

EM 120 Multibeam Echosounder

The EM 120 multibeam echosounder from Kongsberg was used for bathymetric surveying. The system has an operating frequency of 12 kHz, suitable for deep ocean waters, and 191 beams, producing a maximum area coverage per swath of 25 km. The transducer system comprises one projector array, which is mounted along the ships keel line, and a separate receive array, which is mounted in the athwart ship direction.

Survey data were acquired and visualized in real time using Kongsberg's multibeam echosounder software Seafloor Information System (SIS), figure 1 shows a screenshot of the software.

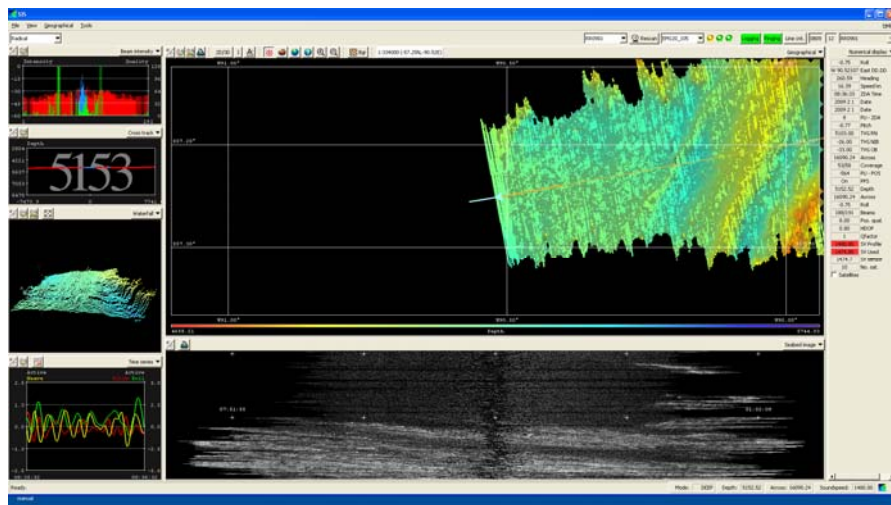


Figure 1: Seafloor Information System was used to visualize survey data in real time

Low quality data were encountered during parts of the cruise (figure 2). These low quality data were attributed to bubbles originating at the sea surface and drawn under the hull along flow lines. Bubbles generate noise which can cause reception problems, but they also absorb acoustic energy which can affect signal transmission as well.

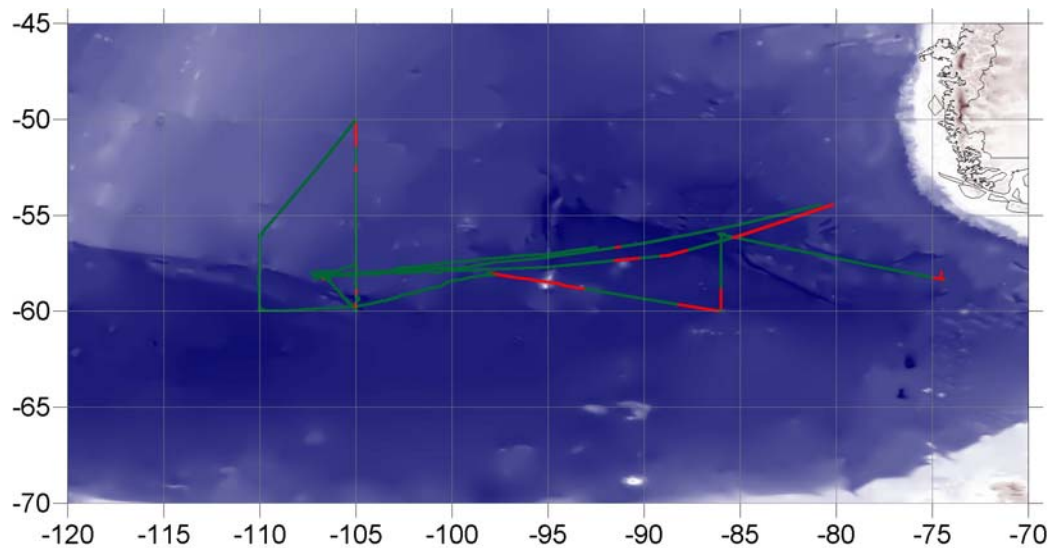


Figure 2: Map of R. Revelle cruise track. Sections in green (red) indicate good (bad) quality of multibeam data, sections in yellow indicate the site of an event (CTD station, mooring, tracer area, etc) and sections in black show missing data.

