Daily temperature variations on Mars

1. Introduction & Pb

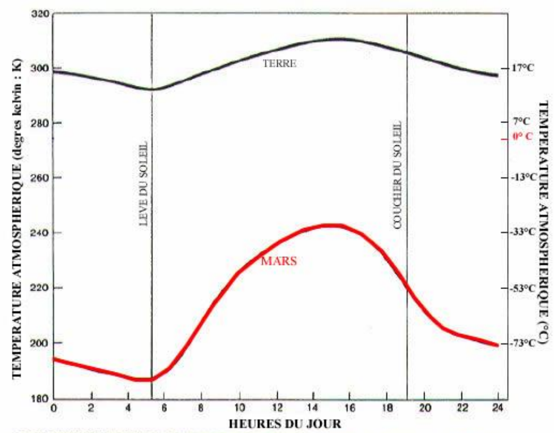
On Mars' surface, we can find summer trends: 20 °C, the breeze of trade winds… But starting with the onset of night, temperature values plummet by several tens of degrees and freezing conditions reaching – 100 °C will prevail until the morning after. In fact, Martian soil, dry and granular, can store only very little heat. Its thermal inertia is very small compared to that of the Earth and its oceans. The atmosphere being thin, temperature variations are more significant.

On Earth, daily temperature variations are less pregnant than those on Mars.

Chart of day-night temperatures of telluric planets:

Planet	T day (°C)	T night (°C)
Mercury	430	-170
Venus	460	450
Terra	15	5
Mars	-23	-93

Comparison between the daily variations of the atmospheric temperature on Viking 1 site and those of a terrestrial desert site (China Lake, California) :



DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the *Viking 1* landing site (*color*) are qualitatively similar to those at China Lake, Calif., a desert site (*black*). In both cases the temperature touches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about three times greater on Mars than it is on the earth. At Viking site range is 55 degrees, from about 187 to 242 degrees Kelvin (−86 to −31 degrees Celsius). At China Lake range is 18 degrees, from 292 to 310 degrees K. (19 to 37 degrees C.).

Case 2 shows a minimal temperature at sunrise.

Daily thermal fluctuations are 3 times stronger on Mars than on Earth.

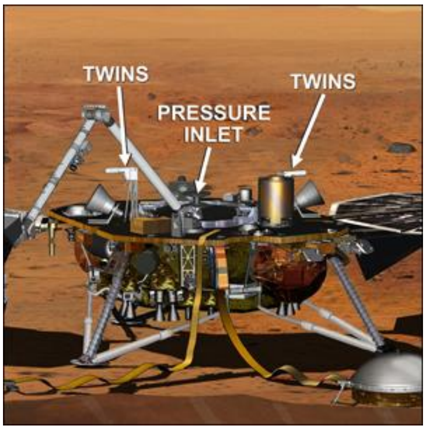
Source: Reserved rights - © 1979 According to Ryan et Henry, JGR

The InSight lander is equiped with a comprehensive weather station (APSS, Auxiliary Payload Sensor Suite).

The various sensors on this station (temperature, weather vane, anemometer, barometer and magnetometer) play a crucial role in the interpretation of data provided by InSight's seismometer SEIS, but also in enhancing the knowledge about Martian weather and its current climate. The knowledge acquired will help us to get a better grasp of weather perturbations on our planet Earth.

The ultrasensitive air-inlet pressure sensor of the APSS weather station installed on the deck of InSight (© NASA/JPL-Caltech/IPGP/Philippe Labrot).

This pressure sensor is ultrasensitive, meaning it is capable to react to variations of pressure at an order of dozen microPascals (i.e. 10-7 mbars). It's installed on the lander's deck, underneath the Wind and Thermal Shield (WTS).



NASA/JPL-Caltech - http://photojournal.jpl.nasa.gov/figures/PIA17358_fig1.jpg

TWINS sensors (Temperature and Wind Sensors for InSight) are thermal anemometers. There are two of them on the deck. The data is recorded at a maximum rate of one per second.

At a rate of 2 times per second, they record air temperature and also wind speed and direction, all this during the entire duration of the mission, that is a Martian year, equivalent to two terrestrial years.

The data that scientists obtain on a regular basis will allow us to better understand the phenomena linked to weather on Mars.

Pb : How can the analysis of meteorological data help us enhance our knowledge on weather perturbations on Mars, as well as on Earth ?

