UPGRADED GROUND-BASED FACILITIES FOR COORDINATED OBSERVATIONS WITH CLUSTER: OPPORTUNITIES FOR MAGNETOSPHERIC RESEARCH, REVISITED

H.J.Opgenoorth and P. Eglitis

Swedish Institute of Space Physics, Uppsala Division, SE-755 91 Uppsala, Sweden
Telephone +46 18303600, fax +46 18403100, e-mail opg@irfu.se and paul@irfu.se
(H.J.O. also at Finnish Meteorological Institute, Helsinki, Finland)

M.Lockwood

Rutherford Appleton Laboratory, Chilton, Didcot, OX1 1OQX UK
Telephone +44 1235446496, fax +44 1235445848, e-mail m.lockwood@rl.ac.uk

Abstract: ESA's first multi-satellite mission Cluster is unique in its concept of 4 satellites orbiting in controlled formations. At the same time the network of ground-based instrumentation for space physics research has never been so versatile and globally distributed as it was during the later ISTP period and will be for the coming years of the ISTP Solar-Maximum Extension and the Cluster II mission. The SuperDARN network has now reached truely global dimensions with multiple radars in both hemispheres, the EISCAT Svalbard radar is completed with two antennas and doubled transmitter power as compared to the status of 1996, the EISCAT mainland radar will be completely renovated by the summer of 2000, and in Scandinavia and Canada new multi-instrument networks have been established. This optimised combination of space physics instrumentation both in space and on the ground will give an unprecedented opportunity to study structure and dynamics of the magnetosphere, and the coupling to the solar wind and the ionosphere. The status of ground-based instrumentation available for support of the Cluster II mission is briefly reviewed, and the most common data sets are introduced. We will discuss ways in which such ground-based remote-sensing observations of the ionosphere can be used to support the multi-point in-situ satellite measurements. In addition a number of WWW URL's will be given, for immediate access to some of the preliminary ground-based data in a distributed form. In the future these multiple coordinated data sets will be accessible from a central server at the Cluster Ground-Based data centre at the Rutherford Appleton Laboratory, RAL, UK.

1. Introduction

During the 2 days just preceding the ESA Cluster II Workshop on Multiscale/Multipoint Plasma Measurements, on September 20/21, 1999, the extended Working Group for Cluster Ground-Based Coordination held a meeting at the Blackett Laboratory, Imperial College, London UK. The aim of the meeting was to discuss the recent status of ground-based facilities with impact on Cluster II, and in particular spread information within the community about the various upgrades in these facilities since the compilation of the "*Satellite-ground-based Coordination Sourcebook Sourcebook*" [ESA, SP-1198] in 1996, which was produced by the working group for the Cluster I mission. The other main aim of the meeting was to identify and nominate experienced scientists to take responsibility and lead sub-working groups for the global combination and coordination of different instrument types and networks. The meeting was attended by 40 scientists and over 30 presentations were given. In the following a short summary of the meeting will be given but more detailed notes are available on the WWW at
http://kevo.irfu.se/cgb/minutes.html. In the case of a discrepancy between this text and the addresses or information given on the above web-page the latter one is most likely the more correct source of information.

For the future and hopefully by the launch of Cluster II it is planned to compile a more formal update of the improvements of instruments, instrument networks and means and methods of combined data presentations mentioned here as an annex to our ESA publication. In this context we will basically present a concise summary of a presentation made at the ESA Cluster II Workshop for Multiscale/Multipoint Plasma Measurements, highlighting the major news-flashes in ground-based support for the Cluster II mission, and giving information on a number of WWW addresses where more information can be found. As these E-mail addresses will probably change until the launch of Cluster II we will soon provide access to all of this information centrally via our main Ground-Based Data-Centre Homepage at RAL, *http://www.wdc.rl.ac.uk/gbdc/gbdc.html*

2. Update of status for available ground-based data by instrument type and network.

2.1 Magnetometers:

All reports given at our meeting and in addition a number of confirmative letters indicate that all magnetometer networks on Greenland, and in Canada, Scandinavia, US, Russia, China and Antarctica were in good shape for the coming Cluster II mission. It was particularly noted that that all networks had remained in at least the status described in the Ground-Based Satellite Sourcebook. A number of upgrades had been undertaken , and even completely new networks like the one in China

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had been established. The relevant URLs for the momentary status of magnetometer networks are given below.

