13.10 FLEET BATTLE EXPERIMENT-JULIET (FBE-J) PART II: A REAL-TIME APPLICATION OF AN ON-SCENE NUMERICAL WEATHER PREDICTION SYSTEM

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1. INTRODUCTION

As research oriented numerical weather prediction (NWP) models continue to be transitioned into operational environments and non-meteorological research communities, a need has evolved for a system to provide an interface to initialize, interpret, and visualize the NWP model's analyses and forecasts. In 1996, the Marine Meteorology Division of the Naval Research Laboratory (NRL) in Monterey, California, developed a prototype interface to the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS™) called the On-Scene Tactical Atmospheric Forecast Capability (STAFC; Cook et al. 1998). The system was later integrated with the Tactical Environmental Data Server (TEDS) and designated the Tactical Atmospheric Modeling System / Real-Time (TAMS/RT). NRL delivered TAMS/RT to the Naval Central Meteorology and Oceanography Center in Bahrain and to the Naval Pacific Meteorology and Oceanography Center in San Diego, California to provide meteorological support for Naval operations. Since 1998, TAMS/RT has been installed at four additional Naval Meteorology and Oceanography Regional Centers (Rota, Spain; Norfolk, VA; Pearl Harbor, HI; and Yokosuka, Japan) and at multiple military/government agencies including the Defense Threat Reduction Agency, Naval Surface Warfare Center, United States Strategic Command, Air Force Technical Applications Center, and Central Intelligence Agency. The installations at the Navy's Regional Centers are part of the Distributed Atmospheric Mesoscale Prediction System (DAMPS) at the Fleet Numerical Meteorology and Oceanography Center (FNMOC).

This paper will discuss COAMPS-OS™ (On-Scene) and the application of COAMPS-OS in the Navy's Fleet Battle Experiment Juliet (FBE-J). The following sections will describe each component of COAMPS-OS beginning with the NWP model, COAMPS. The second section will describe the COAMPS-OS Graphical User Interface (GUI). The third section will discuss the data management component of COAMPS-OS. The fourth and fifth sections will discuss the visualization and web-based monitoring components of the system. The final section will discuss FBE-J and the application of COAMPS-OS in FBE-J. A companion paper (Strahl et al. 2002) describes the application of NOWCAST for the Next Generation Navy in FBE-J.

2. COAMPS

COAMPS is a non-hydrostatic NWP model capable of weather prediction at spatial and temporal scales of 1-100 km and 0-72 hours. A description of the numerics and physics used by COAMPS can be found in Hodur 1997. COAMPS is run as two separate processes, an analysis and forecast. The COAMPS analysis produces the gridded atmospheric fields and boundary conditions used to initialize a COAMPS forecast. COAMPS derives the analysis fields using a previous COAMPS forecast as a “first guess”. If a previous COAMPS forecast is unavailable, the first-guess fields are interpolated from a NOGAPS (Navy's Operational Global Atmospheric Prediction System; Rosmond and Hogan, 1991) 12-hour forecast. The resolution of the NOGAPS 12-hour forecast is one-degree.

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COAMPS first-guess fields are adjusted towards observed values of temperature, wind, and moisture using rawinsondes, surface and ship reports, SSM/I and SSM/T measurements, cloud and water vapor tracked winds, buoy observations, and aircraft reports. In addition to the atmospheric component, the COAMPS analysis includes a three-dimensional ocean data assimilation component to initialize the sea surface temperature and sea ice concentration.

COAMPS permits the nesting of multiple grids of higher resolution within a coarse outer grid. The resolution increases by a factor of three with each inner grid. Each COAMPS grid represents a limited area domain that requires periodic boundary conditions. The boundary conditions of the outermost grid are interpolated from NOGAPS and typically updated every 3 to 6 hours during a COAMPS forecast. The boundary conditions of each inner grid are derived from the grid's outer parent. The position and size of the grids may be configured using the COAMPS-OS graphical user interface described in the next section.

