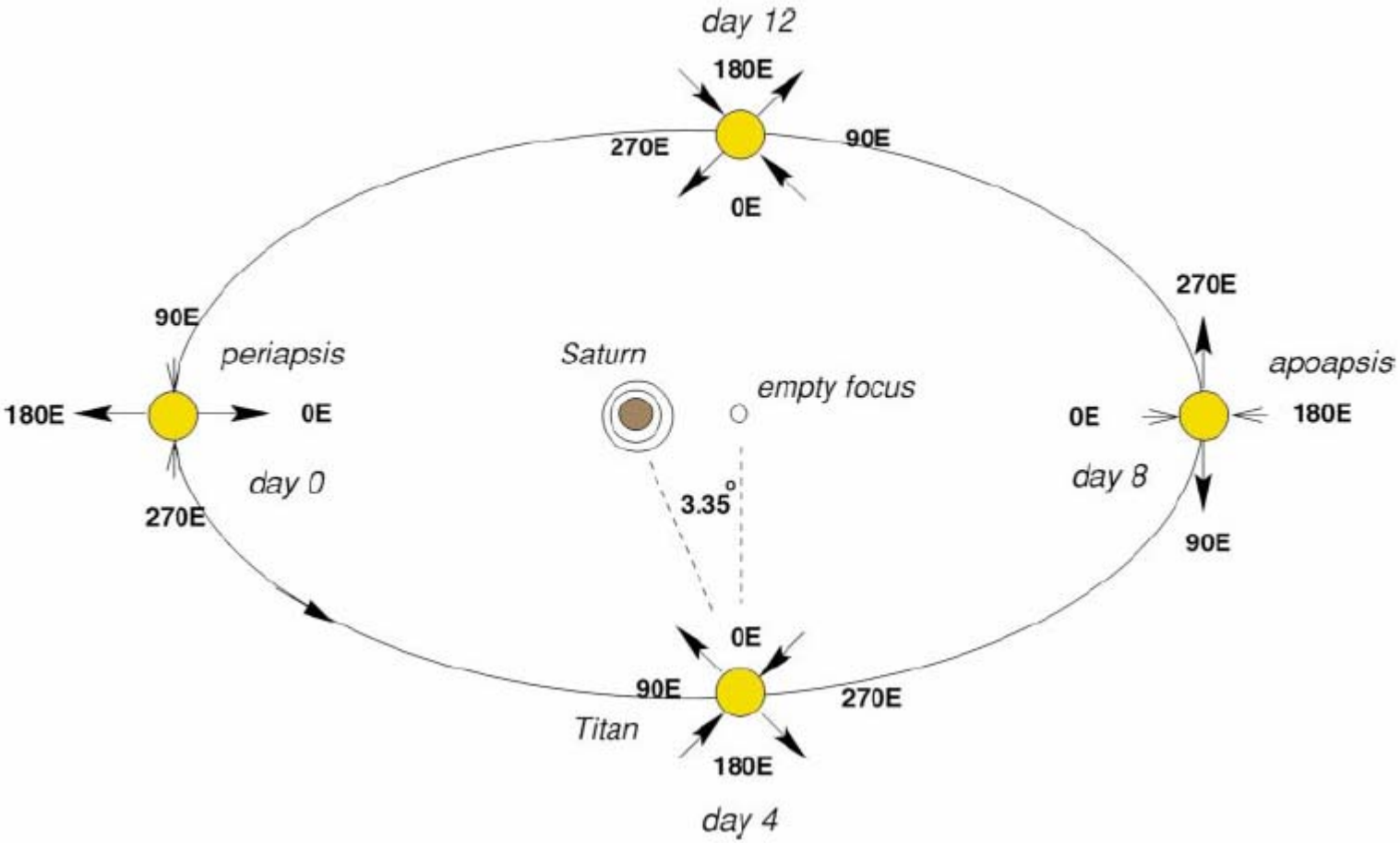


200x70km

T17



What drives the wind ? What causes it to change ? Seasons or tides?

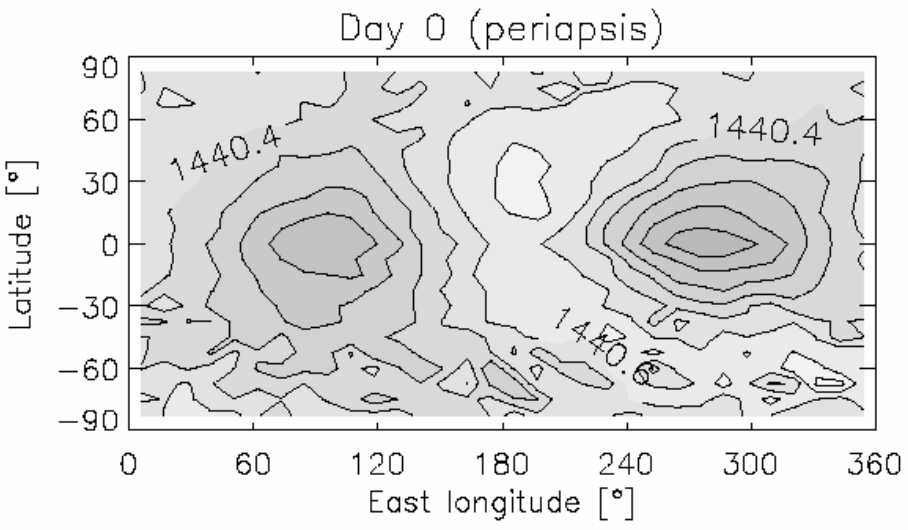


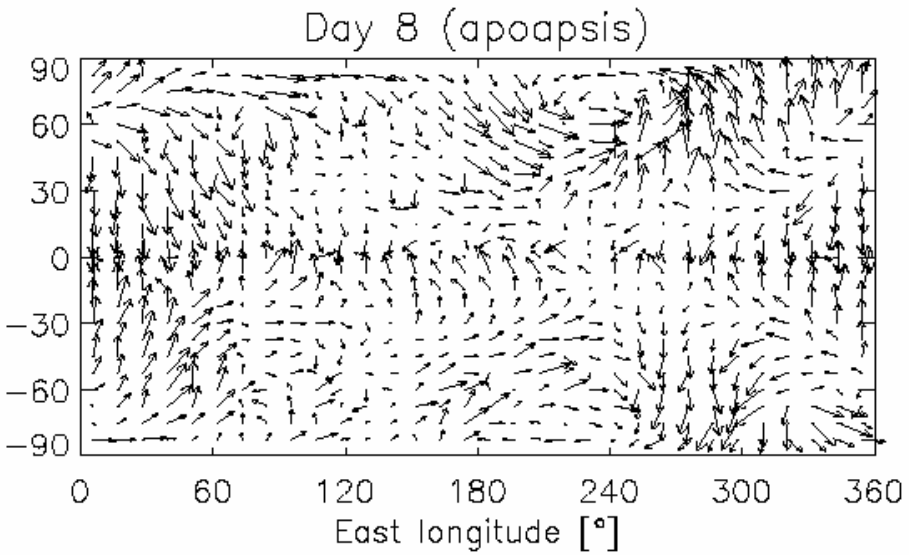
Gravitational Tide in Titan's atmosphere

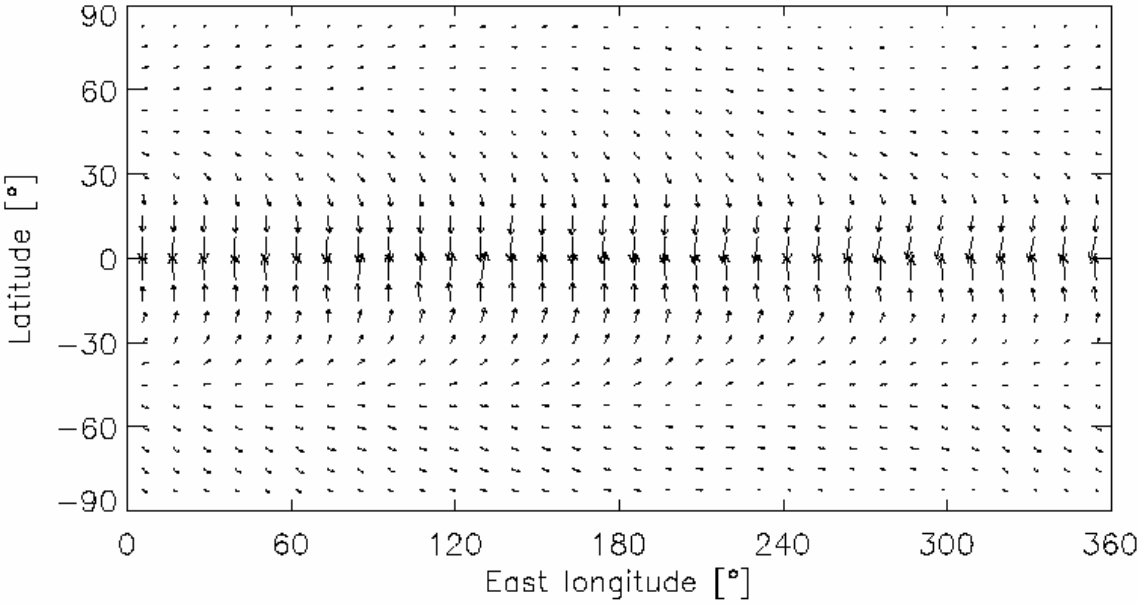
see Lorenz, Symposium on Titan, Toulouse 1991

