Automation of Ocean Product Metrics

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LONG-TERM GOALS

A continual requirement exists to quickly and frequently evaluate the validity and accuracy of oceanographic data, models, algorithms, and products with comprehensible performance metrics that are meaningful and applicable to the supported mission. Results from these evaluations will help make performance improvements to the model and products, better assess the MetOc battle space environment, and provide decision makers with an improved perspective on the MetOc environment and the products.

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14. ABSTRACT

A continual requirement exists to quickly and frequently evaluate the validity and accuracy of oceanographic data, models, algorithms, and products with comprehensible performance metrics that are meaningful and applicable to the supported mission. Results from these evaluations will help make performance improvements to the model and products, better assess the MetOc battle space environment, and provide decision makers with an improved perspective on the MetOc environment and the products.

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OBJECTIVES

NRL will develop and transition to NAVOCEANO new core operational components which will include the required algorithms, methodology, software, and guidance as follows: a) Automated system that will create, and store the metrics of present and future ocean modeling analysis and forecast systems, in real-time and over longer space and time scales, b) A subset of specifically acoustic metrics for the evaluation of oceanographic data and models for ASW support, and c) Automated system that facilitates data collection and provides metrics of user forecasts and the operational impacts of those forecasts.

APPROACH

To meet the above mentioned objectives, the approach will be addressed in the three corresponding areas: 1) ocean modeling, 2) acoustics, and 3) forecast performance and operational impacts of user products. In all these areas automation is the key.

Ocean modeling. Since environmental analyses and forecasts are highly dependent on numerical ocean modelling, the oceanographer forecasters are interested in their accuracy (i.e., MODAS, NCOM, and HYCOM). Some standard metrics are already produced in various capacities and can be automated. Examples include time series comparisons, vertical profile comparisons, axis error of ocean features, anomaly correlation, RMS error, and skill score. Parameters of interest include temperature, salinity, currents, sonic layer depth, and sound velocity gradients. We will further investigate and develop additional metrics as deemed appropriate and investigate the relevance of metrics for overall model performance and specific parameters as they affect acoustic and operational products such as SLD on TL. Ultimately, operational impacts from model output should be identified, for example, how much does the magnitude of currents affect the shape of acoustic arrays towed by ships, the deployment of acoustic sensors such as sonar buoys dropped by the P3 Orion, and glider path performance. Standard data formats will be identified and/or developed. The netCDF-based model data file NAVOCEANO conventions has already been used. Through the Navy Coupled Ocean Data Assimilation (NCODA) analysis and data quality control software (OCNQC), a regular feed of quality-controlled in-situ observations (e.g., XBTs, CTDs, profiling floats, glider data, and surface ship observations) will be used mainly as ground truth. Inter-model comparisons will also be made.

Data structures and formats will be defined to facilitate database queries and analysis of model-observation and model-model comparisons. Software will be designed to support frequent data processing (multiple data cuts per day) and multiple-nested models. Routines for generating automated evaluations of model forecast statistics will be developed and pre-existing tools will be collected to create a generalized tool set, which will include user-interface tools to the metrics data.

Acoustics. Many tools have been developed to evaluate differences between and values of parameters including: sound speed gradients; the ASW parameters such as cut-off frequency and sonic layer depth; wide area transmission loss; acoustic analysis parameters such as acoustic coverage area and graphics capabilities. To facilitate the evaluation and analysis of sound speed in the ocean for ASW support, a set of acoustic metrics is being developed using parameters such as sonic layer depth, below layer gradient, and mixed layer depth. Existing parameters are being broadened for a wider range of ASW scenarios by allowing for multiple source depths and by incorporating range dependence in eight directions. Preliminary capability to view uncertainty products developed under the Uncertainty RTP have also been developed.

Forecast performance and operational impacts of user products. Since it really comes down to evaluating the end user product, this aspect of the project is about collecting real-world METOC data and response to METOC products from the end user (likely the NOATS) and identify ways to improve the products. With feedback from the operations, forecasters can adjust the error of their methods in an objective manner for future products. As work has already been accomplished in the strike warfare area, the concept for adapting methods in ASW will be explored. We will investigate methods of obtaining feedback from the end users and decide on the appropriate questions to be asked which may include timeliness, product finish, assessment helpfulness, sensor deployment success, etc. Once these methods are determined then an automated system will be implemented to facilitate metrics creation perhaps in the form of a web-based survey. In addition the results will be fed back into the production at all levels, i.e. numerical model output and acoustic products, and the user products.

