INDONESIAN JOURNAL OF GEOGRAPHY

RIP CURRENTS SIGNATURES ZONE DETECTION
ON ALOS PALSAR IMAGE AT PARANGTRITIS BEACH, INDONESIA

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ABSTRACT

Having bay and gulf morphology as cresentic beach, Parangtritis coast has been known potentially threat by rip currents hazard. This study aims to identify and detect breaking waves region and surf zone on ALOS PALSAR images, and identify and extract the cove shape shoreline morphology of Parangtritis beach. ALOS PALSAR Fine Beam Single (FBS) HH polarization acquired on 2nd May 2007 and 17th June 2007, off nadir angle 34.3°, and in descending mode level 1.0 were utilized to derive amplitude information using Sigmasar. Shoreline morphology detection showed that the cusps system has not changed much during May to June 2007 when PALSAR images acquired, but might have shifted individually. The use of optical sensor with the same spatial resolution, ALOS AVNIR-2, supports to distinguish the boundary and determine the shoreline morphology of Parangtritis beach.

Keywords : ALOS PALSAR, breaking waves, rip currents, shoreline morphology, surf zone, Parangtritis, Indonesia

ABSTRAK

Sebagai pesisir dengan morfologi tanjung dan teluk yang merupakan cresentic beach, pesisir Parangtritis terkenal dengan ancaman bahaya rip currents. Penelitian ini bertujuan untuk mengidentifikasi breaking waves region dan surf zone menggunakan citra ALOS PALSAR, dan mengidentifikasi morfologi pesisir berupa cove shape shoreline di Pantai Parangtritis. ALOS PALSAR Fine Beam Sigle (FBS) HH polarization yang diperoleh pada tanggal 2 Mei 2007 dan 17 Juni 2007, dengan sudut nadir 34,3° dan mode descending level 1,0 telah digunakan untuk memperoleh informasi amplitudo menggunakan Sigmasar. Deteksi morfologi garis pantai menunjukan bahwa sistem cusps tidak berubah banyak pada Bulan Mei hingga Juni dimana PALSAR diperoleh, namun terjadi pergeseran pada masing-masing cusps. Pemanfaatan sensor optis dengan resolusi spasial yang sama menggunakan ALOS AVNIR-2 mendukung dalam penarikan batas dan menentukan morfologi garis pantai di Pantai Parangtritis.

Kata kunci : ALOS PALSAR, gelombang pecah, rip currents, morfologi garis pantai, surf zone, Parangtritis, Indonesia

INTRODUCTION

Coastal area is a dynamic system contains important natural environments. South Coastal Area of Bantul, Yogyakarta special region in Indonesia, has been known as iconic tourism area, yet also posses natural hazards. Parangtritis area is situated in two environments, namely coastal area with beach ridge landform filled with sand dunes, and beach area with beach cusps morphology (Figure 1). Potential threat of hazards and disasters in Parangtritis area are due to processes of complex physical and dynamic coastal area [*Pusat Studi Bencana (PSBA), 2009*]. Rip currents have been known as threat which drowned some visitors along Parangtritis coast. Despite of the fatalities, fishermen utilize the rips to sail out.

Processes of nearshore region, particularly coastal processes, are so complex. One of coastal process is wave breaking events. Nearshore circulation system consists of onshore flow, longshore currents, and rip currents. Fast flowing rip neck of rip currents extend through the surf zone, decelerating and expanding into rip head past the line of breakers [*Brander and Short*, 2000]. The surf zone is important in forecasting rip currents potential occurrence, in term of scientific and management, particularly risk reduction. Understanding the characteristics of Parangtritis beach nearshore phenomenon is considered important in planning and managing Parangtritis coastal area.

Figure 1. Parangtritis Coastal Area (Google earth view 2006)

Study of wave breaking events location and frequency in shallow water is interesting since these phenomenons are preponderant forcing mechanism for several nearshore region processes [*Haller and Lyzenga*, 2003]. Nearshore water

regions generate widely fine range of surface signature observable by Synthetic Aperture Radar (*SAR*) sensor. Remote sensing techniques are considered feasible method for observing wave breaking, especially over large spatial area [*da Silva,*

et al. 2006 *and Wackerman and Colon*, 2004], though this study were conducted in small area.

Many observations have been done for rip currents measurements, in statistical modeling, field observation, and remote sensing application. However, field survey and in-situ measurement of Rip currents still remains a challenging observation. Identifying breaking waves and surf zone is only one of complex observations and study need to be conducted to understand the dynamic complex of nearshore and beach behavior [*Haller and Lyzenga*, 2003, *and Teodoro*, et al. 2009] in particular rip currents phenomenon. Incoming breaking waves direction angle will affect the angle of rip currents events along the coast [*Sukirman*, 2003].

Breaking waves and surf zone, and shoreline morphology are considered as signatures of rip currents occurrence along Parangtritis beach (Figure 2) in this study. Shoreline changes or movement assessment due to accretion and or erosion is important for coastal zone management, either in scientific or management objectives. Nearshore physical processes, in particular rip currents, can be studied by identifying the signatures on airborne or spaceborne satellite images. Coastal processes can not be registered directly due to temporal discrete characteristic of remotely sensed data [*Wieneke*, 1991]. This study tried to optimize *ALOS PALSAR* spaceborne satellite images to identify and assess coastal process and its signatures.
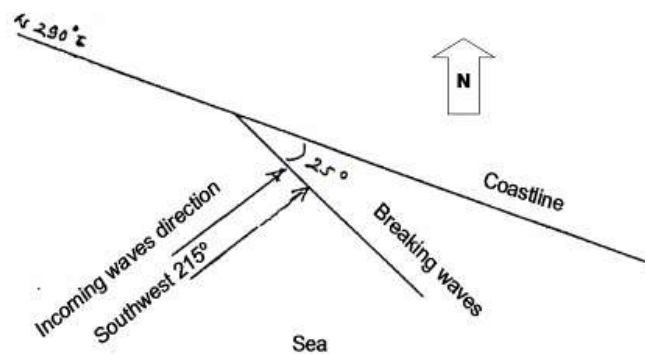

