# Processing Methodologies of Time-Series Dataset in Ground-Based Radar for Near-Real-Time Terrain Change Monitoring

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Ph.D. Thesis

# Processing Methodologies of Time-Series Dataset in Ground-Based Radar for Near-Real-Time Terrain Change Monitoring

（準リアルタイム地表面変化観測のための

地表設置型レーダ時系列データ処理手法）

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# Abstract

Radar imaging technique has been used for earth observation and remote sensing. This active microwave sensing can measure the target information under almost all weather conditions to some extent. Radar imaging with high spatial resolution can be generally achieved by synthetic aperture processing: this type of radar is called synthetic aperture radar (SAR). Radar remote sensing provides not only reflectivity images but also information about target electric and geometric properties. In particular, the radar interferometry technique can estimate the terrain surface elevation and surface displacement by measuring the phase difference between two radar images. Besides, the microwave scattering properties and biophysical and geophysical parameters can be clarified by multi-polarimetric data analysis.

Radar remote sensing has been historically applied to spaceborne and airborne earth surface remote sensing. Meanwhile, from the late 1990s, ground-based radar has been employed as a potential remote sensing tool for more flexible displacement measurement in observation geometry and acquisition interval. Accordingly, this trend demands the near-real-time radar data processing method.

This thesis dedicates to improving the near-real-time ground-based radar observation accuracy and demonstrating the processing method for more informative monitoring. There are mainly two parts of the study performed in this thesis as follows.

The first part deals with the improvement of the displacement accuracy in the framework of near-real-time ground-based radar monitoring. In multi-temporal radar interferometry applications, propagation delay in the troposphere introduces the major source of disturbances known as atmospheric phase screen (APS). The APS significantly degrades the accuracy of displacement measurement. Novel approaches are proposed to compensate for the APS from multi-temporal ground-based radar data. The proposed approaches aim to compensate for the fluctuated APS caused by a spatial inhomogeneous refractivity distribution. As the processing of near-real-time monitoring, a piecewise processing chain is introduced to derive displacement time-series. The proposed framework is validated with the Ku-band ground-based radar datasets measured over the mountainous fields.

The second part investigates the applicability of the polarimetric target decomposition approach for near-real-time ground-based radar monitoring. The ensemble averaging of the coherency matrix in entropy ($H$)/alpha ( $\overline{\alpha}$ ) polarimetric target decomposition is achieved by temporal averaging (termed temporal $H/\overline{\alpha}$ ) that can be realized by a temporally dense series of ground-based radar polarimetric data. The application of the temporal $H/\overline{\alpha}$ is demonstrated to investigate spatio-temporal scattering mechanism variations of the landslide. The evolution of the landslide was observed by Ku-band polarimetric ground-based radar. Time-series analysis of the landslide by the temporal $H$/alpha indicates an obvious temporal transition of the scattering mechanism and change of backscattering stationarity. Applicability of the temporal $H/\overline{\alpha}$ for a change-detection is discussed by comparing it with the classical spatial $H/\overline{\alpha}$ parameters.

**Keywords**— ground-based radar, ground-based synthetic aperture radar (SAR), GB-SAR, radar interferometry, Ku-band, terrestrial radar interferometry, radar polarimetry, atmospheric phase screen (APS), $H/\overline{\alpha}$ target decomposition, landslide, and glacier.