

The Maintenance of Indonesia Geodetic Control Network – In the Earth Deforming Zones

Cecep SUBARYA, Indonesia

Key words: Reference frame; velocity field; deforming zone; GPS

SUMMARY

The increase in geodetic control points positioning by Global Positioning System (GPS) measurements in Indonesia, since the first campaign measurements in 1989 has led to a revolution in the precision, spatial coverage, spatial and temporal resolution of deformation measurements. To observe a trend towards the need for an accurate, seamless statewide control network for all spatial referencing activities are demanding.

In response to these increasing spatial referencing needs, a systematic geodetic network maintenance procedure that minimizes the unique challenges within Indonesia to maintain control values up to date is a key issue. Maintenance procedure includes in monitoring temporal changes in geodetic coordinates due to Earth surface deformation, seismic activity, volcanic deformation, and land subsidence.

With the explosion of annual GPS geodetic surveys since 1992, a large number of recent publications have used subsets of these GPS data to address velocities across plate boundaries in terms of velocities of geodetic monuments throughout the Indonesian archipelago. This paper concludes with some considerations about the knowledge of the velocity field at the Earth's surface within a deforming plate boundary zone is important and may be used in constructing and maintaining geodetic datum that take account of Earth deformation.

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1. INTRODUCTION

The islands of Indonesia lie at the junction of the Eurasia, Australia, Pacific, and Philippine Sea plates, resulting in rugged topography, frequent earthquakes, and active volcanism. In the west, the Australia plate is subducted beneath the Eurasia plate along the Java trench. The direction of convergence is normal to the trench of Java, but oblique to the trench southwest of Sumatera.

Further east, the island of New Guinea, the leading edge of the northward moving Australian continent, is dominated by the rapid oblique convergence (~110mm/yr) between the Pacific and Australian plates. The oblique convergence has produced a complex array of microplates whose motions result in rapid shear, arc-continent collision, oceanic and continental subduction, continental rifting, and seafloor spreading. In West Papua a large section of the continent (the Bird's Head) is being detached along a rapid (80mm/yr) shear zone and subducted at Seram trough.

The complexity of tectonic processes in Indonesia was recognized by geologists long before the widespread acceptance of the theory of plate tectonic and has resulted in numerous geologic and geophysical studies in the region.

Geodetic data with the level of precision available using Global Positioning System (GPS) give us the opportunity to address many outstanding issues by providing two important number of information. First, geodetic data enable us to directly estimate *recent* rates of plate motion. Second, geodetic data can provide an estimate of the regional horizontal surface velocity field that may be used in constructing and maintaining geodetic datum that take account of Earth deformation.

We have conducted GPS studies throughout Indonesia and South and Southeast Asia for the last ten years. For the first time, we integrate the information from these GPS data to gain a more complete picture of tectonic block interactions in the Indonesia region. And then incorporate velocity solutions from each of tectonic block into velocity model by repeated GPS surveys. The reference frame used in the analysis of the entire Indonesia GPS data set is the 2000 International Terrestrial Reference Frame (ITRF2000) computed by the International Earth Rotation Service (IERS).

2. GPS DATA ACQUISITION AND PROCESSING

Our geodetic control network coordinates and velocity field for Indonesia is based on GPS surveys data collected annually from 1992 to 2004 which is part of scientific collaboration between the Indonesian National Coordinating Agency for Surveys and Mapping

TS8 – Reference Frame in Practice

2/6

Cecep Subarya

TS8.1 The Maintenance of Indonesia Geodetic Control Network - In the Earth Deforming Zones

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(BAKOSURTANAL), Scripps Institution of Oceanography, Rensselaer Polytechnic Institute, DEOS Delft University of Technology and GeoForschungZentrum Potsdam to monitor crustal deformation in Indonesia region. Beginning at year 1997 we were included GPS surveys data collected in Asia Pacific Regional Geodetic Project (APRGP) under Permanent Committee on GIS Infrastructure for Asia and the Pacific (PC-GIAP). More than 250 sites have had three or more occupations with at least a year between each observation. Sites in the GPS network were observed continuously for approximately three days during each occupation period. We used a combination of dual-frequency carrier phase and pseudorange GPS receivers of Trimble 4000's, Ashtech Z-XII, and Leica's in the data acquisition.

