MAKASAR FLOOD AREA DETECTION USING SENTINEL-1 GRD SATELLITE IMAGE WITH USE OF CHANGE INDEX AND ESA-SNAP

Dadan Ramdani (1)(2)

[1] Badan Informasi Geospasial (Geospatial information Agency) Jl Raya Jakarta Bogor Km 46 Cibinong West Java Indonesia
[2] Universitas Pakuan (Pakuan University) Jl. Pakuan PO BOX 452 Bogor West Java Indonesia.
Email: dadan.ramdani@big.go.id

KEY WORDS: Flood, ESA-SNAP, Sentinel-1, Change-Index.

ABSTRACT: Flood often located in area that has cloud and it is difficult to detect with optical satellite image. Radar in other hand can penetrate cloud and with this property the image came from radar is suitable for detecting flood area. Sentinel with S band has 2 polarization namely VV and VH. To detect flood area VV polarization can be used. With the equation of change index The area flood can be identified from 2 times of pre-inundation and co-inundation. The flood of makasar can be sensed with sentinel-1 GRD satellite image. The image of preinundation is taken at 1st and 15th January 2019 and coinundation is taken at 25th and 27th January 2019. The images are first processed with basic radar processing of ESA-SNAP software namely apply orbit file with sentinel precise orbit and polynomial degree of 3, calibration to produce sigma0, speckle filtering with lee 3x3 filter , and coregistration to stack the images. After that the images then they are processed with change index formula and are filtered with threshold of 0.8 and above to detect the flood area. The resulting images are the flood area southeast of Makasar city at 25th and 27th January 2019.

1. INTRODUCTION

Flooding is an overflow from a large puddle in an area that is usually not submerged. Floods are the highest form of direct risk from natural disasters and they can be a serious crisis factor, which can be associated with high material property damage, ecological and cultural damage and also loss of human life in flood-affected areas. Urban flooding is a real and growing development change, against the background of demographic growth, urbanization trends and climate change. The cause of the flood is shifting and the impact is growing. Flooding can be caused by more factors, it can be heavy rains, extraordinary tides, tsunamis and high waves.

Flooding can be aggravate by the amount of increase in ground level or other natural disasters such as forest fires, which reduce the supply of vegetation that can absorb rain. Cyclic flooding occurs in many rivers, shaping the surrounding area known as the flood land. During the rainy season, some water remains in ponds or soil, some is absorbed by vegetation, some evaporates, and the rest is sent as surface runoff. Flooding happen when water cannot be absorbed. Water then runs through the land in amounts that cannot be accommodated in river channels or cannot fit in natural ponds, lakes, and man-made reservoirs. About 30 percent of all rainfall becomes runoff(Harbor, 1994).

One of the cornerstones of flood risk management is the information of people at risk and of the authorities and agencies responsible for flood management. Only if the people and decision makers are aware of the flood risk, and only if they are able to evaluate the risk, they can be expected to adequately respond to this thread. The basis of effective and efficient risk reduction measures are risk analyses which take into account the different aspects of the flood risk,

Floods are nothing new. Flooding is a classic problem. Most people are used to experiencing flooding, so reading the flood news is actually not surprising anymore. Because classic and ordinary problems occur, it does not mean there is no need to be solved. The government has spent large funds to deal with flooding.

Rapid runoff water causes soil erosion and sediment deposition together at other places (such as downstream or under shore) (Fabricius, 2005). Reasons for spawning fish and other wildlife habitats can be polluted or destroyed. Some prolonged high flooding can delay traffic in areas that do not have elevated highways. Flooding can disrupt drainage and economic land use, such as disturbing agriculture. Structural damage can occur on bridge abutments, banking lines, drainage canals, and other structures in floods. Waterway navigation and hydroelectric power are often disrupted. Financial losses due to flooding are usually millions of dollars every year, with the worst flooding in US history recently having billions of dollars in costs (Mileti, 1999).

According to (Jha, Bloch, & Lamond, 2012) flooding can be categorized into several types, namely:

Urban flooding can naturally be caused by inundated river water, overflowing water from the sea (rob), or excessive rainwater runoff and cannot seep into the ground. Urban flooding can also be influenced by human behavior in managing and building their environment. For example, full drainage and waste water disposal by rubbish, expanding watertight surfaces due to layers of concrete and asphalt, and poor management of urban drainage.

