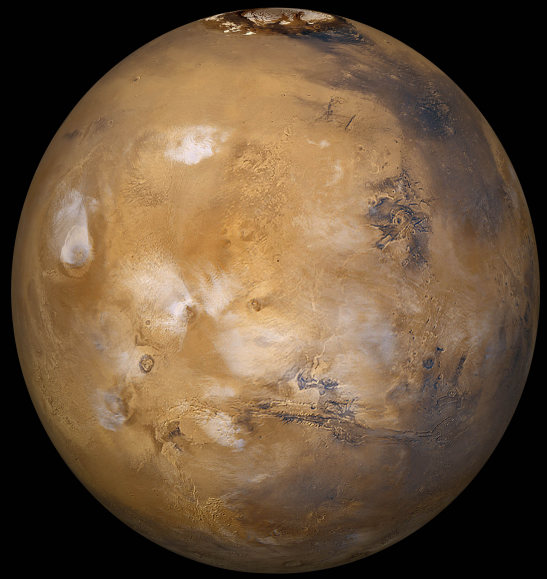
Une plongée dans l'atmosphère de Mars avec InSight

Aymeric Spiga

InSight Education France January 17, 2019

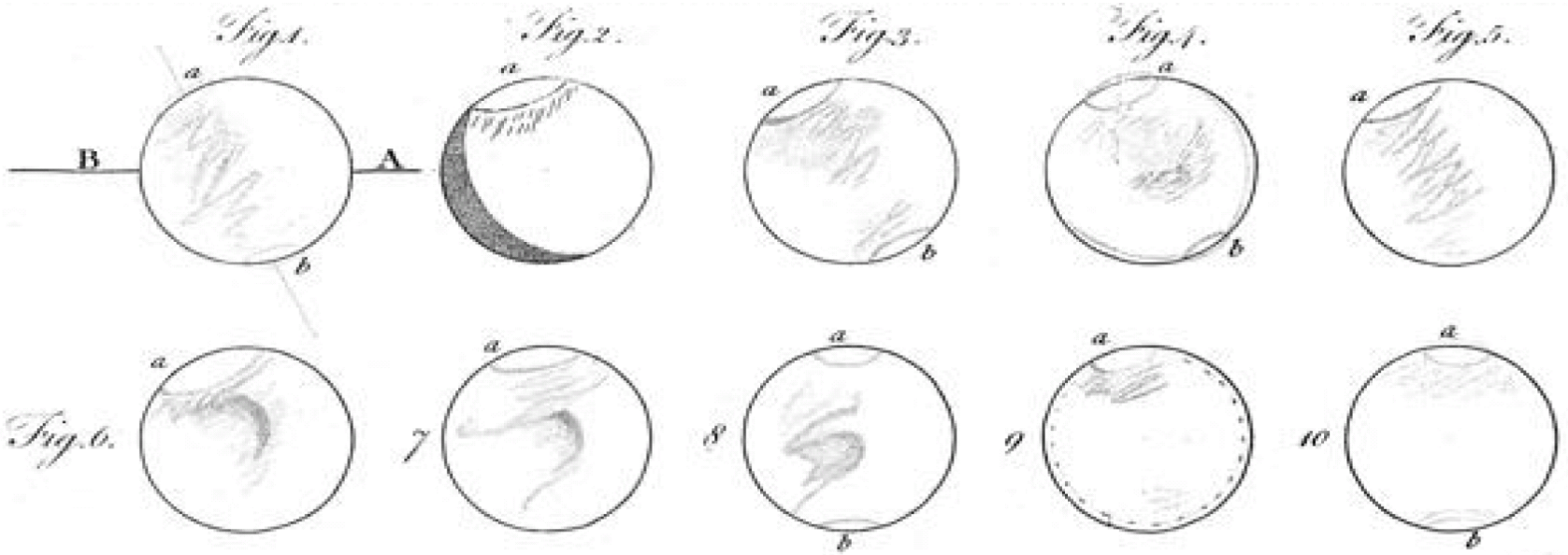
Outline

[XXe-XXIe siècle] Mars, un système géophysique



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

[XVIIIe-XIXe siècle] Mars, une sphère planétaire

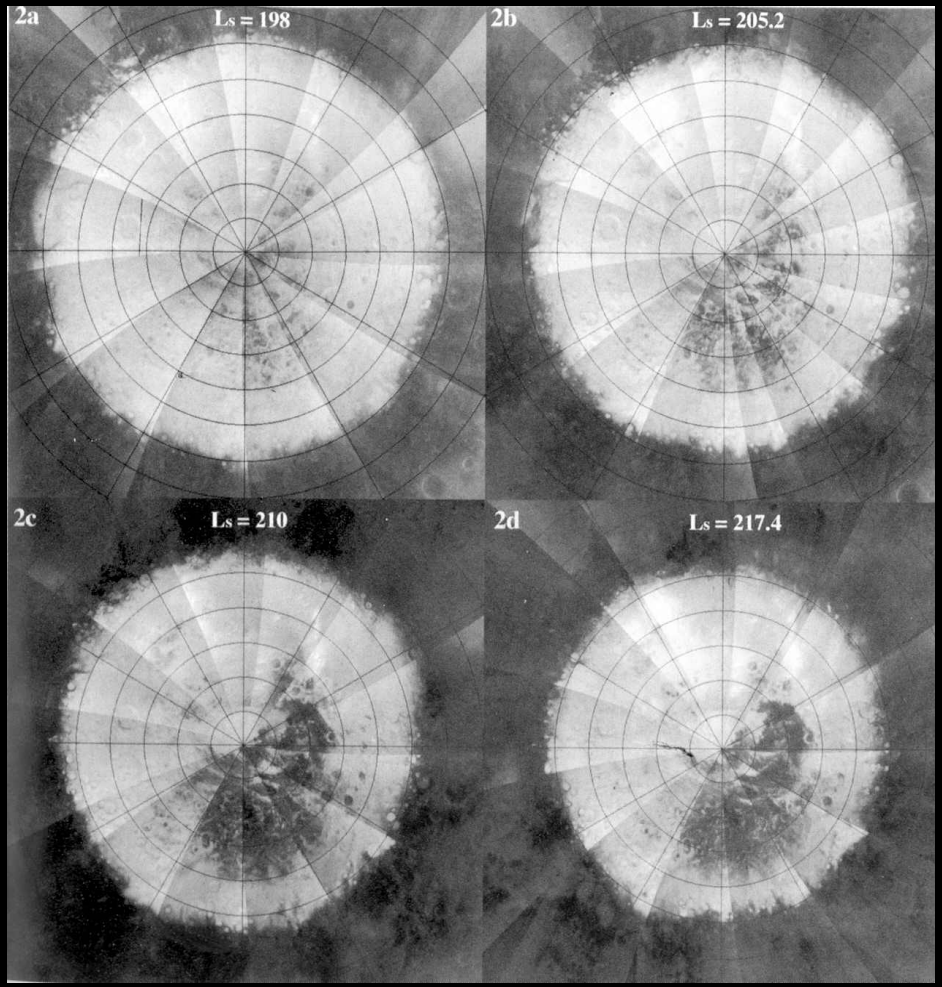


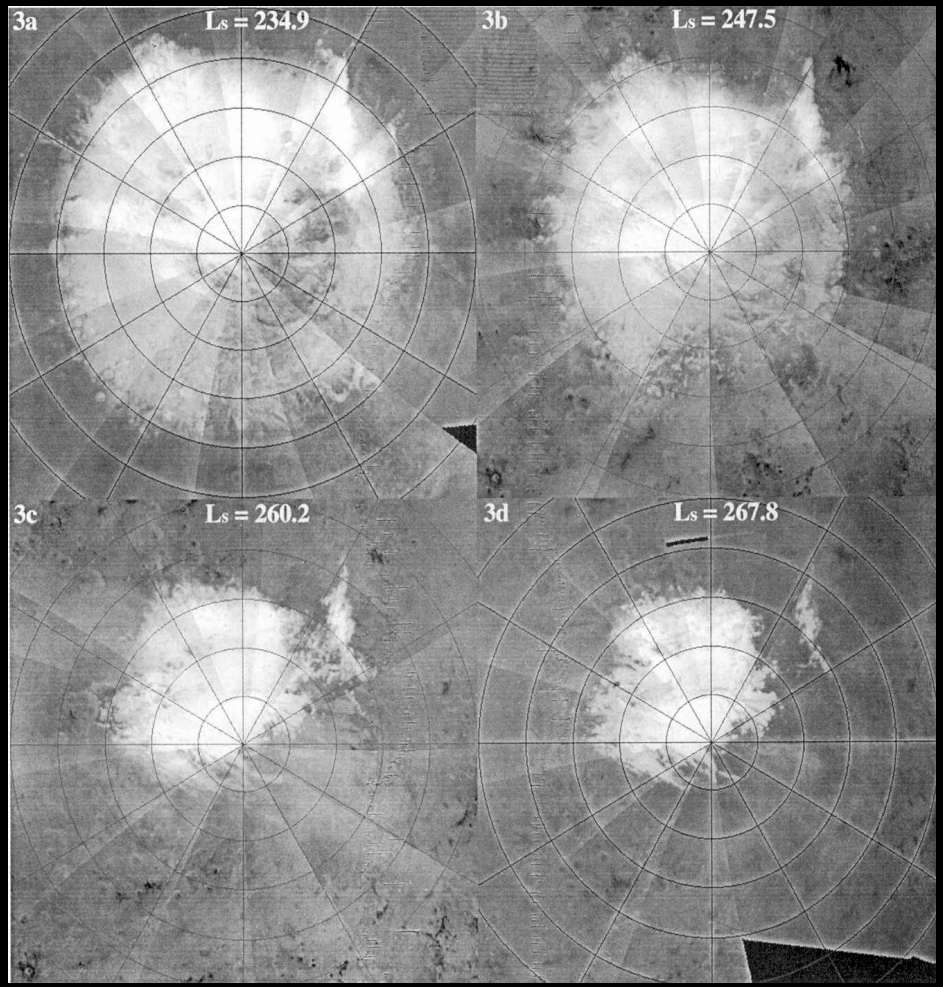
XIX. *On the remarkable Appearances at the Polar Regions of the Planet* Mars, *the Inclination of its Axis, the Position of its Poles, and its Spheroidical Figure; with a few Hints relating to its real Diameter and Atmosphere. By* William Herschel, *Esq. F. R. S.*

[Herschel, Phil. Trans. 1784]

Le cycle du CO_2 sur Mars

Sublimation de la calotte polaire saisonnière sud de CO_2 au printemps

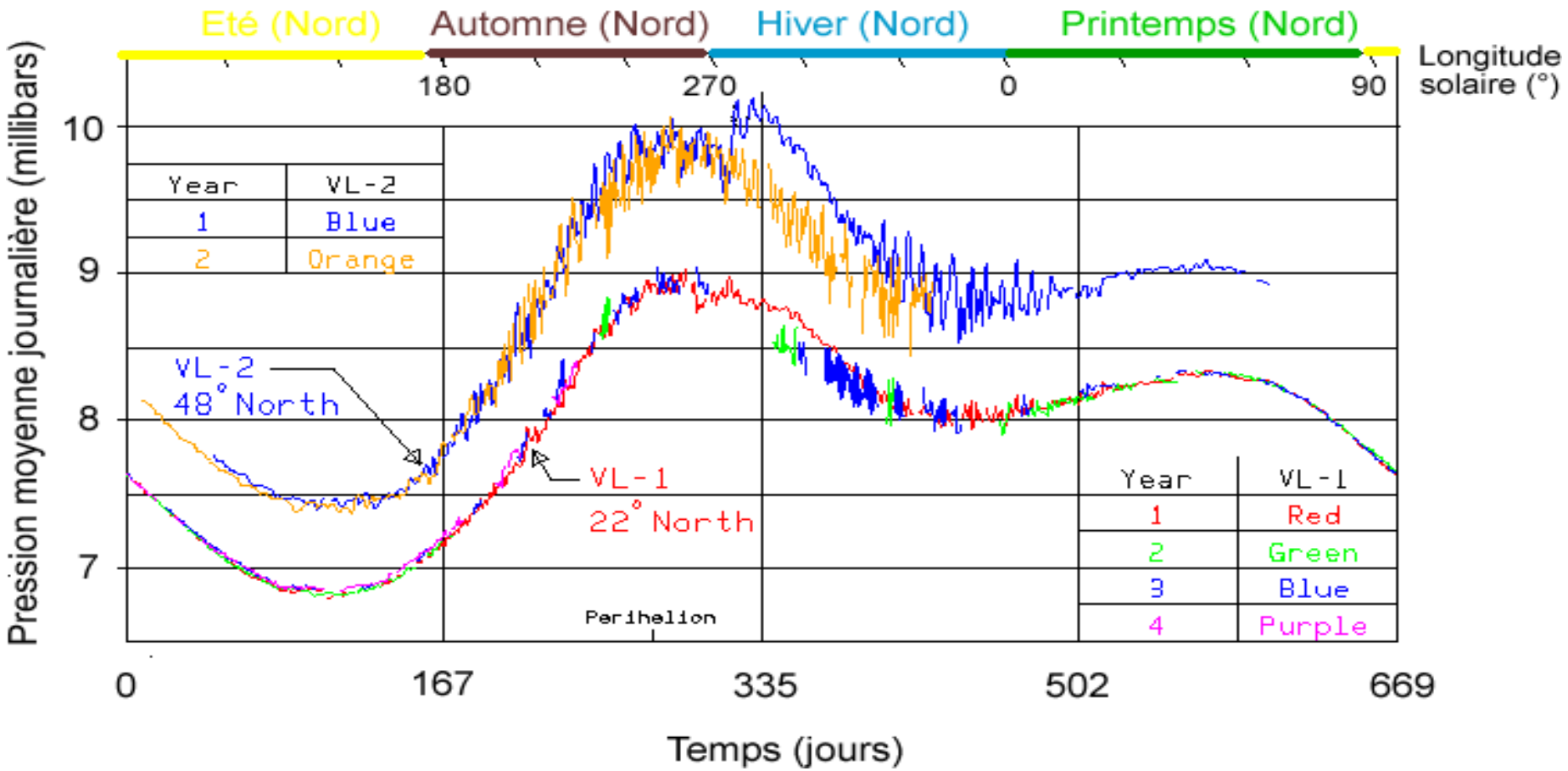




[images Viking assemblées par P. James]

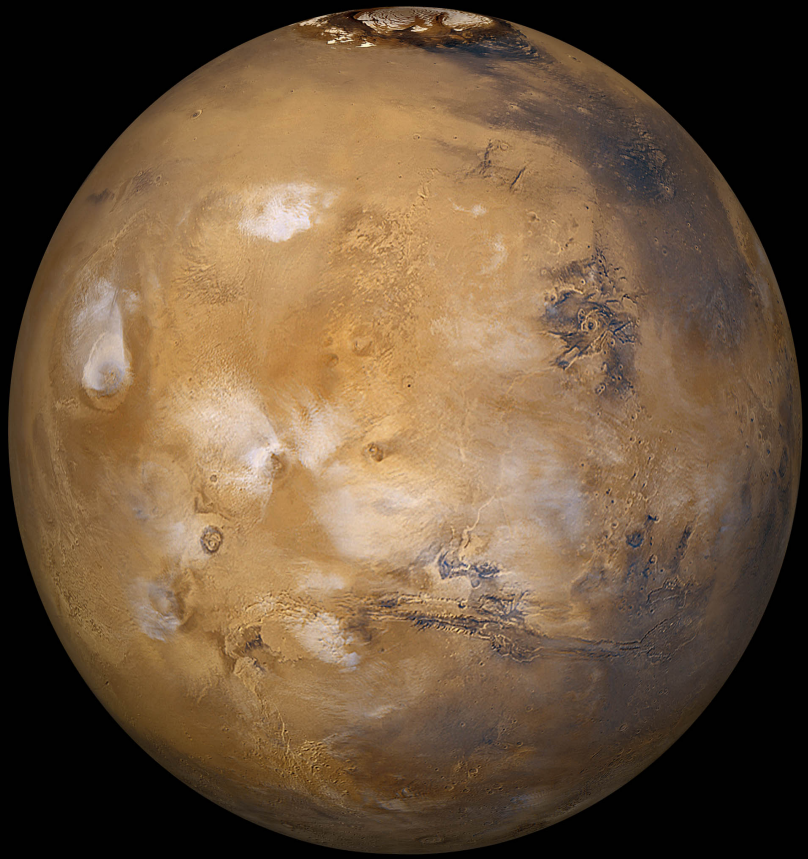
Observations de pression Viking

Chaque point est une moyenne sur une journée

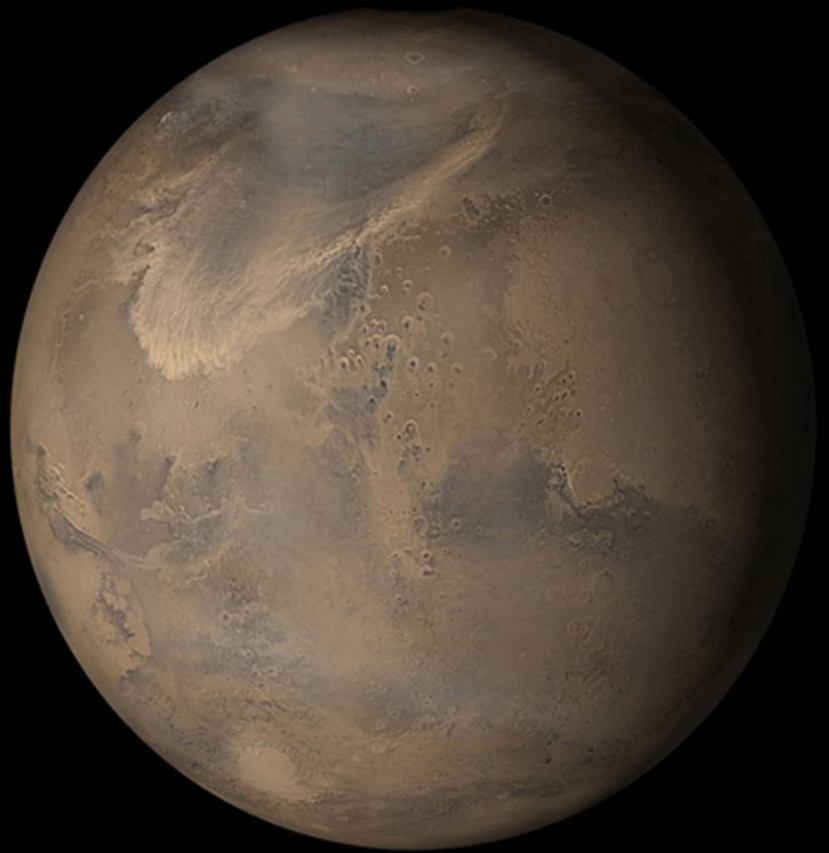


[emprunté au site PlanetTerre, d'après Hess et al., JGR 1981]

