

The Atmosphere of Mars as Observed by InSight

Aymeric Spiga

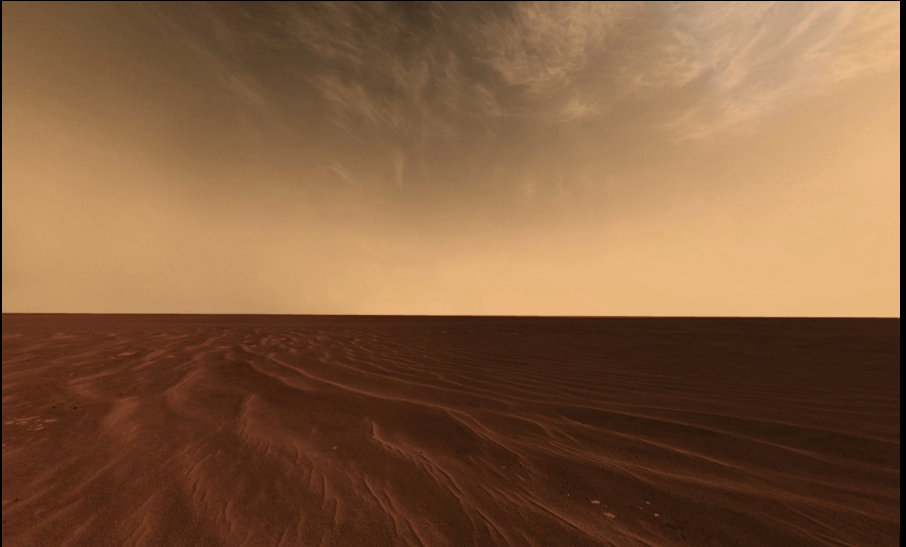


**SORBONNE
UNIVERSITÉ**
CRÉATEURS DE FUTURS
DEPUIS 1257



InSight Education France March 2, 2020

The Martian environment

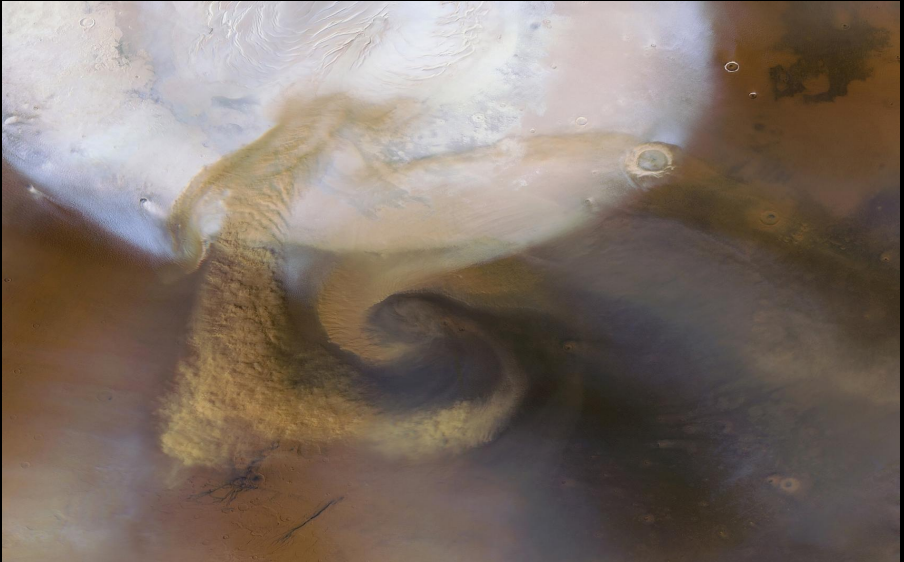


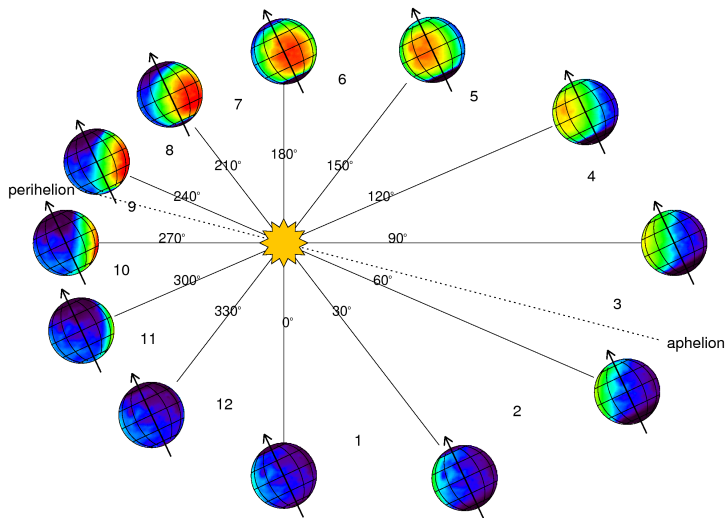
[Pancam on Opportunity Rover]

