FLOOD MAPPING USING SYNTHETIC APERTURE RADAR: A CASE STUDY OF RAMSAR FLASH FLOOD

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ABSTRACT:

Disasters including flash floods, earthquakes, and landslides have huge economic and social losses besides their impact on environmental disruption. Studying environmental changes due to climate change can improve public and expert sector's awareness and response towards future disastrous events. Synthetic Aperture Radar (SAR) data and Interferometric Synthetic Aperture Radar (InSAR) technologies are valuable tools for flood modeling and surface deformation modeling. This paper proposes an efficient approach to detect the flooded area changes using Sentinel-1A over Ramsar flood on 5th October 2018. For detection of the flooded area due to flash flood SARPROZ in MATLAB programming language is used and discussed. Flooded areas in Ramsar are detected based on the change detection modeling using normalized difference values of amplitude belonging to the master image (on 28th September 2018) and the slave image (on 10th October 2018).

1. INTRODUCTION

Disasters cause devastating human and economic losses besides their environmental disruption. There are two types of Geo-hazards including natural hazards (such as landslides, earthquakes, floods, and tsunamis) and human-induced hazards (such as water contamination, land subsidence due to groundwater-extraction and atmosphere pollution) (Tomás and Li, 2017). Flood is a natural disaster that often causes a huge impact on infrastructures, people, and properties, as well as indirectly affecting on the country's economy (Ibrahim et al., 2017; Chang et al., 2008). Main reasons for flood include heavy and high-intensity rainfall, ineffective drainage system, and a high volume of runoff due to increasing impermeable ground surface (Sahoo and Sreeja, 2015).

Remote sensing data including satellite and airborne imagery and altimetry, are widely used to research floodplain inundation, floods, and river hydrodynamics for the last two decades (Schumann, 2017). In bad weather conditions in case of flooding events, Synthetic Aperture Radar (SAR) data due to its nature for penetrating through clouds are better choices over optical sensors. The surface deformation caused by geohazards including earthquakes, landslides, and floods, spaceborne interferometric synthetic aperture radar (InSAR) is a great method due to its high spatial resolution and its ability to acquire the data remotely, (Ferretti et al., 2001; Hooper, 2008).

For land monitoring of forests, water, soil, agriculture, emergency mapping support for natural disasters including flooding, landslide, earthquakes, Sentinel 1A, 1B satellites were launched. Sentinel 1 satellites carry a C-SAR sensor, which has medium and high-resolution imaging in allweather conditions. The C-SAR can obtain night imagery and detecting small movement on the ground, which makes it useful for land and sea monitoring. As Synthetic Aperture Radar (SAR) can provide frequent observations is particularly useful for flood mapping (Alsdorf et al., 2007; Mertes, 2002; Ward et al., 2014) due to its capability to monitor land in any weather conditions (Franceschetti and Lanari, 1999; Marzano et al., 2011; Schumann et al., 2009) and also in night-time (O'Grady et al., 2011; Waisurasingha et al., 2007; Wilson and Rashid, 2005).

For several decades, SAR has been used to extract information about floods based on the different methodologies such as unsupervised classification, active contour models and thresholding (Martinis et al., 2011; Horritt et al.,2001; Hostache et al.,2012; Pulvirenti et al., 2011; Pierdicca et al., 2013; Pulvirenti et al., 2013; Arnesen et al., 2013;). Considering image thresholding techniques, which sets as flooded all the pixels with a radar backscatter lower than a certain threshold value (Mason et al., 2012a, 2012b; Schumann et al., 2010; Townsend, 2002) shows reliable results.

In this research, for disaster monitoring/modeling, a case study of a flash flood based on the data of Sentinel 1A are presented and discussed. In this regard, SAR sensor satellites and InSAR technology for environmental monitoring and disaster management are presented. Following this Section, in Section 2, the study area is discussed. SAR data preprocessing is presented in Section 3. In Section 4, results of Ramsar flash flood detection is presented. Conclusion of this research is discussed in Section 5.

2. STUDY AREA AND DATA COLLECTION

On 5th October 2018 heavy rain occurred in Ramsar in Mazandaran Province recorded 274.6 mm of rain in 24 hours continuing till 6th October. The flash Flood caused extreme material damage causing six deaths in the province of Mazandaran. According to the Iranian Red Crescent Society (IRCS), in the northern province of Gilan, there was noticeable damage in six counties with two deaths reported in Gilan province.

