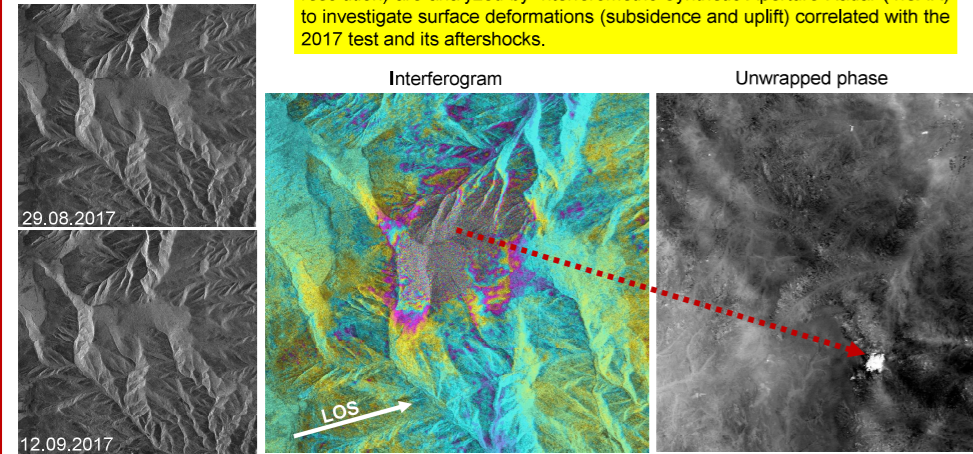


ALOS-2

ALOS-2 (resolution 3 m) Ascending – DInsar - 29.08.2017 and 12.09.2017

Data from the ALOS-2 satellite in the L band (1257.5MHz frequency, 3m resolution) are analyzed by Interferometric Synthetic Aperture Radar (InSAR) to investigate surface deformations (subsidence and uplift) correlated with the 2017 test and its aftershocks.



Clearly fringes in the interferogram

ALOS-2 data were acquired on August, 29th and September, 12th 2017. The sensor had an incidence angle of 43 degrees and a look angle facing east-northeast (Line-Of-Side, LOS).

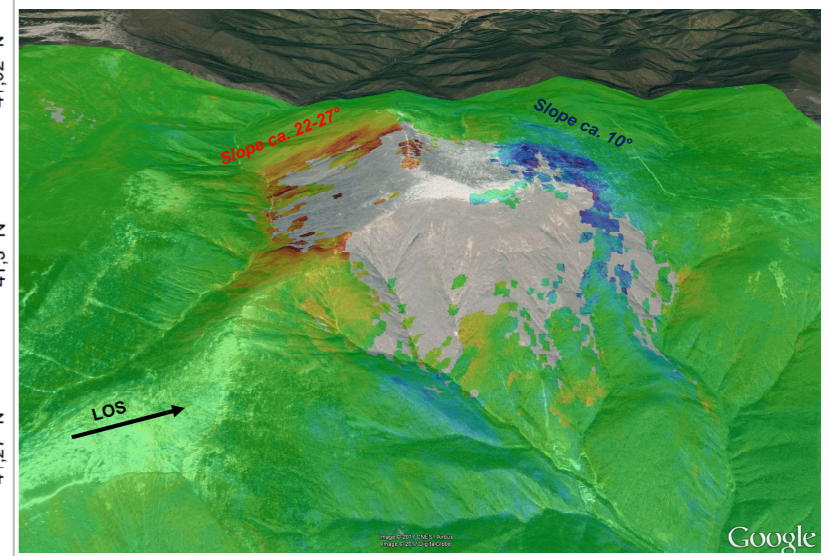
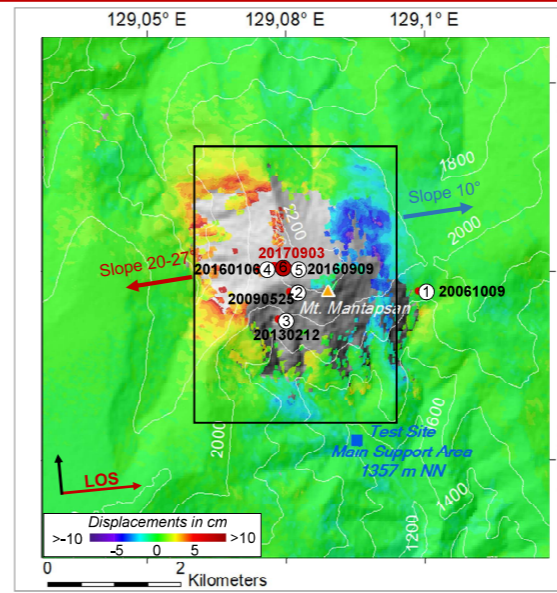
The resulting map of displacements clearly shows an area of subsidence with displacement rates of up to 10 cm around 3 km north of the main support area, and an area with clear uplift of up to 10 cm west of the Mt. Mantap peak.

