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Mapping of flood areas using Sentinel-1 synthetic aperture radar (SAR) images with Google Earth Engine cloud platform – A case study of Chamoli district, Uttarakhand- India

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ABSTRACT

Flood inundation maps, which can be created using satellite images, offer useful information for flood risk preparation, control, communication, response, and mitigation during a disaster. This study discusses the Chamoli disaster, which occurred on February 7, 2021 in Uttarakhand state, India using Sentinel-1 data acquired pre, during, and post the flood to understand its impact on the region. This study also describes an automated flood inundation mapping method based on Sentinel-1 synthetic aperture radar (SAR) data using Google Earth Engine (GEE) platform. In this study, the backscattered product of SAR images after pre-processing from the GEE platform was used. For validation approaches both direct (field data) and indirect (secondary data) is used. Secondary data include optical Remote sensing images from the Sentinel-2 satellite, which were used in the study. For Sentinel-2 data processing ArcGIS has been used. The field data were obtained at different flood-affected areas on different time scales. To summarize, study results from Sentinel-1 SAR data using GEE can be a valuable method for monitoring flood inundation areas during a disaster, as well as enhancing existing efforts to save lives and livelihoods of populations, as well as safeguard facilities and industries.

1. Introduction

Floods are most often caused by hurricanes and torrential rain, or by flooding streams, rivers, or oceans; this form of natural disaster is one of the most common, affecting almost every demographic and region on Earth. Floods, since they are such diverse disasters, provide emergency planners with a vast range of perspectives. During a crisis, the immediate concern is for human life and the resources required to provide emergency service. The Floods Directive of the European Union (EU) describes a flood as the temporary covering of ground by water that is not usually flooded by water. During the monsoon season, heavy river drainage triggers extensive flooding. River flooding is a common natural occurrence that happens when a river catchment absorbs more water than it can handle due to runoff, melting snow, or ice . Floods will damage bridges and homes, destroy power grids, and even cut off parts of towns or rural communities from the first responders that need to access them Long-term worries about severe floods depend on structural damage; food is often the most serious problem since crops are lost and livestock drowns in major flood disasters.

Every disaster occurrence (floods, earthquakes, and cyclones) causes changes in the geometric, dielectric, or both properties of sensing materials, which can be easily tracked using SAR backscatter. The SAR backscatter from flood-affected areas differs from that of non-flooded areas, allowing for precise flood mapping. Several studies have been conducted to explore the effective use of SAR data in flood mapping.

Users with a cloud-based framework, such as Google Earth Engine (GEE), can retrieve and process large amounts of Sentinel-1 data directly in the cloud, rather than downloading and processing it locally. Data processing is done in parallel on Google's computing infrastructure, which greatly increases processing speed and opens up new possibilities for end users. In recent years, the GEE cloud technology has seen widespread use in a variety of remote sensing applications. Several studies make use of time-series EO data from the GEE catalog for a variety of operational purposes, including urban development mapping, global forest transition, global forest watch, and global surface water explorer.

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The GEE platform has several benefits, including the inclusion of multitemporal EO datasets, a parallel processing architecture, and the potential to handle large datasets efficiently. All of the evidence mentioned above indicate that the cloud-based rapid flood mapping solution must be publicly accessible, effective, reliable, and user-friendly to stakeholders and decision-makers.

In this study, flood-affected areas were mapped using Sentinel-1 SAR images and a processing chain in the GEE cloud platform. The GEE is efficient in data handling, simple to implement with few user inputs, has a short processing time, is scalable to larger spatial extent flood mapping, and is universally applicable. GEE is evaluated in this study on the major flood event of Chamoli district, Uttarakhand state, India, on February 7, 2021. Finally, we use Sentinel-1 SAR images to generate operational high resolution flood maps.

