SEE-LAND HYBRID MAP OF GULF OF GDANSK IN ARCGIS ENVIRONMENT

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Abstract

The ensuring of security in the coastal area makes that researches about building geospatial information infrastructure are necessary. The paper shows the results of building this infrastructure by integrating electronic navigational chart (ENC) with orthophotograph, as well as with hydrodynamic and meteorological data from numerical models. Work was concentrated on integration data distributed in different formats. Using of appropriate conventions and NetCDF format helped in a simple way enter multi-dimensional geospatial data from numerical models into the ArcGIS system and allow on visualization. The possibilities of using this applications to search and rescue (SAR) in the coastal zone was tested by comparing the simulated results in an ArcGIS with those obtained during experiments in the Gulf of Gdansk. The research were made in the development project No. O R00010511 and financed by the Polish National Centre for Research and Development.

Keywords: Geographic Information System (GIS), hydrodynamic models, Electronic Navigational Chart (ENC), orthophotograph, NetCDF, standard S-57
Regional terms: Poland, The Gulf of Gdansk in a Baltic Sea, Gdynia Harbor

1. Introduction

This paper will describe the way of integration variety maps in one system – in a see-land hybrid map. This map was created in the project No OR00010511 "Marine Network Centric Geographic Information System illustrated situation in the Gulf of Gdansk area supported by scalable distributed calculating platform" realized in 2010-2012. Nowadays, results from this project are using by the team members to the next researches.

See-land hybrid map contents orthophotographs, digital model of terrain and sea bottom, Electronic Navigational Chart, data from numerical models (weather, wave and hydrodynamic model). Implementation this maps which are stored in different standards and different coordinate systems into

one system was possible thanks to using ArcGIS program. Possibility of reading NetCDF files from numerical models, and additional Viewer S-57 allow on introducing key information into the system.

The goal of hybrid map was achieve excess of information to increase the efficiency of operations, this means having as much as possible information about environment and having tools to quick analyses of situation. Information excess is helpful in emergency situation when time of fast reaction is very important and decide about human life. One of the task was using hybrid map to search in the night. Collected data are very precise and update what is very important for such type of operations. In press we often hear that search on a sea are canceled because of darkness. Our team proposed solution with combination of nigh vision, navigation equipment of search ship and hybrid map. Attention was directed on visualization of situation on a search area and influence environment spatial data on action efficiency.

First part of paper will describe the Gulf of Gdansk area. For this region are available data with high resolution. This is the reason of choosing it on research field, but hybrid map can be spread on another regions if there will be such necessity. Afterwards, will discuss components of hybrid map and the way of its integration into one system. The last one part of paper will present sample of hypothetical operations on the Gulf of Gdansk with using application of hybrid map.

2. The specificity of the Gulf of Gdansk

Baltic Sea is located into the North part of Europe. This is rather small sea, with area about 0,16 sq mi (415 300 km^2), including Kattegat and Dunish straits. Mean depth of Baltic Sea is 171 ft (52,2 m), with the deepest place in the Landsort Depth – 816 ft (459 m). This is the largest sea of low-salinity body water in the world (mean salinity - 7 ‰). It is also distinguished by its division into a series of basins of varying depths, separated by shallow areas or sills (Robakiewicz, 2009). To the Sea flows a lot of rivers and this is the reason of its brackish character. Furthermore, the link with the North Sea is very narrow, the shallowest sill being only 59 ft (18 m) deep. Thus inflows of salt water must be extremely forceful to penetrate and renew the deepest waters of the Baltic Proper. Geologically Baltic Sea is a young sea, it has undergone enormous changes since the last ice age. Sea as we now know it established just about 7 500 years ago.

