International Civil Aviation Organization

THE FOURTH MEETING OF ASIA/PACIFIC METEOROLOGICAL HAZARDS TASK FORCE (MET/H TF/4)

ICAO Regional Sub-Office, Beijing, China

19 – 21 March 2014

Agenda Item 7: Any other business

SPACE WEATHER SERVICES IN SUPPORT OF AVIATION

(Presented by Australia)

SUMMARY

This paper presents information on observed and forecast space weather conditions provided by the Australian Bureau of Meteorology Space Weather Services in support of international air navigation.

1. INTRODUCTION

1.1 The Australian Bureau of Meteorology's Ionospheric Prediction Service (BoM/IPS) has provided space weather information services to the aviation industry since the 1970s, originally in the form of High Frequency (HF) radio communications advice and planning, and more recently in the form of radiation alerts and warnings, geomagnetic warnings, services for satellite communication and navigation, as well as a range of ionospheric and HF radio consultancy services. Established by the Australian Federal government in 1947 under the Department of the Interior, the BoM/IPS became a branch of the Bureau of Meteorology in 2008, expanding the facilities available for space weather monitoring and forecasting to include, for example, improved access to high performance computing and expanded monitoring network infrastructure.

1.2 BoM/IPS is a member of International Space Environment Service (ISES), operates a well-established Regional Warning Centre (RWC) for the Australasian region and is one of 15 RWCs around the world providing space weather observations and forecasts. The BoM/IPS has mentored a number of other RWCs to build space weather capability in other regions, including South Korea and South Africa.

1.3 BoM/IPS is also active internationally through the ICAO Asia/Pacific Ionospheric Studies Task Force in assessing space weather effects on Global Navigation Satellite Systems (GNSS) including Satellite-Based Augmentation Systems (SBAS) and Ground-Based (GPS) Augmentation Systems (GBAS), and as a member of the WMO Inter-programme Coordination Team on Space Weather (ICTSW) which has provided significant input into the development of the ICAO Space

Weather Concept of Operations (ConOps) and draft Standards and Recommended Practices for Space Weather for inclusion in Annex 3.

1.4 Products and services for the aviation industry are provided by BoM/IPS through a customised website interface for tailored products and services (http://www.ips.gov.au/Products_and_Services), subscription-based alerts and warnings delivered via email and SMS, daily and monthly reports, and consultancy services.

1.5 The NOAA Space Weather Prediction Centre (NOAA/SWPC) have developed a set of scales (R for radio blackout, S for solar radiation storm and G for geomagnetic storms) that are widely used by space weather forecast centres and adopted for space weather forecasting and monitoring for aviation. The R3, S3 and G3 levels are used by BoM/IPS for issuing alerts to aviation customers.

2. RADIO BLACKOUTS

2.1 Solar X-ray flare events (NOAA R-scale) ionise the lower ionosphere causing attenuation (absorption) of HF radio waves in the sunlit hemisphere (HF fades). Solar X-ray flux is monitored by satellites, including the NOAA GOES satellite. The effect on HF radio communication is modelled based on peak X-ray flux (see Figure 1). Warnings for possible HF fades are issued based on forecast solar flare activity at R1 level or greater. Alerts for current HF fades are issued based on solar X-ray flux for a threshold value of R3, which indicates the occurrence of an X1 level solar X-ray flare, producing wide area blackouts for HF communications on the sunlit side of the Earth and degradation of low-frequency navigation signals.

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SUBJ: IPS HF RADIO COMMUNICATIONS WARNING 14/15
ISSUED AT 25/2330Z FEBRUARY 2014
BY THE AUSTRALIAN SPACE FORECAST CENTRE.

HF COMMS FADEOUTS EXPECTED DURING DAYLIGHT HOURS
FROM 26-28 FEBRUARY 2014
IF COMMS DIFFICULTIES EXPERIENCED TRY A HIGHER FREQUENCY BAND
_____________________________________________________________

SOLAR ACTIVITY FORECAST       HF COMMS FADEOUTS
26 Feb:  Moderate to high     Possible
27 Feb:  Moderate to high     Possible
28 Feb:  Moderate to high     Possible
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Figure 1. IPS HF Radio Communications warning for possible HF fade due to R1 or greater solar flare event

