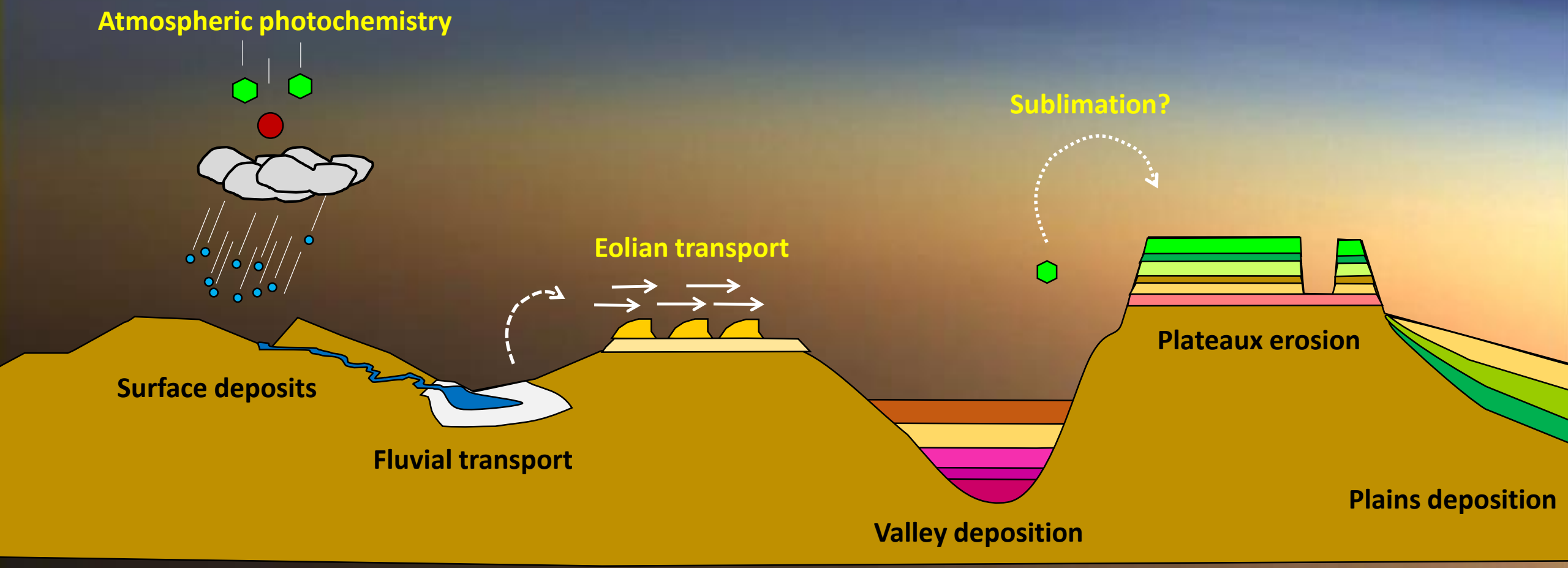
Titan as a Sedimentary World

Michael J. Malaska[1], Rosaly M.C. Lopes[1], Sam Birch[2], Alexander Hayes[2], Ashley Schoenfeld[3], Tiffany Verlander[4], Jani Radebaugh[5], Sebastien Rodriguez[6], and the Cassini RADAR Team

[1]Jet Propulsion Laboratory / California Institute of Technology, Pasadena, CA, [2]Cornell University, Ithaca, NY; [3]University of California, Los Angeles, CA; [4] University of Oklahoma, Tulsa, OK ; [5] Brigham Young University, Provo, UT, [6] University Paris 7 (Paris Diderot), Gif-sur-Yvette, France.



Funding from Cassini Data Analyss Program (CDAP)

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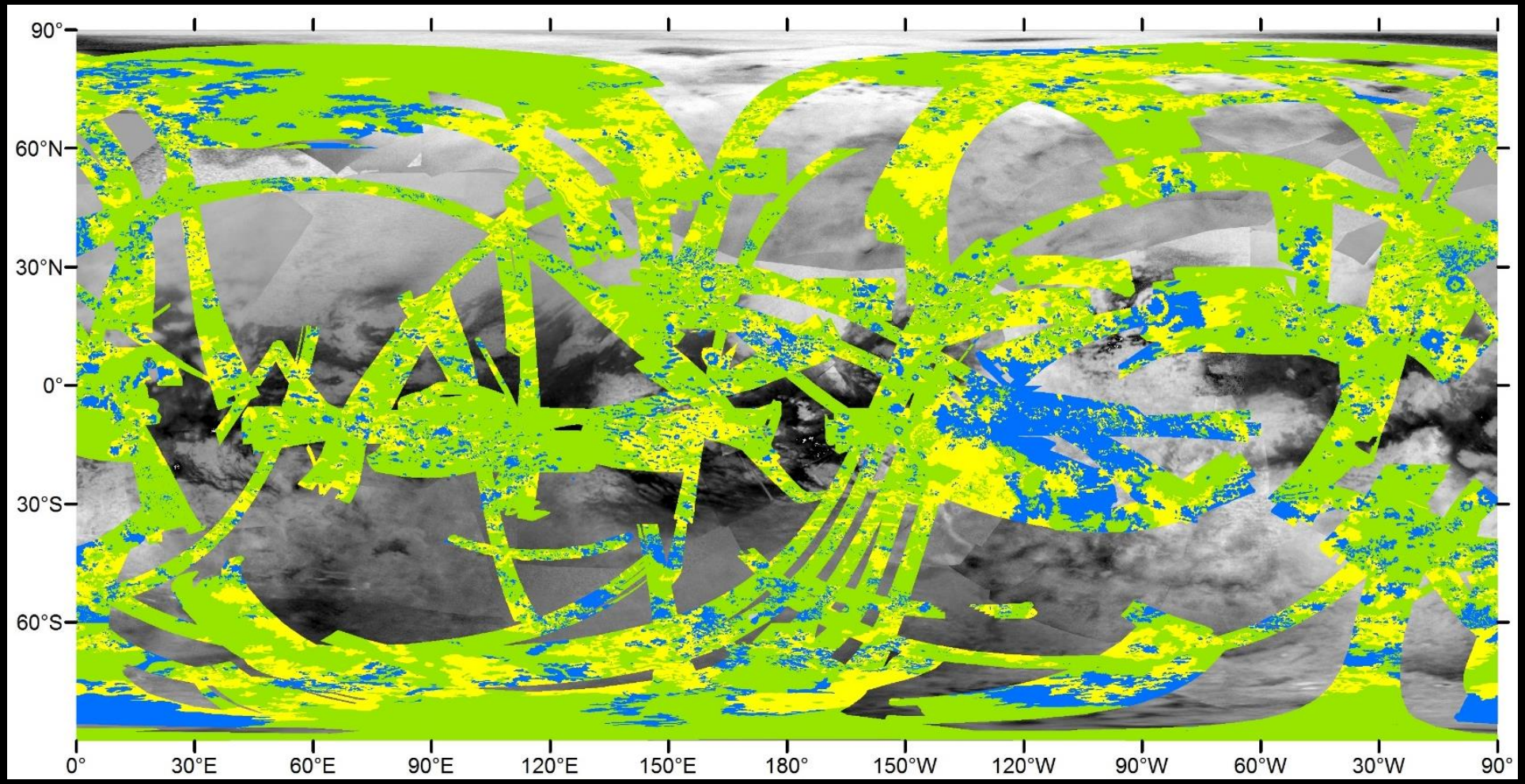
Titan's surface is mostly organics

Mapping and identification of terrains consistent with organic materials



Emissivity most consistent with:

