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Automatic detection of internal wave using particle swarm optimization algorithm

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Abstract. The work demonstrated a new approach for internal wave automatic detection during 2004 tsunami. In this regard, optimization algorithm of Particle Swarm is used with 2-D wavelet transform of ASAR satellite data. It indicates the regulated radar backscatter ranged between -4 to -24 dB. The lowest normalized radar cross section of -28dB is described the low window quarter shelter alongside the Andaman and Nicobar Islands. Nevertheless, the maximum backscatter of -4 dB is pronounced the prevalence of whirlpool in the east of the Andaman Sea. The whirlpool has a radius of 1.9 km which is estimated using optimization algorithm of Particle Swarm. This whirlpool is located above of water depth gradient of 1000 m. In conclusion, the Particle Swarm Optimization has routinely realize internal wave which generated by the 2004 tsunami.

1. Introduction

Internal waves exist as a result of the deep waters of the ocean are denser than the surface waters [1]. In remote sensing imaging, internal waves are between the notable merely predictable of the oceanographic spectacles. The distinctive footprint of irregular modes of brightness and dusky, quasilinear bands are seeming in radar satellite images of the ocean surface, in optical radiometer data, and in real and synthetic aperture radar (SAR) data. If a parcel of deep (heavy) water were to be pulled up towards the surface, gravity would force it back downward. It is the identical concern that may occur if a parcel of ocean water is raised into the air; it would fall once free. The buoyancy of surface waters makes them come back to the surface if they are momentarily pushed downward [2] [3].

Though, there are differing sorts of microwave satellite data footprint of tiny-epoch, internal wave trains that can be terribly disruptive to infer. Since SAR data suited mostly reachable, SAR sensors suited the foremost vital remote sensors for IW detection. They express explicit data approximately of the waveform physical characteristics which, appropriately agreed, afford distinctive quantities not merely involving the IWs, however, conjointly the inside sea and the its microlayer beneath surface [4]. Owing to the fluid mechanics interface of the movable surface flow with the surface wave dynamics, the largeness of the Bragg waves is distended in convergent current zones. Therefore, it is diminished into deviating current zones. Hence, the microwave radar footprint of oceanic internal waves integrates alternating brightness and dusky bands on a duplicate contextual [1].

Nonetheless, there occur conjointly alternative microwave radar footprint of internal waves: generally they involve merely of brightness streaks or entirely of darkness modes. As soon as the wind rate is lower than its threshold for wide-ranging wave creation, utterly brightness modes are bumped into and as soon as the natural look-alikes are in existence, merely dark streaks are evidently treasured [4]. Conversely, microwave radar detection imaging notions accomplished of elucidation these, unique radar footprint of internal waves assessable immobile do not be existent.

The internal waves are mainly generated by tide fluctuations which are ordinarily tremendously nonlinear and arise recurrently in wave envelopes. The gap amongst the waves in an exceedingly wave envelope and conjointly the amplitude decrease from the front to the rear. The largeness of huge internal waves can outstrip 50 m in exactly circumstances. Hypothetically, these extremely nonlinear impressions are usually delineate in terms of interior solitons. Accordingly a wave package involves of various solitons. Solitary wave principles relevant to the skeleton of the creation and transmission of internal solitary waves envisage that, if the ocean depth of the complex water level is extreme minor than the depth of subsurface layer, then the interior soliton should be a "wave of depression" [5].

Consistent with Da Silva et al., [4], radar microwave satellite such as synthetic aperture radar (SAR) surveillances which deliver the greatest indication for the manifestation of the smaller-time interior solitary waves (ISWs) in the coastal waters. This is owing to a appliance somewhere parallel-spreading of internal waves, trotted on the thermocline layer usually tens of meters underneath the ocean surface, which can create a footprint in the surface roughness arena since of the modifying consequence of merging and deviation in the near-surface flows connected with the interior waves. This intonation is utmost operative for short-time of 30 minutes or less for ISWs since the rinsing of short Bragg waves or ripple waves is robust at these epochs. It possibly also to detect duration of internal waves as function of tide fluctuations. In other words, within duration of 12.4 hours, in the existence of seeming films and/or once the surface flows associated with the ITs convince interchanging wind circumstances as function of the wind surface beside tide revealing grander footprint backscatter than tide is effected by wind. Subsequently, the tidal wave can be castoff to pronounce the tsunami, therefore, how can tsunami create internal wave? In actual fact, there is uncertainty that the tsunami can break the ocean water physical properties. As said by Marghany [6], the salinity was extremely increased due to tsunami effects.

