



# GNSS Applications for Space Weather Monitoring in Indonesia

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# OUTLINE

1. Space weather
2. Space Weather Effect on GNSS
3. Space weather monitoring by using GNSS
4. Methodology
5. Status of GNSS Applications for Space Weather Monitoring
6. The Future Plan of Space weather monitoring using GNSS

# 1. SPACE WEATHER

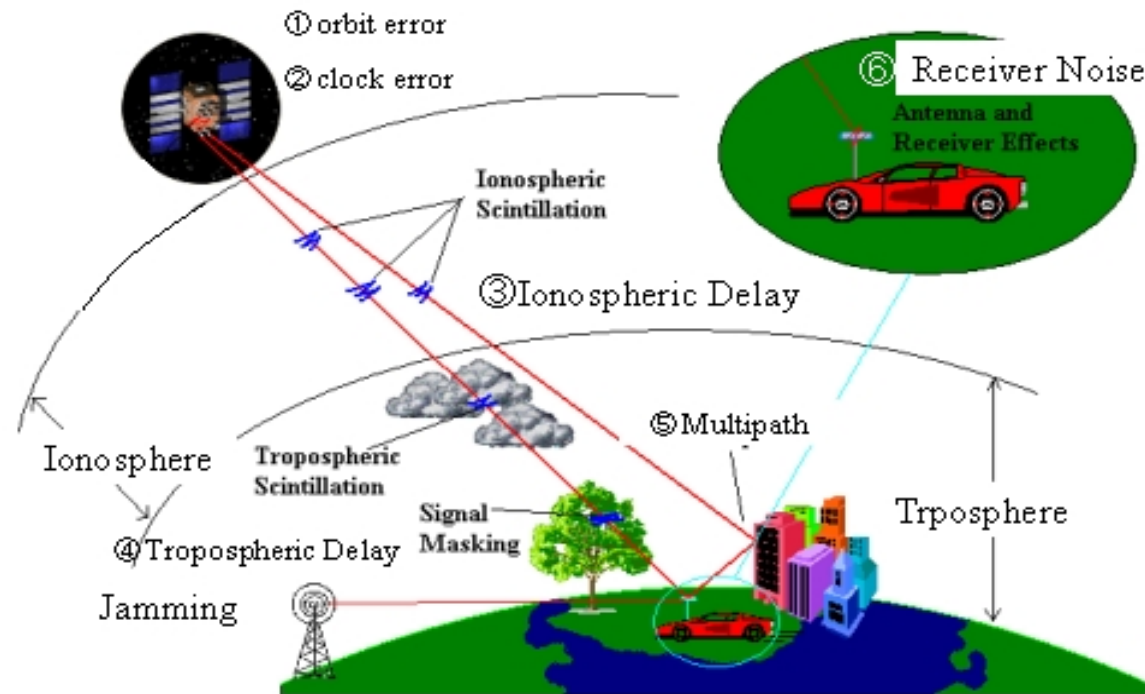
The conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.

The diagram is enclosed in a blue rounded rectangle and contains several components:

- Top Left:** A graph titled "Cycle 23.24 Solar Wind Prediction (June 2000)" showing solar activity from 1990 to 2010. The y-axis represents solar wind speed (km/s) and the x-axis represents time. The graph shows a significant solar storm event around 2003.
- Middle Left:** A diagram titled "The magnetosphere" showing Earth with magnetic field lines. It labels "SOLAR WIND", "SHOCKWAVE", and "MAGNETIC FIELD LINES". Text below explains: "Earth's magnetosphere extends forward about 5 times Earth's diameter, creating a shock wave where it meets the solar wind. The magnetosphere is pushed into a long tail on the back side that extends beyond the Moon's orbit. Earth's plasmasphere is inside the magnetosphere. SOURCE: Cambridge Atlas of Astronomy SPACE.COM".
- Bottom Left:** A chart of atmospheric layers. The left y-axis is "Altitude (km)" from 0 to 500. The right y-axis is "Altitude (mi)" from 0 to 300. The x-axis is "Temperature (°C)" from -500 to 1500. Layers shown include Exosphere, Thermosphere, Mesosphere, Stratosphere, and Troposphere. Specific features like "Active Sun", "Average Sun", "Ionosphere", "Heterosphere", and "Homosphere" are also indicated.
- Center:** A large infographic titled "Space Weather Impacts". It shows "Energetic Electrons" and "Solar Flare Protons" hitting a satellite, causing "Damage to spacecraft electronics". It also shows "Ionospheric currents" and "GPS Signal Scintillation" affecting a satellite. On the ground, it shows "Radiation effects on avionics" on an airplane, "HF Radio wave disturbance", "Geomagnetically induced currents in power systems", "Induced effects in submarine cables", "Magnetic interference in exploration surveys", and "Telluric currents in pipelines".
- Right Side:** A photograph of a scientist in a white lab coat working in a laboratory. Below it is a circular diagram with red arrows showing a cycle of human health impacts, including a person with a headache, a person with a heart monitor, a person with a stethoscope, and a person with a pulse oximeter.