There are two fundamental sound speed measurement inputs into multibeam sonar systems. These are the speed of sound at the keel of the ship in the vicinity of the sonar array, and the profile of sound speed in the water column. The former is used in the sonar's beam forming while the latter is used more directly in the bathymetry calculations. The sound speed at the keel of the ship, local to the array, affects the directivity of the beams produced by the sonar. The result is that the sonar is not exactly looking in the expected direction, introducing considerable error. Sound profiles of the water column, estimated with expendable bathythermographs, were regularly uploaded to the data acquisition system in order to minimize the error.

Survey data were processed with the open-source package MB-System (<http://www.ldeo.columbia.edu/res/pi/MB-System/>). A brief description of the processing steps is given below. Tables 1 and 2 at the end of the section give details of the processed files and the structure of the directory "em120_processed".

1. Data format conversion

The data format of EM120 Simrad multibeam is supported by MB-System as format 56. Since this data format does not store beam flags, the only choice during the processing is to null the flagged beams. This precludes unflagging flagged beams later determined to be good. Also, the raw EM120 format has no space to store the rebinned sidescan, so any corrections or other processing applied to the sidescan is lost. To overcome these restrictions, the raw data format was converted to a native MB-System format (id 57) using the *mbcopy* command.

```
> mbcopy -F-1 -I input_filename.all -O output_filename.mb57
```

2. Generation of filename list for batch processing

The command *mbdatalist* is used to create the list of files to be processed. The filenames contained in the list are usually constrained to geographic boundaries of interest.

```
> ls | grep .all$ > list0  
> mbdatalist -F-1 -I list0 > list1
```

3. Ancillary data

The next step is the generation of ancillary data files. Three types of files are created for each data file. The info files (.inf suffix) contains meta-data and statistics (geographic, temporal and depth bounds, ship track information, and numbers of flagged or zero beams). The fast bathymetry (.fbt suffix) and fast navigation (.fnv suffix) files contain bathymetry and navigation data, respectively, in a format that can be read and processed by the MB-System package. These files are created using *mbdatalist* with the following syntax:

```
> mbdatalist -F-1 -I list1 -N -V
```

4. Automatic bathymetry editing

The command *mbclean* flags bad beams in swath sonar bathymetry data. Simple artifact detection algorithms are applied to the bathymetry before manual edition. The locations of beams are estimated using the navigation and heading of the ship. Ship turns often cause beams of adjacent pings to overlap, causing the distances between these beams to become quite small. This can, in turn, magnify noise in the bathymetry data to produce slope estimates which are excessively large. The applied algorithms are an attempt to automatically identify and flag these anomalous beams. The -D option sets the minimum and maximum allowed distances between beams. Both values are expressed in terms of fractions of the local median depth. Thus, -D0.01/0.20 indicates a minimum distance of 10 meters and a maximum distance of 200 meters for a local median depth of 1000 meters. The -C option specifies the maximum acceptable slope. If no units are specified then the default units are used (tangents). The -M2 option indicates that both beams associated with excessive slopes will be flagged. Therefore -C3.0 and -M2 will flag all beams associated with slopes greater than 70 degrees, approximately. The -G option sets the range of acceptable depth values relative to low and high fractions of the local median depth. The median depth is obtained from the current ping and the pings immediately before and after that ping. Then, for -G0.70/1.30, all depth values less than 0.7 times the median depth or more than 1.3 times the median depth will be flagged. For the options describe above, *mbclean* is invoked with the following syntax:

```
> mbclean -F-1 -I list1 -M2 -C3.0 -D0.01/0.20 -G0.70/1.30 -V
```

