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## Compte rendu FEMME 93

Forum des utilisateurs d'échosondeurs multifaisceaux SIMRAD

Paris, du 15 au 17 septembre 1993

Par André Godin, hydrographe  
Service Hydrographique du Canada  
Région du Québec

Fisheries  
and Oceans

Pêches  
et Océans

Canada

VK  
594  
F45  
1993



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## INTRODUCTION

Cette année, le forum des utilisateurs d'échosondeurs multifaisceaux Simrad a été chapeauté par le consortium français ISM (International Subsea Mapping) qui a son bureau mère à Paris, porte Maillot. L'ISM est composé de trois organismes français, l'IFREMER (35%), BEICIP (15%) et L.D. CANOCEAN (50 %). La principale activité du consortium est la reconnaissance, n'importe où dans le monde, de route pour la pose de câbles sous-marin. C'est suite à l'acquisition de plusieurs systèmes de sondage multifaisceaux grands et petits fonds par l'IFREMER que l'ISM a proposé être les hôtes du forum cette année.

Le nombre de participants, comme le montre la liste en annexe (A), ne cesse de croître d'année en année ainsi que le nombre de systèmes en opération dans le monde (annexe B). Mentionnons toutefois que la délégation du Naval Oceanographic Office (É.-U.) était absente du fait d'un litige survenant à la suite de l'acquisition d'un Simrad EM121 par la U.S. Navy.

Comme par les années antérieures, la formule adoptée pour le forum était des sessions de communications et des rencontres hors-sessions informelles. Les communications des utilisateurs d'échosondeurs multifaisceaux Simrad présentaient leurs expériences tandis que celles faites par Simrad relataient des développements nouveaux de la compagnie. Soulignons la présence cette année encore du Ocean Mapping Group (OMG) de l'université du Nouveau-Brunswick, en la personne du Dr J. Hugues Clarke qui présenta les dernières expériences du projet de chaire Hydrographic Ground Truthing. Le service hydrographique du Canada était représenté par André Godin, hydrographe pour le SHC - région du Québec.

Le programme du forum, lequel énumère les différentes communications, se retrouve dans l'annexe C. La suite de ce compte rendu traite des points saillants tel que vu par l'auteur, mais ne résume pas chaque communication étant donné que ces dernières sont incluses dans le recueil du forum (Proceedings), reproduit dans l'annexe D.

## DÉROULEMENT DU FORUM

### Mercredi 15 septembre

L'ouverture du forum est faite. Le programme du forum nous a remis, dans lequel j'y apprend que le SHC doit faire une présentation le jour même (Installation of EM1000 on a SWATH Vessel), ce qui n'était pas planifié. André Godin mentionne tout de même à Freddy Pøhner qu'il a amené des diapositives traitant du sujet et qu'il fera cette présentation, conjointement avec l'autre, le lendemain. Les membres du Naval Research Lab (NRL) étaient absents pour cette session et il n'y a pas eu de communication de leur part.

Les points dignes d'intérêt pour la première session est l'acquisition d'un EM950 par le Rijkswaterstaat des Pays-Bas et le modèle de propagation d'erreur dans les systèmes multifaisceaux, par Freddy Pøhner. Cette dernière présentation, qui était prévue pour le lendemain matin, a été reportée au 15 du fait de l'absence de Navocean et de mon incapacité à faire une communication non préparée.

Le Rijkswaterstaat a installé un EM950 sur une de leur vedette hydrographique, utilisant un TSS 335B comme centrale de référence verticale, pour faire le monitoring de l'accumulation d'alluvions au pied des Dams et le resondage après déplacement d'épaves. Le monitoring des Dams devant ce faire de façon très précise (10 cm en Z), ils ont effectué une série de tests de précision dont certains se sont fait dans une cale sèche inondée. Cette dernière méthode est intéressante en ce sens que le fond d'une cale sèche, connu ou mesuré de façon précise, constitue une référence absolue. Il est toutefois important de mentionner que des conditions normales d'opération (vitesse, vague,...) sont impossible à reproduire dans une cale sèche ainsi que la présence d'interférences produites par les parois rapprochées de la cale, est difficile à déterminer. À ma demande, une copie du rapport de tests sera envoyée au SHC.

Le modèle de propagation d'erreur reliée aux échosondeurs multifaisceaux sera très pratique pour corroborer nos propres exercices d'évaluation et d'analyse de précisions. Il est néanmoins énigmatique qu'un tel rapport soit émis maintenant, après que tant de systèmes multifaisceaux soient vendus et utilisés. Il semble que ce soit par l'apparition de séries de tests et d'analyses de précision, entrepris dernièrement par les utilisateurs et notamment par le SHC et le OMG, que la compagnie Simrad se sente dans l'obligation d'en faire à leur tour sur leurs propres appareils.

La session se termine par des discussions et une démonstration du logiciel de traitement NEPTUNE, sur station graphique Sun Sparcstation, installée dans la salle des conférences.

Jeudi 16 septembre

La première communication fut faite par Maria T. Kalvic, du NRL, qui s'est finalement joint à nous. Le DOLPHIN et les activités de la firme canadienne Geo-resources Inc. ont été très publicisés lors de cette présentation.

Le SHC a fait une présentation en deux volets : le premier relatait de l'installation du EM1000 sur le Frederick G. Creed et des expériences en découlant alors que le deuxième volet, qui était en fait la communication planifiée, faisait un résumé des activités du SHC en sondage multifaisceaux depuis leur première acquisition (1989) ainsi que, pour refléter le thème de cette session, d'un résumé de nos tests sur les centrales de référence verticale, notamment des tests du TSS 335B faits sur le Frederick G. Creed en mai 1993 et des conclusions s'y rattachant. Une copie des acétates utilisées pour faire cette présentation se trouve à la fin du recueil FEMME 93, dans l'annexe D.

Erik Hammerstad (Simrad Subsea A/S) a dévoilé, dans la présentation "Real Time processing in EM multibeam echosounders", les algorithmes utilisés en temps réel par les systèmes multifaisceaux Simrad, ce qui est une première depuis que le SHC utilise leurs produits. Il mentionne aussi qu'une nouvelle table tracante HP PaintJet offre de très bonnes performances, qui se rapproche à celle que l'on trouve avec les tables Versatec, mais un coût beaucoup moindre. Simrad annonce aussi la mise en marché prochaine de la version 2 de leur système de traitement Neptune. Cette version aurait deux nouvelles fonctionnalités intéressantes, soit la détection automatique d'erreurs systématiques et le retraitement après correction du profil de célérité, ce qui est de plus en plus une nécessité dans les levés multifaisceaux.

L'IFREMER a fait deux communications successives sur leurs systèmes de traitement de données bathymétriques et d'images acoustiques acquises avec leurs EM12 et EM1000. C'est alors que tout le monde s'est rendu compte à quel point la technologie française était développée dans ce domaine. Aucune copie de leurs acétates ne se retrouvant dans le recueil FEMME 93, j'ai reproduit à l'annexe E les notes utilisées par Christian Edy dans sa communication "Software for bathymetric data processing". Quiconque désirant obtenir plus d'informations sur les logiciels développés et utilisés par l'IFREMER consultera le rapport de visite IFREMER — Centre de Brest de André Godin, archivé au centre de documentation du SHC à l'Institut Maurice-Lamontagne. C'est dans le cadre du projet 93-07, de l'entente IFREMER — Ministère des Pêches et des Océans, qui s'intitule "Acquisition, traitement, gestion et utilisation des données denses de bathymétrie acquises par système de balayage acoustique (Simrad EM12, EM100 et EM1000)" que M. Godin, suite à la conférence FEMME 93, a visité certaines installations du centre de Brest. Il y a rencontré messieurs Christian Edy et Jean-Marie Augustin, informaticiens affectés au développement des systèmes d'enregistrement et de traitement des données acquises par des échosondeurs multifaisceaux Simrad. La visite de M. Godin a permis d'établir de très bons rapports avec nos homologues français et des échanges subséquents entre les parties sont anticipés.

L'EPSHOM, le service hydrographique français, a fait l'acquisition d'un échosondeur multifaisceaux grands fonds, le EM12, ainsi que du logiciel de traitement NEPTUNE, dans le but de faire la cartographie des eaux côtières profondes françaises. Le SHOM en étant à ses premières armes dans l'utilisation des systèmes Simrad et l'installation de leur EM12 étant récente, peu de données ont été acquises depuis et il n'y avait pas de résultats significatifs à montrer mis-à-part un tracé en 3-D d'un mont sous-marin, fait avec une technique dont l'innovation a étonné les concepteurs de NEPTUNE, ce qui porte à croire que le SHOM n'a pas perdu de temps à maîtriser ce système. Mentionnons toutefois qu'il est surprenant que le SHOM n'ait pas opté pour les logiciels de traitement de l'IFREMER.

Les méthodes utilisées dans le projet ESMAC (nordic research programme for seafloor characterization and classification) sont très similaires à celles employées dans le projet du OMG "Hydrographic ground truthing". Un fait intéressant est l'orientation de ce projet vers l'établissement d'une base de données qui sera éventuellement standardisée dans les pays scandinaves pour servir la cartographie de leurs eaux. Le prototype se nomme GISMO, pour GIS+Mosaicking.

Une réunion a eu lieu, entre Freddy Pøhner et Erik Hammerstad de Simrad Subsea A/S, John Hugues Clarke du OMG de l'université du Nouveau-Brunswick et André Godin du SHC, afin de discuter des problèmes rencontrés avec les échosondeurs multifaisceaux Simrad opérés par le SHC. Une liste de ces problèmes avait préalablement été faite par J. Hugues Clarke et A. Godin afin de s'assurer qu'aucun de ceux-ci ne soient oubliés et qu'ils soient revus par ordre de priorité. Il a ensuite été convenu que cette liste ferait l'objet d'une requête officielle par le SHC, contenant les évidences des problèmes rencontrés et que ces derniers seront analysés et résolus par Simrad avant le début de la prochaine saison de levés.

## **Vendredi 17 septembre**

La présentation de l'ISM sur le contrat de pose d'un câble de communication reliant l'Europe à l'Asie fut l'une des plus impressionnante et captivante. Le projet SEA-ME-WE2, pour South East Asia - Middle East - Western Europe, avait pour but de relier Jakarta à Marseille en passant par l'océan Indien puis la mer Rouge et la mer méditerranée. Un câble de fibre optique fut étendu sur 18 000 km sur lequel plusieurs pays, tout au long de son parcours, s'y rattachaient. Les navires de l'IFREMER les "Jean Charcot", le "Suroit" et l'"Atalante", équipés de EM12 et de EM1000, ont participé à 5 campagnes de levés pour couvrir quelque 200 000 km<sup>2</sup>. Un excellent moyen pour l'IFREMER de recouvrir les coûts d'opération par du financement extérieur. Le gouvernement Canadien, qui voit son pays dans une situation financière difficile, devrait rendre plus souple ces politiques administratives de façon à favoriser de telles entreprises dans le futur.

Une autre communication digne de mention fut celle d'Erik Hammerstad sur le développement de l'échosondeur multifaisceaux EM121. Ce système grands fonds, à haute définition horizontale (faisceaux de 1°), a été récemment développé pour la U.S. Navy. L'installation du premier système doit se faire à Seattle, de décembre 1993 à février 1994, avec les premiers essais en mer, en mars. Une particularité intéressante de ce système est l'unité de contrôle (Operator Unit) qui sera un micro-ordinateur Sun Sparcstation 10. Le programme de contrôle (OPU) sera écrit en langage C et fonctionnera sur le système d'exploitation UNIX, dans un environnement X-Windows. L'avenir étant de plus en plus aux stations de travail, il serait intéressant d'avoir les EM100 et EM1000 du SHC contrôlés par des Sun Sparcstations. En effet, une station fonctionnant avec plusieurs calculateurs en parallèle (multi-processor), pourrait non seulement contrôler l'échosondeur multifaisceaux et ces unités monitrices d'intégrité ou d'imagerie acoustique, mais aussi des systèmes d'enregistrement de données, de positionnement DGPS et de navigation. L'unité intégrerait tout ce dont à besoin l'hydrographe dans sa tâche d'acquisition de données. Le support technique et l'entretien en serait d'autant facilitée.

## CONCLUSION

Ce forum fut, comme par les années antérieures, une excellente occasion pour le SHC d'échanger ces expériences avec les autres organisations qui opèrent des équipements similaires ailleurs dans le monde. Nous avons de plus pris l'opportunité, alors que les ingénieurs de la compagnie étaient présents, de sanctionner auprès d'eux les problèmes rencontrés avec nos équipements. Le SHC, tant et aussi longtemps qu'il possédera et utilisera des échosondeurs multifaisceaux Simrad, se doit d'assister et de participer activement à ces forums d'utilisateurs.

Le thème majeur de la conférence, et qui suscitait un intérêt unanime, fut la quête des sources d'erreurs et la précision des données acquises dans les levés multifaisceaux. Deux points communs ont ressorti durant les communications et discussions subséquentes, soit la nécessité de résoudre les erreurs causées par l'imprécision ou les limitations des centrales de référence verticales ainsi que celles que l'on retrouve dans les profils de célérités (vitesse du son) de la colonne d'eau. Les variations spatio-temporelles des célérités sont à l'origine d'erreurs importantes dans la mesure des profondeurs des faisceaux extérieurs, principalement avec les systèmes à balayage très large comme l'EM1000 ou l'EM12D. Tous les participants du forum sont d'accord sur le fait que ces problèmes restent à être résolus afin que l'intégrité des données acquises avec les échosondeurs multifaisceaux soit parfaitement conservée.

Plusieurs participants se sont montrés très intéressés par les tests des centrales de référence verticale entrepris par le SHC (Halifax Approaches Matthew Survey 92, TSS 335B/EM1000 on Frederick G. Creed 93, Matthew Motion Sensor Trials 93) et ont demandé qu'on leur envoie une copie des rapports qui en découlent.

Le forum fut admirablement orchestré et nos hôtes, International Subsea Mapping, ont fait honneur à la France de par leur savoir faire et leur hospitalité hors pair. Le site de la conférence était on ne peut mieux choisi et les locaux dans lesquels ont eu lieu les communications, parfaitement adaptés à ce type d'activités.

LISTE DES PARTICIPANTS DU FORUM FEMME 93

**Company**

Blom A/S  
 C & C TECHNOLOGIES  
 CHS, Institut Maurice Lamontagne  
 CSIC  
 SHOM  
 SHOM  
 FFI/U , KJV  
 GENAVIR  
 GENAVIR  
 Geoconsult, A/S  
 Geoconsult, A/S  
 Geomatic A/S  
 Geomatic A/S  
 Geoteam AS  
 Geoteam AS  
 Geoteam UK Ltd.  
 IFREMER Centre de Brest  
 IFREMER Centre de Brest  
 IFREMER Centre de Brest  
 International Subsea Mapping, ISM  
 International Subsea Mapping, ISM  
 International Subsea Mapping, ISM  
 International Subsea Mapping, ISM  
 International Subsea Mapping, ISM  
 International Subsea Mapping, ISM  
 N.E.R.C. Research Vessels Services  
 Naval Oceanographic Office  
 Naval Oceanographic Office  
 NRL Naval Research Lab  
 NRL Naval Research Lab  
 NRL Naval Research Lab  
 Rijkswaterstaat , Directie Zeeland  
 Rijkswaterstaat , Directie Zeeland  
 SAUDI ARAMCO  
 Statens Kartverk, Norges Sjøkartverk  
 Statens Kartverk, Norges Sjøkartverk  
 Stolt-Comex Seaway A/S  
 University of New Brunswick  
 Worldwide Ocean Surveying Ltd.  
 CRM, Compagnie Radio Maritime  
 Radio-Holland Marine  
 Simrad Inc.  
 Simrad Mesotech Systems Ltd.  
 Simrad Osprey Ltd.  
 Simrad Subsea A/S  
 Simrad Subsea A/S  
 Simrad Subsea A/S  
 Simrad Subsea A/S  
 Simrad Subsea A/S  
 Simrad Subsea A/S  
 Simrad Subsea A/S

**Participants**

Bjørn Brandtzæg  
 Pete Alleman  
 Andre Godin  
 Marcel.Li Farran  
 Helene Tonchia  
 Daniel Gueuel  
 Rolf Kristensen  
 J.P. Allenou  
 Mr. Lessouarme  
 Hans M. Gravdal  
 Arvid Pettersen  
 Tore Sannes  
 Tom R. Grovassbakk  
 Kjell Martin Dukefoss  
 Roger Wiik  
 Andrew Morse,  
 Christian Edy  
 Jean-Marie Augustin  
 Xavier Lurton  
 Roger Amar  
 C. Musellec  
 L. Vigier  
 T. Sculler  
 Y. Durand  
 G. Herrouin  
 Edward B. Cooper  
 Terry Duveilh  
 Barbara Reed  
 Christian de Moustier  
 Maria T. Kalcic  
 Joan Gardner  
 Frans M. Mol  
 A.P.M. Pieters  
 Claus Fjord Christensen  
 Egil Sølvberg  
 Kjell Olsen  
 Oddvar Misund  
 John Hughes Clarke  
 Stuart Evans  
 Marcel Ninauve  
 Rein de Koning  
 Regi Chikar  
 John Gillis  
 David Wilson  
 Freddy Pøhner  
 Øyvind Espeland  
 Morten Jacobsen  
 Erik Hammerstad  
 Stein Åsheim  
 Jan Haug Kristensen  
 Bjørn Høyum Larsen

LISTE DES ÉCHOSONDEURS MULTIFAISCEAUX SIMRAD  
EN OPÉRATION DANS LE MONDE

## REFERENCE LIST

MULTIBEAM ECHO SOUNDER SYSTEMS

AUGUST 1993

| System           | Vessel                            | Owner                                                 | Country     | Inst    |
|------------------|-----------------------------------|-------------------------------------------------------|-------------|---------|
| EM 100           | "SIMRAD"                          | Simrad Subsea A/S                                     | Norway      | 1985    |
| EM 100           | "SIMSON ECHO"                     | Simrad Subsea A/S                                     | Norway      | 1986    |
| EM 1000          | "SIMRAD"                          | Simrad Subsea A/S                                     | Norway      | 1991    |
| EM 100           | "GEOFJORD"                        | Norwegian<br>Hydrographic Service                     | Norway      | 1986    |
| EM 100           | "LANCE"                           | Norwegian<br>Hydrographic Service                     | Norway      | 1987    |
| EM 100           | "GEOGRAPH"                        | AS Geoconsult                                         | Norway      | 1987    |
| EM 100           | "BERGEN<br>SURVEYOR"              | Stolt-Nielsen<br>Seaway                               | Norway      | 1988    |
| EM 100           | "NN"                              | Canandian<br>Hydrographic Service                     | Canada      | 1989    |
| EM 100           | "CHR.BRUNINGS"                    | Rijkswaterstaat                                       | Netherlands | 1989    |
| EM 100           | Div.U                             | Norw. Defence<br>Research Estblm.                     | Norway      | 1989    |
| EM 12 Dual       | "L'ATALANTE"                      | IFREMER                                               | France      | 1990    |
| EM 12<br>EM 100  | "OCEAN<br>SURVEYOR"               | Worldwide Ocean<br>Surveying Ltd.                     | England     | 1990    |
| EM 100           | "JOHN<br>McDONNELL"<br>(T-AGS 51) | US Naval<br>Oceanographic<br>Office                   | USA         | 1990/91 |
| EM 100           | "LITTLE-<br>HALES"<br>(T-AGS 52)  | US Naval<br>Oceanographic<br>Office                   | USA         | 1990/91 |
| EM 12<br>EM 1000 | "HESPERIDES"                      | Consejo Superior<br>de Investigaciones<br>Cientificas | Spain       | 1990/91 |
| EM 100           | "MATHEW"                          | Canadian Hydrografic<br>Service                       | Canada      | 1990    |

Cont'd overleaf

| System                | Vessel                  | Owner                                        | Country      | Inst.   |
|-----------------------|-------------------------|----------------------------------------------|--------------|---------|
| EM 100                | "DOLPHIN"               | Canadian Hydrografoc Service                 | Canada       | 1990    |
| EM 100                | "PETER KOTTISOV"        | Hydrographic Office St. Petersburg           | Russia       | 1990    |
| EM 1000               | "CREED"                 | Canadian Hydrografic Service                 | Canada       | 1991    |
| EM 1000               | "LE SUROIT"             | IFREMER                                      | France       | 1991    |
| EM 12<br>EM 1000      | "JEAN CHARCOT"          | LD Canoecean                                 | France       | 1991/92 |
| EM 1000               | "GEOGRAPH"              | AS Geoconsult                                | Norway       | 1991    |
| EM 1000               | "GEOMASTER"             | AS Geoconsult                                | Norway       | 1992    |
| EM 121<br>(1° SYSTEM) | "ZEUS"                  | US Navy                                      | USA          | 1993    |
| EM 1000               | "GEO SURVEYOR"          | Geoteam Ltd.                                 | UK           | 1992    |
| EM 12 Dual            | "L'ESPERANCE"           | S.H.O.M. *                                   | France       | 1992    |
| EM 12                 | "CHARLES DARWIN"        | N.E.R.C. **                                  | UK           | 1993    |
| EM 950                | "PORTABLE"              | C & C Technolgies                            | USA          | 1993    |
| EM 1000               | "RAVELLO"               | Diamar                                       | ITALY        | 1993    |
| EM 1000               | "KARAN 8"               | ARAMCO                                       | Saudi Arabia | 1994    |
| EM 121<br>(1° SYSTEM) | "PATHFINDER" (T-AGS 60) | US Navy                                      | USA          | 1994    |
| EM 950                | "WIJTVLIET"             | Rijkswaterstaat, Zeeland                     | Netherlands  | 1993    |
| EM 950                | "HYLSFJORD"             | Blom A/S                                     | Norway       | 1993    |
| EM 1000               | "GEO SCANNER"           | Geoteam                                      | Norway       | 1993    |
| EM 12Dual<br>EM 1000  | "N.N"                   | Ministry of Transportation and Communication | Taiwan ROC   | 1994/5  |
| EM 950                | "OCTANS"                | Rijkswaterstaat, Noordzee                    | Netherland   | 1993    |

\* Service Hydrographique et Oceanographique de la Marine

\*\* National Environment Research Council

PROGRAMME DU FORUM FEMME 93

## **FEMME 93, FORUM FOR EM MUTUAL EXPERIENCE**

**Paris, France, September 15-17 1993**

### **HOTEL**

Le MERIDIEN Paris Etoile  
81, boulevard Gouvion-Saint-Cyr  
75848 Paris Cedex 17  
Telephone: +33-1-40 68 34 34  
Telefax: +33-1-40 68 31 31  
Telex: 651 952 F

The location of the hotel, relative to the conference venue and the Air France Terminal, is shown on the attached sketch.

Room reservations have been confirmed for all participants who have returned Formal Registration form. The hotel shall endeavour to allow early check-in (12:00 - 13:00 hrs.) for as many guests as possible (for those arriving Wednesday morning).

All rooms are double rooms, no extra charge will be made for those participants wishing to bring their spouse. Special conference room rate FFR 950, excl. meals.

Each guest should settle payment for room and other expenses at check-out time.

### **CONFERENCE VENUE**

Building next to Louis Dreyfus building. Approx. 5 minutes walk from hotel MERIDIEN or from Air France Terminal, see attached sketch. Address:

83, Avenue de la Grande Armee  
75016 PARIS

### **MEALS**

Lunch (Thursday/Friday) and coffee breaks at especially favourable prices in cafeteria/restaurant in Louis Dreyfus building, next to the conference venue (connection by corridor).

Conference Dinner Wednesday night in the hotel, courtesy of Simrad.

### **CONFERENCE PROGRAM**

The conference will open Wednesday at 14:00 hrs. and close Friday at approx. 13:30 hrs. The program will look much like the Tentative Program distributed with the invitation, - but with some additional topics.

The final program will be distributed before the opening session.

For those participants giving presentations: overhead and slide projectors, a video machine and whiteboard/flipover will be available.

