MAUSAM, **62**, 1 (January 2011), 97-102

551.501.86

Error handling in GPS data processing

J. K. S. YADAV, R. K. GIRI and L. R. MEENA

India Meteorological Department, New Delhi – 110 003, India

(*Received 3 February 2010, Modified 15 April 2010*)

e mail : jksmet@gmail.com

सार – हम जानते है कि जी. पी. एस. आँकड़ों का संसाधन जी. ए. एम. आई. टी. प्रोसेसिंग सॉफटवेयर के द्वारा किया जाना त्रुटि रहित नहीं है। इनमें से कुछ आँकड़ें प्रोसेसिंग में भिन्न- भिन्न मॉडयूल्स के सहयोग से प्राप्त किए गए हैं। आँकड़ों की गुणवत्ता अनेक कारकों पर निर्भर करती है, जैसे कि मौसम संबंधी उपकरणों की गुणवत्ता, जिससे मौसम संबंधी आँकड़ें प्राप्त होते है, प्रोसेसिंग का एल्गोरिथ्म जो उपकरण संजाल की समरूपता या असमरूपता पर निर्भर करता है एवं स्थान की अवस्थिति अर्थात् वह स्थान विभिन्न दिशाओं में अवरोध रहित है या नहीं। नई दिल्ली, मुम्बई, कोलकाता, गुवाहाटी और चेन्नै के जी. पी. एस. स्टेशनों के वर्ग माध्य मूल त्रुटियाँ स्थानिक रूप से आपस में संबंधित होती हैं और उपग्रह के उन्नयन कोण के अनुसार इनके प्रेक्षण प्राप्त किए जाते है। नई दिल्ली में वर्ष 2008 के मॉनसून के दौरान कुल वर्षणीय जलवाष्प (आई. पी. डब्ल्यू. वी.) की दैनिक भिन्नता 45 मि. मी. से 65 मि. मी. के बीच दर्शाई गई है।

ABSTRACT. We are aware that the processing of GPS data through GAMIT processing software is not free from errors. Some of them are generated due to different modules involved in processing. The data quality depends so many factors, like quality of met-instrument, which supplies the meteorological data, algorithm of processing which based on the network homogeneity or heterogeneity and location of the site, whether it is free from multi-path etc. The root mean square errors for New Delhi, Mumbai, Kolkata, Guwahati and Chennai GPS stations are spatially correlated and observations are weighted according to the satellite elevation angle. Diurnal variability of Integrated Precipitable Water Vapour (IPWV) has been shown its range from 45 mm to 65 mm for New Delhi during the monsoon season, 2008.

Key words – International GPS Service (IGS), Stochastic model and GNSS.

1. Introduction

In Weather forecasting, various sources of data describing the atmospheric systems and processes are used. The GPS precipitable water vapour data is used in wide range of applications in meteorology, and its diurnal trend is useful in exploring the phases of weather systems, like summer monsoon in this work. Bouma and Steow, 2001, used point-to-point GPS data processing in summer season. Systematic and random errors are modeled by functional and stochastic model approach. The functional approach describes the mathematical relationship between the GPS observations and the unknown parameters, while the stochastic model describes the statistics of the GPS observations (Leick, A. 1995). Many troublesome GPS biases can be removed by functional model approach by differencing and an unmodelled bias, which is not removed by differencing need stochastic model.

Presently, near real time processing of GPS data is using the double-differenced GPS carrier phase measurements based on the least-squares (LS) principle for positioning but this is not free from systematic and random errors. The systematic errors are modeled through functional models but the random errors are realistic errors, stochastic modeling of these errors is very difficult task. Incorrect stochastic modeling will lead to unreliable estimates, which affect the overall accuracy of the measurements.