3. GRAPHICAL USER INTERFACE

The COAMPS-OS graphical user interface (GUI) permits a user to configure the location, duration, and output products of COAMPS without requiring a thorough knowledge of the model, the operating system, or a programming language. The COAMPS-OS GUI is written as a Java applet and loads into web browsers as a plug-in. The GUI is accessible across multiple platforms that support Netscape and Internet Explorer. The platforms include Microsoft Windows (XP, NT, 2000, 98), Sun Solaris, SGI IRIX, and RedHat Linux. The functionality of the COAMPS-OS GUI is briefly described in each section below.

3.1 *Map Projection control panel*

Users may configure the location, size, and projection of a COAMPS domain using the Map Projection control panel. The configuration of a COAMPS grid is started when a user single clicks on a map of the world. The COAMPS-OS GUI loads a new regional map with two COAMPS grids centered over the region selected by the user (Fig. 1). The user may interactively move or resize a grid using the mouse or up/down arrow buttons and add or remove grids using buttons in the control panel. The user also has an option to select a different map projection supported by COAMPS including the mercator, lambert conic conformal, and polar stereographic projections.

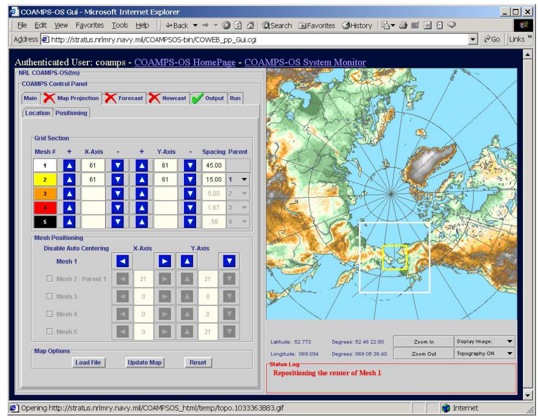

FIG 1. The COAMPS-OS Map Projection control panel may be used to configure the size, resolution, and position of COAMPS grids. The control panel may also be used to set the projection of the regional background map shown on the right side of Figure 1.

3.2 *Forecast control panel*

The Forecast control panel (Fig. 2) allows a user to select the duration of the COAMPS forecast, the data assimilation interval, and frequency of the 3-D output from the model. The forecast length of each inner grid may be configured from the Forecast control panel to be a subset of the parent grid. The default forecast length of each grid is 24-hours. The default value for the data assimilation interval is 12-hours, and the default 3-D model output frequency is 1-hour. The Forecast control panel can also be used to configure the multivariate optimal interpolation (MVOI) analysis for each grid. Inner grids may be analyzed independently or interpolated from the parent grid.

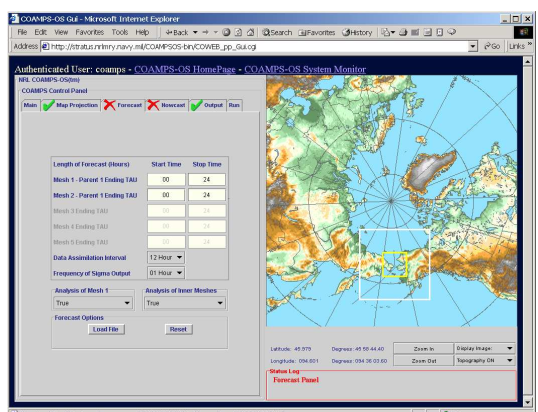

FIG 2. The COAMPS-OS Forecast control panel may be used to configure the duration of a COAMPS forecast, data assimilation interval, and frequency of COAMPS 3-D output.

3.3 *Nowcast control panel*

The COAMPS-OS nowcast is a real-time analysis of a COAMPS forecast. The nowcast runs the MVOI analysis using a COAMPS forecast as the first-guess fields and blends in observations at the valid time of the forecast. Users have the option to set the frequency of the nowcast and the time period when the nowcast is performed. In operational forecasting, a nowcast may be used to provide a current analysis of the atmospheric conditions or analyze the skill of a COAMPS forecast. An example of the Nowcast control panel is shown in Figure 3.

