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Mars Large Scale Meteorology Observed By Insight

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Introduction:

The NASA Mars Insight Lander is providing the best long-duration meteorological station since Viking. In particular, thanks to its very precise pressure sensor [1] and two Wind and Air temperature sensors (TWINS)[1], it could ultimately offer an almost continuous multi-year record of the environment at its landing site in Elysium Planitia (~4.50°N, 135.62°E, -2614 m with respect to the MOLA areoid), starting 14 sols after its landing (around Ls=304° on Martian Year 34).

Insight is located near the equator where the weather activity and day-to-day variability could have been expected to be small. Yet, it is found that its particular landing site, south of Elysium Mons is particularly exposed to meteorological variations and transient eddies. They induce interesting variability in the local pressure and near-surface winds. At the 9th International Conference on Mars, we will present a detailed analysis of the first 200 sols observed by Insight.

Daily Pressure variations. As expected, the daily pressure oscillations induced by thermal tides are the most prominent feature of the pressure signal recorded by Insight. At the beginning of the mission and until Ls=340°, the pressure was usually relatively constant between midnight and 6am (local time), slightly increased between 6am and 9am, decreased by 8% between 6am and 6pm, before a sharp increase between 6pm and 11pm. This cycle was very well predicted by numerical Global Climate Models (see Fig 7. in [2]), except during the ~10 sols regional dust storm observed around Ls=320°-325° which excited interesting thermal tides modes as discussed in Newman et al. (this issue). After Ls=340°, the pressure cycle exhibited additional intriguing variations at night-time with an additional oscillations, with notably a maximum around 8pm-9pm which is stronger than expected by models. The pressure diurnal cycle may also be affected by local or regional effects that remains to be investigated in details.

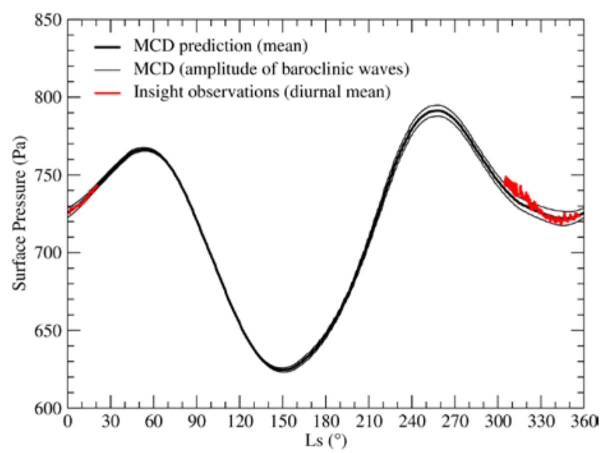

Figure 1. Diurnal mean pressure measured by the Insight pressure sensor until sol 156 (Ls=21°) compared to a prediction from the Mars Climate Database (MCD) notably based on an interpolation from the Viking Lander 1 pressure records forty years ago [2,3]

Seasonal Pressure Variations. The daily averaged pressure data (i.e. with the thermal tides removed) for the first 130 sols are primarily characterized by the large semi- annual oscillation due to the familiar seasonal CO_2 cycle with pressure minima occurring at times when the winter seasonal caps are fully extended and pressure maxima occurring when they first disappear. This evolution can be compared with the seasonal pressure cycle observed by the Viking Lander 1 forty years ago on the other side of the planets by carefully interpolating the Viking record using accurate MOLA data and GCM-predicted wind and temperature field to estimate the meteorological component of the pressure cycle, as provided by the "Mars Climate Database" (MCD) and as described in [3] (see also [4] and [2]). The agreement is excellent (Fig. 1), except at the beginning of the mission where a significant difference that remains to be investigated. Could it reflect the influence of the MY34 equinoctial global dust storm on the CO_2 cycle ? (Fig. 2)

Day-to-day pressure variability. As previously reported by Haberle et al. [5] using Curiosity REMS measurements (not very far from Insight at 4.5°S, 137.4 °E) even at latitude as low as the ones monitored by Curiosity and Insight it is possible to detect and characterize the signature of transient eddies induced by baroclinic wave activity in the Northern hemisphere (Fig. 1). The first sols monitored by Insight (during northern winter) were characterized by beautiful ~2.5 sols regular oscillations (Figure 2), followed by less regular oscillations also dominated by ~7 sols waves as reported by [5].

Wind variability. The measured winds exhibit an interesting variability at various timescales, somewhat predicted by GCMs although much remains to be analyzed.

As predicted by models [2], the seasonal mean wind evolved from a strong flow toward south-east corresponding to the return branch of the Hadley cell during winter (until Ls~330°) to a weaker, more variable "equinoctial" regime.

Every day, the large-scale dominant wind is modulated by a diurnal oscillation induced by the weak, but non-negligible Northward-Eastward slope that characterizes the Insight landing site at regional scale. In theory this oscillation could also result from the planetary scale thermal tides. However GCM numerical simulations performed with an artificially flatten regional topography around Insight suppress the diurnal wind oscillation (whereas the full topography simulations are in good agreement with the observations).

During Northern winter, the observed wind intensity and wind direction was characterized by a strong day-to-day variability. This variability is clearly correlated to the pressure variations (with maximum wind when the pressure is high) and thus to the baroclinic front system (Fig. 2). The day-to-day variations in wind direction have two combined origins. On some sols the large scale wind variations are strong enough to trigger a global oscillation of the mean flow. The changes in wind direction can then be seen on the daily-mean wind records. Sometime the large scale variations only decrease or increase the velocity of the mean flow without significantly modifying its mean direction. Yet this can induce spectacular changes in the observed hourly-mean wind direction since this hourly-mean wind is the sum of the mean flow and of the diurnal slope-wind oscillation. If the mean flow is strong, the additional diurnal oscillation only induce a small variation in the direction. If the mean flow is weak, then the diurnal oscillation dominates and the wind rotates 360° that particular sol.

Conclusion. The Insight meteorological sensors are monitoring a very interesting location. In spite of its low latitude, the Insight landing site is characterized by large variabilities of dynamical origins which constitute an excellent dataset to better understand Mars meteorology and test our numerical General Circulation Model.

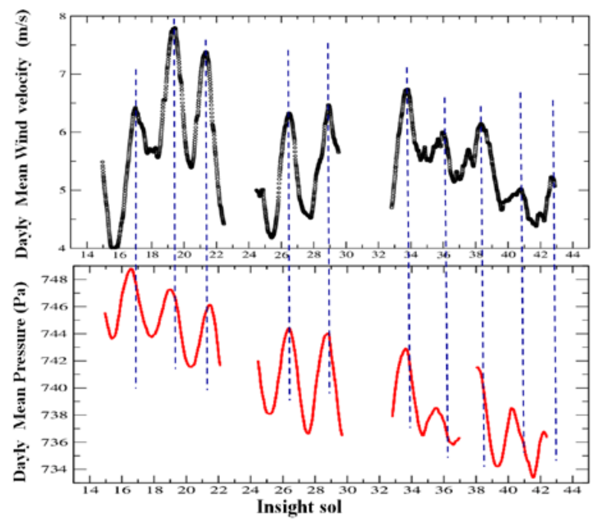

Figure 2. Diurnal mean wind velocity and pressure measured by INSIGHT at the beginning of the mission (Ls=305-320°). The blue dashed lines underlines the correlation between pressure and wind velocity which shows that the strong wind day-to-day variability was then controlled by mid-latitude baroclinic waves.

References::

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