The Applications of GPS CORS in Indonesia: Status, Prospect and Limitation

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Key words: GPS, Positioning, CORS, Indonesia, Reference Frame

SUMMARY

The use of GPS for positioning, surveying and mapping applications in Indonesia is systematically started at the end of 1980s. In this case, static surveying and real time (absolute and differential) positioning are the two most positioning modes being used. The GPS CORS in Indonesia were firstly established by the Indonesian National Coordinating Agency for Surveys and Mapping (Bakosurtanal) with three stations, i.e. in Cibinong (West Java), Medan (North Sumatra) and Parepare (South Sulawesi). In October 2009 the GPS CORS of Bakosurtanal consists of 51 continuously operating GPS reference stations. Several clusters of local GPS CORS have also been established by other governmental agencies and universities.

GPS CORS prospect in Indonesia is very promising especially for maintaining the national spatial reference system to support various applications of positioning, surveying and mapping, such as in land administration, mining and transportation sectors. Observing several natural hazard phenomena in Indonesia, e.g. earthquake, tsunami volcanic eruption, land subsidence and landslide, will also be greatly improved. GPS based mapping of tropospheric water vapor and ionospheric TEC over Indonesia region will also benefit from the enormous data provided by GPS CORS.

The current results of GPS CORS in Indonesia will be presented in this paper, especially those related to maintenance of the national spatial reference system, tectonic deformation monitoring and TEC mapping over Indonesia region. Potential application for land administration will be discussed. Possible limiting factors for sustainable operation of GPS CORS in Indonesia will also be critically reviewed.

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1. INTRODUCTION

GPS is started to be used in Indonesia at the end of 1980s especially for surveying and mapping related purposes. Afterward the applications are started to increase encompassing various fields of application, from geodynamics study and deformation monitoring to land administration, transportation and recreation applications. In this case, static surveying and real time (absolute and differential) positioning are the two most positioning modes being used.

Since 1992, the Indonesian National Coordinating Agency for Surveys and Mapping (Bakosurtanal) has also systematically conducted precise GPS surveys for refining and densifying the national geodetic control network of Indonesia [*Subarya,* 2004]. In this case, Bakosurtanal is responsible for establishing the 0th and 1st order national geodetic network. At present, these networks consisted of more than 950 GPS stations all over Indonesia, defined in the ITRF2005 reference frame. Since 1994, the National Land Agency (BPN) has also started using GPS surveys for establishing the cadastral control networks of Indonesia [*Abidin et al., 1998*]. These cadastral networks are the considered as the 2nd and 3rd order national geodetic networks, and are connected to the 0th and 1st geodetic networks maintained by Bakosurtanal. Since 1993, the Indonesian Ministry of Forestry has also started to use GPS surveys for establishing the control network for forest surveying, mapping and management [*Soetardjo,* 1999]. This forestry control network is connected to the national geodetic control networks. GPS based local geodetic networks were also established sporadically by the govermental agencies and private sectors (e.g. deformation monitoring, mining and energy, real estates, and construction of public utilities), mainly to serve their specific needs.

The GPS CORS (Continuously Operating Reference Stations) in Indonesia were firstly operated by Bakosurtanal since 1996, consisting of three stations in Cibinong,West Java (BAKO station), in Medan, North Sumatra (SAMP station), and Parepare, South Sulawesi (PARE station) [*Matindas and Subarya,* 2009]. Afterward, Bakosurtanal expanded this GPS CORS network, and by October 2009 the network has consisted of 51 stations. Other national agencies, such as the Indonesian Institute of Sciences (LIPI) and BPN have also started establishing their own GPS CORS network. LIPI, in collaboration with the California Institute of Technology (Caltech) and the Earth Observatory of Singapore (EOS), has established the SUGAR (Sumatera GPS Array) [*Caltech,* 2010; EOS, 2010]. This CORS network is mainly aimed to study the nature of large earthquakes in the subduction zones of the Sumatra Island. Recently, BPN has also tested the possibility of using GPS CORS stations for speeding up the land administration process in Indonesia [*Adiyanto et al.,* 2009]. Several smaller and localized GPS CORS networks in Indonesia are also established by the private sectors and universities [*Sunantyo,* 2009].

2. THE NATIONAL GPS CORS OF INDONESIA

In principle, the national GPS CORS network of Indonesia, is officially the one that is established by Bakosurtanal [*Subarya,* 2004; *Matindas and Subarya,* 2009]. This network is usually termed as the Indonesian Permanent GPS Station Network (IPGSN). The primary purpose of the IPGSN is to maintain an accurate and precise geodetic reference frame over Indonesian region, and also to support a wide range of scientific and practical applications such as geodynamics and deformation monitoring, meteorological and ionospheric studies, sea level monitoring, intelligent transportation systems, and real-time based surveying and mapping applications.

