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SPACE-WEATHER ASSETS DEVELOPED BY THE FRENCH SPACE-PHYSICS COMMUNITY

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Abstract. We present a short review of space-weather tools and services developed and maintained by the French space-physics community. They include unique data from ground-based observatories, advanced numerical models, automated identification and tracking tools, a range of space instrumentation and interconnected virtual observatories. The aim of the article is to highlight some advances achieved in this field of research at the national level over the last decade and how certain assets could be combined to produce better space-weather tools exploitable by space-weather centres and customers worldwide. This review illustrates the wide range of expertise developed nationally but is not a systematic review of all assets developed in France.

Keywords: solar wind, energetic particles, space weather

1 Introduction

The near-Earth environment is continually perturbed by magnetised plasma, beams of energetic particles and ionising radiations (X-rays, extreme ultraviolet) produced by the solar atmosphere. Solar winds and powerful ejections propagate to Earth through the interplanetary medium and can drive strong geomagnetic activity. The fastest solar wind (>500 km/s) originates in coronal holes that are visible as dark regions in ultraviolet images of the corona, while the origin of the slowest winds (<500 km/s) is still debated. Intense solar storms,

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known as Coronal Mass Ejections (CMEs), are mostly the result of abrupt changes in magnetic fields situated near active regions on the solar surface. The strongest geomagnetic storms are induced by CMEs (Gosling et al. 1990) but the interaction between the slow and fast solar winds during their propagation to Earth, creates Corotating Interaction Regions (CIRs) that drive frequent weaker geomagnetic storms of which the cumulated effect represents a dominant transfer of energy between the interplanetary medium and the magnetosphere (Borovsky and Denton 2006). The continual battering of the magnetosphere by the solar winds modifies the properties of the radiation belts, and forces motions and reconfigurations of the geomagnetic field lines through magnetospheric convection and substorms (Akasofu 1964; Axford 1969). All these contribute to changing the properties of the ionosphere/thermosphere system and induce currents on the ground.

Our modern society depends heavily on a variety of technologies that are vulnerable to intense geomagnetic storms and solar energetic particle events with very different effects at different locations on the globe. For instance major elements of the power grid are exposed and particularly vulnerable to space weather at high latitudes but this is less true in France and southern Europe. In the last decades, our modern society (worldwide) has become critically dependent on Global Navigation Satellite System (GNSS) systems to direct and control our transport systems. Solar storms generate GHz radio emission and upon impact with the geospace, ionospheric density disturbances that interfere with high-frequency, very-high-frequency, and ultra-high-frequency radio communications and navigation signals from GNSS systems. Exposure of spacecraft to energetic particles during Solar Energetic Particles (SEP) events and radiation belt enhancements can cause temporary operational anomalies, degrade solar arrays, damage critical electronics and blind optical systems such as imagers and star trackers (Baker et al. 2008).

A report from the United States National Academy of Sciences estimated the economic and societal costs attributable to impacts of a major geomagnetic storm in the range of 1000-2000 billion of Euros for the United States alone during the first year following the severe geomagnetic storm with recovery times of 4 to 10 years (Baker et al. 2008). An executive order of the White House was put in place by the president of the United States on 13 October 2016 to coordinate efforts to prepare the United States for a space-weather events.

The following review aims at summarising the assets available in France that are useful for space-weather forecasting. This review summarises the twenty presentations and discussions held at the assembly of the French Astronomical Society in Lyon on 15 June 2016[1]. This article provides an overview of space-weather assets developed by the French space-physics community. It is limited to the effects of space weather in the geospace environment and does not review effects on other planets of the solar system.

2 Space-weather assets in France:

2.1 *Ground-based observatories:*

Solar observatories: The Pic Du Midi[2] (alt. 2877m), Calern[3] (alt.1270m) and Meudon[4] (alt.162m) observatories record images of the solar surface and corona in the H-alpha and CaII-K and CaII-H lines on an almost daily basis.

