ESA Space Weather Programme Study
Alcatel Consortium

Space Weather Service

WP3110

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1. Introduction

Space weather refers to conditions in space that influence technological systems, human's health and endanger life. Space weather services shall therefore inform about the space weather conditions and effects. This information can then be used to mitigate the effects. The specific content of the service is defined by the users' need.

The forecasters play an important role. They form the interface between the scientists and users. A space weather forecast service must therefore use the latest scientific results, be understandable and useful for the customer.

In WP 3100 we present a prototype real-time forecast service of space weather and effects using kowledge-based neurocomputing.

In this WP we classify today's world wide space weather providers into governmental organizations, being or not being Regional Warning Centers within the International Space Environment Services (ISES), and commercial companies.

The services they provide are then described and also what is missing. Recommendations of improvements are suggested, such as including the latest scientific results, better coordination of observations, use of new technology, modeling and Knowledge-Based Neurocomputing (KBN) techniques.

The space weather services and data centers available in Europe are described.
A Space weather center such as the Space Environment (SEC) in Boulder, USA does not exist in Europe.

The infrastructure of a possible future "European Space Weather Center" (ESWC) is outlined. A distributed Center is recommended. Examples of networks and distributed organizations are described: ISES, EUMETSAT, FUN and LOFAR/LOIS.

A World Space Weather Organization (WSWO), similar to the WMO within meteorology, is also suggested. Many of the space weather issues are namely political and the problems caused by the space weather are global and international. All possible resources are needed to be used to solve the problems.

2. International Organizations Today Offering Space Weather Services

Space weather services are provided by both governmental organizations (within or not within International Space Environment Services) and commercial companies. Examples are hereafter described.

2.1 Governmental Regional Warning Centers (RWCs) within ISES

The International Space Environment Service (ISES) is a service of the Federations of Astronomical and Geophysical Data Analysis Services (FAGS) under the auspices of the International Union of Radio Science (URSI) in association with the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG). ISES was called IUWDS (International URSIgram and World Days Service) until 1996. The IUWDS was formed in 1962 as a combination of the former International World Days Service, initiated in 1959 as part of the IGY, and the former URSI Central Committee of USRIgrams which initiated rapid international data interchange services in 1928.

ISES facilitates near-real-time international monitoring and prediction of the space environment by: the rapid exchange of space environment information; the standardization of the methodology for space environment observations and data reduction; the uniform publication of observations and statistics; and the application of standardized space environment products and services to assist users reduce the impact of space weather on activities of human interest.

Three basic functions accomplish the task of the ISES. First, the International URSIgram Service provides standardized rapid free exchange of space weather information and forecasts through its Regional Warning Centers (RWC). Second, ISES prepares the International Geophysical Calendar (IGC) each year. This calendar gives a list of 'World Days' during which scientists are encouraged to carry out their experiments. And third, the monthly Spacewarn Bulletins summarize the status of satellites in earth orbit and in the interplanetary medium.

ISES consists today of 11 regional warning centers (RWC). The RWC of ISES are responsible for providing real-time monitoring and prediction of space weather for the entire globe; each RWC is responsible for providing services in its localized section of the world.

Figure 1. The ISES web site http://ises.sec.noaa.gov/ises/.

2.1.1 ISES Membership Requirements

Regional Warning Center (RWC)

Applicant must:

- Have endorsement by their national government or academic body
- Have timely access to space environment data within their geographical area
- Have capability to provide timely, free exchange of data and products with other ISES members
- Provide near-real-time space weather forecasts and warning services for local users
- Develop forecasts for input to the daily GEOALERT

Duties of RWC:

- Collect space environment data from observatories in their geographical area

- Format interchange data in accordance with ISES code standards
- Provide timely, free, exchange of data, information, and techniques with other ISES members
- Provide near-real-time space weather forecasts and warning services for local users, including a daily GEOALERT
- Assist the public in understanding space weather
- Assist users in space weather related activities
- Prepare and share space weather education materials
- Serve on ISES Directing Board
- Provide reports and attend ISES meetings as needed

Associate Regional Warning Center

Applicant must:

- Have endorsement of a regional warning center
- Have ability to provide timely, free exchange of data and products to local RWC
- Provide near-real-time space weather forecasts and warning services for local users

Duties of associate RWC:

- Collect space environment data from observatories in their geographical area
- Provide timely, free, exchange of data, information, and techniques with other RWCs
- Assist the public in understanding space weather
- Assist users in space weather related activities

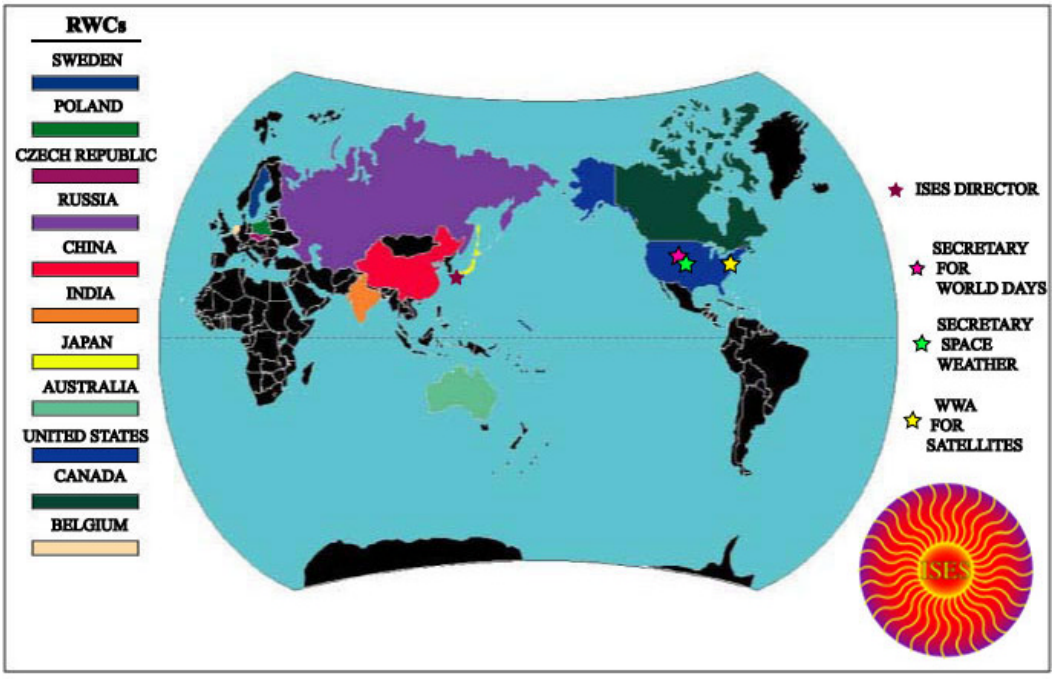

Figure 2. The worldwide distribution of Regional Warning Centers.

Members of the ISES Directing Board

Title	Host institution	Location	Delegate
ISES Director	Communications Research Laboratory	Tokyo	K. Marubashi
Deputy Director	.	.	Vacant
Secretary for World Days	National Geophysical Data Center	Boulder	H. Coffey
WWA for Satellites	Goddard Space Flight Center	Goddard	J. King
Secretary Space Weather	Space Environment Center	Boulder	J. Kunches
RWC Australia	IPS Radio and Space Services	Sydney	R. Thompson
RWC Belgium	Royal Observatory of Belgium	Brussels	P. Cugnon
RWC Canada	Geological Survey of Canada	Ottawa	H. Lam
RWC China	Beijing Astronomical Observatory	Beijing	H. Wang
RWC Czech Republic	Institute of Atmospheric Physics	Prague	D. Buresova
RWC India	National Physical Laboratory	New Delhi	D. Lakshmi
RWC Japan	Communications Research Laboratory	Hiraiso	T. Maruyama
RWC Poland	Space Research Centre	Warsaw	Z. Klos
RWC Russia	Hydrometeorological Service	Moscow	P. Svidsky
RWC USA	Space Environment Center	Boulder	J. Kunches
RWC Sweden	Lund Space Weather Center	Lund	H. Lundstedt
FAGS representative	.	.	E.A. Tandberg-Hanssen
IAU representative	National Geophysical Data Center	Boulder	H. Coffey
IUGG representative	National Geophysical Data Center	Boulder	H. Coffey
USRI representative	Communications Research Laboratory	Tokyo	K. Marubashi
USRI representative	IPS Radio and Space Services	Sydney	P. Wilkinson
USRI representative	Hydrometeorological Service	Moscow	S. Pulinets

Table 1. Members of the ISES Directing Board.

The first governmental organization that has a RWC that we will discuss is Space Environment (SEC), since it's the biggest space weather center and official center for space weather forecasts and services in USA.

