WORLD METEOROLOGICAL ORGANIZATION
_____

COMMISSION FOR BASIC SYSTEMS
COMMISSION FOR AERONAUTICAL METEOROLOGY

INTER-PROGRAMME COORDINATION TEAM ON SPACE WEATHER

FOURTH SESSION

GENEVA, 25-28 NOVEMBER 2013

ICTSW-4/Doc. 10.1(6)
(21.XI. 2013)
_____

ITEM: 10.1

Original: ENGLISH

STRATEGIC PLAN FOR SPACE WEATHER
UK national plans for space weather

(Submitted by David Jackson, Met Office, UK)

Summary and Purpose of Document

UK national plans for space weather are summarised. This helps provide the context for the development of a WMO strategy for space weather (Item 10.4 on ICTSW-4)

ACTION PROPOSED

This document is for information only.

APPENDIX: UK space weather strategy: recommendations

DISCUSSION

1. BACKGROUND

UK National Risk Assessment Space weather discussions started in May 2010 and the Cabinet Office (responsible for Civil Contingencies in the UK) endorsed the Space Environment Impacts Expert Group (SEIEG), which was formed in November 2010. SEIEG provides independent scientific advice, much appreciated by policy-makers. Space weather has been on the UK National Risk Assessment since 2011.

The Met Office 'own' the space weather risk, and are responsible for providing operational space weather alerts and forecasts. Lead government departments are responsible for mitigating the impacts, and co-ordination is provided by the Civil Contingencies Secretariat (CCS) in the Cabinet Office.

Progress since 2011 and gaps

A Royal Academy of Engineering (RAE) Report on "Extreme Space Weather" provided a good evidence base of the potential impact of extreme space weather on the UK. An assessment was made of the impacts of a Carrington-strength event. Major conclusions were:

- Electricity
    - 2 coastal nodes in UK could experience disconnection
- Avionics & ground systems
    - ~1200x risk to avionics; 50x increase in surface radiation
- Satellites
    - ~10% experience temporary outages hours to days – high energy protons
- GNSS – partial or complete loss 1-3 days
- Loss of satellite communications & HF communications
- Radiation risk to aircraft passengers & crew

The Met Office has developed a 24/7 forecasting capability. Further details appear in Section 4. As well as developments in forecasts and research to operations, there is also a need to develop further the process for communicating emerging issues. Examples include:

- National Grid (electricity supply) is building resilience and assurance. How will generators and local suppliers fit into this?
- Knock on impacts of loss of power and GNSS not fully understood.
- Clarity is needed on arrangements for aviation – how will the industry respond and how do we decide it is safe to fly again?
- UK mobile communications looks more resilient than other countries' – but only if power supply continues.
- Uncertain about impact on electronic control systems at ground level.
- Communication with wider resilience community – especially locally – has started. More needed.
- Plans for communication with public in case of an incident needed – public will be concerned.
- All this needs to be co-ordinated with international partners.

2. OVERVIEW OF UK PLANS

Currently, the Met Office and the Cabinet Office are working on a space weather project which seeks to have an overarching plan to formulate how government will respond to sever space weather and its impacts. This plan is intended to also encompass both the Met Office's planning and capability building and the co-ordination of scientific input which is set

out in the UK Space Weather strategy. It also places great emphasis on work with international partners.

The structure of how the various UK organizations will work together appears in Figure 1 and is also summarized as follows:

- Risk identification and Civil Contingency response via Cabinet Office Briefing Room (COBR) and Science Advisory Group for Emergencies (SAGE).
- Met Office interactions (advice, forecasts) with SAGE & COBR
- SEIEG members would provide the basis of the SAGE for space weather
- Met Office is UK operational service provider. It also has plans to transition research to operations in collaboration with UK and international partners.
- Co-ordination of scientific research, and operational applications, is also detailed in the UK Space Weather strategy