The novelty of this work is to implement the algorithm of Particle Swarm Optimization for involuntary revealing of internal wave (IW) from SAR satellite data during 2004 tsunami event. This work hypothesizes that IW can also be automatically detected by the use of Particle Swarm Optimization algorithm from SAR satellite data. In this context, PSO taken into consideration to optimize the initial IW detection using 2-D wavelet transform.

2. Algorithms

There are two algorithms implemented in this study to automatic detection of internal wave in radar satellite data post the 2004 boxing day (Figure 1). These algorithms are 2-D wavelet transform and Particle Swarm Optimization algorithms.

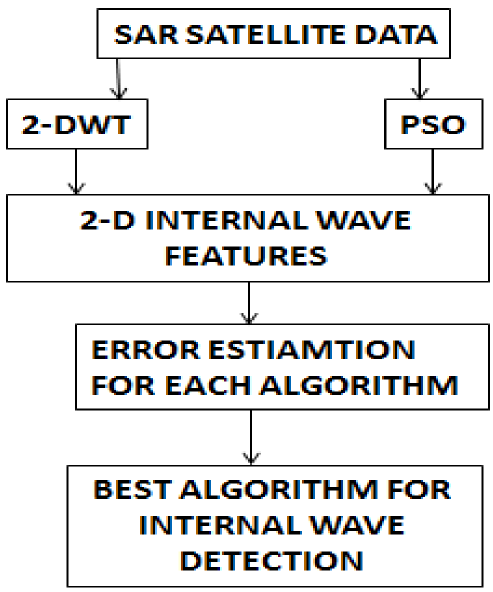

Figure 1. Algorithms used for internal wave automatic detection

2.1 Wavelet Transform

Wavelet transform tool is commonly used for analysing time-varying signals. This technique generates spectral decomposition through the scale model. In remote sensing images investigation, the two-dimensional wavelet transform (2-DWT) serves up as an incredibly effective band-pass filter. With this regard, 2-DWT operated to discrete approaches with altered scales. Beyond, the brilliant proficiency of wavelet transform in time localization for one-dimensional presentation. Under this circumstance, it can supply particular evidence on characteristic description in remote sensing data [7]. These functions nominate the wavelet transform a valuable module for extorting aspects physical properties exactly in remote sensing data. Two dimensional wavelet characteristic having oscillation in x direction only, can be written as follows [8]:

$$\Psi_{s,\tau}(t) = \frac{1}{\sqrt{s}}\Psi\left(\frac{t-\tau}{s}\right) \quad (1)$$

where, $\Psi(t)$ is the transforming function, and it is called the mother wavelet. The two innovative parameters, s and τ are the ruler and transformation of the offspring wavelet. The word $\sqrt{s}$ regulates the vitality for dissimilar rulers, although, the other expressions express the size and conversion of the 2-DWT.

2.2 Algorithm of Particle Swarm Optimization (PSO)

Succeeding Marghany [10], PSO algorithm is considered as a population-established casually examining practice algorithm. It is assumed that N is number of “particles” i.e. physical properties of internal wave and its surrounding environments: bright and dark backscatter variations, linearity, depressions, and direction of propagation in ASAR (Advanced Synthetic Aperture Radar) data. These internal wave features invasive contacts randomly seem in a “solution space” [11]. Thus the optimization problem can be solved for statistics assembling; there is always a criteria (for instance, the adjusted inaccuracy task) for separately particles at their locus in the elucidation dimension [9,12]. The N particles can retain poignant and computing the benchmarks in separately locus the remain which is entitled as the PSO faintness which is unresolved the gages attains fulfilled the threshold level. Therefore, individual internal wave features (particles) maintains its axes in the clarification domain of ASAR that are combined in the supreme appropriateness which requires tremendously accomplished through requested physical features i.e. particles. In fact, the pixel of each feature i.e. particle (m,n,l) denotes a probable solution to the optimization problem. Following Kennedy and Eberhart [9], each agent moves the particle with a direction and velocity $U_{m,n,l}$,