The CLIMSO instrumentation[5] at the Pic du Midi is a suite of two solar telescopes and two coronagraphs, taking one frame per minute in four channels, weather permitting of course: observations of the solar disk in H-alpha (656.28 nm) and in Ca II (393.3 nm), the coronagraphs take images of prominences in He I (1083 nm) and in H-alpha (656.28 nm), all year long (Figure 1). A new detector is being installed to observe the corona in the FeXIII line (1074.7nm), this will complemented with additional instrumentation to measure the coronal magnetic field. Such observations are routinely taken by the Coronal Multi-Channel Polarimeter (CoMP; Tomczyk et al. 2008) coronagraph in Hawaii, this type of instrumentation measures the coronal magnetic field through the Hanle effect. Images taken in FeXIII line can be exploited to infer some properties of the corona using reconstruction techniques (Rachemeler et al. 2014). CLIMSO (Long. 00° West) combined with the CoMP coronagraph in Hawaii (Long. 155° West) will provide more continuous observational coverage of the structure of the coronal magnetic field.

[1] http://2016.sf2a.eu/
[2] http://www.obs-mip.fr/pic-du-midi
[3] https://www.oca.eu/
[4] http://solaire.obspm.fr/
[5] https://climso.fr/

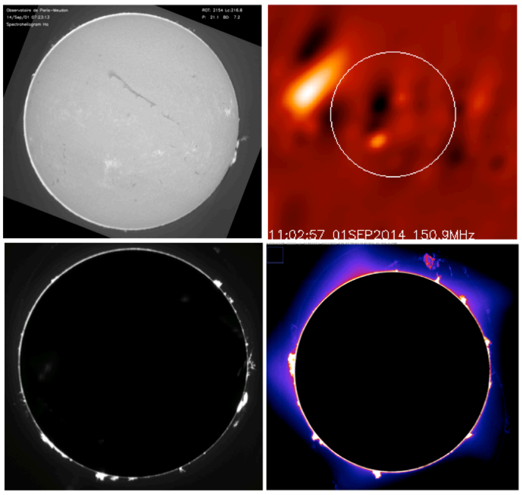

Fig. 1. Observations of the solar disk in H-alpha (656.28 nm) by the Meudon observatory and of the corona at radio wavelength by the NRH at 150.9MHz, HeI (1083nm) and and H-alpha (656,28nm) by the CLIMSO instruments at the Pic Du Midi. The two top images were taken during a major solar storm on 1 September 2014 that erupted behind the East limb of the Sun but caused intense SEP even at Earth (Plotnikov et al. 2016).

A suite of three telescopes to observe the chromosphere in H-alpha, CaII K and Ca II H, G-band is being installed at the Calern Observatory with funding from the Direction Générale de l'Armement as an extension in the optical lines of the French Air Force space-weather project (FEDOME) that currently exploits solar radio observations. These telescopes will record high-cadence H-alpha images of the Sun to be included in the international H-alpha network ([6]). Furthermore the use of the same H-alpha filter and image resolution will ease the merge of these images with those of the Global Oscillation Network Group (GONG). Currently the GONG H-alpha network ([7]) retrieves data at a cadence of one image per minute from only one European observatory in Tenerife. Calern H-alpha observations will provide real-time monitoring of quiescent and eruptive prominences at a cadence up to 10 images per minute allowing also the study of fast evolving phenomena such as the Moreton waves which are believed to be the chromospheric signature of the coronal pressure waves associated with flares/CMEs.

The Nançay radioastronomy station provides a unique set of radio data that can be used for space weather. The Radiohliographe (NRH) provides radio images of the full Sun for 10 frequencies between 100 and 400 MHz. The Nançay Decametric Array (NDA) and ORFEES spectrographs provide radio spectrum respectively between 30-80 MHz and 120-1000 MHz. The high frequencies provide crucial information on the early formation of CMEs low in the corona where plasma density is high and the perturbations of the corona induced by these CMEs such as shock formation (type II bursts) and particles beams from flares (type III bursts). These observations are used continuously by the French Air Force (FEDOME project). The NRH, ORFEES, and NDA are part of a radio survey project called the Radio Monitoring [8] as a joint effort of the Paris Observatory and other solar radio observatories around the world. These radio observations provide in real-time information on the earliest effects of flares, CMEs and particle propagation in the interplanetary medium.

