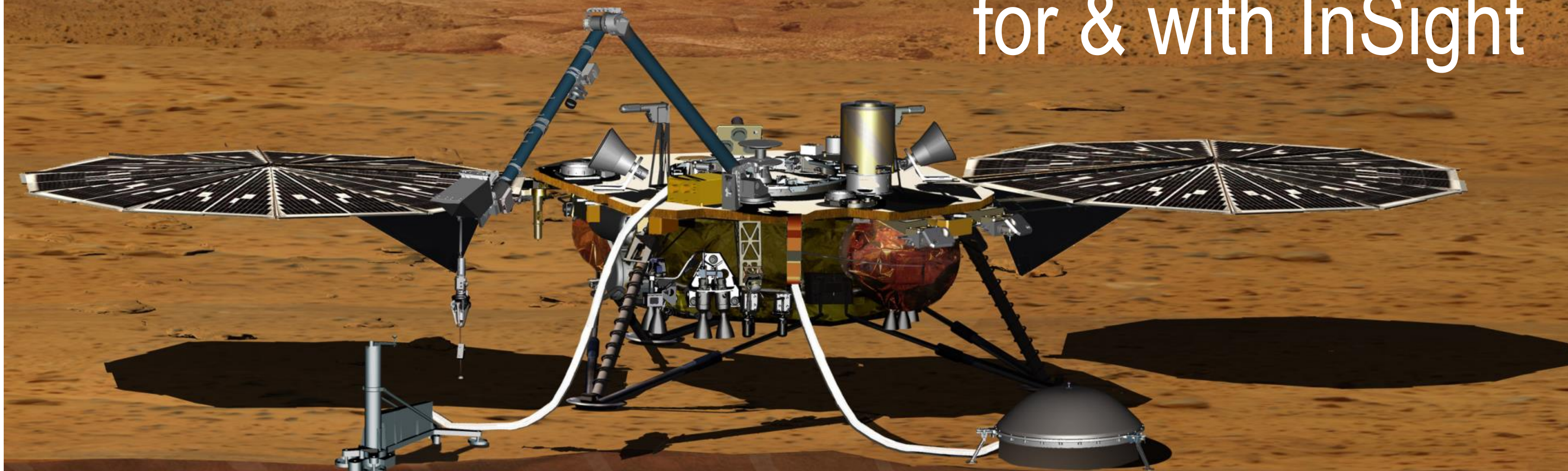
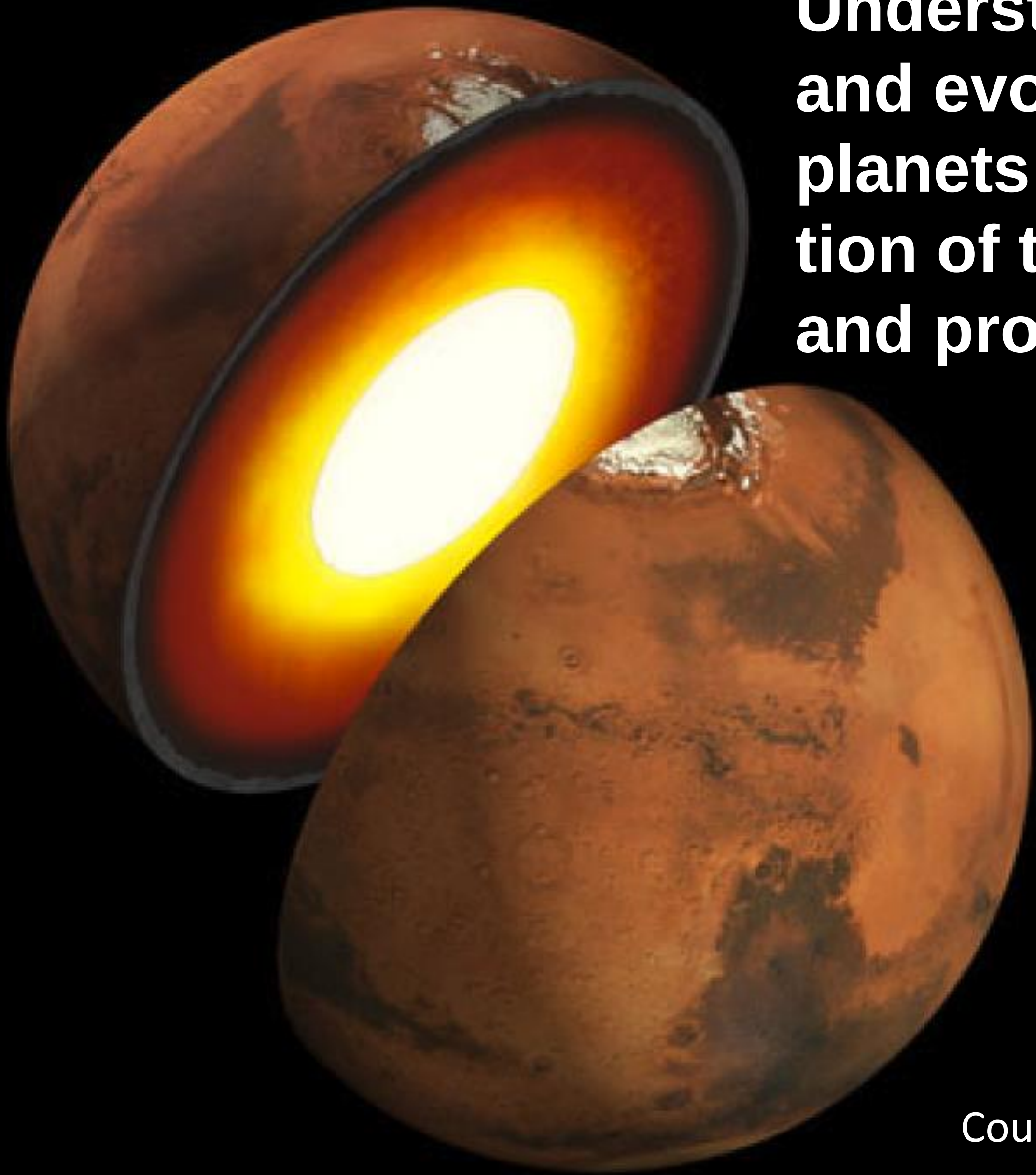
Atmospheric Science for & with InSight



Aymeric Spiga, François Forget,
Ehouarn Millour, Tanguy Bertrand
Laboratoire de Météorologie Dynamique,
Paris, France

Don Banfield
Cornell University

InSight Science Goal:

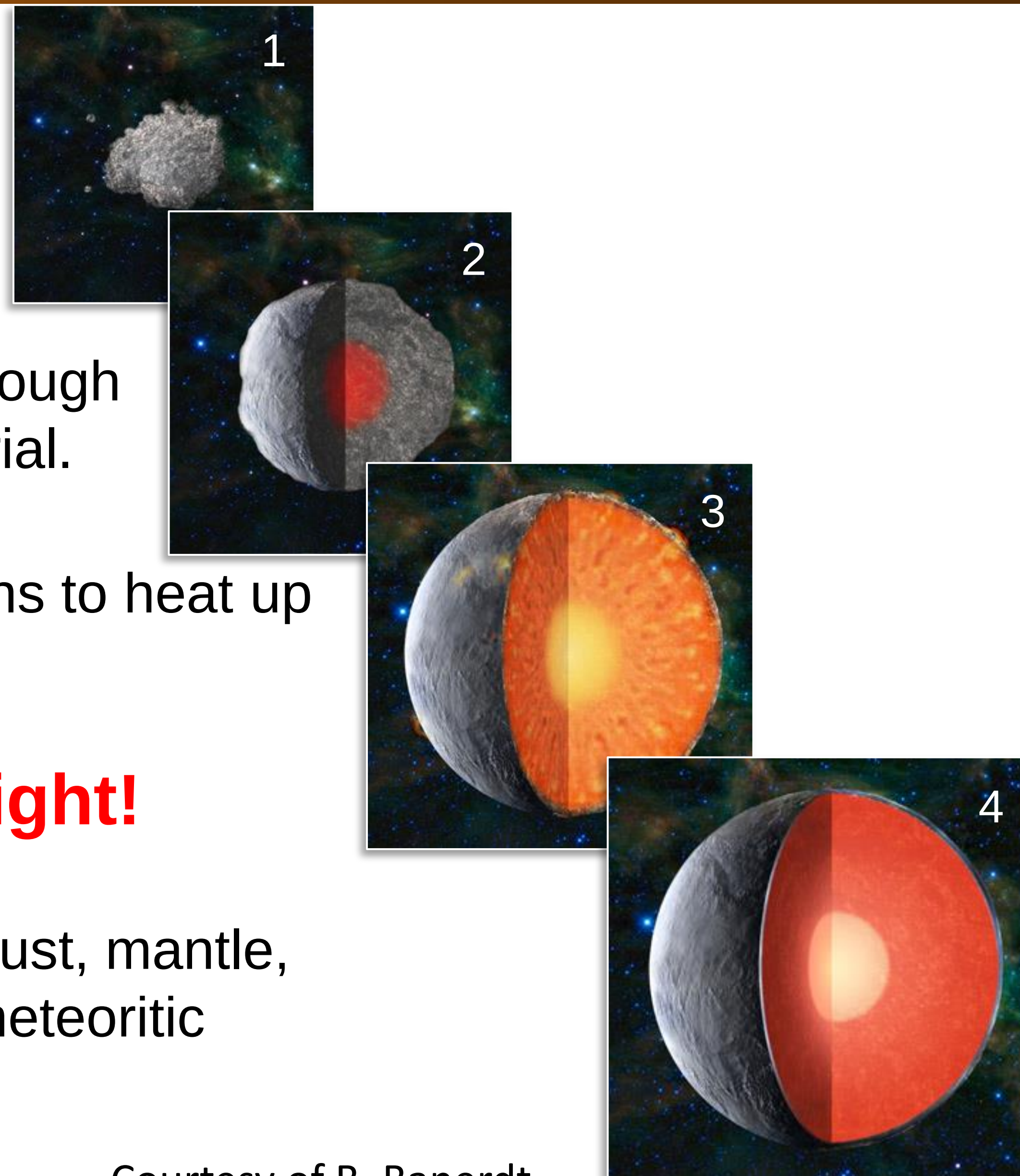


Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars.

- **Seismology**
- **Geodesy**
- **Heat Flow**
- **Magnetism**

Courtesy of B. Banerdt & S. Smrekar

How Does a Terrestrial Planet Form?



1. The planet starts forming through accretion of meteoritic material.
2. As it grows, the interior begins to heat up and melt.
3. Stuff happens! ← **InSight!**
4. The planet ends up with a crust, mantle, and core with distinct, non-meteoritic compositions.

