EPN 2024 RI

EUROPLANET 2024 Research Infrastructure

H2020-INFRAIA-2019-1

Europlanet 2024 RI has received funding from the European Union's Horizon 2020 Research and Innovation Programme under
Grant agreement no: 871149

Deliverable D5.9
Deliverable Title: Advanced Heliopropa Service

Due date of deliverable:	31/05/2023
Actual submission date:	31/05/2023
Nature:1	R
Dissemination level2	PU
Work package:	WP5
Lead beneficiary:	CNRS
Contributing beneficiaries:	
Document status:	Final

Start date of project: 01 February 2020. Duration: 54 months
Project Co-ordinator: Prof Nigel Mason, University of Kent

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1. **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
2. **Dissemination level:**

PU	PP	RE	CO
Public	Restricted to other programme participants (including the Commission Service)	Restricted to a group specified by the consortium (including the Commission Services)	Confidential, only for members of the consortium (excluding the Commission Services)

Outline

1. Introduction

The H2020 Europlanet 2020 Research Infrastructure programme, which ended on Aug 31st, 2019, included an activity called PSWS (Planetary Space Weather Services), which provided 12 services distributed over four different domains (A. Prediction, B. Detection, C. Modelling, D. Alerts) and can be accessed through the PSWS portal (http://planetaryspaceweather-europlanet.irap.omp.eu/):

A1. 1D MHD Solar Wind Prediction Tool – HELIOPROPA,

A2. Propagation Tool,

A3. Meteor showers,

A4. Cometary tail crossings – TAILCATCHER,

B1. Lunar impacts – ALFIE,

B2. Giant planet fireballs – DeTeCt3.1,

B3. Cometary tails – WINDSOCKS,

C1. Earth, Mars, Venus, Jupiter coupling- TRANSPLANET,

C2. Mars radiation environment – RADMAREE,

C3. Giant planet magnetodiscs – MAGNETODISC,

C4. Jupiter's thermosphere,

D. Alerts.

In the framework of the starting Europlanet 2024 Research Infrastructure programme, the Virtual Activity (VA) SPIDER (Sun-Planet Interactions Digital Environment on Request) will extend PSWS domains (A. Prediction, C. Modelling, E. Databases) services and give the European planetary scientists, space agencies and industries access to six unique, publicly available and sophisticated services in order to model planetary environments and solar wind interactions through the deployment of a dedicated run-on-request infrastructure and associated databases.

C5. A service for runs-on-request of models of Jupiter's moon exospheres as well as the exosphere of Mercury,

C6. A service to connect the open-source Spacecraft-Plasma Interaction Software (SPIS) software with models of space environments in order to compute the effect of spacecraft potential on scientific instruments onboard space missions. Pre-configured simulations will be made for Bepi-Colombo and JUICE (JUpiter ICy moon Explorer) missions,

C7. A service for runs-on-request of particle tracing models in planetary magnetospheres,

E1. A database of the high-energy particle flux proxy at Mars, Venus and comet 67P using background counts observed in the data obtained by the plasma instruments onboard Mars Express (operational from 2003), Venus Express (2006–2014), and Rosetta (2014–2015);

E2. A simulation database for Mercury and Jupiter's moons magnetospheres and link them with prediction of the solar wind parameters from Europlanet 2020 RI PSWS services.

A1. An extension of the Europlanet 2020 RI PSWS HELIOPROPA service in order to ingest new observations from Solar missions like the ESA Solar Orbiter or NASA Solar Parker Probe missions and use them as input parameters for solar wind prediction;

This report describes the extension of the HELIOPROPA service for the Europlanet 2024 RI in the context of the new Solar Orbiter and Parker Solar Probe observations.

2. The HELIOPROPA service

The HELIOPROPA service (http://heliopropa.irap.omp.eu/) gives access to an heliospheric propagator for solar wind prediction at planets based on a 1D magnetohydrodynamic propagation model originally developed by Tao et al. (2005).

The service gives access to various solar wind parameters including

- solar wind density,
- temperature,
- velocity,
- dynamic pressure,
- tangential magnetic field

propagated to

- all planets
- selected probes (Juno, Rosetta)
- selected comets (67P)

from observations obtained

- by spacecraft at the L1 terrestrial lagrangian point
- by STEREO-A
- by STEREO-B

3. Extension of the HELIOPROPA service

The service has been extended and now provides access to various solar wind parameters including

- solar wind density,
- solar wind temperature,
- solar wind velocity,
- solar wind dynamic pressure,
- solar wind tangential magnetic field

propagated to

- additional probes (BepiColombo, Solar Orbiter, Parker Solar Probe) – See Figure 1.