Tiberius and Kanselaar (2000, 2003) considered satellite elevation dependent, time-correlation and cross-correlation of the GPS observables. The setting of the elevation cut off angle for this study is 15°. These spatial and temporal correlations in the observations are a function of baseline length and arise from errors caused by the satellite and receiver clock, troposphere, ionosphere

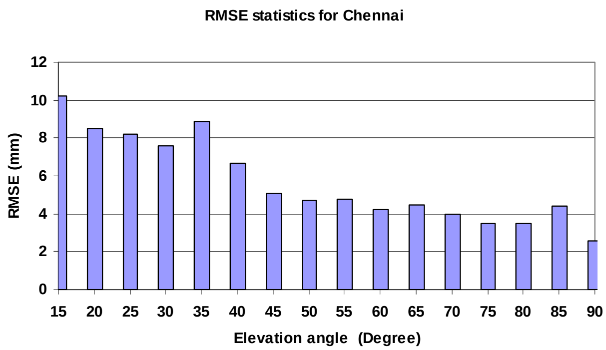

Fig. 1. RMSE (mm) in range measurement for Chennai

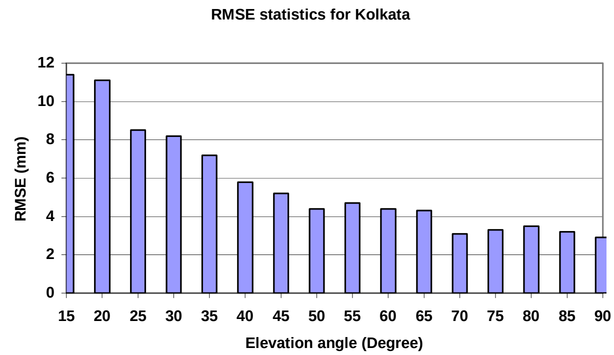

Fig. 4. RMSE (mm) in range measurement for Kolkata

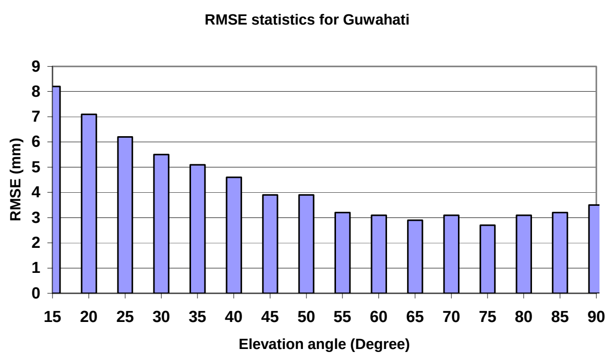

Fig. 2. RMSE (mm) in range measurement for Guwahati

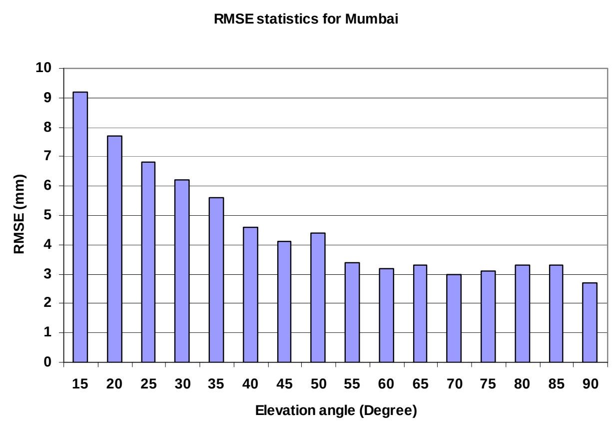

Fig. 5. RMSE (mm) in range measurement for Mumbai

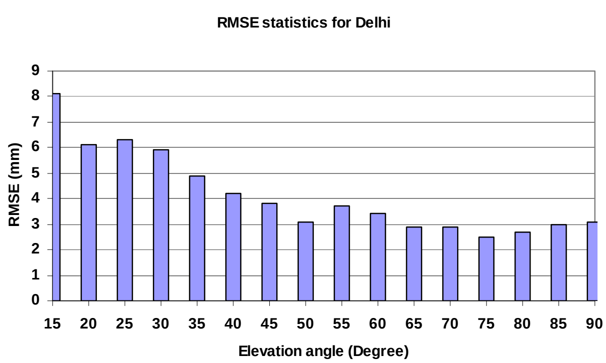

Fig. 3. RMSE (mm) in range measurement for Delhi

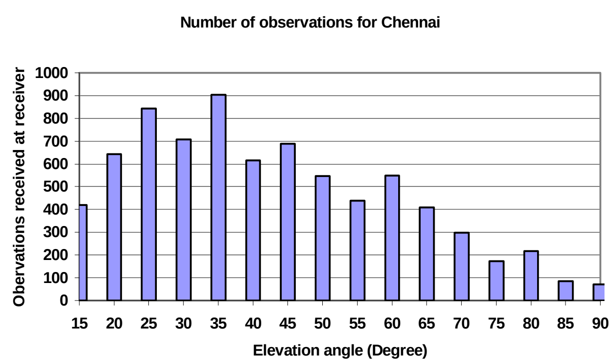

Fig. 6. Elevation angle histogram for Chennai

and orbits. The spatial correlation between the measurements is the basis for the double differencing procedure, whereby one receiver is positioned relative to another receiver with known coordinates but it is very difficult to estimate (Hofmann-Wellenhof *et al*., 1993). In this present study, we have neglected the spatial correlation estimates. The temporal correlation mean that one ground based receiver receives the signal from at least two satellites almost at the same time.

2. Data and methodology

GNSS raw observations data in Receiver Independent Exchange Format (RINEX for five stations have been taken from India Meteorological Department, Lodi Road New Delhi. The observation data is processed using the GAMIT 10.3.1 software (King and Bock, 1999). From the raw data file troposheric delay parameter is