5. Manual bathymetry editing

The command *mbedit* is an interactive editor used to identify and flag artifacts in swath sonar bathymetry data. It is used after *mbclean* for manual inspection and removal of possible bad data not detected with automatic algorithms. To open a file for inspection the command is invoked with the following syntax:

```
> mbedit -I filename.mb57
```

6. Processing of swath bathymetry data

The previous steps have automatically created or edited the parameter files (file extension .par) to identify what options are to be applied to the sonar data. The command *mbprocess* uses these parameters to complete the final step of applying the changes to the data. For each file to be processed (file extension .mb57) a processed file is created (suffix p.mb57). The command is invoked with the following syntax:

```
> mbprocess -F-1 -I list1
```

7. Generation of processed filename list for gridding

Analogous to step 2, the command *mbdatalist* is used to create the list of processed files.

```
> ls | grep p.mb57$ > list2  
> mbdatalist -F-1 -I list2 > list3
```

8. Gathering information of processed files

The command *mbinfo* reads a swath sonar data file or files and outputs information about the files with some basic statistics. In particular it displays the geographic bounding box of the data, useful for the generation of the gridded data. Also reported are the numbers and percentages of good, zero, and flagged data values (good values are those which are neither zero nor flagged as bad). The command can be invoked using the following syntax:

```
> mbinfo -F-1 -I list3
```

9. Gridding

The command *mbgrid* is used to grid bathymetry data contained in a set of swath sonar data files. A weighted average gridding scheme is used. The weighting function is given by:

$$W(r) = A e^{-r^2 a^{-2}}$$

Where r is the distance from the center of the grid point to the data point, a is the distance at which the weighting function falls to e^{-1} of its maximum value, and A is a normalizing factor set so that the sum of all the weights adds to a value of 1. The grid is generated in geographic coordinates using the WGS84 horizontal datum. Grid spacing and geographic boundaries are specified with the options `-E` and `-R` respectively. The output file is in GMT netCDF 4-byte float format. The following syntax is used to invoke the command:

```
> mbgrid -I list3 -E150/0/m! -R west/east/south/north  
> ./list3.cmd
```

10. Conversion of GMT netCDF to Arcview ASCII

Gridded data in GMT netCDF format are converted to ASCII format using the `mbm_grd2arc` command. The command is invoked with the following syntax:

```
> mbm_grd2arc -I input.grd -O output.arc
```

Plotting of processed data was made with Surfer. Figures 3 to 5 show examples of the processed bathymetric data, additional figures can be found at `/em120_processed/plots`.

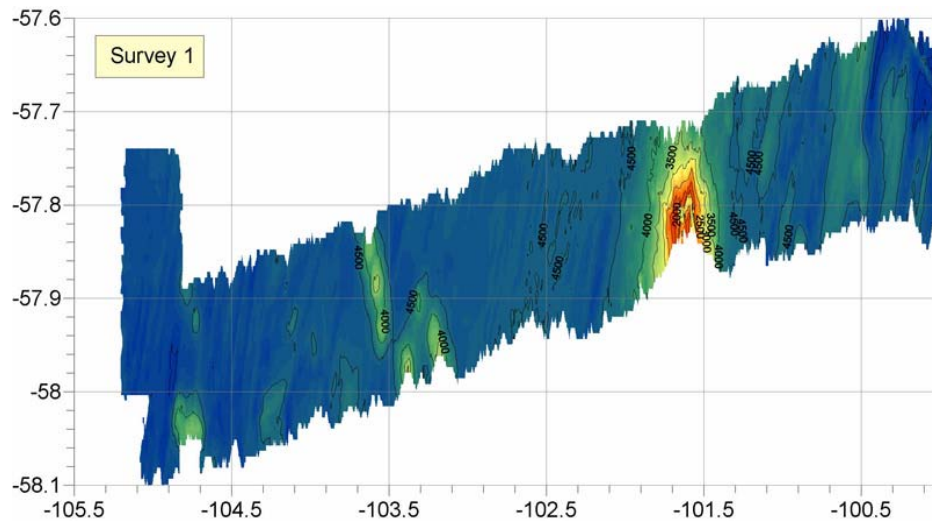


Figure 3: Processed data with MB-System software. Example of Contour gridding.

