HOW TO COPE
WHEN TRAINING DEMANDS DYNAMIC NATURAL ENVIRONMENTS

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ABSTRACT

We all recognize that the natural world is highly dynamic and that the variability in the natural environment can have a profound effect on system performance. When and how do we have to incorporate the dynamics of the atmosphere and ocean into training scenarios? When can we use archival data and when must we replicate the environmental variability that currently exists – variability which participating live systems actually perceive? We discuss current research in generating, delivering and interpreting dynamic synthetic environments and how that can be introduced into constructive, live and virtual exercises. Particular attention is paid to experience in providing METOC (meteorological and oceanographic) data to Fleet Battle Experiments and Global War Games. We conclude with a rationale for linking environmental data delivered to simulations with environmental data used for operational, tactical decision support. While much of the technical work is being reported through the SIW conferences, the focus of this paper is on a broad scope of exercises and novel ways to achieve more comprehensive, realistic training at reasonable cost.

ABOUT THE AUTHORS

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BACKGROUND

If we wish to succeed in achieving readiness through training, we must provide warfighters with training systems that have the touch and feel, the behavior of the systems that they will use in the field. Significant achievements have been scored in the development of simulators and the simulations that drive them. With the computing power now available we are able to add physical performance characteristics to platforms, weapons and sensors that were once merely skeletal representations of the real systems. The physical accuracy once only a part of engineering models is becoming available to real time training simulations.

However, with every advance we make, we encounter new demands. Realistic sensors and systems function in a highly complex and dynamic environment. Simulation developers have worked long and hard on scaling their software to the point where thousands of entities can operate in a single scenario. The inherent, but often bypassed, problem is that all these diverse systems must operate in a single consistent natural environment. As each new entity enters the playing field, it must see and respond to the natural environment in a realistic fashion. Warfighters and their equipment are imbedded in a complex natural environment. The collage that the National Oceanographic and Atmospheric Administration has chosen for the top of its home page expresses this complex of environmental factors in dramatic fashion.[1]

The impact of the natural environment on warfighting is clearly expressed in such documents as the Naval

Fig. 1. Collage from NOAA's Home Page

Mission Essential Task List. For example, the "Naval Task Area 3.2.8 Conduct Fire Support" lists as linked conditions the following environmental factors[2]:

C 1.1.1 Terrain. General characteristics of land areas.
Descriptors: Mountainous; Piedmont; Steppe (pampas, plains, savanna, veldt); Delta (river systems, lakes regions); Desert; Jungle; Arctic

C 1.2.1.3 Sea State. Roughness of seas caused by wind or disturbances. *Descriptors:* Calm to Slight (Beaufort Force < 5, Sea State 3 or less, seas 4 ft or less); Moderate (Beaufort Force 5, Sea State 4, seas 4-8 ft); Rough (Beaufort Force 6-7, Sea State 5-6, seas 8-16 ft); Very Rough (Beaufort Force 8-9, Sea State 6, seas 17-20 ft); High (Beaufort Force 10, Sea State 7, seas 20-30 ft); Extremely rough (Beaufort Force above 10, Sea State above 7, seas 30 ft)

C 1.2.1.7 Sea Room. Availability of space for maritime maneuver. Includes dynamic factors such as confining ice, submerged wrecks, or potentially damaging floating objects such as logs. Applies especially to coastal polar, littoral, or riverine environments.
Descriptors: Unrestricted (open ocean); Moderate (some confining factors); Confined (coastal and riverine waters)

C 1.3.1.3 Weather. Current weather (next 24 hours).
Descriptors: Clear; Partly cloudy; Overcast; Precipitating; Stormy

C 1.3.2 Visibility. Maximum distance to see an object given the moisture and particulate matter (dust, salt, ash) suspended in the atmosphere.
Descriptors: WOXOF (< 1/4 NM); Low (1/4 to 1 NM); Moderate (1 to 3 NM); Good (3 to 10 NM); High (10 to 20 NM); Unlimited (> 20 NM)

Of these factors, only the first, C 1.1.1 Terrain, can be thought of as relatively static (with inherent variability on a geologic time scale). All other factors are dynamic with temporal and spatial scales that must be accounted for in any environmental representation.

When we neglect to represent the essential dynamics of the natural environment, when the performance of military systems remain static over time and space, we train the warfighter to play (not train) with simulators and fail to take the leap from virtual skills development to true operational readiness.

