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DEVELOPING NEAR REAL TIME TEC COMPUTATION SYSTEM FROMGPS OBSERVATION FOR IMPROVING SPATIAL RESOLUTION OBSERVATION OF IONOSPHERE OVERINDONESIA

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Abstract

Ionosphere above Indonesian stretches about 5,120 km toward longitude, and about 1,760 km toward latitude. Assuming that the spatial variation of the ionosphere has a 500 km in longitude direction, and 250 km in latitude direction, by ignoring difficulties of GPS observation from see surface, the required minimum of GPS station in Indonesia is about 72 stations for ionosphere observations with enough spatial resolution. National Institute of Aeronautics and Space (LAPAN) has only several stations that available for GPS receiver site, so that ionosphere observations independently by LAPAN does not meet user needs of spatial resolution of ionosphere observation by using GPS receiver. Hence GPS station operated by other institutions is needed for ionosphere observation. But the GPS TEC data is not yet available at institutions other than LAPAN where most of the GPS data is stored in rinex format. Therefore, it needs a strategy for GPS data management from other institutions so it can be used for ionosphere observations nationally. As a first step, the near real time TEC computing systems has been developed from GPS data established by Geospatial Information Agency (GIA). This paper discusses the GPS-based TEC computing system and its potential application and development to meet the needs of ionosphere data in spatial resolution.

***Key Words**: GPS, ionosphere, observation, resolution, spatial.*

1. Introduction

Ionosphere above the Indonesia cover areas ranging from 11^0S to6^0N and from 97^0E to 141^0E or about from 5,120 kilometers from west to east and 1,760 kilometers from south to north. The ionosphere in the region of about 17 X 144 square degrees over Indonesia is at low latitudes region in the southern part where the peak anomaly is often greater than the peak of the northern part of the equatorial ionosphere anomalies.

For middle latitudes ionosphere conditions can be considered homogeneous within a radius of 500 miles or about 5 degrees. But in Indonesia, especially towards the latitude those assumptions are not entirely correct. Especially during the peak of the equatorial ionization anomaly occurred from noon until late afternoon. With a number of stations around 7 of LAPAN Space Observation Station, installation of equipment for ionosphere observation at all observation sites of LAPAN will not meet the needs of spatial resolution and coverage of observations of ionosphere in Indonesia. Therefore it is necessary to use GPS data from other institutions in Indonesia for ionosphere observation. But the GPS data from the other institutions is still in rinex format so that the GPS TEC is not yet available. Therefore, it needs the computing system of the ionosphere TEC from GPS data.

Buldan (2009) have developed near real TEC computation system TEC from GPS data operated in Singapore by NTUS that provides GPS data every hour and downloadable via the internet. The method should to be developed so that it can be used for computing ionosphere TEC from GPS data. To be able to run automatically computing TEC from GPS data of NTUS need a stable internet connection with enough speed. Only the GPS data from the IGS of which there are two in Indonesia (BAKO and SAMP), one in Singapore (NTUS) and one in Christmas Island (XMAS), a spatial resolution of GPS TEC observations is inadequate to the ionosphere above the Indonesian so that the GPS data in other institutions should also be developed.

Fortunately Geospatial Information Agency (GIA) has developed a network of GPS observations in Indonesia which can be obtained in real-time. Latest Status BIG number of GPS stations in 2009 that as many as 51 Operational GPS receivers spread all over Indonesia (Abidin, 2010) . But the GIA GPS data can not directly be used to get ionosphere parameters. Therefore we develop TEC computation system from the GPS data so that an increase in spatial resolution observations of the ionosphere above Indonesian can be obtained.

2. Equipments, Data, and Method

2.1. Hardware and Software

Equipments used to build computing systems of GPS TEC are the PC located in GIA to process the GPS data in rinex format, GPS data server located in LAPAN to store the GPS combination data, and PC or LAPTOP to estimate and store GPS TEC data. Software used are combiner.exe to read and process the GPS data that resulting combination of phase and code data on L1 and L2 frequencies, fling software to transfer the GPS combination data from PC at GIA to GPS data server at LAPAN, and tecer.exe to estimate GPS TEC and store its results.