and Tokano and Neubauer, Icarus, 2002

instantaneous wind and pressure field from Tokano & Neubauer



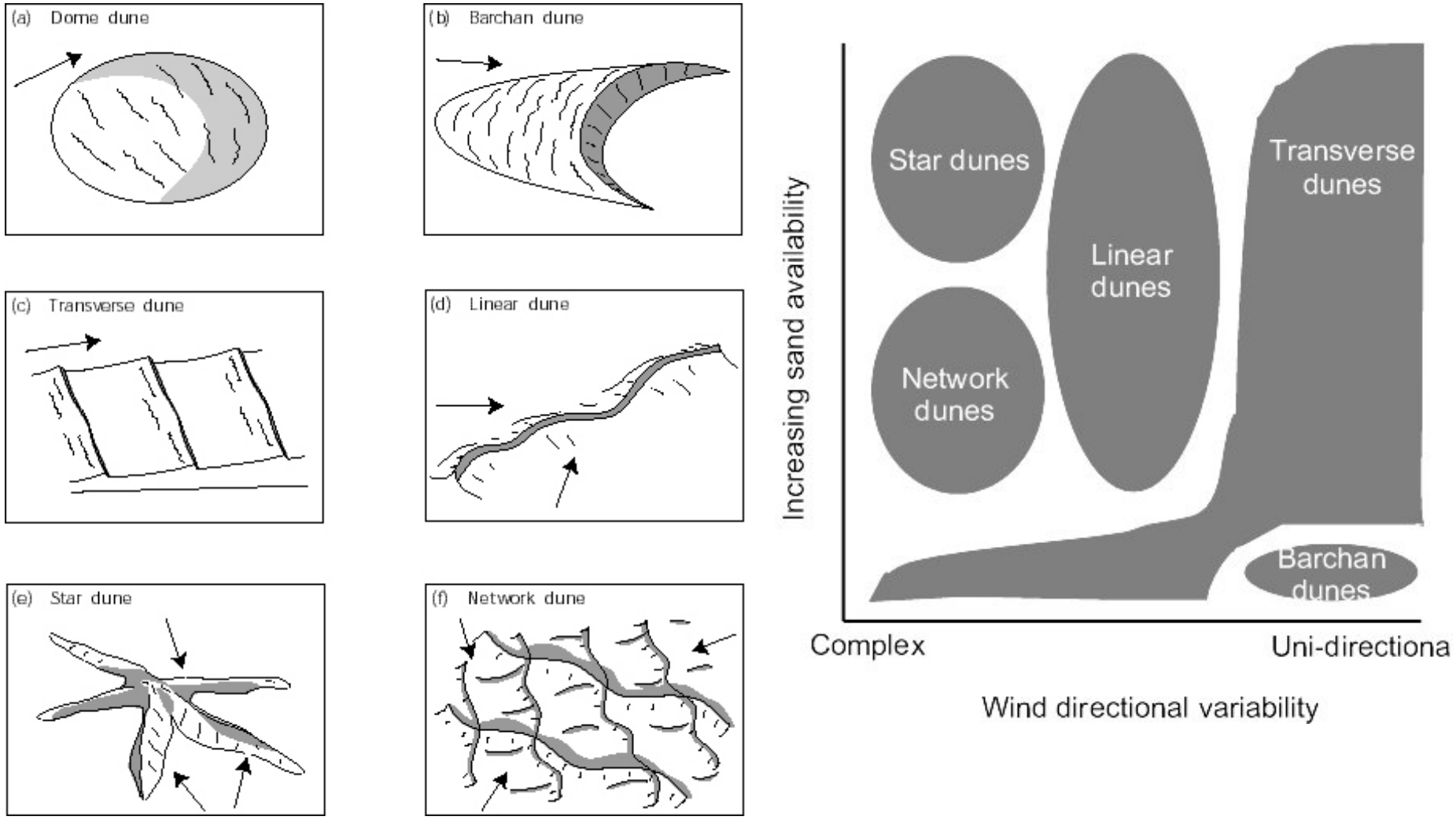




Fluctuating windfield with meridional component, ~0.5m/s, as required for dunes

orbit-averaged windfield gives net equatorward transport from 45 latitude....

dunes at the poles ?



