Performance of SARAL/AltiKa Satellite Altimetry Mission over the Strait of Malacca and the South China Sea

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***Abstract* — Satellite altimetry faces challenges when attempting to monitor sea surface heights (SSHs) in coastal zones due to the rapid changes in sea state and land contamination within altimeter footprints. This leads to the lack of high resolution and data quality observations, thus creating a significant gap in the data availability over the coast. A new generation of SARAL/AltiKa satellite altimetry mission with Ka-band promises a significant refinement of coastal altimetry data and provides unprecedented level of ocean SSH data as close as 10 km from the coastline. In this paper, selective passes of SARAL/AltiKa over the Strait of Malacca and the South China Sea were chosen to examine the performance of SSH data quality over the coast, and relatively compared with Jason-2 satellite altimetry mission.**

Index Terms - SARAL/AltiKa, Jason-2, Coastal Sea Level, South China Sea, Straits of Malacca, Waveform Retracking.

I. INTRODUCTION

As the satellite altimeter approaches the coastal area, the altimeter data become unreliable partly because of abruptly shallow sea floor topography and rapidly changes of measured surface between land and ocean [1]. With the previous generation of radar altimeters, which operated with Ku-band (e.g. Jason-1, Jason-2 and Envisat), the coastal water is poorly observed within ~10 km from the coastline around the South China Sea coastal water [2].

The SARAL/AltiKa satellite altimetry was found to be beneficial for coastal altimetry measurements with higher spatial resolution (up to 40 Hz, or 188 m along-track) than the present Ku-band (20 Hz, or ~300 m along-track) altimetry. It was design with smaller footprint (~4 km) when compared to Jason-2 (~10 km) [3, 4], which makes it excellent in data coverage (99.5%) over the coast with less missing measurement [4]. With high-rate (40 Hz) SARAL/AltiKa observations, the data spatial resolution near the coast can be increased, thus enabling coastal observation much closer to the coast [5].

Global calibration for SARAL/AltiKa has been conducted by Centre National d'Etudes Spatiales (CNES), Indian Space Research Organisation (ISRO) and many other researchers [e.g. 6, 7]. However, limited research focuses on the validation over the Strait of Malacca and South China Sea. The regional validation is important because the ocean characteristic there is significantly different than the other oceans such as the Pacific and Atlantic Oceans.

The Prototype for Expertise on Altika for Coastal, Hydrology and Ice (PEACHI) project is specifically conducted for SARAL/AltiKa mission. The aim is to perform new retracking algorithm for 40 Hz SARAL/AltiKa data in order to improve the accuracy of estimates parameters for scientific application such as coastal area, surface hydrology, ice and open ocean [6].

The purpose of this study is to examine the quality of sea surface heights (SSHs) derived from SARAL/AltiKa satellite altimetry mission over the Strait of Malacca and South China Sea coastal regions as well as to examine how much improvement in the accuracy of sea levels can be achieve from the recently launched SARAL/AltiKa satellite mission. The high-rate measurement of SSH offered by SARAL/AltiKa mission should benefit the study for understanding the sea surface current system and its mesoscale variability. Thus, the exploitation of SARAL/AltiKa altimetry is needed for accurate mapping of coastal sea levels.

II. DATA AND STUDY AREA

The experimental region is around the regions of Strait of Malacca and South China Sea (Fig. 1). The areas were chosen as the main study areas for several reasons. Firstly, it consists of peninsulas, shallow seas, and small islands that exhibits a broad range of topographic features, including coastal plains, beaches, estuaries, oceans and islands. The geographical features around this area produces complicated waveform patterns when it enters the altimeter footprints. Secondly, the climate of the regions are made up of contributions from various weather system causing distinct diurnal rainfall and tropical cyclones frequently pass over the region [7]. Since altimetric waveforms can be seriously distorted by heavy rain associated with cyclones, the data selected in this area can capture diverse waveform pattern due to the temporal variability of coastal sea states.

