MODELING OF SMALL SCALE SURFACE DEFORMATION BASED ON DINSAR RESULT

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ABSTRACT

Monitoring of small scale surface deformation as subsidence and landslides is very important to protect lifeline, manmade structures, buildings and houses, roads and railways, and so on. In order to monitor subsidence and landslides, several technologies were applied. However, these technologies cannot be applied to broad area and it is difficult to understand spatial distribution of affected area of subsidence and landslides. DInSAR analysis can be understand spatial distribution of affected area of subsidence and landslide, therefore, it has high prospect in Japan because Japan has a lot of sites of subsidence and landslides. However, DInSAR analysis cannot extract sub-surface information like depth of source of deformation. In order to enhance a capability of detection of small scale surface deformation as subsidence and landslide by DInSAR analysis, integration use of DInSAR analysis and numerical model and original model for estimation of small scale surface deformation was proposed in this paper.

Proposed model was applied to subsidence which was detected by ALOS PALSAR DInSAR. Target area is located in the North-East part of China. At the target area, large subsidence occurred due to coal mining activity and overuse of ground water. In order to consider way of countermeasure work for subsidence, it is important to know affected area of subsidence, depth of source of subsidence, and so on. Affected area of subsidence can be understood by the DInSAR analysis, however, depth of source of subsidence has difficult to understand by the DInSAR analysis. In order to understand the depth of source of subsidence, numerical model was necessary. Proposed model can be estimating affected area of subsidence and depth of source of subsidence by a few parameters derived from DInSAR analysis. Proposed model was well performed in the simulation of subsidence pattern of 1-D space and it could be estimated depth of subsidence source. However, it wasn't well performed to simulate subsidence pattern in 2-D space. Therefore, proposed model was improved to simulate subsidence pattern in 2-D space by considering the spatial distribution of ground stiffness.

1. INTRODUCTION

Monitoring of small scale surface deformation as subsidence and landslides is very important to protect lifeline, manmade structures, buildings and houses, roads and railways, and so on. In order to monitor subsidence and landslides, several technologies were applied. However, these technologies cannot be applied to broad area and it is difficult to understand spatial distribution of affected area of subsidence and landslides. DInSAR analysis can be understand spatial distribution of affected area of subsidence and landslide, therefore, it has high prospect in Japan because Japan has a lot of sites of subsidence and landslides. However, DInSAR analysis cannot extract sub-surface information like depth of source of deformation. In order to enhance a capability of detection of small scale surface deformation as subsidence and landslide by DInSAR analysis, integration use of DInSAR analysis and numerical model and original model for estimation of small scale surface deformation was proposed in this paper. And proposed model was applied to subsidence of the North-East part of China [1], [2] which was detected by ALOS PALSAR DInSAR.

2. MODEL FOR ESTIMATION OF SHAPE OF SURFACE DEFORMATION

Peck [3] proposed a numerical model for reproducing subsidence due to underground excavation (Eq. 1). In this model, shape of surface deformation of subsidence has expressed by normal distribution function. Therefore, it is difficult to reproduce various pattern of subsidence. In order to reproduce various pattern of surface displacement of subsidence, Peck's model was modified. In modified model (Eq. 2), multiplier factor was changed from 2 to n. By using flexible value to multiplier factor, numerical model enabled reproducing various pattern of surface displacement of subsidence as shown in Fig. 1. Especially, its effect can be seen in Fig. 1(b). In case of Fig. 1(b), surface displacement pattern shows exponential function type. In this case, surface displacement pattern cannot be reproduced by Peck's model, however, it can be reproduced by modified model. The effectiveness of modified model was confirmed by this result.

$$\delta_s = \frac{\delta_{\max}}{\exp\left(\dfrac{d^2}{W_{0.5}{}^2}\right)} \tag{1}$$

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Where, δ_s is surface displacement, $\delta_{\max}$ is maximum value of surface displacement, d is radius distance from the center of subsidence, and $W_{0.5}$ is half width of subsidence trough.

$$\delta_s = \frac{\delta_{\max}}{\exp\left(\frac{d^n}{W_{0.5}{}^n}\right)} \tag{2}$$

Where, n is fitting parameter.

