Application of Sentinel-1A Data in Offshore Wind Field Retrieval Within Guangdong Province

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Abstract. Offshore wind is an important source of information for monitoring the interaction between fishery and marine water vapor environment. In this paper, the CMOD5 function was used to invert the wind field in the coastal waters of Guangdong province in March, May, July and December 2017. Compared with the measured wind speed, the reasonable result of the inversion wind speed is generally higher, with the mean absolute deviation of 1.95 m/s, the root mean square error of 2.7 m/s, and the correlation coefficient of 0.8. Due to the measured data not exactly matching the satellite transit time, the error in December is large. The inversion results of Sentinel-1A images are consistent with the measured data generally, which verifies that the COMD5 function is applicable to the inversion of offshore high-resolution marine wind field in Guangdong province, and provides a possibility for the next step of estimating the wind energy resources and reserves in Guangdong province.

Keywords: Offshore wind · Sentinel-1A · Wind stripe · Synthetic aperture radar · Remote sensing inversion

1 Introduction

Traditional methods of measuring wind are limited by cost and it is difficult to achieve continuous monitoring on a large scale. The low spatial resolution of scatterometer is easy to be affected by land echo in the coastal area, so it's unable to measure areas within a few tens of kilometers near the coast [1, 2]. SAR has the advantages of high spatial resolution, high precision, low cost, and sufficient data resources, and has become an important technical means for inverting the wind field.

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The geophysical mode function (GMF) is a function describing the relationship between radar backscattering cross section and wind speed and wind direction. For the polarization mode of C-band VV, the CMOD5 function is a high wind speed inversion model improved by Hersbach [3] on the basis of CMOD4 function [4]. Based on the RISAT-1 images, Jagdish used the CMOD5.N, CMOD5 and CMOD_IFR2 functions to invert the wind field in the North Indian Ocean [5]. Qi Xianyun used the Yangtze River Port as a research area to compare the suitability of the wind field with CMOD4, CMOD-IFR2 and CMOD5 functions [6]. Based on Sentinel-1 images off the coast of the west coast of the United States, Zhang Kangyu compared several functions of CMOD4, CMOD-IFR2, CMOD5 and CMOD5.N, concluded that the CMOD5 function had higher accuracy in the process of high-precision wind field inversion [7]. The above scholars have used the CMOD5 function to invert the sea surface wind field and get good results. However, due to the particularity of the region, whether the function is suitable for high-precision wind field inversion of SAR images in the coastal waters of Guangdong Province remains to be verified.

With the Sentinel-1 satellite launched in 2014, the sea surface wind field of Guangdong Province was inversion based on CMOD5 function and wind stripe, to explore the Sentinel-1A images are applied to the possibility of the high-resolution wind retrieval in coastal areas of Guangdong Province, and provide a more accurate assessment of offshore wind energy resources in Guangdong Province.

2 Method

2.1 Data Pre-processing

The offshore wind measurement sites selected in this paper are distributed as evenly as possible in the coastal side of Guangdong Province. Sentinel-1A is one of the satellites in the binary system carrying a C-band sensor. The GRD images used in the paper have been processed multilooking, and the interference wide mode is IW, which data is 250 km in width, 20 m in distance resolution and 22 m in azimuth resolution.

Sentinel-1A image preprocessing can be seen in Fig. 1. Radiation calibration is to convert the gray value of Sentinel-1A image into normalized backscattering cross section (NRCS). Speckle filtering is to suppress speckle noise of remote sensing image and remove speckle noise of image itself. Terrain correction is to eliminate image distortion caused by terrain fluctuations.

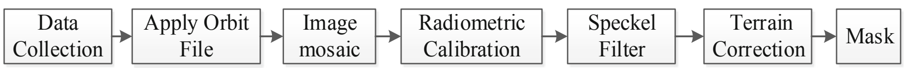

Fig. 1. The flow chart of image data preprocessing procedure

2.2 Wind Retrieval

The spiral of the atmospheric boundary layer is formed on the surface of the vortex, which result the periodic fringe in SAR image, which called the wind stripe [8]. This paper adopted the Fast Fourier Transform (FFT) method based on frequency domain extracted the sea wind direction of SAR image:

$$Y_{l,m} = \sum_{j=1}^{N} \sum_{k=1}^{N} X_{j,k} e^{-\frac{2\pi i(jl+km)}{N}} \tag{1}$$

Where Y is the low spectral number of the image, X is the grayscale value of the image after calibration, $l, m = 1, 2, \cdots, N$.

In this paper, the SAR data with VV polarization mode are adopted, and CMOD5 function was used to invert wind speed. The basic form of CMOD5 function is:

$$\sigma_{vv}^{0} = B_0(1 + B_1 cos\phi + B_2 cos2\phi)^{1.6} \tag{2}$$

Among them, B_0, B_1, B_2 is a function of wind speed V and incident angle θ [9].

