Chair in Ocean Mapping

Current and Future Research Activities Y2001

March 2001

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Introduction

Overview

This report outlines the status and current and future research directions of the Chair in Ocean Mapping (COM) at the University of New Brunswick (UNB). The Chair works within the Ocean Mapping Group at UNB. The Ocean Mapping Group (OMG) was originally formed amongst researchers within the Engineering faculty at UNB in 1988 to address specific needs of the Canadian Hydrographic Service (CHS). As an extension of the Group, in 1991 an Industrial Research Chair in Ocean Mapping was created by the Natural Science and Engineering Research Council (NSERC).

The first phase of the Chair, during which industrial sponsorship funds were matched by NSERC, extended from 1991 to 1996. In 1996 the Chair was renewed for a second phase, although the research funding now came completely from outside sources, with NSERC support reduced to a declining fraction of the Chair salary. In 2000, the Chair entered the third phase where all research support comes from external funding sources, with the University now providing the chairholder salary. This report in 2001 reflects the new Chair as a result of those recent changes.

In 1991, the use of swath sonar systems for precise seabed bathymetry was in its infancy. Whilst deep water systems had been in operation for over a decade, the feasibility of using these sonars for continental shelf and especially hydrographic surveys was not yet a realistic goal. Over the past 10 years the OMG has provided world-leading direction in the use of swath sonar systems for precise marine survey applications. Advances in data calibration, data processing, data analysis and data visualization have been led by OMG research.

As part of this research thrust, it rapidly became clear that an integral part of the Chair was to provide world-class education in these new technologies. To date that training has been primarily provided as a commercial training course initially offered directly to our two strongest supporters (CHS and NOAA) but subsequently opened up to the commercial offshore industry.

In the third phase, the Chair intends combining and redirecting the two roles of :

- Research and
- Education

To ensure that there is both a continued commitment to relevant research in the field of Ocean Mapping but also to ensure that the University can supply the necessary quality of trained undergraduate and graduate marine surveyors that the industry has always relied upon.

In this third phase of the Chair, the University is now committed to supporting the Chair as a full time faculty member. Reflecting this, there will be a much tighter integration of the Chair into the Department of Geodesy and Geomatics Engineering. As a direct result, the Chair now teaches two undergraduate courses along with the graduate courses already offered.

Recent Changes

As of January 1st 2000, John Hughes Clarke took over the Chair following the departure of the previous holder, Larry Mayer and one of the principal investigators, Colin Ware. John Hughes Clarke had previously been a Research Associate and then Senior Research Associate with the Chair since inception in 1991. Larry Mayer and Colin Ware have moved to the University of New Hampshire in the US where they will be leading the new Centre for Coastal and Ocean Mapping (CCOM) there. The CCOM will be supported by NOAA with similar research aims to the COM here. As part of the CCOM there will be a Joint Hydrographic Centre to coordinate the research needs and direction of the U.S. National Ocean Survey.

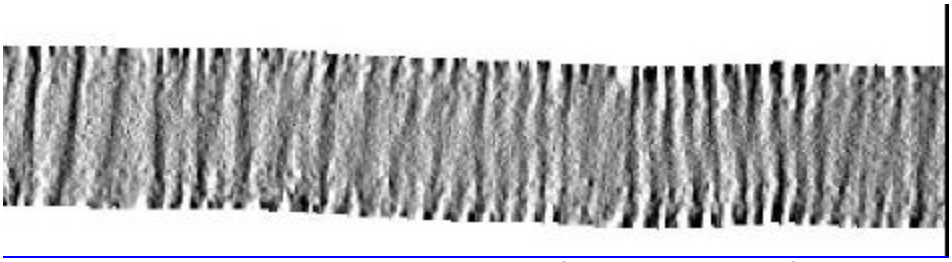
This relationship mirrors the strong association between the Ocean Mapping Group and its primary sponsor, the Canadian Hydrographic Service.

New Research Directions

The Chair constantly seeks input from its sponsoring organisations about the current and upcoming challenges to precise seabed surveying. Based on feedback over the past 18 months it has become clear that, whilst swath sonars are now becoming a standard tool, a number of second order problems are currently holding back their full potential. Therefore, for the next 5 year phase, the Chair in Ocean Mapping intends redirecting its research efforts into the following three fields:

Improved and Automated Field Calibration techniques:

Because acoustic mapping systems represent an integration of multiple sensor packages, system integration has always been of prime concern. Patch Test methods have become standard within the industry. Such methods however, only examine gross static biases present in the system.



short wavelength across-track ridging(~0.5%Z) manifested in a corridor of swath sonar data (EM1002 data , 80m of water, seastate 4).

In order to meet the increasing demand for the delineation of fine scale seabed relief, a growing range of second order artifacts are being recognized that are due to dynamic rather than static effects of imperfect integration. Many of these manifest themselves as periodic oscillations of the seabed data (wobbles). Such second order effects are easy to notice but currently extremely difficult to analyse rapidly in the field. All to often, large datasets, compromised due to imperfect field integration, are brought ashore in the vain hope that post-processing can fix the problem.

We intend to further develop time-series analysis tools that are built into the OMG software suite so that these dynamic errors sources can be more rapidly identified and corrected, preferably in the field. Given the huge expense of rerunning surveys, such new tools could save large sums of money for our supporting agencies.

Integration of water column scattering and current field information with precise seabed data.

Whilst swath sonar systems have primarily been applied to the delineation of the sediment water interface, new research by the OMG has indicated that the same systems can also describe the variations in scattering strength within the ocean volume. By combining this information with synoptic current information (from acoustic doppler current profilers (ADCP's)) we can build a much more complete picture of the ocean. In areas of active erosion and deposition, a closer link between the physical oceanography and the changes in seabed morphology could be established.

Underway research with fisheries multibeams, ADCP's and multi-frequency single-beam scattering strength measurements will be combined (see descriptions below). One of the first applications will be to

investigate sites of critical importance including aquaculture sites, estuarine circulation and the sediment resuspension in areas of dredging.

Temporal and spatial modeling of water mass sound speed structure.