2. Study area and datasets

2.1 Study area

The study area selected for this research work is a Chamoli district, which is the second largest district of Uttarakhand state of India and the location map of the study area is shown in the Fig. 1. Gopeshwar is the district's administrative headquarters. Chamoli district geographically located between 79º 15' 00" E to 80º 00' 00" E Longitude and 29º 15' 00" N and 31º 00' 00 N Latitude and falls in Survey of India toposheet numbers 53 O, M and N. The district has a geographical area of 7,604 square kilometers. The district's elevation ranges from 800-8000 m. The climate of the district is influenced by altitude. From November to March is the winter season. The district has a total population of 391,605, with male and female populations of 193,991 and 197,614, respectively. The population density is 49 people per square kilometer, and the gender ratio is 1000:1019. The national literacy rate is 82.65%, with male and female literacy rates of 93.40 and 72.32 percent, respectively.

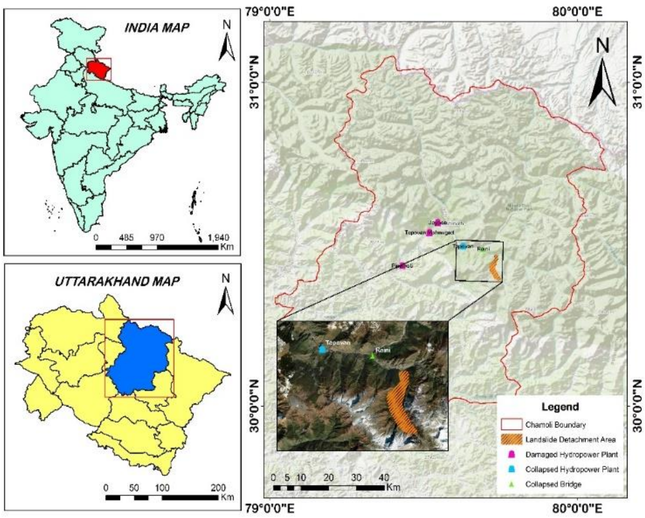

Figure 1. Location map of the study area

2.2 Datasets

For mapping the Chamoli flood event, both SAR and optical images are used. The available Sentinel-1 SAR images from pre, during, and post is used for flood mapping. Sentinel-1 Ground Range Detected (GRD) images collected from the GEE platform are already terrain-corrected σ^0images with a pixel scale of 10 × 10 m. To validate the results, Sentinel-2 optical images that are freely available from USGS Website are used. The Sentinel-2 image acquired pre and during the flood i.e., on 31 Jun 2021 and 10 Feb 2021 was used. The spatial resolution of Sentinel-2 optical images is 10m. In addition to these imaging satellite datasets, global surface water data and DEM, World Wildlife Fund (WWF) Hydro SHEDS data are fetched into the GEE platform for a better understanding of the area's flooding events. Global surface water data and WWF Hydro SHEDS have spatial resolutions of 30 m and 3 arc sec, respectively, and a detailed description of these datasets can be found in the Earth Engine Data Catalog.

3.Methodology

As it works on a parallel processing architecture, the GEE cloud platform can excellently perform various tasks ranging from data retrieval to flood mapping in a systematic way. The flood mapping processing chain is divided into 4 stages, i.e., 1) Sentinel-1 Data Collection, 2) Metadata Filtering, 3) Permanent Water Body Mask Creation and 4) Flood mapping using GEE. Figure 3 shows the conceptual structure of the proposed processing chain for flood mapping using Sentinel-1 with GEE.

