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Recent Space Weather Activities in Australia

Richard Marshall

Space Weather Services

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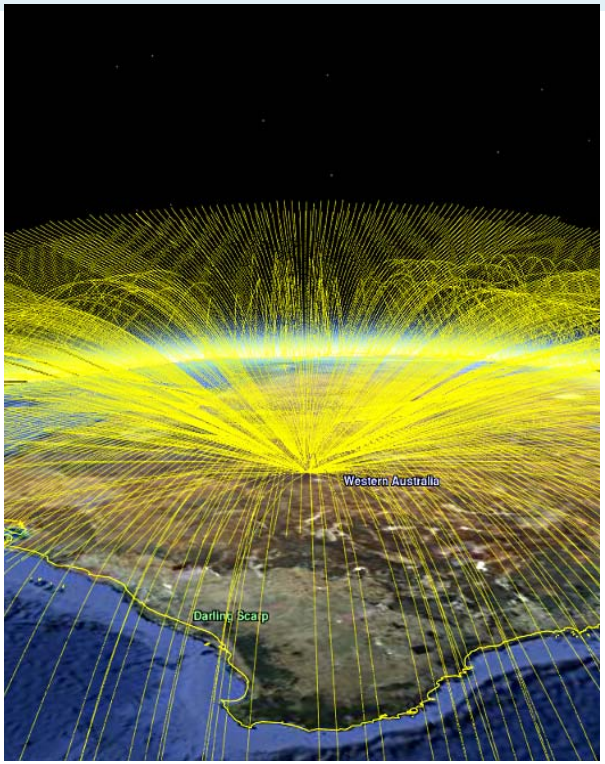

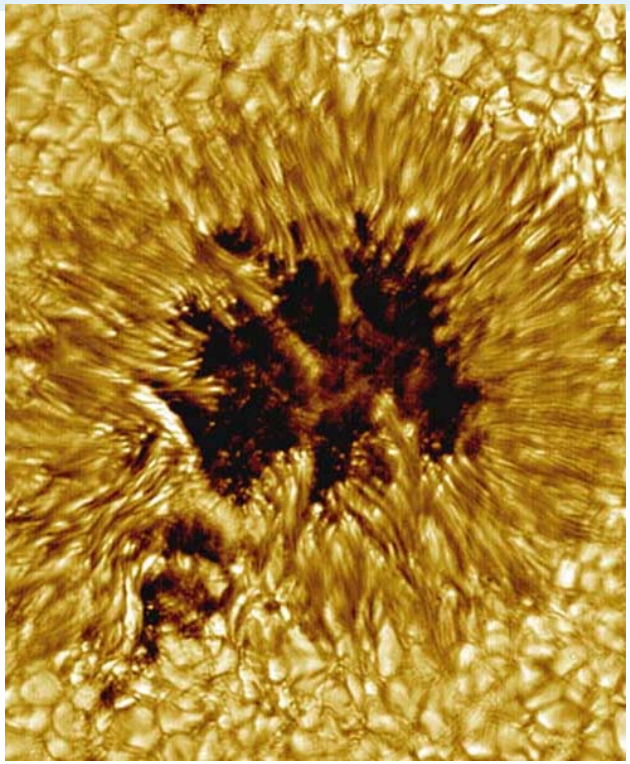

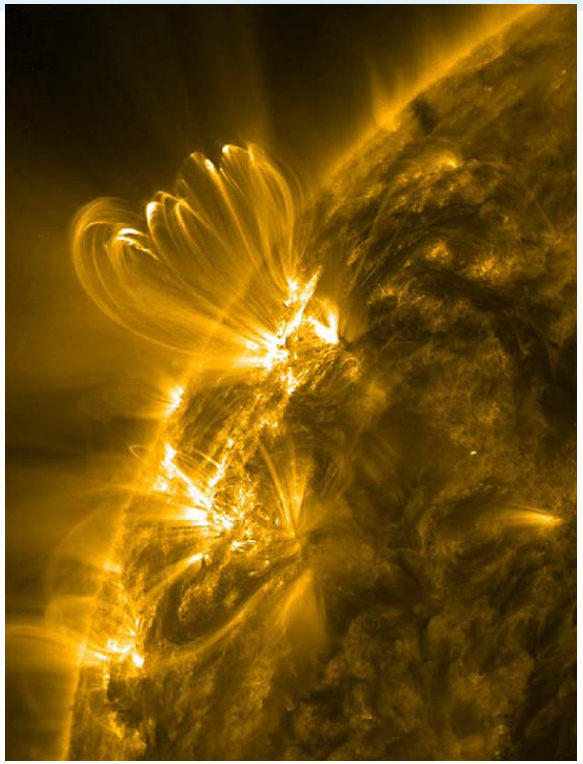

Image courtesy of NASA

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Outline

- Brief History of the Bureau's Space Weather Services
- Space Weather Services Review
- Space Weather Services Inaugural Users Workshop
- Space Weather Users Surveys/Feedback
- Interactions with Government
- Current Space Weather Research Projects

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Our History

- The Ionospheric Prediction Service (IPS) providing HF Radio services and support since late 1940's
- IPS Radio and Space Services since late 1990's when commenced providing additional Space Weather services and support
- Joined Australian Bureau of Meteorology (BOM) in 2007 – still integrating
- BOM Realignment 1 July 2014 – IPS divided entity first time since inception into SWS and SWN
- Munro Review of terrestrial severe weather services (Option 20) triggered SWS review
- Official name change to Space Weather Services 2015 (http://www.sws.bom.gov.au)

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Space Weather Services Review

Space Weather Services Review

- A Review of the Bureau of Meteorology's extreme weather and seasonal forecasting capacity proposed a number of options for obtaining funding for additional terrestrial weather forecasters
- Option 20: 'Cease or reduce the Ionospheric Prediction Service (IPS), or offer it as a commercial service.'
- Government response was to review of the Bureau of Meteorology Space Weather Services (IPS). The reviewers, Professor Paul Cannon and Dr Terry Onsager, provided a comprehensive report including 42 recommendations.

