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The Master Environmental Library (MEL) Project

http://mel.dmso.mil

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ABSTRACT

The Master Environmental Library (MEL) is a World Wide Web (WWW) based data discovery and ordering system providing access via a consistent single interface to oceanographic, terrain, atmospheric, and near space data bases and related tools residing in geographically distributed resource sites with arbitrary data base configurations and data formats. The key features of MEL are a consistent metadata contents standard for the data, a common user friendly interface, a generic order/delivery system, and use of standard transfer formats. Existing data centers can become MEL resource sites without changing their current data management methods or architecture and retain complete control over release of data.

Introduction

The primary objective of the MEL Project is to enable uniform access to distributed data of arbitrary format and related tools to provide consistent common authoritative environmental representations and effects to various modeling and simulation (M&S) users, war fighters, and other support activities. The data types can be gridded, observational, raster, vector, or text. The environmental regimes include the atmosphere and near space, the ocean, and terrain. The data centers can be from the U.S. Department of Defense (DOD), other federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA), and international sources. The data may exist "on the shelf" or may be available through subscription when it is created. The tools include data fusion, visualization, and statistical processing. Products based on the elemental data can be scheduled, on demand, or interactive. The overall criteria for developing such a library infrastructure are to satisfy the Defense Modeling and Simulation Office (DMSO) high level goals of reuse and

interoperability, which are also appropriate for applications outside of M&S.

Background

Modeling and simulation has become increasingly important in U.S. DOD activities, such as training, analysis, acquisition, research and development, test and evaluation, and mission rehearsal, because it offers lower cost supplemental alternatives to the more traditional approaches to these activities. However, in the simulated world the natural environment must be included in a realistic, physically consistent, correlated way to achieve the full value of M&S. This requirement is formally included as part of the DOD M&S Master Plan [1]. To satisfy this requirement, DMSO is funding the MEL Project, a joint project involving the DOD Military Services and other Federal Government Agencies.

Data Discovery and Retrieval

The problem of locating authoritative environmental data is complicated by the fact that there is much data already available and the amount is increasing rapidly, but the data are stored at various distributed data centers using different data bases and are delivered in different formats. Simply locating and retrieving the data for M&S can be a formidable problem. For geospatial data, which include data of the natural environment, such as the ocean, terrain, atmosphere, and near space, a common contents standard for *metadata* (data about data), such as the Federal Geographic Data Committee (FGDC) standard [2], is a powerful key to data discovery. With the rapid development of search engines and web browsers on the Internet, it became possible to create a common, consistent unified interface for parallel browsing of metadata at distributed data sites and for ordering the data itself. The actual details of data extraction, encoding in a standard delivery format, and delivery to the user, are hidden behind the interface.

The key components of the MEL architecture are shown in Figure 1.

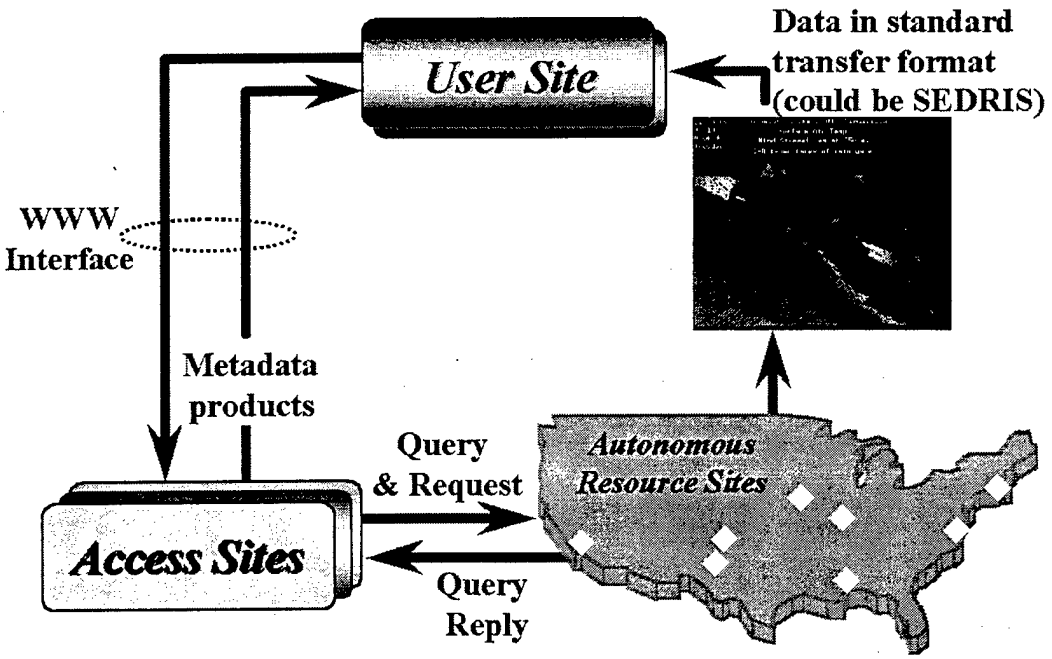

Figure 1. The different components of the MEL architecture are shown, indicating the key role of the access site as a common interface between the user and the data providers (resource sites). (SEDRIS (synthetic environment data representation and interchange specification) is a DMSO supported project that will provide a standardized interchange method for synthetic environment databases.)