Magnetometers and geomagnetic indices: Continuous monitoring of geomagnetic activity has been carried out in France for many decades. France hosts the headquarters of the International Service of Geomagnetic Indices[9] (ISGI) appointed by the International Association of Geomagnetism and Aeronomy (IAGA); ISGI is the reference service for validation, dissemination and stewardship of geomagnetic indices through its official

[6]`http://swrl.njit.edu/ghn_web/`
[7]`http://halpha.nso.edu/`
[8]`http://radio-monitoring.obspm.fr`
[9]`http://isgi.unistra.fr/`

Web portal. The *aa* and *am* indices are currently produced by the School and Observatory of Earth Sciences (EOST) in Strasbourg. New indices are currently being constructed by EOST to capture global geomagnetic activity on timescales of substorms (30 minutes), shorter timescales than the widely used geomagnetic range indices (3 hours).

Ionospheric radars: Monitoring of ionospheric perturbations during geomagnetic storms is carried out worldwide using the SUPERDARN radars. France maintains one radar in the Kerguelen island and is helping with the installation of a new radar in Lannemezan, south of France. SUPERDARN is currently not used for space-weather but could be exploited in the future to provide near-real time updates of the state of ionospheric convection to numerical models through data assimilation techniques. A workshop is held in Nice to discuss and gather community inputs on the organisation of the French ground-based solar observing facilities providing either real time data or long synoptic observing programs able to produce the needed statistic on various events relevant for space-weather ([10]).

Neutron monitors: Providing measurement of the most energetic particles produced during some solar storm. France is in charge of two neutrons monitors, located in Kerguelen and Terre Adélie, which are part of a worldwide neutron monitor network. French neutrons monitors are used on a regular basis for the SIEVERT program (collaboration Aviation Civile - Observatoire de Paris), evaluating the radiation dose for the civil flying personal.

2.2 Space instrumentation designed for space weather:

Among the most important hazards to humans and electronics in space is high-energy particle radiation. Damages to electronics are numerous in kind, so that particle radiation is a main source of operational anomalies on-board spacecraft. The monitoring of particle fluxes in various near-Earth orbits is thus critical to the understanding of these effects, and their potential forecasting. The ICARE_NG instrument, which was flown for instance on the Jason-2 and 3 spacecraft, measures for that purpose electrons and protons in the ranges 250 keV - 4 MeV and 8 - 100 MeV, respectively. Along a similar line of thought, but this time for monitoring the surface electrostatic charging of spacecraft which can lead to significant damages through ensuing discharges (e.g., to electronics, solar panels), one needs to measure the fluxes of low energy ions and electrons (0 - 40 keV range). In addition, the obtained data permit to measure the actual charging over time (providing key information during a potential anomaly). The AMBRE instrument currently flying on the Jason-3 spacecraft was developed for that purpose, and an even smaller version AMBRE 2.0 is currently under development.
Finally, coronagraph imagers for spacecraft have long been developed in France (e.g., LASCO C2 on SOHO). New developments are on-going in this area as well with space-weather applications. This concerns in particular developments in the UV wavelengths for monitoring the UV solar irradiance or the polarisation of the Lyman-alpha line, the latter being able to shed new light on the magnetic structure of the corona and thus of ensuing CMEs and geomagnetic storms. Such spacecraft instrumentation would be directly complementary to the Hanle observations of the corona soon to be made by CLIMSO in the forbidden lines of Fe XIII.

2.3 Numerical models and tools:

Figure 2 provides a flow chart summarising the origins and consequences of major space-weather effects and the numerical models developed by the national community that have either reached sufficient maturity or else showing great potential for space-weather forecasting. Some are being integrated within the European Space-Situational Awareness (SSA, [11]) program and the Virtual Space Weather Modelling Center[12]. These models simulate specific regions of the Sun-Earth system starting from the generation of magnetic fields inside the Sun, to their eruption on the surface, the formation of Coronal Mass Ejections and of the solar wind, the propagation of the solar wind in the interplanetary medium and the evolution of geomagnetic and ionospheric

[10]https://meteospace.sciencesconf.org/
[11]http://swe.ssa.esa.int/
[12]https://esa-vswmc.eu/

activity. Radio-wave propagation models are then used to evaluate or predict the impact on radio systems such as HF/VHF/UHF communications, radars or GNSS receivers. Although many regions of the Sun to Earth system are already modelled, they are not yet coupled together to produce a unique and integrated Sun to Earth numerical model. Many numerical models developed over the last decades have reached sufficient maturity to be useful for space-weather forecasting, their relevance to the different components of the Sun-Earth system are highlighted in Figure 2.