JOINT WARFARE AND DYNAMICS

With great care and technical skill the community has developed some excellent representations of terrain for a tracked vehicle, but when an infrared (IR) sensor enters the mix of systems, numerous changes have to be made to the environment. The sensor operates in a different part of the electro-optical spectrum from vision and responds to environmental and system parameters that are dynamic. Not only must the environmental representation be adjusted, but representations of objects like the tracked vehicle have to change, assuming the characteristics that make then visible to the new sensor. As difficult as it was, terrain was relatively easy, at least to the degree that it stayed in place for a significant time period. Resolution is and will remain a problem, but as an environmental feature, terrain is relatively stable. Ocean and atmosphere change continuously.

We have become accustomed to watching moving fronts[3] and doppler radar screens used by television meteorologists as they show us the weather fronts moving across our local areas. We drive in and out of thunderstorms, rain squalls, fog, and snow flurries on our way home from work. We know in a visceral sense that the atmosphere is dynamic and that such transitory features as clouds cause palpable changes in the local conditions. But we still run simulations under "environmentally neutral" conditions. Yes, there is sun position and perhaps wind, but if they change, they change at once over the whole region involved in the simulation. We tote umbrellas if the forecast predicts rain in an hour or so, but we simulate as though the weather is static for long periods of time.

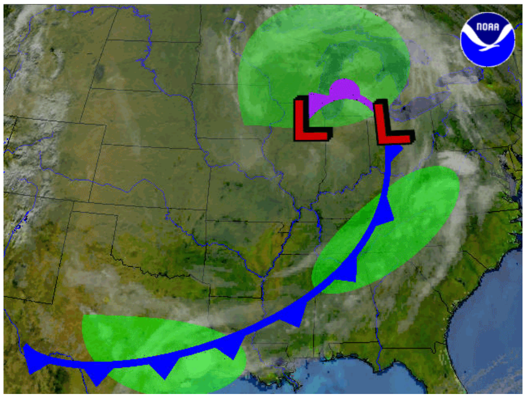

Fig. 2. Typical dynamic weather front depiction.

As we move from single Service to a truly Joint battlespace, we lose our ability to treat atmosphere, land and sea as separate systems that can be pasted together and geo-relocated at will. There is a complex energy exchange budget that controls the global and local environments and it is nowhere more obvious than in littoral regions. Even the terrain is dynamic. The waves in the sand that can cover or expose mines change daily, even hourly, with the wind.[4]

Fig. 3 Moving sands in littoral terrain

Of all the environmental components, the ocean is least well represented in Joint simulations. To most of us not directly involved in the undersea environment, the ocean is characterized by waves and tides. However, our undersea sensors perceive a far more complex environment of varying temperatures, salinities, fronts, current shear, internal waves, entrained bubbles and suspended sediment. We "see" in the underwater environment largely with acoustic systems – sonars. Sound in the water does not just bounce off the seabed or submerged objects (like submarines and mines) the way light in our land based world bounces off structures. The temperature of the water bends sound rays and when they encounter the bottom, they penetrate and travel through the seabed, reemerging into the ocean at another location. Thus, the physical properties of the water (temperature, salinity, pressure) and the composition of the bottom (density, shear modulus, compressional and shear wave velocities) are as important to undersea systems as radiometric properties are for optical systems.

A Naval Perspective of the Littorals

The land, sea and atmosphere impact system performance in the littoral environment. For naval operations, the littorals are the least known and most stressing environment; "least known" in part because any hard data we have about coastal bathymetry becomes obsolete as soon as a storm passes through that region and shifts the sands that compose the near-shore seabed.

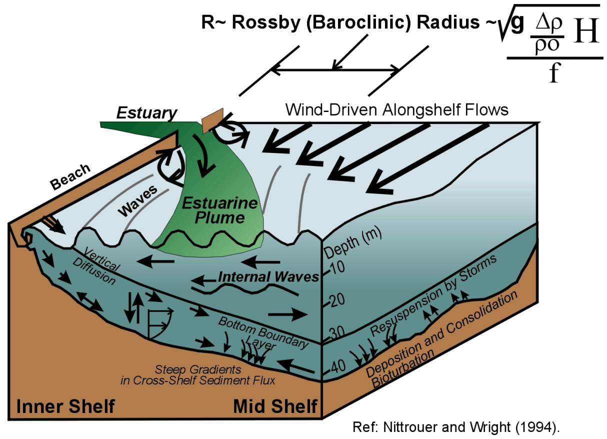

Fig. 4. Dynamic factors operative in the littorals with Rossby Radius providing the operative length scale in terms of reduced gravity (g), densities (ρ), layer depth (H) and planetary vorticity (F).

