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PROCESSING SENTINEL-1A IMAGES USING SENTINEL APPLICATION PLATFORM SOFTWARE TO GENERATE INTERFEROGRAM FOR MEASURE GROUND DEFORMATION IN KELANTAN

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Abstract:

Land subsidence are deposition processes that lead to the earth's surface sinking slowly or suddenly as a result of movement of underground structures. It occurs when the amount of underground water has been pumped out from the certain types of sedimentary rock such as fine grains. Over-exploitation of subsurface water causes compression between clay and silt, resulting in land subsidence. Since 1935, Kelantan has relied on subsurface water as a daily requirement. There are 70% of the total domestic water supply in Kelantan is from groundwater. Consequently, the objective of this study is to monitor groundwater extraction-induced land deformation using Persistent Scatterer (PS) InSAR technique. The PSI method involves the use of large numbers of stack interferograms to determine and monitor deformation. The purpose of the study is to show how to generate interferograms from Sentinel-1A images using the SentiNel Application Platform (SNAP) software before exporting them to the Stanford Method for Persistent Scatterers (StaMPS). Furthermore, this study will focus on the state of Kelantan where the specific places involved in groundwater extractions are in Pintu Geng, Tanjung Mas and Tumpat. This paper will demonstrate how to use the SNAP software to process data.

Keywords:

Land Deformation, Groundwater Extraction, Persistent Scatterer Insar, Sentinel Application Platform

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Introduction

The word land subsidence refers to the process of land erosion and subsidence of the land surface. The term subsidence refers to the land's deterioration or collapse. Artificial boundaries, shifts in drain pattern, heavy rain, or water extraction may all be contributing factors. Subsidence has the ability to inflict damage on highways, structures, and facilities. It is occurring in major urban areas, such as Semarang (Abidin et al.,2013), Bangkok (Aobpaet et al.,2013), Shanghai (Wei,2006), Vietnam (ERBAN et al.,2014), and in China (Zhu et al., 2015). Land subsidence may also be caused by soil compaction, mineral exploration, groundwater depletion, water level changes, and soil erosion. The movement of the earth's surface due to over-flow movements from the underground (gas, oil and mining) and human reservoir (Ashrafianfar et al. ,2010).

Since 1935, Kelantan has been the region in Malaysia that has relied heavily on underground water as an alternate source of water. The people of this state were given tube wells as a result of the flood that hit the region. Tube wells have the same features as standard wells, but they require a special piping to extract surface water (aquifers) (Ismail, 2009). This study aims to demostrate processing Sentinel-1A images using SNAP software to generate interferogram before being exported to Stanford Method for Persistent Scatterers (StaMPS) to generate deformation map.

The latest advancement of radar interferometric processing is Persistent Scatterer (PS) InSAR provides a realistic approach for the reduction of major errors in conventional DInSAR procedures; temporal, geometrical decorrelation, and atmospheric phase. PS InSAR technique does not use all of the pixels in the image, but rather selects pixels based on phase stability (Agarwal et al, 2020). Buildings, sidewalks, exposed rocks, bridges, and other artifacts in the physical world are shown in stable phase pixels. Therefore, PS InSAR is limited to applications that have a large number of bright diffusers, usually man -made structures. A large number of these human structures have an angular shape and often produce very strong reflectors that dominate the background scattering (Hooper et al., 2006; Agram, 2010; Din, 2014).

A new phase of continuous monitoring using Synthetic Aperture Radar (SAR) is underway following the launch of Copernicus Sentinel-1A on April 8, 2014, according to the European Space Agency (2012). Sentinel-1 enables observation of SARs in the C band by means of a single look complex (SLC). There are two satellites involved in the mission, Sentinel-1A and Sentinel-1B, which were launched in April 2016 and cover an area of 250 kilometres. These two satellites are in the same orbits and the repeat cycle is 6 days and the spatial resolution (down to 5 m) (Devanthéry et al., 2016). The Sentinel-1 data is available for free download from the Alaska Satellite Facility (ASF) https://search.asf.alaska.edu/#/.

Materials and Methods

Data Used and Study Area

The study area is in Kota Bharu, Kelantan, see Figure 1 The coordinates of the location are 102^{o} 17' E longitude and 6^{o} 06' N latitude. This site is located in an urban area where groundwater extraction might result in land subsidence. The tabulation of tube well that is registered under the government of Kelantan is located at Pintu Geng, Tanjung Mas and Tumpat (Din et al., 2015). This study produced an interferogram by combining two Sentinel-1A satellite images. The images acquired are 25 September 2017 and 13 April 2021, see Table 1.