Flooding due to surface runoff / pluvial and overland flood. Floods of this nature are usually caused by heavy rain / rainstorms, icebergs that collapse and melt, the overflow of ice lakes, or earthquakes that cause landslides. Whereas human activities that can trigger this type of flood include changes in land use, urbanization and the increase in the extent of waterproof layers due to development.

Floods from the sea (tsunamis, tidal waves, rob) / coastal flooding. Naturally, the causes of this flood include earthquakes, volcanic eruptions in the sea, land subsidence, and coastal erosion. The contribution of humans in causing this type of flood includes the uncontrolled development of coastal areas and the destruction of the environment supporting coastal ecosystems (for example the destruction of mangroves along the coast).

Flooding due to groundwater/groundwater flooding. Naturally it can occur due to a combination of high ground water level elevation and heavy rainfall. This type of flooding can occur in low-lying areas where construction is not controlled or occur in areas with natural aquifers that are disturbed / damaged.

Flash flood. This kind of flood can naturally be caused by overflowing rivers, excessive surface runoff and not being able to seep into the ground, overflowing from the sea, convective storms, or the overflow of ice lakes. In addition, flash floods can also be caused by the failure / collapse of water storage infrastructure, or inadequate drainage infrastructure.

Semi-permanent flooding. This type of flood is naturally caused by an increase in sea level elevation and land subsidence. Poor management of groundwater sources, inadequate drainage systems, and improper urban development also contribute to this type of flood.

High rainfall intensity hit South Sulawesi province. It is caused flood and landslide Regional Disaster Management Agency (BPBD) South Sulawesi said it was still trying to evacuate residents affected by floods and landslides in 13 cities and districts, which so far caused at least 59 people to die and 25 others were missing (BBC_Indonesia, 2019). Some axle road are flooded and it can only be passed by trucks and double cabin cars. In addition, there are some isolated sub-districts that require logistics. To distribute this logistics rapid flood mapping is needed. Until Friday (1/25) at 12.00 West Indonesia Time or three days after the floods struck, South Sulawesi BPBD recorded 106 villages affected by disasters in 61 sub-districts spread across 13 regencies/cities. The 13 regencies/cities include Jeneponto, Maros, Gowa, Makassar City, Soppeng, Wajo, Barru, Pangkep, Sidrap, Bantaeng, Takalar, Selayar and Sinjai (Figure 1).

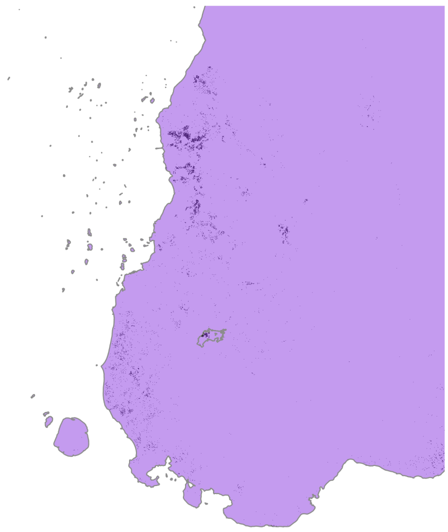

Figure 1: Study area Location

Satellite optical imagery often cannot be used during floods because of the many clouds that cover. while satellite radar imagery can be used during floods because it can penetrate clouds that cover. SAR earth observation data can provide high quality flood maps and information to better assess the flood risk accordingly planning as well as to support civil protection authorities during emergency phase (Psomiadis, 2016).

The scope of this paper is to create flood map of South Sulawesi Province from a series of SAR scenes which can represent boundary floodplain. The study uses time series SAR images of Sentinel-1 ESA's Copernicus satellite system covering the period of before inundation and during inundation. The images of January 1^{st}, 2019 can be seen in Figure 2, the images of January 15^{th} , 2019 can be seen in Figure 3, the images of January 25^{th} , 2019 can be seen in Figure 4 and, the images of January 27^{h} , 2019 can be seen in Figure 5. The methodology tries to identify the flood that occurs in as quickly as posible. VV polarization SAR data provides the opportunity to have a quick detection of the flood area.

