Evaluation of Base Station CORS UDIP and CSEM for monitoring Ground Deformation Sayung Demak Indonesia

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Abstract. Sayung is a subdistrict in Demak Regency which is located on the north coast is very vulnerable to natural disasters such as rob flood, abrasion and deformation of land subsidence. The condition is suspected, among others, by several factors, among others, geological structure as a large area dominated by young alluvium layers are still experiencing compression, loading and retrieval of ground water. It is necessary to do research related to ground deformation. The geodetic method used for monitoring ground deformation by satellite surveys with GNSS. The research was conducted to observe GPS survey in 2015 and 2016. GNSS data would be processed with scientific processing GAMIT 10.6. Strategic of GPS data processing is the important to reach a better accuracy. The purpose of this research is to evaluate the result of calculation of coordinate value and spatial deformation obtained by both base station that is CORS UDIP and CORS CSEM for monitoring ground deformation.

Keywords: Vulnerable, GNSS, CORS, Deformation

1. Introduction
Ground deformation is a change in ground level in the vertical direction to the bottom of a height reference plane which is geometrically represented by height collection point on the ground surface [1]. The speed of ground deformation especially land subsidence is slow (mm) in a relatively long period of time. The phenomena are often found not only in big cities in Indonesia such as Jakarta, Semarang, and Bandung [2] but also in several major cities in the world including in the United States [3], Venezuela [4], Choshuichi - Taiwan [5] and Iran [6].

Demak is a district located in the north of Java Island. Historically, most of the areas of Demak regency, especially on the northern coast, have unstable soil structures, since they were originally swamps. Geographically Demak is highly vulnerable due to enviromental stress, such as abrasion, tidal, land subsidence, and coastal flooding in the rainy season the northern coast of Demak is often flooded and during the dry season the characteristics of the soil are cracked because it comes from the muddy ground structure. The condition is suspected, among others, by several factors, among others, geological structure as a large area dominated by young alluvium layers are still experiencing compression, loading and retrieval of ground water. So it is necessary to do research related to ground deformation. There are several reasearch for Preliminaery study in monitoring landsubsidence. using geodetic method [7] [9]
[11]. It important to know about strategic data processing for having a good accuracy and precision. Comparing method would give description which it suitable processing method due to enhance accuracy.

Administratively, the area of Demak Regency is 89,743 ha divided into 14 districts, 243 villages and 6 kelurahan. Most of Demak Regency is wetland area reaching 51,799 ha (57.72%) and the rest is dry land. 13.77% used for tegalan / garden, 0.05% while not used and 11.16% used for ponds [14].

Demak is one of the districts in Central Java geographically located at coordinates 6 degrees 43 "26" - 7 degrees 09 "43" south latitude and 110 degrees 27 "58" - 110 degrees 48 "47" east longitude. The farthest distance from west to east 49 km and from north to south along 41 km, with an area of 89,743 Ha. lies in 14 villages of Sriwulan, Bedono, Timbulsloko and Surodadi (Sayung sub district), then Tambakbulusan Village, Karangtengah Subdistrict, Morodemak Village, Purworejo and Betahwalang Village (Bonang Subdistrict), Wedung, Berahankulon, Berahanwetan, Wedung and Babalan (Wedung District). The farthest distance from west to east 49 km and from north to south along 41 km, with an area of 89,743 Ha [13] shown in figure 1.

2. Data and Method
2.1. Data Acquisition
Data Observation of deformation of coastal land in Demak Regency has been done by 2015 and 2016. Location Bench Mark separate at 6 Villages / kelurahan all of which are in the District Sayung. 2 Observation marks are in Bedono Village in 2015. GPS measurements made at 7 geodetic monuments. The GPS observation was conducted at May-June 2015 and April-May 2016. Bench Mark for monitoring deformation were located in Sidodadi, Gemah, Tugu, Purwosari, Bedono and Timbulsloko.

