



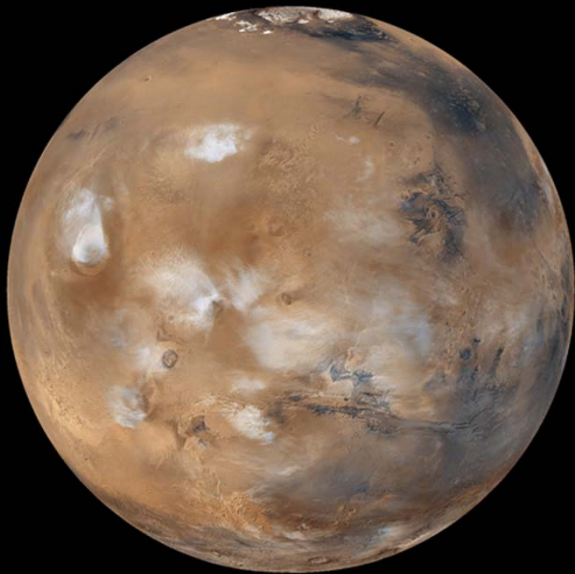
Planetary Surface Processes

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(and former JPLer and ongoing coworker with many at JPL and Caltech)

*rippled sand in Gale Crater MSL landing ellipse
HiRISE image ESP_023957_1755*

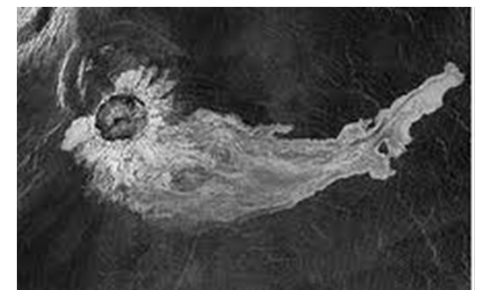
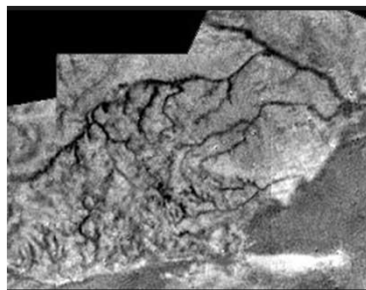
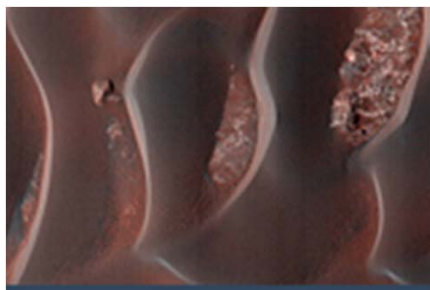


Properties of Bodies with Major Atmospheres

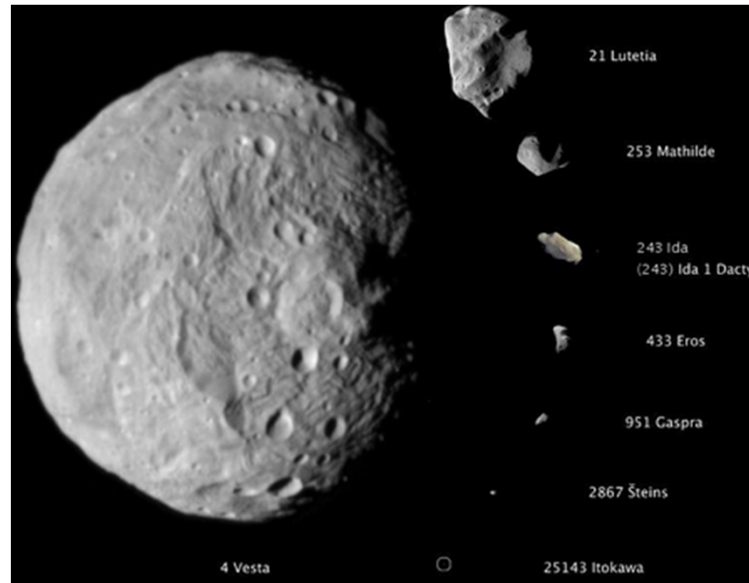
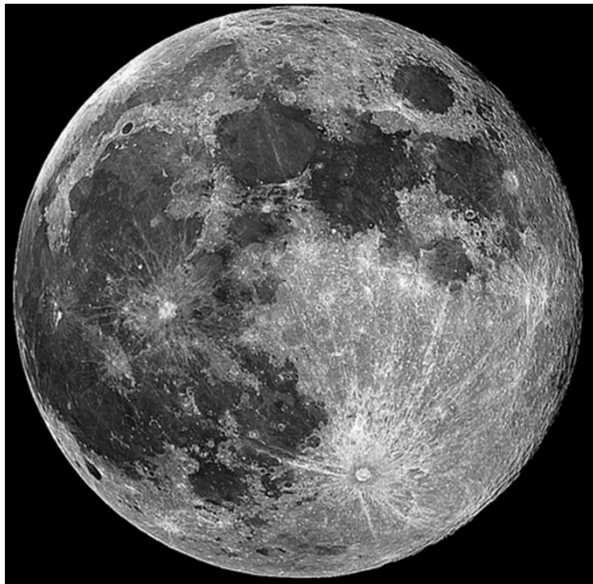
	Venus	Earth	Mars	Titan
Solar distance (AU)	0.72	1	1.7	10.1
Orbital period (d)	224	365	687	10,759 (Sun) 16 (Saturn)
Rotation period	-243 d	24 h	24h 37m	16 d
Axial tilt (°)	177.4	23.4	25.2	0
Diameter (km)	12,104	12,742	6779	5152
Surface gravity (m s ⁻²)	8.9	9.8	3.7	1.4
Surface temperature (K)	737	184-330	130-308	94
Surface pressure (bars)	92	1	0.6	1.5
Typical surface composition	basalt	water; silicates	basalt	water ice; hydrocarbons (liquid, ices, tholins)
Atmospheric composition (lower troposphere)	96.5% CO ₂ 3.5% N ₂	78.1% N ₂ 21.0% O ₂ 0.9% Ar	96.0% CO ₂ 1.9% Ar 1.9% N ₂ 0.1% O ₂ 0.1% CO	95.0% N ₂ 4.9% CH ₄

