TROPOSPHERIC GRADIENTS FROM NUMERICAL WEATHER MODELS AND THE INDIAN CORNS NETWORK

Nabila Putri1, Daniel Landskron1, Gregor Möller1, Johannes Böh1, Yusiti Lumban Gaol2
1Geodesy and Geoinformation, Technische Universität Wien, Vienna, Austria 2Badan Informasi Geospasial, Cibinong, Indonesia

1 INDONESIAN CORNS NETWORK

GNSS are widely used for various applications, such as navigation, surveying, geodynamics monitoring, and atmospheric studies. To fulfill these needs, permanent GNSS stations that operate continuously, known as CORS (Continuously Operating Reference Stations), become necessary. The brief history of the development of the official Indonesian CORS network, InaCORS, can be seen below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Status</th>
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<tr>
<td>1996</td>
<td>Sumatra Andaman earthquake triggered the rapid development of CORS network.</td>
<td>10 CORS sites built in Indonesia.</td>
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<tr>
<td>2004</td>
<td></td>
<td>Other institutions and universities started to build their network of CORS sites.</td>
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<tr>
<td>2009</td>
<td></td>
<td>InaCORS consists of 135 sites (more to be built in the future).</td>
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The main purpose of InaCORS is to maintain an accurate and precise geodetic reference frame over the entire Indonesian region, and to support a wide range of scientific and practical applications, such as geodynamics and deformation monitoring, meteorological and ichnological studies, and other needs in the frame of national mapping (Abdillah et al., 2020).

2 OBJECTIVE

Many of the applications supported by InaCORS require very high accuracy. To obtain the desirable accuracy, various error sources need to be dealt with, including the tropospheric delays. Horizontal gradients are used to account for azimuthal asymmetries of the delays, and can be calculated from numerical weather models or estimated from GNSS observations.

In this study, horizontal north and east gradients from numerical weather models (NWM) will be compared with gradient estimates from InaCORS observations. The purpose is to assess whether gradients from numerical weather models fit well with real observations.

3 GRADIENTS FROM NWM

Steps to obtain horizontal gradients from NWM data can be seen in Figure 2. An example of the gradient result at site BA90 is shown in Figure 3. The gradients at this site show some biases, especially for the hydrostatic gradients. Similar biases also occur at almost all InaCORS sites. The cause for these biases is still unknown.

In general, the wet gradients are larger than the hydrostatic gradients. At several sites, there appears to be an annual periodic pattern, especially for the wet gradients (north gradients), such as at sites CPON and CSAB.

4 GRAD

The mean and standard deviations for each gradient components at all sites is calculated. The result is then plotted on a map of InaCORS sites, to see whether a spatial pattern will emerge.

For hydrostatic north gradients (Gn) (Figure 4a), sites in the southern part of Indonesia, below the equator, have positive values. The values decrease towards the equator and become negative for sites above the equator.

For hydrostatic east gradients (Ge) (Figure 4b), almost all sites have positive values, although the magnitudes are larger for sites located in the western part of the island and decrease eastwards. Sites in Sumatra and Java also tend to have larger values.

For Gn wet (Figure 4c), the mean values are positive for the southern part of the island and negative for the northern part. In Java, the negative values are significantly smaller than the positive values. The mean values for Ge wet (Figure 4d) are positive at sites in the western part of the island and negative in the eastern part. The total gradients have similar patterns as the wet gradients.

The pattern of the mean values for each gradient appears to be influenced by the proximity and cardinal direction of the coast. Mountain ranges along the islands of Sumatra and Java may be an influential factor as well. However, it is difficult to distinguish the two factors and determine which is more influential.

5 GRADIENTS FROM INACORS OBSERVATIONS

Out of 135 InaCORS sites, 2 are currently inactive. Several sites have incomplete observations, due to various reasons (e.g. problems with receivers, offline connection). Data processing for all available InaCORS sites was carried out using network analysis with GAMIT (Herring et al., 2015) by the Geospatial Information Agency.

Total gradients for north and east components were estimated twice a day (i.e. 12 hours apart), at 00 and 12 UTC, from 1 January 2014 until 31 December 2016. The gradient formulation follows Chen and Herring (1997). The outliers are removed from observations, following the 3σ rule. Short data gaps, usually lasting one to two days, occur at all sites. Longer data gaps, which can last for several weeks, also occasionally occur at several sites.

Example of gradients estimates from InaCORS observations at site BA90 is shown in Figure 5.

6 COMPARISON OF GRAD AND INACORS GRADIENTS

Since InaCORS observations do not give estimates for hydrostatic and wet gradients, comparison can only be done for total north and east gradients at 00 and 12 UTC. Four sites are chosen for the comparison, based on their altitude and data availability, namely sites BAKO, CPON, CSAB, and CUBE. The results can be seen in Figure 6. Coordinates of each site are given.

At site BAKO, there are disagreements for Ge in May 2015. Disagreements also appear for Gn throughout the year. Large biases occur at site CPON for Ge. The magnitude of Ge estimates also appears to be slightly larger than GRAD.

At site CSAB, some disagreements occur in the early 2014 for Ge. Period pattern can be seen for both GRAD and estimates. At site CUBE, between May 2015 until September 2015, the magnitude of Ge appears to decrease. This phenomenon can be seen in both GRAD and estimates.

7 CORRELATION COEFFICIENTS

The correlation coefficients r for each site are less than 0.6, with Gn tend to have larger values than Ge on average. Typically, the values range between 0.3-0.4 for Gn and 0.2-0.3 for Ge. The largest correlation coefficients values for both Gn and Ge are 0.59 and 0.38, respectively, at site CUBE. All sites built in 2016 (10 sites) have small values of r for Ge, only 0.27 at the largest. Other sites with very small r values typically have large data gaps that can last for several weeks, or even months. The r values for the four InaCORS sites used in the comparison can be seen in Table 1.

8 CONCLUSIONS

Gradients from NWM (GRAD) appear to be influenced by the proximity and cardinal direction of the coast. Mountain ranges possibly influence the gradients as well. The values of GRAD and gradients from InaCORS are quite small, particularly for Ge, less than 0.6 at all sites. The cause for this needs to be investigated. Despite the small r values, the results from this research provide a good basis for further studies regarding the development of refined tropospheric delay models, particularly the horizontal gradients, for the Indonesian region.

REFERENCES


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