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Smart Climatology System

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14. ABSTRACT

Climatology traditionally obtained by mission planners consists of primarily basic statistics derived from a long-term mean of a data set of station observations or large-scale numerical weather prediction (NWP) analyses. These statistics (e.g., long-term means, max./min. value, and standard deviation) are static in nature; once computed they do not change. These statistics are useful; however, they flatten out the climate anomalies and are unable to represent a range of climatic conditions of a local area. It is desirable that the climate statistics used by mission planners reflect the climate anomalies, recent trends, mesoscale characteristics (high resolution), and up-to-date information. We recommend that we fulfill these mission planner needs by generating on-demand mesoscale/regional climate statistics for any given area and for a specific time period. This project has successfully demonstrated how these mission planning needs can be fulfilled by using the NWP downscaling technique. It is estimated that the on-demand climatology can be generated in one to two months depending on the specific needs and coverage of the domain and time.

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Executive Summary

Simply put, Smart Climatology is Conditional Climatology.

Climatology traditionally obtained by mission planners and decision makers consists of primarily basic statistics derived from a long term mean (usually 30 years) of a data set of station observations or large-scale/coarse resolution numerical weather prediction analyses. These statistics (e.g. long term means, minimum value, maximum value, and standard deviation) are static in nature, once computed they do not change. These statistics are useful; however, they flatten out the climate anomalies such as El Niño/La Niña and are unable to represent a range of climatic conditions) of a local area. It is desirable that the climate statistics used by mission planners reflect the climate anomalies, recent trends, mesoscale characteristics (high resolution), and up-to-date information. This RTP project recommends that we fulfill these mission planner needs by generating on-demand mesoscale/regional climate statistics for any given area and for a specific time period (e.g. Horn of Africa, Spring Season).

This project has successfully demonstrated how these mission planning needs can be fulfilled by using the NWP downscaling technique. Operational coupled mesoscale models with initial and boundary conditions coming from a large-scale reanalysis data set can be employed to generate on demand mesoscale climate statistics for any given area. These mesoscale climate statistics are based on the most current and state-of-the-art numerical atmospheric/ocean model runs for “selected” time periods; and will take only about one to two months (wall time) for the statistics generation and compilation. An important feature is that the selected time period does not have to be continuous, for example, ten most recent El Niño Springs. We also recommend that the high resolution data set to be generated on demand by the current operational mesoscale prediction systems for the reasons that the climate changes; the climate anomaly changes; the numerical model improves; and the data assimilation system improves with time. For example, by FY-12, it is anticipated that the 2-way coupled atmosphere/ocean/wave mesoscale prediction system will be in operations. A previously generated climatology data set sitting on the shelf for any length of time will not be state-of-the-art results when used. It is better to generate the Smart Climatology data set when the needs arise.

We recommend that the Smart Climatology System CONOPS include a “climate Subject Matter Expert (SME) - climatologist” in the loop. FNMOD is perfectly suited to fill this position. FNMOD will be the point of contact or interface to the user community (e.g. decision makers, mission planners). Climatologists can analyze and monitor the production of the Smart Climatology System, and updates climate statistics. It is logical and natural for FNMOD to interpret the user request, order the smart climatology data sets and products, and deliver the products to the requesters with interpretation of the products, contextual information and limitations associated with the products. Automation can be achieved from the point of data ordering to the final product generation. This ‘FNMOD in the loop’ recommendation does not alter any current CONOPS, however, it does ease the data ordering/collecting and product generation cycles.

To understand how the Smart Climatology information is used in decision making process, this project took a Decision Science approach to model the necessary steps for integrating the METOC information in the decision making process. Our current conclusion is that there is a deficiency in our understanding and knowledge of the magnitude of the consequence associated with a METOC event. For managing each risk in the decision making process, two pieces of information must be provided: 1) the “probability” of an event to occur (METOC event probability – within METOC capability) and 2) the “severity” of the damage if we failed to meet the threshold (or the alternatives – a new frontier for METOC community). By combining the probability of occurrence with severity, a matrix is created where intersecting rows and columns define a Risk Assessment Matrix which is the basis for judging both the acceptability of a risk and the management level at which the decision on acceptability will be made. Though it is very difficult to have complete and comprehensive knowledge of all consequences associated with all METOC events, we need to start the learning process by conducting systematic analysis of every climatological data request. We recommend that FNMOD establishes a systematic and sustained effort to collect the severity of the damage information by opportunities.

1 Introduction and Motivation for Smart Climatology On Demand

1.1 Background

Climate is the long-term manifestations of weather; it is commonly defined as the weather averaged over a long period of time. The standard averaging period is 30 years, but other periods may be used depending on the purpose. Climate also includes statistics other than the average, such as the magnitudes of day-to-day or year-to-year variations. The Intergovernmental Panel on Climate Change (IPCC) glossary definition is: “Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.”

The traditional concept of the climatology assumes that the climate is stable. The 30-year average of the weather conditions is assumed to represent the average climatic state of an area. The current thinking, however, is very different from that. Climate changes rather rapidly. It does not matter if it is global or regional climate, the climate will change. For example, Figure 1.1a illustrates the global temperature change, and Figure 1.1b illustrates the regional sea surface temperature change.