Distribution of GPS Survey shown at figure 2. GPS survey were conducted in May – June 15, and the second observation in April - May 2016. GPS survey done using dual frequency geodetic-type GPS receivers Hiper II and Hiper Gb.

![Figure 1. Studi Area of Sayung Demak Regency [13]](image-url)
2.2. Method

This research conducted with two method of GPS data processing as base station. First using GNSS CORS UDIP and station IGS namely, BAKO, CNMR, COCO, DARW, IISC, KAT1, PIMO, SOLO, XMIS and CORS Udip second using CSEM as Base Station. CORS CSEM as the reference station was located on the roof of Telkom Building Kalibanteng, Semarang. GNSS CORS UDIP was located in the top of building B Geodetic Departement, Engineering Faculty Diponegoro University. In the GPS measurements, each epoch has 5 until 6 hour observation. Flowchart can be seen in figure 3. The GPS Data Processing would done using GAMIT 10.6 scientific GPS [Herring, 2010] Data Processing.

![Image of figure 2 showing GPS survey distribution 2016](image)

**Figure 2.** Distribution on GPS Survey 2016

![Image of flowchart showing overall methods used in this study](flowchart)

**Figure 3.** Flowchart showing the overall methods used in this study
To test whether there is any deformation in each bench mark then t test is done. The t test (also called Student’s T Test) compares two averages and will describe they are different from each other. The t test shown differences could have happened by chance. Reference [9] Height change defined as \( \Delta dh_{ij} \) and its rate \( \nu \Delta dh_{ij} \) at each station are derived using the following relation

\[
\Delta dh_{ij} = dh(t_j) - dh(t_i) \quad .
\]

\[
\nu \Delta dh_{ij} = \frac{\Delta dh_{ij}}{(t_j - t_i)}
\]

Null hypothesis \( H_0 : dh_{ij} = 0 \)

Alternative hypothesis \( \Delta dh_{ij} \neq 0 \)

Test statistic is

\[
t = \frac{\Delta dh_{ij}}{\sigma(dh_{ij})}
\]

Which has the customary Student t-distribution if \( H_0 \) is true. The null hypothesis is rejected if.

\[|t| > t_{df, \alpha/2}\]

At a confidence level of 99% (i.e. \( \alpha = 1\% \)), the critical value is \( t_{0.005} = 2.576 \)

F-test is one of statistical test in which the test statistic has an F-distribution. It is most often used to compare two variances, in order to identify the model that best fits the population from which the data were sampled. The test compares the ratio of two variances. If found that the variance is equal, the ratio of the variances will equal 1. The population variances are equal when running an F Test, and assumed that the variances area equal to 4.

The null hypothesis will always be that the variance is equal.

\[
F = \frac{s_1^2}{s_2^2} \quad \text{or} \quad F = \frac{s_2^2}{s_1^2} \quad F = \frac{\text{large sample variance}}{\text{smaller sample variance}}
\]

Table F Distributions

\[
F_{\alpha/2, v_1, v_2} = \frac{1}{F_{1-\alpha, v_2, v_1}}
\]

The null hypothesis used in this statistical test is the method of processing there is no significant difference so that:

\[
H_0 \quad H_0 : dV = 0
\]

\[
H_1 \quad H_0 : dV \neq 0
\]
3. Results and Discussion

3.1. Data Quality Control
GPS observation data in advance is checked to know the quality of data from each point of observation by using TEQC program. GPS observation data have good quality whether or not seen from the value of MP1 and MP2. MP1 and MP2 are moving averaging values, i.e. RMS values from a combination of multipath data recorded.