As error sources due to other external sensors and sensor integration shrink, it is clear that one of the largest remaining barriers is the temporal and spatial variance of the water mass. Efforts to map and monitor this variation have been examined by the group, and the scale of the problem has been quantified.
The reality is however, that imperfect water mass information will remain a problem.

Even when better information is available it is clear that limitations exist within the current commercially available software tools to properly reapply that information. We intend to extend our research to provide robust tools for recalculation and interpolation of water mass properties.

And as an integral part of the research process, all the new results and methods will be incorporated into a variety of education programs that ensure that this information is widely shared throughout the ocean survey community including:

- Commercial training courses
- Undergraduate education within the Dept. of Geodesy and Geomatics Engineering
- Graduate research training within the Ocean Mapping Group.

Contents

Personnel

Faculty

John E. Hughes Clarke	Associate Professor, Chair in Ocean Mapping, GGE Swath Sonar Software Development, Sediment Transport
David Wells	Professor Emeritus, GGE Hydrography, Geodesy
Sue Nichols	Associate Professor, GGE Coastal and Marine Cadastral
Marcelo Santos	Associate Professor, GGE Kinematic Positioning, Geodesy
Karl Butler	Assistant Professor, Dept. Geology Exploration Geophysics

Research Associates and PostDoctoral Fellows

Yanchao Li	Research Associate Fisheries Acoustics
Michael Weber	Honorary Research Associate Palaeoceanography
Martin Gee	Postdoctoral Fellow (4/2001) Submarine slope stability,
Susan Haigh	Contract Researcher Numerical Modelling of Coastal Circulation

Visiting Scientists/Staff 2000/2001

Dave Monahan	Law of the Sea Division, Canadian Hydrographic Service
Veronique Jegat	Hydrography program, ENSIETA, France
Galderic Lastras	Dept. Geology, University of Barcelona
Roger Urgules	Dept. Geological Engineering, Laval

Support Staff

Jerry Zhang	System Manager
Anya Duxfield	Research Assistant (4/2001)
Debbie Smith	Accounting

Graduate Students

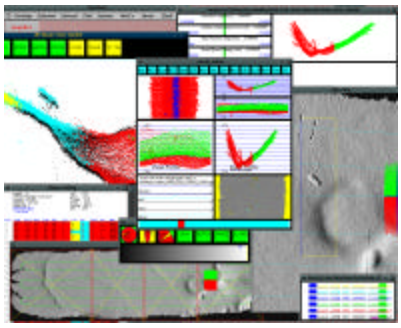
Graham Nickerson	LAM	M.Sc.Eng 1997 +
Aldino Campos	DEW	MEng. 1999+
Doug Cartwright	JHC	MEng 2000+
Tim Kearns	JHC	MscEng 2000+
Enrique Silva	DEW	MEng 2000+
Ted Byrne	JHC	MEng 2000+
Sam Ng'ang'a	SN	PhD 2000+
Sarah Cochrane	SN	MEng 2000+
Michael Sutherland	SN	PhD 2000+

Adjunct Faculty

Dr. Christian deMoustier	Adjunct Research Associate, Scripps Institute of Oceanography
Dr. Larry Mayer	Adjunct Professor, University of New Hampshire
Dr. Colin Ware	Adjunct Professor, University of New Hampshire.
Dr. Gary Melvin	Adjunct Professor, DFO, St. Andrews Biological Station

Active Research Directions

Whilst we intend focusing on the three outlined new research directions, there are a number of continuing active directions of research that we are currently undertaking. These include:



Swath Sonar Analysis Software

Hughes Clarke
Chair Funding

In order to support the core swath sonar research that is active within the Ocean Mapping Group, a UNIX based processing and analysis package (SwathEd) is maintained and continually upgraded. This package contains the following functionality:

- Importation of a wide variety of swath sonar data
- Navigation editing and merging
- Automated and Interactive bathymetric cleaning
  - Interactive by swath
  - Interactive by area
  - Automated by single swath
  - Automated w.r.t. mean surface
- Weighted gridding, reflecting local beam footprint
- Reapplication or modification of water column correction
- Extraction and analysis of motion residuals
- Construction and enhancement of backscatter data
  - Correction for gain changes
  - Correction for pulse length changes
  - Correction for beam pattern residuals
  - Correction for grazing angles
- Registration (mosaicing) of backscatter data
- Calibration (Patch Test, Reference Surface, DelayEditor)

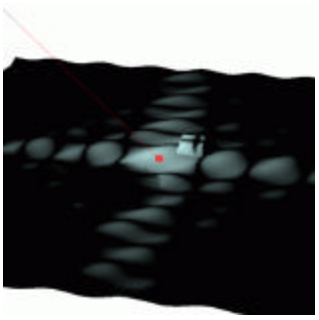
These software ideas and modules have been incorporated in commercial swath sonar processing packages developed by our sponsors including:

- Caris HIPS/ SIPS
- Seabeam SeaView
- NRL HMPS
- Simrad Neptune, Poseidon
- C&C Hydromap

In addition modules of the software are used as-is by the following sponsors:

- **U.S. Geological Survey**
  - – Atlantic (Woods Hole) - EM1000/EM12S
  - – Pacific (Menlo Park) - EM1000/1002/300/3000D
  - – Gulf (St. Petersburg) - EM3000S
- **C&C Technologies** - EM300
- **State University of New York** - EM3000S/D
- **Canadian Hydrographic Survey**
  - Atlantic, (Georges Project) - EM1002
  - Quebec Saguenay - EM3000S/EM1000
  - Newfoundland Roti, Little & Tilt Coves - EM3000S
  - Pacific all operations to end 2000 - EM3000S/EM1002
- **DND Route Survey, Pacific** - EM3000S/EM1002
- **Fugro Jacques Geosurveys** - DF1000, EM1000, Seabat 8101/8111
- **Naval Research Laboratory**
  - Washington - EM121A, EM1000, EM1002
  - Stennis - EM1000, EM1002
- **Naval Oceanographic Office** - EM3000S

Modeling of Swath Sonar Target Detection Capability



Hughes Clarke
Chair Funding

As part of the new IHO standards, remarkable target detection capability is demanded. Currently all manufacturers claim that they meet or exceed these new standards. Field trials run jointly between the CHS and the OMG clearly indicate, that, whilst vertical accuracy criteria can be met, the target detection criteria built into these specifications can only be met under a very limited subset of operating conditions.