Final Integration. The integration of these components is essentially a progression from ocean modeling to product delivery, and all performers must recognize there inherent interdependencies of their areas of expertise. For all areas, metrics will provide feedback for possible adjustments to the procedures, which will not necessarily be automated, but can be used for a value assessment of the product for consumer use automatically. Customer expects software deliverables to be completed via spiral development to meet requirements.

WORK COMPLETED

Data formats and standard procedures for model output (mostly NCOM) and vertical profiles were established. Software functions were developed in C for reading the data files relying on established format standards. Functions are compatible on both Linux and IBM OSs. Software also in MATLAB was developed to ingest the model and observed data. The important point is that this initial task laid the foundation on which to build further capability effectively and efficiently.

A software utility developed in C was implemented to compare netCDF output of two models of differing resolutions, allowing evaluation of the performance of diverse models. Operates on HPC systems and results are output in netCDF.

A software utility was developed and implemented for locating and processing data files resident on IBM machines part of the DoD High Performance Computing (HPC) resources in which the models are running. This included a utility in C to match up model output to observational profiles and to produce statistics, which were then plugged into ArcGIS software for display as user-friendly and readable bar-graphs and plots.

A feature-rich software suite of tools was developed in MATLAB to analyse model fields and data from observed profiles. Tools include: field comparisons between or within model domains including determining differences between SLD, BLG, ILG, DEX and COF; TL comparisons between models and observations; computation of acoustics related statistics; cross-section (slice) views; colour plots with adjustable scale colour bar, histogram charts, profile plots, and tables. Major upgrades included currents analysis tools used by the MIW support and auto-generation of selected movies. An initial draft of a user manual continues to be updated for the MATLAB prototype software. All work mentioned above was accomplished mainly by James Dykes and Josie Fabre. MATLAB tools were developed by Josie Fabre.

In addition to MATLAB tools mentioned above, David Wang used MATLAB to develop the capability to seamless incorporate altimeter wind, wave, and sea surface height observations into a system where they are compared to model output. Specifically, he demonstrated a method of producing statistics as an indicator for model performance for SWAN wave model output for runs during 2006. Results are discussed below. This capability promises to be easily transitioned into the collection of metrics tools already successfully used in the RBC in NAVOCEANO.

Tom Murphree executed an extensive metrics data collection effort during Valiant Shield 07 (VS07). Four ASWC platforms were involved. Data products generated the by reach-back cell (RBC) and information on the product's impacts as perceived by the Navy Oceanographer ASW teams (NOATs) was collected and analyzed to help develop metrics of product performance and their real impacts. The results from the VS07 metrics effort paved the way for the execution of automated data collection and processing tools used during RIMPAC08 this time implementing on the SIPRNET a web-based survey accessible to the NOATs and ASW operators, both of whom would fill out the surveys at the end of their watches. Preliminary results presented to ASW DOO and NOAC COs provided useful information in making certain changes.

Eric Chassignet hired a post-doc at Florida State University to document region-specific metrics and provide such analyses in a report. The focus is on two regions, the Gulf of Mexico and the tropical Pacific Ocean. The Gulf of Mexico was chosen for two reasons: 1) the Loop Current and associated rings form an ideal test data assimilation and prediction test bed (Chassignet et al., 2005) and 2) the warm SST associated with the Loop current has a strong impact on hurricane development. Of particular interest is the SST response to a hurricane since it is not always well resolved by current SST products. The tropical Pacific Ocean was chosen because of the strong upwelling that occurs is along the equator via the Tropical Instability Waves (TIWs). The extent of the cold tongue and associated currents can be measured from the distance of the 26 degree C isotherm from the western boundary.

Jay Shriver is spearheading two efforts, automated eddy/frontal analysis and trajectory tracking. He is overseeing Sean Ziegler, a PhD student working in the eddy/frontal analysis tools and has made some progress with some adjustments to the algorithms. Debugging is still needed for the SST component of the algorithms. The model component is still working reasonably well. Jay is also overseeing work done by a Masters Student, Debbie Franklin, on frontal placement error analysis. In addition, Jay himself is pursuing an effort in trajectory tracking error.