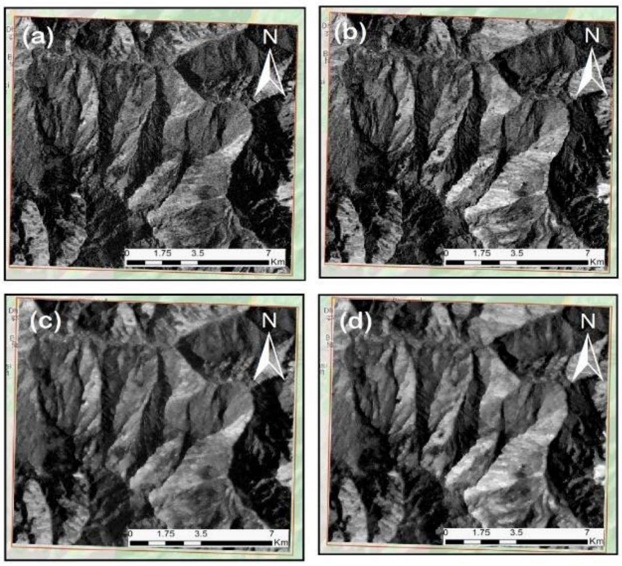

Figure 2. (a) Image captured pre-flood by sentinel-1, (b) Image captured During flood by sentinel-1, (c) Filtered image pre-flood (d) Filtered image During flood

3.4 Validation approach

Both direct (field data) and indirect (secondary data) validation approaches are used. Secondary data include optical remote sensing images from the Sentinel-2 satellite, which were used in the study. The field data were obtained at different flood-affected areas on different time scales.

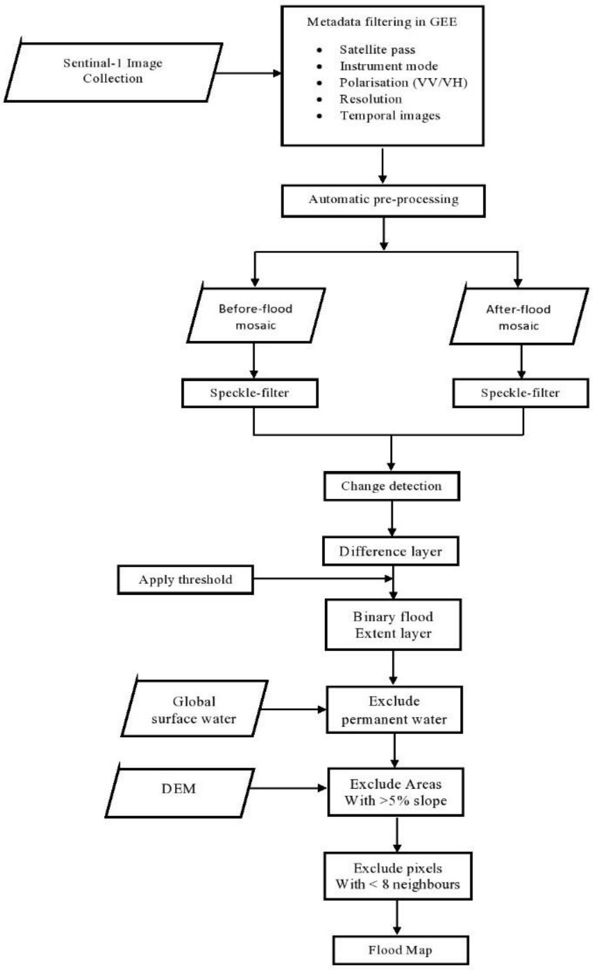

Figure 3. Methodology for processing Sentinel-1A SAR data

3.5 Sentinel-2 data collection and image processing

Optical images captured by Sentinel-2 during 31 Jun 2021 and 10 Feb 2021, are being analyzed and used to locate flooded areas. Optical imaging is commonly used for flood prediction and mapping due to a variety of advantages. The Sentinel-2 image acquired pre and during the flood i.e., on 31 Jun 2021 and 10 Feb 2021 was used. The detailed step-by-step method used on sentinel-2 pre-flood and during-flood images to extract permanent water bodies from the pre-image and to locate flooded areas from the during flood image is shown in Fig 4.