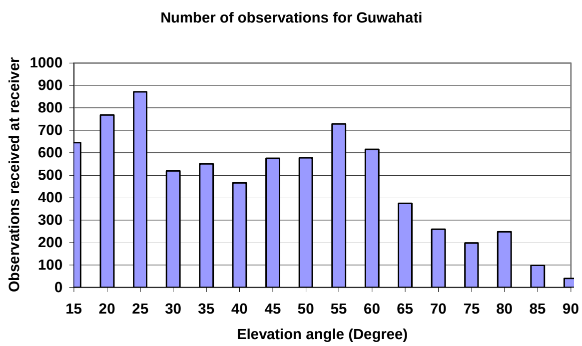

Fig. 7. Elevation angle histogram for Guwahati

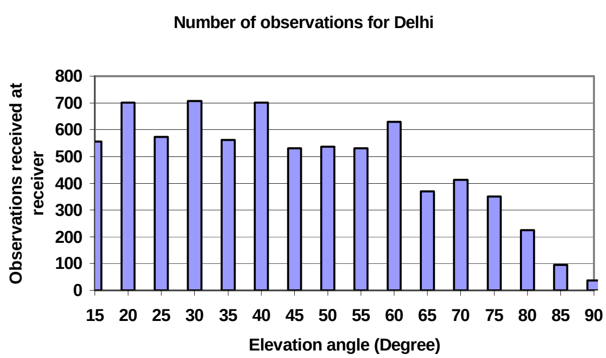

Fig. 8. Elevation angle histogram for Delhi

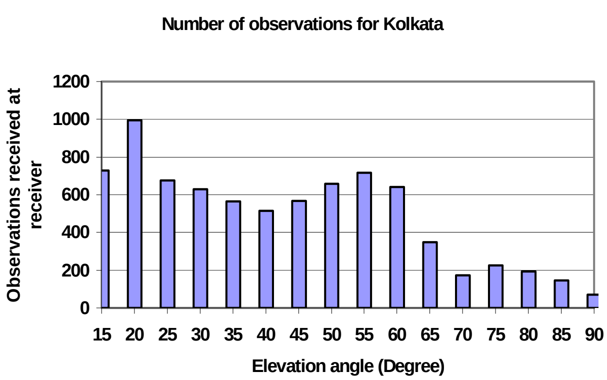

Fig. 9. Elevation angle histogram for Kolkata

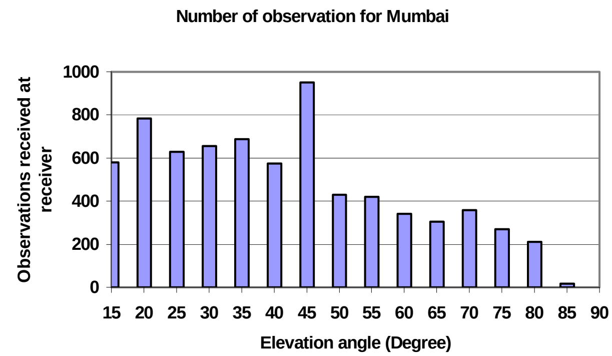

Fig. 10. Elevation angle histogram for Mumbai

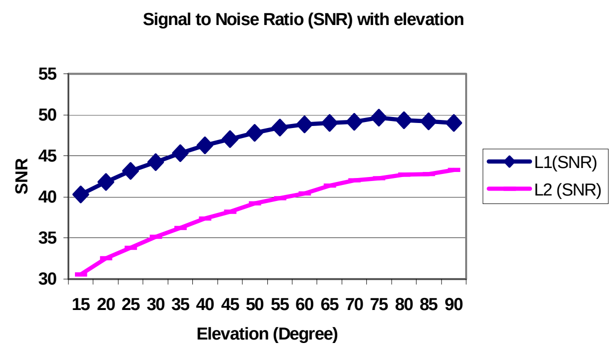

Fig. 11. Elevation dependent SNR values for both L1 and L2 GPS signals

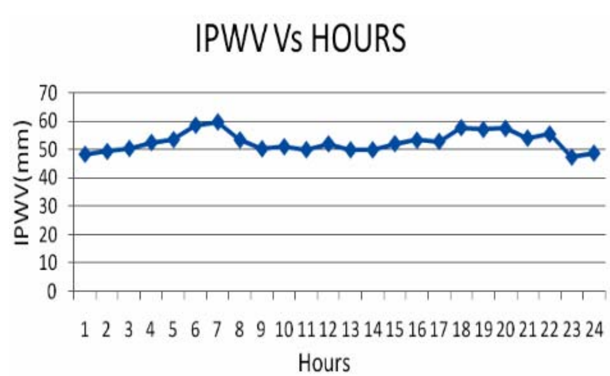

Fig. 12. Diurnal variability of IPWV (mm) for New Delhi (June, 2008)

extracted which is further processed by double difference method for Integrated Precipitable Water Vapour (IPWV).

3. Analysis of results