In order to understand the target detection processing, a numerical model has been built which replicates amplitude or phase detection for a given beam width, sidelobe level, noise level and bottom roughness mode. Using this model, the field performance of a particular sonar may be examined and the effect of varying one of the parameters assessed. Targets of specific dimensions and backscatter strength attributes may be positioned at different locations within a swath to assess the changing target detection capability.

Standards for Swath Sonar Surveys

Hughes Clarke
(funded through Land Information New Zealand)

With the increasing information content and potential uses of swath sonar systems, application of historic survey standards is neither appropriate nor clearly interpretable. New practical interpretations of the current IHO standards (Ed. 4) have been devised for the conduct of contract swath sonar surveys in New Zealand.

See: http://www.omg.unb.ca/~jhc/LINZ_spec/

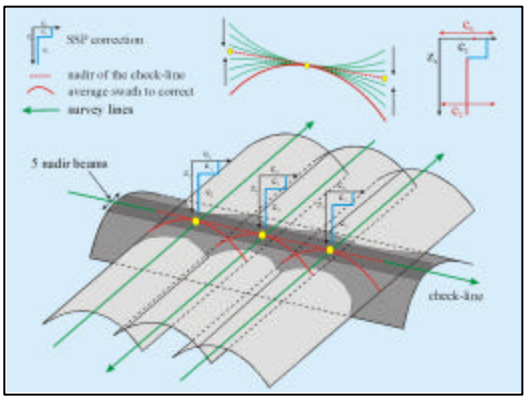
These recommendations allow a more rigorous definition of the survey requirements in a manner easily interpretable by a third-party contractor. As an increasing percentage of nautical charting surveys are being conducted by contract rather than government staff, the need for such clarity is especially pressing.

These standards are now being used as a guide for current large scale mapping surveys on the Irish continental margin and proposed large scale mapping of the Canadian Margin.

Refraction Artifact Correction

Hughes Clarke and Kammerer
Chair Funding and NSERC

An operational reality of swath sonar survey is that there will be imperfect knowledge of the water mass. How these imperfection manifest themselves into the data depends strongly on the sonar hardware geometry. We have modeled the effect of surface sound velocity errors on the common sonar configurations to show how one can recognize these errors (which are dynamic, varying with the array instantaneous orientation).



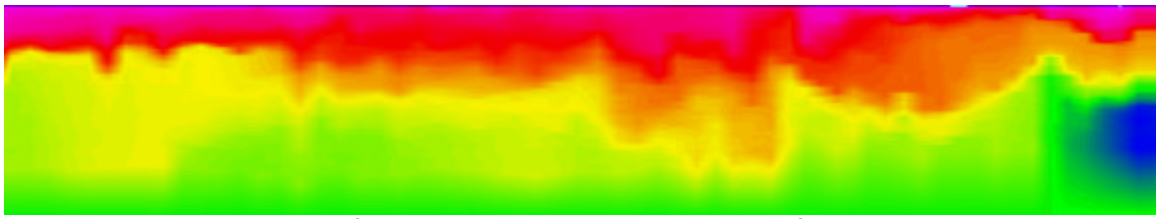
Even with sufficient surface sound velocity information, changes in the deeper structure of the water mass will degrade the quality of the data. Such changes usually manifest themselves over longer time periods so that one can model the error as a slowly varying signature.

Software algorithms have been developed to first empirically and then objectively recognize the characteristic shape of these artifacts and, through a minimisation technique estimate an optimal slowly varying spatial corrector to remove or at least reduce the magnitude of the error.

Integration of Continuous Water Column Information

Hughes Clarke and Lamplugh (CHS)
Chair Funding

Recent development of high speed underway oceanographic profilers as a joint project between the CHS/DFO and Brooke Ocean Technology (BOT) have produced an operational system (the MVP100/200/300) that is now in use on a subset of CHS swath sonar survey platforms.

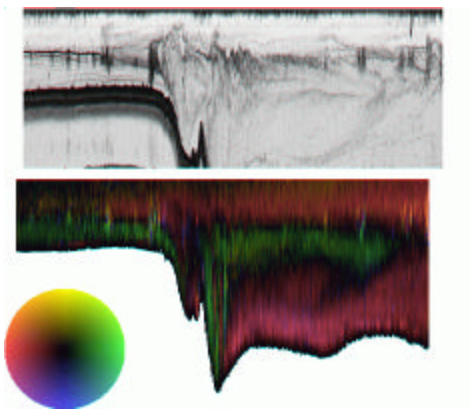


cross section of the sound speed structure on the edge of Georges Bank
(colour range 10m/s, 45 km long profile from 0-100m)

Whilst at this point in time, routine deployment of these sensors only takes place at periods of ~ every hour, as part of OMG field trials it has been shown that these systems can provide water column data as

frequently as once every minute. Such high density data is currently of little practical use, however as commercial software tools are not available to handle a dynamically varying water column.

We have developed software to linearly interpolate the water mass between discrete profiles. These interpolated profiles can be applied as a unique water column for each ping so that the effect of a continuously changing watermass may be mimicked. The maximum time period over which such interpolation is justified has been explored (by examining the resulting errors when compared to the true water mass). At this time, interpolation of time periods much more than 30 minutes is considered to be of minimal value as it is clear that the time and length scales over which the water mass can change are shorter than this. This provides a clear guide as to the optimal use of these underway profiling instruments.



Integration and Visualisation of ADCP Current and Water Column Multi-Frequency Scattering

Hughes Clarke and Cartwright
CFI, Prov. NB and Simrad

As part of our research thrust to better monitor the water column from underway vessels (primarily for the purpose of sound speed field estimation) we have examined other acoustic imaging tools including high frequency scattering and acoustic doppler current profilers.

Even though these tools do not directly map the sound speed field, because the sound speed properties are strongly linked to water mass distribution, if we can monitor the boundaries of these water masses we can more accurately predict the temporal and spatial variation in the water column between our discrete point-specific sound speed profiles.