RESULTS

Figure 1 illustrates the usefulness of the MATLAB GUI in displaying oceanographic fields relevant to ASW. A significant feature within the RIMPAC08 operational area of interest was identified and further investigation revealed that this was a warm eddy within which resulted in complex acoustic signatures. Model variability over time or space is an important indicator of the performance of NCOM and provides insight into the effects of the ocean structure on acoustic prediction performance.

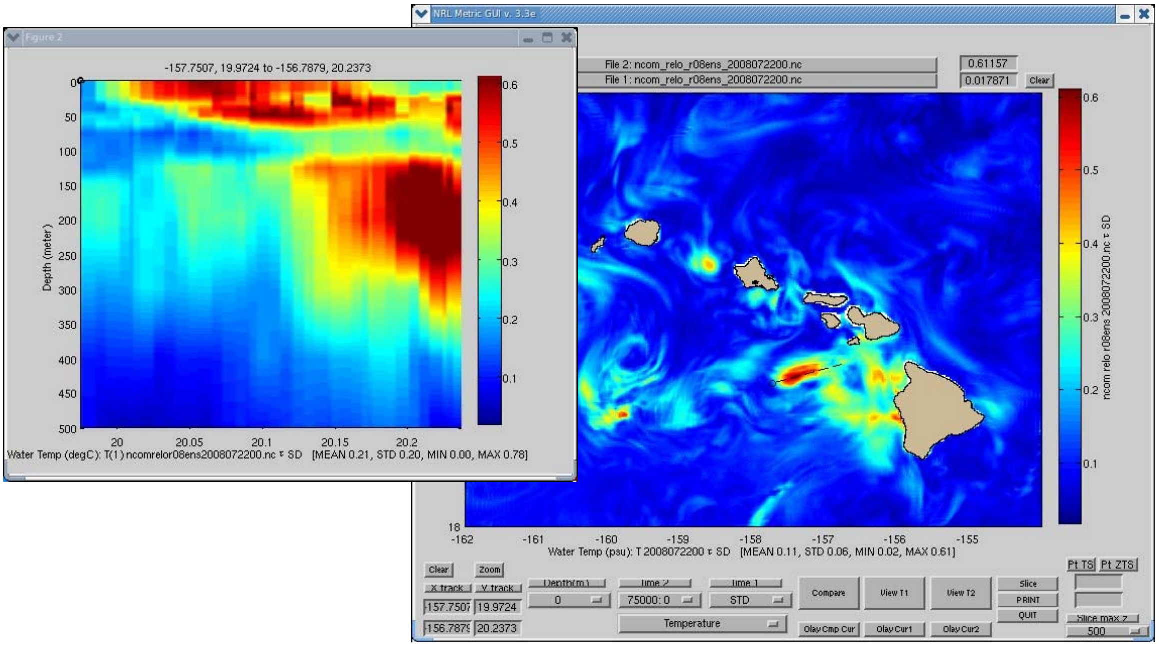

Figure 1: Example of MATLAB display in GUI used at NAVOCEANO by oceanographers in the RBC. A cross-section of the variance of water temperature is displayed based on the line drawn on the plan view of the RIMPAC 08 oparea.