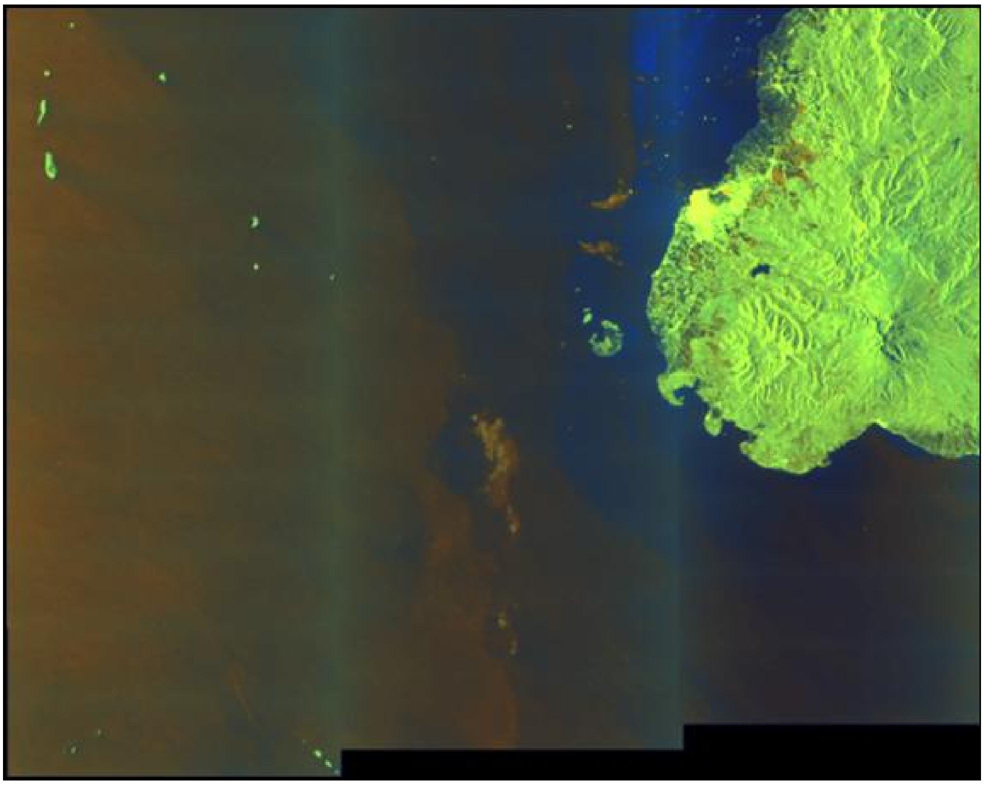

Figure 2: Sentinel 1 S1A_IW_GRDH taken January 1st 2019

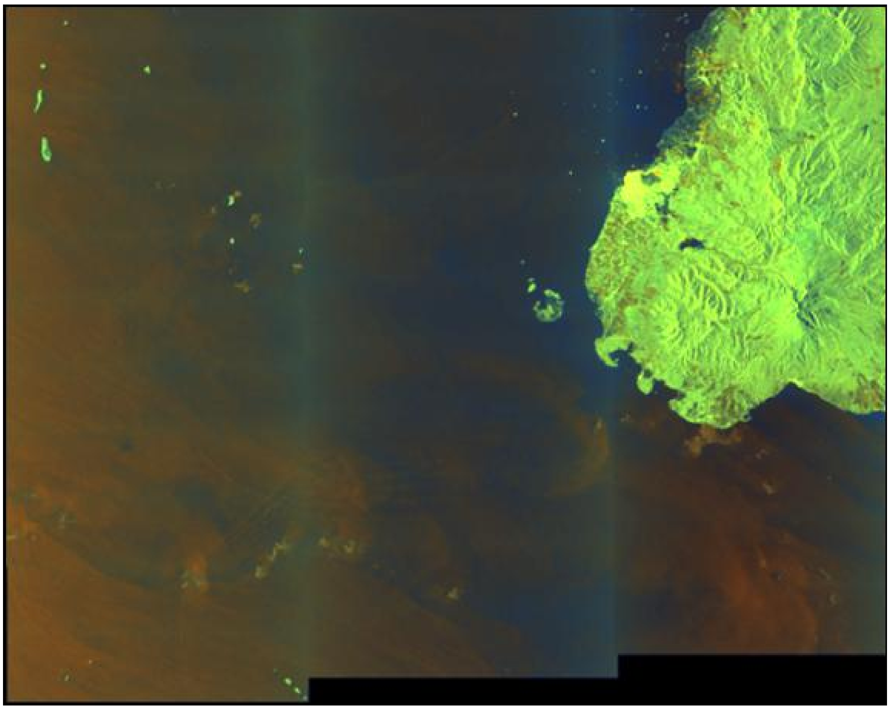

Figure 3 Sentinel 1 S1A_IW_GRDH taken January 15th 2019

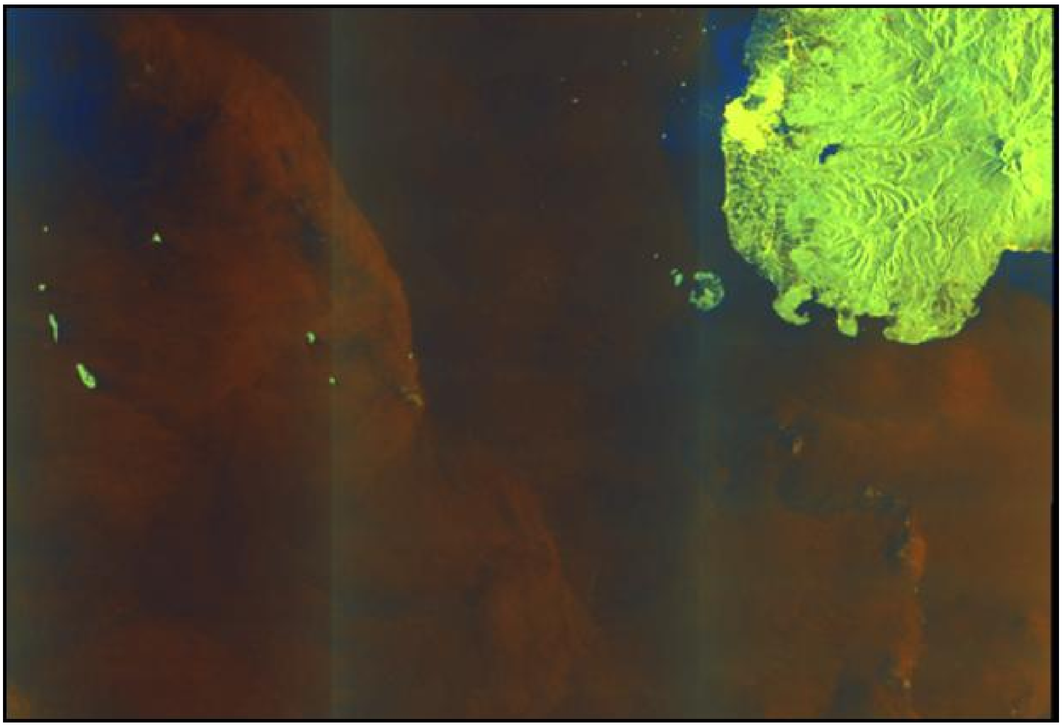

Figure 4 Sentinel 1 S1A_IW_GRDH taken January 25th 2019

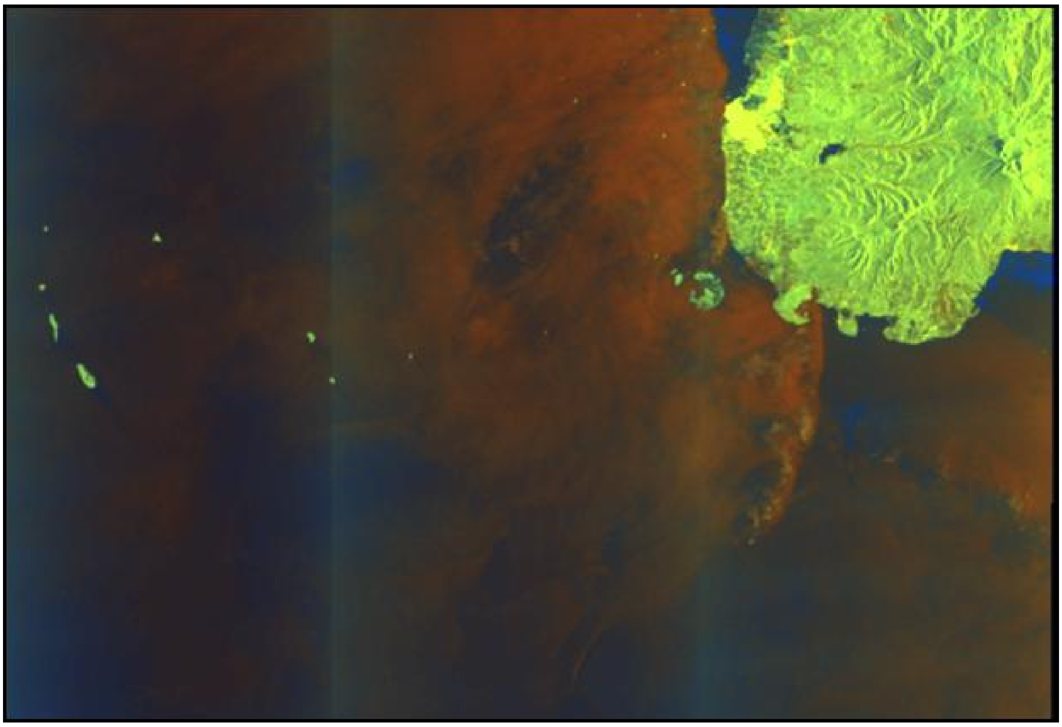

Figure 5 Sentinel 1 S1A_IW_GRDH taken January 27th 2019

2. METODOLOGY

Assessment of flooded areas can be done using radar data, such as the Sentinel-1 SAR imagery provided by the European Space Agency (ESA). Sentinel-1 Level-1 Ground Range Detected (GRD) C-band (SAR-C) data is used for this study. This Sentinel-1 level-1 GRD data is collected in Interferometric Wide (IW) mode, allowing for an image acquisition over a 250km swath with resolution of 10m (5x20m) (Torres et al., 2012).

The software used for processing is SNAP SAR from ESA Copernicus. SAR Image Processing is divided into 2 parts, namely the basic processing of the image and the application of the index change algorithm to detect flood areas. Initial processing consists of several commands in the software namely the application of orbit files, calibration, the application of Lee filters with a size of 3x3 to eliminate speckles, the application of coregistration to stack multiple maps that have different time series, and the application of geometric field correction with range-doppler field correction (Twele, Cao, Plank, & Martinis, 2016).

