CHAPTER - 6
6. SUMMARY AND CONCLUSIONS

While satellite remote sensing methods using electromagnetic waves are widely applied to make near synoptic measurements of sea surface parameters, the opacity of the oceans to these radiations prevent interior observations. Considering the fact that the sound channel in the ocean acts as a wave guide which permits propagation of sound energy over long distances, the concept of ocean measurement using acoustic transmissions - ocean acoustic tomography - was put forward as a complementary remote sensing tool. A single source-receiver pair provides information about the physical properties and the ocean features in the vertical plane due to the multipath nature of the sound propagation. This information can be extracted from the signal and sound field descriptors - travel time, intensity, ray or mode structure etc., travel time being the quantity of prime interest. The acoustic field experiments conducted so far are confined to the mid and high latitude regions in the Atlantic and Pacific Oceans.

The north Indian Ocean has several anomalous features compared to the other oceanic regions similarly situated in a geographical sense, viz., the prevailing monsoons, inflow of various water masses, fresh water discharges etc. Arabian Sea is a dynamically active and oceanographically important body under the influence of the seasonally reversing monsoon
systems. In the present thesis, the Arabian Sea has been examined for its suitability for applying the new OAT methodology. For this purpose, the climatological characteristics of this region are studied and also the seasonal and annual variations in the hydrographic parameters are examined.

The acoustic characteristics of the Arabian Sea and the space-time changes in the sound speed field resulting from the hydrographic variations are examined for use in model simulations. The reference sound speed profiles constructed for different regions in the Arabian Sea exhibited considerable spatial variations. The analytical form of the sound speed profile constructed using Munk's canonical theory has showed considerable deviations from the reference sound speed profiles indicating the necessity to use the standard reference profile based on climatic hydrographic data. Realizing the spatial and seasonal variations of the constituent waters in this area, the reference sound speed profiles for six different grid areas are constructed on seasonal basis to represent the summer and winter periods. This will enable predict the acoustic ray arrival pattern with improved accuracy.

The ray parameters for the summer and winter seasons are obtained and the spatial and temporal variation of acoustic propagation characteristics are examined. Comparison of the results for the summer and winter indicate almost same number of rays existing for both the seasons.
although the geometry of the eigen rays - ray turning depths, ray path lengths - showed variations. If one can model the gradual variation with time of the reference profile in short time step (about a week) during the course of an acoustic experiment, the data kernel can suitably be updated to increase the accuracy of the reconstructed sound speed field. This would also enable in identifying the eigen ray arrivals in comparison with the predicted values obtained from the upgrading process.

The eigen rays for the two seasons are found to be entirely different with different emergence angles, path lengths, travel times and trajectories indicating instability in the system and contradicting the basic assumption of the tomographic study. This seemingly anomalous situation can be rectified when we realize that the changes in the hydrographic parameters and hence the sound speed profile over a period of few days are small and the seasonal changes are the accumulated changes in the hydrography over a period of three months or more. The implication of this feature is that the ray paths need upgradation every few days the hydrographic fields evolved, the sound speed profile also gets modified slowly and one would expect that the ray paths would be stable during that short time interval of 3 or 4 days. Assuming an annual cycle, the upgradation process involves about 100 iterations (steps in time). This procedure will enable us to compare the sound speed profile with the previously iterated value.
The arrival structure of eigen rays for different source-receiver configurations revealed that the pattern remains unaltered with the variations in the depths of the source and the receiver in the vertical. However, the near axial rays will be missing as one of the source or receiver is shifted away from the axis depth in the vertical direction which results in the reduction of the number of rays.

The ray path stability under different hydrographic conditions has been examined by introducing anomalies such as a warm core eddy and cold core eddy. The linearity of the predicted ray arrival times has been inferred for sound speed perturbations up to 12 m/s (3°C) of the warm eddy with limited vertical extent.

Propagation under variable bathymetric conditions across the continental shelf and across a mid oceanic ridge have been attempted. Propagation across the shelf may be useful in the study of the frontal structure associated with shelf break and the upwelling phenomena, while the propagation in the upslope direction resulted in considerable number of ray paths (31) that are resolvable in time, the down slope propagation is effected by the multiple bounces in the shelf before entering the deep ocean and resulted in least travel time spread. As a consequence, the number of resolvable rays reduced to 3.

Acoustic rays on approaching the oceanic ridge have undergone reduction in their loop length while leaving the
ridge their loop lengths elongated.

An increase in the propagation range has increased the number of eigen rays according to the ratio Range/200. For a range of about 300 km, the number of rays and their resolvability are at its optimum.

With the inversion algorithm layer-wise estimate of $\delta c$ are made. Numerical experiments have been carried to reconstruct the sound speed profile using the generalized inverse method considering different oceanic layers and energetic modes. The six layer model with five eigen vectors (modes) has adequately reproduced the features. The estimate of $\delta c$ is added to the summer sound speed profile and this modified/ constructed profile is compared with the winter profile. The curves closely resemble each other.

We feel that the choice of data, is such as to bring exact coincidence. This might have happened because of the process of averaging in the climatological data sets.

CONCLUSIONS:

Even though Levitus data on hydrographic parameters is available season-wise, in our opinion it would be necessary to have monthly data sets to understand the variability of the oceanic parameters and to reconstruct the sound speed profile. When this is done, a model for the sound speed profile could be developed so that the ray paths could be examined for their evolution, it would then be possible to
associate the ray path/ eigen ray trajectories with the travel time data. Essentially this involves upgradation of eigen ray trajectory associated with the changes in the hydrographic parameters. These studies conclusively prove that acoustic propagation techniques could be utilised to study the ocean environment in spite of the two water bodies viz., Arabian Sea and the Bay of Bengal have widely different characteristics within them selves and with other areas such as the regions in the Atlantic Ocean etc.