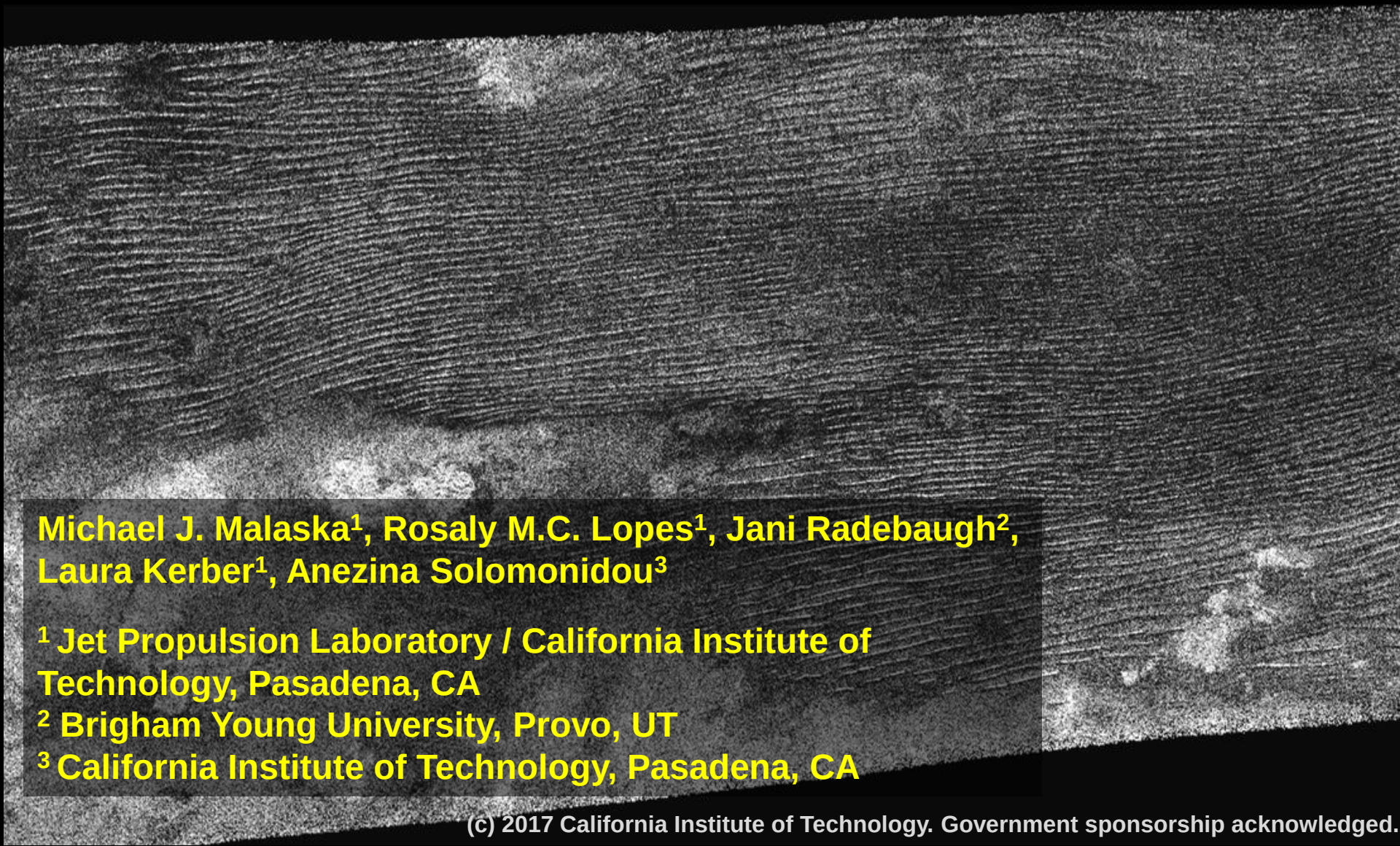
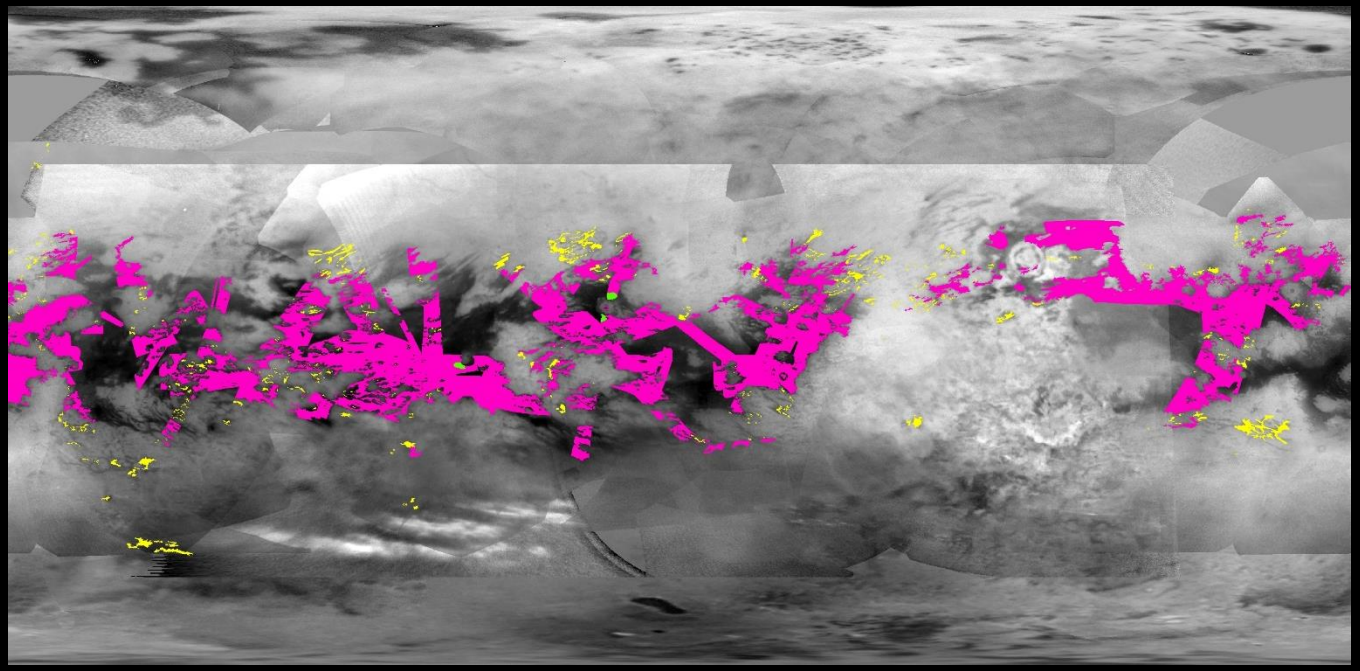
What is the Ultimate Fate of Titan's Dune Sands?



