3.1 OPERATIONAL MODELS AND PERFORMANCE EVALUATION AT FLEET NUMERICAL

Mary Alice Rennick*, Carey Dickerman, Jeffrey Lerner, and Mark Swenson
Fleet Numerical Meteorology and Oceanography Center
Monterey, CA 93943

1. BACKGROUND

The Fleet Numerical Meteorology and Oceanography Center (FNMOC) is the Navy's primary operational production center for numerical weather prediction. Modeling operations include the decoding and quality control of millions of satellite and conventional observations of the atmosphere and ocean, and their assimilation into a comprehensive suite of meteorological and oceanographic analysis and forecast systems. Model output is used directly by Navy, Air Force, and National Weather Service (NWS) forecasters, and as input to a myriad of specialized applications and decision aids.

Users of FNMOC model products range from highly trained meteorological and oceanographic professionals to applications experts with limited knowledge of the systems on which the products are based. To make the products more meaningful and useful to this diverse group of users, an ongoing effort is underway to provide a comprehensive system for evaluating the validity and reliability of the analyses and forecasts. Fundamental goals of the evaluation system are to provide baseline performance levels against which new products can be judged, and to provide forecasters with reliable information regarding expected model performance in distinct geographical and synoptic regimes. Special attention is paid to sensible phenomena that directly impact Naval operations, such as high winds and seas, and conditions in the marine boundary layer.

2. OPERATIONAL MODELS SUITE

A broad spectrum of interdependent meteorological and oceanographic (METOC) models comprises the operational system at FNMOC. The heart of the models suite is the Navy Operational Global Atmospheric Prediction System (NOGAPS). This is a global data assimilation and forecast system developed at the Naval Research Laboratory's Marine Meteorology Division (NRL-MRY), co-located with Fleet Numerical in Monterey. NOGAPS output products provide direct guidance to end users, as well as surface forcing, lateral boundary conditions, and input for other models and applications. The only system that operates independently of NOGAPS is the Optimum Thermal Interpolation System (OTIS), which generates analyses of the ocean thermal structure and sea ice. Plans call for OTIS to be replaced by an ocean data assimilation and forecast system coupled to NOGAPS. Once this is implemented, all Fleet Numerical METOC models will be linked through their dependence on NOGAPS.

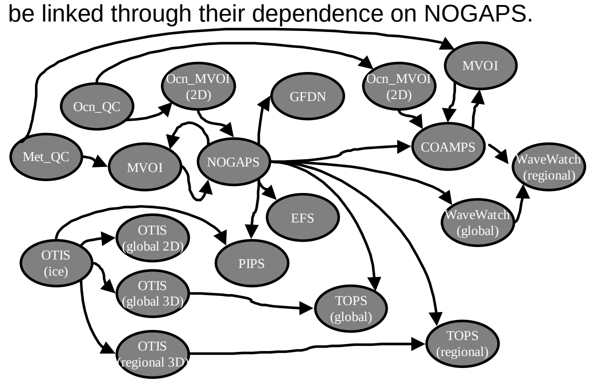

Figure 1. Operational analysis and forecast models. Arrows indicate the flow of information from one system to another.

The relationships among the various analysis and forecast models are shown in Fig. 1. The central role of NOGAPS is evident. Current meteorological observations are decoded and processed by quality control (QC) software, and combined with background fields from a short-range (6-h) NOGAPS forecast using the Multi-Variate Optimum Interpolation (MVOI) data assimilation system to provide initial conditions for the 6 day global atmospheric forecast. Sea surface (including ice) conditions are obtained from a preliminary version of the future ocean data assimilation system (Ocn_MVOI), and held fixed through the duration of the forecast. The Ensemble Forecast System (EFS) is based on multiple instances of NOGAPS running at somewhat lower resolution and using perturbed initial conditions. Other global forecast systems are an ocean wave model, WaveWatch 3, developed at the National Centers for Environmental Prediction (NCEP), and an ocean mixed layer model, the Thermal Ocean Prediction System (TOPS). Both of these models depend on surface wind and (in the case of TOPS) thermal forcing from NOGAPS. Regional models of the atmosphere and ocean include COAMPS™#, a mesoscale forecast system developed by NRL-MRY; a version of the Geophysical Fluid Dynamics Laboratory hurricane prediction system (GFDN); the Polar Ice Prediction