Surface Processes of Bodies with Major Atmospheres

	Venus	Earth	Mars	Titan
Aeolian	✓	✓	✓	✓
Fluvial	✗	✓	minor	✓
Glacial/periglacial	✗	✓	✓	?
Impact	✓	✓	✓	✓
Mass wasting	✓	✓	✓	✓
Seasonal	✗	✓	✓	✓
Tectonics	✓	✓	✓	?
Volcanism	✓	✓	✓	✓
Climate Change	?	✓	maybe	?

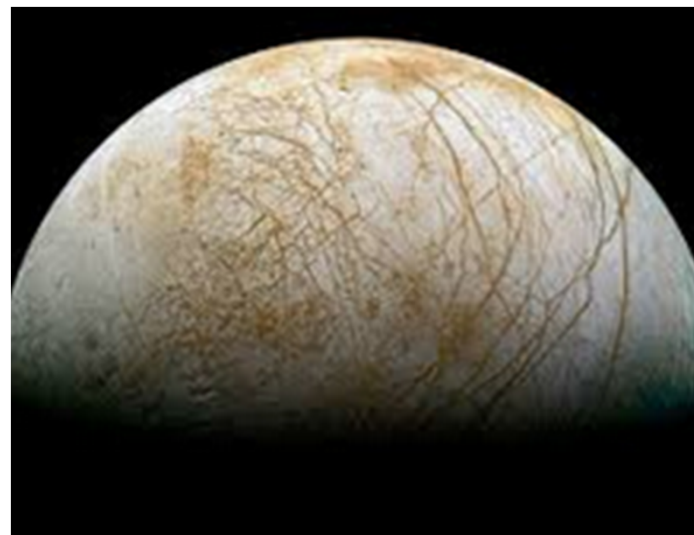


Apology for these objects that are not covered
I can't talk about everything, nor do I know everything



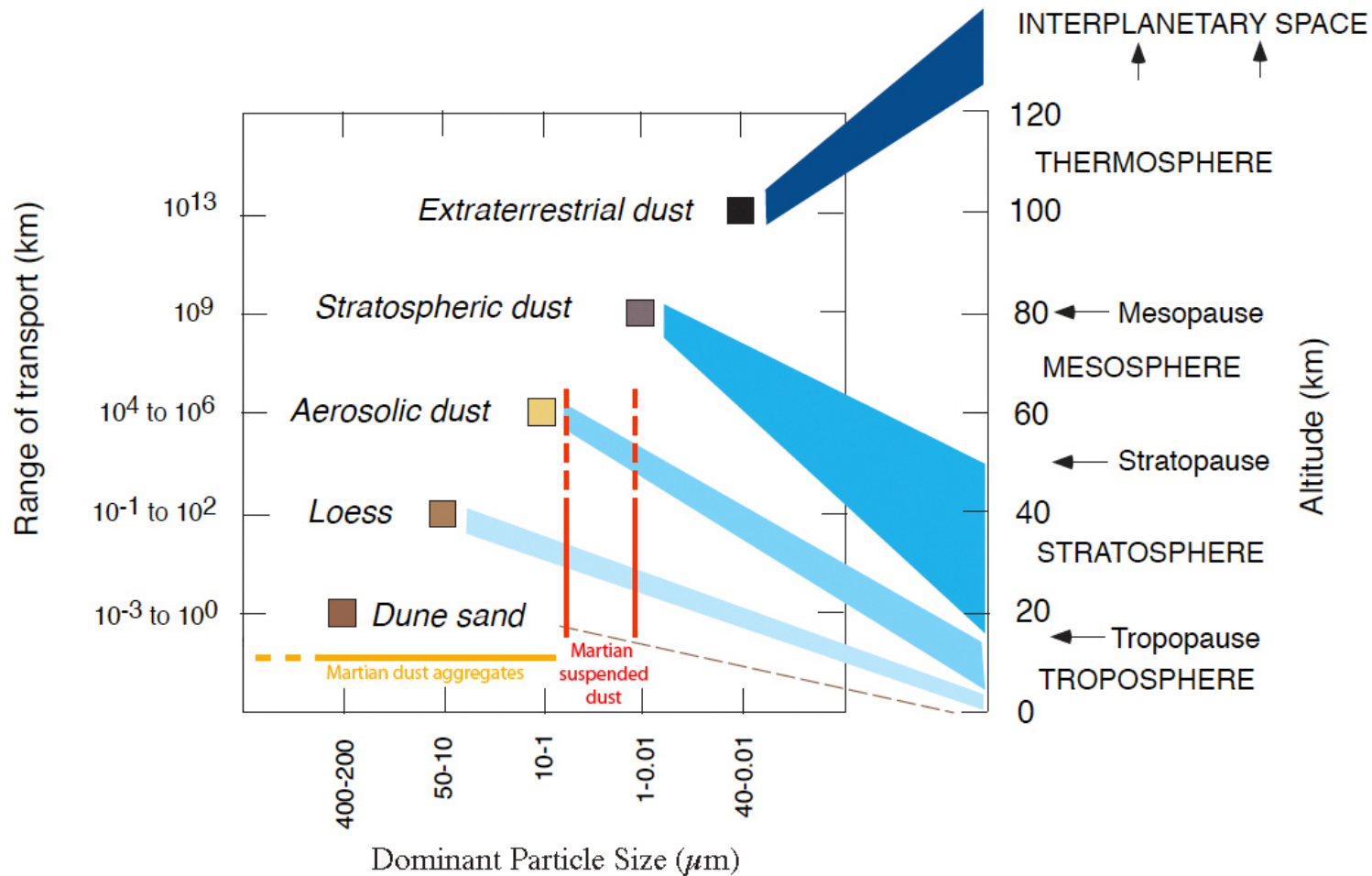
etc.