Cycle du CO_2, des poussières et de l'eau



[Image MOC pendant l'été nord]



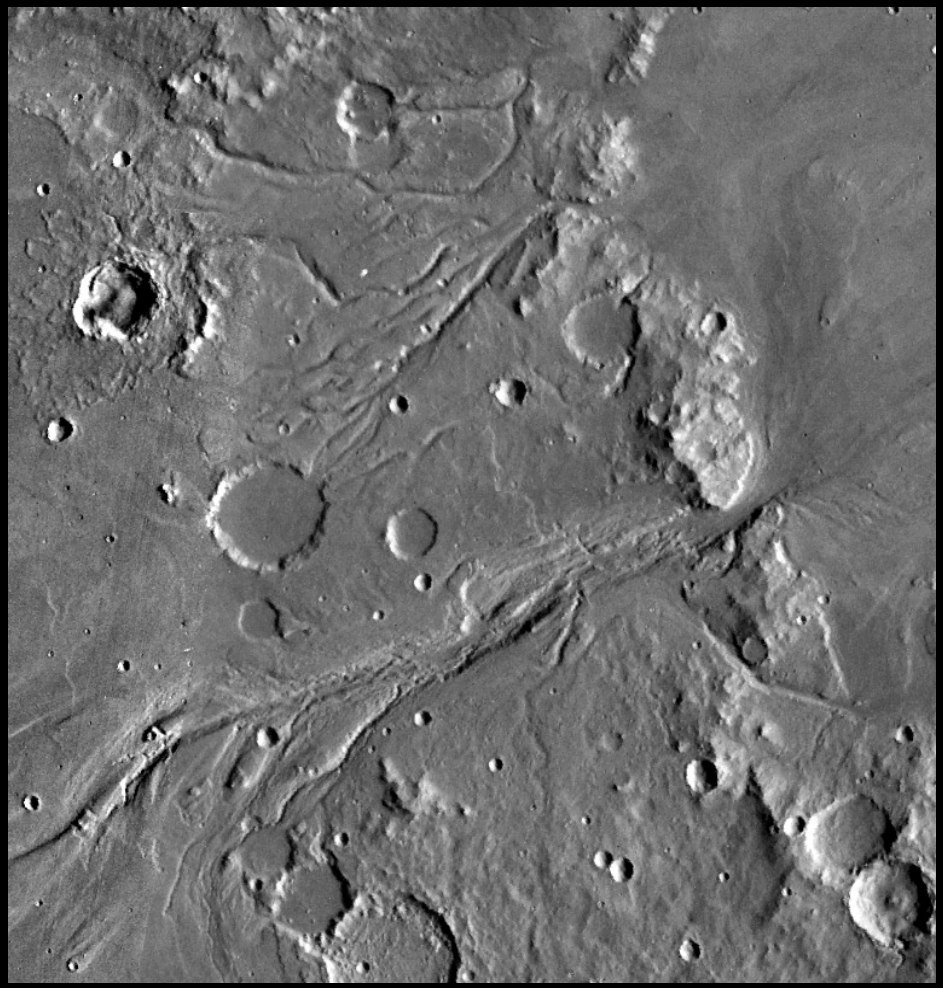
[Image MOC à la fin de l'hiver nord]

The northern polar cap on Mars

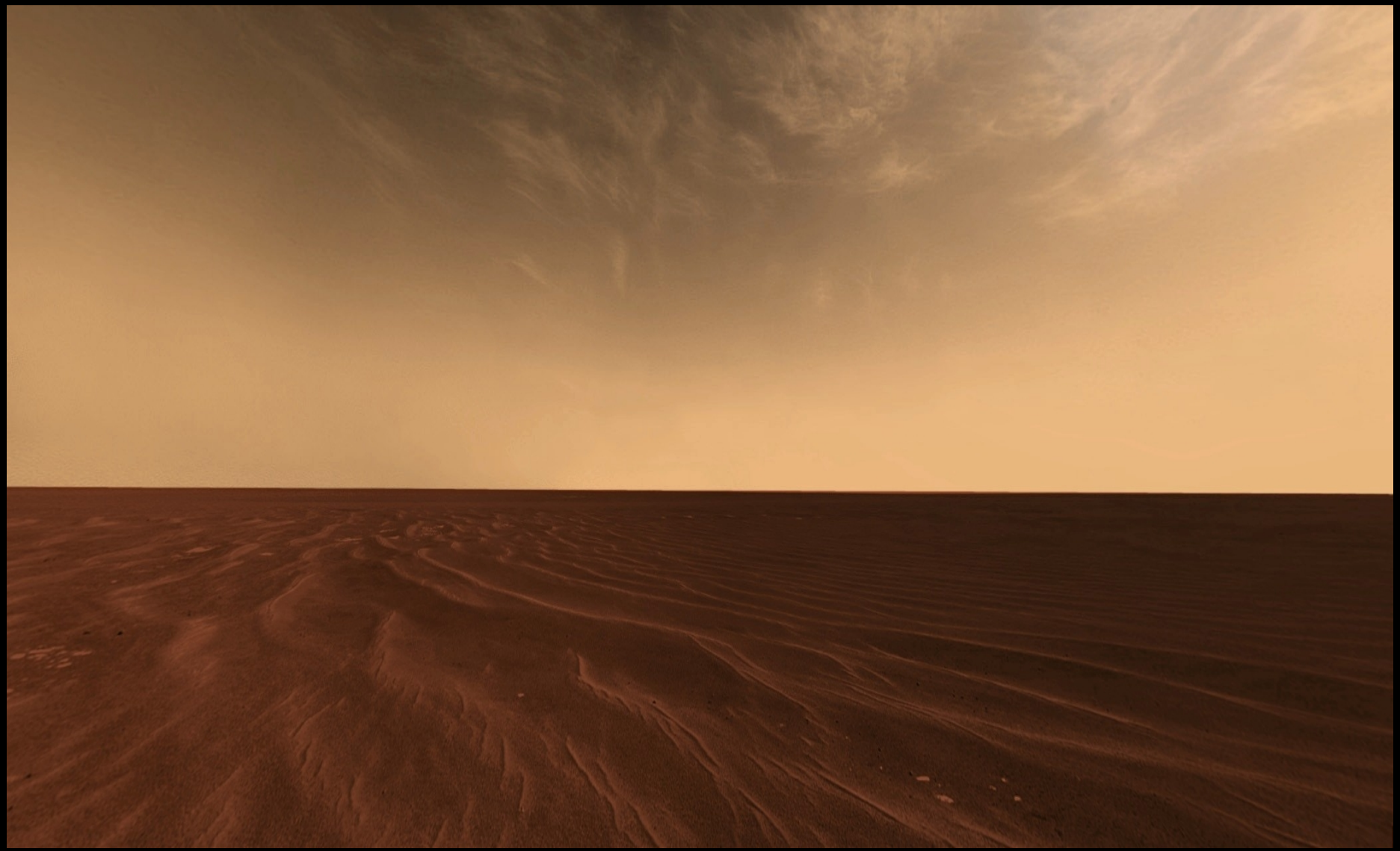
Mars: structures fluviales

Valley network, Parana Valles

Outflow channel, Mariner 9



The Martian environment



[Pancam on Opportunity Rover]

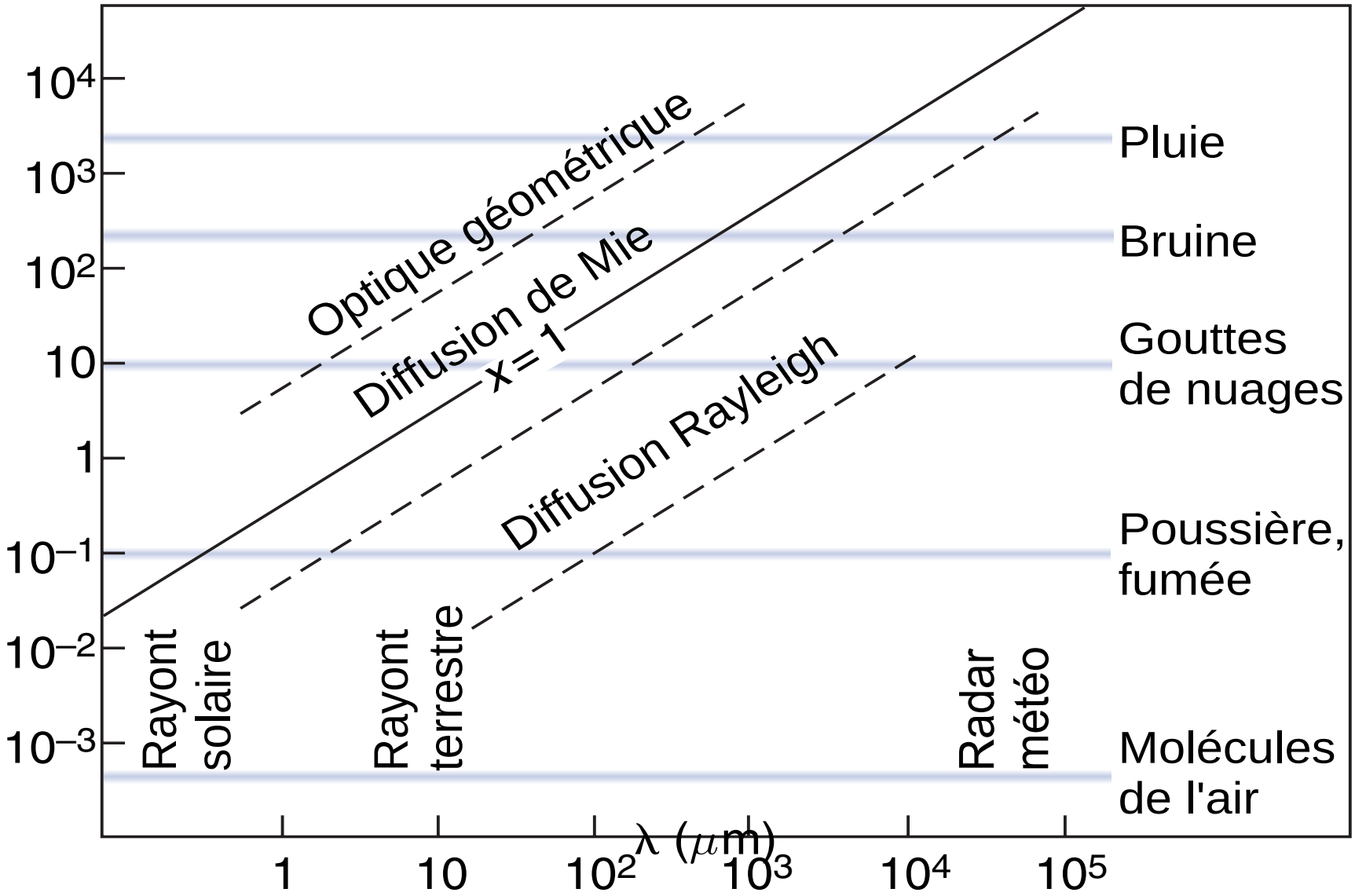
Préambule australien

[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

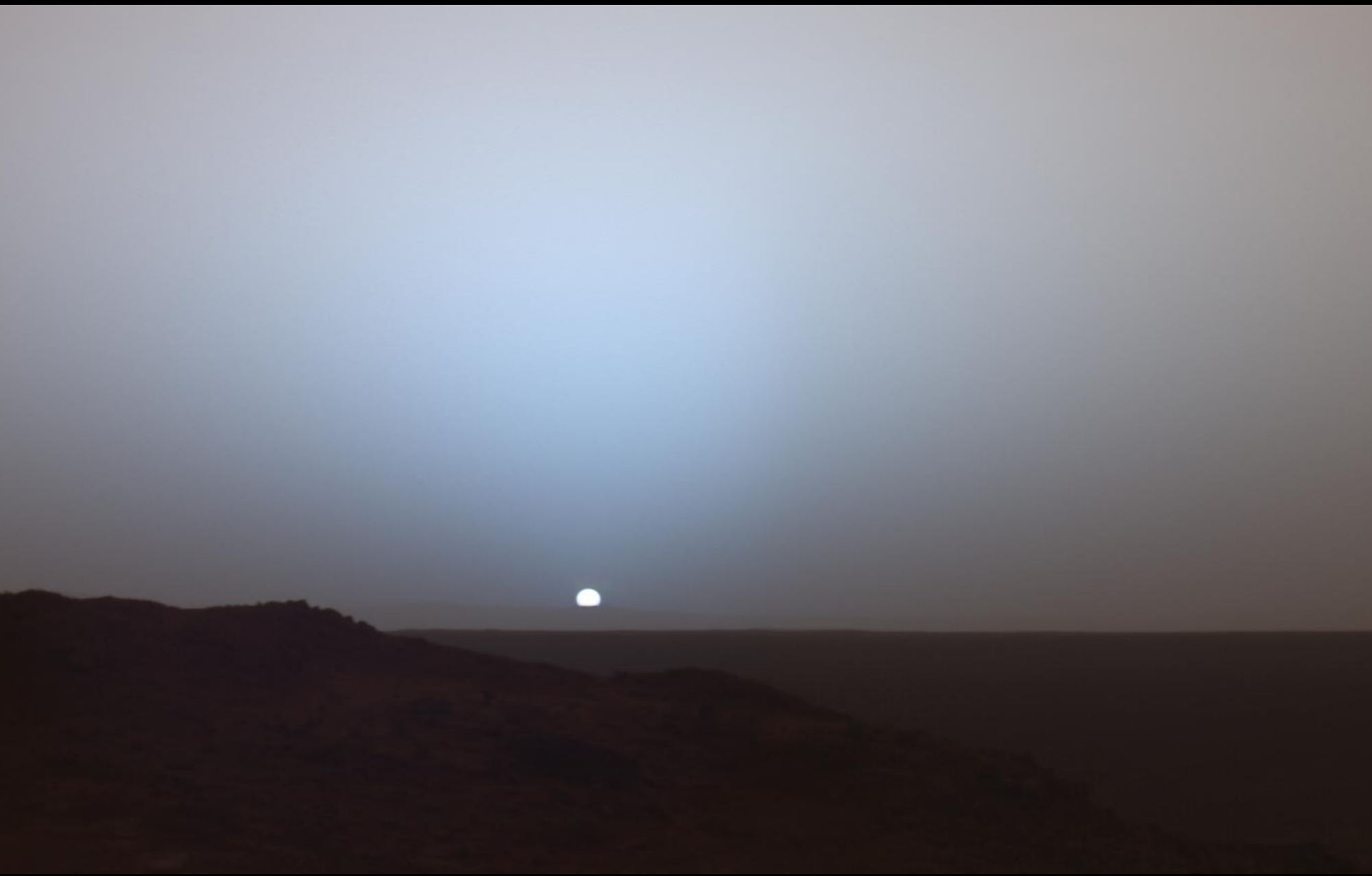


[Figure adaptée de Wallace and Hobbs, Atmospheric Science, 2006.]

