New atmospheric science with the Mars InSight lander mission

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Introduction: The InSight 2018 Discovery mission consists in landing for the first time a geophysical station on the surface of Mars [1]. The InSight lander comprises a seismometer (SEIS) [2], a subsurface heat flow and physical properties package associated with a radiometer (HP3) [3], two color cameras (IDC, ICC) [4], a Doppler receiver/transponder to detect rotation variations (RISE) [5], and a meteorological station (APSS) [6] composed of a highly sensitive pressure sensor and two meteorological booms measuring wind and temperature, akin to the meteorological package on the Curiosity rover (REMS). The InSight mission's highest level goal is to understand the processes of formation and differentiation that have occurred on telluric planets. Thus, the major science objectives of the InSight mission to Mars are to probe for the first time the seismic activity of an extraterrestrial body, to measure its internal heat flux, and to reconstruct the structure of the interior of the planet. Yet atmospheric science remains a key science objective for InSight, for a variety of reasons.

Atmospheric science as a key science goal: First and foremost, a thorough assessment of the seimic noise caused by the atmosphere is a key element of success of the primary science goals of the mission. This is why InSight carry a complement of meteorological sensors, so as to understand when winds preclude good seismology and to possibly remove meteorological effects from the seismic signals. Secondly, from the pure atmospheric science standpoint, InSight is not just another lander on Mars: in addition to adding to the record of atmospheric observations at the surface of Mars, the mission will enable new atmospheric science experiments. For instance, along with meteorological measurements of temperature and winds, InSight will enable to acquire atmospheric pressure at high frequency and unprecedented accuracy. Furthermore, InSight may be the best prototype for a future network of geophysical-meteorological stations at the surface of Mars, just as such networks are deployed on the Earth.

Direct atmospheric measurements: InSight carries basic wind and air temperature sensors (a variant of the wind and air temperature sensors from MSL REMS, with an optimized position of the two booms to enhance the scientific return of wind measurements), as well as a highly sensitive pressure sensor (a Tavis pressure sensor, an improved version of those used on the Viking and Pathfinder missions). The pressure sensor is also equipped with a quad-disk inlet, adapted from those used in terrestrial infrasound detectors, to isolate atmospheric pressure changes from wind-induced dynamic pressure fluctuations. The pressure sensor will be sampled at 20Hz with a response time of at least several Hz, and have a noise level on the order of 10 mPa. This is roughly two orders of magnitude more sensitive than its predecessors, and will be sampled about 1 order of magnitude higher than its predecessors as well.
Profiling of the Mars' atmosphere (density, temperature) using entry probe flight instrumentation (accelerometers, gyroscopes) will be carried out similarly to previous retrievals during lander and rover's EDL (Entry, Descent and Landing). Given the Ls=295° season of landing, propitious to local or global dust storm activity, this new EDL profile will provide a crucial complement to the existing dataset obtained at clearer seasons.

Indirect atmospheric measurements: The seismic measurements will bring a new angle to atmospheric measurements on Mars. Firstly, the knowledge on atmospheric activity can be employed to estimate the atmosphere-induced seismic noise:

- at high frequency, i.e. timescales less than a couple of hours: turbulence [7], dust devils [8], gravity waves [9]
- at low frequency, from daily to annual timescales: thermal tides, planetary waves, seasonal cycles.

The scientific income of seismic measurements on board will be particularly significant for the high-frequency variability. Measuring the form of the wind spectrum on Mars across a large bandwidth, especially up to high frequencies (> 1 Hz), would provide a unique opportunity to study the atmospheric turbulence on Mars. The InSight APSS (wind and pressure) sensors will provide information at low to intermediate frequencies. The lowest frequencies accessible will be set by the wind speed and the measurement height, which determines the typical dominant eddy size. The highest frequencies will be several Hz (limited by the response times of the instruments). The seismic sensors, however, will measure to higher frequencies (up to 100 Hz, depending on the operational mode in use), and are known to be sensitive to atmospheric turbulence. Seismic measurements by InSight will also provide additional constraints on the characteristics of dust devils and convective vortices. The direction of the tilt directly gives the back azimuth of the vortex center as a function of time. Coupled with wind measurements, the back azimuth permits to reconstruct the distance and trajectory of the vortex, without the need for additional modeling. Even without the added dimension of seismic signatures of dust devils, the InSight instrumentation promises to yield a dataset that will surpass previous missions in several ways in characterizing a Martian dust devil population: not only quasi-continuous observations at high cadence, but also instrumental superiority given the sensitivity of the barometer.

Other indirect measurements include more exploratory scientific investigations, such as :

- the evaluation of the atmospheric angular momentum from the RISE experiment;
- investigations on the surface layer using combined atmospheric TWINS-based temperature measurements and surface HP^3 radiometer-based measurements;
- estimates of aeolian erosion and ripple migration from imagery over a Martian year, and comparison with wind measurements;
- attempts to estimate of secular pressure changes (linked to the residual polar caps' mass).

Synergy with existing orbiter: The most relevant point to be discussed at the scientific workshop "From Mars Express to ExoMars" is how synergistic scientific studies could be defined between InSight measurements and Mars Express, ExoMars TGO, and Mars Reconnaissance Orbiter acquisitions. Possible ideas include

- the use of regional context imaging to monitor meteorological events (e.g. dust storms, clouds, etc...) passing over, or close to, the InSight lander;
- the comparison of atmospheric opacity retrieved from InSight (using cameras) with similar measurements from orbit, and the use of those measurements in dust climatologies useful for climat models;
- the study of dust devil occurrences and tracks close to the InSight landing to relate to the convective vortice events detected at the surface – with possible retrievals of tangential wind measurements from orbit;
- the study of aeolian erosion and surface thermophysical properties (roughness, thermal inertia) to compare to orbital retrievals; same with geological context;
- a comparison of available measurements (from orbital to in-situ) with climate modeling at all scales: Global Climate Modeling, mesosale modeling, Large-Eddy Simulations.
- (other ideas welcome)

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