



International Civil Aviation Organization

**THE FOURTH MEETING OF IONOSPHERIC
STUDIES TASK FORCE (ISTF/4)**

New Delhi, India, 05 – 07 February, 2014



**Agenda Item 4: Review of progress of tasks and related action items
(e) Iono Model**

DEVELOPMENT OF IONOSPHERE PREDICTION MODELS FOR INDIAN REGION

(Presented by ISRO, India)

SUMMARY

This paper presents the development of two ionosphere models: Two shell model & a model using Klobuchar-like coefficients for the Indian region. The TEC data from GAGAN network jointly collected by AAI and ISRO was used to validate the two-shell model and to generate Klobuchar-like coefficients for the Indian region. Significant improvement in ionosphere prediction capability over Indian region was observed using both the models.

1. INTRODUCTION

1.1 Two ionosphere prediction models for Indian region were developed using TEC data from GAGAN network.

1.2 The objective was to develop models which may provide better ionosphere prediction capability over the Indian region.

1.3 These two models: Two-shell ionosphere model and a model based on Klobuchar-like coefficients were validated and tested using GAGAN TEC data.

2. TWO-SHELL IONOSPHERIC MODEL

2.1 In SBAS, a near real time grid based Single Shell model is proposed to correct the ionospheric delay at the user aircrafts. Single Shell model is based on the assumption that the whole ionosphere is compressed at a fixed altitude at 350 km.

2.2 This assumption may not be appropriate for the Indian region which falls in Equatorial Ionospheric Anomaly belt. Therefore, a Two Shell model has been developed which incorporates two different shells, at 300 and 500 km altitudes.

2.3 The two-shell model was tested and a statistical comparison between Single and Two Shell models has been done for 72 quiet days of year 2005.

2.4 Figure 1 shows the RMSE at different times of a day for all quiet days of 2005 which include 72 test days from 18 locations spread over Indian region.

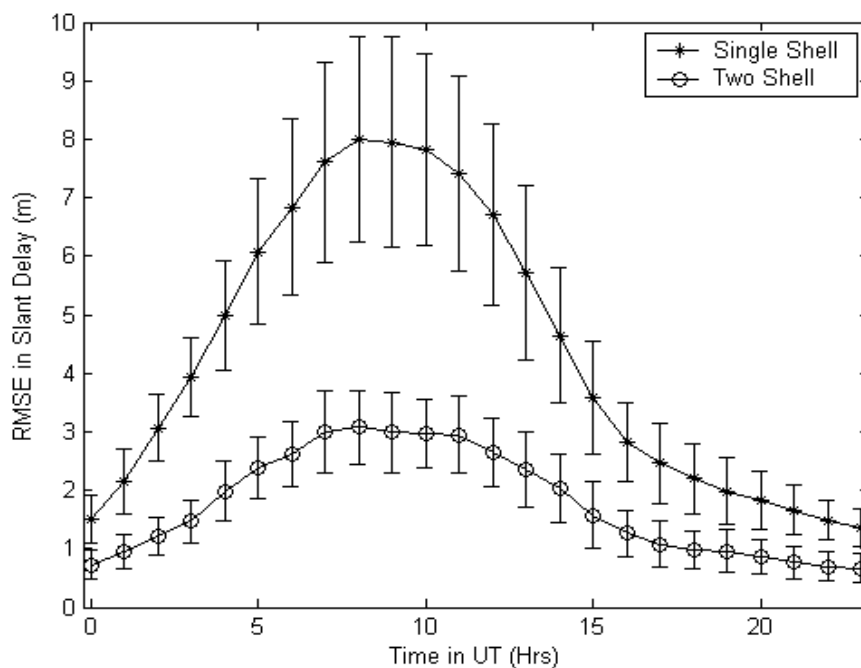


Figure 1: Comparison of RMSE in slant delays (in meters) from Single and Two-shell models for all quiet days of 2005. Vertical bars represent standard deviation.

2.5 In case of Two Shell model, maximum RMSE is only up to 3 meters while in case of Single Shell the error goes up to 8 meters which is of quite high magnitude. This clearly indicates that there is at least 60 % improvement in the performance using Two Shell model for the Indian region.

3 Prediction model with Klobuchar-like coefficients:

3.1 Furthermore, another model was developed in order to provide a more realistic estimate of the ionospheric delay, for near-real-time prediction of ionospheric delay using newly generated (Klobuchar-like) coefficients for the Indian region which are updated at 5 minute intervals.

3.2 To generate new Klobuchar-like coefficients, equation (1) is linearized using Taylor series expansion:

$$T_{iono} = T_{iono}^0 + \sum_{n=0}^3 \frac{\partial T_{iono}}{\partial \alpha_n} d\alpha_n + \sum_{n=0}^3 \frac{\partial T_{iono}}{\partial \beta_n} d\beta_n$$

Using the broadcasted coefficients as an initial guess (T_{iono}^0), ionospheric delay (T_{iono}) is estimated for all visible satellite paths.

3.3 New Klobuchar-like coefficients are obtained by adding the correction terms to the initial guess α and β and are given as below:

$$\alpha_{New}^p = \alpha + d\alpha_p, \quad p = 0, 1, 2, 3$$

$$\beta_{New}^p = \beta + d\beta_p, \quad p = 0, 1, 2, 3$$

3.4 Since the temporal variation of the ionosphere is not significant in 5 minutes, it is assumed that the generated coefficients will remain valid up to the next five minutes. After every five minutes, new set of coefficients will be broadcast. Methodology for the generation and prediction of Klobuchar-like coefficients is illustrated in Fig. 2.