# 2. Space Weather Effect on GNSS

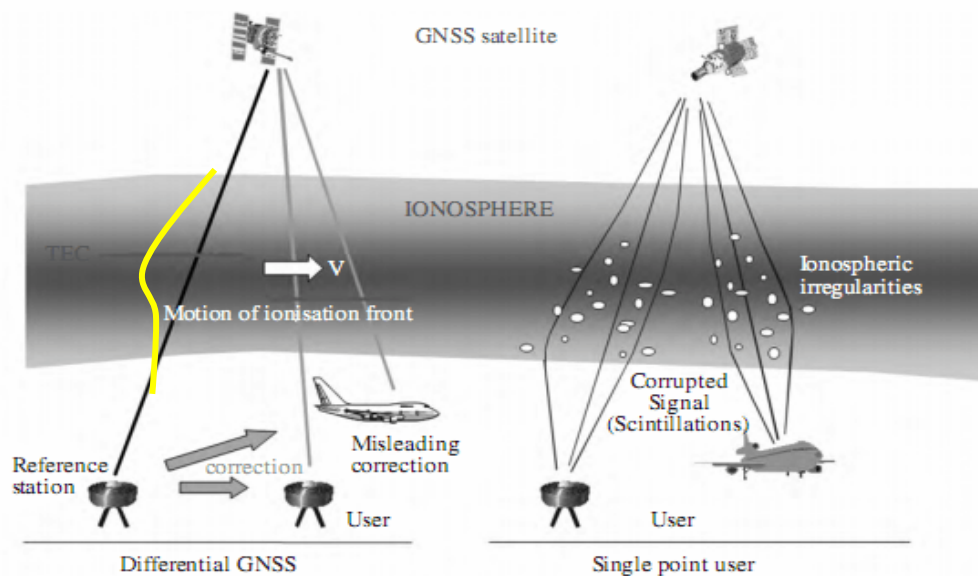
## Errors on GPS Signal



GNSS applications are based on measurement of distance (range) and location of satellite 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**
  - $\sim \text{TEC}/f^2$ , **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 misleading 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

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

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

# 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

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

# 5. Status GNSS Applications for space weather monitoring in Indonesia

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

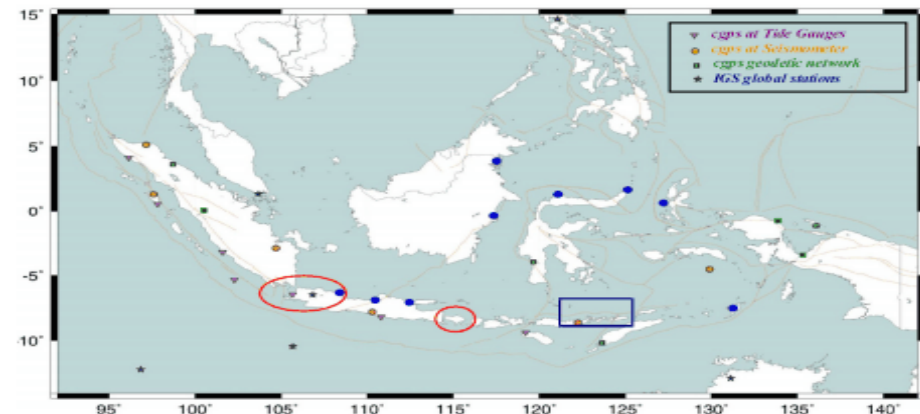
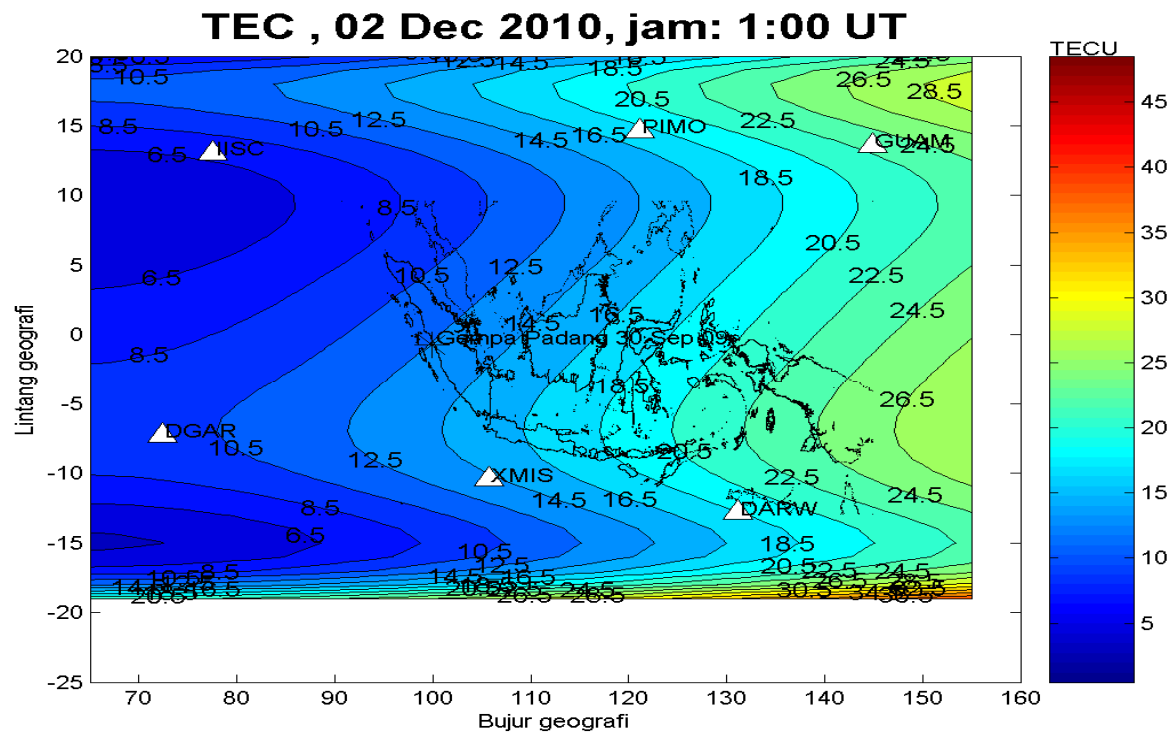


