Early flood detection using SAR images and remote sensing techniques—case study Kut city in Iraq

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Abstract. Floods around the world are a major disaster in both rural and urban areas, but in urban areas impacts are most severe as many people lose their homes and property due to floods. In this study we will address the heavy rains that swept through the Wasit province and the heavy rain that descended from the mountains in Iran to Wasit province and led to floods, these floods were studied using radar images from ESA(European Space Agency) Sentinel-1 satellite before and after the floods on 3rd September, 2018 And November 26th of 2018 which is centered at latitudes 32.6844953 and longitudes 47.3953694 with a dual polarization capability (VV+VH), where the radar images are not affected by the poor weather conditions of clouds and rain day or night and have a capacity of 6-day revisit as compared to multi-spectral images (optical images) that depends on sunlight. All the required processing was carried out through the Sentinel Application Platform (SNAP) and remote sensing techniques, the areas affected by the floods were calculated (1256.34 km²). The results obtained were compared with the results of international organizations such as Charter institute for Disaster management indicating a significant correlation with the results.

Keywords
flood map, Sentinel-1, RADAR, pre-processing.

1. Introduction
In recent decades, the number of weather and hydrological disasters has gradually increased and has affected hundreds of millions of people every year. Floods represent the most common disaster that may occur at different levels, having an effect on the environment, including not only economic damage and ecological imbalances, but also numerous losses of human lives [1].

Iraq has recorded, during the current winter; the highest rainfall compared to the last ten years which resulted in floods and torrents that led to the sinking of a number of villages in the governorates. Especially, Maysan and Wasit had the largest share of the damage and caused the flooding of many villages and the collapse of dozens of homes which forced the families to displace [2].

In order to monitor and estimate flood damages in near-real time, numerous techniques can be used, from a simply digitizing on maps, to using detailed surveys or remote sensing techniques. When using radar satellite images which can be taken day or night also with clouds, the sensor’s ability to penetrate cloud cover and detect water makes an airborne or satellite SAR (Synthetic Aperture Radar) system a powerful tool for flood monitoring, as floods often associate with heavy rain, where it is almost impossible for optical remote sensing instruments to image the water.

Sentinel-1 mission, which is operated by the European Space Agency (ESA) in the frame of the European Union’s Copernicus Program, consists of two systematically acquiring satellite sensors
(1A/1B) with a repeat cycle of six days, which ensures a consistent long-term data coverage and data archive for systematic flood mapping and monitoring purposes [3].

In this paper images acquired from Sentinel-1 Ground Range Detected (GRD) products have been used, they consist of focused SAR data, multi-looked and projected to ground range using an earth ellipsoid model such as WGS84, then the images were processed so as to reveal and delineate the flooded areas [4].

2. Study Area
The study area is represented by Al-kut in Wasit province in south east of IRAQ country as shown in Figure (1), we use two GRD (ground range detection) sentinel-1 SAR images before (03-09-2018) and after (26-11-2018) floods as shown in Figure (2a&2b) centered at (Lat.=32.6844953), Long.=47.3953694) with a dual polarization capability (VV+VH), which can provide more ground surface information and two MODIS images for validation as shown in Figure (2c&2d). Wasit province with the elevation of the area varies from (9-940) m, above sea level and the general slope of land decreases from Northeast to Southwest and from eastern borders towards the center as shown in Figure (3a&3b)[5].

![Figure 1. Location of study area in Wasit province.](image_url)
3. Methodology and data processing

One of the major advantages of using SAR images, apart from its all-weather capability, lies in its ability to sharply distinguish water from other classes, given by the high contrast that exists. Water bodies act as a mirror reflecting surface, their response is low (low backscatter coefficient in SAR images) and thus, look like a dark area. The earth, for its part, gives a much greater amount of radar energy due to the surface roughness and this generates the high contrast between surfaces: soil and water [4].

Figure 2: Sentinel-1 and MODIS data before and after flood

Figure 3. Digital elevation model and slope of Wasit province [5].
Sentinel-1 is designed to work with four different possible operative modes: (i) stripmap, (ii) wave, (iii) interferometric wide swath and (iv) extra wide swath. It supports dual polarization acquisition (HH + HV or VV + VH) for all the modes, with the exception of the wave mode as shown in Table (1).

| Mode                  | Swath (km) | Resolution (m x m) | Polarization |
|-----------------------|------------|--------------------|--------------|
| Stripmap              | 80         | 5 x 5              | Dual         |
| Wave                  | 20         | 5 x 5              | Dual         |
| Interferometric WS    | 250        | 5 x 20             | Dual         |
| Extra WS              | 400        | 20 x 40            | Single       |

The sentinel-1 images were processed and analyzed using SNAP software, Sentinel-1 Toolbox (S1TBX) module developed by the European Space Agency (ESA) which contains a set of tools for readers, writers, analysis and processing for SAR data.

We apply the following steps for both pre and post flood SAR images as shown in figure (4):

1- Data preparation: this is done by downloading freely from Sentinels Scientific Data Hub from ESA as shown in Figure (1a &1b).
2- Subset and multilooking: we do not need to process the whole image, this is done by adding a region of interest (ROI), multilooking to minimize the size of the images.