- For the Greenland arrays (PI's J. Watermann and R.C Clauer) *http://www.dmi.dk/fsweb/projects/wdcc1* and *http://www.sprl.umich.edu/MIST/.*
- For the Canadian Canopus Array (PI J. Samsson) *http://www.dan.sp-agency.ca.*
- For the US MACCS array (PI's J. Hughes and M. Engebretson) *http://space.augsburg.edu.space*
- For the Scandinavian IMAGE (Pi A. Viljanen) which is now the backbone of a new multi instrument array called MIRACLE (see below) *http://sumppu.fmi.fi/image* .
- Additional Scandinavian pulsation magnetometers are operated by the University of Oulu, Finland, contributions: *http://spaceweb.oulu.fi/projects/pulsations.*
- The Russian Arctic stations of the Arctic and Antarctic Research Institute (AARI) in St. Petersburg (PI O. Troshichiev) and a near real time southern hemisphere Polar Cap PC-Index are presented and in more detail described at the URLs *http://www.aari.nw.ru/clgmi/geophys/geophys_2.html*,and *http://www.aari.nw.ru/clgmi/geophys/pc_DATA_2.html*, respectively.
- The Japanese so-called "210-meridian" magnetometer network is maintained and operated by K.Shiokawa , STELab, Nagoya University, and K.Yumoto, Kyushu University. More information and summary data can be found at *http://www.stelab.nagoya-u.ac.jp/ste-www1/proj/project2.html#Software.*
- In Antarctica there are several collaborating arrays (AGONET, PIs M. Candidi, R.C. Clauer, and A. Rodger) which are organised in a central database ADAF (*http://sunserv.ifsi.rm.cnr.it/~adaf*) supported by the Italian National Program for Antarctic Research. A list of all the stations of SCAR nations operating in the Antarctic during Winter 1999 is available at the SCAR webpage *http://www.sprl.umich.edu/MIST/.*
  A new low power magnetometer network is going to be deployed by BAS, at a location conjugate to NE Canada (*http://www.nerc-bas.ac.uk/public/uasd/).*
- In Europe there is one additional subauroral magnetometer array, SAMNET (PI. I. Mann). Full details of SAMNET operations, and access to SAMNET data, are available on the WWW from *http://samsun.york.ac.uk/samnet.html.*
- A new magnetometer network, CHIMAG, has been deployed in China. Data and more details can be found at *http://www-iwfmag.ti-graz.ac.at/chimag.* CHIMAG consists of low latitude ground stations between an L of 1.0 and 1.94, but covering a large range in longitude.
- In addition a report was given on the Intermagnet organisation (Contact person T. Clark). There are 69 observatories and 6 data centres (GINS) which receive 1 minute data from the magnetometer stations within 72 hours. Further information at: *http://www.intermagnet.org*

From amongst the present magnetometer investigators Dr. J. Watermann, DMI was asked to convene and chair a subgroup for the coordination of global magnetometer data. It was particularly noted that the densest northern hemisphere coverage of magnetometers was similar to that of SuperDARN, and the sub-working group accepted the task to work in the direction of a philosophically similar collaboration between the various magnetometer networks, that is, a unified presentation of data and preparation for semi-global data combination. Other subjects for the subgroup to address were the production of :

a) indices: available were PC, AE, and the newly designed Contracted, Standard and Expanded Oval indices at the Ground-based data centre at RAL. A combination of the newly available real time AE index provided by the world-data centre in Kyoto and the Oval indices was recommended. It was furthermore considered possible to utilise Antarctic stations to fill holes in the northern hemisphere instrument coverage. The use of a Pi-2 pulsations index as substorm onset indicator was discussed.

b) summary data: the best and most standard presentation was agreed to be stacked magnetograms in latitude or longitude chains. One should aim at standard presentations and standard baseline and scaling routines for all participating networks.

c) refined data products: Typical magnetometer refined data were presentations of equivalent current vectors, iso-contours maps in spatial or temporal form, and latitudinal electrojet boundaries.

d) contributions to "value added" data combinations: several so-called "value-added" combinations of different data sets were discussed. Most obvious data presentations were global maps, but even upward continuation of the disturbance field observed at ground-level and combinations with radar data (as used in MIRACLE and AMIE) were considered.

