# 運用多期雷達衛星影像進行大規模崩塌潛勢區之地表變形量解算

# Estimation of Time-Series Surface Deformation in Potential Large Scale Landslide Using SAR Satellite Imagery

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## 摘要

本計畫為掌握大規模崩塌潛勢區之活動性與整體變化趨勢，透過時域相關性合成孔徑雷達干涉技術(Temporarily Coherent Point InSAR,TCPInSAR)進行廣域大規模崩塌潛勢區之地表長期變形量分析，藉以釐清崩塌區域內潛在活動區塊之時空變形特徵。自 2014 年 ALOS2 雷達衛星發射以來，本團隊針對水土保持局實施地表位移觀測及細部現地監測等 43 處大規模崩塌潛勢區，陸續在 106 年及 107 年分別解算 10 處與 15 處 ALOS2 雷達影像期程之地表長期變形量。延續前期成果，本計畫在 108 年度針對 18 處大規模崩塌潛勢區，進行 ALOS2 地表長期變形量解算工作，並利用高精度數值地形模型，搭配其他光學影像，輔以地質圖、坡度陰影圖以及崩塌地形特徵判釋資料等，進行大規模崩塌潛勢區之活動性評估。同時，針對 5 處已架設單頻 GPS 地表位移觀測系統之重點邊坡，利用多時序合成孔徑雷達干涉技術(Multi-Temporal InSAR,MTInSAR)，進行時序地表累積變形量分析，以協助釐清其坡面整體運動模式以及崩塌潛勢區分區分塊之活動機制，提供其影響範圍、變形速率與變形機制等，有助於後續現地觀測系統之配置等資訊。

本計畫依計畫書之規劃如期完成:(一)新增 4 處大規模崩塌潛勢區自 2007-2011 年間 ALOS 雷達衛星影像期程之 TCP 長期地表年平均變形量估算；(二)新增 18 處 2014-2017 年間 ALOS2 雷達衛星影像期程之前處理工作與同調性分析;(三)新增18 處大規模崩塌潛勢區，2014-2017 年間 ALOS2 雷達衛星影像期程之 TCP 長期地表年平均變形量估算;(四)利用地形幾何關係將衛星入射方向(Line of sight,LOS)地表變形資訊，轉換為沿大規模崩塌坡面方向位移之方法建置;(五)滾動式檢討全臺 186 處大規模崩塌潛勢區位活動性指標 (LandslideActivity Index,LAI),使用轉換至之坡面之地表變形速率，重新檢討大規模崩塌潛勢區位活動性指標；(六)針對 5 處設有單頻 GPS 地表位移觀測站之重點邊坡，完成大規模崩塌潛勢區之時序地表累積變形量分析，透過雙頻 GPS 連續觀測資料作為外部驗證基準，進行大規模崩塌潛勢區位地表長期變形量之檢核與精度評估；(七) 完成 5 處重點邊坡 InSAR 與單頻 GPS 觀測資料比對與精度評估。利用雷達衛星影像期程內之地表觀測變形量，與坡面上單頻 GPS 地表位移觀測位移資訊，進行 5 處重點邊坡不同時空尺度之地表位移資料比對;(八)結合多時序雷達衛星影像地表

變形分析、單頻 GPS 地表位移觀測資料與現地細部調查成果，研擬 5 處重點邊坡之活動特性與潛在崩塌發育模式，以供未來相關整治規劃之參考。.

**關鍵詞：大規模崩塌潛勢區、雷達衛星影像、時域相關點雷達干涉**

## Abstract

This project has conducted a long-term ground deformation analysis on a wide range of deep-seated landslides using Temporarily Coherent Point InSAR (TCPInSAR) as this technique enables us to clarifythe temporal and spatial deformation characteristics of potential sub-sliding blocks within the sites. Upon the launch of ALOS2 satellite in 2014, our team has, with respect to 43 deep-seated landslide sites under the observation (ground surface displacement) and monitoring (detailed monitoring of selected sites) of Soil and Water Conservation Bureau, successively estimated the long-term deformation of 10 and 15 sites respectively in 2017 and 2018 based on the ALOS2 data. Continuing the results of the previous year, 18 deep-seated landslides are selected in 2019 to estimate their long-term ground deformation based on ALOS2 imagery; and to evaluate their activity using high-precision Digital Elevation Model (DEM) incorporated with aerial photographs, geological map, slope-shade map and interpretation of geomorphological features of landslide.

In the meantime, with respect to five key slopes that have been installed with single-frequency GPS-based displacement observation systems, the Multi-Temporal InSAR (MTInSAR) approach has been adopted to analyze the cumulative ground displacement thereof to clarify the overall slope movement and the sliding structure of deep-seated landslides. This approach not only enables us to understand the scope of impact, deformation rate and failure mechanism of deep-seated landslide, but also facilitates the installation plan for on-site observation and monitoring systems.

Our team has completed this project according to the schedule prescribed in the plan. The completed works are as follows: (1) Estimate the annual average deformation of 4 newly selected sites between 2007 and 2011 based on their Temporarily Coherent Points (TPCs) generated from the ALOS data. (2) Pre-processing and coherence analysis of ALOS2 satellite imagery collected between 2014 and 2017 with respect to 18 newly selected sites. (3) Estimate the annual average deformation of 18 newly selected sites between 2014 and 2017 based on the TPCs generated from the ALOS2 data. (4) Use the geometric relationship of terrain to convert.

Line-of-Sight (LOS) deformation into slope displacement of deep-seated landslide. (5) Adopt a rolling review on the Landslide Activity Index (LAI) of 186 deep-seated landslide sites using the data of converted slope displacement rate. (6) Conduct a multi-temporal ground deformation analysis on five deep-seated landslide sites that have been installed with single-frequency GPS-based displacement observation systems. The long-term deformation results and precision thereof are also verified using dual-frequency continuous GPS observation data. (7) Compare the InSAR and single-frequency GPS data of five key slopes; and evaluate the precision thereof. That is, the estimated ground deformation and slope displacement generated

from the single-frequency GPS data during the satellite altimetry period are used to compare and verify the ground displacement (of different temporal and spatial scales) of the five key slopes. (8) Specify and propose the activity features and failure mechanism of the five key slopes based on the MTInSAR analysis of satellite imagery, single-frequency GPS displacement and field survey data. The results are expectedly to be used for future disaster mitigation and equipment installation plans.
**Keywords**：large scale landslides, SAR satellite imagery, TCPInSAR