EGU General Assembly 2020

EGU2020-9163, updated on 08 Oct 2020
https://doi.org/10.5194/egusphere-egu2020-9163
EGU General Assembly 2020

Mars Regolith Properties as Constrained from HP3 Mole Operations and Thermal Measurements

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The Heat Flow and Physical Properties Package HP^3 onboard the Nasa InSight mission has been on the surface of Mars for more than one Earth year. The instrument's primary goal is to measure Mars' surface heat flow through measuring the geothermal gradient and the thermal conductivity at depths between 3 and 5m. To get to depth, the package includes a penetrator nicknamed the "Mole" equipped with sensors to precisely measure the thermal conductivity. The Mole tows a tether with printed temperature sensors; a device to measure the length of the tether towed and a tiltmeter will help to track the path of the Mole and the tether. Progress of the Mole has been stymied by difficulties of digging into the regolith. The Mole functions as a mechanical diode with an internal hammer mechanism that drives it forward. Recoil is balanced mostly by internal masses but a remaining 3 to 5N has to be absorbed by hull friction. The Mole was designed to work in cohesionless sand but at the InSight landing a cohesive duricrust of at least 7cm thickness but possibly 20cm thick was found. Upon initial penetration to 35cm depth, the Mole punched a hole about 6cm wide and 7cm deep into the duricrust, leaving more than a fourth of its length without hull friction. It is widely agreed that the lack of friction is the reason for the failure to penetrate further. The HP^3 team has since used the robotic arm with its scoop to pin the Mole to the wall of the hole and helped it penetrate further to almost 40cm. The initial penetration rate of the Mole has been used to estimate a penetration resistance of 300kPa. Attempts to crush the duricrust a few cm away from the pit have been unsuccessful from which a lower bound to the compressive strength of 350kPa is estimated. Analysis of the slope of the steep walls of the hole gave a lower bound to cohesion of 10kPa. As for thermal properties, a measurement of the thermal conductivity of the regolith with the Mole thermal sensors resulted in 0.045 $Wm^{-1}K^{-1}$. The value is considerably uncertain because part of the Mole having contact to air. The HP^3 radiometer has been monitoring the surface temperature next to the lander and a thermal model fitted to the data give a regolith thermal inertia of 189 ± 10 $J\ m^{-2}\ K^{-1}\ s^{-1/2}$. With best estimates of heat capacity and density, this corresponds to a thermal conductivity of 0.045 $Wm^{-1}K^{-1}$, consistent with the above measurement using the Mole. The data can be fitted well with a homogeneous soil model, but observations of Phobos eclipses in March 2019 indicate that there possibly is a thin top layer of lower thermal conductivity. A model with a top 5 mm layer of 0.02

Wm-1K-1 above a half-space of 0.05 Wm-1K-1 matches the amplitudes of both the diurnal and eclipse temperature curves. Another set of eclipses will occur in April 2020.