2.1.2 RWC-USA (SWO of Space Environment Center)

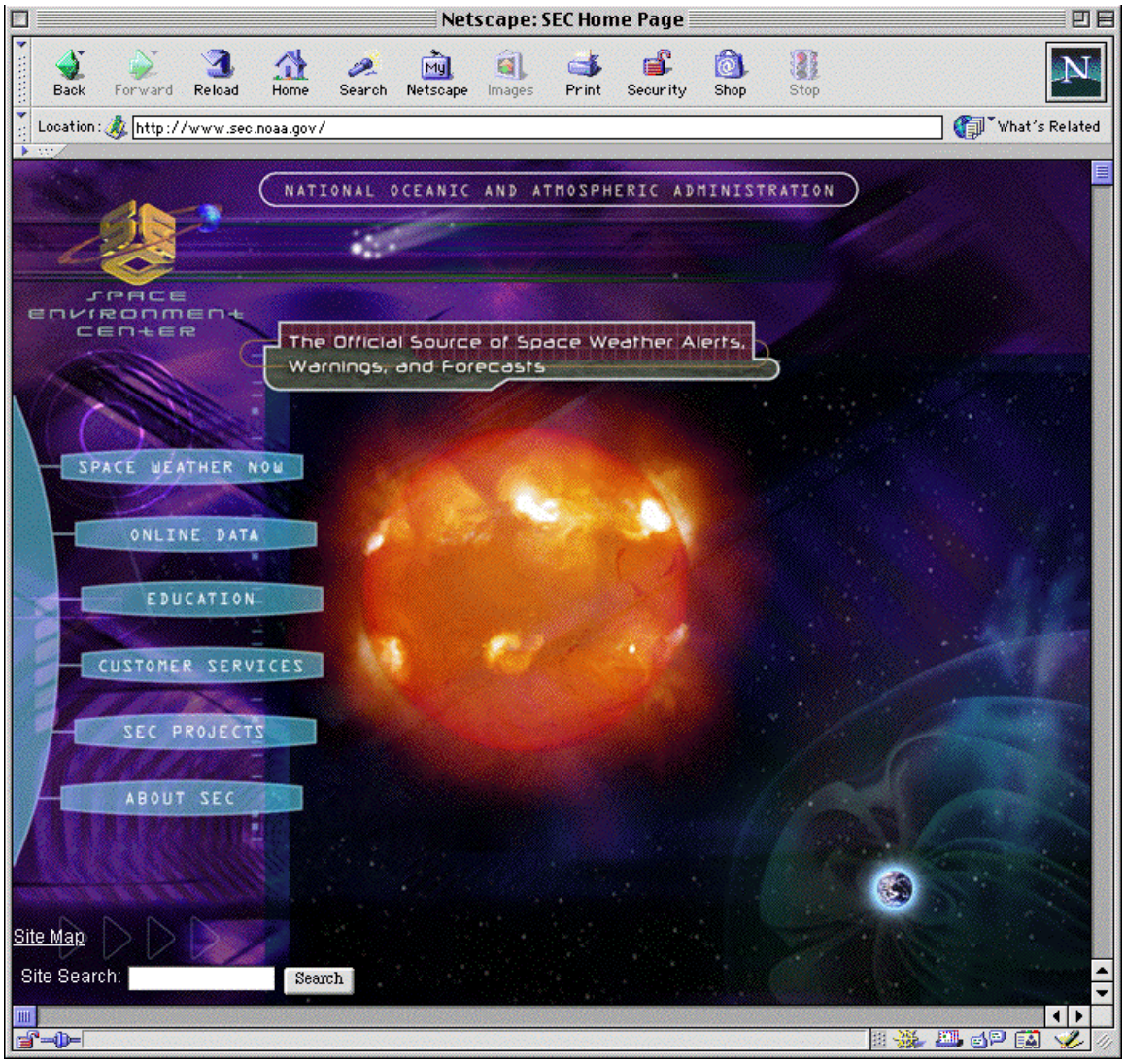

Figure 3. The SEC web site http://www.sec.noaa.gov/

SEC provides:

- real-time monitoring and forecasting of solar and geophysical events,
- conducts research in solar-terrestrial physics, and
- develops techniques to improve monitoring and predicting space weather.

The National Oceanic and Atmospheric Administration (NOAA) is the parent organization of SEC. SEC is one of 7 National Centers for Environment Prediction (NCEP). The SEC Space Weather Operations (**SWO**) is jointly operated by NOAA and the U.S. Air Force, and is the national and world warning center for disturbances that can effect people and equipment operating in the space environment.

Space Weather Operations (SWO) Center

Figure 4. The SWO and RWC-USA.

SWO is a Regional Warning Center (**RWC**) and the World Warning Agency (WWA) of the ISES. In addition, as WWA, SWO acquires and exchanges data between all the RWCs and maintain the international space weather codes used to transmit the space weather data. It also issues international GEO Alert messages (a daily consensus forecast and message of solar and geophysical conditions).

2.1.3 RWC-Australia (IPS)

Figure 5. The IPS web site http://www.ips.oz.au/.

IPS is a unit of the Department of Industry Science and Resources, part of the Australian Government. IPS provides the Australian radio propagation and space environment services and products. This a major site for space weather services. It's a complete site even if services on HF conditions always have been the most important task of IPS. IPS is also offering ionospeheric services for Europe. IRF contributes with ionospheric data. to IPS. IPS has become a World Data Center (WDC).

2.1.4 RWC-Belgium (Brussels)

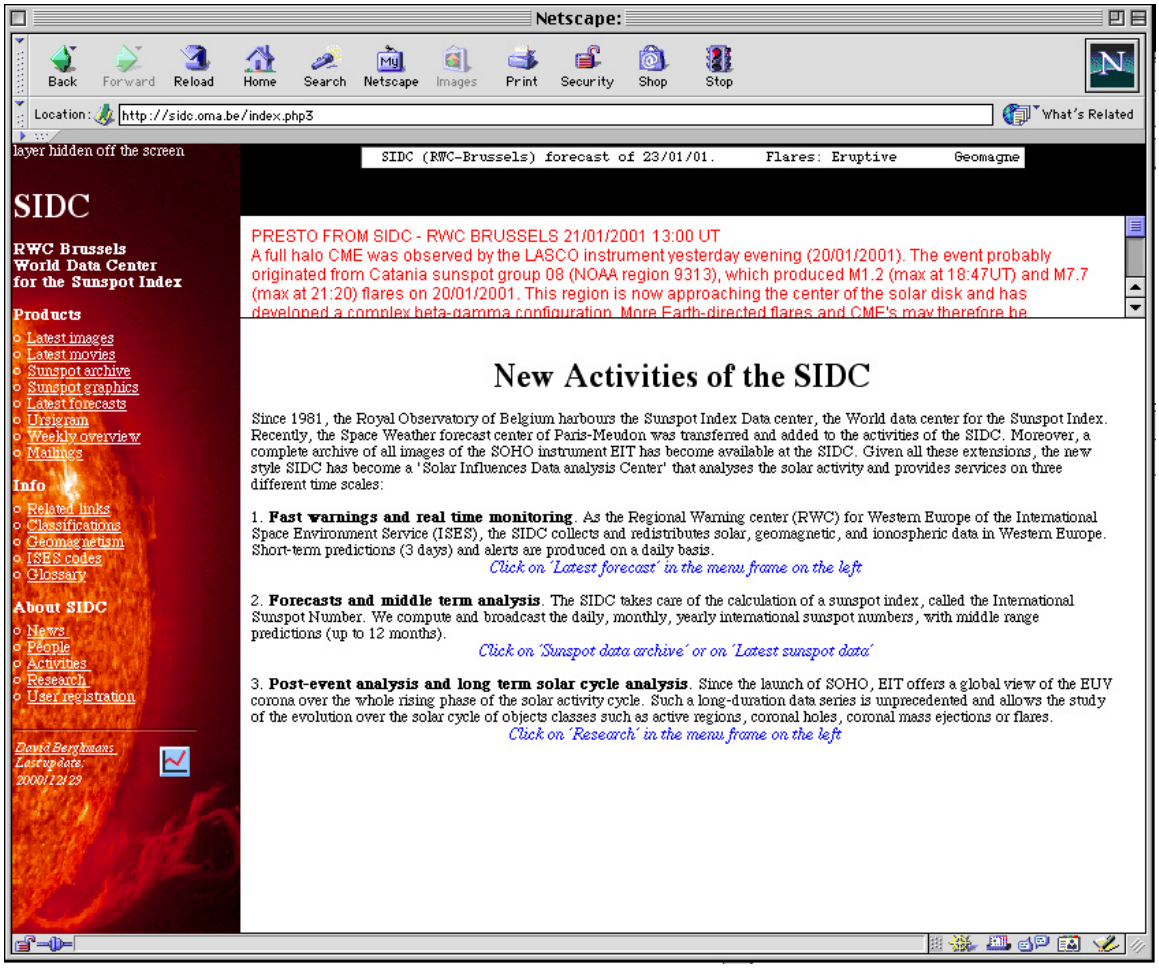

Figure 6. The SIDC web site http://sidc.oma.be/index.php3 .

RWC-Brussels is also World Data Center for the Sunspot index. It's a rapidly growing site. The site forwards forecasts as a RWC, however is providing only own sunspot forecasts. No forecasts of space weather effects are delivered. No commercial products are at the moment available.

2.1.5 RWC-Canada

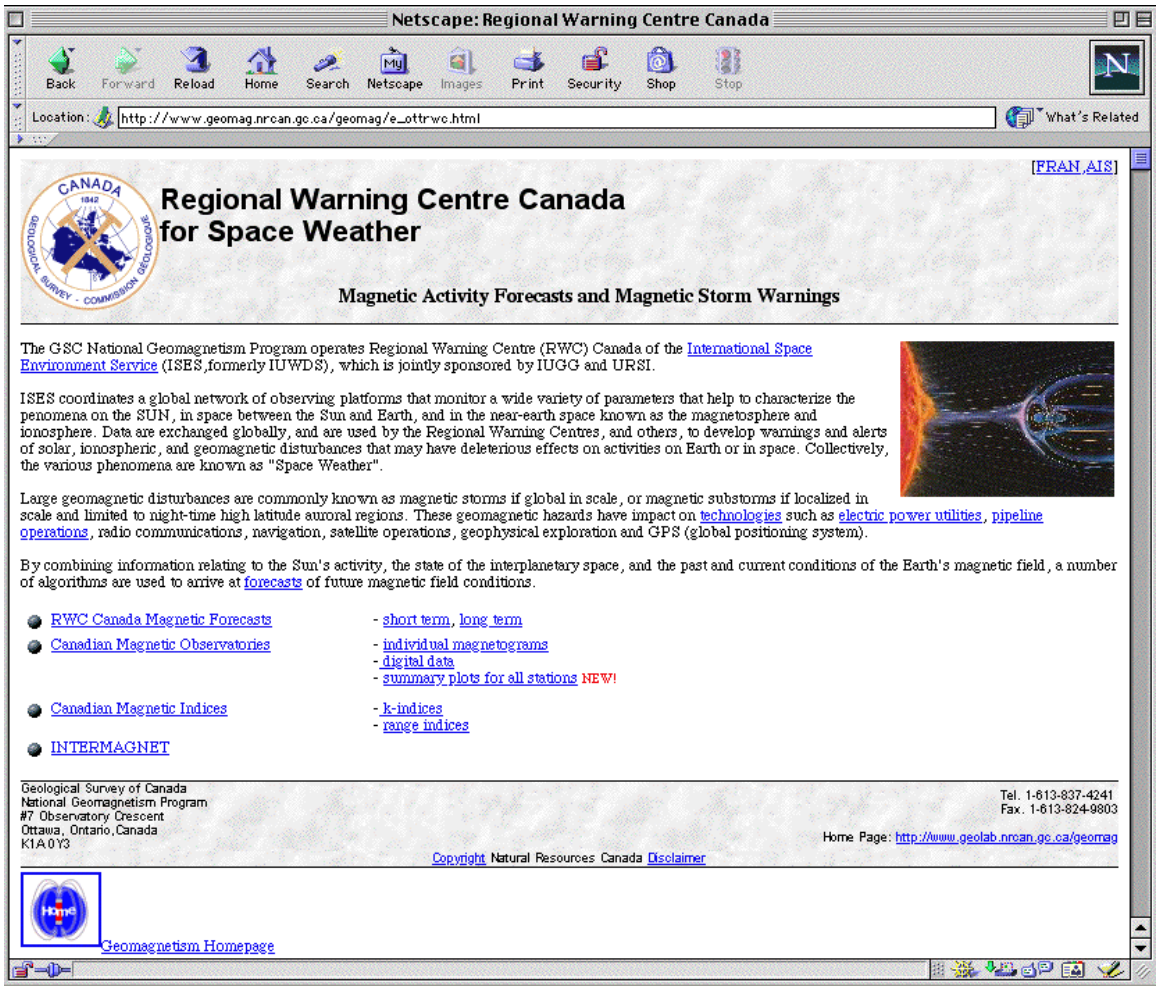

Figure 7. The RWC-Canada web site
http://www.geomag.nrcan.gc.ca/geomag/e_ottrwc.html

The Geological Survey of Canada (GSC) National Geomagnetism Program operates Regional Warning Center Canada. This is also a rapidly growing site. However, forecasting geomagnetic activity has always been a major concern for the RWC-Canada. Dr. David Boteler was elected 2001 Deputy Director of ISES.