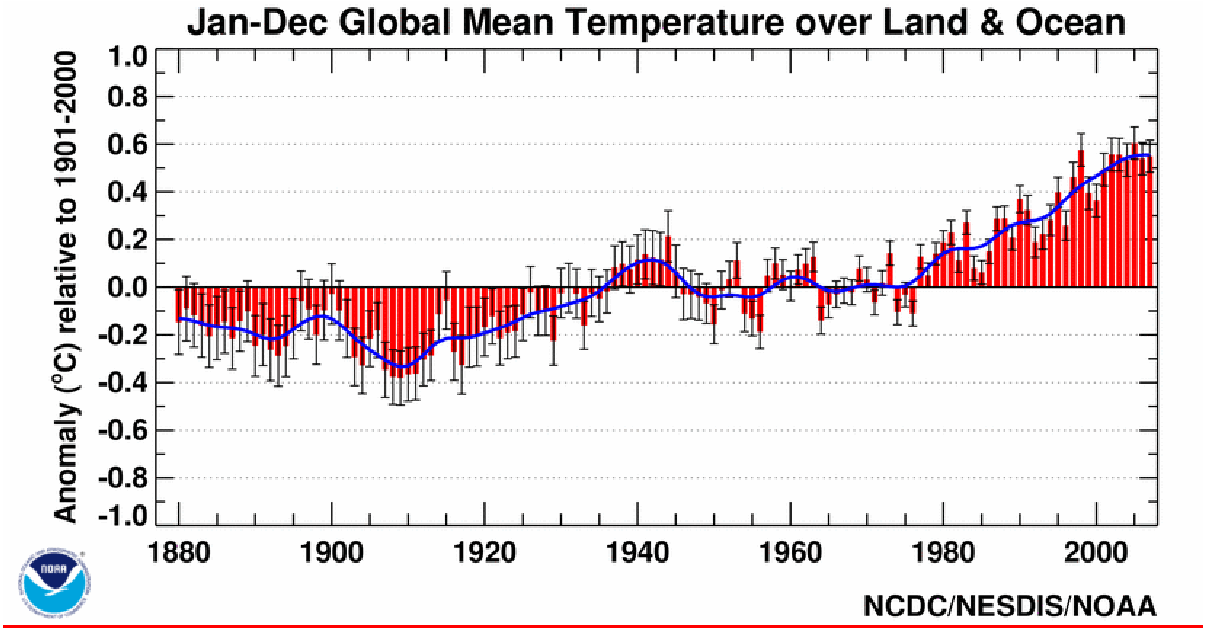

Figure 1.1a NOAA National Climatic Data Center’s Global temperature deviation plot based on the updated Global Land and Ocean data (Nov 2008).

Manuscript approved July 29, 2010.

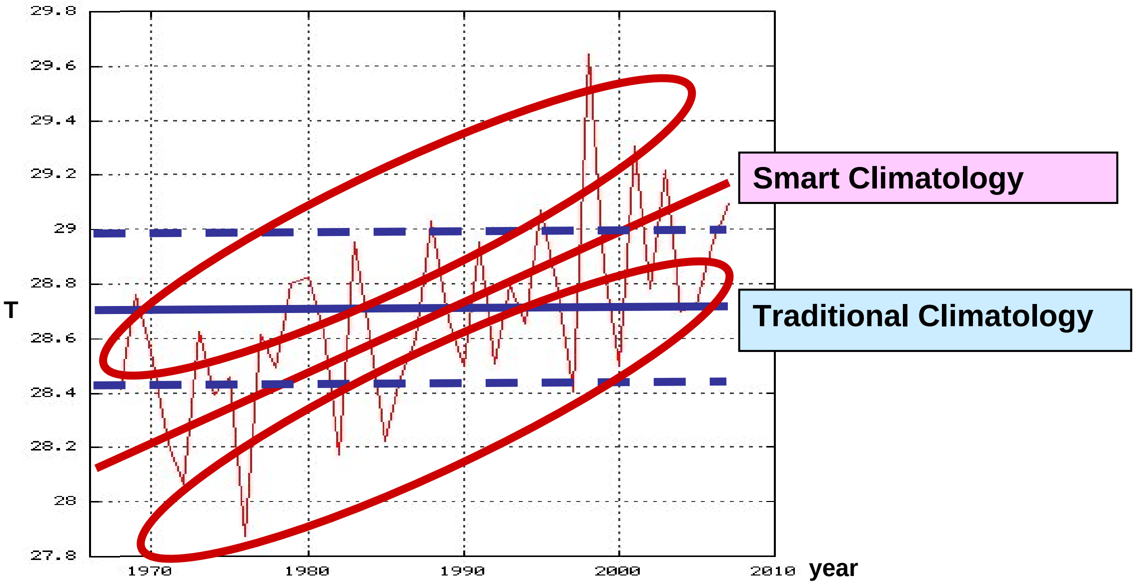

Figure 1.1 Long Term Fluctuations and Trends – Sea Surface Temperature (SST in ºC), East China Sea, Jul-Sep. Note the pronounced interannual variations and long term positive trend. (Courtesy of Professor Tom Murphree. Results from Naval Postgraduate School Smart Climatology Program: Advanced Climatology course project.)

Climate, like weather, is dynamic. The climatic state varies from time to time and from place to place. Climate has a significant affect on military operations, and mission planners must always take atmospheric and oceanic conditions into consideration in order to ensure a mission's optimal success. However, the current methodologies for producing, providing and/or obtaining climatology data are inadequate in several areas such as the resolution of the data provided, the statistical analysis provided, and the request/delivery mechanism for the data and analysis. This climatology on demand (Smart Climatology On Demand) project is intended to evaluate and demonstrate improvements to the current system for providing climatology data for Naval needs and investigate the key factors in implementing an automated, on-demand system for obtaining climatology data. The evaluation and demonstration was conducted in a defined area of the Taiwan Straits using test cases of ocean information and analysis to investigate the different approaches that can be taken to achieve the desired system improvements and their affect on operational planning.

Climatology traditionally obtained by mission planners consists primarily of basic statistics derived from low resolution data such as long term means (LTMs), minimum value, maximum value, and standard deviation at 1º to 2.5º spatial resolution. These statistics, however, flatten out the data and do not account for climate anomalies such as El Niño and La Niña and could skew climate forecasts. In addition, the large scale LTMs ignore the fine-scale weather/ocean features which are crucial information for the mission planners. It is evident that higher resolution is required for missions such as Special Operations (SPECOPS or NSW) or Mine Warfare (MIW) and in littoral regions such as littorals there is a lack of reanalysis data. By obtaining the fine-scale features, many mesoscale climatology "systems" have been established. They compile climatology statistics (long term means) from one area to the next. However, these systems are not flexible. They can not respond quickly for a given area in which potential conflicts may occur. Once the mesoscale climate statistics are compiled, they will never be updated. It would be very desirable to establish a mesoscale air/ocean climatology on demand system which can generate mesoscale climate statistics quickly for a given area. In order to accomplish this goal, an automated system is needed.