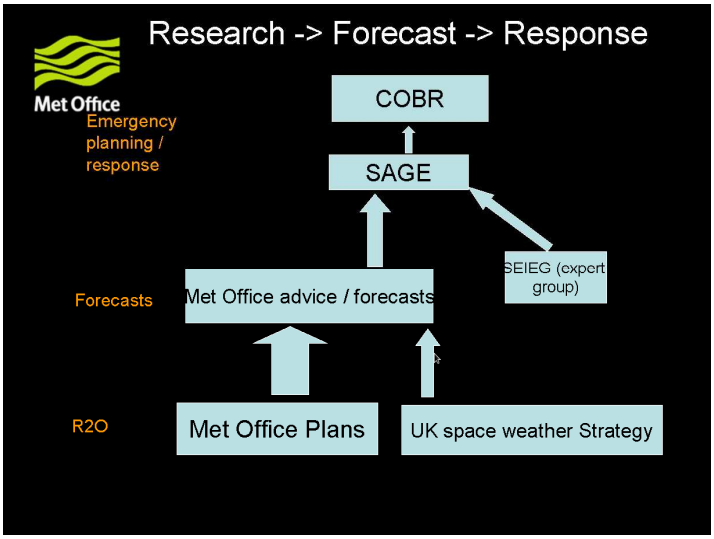

Figure 1. Overview of UK plans for research -> forecast -> emergency response coordination. R2O stands for Research to Operations.

Further details of the constituent parts of this plan (emergency planning / response, forecasts and Research to Operations (R20)) appear in Sections 3-5.

3. EMERGENCY PLANNING / RESPONSE

3.1 COBR

COBR is the crisis response committee that can be set up to coordinate the actions of bodies within the government of the UK in response to instances of national or regional crisis, or during events abroad with major implications for the UK. The constitution of a COBR meeting depends on the nature of the incident but it is usually chaired by the Prime Minister or another senior minister, with other key ministers as appropriate, and representatives of relevant external organizations such as the Association of Chief Police Officers and the Local Government Association. COBR meetings are generally held in one of the Cabinet Office buildings in Whitehall, London. For reference, the equivalent US facility is the White House Situation Room.

3.2 SAGE

SAGE is responsible for the role of science in support of emergency planning and response. SAGE aims to “provide a single authoritative source of science advice to decision makers”, and does this by:

1. Providing advice and explaining the science around the emergency, how the emergency might develop, and explaining key factors that will affect how the situation develops.
2. Pulling science together to improve decision makers' understanding of what's happening – the so what, what might happen etc.
3. Providing advice on scientific and technical solutions.
4. Representing the degree of consensus for the science and explaining any uncertainty to decision makers.

SAGE for Space Weather

Due to the nature of the risk, SAGE would most probably be called before COBR for severe space weather. But if the situation became serious enough, COBR would be convened. SEIEG would be expected to provide the basis of SAGE, and in order to be sure this worked effectively, access to experts would need to be agreed ahead of time.

Other things that need to be discussed and agreed are:

- Trigger points for calling SAGE/COBR
- The alerting procedure..

3.3 SEIEG

SEIEG was formed in November 2010 and provides independent scientific advice, much appreciated by policy-makers. Its first activity was to supply the text for the space weather segment of the NRA, which was developed with a strong emphasis on (peer reviewed) scientific evidence. Now SEIEG is the focus of expert advice into SAGE (as detailed also in Figure 1). One part of its role is as the forum in which the experts can work through differences of opinion and provide an agreed set of advice.

The SEIEG membership includes experts on the impacts side as well as the environment side. There are representatives from the UK academic community and the Met Office and also representatives from organisations such as Public Health England, the Civil Aviation Authority and the National Grid.

4. FORECASTS

The Met Office provides an operational space weather prediction service for the UK via its 24/7 operations centre. Current activities include

- Accessing data & imagery from NOAA & NASA
- Running WSA Enlil operationally (in collaboration with NOAA)
- Providing UK-centric advice and impacts:
    - Geomagnetic observations & alerts working with British Geological Survey (BGS)
    - Daily space weather summaries to UK government and other relevant bodies
    - Enhanced activity during possible major events (eg X class flares & CMEs, May 2013)

Future work in developing Met Office services includes

- Installing more models in collaboration with partners
    - MIDAS ionospheric analyses (Bath University)
    - REFM, D-RAP (NOAA)
- Developing user-focused products for GNSS and other impacts.
- Thermosphere & ionosphere Data Assimilation and use of first principles model (Bath, ATMOP) – in development
- Sunspot recognition and flare prediction assessments

The Met Office approach relies on collaboration with scientific partners, not replication. They collaborate with many UK research institutes and internationally (e.g. NASA; NOAA; WMO & ESA activities)

5. RESEARCH TO OPERATIONS (R2O)

5.1 Met Office Research Plans

The long-term goal of Met Office research is to develop a coupled Sun to Earth modelling system with data assimilation. This will lead to enhanced forecast capacity

Modelling from Sun to Earth: Current R&D Status

Current research (classified by domain) is as follows:
Solar wind – WSA Enlil model is operational, and an ensemble version is in development.