2.1.6 RWC-China

Figure 8. The Space Environment Center and RWC-China web site http://www.bao.ac.cn./bao/org/sec/ .

Space Environment Center (previously Solar Activity Prediction Center) is a sub-center of RWC-Beijing. SEC of Beijing offers three type of solar activity forecasts, short-term (X-ray bursts and proton events), medium-term (one-month in advance, Short-Wave Fade Outs, proton events, sunspot numbers) and long-terms (yearly, 11 years) sunspots forecasts.
No other forecasts are produced by SEC in Beijing and no commercial products are available.

2.1.7 RWC-Japan

Figure 9. The RWC-Japan web site http://hirweb.crl.go.jp/index.html .

RWC-Japan is a very complete space weather service site, covering most of the fields of space weather and effects. They contribute with both data and forecasts of their own. No commercial products are avaialble.

2.1.8 RWC-Poland

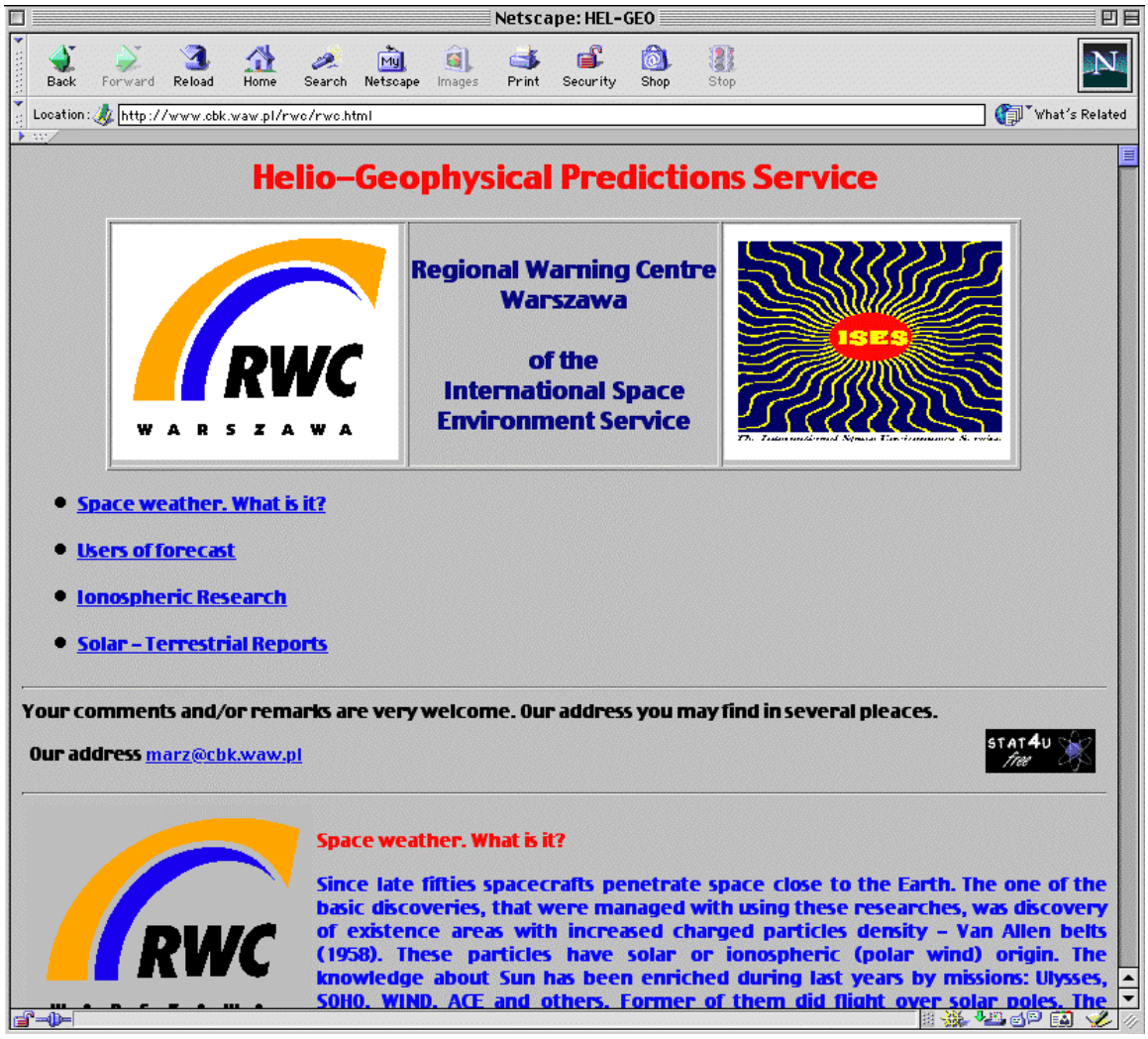

Figure 10. The Helio-Geophysical Prediction Service (RWC-Poland) web site http://wwwcbk.waw.pl/rwc/rwc.html

Limited space weather services are offered by RWC-Poland. They forward RWC data and contribute with own ionospheric information. However, no own forecasts are available. No commercial products are available.

2.1.9 RWC-Sweden (Lund)

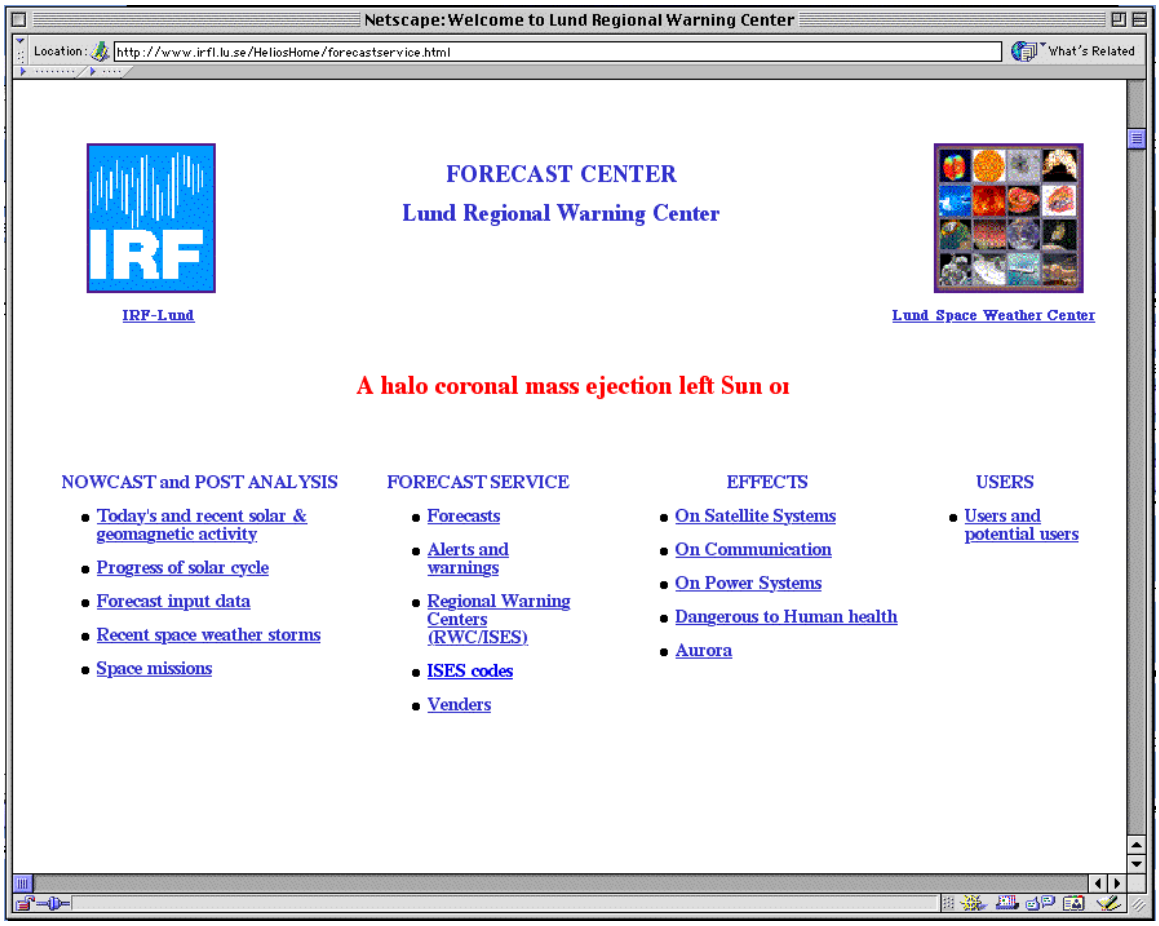

Figure 11. RWC-Sweden in Lund web site http://www.irfl.lu.se/forecastservice.html .

RWC-Lund is part of IRF-Lund which is division of the Swedish Institute of Space Physics. Lund was awarded regional warning center status on May 6, 2000. RWC-Lund has users within the power industry. A Nordic Geomagnetically Induced Current (GIC) Network was established in Lund to improve the contacts between space weather researchers and users within the power industry. RWC-Lund is also offering aurora forecasts to science tourists.
The prototype developed for the ESA Space Weather Program by IRF-Lund, will soon be the user interface for the RWC-Sweden (earlier RWC-Lund).

