PARTICLE SWARM ALGORITHM FOR AUTOMATIC DETECTION OF INTERNAL WAVE FROM ENVISAT DATA DURING 2004 TSUNAMI

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ABSTRACT: This work presents a new approach for automatic detection of internal wave due to tsunami impact. In doing so, such optimization algorithm of particle swarm is implemented with involving of ENVISAT satellite data. The Particle Swarm Optimization algorithm is designed for automatic detection of internal wave from ENVISAT data. The study shows that Particle automatically detect the shows the ENVISAT SAR radar image (Orbit 148) was acquired on 28 December 2004, two days after the tsunami hit Asia. It shows the Indian Andaman Islands and the Ritches Archipelago. The normalized radar cross section is ranged between -4 to -24 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. In conclusion, the Particle Swarm Optimization has automatically detect internal wave. It can be said that 2004 tsunami generated internal wave along the Andaman Sea.

1. INTRODUCTION

In remote-sensing imaging, internal waves are among the foremost simply recognized of the oceanographic phenomena. The distinctive signatures of alternating bands of sunshine and dark, quasilinear strips are perceived in images of the ocean surface, in multispectral radiometer data, and in real and synthetic aperture radar data. Internal waves exist as a result of the deep waters of the ocean are denser than the surface waters (Alpers 1985). 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 (Apel et al., 1975 and Bowden, 1983).

Since SAR data became broadly accessible, SAR sensors suited the foremost vital remote sensors for IW detection. Though, there are differing sorts of microwave radar signatures of short-period, internal wave trains that may be terribly disruptive to interpret. They convey specific data about the characteristics of the interior waveforms that, properly understood, provide distinctive measurements not solely concerning the IWs however conjointly the inside ocean and the ocean surface microlayer (Da Silva et al., 1998). Owing to the fluid mechanics interaction of the variable surface current with the surface waves, the amplitude of the Bragg waves is enlarged in convergent flow regions and is diminished in divergent flow regions. As a consequence, the microwave radar signatures of oceanic internal waves incorporates alternating bright and dark bands on an identical background (Alpers 1985).

Nonetheless, there exist conjointly alternative microwave radar signatures of internal waves: generally they consist merely of bright lines or exclusively of dark bands. As soon as the wind speed is below threshold for general wave generation, exclusively bright bands are encountered and once surface slicks are existent, solely dark lines are clearly seen (Da Silva et al., 1998). Conversely, microwave radar detection imaging theories capable of explaining these, exceptional radar signatures of internal waves quantitatively still do not exist.

The tidally created internal waves are normally extremely nonlinear and occur regularly in wave packets. The gap between the waves in an exceedingly wave packet and conjointly the amplitude decrease from the front to the rear. The amplitude of enormous internal waves can exceed 50 m in some cases. Hypothetically, these extremely nonlinear waves are usually delineate in terms of internal solitons. Accordingly a wave packet consists of many solitons. Solitary wave theories applicable to the outline of the generation and propagation of internal solitary waves predict that, if the depth of the higher water layer is far smaller than the depth of the lower layer, then the inner soliton should be a "wave of depression" (Hsu et al, 2000).

According to Da Silva et al., (1998),Satellite Synthetic Aperture Radar (SAR) observations that provide the best evidence for the presence of the shorter period internal solitary waves (ISWs) in the ocean. This is due to a mechanism whereby horizontally-propagating internal waves, centered on the thermocline typically some tens of meters below the surface, can generate a signature in the surface roughness field because of the modulating effect of convergence and divergence in the near-surface currents associated with the internal waves. This modulation is most effective for short period (30 minutes or shorter) ISWs because the straining of short (Bragg) surface waves (or ripples) is strongest at these periods. It may also be possible to detect tidal period internal waves (with periods of 12.4 hours) in the presence of surface films and/or when the surface currents associated with the ITs induce alternating wind conditions relative to the surface with wind against tide exhibiting larger radar backscatter than wind with tide. Since, the tidal wave can be used to describe the tsunami, so how can tsunami generate internal wave? In fact, there is doubt that the tsunami can reform the ocean water properties. As said by Marghany (2014a), the salinity was extremely increased due to tsunami effects.