The high resolution of SARAL/AltiKa data in 40 Hz and Jason-2 data in 20 Hz from Sensor Geophysical Data Record (SGDR) data were retrieved from the Archiving, Validation, and Interpretation of Satellite Oceanographic ftp site (ftp://avisoftp.cnes.fr). The improved data from MLE-4, Ice-

1 and Ice-2 retracking algorithms were utilised to derived sea levels above a reference ellipsoid. The data were retrieved from SARAL/AltiKa cycles 1-14 and Jason-2 cycles 173 – 219, which correspond to February 2013 - July 2014.

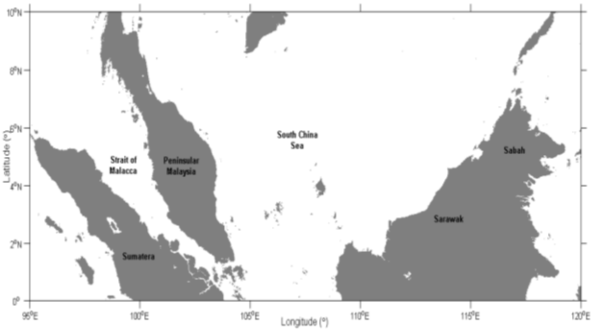

Fig. 1 The region of study areas.

III. Derivation of Sea Surface Height

The derivation of SSHs from retracked range measurements involves numbers of corrections for geophysical signals (e.g., tides and sea state bias) and atmospheric attenuations (e.g. wet and dry tropospheric delay). The height, h, of the sea surface above the reference ellipsoid is given as [8]:

$$h = H - (R_{obs} - R_{retracked} - \Delta R_{dry} - \Delta R_{wet} - \Delta R_{iono} - \Delta R_{ssb}) - h_{tide} \quad (1)$$

where H is satellite altitude, R_{obs} is observed range, $R_{retracked}$ is range corrections, R_{dry} is dry tropospheric correction, R_{wet} is wet tropospheric correction, R_{iono} is ionospheric correction, R_{ssb} is sea state bias correction and h_{tides} is tide correction. The corrections involved in data processing are listed in Table 1.

Table1 List of correction involve in SSH derivation

Type of Correction	**Type of Model**
Tidal Correction	FES2004
Sea State Bias (SSB)	Hybrid SSB
Dry Tropospheric correction	European Center for Medium-Range Weather Forecasts (ECMWF)
Wet Tropospheric Correction	ECMWF
Ionosphere Correction	Global Ionosphere Map (GIM)

IV. Result and Analysis

A. *Computation of SSH Data Availability*

Percentage of data availability was computed based on 14 cycles of SARAL/AltiKa and Jason-2 SGDR data. Since the temporal resolution for both satellite are different, in which SARAL/Altika is 35 days, while Jason-2 is 9 days, the comparison is performed by selecting the closest SARAL/ALtiKa cycle to Jason-2 cycle.

The percentage of data availability of SARAL/AltiKa over the study regions is shown in Fig. 2. SARAL/AltiKa shows high percentage (more than 70%) in data availability at ~3 km from the coast over the Strait of Malacca and South China Sea regions. Even over complex areas such as the southern area of Peninsular Malaysia around Batam (focused on the Fig. 2), the percentage of data availability is >50%. This is due to the smaller footprint of SARAL/AltiKa (~4km). Smaller footprint size contributes in improving the spatial resolution and segregating type of surface in transition zone such as coastal areas and sea ice boundaries. From Fig.2, it is observed that the percentage over the eastern Sabah is low with <50%. This is probably because of the topography of this area which consists of many small islands, sandbanks and shoals affect the altimetric observations