2. Age of students 15 – 17 ans

3. Objectives

Using a Python data processing script, show the information we can collect from the weather perturbations such as the diurnal cycle, the passing of a Dust Devil…

4. Primary subjects

Mathematics – Physics – Python Programming

5. Additional subjects

Earth Science

6. Time required 3hrs

7. Key terms

Geothermal gradient, heat flow, heat dissipation.

8. Materials

- Computer with software
- Excel – Python

9. Background

Thermal inertia of the soil, the rotational period and the atmosphere are the main parameters that control the day-night temperature disparity of a planet.

The **moving average** is a type of statistical average value used to analyse arrays of data, most frequently temporary arrays by removing the temporary fluctuations so that we can highlight longer term trends. This average value is called *moving average* because it is continuously recalculated, using for each rendition a subset of elements in which the newest element replaces the oldest one or is added to the subset.

This type of average value is generally used as a data processing method.

10. Procedures

- On Earth :

You have at your disposal, in « csv » format, the data corresponding to 9/7/2019 (cf csv data sheet) downloaded from the meteo website « WillyWeather » on China Lake Acres site (environment similar to that of Mars).

1. **You will have to represent the Temperature, Pressure and Wind Speed plots provided to you in Python script.**

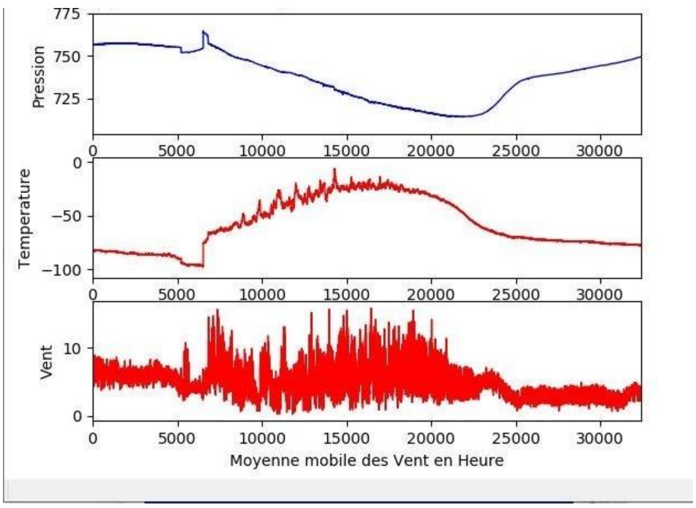
- On Mars :

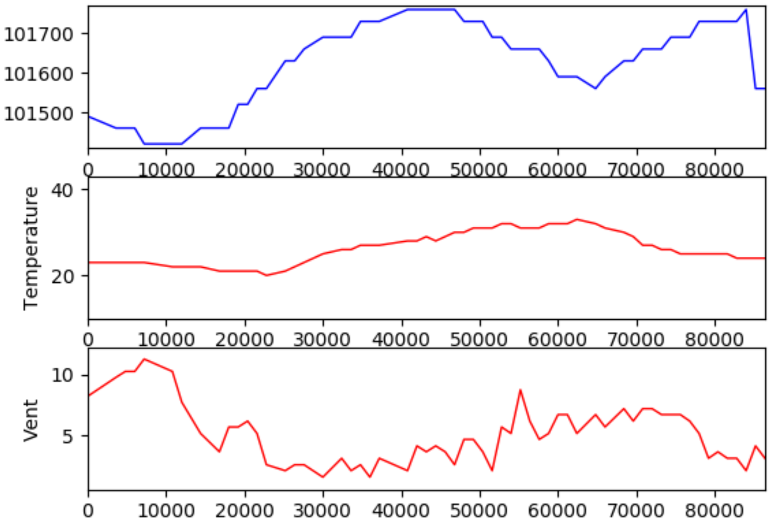
You have at your disposal, in « csv » format, the meteorological data corresponding to the 15th day of the InSight mission (cf csv data sheet).

2. **You will be asked to represent the plots for the parameters provided to you in Python language.**

Expected Results :

On Mars | **On Earth**





Time : second – Temperature : K – **Wind Speed :** m/s – **Pressure :** Pa

3. Compare and interpret the results obtained for Earth with those obtained for Mars.

We can distinguish significant temperature fluctuations on Mars, growing from – 83°C (at night) to 13°C (during day) that correspond to the diurnal cycle of Mars. In contrast, fluctuations in day-night temperatures on Earth are less significant (from 23°C to 32°C). The same goes for pressure.

In order to conduct a sharper study from the data, scientists need to take measurements less « polluted » by irregular values that re-enforce these exceptional phenomena such as dust devils and so on.