Michael J. Malaska[1], Rosaly M.C. Lopes[1], Jani Radebaugh[2], Laura Kerber[1], Anezina Solomonidou[3]

[1] Jet Propulsion Laboratory / California Institute of Technology, Pasadena, CA
[2] Brigham Young University, Provo, UT
[3] California Institute of Technology, Pasadena, CA

Titan’s IR-dark dunes are located in equator



IR dark equatorial dunes

2000 km

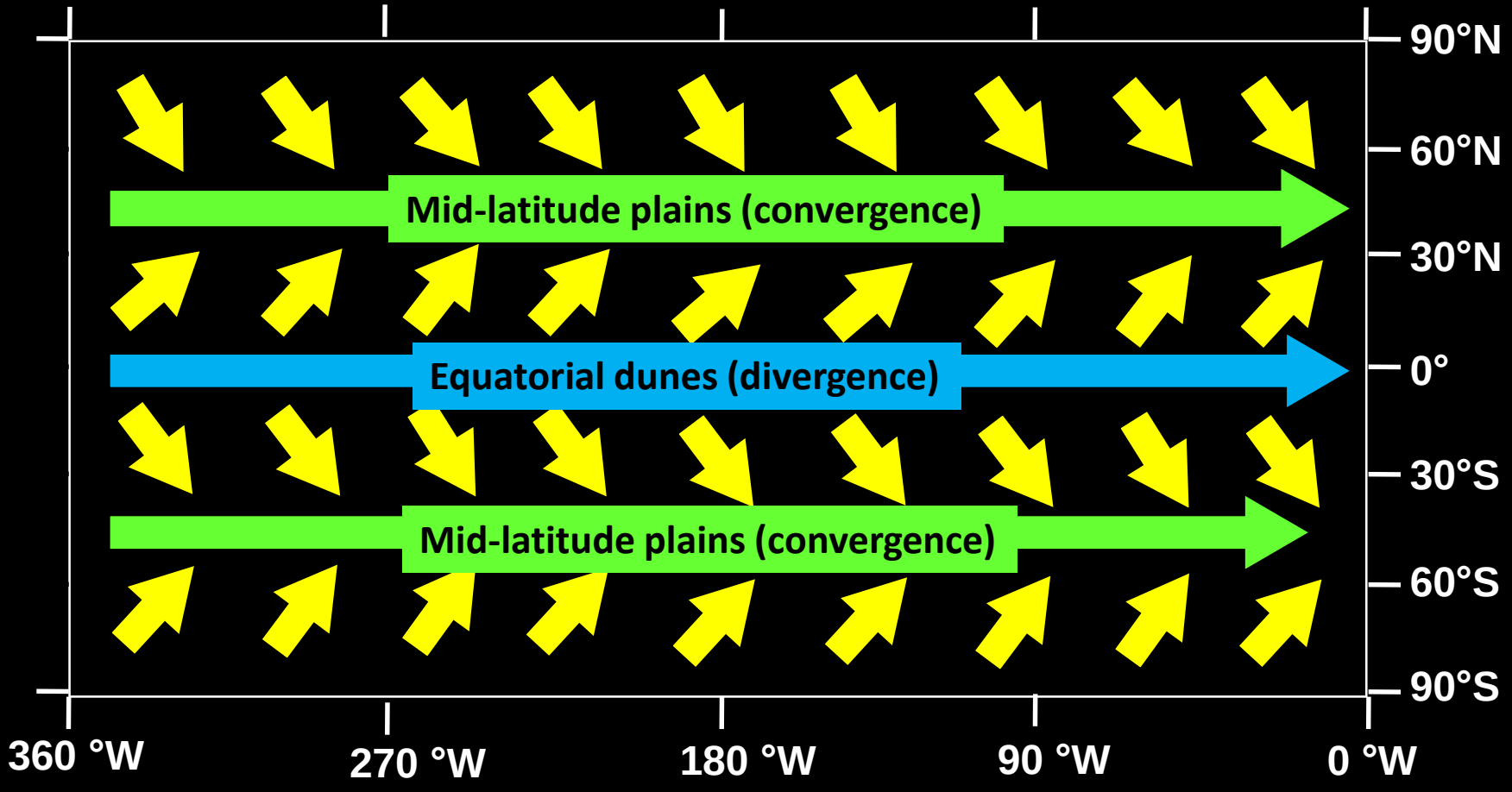
SAR identified terrains

- Linear dunes
- Reticulated (transverse) dunes
- Sand sheet

Lit: Rodriguez et al., Icarus 230 (2014), 168-179

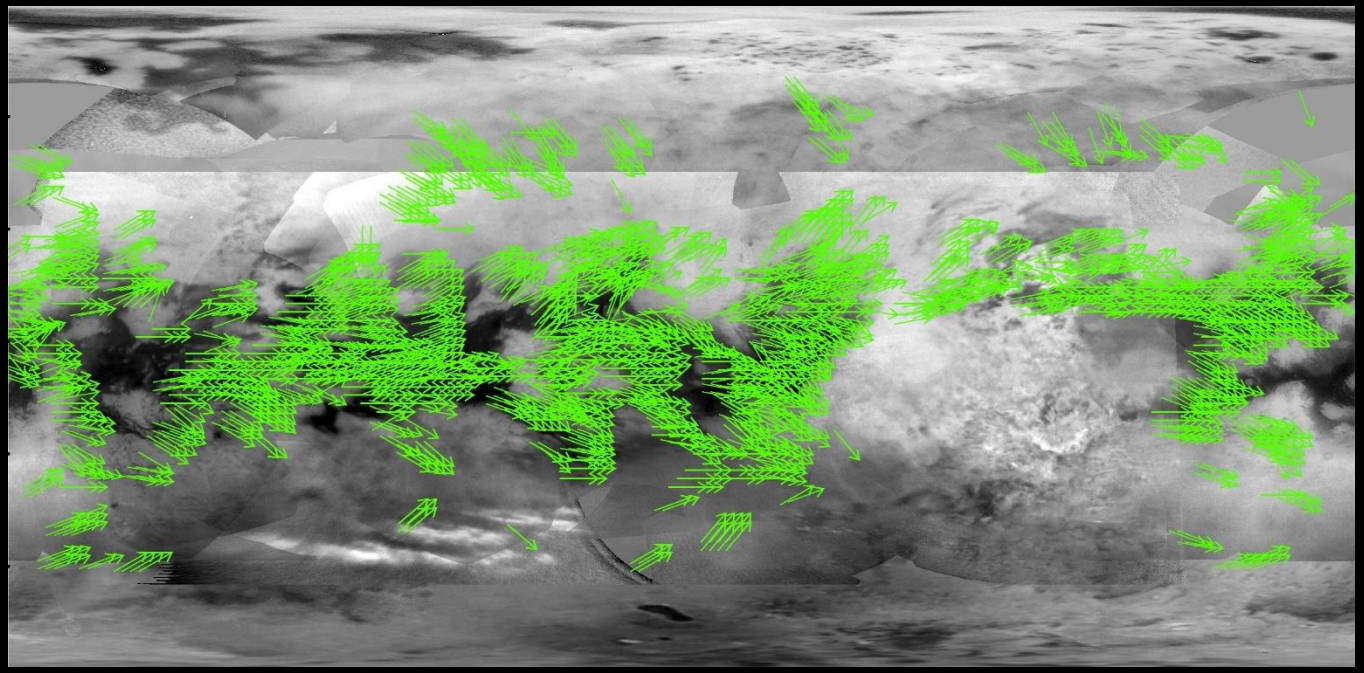
Wind-driven transport in equatorial and mid-latitudes zones

Dunes come from equatorial zone
Equatorial divergence; mid-latitude convergence



Malaska et al., Icarus 270 (2016) 183-196.

Titan materials move W→E from equator to lat 35 deposition bands sand seas → plains



