

# **Utilisation of Acoustics for Monitoring Local and Near-Field Mine Burial Processes: Proof-Of-Concept**

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<http://ocean.st.usm.edu/%7Ecwcurry/mineburial.html>

## **LONG-TERM GOAL**

The goal of the Proudman Oceanographic Laboratory's, POL, contribution to the Mine Countermeasures Programme, is to assess the applicability of recent developments in the application of acoustics, to the high resolution measurement of sediment processes, in the context of its utilisation for advancing our understanding of mine burial.

## **OBJECTIVE**

The objectives of POL's research has been to; (i) Provide guidance design criteria to OMNI Technologies for the development of acoustic suspended sediment and flow measuring instrumentation, which is to be mounted on the surface of a mine. (ii) The development of theoretical frameworks and algorithms to convert the collected acoustic data into hydrodynamic and suspended sediment parameters.

## **APPROACH**

To interact with OMNI technologies, via contact and publications, so as to provide an outline of the potential of acoustics to measure within the near-field of the mine, sediment processes and flow. The aim being to develop acoustically based systems that will improve our understanding of how mines become buried or not as the case may be. Underpinning this approach has been the study, through laboratory and marine experiments, of the application of acoustics to the measurement of small-scale sediment processes.

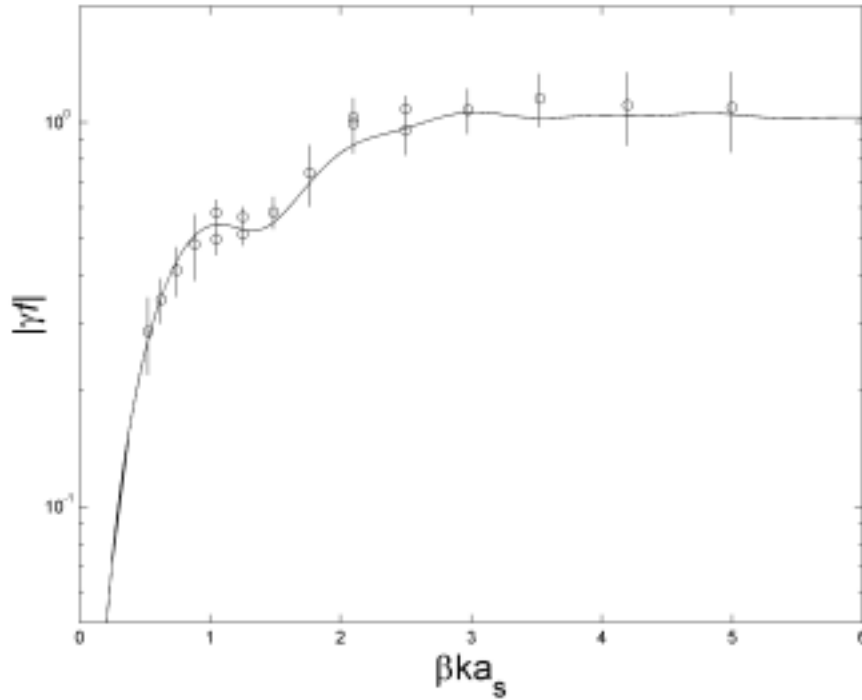
## **WORK COMPLETED**

Nominal specifications of a system design have been completed. This has included frequencies to be used, calibrations required, the necessary sampling and online processing, and data validation schemes. A number of laboratory studies have been conducted to assess the interaction of underwater sound with suspensions of marine sediments, this work is fundamental to inverting the acoustic data for suspension parameters. Also data collected in a large-scale flume facility and the marine environment has been assessed to examine the potential of acoustics to accurately measure the hydrodynamics and flow.

