An Experiment of Internal Waves Observation by Synthetic Aperture Radar

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Abstract: An internal wave observation experiment by SAR in South China Sea is described. Two scenes of Radarsat ScanSAR images were acquired. Internal solitary waves are found in all the two images. It is concluded that these internal waves are generated in Bashi channel. Relationship between internal wave generation and tide is studied based on analyzing of tidal data of Legaspi in Philippine. Using ocean environmental data of this sea area internal waves' amplitude and wave speed are detected by SAR images.
Keywords: Experiment, SAR, Internal waves.

1. Introduction

It is well known that spaceborne Synthetic Aperture Radar (SAR), which is highly sensitive to sea surface roughness, is a powerful instrument to observe oceanic Internal Waves. The launching of Seasat-1 started a new era of internal wave research by spaceborne SAR. Alpers[1] and Small[2] studied the internal wave SAR imaging mechanism and internal wave's parameter detection respectively. DaSilva[3] discussed the use of an ERS-1 SAR fast delivery image in near real-time for guiding an oceanographic cruise in search of internal waves.

Recently, internal wave in northern of South China Sea (SCS) become more interested to researchers. The study Ebbesmeyer[4] combined with the analysis of DMSP images, ADCP (Acoustic Doppler Current Profilers) data and history temperature data indicates that internal solitary waves near Dongsha Islands in northern of SCS rise in small channel in Luzon strait. And they propagate westward after that, the measured current induced by it at work point in outside sea of Lufeng reaches 1.5-2.0m/s (3-4knot), and its intensity can be compared with internal waves in Sulu Sea and Andaman Sea. When the solitary waves propagating westward arrive at shelf slope near Dongsha Islands the refraction effect of under water topography deflect the propagative direction to northwest. Bole[5] established the KdV numerical model and analyzes the internal solitary waves in this area using the observation data and satellite remote sensing images. Liu[6] studied the pole change problem of internal solitary waves and carries numerical modelling. Based on two scenes of RADARSAT ScanSAR images, Hsu[7] analyzed propagation character of the internal solitons near coral reef Dongsha, the wave breaking and merging when pass through the island and interact with each other. In this paper an experiment of internal waves observation by SAR in South China Sea is described. Combining SAR image with background condition the study of internal wave propagation character and parameters detection in northern of South China Sea is carried. It shows that the internal wave monitoring and warning ability of spaceborne SAR.

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2. SAR Image Acquirement

The topography of the Northern of SCS consists of Luzon strait, SCS Basin and Northern of SCS Shelf from east to west. Northern SCS Shelf, which belongs to flat deposit shelf, is seaward of the South China Shelf and distributes as NEE band. The contours of water depth approximately parallel to the coastline. Water depth changes from 4000m to 100m with higher gradient in southeast to Dongsha Islands. Previous study shows that

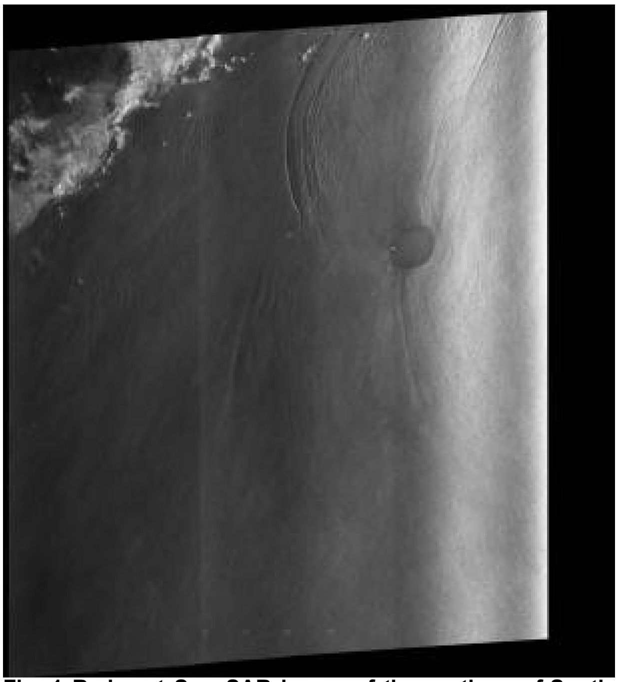

Fig. 1 Radarsat ScanSAR image of the northern of South China Sea, 2002/05/15 06:06

