Water Body Change Detection Based on Sentinel-1 and HJ-1A/B Satellites Data

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Abstract: In the operational water body monitoring work by satellite data, Sentinel-1 and HJ-1A/B satellites data are the proper data source which can be download freely and quickly. The method of water body change detection by using Sentinel-1 and HJ-1A/B Satellite data is presented in order to make full use of these data to obtain water body information. The fusion of Sentinel-1 and HJ-1A/B with high resolution can monitor the water body in all-weather condition. The method is applied in Poyang Lake of China and shows promising results. Comprehensive and effective utilization of multi-source satellite data could provide reliable water body information for water resource management, flood warning, real-time monitoring of flood development, rapid and accurate assessment of flood losses.

1 INTRODUCTION

Earth surface water body is the one of most important water resources. Water body change detection using the satellite can provide useful information for flood disasters monitoring and water resource management (Zheng et al., 2017; Zheng et al., 2016). Synthetic Aperture Radar (SAR) and optical sensors with high spatial resolution are very useful for obtaining detailed water body information (Abileah and Vignudelli, 2011). SAR data with both the two features of high spatial resolution and cloud penetration are very attractive to water body monitoring (Delmeire, 1997; Liao et al., 2004; Lv et al., 2005; Juval et al., 2016), and the high spatial resolution optical data provide the ideal data source for water detection under the clear sky (Tholey et al., 1997; Profeti and Macintosh, 1997). Comprehensive using the SAR and optical remote sensing data both can enhance the all-weather satellite observing capability and data processing efficiency.

2 DATA

In the operational satellite monitoring work, easy to obtain the satellite data is required. Sentinel-1 and HJ-1A/B satellites data all can be download freely and quickly by user register in official website. So, in this paper, the two satellite data mainly are used to monitor the water body.

Sentinel-1 is a space mission funded by the European Union and carried out by the ESA within the Copernicus Program, consisting of a constellation of two satellites, Sentinel-1A and Sentinel-1B. he first satellite, Sentinel-1A, launched on 3 April 2014, and Sentinel-1B was launched on 25 April 2016. The payload of Sentinel-1 is a Synthetic Aperture Radar in C band that provides continuous imagery (day, night and all weather). In this paper, Sentinel-1 is applied to attain surface water information in time for it is not influenced by cloudy and rainy, all-weather observation. The C-SAR instrument supports operation in dual polarisation implemented through one transmit chain and two parallel receive chains for H and V polarisation. Sentinel-1 operates in four exclusive acquisition modes showed in Table 1.

HJ-1A and HJ-1B, launched on 6 September 2008, are as two optical satellites of environment and disaster monitoring and forecasting small satellite constellation. The two satellites are equipped with 3 remote sensors such as wide-coverage CCD scanner, infrared multispectral scanner and hyper-spectral imager, comprising a more complete earth observation remote sensing series characterized by high and medium space resolution, high time resolution, high spectrum resolution and wide coverage. CCD scanner observe

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in parallel to complete scanning and imaging for earth with swath width of 700 km, ground pixel resolution of 30m and 4 spectrum bands(table.2). HJ-1A and HJ-1B have the same orbit with phase position difference of 180°. The revisit period of two CCD cameras is only 2 days after networking.

Table 1: Characters of SENTINEL-1A/B.

Operation mode	Spatial resolution	Swath width	Polarisation
Stripmap(SM)	5×5 m^2	80 km	HH or VV VV+VH or HH+HV
Scan SAR-Interferometirc wide-swath(IW)	5×20 m^2	250 km	HH or VV VV+VH or HH+HV
Extra-Wide swath (EW)	20×40 m^2	400 km	HH or VV VV+VH or HH+HV
Wave mode (WV)	20×5 m^2	20×20km^2 every 100km	HH or VV

Table 2: Channel parameters of HJ-1A/ B CCD.

Channel number	Spectral ranger (μm)	Spatial resolu-tion(m)	Swath width(km)	Repeti-tion cycle(days)
1	0.43-0.52	30	360(single) 700(double)	4(single) 2(double)
2	0.52-0.60	30		
3	0.63-0.69	30		
4	0.76-0.90	30		