FEMME 93

**Tentative time schedule and programme**

-----  
**Wednesday, 15. sept.**

**Session no.1: Shallow Water Mapping**

Chairman: Freddy Pøhner

- 14.00 Welcome remarks F.Pohner Simrad
- 14.15 Shallow water hydrography using EM 950  
on a small launch.  
C&C Technologies
- 14.40 Test of EM 1000 for shallow water applications  
Frans Mol, Rijkswaterstaat
- 15.20 Experience with EM 100/Dolphin system in shallow  
water survey  
Maria Kalcic, NRL
- 16.00 \*\*\* Coffee break \*\*\*

Chairman: Morten Jacobsen

- 16.40 Preliminary Results of Technical Evaluation of  
EM 100 on the USNS McDonnell and USNS Littlehales.  
Barbara Reed, Navoceano
- 17.15 Installation of EM 1000 on a SWATH Vessel  
Andre Godin, CHS
- 17.45 Open discussion
- 19.00 \*\* COCKTAILS \*\* (In hotel)
- 20.00 \*\* CONFERENCE DINNER \*\*

**Thursday, 16. sept**

**Session 2: Error Sources, Mapping Accuracy**

Chairman: Øyvind Espeland

- 09.00 Error Propagation Model for Multibeam Systems  
F. Pöhner, Simrad
- 09.30 Comparison of the Accuracy achieved with the EM 1000  
on the SWATH vessel Creed to the IHO standard.  
Andre Godin, CHS
- 10.00 Experience from multibeam mapping with EM 1000 and  
methods to reduce errors.  
Kjell Dukefoss, Geoteam A/S
- 10.30 \*\*\* Coffee break \*\*\*  
Chairman: Erik Hammerstad
- 11.15 Signal and data processing in Simrad multibeam  
echosounders.  
Erik Hammerstad, Simrad
- 12.00 Field testing of EM 12 dual for "l'Esperance".  
Helene Tonchia, EPSHOM.
- 12.45 Experiments and data processing for acoustic  
seafloor investigations.  
John Hughes Clarke, University New Brunswick
- 13.20 Discussion
- 13.45 \*\*\* Lunch \*\*\*

**Session 3: Data Processing**

Chairman: Stein Åsheim

- 15.00 Processing of bathymetric and imagery data.  
Stein Aasheim, Simrad
- 15.30 Software for bathymetric data processing.  
Christian Edy, IFREMER
- 16.00 \*\*\* Coffee break \*\*\*

**Session 3, continuation**

Chairman: Jan H. Kristensen

- 16.40      Software for acoustic imagery.  
            Jean Marie Agustin, IFREMER
- 17.10      New features in IRAP terrain modeling software.  
            Tore Sannes, Geomatic
- 17.40      ESMAC: A nordic research programme for seafloor  
            characterization and classification.  
            Jan H. Kristensen, Simrad
- 18.10      Discussion

Demonstration of workstation software during breaks and after the presentations are finished.

**Friday, 17. sept****Session 4: Research Vessels**

Chairman: Bjørn Høyem Larsen

- 09.00      Antarctic Experience from R/V HESPERIDES.  
            Jose I. Diaz, CSIC
- 09.45      SE-ME-WE-2: A large cable route survey  
            M. Scuiller, LD Canoecean
- 10.30      \*\*\* Coffee Break \*\*\*
- 11.15      Upgrading the "Charles Darwin" with multibeam  
            mapping capability. New scientific challenges.  
            Ken Robertson, NERC
- 12.00      EM 121, a 1 degree multibeam system for high  
            resolution mapping in deep waters.  
            Erik Hammerstad, Simrad
- 12.30      Integrated system for Hydrographic Office, Taiwan  
            Bjørn Høyem Larsen
- 13.00      Discussion
- 13.30      Conference closing
- 13.45      \*\*\* Lunch \*\*\*

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**SIMRAD MULTIBEAM USER CONFERENCE**

**PROCEEDINGS**

**Shallow water hydrography using EM 950 on a small launch**

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**Model for calculation of uncertainty in multibeam depth soundings**

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**Field testing of EM 12 Dual for "l'Esperance"**

H. Tonchia, EPSHOM

**Experiments and data processing for acoustic seafloor investigations**

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**New features in IRAP terrain modeling software**

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**ESMAC, a Nordic research programme for environmental mapping and characterization of the seafloor**

Jan H. Kristensen and Freddy Pøhner, Simrad Subsea A/S

**Antarctic experience from R/V HESPERIDES**

Jose Ignacio Diaz, Consejo Superior de Investigaciones Cientificas

**SEAMEWE 2, a large cable route survey**

M. Scuiller, ISM

**Upgrading the "RRS CHARLES DARWIN" with multibeam mapping capability.  
New scientific challenges**

Ed Cooper, National Environment Research Council

**EM 121, a 1 degree multibeam system for high resolution mapping in deep waters**

Erik Hammerstad, Simrad Subsea A/S

**Canadian Hydrographic Service EM activities**

A. Godin, CHS

**SIMRAD MULTIBEAM USER CONFERENCE**

Shallow water hydrography using EM 950 on a small launch

Pete Alleman, C&C Technologies INC.

# New-Generation Mapper for Shallow Water Hydrography

## ***New Coastal, Inland Water Imaging System Promises Significant Increases in Productivity with Virtual Real-Time Map Production***

**By Peter J. Alleman**  
*Senior Systems Engineer*

1 nas S. Chance  
President

and

**Art A. Kleiner**  
Project Manager,  
Hydrographic Systems  
C & C Technologies Inc.



Semicircular transducer—here mounted on the bow of C & C Technologies' launch—contains 128 staves for wide-swath imaging from 3 to 300 meters depth. At left, Lake Peigneur as shown in this wiremesh imagery measured a maximum 3 meters depth. After a drill rig punched through the bottom, maximum depths reached 42 meters. Note the incredible erosion that resulted when lake water rushed into the cavernous mine and the spikes created by submerged trees in the subsided area.

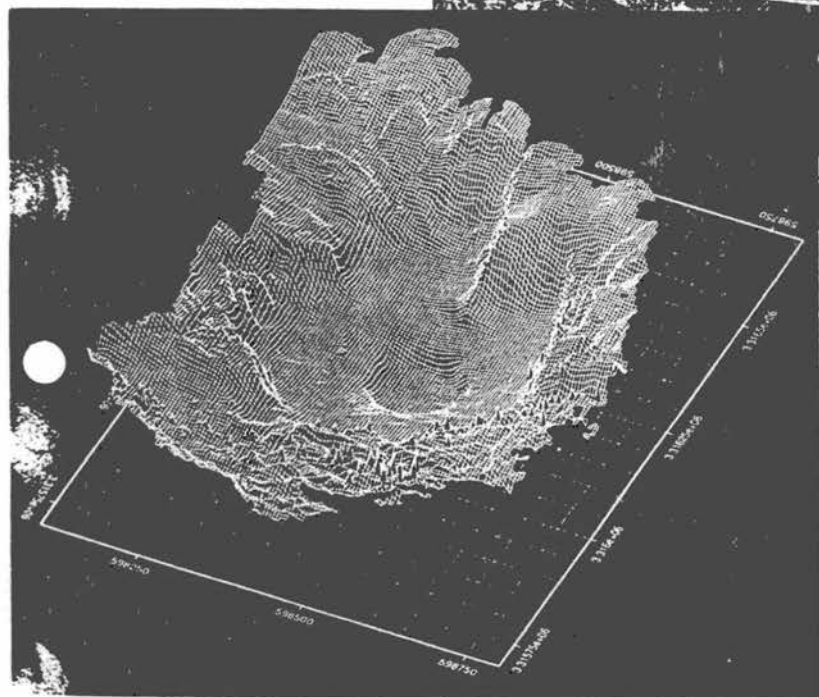
Bend Revetment on the Mississippi River near Carville, Louisiana.

The results were impressive.

Travelling a safe distance from shore, out of the eddies and currents that paralleled the riverbank, data were collected in an ultrawide swath all the way to the top of the revetment. Here was total bottom coverage bathymetry and side-scan imagery, generated by C & C software, of a revetment in its entirety—from water's edge to toe.

However "historical," the event was not without problems.

In shallower areas, where depths



In response to recent maritime disasters and the need to update inadequate coastal charts, Jim and Thomas Chance—formerly of John E. Chance & Associates Inc.—founded C & C Technologies Inc. last July to provide multidisciplinary hydrographic survey services using a high frequency multibeam survey system: Simrad's EM-950 multibeam bathymetric

try and imagery system.

Early in 1993, Lafayette, Louisiana-based C & C received shipment of its first EM-950 bathymetry system installed on a 26-foot aluminum survey launch. To that date, no one had integrated a multibeam system with a vessel of this size. Towed on a trailer by a standard pickup truck, the boat was first dispatched to the New River

below the transducer reached 5 meters or less, "timeouts" or "holidays" occurred. These interruptions lasted for periods of several seconds, limiting data coverage in those areas. Additionally, roll errors were evident in the data mosaics.

Easily discernable in data post-processing by the "sun shading technique," they were aggravated by the EM-950's ultrawide swath width.

C & C, in constant communication with the engineers at Simrad during these trials, remedied the problem by installing new versions of firmware and software. In addition, TSS (U.K.) Ltd. (Weston-on-the-Green, U.K.) rushed over their newest vertical reference unit (VRU), along with a developmental engineer.

This VRU, the model 335-B, employs an analog sampling rate of 85 Hz and is well designed for small vessel shallow water multibeam bathymetry.

#### Lake Peigneur Test Site

The next test site chosen was Lake Peigneur. Only a 20-minute drive from Lafayette near Delcambre, Louisiana, this was the location of a nationally renowned disaster on November 20, 1980, when a drilling rig punctured a salt mine beneath it. Measuring only 1-1/2 square miles in size, the lake was completely drained in a matter of a few hours. Two drilling rigs, one tugboat, and eleven barges were consumed in a gigantic whirlpool. Remarkably, no one was killed.

Remains of a gigantic sinkhole are evidenced in a "wiremesh" 3D picture imaged by the EM-950.

Results of software upgrades at this site demonstrated improvements. Minimum operational depths prior to data interruptions were reduced to the 3.5-meter range. During the test, the boat was subjected to severe roll angles, measuring at up to 12°. This extreme amount of roll, combined with the 26-foot vessel's rapid roll period of 2.3 seconds, produced unmeasurable error on the inner beams, up to a maximum error of 0.5° at the outer edges of the swath, well within expected tolerances.

We worked in conjunction with Simrad and TSS to achieve further improvements. A final upgrade of EM-950 software was available at the next test site—Southwest Pass—a narrow opening where the Vermilion Bay empties into the Gulf of Mexico. Here, tremendous currents abound,

creating shear ridges that rise from 100 to 10 feet in depth. Minimum timeout depths were reduced to the sub-meter level and exceeded expectations.

Further VRU revisions that implement a quadratic predictor to further enhance the 335-B performance have since been developed by TSS; further tests are scheduled.

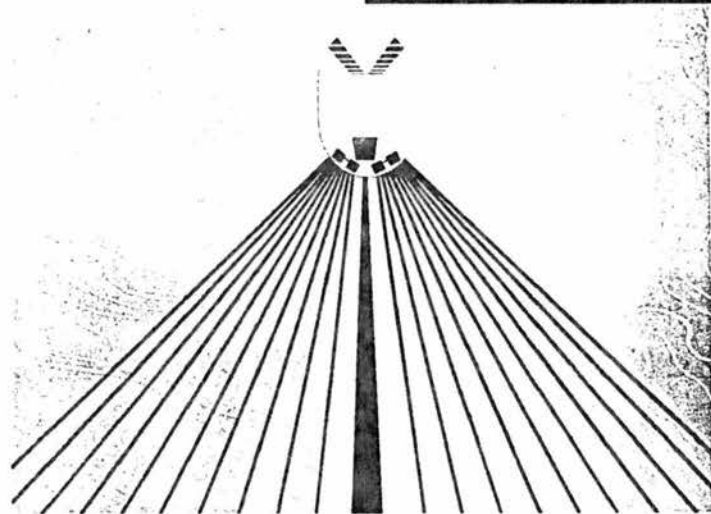
About half of the multibeam bathymetry systems available today use a towed fish. While there are advantages to this type of application, such

as potential reduction in heave, the benefit does not outweigh the risk. It is for this reason that we decided against it.

Implementation of a towed system requires that heading, tow depth, heave, pitch, and roll of the sensor be determined in the fish. This results in added electronics in the water—not an attractive feature. Additionally, the requisite inclusion of winches, cables, and supplementary instrumentation and equipment increases complexity and mobilization costs.

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Towed fish are also subject to stringent minimum depth limitations, resulting in reduced swath coverage and increasing the likelihood of debris entanglement. Also, inland and coastal water currents can wreak havoc on a survey tow.

#### Bottom Detect Method

The 95-kHz Simrad EM-950 achieves accurate ultrawide swaths (up to 7.4 times water depth) at greater data densities than other currently available systems. It does this

by employing a hybrid of amplitude and interferometry. Though both methods, performed independently on all return echoes, produce quality measurements, weighted preference is given to the more accurate phase detection method. The detection method, not dependent upon history, may adapt instantly to changing bottom topography.

Operating depths range from 2 to 300 meters below the transducer, accurate to the greater of 0.3 percent of water depth or 15 centimeters

throughout the swath.

The majority of multibeam systems that operate on the phased array principle use only amplitude detection to calculate travel time of each corresponding sound pulse. Unfortunately, as the angle of incidence to the seabed increases, each echo becomes so smeared in time that accurate amplitude detection is impossible. This condition is exaggerated as the bottom slopes away from the echosounder or exhibits any grade in the along-track direction.

Some side-scan systems derive a depth measurement through phase detection utilizing the interferometric principle. However, this only works when the angle of incidence with the bottom is quite large or the seabed is relatively flat.

Hydrographers, experienced with multibeam echosounders, are familiar with the problems created by variations in near-surface sound velocity. Simrad addressed this problem with the introduction of a unique transducer, semi-circular in shape, that ensures that all beams are transmitted and received at 90° angles to its face. This advancement, coupled with real-time surface velocity corrections, ensures virtually no effect on the data by near-surface velocity variations.

The EM-950 transmits 60 beams, interlaced at up to four times per second, resulting in 120 beams across the total swath. This high ping rate is partially the result of beamforming on receive only. This directly translates into greater data density, which results in higher confidence in data reduction.

Conversely, beamforming on transmission requires lengthy computer calculations used to define a transmission beam relative to the vessel platform.

The development of a single transducer has additional merit over using a set of transducers; it eliminates the demand for a time-consuming, error-prone calibration procedure that burdens multibeam systems.

At the request of C & C Technologies, Simrad developed three software packages that enable the EM-950 to scan in a 190° sector up to the water's edge. This was accomplished quite easily since beamforming is done exclusively through software on receive only. Port and starboard "bank modes" each scan up to the water's edge on their respective sides while concurrently covering 3.7 times

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the water depth on one side at a time. The "channel mode" scans the full 190° sector to the water's edge in both the port and starboard directions.

Another attribute of the EM-950, which we deemed attractive, is its incorporation of an "equidistant beam spacing" mode. This provides an even distribution of soundings across the entire swath, increasing productivity and economy. Other multibeam bathymetry systems are forced to compromise a fixed angular separation between the fan beams. This creates an uneven distribution of soundings, characterized by an excessively high density beneath the vessel and gradually decreasing to an extremely sparse distribution at the swath's outer edges.

It also promotes inconsistency in data reduction and reduces productivity by increasing the percentage of swath overlap required between survey lines.

#### Virtue in Sonar Imaging

Another virtue, setting the EM-950 apart from other multibeam systems, is its sonar capability. Traditional sonars assume a flat bottom when calculating across-track distances and backscatter strength, which

can produce gross errors. Collocated sonar imagery produced by the EM-950 is spatially precise and not distorted by bottom topography. By measuring the calibrated backscatter values in decibels, geometrically correct sonar data are produced in real time.

Most multibeam bathymetry systems do very little to account for the effects of ray bending on the sounding echoes. Simrad addresses this by incorporating the ability for an operator to download a velocity profile directly into the EM-950 operator unit prior to data collection. This can be accomplished through manual input, by RS-232, or by Ethernet™ interface.

Processing hardware consists of a Sun Systems Sparc workstation No. 10 with 2.5-gigabyte hard drive and 64 megabytes of RAM, expandable to 512 Mb. Data storage options are Exabyte or DAT tape.

In-house software, developed by the engineers at C & C Technologies, is used for data collection, presentation, and processing. A color-coded bathymetry waterfall display is presented in real-time data as each survey swath is gathered. Also displayed on

the multitasking workstation in real time is a swath coverage map of the entire survey area, color-coded for depth. This coverage map incorporates pan and zoom features for either detailed or widespread representations. All menus are user-friendly "point and click" options written in the UNIX® X-Windows/Motif environment.

The bulk of all data processing is done in real time during the collection process. Minimal time is demanded for data post-processing due to the speed of C & C software coupled with the precision of EM-950 signal processing. This provides the operator with the option of displaying raw bathymetry and sonar data in real time or processing and buffering "on the fly" prior to visual display.

#### All the Way to the Edge

The EM-950's ability to produce total swath bathymetry all the way up to water's edge promises unsurpassed improvements in the area of speed, cost, and quality. Addition of geometrically correct, collocated, side-scan imagery improves the detection of suspected embankment failures.

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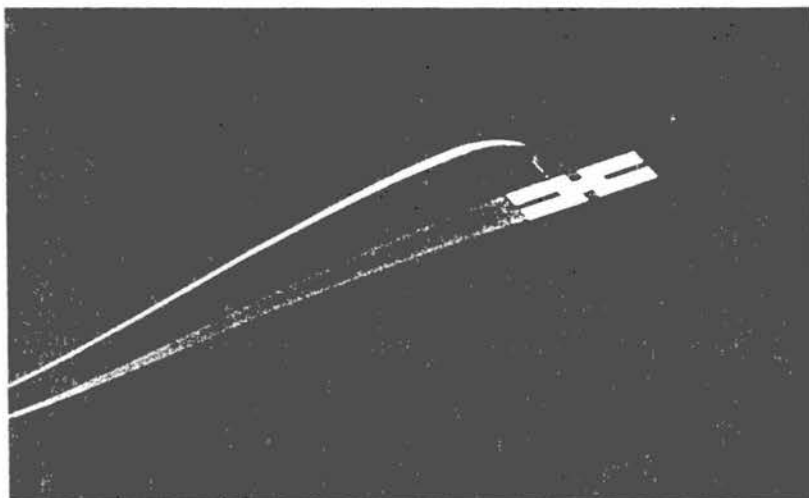
Coastal hydrography is another application where this system will outperform the present-day generation of multibeam echosounders. As detailed by Dr. L. Meyers in a paper given at the Canadian Hydrographic Conference, this system has been successfully utilized at speeds of up to 16 knots by the University of New Brunswick, Canada. This will prove invaluable for cost reduction and efficiency if nations are to develop their Exclusive Economic Zones (EEZs).

**"EM-950's ability to produce total swath bathymetry all the way up to the water's edge promises unsurpassed improvements in the areas of speed, cost, and quality."**

Addressing the need for coastal hydrography, a 40-foot survey launch is currently in production by C & C. This vessel will incorporate a keel-mounted transducer and active roll stabilization.

The perfect tool now exists for submarine cable route surveys. Coastal

hydrographic operations are burdened with velocity changes created by temperature and salinity variations that surround each land mass. These variations produce profound ill effects on data derived by sonar and bathymetric systems employing typical technology. If the goals of cable route surveys are to be achieved, which include the recognition of unfavorable seafloor topography, this fact must be addressed. The EM-950's ability to produce precise collocated bathymetry and sonar imagery, under these conditions, will prove invaluable. /st/



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*Peter J. Alleman—formerly lead UNIX /"C" systems engineer at John E. Chance & Associates—was the primary software developer for the [TAMU] swath bathymetry and imagery system, HI-MAP and DeepTow projects. He has more than 10 years' experience in computer hardware and software integration and holds a bachelor of science degree in physics with honors.*



*Thomas S. Chance formerly was senior vice president of John E. Chance & Associates before he formed C & C Technologies with his brother, Jim. Thomas is well respected in the hydrographic surveying community for his knowledge of and involvement with state-of-the-art multibeam bathymetry and imagery as well as GPS technology. He has a master of science in geodetic surveying, a master of science in industrial management, and a bachelor of science in electrical engineering.*



*Art A. Kleiner was previously the geophysical party-chief for John E. Chance & Associates' HI-MAP project. He has more than 17 years of experience in hydrographic surveying and holds a bachelor of science degree in business administration.*



**SIMRAD MULTIBEAM USER CONFERENCE**

Model for calculation of uncertainty in multibeam depth soundings

Freddy Pøhner, Simrad Subsea A/S

Date: 93.09.09/FP

## Model for calculation of uncertainty in multibeam depth soundings

### 1. Statement of problem

While all echosounders produce soundings with some inherent uncertainty, multibeam echosounders are more sensitive to errors and misalignments of external sensors. For the quality control of hydrographic mapping, it is of considerable interest to understand the influence of the different error sources that contribute. This is important for the actual survey operation, but also to calculate the uncertainty of the soundings which are stored as the end product in the hydrographic database.

We shall assume that all errors have a normal distribution, and can be characterized by the associated standard deviation number. We shall also assume that all error sources act independently.

### 2. Error model

According to what has been stated above, if the depth error is given by

$$E = E_1 + E_2 + \dots + E_n$$

Then the associated standard deviation of the error is found by vector summation of the individual standard deviations

$$S = \text{SQRT}(S_1^2 + S_2^2 + \dots + S_n^2)$$

#### 2.1 The different error contributions

The different error contributions are:

1. Echo sounder system error
2. Positioning system error
3. Time synchronization error
4. Tide measurement error
5. Transducer depth measurement error
6. Heave measurement error
7. Roll measurement error
8. Pitch measurement error
9. Sound velocity measurement error
10. Course measurement error
11. Surface sound velocity measurement error

### 2.1.1 Echo sounder system error

This is the inherent uncertainty of the multibeam echosounder system, provided that no external sensors contribute with any error. It is different for the different models, and dependent upon the following parameters:

I - Instrument model: 1=EM100, 2=EM1000, 3=EM12  
M - operation mode of sounder  
D - depth of water  
 $\alpha$  - Beam angle relative to vertical  
Dt - Detector type used: 1=amplitude 2=phase  
S - Slope angle of seabed terrain

The following calculation model is proposed:

If Detector type=amplitude:

$$S_{11}=dR$$

$$S_{12}=K1 D \tan(\alpha) \tan(TBW) \tan(S)$$

$$S_{13}=K1 D \tan(\alpha) \tan(RBW)$$

Where D=water depth  
S=Bottom slope  
 $\alpha$ =beam angle rel vertical  
TBW=Transmit beamwidth  
RBW=Receive beamwidth  
dR, K1 are echo sounder related parameters

If Detector type =phase:

$$S_{11}=D \tan(\alpha) \tan(df_i)$$

$$S_{12}=K2 D \tan(\alpha) \tan(TBW) \tan(S)$$

In these equations K2 is an empirical echo sounder related constant, while  $df_i$  is the angular uncertainty of the sounding.

Since phase values over a variable number of range samples are used for the estimation of angle within the beam, dfi is reduced when the number of samples increases (further out in the swath). A reasonable calculation model is:

$$n = D \cdot \frac{\tan(\alpha) \cdot \tan(RBW)}{\cos(\alpha) \Delta R}$$

$$dfi = K2 \cdot \frac{RBW}{\sqrt{n}}$$

when  $\Delta R$  is the range sampling resolution of the sounder. To calculate overall uncertainty of the instrument for a specific sounding, calculate

$$S_1 = \sqrt{S_{11}^2 + S_{12}^2 + S_{13}^2}$$

Proposed values for the different sounders:

EM100:      TBW=3°  
               RBW=3° for narrow and wide, 6° for Ultrawide mode  
               dR =max(0.15m or 0.3% of depth)  
               K1 =0.5  
               K2 =0.5

EM1000:     TBW=3°  
               RBW=3°  
               dR =max(0.1m or 0.15% of depth)  
               K1 =0.3  
               K2 =0.3

EM12:        TBW=1.7°  
               RBW=3.5°  
               dR =max(0.4m or 0.1% of depth)  
               K1 =0.3  
               K2 =0.3

### **2.1.2 Positioning system error**

For a certain error in positioning  $E_p$ , the corresponding depth error is

$$E_2 = E_p * \tan(S)$$

when  $S$  = slope angle of seabed. The corresponding standard deviation is

$$S_2 = S_p * \tan(S)$$

### **2.1.3 Time synchronization error**

It is necessary that the depth data from the echosounder is registered in time with the same clock as the position data, so that the 2 data streams can be merged in a correct manner. If there is a delay in the positioning calculations, such that the position fixes are valid not at the instant of time stamping, but at a somewhat earlier instant, then this must be corrected for.

An error in the timing results in a position error, according to the speed of the vessel. This will give a depth error depending upon the local slope angle of the seabed, in the same manner as for other position errors.

$$E_3 = E_{\text{timing}} * \text{Speed} * \tan(S)$$
$$S_3 = S_{\text{timing}} * \text{Speed} * \tan(S)$$

### **2.1.4 Tide measurement error**

The tide measurement error is directly influencing the depth soundings:

$$E_4 = E_{\text{tide}}$$
$$S_4 = S_{\text{tide}}$$

### **2.1.5 Transducer depth measurement error**

This error also includes error caused by draught changes because of fuel consumption etc:

$$E_5 = E_{\text{td}}$$
$$S_5 = S_{\text{td}}$$

### 2.1.6 Heave measurement error

This error is dependant upon the weather conditions, the instrument type used, the dominant period of the waves, as well as changes of ship course. In most cases it is relevant to use the manufacturers statement for accuracy. The error is then

$$E6=Eh$$

$$S6=Sh$$

### 2.1.7 Roll measurement error

As with heave, this error will vary with weather conditions, instrument type, dominant wave periods, and changes of ship course. The roll sensor error will influence the depth soundings according to the following equation:

$$E7=X * \tan(Er)$$

$$S7=X * \tan(Sr)$$

when X is the crosstrack distance of the sounding. Because this error contribution becomes very significant when the swath width increases, it is seen as relevant to apply a better model than just the accuracy number given by the manufacturer. For the Hippy 120 series, the following model is proposed:

$$Er= Ea+Eb+Ec+Ed$$

Ea= Error of alignment and roll sensor calibration

Eb= Basic instrument noise, approx level: Sb= 0.05 deg

Ec= Transient error caused by significant course changes when changing to a new survey line. Hippy 120 will reduce the generated error with a time constant of 120 seconds.