Courtesy of B. Banerdt

InSight Payload

RISE (S/C Telecom)

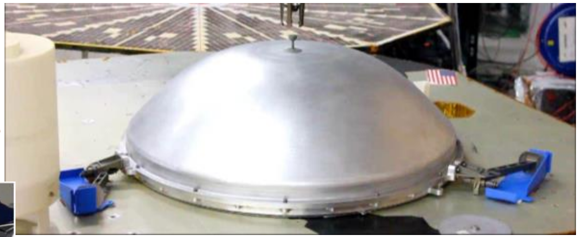
Small Deep Space Transponder

Rotation and Interior Structure Experiment

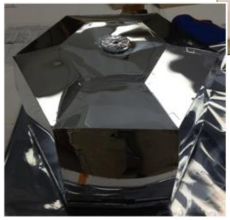
SEIS (CNES) (also IPGP, ETH/SSA, MPS/DLR, IC/Oxford/UKSA, JPL/NASA)

Seismic Experiment for Interior Structure

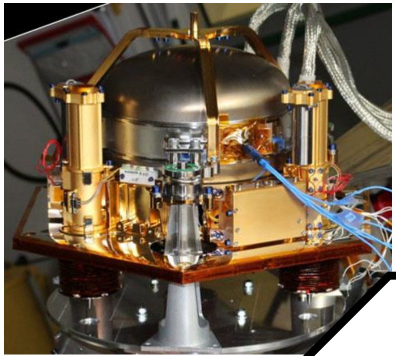
Wind and Thermal Shield (WTS)

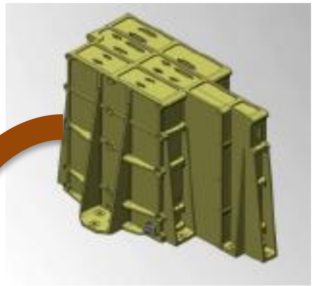


Thermal Enclosure (RWEB)



Sensor Head: VBB, SP, LVL





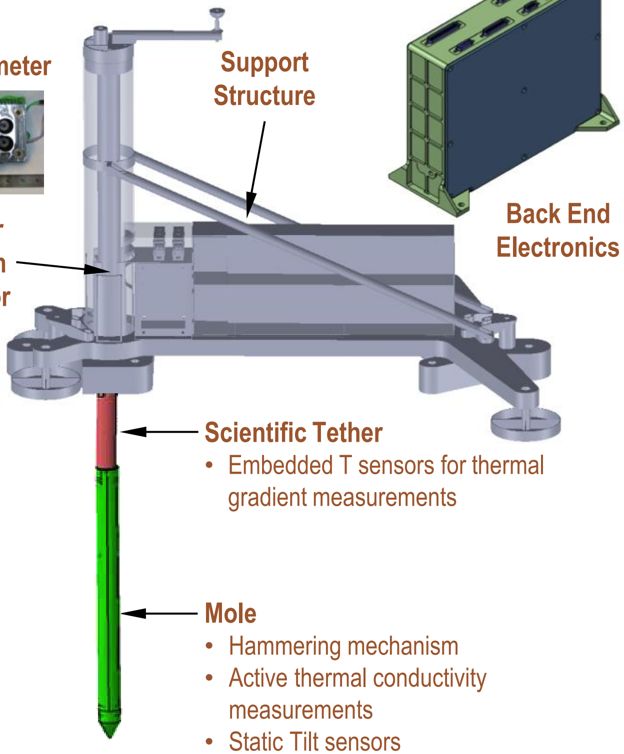
Electronics (Ebox)

Tether (THR)

HP³ (DLR)

Heat Flow and Physical Properties Probe

Radiometer



Support Structure

Back End Electronics

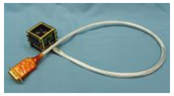
Tether Length Monitor

Scientific Tether
- Embedded T sensors for thermal gradient measurements

Mole
- Hammering mechanism
- Active thermal conductivity measurements
- Static Tilt sensors

APSS (JPL)

Auxiliary Payload Sensor Suite



IFG (UCLA) – InSight FluxGate

Pressure Sensor

TWINS (CAB) – Temp. and Wind for INSight

IDS (JPL)

Instrument Deployment System

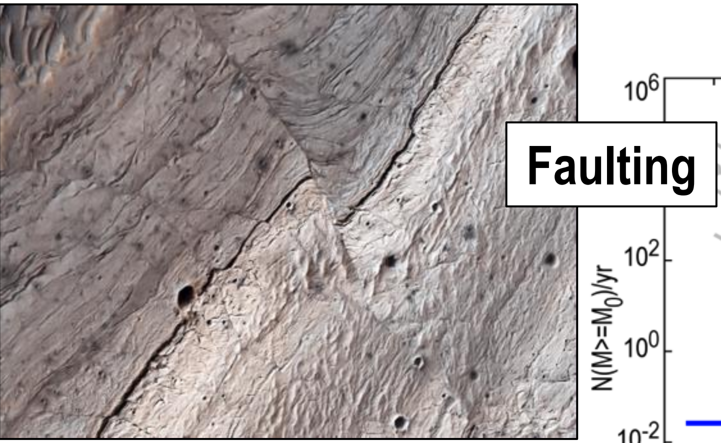
IDA – Instrument Deployment Arm

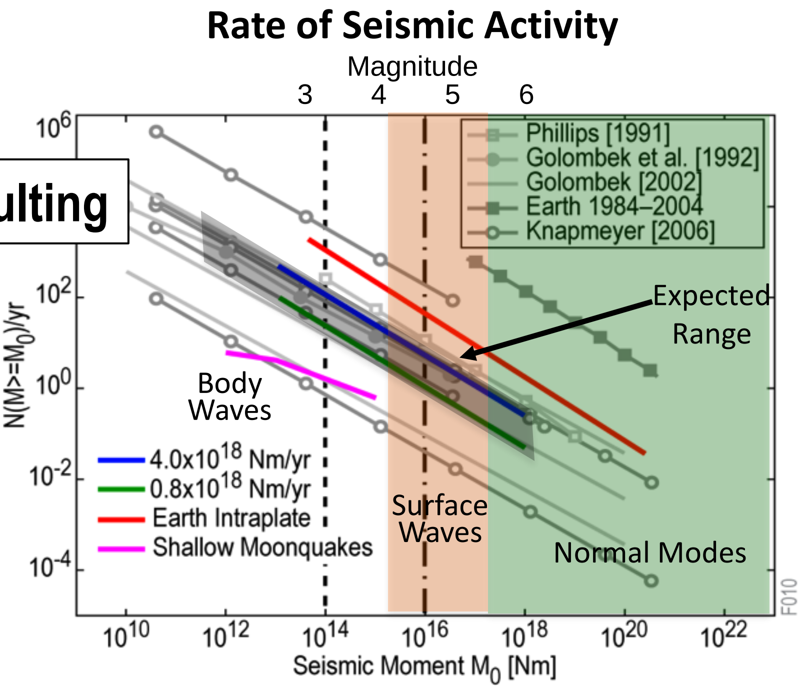
IDC – Instrument Deployment Camera

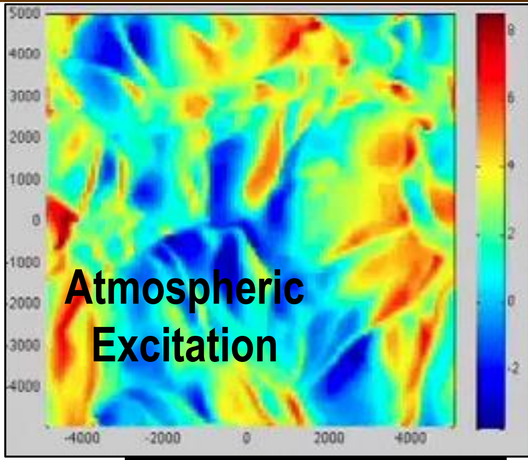
ICC – Instrument Context Camera

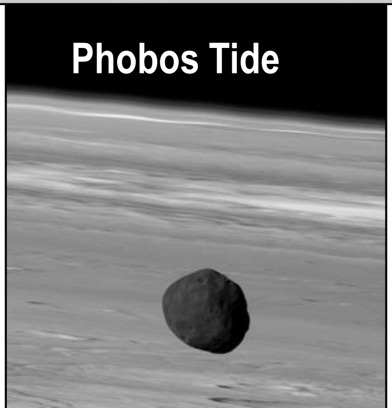
Courtesy of B. Banerdt & S. Smrekar

Martian Seismology – Multiple Signal Sources

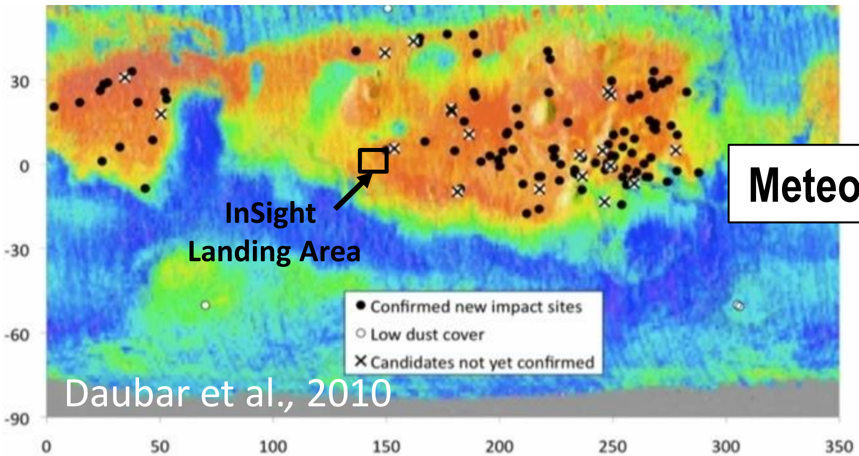


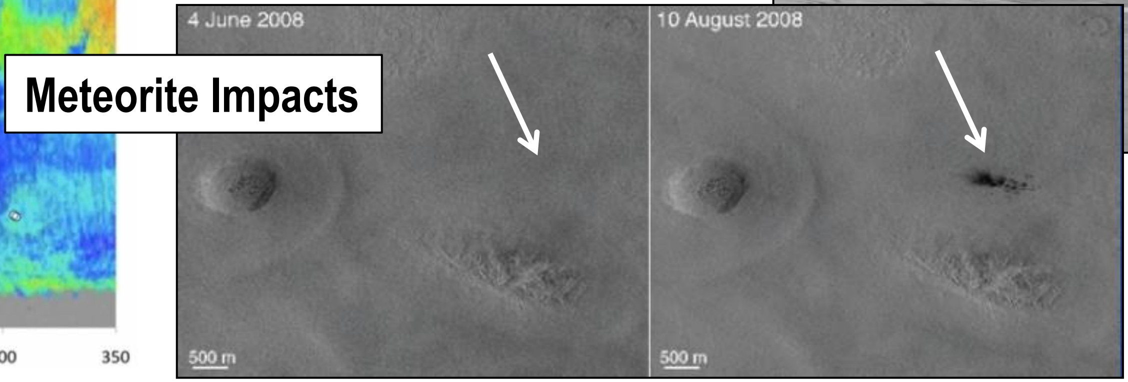






Courtesy of B. Banerdt





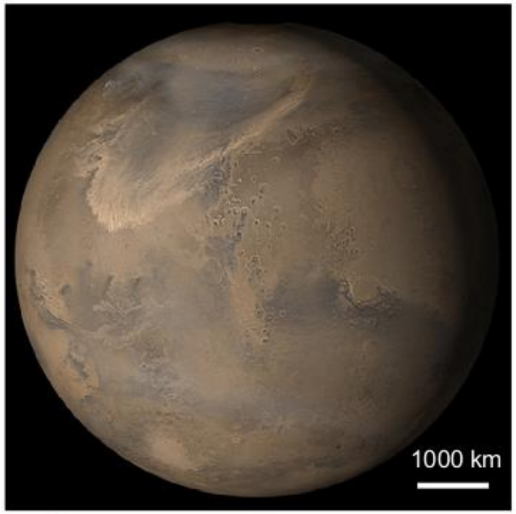
Atmospheric Science expertise and tools …

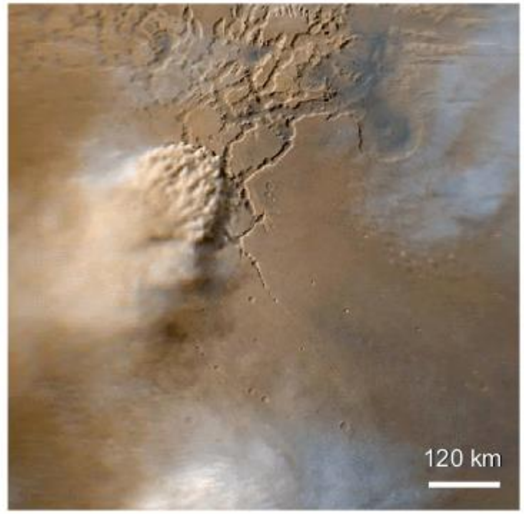
- … **for** InSight
  - Predict environmental conditions to prepare EDL and operations
  - Characterize and minimize seismic noise from the atmosphere

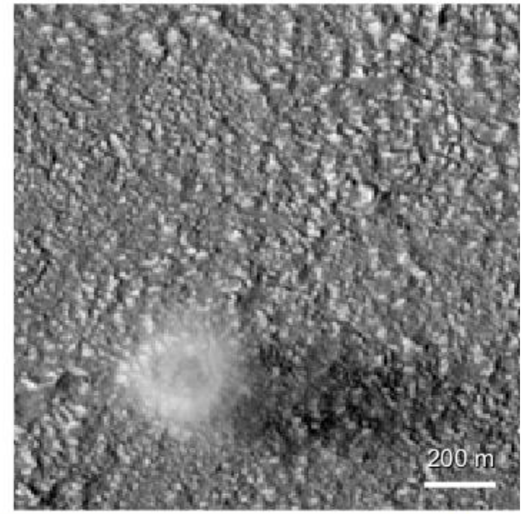
- … **with** InSight

Prepare P,T,winds,tau measurement strategy and interpretation
  - Dust cycle
  - Water cycle
  - Atmospheric perturbations

Tools @ LMD to study the atmospheric environment







... Dust fronts ... Regional dust storms ... Local gusts ... Dust devils ...