Earth largely passed over because we know a lot more and it is not in scope with this talk



Io and Enceladus are mentioned later for volcanics

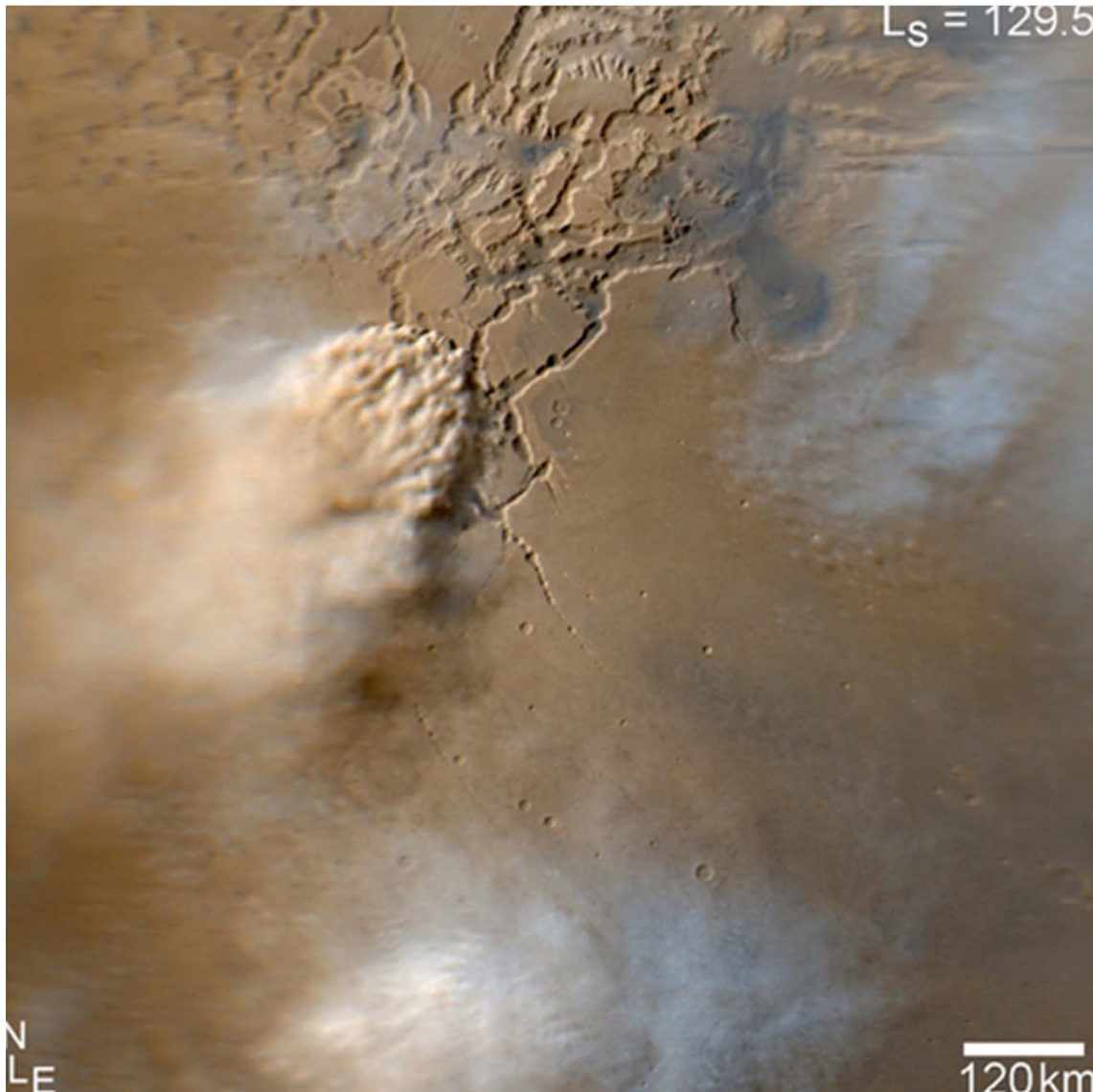
Dust and Dust Aggregates



Comparison of Terrestrial and Martian Dust Transport and Size
 [Bridges and Muhs, 2012; Muhs and Bettis, 2003]

Dust Lifting and Storms

(mostly Earth and Mars)