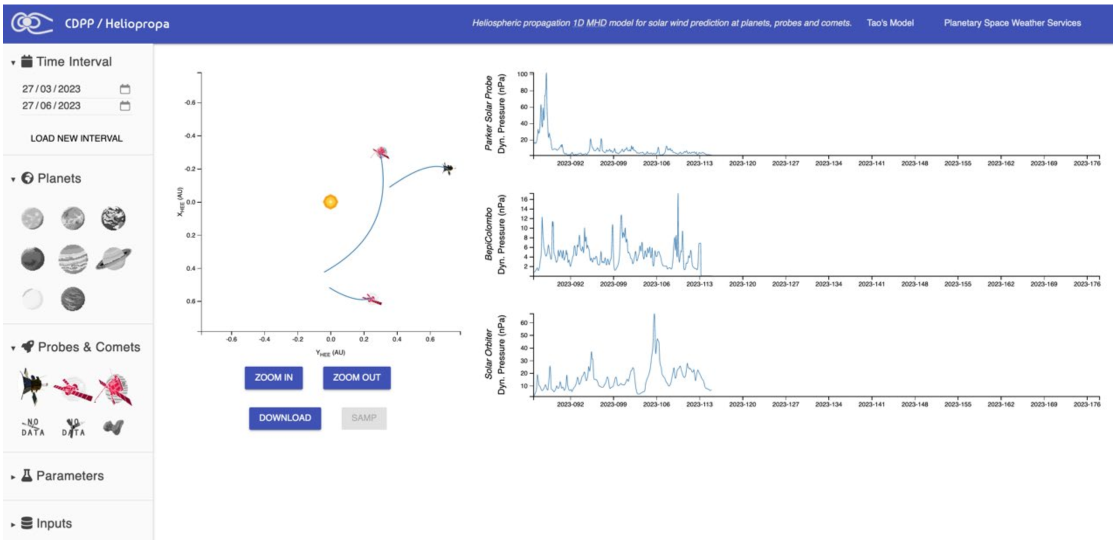

Figure 1: Time series of solar wind dynamic pressure at Parker Solar Probe, BepiColombo and Solar Orbiter as predicted by the 1D Magnetohydrodynamic propagation model of observations obtained at the l1 Lagrangian point of the Earth by OMNI.

The extended HELIOPROPA service has been used in the following publications:

- Kieokaew et al., Physics-based model of solar wind stream interaction regions: Interfacing between Multi-VP and 1D MHD for operational forecasting at L1, Journal Space Weather and Climate, submitted, 2023
- Persson, A., S. Aizawa, N. André, S. Barabash, S. Saito, Y. Harada, S. Heyner, S. Orsini, A. Fedorov, C. Mazelle, Y. Futaana, L. Z. Hadid, M. Volwerk, G. Collinson, B. Sanchez-Cano, A. Barthe, E. Penou, S. Yokota, V. Genot, J. A. Sauvaud, D. Delcourt, M. Fraenz, R. Modolo, A. Milillo, H.-U. Auster, I. Richter, J. Z. D. Mieth, P. Louarn, C. J. Owen. T. S. Horbury, K. Asamura, S. Matsuda, H. Nilsson, M. Wieser, T. Alberti, A. Varsani, V. Mangano, A. Mura, L. Gunter, G. Laky, H. Jeszenszky, K. Masunaga, C. Signoles, M. Rojo, and G. Murakami, Persson, M., Aizawa, S., André, N. et al. BepiColombo

mission confirms stagnation region of Venus and reveals its large extent. Nat Commun 13, 7743 (2022). https://doi.org/10.1038/s41467-022-35061-3

- Aizawa, S., Y. Harada, N. André, Y. Saito, et al., Direct evidence of substorm-related impulsive injections of electrons at Mercury, Nature Communications, in press, 2023
- Aizawa, S., M. Persson, T. Menez, N. André et al., LatHyS global hybrid simulation of the BepiColombo second Venus flyby, Planetary and Space Sciences, 218, doi: 10.1016/j.pss.2022.105499, 2022
- Hadid, L.Z. et al., BepiColombo's cruise phase: unique opportunity for synergistic observations, https://doi.org/10.3389/fspas.2021.71802, 2021
- Santos Costa, D. et al., Implications of short-term variations in Jupiter's inner electron belts observed with the Verylarge array's high sensitivity and angular resolution, PPS01-P18, Japanese Geophysical Union, 23-27 May 2023
- Hadid, L. Z., D. Delcourt, Y. Saito, M. Franz, S. Yokota, B. Fiethe, C, Verdeil, B Katra, F. Leblanc, H. Fischer, M. Persson, S. Aizawa, N. André, A. Fedorov, D. Fontaine, N. Krupp, H. Michalik, J-M. Illiano, J-J. Berthelier, H. Kruger, Y. Harada, G. Murakami, and S. Matsuda, BepiColombo observations of escaping carbon and oxygen ions in Venus magnetosheath, Nature Astronomy, submitted, 2022.