10000 km → 1000 km → 100 km → 10 km → 1 km → 100 m → 10m → 1m

Global Circulation Models

Mesoscale Models

Large-Eddy Simulations

Mars Climate Database:
www-mars.lmd.jussieu.fr

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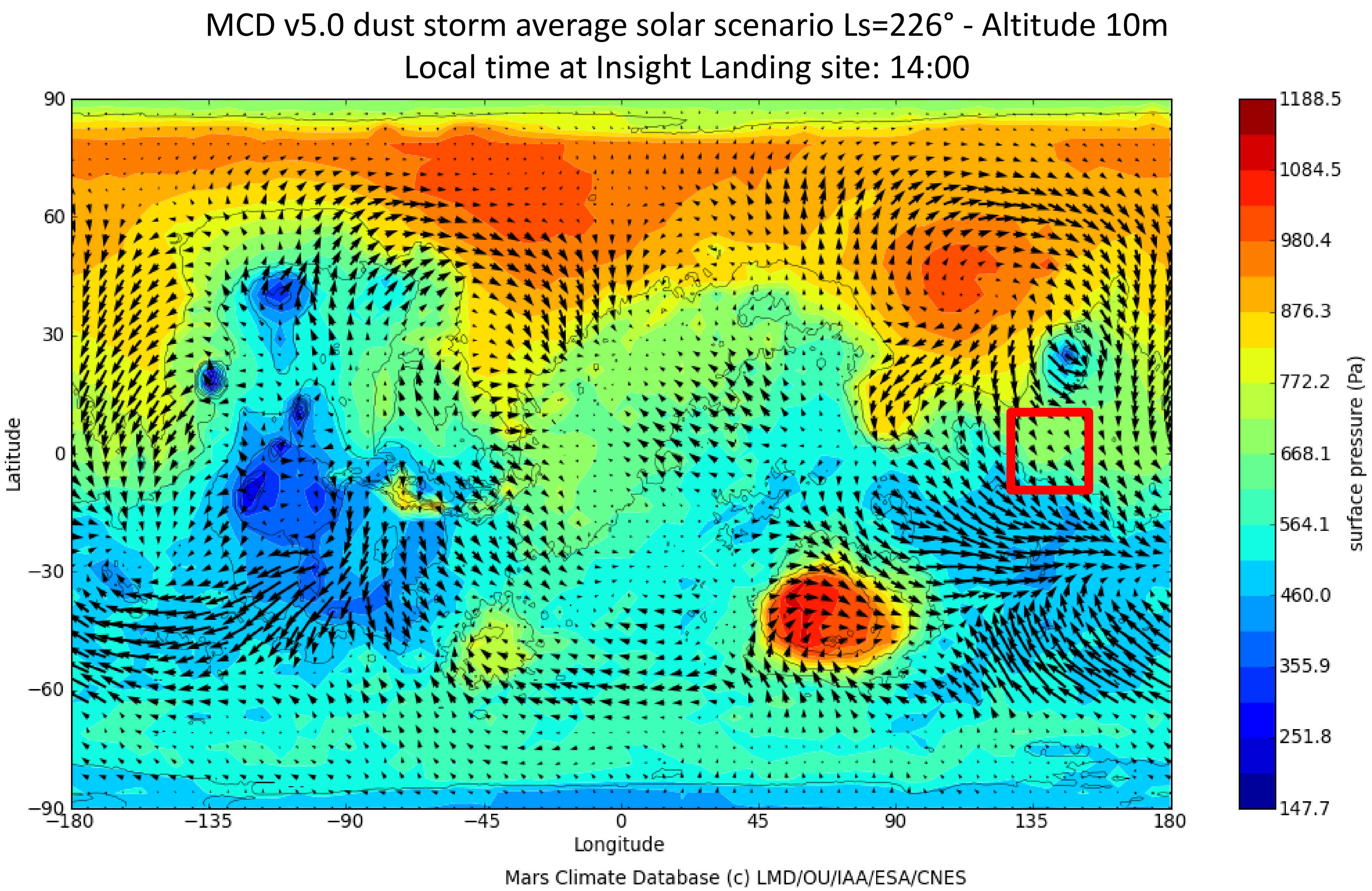
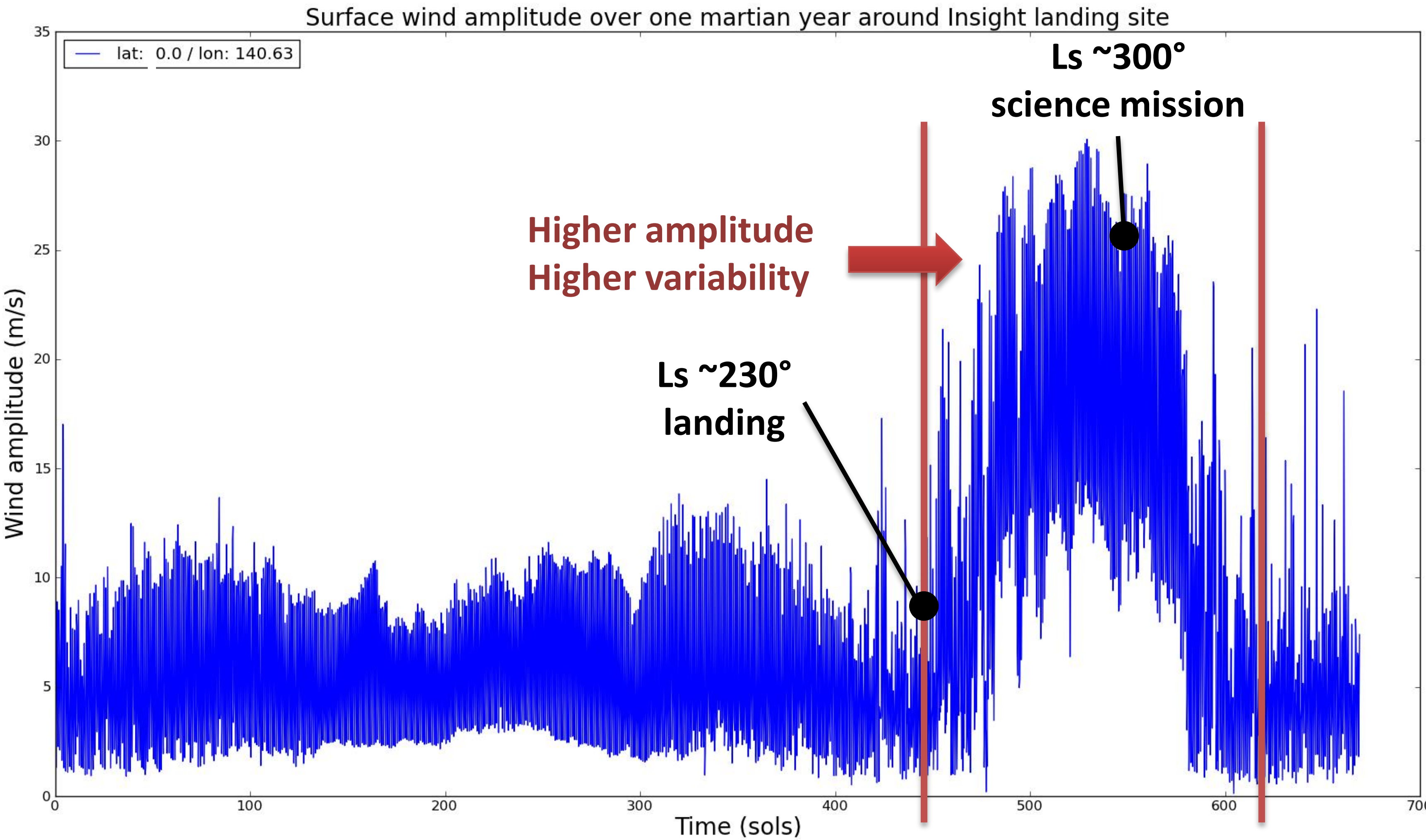
Large-scale winds on Mars @ InSight landing site



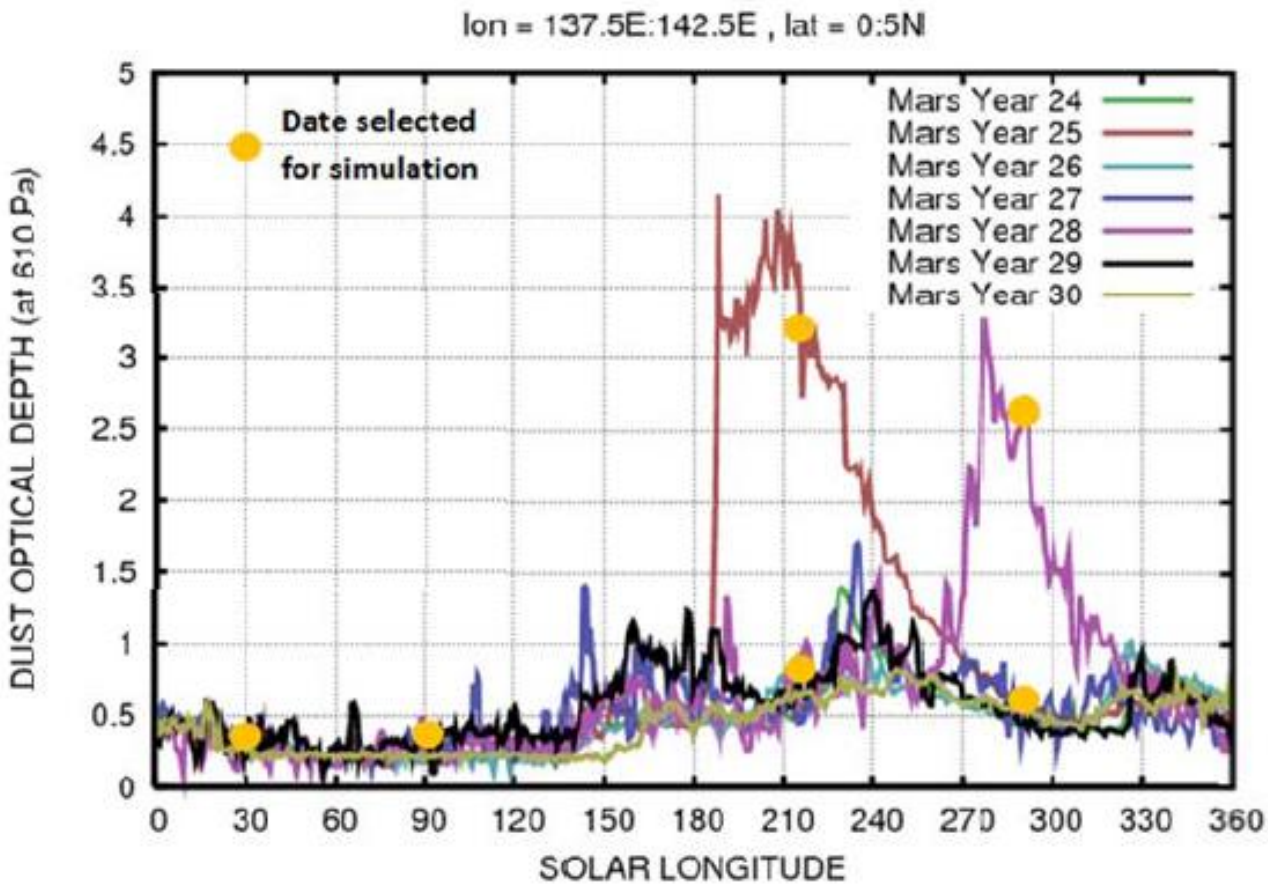
Large-scale winds on Mars @ InSight landing site