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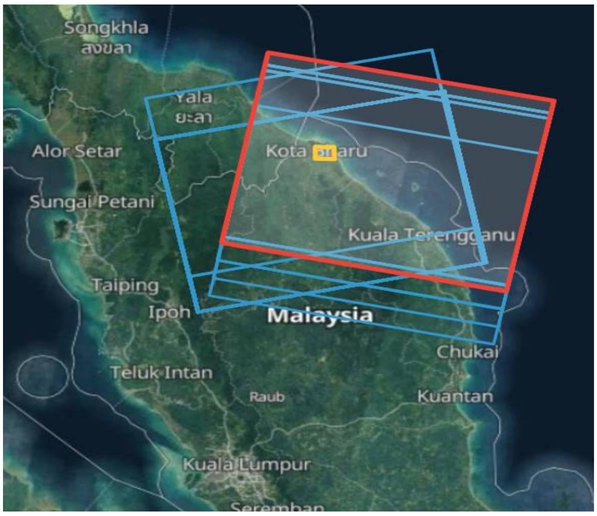

Figure 1: Sentinel-1A's ascending and descending tracks over Kelantan

Table 1: List of Sentinel-1A SLC Images

No	Mission	Acquisition Date	Type	Track	Orbit	Inclination Type
1	Sentinel-1A	20170925	SLC	91	18538	Descending
2	Sentinel-1A	20210413	SLC	91	37438	Descending

Processing Sentinel-1 using Sentinel Application Platform (SNAP)

The SNAP software becomes a multipurpose toolbox which supports both SAR processing and optical data processing. This software is developed by European Space Agency (ESA) for the use of Copernicus Sentinel data in support of the earth observation community in order to facilitate the utilisation, viewing and processing of the remote sensing images (Blasco et al., 2019). Figure 2 illustrates the graph builder's workflow for the SNAP to StaMPS export. In order to make sure the processing going smoothly the computer has 16GB memory RAM, windows in 64-bit operating system, sufficiently free space and when data processing happens, do not use your computer.

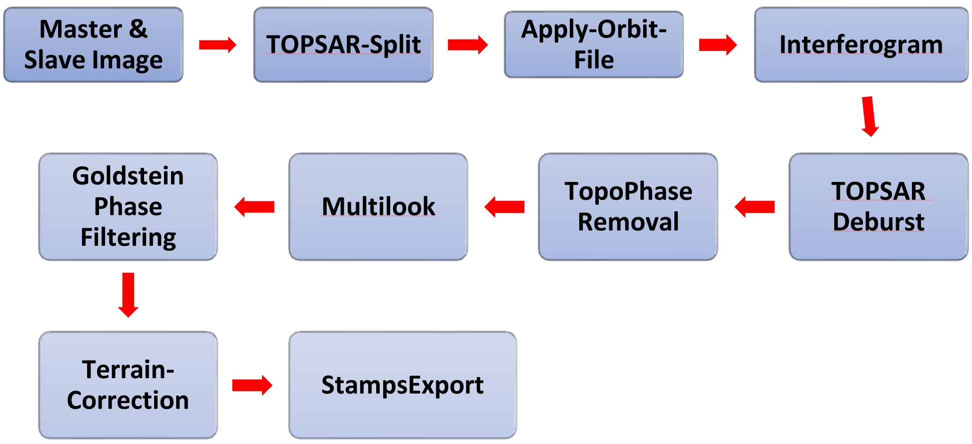

Figure 2: Graph Builder of the SNAP Processing Workflow

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Stack (Master & Slave)

Step two is to determine the master image and the slave image. In this processing the master image is 25 September 2017 and slave image is 13 April 2021. This step gives details on the interferometric stack. Data on acquisition times, sensors, modes and perpendicular and temporal baseline details are described.

Coregistration

The first processing step is coregistration. It is including of TOPSAR split and apply orbit. This process to co-register the images into master and slave with the same sub-swath using the orbits and Digital Elevation Model (DEM). The TOPSAR split is to divide each sub-swath into a separate image using a chosen burst. The parameter used is to select one of the three sub-swath with either IW1, IW2, or IW3. Since this study is monitoring vertical ground movement, the polarisation used is VV as shown in Figure 3.