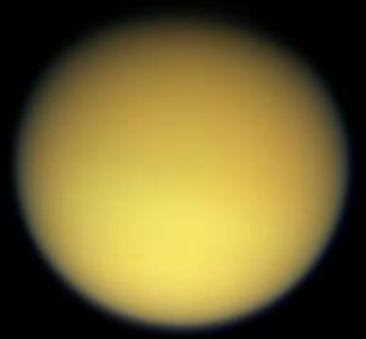
- Water ice
- Not sure
- Organics

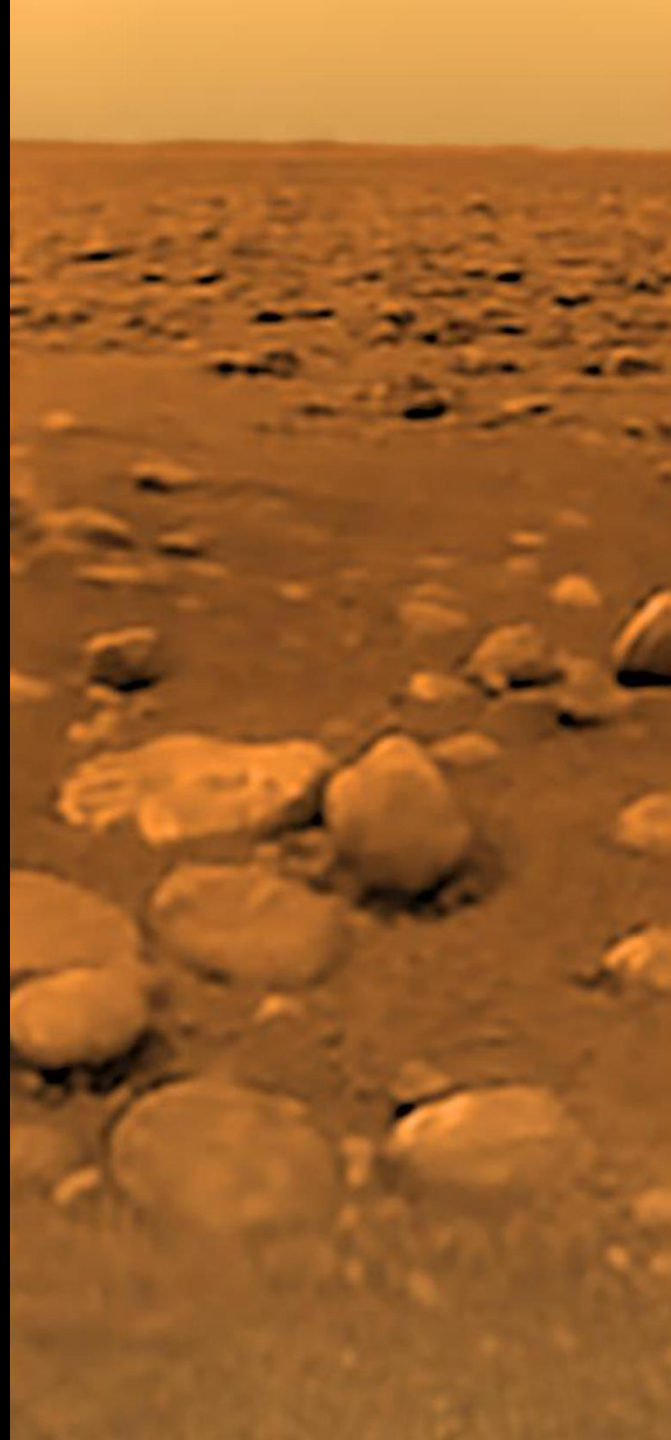
Global map of SAR-mapped terrain units colorized by likely composition

Malaska et al., DPS (2016).

3000 km

Titan geologic processing faster than airfall burial





Before→Now

Icy surface → Organic mantle

Cryovolcanic plains → Organic plains

Organic overcoat → Organics deposited,
transported (reacted?)
processed

"Callisto with Weather" →"Earth without the Drama"

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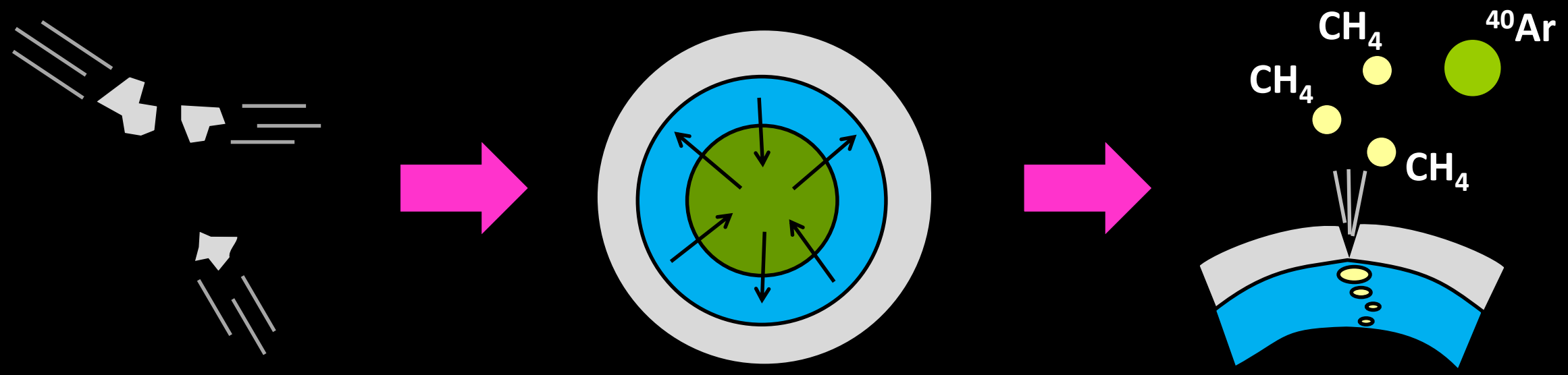
Ultimate source of organics: $CO_2 \rightarrow CH_4$



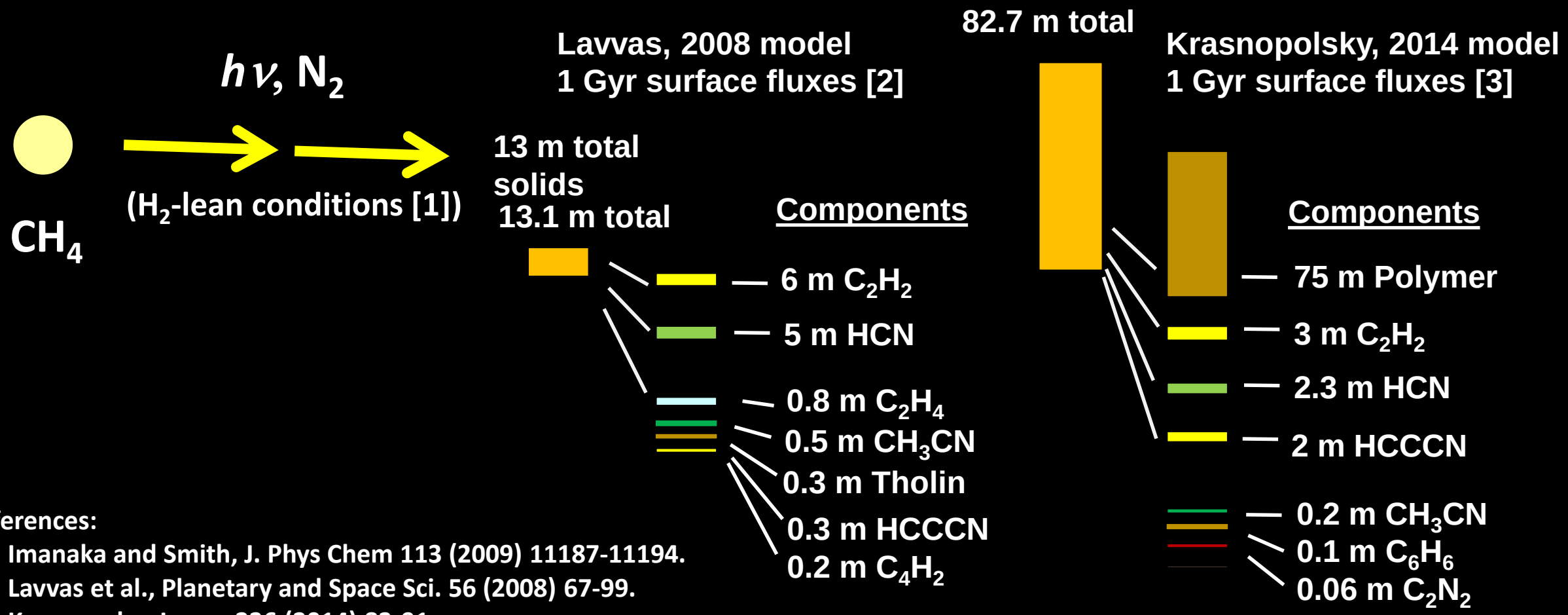
Primordial accretion CO_2

Geochemical conversion $CO_2 \rightarrow CH_4$

Atmospheric methane release

References:
Glein et al., Icarus, 250 (2017) 570-586.
Atreya et al., Planetary and Space Sci. 54 (2006) 1177-1187.