Above the surface ~5m - Simulated with the LMD-GCM over one martian year



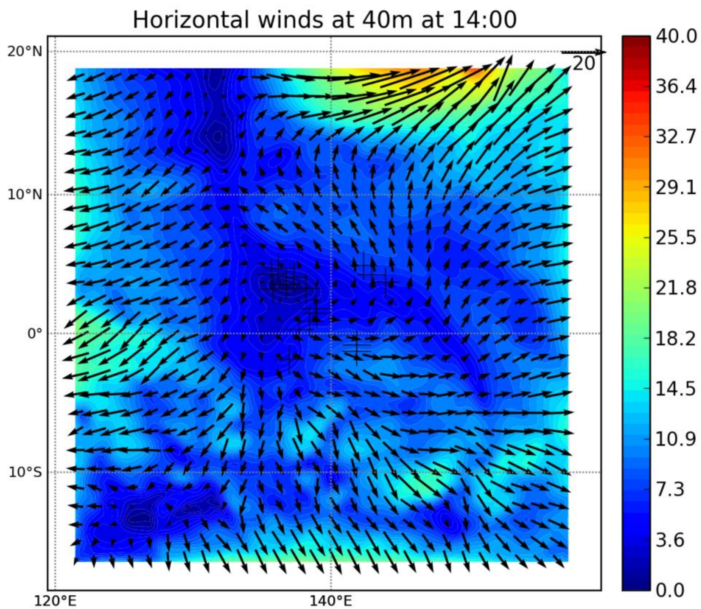
Mesoscale wind study @ InSight landing ellipses

- We focus on what simulations yield for near surface winds at the **4 Insight landing ellipses** (E05, E08, E09, E17).
- **6 Simulations**, using realistic dust scenarios, spread over various Ls (30,90, 226, 293) and Mars Years (MY24, 25, 28).

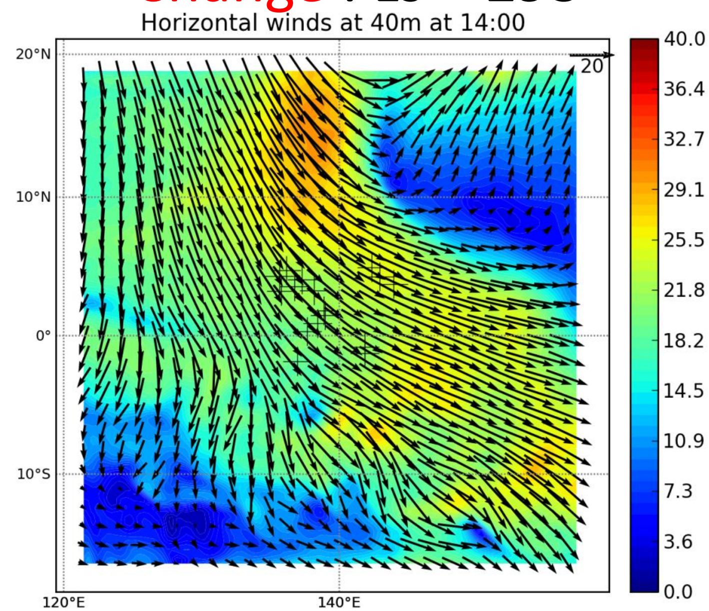


Regional winds : sensitivity to season and dust opacity

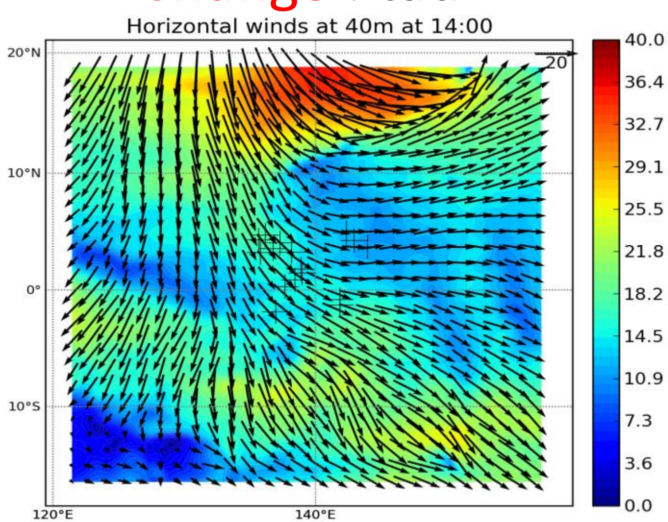
Ls = 226° tau=0.2



Change : Ls = 293°



Change : tau=1



Ls=226°:

ellipses	E17		E09		E08		E05	
τ	*Mean*	*Max*	*Mean*	*Max*	*Mean*	*Max*	*Mean*	*Max*
0.2	6	8	6	14	4	16	4	14
1	14	22	14	22	12	20	12	20
5	12	24	12	24	10	20	10	18

Ls=293°:

ellipses	E17		E09		E08		E05	
τ	*Mean*	*Max*	*Mean*	*Max*	*Mean*	*Max*	*Mean*	*Max*
0.2	18	24	18	24	18	24	18	24
1	18	24	18	22	16	20	14	20
2	12	20	10	18	8	14	8	12

Table 1: Horizontal wind velocities ($m.s^{-1}$) in the four ellipses considered for InSight landing. These values were obtained from mesoscale simulation at 10 m altitude, at local time 14:00, at Ls=226° (top) and 293° (bottom), and performed for three different dust opacities τ.

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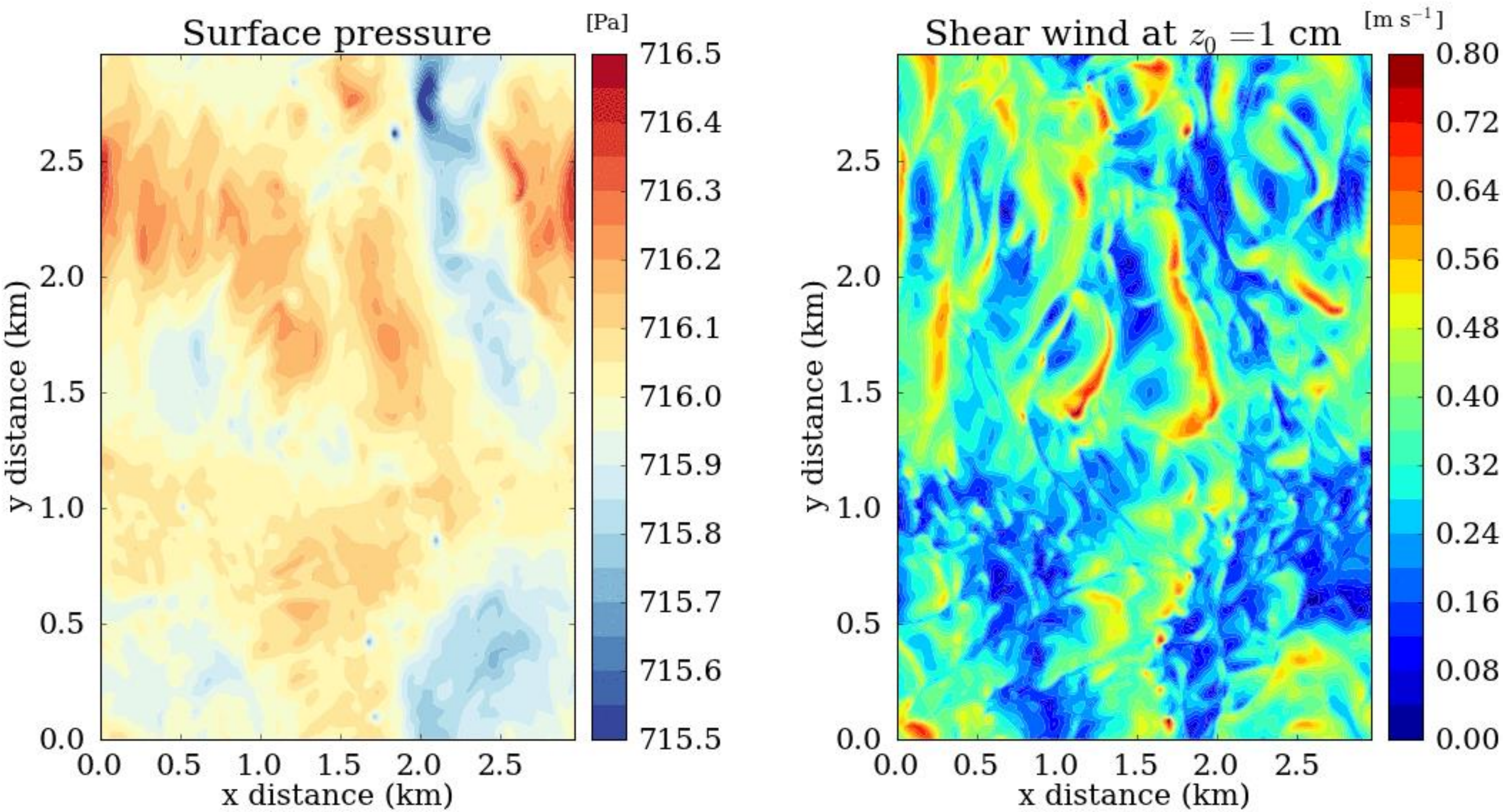
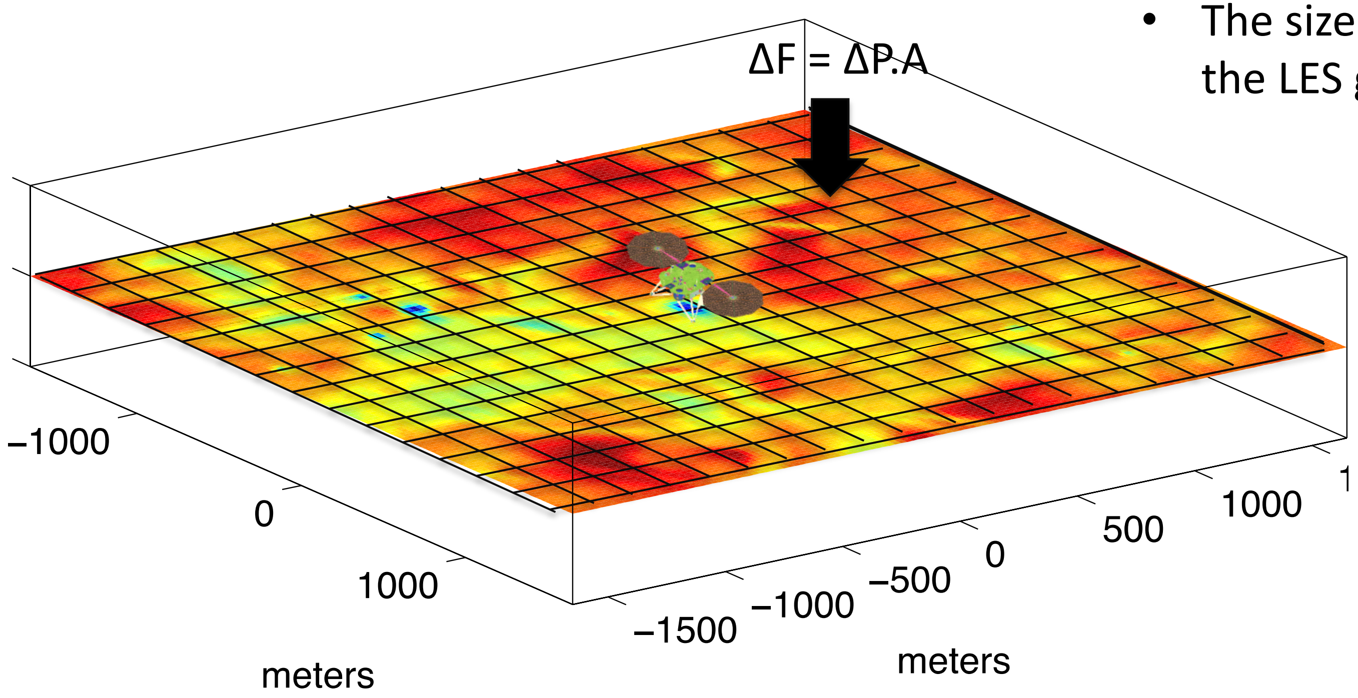
Atmospheric excitation of the surface