We will therefore use particular statistically obtained mean values that allow us to interpret the values with the purpose of excluding the so-called ***aberrant*** values (values distant from other observations made on the same phenomenon). These statistical mean values represent the «**moving average** or **rolling**/**running** average ».

Simple moving averages on 3 values, for a series of 9 measurements.

Mesures	2	3	5	8	8	7	8	5	2
Moyenne glissante	néant	(2 + 3 + 5)/3 3,3333	(3 + 5 + 8)/3 5,3333	(5 + 8 + 8)/3 7	(8 + 8 + 7)/3 7,6666	(8 +7 + 8)/3 7,6666	(7 + 8 + 5)/3 6,6666	(8 + 5 + 2)/3 5	néant

__**Source :**__ https://fr.wikipedia.org/wiki/Moyenne_mobile

In our particular case, the values being related to the atmospheric domain, we will use a « moving average on 6 hours, 8 hours and 12 hours » for Temperature and Pressure values, the same as computing the average values from 0h00 to 8h00, from 1h00 to 9h00, from 2h to 10h00 and so forth…

As our data recordings cover 3 days, we will thus be able to measure the maximum and minimum value of the rolling average to get an idea on the thermic amplitude for a Martian day, etc…

The purpose of using a rolling average is to interpret the potential accidental deviations (twist devil, …).

Operating mode for plotting the moving averages :

- Lists and operations made on the lists
- Curve plots

1) a) Write the **average** function (List_of_numbers) that allows you to obtain the mean value of a list of numbers.

Bonus) Write the **modified_average(List_of_numbers)** function that allows you to compute the mean value without the need for the **sum** function available in Python.

2) Write the **List_extract(p, n, List_of__nbrs)** that allows you to extract a list of a given **n** size starting from a given rank **p**.

3) a) Write the **Compute_Moving_Average (n, List)** function that allows you to obtain the list of moving averages on a n range of values of a given list.

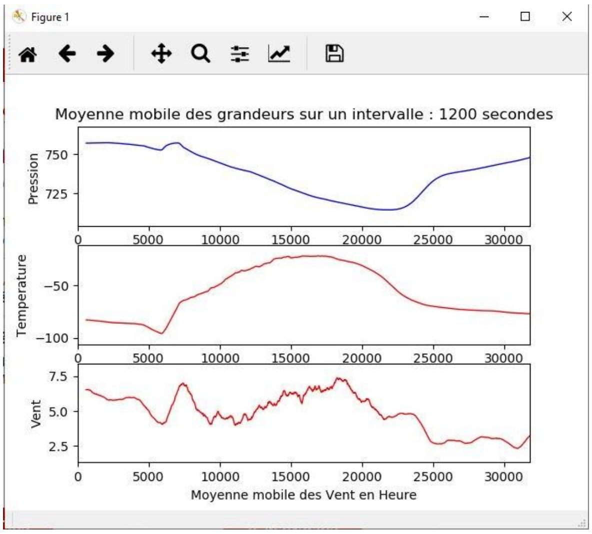
b) Provide the list of moving averages on a range of 8 values on the data recorded:
i) time values ii) temperature values iii) pressure values iv) winds

4) a) Write the **Moving_Average(n, List1, List2, List3,List4)** function that will display the temperature, pressure and wind speed mean values depending on the average time, on a range of 8 time values.
(We take into account the following correlations List1=Time List2=Temperature List3=Pressure List4=Wind)

b) Modify the **least_square_regression(n)** function code to assess the possible correlation between the two averaged physical quantities, Temperature and Pressure.

Colour code of graphs isn't required and will be provided in the student file

Plot obtained with a moving average for 20' of Martian data values:

