THE SOLAR INFLUENCES DATA ANALYSIS CENTER (SIDC)

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ABSTRACT

The "Solar Influences Data analysis Center" (or SIDC) is an operational space weather forecast center, hosted by the Royal Observatory of Belgium. It combines the status of World Data Center (WDC) for the sunspot index and the status of Regional Warning Center (RWC) of the *International Space Environment Service* (ISES). Moreover, we are also co-I in the EIT-LASCO consortium, two instruments onboard SOHO that deliver superb input data for space weather research and forecasts. In this paper we review the data and forecast products that the SIDC can deliver you, our user community and the ongoing and planned science and IT development activities.

1. HISTORY OF THE SIDC

The SIDC was founded in 1981 to continue the work of the Zurich Observatory, when this institution decided to stop publishing the sunspot number. An agreement was therefore taken between the ETHZ at Zurich (represented by O. Stenflo), the Specola Solare Ticinese at Locarno (represented by S. Cortesi) and the SIDC (represented by A. Koeckelenbergh). Following this agreement, the SIDC started in January 1981 with the production of a sunspot index, called International Sunspot Number. The continuity and coherence with the former index of Zurich was assured through the use of Locarno (one of the three main stations of the Zurich network) as reference station.

The sunspot number is the oldest solar index measuring the solar activity and its main interest results from its long-term behavior and the length of its series (Fig.1). For a long time, it was the only index representative of the solar cycle, and many studies on the cyclical behavior of the Sun were led using the sunspot number. That is the reason why the international scientific community, through the International Council of Scientific Unions (ICSU), has renewed many times the expression of its high interest in this index and committed its computation to a specific service like the SIDC.

The SIDC is part of the Department of Solar Physics of the Royal Observatory of Belgium (ROB) and has available the complete archive of the EIT (Extreme UV Imaging Telescope on board SOHO) observations, and the know-how acquired by the local team of co-investigators in the EIT experiment. The archive covers now the whole rising part of cycle 23, and allows long-term analysis of the data.

During Space Weather week (May 2000) in Boulder (US), the ISES assembled and granted the SIDC the official status of RWC for Western Europe. ISES coordinates 10 regional warning centres (RWC) worldwide that exchange mutually the latest space weather related data and make it available to a wide public. In this context, the SIDC now provides daily activity reports and forecasts of the status of the space environment.

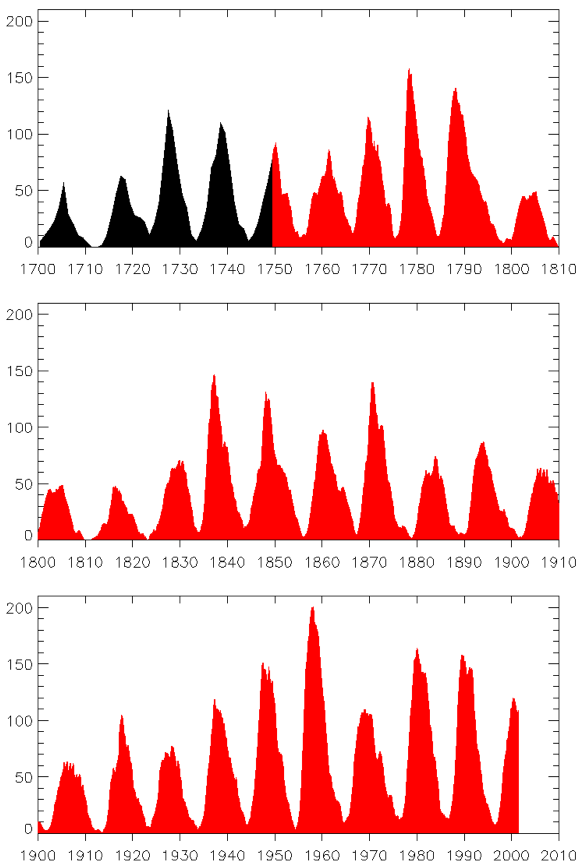

Fig. 1. Evolution of the International Sunspot Number over the latest centuries (in black, up to 1750, yearly averaged; in red monthly averaged).

