

Une plongée dans l'atmosphère de Mars avec InSight

Aymeric Spiga



InSight Education France January 17, 2019

Outline

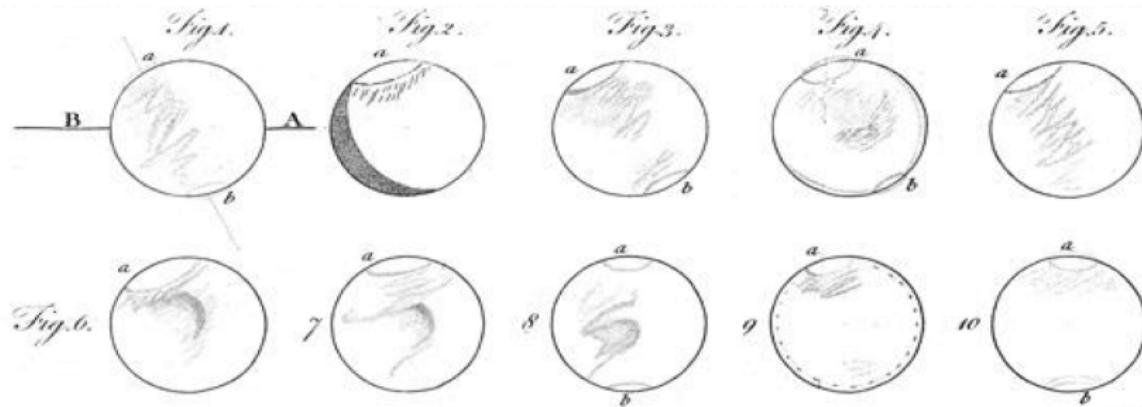
- 1 Mars, sa météorologie, son climat
- 2 Pourquoi InSight a-t-elle une station météorologique ?
- 3 Phénomènes atmosphériques au site InSight

[XXe-XXI^e siècle] Mars, un système géophysique



[Apollo 17, 1972; Mars Global Surveyor, 2002]

[XVIIIe-XIXe siècle] Mars, une sphère planétaire

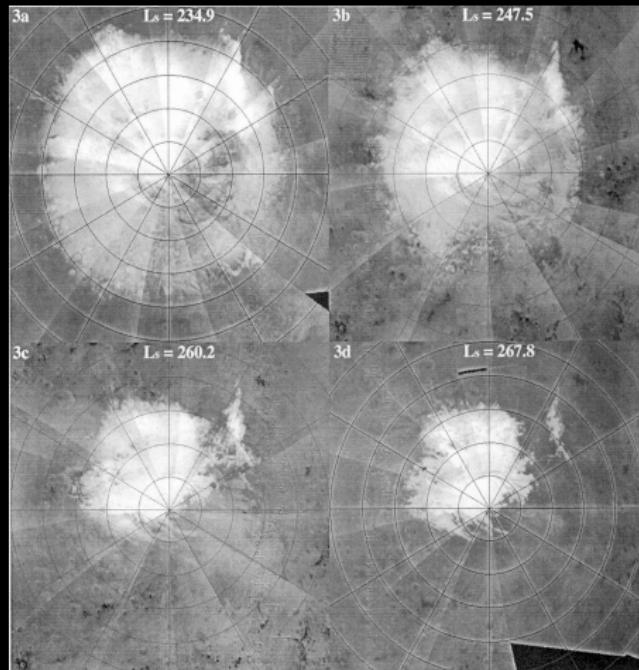
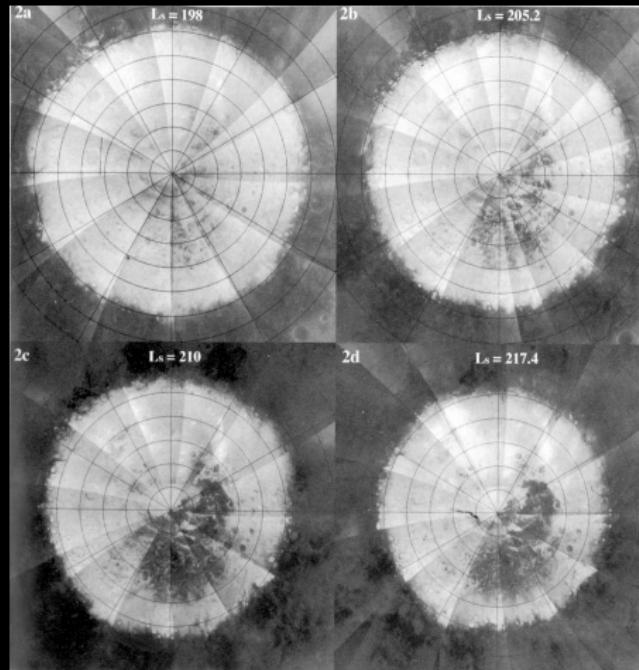


XIX. *On the remarkable Appearances at the Polar Regions of the Planet Mars, the Inclination of its Axis, the Position of its Poles, and its spheroidal Figure; with a few Hints relating to its real Diameter and Atmosphere.* By William Herschel, Esq. F. R. S.

[Herschel, Phil. Trans. 1784]

Le cycle du CO₂ sur Mars

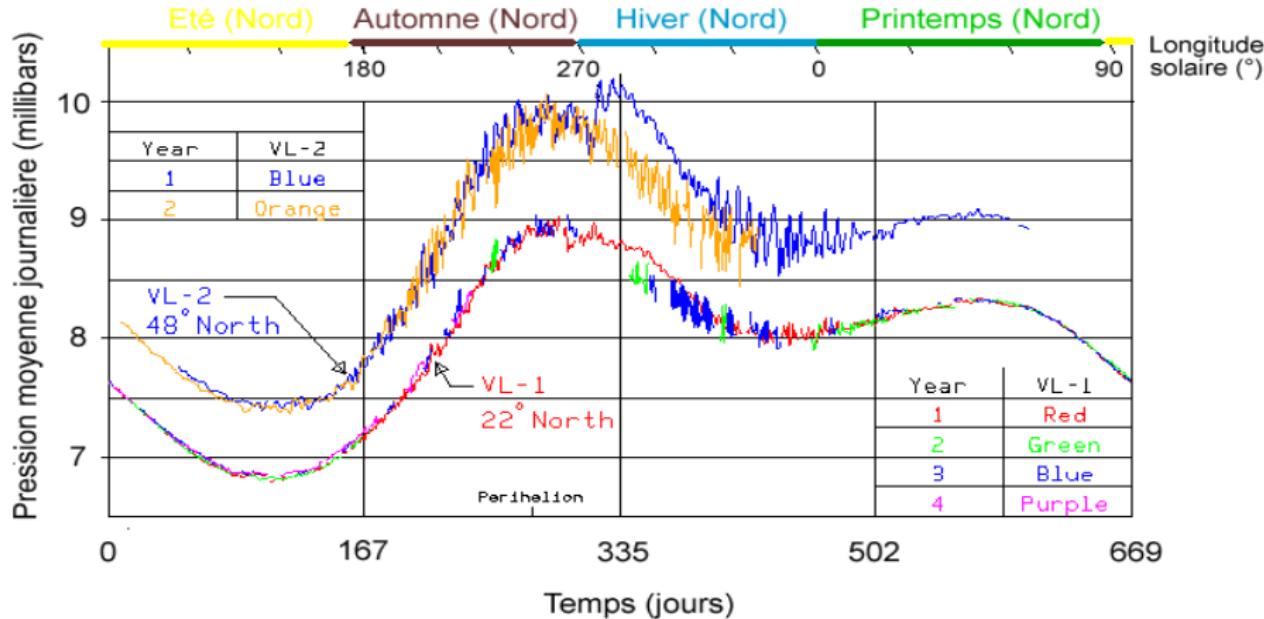
Sublimation de la calotte polaire saisonnière sud de CO₂ au printemps



[images Viking assemblées par P. James]

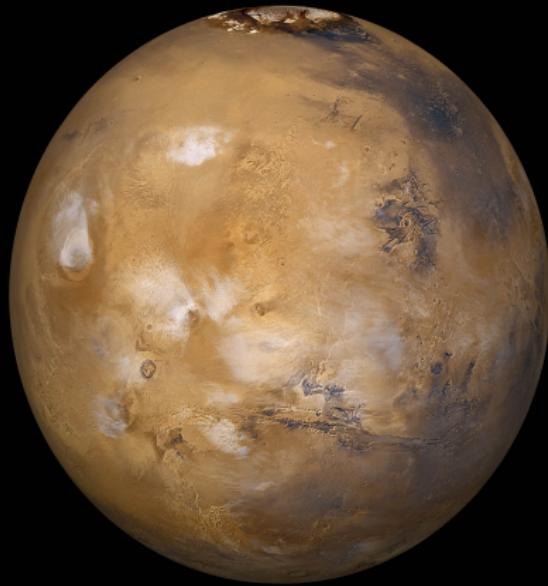
Observations de pression Viking

Chaque point est une moyenne sur une journée

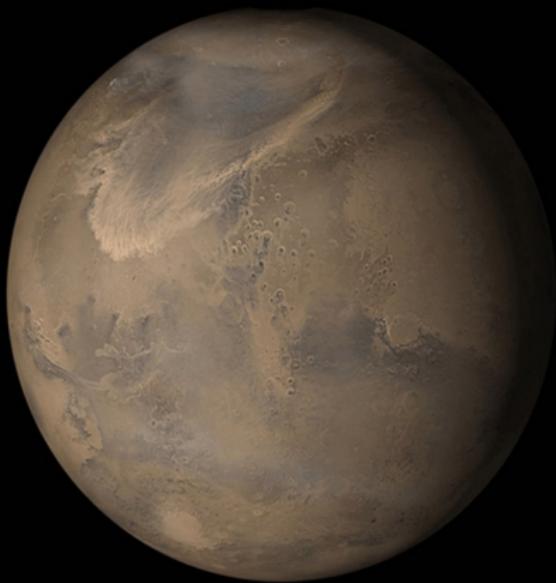


[emprunté au site PlanetTerre, d'après Hess et al., JGR 1981]

Cycle du CO₂, des poussières et de l'eau



[Image MOC pendant l'été nord]



[Image MOC à la fin de l'hiver nord]