2.2. Method

Every hour the GPS data are stored in RINEX format on GIA PC then pseudo range and carrier phase on L1 and L2 frequencies (P1 or C1, P2 and L1, L2, respectively) are extracted, and GPS combination data between L1 and L2 observation are derived. The GPS combination data are automatically uploaded to GPS data server in Space Science Center by using fling software. Combination of GPS data is always detected at data server in LAPAN. If the new GPS combination data are detected, the tecer automatically read and process it to estimate GPS TEC. The detailed GPS TEC computation methodology is as follows.

2.2.1. Extraction of Code and Phase Data from GPS Rinex Data

Code and phase data extraction from GPS rinex data is aimed to get code data of P1(or C1) and P2, L1and L2phase data in the form of a matrix where the column and row show the number of satellite and epoch of observation respectively.

2.2.2. Combination of Code and Carrier Phase on L1 and L2 Frequency.

Combination of P1 or C1 code data (satellite to receiver distance observed at L1 frequency) and P2 (satellite to receiver distance observed at L2 frequency) in the form of the difference between C1 with P1 or P2 is

$$P_{1,2} = P_1 - P_2 \tag{1}$$

The combination of range data obtained from the carrier phase observed in the number of cycles of the carrier wave on L1 and L2 using the equation

$$\Phi_{1,2} = \lambda_1 L_1 - \lambda_2 L_2 \tag{2}$$

Where λ1 and λ2 respectively are the wavelength at the frequency of L1 and L2, L1 is the number of cycles observed by the receiver on L1frequency and L2 is the number of cycles observed at receiver on L2 frequency.

2.2.3. TECEstimation

After combination of GPS data obtained from the Eq. (1) and (2), the value of Slant Total Electron Content (STEC) can be estimated from the equation for code STEC ($STEC_k$), STEC from GPS phase data ($STEC_f$) and STEC from a combination of code and phase GPS data ($STEC_{sm}$)respectively[3)]:

$$STEC_k = \frac{f_1^2\left[(P_1 - P_2) - b_p - B_p\right]}{40{,}3(1-\gamma)} \tag{3}$$

$$STEC_f = \frac{f_1^2\left[(\lambda_1\Phi_1 - \lambda_2\Phi_2) - (\lambda_1 N_1 - \lambda_2 N_2) - b_f - B_f\right]}{40{,}3(1-\gamma)} \tag{4}$$

$$STEC_{SM,N} = \frac{f_1^2\Phi_{1,2}}{40{,}3(1-\gamma)} + \frac{1}{N}\sum_{n=1}^{N}\left(\frac{f_1^2\left[P_{1,2} + (\Phi_{1,2})\right]}{40{,}3(1-\gamma)}\right) + \frac{f_1^2(-b_p - B_p)}{40{,}3(1-\gamma)} \tag{5}$$

Where f_1 is carrier wave frequency on L1,f_2 is carrier wave frequency on L2, γis the ratio between the frequency f_1 to f_2 (= f_1/f_2), b_p and B_p are differential code bias (DCB) between P1 and P2 for receiver and satellite respectively.

2.2.4. Data Synchronization

GPS data resultlted from the combination of GPS code and phase observations are automatically stored in a folder on the combiner PC located at Geospatial Information Agency of Indonesia (GIA). The GPS combination data are automatically synchronized with GPS combination data server at Space Science Center of LAPAN in Bandung by using synchronization software, fling. Whenever there are new GPS combination data, combiner.exe automatically reads rinex data to obtain GPS observations; P1 or C1, P2, L1, and L2, then combine them according to the equation (2-1) and (2-2) and its results are stored in files whose name are same as the files name of rinex files unless the extension are changed from o to c that shows GPS rinex data format (o) to GPS combination data (c). Then the GPS combination files (c file extension)are automatically uploaded to GPS combination data server at Space Science Center in Bandung, if there are new GPS combination data detected on the combiner PC at GIA.

