CHRISTOPH WARMBRUNN, ANDREAS THOSS
Techniche Fachhochschule «Georg Agricola», Germany

BATHYMETRIC MEASUREMENTS FOR THE INSTALLATION OF THE TSUNAMI EARLY WARNING SYSTEM IN THE INDIAN OCEAN

The article describes a concept for a tsunami early warning system (TEWS) which is developed in collaboration with Indonesia as well as bathymetric measurements for installation of this system in the Indian Ocean.

Описывается концепция системы заблаговременного предупреждения о приближении цунами, разрабатываемой совместно с Индонезией, а также батиметрические замеры для установки данной системы в Индийском океане.

The tragic loss of human life caused by the December 2004 tsunami has proven mankind's high degree of vulnerability in the face of natural disasters. Aware of the fact that such disasters cannot be prevented entirely, Germany has committed itself to making a contribution to mitigating the effects of future tsunamis in the Indian Ocean. In collaboration with Indonesia, and as a contribution to the regional tsunami early warning system under the patronage of UNESCO's Intergovernmental Oceanographic Commission (IOC), Germany will implement an early warning system for Indonesia The German Federal Ministry for Education and Research commissioned the "Helmholtz Association of National Research Centres" to develop a concept for a tsunami early warning system (TEWS) for the Indian Ocean which later could also be implemented in the Mediterranean and in the Atlantic Ocean. The high-tech project which cost some 45 million euros ($52 million) is headed by the Potsdam-based Geo Research Center along with half a dozen other German research institutes. The German systems basically works on the principle, that pressure sensors embedded in the ocean bed record every giant wave and every shudder of a seaquake via buoys and satellites to tsunami alarm centers on the coast (Fig.1) There the data is processed and the population alarmed if there is a grave risk. A pressure recorder on the sea bed measures the weight of the water above it – which varies according to wave height - and sends its findings to a buoy on the surface. The buoy monitors the surface conditions and sends this, plus the data from the sea bed, to a satellite which relays it back to a receiving station. The TEWS brings together an intricate mix of cutting-edge technologies, consisting of seismometers, GPS equipment, marine buoys, tide gauges and satellite observation. In all, 10 German buoys will be installed off Indonesia between Bandah Aceh and Bali over the next three years. At the same time, seismometers and coastal tidal gauges will also be set up (*Möller*, 2005). Before the begining of laying out the first two buoys and the installation of the whole system a lot of basic research had to be done. Most important for the TEWS is to detect the perfect location for the Ocean Bottom Units (OBU) and for the buoys. The expedition SO186 on the Research Vessel

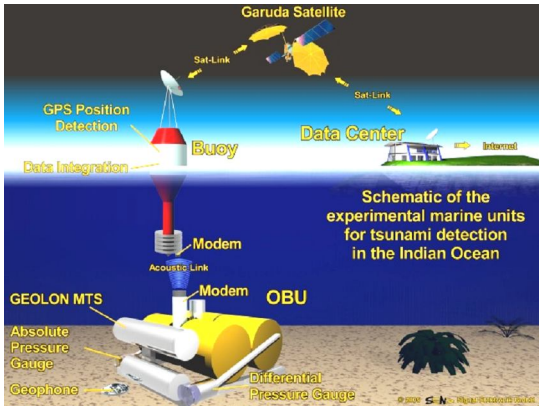


Fig.1. The system of the TEWS



Fig.2. Research Vessel “Sonne”

Sonne (Fig.2) was responsible for this part of the development. The analysis of the seafloor structure with multi beam echo sounders is part of the field of bathymetric measurement. Bathymetry \Ba*thym"e*try\, n. [Gr. ba`qos depth + -metry.], the art or science of sounding, or measuring depths in the sea. The basic measurement of most sonar systems is the time it takes a sound pressure wave, emitted from some source, to reach a reflector and return. The observed travel time is converted to distance using an estimate of the speed of sound along the sound waves travel path. On the RV Sonne a multi beam echo sounder from the company Kongsberg, Trondheim is installed. The sonar sends sound waves called “pings”. The nominal sonar frequency is 12 kHz with an angular coverage sector of up to 150 degrees and 191 beams per ping (Fig.3 and Fig.4) Achievable swath width on a flat bottom will normally be approximately 5,5 times the water depth (*EM 120 Operator Manual*, 2002). To give an idea of the performance, that can be achieved, here are some facts:

In a water depth of 4.000 m:

