Geospatial Tactical Decision Aids

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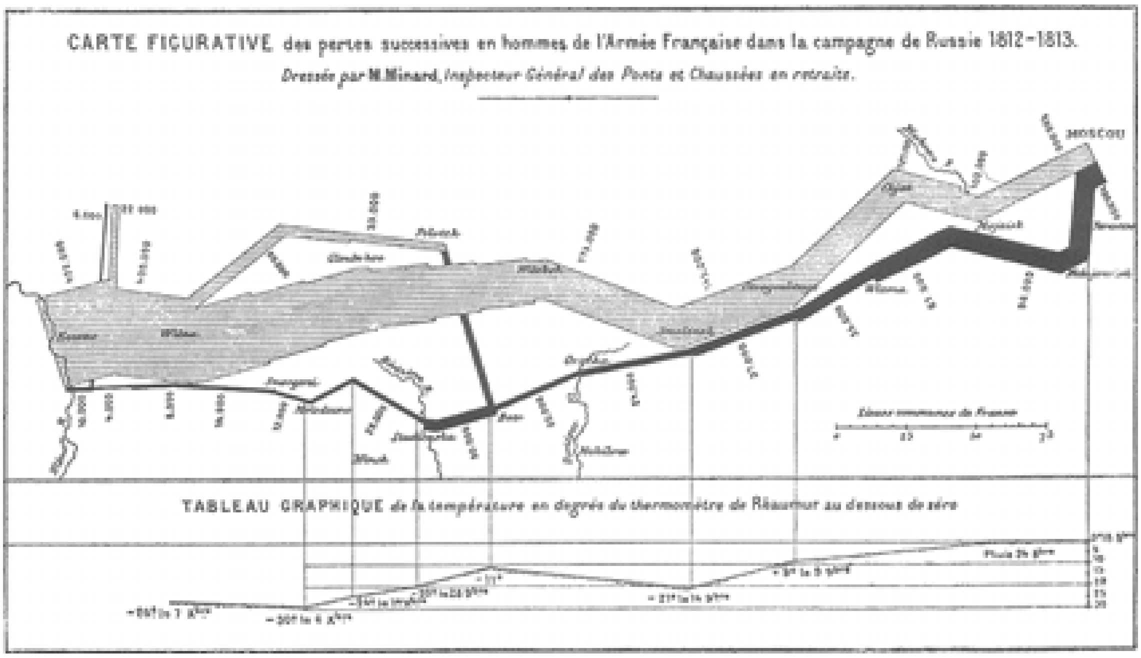
Abstract

Environmental conditions are known to affect the efficiency and effectiveness of military platforms, weapon systems and personnel. The translation between the environmental conditions and the impact they may have on platforms, weapon systems and personnel is made based on pre-defined tables that result in a coloured mission impact diagram. These diagrams are specific to short area extensions. For large areas, where, weather and oceanographic conditions are necessarily different from place to place, these MID do not provide the decision maker with the whole picture. A new MID concept was tested for a major Portuguese Armed Forces national exercise. A WEB GIS was developed in order to provide 2D geospatial related MID information through a private network. Besides the 2D geospatial visualization of the variation of each feature MID, users can interactively get the traditional MID for each pixel of interest. It's a new dimension for MID.

Introduction

Environmental conditions are extremely relevant for the outcome result of military operations. Consequences can be expected at the performance level of human resources, platforms, weapons and sensors. Historical evidence of environmental conditions impacts is, for example, the D day of World War II that occurred on June 6th 1944 because weather and sea state conditions prevented the invasion of Normandy to happen on the previous day. Another environmental impact emblematic operation was the Napoleon invasion of Russia in 1812. The French campaign started with 422.000 troupes, only 100.000 reached Moscow and when the retreat was finished, only 10.000 men were left. “General Winter” did it all by itself. Picture 1 shows a famous graph by Charles Minard representing the number of troupes during the campaign throughout the time. The width of the line is proportional to the number of men and should be read from left to right as the direction for the invasion, and right to left as the direction for the retreat. At the bottom of this image, there is a graph showing the negative temperatures (in Celcius degrees) suffered at each stage of the operation [1].



Picture 1 – Map by Charles Joseph Minard (1781-1870), published on 1861, showing the variation on the number of Napoleon troupes during the invasion of Russia in 1812.

