Capabilities of SAR and optical data for rapid mapping of flooding events

Lisa Fischell[1], Daria Lüdtke[1,2] and Moses Duguru[1]

1 United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)
Platz der Vereinten Nationen 1 - 53113 Bonn, Germany
Tel.: + 0049 1747 885500
lisafischell@protonmail.com; moses-john.duguru@un.org

2 Direçao-Geral do Território
Rua Artilharia 1, 107 - 1099-052 Lisbon, Portugal
Tel.: +351 21 381 96 00
luedtke.daria@gmail.com

Abstract

A growing amount of population and economic assets globally are located in areas at risk of flooding. With an increasing frequency of flooding events, better and easier-to-produce mapping products to aid response and relief decisions are needed. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) recommends the use of optical imagery and radar at different spatial and temporal resolutions for flood mapping. Both data sources are established in practical application and scientific literature for flood extraction and both have product-specific advantages and drawbacks. Only very few papers [1] have so far compared the differences between the two methods directly. We therefore compare mapping products from Sentinel 1A and 2A data of the same flooding incident regarding their limitations, advantages, processing time, and a variety of complexity indicators. Our study found a symmetrical difference of 75.53 km^2. In comparison to the optical imagery analysis resulted in a slightly larger overall area and a much higher number of polygons.

Keywords: rapid, flood, mapping, radar, optical

1. Introduction to topic

The increasing frequency of flooding events [2] in combination with the constantly increasing number of economic assets and dense population located in flood prone sites have amplified the need to better use of Earth Observation (EO) based information for disaster management. EO based mapping products can provide information on the flood extent and facilitates extensive spatial analysis of the flood event.

A fast response to a flooding incident is vital to minimize the impact and potential damage of flooding. Decision makers and disaster management are often reliant on mapping products to make relief decisions. EO data can provide the relevant information with the spatial and temporal coverage to drive the decision-making in a limited time frame [3]. It is especially suited since it does not require labour- and time-intensive in-situ information. The European Space Agency (ESA) makes EO data from its Sentinel mission available free-of-charge to disaster managers.

In literature, the process of creating map products in a small time frame is often referred to as "rapid mapping". Since the definition of the term "rapid" is often vague this paper adapts the definition of the Copernicus EMS (Emergency Management Services), which calls are mapping procedure taking less than 12 hours from the data acquisition to the final mapping product "rapid".

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Only very few papers [1] have so far compared the differences between the two methods directly. Literature research showed that no papers currently exist which directly compare results of both methods using a single case study. This paper therefore aims to compare mapping products from Sentinel 1A & 2A data of the same flooding incident.

2. Radar and optical imagery based flood mapping

Optical remotely sensed imagery has been used over the last four decades for traditional as well as disaster-related spatial analysis. It is a composition of optical and infrared wavebands across the electromagnetic spectrum collected by a weather- and daylight dependent sensor. A handful of systems such as the Landsat Program and ESA's Sentinel satellite series have established themselves as common data sources due to their spatial and temporal resolutions as well as due to their data accessibility [4, 5].

Besides allowing users to conduct dense time-series analysis [6, 7], capture dynamic and static change processes [8], and to overcome measuring gaps due to weather conditions [9, 10], optical imagery has been successfully used to determine and extract flood areas [11, 12, 13]. Optical imagery has high potential for rapid disaster mapping since it is available from a multitude of sensors and relatively easy to interpret due to its band composite in the visible wavelength range. Nonetheless, using optical data has a series of drawbacks when used for flood mapping [5, 6]. These include:

- Subjected to daylight and weather conditions.
- Neither penetrates vegetation nor soil, only detects surface tops.
- Not responsive to dielectric properties.
- Affected by topographical effects.
- Affected by sun-glint [5, 6].

Synthetic aperture radar (SAR) presents an alternative to flood mapping with optical imagery. It is an active sensor that can acquire usable data even in cloudy scenes and during night time. It is typically a single band product (single wavelengths per sensor) that can provide information about vegetation and soil [5, 6]. Unlike optical imagery, SAR instruments can be used for flood mapping irrespective of daytime and cloud cover of the scene. Moreover, its sensitivity to land cover structure and dielectric properties allow to determine the extent of open water bodies [3].

Recently, the use of high-resolution 3D flood information from radar imagery for flood hazard management [3] has been studied. Other relevant applications include the assessment of flooding over large areas and the effectiveness of relief measures [14], and mapping flood boundary delineations [15]. SAR data also has a variety of limitations to be considered in the process of data selection:

- Often limited to binary segmentation into flooded and non-flooded.
- Unable to record flooding in urban areas (corner reflection principle).
- Noise and increased measurement uncertainty through speckle.
- Polarization modes
  (HH should be the preferred mode due to the horizontal orientation of a water body).
- Higher difficulty to interpret information.
- Require relatively high energy provision for observation on the satellite [5,6].

3. Methodology

3.1. Study area

In April 2017, the region of Queensland, Australia, was inundated by flood waters following the rising river level over several days until its peak that is captured by the processed satellite imagery from April 8th. For this study, a site at the Fitzroy River around the city of Rockhampton in Queensland of ~1000km^2 was chosen. This site is particularly suitable since it includes a variety of Land Cover Land Use (LULC) types which will be represented in the mapping result. Therefore, the final assessment is more applicable and comprehensive for other potential areas of interest.

3.2. Data

Both images were obtained from the Copernicus Open Access Hub of ESA's Sentinel missions. The sensing period after the flooding event to compare radar and optical imagery is under ideal, cloud-free conditions in order to obtain a clear view on the flooded area with both data types.