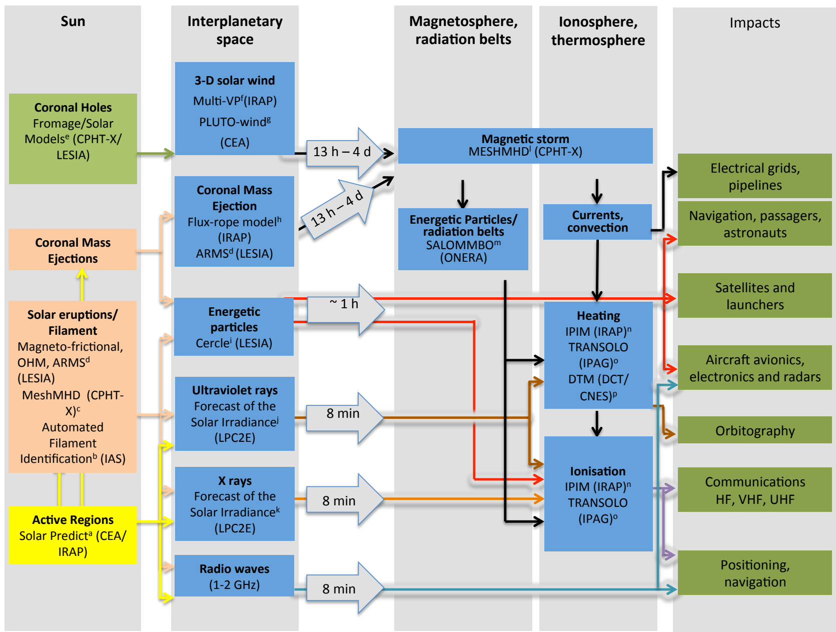

Fig. 2. A flow chart showing the causes and effects of space-weather events. The figure also lists the assets/numerical models developed in France that are capable of simulating a particular phenomena. The numerical techniques include: (a.) Jouve et al. (2011) Hung et al. (2015), (b.) Buchlin et al. (2012), (c.) Amari et al. (2014), (d.) Masson et al. (2009), Zucarello et al. (2015), Masson et al. (2013), (e.) Amari et al. (2014), (f.) Pinto et al. (2016), (g.) Reville et al. (2015), (h.) Rouillard et al. (2016), (i.) Lantos et al. (2005), (j. k.) Vieira et al. 2010, (l.) Amari et al. (2014), (m.) Bourdarie et al. (1996), (n.) Marchaudon and Blelly (2015), (o.) Lilensten et al. (1989), (p.) Bruisma et al. (2003). The links to the internet pages of the various facilities are given in the text.

To be useful for space-weather forecasting, a particular model must run sufficiently fast to provide a prediction of the future state of a particular region of the Sun-Earth system. The complexity of the system usually forces simplifications of the problem to be carried out by breaking down the problem into a sequence of manageable components. Each component may be dealt with completely different approaches instead of implementing a self-consistent integrated numerical approach. For instance, modelling the effect of solar activity on the interplanetary medium is usually separated into two components -; one - is the background solar wind —- the large-scale structure of which is regulated by the slowly varying topology of the coronal magnetic field and by solar rotation, and the second component, superposed to the first one, are the CMEs that are sudden, often dramatic, transitions in the structure of the corona with the release of complex magnetic structures in the interplanetary space. These CMEs will interact strongly with the background solar wind sometimes increasing their geoeffectiveness' (Lavraud and Rouillard, 2015). The slowly varying structure of the background solar wind co-rotates with the Sun allowing numerical models to forecast the properties of the near-Earth environment many days in advance. However CMEs are not only harder to forecast because of their complex structure but also because they can reach the Earth in the matter of hours only. This often forbids some more accurate but too long numerical computations. Of course, all these phenomena are modulated by the 11-yr solar cycle (e.g. Pinto et al. 2011) and by even longer modulation cycles such as the Gleissberg cycle.