Due to its impact, the need to provide, in a systematic way, environmental information to support military operations, lead to the development of the “rapid environmental assessment” (REA) concept. For naval military operations this concept implies a series of tasks concerning the gathering and production of environmental information at three different time stages. At the planning phase, 2 to 3 months before theatre operations, climatology data and information are compiled for several environmental factors relevant for the area of interest and type of predicted operations (e.g. air temperature, hydrology, sea state, ect), as well as base map geographic data (e.g. digital terrain models, land and sea digital maps). The second stage occurs just before theatre operations start and includes the gathering of field data for initial feed of high resolution prediction models for environmental conditions. The third stage occurs during theatre operations and includes the gathering of in situ data by all available means to feed assimilation models and output short and mid term environmental conditions predictions.

The prediction of environmental conditions is not an end on itself. There is a need to estimate their impact on human resources, platforms, weapons and sensors performance in order to assess their effectiveness for certain types of operations (e.g. the impact of sea state conditions on a frigate replenishment at sea operation). Evaluation of environmental conditions impact on resources is an information product that is part of a set of tools available to tactical decision makers that are generally designated “tactical decision aids” – TDA. The most common TDA used to report expected environmental conditions impact on resources is designated “Mission impact diagram” – MID. MID present, in a very concise and explicit way, the expected efficiency of resources use at a certain time, reducing the complexity of the environmental picture interpretation. The decision maker does not need to be an environmental expert [2]. Environmental impact on resources is provided in a table listing all combinations of resources/operations versus time and the result is showed in colourful way: red if high impact is expected

(and resource should not be used), yellow if some impact is expected and green if no impact is expected.
This type of MID is adequate for small sized area theatres of action, meaning up to the size where geospatial variation of environmental conditions is small enough not to imply the provision of several diagrams. For operations at multiple locations, large areas or where spatial variation of environmental conditions are relevant, it is necessary to produce multiple MID diagrams in order to provide tactical decision makers with the best local impact assessment.

For the Portuguese Armed Forces military exercise "Lusiada 2006", a geo-spatial MID concept was developed and implemented to support field operations. The next sections describe the methodology used and the output results of the system.

Data Sources and Methodology

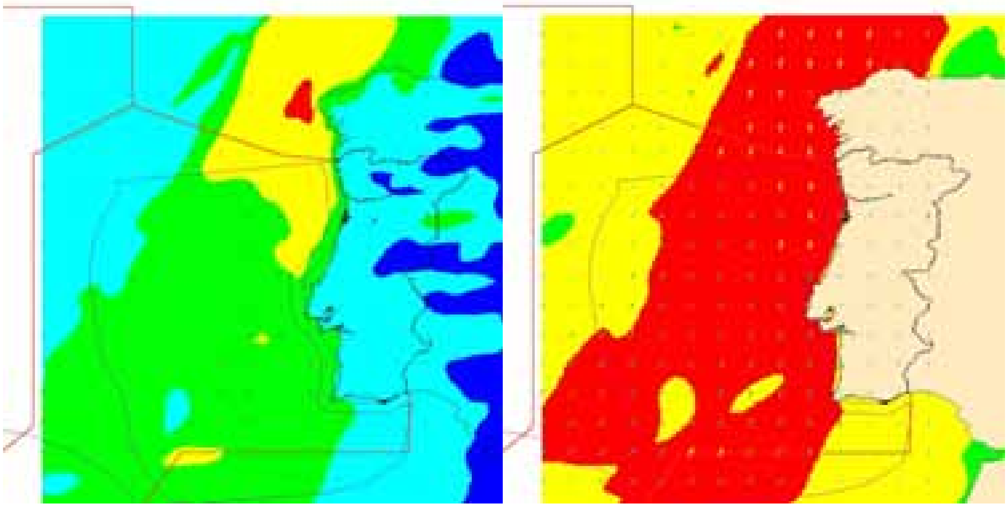
The Portuguese Hydrographic Institute is the national organization responsible for producing official nautical charts, both paper and electronic. It also develops studies and research in several marine sciences such as physical and chemical oceanography, marine geology, hydrography and safety of navigation. All data collected is stored in a centralized database developed by a Data Centre. This Centre is also responsible for developing geographic information systems for both military and research activities.

The physical oceanography department has implemented several marine prediction models (sea state, tide, drift, etc) that constitute the MOCASSIN system. Some are assimilation models that are forced by local observations and wind predictions. Weather predictions used to force some of these models are daily provided by the national meteorological centre. For the purpose of this military exercise, data from WW3 and SWAN sea state prediction models, and ALADIN weather prediction model were used. These data provided an estimation of significant wave height, wave direction, surface air temperature, surface air pressure, wind velocity and wind direction. All these data were made available in ASCII text format organized in a grid, such as a geo-spatial matrix.