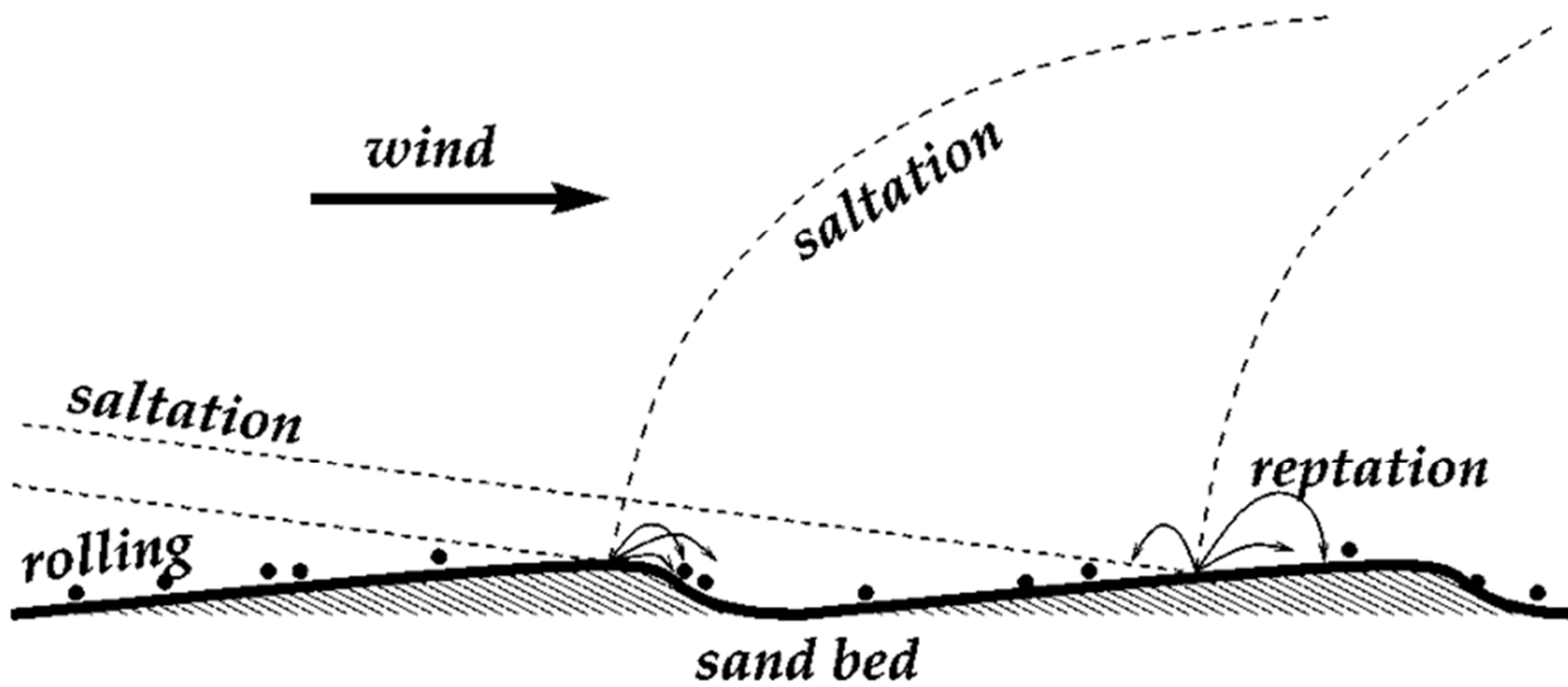


Known: The approximate mechanisms, conditions, locations, and times of year when local, regional, and (in the case of Mars) global storms occur

Unknown: Precise prediction of storms more than a few days in advance and location centers to a few km or less

Solution: Rapid repeat data collection:

- images
- surface and atmospheric temp.
- opacity/dust profiles



Sand Dunes and Ripples

(mostly Earth, Mars, and Titan)

Known:

Earth: Threshold speeds, fluxes, and abrasion rates.

Mars: Some dunes move; fluxes in some places; ~threshold

Titan: Dunes exist

Unknown:

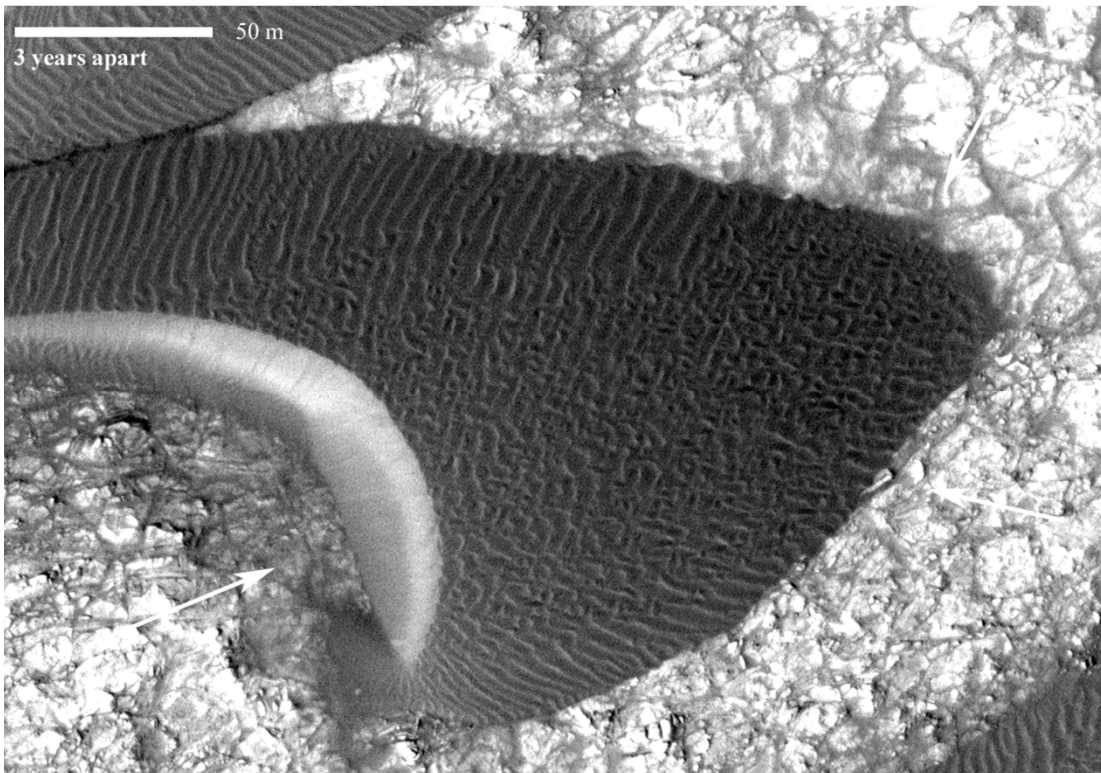
Earth: Relative contributions of ripple and dune fluxes