Management response

Overall, the Bureau supports the findings and recommendations of the review and is of the view that their implementation will:

- considerably strengthen the efficiency, effectiveness and productivity of the SWS;
- reinforcing the positioning of the SWS as a core function delivered through the Bureau's Hazards, Warning and Forecasts Division; and
- ensure improved awareness and preparedness by government in relation to the hazard potential and risks posed by space weather events and steps to assist in mitigating their impact.

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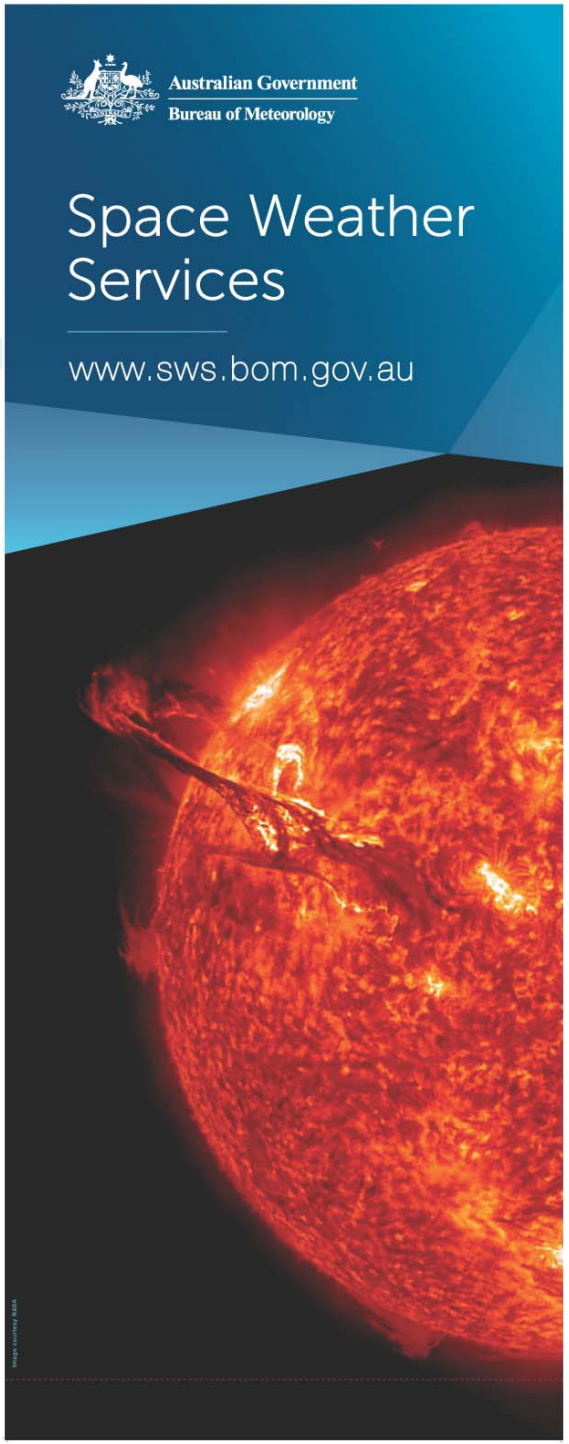
Inaugural SW Users Workshop

- Recommendation of SW Review
- Promotional and educational activity with major stakeholders, customers and the Bureau management
- 120 Participants including general public and a good cross section from industry - power and pipeline corrosion engineers, major Australian airlines, Defence, aurora enthusiasts, government sector, satellite operators, GNSS, and transport
- Plenary sessions and parallel focus groups
- Opportunity to launch re-branding
- Very positive feedback from participants and suggestions for service improvements



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SW Workshop Programme

Time	Session	Presenter
08:30 - 09:00	Tea, Coffee and Cakes	
09:00 - 09:15	Welcome	Bureau of Meteorology
09:15 - 09:20	Housekeeping	MC
09:20 - 09:50	An Introduction to Space Weather	**Colin Waters** Centre for Space Physics Research, University of Newcastle
09:50 - 10:10	Observing Space Weather	**Terry Stiles** National Operations Manager, Bureau of Meteorology
10:10 - 10:30	The Bureau's Space Weather Services	**Colin Yuile** Manager Space Weather Services, Bureau of Meteorology
10:30 - 11:00	Morning Tea	
11:00 - 12:30	HF & VHF Part I	Chair: **Murray Parkinson**, Space Weather Services
11:00 - 12:30	Aerospace Part I – GNSS Positioning, Navigation and Timing	Chair: **Mike Terkildsen**, Space Weather Services
11:00 - 12:30	Power Networks and Pipelines	Chair: **Richard Marshall**, Space Weather Services
11:00 - 11:45	ASFC Tour #1	
11:45 - 12:30	ASFC Tour #2	
12:30 - 13:30	Lunch	
13:30 - 14:45	HF & VHF Part II	Chair: **Murray Parkinson**, Space Weather Services
13:30 - 14:45	Aerospace Part II – Satellites and SATCOM	Chair: **Dave Neudegg**, Space Weather Services
13:30 - 14:45	Aurora and Space Weather Enthusiasts	Chair: **Rakesh Panwar**, Space Weather Services
13:30 - 14:15	ASFC Tour #3	
14:15 - 15:00	ASFC Tour #4	
14:45 - 15:15	Afternoon Tea	
15:15 - 15:30	International Activities in Space Weather	**Mike Terkildsen** Space Weather Services, Bureau of Meteorology
15:30 - 16:00	Impacts of Neutron Radiation from Solar Energetic Particles (SEPs) on Aviation	**Ian Getley** PCAIRE Inc
16:00 - 16:25	Space Debris as a Component of Space Weather	**John Kennewell** Australian Space Academy
16:25 - 16:50	Extreme space weather events and the potential cost to modern-day society	**Brett Carter** SPACE Research Centre, RMIT University
16:50 - 17:00	Closing Remarks	**Colin Yuile** Manager Space Weather Services, Bureau of Meteorology