Figure 2. Rip Current Mechanism at Parangtritis Beach [*Sukirman*, 2003]

THE METHODS

Research Area

This study was conducted in Parangtritis coastal area which lied between 7º59'14" - 8º1'45" S and 110º16'40" - 110º20'22". Parangtritis coastal area is administratively located in the area of Parangtritis Village, Kretek sub-district, Bantul District, Yogyakarta Special Province, Indonesia. The village consists of Depok Hamlet, Grogol Hamlet, Mancingan Hamlet, Parangwedang Hamlet, and Parangkusumo Hamlet. South part of Parangtritis village is coastal area (Figure 3). Many utilization and interests, mainly tourism and fisheries, supported this village livelihood.
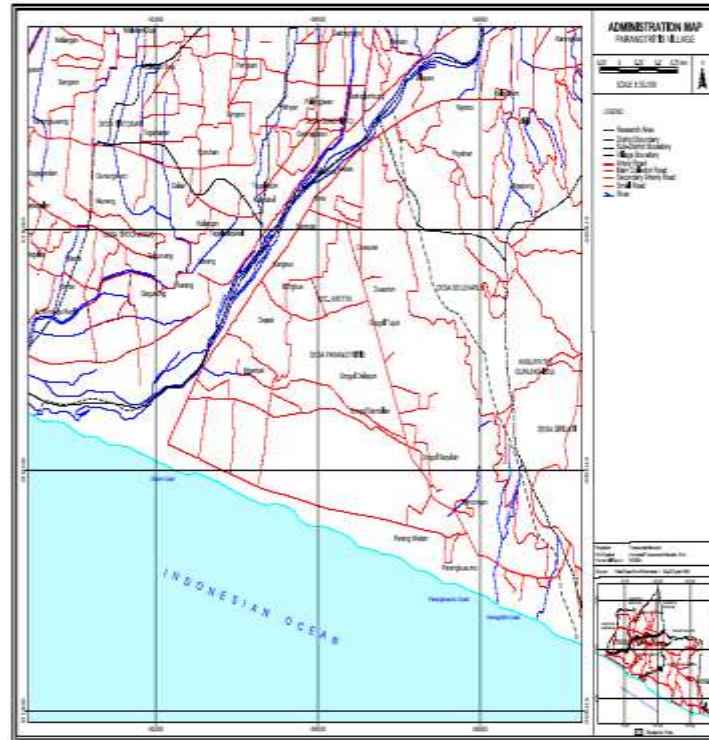
Figure 3. Administration Map of Parangtritis Village

Topographicaly, Parangtritis village range between 0 – 35 meter, particularly in the southern part which adjacent to sea. The hills at Northeast reach range height between 175 – 350 meter [*Pujotomo*, 2009]. Based on the 25-year-monthly rainfall, this area is included in the tropical wet or dry savanna climate (Aw) in the Köppen climate classification system. *Verstappen* [1983] stated that the east wind direction in this area is close to 325^0NE [*PSBA*, 2009]. Geographically, Parangtritis village area boundary is limited by coastal alluvial plain Northward, escarpment Eastward, Indian Ocean Southward, and Opak River Westward.

Data sets
This paper presented rip currents zone signatures identification at Parangtritis beach, namely breaking waves region and surf zone and shoreline morphology. Two scenes of *ALOS PALSAR* data level 1.0 (raw data) were utilized in this study. The two scenes are in operational mode of Fine Beam Single (*FBS*) *HH* polarization, acquired on 2nd May and 17th June 2007,

off nadir angle 34.3º, and in descending mode. *PALSAR* satellite image is a grayscale image, thus consist data matrix which values represent intensities within range 0 – 255 in this study. These images data consist of phase and amplitude information. In pre-processing step, intensity image processing and geo-coding were conducted to derive the information needed. These processes were utilizing Sigmasar software developed by *Shimada* [1999].

Result from intensity image processing then geo-coded, thus we got *PALSAR* images level 1.5. In the processing step, edge detection operator was then applied to identify breaking waves region and surf zone based on the backscattering response reflected on the images. Regioning the breaking waves and surf zone was conducted on MatLab command. The extraction of shoreline morphology was conducted on *ENVI* and *ArcGIS* software. The procedure can be seen in Figure 4.
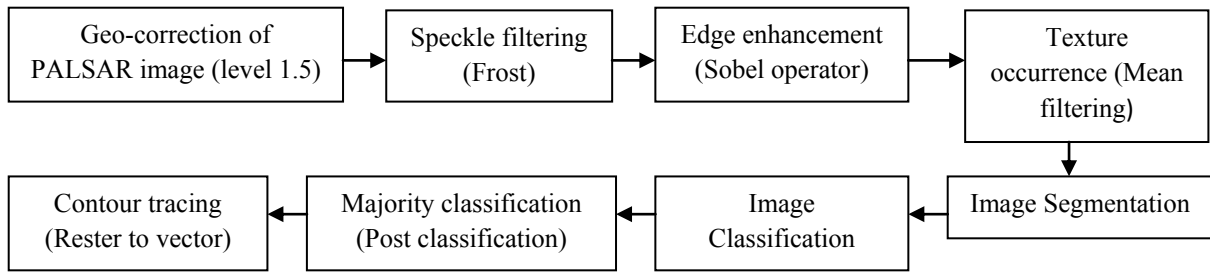
Figure 4. Shoreline morphology extraction procedure

