On the Development of Deformation Model for the Indonesian Geospatial Reference System (IGRS) 2013

Susilo SUSILO, Hasanuddin Z. ABIDIN, Irwan MEILANO, Kosasih PRIJATNA, Benyamin SAPIIE, Antonius B. WIJANARTO, and Joni EFENDI, Indonesia

Key words: deformation model, semi-dynamic datum, Indonesia, GPS, ITRF2008

SUMMARY

On 11 October 2013, Geospatial Agency of Indonesia launched a new geocentric datum named the Indonesian Geospatial Reference System 2013 (IGRS 2013). This new datum is a semi-dynamic datum in nature, which uses the global ITRF2008 reference frame, with a reference epoch of 1 January 2012. A deformation (velocity) model is used to transform coordinates from an observation epoch to or from this reference epoch. For its initial implementation, the model considers an initial deformation model setting based on 4 tectonic plates, 7 tectonic blocks, and 126 earthquakes. At present, the velocity model of IGRS 2013 is mainly realized using the GPS-derived rates at survey mode (sGPS) stations and continuous GPS stations, covering the period from 1993 to 2014. These GPS data are managed by the Geospatial Agency of Indonesia (BIG), Land Agency of Indonesia (BPN), and the Sumatran GPS Array (SUGAR). The GPS data is reprocessed and analysed using using the GAMIT/GLOBK 10.5 processing software suite. The derived velocities field shows the spatial variation of velocity direction and magnitude, which represents various plates or blocks tectonic motion in Indonesia region. This information is useful for development of the deformation model of IGRS 2013.

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1. INTRODUCTION

Indonesian Geospatial Information System (IGRS) 2013 is a new geodetic datum in Indonesia. It was launched on 11 October 2013 by Geospatial Information Agency (Badan Informasi Geospasial) of Indonesia. The previous datum called Datum Geodesi Nasional 1995 (DGN95) is inadequate forsurveying and mapping in certain region of Indonesia, and also for some current and emergingapplications due to on-going tectonic activities in Indonesia region (Abidin et al. 2015). IGRS 2013 is a semi-dynamic datum in natural, where the coordinates of the geodetic control network defined on International Terrestrial Reference Frame 2008 (ITRF2008) (Altamimi et al. 2011) at epoch reference on 1 January 2012 (BIG 2013). As a semi-dynamic datum, the changed of the coordinates of IGRS2013 in corporate with the plate/block motion and earthquake is represented by velocity/deformation model. The transformation geocentric coordinates to or from epoch reference of IGRS 2013 will be use this velocity (deformation) model. Until now, the velocity model is derived from GPS data observation only. There is two types of GPS data that used for derived the velocity model, sGPS (survey mode) and cGPS (continuous mode).

The previous initial velocity model was derived from 2007 – 2009for sGPS data and 2010 – 2013 for cGPS data (Abidin et al. 2015) and updated for longer time span GPS data from 1996 – 2013 (Susilo et al. 2015). In this paper we update the velocity model using the longer time span GPS data including several sGPS data on 2015.

2. DEVELOPMENT OF VELOCITY (DEFORMATION) MODEL IGRS2013

2.1 GPS Activity In Indonesia

The GPS activity in Indonesia was started since 1989 which BAKOSURTANAL (the former of BIG) was established the geodetic control network for study geodynamic in Sumatera using GPS campaigns survey, trough the GPS-GPS (GlobalPositioning System For Geodynamic Project) program which lasted up to 1994 (Abidin et al. 2015). This program was continued for others Indonesia region to establish the zeroth and first order geodetic network. The first geocentric datum for the geodetic control network in Indonesia was declare on 1995, called National Geodetic Datum 1995 (DGN95) and using precise GPS observations (Subarya and Matindas 1996). This datum realized by 60 of zeroth order geodetic network and and 660 of first order geodetic network monuments.

The Sumatran mega-thrust earthquake 2004 and Nias earthquake give an advantage on the development of GPS stations in Indonesia. Since the end of 2007, the development of continuous

GPS (cGPS) inIndonesia regions was quite impressive. There are more than 300 cGPS GPS stations (BIG, LIPI/EOS, BPN) and 1000 sGPS GPS stations in Indonesia. In 2015, BIG established 11 new cGPS stations and 20 sGPS stations. Figure 1 shows the recent distribution of continues GPS (cGPS) and campaign GPS (sGPS) stations in Indonesia. Using the available data since from 1993 until 2015 we updated the velocity model of IGRS2013.

