GNSS Applications for Space Weather Monitoring in Indonesia

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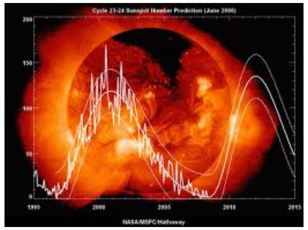
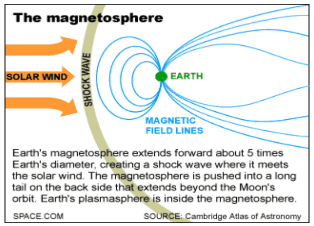
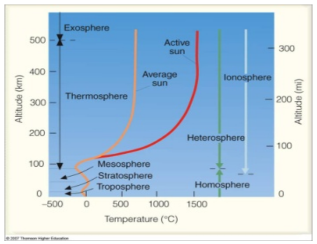
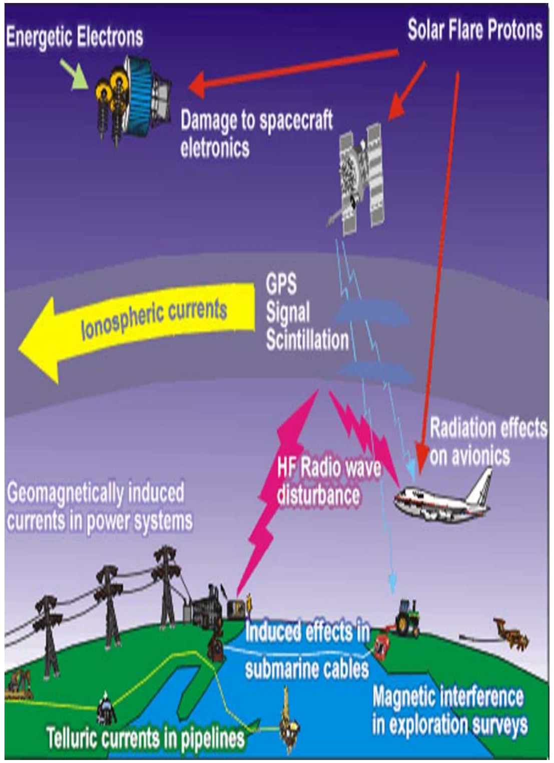
1. SPACE WEATHER

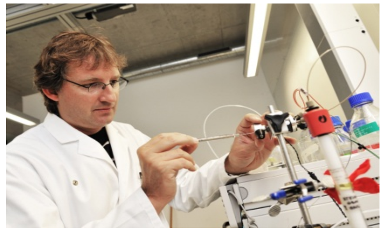
The conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.

