Hydroacoustic Studies Using HydroCAM – Station-centric Integration of Models and Observations

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1. Summary of Activities

BBN's work from January through March of 2003 was focused on data collection, data analysis and software development. We continued our efforts to collect ground truth hydroacoustic data from sub-sea earthquakes in the Indian Ocean. These data are recorded on the International Monitoring System stations at Diego Garcia and Cape Leeuwin.

The software development effort spanned two areas. Fixing problems and making small improvements to HydroCAM based on meetings at AFTAC in September 2002. We have also begun development of the software that will integrate local high-resolution bathymetry into lower-resolution global bathymetry for acoustic path predictions in HydroCAM. We hope that this will improve HydroCAM's ability to predict acoustic blockage.

Unfortunately, due to corporate travel restrictions stemming from the war with Iraq, BBN will not be able to participate in the International Hydroacoustics Meeting in Hobart, Tasmania in May. However, we plan to provide Phil Harben with material to present and we plan to participate in the annual Seismic Research Review in Arizona this September.

2. Introduction

The current contract's period of performance began on September 4, 2002. The initial increment of funding is intended to cover BBN's work through January 31, 2003. Pre-contract costs were authorized for the two weeks between August 5 and August 16, 2002. This pre-contract money was used to prepare for the Seismic Research Review Meeting in Ponte Vedra Beach, Florida in early September.

At the Seismic Research Review meeting, BBN presented past research on localization of hydroacoustic events using reflections from continents and other bathymetric features. This past research was presented under this contract because of the nearly coincident deadline for papers and funding of this contract. No new research under DOE funding had been conducted at that time.

This contract's research is intended to extend the capability of BBN's Hydroacoustic Coverage Assessment Model (HydroCAM). Specifically, the effort is designed to improve HydroCAM's database and modeling capabilities with respect to hydroacoustic blockage. In this first phase (September 2002 – January 2003) BBN is undertaking three tasks. First, BBN is investigating blockage by analyzing events in the Indian Ocean that are recorded at the International Monitoring System (IMS) stations at Diego Garcia and Cape Leeuwin. Second, BBN will attempt to improve HydroCAM's blockage modeling capability by integrating high-resolution bathymetry into HydroCAM near IMS stations.

The third task in this contract is a support-oriented one. BBN is tasked to support the HydroCAM and modeling needs of DOE and AFTAC. Lawrence Livermore National Laboratory (LLNL) and AFTAC are the two primary users of HydroCAM. In the past BBN has also supported them by performing event-driven data analysis and modeling tasks.

Therefore, BBN expends significant effort maintaining the HydroCAM software and addressing any issues/needs that our contacts at DOE and AFTAC might have.

What follows is a complete summary of BBN activities on these tasks from January 2003 – March 2003.

3. Data Collection

In 2000, when the Diego Garcia IMS station came on line, BBN began compiling a ground truth database of hydroacoustic event data recorded at that station. When the Cape Leeuwin station began transmitting data, that data was included in the database. BBN has accumulated over 130 seismic events at these stations. In addition, BBN has archived other event data. As part of this contract, BBN will provide that data for integration into the DOE Knowledge Base.

Figure 1 shows a map of the Indian Ocean, with locations of seismic events for which BBN has archived ground truth data.

Hydroacoustic Event Database – Analyzed Events for 2001-2003 – 132 events

Figure 1 – Hydroacoustic Event Locations for BBN’s Ground Truth Event Database

The format of the database follows the CSS version 3 schema. From this schema, four files are included for each event:

- ?? A waveform data file (.w extension)
- ?? A waveform description file (.wfdisc extension) – contains meta-data for the event like sampling rate, waveform time, etc.
- ?? An origin file (.origin extension) – contains the ground truth event data (location, magnitude, etc.)
- ?? A waveform tag file (.wftag extension) – contains the event identification information.

BBN is currently developing a Matlab-based data viewer that will allow users to view the waveform data for a selected event at any of the stations for which there is recorded data.

We plan to deliver the first installment of this database in the second quarter of 2003.

4. Data analysis

BBN has accumulated gigabytes of event data from the IMS stations in the Indian Ocean. We've certainly only scratched the surface on the data analysis that can be done on this data. However, we are focusing on a number of topics of interest to DOE, AFTAC, and BBN:

- ?? Hydroacoustic blockage
- ?? Hydroacoustic reflections
- ?? Synergy between hydroacoustic and seismic sensors
- ?? Signals from continental events recorded at hydroacoustic stations

To that end, BBN has analyzed a number of seismic events and a variety of other signals. We are currently narrowing our scope so that we can prepare the abstract, paper and poster required for participation in the annual Seismic Research Review in Arizona this September.

