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Processing and data analysis of time-lapse microgravity due to ground water level changing in baseline stage of CO_2 injection

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Abstract. Monitoring stability of the field in research area using time-lapse microgravity method has been done with data acquisition process in 2014 and 2016. This method requires high accuracy in μGal units. Since we use relative gravimeter, drift performance from instrument is also influential to the data significantly. In this paper we conducted reprocessing data using closer reference station from research area thus the drift effect cause by mobilitation time and duration of instrumental resting can be reduced. In conditions prior to injection, ideally the change in gravity value in the area would be very small with the assumption of the absence of injection activity. However, after the processing data stage we can see time-lapse microgravity anomalies within the range of ± 80 μGal. This anomaly was assumed occurred by instrument effect (typical for spring sensors) in field measurement and shallow hidrology effect (ground water level change). From the gravity surveys in 2014 and 2016, there is big difference in long term drift between 2014 and 2016 data, which is 2014 has average value of 320 μGal/day and 2016 has average value of 120 μGal/day. Other than that, in repeatability test, 2014 has 54% and 2016 has 77% from total data that is within the range of deviation ± 10 μGal (repeatability value in accuracy of ideal Scintrex CG-5). Analysis of gravity data measured in three benchmark (BM) was also performed to know the gravity variation rate in research area.

1. Introduction

In this paper we conducted reprocessing data from previous study [1] with BM1 as closer reference station. As shown in figure 1A, TOP (previous reference station) has approximately 30 km distance away from research area. Since we used relative gravimeter to perform data acquisition, there may be systematic errors can be present on account of instrumental drift and gravity gaps due to vibration on gravimeters while mobilitation to research area. To minimize the systematic errors, the time gap between reference station – grid stations (research area) and duration of instrumental resting should be reduced. Therefore, we conducted analysis for near surface anomalies due to ground water level change.

In addition of this work, gravity data measured in benchmark was analyzed to see gravity variation rates in research area. We conducted additional survey for benchmark stations (BM1, BM2, and JPN) in 2017 and 2018. This additional data will be evaluate and compare with absolute gravimeter in the future. Some studies [2 and 3] of absolute gravimeter absolute also provide variation rate in several years, so the value of gravity in the reference station of our study area need to be measured carefully.

Grid stations distributed in research area as shown in figure 1B. Red dot plot distributed in the Southern part of research area, while blue dot plot distributed in the Northern part of study area. Red and blue plot indicated location stations that measured by two Scintrex CG-5 during 2014 and 2016 surveys.