All the processing needed to get these data and produce geo-spatial MID was performed on a Windows XP workstation with a 3 Ghz processor, 1 GB RAM and 80 GB hard disk, with the ArcGIS Desktop 9.1 system with the spatial analyst extension and ArcIMS 9.1.

In order to get a geo-spatial MID it was necessary to transform some of the discrete grid data into continuous surfaces (e.g. wave height, wind speed). Considering the type of phenomena and the grid resolution, this was performed using a second degree order inverse distance weighted interpolation, limiting local calculations to the 12^{th} nearest grid points. The output surfaces spatial resolution was set to 5 km.

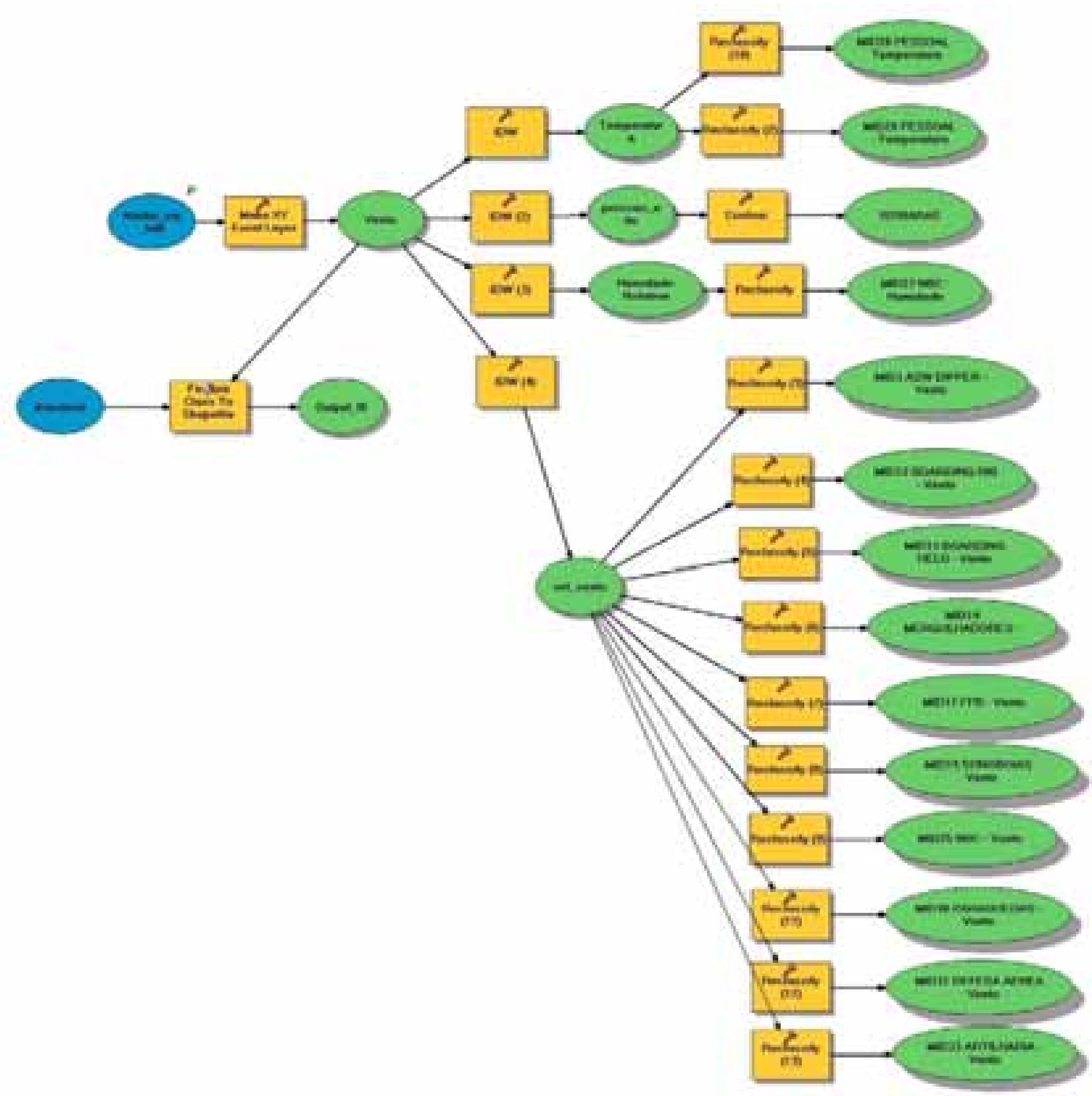
The next step was to generate each geo-spatial MID based on the phenomena surface values and the type of resource/operation. Coding the environmental conditions into geo-spatial MID was performed using the reclassification function as a lookup table. This function looks at the value of each phenomena pixel, compares it with the reclassification classes and assigns it a value of 1, 2 or 3 that is then symbolized with green, yellow and red color. Picture 2 shows the spatial variation of wind sped (left image) and the corresponding MID (right image) for a certain type of resource/operation. The type of resource/operation, lookup values and wind velocity legends are not presented due to the fact that they are classified.