Coucher de soleil martien

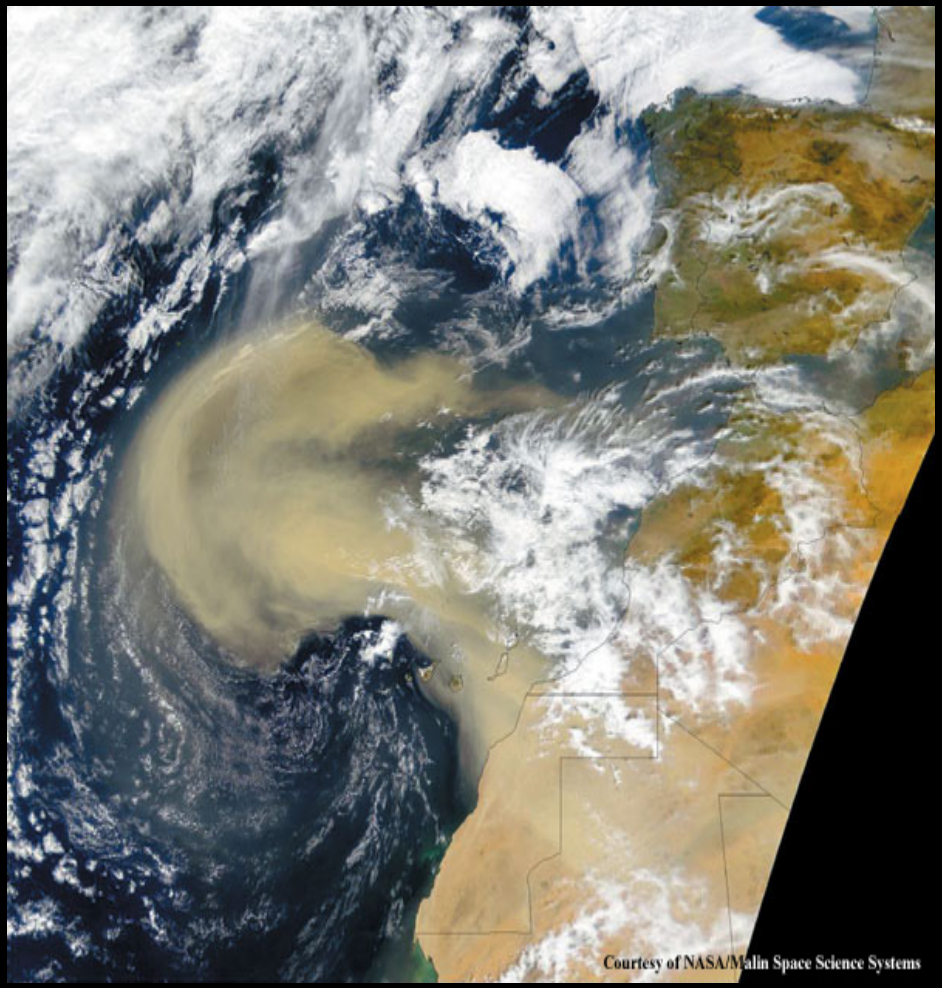
[Image par Pancam à bord de Spirit 2005 (référence PIA07997)]

Coucher de soleil martien



Tempêtes de poussière

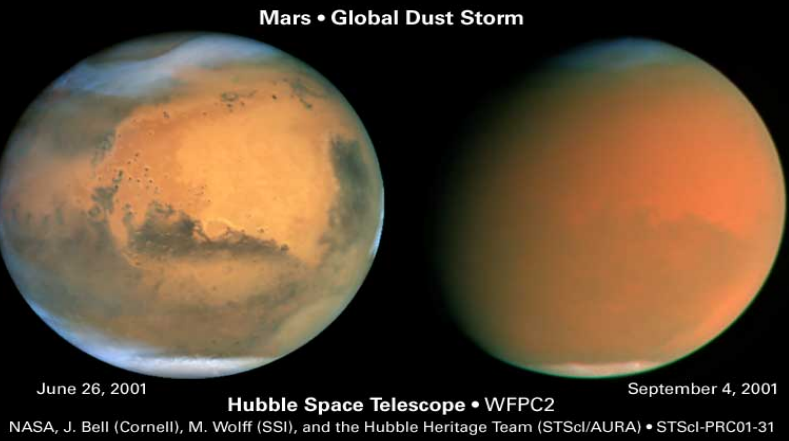
Terre

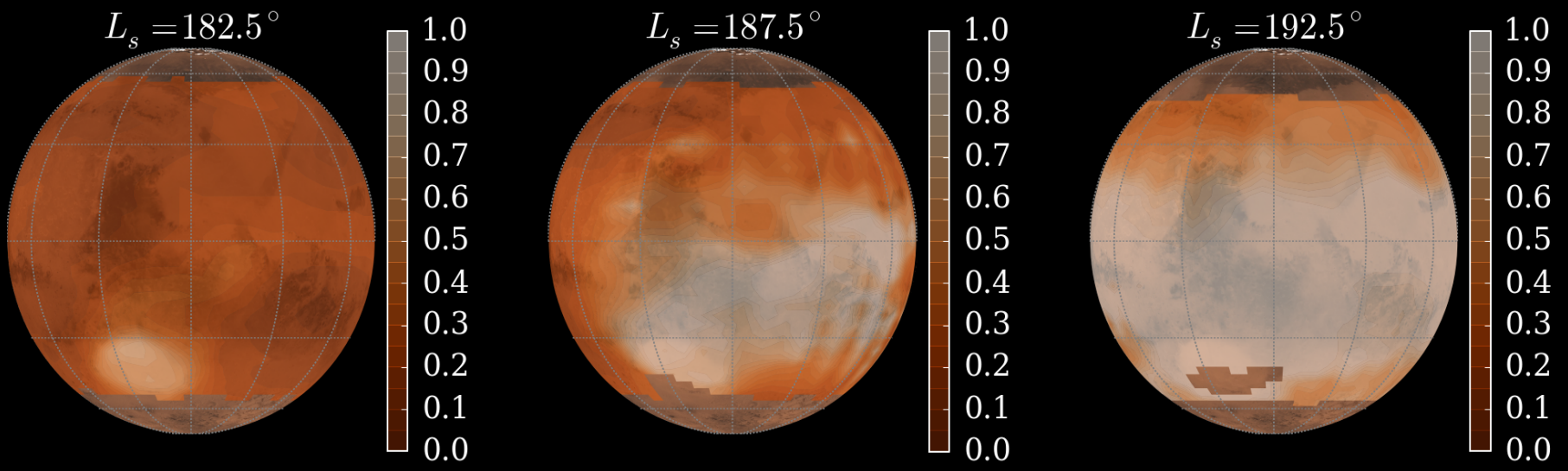


Mars

[Référence image PIA02807]

The onset of the MY25 global dust storm





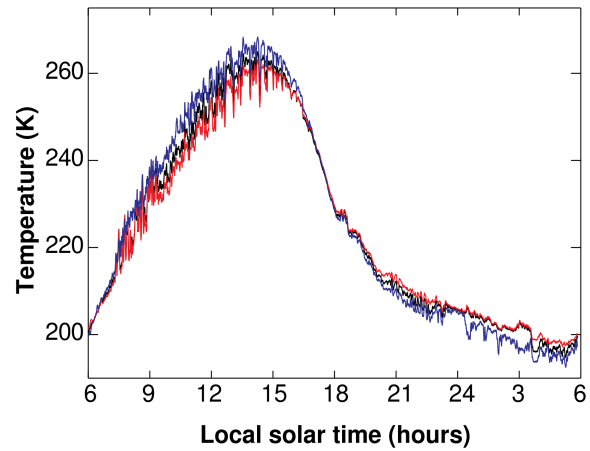
[Made after Thermal Emission Spectrometer by Smith et al. 2001]

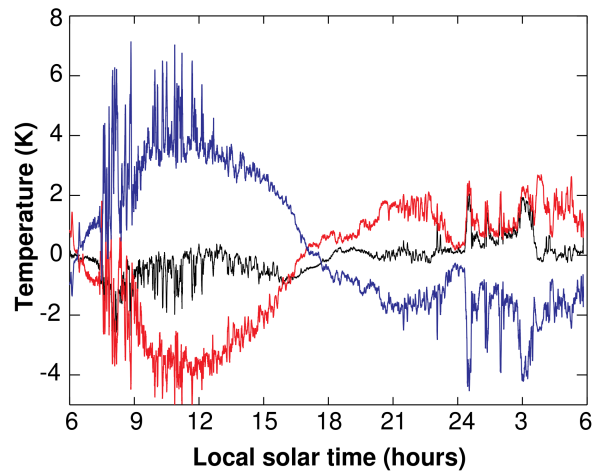
Near-surface temperature on Mars

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

Meteorological mast

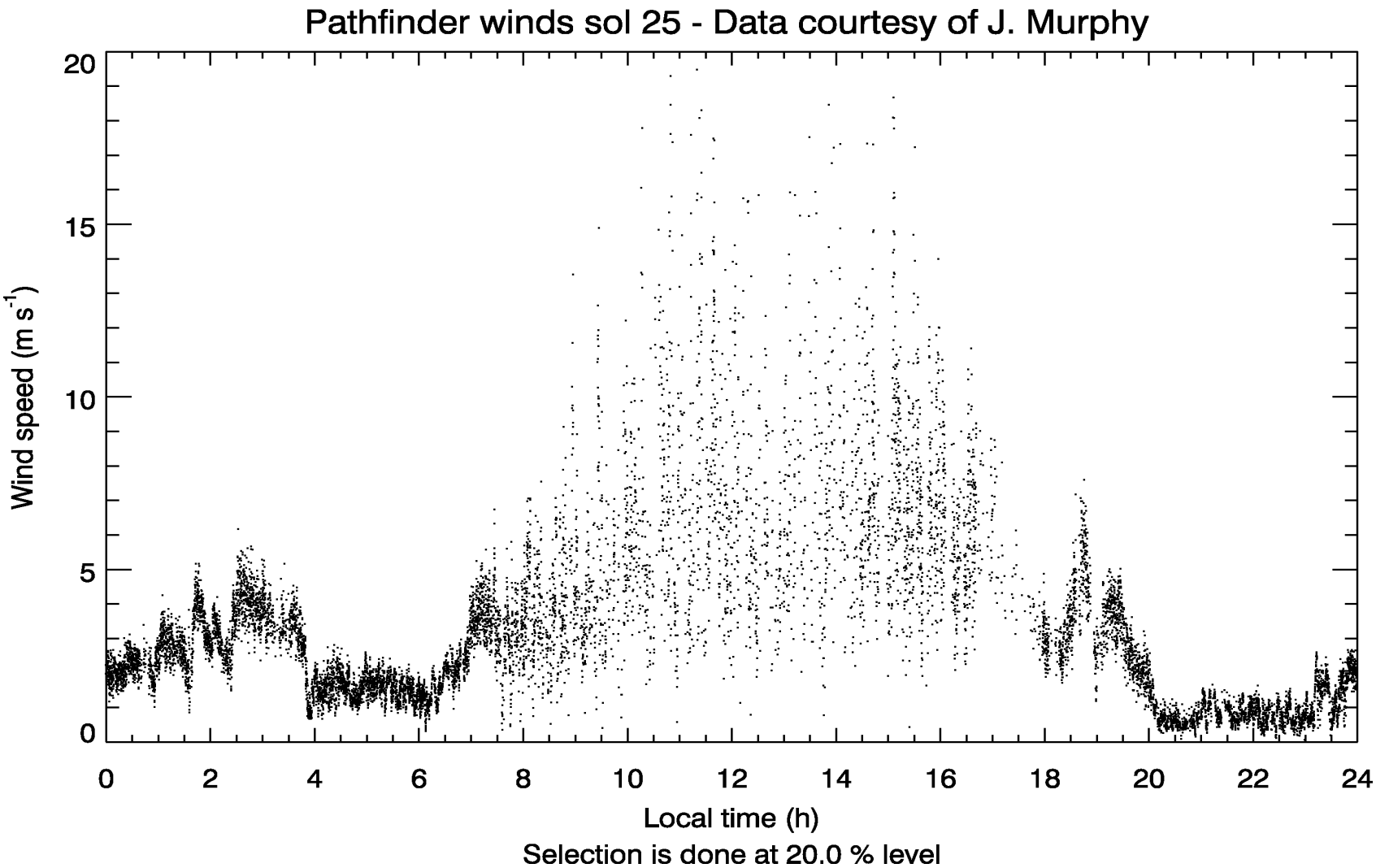
Measured at 100, 50, 25 cm





[Schofield et al., 1997]

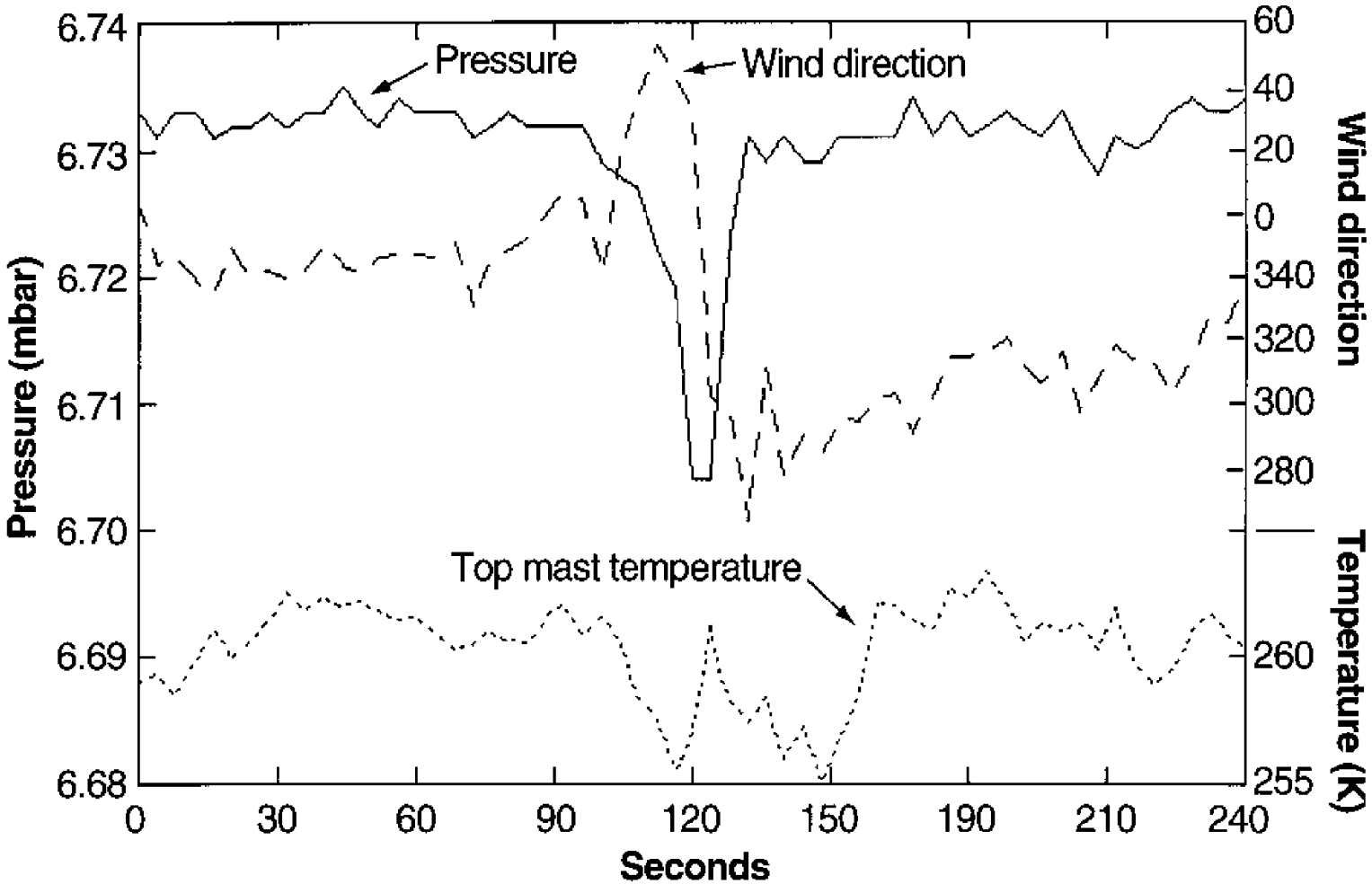
Near-surface wind observations on Mars



[J. Murphy, unpublished]