Apply orbit is used to adjust the orbits in both the split products with Sentinel Precise orbit files. The DEM type used is SRTM 3sec that is automatically downloaded by SNAP.

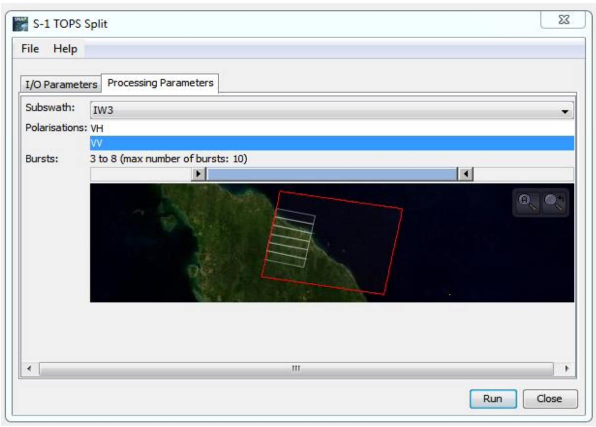
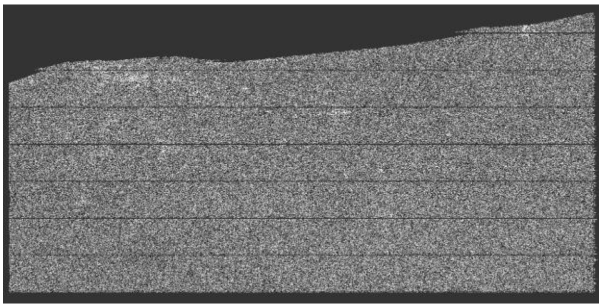


Figure 3: TOPSAR Split

Interferogram Formation

A complex interferogram is then produced after the flat earth step has been removed. Interferometric signals are subject to curved reference surfaces in order to determine the flat-earth phase. The data used to remove the complex interferogram are using the orbital and metadata information. The SRTM 3 arc-seconds Digital Elevation Model (DEM) simulates and subtracts topographical phases that is automatically download in SNAP (Foumelis et al., 2018). Figure 4 shows the intensity and phase interferogram from master and slave images.



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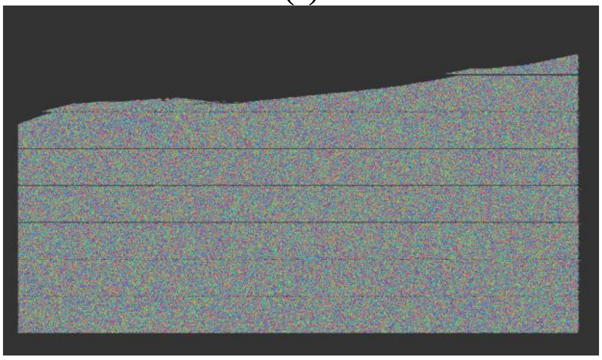
(a)



(b)

Figure 4: Coherence (coh_IW3_VV) (a) and Interferogram (Phase_ifg_IW3_VV) (b)

Deburst

Each product in the TOPSAR Interferometric Wide (IW) SLC series consists of one image per swath per polarisation. In IW products, there are three swaths, and each sub-swath is composed of a series of bursts, each of which is processed as an SLC image. Each burst image of each object is merged into a sub-swath image with a black-fill delineation in between, as shown in Figure 5 (Braun and Veci, 2020).