In total, 39 counties (154 towns and villages) have been affected by the flash flood with more than 660 damaged homes. Ramsar (see Figure 1) is located in the west of Mazandaran province of Iran. The annual average rainfall of the area is around 1200 mm. July and August are the hottest months with a maximum temperature of 29° C where January is the coldest one with a minimum temperature of 3° C.

For the study, two Single Looks Complex (SLC) of Sentinel 1A one belonging to 28th September 2018 (before flood in Ramsar) (see Figure 2a) and other one belonging to 10th October 2018 (four days after the flash flood in Ramsar) (see Figure 2b) for change detection modelling based on the SAR data using SARPROZ in MATLAB programming language are used. Properties of utilized Sentinel 1-A SLC images for the Ramsar flash flood are presented in Table 1.



Figure 1. Study area (Ramsar) in Google Earth Pro.



Figure 2. a) SLC Sentinel 1A image before the flash flood (left image, master image) b) SLC Sentinel 1A image after the flash flood (right image, slave image).

Granule SLC Name	Orbit	Acquisition Mode	Acquisition Date	Pass
S1A_IW_SLC1SDV_20180928T143616_20180928T14 3643_023900_029BE2_92D2	23900	IW	2018-09-28	Ascending
S1A_IW_SLC1SDV_20181010T143617_20181010T14 3644_024075_02A1A1_C0E9	24075	IW	2018-10-10	Ascending

Table 1: Single Look	Complex (SLC) of Sent	inel-1A images propertie	s of the study area
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3. DATA PROCESSING

As shown in Figure 3, for flood modeling, the master and the slave image are required to be co-registered using ground control points. Co-registration guarantees that each ground target is related to the same (range, azimuth) pixel in both the slave and the master images. (Figure 4). Co-registration will "align" all images pixel-by-pixel which allows for the comparison of the two images pixel-by-pixel.



Figure 3. Workflow chart for flooded area detection caused by Ramsar flood.



Figure 4. Co-registered image processed in SARPROZ in MATLAB.

In the pre-processing phase, Reflectivity map and amplitude stability Index are calculated (see Figure 5). For the mask for sparse point selection, local maxima algorithm is used.



4. RESULTS

For flood modeling, the difference between the intensity of the two SAR images is required to be calculated. Amplitude values of the slave and the master images are compared, and their normalized difference with filter window of 5 and threshold of 0.3 is calculated (values below 0.3 would be considered as zero) (see Figure 6). A positive value (red) means the slave image intensity is greater than the master image and a negative value (blue) means the slave image is smaller than the master image.

For flood modeling, the intensity of the slave image should be smaller than the master image. Values of higher than zero are required to be cut out in a resampling process. Figures 6 and 7 show flooded areas in Ramsar based on the change detection modeling using normalized difference values of amplitude belonging to the master image (on 28th September 2018) and the slave image (on 10th October 2018).







Figure 7. Flooded areas in Ramsar based on the change detection in Google Earth Pro processed in SARPROZ in MATLAB.

The difference between the intensity of the two SAR images shows a minimum value of -0.5790 and a maximum value of 0.5624 in the study area of Ramsar from 28th September 2018 to 10th October 2018.

Results of the difference between the intensity of the two SAR images before and after the Ramsar flood on 5th October 2018 show 6321 pixels with a negative value (flooded areas) and 2886 pixels with a positive value. Considering a spatial resolution of 2.3 meters by 14.1 meters for Sentinel 1-A SLC IW images, an area of 204990.03 m2 (0.205 km2) in Ramsar has been affected by the Ramsar flash flood.

5. CONCLUSIONS

In this research, use of the SAR data of Sentinel 1A for the heavy rain on 5^{th} October 2018 in Ramsar is discussed. The normalized difference of amplitude values of the two SAR images belonging to before (the master image) and after (the slave image) the flash flood was used to model flooded areas in Ramsar in Mazandaran Province of Iran.

Geoinformation derived from Earth observation (EO) plays a key role for detecting, analyzing and monitoring landslides to assist hazard and risk analysis. Free and commercial Earth Observation (EO) satellites sensor data are a key factor for large area environmental monitoring. Due to several climate change phenomena (e.g., increase of temperature due to greenhouse gasses, droughts) in recent years and their impact on the environment causing disasters such as flash floods and earthquakes, use of SAR satellite sensors is valuable information sources for monitoring current and to predict future disastrous phenomena.

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