Numerous studies on rip currents based on the mechanisms, namely wave and structural interaction, have been conducted. This study conducted mainly on optimizing *PALSAR* images to identify, detect breaking waves and surf zone. The signature of rip currents reflected on the shoreline morphology is considered as parameter along Parangtritis beach as cresentic cuspate beach. This research is considered as preliminary study on dynamic Parangtritis's beach rip currents. The result can be validated by using bathymetry data, tidal waves data, and observatory or fieldwork checking, also comparison with previous researches executing the same objects in the same time record. This study might support other research related to rip currents process as coastal hazard, particularly planning and managing coastal area due to risk reduction. Flowchart of this study can be seen in Figure 5.
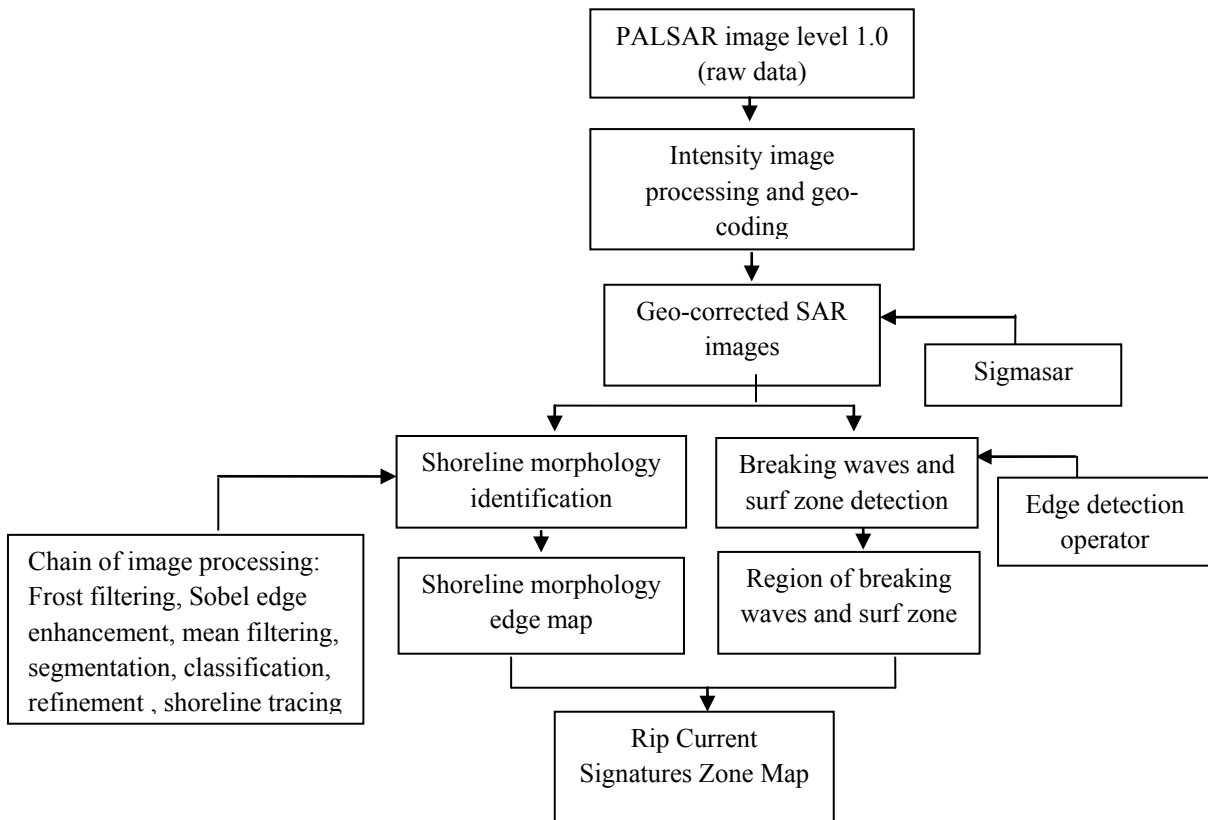

Figure 5. Flowchart study

RESULTS AND DISCUSSION

Intensity Image Processing and geo-coded Images

SAR imaging process is coherent. *SAR* method termed referring to the concept of creating the effect of a very long antenna by signal analysis [*Cumming, et al.* 2005]. *PALSAR* raw data were evaluated mainly in the initial calibration phase and exhibit good characteristics [*Shimada, et al.* 2009]. Several techniques have been developed and applied for *SAR* images based on the characteristics of *RADAR*, including multi-looks processing. Amplitude information from raw data was first processed to derive study area. Run 4 times multi-look processing to reduce speckle noise, thus the dynamic process of wave breaking which continuously occur onshore can be identified.
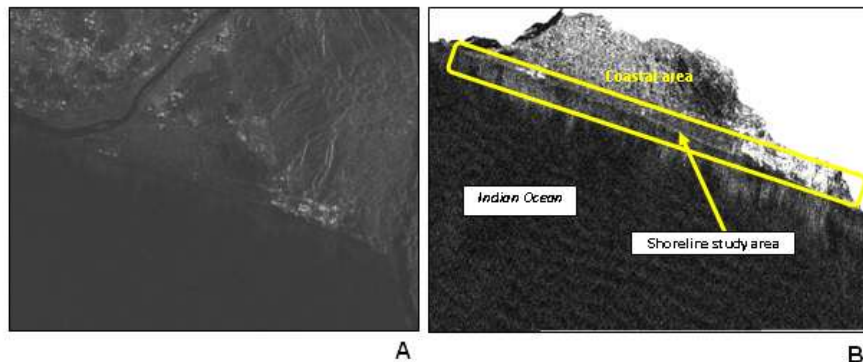

Figure 6. Study Area (A) and Study Area Derived from Raw Data in Intensity Image Processing (B)

Result from intensity image and geo-code processing is shown in Figure 6. Figure 6 (a) shows most of Parangtritis village where this study conducted. To specify targeted region, the whole scene was cropped particularly at Parangtritis coast and nearshore region (Figure 6b). Nearshore region where breaking waves and surf zone identified are visually shown in Figure 7 and Figure 8.