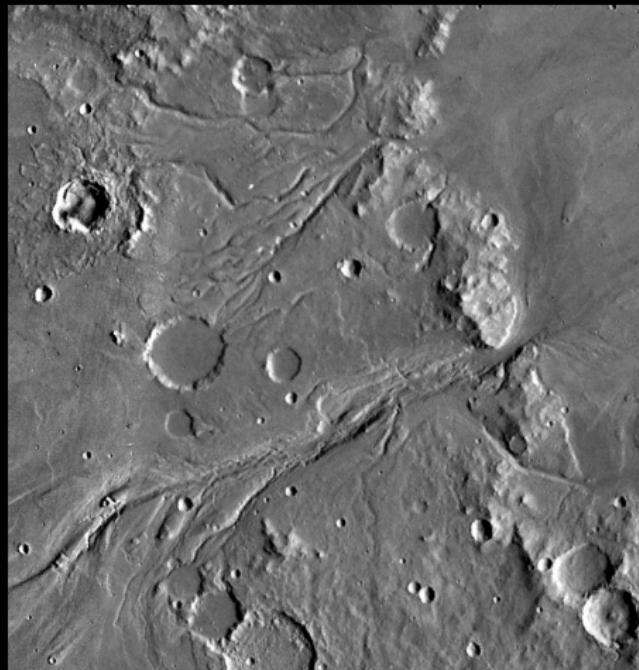
The northern polar
cap on Mars

Mars: structures fluviales

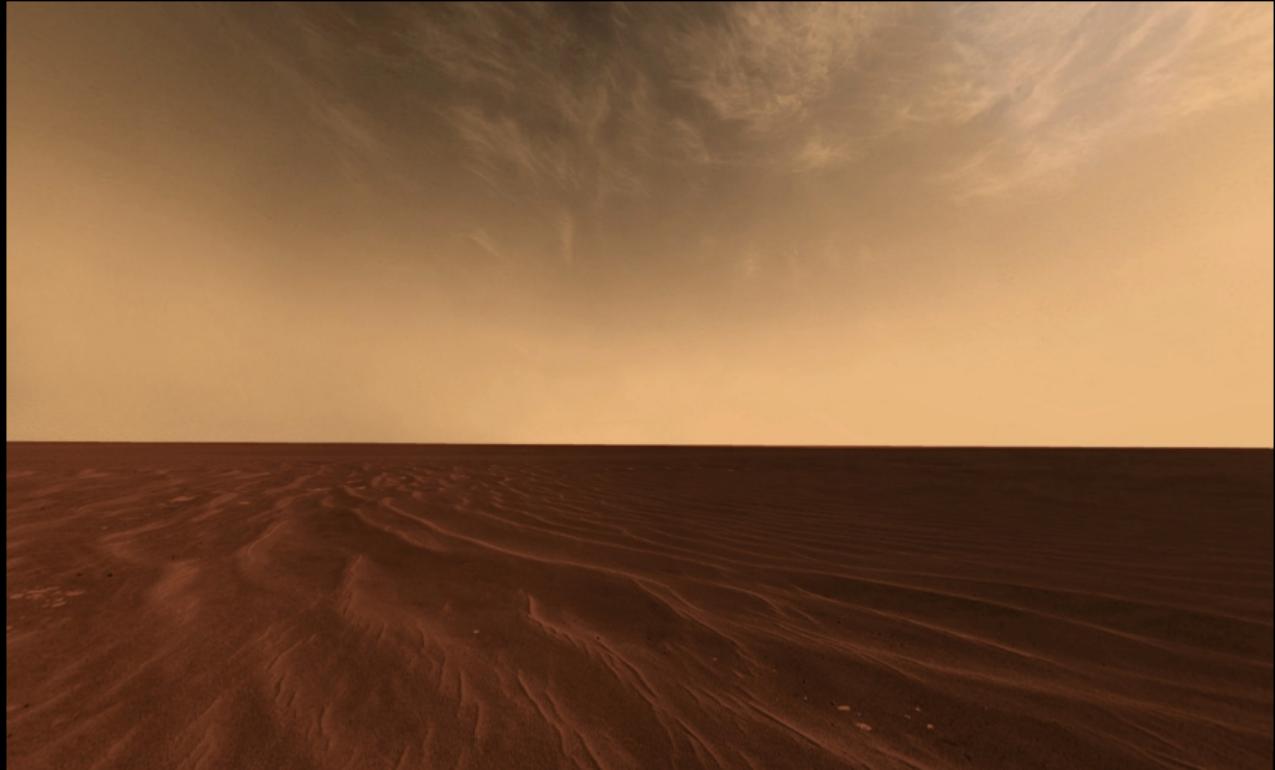
Valley network, Parana Valles



Outflow channel, Mariner 9



The Martian environment



[Pancam on Opportunity Rover]

Préambule australien



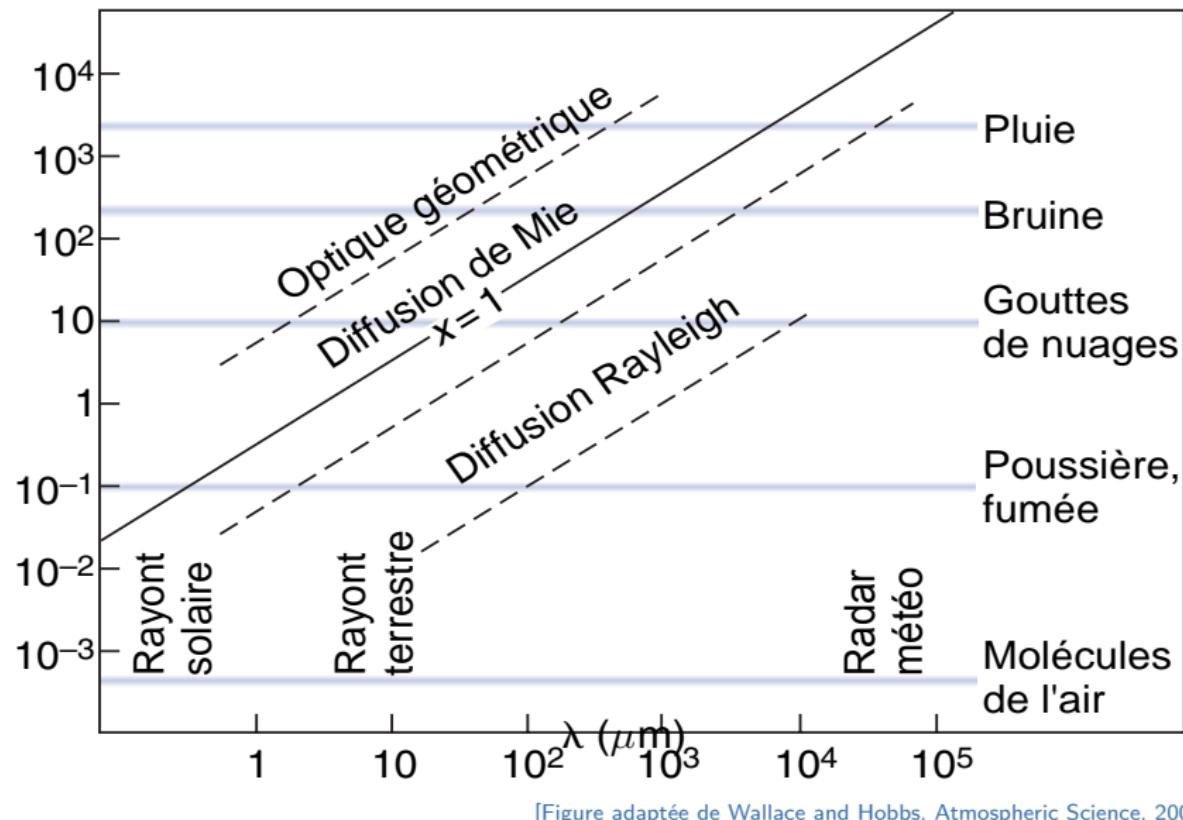
[Site internet The Big Picture http://www.boston.com/bigpicture/2009/09/dust_storm_in_australia.html]

Préambule australien ... pendant une tempête de poussière !



[Site internet The Big Picture http://www.boston.com/bigpicture/2009/09/dust_storm_in_australia.html]

Type de mécanisme de diffusion



Coucher de soleil martien



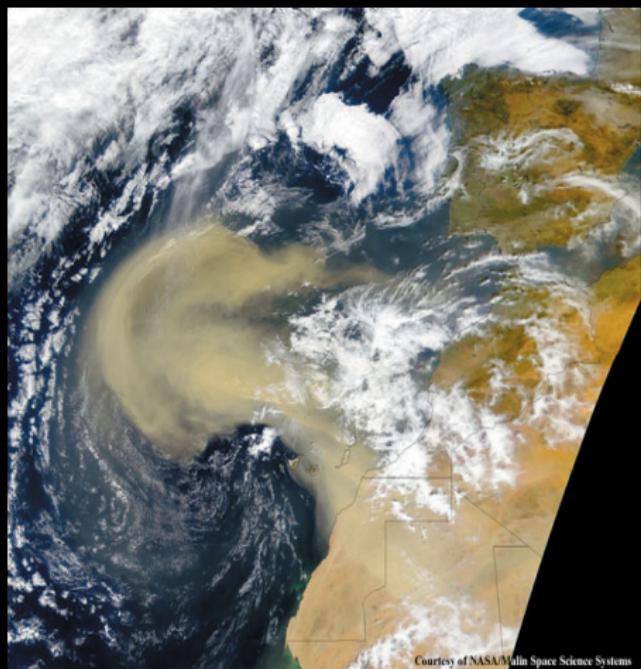
[Image par Pancam à bord de Spirit 2005 (référence PIA07997)]

Coucher de soleil martien



Tempêtes de poussière

Terre



Courtesy of NASA/Malin Space Science Systems

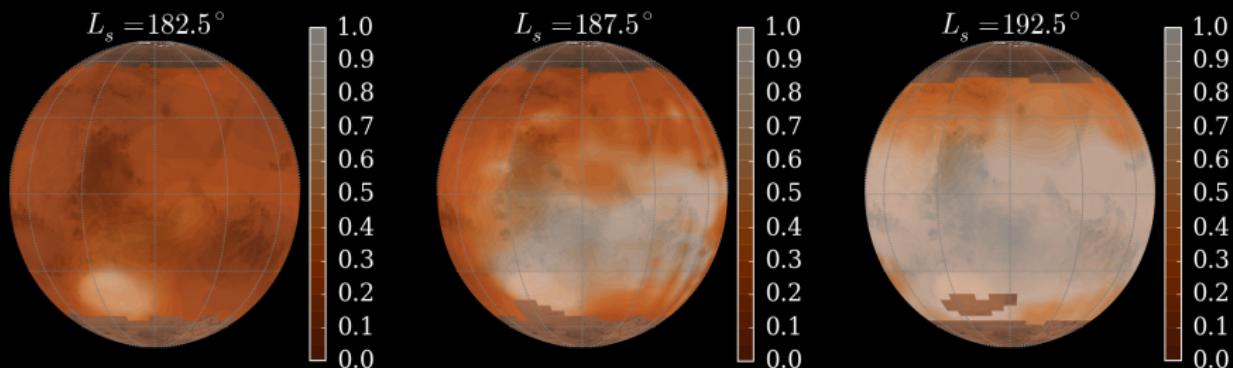
Mars



Courtesy of NASA/Malin Space Science Systems

[Référence image PIA02807]