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Inaugural SW Users Workshop

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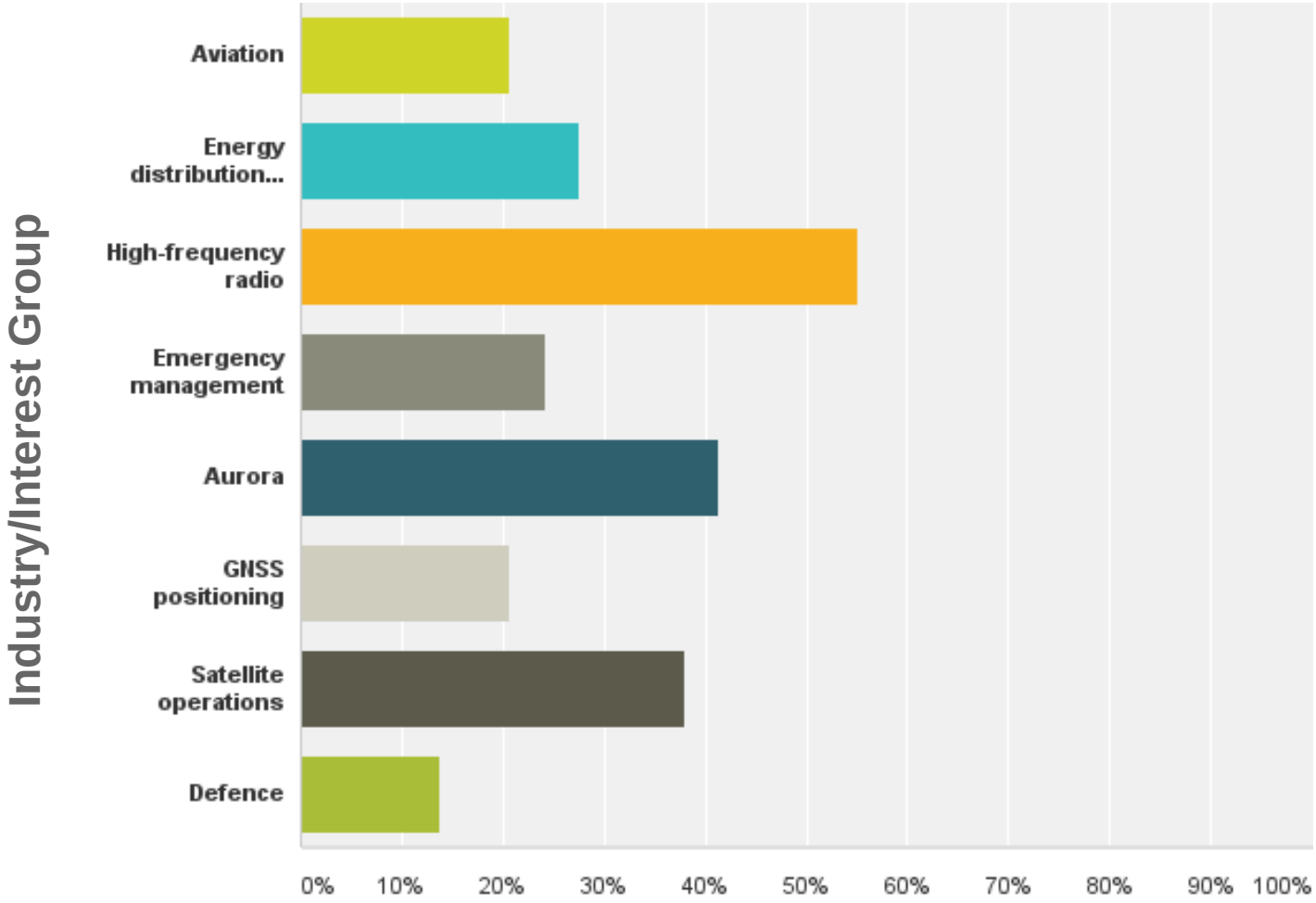
SW Workshop Survey

Response rate: ~%30



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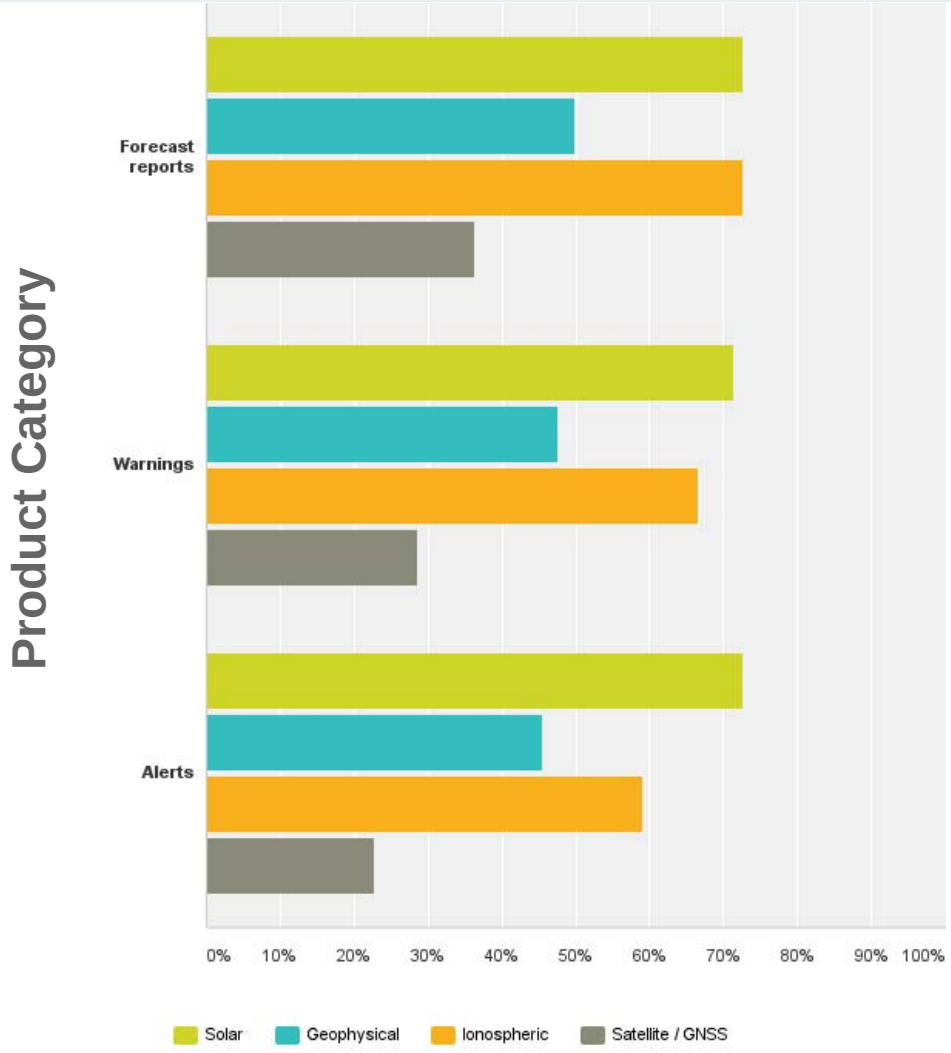
SW Workshop Survey
Product Category



