Wave refraction analysis in shallow water using X-band nautical radar

University of Tsukuba, Student Member, ○G. M. Jahid Hasan
University of Tsukuba, Regular Member, Satoshi Takewaka

Abstract

A X-band nautical radar system is employed to observe the near shore region along the HORS pier at Hazaki, Japan. The radar system provides instantaneous distribution of wave crests along the shoreline. The image sequence comprises a clear spatial and temporal variation of the wave pattern. The filtered image sequences were constructed using average frequency corresponding to the spectral peak of radar images. The wave angle was estimated from radar images and compared with linear refraction analyses. The observed discrepancy may happen due to nonlinear characteristics of shallow water waves as well as long shore current.

1. Radar Measurements

Radar measurements were conducted at the research pier HORS located at Hasaki. The radar echo signals are sampled in 2 *s* intervals and converted to a rectangular image of 1024 pixels in along shore and 512 pixels in cross shore direction. The horizontal extent of the image is 5556 *m* and the vertical extent is 2778 *m*. Each pixel corresponds to a square of 5.4 *m*. Fig. 1 shows a typical radar image during a typhoon event. Vertical streak in the middle of the figure is the pier and the waves are approaching obliquely towards the shore. The images have pixel intensities between 0 and 255 with brighter pixels corresponding to the location of higher signal returns.

2. Temporal Filtering

Radar image comprises with different frequency waves, necessitate filtering for a particular dominating wave. The sequence of radar images were filtered here with frequency (f=0.0586 *Hz*), which is close to the average of the spectral peak at every locations, to yield an image sequence with single frequency component. One of the filtered images is shown in Fig. 2, which also shows the coordinate system for this study. The filtered sequence of images was analyzed to calculate wave parameters such as wave numbers, refraction angles etc.

3. Refraction Analyses

The filtered image sequence represents the passage of a dominant wave and used here to estimate the wave number k and their incident angle along a cross shore line. The k value

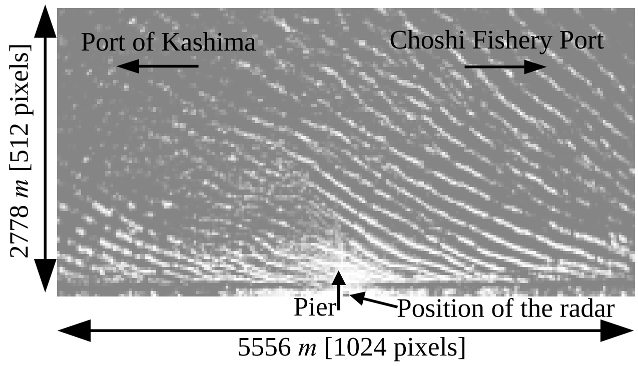

Fig 1: Typical radar image with its extent during typhoon BANYAN (July 26, 2005).

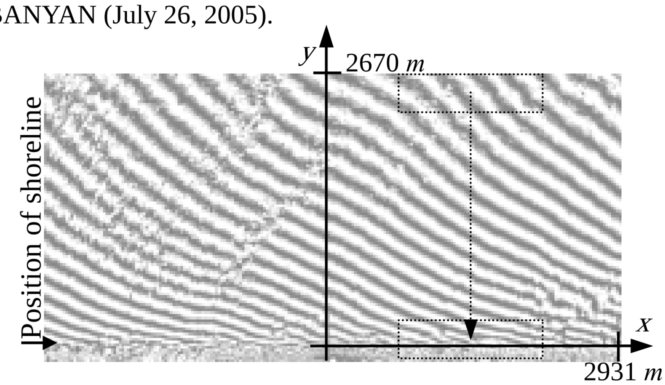

Fig 2: Typical filtered and decomposed image with the co-ordinate system.

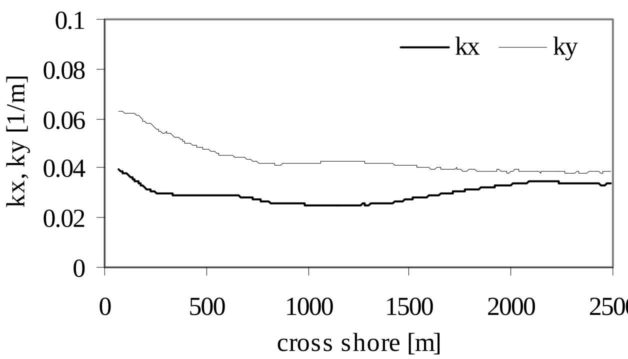

Fig 3: x and y component of wave number calculated from filtered images.

Key words: X-band nautical radar, filtered image, refraction angle, wave ray, and shallow coastal region.