2. AVAILABLE DATA PRODUCTS AND USER COMMUNITY

The wide range of time scales, over which the Sun is evolving, is reflected by the various warnings, reports and data products that are issued at the SIDC. Table 1 shows the different products provided by the SIDC.

Table 1. Top favorite products.

Product	Subscriptions
Monthly sunspot bulletin	**559**
Weekly activity bulletin	**147**
Daily activity report and forecast	**160**
Fast warning messages	**178**
+ about 10 less popular products	

The products are freely available to both the scientific community as well as to the wide public, at the anonymous ftp site ftp://omaftp.oma.be (directory dist/astro/sidcdata), and at the Web address: http://sidc.oma.be. This web site receives on average 1500 visitors per week. We estimate that 8 % of our visitors come from within Belgium, 40% within Western Europe and 30% from North America. The web site also contains a long list of 'Solar Influences links' to institutes worldwide, as well as an overview of the latest SOHO movies and images. Clickable maps of the Earth and Sun are provided for a fast and intuitive access to various data. The information on the web site and on the ftp server is updated as soon as new data become available.Various data products are also sent by email to in total about 365 users. After a registration procedure on the http://sidc.oma.be web site, new users can also receive all these messages via email, as soon as they are produced. The paper version of the monthly *Sunspot bulletin* has a circulation of around 450 copies.

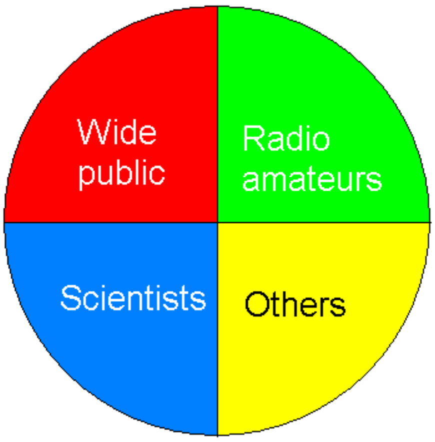

Fig. 2. Profile of user community

Our user community can be split in 4 roughly equally numbered groups (Fig. 2). First of all, the 'wide public' is an important user group. This includes amateur astronomers, aurora tourists and occasional website visits by 'net surfers'. These people are mainly looking for entertainment (pretty solar imagery) and astronomical education. A second large group are the radio amateurs. Solar effects on radio propagation have been known since a long time in this community. A third group is formed by scientists. These are mostly space scientists in different sub-branches, but includes also on the order of 15 climatologists and a handful of medical scientists. Finally, the fourth group consists of a variety of users ranging from international organisations (UNESCO, IAU, ISES) and companies to individuals belonging to aircrew and to the military.

3. THE INTERNATIONAL SUNSPOT NUMBER

The sunspot number is the oldest solar activity index. In 1849, R. Wolf of the Zurich Observatory proposed the now widely used formula:

$$R = K\,(10\,G + S), \qquad (1)$$

in which S represents the number of observed sunspots and G the number of observed sunspot groups. The quality factor K was introduced later on, to compare results from different observers, sites and telescopes. The task of the SIDC consists in collecting the observations from as many stations as possible world wide, to determine the appropriate K factor for each of them and to extract an overall 'international sunspot number' from all these observations in a good statistical sense. The full procedure has been described elsewhere [1, 2] and has been omitted here for brevity.

As some observing stations have faster communication possibilities (e-mail) than others (regular mail), this task is split in two stages: first a provisional value is calculated and later on, when all observations have been received, a definitive value is adopted. The number of stations collaborating to the program of the provisional sunspot numbers is typically around 40. The geographic distribution of the observers is: 10% from Belgium, 60% from other European countries, and 30% from the rest of the world. Our collaborators are for 35% professional astronomers, the rest being amateurs and other various contributors, such as military stations and meteorological stations. For the definitive sunspot number, typically 70 stations are available.

The quality of the output Ri data is regularly checked by comparisons with about 20 selected good stations (including the Locarno reference station) and the 10.7 cm radio flux. Comparisons are also made occasionally with the Sunspot Number calculated by the American Association of Variable Stars Observers (AAVSO).

