Research on Extraction Method of River Water from MODIS Image of Mountainous Areas in Western Sichuan and Optimized by DEM Data

Bo Li¹, Meikai Wang², and Jun Tang²

1Joint Laboratory of Information Technology in Water Resources, Sichuan University, China
2Institute of Intelligent Control, Sichuan University, Chengdu 610065, China

Abstract. This paper has studied the extraction method of river water in the mountainous area of western Sichuan. We combine the two advantages of higher time resolution of MODIS and digital simulation of DEM surface terrain. This method can remove the shadow of the river and refine the effect of water. We have the advantage of applying MODIS to river monitoring. However, due to the narrow river channel in the western Sichuan Mountains, the region has mountain shadows and mixed snow cover, which makes the river edge areas blurred. We use existing methods to extract water bodies and the real situation is different. In order to apply the advantages of MODIS data to the monitoring of Mountain Rivers in this experiment, we selected the area flowing through the upper reaches of Minjiang River as a typical research area. After sampling and analyzing the typical features in the MODIS data for multiple days, this experiment The NDVI method was improved, and then it was combined with the MODIS band 1 data to obtain the mountain water body enhancement index (MEWI). In the end, this experiment realized the fuzzy treatment of mountain gullies in the image and highlighted the water body. Based on the previous work, we removed the blurred shadows of the edges of the MEWI water body by extracting regions with lower DEM slopes. The results show that after removing the channel shadow based on DEM, the channel water body is refined.

1. Introduction
The western part of Sichuan is located on the eastern edge of the Qinghai-Tibet Plateau, and earthquakes, landslides, mudslides and other geological disasters occur from time to time. The occurrence of these geological disasters often induces the collapse of mountains, which seriously threatens people's safety, and often blocks rivers to form dammed lakes. Therefore, it is of great significance to use real-time remote sensing technology to carry out real-time monitoring of Mountain Rivers.

We found that DEM data can digitally simulate the terrain and landforms, and many scholars have used it to monitor river water bodies. Zhao Bingxue used OLT images and DEM data to extract mountain water bodies [2]; we extracted cross-section topographical data [3]; scholars used DEM data to extract the catchment area upstream of the river and the slope within a certain range near the river, and established The function relationship between the cross-section width and the river can be used to
construct river width models suitable for different river basins [4]; scholars compare threshold method, spectral relationship method, NDWI index, MNDWI index, EWI index method, CIWI index method, PRWI advantages and disadvantages of the index method for river water extraction [5]; scholars study DEM data as the basis, and use the ArcGIS hydrological analysis module to automatically extract river networks and river systems in the study area [6] [9]; In the process, it is often necessary to extract water bodies from remote sensing images and monitor the changes in the area of water bodies. Therefore, the water extraction technology of remote sensing images has attracted much attention. At present, the main methods for extracting water bodies using MODIS images are: ratio vegetation index method (RVI) using the MODIS first and second band combination, normalized vegetation index method (NDVI) [7] [8]; using MODIS Nos. 2 and 4 The normalized difference water body index method (NDWI) of wave band combination and its improvement method-MNDWI; the mixed water body index model method (CIWI) using MODIS wave band 1, 2, and 7 wave band combination. The above water body extraction method has achieved good results in the plain area. However, the terrain and landforms in the western mountainous region of Sichuan are quite special. The area of river water body is generally small, which requires high spatial resolution of remote sensing data. Limited by the spatial resolution of MODIS remote sensing data, the use of MODIS data for river water extraction alone often has a huge contrast with reality.

In view of the characteristics of rivers in the mountainous areas of western Sichuan, based on sampling and analysis of typical surface reflectances, this article uses MODIS data to carry out river water extraction for selected typical research areas, and refine the extracted images using DEM data. The river makes the results consistent with the facts.2. In the MODIS data, the reflectivity of the water body in the first band (0.62 ~ 0.67μm) is greater than that in the second band (0.82 ~ 0.87μm). The reflectance of vegetation and soil in the second band is significantly higher than that in the first band. The reflectance of towns in the first and second bands is similar, but the overall reflectance is higher than that of water. Therefore, the reflectance of the second wave band minus the reflectance of the first wave band is negative. This feature is not available in most other features.