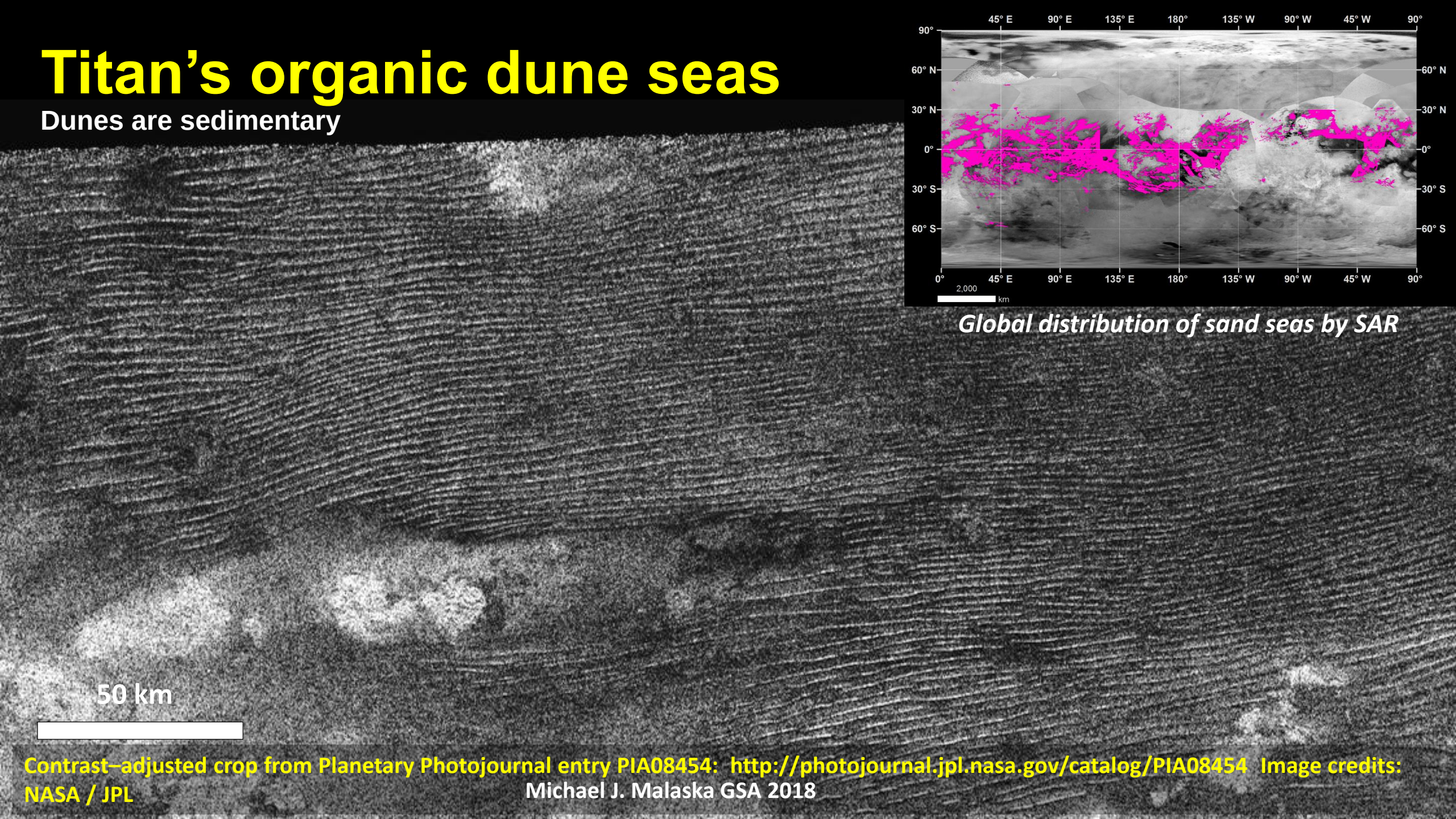
CH_4→solids: Titan's organic molecule surface flux



References:
[1] Imanaka and Smith, J. Phys Chem 113 (2009) 11187-11194.
[2] Lavvas et al., Planetary and Space Sci. 56 (2008) 67-99.
[3] Krasnopolsy, Icarus 236 (2014) 83-91. .

Titan’s organic dune seas

Dunes are sedimentary



Global distribution of sand seas by SAR

Contrast–adjusted crop from Planetary Photojournal entry PIA08454: http://photojournal.jpl.nasa.gov/catalog/PIA08454 Image credits: NASA / JPL

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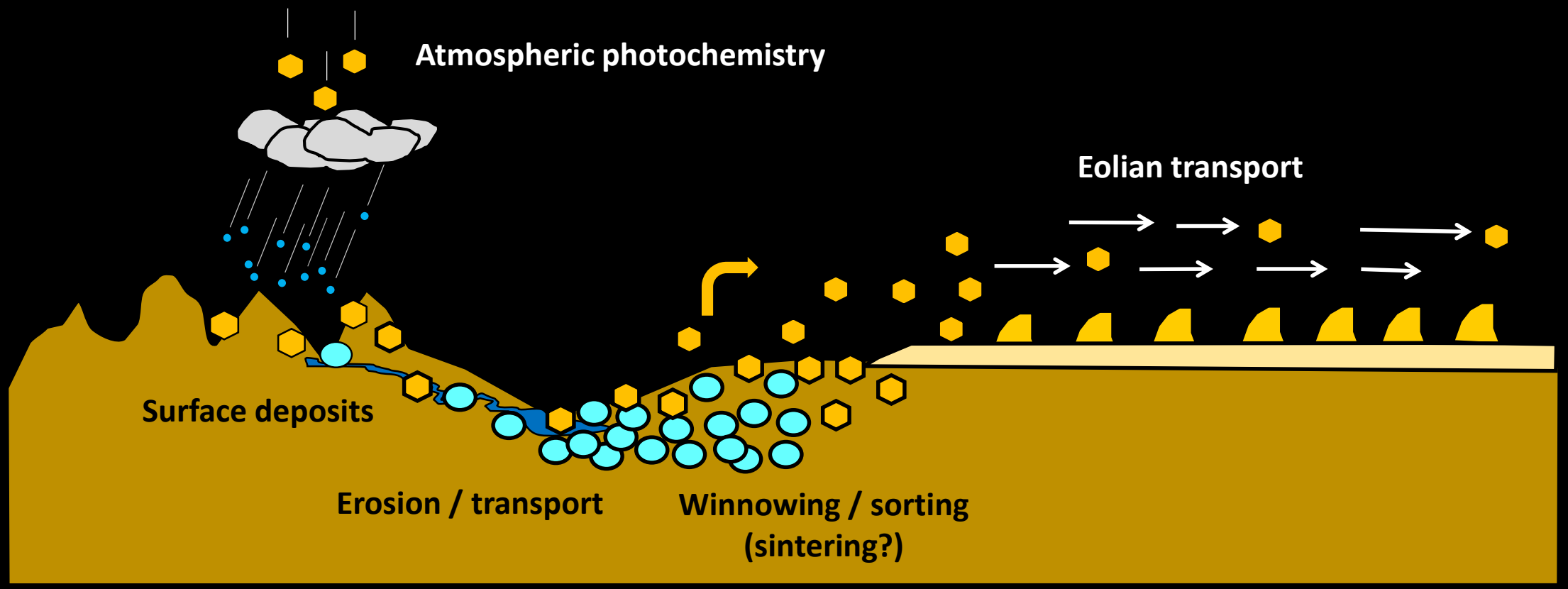
Organic airfall to dunes



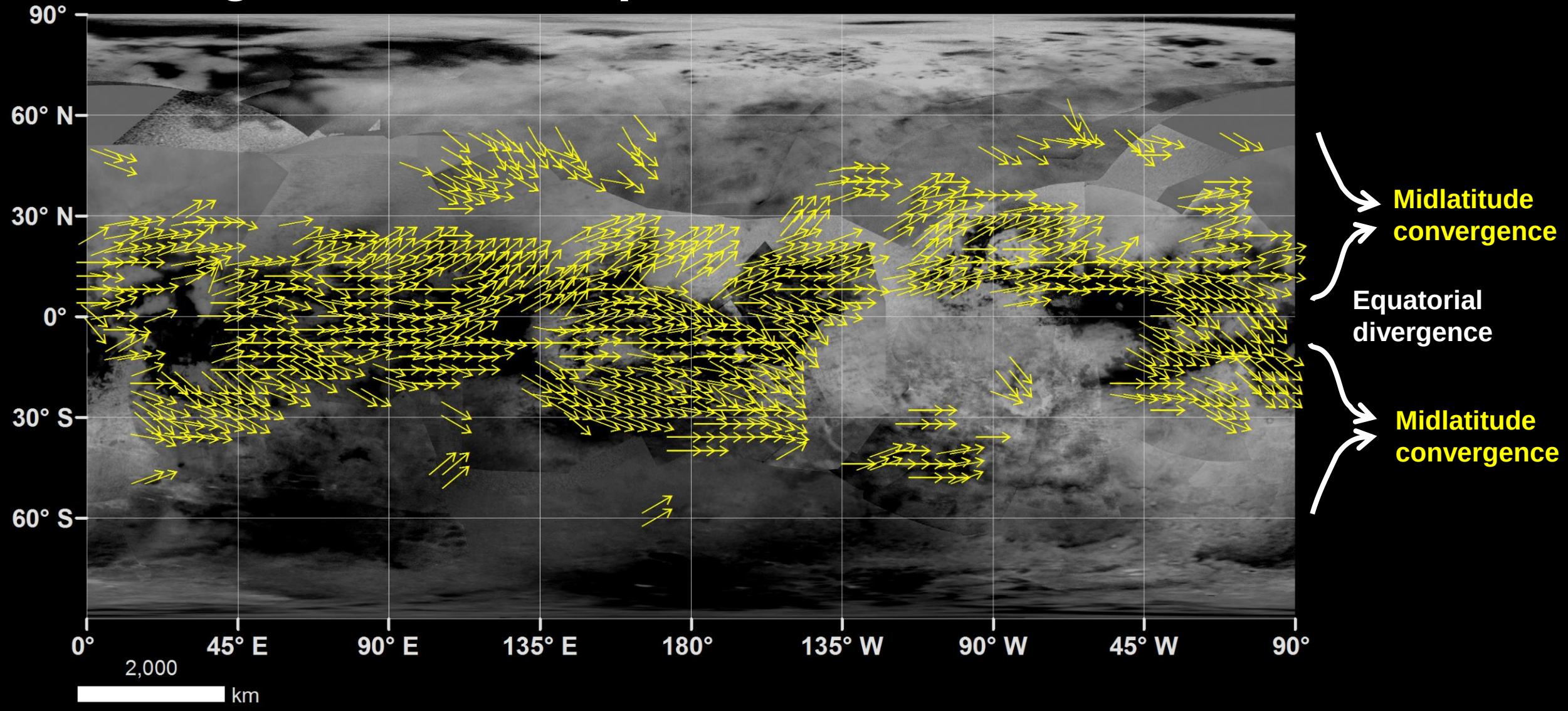
Organic covered ice mountains
VIMS bright unit

Ice outwash
VIMS blue unit

Organic dunes
VIMS brown unit

References:
Brossier et al., JGR-Planets 123 (2018) .
Barnes et al., Planetary Science 4 (2015).