The onset of the MY25 global dust storm

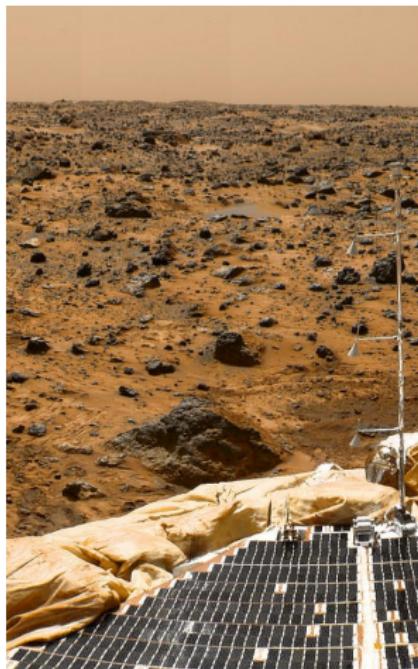


[Made after Thermal Emission Spectrometer by Smith et al. 2001]

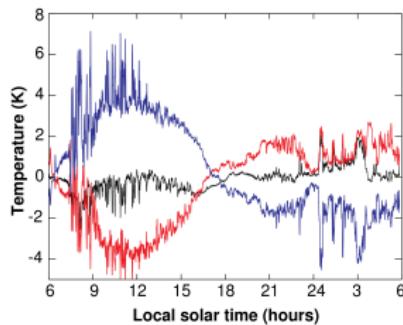
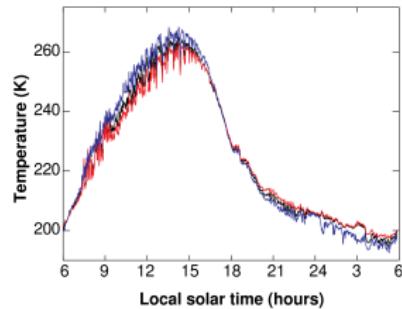
Near-surface temperature on Mars

Monitored by Mars Pathfinder (1997), summer latitude 20°

Meteorological mast

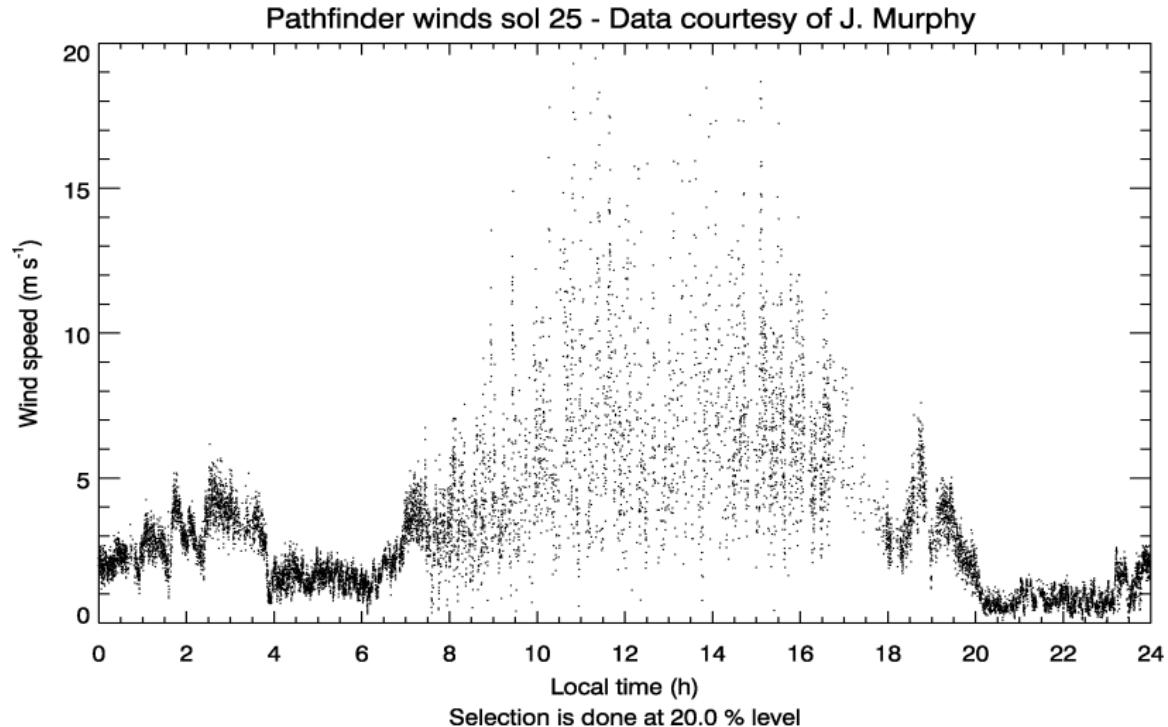


Measured at 100, 50, 25 cm



[Schofield et al., 1997]

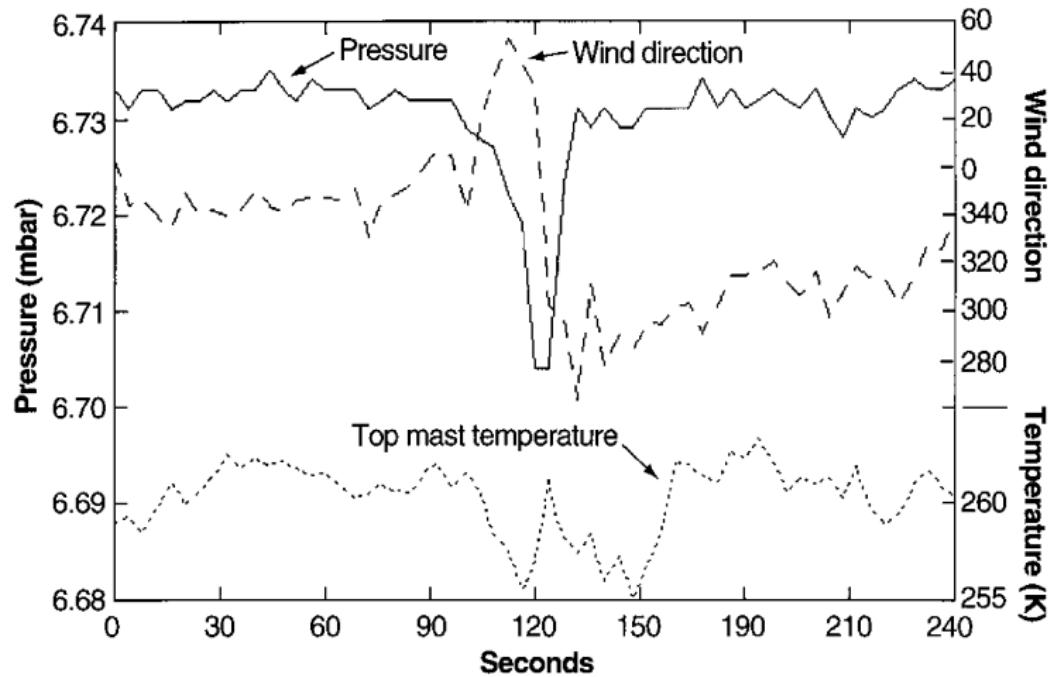
Near-surface wind observations on Mars



[J. Murphy, unpublished]

Meteorological perturbations caused by a dust devil

Pathfinder measurements (see also recent measurements by Phoenix and Curiosity)



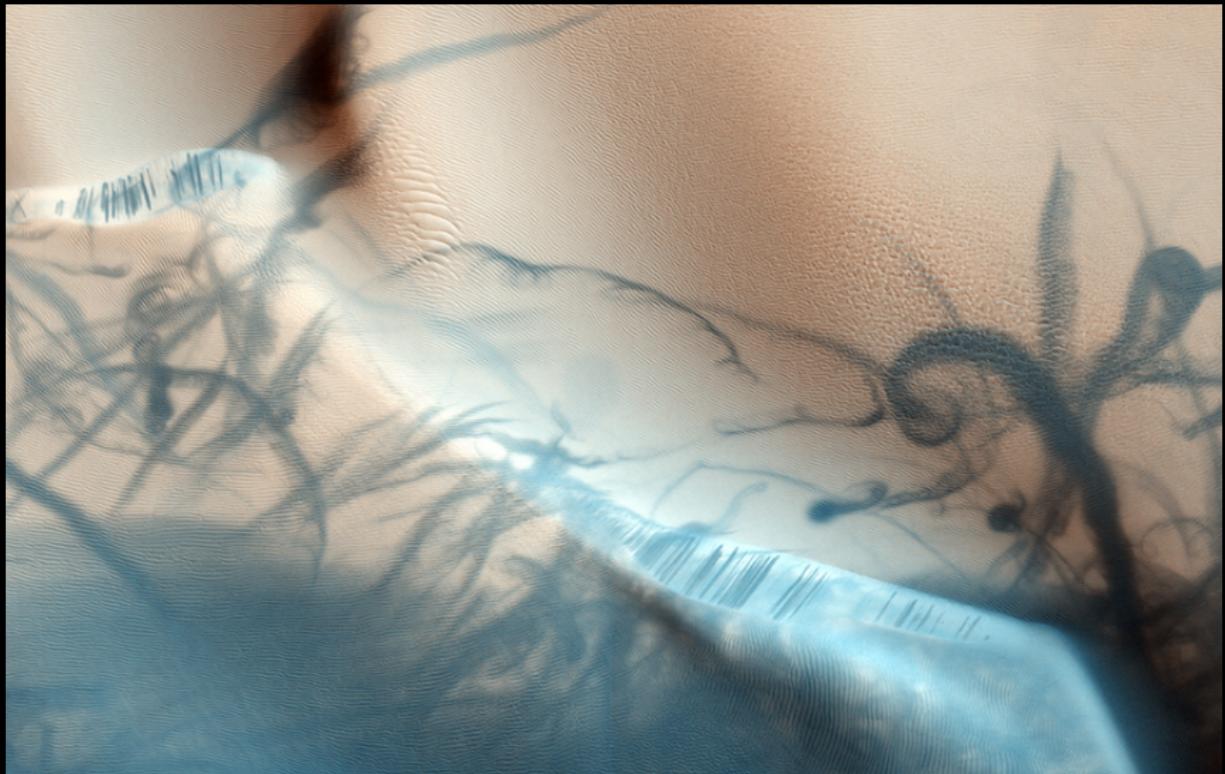
[Schofield et al. Science 1997]