Midlatitude convergence

Equatorial divergence

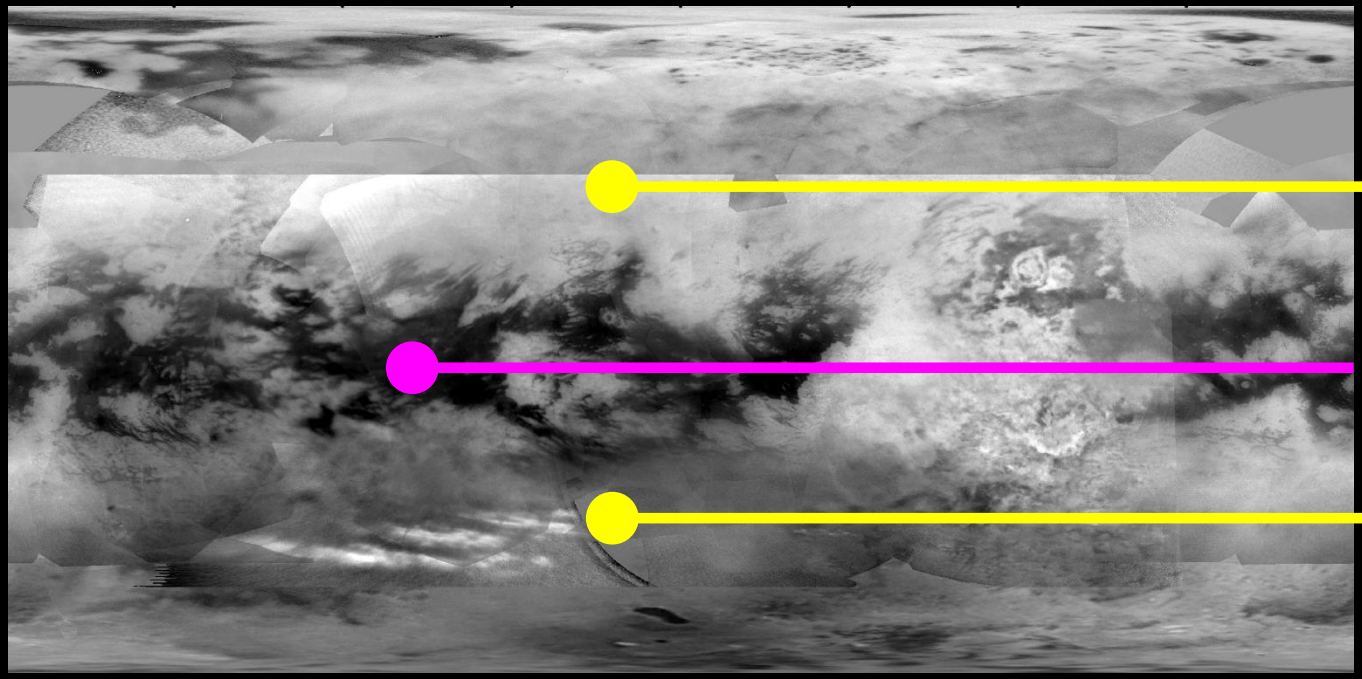
Midlatitude convergence

2000 km

Evidenced material flux directions

Malaska et al., Icarus 270 (2016) 183-196.

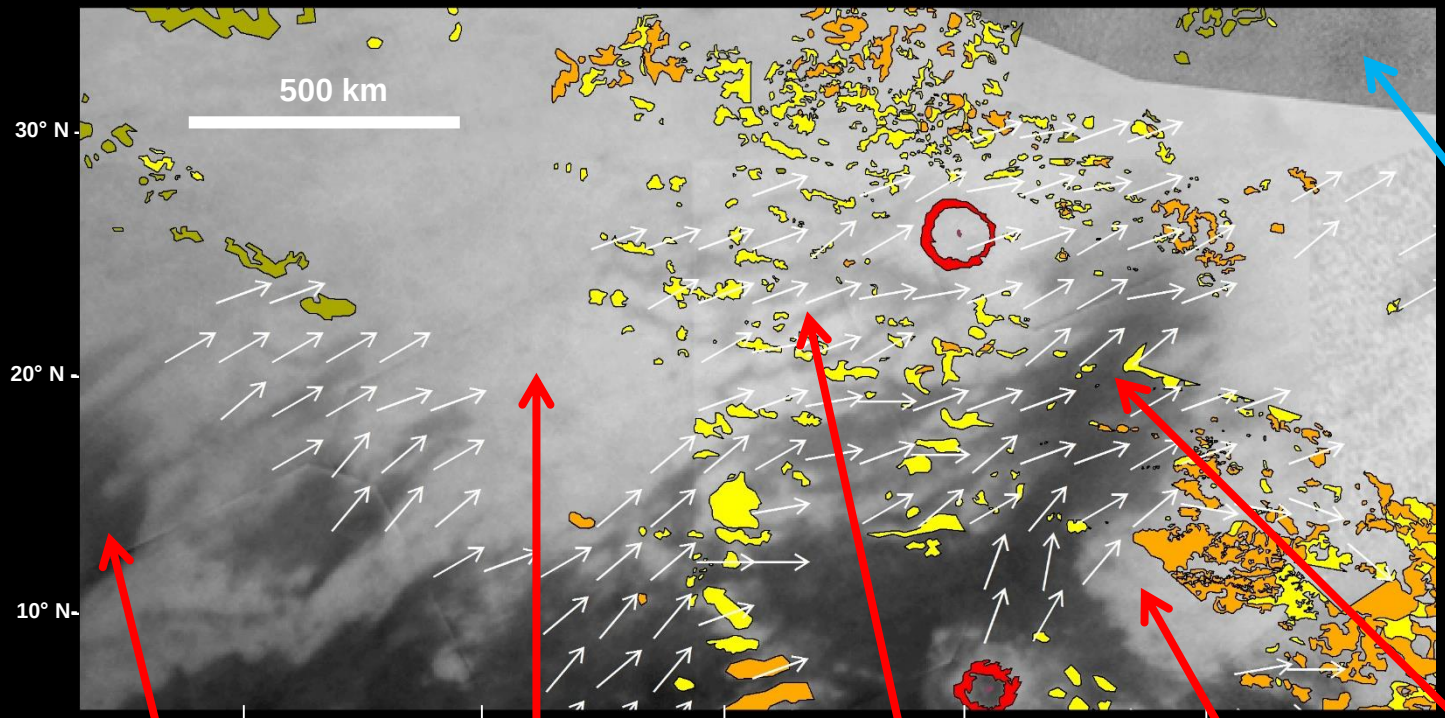
The Mystery:
Where do the IR-dark dune materials go?