5. Software Development/Support

5.1. HydroCAM 4.0

HydroCAM version 4.0 is currently under release testing. This version of HydroCAM includes all of the bug fixes and simple improvements requested by AFTAC in our meeting last fall. Appendix A shows the status against the software change requests generated as a result of that meeting. There is very little new functionality in the release. However, this release will be Matlab 6.5 compatible. We have incremented the release number to signify the first release of the new contract.

5.2. High-Resolution Bathymetry Integration (HydroCAM 4.1)

Work has begun to integrate the 15-second resolution bathymetry that we have near Wake Island into HydroCAM's path predictions. In the paper that we presented at the 2001 SRR in Jackson Hole, WY, we theorized that with a detailed knowledge of the bathymetry near a hydroacoustic station, we would be able to improve our predictions of acoustic blockage. It is also theorized that using a small set of high-resolution bathymetry within a global lower-resolution bathymetry database will prevent a prohibitive memory or processing load.

The concept for the integration of the local high-resolution bathymetry with global lower-resolution bathymetry is shown in Figure 2.

Figure 2 – Concept diagram for the integration of local high-resolution bathymetry into HydroCAM's acoustic path calculation

5.3.Database Viewer

BBN is developing a database viewer in Matlab that will allow the user to quickly and conveniently select events and perform basic analysis. We hope that we will be able to deliver this viewer in one of our database deliveries this spring. Figure 3 shows the initial database viewer GUI design.

Figure 3 – BBN Hydroacoustic Event Database Viewer

6. POA&M for Q2 2003

In the second quarter of this year, BBN plans to continue its research on improving blockage prediction via improved bathymetry and studies using real data. We will continue our search for high-resolution bathymetry near stations in the Indian and Atlantic oceans. We will also continue to collect and analyze data in our effort to improve our models by comparing them to collected data.

In late May, we will begin our preparation for September's Seismic Research Review meeting by submitting our abstract.

6.1. Gantt Chart

6.2. Labor Budget

For the second quarter of 2003, we will scale back our labor in order to save funding for the rest of the year. We anticipate that Jay Pulli and Zach Upton will work at a rate of 30-40 hours/month for the quarter. Charging will increase slightly near the end of the quarter and throughout the summer so that we can continue our research and support while preparing for the annual Seismic Research Review meeting.

6.3. Risks

A research and support contract of this nature is relatively low risk. As stated in the introduction, our primary responsibilities are to support DOE and AFTAC with research and software support.

The only significant risks that could effect BBN making all of it's proposed improvements to HydroCAM are related to acquiring local high-resolution bathymetry near the current and proposed IMS stations. We anticipate that we will be able to find these data, but it may require the release of a classified version of HydroCAM.

7. Appendix A – Software Issues and Resolutions

Issue #	Issue	Status	Resolution Date
1	AFTAC needs a distribution that includes source code and Sandwell and Smith databases	CD shipped to AFTAC October 7, 2002	10/7/2002
2	LLNL needs a full distribution with all source code and databases	CD shipped to LLNL January 10, 2003	1/10/2003
3	HydroCAM's GlobeRay model will not calculate rays for stations near the Arctic Circle.	GlobeRay model code was modified so that it will not crash when the environment database limits are exceeded by the bathymetry database	3/31/2003
4	When HydroCAM plots the ray output of GlobeRay, it plots the rays on the map three times. This is time-consuming and cumbersome.	The Matlab code that drives path plotting was be modified such that the paths are plotted once and then refreshed when the network is overlayed on top.	2/18/2003
5	There is a 500,000-point limit to the PathtoGrid. This is a problem when converting ocean-wide ray fans into grid files.	Editing the Constants.hh header file and recompiling the HydroCAM models solved the problem. Currently, BBN is working with a 1 million point limit. Future plans include modifying this code to scale the maximum number of points to the available system memory	12/20/2002
6	HydroCAM model code will not compile	C and Fortran code updated so that it compiles and is up-to-date.	12/20/2002
7	HydroCAM is not updated to reflect Matlab platform updates	Code has been tested in Matlab 6.3 and updated. Code will be tested and updated in Matlab 6.5 in Q1 2003	3/31/2003
8	It would be useful to have a button that sets grid limits to the maximum database limits. This occurs on several forms, and would be a convenient improvement.	Button added to Path form, database forms, etc.	2/3/2003