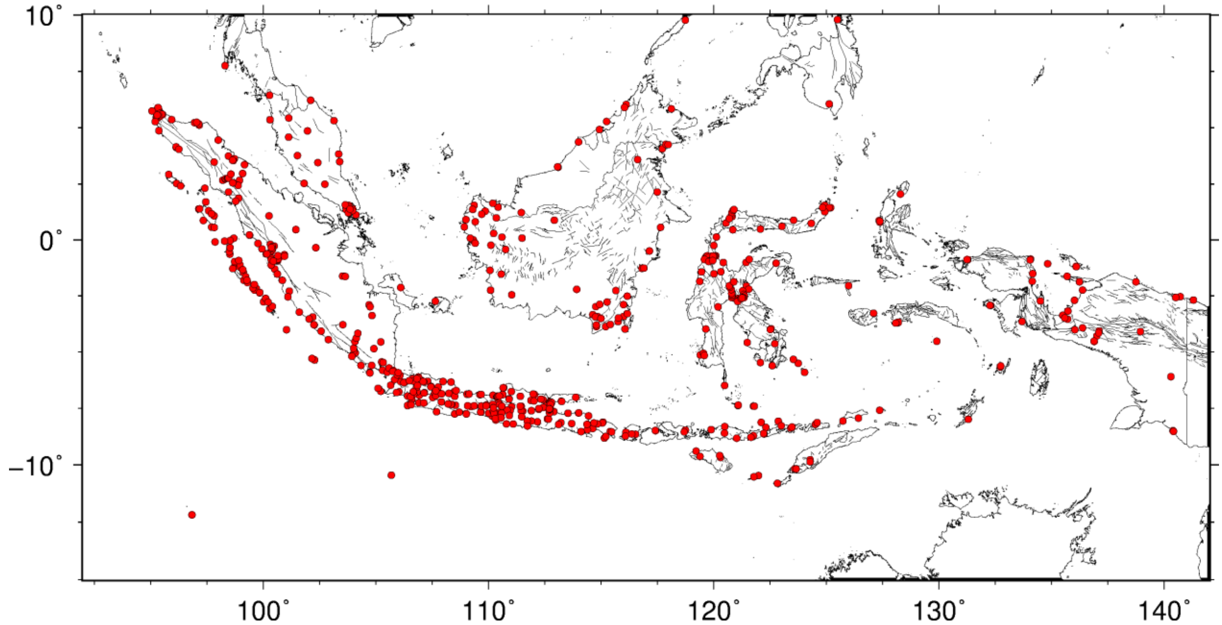

Fig 1: Distribution GPS stations (cGPS and sGPS) in Indonesia from BIG, LIPI, BPN for this research including GPS stations another countries. Red line is blocks boundaries from MORVEL 56 (Argus et al. 2011). Faults lineation downloaded from the East and Southeast Asia (CCOP) 1:2000000 geological map. (After Susilo et al. 2015)

2.2 GPS Processing

All GPS data started from 1993 until 2015 was processed using GAMIT/GLOBK 10.5 software suite (Herring et al. 2010a, b, c). We used ~22 IGS regional stations in the processing to tie our network with the ITRF2008. A three step approach was used in the GPS processing analysis (Reilinger et al 2006). In the first step, we estimate the daily positions together with the atmospheric, and earth orientation parameters using a loose apriori constraint for all networks from GPS phase observations. The position and covariance of all network solution from first step will be combined with the global IGSsolutions from MIT processing center (http://everest.mit.edu). Then, we remove the outliers and offset due to earthquake or antenna changes by examined the position time series. The post seismic deformation (Fig. 2) due to earthquake was removed by applying the logarithm function from Nikolaidis (2002). In the third step we estimate the positions and velocity from the clearly daily position time series. We map the loosely constraint solution into a well-constraint ITRF2008 by minimizing the position and velocity difference of selected sites from with a priori value of IGb08 on ITRF2008 realization.

