Spectral Characteristics Analysis of Wetland in Three Provinces of Northeast China Based on FY3/MERSI Data

Rui Feng1, Jinwen Wu1, Wenying Yu1, Ruipeng Ji1, Pengshi Chen2, Yushu Zhang1, *

1Institute of Atmospheric Environment, China Meteorological Administration, Shenyang 110166, China
2Institute of Meteorological Sciences of Liaoning Province, Shenyang 110166, China
*Corresponding author: yushuzhang@126.com

Abstract. For quickly and efficiently extracting large-scale wetland information to the FY3/MERSI sensor satellite data, and based on the FY3/MERSI data from 2011 to 2016, this paper analyzed the time series original spectra and its NDVI and NDWI index change characteristics of lake, reservoir, paddy field and marsh wetlands in three provinces of Northeastern China. The results showed that there are differences in the spectral curves, NDVI and NDWI indexes of different wetland types, especially the marsh wetlands, paddy fields and other landforms with a growth circle that have more significant differences in spectral curves and index curves than that of lakes, reservoirs and rivers. The data provides a preliminary method for the research and business application of China Fengyun series satellite MERSI sensor data.

1. INTRODUCTION
Wetland is one of the most biodiverse ecological landscapes in nature, which is called the major ecosystems together with forests and oceans in the world. It is called the "Kidney of the Earth" and "Gene Pool of Species"[1-3]. With changes of the natural environment and the unreasonable utilization of wetland resources, wetland degradation has become a global phenomenon [4-7]. Therefore, to timely and accurately grasp the changes of regional wetland ecosystems by dynamically monitoring wetlands has a great significance for studying restoration and protection of wetlands, planning of ecological environment and change of carbon cycle in the global wetlands [8-10].

Remote sensing data is easy to obtain and has characteristics such as wide coverage, high repetition frequency and large amount of information, which has been widely used in wetland classification research [11-13].

Low resolution satellite data have low spatial resolution, but their wide monitoring space, convenient access and abundant spectral information, especially the high revisit cycle of twice a day, make the research on wetlands in region and even in the world possible [14-15]. Based on the FY3/MERSI data from 2011 to 2016, this paper analyzed the time series original spectra and NDVI and NDWI indexes wetlands such as lake, reservoir, paddy field and marsh in three provinces of northeastern China, which provides basic data and methods for the China Fengyun series satellites to carry out large-scale wetland extraction.
2. METHODOLOGY

2.1 Study area and representative wetland selection

The study area was the three provinces of northeastern China where there are most wetlands in China, accounting for about 48.3% of the total wetland in China [16]. The distribution is relatively concentrated. They are mainly distributed in Sanjiang Plain, Xing’an Mountains, Changbai Mountain, Songnen Plain and Liaohe River Delta. 12 wetlands such as Zhalong in the three provinces of northeastern China have entered The List of Wetlands of International Importance in China, accounting for 24.5% of the national total.

In this paper, the representative wetland selection of natural wetlands (marsh wetland and lakes) and constructed wetlands (reservoirs and paddy fields) was conducted. We selected Panjin, Zhalong and Xianghai wetlands for marsh wetlands; Xingkai Lake, Jingpo Lake, Songhua Lake, Chagan Lake and Wolong Lake for lake wetlands; Baishi Reservoir, Dahuofang Reservoir, Erlongshan Reservoir, Huanren Reservoir, Lianhua Reservoir, Shitoukoumen Reservoir for reservoirs; as well as paddy fields in the three provinces of northeast China are selected as the research objects. For the specific distribution, refer to Figure 1.

2.2 Data sources

FY3/MERSI data were selected from 2011 to 2016. To facilitate the extraction of wetland information, time phase of remote sensing data was from April to October, and cloud coverage was lower than 15%. FY3/MERSI came from China Satellite Data Service Network. FY3/MERSI data were selected for 25 day, with 1-5 channel data resolution of 250m, 6-20 channel data resolution of 1000m, and resampling of 250m at operation. FY3/MERSI data were processed in the "Northeast China Wetland Remote Sensing Monitoring and Evaluation Application Demonstration System", which include data projection, remote sensing image geometric correction and registration, data resampling, vector geographic information addition.