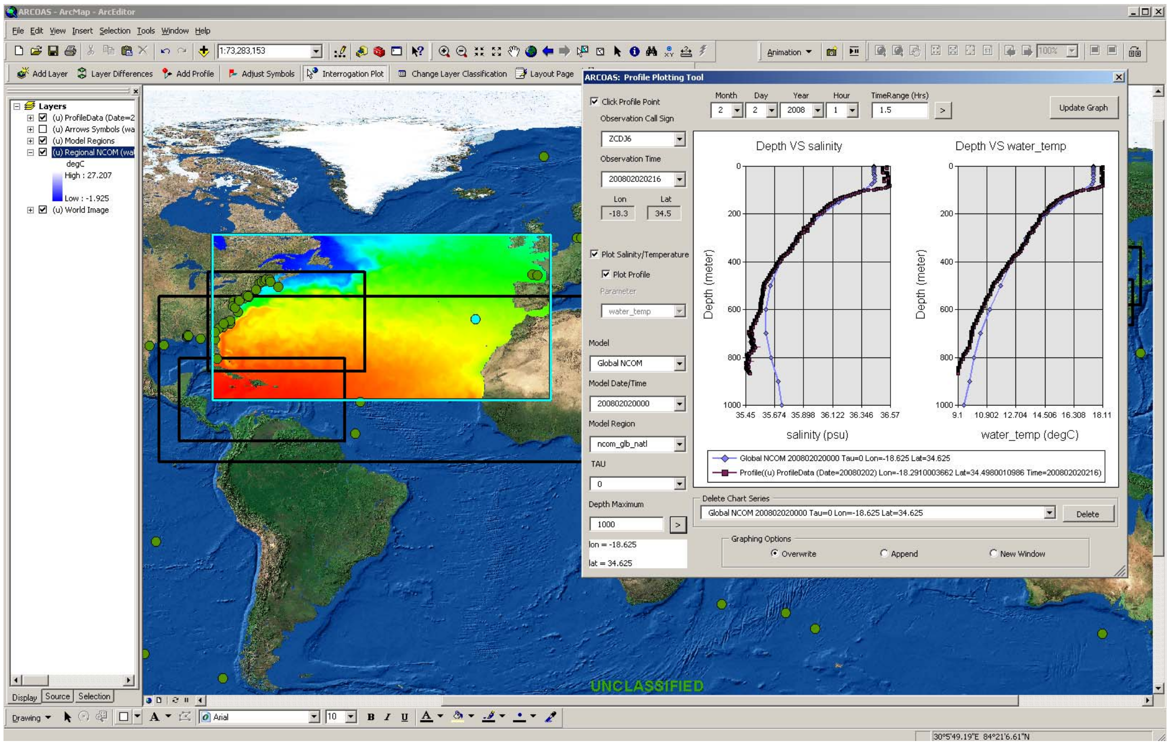

Figure 2: Example of display in the ARCOAS GUI used at NAVOCEANO by oceanographers in the RBC. A plan of vew of temperature from NCOM is displayed as a raster layer. A point within that same domain was selected to present the profiles of models and observed temperature and salinity at that point.

The MATLAB prototype capabilities follow a transition model of spiral development which allows real operational users to test capabilities and provide feedback to help plan develop tools to a mature transition readines level, in other terms, TRL 8. Processing of data and model comparisons are also being developed to run "under the hood" and the results of the comparisons and statistics calculation can be displayed using GIS GUIs and tools such as the plan view and selected profiles displayed within the ASW Reach-back Cell Oceanography Analysis System (ARCOAS) depicted in Figure 2. Also, model performance metrics in the form of statistics of model vs. observations can be displayed in a window of ARCOAS in an initial demonstration capability as depicted in Figure 3. A fully automated system builds a database of comparisons between model output and observation profiles which consist of paired match-up profiles grouped in 24-hour segments. Their mean differences, RMS errors, and correlations are computed for each model run for each model level. Several model runs are displayed in a series providing an indicator of model performance trends. For example, the RMS error of the 0-24 hour forecasts are usually less than the 24-48 RMS error, which is normally expected.

