FNMOC 2001: The New System Architecture

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The Fleet Numerical Meteorology and Oceanography Center (FNMOC) has selected a vendor and determined the new system architecture to allow it to provide improved and more timely atmospheric and oceanographic analyses and predictions well into the next decade. The new architecture is described and specifics of the upgrade discussed.

I. Introduction

Fleet Numerical Meteorology and Oceanography Center is the principal United States Department of Defense (DoD) operational meteorological and oceanographic (METOC) analysis and prediction center. It is one of a half-dozen internationally recognized operational centers for both global and regional atmospheric models, and is widely acclaimed in performing operational global meteorological, oceanographic, and coupled air-ocean modeling. These models assimilate global atmospheric and oceanographic observations several times daily into global and regional METOC models that treat the coupled air-ocean environment as an integrated system, producing forecasts out to a week and beyond. These products are then distributed to regional centers for further dissemination, and are also available to DoD activities worldwide through direct access via dial-up systems and internet technology.

Customers for Fleet Numerical products are primarily Navy and Marine Corps forecast sites including deployed units and ships, but also encompass forecast activities worldwide from all services. Other customers include a variety of Joint Operating Forces, command and control and other DoD activities, a whole spectrum of other U.S. federal agencies, allied forces and the general public.

II. Existing Computer System

The Primary Oceanographic Prediction System (POPS) resulted from Navy requirements for a new suite of computer models to provide operational forces with environmental information affecting a new generation of deployed platforms, weapons, and sensor systems. In 1990 the POPS1 supercomputer system was installed at the Naval Oceanographic Office at Stennis Space Center, MS, and in 1991 POPS2 installation began at Fleet Numerical for real-time operations and forecasting. In 1995, the POPS1 program became a Major Shared Resource Center (MSRC) under the DoD High Performance Computing Modernization Program, leaving the POPS2 system at Fleet Numerical the only remaining portion of the POPS program.

The POPS2 system arrived in phases at Fleet Numerical, beginning with a Cray Y-MP 2E/232 which operated the relational data base management system. With the installation of the Cray Y-MP C90-8/256 in 1992, Fleet Numerical received the computational and automation capability to run large oceanographic and atmospheric models. A second Cray Y-MP C90-8/512 arrived in August 1998, and the first C90 has subsequently been upgraded to a C90-16/512. In 1997 the existing Cray YMP-2E was

replaced by two Cray J90SEs running the UNICOS multi-level security (MLS) operating system, which form the present data management configuration.

Pre-processing and post-processing of data associated with the model runs occur on the Oceanographic and Atmospheric Support and Information System (OASIS), which consists of a suite of powerful Sun workstations. The OASIS system in turn is connected to the Distributed Processing System (DPS) to ingest the incoming data and distribute the outgoing products to the customers. In 1997 and 1998 OASIS and DPS were merged into the POPS program, to form a single operational information system at Fleet Numerical.

Figure 1 shows the existing (1999) hardware configuration, with preliminary connections to the upgrade equipment.