Modelling boundary layer seismic noise with Large-Eddy Simulations



Simplified pressure noise model: methodology

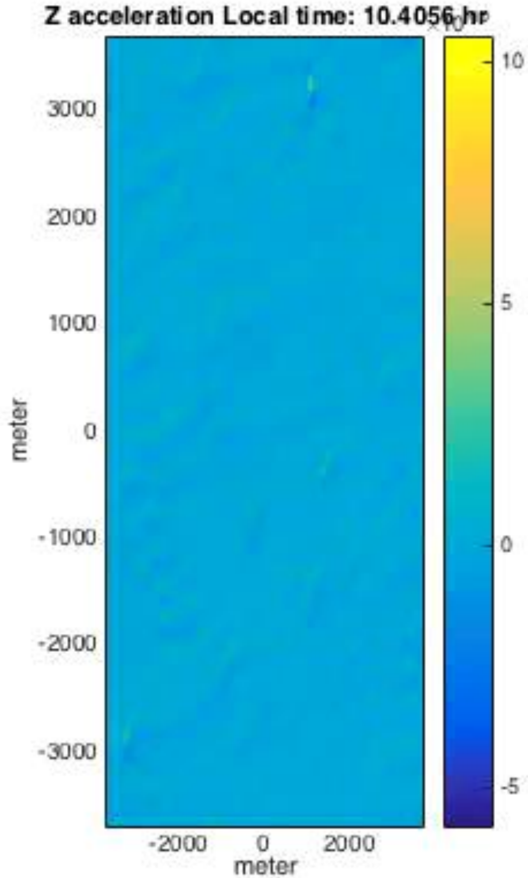
- For every section of the LES grid, the variation of the vertical force exerted on the ground at the center of the section of the grid is calculated.
- Then, the displacement of the ground at the seismometer feet will be a sum of the displacements caused by each section of the grid (each considered to be a point source).
- Once the vertical displacement at each of the seismometers feet has been calculated, the resulting acceleration tilt can be found.

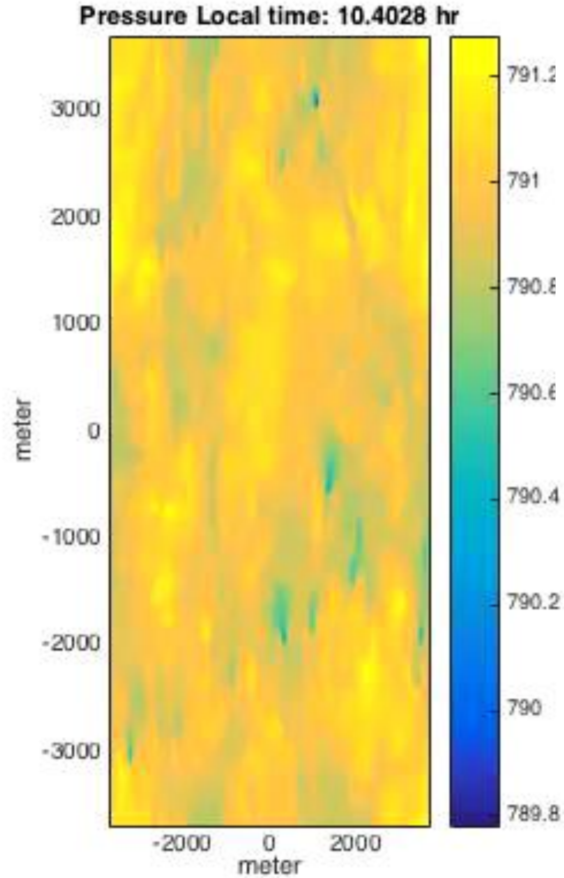


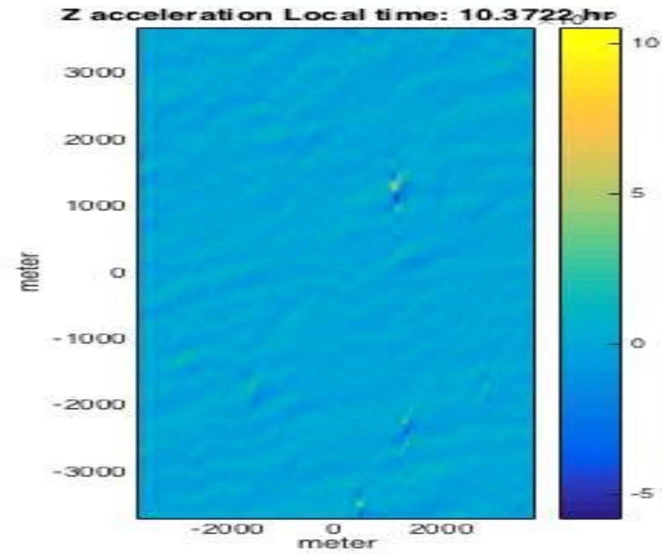
- The size of each section of the LES grid is 50 m x 50 m.

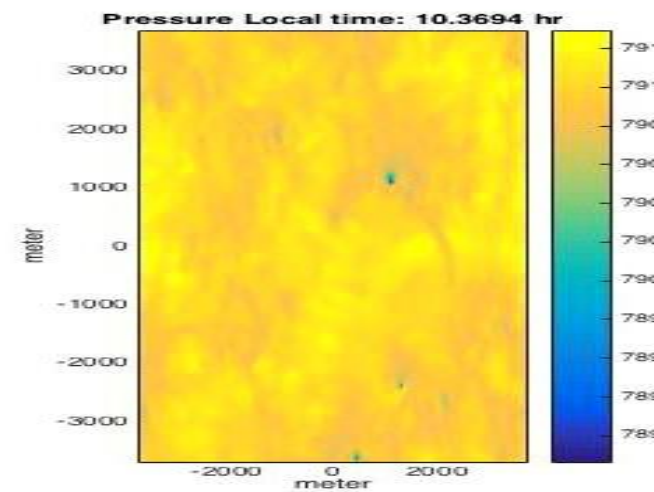
Courtesy of N. Murdoch

Dustdevils on the Vertical Component (3/3)









Courtesy of P. Lognonné

Atmospheric Science expertise and tools …

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  - Predict environmental conditions to prepare EDL and operations
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- … with InSight

Prepare P,T,winds,tau measurement strategy and interpretation

  - Dust cycle
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Atmospheric science with InSight

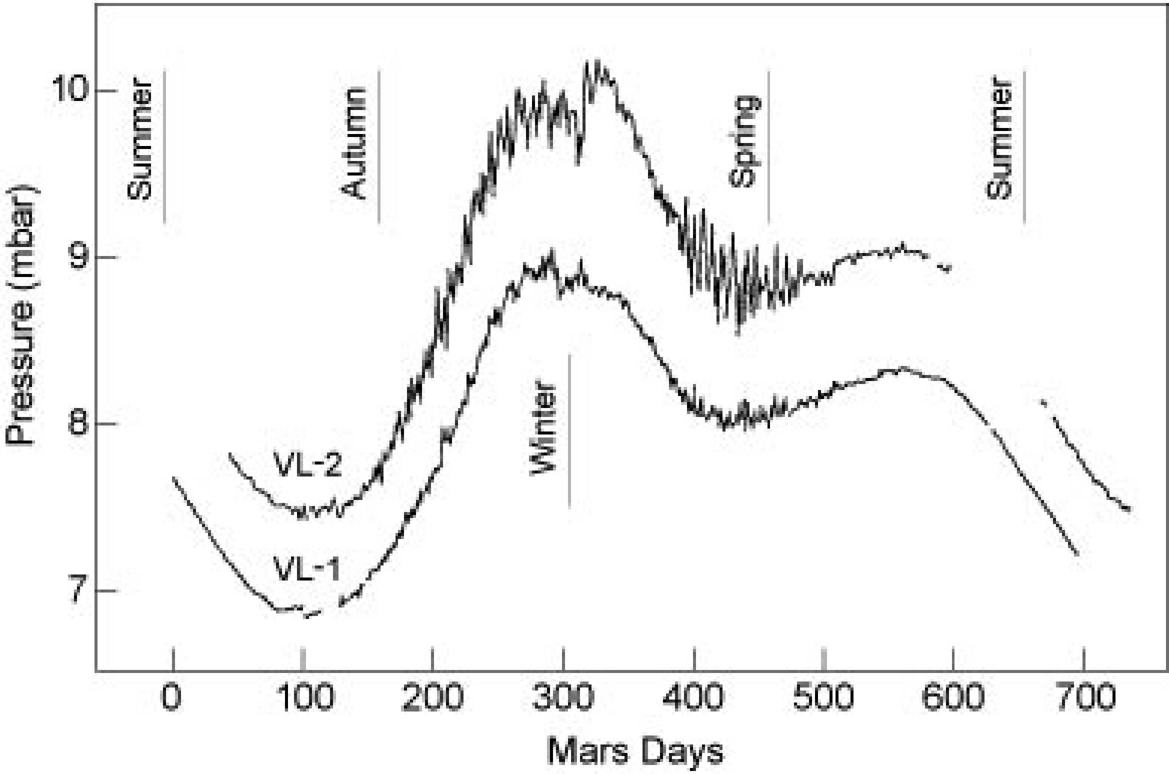
- Insight offers opportunities to improve our knowledge of the Martian atmospheric system:
  - **Long term** high accuracy measurements of **winds, temperature, pressure**
  - **Dust devil** detection and monitoring, but also **convective activity evaluation** using high freq. pressure measurements
  - **Dust opacity measurements** (using camera and effective dust deposition on solar panels)
  - **Water ice cloud** and **near-surface fog cycles** (seasonal and diurnal) studies
  - …

Pressure : THE meteorological variable

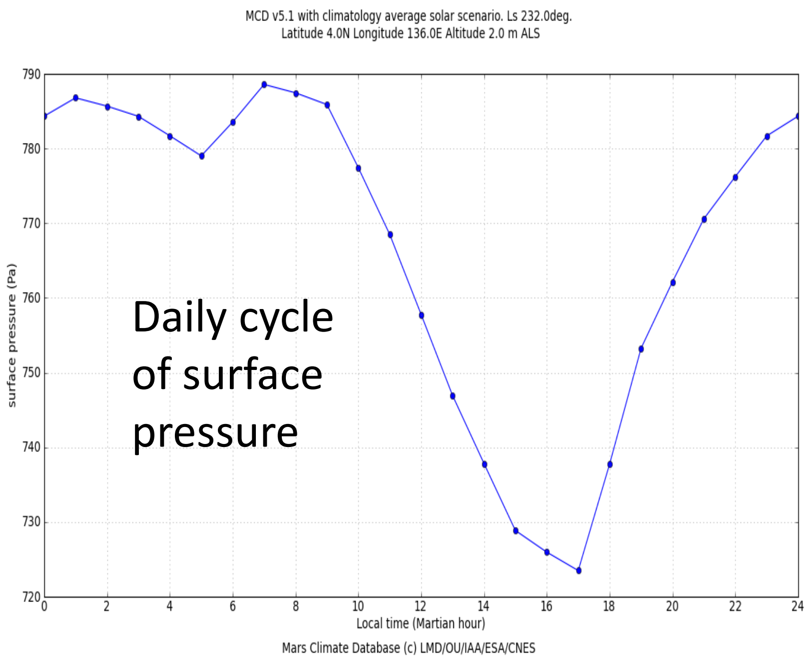
- Interannual & Seasonal variations
  - CO2 condensation cycle
- Day-to-day variations
  - passing weather patterns (~~equator~~)
- Diurnal variations
  - thermal tides
- Hour-to-hour variations
  - gravity waves, slope winds
- Minutes-to-minutes variations
  - boundary layer convection, gravity waves
- Second-to-second variations
  - convective vortices (dust devils)

