Australian Bureau of Meteorology
Space Weather Services:
Recent Initiatives


SWPC Space Weather Workshop
28 April 2016
Australian Bureau of Meteorology
Space Weather Services
www.sws.bom.gov.au

- 2008 Renamed "Space Weather Services" (SWS) section within Bureau of Meteorology **Hazards Prediction Branch**.
- Contact details changed office@ips.gov.au → sws_office@bom.gov.au

- **Australian Space Forecast Centre** (ASFC) team consists of
  - 4 Senior Space Weather Forecasters (SSWF's).
  - 7 Space Weather Forecasters (SWF's)
  - Weekly rotation cycle
- Move to 24/7 forecast centre coverage for significant events.
1. **Overview of Space Weather Services**
   - Space Weather Network
   - Online Services

2. **National Positioning Infrastructure Project**

3. **Ionospheric Modelling and Forecasting**
   - Data Driven Models

4. **Solar and Geophysical Forecasting tools**
   - Solar Forecast Tools
   - Severe Space Weather Model

5. **Recent engagement with …**
   - Critical Infrastructure Groups & Aviation.
   - Key Stakeholders/Industry/General Public
1. SWS Overview: Space Weather Network Sensors and Locations
1. SWS overview: Online Products and Services

You can subscribe to SWS reports & alerts delivered by email. Some alerts can also be delivered by SMS.

Solar Conditions
- Solar Wind Speed
- X-Ray Flux
- X-Ray Flares
- Latest Culgoora Spectrograph
- Latest Culgoora H-Alpha Image

Geophysical Conditions
- Geomagnetic Warning
- GEOSTAT Alert
- Geomagnetic Alert
- Aurora Alert
- K-Index
- pc3-Index
- AusDSt-Index
- GIC-Index

HF Propagation Conditions
- HF Comms Warning
- Current HF Fadeout
- HF Fadeout Warning
- Polar Cap Absorption

Ionospheric Conditions
- Australasia
- World

TEC Conditions
- Australasia
- World

Note: Information on this page is updated frequently. To refresh the page, hold down the “SHIFT” key and click the “Refresh” or “Reload” button on your browser to refresh this page to obtain latest data.
2.1 Ionospheric modelling to support the National Positioning Infrastructure

• 2.5 year research project with collaboration between
  – Bureau of Meteorology's Space Weather Services
  – Cooperative Research Centre for Spatial Information (CRCSI)

• Aims to deliver a highly accurate real time ionospheric model to support the operational implementation of PPP-RTK (Precise Point Positioning Real-Time Kinematic) for the National Positioning Infrastructure.
2. National Positioning Infrastructure

"Instantaneous, reliable and fit-for-purpose access to positioning and timing information anytime and anywhere across the Australian landscape and its maritime jurisdictions"
2. NPI: Multi-GNSS compatible.

- Australia one of few countries that will receive positioning signals from six systems.
  - GPS - USA
  - Beidou - China
  - Galileo - Europe
  - QZSS - Japan
  - IRNSS - India
  - GLONASS – Russia
- Multi GNSS = Faster PPP convergence

Visible GNSS satellites across the globe by 2020.
Copyright (c) 2009 Japan Aerospace Exploration Agency
2. National Positioning Infrastructure project

- CORS (Continuously Operating Reference Station) networks operated independently on an ad-hoc basis by state governments and industry
  - However, an Australia wide CORS network (@70km spacing) would be too expensive.

- PPP-RTK provides standard PPP users with additional information (ionosphere, ephemeris data, clock offset) derived from a reference network, enabling high accuracy & low convergence times.
  - Bottleneck though is with the accuracy with which ionospheric corrections must be provided to the user.

- Success of the PPP-RTK implementation for the NPI requires a significant improvement in ionospheric modelling accuracy over existing capability
  - precise sub-TECU ionospheric corrections required to enable rapid ambiguity resolution to achieve positioning at the level of a few cm.
2. Ionospheric Modelling challenges for the Australian region.

**Low latitudes**
- Equatorial Plasma Bubbles (EPB)
- Large spatial gradients
- Ionospheric Scintillation

**Mid latitudes**
- Storm-Enhanced Density (SED)
- Medium Scale Travelling Ionospheric Disturbances (MSTID)

**High latitudes**
- Storm-Enhanced (Sub-Auroral) gradients
3. Data Driven Ionospheric Modelling

• **Model types**
  – Regressions
  – Neural networks
  – Decision trees

• **Data requirements.**
  – Training / test data covers long time period (> 1 solar Cycle).
  – All model parameters required at each time point (all or none).
  – Operational data consistent with training data.