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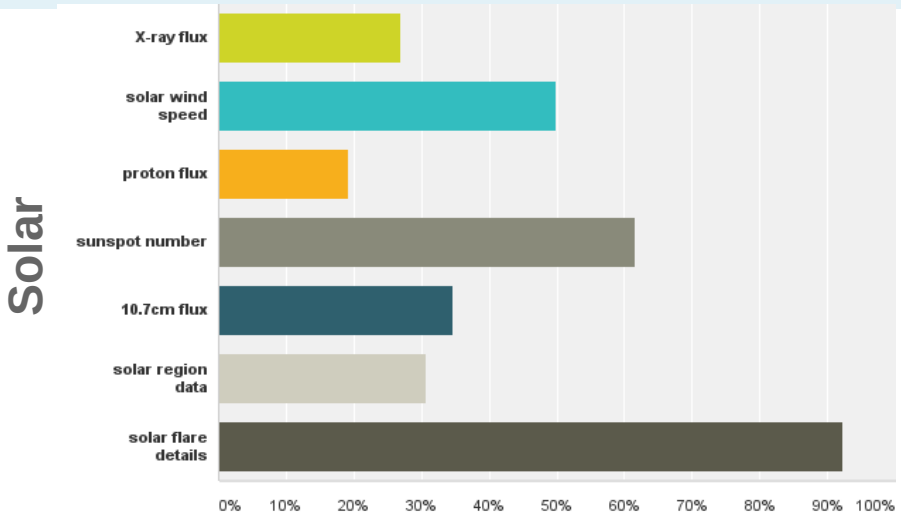
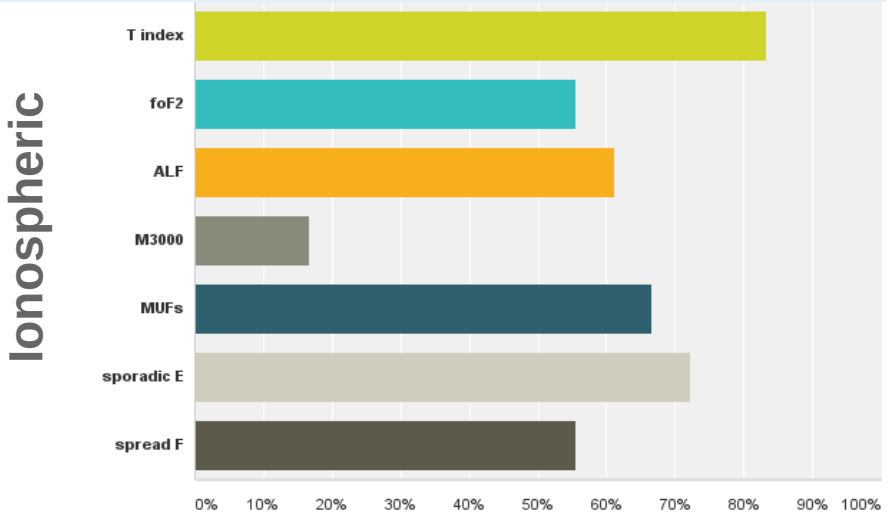
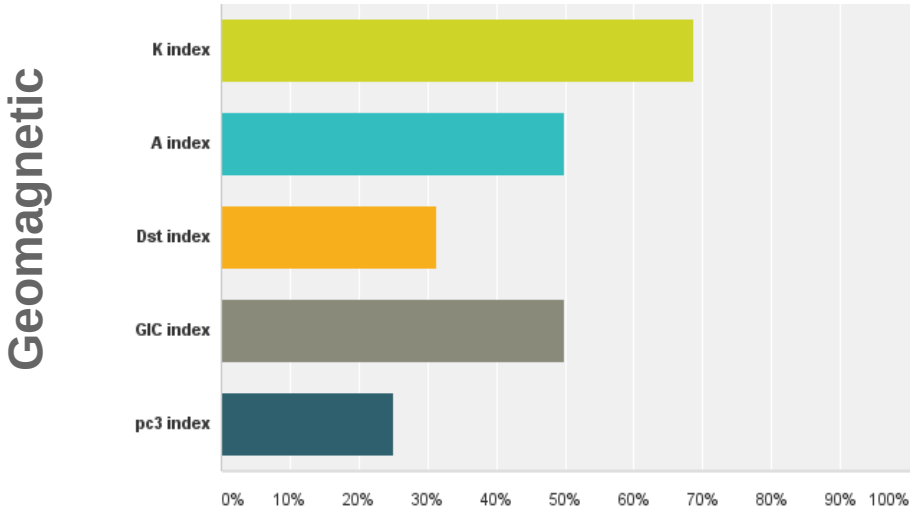
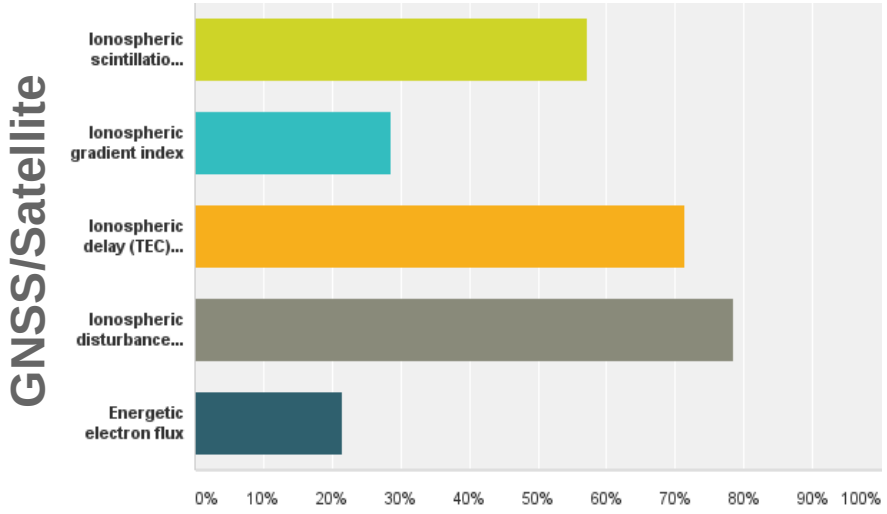
SW Workshop Survey Products