2.2 Other Governmental Organizations

2.2.1 British Geological Survey

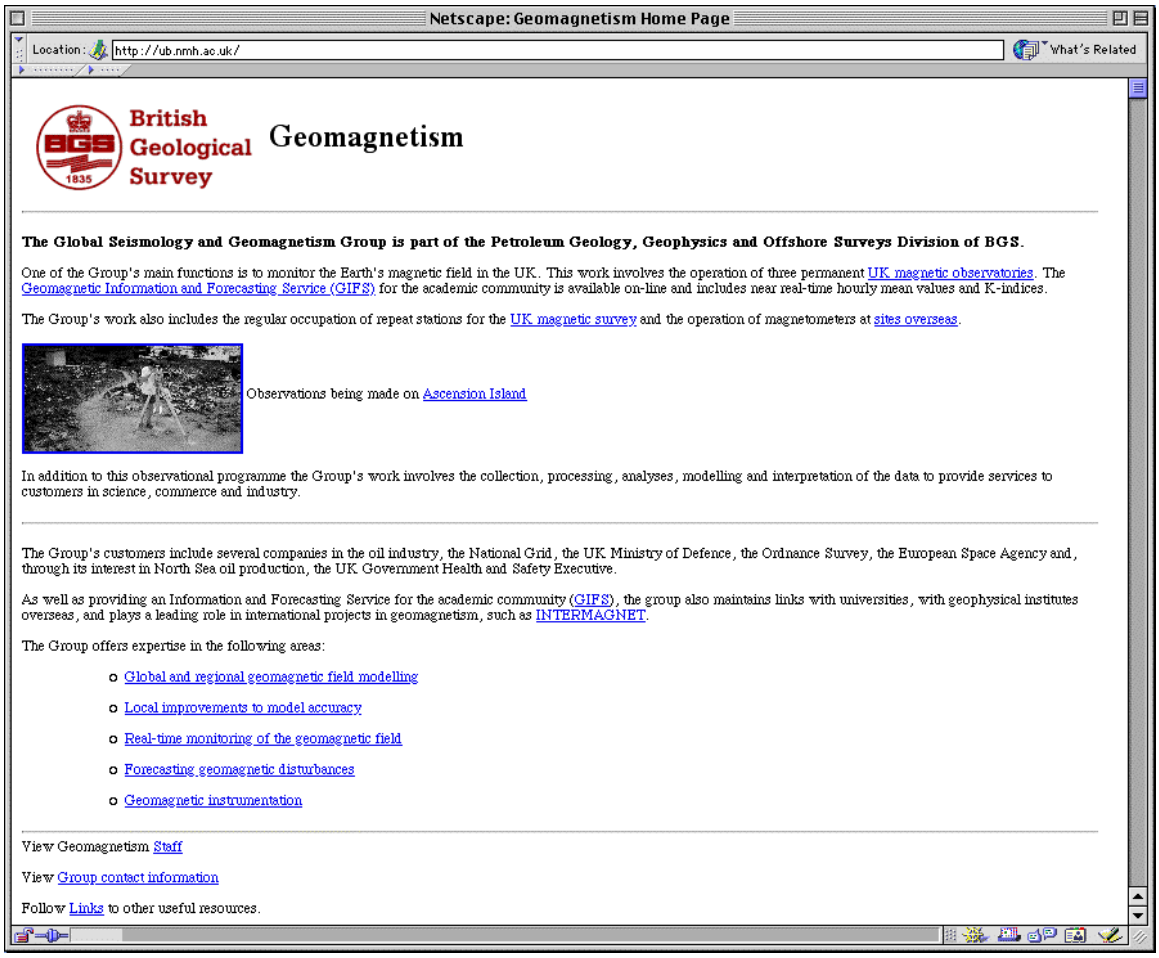

Figure 12. The British Geological Survey Geomagnetism web site http://ub.nmh.ac.uk/ .

The Global Seismology and Geomagnetism Group is part of the Petroleum Geology, Geophysics and Offshore Surveys Division of British Geological Survey (BGS).

One of the Group's main functions is to monitor the Earth's magnetic field in the UK. This work involves the operation of three permanent UK magnetic observatories. The Geomagnetic Information and Forecasting Service (GIFS) for the academic community is available on-line and includes near real-time hourly mean values and K-indices.

The Group's work also includes the regular occupation of repeat stations for the UK magnetic survey and the operation of magnetometers at sites overseas.
The Group's customers include several companies in the oil industry, the National Grid, the UK Ministry of Defense, the Ordnance Survey, the European Space Agency and, through its interest in North Sea oil production, the UK Government Health and Safety Executive.
As well as providing an Information and Forecasting Service for the academic community (GIFS), the group also maintains links with universities, with geophysical institutes overseas, and plays a leading role in international projects in geomagnetism, such as INTERMAGNET.

2.2.2 Meteorological Centers

The Swedish Meteorological and Hydrological Institute (SMHI) provides together with the Swedish Radiation Protection Institute (SSI) the Swedish UV-index and information of Stratospheric ozone to public and other customers. NOAA maintains the web site below with other internationally organizations providing radiation services. These services illustrate the space weather's influence on human health. The SSI is also carrying out measurements of the radiation on board airplanes.

Figure 13. The WMO UV web site http://www.srrb.noaa.gov/UV/ .
These services illustrate the space weather's influence on human health. The SSI is also carrying out measurements of the radiation on board airplanes.
Meteorological Center are also important for studies and forecasting of climate and weather changes due to solar activity. Studies of the relationship between the solar activity and climate changes are carried out at DMI and DSRI in Denmark and at MRI in Kiruna and IRF-Lund in Sweden.

2.2.3 Military

Figure 14. The 55th Space Weather Squadron web site http://www.schriever.af..mil/55swxs/factsht.htm .

The 55th Space Weather Squadron, a component of the Air Force Weather Agency, is located at Schriever Air Force Base, Colorado, USA. The mission of the 55th Space Weather Squadron is to provide space environmental analyses, forecasts and warnings to enhance the capability of worldwide Department of Defense forces and Federal agencies. Department of Defense customers include high priority national space programs, North American Aerospace Defense Command, United States Space Command and Air Force Space Command.

The 55th Space Weather Squadron processes solar optical and radio, ionospheric, and geomagnetic data from global networks of ground-based sensors. Using computer models of the space environment, forecasters combine this data with energetic particle measurements, electric and magnetic field information, and other space-based sensor data from Defense Meteorological Satellite Program (DMSP) and other spacecraft. The center issues alerts, warnings, and forecasts to military space organizations, and shares information with the National Oceanic and Atmospheric Administration (NOAA) through Operating Location -A , which alerts civilian users including the National Aeronautics and Space Administration (NASA).

Some of the factors monitored at the center include disturbances in the ionosphere which interfere with spacecraft and ground-based communications, solar flares and their effects on defense systems, and changes in atmospheric density which impact accurate predictions of satellite and space debris decay from orbit.

In Europe no similar services are offered. However, space weather research within defense organizations are carried out. An increased interest in space weather among European military has also been notised.

2.3 Commercial Companies

2.3.1 Associate RWC - Collecte Localisation Satellite (France)

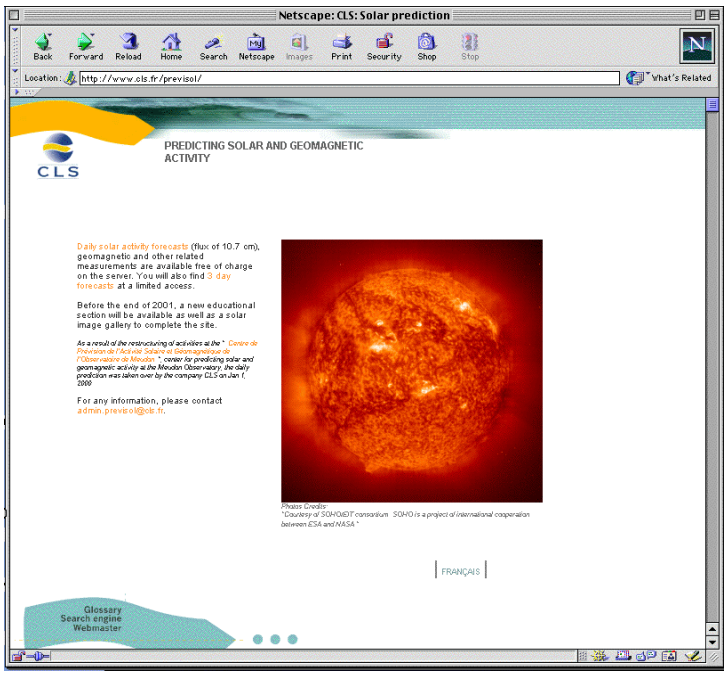

Figure 15. The ARWC – Collecte Localisation Satellite web site http://www.cls.fr/previsol/ . Collecte Localisation Satellite (CLS) in France participate within ISES, but since it's a company it's a associate RWC and not a full RWC. CLS took over January 1 2000 the predicting of solar and geomagnetic activity, RWC-Paris (Meudon) provided.

2.3.2 Metatech (USA)

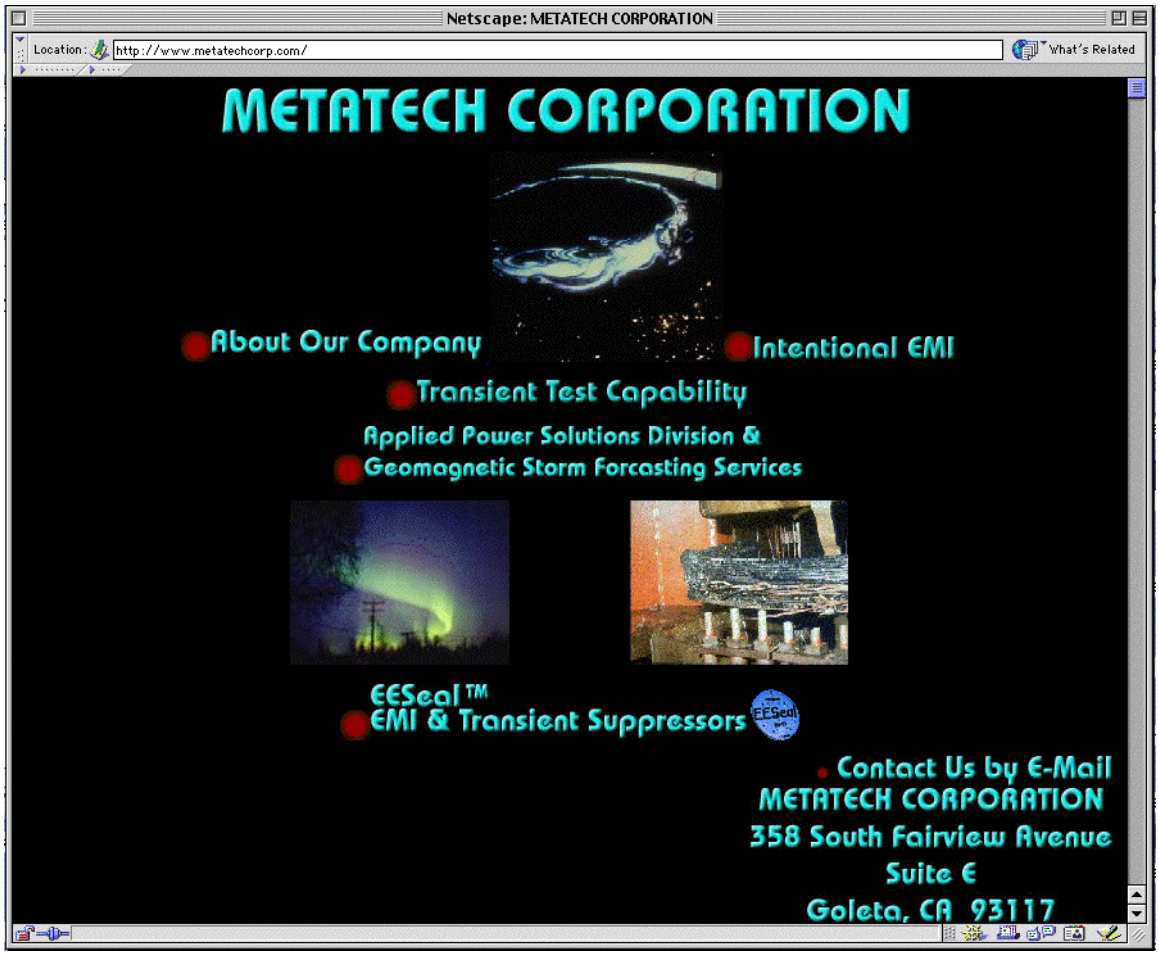

Figure 16. The Metatech web site http://www.metatech.corp.com/ .

