IL NUOVO CIMENTO **42 C** (2019) 48
DOI 10.1393/ncc/i2019-19048-3

COLLOQUIA: SoHe3 2018

# The Heliospheric Space Weather Center: A novel space weather service

M. CASTI(1), A. F. MULONE(1), R. SUSINO(2), G. CHIESURA(1), D. TELLONI(2), R. DE MARCH(1), E. ANTONUCCI(2), R. MESSINEO(1), A. BEMPORAD(2), F. SOLITRO(1), S. FINESCHI(2), E. MAGLI(3), G. NICOLINI(2), F. CARONTE(1) and M. MESSEROTTI(4)

(1) *ALTEC S.p.A. - Corso Marche 79, 10146 Torino, Italy*
(2) *INAF, Osservatorio Astrofisico di Torino - Via Osservatorio 20, 10025 Pino Torinese, Italy*
(3) *Politecnico di Torino - Corso Duca degli Abruzzi 24, 10129 Torino, Italy*
(4) *INAF, Osservatorio Astronomico di Trieste - Loc. Basovizza 302, 34149 Trieste, Italy*

received 28 December 2018

**Summary.** — The Heliospheric Space Weather Center project is the result of the synergy between the Aerospace Logistics Technology Engineering Company (ALTEC S.p.A.) and the INAF-Astrophysical Observatory of Torino, both located in Turin, Italy. The main goal of this project is to provide space weather medium and short-term forecast, by combining remote-sensing and in situ open data with novel data analysis technologies, giving to scientists the possibility of designing, implementing, and validating space-weather algorithms using extensive data sets.

## 1. – Introduction

The functioning and the reliability of electrical/electronic and space-based technologies are essential elements for modern society. As a consequence, our vulnerability to space weather phenomena is rapidly increased, giving rise to technological hazard related to navigation and timing systems, electrical power grids, radio communication, etc. For this reason, it is extremely important to be able to predict such phenomena, for limiting their impact [1].

Space weather phenomena have their origins in the Sun and propagate through the heliosphere, until reaching Earth magnetosphere. Their signatures are observable in several data sets, acquired by in situ and remote sensing space and ground-based instruments, with different time-scales. For this reason, a space weather forecast system should be able to manage several data types providing the event forecast within a processing time as short as possible.

 

The Heliospheric Space Weather Center (HSWC) [2] has been developed aiming at analyzing solar and heliospheric data, providing a quick response. Data analysis is performed by three different pipelines, which detect Coronal Mass Ejections (CMEs) and retrieve the physical features necessary for forecasting their impact time on the Earth magnetosphere. One of the main feature of the HSWC is the use of metadata for enabling data access.

In this paper at first, a brief description of used data and algorithms is presented. The system architecture is described afterwards, in order to highlight its features. Then, data management elements are pointed out with a particular interest on the adopted data model. At last, conclusions and future prospects are discussed.

## 2. – Solar data for space weather forecast

The Heliospheric Space Weather Center main objective is to detect Coronal Mass Ejections in their early stages and to provide a forecast related to their impact on Earth magnestosphere. Since the absence of a well-defined forecast classification in literature, we referred to medium-term forecasting as predictions up to 2 days and to short-term forecasting as predictions up to 2 hours. The medium-term and short-term forecast prediction services provided by the Heliospheric Space Weather Center consist of high-speed solar wind streams and magnetic clouds ejected by the Sun identification plus the alerting for phenomena reaching the Earth's magnetosphere. Aiming at this, three different pipeline, each of them based on a specific type of data, have been implemented.

**2**˙1. *Medium-term forecast*. – The set of algorithms composing the data pipeline for medium-term forecast processes images of the solar corona acquired by the LASCO coronagraph, payload of the NASA SOHO satellite. These data are available with a frequency of about 12 minutes and are acquired by two different detectors, i.e. C2 and C3. Each one of them observes a different portion of the solar corona: C2 field of view goes from 1.5 to 6 solar radii, while C3 images the corona from about 3.5 to 30 solar radii. These images give the opportunity to observe CMEs in their first manifestation and evolution. In this respect, when a CME is detected, all the images in which it appears are used to compute its physical features and kinematic parameters. The outcome is a forecast of the detected CME arrival onto the Earth's magnetosphere up to a few days ahead.