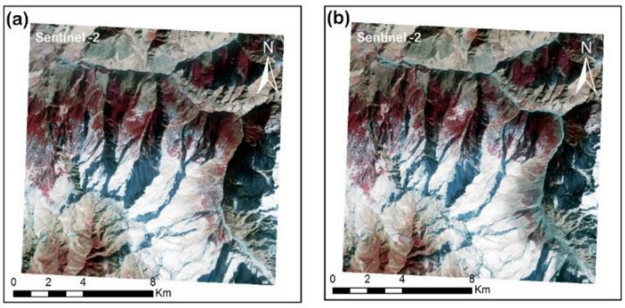

Figure 4. (a) & (b) Pre-flood and during flood image by sentinel- 2 respectively

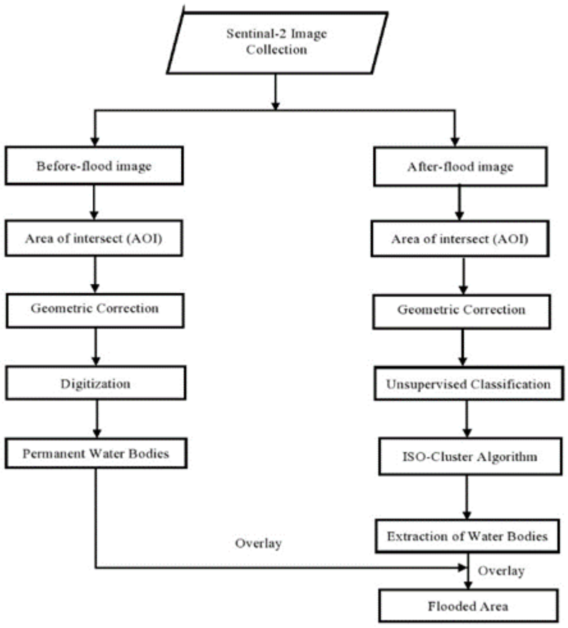

Figure 5. Methodology for processing sentinel-2 optical data

4 Results and discussions

4.1 Flood mapping using GEE for Sentinel -1 image

The images are classified as pre-flood, flood, and post-flood based on the duration of the flood. The images acquired are 10th of February designated as flood images.SAR images are naturally degraded by granular noise such as speckle noise due to the coherent nature of the scattering phenomena. All σ^0 images are converted to natural scale from decibel (dB) scale as the first step in the flood mapping process. For a refined Lee speckle filter with a 3 × 3 window size, a user-defined function is created. DEM available on the GEE cloud platform with a spatial resolution of 3 arc sec was used. When generating flood maps at the district level, it is important to mask out higher elevation regions to reduce computing time.This is accomplished by importing the HydroDEM into GEE from terrain data obtained with. Terrain() is an operation. Using the .select() operator, the slope image was obtained from the terrain dataset. Finally, the flood affected areas are extracted and the result is shown in the figure 6.

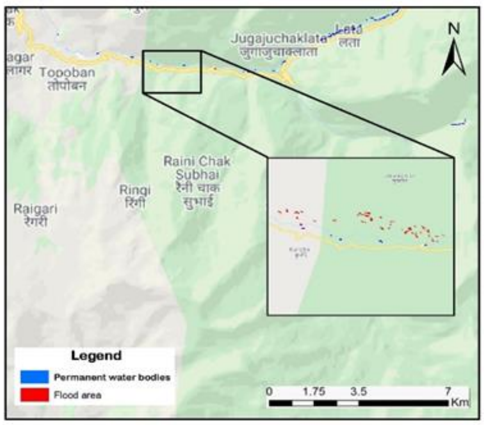

Figure. 6 Flood affected areas observed by Sentinel -1 SAR data using GEE

4.2 Flood mapping using ArcGIS for Sentinel -2 image

The optical sensors' inability to penetrate the clouds, as well as their reliance on the sun's illumination, limit the availability of optical imaging during the flood period. However, optical sensor data is less expensive and easier to read than SAR data. The optical image captured during the flood on 10 February 2021 with the Sentinel -2 sensor is taken into account. The image is first geometrically corrected. The satellite imagery is then classified using ISODATA, an unsupervised classification technique. It separates the image into several objects based on their homogeneous characteristics and classifies/clusters them. First, the image is divided into five class. The water features are then highlighted from the classified image using the recoding technique. The inundated areas are later extracted from the image by overlaying the digitized mask. The extracted resultant water layer is illustrated in Figure 8. Flood assessment and mapping are used not only to locate affected areas, but also to monitor the sustainability of environments.

