Rapid Flood Mapping based on Remote Sensing Cloud Computing and Sentinel-1

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Abstract. Flood is a natural disaster with the highest frequency and the widest influence range in the world, which seriously restricts human survival and economic development. Obtaining flood inundation range quickly and accurately has important practical significance for flood disaster assessment, rescue and resource allocation. Based on Google Earth Engine cloud platform and Sentinel-1 radar images, a quick flood inundation range extraction model is constructed and applied to the analysis of severe floods in Matala District, Sri Lanka in May 2017. The results show that the flood in Matala area is mainly concentrated in the south and southwest, and the surface water area has expanded by 5 times, among which the flood area in Thihagoda district is the most serious, accounting for 29.28% of the total area. The model has high efficiency and strong feasibility, which can be widely used in flood emergency monitoring.

Keywords: remote sensing cloud computing, Sentinel-1, flood mapping.

1. Introduction

Flood is a natural disaster with the highest frequency and the widest influence range in the world, which seriously restricts human survival and economic development [1, 2]. It is of great practical significance for flood disaster assessment, rescue and resource allocation to obtain the area of flood inundation quickly and accurately.

With the development of radio electronic technology, sensor technology, computer technology and aerospace technology in recent years, remote sensing technology has developed rapidly and has been widely used in flood disaster monitoring [3]. Scholars all over the world have carried out extensive research on the extraction of flood inundation range from optical and radar images. Hess et al. proved through experiments that SAR images can quantify the inundation degree of forest flooded areas and can be applied to real-time flood monitoring [4]. Matgen et al. put forward a flood range extraction
model combining threshold method and regional growth method, and extracted the flood inundation range of Saiwen River and Honghe River basins. The results show that the model has the potential to extract flood range accurately by using SAR images [5]. Tsanis et al. use GeoEye-1 stereo pairs to generate high-resolution DEM, and carry out flood area management and mapping applications [6]. Cian et al. proposed a normalized differential flood index model and applied it to the flood disaster analysis in Venito, Malawi and Uganda. The results show that this method is simple and accurate for flood extraction [7]. Amitrano et al. proposed an unsupervised fast algorithm for extracting flood inundation area based on Sentinel-1 images, and proved the potential of this method through experiments [8]. Based on the spectral index, hue and saturation of Sentinel-2 images, Goffi et al. proposed an algorithm for automatic extraction of flooded areas [9].

Although scholars around the world have proposed many flood inundation range extraction models for different sensor images, but these models are based on the existing pre-and post-disaster images and do not include the process of image selection. Image download and preprocessing often take a lot of time, and the commercial high-resolution images selected by some models are expensive, which is not conducive to large-scale promotion and use. The relevant decision-making departments of flood control and disaster relief need the latest information on the scope and area of flood, which requires high accuracy and timeliness of the extraction algorithm. Based on the powerful computing power of Google Earth Engine cloud platform, this study uses free Sentinel-1 images to build a full-process model covering image selection, data preprocessing and flood inundation area extraction, and provides an effective solution for fast and accurate extraction of flood inundation area.

2. Materials and Methods

2.1. Study Area

The study area is located in the south of Sri Lanka, with alpine areas in the north and plains in the middle and south. In mid-late May 2017, the area suffered persistent strong winds and torrential rains, causing severe floods and landslides. To test the accuracy of the OTSU-Threshold method, the central and eastern part of the region is selected as the study area of water extraction accuracy, where the environment is complex and there are many factors affecting the accuracy of water extraction, which requires high universality and accuracy of the water extraction model. The location of study area is shown in figure1.

![Figure 1. Location of study area](image)
2.2. Data

Google Earth Engine is a cloud platform provided by Google for online visual calculation and analysis of a large number of global-scale geoscience data [10]. The platform mainly stores the data from satellite images and other earth observation data databases, and provides sufficient computing power to call and process the stored data. Google Earth Engine provides online JavaScript API and offline Python API, and users can quickly build Web services based on Google Earth Engine and Google cloud by calling API. The Sentinel-1 data needed in this study comes from the "COPERNICUS/S1_GRD" dataset provided by the Google Earth Engine cloud platform. Sentinel-1 image pre-processing needs to use Google Earth Engine coding to search all the images in the study area, at the same time, filter the data, select IW mode, VV polarization radar data, and filter according to time, then use Refined Lee filtering [11] algorithm to remove noise, and finally mosaic and clipping.