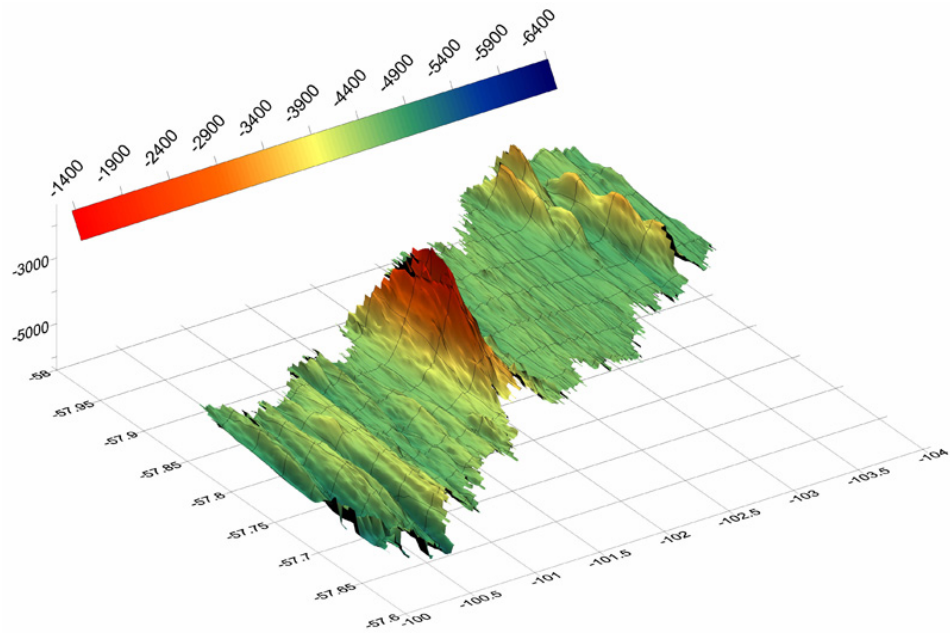


Figure 4: Processed data with MB-System software. Orthographic view (same domain as figure 3).