The Gulf of Gdansk is in the southern part of the Baltic Sea, bordered by Poland on the west, south, and southeast and by Kaliningrad - province of Russia - on the east. The gulf extends 40 mi (64 km) from north to south and 60 mi (97 km) from east to west and reaches its maximum depth, more than 371 ft (113 m), in its northern section. It is named after the adjacent port city of Gdansk in Poland. The Gulf of Gdansk is excreted by straight line from Rozewie Cape (54°50´N, 18°20´E) to Taran Cape (54°58´N, 19°59´E). This line cut through the deepest part of Gdansk Depth. The coastline has semicircle shape from south side and from west-north gulf is closed by Hel Peninsula. The rest one of body water is open and allow on free mass water movements between the

Gulf of Gdansk and the South Baltic. Big influence on the hydrodynamic condition has Vistula River, which is the longest polish river (0,65 mi (1047 km)) and transport to the Gulf huge amount of water (annual outflow in 2006 was 1,5 cu mi (62000 mln m^3)), (The Flood…,2007).

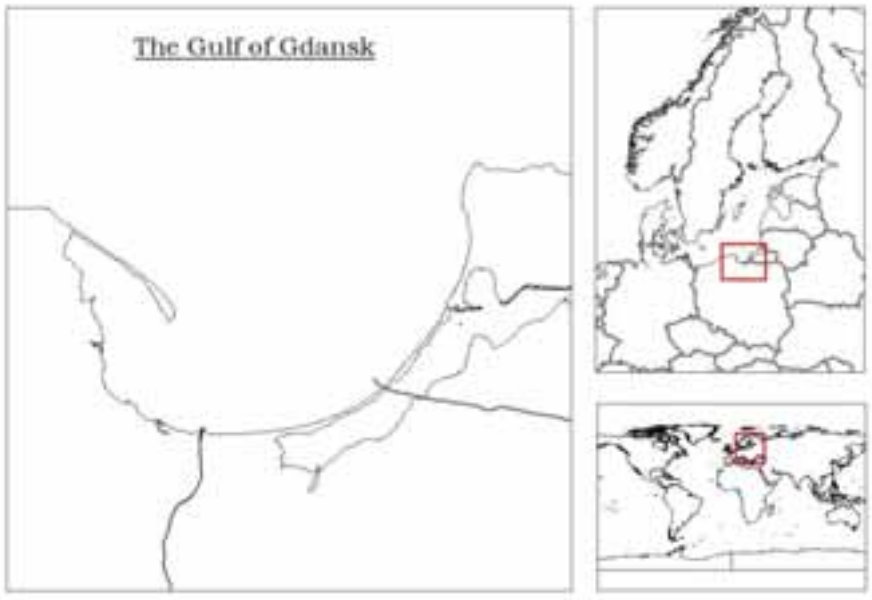


Fig. 1. Geographical location the Gulf of Gdansk

To generally describe hydrodynamic conditions have to be mentioned about temperature, salinity and currents:

- Water temperature changes seasonally, but it is not uniform throughout the whole water body, which has a layered temperature structure. Mean monthly water surface temperatures is in the range 2°C to 18°C over the year. In the deepest part of Gulf (below 262 ft (80 m)) water temperature shows a slow increase to the maximum temperature (Robakiewicz, 2009).
- As it was mentioned salinity in the Baltic Sea is low. Also in the Gulf of Gdansk does not exceed 7,6‰ (Robakiewicz, 2009). Spatial differentiation in salinity mainly dependent on morphological conditions. It can be identified some fairly major differences between the coastal zone, deep parts of the Gulf, and the Baltic Proper. Not without influence is Vistula River which provides fresh water.
- In the Gulf of Gdansk wind is the main driving force of water motion. Wind currents are generated as a consequence of wind stress acting on the free surface. This force makes the surface move, and energy-momentum causes it to transfer to the deeper parts. When wind sustained for long periods we observe gradient currents. In such cases the water level increases in some parts of the water body, while in others it decreases. Density currents are also in the Gulf of Gdansk. They are created in the event of non-uniformity of water density (Robakiewicz, 2009).

