DEVELOPING RAPID ENVIRONMENTAL ASSESSMENT AT NURC

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BACKGROUND

The objective of Rapid Environmental Assessment (REA) is to provide a methodology package that can be used in crisis situations to predict environmental parameters of operational interest within a tactically usable time scale. Applications include antisubmarine warfare (ASW), mine warfare (MW), and acoustic warfare (AW) operations in areas that have not been previously surveyed, or where actual knowledge is very limited.

The origins of REA lie in NATO's post-Cold War shift in military operations toward regional crisis management as described in this timeline:

- July 10, 1992. The North Atlantic Council agrees on a NATO maritime operation in the Adriatic Sea in coordination and cooperation with the Western European Union to monitor compliance with United Nations (UN) sanctions imposed on Serbia and Montenegro (UN Security Council [UNSC] resolutions 713 and 757).
- July 15, 1992. The NATO Defense Planning Committee orders NATO ships to conduct surveillance, identification, and reporting in the Adriatic Sea starting July 16, 1992.
- April 17, 1993. UNSC approves Resolution 820, strengthening previous restrictions to merchant traffic to/from the former Yugoslavia, extending enforcement to territorial waters.

These events triggered the need to have environmental information about the Adriatic Sea relevant to navy operations. During the Cold War era, the Adriatic Sea was not considered for possible NATO operations; thus, there was very limited environmental information to support NATO Maritime Forces, especially regarding mine countermeasure (MCM) operations. Mine threat was one of the main concerns due to the large mine stocks available in the Federal Republic of Yugoslavia.

Conducting NATO maritime operations outside the traditional Cold War era strategies and areas has changed the nature of environmental-data-support requirements where detailed, high-resolution data, mostly in coastal waters, are needed rapidly.

When AFSOUTH (Allied Forces Southern Europe) was tasked to conduct operations in the Adriatic Sea, the Supreme Allied Commander Atlantic (SACLANT) Undersea Research Centre

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(SACLANTCEN) was also called in to help with environmental data assessment that was especially aimed at MCM operations in the area. Lack of techniques, equipment, and procedures at that time led SACLANTCEN to initiate a new approach to REA.

In 1995, SACLANT identified REA as a new underwater warfare operational requirement. Responding to this request, the military oceanography (MILOC) group, which coordinates military oceanographic activities according to strategies that support NATO's operations and exercises, conducted rapid-response surveys from 1996 to 1998 to evaluate existing know-how and technology and to guide research and development requirements for future REA activities. These surveys were conducted under SACLANTCEN guidance as a collaborative effort involving the MILOC group and civilian and military research and development establishments of NATO nations and commands to test emerging REA capabilities and identify shortfalls. A conference hosted by SACLANTCEN in 1997 (Pouliquen et al., 1997) summarizes the REA status at that time.

SACLANTCEN ASSETS IN THE EARLY 1990s

Initiatives started in 1992 made SACLANTCEN one of the leading institutions in the REA field. During rapid-response surveys, SACLANTCEN already had new methodology (summarized below) to demonstrate REA applications. Rapid Response 1996 (RR-96) was the first MILOC survey designed by SACLANTCEN for immediate support of a naval exercise with acoustic and environmental data (Pouliquen et al., 1997).

DIRECT METHODS

Direct methods were developed and used during RR-96 as ground truth to demonstrate the capacity for obtaining acoustic parameters. These remote techniques can be deployed by air or submarine and used as payloads on autonomous underwater vehicles (AUVs).

Expendable Bottom Penetrometer (XBP)

During RR-96, a new REA tool developed jointly by SACLANTCEN and Lamont-Doherty Earth Observatory of Columbia University was used for assessing certain seafloor geotechnical properties that are important in planning and carrying out navy operations. The new tool, called an expendable bottom penetrometer (XBP) (Akal and Stoll, 1995, 1996), can be launched from a moving ship, aircraft, or submarine using techniques similar to those for expendable bathythermographs (XBTs) (Figure 1).

