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Strategy Implementation Time Lapse Microgravity Method for Monitoring Subsidence

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Abstract. Microgravity over time is the development of methods of gravity with specificity was repeated measurements in the same place at different times using Gravimeter order μGal. Implementation strategies method is as follows (1) modeling the response of the gravity anomaly caused by the source anomaly that the target of survey, (2) calibration gravimeter, (3) determination of the point of the base which is stable and does not undergo subsidence during, (4) specify looping point measurement measuring used to guidelines for measurement in the next period, (5) the processing of the data that begins with the correction tide and drift correction, (6) to calculate the value of gravity micro across time (7), further correction by using filters MBF (Model Based filter). This filter will minimize one source of micro gravity anomaly between the time to obtain the source of the anomaly targeted surveys, (8) calculates the subsidence based micro gravity anomaly between the time the filtering results. An example is the monitoring of subsidence in Semarang were conducted in the period 2002-2005 which shows subsidence has occurred in the city of Semarang. The maximum subsidence occurred in the north of 16 cm/year.

INTRODUCTION

Methods of gravity is one of the methods of physics have used to some surveys. The concept of this method is to find their gravity anomaly somewhere. The magnitude of this anomaly in the next dimension μGal invers to obtain density (ρ). The magnitude of the mass of this type will show presence survey targets a calm beneath the surface. In addition, this method has also been used to monitor subsidence and other phenomena namely is as follows [1] combining the gravity data with geologic data to study the history of subsidence in the United Arab Emirates, [2] seeking the relation between the depth, age, gravity plate continents, [3] using the application geophysical to detect subsidence, [4] time lapse microgravity method and geotechnical for monitoring subsidence Chesire UK, [5] analysis of subsidence three-dimensional modeling of gravity micro between the time on the edge of the continent Namibia, [6] Analysis subsidence source in Jakarta using time lapse microgaraity data period of 2009-2010, [7] Observation of changes in elevation and gravity in the geothermal field in SW Iceland Reykjanes Peninsula, [8] Estimation of groundwater based on changes in gravity data and climate change in Australia, [9] to monitor land subsidence in the mine by using gravity. Research carried out is generally observed changes in gravity in order μGal. This allows for support equipment gravimeter that from time to time experienced growth. In line with the rapid increase in digital technology by the end of 1980, the problem of reading accuracy can be improved by the use of digital readout systems. At the end of 2000, Lacoste & Romberg gravimeter issuing digital full-called gravitons with an accuracy of 1 μGal and semi digital gravimeter which is the development of type G Lacoste & Romberg equipped with digital reading system with accuracy 1-5 μGal. Scintrex early 2002 also issued a fully digital gravimeter called Scintrex Autograv CG5 with an accuracy of 1 μGal. With the availability of digital gravitmeter systems fully or semi-digital, the obstacles associated with the tools to observe changes in the gravity field in order μGal can be eliminated. An increase accuracy gravimeter and the development of digital systems, the application of gravity methods to source anomalies near the surface and are related tothe environment as well as for the purpose of monitoring is increasingly used.

The studies mentioned above explain generally use methods of gravity for purposes of monitoring subsidence and surveying natural resources eat it in combination with other terrestrial surveys. The use of time lapse microgarvity method are generally not be explained in detail. Therefore, it seems necessary to explain how it used for a survey. To simplify the explanation used an example of subsidence survey conducted in Semarang periods 2002-2005 and 2012-2014.

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METHOD

Methods of micro gravity between the time a development method is the concept of gravity can be written by equation (1) as follows

$$(g_{obs(2)} - g_{obs(1)}) = \left(G\int_0^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \frac{\Delta\rho(\alpha,\beta,\gamma,\Delta t)(z-\gamma)}{\left[(x-\alpha)^2 + (y-\beta)^2 + (z-\gamma)^2\right]^{3/2}} d\alpha d\beta d\gamma \right) + c(h_2 - h_1) \quad (1)$$

where $g_{obs(2)}, g_{obs(1)}$ is gravity value on diffrent period, G is Universal garvity constant, $\Delta\rho$ is density change, α, β, γ is density coordinat, x, y, z is position coordinate, c : tide correction constan, (h_2-h_1) elevation change.