Mars, a world of CO₂, dust, H₂O



View of the north pole, about 2500 km across

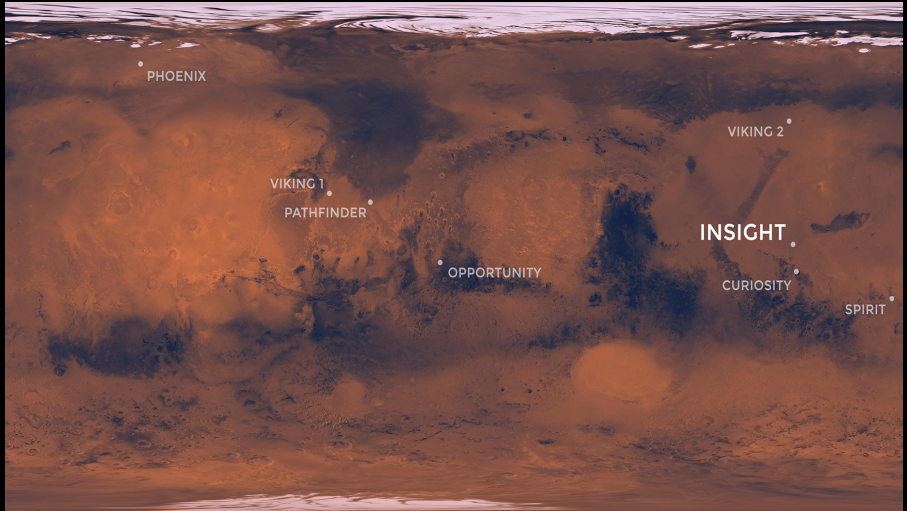




[Read and Lewis, 2004]

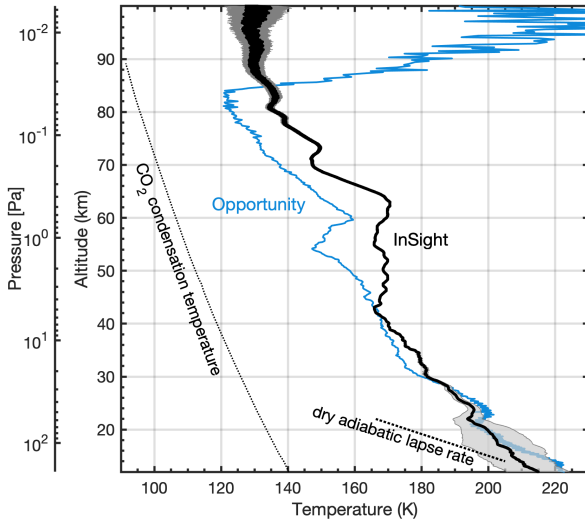
- 1 InSight observing the atmosphere
- 2 Seasonal large-scale tendencies
- 3 Daily and diurnal variability
- 4 Gravity waves and bores
- 5 Turbulence

InSight landing site in Elysium Planitia

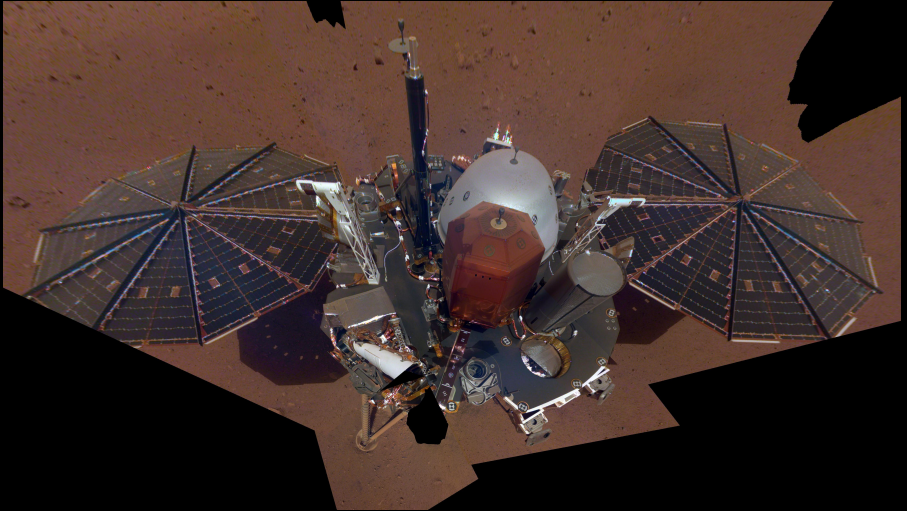


[PIA22232]

InSight Entry, Descent, Landing profile

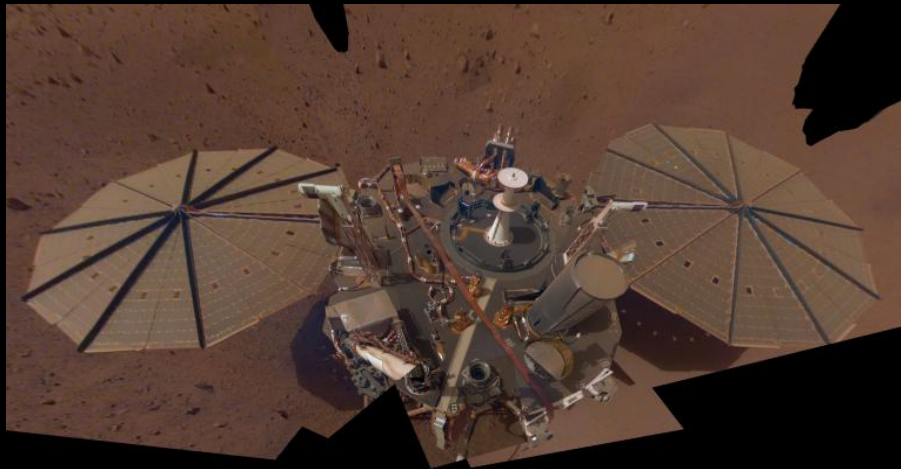


InSight “selfie” mosaic before deployment



[PIA22876 NASA/JPL]