Some of the dynamic processes that drive the littoral environment are shown schematically by Rittrouer and Wright in Fig. 4.[5] The slope, curvature and composition of the seabed are vital factors in determining the flow of fluid, the development of surf and the entrainment of bubbles and sediment. The water mass is also affected by cyclic forces including tidal flow and diurnal changes in temperature in the surface layer of the water. Rain on shore and the consequent flow of fresh water into the sea alter the properties of the coastal water. Currents resulting from density differences, astonomical (tidal) forcing, wave-shoreline interaction and wind stress, change on time scales running from minutes through seasonal.

Does the spectrum of observed littoral variability have any tactical effect on military systems and operations? Often, sea state, surf conditions, water depth, temperature, and current (magnitude and direction) are go/no-go factors for an amphibious or near shore mission. These factors govern whether many systems can even be deployed without damage, danger to personnel and unacceptable exposure to adversarial countermeasures. Non-acoustic sensors, cameras and lidars, are dependent upon water clarity. The presence of many bubbles can scatter the light, preventing it from reaching the target for which it is searching. Similarly, entrained sediment and biological matter can obscure an object from a typical non-acoustic sensor. The entrainment of bubbles and presence of large quantities of biological material in the water column are related to dynamic meteorological and oceanographic (METOC) processes. The changeable ocean thus has a defining effect on deployability and effectiveness of systems.

The operation of acoustic sensors has been parameterized by what is known as the sonar equation. Sonars operate either passively or actively. In passive mode, a sonar is a listening device. When operating actively, a sonar transmits sound and listens for an echo from a submerged object or target. The operative equations are:

Passive Sonar Equation
SL – TL = NL – DI – DT

Active Sonar Equation
SL – 2TL + TS = RL + DT

where
SL = source level
TL = transmission loss
NL = strength of ambient noise
TS = target strength
DI = directivity index of the sonar
RL = reverberation level
DT = detection threshold of sonar

Of these factors, transmission loss, ambient noise and reverberation level depend upon the ocean environment. To compute transmission loss, one solves the hyperbolic wave equation using one of a number of approximations, all of which are dependent upon the properties of the fluid medium. A fully elastic form of this equation accounts for penetration of the sound into the seabed and thus is dependent upon the density, shear modulus, compressional and shear wave velocities in the sea floor. All models have to account for the scattering of the sound from the time variant sea surface. Reverberation refers to any process that scatters sound or introduces extraneous sound into the acoustic field. The manner in which it is computed in conjunction with transmission loss differs with the various mathematical methods employed; however, reverberation is also environmentally driven. The computation of each of these terms in the sonar equation is a complex process. The choice and matching of computational approaches lends yet another layer of technical detail that is still subject to scientific debate among specialists.

Rather than provide a mathematical formulation of these dependencies, we will provide evidence drawn from the computations made during Fleet Battle Experiment Hotel (FBE-H). This work was done in part to document the tactical effect of the synthetic natural environment developed for FBE-H.

Data from Fleet Battle Experiment Hotel

The comparisons are based on water column data derived from a coastal ocean model. The model, Estuarine Coastal Ocean Model (ECOM) is a version of a well-known and widely used ocean model called the Princeton Ocean Model (POM).[6] ECOM accounts for dynamic balances typical of coastal regions: local acceleration, non-linear advection, turbulent diffusion, pressure effects due to three-dimensional differences in density, and the temporal and spatial changes in the sea surface (tides, wind-induced setup or setdown). ECOM includes the ability to handle time-varying river discharges as well as fluxes of momentum, rainfall and heat through the air-sea interface. The latter include diurnal effects such as offshore variable wind stresses associated with sea breezes and day-night heating and cooling, as well as several-day effects associated with synoptic scale weather systems.[7]

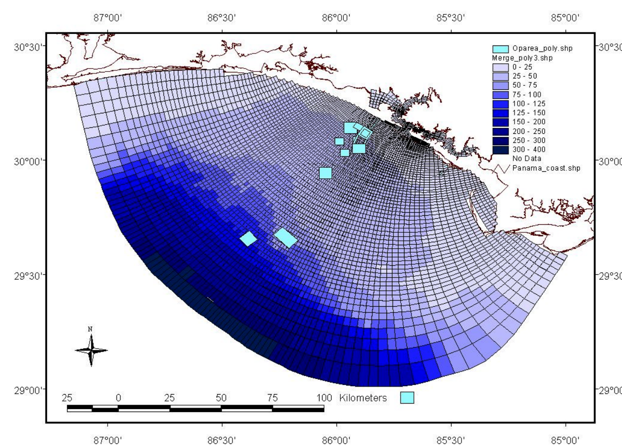

Fig. 5. ECOM computational grid for FBE-H

The ECOM model was run for the region of the Gulf of Mexico near Panama City, Florida, where the mine warfare portions of the experiment were located. Figure 5 shows the horizontal resolution of the computational grid; eleven layers spanned the vertical water column in each grid cell.