In maritime economy of Gulf of Gdansk recently views very dynamic changes. It is connected with economic changes in Poland and in the Word. In the Gulf of Gdansk are located two (with three) main harbors in Poland: in Gdansk and in Gdynia. It is difficult to say which of it is more significant. In the Gdansk Trade Port reloads mainly bulk cargoes: coal, koks, sulfur, wood, grain. North Gdansk Port specialized in reloads petroleum because of neighborhood of Gdansk Refinery Lotos SA. Gdynia Harbor is more miscellaneous. There is trade port where reloads containers, fishing, passenger and military port as well. In the area of south and east Baltic Sea harbor in the Gulf of Gdansk have the best localization and achieve successes. In both cities are also shipyards. Besides, in smaller coastline cities also develop fishing and maritime tourism. Touristic sea sailing an windsurfing is very popular. In the Hel Peninsula are very good conditions for kitesurfing as well. Tourism infrastructure is good develop, including hotel base and touristic attraction. Each year this region visit several thousand of people from Poland and World.

3. Hybrid geodatabase maps

Development of new technology is causing of expand threats list unknown today phenomena. Modernization and security services use this technology also to eliminate or reduce risk to minimum. Non-use so far technology in Poland is a hybrid map which main repository is created in a network-centric geodatabase in ArcGIS environment. To have stable, complete and current situation the units which obtain, manage and use information should be linked (preferably in real time) to exchange information. In summary, the main purpose of creating hybrid maps is having information excess to increase operations efficiency.

The structure of upgraded geodatabase is adjusted to have a dialog between stored data describing lithosphere, atmosphere and hydrosphere (i.e. composing in any combination with each other and with other types of data). Collected data allow also on simulation variety phenomena. Extremely important is the ability to depict current situation in the region. This requirement ensures system with necessary components:

- Geographical Information System,
- data from Electric Navigational Chart,
- data from atmospheric and hydrodynamic models and from another applications,
- terrestrial data (e.g. orthophotograph, topographic map).

Below is short description of contents hybrid map.

Ortophotograph

Orthophotograph is a source of actual information about the area. It was made in 2012 with resolution 0,32 ft (10 cm). Because of big weight sets of orthophotographs (about 310 GB) system use two set with different resolution. First is in resolution 16,4x5 16,4 ft (5x5 m) and is screening in lower scale than 1:5 000. It was achieved by resampling of source material. It cover all area. The second one is in the primary resolution 0.32 ft (10 cm) and cover coastline.

Fig. 2. Ortophotograph of Gdynia Harbor

Digital Terrain Model

Digital Terrain Model (DTM) contain information about high and topography of area. This data can be used to analyses of visibility and slope and aspect of relief. In a hybrid map DMT of land was made using remote sensing techniques, photogrammetric techniques and using data from laser scaling LIDAR. This map is connected with DMT of body of the Gulf of Gdansk descended from Electronic Navigational Chart (ENC). Achievement of continuous layer this both different environment which are usually separately, guarantee spatial data cohesion and allow on advanced analyses of both environment. This is very useful in strategic places located at the junction of land and sea such as port.