A feasibility study has been performed in order to further extend the service and make it possible to propagate observations obtained

- by the Solar Orbiter spacecraft,
- by the Parker Solar Probe spacecraft.

As input parameters, the 1D magnetohydrodynamic propagation model requires the following observational ones:

- solar wind density,
- solar wind ion temperature,
- solar wind ion velocity,
- solar wind tangential magnetic field.

However, some limitations were identified with the required input parameters from Solar Orbiter and Parker Solar Probe in order to ingest this feasibility study within the HELIOPROPA service, as shown below.

Solar Orbiter data

The input Solar Orbiter magnetic field and plasma observations from the Magnetometer (MAG) and Proton Alpha Spectrometer (PAS) is continuosly ingested once publicly available from the ESA Solar Orbiter official archive (http://soar.esac.esa.int/soar/) in the Automated Multi-Dataset Analysis tool (http://amda.cdpp.eu) of the French space plasma data center (CDPP, http://cdpp.eu) as shown in Figure 2.

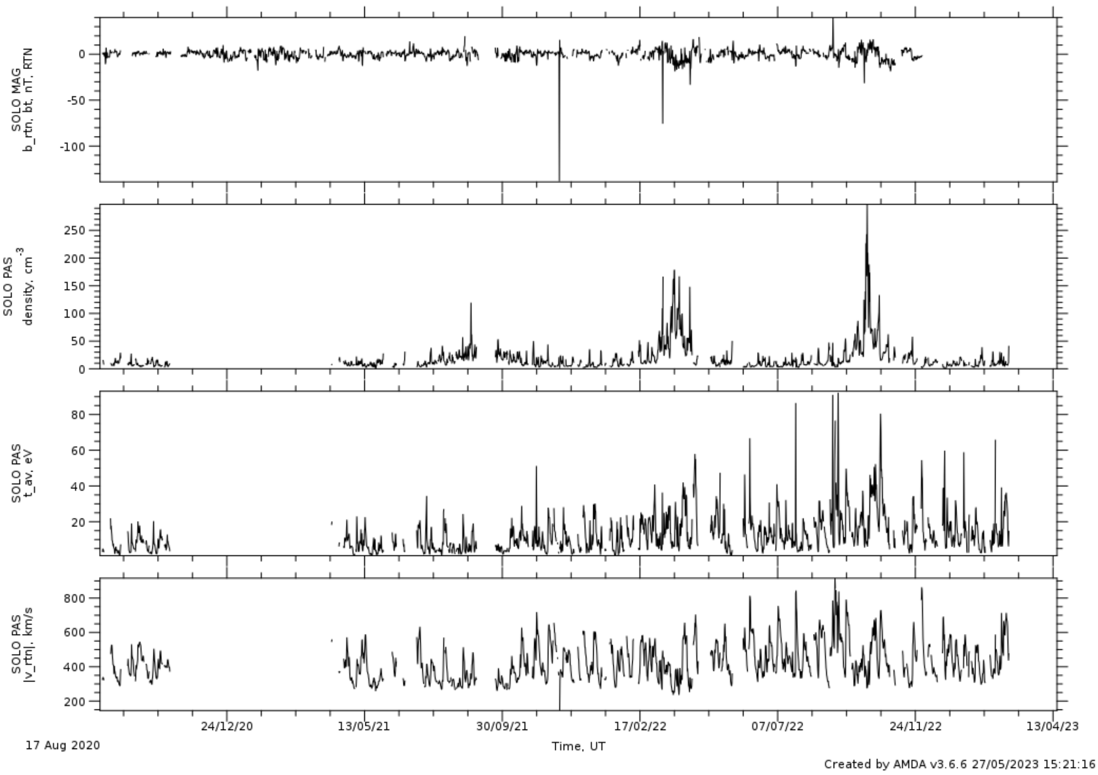

Figure 2: Time series of solar wind tangential magnetic field, density, temperature, velocity from Solar Orbiter observations.

Figure 2 reveals some time discontinuities in the PAS datasets due to uncontrolled reboots of the Data Processing Unit of the instrument suite Solar Wind Analyzer (SWA) to which PAS belongs. This results in some instabilities and inaccuracies of the 1D magnetohydrodynamic propagation model lying at the root of the HELIOPROPA service when this data is propagated in the heliosphere, making the service not reliable as yet. It will be possible in the near future to correct this issue once the issue of the DPU in the SWA instrument suite is completely solved. In addition, we note that the MAG data is not delivered to the SOAR anymore since the end of 2022.