The XBP contains a sensitive accelerometer that measures the time history of deceleration as it impacts and penetrates the seafloor. This information is integrated to obtain the force exerted

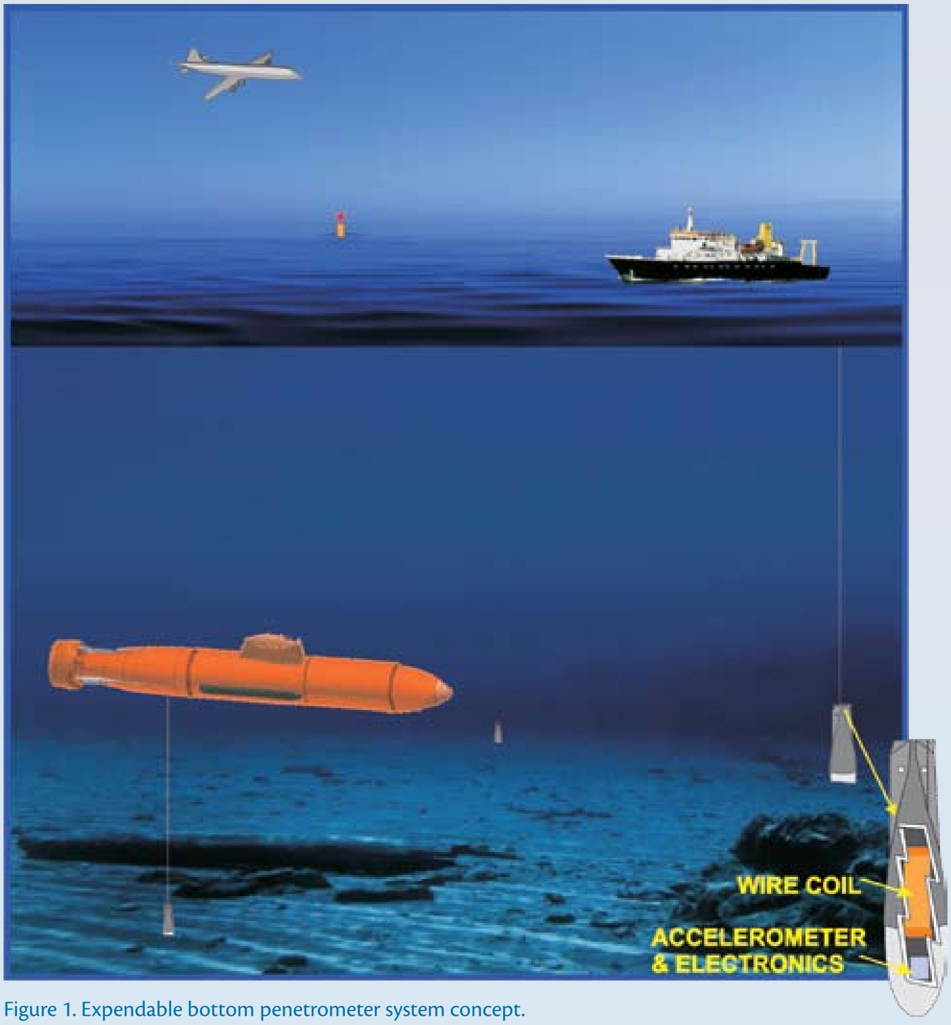

Figure 1. Expendable bottom penetrometer system concept.

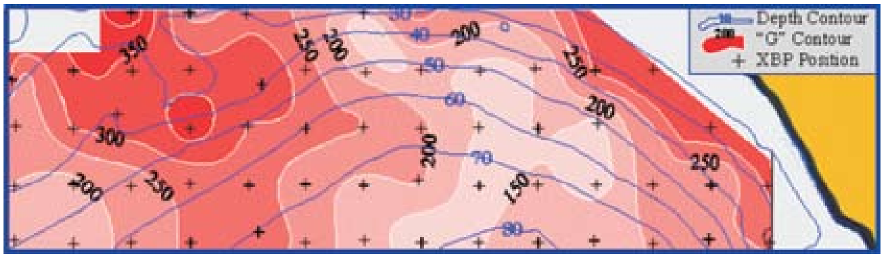

Figure 2. Example sediment bearing capacity map obtained with expendable bottom penetrometers.