Positions and site velocities of the GPS data were estimated using GAMIT version 10.1 (*King and Bock, 2000*) and GLOBK/GLORG version 5.0 (*Herring, 2000*) on PC-based with LINUX O/S. The procedure used in this type of analysis has been presented in a large number of recent publications (e.g. *Herring et al., 1990; Feigl et al., 1993; Tregoning et al., 1994; and Bock et al., 2003*). We used precise IGS orbits in our daily solutions, and combined our daily solutions with solutions from a global set of sites in GLOBK for reference frame stabilization. Our GPS station coordinates and velocities have been calculated relative to ITRF2000 using GLORG, constraining the ITRF2000 coordinates and their velocities. Solutions we obtained for global sites agree well with ITRF2000 velocities, usually within a few mm.

3. ITRF2000 HORIZONTAL SURFACE VELOCITY FIELD

It is well known that global velocity models, predict only the rigid-body motion of major tectonic plates (e.g., Eurasia, Pacific, Australia) and cannot account for the velocity field in tectonically complex areas. Nonetheless, since velocity models such as NUVEL-1A account for the sum of global plate motion, we can compare them to velocities obtained from regional geodetic networks to infer zones of crustal deformation and the existence of tectonic microplates.

Recent velocities derived from our GPS surveys in Indonesia are plotted in Figure 1 in ITRF2000. Our results reveal several description of the region by identifying any distinct tectonic blocks, estimating their motion, and estimating slip rates along active faults. The velocity fields which are plotted in Figure 3 (The Southeast Sumatera block are rotating in a clockwise direction), Figure 4 (The East Sulawesi block are rotating in a counterclockwise direction), and Figure 5 (The Bird's Head portion of Papua after Ransiki earthquake October 2002 and shows several deforming features).

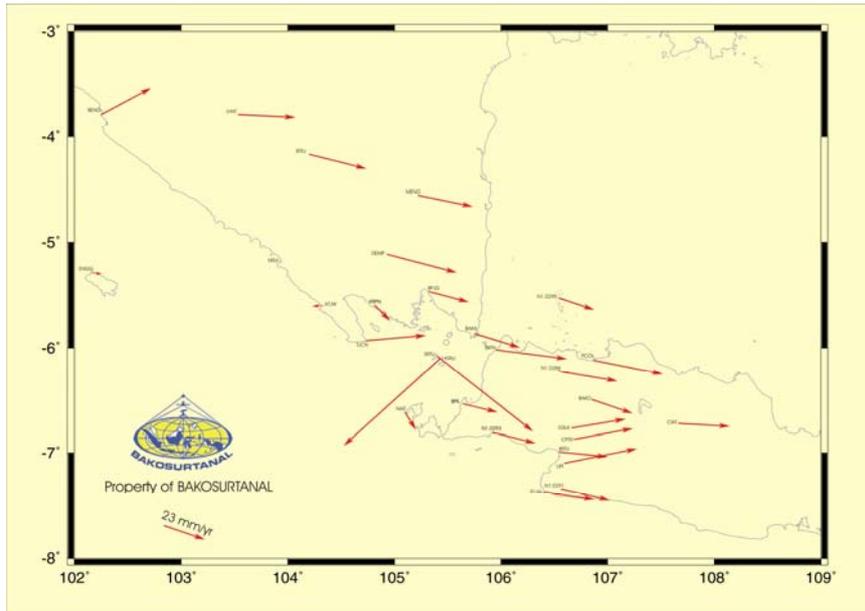


Figure 3: The velocity field around Sunda Strait shows the Southeast Sumatera block are rotating in a clockwise direction

