International Civil Aviation Organization

ALLPIRG/5-IP/14
20/03/06

INFORMATION PAPER

FIFTH MEETING OF THE ALLPIRG/ADVISORY GROUP

(Montreal, 23 – 24 March 2006)

Agenda Item 5.2: Global harmonization of RNP/area navigation (RNAV) implementation

GPS-AIDED GEO AUGMENTED NAVIGATION (GAGAN) IN INDIA

(Presented by India)

SUMMARY

GAGAN will provide augmented information for satellite navigation to the aircraft flying within Indian FIRs, which consist of seven boundaries. India is situated near the vicinity of equator. In the equatorial region, the ionospheric variations are very predominant which affect the GPS as well GEO signals. It has therefore been decided to go for Iono-Tropo modeling over Indian airspace after collecting TEC data over an extended period of time from eighteen TEC stations, which have been established for the purpose. This is an update and also future roadmap of the project.

Action by ALLPIRG/5 is in paragraph 7.

1. INTRODUCTION

1.1 India has presented an Information Paper during NSP meeting (11-21 October 2005, Montreal) on the subject. This is an update and also future roadmap of the project. GAGAN will provide augmented information for satellite navigation to the aircraft flying within Indian FIRs, which consist of seven boundaries.

1.2 India is situated near the vicinity of equator. In the equatorial region, the ionospheric variations are very predominant which affect the GPS as well GEO signals. It has therefore been decided to go for unique regional Iono-Tropo model over Indian airspace after collecting TEC data over an extended period of time from eighteen TEC stations which have been established for the purpose.

1.3 After analyzing the data for twenty months, it has been observed that seven more TEC stations are needed in the mid-region of the India where equatorial anomaly is very high.

2. IMPLEMENTATION TIMESCALE

2.1 **Technology Demonstration Systems (TDS):** This phase requires implementation of a minimum configuration system that would demonstrate the capability of the system to support up to precision approach over limited region of the Indian airspace and will serve as proof of concept. The performance objective of this system is to meet the ICAO SARPS requirements. The TDS will consist of eight Indian Reference Stations (INRES), an Indian Mission Control Center (INMCC), two Indian Land Uplink System (INLUS), space segment, required communication links and necessary software for navigation and communication during the TDS phase. In the scope of this phase second frequency L5 is being incorporated in both space and ground segments. The TDS will be completed in the year 2006.

2.2 **Initial Experimental Phase (IEP):** In this phase, TDS will be expanded to cover the entire Indian airspace and requisite redundancies will be added to the system. The system will be available for trial operations and the data collected by Airports Authority of India (AAI) during such trial operations would be analyzed to further improve the system, wherever considered necessary, to achieve compliance of ICAO SARPS. The IEP will be completed in a period of 18 months after the development, testing and validation of TDS.

2.3 **Final Operational Phase (FOP):** during this phase, the GAGAN program will be matured. Extensive tests would be carried out to establish the system stability of various elements of the system as a whole. The system will be put in extensive use for its evaluation with respect to ICAO SARPs. Certification and validation of the system will be completed before declaring the system operational. The FOP will be completed in a period of two years after the successful implementation of IEP.

3. CURRENT STATUS OF GAGAN

3.1 Infrastructure for installation of INRES at Delhi, Kolkatta, Guwahati, Portblair, Ahmedabad, Banglore, Jammu and Trivanthapuram is in place.

3.2 All eight INRES equipment have been installed and seven stations have been linked through OFC to INMCC for connectivity test. All the station data are being recorded at INMCC, Banglore.

3.3 The installation of GPS-TEC at all eighteen stations has been completed. Ionospheric data from eighteen TEC stations is being analyzed by number of Indian universities and R&D institutions involved in ionospheric studies for development IONO-TROPO model that is suitable for Indian airspace.

3.4 After doing the extensive analysis, it is proposed to install seven more GPS-TEC receiver in the mid region of India due to equatorial Indian anomaly (EIA) where ionospheric variation is very high.

3.5 It is further observed that scintillation is very active up to 60 degrees elevation based on twenty months data.

3.6 Infrastructure for INMCC and INLUS at Banglore is in place and installation of GAGAN equipment has been completed.

3.7 Infrastructure for providing standby connectivity through V-SAT from all INRES to INMCC is in progress, which will be completed by June 2006.