| Year | Station | MP1    | MP2    | GPS Type            | DOY |
|------|---------|--------|--------|---------------------|-----|
| 2015 | WNSR    | 0.570400 | 0.623026 | Topcon Hiper II   | 122 |
| 2015 | PDSR    | 0.078153 | 0.126307 | Astech Promark800 | 122 |
| 2015 | TMBL    | 0.111019 | 0.217499 | Astech Promark800 | 122 |
| 2015 | SURO    | 0.480724 | 0.494162 | Topcon Hiper II   | 124 |
| 2015 | DADI    | 0.089762 | 0.160813 | Astech Promark800 | 124 |
| 2015 | PRWS    | 0.071471 | 0.163779 | Astech Promark800 | 124 |
| 2015 | SIDO    | 0.669758 | 0.736448 | Topcon Hiper II   | 126 |
| 2015 | GEMA    | 0.070251 | 0.124984 | Astech Promark800 | 126 |
| 2015 | TUGU    | 0.142555 | 0.201344 | Topcon Hiper GB   | 126 |
| 2016 | WNSR    | 0.300293 | 0.314016 | Topcon Hiper GB   | 114 |
| 2016 | PRWS    | 0.518471 | 0.544309 | Topcon Hiper GB   | 114 |
| 2016 | SIDO    | 0.481011 | 0.48126  | Topcon Hiper II   | 114 |
| 2016 | GEMA    | 0.311381 | 0.305413 | Topcon Hiper II   | 115 |
| 2016 | TUGU    | 0.343395 | 0.357062 | Topcon Hiper GB   | 115 |
| 2016 | TMBL    | 0.681992 | 0.571695 | Topcon Hiper GB   | 115 |
| 2016 | SURO    | 0.353386 | 0.338689 | Topcon Hiper GB   | 116 |
| 2016 | DADI    | 0.621246 | 0.583523 | Topcon Hiper GB   | 116 |

In 2015 shows that the moving average value of MP1 and MP2 has value less than 0.5, it means that there are no significant multipath as long as GPS observation. A considerable in 2016 multipath effect occurs at three points WNSR, TMBL and DADI. The poor quality of data is influenced by several factors that occur in the field, such as rain, the environment around the observation point that many obstruction and trees as well as the factors of equipment that is quite influential.

3.2. Result of Data GPS Processing using CSEM
The results of processing using Base Station CSEM can be seen in Table 2. The result shows that the standard value of deviation in the direction X 0.0039 – 0.0045, Y 0.0047 – 0.0049 and Z 0.0035 – 0.0047 Z.
The results of processing using Base Station is not significant enough, so the statistical test shows no high change in the direction high change in question is smaller than 1.96. The high change in question is the decline that occurs in 7 points, although the SURO point has decreased, but the decline at that point is not significant enough, so the statistical test shows no high change.

### Table 2. Coordinate 3D Cartesian Network CSEM Method

| Station | Year   | X       | Y       | Z       | std X | std Y | std Z | h        |
|---------|--------|---------|---------|---------|-------|-------|-------|----------|
| PRWS    | 2015   | -2217365,724 | 5930844,540 | -765128,9478 | 0.0039 | 0.0047 | 0.0035 | 28.52408 |
| WNSR    | 2015   | -2215939,663 | 5931507,728 | -764119,404 | 0.0040 | 0.0048 | 0.0037 | 27.78359 |
| SIDO    | 2015   | -2219010,166 | 5930248,619 | -764969,655 | 0.0040 | 0.0047 | 0.0037 | 27.09083 |
| GEMA    | 2015   | -2219058,490 | 5930468,196 | -763140,325 | 0.0039 | 0.0047 | 0.0037 | 27.44666 |
| TUGU    | 2015   | -2219848,755 | 5930322,289 | -761984,428 | 0.0039 | 0.0047 | 0.0047 | 27.64855 |
| TMBL    | 2015   | -2218703,448 | 5930946,940 | -760463,879 | 0.0042 | 0.0048 | 0.0038 | 27.26408 |
| SURO    | 2015   | -2219836,606 | 5930737,920 | -758794,972 | 0.0040 | 0.0048 | 0.0037 | 27.07961 |
| DADI    | 2015   | -2220521,107 | 5930610,887 | -757795,196 | 0.0043 | 0.0049 | 0.0040 | 27.56375 |
| PRWS    | 2016   | -2217365,728 | 5930844,529 | -765128,940 | 0.0041 | 0.0048 | 0.0037 | 28.51381 |
| WNSR    | 2016   | -2215939,630 | 5931507,682 | -764119,408 | 0.0043 | 0.0048 | 0.0040 | 27.72983 |
| SIDO    | 2016   | -2219010,166 | 5930248,619 | -764969,655 | 0.0040 | 0.0047 | 0.0037 | 27.09083 |
| GEMA    | 2016   | -2219058,486 | 5930468,138 | -763140,329 | 0.0043 | 0.0048 | 0.0039 | 27.39212 |
| TUGU    | 2016   | -2219848,742 | 5930322,234 | -761984,421 | 0.0044 | 0.0049 | 0.0041 | 27.5924 |
| TMBL    | 2016   | -2218703,413 | 5930946,903 | -760463,894 | 0.0045 | 0.0049 | 0.0043 | 27.21941 |
| SURO    | 2016   | -2219836,564 | 5930737,933 | -758794,970 | 0.0044 | 0.0049 | 0.0041 | 27.07694 |
| DADI    | 2016   | -2220521,158 | 5930610,882 | -757795,195 | 0.0045 | 0.0049 | 0.0042 | 27.57672 |