2. Characteristics of water bodies in MODIS data

We found in MODIS remote sensing data that the features of ground reflectance are different, and the salient features of water bodies are:

1. The electromagnetic wave absorptivity of the pure natural water on the surface in visible and near-infrared bands (0.4 to 2.5 μm, corresponding to the 1 to 19 bands of MODIS data) is significantly higher than most other surface features. In the visible light band, the reflectance of the water body is generally low, generally 4% to 5%, and gradually decreases with the increase of the wavelength, to about 2% to 3% at 0.6 μm. In the near-infrared band, the water body absorbed almost all of its energy, similar to a "black body".

2. In the MODIS data, the reflectivity of the water body in the first band (0.62 ~ 0.67μm) is greater than that in the second band (0.82 ~ 0.87μm). The reflectance of vegetation and soil in the second band is significantly higher than that in the first band. The reflectance of towns in the first and second bands is similar, but the overall reflectance is higher than that of water. Therefore, the reflectance of the second wave band minus the reflectance of the first wave band is negative. This feature is not available in most other features.

However, the reflectivity characteristics of water bodies change with factors such as the area of the water body, the sand content of the water body, and the chlorophyll content of the water body [10]. Moreover, the rivers in the mountainous areas of southwest China are mostly narrow, and the width of the rivers often does not exceed 250m. Therefore, in the MODIS image data, the water pixels of the Mountain Rivers are mostly mixed pixels. There are some differences.
3. Water extraction in western Sichuan

3.1. Sampling and analysis of remote sensing image of typical surface features in mountain areas

This article takes China’s 1: 1 million electronic water system map and 1: 800,000 residential digital map as references, determines the typical feature distribution range by visual observation, and then performs artificial pixel sampling to read out the MODIS reflectance data in the first and second bands. And RVI, NDVI values, finally identified several features with similar characteristics to water bodies, recorded in Table 1.

| Feature Name          | 1st Band Reflectance | 2nd Band Reflectance | RVI       | NDVI       |
|-----------------------|----------------------|-----------------------|-----------|------------|
| Pure water            | 0.068–0.071          | 0.055–0.063           | 0.821–0.971 | -0.107~ -0.061 |
| Mixed water           | 0.036–0.082          | 0.081–0.122           | 1.010–2.259 | 0.044–0.497 |
| Town                  | 0.079–0.091          | 0.077–0.097           | 0.946–1.513 | -0.031–0.036 |
| Mountain shadow       | 0.014–0.019          | 0.007–0.033           | 0.512–1.773 | -0.223–0.216 |
| Snow cover            | 0.143–0.535          | 0.172–0.565           | 1.000–1.059 | 0.014–0.036 |
| Mixed snow cover      | 0.049–0.143          | 0.074–0.172           | 1.037–2.187 | -0.021–0.451 |

RVI and NDVI are:

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RVI = \frac{R_{\text{band2}}}{R_{\text{band1}}} \quad (1)
\]

\[
NDVI = \frac{(R_{\text{band2}} - R_{\text{band1}})}{(R_{\text{band2}} + R_{\text{band1}})} \quad (2)
\]

Among them, \(R_{\text{band1}}\) is the reflectance of the first band of MODIS; \(R_{\text{band2}}\) is the reflectance of the second band of MODIS.

The mixed snow cover in Table 1 refers to the snow cover area on the edge of a large area of snow cover where the snow is thin and mixed with a lot of other feature information; the mixed water body refers to the water body area that contains other feature information in the water pixel.