〒305-8573, Graduate school of Systems and Information Eng., Tsukuba, Ibaraki, Email: hasan@surface.kz.tsukuba.ac.jp

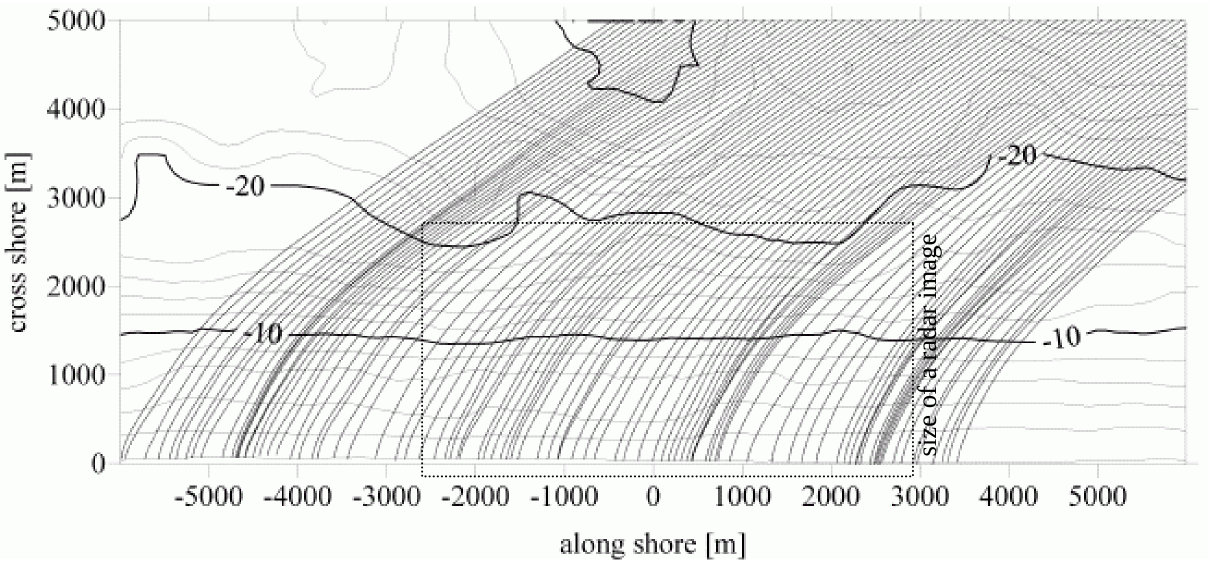

Fig 4: Wave ray patterns and bathymetric contours at every 2.0 meters depth. The dotted box shows the extent of a radar image.

estimation started from offshore. A region is considered for estimating the average value at every location. The x and y components of wave number, k_x and k_y were calculated after applying FFT at local regions (1389.0 m x 347.25 m) shown as dotted box in Fig. 2. The data length for FFT is larger than the wavelength, which is observed in the filtered image. Fig. 3 shows the cross-shore distributions of wave numbers. The angle, $\theta = tan^{-1} (k_x / k_y)$ can be considered as refraction angle for the dominating wave component.

The bathymetric data, which is required for wave ray analyses, were collected from Japan Coast Guard (Fig. 4). Incident wave angles at offshore locations used for wave ray analyses were deduced from NOWPHAS (http://www.mlit.go.jp/kowan/nowphas/) record during the typhoon event. Estimated wave rays for waves with 17 s (0.0588 Hz) period are shown in Fig. 4. The figure also shows the depth contours at every 2.0 m depths. The waves

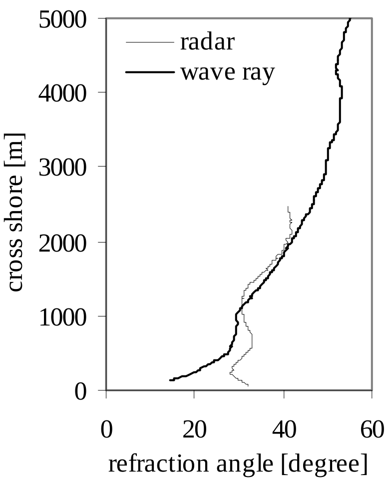

Fig 5: Comparison between refraction angle calculated from radar images and wave ray analysis. Refraction angle 0° means the shore normal incidence.

were approaching obliquely, refracted slowly until it reaches the water depths of 10 m, and finally refracted rapidly when it comes close to the shore.

The wave angle that was estimated using filtered radar images is compared with the angle estimated from wave ray computation (Fig. 5). In general, the refraction angles are reducing with decreasing depths from offshore to onshore, which is observed in both results. However, at cross-shore location from 1100 m to 600 m, the wave ray angle is slowly reducing whereas the radar wave angle is increasing. The long shore currents as well as shoaling effects might be the possible causes for the discrepancies in this pocket.

Multiple directional variations of wave crest also found near the offshore border in the filtered images. The increasing nature of the wave angles above 2000 m of cross-shore may be affected by this variation.

Moreover, near the shoreline, it is hard to estimate the wave numbers due to existence of noises in the local data window.

4. Concluding Remarks

The present study analyzed the radar images captured during a typhoon event and assessed their usability to estimate the refraction process. The estimated wave angles follow the general tendency of decreasing nature with decreasing water depths despite some discrepancies have been observed. The effects of long shore current and non-linearity should be considered in the near shore region for better understanding of this process.