After data preprocessing Sentinel-1A images, we used FFT to extract the image wind stripe information, then contrasted CCMP data, and removed the 180° ambiguity of the wind direction (see Fig. 2). Finally, inverted the offshore wind speed based on CMOD5 function. The wind field inversion flow chart is shown in Fig. 3.

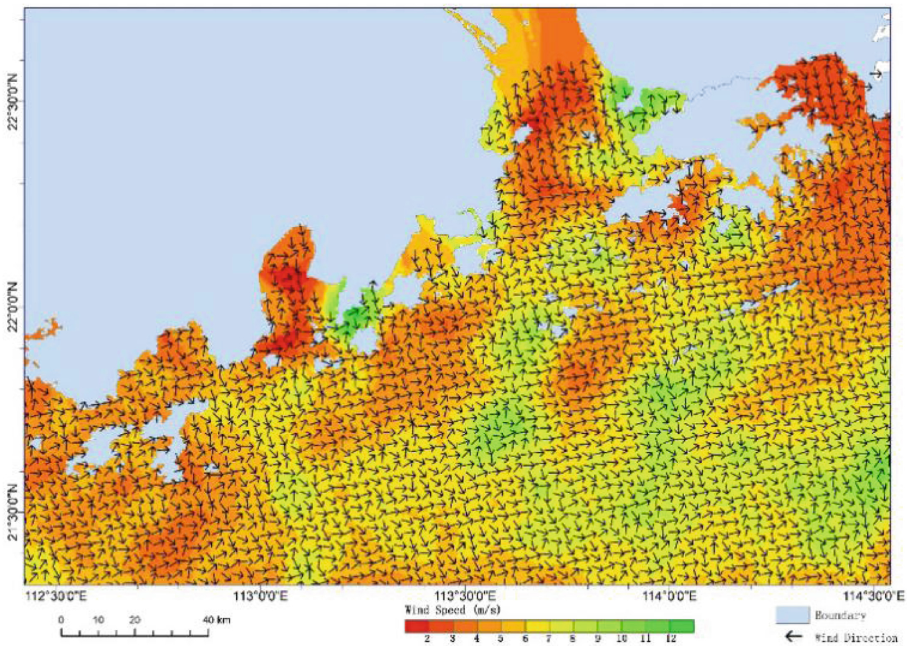

Fig. 2. An inversion wind field near the Pearl River Delta of Guangdong province

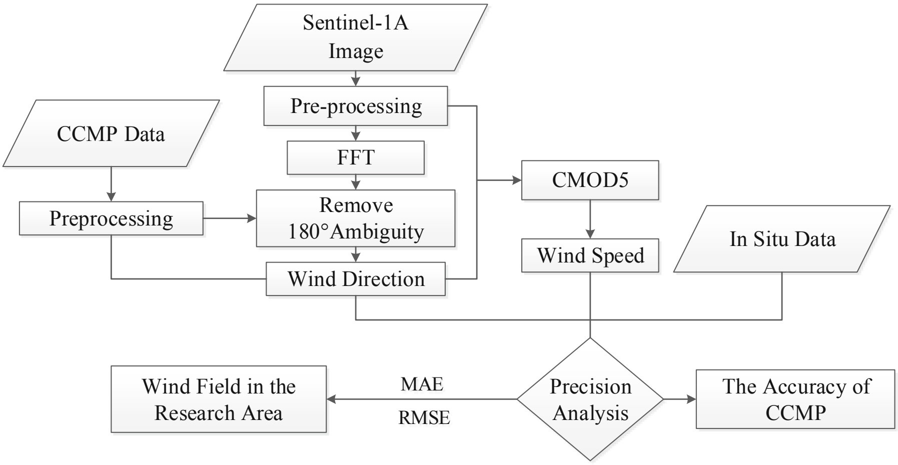

Fig. 3. The flow chart of wind field inversion

3 Results and Discussion

3.1 Compare with the Measured Data

The average wind speed of the inversion within 3 km of each station was taken as the inversion wind speed of the station. The MAE of the wind speed inversion is about 1.95 m/s, with RMSE of 2.70 m/s, and the correlation coefficient of 0.8. On the whole, the two sets of data have small error and high correlation, indicating that the overall inversion wind speed of these samples is consistent with the in situ wind speed.

From the comparison and analysis of inversion results from different months (Table 1), it can be seen that the inversion wind speed of CMOD5 function is higher than the measured wind speed, the average wind speed in March, May and July are relatively close, but the wind speed in December is significantly higher than other three months, with the average wind speed of 8.71 m/s. This is due to the winter in the coastal areas of Guangdong province, under the influence of cold air, the sea surface wind speed increasing significantly compared with other seasons. The MAE and RMSE in March, May and July between the inversion results and the measured data are both less than 2 m/s, and the correlation coefficient is also within the range of 0.7 to 0.9, indicating that there is a good consistency and correlation between the two sets of data in these three months, and the inversion results have a high accuracy. In December, the MAE is 3.64 m/s and the RMSE is 4.49 m/s, it can be seen that there was a large error between the retrieved wind speed and the in situ data. It can be seen that the inversion wind field in December has a large deviation from the measured data, most of which is due to the time difference between the image acquisition time and the measured data, in the case that the sea surface wind field changes greatly in winter, the wind speed is caused the difference between the two is also very large.

