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User report

COMBIS version 3.0

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Report title

COMBIS version 3.0

Abstract (not more than 200 words)

The development of COMBIS has focused on passive sensor networks. In order to evaluate different scenarios such as protection of our home basin, during transit or during covert operations there has been a need to develop a sensor network tool within COMBIS. Today, COMBIS has the capability of demonstrating new models/functions/concepts in virtual operation areas. This hopefully leads to an increased dialogue with users both on a tactical and operational level. Our vision of the future is that COMBIS is used as a test platform for new ideas which then are implemented in simulation frameworks. Then, scenarios can also be simulated and more intensive feedback to researchers can take place.

The implementations in COMBIS version 3.0 embrace; a map editor, a sediment editor, a tool for setting up passive sensor networks, defining the oceanographic environment and sediment parameters, simple acoustic sensor models and setting detection parameters. The passive sensors include both acoustic and electromagnetic surveillance methods. Detection probabilities are calculated using the sonar equation and the corresponding electromagnetic simplification (ELFE equation).

Keywords

COMBIS, Tactical decision aids, passive sensor network

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COMBIS version 3.0

Sammanfattning (högst 200 ord)

För att kunna utvärdera scenarierna; försvar av hemmabas, under förflyttning och dolda framskjutna operationer har ett verktyg för utvärdering av passiva sensornätverk utvecklats i COMBIS. Genom att kunna utvärdera nya metoder och funktioner i ett sådant område hoppas vi att dialogen med användaren kan öka, både på det taktiska och operationella planet. I framtiden kommer COMBIS att kunna användas som en första plattform där nya idéer testas som senare kan implementeras i simuleringsramverk. Där kan användaren utvärdera scenarier där de nya idéerna finns med. Därigenom kan ytterligare ökad återkoppling till forskarna åstadkommas.

I denna version av COMBIS har följande verktyg inkorporerats; kartverktyg, sedimentverktyg, möjlighet att sätta upp ett passivt sensornätverk, definiera den oceanografiska miljön samt de geologiska parametrarna, enkla akustiska sensormodeller och verktyg för att sätta detektionsparametrar. Både akustiska och elektromagnetiska passiva sensorer kan utvärderas. Detektionsberäkningarna bygger på sonarekvationen och dess motsvarighet i det elektromagnetiska fallet (ELFE).

Nyckelord

COMBIS, Taktiska stödsystem, passiva sensor nätverk

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Contents

1. History

During three years an information system for tactical aid and analysis in maritime environments, COmbined Maritime Background Information System (COMBIS), has been developed. During the first year, wave propagation models and arrangements to view the results from the calculations were implemented. The novelty with COMBIS was the combination of three surveillance methods all included in one tactical decision aid. Most of the tactical decision aids today are based on acoustic surveillance methods while both electromagnetic and optic techniques were demonstrated in COMBIS. Electromagnetic fields are calculated with a wave propagation program and an empirical relationship calculates the penetration of a green laser from an airborne instrument. The Graphical User Interface (GUI) made it relatively simple for the user to run the models and to view the result. In addition to wave propagation a data base with some observations was implemented in the first version. There were also some tools developed to view the observations and to set geoacoustic/geoelectromagnetic parameters. Details about COMBIS version 1.0 and its tools can be found in Sigg and Schiöld (2002).

During the second year, COMBIS was modified quite extensively. Three scenarios were discussed and used as guidelines for the research performed within the project. The scenarios can be described as: to protect our home basin, to protect ourselves during transit and protection during covert surveillance. This led to a re-programming of the GUI to prepare COMBIS for future demonstration capabilities. We also wanted to be able to compare wave propagation and detection probabilities in a simple way and that accelerated the modification of COMBIS as well.

At maximum three windows are now present on screen and in order to handle all features and functions an approach with menus was taken. In the COMBIS main window one can choose to run acoustic, electromagnetic or optic calculations. Here input of frequencies, transmitter depth, output grid and the choice of models were made. In the COMBIS activity window all the environmental input data to the wave propagation models was managed. In this window, the results from the calculations were displayed as well. The third window displays the bathymetry over the Baltic Sea and the observations that exist in the data base.

The idea with a combination of surveillance methods was of course pursued in version 2.0 and the re-programming of the GUI facilitated the comparison of the model calculations. In addition to the re-programming several new functions were implemented. An oceanographic climatology data base has now been implemented in COMBIS and it is possible to both explore profiles as well as cross sections. Not present in most of today's tactical support systems and demonstrated in COMBIS is the possibility to estimate the electromagnetic variables in the sediments, to use oceanographic forecasts and to estimate the three dimensional oceanographic environment from measurements. We believe that these functions will be a part of future tactical decision aids. In addition, two more acoustic models were implemented. One is using a horizontally stratified media and the other one is a ray tracing model. All information about the new features in version 2.0 can be found in Sigg and Schiöld (2003).

In COMBIS version 3.0 the GUI design is similar to version 2.0. During 2004, focus is on passive sensor networks. In earlier versions evaluation of one sensor and one ship was possible. However, an operation area is often covered with several passive sensors and it is important to evaluate the performance of these before they are deployed. When implementing a passive sensor network evaluation tool one has to consider not just one dimension. This complicates the creation of such a tool. First of all a map tool was added with the possibility to draw your own map (in two dimensions). Then, the environment has to be specified in the area. For the oceanographic environment two options are available. Either one can use one observation representing the whole area or one can use the oceanographic estimation tool to calculate the three dimensional oceanographic field. This tool was slightly modified in order to handle this new situation. The sediments and their properties also have to be set. A similar editor compared to the map editor was thus developed. Finally, tools for the properties of the sensors and the calculation of detection probabilities were developed. Another focus has been on the penetration of green laser. For a given target detection probabilities are calculated using a Monte Carlo technique. A look up table has been implemented in COMBIS and similar plots as for acoustic/electromagnetic detection probabilities can now be presented.

The main structure of this report is divided into three parts; an evaluation of the COMBIS concept (Chapter 2), an overview of the new implementations in COMBIS (Chapter 3) and finally a user's guide how to use the new features (Appendix). The new implementations concern the DAT modifications (Chapter 3.1), the Monte Carlo simulations for penetration of green laser (Chapter 3.2) and a description of the passive sensor network evaluation tool (Chapter 3.3). Chapter 2 is relatively simple to follow but Chapter 3 requires some technical background or that the reader has access to the references.

2. An evaluation of the COMBIS concept and future development

The aim of COMBIS is to demonstrate new tactical support functions and improved models of any kind. Not only acoustics has been implemented but also electromagnetics and electrooptics which are important complements to acoustics in shallow water warfare. In this way, COMBIS is a new concept not similar to other operational tactical support systems. From researchers point of view COMBIS has been an opportunity to present ideas and to test new models allowing the users to closely follow the research performed at FOI. From a users perspective a direct communication with the researchers has been facilitated. This has been very fruitful for both communities. Our idea is to use the scenarios discussed in the introduction as guidelines for the research that we perform. The Royal Swedish Navy (RSwN) may confront these scenarios in the near future. Feedback on the scenarios has been given from the users and today we can focus on the important parts of these. Especially, it was concluded that we should focus on the first and third scenario. Protection during transit (to international operations) has a lower priority. Thus, as it seems, COMBIS is a good link between researchers and users.

Evidence on that COMBIS has been an appreciated product is the number of requests of using COMBIS. Already after the first year COMBIS was used by the Swedish Defence Material Administration, FMV. Requests have come from two different sub-organizations in the RSwN but since the program needs MATLAB it has not been delivered yet. A modified version of COMBIS has been delivered to another FOI project about acoustic wave propagation in air. Finally, COMBIS has been used in the Torpedo Mine Sensor (TMS) project for evaluation of scenarios.

Future implementations concern areas such as signatures, active sonars and improved passive sensor models. Today, active acoustic detection techniques are more frequently used than passive ones. Active detection is not present in COMBIS and since this technique is of such importance it should be implemented as well. At present, only simplified passive sensor models are present and more work is needed here as well. A release of COMBIS is then planned for educational purposes and analysis. The purpose of this release is to increase the communication with the users and to get even more feedback on COMBIS, different scenarios and the research performed at FOI.