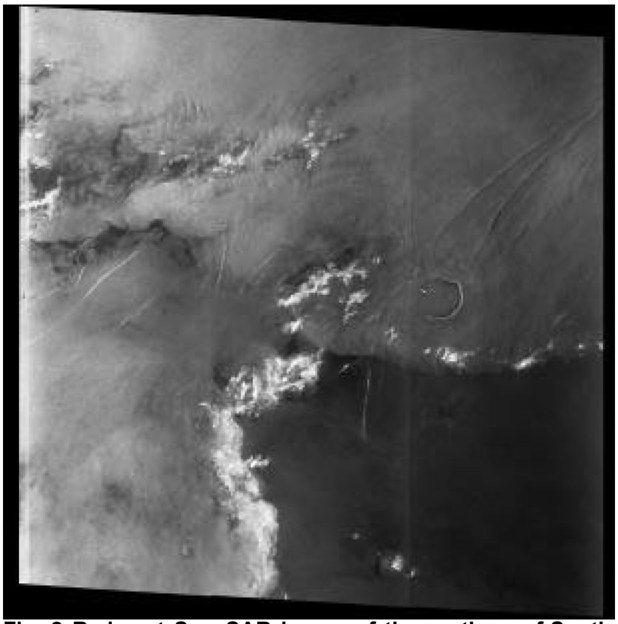

Fig. 2 Radarsat ScanSAR image of the northern of South China Sea, 2002/05/16 18:23

the thermocline in northern of South China Sea become very strong in May after its developing in April. Thus, in the middle of May internal wave can be easily encountered in the sea area near Dongsha Islands. So we carry our SAR observation experiment here. In fact, the internal wave occurs frequently in May in the South China Sea by the statistic research using SAR image[8].

RADARSAT SAR has the unique ability to shape and steer its radar beam over a 500 km range. It can revisit same area within 2 days, which is meet to our need. On the 15th and 16th May 2002 ScanSAR images were taken of the experiment region by RADARSAT. There is 36 hours separation between two images' acquirement. The two images have same swath 300km and spatial resolution 50m×50m. It is very fortunate that internal waves can be seen in all the two images. One can find at least 4 packets of internal waves propagated westward in each image.

3. Data Analysis

1) Interpretation of Internal Waves SAR Images

We take 2 images registered on bathymetry map and use solid line (the first scene) and dashed line (the second scene) to drawing wave crest of internal wave. Finally, we have internal wave linear drawing figure (Fig.3). In Fig.3, four internal wave's occurring locations are labeled by A, B, C, and D. It is evident that internal wave occurring locations at two images are almost identical. These 2 images have 36 hours separation, which almost three times as semi-diurnal tide period. So we can reckon that the internal wave is resulted from interaction of semi-diurnal tide with shallow water topography, which is coincident with Ebbesmeyer's conclusion[4]. We can know that 36 hours separation between area A and D's internal wave. Obviously,

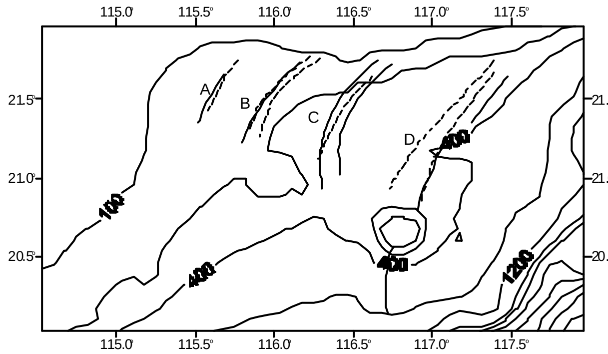

Fig. 3 Line drawing of internal waves in experiment region interpreted by two SAR images.

internal wave of area A on the second image is an evolution result of internal wave of area D's on the first image.

2) Analysis of Background Condition

From Fig.3, it is shown that time intervals are six semi-diurnal tide cycles between internal wave of point A from Fig.1 and internal wave of point B from Fig.2. Internal wave generates continuously at least 3 days. This paper considers internal wave of the northern of South China Sea usual generating at Luzon Strait, so we collected tide data of Philippines's Legaspi harbor to analyze, this harbor's tidal type same as Bashi Channel with 3-4 minutes difference. Legaspi harbor lies eastern Philippines, which has an typical semi-diurnal tide. From internal wave SAR image, we can know:

AB=30km, BC=45-50km, BC=50km, CD=55-75km, we herby reckoned internal wave propagation is 1.3-3.2 knots. It is shown that internal wave's propagation velocity is reduced when it comes into continental shelf. In this way, if internal wave propagation at 2.5 knots, then the internal waves in first image occurred early on 10th May, which is spring tide base on Legaspi harbor tide data. Therefore, it is confirmed that internal wave of the Northern of South China Sea are very frequent, and internal wave usual occurring on spring tide period.