We compared the effect on ECOM output and associated sensor performance of using bathymetric databases of different resolution.[8] We examined the side scan sonar ranges for shallow and very shallow water regions (10 to 200 ft depth) as the water column evolved in response to observed forcing over a period of several days. The changes in sonar performance were significant in the very shallow water region (10 to 40 ft depth) where the dynamics caused vertical mixing. These sonar systems operate close to the seafloor; therefore, changes in temperature near the bottom produce significant changes in sonar performance. The sonar would typically be towed 2m to 3m above the bottom and would be looking downward to detect mines located on, in or suspended just above the seabed. Figure 6 shows the locations of the two sites compared. The narrow blue lines extended toward shore are amphibious approach lanes and depict typical routes for transporting troops and equipment to the beach.

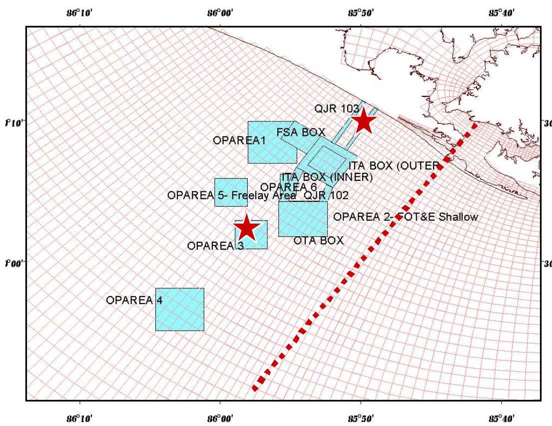

Fig. 6. Detail of mine warfare operations area.

The data shown in Figure 7 begins with the time evolution of the temperature in the water at the point of interest, in this case the approach lane marked by the upper star in Figure 6. All measurements take place at that one point. All changes are due to the time evolution of the environment.

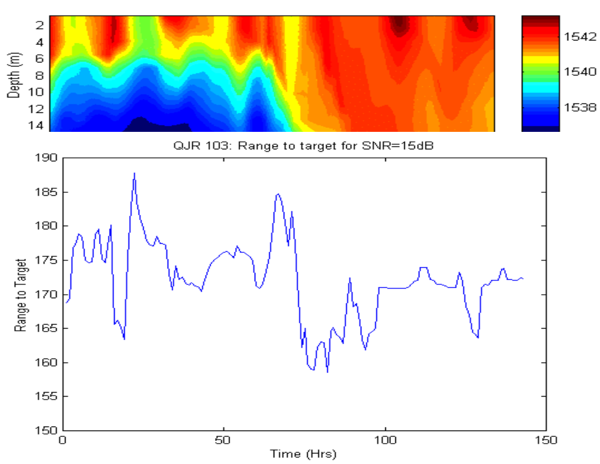

Fig. 7. Temperature evolution and consequent changes in detection range to a target at 15dB in very shallow water

The lower graph shows how far a 15dB signal would be heard. Mine search routes are designed based on assumed ability to sense a signal of given magnitude. Focus your attention at 6m above the bottom. Over a period of 140 hours, the performance changes span the range from less than 160m to more than 185m. If a mine normally producing a signal excess of 15dB, were expected to be seen at 170m, it would not have been during the period when the vertical mixing was taking place. It would just barely have been seen for the two days following. Prior to that time, it would have been detected virtually all the time.

The performance in deeper water is significantly different. The same data sets for the deeper water region show much less change. Again, observe 6m above the bottom. There is no deep mixing similar to what appears at hour 60 in shallow water. As a consequence, the detection range of the system is far more stable.