We do not observe IR dark materials in mid-latitude deposition belts

Detail: Dune sands crossing Plains

But why no dark dunes in 35°N convergence zones?



No observed sands deposited at 35°N?
Where do they go?
Dunes→ undiff plains?

Dune sand sea

Dune sands must transport across plains

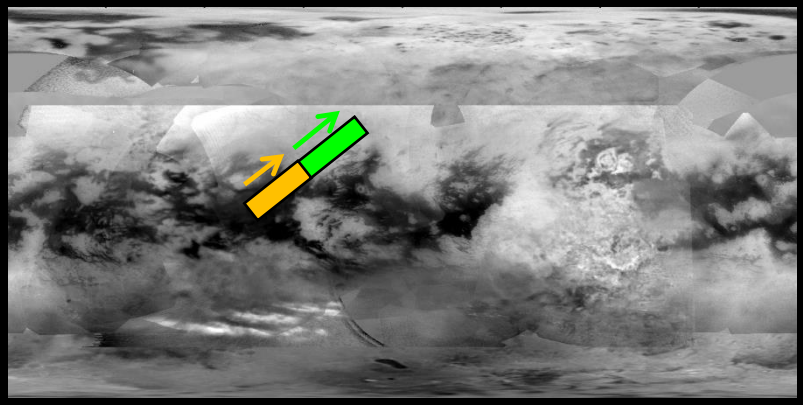
Sands focused by hills and deposited

Topography forces sand flux to N

Increased sand amount creates embayement

Malaska et al., Icarus 270 (2016) 130-161.

Possibilities:



1) Sub-resolution dunes

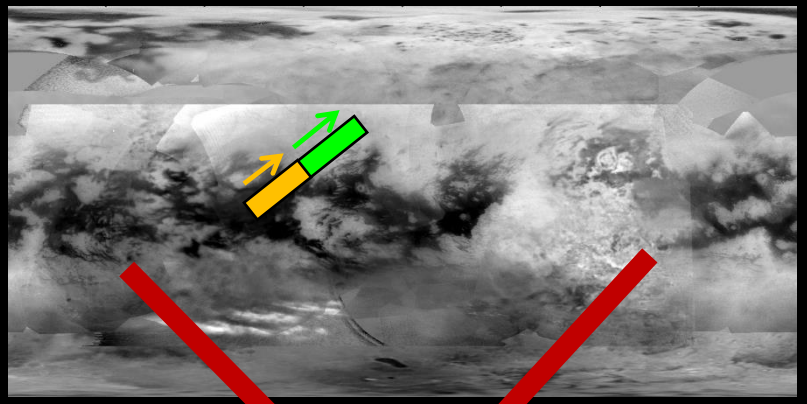
2) Termination due to changing wind regime

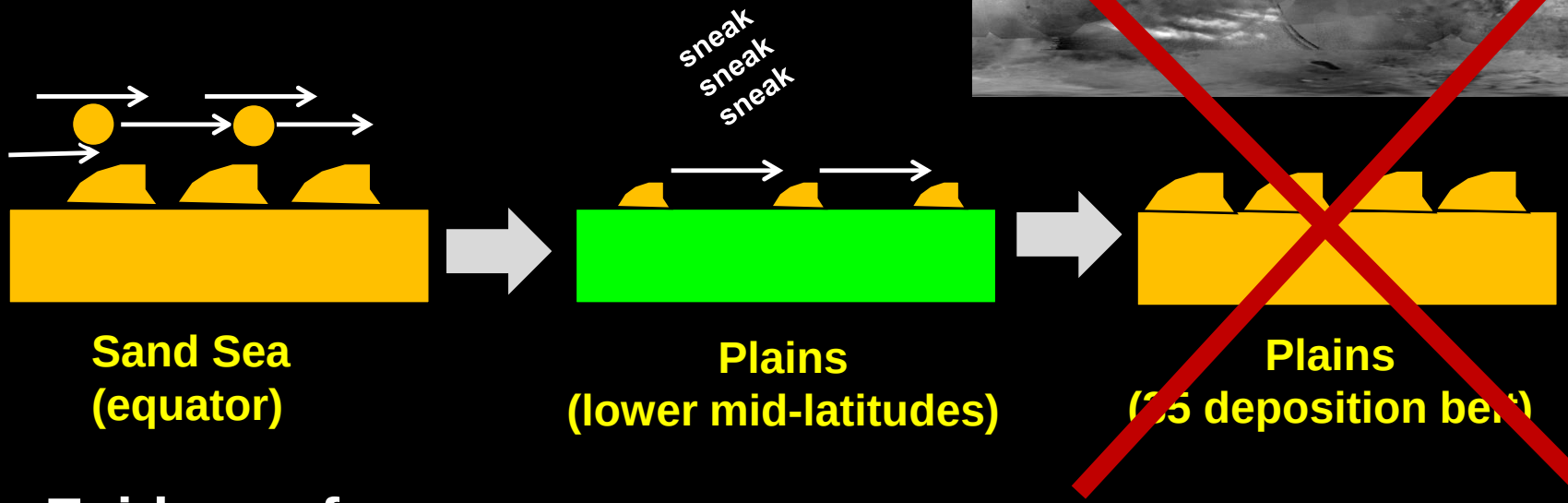
3) Interception of dunes by fluvial channels