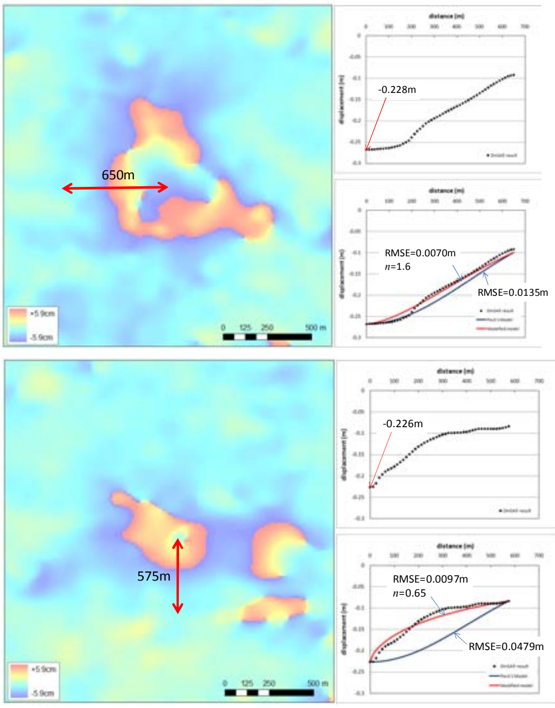


Figure 1. Result of DInSAR and reproduction and comparison of profile of surface displacement by Peck's model and modified Peck's model

3. MODEL FOR ESTIMATION OF SOURCE OF SURFACE DEFORMATION

Mogi's model [4] is famous for the estimation of source of subsidence due to the volcanic activity. This model has possibility to apply for estimation of subsidence in urban area. However, it has a few unknown parameters and depth of subsidence source is different between case of volcano and urban area. Thus, very simple model for estimation of source of subsidence was proposed in this paper. To estimate depth/ground stiffness of subsidence area from DInSAR result, very simple model that shown in Eq. 3 was proposed. Model is considered based on nonlinear curve of deformation pattern of subsidence. The main parameter of this model is both minimum and maximum value of surface displacement that can be derived from DInSAR analysis. Normally, maximum displacement can be measured at the center part of subsidence pattern on the differential interferogram. And also, minimum displacement can be measured at the outside of subsidence pattern on the differential interferogram. Using these parameters and predictable parameters as ground stiffness and depth of source of subsidence, surface displacement can be calculated.

Fig. 2 shows effect of predictable materials and its variation. And Fig. 3 shows validation result of proposed model based on the simulation of laboratory test. From the validation result, proposed model reproduced result of laboratory test precisely was confirmed.

$$\delta_s = \delta_{\max} - (\delta_{\max} - \delta_{\min}) \frac{d^n}{m \cdot (10f)^n + d^n} \tag{3}$$

Where, δ_s is surface displacement, $\delta_{\max}$ is maximum value of surface displacement, $\delta_{\min}$ is minimum value of surface displacement, d is radius distance from the center of subsidence, n is fitting parameter, m is material parameter, and f is depth of source of subsidence.

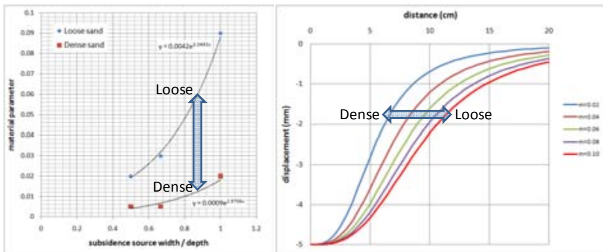


Figure 2. Effect of material parameter "m" as ground stiffness

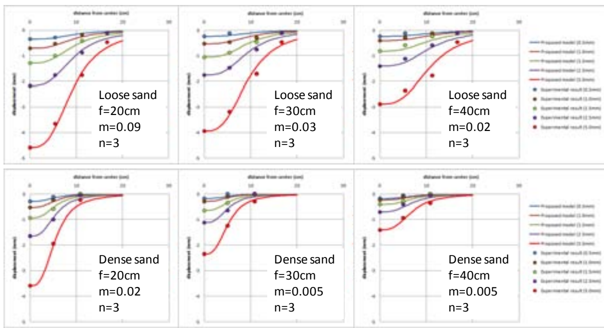
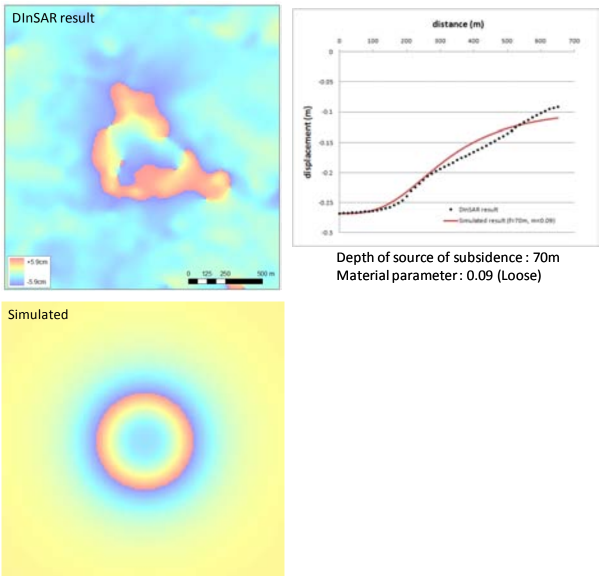