A 800m-tall Martian dust devil



[HiRISE image, Feb. 2012, 35.8N 207E, credits NASA/JPL-Caltech/University of Arizona]

Graffitis martiens ! Champ de dunes Arabia Terra



[HiRISE, Mars Reconnaissance Orbiter, 2009]

Le cycle des poussières sur Mars : Accumulation



Spirit sol 9 (Jan. 11, 2004)

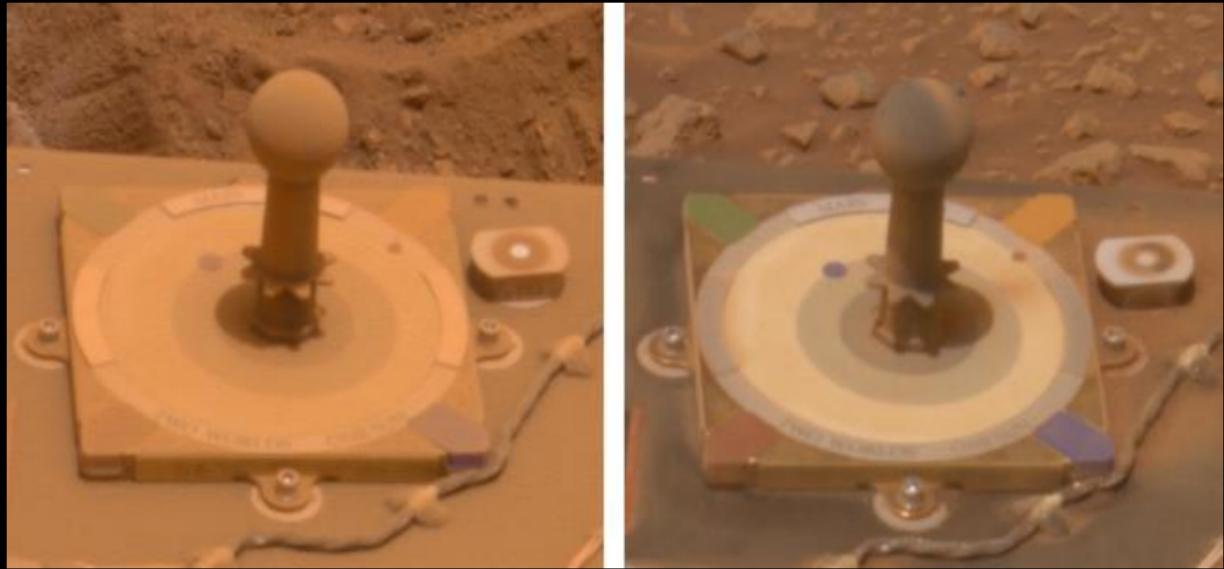
Spirit sol 357 (Jan. 3, 2005)



[Pancam on Spirit rover PIA07303]

Nettoyage du rover Spirit !

Images prises à 10 jours d'intervalle

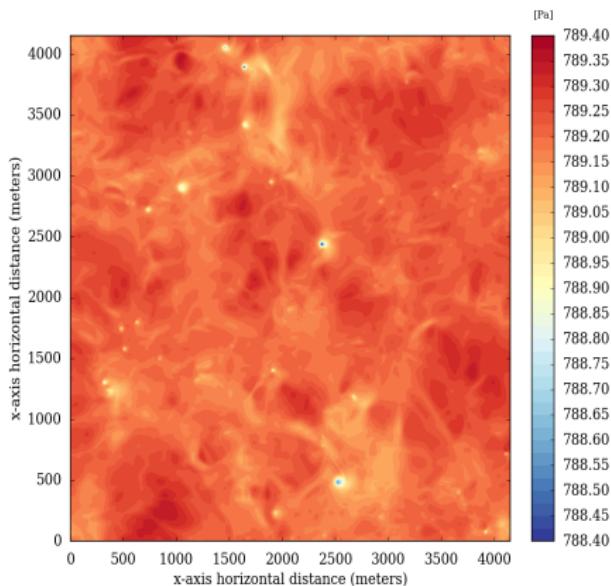


[Pancam on Spirit rover PIA07492]

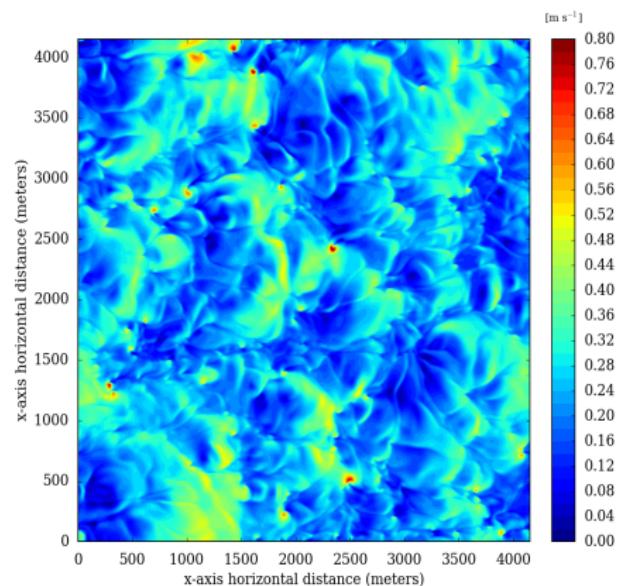
Large-Eddy Simulations for Insight

horizontal resolution 10 m, results at local time 9AM

Surface pressure

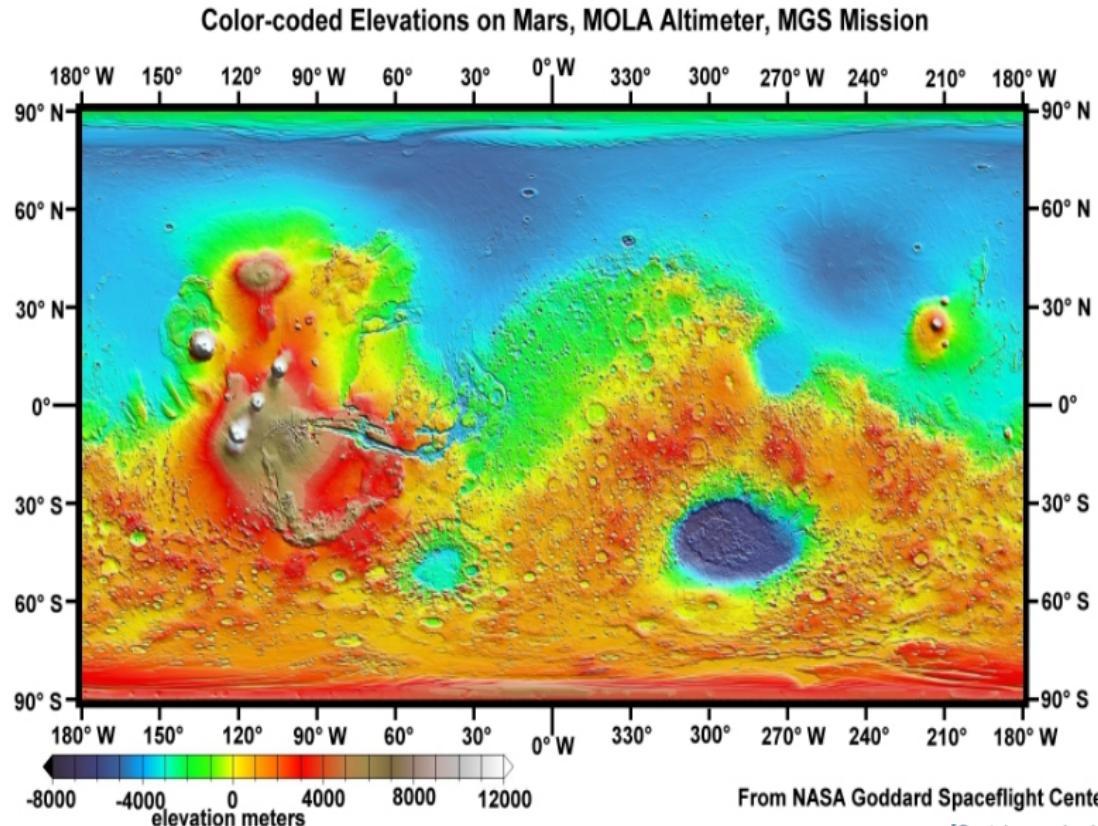


Friction velocity



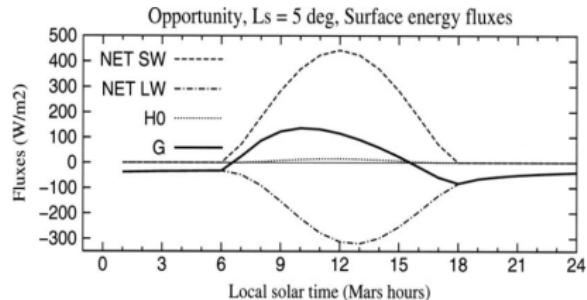
[Spiga et al. Space Science Reviews 2018]

Mars' topography by the MOLA altimeter



Energy budget for Martian surface

Surface energy budget
 $F_{\text{LW}} + F_{\text{SW}} = G + H_s + LE$



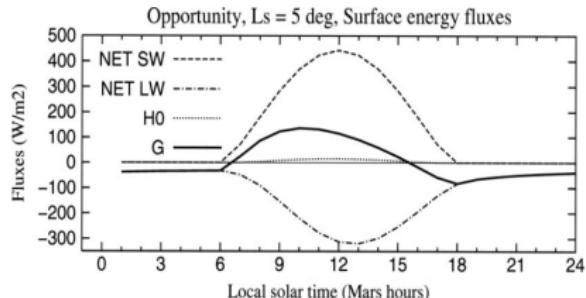
[Savijärvi and Kauhanen, QJRMS 2008]

Energy budget for Martian surface

Surface energy budget

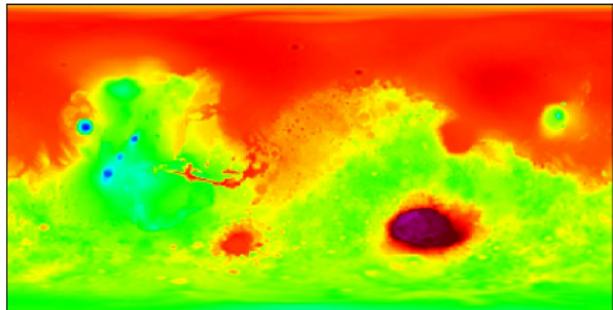
$$F_{\text{LW}} + F_{\text{SW}} = G + H_s + LE$$