The flexibility of COMBIS is also planned to be addressed. Especially, ideas presented in the COMBIS platform should be exchanged with the Modeling and Simulation community. In order to develop tactics and to evaluate scenarios the use of simulation frameworks are increasing today. Our vision is to use COMBIS as the first platform to test new ideas and concepts on (Fig. 1).

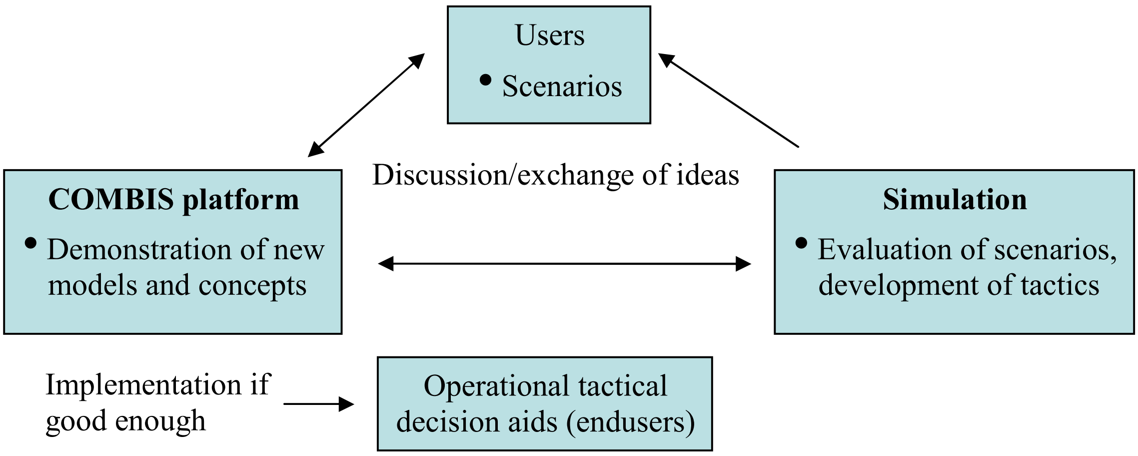

Figure 1. A sketch over our vision.

Feedback from users can be received immediately when ideas are implemented in the COMBIS platform and discussions on scenarios may take place. The ideas and concepts can then be implemented in a simulation framework where the discussed scenarios are evaluated. It is also possible to implement the ideas operationally if found to be good enough. The evaluation of the scenarios using a simulation framework can then be used in the ongoing work with COMBIS. Thus, not only tactics is developed but also a direct feedback to the researchers is facilitated. This vision implies a strong relation between research, scenarios and development of tactics and this will hopefully increase the capabilities of the RSwN significantly concerning underwater warfare. In view of this, COMBIS as it has been developed so far is the first step to fulfill the vision. During the next few years we aim to expand the concept into the proposed larger context.

3. New implementations in COMBIS

3.1 DAT modifications

The first modification of the DAT tool was to use climatology from the climatology data base as a first guess in the data assimilation procedure. In version 2.0 the climatology was crudely estimated from the observations used in the assimilation procedure. This is not correct and since COMBIS is equipped with climatology statistics these should be used instead. However, we are faced with some problems just using the climatology profile as it is. The bathymetry in an area is depending on the horizontal scale used to describe the depths. The climatology represents a horizontal scale of about 50 km and therefore the climatology profile is probably less deep than the deepest part in the area. First a fixed vertical grid was set, starting at the surface down to 500 m depth (0, 5, 10 … 30, 40, 50 … 100, 150, 200, 300 … 500). This vertical resolution is good enough to capture most of the details in the profiles. The climatology profile is then interpolated onto this grid. Outside the range of the climatology profile a constant value of the lowest climatology measurement is used. The observations are then exposed to the same procedure. However, if an observation profile is shorter than the depth where the observation is taken, it is extended with climatology values. This means that the first guess (climatology profile) and all observations are equally long using the fixed vertical grid as reference. The reference vertical grid is truncated at the maximum depth of the analysis area. The modified climatology and the modified observations are now used in the data assimilation procedure and the outcome of the analysis is a three dimensional rectangular grid of temperature and salinity estimations. The last step is now to mask out all values in the bottom layers. The advantage of this approach is that all input values located in the bottom layers do not influence the estimation process since the process is using the difference between the climatology and the observations. The observations were already set to the climatology in these layers and therefore the resulting difference is zero.

3.2 The electrooptical wave propagation model

Earlier versions of COMBIS have used an empirical model to estimate the penetration depth of green laser. Results have been displayed as penetration depths in meters or detection/no detection. However, proper detection probabilities have not been accessed in these versions. Therefore, an approach with Monte Carlo simulations has been taken but since these are quite computational demanding a stand alone program was run instead of implementing this approach in COMBIS. The output from this stand alone program is a look up table where detection probabilities are listed as a function of depth and optical attenuation. For simulation of target detection probabilities, numerous two-way beam propagation simulations were performed. The target size was set to a small submarine/medium sized AUV. In order to get the statistical variations, the surface waves, receiver noise and the flight direction influenced the result. This is the essence of Monte Carlo simulations, to re-run the same case with only small changes in sensitive parameters. The fixed parameters in this case are target depth and optical attenuation. The false alarm rate is set to 0.01 percent. This is repeated for different fixed combinations of target depths and optical attenuations. So far a day time look up table has been established. Details of the electrooptical beam propagation model and the Monte Carlo approach can be found in Tulldahl and Olsson (2004).

3.3 Sensor network evaluation tool

This chapter describes an environmental tool where it is possible to create and edit maps, set sediment parameters and the hydrography (Chapter 3.2.1). The other important part of the evaluation tool is the sensor network itself and all related data that have to be set in order to perform a calculation (Chapter 3.3.2). Examples of data settings are positions, sensor characteristics, choice of wave propagation models and target specifications.

3.3.1 Map editor, sediments and hydrography

The map editor is a graphical tool based on a grid approach. A two dimensional grid is set manually and a tool appear showing this grid. Now, the user is able to mark a sub-area within the selected area. The depth of the sub-area is set in another window presented on the screen. In this way bathymetry of an operation area is created. The result is stored in cdf-format and the map can be loaded whenever wanted. The creation of the map is performed interactively and the modifications are immediately shown in the map tool since the map is re-drawn for every new depth setting.

The sediment parameters are set with a similar editor. It is not necessary to use the same grid resolution as when creating the map. For an one-layer homogenous sediment it is possible to specify the whole area as one homogenous layer and only define one set of parameter values. The parameter settings are the same as in earlier versions of COMBIS but now a two-dimensional area can be set rather than just a track. Another difference is that sediments not necessarily need to have the same shape as the bottom topography. Thus, in this version there are more degrees of freedom to elaborate on the spatial distribution of the sediment thicknesses. A simpler way to set the sediment parameters in an area is to use the track tool but then only homogenous layers can be treated.

The hydrography is set either using one profile representing the whole area or using the new DAT tool. The new DAT tool allows the user to estimate the three dimensional oceanographic environment in the particular area of interest, as mentioned in Chapter 3.1.

3.3.2 The sensor network

Two kinds of sensors can be used in the network, electromagnetic and acoustic ones. When adding a sensor the user is asked which type of sensor and what position it will have. In relation to the sensor one has to specify the surveillance area around the sensor. Three parameters are set; radius, step and number of sectors. The radius defines how far from sensor point calculations are performed, the step how often output is sampled along the track (radius/step gives the resolution in meters) and finally the number of sectors give how many tracks are calculated in the circle around the sensor.

Target related input must also be set. This is done in the detection window where the source frequency, source strength and source depth are defined. The choice of model is also set here for the acoustic calculations, JEPE or MODELOSS. So far NLAYER 2.0 is the only choice for electromagnetic wave propagation calculations. When just changing the source strength another transmission loss calculation is not necessary. Then, it is possible to use the old field strength calculations and only update detection probabilities. In this way, the user may play around with different source strength values and to investigate the behavior of the detection ranges relatively fast. The result of the detection probabilities are presented in the user-defined map where the sensors are indicated and a colored plot is showing the result.