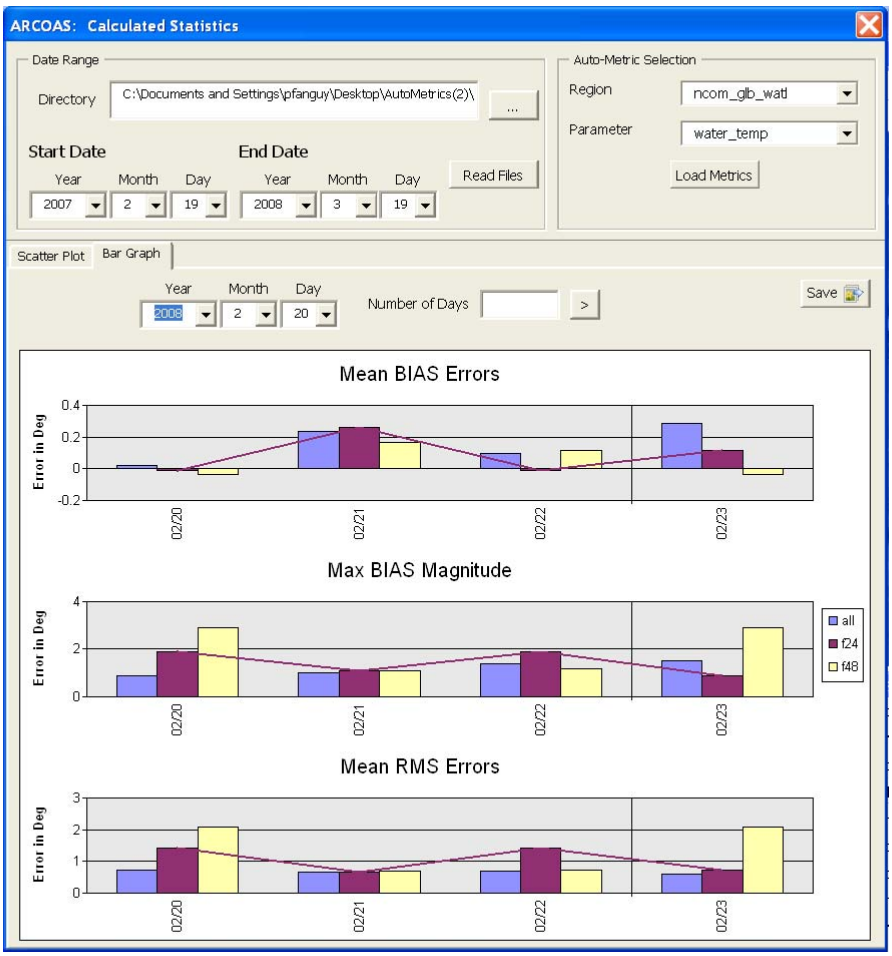

Figure 3: Initial capability in displaying statistics of comparisons between model and observation profiles as summary bar graphs within the ARCOAS GUI used at NAVOCEANO by oceanographers in the RBC.

Automated eddy detection and comparison algorithms are being developed and refined for practical implementation. Figure 4 shows an example of what the user might see after the eddy detection algorithm is finished with the sea suface termperature output from a model like NCOM. The next step is to compare the eddy detection results from model and satellite observed sea surface temperature and provide a variance depiction.

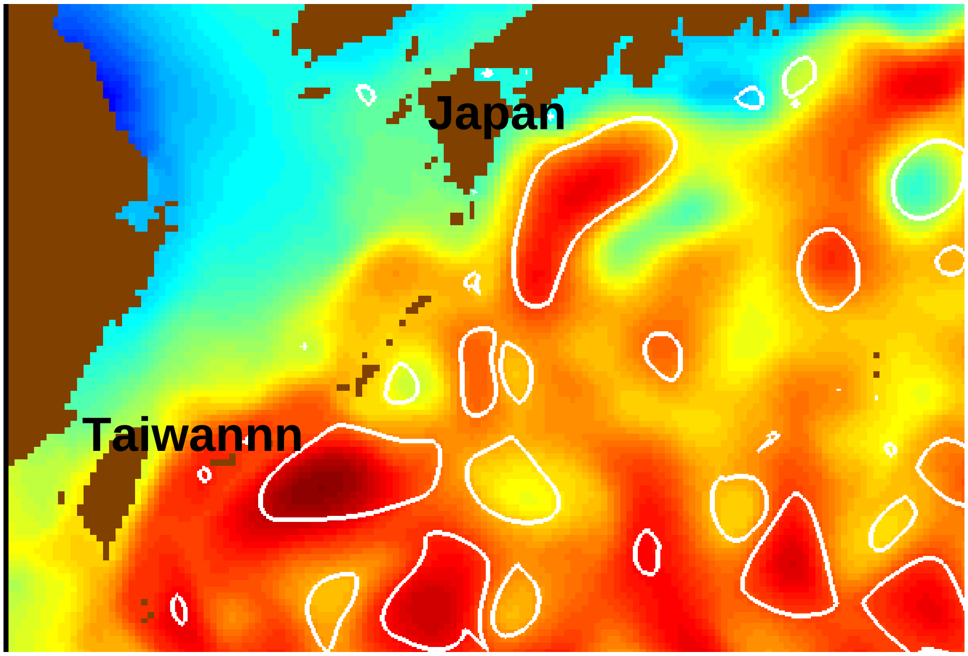

Figure 4: Results demostrating the automated eddy detection capability using algorithms based on the distribution of the temperature gradient field.

During the year of the DART06 trials which happened to be prior to the commencement of work on this RTP, the SWAN wave model was run to support research operations. In the spirit of cooperation with NATO participating countries the meteorological model run by the Croatian Meteorlocgical Office provided the wind forcing for SWAN. Altimeter observations for surface winds and waves were made available and were compared to the wind and waves of both models. A graphic displaying the comparisons in Figure 5 shows that in an area in the northern Adriatic Sea, SWAN modelled with low skill based on the correlation coefficient and best-fit liear slope that results from comparisons of many observations to model values. The first inclination is to check the wind forcing since winds are a dominant factor in the generation of wave energy. But since the skill of the modelled winds turned out to be high, one can immediately rule out the most blamed factor of inaccurate wave model predictions. This capability to bring such a comprehensive set of altimeter observations together to compare with the model was developed in MATLAB.