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

2. ALGORITHM

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 (Marghany 1999). 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 (Marghany 2002):

$$\Psi_{s,\tau}(t) = \frac{1}{\sqrt{s}} \Psi\left(\frac{t-\tau}{s}\right) \qquad (1.0)$$

where, $\Psi(t)$ is the transforming function, and it is called the mother wavelet. The two new variables, s and τ are the scale and translation of the daughter wavelet. The term $\sqrt{s}$ normalizes the energy for different scales, whereas the other terms define the width and translation of the wavelet.

2.2 PARTICLE SWARM OPTIMIZATION (PSO)

Succeeding Kennedy and Eberhart (1995) and Marghany (2015), Particle Swarm Optimization (PSO) is a population-based randomly searching process. It is assumed that there are *N* "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 data. These internal wave features invasive contacts randomly seem in a "solution space" (Xie et al., 2003). Thus the optimization problem can be solved for data clustering, there is always a criteria (for example, the squared error function) for every single particle at their position in the solution space (Kennedy et al., 1997). The *N* particles will keep moving and calculating the criteria in every position the remain which is named as fitness in PSO pending the criteria reaches satisfied threshold. Therefore, each internal wave features (particles) maintains its coordinates in the solution space of ASAR which are combined with the finest fitness that has extremely accomplished by 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 (1995), each agent moves the particle with a direction and velocity $v_{m,n,l}$,

$$p_{m,n,l} = p_{m,n,l} + v_{m,n,l}, \qquad (2.0)$$

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

$$v_{m,n,l} = v_{m,n,l} + c_1 r_1 (lbest_{m,n,l} - p_{m,n,l}) + c_2 r_2 (gbest_{m,n,l} - p_{m,n,l}) \quad (3.0)$$

where $lbest_{m,n,l}$ is the local best particle, $gbest_{m,n,l}$ is the global best particle, 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 g_{best} particle and the agent local best l_{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 (Marghany 2014b)

$$\begin{aligned} v_{m,n,l} = {} & w \cdot v_{m,n,l}(t-1) + c_1 \cdot r_1 (p_{m,n,l}(t-1) \\ & - \psi_{m,n,l}(t-1)) + c_2 \cdot r_2 (p_{m,n,l}(t-1) \\ & - \psi_{m,n,l}(t-1)) \end{aligned} \quad (4.0)$$

$$\psi_{m,n,l} = \psi_{m,n,l}(t-1) + v_{m,n,l}(t) \quad (5.0)$$

where $\psi_{m,n,l}$ is the position of the particle for wavelet transform, $v_{m,n,l}$ is the current velocity of the particles in $m \times n \times l$. The velocity is regulated by a set of rules that influence the dynamics of the swarm. Further, there are several parameters must be considered such as initial population, representation of position and velocity strategies, fitness function identification and the limitation (Dorigo et al., 2008). These parameters are for PSO performances. Following Ibrahim et al., (2010) the initial swarm particles proposed PSO is initialized to contain 3000 points of particles for $\psi_{m,n,l}$ and velocity $v_{m,n,l}$. The points had been randomly selected in the azimuth and range directions wavelet transform of ASAR data.

3. RESULTS AND DISCUSSION

Figure 1 shows the bathymetry variations of the Andaman and Nicobar Islands. The water depth along Andaman and Nicobar Islands is ranged between 200 m to 3000 m. The Andaman and Nicobar Islands on the western side of the Andaman Sea are volcanic in origin. The sills between the islands, as well as a number of underwater volcanic seamounts, are all potential sources of internal waves. The result is an area rich in internal wave excitations and complex soliton - soliton interaction.

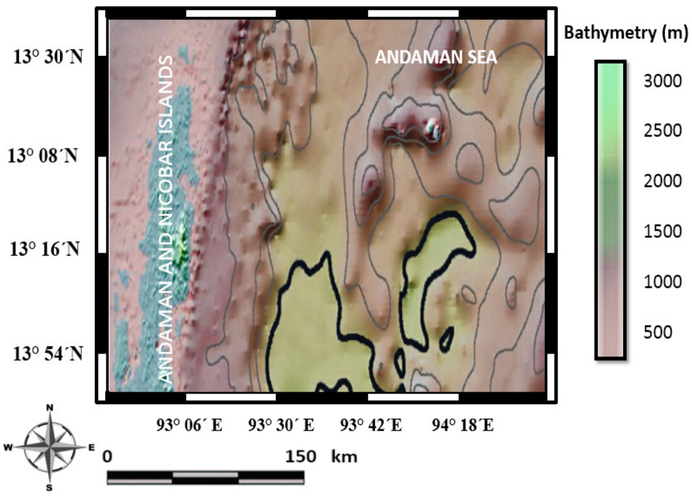

Figure 1. Bathymetry along Andaman and Nicobar Islands.