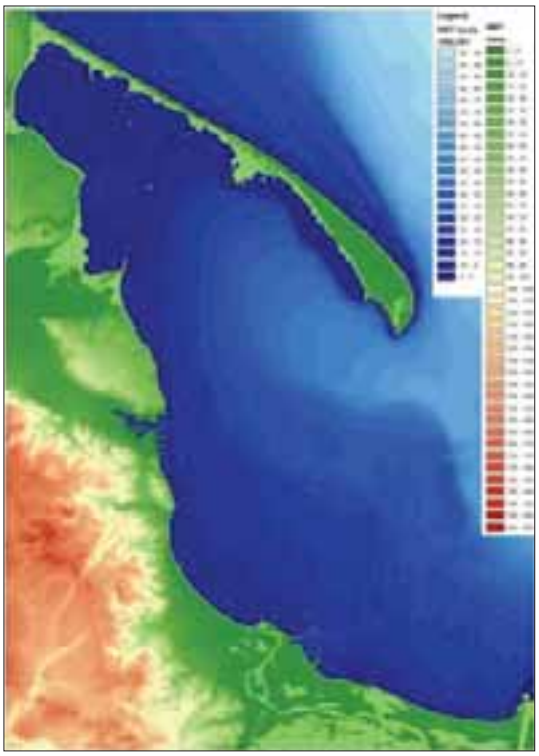


Fig. 3. Digital Terrain Model with Digital Seabed Model

Electronic Navigational Chart

Electronic Navigational Chart is a digital equivalent of traditional paper navigational map prepared in accordance with the standards of International Hydrographic Organization (IHO). Standardization gives instruction about the way of symbolization, using format and building structure, which made map commonly used on the entire world. Currently, for vector hydrographic spatial data is used IHO Transfer Standard for Digital Hydrographic Data – S-57. ENC describes details for sea environment with the seabed, navigational elements and adjoining land area. In Poland ENC is distributed by

Hydrographic Office of the Polish Navy (pl.BHMW/ en. HOPN) which is a service supporting the Navy terms of navigation, hydrography, meteorology and oceanography.

In the hybrid map data from ENC contain data for Polish Exclusive Economic Zone (Polish EEZ), in particular the Gulf of Gdansk body water. ENC is selected on six bands which differ from each other scale, i.e.: overview (smaller than 1:1 500 000), general (1:600 001-1:600 000), coastal (1:150 001 - 1:600 000), approach (1:50 001 – 1:150 000), harbor (1:5 000 – 1:50 000) and berthing (larger than 1:5 000) [17]. This bands are distributed in cells usually in rectangular shape. For visualization of the Gulf of Gdansk are used three cells from coastal band, five from approach band and two form harbor band.

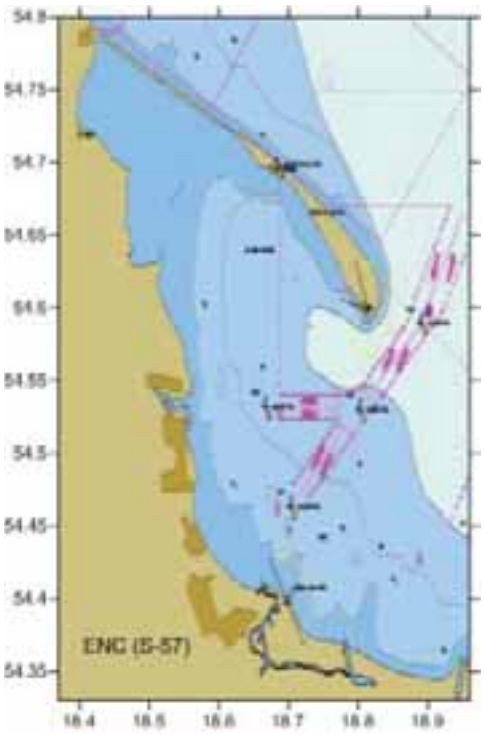


Fig. 4. Electronic Navigational Chart

Data from cells were imported to ArcGIS environment using extension "Data Interoperability" which operating data in S-57 standard. This extension allow also on import updating cells what is fundamental for presented data in high quality. Visualization data S-57 is possible thanks to add-on S-57 Viewer. Data are visualize using S-52 standards what allow on apply various S-52 properties such as Color Scheme or Safety Contour Depth. In ArcGIS environment ENC can be queried and analyzed using different ArcGIS commands and tools and can be also overlay with other supported ArcGIS formats.

Data from numerical forecast models

Meteorological data in a hybrid map are imported from Unified Model for Poland Area (UMPL). It was first regional numerical model in Poland and it works operationally in Interdisciplinary Center for Mathematical and Computer Modeling (ICM) from 1997. Model was mezoscale version of created in Great Brittan and used by British Meteorological Service forecast Unified Model (UM) in version 4.5. Form 2008 UM works in ICM in version 6.1. Model has relatively high resolution 2,9 mi (4 km) and cover Poland and Baltic area. It gives very reliable forecasts on 60 hours.

In ICM also works operationally WAve Model (WAM). WAM predicts wave properties such as significant wave height, mean wave direction and frequency and swell wave height. Recently, in the Institute of Oceanography in University of Gdansk (IO UG) start working WAM model with resolution 2 Nm. Hybrid map can import data from this model.