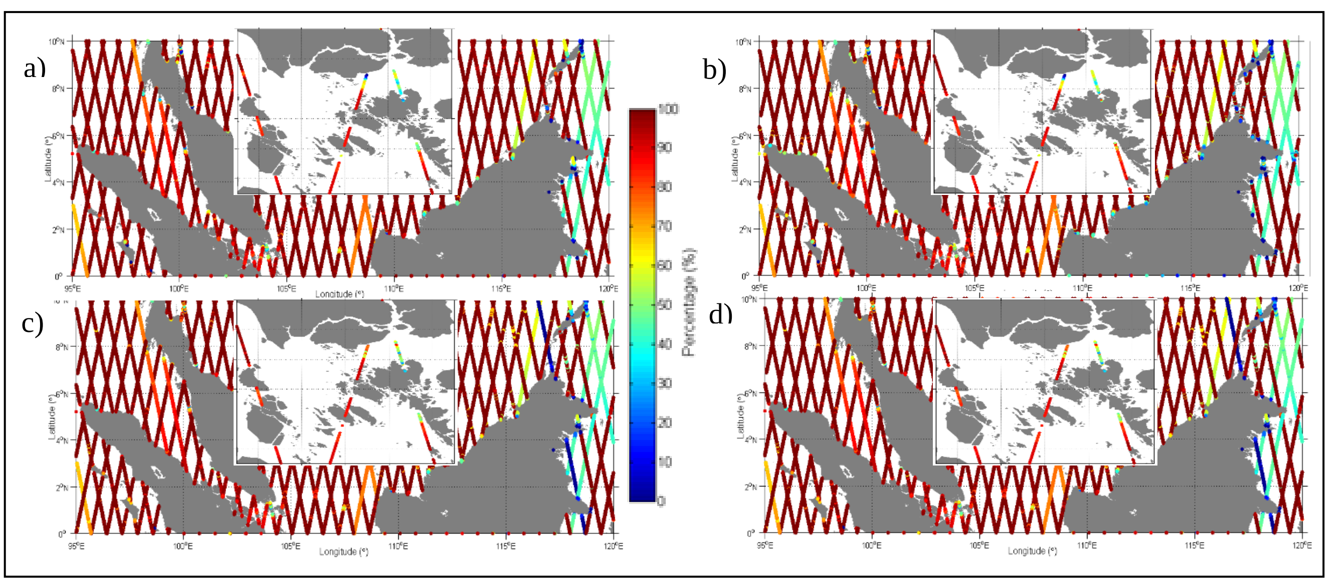

Fig. 2 Percentage of SSHs data availability derived from a) on-board, b) MLE-4, c) Ice-1.and d) Ice-2 retracked SSHs. The small figure shows the southern part of Peninsular Malaysia, around Batam. This area is the most complex area with many small islands.

Examples of SARAL/AltiKa retracked sea level anomalies (SLAs) from MLE-4, Ice-1 and Ice-2 retrackers near the coast of the study areas are shown in Fig. 3. The location of the passes is shown in Fig 3(a). The blue circles show the area of retrieved SLA (within 30 km form coastline). As shown in the Fig 3(b), the SLA for pass 451 is noisier than pass 36. The area of retrieved SLAs for pass 451 is more complex by the existence of islands compared to pass 36.

Fig 3 also shows that the retracked SLAs are extended within 3 km to the coastline. Based on the SLAs profile, the minimum distance of SARAL/AltiKa data are computed.