InSight “selfie” mosaic after deployment



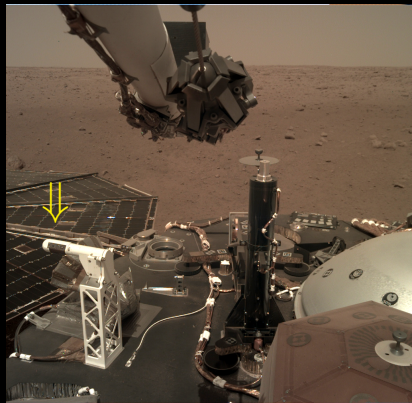
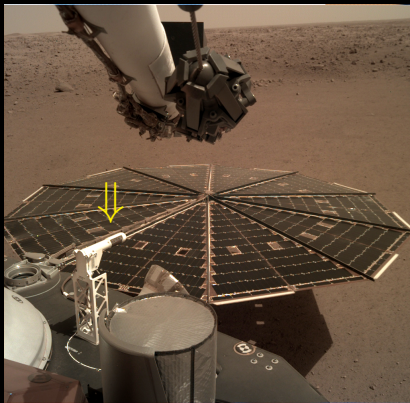
[PIA23203 NASA/JPL]

Temperature & Wind for INSight (TWINS)



Two outward facing booms, 1 Hz sampling

- Wind: response ~ 1 s, accuracy ~ 1 m/s speed, $<22^\circ$ direction
- Temperature: response ~ 30 s, ~ 5 K accuracy, 0.1 K resolution

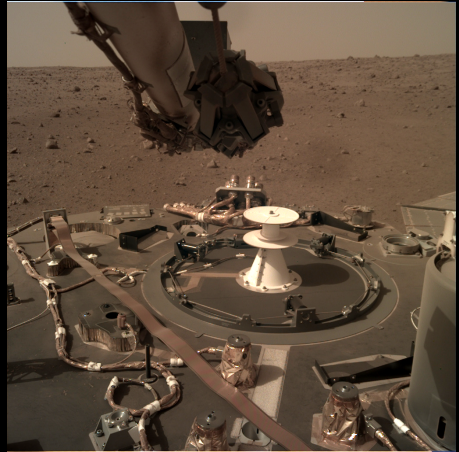
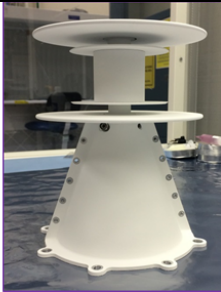


[PIA22736 NASA/JPL]



APSS pressure sensor

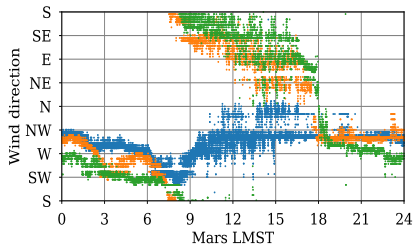
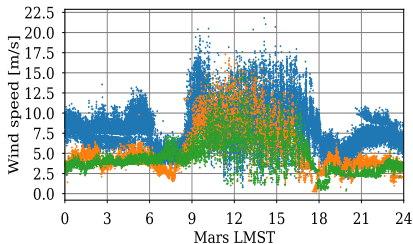
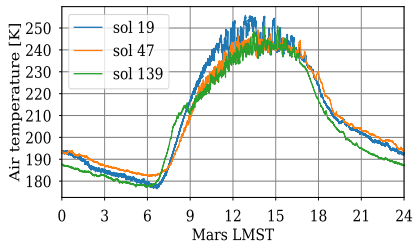
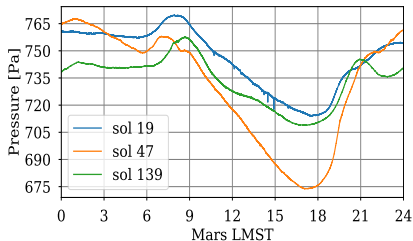
- 20 Hz sampling ($\lesssim 7$ Hz above self noise)
- 10 mPa noise level
- quad-disc inlet to reduce wind noise
- absolute calibration and drift $\lesssim 1.5$ Pa



[sol 106 IDC deck mosaic]

Typical sols experienced after landing

sol 19 [northern winter] sol 47 [regional dust storm] sol 139 [northern spring]