The detection probabilities are calculated using the passive sonar (Lurton, 2002) and the passive ELFE equation (Mattsson et al., 2004). The passive sonar equation consists of five contributions; transmission loss (TL, from JEPE or MODELOSS), source level (SL), noise level (NL), directivity index (DI) and detection threshold (DT) giving the signal excess (SE):

$$SE=SL + DI - NL - TL - DT \quad (1)$$

Similarly, an ELFE equation for passive electrode sensors is formulated;

$$SE = SL - DT - NL + PG + GE - TL \quad (2)$$

where TL = Energy transmission loss from the source to the sensor (calculated by NLAYER 2.0), DT = signal-to-noise ratio level (SNR), NL = background energy level at the sensors, SL = Source energy level, PG = Processing gain from reference filtering (PG = 0 dB with no
reference filtering) and GE = Geometric effects of the sensors (GE = 0 dB for a 5m electrode system). Notice that instead of a directivity index two other terms (PG and GE) contribute to signal excess. The amount of signal excess determines the detection probabilities both in the acoustic and the electromagnetic case.

Acknowledgements

The authors would like to thank Eva Dalberg for providing the detection tools and Michael Tulldahl for providing COMBIS with a look-up table for optic detection probabilities.

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Lurton X., 2002: An introduction to underwater acoustics – principles and applications. *Springer-Verlag, New York, Inc.*

Mattsson J., Krylstedt P., and M. Karlsson, 2004: Recovery of the sub-bottom conductivity profile from electromagnetic data collected off the coast of San Diego. In proceedings of the 4th international conference on marine electromagnetics, *MARELEC 2004.*

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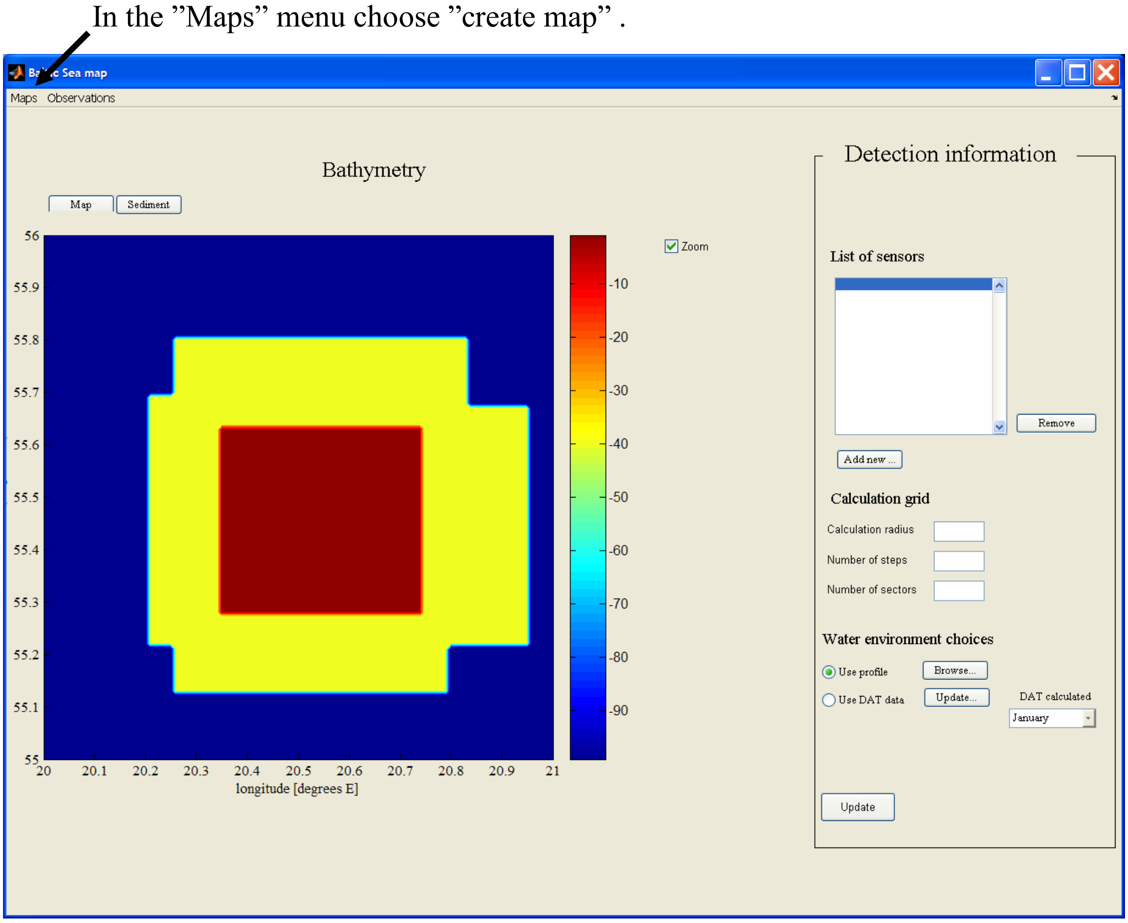
Tulldahl M. and A. Olsson, 2004: Development of an electrooptical beam propagation model for implementation in COMBIS. FOI Memo 929.

Appendix

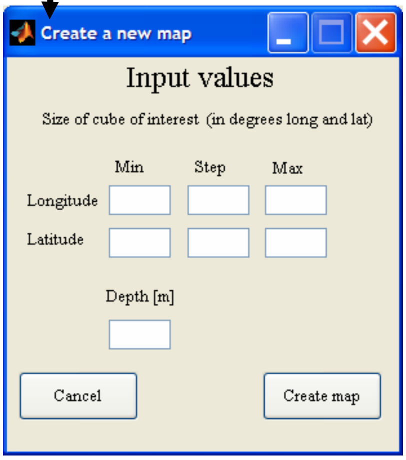
In this appendix a manual describing the map editor, sediment editor, sensor network generation, detection options and results is presented. A practical example is given with the objective to make it easy for reader to follow all the steps necessary to obtain sensor coverage for a given area. The tutorial is divided into 7 steps; make your own map, make a sediment map, load the map for evaluation of a sensor network, set sediment parameters, the oceanographic environment and the set up of the sensor network, a detection editor and sensor coverage. In order to get started, go to the window named “Baltic Sea map”.

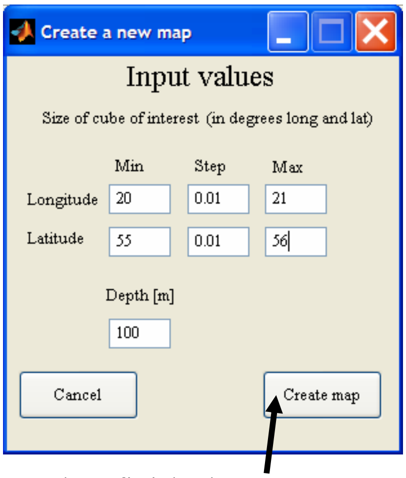
Step 1: Make your own map

In the ”Maps” menu choose ”create map” .



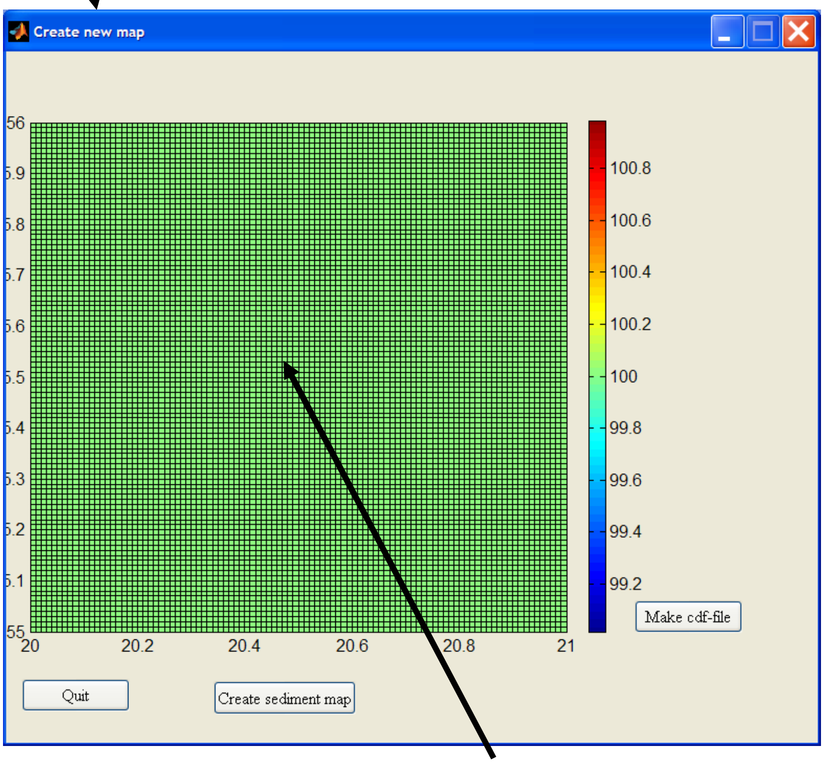
A new window appear, “Create a new map”, and here you define the size of your area and the mean depth.