From double differences, linear combinations of observations on two wavelengths have been made which is used to eliminate the ionospheric errors. If the baseline length is more than or equal to 100 km then accuracy of the positioning is affected because the lower amount of observations common for both sites building the baseline. In the GAMIT processing a variance-covariance (VC) matrix of zero order difference for raw observations is made (Mikhail, 1976). It is assumed that all the measurements are independent and having the same variance. But this assumption is not true due to unmodelled or residual errors having varying noise levels in the doubly differenced observable.

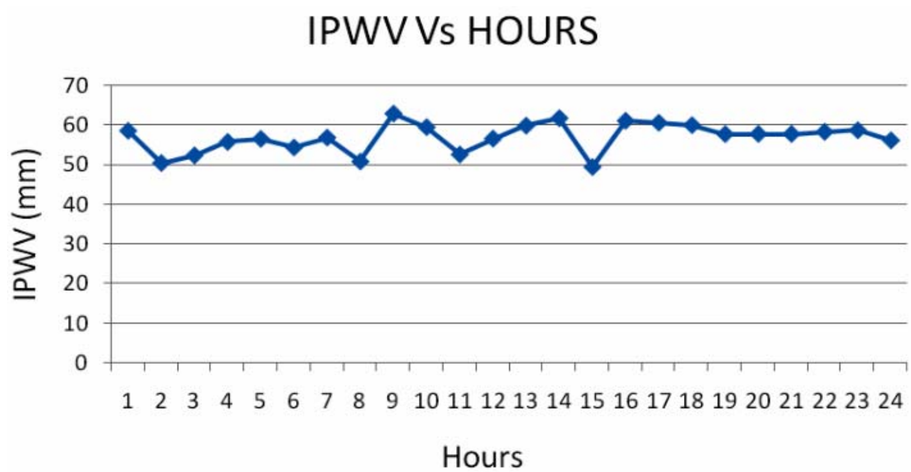

Fig. 13. Diurnal variability of IPWV (mm) for New Delhi (July, 2008)