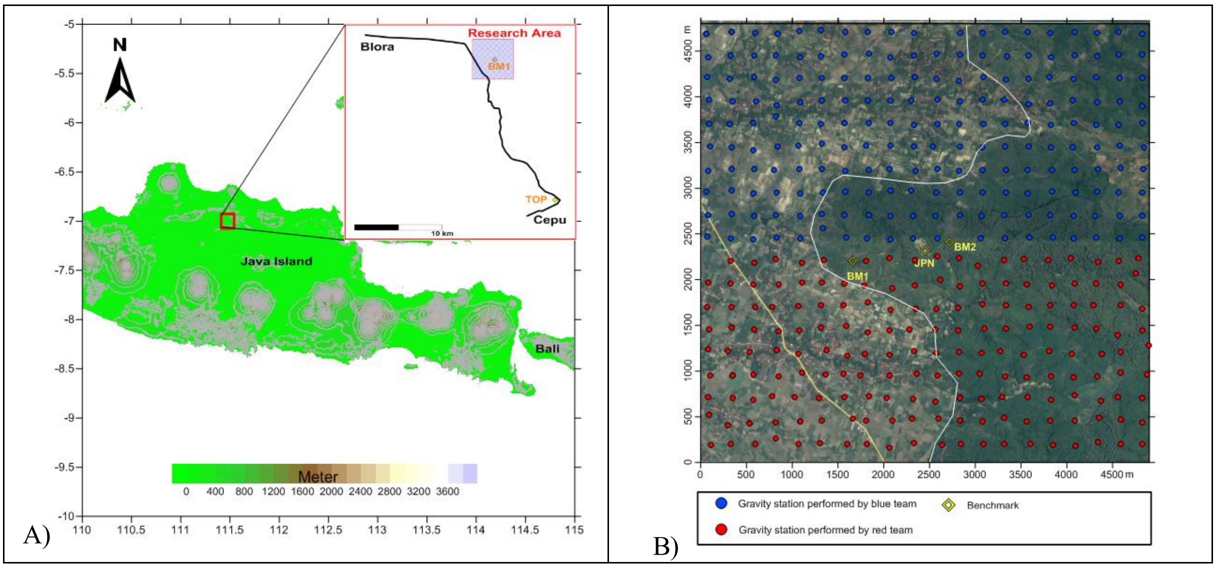

Figure 1 A) Research area located between Cepu and Blora and B) Grid stations distribution in research area.

2. Data Processing

The data used for making time-lapse microgravity (TLM) map are data acquisition in 2014 and 2016. Figure 2 shows long-term drift comparison in 2014 and 2016 surveys with linear approximation. Long-term drift is shown as linear trend of gravimeter performance from the first day until the last day of the survey, while short-term drift is defined as gravity change form first measurement until last measurement in one day or one loop. Drift correction for our data is shown as histogram in figure 3. The daily drift is expected very small within the range of less then 35 μGal.

Based on figure 2, long-term drift in 2014 survey from red and blue team respectively are 345 and 312 μGal/day, while long-term drift in 2016 survey from red and blue team respectively are 83 and 162 μGal/day. Based on figure 3, we have percentage of drift correction value < 35 μGal in 2014 and 2016 respectively are 85.6% and 94.8%.

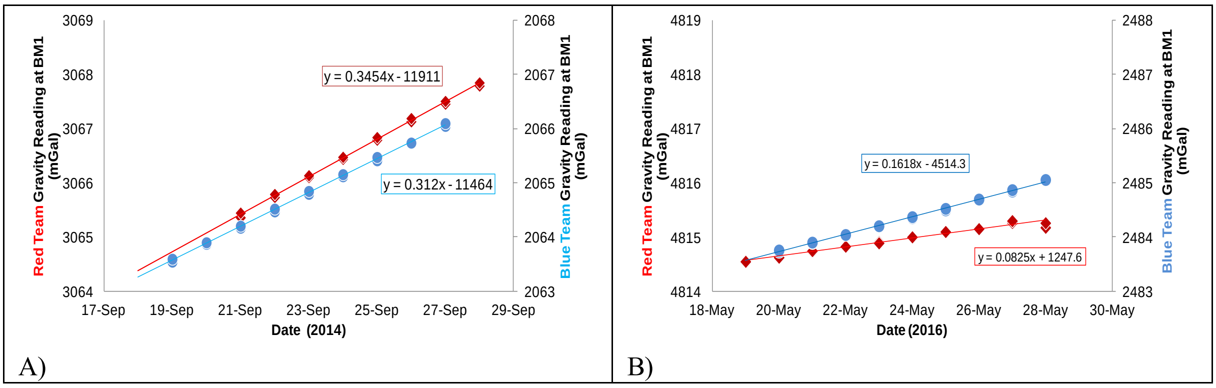

Figure 2. Long-term drift comparison (red and blue team): A) 2014 survey and B) 2016 survey.