$$O_{m,n,l} = O_{m,n,l} + U_{m,n,l}, \quad (2)$$

where $O_{m,n,l}$ represent particle and $U_{m,n,l}$ is the velocity of the 4-D particle in the *i,j,k* agents, respectively.

$$U_{m,n,l} = U_{m,n,l} + c_1 r_1 (lbest_{m,n,l} - O_{m,n,l}) + c_2 r_2 (ubest_{m,n,l} - O_{m,n,l}) \quad (3)$$

where $lbest_{m,n,l}$ is the local finest element, $ubest_{m,n,l}$ is the universal greatest element, r_1 and r_2 are random variables and c_1 and c_2 are the swarm system variables. After each iteration the global best u_{best} particle and the agent indigenous finest I_{best} particle are evaluated based on the maximum fitness functions of all particles in the solution space. Then equation 1 can be expressed as follows [9]:

$$\begin{aligned} U_{m,n,l} &= w \cdot U_{m,n,l}(t-1) + c_1 \cdot r_1 (O_{m,n,l}(t-1) \\ &\quad - \Phi_{m,n,l}(t-1)) + c_2 \cdot r_2 (O_{m,n,l}(t-1) \\ &\quad - \Phi_{m,n,l}(t-1)) \end{aligned} \quad (4)$$

$$\Phi_{m,n,l} = \Phi_{m,n,l}(t-1) + U_{m,n,l}(t) \quad (5)$$

where $\Phi_{m,n,l}$ is the position of the particle for wavelet transform, $U_{m,n,l}$ is the current velocity of the particles in $m \times n \times l$. The rate of speed is regulated by a regular procedures which influence the crescendos of the flock. Further, there are a number of parameters must be deliberated for instance, preliminary inhabitants, depiction of locus and rapidity schemes, fitness function classification and the restraint [13]. These restrictions are for PSO accomplishments. Following Ibrahim et al. [14] the preliminary flock elements anticipated PSO is modified to enclose 3000 plugs of specks for $\Phi_{m,n,l}$ and rate of speed $U_{m,n,l}$. The plugs had indiscriminately nominated in the azimuth and range directions wavelet transform of ASAR data.

3. Results and Discussion

The depth variations of the Andaman and Nicobar Islands is ranged between 200 m to 3000 m (Figure 2). In the western adjacent of the Andaman washbasin, the Andaman and Nicobar Islets are volcanic in beginning. The ridges between the islands, along with a quantity of submerged volcanic seamounts, are all impending causes of IW. The consequence is a zone which is irritating in IWs which are multifaceted soliton-soliton interface.