In the Institute of Oceanography in University of Gdansk (IO UG) works also one more numerical model: Ekohydrodynamic model M3D. Model was established in IO UG in 1995-1997 as a modified to Baltic condition version of Princeton Ocean Model (POM), (Kowalewski, 1997) .This

model consist with two parts – eco and hydrodynamic. Model is 3D and in vertical is divided on 18 layers in σ-coordinates. Part eco is called as Production and Destruction Organic Matter Model (ProDeMo) and gives simulation e.g. biogenic substances, oxygen, phytoplankton and zooplankton biomass. The second part – hydrodynamic – gives e.g. sea temperature, currents, sea level, salinity. In a hybrid map is used hydrodynamic part of M3D with resolution 0,5 nm on the Gulf of Gdansk and 1 kb (0,1 nm) in its west area.

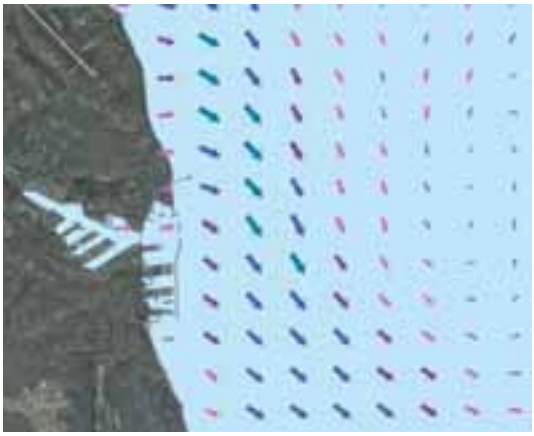
a)  b) 

Fig. 5. Sea currents in resolution 1 kbl (a) and 0,5 (b) Nm with orthophotograph

Integration multi-dimensional spatial data from all mentioned numerical models was possible because of using NetCDF formats. ArcGIS, allow on successfully processing and visualization files in NetCDF. This standard was formed in UCAR Unidata Program Center and is defined as a group of data format, interfaces and software libraries which support creation, access and cooperation between files. Files in NetCDF have multidimensional data organized in tables what allow on treatment time as an additional dimension (4D). Using Time Slider, tool ArcGIS program, we can choose for example field with information about wind in appropriate hour and depth and create animation in real time.

NetCDF files are self-describing. This means they have information (metadata) about data contained in them. Because of that, we can interpret recorded data without any additional information. Metadata contain information about recorded parameters (e.g. SI unit, correct data scope, means code when there is no data etc.) and about data source and geospatial property (measurement of tables, resolution, projection etc.). Attributes metadata usually contain also series of important information about data origin, source, and their status or about authors etc. Besides, they allow bind geographical data and calibrate the axis properly.

Tab. 1 List of parameters in a hybrid map from different numerical models.

Parameter name	Depth or high above sea level (m)	Model (Institution)	Forecast (hour)	Resolution (km)
air temperature	+ 2	UM v. 6.1 (ICM)	60	4
wind speed	+ 10	UM v. 6.1 (ICM)	60	4
wind direction	+ 10	UM v. 6.1 (ICM)	60	4
air pressure	0	UM v. 6.1 (ICM)	60	4
cloudnies	-	UM v. 6.1 (ICM)	60	4
significant wave height	0	WAM (IO UG)	84	3,7
wave direction	0	WAM (IO UG)	84	3,7
water temperature	0, 5, 10, 15, 20, 30, 40, 50	M3D (IO UG)	60	0.18 – 0.9
sea level	-	M3D (IO UG)	60	0.18 – 0.9
salinity	0, 5, 10, 15, 20, 30, 40, 50	M3D (IO UG)	60	0.18 – 0.9
current speed	0, 5, 10, 15, 20, 30, 40, 50	M3D (IO UG)	60	0.18 – 0.9
current direction	0, 5, 10, 15, 20, 30, 40, 50	M3D (IO UG)	60	0.18 – 0.9

Gdynia Harbor

Hybrid map contain also map of Gdynia Harbor in 3D. This map was made using laser technique. In 3D are buildings, harbor infrastructure and ships which are still moored. Ship models were constructed to put them in any place in the water body. There were also made panoramas in 360° as an element of information form for security harbor services. Besides, hybrid map contain standard map (2D) of Gdynia harbor and neighbor area.