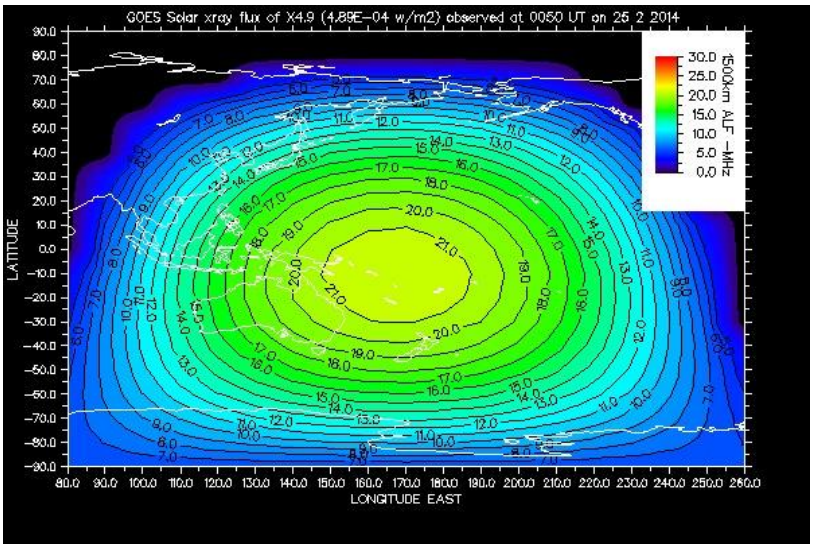


Figure 2. Modelled effect on the minimum HF radio frequency available for communication on a 1500km circuit during an R3 Solar X-ray event (refer http://www.ips.gov.au/HF_Systems/6/2/2)

3. SOLAR RADIATION STORMS

3.1 Energetic solar radiation storm events (NOAA S-scale) result in degraded HF radio propagation throughout the polar regions and navigational position errors, and may last for multiple days. Proton flux is monitored using particle detectors onboard the NOAA GOES satellite. HF blackout in the polar regions is monitored using high latitude riometers (passive HF radio receivers), and ionosondes (HF radio vertical sounders). Alerts for aviation are issued for degraded polar HF conditions at the S3 threshold, which indicates a flux level of ≥10MeV protons of 10^3 particles.s^{-1}.$ster^{-1}$.cm^{-2} at geosynchronous orbit and is indicative of possible radiation hazards in high flying aircraft, and degraded HF propagation through the polar regions.

3.2 Ground-level events. Ground-level events (GLEs) are detected by cosmic ray telescopes at high latitudes. GLEs occur approximately 16 times per solar cycle. They are an indicator of possible radiation hazard at high latitudes and altitudes due to solar energetic particles. These are also related to the S-scale, but are a ground-based observation rather than a satellite-based observation.

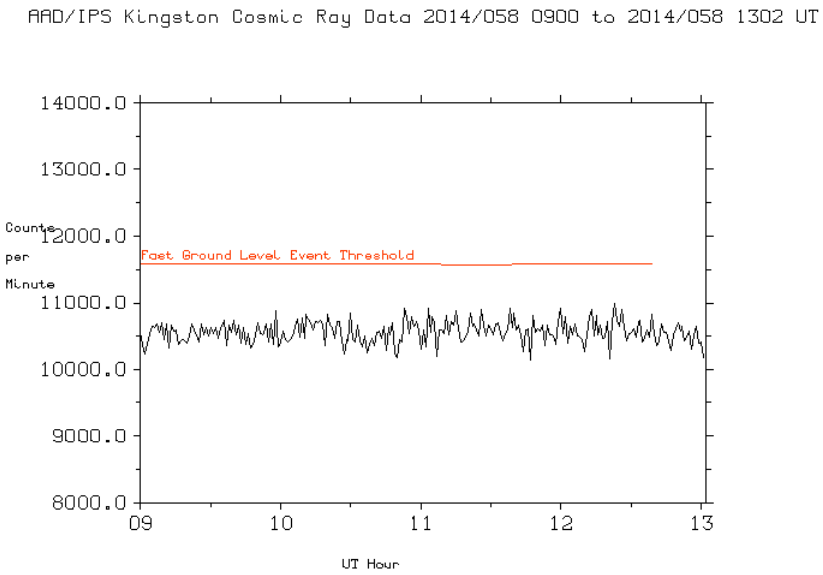


Figure 3. Cosmic ray monitoring for automated detection of Ground Level Events (GLEs), an indicator of possible radiation hazard at high latitudes and altitudes (refer http://www.ips.gov.au/Geophysical/1/4)

4. GEOMAGNETIC STORMS

4.1 Alerts for aviation are issued for geomagnetic storm conditions at the NOAA G3 threshold, which indicates a geomagnetic storm with a 3-hourly Australian region K-index (geomagnetic storm index) of at least 7.