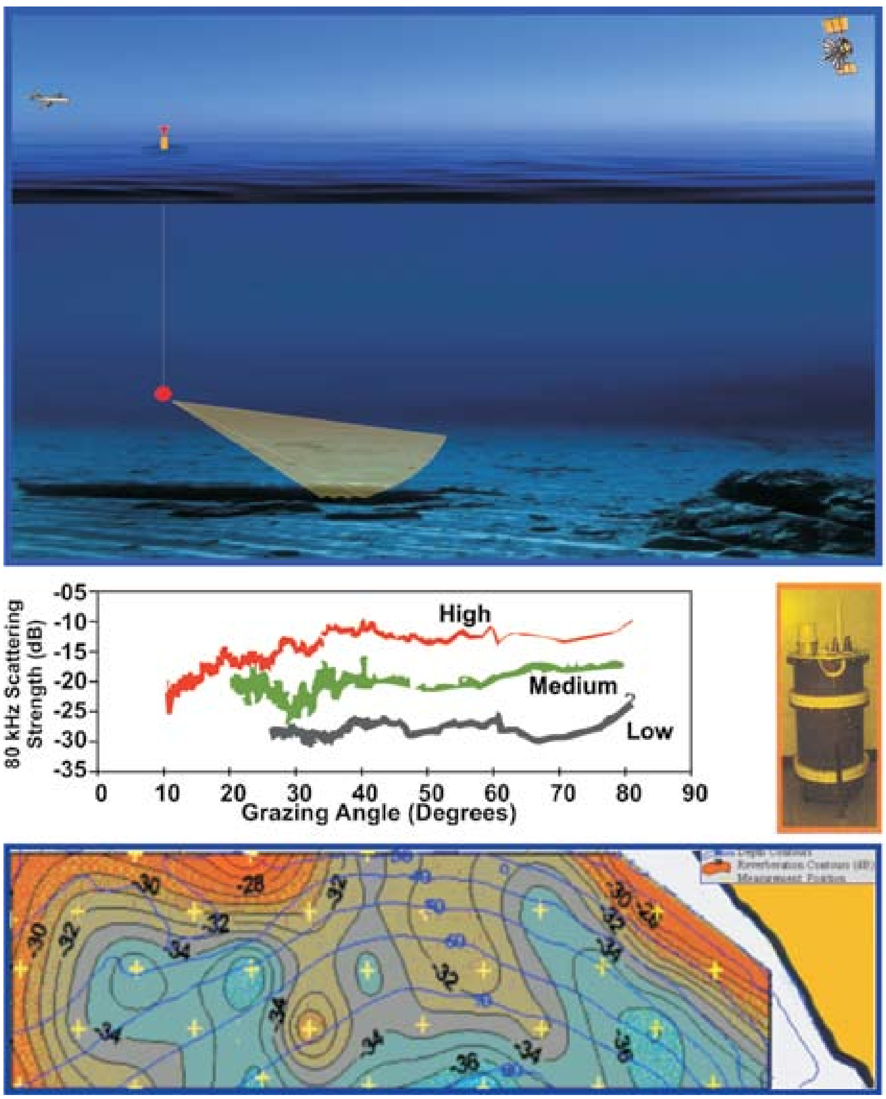

Figure 3. Different levels of backscattering data obtained with the prototype REA reverberation, ambient noise, and depth measurement buoy at one of the experiment sites.

on the probe by the sediment as a function of depth of penetration. Because the force on the probe is directly related to the undrained shear strength of the sediment through well-known bearing capacity relationships, the shear strength, which is one of the principal parameters necessary for evaluating mine burial potential, may be derived from the data in a direct way. Moreover, additional information about the geoacoustical characteristics of the sediment (e.g., whether it is granular or fine grained) can also be determined from analysis of the deceleration signature.

During surveys, numerous XBPs were dropped over an area in a rectangular pattern with the objective of defining sediment properties in certain regions of interest to the AW, MW, and ASW communities. These areas were then classified as to sediment type and parameters pertinent to mine burial.

Figure 2 is an example of a chart showing sediment types within a 140 km^2 area where 70 penetrometers were deployed. The quantitative information contained in this type of chart is not available from any other remote-sensing technique currently in use and illustrates the importance of this kind of reconnaissance.