In addition to the traditional long term means, for effective application of climatological data, a spectrum of analyses of such data needs to be made available. Long term means are commonly available but other statistical measures may not be provided for all products. Some the measures that should be provided include among others:

- Max, min, mean, mode
- Anomaly values compared to long term mean
- Frequency of occurrence
- Mean temporal duration (e.g. wet vs. dry April)

There are a variety of difficulties to actually providing operational climatology. In general, actual observational data are limited or sparse for many geographical areas, particularly in the area of conflicts. As a consequence it is necessary to run models to produce data for missions in most areas of interest. However some models are not well suited to the locale, e.g., WAVEWATCH III may not provide an adequate answer for near shore wave analysis and it would be necessary to run other models to produce the needed high resolution data. Production of high resolution data can be costly and time consuming. Consider the CPU time/cost to produce 10 year high-resolution winds from Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®[1]). This data production required approximately 120 days of 16 CPUs running 24/7.

In considering possible approaches to smart climatology, an issue that arises is why should we generate high resolution datasets instead of just using archived data? Several factors are involved. First, prediction systems are upgraded constantly and a model that represented the state-of-the-art in 1987 is not the most advanced model in 2009. In addition, the operational model runs may have data cut off issues and will affect data assimilation and the quality of output. Comparisons between NCEP/NCAR 2.5 degree re-analyses and NOGAPS analyses showed regions with significant differences in relative humidity (850 mb) and air temperature (1000 mb). The overall approach we propose for developing Smart Climatology On Demand is shown in Figure 1.2.

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[1] COAMPS® and COAMPS-OS® are registered trademarks of the Naval Research Laboratory.

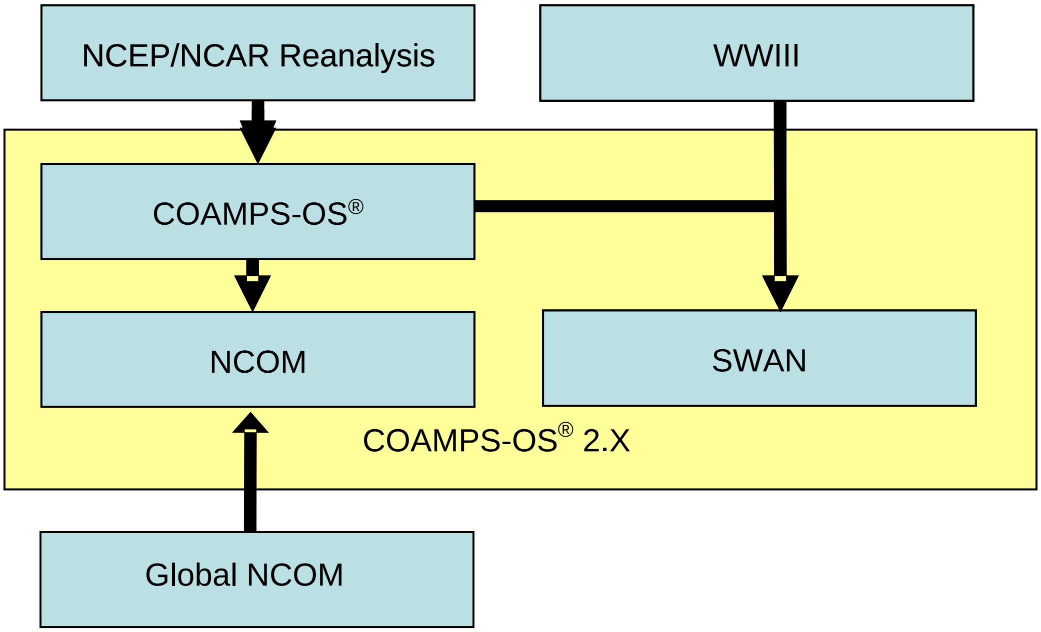


Figure 1.2 Approach for Smart Climatology On Demand

1.2 Climate Anomalies and Effects

Climate can be defined as a region's general weather patterns over time. Weather simply accounts for short term atmospheric conditions; whereas, climate creates a composite of all the variations in a region's weather patterns over a long period of time. Although a region's climate may commonly follow a certain trend, certain natural phenomena may influence it to deviate from the norm. The net effects of these climatic anomalies on military operations are the weather extremes. If the operational planning does not take these climatic extremes into account, the actual operations may encounter "surprises" of the weather conditions. For example, the wetness of the condition may exert a severe impact on trafficability. Frequency of the dust events may change the course of operations. In the concept of Smart Climatology on Demand, we recommend that Subject Matter Experts (SME's) should first examine the targeted region and season and determine what time period (or periods) should be included in the Smart Climatology for that particular case.