Table 1. Comparison of wind field inversion results by month.

Month	Number of samples	Average measured wind speed (m/s)	Average retrieval wind speed (m/s)	MAE (m/s)	RMSE (m/s)
March	9	6.99	7.16	1.57	1.74
May	15	4.02	5.17	1.47	1.93
July	18	5.97	6.10	1.23	1.57
December	14	8.71	10.46	3.64	4.49
All	56	6.30	7.11	1.95	2.70

3.2 Compare with the CCMP Data

In order to further discuss the reason for the large inversion error of wind speed in December, we compared the CCMP data of December with the data of the actual measurement station, and found out that MAE and RMSE are 2.96 m/s and 4.02 m/s respectively, with the correlation coefficient of 0.59 (Table 2). It can be seen that there are also some differences between CCMP data and in situ data in December, which is similar to the comparison between wind speed inversion result and in situ wind field data. In December of winter, the wind speed is the strongest, the number of windy days is the highest, and the number of windy days in the northeastern South China Sea can reach more than 20 days [10]. While the Sentinel-1A satellite transit time, the CCMP data time and actual measurement time points were not completely matched, resulting in large deviations between the retrieval wind field, the forecast wind field and the measured data in the weather with high wind speed.

Table 2. Comparison of CCMP wind fields in December

Station	Average measured wind speed/(m/s)	Average CCMP wind speed/(m/s)	MAE/ (m/s)	RMSE/ (m/s)
G3358	7.65	13.08	5.43	6.85
G7427	9.40	7.00	3.54	4.28
59490	1.7	7.61	5.80	5.80
G3704	2.87	4.66	1.85	2.24
G3597	14.35	13.31	1.30	1.66
G1368	13.05	8.60	4.45	4.48
G7526	11.40	11.46	0.27	0.28
Total	8.71	9.18	2.96	4.02

4 Conclusion

The reasonable inversion results in this paper prove the applicability of the COMD5 function in the research area, and provides the possibility for further estimation of wind energy resources in Guangdong province based on Sentinel-1A images. In addition, we conclude that the inversion wind speed of the CMOD5 function is mostly higher than the actual wind speed, and the characteristics of the offshore wind speed in Guangdong Province in December are verified to be larger than other seasons, leading to a large error between the inversion wind speed and the measured data. Further work like a large-scale wind farm retrieval or other methods will be applied.

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References

1. Zhang, L., Shi, H., et al.: Overview of methods for satellite borne SAR image retrieval of sea surface wind field. Mar. Sci. Bull. **31**(6), 713–720 (2012)
2. Monaldo, F.M., Thompson, D.R., Beal, R.C., et al.: Comparison of SAR-derived wind speed with model predictions and ocean buoy measurements. Geosci. Remote Sens. IEEE Trans. **39**(12), 2587–2600 (2002)
3. Hersbach, H., Stoffelen, A., Haan, S.D.: An improved C-band scatterometer ocean geophysical model function: CMOD5. J. Geophys. Res. Oceans **112**(C3), 6–24 (2007)
4. Stoffelen, A., Anderson, D.: Scatterometer data interpretation: estimation and validation of the transfer function CMOD4. J. Geophys. Res. Oceans **102**(C3), 5767–5780 (1997)
5. Jagdish, K.S.A., Chakraborty, A., Kumar, R.: Validation of wind speed retrieval from RISAT-1 SAR images of the North Indian Ocean. Remote Sens. Lett. **9**(5), 421–428 (2018)
6. Qi, X., Zhou, Y., Tian, B., et al.: Inversion of the wind field near the Yangtze River Estuary based on Sentinel-1A. J. East China Norm. Univ. (Nat. Sci.) (6), 126–135 (2017)
7. Zhang, K., Huang, J., Xu, X., et al.: Spatial scale effect on wind speed retrieval accuracy using sentinel-1 copolarization SAR. IEEE Geosci. Remote Sens. Lett. **PP**(99), 1–5 (2018)
8. Chang, J.: Research on spaceborne SAR remote sensing technology and application of offshore offshore wind energy. Ocean University of China, Qingdao (2012)
9. Han, Y.: SAR and CALIPSO data inversion of sea surface wind speed, pp. 1–57, Ocean University of China, Qingdao (2010)
10. Wang, H., Sui, W.: Analysis of seasonal variation of offshore wind in 18 coastal regions of China based on CCMP wind field. Meteorol. Sci. Technol. **41**(4), 720–725 (2013)