I-16

Wavelet Analysis for Internal Wave Monitoring in SAR Image

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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. 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. This paper analyzes the detection of internal wave and noise reduction in SAR image by using Symlet wavelet analysis. For speckle filtering in SAR image, Symmetry Daubechies wavelets performed to better than standard filter such as Lee, Kuan (2)

2. MATERIAL AND METHODS

Quick look ERS-2 SAR image data around Lombok Strait from 1996 to 2001 is used to monitor the occurrence of internal wave in SAR image. Meanwhile sea surface temperature (SST) data, derived from NOAA AVHRR images, is obtained to compare water-mass distribution and ocean circulation with sea surface roughness from ERS-2 SAR data. 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. So far, internal wave around Lombok Strait has been studied by using ERS SAR data (3).

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 (4):

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

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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:

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

$$P(y) = \sum_{k=0}^{N-1} C_k^{N-1+k} y^k, \quad m_0(\omega) = \frac{1}{\sqrt{2}} \sum_{k=0}^{2N-1} h_k e^{-ik\omega w}$$

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.

3. 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. 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. 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. The difference of this ratio between original image and de-synthesized image is about 0.02%. Strong internal wave is pointed by arrow (figure 1). The wavelength of image is about 5 km.

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 satellite images can be used for feature detection and image enhancement.

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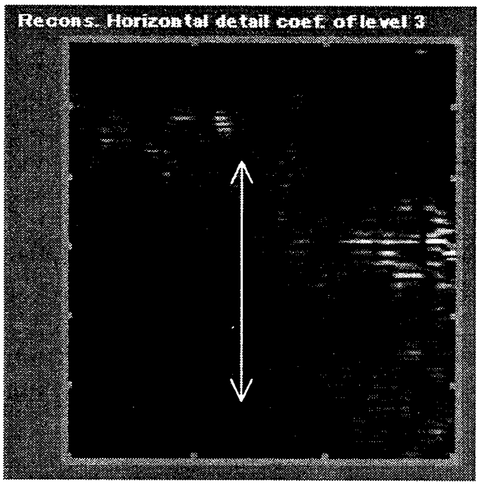

Figure 1. Quick look images of ERS SAR data (1997/11/5) and Symlet analysis result. Strong internal wave is detected on horizontal detail coefficient of level 3. Crests of internal waves are pointed by arrow.