The user no longer has to deal with each provider separately, thus avoiding a variety of interfaces, methods of data querying and ordering, and different transfer formats. Such local variations are concealed behind the consistent single interface (access site). The data are left under the local control of the provider (resource site), who has only to create and maintain indexed metadata in the standard contents format for it to be searchable over the library system. The actual details of sending queries and requests from the access site and data extraction and delivery are made generic to the greatest extent possible and customized as necessary for each resource site. Utilizing the fewest and most standard transfer formats possible and providing the corresponding decoders greatly simplifies the effort of the user to work with the data delivered. By using web technologies MEL exploits the power of the market place for rapid technology development and de facto standards, for both unclassified and classified networks. This is consistent with the DMSO guidelines of reuse and interoperability of systems. As the technology evolves, it is straightforward to incorporate improvements into the basic architecture. Furthermore, the architecture is extensible to resource sites that will be processing sites for running models or tool applications. MEL resource sites are shown in Figure 2.

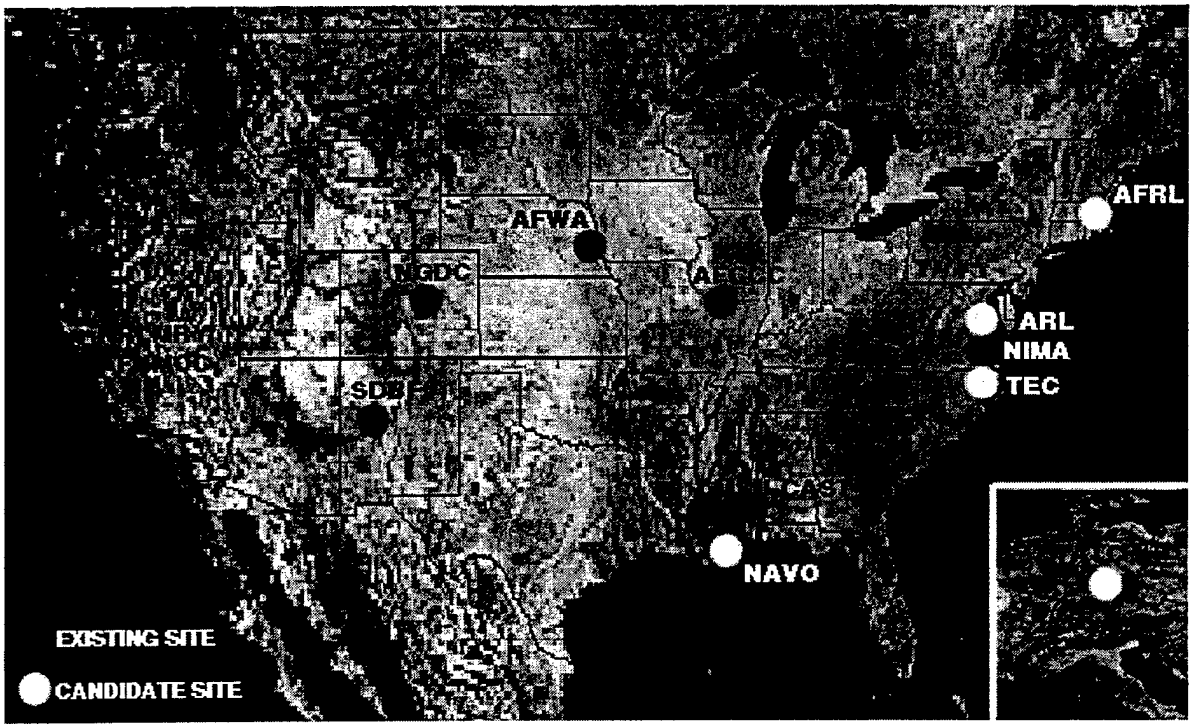

Figure 2. The current MEL resource sites are:

- Air Force Combat Climatology Center (AFCCC) - Scott Air Force Base (AFB), Illinois
- Air Force Materiel Command and Aeronautic Education and Training Command, Simulation Data Base Facility (SDBF) - Kirtland AFB, New Mexico
- Air Force Research Laboratory (AFRL) - Hanscom AFB, Massachusetts
- Air Force Weather Agency (AFWA) - Offutt AFB, Nebraska
- Army Research Laboratory (ARL), Battlefield Environment Division (BED) - Adelphi, Maryland
- Army Topographic Engineering Center (TEC) - Fort Belvoir, Virginia
- Mississippi State University (MSU), Center for Air and Sea Technology (CAST) - Stennis Space Center (SSC), Mississippi