* *Corresponding author address:* Mary Alice Rennick, FNMOC, 7 Grace Hopper Ave. Stop 1, Monterey, CA, 93942; e-mail: MaryAlice.Rennick@fnmoc.navy.mil.

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System (PIPS); and regional implementations of OTIS, TOPS, and WaveWatch 3. COAMPS™ maintains its own data assimilation cycle, using the same QC processes as NOGAPS, and retrieves lateral boundary conditions at three hour intervals from NOGAPS forecasts. GFDN derives its initial and lateral boundary conditions from NOGAPS fields. PIPS and regional TOPS rely on surface forcing fields from NOGAPS, while regional WaveWatch is forced by COAMPS™ winds and lateral boundary conditions from global WaveWatch. PIPS is initialized from the ice OTIS analysis of SSM/I observations. Regional and global OTIS depend mainly on ice OTIS and ocean thermal observations.

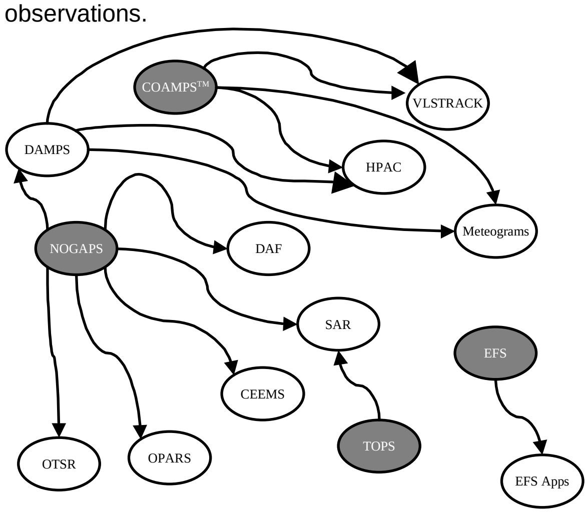

Figure 2. Major applications that rely on operational METOC model input. Arrows show dependencies on forecast models.

Navy and other forecasters use the output fields from these analysis and forecast systems as guidance tools. In addition, a number of applications and decision aids use them as input from which to generate specialized forecasts to meet user-specific needs. Some of the more important applications, and their dependencies on the primary analysis and forecast systems, are depicted in Fig. 2. Some of these applications are run routinely at FNMOC. Others are run on demand, either at FNMOC or by users, such as the Navy's regional forecast centers. Where appropriate, web-based interfaces are under construction to make the applications available as Web services. Traditionally, most of the applications have been based on NOGAPS output. These include Derived Atmospheric Fields (DAF), which computes such things as the probability of clear air turbulence, contrail formation, and ground fog; Optimal Aircraft Routing System (OPARS) and Optimal Track Ship Routing (OTSR), which optimize aircraft and ship routes for fuel conservation; Contributions of Environmental Effects on Missile Systems (CEEMS), which provides support for missile targeting; and various tropical cyclone forecast aids. The Search and Rescue (SAR) system uses winds from NOGAPS or COAMPS™ and ocean conditions from global or regional TOPS as appropriate to support ocean rescue operations. Several applications generate probabilistic forecasts based on the EFS. Among the more popular products are probabilities of precipitation, gale winds, and Shamals; and time series showing the expected range of individual parameters at fixed locations. Recently, several applications have been implemented to utilize COAMPS™ output. These include meteograms, and dispersion models, such as the Hazard Prediction Assessment Capability (HPAC) and Vapor-Liquid-Solid Track (VLSTRACK). Finally, FNMOC and the Regional Centers have the capability to run the Distributed Atmospheric Mesoscale Prediction System (DAMPS), which is a hardware/software combination that provides a self contained COAMPS™ capability using NOGAPS fields as lateral boundary conditions.