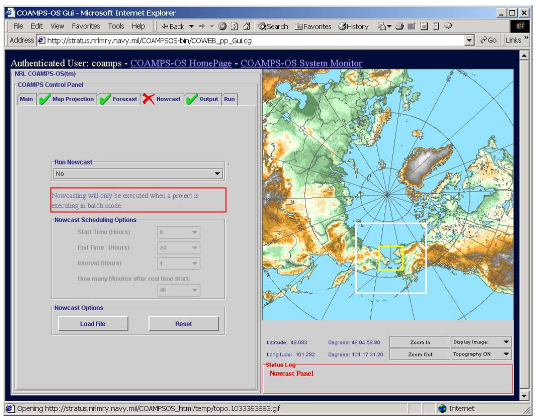

FIG 3. The COAMPS-OS Nowcast control panel may be used to enable the MVOI analysis and set the frequency of the analysis.

3.4 *Output control panel*

The Output control panel (Fig. 4) allows a user to select the type and frequency of 2-D output from COAMPS. Output fields may be selected for each COAMPS grid at height surfaces (AGL), isobaric levels, and the surface. Users may select different output fields for each nest, and different frequencies for each set of output fields. Sample output products from COAMPS include clouds, precipitation, U and V wind components, temperature, and relative humidity. Users may load previously saved output selections into the Output control panel to bypass the process of reselecting the output.

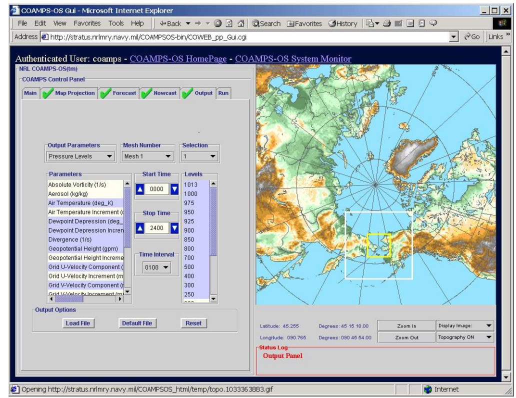

FIG 4. The COAMPS-OS Output control panel may be used to select 2-D output parameters for COAMPS.

3.5 *Run control panel*

The Run control panel (Fig. 5) allows users to select the basetime of a COAMPS forecast. Available times shown in the Run control panel are based on the most recent NOGAPS fields available to be used as COAMPS boundary conditions. A COAMPS forecast can be started interactively or set to execute at a specific time(s) each day.

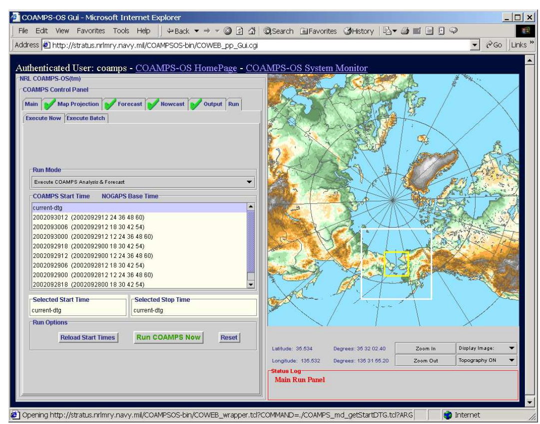

FIG 5. The COAMPS-OS Run control panel may be used to start the COAMPS analysis or forecast interactively or set the model to run at a specific time each day.

3.6 *Additional graphical interfaces*

COAMPS-OS includes additional applications to interface with the input to COAMPS and the output produced by COAMPS. The applications are summarized in Table 1. Examples of each application are shown in Figures 6-8.

TABLE 1. Applications used to interface with COAMPS input and output fields are described below. Each application is accessible from a password-protected link on the COAMPS-OS homepage.

