EPSC Abstracts
Vol. 11, EPSC2017-178-2, 2017
European Planetary Science Congress 2017

Testing space weather connections in the solar system

B. Grison (1), J. Souček (1), V. Krupař (1), D. Píša (1), O. Santolík (1), U. Taubenschuss (1) and F. Němec (2)
(1) Institute of Atmospheric Physics CAS, Prague, Czech Republic , (2) Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic. (grison@ufa.cas.cz / Fax: +420 272762528)

Abstract

This study aims at testing and validating tools for prediction of the impact of solar events in the vicinity of inner and outer solar system planets using in-situ spacecraft data (primarily MESSENGER, STEREO and ACE, but also VEX and Cassini), remote Jovian observations (Hubble telescope, Nançay decametric array), existing catalogues (HELCATS and [2]) and the tested propagating models (the ICME radial propagation tool of the CDPP and the 1-D MHD code propagation model presented in [1]). We achieved our results using AMDA and VESPA web tools.
We first present the results concerning ICME propagation between various bodies of the inner solar system, starting from Mercury. Then we investigate the prediction facilities to two outer planets, Saturn and Jupiter.

1. ICME propagation: testing the CDPP propagation tool

The CDPP propagation tool is publicly available online (URL: http://propagationtool.cdpp.eu). Running the propagation tool for each of the 61 suitable events in the catalogue of ICME observations at Mercury by the NASA spacecraft MESSENGER [2], we could identify the ICMEs that probably hit another object of the solar system. The objects are spacecraft orbiting around planets (MEX at Mars, VEX at Venus) or at 1 AU (ACE, Stereo A and B). The necessary inputs for the propagation tool (in addition to the start point, MESSENGER in the present case) are: radial velocity (default value 500 km/s), wideness of the CME at the Sun (default value 45 deg) and the end point (VEX, MEX, ACE, Stereo A and B). The catalogue entries can be summarized as following:

- Time coverage: from 2011-05-19 to 2014-09-02
- Number of Records: 143
- Number of Pairs: 45 (Stereo-A:11, Stereo-B:6, Earth:4, Venus:16, Mars:8)

Detailed comparisons between observations and propagation tool predictions lead us to the following results. The propagation tool is accurate for impact prediction (84%) with a time accuracy of about 10 hours. We also propose to slightly modify the default parameters of the propagation tool by increasing the default radial propagating velocity by 50 km/s (550 instead of 500 km/s). We also note that the ICME propagation velocity decreases with increasing distance from the Sun (see Table 1).

Table 1: Mean ICME propagating velocity and standard deviations, between MESSENGER and target (observations).

Target	V_{prop} km/s	σ km/s
ALL	603	162
VENUS	639	169
1 AU	584	160

In addition to corresponding statistics, we also present the case study of an ICME that is observed at Mercury by MESSENGER, then at Venus by VEX and at L1 by ACE.

We finally simulate the evolution of the Dst index with ICME observations at ACE, Stereo A and Stereo B locations. This allows predicting not only ICME impacts, but also the corresponding potential geomagnetic effects.

2. Event predictions at the outer planets

2.1. Saturn

The 1-D MHD numerical code ([1]) permits to propagate interplanetary magnetic field (IMF) and solar wind properties inside the heliosphere. Inputs are in situ observations of these parameters (solar wind density, velocity, dynamic pressure, IMF tangential component). This model has been previously tested at

Jupiter with comparisons to Galileo data [1]. The most important observational constraint is the angle between the target, the observation point and the sun (Θ, Galileo-Earth-Sun angle in [1], Cassini-Stereo-Sun angle in our study). The lower Θ is, the better the predictions are.

We collect measurements of the solar wind velocity (Cassini/MIMI instrument), electron plasma density (Cassini/RPWS) and three components of the magnetic field (Cassini/MAG). The solar wind velocity and density measurements time intervals overlap is very short and occur for large Θ. Thus the plasma dynamic pressure cannot be derived from measurements. The time coverage of the plasma density is irregular while the solar wind velocity measurements occur mainly during the last part of Cassini's cruise to Saturn, so still far from the planet. We thus present only short time intervals of comparisons between plasma density observations and predictions.
Cassini/MAG data provide a continuous coverage of the IMF tangential component (B_t). B_t is also predicted by the model [1]. Figure 1 presents a 5 days window of both predicted and observed values of B_t. We present in our study a comparison of the B_t prediction accuracy of the model in function of Θ.

We emphasize here that the model predictions and the Cassini/MAG data used for this study are publicly available on the AMDA tool of the CDPP.

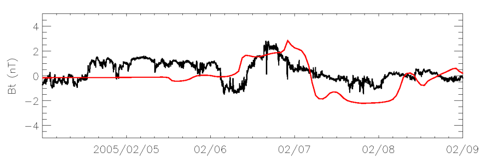

Figure 1: Example of comparison between observations (black line, Cassini/MAG measurements) and 1-D MHD simulations (red line) of the tangential component of the magnetic field.

2.2. Jupiter

There has been a large gap in in-situ data at Jupiter since the end of the Galileo mission and the recent arrival of JUNO. We thus propose to include remote observations for testing MHD propagation model [1]. Applying the propagation tool to all ICME events observed by Stereo-A and Stereo-B in the HELCATS catalogue, there are potentially 149 ICMEs that impacted the Jovian magnetosphere during the 2007-2014 period (see Table 2).

The Hubble images of Jovian aurorae and the radio emissions from the auroral regions observed at the Nançay radiostation are available through the VESPA web service. The last part of our study concerns a potential correlation of the 149 dates of predicted ICME impacts with an intensification of the remotely observed auroral activity.

Table 2: Number of predicted Jupiter-ICME encounters based on the HELCATS catalogue and the CDPP propagation tool.

Observatory	Total events	Impact
Stereo-A	550	73
Stereo-B	512	76

Acknowledgements

This work has been carried out with the support from the Europlanet 2020 research infrastructure. Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 654208. We acknowledge the CDPP for their support. We thank G. B. Hospodarsky (University of Iowa) for the Cassini/RPWS density estimates and the team of M. E. Hill (JHU/APL) for the list of the averaged solar wind speeds obtained by the Cassini/MIMI instrument.

References

[1] Tao, C., R. Kataoka, H. Fukunishi, Y. Takahashi, and T. Yokoyama (2005), Magnetic field variations in the Jovian magnetotail induced by solar wind dynamic pressure enhancements, J. Geophys. Res., 110, A11208, doi:10.1029/2004JA010959.

[2] Winslow, R. M., N. Lugaz, L. C. Philpott, N. A. Schwadron, C. J. Farrugia, B. J. Anderson, and C. W. Smith (2015), Interplanetary coronal mass ejections from MESSENGER orbital observations at Mercury, J. Geophys. Res. Space Physics, 120, 6101–6118, doi:10.1002/2015JA021200.