El Niño and La Niña are two thoroughly studied climate anomalies that commonly occur in the Pacific Ocean, but affect climate around the globe. El Niño can be defined as a periodic increase in sea surface temperatures (SST), and La Niña can be defined as a periodic decrease in SSTs. El Niño and La Niña periods are defined by the SSTs observed in the Niño 3.4 region, an area in the Pacific Ocean between 5°N and 5°S and 120° and 170°W. (See Figure 1.3)

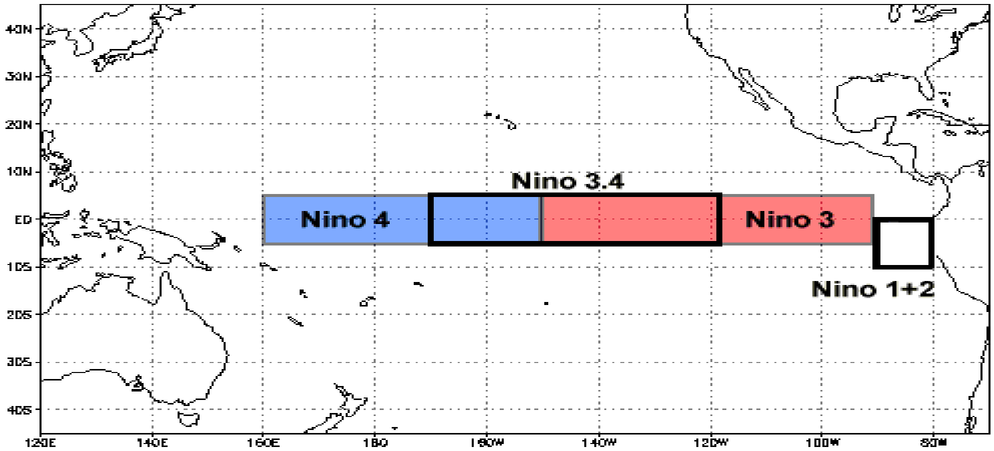


Figure 1.3 The Niño regions in the Pacific Ocean from [Niño 3.4]

According to the National Oceanic and Atmospheric Administration (NOAA), El Niño is present when observations in the Niño 3.4 region indicate at least a +0.5°C increase in the average SST for at least 5 consecutive months, and La Niña is present when observations in the Niño 3.4 region indicate at least a -0.5°C decrease in the average SST for at least 5 consecutive months.

Although NOAA can not distinctly forecast El Niño or La Niña, it maintains records on all of its historical data in hopes of finding a pattern. The Oceanic Niño Index (ONI) is the main source that is used to classify prior months as El Niño or La Niña and the strength of each event. This classification is based on the three-month running-mean SST's departure from average in the Niño 3.4 region. Figure 1.4 below illustrates the ONI and each month's average SST difference from the norm over a period of 57 years.

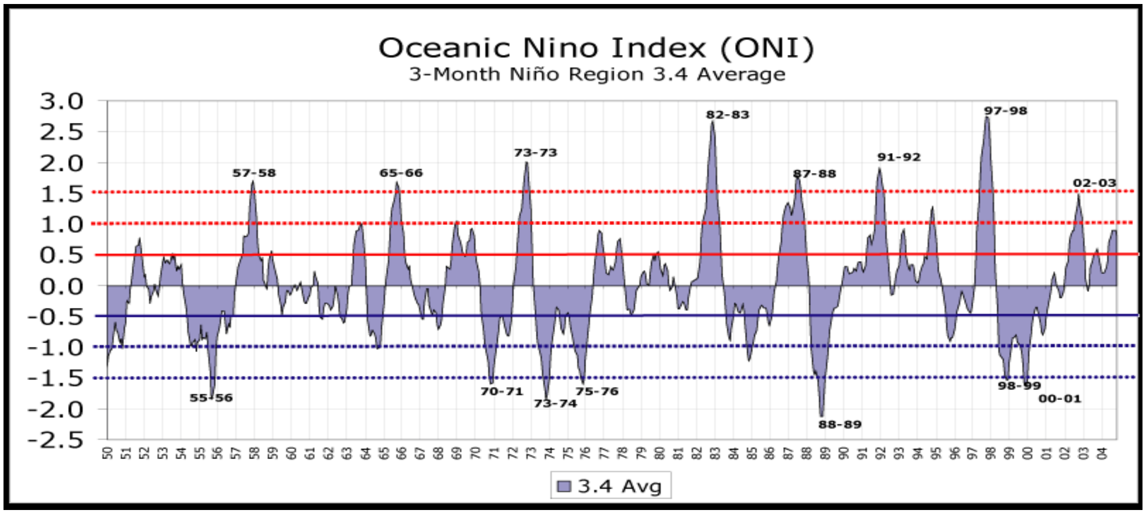


Figure 1.4. The ONI which is used to classify seasons as El Niño or La Niña.

The Multivariate ENSO (El Niño/Southern Oscillation) Index (Figure 1.5) is another source that catalogs historical El Niños and La Niñas. This calculation, however, is based on

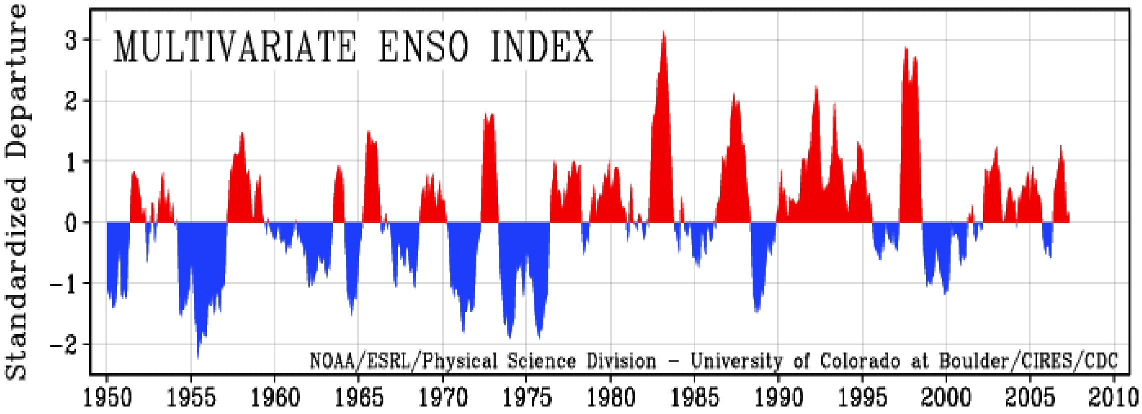


Figure 1.5 Multivariate ENSO Index which incorporates different variables to determine the strength of an El Niño or La Niña season from [ENSO 1]

six different variables observed in the tropical Pacific: sea-level pressure, zonal (U) and meridional (V) components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky. Both of these indices can be used to study previous occurrences of these phenomena and possibly predict future occurrences.