We have developed software to integrate Knudsen scattering profiles with concurrently collected ADCP data. These tools allow us to build up a picture of the temporal evolution of the water column. In order to test these tools under the most critical conditions, we have focused on the particularly dynamic environment of the Lower St. John River Estuary. Y2001 research is planned to extend the project to the Frazer River mouth wherein CHS survey activity is currently particularly focused.

Mapping and Monitoring of decimeter-level seabed change

Hughes Clarke, Parrott GSC, Danforth USGS
(funded through CFI, Prov. NB. and Simrad)

With sufficient calibration and absolute control, shallow water multibeam sonars should be capable of mapping decimetre level seabed change. The sedimented seafloor can be a very dynamic interface. This is particularly true in the high energy of the coastal zone where the sediment on the seabed is continually being remobilised. This is often the natural result of winds, waves, current and tides but also increasingly it is a product of man's interaction with that environment.

Typical scales of erosion and deposition range for a few centimetres to a few decimetres. Conventional depth measurements are normally only achievable with an absolute accuracy of a several decimetres. Until recently, even this has only been possible at spot locations or along two-dimensional profiles using single

beam echo sounders. Multibeam echo sounders, however, for the first time, potentially allow us to view the sediment-water interface at that resolution over the whole surface. The same sources of error, however, that plague single-beam echo-sounding (and some addition new ones that affect multibeam sounders only), make it operationally extremely difficult to be able to resolve this small scale erosion and deposition using underway acoustics.

If a robust method to map and monitor the sediment water interface at scales of a decimetre could be developed it would allow researchers and engineers to better understand the effect of natural and man made influences on the seabed. Whilst the possible field of applications would be very broad, three applications, particularly relevant to Canada, will be specifically addressed using the funded infrastructure:

1. Build-up and dispersal of organic debris under Aquaculture sites
2. Quantification of naturally occurring sediment transport rates and volumes
3. Scour and deposition around man made structures

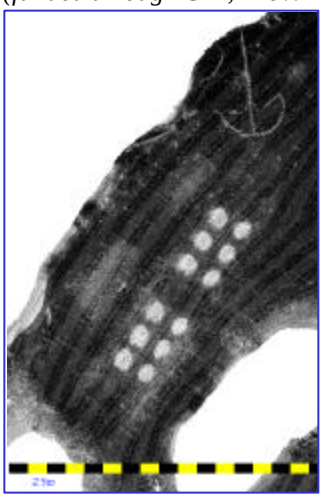
To support this research, infrastructure funding has been successfully obtained to buy hardware including:

- Simrad EM3000 multibeam sonar
- Seatex MRU-6 motion, heave and heading sensor
- RDI 600 kHz Monitor ADCP.

The intent is to use this hardware to support local field research programs into the three applications using frequent repetitive surveys (weekly, monthly) to demonstrate the feasibility of monitoring decimetre-level seabed changes

Aquaculture Site Monitoring

Hughes Clarke, Wildish (DFO) and Tlusty(NEA)
(funded through CFI, Prov. NB and Simrad)



A joint research project between DFO science and the OMG has followed up on earlier OMG results in deploying high frequency multibeam sonars immediately adjacent to active salmon mariculture sites. The original surveys in Bay D'Espoir, NF indicated that the build up and redistribution of organic-rich salmon farm waste (excess food and excrement) could be accurately monitored using the backscatter and bathymetric imaging capability of a Simrad EM3000S.

Most recent results (October 2000) in the Letang and Bliss Harbour areas of New Brunswick (see EM3000 backscatter image to the left) , indicate that the build of the material is strongly influenced by the site location with respect to the tidal current activity in the area. Whilst the most favoured sites are in sheltered bays (for hardware preservation reasons) it is clearly these sites in which the most negative impact is observed on the bottom benthos.

A multi year repeat monitoring program is now planned to assess the temporal variability of the acoustic signature of the salmon farming. By observing both active and abandoned sites, the long term effect of this critically important industry can be observed.

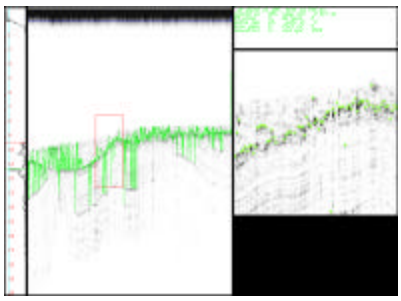
Slope Stability COSTA

Gee, Hughes Clarke, Locat (Laval), Piper (GSC), Mosher(GSC)
(funded through NSERC CRD)

Canada's continental margin and coastline is the focus of more and more attention as we see increasing economic activities in various fields including natural resources (oil and gas), transportation (port development), electrical transmission and communication (fibre optics cables, etc…). It is clear that the major natural hazards threatening economic activities and populations along the Canadian coastline are earthquakes, submarine landslides and tsunamis. The goal of this project is, consequently, the assessment of continental slope stability along the Canadian continental margin, estuaries and fjords with respect to natural processes and human activity.

Over a period of four years, we will make a comparison between well-investigated sites in the Atlantic and the Pacific, develop new analytical approaches based on field, laboratory and numerical modeling of submarine landslide. To achieve our goal will require the establishment of a precise database, the integration of field (seismic and multibeam surveys) and laboratory data (e.g. strength testing) in a 3 dimensional model that will represent the full extent of a submarine landslide hazard. Some aspects related to the transition from slide to catastrophic movements will also be evaluated with small scale physical models. This visualisation will be incorporated in a new approach to define the hazard and integrate it to a risk assessment methodology which will help us evaluate the risks involved, in a given marine environment, with regards to earthquakes, landslides and tsunamis.