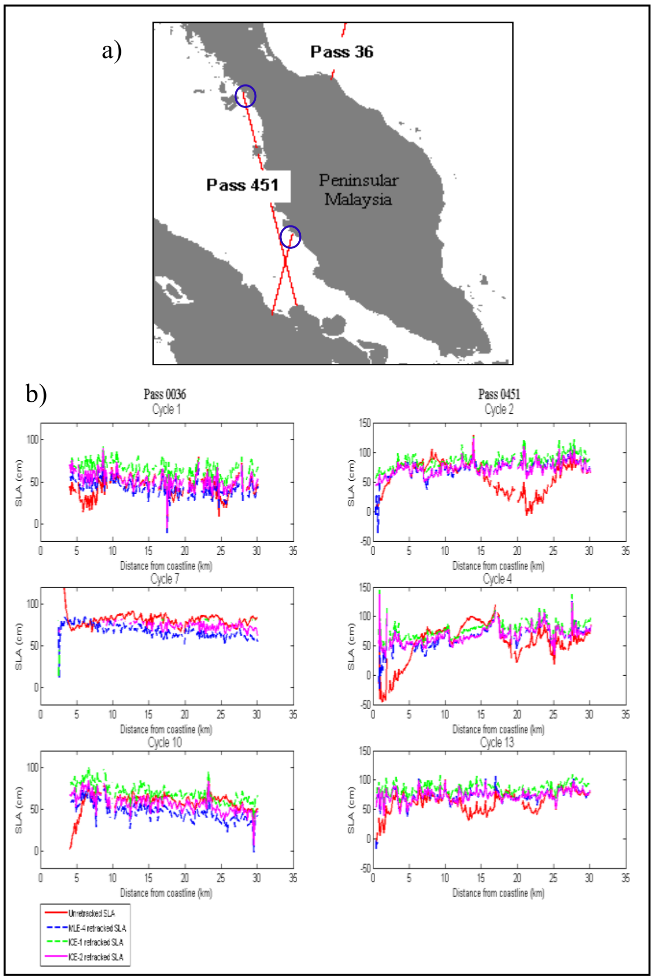

Fig. 3 a) The area of retrieved SLAs. b) SLAs profile of SARAL/AltiKa altimetry from passes 36 (left panel) and 451 (right panel).

Fig. 4 shows the minimum distance of SARAL/AltiKa data for several passes around the Strait of Malacca and the South China Sea. The figure indicates that SARAL/AltiKa retracked SSHs can provide data within 3 km from the coast. This is extremely better than the performance of Jason-2 missions, which can generally provide data beyond ~5-10 km from the coast (Deng and Featherstone, 2006; Idris and Deng, 2012), depending on the coastal characteristics.

The level of performances for every retrackers are different for different passes. For examples, for passes 978 and 36, the three retrackers have the same level of performance with the minimum distance to the coast is ~1 km. This is in contrast with pass 421, where MLE4 retracker is only available ~3 km beyond the coast, while Ice1 retracker is available at ~1 km from the coast. Passes 421 and 851 show the performance of Ice-1 retracker is better than MLE4 and Ice-2 retrackers. This is because, the performance of retrackers is depending on coastal sea states, in which different coastal characteristics gives different impact to the altimetrics signals. Ice-1 retracker is proved to be the best retracker over Straits of Malacca and South China Sea coastal regions with mean of minimum distance from the coastline is 0.95 km compared to those of two retrackers of MLE-4 and Ice-2 retrackers with 1.7 km and 1.4 km respectively.

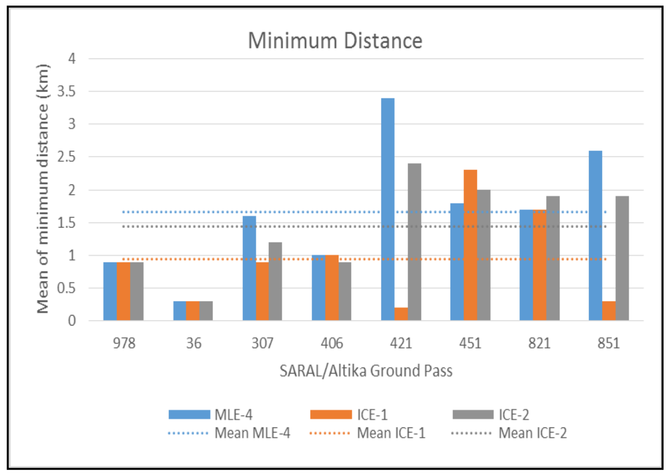

Fig. 4 Minimum distance of SARAL/AltiKa for MLE-4, Ice-1 and Ice-2 retracked SLAs over the Strait of Malacca and South China Sea.

B. Relative Comparison of Derived SSH with Jason-2

The quality of the waveform shape at cross-over point over the coastal water of the Strait of Malacca and South China Sea is assessed in this section.