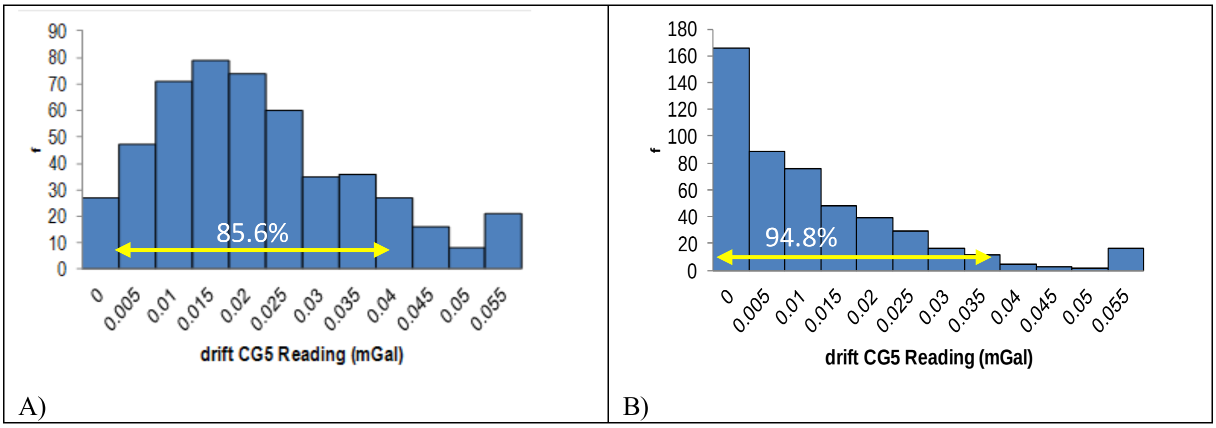

Figure 3. Histogram comparison of drift correction using linear drift approximation applied in each gravity reading A) 2014 survey and B) 2016 survey.

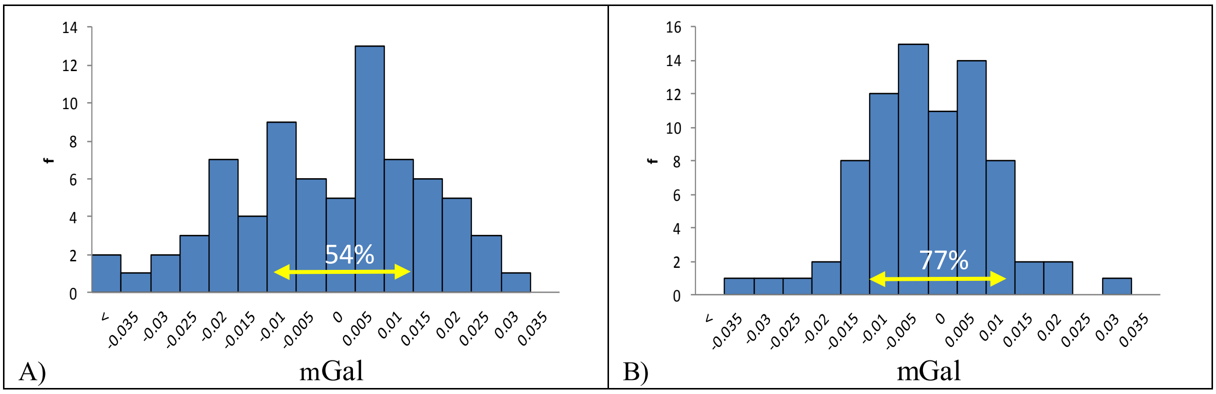

Figure 4. Histogram comparison of repeatability test in repeat stations in A) 2014 survey and B) 2016 survey.

3. Gravity Data in Benchmark Stations

The benchmark stations that we analyzed include 3 stations: BM1, BM2, and JPN stations where the three stations are bound by the same base point which is TOP stations that have been measured using absolute gravimeter (A10) with observed gravity value is 978131.340 mGal (survey in 2014). These three stations were selected based the criteria of having a stable value, close to the location of the target well, the distance between the stations were not far away, and these stations were measured by the absolute gravimeter. The reason for this analysis is that there is a possibility that the value of gravity variation changes annually on each station and the limitations of absolute gravity data on each station. The purpose of this analysis is to obtain an average change in annual gravity variation rates on the analyzed station so that in the future can be compared the gravity value using absolute gravimeter with the value of relative gravimeter that has been corrected by annual gravity variation rates. To see the picture set of data repeatability every year, we conducted data processing that called loop readings as illustrated shown in figure 5.