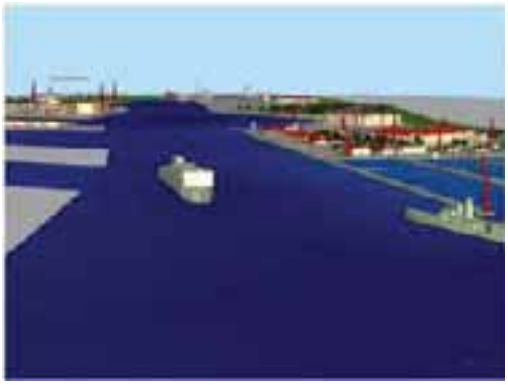


Fig. 6. Simulation of ship track in Gdynia Harbor in 3D.

4. Using of hybrid maps in emergency situations

Presented hybrid map follow the current trends in priority research direction and concern technological area associated with safety of sea zone and safety of public zone in the field of harbor. Hybrid map allows on development of methods for port security command support, optimization of sourcing and distribution of information in the prevention and crisis management in the Gulf of

Gdansk, construction and research of hybrid map as a decision-making base. Below are described three chosen scenarios that show ability of using hybrid map in harbor and on open sea.

Scenario 1 *Spillage of oil from damaged tank in a sea.*

To the hybrid map was made experiment with prototypical implementation of algorithm simulated spread of contamination (in the air, on/in a sea). Result of sample simulation is on Fig. 7 . Services responsible for combating contaminations in Poland is Maritime Search and Rescue Service. They have to reduce spillage, pomp out harmful and dangerous substance, emergency tow ship and eliminate contamination. Using hybrid map to this aims we can use:

- Electronic Navigational Chart with localization of event;
- simulation of spreading spill oil in the function of time
- appoint of danger zone (minimum 160 ft (50 m));
- appoint of infrastructure and another ships which are in the range of danger zone (registration of updating position ships is in Automatic Identification System – AIS);
- appoint amount of units needed to this action

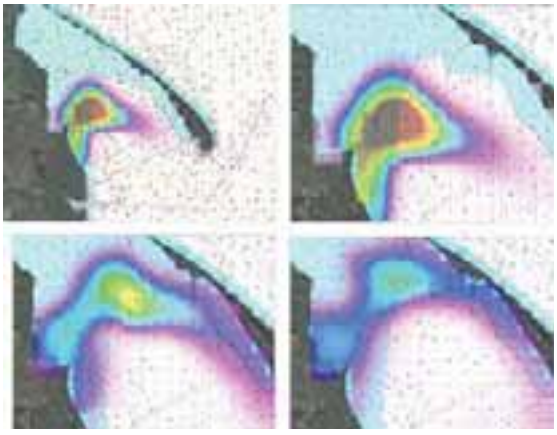


Fig. 7. Simulation of spreading contamination in a function of time.

Scenario 2 *Two people in the water about 3 nm from harbor (night)*

Night is the most unfavorable time of day for taking rescue action on a sea. Mostly action are canceled till the sunrise. Experiment took in July 2012 at the Gulf of Gdansk showed that hybrid map is very useful for rescue unit equipped with the night vision. The crew is in some sense dependent on a hybrid map because they adapt movement of ship according with data on a screen. Map with updating position is they eyes.

Experiment was to tracking buoy and phantom in the sea and compared it with simulation results taking in hydrodynamic model M3D and visualized in a hybrid map. Buoy had positive displacement and was equipped with steel foot, thank that its move was causing mainly by sea currents. Because of its weight (about 85 kg) and a steel foot it imitates the man who fell into the water without any rescue device. Phantom had a lifejacket so his move was also caused by wind. Both facilities were equipped with

Fig. 8. Rescue unit in the vision night

GPS transmitters to continuously record their location.