Simple model:

$$Ec=2.0 - T/7.5 \text{ when } T(\text{time since course change}) < 15\text{min}$$

Ed= Varying error, caused by horizontal accelerations due to variations in course of vessel, and/or waves.

Typical level is 0.05 to 0.3 degrees. Simple model:

$$Sd=0.2 * (1-SQ) + 0.03 * Wh$$

when SQ=Steering Quality, in scale 0(bad) to 1(very good), and Wh= typical wave height

The calculation of overall std deviation of roll, Sr, becomes

$$Sr=\text{SQRT}(Sa^{**2} + Sb^{**2} + Sc^{**2} + Sd^{**2})$$

### 2.1.8 Pitch measurement error

The pitch measurement error is governed by the same factors that determine the roll measurement error. The effect of a pitch error is however less grave, since it will lead to a positioning error of the soundings rather than change the sounding values.

$$\begin{aligned}E8 &= D * \tan(Epi) * \tan(S) \\ D8 &= D * \tan(Dpi) * \tan(S)\end{aligned}$$

The calculation of Epi and Spi are as for the roll, except than alignment and calibration term may have a different value.

### 2.1.9 Sound velocity measurement error

The sound velocity profiling instrument has a limited accuracy, and the sound velocity structure in the water may change to a higher or lesser degree throughout the survey. The basis for a calculation is then that the profile is known only with a limited accuracy, represented by Ss - standard deviation of sound velocity information.

Using  $c(d)$  for sound velocity as function of depth, and  $\alpha$  for a beam's angle with the vertical, the depth of a slant sounding is given by

$$D = \int_0^T c(d) \cos(\alpha) dt$$

Its relative position is

$$X = \int_0^T c(d) \sin(\alpha) dt$$

The beam angle varies according to:

$$\sin(\alpha) = \frac{c(d)}{c_0} \sin(\alpha_0)$$

A small error in the sound velocity profile will have an effect which can be calculated by partial differentiation:

$$E_9 = \int_0^T \Delta c \frac{\partial}{\partial c} c(d) \cos(\alpha) dt + \tan(S) \int_0^T \Delta c \frac{\partial}{\partial c} c(d) \sin(\alpha) dt$$

### 2.1.6 Heave measurement error

This error is dependant upon the weather conditions, the instrument type used, the dominant period of the waves, as well as changes of ship course. In most cases it is relevant to use the manufacturers statement for accuracy. The error is then

$$E6=Eh$$

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$$E7=X * \tan(Er)$$

$$S7=X * \tan(Sr)$$

when X is the crosstrack distance of the sounding. Because this error contribution becomes very significant when the swath width increases, it is seen as relevant to apply a better model than just the accuracy number given by the manufacturer. For the Hippy 120 series, the following model is proposed:

$$Er= Ea+Eb+Ec+Ed$$

Ea= Error of alignment and roll sensor calibration

Eb= Basic instrument noise, approx level: Sb= 0.05 deg

Ec= Transient error caused by significant course changes when changing to a new survey line. Hippy 120 will reduce the generated error with a time constant of 120 seconds.

Simple model:

$$Ec=2.0 - T/7.5 \text{ when } T(\text{time since course change}) < 15\text{min}$$

Ed= Varying error, caused by horizontal accelerations due to variations in course of vessel, and/or waves.

Typical level is 0.05 to 0.3 degrees. Simple model:

$$Sd=0.2 * (1-SQ) + 0.03 * Wh$$

when SQ=Steering Quality, in scale 0(bad) to 1(very good), and Wh= typical wave height

The calculation of overall std deviation of roll, Sr, becomes

$$Sr=\text{SQRT}(Sa^{**2} + Sb^{**2} + Sc^{**2} + Sd^{**2})$$

### 2.1.8 Pitch measurement error

The pitch measurement error is governed by the same factors that determine the roll measurement error. The effect of a pitch error is however less grave, since it will lead to a positioning error of the soundings rather than change the sounding values.

$$\begin{aligned}E8 &= D * \tan(Epi) * \tan(S) \\ D8 &= D * \tan(Dpi) * \tan(S)\end{aligned}$$

The calculation of Epi and Spi are as for the roll, except than alignment and calibration term may have a different value.

### 2.1.9 Sound velocity measurement error

The sound velocity profiling instrument has a limited accuracy, and the sound velocity structure in the water may change to a higher or lesser degree throughout the survey. The basis for a calculation is then that the profile is known only with a limited accuracy, represented by Ss - standard deviation of sound velocity information.

Using  $c(d)$  for sound velocity as function of depth, and  $\alpha$  for a beam's angle with the vertical, the depth of a slant sounding is given by

$$D = \int_0^T c(d) \cos(\alpha) dt$$

Its relative position is

$$X = \int_0^T c(d) \sin(\alpha) dt$$

The beam angle varies according to:

$$\sin(\alpha) = \frac{c(d)}{c_0} \sin(\alpha_0)$$

A small error in the sound velocity profile will have an effect which can be calculated by partial differentiation:

$$E_9 = \int_0^T \Delta c \frac{\partial}{\partial c} c(d) \cos(\alpha) dt + \tan(S) \int_0^T \Delta c \frac{\partial}{\partial c} c(d) \sin(\alpha) dt$$

Performing the differentiation, one gets:

$$E_g = \int_0^T \Delta c \left[ \cos(\alpha) - 2 \left( \frac{c}{c_0} \right)^2 \frac{\sin^2(\alpha_0)}{\cos(\alpha)} + 2 \tan(S) \frac{c}{c_0} \sin(\alpha_0) \right] dt$$

Assuming that the sound velocity variations are small, one obtains the approximated formula:

$$E_g = D \frac{\Delta c}{c_0} [1 - 2 \tan^2(\alpha_0) + 2 \tan(S) \tan(\alpha_0)]$$

It can be seen that the error consists of 3 terms. The first represents the vertical error, as for a traditional echosounder.

The second term is the depth error caused by the raybending effect, and the third term represents the position shift of the sounding, and the depth error which comes from a position shift in a sloping terrain. When calculating the standard deviation of the error, it is necessary to do vector summation of the 3 terms:

$$S_g = S_s \frac{D}{c_0} \sqrt{1 + 4 \tan^4(\alpha_0) + 4 \tan^2(S) \tan^2(\alpha_0)}$$

Please note that  $S_s$  in this case is to be understood as the standard deviation of the mean value of the error in sound velocity over the water column. Random variations of the sound velocity with correct mean value will not generate any error.

#### 2.1.10 Course measurement error

Gyro compasses are subject to slow variations, and are less accurate in northern areas. They are also disturbed during turns, and will after a turn suffer from slowly dying transient errors.

However, the net effect is a positional shift of the soundings, not a change of sounding values. It is therefore suggested to use an estimated value for the level of error, according to the quality, calibration and tuning of the actual compass. The error is then

$$E_{10} = X * \tan(E_c) * \tan(S)$$

$$S_{10} = X * \tan(S_c) * \tan(S)$$

### 2.1.11 Surface sound velocity error

The surface sound velocity may affect the direction of the receive beams. If the receive beam is perpendicular to the transducer, no beam steering is necessary, and the value of the sound velocity is without importance. This is the case for transducers built as circular arcs, within the swath that can be covered by symmetrical beamforming. For example, the EM 950 and EM 1000 transducer is insensitive to the velocity of sound within +/-60 degrees. A maximum beamsteering angle of 15 degrees is thus required to cover +/-75 degrees. Flat face transducers are in contrast based upon electronic beamsteering, with steering angles up to 60 degrees. Such transducers are much more sensitive to measurement errors of the velocity of sound near the transducer. The equation governing the beamsteering process, is

$$\sin(\beta) = c \cdot (\Delta t / L)$$

when  $\beta$  is the steering angle,  $L$  is the length of the active array, and  $\Delta t$  is the beamsteering time delay. For a measurement error  $EC_s$  of the surface velocity, an error in the beams pointing angle will be generated, which will act in a similar way as the roll measurement error. The depth error will be different for different instruments:

For EM 100:  $E_{11}=0$

For EM 1000/EM 950:

$E_{11}=0$  for  $\alpha < 60$ , and for  $\alpha > 60$ :

for  $\alpha > 60$ :

$$E_{11} = Y \cdot \frac{ES_v}{S_v} \cdot \sin(\alpha - 60) \cos(\alpha - 60)$$

:For EM 12/EM 121:

$$E_{11} = Y \cdot \frac{ES_v}{S_v} \cdot \sin(\alpha) \cos(\alpha)$$

$S_{11}$  is calculated accordingly.

## Explanation to illustrations

-----

Fig.1 is a logical flow chart, indicating how the different error contributions act.

Fig.2-7 represent the results of the error model, for the following case:

|               |           |
|---------------|-----------|
| Instrument:   | EM 1000   |
| Water depth:  | 100m      |
| Bottom slope: | 2 degrees |
| Survey speed: | 8 knots   |

Standard deviation of uncertainties:

|                 |     |     |
|-----------------|-----|-----|
| Heave:          | 5   | cm  |
| Roll:           | 0.1 | deg |
| Pitch:          | 0.1 | deg |
| Heading:        | 0.5 | deg |
| Sound vel prof. | 0.5 | m/s |
| " surface       | 0.5 | m/s |
| Tide level:     | 5   | cm  |
| Relative timing | 0.1 | sec |

Fig. 8-9 represent the (very first) output of this error model, programmed as part of Neptune, and using real data, including the sounding values and the quality factors.  
Instrument is EM 1000, depth is approx. 90 meters.