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## RESULTS

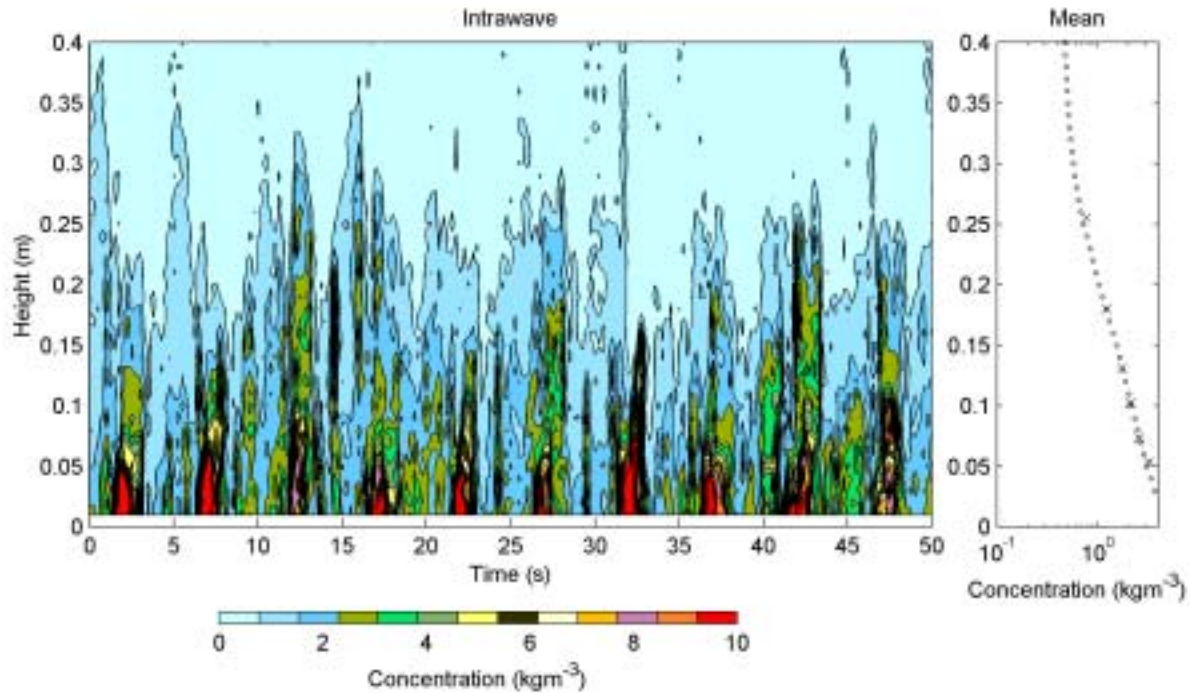
The measurement of the scattering characteristics of suspensions of marine sands has been carried out in a purpose built sediment-acoustic tower. The system generates a homogenous suspension in the mid-section of the tower, and allows detailed studies to be conducted on the interaction of sound with suspensions. An example of the results obtained is shown in the figure 1. The data show the variation of the backscattered form function,  $f$ , a parameter that describes the scattering characteristics of the sand grains, against  $ka_s$ , where  $k$  is the wave number of the sound in water, and  $a_s$  is an equivalent sphere radius of the grains.



**Figure 1** Measurements of the form function (o) and a modified sphere model (-).  $\beta$  and  $\gamma$  are scaling parameters associated with the sand particles being irregular in shape.

To describe the scattering behaviour of the suspended sediments a modified sphere model was used. The measurements and theory presented here and those of others studies (1-3) show that we can model to first order the backscattering characteristics of suspensions of marine sands. The significance of this work is that it provides a basic framework for the inversion of acoustic data to suspended sediment parameters.

To assess the capability of inversion algorithms, data collected in a large-scale wave flume facility, 300 m in length, 5 m in width and 7 m in depth have been analysed (2). An example of the intra-wave suspended sediment concentration, and mean concentration profile compared with pump samples is shown in figure 2.



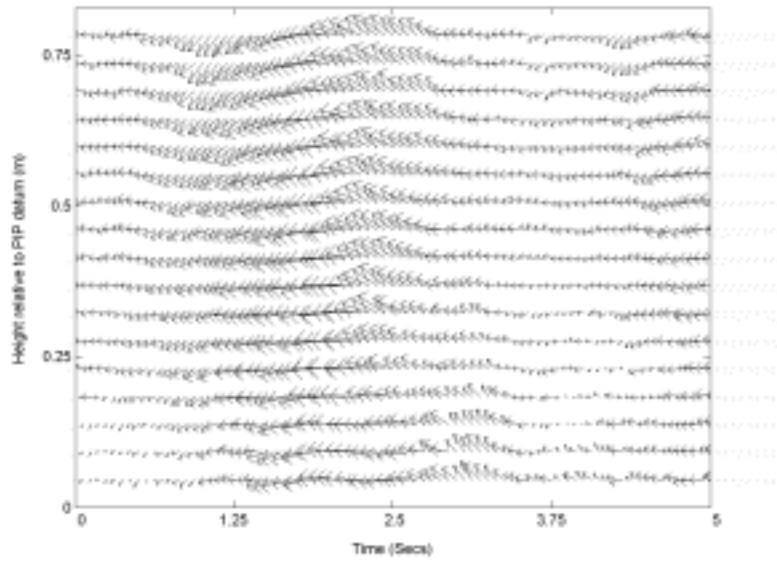
**Figure 2. Intra-wave concentration profiles obtained acoustically and comparison of the mean profile (o) with pump sampled data (x).**

The wave period was 5s and the velocity amplitude  $1 \text{ ms}^{-1}$ . The data show the capability of acoustics to measure high resolution profiles and the mean plot shows the measurements are accurate. The observations show the detail that can be obtained using acoustics and it is expected that comparable observation from the acoustic instrumentation on the mine will provide valuable information on mine burial.