Picture 2 – Geo-spatial variation of windspeed and its corresponding MID geo-spatial variation for a certain resource/operation.

The "Lusiada 2006" military exercise included forces from the Navy (including marines), Army and Air Force. A total of 39 geo-spatial MID were to be produced for each epoch of interest. In order to make this an efficient procedure three processing models were developed with ArcGIS model builder. These models take the oceanographic and meteorological models text files output and generate the 39 MID for one epoch in about 10 minutes. Picture 3 shows one of the three processing models, that reads the meteorological data and produces its 13 related geo-spatial MID, as well as 5 surfaces representing several aspects of the expected environmental conditions (i.e. pressure lines, surface air temperature, surface pressure, relative humidity and wind [direction and speed]).

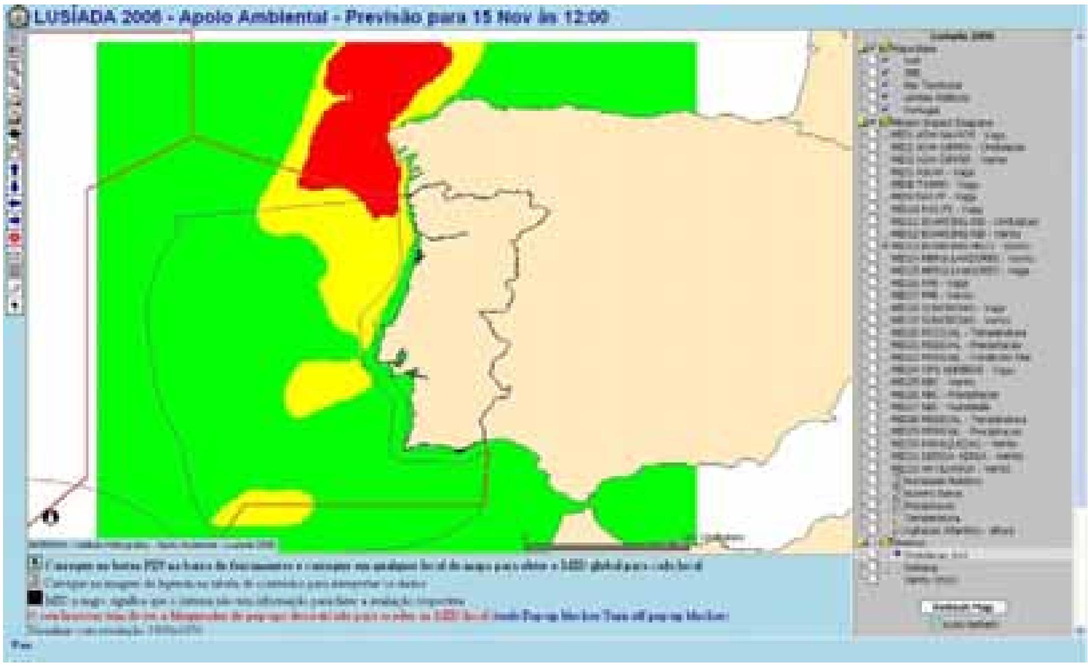
After processing data to get the necessary MID for a certain epoch, it was necessary to make them available to planning and tactical decision makers. MID integration on a system was complemented with base map data such as coastline, territorial waters line, exclusive economic zone and search and rescue areas. Also, some of the phenomena real values were included in order to give experts a chance to look at raw values if there was a specific need for that. The next section describes the way data was made available throughout a private military network.