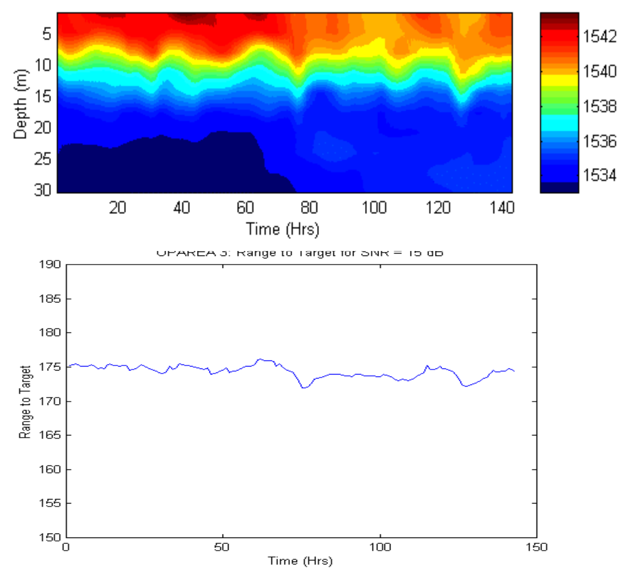

Fig. 8. Temperature evolution and consequent detection ranges for 30m water depth

It is important to note that in the shallow water, the changes are not happening day to day, but rather hour to hour. The spatial scales relevant to system performance in very shallow water are much shorter than they are when the water depth is well in excess of 40m. [NB: MCM definition of “shallow water” is 40 to 200 feet, not meters.]

Atmospheric Dynamics in the Littorals

The coastal energy exchanges among land, air and sea create a number of dynamic local effects that require meso- and microscale modeling including land-sea breezes, convective processes, coastal rainbands and fog. Models that are particularly sensitive to atmospheric conditions include the critically important hazardous material dispersion models. The land-sea breezes that result from the differential heat absorption and radiation are dynamic events local to the shore that can have a significant effect on the transport of various biochemical materials.

Land, air and sea are coupled at the coastline and, in Joint simulations, must be modeled at the appropriate temporal and spatial scales to realistically affect all battlefield systems.

DYNAMIC DATA FOR WARGAMES

Archival data is vitally important for developing the statistics of the synthetic natural environment for simulations. Statistics alone, however, are not sufficient. Statistics can bound system response and provide "n-sigma" operating envelopes. However, statistics cannot provide the continuous evolution in space and time of specific environmental events that often determine the outcome of a campaign. Most major conflicts throughout history were seriously impacted by the changing state of the environment. Archival data is where we begin, but not where we end.

Wargames, if realistic, typically span days to weeks. Therefore the proper evolution of the ocean and atmosphere is critical to producing a high fidelity game. For littoral wargames, the temporal and spatial scales of the simulated environment must be matched to the tactically significant performance parameters of the systems involved. The complex structure (amplitude and phase) of specific environmental features evolving on these scales dictates that models be used to generate the data for the simulation starting and consistent with the archival statistics. This will always be true because our measurements will always be sparse in comparison to the detail required. Interpolation is the simplest model used; however, full dynamical models provide far better temporal detail.

Generating Dynamic Data from Archival Data

Archives of atmospheric data typically produce one or more data points per day per location. Measurement locations for a given region are generally sparse. These statistics can be used to initialize and correct mesoscale models to produce data at the required spatial and temporal resolution. For example, the Global 2001 Wargame at the Naval War College was situated in the Persian Gulf. The Gulf is a littoral region with a complex circulation pattern composed of flow from the ocean, past the straits and around the gulf. Different layers in the vertical may be flowing in different directions at different times of year. The METOC officers developing the environment for the wargame selected snapshots of typical weather patterns from one period in the archives as the starting point. These regional fields were used to initialize an atmospheric model, COAMPS. COAMPS computed hourly forecasts, like those provided daily to the Fleet. The forecasts contained the surface forcing conditions, cloud cover and other initializing parameters required for ECOM to produce ocean variability for the same time period. Thus a coupled METOC environment was developed.

Environment and the Op Tempo of the Wargame

Most models used for the wargame do not respond directly to the environment; however, reports of the environment are used to set performance parameters for the sensors and systems in the simulation. Training exercises also have objectives that transcent the execution of the simulations that stimulate those being trained. Some objectives push the trainees into decision making forced by the course of events in the game. When the operations are running too easily, it is fairly common to have the game umpires impose "difficult conditions" to slow the pace of the exercise and force more difficult decisions. On the other hand, if things get bogged down, it is often the environmental conditions that are changed to speed up the action.

While this manipulation of the natural environmental is anything but natural, careful planning can enable the appropriate transitions. For Global 2001, specifications were developed for three types of historical snapshots. One represented normal conditions, but a the others were specifically sought to typify difficult operating conditions. When the historical data was chosen, it was selected from a time period in which excellent weather deteriorated rather quickly. Three sets of data, not two, were selected from a single time history. One representing good weather, one representing inclement weather and a transition data set. The collective conditions provided relatively smooth transition capability.