The arrow in Figure 7 and ellipse on Figure 8 show breaking waves and surf zone where rip currents usually generate and occur. Those figures are optic images utilized here as comparison to L-band microwave. The optical images were taken different years, so they are employed here to help visualizing the region of breaking waves and surf zone.

Figure 7. Oblique Aerial Photo of Parangtritis Coastal Area [*Barandi, 2003 in PSBA*, 2009]
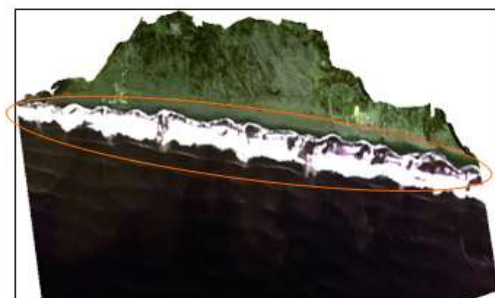

Figure 8. Breaking waves and surf zone on AVNIR-2 acquired on 17th June 2008 (METI-JAXA)

The whitewater breaking waves signatures are compared to radar backscatter from active breaking regions, as also modeling experiment conducted by *Theodoro et al.* [2009]. The backscatter increase due to high turbulent rough nearshore water region processes and reflected on the surface pattern when the waves break. Ripples and plumes reflect on the backscattering [*ERSDAC*, 2006], due to roughness of nearshore water region that increase amplitude of the small-scale waves within breaking regions and implied bright radar cross section for breaking regions [*Wackerman and Colon*, 2004].

Breaking waves and surf zone in Parangtritis coast located within range 100 m − 300 m. Most of the mass travels to the shoreline and creates currents after break on the shoreline, when waves reach the breaker zone. Longshore currents occurrence will generate rip currents. Cove shape shoreline is commonly occurrence location of rip currents. Thus, cove shoreline morphology is considered important to extract as on of rip currents signatures zone detection from *PALSAR* image.

Edge Detection
Radar in remote sensing carries its own illumination. Illumination changes contribute to increasing of images intensity changes [*Zhenjun and Jianshe*, 2000]. In Synthetic Aperture Radar, scene with no texture an edge can be defined as an abrupt change in the reflectivity [*Fjortoft, et al.* 1999]. This study tried to apply optimum smoothing filter and detect intensity changes at given scale spatial resolution to detect changes of the images reflecting the breaking waves and surf zone due to local luminance change [*Zhenjun and Jianshe*, 2000, and *Grigorescu, et al.* 2004]. Apply edge detection operator to detect intensity changes of the object with strong intensity contrasts from one pixel to the next [*Green*, 2002].

Edge detectors were designed to detect changes or discontinuities in image features to be as close as possible to real edges and good noise rejection property [*Sirin, et al.* 2005, and *Liu and Jezek*, 2004], in which *SAR* images suffer from. This study applied Sobel edge detection operator, performing 2-D spatial gradient measurement on the image refer to equation (1) and equation (2). The actual Sobel edge detector uses a pair of 3 × 3 convolution mask (Figure 9).

-1	0	1
-2	0	2
-1	0	1

Gx

1	2	1
0	0	0
-1	-2	-1

Gy

Figure. 9. Convolution kernel on 3 × 3

Equation of gradient magnitude calculation:

$$|G| = \sqrt{Gx^2 + Gy^2} \qquad (1)$$

An approximate magnitude can be calculated using:

$$|G| = |Gx| + |Gy| \qquad (2)$$

Result from applying Sobel edge detection operator and Gaussian filter on *PALSAR* images can be inspected in Figure 10 and Figure 11. Wave breaking events are region identified, not individually. Dominant backscatter on the image reflecting highest roughness surface of breaking region, thus reflected brighter image. Those figures show location where breaking waves mostly occur dynamically.
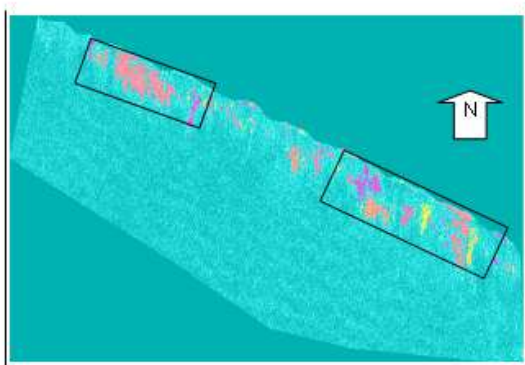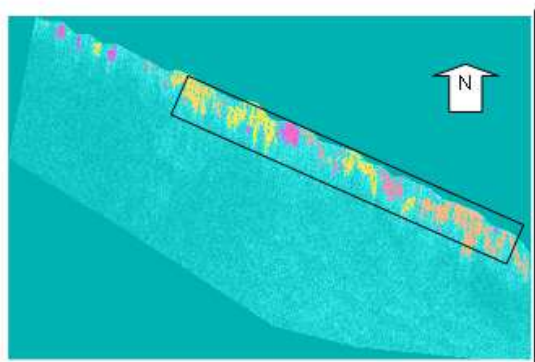
Figure 10. Image acquired on 2nd May 2007

Figure 11. Image acquired on 17th June 2007

Different color shown in Figure 10 and Figure 11 represent varied digital number (*DN*) of each pixel as processed using edge detector and help visualizing the result. The color did not represent any specific value, but randomly clustered. From the figures, we can see the occurrence of breaking waves events are mostly located at Eastern part of Parangtritis coast.