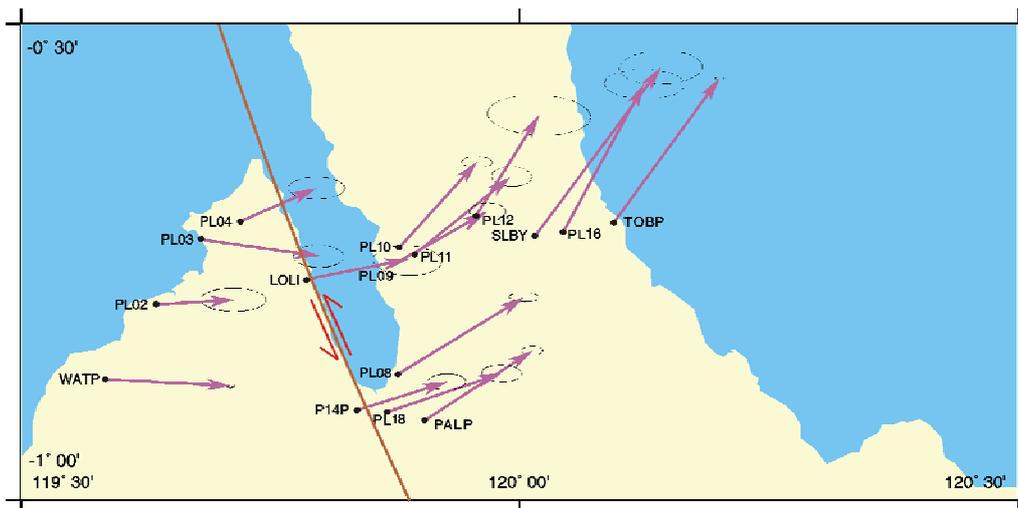


Figure 4: The velocity field along Sulawesi Palu-Koro fault shows the East block of the fault are rotating in a counterclockwise direction



Figure 5: The velocity field of the Bird's Head portion of Papua after Ransiki earthquake 10 October 2002, $M_w = 7.6$

4. DISCUSSION

Although the no-net-rotation (NNR) NUVEL-1A model (*Argus and Gordon, 1991; DeMets et al., 1994*) in Indonesia region considers only the motion of the major plates (Eurasia, Pacific, and Australia), it comes remarkably close to describing the velocity field of West Indonesia. Velocities for sites in East Sumatera, Java, Bali, Kalimantan, Southwestern part of Sulawesi, and North Australia are similar to the NNR-NUVEL-1A (NNRA) velocities. In contrast, large discrepancies between the GPS results and NNRA model occur along the eastern Banda arc, Molucca, northern Sulawesi, and in West Papua.

In presenting our results we intent here has been to illustrate the complexity of tectonic setting in Indonesia region. It is difficult to obtain a more precise estimate of the changes in geodetic station coordinates. However, further studies still ongoing to gain some insight into the spatial and temporal details of the dynamics and crustal deformation in the region to come to an end decision in using static, semi-dynamic, or dynamic geodetic datum.

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BIOGRAPHICAL NOTES

Cecep Subarya received his Master of Surveying Science from University of New South Wales, Sydney, Australia in 1991. In 1978, he began work at National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL). His work at BAKOSURTANAL has been focused on the use of GPS, including high precision Indonesia Geodetic Control Network, and the application of GPS on tectonics. Cecep has been fully involved in scientific collaboration with foreign researchers to monitor crustal deformation in Indonesia region, and active in Asia Pacific Regional Geodetic Project under Permanent Committee on GIS Infrastructure for Asia and the Pacific.