• **Benefits**
  - Simpler to develop & implement.
  - Exploits considerable archive of space weather data.

• **Limitations**
  - Availability of relevant and suitable data for training / real time operation.
  - Trend towards climatology in poorly specified models.
3. Quiet-Time $f_0$F2 model and Short Range Forecasting

- Motivation: Improvement in short term HF forecasting for the local Australian region.
- Study of data gathered from 50 years of $f_0$F2 observations.
  - Result: Model of non storm-time ionospheric support.
  - Support daily operations: 3 day T-Index forecast.

Further analysis into…
- Storm time behaviour and underlying trends.
- Cause and trends seen in this variability.
3. Regional Specific Forecasting and TEC/\(f_0F2\)

**Spherical Cap Harmonic Analysis (SCHA)**

- Modeling the Australian region
  - Top-side TEC mapping
  - Bottom-side ionospheric sounder model (Vertical and Oblique ionograms)

- **TEC/\(f_0F2\) forecast model**
  - Combined use of the Principal Component Analysis (PCA) and artificial Neural Network (NN) for topside ionospheric model.
  - Utilise Neural networks due to the non-linearity of the ionosphere.

- Tools used to assist with daily forecasts and nowcasts in the ASFC...
  - Enlil (SWPC)
  - Flarecast Model (SWS)
  - Flare Probability Model (SWS)
  - Severe Space Weather model (SWS)

- **Enlil**
  - Low resolution simulations of ambient solar wind conditions.
  - CME modelling via parameters obtained from CAT tool.
  - Simulation times ~1hr (8 core Linux workstation).
4. Forecasting Tools: Flarecast

- Automated solar flare forecast based on region characteristics
- Deterministic model: uses Solar Dynamic Observatory (SDO) or GONG HMI solar magnetograms and image processing to automatically identify active regions.
- Output is generated in near real-time as new input data becomes available.
- Many different parameters of the active region and the neutral lines are estimated.
- Estimates capability of a region to produce M, M5+ or X-class solar flares.
4. Forecasting Tools: Flare Probability Model

Statistical Model: to estimate the probability over the next 24 hours of an X-ray solar flare $\geq M1(\geq X1)$ in magnitude (peak flux)

Model selection is based on data availability, using all or a subset of these region characteristics:

- Location
- Classification
- Area / areal growth rate
- Number of spots
- Magnetic complexity
- Magnetic characteristics (length of neutral line, maximum N-S magnetic gradient, ++)
- Recent flaring history
4. Forecasting Tools: Severe Space Weather (SSW) Model

- Operational GUI used within the ASFC.
- General linear statistical model as a back-end, providing both binary and probabilistic forecasts for SSW.

Inputs include...

- Location of active region on solar disk
- X-ray flare magnitude/duration
- Presence of halo CME (CME width)
- CME speed
- Prediction of $D_{st} < -250nT$
5. Critical Infrastructure Groups: Severe Space Weather events

- Australian Energy Market Operator (AEMO) manages both wholesale and retail markets in electricity and gas across all of Australia (one of few worldwide)
- In-situ sensors for GICs (observed in both power grids and pipelines)
- SWS has implemented Severe Space Weather Warnings as an integral part of mitigating procedures for power networks
  - Development of the GIC-index, to quantify periods of GIC activity
  - Modelling the power grid response to space weather storms is intended to form part of the mitigating procedures and is a work in progress
5. Aviation Space Weather strategy

To enable space weather products produced by the Bureau to be more specific and relevant to the aviation industry

- Aviation focussed user workshop planned for the second half of 2016
- Focus on
  - Working with the aviation industry to tailor current products & services (impact focussed)
  - Identify un-met aviation user needs.
  - Determine need for specific space weather products through a common portal with Bureau’s Aviation Weather Services.
- Short term: Space weather training for aviation meteorologists
- Longer term: Develop products and services addressing user requirements identified in consultations
5. Recent Customer Engagement

- 2014: Review of Space Weather Services
- Positive recommendations from reviewers, review committee and small number of key stakeholders.
- Interaction with over 100 stakeholders + members of the general public.
- January 2016: customer survey distributed through via email, feedback was received from over 700 customers.
Thank you…

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Extra info/graphics on NPI (spare)
Data driven Ionospheric Modelling

- Trialing use of both Vertical and Oblique ionograms
- 7 Vertical Incidence Sounders (VIS) on the Australian mainland, 7 Oblique paths.
- Data fed into ionospheric SCHA model
  - Increased spatial resolution of real time ionospheric maps.
  - Observation of MSTID's.