For more information: http://www.costa-canada.ggl.ulaval.ca/



Single Beam Data Enhancements

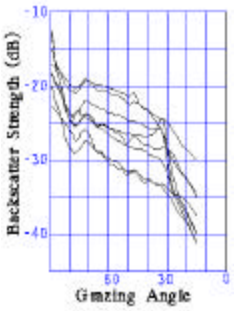
Hughes Clarke and CHS
(Chair Funding)

Whilst swath sonar systems are increasingly being implemented by the world's hydrographic agencies, it has remained clear that there are specific environments in which the single beam and sidescan survey model will remain the dominant tool. Areas include, water depths less than ~8m and areas of high potential grounding hazard.
We have examined the new potential now being offered from a subset of single beam sonar manufacturers that is evident in full digital waveform logging. Using a Knudsen 320 B/P system we have developed unique new software to extract the full echo envelope data for a variety of purposes:

- Improved bottom detection
- Analysis of water column echo information (as an aid to physical oceanographic studies)
- Analysis of subbottom echo for shallow geophysical surveys.

This tools are particularly significant for our major sponsor, the CHS. The CHS continues to operate dual frequency Knudsen 320M's in all regions. Whilst the current mode of operation does not retain the echo envelope information (except in paper hard copy), all the existing hardware is capable of retaining this information.

Now that digital processing is sufficiently fast, it is possible to incorporate this new information into the standard processing stream. Whilst the tools allow improved confidence in bottom detection (the prime aim of hydrography) it also allows the user to deliver environmental information concurrently. With the increasing shift of inshore surveys from strictly hydrographic to coastal zone management issues, the ability to retain this information with no extra hardware cost is an important factor.



Seafloor Characterisation using Backscatter Angular Response

Hughes Clarke Danforth and Gardner (USGS)
Funded through USGS and NSERC Research Grant

This research has focused on extracting the angular response of backscatter from near-calibrated multibeam sonars as a tool for seabed classification. Because of the high aspect ratios of multibeam sonars, the variation in backscatter strength from near vertical incidence to lower than 15 degree grazing may be routinely extracted. The variation in backscatter strength over this range of grazing angles has previously been ignored from conventional sidescan backscatter surveys due to their low aspect ratios.

This angular response actually makes it harder to interpret conventional backscatter mosaics. The early part of this research actually came out of developing methods to minimize the changes in shape of the angular response. A by-product of this was ext racting that signature. Efforts to correlate the observed angular response with theoretical curves are currently hindered by imperfect data reduction. This is principally a result of:

- Imperfectly measured source levels and receiver gains
- Small changes in beam patterns
- Software problem in acquisition systems.

At this time the focus is on using empirical methods to attempt field calibration of the residual data artifacts so that the shape of the angular response may be repeatably extracted from sequential surveys. Most recently a new research thrust has developed to extract this backscatter data from other commonly used sonar systems including NOAA ELAC and RESON systems.

Trials and testing of new swath sonar systems

Hughes Clarke
(funding from CHS, USGS, RNZN, RAN)

One of the major roles of the OMG over the past 8 years has been the trial and testing of new or upgraded swath sonars. This originally was done on an informal basis for the CHS as each new sonar or peripheral sensor came on line.

- 1991/2 CSS Matthew EM100
- 1992/3 - CSS Frederick G. Creed EM1000
- 1994/5 – CSS Frederick G. Creed Applanix POS/MV
- 1996/7 - CSS Puffin/Plover/Petrel EM3000S
- 1999 - CCGS Young EM1002

This has since taken a turn whereby other swath systems being mobilised are checked, analysed and calibrated by OMG staff. In recent years this has included:

- 1996 – EM1000, C&C Technologies – USGS Seafloor Mapping Program
- 1997 - EM300, C&C Technologies – USGS Seafloor Mapping Program
- 1998 - EM3000D, C& C Technologies – USGS Seafloor Mapping Program
- 1999 - ATLAS MD2/30, Royal New Zealand Navy
- 1999 - Simrad EM1002 Clearwater Fine Foods.
- 2000 - ATLAS Fansweep 20-100, Royal Australian Navy

This work provides a unique opportunity to quantitatively assess the capability of newly emerging hardware. This information can be used to update training material and to redirect current research thrusts to take account of the rapid advances in technology seen in the marketplace.

SeaFloor Mapping for the USGS

Hughes Clarke and Gardner (USGS)
USGS Dept. Interior Funding

The Ocean Mapping Group has been providing guidance and training toward the conduct of large scale USGS continental shelf mapping projects. This provides a particularly challenging opportunity for software development as the USGS programs take place on a larger scale than any active program in Canada. Furthermore these programs are often critically dependent on backscatter images and thus provide demands not seen with other users.

Unusual demands include:

- Using predicted tides in outer shelf environments.
- Using multi year additions to surveys using either new or software upgraded sonars.
- Requiring unusual vertical datums (lake elevations in 1000's of metres).
- A focus on resolution over accuracy making the problem of dynamic errors particularly pressing.

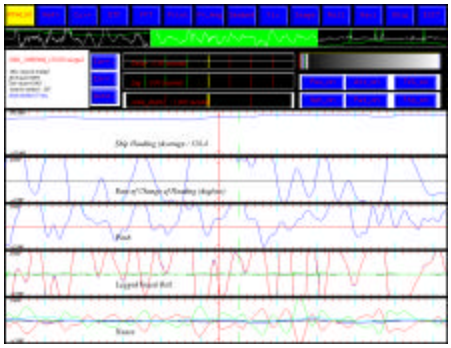
For recent examples please see:
http://walrus.wr.usgs.gov/pacmaps/site.html

Quantitative intercomparison of swath sonar system capabilities

Hughes Clarke
Chair funding

As one of the few research groups world wide who are actively investigating the accuracy and resolution of swath sonar systems, we continuously have the opportunity to assess the capability of new systems that come on the market. Originally this was achieved through the field demonstrations that took place along with the early Multibeam Courses.
These results have been compiled and released on our web pages:
http://www.omg.unb.ca/~jhc/uschc96/ and http://www.omg.unb.ca/~jhc/uschc97/

We continue to have the opportunity to assess either new systems or significant system upgrades. Increasingly this is happening as part of contract sea trails. Wherever possible we strongly encourage the client to allow the trial results to be made available to other potential users of the systems.