- National Oceanic and Atmospheric Administration (NOAA), National Geophysical Data Center (NGDC) - Boulder Colorado
- National Imagery and Mapping Agency (NIMA) - Merrifield, Virginia
- Naval Oceanographic Office (NAVOCEANO) - SSC, Mississippi
- Naval Research Laboratory (NRL), Marine Meteorology Division (MMD) - Monterey, California
  With Fleet Numerical Meteorology and Oceanography Center (FNMOC) - Monterey, California
- Terrain Simulator Center, Seventh Army Training Command (7ATC), U.S. Army Europe, Grafenwohr, Germany

In addition to providing a uniform consistent query and request interface, MEL also provides authoritative environmental data, as illustrated in Figure 3, and physically

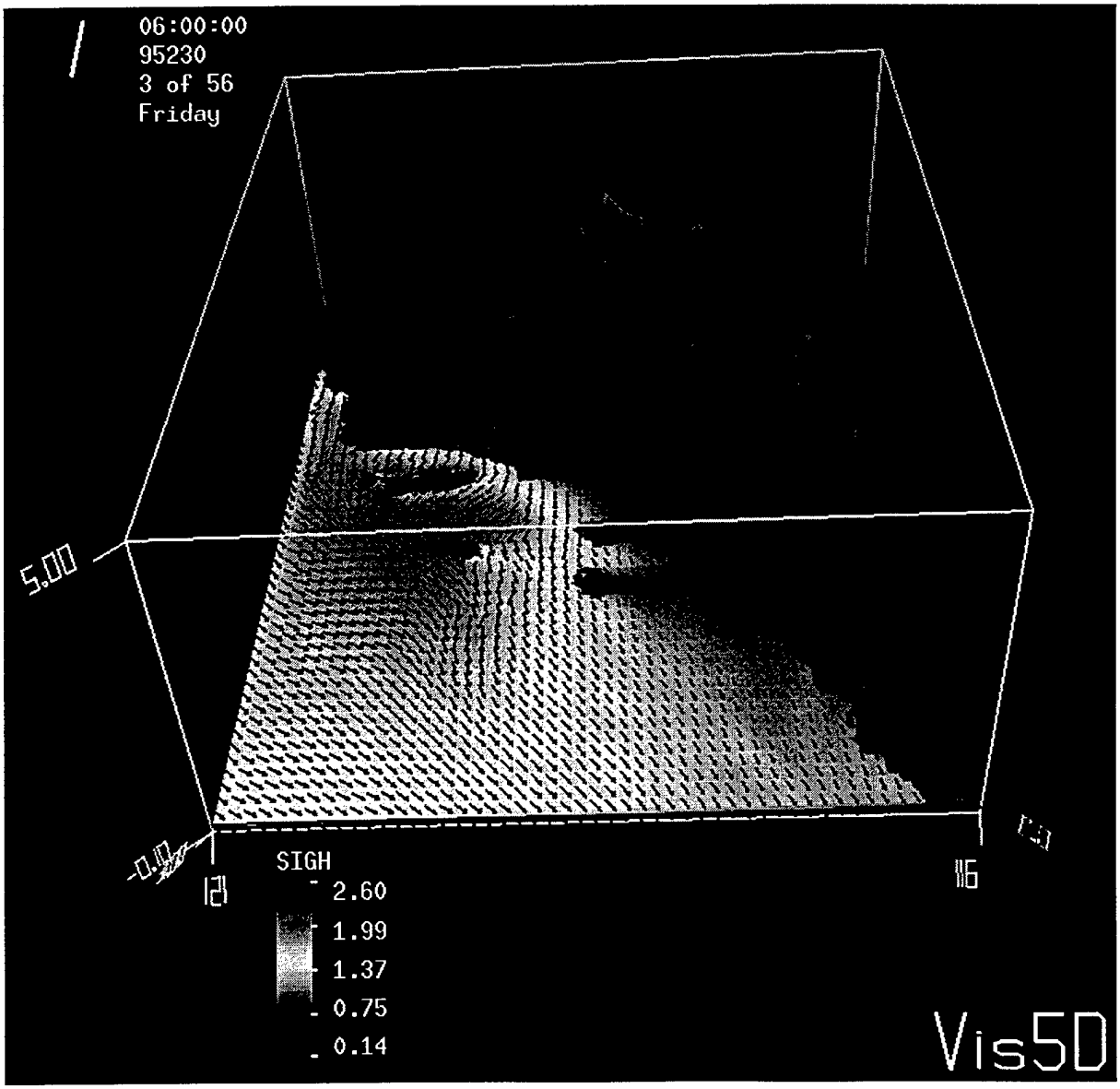

Figure 3. An example of wave direction and significant height from a wave model for the Synthetic Theater Of War (STOW) area in the South West USA. Displayed through VIS5D software. (Vertical dimension exaggerated)

consistent scenario data base generation, as shown in Figure 4, which is required in complex synthetic environments (e.g., the surf zone) when atmospheric and oceanographic models of different spatial and temporal scales interact to produce data sets of high resolution.