Figure 1. The current status of the Indonesian Permanent GPS Stations Network (IPGSN). It consists of 14 stations located around the Sunda Strait and West Java and 7 stations in the eastern end of Java and Bali Island (inside open red ellipses); 10 stations are located along Flores thrust-fault (inside 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

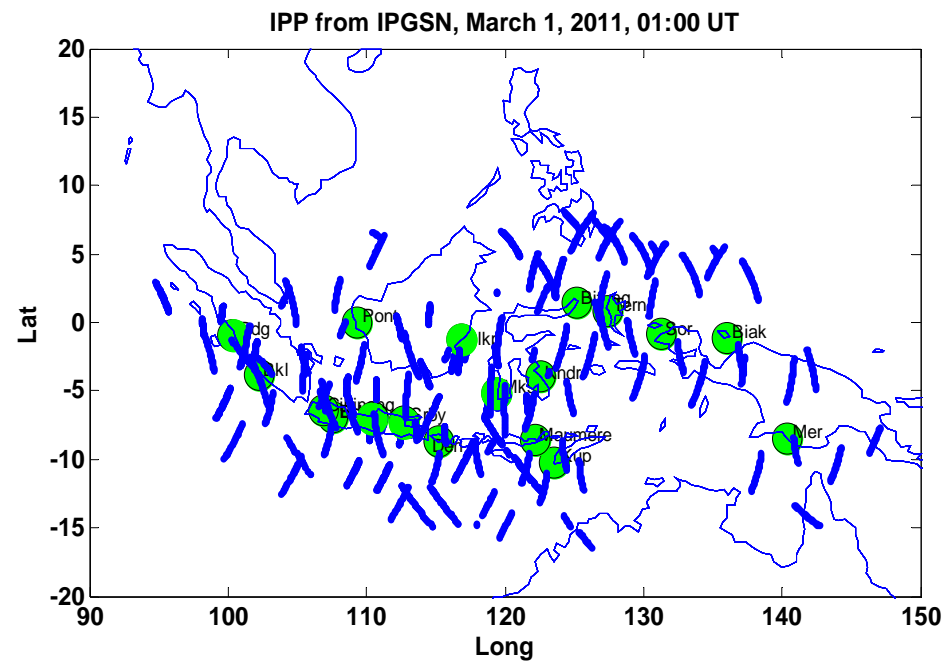
DCB receiver and satellite are available from internet