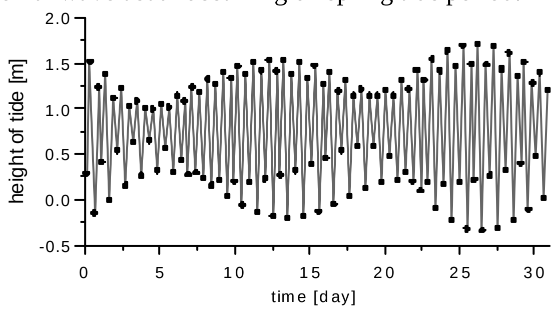

Fig. 4 Legaspi tide data

3) Internal waves parameters detection

Solitary wave's solutions can be Hajii[9] expressed as

$$h(x,t) = h_0 \sec h^2(((x - x_c) - c_1 t)/L \qquad (1)$$

where ς_0 is maximum pycnocline displacement, x_c is the soliton central position, and the soliton half width L is

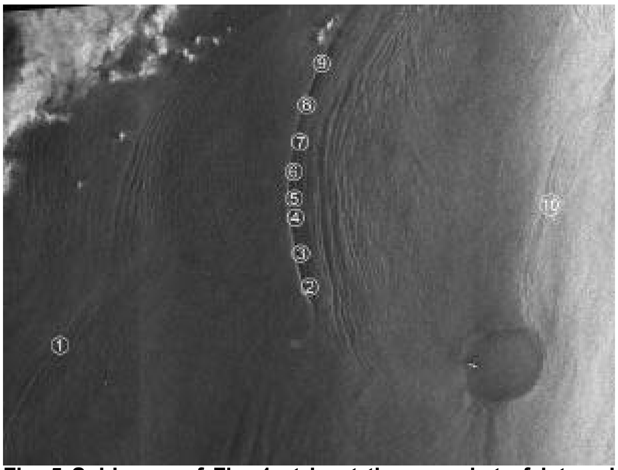

Fig. 5 Subimage of Fig. 1 at least three packet of internal waves can be seen

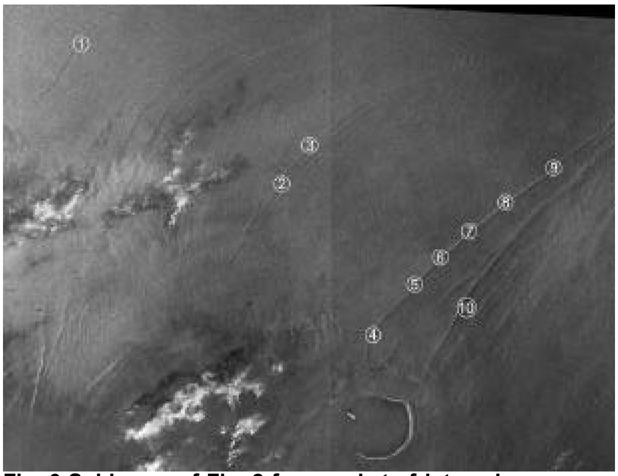

Fig. 6 Subimage of Fig. 2 four packet of internal waves can be seen

given by L^2=12â/(ç$_0$á), where á and â are coefficient of nonlinearity and dispersion respectively. Furthermore, D=1.32L, so it is easily to estimate internal wave amplitude. Therefore, we select eight points on two subimage in order to estimate internal wave amplitude. The background stratification parameters are obtained from historical in situ data.

Table1 is internal wave amplitude estimate results, which are mostly fasten on 10-20m. The amplitude gradually reduces as internal wave propagation in shore. Because internal wave relevant environment data are limited and under the interfacial internal wave's supposition, estimate results have a part of errors. Those can be improved by considering continuous stratification case.

Table 1. Amplitude detection results of internal waves in Fig. 5 and Fig. 6

Internal wave	In first image				In second image			
	1	2	3	8	3	4	7	10
Water depth (m)	180	340	320	270	280	210	250	310
Pycnocline depth (m)	40	50	50	40	40	70	55	65
D(m)	360	313	412	302	354	334	403	257
Amplitude (m)	6	21	11	13	9	29	12	50

4. Conclusion

This paper describes an internal wave SAR observation experiment, because we have not relevant synchronous in-situ data, so we only have some qualitative and quasi-qualitative analysis. From above shown as

1. The northern of South China Sea internal wave occurs frequency were very usual in May and sustaining brings on spring tide period. Furthermore, it is in favor of SAR imaging that this period South China Sea's sea state is low.
2. Radarsat ScanSAR Narrow is an ideal mode for internal wave monitoring, and which a primary way can obtain continuous monitoring data on a packet of internal wave.
3. Radarsat ScanSAR can guide an oceanographic cruise in search of internal waves in the northern of South China Sea.

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