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Figure 1: Present Day Plate Motion in Indonesia in ITRF2000

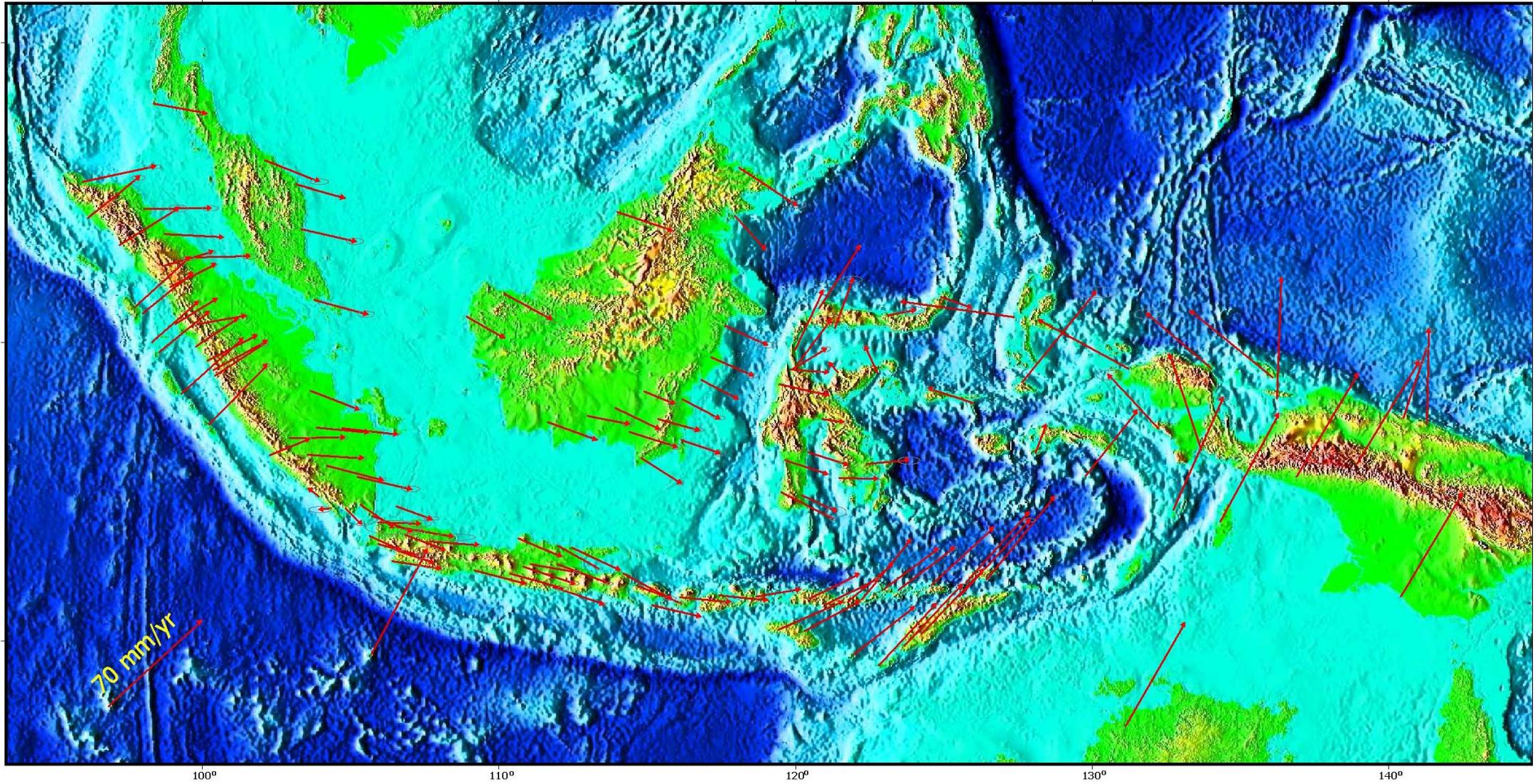


Figure 2: Present Status Indonesian Geodetic (Horizontal) Control Network