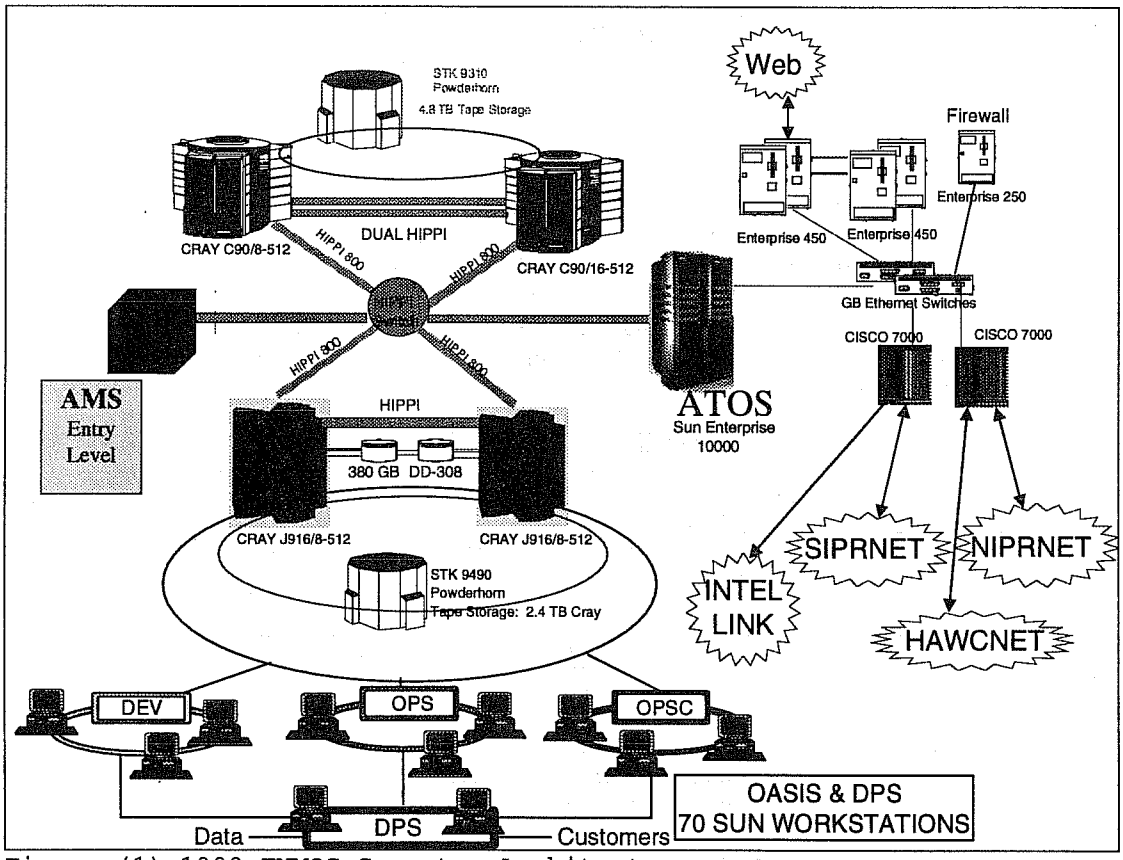

Figure (1) 1999 FNMOC Computer Architecture.

III. Products

Using the POPS2 system, Fleet Numerical runs a suite of numerical models to increase the safety and effectiveness of DoD operations. The flagship global atmospheric model generates output fields used directly for forecasting and also provides boundary conditions or parameters to feed all of the other models at FNMOC. It is also the only global meteorological model operated by DoD. A brief description of FNMOC modeling capabilities follows.

The Navy Operation Global Atmospheric Prediction System (NOGAPS) is a global spectral atmospheric model running twice daily at 159 spectral wave horizontal resolution with 24 vertical levels (Hogan and Rosmond, 1991). NOGAPS fields drive the Global Wave Model (WAM; WAMDI Group, 1988), Thermal Ocean Prediction System (TOPS; Clancy and Pollak, 1983) for ocean mixed-layer currents, and Polar Ice Prediction System (PIPS; Cheng and Preller, 1992). A lower resolution, 79 spectral wave version of NOGAPS runs as a ten-member ensemble. Details are given in Table 1.

Analysis	Atmospheric	Multivariate Optimum Interpolation Analysis, .75°, 4 valid times daily, 6-h update cycle
	Oceanographic	Thermal Optimum Interpolation Analysis, .25°, once daily
	Ice	Optimum Interpolation SSM/I Analysis, .25°, twice daily
Forecast	Atmospheric	0-144 h, 159 spectral waves, 24 levels, twice daily Ten member, 10 day ensemble, once daily
	Oceanographic	wave model, 1°, twice daily thermal structure, 1°, daily surface currents,
	Ice	25 km coupled ocean & ice, daily

Table 1. 1999 Global Analysis and Forecast Capabilities

The NOGAPS fields also provide horizontal boundary conditions for the regional, relocatable Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS; Hodur 1997). Each COAMPS area includes a regional ocean thermal analysis and a regional wave model forced by the COAMPS winds. Additionally, the Geophysical Fluid Dynamics Navy (GFDN) model provides moving regions nested within NOGAPS for tropical cyclone forecasting (Rennick, 1999). Regional forecasting capabilities are detailed in Table 2.

Analysis	Atmospheric	Multivariate Optimum Interpolation Analysis, 81/27/(9) km, 2 or 4 valid times daily, 12 or 6-h update cycle
	Oceanographic	Optimum Interpolation SST, Sea Ice, 81/27(/9) km, 12 or 24-h update cycle
Forecast	Atmospheric	0-48/48(/24) h, 4 areas, 81/27(/9) km, 30 levels, 2 or 4 times daily
		0-84 h tropical cyclone model, 1:1/3:1/6°, up to 3 storms, twice daily
	Oceanographic	wave model, 4 areas, 25 km, twice daily

Table 2. 1999 Relocatable Analysis and Forecast Capabilities

These regional models have been so enthusiastically received that resources to run more regions are extremely limited; demand has grown to meet and exceed the capacity of the present dual-Cray system.