• the sonar covers profiles with up to 22.000 m

• one footprint of one beam is 20.000 m² large

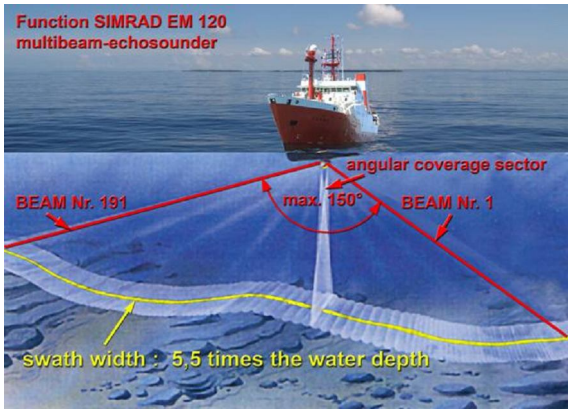
• 4.000 km² covered seafloor per day

What else is important about multi beam echo sounding. The speed of sound in sea water is roughly 1500 meters/second. However the speed of sound can vary with changes in temperature, salinity and pressure. These variations can drastically change the way sound travels through water, as changes in sound speed between bodies of water, either vertically in the water column or horizontally across the ocean, cause the trajectory of sound waves to bend. Therefore, it is imperative to understand the environmental conditions in which sonar data is taken. The speed of sound increases with increases in temperature, salinity and pressure. Although the relationship is much more complex, to a first approximation, the following table provides constant coefficients of change in sound speed for each of these parameters. Since changes in pressure in the sea typically result from changes in depth, values are provided with respect to changes in depth.

• Change in Speed of Sound per Change in Degree C ---> + 3 meters/sec)

• Change in Speed of Sound per Change in ppt Salinity ---> + 1.2 meters/sec

• Change in Speed of Sound per Change in 30 Meters of Depth ---> + .5 meters/sec) (*MB-System Cookbook*, 2006)