Meteorological perturbations caused by a dust devil

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

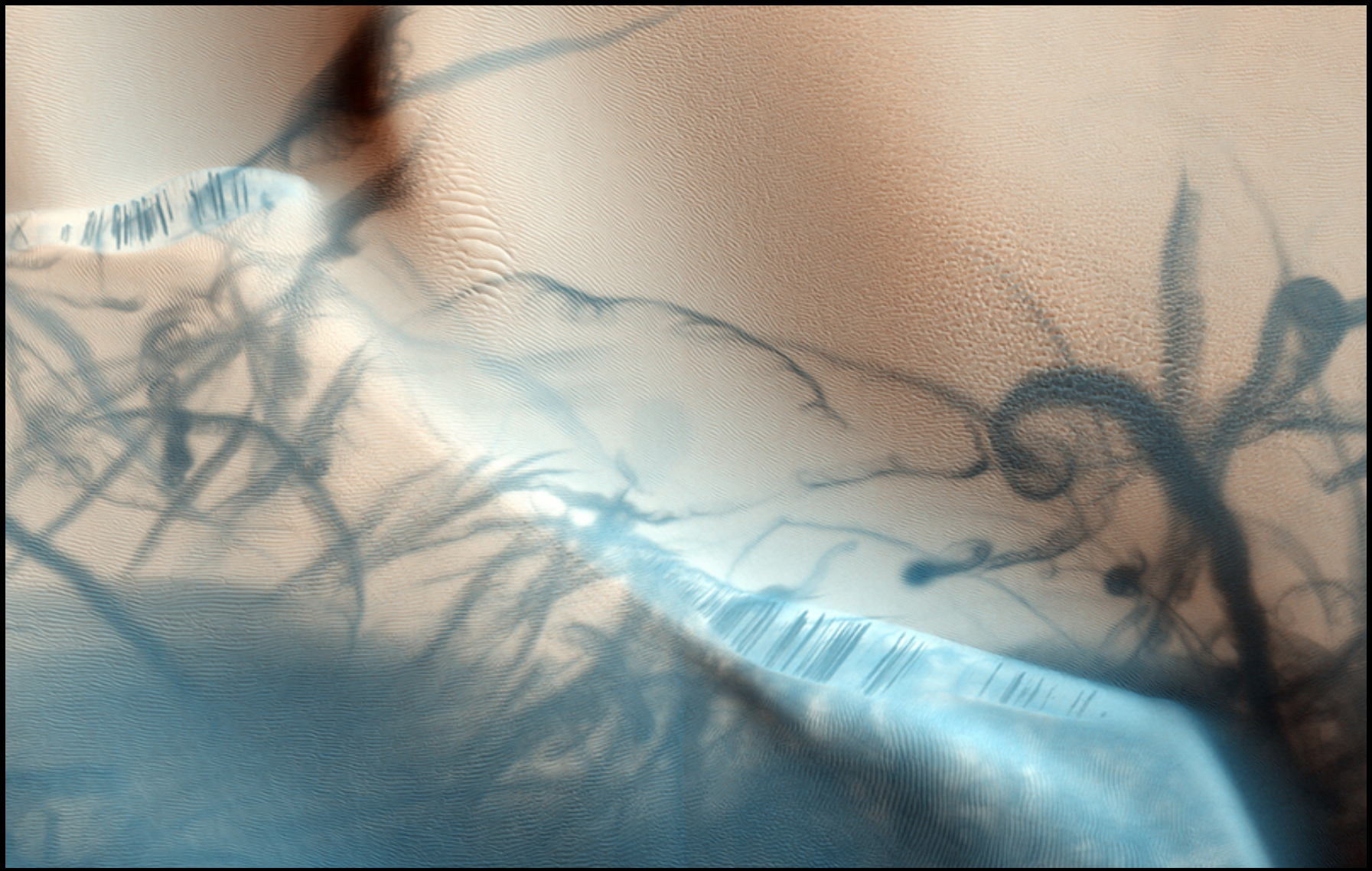


[Schofield et al. Science 1997]

A 800m-tall Martian dust devil

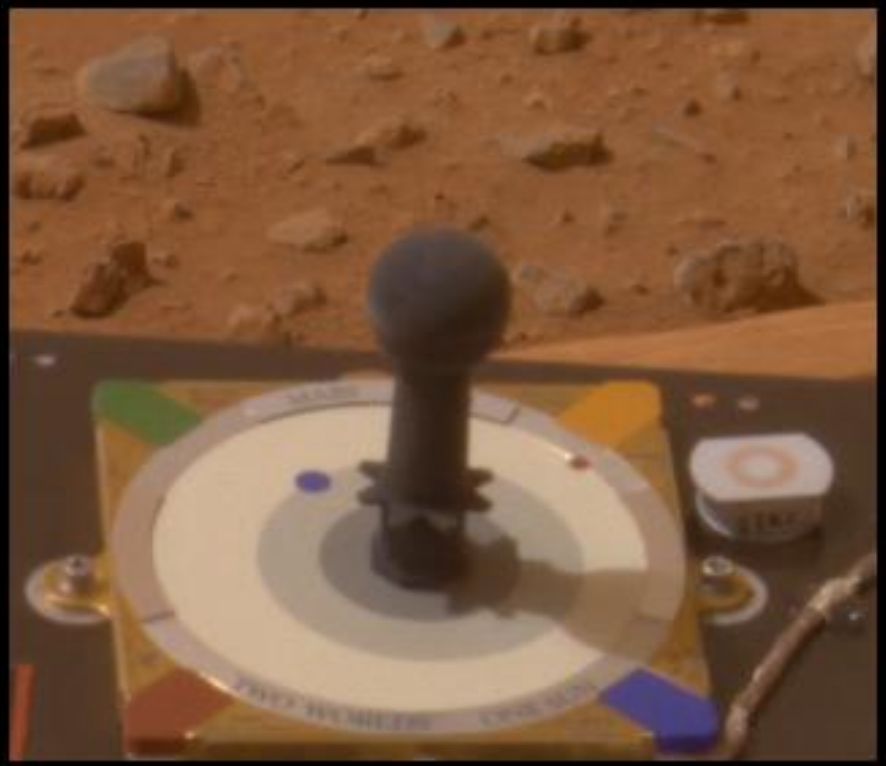
[HiRISE image, Feb. 2012, 35.8N 207E, credits NASA/JPL-Caltech/University of Arizona]

Graffitis martiens ! Champ de dunes Arabia Terra



[HiRISE, Mars Reconnaissance Orbiter, 2009]

Le cycle des poussières sur Mars : Accumulation

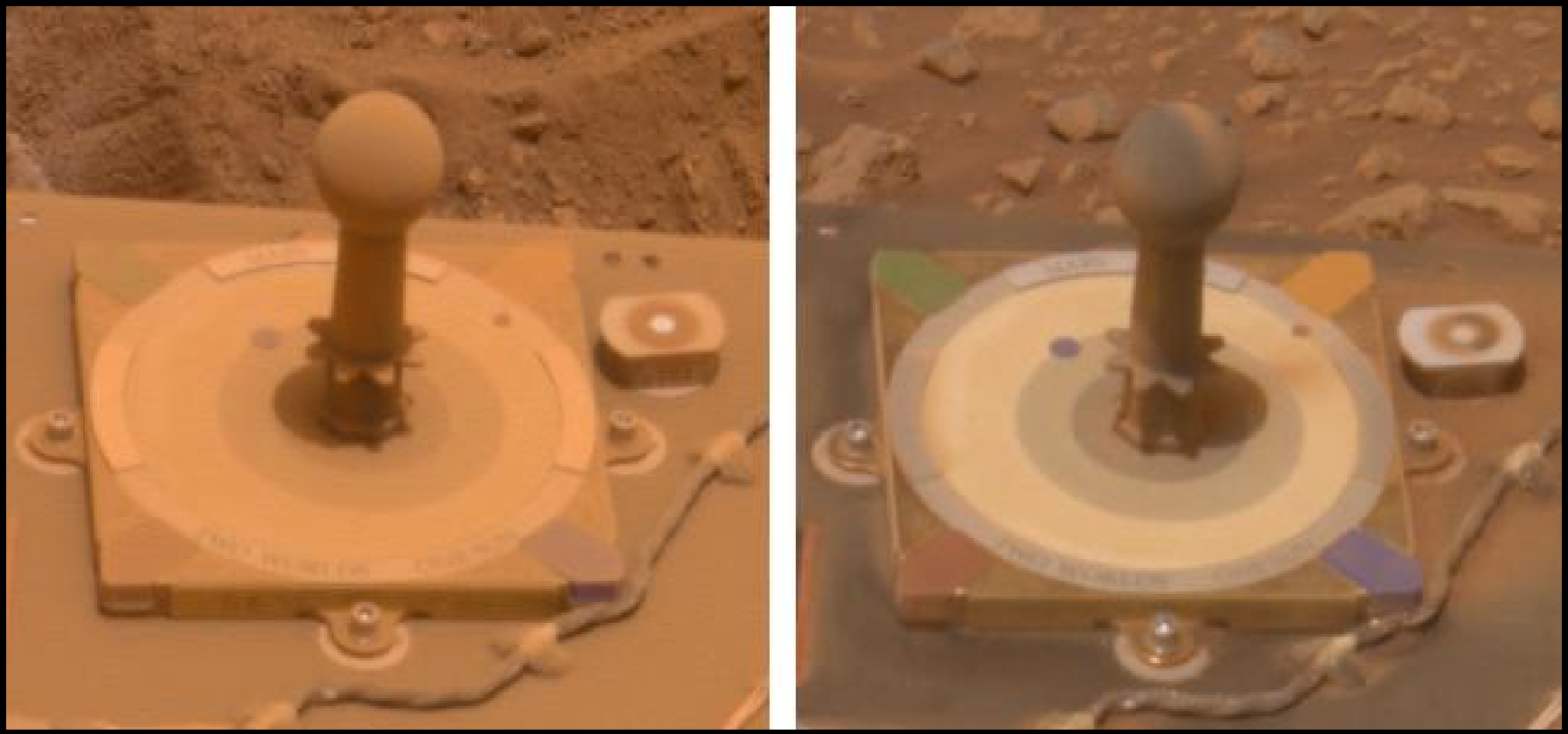


Spirit sol 9 (Jan. 11, 2004)

Spirit sol 357 (Jan. 3, 2005)

[Pancam on Spirit rover PIA07303]

Nettoyage du rover Spirit ! Images prises à 10 jours d'intervalle

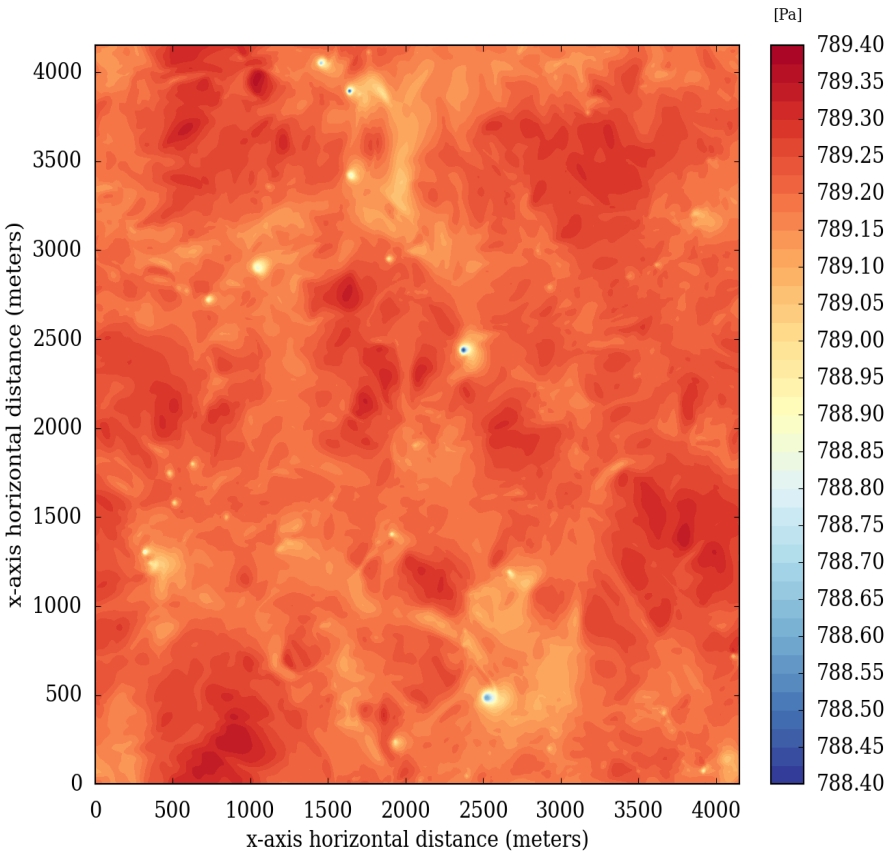


[Pancam on Spirit rover PIA07492]

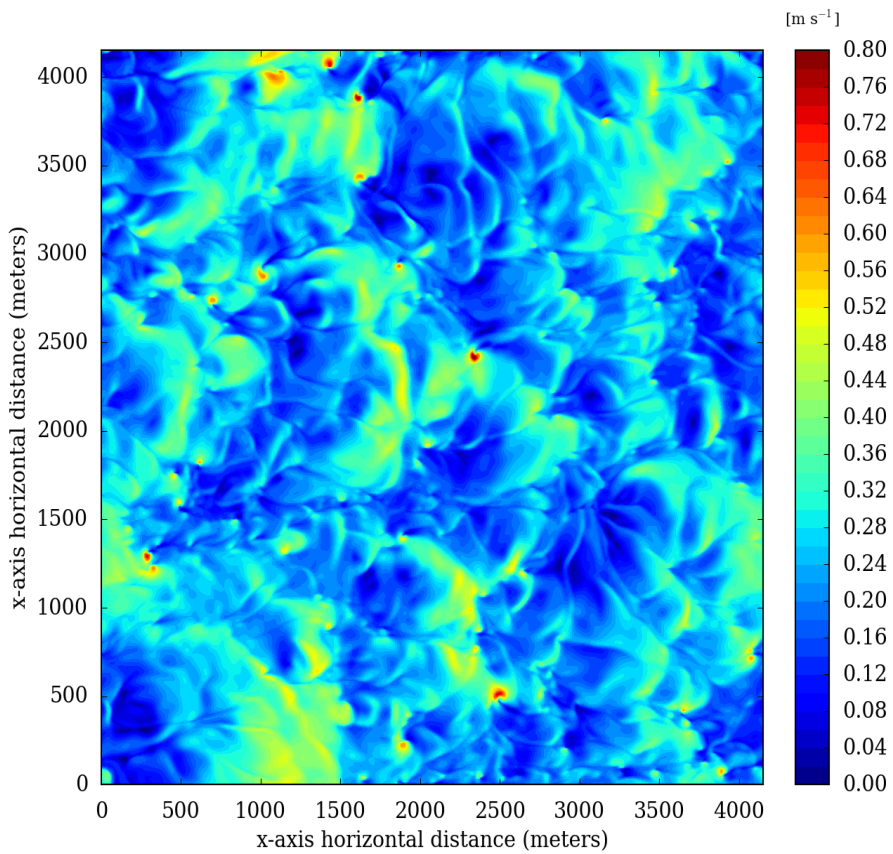
Large-Eddy Simulations for Insight

horizontal resolution 10 m, results at local time 9AM

Surface pressure

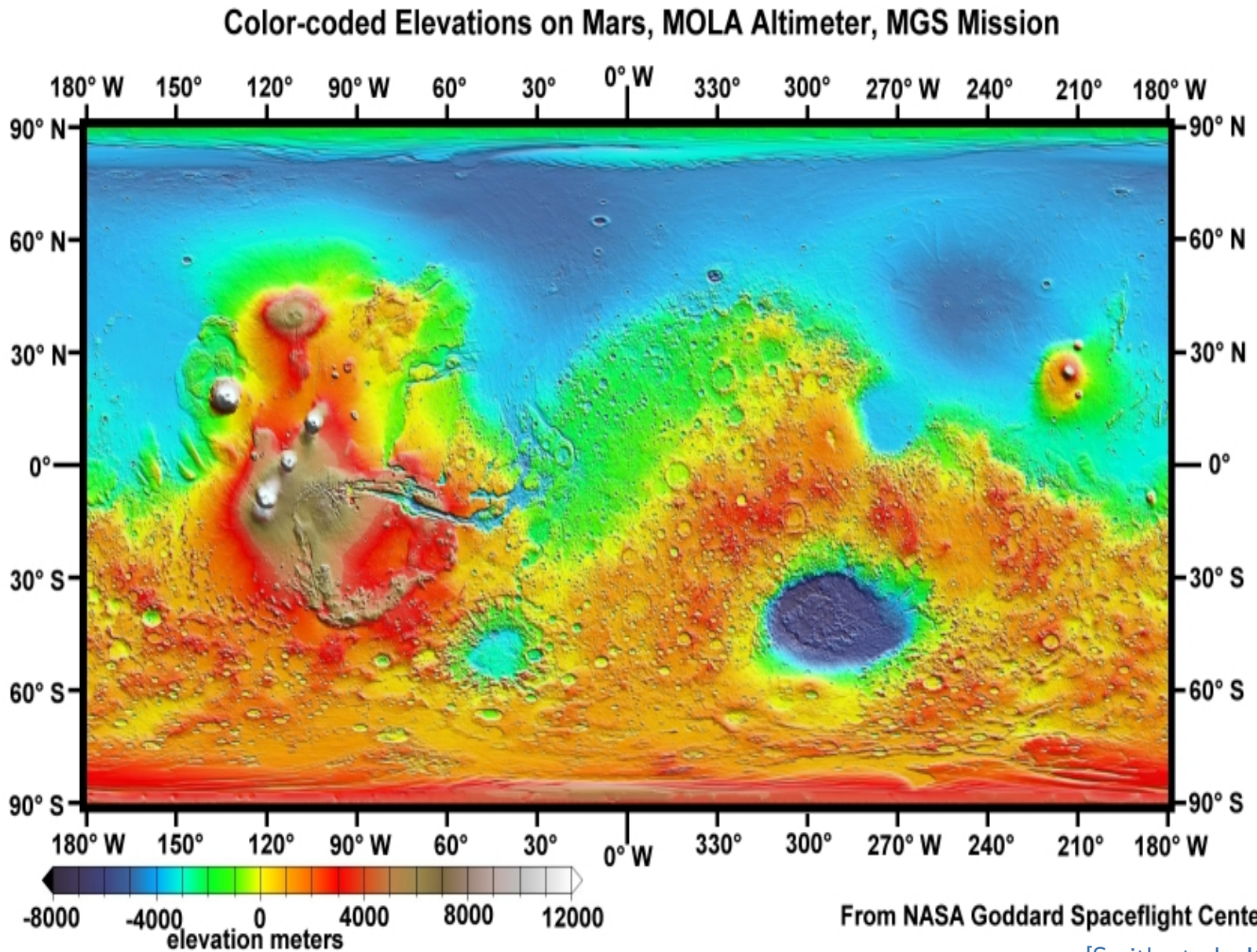


Friction velocity



[Spiga et al. Space Science Reviews 2018]