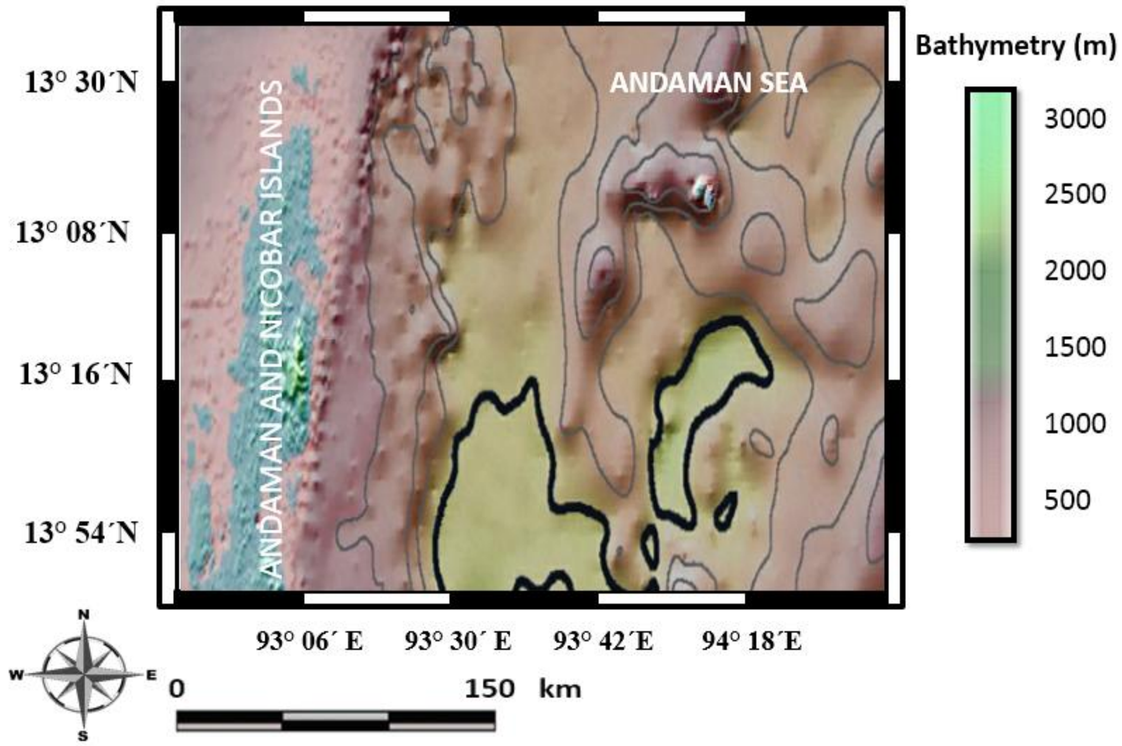

Figure 2. Bathymetry along Andaman and Nicobar Islands

On 28th December 2004 which was post the boxing day, ENVISAT SAR satellite data image of Orbit 148 was gained by ESA (Figure 3). It spectacles the Indian-Andaman Islets and the Ritches Archipelago with the deepest bathymetry more than 3000 m water depth. The radar backscatter is ranged between -24 to -4 dB. The lowest normalized radar cross section of -28dB is described the low window zone shelter along the Andaman and Nicobar Islands. However, the highest backscatter of -4 dB is described the occurrence of whirlpool in east of the Andaman Sea. This whirlpool is located between latitude of 14° N to 15° N and longitude of 94° E and 96°E. The whirlpool has radius of 1.9 km and located above of water depth gradient of 1000 m. It was rotated in anticlockwise direction (Figure 3).