# Multibeam echosounder error propagation model

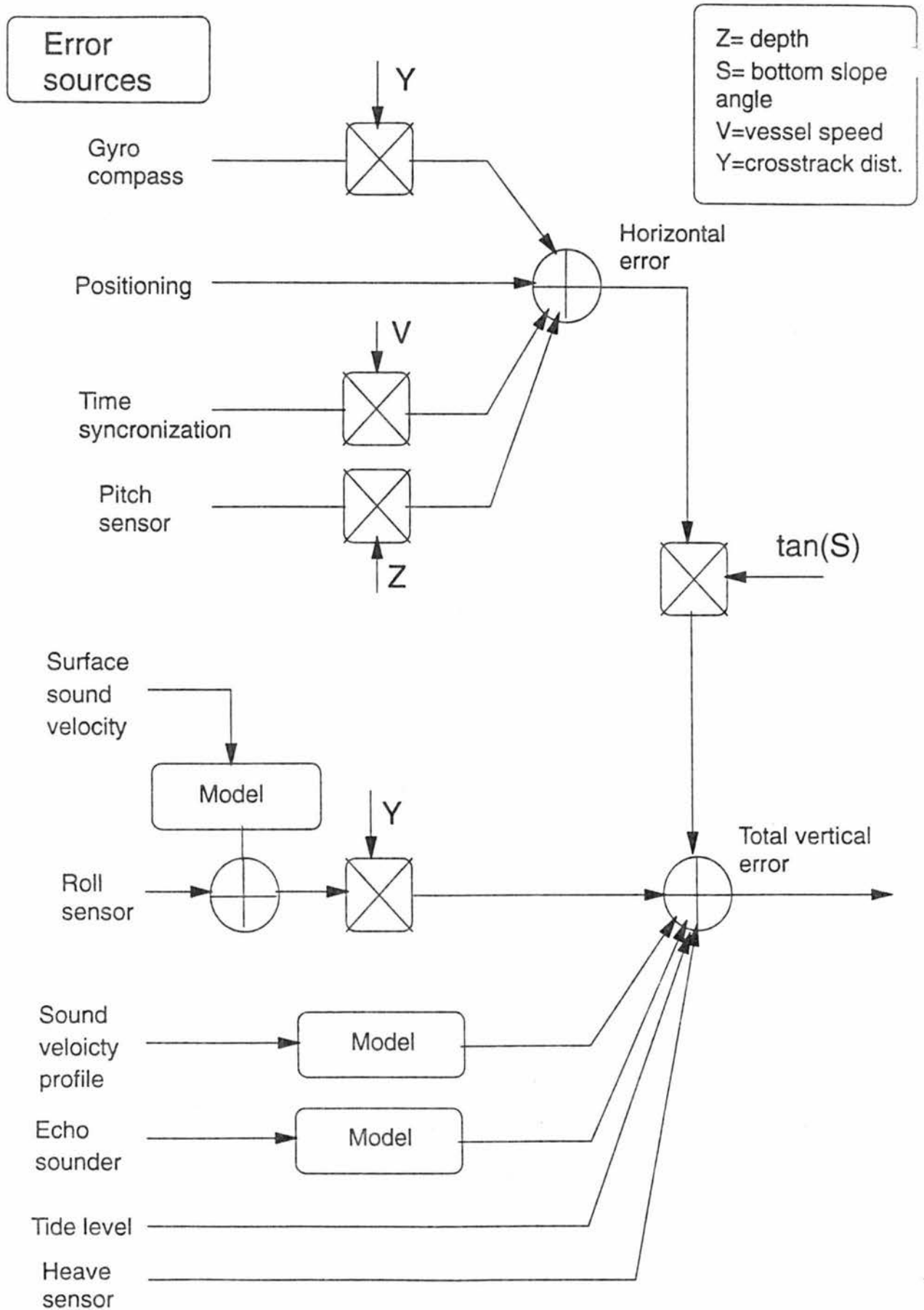


Fig. 1

Sounding position error

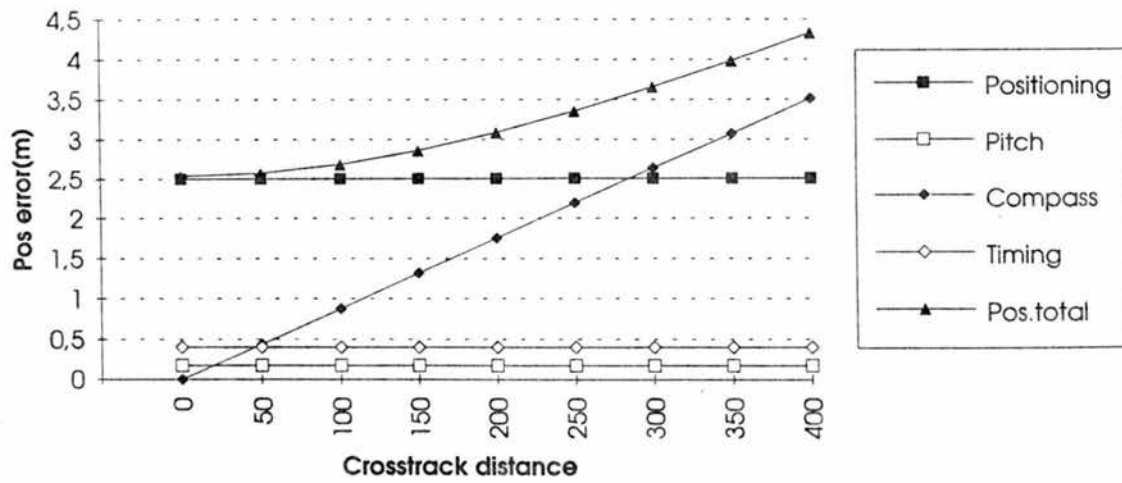


Fig 2

Vertical error caused by positioning errors

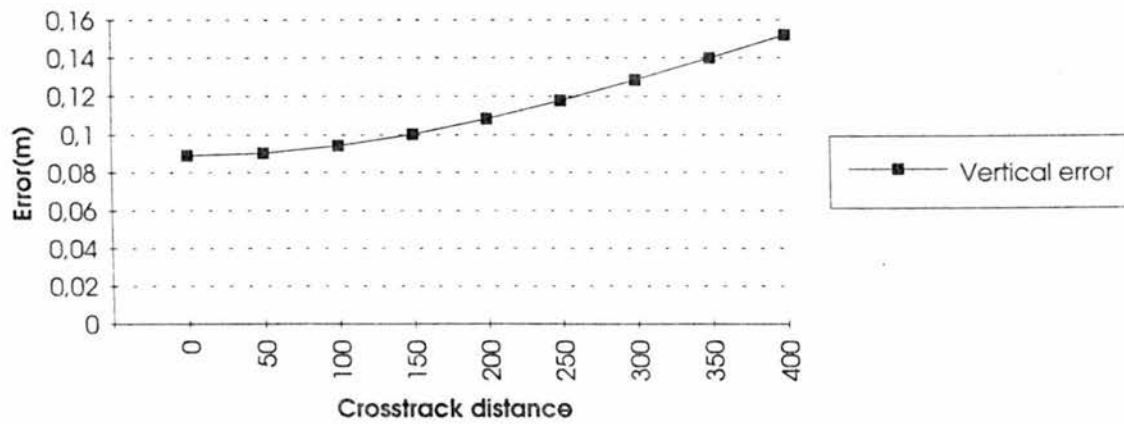


Fig 3

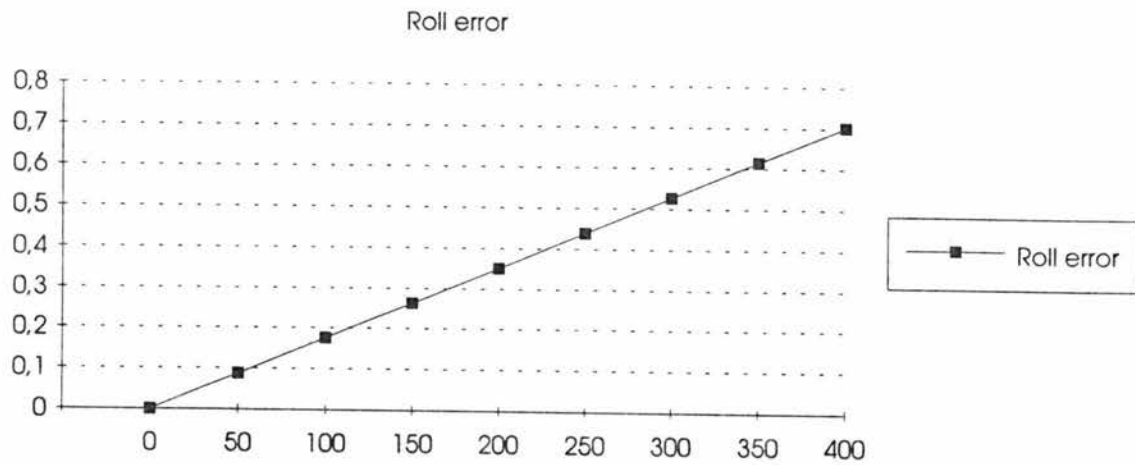


Fig 4

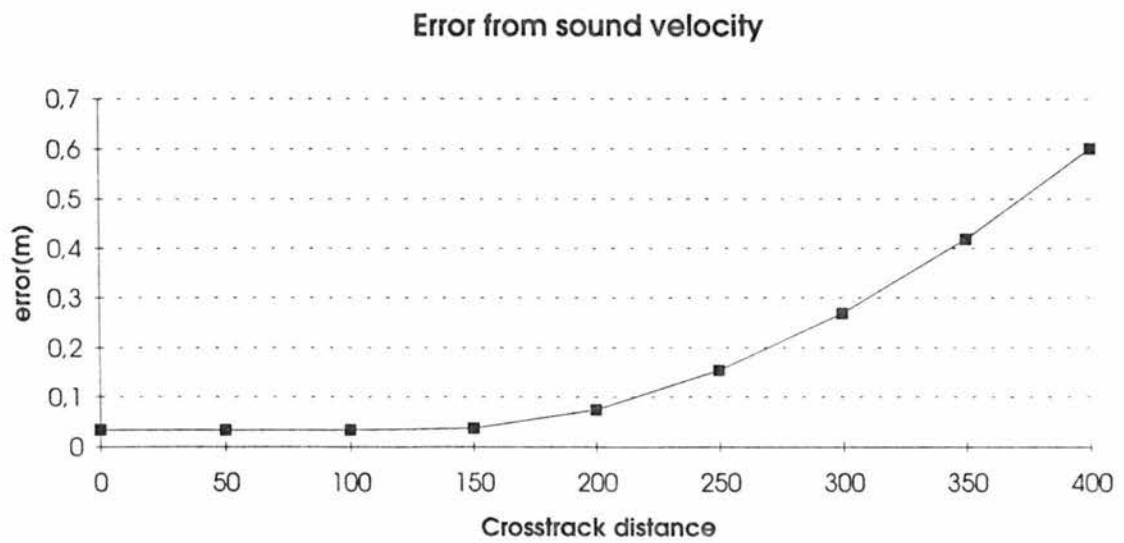


Fig 5

## Effect of surface sound velocity

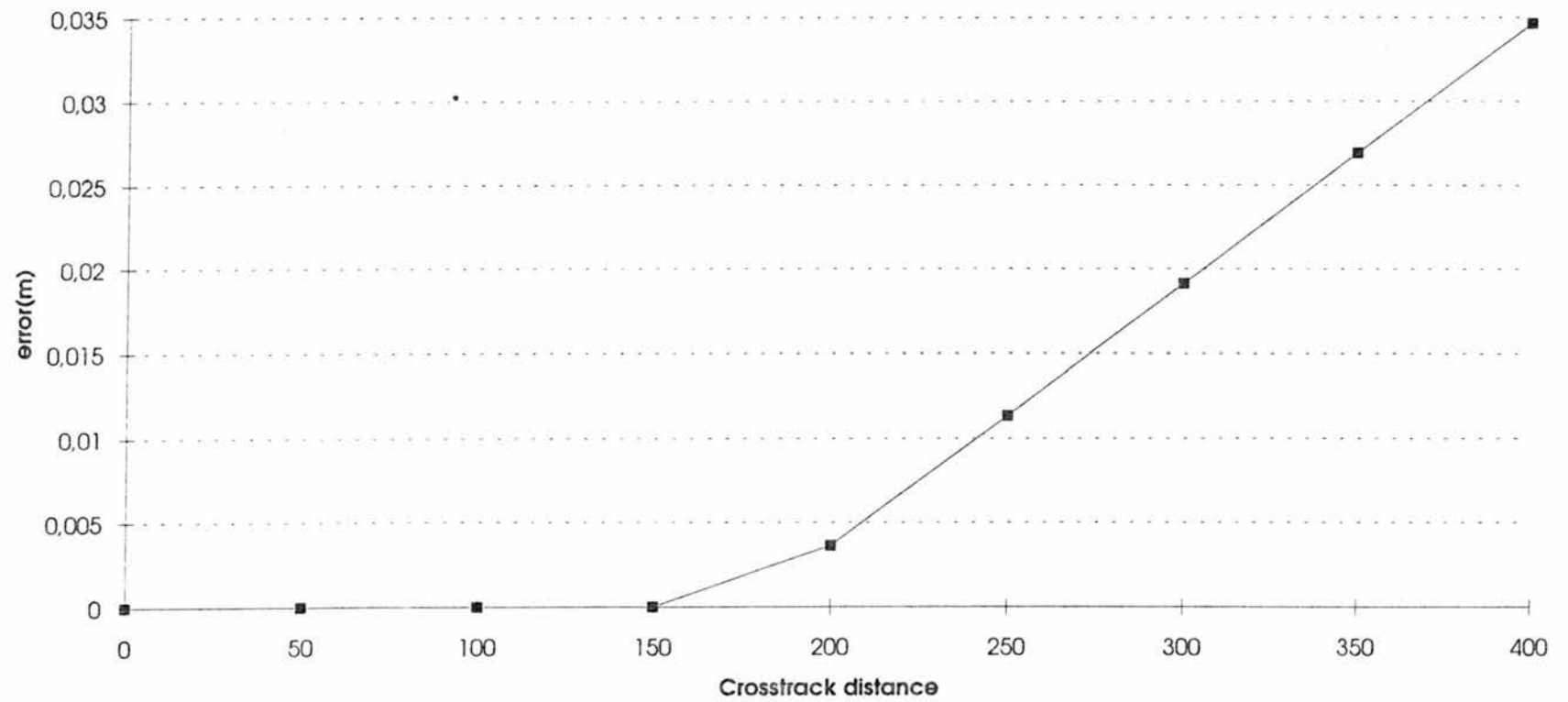


Fig 6

EM 1000 total system error

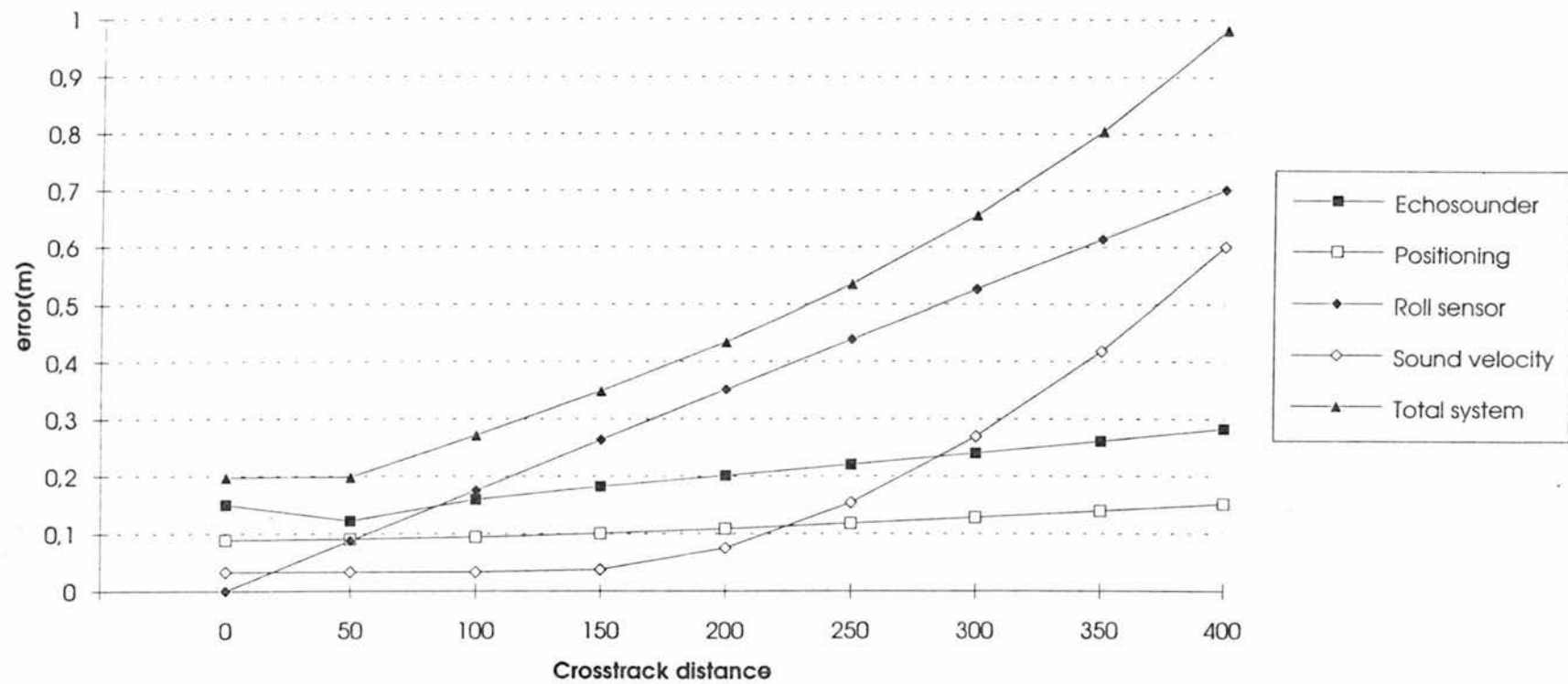


Fig 7

Depth and dz for one Ping

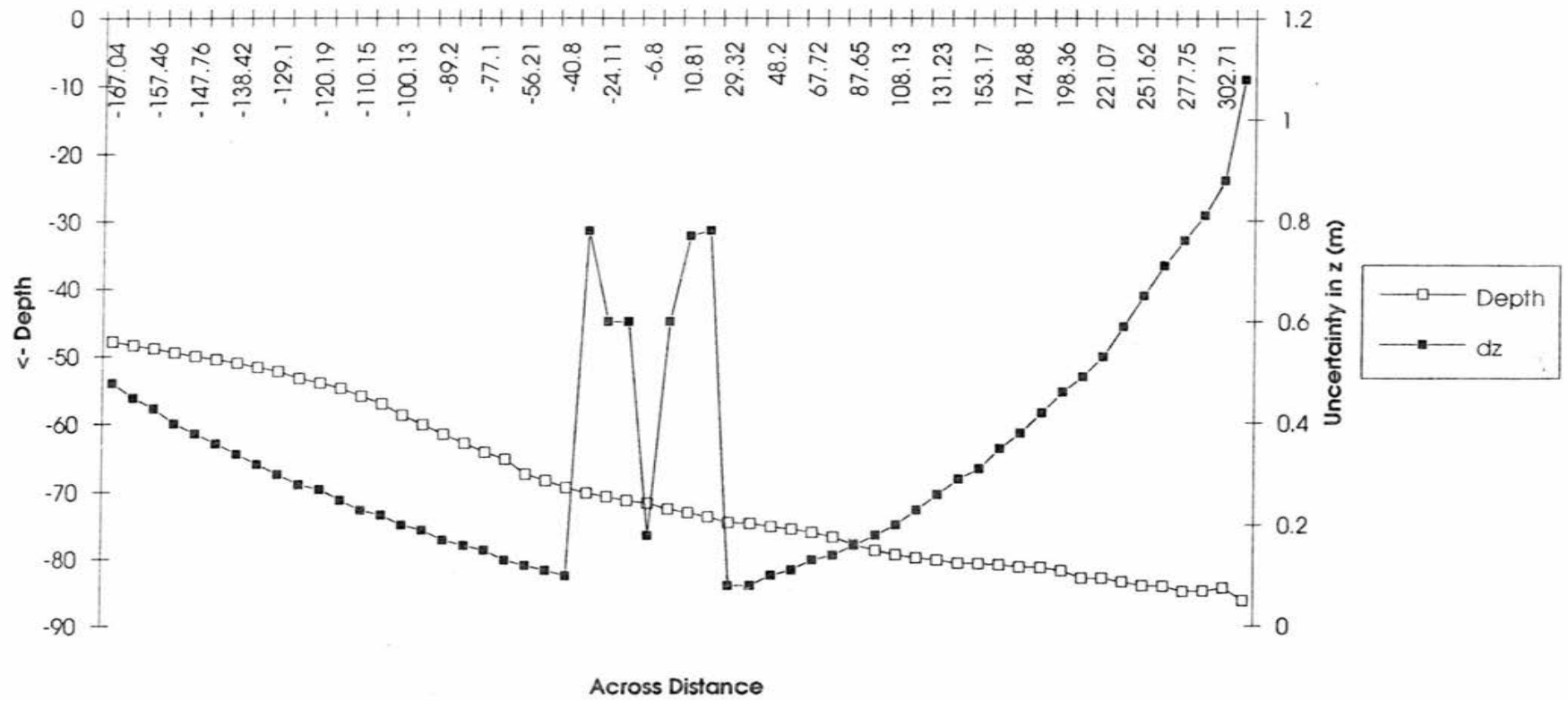


Fig 8

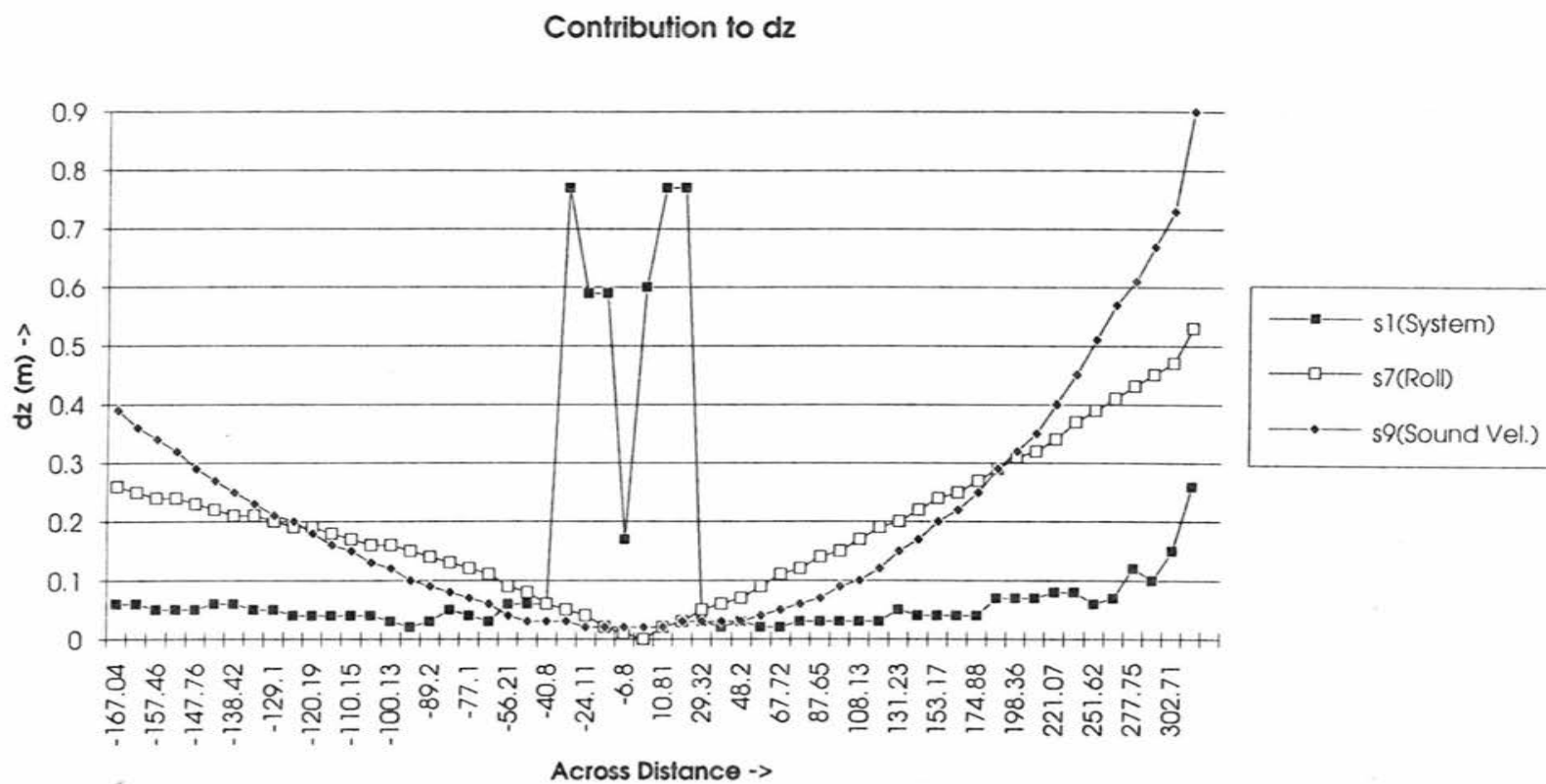


Fig 9

**SIMRAD MULTIBEAM USER CONFERENCE**

Experience from multibeam mapping with EM 1000 and methods to  
reduce errors

Kjell Martin Dukefoss, Geoteam A/S

FEMME 93

PARIS

EXPERIENCE FROM MULTIBEAM MAPPING WITH EM1000  
AND METHODS TO REDUCE ERRORS

Kjell Martin Dukefoss  
GEOTEAM AS

## GENERAL

Geoteam AS has experience with multibeam mapping since an EM1000 was installed in Geo Surveyor in April 1992. From July 1993 another EM1000 was also installed in Geo Scanner. Untill December 92 all processing of multibeam data was done by Blom AS in Oslo as Geoteam at that time did not have the software to process such data. Since January 1993 Geoteam has had systems for processing of multibeam data on board the vessels and in the office.

The experience we have had with the multibeam systems and connected subsystems will be illustrated by some data examples showing the effect on the depth data by various errors and as comparisons between some subsystems. Comments will be made to the nature of the errors/problems and the methods used or to be used to reduce inaccuracies in the final depth data.

## COMMENTS TO THE ILLUSTRATIONS

### Figure 1.

- This example shows some artifacts created by IRAP. The area has been gridded by relatively standard parameters on a 5x5 m grid from data with an average density of 1 depth point per ca 20 m<sup>2</sup>. In a small area where several profiles overlap there is 1 depth point per 4 m<sup>2</sup>. With the processing parameters used this resulted in several 3 to 4 metres deep holes being created where the seabed is flat. When Blom contacted Geomatic about this problem this was quickly resolved. A bug in some program routine caused these artifacts when the depth point density was much higher than what the gridding parameters were set for.

### Figure 2.

- The same section of a profile contoured from 5x5 and 25x25 m grid size. The lower map show the general depth of an almost flat seabed. The upper map show some more details in the central part, but is otherwise useless due to the effects of a constantly varying error in the applied roll value.

### Figure 3.

- The logged roll/pitch/heave data and the corresponding depths from selected beams. The plotted depths have been offset by 2 metres between each beam shown. The significance in the upper two plots is the time-correlation between the roll value and the depth error. The maximum depth error appear when the roll value is close to zero. No depth error is apparent when the roll value is at its maximum. This means that the depth errors is at its maximum when the rate of change in roll is at its maximum, hence the error must be caused by a delay in the applied roll values.

The lower plot show the depths from the same beams after a simple correction for roll delay has been applied. Following this improvement a similar correction routine was applied in the processing software.

In parallel to working with improvements of already collected data we were in contact with Simrad to find a better solution to this problem, and this solution would have to be implemented in the EM1000. The result of these discussions were that Simrad implemented a correction for the internal delay in the system itself and made possible for the system

operator to input to the EM1000 the delay in the VRU-sensor being used. These improvements have greatly extended the weather window for collecting useful data.

**Figure 4.**

- Some time later the vessel reported that the time delay problem again appeared in the data even though the operator input of delay in the VRU was correct. A plot of the recorded pitch/roll/heave data showed that this time there was another reason. In the plotted data the typical ca 10 second roll period is still seen, but the dominant feature is a period close to 1 minute. The Hippy 120 used will give erroneous heave data when the period becomes longer than ca 30 seconds and this was obviously the case in these data.

**Figure 5.**

- Another type of variable roll error that occurs when the Hippy 120 is used as the VRU is the drift in the vertical reference point. The "vertical" that the Hippy refers its roll and pitch to is over time slowly varying with up to  $\pm 0.5$  degrees. There is some indication that the magnitude of error is depending on the movement of the ship (sea state). The figure shows the effect of this on the contours on a relatively flat seabed. All profiles in this example have been run in the same direction and they all have a roll error of the same sign but of varying magnitude.

**Figure 6.**

- This figure shows 4 crosssections through 3 parallel profiles. The distance in time between the crosssections is approx. 1 hour. Two different problems are seen in these examples. There is a roll error which for profile 236 is different in each crosssection. Also, there is a varying sound velocity error in the data set.

To enable corrections for the varying roll error to be determined crossprofiles are needed. However, for some types of surveys this is not practical and other solutions should be sought.

**Figure 7.**

- These are some of the sound velocity profiles collected during the project from which also the examples in figure 6 comes. Based on the customers previous experience he decided that the same sound velocity should be used throughout the project which were to last for approx. 30 days. The sound velocity profile from 16/8 was used in the EM1000. The sound velocity profile did not only vary with time, but there were at times great difference in the profiles in each end of the survey area.

In this project a correction for sound velocity was implemented in the processing of the data. These corrections did only correct for variations in the sound velocity over time (as measured at intervals in a selected position) and not the variation over a distance that was seen.

The variation in sound velocity profile with time and over a relatively short distance that was experienced in this project is often observed along the west coast of Norway.

To better be able to handle large variations in sound velocity, the possibility to properly correct for sound velocity in the processing of the data must be implemented.

**Figure 8.**

- Example of a problem that may occur when surveying in fiord areas. The seabottom consist of very soft sediments in the deep areas and of rock in the steeper and shallower areas. This often results in spikes in the beams pointing towards the deep, soft bottom. This necessitates a lot of cleaning of data in the processing. The problem may not be relevant for many users

of the multibeam systems but needs to be looked into for future use in the fiord areas of Norway.

**Figure 9.**

- This is a typical example of the seabed off the coast of Norway. In such a terrain any errors in gyro and pitch will significantly influence on the accuracy of the final terrain model.

**Figure 10.**

- An example that shows the difference between two gyros. There was a static calibration difference of 0.9 degrees between the two which it is not corrected for. This magnitude of difference has been observed between various gyros during several surveys and indicates that the accuracy of a gyro is not good enough for use with an EM1000.

**Figures 11 - 13.**

- In an attempt to find a way to get attitude data of good quality without the expense for an INS Geoteam has been testing a GPS vector system against the attitude sensors onboard a survey vessel. Some examples are shown in figures 9 to 11. In the examples is shown the vessel heading, the instantaneous difference between the GPS vector and the attitude sensor and a filtered difference between the two. Calibration offsets are not corrected for.

The tests show that the noise in the GPS vector used is so large that instantaneous differences can not be used. The filter period used to avoid phase jumps in the GPS vector is too long for the filtered difference to be used for any correction of the attitude data.

Further tests and development need to be done before such a system can be made operational.



## ERROR IN IRAP

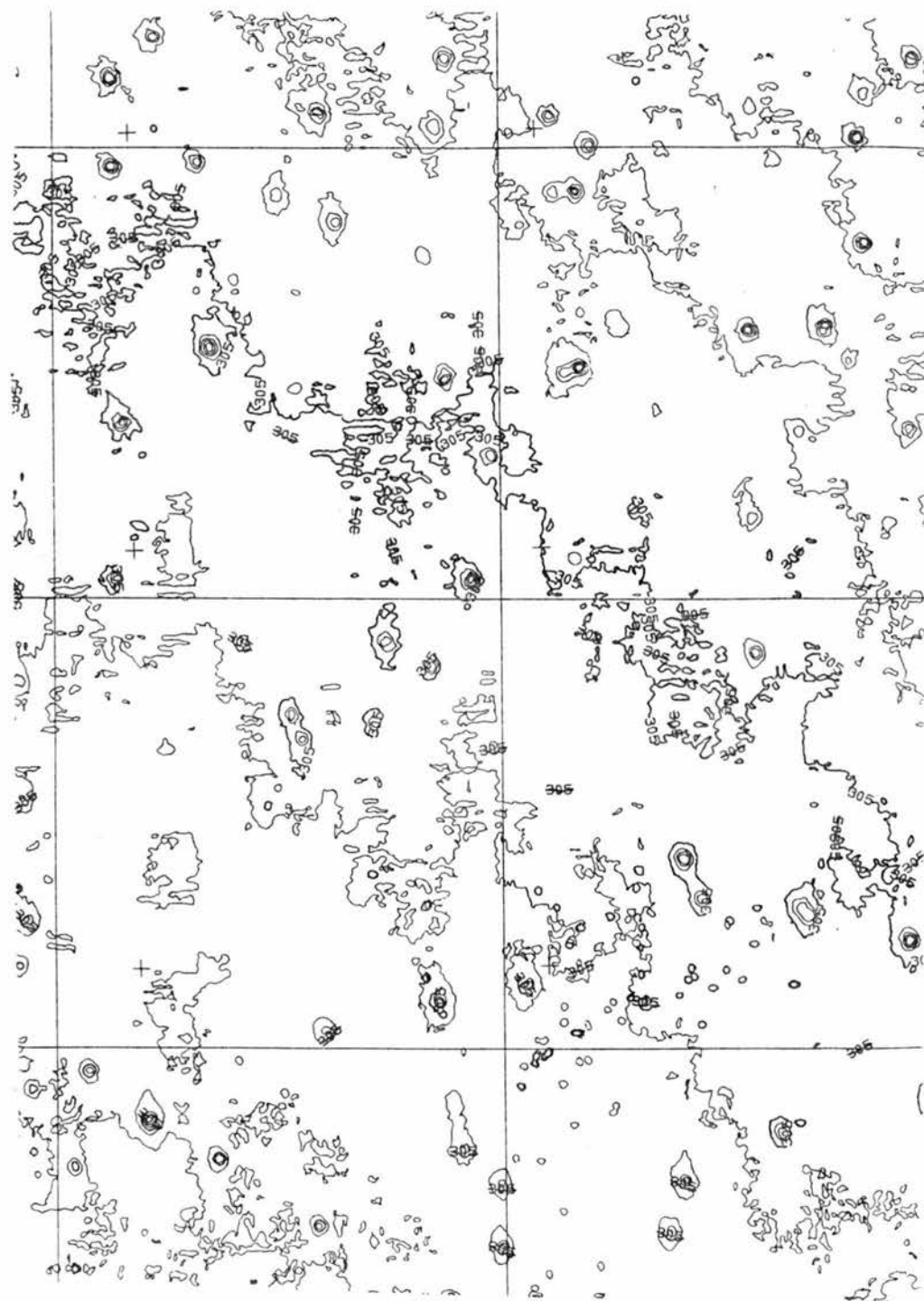
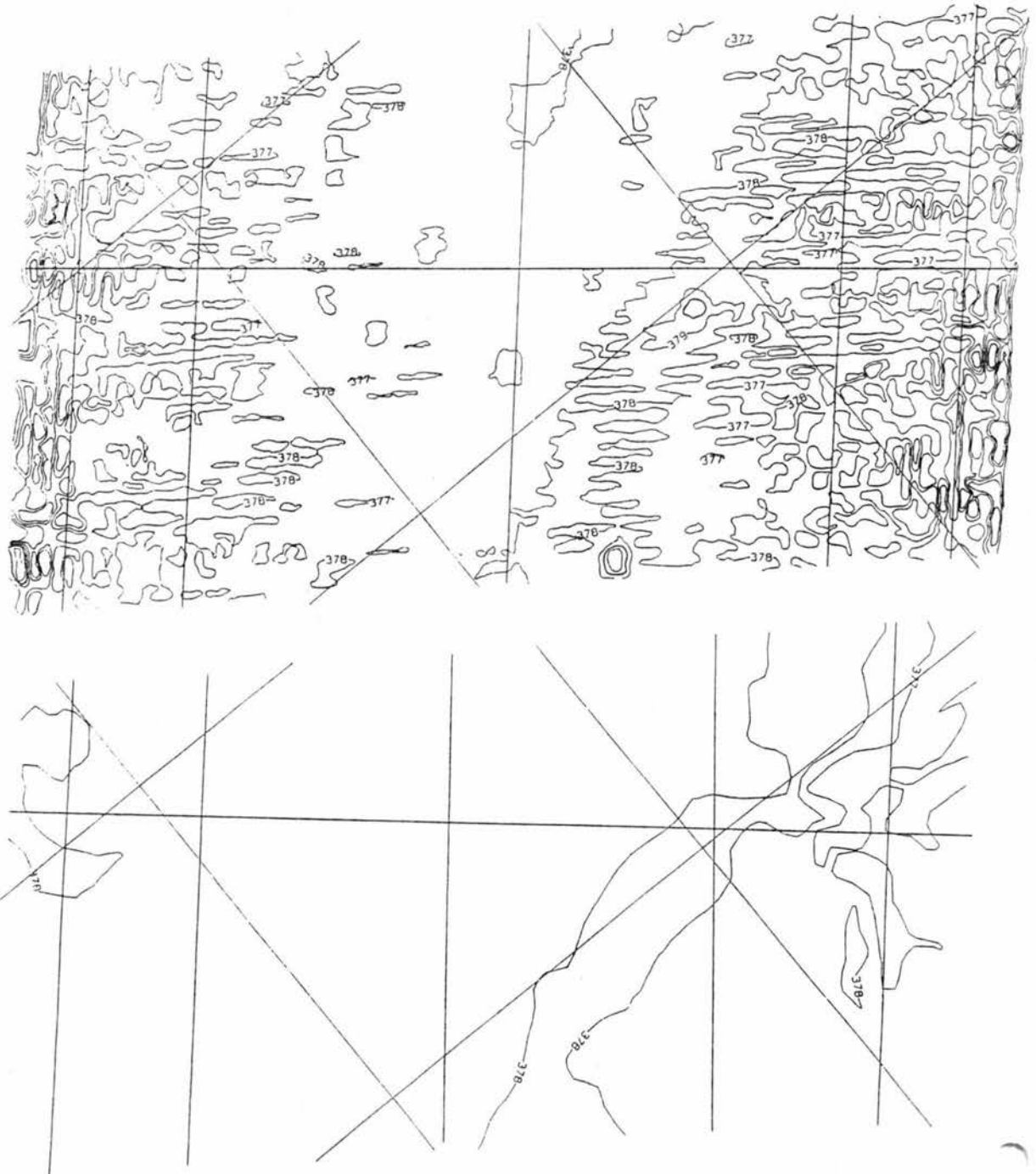