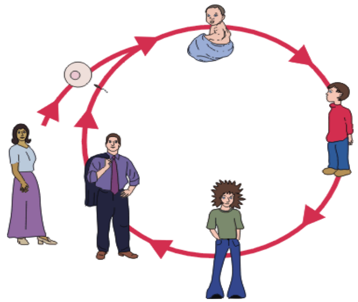




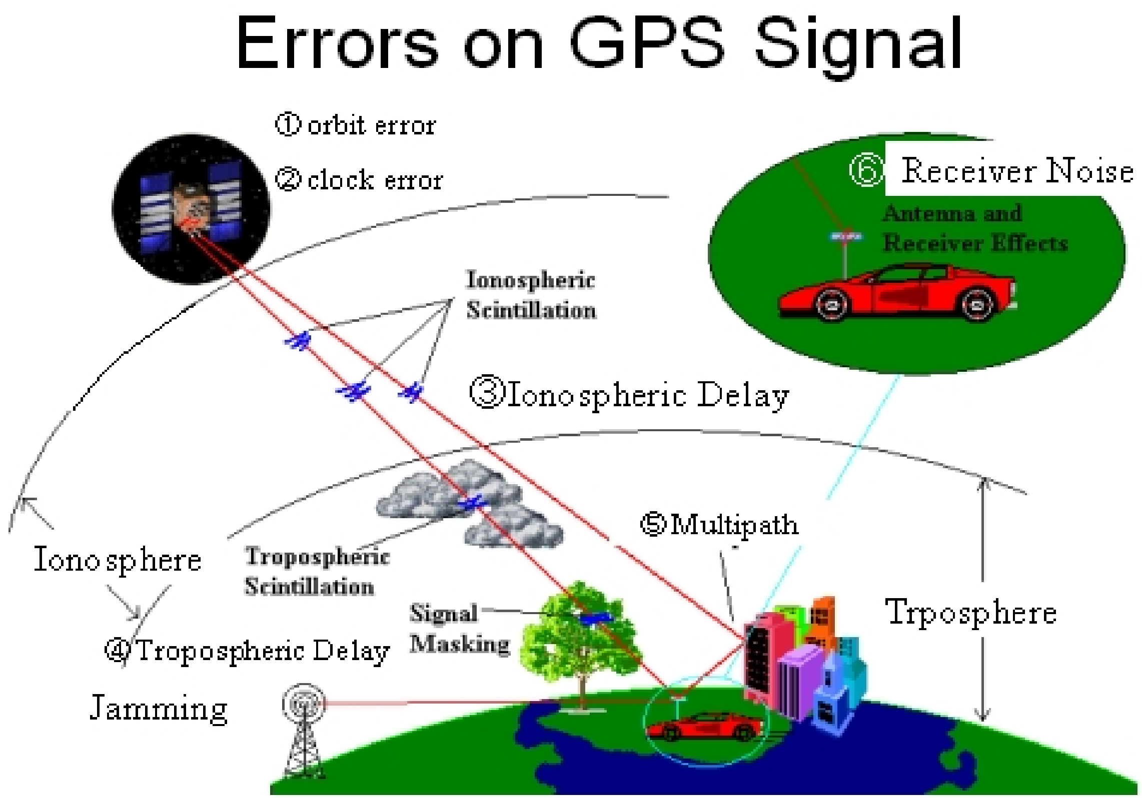








2. Space Weather Effect on GNSS



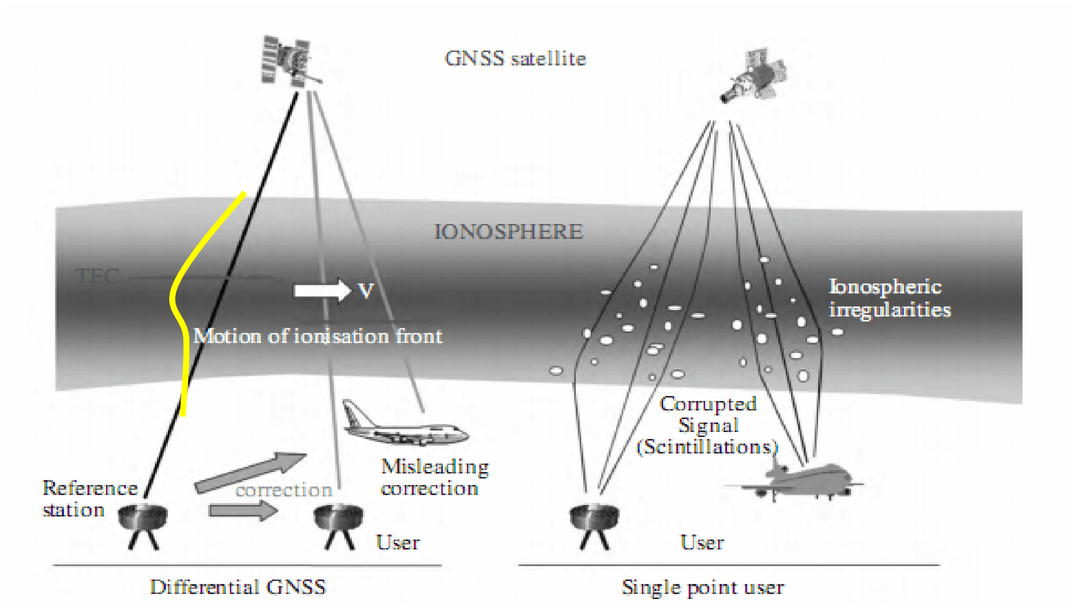
GNSS applications are based on measurement of distance (range) and location of satellit that are experiencing errors resulting from orbit determination, ionospheric delay and so on.

Ionospheric effects on GNSS

•Interaction of GNSS signal with ionosphere causes first order ionospheric delay
• ~TEC/f^2, regular error
•Reduced by dual GNSS receiver.

•Ionospheric irregularity (irregular error) may cause significant degradation of GNSS signals.

✓Strong ionospheric gradient can reduce accurations of DGPS. Ground based augmentation system can give mislieading corrections to aircarft (dangerous during landing)



Small scale ionospheric perturbations cause diffraction of GNSS signals, lead to loss of lock of the receiver.

3. Space weather monitoring by using dual frequency GNSS receiver

Measurable changes in phase and amplitude of GNSS transmitted radio waves can effectively be used to obtain essential information on space weather effects traced in the ionosphere by using dual frequency GNSS receivers