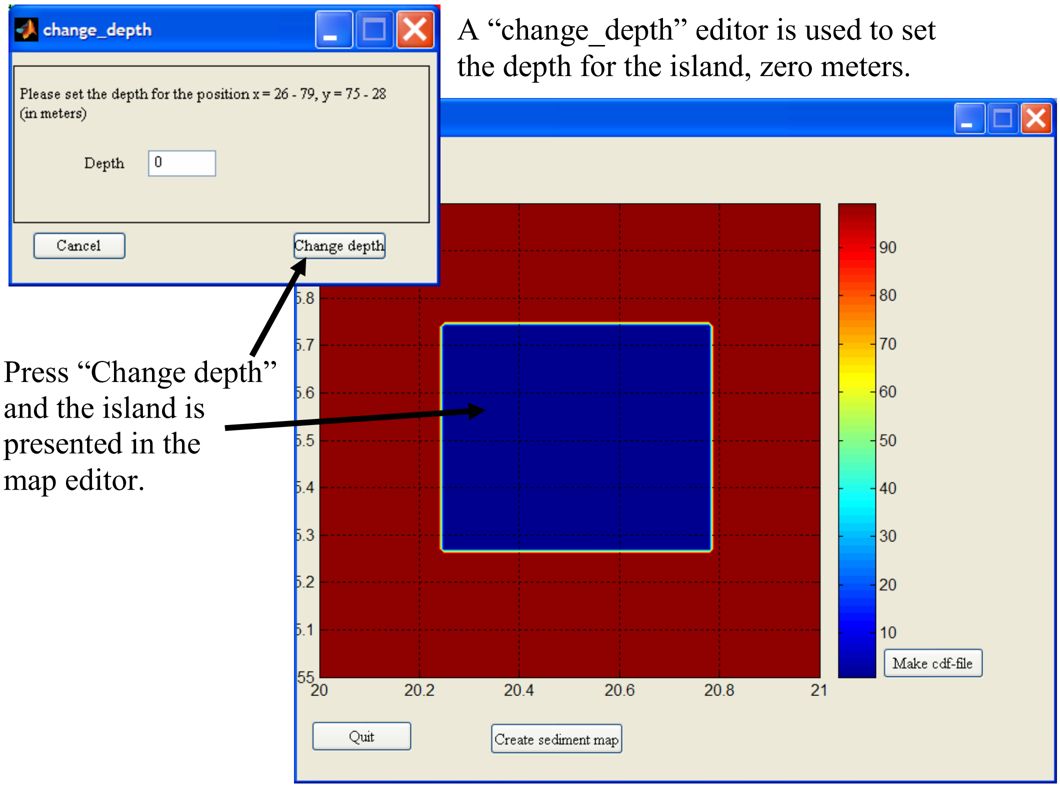
When finished press “Create map”.

The map editor “Create new map” is then presented.



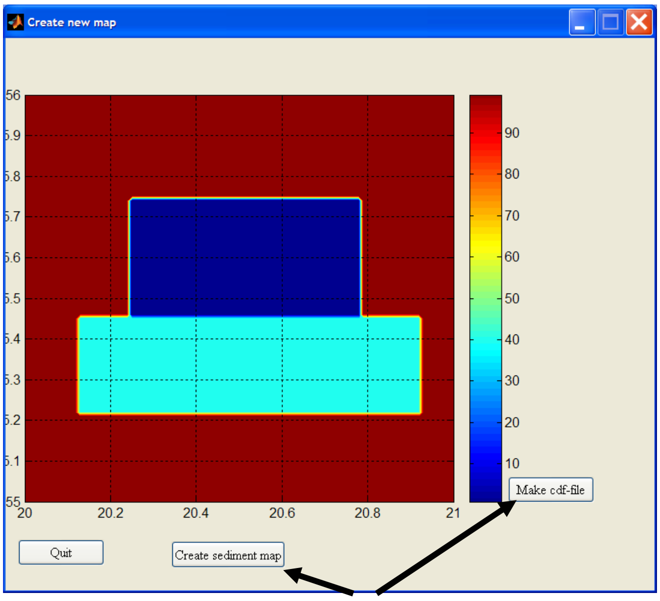
Draw an area with your mouse to create an island.

A “change_depth” editor is used to set the depth for the island, zero meters.



Press “Change depth” and the island is presented in the map editor.

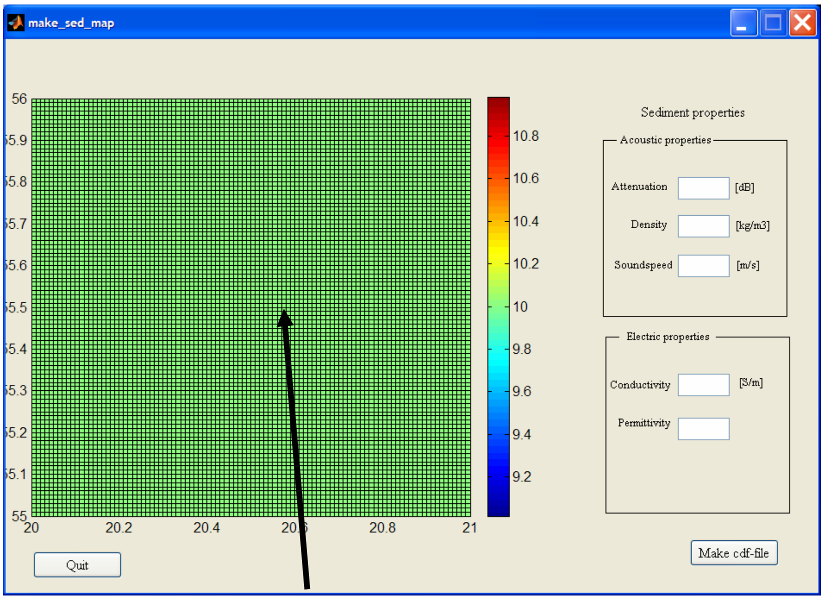
An island with some shallow areas to the south is then created. A colorbar indicates the depth.



When finished press either “Create sediment map” or ”Make cdf-file”. In this case press the first alternative.

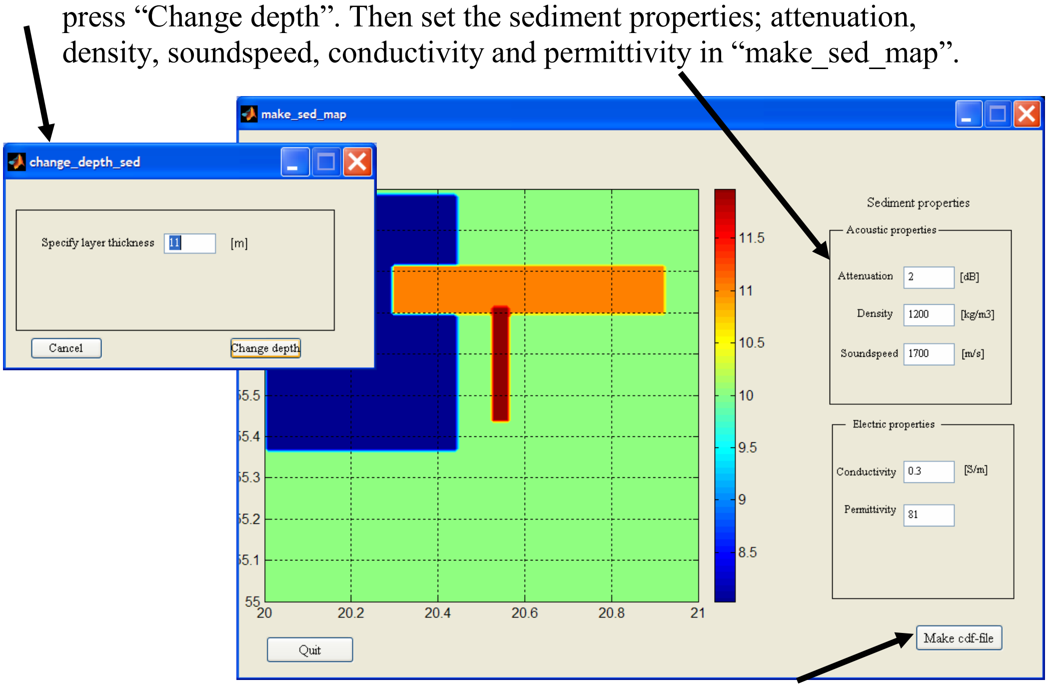
Step 2: Make a sediment map

We then would like to create a two dimensional sediment map. A "make_sed_map" window appears when pressing "Create sediment map" in the "Create new map" window.



