UK SPACE WEATHER INITIATIVES

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ABSTRACT

The UK has a very active research programme in solar physics, solar-terrestrial physics (STP) and the space environment, the areas relevant to space weather. In addition, insurance companies and satellite manufacturers are interested in assessing the risks due to space weather. Here we review present UK activities in these areas.

There is substantial UK involvement in space missions, in ground based facilities and in theory. A strong track record with missions including AMPTE, CRRES and SMM has led to the current space mission involvements including SOHO, Yohkoh, Ulysses, Polar and the space shuttle. There are three UK Principal Investigators on Cluster. In ground based research there are involvements in EISCAT and ESR and the UK leads several facilities including Cutlass. In theory and modelling there are important efforts to understand processes on the Sun, in the interplanetary medium, in our magnetosphere, ionosphere and atmosphere. The UK solar-terrestrial physics community recently compiled a plan for activities in the next millennium, which identifies several new initiatives. These include space missions and ground-based facilities designed to advance the science.

In addition, several initiatives are underway to apply the scientific work in the sense of identifying harmful effects of space weather and providing the possibility of forecasting. A number of groups are working in these areas and examples are given.

1. INTRODUCTION – COMMUNITIES INVOLVED

Space weather can broadly be defined as the study of the space plasma and radiation environment. More specifically the term covers the sun-solar wind-Earth system and cosmic radiation with particular reference to the effects on mankind and his space and ground systems. We can consider events on the Sun as the cause and the response of the interplanetary and terrestrial environments as the effect. The cause-effect relationship, the development of forecasting techniques and the study of direct effects on technological systems are all aspects of space weather. In general the cause-effect studies are pursued in universities and research establishments while those concerned with direct effects are end users in industry, space agencies or other organizations. Some UK academic institutes also deal with the direct effects or applications side as we see below.

All of this work constitutes the study of space weather but the actual application to customer needs has only been effected in a few cases. With the increase in the level of electronics integration on satellites, the use of potentially dangerous orbits for commercial systems and the need for academic scientists to justify their work, space weather has become a fashionable and important topic. Work of relevance to this broad definition of space weather spans several UK communities:

1. Solar-terrestrial physics (space and ground-based, theory)
2. Solar physics
3. Research institutes
4. Insurance companies
5. Satellite manufacturers

Of these 1-3 are concerned with the cause-effect relationship and 4 and 5, with a subset of 1-3, are concerned with applications.

In this paper we set out to summarise the UK efforts in space weather. The information presented is likely not to be complete but represents the most visible aspects at present.

2. GROUPS WITH OUTPUT IN SPACE WEATHER

In preparing for this paper an electronic mail request for information, in terms of a summary of involvement and a key result, was sent to the UK communities listed

in 1-3 above. For 4 and 5 we have relied on knowledge from individual contacts as this part of the community is not as well integrated as communities as are 1-3.

Responses from university groups to this email request, with a brief summary of the nature of the work reported, are listed below. In addition, material presented at the ESTEC workshop is shown in **bold** and details appear elsewhere in these proceedings.

Universities:

Aberystwyth (STP studies, **ionospheric tomography, plasmasphere effects on GPS**)
Glasgow (solar studies, neural network sunspot prediction, Geostorm consultancy, IPS)
Imperial College (STP studies, **storm prediction** – with NRL, **Swarm**, atmosphere)
Leicester (STP studies, **Cutlass, SuperDARN ground based radars**, radio propagation)
MSSL-UCL (STP & solar studies, surface and deep dielectric charging, **radiation belt modelling**, acceleration mechanisms, **Swarm**, insurance studies)
QMW (STP studies, **Swarm**)
Sheffield (STP studies, **plasmasphere modelling**)
Southampton (**cosmic rays**, solar proton prediction, F region variability – with Boston)
Sussex (STP studies, particle correlation)
UCL (STP studies, atmosphere and thermosphere)
Warwick (STP studies, sandpile modelling)

Non-university answers to the email request were as follows (material presented here in **bold**):