3 METHOD

3.1 Water Body Identifying Based on HJ-1A/B

HJ-1A/B data have 30-m spatial resolution. For the CCD sensor, red channel 1(0.63~0.69 μ m) and near infrared channel (0.76~0.90 μ m) are taken as the main channels for water detection due to the specific spectral properties in these two channels. Red channel has low reflectance over vegetation and bare land but relatively higher reflectance over water surface. Opposite to red channel, near infrared channel has much higher reflectance over vegetation and land but much lower reflectance over water surface. In addition, considering atmospheric absorption and cloud contamination, it is difficult to use single channels to distinguish water from land. Therefore, the ratio between red channel and near infrared channel are more effective variables instead of single channel reflectance to separate water from vegetation, bare land, and cloud shadow. A threshold method or decision–tree method can be used to detect earth surface water by using the ratio (Zheng, 2008; Zheng et al., 2013):

$$\frac{R_{inf}}{R_{red}} < R_T \qquad (1)$$

Where R_{inf} and R_{red} are the reflectance of near infrared channel and red channel respectively, R_T is the thresholds of the ratio.

3.2 Water Body Identifying Based on Sentinel-1

Under rainy weather conditions, Sentinel-1 data is quite ideal water body monitoring because it not only has high spatial resolution, but also can penetrate cloud. The software SNAP is used to process the Sentinel-1 data, Firstly, the level-1 Sentinel-1 data was processed for the radiometric calibration, and the backscatter coefficient could be calculated; Secondly, Sentinel-1 data was processed for topographic correction. Furthermore, SAR images are subjected to an inherent granular noise called speckle, degrading the quality of the image and making water extraction more difficult. The adaptive Gamma filter produces speckle removed images with relatively low processing time (Martinis et al., 2009). This method was ultimately selected for speckle removal, as it was effective for all of the available SAR resolutions, angles, and sensor modes (Long et al., 2014). Sentinel-1 data was removed speckle based on the filter method. Last, water has lower backscatter signature than other surface features in SAR imagery, so it can be identified based on the threshold method as follows:

$$\sigma_{SAR} < \sigma_{T\_flood} \qquad (2)$$

Where R_{inf} and R_{red} are the reflectance of near infrared channel and red channel respectively, R_T is the thresholds of the ratio.

3.3 Water Change Detection with Multi-Source Data

Comparison of two different time water body can analyze the water change information. Although SAR has many advantages for being used to detect the water body at all-weather condition, the procedure of processing the SAR data is much harder than optical remote sensing data, and it also can't determine water change area if only using radar image. HJ-A/B data can be used to obtain background water body. Therefore, water change area can be confirmed by combining the Sentinel-1 image at cloudy and rainy day during flood season and HJ-A/B image before flood season as follows:

$$W_{cha} = W_{SAR} \cap \overline{W}_{OPT} \quad (3)$$

Where W_{cha} is the water extent extracted by Sentinel-1 image during flood season, W_{OPT} is the water extent extracted by HJ-A/B image before the flood season.

4 RESULT AND ANALYSES

The method described in section 3 is applied to monitor the water body change in Poyang Lake of China. Poyang Lake, located in Jiangxi Province, is the largest freshwater lake in China(Figure 1). The lake is fed by the Gan, Xin, and Xiu rivers, which connect to the Yangtze through a channel. Water body change of Poyang Lake can indicate the climate change and effect of human activity. Using satellite data to monitor the water body of this lake is valuable and meaningful (Zeng et al., 2017; Andreoli et al., 2007). Poyang Lake was hit by severe heavy rains in early June of 2017. The rise of water level in lakes caused water body enlarging. Because of the interruption of precipitation, effective optical remote sensing data can't be obtained, Sentinel-1 data in flood season and HJ-1A/B data before the rainfall are used to research the lake area change. The Poyang lake is observed at least every 6 days from Sentinel1A/B and at least 2 days from HJSentinel-1 data on June 24 of 2017 and HJ-1B data on May 25 of 2017 were acquired. This Sentinel-1 data is imaged by IW model and VH polarisation. Based on the method in section 3, Poyang Lake water area production on June 24 shows that the water area of Poyang Lake is about 3307 km^2 (Figure 2), this result was compared to the Poyang Lake water area production by HJ-1B data on May 25. The comparing result indicated that the lake area increase by about 43% in flood season (Figure 3). In order to validate the monitoring result, the field investigation of Poyang Lake was carried out. The typical water samples were selected to investigate base on the water changing thematic map (Figure 4). The GPS data and photos of the scene account for the satisfying effect of water body monitoring result, which indicated locally the good accordance between field measurement and extracted water. The water areas with a significant increase are mainly located in the middle and east of Poyang Lake. Based on these water monitoring and assessing production, the water change information can be showed obviously.