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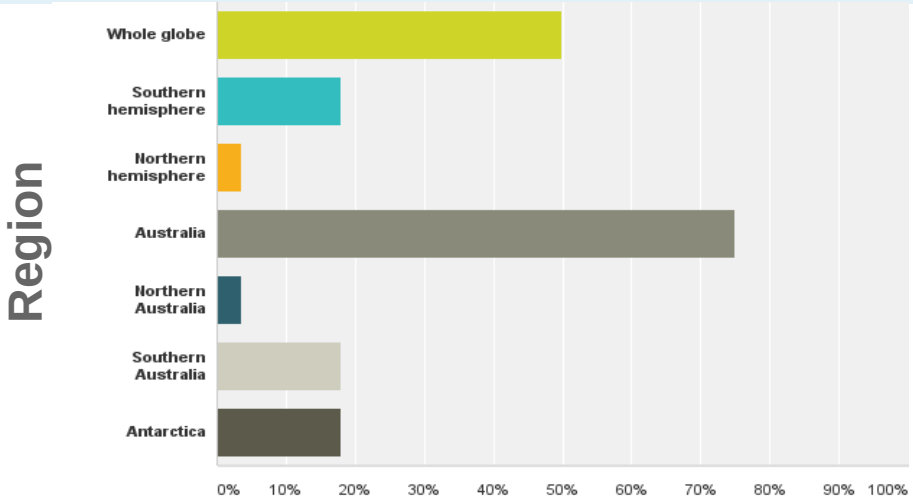
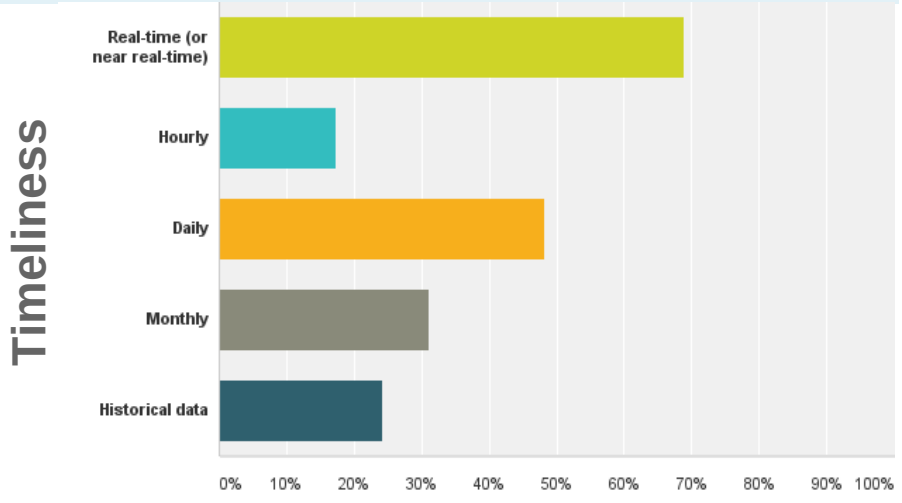
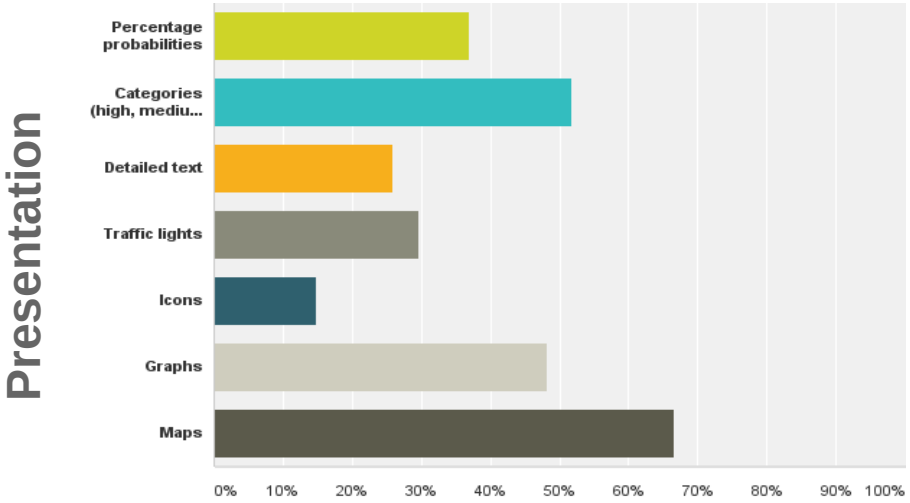
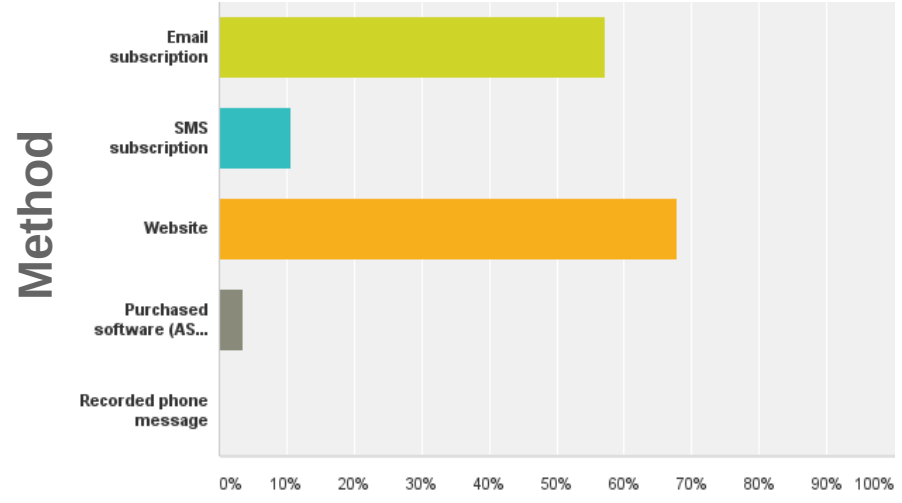
SW Workshop Survey Delivery