Fig. 14. Diurnal variability of IPWV (mm) for New Delhi (August, 2008)

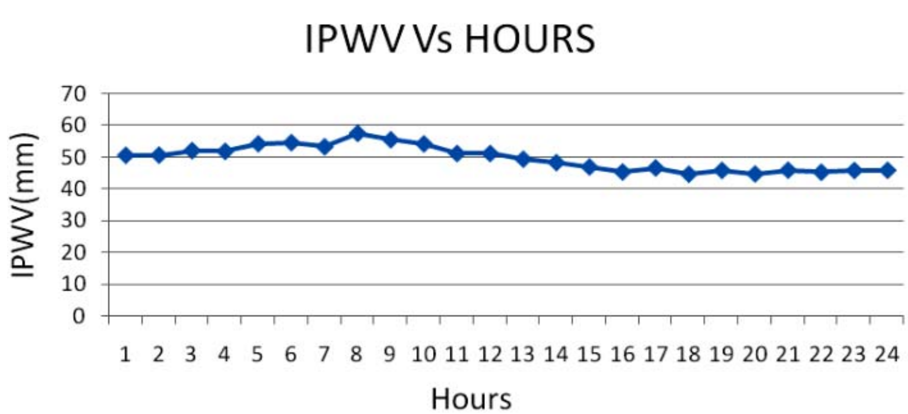

Fig. 15. Diurnal variability of IPWV (mm) for New Delhi (September, 2008)

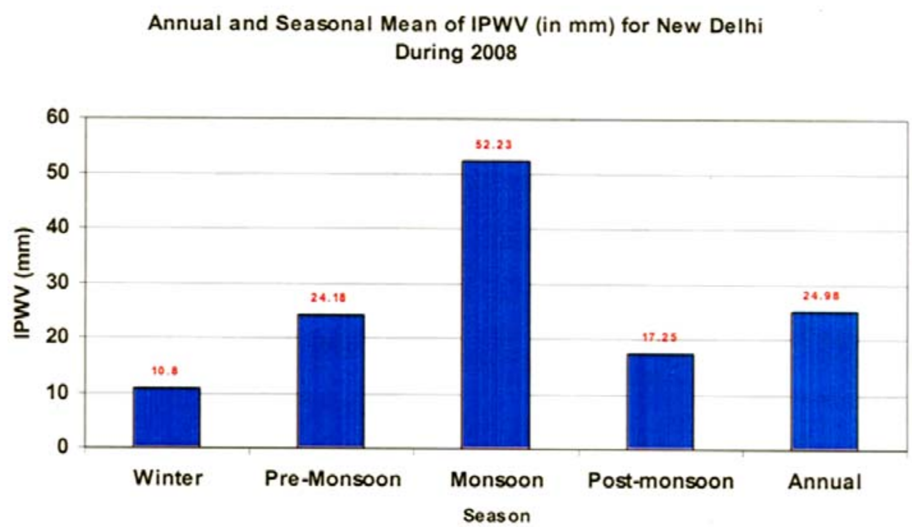

Fig. 16. Annual and seasonal variation of IPWV (mm) for New Delhi, 2008

TABLE 1

Baseline length dependent weighting

S. No.	Name of Baseline	Length in meter	RMSE in meter	RMSE after post fitting the model in meter
1.	Chennai-Guwahati	1861310.64	0.00912	0.00632
2.	Chennai-Delhi	1741263.27	0.00752	0.00587
3.	Chennai-Kolkata	1350289.93	0.00793	0.00521
4.	Chennai-Mumbai	1022902.15	0.00735	0.00396
5.	Guwahati-Delhi	1444136.08	0.00961	0.00561
6.	Guwahati-Kolkata	515138.66	0.00665	0.00353
7.	Guwahati-Mumbai	2078063.75	0.01079	0.00749
8.	Delhi-Kolkata	1299045.58	0.00905	0.00749
9.	Delhi-Mumbai	1161670.13	0.00567	0.00433
10.	Kolkata-Mumbai	1660166.70	0.0100	0.00657

3.1.1. *Diurnal variation of IPWV (mm)*

The diurnal variation of monsoon season, 2008, IPWV of New Delhi has been shown in the (Figs. 12-15). The trend of June and September months is almost the same and the IPWV values lies from 45-60 mm. During the active phase of monsoon the IPWV values lies from 60-65 mm.