Figure 2

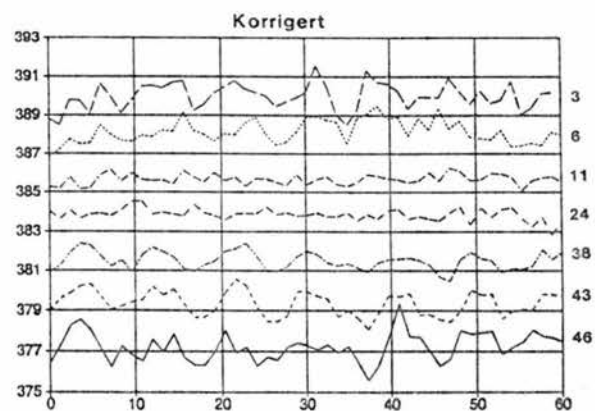
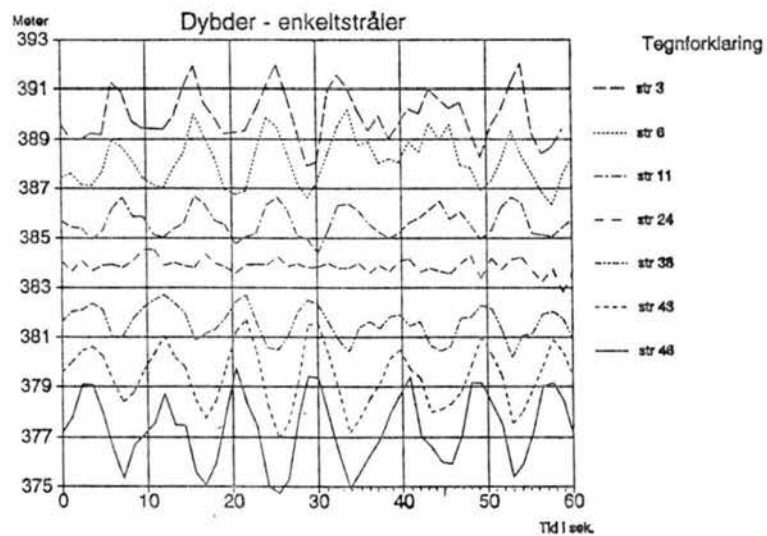
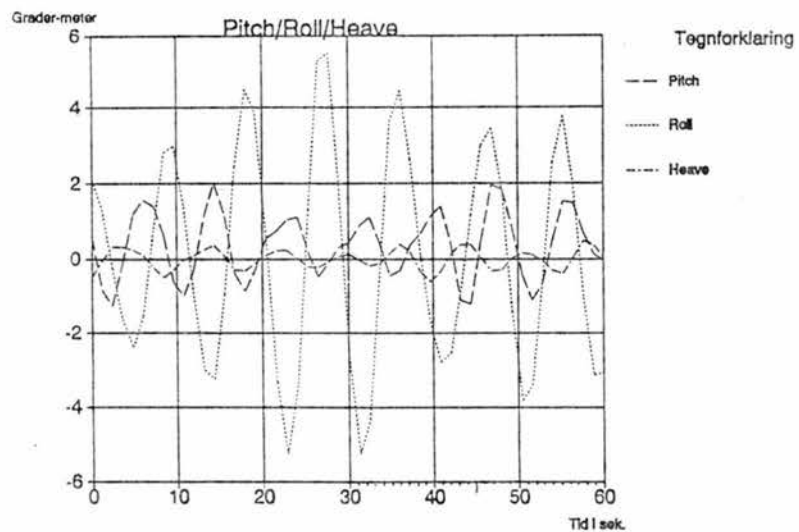
## EXAMPLE MAPS

### TIME DELAY IN ROLL





## TIME DELAY IN ROLL SENSOR



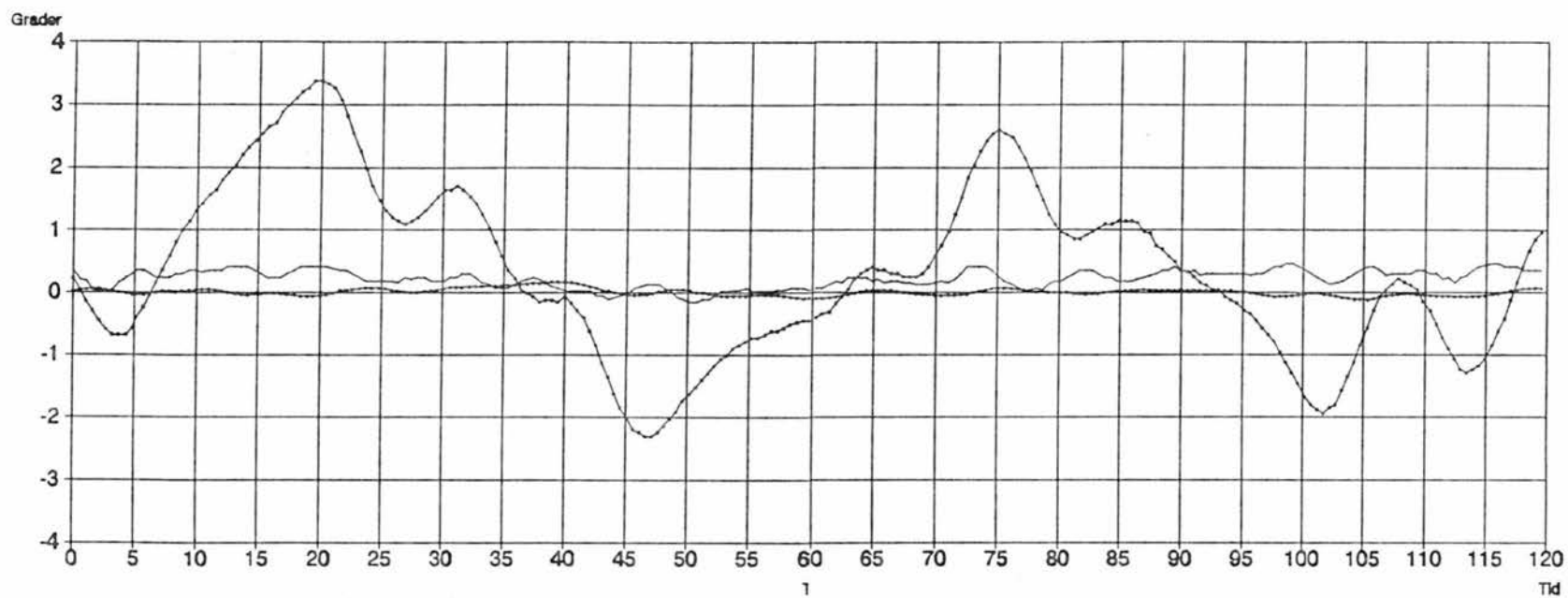
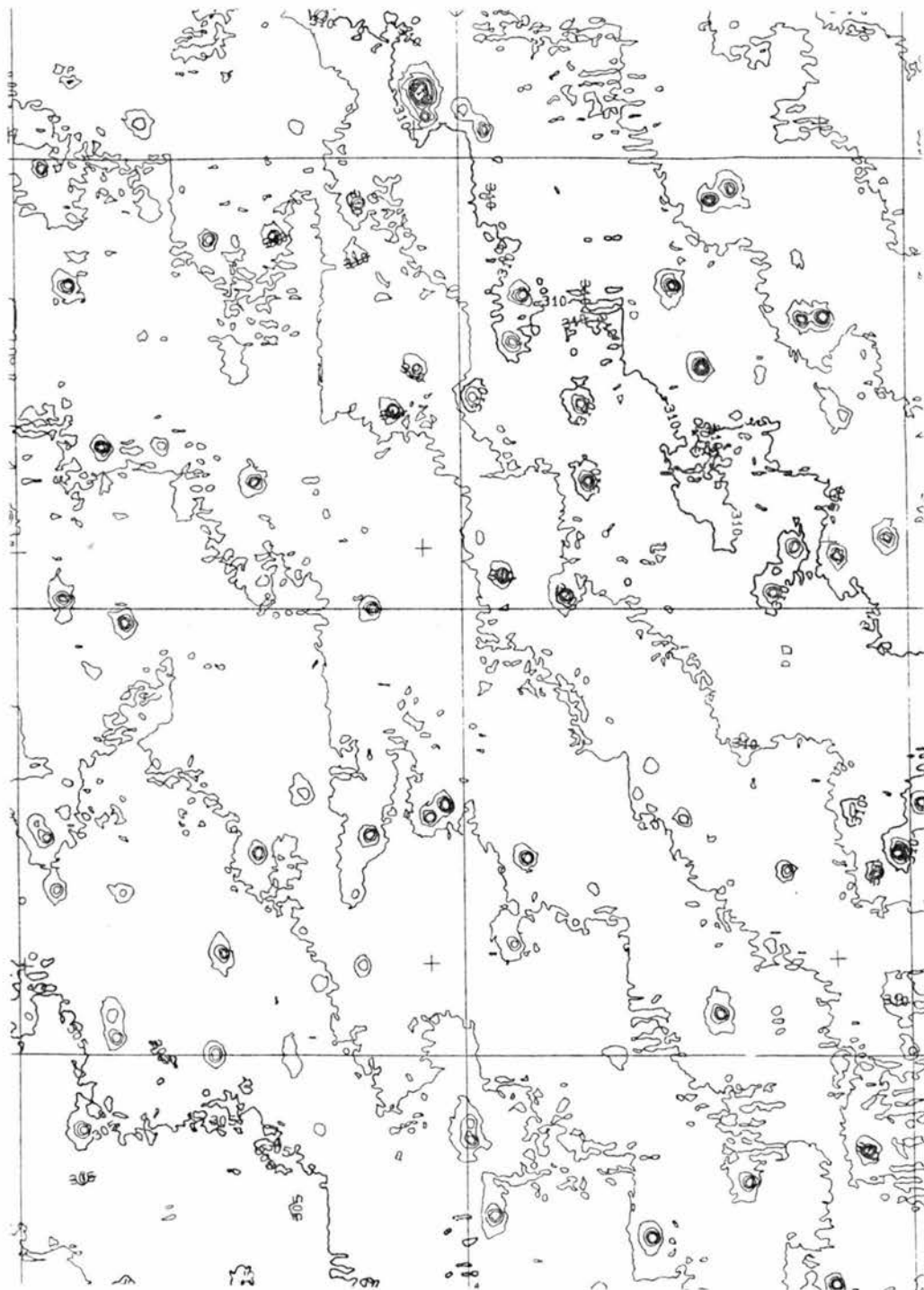


