



DE GRUYTER  
OPEN

DOI 10.2478/pesd-2018-0038

PESD, VOL. 12, no. 2, 2018

## MAPPING SNOW FOR AREA WHERE WAS DETECTED GROUND DISPLACEMENT: A CASE STUDY OF IAȘI COUNTY

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**Key words:** detected ground displacement, Sentinel, NDSI, Landsat

**Abstract:** The main goal of this paper is to detect snow in areas where was detecting and mapping, using Differential Radar Interferometry (DInSAR) technique, ground displacement. DInSAR is a powerful tool to detect and monitor ground deformation. Iași county is considered as study area in this research. Study area is geographically situated on latitude 46°48'N to 47°35'N and longitude 26°29'E to 28°07'E. For this paper, to detect and mapping ground displacement, was used Sentinel – 1 images, provided free by The European Space Agency (ESA), for January 2018, with vertical polarization (VV), ascending orbit and Interferometric Wide swath (IW) mode operated. SNAP was used to process the Sentinel – 1 images. Landsat-8 OLI was taken to detect areas cover with snow using Normalized Difference Snow Index (NDSI) - a numerical indicator that shows snow cover over land areas. ArcMap was used to create NDSI map after Landsat-8 data was preprocessed. The presence of snow has been observed both in the areas where it exists vertical displacement positive and negative.

### 1. Introduction

Interferometric synthetic aperture radar (InSAR), one of the geodetic technique that uses 2 / more single-look SAR images to realize maps of surface deformation (ground displacement) or digital elevation (DEM) (Massonnet et

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al., 1998; Hanssen 2001). This technique has applications for monitoring natural hazards (earthquakes, volcanoes and landslides), in engineering, in particular monitoring of subsidence and/or structural stability. InSAR detect centimetre-scale displacement/deformation changes (Zebker et al., 1997).

Data acquired by space-borne SAR sensors and reprocessed through Differential SAR Interferometry (DInSAR) techniques are an important technological development for landslide investigations (Hilley et al., 2004; Cascini et al., 2009; Guzzetti et al., 2009; Cascini et al., 2010; Bovenga et al., 2012). DInSAR - a remote sensing (RS) technique - exploits interferogram (the phase difference) between pairs of SAR data collected obtained for the same zone at different times and from enough near orbits, allowing to estimate displacement maps with a precision of centimeters or millimeters. At the beginning the technique was created to detect and map the ground movements caused by a single natural trigger event - earthquakes (Massonnet et al., 1993) or a volcanic unrest (Massonnet et al., 1995). DInSAR techniques were afterwards extended to generate deformation time series realized by inverting temporal strings of DInSAR interferograms (Berardino et al., 2002; Ferretti et al., 2000, 2001; Hooper, 2008; Mora et al., 2003; Werner et al., 2003). These interferometric approaches, allow searches the temporal evolution of ground movements caused by natural hazards and human activities (Hilley et al., 2004; Borgia et al., 2005; Dixon et al., 2006; Bell et al., 2008; Lanari et al., 2010).

One of the usual global climatological phenomenon, snow, is well-known to be a important constituent of the hydrological component and ecological hazard. Snow, in some parts of the Earth, is usually limited to the higher altitudes and is considered to be one of the most disastrous natural hazards. Therefore, mapping the snow cover is important to the hazard moderation and basins management. It is also important for weather and hydrological forecasting. For identifying the snow presence, satellite sensors includes the observations between 0.66 and 1.6mm (<https://eos.com>).

In this paper was mapped snow using NDSI for area where was found vertical displacement in Iasi county. To detect and map ground displacement was used Sentinel – 1 data and for mapped snow was taken Landsat – 8 images.

## **2. Data and methods**

### **2.1. Study Area**

Study Area is geographically situated on latitude 46°48'N to 47°35'N and longitude 26°29'E to 28°07'E. Neighbours of Iași county are Botosani to the North, Neamt to the West, Vaslui to the South and Rep. of Moldova to the East. Iasi County overlay on: Jijia Hills, Suceava Plateau and Central Moldavian Plateau, 3 main subunits of the Moldavian Plateau, and has a area of 5,497 km<sup>2</sup>. This

administrative unit is hit by heavy rains, floods, droughts and at larger periods of time by landslide events and earthquakes (Margarit et al., 2014).