The establishment of IPGSN network was initiated in 1996 which is started with three stations in Cibinong (West Java), Sampali Medan (North Sumatra) and Parepare (South Sulawesi). The network was afterward systematically strengthened with more stations, and after the Sumatra-Andaman earthquake and tsunami of 26 December 2004, the IPGSN network was rapidly developed. This rapid development is part of the development of the Indonesian Tsunami Early Warning System (InaTEWS). Afterward, Bakosurtanal expanded this GPS CORS network, and by October 2009 the network has consisted of 51 stations. The current status of IPGSN is depicted in Figure 1.

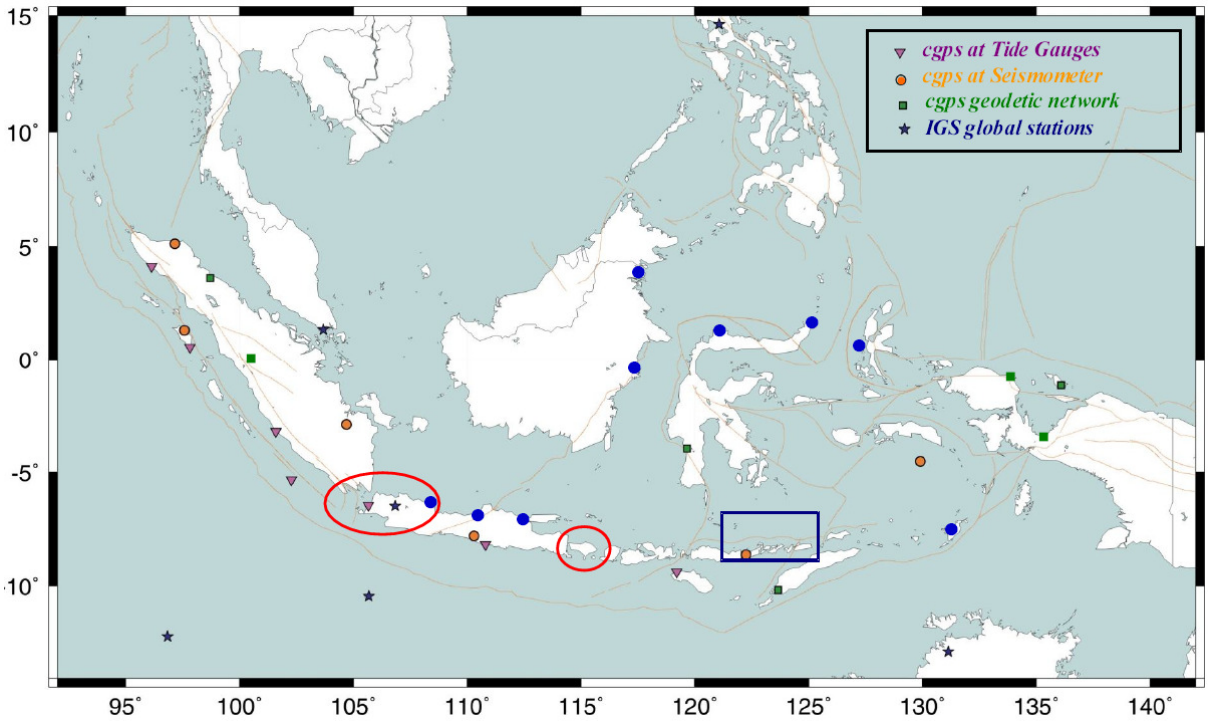
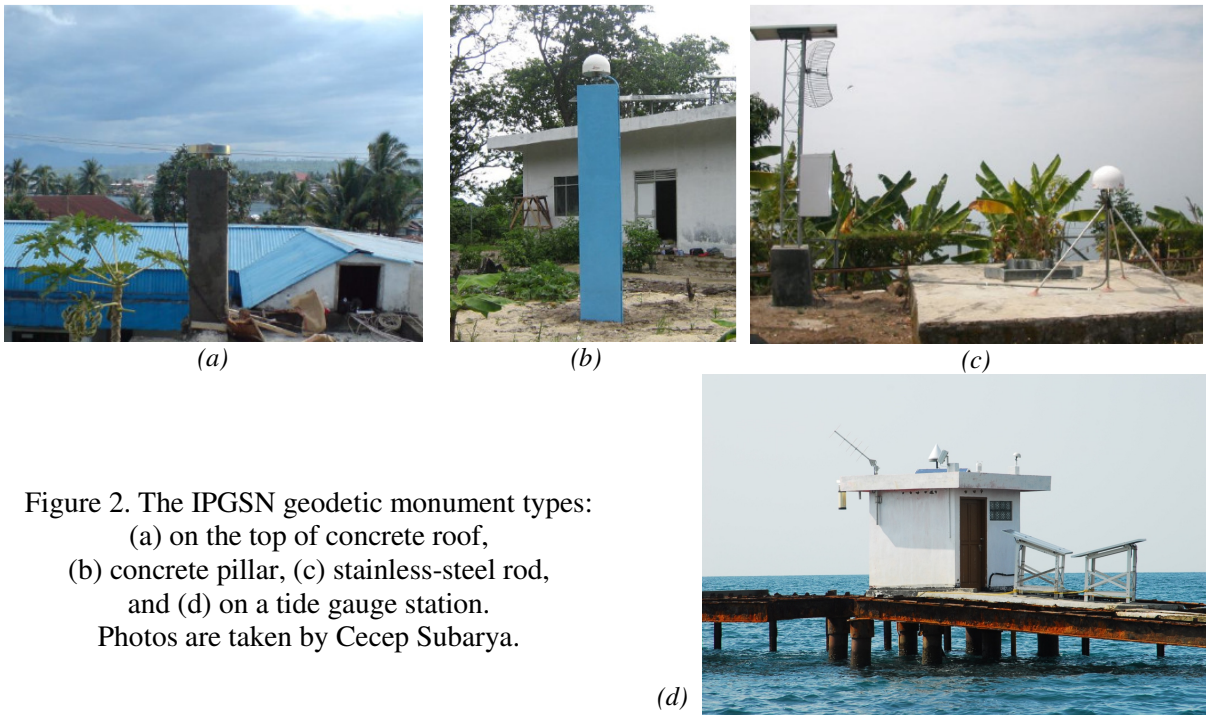