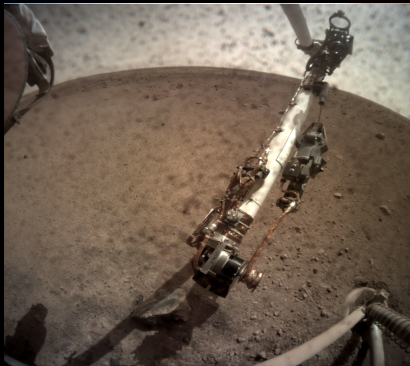


InSight color cameras



weekly IDC tau, daily ICC tau, occasional dust devil / cloud surveys

IDC: 45° FOV, on forearm



ICC: 180° FOV, below deck



Noctilucent clouds



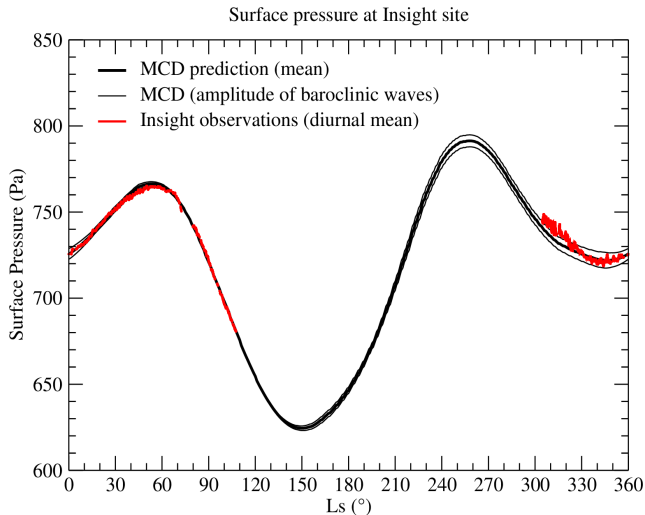
[sol 145]

- ☞ at the transition between northern winter and spring
- ☞ just after sunset
- ☞ at least 50 km above surface (given position of the Sun)
- ☞ suggesting CO₂ ice particles – H₂O ice not ruled out
- ☞ east-southeasterly wind speeds of 40-60 m/s assuming 60 km altitude

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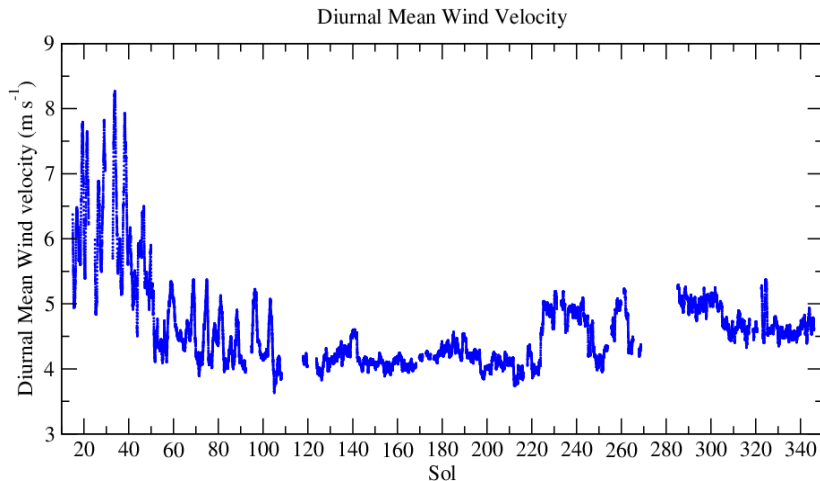
Seasonal variations of pressure

Pre-landing estimates + InSight's first 350 sols



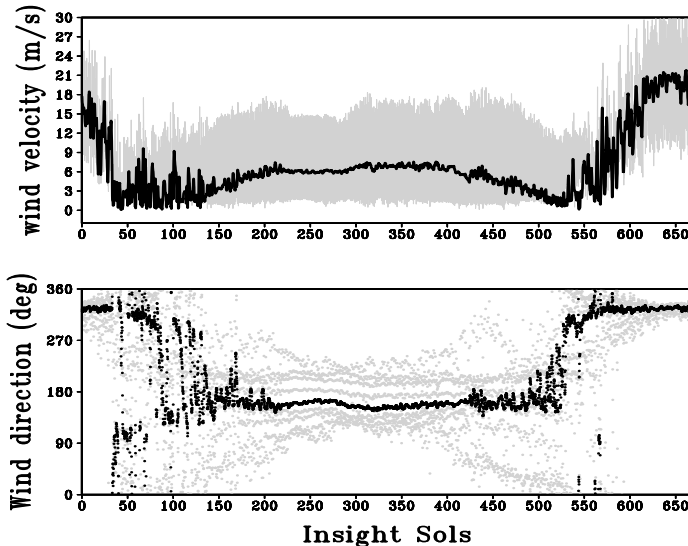
Seasonal variations of wind speed

InSight's first 350 sols



Predicted evolution of wind by LMD GCM

Remake with different time axis of Figure 8 in Spiga et al. SSR 2018

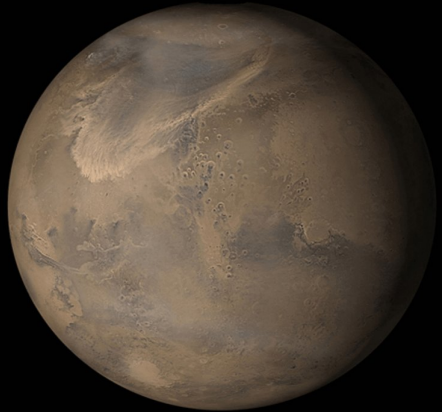
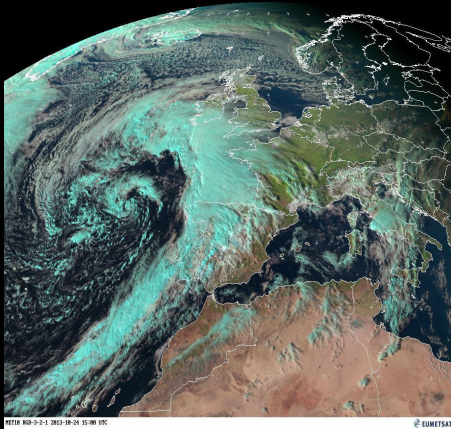