Almost all GPS-derived ellipsoidal height changes indicated that they passed the statistical testing, and it could be concluded that with 99% confidence level, there were significant ellipsoidal changes at all the stations during the period between May-June 2015 and April-May 2016. In table 3, shows that most stations experience a high change marked by the value of T > count of T table and the SURO point does not change high, because the result of T count is smaller than 1.96. The high change in question is the decline that occurs in 7 points, although the SURO point has decreased, but the decline at that point is not significant enough, so the statistical test shows no high change.

### Table 3. T test

| Station | Dh12 cm | s(σdh12) (mm) | ttes | Deformation |
|---------|--------|---------------|------|-------------|
| PRWS    | 1.027  | 4.90          | 2.095918 | Yes         |
| WNSR    | 5.376  | 4.94          | 10.88259 | Yes         |
| SIDO    | 2.487  | 4.92          | 5.054878 | Yes         |
| GEMA    | 5.454  | 4.91          | 11.10794 | Yes         |
| TUGU    | 5.615  | 4.94          | 11.3664 | Yes         |
| TMBL    | 4.467  | 4.96          | 9.006048 | Yes         |
| SURO    | 0.267  | 4.93          | 0.541582 | No          |
| DADI    | 1.297  | 4.95          | 2.620202 | Yes         |

3.3. Result of Data GPS Processing using UDIP and IGS

The results of processing using Base Station UDIP and IGS can be seen in table 4. The result shows that the standard value of deviation in the direction X 0.0042 – 0.0047, Y 0.0047 – 0.0049 and Z 0.0033 – 0.0045 Z.
Table 4. Coordinate 3D Cartesian Network UDIP and IGS