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

$$P_{1,2} = P_1 - P_2 \qquad \Phi_{1,2} = \lambda_1 L_1 - \lambda_2 L_2$$

4. Methodology

1. Extract code and phase data from GPS RINEX files

2. Combine GPS code data : $$P_{1,2} = P_1 - P_2$$

3. Combine GPS phase data $$\Phi_{1,2} = \lambda_1 L_1 - \lambda_2 L_2$$

4. Compute TEC

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

5. Status GNSS Applications for space weather monitoring in Indonesia

1. Near real time IGS (GPS) based TEC monitoring
2. IPGSN-based TEC computation

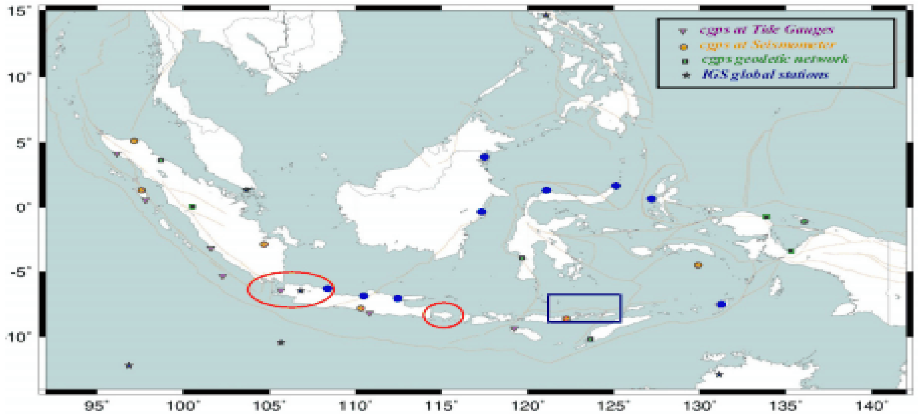
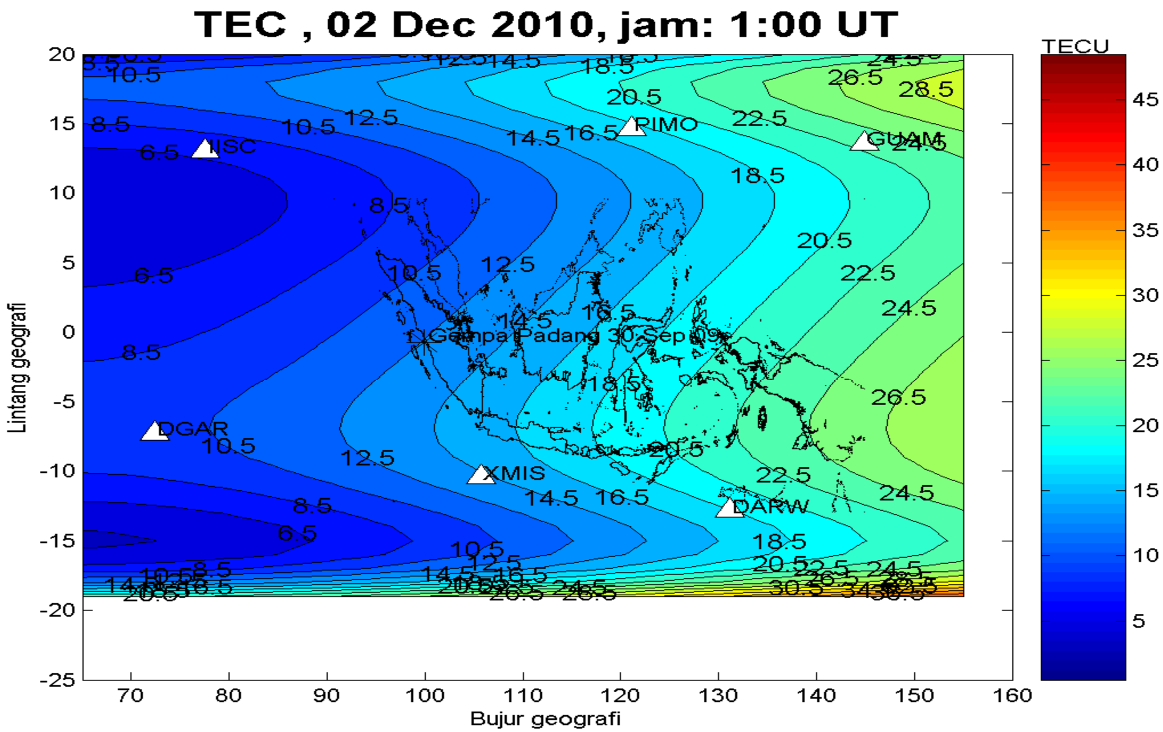


Figure 1. The current status of the Indonesian Permanent GPS Stations Network (IPGSN). It consists of 14 stations located around the Sunda Strait and West Java and 7 stations in the eastern end of Java and Bali Island (inside open red ellipses); 10 stations are located along Flores thrust-fault (inside open blue square); 7 stations near seismometer stations (orange circles); 7 stations near or on tide gauge stations (reverse triangles); 7 geodetic (old) stations (green squares); and 10 stations will be install in 2010 (blue circle). After *Matindas and Subarya* (2009).

Near Real Time Ionospheric Monitoring Over Indonesia Using IGS GPS data



TEC map: absolute value, can be used for ionospheric correction of SF-PPP

DCB receiver and satellite are available from internet

For callibration of TEC

Buldan, 2011, in progress

Latest development of IPGSN-Based TEC Observations

18 GPS stations (established by BAKOSURTANAL): ionospheric monitoirng over Indonesia by LAPAN (develop the software: manage GPS data, and compute TEC, RAW TEC (uncallibrated))

