First Atmospheric Results from InSight APSS

Conference or Workshop Item

First Atmospheric Results from InSight APSS, D. Banfield[1], A. Spiga[2], C. Newman[3], R. Lorenz[4], F. Forget[2], D. Viudez-Moreira[5], J. Pla-Garcia[5], M. Lemmon[6], N. Teanby[7], N. Murdoch[8], R. Garcia[8], P. Lognonne[9], B. Kenda[9], D. Mimoun[8], O. Karatekin[10], S. Lewis[11], W.T. Pike[12], N. Mueller[13], E. Millour[5], S. Navarro[6], L. Mora Sotomayor[6], J. Torres[6], A. Molina[6], J.-A. Rodriguez-Manfredi[6], S. Smrekar[14], B. Banerdt[14], and the InSight Science Team, [1]Cornell Center for Astrophysics and Planetary Science, Cornell University, 420 Space Sciences, Ithaca, NY 14853 (banfield@astro.cornell.edu), [2]Laboratoire de Meteorologie Dynamique (LMD), Paris, France, [3]Aeolis Research, Pasadena, CA, [4]Johns Hopkins University Applied Physics Lab, [5]Centro de Astrobiologia, Madrid, Spain, [6]Space Science Institute, [7]University of Bristol, [8]Institut Superieur de l'Aeronautique et de l'Espace (ISAE), Toulouse, France, [9]Institut de Physique du Globe de Paris, Paris, France, [10]Royal Observatory of Belgium, [11]Open University, UK, [12]Imperial College, London, [13]DLR Institute of Planetary Research, [14]Jet Propulsion Laboratory, Pasadena, CA

Introduction: NASA's Mars InSight Spacecraft landed on Nov 26, 2018 (L_s=295°) in Elysium Planitia (~4.5°N, 136°E). InSight's main scientific purpose is to investigate the interior structure and heat flux from Mars, but it is also equipped with instrumentation that can serve as a very capable meteorological station. To remove unwanted environmental noise from the seismic signals, InSight carries a very precise pressure sensor (PS) and the first magnetometer (IFG) to the surface of Mars. Additionally, to aid in removing the atmospheric pressure-induced seismic noise, and to identify periods when wind-induced seismic noise may reduce sensitivity, InSight also carries a pair of Wind and Air temperature sensors (TWINS). These three sensors comprise the Auxiliary Payload Sensor Suite (APSS) [1]. Complementing this are a radiometer in the HP^3 suite to measure surface radiance, the seismic measurements of SEIS which can record interesting atmospheric phenomena, and the InSight cameras to image clouds and dust devils and estimate atmospheric opacity from dust or clouds. The Lander also carried accelerometers that can be used to reconstruct the atmospheric structure during descent. We will discuss results drawn from atmospheric measurements on board InSight from the first months of operation, highlighting the new perspectives permitted by the novel high-frequency, and continuous nature of the InSight data acquisition. Details on pre-landing scientific perspectives for atmospheric science with InSight are found in [2].

Description of APSS-PS & TWINS: InSight's pressure sensor is a fast-response, high precision instrument compared to previous Mars pressure sensors. It is sampled at 20Hz continuously and has a single observation noise level of about 10 mPa. The absolute calibration is accurate to about 1.5 Pa with expected drift over the 1 Mars year of the mission of <~1.5 Pa. It is equipped with a special Quad-disk inlet to greatly reduce wind-induced dynamic pressure perturbations [1].

The wind and air temperature sensors for InSight have high heritage from the REMS sensors from the Curiosity rover [3], with specific improvements to their ability to operate under cold conditions. The two booms face opposite directions near the edge of the lander deck to minimize wind and air temperature perturbations from the lander itself. The resolution of the air temperature measurements is about 0.1K (with an absolute accuracy of <5K). The wind sensors are able to distinguish wind directions with an angular resolution of <22°, and wind speed to ~0.4 m/s for low wind speeds, rising to ~2 m/s for higher wind speeds [1].

Comparison of Data and Models: A key motivation for sending meteorological instrumentation to the surface of Mars is to validate and improve the atmospheric models we rely on not only for scientific understanding of processes on Mars, but also for (e.g.) landing planning and safety. The first steps in this validation include comparison of existing models with the in situ observations from InSight.

Diurnal Variation and Mean Pressure (with Seasonal Trend). The pressure signal recorded by InSight shows a regular daily variation, controlled by thermal tides which are well predicted by several Mars GCMs. The significant seasonal pressure variations are also evident in InSight's pressure record.

Air Temperatures. The shape and amplitude of the diurnal cycle evident in InSight data is fairly well captured by models, with slight offsets likely reflecting differences between the model-specified and actual surface properties (e.g., thermal inertia).

Winds. Two main large-scale seasonally-varying wind regimes were predicted for the InSight landing site, both dominated by the Hadley circulation. In Northern winter (when landing occurred) the return flow is generally north to south, whereas is northern summer, the return flow is the reverse (generally to the north) [2,4].