Recent numerical advances: Between the low corona and 1AU, the characteristic scales over which transients evolve change by several orders of magnitude imposing formidable challenges to theorists wishing to model the corona-interplanetary medium in a single numerical domain. Several approaches are at hand to surmount these challenges including adaptive mesh refinement on structured and unstructured mesh. The latter is used by a number of models recently developed to model CMEs. Unstructured mesh is a tessellation of the numerical domain into simple geometrical shapes (triangular, tetrahedral), while computationally intensive, it permits more accurate finite-element analysis to be carried out in certain regions where plasma parameters have strong gradients. At the Sun, these regions are critical because they correspond to regions where strong non-potential fields can develop and lead to CMEs. A reconstruction of the coronal magnetic field driven by photospheric magnetic fields was recently successful at modelling the pre-eruptive phase of a CME and its free energy (Amari et al. 2014), this tool is potentially useful as a forecasting tool of CME eruptions. MHD codes using Adaptive mesh refinement such as ARMS are also very promising for the next generation of solar storm modelling. Event though it is computationally intensive, it allows to resolve the small-scale while keeping the large scale dynamics, i.e., study the CME initiation and follow it through the heliosphere. To become more tractable, the evolution of a CME is often split into different manageable sequences of physical processes. Grid modelling is another possible mean of using numerical simulation in space-weather application. Ahead of an eruptive event, grids of parametrised numerical runs, using simplified approximations are executed. When an observed event is triggered, the model which best fits a selection of observable is selected. This observationally-constrained model can then be used as a reliable element in the space weather modelisation pipeline. Recent numerical work exploiting a magneto-frictional approach and force-free field models driven by measured photospheric magnetic field have successfully capture the dynamics of observed emission and the loss of equilibrium of CMEs in the early phase of the eruption process (Savcheva et al. 16). Parametric simulations can also be used to constrain the eruptivity criterions of solar magnetic fields (Zuccarello et al. 2015). In order to predict the eruptivness of an active region and capture the loss of equilibrium of a filament, a promising and challenging solution is to perform data-driven and/or data- inspired simulation, capabilities possessed by the OHM (LESIA) code, i.e., which can use the observed magnetogram as initial condition (Masson et al. 09). When CMEs reach the heights imaged by coronagraphs, CME properties such as speed and flux rope orientations can be inferred, the propagation of CMEs from the upper corona to the typical heights where interplanetary models take over (20 Rs) may also be modelled using other semi-analytical models exploiting coronographic observations. In a similar manner to terrestrial-weather forecasting, we often resort to parametrisation, empirical laws and data assimilation techniques so that a particular numerical model becomes useful for space-weather forecasting.

Parameterisation and analytical approaches: The process of parameterisation is used to capture and account more instantaneously for the effect of CERTAIN processes by relating them to variables on scales that can be resolved by a particular model. Parameterisation is employed in all numerical models of the Sun-Earth system either when a physical model is still lacking, when the processes at play are too complex and forbid a physics-based approach or when processes occur on scales unresolved by the numerical grid but have macroscopic effects. For instance, instead of modelling the complex structure of a CME space-weather applications usually resort to the parameterisation of CME properties (dimensions, direction of propagation, speed and internal magneto-plasma properties) and use simple analytical representations of CMEs, such as the 'ice-cream cone' model widely used to inject hydrodynamic CME in global 3-D MHD simulations. This speeds up computation considerably. Novel and fast prototype models with great potential for faster forecasting of CME formation and eruption are being developed by a number of research groups in France, they include magneto-frictional models (Pariat et al. 2016) and simple flux-rope models[13]. Parameterisation is also used to fold in the heating of the solar corona that ultimately leads to the solar wind; this is done in the new 1-D hydrodynamic MULTI-VP model of the solar wind[14] (Pinto et al. 2016) and the 3-D MHD PLUTO stellar wind models (Reville et al. 2016). Parameterisation is also used to model geomagnetic activity, magnetospheric convection, solar irradiance and particle precipitation that will drive advanced models of the ionosphere such as the kinetic/kinetic-fluid codes IPIM (Marchaudon and Blelly 2015) and TRANSOLO (Lilensten et al. 1989), or to model source and loss rates of certain particle populations in the radiation belts in the SALAMMBO transport code (Bourdarie et al. 1996; Maget et al. 2015).