Metatech sells a forecast system of geomagnetically induced currents and effects on power systems. The National Grid in England has purchased such a system. Contacts with Swedish power companies have also been taken.

2.3.3 STP Dispatch (Canada)

Figure 17. The Solar-Terrestrial Dispatch web site http://solar.spacew.com/ .

The Solar Terrestrial Dispatch provides information about space weather and effects. They have also develop software programs and sell internet space weather courses. STP Dispatch is an initiative of Cary Oler.

2.3.4 Active Sun AB (Sweden)

Active Sun AB is a Swedish company located at the Science and Technology Parks Ideon in Lund. Active Sun ells aurora forecasts to science tourists. The forecasts are based on real-time ACE solar wind data and aurora observations. The forecast models are based on neural networks. The forecasts are delivered as SMS and voice messages.

3. Reviewing Existing Space Weather Services

3.1 Summary of Services

Name	A	B	C	D	E	F	G	H	I	J	K	L

RWC USA	yes	yes	yes	yes	yes	d/h	yes	no	24h7d	yes	yes	yes
RWC Australia	yes	yes	yes	yes	no	d/h	yes		closed Sa,Su	yes	yes	yes
RWC Sweden	yes	yes	yes	yes	yes	d/h	(yes)	yes	24h7d	yes	yes	yes
RWC Canada	yes	yes	yes	-	-	-	-	-	12-21 ClosedSa,Su	yes	-	no
RWC China	yes	yes	yes	no	no	no	no	no	8hrs 5days	-	no	no
RWC Japan	yes	yes	yes	yes	yes	d/h	yes	no	23.30-08,7d	yes	yes	no
RWC India	yes	yes	yes	no	no	no	yes	no	03-12 closed Sa,Su			
RWC Russia	yes	yes	yes	yes	no	-	yes	no	24h7d	-	-	no
RWC Belgium	yes		yes					no				
RWC Poland	yes	yes	yes	no	no	no	no	no	7-14 closed Su	no	no	no
RWC Czechoslovakia	no	no	yes	no	no	no	no	no	closed Sa,Su	no	no	no
B G S UK	no	yes	yes	no	no	d/h	no	no	-	no	no	yes
Metatech	no	no	no	no	no	no	no	yes	yes	yes	yes	yes
STP Dispatch						d			yes	-	yes	yes

Table 2 is available at the internal Lund Space Weather Center site http://www.irfl.lu.se/swprogint/servicedef.html. Links are given to the existing service providers.

A center is a provider if the center collects and distribute the data, i.e. the center doesn't need to make the observations by itself.

The letters in the table stand for:

A: Provider of solar data:
B: Provider of geomagnetic data:
C: Provider of ionospheric and atmospheric data:
D: Provider of real-time solar forecasts:
E: Provider of real-time solar wind forecasts:
F: Provider of daily and hourly geomagnetic activity forecasts: geomagnetic indices Ap, Kp, Dst, AE, local geomagnetic field.
G: Providers of real-time atmospheric forecasts: foF2
H: Provider of real-time forecasts of effects: Satellite anomalies, GICs

I: Service Distribution: Via WWW pages, e.mails, SMS messages, Wap, Voice mail or fax 24 hrs (24h) or less.
J: Use of new scientific results:
K: Understandable explanations to the users: Such as SEC/NOAA Space Weather Scales for Geomagnetic storms (1-5), Solar Radiation storms (1-5) and Radio blackouts (1-5)
L: Commercial products:

3.2 European Available Space Weather Services

Three RWCs exist in Europe, in Belgium, Poland and one in Sweden. Also one ARWC exist in Europe, CLS in France. Several companies also exist. e.g. in Sweden, Finland and England.

4. Space Weather Services as Defined by Users' needs

As mentioned in the introduction the space weather service is defined by the users' needs.

Users	Problems	Presently satified needs	Services missing
-	*Surface charging* : Is probable at Kp>=6 during geomagnetic storms	F, N, P exist of Kp (Lund, SEC). LANL sensors.	Better coverage of the local satellite space environment.
-	*Bulk charging* : Starts when the >MeV electron fluxes exceed 1000 particles/cm²/sec/ster	GOES electron flux sensors give N. Rice MEPN gives F.	Better coverage of the local satellite space environment.
Satellite design, launch and operation	*Single Event Upsets* (SEU): Occurs for particles >50 MeV at times of Proton Events (SPEs) and Galactic Cosmic Rays (GCR) exceeds GeV.	GOES proton detectors give N and Neutron monitors give N of GCR.	F of SPE and GCR.
-	*Spacecraft drag* : In general starts when 10.7 cm flux > 250 solar flux units and Kp>=6	Both N and F of 10.7 cm solar flux (NRC/CNRC, SEC) and Kp (Lund, SEC) exist.	UV monitoring would give better N and F.
-	*Radio frequency interference and scintillation* : At times, the Sun is within 1 degree of a satellite as seen from ground antenna.	N of radio burst exist (NRC/CNRC, CRL Japan). F of ionospheric scintillation (NWRA).	F of radio bursts.
-	*Spacecraft orientation effects* : Starts at Kp>=6 during geomagnetic storms and at times of magnetopause crossings.	Both N and F of Kp (Lund, SEC) are available. GOES satellites identify crossings.	-
Civil aviation	*Radiation hazard to crew. Danger to avionics. Disrupt of GPS communication.*	N of GCR, SPE exist	F of GCR and SPE
Man in space	*Radiation hazard*	GOES gives N of SPE.	F of SPE.
Communication	*foF2, MUF,shortwave fadeouts and disruption of GPS communication.*	F,N of fOF2 and MUF (IPS, BAL)	F of disruption of GPS communication.
Power supply and generation	*Geomagnetically Induced Currents* (GIC)	F and N of GIC (Lund)	More geographic locations & higher accuracy F.
Oil and gas distribution	*Geomagnetically Induced Currents* (GIC)	F and N of GIC (Lund)	More geographic locations & higher accuracy F.
Prospecting	*Estimates of local geomagnetic field changes*	N, F of local geomagnetic field changes exist. Very little F exist (Lund).	More geographic locations & higher accuracy of F.
Re-insurance	*All space weather (SW) effects*	Some estimates of space weather (SW) effects	Estimates of all SW effects.
Tourism	*Aurora forecasts*	Lund gives F for Kiruna region, York, Univ. for U.K. and SEC gives tips on viewing the aurora.	More geographic locations.

F = Forecasting **N** = Nowcasting **P** = Post-event analysis

Table 3: The table above briefly shows presently available space weather services for specific problem and also what services are missing. The table is available as a web page with the address http://www.irfl.lu.se/swprogint/usersneeds.html.

Two web pages containing forecasts available, at operational or at a research stage, have been produced. The web addresses are

http://www.irfl.lu.se/HeliosHome/forecast_esa_listu.html

and http://www.irfl.lu.se/swprogint/forecastpage.html

A more complete discussion of the users' requirements is given by R.B. Horne in WP 1300 and WP 1400. Several user requirements were identified. They fell into four categories:

a) Prediction of Space Weather events (table 3.1)
b) Prediction of physical quantities that directly impact the users (3.2)
c) Continuous measurements of the system (3.5)
d) Post-event analysis (4.1)

The Space Weather Prototypes WP 3220 and 3230 try to satisfy some of these requirements.

As an example we will here illustrate the requirements of power companies and how they will be fulfilled with the Lund Space Weather Prototype.

a) A Halo CME is detected by LASCO onboard SOHO. Large-scale magnetic field changes might be used to predict the CMEs. The arrival time at L1 is calculated.
b) When the halo CME has arrived at L1, the geomagnetically induced current is forecasted using ACE real-time solar wind data as input to trained neural networks.
c) GICs are measured continuously.
d) The Prototype has access via the database to earlier cases for post analysis.

5. Suggested Improvements of Space Weather Services

a) **Closer collaboration between users within industry and providers of space weather services to make services understandable and useful**:

In order to give the users, of technological systems, a service that is understandable and what they need a much closer collaboration between the user and the providers of space weather services is recommended.
A Nordic GIC Network was created in Lund in September 1999 in order to identify persons to contact. Other networks are therefore recommended to be initiated among other users and providers.

b) **Use of KBN techniques in order to be able to offer services 24 hrs and 7 days a week**:

The service must be available 24 hours a day and 7 days a week. To accomplish that KBN techniques are recommended to be used. The use of KBN techniques makes it possible to deliver automatic service.The prototype 1 is such an example. Neural networks model the relationship between the space weather and the effect. Knowledge is extracted and coded into the neural network. The use of KBN techniques makes it possible to deliver automatically the space weather service.

c) **Better use of the latest results and related results within science in forecast models:**

Use of intelligent hybrid systems makes it possible to faster develop models using latest results and knowledge from different sources. For explanation and post analysis distributed hybrid and MHD models are recommended.