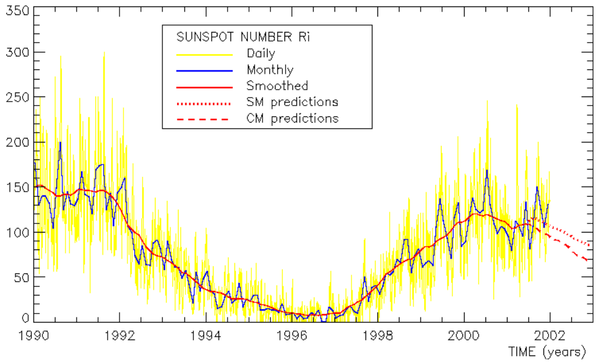

Fig. 3. The International Sunspot number, evolution over recent years and forecasts.

Asymetry between the North and South solar hemisphere is monitored with the hemispheric sunspot numbers Rn (North) and Rs (South). They are calculated in the same way as the total sunspot numbers, but separately for both hemispheres. The number of contributing stations is around 30 for the provisional values and 50 for the definitive ones. The results are normalised to the International Sunspot Number, in order to satisfy the relation Rn + Rs = Ri.

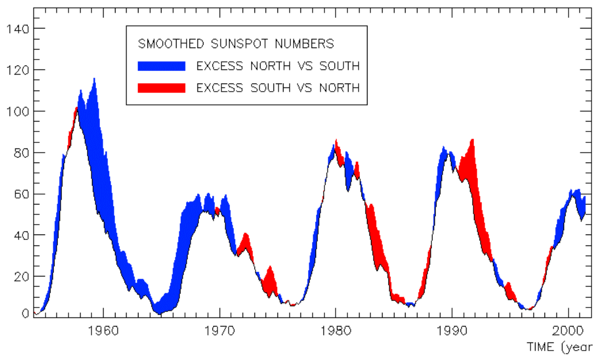

Fig. 4. North versus South component of the International sunspot number.

Waldmeier [6] carried out a careful examination of the cycles (up to cycle 18) and subsequently defined classes of cycles that he used to build a set of standard curves. By shifting these curves to align their respective maxima, he remarked that all the curves were crossing each other in a very small region near R=50, so that the time interval between the crossing "point" and the maximum is roughly constant (1.9 year). From this property Waldmeier derived a method for predicting the position and amplitude of the maximum (see also [5]). Since 1981, the SIDC proposes 12-month predictions based on Waldmeier's standard curves (Fig. 3, SM). A detailed analysis of various forecasting techniques [3] showed that purely statistical methods tend to be inaccurate in the rising phase of the solar cycle. A precursor method was proposed that employs the geomagnetic aa index as a proxy indicator of the "new" magnetic field that builds up in the polar regions of the Sun when the old cycle is declining. This forecasting method [4], has been implemented in the SIDC software and provides an alternative set of predictions since 1997 (Fig. 3, CM).

Both forecasting methods, like many others, use the time of occurrence of the smoothed sunspot number minimum as input. However, the position of the "true" minimum of activity is subject to controversy, due to different considerations, e.g. the separation between the "old" and the "new " cycles. A "corrected" latest minimum is used for instance by the SEC (NOAA, USA) for its predictions. We have considered the possibility of using a time of minimum calculated from a cubic regression on the monthly sunspot number, instead of the usual definition. Such a new definition seems to give a more accurate starting point for the predictions in many cycles: for instance, for cycle 23, the minimum occurs in August 1996 instead of May.

4. DAILY SPACE WEATHER FORECAST

Since January, 1, 2000 the SIDC issues space weather forecasts in the context of the ISES network. The International Space Environment Service (ISES, http://www.sec.noaa.gov/ises/ises.html) is a joint service of URSI, IAU and IUGG and a permanent service of the Federation of Astronomical and Geophysical Data Services (FAGS, http://www.kms.dk/fags). Via the ISES network of Regional Warning Centres (RWCs), data and forecasts of the space weather are mutually exchanged. From 1965 onwards, the Observatory of Meudon (Paris) acted as the RWC for Western Europe. In January 2000, when the Observatory of Meudon was unable to continue this service, the RWC activities were transferred to the SIDC. During Space Weather week (May 2000) in Boulder (US), the ISES assembled and granted the SIDC the official status of RWC for Western Europe.