Based on mathematical modeling and simulation of synthetic data to equation (1) results showed that the effect of topography has no effect on time lapse micro gravity anomalies. Time lapse microgravity anomaly is affected by changes in elevation (subsidence) very point. Consolidation is causing subsidence did not cause the land mass is lost so Bouguer correction is not done. Equation (1) indicates that the difference between the value of the gravity of measurement results caused by changes in the subsurface density associated with changes in the depth of ground water level and subsidence.

After know the basic equation time lapse microgravity method do some activity that can be described as follows: (1) modeling the response resources of time lapse micro gravity anomaly. As an example for this purpose modeled subsidence caused by groundwater abstraction (Figure 1). The following parameters: first, a clay layer has a thickness of 10 m and ρ=1.9 gr/cm^3, a second layer of sand with a ρ = 2.0 gr/cm3. Aquifer porosity is 30%, change in density due to declining groundwater levels $\Delta\rho$=0.3 gr/cm^3. The third layer in the form of clay with a thickness of 10 m and ρ=2.1 gr/cm^3, (2) calibration tool to determine if the tool is in conformity with its accuracy. The activities at this stage for member fish credence to the research institute, and how the level of precision tools gravimeter, (3) Make a loop measuring point, where the loop will be used in subsequent periods with the provisions of the order of picking gravity data at that point in the looping sequence may not be changed, (4) Measurement of gravity data by considering the season. Recommended in different seasons, namely dry season and rainy. Besides the measurement time in the morning or at night, adjusting the conditions. Certain places suggested crowded traffic measurements carried out at night to reduce vibrations that occur, (5) Correction should be done initial correction, the tide correction and drift correction. The following equations 1 and 2 are used for tide correction and drift correction.

$$\boldsymbol{Tide} = \frac{\mathbf{3Gr}}{\mathbf{2}}\left\{\frac{\mathbf{2M}}{\mathbf{3d^2}}(\mathbf{sin^2p - 1}) + \frac{\mathbf{Mr}}{\mathbf{d^4}}(\mathbf{5cos^3p - 3cosp}) + \frac{\mathbf{2S}}{\mathbf{3D^3}}(\mathbf{3cos^2q -})\right\} \quad (\mathbf{2}\,)$$

$$drift = \frac{g_{akh} - g_0}{t_{akh} - t_0}(t_n - t_0) \quad (3)$$

where Tide is tide correction, p is months zenith angle, q is solar zenith angle, M is month mass, S is solar mass, d is distance between the center of the earth to the moon, D is distance berween the center of the sun to the earth, g_{akh} is gravimeter readings at the end of looping, g_o is gravimeter readings at early looping, t_o is time of reading of early station, t_n reading of the station to the time n, t_{akh} is time of reading of the last station for each looping, (6) further correction further micro gravity data over time to note is the target to be searched. Based on the equation 1 is known that the source of the gravity anomaly is the time between the micro subsidence and groundwater level changes. Further correction is done by MBF (Model Based Filter) built, (7) interpretation qualitatively and quantitatively by adding rainfall data that occurred during the measurement time span.

RESULT AND DISCUSSION

The results described part of the process is the implementation of strategy that consist of (1) modeling the response anomalies due to subsidence and dynamics of groundwater level (1) plotting the data points measuring gravity, (2) Example looping, (3) Tide correction and Drift correction up gravity values obtained observation, (4) filtering of data gravity anomaly observations to obtain due to subsidence, (5) contour map making subsidence base on time lapse microgravity data. As explained above that for modeling the response anomalies created an anomalous source of the subsurface with adjustable physical parameters in field conditions as Figure 1 which illustrates the land subsidence and groundwater level dynamic.