The effects of these phenomena are clearly illustrated in Figures 1.6-8 showing variation in significant wave heights using composite means. A composite mean of climate condition can be defined as a long term average that considers data only from identified climatic anomaly periods. Rather than using simple long term means, which disregard the extreme outliers and mesh the unlimited range of values into a single insignificant number, using composite means provides a long term mean that reflects a given phenomena such as El Niño. It is believed that composite means are more effective and produce more meaningful statistics. The graphics below demonstrate the need to examine the use of composite means for such common phenomena. Figure 1.6 is a graphic of a LTM of September’s significant wave height created from WAVEWATCH III data. All of the average heights in the Septembers from 1993 to 2002 are averaged together to produce the LTM of the region. The second graphic (Figure 1.7) demonstrates variation from the LTM during an El Niño period. The colors represent the amount of change from the norm. The third graphic (Figure 1.8) demonstrates variation from the LTM during a La Niña period. Once again, the colors indicate the degree of change from the LTM.

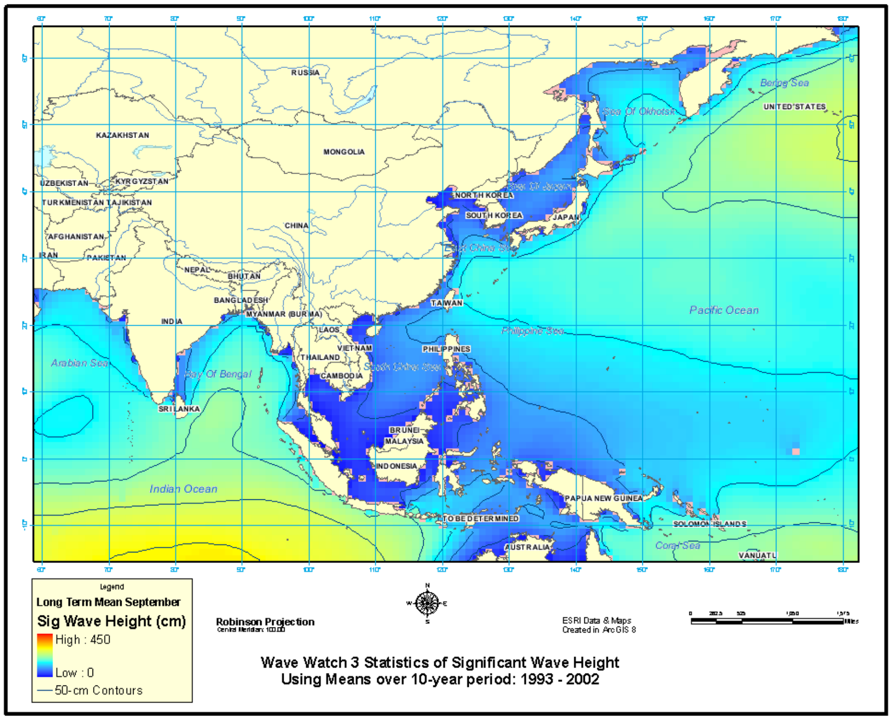


Figure 1.6: Long term mean (LTM) of significant wave height for September 1993-2002

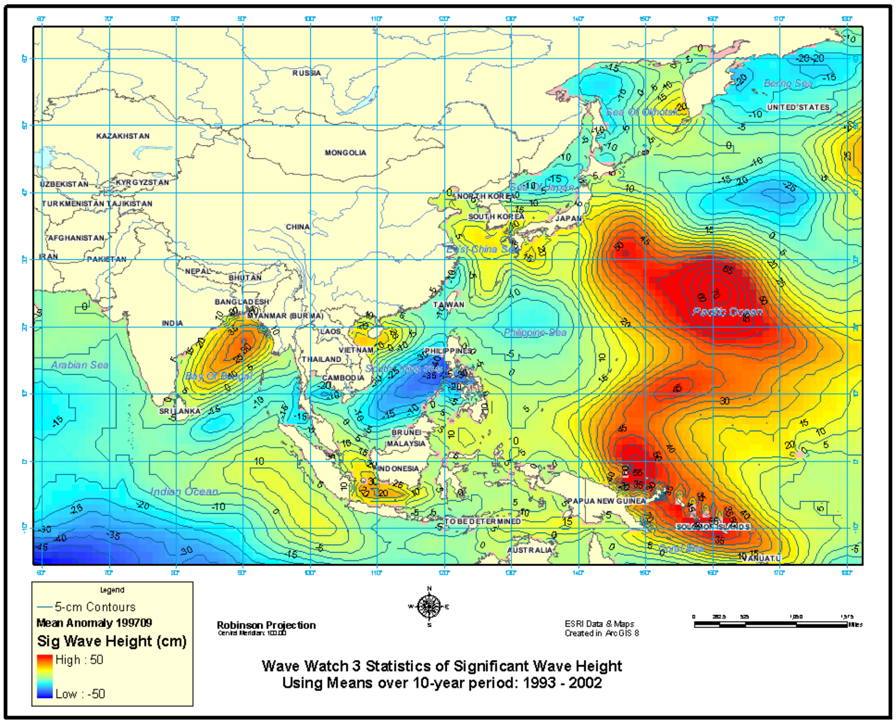


Figure 1.7: El Niño variations from LTM of significant wave height in September 1997