[13] `http://spaceweathertool.cdpp.eu`
[14] https://stormsweb.irap.omp.eu/

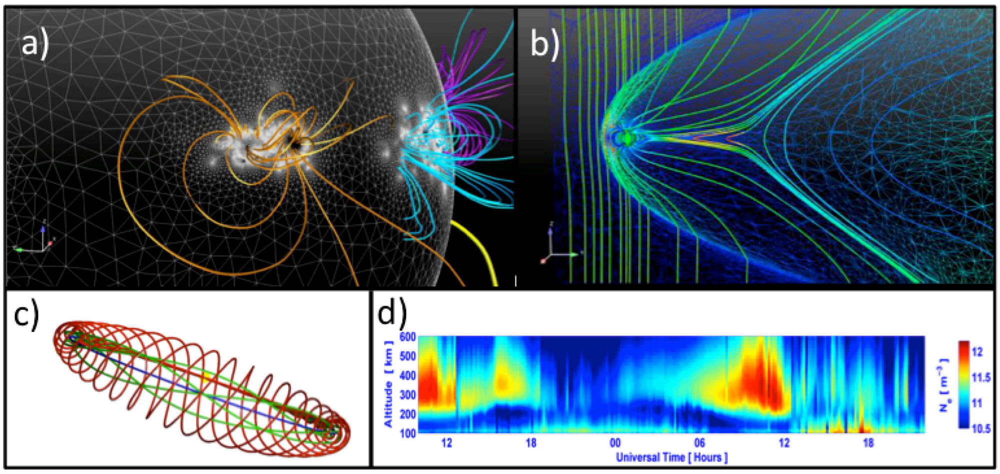

Fig. 3. (a) Magnetic reconstruction of the active regions based on a nonlinear force-free field model on an unstructured grid (Amari et al. 2015), (b) meridional cut of the global 3-D MHD simulation of a magnetosphere on a unstructured grid (source: courtesy of Tahar Amari), (c) a semi-analytical magnetic flux rope 3-D model (Rouillard et al. 2016), (d) simulated ionospheric densities using the IPIM 16-moment kinetic-fluid code (Marchaudon and Blelly 2016).

Data assimilation: The output of a numerical model will depend critically on the quality of the input data, the validity of the assumptions used in the model and the level of predictability of the system. The error involved in measuring the initial conditions, and an incomplete understanding of processes at play in space weather requires us to use advanced data assimilation techniques. Data assimilation is used to provide continually fresh input data and to test and correct a numerical model against the most up to date data. These data may be direct measurements of physical quantities such as magnetic fields measured in-situ or through remote-sensing observations (e.g. solar magnetograms). A number of models in France have made major progress in this field, these include the solar-cycle forecasting codes exploiting 4-D variational data assimilation techniques to constrain advanced solar dynamo models (Jouve et al. 2011; Hung et al. 2015), the SALAMMBO model that exploits proven methods to reconstruct aspects of the energetic electron environment through direct insertion, which runs a physics-based code that substitutes the in situ measurements as they become available and transports particles to regions of interest that may not have direct measurements (Maget et al. 2015). Of course the forecasting improvements brought by data assimilation techniques will depend on how well the measurements to be assimilated resolve the characteristic scales over which the system varies in space and time. There is considerable interest within the community in placing instrumentation (c.f. section before) on numerous platforms including nano-satellites to obtain more comprehensive measurements of the near-Earth environment that would be assimilated to numerical models. A workshop gathering space- and terrestrial-weather forecasters will be held in Toulouse to identify potential collaborations between the two communities on the subject of data assimilation[15].

Ensemble forecasting: In an effort to quantify the large amount of inherent uncertainty remaining in numerical predictions, ensemble forecasts have been used in terrestrial weather forecasting since the 1990s to help

[15] `https://meteo-2016.sciencesconf.org/`

gauge the confidence in the forecast, and to obtain useful results farther into the future than otherwise possible. This approach is at its infancy in space-weather forecasting but some first projects are in place to exploit multiple realisations of solar magnetograms from the US Air Force Air Force Data Assimilative Photospheric Flux Transport (ADAPT) (Arge et al. 2010) maps to run the Solar Models[16] and the MULTI-VP[17] solar wind model.

Possible synergies between numerical models: A number of synergies between the different numerical models developed nationally were identified during the workshop. For instance, forecasts of the electromagnetic radiation emitted by the Sun could be be used to drive advanced models of the global ionosphere-thermosphere system. Numerical models of the coronal magnetic field could be exploited by solar wind models extending from the Sun to 21.5 Rs, and beyond 21.5 Rs 3-D MHD models of the wind model could take over.