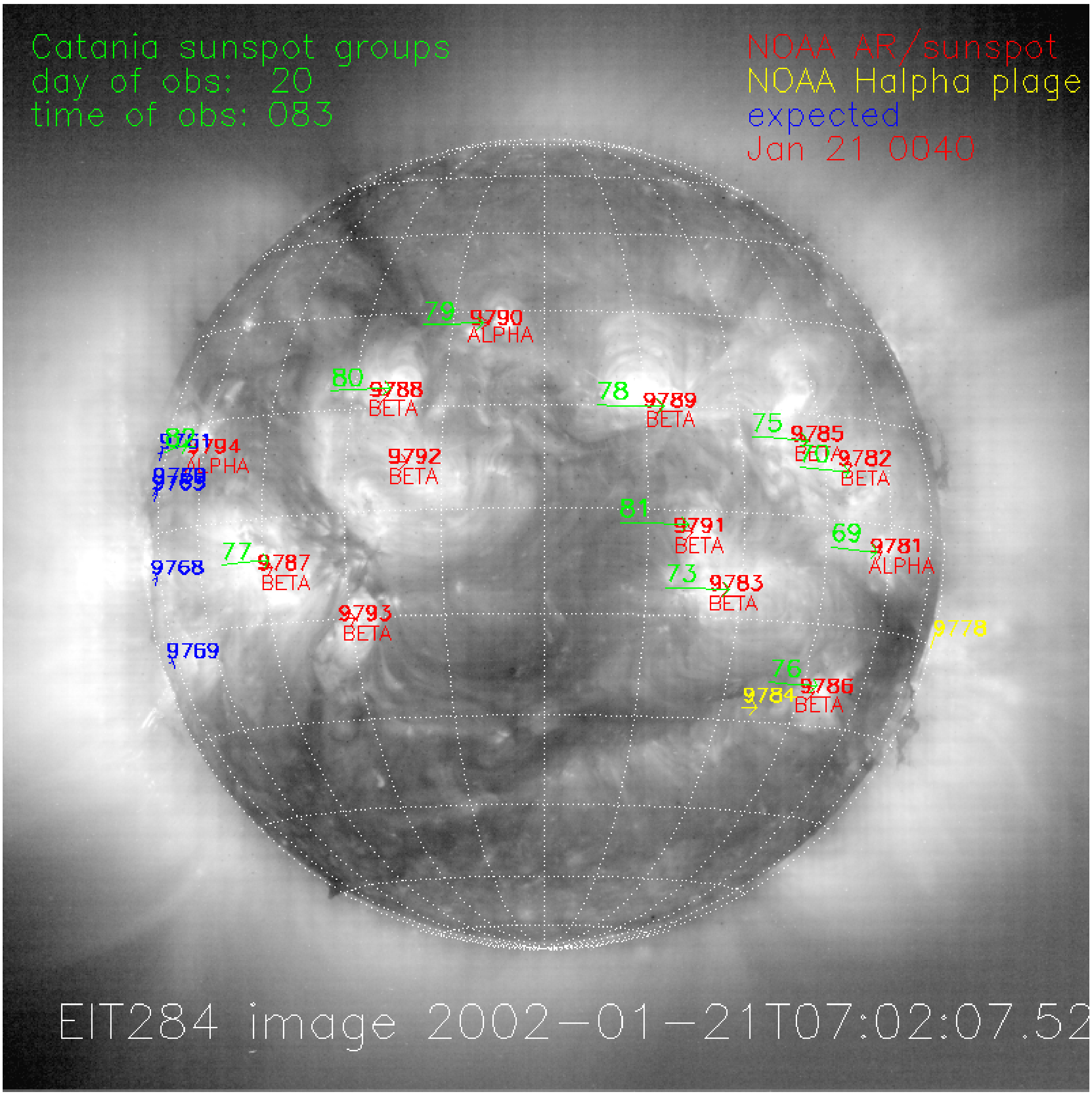

Figure 5 : Overview map of solar activity. This activity map combines the lastest EIT 284 Å coronal image, sunspot data from the Catania Astrophysical Observatory (I) and the NOAA active region classificiation. This map can be found on the SIDC website as a *clickable map* (containing pop-up windows and links to more detailed information of each active region and sunspot group) and is updated as soon as new information is available.