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SW Workshop Feedback

- Aviation – scintillation forecasts for trans-equatorial flights; polar forecasts (SEP?); IPad Apps displaying HF charts; improved spatial and temporal information; more user friendly terminology; operationally useable forecasts and alerts
- Mobile apps for a number of industries including power
- More accurate forecasts for Power industry (timing and magnitude); GIC proxy in various format
- Better models for satellites eg., SEP forecasts
- Data delivered via APIs – most industries but particularly aurora app developers
- Better ionospheric models for GNSS; possible use of TEC data in QC
- Southern hemisphere NOAA scales, eg G-scale
- Proton flux plots to indicate high, medium, low etc
- Configurable web interface data-to-industry for product delivery
- 24/7 operations (ICAO)
- Aurora best viewing places; combine alerts with cloud information
- Forecast verification

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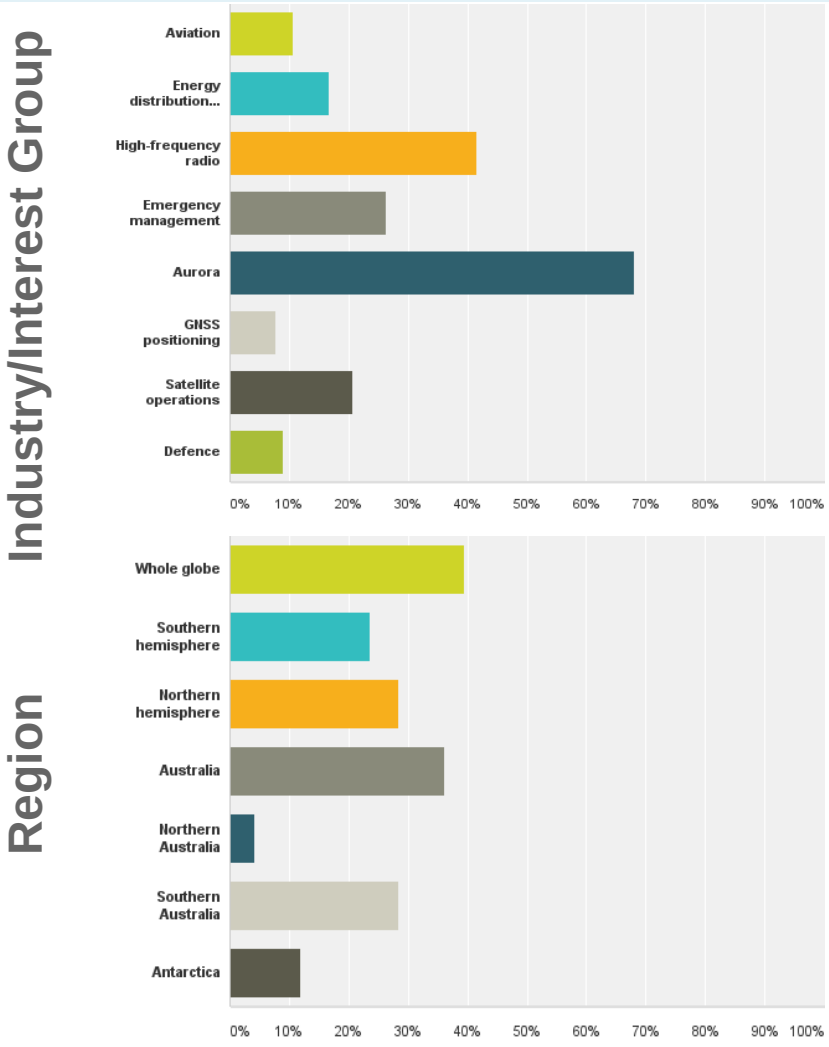
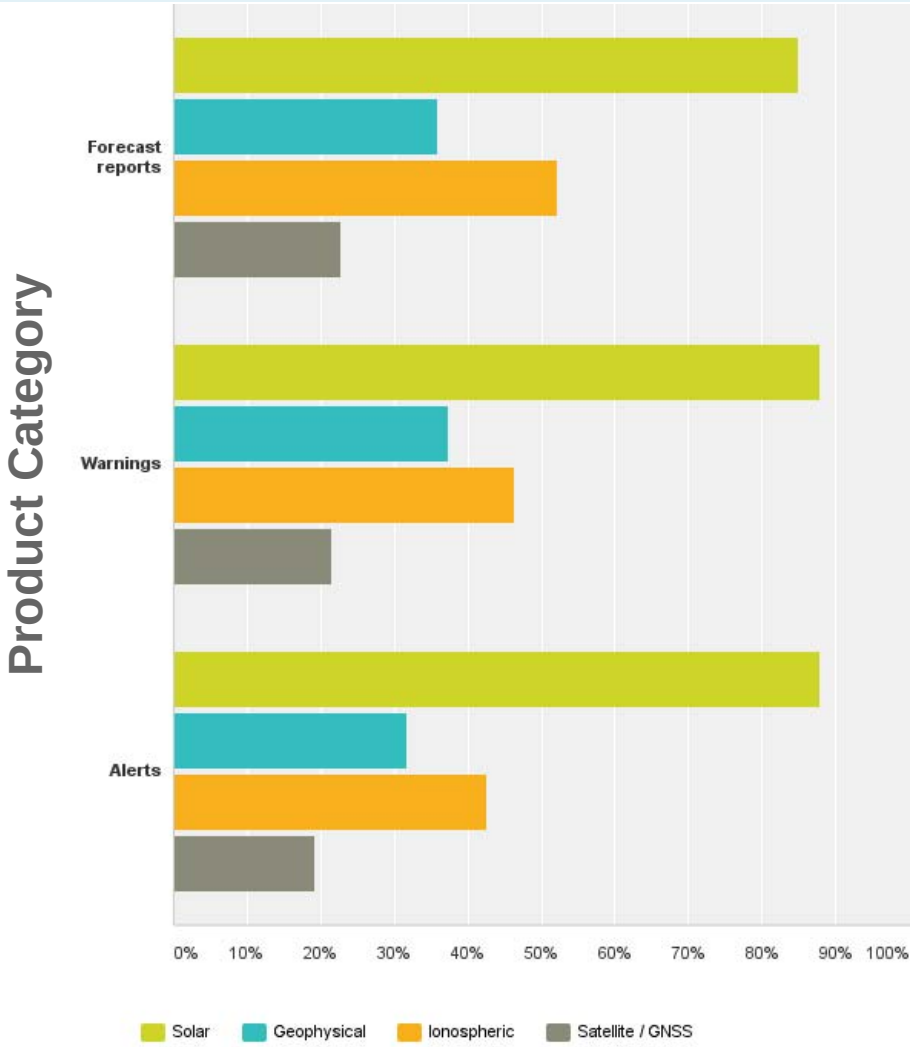
General Survey