Shoreline morphology extraction

Monitoring of the coastal morphology from space borne images is one of interesting field of shoreline extraction study. Shoreline morphology which has a cove form is the mark of the location where rip currents occur generally, because in the cove, the energy of the longshore current and the energy of the breaker are accumulated and released back to the sea through a focused channel. The orientation of the shoreline and the angle of incoming waves are key features to note when assessing the potential for rip currents formation at a particular beach. Parangtritis coastal area has cresentic beach type which usually reflected on the bay and cusps form alternately. This beach morphology tried to be extracted from *PALSAR* intensity image processing data. Reference shoreline was used to compare the morphology of the bays and cusps of Parangtritis beach (Figure 12). Result of shoreline morphology extraction can be seen on Figures 13 and Figure 14.
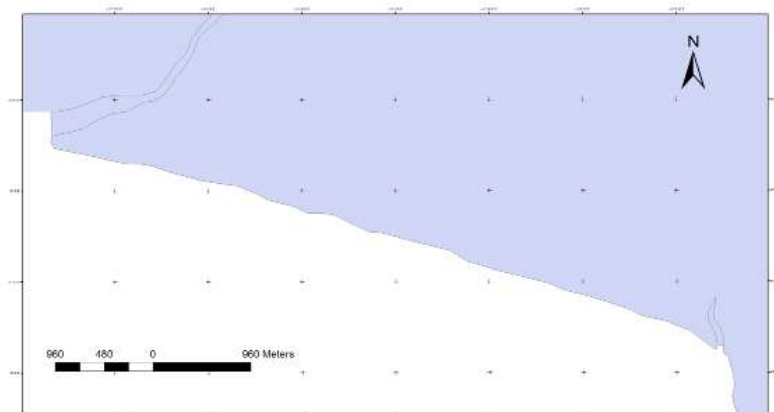

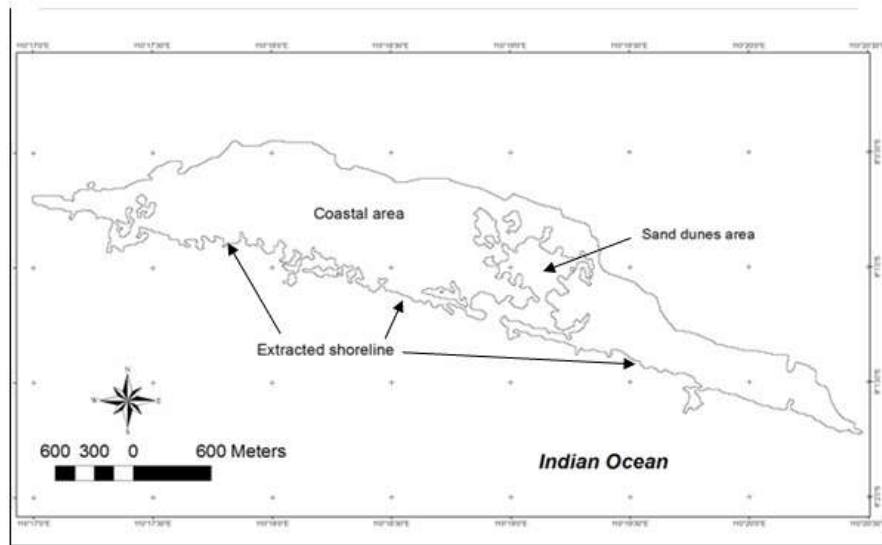Figure 12. Reference shoreline based on Bakosurtanal's Base Map 1999

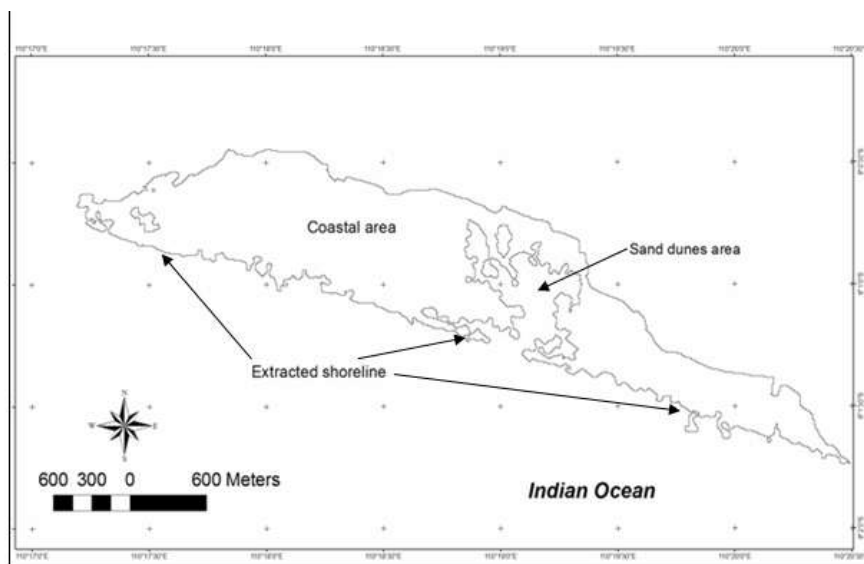Figure 13. Shoreline morphology extraction from *PALSAR* image acquired 2nd May 2007

Figure 14. Shoreline morphology extraction from PALSAR image acquired 17th June 2007

In this chapter, application of *ALOS PALSAR* and *ALOS AVNIR-2* on regioning breaking waves and surf zone, and shoreline extraction will be discussed. Comparison between microwave sensor (*PALSAR*) and optic sensor (*AVNIR-2*) to observe rip currents as nearshore phenomenon will be presented here.