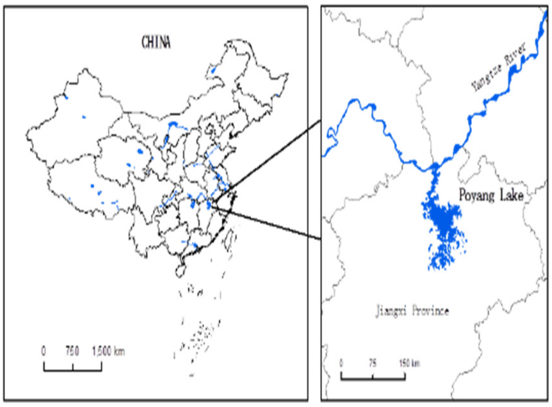

Figure 1: Location sketch map of Poyang Lake.

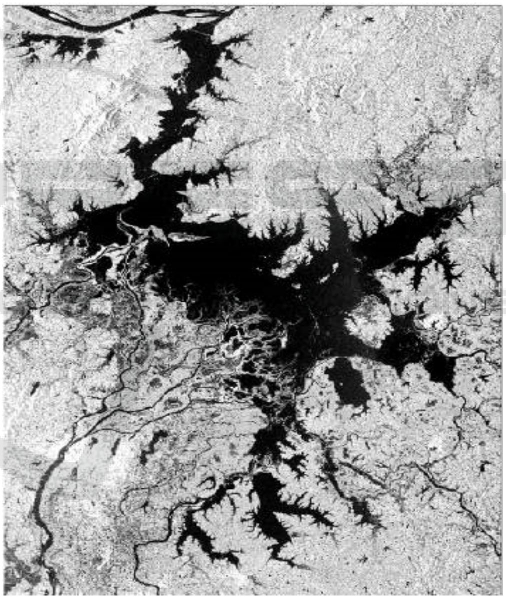

Figure 2: Sentinel-1 monitoring image on June 24, 2017.

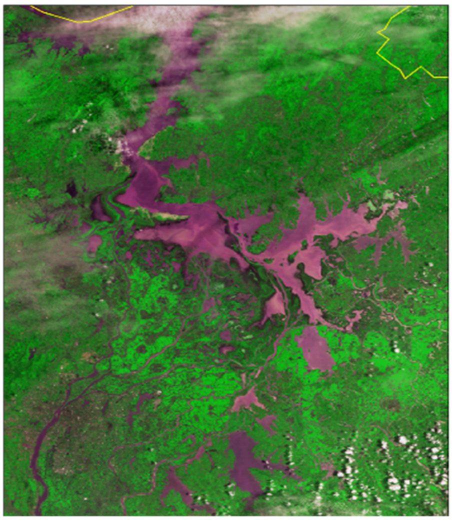

Figure 3: HJ-1B monitoring image on May 25, 2017.

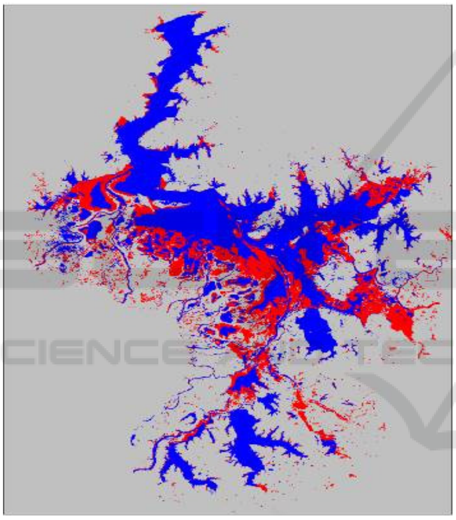

Figure 4: Water changing thematic map.

5 DISCUSSION AND CONCLUSIONS

The method of water change mapping by synergizing different types data was developed and tested. Sentinel-1 data in flood season and HJ-A/B data before the flood season are employed. The result shows the comprehensive and effective use of multi-source satellite data can give reliable earth surface water body change information. The method also is proper to other satellite data such as Chinese GF-3 and GF-1 data.

The optical remote sensing data, such as Landsat/TM and Sentinel2 A/B data which have the short wave infrared (SWIR) band is often applied to detect the water body, for high turbid waters, the SWIR channel is preferred. So, the choice of the best spectral band(s) is required according the characteristic of satellite data before detecting the water body information. Furthermore, increasing the satellite data revisiting time is also especially important for short-time events as floods. Geostationary satellite data, such as FengYun-4 and Himawari-8 data with high spatial and temporal resolution also can be used to monitor the water body dynamically.

With the fast development of earth observation technology, more types of satellite data can be available easily. The method of water body mapping based on multi-source satellite data will be improved continually.

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