International Civil Aviation Organization

FOURTEENTH MEETING OF THE COMMUNICATIONS/NAVIGATION/SURVEILLANCE AND METEOROLOGY SUB-GROUP OF APANPIRG (CNS/MET SG/14)

Jakarta, Indonesia, 19 – 22 July 2010

Agenda Item 5: **Navigation:**

5) other radio navigation issues

IONOSPHERE CHARACTERISATION IN AUSTRALIA TO SUPPORT GBAS IMPLEMENTATION

(Presented by Australia)

SUMMARY

This Working Paper outlines the methodology and results of the Australian ionosphere study. Australia supports continued cooperation in Asia Pacific to establish a regional ionosphere model. States are encouraged to consider the validity of the existing ionosphere threat model developed in Conterminous US (CONUS) for the entire mid-latitude region. It will eliminate the requirement for individual States in this region to conduct their own ionosphere studies and encourage early implementation of GNSS augmentation systems. It is also recommended that focusing on the characterisation of ionospheric anomalies in the equatorial regions will contribute to a global ionosphere model. This will build confidence in world-wide transition to GNSS-based precision navigation applications.

This paper relates to

Strategic Objectives:
A. Safety – Enhance global civil aviation safety
D. Efficiency – Enhance the efficiency of aviation operations

Global plan initiatives:
GPI-17Data link applications
GPI-21Navigation systems

1. Introduction

1.1. Australia provided a working paper at the APANPIRG CNS/MET SG/13 meeting in July 2009, recommending regional cooperation to characterise the ionosphere model for Asia Pacific. APANPIRG and ICAO Asia Pacific Office have supported this recommendation and, in February 2010, invited States in the region to nominate a focal point of contact for exchanging ionospheric data. This is a critical step towards establishing an ionosphere model to support implementation of GNSS-based precision navigation both regionally and globally.

1.2. Australia is implementing an FAA-certified Ground Based Augmentation System (GBAS), Honeywell SmartPath™ SLS-4000, at Sydney International Airport for Category I precision approach service. The GBAS has incorporated an ionosphere threat model to protect users from worst-case ionosphere anomalies, known as ‘ionopsheric storms’.

1.3. An anomalous ionospheric gradient is modelled as a linear, semi-infinite wave front with constant propagation speed as illustrated in Figure 1. The three key parameters of the existing GBAS ionosphere threat model are:

- the spatial gradient *(g)* in slant ionosphere delay between maximum and minimum delays);
- the width *(w)* of the linear change in delay; and
- the forward propagation speed *(v)* of the wave front relative to the ground.

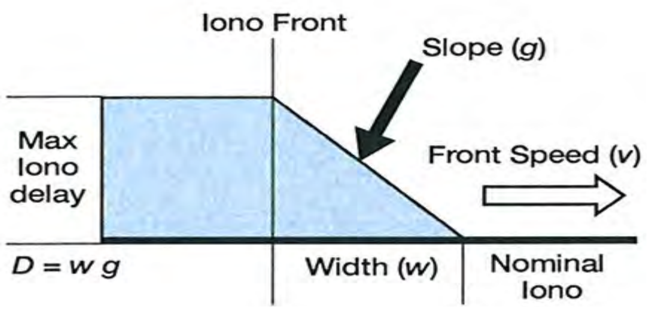

Figure 1. Ionospheric Anomaly Wave front Model (the ‘wedge’ model)

The upper and lower bounds on the three key parameters of the ionosphere threat model were determined by analysing a large set of GPS data collected from the mid-latitude sites across Conterminous US (CONUS) in 2000-2004.

