An Environmental Decision Support System for Water Issues in the Oil Industry

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Abstract. Many decision makers are hindered in their daily work by "un-integrated" systems which can force them to move data around between tools which are only more or less compatible. Because environmental models play an important role in environmental decision support systems, the integration of models into user-friendly integrated decision support systems is essential to the support of such users. This paper presents a decision support system supporting users involved in the protection of the Coatzacoalcos River in Mexico near the largest agglomeration of petrochemical installations in Mexico, which are operated by the Mexican oil company Petroleos Mexicanos. At the same time, the area is densely populated and important for agriculture.

The system was built in a collaboration of the Mexican Petroleum Institute, the Environmental Informatics Group, and cismet GmbH and is based on cismet's geospatial application suite called *cids*. It integrates several tools and models into a holistic, user-centered application.

Keywords: Environmental decision support; environmental information systems; oil pollution; environmental model integration

1 Introduction

Management of environmental challenges is inevitably complex. Many technical disciplines are involved, and a tremendous amount of information must be interpreted in order to arrive at rational and effective management decisions. Even highly trained environmental managers are challenged by the breadth of the decision problems they face.

Therefore, environmental information systems that can help environmental managers to arrive at high-quality decisions are indispensable. The present paper describes an environmental decision support system (EDSS) that integrates mathematical process models of environmental phenomena with geographic information systems (GIS) technology in order to support petroleum facility managers as they attempt to determine which resource management actions will be most effective in the reduction of surface water degradation related to petroleum processing within an important watershed in Mexico.

The Coatzacoalcos River in Mexico is challenged by several petroleum processing facilities. An environmental decision support system, called ANAITE, has been developed to help environmental managers minimize the impact of oil processing on the surface water quality of the river. The ANAITE EDSS is described in this paper.

2 Requirements of end users

In any interactive computing system, understanding the needs and capabilities of the users is essential to a successful design of the systems to support them. This is certainly true of environmental decision support systems, whose users are often technically trained but not completely comfortable with information technology, or even all of the technical aspects of the decision problems they face.

That is the case with the ANAITE decision support system. The first version of the system targets a primary user who is a technical manager of an oil processing facility. This type of user is trained in process, chemical, or environmental engineering, and is trying to determine which interventions at this facility will achieve the greatest gains in water quality for the invested resources.

ANAITE is heavily based on sophisticated mathematical models of hydrodynamics and the advective-dispersive transport of pollutants. However, it is important to know that the primary end users of the system are *not* modelers. They will very likely be aware of the existence and use of mathematical models describing water quality, and it is assumed that they value, and to some extent trust the results of such models, at least under circumstances appropriate to their use. But their interest is for the EDSS to insulate them from technical details of the model so that they can, instead, focus on their domain, namely making operational decisions that will impact water quality.

2.1 Focus on what is needed

The principal upon which ANAITE, like other effective environmental decision support systems, is based is that decision makers facing multidisciplinary problems *cannot* be experts in all aspects of these problems. Scientists, mathematicians, engineers, and other specialized experts may have produced, in their respective domains, important insights that would be extremely relevant to a particular decision problem. However, if these insights are not delivered to decision makers in an accessible form, they will not help. Indeed, they may hinder high quality decision making by so thoroughly obfuscating the decision making process that even “good guesses” are hard to make. Stated more succinctly, decision makers need “computer support which provides everything that they need, but *only* what they need” [1].

2.2 Needs analysis

In an interactive process between the project partners, a systematic analysis of the users' needs was carried out. While a few different categories of users were identified, the first among these – the primary user – is the environmental manager already mentioned. The first version of the ANAITE EDSS focuses on this primary user. This analysis shows that the environmental manager making the decisions about how best to invest in pollution mitigation needs to use models but, though technically trained, is not a modeler. Therefore, a key requirement of the ANAITE EDSS is the ability to integrate sophisticated mathematical models of water quality and pollutant behavior without requiring the user to interact directly with these models.

It also became clear that access to available data about the catchment in question would be critical – again without expecting the decision maker to know how to find or manipulate these data. And representations of these data would need to be easy to interpret, with representations specifically designed for the particular decisions the user needs to make. This means that the EDSS would have to make it particularly easy to access and represent environmental data, and, following an important precept of good human/computer interface design, allow movement of data between various domains, to include conventional data plots, spatial representations, analytical tools and so forth in an integrated fashion.