The SAR orbit product are generally inaccurate and can be refined with the precise orbit files. Precise orbits are created a few weeks after getting and they are automatically download from Array's servers (Luis Veci, 2015). If it is not found, it can be looked in the web site at https://qc.sentinel1.eo.esa.int/ and placed the downloaded file into the auxdata folder.

SAR data level 1 images, is not corrected with radiometric corrections and it is significant radiometric noise remains. Therefore SAR images must be corrected by radiometric correction so that the pixel value represents the radar back-scatter of the reflecting surface. Comparison of SAR images obtained by different sensors or from the same sensor but at different times, in different modes, or processed by different processors requires also radiometric correction (LUIS Veci, 2015).

Speckle is create by random constructive and destructive interference producing noise throughout the image. To reduce the amount of speckle a filters can be applied to the data at the cost of blurred features or reduced resolution. The filter to reduce speckle is a Lee Filter. The use of Lee filter is based on (Amitrano, Di Martino, Iodice, Riccio, & Ruello, 2018)which has tested the Lee algorithm with satisfactory results. With this filter the resolution of the image is reduced to 30 m. The batch for basic processing can be seen in Figure 6

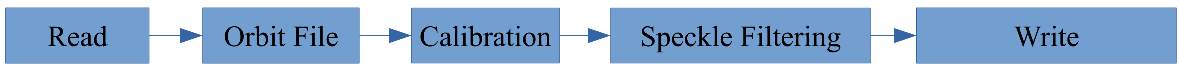

Figure 6: Batch basic Processing of the SNAP ESA Sentinel-1 Toolbox

The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar back-scatter of the scene. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data.

After the initial processing is finished, the index change algorithm is applied using VV polarization is formulated as follows:

$$CI = \frac{(I_2 - I_1)}{(I_2 + I_1)}, \quad CI \in [-1, 1] \qquad (1)$$

where I_1 and I_2 are the pre-event and post-event images, respectively.
To produce a flood map, the results of the change index algorithm are filtered using a threshold of 0.8 and above.

3. Result and Discussion

The calculation of the basic processing of the SAR-C Sentinel-1 Level-1 GRD SAR data from the SNAP SAR from ESA is performed using the SNAP SAR Sentinel-1 software from ESA

Copernicus SAR Image Processing. The results of the calculation can be seen at Figure 7, Figure 8, Figure 9, and Figure 10 are respectively for images of January 1^{st}, 25^{th} , 15^{th} , and 27^{th} .