3.8 A geo-stationary payload in C-Band and L1 and L5 frequencies will be carried by GSAT-4 (fabricated and developed by ISRO) placed at 82 degrees E. GSAT-4 is scheduled for launch by December 2006.

3.9 At present GAGAN ground segment is under integration test and data collection at INMCC Banglore has begun.

4. IONOSPHERIC DATA ANALYSIS RESULTS

4.1 In the Indian equatorial and low latitude region because of large variations in the altitude of the peak electron density from equator to crest and beyond (250 to 650 km) and from day to night the use of a constant value of IPP altitude of 350 km is likely to introduce errors in the conversion of STEC to VTEC; particularly at low elevation angles of the GPS satellite passes because of the presence of large electron density gradients in and around the EIA region. Figures 1 and 2 (Appendix refers) represent comparison of the VTEC using different technique with 5 degrees and one degrees grid size.

4.2 Study reveals passes with elevation angles >50º are good for conversion of STEC to VTEC in the Indian zone.

4.3 TEC varies from 5 to 50 TEC units at the equator and from 5 to 90 TEC units at the crest region, which corresponds to range variations of about 1 to 8 meters at the equator to 1 to 15 meters at the crest region. These values will go up in high solar sunspot anomaly (HSSA) periods.

4.4 The intensity of scintillations (S4 index) is minimum at the equator (3 to 6dB) and maximum around the anomaly crest region (>10 dB).

4.5 The occurrence of scintillation is high during the post-sunset to midnight hours. Occurrence of strong scintillations (>10 dB) is confined to 15 to 25º Geog. Latitudes. Scintillations mostly occur during the equinoxial months with practically no activity during summer and winter months during this low SSA periods of 2004-2005. Percentage of scintillation during January 2004 to July 2005 of different intensities is depicted in Figures 3, 4 and 5 (Appendix refers).

4.6 Total number of 1360 bubbles is observed (mostly during the equinoxial months March, April, September, October of 2004 and February, March of 2005) over the entire Indian region.

4.7 This number of bubbles & loss of locks will certainly go up during the HSSA period creating more problems to the Trans-ionospheric communications and navigation

5. TECHNOLOGY SUPPORT OF DEVELOPMENT AND MAINTENANCE OF GAGAN

5.1 ISRO in association with the AAI will be developing the entire system through all the stages of TDS, IEP and FOP. ISRO will continue to provide technology support, maintenance and

replenishment of the space segment of the system, as and when required, to maintain the system as a robust system.

6. CONCLUSION

6.1 GAGAN has the capability of providing the augmentation service within GSAT-4 footprint, which covers a large portion of the Asia-Pacific region.

6.2 Necessary Ionospheric and Tropospheric (IONO-TROPO) models for GAGAN are under development GAGAN system takes into account the fact that in the equatorial ionosphere the spatial and temporal variability is much greater, even during equate magnetic conditions and therefore a model specifically for this region has to be developed to take care of the variations.

6.3 This model will take care of scintillation effect on GPS/ GEO signal. It is observed at few TEC station scintillation is very high for two to three hours.

6.4 GAGAN would be developed to meet the ICAO GNSS SARPs and it should be interoperable with WAAS, EGNOS, MSAS and GRAS.

7. ACTION BY ALLPIRG

7.1 The ALLPIRG/5 Meeting is invited to take note of the information presented in this paper.

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APPENDIX

Figure 1. Comparison of VTEC using different technique for grid size of 5x5 degrees.