For calibration of TEC

Buldan, 2011, in progress

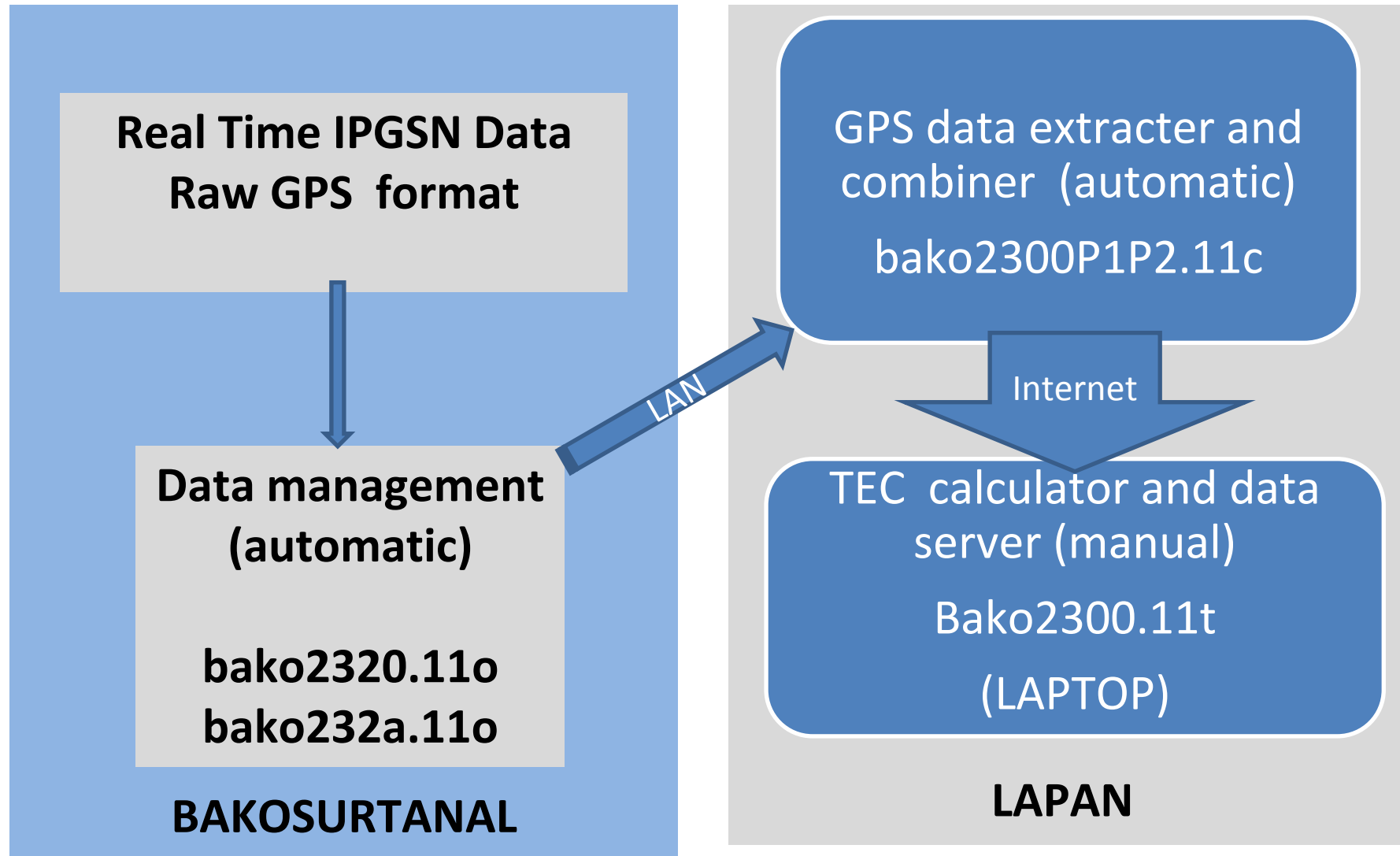
# Latest development of IPGSN-Based TEC Observations