Application	Description
HPAC Interface	Formats COAMPS output for use with the Hazardous Prediction Assessment Capabilitiy (HPAC)
Station Interface	Add point locations for meteograms and Skew-T graphics
VLSTrack Interface	Format COAMPS output for use with the Vapor Liquid SolidTracking (VLSTrack) Program
WMO Interface	Formats and ingests observations into the observational database used by the COAMPS analysis

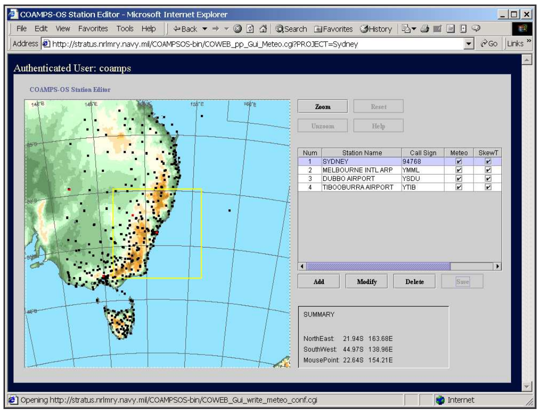

FIG 6. The COAMPS-OS Station Interface is used to select point locations for producing meteograms and Skew-T graphical products. The interface downloads WMO station locations from the Navy's Tactical Environmental Database Server (TEDS). The frequency of the Skew-T products is determined by the 3-D output frequency selected in the COAMPS-OS GUI Forecast control panel.

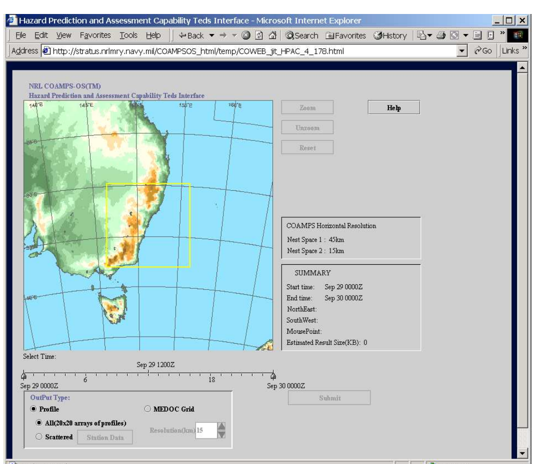

FIG 7. The COAMPS-OS HPAC interface may be used to extract and format data to run the Hazardous Prediction and Assessment Capability (HPAC). A similar interface exists for VLSTrack.

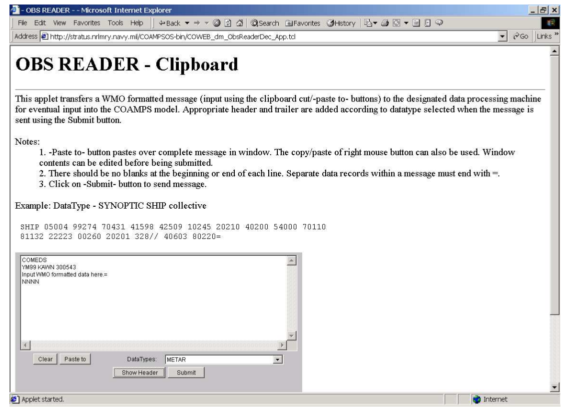

FIG 8. The COAMPS-OS Observation Reader may be used to put a WMO formatted message into the Navy's Tactical Environment Database Server (TEDS). The most recent observations are extracted from TEDS each hour and made available to the COAMPS analysis.

4. DATA MANAGEMENT

A data management component is included with COAMPS-OS to automate the process of formatting input data for COAMPS and archiving output data produced by COAMPS. Daily input data requirements for COAMPS may exceed 300 Megabytes with the amount of data varying with the number of available observation types and the frequency of NOGAPS forecasts. The amount of disk space required for COAMPS output varies with the size and number of COAMPS grids and the number of selected output fields for each grid. A typical triply-nested 36-hour COAMPS forecast may produce 2.5 Gigabytes of output.

The data management component of COAMPS-OS includes an interface with the Navy's Tactical Environmental Data Server (TEDS). The interface with TEDS extracts and formats NOGAPS and observational data for the COAMPS analysis and archives COAMPS output data into TEDS. NOGAPS grids are extracted from TEDS and formatted for COAMPS twice each day at 1100Z and 2300Z. Atmospheric and oceanographic observations are extracted from TEDS once each hour. Additional data management routines run during each COAMPS forecast and format data for ingestion into TEDS. The COAMPS output fields are stored in TEDS for the three most recent forecast periods.