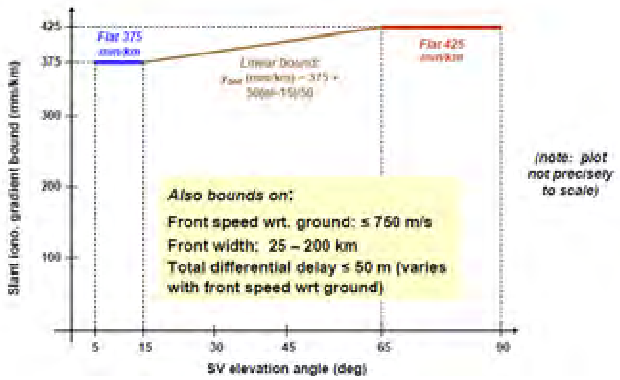

Figure 2. FAA-certified GBAS Ionosphere Threat Model

2. Ionosphere Characterisation in Australia

2.1. **Objective**

Airservices Australia engaged IPS Radio and Space Services (‘IPS’) to identify and characterise ionosphere anomalies that occurred in the mid-latitude Continental Australia region in the last solar cycle. IPS is a subsidiary of the Australian Bureau of Meteorology. The objective of the study was to confirm the validity of the existing GBAS ionosphere threat model for operation under Australian ionospheric conditions. FAA and Honeywell provided independent review of the IPS draft and final reports.

2.2. **Methodology**

The Australian ionosphere anomaly study followed the CONUS methodology closely and consists of:

- storm identification;
- sourcing dual-frequency GPS data;
- data pre-processing;
- identifying potential large gradient regions;
- auto-processing for large gradient events;
- manual vetting;
- gradient analysis; and
- comparison with the CONUS threat model.

Dual-frequency GPS data from networks of continuously operating reference stations (CORS) were sourced from the following organisations:

- Geoscience Australia (Australian Regional GPS Network (ARGN) and South Pacific Regional GPS Network (SPRGN)).
- Victorian Department of Sustainability and Environment (GPSNet).
- Queensland Department of National Resources and Water (SunPOZ).
- Landgate, Western Australia.
- National Measurement Institute, Sydney.
- IPS Radio & Space Services, Bureau of Meterology.
- International GNSS Service.
- Land Information New Zealand (PozitioNZ).

Wide-area GPS networks (with baseline between GPS station pairs >200km) were used to identify regions of interest during ionospheric storms. Local-area GPS networks (with shorter baselines <100km) were used to further analyse these regions for ionospheric gradient parameters. Ionospheric gradients were determined using two GPS stations observing the same satellite.

Compared to the dense networks of GPS receivers (from WAAS, NGS-CORS) in CONUS, there was a lower density of dual-frequency GPS stations in Australia during the most active phase of the last solar cycle. Furthermore, the majority of GPS receivers are located in the Eastern states of Australia. The Australian methodology included additional steps to overcome GPS data availability constraints:

- The capacity of each GPS network to detect the full range of ionospheric gradients was assessed.

- The analysis conducted using East-coast GPS networks was assumed valid for the remainder of mid-latitude Australia (i.e. longitudinal invariance in ionospheric storm response over the mid latitude region).

2.3. Australian Results

The following ionospheric storms were identified in Australia during 2000-2008. The anomalous ionospheric gradients associated with these storm days were analysed.

#	Ionosperic Storm Days
1	15/07/2000
2	6/11/2001
3	29/10/2003
4	30/10/2003
5	25/07/2004
6	8/11/2004
7	10/11/2004
8	15/12/2006

Table 1. Ionospheric Storm Days in Continental Australia Region (2000-2008)

All observations of anomalous ionospheric gradients in the mid-latitude Australian region fell within the bounds of the FAA-certified GBAS ionosphere threat model. The worst-case ionospheric gradient observed in Australia was 148mm/km, significantly below 412mm/km observed in CONUS. Consequently, the existing GBAS ionosphere threat model is very conservative and sufficient for use in Australia.