The behavior of SARAL/AltiKa waveforms near the coast was compared with Jason-2 at several crossover points. First crossover point is located near Batam between SARAL/AltiKa pass 322 and Jason-2 pass number 242 (Fig. 5). This location is situated at a complex area surrounded by many small islands and very close to the land (~2.5 km). The impact of land is significant on both SARAL/AltiKa and Jason-2 waveforms. Nevertheless, Jason-2 waveforms are much noisier than those of SARAL/AltiKa especially in the waveform trailing edge. Second crossover point is near Sabah, situated at less complex area and father (~4.9 km) from coastline (Fig. 6). The impact of land is still significant on both waveforms. However, the impact of land is more obvious on Jason-2, indicated by high peak of amplitude.

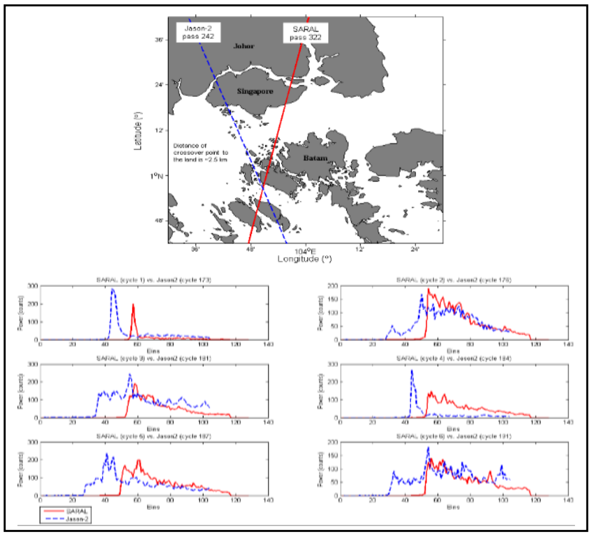

Fig. 5 Waveforms patterns at cross-over point between SARAL pass 322 and Jason-2 pass 242 near Batam.

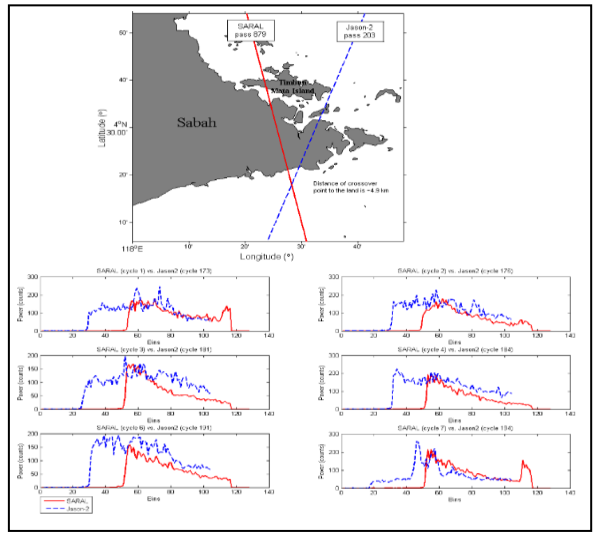

Fig. 6 Waveforms patterns at cross-over point between SARAL pass 879 and Jason-2 pass 203 near Sabah.

V. Summary

In this study, we evaluated the performance of SARAL/AltiKa retracked SSHs over the Strait of Malacca and South China Sea coastal regions. SARAL/AltiKa shows good data availability with percentage of more than 70% within 3 km from the coastline of the study regions. Ice-1 retracker shows a best performance for the regions with mean of minimum distance from the coastline is 0.95 km compared to those of two retrackers of MLE-4 and Ice-2 with mean of minimum distance from the coastline is 1.7 km and 1.4 km, respectively. The impact of land on SARAL/AltiKa waveforms also less significant than on Jason-2 waveforms.

Further research is currently conducted to validate the sea level with in-situ measurement. The derived sea level will go through relative validation with Jason-2 satellite mission and absolute validation with in-situ tide gauge data over the Straits of Malacca and South China Sea regions.

Acknowledgement

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