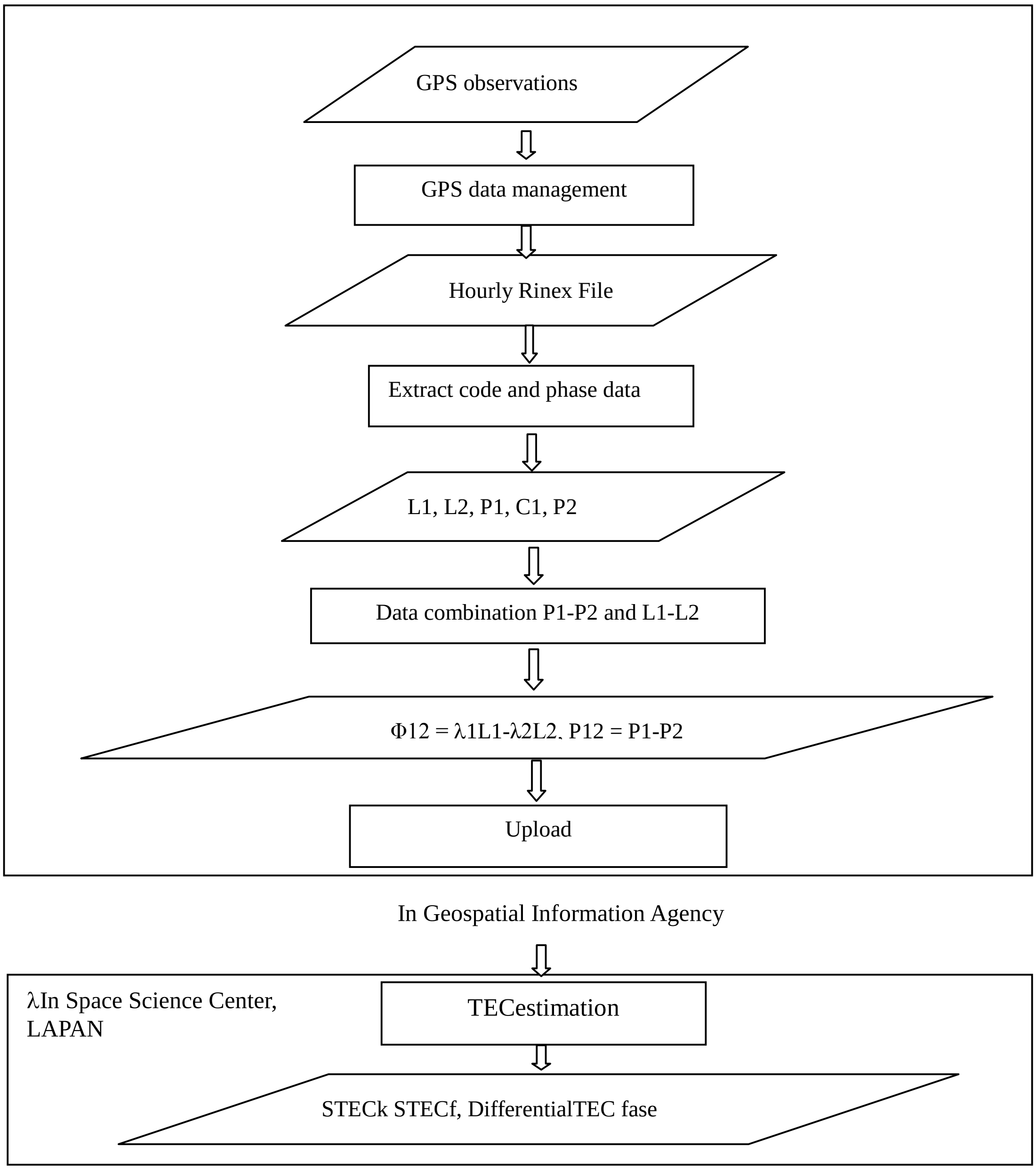

Fig. 1. Flowchart of TEC computation system

2.2.5. GPS TEC Data Formating and Storing

TEC data calculated by Eq. (3), (4) and (5) are stored in ASCII format with mXn matrix structure, where m indicates the number of rows according to the epoch of observation, and n shows the number of columns that consist 11 columns, from first to last column are hour, minute, second, latitude, longitude, elevation,prn, STECk, STECf, DSTECf, and STECsm. Last four columns of each of the data are STEC derived from GPS code data, STEC derived from GPS phase data, the differential phase TEC, and STEC from combination of code and phase of GPS data.The algorithm of the TEC computing system from GPS observations are shown in Fig.1.

2.2.6. Integration and Automatization

GPS TEC computation system is consist sub-systems from GPS data management, combination of GPS data at combination PC in GIA in Cibinong, transfer its resultsto server data at Space Science center in Bandung, and files storage server of GPS TEC data.The each sub system and part of the process are integrated, so that the processes are automatically running from combining, transferring estimating TEC, naming files and the storing the TEC data at TEC server data.