### ***2.2. Sentinel & Landsat data***

Sentinel-1A satellite was successfully launched by The European Space Agency's (ESA) on April 3<sup>rd</sup>, 2014, by a Soyuz Rocket. According to ESA, S-1 SAR has a dual polarisation radar capability. Sentinel can transmit a signals and receive their in both polarisations (horizontal and vertical) ([sentinel.esa.int](http://sentinel.esa.int)).

Launched on February 11, 2013, Landsat 8 is the future of Landsat satellites. System is collecting imagery to be used in science, agriculture, business, education etc ([www.nasa.gov](http://www.nasa.gov)).

The Landsat Program provides repetitive acquisition (14 day) of high resolution multi-spectral data of the Earth's surface. The Landsat data represents the longest record of the Earth's surfaces as seen from space ([www.nasa.gov](http://www.nasa.gov)).

In this paper was used Sentinel-1A images, downloaded free from a hub of The European Space Agency (ESA), with SLC product type, IW sensor mode and vertical polarisation for January 2018 and Landsat 8 OLI image for same period.

### ***2.3. Data processing***

DSInSAR is a RS technique able to determine surface deformation on the ground using complex satellite radar datasets. This technique uses the interferometric phase resulting by the computation of the phase difference between a pair of SAR images. Interferogram offers the phase information that are related to the topography of the study area, and the displacement occurred in the time between the 2 images used Crosetto et al., 2016).

Sentinel-1 images was processing in SNAP (Sentinel Application Platform), provided by The European Space Agency (ESA). During the data processing was set the condition that coherence to be greater than 0.5 for each pixel.

Preprocessing of the Landsat-8 OLI images represents operations that prepare images for subsequent analysis that attempts to compensate and/or correct for systematic errors. The images are subjected of a few corrections like radiometric or atmospheric ([mininggeology.blogspot](http://mininggeology.blogspot))

NDSI represents the reflectance difference between visible (green) and shortwave infrared (SWIR). It controls the variance of 2 bands (one in the NIR (near infrared) or SWIR and another one in the visible parts of the spectrum). This is useful for snow mapping. Snow is also highly absorptive in the NIR or the SWIR part of the spectrum ([eos.com](http://eos.com)). Values of NDSI > 0.4 typically indicate the presence of snow.

NDSI is calculated by following the formula:

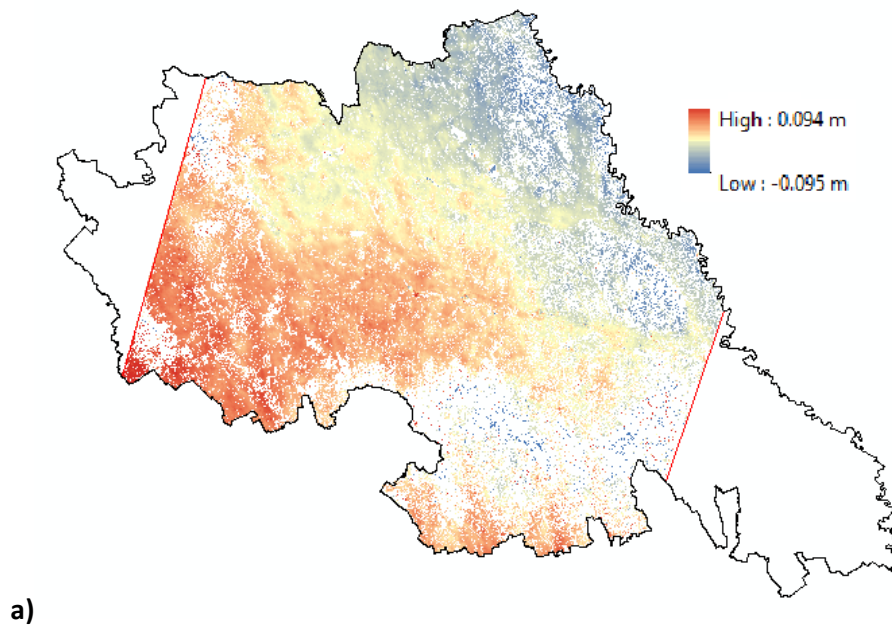
$$\text{NDSI} = (\text{Green} - \text{SWIR}) / (\text{Green} + \text{SWIR})$$