Mountain shadow is an important factor affecting the accuracy of water extraction. To effectively restrain the influence of mountain shadow on the accuracy of water extraction, the method of terrain modeling [12] is used to generate mountain shadow. By downloading DEM data of Matala study area (N05E080, N06E079, N06E080) in geospatial data cloud (http://www.gscloud.cn/)), mosaic and cropping are carried out with ENVI 5.3 software. Mountain shadows are generated based on Hillshade tool in ArcMap10.3, and converted into vector data, and uploaded to Google Earth Engine cloud platform to form mountain shadow mask data.

2.3. Methods

2.3.1. OTSU-Threshold Method. Compared with other rough ground objects, the surface water body is smooth, and the electromagnetic wave signal emitted by SAR is reflected back less on its surface, and the reflection is similar to the specular reflection, so the echo signal received by SAR is weaker, and the gray value of the pixel of the water body in the SAR image is lower, showing black or dark black in the image. At present, the main models of water body information extraction using radar images include threshold segmentation, independent component analysis, object-oriented segmentation and terrain-aided information extraction [13]. Because of its simple principle, fast and convenient, threshold segmentation method is the most widely used in extracting water from radar images [14].

The accuracy of the threshold affects the accuracy of water extraction. In this study, the OTSU [15] method is used to determine the threshold. OTSU is a widely used algorithm for dynamic determination of threshold, which can realize adaptive dynamic determination of image threshold by maximizing class variance and not being affected by image contrast and brightness. The main principle is to use the idea of clustering to divide the image into two parts according to the gray level, so that the difference between each part is the smallest and the difference between the two parts is the largest. The appropriate gray level is determined by calculating the variance. The process of calculating the optimal threshold t of OTSU algorithm is as follows:

\[
\delta^2 = P_{nw} \cdot (M_{nw} - M)^2 + P_w(M_w - M)^2 \\
M = P_{nw} \cdot M_{nw} + P_w \cdot M_w \\
P_{nw} + P_w = 1
\]

\[
t = \arg \max_{x_{stsy}} \{P_{nw} \cdot (M_{nw} - M)^2 + P_w(M_w - M)^2\}
\]  

\(\delta\) is the inter-class variance of water and non-water; \(M_w\) and \(M_{nw}\) are the pixel mean of water and non-water respectively; \(P_w\) and \(P_{nw}\) are the possibility that a single pixel is water and non-water respectively; \(M\) represents the gray average of the whole image.

2.3.2. Quick Extraction Model of Flood Inundation Range. The determination of the flood inundation range first needs to obtain the images before and after the flood, and the flood has the characteristics of sudden and uncertainty, and the remote sensing satellite has a certain revisit period, so the selected image
must have a certain timeliness. Google Earth Engine cloud platform not only provides online transfer and batch processing of Sentinel-1 images, but also has sufficient computing power, which provides an effective solution for online quick extraction of flood area. The quick extraction model of flood inundation area based on Google Earth Engine and Sentinel-1 images is shown in figure 2.

**Figure 2. Quick extraction model of flood inundation range**

First, the quick extraction model of flood inundation range needs to select the most suitable Sentinel-1 images before and after the disaster based on the Google Earth Engine cloud platform, and then preprocess the selected images, such as filtering, mosaic, cropping and so on. Then the water body was extracted by OTSU-Threshold method. After the extraction is completed, it is necessary to carry on the superposition analysis and the elimination of mountain shadow, and finally form the flood inundation area.

3. Results and Discussion

3.1. Accuracy Analysis of Water Extraction

The Sentinel-1 and Sentinel-2 images covering the water extraction accuracy of the study area in the same period of September 2018 were selected, and the OTSU-Threshold method was used to extract the water body. The results are shown in Figure 2.