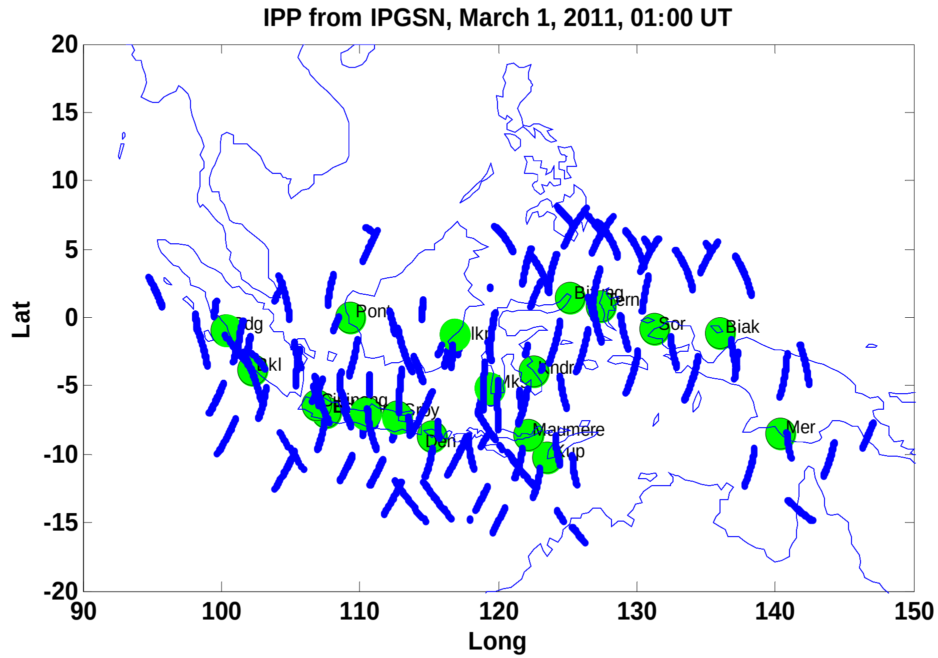


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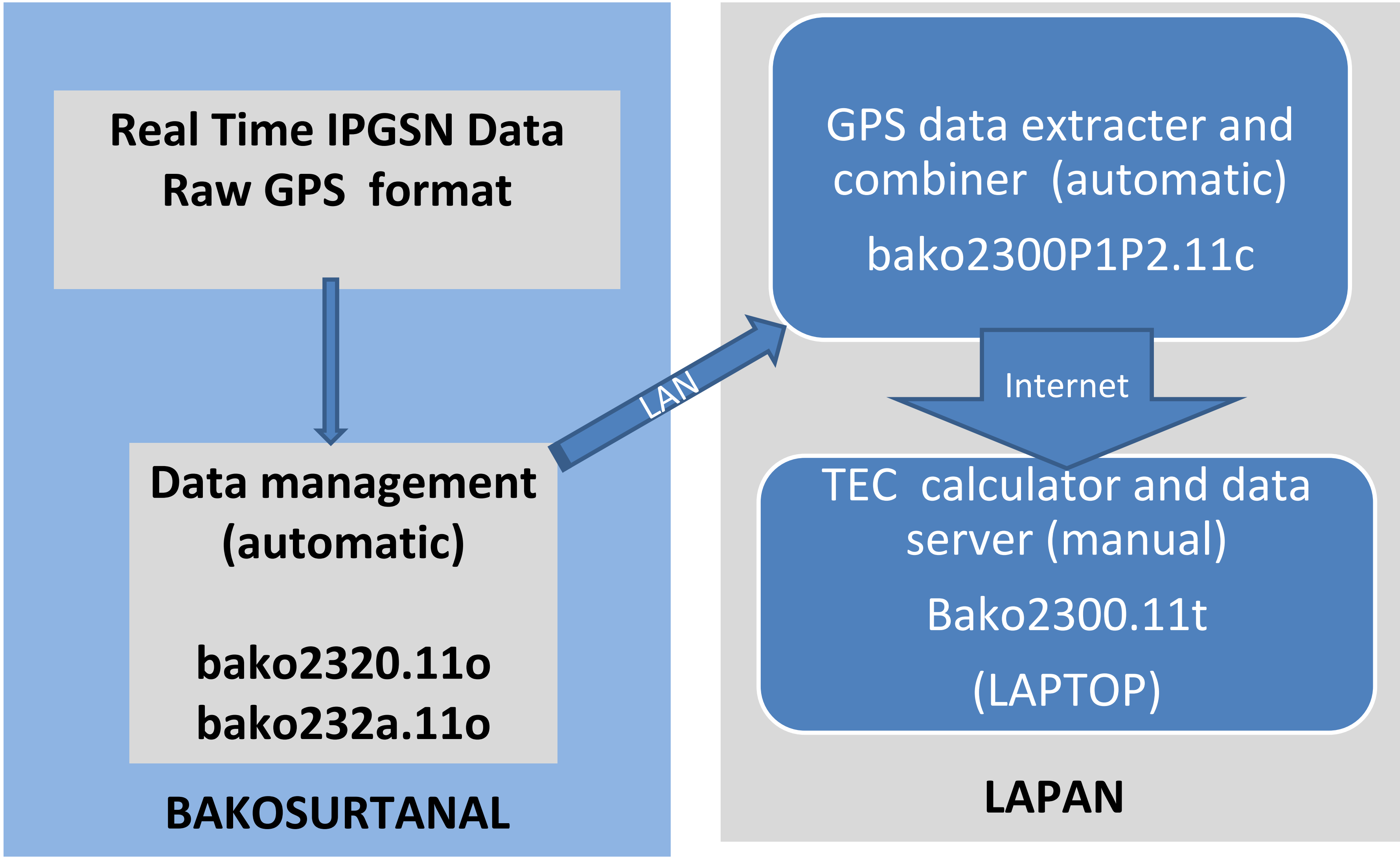