BAS (ionosphere studies, 'killer' electron acceleration)
BGS (magnetic observatories, Ap prediction, warning service)
DERA (Malvern and Farnborough, predictions of ionosphere foF2 and GEO electrons, internal charging code**, space radiation measurements**)
RAL (Solar, STP & **ground based studies**, STP, WDCC1, SEDAT data facilities)

From these responses it can be seen that there is a wide UK involvement in many areas of space weather research ranging from front-line work in solar and heliospheric physics, magnetospheric physics, ionospheric and atmospheric physics to applications studies. In addition the list includes a possible multi small satellite constellation mission to study the Earth's magnetosphere (Swarm, see Schwartz et al., these proceedings).

We should stress again that the list is not complete but instead represents the responses to a request for information. The responses show that the UK has a strong and broad programme of relevant activities. Funding is from a variety of sources. The first steps are now being taken to improve communication between the different communities involved.

3. AN EXAMPLE - MSSL-UCL ACTIVITIES

As an example of the depth of expertise available in the UK we consider the MSSL-UCL programme in a little more detail. The programme includes scientific research in two of the Laboratory's science groups: space plasma physics (Polar, Interball, CRRES, STRV-1a, Giotto, AMPTE, Cluster-II and Cassini missions) and solar physics (Yohkoh, SOHO, Solar-B missions). In addition, the applications programme covers several areas:

- Instruments were provided for Meteosat-2 (surface charging) and Meteosat-3 (deep dielectric charging). A link between deep dielectric charging and spacecraft anomalies was established using data from Meteosat-3 (Coates et al 1990, Rodgers et al 1991, Wrenn 1995)
- Participation in ESA contracts on spacecraft charging (computer and lab simulations, some with AEA, DERA), radiation belt modelling (with BIRA/IASB and others)
- STRV-1a cold ion detector (in GTO) can also be used as a >750 keV electron detector. Johnstone, Iles & Buehler (1998) show that the acceleration mechanism of these dangerous radiation belt electrons is linked to the solar wind speed but is independent of magnetic storms. This may form the basis for forecasting radiation belt conditions. CRRES work is also important in particle acceleration processes.
- Studies for the insurance industry on space weather effects are starting, via the Benfield-Greig Hazard Research Centre at UCL and the TSUNAMI initiative
- Studies of radiation effects on aircrews are starting; also contact has been made with the electricity supply industry.

We have used the MSSL-UCL programme as an example. As is clear from Section 2, the expertise in the various UK groups is complementary and the sum provides a formidable programme of capability and experience with strong international links.

4. PLANS FOR THE FUTURE

The recently produced UK STP community long-term plan (led by S.J. Schwartz of QMW) identifies a possible roadmap for the UK STP science programme.

This science programme is distinct from, but of relevance to, applications studies. The plan includes:

- Space missions. A phased approach is taken for STP beyond Cluster, Ulysses, Polar and others. This includes several small satellite missions leading ultimately to a Swarm mission. In solar physics instrumentation for Solar-B is already approved by PPARC.

- Ground based facilities

- Theory/modelling initiatives

While the STP plan contains some work with direct relevance to space weather, there is also a separate applications programme in several of the science groups and other groups elsewhere which is completely distinct from this plan. Future work in these applications programmes will include further links with the insurance industry, and ideas for new predictive capabilities.

Future space weather related activities should retain the individual studies but improve community links. The UK is strong in all of the relevant areas but there may be further strength from increased awareness and harmonisation of the activities. However, in a fashionable subject such as space weather we should be cautious to avoid a bandwagon effect. In particular the science and applications studies should be kept separate to protect and distinguish funding in both areas.

In addition, the UK has strong and vital international links in both Europe and the US. The science community, and the applications community, are both international in extent. Nevertheless there is the potential and the need for increased national and regional space weather research.

In conclusion, UK activities span all aspects of the space weather environment from Sun to Earth. The UK has the lead in several of these areas and it is anticipated that this will provide the UK with a key role in any future international programme of space weather studies.