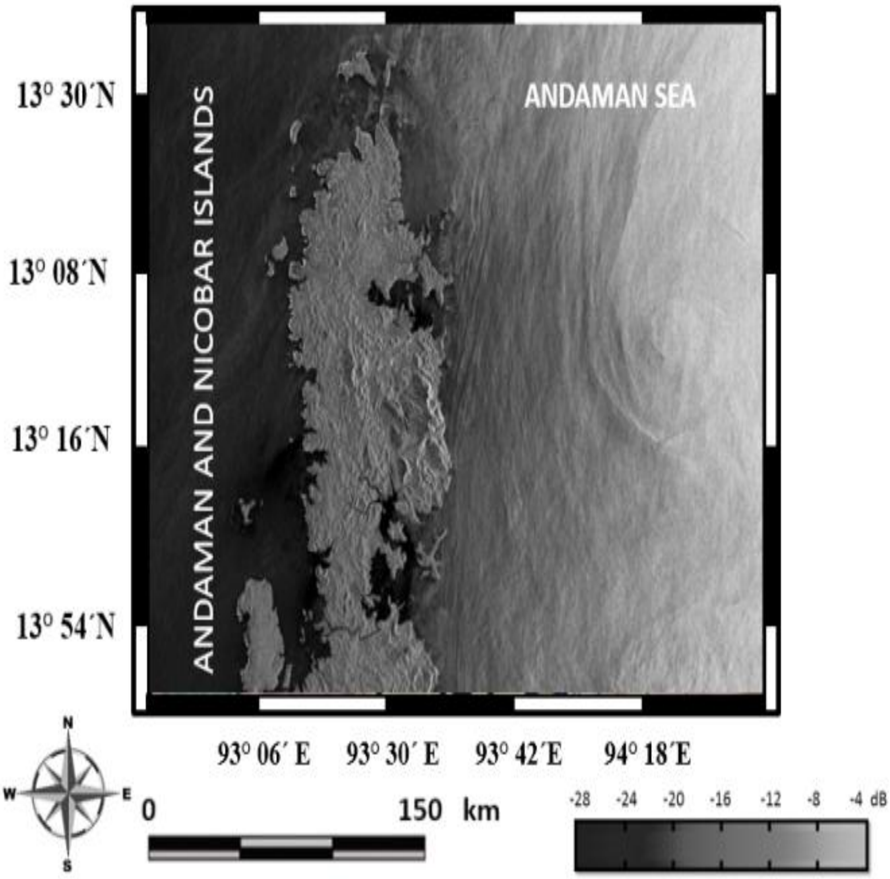

Figure 3. ASAR ENVISAT of Andaman and Nicobar Islands

Figure 4 shows the result optimization of wavelet transform using PSO algorithm. It is obvious the clear appearance of edge of internal wave. In fact**,** the PSO circumvents a shrinking determination by assembly a biased amalgamation of successively mean with the neighbour close pixels of the 2-DWT. This abridged the clatter in the piece s' edge extents starved of trailing superiority perceptiveness. Evidently, PSO within approximately 1 hour within 1000 iterations is able to reconstruct 2-D of internal wave with RMSE of 0.43.

The implementation of PSO with 2-D wavelet transform phase assisted to determine optimal grows regions across the continuing and discontinuing internal wave edges. In fact, in PSO system, particles are impartial of every other and their movements are ruled with the aid of a set of rules. With this concern, PSO synchronized sequences sides of the internal wave edge (Figure 4).

The PSO algorithm commences by creating random locations for the particles, within an initialization pixels of the internal waves in ASAR image. Particles in PSO algorithm can also be modified to zero or to minor random values to avoid particles from withdrawal the search space of internal wave pixels during the first iterations (figure 3a). Throughout the core loop of the algorithm, the velocities and locations of the particles are iteratively rationalized until the ending condition is encountered.

It ought to be noted that sturdy 2004 earthquakes have an adequate two replacement of power for necessary conversion of the water column layer characters. Tenths of a segment of the power of an quake is adequate for creating on the bathymetry of a temperature variance with an attribute parallel size, restrained by approach of a percentage of kilometres and with a temperature eccentricity of the demand of 1°C. State that an equal measure of rule which is a smaller quantity than 1% of the quake magnitude and is expended at the creation of tidal or tsunami waves.

