MAGNETIC VARIATIONS OF A SOL OBSERVED OVER A YEAR ON MARS WITH INSIGHT. Anna Mittelholz1, C. L. Johnson2,3, S. N. Thorne4, V. Yau2, S. Joy5, E. Barrett2, M.O. Fillingim6, F. Forget7, B. Langlais8, A. Spiga9, S. E. Smrekar3, B. Banerdt1, 1ETH Zurich, Switzerland (amittelholz@erdw.ethz.ch). 2Dept. of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. 3Planetary Science Institute, Tucson, AZ 85719, USA. 4Earth, Planetary and Space Sciences, UCLA, Los Angeles, CA 90095-1567, USA. 5Jet Propulsion Laboratory, 4800 Oak Dr, Pasadena, CA 91109, USA. 6Space Sciences Laboratory, University of California, Berkeley, CA, USA. 7Laboratoire de Météorologie Dynamique / Institut Pierre Simon Laplace, Sorbonne Université, Centre National de la Recherche Scientifique (CNRS), École Polytechnique, École Normale Supérieure (ENS), Paris, France. 8Laboratoire de Planétologie et Géodynamique, UMR 6112, Université de Nantes, Université d’Angers, CNRS, Nantes, France. 9Institut Universitaire de France, Paris, France.

Introduction: The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission landed on Mars in November 2018 [1]. October 2020 marked the one-martian-year milestone since landing. Among InSight’s instruments, the InSight FluxGate Magnetometer (IFG) is part of the Auxiliary Payload Sensor System (APSS) that monitors the environmental conditions around the lander [2]. However, the IFG is also the first magnetometer to operate on the martian surface, and it has enabled characterization of crustal and time varying magnetic fields [3,4]. In this study, we focus on the latter and expand on a previously-published study that investigated diurnal field variations for the first 389 sols of InSight operations [4]. Specifically, we focus on variations of the magnetic field within and among sols over one martian year and compare these observations with predictions for magnetic fields due to ionospheric currents.

IFG Data: We use calibrated 0.2 Hz data from the start of the mission up to sol 668 to cover a full martian year. The coordinate system is the Lander Level Frame in which $B_x$ points North, $B_y$ East and $B_z$ Down [5]. Data towards the end of the first year on Mars become increasingly sparse due to spacecraft power constraints. Earlier data gaps are due to Payload Auxiliary Electronics anomalies, and a spacecraft safing event during solar conjunction in 2019.

The Magnetic Field over Time - Diurnal Variations: We examine diurnal variations by detrending individual magnetic field components for each sol and binning in 10000 local time bins (~9 s). The median sol is represented by the median in each local time bin for all sols (Fig. 1). Over one martian year, the median diurnal signal peaks at around 10 nT in all components with the largest variations in $B_z$ (Fig. 1). Nighttime data amplitudes are small. Individual sols show diurnal variations with typical peak amplitudes of $20–40$ nT in the early to midmorning (not shown; see [4]). However, although peak amplitudes consistently occur in the early to mid morning, their magnitude and precise timing change through the mission (Fig. 2). To examine the long-term evolution of the diurnal field we compute the median diurnal signal over 26-sol intervals (e.g., Fig. 1). We compute a running 26-sol median field to investigate the long-term peak amplitude evolution of the diurnal variations (Fig. 3; purple). Over the martian year of InSight observations, the peak diurnal field varies and reaches its maximum around sol 100 and again around sol 550 (Fig. 2 and Fig. 3).

Figure 1: The median magnetic field components for a sol in mean local solar time (MLST) bins throughout a martian year (black solid) with standard deviation (black dashed), and for 26-sol median fields for different time frames (see legend).

Wind-driven ionospheric currents: Ionospheric currents vary due to seasonal changes in the ionization profile, in the winds, and in the altitude range of the dynamo region, that is, the region in which electric currents can be produced [e.g., 6]. Here, ions are collisionally coupled to neutral winds while electrons gyrate about magnetic field lines. This differential
motion of ions and electrons leads to currents. We use MAVEN satellite magnetic field data and a Mars global circulation model (MGCM) to predict the temporal evolution of wind-driven fields in the ionosphere and compare these predictions with IFG data (see [4] for details). MAVEN data provide an estimate of the background magnetic field, and the MGCM provides predicted electron density and wind speeds over a martian year. We further evaluate the boundary heights of the dynamo region (see [4] for details) and calculate the corresponding altitude profile for the current density. Integration of the current density across the dynamo region allows estimation of the magnetic field strength due to the resulting electric current. This however requires an assumption about the geometry of the current and we evaluate a lower and upper bound for the magnetic field, assuming an infinite current sheet and a line current, respectively (Fig. 3). We also evaluate scenarios with dust storms; these predict increased magnetic field amplitudes. A comparison of magnetic field observations from IFG data with MGCM derived estimates show that IFG data lie between the predicted upper and lower bounds. Increased magnetic field amplitudes are observed during the times of observed regional dust storms. The increase around sol 550 was predicted in [4] and extended mission observations can further verify this. Other predicted changes from wind driven field, e.g. between sol 180-300 and 300-420 are not seen in the IFG data.

Conclusions and Outlook: We observe diurnal variations in the surface magnetic field with typical peak amplitudes between 20-40 nT in the early to midmorning. Higher amplitudes are observed around sol 100 and 550. We attribute some of this observed variability to ionospheric magnetic fields. The amplitude and seasonal variability of the surface magnetic fields are generally consistent with those predicted from wind-driven currents in the ionosphere. Moreover, regional dust storms in the vicinity of the InSight landing site are responsible for the higher magnetic field amplitudes observed in the IFG data during dust season. InSight observations taken during the extended mission will provide further constraints on diurnal field variations and ionospheric currents.

Figure 3: Wind driven magnetic field response, |B| at the surface assuming that the dynamo region is a line current (solid line) or a current sheet (dashed line). The black line shows an average scenario; the red line shows a dust storm scenario during dust season. The brown areas highlight times during which regional dust storms occurred during the InSight mission. The purple curve shows the maximum amplitude of the observed magnetic field in a 26-sol running window (examples shown in Figure 1) for comparison with wind-driven predictions.

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References: