Space Weather Services and R&D at the Met Office

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Overview

- UK Space Weather Drivers
- Developing operational space weather services
  - training forecasters
  - developing our own services
  - mirroring SWPC services
- R&D activities
  - Current activities
  - Future plans
- Outlook

UK Space Weather Drivers

- House of Commons Science & Technology Committee evidence session addressed
  - Risk to UK resilience
  - International collaboration
- Expected to become part of UK National Risk Assessment
  - SEIEG has provided an initial realistic worst case scenario
- New UK Space Security Policy
  - Includes natural & deliberate damage
  - Will set future context for space weather?

Why the Met Office should be involved in Space Weather Services

- Resilient, reliable 24/7 operational service delivery (terrestrial weather forecasts)
- Can contribute relevant observations, eg:
  - Ground GPS over UK
  - Download stations for COSMIC GPSRO (reduce latency)
  - ATDNet lightning (D-region height)
- Experience in observation reception, QC, monotoring
- Applicable R&D experience (see also later): data assimilation, physical models.

Training Forecasters

- We have developed a “Space Weather Primer”: 2 hr overview of space weather science, impacts and products
  - Presented to RN and RAF personnel (since 2006)
  - Presented to MetO Defence-facing staff (more recently)
  - Now extended to All Hazards forecasters
- Met Office staff have visited SWPC – knowledge exchange and awareness of “best practice”
- Training programme started March 2011 and running through to end of 2011.

Developing our own services

- Receiving Space Weather data and alerts from eg SWPC, BGS
- All Hazards Guidance (see below) – includes space weather alerts
- Further development of own services will come as forecaster training nears completion
- Possible further development include:
  - Validation and tuning of existing products over Europe using own and partners' data: eg using ATDNet lightning data to infer details of D-region
  - Using European ionospheric nowcasts from MIDAS (Bath University) in our operations centre.

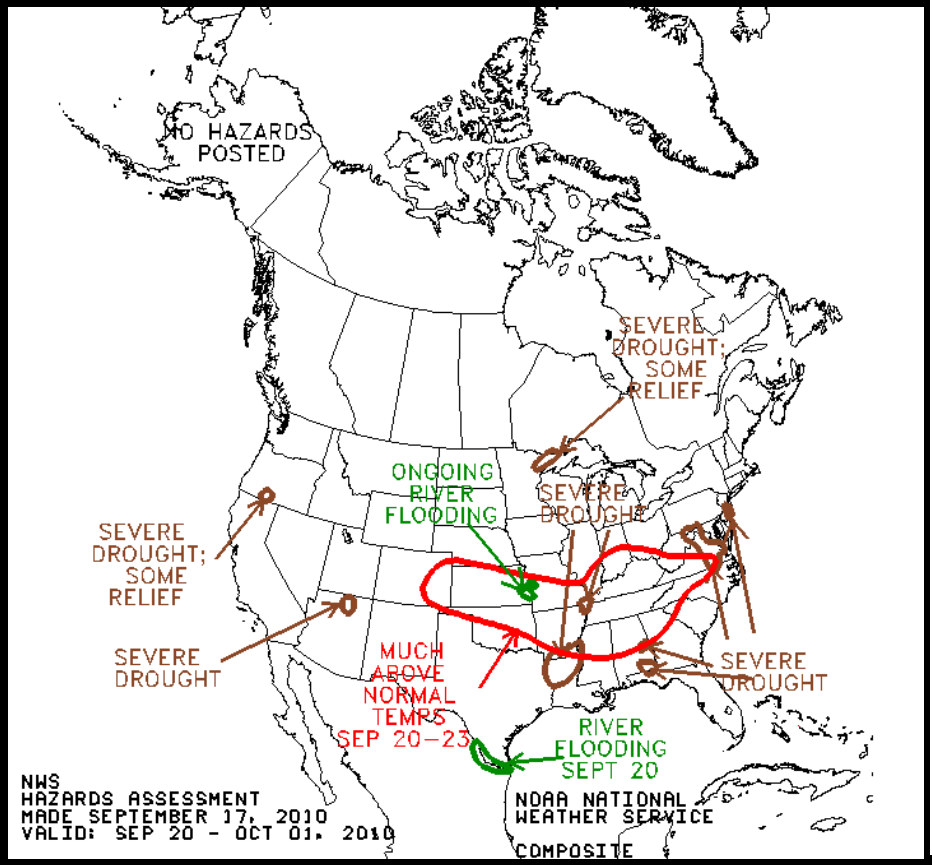
All Hazards Guidance

- In an increasingly interconnected and interdependent world, the list of potential sources of disruption to organisations is long, eg:
  - Severe weather – storms, flooding, or extremes of temperature;
  - Disease – such as pandemic flu or foot & mouth;
- The Met Office is developing an All Hazards facility, in partnership with other agencies.
- Initial impetus was flood forecasting, but Space Weather alerts shall be included as well

Geomagnetic storm service

- Will form part of the multi-hazard summary pdf
- Issued daily – but an update will be issued when a geomagnetic storm is detected by the ACE satellite
- Multi-hazard pdf will be issued to hazard task group members and may also be trialled with National Grid
- Issued in consultation with BGS

All hazards guidance service for Europe?



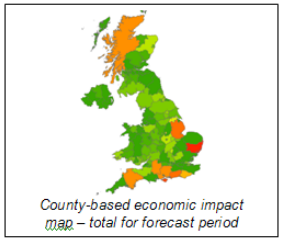
HAZARD CENTRE ASSESSMENT

Alert level 2

This Hazards Assessment is intended to provide emergency managers, planners, forecasters and the public advance notice of potential hazards related to space, climate, weather, hydro-meteorological, geological and man-made events. It integrates existing FFC, Scottish FFC, NSSWS and EA official warnings and forecasts, (6-10 day) and long-range (monthly and seasonal) forecasts and outlooks, and BGS and space analyses and forecasts, which use state-of-the-art science and technology in their formulation.

Synopsis to 12th November 2010

Power and transport networks likely to be affected in SE England tonight as flood and wind disrupts power lines and leave roads and rail routes impassable. Katla volcano remains active and could erupt in the next few days; resulting ash cloud avoiding UK airspace. Power supply returning to normal levels this morning as geomagnetic storm levels subside.



County-based economic impact map – total for forecast period

Hazards

- ***Flooding***. Surface water flooding likely to affect parts of Norfolk, Suffolk, Essex and Kent with a coastal surge event increasing flooding risk in coastal Essex and Kent tonight. Dover port and major routes in and out of the port likely to be affected. See latest EA flood warnings
- ***Wind***. Power cuts likely to affect Kent as wind gusts exceed danger threshold levels 2. High sided vehicles at risk of over topping due to cross wind expose on M20.
- ***Landslides***. Disruption to road and rail possible in Kent, especially on A312 near Margate.
- ***Drought.*** On-going drought in NW England. Some relief likely in the coming days as Met Office predicts a further 30-70mm rainfall in the next 5 days.
- ***Volcanic.*** Winds forecast westerly leading to ash cloud dispersion east of Katla. Major eruption could trigger a minor tsunami.
- ***Geomagnetic storm*** began at 05:55 AM UTC. Space weather storm levels reached Strong (G3) levels on the Geomagnetic Storms Space Weather Scale. The source of the storming is an Earth-directed Coronal Mass Ejection associated with a weak solar flare that occurred in Active Region. This is expected to be an isolated storm that should subside quickly. Electric power systems, spacecraft operations, high-frequency communications, GPS, and other navigation systems may be affected.

Mirroring SWPC Services

- Reason – Adds resilience to space weather services supplied by SWPC
- Step in this process
  - Agreed Met Office access to E-SWDS (done)
  - Building infrastructure (now – Nov 2011)
  - Deliver services (eg on Website) – Dec 2011

R & D

How can the Met Office meet Space Weather R&D challenges?

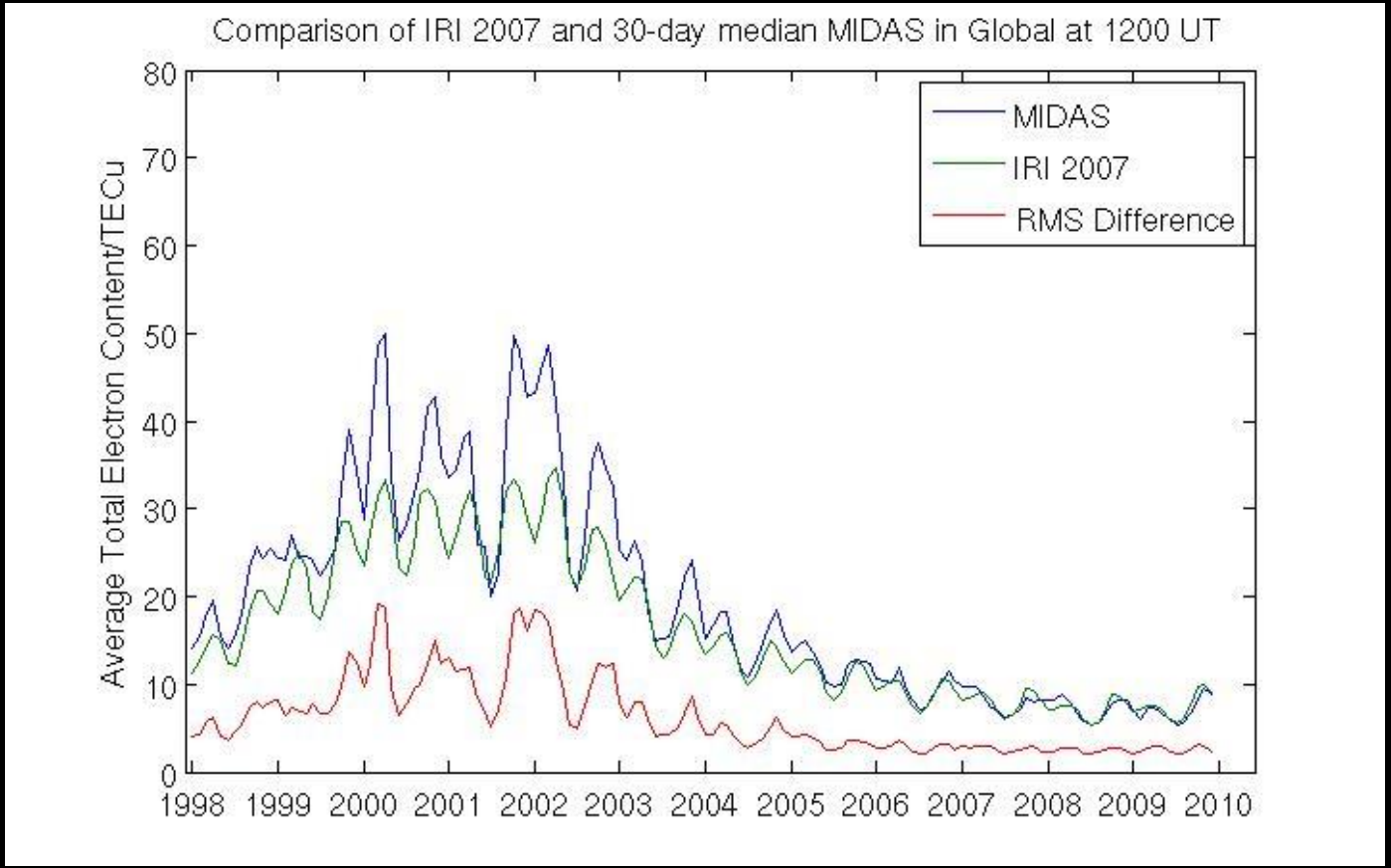
- Data Assimilation
  - (now) contributes strongly to improved ionospheric nowcasting and predictability
  - (later) essential for the benefits of a coupled modelling system to be realised
- Lower atmosphere modelling expertise – development of surface to thermosphere / ionosphere models
- Apply operational NWP experience to space weather (eg verification)
- Aim is to complement, not supplant, existing UK and international knowledge.

Met Office Space Weather Research activities - current

- "first generation": developing an ionospheric analysis system based on an empirical model (MIDAS; Bath University) – build infrastructure, ionospheric nowcasts, independent assessments (current / near future)
- "second generation": develop DA for thermosphere / ionosphere forecast / analysis system based on a physical model (EU ATMOP project) – uses infrastructure from above, better ionospheric forecasts (at least for quiet periods) (~5 years)

“First generation”

Comparison of MIDAS and IRI2007 TEC



- Global monthly median MIDAS and IRI TEC: 1998-2010

Chartier, Mitchell and Jackson (in preparation)

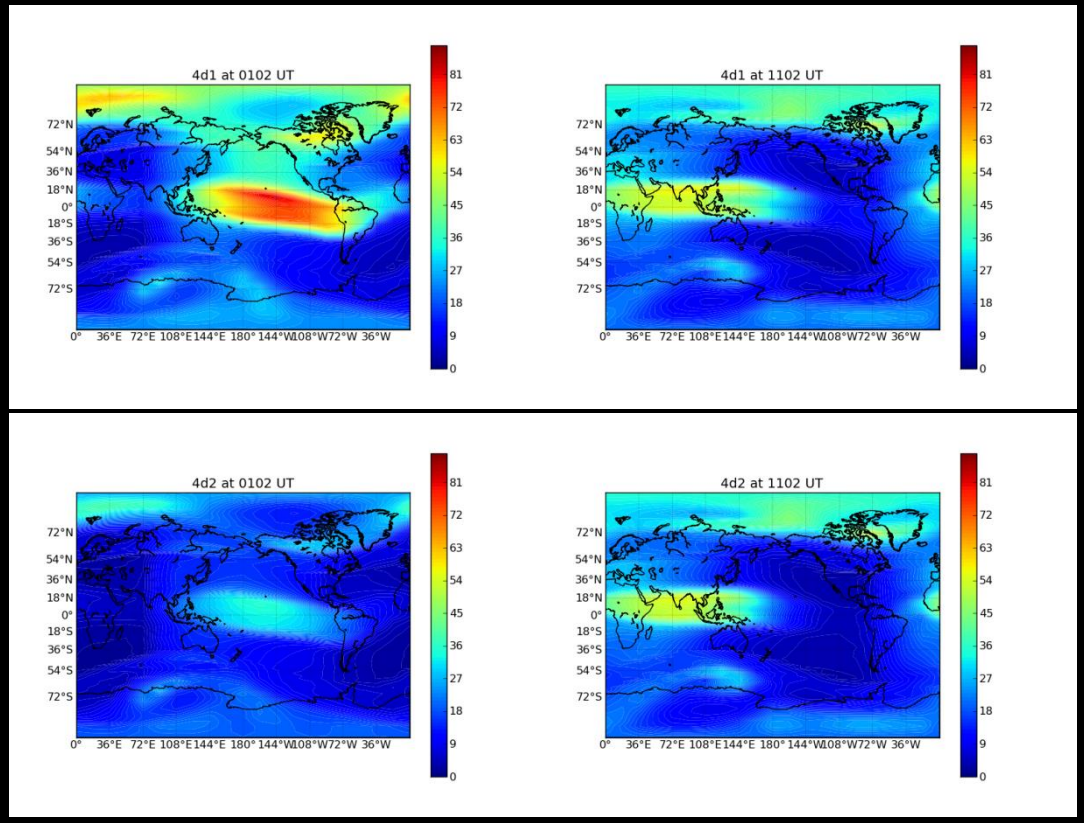
“Second generation”

Design of thermosphere / ionosphere DA system

- Uses CMAT2 (UCL) model (but assimilation code will be flexible enough to run with any model)
- Observations
  - Thermosphere: accelerometer inferred densities (GOCE, GRACE, CHAMP); Mean (TLE, radar) densities
  - Ionosphere: Ground GPS, GPSRO
- Assimilation cycles:
  - rapid (15-30 mins) for available ionosphere data
  - every 6 hrs for thermosphere – utilise thermosphere / ionosphere correlations so that better observed ionosphere can constrain thermosphere

Second generation – ionosphere/thermosphere linkages

- CMAT2 model simulations with same (different) initial thermospheres (ionospheres)
- Ionospheres didn't converge again until after ~9 hrs (Shunk & Sojka, 1987)
- But thermospheres in both runs hardly affected (at least below ~450 km)
- Reasonable to omit iono/thermo cross-correlation in 15/30 min update