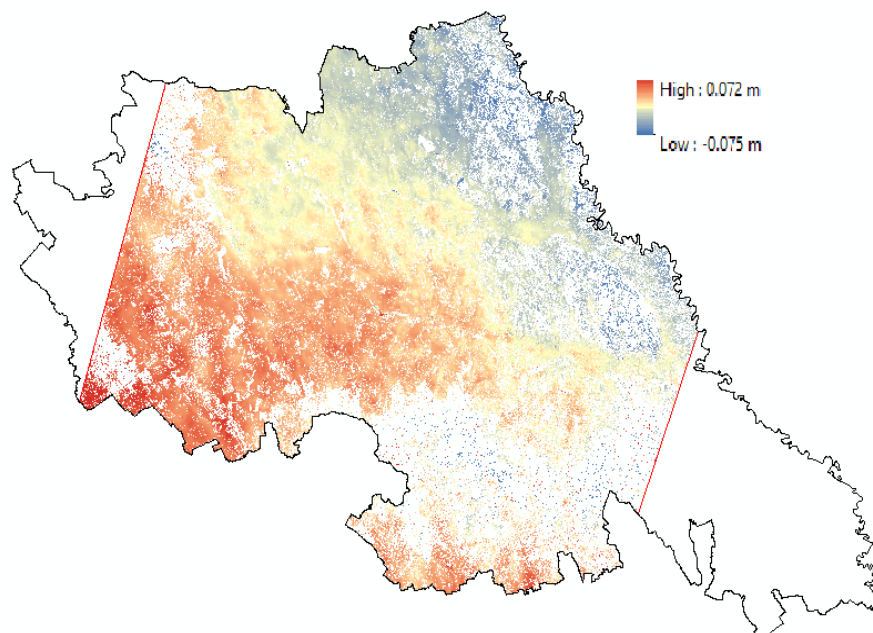
Landsat-8 OLI image was processing in ArcMap to create covering snow map using NDSI.

### 3. Resluts and discussion

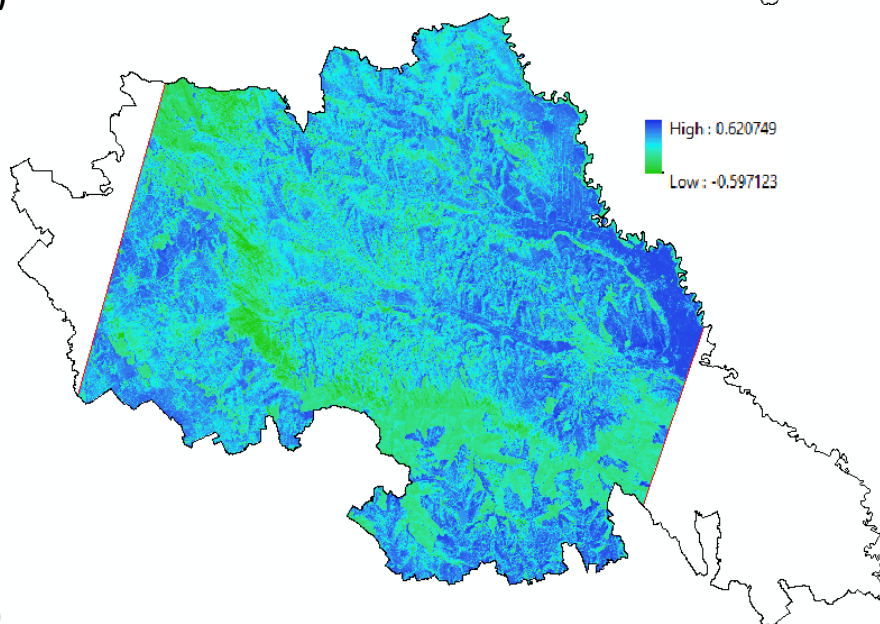
Figure 1.a shows the land movement in the line of sights (LOS). The displacements vary between -95 and 94 millimeters in relation to the LOS. The vertical displacement varies between -72 and 75 mm for study area. It was noticed that negative values for vertical displacement was in the north-east and east of Iasi county.