80-kHz Backscattering

Another new technique recently developed at SACLANTCEN has been used onboard R/V *Alliance* where acoustic data were collected at 80 kHz as part of the high-frequency acoustic reverberation component of RR-96 (Figure 3). The aim of this technique is to describe the nonuniformity of the seafloor environment—whether it is composed of areas of different sediment types, pockets of shells, or fields of *Posidonia* sea grass. The intent of this system is to provide a quick estimate of the acoustic properties of a site at frequencies relevant to mine-hunting sonars.

During rapid-response experiments, various sites were examined with these systems (Figure 4). Scattering strength as a function of grazing angle indicates the average reverberation levels that can be expected with an 80-kHz system, while the amplitude probability distribution function (PDF) gives an estimate of clutter (i.e., portions of the return that are consistently above the mean reverberation level) (Lyons et al., 1997).

Three sites were chosen as examples of three different observed reverberation regimes. The expected mean reverberation levels can be estimated quickly from the graph shown in Figure 3, with red exemplifying high, green medium, and blue low reverberation levels. The high scattering rates were the result of numerous shellfish covering the seafloor, while lower levels indicated a very smooth, featureless seafloor. As an indicator of clutter, the amplitude PDF of scattering cross section per unit area values was examined.

SIMULATION MODEL DEVELOPMENT AND VALIDATION

As the techniques presented here indicate, some of the methodology depends on the presence of special platforms and equipment. Use of these types of measurements may not be possible during a crisis situation. Therefore, verified simulation models, such as REA methodology, can provide the necessary information for predicting environmental parameters of operational interest.

Propagation

To a large extent, the performance of a sonar system can be described by a sonar equation. Transmission loss, reverberation level, and ambient-noise level are the parameters determined by the medium. Transmission loss describes the magnitude of acoustic energy lost while it travels through the ocean. As a parameter, it contains all the effects of different propagation conditions.

The measurement technique described above involved deployment of an acoustic sound source (by a ship or aircraft) to transmit signals along a track and acquisition of these signals with receivers at the end of the track. Environmental parameters that affect acoustic propagation were also simultaneously measured to provide data for modeling and interpretation of the results. Figure 5 shows an example from

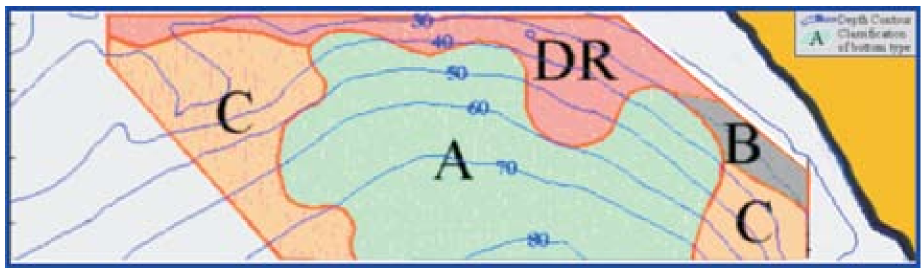

Figure 4. Description of an area for mine counter measure applications, according to sediment bearing capacity and bottom scattering strength characteristics.