| Station | Year | X (m)   | Y (m)   | Z (m)   | std X | std Y | std Z | h (m) |
|---------|------|---------|---------|---------|-------|-------|-------|-------|
| PRWS    | 2015 | -2217365,806 | 5930844,518 | -765128,990 | 0,0042 | 0,0048 | 0,0033 | 28.5374 |
| WNSR    | 2015 | -2215939,747 | 5931507,711 | -764119,445 | 0,0042 | 0,0048 | 0,0036 | 27.8019 |
| SIDO    | 2015 | 2219010,242  | 5930248,600  | -764969,695  | 0,0040 | 0,0047 | 0,0035 | 27.1043 |
| GEMA    | 2015 | -2219058,563 | 5930468,172  | -763140,365  | 0,0042 | 0,0048 | 0,0034 | 27.4548 |
| TUGU    | 2015 | -2219848,835 | 5930322,227  | -761984,456  | 0,0038 | 0,0047 | 0,0032 | 27.6221 |
| TMBL    | 2015 | -2218703,520  | 5930946,922  | -760463,917  | 0,0042 | 0,0048 | 0,0037 | 27.2767 |
| SURO    | 2015 | -2219836,657  | 5930737,849  | -758795,002  | 0,0038 | 0,0047 | 0,0032 | 27.0352 |
| DADI    | 2015 | 2220521,173   | 5930610,792  | -757795,221  | 0,0044 | 0,0049 | 0,0039 | 27.5014 |
| PRWS    | 2016 | 2217365,830   | 5930844,464  | -765128,993  | 0,0041 | 0,0048 | 0,0036 | 28.496 |
| WNSR    | 2016 | 2215939,745   | 5931507,623  | -764119,461  | 0,0044 | 0,0049 | 0,0040 | 27.721 |
| SIDO    | 2016 | 2219010,226   | 5930248,477  | -764969,709  | 0,0045 | 0,0048 | 0,0040 | 26.986 |
| GEMA    | 2016 | 2219058,579   | 5930468,035  | -763140,357  | 0,0043 | 0,0048 | 0,0039 | 27.332 |
| TUGU    | 2016 | 2219848,861   | 5930322,148  | -761984,449  | 0,0047 | 0,0049 | 0,0045 | 27.557 |
| TMBL    | 2016 | 2218703,509   | 5930946,799  | -760463,925  | 0,0046 | 0,0049 | 0,0045 | 27.159 |
| SURO    | 2016 | 2219836,666   | 5930737,847  | -758795,020  | 0,0043 | 0,0048 | 0,0039 | 27.038 |
| DADI    | 2016 | 2220521,270   | 5930610,781  | -757795,241  | 0,0046 | 0,0049 | 0,0043 | 27.528 |

Result of T test indicates that almost all GPS-derived ellipsoidal height changes passed the statistical testing. It could be stated that with 99% confidence level, there were significant ellipsoidal changes at all the stations during the period between May-June 2015 and April-May 2016 except Suro the station. In table 5. The high subsidence level that occurs in 7 points, although the SURO point has decreased, but the subsidence level at that point is not significant enough, so the statistical test shows no high change.

Table 5. T test Network GNSS UDIP and IGS as Reference Base Station

| Station | h 2015 (m) | h 2016 (m) | Dh12 cm | s(σdh12) (mm) | t-test | Deformation |
|---------|------------|------------|---------|---------------|--------|-------------|
| WNSR    | 27.8       | 27.72      | -8.1    | 5             | -16.3  | Yes         |
| SIDO    | 27.1       | 26.99      | -11.9   | 4.9           | -24.1  | Yes         |
| GEMA    | 27.45      | 27.33      | -12.3   | 4.9           | -24.9  | Yes         |
| TUGU    | 27.62      | 27.56      | -6.5    | 5             | -13.1  | Yes         |
| TMBL    | 27.28      | 27.16      | -11.7   | 5             | -23.6  | Yes         |
| SURO    | 27.04      | 27.04      | 0.3     | 4.9           | 0.7    | No          |
| WNSR    | 27.8       | 27.72      | -8.1    | 5             | -16.3  | Yes         |

3.4. Spatial and geometry analysis

Differences Base Station using to station CSEM and UDIP can be seen from the coordinate value and standard deviation, can be seen in table 6. The highest difference value on the x-axis is located at WNSR of 11.5 cm while for the Y component of 14.2 cm is located, for the Z direction of 5.4 cm in SIDO. The maximum difference for ellipsoid height reach 10.48 cm at SIDO.
Table 5. Coordinates Difference between UDIP and CSEM as Base Station