4) Physical destruction of dune materials due to friability

5) Chemical modification of dunes

Subresolution dunes:
(they are too tiny to see)

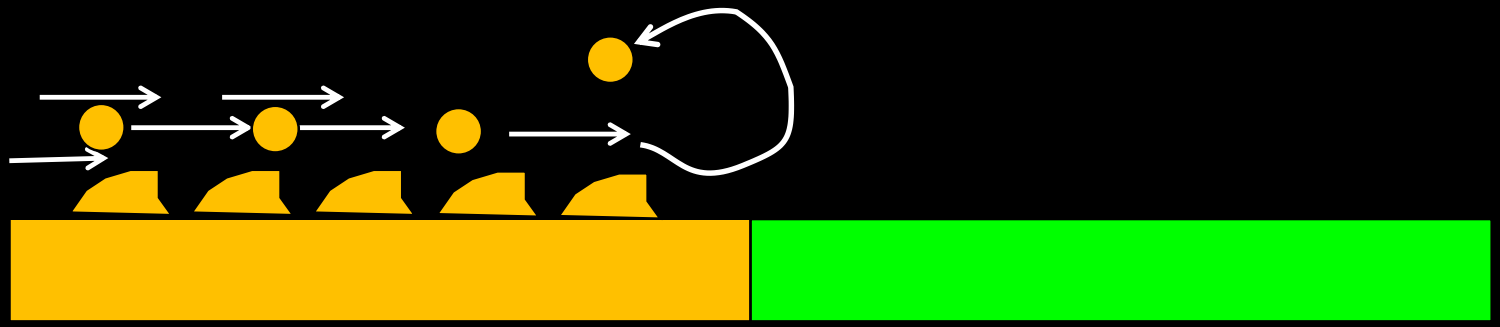




Evidence for:
IR spectra of plains at lower latitudes has more "dune-like" signal, consistent with dunes entering

Evidence against:
We don't see dark material in 35 deposition area, implies hasn't gotten there yet?
Not enough time/flux to get there?

Termination due to changing wind regime:

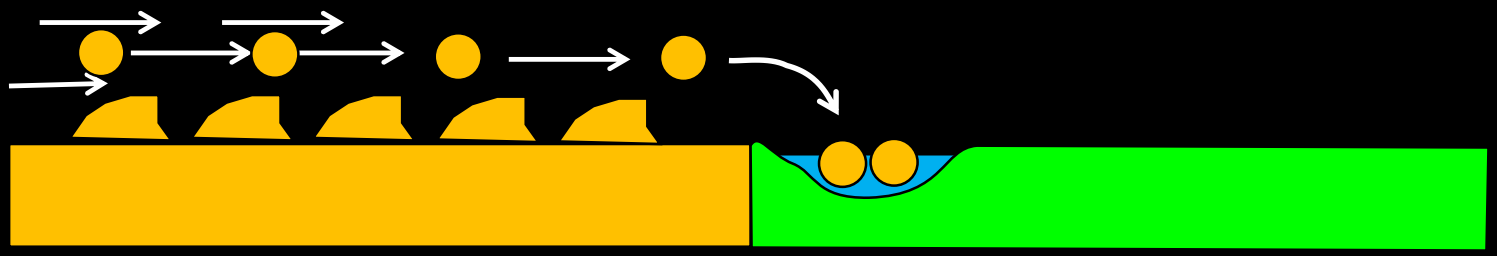


Evidence for:

Evidence against:
Alignment of windstreaks and other features in plains.
No evidence of windshift.
Evidence of sediment-starved dunes near plains contact
IR evidence that some dune material crosses into plains