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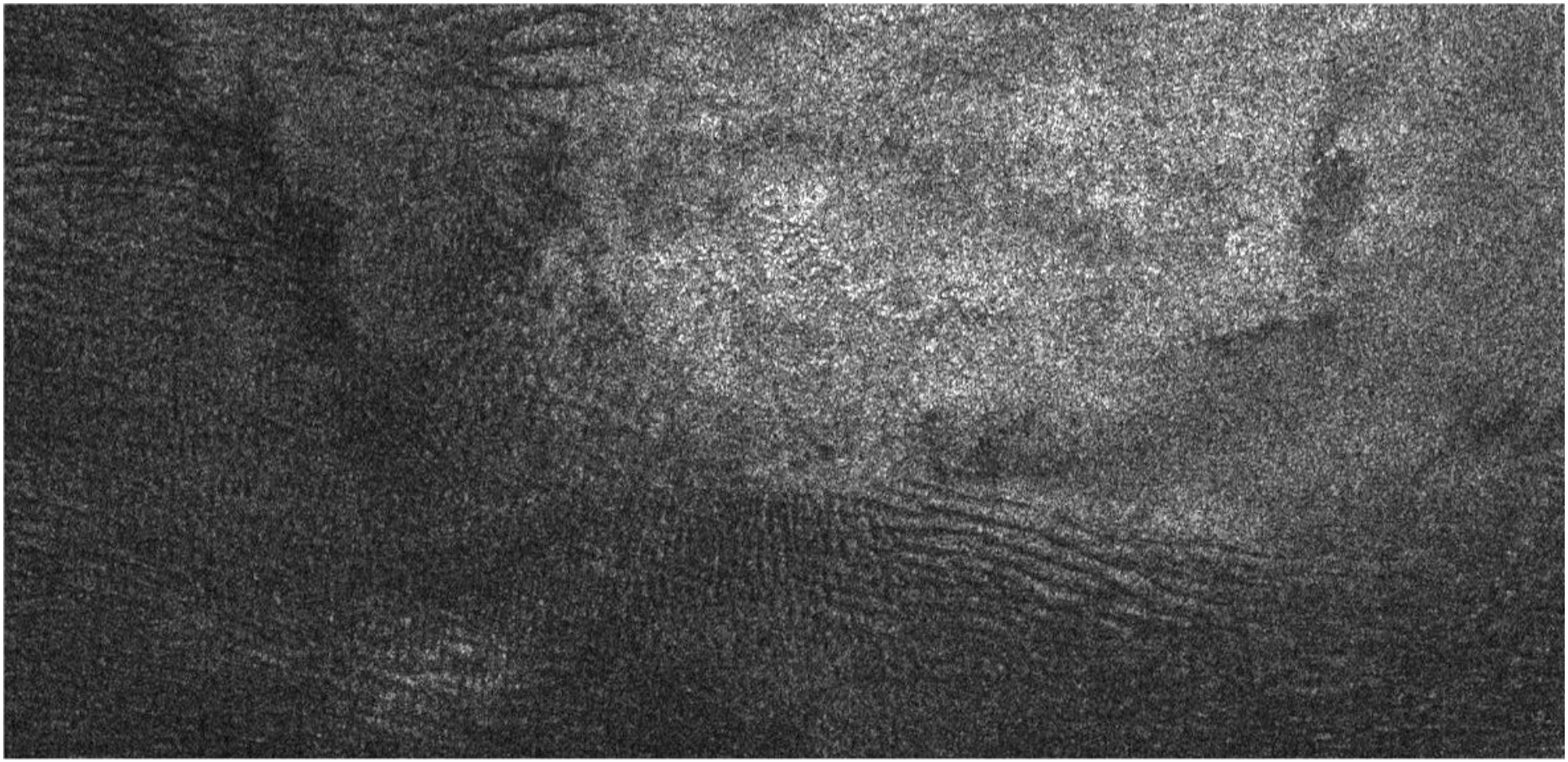
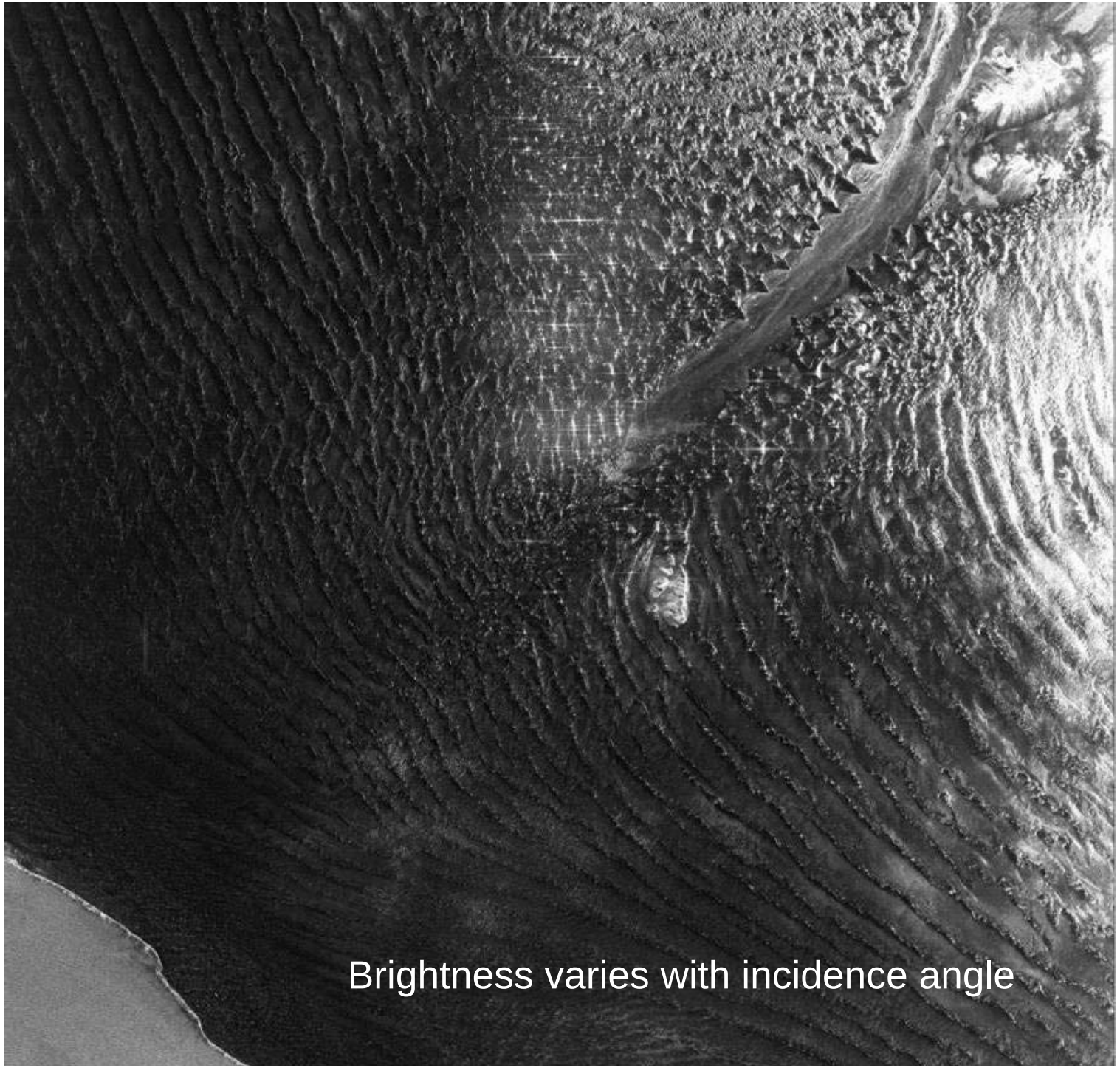
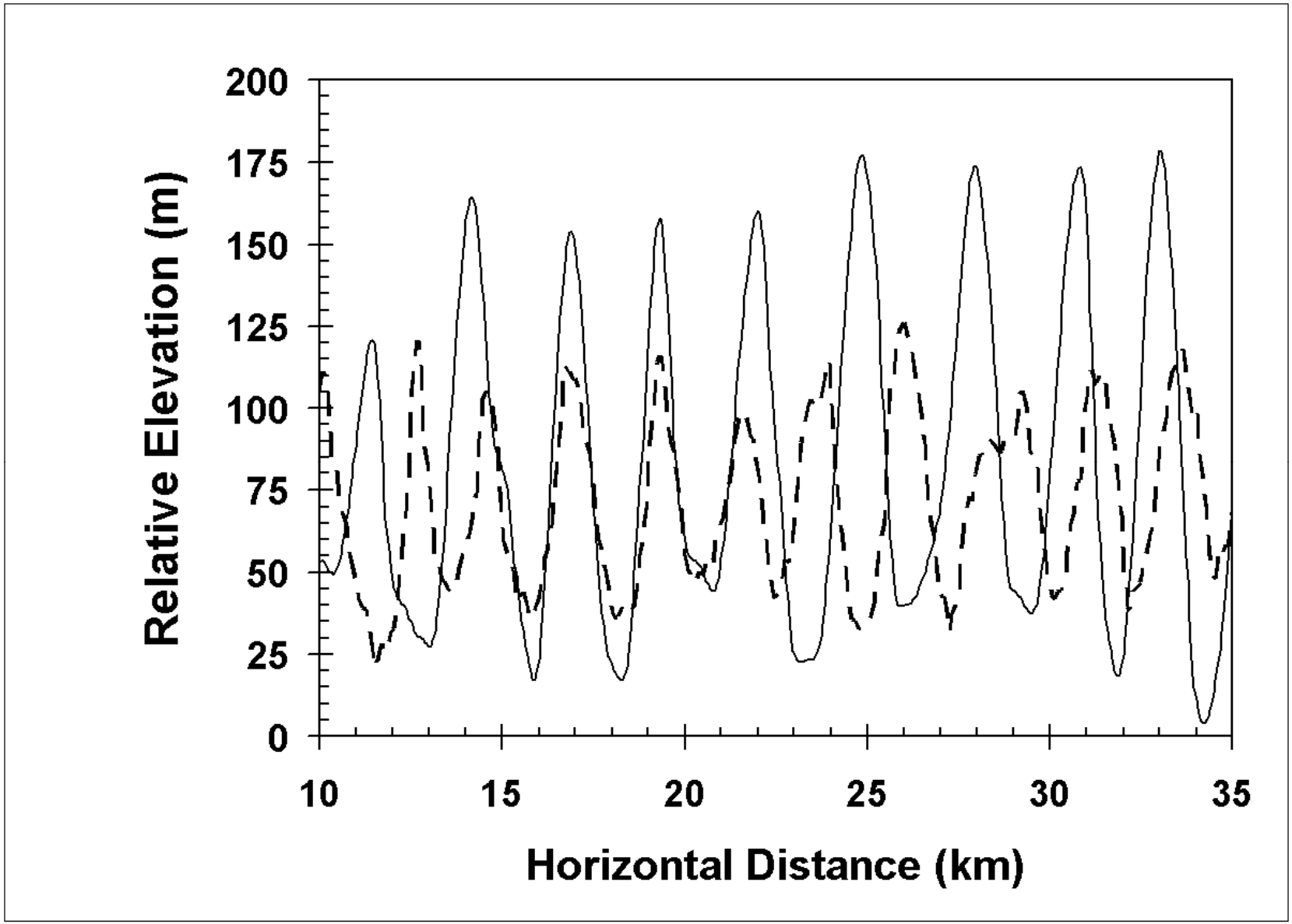
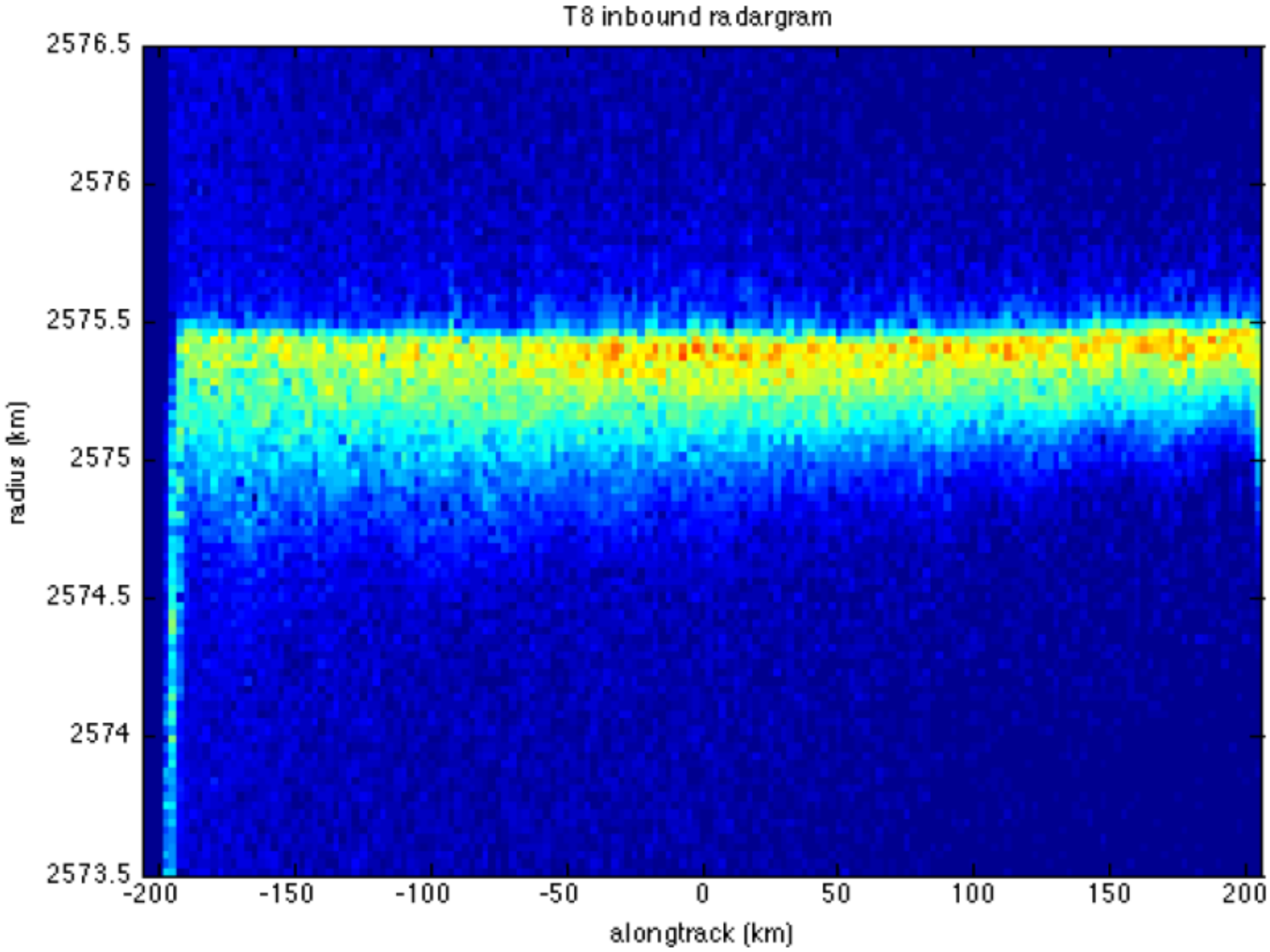
Dunes so far appear longitudinal everywhere, except in one spot (S of Adiri) where flow around apparent topographic rise may ‘straighten’ fluctuating flow - forming transverse dunes




Brightness varies with incidence angle

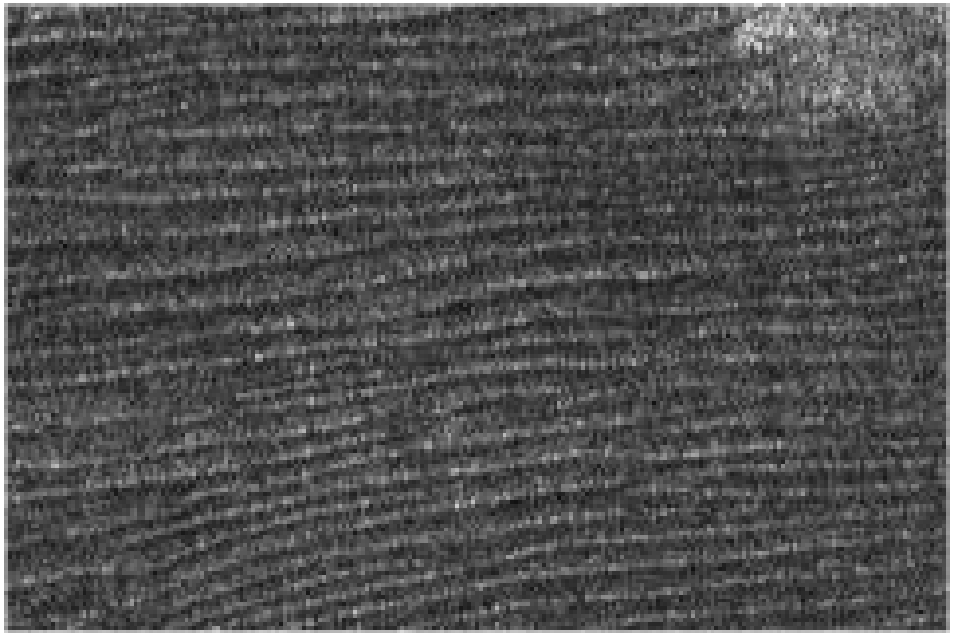
Radarclinometry



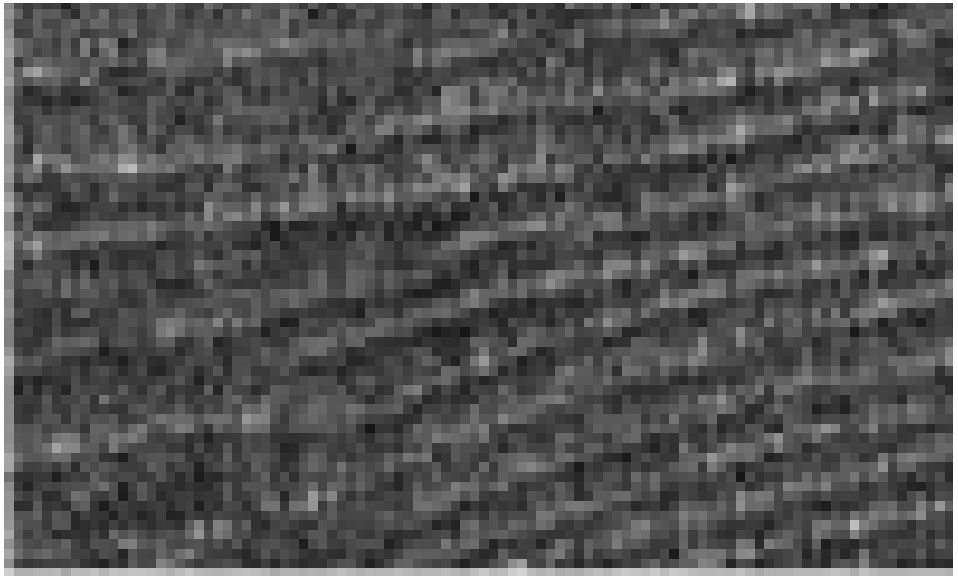


Sand seas are remarkably flat (on scales >> those of the dunes..)

