應用 InSAR 於地面高程變化解析

Application of InSAR for Ground Elevation Change Analysis

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摘　要

雷達干涉技術（Interferometric Synthetic Aperture Radar, InSAR）是一種結合衛星雷達影像與干涉原理的遙測技術，可用於高精度的地表變形監測。相較於傳統依賴離散點位觀測的大地測量方法，InSAR 能提供大範圍、連續性的地表變形資訊，具備空間解析度高、觀測頻率快、量測成本低廉等優勢。由於其採主動式雷達訊號進行觀測，不受天候與光照條件限制，特別適用於長期、廣域及環境敏感區域（如泥炭地、都市地區、山坡地）之監測工作。近年來，InSAR 已被廣泛應用於地層下陷、滑動地變、地震變形與基礎建設穩定性分析等領域，成為空間資訊技術中重要且具發展潛力的監測工具。

本次研究場域為南投頭社盆地，整合多時期衛星雷達影像與 GNSS 固定站觀測資料，進行差分雷達干涉分析（DInSAR）。透過干涉對影像處理、地形效應扣除、相位解纏等步驟，計算影像時間範圍內沿雷達視距（Line of Sight, LOS）方向之地表位移量，並比對 GNSS 實測結果進行誤差分析與結果驗證。研究資料來源包含經濟部地質調查與礦業管理中心、交通部中央氣象署所設 GNSS 站點，以及公開精密軌道資料、數值地形模型（DTM）與雷達影像。

結果顯示，InSAR 可明確揭露頭社盆地泥炭地區域沉陷熱點與沉陷速率空間分布，且與 GNSS 觀測結果相符，驗證該技術於高靈敏度地區之適用性。本研究亦探討雷達波對地表粗糙度、土壤含水量與植被覆蓋之敏感性，指出資料時序與環境因子為影像品質與解算精度之關鍵影響因素。

綜上所述，InSAR 技術不僅具備高解析與高效率優勢，更能提供泥炭地永續管理與災害潛勢預警之關鍵遙測依據，具高度應用與發展潛力。

關鍵字：雷達干涉技術、GNSS、遙測監測、泥炭地、地表高程變化

Abstract

Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing technique that integrates satellite radar imagery with interferometric principles to monitor surface deformation with high precision. Compared to traditional geodetic methods relying on discrete point-based measurements, InSAR provides wide-area, continuous surface deformation data with advantages including high spatial resolution, frequent observation cycles, and cost-effectiveness. As an active radar system, it operates independently of weather or lighting conditions, making it particularly suitable for long-term monitoring in extensive and environmentally sensitive regions such as peatlands, urban areas, and mountainous terrain. In recent years, InSAR has been widely applied in areas such as land subsidence detection, slope movement analysis, earthquake deformation, and infrastructure stability assessments, establishing itself as a vital tool in geospatial monitoring.

This study focuses on the Toushe Basin in Nantou County, employing Differential InSAR (DInSAR) analysis by integrating multi-temporal satellite radar imagery and GNSS fixed-station observations. Through image interferometry, terrain correction, and phase unwrapping, displacement along the Line of Sight (LOS) was calculated, and the results were compared with GNSS observations for accuracy validation. Data sources included GNSS stations operated by Taiwan's Central Geological Survey and Central Weather Administration, along with publicly available precise orbit data, digital terrain models (DTM), and radar imagery.

The results reveal that InSAR effectively identifies spatial patterns and subsidence hotspots within the peatland region of the Toushe Basin, aligning well with GNSS measurements and verifying its applicability in highly sensitive zones. The study also investigates the sensitivity of radar signals to surface roughness, soil moisture, and vegetation cover, highlighting that temporal image selection and environmental conditions critically influence image quality and processing accuracy. Overall, InSAR demonstrates strong potential as a high-resolution, efficient, and reliable remote sensing method for sustainable peatland management and subsidence risk assessment

keyword：Interferometric Synthetic Aperture Radar (InSAR)、Global Navigation Satellite System (GNSS)、Remote sensing monitoring、Peatland、Surface elevation change