Sprint and Drift Methodology

While the game lasts only a week, it may span as much as a month in the scenario. During the day, the players are subjected to current conditions and they direct operations and plans in real time for that day. This real time operation is called “drift”. The next day when they return, however, the game may well be set several days or weeks from where they ended. The evolution will be based on the decisions they made the prior day. Tactical decision tools and faster than real time simulations progress the game in their absence. This faster than real time evolution of the game is called “sprint”.

Global 2001 employed a new tool for the daytime drift phase of the game. In collaboration with the Navy Warfare Development Command (NWDC) collocated at Newport, the Naval War College stimulated the drift phase with the simulation JSAF. JSAF is a real time, entity level simulation developed by DARPA under the STOW program. It has been adapted and used by NWDC for Fleet Battle Experiments. Unlike the decision support tools and simulations used in wargames, JSAF can ingest a dynamic environment and has numerous entities that respond to environmental data. The hourly dynamic data sets computed from the historical snapshots were used by JSAF during the daily exercises. For JSAF the evolutionary set data set was particularly important in providing a natural transition between typical and inclement weather and ocean. Whenever the game umpires deemed it essential to transition abruptly between weather conditions, JSAF could upload a new set of data in a few minutes.

Thus the tools used for the “sprint” received snapshots because they cannot handle the dynamic data and JSAF worked with hourly dynamic data sets. This type of experimentation with training methods would not have been possible as recently as one year ago.

DELIVERING DYNAMIC DATA TO JSAF

A real time simulation can and should work with dynamic data. Once that premise is accepted, additional issues must be addressed. In all cases, the synthetic natural environment must be generated for, delivered to, and interpreted correctly and consistently by the simulation. There are significant technical problems in each of these steps. .

Generating Appropriate Dynamic Environments

In designing the synthetic natural environment, the first question addressed must be, “How much is enough?” The highest resolution environment everywhere may be as useless as providing no variability at all. The answer has three components:

- What is necessary to capture the temporal and spatial scales of the natural phenomena typical in the battlespace?
- Which environmental factors are tactically relevant to (can be sensed by) the systems involved?
- What are the computing, display and tempo demands and limitations inherent in the action of this particular scenario?

The first question produces the most stringent data requirements. However, for military simulations, the second question is just as important. Any parts of the natural environment that do not affect the systems involved are irrelevant and need not be represented. Thus, if there are no coastal operations involved in a theatre air defence simulation, high resolution temporal and spatial variability in the littorals does not need to be represented. If the scenario is very short, temporal evolution may be irrelevant, but high spatial resolution may still be essential.

Physical Criteria for Spatial and Temporal Scales

If we make the premise that we can and must use model data to create the synthetic natural environment, in that decision we also provide the means for examining the appropriate temporal and spatial scales based on correlation techniques (see references 7,8). The methodology is as follows. Run the hydrodynamic model (atmosphere or ocean) at the finest scale possible, finer than one would ever use. Choose critical transects or cuts through the modeled space and compute the correlation in time at each point along the transect. When the correlation falls below a predetermined level, you have exceeded the appropriate refresh rate. The same operation is performed in space to determine how close sampled points have to be to maintain a smooth transition from point to point.

This approach was used to determine the spatial grid and refresh rates of the data provided to FBE-H.

Distributing Dynamic Data

The data sets developed for FBE-H were computed on an orthogonal curvilinear grid.[9] This type of grid allows for variable resolution while at the same time saving storage and compute time. Several problems in serving the data resulted from this choice of grid and data format. JSAF used TAOS (Total Atmosphere and Ocean Server) as the environmental data server. TAOS required modification to read the NetCDF file type and serve data on a non-rectilinear grid. TAOS had the very valuable capability of ingesting data during execution; therefore, it was easily able to manage dynamic data. OASES, the fully High Level Architecture (HLA) compliant replacement for TAOS, is being modified to have the equivalent capabilities.

Interpreting Dynamic Data – A Case for Servers

We selected a side scan sonar operating in shallow water to be the first candidate to respond to a dynamic ocean environment. It provided a stressing case because the shallow water environment is most sensitive to short time, small scale environmental changes. It must also use the active sonar equation, hence involving a comprehensive set of environmental parameters including bottom contour and bottom type, sound velocity profile, entrained bubbles, suspended sediment, current, salinity changes, biological clutter and target information for mines. Rather than inventing a new sonar model, we sought a model developed for other purposes, but with which the community was familiar. We found a system that had been developed as a training toolkit for human users which was able to use all the appropriate environmental parameters and return a signal excess from which a detection could be determined. We chose to develop this toolkit (PC Shallow Water Acoustic Toolkit or PCSWAT) into a server for JSAF.[10] Once the development was complete, we could be certain that all systems were responding to the same environment in a thoroughly consistent manner because they all polled the same PCSWAT server.