Data coherence between these two times has a mean value of 0.6 for the investigated area. For areas that show surface deformation the coherence values range from 0.2 to 0.8.

Processing Parameter	
Filter Methode	Goldstein
Unwrapping Methode	Minimum Cost Flow
Unwrapping Decomposition	Level 2
Unwrapping Coherence Threshold	0.2
Product Coherence Threshold Final	0.25
Resolution Final	10 m

Data from August, 29th and from September, 12th 2017 are investigated. Arrows indicate slope direction and angle. Numbered circles indicate the epicenters of the tests from 2006 to 2017. The black solid box delineates an area of around 34 km² in which the surface displacement is between -10 and +10 cm.

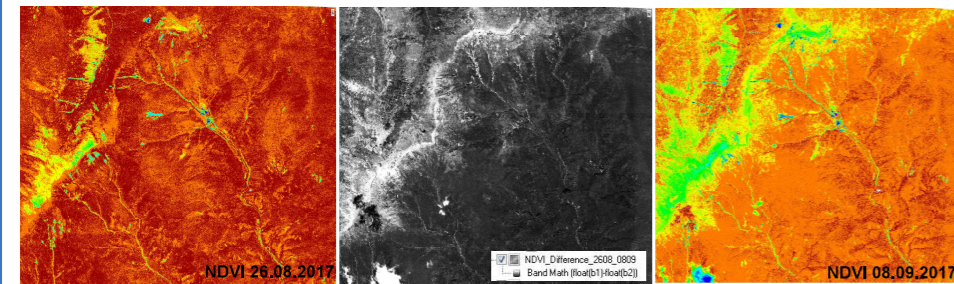
In the central part of the Mt. Mantap massive, coherence values dropped significantly below 0.25 due to very strong ground deformations.



Results of DInsar in the nuclear test area superimposed on Google Earth

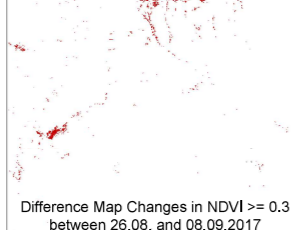
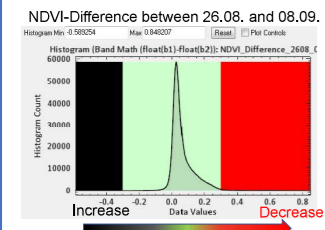
Pleiades