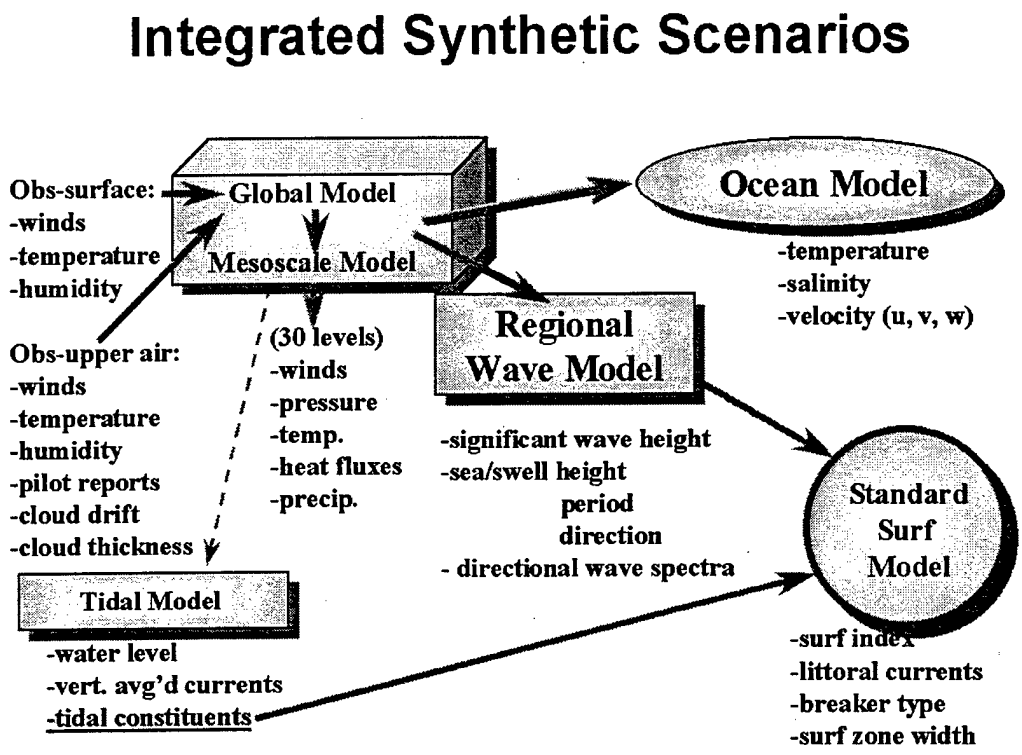

Figure 4. This illustrates how observations are used to initialize a numerical global atmospheric forecast model which is used to initialize a mesoscale model which in turn provides some of the input for ocean, tidal, wave, and surf models to develop an integrated synthetic scenario.

Java Interface

In addition to the original HyperText Markup Language (HTML) interface, a Java interface for querying the system and visualizing the results has been developed [3].

Query Interface: An interactive and intuitive Java applet allows the user to formulate a query based on three attributes. The *spatial coverage* of the data can be specified on a zoomable map by rubberbanding a region of interest (Figure 5). Alternatively, actual latitude/longitude values of the bounding box can be entered in type-in boxes. Further, the user can choose how the specified region is to be queried against the metadata records. The region of interest can be used to return records whose spatial extents are entirely within it, those that intersect it or those that completely cover it. Any combination of these is also possible.

Another searchable attribute that can be specified is the *temporal range*. The user can specify a beginning and ending date of interest and how this range is to be queried against the metadata records analogous to the spatial coverage discussed above. Visual feedback is provided for the current choice.

The user can also include *keywords* to be used in the search. Keywords can be typed into a text area or can be selected from lists organized in a hierarchy that follows the FGDC metadata standard or other standard listings.