IV. POPS2-Upgrade (POPS2-U)

With the POPS2 system in the 7th year of its 8-year life cycle, an upgrade is under way that will occur incrementally through 2001. POPS2-U will provide capabilities for an end-to-end, enterprise-wide information system for the receipt and processing of global and regional meteorological and oceanographic data, and the production and delivery of digital data and products to DoD users and other government agencies. The POPS2-U System encompasses the entire FNMOC enterprise and will replace what was previously three information systems: POPS2, OASIS, and DPS. POPS2-U is comprised of the Applications, Transactions, and Observations Subsystem (ATOS) and the Analysis and

Modeling Subsystem (AMS). Figure (2) shows the final hardware configuration for the POPS2-U.

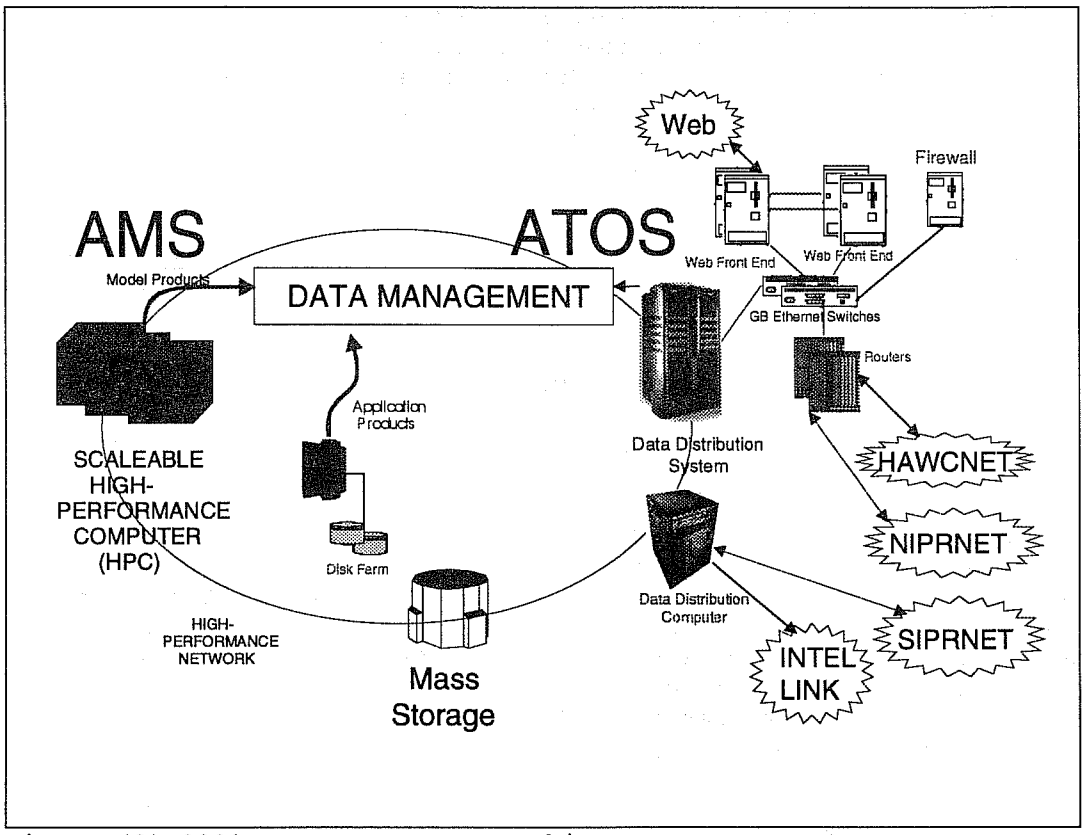

Figure (2) 2001 FNMOC Computer Architecture.

Applications, Transactions, and Observations Subsystem (ATOS).

ATOS will handle the Data Management, Data Preparation, Product Distribution, Data Ingest, and Product Viewing functions, as well as all of the communications from the modeling computers to the customers.

The initial ATOS system consists of a SUN Enterprise 10000 (E10K) installed in October 1998, with 16 CPUs with 1 GB memory per CPU and 500 GB fully mirrored hard disk drive, for a total capacity of 250 GB. There is an additional domain consisting of 8 CPUs with 1 GB memory per CPU, and 128 GB of disk space for satisfying other communications functions as required. The E10K is expected to grow until it is capable of providing the full capability to maintain ATOS operations, which may be a system with the full complement of 64 processors and 64 gigabytes of memory.

Two Sun Enterprise 3500s (E3500s) will link ATOS to the outside world as firewall and web server. The two systems will be set up so that each can take over the functions of the other in the event of a failure.