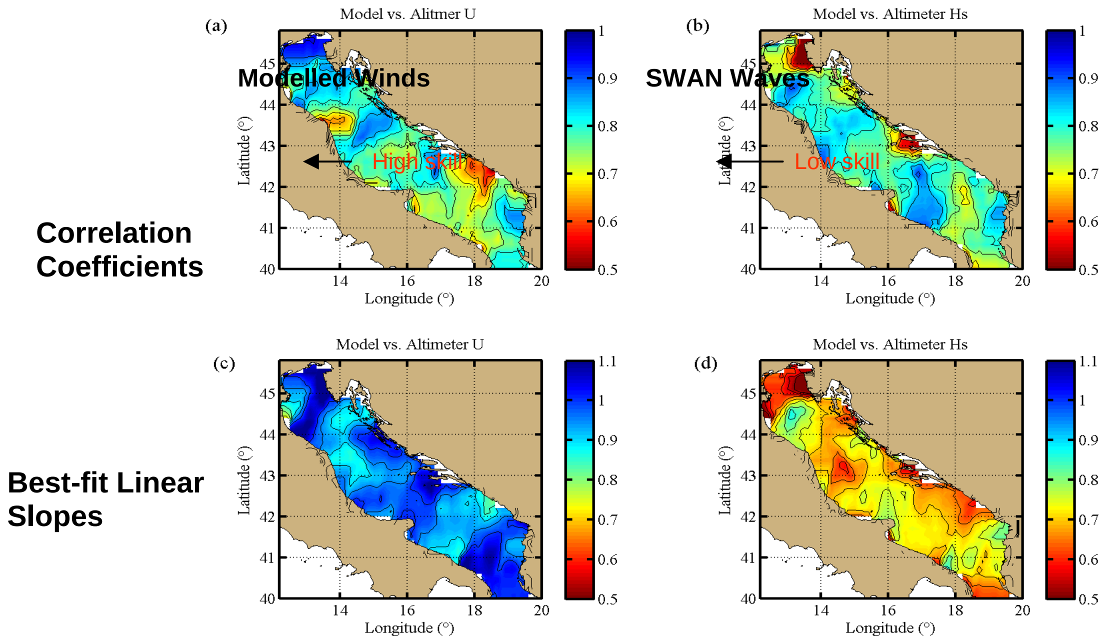

Figure 5: Model verses altimeter observations of the Adriatic Sea for most of 2006 during which DART06 was executed. Skill is indicated by the metrics of correlation coefficient and best-fit linear slopes that result from differences between model and observed. In an area in the northern Adriatic high skill in modelled winds coincides with low skill in modelled waves.

IMPACT/APPLICATIONS

High-profile exercises (e.g. VS07, RIMPAC08) were supported within the RBC at NAVOCEANO demonstrating work-in-progress tools. The capabilities used so far by the oceanographers during these exercises have been found useful based on positive feedback from the users in both the ASW and MIW reach-back cells. The SWAN wave model predictions supporting the Naval Undersea Warfare Center within NATO during DART06 were consistently useful and well accepted. Evaluation of wave model performance in the Adriatic during DART06 revealed modelling system shortcomings that have since been resolved.

TRANSITIONS

The ASW and MIW RBCs within NAVOCEANO are now using intermediately developed capabilities to support operations and exercises. These capabilities include the MATLAB GUI installed on local NAVOCEANO computers and code installed on the classified and unclassified DoD HPC systems. Results from the automated metrics software on these systems are currently being automatically transferred to the local SAN for display.

RELATED PROJECTS

The ASW Reach-back Cell Analysis System funded by SPAWAR PMW 120 was described above to render results generated by the tools developed in this project. Capabilities from the Adaptive Sampling and Uncertainty RTPs are being extended to support development of MATLAB tools in this project. The NOPP program funded NRL personnel who provided guidance as to the types of metrics are important and the techniques for producing them. The NSW Metrics and ASW Metrics projects are headed by Tom Murphree who is also supporting this RTP.

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