Values of NDSI vary between -0.59 and 0.62 and values over 0.4 indicate presence of snow. Mean value for NDSI is 0.29. Figure 1.d shows a map with areas covered by snow in zones affected by vertical displacement for Iasi county.





b)



c)

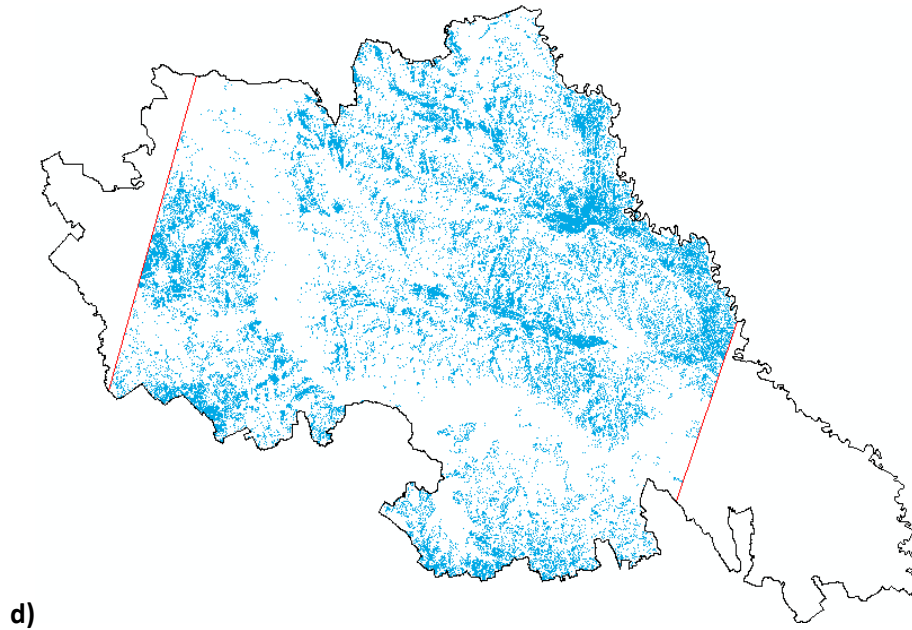


Fig. 1. a) Ground displacement in Line of Sight; b) Vertical ground displacement; c) NDSI map; d) Snow in areas where was mapped ground displacement

It noted that areas covered by snow was found in both case, for subsidence and uplift ground. If snow could affected or amplified land movements in these areas, it can not be said with certainty, and for a comprehensive conclusion it is recommended in future studies an on-the-spot research

### Conclusions

The main goal of this paper was to detect and map snow in areas affected by ground displacement. To detect and map ground displacement was used Differential Radar Interferometry (DInSAR) technique. Iași county was considered as study area in this study. In this research was used Sentinel-1A images, provided free by The European Space Agency (ESA), with SLC product type, IW sensor mode and vertical polarisation for January 2018. Sentinel-1 images was processing in SNAP, while Landsat-8 image was processed in ArcMap to obtain NDSI map.

The vertical displacement varies between -72 and 75 mm for study area. It was noticed that negative values for vertical displacement was in the north-east and east of Iași county. It noted that areas covered by snow was found in both case, for subsidence and uplift ground. If snow could affected or amplified land movements

in these areas, it can not be said with certainty, and for a comprehensive conclusion it is recommended in future studies an on-the-spot research.

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