Monitoring the status of the solar activity is done on the basis of encoded ISES messages from the other RWCs, from ground-based observatories in Western Europe and from satellite data available via the WWW. The experience of our team with the EIT and LASCO instruments turns out to be crucial. Both instruments are the best worldwide to detect respectively the onset and propagation through interplanetary space of coronal mass ejections (Fig. 5, 6). In particular, image sequences from these two instruments yield very clear insight on the recent evolution of the solar activity.

Our daily forecast bulletin gives three-day predictions of the 10.7 cm solar flux (an EUV proxy) and of the Ap index (planetary index of geomagnetic activity). Solar proton levels and solar flaring is predicted on a 2-day basis. Also, a review of the activity of the preceding day is given with the summarised characteristics of the main noticeable events. The daily forecast is issued daily around 1300 UT. The fast warning messages (called "PRESTO") are issued as soon as an event or evolution takes place that might be important for the space environment.

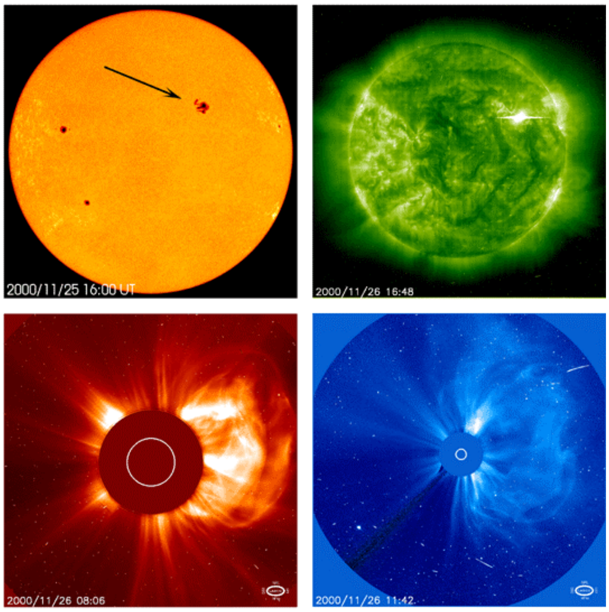

Figure 6. The use of SOHO data for space weather forecasts. Top left: a sunspot group is developping a complex structure, as seen in white light images from MDI. Top right: an eruptive flare is seen with EIT/195 Å. Bottom: LASCO coronagraphs showing the CME.

5. QUALITY CONTROL OF FORECASTS

We have recently started a program to monitor the quality of our space weather forecasts. The general conclusion is that the accuracy of the forecasts is slowly but continuously getting better, probably because our forecasters are getting more experienced. Tables 2, 3 and 4 summarise the resulting statistics over the past 10 months.

In Table 2, we show the statistics of the predicted versus observed 10.7 cm radio flux of the SIDC (top 3 lines) and -as a comparison- the same results based on the forecasts by the *Space Environment Service* (SEC/NOAA bottom 3 lines). The first column shows, that on average the SIDC slightly overestimates the 10.7 cm flux of the coming days, while SEC underestimates it. Root-mean-square (RMS) deviation (about 6 % for the first day) and the correlation coefficient (predicted vs observed) are comparable for the SIDC and SEC forecasts. It can be noted from Table 2 that the SIDC is performing marginally better than SEC, but the statistical significance of this difference is disputable. In any case, these results show that the SIDC forecasts are competitive.

When predicting solar flares, there are four possibilities depending on whether a flare occurred or not, and whether it was predicted or not. Three out of these four possibilities correspond to the columns in Table 3, while the forth possibility (no flare predicted and no flare happening) has been omitted. Table 3 shows that nearly 2 out of 3 flares are predicted. This is consistent with the exact formulation of our forecast which is 'more than 50 % chance for M or X flare'.

Finally, Table 4 gives the results in the same format for the SIDC prediction of geomagnetic activity above the minor storm level (A=39). Nearly 1 out of 2 storms are predicted 1 day in advance. However predictions for the second and third day turn out to be particularly bad. No comparisons have been made yet with the predictions of other space weather forecast centers. Note that if we would have included the forth possibility (correct forecast of no storm situation), our success rate would have been spectacularly good, as indeed no storm happens most of the time.