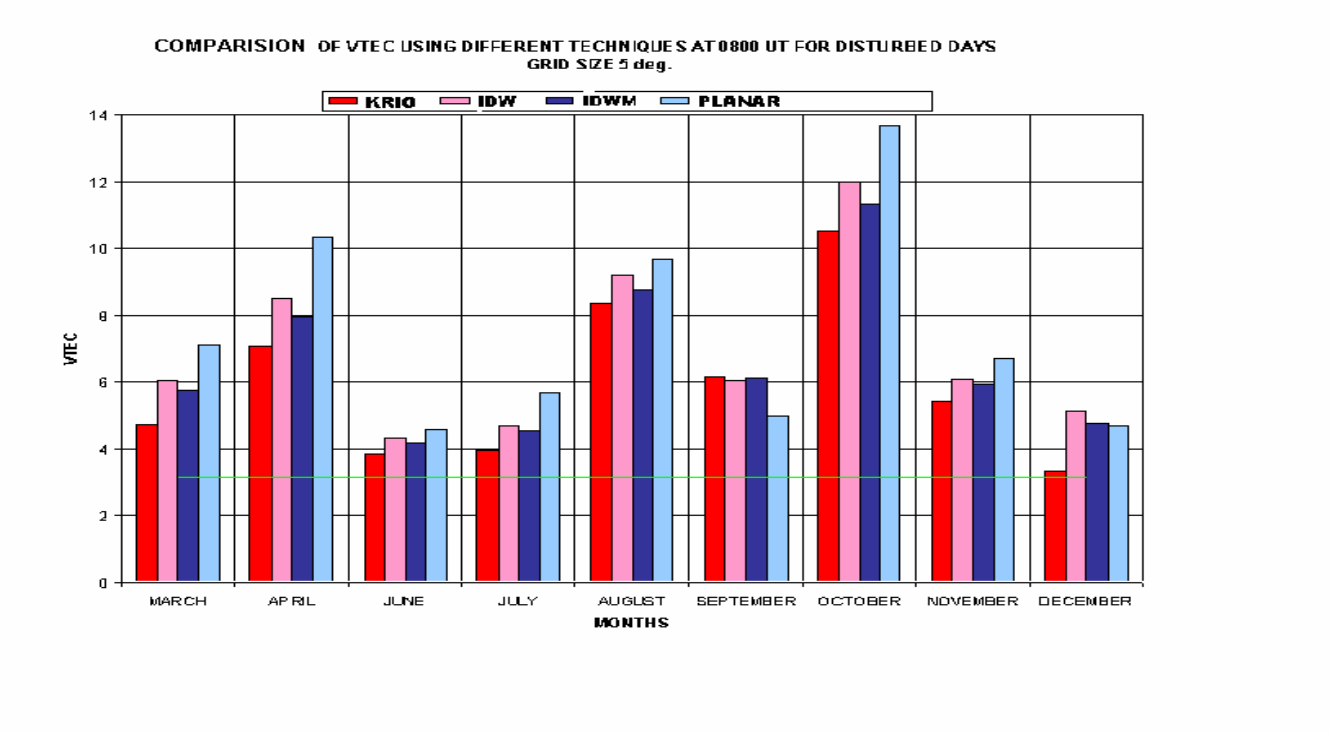


Figure 2. Comparison of VTEC using different technique for grid size of 1x1 degree