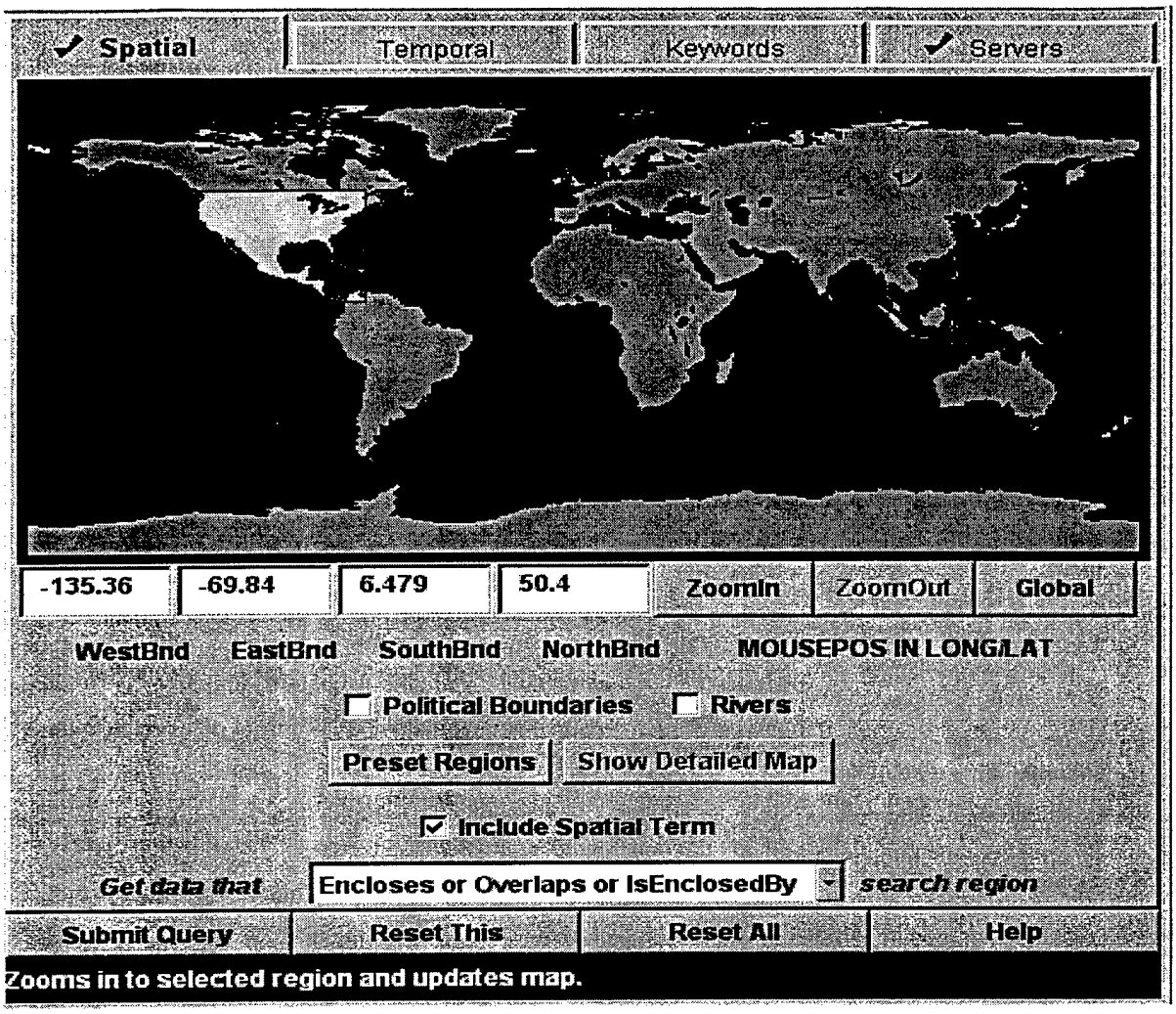

Figure 5: The Java query applet allows the user to interactively formulate a query. The figure shows the spatial coverage panel for specifying a region of interest.

When a query is submitted, the access site performs a parallel search of the MEL resource sites. The search can be limited to *specific sites* through another interactive panel that includes a clickable map.

Query Results Visualization: The search returns a list of references to metadata records that satisfy the query. To aid in the decision as to which of these 'hits' are really interesting, certain attributes are returned from the search and visualized in another Java applet that appears in a dynamically created page. Users can then visually compare metadata records based on these attributes without having to look at the metadata records. Records that are not particularly interesting can be eliminated quickly, and the list of hits can be filtered by refining the query without actually doing a new search.

The query visualization applet contains two main areas: a command area that manages the list of hits and a visualization area where the attributes of the color coded items are displayed (Figure 6). The attributes that are visualized are the spatial boundaries, the temporal ranges and the browse graphics.

The bounding boxes of the selected items are displayed on a map. This is another instance of the map panel that exists in the query applet and the user is thus able to zoom in and out. This is very useful since the user can zoom in to a region where there are many metadata records to differentiate better between them. Users can point to a colored rectangle and get the quantitative information of the bounding box. Users can subset the list of items based on a region of interest.