Table 2. 10.7 cm radio flux forecast. Statistics of predicted versus observed 10.7 radio flux (DRAO, Canada), from February to December 2001 (in sfu).

	BIAS	RMS	CORR COEFF
SIDC day 1	0.75	10.28	0.97
SIDC day 2	1.16	15.26	0.94
SIDC day 3	2.46	20.04	0.90
SEC day 1	-1.51	10.86	0.97
SEC day 2	-1.72	15.62	0.93
SEC day 3	-2.07	20.57	0.87

Table 3. Forecast 'more than 50 % chance for M or X flare' during period mentioned.

	Success	False alert	miss
First 24hr	64 %	20 %	16 %
First 48hr	62 %	8 %	30 %

Table 4. Forecast of geomagnetic storms. Criterion: "A observed and A predicted both > 39" (A from Wingst observations).

	Success	False alert	Miss
Day 1	46 %	23 %	31 %
Day 2	16 %	33 %	50 %
Day 3	8 %	15 %	76 %

6. SCIENCE ACTIVITIES AND IT INFRASTRUCTURE DEVELOPMENT

The daily operations of a space weather forecast center like the SIDC involve a significant effort to have all the data streams processed in an automated and timely way. We have developed an IDL-based software package “PreviMaster” that processes automatically the incoming, ISES messages and gets autonomously additional data from the web/ ftp servers. This package is inspired from the “PreviSol” software, previously in use at the Meudon Observatory. The novelty of this new package is that it uses the collected information to build a private website acting as a “virtual forecast room” called “PreviWeb”. This tool allows the forecaster in duty to make predictions from any PC connected to the internet and monitor the evolution of the space weather from home.

Currently, the forecasting techniques depend largely on `empirical' rules-of-thumb. It is therefore important to have basic research to replace and/or support this untested human experience.The complete EIT archive covers now the whole rising part of cycle 23, and allows long-term analysis of the data. We have recently started a full scanning project of the archive, with the purpose of detecting and qualifying transient events and large scale structures in the corona (Fig. 7). The ROB is also co-investigator of the SECCHI package onboard the STEREO mission (launch 2004). The EUV imager, the Heliospheric imager and the coronagraph onboard each of the twin spacecrafts forming this mission are designed to follow solar wind structures from their solar origin up to the Earth's magnetosphere with a stereoscopic view. Therefore, STEREO will provide for the first time the possibility of monitoring in three dimensions the triggering and acceleration of CMEs, their journey through the solar wind and their arrival at the Earth's magnetosphere.

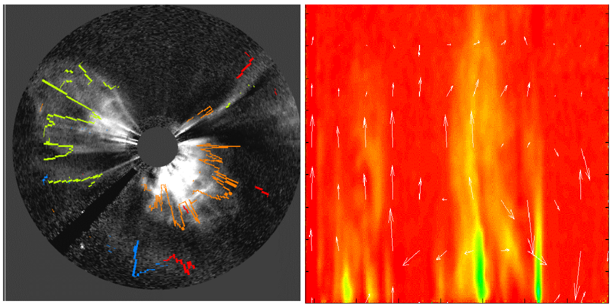

Fig. 7. Automated detection of CMEs in LASCO data (left) and flow field and speeds detected in erupting CME (right).

7. CONCLUSIONS

Space weather is a new and flourishing interdisciplinary science with direct relevance for technological systems. Varying solar activity from cycle to cycle might have an important impact on the climatic evolution on earth. Therefore, both on the short as well as on the long time scales, the study of 'Solar influences' is important for society as a whole. As a service centre of the Royal Observatory of Belgium, the SIDC provides to the wide public a number of data products, forecasts and warnings that can help in identifying and anticipating these Solar Influences. For future growth and development of these services, it is essential to have a wide network of international collaborations. This is why we have embedded the SIDC in the World Data Centre network (FAGS), the Regional Warning Centre system (ISES) and linked it with our involvement in the EIT and LASCO instruments onboard SOHO (ESA/NASA). In this context, we are ready to participate enthusiastically to any ESA initiative on Space Weather.

8. REFERENCES

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