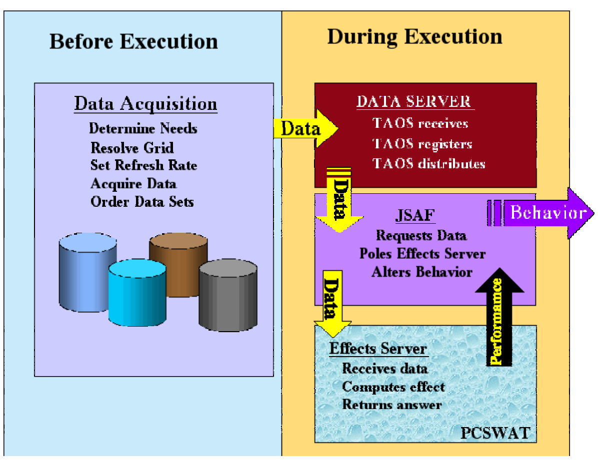

Fig. 9. Process of developing, serving and interpreting dynamic environmental data in JSAF

The flow of information in Fig. 9 shows how the data was developed, served and interpreted by JSAF during FBE-H.

EXPERIMENTATION AND IN-STRIDE ENVIRONMENTAL DATA

Experimentation as carried out in Fleet Battle Experiments places stringent restrictions on the synthetic natural environment that absolutely preclude the use of historical data.[11] An FBE is conducted in coordination with live Fleet assets. The role of the simulation is to provide capabilities not available among the assembled live assets. These capabilities could be systems already under development but not ready for delivery, or they could be capabilities that are just envisioned. In some cases, they could be fleet assets not available for the exercise but needed to round out the scenario.

Where Historical Data Cannot Be Used

JSAF as used by the FBE employs very little of the STOW visualization capability. The primary output of the simulation goes to the actual common operational picture by creating the same data messages that live systems produce. Visualization of the environment is not vital. What is critical, however, is that the simulation and the live forces experience the same environment. No predetermined set of historical date will provide this capability. The only viable option is to compute the synthetic environment in-stride from the available operational data – the data that will be provided to the live forces.

Using Operational Data to Create In-Stride Environments

The Fleet already uses nowcasts and forecasts for the atmosphere. For FBE-H, a littoral ocean model, driven by the operational atmospheric forecasts, was used to provide nowcasts for the ocean correlated to the atmospheric forecasts. The models used were those employed to create the pre-computed, dynamic environment for Global as described previously.

The hydrodynamic models of the ocean are initial value models and have to be “spun up” using historical data for the region in question. As they stabilize, they begin to assimilate forcing fields (atmospheric and ocean parameters) from near real-time sources. Several weeks of data are used to spin up the model; however, as the model runs faster than real time, the process takes no more than days. When the FBE simulation begins, the model is ready to assimilate the current forecast information.

Several times a day, the Fleet Numerical Meteorology and Oceanography Command (FNMOC) broadcasts to the operational Navy atmospheric forecasts out to 72 hours. We chose the midnight set and computed 48 hours of ocean predictions coordinated on an hourly basis with the first two days of weather forecasts. These were ready at the start time of the exercise each day. Thus the simulation and the Fleet assets were in the same atmosphere, and the ocean representation in the simulation was a precise estimate (defined error bounds) of the state of the ocean, given the observed and forecast data available.

Making Research Capabilities Operational

We are reporting here on the results of research to provide a high fidelity maritime environment for JSAF. It is critically important that we follow this work with an assessment of the quality of input data to the models required to produce tactically viable predictions. We intend to use sensitivity studies and in-situ data comparisons to achieve this. There are numerous data sources and their quality and resolution is not the same. The goal is to provide tactically significant environmental data for experimentation when fleet assets are involved. For littoral operations, this means that the computed temperature profiles and currents have to be very close to observed values – close enough that the systems using the computed values perform the same way they would if they had access to actual environmental measurements.