3.1.2. *Annual and seasonal variation*

The annual and seasonal mean of IPWV (mm) for New Delhi during 2008 indicates that the annual mean is equivalent to that of the pre-monsoon season and during monsoon season it is maximum (Fig. 16).

3.2. *Satellite elevation angle dependent weighting*

Systematic errors in GPS measurement are related to the signal to noise ratio, atmospheric delay and multi path errors, which may be closely connected to satellite elevation angles. The effects of these errors are different for each satellite. Therefore GPS measurements from different satellites may not have the same accuracy. In the present paper the following satellite angle based sine function proposed by (King and Bock, 1999) is used.

$$\sigma^2 = A^2 + B^2/[\sin(elv)]^2$$

Where, σ^2 is the variance in raw GPS measurements, A and B are constants.

The root mean square (mm) statistics in range (Satellite to receiver) for five GPS stations are shown in the (Figs. 1-5) along with the elevation angle histograms (Figs. 6-10). It is seen from the graphs that the RMSE values are higher at lower elevations, it may be due to the multi-path signal errors. So, we can say that the site for the new installation of GPS stations should be away from tall buildings, trees and other satellite antennas to avoid interference.

3.3. *Baseline length dependent weighting*

From Table 1 it is clear that, the estimation error in baseline length is reduced appreciably after using the elevation dependent stochastic model approach. The reference value used in Table 1 is the fitting solution of three years daily position estimates of the IGS solution processed by Scripps Orbit and Permanent Array Centre (SOPAC) USA. The sine angle dependence of the model is sensitive to tropospheric measurements. It is suitable for Integrated Precipitable Water Vapour (IPWV) measurement from tropospheric time delay.

3.4. *Signal to Noise Ratio (SNR)*

The L_1 (1.5 GHz) L_2 (1.2 GHz) signals affected by the atmosphere and are the key parameters for GPS receiver performance, which directly affects the precisions of GPS observations (Langley, 1997). For GPS observations SNR is introduced as a quality indicator and used in constructing the stochastic model for high accuracy applications. The idea is that each satellite has a different precision, which is dependent on the SNR information. The satellite that has a high SNR value will be less noisy than the satellite with a low SNR value. For the present stochastic model approach the SNR values at different elevations are shown in the Fig. 11.

4. Conclusions

(*i*) The IPWV of New Delhi trend for June and September months lies between 45-60 mm and during the active phases of monsoon in July and August the IPWV values lies between 60-65 mm.

(*ii*) The root mean square error (RMSE), decreases as the satellite elevation increases. It may be due to multi-path errors which contribute more at lower elevations.

(*iii*) The strength of the satellite signals in terms of Signal to Noise Ratio (SNR) increases with the elevation for both the frequencies L_1 & L_2.

References

Bouma, H. R. and Steow, B., 2001, "GPS observations of daily variations atmospheric water vapour content", *Phys. Chem, Earth*, **26**, 389-392.

Hofmann-Wellenhof, B., Lichtenegger, H. and Collins, J., 1993, "GPS Theory and Practice", Second edition, Springer-Verlag.

King, R. W. and Bock, Y., 1999, "Documentation for GAMIT GPS analysis software", Mass Ins. of Tech., Cambridge Mass.

Leick, A., 1995, "GPS Satellite Surveying", John Wiley & Sons, Inc., New York, N.Y.

Langley, R. B., 1997, "GPS receiver system noise", *GPS World*, **8**, 40-45.

Mikhail, E. M., 1976, "Observations and Least Squares", IEP, New York.

Tiberius, C. C. J. M. and Kanselaar, F., 2000, "Estimation of the stochastic model for GPS and phase observables", *Surv. Rev.*, **35**, 277, 441-454.

Tiberius, C. C. J. M. and Kanselaar, F., 2003, "Variance component estimation and precise GPS positioning: Case study", *J. of Surveying and Eng*., **129**, 1.