6. Data Provided by Reception and Data Centers

6.1 Data Provided

DATA	EUROPEAN	NON-EUROPEAN
SOLAR DATA		
Global oscillation,MDI/SOHO	ESA	Stanford, USA
Global oscillations (GONG)	IAC, Spain	International
Solar Magnetic Field Data		
MDI/SOHO	ESA	Stanford, USA
Wilcox Solar Observatory		Stanford, USA
Big Bear Solar Observatory		Calif. USA
Mees Solar Observatory		Hawaii, USA
Mount Wilson Observatory		Calif., USA
National Solar Observatory		USA
Themis, GVT	France, Germany	
3D solar magnetic field, Irkutsk		Russia
Solar Images		
Latest SOHO, LASCO, EIT,MDI images	ESA	NASA, USA
Current solar images, SDAC		International
Yohkoh SXT images		USA, Japan
Big Bear Solar Observatory		Calif., USA
Mount Wilson Observatory		Calif., USA
BASS 2000, INSU/CNRS	France	
Nancay radio solar images	France	
Nobeyama Solar Radio Obs.		Japan
Solar radio observations CRL		Japan
List of Solar Phenomena		
CME list, NRL		USA
EIT Activity Report	ESA	NASA, USA
Solar Proton Events, SEC		USA
BATSE Solar Flare Server		USA
List of Solar Active Regions, SEC		USA
Sunspot numbers, NGDC		USA
WDC sunspot index	Belgium	
Solar Radiation Data		
GOES X-ray Data		USA
UV-index, NOAA		USA

10cm solar radio flux		Canada
Daily total solar irradiance, NGDC		USA
Cosmic Ray Data		
Cosmic Ray Data, NGDC		USA
Cosmic Ray Data, IZMIRAN		Russia
Solar Wind Data		
SOHO,CELIAS	ESA	NASA, USA
ACE		NASA, USA
OMNIWeb, NSSDC		USA
COHOWeb, NSSDC		USA
IMP8, MIT		USA
WIND, MIT		USA
TERRESTRIAL DATA		
Magnetospheric Particle Data		
Cluster Science Data System	ESA	
GOES electron, proton data		USA
Earth's trapped radiation environment, SPENVIS	Belgium	
Aurora		
IMAGE, SWRI		USA
Polar VIS, Iowa		USA
UV Imager, MSFC		NASA, USA
POES, NOAA		USA
Aurora page, MTU		USA
Aurora page, York	England	
Aurora page, IRF-K,L	Sweden	
Ionospheric Data		
HF-Propagation Reports, NOAA		USA
IPS-Radio Space Services		Australia
Ionosonde data, IRF	Sweden	
Ionosonde data, RAL	England	
Ionospheric Data Archived, NGDC		USA
TEC maps, GPS, JPL		USA
Ionospheric maps, GPS, DLR	Germany	
Ionospheric Convection, SuperDARN		USA
Geomagnetic Field Data		
Magnetometer sites, data, IRF-L	Sweden	
The geomagnetic field, NGDC		USA
Geomagnetic Data Services, WDC-C2		Japan
Canadian National Geomagnetism Program		Canada
British Geological Survey (Geomagnetism)	England	
Erdmagnetisches Obs.,Wingst	Germany	
Stratospheric and Tropospheric		

Data		
Dynamic state of atmosphere, winds, waves, turbulence,..MST, Esrange	Sweden	
National Climate Data Center, NOAA		USA
Global Warming Update, NOAA		USA
Atm. Chemistry&Dynamics, TOMS		NASA, USA
Ozone Depletion, Ohio		USA
Weather Net, UMich.		USA
EFFECTS ON TECHNOLOGICAL SYSTEMS		
Satellite Anomaly Data Base, NOAA		USA
Radiation Effects Data Base, JPL		NASA, USA
Cosmic Ray Effects on MicroElectronics, CREME		USA
Nordic GIC Network Data Server, IRF-L	Sweden	
HEALTH EFFECTS		
Effects from Increased Exposure to UV-B		USA
GENERAL DATA RESOURCES		
Space Weather Resources, Rice		USA
WWW Space Physics Resources, SwRi		USA
Space Weather Relevant Assets at NSSDC		NASA, USA
Space Weather Resources at SSDOO		NASA, USA
NGDC		USA
CDAW Data Center		NASA, USA
GEM Storm Web pages, LANL		USA
ISTP		USA
World Data Center System		International
SPENVIS	Belgium	
ESA Space Weather Site	ESA	

Table 3. The web adresses to the sites are available on the site http://www.irfl.lu.se/HeliosHome/spwdata.html

6.2 World Data Centers

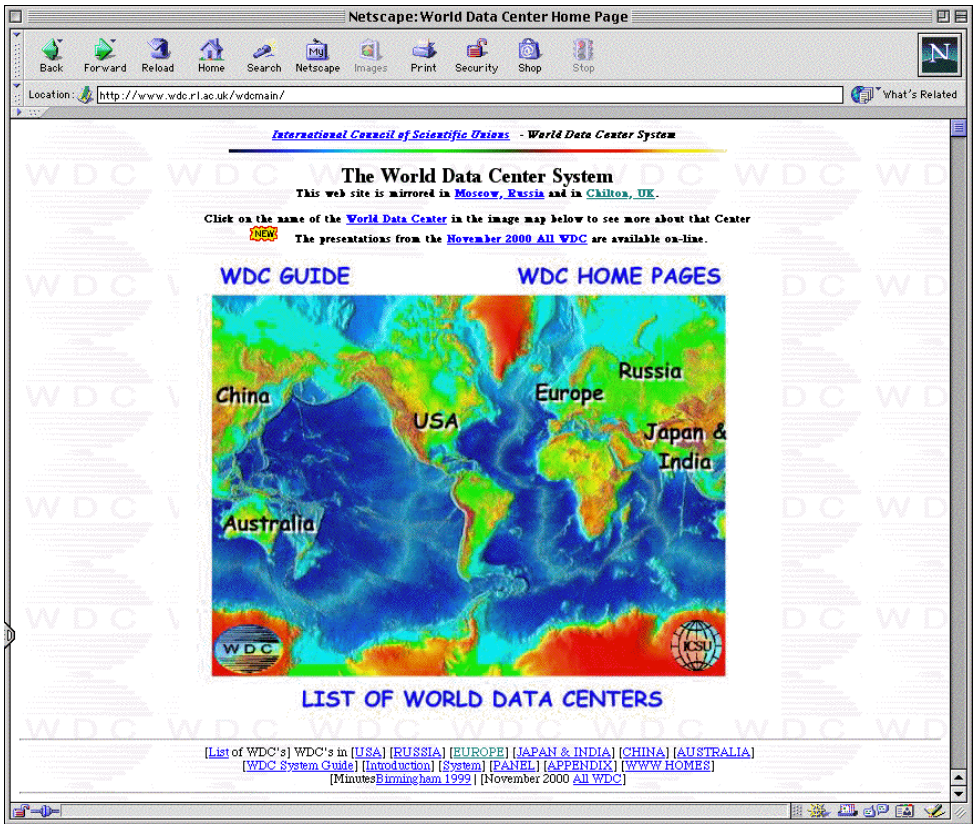

Figure 18. The World Data Center web site http://www.wdc.rl.ac.uk/wdcmain/ .

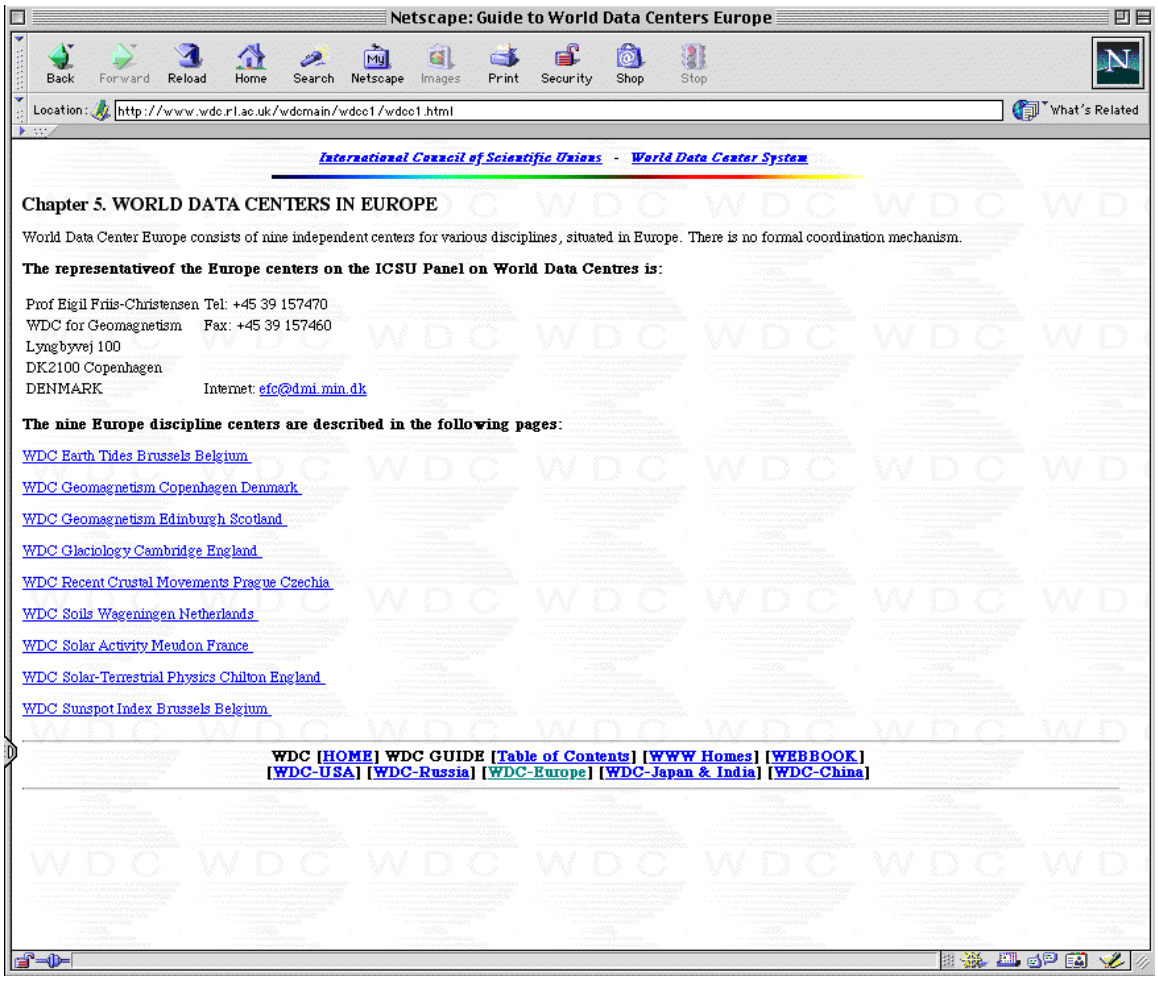

Figure 19. The World Data Center in Europe web site http://www.wdc.rl.ac.uk7wdcmain/wdcc1/wdcc1.html .