**2**˙2. *Short-term forecast*. – Short-term forecast services are provided by processing data acquired by in situ instruments, which are on-board of satellites orbiting around the Lagrangian point L1. In particular, these data concern the heliospheric magnetic field, the solar wind velocity, the proton density and temperature. The designed pipeline processes in near-real time data acquired by NOAA DSCOVR satellite payloads and predicts geomagnetic storms. These measurements are available with 1-minute frequency and the pipeline forecast is provided up to a few hours before the storm occurrence. When a CME propagates through the heliosphere, the previous listed physical properties of the interplanetary medium assume a characteristic pattern. The algorithms that compose this pipeline are able to detect the CME transition at L1 and to provide the related forecast.

**2**˙2.1. Machine learning. Short-term forecast is also provided by the neural network pipeline, which processes DSCOVR payload data. The final goal is to predict DST geomagnetic index few hours in advance. As a matter of fact, DST index measures the geomagnetic activity and it is used to assess the severity of the magnetic storms caused by the CMEs. The pipeline is based on a trained neural network to tell if a weak, moderate or intense storm is about to happen in 2, 4 or 8 hours.

## 3. – System Architecture

The architecture of Heliospheric Data Center (HDC), a part of the Heliospheric Space Weather Center, consists of (i) data stores to archive input data, (ii) a metadata data store and (iii) processing data stores for preparing data. All of them are handled by the product manager, which is a component that offers a transparent data access service.

ALTEC defined and developed a framework whose main goal is to process big amount of data allowing a seamless connection between collected information and analyses performed by end users. This distributed framework is the ALTEC Space Data Processing (ASDP), designed to provide a flexible system capable to handle and process a large variety and amount of data. ASDP allows integrating both existing and new coded algorithms, enabling automatic processing of large data sets and complex pipelines.

## 4. – Data Management

**4·1.** *Data Flow.* – The main goal of data management is to retrieve data to be processed from several repositories, e.g. HTTP and FTP. Moreover, input data are heterogeneous in terms of format and availability frequency. In fact, the HSWC pipelines process images of the solar corona (fts files) and in situ measurements (json, cdf or netcdf files). The component in charge of retrieving such data is the crawler, which subsequently triggers the internal ingestion and processing pipelines. All data ingested and generated in the Heliospheric Data Center are available for the users.

**4·2.** *Data Model.* – During the ingestion phase, metadata are extracted from each product. This is a key factor to organize the solar data sets.

The HSWC makes use of SPASE [4], the most widespread data model in virtual observatory. SPASE allows describing all the resources in a heliophysics data environment. Its aim is unifying and improving existing Space and Solar Physics data models, describing accurately data structure.

In order to describe processing pipeline products in output, SPASE is extended using ESPAS. ESPAS is a data e-infrastructure facilitating discovery and access to observations and model predictions of the near-Earth space environment [3]. ESPAS gives the opportunity to relate the products with its processing, which is of the most importance.

## 5. – Conclusions and future prospects

The Heliospheric Space Weather Center has been developed in order to provide short- and medium-term forecast related to Coronal Mass Ejections and their impact on Earth magnestosphere. Due to the center capacity to manage different data products, data stores, frameworks and libraries, future developments will be the data archive extension and the development and integration of new pipelines that use physics-based algorithm and/or exploit deep learning techniques.

REFERENCES

[1] SCHRIJVER C. J. *et al.*, *Advances in Space Research*, **55** (2015) 12 pp.2745-2807.
[2] CASTI M. *et al.*, *Proc. of the 2017 conference on Big Data from Space (BiDS'17)*, **1** (2017) pp.359-362 doi: 10.2760/383579.
[3] BELEHAKI A. *et al.*, *Advances in Space Research*, **58** (2016) .
[4] MERKA J., NAROCK T. W., SZABO A., *Earth Science Informatics*, **1** (2008) pp.35-42.