Automation is based on file detection in folder where software works. GPS combination data are stored in separate folders according to the year and the number of days of year. Data that has been stored in a folder are then detected by the software fling and automatically uploaded to the Space Science Center and can be accessed from ftp://foss.dirgantara-lapan.or.id.

3. Results and Discussions

Naming files of GPS combination data are same with naming RINEX data files except the last extension used is the letter C (initial letter of combination). So the rinex format of GPS data, for example ckup252a.13, after reading the code and phase data, combiner.exe creates 6 files of GPS combination data; csem252aP12.13c, csem252aP21.13c, csem252aL12.13c, csem252aL21.13c, csem252apos.13c and csem252aepok.13c . Additional P12 and P21 in the file naming to distinguish P1-P2 and P2-P1, as well as L12 and L21. Addition epok name and posin files pf combination are to store the time and position of GPS observation. Fig. 2 shows an example of the GPS combination data for GPS station in Kupang (ckup) on 10 September 2013 at 01:00 UT.

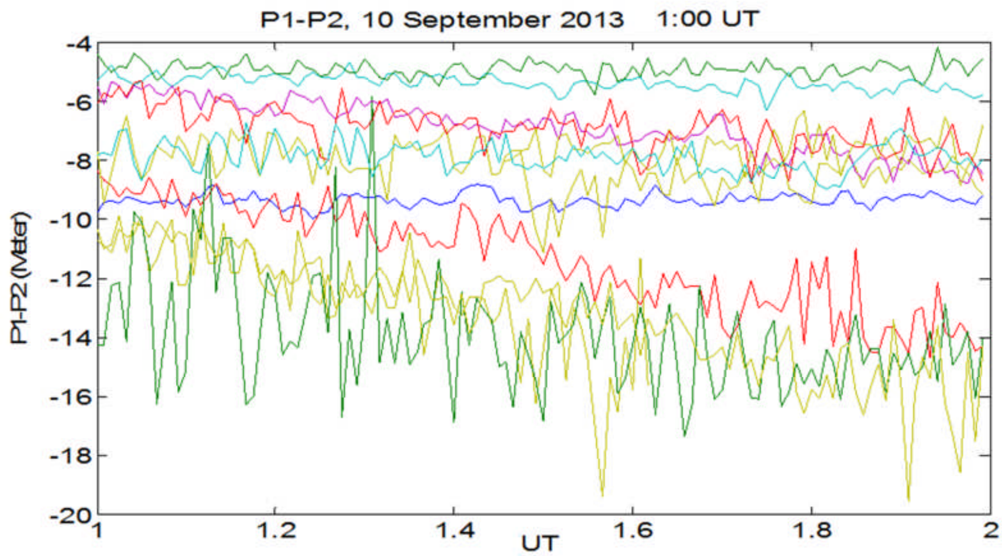

Fig. 2. Result of GPS combination data, P1-P2 on September 10, 2013 at 1:00 UT from CKUP GPS station.

The file extension of GPS combination data is YYC where YY indicates the last two digits of the year and c show combination, is detected by software teccalcutator.exe. If there are set of GPS combination data in the folder, teccalculator.exe will converts it to the TEC and creates TEC file from GPS observation on 10 September 2013 at 8 UT with name csem253b. 13T. Example of teccalculator.exe output for GPS data of 10 September 2013 is shown in Fig. 3.