5. VISUALIZATION

COAMPS-OS includes a visualization component to produce graphical products from GrADS (Gridded Analysis and Display System), GMT (Generic Mapping Tools), and Vis5D. The products are created during each forecast hour while the model is running and displayed on an interactive web-based product matrix. COAMPS-OS provides a user interface to GrADS to edit and add graphical products to the web pages. Products produced by COAMPS-OS are summarized in Table 2. Examples are shown in Figures 9-13.

Table 2. The COAMPS-OS graphical products are described below. Examples of each product are shown in Figures 9-13.

Product Type	Description
2-D Graphical Products	Depictions of atmospheric fields at the surface, on height surfaces, and on isobaric levels (Fig. 9).
Meteograms	Plots of atmospheric fields at locations as a function of time. (Fig. 10)
Observations	Locations of observations used by the COAMPS analysis (Fig. 11)
Skew-T	Profiles of temperature, dewpoint, and wind on a Skew-T diagram. (Fig. 12)
Vis5D Files	3-D Data from COAMPS formatted for Vis5D (Fig. 13)

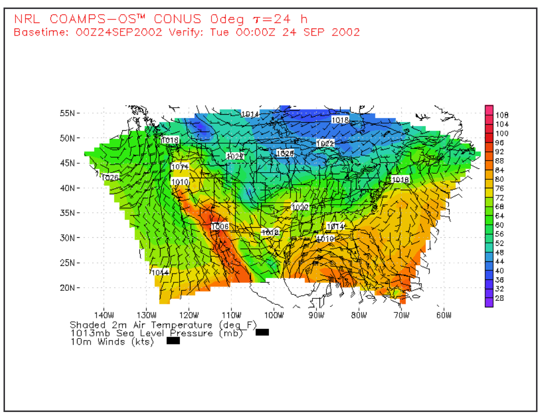

FIG 9. The COAMPS-OS 2-D graphical product depicts a 24-hour forecast of two-meter air temperature (°F), ten-meter wind (knots), and sea level pressure (mb). The basetime of the forecast is 0000Z, 24 September 2002.

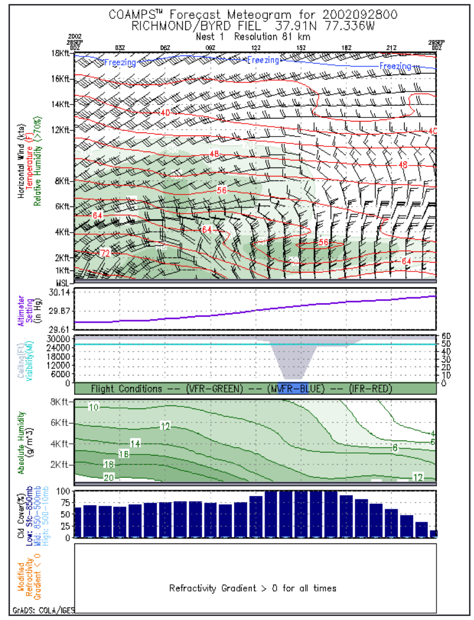

FIG 10. The COAMPS-OS Aviation Meteogram depicts the vertical profiles of wind (barbs), temperature (°F), and relative humidity (percent) at KRIC (Richmond International Airport) for a 24-hour forecast beginning at 0000Z, 28 September 2002. Other fields shown in the meteogram include (from top to bottom), altimeter setting (inches of Hg), ceiling height (ft) and visibility (miles), absolute humidity (gm^{-3}) as a function of height, cloud coverage (%), and modified refractivity gradient.

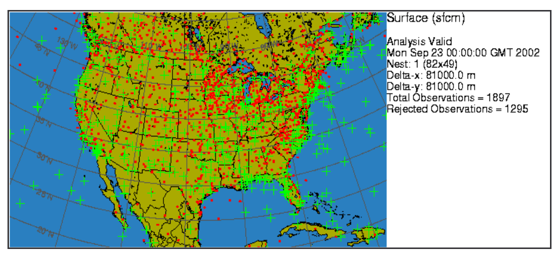

FIG 11. The COAMPS-OS observation plot shows surface observation locations used by the COAMPS analysis. Green crosses indicate observations accepted by the COAMPS analysis, and red dots indicate observations rejected by the COAMPS analysis. The analysis is valid at 0000Z, 23 September 2002.