Breaking waves and Surf Zone Regioning
Rip currents extend through the surf zone, decelerating and expanding into rip head

past the line of breakers [*Brander and Short*, 2000]. The circles show possibility of rip currents occurrence (Figure 15). This would require ground check as validation in the same time as *PALSAR* images taken. Quantitative field measurement is the limitation of this study. Previously, Figure 10 and Figure 11 show nearly indistinctive wave breaking and surf zone pattern.
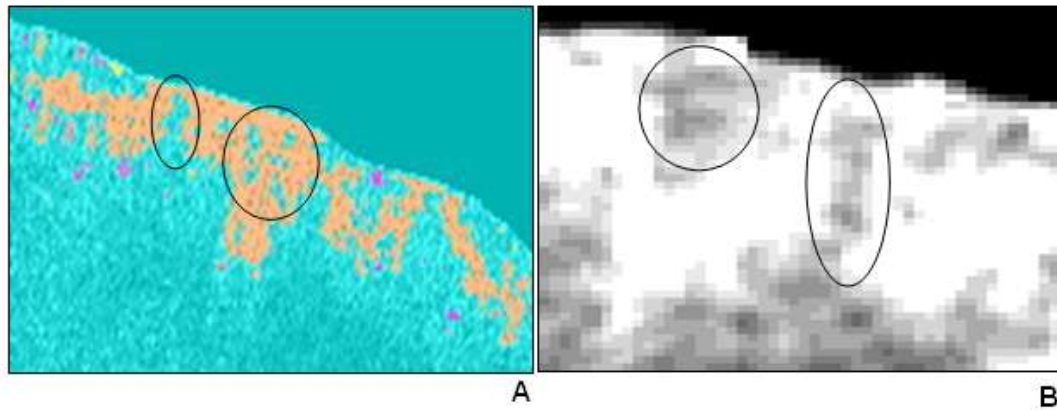
Figure 15. Rip currents possibility of occurrence

Breaking waves and surf zones are commonly high velocity region which reflect on strong backscattering cross-section. Rips are best identified by looking for narrow and persistent dark gaps in the surf zone using optic remote sensing regarding on the spatial resolution as well. Rough surface area has strong backscatter strength and consequently the areas are shown brighter than the other areas. Darker areas have weak backscattering strength and show smooth surface against microwaves. Due to *PALSAR* characteristics, rip currents will be seen darker than surrounding in contrast to high backscatter of breaking waves, instead of brighter image from neighboring objects (Figure 15b), as also stated in *Joseph* [1993]. To prove that Rip currents occurrence indeed show darker areas, field observation was conducted on 26th September 2010. Rip currents can be identified by observing the currents which heading to the sea and cutting the breaker zone which will create a gap, no wave breaking process in this zone (Figure 16).

Figure 16. Rip currents appearance

Synthetic Aperture Radar (*SAR*) can be complementary to optical satellite images in coastal monitoring. As stated in da *Silva, et al*. [2006], and *Wackerman and Colon* [2004], some studies have achieved success in observing nearshore water regions surface signatures using *SAR*, acquire breaking waves signatures. Breaking waves and surf zone reflect changes of bathymetry. Rip flows commonly within distinct topographic channel. Bottom morphology of Parangtritis coast would encourage the validation of rip tunnel.

Shoreline Morphology Extraction
Boundary detection is what shoreline detection mostly dealing with. Distinguishing shoreline is well-known problem in remote sensing, particularly using *SAR* data. *SAR* images have been well known suffered from speckle which

obstructs interpretation process. Shoreline detection obstacle of *PALSAR* images in this study was defining the exact shape boundary between land and sea due to dynamic process of Parangtritis coast which affected by Indian Ocean and the weather. Shoreline morphology is considered important to monitor in which reflected nearshore dynamic processes, particularly rip currents signatures along Parangtritis cresentic beach.

The precise position and shape of the shoreline needed in this study was preserved using edge-preserving operator to remove the image noise. The Lee filter, Frost filter, Kuan filter, Median filter, and Gamma Maximum a Posteriori filter can be used to suppress radar speckle while preserving edges [*Liu and Jezek*, 2004]. Frost filter differs from Lee filter in that the scene reflectivity is estimated by convolving the observed image with the impulse response of the *SAR* system and it averages less in the edge areas to preserve the edge [*Sheng*, 1996]. Frost filter was promising shown good result to reduce the speckle in this study compare to Lee filter to proceed edge enhancement on Sobel low-pass convolution. The texture occurrence then being smooth using mean filtering, to reduce the amount of intensity variation between one pixel and the next. Constant reflectivity or the texture of *PALSAR* images were segmented. Segmentation of *SAR* images based generally on grey levels and textures [*Zaart, et al.* 2002]. Estimating the threshold was the most crucial in the segmentation process to determine the classes or cluster based on grey scale values. To define boundary between land and sea, parallelepiped classification and majority post-classification were conducted to extract the shoreline.

This study applied edged-based methods which tried to identify the transitions between different regions as stated in [*Fjortoft*, 1999]. Some locations which are

actually sea, due to sediment transport of nearshore circulation, reflected same gray scale digital number (*DN*) on the *PALSAR* images. This affected shoreline morphology extraction which based on the *DN* (Figure 15 and 16). The boundary between the land and sea could hardly justify due to the same value of *DN*.

Kernel operation used in this image processing is 3 x 3. The larger the Kernel size applied, the smoother effect on *SAR* images. However, this might reduce some information which intentionally derived from. The choice of kernel size is a compromise between a desired noise reduction and keeping the image sharpness. Thus, this study applied 3 x 3 Kernel size aimed to suppress the noise whilst preserving the edges regarding on rip currents assessment on shoreline morphology. Illuminated object on *PALSAR* images might have recorded on same digital number which in a way affected segmentation and classification. The result of shoreline morphology extraction as seen in Figure 17 mostly affected by signal return from the sea and land area, related to L-band characteristic. Inadequate contrast and speckle effect generated by coherent signal-scattering complicated the shoreline detection obstacle as also stated by *Lee and Jurkevich*, [1990].