Picture 3 – Processing model to produce MID related to meteorological data

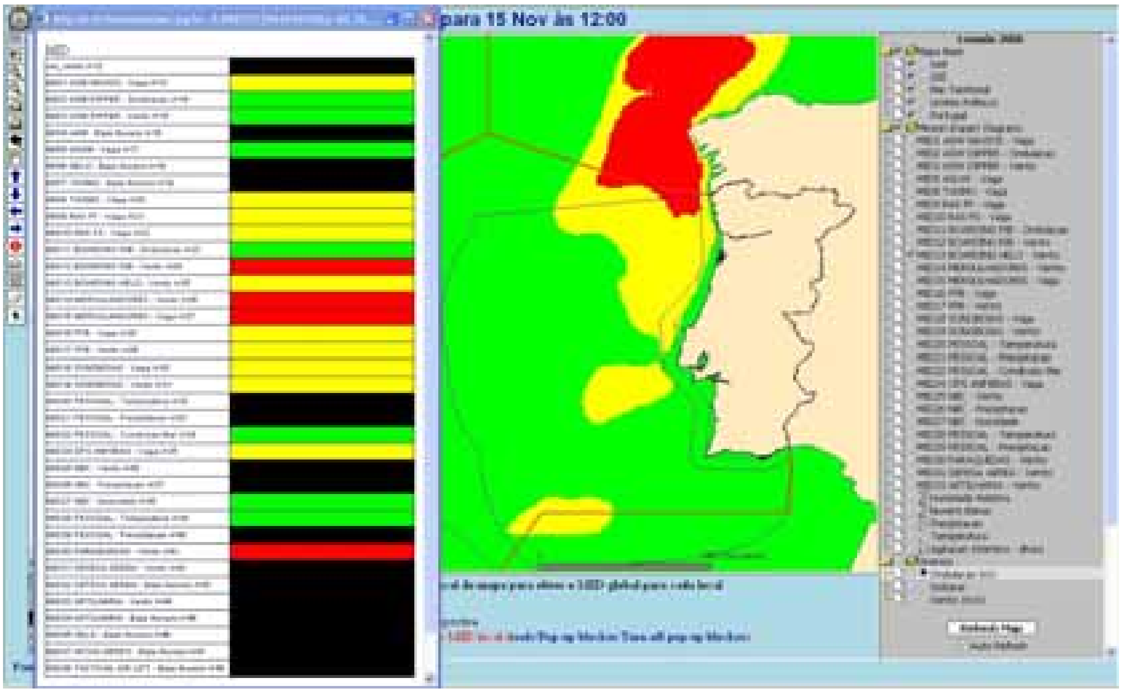
MID Information Product

Geo-spatial MID were made available through ArcIMS technology over a private military network. A data service, based on the ArcGIS Desktop project file, and a webgis page were produced. The table of contents of this page was customized in order to allow only one MID to be visible at a time, avoiding miss interpretations by users. The page also included basic GIS functionality such as the ability to zoom in, zoom, out, pan and query data. Picture 4 shows the graphical interface provided to users, with interactive analysis tools on the left panel, then the geographic display at the centre and the table of contents, including the 39 MID layers, at the right side. The green area means that boarding helo operations could be performed without any expected environmental impact. The yellow area means that this type of operation could be affected by environmental conditions, while the red area means that operations were to be strongly affected by environmental conditions and should not be performed.



Picture 4 – Geo-spatial MID for “boarding helo” operations.

To complement the visualization of MID geo-spatial variation, a specific tool was developed together with programming experts from ESRI-Portugal. This tool provides the ability to, interactively, query any pixel on the display and get, in a pop-up window, the complete MID diagram for that pixel. So, besides being able to see the geo-spatial variation of a certain MID, the user is able to see them all for a certain area of interest (Picture 5) in a table format. Due to the fact that not all MID are o be determined over all areas (sea/land), another colour was added to the MID table – black, meaning that a certain MID is not available for that specific location. It is a new dimension for MID exploitation provided in a very simple but efficient way.



Picture 5 – Geo-spatial MID variation data complemented with local MID table for a certain pixel just offshore Portugal.

Conclusions

Due to the fact that environmental conditions are relevant on the use of military resources on field operations, their previous impact estimation is very important for decision makers. This paper describes the method used during a Portuguese military exercise to make a set of 39 geo-spatial MID available through a private communications network, using webGIS technology.

ArcGIS model builder proved to be an excellent tool to make the processing of all data very efficient and ArcIMS proved to be a very good and simple to use mean to make data available to users.

Developments in this area are expected to occur at several levels. MID can go down to the individual platform level, to the daily availability and to multiple epoch analysis. New MID can be developed based on multiple conditions analysis (e.g. crossing air temperature and humidity to estimate their combined impact on human resources performance) and it is also possible to estimate a numeric percentage impact value for better decision making.

References

[1] http://en.wikipedia.org/wiki/Image:Minard.png visited on 2007-03-13.

[2] Grasso, R., Giannecchini, S. (2006). *"Geo-spatial Tactical Decision Aid systems: fuzzy logic for supporting decision making"*. Fusion 2006, The 9th International Conference on Information Fusion 2006, Florence (Italy).

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