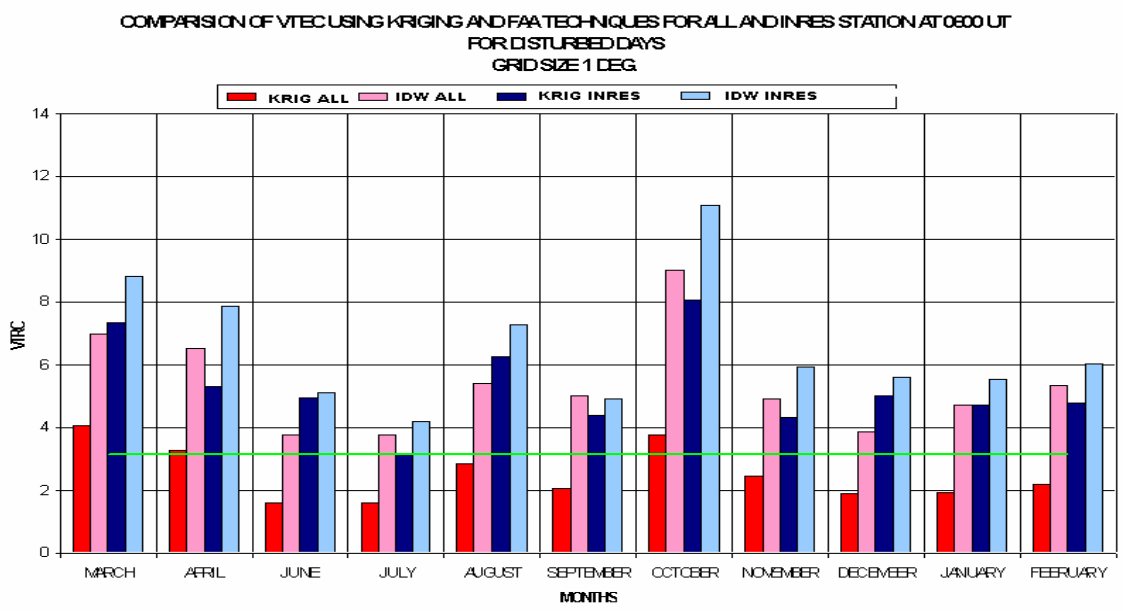


Figure 3

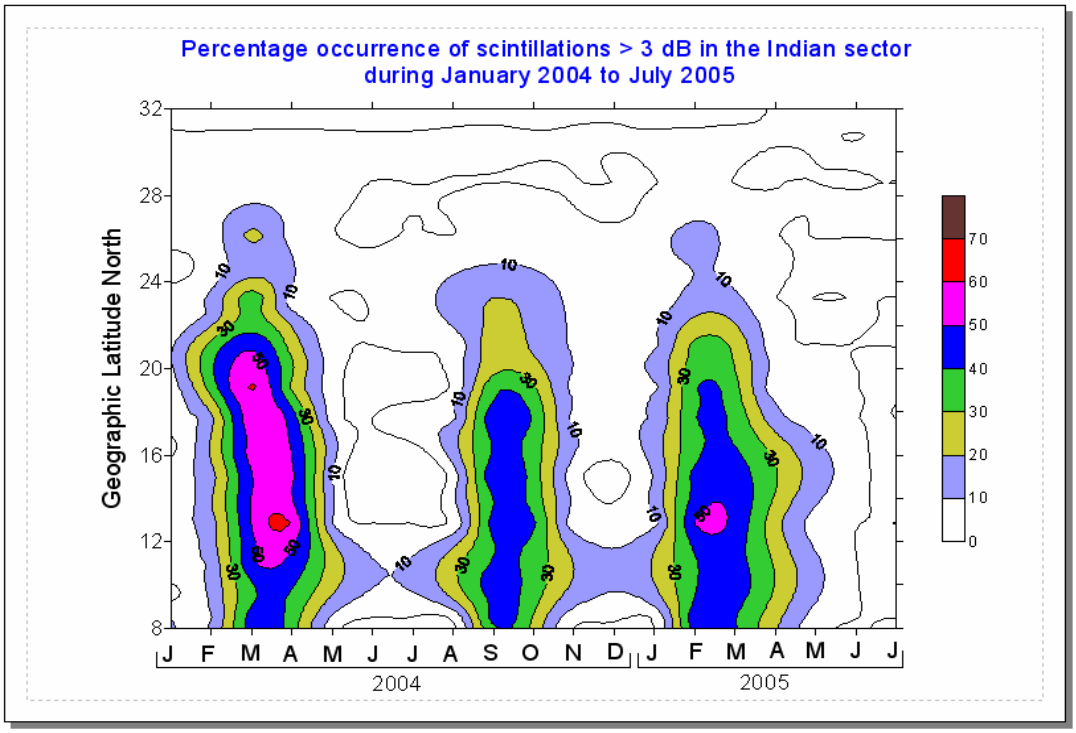


Figure 4

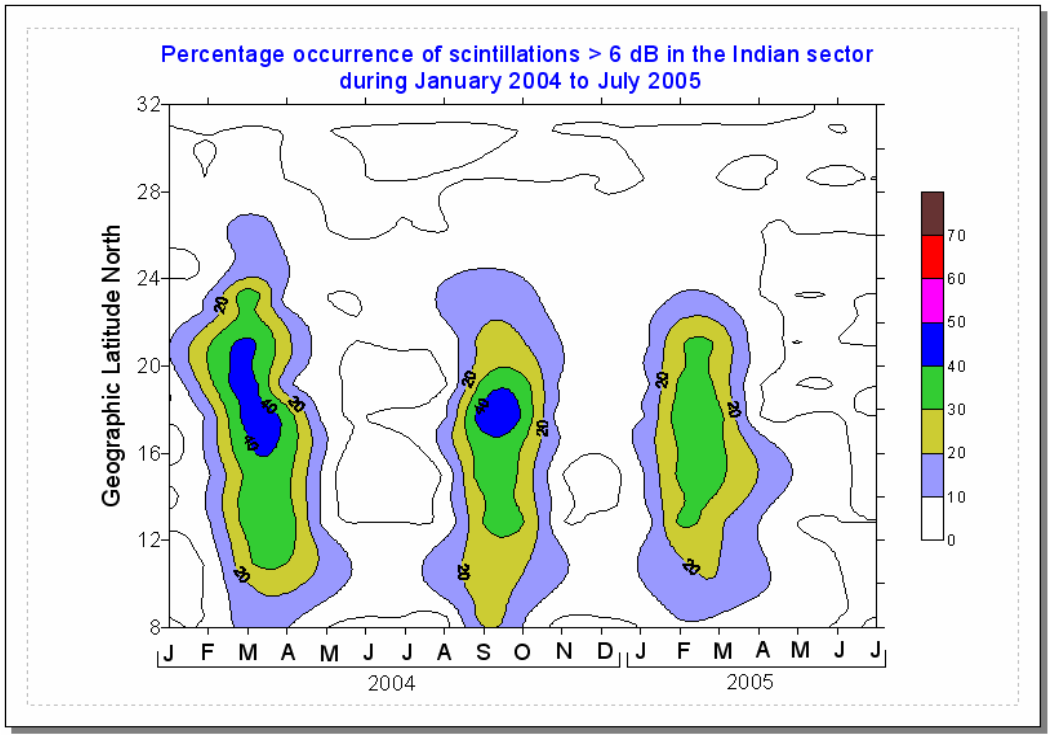
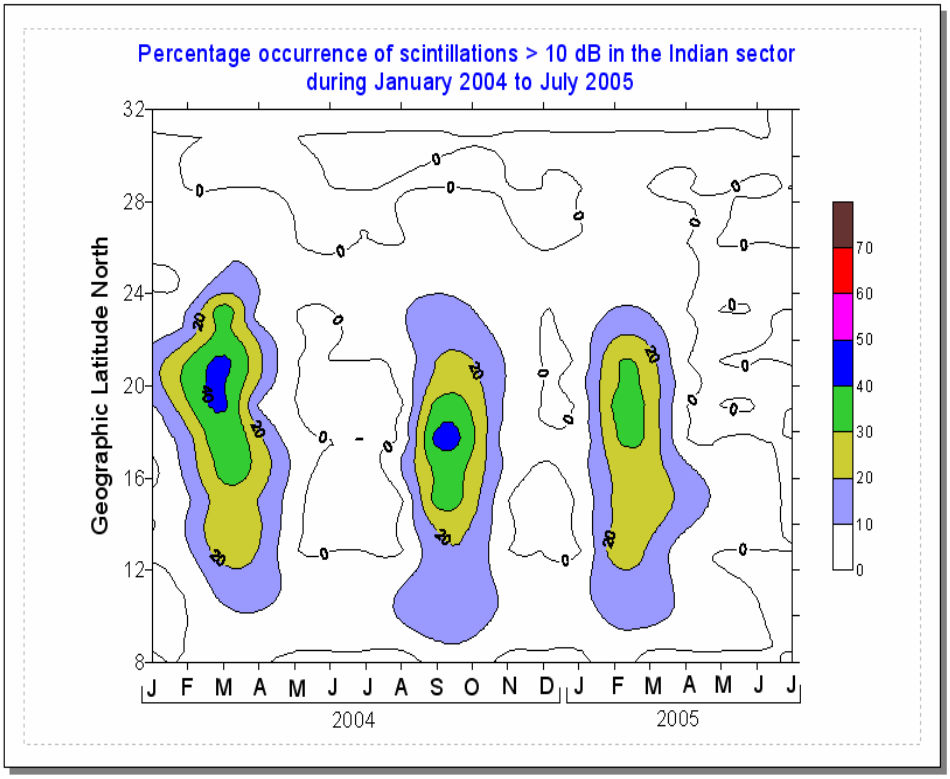


Figure 5


Percentage occurrence of scintillations > 10 dB in the Indian sector
during January 2004 to July 2005
Geographic Latitude North
32
28
24
20
16
12
8
J F M A M J J A S O N D J F M A M J J
2004
2005
70
60
50
40
30
20
10
0

— END —