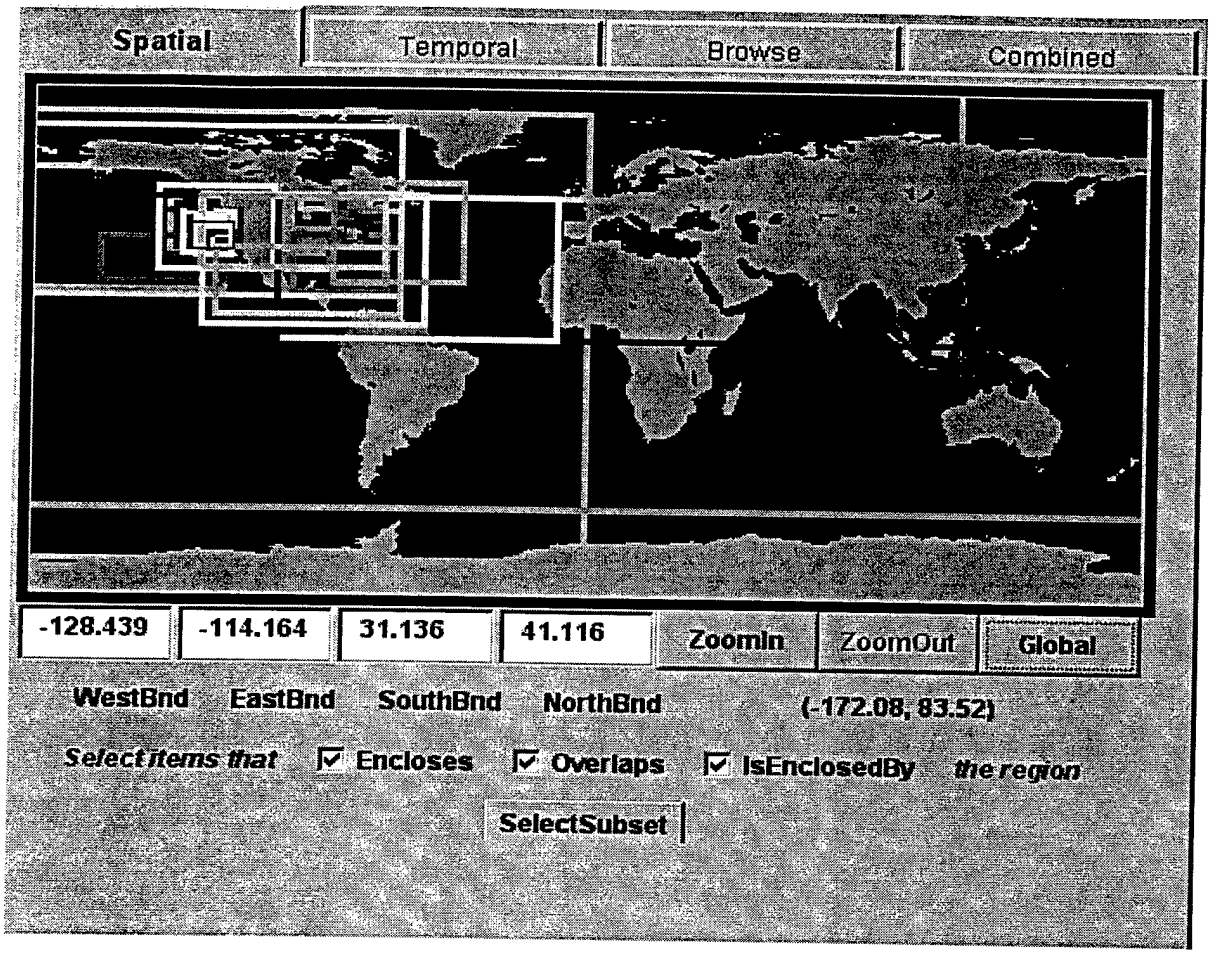

Figure 6: The query results visualization applet allows the user to visualize different attributes of the search results. This figure shows the spatial coverages visualization tool. The bounding boxes of the items are displayed on a map in their own color codes.

The temporal ranges are visualized by displaying line segments that are placed in the context of a time line. The resolution of the time line can be changed by zooming in and out of a time window. Users can subset the list based on how this window interacts with the ranges of the items. The quantitative information regarding the temporal range can be obtained by pointing to a line segment.

Browse graphics is a field in the FGDC metadata standard. It is a list of Uniform Resource Locators (URL) that reference any mime-type, such as an image or movie, which provides some extra information about the data set. These are visualized in the applet by displaying appropriate icons. A user can thus see which items have how many and what kind of browse graphics. These can be downloaded by clicking on the icons.

Product Generation In MEL

Most data providers in the MEL system provide basic environmental data such as winds, temperature, wave height, etc., though some offer products derived from these basic parameters. Because such products are often the information of most interest to M&S users or war fighters, the basic MEL system is being enhanced to provide some capability for product generation. Several initial applications are described below.

Data Oriented Application: In this case, the order form for a given data set contains an additional section of possible processing options, such as creating graphics or computing statistics for every "field" selected, or a special list of "derived fields" could be presented as an option. In either case, the product involves only the selected data set, and

processing occurs at the site where that data is stored.

Product Oriented Application: In this case the user searches for and selects a metadata record describing a field which can be produced from one or more data sets. The data sets that can be used for generating the product are pre-determined and the options on the order form are "input data set dependent". As a further extension, data sets can be located at one or more resource sites other than the product generator site.

Interactive Application: Here the user is connected via MEL to an "island of computation" where some interactive application is used on a selected data set. This could be generalized to include "shopping" for products. A further extension would be to allow data sets to be delivered to the interactive site prior to the user being connected there.

Local Application: A local application could be developed to receive, manage, and work with data delivered from MEL. Many plug-in modules could be developed to do anything from data interpolation to the computation of derived fields to data visualization. This, of course, would require strict version control on a potentially very complicated piece of software, and the user would need a machine capable of the necessary processing. It does, however, eliminate much of the load from MEL servers.