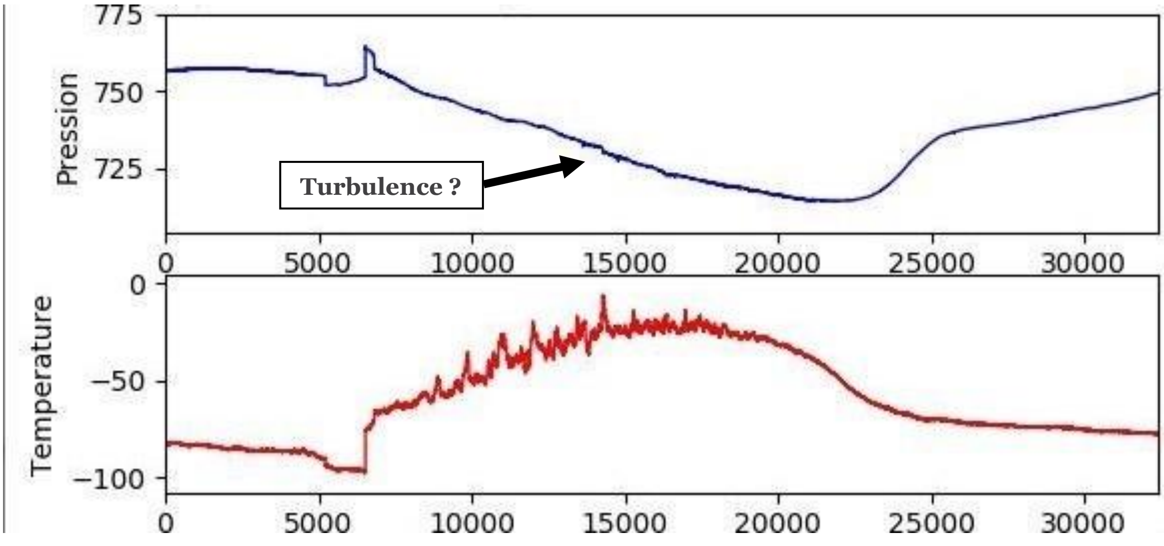


We can observe on the 'Pressure on Mars' plot large scale waves known as « thermal tides ».

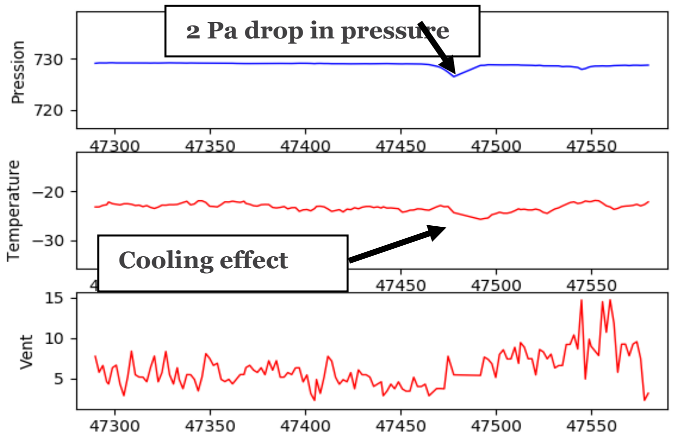
Basically, thermal tides are global-scale waves generated by fluctuations in the regular day-night cycle in the Sun's heating of atmosphere (insolation). These waves are displayed on wind components and they evolve with local solar time.

We observe a significantly marked diurnal cycle and violent winds up until sunrise. They are due to the cooling T° close to the ground during the night.

We observe on the Martian data plot (below) two perturbations that could be local «dust devil » whirlwinds, but we should carry out a more precise sampling in order to make sure of their presence:



Sampling on 250 seconds of Martian data isolating the Dust-related data we observed in the previous plots:

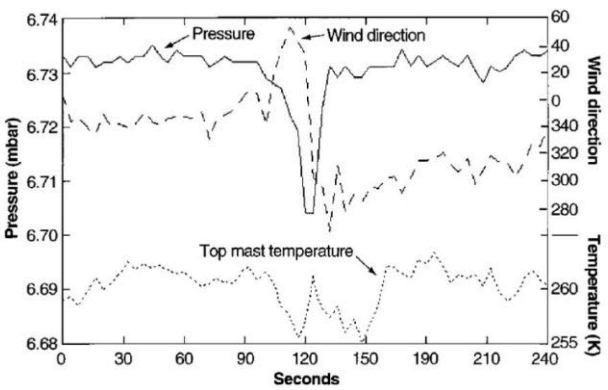


The thermal tides in the atmosphere of the planet Mars have a much higher amplitude than that of the Earth because thermal forcing is very strong due to the infrared absorption of atmospheric CO2, the absorbtion of infrared radiation emitted by the surface and the fact that the atmosphere on Mars is thinner.

The effect that atmospheric tides have on zonal and meridian average flow is therefore of great significance in the Martian atmosphere.

Comparison of the results obtained with data downloaded from Pathfinder website defining a Dust on Mars :

Pressure (hPa), wind (m/s) et temperature (K) measurements available on the Pathfinder site:



The data sampling rate is 4s. A dust devil passing through at cyclostrophic balance above the lander is reflected in a 2.5 Pa dew point depression and a decrease in temperature of approximately 5K. Wind's characteristic circulation was also recorded by the anemometers on Pathfinder, however the calibration issues didn't make possible to have an accurate measurement of the fluctuating wind amplitude. Image by Schofield et al. [1997].

