On the Development and Implementations of the New Semi-Dynamic Datum for Indonesia

Susilo SUSILO¹, Hasanuddin Z. ABIDIN²,
Irwan MEILANO², Benyamin SAPEII²

1) Center for Geodetic Control Network and Geodynamic,
Geospatial Information Agency, Jalan Raya Jakarta-Bogor
Km. 46, Cibinong, Indonesia
2) Institute of Technology Bandung, Jl. Ganesa 10 Bandung, Indonesia

Indonesian Geodetic Datums

1862 - 1970
Local Topocentric Datum
Static Datum
Datum Genuk, Bukit Rimpah, Gunung Sahara, Serindung, Moncong Lowe, T21 Sorong

1970 - 1995
National Topocentric Datum
Static Datum
Datum ID74

1996 - 2013
National Geocentric Datum
Static Datum
DGN95

2013 - …
National Geocentric Datum
Semi-dynamic Datum
SRGI2013
Deformation Model

Launched on
October 17th
2013
Geodetic Datums in Indonesia

1. Dutch Colonial Time: LOCAL TOPOCENTRIC DATUM (Several, Static Datum)
2. ID 1974 : NATIONAL TOPOCENTRIC DATUM (Padang Datum, Static Datum)
3. DGN 1995 : NATIONAL GEOCENTRIC DATUM (Static Datum)
4. SRGI 2013 : NATIONAL GEOCENTRIC DATUM (Semi-Dynamic Datum)

Indonesian Local (Topocentric) Datum

Reference Ellipsoid: Bessel 1841 (a = 6377397 m, 1/f = 298.15)
Indonesian Local (Topocentric) Datum

Realization of Local (Topocentric) datum in Indonesia was conducted using Triangulation method.

<table>
<thead>
<tr>
<th>Region</th>
<th>Started</th>
<th>Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Java &amp; Madura</td>
<td>1862</td>
<td>G. Genuk (Batavia)</td>
</tr>
<tr>
<td>Sumatera</td>
<td>1883</td>
<td>G. Genuk (Batavia)</td>
</tr>
<tr>
<td>Bangka</td>
<td>1917</td>
<td>Bukit Rimpah</td>
</tr>
<tr>
<td>Sulawesi</td>
<td>1913</td>
<td>Moncong Lowe</td>
</tr>
<tr>
<td>Flores</td>
<td>1960</td>
<td>G. Genuk (Batavia)</td>
</tr>
</tbody>
</table>

courtesy of Edi Priyanto, BIG

Hasanuddin Z. Abidin, 2014
Geodetic Datum in Indonesia

1. Dutch Colonial Time: LOCAL TOPOCENTRIC DATUM (Several, Static Datum)
2. ID 1974 : NATIONAL TOPOCENTRIC DATUM (Padang Datum, Static Datum)
3. DGN 1995 : NATIONAL GEOCENTRIC DATUM (Static Datum)
4. SRGI 2013 : NATIONAL GEOCENTRIC DATUM (Semi-Dynamic Datum)

Datum Indonesia 1974 (DI-1974) (Padang Datum, Static Datum)

1. Coordinates of Datum Point (Padang, West Sumatra):
   \[ \lambda = 00^\circ 56' 38,414'' \]
   \[ \phi = 100^\circ 22' 08,804'' \]
   \[ h = + 3,912 \text{ m} \]

2. Reference Ellipsoid : INS (Indonesian National Spheroid), with \( a = 6378160 \text{ m} \), and \( f = 1/298.247 \) (based on the GRS 1967 figure but with 1/f taken to 3 decimal places exactly)

3. Realized using geodetic surveys based on Doppler Satellite observation.
Doppler Stations in Indonesia

courtesy of Ir. Edi Priyanto, BIG

Geodetic Datum in Indonesia

1. Dutch Colonial Time: LOCAL TOPOCENTRIC DATUM (Several, Static Datum)
2. ID 1974 : NATIONAL TOPOCENTRIC DATUM (Padang Datum, Static Datum)
3. DGN 1995 : NATIONAL GEOCENTRIC DATUM (Static Datum)
4. SRGI 2013 : NATIONAL GEOCENTRIC DATUM (Semi-Dynamic Datum)
(Geocentric Datum, Static Datum)