Future Met Office Space Weather Research activities

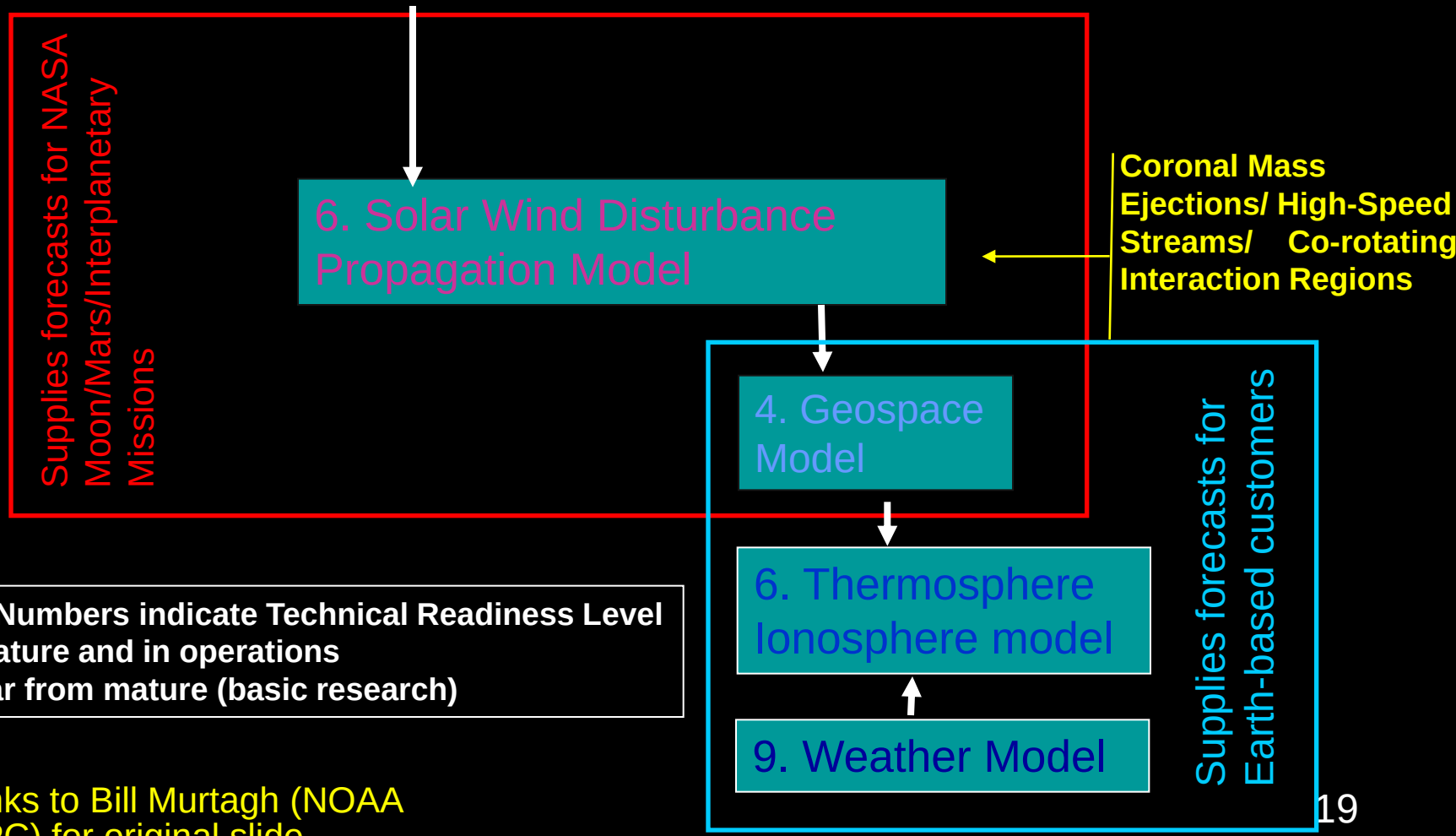
- "Sun to Mud": coupled solar – surface models plus coupled DA (in collaboration with NOAA and/or UK). Possibility of forecast capability up to ~ 5 days. (>5 years)

Motivation for a coupled system

Storm Type	Current Predictive Capability	Potential for future improvement
Geomag.	Good – obs + iono. nowcast	Good - Coupled models (solar wind (quite mature) / geospace – surface)
SEP events	Fair – obs + iono. nowcast	(less) Good - Coupled models (energetic particle transport model (immature) / geospace – surface)
Radio blackouts	Poor	Fair- Coupled models (solar irradiance prediction model (immature) / geospace – surface)

Clear that a coupled system can improve predictive capabity

"Sun to Mud" Space Weather Prediction System:



Note: Numbers indicate Technical Readiness Level
9 = Mature and in operations
1 = Far from mature (basic research)

Thanks to Bill Murtagh (NOAA SWPC) for original slide

Challenges and Opportunities

- Lots of resources needed – even for just the surface to iono/thermosphere part
- Do we go for “quick wins” (bolt together existing models) or next generation state of the art?
- DA is a challenge in the ionosphere, but more so in (any) coupled system
- A large and important project like this can help collaborative partnerships develop (and, we hope, be attractive to funding agencies)

Outlook

- Met Office is well set up to contribute a lot to Space Weather services and R&D
- Met Office Space Weather services (with associated training) in development
- Associated R&D programme shall lead to pullthrough of improved services and operational forecasts
- Large challenges call for interdisciplinary collaborations which utilise the skills of partners to maximum effect

Questions and answers