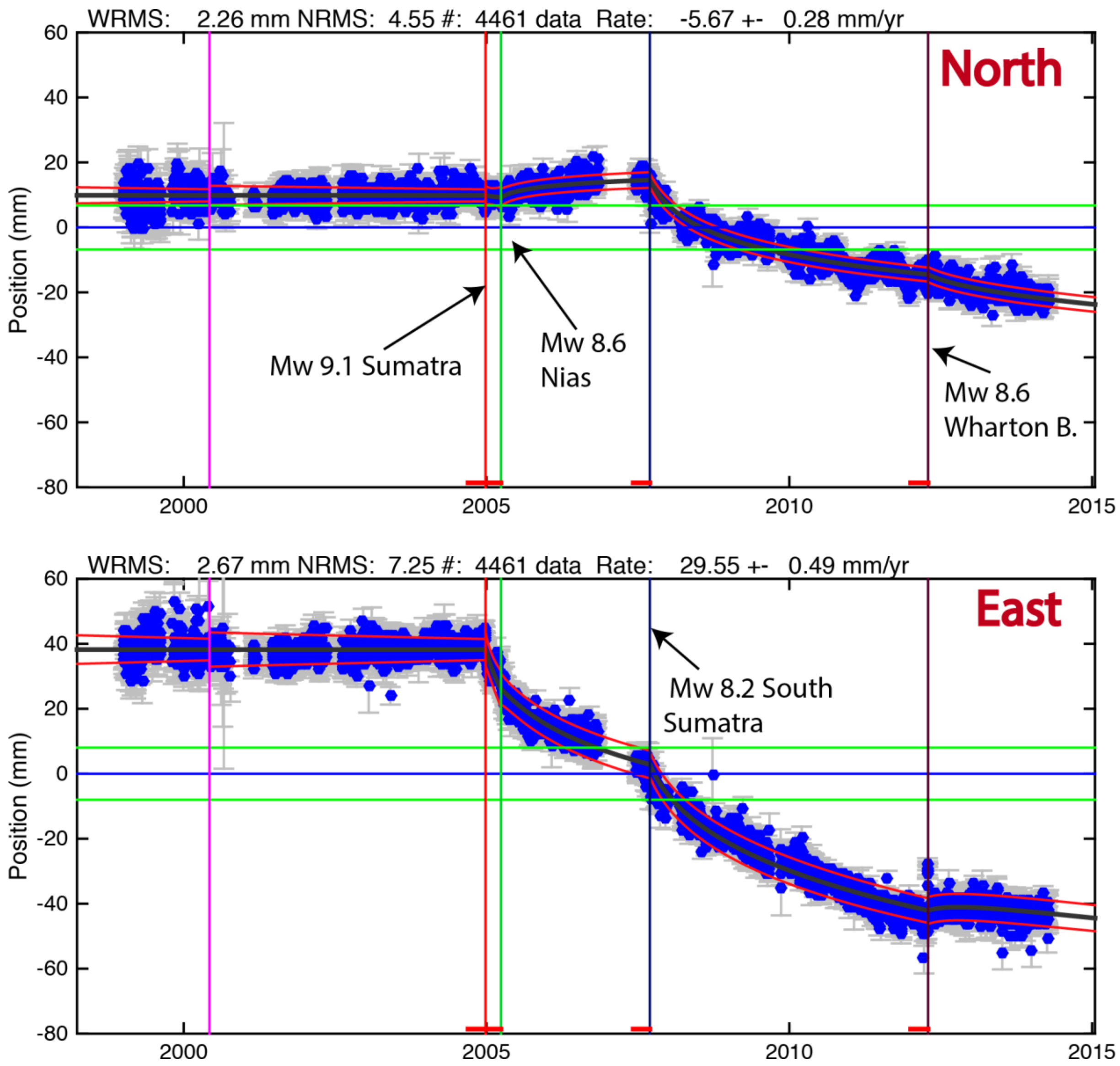

Fig. 2: Post-seismic deformation on the NTUS position time series (Susilo et al. 2014)

2.3 Velocity Model of IGRS2013

The GPS velocity model from our result shows in Fig. 3. The velocities show the different on magnitude and direction depend on where the GPS sites located in the plate/block. In general, the directions of velocities describe the motion of each plate/block. The different of this result from the previous is the number of sites in the Sunda block that have velocity. Our analysis shows that the post-seismic deformation due to great earthquake still affected to GPS sites.