http://www.lpi.usra.edu/meetings/lpsc2007/pdf/1329.pdf

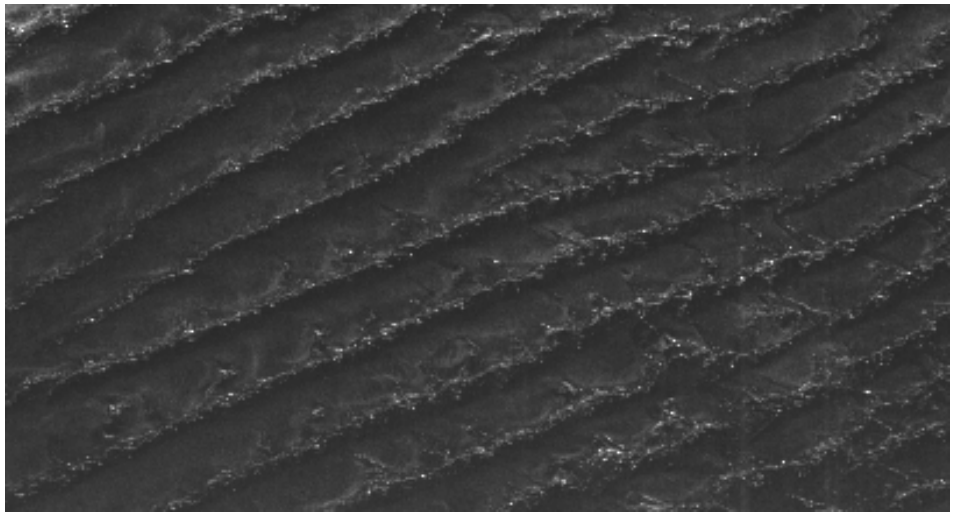


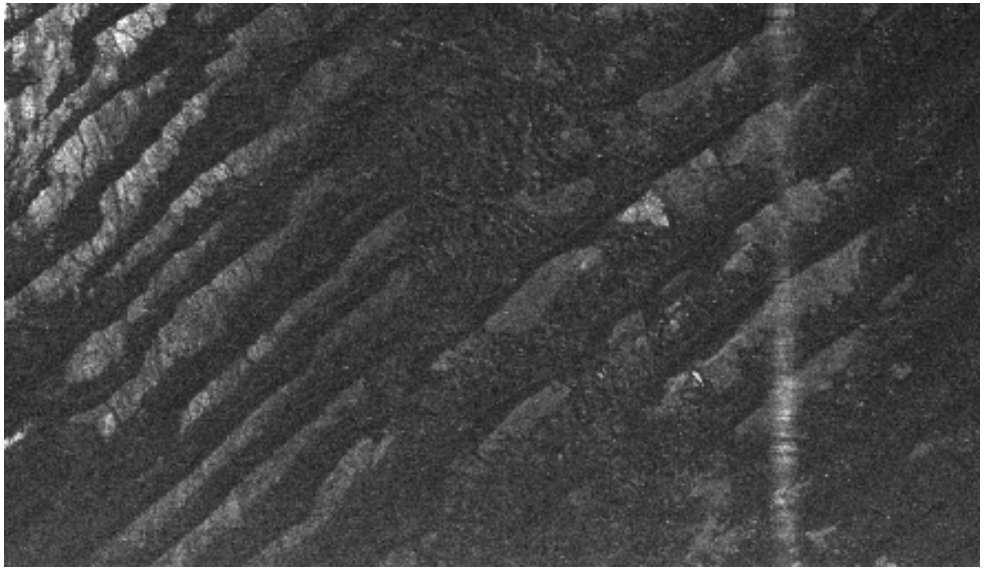
75x50 km segment of Cassini Ku-band SAR acquired October 2005 during T8 flyby over Belet

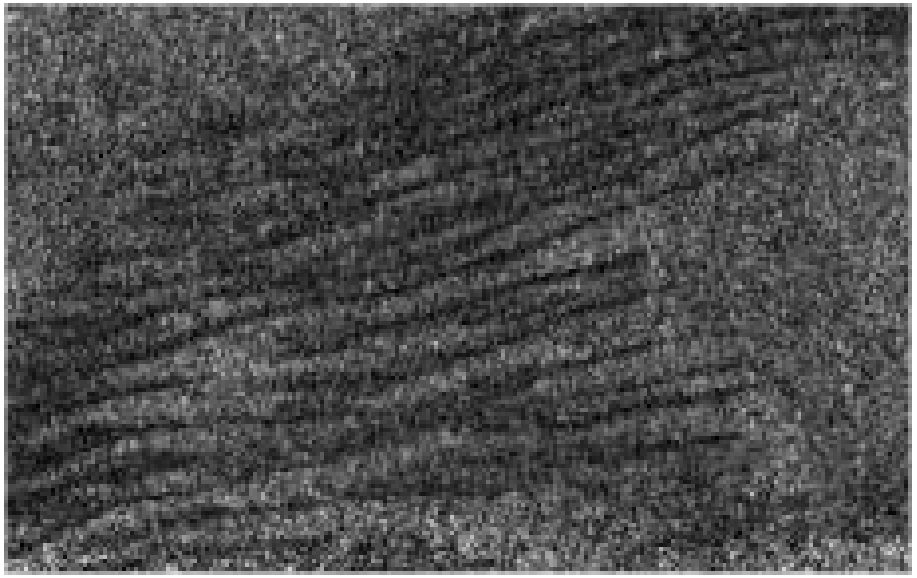


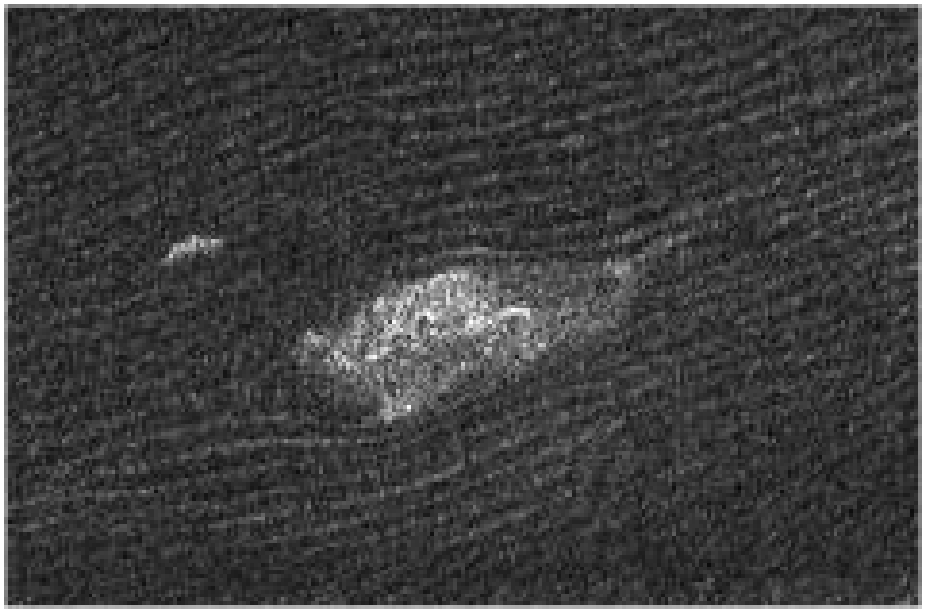
zoom to 30x20km

30x20km segment of SIR-C L-band image of Namib desert acquired in 1994. Data Take 58.40 Processing ID 44419