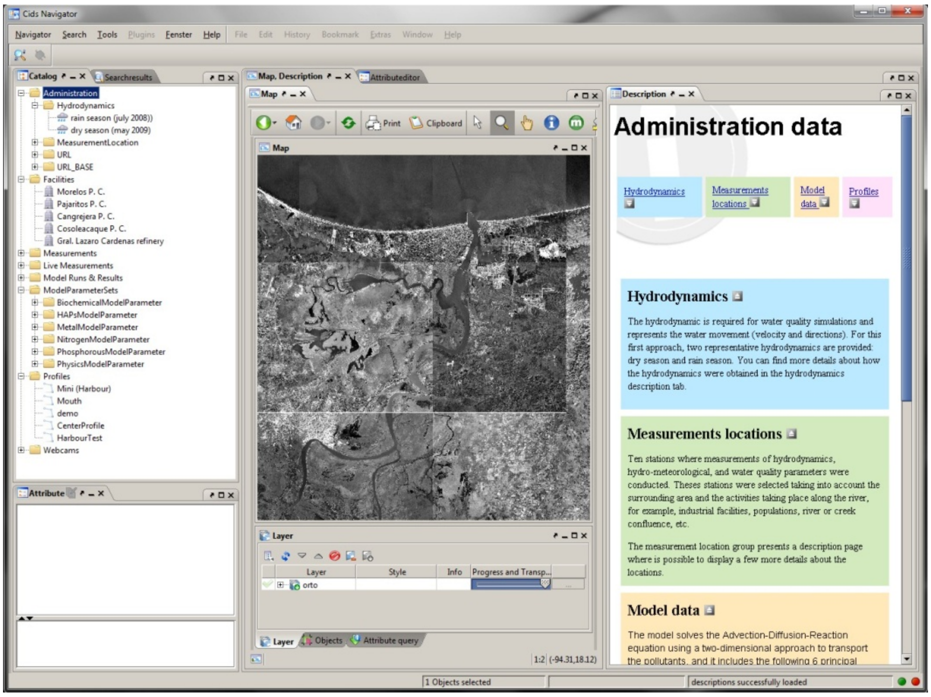
The first level analysis reveals use cases in the following major areas

- Administrative-level activities (maintenance of users, data, information sources, external services etc.)
- Management, display and visualization of facility-related information (chemical plants, their location, extent, risks and so forth)
- Management, display and visualization of data related to the geography of the area (population, installations, etc.)
- Notification, reporting, potentially alerting
- Configuration of models and model runs, including choice of initial conditions
- Execution of models, documentation of model runs
- Visualization of simulation results, in context with geographic and facility-related information, various cross-sections through data both in time and space
- Storing and management of simulation results
- Management and execution of complete simulation ensembles (i.e. simulations with variations over parameters and initial conditions)

All use cases have in common that users be relieved from notorious time consuming tasks like managing model input and output data sets, moving data between tools and overcoming intricacies of tool incompatibility. Therefore a holistic solution is needed both for data/model/system management and for scientific analysis including interactive visualization.

3 Details of the application

Using the *cids* platform (which will be described in chapter 4), it was straightforward to design an EDSS that gives users direct access to data from various sources, to see this information in a spatial context, and to drill down into more in-depth information to help them understand what they're looking at. Figure 1 shows the main screen of the ANAITE EDSS.



Administration data

Hydrodynamics

The hydrodynamic is required for water quality simulations and represents the water movement (velocity and directions). For this first approach, two representative hydrodynamics are provided: dry season and rain season. You can find more details about how the hydrodynamics were obtained in the hydrodynamics description tab.

Measurements locations

Ten stations where measurements of hydrodynamics, hydro-meteorological, and water quality parameters were conducted. Theses stations were selected taking into account the surrounding area and the activities taking place along the river, for example, industrial facilities, populations, river or creek confluence, etc.

The measurement location group presents a description page where is possible to display a few more details about the locations.

Model data

The model solves the Advection-Diffusion-Reaction equation using a two-dimensional approach to transport the pollutants, and it includes the following 6 principal

Fig. 1. Main screen of ANAITE

The user can interact with the information using three main paradigms: 1) the catalog (left part of main screen), 2) a spatial view (center part), and 3) data, model results and so forth including background information (rightmost part of main screen, as well as various other tabs). It is worth noting the obvious importance given to the spatial display of information. Environmental management problems are fundamentally spatial, and environmental managers are keenly aware of "place" when it comes to making management decisions. Therefore, spatial representations of the sort provided by geographic information systems (GIS) are a natural component of an EDSS. But a GIS itself is not an EDSS, primarily because standard GIS products provide far more options than are needed by a decision maker, and therefore are not well customized for users. Rather, elements of GIS are drawn into successful EDSS implementations only as needed. The ability to use spatial data already available from GIS datasets further promotes the use of compatible GIS components in EDSS implementations. Figure 2 shows an ANAITE screen in which GIS maps of the Coatzacoalcos River region are made available to the decision maker in a way which does not require them to be GIS experts.