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

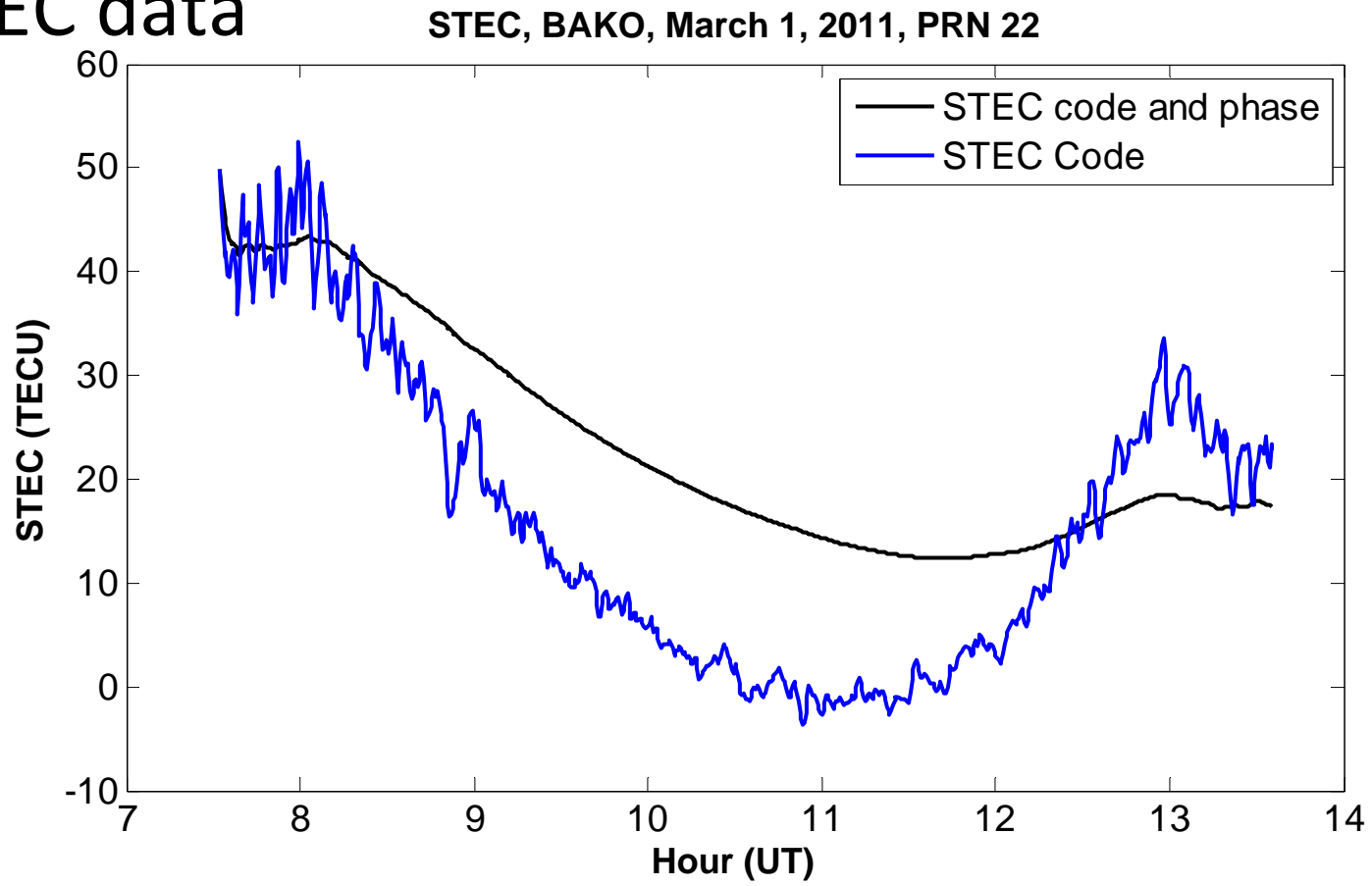


Buldan et.al., 2011

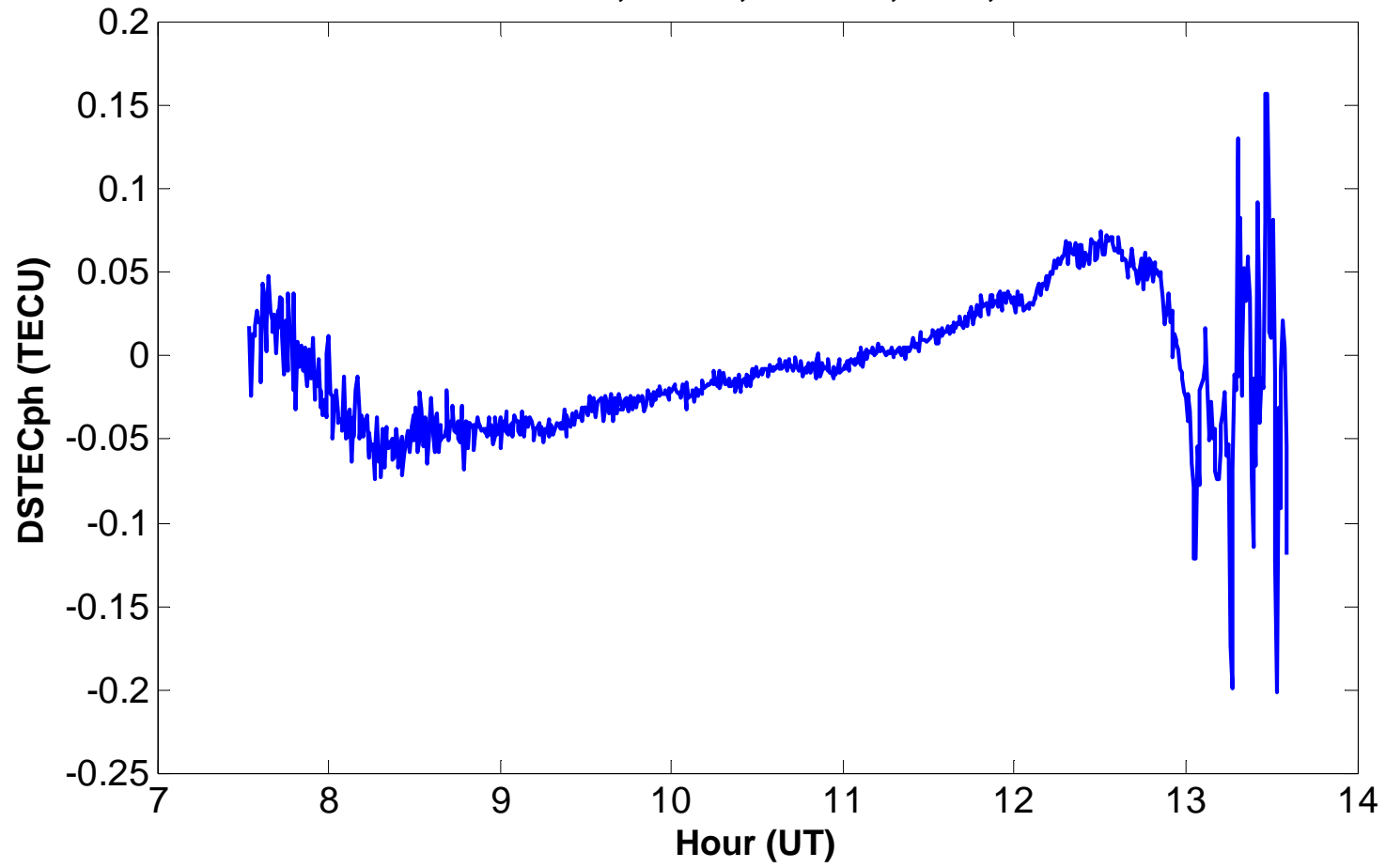
# Diagram Block of TEC computation System



