TROPOSPHERIC GRADIENTS FROM NUMERICAL WEATHER MODELS AND THE INDONESIAN CORS NETWORK

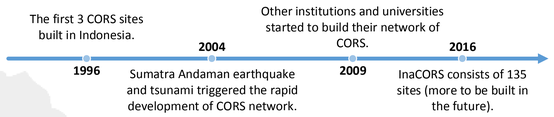
Nabila Putri[1], Daniel Landskron[1], Gregor Möller[1], Johannes Böhm[1], Yustisi Lumban Gaol[2]

[1]Geodesy and Geoinformation, Technische Universität Wien, Vienna, Austria [2]Badan Informasi Geospasial, Cibinong, Indonesia

BADAN INFORMASI GEOSPASIAL

1 INDONESIAN CORS 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), have become necessary. The brief history of the development of the official Indonesian CORS network, InaCORS, can be seen below:



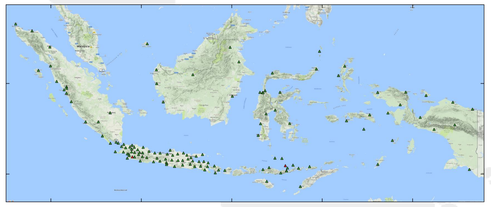


Figure 1 The status of InaCORS network at the end of 2016. Source: Geospatial Information Agency, 2017.

The main purpose of InaCORS is to maintain an accurate and precise geodetic reference frame over Indonesian region, and to support a wide range of scientific and practical applications, such as geodynamics and deformation monitoring, meteorological and ionospheric studies, and other needs in the frame of surveys and mapping (Abidin et al., 2010).

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 asymmetry 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 gradients 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 BAKO 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.

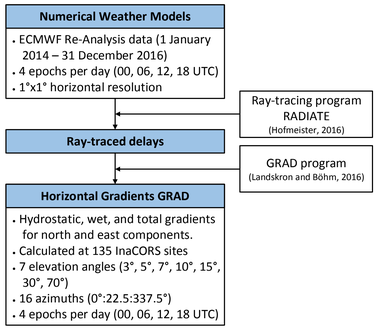


Figure 2 Steps to obtain horizontal gradients from numerical weather models.

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 north gradients (Gn wet), such as at sites CPON and CSAB.

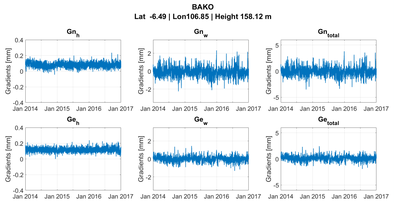


Figure 3 An example result from NWM of gradients for site BAKO (part of the IGS network).

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.

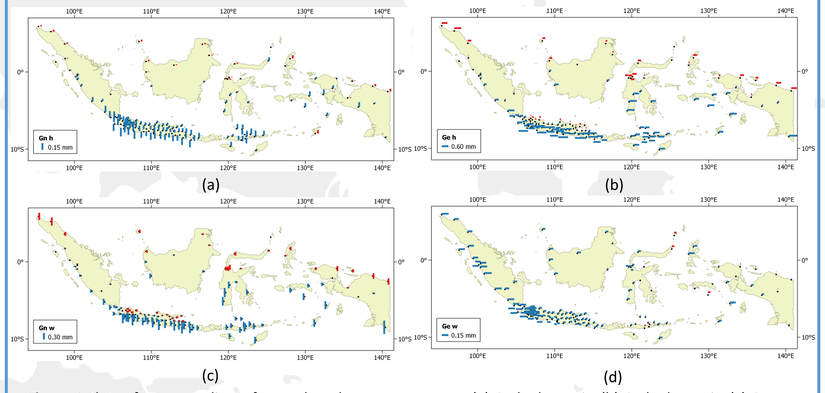


Figure 4 Plots of mean gradients for north and east components: (a) Gn hydrostatic, (b) Ge hydrostatic, (c) Gn wet, (d) Ge hydrostatic. Total gradients have similar patterns as wet gradients. Blue shows positive values, red shows negative values.

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.

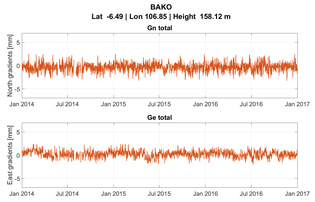


Figure 5 Gradients estimates from InaCORS observations at site BAKO.

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 obervations, 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 BAKO 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 latitude and data availability, namely sites BAKO, CPON, CSAB, and CUKE. The results can be seen in Figure 6. Coordinates of each site are given.

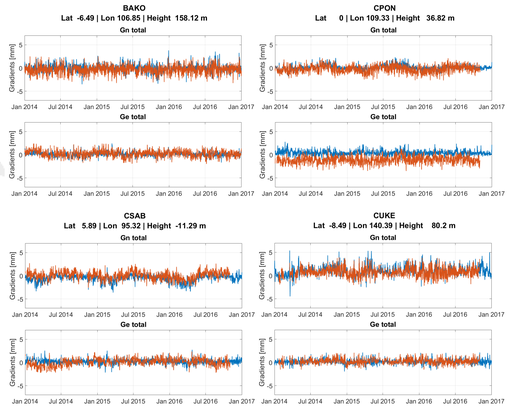


Figure 6 Comparison of gradients from GRAD and InaCORS at four sites (BAKO, CPON, CSAB, and CUKE). Blue: GRAD, orange: gradients estimates from InaCORS.0

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 Gn 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 CUKE, between May 2015 until September 2015, the magnitude of Gn 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 CUKE.** 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.

Table 1 Correlation coefficients

Site	r Gn	r Ge
BAKO	0.44	0.35
CPON	0.45	0.07
CSAB	0.51	0.13
CUKE	0.59	0.38

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 *r* 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

Abidin H.Z. et al. (2010): The applications of GPS CORS in Indonesia: Status, prospect, and limitation. Proceedings of the FIG Congress 2010.

Chen G. & Herring T.A. (1997): Effects of atmospheric azimuthal asymmetry on the analysis of space geodetic data. J. Geophys. Res., 102, 20489-20502.

Herring T.A. et al. (2015): GAMIT reference manual. MIT.

Hofmeister A. (2016): Determination of path delays in the atmosphere for geodetic VLBI by means of ray-tracing. Geodesy and Geoinformation, TU Wien.

Landskron D. & Böhm J. (2017): Refined discrete and empirical horizontal gradients in VLBI analysis. J. Geod, 1-13.

ACKNOWLEDGEMENTS

This study was supported by the OeAD through the Ernst Mach Grant - ASEA-UNINET. The authors would like to acknowledge the Austrian Science Fund (FWF) for funding project Radiate ORD (ORD-68). The Indonesian CORS network data were kindly provided by the Center for Geodetic Control Network and Geodynamics, Geospatial Information Agency (PJKGG, BIG).

This presentation participates in OSPP

EGU Outstanding Student Poster & PICO Contest

nabila.putri@geo.tuwien.ac.at