Moving sediments: Equator → Mid-latitudes



Inferred material flux directions

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

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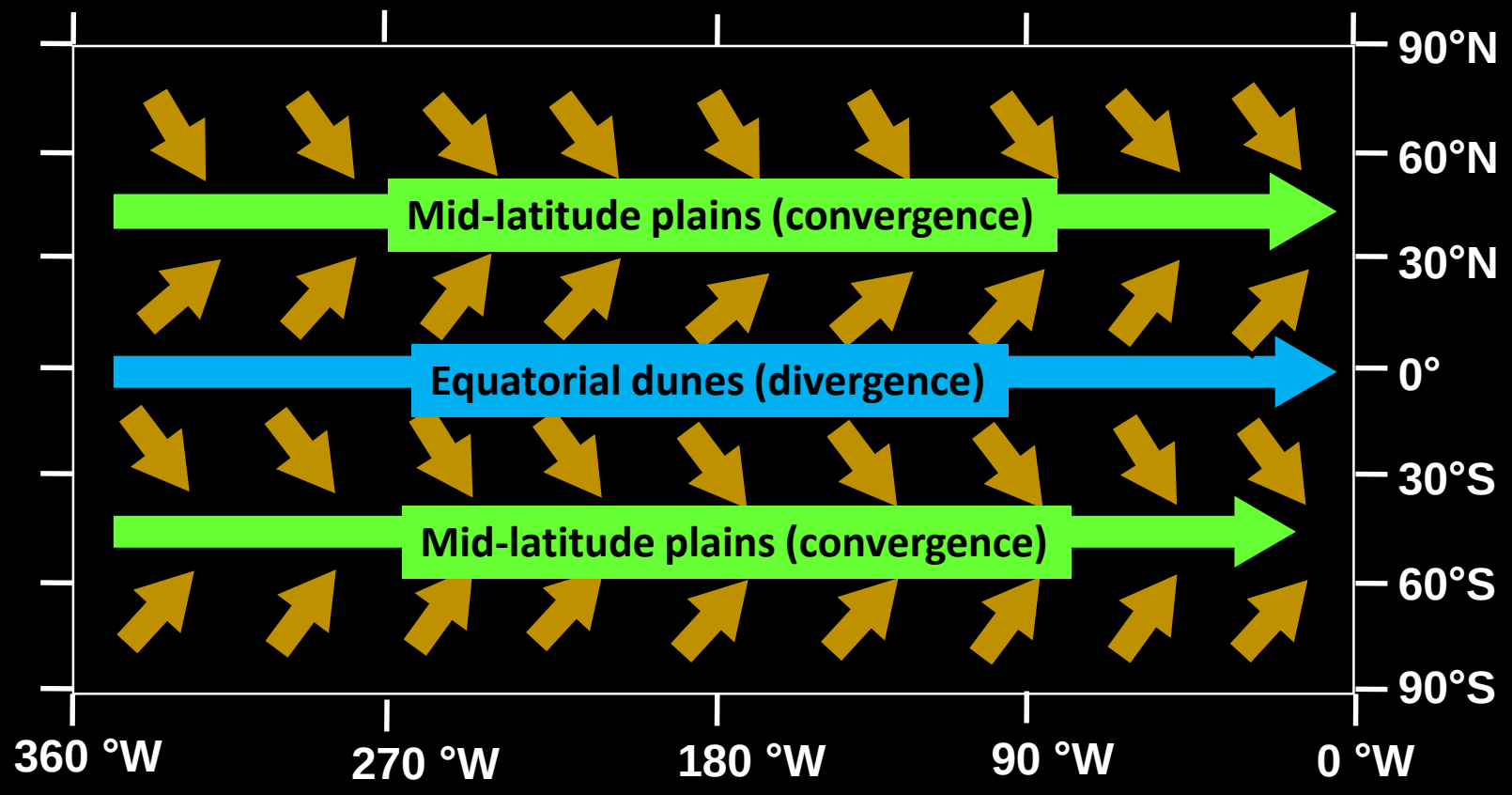
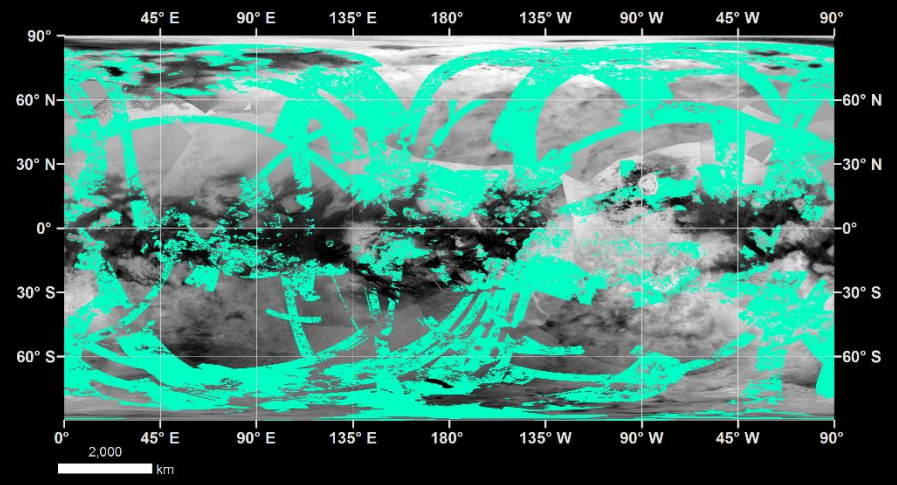
Dunes → Undifferentiated Plains

Titans organic plains may be sedimentary





Global distribution of undifferentiated plains by SAR

Equatorial divergence; mid-latitude convergence

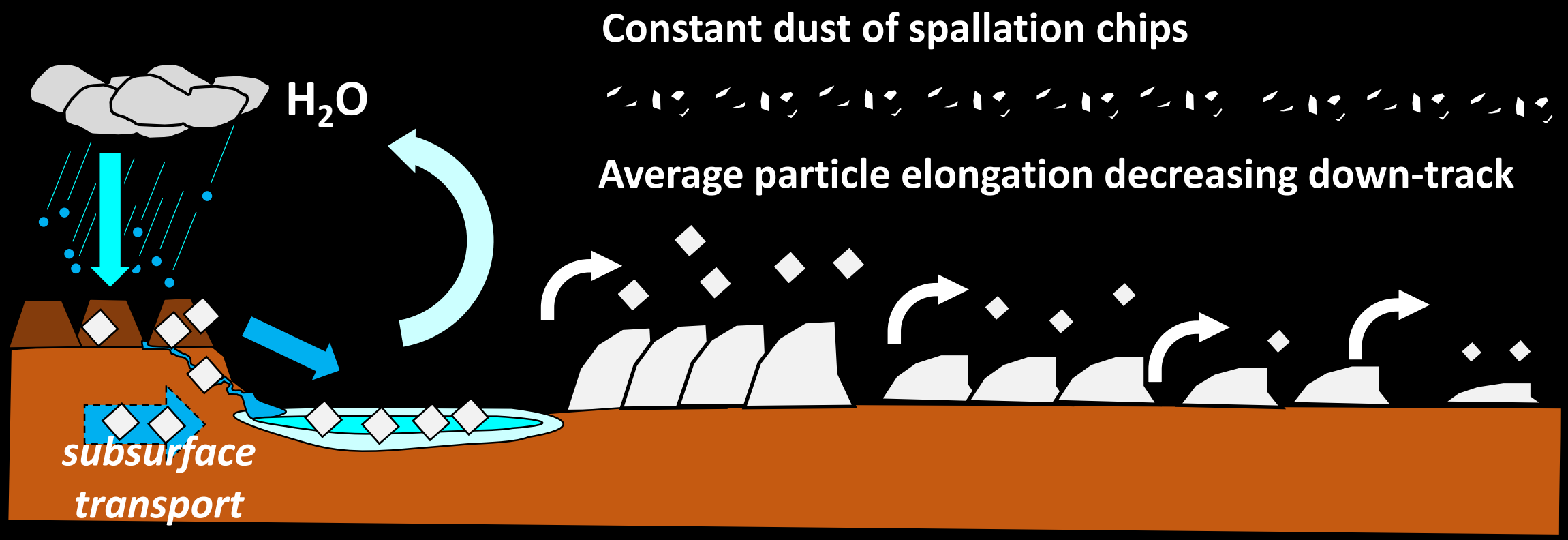
Dune material comes from equatorial zone

Undifferentiaed plains found in mid-latitude convergence zones

References:
Malaska et al., Icarus 270 (2016) 183-196.
Lopes et al Icarus 270 (2016) 162-182.