Table 1. Data information

Satellite	Bands used	Bands available	Spatial resolution	Revisit time	Sensing period
Sentinel1A SAR	C-Band	C-Band	20m	6 days	2017-04-07
Sentinel2A MSI	B3, B8	12 Bands	10m	5 days	2017-04-08

3.3. Workflow

The workflow for both, imagery and radar based flood mapping, are based on Recommended Practices (RC) from (UN-SPIDER) and are displayed in Figure 1.

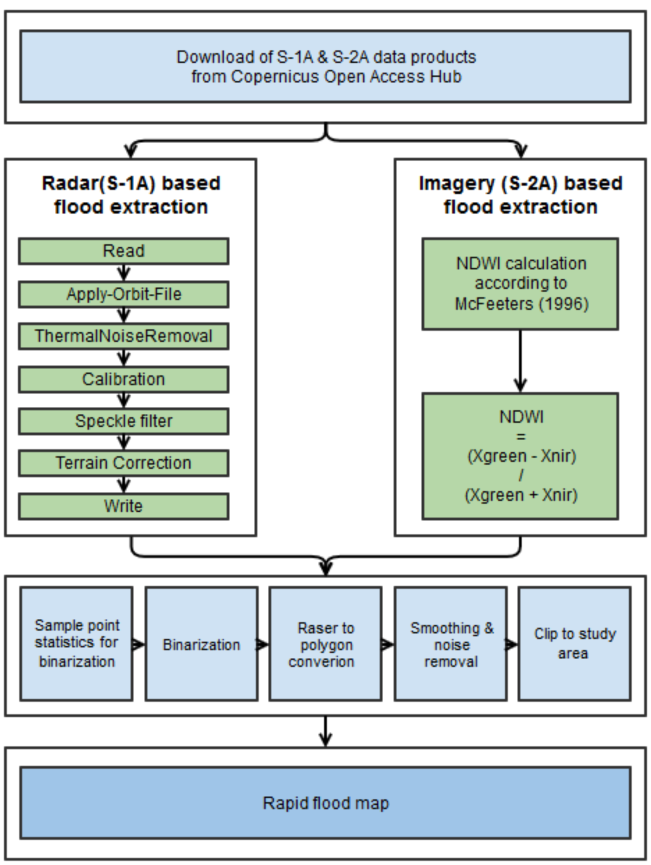

Figure 1. Workflow chart

4. Results

Imagery based flood mapping resulted in a slightly larger area of 206.25km^2. This is most likely linked to the limited capability of SAR data to identify water features in urban areas. The number of polygons presented the most considerable difference between the two methods as optical imagery produced ~22 times the number of polygons. The symmetrical difference calculation found an overall difference of 71.79km^2.

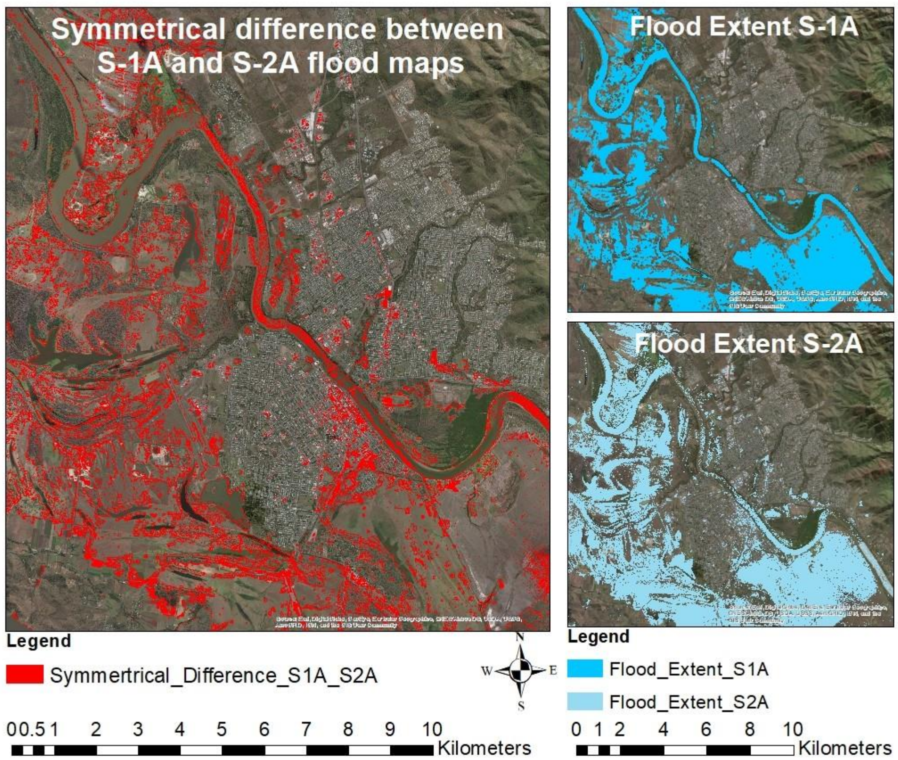

Figure 2. Floods extents of radar (top right) and optical imagery (bottom right) and their symmetrical difference (left)

Table 2. Results and indicators

	Results	
	Imagery:	Radar:
Area extent	206.25km^2	182.06km^2
Polygon number	28249	1238
Symmetrical difference	71.79 km^2	
Processing time	47.38 in ArcGIS	11.41 min in SNAP 30.2 in ArcGIS

5. Conclusion

Based on the results of our study we found both methods have similar processing times making both suitable for rapid flood mapping. Optical based flood mapping was found to be especially suitable for urban flood detection although it can be heavily affected by sun-glint in cloud free imagery. The radar based flood extent produced a slightly smaller flood area with a much smaller number of polygons. This was found to be advantageous for fast processing and the handling of the dataset. Whilst this method did not perform well for mapping urban floods it is independent of weather conditions and data can be obtained at day and night time.

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