- TEC data

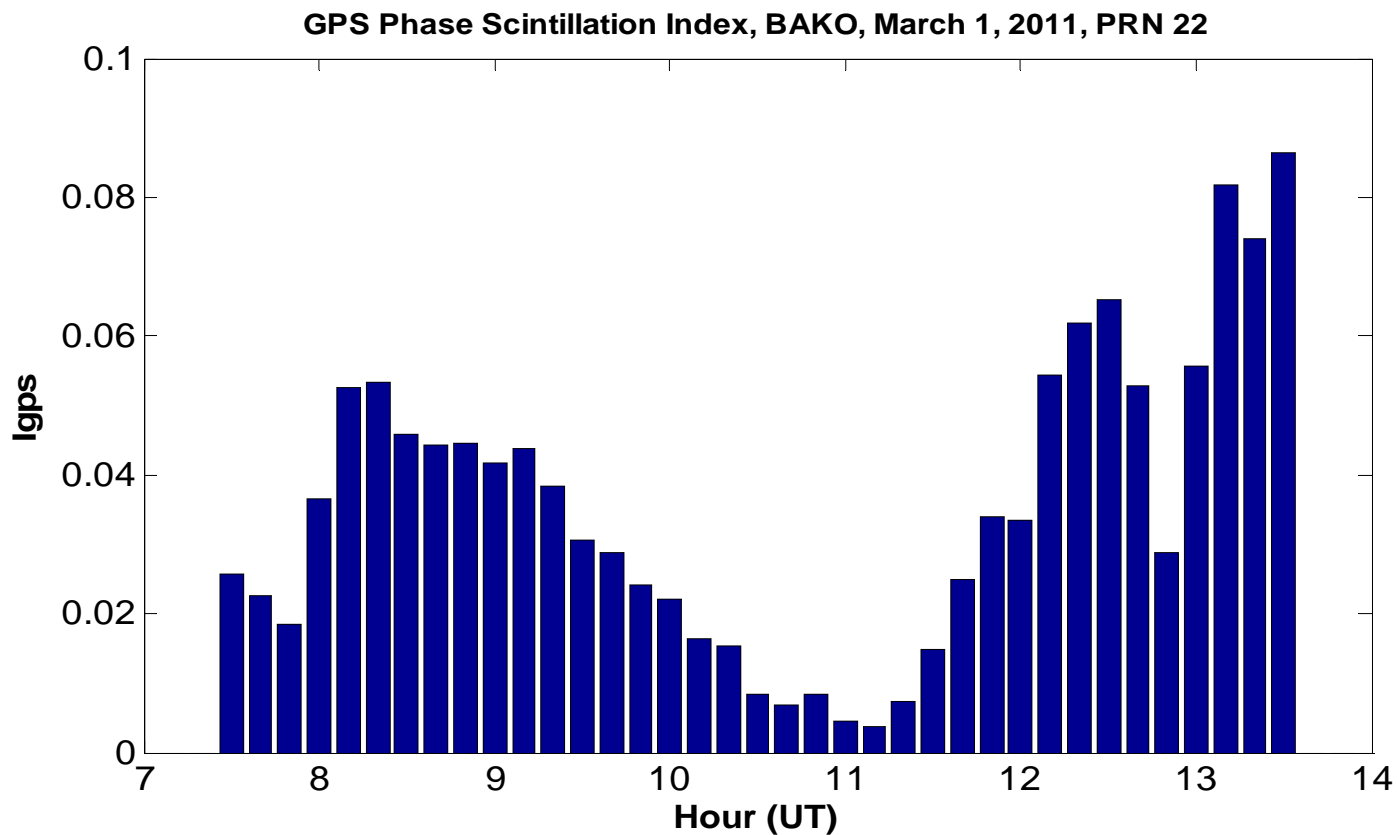


DSTEC Phase, BAKO, March 1, 2011, PRN 22

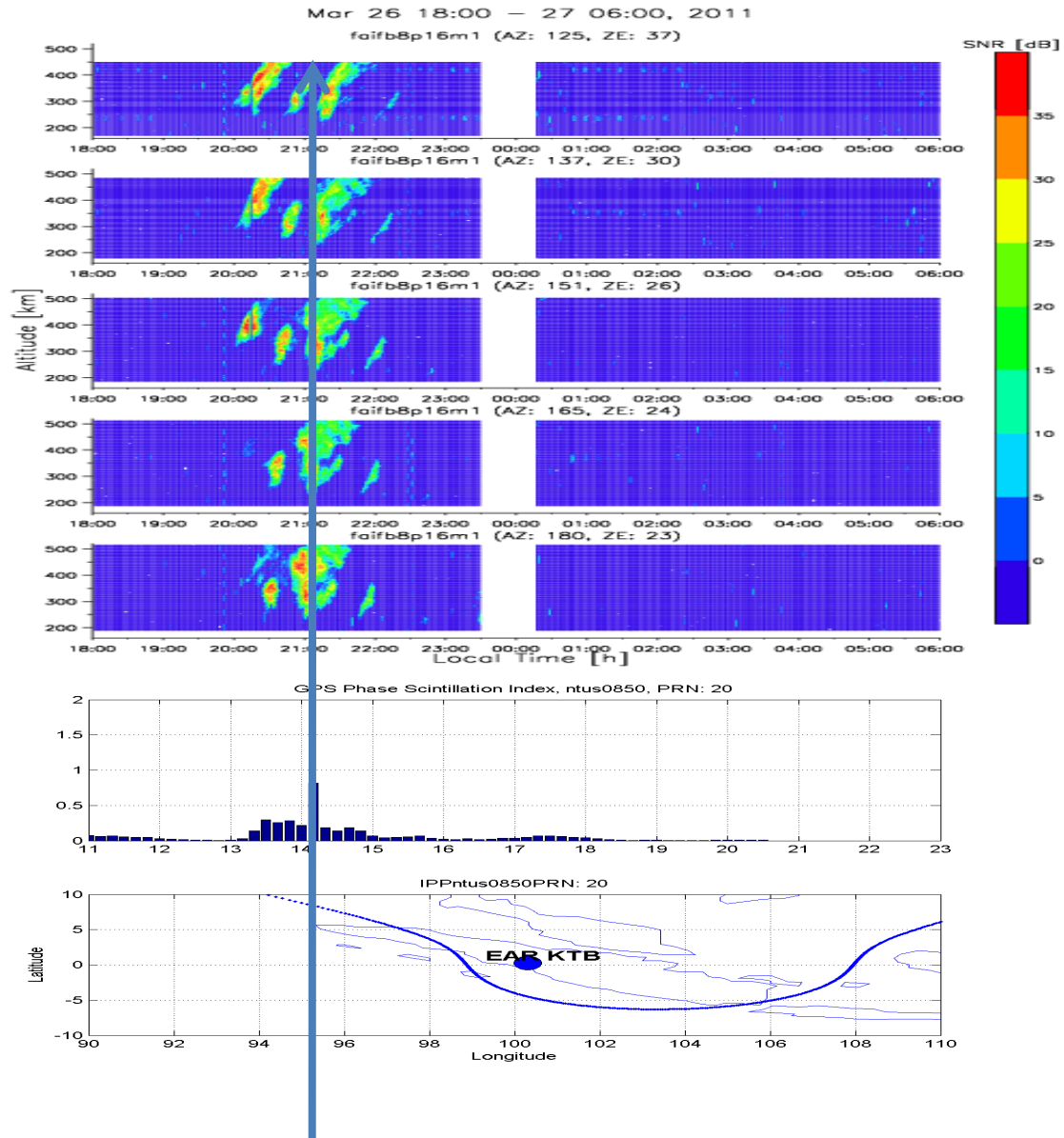


# Application of GPS TEC: GPS Phase Scintillation Index: $I_{gps}$

$$I_{gps} = \sqrt{\frac{1}{N} \sum_{n=1}^N (DSTECC)^2_n}, DSTECC_n = STECCph_{t+1} - STECCph_t$$