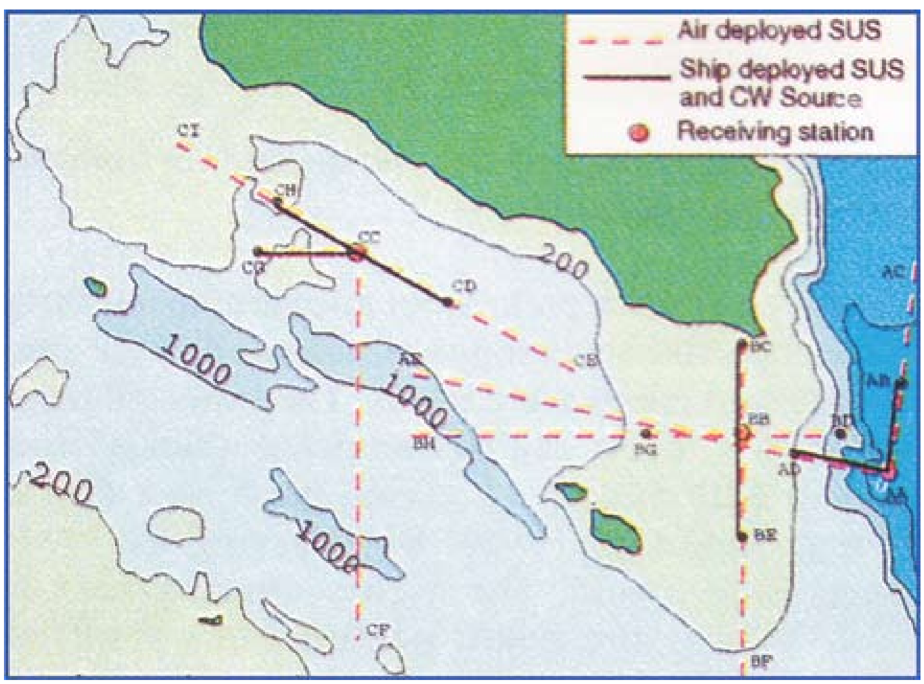

Figure 5. Transmission loss measurement tracks covered during RR-96 where a continuous wave (CW) transmitting sound source and a broad frequency band generating small-size explosive signal underwater sound (SUS) source were used.

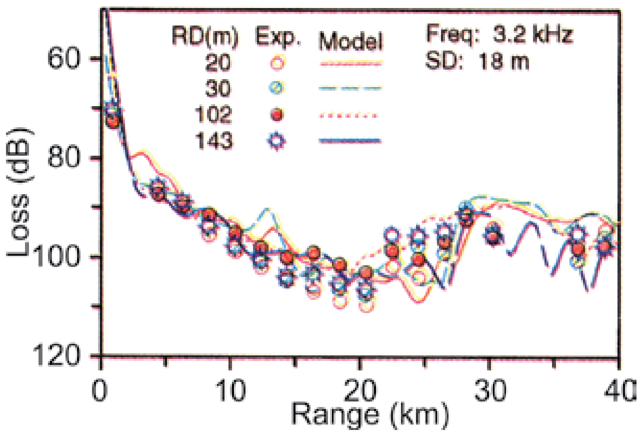

Figure 6. Measured and calculated transmission losses at different depths.

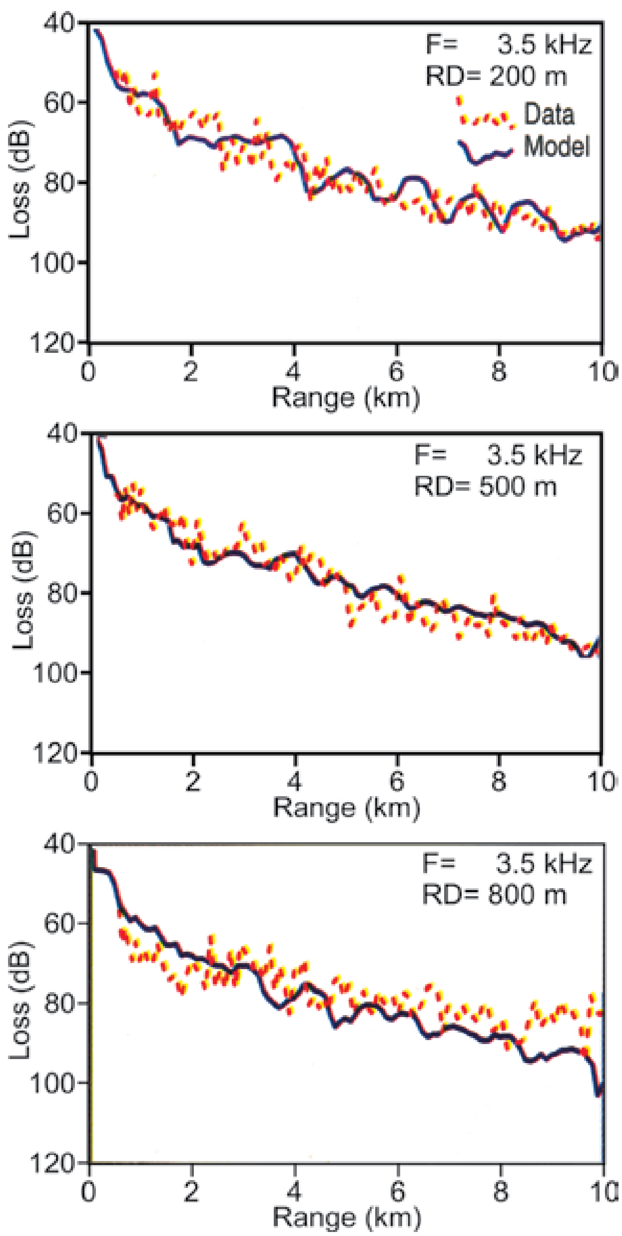

Figure 7. Data/model comparison for a continuous wave source and receivers at different depths.