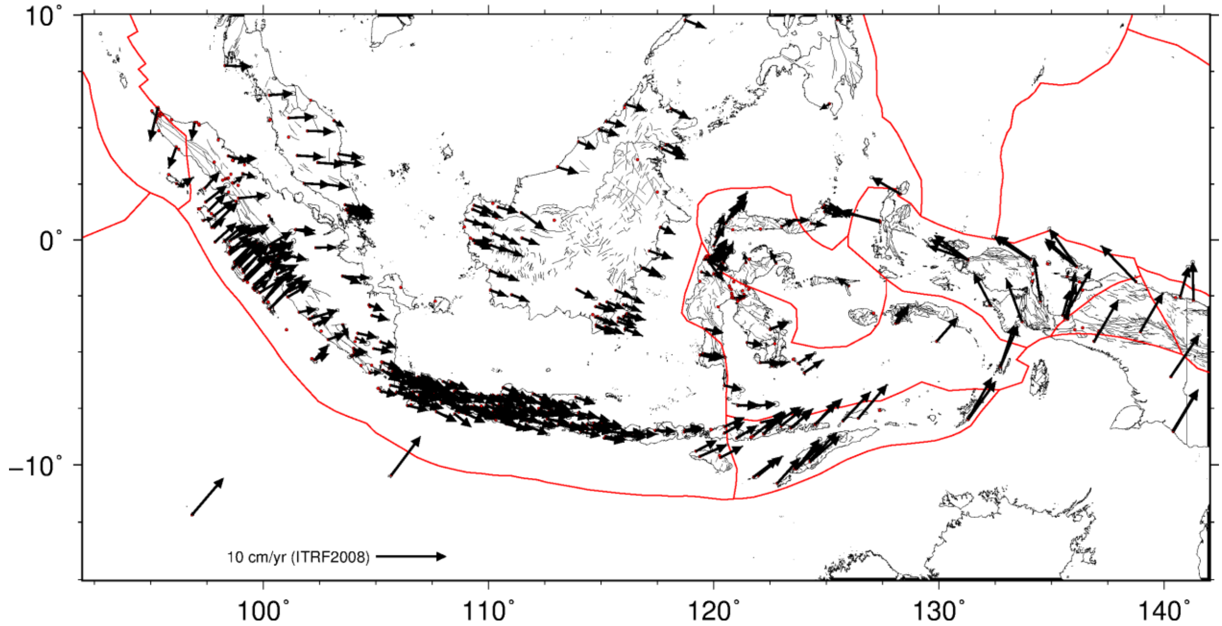

Fig. 3: Velocity model of IGRS2013 with respect to ITRF2008. Red line is blocks boundaries from MORVEL 56 (Argus et al. 2011). Faults lineation downloaded from the East and Southeast Asia (CCOP) 1:2000000 geological map.

In order to construct the velocity (deformation) model, it is very important to define that in the regional reference frame. By minimizing the velocity of 43 GPS sites that located in the Sunda block, we estimate the Sunda block pole rotation parameter. The wrms of the residual velocity (obs-model) is 1.17 mm/yr for North component and 0.79 mm/yr for East component, respectively. Fig. 4 shows the residual velocity with respect to Sunda block. From the velocity on Fig. 4, we can see that the residual velocities of GPS sites that located in the western of main land Sumatera still have big magnitude. In our suggestion maybe there is another block should be defined. If we look at the boundaries of the MORVEL56, we suggest that the boundaries not quite well to use in the development of deformation model for IGRS2013.