6.3 WDC in Europe and Data Networks.

There a nine WDCs in Europe. Of special interest for space weather are: WDC Geomagnetism in Copenhagen, Denmark. WDC Geomagnetism in Edinburgh, Scotland.
WDC Solar Activity in Meudon, France. WDC Solar-Terrestrial Physics in Chilton, England.
WDC Sunspot Index in Brussels, Belgium.

Figure 20. WDC for solar-terrestrial physics in Chilton in England web site http://www.wdc.rl.ac.uk/

Network	www address
European Solar Magnetometry Network	www.astro.su.se/~dorch/esmn/
EISCAT Network	http://eiscathq.eiscat.com/
Ground-based Ionospheric Observations, DMI	web.dmi.dk/solar-terrestrial/ground_ionosph_obs/home.html
Nordic GIC Network	www.irfl.lu.se/HeliosHome/nordicgicnetwork.html

Table 4. European Data and observation networks.

7. A Future European Space Weather Center

7.1 A European Space Weather Center (ESWC) – Its constituents

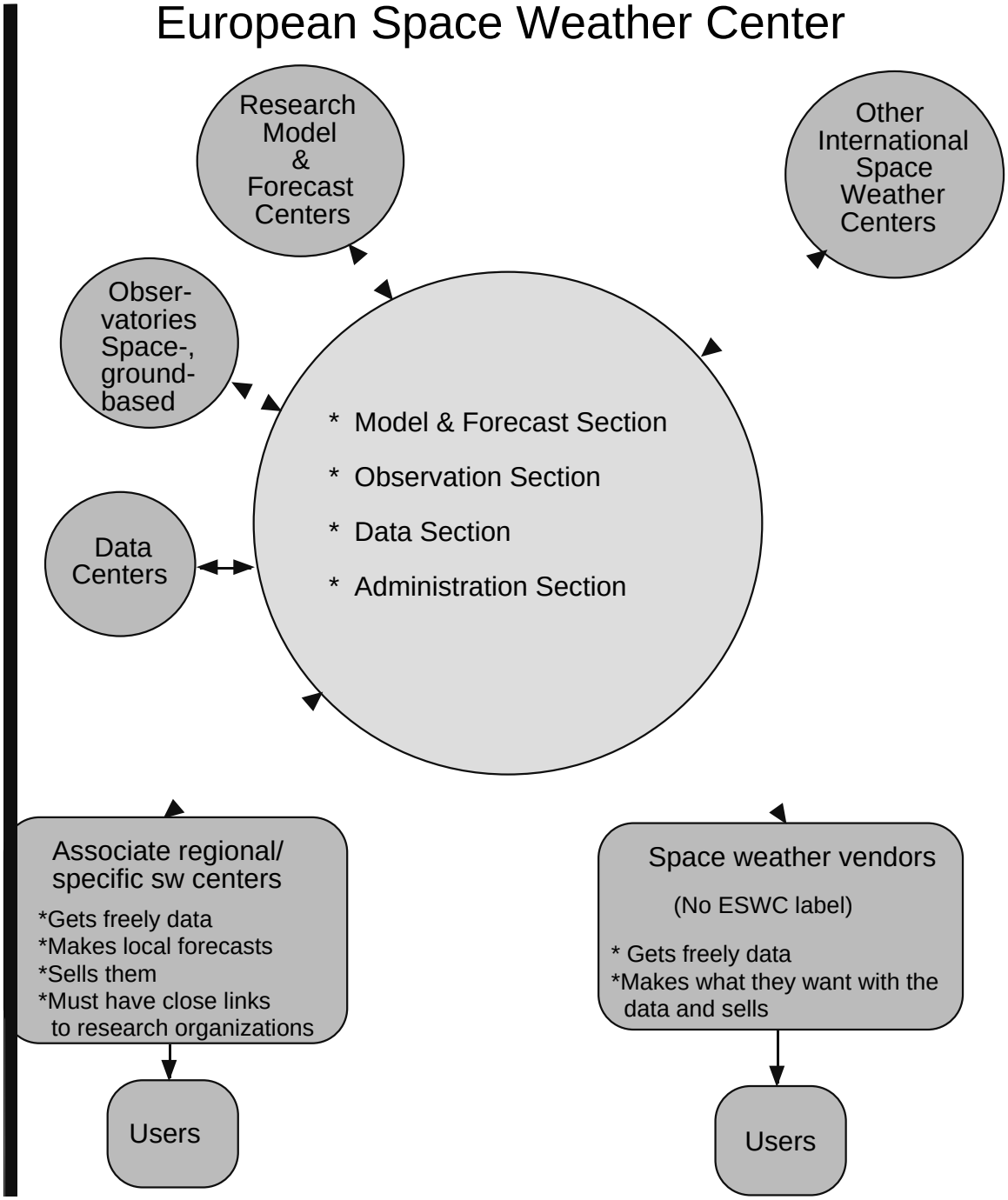

Figure 21. shows the proposed European Space Weather Center.

In previous chapters we have described the existing space weather service and data centers. We suggested improvements of data and reception centers. In this chapter we outline a future "European Space Weather Center" (ESWC) (Figure 21).

Several international space weather centers already exist e.g. the Space Environment Center in USA and IPS in Australia, but none in Europe. A European Space Weather Center should particularly represent the European interests and guarantee European sovereignty. It should offer services of specific interest to Europe. ESWC would strengthen the European commercial companies in their relation to US companies. A ESWC should also be integrated in the international networks of space weather services. A World Space Weather Organization is therefore also suggested (Figure 22).

A ESWC should make use of the specific expertise at European Centers by associating those centers to the ESWC (Model and Forecast Section). Such centers are Research Model and Forecast Centers. Since ESA/ESTEC has the organization for such center, ESTEC is suggested as the location for such center. We also suggest ESA/EU to support/finance the associated research centers and the activities at ESWC. The Research centers are expected to contribute with models and global forecasts.

A ESWC should provide, collect, archive, freely distribute the data (Data Section) and freely distribute global forecasts (Forecast Section). Data Centers and Observatories should contribute with data. However, the ESWC should also operate and maintain its own space and ground segments (Observation Section). The administartion section shall among other things arrange workshops, training, give labels to regional/specific space weather (sw) centers together with the other sections.

The local and regional forecasts should be provided by the Associated/specific and vendors of space weather. As already mentioned, 11 RWC exist within the ISES organization and one ARWC. SEC has its SWO as RWC. Europe has four RWCs and one ARWC.

A Nordic GIC network was established after a Nordic GIC meeting in September 1999. The network consists of representatives from power companies within the Nordic countries interested in the space weather effects of geomagnetic induced currents (GICs) and representatives from the research community. The network idea has been a success and the network has been suggested to be extended to include members even outside the Nordic countries. We therefore recommend the establishment of such networkss of users.

7.2 EUMETSAT

Since forecasting space weather has many similarities with forecasting the tropospheric weather we have studied the infrastructure and organization established for carry out weather forecasts. EUMETSAT is such a European intergovernmental organization for the exploitation of meteorological satellites. It operates the present geostationary METEOSAT satellites, the successor MSG, and the future polar METOP. After preprocessing of the satellite data, they enter into the Application Ground Segment of EUMETSAT. This segment consists of the two parts: a centralized processing facility located at the EUMETSAT headquarter in Darmstadt that generates standard meteorological products and makes them available to users all over the world. And secondly a number of (presently 7) of Satellite Application facilities (SAFs) which are specialized centers that perform decentralized processing of satellite data and that generates specialized thematic derived products including application software. The products generated by SAF's are used for operational meteorology and for research. Each SAF consists of a consortium

of institutes from EUMETSAT member states, one of which acts as host institute (mostly National Meteorological Services).

The SAF's services belong to three main type:

- development and distribution of software packages to users for local operational
- applications or local off line data processing in the user's environment
- off-line product services
- real-time product services

All products are distributed and archived using the centralized standard EUMETSAT data distribution and archiving chain.

There are many similarities between EUMETSAT/SAFs and SECs/RWC/ISES and also interesting differences. There is however no corresponding World Space Weather Organization to the UN WMO.

7.3 ESWC as part of a World Space Weather Organization (WSWO)

Space weather and the effects are global and international problems. It should therefore be solved internationally. The problems are therefore also often of political character and need to be solved by an international organization. Within the field of meteorology, WMO exist. We therefore suggest establishing a similar WSWO for the field of space weather.

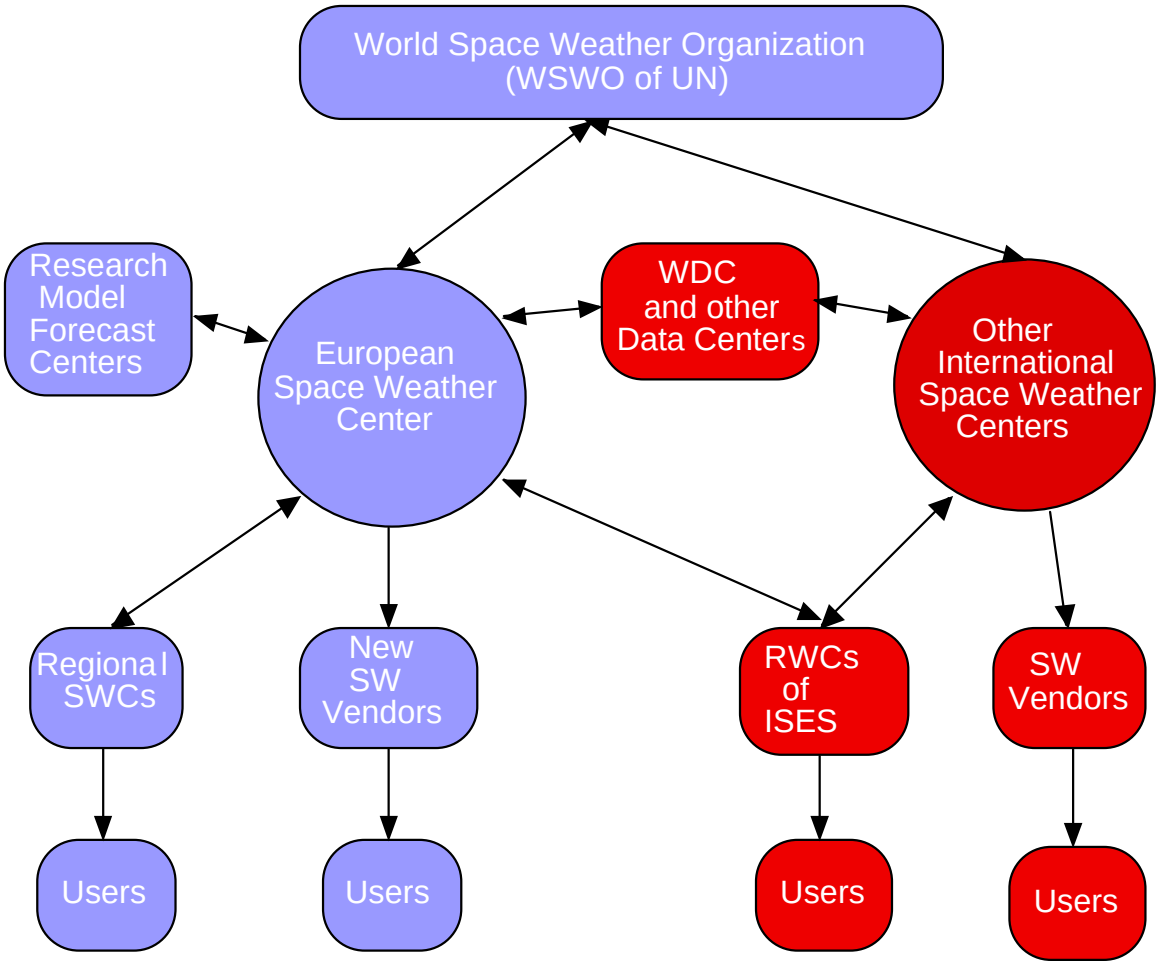

Figure 22. Existing organizations are shown in red and suggested in blue.