Use the same technique as in the map editor. Draw an area using the mouse.

Set the sediment layer thickness in the "change_depth_sed" window and press "Change depth". Then set the sediment properties; attenuation, density, soundspeed, conductivity and permittivity in "make_sed_map".

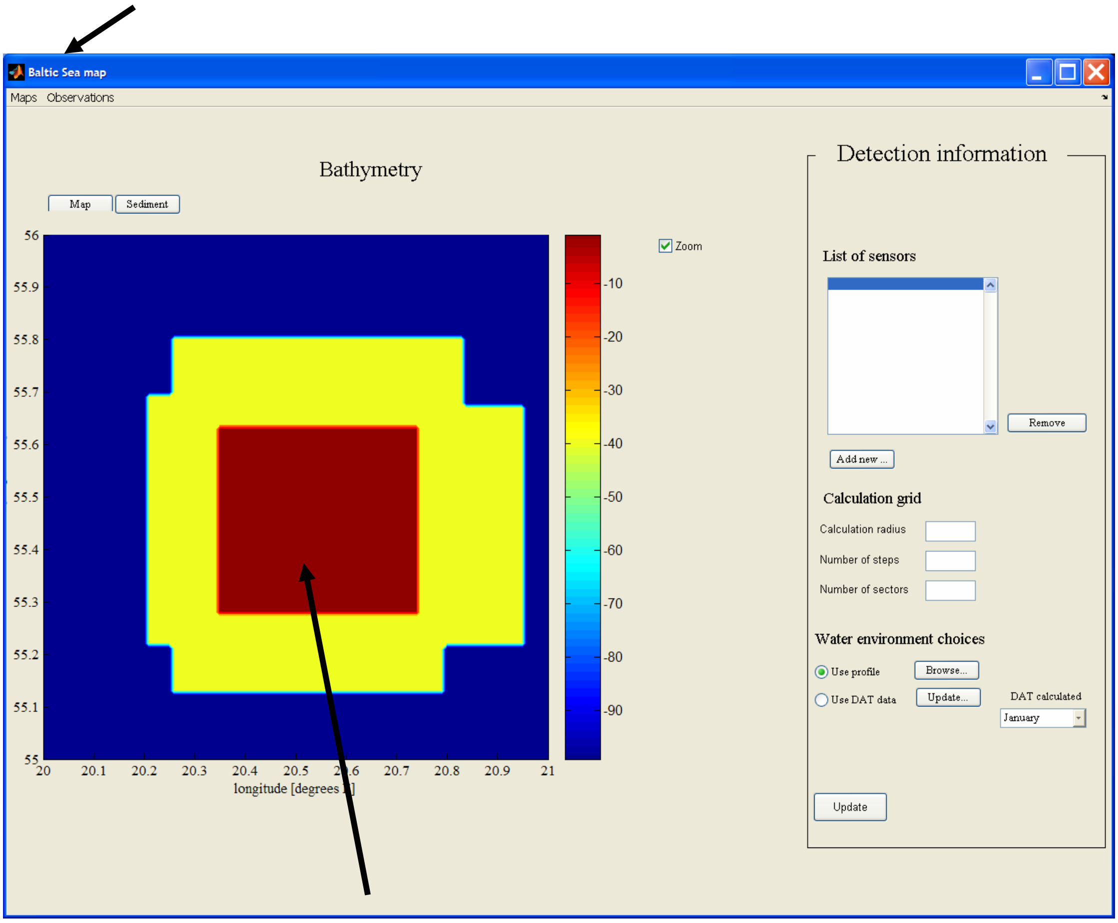


When finished press "Make cdf-file". If another sediment layer is wanted just press "Create sediment map" again in the "Create new map" window.

Step 3: Load the map for evaluation of a sensor network

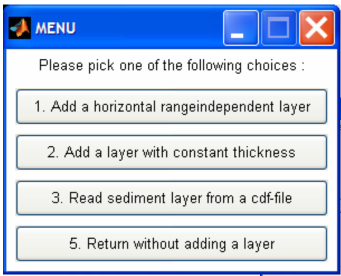
Now, the two first steps are ready. With the map editor many different operation areas can be defined. Harbors, base and archipelago areas can easily be set up with the map editor.

Finally do not forget to press “Make cdf-file” in the map editor. The map can now be loaded into the “Baltic Sea map” window by choosing “Load” in the “Maps menu”.

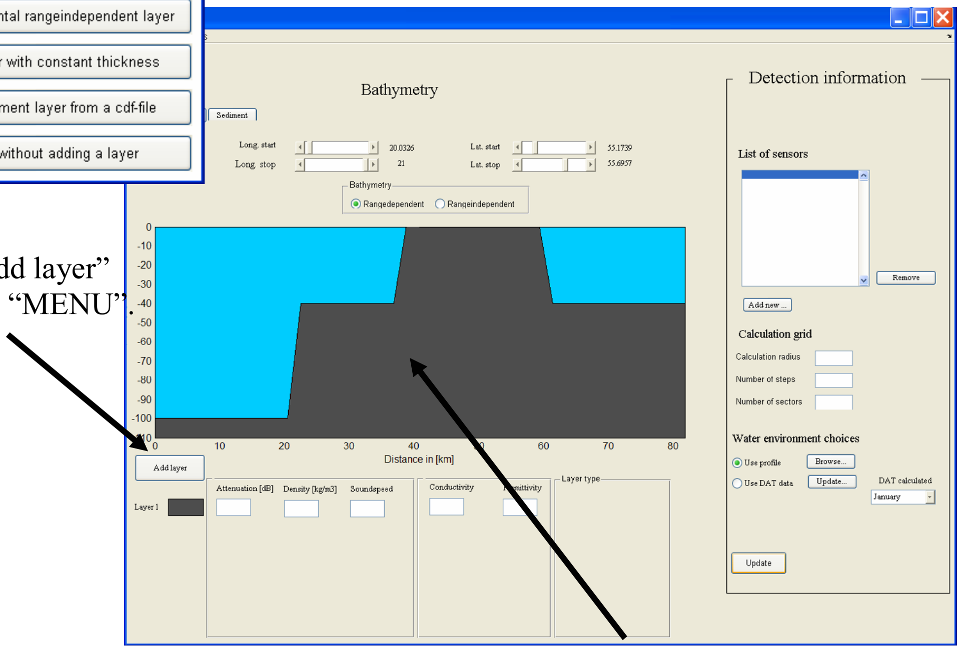


Here is a loaded map showing an island surrounded by shallow areas. To view sediments press “Sediment” in the “Baltic Sea map”.

Step 4: Set sediment properties

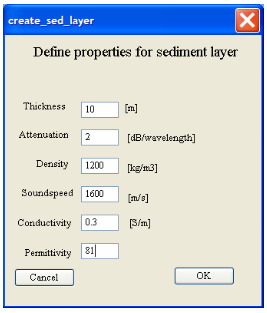


Now the sediment must be specified. Three alternatives are available 1 to 3 in the “MENU”.

