（ 続紙 1 ）

京都大学	博士（工学）	氏名	Panggea Ghiyats Sabrian
論文題目	Improvement of Differential Interferometric Synthetic Aperture Radar (D-InSAR) technique to accurate and overall displacement monitoring in geothermal fields for sustainable resource use（持続可能資源使用を目指した地熱フィールドでの高精度で全域にわたる変位モニタリングのための差分干渉 SAR 処理法の改良）		

（論文内容の要旨）

Topographic change or deformation of the ground surface detected through Differential Interferometric Synthetic Aperture Radar technique (D-InSAR) can be used to specify permeable fracture zones that act as upward pathways of hydrothermal fluids in geothermal areas. Such pathways are essential to locate production wells for geothermal power generation and development of geothermal resource. For accurate measurement of surface displacement by D-InSAR, time series analysis is indispensable, because this analysis can minimize spatial and temporal decorrelation between image pairs of the same SAR scene with different acquisition dates. The time series analysis, which uses many SAR image pairs whose baseline lengths are adequately short to keep high coherence for interferogram generation, has been implemented by several methods, typically multi-temporal InSAR (MT-InSAR), persistent scatterer (PS), and small baseline subset (SBAS). This study aims to develop a new MT-InSAR method that enables accurate and overall monitoring of surface displacement in geothermal fields for sustainable, long-term resource use, by combining lineament density (an index of degree of fracture development), topographic property, water geochemistry, and geophysical data. This monitoring contributes to detect high permeability zones and resultantly, high potential zones of geothermal resource. As the most suitable test areas for this purpose, I selected the Bandung basin (2000 km^2) with several geothermal fields such as Patuha, Wayang Windu, and Tangkuban Parahu in West Java, Indonesia. The most noted outcome of this study is realization of clarifying vertical and horizontal east-west (E-W) displacements over the whole study area by an application of geostatistical methods, although interferograms appear in only half of the study area due to the low coherence between image pairs. Effectiveness of this method is examined by a case study of the Aso volcano with enough amount of GPS data for the displacements and a comparison between the measured and detected displacements. As the result, the method was verified by their agreement within the 95% confidence level. This dissertation consists of eight chapters and the followings are outlines of each chapter.

Chapter 1 provides an introduction to this research with the background, objectives, and brief reviews of principles of the main topic, MT-InSAR. The study area, Bandung basin and the targeted geothermal fields as well as the SAR dataset used in this study are also explained.

As a new MT-InSAR technique, Chapter 2 examines an applicability of InSAR stacking method by a combination of PS and SBAS-InSAR with different wavelength, C and L band data, and demonstrates an accuracy of the detected displacement result for a tropical area as the Bandung basin.

京都大学	博士（工学）	氏名	Panggea Ghiyats Sabrian

Chapter 3 proposes an overall displacement monitoring method by MT-InSAR combined with geostatistics for densely vegetated and low coherence areas with partly absences of interferogram. The method, termed two-dimensional, geostatistical, multi-temporal InSAR method (2D-G-MT-InSAR), is tested for C-band Sentinel-1 scenes of the Aso volcano with continuous GPS measurement dataset and demonstrated to be effective by the agreement between the measured and detected displacements. The resultant displacements reveal the detailed topographic change patterns caused by the volcanic and seismic activities after the Kumamoto 2016 Earthquake.

The 2D G-MT-InSAR is applied to the Tangkuban Parahu geothermal field with the most active volcano in the northern Bandung basin in Chapter 4. Using the obtained vertical and horizontal E-W displacement patterns, a heat source model that controls the geothermal system in this field is constructed. This result can provide the highest potential zone of geothermal resource for the power generation.

Chapter 5 also applies 2D G-MT-InSAR with the Sentinel-1 dataset to specify high permeability zones in the Patuha geothermal field by combining the obtained vertical and horizontal E-W displacements, lineament density, and radon concentration in soil gas as a geochemical property. These datasets are integrated using geographic information system (GIS) and high permeability zones are selected by the weight of evidence (WoE) method. The correctness of selected zones is checked by the positional agreement with the known major faults.

More detailed examination of 2D G-MT-InSAR is implemented in Chapter 6 for targeting four geothermal fields around the Bandung basin. Near the geothermal manifestations, weakly positive correlations between the vertical displacement and lineament density are observed in each water type (sulfate, chloride, and bicarbonate). The largest vertical displacement is identified in the sulfate water type, and displacements in the chloride- and bicarbonate-type areas are to the same degree. The permeable zones are determined by the supervised maximum likelihood classification using the vertical displacement, lineament density, and elevation and their correlation with water type.

Chapter 7 examines a possibility of the 2D G-MT-InSAR-derived vertical and horizontal E-W displacements for sustainability assessment of geothermal resource use by combining microearthquake and radon concentration data by selecting the Wayang Windu geothermal field with a working geothermal power station of 227 MW. Suitable location of production wells for a long-term use of geothermal resource is identified by the proposed method and evaluation map.

Chapter 8 is the general conclusion of this PhD dissertation by summarizing the most important results in Chapters 2 to 7. Important future works that can develop this research are also described for furthermore accurate detection of topographic displacement for geothermal resource use.