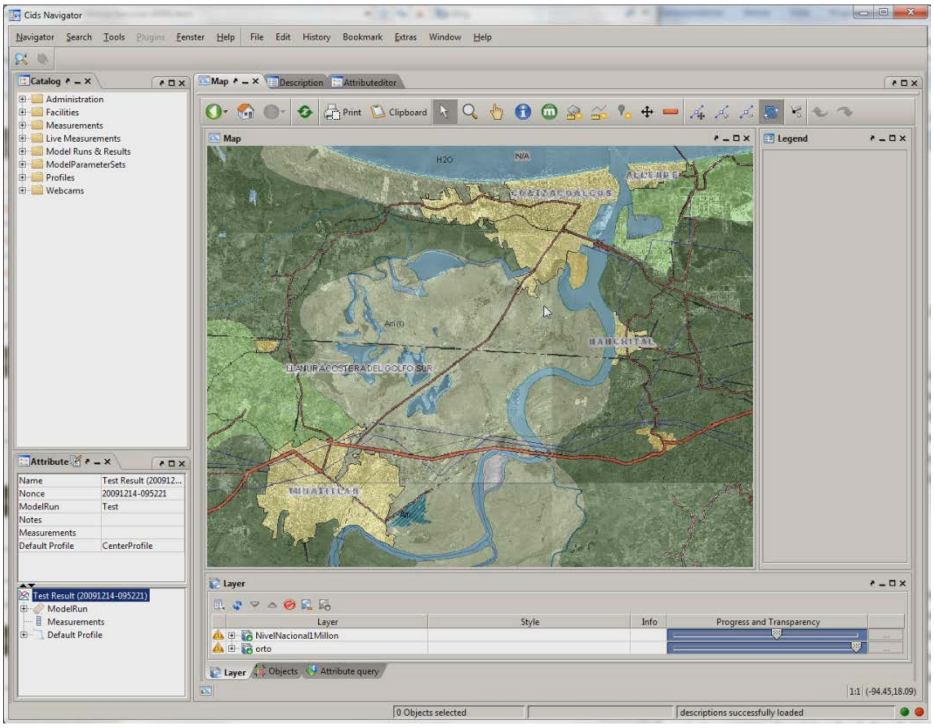


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Fig. 2. ANAITE Maps Screen

A particularly useful characteristic of the ANAITE EDSS is that the users need not take special action to move data from the non-spatial to the spatial domain. When they discover a data set of interest, perhaps a set of water quality measurements made during a particular study, they need only drag this data set onto the spatial display window for the system to use embedded spatial information in the data to represent them on the map. This sort of capability removes the burden of data formatting and management expertise from the primary user and allows them to focus instead on their environmental decision domain. Systems lacking such support generally preclude use by decision makers not possessing significant information systems expertise, which is one reason that many EDSS implementations in the past have gone unused by real decision makers.

ANAITE is designed to support “what if” scenario analyses in which the environmental manager postulates different values for chemical discharges into the river, at different locations, in order to see what impact these changes might have at various points along the river. A significant level of human analysis is required to compare the results of various scenarios, because water quality requirements or expectations generally differ at different locations. For example, one location might be where a town has an intake for a drinking water supply, another might include a swimming beach, and a third might be an important fishery. Acceptable variations in water quality for these three examples must be judged in their social, as well as technical, contexts, a task only effectively done by a human being.

To do this requires representation of the modeling and simulation results to the environmental manager in a way which is readily interpreted by them, and generally using a variety of techniques. For example, in Figure 3 one can see an overview of water quality variations computed by the various models for a scenario in their spatial context, along with information about co-located social structures.