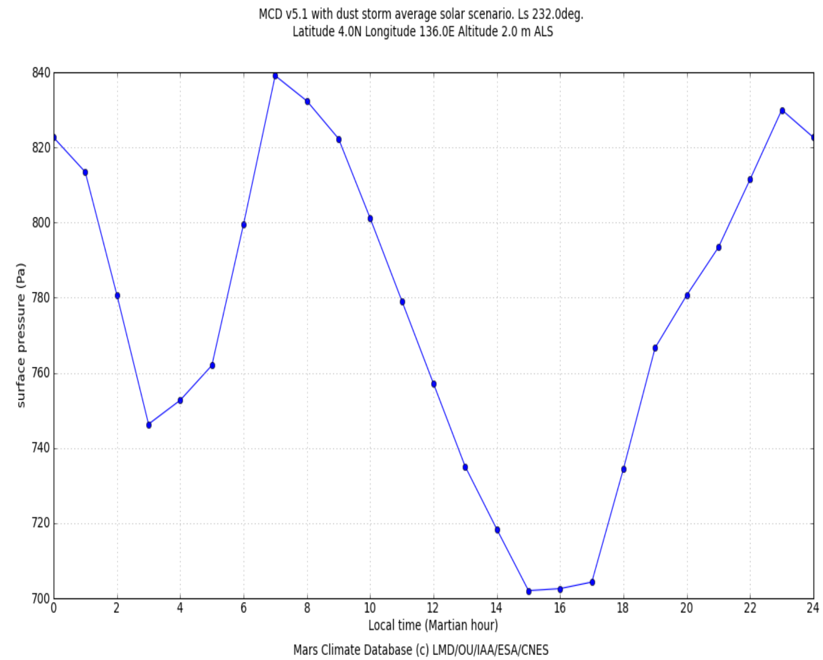
Seasonal and Secular Pressure Record

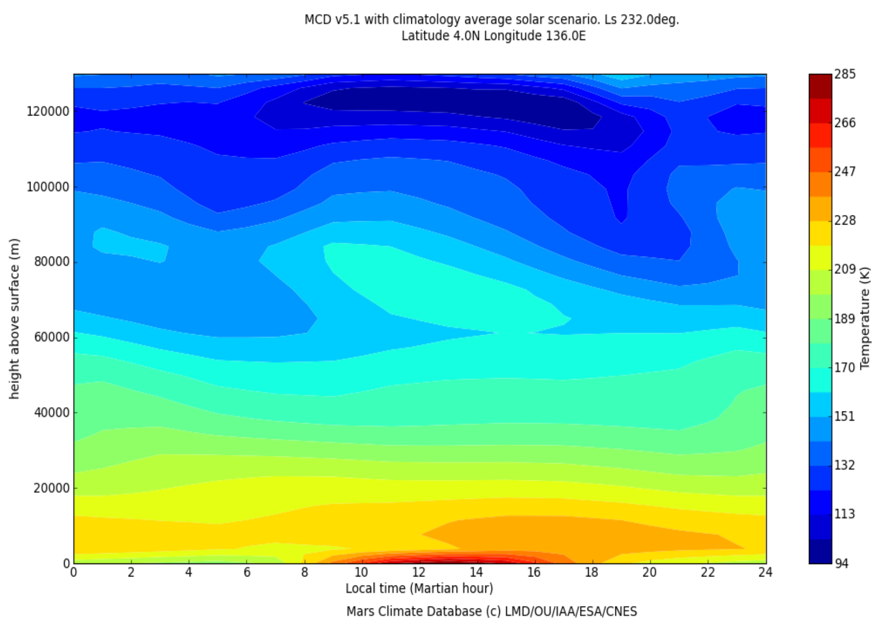
- Monitor seasonal pressure changes
- High accuracy/stability desired to constrain secular pressure trends
  - Residual Polar Cap losing mass? (Malin et al. ‘01)
  - Accurate pressure measurements can detect this (Haberle and Kahre, ‘10)
  - Pressure stability TBD

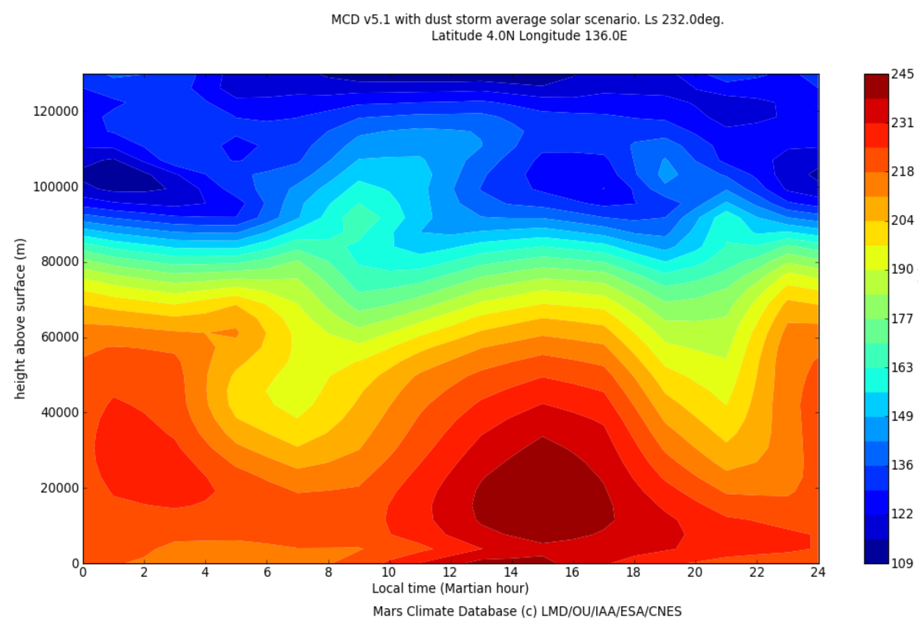


Thermal tides : typical vs. dust storm conditions



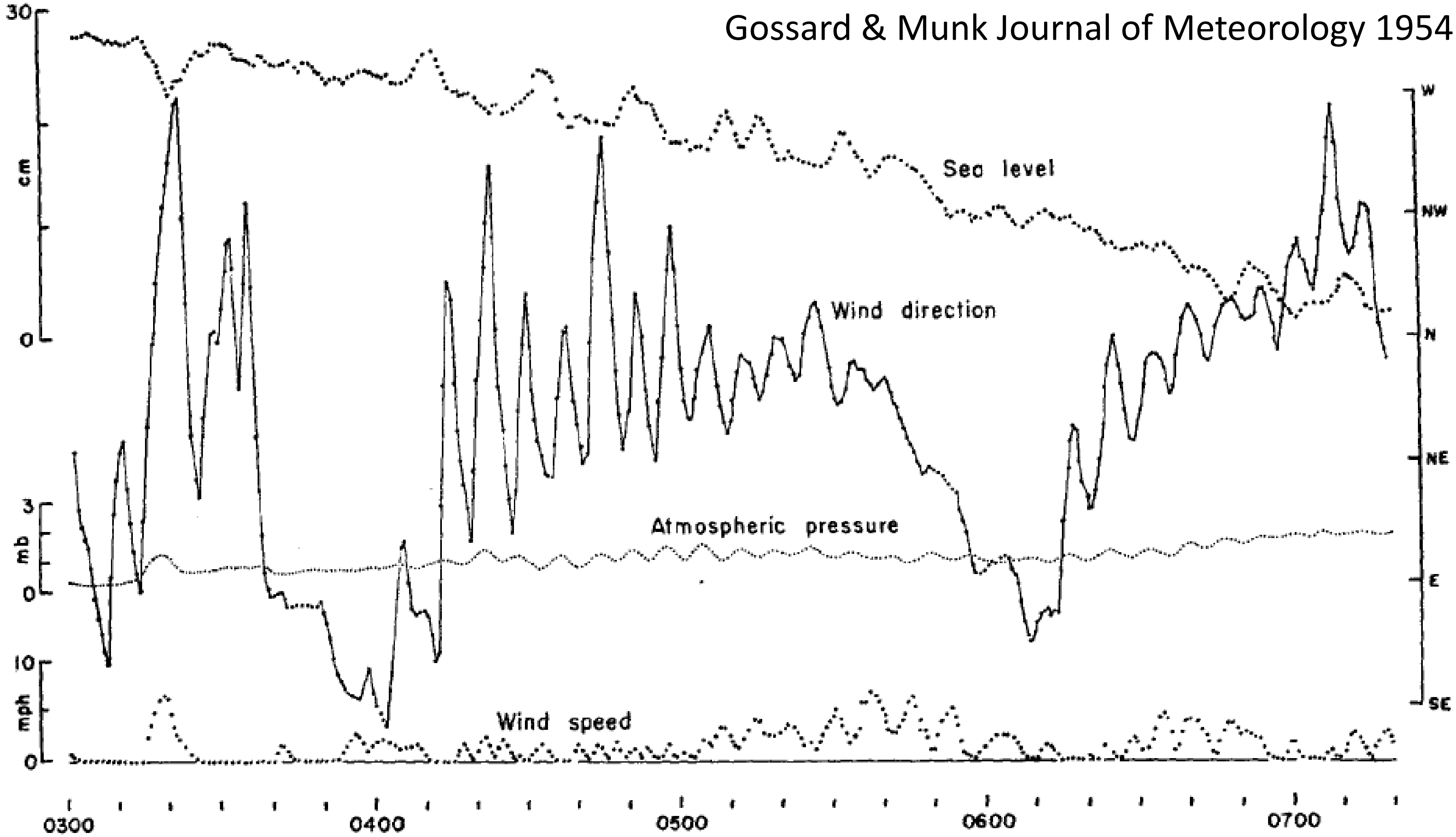




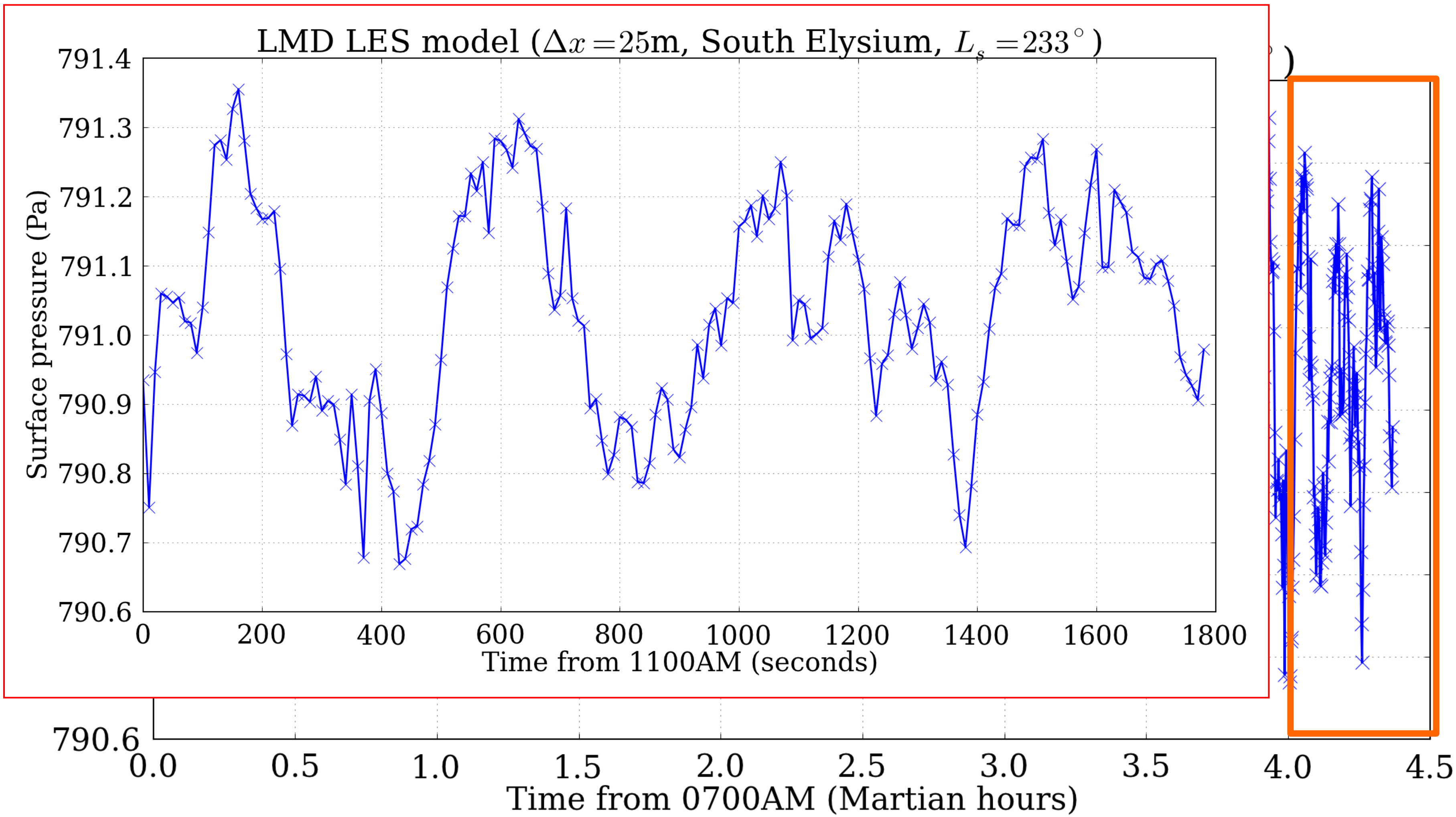


Gravity waves → observed on pressure ?