Response rate: ~ 700 responses





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Government Interactions

- Bureau's facebook page – aurora Australis (https://www.facebook.com/bureauofmeteorology)
- Department of Industry Energy Sector Group - National Energy Security Assessment – paragraph on space weather
- NSW Department of Energy and Resources – paper for SEMC proposing support for a national space weather strategy
- Department of Industry Space Utilisation Policy
  - Encourage closer cooperation between civilian and Defense research in domains that contribute to a stable and safe space environment, including space weather and space situational awareness.
  - The Bureau of Meteorology is the Australian Government Agency responsible for Australia's civilian space weather activities
- Department of Industry Space Coordination Committee State of Space report (SCoI, SSA)
- CRC Spatial Information funding for National Positioning Infrastructure project
- Attorney General's Department Trusted Information Sharing Network for Critical Infrastructure Resilience (includes Energy, Transport, Comms, Finance, Health, Water, Space sectors) held annual desktop training exercise based on an extreme space weather event

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TISN Desktop Exercise 2014

BOM SSWW ALERT

Wed 03 Nov 1100hrs the BOM has detected a large, fast, earth directed Coronal Mass Ejection (CME) the size of which is likely to result in a an extreme geomagnetic storm of an unprecedented scale not previously witnessed or recorded in modern times.

This CME will result in a geomagnetic storm with significant impacts to critical infrastructure. This event is expected to hit Australia within 12 - 24hrs and last up to 72hrs with potential peaks and troughs.

Given the scale of this event owners and operators of Critical Infrastructure should be prepared for a worst case scenario. Existing BOM modelling predicts:

- Partial loss of satellite infrastructure and disruption to satellite communications is highly likely
- Significantly degraded and unreliable PNT systems is highly likely
- Intermittent disruptions to VHF/UHF telecommunications systems is highly likely
- Loss of primary and secondary HF communications systems highly likely
- Total loss of power system is unlikely, however, instability and transformer damage is highly possible – worst case scenario may be possible prolonged outages to major metropolitan area(s)

Extreme space weather event impacts highly interconnected, recommendations for Space Weather in BCPs, Bureau social media article

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Research

- CRCSI NPI project funding for 3D ionospheric model to obtain cm accuracy (Bureau, Universities, 2 commercial partners - 2.5 FTE)
- Solar wind modelling ARC-linkage grant (Bureau and Syd Uni)
- Probabilistic flare forecast modelling (delivered to WIS)
- GIC Project ARC-linkage grant (Bureau, UoN, AEMO, TNSPs)
- Severe storm forecast statistical modelling
- Ionospheric storm forecasts for MUF predictions
- Ionospheric scintillation studies (RMIT, Bureau)
- University of Newcastle (many related space physics studies)
- Collaborations with NICT on ionospheric modelling in our longitude sector

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CRC-SI P1.21. Ionospheric modelling to support ambiguity resolution for PPP-RTK

Objectives

"The project will deliver the algorithms and prototype source code needed to compute and deliver an ionospheric model to support the operational implementation of PPP-RTK through the Analysis Centre Software (ACS)... "

"The research challenge is to be able to provide sufficiently accurate ionospheric corrections in order to achieve cm level PPP-RTK positioning across the full service region at achievable reference network densities, and within an acceptable margin of service availability."