Parker Solar Probe data

The input Parker Solar Probe magnetic field and plasma observations from the Magnetometer (FIELDS MAG), Solar Probe Analyser (SPAN) ion and Solar Probe Cup (SPC) are continuosly ingested once publicly available in the Automated Multi-Dataset Analysis tool (http://amda.cdpp.eu) of the French space plasma data center (CDPP, http://cdpp.eu) as shown in Figure 3.

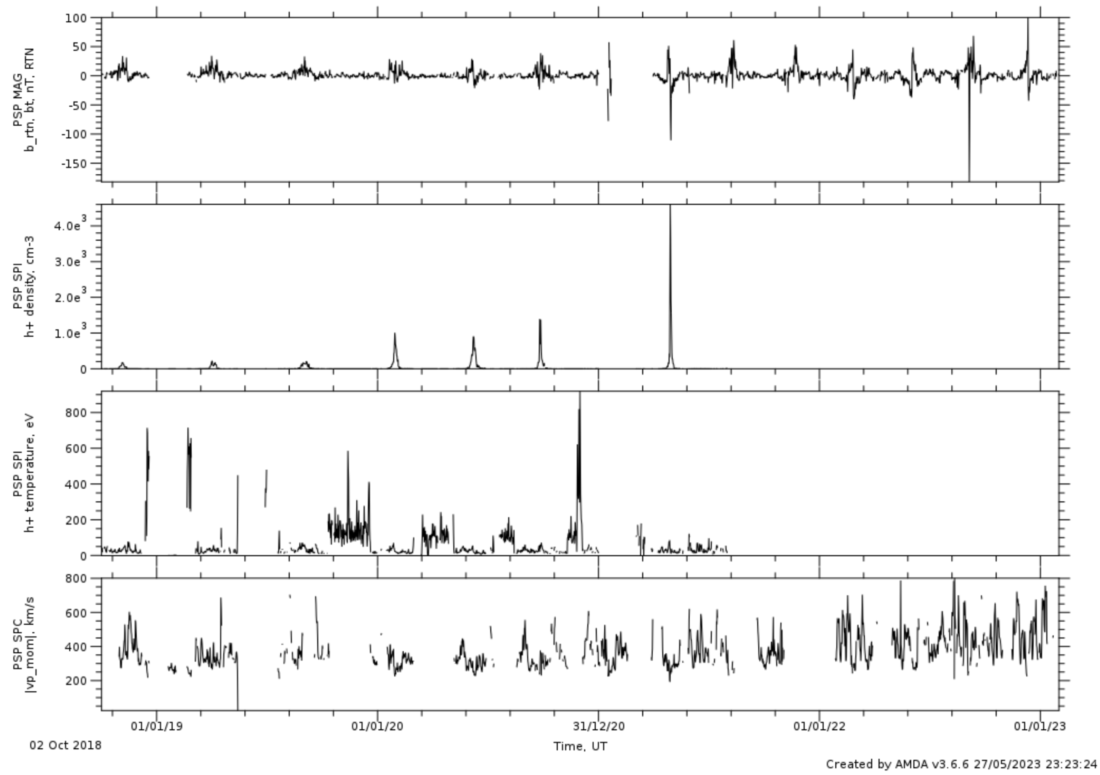

Figure 3: Time series of solar wind tangential magnetic field, density, temperature and velocity from Parker Solar Probe observations.

Figure 3 again reveals some discontinuities in the Parker Solar Probe datasets due to operational constraints that make them challenging to use as inputs for the 1D magnetohydrodynamic propagation model lying at the root of the HELIOPROPA service. In addition, some of the required input parameters such as the solar wind ion temperature and velocity have not yet been derived and made available in the public databases accessed by the AMDA tool and used in the service.

4. Conclusions and Perspectives

The HELIOPROPA service has been extended in order to provide prediction of the solar wind parameters at BepiColombo, Solar Orbiter, and Parker Solar Probe. The resulting advanced HELIOPROPA service has already been successfully used in several publications and presentations. A feasibility study to ingest in the service input solar wind observations from Solar Orbiter and Parker Solar Probe is ongoing. Although the pipeline has been developed, the 1D magnetohydrodynamic propagation model lying at the root of the HELIOPROPA service proved not yet reliable enough scientifically to be made available in the service. This will be improved in the near future when the limitations arising from the observational data will be solved.

5. References

Tao et al., Magnetic field variations in the Jovian magnetotail induced by solar wind dynamic pressure enhancements, Journal of Geophysical Research-Space Physics, Volume 110, Issue A11, CiteID A11208 , doi:// 10.1029/2004JA010959, 2005