Internal Wave Detection in SAR Image

YESSY ARVELYNA,*

MASAKI OSHIMA*

**Tokyo University of Mercantile Marine*

Department of Ocean Information System Engineering,

2-1-6 Ecchujima, Koto-ku, Tokyo 135-8533, Japan.

Phone: (+81) –3-3641-1172. Ext. 8705, 8706 Fax: (+81)-3-5245-7417

{oshima,yessy_a}@ipc.tosho-u.ac.jp

ABATRACT

Bragg scattering process in sea surface represent the meso-scale feature of sea processes in SAR image. SAR image data is used to for large scales area of monitoring on near real time data. In this research, wavelet analysis is applied to monitor internal wave in ERS-2 SAR image. Wavelet transform of SAR image can be used as feature detection and image enhancement. Furthermore, wavelet analysis use of local analysis to analyze a shorter region in image in time and scale data, allow precise information than time and frequency region analysis such as Fourier analysis.

Internal wave in ERS-2 SAR image were observed around Lombok Strait during 1996-2001 by using 2D Symlet analysis. Symlet wavelet allows the symmetric extension of data at the image boundaries, prevents discontinuities by a periodic wrapping of data in fast algorithm and space-saving code. The detection result is compared with Radon Transform, which shown that wavelet analysis has advantage in spatial analysis which is make easier in detection. Lombok Strait is chosen as study area because this strait is a major passage of the flow from Pacific Ocean to Indonesian seas (ARLINDO) and passage of Indian Ocean Kelvin wave to Makassar Strait.

Keyword: SAR image, internal wave, wavelet analysis.

1. INTRODUCTION

Internal wave is generally produced in upper layer of sea surface by tidal and atmospheric condition. These waves tend to become soliton-like with large amplitudes within several kilometers. Internal waves perturb current and density field, initiate bottom sediment re-suspension and mix nutrients to photic zone. The detection of internal wave would be necessary for the design of deepwater offshore production facilities (1).

Recently, SAR image data is frequently used to monitor various sea processes at and near sea surface such as internal wave because of the capability in large scales area of sea monitoring by using near real time data. In shallow waters, internal waves are visible in SAR image because it modulate sea surface, increase/decrease sea surface roughness, which is affected to radar backscatter through Bragg scattering process (2). In the valleys of modulation waves, diffuse scattering occur more than in its crest lowering backscattering coefficient. Then, in SAR image the valley of wave appears darker than crest. In a wave packet, internal wave appears as dark and white strips in image. The length between crests in wave packet is used to calculate the speed of internal wave. Then combined with seawater density, the oceanic mixed layer and the period of wave can be observed (3).

This paper analyzes the detection of internal wave and noise reduction in SAR image by using wavelet analysis. Previous research applied Gaussian wavelet transform to track the evolution of mesoscale features such as oil spill, fronts, eddie, data reduction and image enhancement (4). For speckle filtering in SAR image, Symmetry Daubechies wavelets performed to better than standard filter such as Lee, Kuan (5)

2. MATERIAL AND METHODS

Quick look ERS-2 SAR image data around Lombok Strait from 1996 to 2001 is used in detection of internal wave in SAR image. Lombok Strait is chosen as study area because this strait is a major passage of the flow from Pacific Ocean to Indonesian seas (ARLINDO) and passage of Indian Ocean Kelvin wave to Makassar Strait (6). So far, internal wave around Lombok Strait has been studied by using ERS SAR data (7).

2.1. Wavelet Analysis

Wavelet analysis performs local analysis to analyze a shorter region in image in time and scale data. Thus it allows more precise information than time and frequency region analysis such as Fourier analysis. As nearly symmetrical wavelet adopted from Daubechies wavelet, two-dimensional Symlet wavelet is chosen to allow the symmetric extension of data at the image boundaries and prevents discontinuities by a periodic wrapping of data. Furthermore with orthogonal analysis and existence of scaling function allow fast algorithm and space-saving code. Symlet wavelet is described as follows (8):

$$W(z) = U(z)\overline{U\left(\frac{1}{z}\right)}$$

where U > 1, with consideration that function $|m_0(\omega)|^2$ as a function W of $z = e^{i\omega}$, which is applied on following equation:

$$|m_0(\omega)|^2 = \left(\cos^2\frac{\omega}{2}\right)^N P\left(\sin^2\left(\frac{\omega}{2}\right)\right)$$

which is derived from,

$$P(y) = \sum_{k=0}^{N-1} C_k^{N-1+k} y^k$$

$$m_0(\omega) = \frac{1}{\sqrt{2}} \sum_{k=0}^{2N-1} h_k e^{-ik\omega}$$

where m_0 is scaling function, P(y) is transfer function and C_k^{N-1+k} denotes the binomial coefficient.