7.4 Øresund Region – A European Region with Active Space Weather Research and Services

The region encompasses Scania and Zealand and has Copenhagen-Malmö-Lund as its hub. Within a radius of about 100km, there are 3.5 million people. EU has designated the region as a model region for greater employment. The Öresund region is one of Europe's great centers of research and learning. Fiften universities and university colleges provide places for more than 120 000 students. From economic point of view, Øresund region is one of Europe's strongest. Universities and university colleges work closely together with trade and industry in the region. Examples of that are Science Parks such as, Ideon in Lund, Malmö, CAT in Roskilde, and Symbion in Copenhagen.

Figure 23: Öresund Bridge - Both Copenhagen and Lund are easily accessed from the whole Europe.

In Copenhagen

- DMI, Solar-Terrestrial Physics Division, (Director Torsten Neubert, member of SWWT)
- DSRI, Danish Space Research Institute (Director Eigil Friis-Christensen, member of SWWT)
- Word Data Center
- Univeristy and Institute of Technology

In Lund

- IRF-Lund, participates in ESAs Space Weather Program
- Lund Space Weather Center
- Regional Warning Center - Sweden (International Space Environment Services (ISES))
- IRF-Lund archives SWEN
- IRF-Lund participates in the LOIS project
- IRF-Lund has collaborated with the power industry during many years
- A space weather company – Active Sun AB is located at Ideon in Lund
- Lunds University och Lund institute of Technology
- Ideon with companies such Ericssons research divisions working on 4G mobile phones

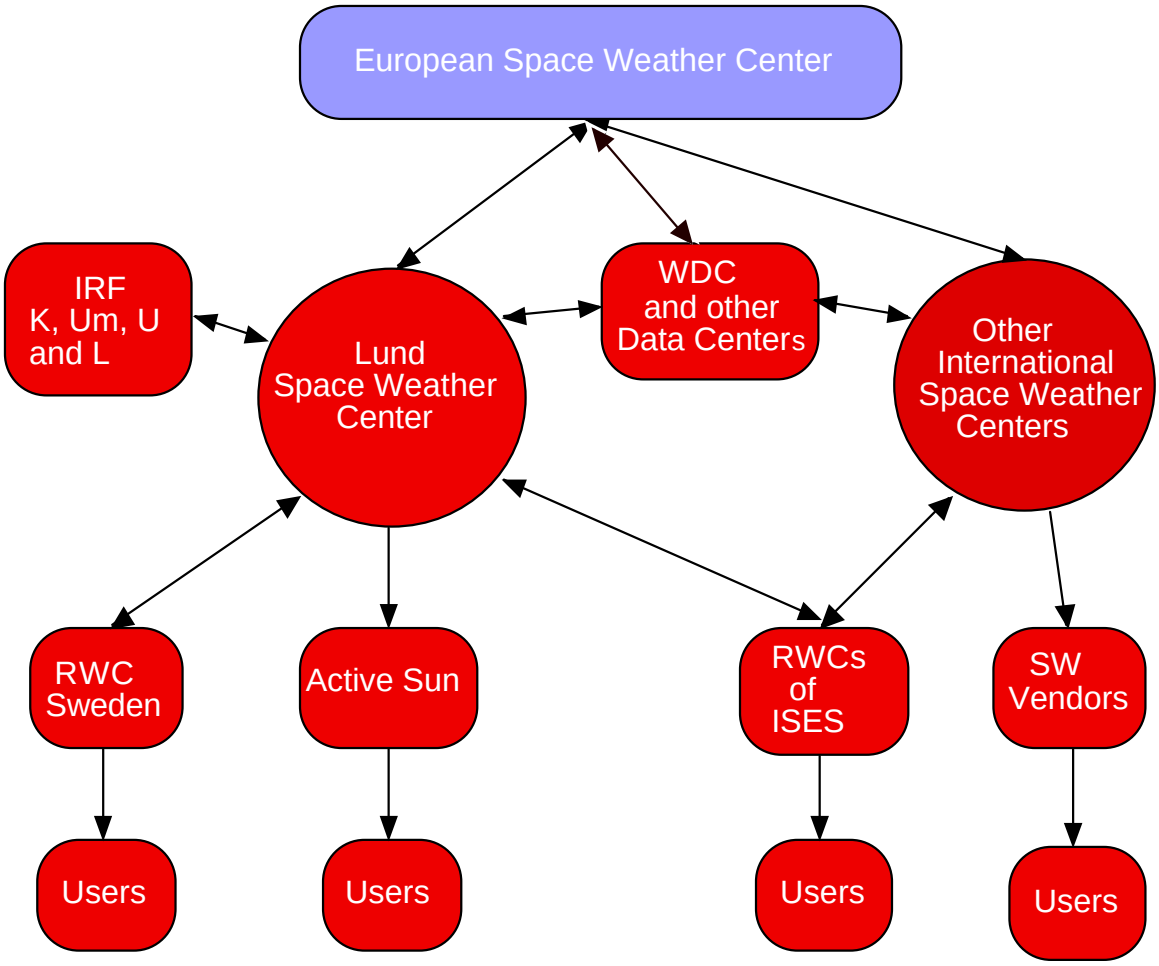

Figure 24 shows embryot of a regional space weather center – Lund Space Weather Center (LSWC). The Center has research divisions (IRF), a regional warning center (RWC-Sweden) and a space weather company associated to it.

Øresund Science Region

Recently also Øresund Science Region has been established consisting of Øresund Environment (Space?), Medicon Valley Academy, IT Øresund IT and Øresund Food.
Øresund Science Region is planned to be the biggest project after the building the bridge. It will be supported by EU (Interreg III).

The Plans of LOIS/LOFAR and a Solar Radar – A New Space Weather Facility

An array of low frequency radio of receiving and emitting antennas is discussed for southern Sweden.. Especially interesting for space weather services is the plans for a solar radar, tracking coronal mass ejections from the Sun. If built, then it will be the only in the whole world. It could be a very important European facility.

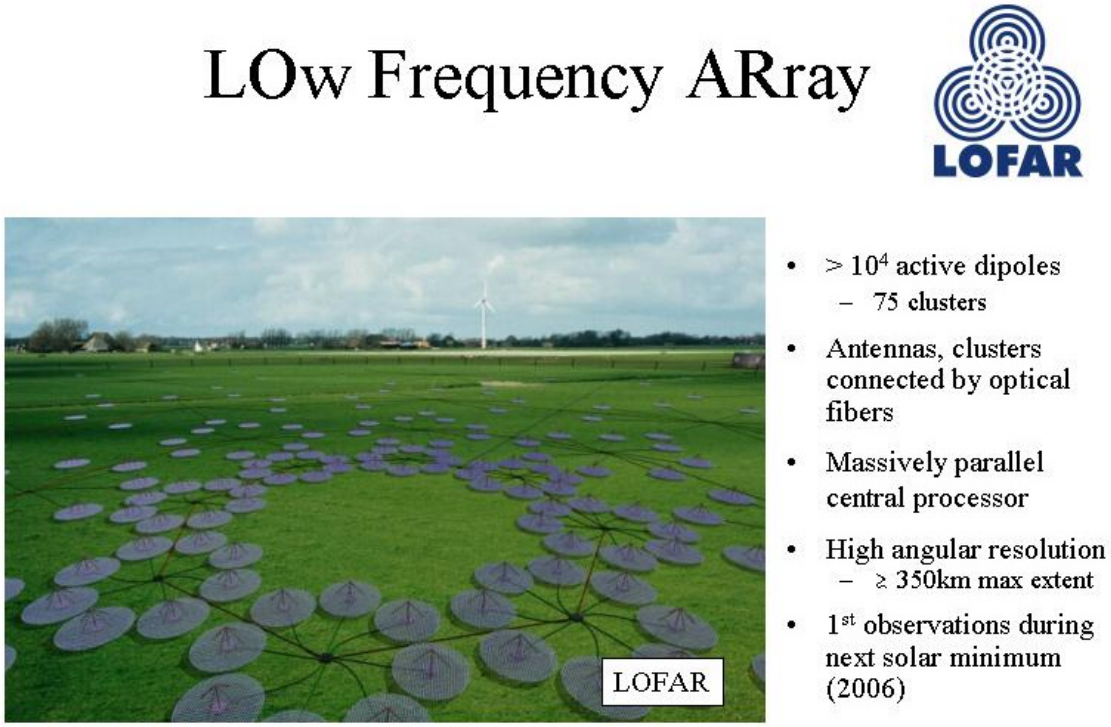

Figure 24. Array of antennas suggested for LOFAR/LOIS.

8. Summary

We have described the organizations collecting space weather data, providing users with, forecasts, nowcasts and post analysis possibilities. Very few of the organizations offer 24 hours a day 7 days a week services and useroriented services. We suggest improvements.
We outline a future European Space Weather Center. A new type of regional interest networks e.g. a Nordic GIC network is also described. Finally, we also suggest establishing a World Space Weather Organization (WSWO) within UN. This organzation would guarantee international access to global data, and solve political problems.

Acknowledgement

I thank the members of the Alcatel consortium who have contributed with ideas and valuable suggestions.

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