Figure 1. The current status of the Indonesian Permanent GPS Stations Network (IPGSN). It consists of 14 stations located around the Sunda Strait and West Java and 7 stations in the eastern end of Java and Bali Island (inside open red ellipses); 10 stations are located along Flores thrust-fault (inside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

All stations of IPGSN use the high precision L1/L2 geodetic type GPS receivers (i.e. Ashtech UZ-12, Leica GRX1200 family, Topcon GB-1000 and Net G3, and Septrentio PolarX2) with choke ring antennas and radomes, and most of the GPS receivers equipped with meteorological (temperature, pressure and humidity) sensors [*Subarya et al.,* 2010]. Besides GPS receiver, the station also equipped with a radio or VPN-IP modem for data communication, sufficient batteries and solar panels to charge the batteries. GPS data is recorded at 1Hz rate and streamed in real time or near real time of 1 hour latency to the data processing center at Bakosurtanal office in Cibinong, West Java. Considering the stringent geodetic requirements for the IPGSN, stable geodetic monuments are constructed at all locations with various types of geodetic monuments as shown in Figure 2.



(a) *(b)* *(c)* *(d)*

Figure 2. The IPGSN geodetic monument types:
(a) on the top of concrete roof,
(b) concrete pillar, (c) stainless-steel rod,
and (d) on a tide gauge station.
Photos are taken by Cecep Subarya.

3. STATUS OF OTHER GPS CORS IN INDONESIA

Besides the national GPS CORS established and maintained by Bakosurtanal, other national agencies, such as the Indonesian Institute of Sciences (LIPI) and BPN have also started establishing their own GPS CORS network.

LIPI, in collaboration with the California Institute of Technology (Caltech) and the Earth Observatory of Singapore (EOS), has established the SUGAR (Sumatera GPS Array) network, consisting of 32 continuous stations [*Natawidjaja,* 2010]. The location and distribution of these stations are shown in Figure 3. The location and distribution of these stations are shown in Figure 3. All stations are equipped with the dual-frequency geodetic type receivers, with choke ring antennas and radomes; and record the data with 1 Hz data rate. The data collected by this CORS network has been used to study the deformation related characteristics of large earthquakes in the subduction zones of the Sumatra island.