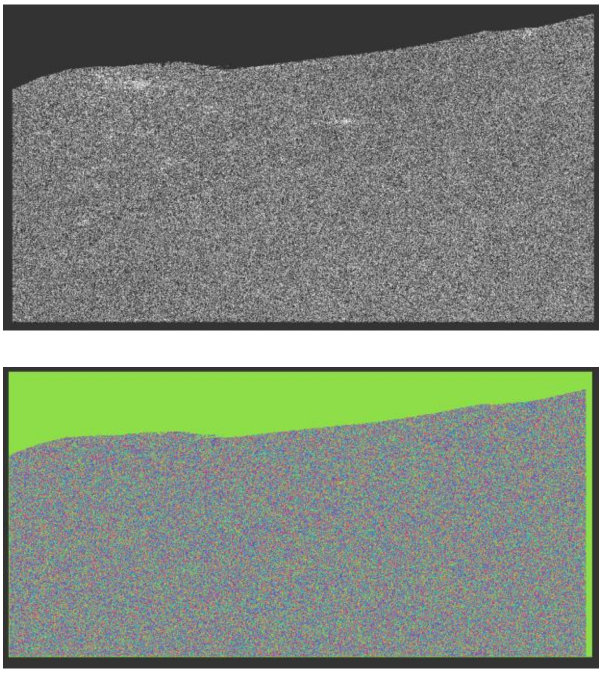


Figure 5: Coherence (Top) And Interferogram (Bottom) in Single Image After the Lines Between Burst Is Removed and All Bursts Are Combined

Topographic Phase Removal

Topographic phase inputs are generally eliminated using the known DEM to highlight deformation-related phase signatures. Sentinel-1 Toolbox will create an interferogram using

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the DEM reference, which is removed from the processed interferograms, by the Topographic Phase Removal Operator (Ferretti et al., 2007).

Multilooking
Multilooking is the process of eliminating speckle noise by combining images from two different scenes but in the same area. As a result, the multilook image improves image interpretability. Furthermore, multilook visualization can be used to create a product with a defined image pixel size (Small and Schubert, 2008).

Phase Filtering
A known DEM is typically used to remove topographic phase contributions to show phase in relation to deformation. The filtering used is Goldstein phase filtering. This phase filtering is to enhance the phase unwrapping accuracy (see Figure 6) (Goldstein and Werner, 1998).

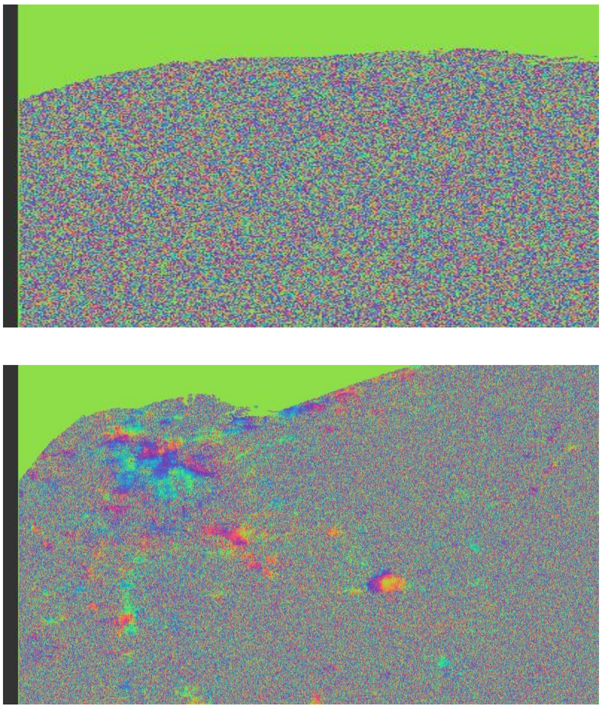

Figure 6: Interferogram Before (Top) and After (Bottom) Filtering using Goldstein Phase Filtering

Geocoding
The interferometric phase image must be projected onto a spatial coordinate system using a DEM-assisted geocoding step before the data can be used by geoscientists. The map projection used is WGS84 and DEM is SRTM 3sec. Figure 7 shows the interferogram is integrated with Google Earth.

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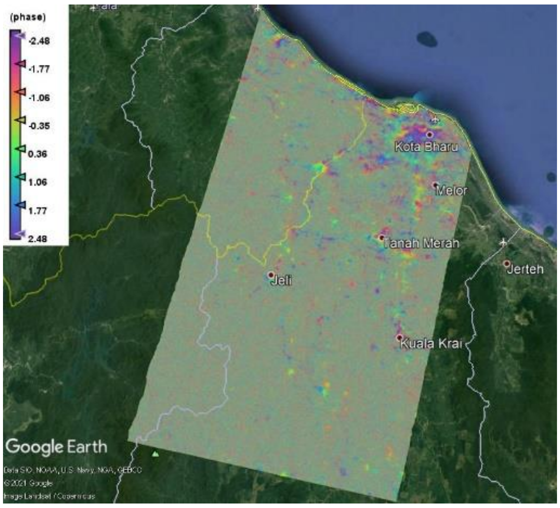

Figure 7: Interferogram with Map Projection WGS84

Source: (Google Earth)

StaMPS Export

StaMPS export is use to generate the data to be used in the application of StaMPS Persistent Scattering Interferometry (PSI). Each data stack is exported separately using the StaMPS export operator until pairs of co-registered master-slave SLCs and differential interferograms have been successfully produced. When a standard directory is established, the results of the SNAP TOPS InSAR are exported into a subfolder based on stamps-compatible format. The subfolder generated are DEM, diff0, geo and rslc (Foumelis et al., 2018).

