

LARGE SCALE OCEAN CURRENTS DECOMPOSITION FROM SAR DOPPLER INFORMATION AND NRCS

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Abstract—It has been confirmed that spaceborne SAR can be used for measuring sea surface current and three-dimensional Ekman current under strong storm. However, retrieval of different ingredients of sea surface current from SAR Doppler information remains an important problem. In this study, we attempt to retrieve sea surface two-dimensional Ekman current as well as geostrophic velocity fields based on the combination of SAR backscatter coefficients NRCS and Doppler information. Results show that the retrieval scheme proposed in this study is effective and suitable for different current ingredients retrieval that under general sea surface state.

Keywords—SAR Doppler, current direction retrieval, Ekman current, geostrophic current

1. INTRODUCTION

Ocean current is one of most important marine research topics. Large-scale Sea surface currents on the sea surface are generally composed of geostrophic or quasi-geostrophic currents, Ekman currents, and background currents. For ocean current remote sensing, spaceborne SAR is the main technology, such as Sentinel-1 satellite of European Space Agency, which has released retrieved ocean current product. In terms of ocean current remote sensing, [1] proposed the DopRIM model in 2005 and discovered that spaceborne SAR Doppler information can be used to retrieve ocean currents. In 2013, [2] retrieved the two

components of geostrophic current from long time series ascending and descending satellite images. In 2019 and 2020, [3] and [4] proposed new current direction retrieval methods in an attempt to retrieve sea surface vectors. In 2022, [5] successfully retrieved the three-dimensional vector field of Ekman current under strong storm, and [6] also proved that the sea surface velocity measured by spaceborne SAR is not radial.

In this paper, we will explore the separation scheme of sea surface geostrophic current and Ekman current from retrieved sea surface current image, and provide an effective method for the retrieval of two-dimensional sea surface Ekman current as well as the velocity field of sea surface geostrophic current.

2. DATA AND METHOD

2.1 Data

In the study we choose the IW mode OCN product of Sentinel-1 satellite as the research data. The product include sea surface velocity parameter Radvel, and 10 meters wind field parameter Windspeed and Winddirection. Radvel is retrieved from SAR Doppler information, and Windspeed with Winddirection are retrieved from the NRCS. We also take numerical model data ECMWF wind speed and ECMWF wind direction as reference. These two parameters are simulated by the middle-scale weather model ECMWF. The retrieved 10 meter wind field product can be used to calculate Ekman current that generated by the sea surface

wind. The selected OCN image is imaging at Gulf of Thailand on Dec. 3, 2020 around 11am., shown as Fig.1. From the currents field distribution in Fig. 1, we can see that sea surface velocity mainly consists of geostrophic current component represented by Box A, Ekman current component represented by Box B, and the background current component represented by Box C. Among them, geostrophic current take the main information of Fig.1 on sea surface current field.

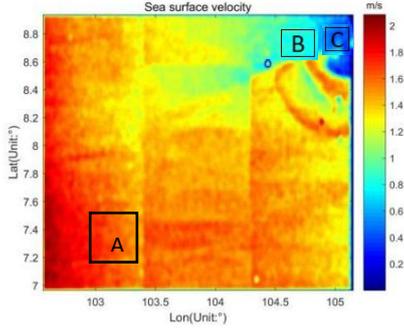


Fig.1 Retrieved sea surface current from SAR Doppler information. Box A represents for the geostrophic current ingredient of sea surface current, Box B for the Ekman current ingredient and Box C for the background current ingredient.

Since the ingredients of sea surface geostrophic current and Ekman current are superimposed on the image, the overall distribution of Ekman current cannot be directly shown Fig.1, while the background current generally satisfies that current velocity is less than 0.2m/s.

2.2 METHOD

In 2022, [5] calculated the three-dimensional Ekman current field from the classic Ekman current theory at the sea surface area that without geostrophic current. The calculation highly rely on the retrieval of Ekman depth, which can then be used to calculate the three-dimensional u and v component fields in Ekman current theory. However, at the general sea surface area, geostrophic current take the main

part which must need to take into consideration when retrieving sea surface current, so retrieval Ekman current under the condition of strong geostrophic current and then calculating geostrophic current is the total work of this study.

Firstly, we calculate the Ekman current part. The solution for the components u in the east-west direction and v in the north- south direction of Ekman current are

$$u = \frac{\sqrt{2}\pi}{f\rho_0 D} e^{\frac{\pi z}{D}} [\tau_x \sin(\frac{\pi z}{D} + \frac{\pi}{4}) + \tau_y \cos(\frac{\pi z}{D} + \frac{\pi}{4})] \quad (1)$$

$$v = \frac{\sqrt{2}\pi}{f\rho_0 D} e^{\frac{\pi z}{D}} [-\tau_x \cos(\frac{\pi z}{D} + \frac{\pi}{4}) + \tau_y \sin(\frac{\pi z}{D} + \frac{\pi}{4})]$$

where wind stress τ can be calculated from the wind field that retrieved from SAR NRCS data (shown in Fig.2). In the above equation (1), once the Ekman depth D is calculated, the three-dimensional Ekman current can be directly calculated from the wind field data retrieved from satellites. And based on the empirical calculation formula of Ekman depth D

$$D = \frac{7.6 * V}{\sqrt{\sin(lat)}} \quad (2)$$

where V is the wind speed and lat is the latitude of the research area. From equation (2), we find that Ekman depth D is only a function of sea surface wind speed. Therefore, with wind speed retrieved from SAR NRCS we can directly calculate Ekman depth D. By substituting the calculated D into equation (1), u and v components of Ekman current can be obtained easily as well. The whole retrieval scheme is shown in Fig. 2