Figure 4

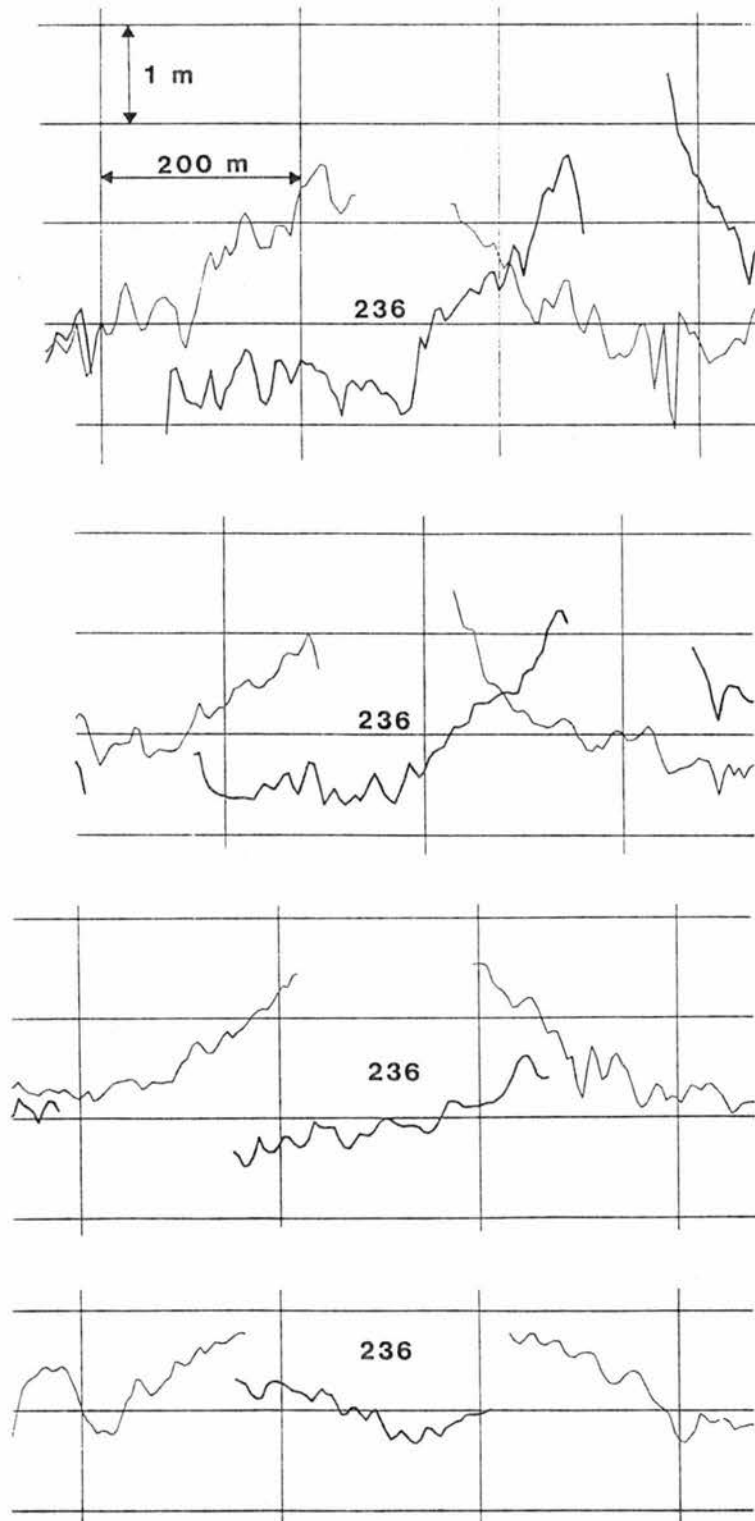


## ERROR IN ROLL



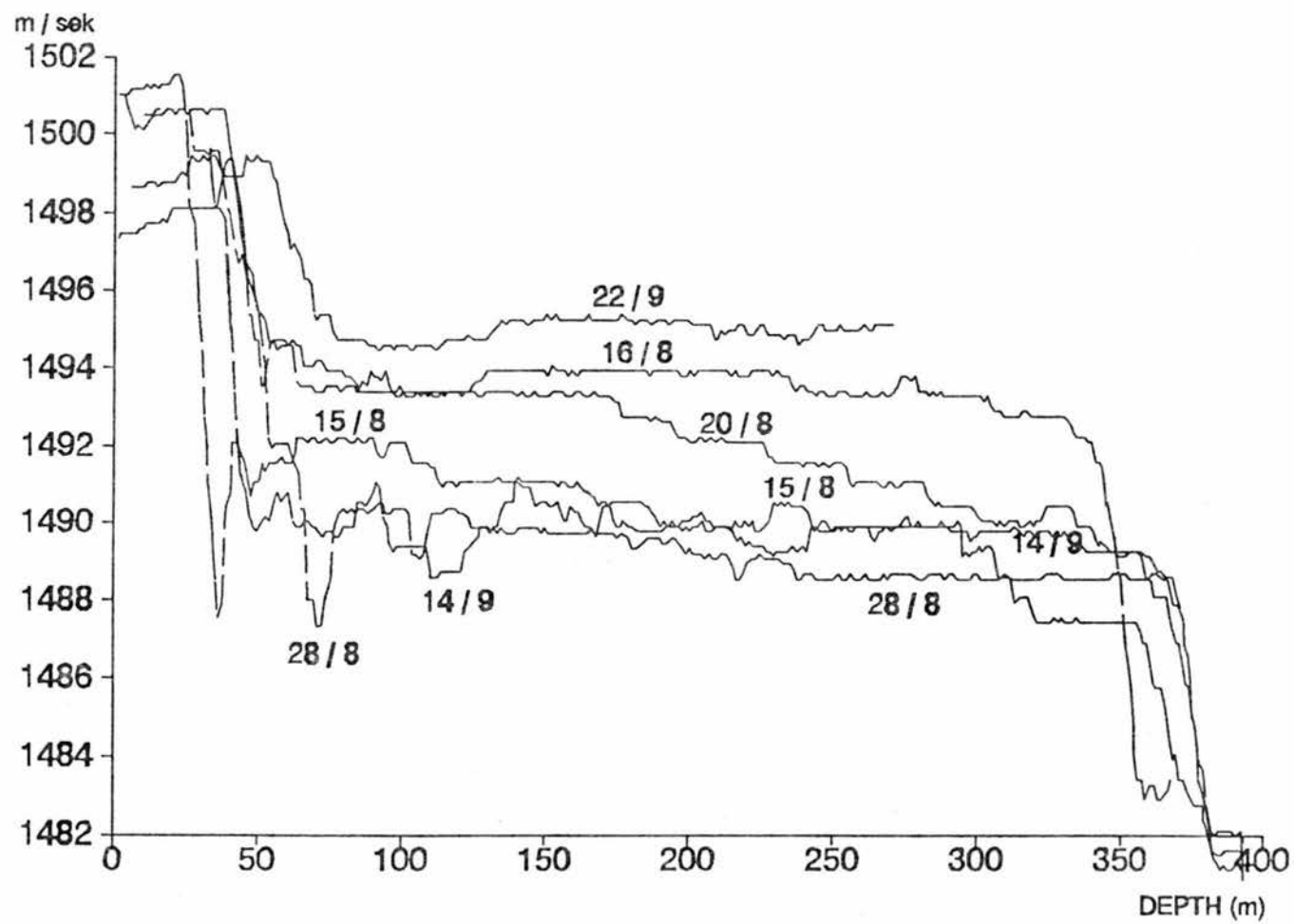


## EXAMPLES OF VARYING ROLL ERROR



15/8 - 22/9

## EXAMPLES





Figure

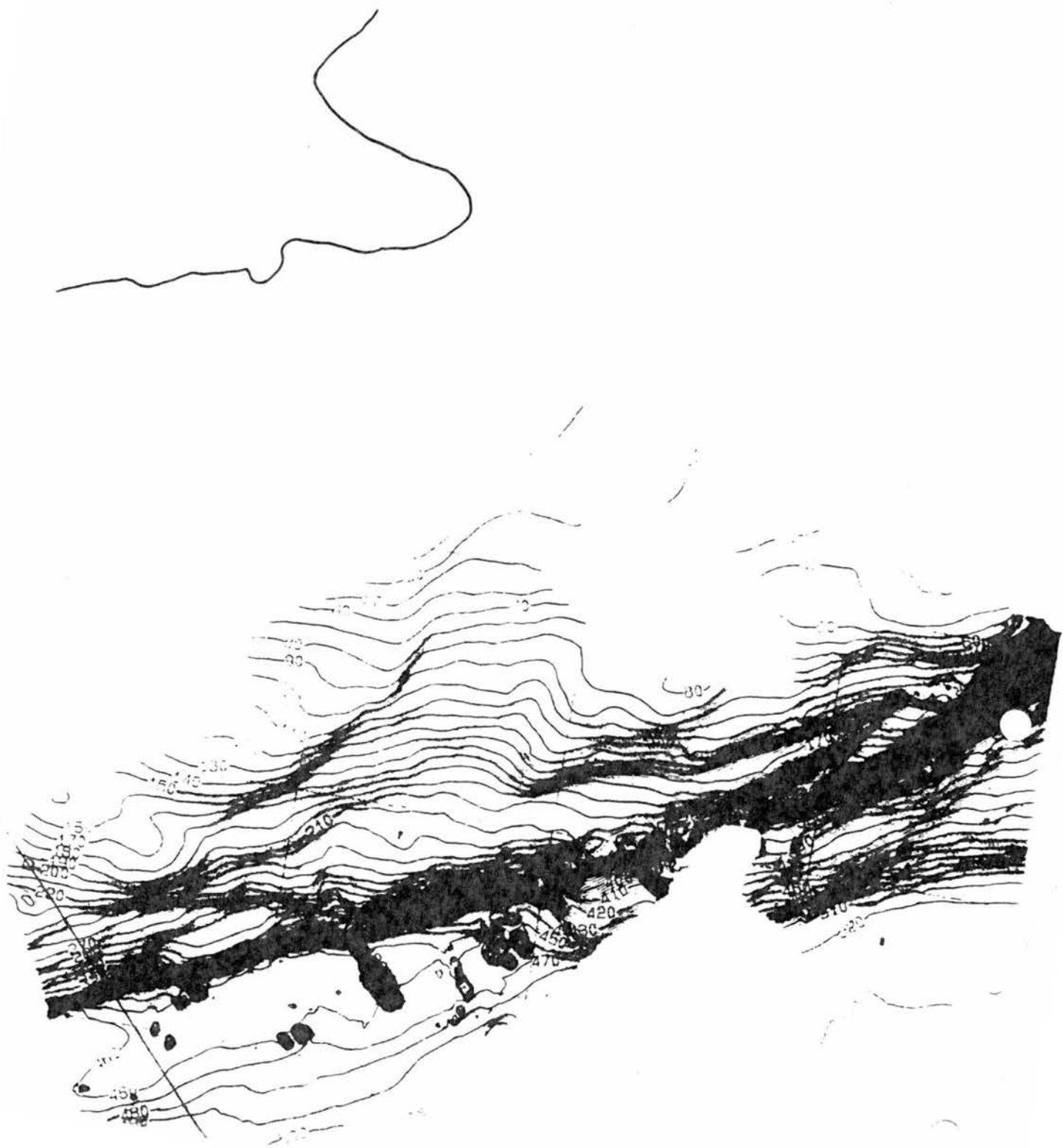




Figure 9

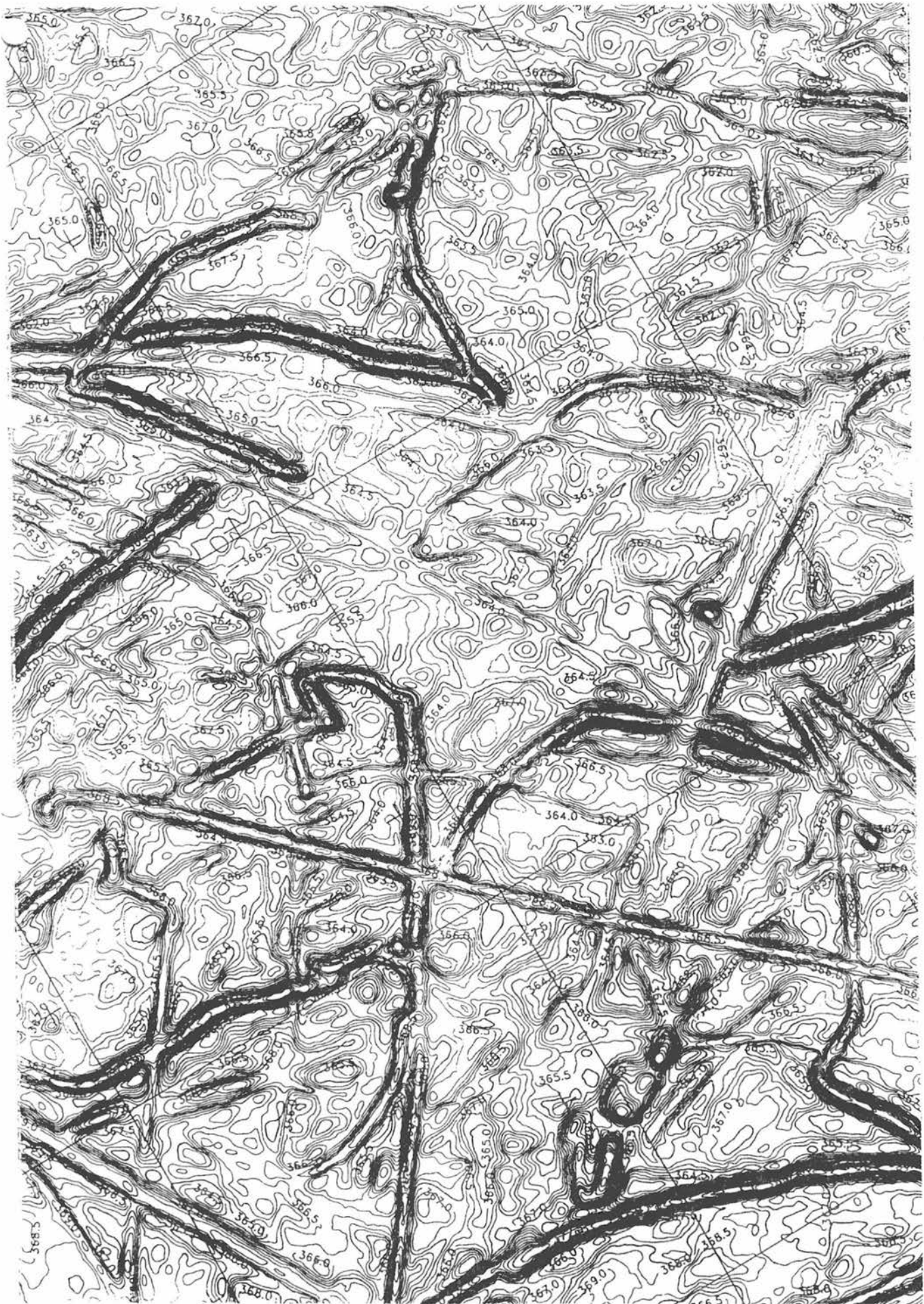
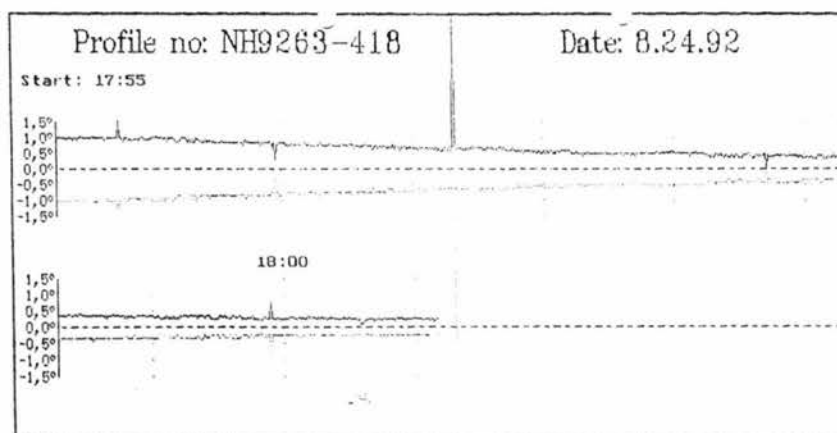
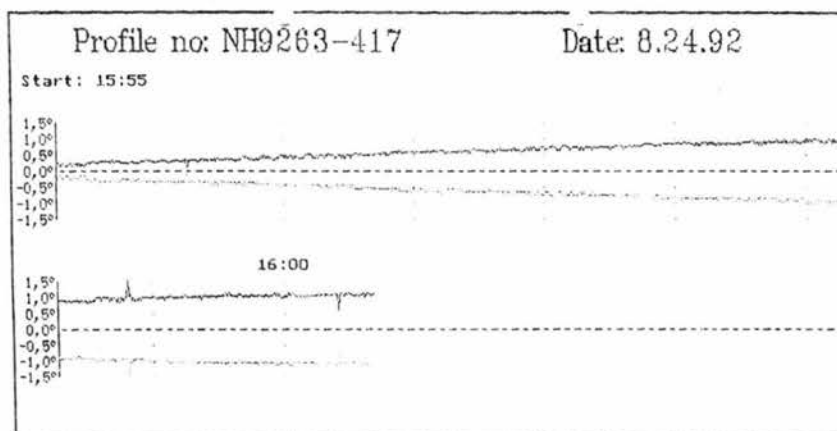
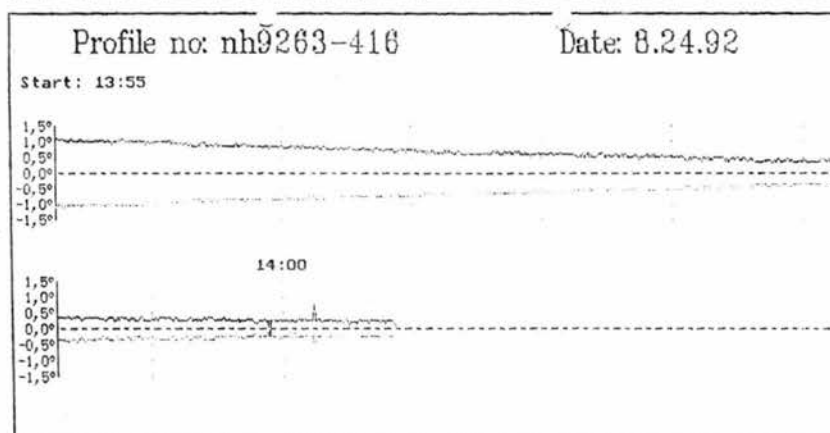
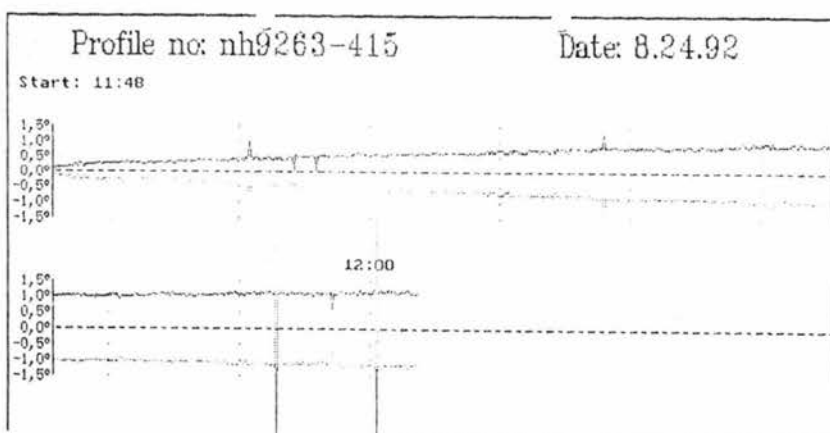




Figure 10

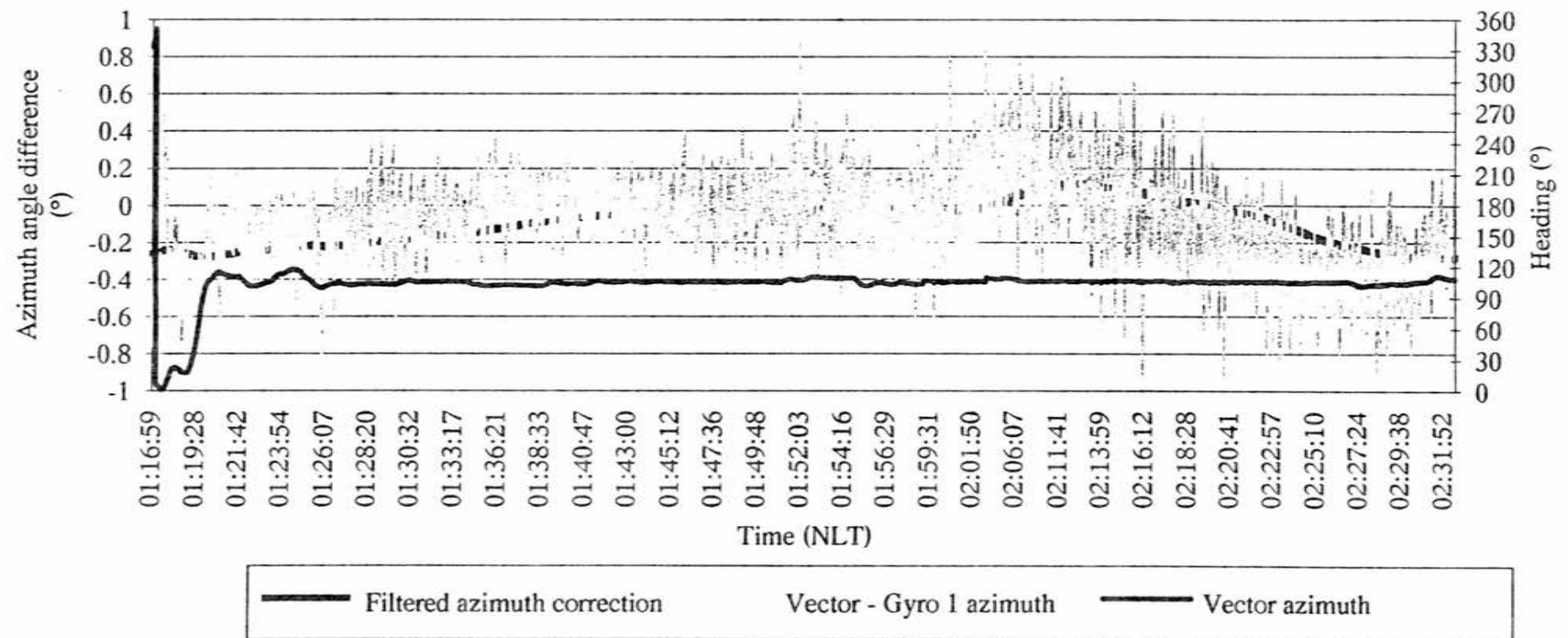
## GYRO COMPARISONS





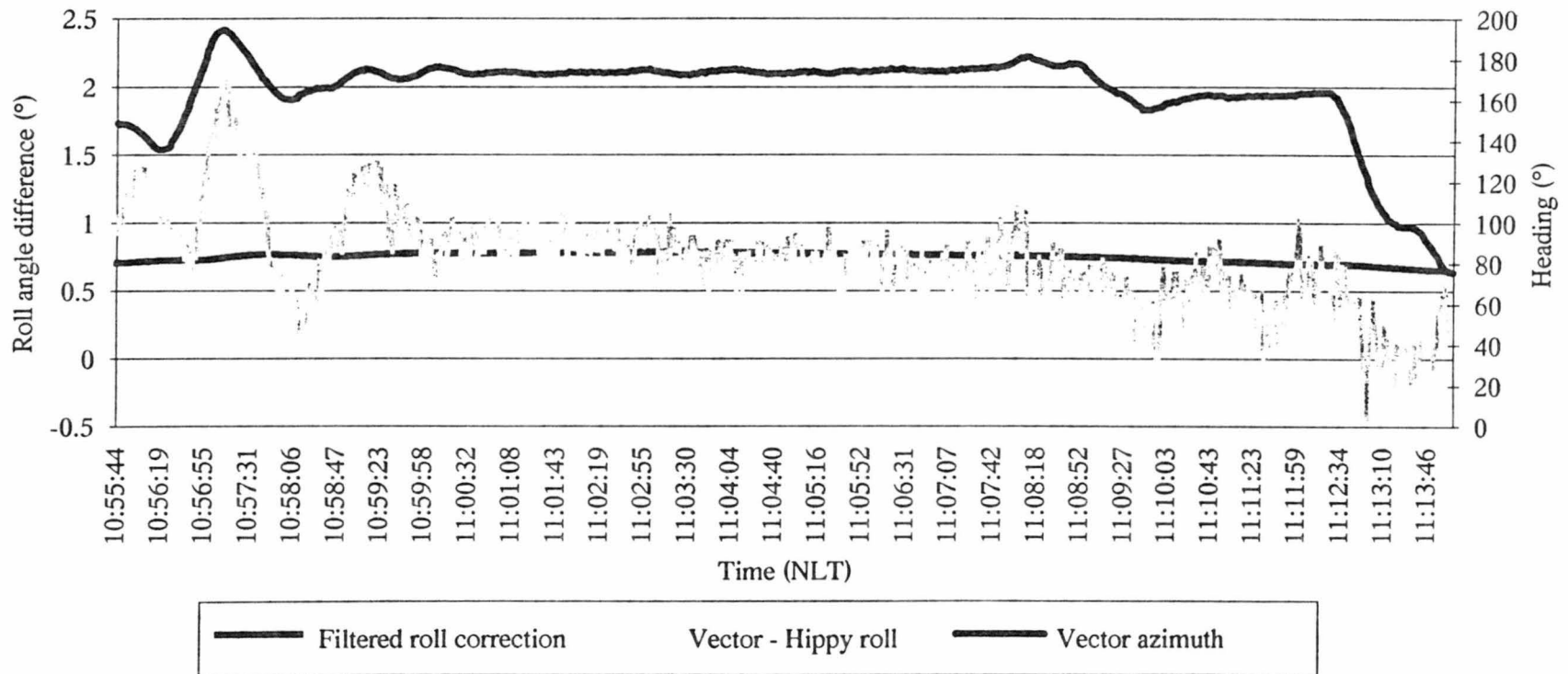
Vector - Gyro 1 azimuth difference, Filtered azimuth correction  
and Heading

18.03.93 01:16 - 02:31 NLT



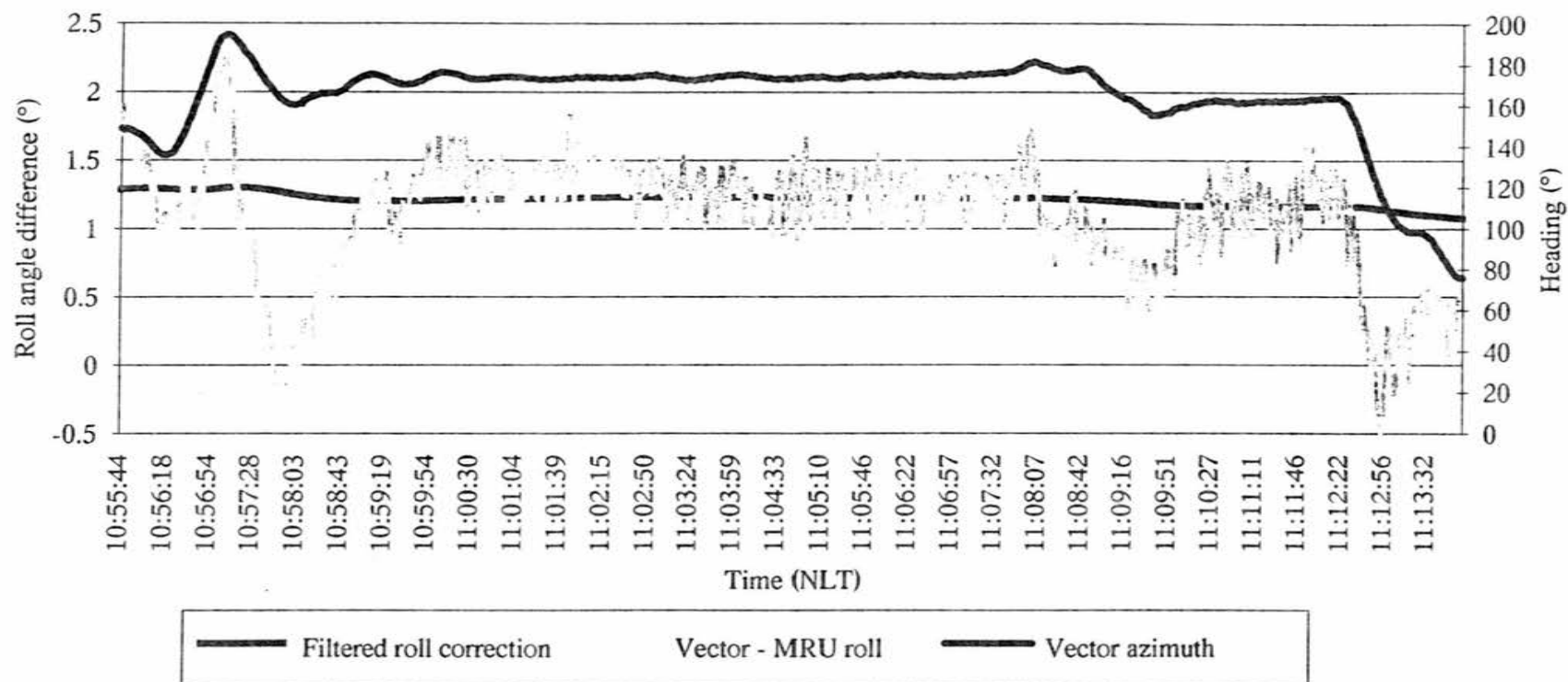


**Vector roll - Hippy roll, Filtered roll correction and Heading**  
**22.03.93 10:55 - 11:13 NLT**





Vector roll - MRU roll, Filtered roll correction and Heading  
22.03.93 10:55 - 11:13 NLT



**SIMRAD MULTIBEAM USER CONFERENCE**

Real Time processing in EM multibeam echo sounders

Erik Hammerstad, Simrad Subsea A/S

## REAL-TIME PROCESSING IN EM MULTIBEAM ECHO SOUNDERS

TRU:        Transmit beamforming

             Gain control of receiver

             Receiver beamforming

             Frequency filtering

             Calculation of beam data

             Data transfer to BDU

BDU:        Determination of bottom windows

             First round bottom detection

             Spike filtering

             Second round bottom detection

             Spike filtering

             Data transfer to OPU

             Parameter determination for next ping

             Ping command to TRU

OPU:        Footprint calculation

             XYZ calculation including raybending and roll delay

             Transfer of data to logging device

## BEAMFORMING



Phase shift or an equivalent time delay added to each element:

$$\Theta = 2 \pi f i \Delta \sin \theta / c \quad \text{or} \quad \tau = i \Delta \sin \theta / c$$

where

- $c$  is sound velocity
- $f$  is sonar frequency
- $i$  is element number
- $\theta$  is beam pointing angle

Error in  $c$  or error in  $\Delta$  causes an error in depth:

$$(\delta D/D) = \frac{(\delta \Delta/\Delta)}{(\delta c/c)} \tan \theta \tan(\theta - \Phi)$$

where  $\Phi$  is array mounting angle

## GAIN CONTROL

Receiver gain is set to give optimum dynamic range in receiver.

Fixed gain set at ping time, time varying gain (TVG) runs during ping.

TVG is predictable from stored data to allow postprocessing compensation of gain.

### Sonar Equation

Source Level:  $SL = 170.8 + 10 \lg P_a + DI_T$

Directivity Index:  $DI = 46.2 - 10 \lg \Phi_x \Phi_y$

Echo Level:  $EL = SL - 2 TL + BS$

Transmission Loss:  $2 TL = 2 \alpha R + 40 \lg R$

Noise Level:  $NL = NSL + 10 \lg \tau - DI_R$

Backscattered Signal far out ( $\theta \geq 25^\circ$ ):

$$BS = BS_0 + 10 \lg \cos^2 \theta + 10 \lg A$$

Backscatter Area:  $A(\theta) = \frac{1}{2} c \tau \Phi_T R / \sin \theta$

Backscattered signal at normal incidence:

$$BS = BS_N + 10 \lg A$$

Backscatter Area:  $A(0) = \Phi_R \Phi_T R^2$

$BS_0$  and  $BS_N$  are seabed dependent constants. Inbetween this seabed BS can be assumed to change linearly with angle. These values are estimated by the BDU from previous pings.

## BEAM SAMPLE DATA

- A: Instantaneous fullbeam sample amplitude in dB, corrected for gains and beam patterns to give calibrated backscattering value if the bottom is flat. The fullbeam is derived from the sum of the two overlapping halfbeams.
- $\Phi$ : Electrical phase difference between halfbeams. The phase is derived from the complex conjugate product of the two overlapping halfbeams. This product is averaged over a number of samples (determined by the BDU) before the phase is calculated, thus reducing the effect of glint (destructive interference) and noise.
- QA: Sliding average of the amplitude calculated every fourth sample over a number of samples as determined by the BDU.
- QP: Sliding average of the phase calculated every fourth sample over a number of samples as determined by the BDU (EM 12 only).

For the EM 12 the TRU in addition uses the QA and QP values to predict possible start of bottom echo in every beam (alarms).

## BOTTOM WINDOWS

EM 1000: From previous pings the range to the bottom is predicted in each beam. Mode dependent length windows as determined by data transfer capacity then restrict the data collection around these predicted ranges. The windows increase with beam pointing angle away from straight down in shallow and intermediate modes.

EM 12: The alarms are used to determine where the bottom is in each beam. Several close alarms are required and the result is spike filtered over the beams. For beams with no accepted alarms the start of bottom is estimated from neighboring beams.

Window lengths are preestimated from the depth straight down (expected depth) and the bottom slope as determined from previous pings. Only data within the windows are used in the rest of the processing which is started with the unpacking and sorting of the data transmitted by the TRU.

If the condition flag has been set to "Poor" or "Awful" the alarms are not fully trusted, and an estimate of where the bottom starts is also based on the expected depth and the windows are lengthened. Note that ping rate might suffer because of this.

## FIRST ROUND BOTTOM DETECTION

- Done independently beam by beam starting with the outer beams.
- Phase detection done first by fitting a second order curve within a range where phase is within  $\pm 60^\circ$  and a first order curve within a 25% smaller range, both by a least squares method. The detection is accepted if the variance is below a limit determined by steepness of phase curve (larger variance for steep curves). The detection point is the zero crossing of the curve with least variance.
- In the EM 12 a search for where to do the curve fit is done in the QP values for the highest, lowest and zero value in-between.
- In the EM 1000 a search is done in the QA values for a peak, and then the range is estimated from a coarse linear curve fit to a few phase samples within the peak.
- If the phase detection is rejected, a search for a peak in QA is done, and a center of gravity calculation is done within the -10 dB values down from the maximum QA. The search in range is limited to avoid detection on multiple reflections. An amplitude detection is accepted if the echo is short enough and its amplitude is sufficiently high with respect to average bottom backscattering as determined from previous pings.
- In the EM 12 a second phase detection is performed after a successful amplitude detection (only linear curve fit) in case the first search in QP did not find the bottom.

## SECOND ROUND BOTTOM DETECTION

- Done on all beams with no detections in first round or with detections rejected by spike filter.
- Limits in range are set by the ranges in the neighboring beams with accepted detections.
- Acceptance criteria are loosened due to added confidence in predicting where the bottom is.
- As in first round a phase detection is done first (only linear fit) and an amplitude detection done only as a last resort.
- If equidistant beam spacing is used and the length over which accepted phase detection curve fits have been done are long with respect to expected beam range separations, a new phase detection (only linear fit) is performed over a limited window length.

FEMME 93  
Paris, France, 15 - 17 September 1993

Forum for EM Mutual Experience

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**SIMRAD MULTIBEAM USER CONFERENCE**

Advances in multibeam echo sounder technology

Hammerstad/Åsheim/Nilsen/Bodholt, Simrad Subsea A/S

# Advances in Multibeam Echo Sounder Technology

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## Introduction

The SIMRAD EM family of multibeam echo sounders are characterized by extremely wide swath widths with up to 190° angular coverage, high accuracy due to interferometric bottom detection, integrated sonar imaging (sidescan), and ease of operation. Continuous improvements of these systems are being made as a result of user experience and new requirements. Examples of requirements which have recently been addressed are the implementation of equidistant horizontal sounding pattern across track, and the capability of surveying all the way to the water surface along shorelines.

Simrad Subsea has in the nineties sold 7 EM 12 deep sea systems, 11 EM 1000 intermediate depth systems, and 4 EM 950 shallow water systems, in addition to the 14 EM 100 systems delivered in the eighties, thus making Simrad the major manufacturer of multibeam echo sounder systems today. Recently Simrad delivered the first commercial 1° deep sea multibeam echo sounder, the EM 121, to the US Navy. Simrad Inc., Lynnwood, WA, has received the contract for delivering the EM 121A, a modified EM 121, to the T-AGS 60.

As the multibeam echo sounder systems are maturing, the efforts of both users and Simrad are shifting towards getting more out of the data collected, i.e. to improve the postprocessing and to find novel postprocessing methods, especially in the use of the sonar image data. This shift is reflected in this paper with a major part dedicated to the new generation of the Simrad postprocessing systems for multibeam echo sounder data. This includes both real-time processing and postprocessing of the EM echo sounder data to deliver end results such as bathymetry and sonar image visualization, charts, 3D views, sonar image mosaics, and seabed classification.

## Equidistant horizontal beam spacing

Until last year, all multibeam echo sounders have used a regular beam spacing in angle. The resulting sounding pattern across the swath on the bottom is then nonuniform, with spacing increasing away from the ship track. With the typical coverage restricted to 90°, the maximum spacing ratio is only 1.4, but this increases rapidly with increasing coverage sector, to 2 for 120° (EM 12S-120) and to almost 4 for 150° coverage (EM 12D, EM 950 and EM 1000). This large variation in spacing makes the postprocessing inefficient, either requiring a restriction in accuracy or in resolution. To resolve this problem, the beam spacing of all Simrad systems was last year upgraded with a beam spacing giving a regular horizontal sounding pattern across track.

The beam spacing which gives a regular sounding pattern across track is characterized by having a constant spacing of the beams in the tangent of the beam pointing angle. As the Simrad multibeam echo sounders have their beamforming done purely in software, it was relatively easy to implement such a beam spacing. However, because it gives many tightly spaced beams in the outer parts of the coverage sector, a disadvantage is readily apparent at depths or in conditions where full coverage is not available, the number of usable beams may then drop rapidly. The solution has been to implement several coverage sectors with less angular coverage for deeper waters, and to have the echo sounder monitor the performance of the outer beams so as to always choose the optimum coverage sector. As an example, there are five different coverage sectors in the EM 12D with equidistant horizontal beam spacing, with 150°, 140°, 128°, 114° and 98° angular coverage, while only a single 150° sector was implemented with 1° beam spacing.

## **Surveying to the water surface**

Along shorelines and in rivers, the efficiency in the use of multibeam echo sounders has been restricted due to their limited swath width in shallow waters and to their incapability of surveying to the water's edge, thus requiring additional instruments such as sidescan and profiling sonars. This is due to the need for a minimum depth below the transducer and for having the transducer submerged in the water with some safety margin for vessel movements, and that the outermost beams are pointing at least 15° or more downwards. In the EM 950 and EM 1000 the recent introduction of three embankment modes (for channels and port and starboard banks) where the outer beams point 5° upwards have overcome this problem. This was done by providing the new modes with expanded transmit beam patterns, receiver beams moved upwards, and with special detection methods for the outermost beams.