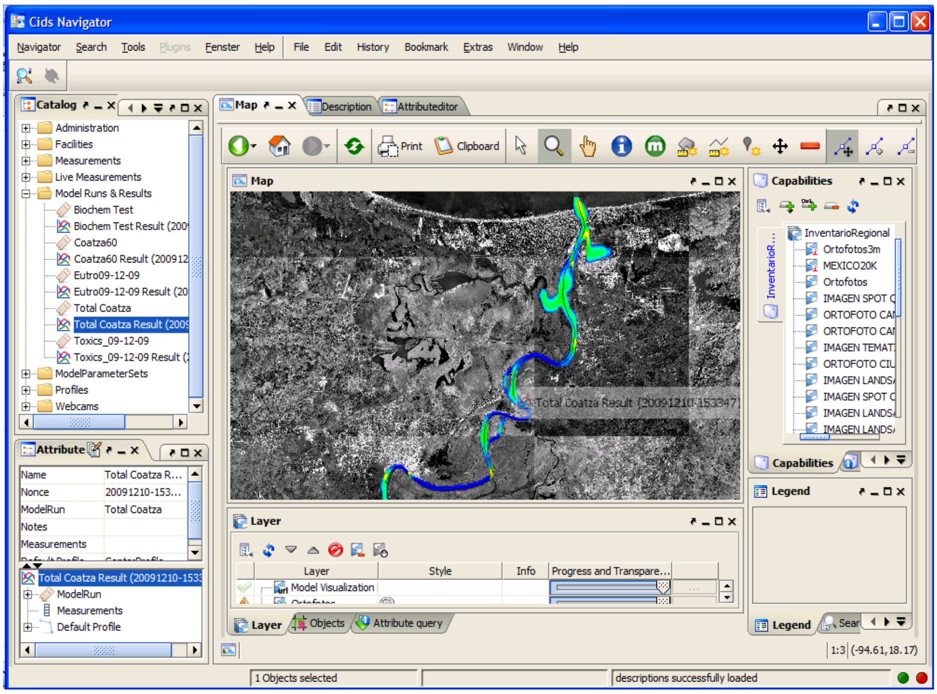

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Fig. 3. Spatial Visualization of Simulation Results

In Figure 4 one can see these same results with a more precise representation of their quantitative values, albeit without most of the spatial context present. This flexibility of representation, again without the requirement of special information systems expertise, is a great facilitator of high quality decision-making.

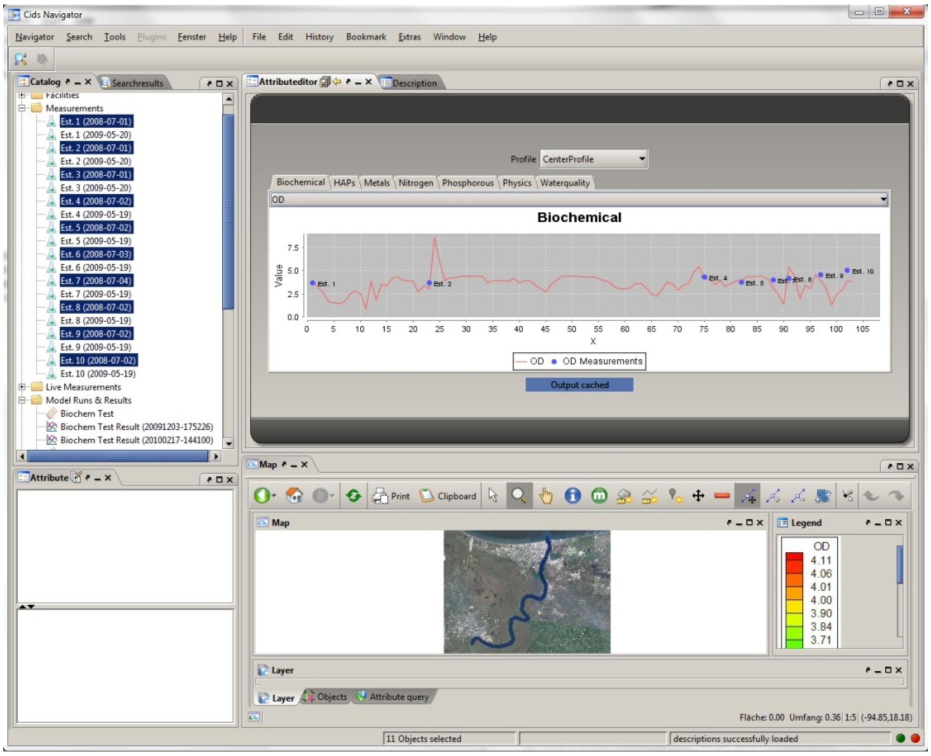

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Fig. 4. Concentration Profiles

4 System platform

ANAITE has been implemented using the geo-spatial application suite *cids* of cismet Gmbh. *Cids* is both a distributed integration platform for distributed geo-spatial environments, and a highly integrated software development environment for interactive geo-spatial systems.