**Figure 3. Results of water extraction**
Through the comparison between the extraction results and the image superposition, and combined with the visual interpretation results, it is found that the water body extraction result is better in the southeast part of the study area, and the radar image has strong penetration ability, which is not affected by the cloud layer. It can effectively avoid the influence of clouds and cloud shadows on the extraction results of water bodies. In the southwest mountain area of the study area, some mountain shadows are mistakenly divided into water bodies by OTSU-Threshold method. To avoid the influence of mountain shadow on the accuracy of water extraction, it is necessary to mask the extraction results by using the mountain shadow data after terrain modeling. In the cloudless plain area of the study area, the OTSU-Threshold method can extract the water boundary accurately. By selecting 100 water samples and 100 non water samples and calculating the confusion matrix [16], the overall accuracy of Otsu-Threshold method is satisfactory, reaching 90.23%, indicating that the model can be applied to flood dynamic monitoring.

3.2. Analysis of Flood Inundation Range

It is confirmed that the Sentinel-1 image on May 12, 2017 is the pre-disaster image of Matala District, and the Sentinel-1 image on May 30 is the post-disaster image. The extraction result of flood inundation area in Matala area is shown in Figure 4. It is found that the floods in Matala are mainly concentrated in the south and southwest, and scattered in other areas. According to statistics, the pre-disaster water area of the study area is 10.3 km², and the post-disaster water area is 62.58 km². The surface water area of Matala District has expanded five times, of which the disaster in Thihagoda is the most serious, with the flood area accounting for 29.28% of the total area; there is a large flood inundation area at the junction of Malimbada and Kamburupitiya and Matara Four Gravets. Through the superposition analysis of the flood inundation range of Matala area extracted in this study and the flood inundation range based on TerraSAR-X satellite published by IWMI (International Water Management Institute) [17], it is found that the two results are highly consistent, which shows that the model proposed in this paper has high feasibility and practicability.

Figure 4. The results of flood information extraction
The rapid extraction of flood inundation area has always been the focus of global scholars in the field of water remote sensing [18]. Relying on the powerful computing power of Google Earth Engine cloud platform, combined with freely available Sentinel-1/2 images, a whole process model covering image selection, data preprocessing and flood inundation area extraction is constructed. Compared with the flood extraction model proposed by Matgen [5] and Cian [8], the advantage of the flood inundation range extraction model based on Google Earth Engine and Sentinel-1 images is that it greatly shortens the time of image selection and preprocessing, and embeds the OTSU-Threshold method into the cloud platform by coding, thus realizing the fast extraction of flood inundation area efficiently and accurately. The model effectively avoids the image of cloud and cloud shadow on the extraction accuracy of water body, but there are some pores in the extracted flooded area due to the influence of wind waves and surface features, which affects the accuracy of the extracted area. In the later stage, the research on the post-processing methods of image extraction results should be strengthened to eliminate or reduce the pore area.

4. Conclusions
A quick extraction model of flood inundation range based on Google Earth Engine and Sentinel-1 images is constructed in this study, which successfully applied to flood analysis in Matala District, Sri Lanka in May 2017. The results show that the floods in Matala are mainly concentrated in the south and southwest, and scattered in other areas. According to statistics, the pre-disaster water area of the study area is 10.3 km², and the post-disaster water area is 62.58 km². The surface water area of Matala District has expanded five times, of which the disaster in Thihagoda is the most serious, with the flood area accounting for 29.28% of the total area; there is a large flood inundation area at the junction of Malimbada and Kamburupitiya and Matara Four Gravets. After analysis, it is found that the extraction results of Matala region are highly consistent with those published by IWMI. The model makes full use of the characteristics of OTSU-Threshold method and realizes low-cost and high-efficiency flood inundation range mapping with the help of the super computing power of Google Earth Engine cloud platform. It can be widely used in flood emergency monitoring in various areas, and has important practical significance for flood disaster assessment, rescue and resource allocation.

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