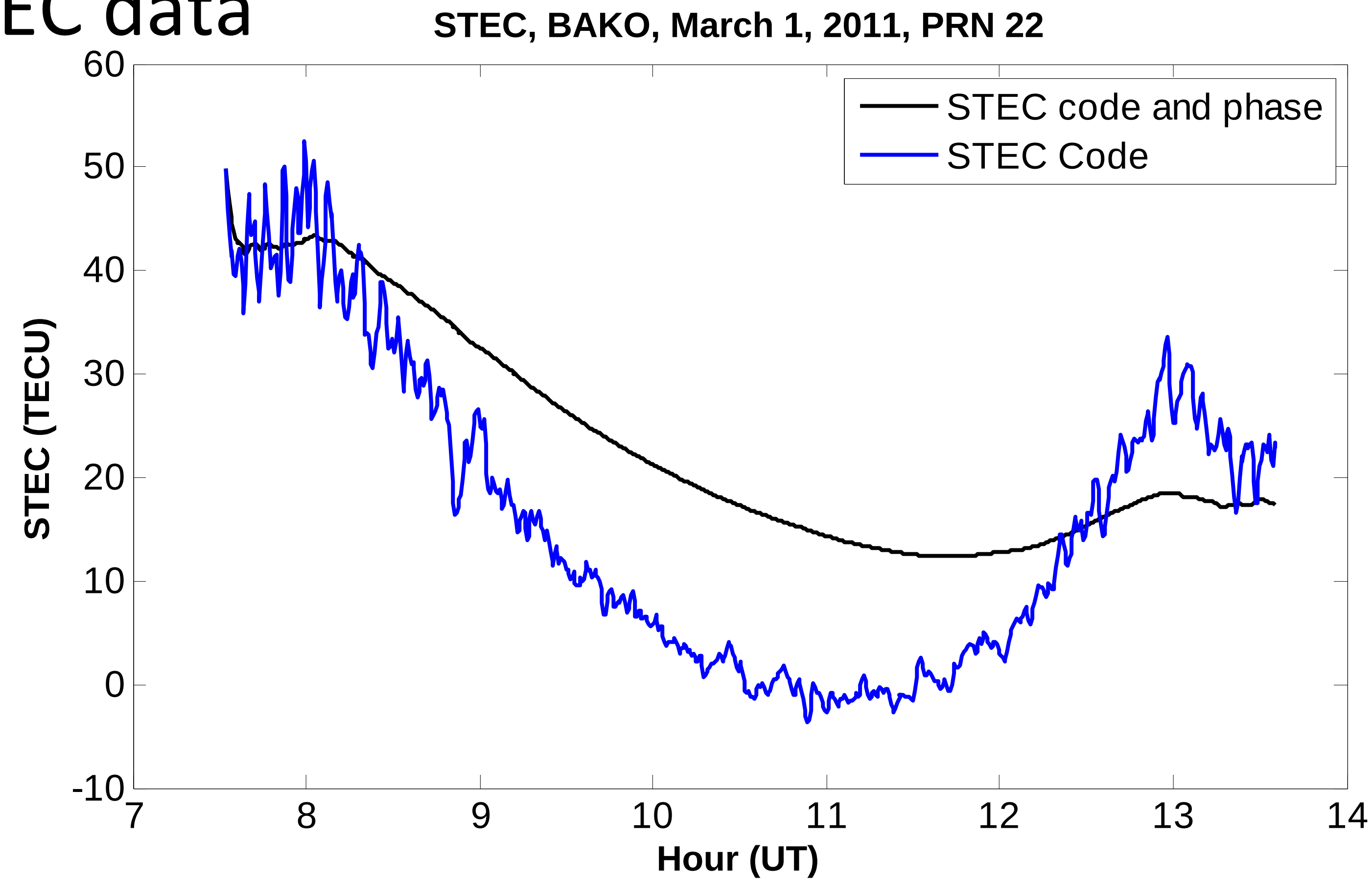
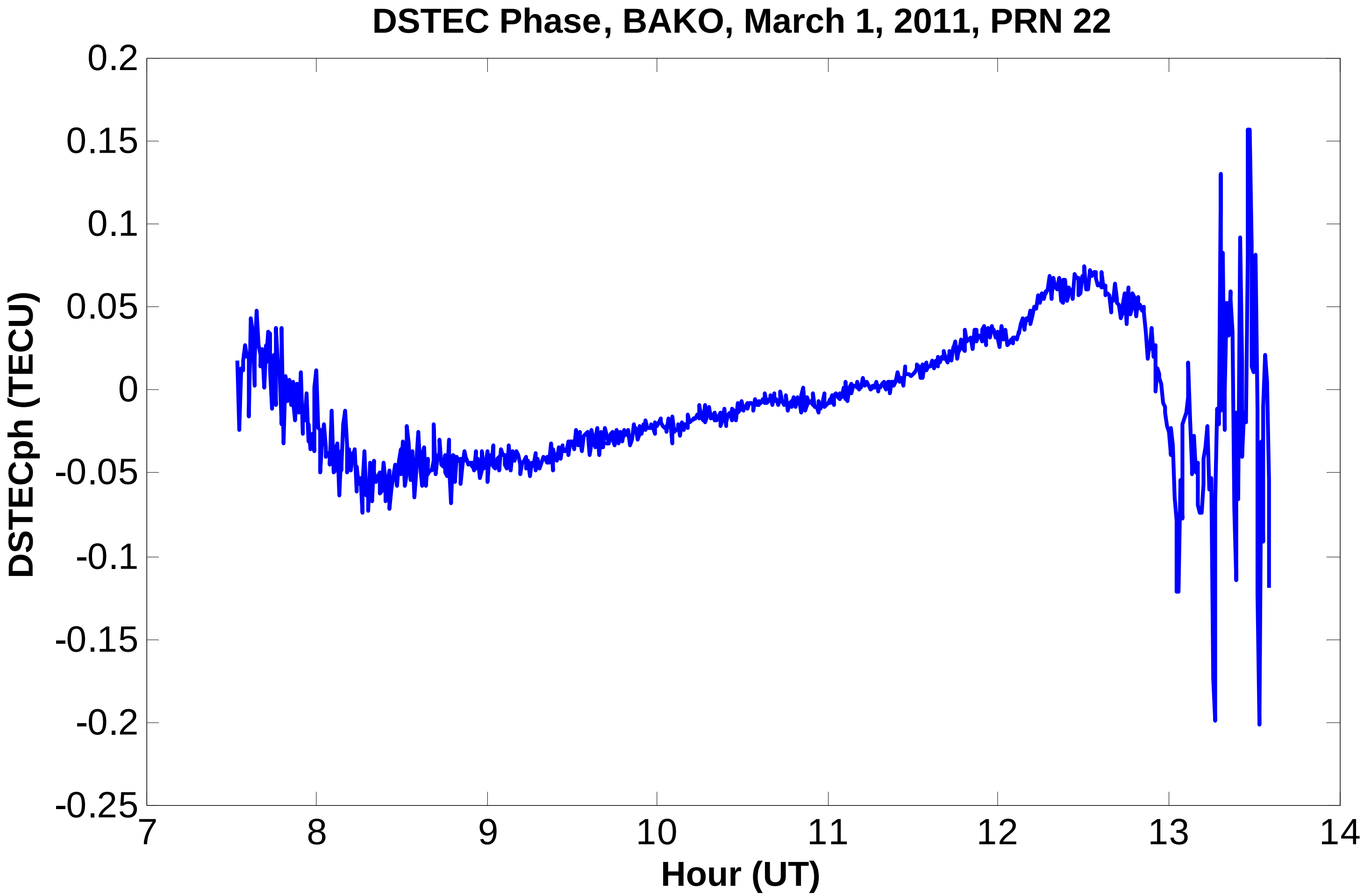
Diagram Block of TEC computation System