StaMPS Processing

The subfolder that generate from StaMPS export will be used in StaMPS processing using Linux. In Linux, we need some basic in coding, compiling and command line. It is different with SNAP software; StaMPS is no graphical user interface. This processing also uses MATLAB to analyse the data and creating time series. The manual of StaMPS processing is provided by Andy Hooper (Hooper et al., 2018).

Main Results

The integration of SNAP-StaMPS for semi-automated Sentinel-1 image processing was successfully demonstrated. Since the aims of this study is demonstrate processing Sentinel-1 images using SNAP software to generate interferograms before being exported to StaMPS. As shown in Figure 8, the results of this study were obtained using the SNAP software. Coherence is defined as the difference between two SAR images in terms of the complex correlation coefficient (Lu et al., 2018). The area in white is urban areas, vegetated area in dark and very dark area is river or lake. In interferometry, coherence provides an opportunity to deconstruct an interferogram or create a deformation map. There are more than 20 stacks of interferogram SAR images required to obtain deformation maps during processing in StaMPS.

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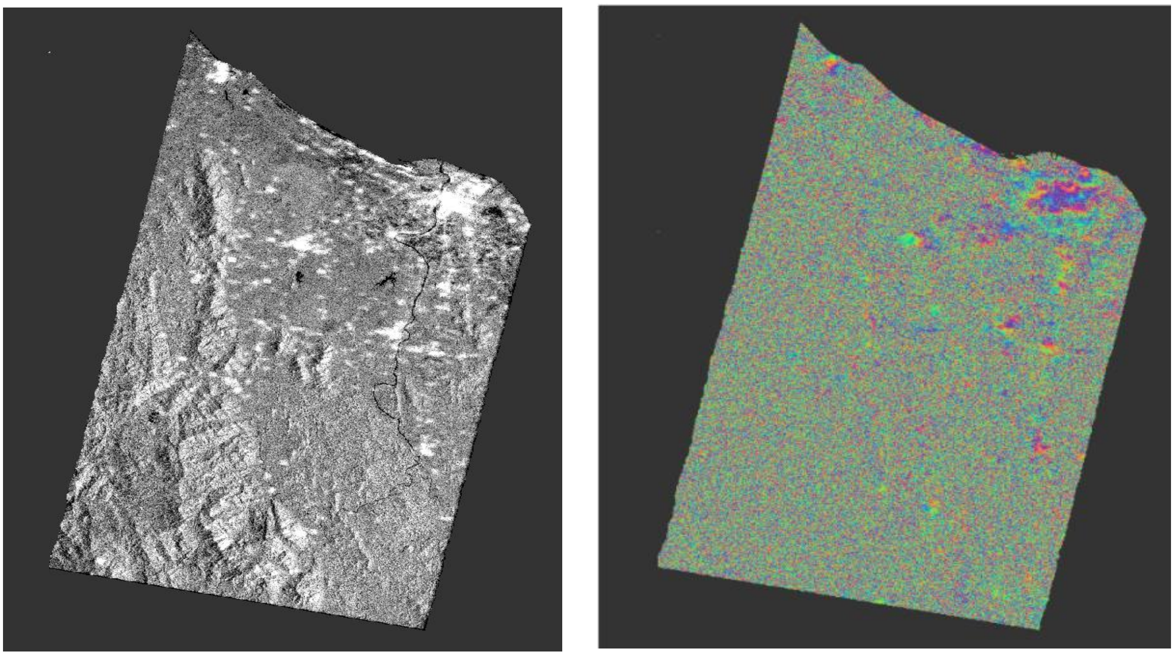

Figure 8: Coherence (left) and Interferogram (right)

Conclusion

Based on the results obtained from this study, it can be concluded that the SNAP software can be used to process the Sentinel-1A images to generate interferogram. This is the semi-processing before continued with the StaMPS processing. This ground deformation is a slow deformation process and requires to use of interferometric images over long intervals.

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