Mars' topography by the MOLA altimeter

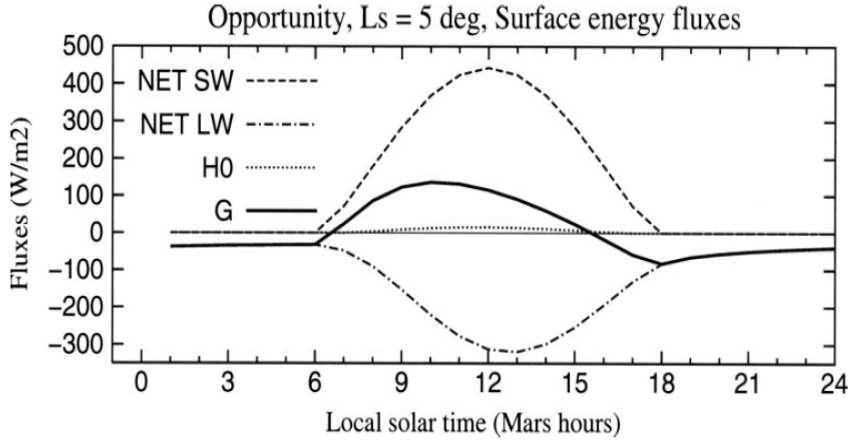


[Smith et al. JGR 2001]

Energy budget for Martian surface

Surface energy budget

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



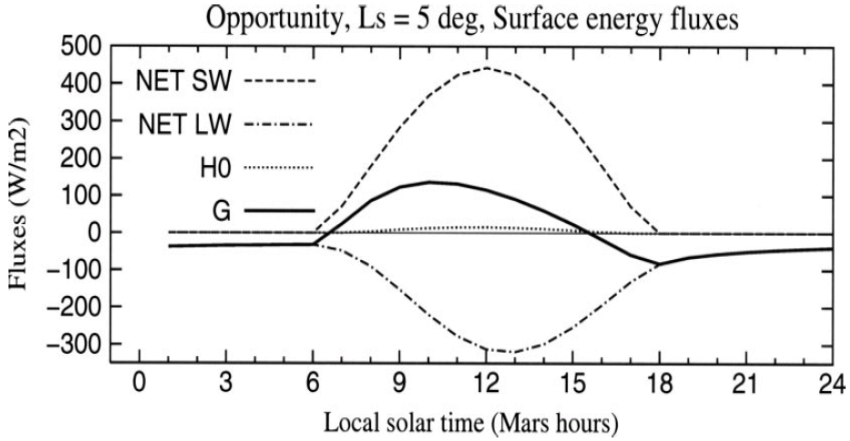
[Savijärvi and Kauhanen, QJRMS 2008]

Energy budget for Martian surface

Surface energy budget

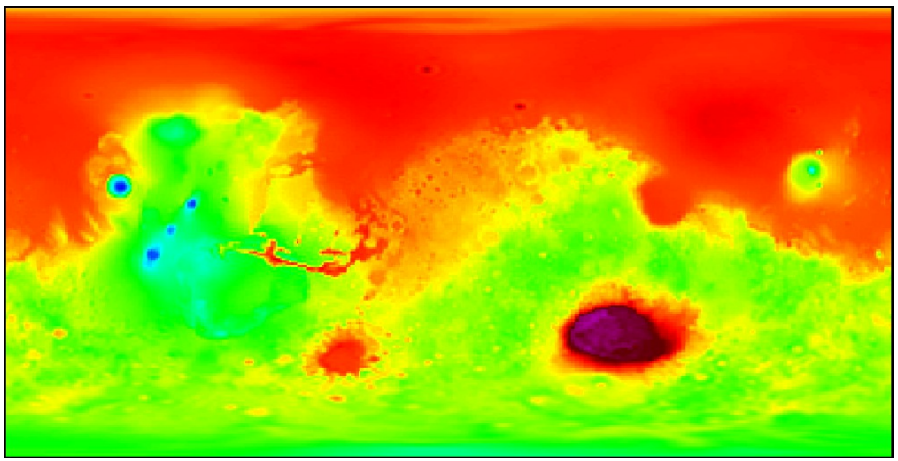
$$F_{LW} + F_{SW} = G + H_s + LE$$

$\rightarrow$ radiative equilibrium

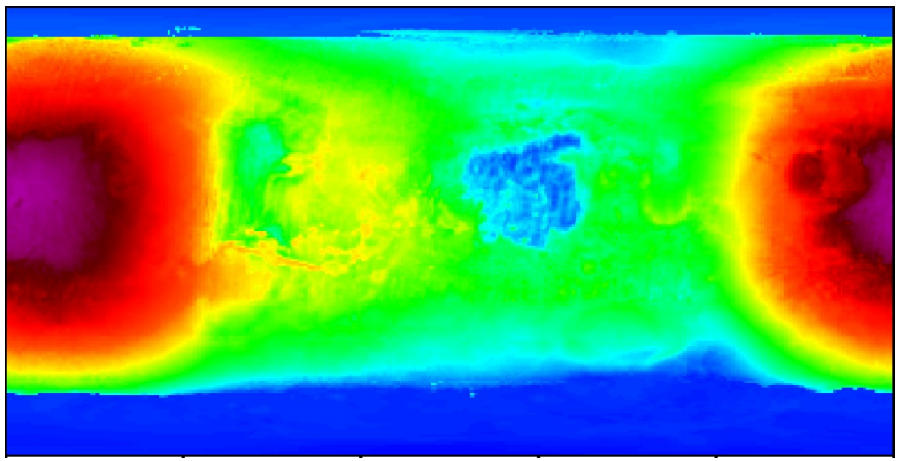


[Savijärvi and Kauhanen, QJRMS 2008]

Topography



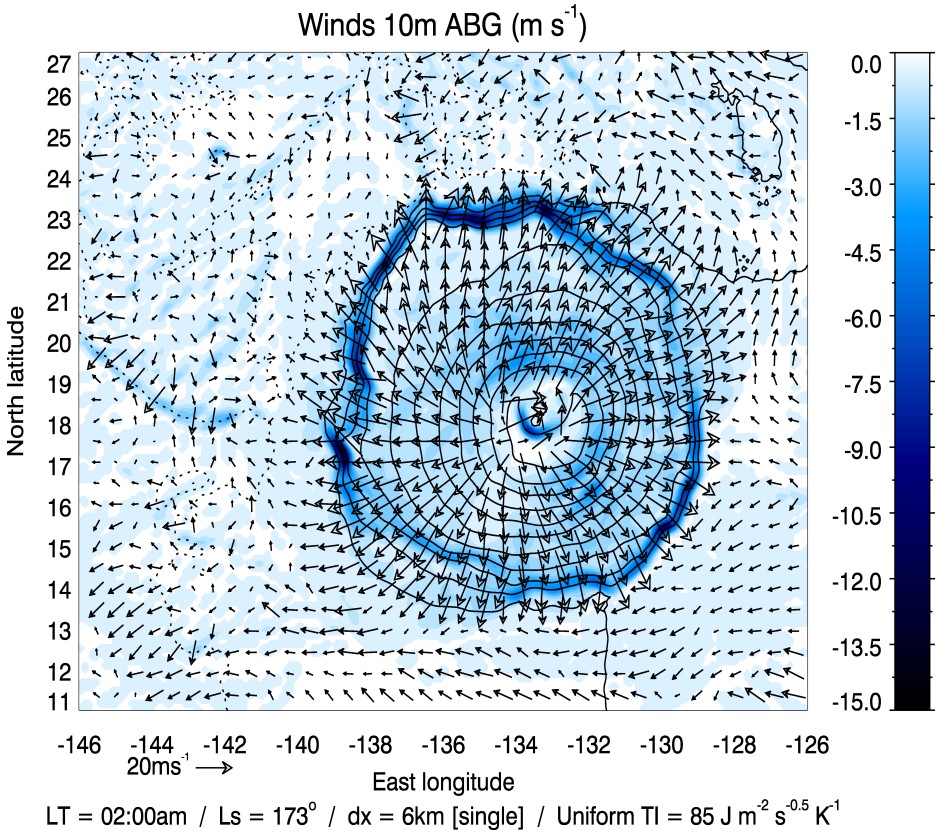
Surface temperature



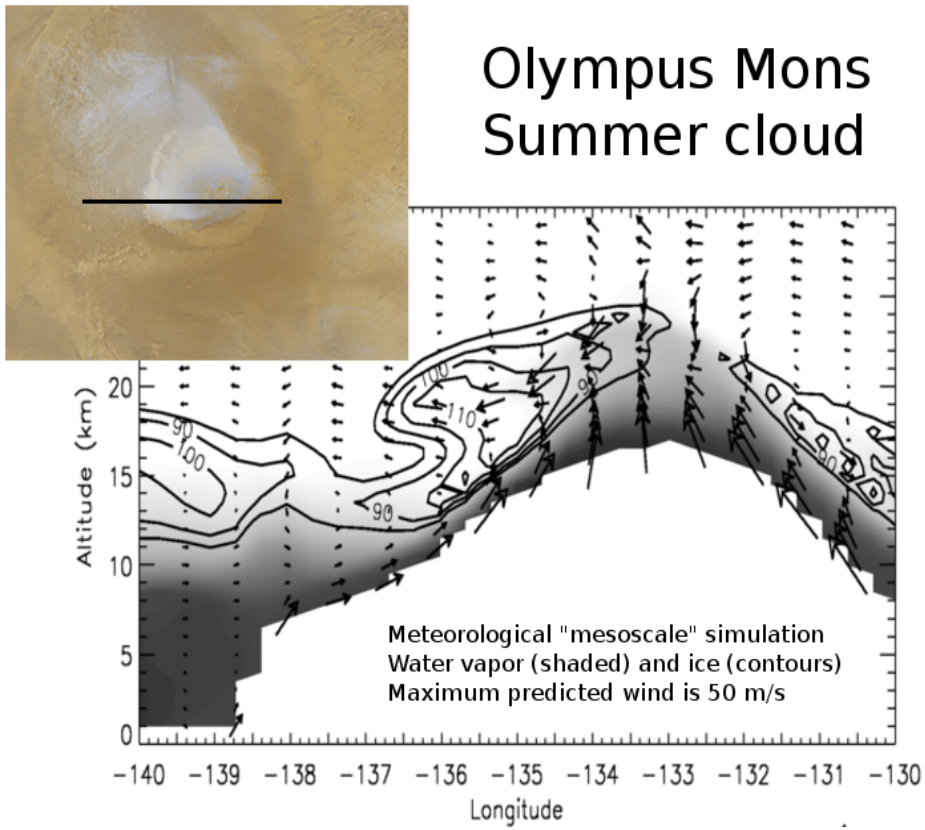
[outputs from the UK Mars GCM]

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

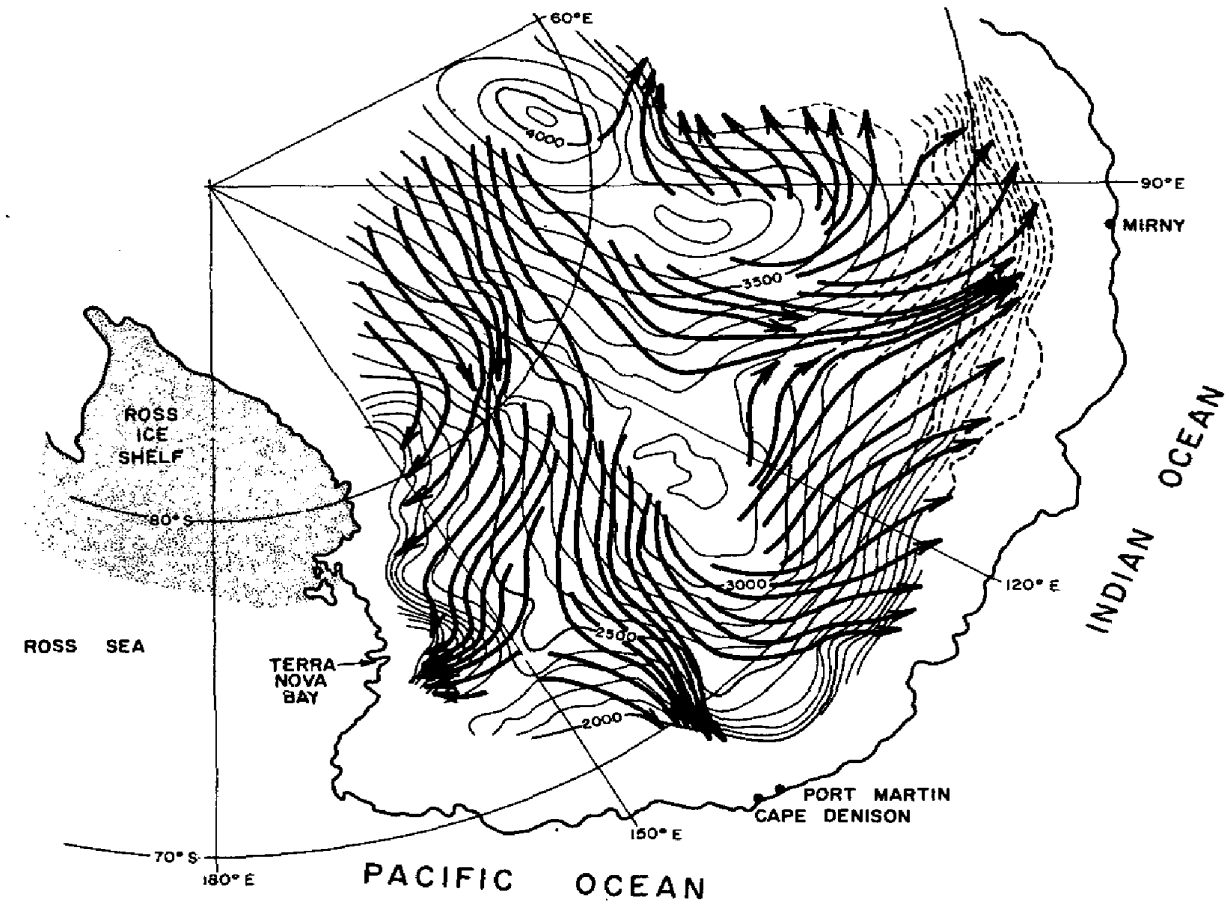
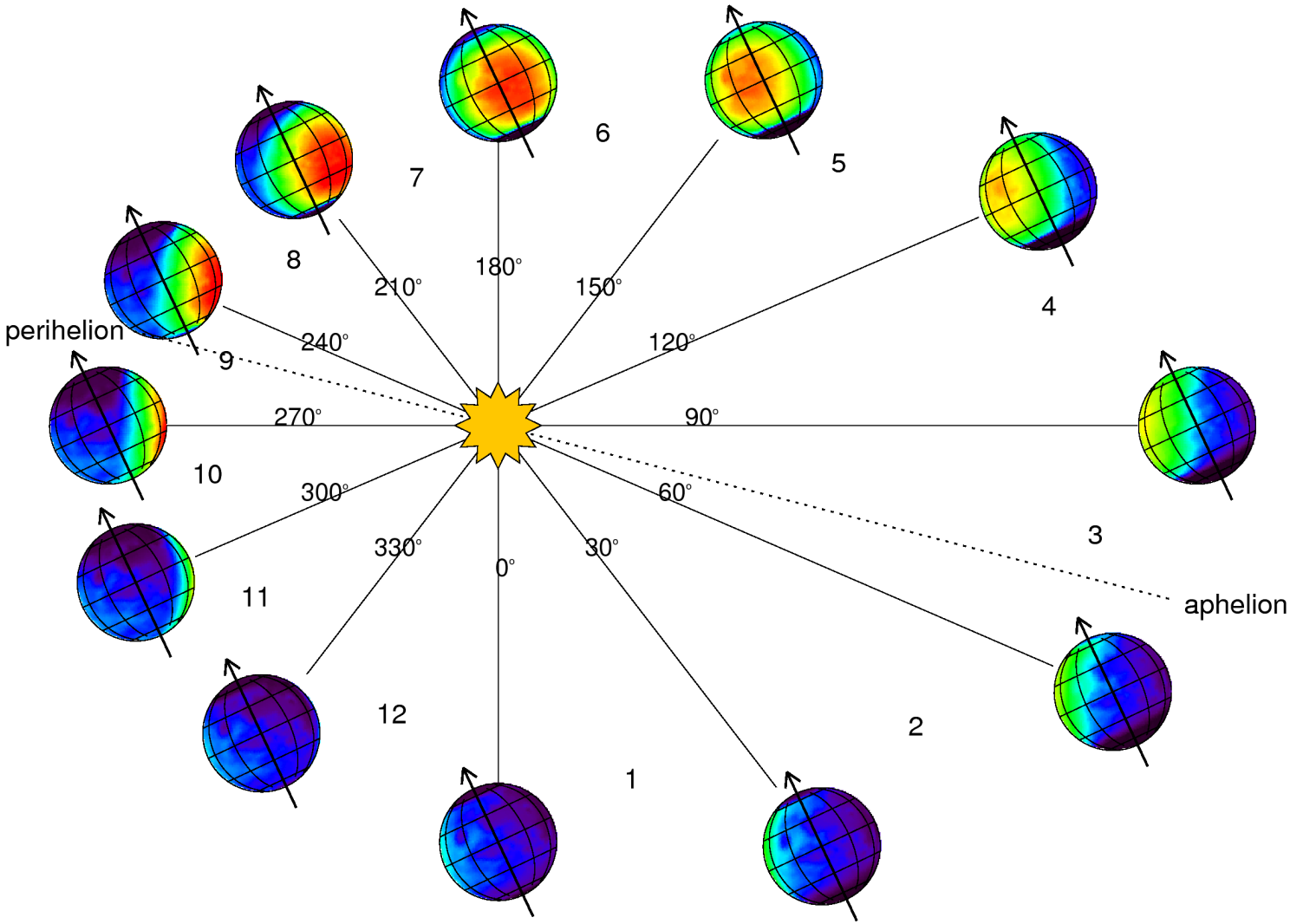


FIG. 2. Time-averaged winter flow pattern over the surface of the Antarctic based on model wind calculations of Parish (1982).