A comparison of simulated routes of phantom movement made using by numeric hydrodynamic model with results observed in experiment on a sea showed quite good convergence. The rescue unit started action 2 hours after the event. Phantom drifted about 0,4 mi (700 m) in the meantime. Calculated position by model M3D was only depend on sea currents (the wind was not used in this case). Besides, rescue unit had updated data about their position and predicting position of survivor what is particularly important at night. To this action was used:

Fig. 9. Simulation of phantom movement on a different depth (black points are on the surface, other points – deeper) and real track of phantom (red line).

- hydrometeorological data to simulate movement of survivor,
- Electronic Navigational Charts,
- record from GPS tracking of rescue units.

Scenario 3 *Ship occupied by terrorists*

Terrorism is one of main treatments of safety in the world today. History know situation of occupation ship, an example is passenger ship "Achille Lauro" rapt by terrorists in Egypt in 1988 and container "City of Xiamen" rapt by pirates in Nigeria in April 2013. The emergency services can meet with ship which was occupied on a open see or in harbor. Then they can do analyses range of visibility from the occupied unit to appoint places where emergency forces can move invisibly for terrorist. Important is analyze of real terrain and all obstacles giving possibility to reach taskforces so close as they can. In the hybrid map they can use:

- orthophotograph;
- orthophotograph with localization of ship occupied by terrorists;
- appoint range of visibility from stern, from middle part of ship, and from bow;
- imposition of all three zones on the orthophotograph to sea safety and invisibly from the ship places.

Fig. 10. Visibility from all places in a ship

Hybrid map is an information platform which gives spread knowledge about situation on area of Gulf of Gdansk and Gdynia Harbor. Aim of creation this map was to serve data various emergency resorts to coordinate an action, prevent against treatments and serve updating information. In the future, hybrid map will be made as a web application which spread possibilities of using it especially in a field of emergency situation. In such case time has a key value so web technology can be used to save it.

5. Summary

South area of Baltic Sea is under the jurisdiction of Polish sea state services. In Poland there is no such system which include information from land and sea area, integrated so many information in such high resolution like sea-land hybrid map. This paper demonstrate that join maps with variety standards, formats and coordinate system is possible in ArcGIS system. This integration allow on using wide spectrum of commands and tools which gives this program. GIS environment seems to be a future of variety systems dedicated e.g. emergency services in Poland and in the World.

Hybrid map contain important environmental information. Current short-term forecasts from mathematic models, including meteorological conditions (speed and direction of wind, temperature, humidity and atmospheric pressure) hydrological conditions (water temperature, salinity, sea level) and hydrodynamic conditions (sea currents, wave condition) are essential for generating additional layers into electronic charts. Obtained data complete information acquired by traditional electric navigational chart (ENC). Additionally, there is possibility of view situation in the coastline by having orthophotographs in high resolution 0,3 ft (10 cm) and Gdynia Harbor map in 2D and in 3D.

Almost each information in the surrounding us world has reference in space, its own coordinate XY. GIS systems and mathematical models try to create digital environment which seems to be mathematical mirror of real world. Land-hybrid map contain so much information that they can be used in variety situation and by variety users. Skilful selection of information and fast analyzing can give quick solution which is important in situation of life treatment. Hybrid map gives supremacy of information about environment which is on a interface of two environment – sea and land, where the activity (society, tourism, trade, economy) is quite big (because of two big harbors) and specified.

The team of scientists and practitioners worked on this project plan to develop this map into web application. Each of team members use this information platform for its own researches which, in sum, will give more possibilities for using this map. The researchers are led in a several fields: to use hybrid map in night search action, to predict movements of survivor (object) using data from numerical model and variety mathematical algorithms (fuzzy sets, graphs theory, probabilistic). They also test fuzzy sets in identification of accident place at the sea using information from observer in the land. Studies are also lead in mentioned research units to distribute information from numerical models with higher resolution and quality

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