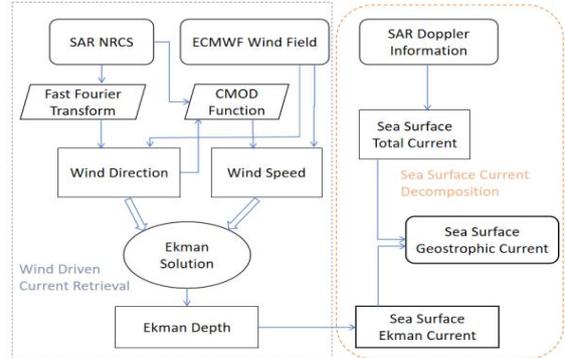


Fig.2 Retrieval scheme for calculating Ekman current and geostrophic current from the retrieved wind and current fields on sea surface.

3. RESULTS AND DISCUSSION

From the retrieval scheme in Fig.2, Ekman depth with Ekman current components u , and v are calculated from the sea surface wind field data. Combined with the sea surface total current field image which is retrieved from SAR Doppler information, the ingredient of sea surface geostrophic current can be extracted by subtracting Ekman current ingredient from total current field. All the retrieval results are shown in Fig.3 and Fig.4.

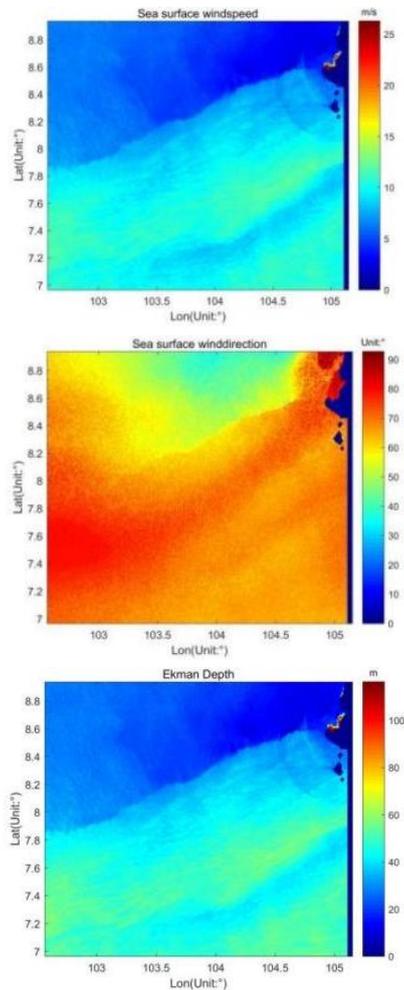


Fig.3 Retrieved sea surface wind field with calculated Ekman Depth.

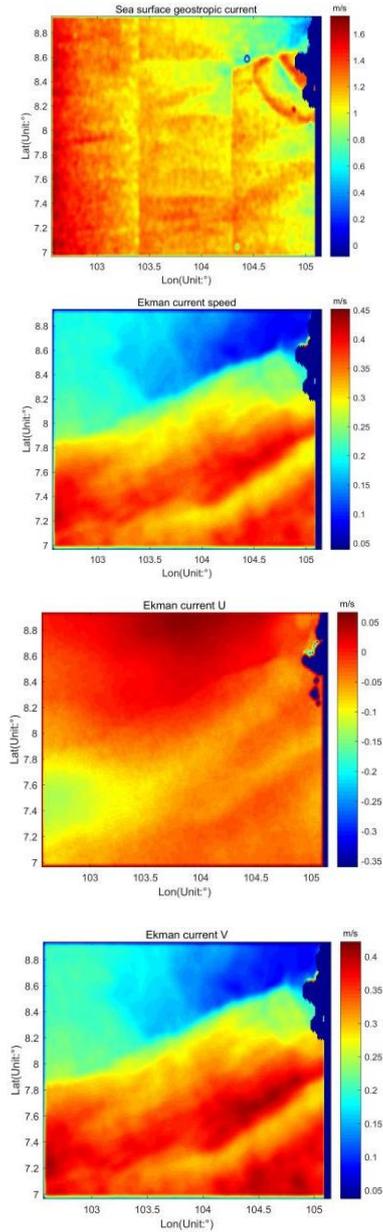


Fig. 4 Retrieved sea surface geostrophic current and Ekman current with its two components u and v .

From Fig.3 we can see that the value distribution texture of Ekman Depth image is similar with the one of sea surface wind speed image, as well as the one of Ekman current speed image in Fig.4. The component u of Ekman current has a different value distribution to the component v in Fig.4. But geostrophic current image in Fig.4 has a similar texture with the sea surface current image in Fig.1.

For the similarity of value distribution between Ekman Depth image, wind speed image and Ekman current speed image, the reason is Ekman Depth is directly calculated from wind speed, while [5] also proved that Ekman current speed is the function of Ekman Depth, so their images look both similar. The component u are in north-south direction, while v in west-east direction, so their images are not same.

For the retrieval of sea surface geostrophic current part, the ingredient of background current is also superimposed on Fig.4b, which leads to a bias on the geostrophic current result. However, so far we know little about the properties of background current of the sea surface, so we can not separate geostrophic current from the background current individually. Therefore sea surface background current remains a great problem to further research.

With the decomposition of Ekman current and geostrophic current, both Ekman pumping and Rossby wave can be easily identified from remote sensing images. Ekman pumping has a general effect on marine ecosystem, while Rossby wave indicates the changes of ocean dynamic system and basin-scale climate system. So with this study, more new researches are expected to be conducted.

4. REFERENCES

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