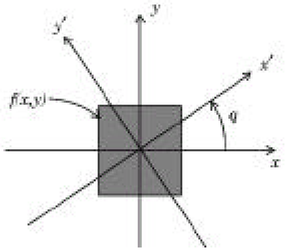
Symlet wavelet is tested with different level of synthesize image on horizontal, diagonal, and vertical detail, and approximation to detect internal wave in image. Since SAR image consist speckle noise reducing information in image, threshold is applied to enhance image (de-noise). Mean to standard deviation ratio is used to compare the result of noise reduction.

2.2. Radon Transform

The result of detection is compared with Radon Transform one of powerful method in edge detection by using Hough Transform. Radon Transform computes projection of an image matrix along specified directions as follows:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} ? \begin{bmatrix} ?\cos ? & \sin ? \\ ?? \sin ? & \cos ? \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$R_?(x') ? \int_{??}^{?} f(x' \cos ? ? y' \sin ?, x' \sin ? ? y' \cos ?) dy'$$



3. RESULTS AND DISCUSSION

Strong internal wave in the form of soliton group in ERS-2 SAR image were observed in Lombok Strait during 1996-2001 by using 2D Symlet analysis (table 1). Symlet wavelet is applied with different coefficient (a) and level. Higher level of computation retain smoother version of image. Meanwhile higher coefficient compressed the wavelet. It found that the crests of internal wave are detected on horizontal and vertical detail coefficient at level 3 to 5 (figure 1 and 2). Lower threshold between 4-6.5 is applied to the detail coefficient for the wavelet to reduce noise in image. Higher coefficient i.e. a = 6 shows the lowest mean to SD ratio of image. Image intensity is proportional to backscattering of coefficient. The diffuse scattering of radar backscatter in valley of wave occurs more than on its crest, lowering backscattering coefficient. Thus in profile of image intensity, the crest of internal wave appears higher than crest in profile (figure 4). In figure 2, the speed of internal wave can be measured from the distance between crest. The wavelength of image is about 5 km. Figure 1 and 2 show the detection results of internal waves on November 5, 1997 and September 5, 1999. Strong internal wave is pointed by arrow. The result of detection with Radon Transform is shown in figure 3. The crests of internal wave are detected as lines along 0^o, 90^o, and 180^o, and located from about –135 to 50 or at middle to bottom of image.

4. CONCLUSION

The use of wavelet analysis has been demonstrated to for internal wave analysis in ERS-2 SAR images data. The wavelet transform of images can be used for feature detection and image enhancement. The projection of Radon transform uses the information about degree of projection and position of detected feature. Thus, wavelet analysis has advantage in spatial analysis to detect internal wave in SAR image, which is make easier in detection.

Acknowledgements

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Table 1. The incidence of internal wave in ERS-2 SAR image

No.	Location of incidence of internal wave	
	Lombok Strait	**near Kanggean Island**
1.	1996/4/23	1996/4/23
2.	1996/4/24	-
3	-	1996/12/25
4.	1997/7/7	-
5.	1997/9/30	-
6.	1997/10/1	-
7.	1997/11/5	1997/11/5
8.	1998/11/4	1998/11/4
9.	1999/12/15	1999/12/15
10.	1999/12/31	-
11.	2000/1/19	-
12.	2001/8/20	-
13.	2001/9/5	-

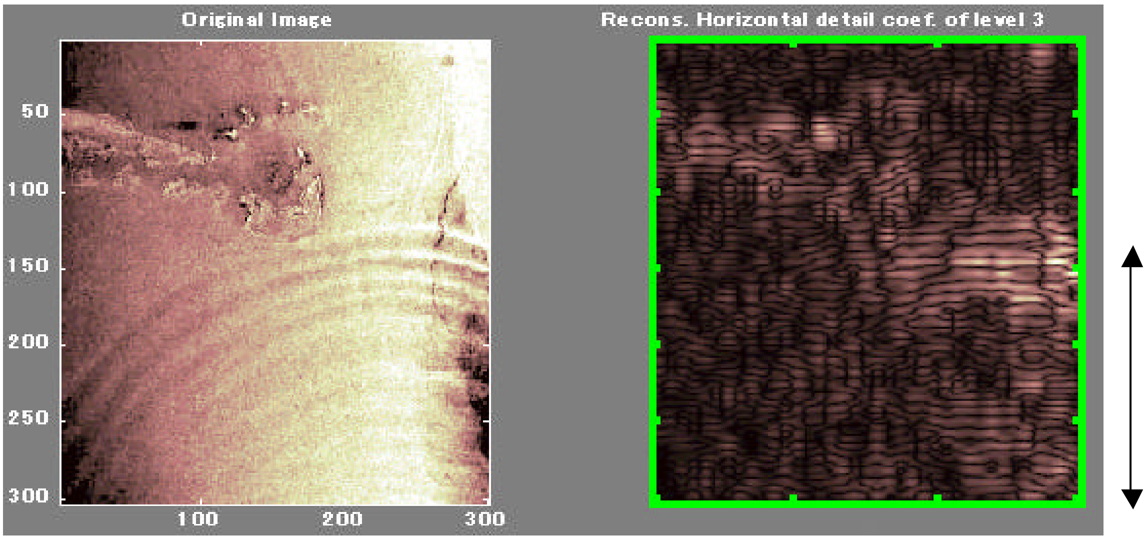

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Figure 1. Detection Result by using Reconstruction Horizontal Level 3 of Wavelet Analysis