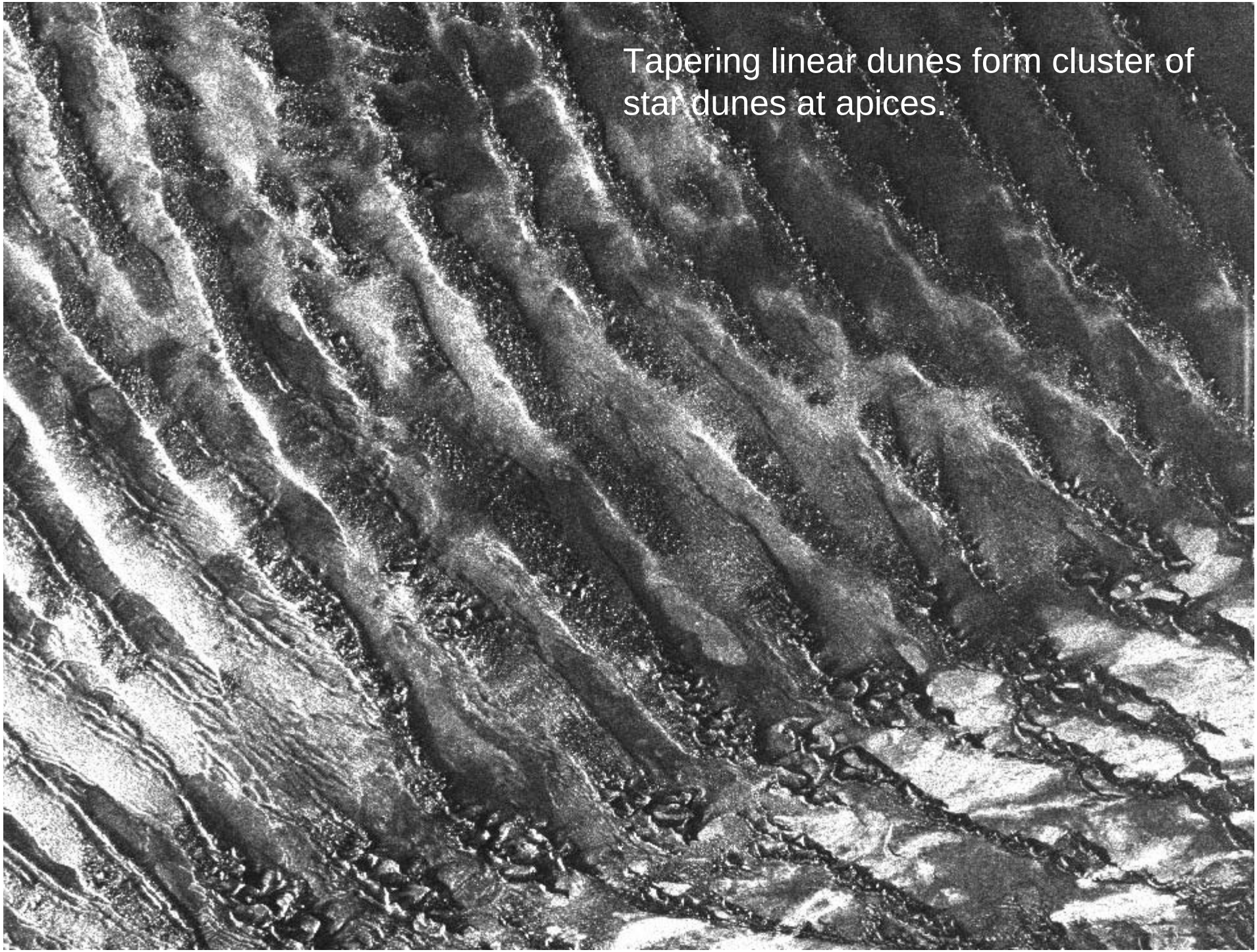


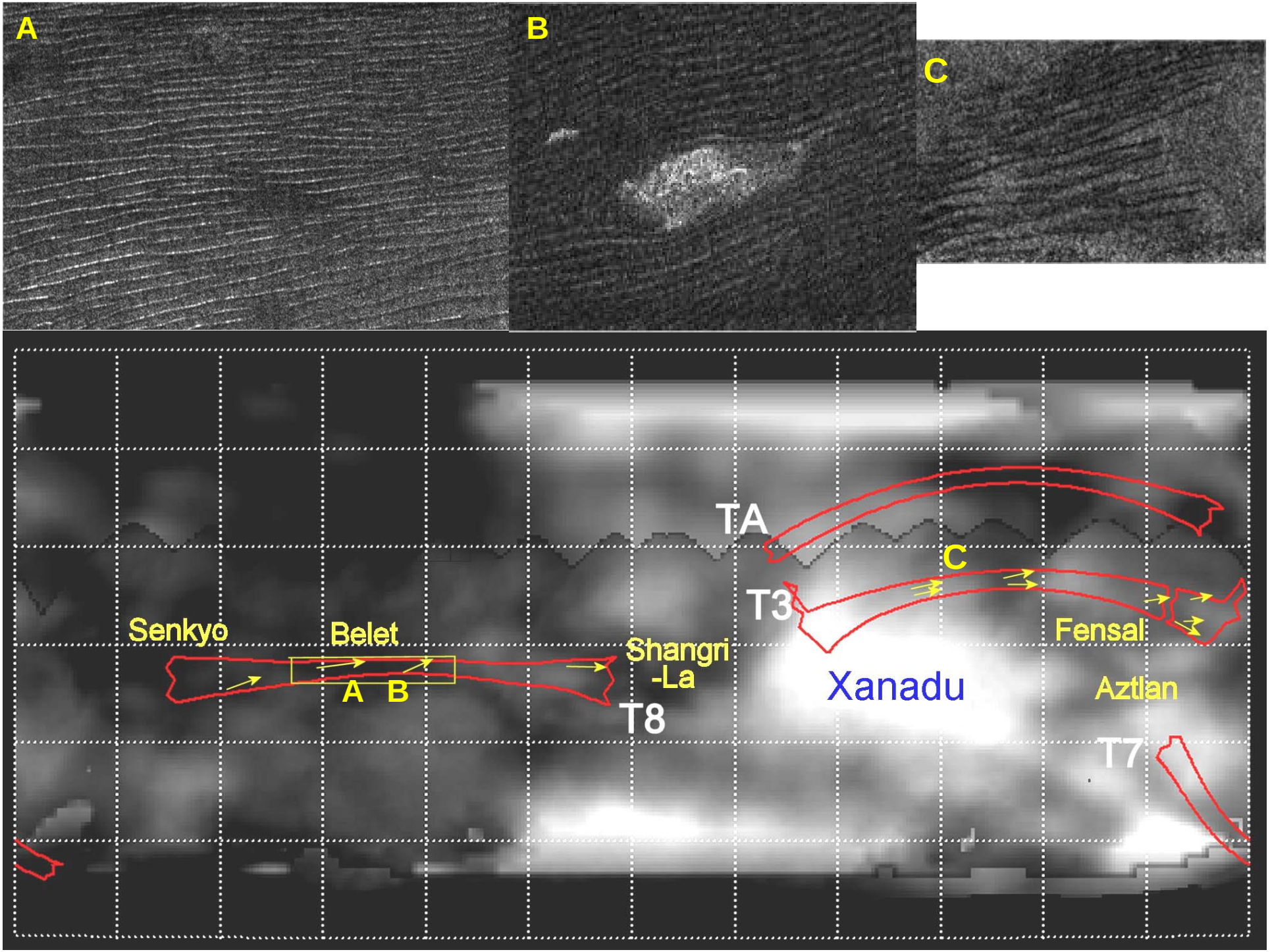


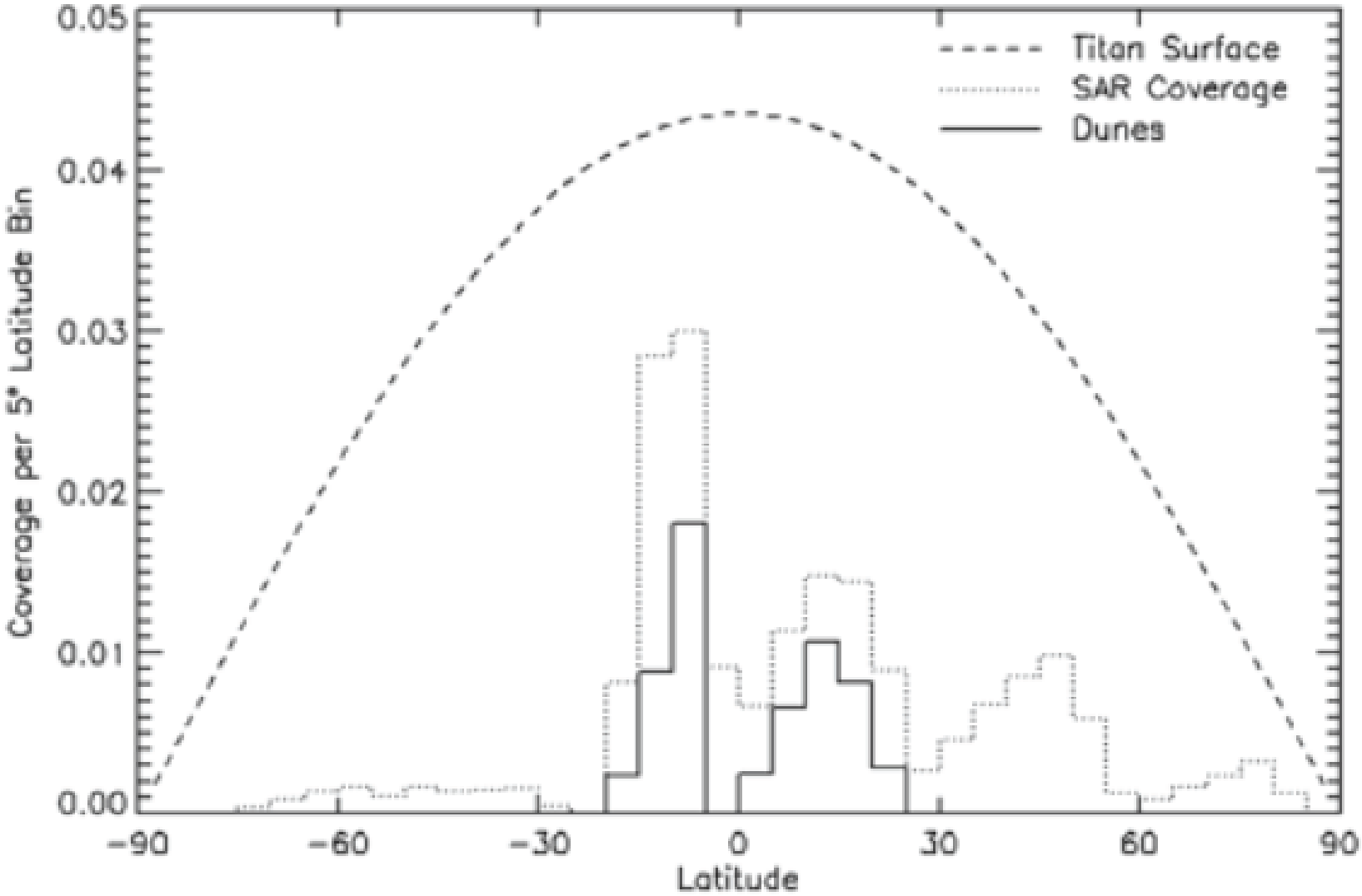


SIR-C / Cassini comparison. T3 morphology consistent with shallow (thinning) dunes - lower sand supply ?