1. First national geocentric datum.
3. Realized using GPS static surveys and continuous observations (GPS CORS)

GPS Control Stations in Indonesia (2002)

courtesy of Edi Priyanto, BIG
GPS Control Stations in Indonesia (2008)

courtesy of Cecep Subarya, BIG

Around 950 stations

Hasanuddin Z. Abidin, 2014

Geodetic Datum in Indonesia

1. Dutch Colonial Time: LOCAL TOPOCENTRIC DATUM (Several, Static Datum)
2. ID 1974 : NATIONAL TOPOCENTRIC DATUM (Padang Datum, Static Datum)
3. DGN 1995 : NATIONAL GEOCENTRIC DATUM (Static Datum)
4. SRGI 2013 : NATIONAL GEOCENTRIC DATUM (Semi-Dynamic Datum)

Hasanuddin Z. Abidin (2014)
Tectonic Complexity of Indonesian Region

- Intersection of 3 major plates.
- Wide range of tectonic environments, including island arc volcanism, subduction zones, and arc-continent collision

Seismic Complexity of Indonesian Region

- Complex plate boundaries
- High seismicity, shallow EQs mostly confined at the subduction zone
**TECTONIC COMPLEXITY OF INDONESIAN REGION (DISPLACEMENT)**


---

**Coordinate Displacements**

3D coordinate displacements due to motion of tectonic blocks

- 28 cm
- 65 cm

Coordinate displacements due to tectonic block motion since 1996, from GPS observations; courtesy of Susilo (ITB).

courtesy of Irwan Meilano (ITB)
Coordinate Displacements

3D coordinate displacements due to earthquakes

Coordinate displacements due to earthquakes since 1996, from GPS observations; courtesy of Susilo (ITB).

courtesy of Irwan Meilano (ITB)

Indonesian Geospatial Reference System, IGRS 2013
Sistem Referensi Geospasial Indonesia, SRGI 2013
(launched: 11 October 2013)

- Semi-Dynamic datum.
- Connected to the global ITRF2008 reference frame.
- Reference epoch: 1 January 2012
- Reference Ellipsoid: WGS 1984
  \( a = 6378137.0 \text{ m}; \ 1/f = 298.257223563 \).
- If a new version of the ITRF reference frame becomes available, then the IGRS reference frame will also be updated accordingly.
- A velocity model, which incorporates tectonic motion and earthquake related deformation, is used to transform coordinates at an observation epoch to or from this reference epoch.

Hasanuddin Z. Abidin (2014)
Realization of IGRS2013

Plate boundaries from Argus et al. (2011)

Deformation model based on 4 tectonic plates, 7 tectonic blocks, and 126 earthquakes data

courtesy of Susilo (BIG).

Hasanuddin Z. Abidin, 2014
Continuous GPS of BIG Indonesia

Total in 2013 = 118 Stations

Hasanuddin Z. Abidin (2014)

Continuous GPS of BPN Indonesia

Total in 2013 = 183 Stations

Hasanuddin Z. Abidin (2014)
Static GPS of BIG Indonesia

Total in 2013 = 1350 Monuments

Hasanuddin Z. Abidin (2014)

New Velocity Model of IGRS 2013

New velocity model after Abidin et al. (2015), derived from 1996 – 2013 GPS data
Closing Remarks (1)
Updating the Velocity Model

- What are the criteria for updating the model?
- Time period and spatial coverage for updating the velocity (deformation) model?
- Reasons for updating the model?
  1. Displacements due to tectonic plates and blocks motions.
  2. Earthquakes related deformations.
  3. Displacements due to landslides, volcanic eruptions, land subsidences, etc.

Hasanuddin Z. Abidin (2014)

Closing Remarks (2)
Socialization of IGRS 2013

- Education and socialization to all related users and stakeholders, about all aspects of the datum change, has to be well conducted.
- Fast, reliable and user-friendly web-based and online service systems must be established for the implementation of the new datum.
- BIG (Geospatial Agency of Indonesia) has to be a leader in implementation and socialization of this new datum.

Hasanuddin Z. Abidin (2014)
Thank you very much for your attention
Realization and Implementation of SRGI 2013

Deformation (Velocity) Model has to be established for $t_{\text{obs}} \leftrightarrow t_{\text{ref}}$ coordinate transformation

- **The model coverage: all over Indonesia.**
- **Indonesian area cannot be represented only by a single velocity model.**
- **Updating time for each model?**
- **How to accommodate the deformation related earthquakes?**
2 Velocity Model based on the plate motion model MORVEL (*DeMets et al. 2010*)

![Map of Velocity Model](image1)

courtesy of Irwan Meilano (ITB) and Susilo (BIG).

Hasanuddin Z. Abidin, 2014

---

2 ITRF 2008 velocities at the BIG GPS CORS stations computed using GPS CORS data from 2010 to 2013

![Map of ITRF 2008 Velocities](image2)

courtesy of Susilo (BIG).