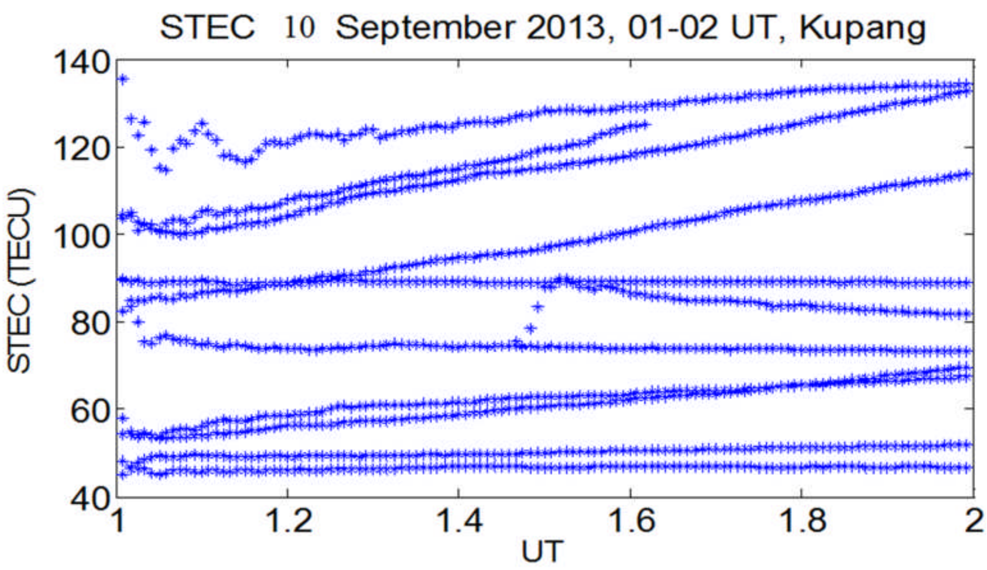

Fig. 3. STEC from CKUP (Kupang) GPS station, September 10, 2013 from 01:00 -02:00 UT.

For one day for all satellites, as it can be seen in Figure 3-3, diurnal variation of STEC reaches a maximum and minimum at certain hours. STEC usual reach same minimum value that is not dependent on location before sunrise between 03-05 LT and reach maximum value that depending on the location caused by geomagnetic control, where it is usually at low latitude regions occur in interval of 12-16 LT.

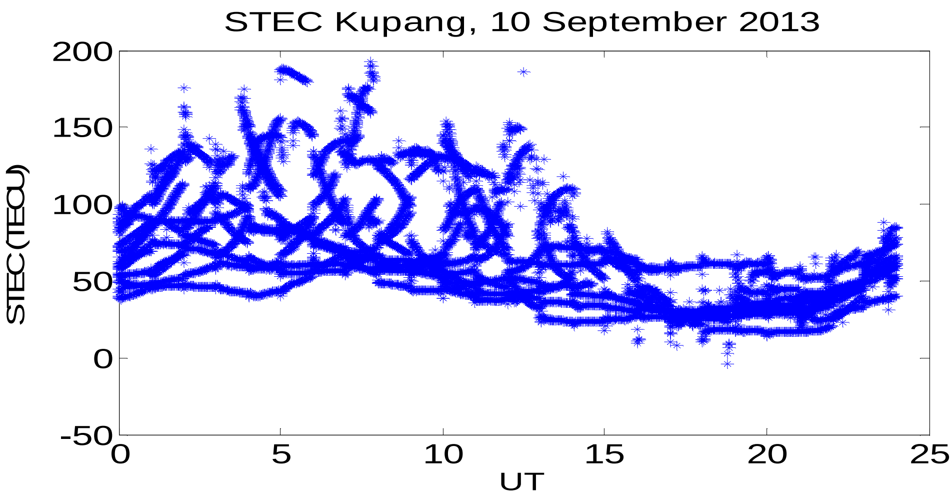

Fig. 4. STEC Kupang, September 10, 2013

The teccalculator.exe that automatically detects GPS combination data is installed on LAPTOP or desktop computer so that estimation process from GPS combination data to GPS TEC can be done anywhere and anytime as long as internet connection available.

Fig.5 shows the GPS satellite distance from BAKO station on March 1, 2011 from C1 code GPS signal and Fig. 6shows the GPS satellite distance from P2 code observations. But both observations does not clearly show the difference after passes through the ionosphere due to its effect on GPS signal is very small compare with the GPS satellite to the receiver. Fig. 7 shows that ionospheric effects became clear especially around 09:00 UT (16:00 LT) from C1-P2. After GPS phase data combination as shown inFig. 8, L1-L2is more smoothly thanC1-P2, but on a small elevation angle , the slip cycle is more frequentlydetected