[Parish et al., 1983]

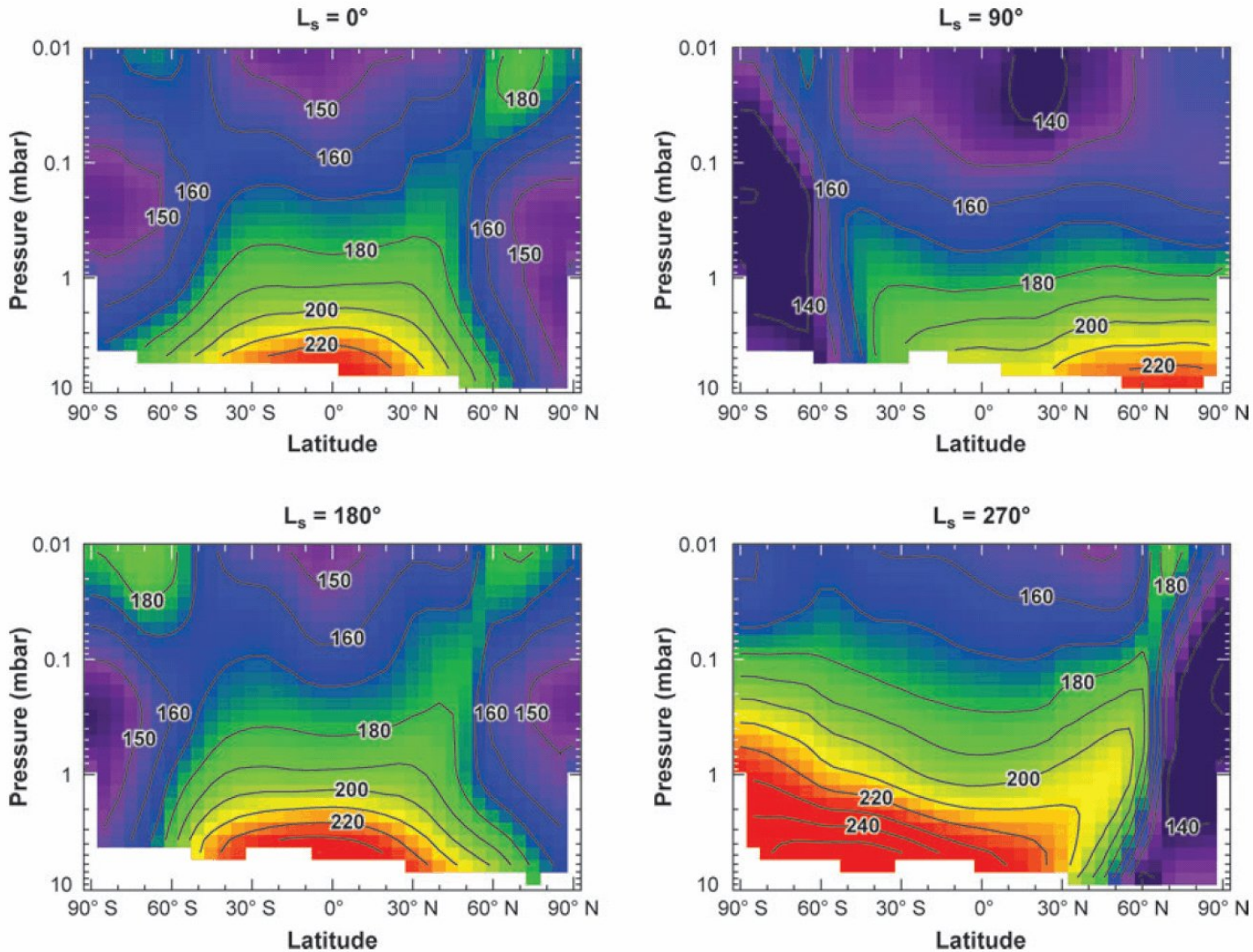
Saisons martiennes



[Read and Lewis, 2004]

Saisons martiennes

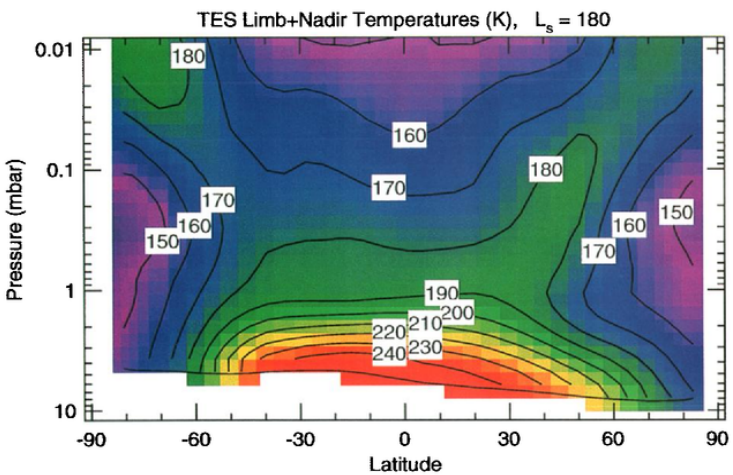
Structure thermique obtenue par spectrométrie IR



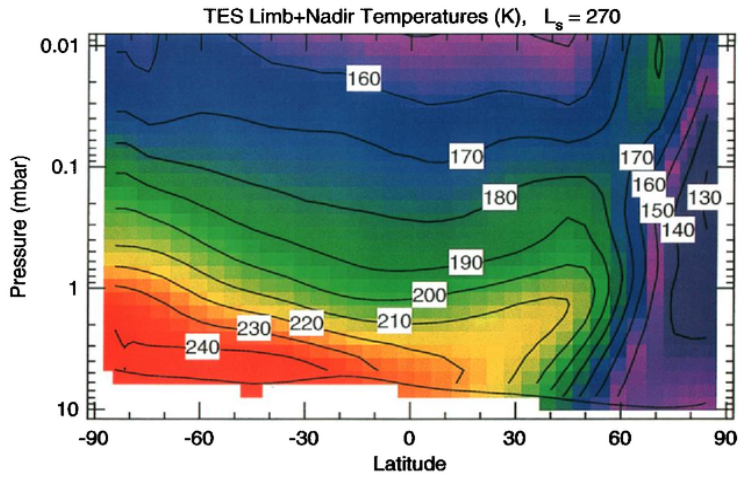
[Smith, 2008]

Equilibre du vent thermique sur Mars : Exploitation

Printemps Sud

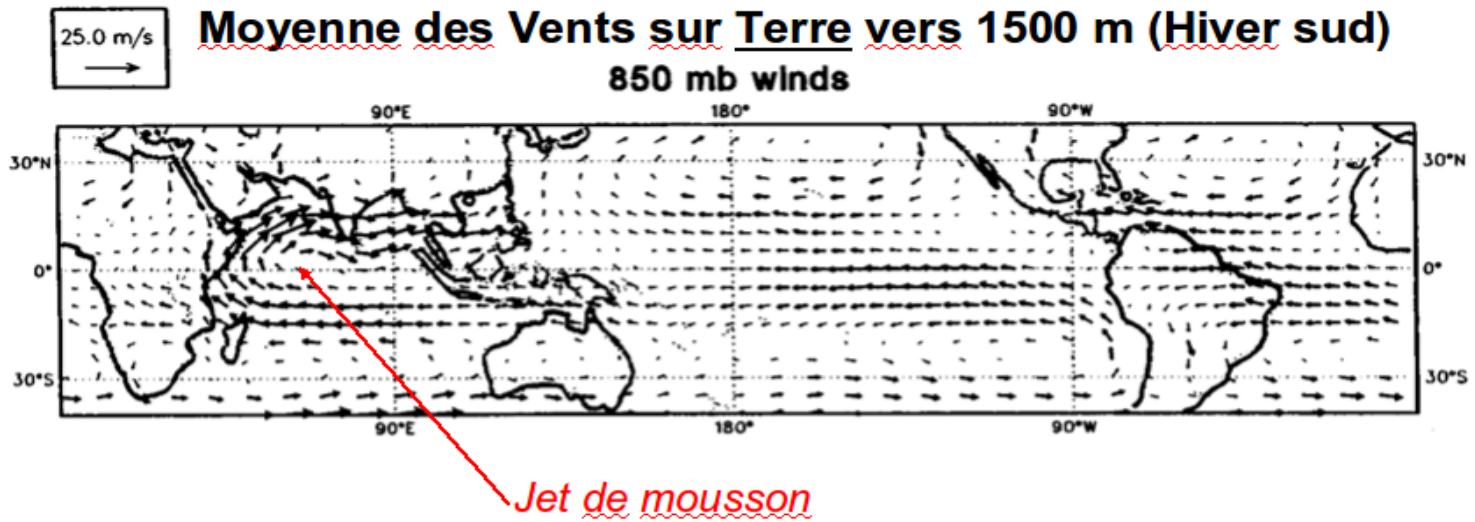


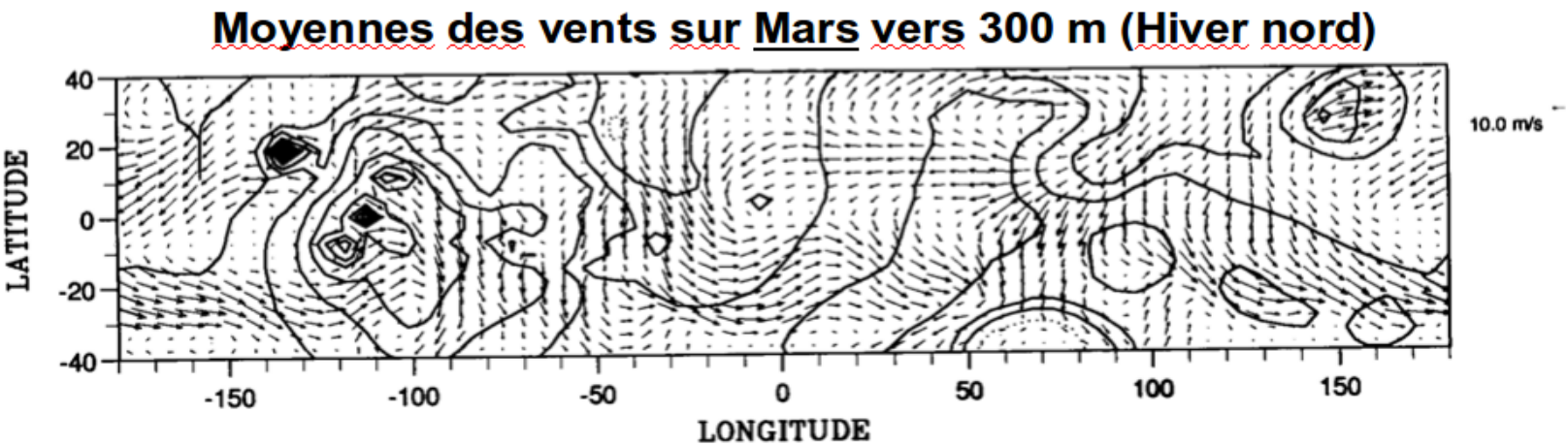
Eté Sud



[Smith et al., 2001]

Vents de mousson et courants de bord ouest

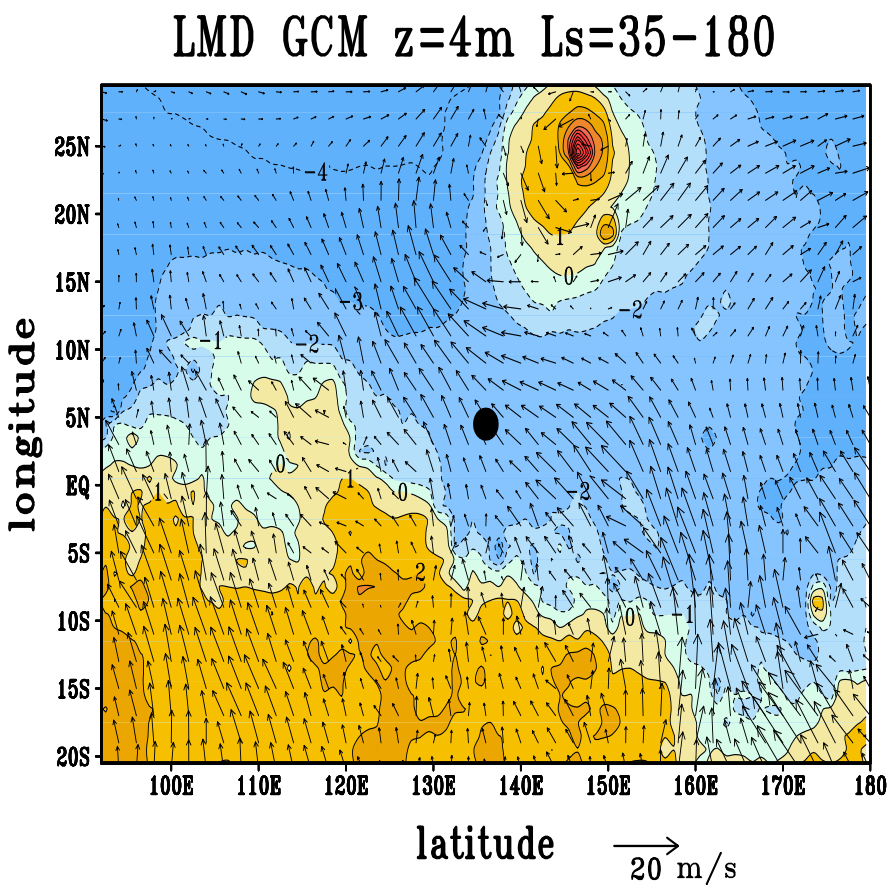




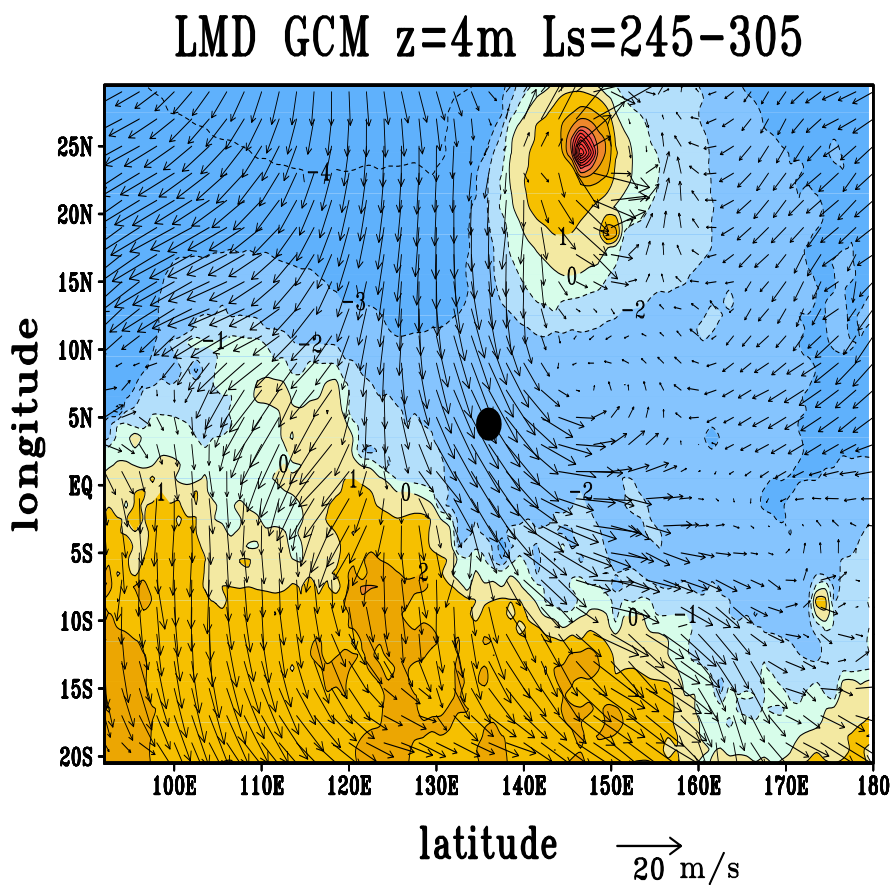
[Transparent F. Forget]