Termination due to fluvial interception

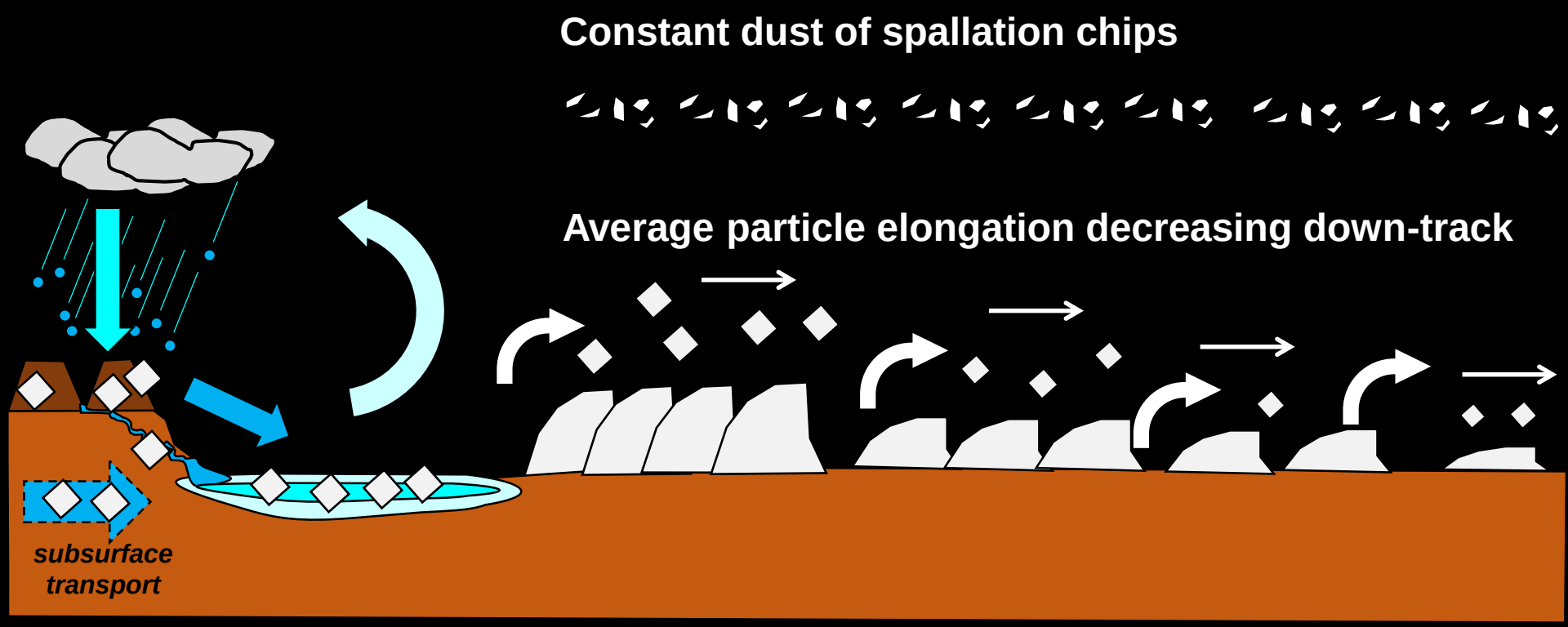
Earth Namib sand sea example



Evidence for:
Titan's mid-latitudes thought to be wetter.
(Why?) Huygens image of subresolution channels

Evidence against:
Channels usually combine to larger channels, streams, rivers. No evidence for big rivers in mid-latitudes.
Maybe they dry out or soak in?
(Then they aren't very good rivers, now are they?)

Physical destruction – Earth gypsum
White Sands National Monument, NM



Evaporite deposit