http://www.lpi.usra.edu/meetings/lpsc2006/pdf/1249.pdf

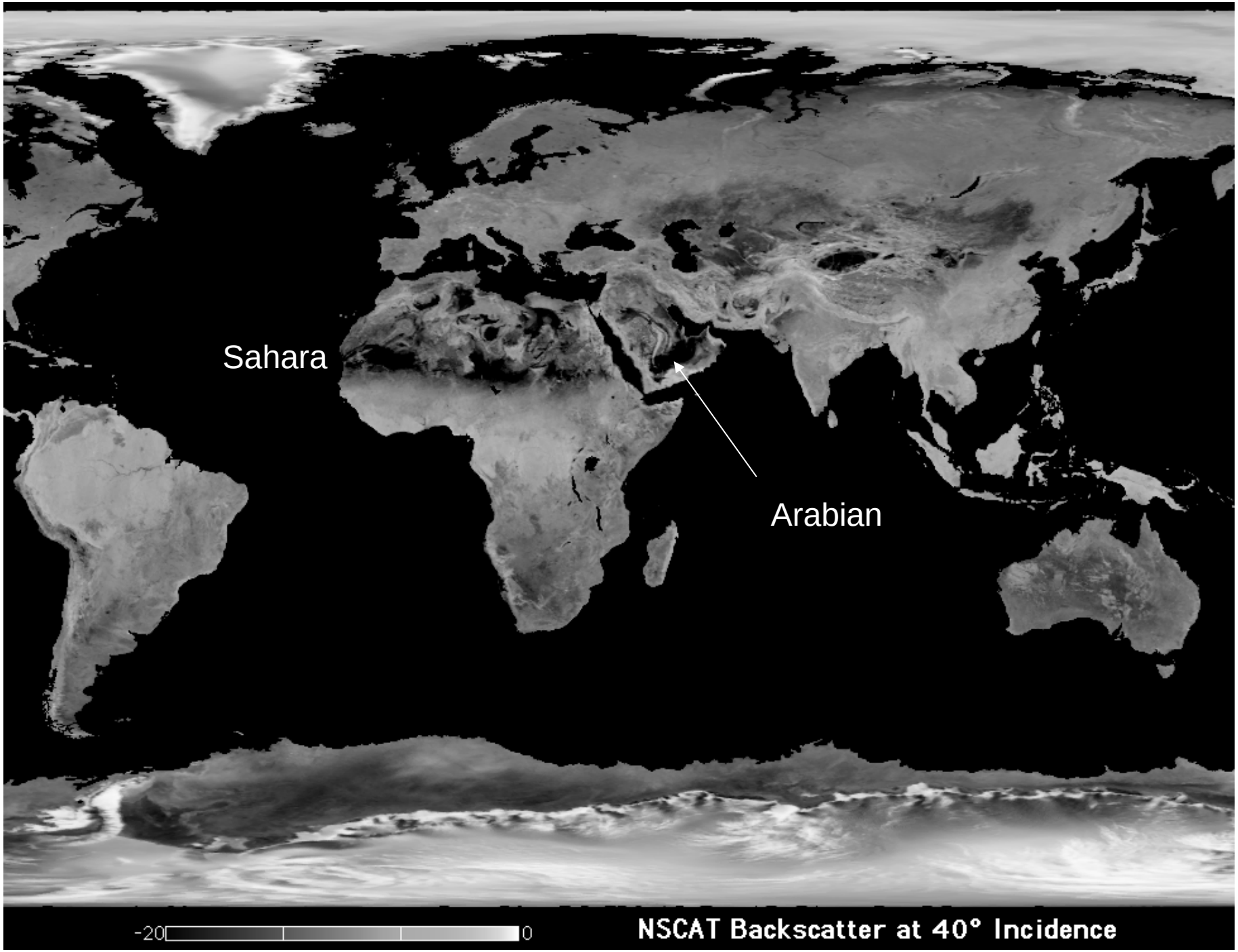

Tapering linear dunes form cluster of star dunes at apices.

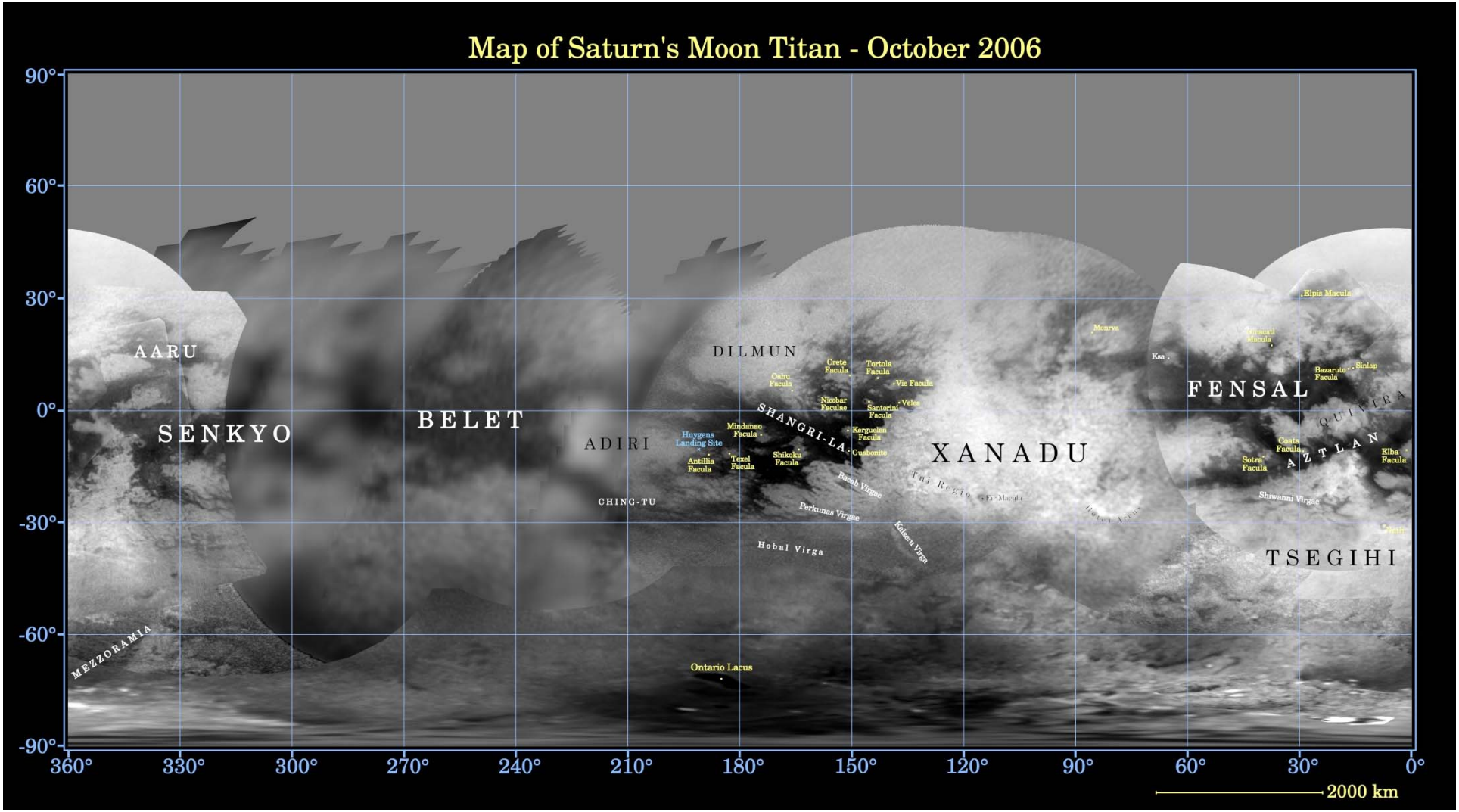

A
B
C
TA
C
T3
Senkyo
Belet
A
B
Shangri
-La
T8
Xanadu
Fensal
Aztlan
T7



Dunes cover about 40% of the tropics observed so far – extrapolation suggests around 20% of total surface is covered. But why only in tropics?

http://www.lpi.usra.edu/meetings/lpsc2007/pdf/1412.pdf


Sahara
Arabian
-20
0
NSCAT Backscatter at 40° Incidence



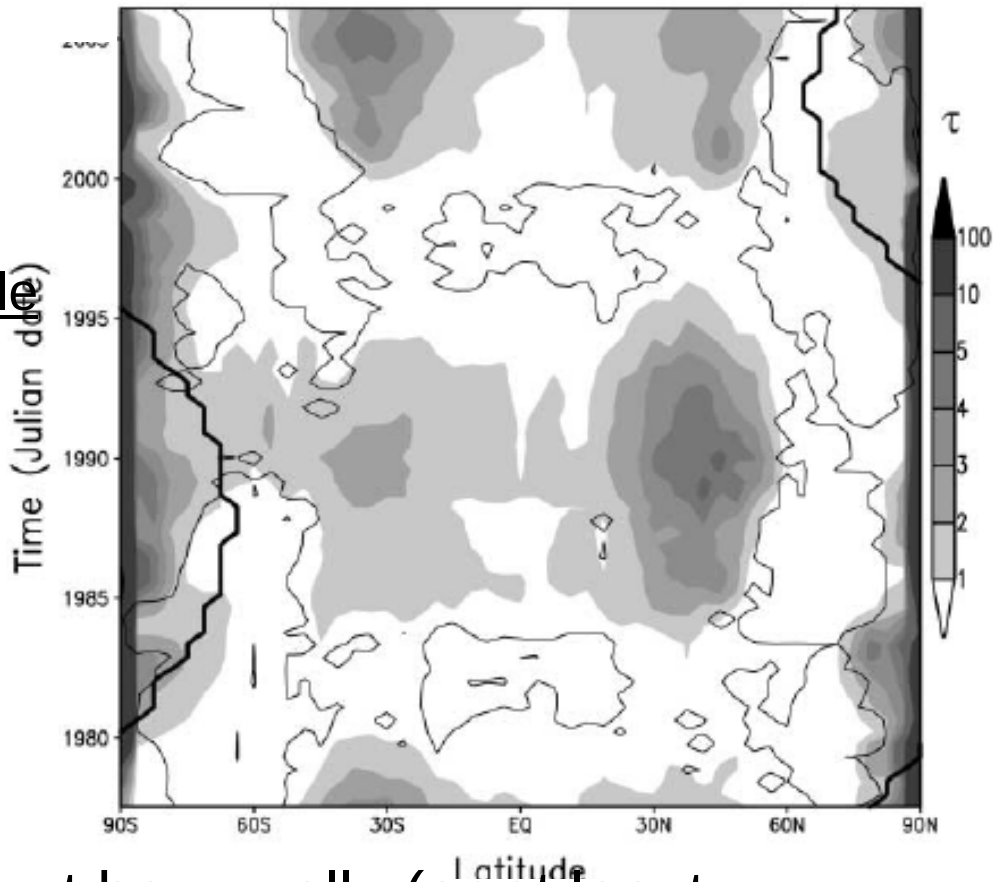
- Belet : Malay afterworld reached by a flower-lined bridge
- Shangri-La : Tibetan mythical land of eternal youth.
- Senkyo : Japanese ideal realm of aloofness and serenity, freedom from wordly cares and death.
- Fensal : In Norse mythology, magnificent mansion of Frigga, to which she invited all married couples who had led virtuous lives on Earth to enjoy each other's company forever.