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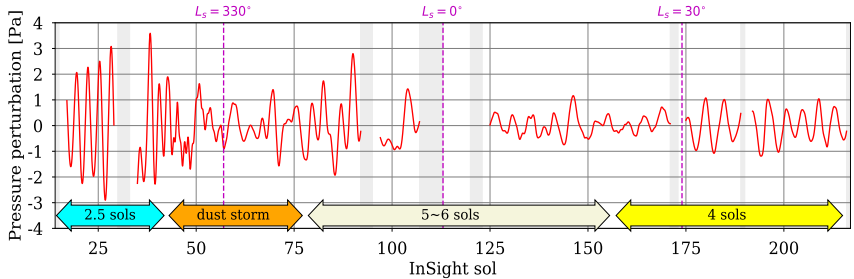
Après la pluie le beau temps

Fronts and baroclinic instability



Weather controlled by baroclinic waves

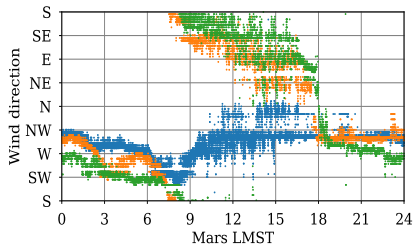
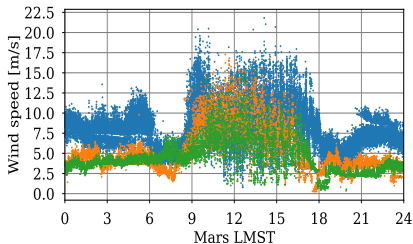
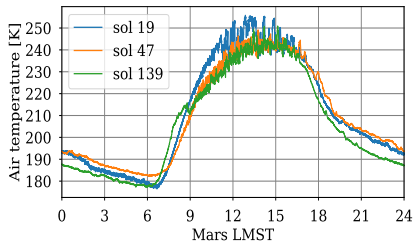
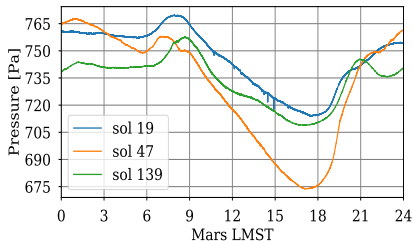
Surprising for equatorial site, very clear signal



[Banfield, Spiga et al. Nature Geoscience 2020]

Typical sols experienced after landing

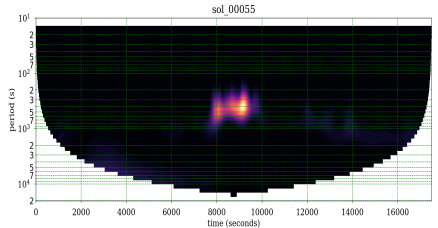
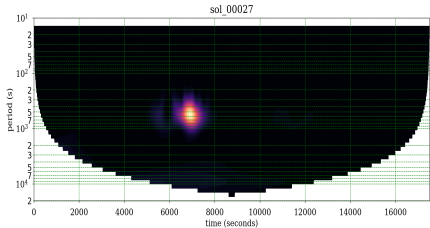
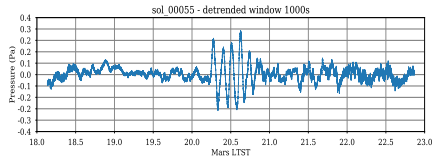
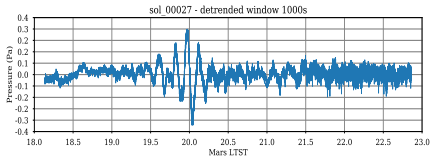
sol 19 [northern winter] sol 47 [regional dust storm] sol 139 [northern spring]



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Evening atmospheric activity

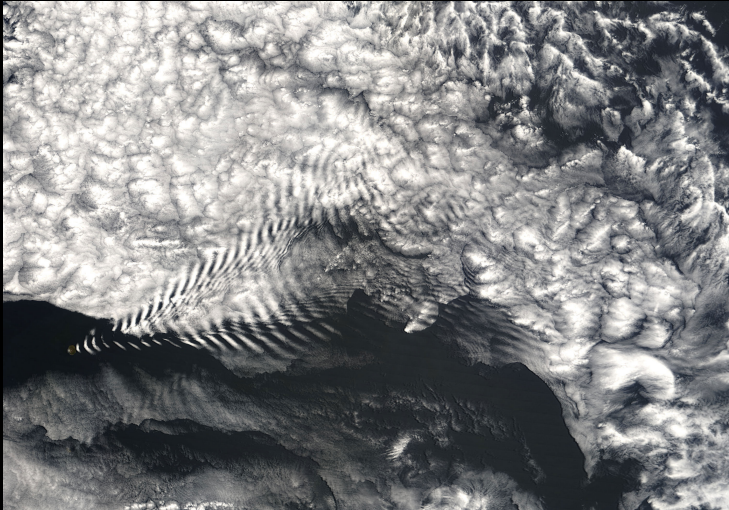
gravity wave oscillations & shear-driven turbulence