Terrestrial analog of dune grains to dust – gypsum

White Sands National Monument, NM

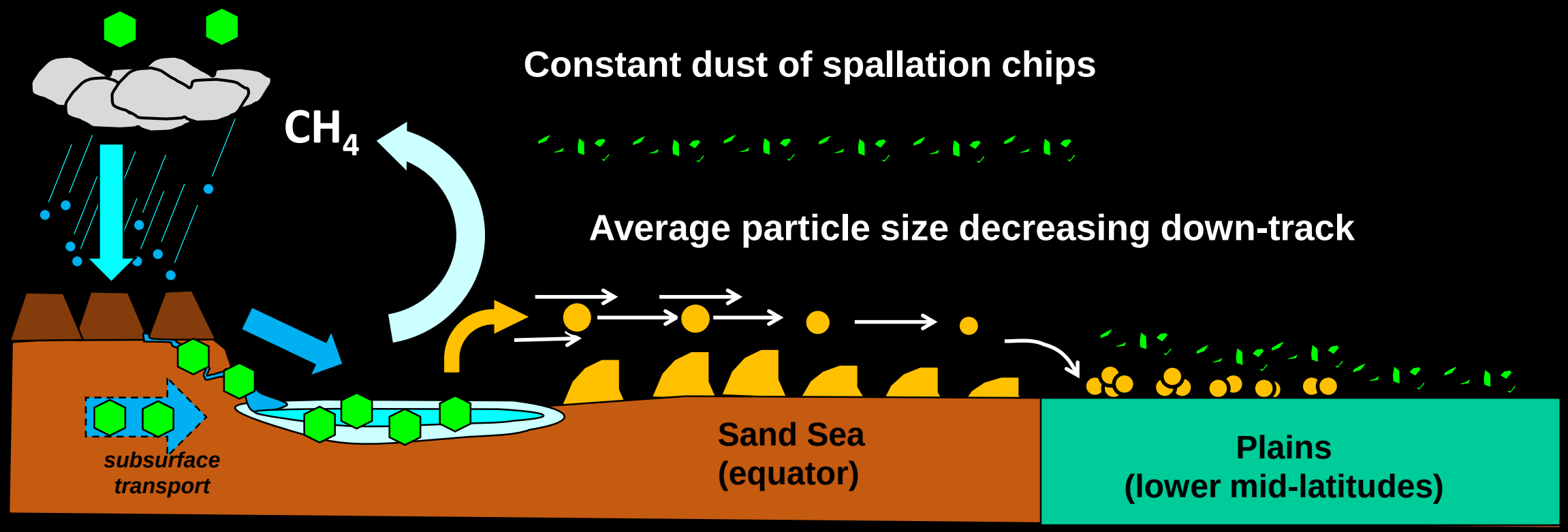


Evaporite deposit

Wind mobile gypsum dunes → Suspended load of fine sand paricles

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

Titan undifferentiated plains as a loess deposit?



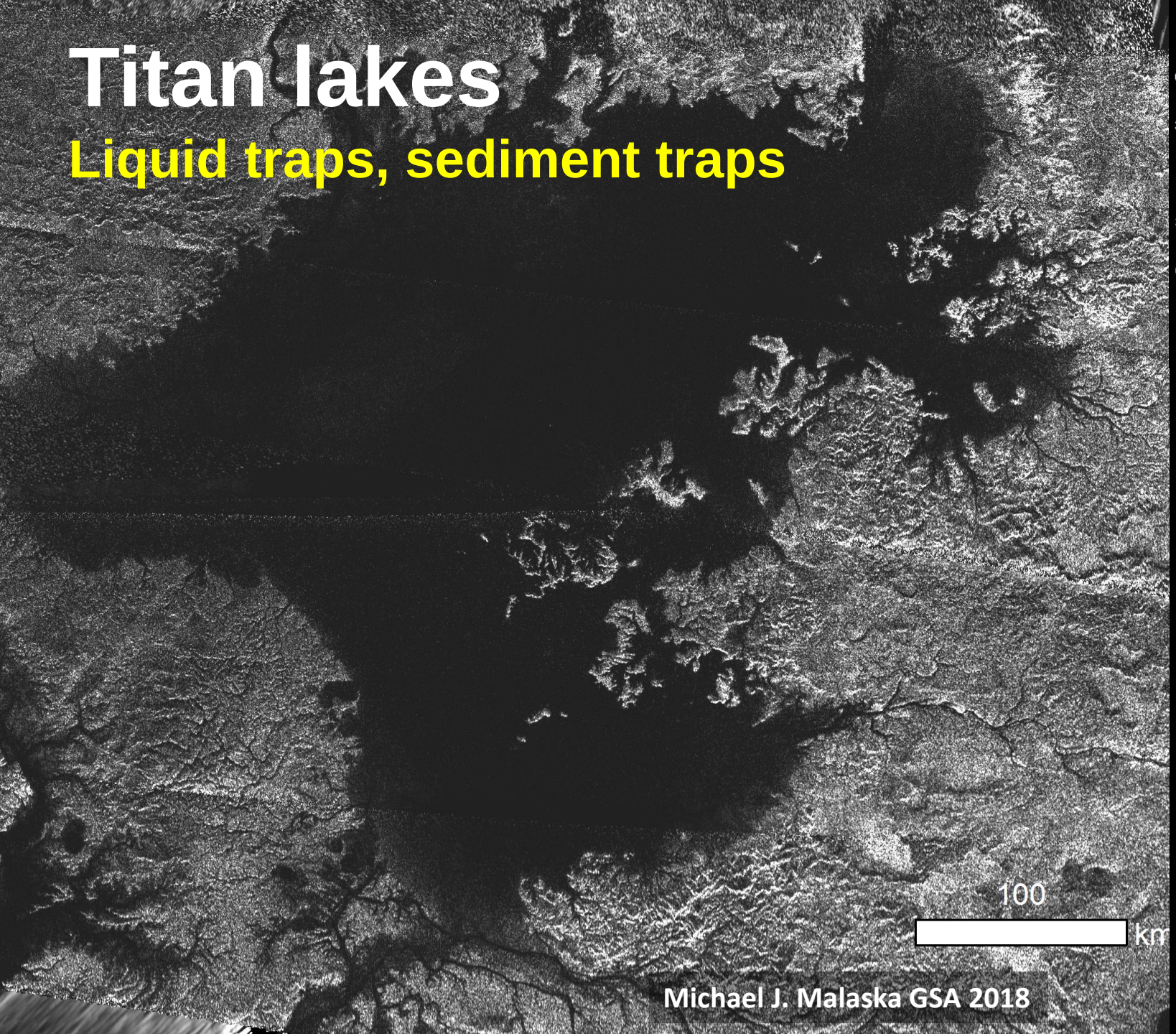
Evaporite deposit

Wind mobile organic dunes → Organic dusts settle out

References:
Electrostatics of Titan organic materials: Mendez-Harper et al., Nature Geoscience 10 (2017) 260-265.
Friability of organic Titan materials: Yu et al., JGR Planets 123 (2018), 2310–2321.