The diurnal cycle of wind speed and direction was predicted by the models to increase in speed during daytime in northern winter but at night in northern summer [4], with thermal tides rotating the wind from azimuth 300° at midnight counterclockwise to ~210° by dawn, then back to ~340° by mid-afternoon returning to 300° around sunset. We will discuss the agreement between InSight wind data and the models.

Convective Vortices: Abundant transient drops in pressure have been observed, interpreted to be caused by convective vortices in the Planetary Boundary Layer, which are known as dust devils when the vortex is made visible by entrained dust particles. Preliminary indications are that in the northern winter season in which InSight started its operations, these vortex encounters happen more frequently at Elyisum than those observed by Pathfinder, Phoenix or Curiosity, but the vortex activity is highly variable from sol to sol. No dust devils have been imaged in the first five weeks of operation, although the small number of images taken means this is not a meaningful constraint, and it is known from the presence of dust devil tracks in this region [5] that dust raising must occur. We will report on progress to more robustly assess the population and its variation with time, compare with LES and regional simulations [2], and reconstruct the geometry of individual encounters [6,7] to permit interpretation of their geophysical signatures (notably seismic tilt – e.g., [6,8])

Sol-to-sol pressure variability: In addition to the diurnal and seasonal pressure changes mentioned above, InSight's pressure sensor includes expression of multi-sol periodicities in the data. These are consistent with the signatures of baroclinic waves seen in previous years traveling around the planet on the northern winter polar vortex (e.g., [9,10]). We will discuss any correlation that these distant waves have with the local winds and/or vortex abundance. We will also present correlations of these multi-sol pressure oscillations with those observed by Curiosity and from orbit by MRO-MCS to better understand the global structure of these traveling wave modes.

Turbulent Power Spectrum: The power spectrum computed from 1 Hz time series of pressure, temperature, and winds is consistent with the -5/3 spectral slope expected in the inertial range from the Kolmogorov theory (e.g., [11]). The energy at mHz frequencies, corresponding to large eddies in daytime (i.e., convective cells and vortices), decereases soon after sunset and through the night because of the ultra-stable conditions close to the surface.

For the first time, the pressure sensor on board InSight is able to acquire time series at a frequency of 20 Hz, which enables exploration of the higher frequency part of the inertial range. Preliminary analysis shows that a careful assessment of the instrument transfer function needs to be carried out before firm conclusions can be made on this key topic.

Summary: InSight is collecting one of the most complete meteorological data sets from the Martian surface, with continuous sampling of high resolution pressure, air temperature, and winds and intermittent observations of atmospheric opacity, surface upwelling radiance, and solar array currents. We will discuss the initial atmospheric scientific contributions to come from InSight's earliest observations.

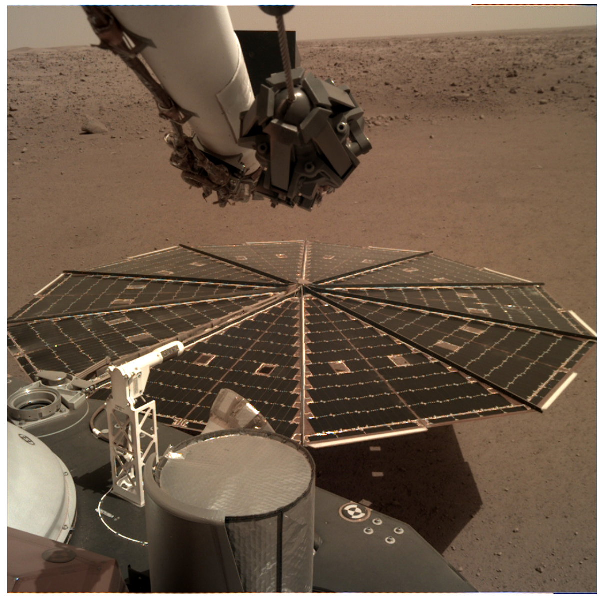

Figure 1. InSight Instrument Deployment Camera (IDC) image from Sol 10, showing one of the Temperature and Wind for InSight (TWINS) Booms (lower left) looking out over the solar panel. The pressure sensor inlet is under the Wind and Thermal Shield (WTS) at the extreme lower left, which is still on the lander deck in this early image from Mars.

References:

[1] Banfield, et al. (2018), *Sp. Sci. Rev.* **215**:4
[2] Spiga, et al. (2018) *Sp. Sci. Rev.* **214**:7
[3] Gomez-Elvira et al. (2012) *Sp. Sci. Rev.* **170**, 583-640
[4] Newman, et al. 2019, LPSC 51
[5] Reiss and Lorenz (2016) *Icarus*, **266**, 315-330
[6] Lorenz (2016) *Icarus*, **271**, 326-337
[7] Murdoch et al., 2019, LPSC 51
[8] Kenda et al. (2017) *Sp. Sci. Rev.*, **211**, 501-524
[9] Barnes (1980) *J. Atmos. Sci.,* **37**, 2002-2015
[10] Banfield et al. (2004) *Icarus*, **170**, 365-403
[11] Larsen et al (2002), *Boundary-Layer Meteorology*, **105**, 451-470