2.4 National Data Centers: assets for post-event analysis

Reliable access to a wide range of datasets is of prime importance for post-event analysis and validation of numerical models. The French heliophysics community is heavily involved in the development of three complementary databases, which are: (1) which are BASS2000[18], for ground-based solar observations (including Pic du Midi, Meudon, and Calern), MEDOC[19] for space solar observations (including SoHO, STEREO, PICARD, and SDO), and the CDPP[20] (Plasma Physics Data Center) for in-situ plasma measurements and radio observations of natural plasma in the solar system. They ensure the archiving, redistribution and valorisation of these datasets relating to the heliosphere, the Sun, the interplanetary medium, and the planetary magnetospheres. These datasets are of prime importance for post-event analysis and validation of numerical models.

The data centres have a long-standing expertise at developing fast and reliable services to the different space-physics communities. In addition to the archiving and redistribution of data from observations or measurements, they also provide derived data products of added value, as well as tools to explore and use the data. For example, MEDOC distributes temperature and emission measure maps[21] derived from SDO/AIA data, and provides a HelioViewer server to be used from a web interface[22] or from the JHelioViewer client;this tool can be used to browse solar data associated to space weather events. For heliospheric plasma measurements, the CDPP provides the AMDA[23] (Automated Multi-Dataset Analysis) advanced data-mining tool, in which users can interactively handle online data (real-time and archived), combine various physical parameters, conduct conditional searches, and interface data with other community tools. The CDPP Propagation Tool helps calculate the trajectory of solar disturbances (such as coronal mass ejections) and energy particles, and highlights the link between solar and heliospheric events. For a given observation date at the Sun, users obtain the estimated times of the corresponding in situ observations, and they can be automatically directed either to MEDOC movies and observations, or to in situ measurements hosted on the AMDA. Such a tool is extremely valuable for space-weather studies.

3 Conclusion:

The interest in exploiting French national assets and learning about the effects of space weather is rapidly growing among major French national agencies, including Météo France, L'Armée de l'Air (FEDOME project), la Direction Générale de l'Aviation Civile (projet SIEVERT), EDF (centre de recherche et développement, EDF Energy). The CNRS via the National Institute for the Sciences of the Universe (INSU) and the CNES recognise a large number of our national space-weather assets however there is little funding available to go beyond pure science and to convert our assets into useful space-weather forecasting tools. In response to a request from governmental institutions in France, including the Ministry of Research, a report prepared by a team of scientists and engineers, called the GTME, lists the current space-weather assets in France, the impact of space weather

[16] http://solarmodels.cpht.polytechnique.fr/
[17] https://stormsweb.irap.omp.eu/
[18] http://bass2000.obspm.fr/
[19] https://idoc.ias.u-psud.fr/MEDOC
[20] http://cdpp.eu
[21] http://medoc-dem.ias.u-psud.fr/
[22] http://helioviewer.ias.u-psud.fr/
[23] http://amda.cdpp.eu/

at the latitudes of the French territories and the current deficiencies in the space-weather program in France.

The strong interest of the French science community for space weather covers major corner stones of space-weather activities:

- To further test and develop our numerical models: indeed space-weather forecasting is the ultimate test for many of our theories and numerical models: forecasting solar storms formation, propagation and interaction with the Earths environment in real time is a powerful way of validating many home-grown models.
- To study and promote the launch of space-weather observatories such as the Carrington project to monitor the Sun and the Sun-Earth line from a vantage point situated outside the Sun-Earth line and smaller observatories to monitor in real-time the state of the Sun-Earth system.
- To promote and expand our data processing and assimilation techniques via our unique set of interconnected data centers (MEDOC, CDPP, BASS2000),
- To further develop our space and ground-based instrumentation that represents a formidable contribution for space-weather predictions. The community would like to develop and integrate these assets in the rapidly growing network of international space-weather assets.

It was concluded at the workshop held in Lyon that the SSA programme is the right framework to promote these national space-weather assets. The community maintains collaborations at the European level through funded projects such as the H2020 FlareCast project aiming to improve solar eruptions. The space-weather segment of SSA currently includes Expert Service Centres in Solar and Heliospheric Weather, Space Radiation, Ionospheric Weather, and Geomagnetic Conditions. France's contribution to SSA would strengthen Europe's effort at constructing a space-weather prediction center. A conclusion of the workshop was that the community should coordinate its space-weather activities more efficiently. The idea was proposed that a new national entity, officially recognised by the National Institute for Sciences of the Universe (INSU) should be created that would promote synergies and help coordinate the various space-weather projects listed in this paper.

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