- A solar wind persistence model for benchmarking / validation (Owens et al, 2013, Kohutova et al, 2013) has been developed and will be transitioned to operations soon
- Improved methods of tracking solar wind features (eg Tucker-Hood, Reading University)

Magnetosphere – no first principle models planned to be used, although there are plans to install the REFM for radiation belt forecasts
Ionosphere / neutral atmosphere - Real time regional ionospheric total electron content nowcast for Europe (MIDAS)

- Thermosphere: Data assimilation and ionosphere coupling research.
- Whole atmosphere model plans, aimed at extending the Met Office NWP model up to 600 km.

This is also illustrated in Figure 2.

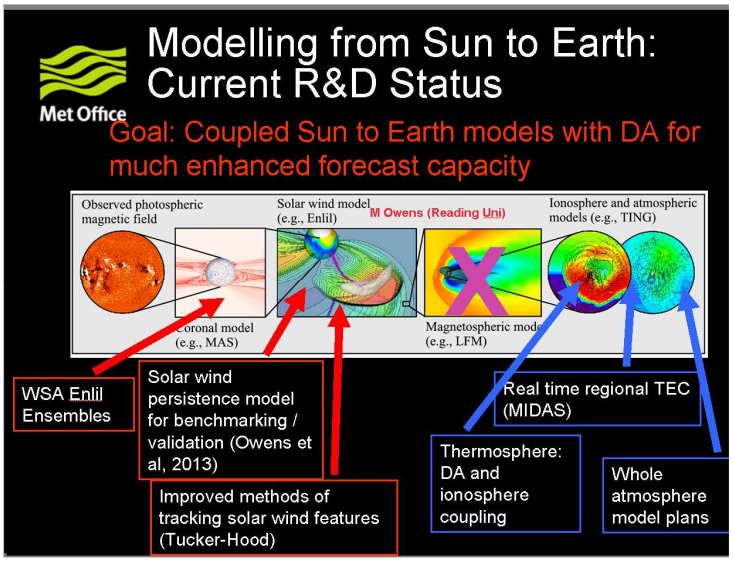

Figure 2. Overview of Met Office modelling from Sun to Earth R&D: current status..

Modelling from Sun to Earth: Future System

Future research (classified by domain) is as follows**:**
Solar wind – Ensemble WSA Enlil-like model operational

- flare and radiation storm models

Magnetosphere –Implement existing (US?) magnetosphere model
- Later – develop UK model.

Ionosphere / neutral atmosphere - Coupled thermosphere / ionosphere data assimilation
- Whole atmosphere NWP model.

All three domains shall be coupled and run in ensemble mode and with data assimilation. There shall also be near real time forecast verification and applications (e.g. GIC models) running off the coupled model output.

This is also illustrated in Figure 3.

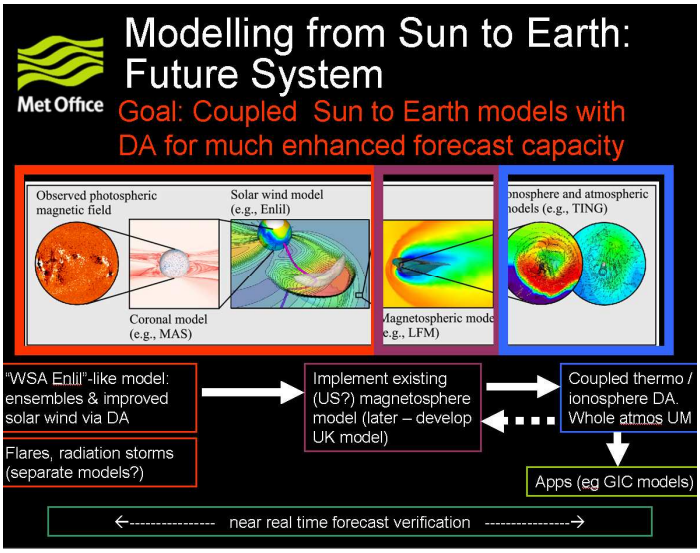

Figure 3. Overview of Met Office modelling from Sun to Earth R&D: future system.

5.2 UK Space Weather Strategy

The UK's strong skills can advance space weather forecasting through a mix of national activities and collaboration with international partners. The global nature of the threat from space weather and the diversity of instrumental, data exchange and modelling facilities needed, makes this an excellent topic for international partnerships.