| Station | Year | \( \Delta X (m) \) | \( \Delta Y (m) \) | \( \Delta Z (m) \) | \( \Delta \text{Std } X \) (m) | \( \Delta \text{Std } Y \) (m) | \( \Delta \text{Std } Z \) (m) | \( \Delta h \) (cm) |
|---------|------|----------------|----------------|----------------|-----------------|----------------|----------------|----------------|
| PRWS    | 2015 | 0.082          | 0.022          | 0.042          | 0.0004          | 0.0001         | -0.0002        | -1.33          |
| WNSR    | 2015 | 0.084          | 0.017          | 0.041          | 0.0001          | 0.0000         | -0.0001        | -1.83          |
| SIDO    | 2015 | 0.076          | 0.019          | 0.040          | 0.0000          | 0.0000         | -0.0002        | -1.35          |
| GEMA    | 2015 | 0.073          | 0.024          | 0.040          | 0.0003          | 0.0001         | -0.0002        | -0.81          |
| TUGU    | 2015 | 0.080          | 0.062          | 0.028          | -0.0001         | 0.0000         | -0.0015        | 2.65           |
| TMBL    | 2015 | 0.072          | 0.018          | 0.038          | 0.0000          | 0.0000         | -0.0002        | -1.26          |
| SURO    | 2015 | 0.051          | 0.071          | 0.030          | -0.0002         | 0.0000         | -0.0005        | 4.44           |
| DADI    | 2015 | 0.066          | 0.095          | 0.025          | 0.0000          | 0.0000         | 0.0000         | 6.23           |
| PRWS    | 2016 | 0.102          | 0.065          | 0.053          | 0.0000          | 0.0000         | -0.0001        | 1.78           |
| WNSR    | 2016 | **0.115**      | 0.059          | 0.053          | 0.0001          | 0.0000         | 0.0000         | 0.88           |
| SIDO    | 2016 | 0.060          | **0.142**      | **0.054**      | 0.0006          | 0.0001         | 0.0003         | 10.48          |
| GEMA    | 2016 | 0.093          | 0.103          | 0.028          | 0.0000          | 0.0000         | 0.0000         | 6.01           |
| TUGU    | 2016 | 0.119          | 0.086          | 0.028          | 0.0003          | 0.0001         | 0.0004         | 3.54           |
| TMBL    | 2016 | 0.096          | 0.104          | 0.031          | 0.0001          | 0.0000         | 0.0002         | 6.04           |
| SURO    | 2016 | 0.102          | 0.086          | 0.050          | -0.0001         | 0.0000         | -0.0002        | 3.89           |
| DADI    | 2016 | 0.112          | 0.101          | 0.046          | 0.0001          | 0.0000         | 0.0000         | 4.87           |

F statistical test is used to determine whether there is difference in the measurement results by processing 2 methods from two years observation. This test is done by comparing the variance of the two processing gps data methods. The result of f test using gps data in 2015 and 2016 gets smaller values than the F table, \( (F_{\text{tes}} < F_{\text{table}}) \), so the null hypothesis is accepted all. The conclusions were the GPS data processing using the GAMIT scientific software with the CSEM or UDIP as base station is not significantly different. Shown on table 5.

Table 6. F test

| Method | Year | Variance         | \( F_{\text{tes}} \) | \( F_{\text{table}} \) |
|--------|------|-----------------|----------------|----------------|
| CSEM   | 2015 | 0.000134941     | 0.483          | 6.61           |
| UDIP + IGS | 2015 | 0.00062255     | 6.61           |
| CSEM   | 2016 | 0.000042055     | 0.461          | 6.61           |
| UDIP + IGS | 2016 | 0.000087028     | 6.61           |

3.5. Deformation Map

Due limitation GPS data observation not covering of whole of area study cause the contour map doest not good enough. Shown at the figure 4 dan 5, pattern of typical subsidence have not look similar because of the type of interpolation. figure 4 using IDW interpolation form result of CSEM Base Station and figure 5 using Kriggig interpolation UDIP IGS Network.
4. Conclusions

The statistical t test shown that each method has similarity result that station SURO has a test smaller than 1.96, it means there was not have deformation in vertical direction. Root Mean Square Error (RMSE) CSEM as base station shows a relatively small value compared to the RMSE UDIP IGS Network. because the distance baseline CSEM is shorter than UDIP IGS Network. With limitation of time occupation about five – six hours, CSEM base station is more better than UDIP IGS Network. For increasing accuracy, UDIP IGS network can be done with extend time of occupation to have better accuracy.

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