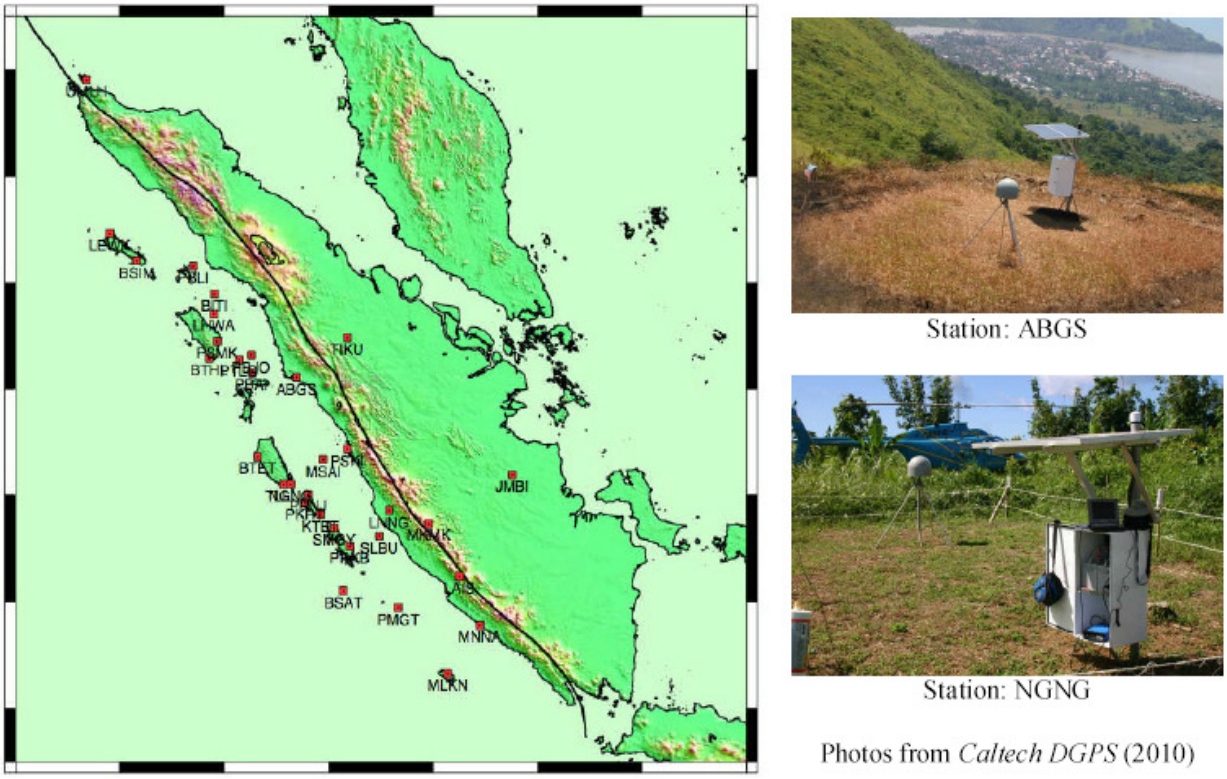


Figure 3. The location and distribution of 32 SUGAR stations.

In order to speed up the land administration process in Indonesia, BPN has also started to establish GPS CORS, consisting of Class-A and Class-B type stations (see Figure 4). Three stations around the capital city of Jakarta, i.e. Tangerang, Bekasi and Bogor, have been established and tested [*Adiyanto et al.,* 2009]. In 2010, other 33 CORS stations will be established in Java and Bali and other strategic areas outside Java and Bali.

Figure 4. Planned location and distribution of BPN GPS CORS station in Java [*Adiyanto and Wibisono,* 2009]. Class-A and Class-B stations are denoted with red and yellow circles respectively.

All of the BPN CORS stations will be equipped with dual-frequency geodetic-type GPS receivers. The Class-A type stations will be established on the ground and planned to have specification and performance comparable to the IPGSN stations maintained by Bakosurtanal. The Class-B type stations will usually installed on the building, preferably in the land office building in the corresponding areas, as shown in Figure 5.

Figure 5. The first three BPN CORS stations; from *Adiyanto et al.* (2009).

Several universities, namely Institute of Technology Bandung (ITB) in Bandung, University of Gajah Mada (UGM) in Yogyakarta and Institute of Technology 10 November (ITS) in Surabaya have also established GPS CORS stations in their campuses. In this case, the Geodesy Research Division of ITB, in cooperation with GSI Japan, ERI University of Tokyo, and Bakosurtanal, has established 5 GPS CORS stations as shown in Figure 6. The main aim of this CORS network is to study the inter-seismic deformation of active faults in West Java, e.g. Cimandiri, Lembang and Baribis faults [*Abidin et al,* 2009].

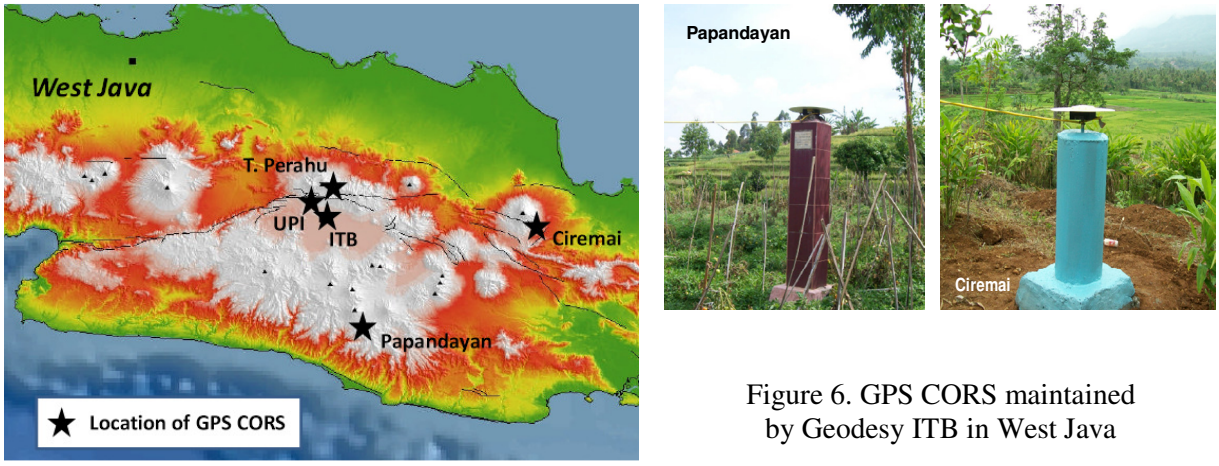


Figure 6. GPS CORS maintained by Geodesy ITB in West Java

4. APPLICATIONS OF GPS CORS IN INDONESIA

GPS CORS in Indonesia will be useful for various existing applications in Indonesia and also will create more innovative applications, both in real-time and post-processing modes, as shown in Table 1.