Use of MEL Beyond DOD M&S

MEL was designed to meet a need for access to authoritative environmental data and products for DOD M&S, but the architecture is general enough to accommodate the more general issue of geospatial data discovery and retrieval. Here we consider how such library systems can interoperate in a more synergistic fashion to expand greatly the pool of searchable metadata and provide access to the underlying data. This would allow different agencies, be they federal, foreign, or international, to share data resources, subject to local access control. Below we discuss different levels of interoperability among library systems.

Metadata Interoperability: The unifying factor behind data discovery is metadata. The value of systems like MEL can be mutually enhanced by adoption of a common metadata standard among data centers, thus allowing the scope of searchable metadata to be extended, in the case of MEL, beyond DOD. Any project that follows the guidelines for being a node in the National Geospatial Data Clearinghouse will be metadata interoperable [4]. Metadata interoperability basically means FGDC style metadata is searchable on the Internet via the Z39.50 protocol. FGDC has full online instructions on how to create metadata, how to download and install the necessary server software, and how to register as a node. A new version of the "Isite/GEO server" software is finishing beta testing and is available through the FGDC. In the metadata are optional fields for "Online_Linkage" and "Distribution_Information" which are used to provide either a hyperlink to the data or textual information on how to obtain the data.

Metadata Search Gateway: FGDC would like to be a site where all nodes (MEL, federal, state, etc.) are registered. Different projects such as MEL, NOAA Server [5], Earth Observing System Data and Information System (EOSDIS) [6], etc., desire their own gateways (search interface to a list of servers) for various reasons. These reasons include:

- desire to customize the search interface for their own needs;
- need to have a central point of access to their own resources;
- don't want to depend on FGDC Clearinghouse.

The MEL project has developed advanced HTML and Java interfaces for Internet searching of metadata by Wide Area Information Search (WAIS) servers. FGDC is funding the MEL developers to customize and integrate these interfaces to the new Isite/GEO server software. FGDC and MEL will use this for their respective gateways and will make it available to other groups who need to have their own gateway with the hope that discussion will be open and improvements will be shared. This type of interaction should help speed up development of improved gateways while the nodes remain interoperable at the metadata level. Many groups such as the Global Change Data and Information System (GCDIS) [7], EOSDIS, and NOAA Server have already expressed interest in getting access to the gateway code.

Transparent Data Access: Some of the issues involved with transparent access to environmental data at distributed sites include:

- access constraints (cost, approval, etc.)
- ordering
- delivery method
- data format and delivery format
- size of data

The FGDC metadata standard addresses these issues by providing optional fields to describe aspects of data ordering, formats, etc. There are now official or unofficial "rules" for providing data. Various projects are designing their own order/delivery systems to suit the needs of their perceived user communities.

MEL has developed a generic data ordering and delivery system for use by MEL resource sites. It is based on a "choice/subset" description which is an extension (FGDC will allow extensions soon) to the metadata record. A common gateway interface (CGI) at the MEL Access Site generates a custom form based on this choice description. A suite of MEL Resource Site Software (MRSS) supports processing orders, access control, data extraction, and automated data delivery. Extraction must be customized for each resource center.

MEL makes this software available to other groups, subject to sponsor approval. The software is highly customizable so as to implement the rules of business at each resource site. The MEL project suggests the use of "standard" formats such as GRIdded Binary (GRIB) and Binary Universal Format for the Representation of meteorological data (BUFR), but the software is not dependent on any particular format.

Data Access Details: The following are several approaches to data access, with the choice of approach dependent upon resources at the data site:

- **MEL Data Ordering and MEL Resource Site Software (MRSS):** The MEL generic ordering interface provides for centralized ordering from many different sites. The MRSS provides order processing, access control, data extraction (customized per site) and data delivery services. The Department of Commerce's NOAA Server project has expressed interest in the MRSS. The Solar Terrestrial Physics Division at NOAA's National Geophysical Data Center (NGDC) will install the MRSS after they develop data extractors to work with MEL. Currently, NGDC is a limited MEL node in that its metadata is searchable through MEL, but data access must be done through the NGDC interface.

- **MEL Link to Local Browsing/Ordering System:** In cooperation with NGDC we are developing a simple method for using existing browse systems, such as NGDC's Space Physics Interactive Data Resource (SPIDR) [8], for ordering data through MEL. After discovering metadata, a link will take the user into the SPIDR system with area and time initialized. Users will browse as usual and click an order button for desired data sets. In effect, users add items to their shopping basket. When finished, the information is transferred to the MEL order form and the order is sent and processed by the MRSS. This allows for a custom browse/order interface that uses the best (or the existing) interface to a particular type of data rather than the generic approach MEL has taken so far. It allows for the specifics at the inventory level to be exposed where the metadata might be more general.

- **NOAA Server Browsing and Coplotting:** The NOAA Server development group is concentrating its efforts on near real time browsing and coplotting of different types of data from different sites. This would involve some type of generic interface to a data or browse server at data centers. The purpose is not for analysis but as a browsing aid to help users find the data of interest before ordering. The MEL project is very interested in NOAA's progress, since this provides a third approach to browsing/ordering, namely a generic server that can get at inventory level information as opposed to MEL's current generic metadata level approach and the site specific (SPIDR/MEL) approach mentioned above.