3. PRODUCT VERIFICATION PROCEDURES

Fundamental meteorological forecast fields are routinely verified using traditional methods. That is, NOGAPS and COAMPS™ forecast fields of heights, winds, and temperatures at standard isobaric levels are interpolated to rawinsonde locations and compared to verifying observations. Bias, standard deviation, and root-mean-square errors are computed at 12 hour forecast intervals. For NOGAPS, similar statistics, as well as height and sea level pressure anomaly correlations are computed versus verifying analyses. COAMPS™ surface forecasts are also compared to verifying surface land and ship observations. All verification statistics are stored in a database, from which they can be retrieved and analyzed in various ways. Summaries are posted regularly in the Monthly Summaries section of the FNMOC web site (http://www.fnmoc.navy.mil/PUBLIC/MODEL_REPORTS/MONTHLY_MODEL_SUMMARY/). These traditional verification statistics are useful for documenting the overall performance of the models, but more specialized verifications are needed to assess the usefulness and reliability of applied products.

FNMOC is addressing these needs through qualitative and quantitative procedures. A group of military and civilian meteorologists from FNMOC and NRL-MRY meets daily to review the performance of COAMPS™ in regions of significant weather and/or of particular relevance to Naval operations. They compare analysis and forecast fields to all available *in situ* and remotely sensed verification data. Their emphasis is on feature verification, rather than point by point comparisons with observations. Their work is documented in case studies and compilations of generalized model tendencies, as well as through direct communications with Fleet users. More information on the work inspired by the verification group may be found in papers by Dickerman and Nachamkin, elsewhere in these proceedings.

More quantitative information related to the accuracy of specific quantities is also available. Because high winds and seas are of particular concern to ships at sea, WaveWatch 3 wave heights are routinely compared to wave heights derived from ERS-2 altimetry data. The EFS gale wind probabilities have been the subject of ongoing verification studies based on SSM/I and scatterometer wind measurements. Modifications to the gale wind calculation suggested by these studies have resulted in a reduction in the statistical false alarm rate. Tropical cyclone track and intensity forecasts from NOGAPS, COAMPS™, and GFDN are carefully scrutinized using a variety of metrics. Lerner and Strahl detail these in a paper elsewhere in these proceedings. TOPS currents are used to simulate the tracks of drifting buoys to provide a measure of confidence in SAR support.

4. SUMMARY AND OUTLOOK

Fleet Numerical operates a highly integrated suite of global and regional METOC models to support the military and other customers throughout the world. The exact description of that suite is continually evolving, but always centered on the global atmospheric model, NOGAPS. Anticipated fundamental changes in the system during the next year include the replacement of the atmospheric MVOI data assimilation system in NOGAPS and COAMPS™ with a variational system known as the Navy Atmospheric Variational Data Assimilation System (NAVDAS). The incremental implementation of the MVOI-based ocean data assimilation system will include an ocean prediction system to provide continuity from one analysis time to the next, and ultimately, full coupling with NOGAPS.

More applications-specific additions will be boundary layer ducting parameters and dust/aerosol products based on COAMPS™. These are currently undergoing final tests and evaluation before being released to customers. Several new Web interfaces are under development to allow users to tailor products to their specific needs. Among these are meteograms, forecast soundings, ensemble plumes, and weather forecasts along a user-specified track.

The verification challenges posed by the new data assimilation systems, more tightly integrated air-ocean systems, and specialized applications products are substantial. FNMOC is meeting them with a combination of traditional statistical verification techniques, expert subjective verification, and the transfer of subjective experience to automated and semi-automated systems.