In loop readings, data were processed by linear drift approach. We used all sets of readings in each measuring station. If set of readings exceeds five data values, then a set of readings is formed of five values that represent the entire set of readings by searching the value of minimum, quartile one, median, quartile three, and maximum of the data so that each data processing can reach up to 125 loops per one day of measurement. Table 1 shows total amount of repeatability data with loop readings in every station each year.

Gravity surveys in research area have been conducted in September 2014, May 2016, August 2017, and June 2018. Figure 6 shows a boxplot of repeatability in every station each year. All of the station gives a similar trend where in 2017, box plot trend was decreasing compared to other year. Mark ‘x’ in each box plot represent value of average of gravity reading in respective year. Each average value was arranged as shown in figure 7 to make a trend as average of gravity variation rates period September 2014 until June 2018. BM1 and BM2 shows a positive trend but JPN shows a negative trend. Average of gravity variation rates in BM1, BM2, and JPN respectively are 0.005 µGal/year, 0.005 µGal/year, and – 0.001 µGal/year.

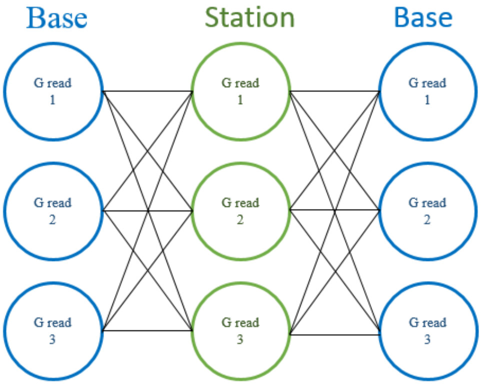

Figure 5. illustration of processing data with loop readings

Table.1. Total amount of repeatability data with loop readings in every station each year

Repeatability Data	2014	2016	2017	2018
BM1	34	190	100	180
BM2	34	240	100	144
JPN	32	150	100	252