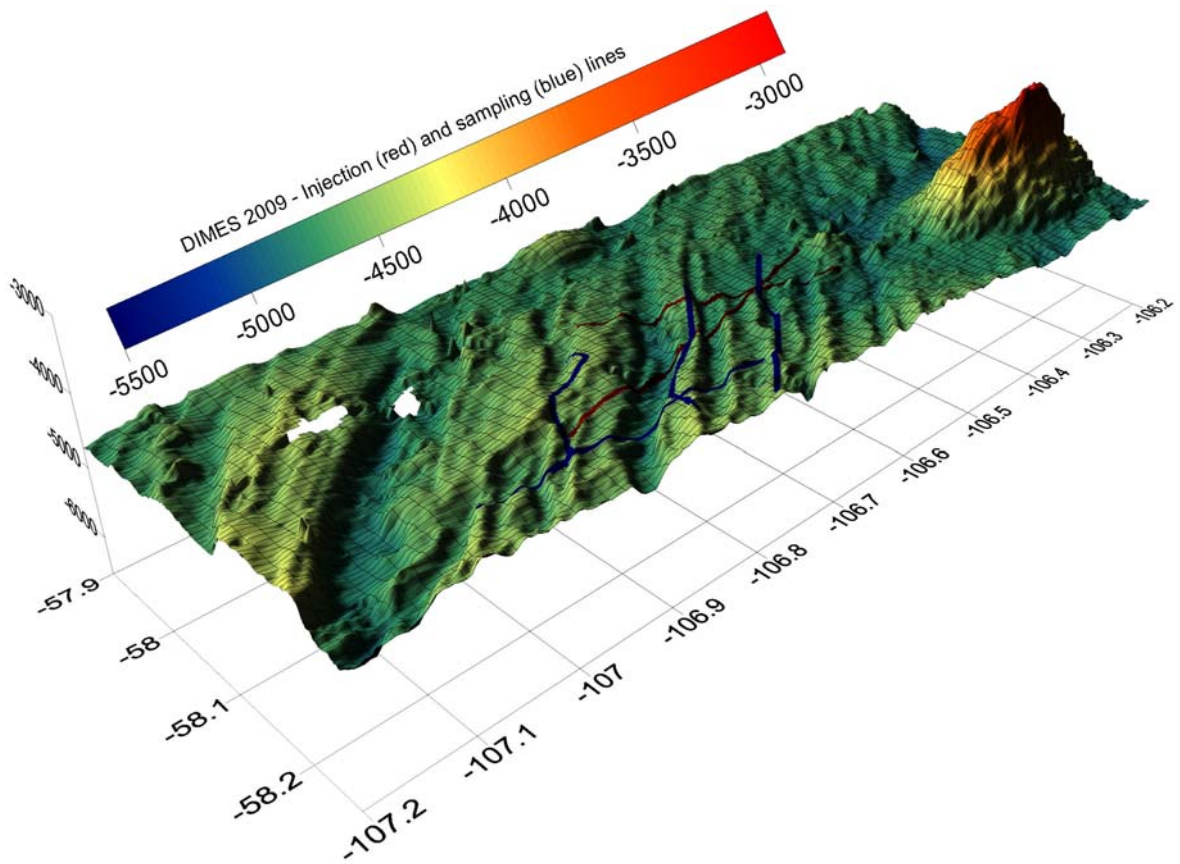


Figure 5: Orthographic view of tracer injection area

Begin		End		Directory	Description
Index	Date	Index	Date		
3	1/12/09 9:40	14	1/12/09 15:05	/data/moorings/#1	mooring #1
15	1/12/09 15:06	82	1/14/09 0:39	/data/s01	transit mooring #1 - #2
83	1/14/09 0:40	112	1/15/09 3:03	/data/moorings/#2	mooring #2
113	1/15/09 3:04	153	1/15/09 23:33	/data/s02	transit mooring #2 - #3
154	1/15/09 23:34	169	1/16/09 5:38	/data/moorings/#3	mooring #3
170	1/16/09 5:39	247	1/17/09 19:40	/data/s03	transit mooring #3 - #4
248	1/17/09 19:41	261	1/18/09 2:17	/data/moorings/#4	mooring #4
262	1/18/09 2:18	291	1/18/09 17:17	/data/s04	transit mooring #4 - #5
290	1/18/09 17:18	303	1/18/09 23:17	/data/moorings/#5	mooring #5
304	1/18/09 23:18	388	1/20/09 17:47	/data/s05	transit mooring #5 - #6
389	1/20/09 17:48	399	1/20/09 23:17	/data/moorings/#6	mooring #6
400	1/20/09 23:18	463	1/22/09 7:30	/data/s06	transit mooring #6 - CTD line
464	1/22/09 7:47	625	1/25/09 16:17	/data/CTD	CTD line - part 1
626	1/25/09 16:18	747	1/28/09 4:59	/data/s07	transit CTD line - EEZ
748	1/31/09 1:48	897	2/3/09 4:47	/data/s08	transit EEZ - Injection site
898	2/3/09 4:48	1269	2/11/09 6:34	/data/injection	Injection/Sampling site
1270	2/11/09 6:35	1303	2/11/09 23:33	/data/s09	transit Injection site - CTD line
1304	2/11/09 23:34	1373	2/13/09 10:34	/data/CTD	CTD line - part 2
1374	2/13/09 10:35	1386	2/13/09 17:04	/data/s10	transit CTD line - Injection site
1387	2/13/09 17:05	1655	2/19/09 8:15	/data/injection	Injection/Sampling site
1656	2/19/09 8:16	1815	2/22/09 15:49	/data/s11	transit Injection site-EEZ

Table 1: Details of processed files sort by task

subdirectory	description
/data/.../ancillary	Ancillary data of processed files sort by event (see table 1)
/data/.../raw_id57	Raw data in MB-System format (see processing steps) sort by event (see table 1)
/data/.../processed	Processed files sort by event (see table 1)
/output_ascii	Grid Bathymetry in ASCII format sort by event (see table 1)
/output_netcdf	Grid Bathymetry in netcdf format sort by event (see table 1)
/plots	Plots of selected areas
/scripts	Scripts (matlab and bash)

Table 2: Contents of directory /em120_processed