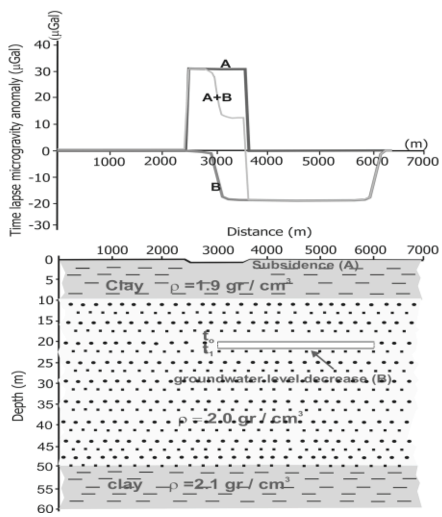

FIGURE 1. Modelling the response anomalies due to subsidence and groundwater dynamics A is anomaly response by subsidence, B is anomaly response by groundwater level decrease, and A+ B is a combination of two sources of these anomalies

Assumed subsidence occurred at coordinates 2500 - 3500 m which amount is at $t_0 = 0$ and $t_1 = 10$ cm. At coordinates 2500 - 5500 m (Figure 1) each - each the size of 1.5 m with the position of the ground water level at $t_0 = t_1 = 20$ m and 21.5 m. The maximum response of the gravity anomaly due to subsidence and decreased water level is 12,196 μGal, 30,706 μGal dan 13,376 μGal.

After modeling the anomalous source of the next stage is to determine the position where the measuring point of gravity. The position and distribution layout measuring point is very important. This has to do with the target to be searched and added to the target is under the earth's surface. The target depth is usually determined from a distance 1/3 outermost points. For example, if the target is based on geological studies is 100 meters below the earth surface, then the distance at the outermost point of the study site is 300 meters. In the next stage is to determine looping. The basis is the time to first measurement time looping around 3 hours assuming that the spring in gravimeter experiencing fatigue. Looping begins and ends at the base. For time lapse microgravity survey data collection each point on the loop should not be changed and must be fixed. After completion of the measurement is completed, the next stage is to make Tide corrections and Drift corrections by using equation 2 and equation 3. Processing gravity data for the looping until gravity observations obtained as shown in Table 1

TABLE 1. Example of Tide and Drift Correction for one loop

No	Station	Time	Alliod (miliGal)	Tide Obs Correction	Drift Correction	Grav obs (miligal)	Local grav (miliGal)
1	Kop. A.Yani 15	15:32	0.00	0.121	0.000	0.121	0.000
2	Kop. A.Yani 16	15:40	- 0.74	0.123	0.001	-0.618	-0.739
3	TTG 446	15:55	19.30	0.123	0.002	19.421	19.300
4	Poncol	16:32	19.44	0.119	0.003	19.556	19.435
5	Girli 01	17:13	19.27	0.104	0.008	19.796	19.675
6	SMU 14	18:22	19.04	0.059	0.013	19.086	18.965
7	Kop. A.Yani 16	19:44	0.1	0.042	0.020	0.122	0.001
8	Kop. A. Yani 15	19:46	0.1	0.041	0.020	0.121	0.000

To clearly reading of qualitative measurement results is lacking, then the next step is to create a contour map of gravity values for each measurement. If you owned a set of micro-gravity data over time, such as 5 sets of data with different periods, then as a reference the gravity anomaly is the difference between the value of gravity now with gravity measurement value prior period. Time lapse microgravity anomaly data filtered using MBF designed to minimize the source of the anomaly in the form of soil water dynamics and vice versa. Here is an example of filtering the data input of time lapse microgravity anomaly of period September 2002 - November 2005, MBF filter shapes, output as in Figure 2 below.