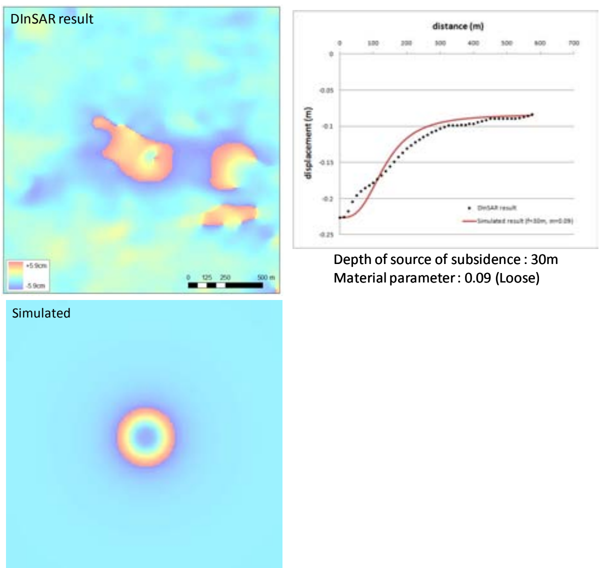
Figure 3. Reproduction and comparison of laboratory test by proposed model

3.1. Application for reproducing of DInSAR result

Proposed model was applied for estimation of depth/ground stiffness from DInSAR result. Firstly, material parameter was considered by assuming ground stiffness from loose to dense condition. From consideration, loose condition of ground stiffness was estimated. Then, material parameter with 0.09 was estimated. Secondly, depth of source of subsidence was estimated using material parameter with 0.09. From comparison of various depth, depth with 70m shows good agreement with profile of DInSAR result as shown in Fig. 4(a). And simulated DInSAR result was obtained as shown in Fig. 4(a). Assuming that same ground material distributed in test site 2, depth of source of subsidence at test site 2 was estimated by same procedure of test site 1. Then, depth of source of subsidence at test site 2 with 30m was estimated as shown in Fig. 4(b). And simulated DInSAR result was obtained as shown in Fig. 4(b). From both results,



(a) Test site 1



(b) Test site 2

Figure 4. Comparison of DInSAR result and simulated result by proposed model

proposed model can be reproduced profile of surface displacement was confirmed. However, it cannot be reproduced planer distribution of surface displacement because constant value of ground material was applied to whole area in this analysis.

3.2. Introduction of parameter plane

In order to reproduce planer distribution of surface displacement, ground material parameter plane was considered. By the characteristic of proposed model that can be changed surface displacement profile curve by material parameter, different value of material parameter was applied in any places. Fig. 5 shows the result of consideration of ground material plane. In the simulated result, proposed model was reproduced the shape of distribution of surface displacement better than before consideration of ground material that shows in Fig. 4. From this result, effect of application of ground material parameter plane was confirmed. And it was shown that possibility of reproducing of DInSAR result, and it has a possibility to estimate distribution of ground material using both DInSAR result and proposed model.

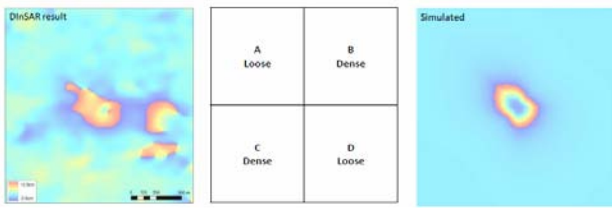


Figure 5. Effect of introduction of ground material plane for proposed model

4. CONCLUSIONS

In this paper, a modified model and proposed model for estimation of small scale surface displacement was proposed. Both modified model and proposed model was derived from the result of DInSAR analysis. Especially, proposed model was shown good agreement with laboratory test as well as DInSAR result. However, proposed model was difficult to reproduced 2-D distribution of deformation. Therefore, introduction of material parameter plane was considered. By consideration of material parameter plane, proposed model was reproduced distribution of surface displacement precisely than the previous one. From this result, introduction of material parameter plane for proposed model shown possibility of reproducing of DInSAR result, and it shown possibility to estimate distribution of ground material using both DInSAR result and proposed model was confirmed.

5. REFERENCES

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