- TEC data

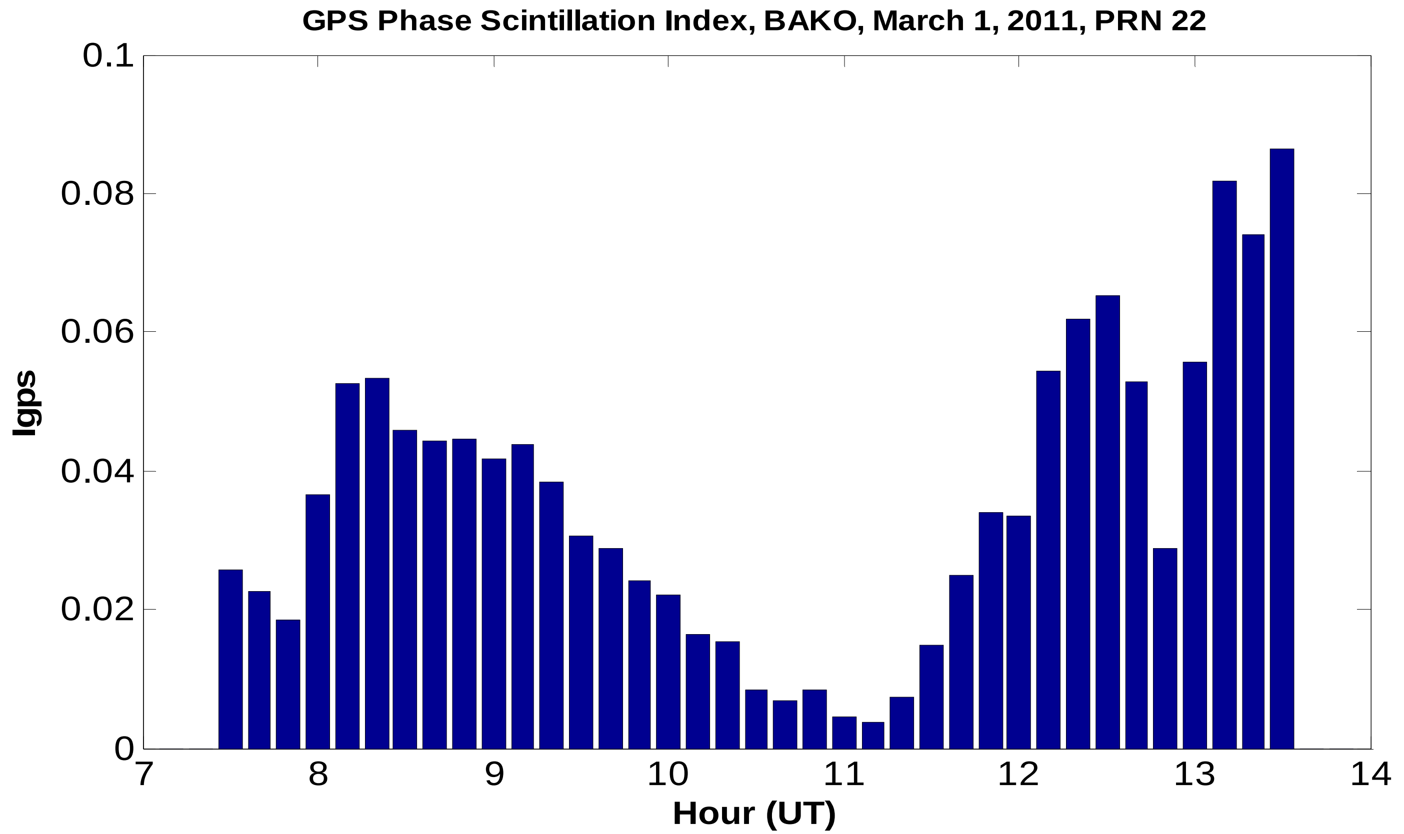


STEC, BAKO, March 1, 2011, PRN 22
STEC code and phase
STEC Code
STEC (TECU)
Hour (UT)
60
50
40
30
20
10
0
-10
7
8
9
10
11
12
13
14