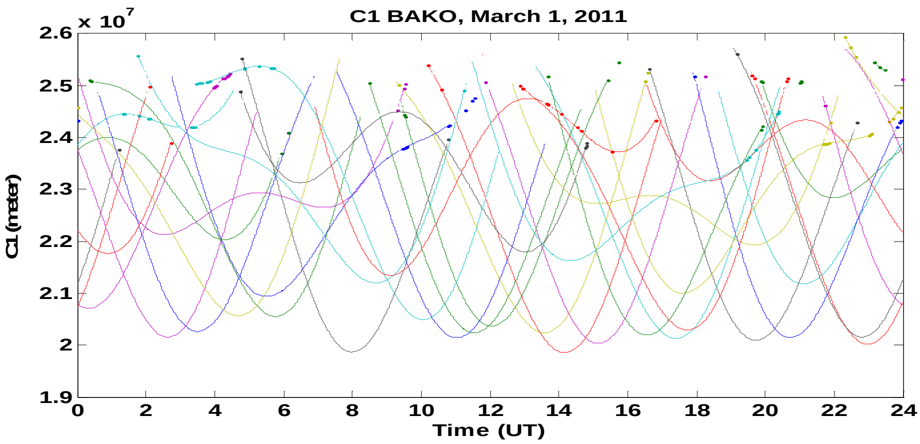

Fig. 5. Range observation of satellite from BAKO GPS station using C1 GPS code data.

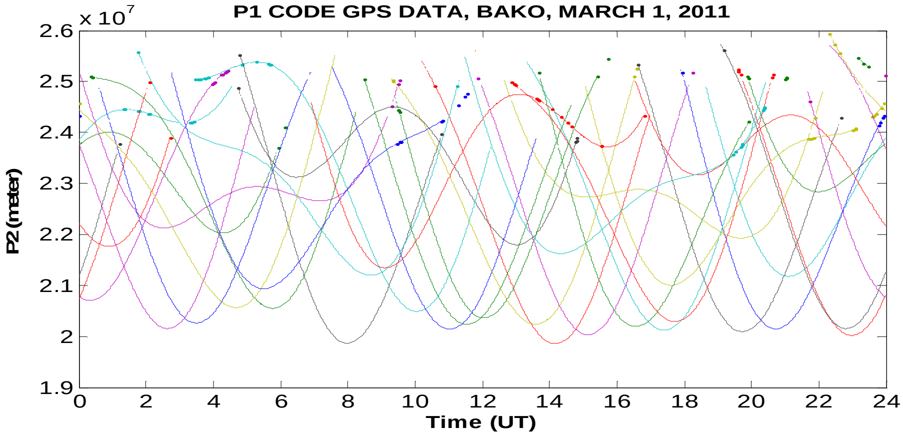

Fig. 6. Range observation of satellite from BAKO GPS station with P2 GPS code data.

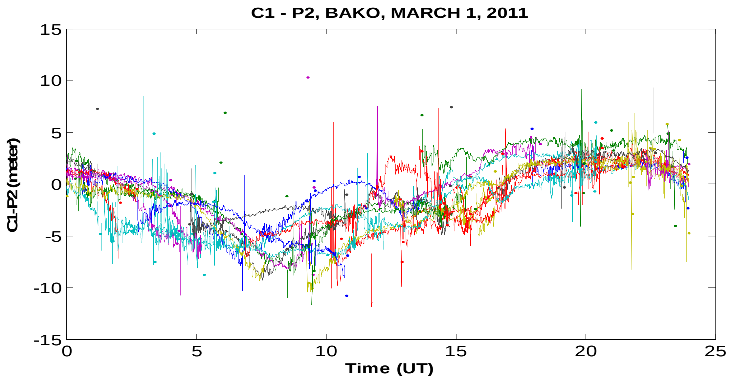

Fig. 7. GPS data combination, C1 - P2 on March 1, 2011

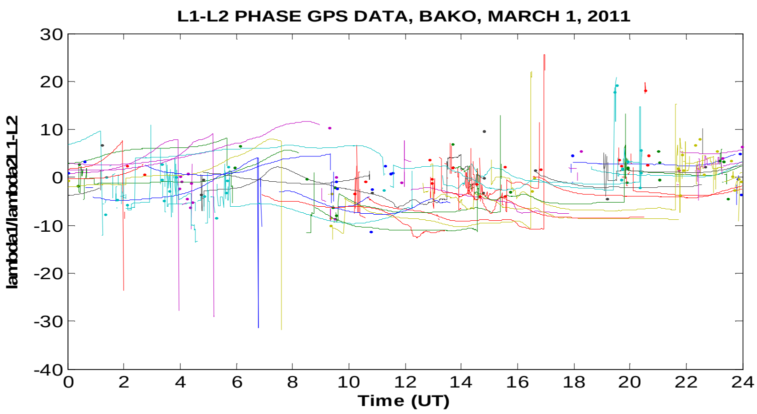

Fig. 8. Difference of range fom carrer phase observation, between L1 and L2, $\frac{\lambda_1}{\lambda_2}(L1-L2)$.