3- Calibration: the objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter, essentially in flood extraction as shown in Figures (5a & 5b).

![Calibrated images](image1)

**Figure 5.** Calibrated images

4- Geometric correction: The original SAR image is inverted in the SNAP, it is displayed according to the order of data acquisition, which is not according to a cartographic representation, to re-project the images from geometry of the sensor to the geographic projection, terrain correction was applied. For this case study, the WGS84 geographic projection was used. Terrain correction will geocode (Geocoding converts an image from Slant Range or Ground Range Geometry into a Map Coordinate System) the image by correcting SAR geometric distortions using a digital elevation model (DEM) and producing a map projected product [6]. The Digital Elevation Model used to correct the terrain was Shuttle Radar Topography Mission (SRTM) with spatial resolution 3 arc-second (90m), the corrected image shown in Figures (6a & 6b).

![Corrected images](image2)

**Figure 6.** Corrected images by geometric correction.

5- Create a stack: the resulted image for the above will be stacked.

6- Determination of areas covered by water: To separate water from non-water a threshold has been selected. For this purpose, the histogram of the filtered backscatter coefficient was
analyzed. Low values of the backscatter correspond to the water and high values correspond to the non-water class as shown in Figures (7a & 7b).

![Figure 7](image_url)

**Figure 7.** Histogram of the image taken on a) 3-9-2018 and b) 26-11-1028

\[
\text{If } \text{Sigma0} \_\text{VV} < -24.26 \text{ then 1 else 0} \quad (1)
\]

After establishing the threshold, a binary image was created. Details of the image obtained by overlapping the water body, before and after the floods, can be seen in Figure (8), where the flooded area is colored with red and the non-flooded area with other color also the river distinguished from flooded area with black color as shown in Figure (8).

![Figure 8](image_url)

**Figure 8.** Overlaying the water body in the two-time periods-details.

7. Calculate flooded area: to calculate the surface covered by water after flood, the images have been processed in ArcMap software by reclassifying the image then extracting the flooded area then converting the raster image to shape file and calculating the area (1256.34 Km²) as shown in Figure (9).
4. Rain in Iraq

Increasingly available and a virtually uninterrupted supply of satellite-estimated rainfall data is gradually becoming a cost-effective source of input for flood prediction under a variety of circumstances.

To estimate the rainfall in (23-25/11/2018) we use the TRMM (Tropical Rainfall Measuring Mission) precipitation satellite data which causes flood in Wasit province, east of Iraq. Heavy rainfall in east of Wasit ranged from (59.24-29.82)mm/h as shown in figure (10a) also the west of Iran near Wasit province the rain ranged (97.0-48.55)mm/h for the same period as shown in figure (10b).

Figure 10. Rainfall in Iraq and Iran at (23-25/11/2018)

These floods have been transformed to revive Hur Al-shuweja and the topographical factors (low digital elevation model (DEM) as shown in figure (3a) that have helped it. The multispectral images from MODIS satellite were used with 250 m resolution to display how the Hur Al-shuweja was revived as shown in Figures (2c & 2d).
5. Charter image

The application of the processing chains within rapid mapping activities significantly has helped to improve the delivery time of the crisis information to the users during flood-related activations within the frame of the International Charter ‘Space and Major Disasters’ [7,8].

We are a member in Charter, so we make an announcement that there is a disaster in Wasit, after a while Charter will send images of this disaster as shown in figure 11.

![Charter Image](image1)

**Figure 11. Charter Image.**

Figure 12 shows the big correlation between the charter image as compared with the resulted image from application of the above method.

![Result of the method](image2)

**Figure 12. Result of the method.**

6. Conclusion

Sentinel-1 provides images of the Earth's surface regardless of weather conditions, day or night and has a capacity of 6-day revisit, providing information in various fields, from monitoring the effects of floods up to monitoring ice from polluted waters. Sentinel-1 is a two-SAR satellite constellation designed to guarantee global coverage with a revisit time of 6 days, where the images were processed and analyzed using SNAP software, Sentinel-1 Toolbox (S1TBX) module developed by ESA.

To analyze the flood damage Sentinel-1 SAR data was used, collected in the Ground Range Detected (GRD) mode with dual polarization capability (VV+VH), which can provide more ground surface information, the satellite images were captured consecutively by satellite Sentinel-1, before and after the flood took place, the acquisition dates are 03 September 2018 and 26 November 2018.

After a series of pre and post flood processing, the resultant image is opened in Arcmap to calculate the flooded area (1256.34 km²), which is a good way to estimate the area of damage caused by the flood quickly and precisely, the resulting image also shows a great match with the Charter image.

One of the major advantages of using SAR images to penetrate clouds is to sharply distinguish water from other classes, given by the high contrast that exists. Water bodies act as a mirror reflecting surface, their response is low (low backscatter coefficient in SAR images) and thus, look like a dark area. So, SAR images can be used for early detection of flood remotely and precisely.
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