→ radiative equilibrium

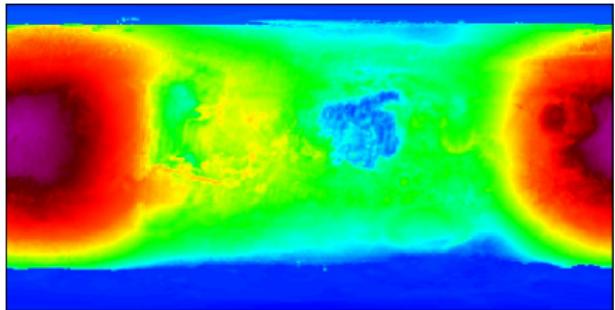


[Savijärvi and Kauhanen, QJRMS 2008]

Topography



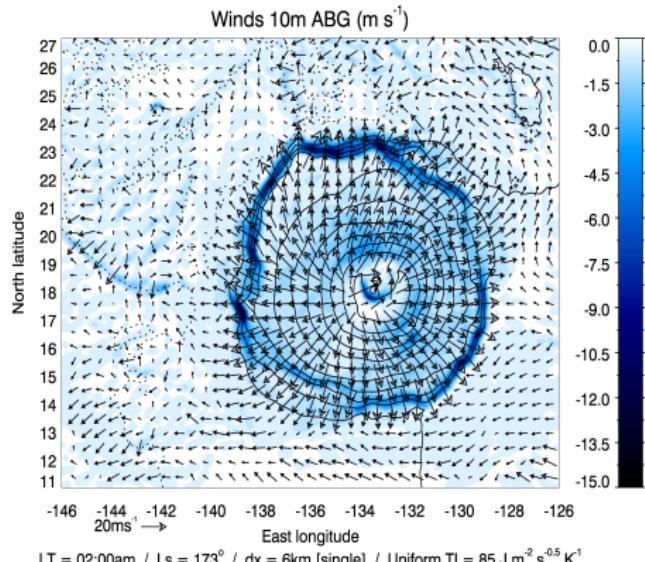
Surface temperature



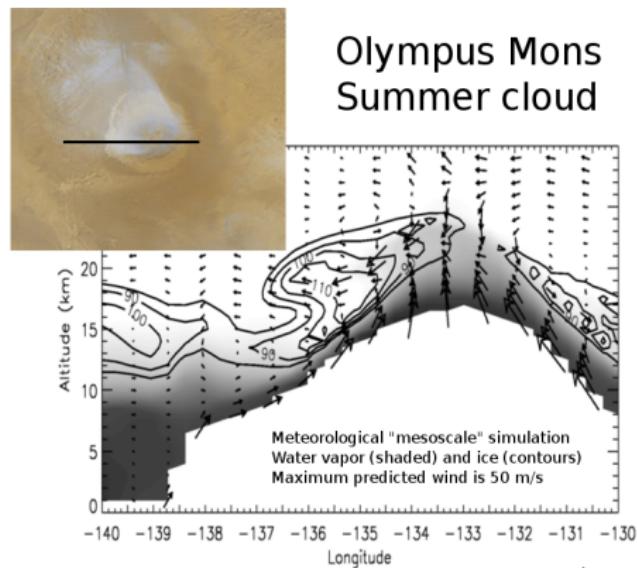
[outputs from the UK Mars GCM]

Katabatic and anabatic winds

Nighttime downslope



Daytime upslope



[Spiga and Forget JGR 2009; Spiga PSS 2011; Spiga et al. Icarus 2011; Toyota et al. PSS 2011]

Katabatic wind over Antarctica

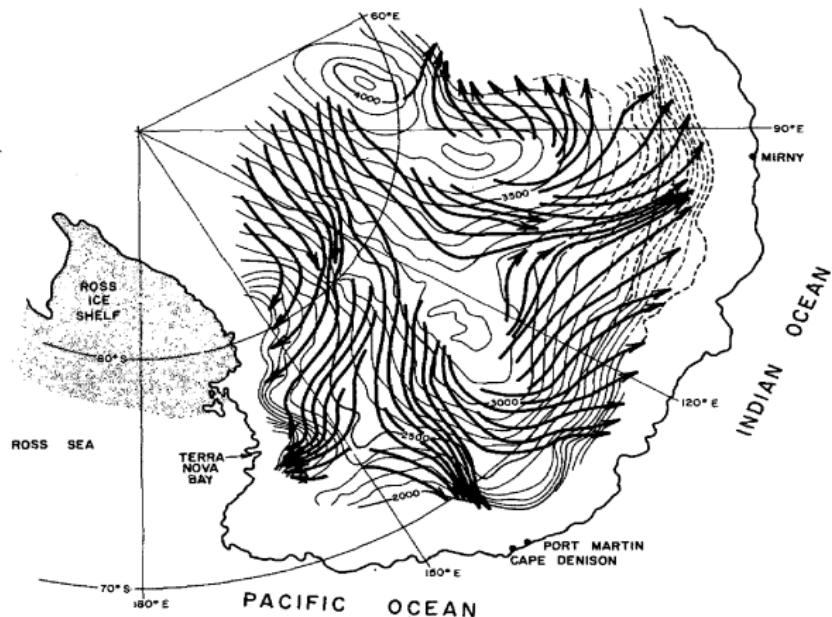
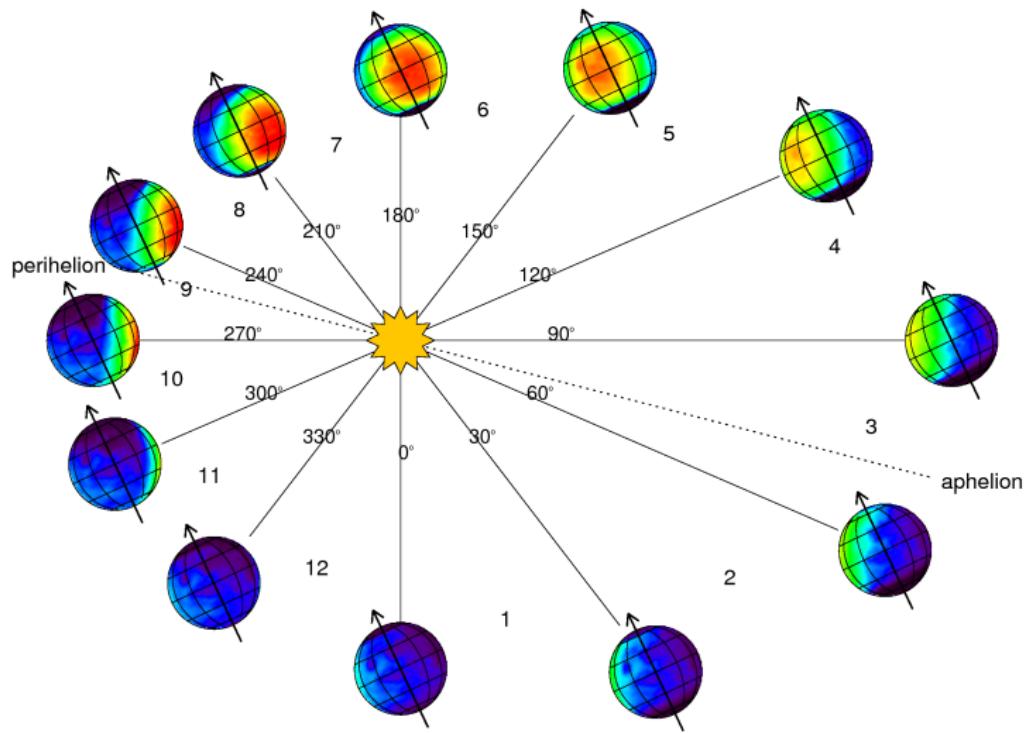


FIG. 2. Time-averaged winter flow pattern over the surface of the Antarctic based on model wind calculations of Parish (1982).

[Parish et al., 1983]

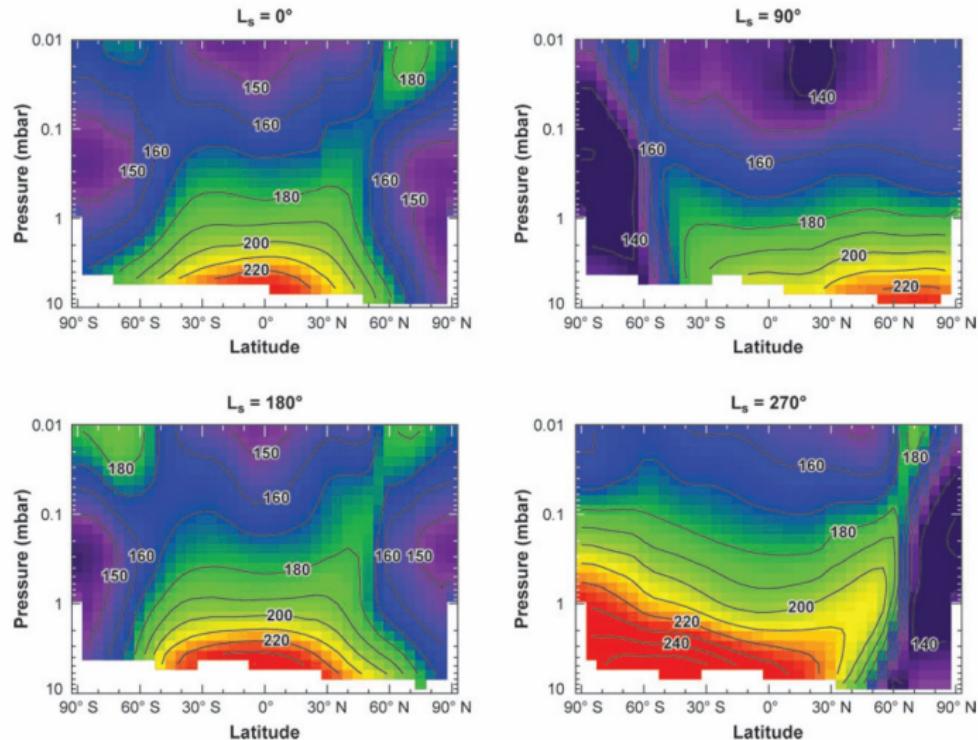
Saisons martiennes



[Read and Lewis, 2004]