Shoreline morphology extraction of 2nd May and 17th June 2007 *PALSAR* image in Figure 17 shows some changes or shifting at some location, but not wide enough spatially (see the circles). During time period when *PALSAR* images acquired on May – June, the wind blown from Indian Ocean at the same direction within ten months and wider fetch as stated in *Gingele, et al.* [2002]. High wave from Indian Ocean might affect nearshore processes at Parangtritis coast.

Rip currents usually do not occur in a single place (Figure 18 and 19), but might occur in many places based on the

upcoming waves and winds from the ocean to the land, and in tropical areas rip currents are also influenced by the season. Some field observations have been conducted related to Parangtritis's rip currents phenomenon and proved that mechanism of wind and waves affected the Rips [*Sukirman*, 2003, *PSBA*, 2009, and *Susmayadi*, 2010].

Spatial and temporal resolution of *PALSAR* images, Reference shoreline, and rip currents position shown in Figure 18 and 19 are different. These figures were shown only to give visualization possibility of Rip currents occurrence based on the cove of cuspate of Parangtritis cresentic beach.
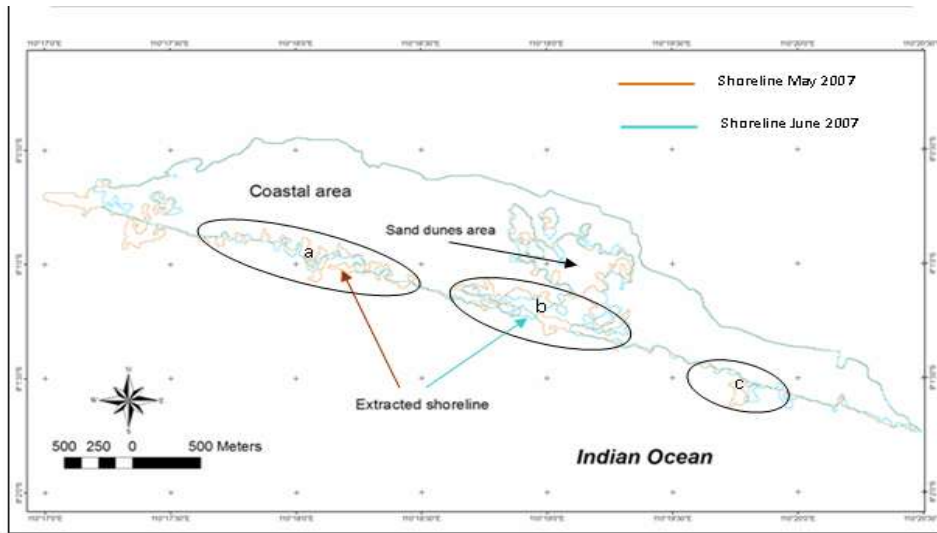

Figure 17. Shoreline extraction of 2nd May and 17th June 2007 *PALSAR* images
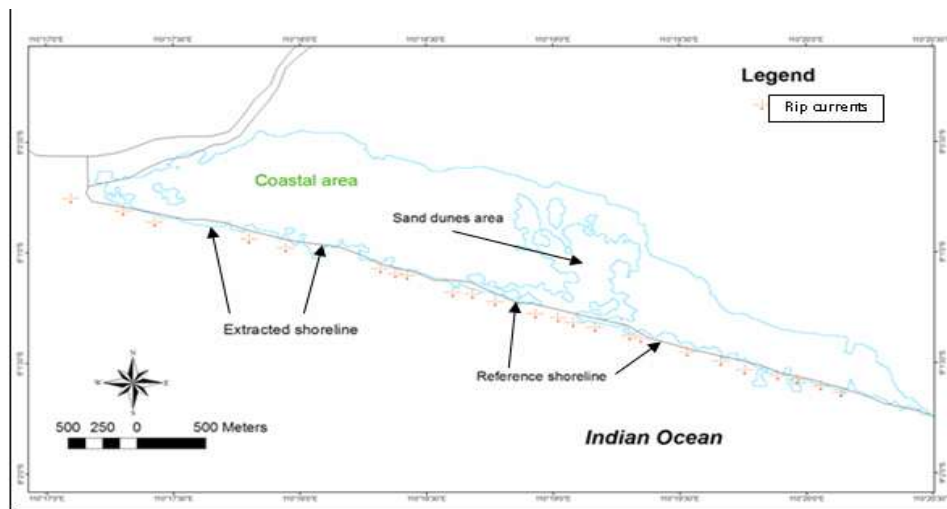

Figure 18. Shoreline extraction of 2nd May *PALSAR* on Reference Shoreline 1999 and Rip Currents Occurrence 2006
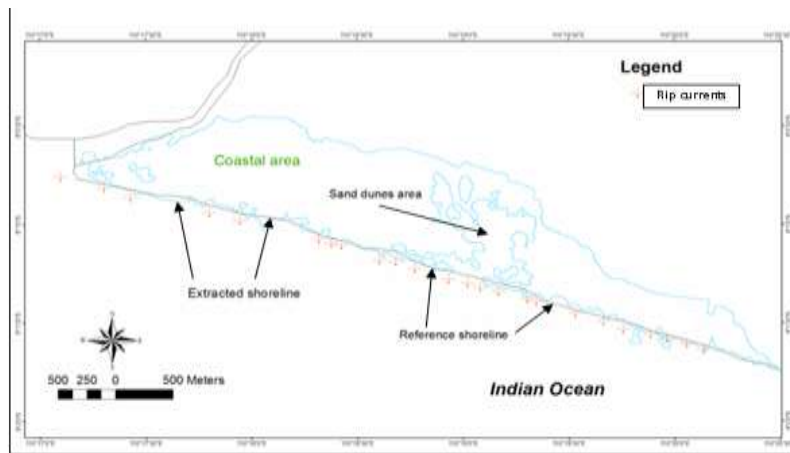
Figure 19. Shoreline extraction of 17th June *PALSAR* on Reference Shoreline 1999 and Rip Currents Occurrence 2006

***ALOS* Advanced Visible and Near Infrared Radiometer type-2 (*AVNIR-2*) for Regioning Breaking Waves and Surf Zone and Shoreline Morphology Detection**

The contrast between sea and land can be identified and distinguished visually and directly from optical images with spatial resolution like *AVNIR-2*. The challenge is to extract the same subject using the same approach as applied on *SAR* images. The sea in *SAR* is likely more homogeneous in grey level than the land, while on optical images the difference is so distinct. Breaking waves and surf zone identification and regioning on *AVNIR-2* was conducted based on pixel value.