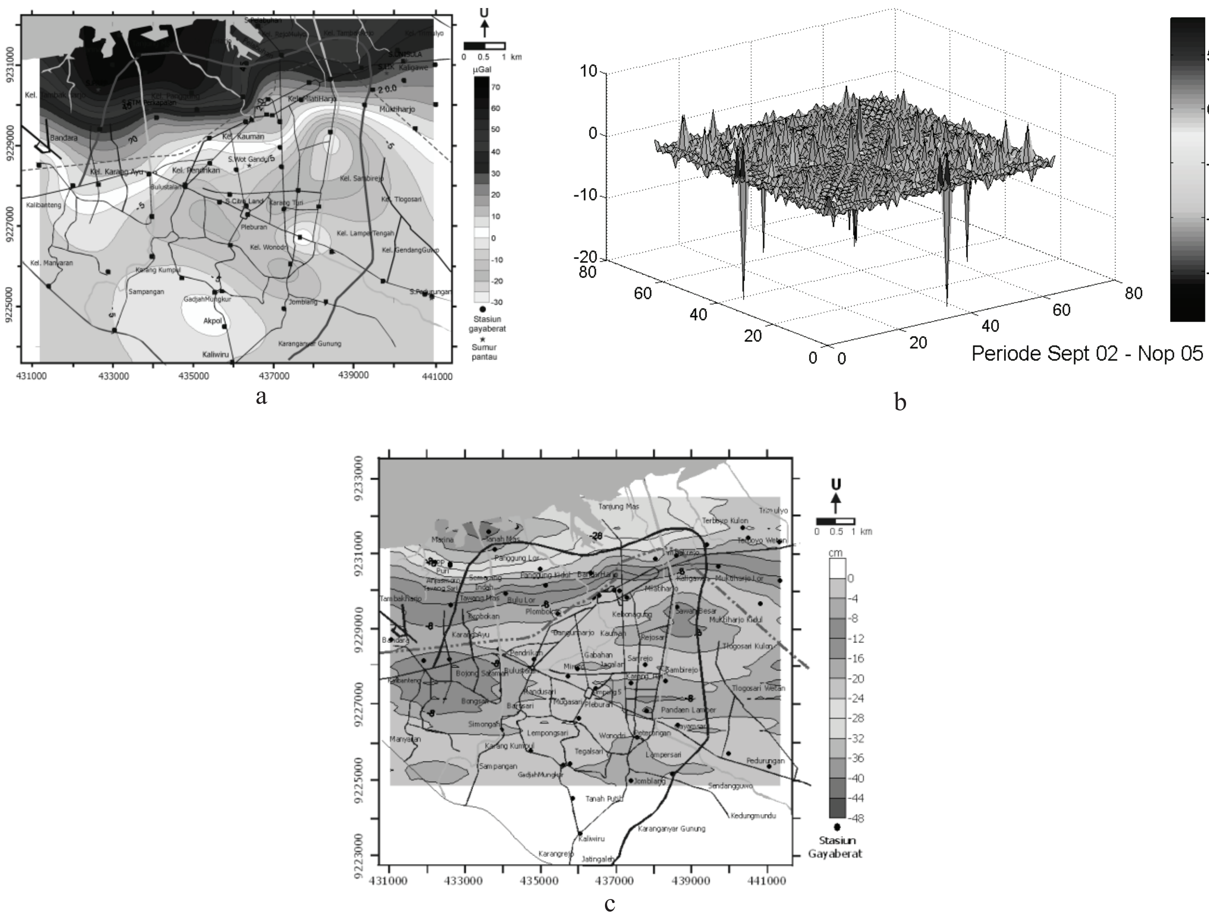

FIGURE 2. Process filtering time lapse microgravity data, a. time lapse micro gravity anomaly (input), b. MBF filter shape, c. Subsidence anomaly (output)

Based on the data obtained from the subsidence survey of time lapse microgravity it is known that the greatest subsidence in the northern city of Semarang exactly in the harbor and its surroundings. Avarage large subsidence that occurred in the area each year is 16 cm. These results did not differ with studies that have been conducted by previous researchers like [10], [11], [12] which states naturally the northern city of Semarang to consolidate his form in the form of ground subsidence. Subsidence process is accelerated by human activity under water use for everyday purposes, the industry is increasing from year to year.

CONCLUSION

Survey Gravity Micro over time can be used for monitoring subsidence by observing the following (1) Need to make a model response gravity anomaly micro caused by the source or target to be searched for in the survey, (2) Gravimeter must have an accuracy in the micro for to read a very small change, (3) the survey is characterized by looping measurements within a predetermined time, then the position of the measuring point must be maintained so as not to shift or sinkhole, (4) for the tide correction should be done using other gravimeter. The main Gravimeter used for measurements in the field, (5) The value of the tide correction must be observed by looking at the specifications gravimeter. If the value is greater tide that is required then the measurement should be repeated for the points on a particular loop

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