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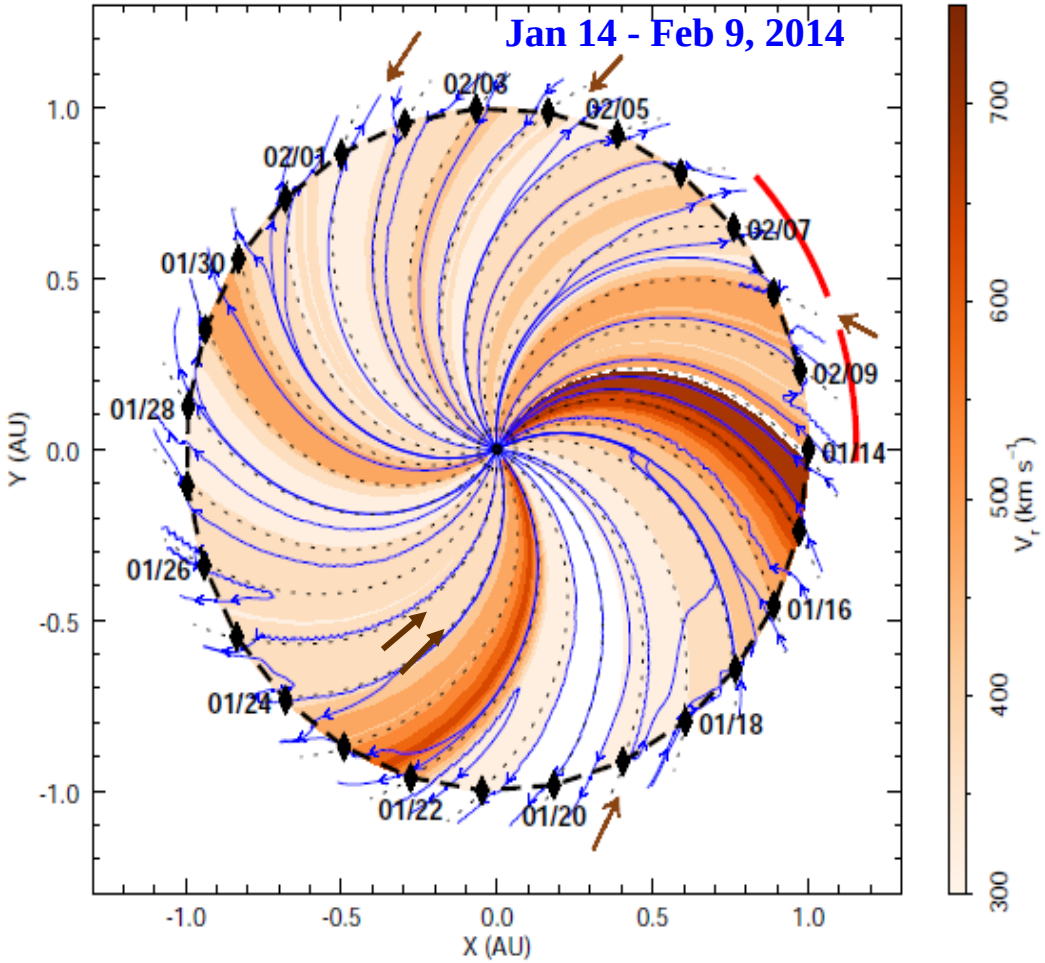
Magnetic Field Line Mapping



Sector boundary **ICME**

Magnetic field lines in solar equatorial plane for solar rotation Jan 14-Feb 9, 2014, predicted using near-Earth solar wind observations (background - **solar wind speed map**):

- Magnetic connection between Sun (center) and Earth (moving clockwise around 1 AU circle)
- Field configurations: open (may not be Parker spiral-like) or loops
- Applications: predicting connectivity of ARs, CMEs, shock waves, and SEP events to Earth

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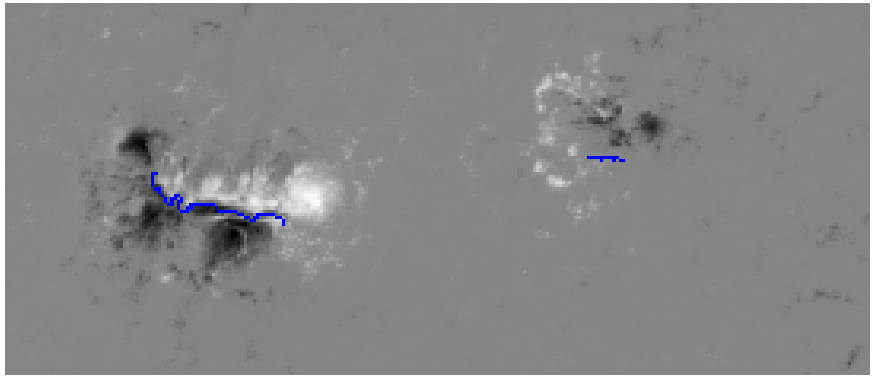
Flarecast Model Upgrade

The Australian Space Weather Service, Bureau of Meteorology, is implementing an automated probabilistic solar flare forecast model based on Flarecast, region characteristics and previous flaring history. Flarecast uses Solar Dynamic Observatory (SDO) HMI solar magnetograms to automatically identify active regions and their characteristics by analyzing features on the solar disc in near real time. These characteristics, along with recent flaring history, have been used to train a statistical model for flare probability. The model outputs in the form of probabilities for M- and X- class flares are generated in near real time as new input data becomes available.



To the right is a summary of the best results using a combination of 1, 2 and 3 Flarecast parameters. Additional parameters are currently being analyzed.

Parameter(s)	P_d for fp = 20%, Instant	P_d for fp = 20%, Averaged	P_d for fp = 10%, Instant	P_d for fp = 10%, Averaged
1 par, M + X	77.1	75.4	58.5	62.7
1 par, M5 + X	90.7	85.9	74.4	78.0
1 par, X	93.6	96.2	83.9	85.2
2 par, M + X	79.3	81.0	59.9	64.1
2 par, M5 + X	92.9	91.9	77.0	81.5
2 par, X	96.3	100	86.9	100
3 par, M + X	81.8	82.3	63.5	65.9
3 par, M5 + X	96.2	92.5	81.5	83.5
3 par, X	100	100	87.9	96.0

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The 1st paper was submitted to J. Geophys. Res. Hopefully, it will be accepted in the near(est) future.

Regarding the 2nd paper, I saw a first draft only. I think it has not been submitted yet but it will be. The papers' details (titles, authors and Abstracts) are as follows:

1) Mapping magnetic field lines between the Sun and Earth,

B. Li, Iver H. Cairns, J.T. Gosling, G. Steward, M. Francis,

D. Neudegg, H. Schulte in den Baumen, P.R. Player, and A.R. Milne

2) Comparisons of Predicted Magnetic Field Lines with the Observed Paths of Type III Solar Radio Bursts

B. Li, Iver H. Cairns, G. Steward, D. Neudegg, M. Francis, D.M. Malaspina, and V.V. Lobzin

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BOM Structure