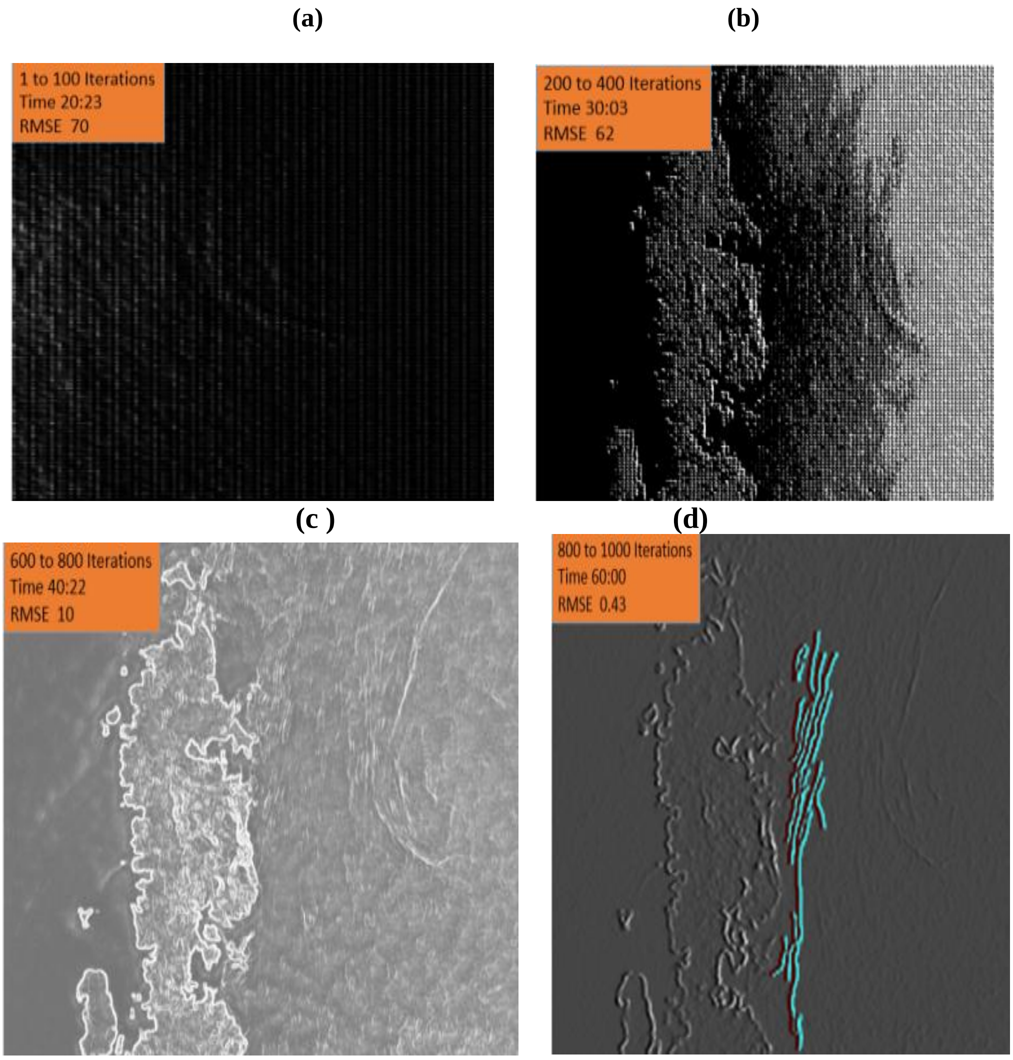

Figure 4. Particle Swarm Optimization with different iterations (a) 100 ,(b) 400, (c) 800 and (d) 1000 iterations for internal wave automatic detection

In addition, PSO algorithms constructed the discontinuity in quality order. This is appropriate in the extraordinary greatness stripe or arch of immobile stretch and in the vicinity squat bend frontier is acknowledged as existence amongst edge features and high speckle intensities in ASAR data. This agrees with the work are delivered by Kennedy and Eberhart [9] ; Marghany [7]; and Marghany [10].

4. Conclusion
This investigation presents a novel method for automatic detection of internal wave due to tsunami impact. In doing so, such optimization set of rules of particle swarm is is implemented with involving of ENVISAT satellite data. In this view, PSO is designed in automatic detection of internal wave from ENVISAT data. The study shows ENVISAT backscatter is ranged between -4 to -24 dB. Further, smallest normalized radar cross section of -28dB is pronounced as the low window zone shelter along the Andaman and Nicobar Islands. Conversely, the highest backscatter of -4 dB is described the occurrence of whirlpool in the east of the Andaman Sea. This whirlpool is located between latitude of 14° N to 15° N and longitude of 94° E and 96°E. The whirlpool has a radius of 1.9 km and located above of water depth gradient of 1000 m. In conclusion, the Particle Swarm Optimization has automatically detect internal wave. It can be said that the 2004 tsunami generated internal wave along the Andaman Sea.

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