Mars: Detailed fluxes, threshold, seasonal effects; ties to surface conditions

Titan: Mostly everything

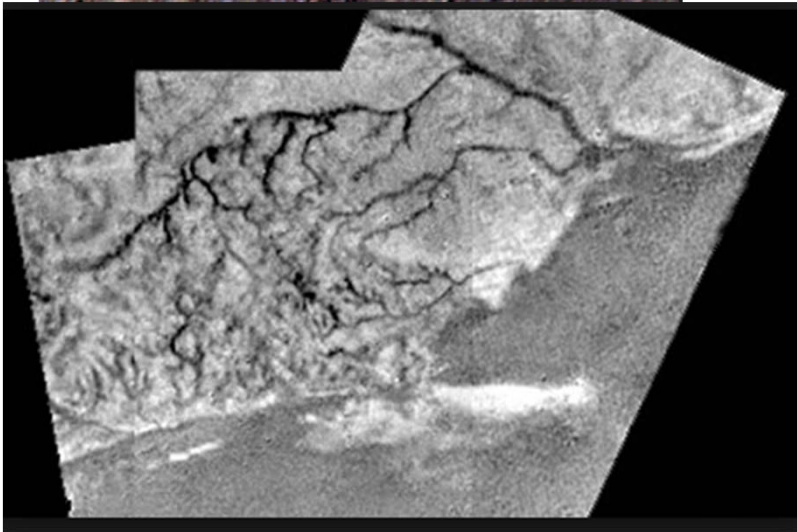
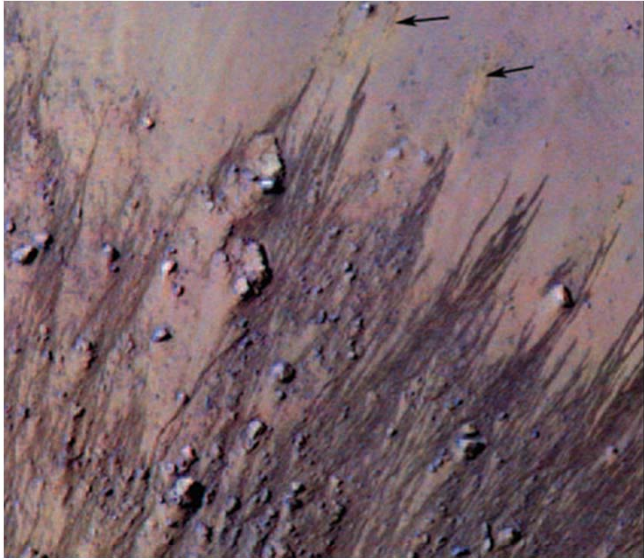
Solution: Rapid repeat, high resolution tracking

- images
- topography
- surface winds



Fluvial

(Earth, Mars, and Titan)



Known:

Earth: A ton.

Mars: Ephemeral activity

Titan: Extant

Unknown:

Mars: Timing and conditions of
ephemeral gully and RSL flow

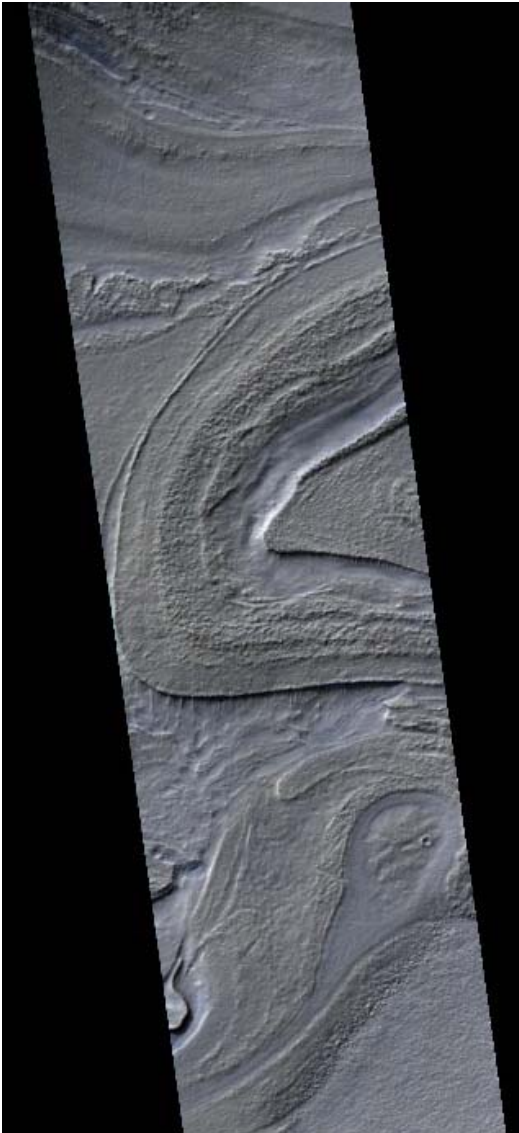
Titan: Mostly everything: Timing,
fluxes, erosions rates, etc.