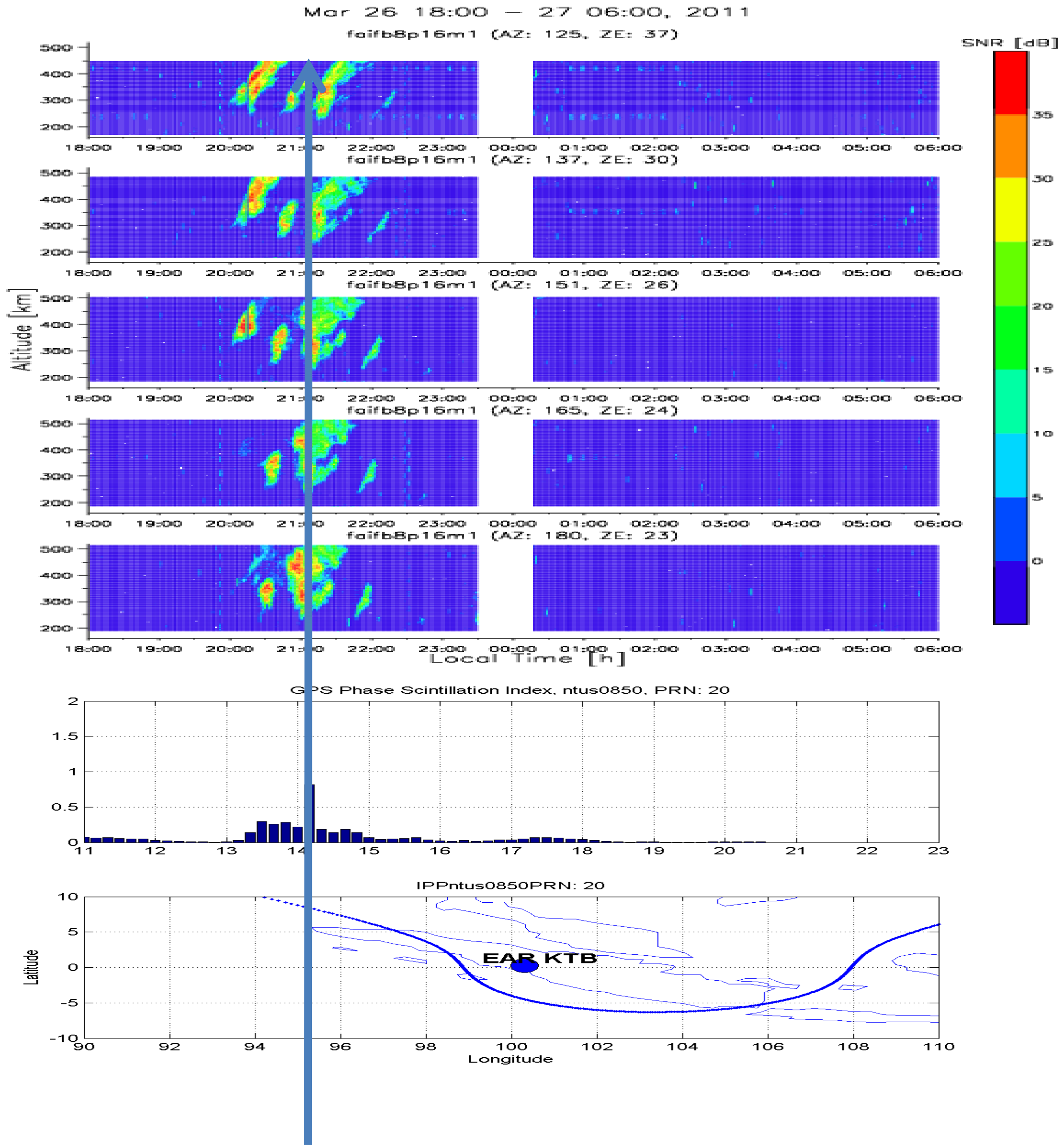

DSTEC Phase, BAKO, March 1, 2011, PRN 22
DSTECph (TECU)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
7
8
9
10
11
12
13
14
Hour (UT)

Application of GPS TEC:
GPS Phase Scintillation Index: Igps

$$Igps = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(DSTEC)^2{}_n}\,,\; DSTEC_n = STECph_{t+1} - STECph_t$$