Dynamic error analysis and correction

Hughes Clarke
Chair Funding

As swath sonar systems have improved, the dominant influence of error sources due to bottom detection, orientation and refraction have gradually reduced. Today it is quite feasible to deliver hydrographic quality survey data. Indeed, it is clear that the 1-2.3% accuracy standards invoked are far larger than the resolution capability of these sonars (which exist at the ~0.2% level). In order, however, to exploit this resolution capability, small error sources, previously ignored,

have come to be seen as a major barrier in the delivery of high quality products.

These small error sources often only manifest themselves as periodic oscillations of the seafloor at the ~<0.5% level. Yet, because of improvements in visualization they are increasing apparent. Their cause is usually due to small imperfections in the system integration .

The OMG has been aware of these problems since 1992 and has developed custom software (the DelayEditor toolkit) to investigate them. Nevertheless, such tools are still not available in the commercial software sector and the existing OMG tools are not very intuitive and rely on human interpretation. The intent here is to automate the analysis process so that less trained staff can recognize and fix these small residual problems. This is the one of the particular focuses of our new active research.

PalaeoOceanography

Weber and Mayer
NSERC funding

1. High-Resolution Marine Paleoclimate Time-Series : M.E. Weber and L. A. Mayer

As the Canadian contribution to the international IMAGES program, we have joined the NSERC-sponsored Climate System History and Dynamics project aimed at bringing together climate modelers and paleoclimate data collectors to gain a better understanding of the nature of climate change. Our contribution to this program has been to collect long undisturbed deep-sea cores and to develop ways to use automated, near continuous measurements of physical properties collected with a Multi-Sensor Core Logger and optical properties collected with a Minolta spectrometer to produce very high-resolution records of paleoclimate indicators. We now explore the nature of variability in these time series to gain insight into the forcing factors and earth's response to climate change. We also begin to predict the variation of important climate proxies such as stable oxygen isotopes, carbonate and organic carbon from logging data. As part of this effort, we have developed an interactive 3-D visualization of the role that orbital forcing (Milankovitch forcing) plays in controlling insolation. We have also developed tools for interactively exploring multidimensional spectra of these time series (evolutionary spectra) that help in understanding the interplay of factors responsible for long-term climate evolution.

2. Quaternary Climate Evolution in the Eastern Equatorial Pacific :M.E. Weber

During several ship expeditions we collected paleoceanographic data from piston cores and from sites drilled by the Ocean Drilling Program (ODP) in the Eastern Equatorial Pacific. High-resolution downcore log measurements of physical and optical properties allow, for the first time, the extraction of carbonate and opal records at unprecedented temporal resolution (approximately 1000 years for the last 1.3 million years). We collected additional paleoclimatic and paleoceanographic proxy data from sediment cores (sea-surface temperature records derived from alkenones, organic carbon, and stable isotopes) to explore both the spatial and temporal evolution of climate with respect to the forcing factors across the equatorial zone of high productivity.
Deep-sea carbonate responds primarily to orbital variations on the 100,000 year cycle of eccentricity as well as to insolation changes on the 21,000-year band. Carbonate contents and carbonate accumulation rates were highest during the transition from cold to warm climate, whereas dissolution was strong on the transition from warm to cold climate. Productivity in surface waters was clearly enhanced during peak cold times, when sea-surface temperatures were lowest.

For further information : (http://www.omg.unb.ca/~mweber/Projects.htm).

Fisheries Multibeam

YanChao Li. Melvin and Mayer
NSERC, PRC and Simrad funding

The current work is involved in the application of specially designed multibeam sonar (SM2000) to fishery researches. Unlike the traditional sonar that is designed to gate out the mid-water signals, this one allows us to capture both the mid-water and the bottom returns. The broad water column coverage will give us much information for accurate data analysis. Meanwhile the large data resulted from the survey requires prompt processing. One goal of the research is to find a way to correctly interpret the signal data in term of bio-mass; and another one is to develop highly efficient software tools to do real-time 3D visualization and signal analysis.

Coastal Legal Boundaries

Nichols, Sutherland, Byrne, N'gan'ga, Cockburn
GEOIDE funding

Good Governance of Canada's Oceans depends on knowing what resources (living and non-living) there are to govern; who holds the rights and responsibilities for their safe and orderly conservation, distribution and exploitation; and the spatial limits (boundaries) of those rights and responsibilities.

The project is concerned with good governance of Canada's oceans and will focus mainly on identifying marine limits and boundaries.

The deliverables will include demonstrations of how geomatics technologies can be used by decision makers to identify the socio-economic, legal, and environmental impact of boundary uncertainties, evaluate boundary alternatives, and resolve the issues. The results are expected to have immediate applications elsewhere in Canada. They will also assist Canada in continuing to be an international leader in ocean governance and marine geospatial data infrastructure.

The objectives of the project are:

- To Identify and Evaluate Boundary Information Requirements for Good Ocean Governance
- To Investigate Spatial Data Uncertainty and Its Impact on Data Integration and Boundary Delimitation
- To Develop and Enhance Prototype Visualization Tools for Marine Boundary Delimitation

Included in this project are three case studies:

- New Brunswick provincial and county marine boundary components
- A proposed Marine Protected Area in the Bay of Fundy near Musquash Estuary
- A portion of the Atlantic extended continental shelf boundary

For more information see: http://www.unb.ca/GGE/Research/OceanGov/

Education and Training Options

By 1994 it was increasingly apparent that, as the new swath sonar technology was evolving, there was a growing urgency to provide matching education and training in these systems. The initial requirement was for a training program that addressed existing employees in our major government sponsoring organisations (CHS, NOAA, NavO and NRL). To meet this demand, in 1994, the OMG put together a training package. The first "Multibeam Course" was given in August 1994 in St. Andrews New Brunswick. Since that time, the course has been presented 22 times whilst continuously evolving and is now open to the worldwide marine survey community:

The Multibeam Training Course

1. August 1994 : USCHC Course, St. Andrews, Canada

2. March 1995 : RDANH Course, Hundested Denmark
3. June 1995 : USCHC Course, St, Andrews, Canada

4. March 1996 : Nautronix-WAHS Course, Fremantle, Australia
5. March 1996 : USACE-TEC Course, Mobile, USA
6. June 1996 : USCHC Course, St. Andrews, Canada