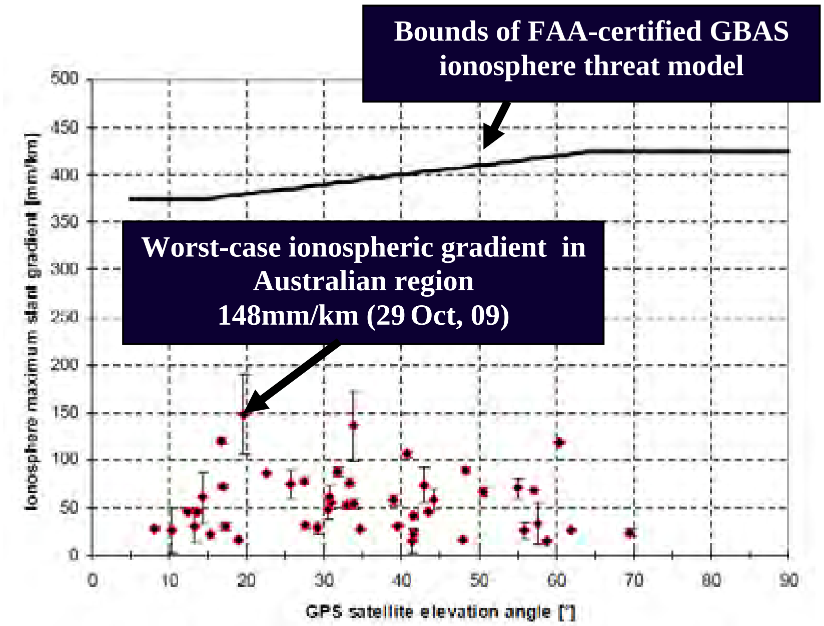

Figure 4. Australian Ionospheric Gradients fit within the FAA-Certified GBAS Ionosphere Threat Model

3. Global Ionosphere Characterisation

3.1 Characteristics of the ionosphere can be broadly divided into three distinct regions: the mid-latitude region, the equatorial region and the high-latitude region. Ionosphere study results can be extrapolated across countries in the same latitude region. This is based on the longitudinal invariance assumption (i.e. the most significant variations in ionosphere characteristics arise from differences in latitudes rather than longitudes).

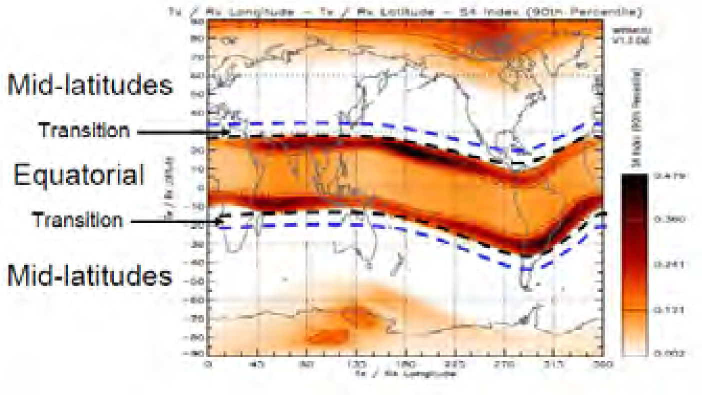

Figure 5. Global Ionosphere Regions

3.2 The Australian ionosphere study has shown that the worst-case ionospheric gradient (148mm/km) found in the mid-latitude Australia region was significantly less severe than that in CONUS (412mm/km). There have been comprehensive ionosphere anomaly analyses undertaken by a number of countries, including USA, Germany, Chile and Brazil. These studies confirmed that the CONUS ionosphere threat model conservatively contains the worst-case ionosphere anomalies in various mid-latitude regions. States are encouraged to consider the validity of the CONUS ionosphere threat model for the entire mid-latitude region world-wide. This will eliminate the requirement by individual countries to conduct their own ionosphere studies when planning the implementation of GNSS augmentation technologies.

3.3 Efforts to characterise ionospheric anomalies for equatorial regions are ongoing. Ionosphere studies being undertaken by Japan, especially in the Southern region of Japan, and other States could help complete a global ionosphere model outside the mid-latitude region.

3.4 Australia is planning to conduct further ionosphere anomaly study for Darwin and Northern Australia which are located in the transition band between the mid-latitude and equatorial region. GPS stations from these regions commonly observe GPS satellites to the North with line-of-sight ray paths from GPS receiver to satellites passing through the equatorial region. Australia will contribute any new findings to support the characterisation of ionosphere anomalies in the equatorial region.

3.5 Severe ionospheric storms, caused by solar flares and coronal mass ejections, are very rare events. They only occur once or twice every 11 to 12 years. The effects and impact of these events on GNSS signal propagation errors have been extensively researched over the past decade. Certified GNSS augmentation technologies, such as GBAS, exist today and incorporate conservative mitigations to protect users against unusual ionosphere anomalies. States are encouraged to adopt these technologies in regions where an ionosphere threat model is well established.

4. Action requited by the Meeting

The group is invited to:

a) note the content of this Working Paper;

b) accept the validity of the CONUS ionosphere threat model for the entire mid-latitude region; and

c) focus regional ionosphere characterisation effort on the equatorial region.

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