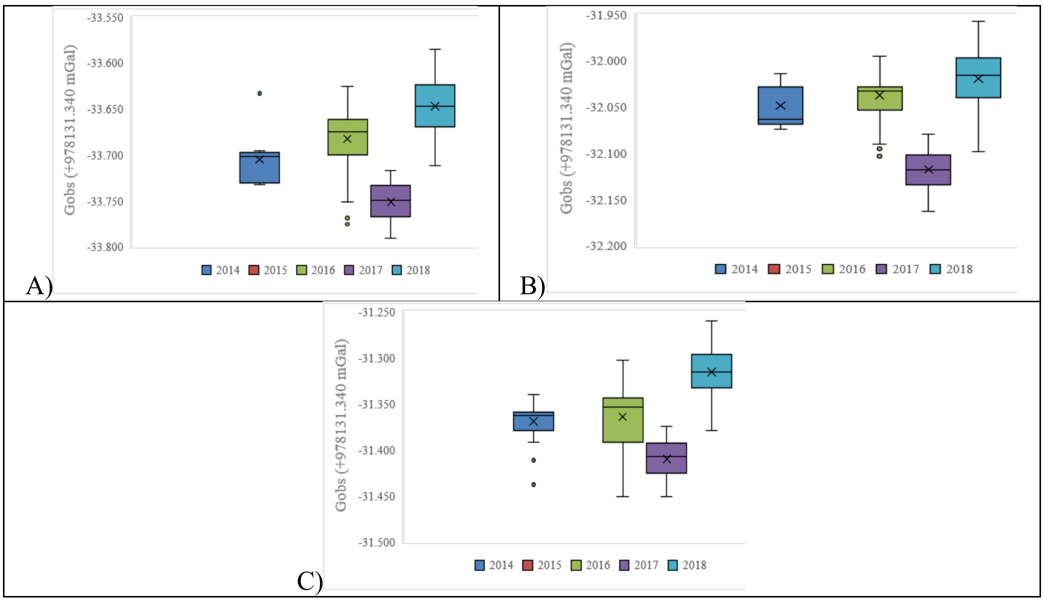

Figure 6. Box plots of repeatability data from loop readings in: A) BM1, B) BM2, and C) JPN stations.

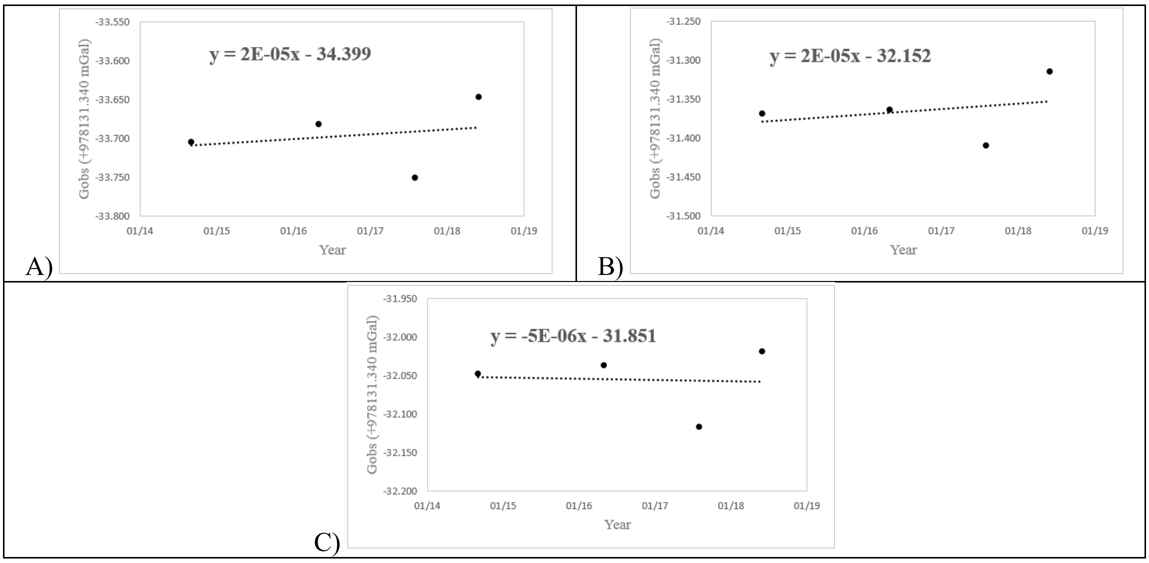

Figure 7. Average of gravity variation from September 2014 until June 2018 in: A) BM1, B) BM2, and C) JPN stations.

4. Result and Analysis

4.1 Time-lapse Microgravity Map

The value of gravity observation in 2016 and 2014 was subtracted to get anomaly of time-lapse microgravity (TLM) map. Anomaly value is taken in range of -80 to +80 µGal consider existence of monthly gravity changed which had correlation with rainfall and ground water level. Figure 8 shows stations that has value exclude ±80 µGal and TLM map which has been produced exclude that data.