4.2 Severe space weather events. The severe space weather (SSW) service is a forecasting and alert service for very high threshold space weather events (G5 and S4/5). This is driven by growing demand for an advance warning of severe space weather events from various critical industries such as power networks, aviation, critical infrastructure, and emergency services. The SSW service is a combination of improved modelling of high threshold events, procedural improvements in the space forecast centre, and tailored communications for critical industries. The SSW service aims to identify, with reasonable lead time, solar disturbances with the potential to produce a G5 level storm. Storms at that level occur, on average, approximately 4 times per 11-year solar cycle, and may produce significant anomalous ionospheric gradients at all latitudes affecting GNSS-based navigation, as well as significantly impacting HF radio communications. Primarily, the alert service is a forecast with varying lead times from 1-72 hours. There is also a real-time monitoring component to issue immediate alerts on the observation of an SSW level storm event.

5. SERVICES FOR SATELLITE BASED NAVIGATION

5.1 Ionospheric scintillation monitoring and alerts. BoM/IPS maintains a network of ionospheric scintillation monitors in Northern Australia in support of Global Navigation Satellite Systems (GNSS) based navigation and satellite communications near the equatorial ionospheric anomaly region. The network monitors ionospheric scintillation levels and GNSS satellite loss of lock, with alerts based on threshold levels of ionospheric scintillation index 'S4'.

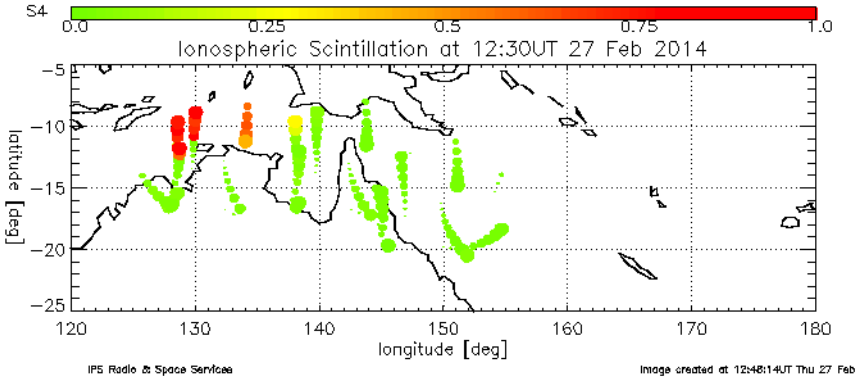


Figure 4. Real time map of ionospheric scintillation level across northern Australia (refer http://www.ips.gov.au/Satellite/1/2)

5.2 Anomalous ionospheric gradient monitoring and alerts. The Anomalous Ionospheric Gradient (AIG) alert service is currently being developed and is designed to alert GNSS users of the presence of ionospheric gradients above a critical threshold. The service is based on monitoring data from short-baseline GNSS Continuously Operating Reference Station (CORS) networks, from which estimates of peak ionospheric gradient (in mm of slant delay per km of baseline) can be calculated.
Text to be inserted

6. HF FREQUENCY MANAGEMENT

6.1 Hourly and daily HAP (Hourly Area Prediction) charts for HF frequency selection for communication from specific locations, based on current ionospheric conditions. Hourly NAP (Network to Area Prediction) charts for HF communication using multiple base locations and a defined operational area. Predictions superimposed on Flight Information Regions (FIRs).