Saisons martiennes

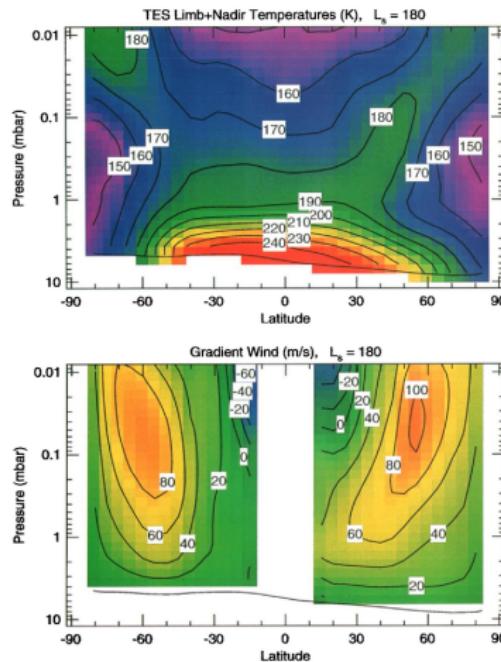
Structure thermique obtenue par spectrométrie IR



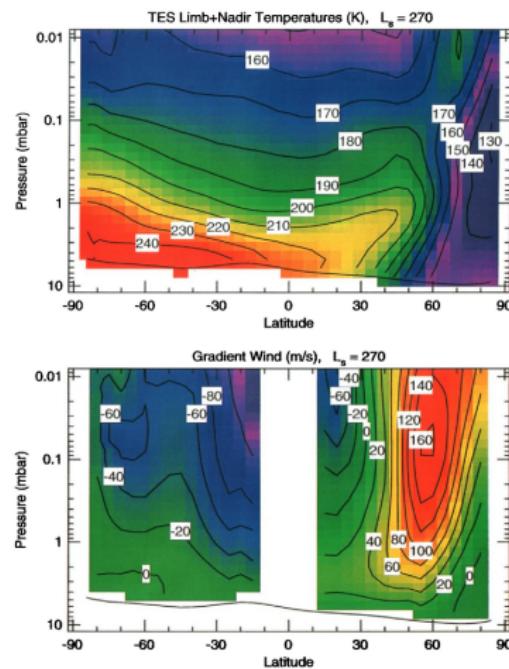
[Smith, 2008]

Equilibre du vent thermique sur Mars : Exploitation

Printemps Sud

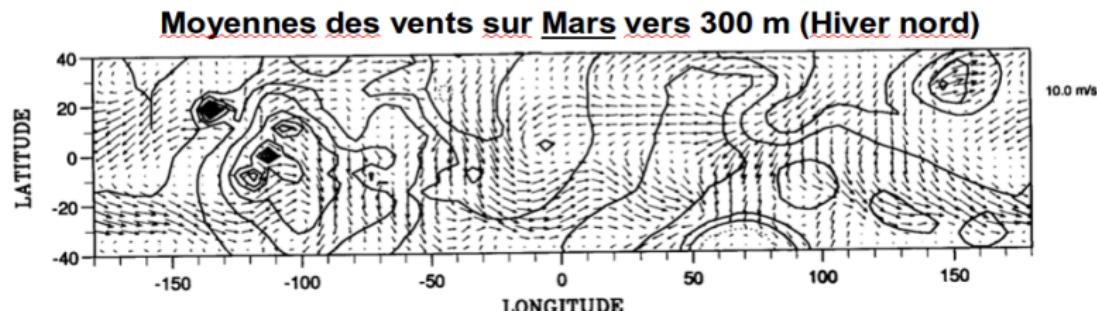
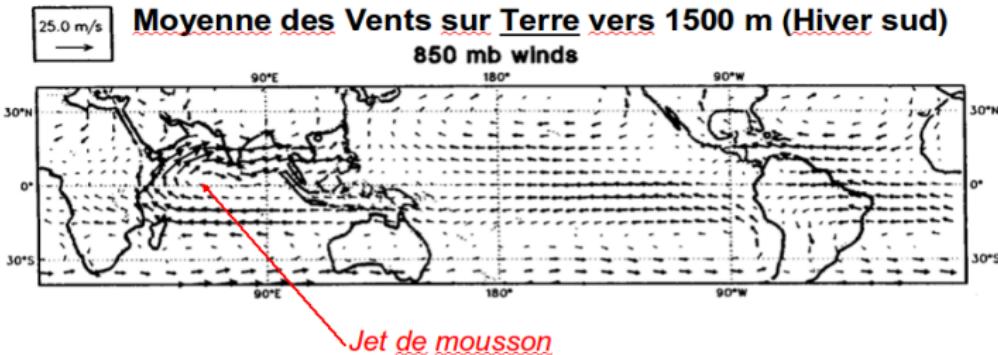


Eté Sud



[Smith et al., 2001]

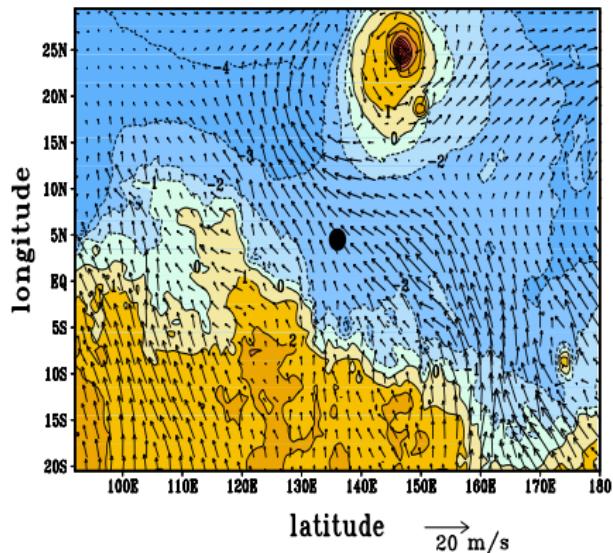
Vents de mousson et courants de bord ouest



Large-scale wind regimes at InSight landing site

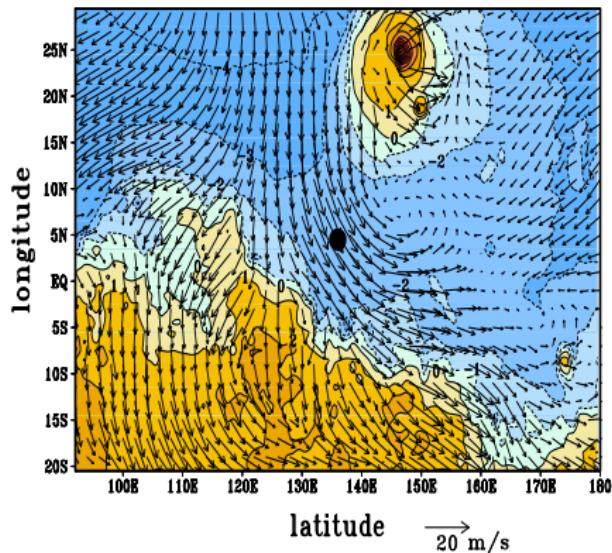
spring-summer \mathcal{R}_1

LMD GCM z=4m Ls=35-180



fall-winter \mathcal{R}_2

LMD GCM z=4m Ls=245-305



[Spiga et al. Space Science Reviews 2018; from Pottier et al. Icarus 2017 GCM simulations]

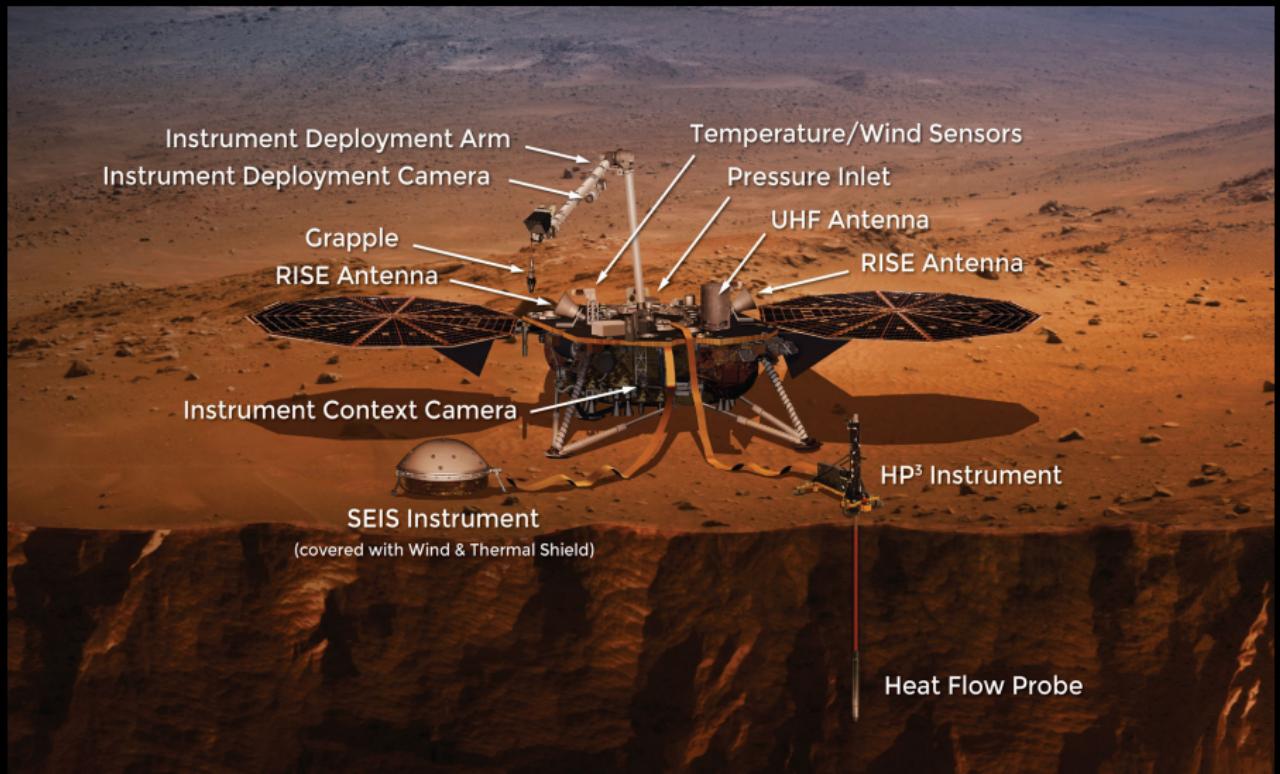
Pressure: THE meteorological variable

Variability	Associated phenomena
Secular	CO ₂ cap mass budget
Interannual	global dust storms
Seasonal	CO ₂ cycle, atmospheric dynamics
Day-to-day	baroclinic waves
Diurnal	thermal tides, slope winds
Hour-to-hour	gravity waves, slope winds
Minute-to-minute	boundary layer convection
Second-to-second	convective vortices & cells
Below second	inertial / dissipation turbulence

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- 2 Pourquoi InSight a-t-elle une station météorologique ?
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InSight 2018 mission to Mars



[NASA InSight website: artist's Concept of InSight Lander on Mars]

InSight: an equatorial geophysical station

- ☞ 24/24 meteorological package
- ☞ high-resolution pressure measurements
- ☞ color cameras
- ☞ radiometer, gravity measurements, EDL, etc . . .