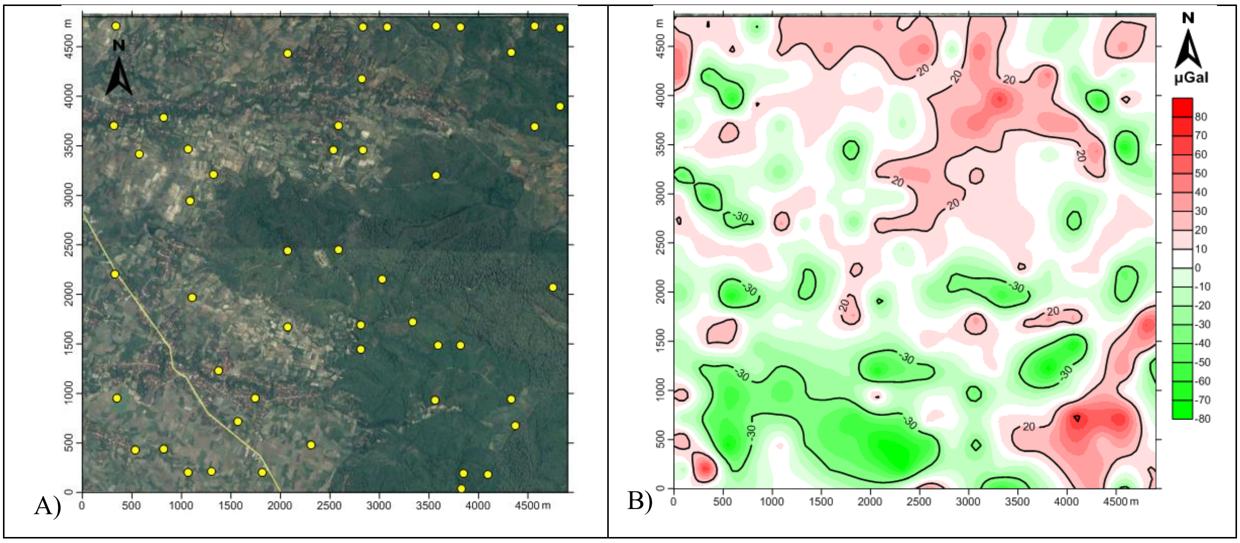

Figure 8. A) stations distribution that shows outlier TLM values (<-80 and >80 µGal) B) TLM anomaly map 2016 – 2014.

4.2 Modelling of Ground Water Level

In the research area has been conducted hydrology survey by ITB research team that provides base data of ground water level (GWL) in 2017 (February). We considered base of GWL in 2017 by gravity observation in 2016 with assumption there is no change of GWL in that period (to simpifly the model). Therefore, base of GWL in 2014 can be known by modelling of GWL period 2014 – 2016. TLM map becomes g observed and change of GWL can be calculated since the base of GWL in 2016 has been known. The results of both addition and reduction in GWL become base of GWL in 2014.

As shown in figure 9, positive value in anomaly TLM map indicates addition of GWL and negative value in anomaly TLM map indicates reduction of GWL. The western part of TLM map is forest area which has higher elevation than the eastern part of TLM map which is local people village and rice field. Type of ground water in this research area is unconfined aquifer so the main control for ground water flow is strongly influenced by the formation and elevation of the topography. Anomalies from TLM map in research area modeled with near-surface effect which is from ground water level change. Based on the model in figure 9, high anomalies (up to 40 μGal) can be caused by ground water level change up to + 3.9 meters, while low anomaly (up to -30 μGal) can be caused by ground water level change up to -3.4 meters.