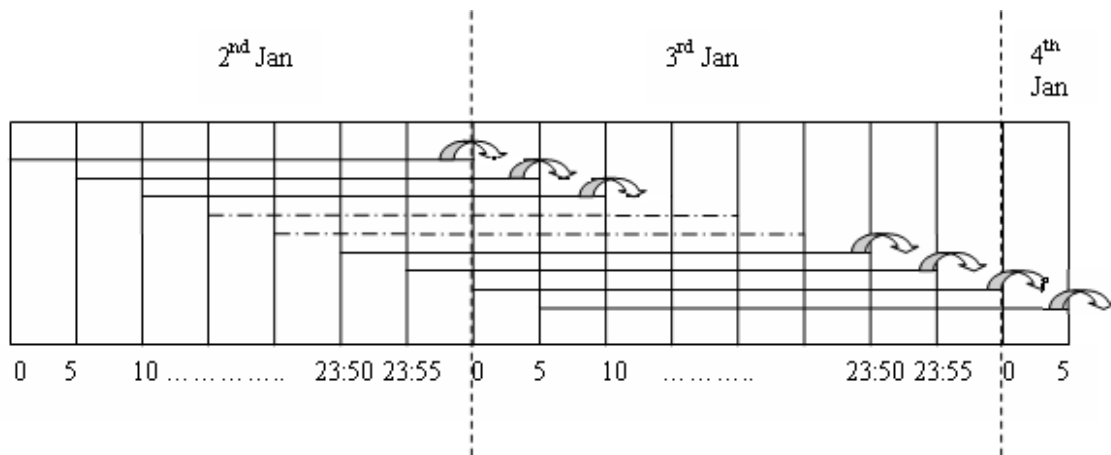


Figure 2: Generation of Klobuchar-like coefficients for near real-time prediction of ionospheric delay.

3.5 Performance of the prediction is evaluated for the geomagnetic quiet (A_p index < 50) days and validation of the model has been done in the absolute positioning mode for both quiet and severely disturbed (A_p index > 300) days of 2005 and 2007.

3.6 Prediction accuracy is significantly improved approximately by 30% using the proposed methodology over the GPS broadcast coefficients.

3.7 Following table provides the improvement in ionospheric delay prediction using Klobuchar-like coefficients. It may be observed that on an average there is approximately 30% improvement in estimation of ionospheric delay for the GPS stations mentioned in the table.

Coefficient Type			
GPS Stations	Statistical Types	Original Klobuchar	New Klobuchar
Shimla (31.1N, 77.1E)	TRMS (m) RCP (%)	2.7230	1.2644 53.57
Delhi (28.6N, 77.2E)	TRMS (m) RCP (%)	2.5308	1.4199 43.90
Jodhpur (26.3, 73.1E)	TRMS (m) RCP (%)	2.4374	1.6883 30.73
Bhopal (23.3N, 77.3E)	TRMS (m) RCP (%)	2.3376	1.8998 18.73
Ahmedabad	TRMS (m)	4.1284	2.5237

(23.1N, 72.6E)	RCP (%)		38.87
Hyderabad (17.5N, 78.5E)	TRMS (m)	1.8409	1.7755
	RCP (%)		3.55
Bangalore (13.0N, 77.7E)	TRMS (m)	1.5339	1.4993
	RCP (%)		2.26
Total Mean	TRMS (m)	2.5046	1.7244
	RCP (%)		27.37%

3.8 Improvement in position accuracy is also obtained using the prediction methodology along with the new coefficients for the Indian region. Following Figure 3 provides the improvement in position accuracy.

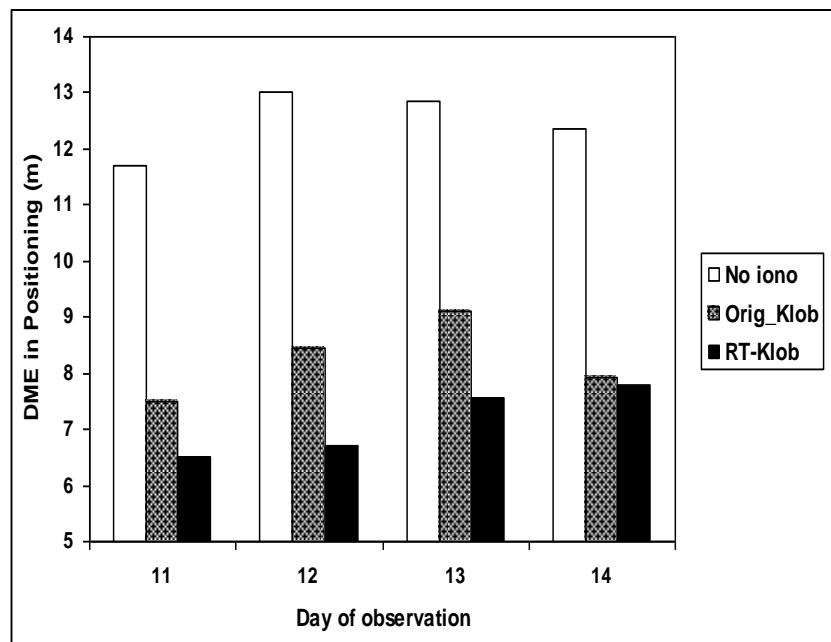


Figure 3: Daily mean error (DME) in positioning (in meters) for four consecutive days from 11-14 September 2005. White bar represents DME without ionospheric delay, checked bar with ionospheric delay using broadcast Klobuchar coefficients and black bar with new Klobuchar-like coefficients.

ACTION REQUIRED BY THE MEETING

- 4.1 The meeting is invited to:
- a) note the results presented in the paper, and
 - b) discuss any relevant matters as appropriate.