When measuring up the sides of embankments, the geometry is such that although in many cases the standard Simrad interferometric phase and center of gravity amplitude bottom detection algorithms can be used, special precautions and methods have to be implemented. The major problem to be overcome is to differentiate between the seabed reflections and those that involve reflections from the water surface and multiple reflections in the very short water column. These extraneous echos come very soon after the first seabed reflection and may often be stronger.

When the bottom slope is not too steep upwards, the echo will be long and amplitude detection will automatically be discriminated against by the standard software, which does not accept amplitude detections on long echos as the resulting accuracy will be poor. Interferometric detection can be used however, although when the depth becomes too small, the phase curve describing the angle of arrival is distorted, but the standard rejection criteria will avoid detections when multiple echos start to arrive. Experience has shown that good detections are possible in such a geometry provided that the incidence angle is less than about 80°.

For steep sides the resulting echo will be too short for good phase detection (resembling the normal incidence case straight down) and the problem becomes that of discriminating a first short return from that of the longer and often stronger multiple echo coming

afterward. Such a first peak echo detector has been implemented in the software and has been seen to be working well.

## **The new EM 121**

The SIMRAD EM 121 is the first commercial multibeam echo sounder system with 1° beamwidth both in the transmitter and receiver beams. It has 121 beams with 120° coverage and a frequency of 12 kHz, and is expected to achieve a swath width of 30 km to full ocean depth with a minimum depth capability of 10 m. The transducers have 140° coverage to cater for up to 10° roll without sensitivity loss, which is achieved with a cylindrical transmitter array with 58 modules with 11 elements each, and a receiver array with 144 line hydrophones. The hydrophones each have 14 elements with a variable element spacing to reduce sidelobes.

The EM 121 is based upon the same principles as the earlier Simrad multibeam echo sounders, but the capabilities of the processing electronics have been upgraded to handle the large number of beams using DSPs instead of bit-slice processors. The use of a UNIX server with X-terminals for the operator interface and data logging is new, as is the integration of the postprocessing system with the echo sounder.

The first EM 121 was delivered on schedule to the US Navy in July this year, and will be operational shortly. It is expected that the technology of the EM 121 will be used in new Simrad multibeam echo sounders, but may also be retrofitted to existing systems. This will result in smaller systems with a larger number of measurements (beams) and better accuracy.

## **Current Simrad processing systems for multibeam data**

The Mermaid system logs raw datagrams from the multibeam echo sounder via Ethernet to disk for later processing. Mermaid controls the data storage and organizes the data into surveys and lines. These data can be moved to the postprocessing computer by tape (if the processing is done at a different site), or over a local area network. Backup is done to tape by the user when so desired.

The Neptune postprocessing system starts with the data logged by Mermaid. These data might be separated into separate files for positions, depths, etc., or logged on a single file. This is all controlled by the user operating Mermaid.

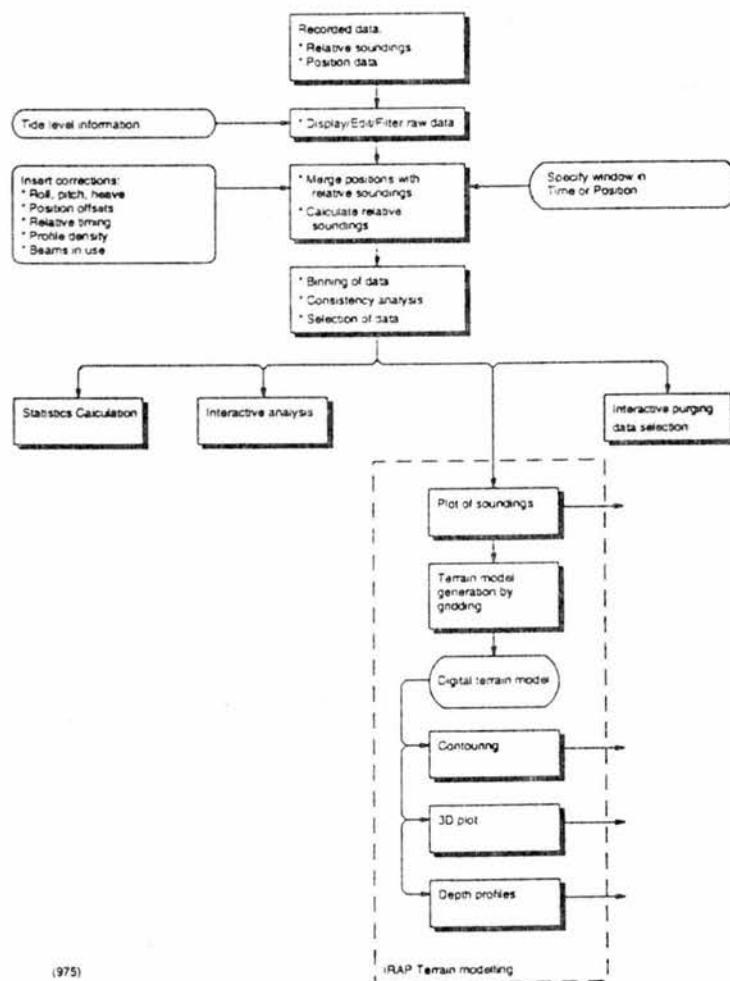
The processing is based on line by line processing, or by clustering an arbitrary number of lines into a processing set which is treated as one line further through the processing. Positions and depths are processed separately and merged together later. Figure 1 shows the flow chart of the Neptune system today.

The position processing consists of:

- Visual inspection
- Spike removal
- Smoothing
- Manual editing
- Adjusting to known position fixes
- Generation of cleaned sailing line file

Key words for depth processing are:

- Visual inspection
- Manual editing



(975)

Figure 1, Neptune-1 processing steps

As the position and depth data are merged to absolute positioned depth measurements, corrections can be done for offsets in attitude data (roll, pitch, heave and heading), in transducer position, and in timing of positions and depths, and tidal data may be added.

The merged data can be transformed into a user selected projection for further processing. The merged data contain much more information than the xyz triplets, and this is utilized in the data cleaning module of Neptune.

The data cleaning module is based on a statistical analysis of the data set. The geographical area of the data is divided into cells with a size defined by the operator. Depths from different lines and beams will in general be found in each cell, and a comparison of the depths in each cell can be used to spot erroneous data.

A statistical calculation is performed for all cells. The standard deviation (STD) of each cell is calculated with respect to a reference plane inside each cell. This reference plane is generated by a least squares method. Each point's distance to the reference plane (the residual) is also calculated. The statistical calculations result in the following statistical values for each cell:

- Shallowest measurement
- Deepest measurement
- Mean depth
- STD
- Number of depths
- Noise level (STD/mean in %)
- The nearest measurement to the plane

In addition the information of each single depth point now includes:

- The residual
- The position (X,Y,Z)
- The time of measurement
- A quality factor
- The signal strength
- The detection method (amplitude or phase)
- The ping number
- The beam number
- A status flag (active/passive)

All the statistical cell values can be presented in a colour coded display to help the operator spot trouble areas. The display of too shallow or deep values in a cell will show where spikes stand out from the surrounding data. The operator can then select the trouble area interactively for closer inspection. A dedicated tool is available for this inspection. This tool can display correlations between any two attributes of the depth points in the selected area. The user can from this tool pinpoint data to be "flagged" out of the data set. In the same way any other colour coded presentation of the cell values can be used to find trouble areas in the data set, bring them into the correlation display and edit the data set. However, the cleaning of large amounts of data can also be done by setting some criterias that the data must fulfill to be accepted. Three typical criterias which can be used are (several others are available):

- Remove all depths further from the plane than a specified multiple of the noise level
- Remove all depths outside specified depths
- Remove all depths outside specified distances from the plane of the cell.

After cleaning the data by the data cleaning module of Neptune, they are exported to the digital terrain modelling module (IRAP). Several sets of data outputs from the data cleaning module can be merged before the terrain modelling is run. The output from the digital terrain model is typically:

- Grid representation of the terrain
- Contour maps
- 3D plots
- Fair sheets
- Profiles

The IRAP digital terrain modelling module is based upon a stand alone system usually used in modelling oil reservoirs, but modified for hydrographic processing. It was chosen for Neptune due to its superiority in handling large data sets, processing speed, and the high quality of the algorithms used.

## Future Simrad processing systems for multibeam data

The Simrad processing systems have been designed based upon two important principles, making upgrades, additions and use of new technology easy:

1. The HW platform must be scalable, i.e. workstation technology.
2. The SW platform must be portable, i.e. use of UNIX, X11, Motif and C.

Thus in addition to upgrades of the two existing products described above, in the near future three new SW products for workstations will be introduced. These will deal with real time visualization (Merlin), sonar mosaicing (Poseidon), and sea floor classification (Triton).

Today's processing systems are concentrated on bathymetric data which for most users are the main activity. However, there are more data available from the Simrad multibeam echo sounders and these data are just waiting to be processed. The SW of tomorrow will include the sonar imaging data (sidescan) in the processing. Products for sonar mosaicing connected to the bathymetry will be developed as well as tools for sea floor classification.

Much efforts will still be put into the processing of bathymetric data, and the following subjects will be addressed in the Neptune-2 system (see figure 2) to be introduced at the end of this year:

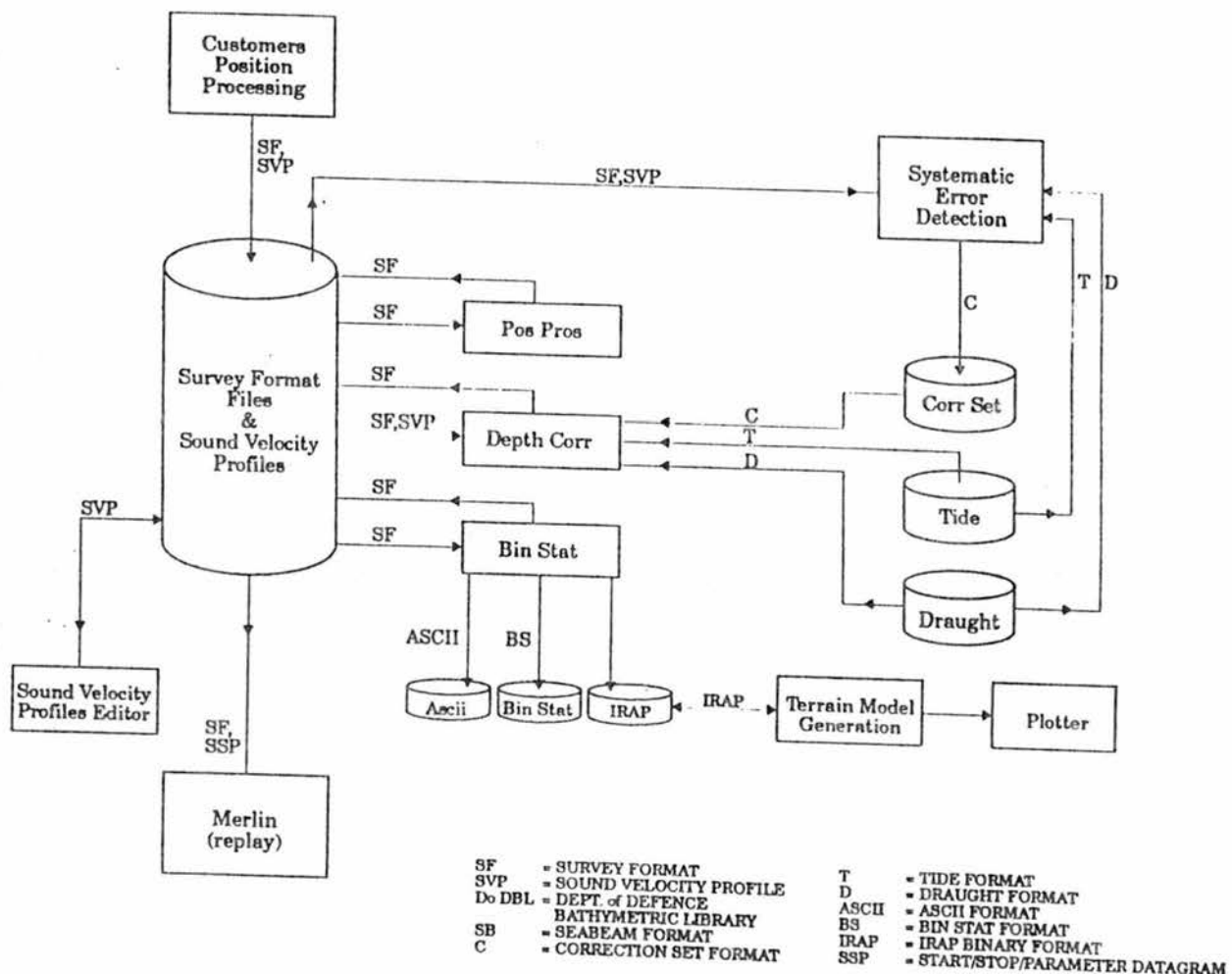


Figure 2. Neptune-2 Data Flow Diagram

- Development of tools for detection of systematic errors
- Possibility for reprocessing with revised sound velocity profiles
- Documentation of the measured error of each depth
- Change from file oriented processing to interactive "point and click"
- New methods and algorithms for data cleaning
- Modern graphic interface on all modules
- 3D visualization of selected regions
- New end products (colours, shadows, 3D, combinations)
- Real time visualisation and statistics

Real-time processing and postprocessing will be more closely integrated to decrease the time from data collection to final products. As hardware gets more and more powerful, we will see an increasing use of 2D and 3D graphics in the real-time visualization of the sea floor, real-time sonar mosaicing and sea floor classification. The Simrad system for logging and real-time visualization, Merlin, will be available late this year, and will add high quality visualization to the logging system. The "read after write" principle is followed to ensure the operator that the data has been stored on disk.

Sidescan sonar mosaicing has been done for some years, but the processing of sonar imaging data from the multibeam echo sounder is quite new. The SIMRAD EM systems tags the sonar data to its beams, and thereby to more precise positions on the sea floor. The data set is large, and so is the resulting output of the sonar mosaic processing. The processing of this kind of data is a challenge for people dealing with graphic visualisation as well as those occupied with data compression. The Simrad system for sonar mosaicing, Poseidon, will address these problems, and in addition integrate its processing with the Neptune system. The resulting end products will be sonar mosaic plots in

2D, alone or in combination with bathymetric data products such as contour plots and 3D presentations. Several methods for adjusting the backscatter level, for example taking into account seabed slopes in all directions, will be developed in addition to methods for merging overlapping lines.

In the Triton sea floor classification module, EM1000 and EM950 sonar imaging data will be utilized. The system can be trained on known sea floor areas, and use this for further processing. The system also comes with a set of calibration areas that can be used directly in the classification. The data from Triton will be integrated with the Neptune and Poseidon modules, and thus make it possible to generate combined end products from all these module.

## Conclusions

Simrad has a policy of continually improving its family of multibeam echo sounder systems in accordance with user requirements and the availability of new technology. Recently equidistant horizontal beam spacing has been introduced and the shallow water systems have been given the capability of measuring to the water's edge on shore lines. Simrad will also introduce new echo sounder systems according to market requirements, as exemplified by the new EM 121 delivered to the US Navy.

The processing of bathymetric multibeam echo sounder data is being upgraded with new capabilities such as sound velocity profile reprocessing and new and better methods for detection of systematic errors. The major challenge for the future is connected to the ability in handling the large amount of sonar imaging data, and to utilize these data to reveal new secrets of the sea floor. The two most important areas are sonar mosaicing and sea floor classification.

**SIMRAD MULTIBEAM USER CONFERENCE**

Field testing of EM 12 Dual for "l'Esperance"

H. Tonchia, EPSHOM

## **FEMME 93**

### Comments

#### Summary :

SHOM has installed an EM12 dual on board the L'Espérance a 30 year old trawler. To avoid any trouble with the VRU and the gyro, SHOM installed a SAGEM inertial platform : the MICROCIN, that costs about 2 000 000 francs. We never noticed any error in the soundings due to the VRU.

The first sea trials were held in April and May 1993. They began by a calibration as explained in the SIMRAD manual. The roll calibration was OK, we measured a  $0.05^\circ$  offset in roll. The pitch and time delay calibration gave us some headache, because we were not able to understand the results. SIMRAD discovered some bugs in the software so we were able to perform the final sea trails in June and July 1993.

We were not able to use the data from the sound velocity probe we had bought, because it was obviously wrong.

During the sea trials we performed :

- A comparison between the EM12 and a single beam echo sounder, a 13 kHz Raytheon, on a flat abyssal plane.
- A comparison between all the beam of the EM12 and a reference made with the best beams as deduced from the former comparison. The data came from a dense survey of the Biscaye sea mount, done in two direction.
- A survey of the continental slope.

The abyssal plane was surveyed in late April, the EM12 being forced in the 128° EDBS mode. We noted that there was no bias between the two echo sounders as far as the vertical data were concerned but we discovered that, statistically the bottom measured by the EM12 was shallower on the outer beams.

This bias was confirmed by the processing of the Biscaye seamount data and the continental slope data.

The problem of the shallower data on the outer beam is being solved by SIMRAD and would result from a longer transducer array than planned. Still, the bias curve shows also some deeper depths at an incidence of  $7^\circ$ , this has not yet been explained or corrected.

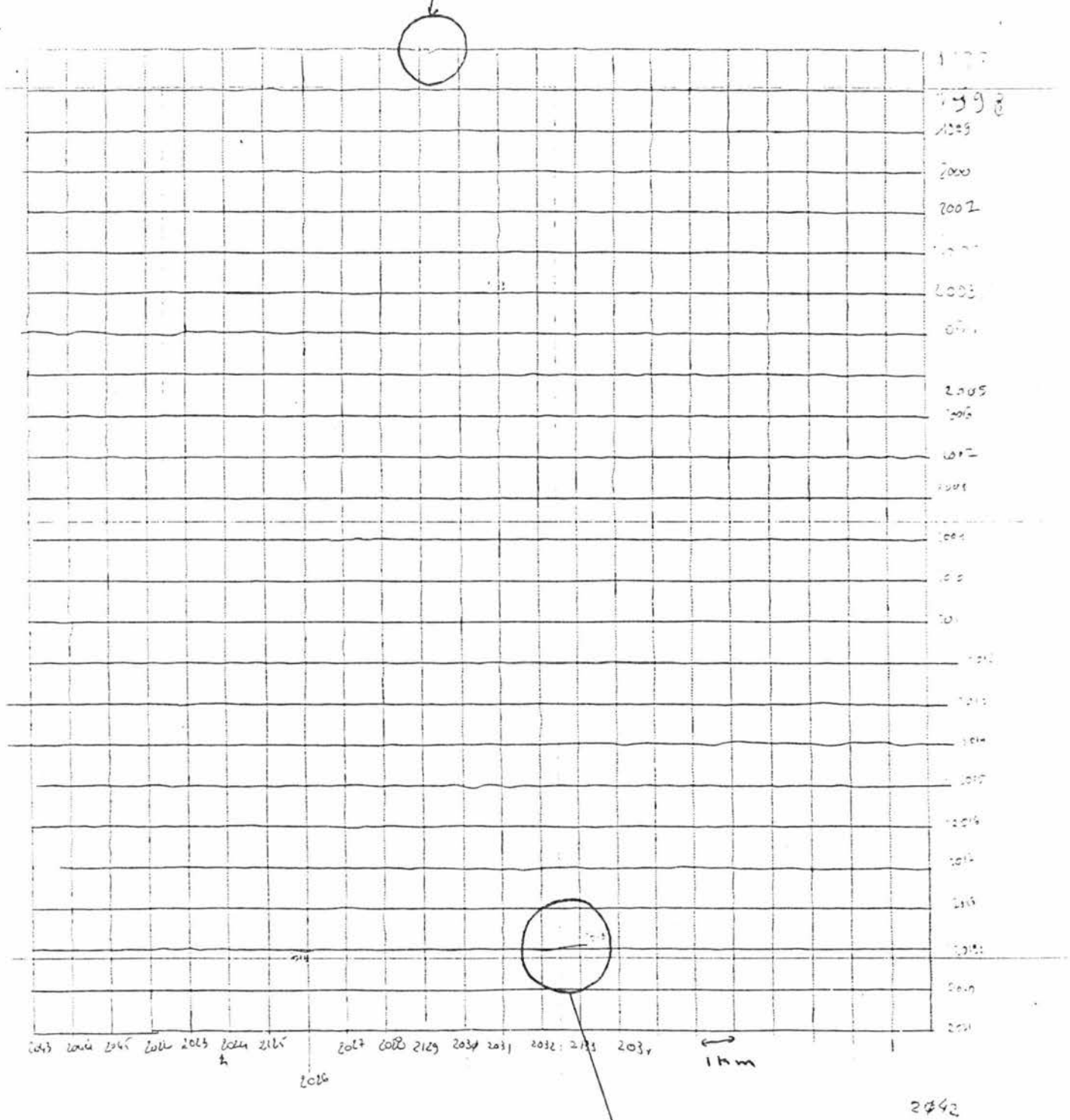
## **ANNEXE - A**

### **Real time plotss Description of the annexes**

- A-2 : Real time plot of the localisation, during the Mount Biscaye survey. the plot is only made during logging.
- A-6 : Other kind of real time plot with colour points. This plot is made continuously with a Paintjet printer. So can it serve for the control of the sounder's working during a transit. However to the request of users, the plotting is stopped during the sounder's "blanks". On the other hand loss of bottoms on groups of beams and bias appear on it. We can observe on this plot :
- a general curving : shallower bottom on the external beams,
  - two "ruts", very near from the centre, which correspond to the orange spots in the red backgrounds or yellow ones in the orange backgrounds,
  - two shoals running outside of the "ruts".

This confirms the curves of statistic bias ( see annexe D-1 ).  
The colour change appear every 20 m.

sauts GPS



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\reprise de profil

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|        |          |            |              |
|--------|----------|------------|--------------|
| 484.7  | 07:20:00 | N4554.0413 | U009857.5851 |
| 4864.8 | 07:00:00 | N4514.0347 | U009857.5804 |
| 4884.0 | 06:40:00 | N4512.0349 | U009857.5894 |
| 4867.5 | 06:20:00 | N4541.5452 | U009901.6944 |
| 4861.2 | 06:00:00 | N4542.5403 | U009907.2234 |
| 4873.4 | 05:40:00 | N4512.5771 | U009911.7924 |
| 4865.2 | 05:20:00 | N4544.5701 | U009911.9834 |
| 4852.7 | 05:00:00 | N4550.6078 | U009911.9797 |
| 4859.8 | 04:40:00 | N4554.6450 | U009912.6922 |
| 4859.8 | 04:20:00 | N4558.7336 | U009911.9864 |
| 4891.9 | 04:00:00 | N4502.8471 | U009911.9874 |
| 4882.0 | 03:40:00 | N4503.6130 | U009916.7514 |
| 4891.9 | 03:20:00 | N4503.5014 | U009922.6724 |
| 4891.9 | 03:00:00 | N4502.0643 | U009926.3757 |
| 4891.9 | 02:40:00 | N4558.0162 | U009926.3782 |
| 4891.9 | 02:20:00 | N4553.9074 | U009926.3867 |
| 4891.9 | 02:00:00 | N4550.0570 | U009926.3012 |
| 4891.9 | 01:40:00 | N4548.2190 | U009926.3782 |

Plot B1 :

This plot shows the survey of a little part of the abyssal plane. The name of the survey "zone IFREMER" comes from the fact that the nautical chart (made by SHOM) showed a perfectly flat abyssal plane in this part of the bay of Biscaye and an IFREMER chart mentioned a small seamount on our way to our next survey, so we decided to survey it.

As it is we didn't find any seamount but, as the sea floor is perfectly flat we can see the bias of the EM12, both the horns (or trenches) around the ship track and the shallower depths toward the outer beams. One can also notice the noise in the data around the track.

Plot B2 :

This is the data of a single line. The swath is 20 km wide, but the outer beams are too noisy for hydrographic standards. The bias appears along the ship track, part of the central beams noise has been removed during the post-processing.

The EM12 stopped (due to some bug) and it took a quarter of an hour for the operator to be aware of it and 5 minutes to restart it. That is why there is a wide gap.

The small gap must be due to a long ping failure.