period: 400-700 seconds

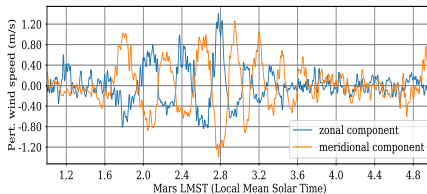
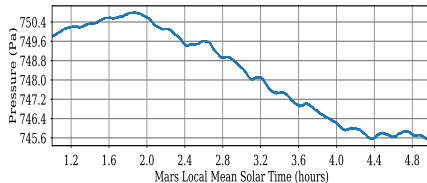
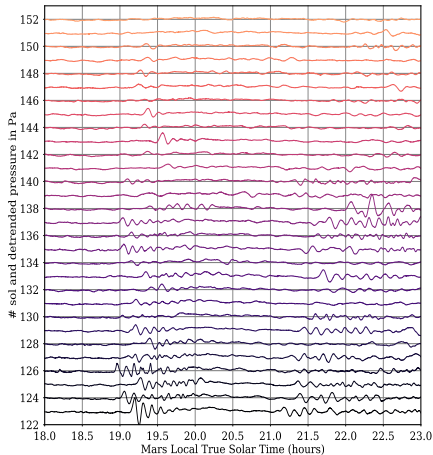
[wavelet Python code by E. Predybaylo based on Torrence and Compo 1998 paper]

Nuages orographiques vus par TERRA/MODIS



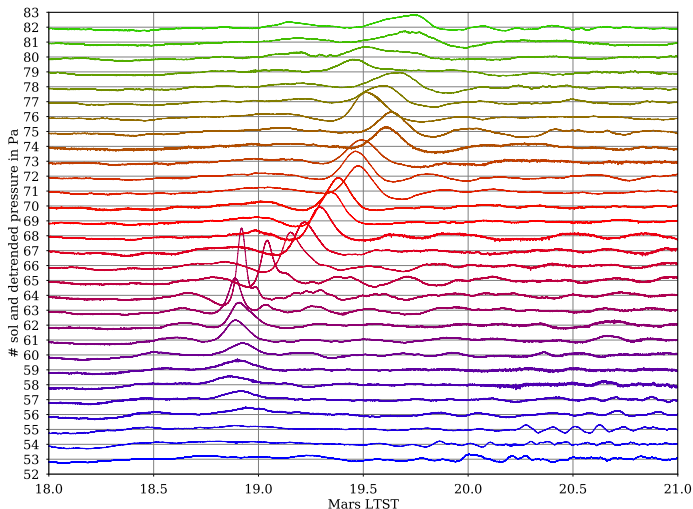
[NASA Earth Observatory : <http://earthobservatory.nasa.gov>]

Gravity waves detected by InSight



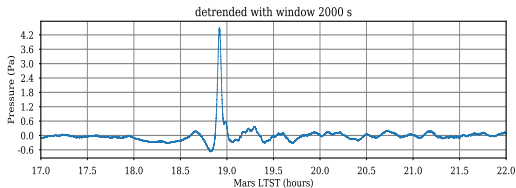
[Banfield, Spiga et al. Nature Geoscience 2020]

Temporal evolution of the bump signature



Bore and solitary waves detected by InSight

Analogous to “Morning glory” on Earth...?

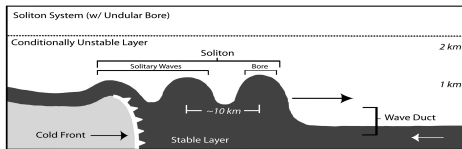


- Pressure jump/bump
- Followed by P,T waves
- Ambient wind change
- Also observed in the morning (pre-sunset)

1. Density current: Katabatic flow from Elysium Mons

2. Strong wave-ducting mechanism

- Neutral layer (remainder of daytime PBL) on near-surface stable layer
- Reinforcement of low-level jet with increasing dust opacity [Joshi+97]

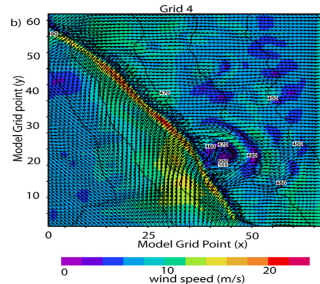
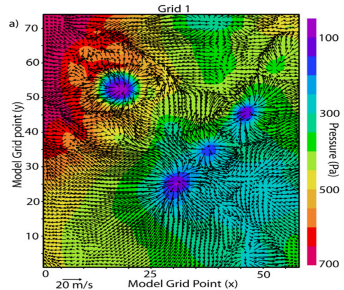
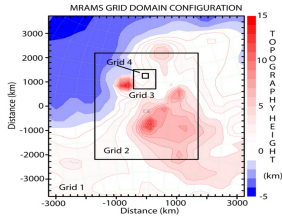
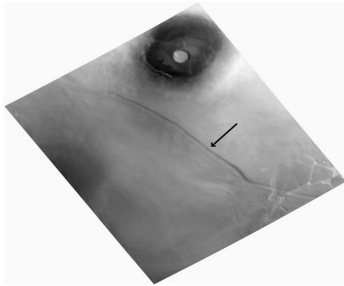


[Hartung et al. MWR 2010]



[Mick Petroff, Burketown (AUS) August 2009]

Atmospheric bore waves on Mars



[Figures from Sta Maria et al. Icarus 2006 and Hunt et al. 1981]