one of the tracks covered during RR-96.

In support of RR-96 operations, broadband (50–3200-Hz) acoustic data from an explosive source and 3.5-kHz continuous wave data from a towed sound source were acquired and processed onboard. During acoustic measurements, seafloor and oceanographic features were also monitored, providing a set of parameters for acoustic propagation modeling. Figure 6 shows a comparison of measured and computed transmission losses for different receiver depths (Feria et al., 1996).

Due to the complexity of the environmental features affecting the acoustic propagation along the various tracks in this area, a suite of two-dimensional range-dependent and range-independent models had to be used to handle the various shallow- and deep-water scenarios at low and high frequencies. Ray-based models such as GSM, MOCASSIN, and HODGSON (Schneider, 1995) were selected for deep-water problems, while wave models such as PAREQ (Schneider, 1995), RAM (Schneider, 1995), and C-SNAP (Breeding et al., 1994) were used for modeling in shallow-water regions. Computational speeds, as well as the ability to treat bottom effects and sloping bottoms, were among the main criteria used for choosing among the models.

The model/data comparison presented here is intended to give a qualitative and quantitative illustration of the degree of predictability that can be obtained in the three areas. Figure 7 presents some examples of propagation losses as a function of range for some selected tracks.

Ambient Noise

The ambient noise field limits detection ranges of passive sonar systems and active systems at long range. The objective of acquiring noise-field measurements during rapid-response surveys was to determine the residual acoustic noise field in the RR-96 area and thus understand the physical processes that generate the field and verify the prediction models for any given condition.

The measurement techniques involved performing a polygon maneuver with a towed array, during which the noise levels were measured for each beam along each side of the polygon. A shipping survey was conducted by aircraft throughout the measurement period to provide near-to-intermediate range shipping data for modeling and interpretation of the results. These measurements improved the ambient noise model, enabling prediction of ambient noise levels in an area by monitoring the shipping density through remote-sensing techniques.

Horizontal directionality measurements are presented in the form of polar plots at selected frequencies. The polar plot in Figure 8 represents noise levels relative to omnidirectional levels. As an aid to interpretation of the results, the plots are overlain on a nautical chart of the area, together with a plot of the aerial shipping survey.

The information obtained from shipping surveillance was used to calculate the noise characteristics of the area. Figure 9 compares the measured data from sonobuoys and the SACLANTCEN towed array compared with RANDI 3-1 (Breeding et al., 1994) ambient noise model outputs.

Figure 8. Shipping density and 50-Hz directional ambient noise pattern.