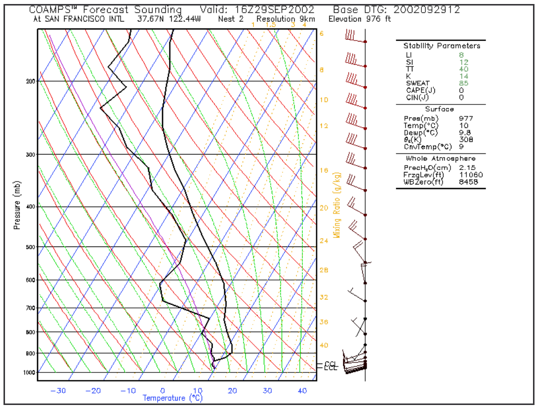

FIG 12. The Skew-T plot shown for KSFO is valid at 1600Z, 29 September 2002. The Skew-T profile represents a 4-hour COAMPS forecast. All Skew-T plots in COAMPS-OS use data from the nearest COAMPS gridpoint within the innermost grid containing the station.

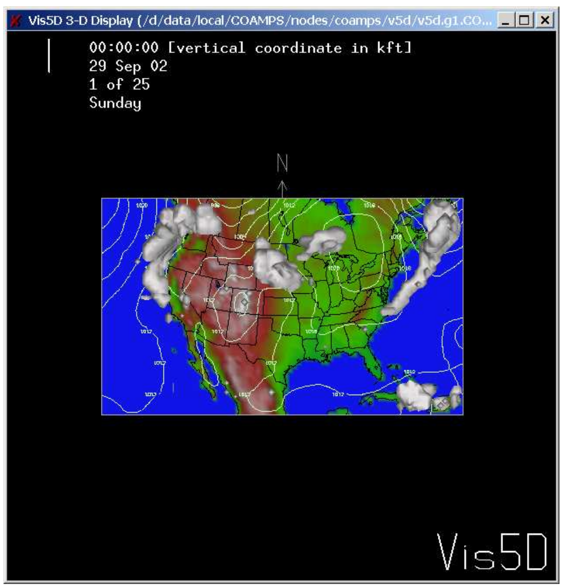

FIG 13. The Vis5D graphics window shows a COAMPS analysis of cloud water and sea level pressure valid at 0000Z, 29 September 2002. Isosurfaces of cloud water are shown in white for a 0.01 g kg-1 surface. Contours of sea level pressure are shown in white and labeled in millibars.

6. MONITOR CAPABILITIES

As described in the previous sections, COAMPS-OS includes components to initialize and run COAMPS, manage input and output data to/from COAMPS, and create graphical forecast products. COAMPS-OS also includes a web-based resource called the Remote Monitor to monitor the activity of each component in COAMPS-OS and report the status of each application. Additional capabilities of the Remote Monitor include producing plots of model forecast time as a function of real-time and archiving a history of COAMPS runs. An example of the Remote Monitor main page is shown in Figure 14.

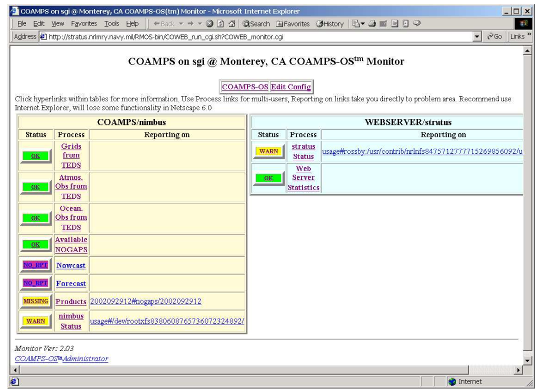

FIG 14. The COAMPS-OS Remote Monitor displays the status of each COAMPS-OS component including the COAMPS analysis/forecast status, the data retrieval status, and the status of the graphical products. A link may be selected for more detailed information about a status report.