Titan lakes

Liquid traps, sediment traps



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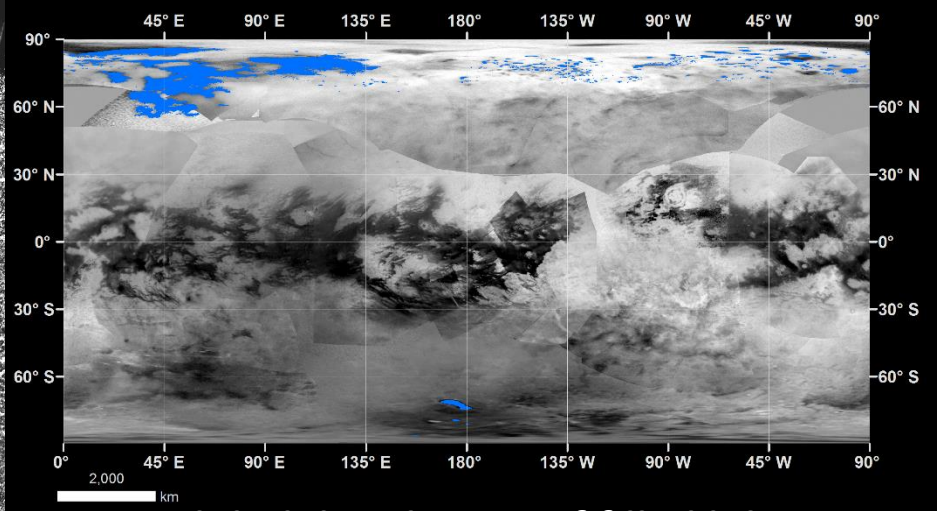
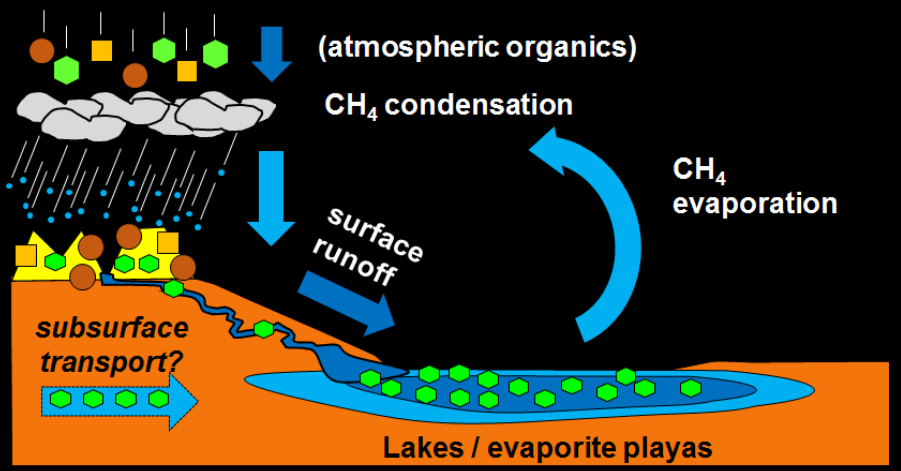


Global distribution of filled lakes

Titan methane cycle

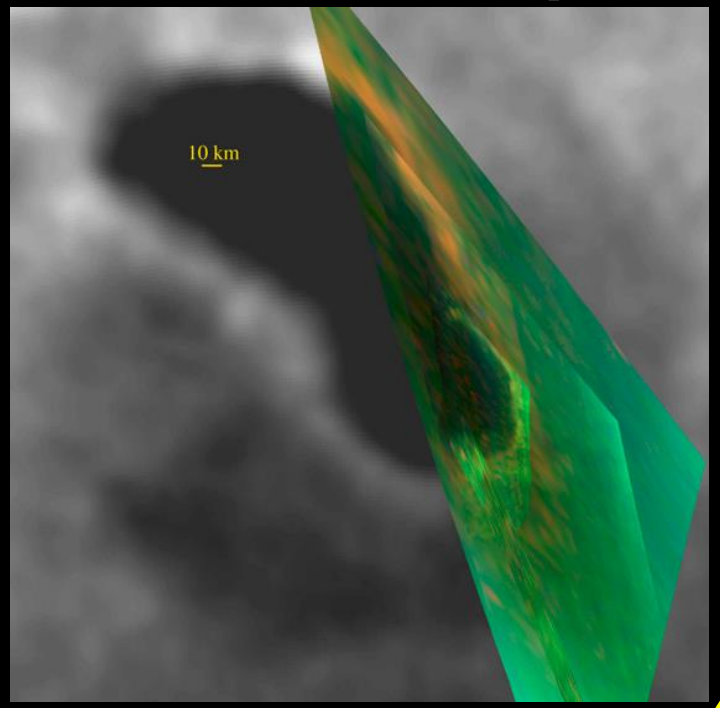


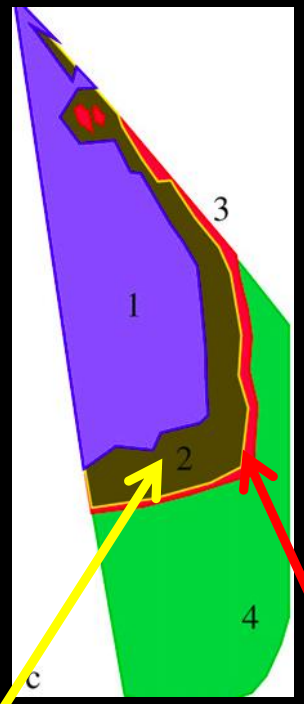
Reference:

Hayes et al., Nature Geoscience 11 (2018), 306-313.

Sediments in lakes

Titan lake evaporite deposits



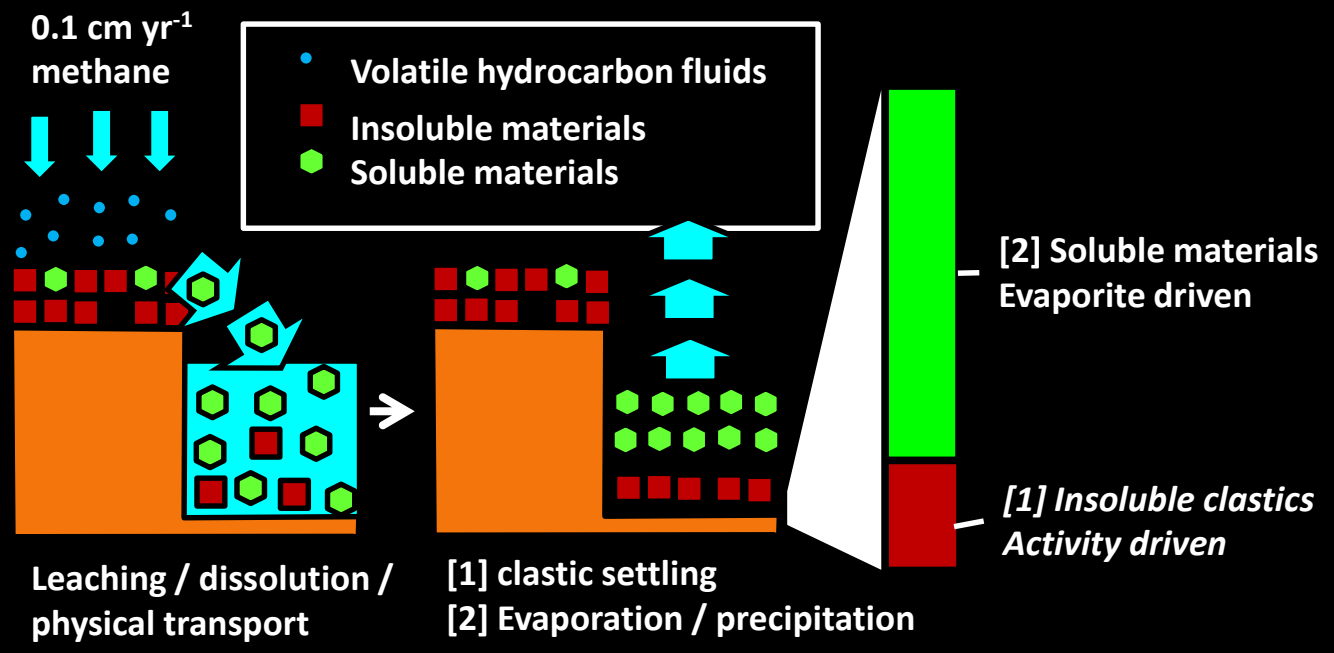


Ontario Lacus VIMS "bathtub ring"

Unit 2 - dark organic mudflat

Unit 3 - bright organic evaporite

Putative Titan cyclic layer sequence



References:

Barnes et al., Icarus 201 (2009) 217-225.

MacKenzie et al., Icarus 243 (2014) 191-207.

Cordier et al., Icarus 270 (2016) 41-46.

Malaska et al., Habitability of Ocean Worlds (2014), Abstract 4020

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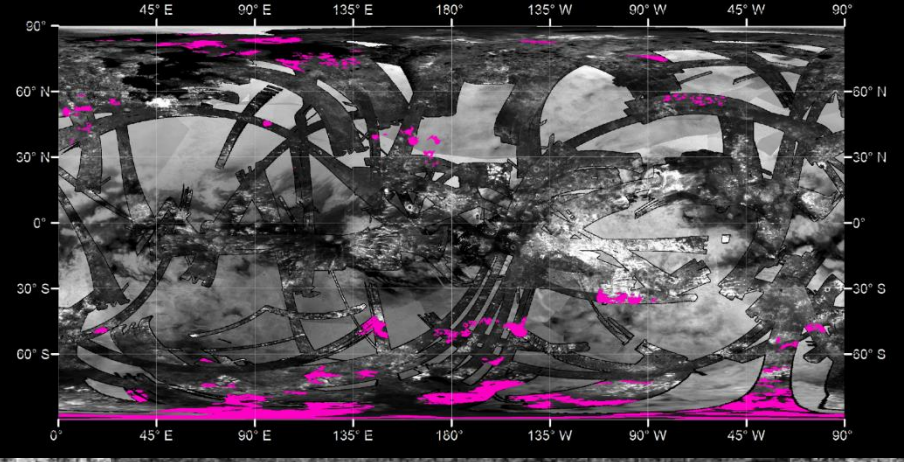
Titan labyrinths: Dissected plateaux