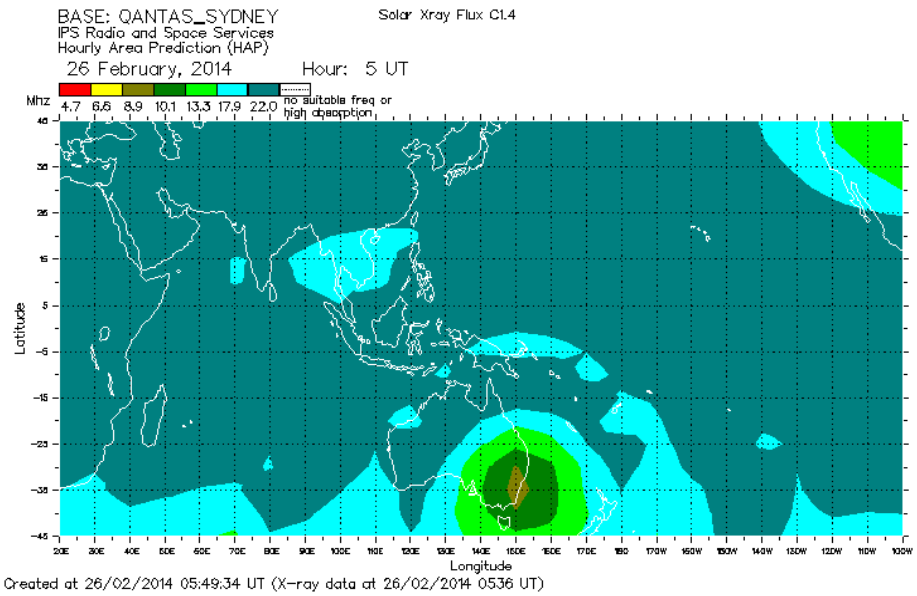


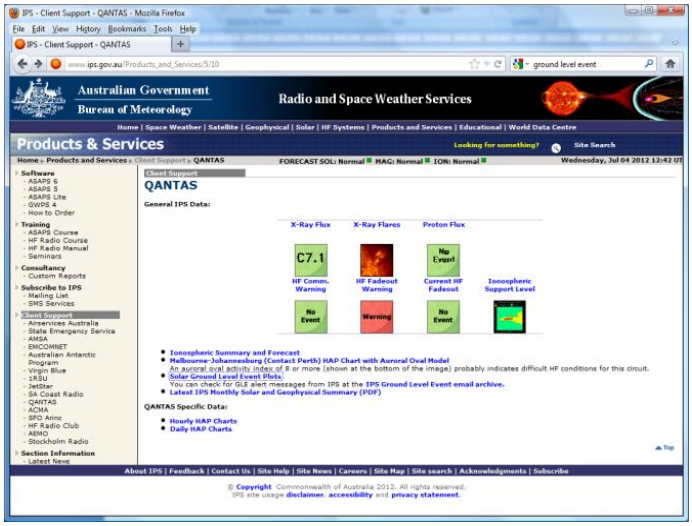
Figure 5. Hourly Area Prediction (HAP) chart for HF frequency selection from a base at Sydney, as produced for Qantas (refer http://www.ips.gov.au/Products_and_Services/5/10/1)

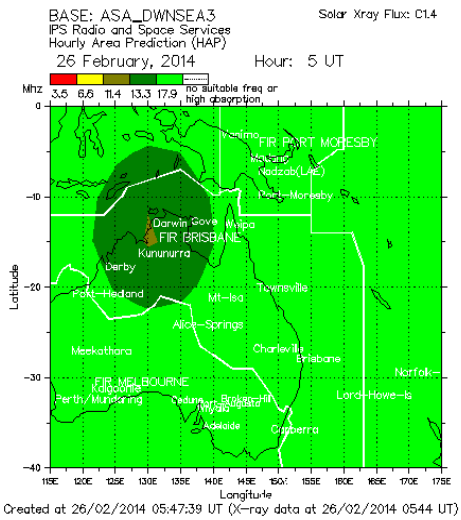
7. AVIATION SPECIFIC WEB PAGES

7.1 The BoM/IPS has established a number of customised web-pages for aviation industry clients such as Airservices Australia, and individual airlines such as Qantas, Virgin Australia and Jetstar. These pages draw together all relevant space weather forecast and monitoring information, as well as customised HF prediction tools into a single stop webpage for each customer.

Examples can be found at:

- QANTAS: http://www.ips.gov.au/Products_and_Services/5/10
- Airservices Australia: http://www.ips.gov.au/Products_and_Services/5/1





8. CONSULTANCY SERVICES

8.1 BoM/IPS has conducted consultancies for the aviation industry for more than 30 years. Historically this has been primarily for HF radio communication network planning and frequency management. Other, more recent consultancies include validation of the Conterminous United States (CONUS) ionospheric threat model within the Ground-Based (GPS) Augmentation System (GBAS) for operation and certification in the Australian region; a consultancy undertaken for Airservices Australia in 2010.

9. ACTION BY THE MEETING

9.1 The meeting is invited to note the information in this paper.

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