2.3 Sample selection

According to the characteristics of wetland in study area, a wetland classification system was established, including 6 land form types like lakes, reservoirs, paddy fields, marsh wetlands and rivers. In order to reduce the influence of the singular value of the spectrum, a 3×3 pixel window was set around the pixel where the sample point was located, and the average value of the effective spectral data in the window was calculated.
2.4 Index calculation

The Normalized Difference Vegetation Index (NDVI) and Normalized Different Water Index (NDWI) were used to analyze time series changes of lakes and reservoirs, rivers, paddy fields and marsh wetlands. The NDVI was calculated by the following formula [17]:

$$NDVI = \frac{\rho_{air} - \rho_{red}}{\rho_{air} + \rho_{red}}$$  (1)

Where: $NDVI$ is the Normalized Difference Vegetation Index; $\rho_{air}$ is reflectivity of near infrared band, and $\rho_{red}$ is reflectivity of red band. In FY3/MERSI, 3-channel and 4-channel were used for calculation.

The NDWI was calculated by the following formula [18]:

$$NDWI = \frac{R_{green} - R_{air}}{R_{green} + R_{air}}$$  (2)

Where: $NDWI$ is the Normalized Different Water Index; $R_{green}$ is reflectivity of green band; and $R_{air}$ is reflectivity of near infrared band. In FY3/MERSI, 2-channel and 4-channel were used for calculation.

3. Spectral characteristics analysis of wetlands

3.1 Spectral characteristics analysis of lakes and reservoirs

In the remote sensing images, both lakes and reservoirs showed planar features, and their edges were distinct from other land features. With influence of water temperature, water depth, impurity content, water area size and other factors, the spectral characteristics are different for different lakes and reservoirs. However, the spectral curves of these lakes and reservoirs had a very high similarity. It can be seen from the FY3/MERSI spectral reflectance curves that the reflectance value decreases from blue and green to red band within the visible range, and reflectivity of the red band (685nm) ranges from 4% and 9%. There were double strong and weak peaks for in the near infrared region. Both peaks were in the shortwave infrared region, which are near 865nm and near 1640nm, respectively. Reflectance trough was near 940nm, less than 6%. For the specific reflectivity changes, refer to Figure 2.

![Fig. 2. Reflectance spectral curves of lake and reservoir](image)

3.2 Spectral characteristics analysis of paddy fields

The rice transplanting period in the three provinces of northeastern China is basically in late May. Therefore, from the perspective of spectral reflection characteristics of paddy fields, the spectral reflectance changes in early May and mid-May were closer to the water body, that is, there was higher
reflectance in the blue and green bands, but there were still some differences between its reflectivity and clean water changes due to the shallow water surface. After transplanting of rice, the spectral characteristics of the paddy fields gradually showed the spectral characteristics of vegetation with continuous growth of plant, reflectivity of blue and red bands gradually decreased and reflectivity of the near infrared band increased gradually. With progress of rice growth, reflectivity of near infrared showed a change of first increase and then decrease. In early August, rice entered into heading stage and reflectivity in the near infrared band reached the maximum value of 38%. See Figure 3 for details.

Fig. 3. Spectral curve of paddy fields

3.3 Spectral characteristics analysis of marsh wetlands
For marsh wetlands, 3 representative wetlands were selected, including Panjin, Zhalong and Xianghai wetlands. From perspective of spectral reflectance characteristics of vegetation in marsh wetlands, its spectral characteristics were very similar to that of rice. In early August, reflectivity in near infrared band reached the maximum value of 32%. However, it could be distinguished on the time changes of spectral curve due to the difference of rejuvenation period between wetland and paddy field. The near-infrared spectrum of marsh wetland increased progressively from mid-May with the growth of crops while high value region of near-infrared reflectivity of rice suddenly increased around mid-June, showing a step-by-step increase, as shown in Figure 4.

Fig. 4. Spectral curve of marsh wetlands

3.4 Spectral characteristics analysis of rivers
From perspective of spectral reflection characteristics of river wetlands, the spectral characteristics were similar to the reflection spectra of lakes. The high value region of reflectivity was also concentrated in the blue-green light bands. However, it was affected by other vegetation types, especially for the river wetlands, high value also appeared in the near-infrared band, around 865nm, while low value appeared around 940nm (18 band).
3.5 Analysis on change of NDVI and NDWI index time series
The time series changes of NDVI and NDWI indexes of lakes and reservoir, river, paddy field and marsh wetlands from May to October are shown in Figure 6. From perspective of NDVI values, NDVI value was all below 0 for lakes and reservoirs and was a single peak for curve paddy field. The NDVI value of paddy field in the middle and early May was very close to the NDVI value of rivers. With transplanting of rice in the three provinces of northeastern China in late May, the vegetation index started to increase slowly. NDVI value of paddy field began to increase rapidly in early June due to turning green of rice from the end of May, with the steep growth slope. It reached the maximum value of about 0.67 at heading stage in early August, and then started to decrease slowly, and the vegetation index tended to be stable after entering the mature period. NDVI curve of marsh wetland was similar to that of paddy field. However, as marsh wetland returned to green earlier, NDVI value started to increase slowly in late May and reached the highest value in early August, and then decreased slowly, with no steep growth slope phenomenon. From perspective of NDWI value, the change curve was opposite to the NDVI curve, and the NDWI values of lakes and reservoirs were all greater than 0, while NDWI values of other three land form types were lower than 0. NDWI value of crops was lower during their vigorous growth, the NDWI values of paddy field and marsh wetlands all reach the lowest values in early August, namely, -0.49 and -0.58, respectively. The NDWI value of rivers varied slightly, fluctuating between -0.1 and -0.2.