ATOS will host the functions currently performed by OASIS, DPS, and various other applications machines at Fleet Numerical. These functions include the data preparation functions consisting of the data

decoders and data quality control software, which will prepare observations from varied sources for ingestion into the numerical models. Additionally, satellite data, comprising atmospheric and oceanographic observations as well as ice data, will be processed on ATOS, with additional workstations to handle real-time ingest and interactive request processing. The processed data will be written into the upgraded database management software, ISIS2000, which will be discussed in more detail in another paper. ISIS2000 will maintain consistency of databases between the ATOS and AMS platforms, for model ingestion and field output.

The output fields received on ATOS will then be available for various product creation and viewing applications, and for the communications system to distribute to customers.

Analysis and Modeling Subsystem (AMS).

AMS is the high-performance part of the POPS2-U system, on which the numerical models will run.

Just as with the original POPS2 system, the AMS portion of POPS2-U will arrive in a phased installation. Phase I, consisting of a Silicon Graphics Origin 2000 (SN0), was installed in October of 1999. The Origin 2000 is a scalable 128-processor system that uses distributed shared memory (DSM) with cache coherence. The system has 1 GB memory per CPU and 3.7 TB of RAID disk storage. It will function as a code migration platform preparatory to Phase II, which will be installed incrementally through early 2001.

Phase II will be a next generation Silicon Graphics high-performance platform, referred to as the SN1, with at least 512 processors for unclassified operations and at least 32 processors to handle data mixing and analysis for classified operations. The final configuration of processors and memory will be under review as installation and model transition progresses.

Benchmarking tests show that the final unclassified system will meet 33 times the original C90 computational power, and exceed by 10 times today's dual C90 configuration. The speed is projected at 100 Gflops (sustained) on NOGAPS, which corresponds to one minute of wall-clock time per forecast day, down from 16 minutes per forecast day on the present system.

AMS will host the high-performance models for meteorological and oceanographic forecasting, beginning with atmospheric and oceanographic data assimilation, NOGAPS, COAMPS regions, a new wave model for both global and regional areas, and a full-physics oceanographic model to forecast oceanographic temperature, salinity from the surface to the bottom. ISIS2000 will be resident on AMS to supply and receive numerical fields for the high-performance models, and provide those fields to ATOS.

The Navy Atmospheric Variational Data Assimilation System (NAVDAS) will analyze atmospheric fields using 3D variational techniques, and will provide a flexible atmospheric data assimilation platform for use with both NOGAPS and COAMPS. It will replace the existing optimal-

interpolation components of both NOGAPS and COAMPS, and will incorporate new data types as they become available.

With the more powerful computing capabilities on the new machine, NOGAPS will be able to receive enhancements. Higher horizontal and vertical resolutions will make possible more accurate forecasts valid to longer periods. Additionally, improvements to model parameterizations and numerical techniques will increase accuracy. Going to higher resolution in NOGAPS will permit higher resolutions for regional COAMPS areas as well.

Oceanographic modeling will realize improvements on the new architecture as well. Fleet Numerical will be transitioning from WAM to Wave Watch III (Tolman, 1998) to provide the global and regional forecasts of ocean wave parameters, due to its better depiction of both peak events and nulls. Additionally, ocean physics modeling will transition from the current OTIS analysis to an ocean multi-variate optimal interpolation system, that will provide 3D temperature and salinity fields capable of initializing a full-physics oceanographic model. Tables 3 and 4 summarize projected capabilities on the new architecture.

Analysis	Atmospheric	3 - D Variational Data Assimilation
	Oceanographic	3-D Multivariate Optimum Interpolation Analysis (T, s, u, v)
	Ice	
Forecast	Atmospheric	0-168 hours, 319 spectral waves, 50 levels, twice daily 24 member, 14 day ensemble, once daily
	Oceanographic	12 km ocean circulation/thermal model, once daily wave model, 50 km, twice daily
	Ice	25 km ocean & ice, once daily

Table 3. 2002 Global Capabilities

Analysis	Atmospheric	3 - D Variational Data Assimilation
	Oceanographic	3-D Multivariate Optimum Interpolation Analysis (T, s, u, v)
Forecast	Atmospheric	0 - 48 h, 8 areas, 54/18/6 km, 50 levels, 2 or 4 times daily
		tropical cyclone model, up to 4 storms, twice daily
		0 - 48 h boundary layer model, 10 areas
	Oceanographic	wave model, ocean circulation/thermal model, 8 areas, 18 km, twice daily

Table 4. 2002 Relocatable Capabilities

V. Summary

The POPS2-U project at Fleet Numerical represents a badly-needed upgrade to a capable but dated system. The added capability will permit an increase in model resolution and improvements in model physics, which have long been held in abeyance due to resource limitations. This upgrade will position Fleet Numerical to provide higher resolution products, with forecasts available for longer duration, and communicated to more customers.

VI. Acknowledgments

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