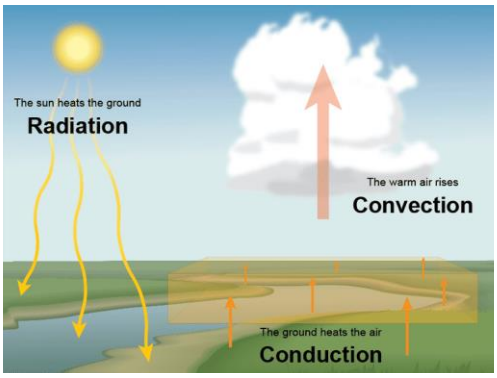
Source : Thesis by M. Aymeric Spiga « Mesoscale dynamic model of the Martian atmosphere: defining a meteorological model and analyse of observations made by OMEG/Mars Express »

Modelling the physical phenomena at the root of local whirlwind formation:

In an arid area, air close to soil surface is heated in a different manner. The heat will be transfered vertically by the radiation to a layer of colder dry air and will undergo an upward thrust according to Achimedes' principle and reach convection.

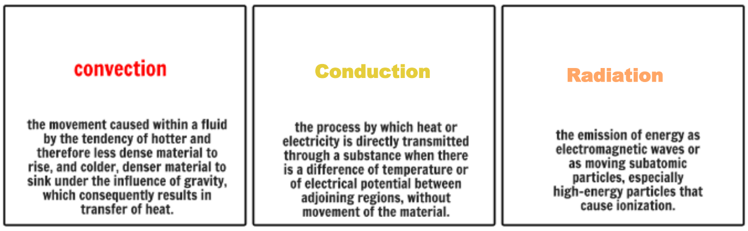
The arrival of a horizontal transport of air mass will generate a rotation in the air which will then confine all the dust in its proximity.

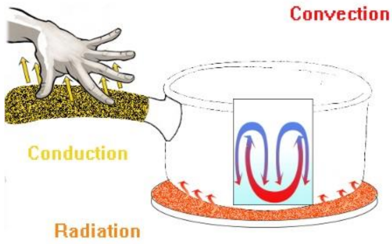
The altitude and diameter of a a whilwind depends on the air's instability and dryness.



Source : https://www.thoughtco.com/what-is-convection-4041318

<u>Plan three simple experiments to get a model for each heat transfer method:</u> Convection – Conduction – Radiation. You can only use the materials provided for you.





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11. Discussion of the results and conclusions

Martian weather resembles that of Earth in many ways. It is basically abundant in storms, tornadoes, dust…

And yet, Mars sets itself apart from planet Earth. Martian atmosphere is in fact not so thick, the phenomenon of diurnal wind variation, of so little significance on Earth, is identified by the great fluctuations in the day-night cycle.

The analysis of meteorological data allowed us to discover weak signals in the large-scale cosmic structure (thermal tides) and fast signals in the local scale (whirlwinds and convective turbulence).

En effet, les oscillations diurnes de la température et du vent à la surface excitent indirectement toutes les autres couches de l’atmosphère. Ce qui entraîne la vibration de la couche atmosphérique martienne ou plus exactement propage des ondes de de fréquence diurne (une oscillation par jour) appelée « onde de marée thermique ». Ces oscillations diurnes vont interagir avec les autres vents et influencer la circulation atmosphérique qui sera enregistrée inévitablement par le sismomètre SEIS.

In fact, diurnal variations of temperature and wind values found at the horizon indirectly stimulate other layers of the atmosphere. Which therefore stimulates the vibration of the Martian atmosphere or more precisely propagates waves of diurnal frequency (one amplitude per day) called « atmospheric thermal tides». These diurnal oscillations will interact with other winds and have an effect on atmospheric circulation inevitably captured by SEIS.

Once the data is continuously collected, meteorologists responsible for this mission will have to separate the thermal tides from the data provided by InSight’s seismometer SEIS.

12. Explore More (additional resources for teachers)

- “Planet Mars” : Edition Belin – François Forget, François Costard – Philippe Lognonné

- M. Aymeric Spiga’s Thesis « Mesoscale dynamic model of the Martian atmosphere: defining a meteorological model and analyse of observations made by OMEG/Mars Express »