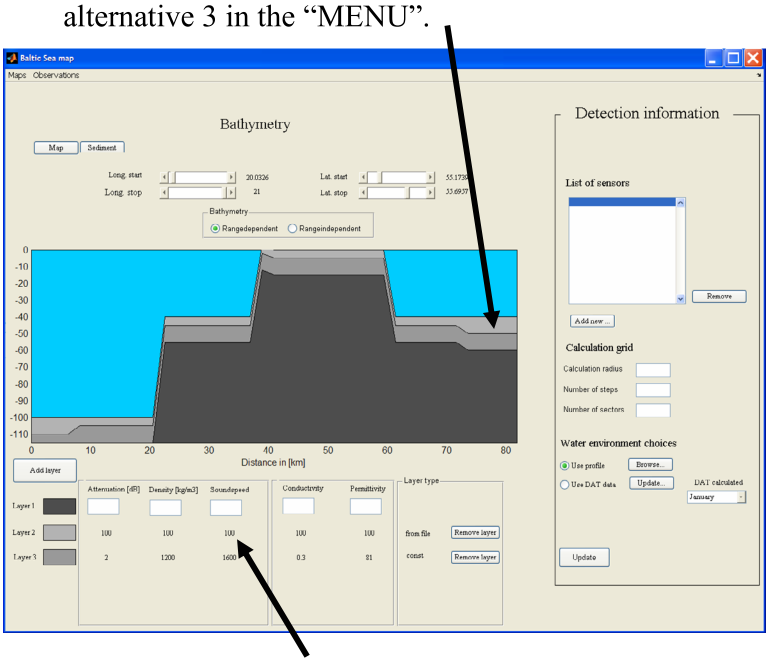


Press “Add layer” to get the “MENU”.

Here is a cross section over the island and the default assumption is that only bedrock is present.



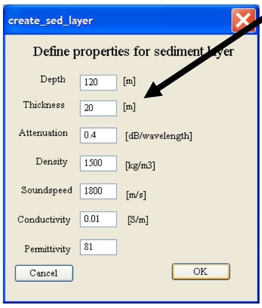
First the created sediment map is loaded by pressing alternative 3 in the “MENU”.

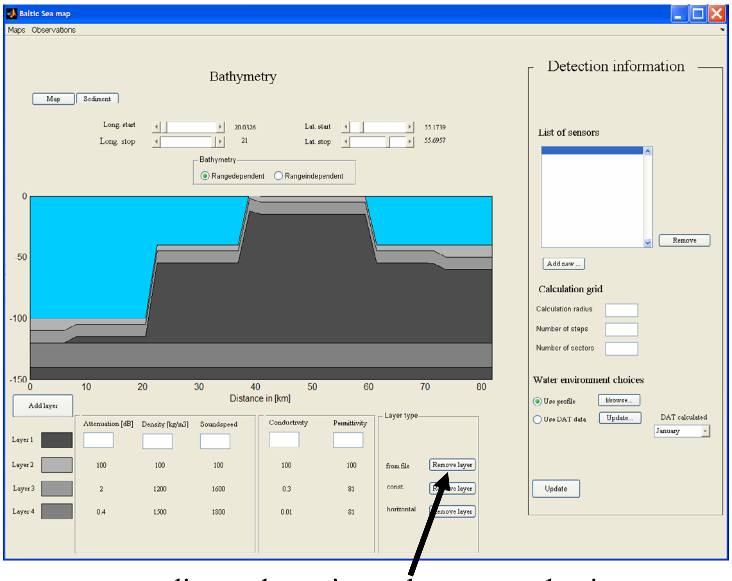


Then a layer with constant thickness (10 m) is added by pressing alternative 2 in the “MENU”. Properties for the constant sediment layer are set in “create_sed_layer”.

Here the sediments and their properties are presented.

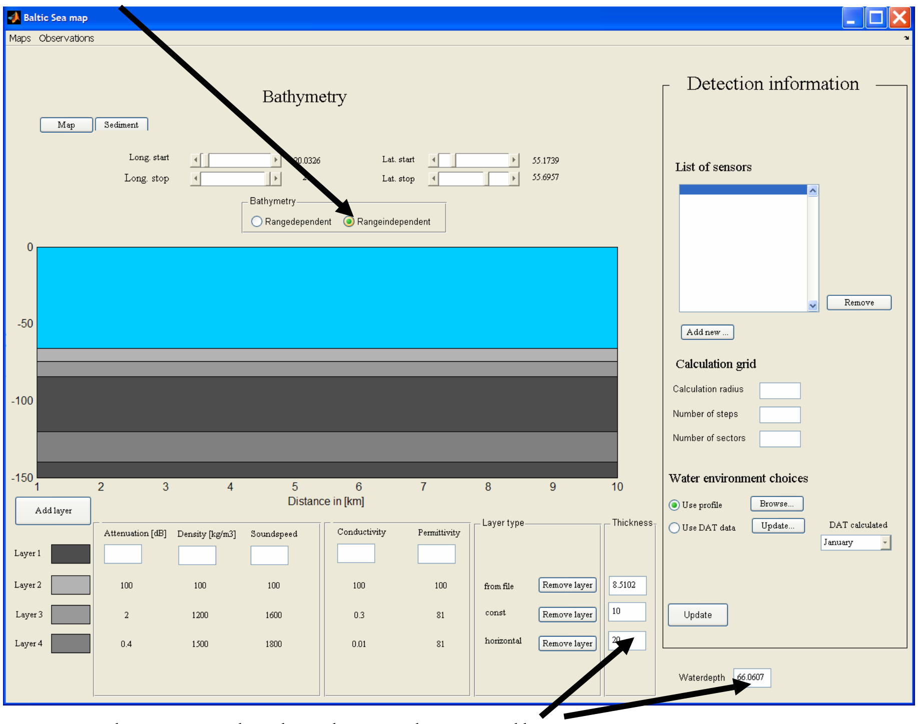
Also a horizontal layer can be added in the existing sediment structure, just press 2 in the "MENU". Both the depth and thickness must be set.





If you regret a sediment layer it can be removed using "Remove layer". Bedrock properties must always be set.

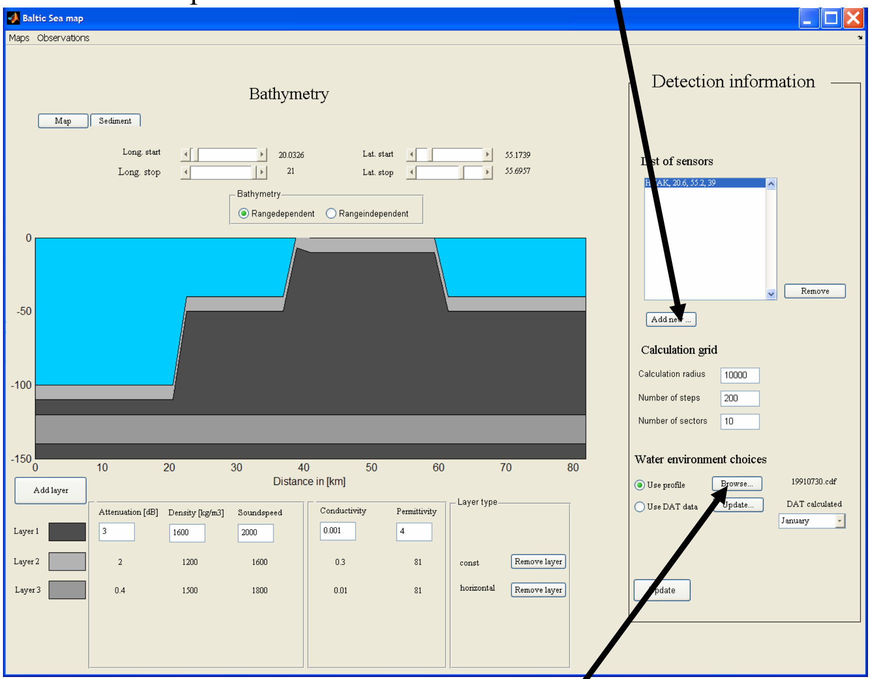
For the range-independent models a mean is estimated from the real bathymetry and sediments. Just press "Rangeindependent" to view the resulting mean.



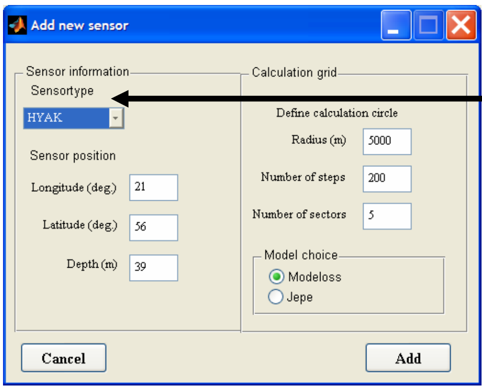
The mean values can also be changed manually.