It can be found from Table 1 that due to the influence of other features, the reflectance of the mixed water body in the second wave band is significantly higher than that of the pure water body in the second wave band. This results in the RVI of the mixed water body being greater than 1, and the NDVI is positive. No longer has the obvious feature that the water body RVI is less than 1, and NDVI is negative. The NDVI value of the mountain shadow and mixed snow cover area may show negative values. The NDVI range and the NDVI range of the mountain water body intersect non-empty. The RVI range of the mixed water body and the RVI range of several other features are not empty. RVI and NDVI methods are difficult to extract river water bodies, and it is impossible to select appropriate thresholds to separate water bodies from snow cover, towns, and mountain shadows.

It can be seen from Figures 1 and 2 that there are many gullies in the mountainous area and a large snow cover area. It is also difficult to identify the river water body from the RVI and NDVI images. Among the existing water extraction methods, the RVI and NDVI methods use MODIS bands 1 and 2 to combine, while other methods use bands with a spatial resolution of only 500m to combine, which is obviously not suitable for mountain river water extraction. Therefore, the existing water extraction methods need to be improved to meet the application.
3.2. Improved methods for water extraction in Mountain Rivers

The first band of MODIS data is the red light band. In the image of this band, the contrast between the water body and the adjacent bare surface and vegetation coverage area is large, while the shadow of the mountain area is relatively small, and the reflectance is similar. Moreover, the reflectance $R_{band1-w}$ of the first band of the water body is significantly higher than the reflectance $R_{band1-s}$ of the band 1 in the shadow of the mountain, and $R_{band1-w} > 2R_{band1-s}$ (where $R$ represents the sample average). In order to blur the mountain gully and highlight the water body of the river, the above characteristics can be used. First, the MODIS first band reflectance data $R_{band1}$ is compared with its mean value to form a dimensionless constant $M_{band1}$, which is then combined with NDVI to obtain the mountain water body enhancement index (MEWI), where

$$MEWI = NDVI - M_{band1}$$  \hspace{1cm} (3)

$$M_{band1} = R_{band1} / MEAN(R_{band1})$$ \hspace{1cm} (4)

After many experiments, the average reflectance of the first band of a MODIS image with little or no cloud is $MEAN(R_{band1}) < 0.1$. Through $NDVI - M_{band1}$, the contrast between the water body of the mountain river in the image and the adjacent area increases, while the contrast between the shadow of the mountain area and the adjacent area decreases. It can be seen from Figure 3 that the mountain gully is blurred in the MEWI image, and the river water body is easier to identify.

3.3. Research on Image Enhancement

The aforementioned contrast stretch is a fast 2% linear stretch, which is only a 2% crop at both ends of the displayed data. Although the water body in the MEWI image is easier to identify than the water body in the RVI and NDVI images, with the blurring process of mountain gully, the boundary between the water body and the neighboring features becomes more blurred. Therefore, the image needs to be enhanced to make the water body more prominent.

Most of the pixels in the MEWI image are distributed near 0 as shown in Figure 4 (a). The snow cover (excluding the mixed snow cover) has a higher reflectance in the first band. $R_{band1-snow} > 10\%$

Therefore, $NDVI \approx 0$ the MEWI value of the snow cover is lower. $MEWI_{snow} < -1$ (Representing the sample mean), but mountain water bodies do not have this characteristic and the water
body MEWI is higher than -1. You can use this \( MEWI < -1 \) feature to crop the part and then stretch the contrast to change the image to the contrast coordinates of 0 ~ 255 for display. The enhanced MEWI image is shown in Figure 5 and its histogram is shown in Figure 4 (b). Comparing Fig. 5 with Fig. 3, it can be seen that, after the image enhancement method is processed, the river water body is more prominent.