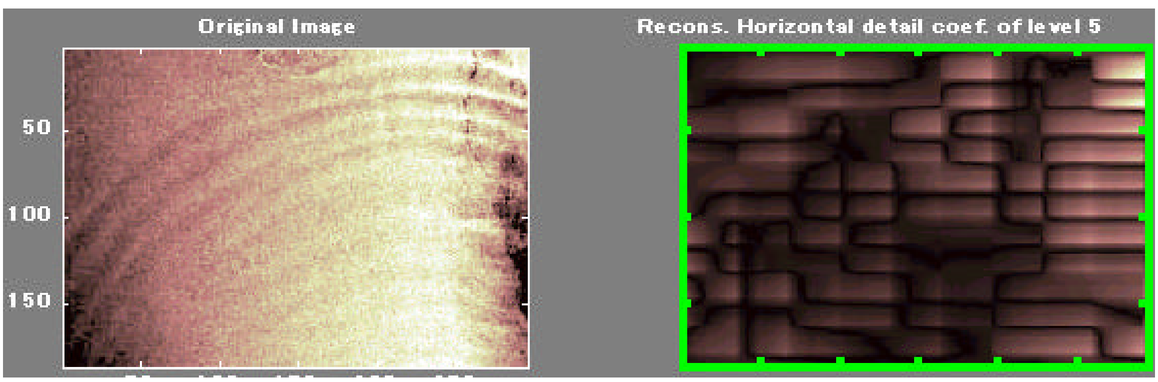

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Figure 2. Detection Result by using Reconstruction Horizontal Level 5 of Wavelet Analysis

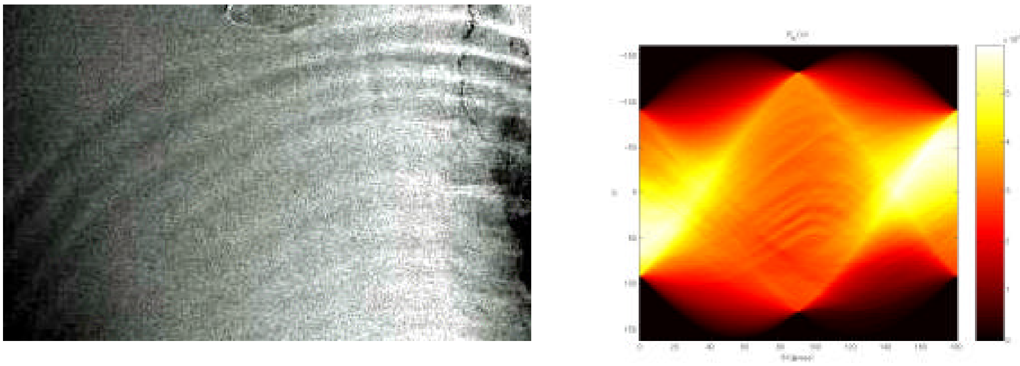

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Figure 3. Detection Result of Internal Wave with Radon Transform

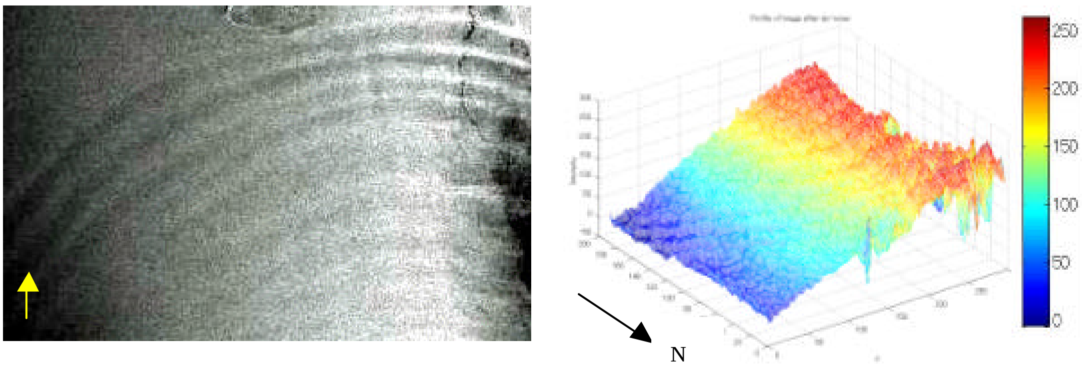

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Figure 4. Profile of image intensity of internal wave in ERS SAR image data