Pleiades (resolution 2 m) – Change Detection NDVI - 26.08.2017 and 08.09.2017



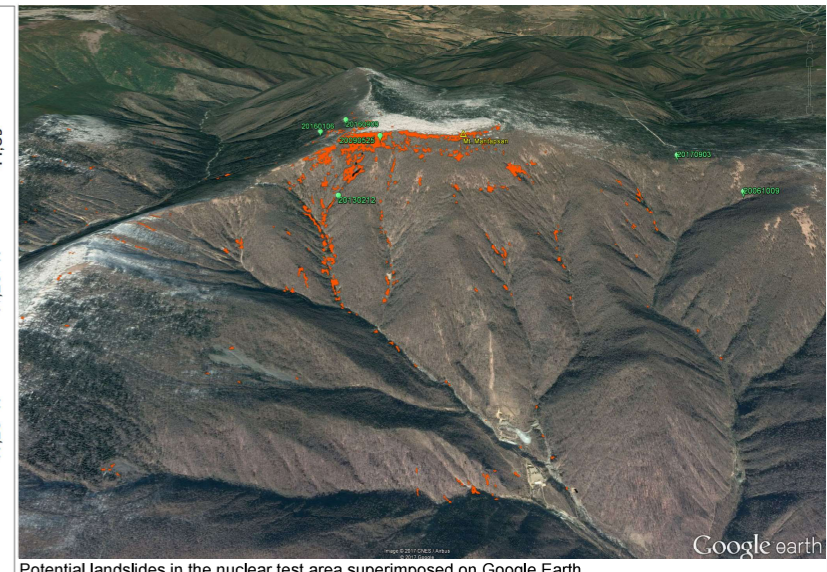
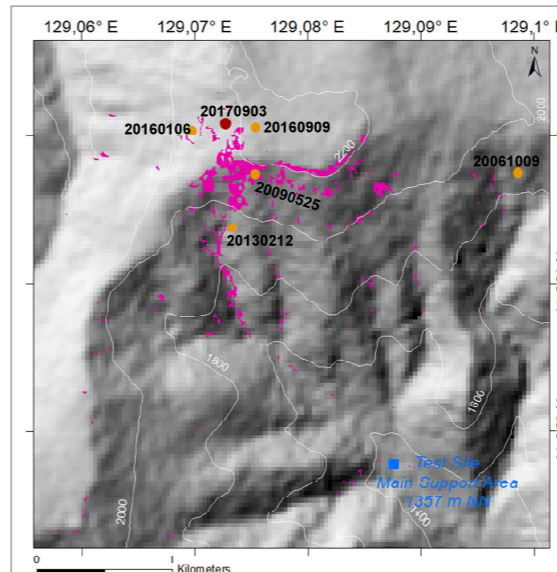
The method of change detection analysis based on the Normalized Differential Vegetation Index (NDVI) is applied.

To validate the displacement maps of the DInSAR analysis of the nuclear test, Pleiades data sets from 26 August and from 8 September 2017 were processed to reveal surface characteristics related to the underground test. This relation is concluded by the strong temporal and spatial connection of the landslides to the test and aftershock origin time and epicenter locations. Change detection analysis show numerous landslides activated during the test and aftershocks.



Difference NDVI 26.08.2017 minus 08.09.2017.
Red = Changes in difference of NDVI between 26.08. und 08.09.2017 <= 0.3 (NDVI 26.08. > NDVI 08.09.)
Black = Changes in difference of NDVI between 26.08. und 08.09.2017 (NDVI 08.09. > NDVI 26.08.)
Result: Strong decrease in NDVI aftershocks shows numerous landslides

The figure to the right shows the change detection analysis based on NDVI (Normalized Difference Vegetation Index) from Pleiades with potential landslides (in purple patches) triggered by the 2017 nuclear test. Numbered circles indicate the epicenters of the tests from 2006 to 2017.

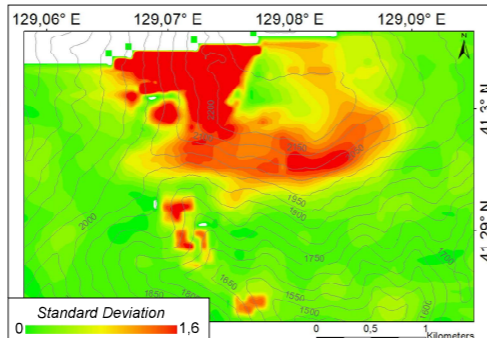
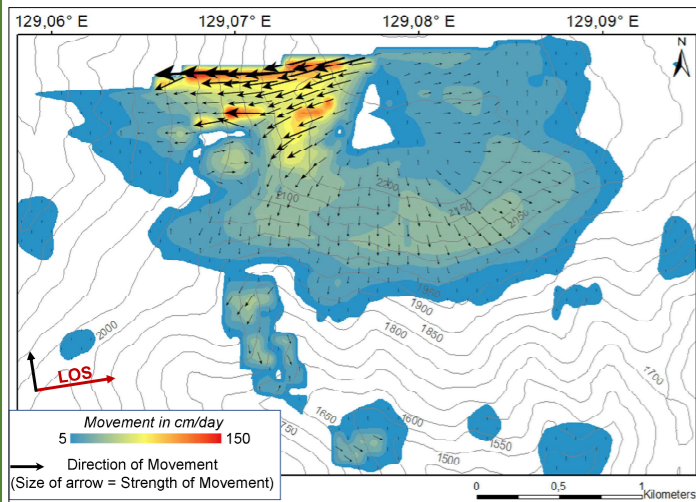