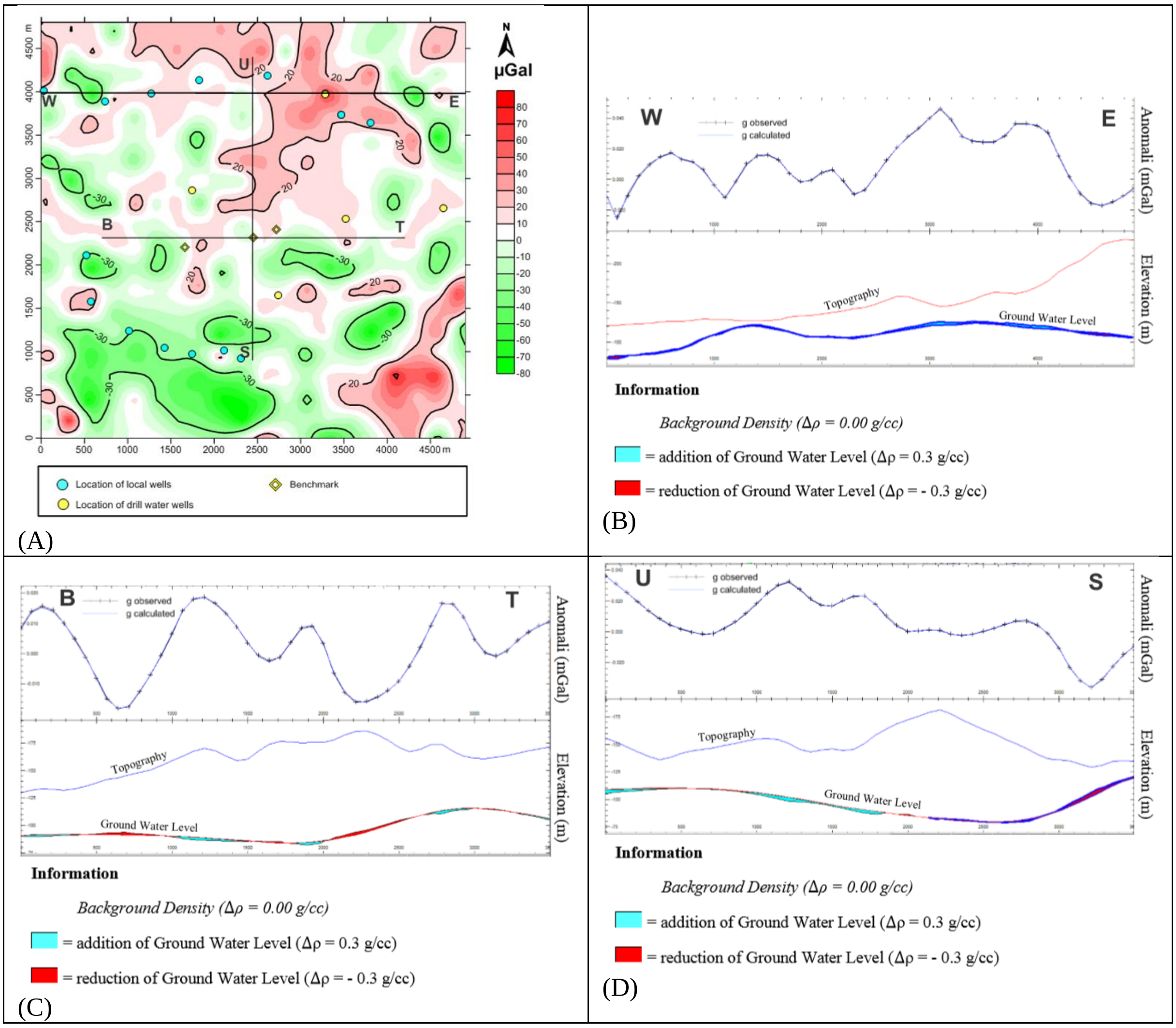

Figure 9. Modeling of ground water level in research area period 2014 – 2016: (A) TLM Map with sections location, (B) TLM model in WE section, (C) TLM model in BT section, and (D) TLM model in US section.

5. Conclusion

Gravity data in benchmark station shows gravity variation have a very small changes that indicates research area are relatively stable, average changes in BM1, BM2, and JPN stationsrespectively are

0.005 µGal/year, 0.005 µGal/year, dan - 0.001 µGal/year. . Anomalies from TLM map in research area modeled with near-surface effect which is from ground water level change. Based on the model in figure 9, high anomalies (up to 40 µGal) can be caused by ground water level change up to + 3.9 meters, while low anomaly (up to -30 µGal) can be caused by ground water level change up to -3.4 meters.

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