2.2. Coherent scatter radar systems:

The Super Dual Auroral Radar network (SuperDARN, PI R. Greenwald) remains in its phase of constant expansion. The total complement of SuperDARN radars is now 6(+3) in the northern hemisphere and 6(+1) in the south. The additions in brackets refer to radars that are being constructed but are not yet deployed. In contrast to magnetometer arrays the SuperDARN radar operation is subject to careful scheduling, which will be particularly important for Cluster II operations. Information and quicklook data relating to the SuperDARN radars can be found at

http://superdarn.jhuapl.edu/ and for the European CUTLASS-radar pair in particular at *http://ion.le.ac.uk/cutlass/cutlass.html*
The scheduling procedure and coordination with CLUSTER was discussed and recommended that similar procedures as for EISCAT and other incoherenc scatter radars should be followed (see below).
Ionospheric Heaters as magnetospheric tools give a new and exciting science opportunity, which was recently put forward by the Leicester group with their plan for Space Plasma Exploration by Active Radar (SPEAR, PI T.Robinson). SPEAR will not just be a Heater but also serve as a magnetospheric radar operating in the 4-6 MHz band. The new geophysical science which could be conducted and the new types of experiments which had already been tested and achieved at the EISCAT Heater included a technique for tagging field lines which had been demonstrated to work successfully with a FAST conjunction. Direct magnetospheric sounding might also be possible, but only if the ionospheric plasma frequency comes down to values below the operating frequencies, which is often the case for Svalbard. It was hoped that the system would be fully operational by April 2003 which might be a bit late for the Cluster mission. However, a number of experiments planned for SPEAR could already be carried out with the EISCAT Heater system.
The **STARE radar** has again become operational as a Finnish/German joint venture since late 1997 (PIs P.Janhunen and E.Nielsen). More information concerning STARE, its range and operating resolutions, and the science potential can be found on the current WWW pages:
http://www.geo.fmi.fi/PLASMA/RADAR/STARE/ and
http://www.mpae.gwdg.de/mpae_projects/STARE/STARE.html
Data from a global network of **Dynasondes, Ionosondes and Digisondes** is now accessible through the world data centre at RAL. Often the more modern techniques utilised by these instruments can effectively complement other radar measurements. The digisonde community now provides summary plots on the web but more work was needed before dynasonde data could be automatically scaled for the production of summary plots.
A subworking group for the coherent scatter radar community was formed in a similar manner as for the magnetometer community, to be convened by M. Lester, University of Leicester. It was agreed that in close collaboration with the incoherent scatter radar community this sub-working gorup should define and prepare radar data indices, summary plots, refined data products and global combination of data. However, in addition to these standard tasks, which were similar to the tasks of the magnetometer sub-group, even the scheduling and determination of suitable combined operational modes, both also with respect to incoherent scatter radar systems, were to be addressed.

2.3. Incoherent scatter radar systems:
Millstone Hill data had been on the web five years before the internet existed. The current database took the form of MADRIGAL, which was probed by SPARC as well as other World Wide Web tools (*http://sparc1.si.umich.edu/sparc/central/page/SPARC Madrigal*, an additional homepage exists at *http://www.eiscat.uit.no/madrigal*). Thanks to MADRIGAL the incoherent scatter data of not only Millstone Hill but even from Söndre-Strömfjord and EISCAT could now be combined with SuperDARN data in real time and form part of their instantaneous global convection model (see discussion below). The complementary nature of incoherent scatter and coherent scatter radar systems was strongly emphasised.
It was confirmed that the **US Incoherent Scatter Radar at Söndre Strömfjord, Greenland** will actively participate in the Cluster II coordination (contact person, J. Kelly, SRI).
Recent improvements of the **EISCAT and ESR radars** included the final installation of the second antenna on Svalbard and two entirely new UHF klystrons at the mainland radar, which will significantly increase the operational capabilities for both radars. Also new experiments have been developed, which utilise just two alternating codes and made detailed measurements over a range extent of 90 to 1100 km possible. It was anticipated that there will be a European mirror of SPARC by the time of CLUSTER. As for the coherent scatter community careful scheduling is requested ahead of any conjunction opportunity. For more details see http://www.eiscat.uit.no.
It was noted that the incoherent scatter radars were very complementary to the coherent radar network, and that many problems, in particular the scheduling procedures, were very closely related. It was proposed for Tony van Eyken (EISCAT HQ) and Mark Lester (with some involvement of Mike Lockwood) to jointly convene an overall radar sub-working group. Radar data indices still had to be defined, but as summary data the standard latitude versus time plots of echo strength and velocity for Coherent Scatter Radars and altitude versus time plots of plasma parameters for Incoherent Scatter Radars were given. SuperDARN vector maps and combined data sets should be discussed. Special areas to be addressed should be the combination of suitable radar modes and time scheduling. In particular it was noted that one should avoid to run special (discretionary) time on any radars when key conjunctions with CLUSTER occurred.