Global distribution of labyrinths

Greater Sikun Labyrinthus region:
Planetary Photojournal Image PIA10291

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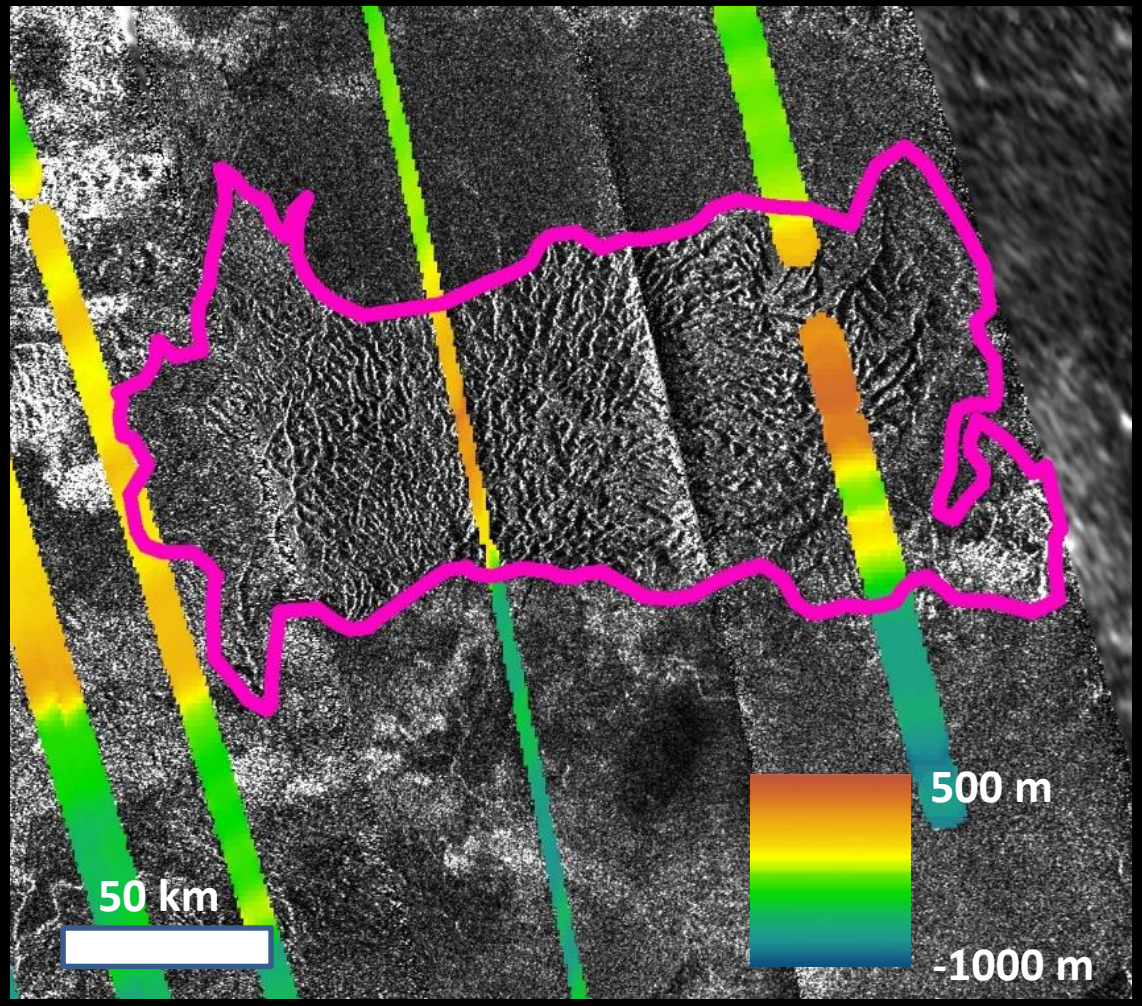
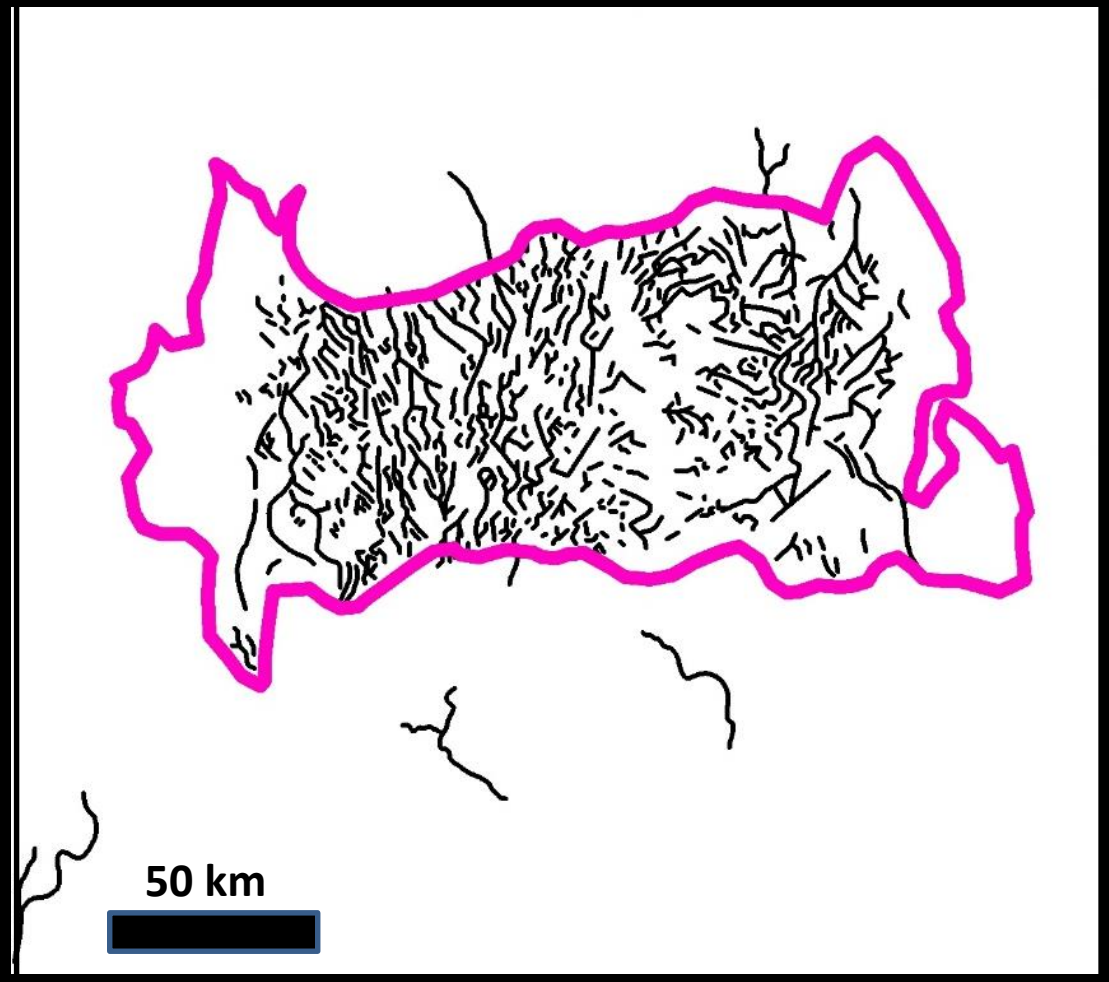
Titan labyrinths are elevated and highly dissected