Studying Martian atmosphere is not InSight's primary science goal; YET

- ☞ Crucial for InSight's key science objectives
- ☞ Needs coordination between instrument team & WGs
- ☞ Geophysical station also means Meteorological station
- ☞ Possible new science and ideas.

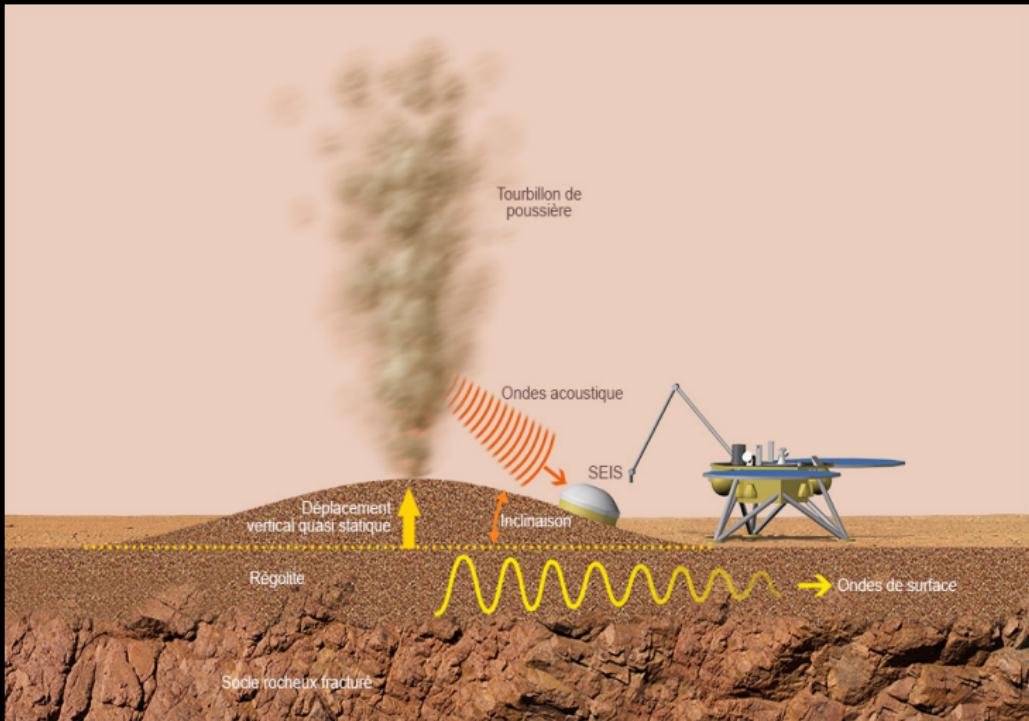
InSight is a meteorological station

Spiga et al. Space Science Reviews 2018

To improve our knowledge of Mars' atmosphere

- ☞ A complete EDL profiling from thermosphere to PBL
- ☞ High-accuracy acquisition of winds, T , p (seconds \Rightarrow seasons)
- ☞ High- f measurements: monitoring dust devils and gustiness
- ☞ Unprecedented seismic measurements of atmospheric activity
- ☞ Simultaneous measurements of surface + air temperatures
- ☞ Atmospheric Angular Momentum through rotation variations
- ☞ Dust τ measurements (camera + deposition on solar panels)
- ☞ Water ice cloud and near-surface fog (seasonal and diurnal)
- ☞ New: secular pressure variations, dust storms, surface layer, ...

Seismic signatures of convective vortices

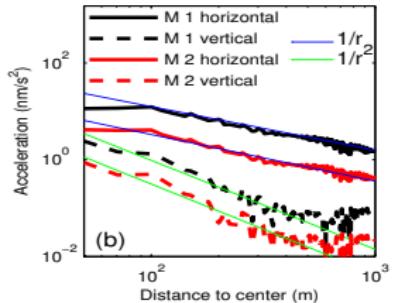
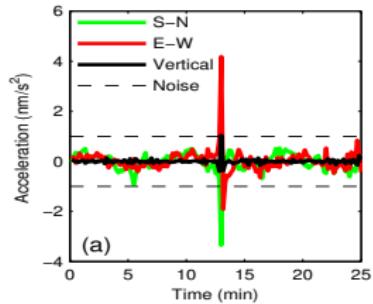
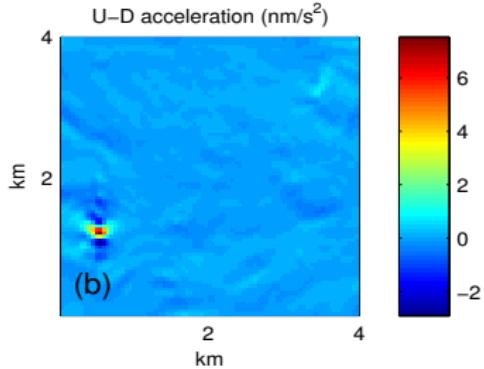
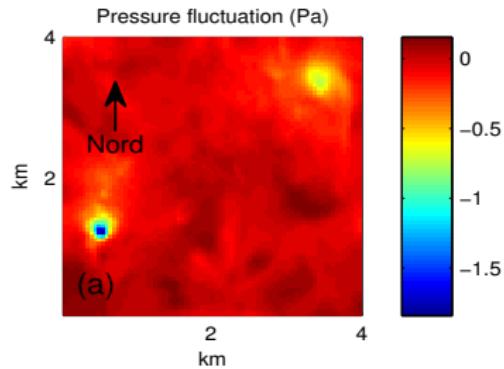


[Crédits IPGP]

Seismic noise of dust devils (for InSight / SEIS)



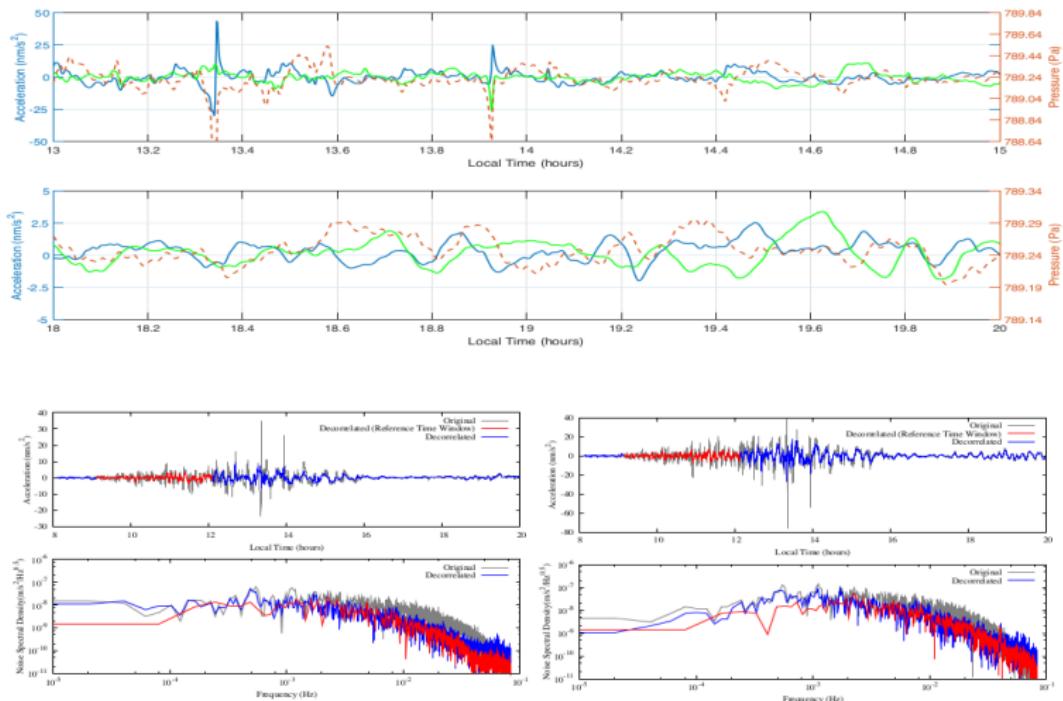
Large-Eddy Simulations + Sorrell theory



[Kenda et al. Space Science Reviews 2017]

InSight decorrelation strategy tested

with the synthetic “noise” from LES pressure field (in windy & calm conditions)



[Murdoch et al. Space Science Reviews 2017]