428000E  
4067000N

ZONE IFREMER (BIAIS NON CORRIGE)

484000E  
4067000N

9:20

9:00  
470000

46:00 4050000

4050000 46:00

45:40

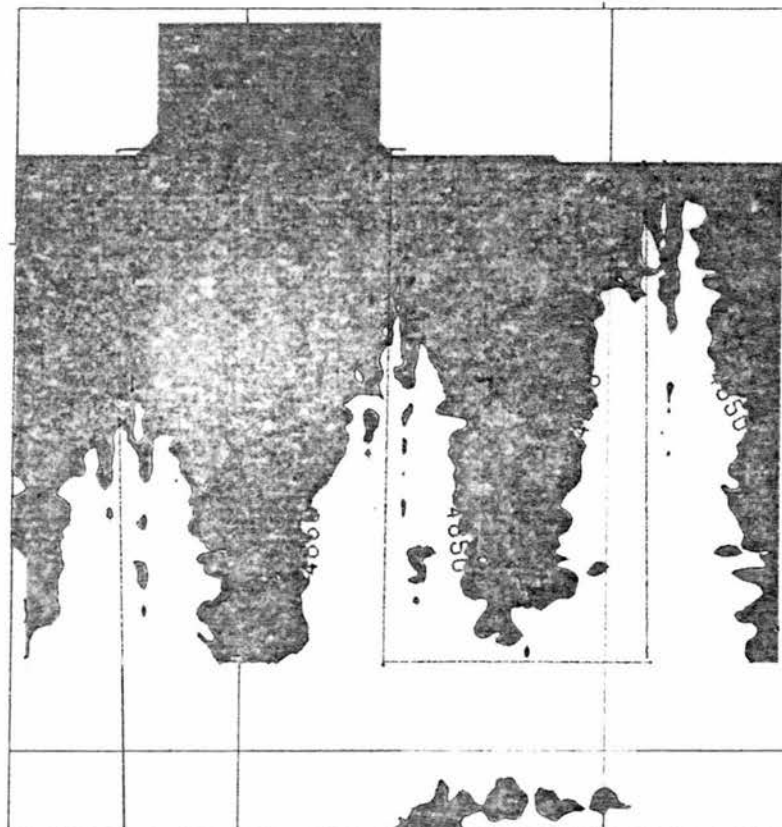
45:40

428000E  
4008000N

9:20

470000  
9:00

484000E  
4008000N



the ship position.

( 132

TRANSIT DU 280693 (BIAS NON CORRIGE . OUVERTURE 140)

475000E  
4132000N

693500E  
4132000N

475000E  
4132000N

8:00

7:00

570000

670000

46:30

46:30

46:00

46:00

475000E  
4047500N

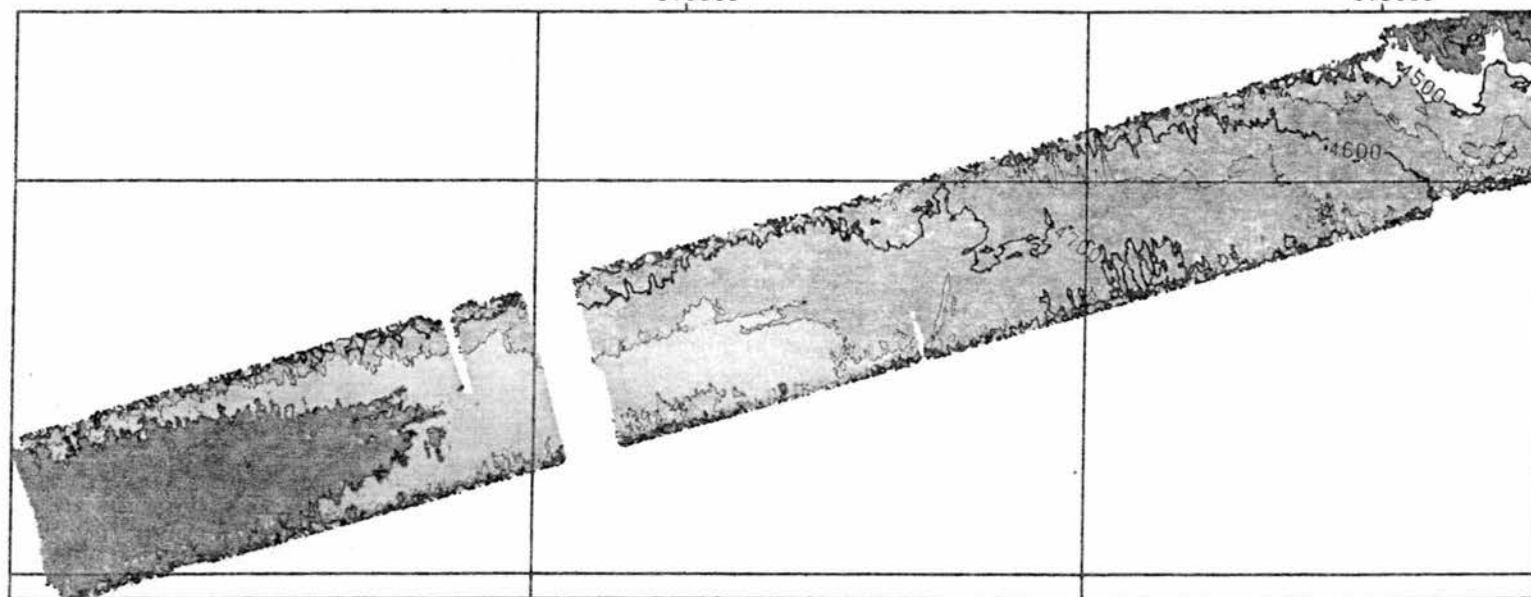
693500E  
4047500N

8:00

7:00

570000

670000



## **ANNEXE - C**

### **Detection ( operator's monitor ) Description of the annexes**

All the annexes which are following are screen dumps of the operator's monitor. This screen is made of two windows on the left part and of one on the right part.

The window on the left top always shows the soundings of the last ping, drawn according to their distances from the ship's axle. The right window contains the menus in its top part and various information in its bottom part.

The window on the left bottom can show :

- the depth of a beam according to time ,
- the celerity graph ,
- the detection window ,
- the " echogramm" of a beam : it is a kind of sound

graph representation, abscissa represent time and ordinates give the signal's energy according to time, in the detection window.

- C-1 : Working of the sounder with 1 degree beam spacing. We can observe in the top part of screens the layout of the soundings on the seabed, when beams are spread every degree. We get a very high density in the centre. We also notice, near the centre, two "ruts" which also appear in the curves of statistic bias ( see annexe D-3 ). The bottom parts of screens represent the amplitude signal and the phase curve of the starboard beam nr 3. Here we have a detection by phase.
- C-2 : Working of the sounder in the EDBS mode , 140° opening. Soundings are regularly spread. We still notice the presence of the ruts in the centre's neighbourhood .We see in the window right at the bottom that no detection has been made with the starboard beam nr 30. It seems that the pre-detection window was not correctly positioned.
- C-4 : Noise of detection : noise is high concerning the most lateral beams but also a group of beams near the vertical. The upper screen shows, in its lower window, the sounding according to time, detected by the beam nr 81 ( central - see black spot on the upper graph), while the lower screen shows the beam nr 73. We notice the remarkable increase of the noise for this last beam, increase which also appears in the mean deviation curves ( see annexe D-7 ).

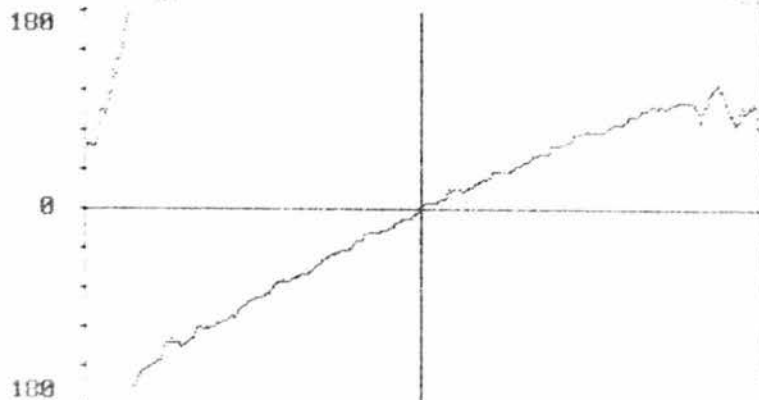
11000m

OP.UNIT 93/06/23 13:46:12

## GRAPHIC MENU

- C.1 -

BEEPER ON  
 DISPLAY SCOPE  
 PRINTER **HARDCOPY**  
 BEAM-NUMBER S 30  
 ATHWART PROFILE  
 ALONG-TR.PROFILE  
 SOUND-VELOCITY  
 ECHOGRAM  
 STAVE



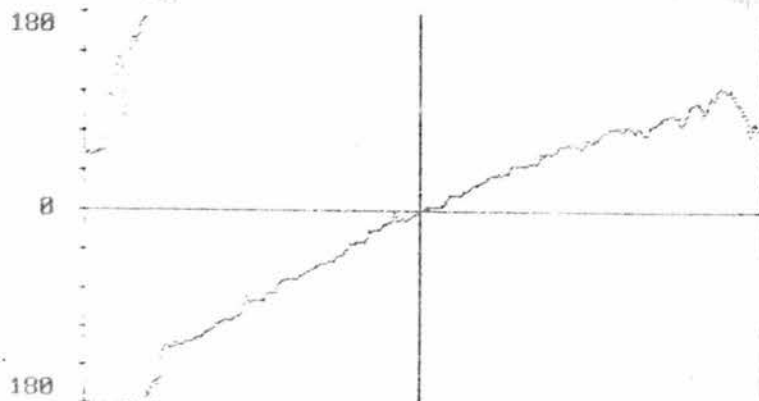
Depth: 4827.80 m  
 Width: 22006.00 m  
 Heave: 0.06 m  
 Roll: 0.97 dg  
 Pitch: 0.14 dg  
 Td.Tilt: 0.00 dg  
 Gyro: 178.4 dg  
 Td.Sound Vel: 1510.6 m/s  
 Lat: N 45 54.7749 dg  
 Lon: W 009 51.9969 dg

11000m

OP.UNIT 93/06/23 13:21:52

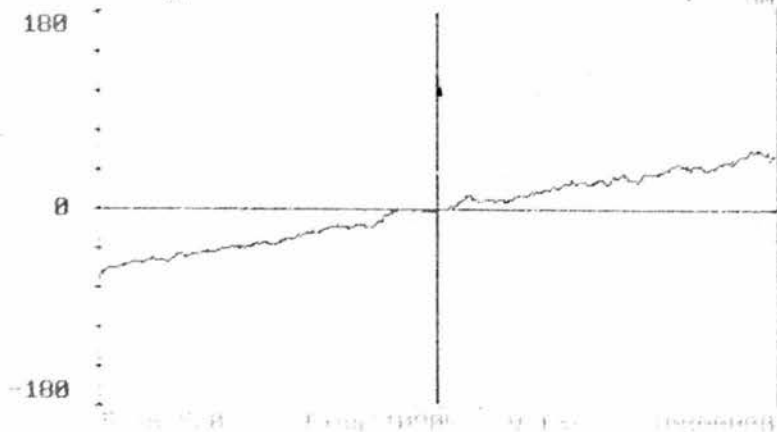
## GRAPHIC MENU

BEEPER ON  
 DISPLAY SCOPE  
 PRINTER **HARDCOPY**  
 BEAM-NUMBER S 30  
 ATHWART PROFILE  
 ALONG-TR.PROFILE  
 SOUND-VELOCITY  
 ECHOGRAM  
 STAVE



Depth: 4820.80 m  
 Width: 22402.00 m  
 Heave: 0.04 m  
 Roll: -1.58 dg  
 Pitch: 0.94 dg  
 Td.Tilt: 0.00 dg  
 Gyro: 177.8 dg  
 Td.Sound Vel: 1510.1 m/s  
 Lat: N 45 59.3016 dg  
 Lon: W 009 51.9790 dg

-11000m



OP.UNIT 93/06/23 11:54:32

GRAPHIC MENU

BEEPER ON  
DISPLAY SCOPE  
PRINTER HARDCOPY  
BEAM-NUMBER S 30  
ATHWART PROFILE  
ALONG-TR.PROFILE  
SOUND-VELOCITY  
ECHOGRAM  
STAVE

Depth: 4831.80 m  
Width: 22102.50 m  
Heave: -0.88 m  
Roll: 2.08 dg  
Pitch: 1.07 dg  
Td.Tilt: 0.00 dg  
Gyro: 89.9 dg  
Td.Sound Vel: 1510.0 m/s  
Lat: N 45 55.0850 dg  
Lon: W 009 47.2778 dg

-10000m



OP.UNIT 93/06/23 11:45:25

GRAPHIC MENU

BEEPER ON  
DISPLAY SCOPE  
PRINTER HARDCOPY  
BEAM-NUMBER S 30  
ATHWART PROFILE  
ALONG-TR.PROFILE  
SOUND-VELOCITY  
ECHOGRAM  
STAVE

Depth: 4829.60 m  
Width: 20727.00 m  
Heave: -0.40 m  
Roll: 0.10 dg  
Pitch: 0.60 dg  
Td.Tilt: 0.00 dg  
Gyro: 88.7 dg  
Td.Sound Vel: 1509.9 m/s  
Lat: N 45 55.0866 dg  
Lon: W 009 49.5928 dg

-13888m

OP.UNIT 93/06/28 14:54:26

GRAPHIC MENU

BEEPER ON  
 DISPLAY ALONG TR  
 PRINTER HARDCOPY  
 BEAM-NUMBER 81  
 ATHWART PROFILE  
 ALONG-TR.PROFILE  
 SOUND-VELOCITY  
 ECHOGRAM  
 STAVE

Depth: 4699.60 m  
 Width: 23153.00 m  
 Heave: 0.00 m  
 Roll: -0.93 dg  
 Pitch: 0.23 dg  
 Td.Tilt: 0.00 dg  
 Gyro: 75.9 dg  
 Td.Sound Vel: 1512.3 m/s  
 Lat: N 46 24.7793 dg  
 Lon: W 007 09.1541 dg

-13888m

OP.UNIT 93/06/28 14:03:53

GRAPHIC MENU

BEEPER ON  
 DISPLAY ALONG TR  
 PRINTER HARDCOPY  
 BEAM-NUMBER 73  
 ATHWART PROFILE  
 ALONG-TR.PROFILE  
 SOUND-VELOCITY  
 ECHOGRAM  
 STAVE

Depth: 4724.00 m  
 Width: 22840.50 m  
 Heave: -0.14 m  
 Roll: 0.59 dg  
 Pitch: 0.53 dg  
 Td.Tilt: 0.00 dg  
 Gyro: 75.8 dg  
 Td.Sound Vel: 1511.4 m/s  
 Lat: N 46 21.8595 dg  
 Lon: W 007 23.8305 dg

## **ANNEXE D**

### **Curves of bias and mean deviation Description of the annexes**

#### **Curves of bias**

Comparisons between curves are made with the same incidence and as soundings are regularly spread along the ground, we get a good image of the bottom. The numbers on the bottom of the plots refer to the beam numbers in the EDBS mode with the narrower opening. The numbers on the upper part refer to the beam number in the wider mode.

- D-1 : Curves of intervals are got for deep flat bottoms ,with the modes 128° and 140° ,left sounder.
- D-2 : Idem ,right sounder.
- D-4 : This one show the curves compute from the 140° opening data and from two lines surveyed in the good old 1° mode. The data of the 1° spaced beam mode has been processed so as to be compared at the same incidence.
- D-7 : Comparison between curves of intervals of the Mount Biscaye ( 128° ) and of the abyssal plain (140°), left sounder.
- D-11 : Comparison between the results of the sounders of the "Atalante" and the "L'Espérance" for various bottoms.

Translations of annotations :

D-1 :

Comparison April 128 dg and June 140 dg / April Raytheon  
( April '93 - June '93 )

Mean depth : 4820 m  
Thick line : Deep bottoms ,128 °  
Sounding zone : Deep flat bottoms ,abyssal plain  
Mode : 140° and 128°

Port beams ' numbers.

23th of July 1993 sailing.

D-2 :

Comparison April 128 dg and June 140 dg / April Raytheon  
( April '93 - June '93 )

Mean depth : 4820 m  
Thick line : Deep bottoms ,128 °  
Sounding zone : Deep flat bottoms ,abyssal plain  
Mode : 140° and 128°

Starboard beams ' numbers.

23th of July 1993 sailing.

D-4 :

Comparison April 150-1 dg and June 140 dg / April Raytheon  
( April '93 - June '93 )

Mean depth : 4820 m  
Thick line : Deep bottoms ,150 ° mode 1°  
Sounding zone : Deep flat bottoms ,abyssal plain  
Mode : 140° and 150° ( 1° )

Starboard beams ' numbers  
( beam 30 = incidence 60 ° )  
( beam 51 = incidence 45 ° )

20th of July 1993 sailing.

D-7 :

Comparison deep flat bottoms 140 dg / Mount Biscaye 128 dg  
( June '93 - July '93 )

Mean depth : 3100 m and 4820 m  
Thick line : Mount Biscaye ,128 °  
Sounding zone : Deep flat bottoms and Mount Biscaye  
Mode : 140° and 128°

Port beams ' numbers

20ht of July 1993 sailing.

D-11 :

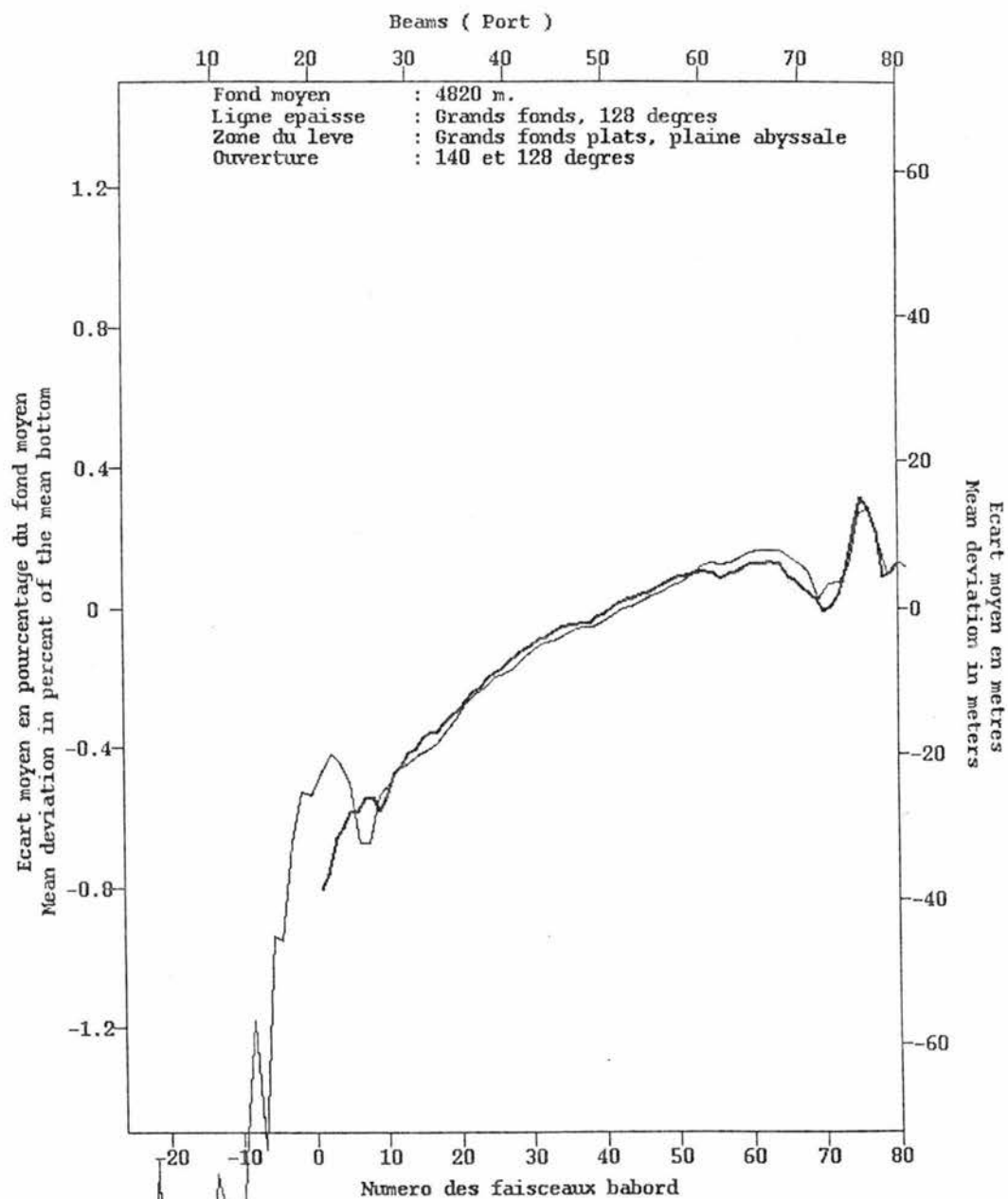
Mount Biscaye : drawing of the mean deviation curves according to the  
aperture in dg

Mean depth : 3100 m ( large line )  
Thin line : "Atalante" curves provided by SIMRAD ( depth : 2850 m )  
Sounding zone : Mount Biscaye  
Mode : 128 dg

Port beam incidence in degrees

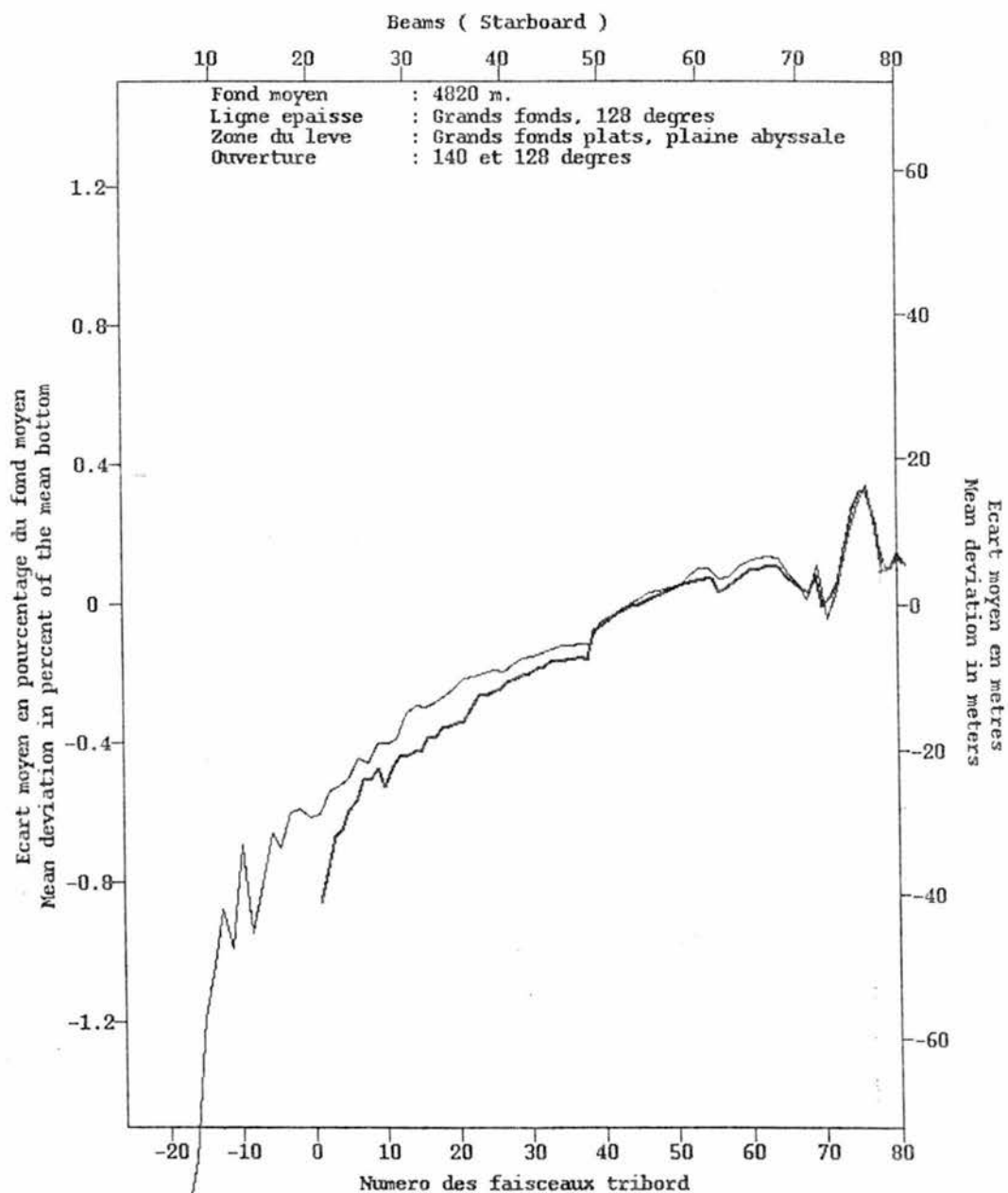
26th of July 1993 sailing.

Comparaison avril 128 deg et juin 140 deg / Raytheon d'avril  
( avril 93 - juin 93 )



Sortie du 23 juillet 1993.

Comparaison avril 128 deg et juin 140 deg / Raytheon d'avril  
( avril 93 - juin 93 )



Sortie du 23 juillet 1993.