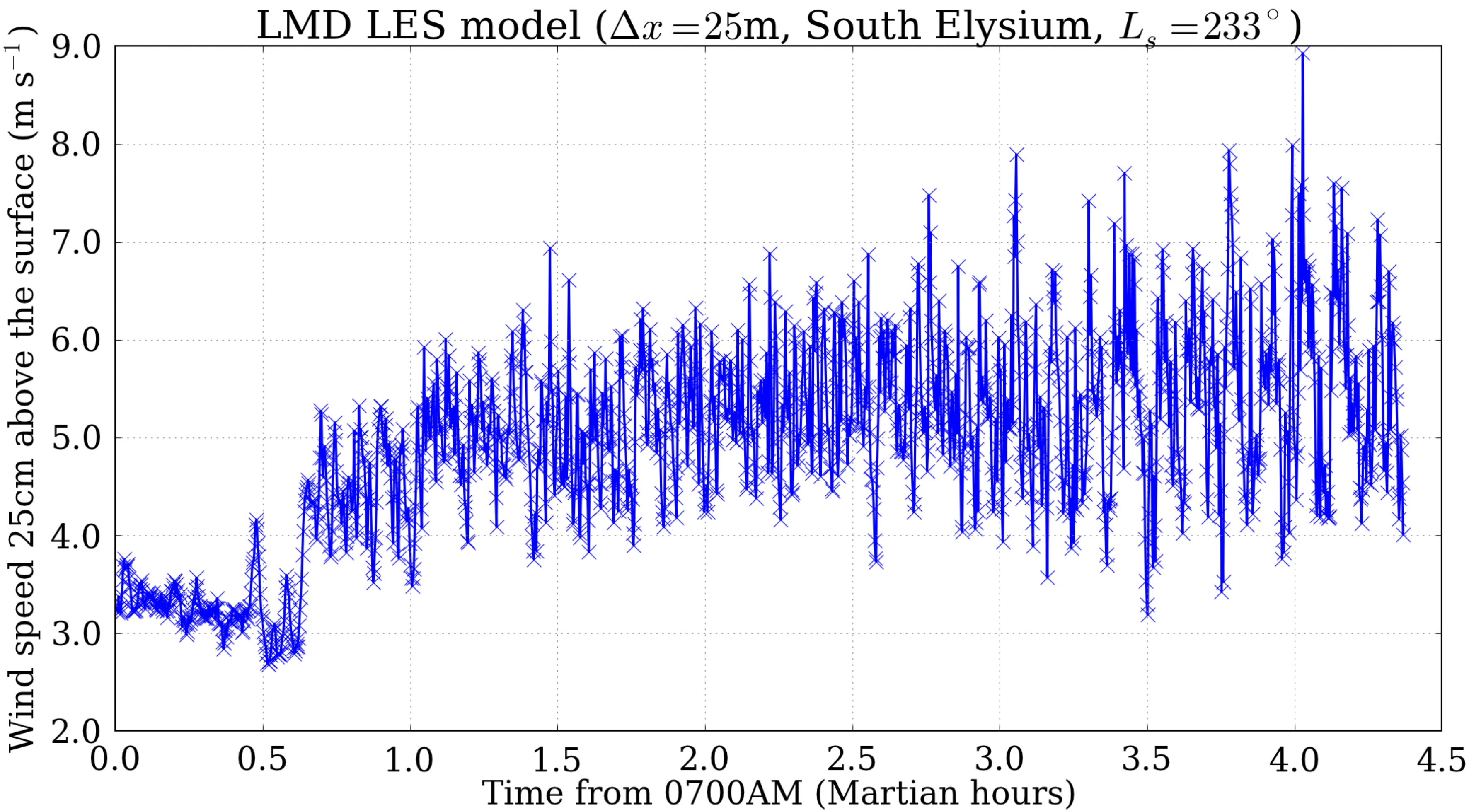
Terrestrial measurements
Gossard & Munk Journal of Meteorology 1954



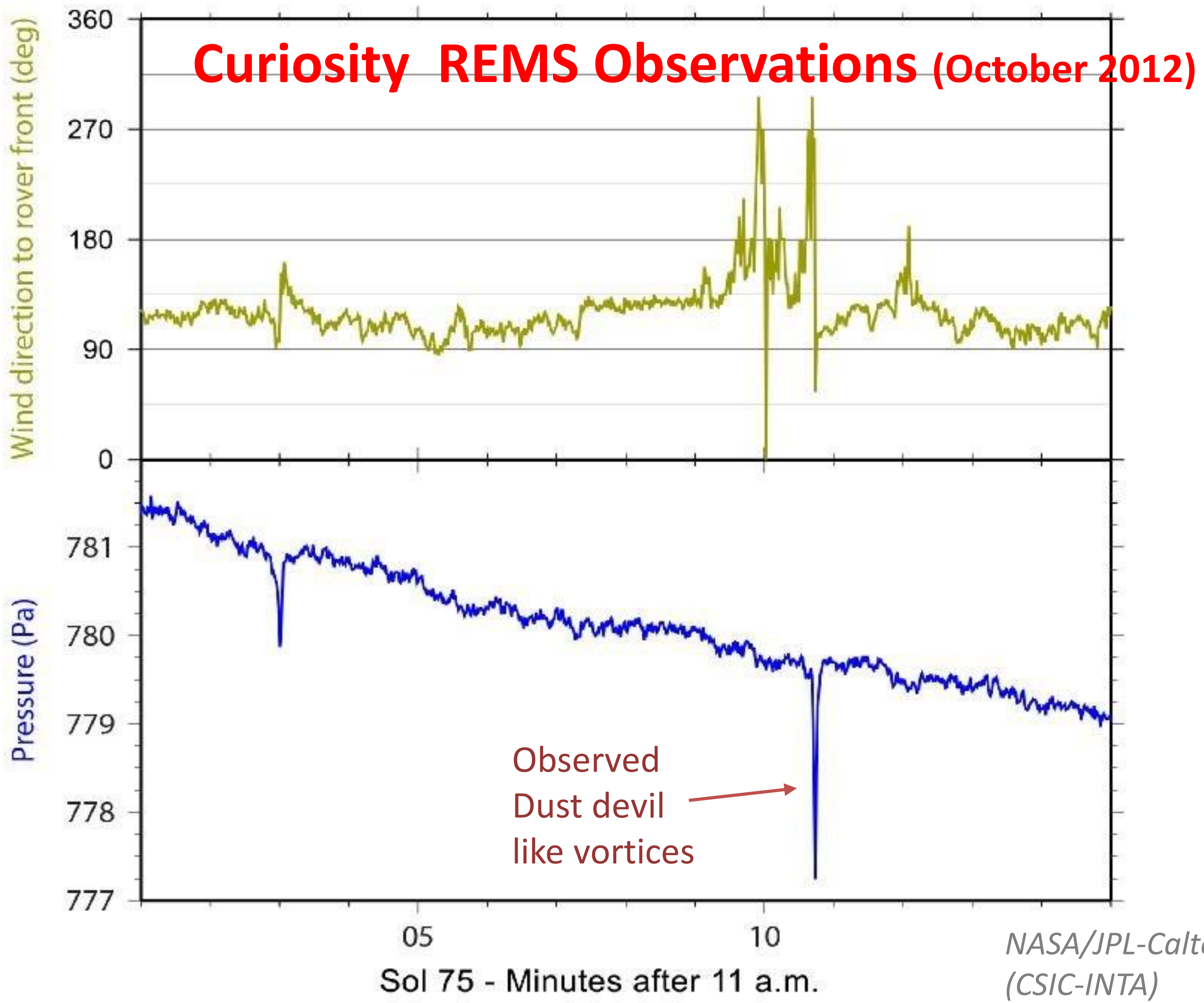
Surface pressure variations : convective cells



Turbulent horizontal winds

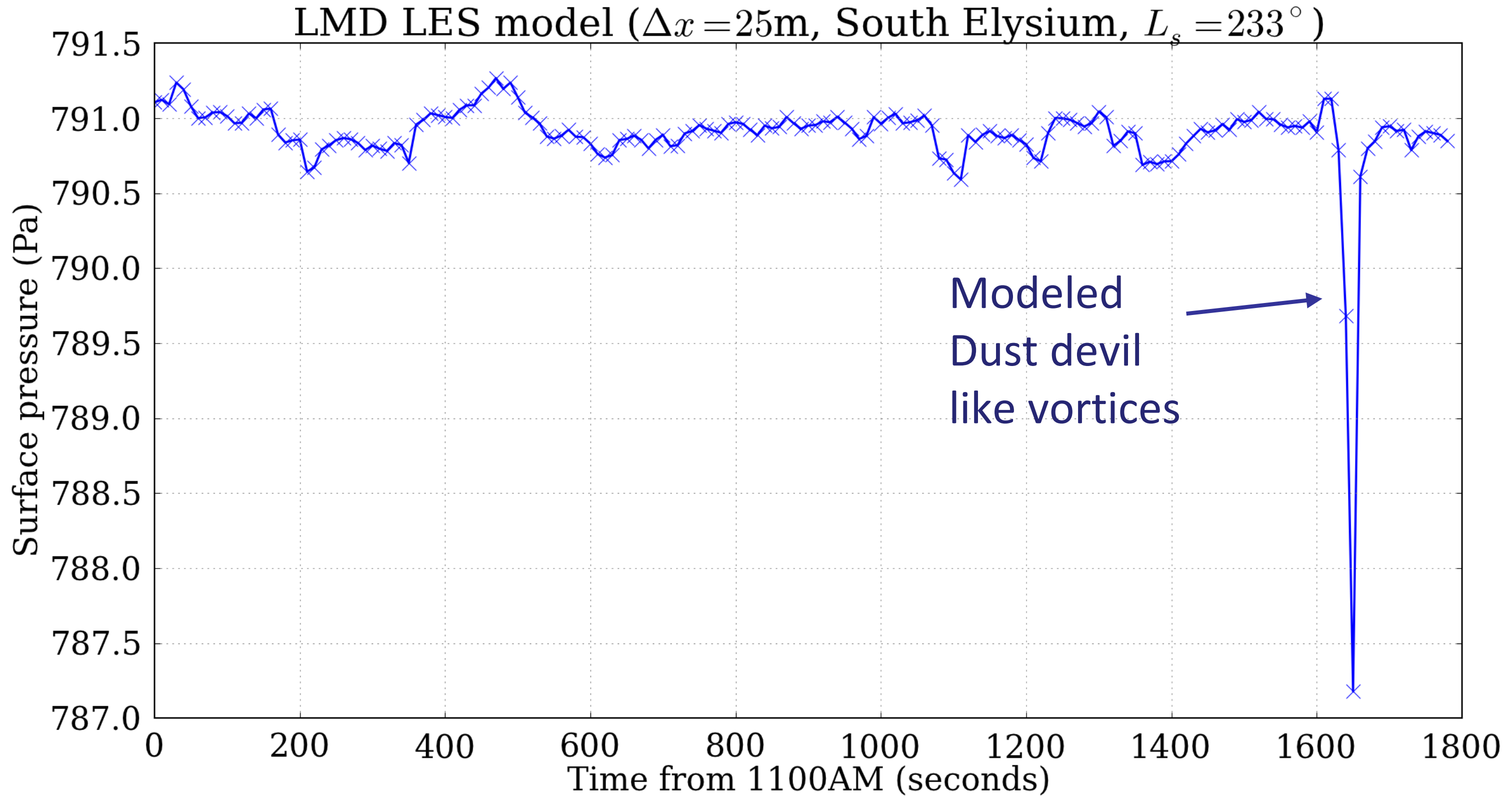


Surface pressure variations : convective vortices



NASA/JPL-Caltech/ CAB (CSIC-INTA)