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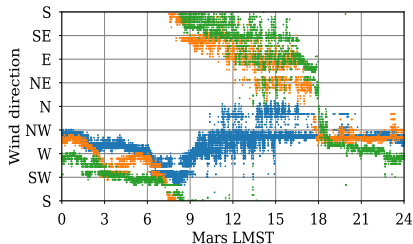
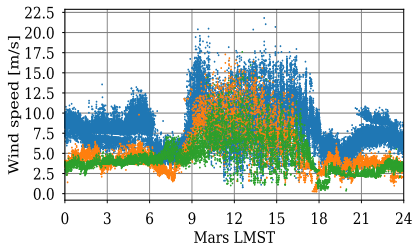
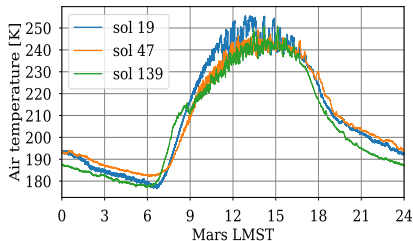
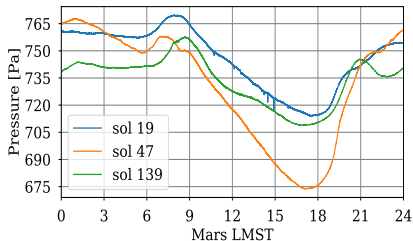
InSight within the Martian PBL



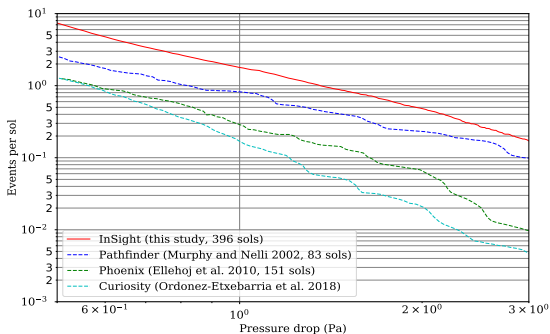
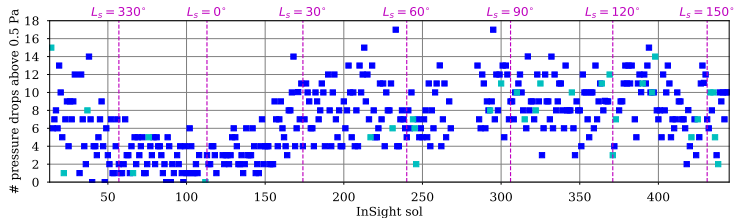
[Extract from an original drawing by Manchu]

Typical sols experienced after landing

sol 19 [northern winter] sol 47 [regional dust storm] sol 139 [northern spring]



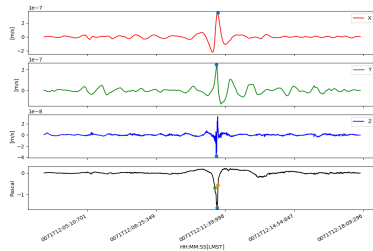
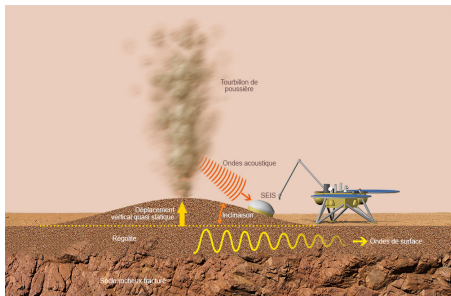
Pressure drops detected by InSight/APSS



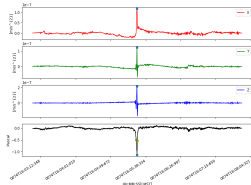
Top 10 drops in Pa

DROP	LTST	SOL
-9.183	13.534	065
-7.445	11.569	323
-6.762	12.597	231
-6.597	10.454	442
-6.434	15.150	254
-6.305	11.509	233
-5.762	14.131	019
-5.667	12.727	039
-5.353	12.557	385
-5.181	14.158	170

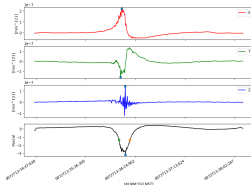
Seismic signatures of convective vortices



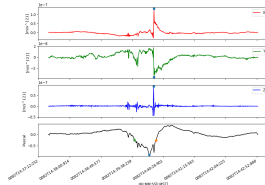
Peaked



HF oscillation



Complex



Dust devil tracks at InSight landing site

Difference between two HiRISE images 5 sols apart

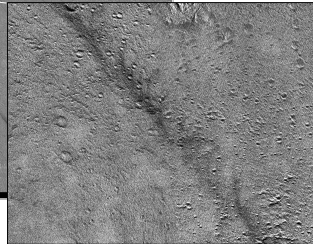
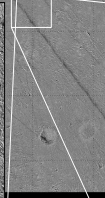
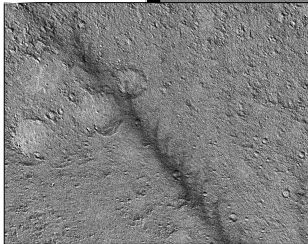
Simple ratio: 2018-12-11/2018-12-06 (warped)

Dependence with illumination is almost cancelled out. New tracks should appear darker

Most of the time,
tracks are very linear.