Step 5: The oceanographic environment and set up of the sensor network

Now it is time to set up the sensor network. Press “Add new” and a sensor editor “Add new sensor” is presented.

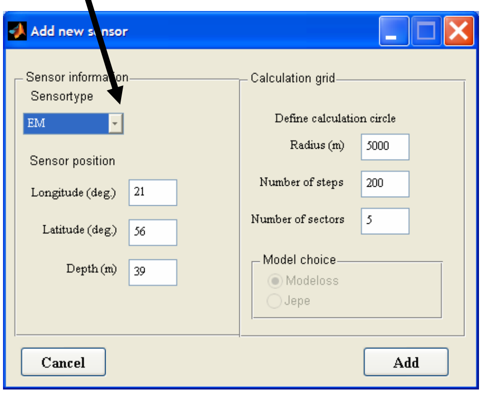


Two alternatives can be used when specifying the oceanographic environment; one profile or using the DAT estimation method. Here a profile is used. Use “Browse” to load a profile which must be in cdf-format.

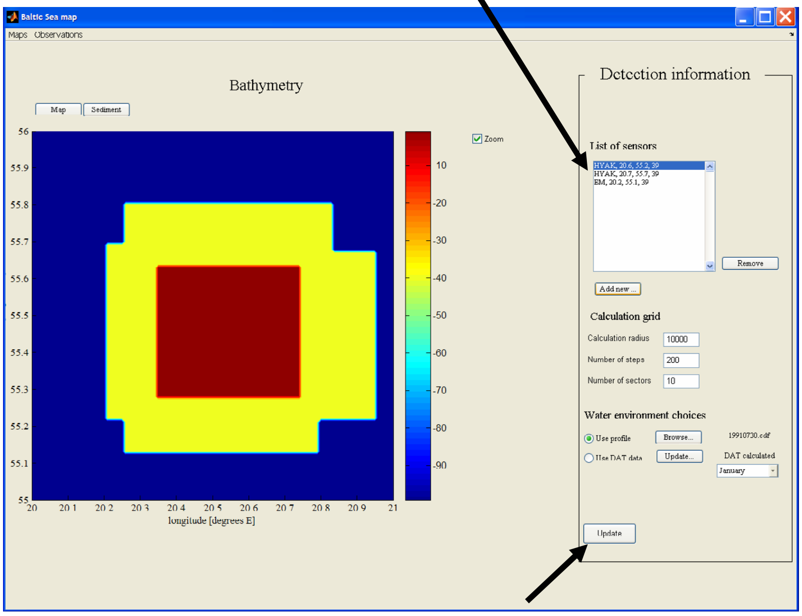


Two sensor types can be specified in the “Add new sensor” window; acoustic and electromagnetic. Press “Add” when finished.

The position and the calculation grid are set here. The radius, number of steps (radius/steps= resolution of output) and number of sectors define the surveillance area. In the acoustic case a model choice can be made.

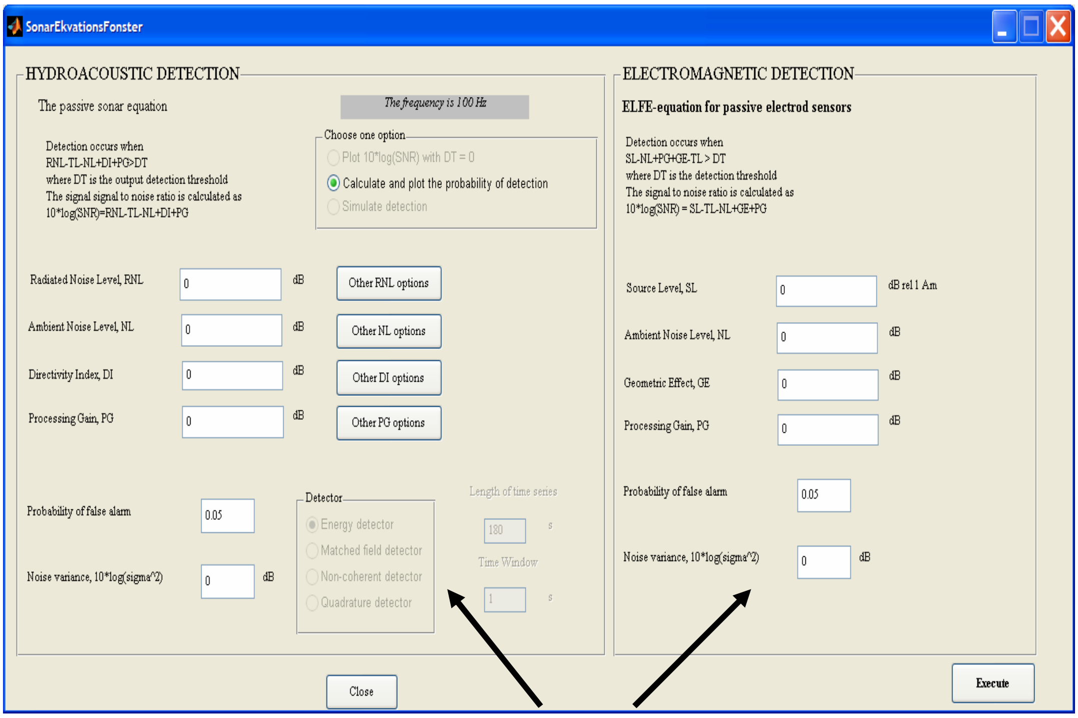


Now, all the environmental parameters are set and the sensor network is specified. Added sensors appear on the list.

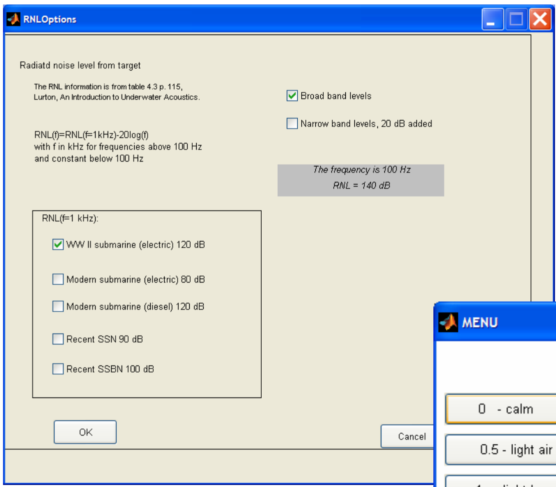


Press “Update” to open the detection editor “SonarEkvationsFonster”.

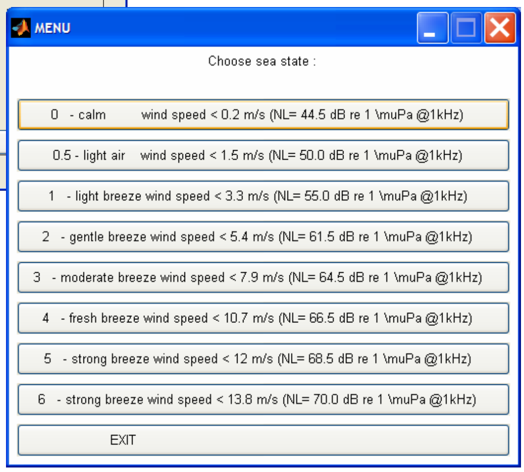
Step 6: Detection editor



The acoustic and the electromagnetic parts are presented in the same window. The passive sonar and ELFE equations are used. Type in your own values or use the options buttons.

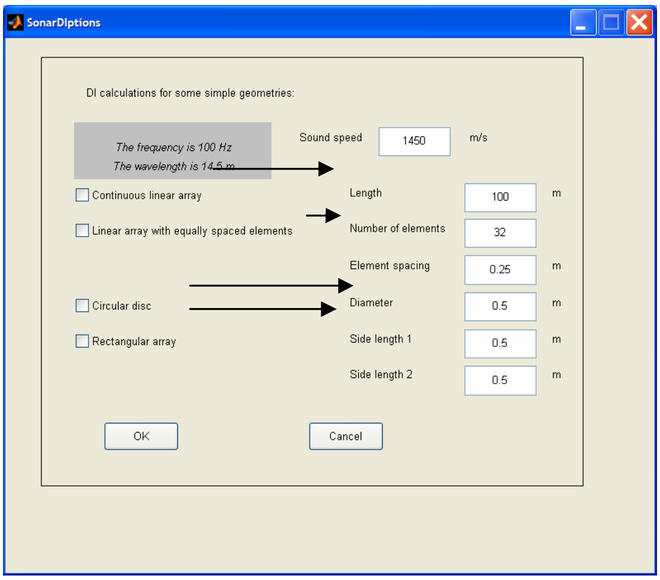


If you press “Other RNL”- and “Other NL options” the following windows appear. The NL is estimated from the Knudsen curve by choosing proper seastate in the “MENU”.



