New Insight-Internal Wave Detection Using Altimetry Data

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Introduction

Internal wave induced surface signatures can be detected clearly by satellite images, but the surface elevation in vertical direction cannot be detected directly. Radar altimeters are important tools designed to study sea surface height with centimeter-scale precision. High sampling records of Jason-2/3 are used to study internal waves, combined with quasi-synchronous satellite images. The ocean and land color instrument (OLCI) and synthetic aperture radar altimeter (SRAL) on Sentinel-3A satellite can provide perfect synchronous data to extract three-dimensional sea surface signatures induced by internal waves, synchronous pairs are collected and analyzed. Conventional altimetry only measures along-track profile, the new generation altimeter based on radar interferometry can provide across-track measurements as well. Data of the new generation altimeter China Imaging altimeter (CIALT) is used to study internal waves in the South China Sea (SCS) and some preliminary results are presented.

Conventional altimetry data results

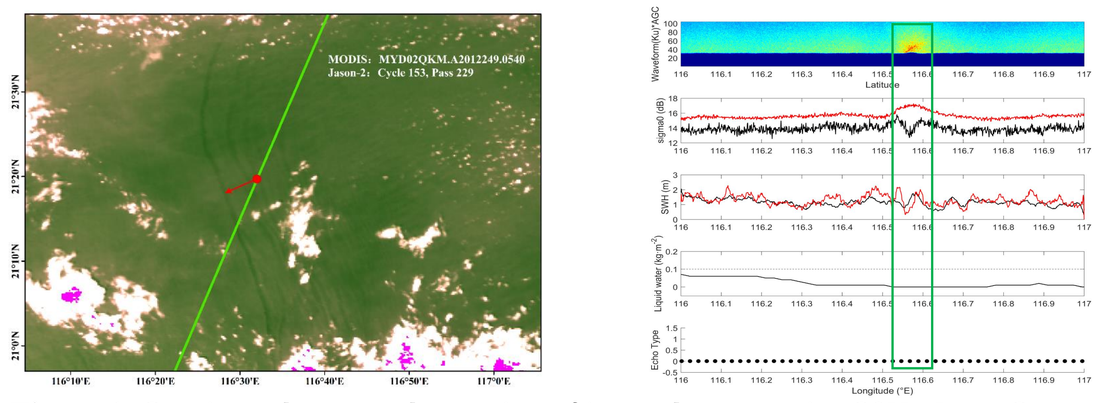
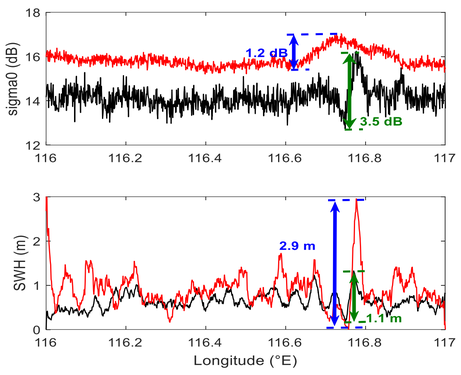
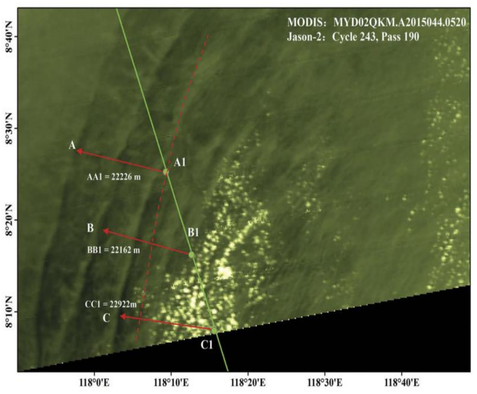


Figure 1. Quasi-synchronous observation of internal waves using 20Hz Jason-2 records and MODIS image in the SCS (left graph). The green line indicates the ground tracks of Jason-2. Distributions of geophysical parameters extracted from Jason-2 records are shown in right graph.



Date	Cycle	Pass	$\Delta\sigma_{Ku}$(dB)	$\Delta\sigma_C$(dB)	ΔSWH_{Ku}(m)	ΔSWH_C(m)
09 May 2012	141	229	**3.5**	1.2	1.1	**2.9**
06 Aug. 2012	150	229	**3.2**	1.7	0.8	**1.6**
05 Sep. 2012	153	229	**3.1**	1.4	1.0	**1.8**
13 Feb. 2015	243	190	**3.0**	0.6	0.9	**2.1**
24 Mar. 2015	247	190	**3.9**	0.9	1.0	**1.7**
09 Apr. 2017	043	012	**2.1**	0.5	1.6	**2.4**

Figure 2. Band sensitivity to internal wave modulations.