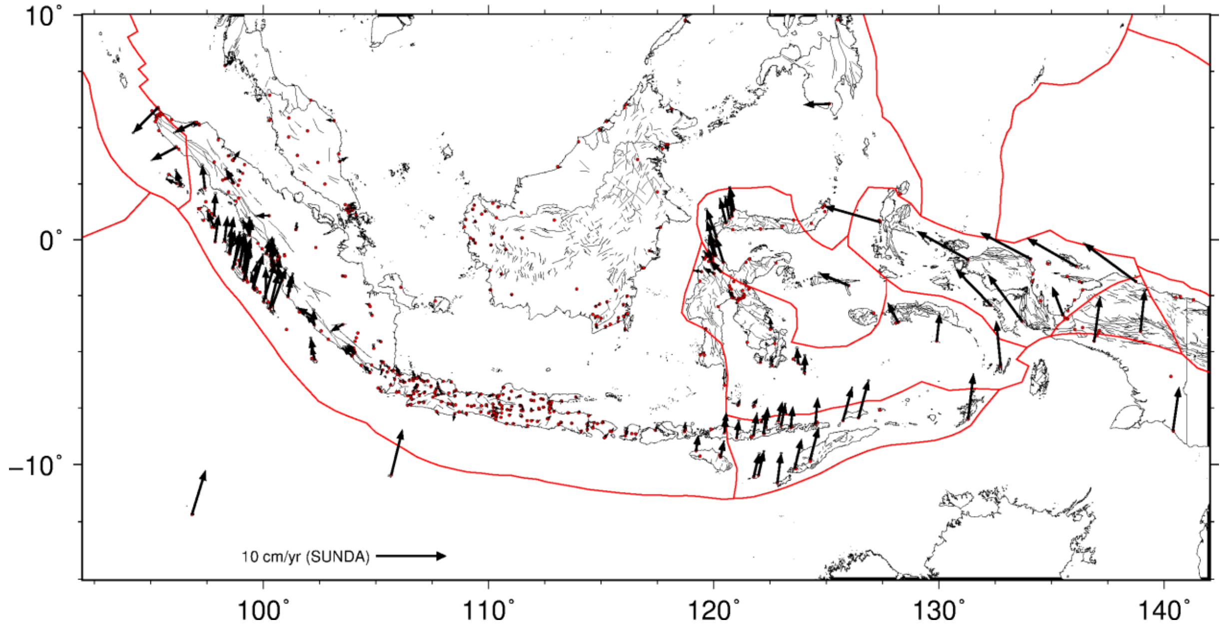

Fig. 4: Residual velocity model with respect to Sunda block. Red line is blocks boundaries from MORVEL 56 (Argus et al. 2011). Faults lineation downloaded from the East and Southeast Asia (CCOP) 1:2000000 geological map.

3. CONCLUSIONS

This research updated the velocity (deformation) model of IGRS2013 using GPS observation starting from 1993 until 2015. The result shows that the number of velocity model was increasing by adding the longer time span GPS data. This research shows the residual velocity with respect to SUNDA block. The updating velocity model of IGRS2013 will be useful to improve the deformation model of IGRS2013.

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CONTACTS

Mr. Susilo SUSILO
Geospatial Information Agency (BIG)
Jl. Raya Jakarta-Bogor KM. 46
Cibinong, INDONESIA
Tel. +62-21-8758061; Fax +62-21-8758061
Email: susilo@big.go.id; susilosarimun@gmail.com

Prof. Dr. Hasanuddin Z. ABIDIN
Geodesy Research Group, Faculty of Earth Science and Technology,
Institute of Technology Bandung (ITB)
Jl. Ganesha 10
Bandung, INDONESIA
Tel. +62-22-2530701; Fax. +62-22-2530702
Email: hzabidin@gd.itb.ac.id; hzabidin@gmail.com

Dr. Irwan Meilano
Geodesy Research Group, Faculty of Earth Science and Technology,
Institute of Technology Bandung (ITB)
Jl. Ganesha 10
Bandung, INDONESIA
Tel. +62-22-2530701; Fax. +62-22-2530702
Email: irwan.meilano@gmail.com

Dr. Benyamin SAPIIE
Applied Geology Group, Faculty of Earth Science and Technology,
Institute of Technology Bandung (ITB)
Jl. Ganesha 10
Bandung, INDONESIA
Tel. +62-22-2530701; Fax. +62-22-2530702
Email: bsapiie@geodin.net

Dr. Kosasih PRIJATNA
Geodesy Research Group, Faculty of Earth Science and Technology,
Institute of Technology Bandung (ITB)
Jl. Ganesha 10
Bandung, INDONESIA
Tel. +62-22-2530701; Fax. +62-22-2530702
Email: prijatna@gd.itb.ac.id

Dr. Antonius B. WIJANARTO
Geospatial Information Agency (BIG)
Jl. Raya Jakarta-Bogor KM. 46
Cibinong, INDONESIA
Tel. +62-21-8758061; Fax +62-21-8758061
Email: antonius.bambang@big.go.id

Mr. Joni EFENDI
Geospatial Information Agency (BIG)
Jl. Raya Jakarta-Bogor KM. 46
Cibinong, INDONESIA
Tel. +62-21-8758061; Fax +62-21-8758061
Email: joni.efendi@big.go.id