The existence of GPS CORS networks will be very useful for Indonesia, a vast archipelago consisting of more than 17.000 islands and has population of more than 200

millions. GPS CORS stations will be useful as the reference stations for various GPS-based positioning, surveying and mapping applications. Differential based GPS positioning for various applications, such as for topographic and thematic mapping, marine surveying, photogrammetry, oil and gas exploration and exploitation, cadastral surveying, construction surveys, forestry and agriculture mapping, and for boundary demarcation; will be benefitted by GPS CORS stations.

Table 1. Existing and potential utilization and function of GPS CORS.

Utilization and Function of GPS CORS	
Real-time mode	**Post-processing mode**
Early warning system for various natural hazards in Indonesia.	The coordinate reference frame for various positioning, surveying and mapping applications in Indonesia.
The Network-RTK system for surveying and mapping applications.	The coordinate reference frame for monitoring and studying natural hazard phenomena in Indonesia
The reference stations for supporting various navigation and transportation applications (land, marine, air).	The monitoring network for geodynamics and tectonic studies in Indonesian region.
Integration, checking and validation for various coordination reference systems	Studying and mapping the characteristics of troposphere and ionosphere above Indonesian territory.

GPS CORS will also have significant impact for natural hazard mitigation applications. The Indonesian archipelago located at the junction of the Eurasia, Australia, Pacific, and Philippine Sea plates, resulting in wide spectrum topography, frequent earthquakes, and volcanism [*Hamilton,* 1979]. In the west, the Australia plate subducts beneath the Eurasia plate along the Java trench while to the east, the continental part to the east, the continental part of the Australia plate collides with the Banda arc and the Pacific-oceanic plate. Indonesian region is therefore prone to earthquakes, tsunamis and volcanic eruptions. Considering is rugged topography and usually heavy rainfall, landslide and flooding are also other prominent natural hazards that continuously affecting Indonesia. Land subsidence moreover also affecting some large cities in Indonesia. Up to now since about 1992, GPS surveys have been extensively used to study the characteristics and aspects of several natural hazard phenomena, namely earthquake [e.g. *Bock et al., 2003*; *Subarya et al.,* 2006; *Abidin et al.,* 2009], volcanic eruption [e.g. *Abidin et al.,* 2004; 2005; 2008c], land subsidence [e.g. *Abidin et al.,* 2008a; 2008b], and landslide [e.g. *Abidin et al.,* 2007].

By also using continuous GPS data from GPS CORS stations, then more detail characteristics of natural hazard phenomena can be studied, as shown by the examples in Figure 7. These results based on GPS continuous data are related to the 13 September 2007 Bengkulu earthquake [*Meilano et al.,* 2009] and the eruption of Papandayan volcano on 20 November 2002 [*Abidin et al.,* 2005].

Based on the examples shown in Figure 7 it can be realized that by locating GPS CORS stations on specific areas on and around subduction zones, active faults and active volcanoes, the CORS system may also function as the early warning system for earthquake and volcano eruption. However, in order to realize it, this potential use of GPS CORS for the early warning systems have to be supported by the reliable real-time data communication and powerful and sophisticated real-time GPS data processing.