Solution:

Mars: Continuous monitoring of
ephemeral flow areas in morning

Titan: Higher spatial and temporal
resolution.

Glacial/Periglacial (Earth, Mars, and Titan)



Known:

Earth: A lot

Mars: Evidence for ground ice and possible rock glaciers

Titan: Little

Unknown:

Mars: Do rock glaciers flow? Does ground deform periglacially today?

Titan: Mostly everything

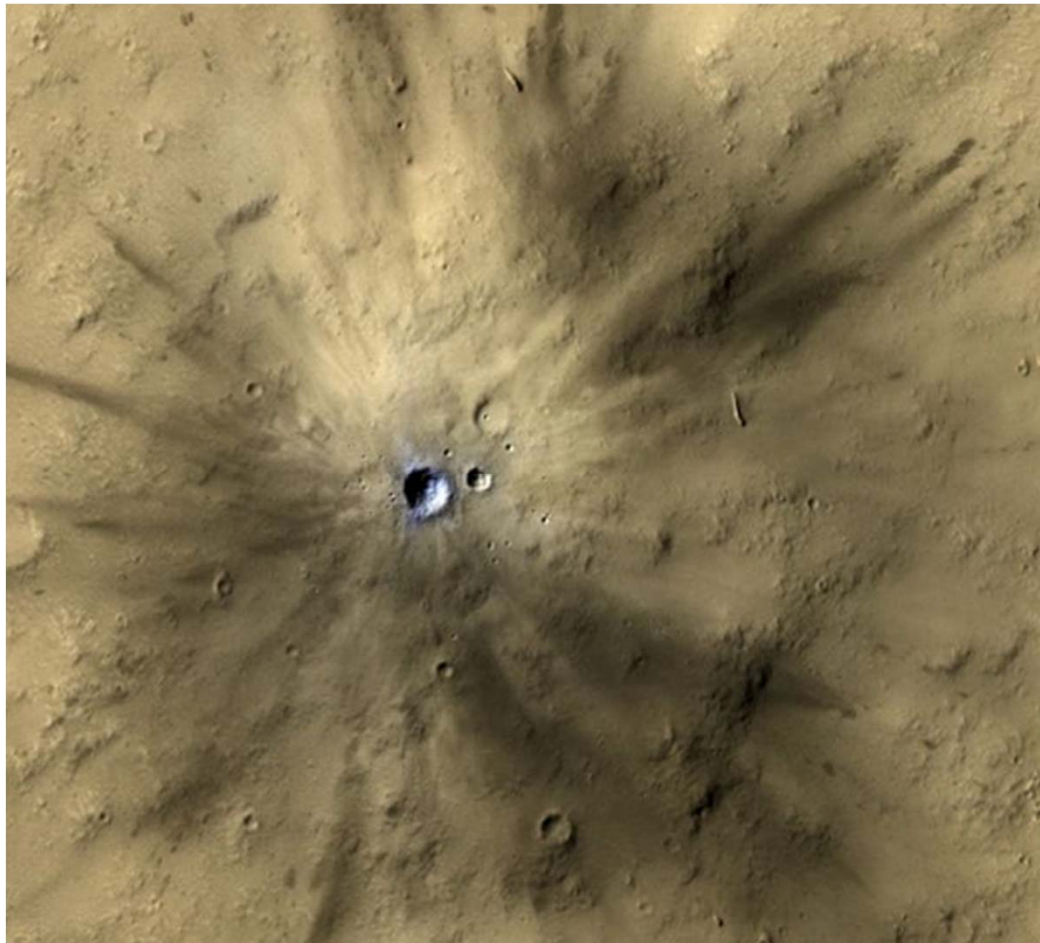
Solution:

Mars: High resolution mapping and topography for surface changes (can be done now to decimeter scale)

Titan: Similar measurements with radar or balloons?

Impact (everywhere)