The Latitudinal Distribution of Clouds on Titan

SCIENCE VOL 311 13 JANUARY 2006

P. Rannou,[1*] F. Montmessin,[1,2] F. Hourdin,[3] S. Lebonnois[3]

The global cycle then drives methane from equatorial and tropical to polar regions. Methane is probably not stable in tropical regions on geological time scales,



NB – for dunes, low latitudes must be usually (or at least sometimes) dry. But we see channels not far from Huygens landing site, so the area is not always dry……

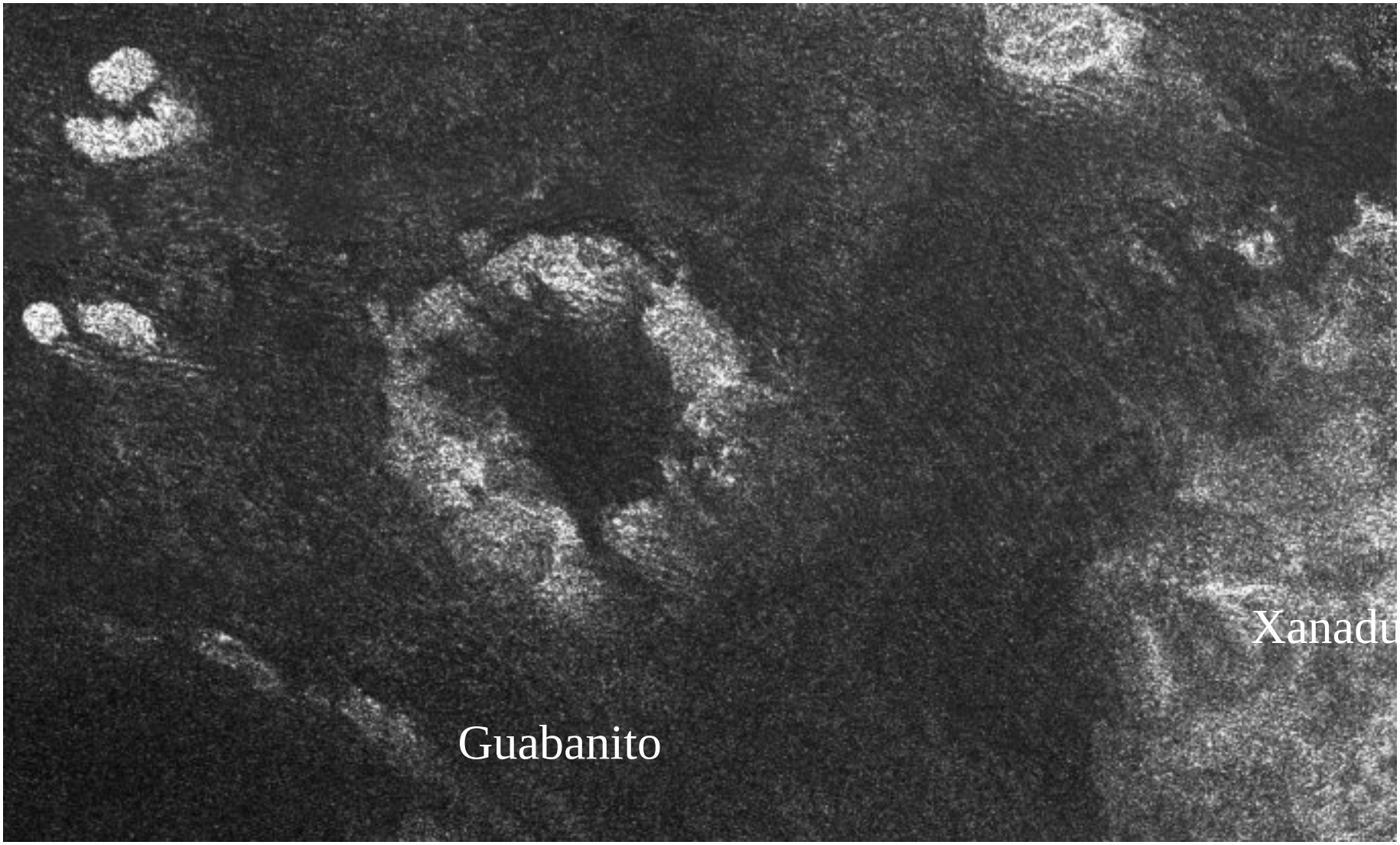
Sand Composition

- Dunes material is radar-dark. Emissive. Consistent with low dielectric constant. Probably not silicate rock. Ice, organics?
- Material is optically dark - favors organics? VIMS sees specific signature
- Material either has to be erodable into sand-sized grains, or can stick into sand-sized aggregates that are not readily destroyed.

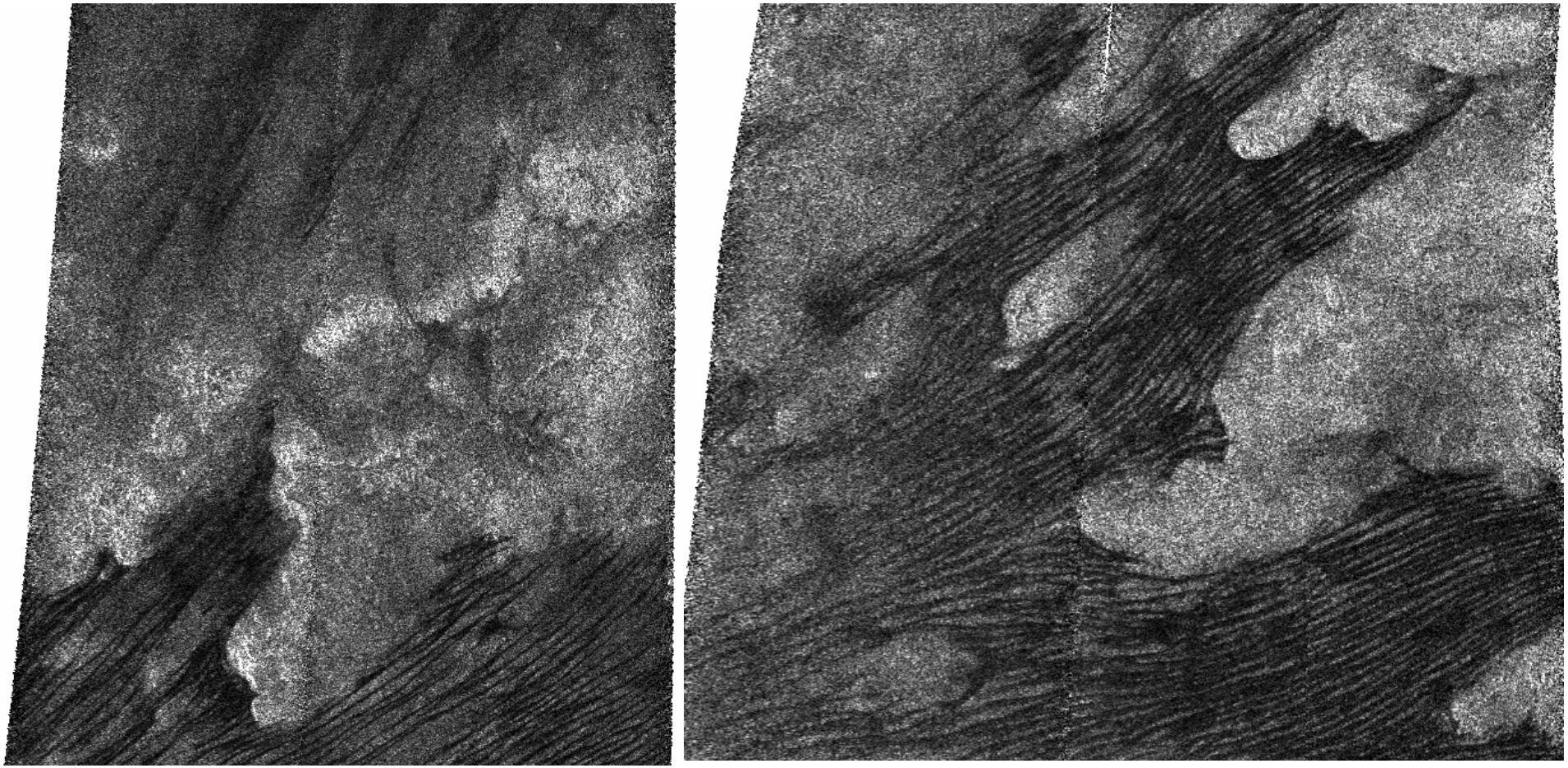
Implications - Sand Budget

- Belet dunefield (at least 200x1500km) with dune height of ~100m demands an origin for ~10^4-10^5 km^3 of material
- Exceeds likely impact production (main source on Venus)
- Fluvial erosion, or photochemical production, seem most likely candidates
- (Formation time ~10^4 yr. Global transport time ~10^7 yr)

