CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 SUMMARY

There exists the potential for tsunami detection from a satellite utilizing active and passive remote sensing sensors. Because of this potential, tsunami detection and early-warning systems should be analyzed to investigate the benefits and trades of conducting surveillance and monitoring of the deep ocean from space. Some of these satellites carry operating radiometers and even observed the 2004 Indian Ocean tsunami.

The position of a whole system for tsunami early-warning and recognition cannot be highlighted enough. The space borne system can be used to screen more than the oceans and can help many diverse scientific fields with synchronized data sets. Overall, the space borne system has more prospective to witness the early event that creates a tsunami because it will monitor the overall ocean. Because of the possible in a space borne system, not only can tsunami be more efficiently detected, but alternative areas can see development and embellishments to their field's database network. The disaster risk associated with tsunami makes it imperative that the new system have a chance to prove its worth. Those at risk rely on the ethical evaluation of the tsunami detection system. They trust that the scientific community is conducting research for this topic with the true value of human life at heart.

Tsunamis are currently detected by a network of tsunameters, seismographs, and tide gauges. This network is proficient, but has weaknesses. It cannot effectively warn threatened communities in all cases because of the locations of the sensors. It is vulnerable because it has two one-point system failures.

The capability of SAR and RADAR to analyze the dynamic characteristics of the observed objects on the Earth surface makes the RADAR particularly fit for Ocean observation in commercial, surveillance and strategic context. For strategic context the major interest of this activity field is from the space and defense application point of view. From the commercial and surveillance contexts, the extensive use of the RADAR and SAR remote sensing for the global monitoring capability with high resolution and for the sensitivity to the oceanography phenomena. The major problem is to extract the informative content in very complex scenarios, where the useful signal of the moving tsunami waves is always contaminated with noise.

Two different works have been demonstrated in this thesis. The first one was to compute and analyze the tsunami wave parameters. The second work was concerned with the retrieval of tsunami early warning using radar remote sensing technique.

Chapter 1 introduced the detailed explanation of tsunami generation and propagation, RADAR and SAR geometry and its properties with the imaging of ocean surface waves. Ship-borne AIS has also been explained in this chapter. A brief explanation of SAR-ship as well as SAR-ocean imaging mechanism was demonstrated to understand the basic concept and phenomenon. Various objectives and scopes were also concluded.

Chapter 2 discussed the various literatures related to the research work were studied. Based on the previous researches, the problem concerned to research topic was found.

Chapter 3 demonstrated the theory of tsunami generation and its propagation from deep-to-intermediate-to-shallow water regions. The methodology to perform the first objective was explained and the computation of water wave frequency along with its wave number and wavelength has also been obtained. The results for wave potential, orbital velocity, acceleration and celerity of waves was calculated and estimated with respect to the direction of propagation in all three levels of ocean i.e. deep, intermediate and shallower regions. The suitable results were simulated over the MATLAB programming interface for the various water depths in all three conditions. The validation has also been done for all three water wave conditions.

Chapter 4 is concerned for the second task of this work; radar dataset was acquired using one of the literatures over the coast of Japan peninsula using Kinaoshi, Hokkaido (A088) radar. Tsunami detection function was developed which is well known as q-factor estimates. q-factor works on the principle of selected radar band threshold. The q-factor demonstrates an abrupt conversion in extent around 8 minutes afterward the start of the tsunami speed relationships. At this opinion, the speed is deteriorating, representing that the tsunami is stirring away from shore, subsequent in the undesirable Tsunami detection function (*q*-factor).

5.2 CONCLUSIONS

This thesis supports the use of a space borne system of radar remote sensing tool to effectively monitor the whole of the earth's oceans. The outcome of research can provide a new, applicable system to save lives and increase the warning time for vulnerable communities. The long history of tsunami shows that it is time to put new technology to use to help those at risk create safety nets and add to their security. The physics based model relies on the underlying background physics of ocean waves. Tsunami in deep water is difficult to detect because they have a long wavelength and small amplitude.