2.4. Optical data:
Imagers in Scandinavia: 5 new digital all sky cameras were now in operation plus one more Italian camera to be included on Svalbard soon. The routine camera mode was one image of the 557.7 nm green line every 20 secs and an image of the 630.0 nm red line every minute. These sampling rates could be changed for campaign operation. Keograms (latitude versus time diagrams of

auroral intensity) are available as first quick-look data on the WWW, *http://sumppu.fmi.fi/MIRACLE/ASC/*, and on the basis of this full data could be obtained by email contact with K.Kauristie. M.Syrjäsuo is developing techniques to automatically digitise the images. Other optical instrumentation include ALIS (contact A.Steen at IRF-Kiruna) and 5 photometers run by K.Kaila, Oulu University (4 in Scandinavia and 1 in Antarctica). ALIS plans to coordinate its campaign type of operations with EISCAT, as concerns Cluster associated operations.

Imagers in Canada: A new network of auroral all-sky imagers NORSTAR (PI E. Donovan) is planned in Canada in close conjunction with the CANOPUS multi-instrument array. The initial plan was for 4 new stations (and 4 more later) to be deployed. Each station comprises an all-sky camera, a photometer and a spectrograph. It would be possible to obtain high resolution maps of the characteristics and flux of auroral particles. The addition of proton aurora detectors will add interesting science opportunities for the studies of the relationship between inner magnetosphere dynamics and variations in diffuse proton aurora.

Imagers on Svalbard: There exist several Meridian Scanning Photometers and All Sky Cameras on Svalbard. Considering that there is a 100 km baseline between the stations at Ny-Alesund and Longyearbyen, tri-angulation of the auroral emission altitude and other advanced analysis methods, e.g., a diagnosis of the three-dimensional structure of aurora by tomographic methods will be possible

Imagers in Antarctica: Four months of complete ionospheric darkness (6 on the ground) in Antarctica will lead to an even better optical season for Cusp auroral observations than on Svalbard, which is the only point in the northern hemisphere admitting observations of dayside aurora. However, this advantage has to be balanced against the poor overlap between stations (due to the size of the continent) and the frequent problems with cloudy conditions. Information about the optical AGONET stations and data products such as keograms can be found at:
http://sprg.ssl.berkeley.edu/atmos/data/. Further to this even detailed South Pole station information exists, courtesy of Prof M. Ejiri, NIPR, at:
http://isch7.nipr.ac.jp/~asi-dp/.

Another new all-sky camera equipped with four interferential filters (430 nm, 560 nm, 630 nm) has been installed at the station Terra Nova Bay by ENEA and CNR-IFSI in the framework of the Italian National Program for Antarctic Research during 1999.

As Convenors of an optical sub-working group E. Donovan, University of Calgary, and J. Moen, UNIS, were proposed. The possibilities for optical networks to produce indices, summaries, refined, and value added data were discussed and in particular an optical activity index was considered to be useful. As summary data standard keograms would easily fit into the context of magnetometer and radar data. Typical refined data-sets were combination of images and determination of precipitation boundaries. The Sub-WG will furthermore address the question whether the large gaps in coverage could be filled with new equipment by the time of the Cluster mission. It was noted that careful campaign planning may become necessary for the short period of winter dayside auroral observations, and that furthermore conjugated measurements in Antarctica and coordinated measurements on the Canadian nightside auroral oval during these periods were important additions to the Svalbard optical Cusp observations. During other occasions coordinated dawn, dusk, and midnight campaigns utilising, respectively, Scandinavian, Greenland and Canadian instruments were another interesting option. Concerning the status of complementary space-craft borne imagers it was concluded that Polar was hopefully operational to 2002, and IMAGE would be launched in Feb 2000. Also the DMSP satellites would contain synoptic map imagers. It was recommended that the optical sub-working group should establish contacts with the satellite imager groups.