Known: Impacts occur; approximate rates as a function of size

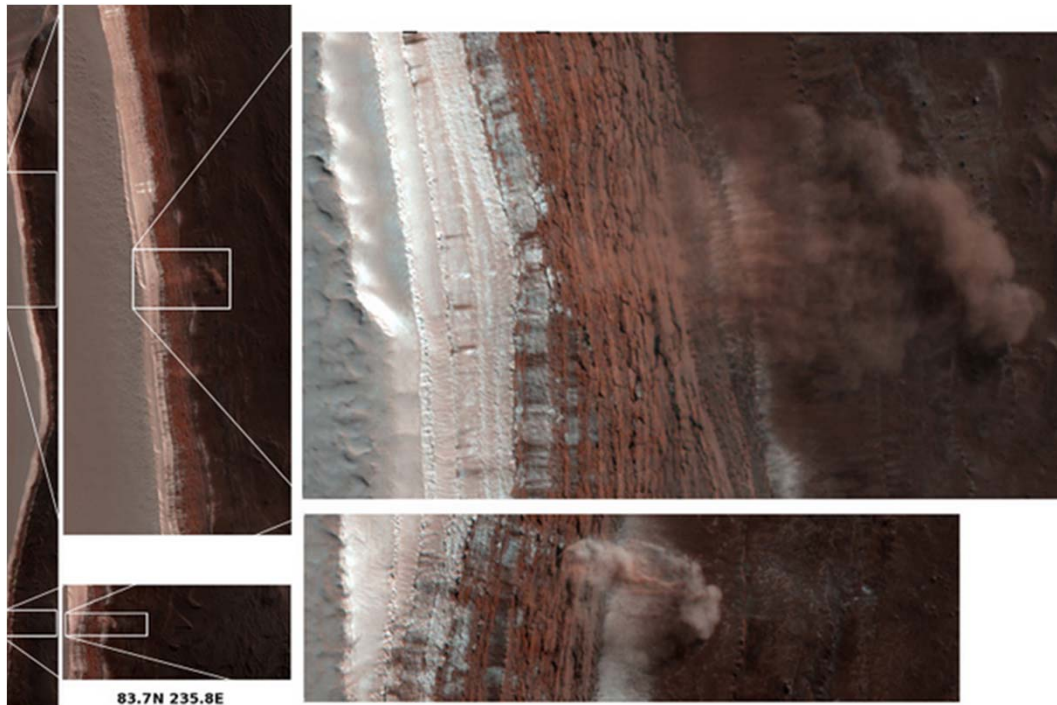


Unknown:
Other planets: Production curves at lower size range: *How many impacts are occurring and when?*

Solution: Ability to detect an impact down to small size *anywhere* on a surface (WAC?) and then zoom in with high imagery. Similar to MARCI/HiRISE on Mars, but what about elsewhere?

Mass Wasting (everywhere)

Known: Landslides occur; rough idea of necessary conditions

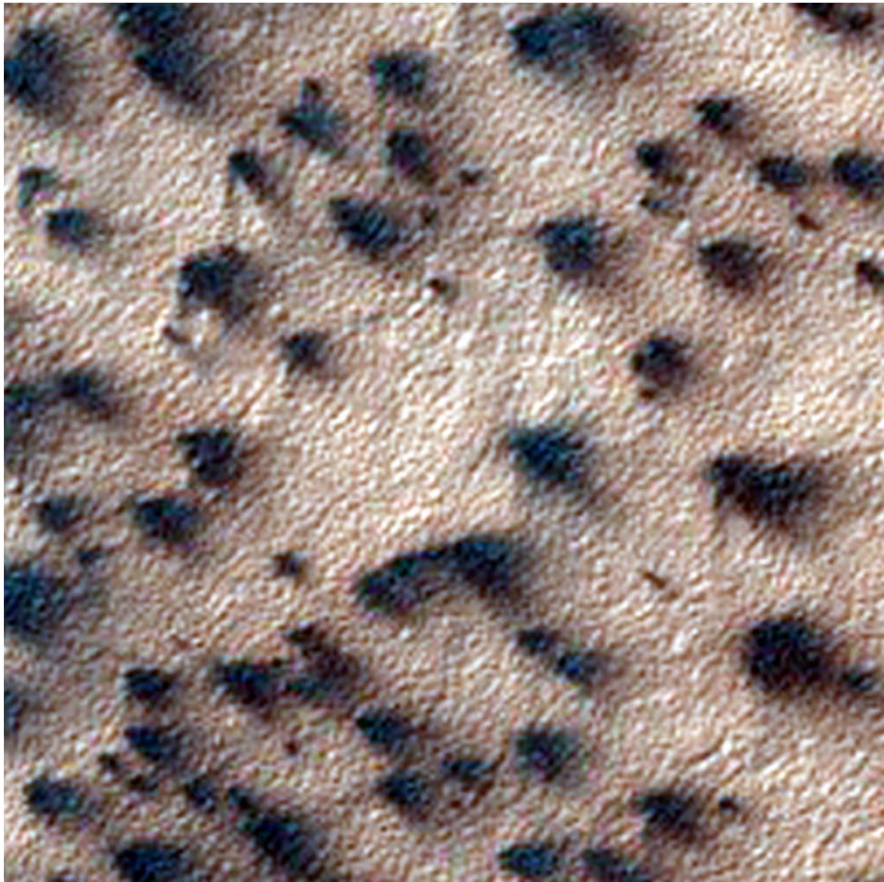


Unknown:
Especially for other planets: Timing, formative conditions, dynamics

Solution: Ability to detect mass wasting down to small size *anywhere* on a surface. Remote measurement of surface conditions. Monitoring of dynamics.

Seasonal Processes

(Earth, Mars, Titan)



Known: Diverse topic. Earth: A lot known; Mars: Condensing and Sublimating CO₂ main drive; Titan: Precipitation rates, lake levels probably change

Unknown:
Mars: Timing and effects on surface erosion and landforms; Titan: Just about everything

