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Solar wind propagation delay predictions between L1 and Earth based on machine learning

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GNSS positioning errors, spacecraft operations failures and power outages potentially originate from space weather in general and the solar wind interaction with the geomagnetic field in particular. Depending on the solar wind speed, information from L1 solar wind monitor spacecraft only give a lead time to take safety measures between 20 and 90 minutes. This very short lead time requires end users to have the most reliable warnings when potential impacts will actually occur. In this study we present a machine learning algorithm that is suitable to predict the solar wind propagation delay between Lagrangian point L1 and the Earth. This work introduces the proposed algorithm and investigates its operational applicability to a realtime scenario.

The propagation delay is measured from interplanetary shocks passing the Advanced Composition Explorer (ACE) first and their sudden commencements within the magnetosphere later, as recorded by ground-based magnetometers. Overall 380 interplanetary shocks with data ranging from 1998 to 2018 builds up the database that is used to train the machine learning model. We investigate two different feature sets. The training of one machine learning model DSCOVR real time solar wind (RTSW) like data which contains all three components of solar wind speed is used. For the other machine learning model ACE RTSW like data which only provide bulk solar wind speed will be used for training. Both feature sets also contain the position of the spacecrafts. The performance assessment of the machine learning model is examined on the basis of a 10-fold cross-validation. The major advantage of the machine learning approach is its simplicity when it comes to its application. After training, values for the different features have to be fed into the algorithms only and the evaluation of the propagation delay can be continuous.

Both machine learning models will be validated against a simple convective solar wind propagation delay model as it is also used in operational space weather centers. For this purpose time periods will be investigated where L1 spacecraft and Earth satellites just outside the magnetosphere probe the same features of the interplanetary magnetic field. This method allows a detailed validation of the solar wind propagation delay apart from the technique that relies on interplanetary shocks.