# 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 network

LAPAN (3 station)

BPN ( CORS: 31)

BAKOSURTANAL (IPGSN : 70)

LIPI (SUGAR: 25 )

ITB (CORS: itb1)

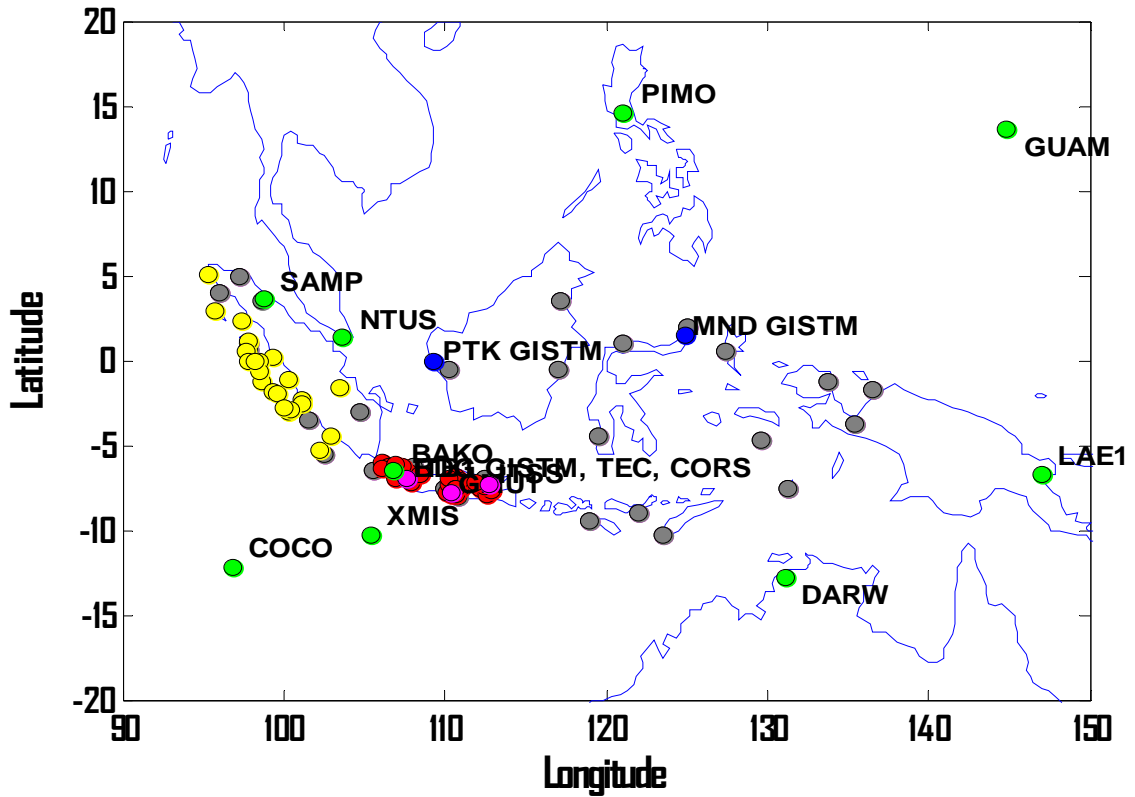
UGM (CORS: gmu1)

ITS (CORS: itss)



18 GPS receiver: real time

GPS OBSERVATIONS NETWORKS IN INDONESIA



132 GPS receiver

# PLANS: DEVELOPMENT OF SPACE WEATHER MONITORING USING GNSS IN INDONESIA

Activity	2011	2012	2013	2014
LAPAN AND BAKOSURTANAL SPACE WEATHER MONITORING NETWORK	18 GPS receiver BIG	30	47	R E A L  T I M E  D A T A
LAPAN and BPN SPACE WEATHER MONITORING NETWORK		33 GPS receiver BPN	47	
NATIONAL SPACE WEATHER MONITORING NETWORK			100 (LAPAN) BAKOSURTANAL BPN ITB, UGM, ITS	

# Needs:

- Increase data storage capacity
- Upgrade the data communication and networking infrastructure (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 continuous 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 Universities CORS network to provide the real time ionospheric conditions over Indonesia

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

**THANK YOU FOR YOUR ATTENTION**