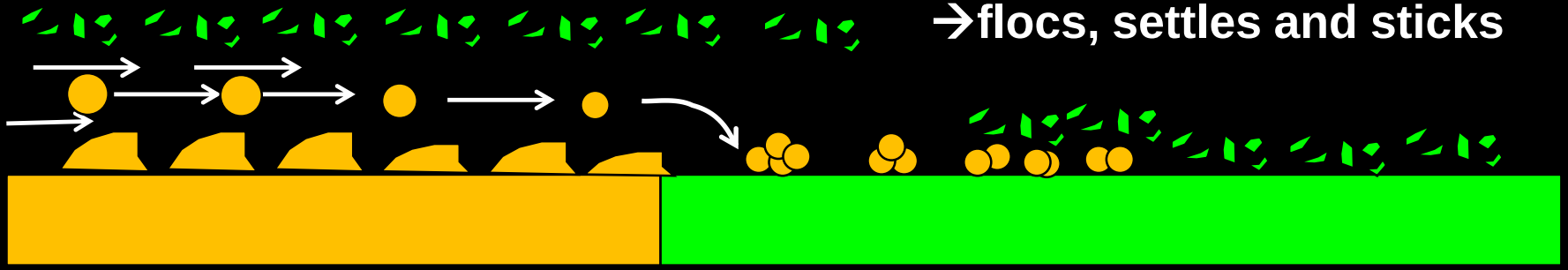
Wind mobile gypsum dunes → Suspended load of fine sand paricles

Jerolmack et al., JGR 116 (2011) F02003.

Titan destruction of dune grains due to friability

(like gypsum, not quartz)

Smaller particles
higher forces
→flocs, settles and sticks



Sand Sea
(equator)

Plains
(lower mid-latitudes)

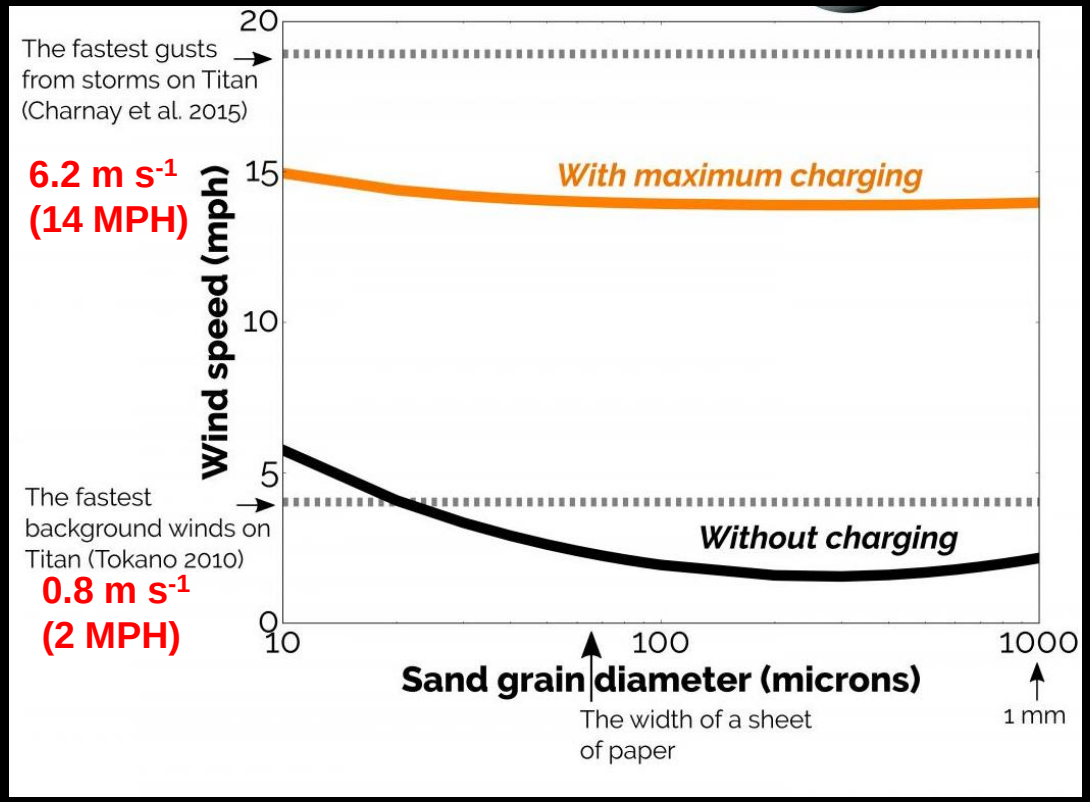
Evidence for:
Friability for Titan's dunes unknown
Consistent with decreasing sand supply
Radiometry of dunes and plains are similar (same stuff)