![Figure 4. Histogram of MEWI image](image)

![Figure 5. MEWI image of the junction of Minjiang and Zagunaohe](image)

3.4. DEM refines the river

After the enhancement of the image, the water body of the river channel is obviously prominent, but when the mountain gully is blurred, the river edge is also blurred to form a shadow. Figure 5 shows that the width of the Zagunao River is significantly wider than that of the Minjiang River. This does not meet the facts, so it is necessary to refine the river to make the channel conform to the real situation. The river channel is often between valleys, and the terrain is significantly lower than the surrounding. DEM data can more accurately describe the terrain and landforms on both sides of the river through digital simulation of the terrain, and combined with MEWI, it can remove the shadow of the river.

The decision tree was used to extract the significantly lower-level areas in the DEM data, and a shp file was generated. The shp file was used to crop and remove the MEWI image after snow cover and image enhancement, and cut out the shadows along the river edge to make the river width the same as the real situation.

![Figure 6. DEM data image](image)
4. Analysis of experimental results

In this paper, the areas that pass through the upper reaches of the Minjiang River in western Sichuan: Songpan County to Dujiangyan City (East Longitude: 102º9'-104º1', North Latitude: 30º2'-32º3') are selected as typical research areas. The upper reaches of the Minjiang River runs through the north-south uplift belt of Laoshan and Longmen Mountains. The mountains in the basin are stacked and the terrain is dangerous. The total drop in the upper reaches of the river is greater than 3000m ($\nabla_{4040} - \nabla_{731}$), and the width of the river is increased from 20~35m (Songpan Hydrological Station) to 180m (Zipingpu Hydrological Station) [11].

The upper reaches of the Minjiang River in the study area were evaluated for MEWI and then image enhancement was performed. The results are shown in Figure 5. Using DEM data, a decision tree was used to generate the shp file, and the augmented reality MEWI was cut. In the end, Zagu Naohe was significantly refined, and the result is shown in Figure 7. This article takes an image of the 1: 1 million electronic water system map of the upper reaches of the Minjiang River in China as the Reference, as shown in Figure 8.

![Figure 7. MEWI image after DEM refinement](image1)

![Figure 8. Water system diagram of the lower reaches of the Minjiang River](image2)

Comparing Fig. 7 and Fig. 8, it can be found that removing the shadows in the MEWI image by using DEM can highlight the water body of the mainstream river in the upper Minjiang River and refine the channel so that the width of the Zagu Naohe River channel is smaller than that of the Minjiang River, which is in line with the real situation in the water system diagram in Figure 8. For rivers below level 5, because the channel is very narrow, there is almost no contrast with surrounding features in the MODIS image and it is difficult to identify. Therefore, rivers below level 5 cannot be extracted by this method.

From Figure 5 and Table 1, it can be concluded that, due to the influence of the mixed pixels, the reflectance of the water body in Band 2 increases, which makes the mountain water bodies and towns have similar NDVI values, and it is impossible to separate them with a suitable threshold. In the first band, the difference between the reflectivity of the water body and the town is not large, which makes it difficult to use MEWI method to separate the water body from the town. However, in the MODIS image, the urban area usually does not change much and can be removed manually.

5. Conclusion

There are many gullies in the mountainous areas of western Sichuan. River water bodies are mostly mixed pixels. It is difficult to extract mountain water bodies using RVI and NDVI. From the stretched images of RVI and NDVI, it is also difficult to identify the river water bodies visually. In this paper, the NDVI and MODIS band 1 data are combined to obtain the Mountain Water Enhancement Index (MEWI), which can achieve fuzzy treatment of mountain gullies and highlight river water bodies. After the image enhancement, the river water body is clear and discernable, and then the DEM data is used to remove the fuzzy shadows on both sides of the river. The effect is better than the method using MODIS data alone. By comparing MODIS remote sensing images from different time periods, the water body area changes in Mountain Rivers are monitored to provide decision-making basis for disaster prevention and reduction.
According to the development trend of remote sensing application technology, based on the research work in this paper, it is very valuable to improve the computer automatic extraction and mapping of mountain river water bodies.

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