The UK space weather research community and the Met Office have recently worked together to produce a UK Space Weather Strategy. The strategy has three aims:
- **Provide a cross-organisational framework to support space weather research and operations;**
- **Better link research and development to operations;**
- **Encourage increased collaboration and integration**

The strategy makes four major recommendations:
- **Recommendation 1: Development of, and support for, operational activities**
- **Recommendation 2: Improved technology for space weather mitigation**
- **Recommendation 3: Improved understanding of space weather phenomena**
- **Recommendation 4: Organisation and management**

Details of the recommendations appear in the Appendix. The full Strategy document is available from
http://www.ukssdc.ac.uk/twiki/bin/view/UKUSSpaceWeather/SpaceWeatherstrategy .

UK SPACE WEATHER STRATEGY: RECOMMENDATIONS

Recommendation 1: Development of, and support for, operational activities

Develop and maintain a coordinated programme of UK space weather operations, in conjunction with international partners, to inform operational services and improve fundamental understanding of space weather phenomena. This programme should include:

- Development and maintenance of a 24x7 space weather prediction capability;
- Support for rapid post-event analysis,
- Development and maintenance of a programme of space- and ground-based measurements to underpin these services. This must include development and maintenance of systems for international exchange of space weather data.

Space weather operations should be embedded in wider national activities to mitigate natural hazards. Specific focus should be on:

- Ensure continuing programme of operational, not research-mode, instruments to underpinning operational forecast services;
- Assessment of HPC requirements for operational forecast systems and a plan for ongoing provision of this;
- Data Stewardship: Collaboration with Research and Government agencies on storage of observation and forecast data;
- User requirements: Continued interaction with industry and Government to drive user-focused products and developments.

Recommendation 2: Improved technology for space weather mitigation

The UK should encourage technology developments that improve our ability to mitigate space weather impacts, especially on CNI, including (a) the development of more resilient technologies, and (b) the development of instruments for a long-term programme of operational space weather measurements. Technologies to be studied include:

- Protection of power grids - greater transformer resilience, devices to block quasi-DC currents;
- Improved GNSS - improved receiver design that is more resilient to signal scintillation effects;
- Improved radiation protection and robustness of spacecraft systems;
- Development of operational space-based imaging systems (to observe the Sun, solar wind structures and the aurora; to make in-situ measurements of particles and fields)
- Development of low-cost good-quality ground-based optical, radio and radar sensors for space weather, including deployment of ocean observatories to fill major observing gaps.
- Exploitation of radio astronomy techniques for remote sensing of solar wind conditions.

Recommendation 3: Improved understanding of space weather phenomena

The UK should pursue a coordinated programme of research into space weather phenomena in areas that have clear potential for pull through into operations, including:

- Monitoring and modelling of solar events including the propagation of CMEs and the wider evolution of the solar wind including SIRs between the Sun and the Earth; forecasting their arrival at Earth and the state of their embedded magnetic fields;
- Modelling the generation of high energy particles in solar corona, the solar wind and the magnetosphere and the extent and duration of the resulting SEP events in the Earth system;
- Assessing how solar observations can be applied to improve forecasting of geoeffective CME, SIR and SEP events;
- Monitoring and modelling how the Earth's magnetosphere extracts and focuses energy from CMEs and SIRs to produce adverse environments;
- Monitoring and modelling the global state of the ionosphere-thermosphere system to highlight and ultimately predict disturbances that can impact operations of many vulnerable systems;
- Transitioning research to operations by developing useful products from models of the near-Earth environment;
- Supporting the design of new systems to lower their vulnerability to space weather effects; and
- Understanding the implications of long-term change in solar activity and in the geomagnetic field for all the above research areas ("space climate change"), as well as their implications for long-term changes in climate variability.

Recommendation 4: Organisation and management

A UK Space Weather Strategy Board (SWSB) should be established to provide overall leadership, and where appropriate, governance of UK space weather activities: observations and measurements, operational services, technology and research. SWSB would advise on proposal development and prioritisation, ensure coherency of work, avoid duplication. Space weather activities, where appropriate, should be integrated with wider international activities. To promote long-term sustainability of operations, a key focus should be to maintain and enhance UK involvement in the space weather activities coordinated by organisations such as COPUOS, WMO, ESA. The UK should promote coordination of space weather research through engagement with international member-led organisations such as EGU and relevant bodies in ICSU e.g. IAGA and COSPAR.