Cids has been developed and improved over more than 10 years and has been heavily driven by the WuNDa city information system [2]. At the core is a distributed integration platform (Figure 5) which is capable of integrating information and processes from a variety of different systems such as GIS systems, standard databases, document management systems, computational systems like models and so forth. The platform is particular useful for workflows which need a combination of information and processes from different source systems.

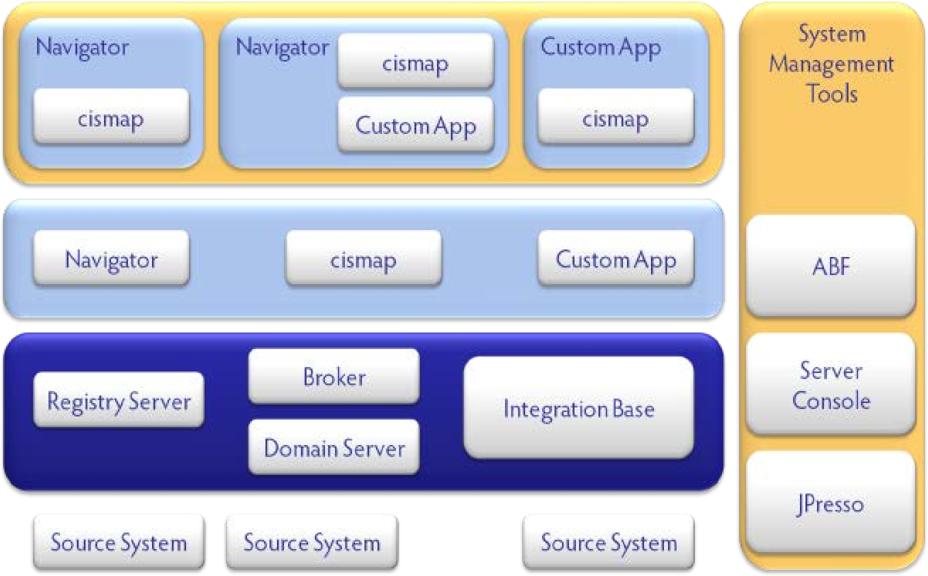

Fig. 5. *cids* platform architecture

The core contains a domain-based service layer and a distributed meta database (registry server, broker, domain server, integration base), which jointly manage the network of attached data sources and services. Spatial services are integrated according to OGC standards, and the platform is compliant with OGC standards as well. The management of the service network is carried out with a variety of systems management tools, with a Netbeans-based *cids*-IDE (named ABF) in the centre. The platform includes distributed user management, authorisation and domain management for customisation according to the structure of the organisation and workflows. The platform includes a sophisticated access management component and can be personalised for user groups and individual users. Computational processes like the ANAITE models are generally integrated through OGC WPS compliant services.

The end user usually interacts with the system through two types of applications. The Navigator is a standard application deployed with all installations. It can be used to manage the information in the network and is particularly useful for cross-system search and retrieval, in space, time and topic. The Navigator is often used for *ad hoc* activities, which have not been pre-defined as work flows. The Navigator views are usually customised to the information classes which the particular organisation manages (both for space and themes).

The second type of applications are Custom Applications, specialised spatial/non-spatial workflows which support specific end user tasks. These CustomApps can also be shown inside the Navigator using a Plugin mechanism.

The ANAITE implementation is based on the Navigator.

5 Integration of models

The integration of models into an EDSS raises both technical and scientific issues. From a technical perspective, it causes some overhead for application developers. In the case of ANAITE, the wrapping of the models was not really done in a systematic way, due to constraints of time and resources in the project. Model integration usually goes along with integration of sensor information and integration of model results. In ANAITE all computational processes have been integrated in an *ad hoc* fashion by wrapping them into *arbitrary* web services. Results are stored back into the sensor data bases and as OGC compliant layers for visualization.

In order to integrate models and associated input and output data sets, including sensors, in a systematic way, one should usually use standards of the OGC SWE suite and similar standards including the WPS specifications (Web Processing Service) [3]. A systematic approach to linking such models, including related sensor information, should include approaches like the ones forwarded in SANY [4]. Projects like SUDPLAN [5] [6] are currently advancing such systematic concepts.

But from a scientific perspective, model integration includes important *conceptual* issues such as harmonization of modeling assumptions, and the application of model calibration and validation techniques [7]. While beyond the scope of the present paper, it is important to recognize that one cannot simply “plug” two models together and expect the results to be meaningful. In the case of ANAITE, the hydrodynamic and advective-dispersive models were co-developed in a way which ensured their compatibility. The cids platform then allowed them to be integrated, as a partnership, into the resulting environmental decision support system.

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