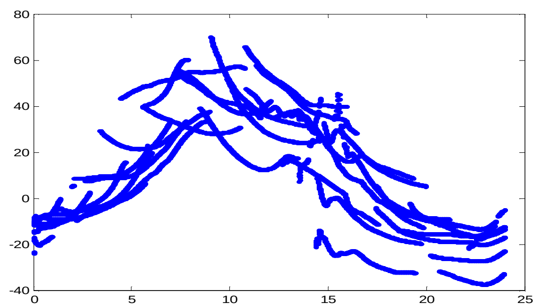

Fig. 9. STEC sm derived from STEC code and STEC phase.

Fig. 9 shows the STEC value that has been smoothed by phase (phase leveling method) as expressed by Eq. (5). STEC is raw TEC data that still have bias from satellite hardware as well as receiver hardware. The STEC data is stored in ASCII format with a structure as shown in Figure 3-9. In data file from column 1 to 11 show hours (H), minutes (min), second (Sec), latitude (Lat), longitude (long), elevation (elev), satellite number (prn), STEC code (STECp), STEC phase (STECph), Differential phase STEC (DSTECph) and STEC code smooted by phasen data (STECsm).Figure 3-10 shows that STEC from GPS code only contain more noise than the STEC from code smoothed by phase.

1	2	3	4	5	6	7	8	9	10	11
H	Min	Sec	lat	long	elev	prn	STECp	STECph	DSTECph	STECsm

Fig. 10. Formatand structure of GPS TEC data

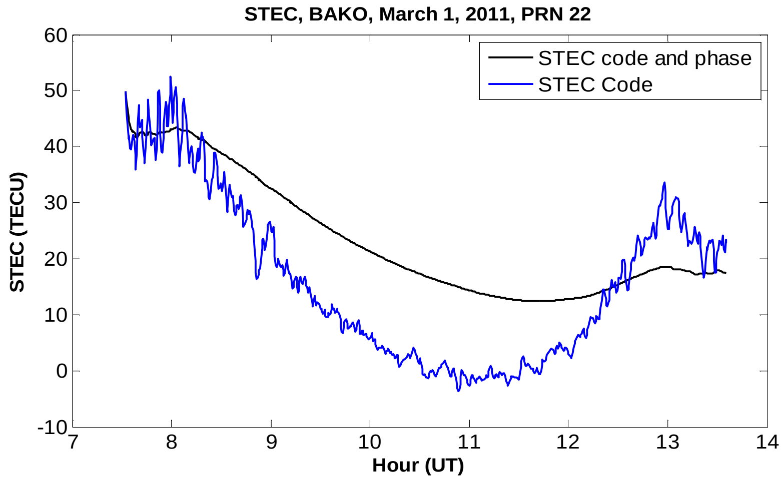

Fig. 11. STECcode and its comparison with TECsm.

4. Conclusion

In an attempt to increase the resolution of ionosphere observations, the near real time TEC computing systems have been developed from GPS data operated by Geospatial Information Agency. The system consists of 3 computers, each of which serves to GPS data processing and its conversion to a combination of GPS data and transfer the data to a computer server at Space Science Center of LAPAN in Bandung, and a computer used to detect incoming GPS combination data and calculate TEC from these data. The system has run smoothly and the GPS data can be accessed from ftp://foss.dirgantara-lapan.or.id. The TEC computing systems that are developed are more flexible than the earlier developed systems since it does not need to be connected continuously with the internet to detection of GPS data execution time but using a new GPS data detection in a folder during computing TEC. The constraints of the existing system in generating data TEC which includes over Indonesia's license software for GPS in addition to Topcon are not permitted to generate data every hour. So until now the number of GPS data that are processed for the computing TEC is limited to ten stations using top con GPS.

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