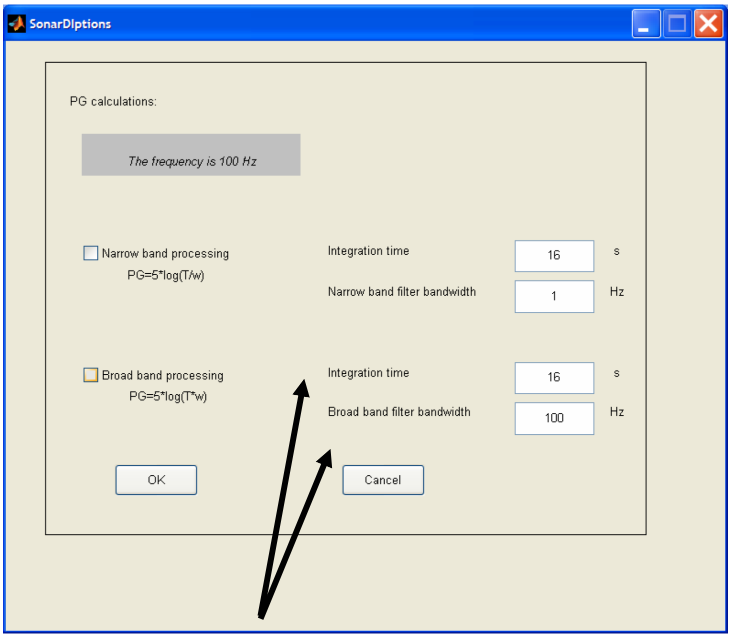
Choose proper submarine and characteristics of noise (broad or narrow band) in the “RNLOptions” window.

The directivity is calculated from the geometric design of the sonar. The window “SonarDIptions” appears when pressing “Other DI options”.



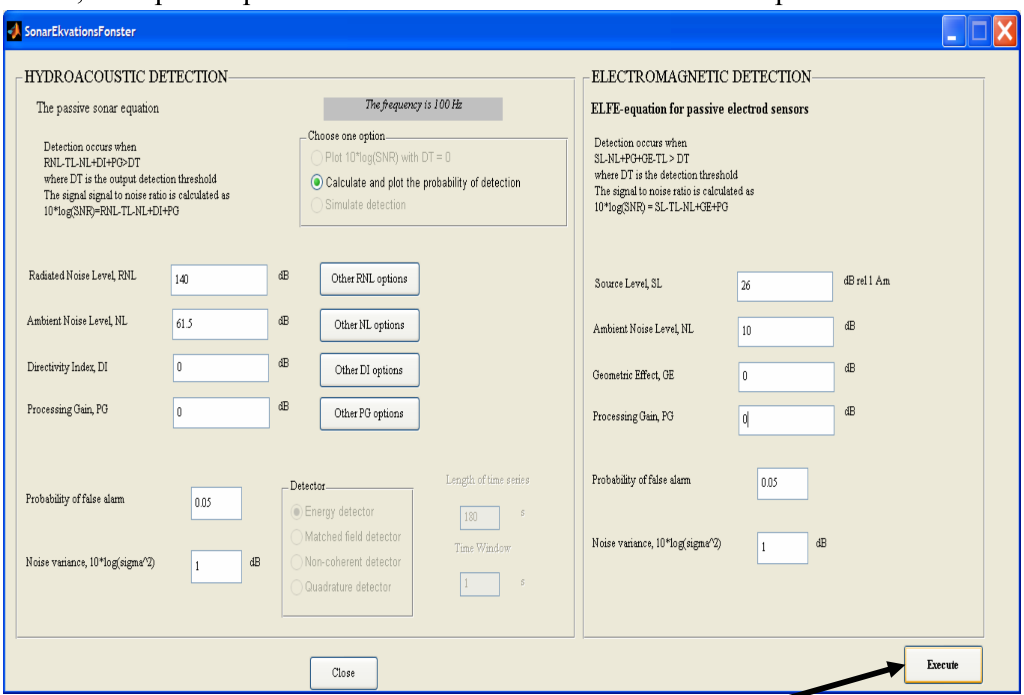
Four choices are available. Every design needs its own input.

The processing gain is calculated using integration time and filter bandwidth. Choose between broad band and narrow band options.



Give proper values on the integration time and the filter bandwidth. Press "OK" when satisfied.

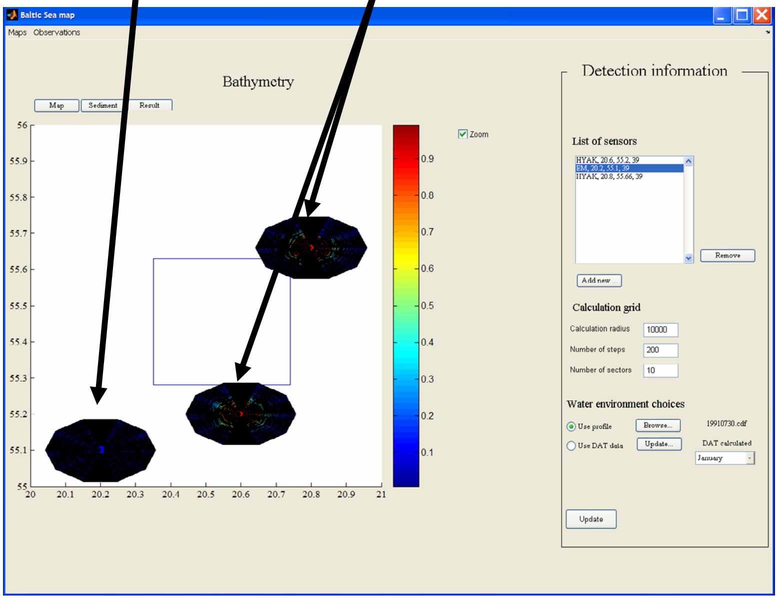
Now, all input is specified in order to calculate the detection probabilities.



Press "Execute" to run transmission loss calculations and to present detection probabilities.

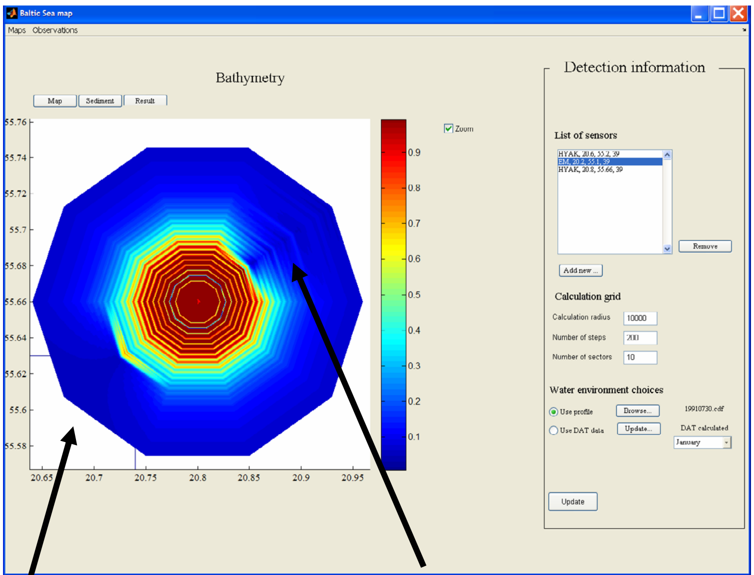
Step 7: Sensor coverage

One electromagnetic and two acoustic sensors are present.



The result is presented in a separate window "Result". The contour line of zero meter bathymetry is shown together with the sensor coverage.

The northern most acoustic sensor is zoomed into. Notice how the geometry influences the result.



The island.

A change from 40 to 100 m depth.