Date	Cycle	Pass	MODIS image	Distance (m)	Time interval (min)	Calculated results (m s^{-1})	Theoretical results (m s^{-1})
06 Aug. 2012	150	229	MYD2012219	29446	267	1.78	1.35
05 Sep. 2012	153	229	MYD2012249	7414	112	1.10	1.43
13 Feb. 2015	243	190	MYD2015044	22226	247	1.50	1.83
				22162		1.50	
				22922		1.55	
09 Apr. 2017	043	012	MYD2017099	15410	175	1.47	1.42
06 Jun. 2017	048	229	MYD2017157	23426	226	1.78	1.37

Figure 3. Propagation speeds of internal waves were extracted by quasi-synchronous observations. The left graph shows a case study in the Sulu Sea and the right graph shows the results of six matched pairs.

- ◆Large scale internal waves can be detected by high sampling records of conventional altimetry data, such as Jason-2/3.
- ◆Ku band is more 'sensitive' to the modulation of internal waves when considering Sigma0 and C band is more 'sensitive' when considering SWH.
- ◆Propagation speed of internal waves calculated from quasi-synchronous pairs are close to the theoretical results from the KdV equation.

SAR mode altimetry data results

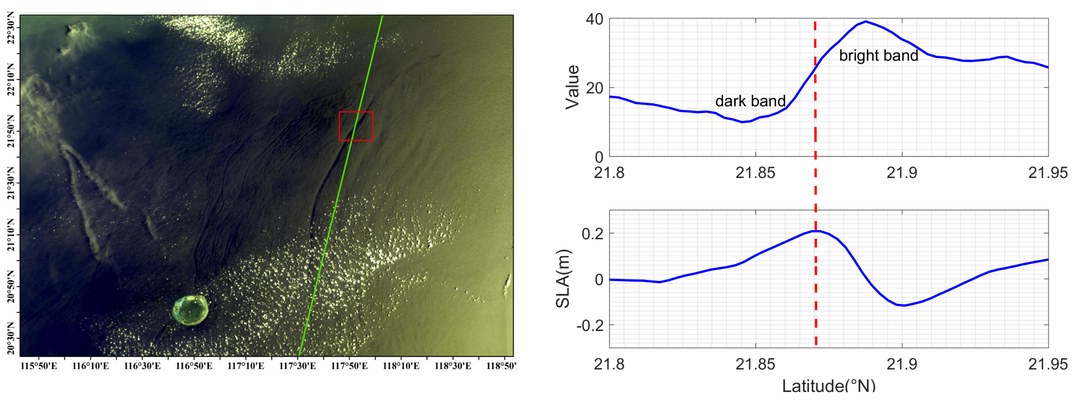


Figure 4. Synchronous detection of internal waves in the SCS using OLCI image (right graph) and SAR mode altimetry data. The green line indicates the ground tracks of altimeter. The right graph shows the profile extracted from OLCI image and SSHA of SRAL records.

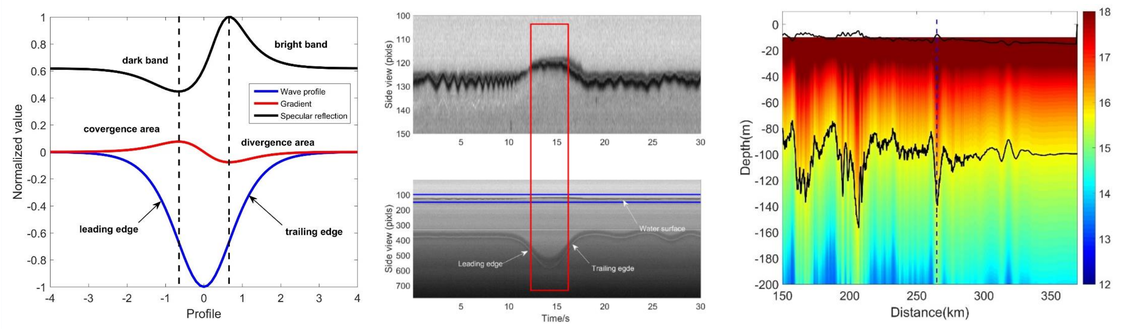


Figure 5. Conceptual graph of the opposite-phase relation between the profiles of internal wave and the surface elevation (left graph). The middle graph shows the experiment results and the right graph shows the results of MITgcm.

- ◆Sentinel-3A can provide 100% SAR mode altimetry data with increased along track resolution.
- ◆Perfect synchronous detection of internal waves using OLCI and SRAL boarded on Sentinel-3A.
- ◆Opposite phase relation can be found with synchronous detection and also agree well with lab experiment and MITgcm results.