A quote from Charles Baudelaire

*Tu m'as donné ta boue
et j'en ai fait de l'or.*

*You gave me your mud
and I have turned it to gold.*

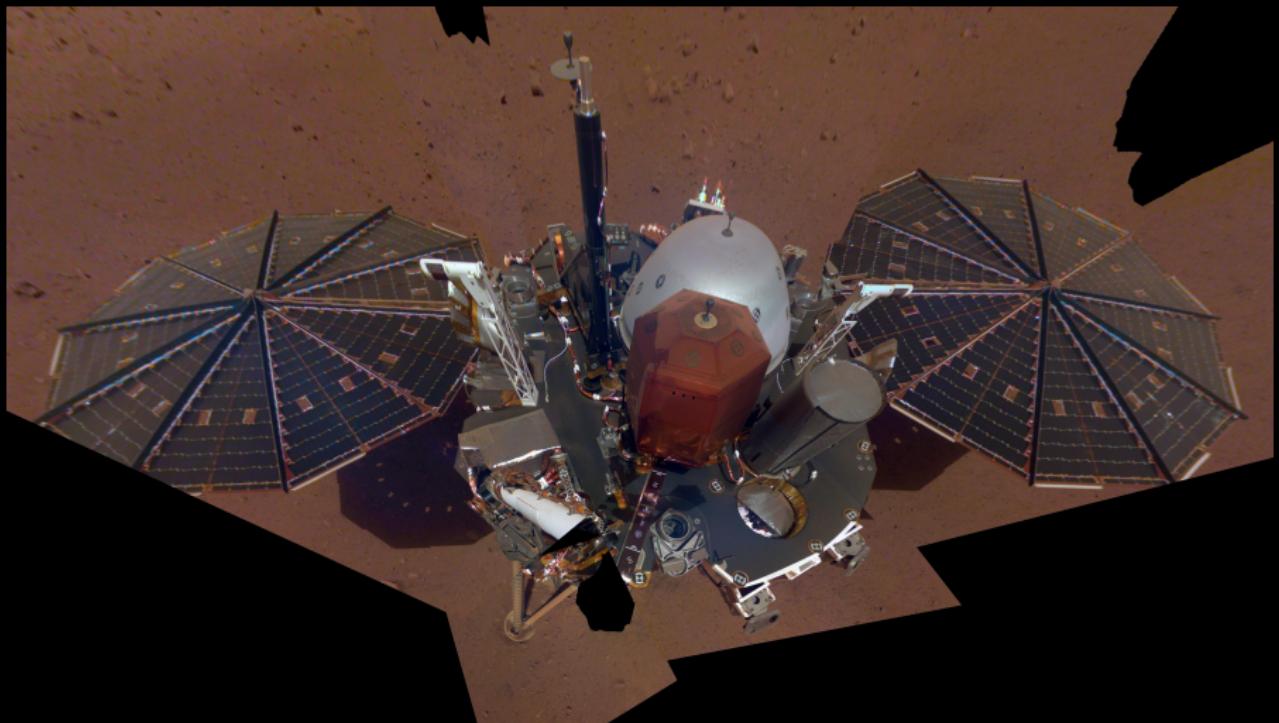


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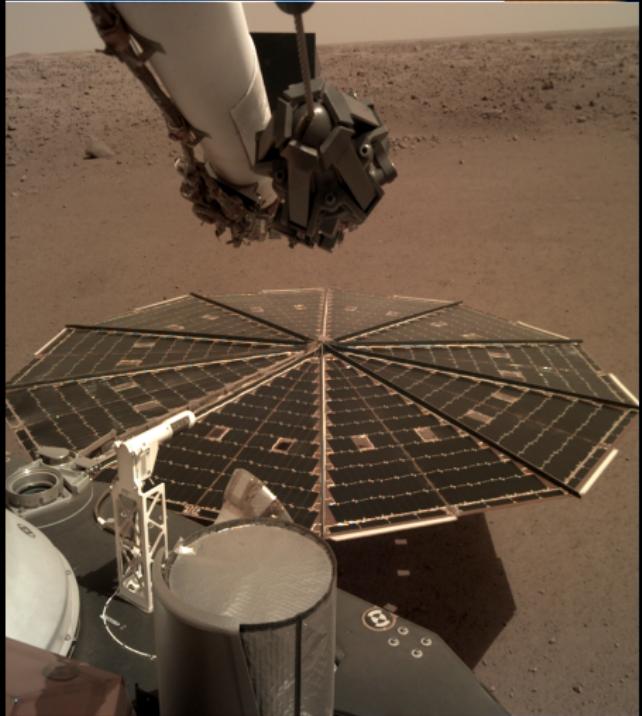


InSight “selfie” mosaic

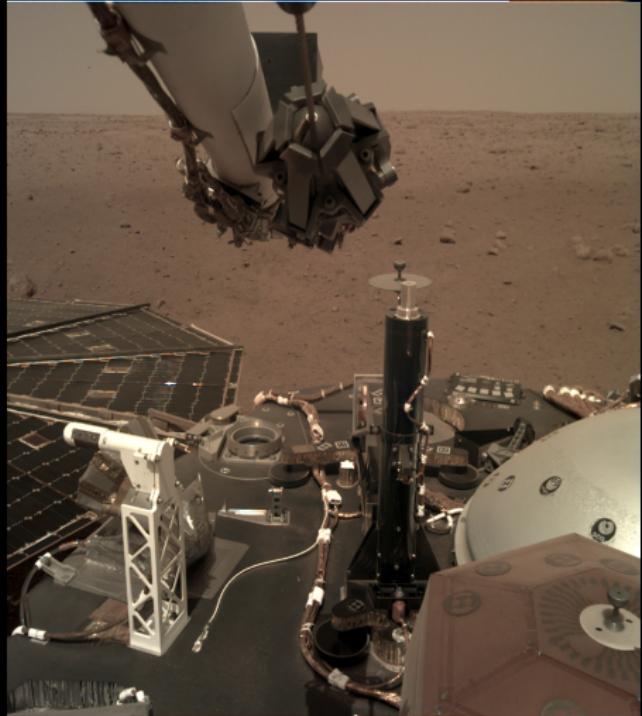


[PIA22876 NASA/JPL]

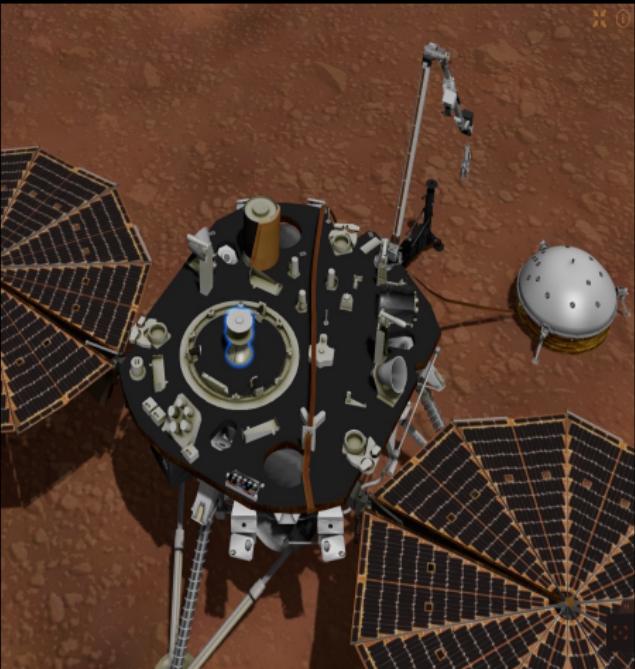
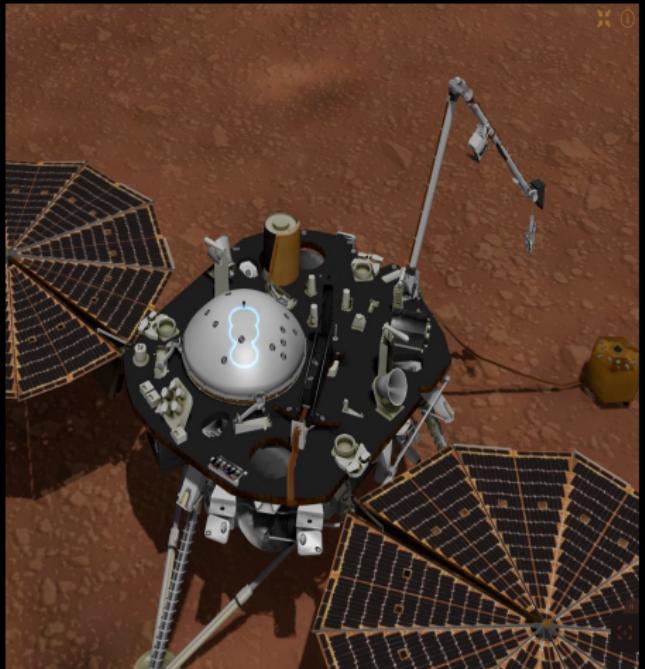
TWINS on board InSight



[PIA22736 NASA/JPL]

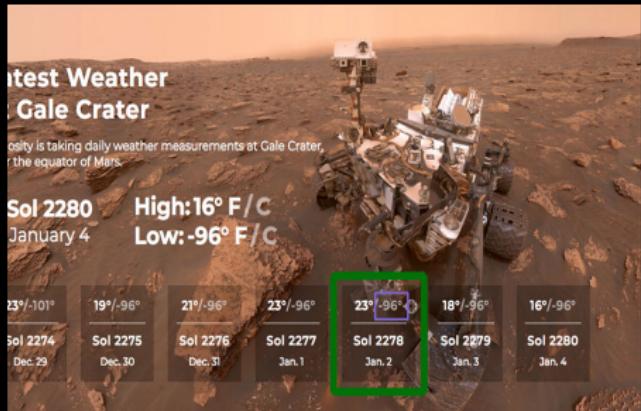


APSS pressure sensor



[site SEIS/InSight P. Labrot]

NASA website for weather reports



Latest Weather at Elysium Planitia

Mars Climate Database (online version)

<http://www-mars.lmd.jussieu.fr/mars/access.html>

Mars Climate Database v5.2: The Web Interface

Mars Climate Database v5.2: The Web Interface		
		
One-click presets LANDING SITE & DATE <ul style="list-style-type: none"> Land now at equator! InSight Curiosity Phoenix Opportunity Spirit Pathfinder Viking 1 Viking 2 	Main settings <small>(reset)</small> <input checked="" type="radio"/> MARS date Solar longitude (Ls) 57 degrees Local Time 0. Martian hour <small>write a value (or) a range 'val1 val2' (or) 'all'</small> <input type="radio"/> EARTH date YY / MM / DD @ hh:mm:ss UTC 2017 / 9 / 6 @ 0 : 9 : 15	Advanced settings and information If longitude is a free dimension, local_time value is <input checked="" type="radio"/> at longitude 0 <input type="radio"/> fixed for the whole planet
TIME OF DAY Morning Afternoon Evening Night	CUSTOMIZE COORDINATES ON MARS <small>write a value (or) a range 'val1 val2' (or) 'all'</small> <ul style="list-style-type: none"> Latitude all degree North Longitude all degree East Altitude 10. m above surface 	Earth Julian Date 2458002.5 Mars MY 34 - MM 2 - dd 120 / 609 EARTH DATE >>> MARS DATE
ALTITUDE Near surface Boundary layer Troposphere Mesosphere Thermosphere		<ul style="list-style-type: none"> Dust/EUV scenario climatology ave solar Use high-resolution topography <input type="radio"/> off <input checked="" type="radio"/> on Zonal averaging (only lat/alt plot) <input type="radio"/> off <input checked="" type="radio"/> on Figure format <input checked="" type="radio"/> PNG <input type="radio"/> PNG hi-res <input type="radio"/> EPS
INTEREST Atmosphere Winds Weather Water cycle Chemistry Landing engineering Glaciology Surface meteorology Radiative balance	CUSTOMIZE VARIABLE(S) TO BE DISPLAYED Variable 1 Temperature (K) Variable 2 (None) Variable 3 (None) Variable 4 (None)	<ul style="list-style-type: none"> [1D] Log(values) <input type="radio"/> off <input checked="" type="radio"/> on [2D] Colormap blue green yellow red [2D] Values range _____ to _____ [2D map] flat <input type="radio"/> lat <input checked="" type="radio"/> lon [2D map] Transparency (%) _____ [2D map] Wind vectors <input type="radio"/> off <input checked="" type="radio"/> on [2D map] Point at lat _____ lon _____
PLOT REQUEST Daily cycle Vertical profile Altitude/time plot Global map Sphere	SUBMIT	Mars Climate Database (c) LMD/OU/IAA/ESA/CNES. Open source python interface by A. Spiga (LMD). Javascript time conversion by E. Milour (link).