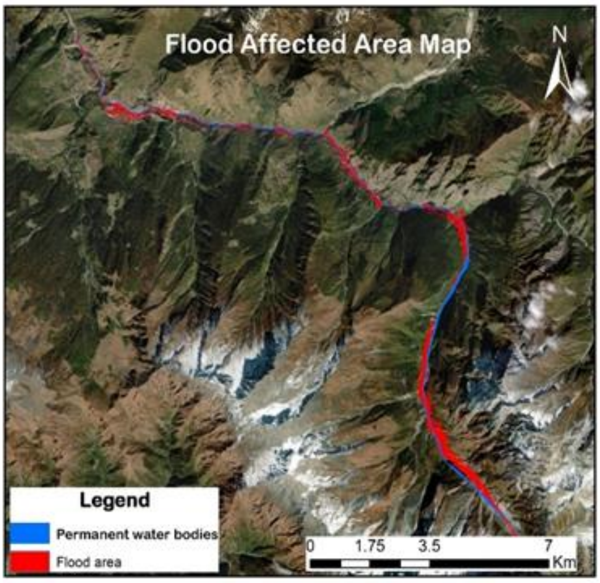

Figure 7. Flood affected areas observed by Sentinel -2 optical data

5.Conclusion

In this study, a practical technique for flood monitoring at the required spatial resolution was proposed using SAR images. Its specific aim was to highlight the possible use of Sentinel-1 SAR data sets from the European Earth Observation mission for flood monitoring in the Chamoli district of Uttarakhand state on February 7, 2021. Our analysis of the various Sentinel-1 parameters revealed that the best results were obtained using the VV polarization configuration.

The methodology for extracting the flood-affected region using optical images was also discussed in this study. The flooding zone is identified by overlaying the digitized pre-flood image mask on the extracted water layers. As a result, we may conclude that geospatial and earth observation tools provide timely data for effective decision-making and comprehensive flood disaster management. Because of the weather conditions during floods, it is difficult to obtain cloud-free optical data, and SAR data should be used to estimate the flooded region. This method was established by using a publicly accessible data and analysis tool, GEE, which can be especially beneficial to developing countries. The established flood prone areas will serve as crucial inputs for flood modelling and analysis, assisting in flood risk management.

Figure 8. Aerial and field photographs (a – i) showing Chamoli flood disaster

The research was carried out in Google Earth Engine, a cloud-based integrated development environment (IDE) platform, and code was written in JavaScript, which is the code link of the evaluated work and performance. https://code.earthengine.google.com/a28356f36fa16b6b78b31ee35edde970

References

Anusha N, Bharathi B (2020). Flood detection and flood mapping using multi-temporal synthetic aperture radar and optical data. The Egyptian Journal of Remote Sensing and Space Sciences 23, 207-291.

Tanguy, M, Chokmani K, Bernier M, Poulin J, Raymond S (2017). River flood mapping in urban areas combining Radarsat-2 data and flood return period data. Remote Sens. Environ. 198, 442–459.

Werle D, Martin T. C, Hasan K (2000). Flood and coastal zone monitoring in Bangladesh with Radarsat ScanSAR: technical experience and institutional challenges. Johns Hopkins APL Tech. Dig. 21(1), 148–154.

Rahman R, Thakur PK (2018). Detecting, mapping and analysing of flood water propagation using synthetic aperture radar (SAR) satellite data and GIS: A case study from the Kendrapara District of Orissa State of India. The Egyptian Journal of Remote Sensing and Space Sciences 21, S37-S41

Faizan M O (2021). Sentinal-1 SAR Data Preparation for Mapping of Water Bodies – A CASE STUDY, International Journal of Research Publication and Reviews Vol (2) Issue (2) 129-137

Li J, Wang S (2015). An automatic method for mapping inland surface waterbodies with Radarsat-2 imagery. International Journal Remote Sensing. 36(5), 1367–1384.