Large-scale wind regimes at InSight landing site

spring-summer $\mathcal{R}_1$



fall-winter $\mathcal{R}_2$



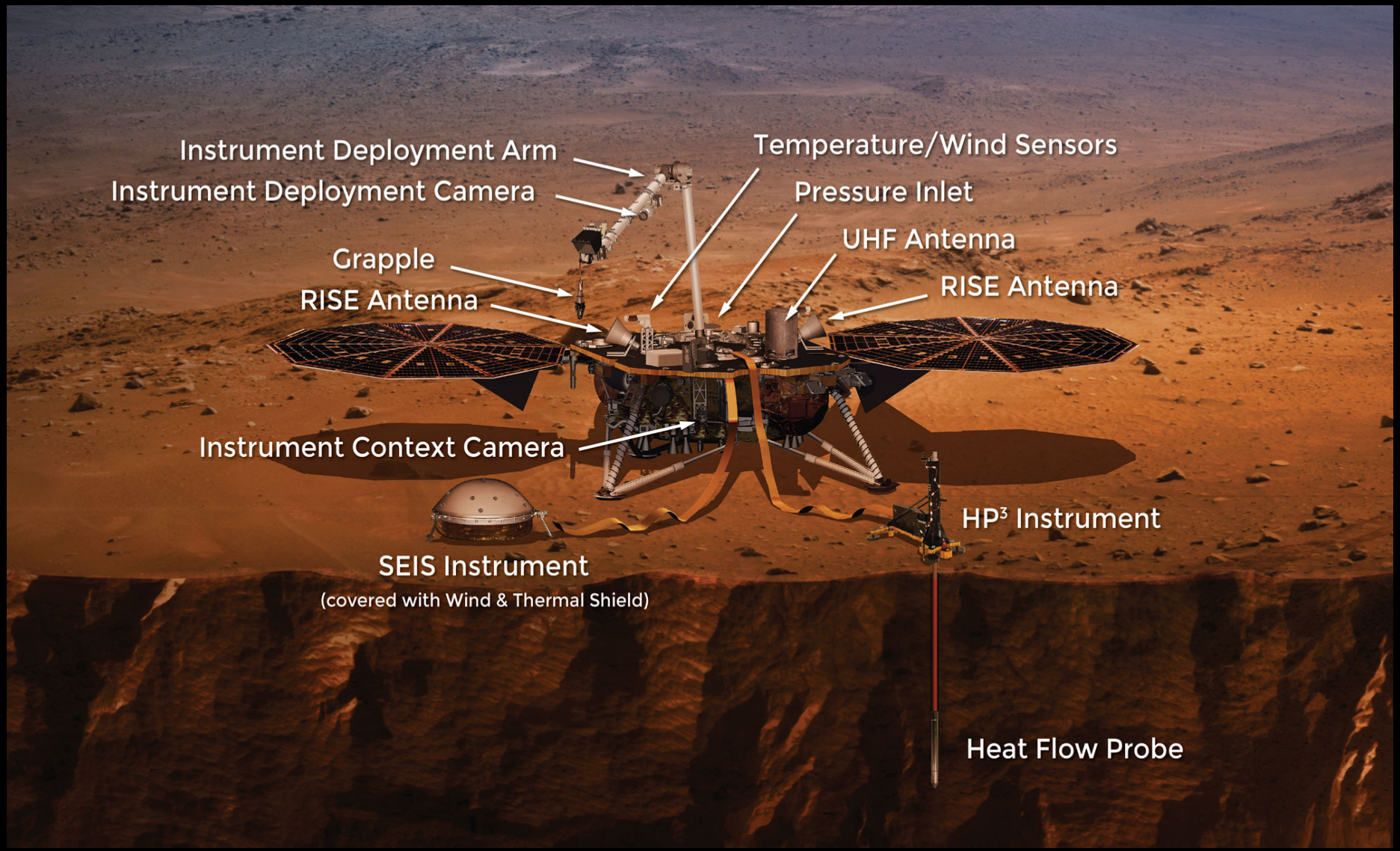
[Spiga et al. Space Science Reviews 2018; from Pottier et al. Icarus 2017 GCM simulations]

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

Outline

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.

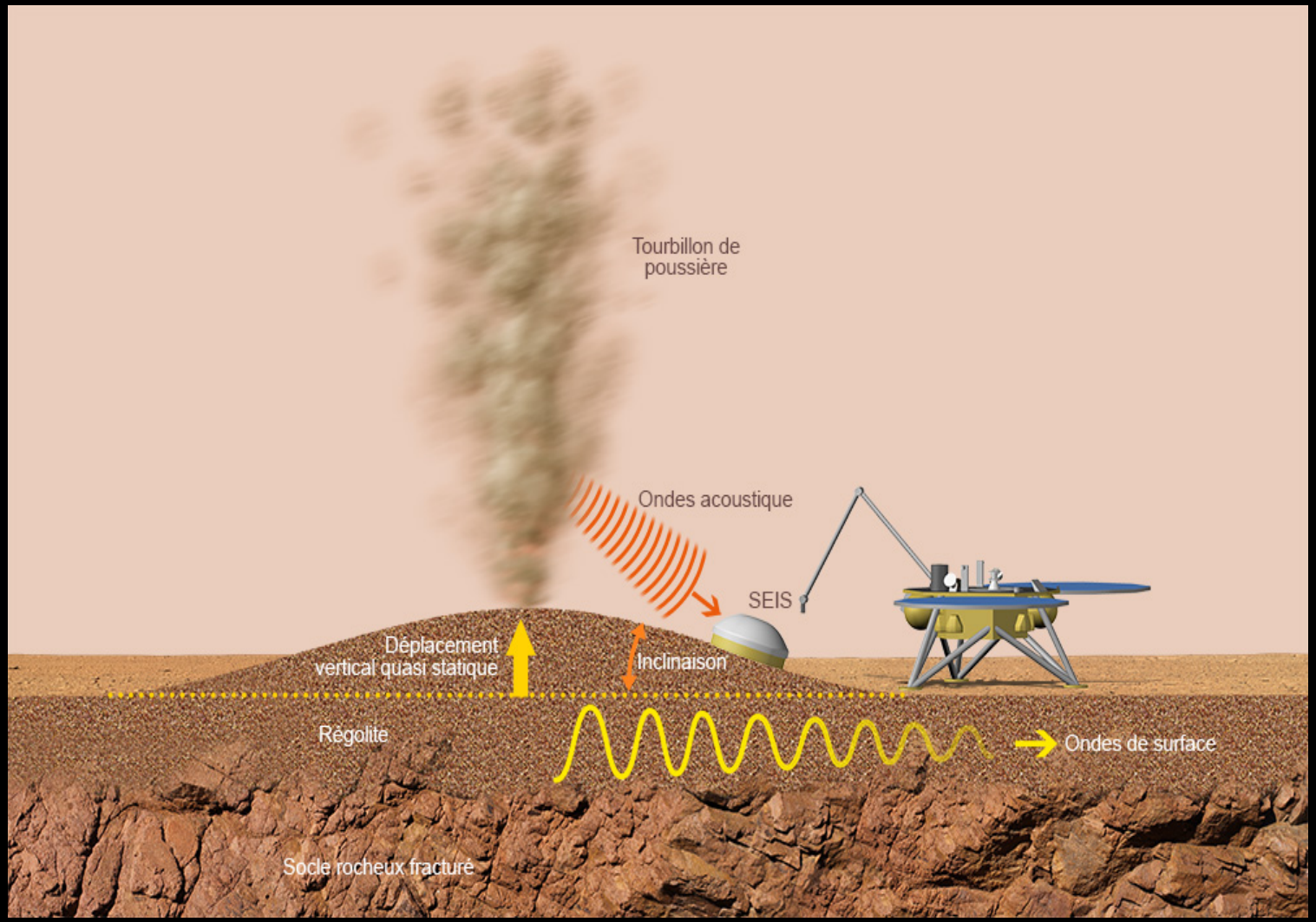
InSight is a meteorological station

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, ...

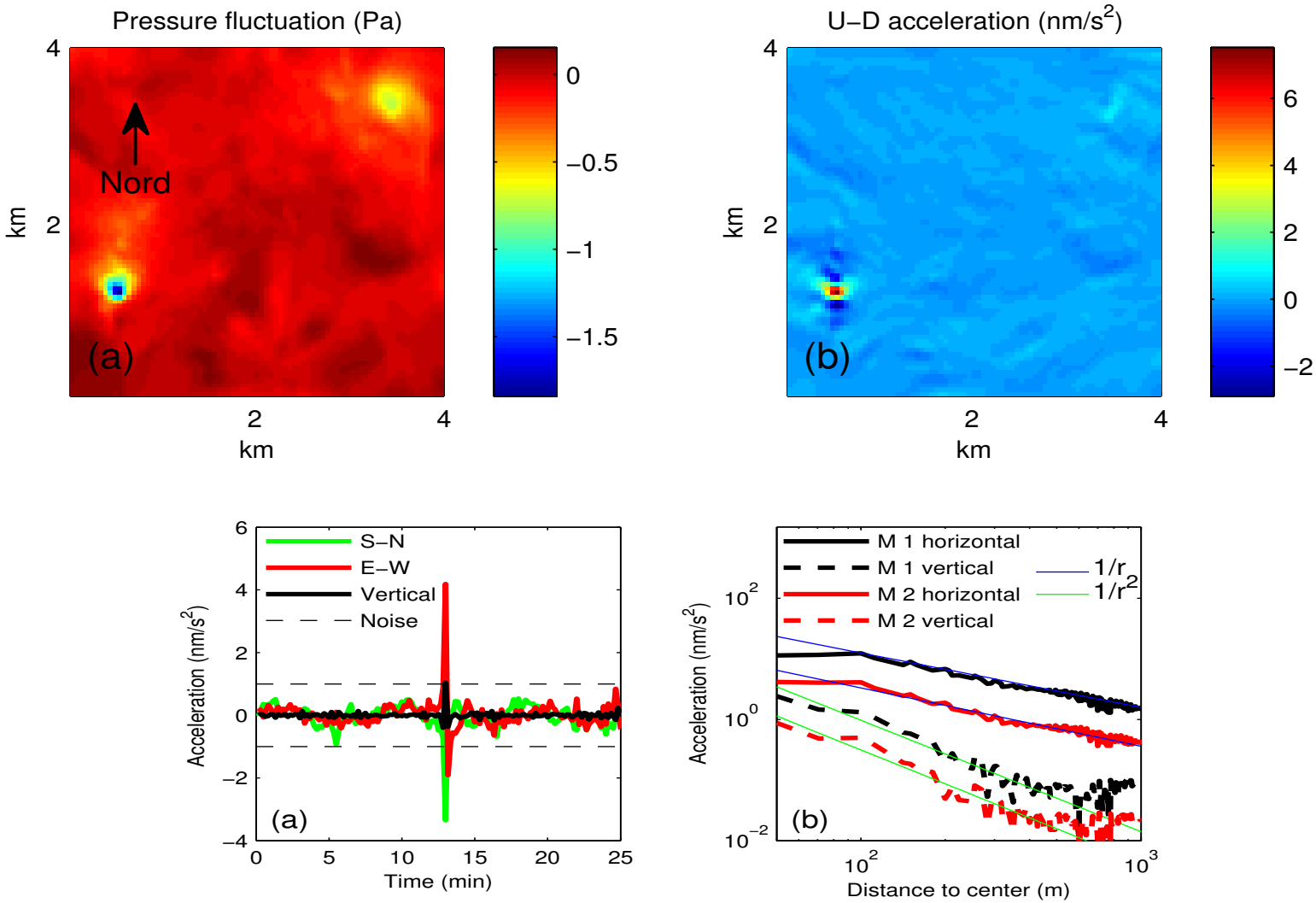
Seismic signatures of convective vortices



[Crédits IPGP]

Seismic noise of dust devils (for InSight / SEIS)

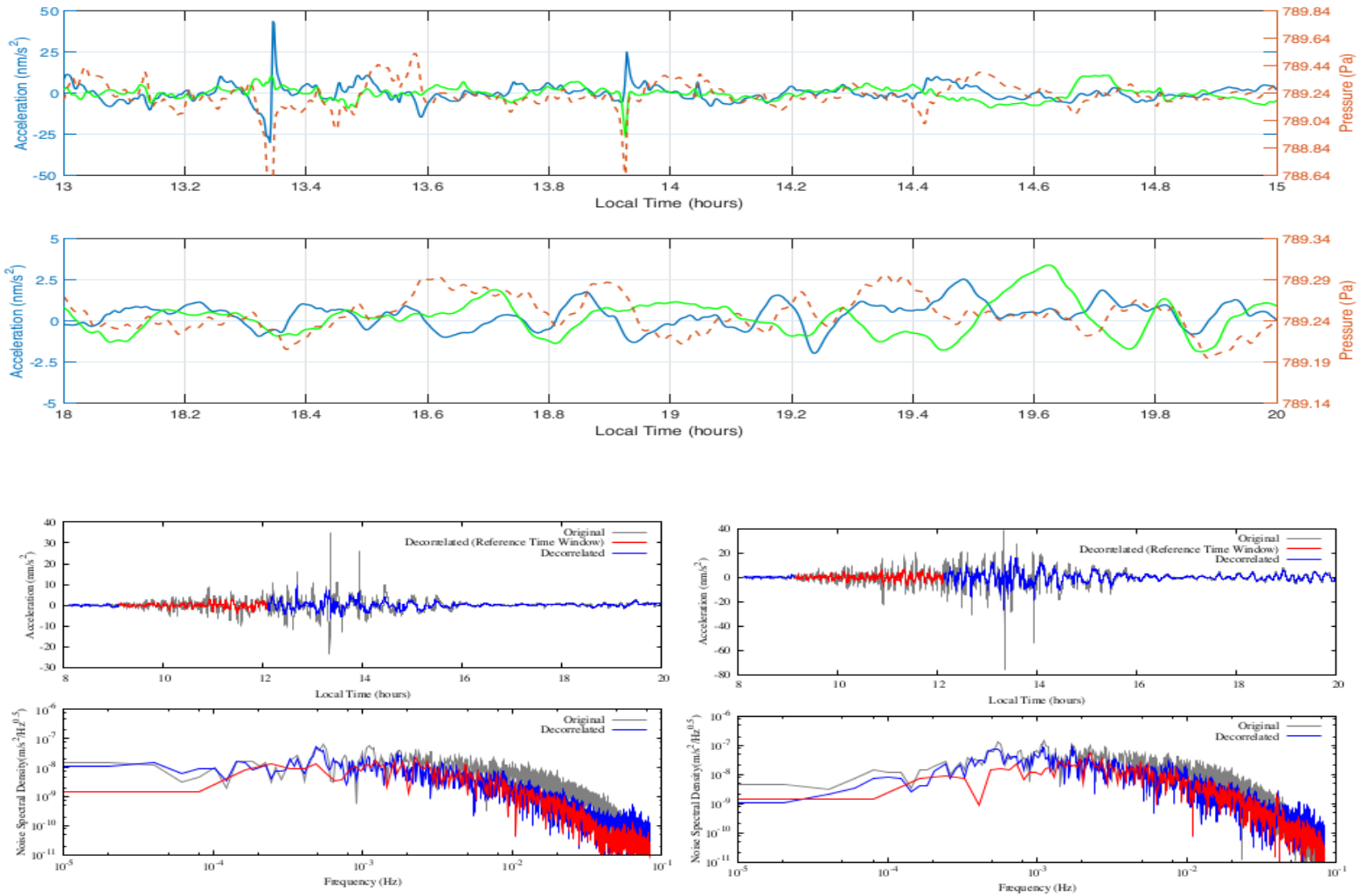
Large-Eddy Simulations + Sorrell theory



[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]

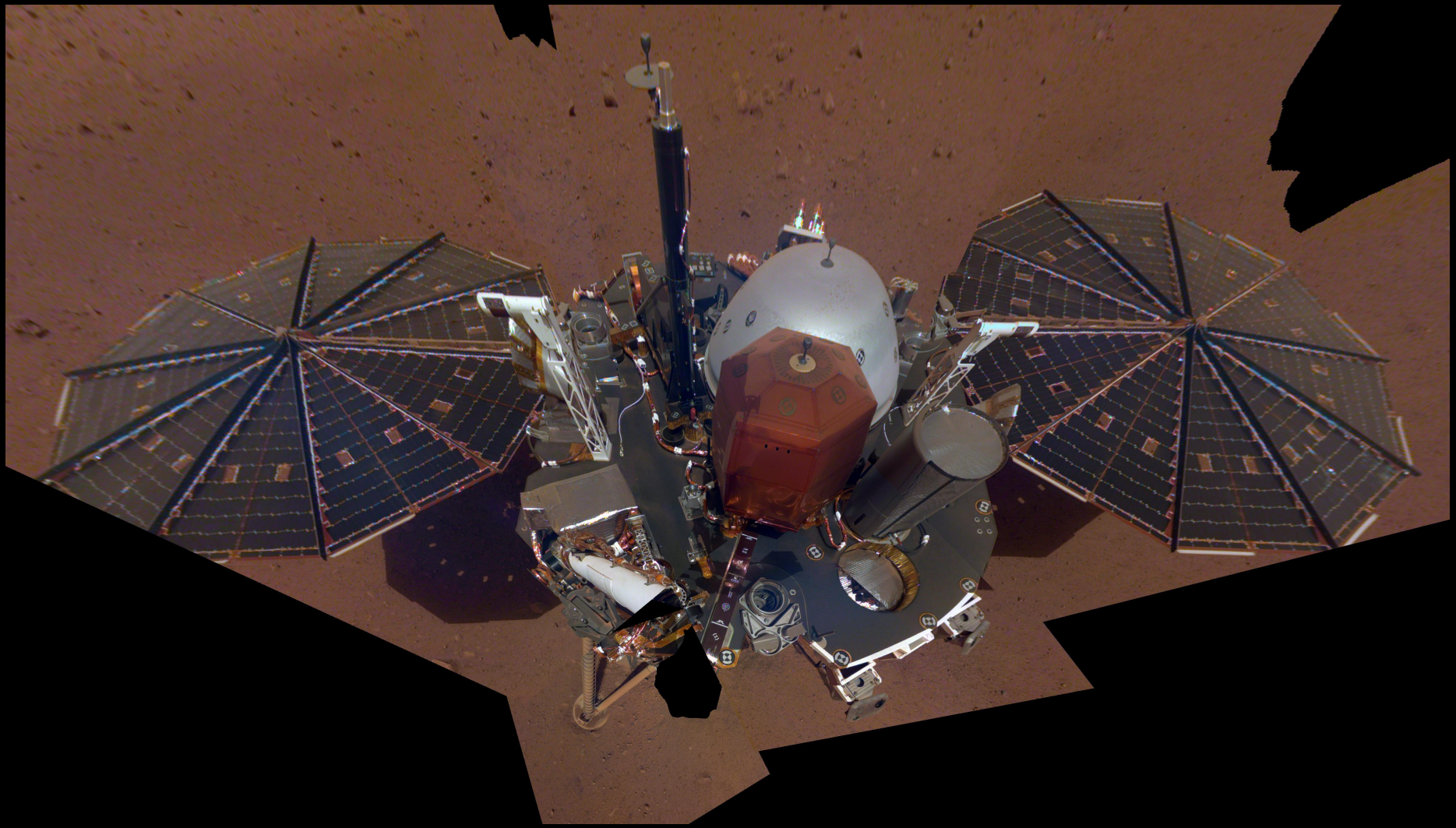
A quote from Charles Baudelaire

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.