2.5. Imaging Riometers in Greenland and Scandinavia:

Three out of some ten imaging riometers in the northern hemisphere are operated by DMI in collaboration with various research institutions worldwide. A comprehensive list, valid for 1995, appeared in the *Satellite Ground-Based Coordination Source Book*, ESA SP-1198. Riometers are suitable to detect energetic particle precipitation by measuring the increase in cosmic noise absorption caused by their ionizing effect on the upper atmosphere. Since energetic charged particles are guided along the geomagnetic field lines, direction-sensitive imaging riometers offer an excellent way of field line tracing. Simultaneous absorption images from conjugate stations and/or satellite measurements of charged particle fluxes will thus allow to test and improve magnetic field models. Imaging riometers have also proven to be very useful for tracking the spatial progression of absorption events, i.e. the spatial progression of bands or filaments of energetic particle precipitation. Three existing northern hemisphere imaging riometers constitute a west-east chain at approximately equal invariant latitude just below 75° (Iqaluit, operated by University of Maryland; Sondre Stromfjord and Longyearbyen operated by DMI), and two others (Tjørnes, operated by the Japanese National Institute of Polar Research, and Danmarkshavn operated by DMI) form a meridian chain. Installation of an imaging riometer at a new site, Constable Point, at the Greenlandic east coast, is being proposed. The location is at the cross point of the above latitudinal and longitudinal chains and would fill the wide gap between the adjacent stations in the region. Field line tracing based on the Tsyganenko 1996 model indicates that the Antarctic imaging riometer at the Chinese Zhongshan station maps, varying with season, local time and solar wind conditions, to a conjugate location somewhere within the triangle, Longyearbyen - Danmarkshavn - Constable Point. With a new installation at Constable Point, extensive conjugate mapping on the basis of absorption pattern recognition and an improved interpolation scheme will be possible.

Contact person for the DMI-operated imaging riometers is Peter Stauning at DMI (pst@dmi.dk) who is also able to provide names of the responsible scientists and points of contact for the other imaging riometers in the northern and southern hemispheres.

It was argued that in particular the imaging riometers had much in common with both radar and optical types of instruments and so a close collaboration with both sub-working groups was recommended. It might be possible to achieve a more quantitative link to the electrodynamics of the ionosphere by a real mapping of high energetic precipition regions into the convection patters derived by the radars.

2.6. Other supporting measurements:

Dedicated rocket campaigns were planned between the US and Norway during the CLUSTER II period. The main agents involved were N. Maynard and R. Pfaff. Proposals are submitted, but no decision would become public until the turn of the year. It was emphasised that any rocket launch would be driven rather by the ionospheric conditions present. A launch decision would not be made on the sole criterion of a CLUSTER conjunction.

A number of **dedicated balloon launches** were planned for 2000-2002. A typical proposed experiment was to launch from N. Scandinavia and/or Svalbard and allow the balloon to drift westward onto to higher L-shells. The balloons would carry small payloads with x-ray, E-field and auroral emission instruments. It was pointed out that the radar networks were important complements for the balloon operations and a balloon trajectory from say the ESR to Söndre Strömfjord could stimulate exciting dividends. It was agreed the balloon experimenters should keep in close touch with the radar working group to optimise trajectory plans and radar operations.

It is expected to have 3-5 **LANL geostationary satellites** (G. Reeves) taking data simultaneously for the duration of the cluster mission. Because of redundancies in tracking the most common number of satellites from which data is available is 4. Currently there is reliable coverage from 3 but at least one more launch is expected between now and Cluster's launch. The addition of a new satellite may return to a situation where there may be a satellite with a footpoint over Scandinavia, if we are lucky. Quicklook data is available from a well organised homepage at *http://leadbelly.lanl.gov*.