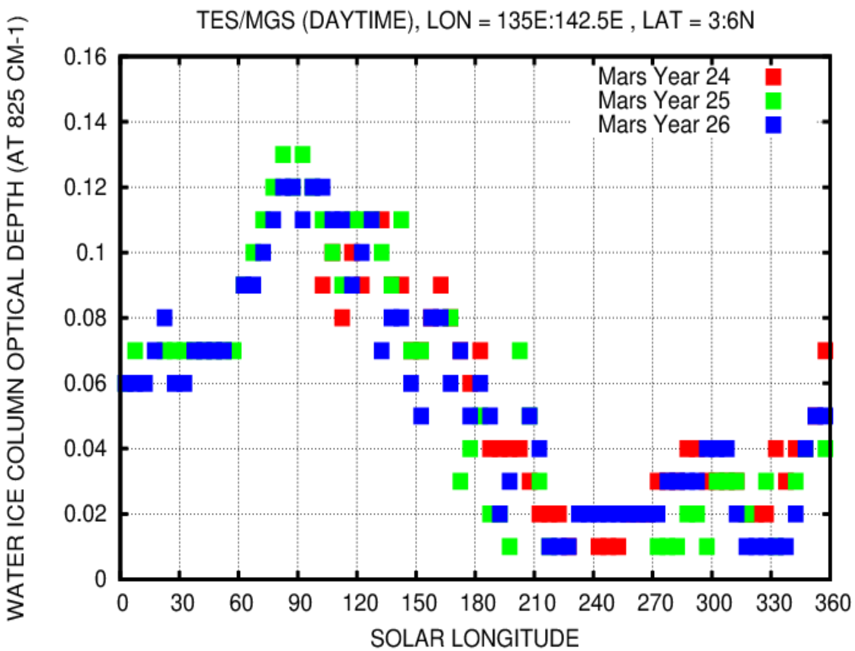
Surface pressure variations : convective vortices



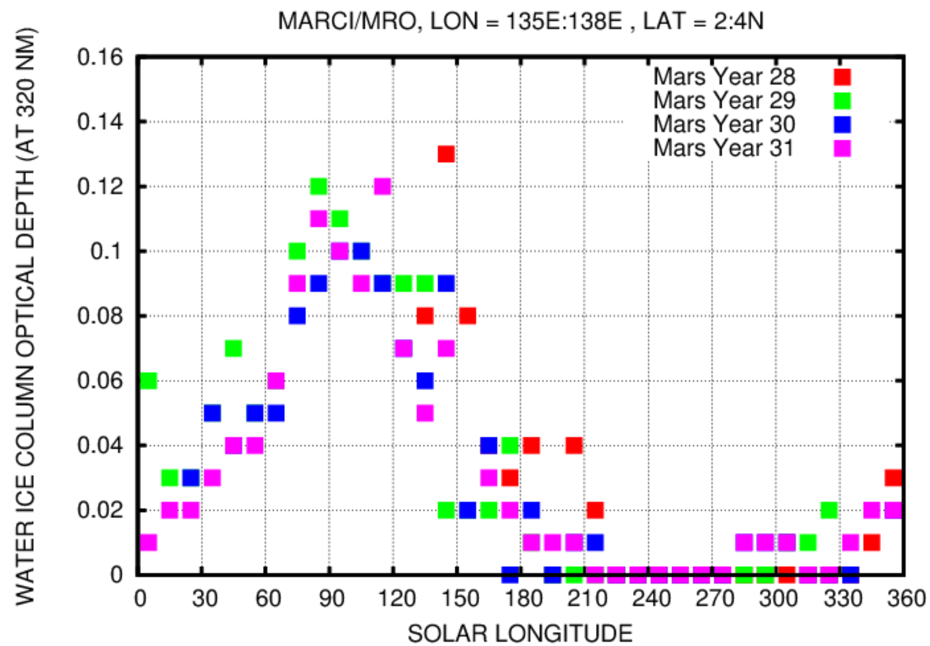
Atmospheric science with cameras

- Clouds : diurnal and seasonal evolution
- Dust opacity: seasonal evolution and storm monitoring
- Aeolian processes: witness lifting events (and assess wind threshold for motions?), seasonal evolution of ripple migration

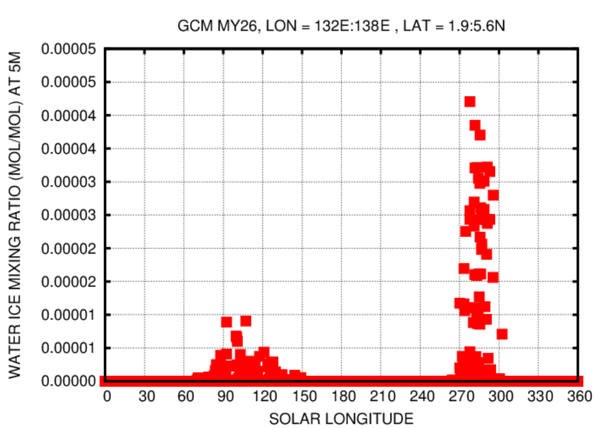
Seasonal cycle of water ice clouds and fogs



TES (**daytime** IR observations) water ice cloud optical depth database (Smith 2008)



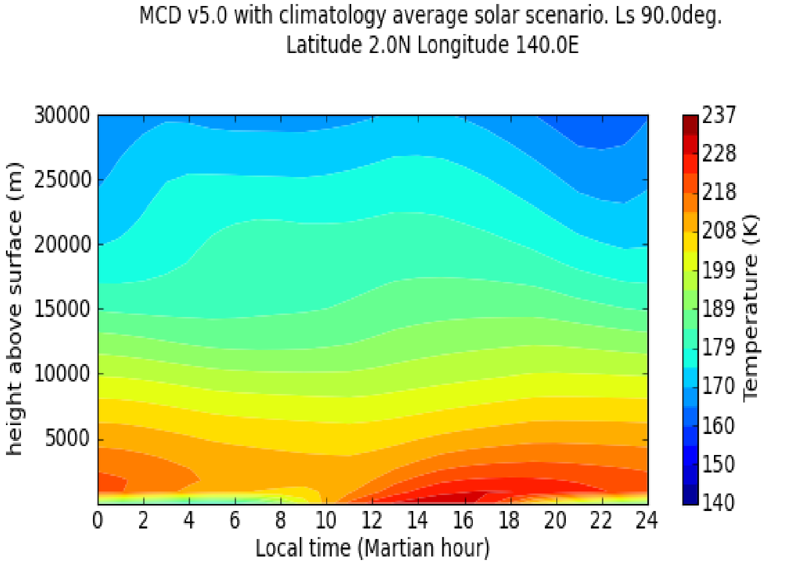
MARCI (**daytime** UV observations) extracted from SSI MARCI cloud optical depth database (Wolff et al. 2013)

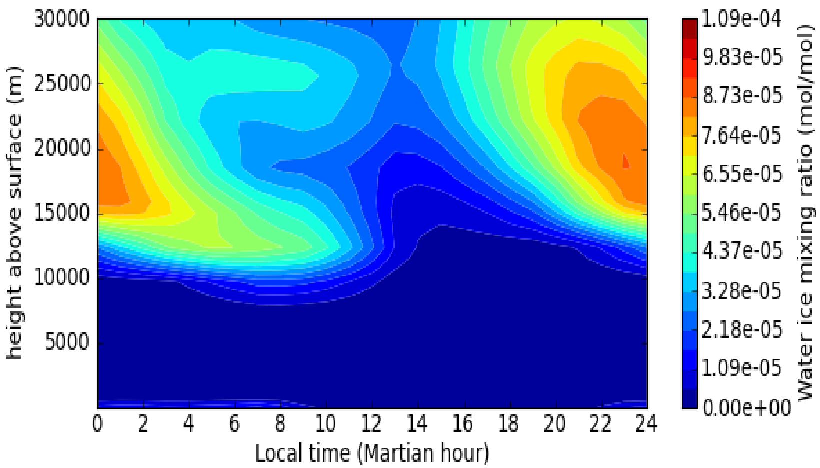


- GCM prediction of water ice fog near the surface
- Fog present only at distinct times of year

Diurnal cycle of water ice clouds and fogs

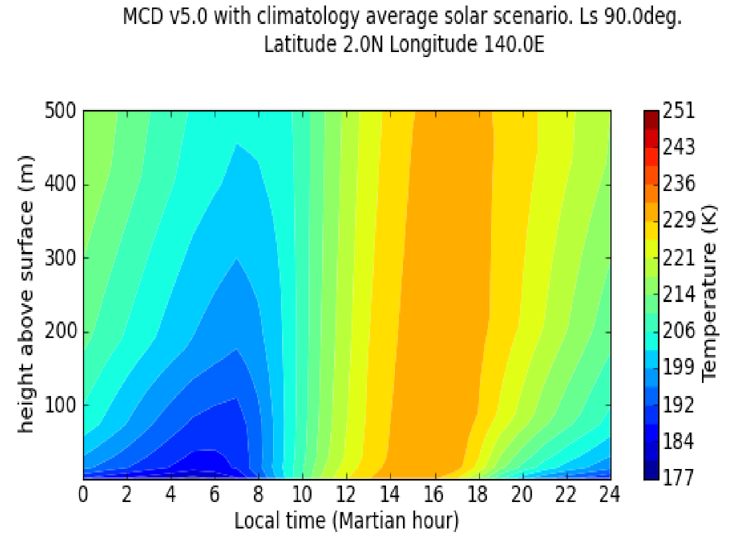
Thicker clouds develop during the night

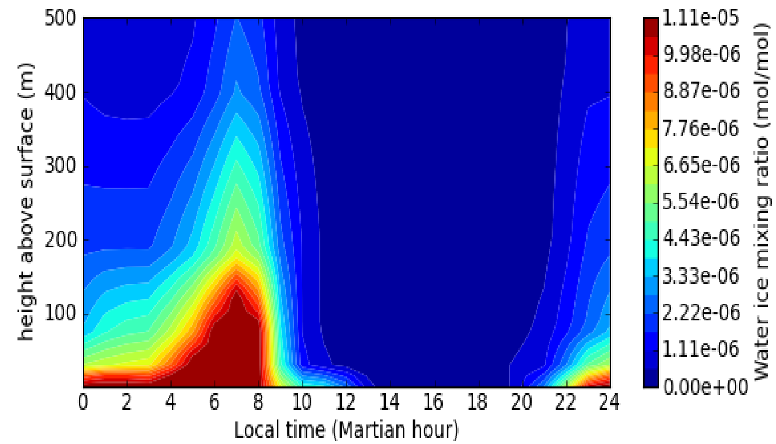




Mars Climate Database (c) LMD/OU/IAA/ESA/CNES

Near surface fog develops during the night and vanishes at daybreak.





Mars Climate Database (c) LMD/OU/IAA/ESA/CNES

Summary and Conclusions

- InSight: equatorial lander with meteorological package + high-resolution pressure sensor + cameras

- Increment existing datasets : wind, T, dust opacity, clouds
- Pressure
  – Increment existing large-scale diagnostics
  – New science for boundary layer and gravity waves

- LMD atmospheric models: GCM, mesoscale, LES
  – Involved for preparation & analysis
  – Happy to help with atmospheric expertise