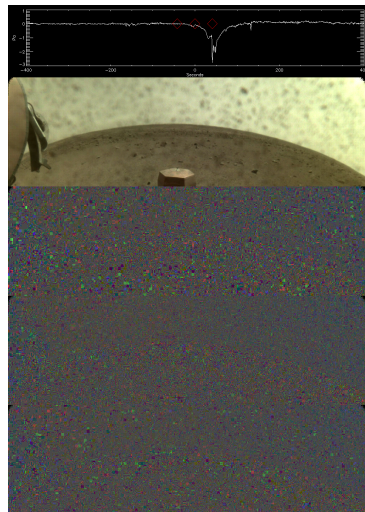
For the largest
"Raked" structure as
some places: linked to
kind of spiral/swirl
motion due to local
turbulence?

width ≈ 13 m
closest distance from
the lander ≈ 400 m



No dust devils insofar

- ☞ dust devil campaign: set of 6 color images with 3 RGB channels mapped to different times, few % stretch, moving things = rainbows
- ☞ regular ICC images: hundreds between 0800 and 1730
- ☞ regular IDC images: tens between 0930 and 1530



[sol 38 RGB survey and simultaneous pressure record]

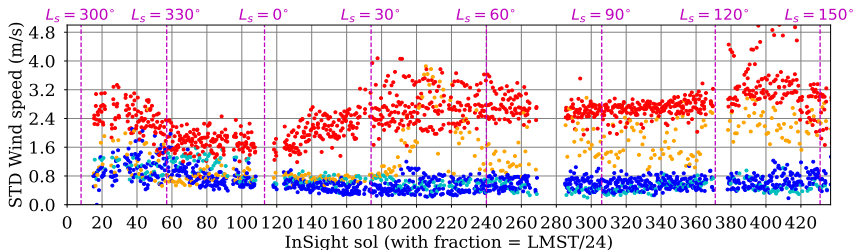
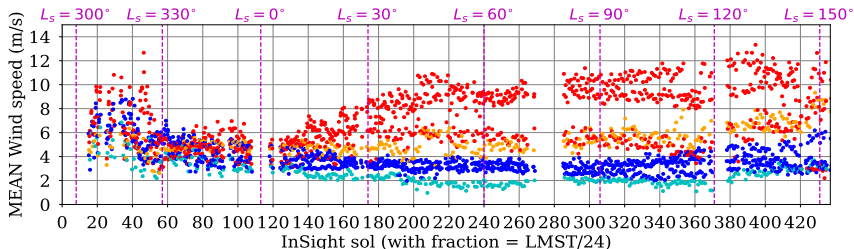
Wind: ambient (top) and turbulent (bottom)

06:00→09:00

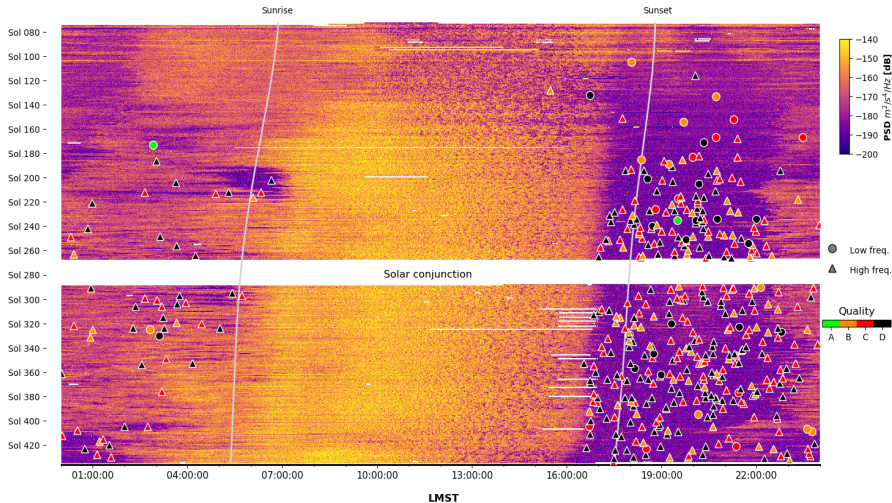
09:00→18:00

18:00→21:00

21:00→06:00



Seismic event and atmospheric noise



[Figure by InSight Mars Quake Service]

The Atmosphere of Mars as Observed by InSight



Banfield*, Spiga* et al. Nature Geoscience 2020

<https://rdcu.be/b17sZ>

- 👉 unprecedented continuity, accuracy, and frequency sampling
- 👉 uniquely sensitive to large-scale and regional weather
- 👉 first complete *in-situ* coverage of a regional dust storm on Mars
- 👉 imaging enabled to measure winds in the upper atmosphere
- 👉 largest-recorded vortex activity, dust devil tracks and solar-panel cleaning events, but no visible dust devils
- 👉 novel, extensive catalog of atmospheric gravity waves, including bores in the aftermath of the dust storm
- 👉 an entirely new territory in the higher-frequency range: surprising similarities with Earth's turbulence and detection of infrasound



Daily Weather Report Outreach Page

<https://mars.nasa.gov/insight/weather>

Latest Weather at Elysium Planitia

InSight is taking daily weather measurements (temperature, wind, pressure) on the surface of Mars at Elysium Planitia, a flat, smooth plain near Mars' equator.

Sol 106
March 15

High: -16° F | C
Low: -96° F | C

Sol 100
Mar. 8

High: -14° C
Low: -96° C

Sol 101
Mar. 9

High: -14° C
Low: -96° C

Sol 102
Mar. 11

High: -17° C
Low: -97° C

Sol 103
Mar. 12

High: -19° C
Low: -96° C

Sol 104
Mar. 13

High: -14° C
Low: -96° C

Sol 105
Mar. 14

High: -15° C
Low: -96° C

Sol 106
Mar. 15

High: -16° C
Low: -96° C