Neutral wind measurements are important for the complete understanding of the ionosphere magnetosphere energy budget, as the thermosphere acts as both an energy sink and as a source of energy input into the ionosphere. A large data base of thermospheric neutral wind data now exists. UCL in London (PI. A. Aylward) currently possess two Fabry Perrot Interferometers in Kiruna and one on Svalbard. With other groups there is good coverage throughout northern Scandinavia. New plans were for a spectrograph to be installed on Svalbard in December 1999, which would be able to make subsecond resolution measurements down to scale sizes of the ion-gyroradius with the intention of looking at small scale structure in the aurora. FPIs can achieve a resolution of 1 minute in each pointing direction but the exact resolution depends on the observational mode. More information can be found at
http://cat.apg.ph.ucl.ac.uk

TEC and tomography: The Radio and Space Physics group at The University of Wales, Aberystwyth monitors the Total Electron Content (TEC) at polar latitudes since 1991 using phase coherent signals from the Navy Ionospheric Monitoring System (NIMS), previously the Navy Navigation Satellite System (NNSS). Transmissions from the Global Positioning System (GPS) have been used to estimate the contribution of protonospheric content on ray paths to the U.K.

The measurement of NIMS TEC by several spaced receivers aligned in longitude provides opportunity for tomographic imaging of the ionosphere. Development of this new technique during recent years by the group at Aberystwyth, has lead to a powerful means of imaging space plasma complementary to other techniques. In essence the method measures the TEC along many satellite-to-ground ray paths that intersect at ionospheric heights, with the data set being inverted in a reconstruction algorithm to yield a two-dimensional image of electron density in the region of ray-path intersection. The method is particularly adept at imaging horizontal structures in the plasma on scales of tens to hundreds of kilometres such as ionisation blobs, patches, troughs and boundary gradients. With four receivers deployed by the group at Ny-Ålesund, Longyearbyen, Bjørnøya and Tromsø for routine observations, images can be produced of footprints of key magnetospheric processes.

The Greenland West Coast Ionospheric Tomography Experiment is a collaboration between the Applied Research Laboratories, University of Texas, Austin (ARL:UT) and the Danish Meteorological Institute (DMI). ARL:UT plans to field four NIMS satellite radio receivers at DMI magnetometer sites along the Greenlandic west coast. Qeqertarsuaq (Godhaven), Kangerlussuaq (Sondre Stromfjord), Nuuk (Godthab) and Narsarsuaq have been selected so far, and receiver installation is expected to take place in spring 2000. Future fielding of additional receivers at other DMI magnetometer sites is not excluded, and future modification of the equipment to permit reception of GPS radio signals is also possible.

The satellite radio signals received at the ground stations will be used to construct two-dimensional tomographic images of the ionosphere (electron density as a function of altitude and magnetic latitude). It is expected that a suitable satellite pass occurs approximately once per hour. The Greenland digisondes, and in particular plasma density profiles obtained from the Sondrestrom incoherent scatter radar, can provide means of intercalibrating the results from the tomographic method. The tomographic method is limited by the fact that, for an inversion of measurements from a full satellite pass, an ionosphere has to be assumed which remains stable for some 15-20 min. Contact persons are G. Bust at ARL:UT (gbust@arlut.utexas.edu). and T. Neubert (torsten@dmi.dk) and J. Watermann (jfw@dmi.dk) at DMI.

3. Data refinement and combinations of datasets

A typical example of a refined or "value added" set of ground based data are **SuperDARN Global Convection Maps** developed by M. Ruohoniemi, APL. In the northern hemisphere, line of sight velocity data from the six operational SuperDARN radars are taken and fitted to a grid 1 degree square in latitude and longitude The result is one vector per grid square for each radar; in cases of two or more vectors per grid square, the data is merged. The line-of-sight velocity data is used to constrain the model solution. A convection pattern is produced using a Spherical Harmonic Fitting technique. From comparisons with Millstone Hill data, it was found that the equatorward boundary of coherent scatter corresponds to the equatorward boundary of ionospheric convection, and it is used as a proxy for the Zero Potential Boundary. Each convection pattern has a maximum and a minimum, therefore it is often possible to estimate the cross polar cap potential. Currently the results are quite often model biased, but the method will become more accurate as more radars are added in the Alaska sector. It is possible to combine other data sets like Millstone Hill and EISCAT in real-time, and DMSP after the fact.