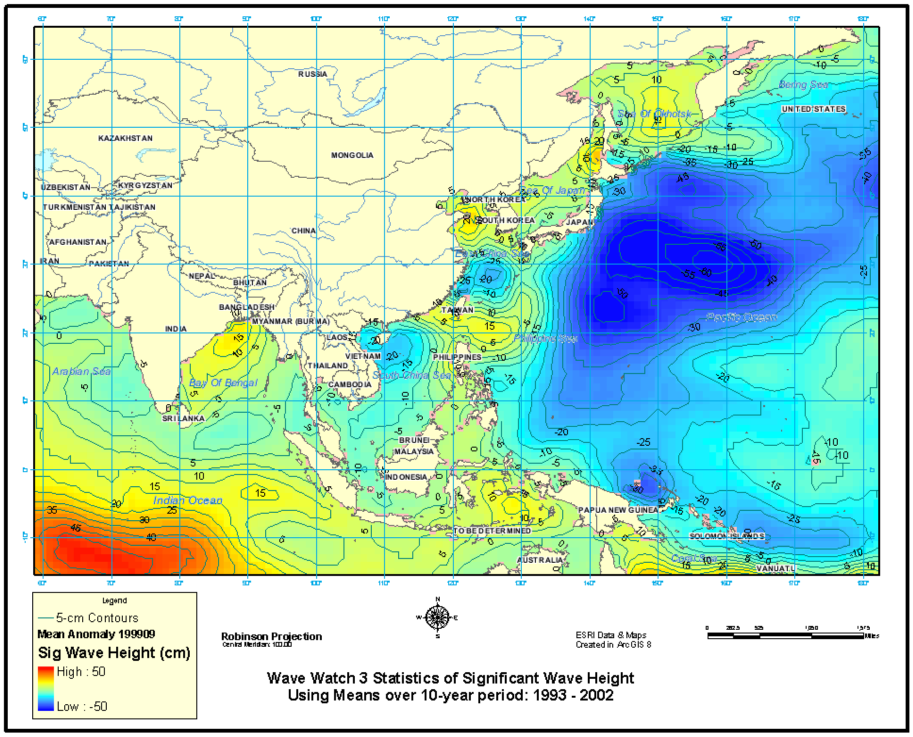


Figure 1.8: La Niña variations from LTM of significant wave height in September 1999

1.3 Need for High Resolution Data

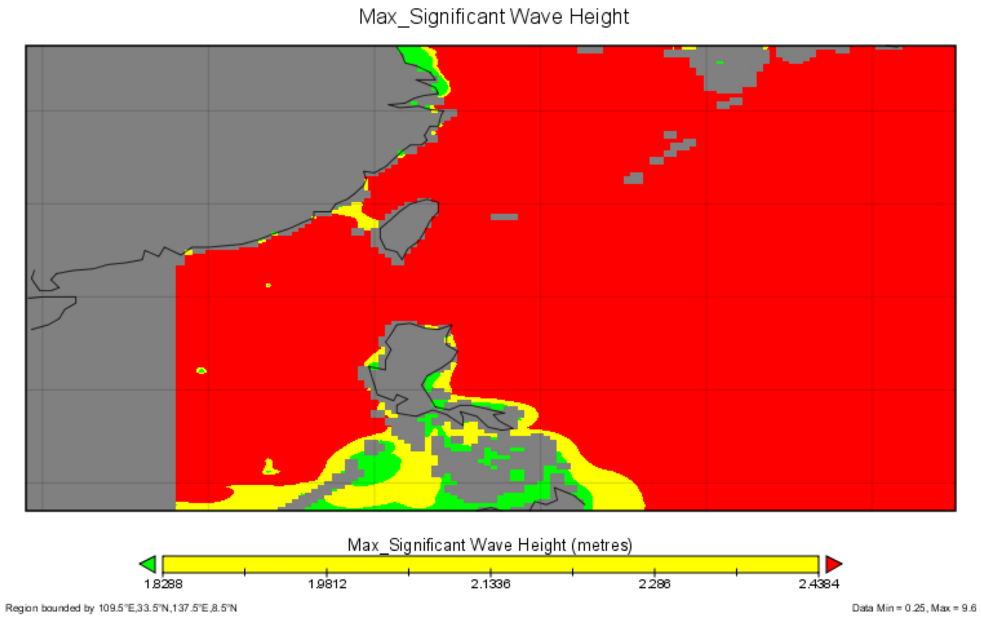
Climatology traditionally obtained by mission planners consists primarily of basic statistics derived from low resolution data such as long term means, minimum value, maximum value, and standard deviation at 1° to 2.5° spatial resolution. These statistics are useful, however, they flatten out the climate anomalies such as El Niño/La Niña and ignore the local topography and related fine-scale weather features. Many reputable and rich climatic data sites provide data access free of charge (See Appendix A for some major sites).

At present climatology data across the globe used at Fleet Numerical Meteorology and Oceanography Detachment (FNMOD), currently at Asheville, NC (to be moved to Monterey, CA). The following Table 1.1 shows illustrative examples of some of the commonly used or available data sets via the internet. Other climatology information can be obtained from a variety of data sets and systems, which are listed in Appendix B.

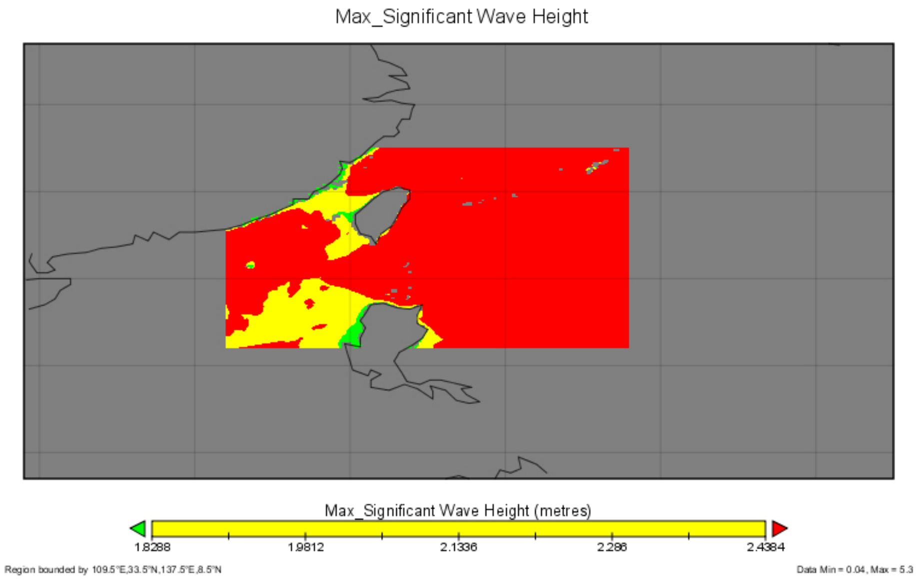
Table 1.1 Commonly Used Climatology Data Sets [FNMOD 1]