The variation of each fault parameters have been calculated with the magnitude from 6.0 to 9.5 which is recorded as minimum and maximum magnitude values in various literatures. It is found that, the values of fault parameters show the linear response till the magnitude of 7.5. *e.g.,* at *M*7.5, the length is 80*Km*, width is100*Km*, area is 1000Km^2, and displacement is 200*cms*. This shows smaller values as compared to the earthquake magnitude *M*9.5 at which all the parameters shows very large response. Furthermore, it is recorded that, the fault parameters variation depends on the values of earthquake with the non-linear response after *M*7.5. As a consequence, works have been carried out based on computation of tsunami Eigen functions such as its potential, wave angular velocity, orbital linear velocity, celerity, acceleration in deep, intermediate and shallower water regions. The algorithm was used based on Airy's wave theory and dispersion relationships.

As per the bathymetry and geological aspects, the deep, intermediate and shallow water regions are assumed to be from 7 to 10*Km*, 4 to 7*Km* and 0 to 4*Km* respectively. The values of angular frequencies in deep water shows the lesser response as compared to other two water conditions because, in deep water the angular velocity of water particles travels with the lesser speed as compared to the shallower region as per Airy's wave theory. The values of angular velocity at depth of 9.8km show 0.0621*rad/s* while in intermediate water it shows the response of 9.904*rad/s* at water depth of 5.2*Km* and at the water depth of 900*m* under shallower region the velocity value is very high *i.e*. 93.96*rad/s*. It indicates the higher impact on coastal region.

The third step involves the simulation study of measurement of tsunami Eigen functions such as orbital velocity, acceleration, wave potential in deep, intermediate and shallower water regions.

The simulation result shows the resultant orbital velocity in deep, intermediate and shallow water regions are 0 to 0.1*m/s*, 0 to 10*m/s* and 0 to 1000*m/s* respectively. Furthermore, the resultant acceleration for all respective conditions is measured as 0 to 0.01m/s^2, 0 to 0.5m/s^2 and 0 to $10x10^4 m/s^2$ respectively with the assumed water depths. The orbital acceleration at the water depth of 900*m* which is shallower in nature shows the result of $9x10^4 m/s^2$, hence the dynamic forces are very high approximately 1 *Km* from the beaches. Once the Tsunami waves approaches to the beach, wave height increases whereas particle acceleration decreases because near the coast, due to geological structure of the earth's surface, inertia and gravity forces increase to the extreme limits, while particle acceleration and velocity values reach close to zero. Similarly, the simulation result for the maximum wave potential is measured in all three water conditions are 20, $2x10^4$ and 5 which represents the amount waves transformed from deep to shallower regions with respect to the wave length and direction of propagation. The validation of each result has also been presented with the standard simulated data which shows the results as less than 10% of the accuracy.

A radar remote sensing technique was applied to calculate the tsunami arrival signal (*q*-factor) to detect the minimum time travel from deep region of ocean to the coastal region segment over the coast of Japan using A088 radar dataset obtained from Lipa *et.al.*,2011. The tsunami motion is mainly strong in the bands added from the radar; closer to coast the drift is sidetracked similar to coast, reducing the vertical component displayed in these plots. This radar functions for only 40 *minutes* in the hour, causing in the 20-*minutes* gaps noticeable in plots. The entrance of the tsunami is specified by relationship between velocities in altered bands early about 2.5*h* afterward the volcanic activity.

5.3 FUTURE RESRARCH DIRECTIONS

Taking into account the real context in which the techniques can be applied, we propose the following strategy for the future research.

- The early stage of tsunami physical characteristics has emphasized the importance of phenomena that have obtained the various extensive considerations in the remote sensing works.

- Research in the pitch was mainly sub-instated by information from LEO satellites. However, unless an inter-linked group of a huge number (<50) of satellites is measured, LEO satellites cannot contest the challenging necessities posed by near-field tsunami early cautionary. All possible interplanetary platforms have then been measured a stratospheric aircraft were found to be able to serve as ideal stages for uninterrupted monitoring of large ocean areas.
- The physical description of tsunami waves from a radar remote sensing viewpoint is still in its early stages, more data is desirable for a vigorous description.
- For further future effort, the proposal can be made for refining the communications infrastructure of the tsunami warning method by means of fiber optic cables for the submerged cables that enables real-time monitoring of the designated marine areas and remote outline and that can further be integrated with the satellite and space borne platforms to sense the various seismic activities.
- Overall, the work done in the future to further the study of a new system for tsunami early-warning and detection can only increase the understanding of dangerous tsunami waves and their properties. The communities at risk will benefit greatly from the study of detection systems. If the new system is shown to hold improved abilities, hopefully the system can be implemented by the will of the political and scientific communities to help out millions of human lives living in the shadow of tsunami risk.