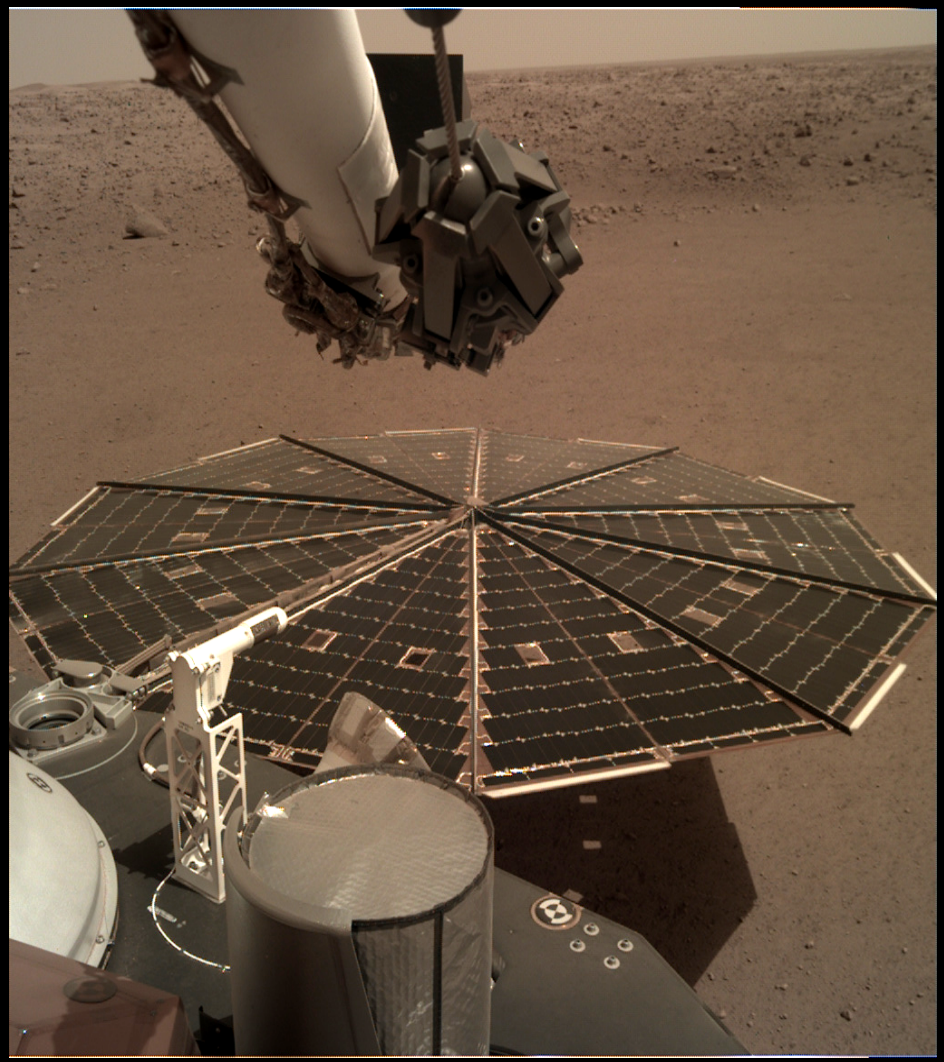
Outline

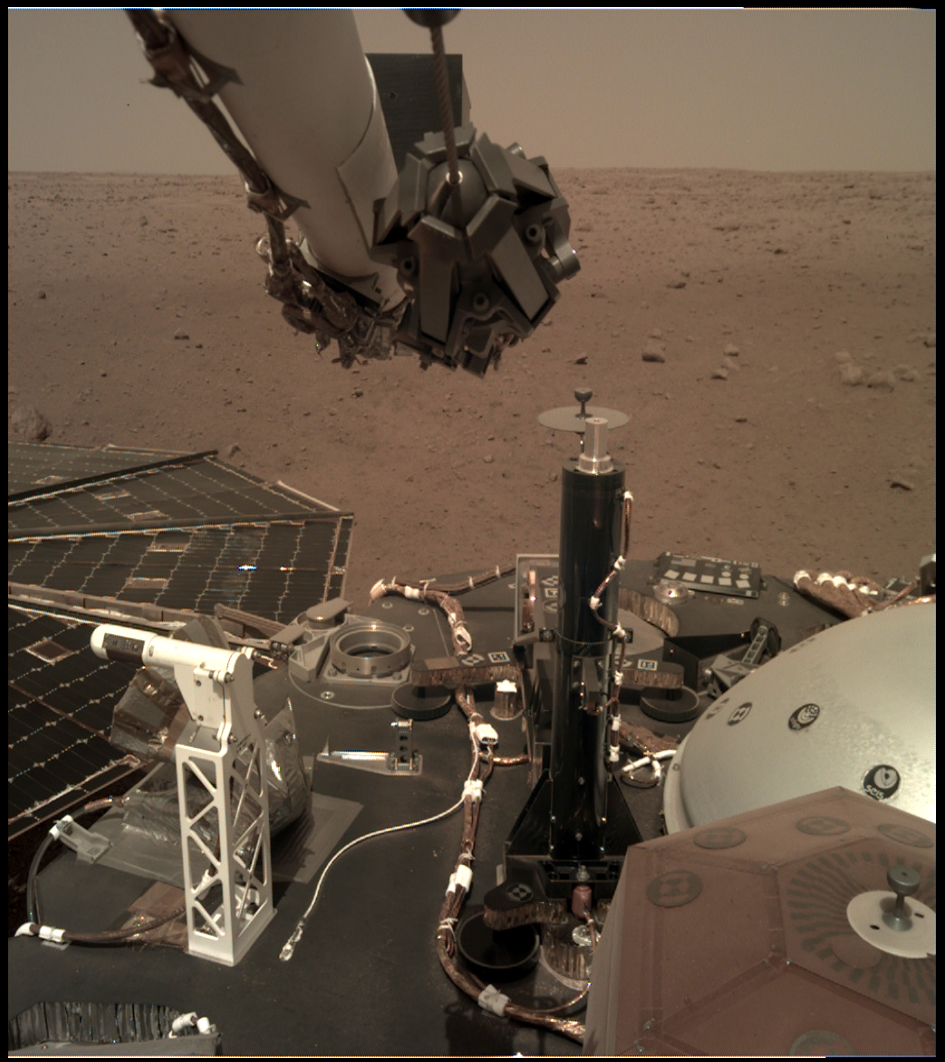
InSight "selfie" mosaic



[PIA22876 NASA/JPL]

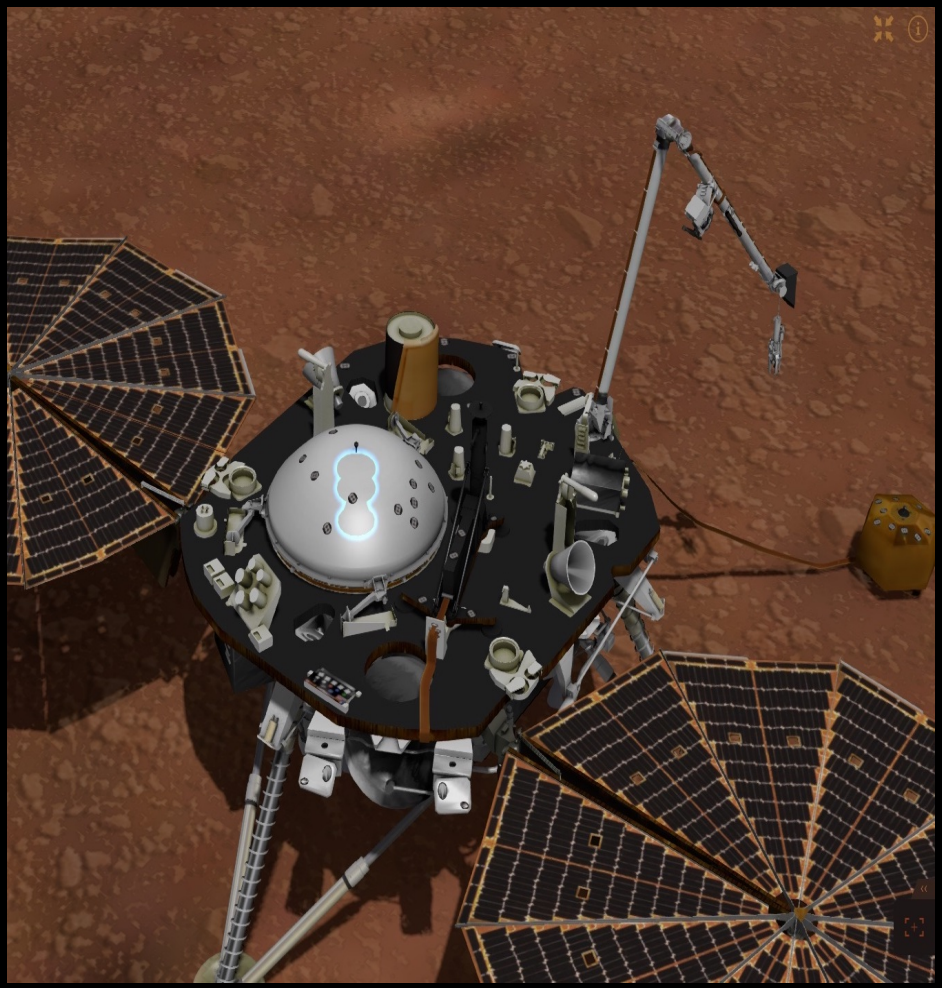
TWINS on board InSight

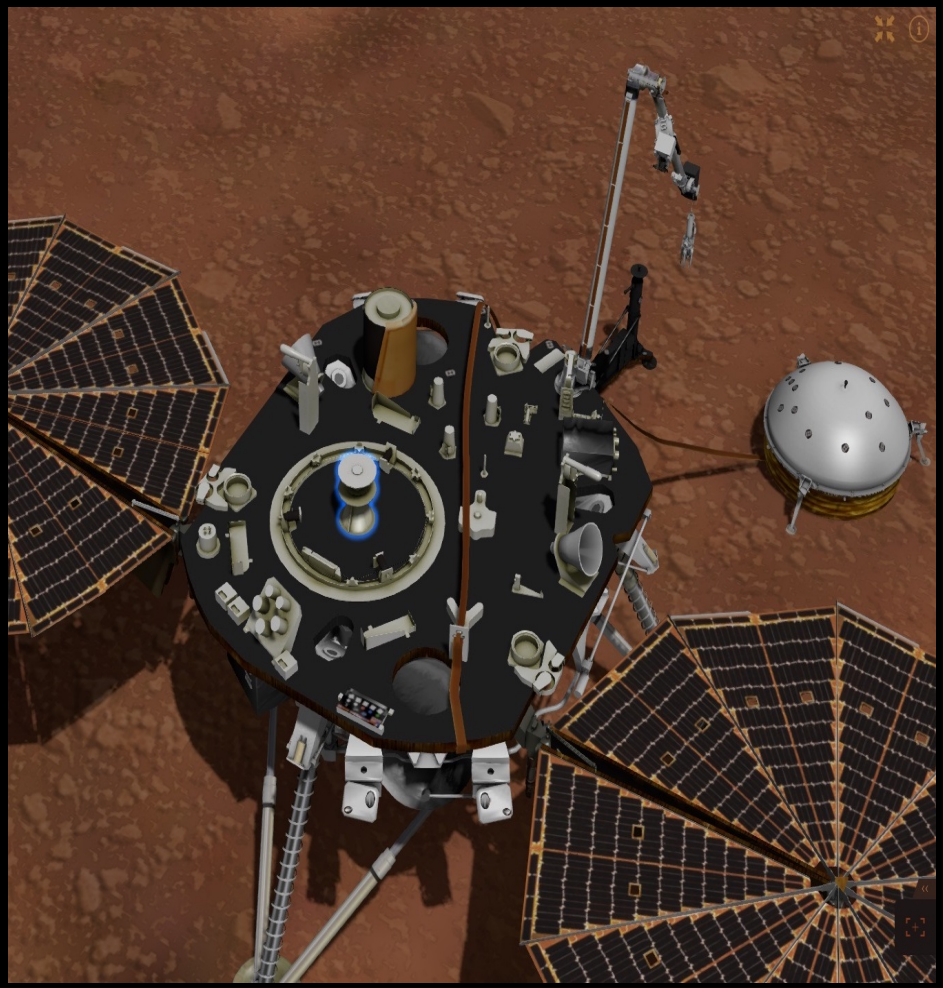




[PIA22736 NASA/JPL]

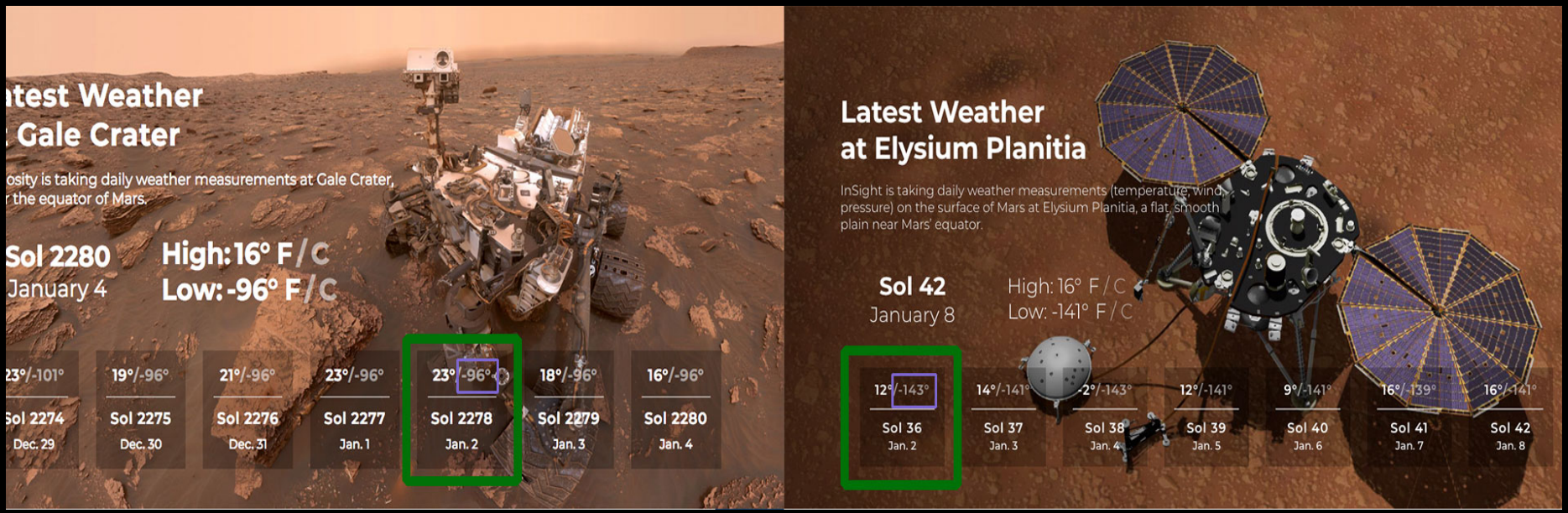
APSS pressure sensor





[site SEIS/InSight P. Labrot]

NASA website for weather reports



Mars Climate Database (online version)

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