7. February 1997 : Racal Surveys, Gt. Yarmouth, U.K.
8. June 1997 : USCHC Course, St. Andrews, Canada
9. December 1997 : Nautronix-WAHS Course, Fremantle, Australia

10. February 1998 : US NavO, Gulfport, USA
11. March 1998 : USCHC Course, Victoria, Canada
12. April 1998 : GSC-A Course, Halifax, Canada
13. October 1998 : Nautronix-WAHS Course, Singapore
14. December 1998 : US NavO, Gulfport, USA

15. February 1999 : US NavO, Gulfport, USA
16. March 1999 : USCHC Course, Seattle,, USA
17. June 1999 : Royal Australian Navy, Cairns,, Australia
18. October 1999 : Scottish Hydrographic Society, Aberdeen, Scotland

19. February 2000 : US NavO, Gulfport, USA
20. April 2000 : USCHC Course, Burlington, Canada
21. August 2000 : Royal Australian Navy, Cairns, Australia
22. October 2000 : Scottish Hydrographic Society, Aberdeen, Scotland

and upcoming in 2001

23. January 2001 : Scripps Institution of Oceanography, San Diego, USA
24. June 2001: US NavO, Gulfport, USA
25. October 2001 : Hydrometrica, Amsterdam, Holland
26. December 2001 : CCOM, UNH

These courses, however, were specifically designed to present the core information in a very rapid time frame. This best suits existing employees of government and private organisations that have an ongoing workload. However, to best address future marine surveyors, it was quickly realised that this information

should be brought into the undergraduate curriculum so that young surveyors, entering the field would already have this knowledge.

From 1995 to 1999, the content of the commercial course was gradually incorporated into the UNB Geodesy and Geomatics Engineering undergraduate and graduate program. At first the course was given only as a graduate level course. But from year to year, an increasing percentage of the material was embedded into the undergraduate curriculum.
GGE teaches one of the few University-level IHO Category-A-certified hydrographic survey programs. The curriculum associated with that certificate is only gradually evolving to meet the new requirements of the swath sonar revolution. Nevertheless, the needs of UNB survey graduates are much more immediate as it relates to their job prospects in primarily the offshore commercial sector (who do not have a strong input into the IHO program).
Offshore survey companies are increasingly desiring that their new employees be already familiar with swath sonar surveying. In the short term they have been sending their staff to our course, but it is clear that by providing our students with this knowledge it provides them with a significant employment advantage.

In 2001 the process is now complete. The principal components of the commercial course are now fully presented in our undergraduate program. The graduate multibeam course assumes this knowledge already and focuses the graduate students on advanced problems in dealing with swath sonar technology. This model is now also being adopted by other hydrographic survey schools as witnessed by the attendance of lecturer from other schools on our commercial swath survey course (RN school, Hong Kong Polytechnic, Plymouth, Univ. College London).

This natural evolution has brought the COM closer into the Department. As the University takes over the support for the Chair salary, it is fitting that this occur. The Chair now teaches two of the three undergraduate ocean survey courses. It is our strong belief that this increased education role of the Chair actually benefits the sponsors directly (who are significant employers of our graduates).

GGE Marine Survey courses :

UNDERGRADUATE:

SE3353 Imaging and Mapping II, Acoustic Imaging Systems

Hughes Clarke
Theory of, and operational issues in acoustic marine surveying.
http://www.omg.unb.ca/GGE/SE_3353.html

SE5072 Kinematic Positioning and Hydrographic Data Management

Wells and Santos
Marine positioning and data management

SE5083 Hydrographic Field Operations

Hughes Clarke
Planning, execution and data processing for a coastal marine field program
http://www.omg.unb.ca/GGE/SE_5083.html

details of prior field survey courses:
http://www.omg.unb.ca/GGE/previous_hydro_ops.html

GRADUATE:

SE6023 Multibeam Sonar

Hughes Clarke
Research Topics on Swath Sonar Systems.
http://www.omg.unb.ca/GGE/SE_6023.html

SE6022 Special Topics on Ocean Mapping

Hughes Clarke
Research Topics in Ocean Mapping (Sediment Characterisation, Coastal Physical Oceanographic Phenomena, Marine Sedimentation, Environmental Monitoring).

SE6021 Special Studies in Hydrography

Wells
Research Topics in Aspects of Hydrography

Recent Graduate Theses

Edouard Kammerer (Ph.D) - 2000 - "A New Method for the Removal of Refraction Artifacts in Multibeam Echosounder Systems"
Sean Galway (M.Sc.E.) - 2000 - "The Integration of Multibeam Sonar Data with Huntec Sub-bottom Profile Data into a Marine GIS"
Miguel Pacheco (M.Eng.) - 2000 - "Product Specifications for Marine Information Objects"
Steve Bloomer (Ph.D) - 2000 - "Examination of the Potential of Seismic Reflection Data for Paleoceanographic Studies - Case Study from the Eastern Equatorial Pacific Ocean"
Jose Vincentes Martinez (MEng) - 1999 - "Analysis of Multibeam Sonar Data for the Characterization of Seafloor Habitats"
Semme Dijkstra (PhD) - 1999 - "Software Tools Developed for Seafloor Classification"
James Allan Clarke (MEng) - 1999 - "A proposed submarine electronic chart display and information system"
Edward Bartlett (MEng) – 1998 – " In search of chaotic elements in the Bay of Fundy water level measurements"
Joao Paulo Ramalho Marrieros (MEng) - 1998 - "Performance analysis of GPS attitude determination in a hydrographic survey launch"
Luis Miguel Pais (MEng) - 1998 - "A case study of the production of an S-57 ENC with CARIS tools"
Richard Phelan (MEng) – 1997 – " OTF GPS for eastuarine dredging and sounding surveys"
Michel Brissette (MEng) - 1997 - "The applications of multibeam sonars in route survey"
Andre Godin (MEng) - 1997 - "The calibration of shallow water multibeam echo sounding systems"
Fernando Manuel Freitas Artilheiro (MEng) - 1997 - "Analysis and procedures of multibeam data cleaning for bathymetric charting"
Fahad Al-Amri (MEng) - 1997 - "Sound speed variations in the Arabian Gulf and their effect on multibeam echo sounding"
Ziquin Du (PhD) - 1995 - "Uncertainty handling in multibeam bathymetric mapping"
Steve Deloach (MEng) - 1995 - "GPS tides, a project to determine tidal datums with the Global Positioning System"
Dave Dodd (MEng) – 1994 – " Accuracy of the UNB Real-Time Differential GPS"

Funding and Financial Commitments

Funding for the Chair in Ocean Mapping comes from two sources:

- Sponsorship funds
- Other research organisations

To maintain the Chair staffing at the current levels and to support the necessary computing facilities and travel to international meetings, an annual budget of **~C$165k** is required. To date, this level of support has been met or exceeded. The continuation of this level of support, however, will require ongoing commitment from the sponsors of the Chair. That in turn requires that the Chair can show continued relevance and usefulness toward the marine survey community.