Figure 7: the results of the calculation with Basic Processingof January 1st 2019 image

Figure 8: the results of the calculation with Basic Processingof January 25th 2019 image

Figure 9: the results of the calculation with Basic Processingof January 15th 2019 image

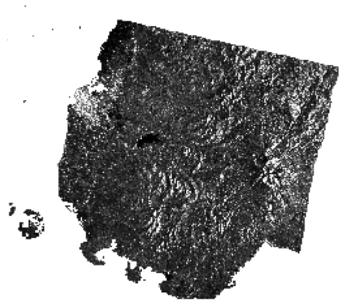

Figure 10: the results of the calculation with Basic Processingof January 27th 2019 image

The use of change index of equation (1) is done on pairs of images with the same satellite and direction. the paired images are January 1 2019 with January 25 2019 and January 15 2019 and January 27 2019. The result can be seen in Figure 11 and Figure 12.

Figure 11: The result of Change Index formula of January 1st and January 25th 2019 Images

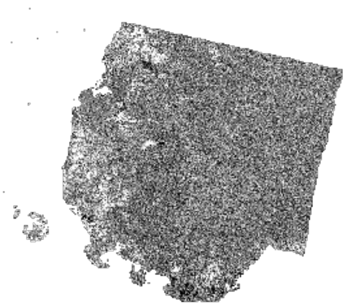

Figure 12: The result of Change Index formula of January 15th and January 27th 2019 Images

To separate the submerged area from the surroundings, a high pass filter with a limit of 0.8 is used. The result can be seen in

Figure 13: flooded areas from January 1st and January 25th 2019 Images

Figure 14: flooded areas from January 15th^{t} and January 27th 2019 Images

4. **Summary**

The image of preinundation is taken at 1st and 15th January 2019 and coinundation is taken at 25th and 27th January 2019. The images are first processed with basic radar processing of ESA-SNAP software namely apply orbit file with sentinel precise orbit and polynomial degree of 3, calibration to produce sigma0, speckle filtering with lee 3x3 filter , and coregistration to stack the images. After that the images then they are processed with change index formula and are filtered with threshold of 0.8 and above to detect the flood area. The resulting images are the flood area southeast of Makasar city at 25th and 27th January 2019.

5. **Reference**

Amitrano, D., Di Martino, G., Iodice, A., Riccio, D., & Ruello, G. (2018). Unsupervised rapid flood mapping using Sentinel-1 GRD SAR images. *IEEE Transactions on Geoscience and Remote Sensing*, *56*(6), 3290–3299.

BBC_Indonesia. (2019). Banjir Sulawesi Selatan terparah dalam satu dekade terakhir, 59 orang meninggal. Retrieved August 30, 2019, from https://www.bbc.com/indonesia/indonesia-46970541

Fabricius, K. E. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine Pollution Bulletin*, *50*(2), 125–146.

Harbor, J. M. (1994). A Practical Method for Estimating the Impact of Land-Use Change on Surface Runoff, Groundwater Recharge and Wetland Hydrology. *Journal of the American Planning Association*, *60*(1), 95–108. https://doi.org/10.1080/01944369408975555

Jha, A. K., Bloch, R., & Lamond, J. (2012). *Cities and flooding: a guide to integrated urban flood risk management for the 21st century*. The World Bank.

Mileti, D. (1999). *Disasters by design: A reassessment of natural hazards in the United States*. Joseph Henry Press.

Psomiadis, E. (2016). Flash flood area mapping utilising SENTINEL-1 radar data. *Earth Resources and Environmental Remote Sensing/GIS Applications VII*, *10005*, 100051G.

Torres, R., Snoeij, P., Geudtner, D., Bibby, D., Davidson, M., Attema, E., … others. (2012). GMES Sentinel-1 mission. *Remote Sensing of Environment*, *120*, 9–24.

Twele, A., Cao, W., Plank, S., & Martinis, S. (2016). Sentinel-1-based flood mapping: a fully automated processing chain. *International Journal of Remote Sensing*, *37*(13), 2990–3004. https://doi.org/10.1080/01431161.2016.1192304

Veci, Luis. (2015). *TOPS Interferometry Tutorial*.

Veci, LUIS. (2015). Sentinel-1 Toolbox: SAR Basics Tutorial. *ARRAY Systems Computing, Inc. and European Space Agency: Paris, France*.