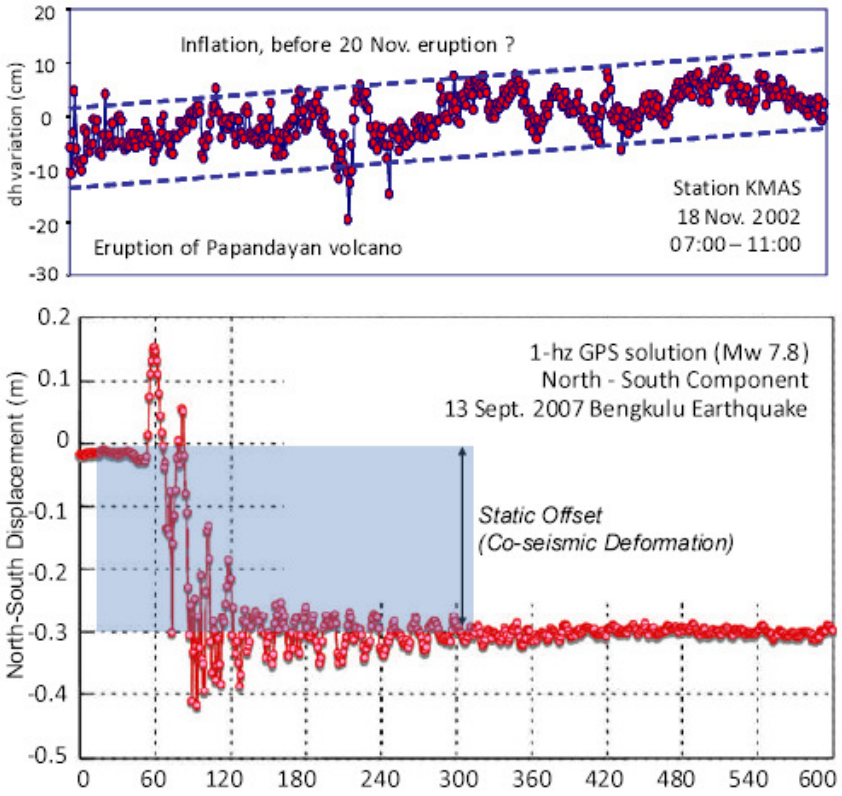


Figure 7. The potential applications of GPS continuous data for studying the characteristics of deformation related to the eruption of Papandayan volcano on 20 Nov. 2002 (above) and the 13 Sept. 2002 Bengkulu earthquake (below)

The existence of dense and reliable GPS CORS stations in Indonesia will actually be beneficial not only for natural hazard mitigation; but it will also important for supporting surveying and mapping applications, GPS-based meteorology, and Intelligent Transport System (ITS) of Indonesia. In order to support the transportation sectors, the CORS should also have a functional capability of being as regular DGPS (Differential GPS) system.

In the case of surveying and mapping, GPS CORS will have tremendous impacts in Indonesia, mainly for cadastral, construction and public utility, and mining surveying and positioning related activities. In the case of transportation sector, land and marine sectors will be most benefitted.

The potential use of GPS continuous data for mapping of Total Electron Content (TEC) over Indonesian region is indicated by the results shown in Figure 8. These monthly TEC models were derived using data from 10 GPS CORS data in and around Indonesia, i.e. from 6 IPGSN stations (SAMP, BAKO, KOEP, TOLI, PARN and BIKL) and 4 IGS stations (NTUS, COCO, DARW, and PIMO). More detail and comprehensive results on this ionospheric study can be seen in *Muslim* (2009). As in the case of GPS derived coordinate variation, the GPS derived TEC values have also the potential to be used as a kind of early warning for large earthquake, as shown by example given in Figure 9. In this case, it can be seen that a few days prior to the 26 December 2004 mega thrust Sumatra-Andaman earthquake, the ionospheric anomalies can be seen in GPS derived TEC using SAMP, NTUS and IISC continuous GPS data [*Muslim,* 2009]. However more research is still needed to clarify this pre-seismic GPS derived ionospheric anomaly.