Dataset	Spatial Resolution	Number of Years
NCEP/NCAR	2.5°	1948 – present
SMGC	1°	1854 - 1998
UAGC	2.5°	

All of these data sets contain low resolution data of 1°-2.5°, which is not adequate for many Navy missions. The gridded regions produced by these coarse resolutions have side lengths of 60-150 nautical miles, thus providing fairly general observations for a vast area. Historical climate data, obtained from NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research), combines a series of observations from weather stations and satellite images to produce a global model of the earth's atmospheric climatology with sets of data from the past 57 years. The coarse data sets from NCEP/NCAR, however, result in low resolution models that do not provide necessary resolution for Navy missions. One of our main objectives in this project was to identify what effect the higher resolution data would have. To illustrate this we show in Figures 1.9 and 1.10 examples comparing the results of analysis of high and low resolution data. Clearly in the higher resolution examples, several potential differences appear in the operational area that would influence mission planning and potentially would impact operational decisions. These figures are utilizing the data the production of which will be described in the following section of the report.



a. Low Resolution- 22Km



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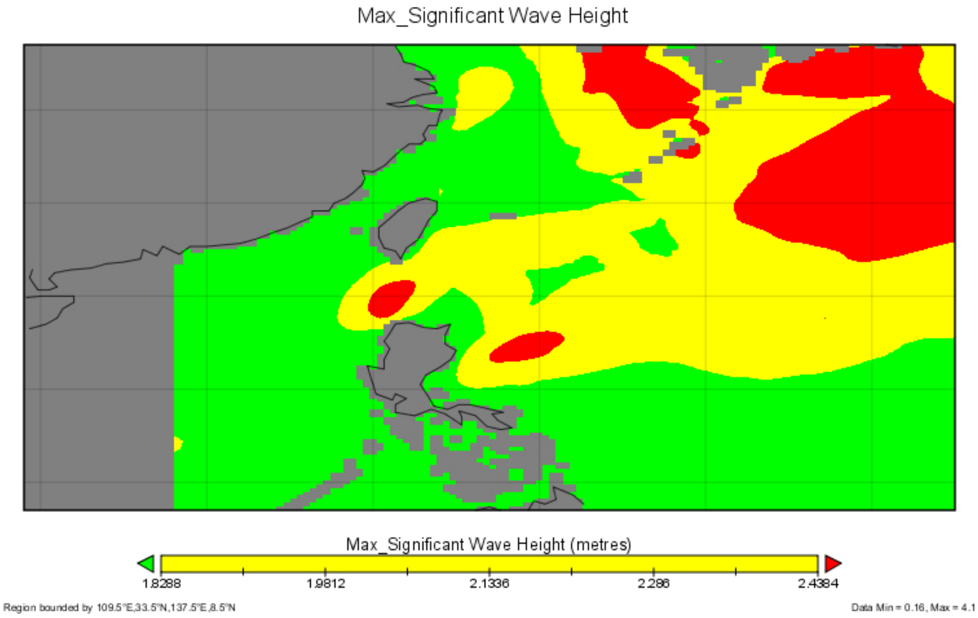
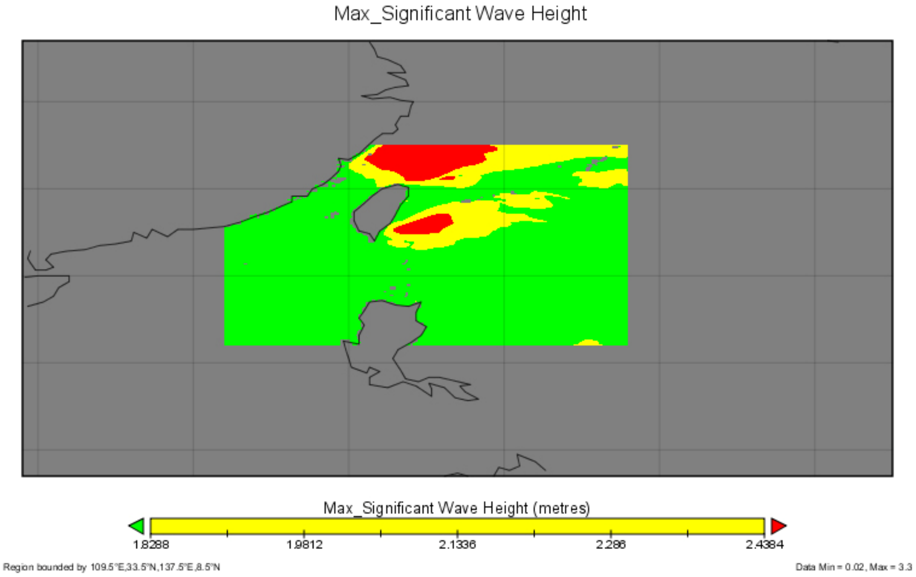
b. High Resolution – 5 Km

Figure 1.9. Comparison of Resolutions of Maximum Significant Wave heights for El Niño



a. Low Resolution- 22Km



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b. High Resolution – 5 Km

Figure 1.10. Comparison of Resolutions of Maximum Significant Wave heights for La Niña

2 Data Production Issues

2.1 Downscaling/Reanalysis Data

Until recently, the climate data sets are constructed through the use of daily data analyses that supported the real-time weather forecasting. These analyses are very inhomogeneous through a long-term period, as there have been major data assimilation technique improvements in the numerical weather prediction systems. The usage of satellite data, for example, is markedly different than the past practice. This played havoc with climate monitoring, as these improvements often produced changes in the apparent climate. The solution of the problem is “reanalysis” which uses a frozen state-of-the-art data assimilation system, and a data base as complete as possible. The data set produced from the reanalysis has a homogeneous quality through out the entire data period. Many organizations have committed major efforts and reproduced such 30-50 years global reanalysis data sets for the purpose of climate monitoring (e.g. ECMWF, NCEP/NCAR etc). However, current climatological reanalysis data set is available at a low resolution (~250km resolution).