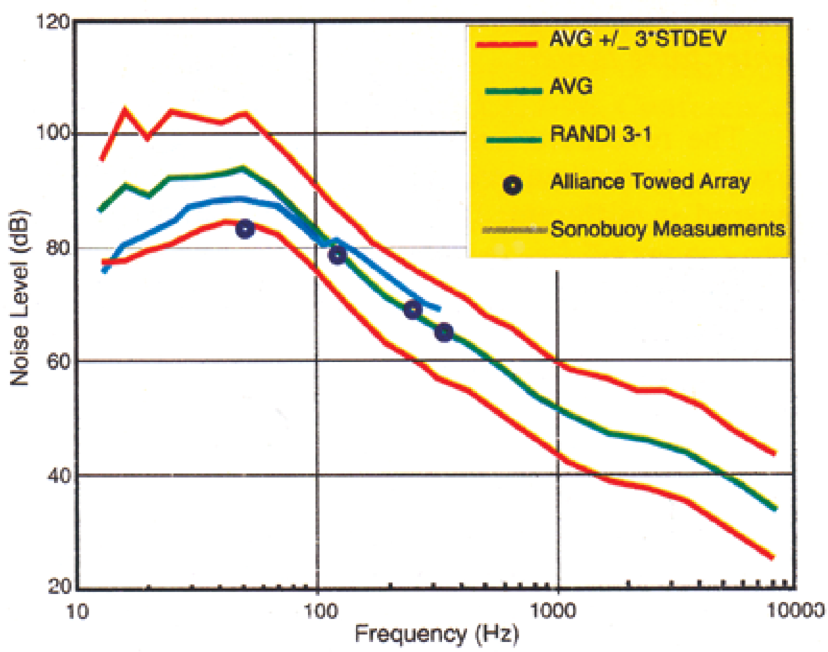

Figure 9. Measured and simulated ambient noise.

Reverberation

Reverberation is the scattering of sound from the ocean volume, surface, and bottom. It limits active sonar performance by masking the target echo. At low frequencies (below 1 kHz), bottom reverberation tends to be stronger than surface and volume reverberation; at higher frequencies, surface reverberation is significant if the wind speed is high. Volume reverberation can also be important when fish are present.

During RR-96, reverberation measurements were acquired from R/V *Alliance* using explosive sources whose returns were received by SACLANTCEN's towed array. These data were used to characterize the areas and, by comparing them with model predictions, to obtain estimates of bottom loss and scattering strengths.

The reverberation data received on the towed array were converted into time series of spatial beams steered in different directions. By mapping time into range and beam-angle into azimuth, the data were displayed as intensity levels on a polar plot, similar to a radar display. Figure 10 shows the reverberation field superimposed on a bathymetric chart. This technique remotely senses a large area to identify positions of false targets. Verification of reverberation models with this type of data permits mapping of local seafloor features to reverberation characteristics of an area.

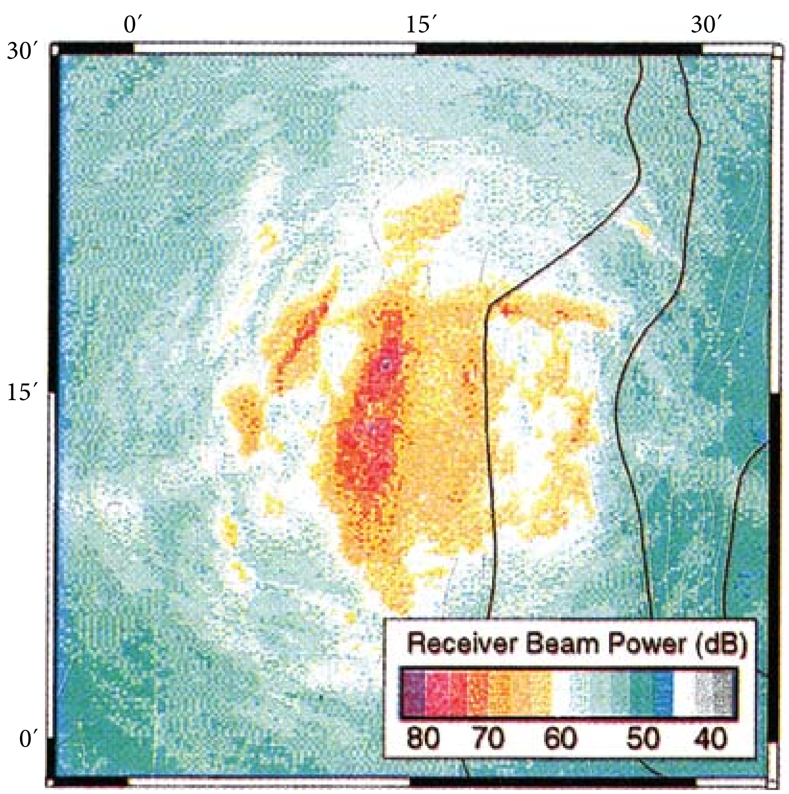

Figure 10. Reverberation field showing false shallow-water targets.

Forecasting Ocean Conditions

Oceanographic conditions of the RR-96 area were obtained in quasi real time by applying available databases and ship- and airborne measurements to numerical dynamic models for nowcasting and forecasting where rapid data acquisition evaluation and data transmission were essential.