- **Future Trends:** The Open GIS consortium [9] is working on defining catalogue and data model interfaces, which will help promote interoperability of GIS-type data. The OGIS group has major endorsements by industry and NIMA, and thus its work is of considerable interest to MEL, NOAA Server, and other similar systems.

Conclusions

Significance of the MEL Project: MEL is the first data discovery and ordering system that allows a user to query Navy, Army, Air Force, NIMA, and certain non DOD centers for the existence of geospatial data that satisfies the user's criteria, and to request either archived data or data that can be made available by subscription. The data can be from any of the natural environmental domains of terrain, ocean, atmosphere, and near space. The MEL system is completely transferable to a classified network that obeys the usual Internet protocols.

The architecture of MEL was implemented for M&S users and will be the environmental library structure of choice for joint DOD M&S, but it is applicable to a far wider range of uses. In particular, its approach is a powerful paradigm for many joint situations that require the acquisition of data from distributed dissimilar sources and the integration and manipulation of the data for use by decision makers.

In a Dec. 18, 1996 press release on "Global Locator Service for Environmental Information" [10], Vice President Gore is quoted as saying, "Unfortunately, many potential users either do not know that it (global environmental information) exists or do not know how to access it. This initiative will make use of base standards that are so essential for people to find the environmental data and information they need." The standard he was referring to is ANSI Z39.50, which is at the core of the MEL system, and the initiative was the Global Information Society initiative, which was organized by the G7 (Canada, France, Germany, Italy, Japan, United Kingdom, United States) and the European Commission. This is a major step in getting international agreement on data discovery protocols. This announcement coupled with the pending FGDC/MEL gateway interface to both MEL and FGDC Clearinghouse should greatly increase the accessibility of metadata for environmental data and products on the Internet.

Future Plans: The emphasis of MEL development in FY98 will be on increased robustness of the architectural implementation and transition of a basic system for M&S users. The architecture will be structured to enable other applications direct access to the MEL services, rather than going through the current query interface. The project also expects to expand its customer base beyond M&S to include joint operational users who require access to distributed sources of geospatial data and to continue its coordination and collaboration with other library systems.

Acknowledgments

The U.S. Defense Modeling and Simulation Office (DMSO) has provided project funding for the significant contributions in technical personnel support provided by the MEL Resource Site offices and agencies listed previously. In addition to those organizations, significant contributions have been made by representatives of the Commander, Naval Meteorology and Oceanography Command (CNMOC), the Naval Air Warfare Center - Training Systems Division (NAWC(TSD)), Headquarters, Army Training and Doctrine Command (TRADOC), National Simulation Center (NSC), the U.S. Defense Advanced Research Projects Agency (DARPA) Synthetic Environments Program, and the Applied Physics Laboratory (APL) of Johns Hopkins University (JHU).

The Under Secretary of Defense (Acquisition & Technology) (USD(A&T)) designated M&S Executive Agents (MSEAs) for the authoritative representation of the natural environment. They have served as subject matter experts in reviewing the MEL design and are responsible for the registration of resources to meet the needs of the M&S community. The environmental MSEAs are the National Imagery and Mapping Agency (NIMA), Department of the Navy, and Department of the Air Force, for terrain, ocean, and atmosphere and space respectively. The designated MSEAs have established the following offices to execute responsibilities: Terrain Modeling Project Office under NIMA, Ocean Executive Agent Office under the Oceanographer of the Navy, and the Air & Space Natural Environment Executive Agent Office under the Air Force Combat Climatology Center. The mission of the MSEAs is to enable M&S developers and users to represent their domain areas of responsibility rapidly, thoroughly, authoritatively, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, reuse, and confidence.

About the Authors

Dr. Richard A. Siquig is a physicist with the Naval Research Laboratory, Marine Meteorology Division. He is the project lead for the development and fielding of the Master Environmental Library. He has conducted prior research in environmental effects on unmanned aerial vehicles and the determination of ship tracks in clouds and is the project lead for the Weather Scenario Generator Project, which will exploit the MEL services architecture to generate tailored weather scenarios for simulation applications. He holds a Ph.D. in Astrophysics from the University of Colorado.

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Steven J. Lowe is an Atmospheric Scientist with SAIC. He is the technical lead for the Weather Scenario Generator Project and a developer in the Master Environmental Library (MEL) Project. He holds an advanced degree in Aerospace Engineering from the Virginia Polytechnic Institute. His primary responsibility is the generation and exchange of physically consistent, integrated synthetic natural environment scenarios in support of major DOD simulation programs. He also actively develops software applications for the exchange, analysis, and visualization of scientific data types, specializing in meteorological data. His research interests include numerical weather modeling, air-sea interactions, satellite meteorology, CORBA, Java, and VRML.

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[7] Global Change Data and Information System.
http://www.gcdis.usgcrp.gov/

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echristi@usgs.gov