Potential landslides in the nuclear test area superimposed on Google Earth

TerraSAR-X

TerraSAR-X Spotlight (resolution 3 m) - Offset-Tracking - 26.08.2017 and 06.09.2017

This method measures feature motion between two images using patch intensity cross-correlation optimization and can estimate the movement in range and azimuth



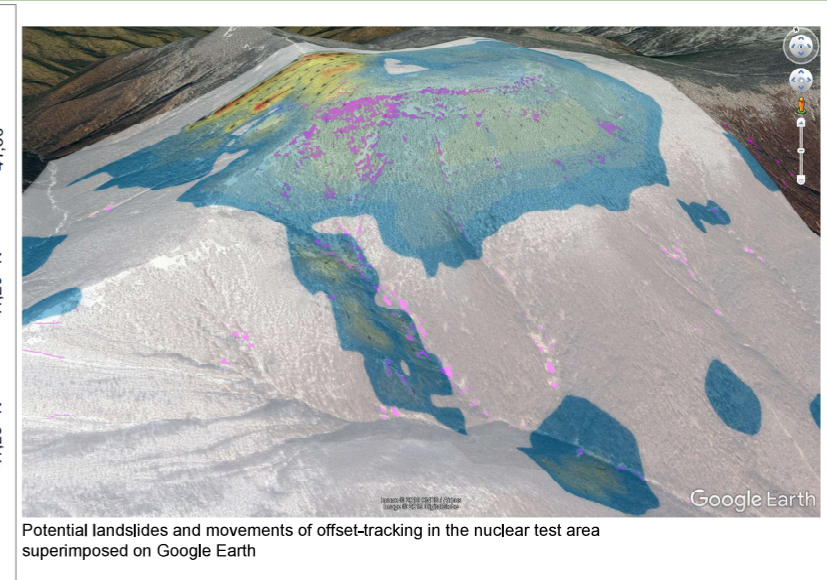
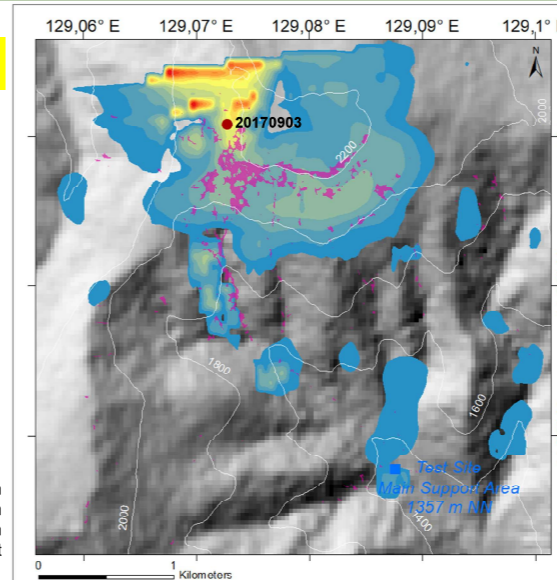
This method is more robust than DInsar and provides additional information since interferograms are mainly sensitive to the displacements in range and DInsar is limited by coherence loss. The benefit of using the offset-tracking is that this method is less affected by the decorrelation problem. Therefore, the deformation signal could be better resolved even in some damaged areas where the interferometric phase may be lost due to decorrelation.

Processing Parameter	
Registration Window	128 Pixel
GCP Grid	60 m
Cross-Correlation Threshold	0,1

The partially strongest movements can be found on the western flank of Mt. Mantap with up to 1.50 m / day (15 m in 11-days) with a west to south-west direction. The standard deviation in the movement area is up to 1,6.

The movement areas cover the areas where landslide activities are extracted from the Pleiades data.

The figure to the right shows the change detection analysis via NDVI (Normalized Difference Vegetation Index) from Pleiades with the potential landslides (in purple patches) triggered by the 2017 nuclear test and the movements from the offset-tracking.



Potential landslides and movements of offset-tracking in the nuclear test area superimposed on Google Earth