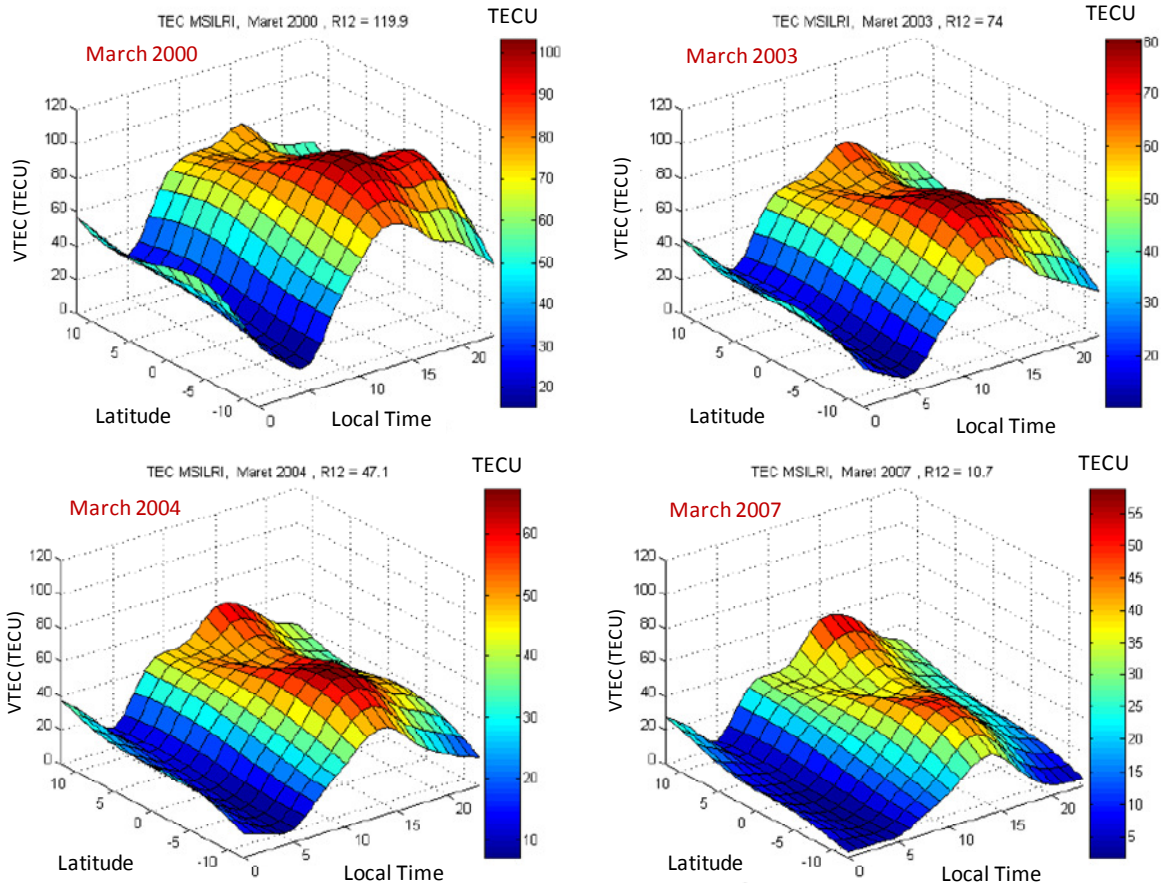


Figure 8. Example of Monthly TEC Model for Indonesia from GPS Continuous Data [*Muslim,* 2009].

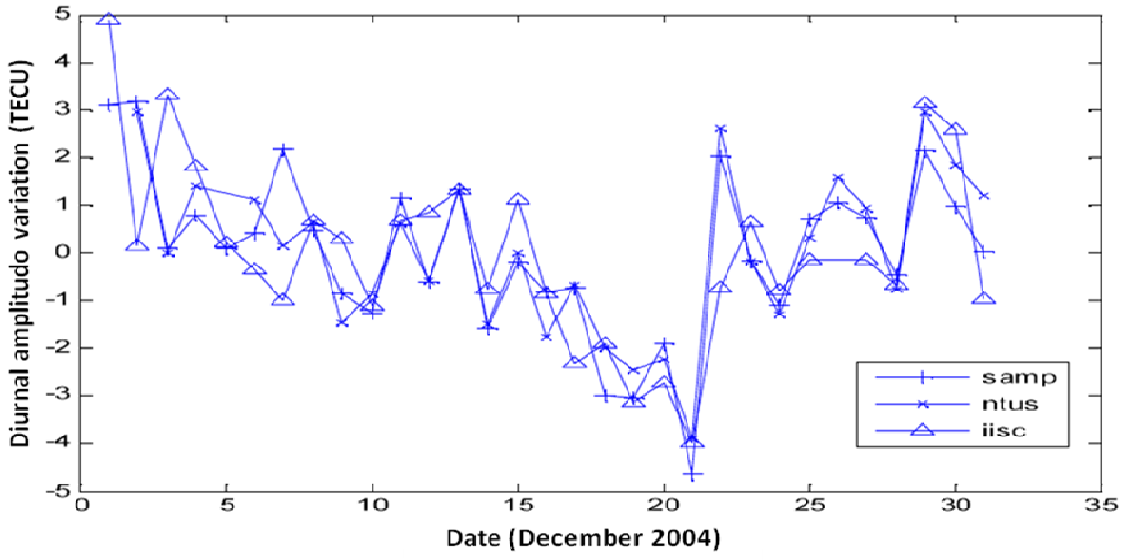


Figure 9. Ionospheric TEC anomalies prior to the 26 December 2004 Earthquake ? [*Muslim,* 2009].

Several National GPS CORS (IPGSN) stations can also become part of the Indonesian Tsunami Early Warning System (ITEWS) which is now in the process of establishment by the Indonesian government. The sensors of the ITEWS comprise seismometers, GPS instruments, tide gauges and buoys as well as ocean bottom pressure sensors as shown in Figure 10.

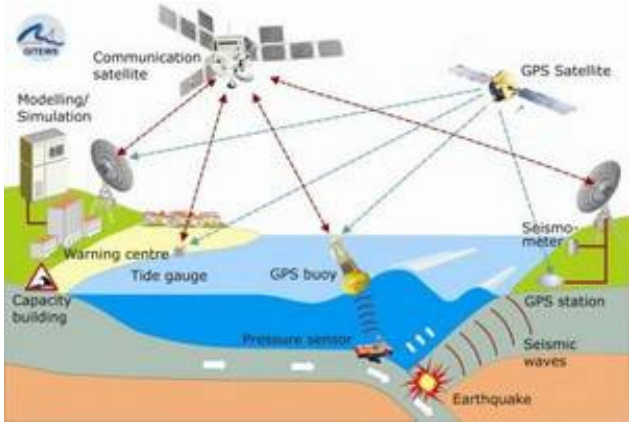


Figure 10. The Indonesian Tsunamy Early Warning Systems [*GITEWS*, 2010]

5. CHALLENGES AND LIMITATIONS

In establishing, operating and maintaining the good and reliable GPS CORS network covering all region of Indonesia, there are several challenges and limitations that have to be properly taken into consideration. These factors have both structural and cultural natures, and can be summarized as in the following points.