4. CONCLUSION
In this paper, the time series FY3/MERSI data were used comprehensively to analyze the spectral information of many underlying surfaces. The main conclusions were as follows:

There are differences in the spectral curves for different types of wetlands, especially for the marsh wetlands and paddy fields with growth cycles. The differences are more obvious, as compared with the spectral curves of lakes, reservoirs and rivers. The spectra of lakes, reservoirs and rivers conform to the changing characteristics of water bodies, especially for lakes and reservoirs. Spectral characteristics of rivers are slightly different from that of pure water bodies due to the influence of
riverbed width and riparian vegetation. Lakes, reservoirs and rivers have low reflectivity near 940nm. However, the high reflectivity of the rivers occurs near 865nm, which is higher than that of the blue band, while that of the blue band for lakes and reservoirs is higher than reflectivity of 865nm.

For the NDVI and NDWI indexes, the time series change characteristics are obvious. In particular, exponential curves of different types of wetlands differ greatly with seasonal changes, and the curves of lakes and reservoirs and rivers have little change during the whole growth period. The curves of paddy field and marsh wetlands show a single peak or a single valley, but there is a steep slope in the curve of the paddy field, and the change in the marsh wetland is gentle. Therefore, the wetlands can be extracted relatively clearly by using the changing characteristics of NDVI and NDWI in different wetlands at key crop development stages.

Acknowledgement
This study was financially supported by the Key R&D Program of Liaoning Province (2018108004) and the Program of the Laboratory of Radiometric Calibration and Validation for Environmental Satellites, the China Meteorological Administration.

References
[1] B. Cui, Z. Yang, *Wetlands*, 1–10(2009)
[2] X. Mou, X. Liu, B. Yan, B. Cui, *Wetland Science*, 13, 19-26(2015)
[3] P. Wang, R. Wan, G. Yang, *Wetland Science*, 15,114-124(2017)
[4] D. Han, Y. Yang, Y. Yang, K. Li, *Acta Ecologica Sinica*, 32, 1293-1307(2012)
[5] Z. Szantoi, F.J. Escobedo, A. Abd-Elrahman, L. Pearlstine, B. Dewitt, S. Smith, *Environmental Monitoring Assessment*, 187, 262-277(2015)
[6] M. Gracz, P.H. Glaser, *Wetlands Ecology Management*, 25, 87-104(2017)
[7] H. Lu, *Village Technology*, 2, 75-76(2017)
[8] S. Zhang, S. Zhang, J. Zhang, *Chinese Geographical Science*, 10, 68-73(2000)
[9] M. Lu, L. Sheng, L. Zhang, *Wetland Science*, 11, 114-120(2013)
[10] V. Klemas, *International Journal of Remote Sensing*, 34, 6286-6320(2013)
[11] K. Kindscher, A. Fraser, M.E. Jakubauskas, D.M. Debinski, *Wetlands Ecology and Management*, 5, 265-273(1998)
[12] R. Chopra, V.K. Verma, P.K. Sharma, *International Journal of Remote Sensing*, 22, 89-98(2001)
[13] C. Prigent, E. Matthews, F. Aires, W.B. Rossow, *Geophysical Research Letters*, 28, 4631-4634(2001)
[14] D.A. Roshier, R.M. Rumbachs, *Journal of Arid Environments*, 56, 249-263(2004)
[15] M. Zhang, Y.N. Zeng, Y.S. Zhu, *Journal of Remote Sensing*, 21, 479–492(2017)
[16] Y.Y. Chen, J.Z. Ma, X.T. Liu, *China wetlands encyclopedia*; 10–15(2009)
[17] J.W.J. Rouse, R.H. Haas, J.A. Schell, D.W. Deering, *Monitoring vegetation systems in the Great Plains with Ers*, 351(1974)
[18] S.K. Mcfeeters, *International Journal of Remote Sensing*, 17, 1425-1432(1996)