To assess the capability of acoustics to measure the hydrodynamics a 3-axis coherent Doppler profiler was deployed in the marine environment. The provisional outcome of this deployment is shown in figure 3. The data show detailed measurements of the flow. These measurements show the potentiality of acoustics to map out the velocity field as the flow advects past the instrument.

## IMPACT/APPLICATION

The observations presented here and those from other workers (4-6) show that acoustics has an important and expanding role in its application to the measurement of suspended sediment parameters and the hydrodynamics. It is anticipated that the outcome of the work reported here and its input into the design of the acoustically instrumented mines, will contribute over time, to providing a framework for assessing the relationship between the presence of the mine, its impact on the local hydrodynamics and sediment mobility, and thereby gain insight into the burial mechanisms.



**Figure 3. Vector plot of the vertical and horizontal velocity components from a 3-axis coherent Doppler system with height above the bed.**

## TRANSITIONS

The measurements, analysis, and theoretical framework from the present study have been made available to OMNI technologies for the development of the acoustic components of the mine. This has enabled the formulation of system designs, and familiarised the company with the acoustic approach to the measurement of benthic processes.

## RELATED PROJECTS

A number of European projects of which the present author was a partner have direct relevance to the use of acoustics for measuring small scale sediment processes. These include; (i) TRIDISMA Three dimensional sediment transport measurements by acoustics.

[[http://www.uea.ac.uk/~e470/www\\_trid.htm](http://www.uea.ac.uk/~e470/www_trid.htm)] . (ii) COAST3D Modelling and measuring bathymetric evolution. [<http://www.hrwallingford.co.uk/projects/COAST3D>] . (iii) INDIA The study of sediment processes in an inlet. [<http://www.pol.ac.uk/india/INDIA.html>] .

## REFERENCES

- 1.Hay, A.E., 1991. Sound scattering from a particle-laden turbulent jet, J. Acoust. Soc. Am., 90, 2055-2074.
- 2.Cheng He and Hay, A.E. 1993, Broadband measurements of the acoustic backscatter cross section of sand particles in suspension. J. Acoust. Soc. Am. 94 (4), 2247-2254.

3. Thorne, P.D., Sun, S., Zhang, J., Bjorno, I., Mazoyer, T., 1997. Measurements and analysis of acoustic backscattering by elastic cubes and irregular polyhedra. *J. Acoust. Soc. Am.* 102 (5), Pt. 1, 2705-2713.
4. Thorne, P.D., Hardcastle, P.J., 1997. Acoustic measurements of suspended sediments in turbulent currents and comparison with in-situ samples. *Journal of the Acoustical Society of America* 101 (5) (Pt. 1), 2603-2614.
5. Zedel, L., Hay, A.E., 1999. A coherent Doppler profiler for high-resolution particle velocimetry in the ocean: laboratory measurements of turbulence and particle flux, *Journal of Atmosphere and Ocean Technology*, 16, 1102-1117.
6. Vincent, C.E., Marsh, S.W., Webb, M.P., Osborne P. D. 1999. Spatial and temporal structures of suspension and transport over megaripples on the shore face, *Journal of Geophysical Research*, Vol. 104(C5), 11,215-11,224.

## **PUBLICATIONS**

- Thorne, P.D., Watkins P.K., Williams J.J. 2001. A study of intra-wave suspended sediment entrainment using acoustics. Conference held at the Southampton Oceanographic Centre 9-12 April 2001, 'Acoustical Oceanography' and published by the Institute of Acoustics, UK, Vol 23(2) *Acoustical Oceanography*. 392-398
- Betteridge, K.F.L., Thorne, P.D., Bell P.S. 2001. Acoustic measurements of sediment flux profiles in an estuarine environment. Conference held at the Southampton Oceanographic Centre 9-12 April 2001, 'Acoustical Oceanography' and published by the Institute of Acoustics, UK, Vol 23(2) *Acoustical Oceanography*. 407-414
- Thorne, P.D., Butler, M.B., 2001. Measurements of the scattering properties of suspensions of marine sand. Conference held at the Southampton Oceanographic Centre 9-12 April 2001, 'Acoustical Oceanography' and published by the Institute of Acoustics, UK, Vol 23(2) *Acoustical Oceanography*. 392-398
- Betteridge, K.F.E., Thorne, P.D., Bell P.S., 2001. Assessment of acoustic coherent Doppler and cross-correlation techniques for measuring near-bed velocities and suspended sediment profiles in the marine environment. *J. Atmos. Oceanic Tech.* (In press).
- Rose C.P. Thorne P.D. Measurements of suspended sediment transport parameters in a tidal estuary. *Continental Shelf Research*. In Press
- Thorne P.D. Hanes D.M. A review of acoustic measurements of small-scale sediment processes. Under review.
- Thorne P.D. Williams J.J. Davies A.G. Suspended sediments under waves measured in a large flume facility. Submitted to the *Journal of Geophysical Research*