Hasanuddin Z. Abidin, 2014
The Helmert transformation parameters of the estimated GAMIT/GLOBK solution with respect to ITRF2008 epoch 2005

Preliminary Euler pole parameters as estimated from GPS CORS solutions in Indonesia.

<table>
<thead>
<tr>
<th>Plate</th>
<th>Latitude (deg)</th>
<th>Longitude (deg)</th>
<th>Rate (deg/Myr)</th>
<th>Semi Major (deg)</th>
<th>Semi Minor (deg)</th>
<th>Azimuth (deg)</th>
<th>Rate uncertainty (deg/Myr)</th>
<th>wrms (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU</td>
<td>32.119</td>
<td>37.615</td>
<td>0.635</td>
<td>0.18</td>
<td>0.04</td>
<td>106.0</td>
<td>0.0006</td>
<td>0.44</td>
</tr>
<tr>
<td>BS</td>
<td>0.271</td>
<td>120.474</td>
<td>2.083</td>
<td>0.36</td>
<td>0.03</td>
<td>348.3</td>
<td>0.0918</td>
<td>1.04</td>
</tr>
<tr>
<td>BH</td>
<td>-52.415</td>
<td>54.260</td>
<td>0.536</td>
<td>5.33</td>
<td>0.12</td>
<td>85.7</td>
<td>0.0037</td>
<td>0.20</td>
</tr>
<tr>
<td>MO</td>
<td>8.015</td>
<td>-49.090</td>
<td>1.198</td>
<td>1.99</td>
<td>0.11</td>
<td>55.1</td>
<td>0.1774</td>
<td>0.06</td>
</tr>
<tr>
<td>SU</td>
<td>45.162</td>
<td>128.115</td>
<td>0.313</td>
<td>1.42</td>
<td>0.14</td>
<td>27.8</td>
<td>0.0052</td>
<td>0.70</td>
</tr>
<tr>
<td>TI</td>
<td>2.461</td>
<td>113.389</td>
<td>1.350</td>
<td>0.27</td>
<td>0.02</td>
<td>322.3</td>
<td>0.0260</td>
<td>2.64</td>
</tr>
</tbody>
</table>

In the above Table: AU = Australian plate; BS = Banda Sea block; BH = Birds Head block; MO = Molucca Sea block; SU = Sunda block; TI = Timor block

courtesy of Susilo (BIG).

Hasanuddin Z. Abidin, 2014
3 Updating Velocity Model

Fig 2. One dimensional position of a mark against time. Dotted line shows the actual movement of the mark. The solid line is the initial deformation model and the dashed line is the revised deformation model after the time of updating, indicated by the vertical dashed line.

Ref.: Blick et al. (2005)

Fig 3. Coordinate of mark defined by deformation model that does not include the deformation event.

Fig 4. Coordinate of mark defined by deformation model incorporating a patch to model the deformation event.

3 Impact of Earthquakes related deformation

- Inter-seismic
- Co-seismic
- Post-seismic

Hasanuddin Z. Abidin (2014)

Figure 3. Deformation model in practice showing how cumulative patches can accommodate seismic deformation within an interseismic deformation model.

Ref.: Stanaway et al. (2012)
3 Impact of Earthquakes related deformation

- What magnitude of earthquake should be considered? Larger than Mw 6.0?
- Spatial coverage of the deformed area that should be considered?
- How fast the model should be updated?
- Socialization to the users?

http://srgi.big.go.id/peta/jkg.jsp
Closing Remarks (1)

✓ How to synergize the velocity model derived using the plate motion model (e.g. MORVEL) with the velocity field estimated using pGPS and GPS CORS data?

✓ Can the existing plate and block motion model be able to accurately predict the velocity field for all over Indonesia. In this case, the interplate coupling models for all plates and blocks interfaces in Indonesian region should also be established.

✓ Detail mechanisms on handling secular trends, earthquakes offsets (co-seismic deformation), and post-earthquakes motion (post-seismic deformation) should also be established.

Hasanuddin Z. Abidin (2014)

Closing Remarks (2)

✓ The Indonesian GPS CORS network should be densified to cover all of Indonesia, especially Borneo Island and the eastern parts of Indonesia. With a denser GPS CORS network, the deformation model of IGRS 2013 can be estimated more reliably and in more detail.

✓ Cooperation and coordination with all related positioning and mapping institution in Indonesia (e.g. BPN, Army Topographic Agency, Navy Hydrographic Agency) should also be maintained by BIG throughout the implementation process of IGRS 2013.

Hasanuddin Z. Abidin (2014)
Terima Kasih