Evidence against:
IR/VIMS evidence, need to add some sort of chemical coating

Interparticle forces of organics

Organics good at holding charges

Increase charge → increase interparticle forces



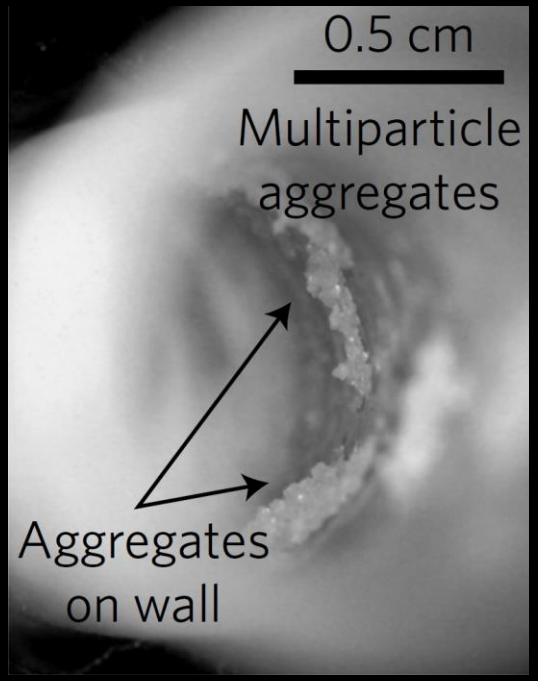


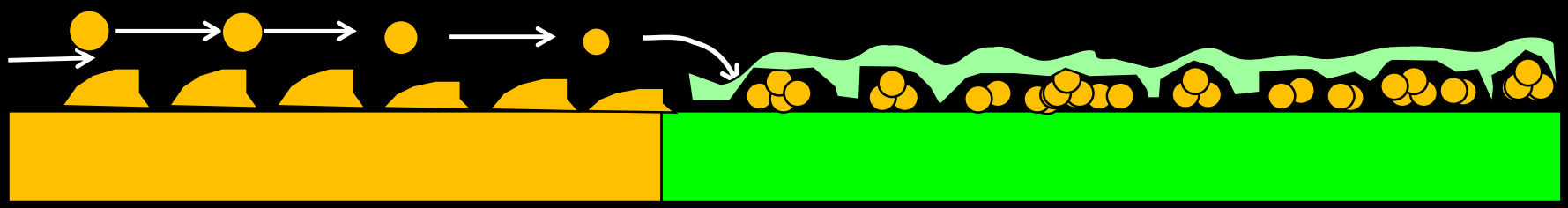
Image credit: G.D. McDonald, J.S. Mendez Harper

Higher forces → higher threshold frictional windspeeds for saltation
Leaching of non-charge holding materials? → aggregation, sticking?

Mendez-Harper et al., Nature Geoscience 10 (2017) 260-265.

Chemical weathering/modification

weathering of non-mobile sands – “a rolling grain gathers no rind”



Sand Sea
(equator)

Plains
(lower mid-latitudes)

Evidence for:
Latitudinal influence, climate, or chemistry from atm?
“Weathering rind” → leaching (dissolution), or efflorescence (dissolution, transport, evaporation)

Evidence against:
Dune structures (faces) not observed in SAR
Not just a simple blanket over dunes

Organic efflorescence demo

Saturated solution of 4-bromochlorobenzene in heptanes
Added into charcoal substrate : dark→bright

T = 0 min

T = 24 min

T = 32 min

T = 51 min

Dark substrate turns white as dissolved soluble materials are wicked up and precipitated on drying.

T = 143 min

(images by Mike Malaska)

Titan Dunes → Titan Plains?

Dark→Bright

No linear or transverse dune structures in plains

No one modification hypothesis fits perfectly

Transformation of dune materials into other "structures" (fines, flocs) seems to fit lack of linear or transverse dune presence in plains, and also radiometry.

Some form of spectral modification or IR-bright coating on top surface seems required.