1. The reliability of the GPS CORS will strongly depend on good and reliable communication links between the continuous GPS stations and its data processing centre. In the case of IPGSN which is maintained by Bakosurtanal, its locations are located all over Indonesia, and the data processing centre at Bakosurtanal, Cibinong in West Java. Considering the vast area being cover, the archipelagic nature of Indonesia, relatively high spatial divide in the communication infrastructure inside the Indonesian region, and the remoteness of most of continuous GPS stations, the internet and satellite-based communication link seem to be the most effective solution for IPGSN. However, this mode of communication is relatively expensive; and in the case of internet connection, the 100% integrity and reliability cannot always be achieved, even in Java island region which has a relatively best communication infrastructure.

2. In order to have good, reliable and continuous mode of operation, all remote continuous GPS stations will also require proper and continuous maintenance and caring. Each station will therefore need proper resources all year long, e.g. electrical power supply, related hardware and software resources, and human resources for checking and taking care the station site and equipments. The difficulty in operating and maintaining the GPS CORS station in Indonesia will vary and usually getting more difficult when its location getting farther away from Java island and/or from the urban areas. The financial support for the daily operation and maintenance of GPS CORS stations therefore should always be considered, preferably in the long term basis. In the case of national GPS CORS such as IPGSN, the political will and continuous support from the central government is indeed necessary.

3. Maintenance and operation of the relatively large scale GPS CORS networks in Indonesia, such as those presently maintained by Bakosurtanal and in future also by BPN; will require also conducive and professional working culture, and also good support from dedicated and professional human resources. This human capital, is not needed just to operate and maintain the whole system, but also to process the collected data and analyze the obtain results for various applications and interests. At present times, the working culture in the government offices are not always compatible and suitable with the working culture needed for maintaining and operating the good and reliable GPS CORS networks. The number of qualified and dedicated persons for maintaining and operating GPS CORS should also be increased and provided with proper reward and remuneration. In this case, outsourcing part of the operational and maintenance activities of GPS CORS network to the private company may also be considered.

4. Since the large scale GPS CORS network covering Indonesian region will require substantial amount of qualified human capital, the related human resource development program should also be systematically planned by the related institutions (e.g. Bakosurtanal and BPN). In terms of high learning institutions, at present times in Indonesia there are four state universities (ITB Bandung, UGM Yogyakarta, ITS Surabaya, and Undip Semarang) and three private universities (Itenas Bandung, ITN Malang, University of Pakuan Bogor) that have study programs on surveying, geodesy and/or geomatics engineering. In the context of GPS CORS related capacity building in related institution, those high learning institutions, besides supplying their graduates can also offer various Continuing Education Programs (CEP) for enhancing the competency of human resources belonging to various agencies related to the GPS CORS programs.

6. Since the development of good and reliable national GPS CORS network (e.g. IPGSN) will absorb a lot of money and efforts, the use of the system is preferably not just only for supporting one specific sector such as positioning, surveying and mapping. Instead it should also support other national needs and interests, such as natural hazard mitigation and intelligent support system. Since each application usually will have their own specification on data requirement and management, then the GPS CORS system should be adaptively designed and operated to fully support those various applications.

6. CLOSING REMARKS

World-wide development of GPS CORS is increasing rapidly, due to increasing availability, accuracy, reliability and integrity of GPS systems; and also to advancements in electronics, instrumentation and control fields. The applications of GPS CORS in Indonesia has also steadily growing and has good opportunity to serve various national, regional and local needs and interests. The existence of good and reliable GPS CORS network covering the Indonesian archipelago would greatly increase our ability of observing the Earth system dynamics and phenomena in the region; and at the same time increasing the accuracy and reability of the

national spatial (geodetic) reference system for supporting various applications and needs related to positioning, navigation, surveying and mapping in the Indonesian region.

The advancements of GPS CORS networks in Indonesia should also be supported by proper legal infrastructures and qualified human resources. The support and endorsements from central government, parliament, related governmental agencies and high learning institutions will therefore also be important for suistainable development of GPS CORS in Indonesia.

Finally, it should be emphasized that some of GPS CORS applications in Indonesia (e.g. positioning, surveying and mapping and also intelligent transportation systems), if professionally managed can generate a substantial amount of revenue for government and also private sector. Therefore if is considered suitable, the business prospects and plan of the national GPS CORS system of Indonesia should also be taken into consideration and systematically be prepared.

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BIOGRAPHICAL NOTES

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