Igps phase scintillation index and FAI



Buldan et. al., 2011

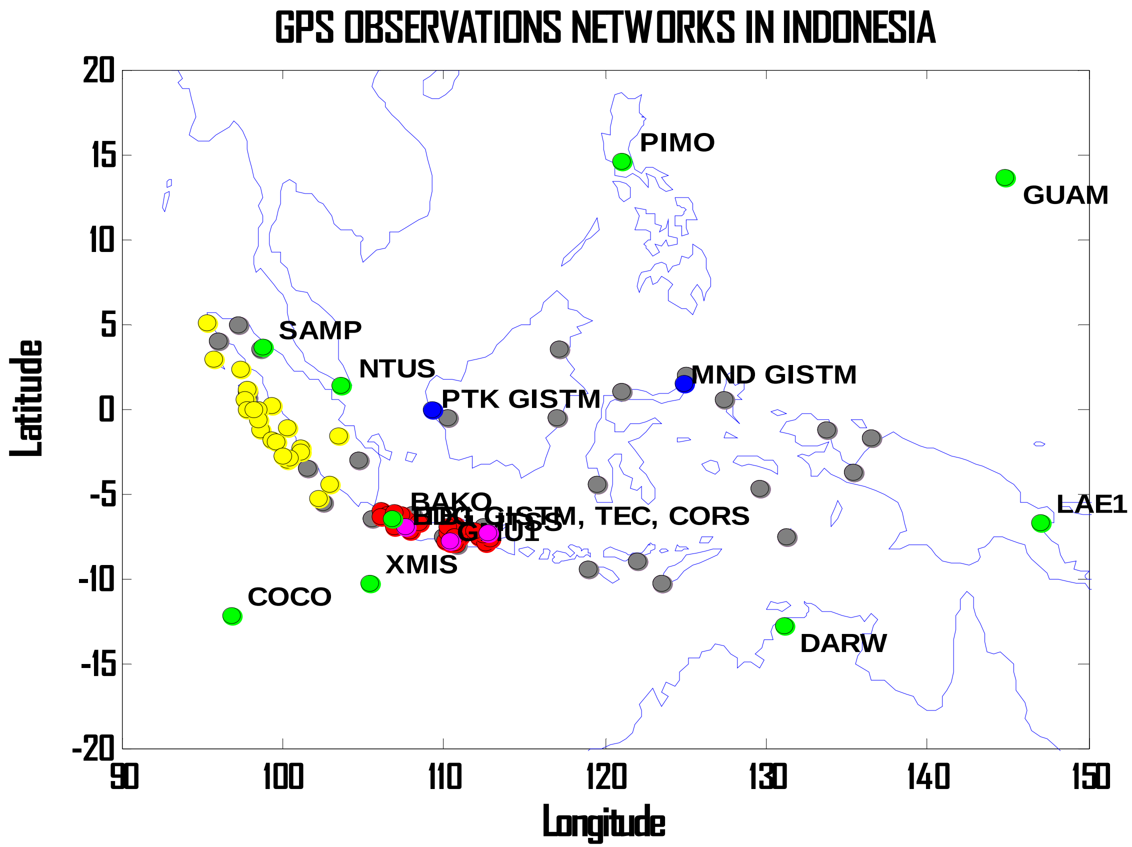
6. Future Plans of Space Weather Monitoring using GNSS in Indonesia

- GPS stations network in Indonesia
- Plans of Space Weather monitoring

GNSS observation network in Indonesia

6 Institutions have established GPS observation nework

LAPAN (3 station)
BPN (CORS: 31)
BAKOSURTANAL (IPGSN : 70)
LIPI (SUGAR: 25)
ITB (CORS: itb1)
UGM (CORS: gmu1)
ITS (CORS: itss)



132 GPS receiver

18 GPS reciever: real time

PLANS: DEVELOPMENT OF SPACE WEATHER MONITORING USING GNSS IN INDONESIA

<table>
<tr><th>Activity</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td>LAPAN AND BAKOSURTANAL SPACE WEATHER MONITORING NETWORK</td><td>18 GPS receiver
BIG</td><td>30</td><td>47</td><td rowspan="3">R
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<tr><td>LAPAN and BPN SPACE WEATHER MONITORING NETWORK</td><td></td><td>33 GPS receiver
BPN</td><td>47</td></tr>
<tr><td>NATIONAL SPACE WEATHER MONITORING NETWORK</td><td></td><td></td><td>100 (LAPAN)
BAKOSURTANAL
BPN
ITB, UGM, ITS</td></tr>
</table>

Needs:

- Increase data storage capacity
- Upgrade the data communication and networking insfrastructure (5 space observatory → 7 SO: Manado in Sulawesi and Biak, Papua)
- Humans resources development: acquisition, data processing and maintaining, networking and dissemination
- Enhance the synergy among research and education institutions

  LAPAN-BIG-BPN-ITB-ITS-UGM, and international institutions

Conclusions

Mitigation of Space Weather Effect in Indonesia for GNSS application is requiring real time and continous GNSS stations

Development of GNSS applications for space weather monitoring in Indonesia is ongoing research on space observation technology using GNSS

Status of GNSS applications for space weather monitoring using GNSS are including ionospheric TEC and scintillation estimation from IPGSN, ionospheric mapping using IGS.

Future plans of GNSS applications for space weather monitoring using GNSS are including the using BPN CORS network and Univerities CORS network to provide the real time ionospheric conditions over Indoensia

The GNSS applications for space weather monitoring are requiring the synergy among research and education institutions, human resources development, and insfrastructure development.

THANK YOU FOR YOUR ATTENTION