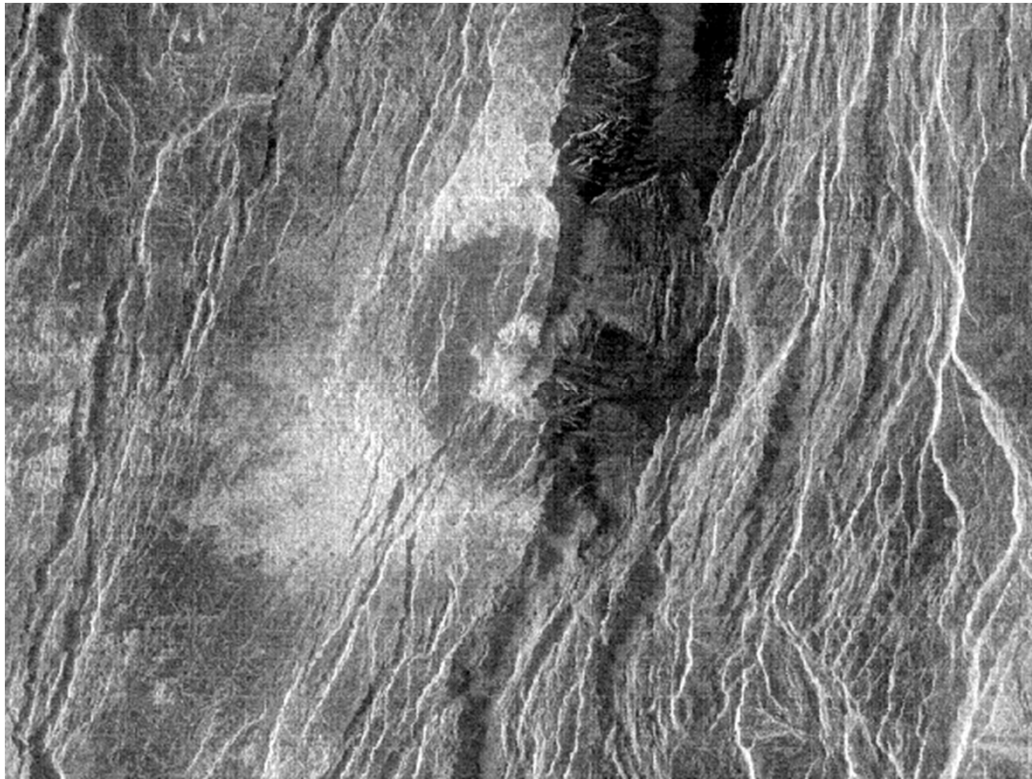
Solution: Rapid repeat data collection: Images, temperatures, frost composition (Mars), precipitation (Titan)

Active Tectonism (everywhere)

Known:

Earth: A lot

Other planets: Mapping of faults



Unknown:

Other planets: Frequency and amount of fault slip

Solution: High resolution images and topography (capability already exists For Mars and the Moon)

other worlds may be tectonically inactive such that nothing will be found, but we can look

Active Volcanism

(Earth, Io, Enceladus; maybe others)



Known:

Earth: A lot

Io, Enceladus: Plumes erupt frequently

Venus: Volcanism could be active

Mars: Venting could be possible

Unknown:

Io, Enceladus: Timing, eruption dynamics

Venus, Mars: Is anything happening currently?

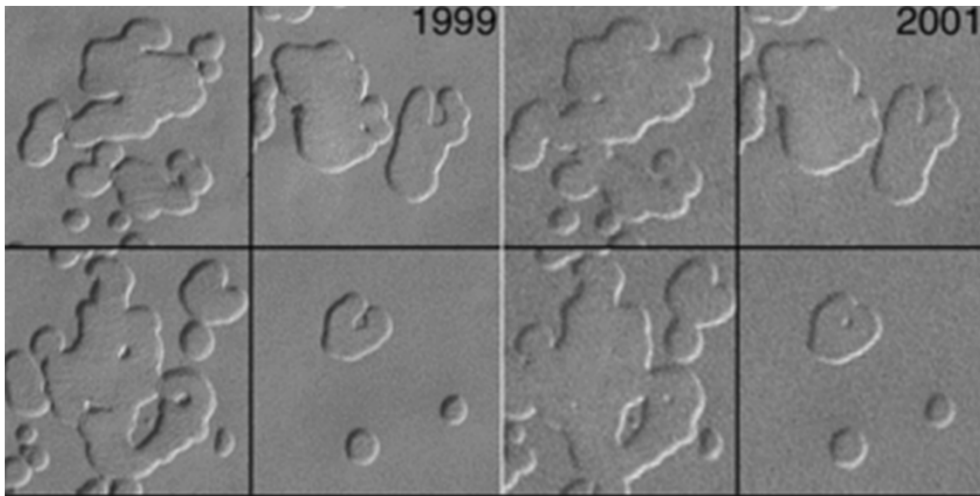
Solution:

Io, Enceladus: Rapid repeat data collection

Venus: Radar emissivity and atmospheric composition (H_2SO_4 , etc.)

Mars: Methane detection? High resolution nighttime radiometry?

Climate Change (Earth; Mars?, Titan??)



Known:

Earth: A lot (*out of scope to cover here*)

Mars: Driven by obliquity/precession changes; CO₂ cap loss?

Titan: Lower pressures in past?

Unknown:

Mars, Titan: Is anything happening currently?

Solution:

Mars: Precise, detailed, and continuous measurement of mass balance of CO₂ and H₂O ices and frost

Titan: Long term mass balance of hydrocarbon ices????

Possible Systems

	Venus*	Mars	Titan*	Io/Enceladus
dust	NA	1	1	NA
dunes/ripples	~NA	1,2	1,2	NA
fluvial	NA	1,2	1,2	NA
glacial/periglacial	NA	2,3	2,3	NA
impact	2,4	2,4	2,4	2,4
mass wasting	2-5	2-5	2-5	2-5
seasonal	NA	1,2,5	1,2,5	NA
tectonics	2,3	2,3	2,3	2,3
volcanics	6	6	6	1
climate change	NA	2,3	2,3	NA

1) Rapid repeat data collection, 2) High resolution, 3) Topography, 4) Global detection, 5) Continuous monitoring, 6) Other

**Radar or balloons/aerial platforms required*

Is This a Solution for Many of Our Problems?

Google buys startup Skybox Imaging for \$500 million

BY STEPHEN CLARK

SPACEFLIGHT NOW

Posted: June 10, 2014



Google has agreed to purchase Skybox Imaging, a Silicon Valley startup specializing in collecting Earth imagery from space, for \$500 million in a deal that could springboard Google into a new business beaming broadband Internet from orbit with a proposed network of up to 180 satellites.



Photo inside Skybox Imaging's satellite clean room. Credit: Skybox Imaging