Figure 2 shows the ENVISAT SAR radar image (Orbit 148) was acquired on 28 December 2004, two days after the tsunami hit Asia. It shows the Indian Andaman Islands and the Ritches Archipelago. The normalized radar cross section 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 2).

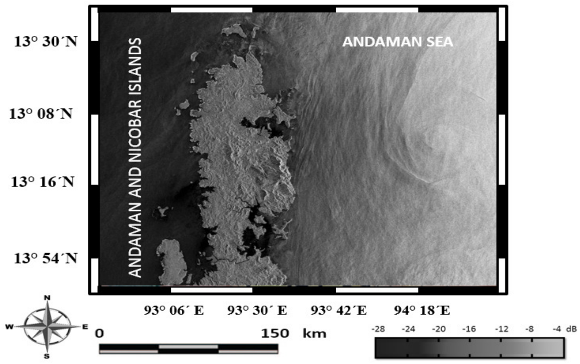

Figure 2. ENVISAT of Andaman and Nicobar Islands.

Figure 3 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 decreasing resolution by making a weighted combination of running average with the neighbor surrounding pixels of the wavelet transform. This reduced the noise in the feature s' edge areas without losing edge sharpness. Clearly PSO within approximately 1 hour within 1000 iterations is able to reconstruct 2-D of internal wave with RMSE of 0.43.

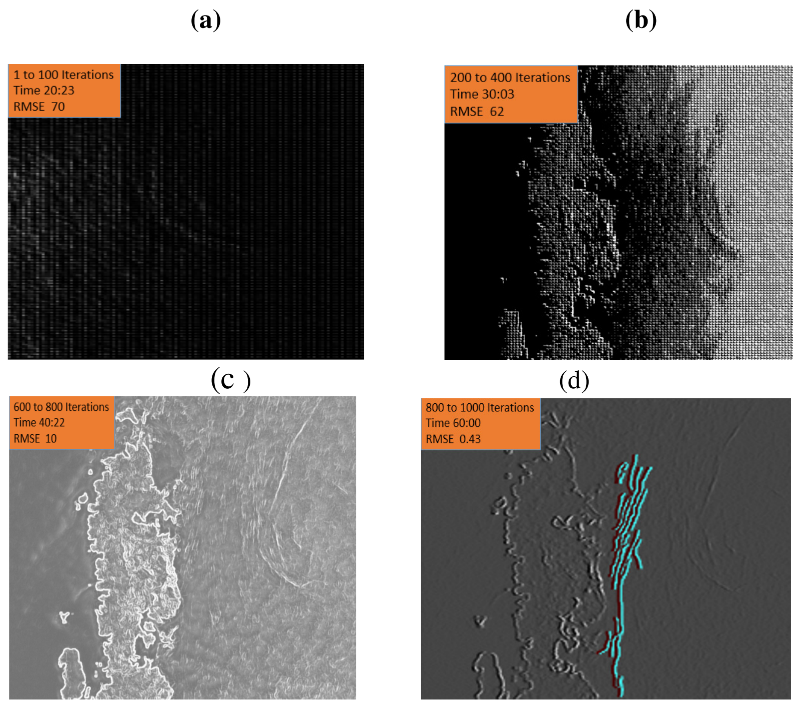

Figure 3. Figure 3. Particle Swarm Optimization with different iterations (a) 100 ,(b) 400, (c) 800 and (d) 1000 iterations for internal wave automatic detection.

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 3). 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 a ending condition is encountered.

In addition, PSO algorithms constructed the discontinuity in quality order. This is appropriate in the high intensity line or curve of fixed length and locally low curvature boundary is known to exist between edge elements and high noise levels in ASAR data. This aggress with the work are delivered by Kennedy et al., 1997; Marghany 2014; and Marghany 2015).