The Fleet is implementing a tactical environmental data server (TEDS) to supply environmental data to the various tactical decision support systems shipboard. Through use of appropriate API's (application program interfaces) TEDS could also provide data to OASES or similar data server for simulations. Navy would then have a single source of onboard data for operational planning, rehearsal, training and simulation. Research with the ECOM model shown here could readily be transitioned into the Naval Oceanographic Office's Shallow Water Forecast System (SWAFS) and the Modular Ocean Data Assimilation System (MODAS), which also use various versions of the POM model. By transitioning the full in-situ nowcast and forecast capability to shipboard systems, all systems could reach into TEDS for the critically important dynamic environment. Tactical decision systems and simulations would produce better estimates the performance of their sensors and systems. Further, those estimates would be more consistent. The emphasis on variability and its effect on tactical systems is also critically important for assessing the adequacy of environmental data available for operational missions.

We place a high value on "train as you fight". By providing a single environmental picture for all shipboard system, an environmental picture that reflects the essential variability and dynamism of the

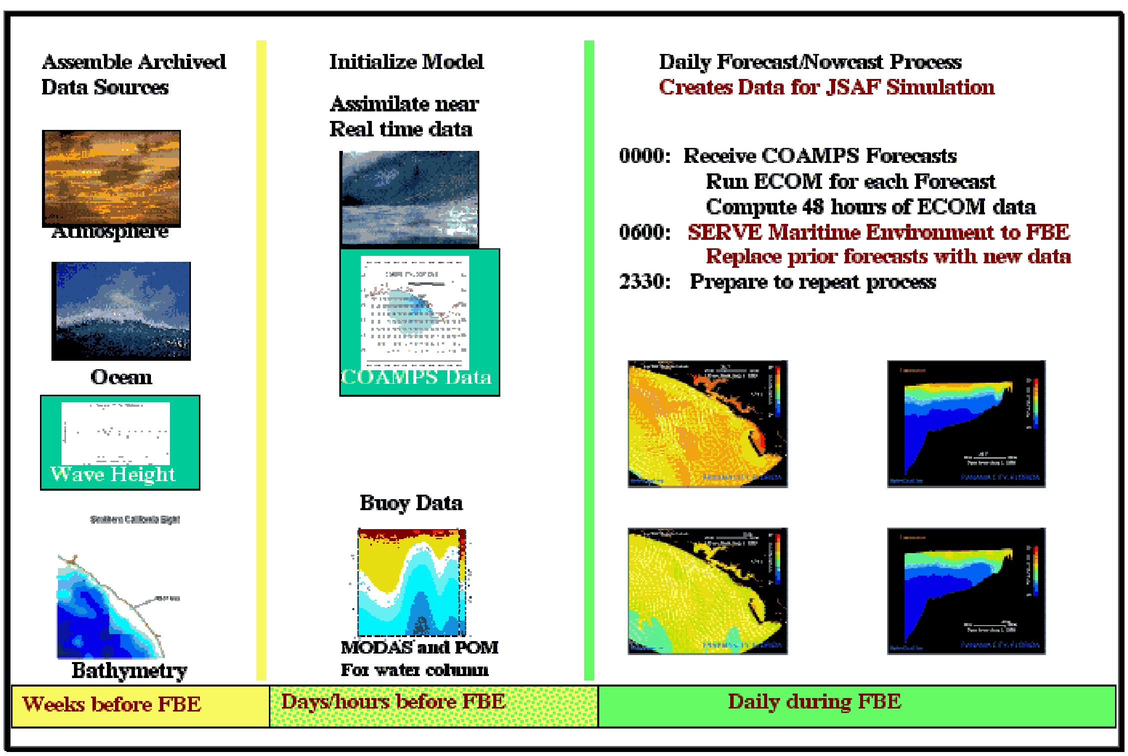

Fig. 10. Process for computing in-stride synthetic ocean environment from operational data

maritime environment, we would be taking a large step toward achieving that training vision.

CONCLUSION

The natural environment in littoral regions is dynamic to an extent that is tactically significant. We have demonstrated that an integrated system of state-of-the-art models, specialized data servers and appropriate environmental effects servers can make high fidelity littoral variability available to real time simulations like JSAF. Historical data, if statistically robust, form an adequate basis for creating dynamic environments useful for constructive training exercises or wargaming. Historical data cannot be the basis for experimentation when live forces are involved. In such an experiment, the simulation must experience an environment that is as close as possible to that experienced by live forces. Appropriate environmental data can be computed and served to JSAF to place the simulation and the live forces in the same battlespace.

For all simulations, but particularly for training systems, a critical metric for success is that the simulation create system performance that replicates to the extent possible what would be experienced in the field. For most systems, that implies providing a tactically realistic natural environment. By so doing, we create a training environment that develops relevant skills in an operational setting that truly enhances readiness.

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