Detail of Katain Labyrinthus

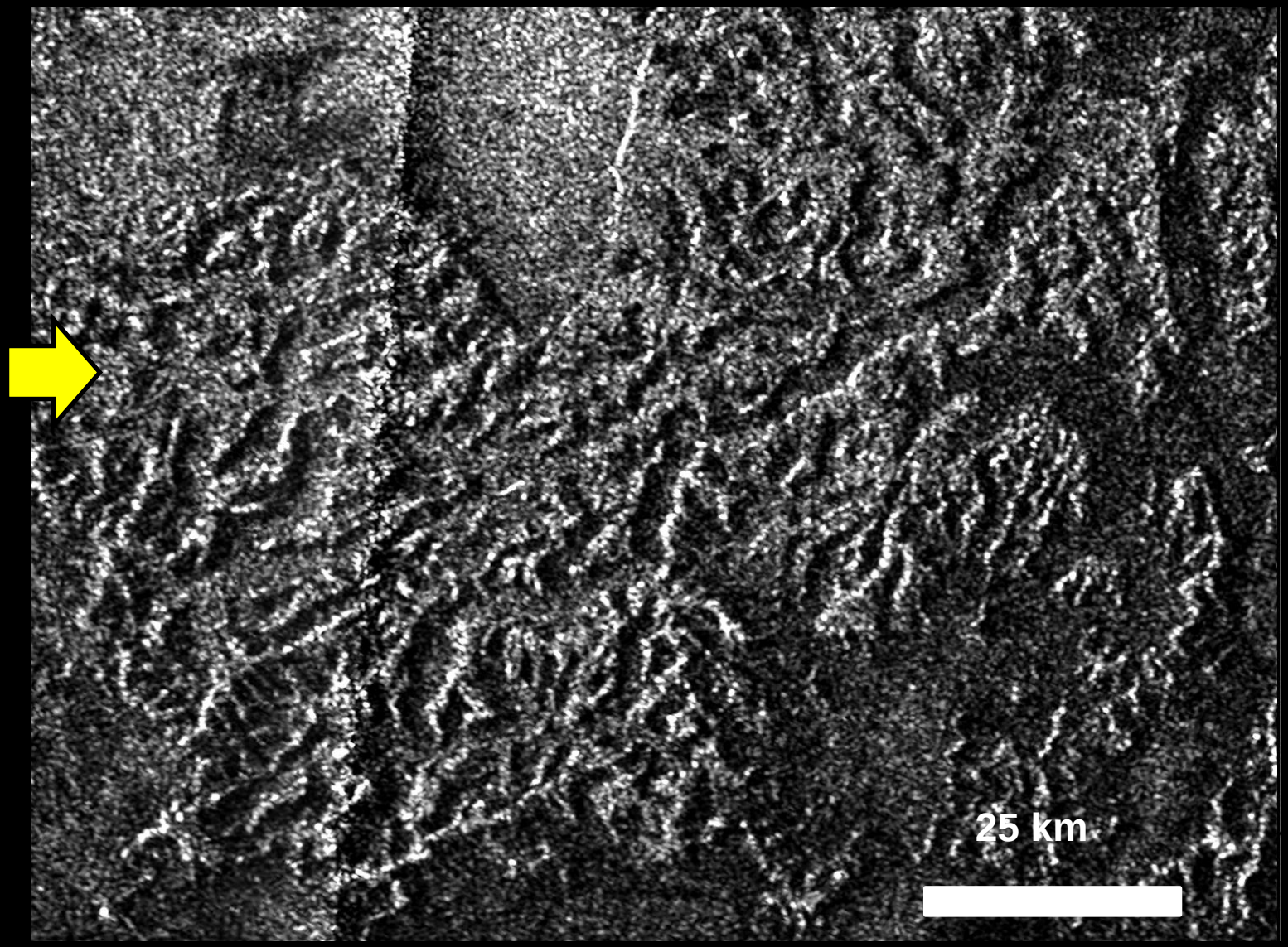


Corlies et al., 2017 elevation data

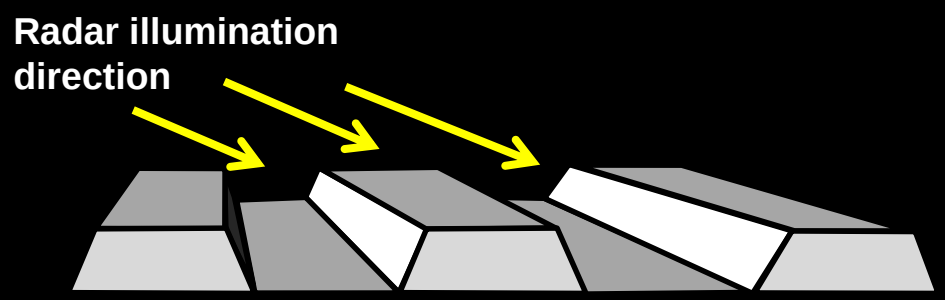


Channel trace by Meghan Florence

Titan labyrinths - Dissected organic plateaux



Sikun Labyrinth, Titan [77.8°S, 28.5°W]



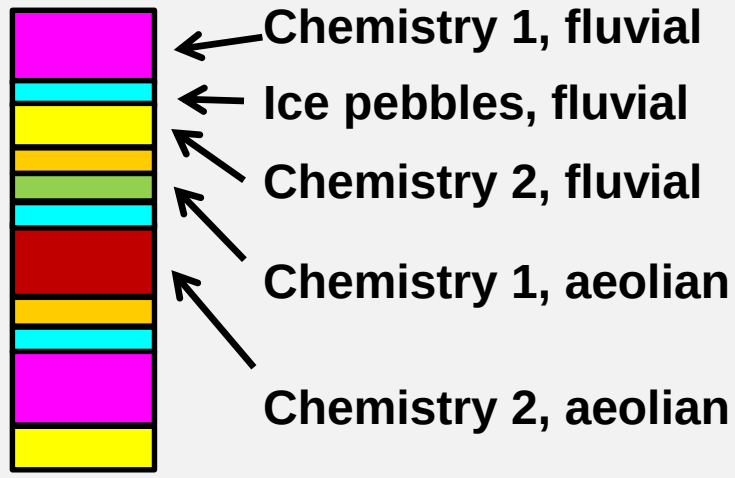
- High emissivity
- Consistent with organic materials – like dunes, plains
- Up to 500 m high
- Stratigraphically older than plains and dunes

Labyrinth formation – Uplifted organic sedimentary stack

"Colorado Plateau style" scenario – basin sediments, lithificationn, uplift, dissolution

1. Basin sediments lithified (evaporite?)
2. Uplift
3. Dissection (dissolution)
4. Valley fill

Possible layer stack section – synthesis/transport/deposition history



Explains

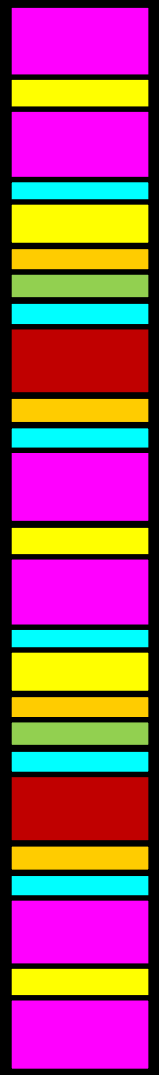
- Plains sediments at margins
- Morphology/emissivity from local deposits

Requires

- Uplift mechanism
- Soluble matrix ($<C_5$) and grain transport

Malaska et al., in prep.

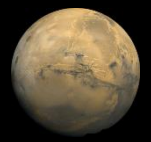
Layered history – and what we could learn

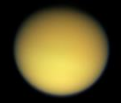


Transport: fluvial, eolian, dissolution
Wet/dry/wind

Episodic (rainfall event, windstorm)
Seasonal
Epochal (Milankovič cycles)

Like
Earth
Mars

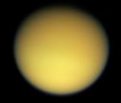




Synthesis history
Sunlit/shaded/solar flux

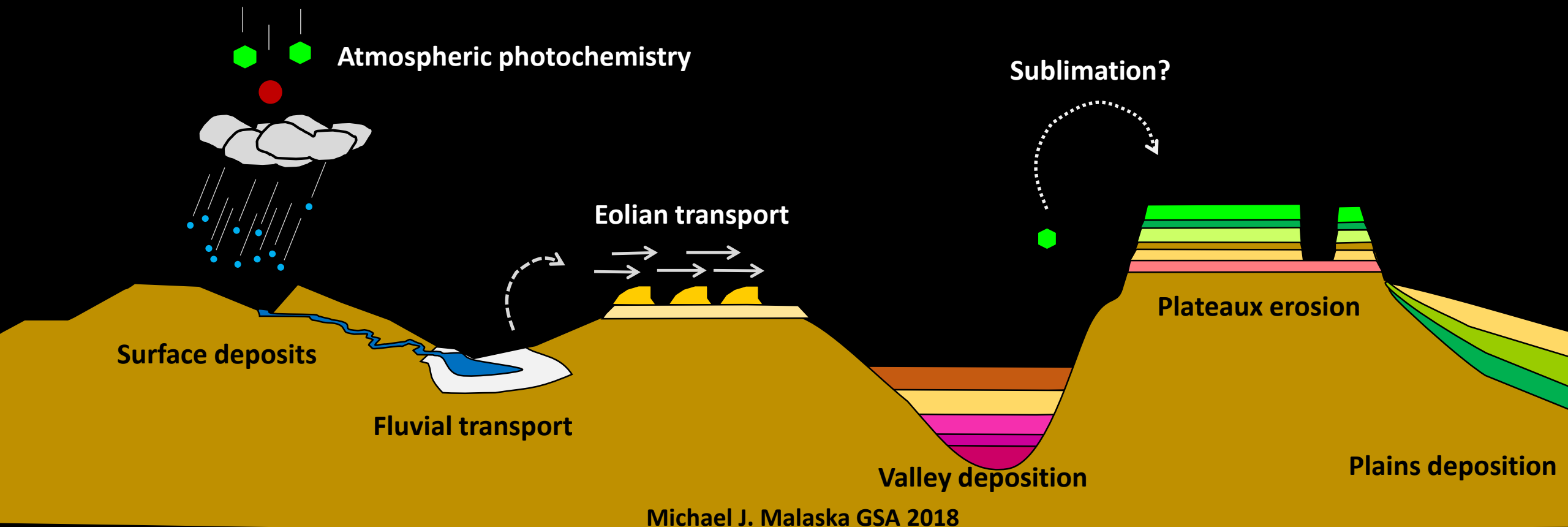
Seasonal
Epochal
Solar output history

Not Like Earth
Organic world
specific



Sediment World Titan – Like Earth, but different

- Titan organic sediments derive from photochemistry
- Eolian, fluvial, dissolution, (sublimation?)
- Latitude dependence: equator→plains



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