Image processing which conducted on rip currents signatures zone detection using *ALOS PALSAR* and *AVNIR-2*, is one of step to further analyze the vulnerability and risk of coastal area due to natural hazards. Shoreline morphology which derived from *PALSAR* image indicating nearshore dynamic process in the east, sand dune area, and the middle-west along Parangtritis beach. *AVNIR-2* data extraction to determine the wave breaking region and surf zone associated with rip currents reveals that indeed the rips follow the shoreline morphology distribution pattern that forms a cove (Figures 20 and Figure 21).
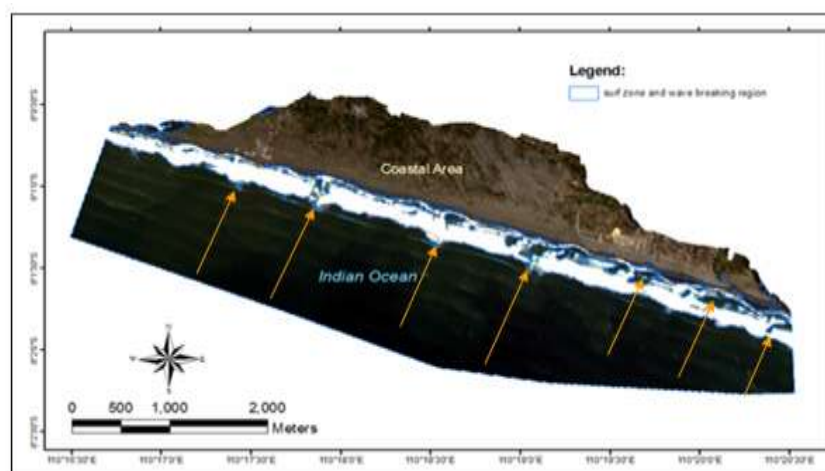

Figure 20. Surf zone and Wave breaking region associated with Rip Currents (arrows) on 17th June 2008 *AVNIR-2* image

The movement of rip currents locations in Parangtritis beach is usually in line with the movement of the cove and headland morphology formed in the shoreline. Figure 21 presents breaking wave region and surf zone associated with Rip currents (arrows) occurrences on 17th June 2008 *AVNIR-2* image and 17th June 2007 *PALSAR* image. Straight forward image fusion technique was applied to optical sensor of *ALOS AVNIR-2* and microwave sensor *ALOS PALSAR*. Figure 21 is considered final result of this study which is rip currents signatures zone detection on *ALOS* sensor, *PALSAR* and *AVNIR-2* respectively.

This study is considered as preliminary research in using ALOS PALSAR and AVNIR-2 for assessing nearshore region dynamic processes, such as rip current, breaking waves, and shoreline changes. Further validation is the next step to be developed.
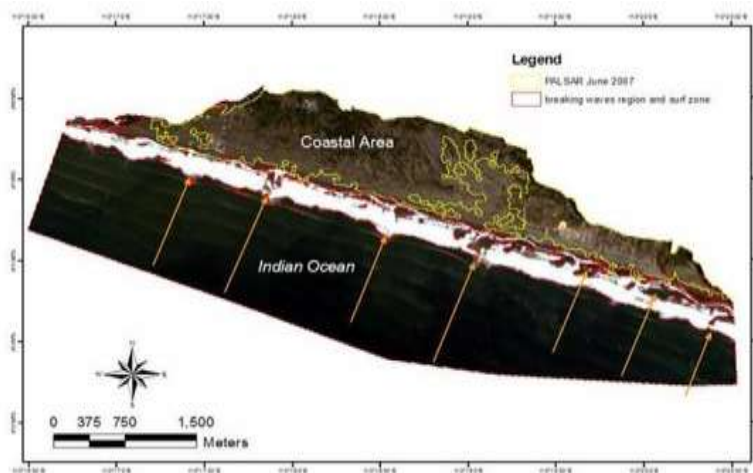

Figure 21. Breaking wave region and Surf Zone associated with Rip currents (arrows) on June 2008 *AVNIR-2* image and June 2007 *PALSAR* image

CONCLUSION

Breaking waves and surfing zone reflect dynamic complex nearshore water region processes. Edge detection operator applied to identify waves breaking region and surf zone shown promising result. Dark patch breaking high backscatter pattern indicates rip current signatures occurrence. However, waves breaking were not individually identified, but clustered in the surf zone. This study applied 3 × 3 moving window or kernel which considered as the optimum size due to 10 meters spatial resolution of *PALSAR* and *AVNIR-2* respectively.

Chain of image processing to extract shoreline morphology still possible to be enhanced further more to get detail shoreline morphology extraction result. Edge detection and speckle filtering algorithm applied in this study are part of image enhancement, particularly the use spatial filters. Extraction shows that the cusps system has not changed much within one month, but might shifted individually (spatially shown from the images). The direction and intensity of rip currents might be different and this can be justified by exploring optical sensor, like *AVNIR-2* which has same spatial and temporal resolution with *PALSAR*.

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