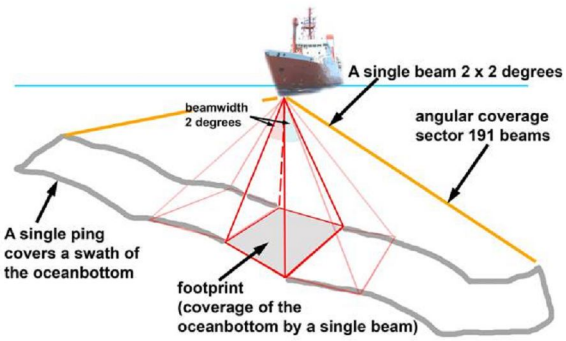


Fig.3 and Fig.4. The function of SIMRAD EM multi beam echo sounder

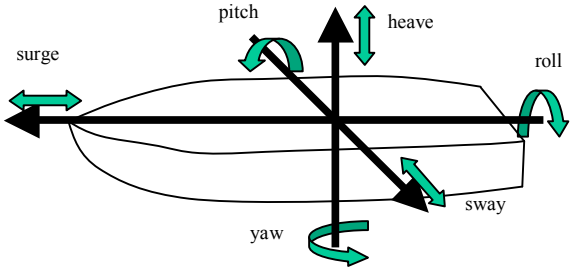


Fig.5. Motions of a ship

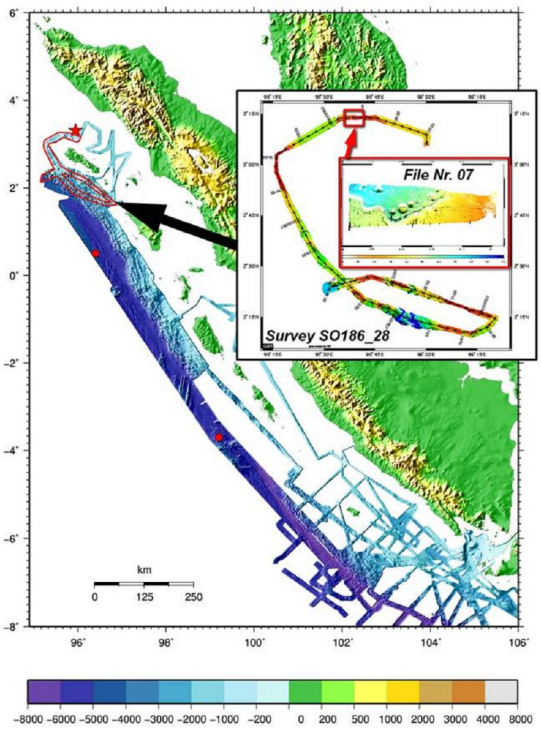


Fig.6. Bathymetric campaign

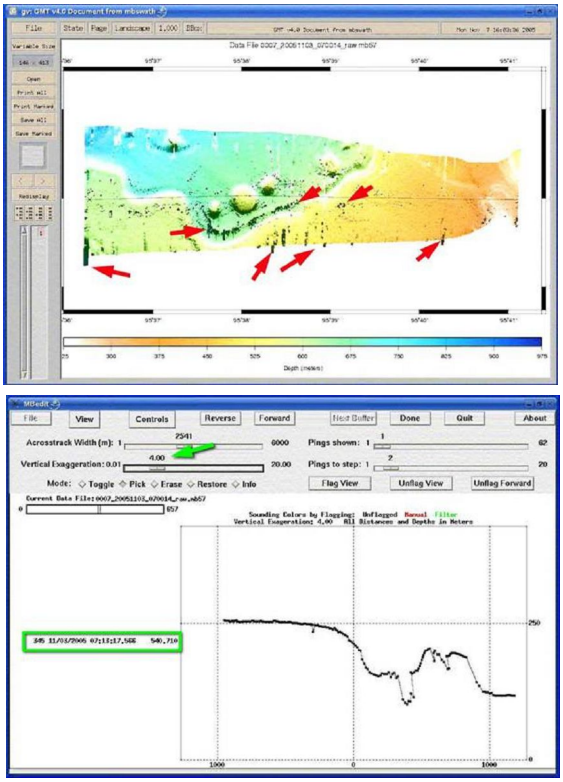


Fig.7 and Fig.8. Measurement Errors

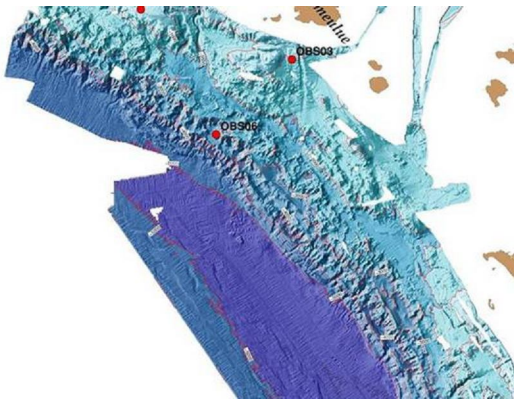


Fig.9. Digital terain model

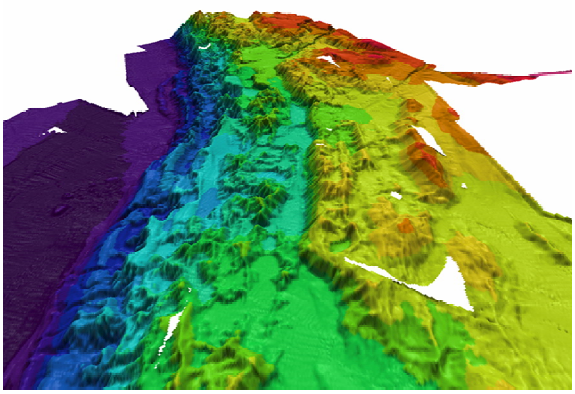


Fig.10. Program Fledermaus

Important for accurate data is the understanding of the motion of ship itself (Fig.5). There are six motions for a ship three linear and three rotational: surge, sway, heave, pitch, roll, and yaw. Surge is the linear motion fore and aft. Sway is linear motion in a sideways direction. Heave is the linear motion in a vertical direction. Pitch is rotational motion in which the bow goes down and the stern goes up, or vice versa. Roll is the sideways rotation. Yaw is rotational motion about the vertical axis. Therefore it is necessary to calibrate the ship motion sensor right before a new bathymetric campaign. Otherwise resulted data are not reliable.

How a campaign is built up and what are the results of the gained data will now be described. Every campaign consists of so called "Suryeys". Once a day a new survey is started. A survey is then splited into "Files" (Fig.6). These file have data of half an hour multi beaming. When you look further on, a file consists of single pings sent out by the sonar. As you can see in Fig.7 and Fig.8, the data has some errors. This is because of air bubbles or fishshoals, that reflect the sound waves incorrectly. All row datas have to be considered after the campaign. As a part of our diploma, we had to examine every single ping carefully. It is most important to find the real errors and correct these errors by smoothing or interpolating. The devil is in the detail! During the whole journey 60.000 pings had to be oberserved afterwards. One speak of profil orientated controll of row data. With the useful help of the MB-System program, the work can be done half-automatically. After having eliminated all errors, one can grid the data and establish a digital terrain model with Linux based GMT software (Fig.9). Therefore all datas are in the WGS84 format, it is not necessary to transform into another geodatic system. It is also possible to use the X/Y/Z coordinates for a 3D program, such as Fledermaus (Fig.10). The animated Fledermaus programm allows the viewer to fly through the terrain and gives him a perfect imgage of the seafloor structur.

SOURCES

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