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MoMo’s prediction of Mars’ ionosphere contribution to InSight RISE Doppler data

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The NASA InSight mission is operating from the surface of Mars for more than a year. RISE (for Rotation and Interior Structure Experiment) is one of the scientific payloads of InSight. This radio-science experiment consisting in an X-band transponder and two horn-antennas enabling two-way coherent radio-link between Mars and the Earth [Folkner et al., 2018]. The main goal of RISE is to measure the slight modulations of the nutational motion of the spin axis of Mars induced by the liquid core of the planet in order to constrain its interior structure and core properties. To increase our chance to achieve this challenging goal, we must calibrate the RISE Doppler data by accounting to 2nd order effects like the Mars atmospheric noise.

This study shows the predicted contribution of the Martian ionosphere to the RISE data collected so far. To do so, we use a new empirical model of the Mars’ ionosphere called MoMo [Bergeot et al. 2019]. This model is based on the large database of Total Electron Content (TEC) derived from the subsurface mode of the Mars Express MARSIS radar. The model provides the vertical TEC as a function of solar zenith angle, solar activity, solar longitude and the location. Using MoMo, we produce vTEC maps for Mars that are then used to estimate the slant TEC in the Earth line of sight, enabling to infer the phase delay and Doppler shift affecting the RISE X-band measurements. These computed effects are shown to be of the order of 10^{-3}mm.s^{-1} in Doppler observables, with a larger effect around sunrise and sunset. This is about one order of magnitude below the typical measurement noise of RISE, but it is comparable to the contribution of the liquid core in the Doppler (~10^{-3}-10^{-2}mm.s^{-1}).

The MoMo model is suitable for any Mars radio-science data calibration, and in particular the forthcoming ExoMars 2020 LaRa measurements [Dehant et al. 2019]. The predictions made with MoMo will be of great use either for the data corrections or to define the timing of observations in order to avoid operating when the TEC rapidly varies (i.e. close to sunrise and sunset). The model output is further discussed here in terms of climatologic behavior of the Mars’ ionosphere. For comparison, we also investigate the contribution of the Earth ionosphere using Global Ionospheric

Maps (GIMs) based on GNSS data.