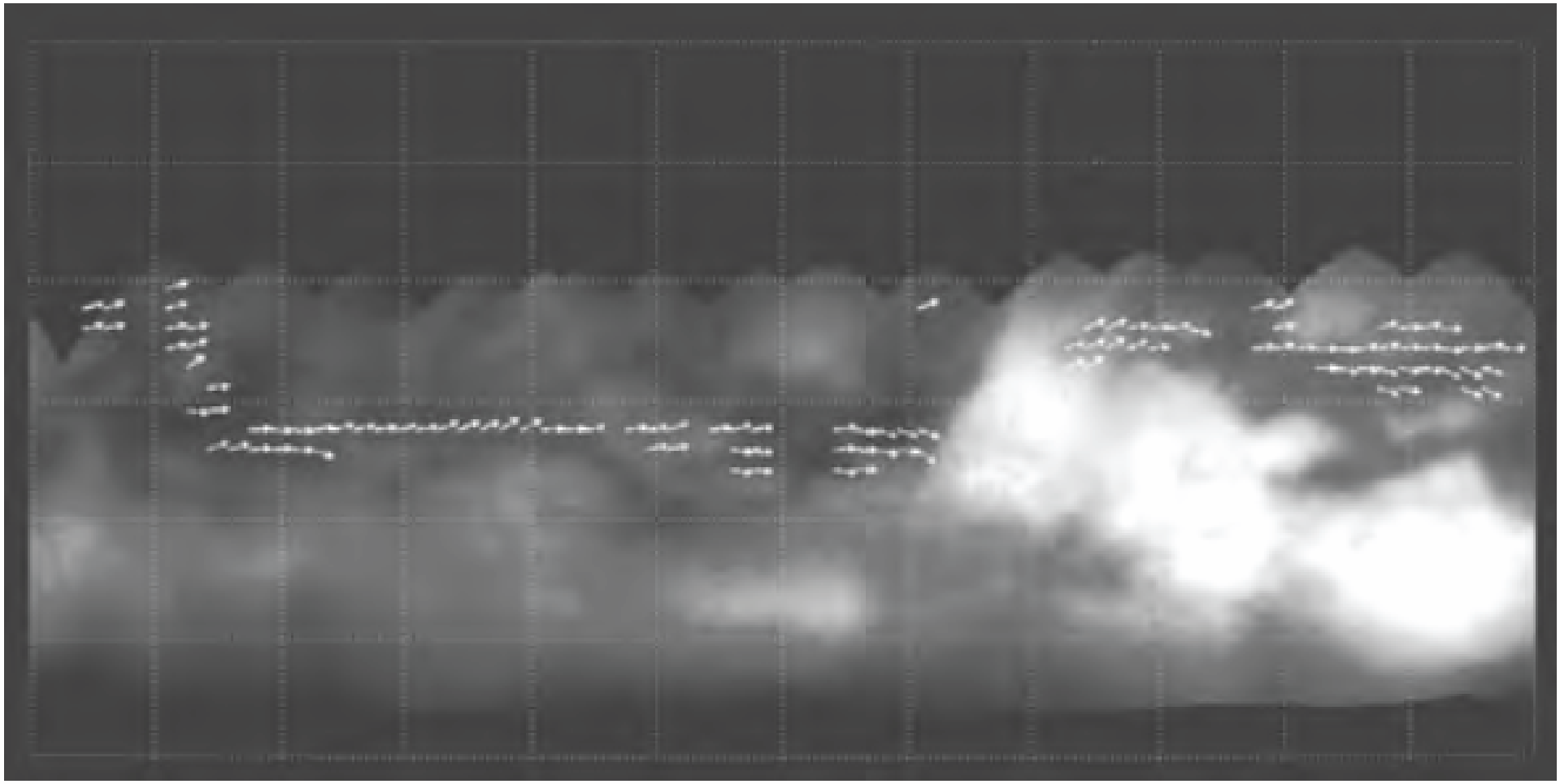
T13 RADAR in Shangri-La - pronounced southward deviation of dunes



Low-latitude part of T21 shows dunes with striking style of interaction with topography : apparent ‘blocking’. (transport direction appears generally to the east everywhere)

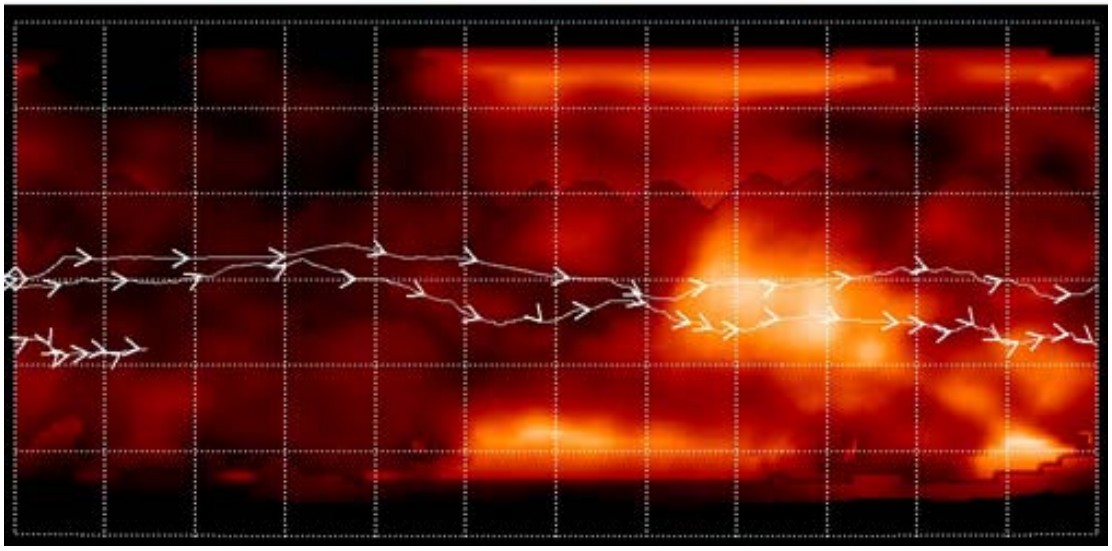


Dune Orientations reveal global wind pattern



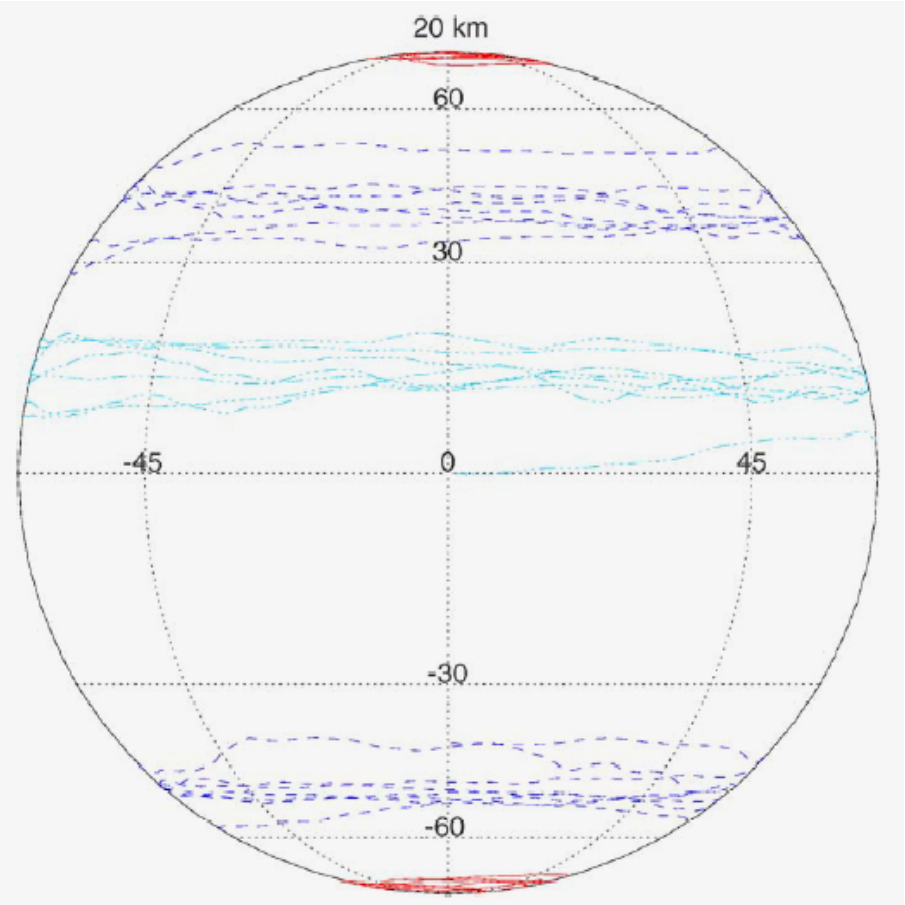
Jani Radebaugh at BYU has measured nearly 10,000 individual dunes!

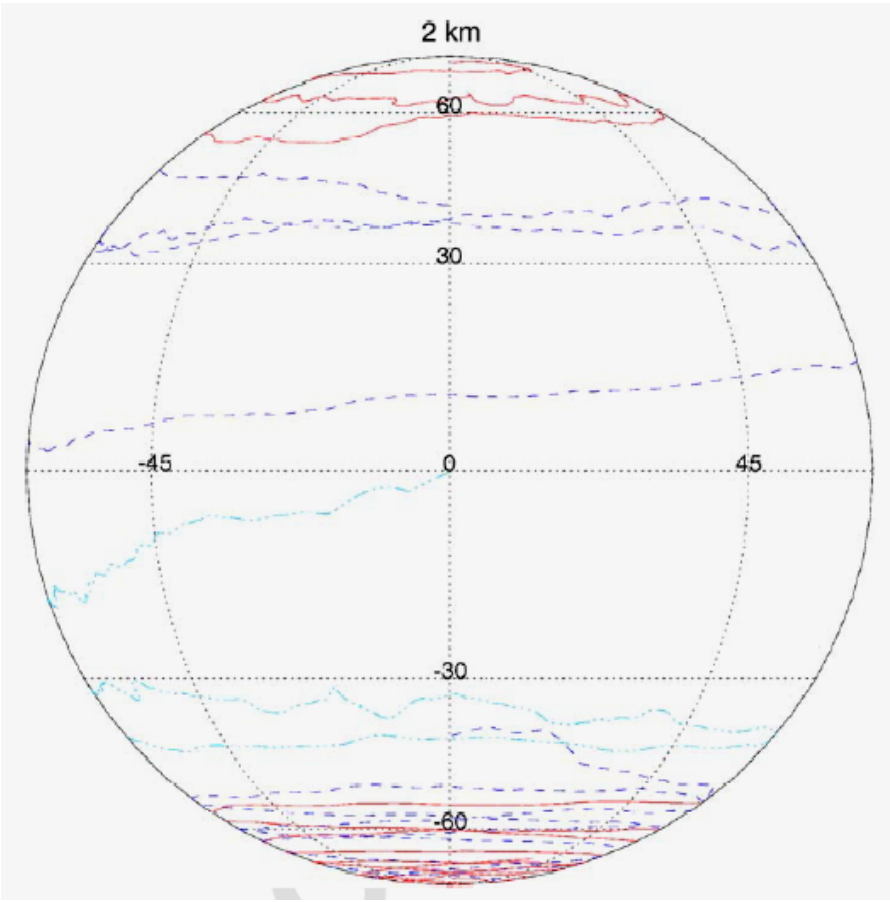
http://www.lpi.usra.edu/meetings/lpsc2007/pdf/1412.pdf



Hot-air balloon (‘Montgolfière’) can make many times round-the-world flights.

Exploit (predictable?) tidal winds to direct drift…





Because the tidal wind introduces a significant periodic meridional component to the wind, balloons do not drift just E-W, but sail across a band of latitudes.

Tokano and Lorenz, GCM Simulation of Balloon Trajectories on Titan, *Planetary and Space Science*, 2006

Outlook

- This discovery opens a whole new world for aeolian studies
- Implications for sand supply, cohesion and windfield, supporting tidal wind model?
- (so far) high latitude dark regions have no dunes. Weaker tidal winds? No sand left (but still dark)?. Too damp for sand to move ?
- Dunes were instrumental in helping co-locate DISR and RADAR imagery

Outlook (cont’d)

- Large areas of deep material with consistent fine-grained material makes useful ‘calibrator’ target area for remote sensing
- Dune patterns give us a way to map winds for future missions like a balloon
- Dunes the easiest place for a Titan lander ?