Such convection maps are an important science tool as they provide a reasonably good idea of instantaneous global features, however for detailed studies careful comparison with original line of sight velocities is highly recommended. The real time convection maps and cross polar cap potential estimates, however, provide a very valuable quick look monitoring tool. It is also planned to produce convection maps for southern hemisphere radars in a similar fashion.

A new **multi-instrument network MIRACLE** (*Magnetometers, Ionospheric Radars, All-sky Cameras Large Experiment*) has been established in Scandinavia. It was designed to look at scales between those of a point and the field of view of one SuperDARN pair. The concept of MIRACLE is to combine the measurements of three complementary networks of stations, magnetometers, All-Sky cameras and a twin VHF radar experiment into two dimensional maps of ionospheric plasma parameters. The spatial coverage of the MIRACLE network and the four CLUSTER satellites at perigeum, in a string of pearls configuration, matches very well. MIRACLE provides are a number of "value-added" data products which are described in more detail *http://sumppu.fmi.fi/MIRACLE/*

The **Coupled Thermosphere, Ionosphere, Plasmasphere global general circulation model** (CTIP) provides a powerful tool for the understanding of ionospheric and thermospheric dynamics (Contact person George Millward, UCL London). It was considered possible to do special runs at high resolution in conjunction with the SuperDARN convection model.

For the production of **Magnetic Indices** it was decided to start a closer collaboration with the Kyoto WDC realtime AE index for the standard oval index (SO). A lot more stations had been included in the contracted and expanded oval indices (CO and SO) since the last report in the ESA publication. All indices are AL-like indices.

4. Coordination of ground-based multi-instrument data with Cluster

The method for the identifications of conjunctions and constellations and appropriate modifications of the Cluster operations according to the Cluster Master Science Plan (MSP) had not changed very much. It would certainly be useful to have new Orbit Visualisation Tools, as are recently developed by the group at IRF-Uppsala. It was noted that the MSP schedule could only be changed in distinct blocks since there were operational constraints with respect to transmitting data back to the ground station. It was stressed that the ground-based community must agree as a whole before any MSP alteration was proposed. The procedure would be coordinated by the GB PI Hermann Opgenoorth with appropriate consultation of the working group. An E-mail cycle procedure for the planning of such requests and their forwarding to the Cluster SWT will be established.

5. Data management and central database at RAL

The **Cluster Ground Based Data Centre** which can be accessed from the central site: *http://www.wdc.rl.ac.uk/gbdc/gbdc.html* This resource was developed prior to the original CLUSTER I launch, and includes information about ground-based stations, tools for planning experimental operations and scientific data. It will be necessary to update to these pages to the standard and status of 1999, and everybody is invited to visit these pages, check the on-line list of data resources and contributing stations and provide updates. The design of a UK data summary page is suggested to provide the starting point for the design of a future CLUSTER oriented summary page. In essence it will consist of a single interactive URL in which one selects a time interval and instrument types and/or geographical coverage. Consequently the appropriate summary plots from all requested instruments are fetched and plotted in one common summary format. This way the user is provided with a unified overview, but "hits" are still registered on every PI's home computer. It was decided that 24 hour daily plots (00UT –24UT) was a good format for all summary data presentation.

It was furthermore noted that there exists a new **data centre for space physics data in France, CDPP**, *http://cdpp.cesr.fr*, which already offers access to several datasets, and the number will increase signifcantly during the coming months with, in particular, recent INTERBALL and WIND data. In addition to providing data access, CDPP is participating with other centres (RAL, NSSDC, SwRI,...) in a joint effort to promote a Space Physics Search Tool based on a philosophy similar to Astrobrowse, a methodology developed by astronomers with data objects.

6. Summary and Conclusions

In summary we can state that virtually all participating instruments and networks have not only survived, but have been updated, modernised and expanded to some remarkable degree. We are convinced that the ground-based community is now better than ever prepared to meet the challenge of unique science opportunities provided by the Cluster II multi-spacecraft mission.

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Modelling and Data Analysis Tools