Imaging altimetry data results

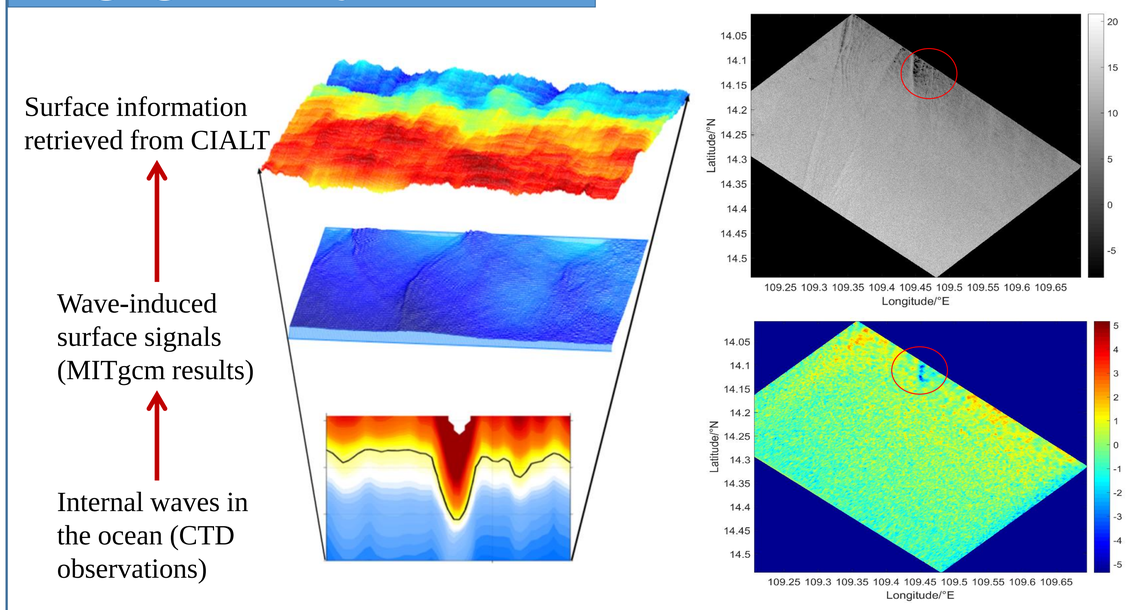


Figure 6. The left graph shows the conceptual graph of detection of internal waves using CIALT data. The right graph shows a case study of internal wave using CIALT images (Top figure shows the map of Sigma0 and the bottom figure shows the map of retrieved sea surface height from CIALT data).

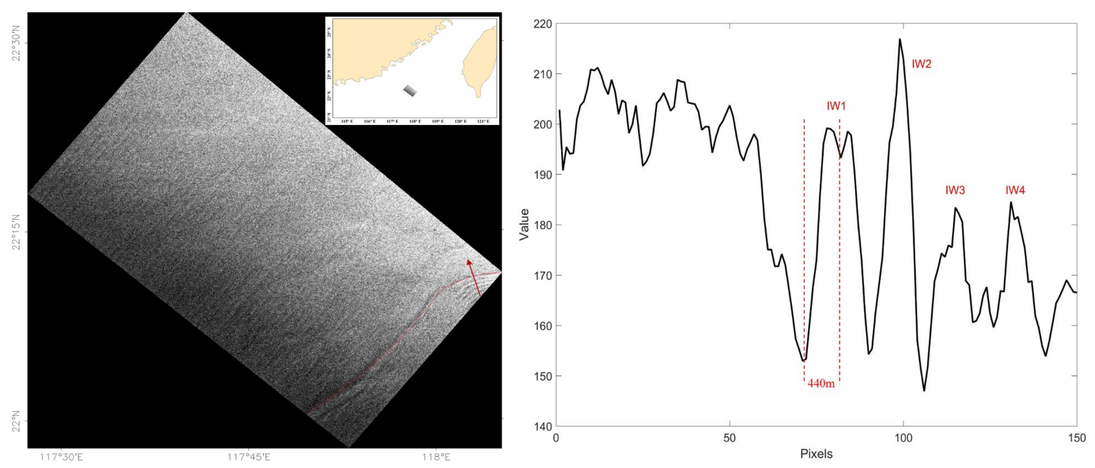


Figure 7. Internal wave detection using CIALT image in the SCS (left graph), the propagation direction is 336°. The right graph shows the extracted profile and measured peak to trough distance. The calculated amplitude of leading wave is 61.1m.

- ◆ Wide swath, three-dimensional information of sea surface can be obtained but need more collected data.
- ◆ Wave packet with dark and bright bands can be observed and parameters of internal wave can be retrieved.

Conclusion

Developments in remote sensing techniques have bring new insights to the investigation of internal waves. With increased resolution and swath, altimetry data will be an important data source for the study of internal waves. The transition from two-dimensional to three-dimensional surface information investigation of internal waves can be foreseen.