Water-column data were collected using standard conductivity, temperature, depth (CTD) profilers and expendable probes for temperature (XBT and air-dropped XBT [AXBT]) and conductivity (XCTD). Surface temperature distribution was obtained using data from the US National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (AVHRR) satellites. Remote-sensing images were processed at SACLANTCEN and were made available to users via the Data Fusion Center's Internet server. Current measurements also were acquired with shipborne acoustic Doppler current profilers and drifters.

The Harvard Ocean Prediction System (HOPS) was configured for RR-96 in collaboration with Harvard University and with the support of the US Office of Naval Research. Figures 11 and 12 show examples of resulting predictions (Sellschopp and Robinson, 1997).

Data Management and Exchange

For RR-96, another first concept was introduced with establishment of an Internet server at SACLANTCEN for data dissemination. Four NATO naval vessels were equipped with portable computers, modems, and cellular phones to transfer data to and from the server via dial-in access (Trangeled, 1997). Other organizations such as the US Naval Oceanographic Office (NAVOCEANO), the US Naval Research Laboratory (NRL), and the Acoustic Research Laboratory in the United Kingdom established connections over the Internet. For the communication technology existing at that time, this demonstration was the beginning of a new era within NATO for data management and exchange during an operation.

CONCLUSIONS

RR-96 was the first coordinated effort within NATO to demonstrate REA state-of-the-art applications, and it successfully illustrated the possibilities of the SACLANTCEN REA methodology. Some of the techniques have since been improved, especially remote sensing and ocean dynamic modeling.

Research and development for AUV technology can be defined as the most important breakthrough in the REA field for covert operations. Although AUVs with longer autonomy and accurate navigation have been developed, there is still a need for new payload sensors and systems, especially using micro electro mechanical systems technology.

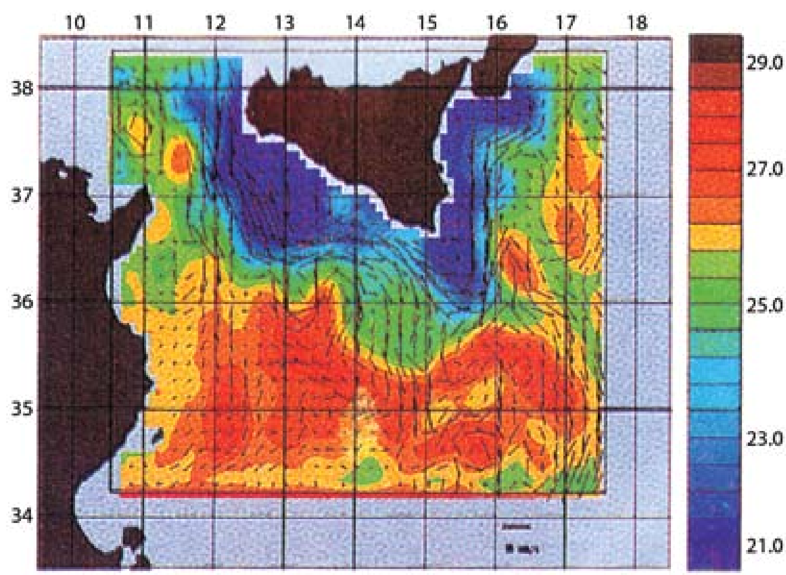

Figure 11. Dynamical analysis surface temperature and current simulations. *Sellschopp and Robinson, 1997*

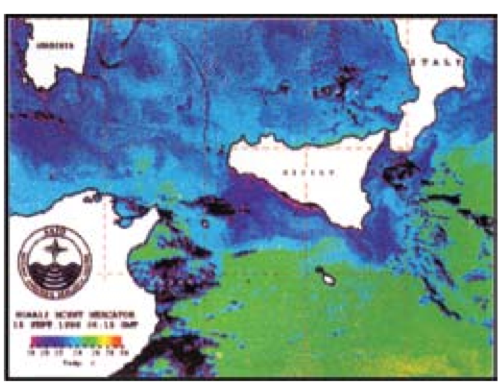

Figure 12. Surface temperature from remote sensing. *Sellschopp and Robinson, 1997*

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