7. FLEET BATTLE EXPERIMENT JULIET (FBE-J)

COAMPS-OS was delivered to the Naval Pacific Meteorology and Oceanography Center (NPMOC-SD) in San Diego, California, in June 2002 to support the Fleet Battle Experiment Juliet (FBE-J). The following public affairs release statement from NPMOC-SD describes the center's role and responsibilities in FBE-J:

"Congress directed the military in 2001 to conduct an experiment to explore critical warfighting challenges at the operational level of war that may confront U.S. military forces in the future. The Naval Pacific Meteorology and Oceanography Center (NPMOC) San Diego responded to the call by providing METOC support to the more than 13,500 personnel from all of the military services engaged in Millennium Challenge 2002 from July 24 to August 15, 2002.

Millennium Challenge combined live field forces and computer simulations at 26 locations across the country in one of the largest, most complex military experiments in history. The exercise was meant to transform a future fighting force to meet the threats of the 21st century. Concurrently, over 4,000 Sailors nation-wide were involved in the Navy's contribution to the joint experiment called Fleet Battle Experiment Juliet (FBE-J). FBE-J's goal was to refine the Navy's operations planning processes, improve ship-based command and control, and enhance integration between intelligence and operational information networks. FBE-J also tested new methods of mine warfare, anti-surface and submarine warfare, and theater air- and missile-defense in addition to integrating time-critical targeting efforts.

Navy METOC was represented at the operational and tactical level during MC-02 by NPMOC San Diego. The Joint Task Force Commander's west coast forecasting reachback center was lead by LT Brady Brown from Mobile Environmental Team (MET) San Diego. The eastern oparea distributed reachback center was located at Davis-Monthan AFB in Tucson, AZ under LCDR (sel.) John Simms from MET NLMOC. The Joint Forces Maritime Component Commander (JFMCC) METOC Staff Officer was LCDR A. J. Reiss aboard USS CORONADO. Also supporting operations were LCDR John Dumas, USS BOXER OA Division Officer, and ENS James Spriggs at Mission Support Center, CNSWG ONE.

MC-02 executions involving METOC predictions included the entire spectrum of warfare, from airstrikes, mine countermeasures, amphibious assaults, urban and littoral combat, sea control, and special operations. Five live-fire ranges required detailed forecasts, from the deserts of Nevada, Camp Pendleton on the California coast, San Clemente Island offshore, and the SOCAL submarine ranges to the west. Fourteen daily Joint Oparea Forecasts (JOAF) were produced as well as over two hundred specialized tactical decision aids including AREPS, HPAC, GFMPL, and SLAP. Also tested during MC-02 was a prototype Geospatially Enabled METOC (GEM). This product displays multiple thresholded weather fields selected to meet individual warfighter's needs on a geographic information system (GIS) over projected satellite imagery. Key to inception of this concept are CDR Eric Westreich and AGCS (SW) Robert Duckstad from NPMOC San Diego, under Commanding Officer CAPT Ray Toll.

Preparations have already begun for Fleet Battle Experiment KILO, which will be held in early 2003. METOC Support for FBE-K is being planned by LCDR John Whelan of NPMOC Yokosuka, to include updated GEM tools. More information on MC-02 and FBE-J is available at: http://www.jfcom.mil/about/experiments/mc02.htm and http://www.nwdc.navy.mil/Conference/FBEJ/."

The Mobile Environmental Team (MET) leader at NPMOC-SD indicated that COAMPS-OS was used to forecast electomagnetic (EM) and electrooptical (EO) propagation path conditions off the southern California coast. Although the COAMPS forecasts were not rigorously validated due to the time constraints imposed by the exercise, the MET leader felt COAMPS significantly improved the EM and EO propagation predictions over those traditionally produced using a single upper air observation. The forecaster attributed the improvement to the model's ability to accurately represent the variability of surface characteristics along the southern California coast. Future versions of COAMPS-OS will include an automated component to graphically represent model errors in the forecast fields to help improve the operational forecaster's ability to rate the skill of the model.

8. REFERENCES

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9. ACKNOWLEDGEMENTS

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