Sponsors

The Chair in Ocean Mapping at UNB can only survive as long as there is external funding. The Chair, originally set up as an NSERC Industrial Research Chair, originally survived by the combination of Industrial Sponsorship together with matching funds from NSERC. In 1996, on the renewal of the Chair the matching funds were withdrawn. From that point on the Chair has been fully dependent on external funding (from Canadian or International, Commercial or Government organisations). At this point there are 12 sponsors.

Current Sponsoring organisations

1.	Universal System Limited (CARIS)	1991-
2.	U.S. Naval Oceanographic Office	1997-
3.	State University of New York	1998-
4.	Defense Research Establishment Canada	1999-
5.	University of New Hampshire	2000-
6.	Canadian Hydrographic Service	1991-
7.	PetroCanada	1991-
8.	Kongsberg Simrad Mesotech	1993-
9.	U.S. Naval Research Laboratory	1996-
10.	Fugro Jacques Geosurveys	1996-
11.	U.S. Geological Survey	1996-
12.	C&C Technologies	1996-

The sponsorship model originally grew out of the NSERC Industrial Research Chair concept. At that time 4 initial sponsors (CHS, ACOA, USL, PetroCanada) were found that provided research funding. It was not expected that additional sponsors would necessarily be found.

However, within a few years of start up, a number of commercial and foreign government organizations approached the Chair with requests to share in the research output of the Group. Further sponsorships were thus introduced with the minimum financial commitment being equivalent to the lowest theoretical input of the original sponsors (C$25k per year). As demand grew outside Canada, a level of US$25k per year was set for non-Canadian sponsors. Sponsors have to make an initial commitment for 5 years, but thereafter their continued sponsorship is decided on an annual basis dependent on the continued relevance of the relationship.

Active sponsors have access to all current research results from the group (at a source code level) and are free to call upon the chair personnel to provide informal advice on operational survey issues. In addition, the chair actively seeks advice on new relevant research directions. The continued success of the chair is thus clearly critically reliant on the continued relevance and leadership of Chair research. As this document outlines, new focused research directions are envisaged based on current sponsorship suggestions.

Other Sources of Funding (Current)

Whilst the sponsorship funding is the prime source of support for the core Chair research program, all the researcher working with the Chair have been successful in attracting funding from other research agencies. This funding allows us to complement Chair research, which is by design very focused on immediately relevant problems, with research into more long term and esoteric problems.

Projects names (details of which are included in the list of current research) and level of funding include:

Multibeam sonar for mapping and monitoring decimetre-level seabed changes

Canadian Foundation for Innovation, Province of New Brunswick, Kongsberg Simrad
Hughes Clarke C$340,000 one-time infrastructure grant

Good Governance of Canada Oceans

GEOIDE
Nichols and Hughes Clarke et al., C$ 200k pa

Extraction of backscatter information from US Government Contract Surveys

U.S. Geological Survey
Hughes Clarke, C$45k pa

COSTA-CANADA , continental slope stability

NSERC Collaborative Research Grant,
Hughes Clarke and Gee, sub contract - C$31k pa .

Extracting Seabed Information from High Density Acoustic Sonar Surveys.

NSERC Research Grant
Hughes Clarke C$24k pa

Climate History and Dynamics

NSERC Collaborative Research – Univ. of Toronto
Mayer and Weber –sub contract - C$86k pa.

The application of multibeam sonar to fish school mapping and biomass estimates

NSERC Collaborative Research –. (NSERC, Pelagic Research Council, DFO and Simrad)
Mayer, Melvin and Li, C$48k pa

Hardware Capabilities

In order to conduct OMG research, a mixture of Unix and Windows platforms are maintained. For the core swath sonar data processing applications (SwathEd) , the UNIX platforms are the prime tool. SwathEd is currently supported on SGI, DEC, Solaris or Linux. For historical reasons SGI is the most used hardware platform. SUN operability is maintained to support sponsors who use that hardware (SUNY, C&C) and DEC is supported for CHS operations.

To take advantage of the cheap PC hardware, Linux support was introduced in 2000. It is intended that Linux be the main operating system for SwathEd in the future. Recent purchases have been Linux hardware only (with the exception of two SGI's which were purchased second hand).

SGI-Irix 6.5

2 – SGI Extremes	(clownfish and southern)
4 - SGI 02's	(solomon, cyclops, bliss and blacks)
2 – SGI indigos	(eyeball and arctic)
1 – SGI Indy	(indian)

Compaq/DEC

1 DEC Alpha	(alpha)

Solaris

1 – SUN Sparc20	(coral)
1 – SUN Sparc 2	(atlantic)
1 –Sun Sparc X	(hudson)

Linux

1 Dell	(louise)
1 Dell	(dipper)

Windows

2 Dell 300	(erie, letang)
1 Dell 600	huron
1 Dell 450	yanchao
2 IBM laptops	

Plotters

HP 650
HP 2500
Lexmark 1200dpi

SCSI Disks

2x 50 Gb (on DEC)
3 x 36 Gb (RAN, Kenneb and Other)
4 x 18 Gb (CHS, X Y Z)
various 9's, 4's, 2'sand 1's…….

Tapes Drives

DLT
Exabyte
DAT

Publications:

2000

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1995-1998

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http://www.unb.ca/GGE/Research/Research.html