It ought to be noted that sturdy 2004 earthquakes have an adequate two reserve of power for necessary transformation of the ocean stratification shape. Tenths of a share of the strength of an earthquake is sufficient for formation on the ocean floor of a temperature anomaly with a feature horizontal size, measured by way of lots of kilometers and with a temperature deviation of the order of 1 ◦C. Note, that a comparable quantity of power (less than 1% of the earthquake power) is spent at the formation of tsunami waves.

6. CONCLUSIONS

The work demonstrated a new approach for internal wave automatic detection during 2004 tsunami. With this regard, optimization algorithm of Particle Swarm is used with 2-D wavelet transform of ASAR satellite data. It indicates the normalized radar cross section is 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 east of the Andaman Sea. The whirlpool has radius of 1.9 km and two placed above of water depth gradient of 1000 m. In conclusion, the Particle Swarm Optimization has routinely realize internal wave which generated by 2004 tsunami.

References

Alpers, W.,1985. Theory of radar imaging of internal waves, Nature, 314, 245-247.

Apel, J.R., Byrne, H.M., Proni, J.R. & Charnell, R.L., 1975. Observation of oceanic internal and surface waves from the Earth Resources Technology Satellite, J. Geophys. Res., 80, 865-881.

Da Silva, J.C.B., Ermakov, S.A., Robinson, I.S., Jeans, D.R.G. & Kijashko, S.V., 1998.Role of surface films in ERS SAR signatures of internal waves on the shelf, 1. Short-period internal waves, J. Geophys. Res., 8009-8031.

Bowden, K. F., 1983, "Physical oceanography of coastal waters.

Dorigo, M., de Oca, M.A.M. and Engelbrecht, A., 2008. Particle swarm optimization. *Scholarpedia*, *3*(11), p.1486.

Kennedy, James, and Russell C. Eberhart, 1997. "A discrete binary version of the particle swarm algorithm." *Systems, Man, and Cybernetics, 1997. Computational Cybernetics and Simulation., 1997 IEEE International Conference on*. Vol. 5. IEEE, 1997.

Kennedy, J. and Eberhart, R. 1995. Particle Swarm Optimization. (14): 1942--1948.

Ibrahim, S., Abdul Khalid, N.E., Manaf, M. 2010. Computer aided system for brain abnormalities segmentation. Malaysian Journal of Computing (MJOC) 1(1)*: 22-39.*

Hsu, M.-K., Liu, A.K. and Liu, Ch, 2000. A study of internal waves in the China Seas and Yellow Sea using SAR, Continental Shelf Research, 20, 389-410.

Marghany, M., 1999. Internal wave detection and wavelength estimation. In *Geoscience and Remote Sensing Symposium, 1999. IGARSS'99 Proceedings. IEEE 1999 International* (Vol. 1, pp. 163-165). IEEE.

Marghany, M., 2002. Polarised TOPSAR operational model of internal wave generation mechanism. In *Geoscience and Remote Sensing Symposium, 2002. IGARSS'02. 2002 IEEE International* (Vol. 5, pp. 2847-2849). IEEE.

Marghany,M 2014a, "Simulation of Tsunami Impact on Sea Surface Salinity along Banda Aceh Coastal Waters, Indonesia. Advanced Geoscience Remote Sensing". In M. Marghany (ed.), Intech publisher, Croatia, pp.229-251.

Marghany 2014b. Particle Swarm Optimization for Geological Feature Detection from PALSAR Data. 35th Asian Conference of remote sensing, at Nay Pyi Taw, Myanmar, 27-31 October 2014. a-a-r-s.org/acrs/administrator/components/com.../OS-140%20.pdf. [Access August 29 2017].

Marghany 2015. Copper mine automatic detection from TerraSAR-X using particle swarm optimization. CD of 36th Asian Conference on Remote Sensing (ACRS 2015), Manila, Philippines, 24-28 October 2015,a-a-r-s.org/acrs/administrator/components/com.../files/.../TH3-2-1.pdf.

Xie, X., Zhang, W. and Yang, L., 2003. Particle swarm optimization. *Control and Decision*, *18*, pp.129-134.