The need for high-resolution climatology data set is not limited to military operations. Civilian activity planning decision makers (e.g. long-term energy consumption planning, water resources planning, etc) also have a desperate need for high-resolution data set for their perspective regions. Of course, it is possible to produce a high-resolution mesoscale reanalysis data set for use in mission planning. However, that would be a major undertaking for a give region and a give season. An alternative method to reanalysis is downscaling from the low resolution reanalysis data. The downscaling product will never be as good as the “reanalysis”. However, downscaling can produce the data set very quickly and it is an extremely useful tool for regions where strong external forcing exists (e.g. strong frontal passage, abrupt terrain areas, and coastal regions.)

If the concept is “climatology on demand”, then it is not likely that one can generate a re-analysis mesoscale climatology set in a short order or with limited resources. The low resolution reanalysis data is usually sufficient for open ocean such as in the middle of the Pacific Ocean; whereas in the area of Persian Gulf with high terrains or Korea peninsula the downscaling is a suitable alternative to high resolution reanalysis where the low-resolution reanalysis data is enhanced by the external forcing to create the high-resolution data set needed by military operations.

The need for mesoscale climate information is the single motivation for the need of downscaling. The idea of using the downscaling technique to provide mesoscale climate information which cannot be provided by global climate model started in early 2000’s. Florida State University’s Center for Ocean-Atmospheric Prediction Studies (COAPS) has used this technique to forecast the Seasonal Surface Temperature and Precipitation by using Nested Regional Spectral Model. In the last few years, formalized large-scale national and international downscaling projects have been formed (e.g. NARCCAP, MRED, ENSEMBLES, CIRCE and CORDES):

> The North American Regional Climate Model Assessment Program (NARCCAP) sponsored by NSF, NOAA, DOE was set up to explore ways to satisfy users' needs for higher resolution climatic information. NARCCAP's objectives are 1) to provide high resolution climatic information by using results of global climate models as boundary conditions for regional climate models and 2) to develop scenarios of contemporary and future climate at spatial scales of 50 km for use in assessing impacts of climate change. (http://www.narccap.ucar.edu/)
>
> Multi-Regional Climate Models (RCM) Ensemble Downscaling of NCEP Climate Forecast System (CFS) Seasonal Forecasts (MRED) is a sister project patterned after NARCCAP: using output from the National Centers for Environmental Prediction (NCEP) global model as input to fine-scale regional models. The project objective is to demonstrate the usefulness of multi-model downscaling of global seasonal forecasts for hydrologic applications over the U.S. with emphases on
>
> – Studies of dynamical downscaling have mostly focused on climate projections.
> – Studies of strategies for producing ensembles of downscaled seasonal predictions.
> – Providing predictions at higher resolution and regional level for hydrologic applications.
> – With initial focus on winter (snowmelt and terrain, ENSO signal, etc) (http://rcmlab.agron.iastate.edu/mred/)
>
> The ENSEMBLES is a European Union funded project because the end-user applications for climate change impact studies require accessing and post processing huge amounts of information (reanalysis, global climate model projections, etc.) over particular regions of interest. This information is typically distributed in different repositories, which use different formats, data conventions and storage systems. Moreover, different post-processing algorithms (bias removal, interpolation, calibration with observations, etc.) are typically applied to the accessed data before using the resulting time series to feed the impact models. The ENSEMBLES Downscaling Portal (www.meteo.unican.es/ensembles) has been developed with the EU-funded ENSEMBLES project (www.ensembles-eu.org) following an end-to-end approach to fill the gap between the coarse-resolution model outputs and the high-resolution/local needs of end users. The portal is based on Internet and GRID technologies allowing the transparent use of distributed resources, both for data and computation - so connecting data providers and end users in a Web-based transparent way.
>
> Climate Change and Impact Research in the Mediterranean Environment (CIRCE) is another EU project. CIRCE aims to predict and to quantify physical impacts of climate change for the Mediterranean; to evaluate the consequences of climate change for society and the economy; to develop an integrated approach to understand

combined effects of climate change and to identify adaptation and mitigation strategies, jointly with regional stakeholders

Coordinated Regional Downscaling Experiment (CORDEX) is a project within the WMO World Climate Research Program. Its objective is to organize an international coordinated framework to produce an improved generation of regional climate change projections world-wide for input into impact and adaptation studies for International Panel for Climate Change (IPCC) Assessment Report (2013-2019). CORDEX will produce an ensemble of multiple dynamical and statistical downscaling models considering multiple forcing Global Climate Models (GCMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5) archive. Initially 50-km grid spacing has been selected, favoring engagement of wider community. Multiple common domains covering all (or most) land areas in the World have been selected (with initial focus on AFRICA).

2.2 Downscaling of NCEP/NCAR Reanalysis Data Sets

In order to create downscaling high resolution data set for this Smart Climatology System project, data from NCEP/NCAR Reanalysis is fed through COAMPS which downscales the NCEP/NCAR reanalysis to provide better mesoscale features. The final output from this conversion contains improved resolutions from 250km up to 3 km. The new COAMPS outputs consist of three nests which are fed into WAVEWATCH III/SWAN to produce model output of significant wave height, wave direction and period. Since the atmosphere controls many of the conditions in the ocean, COAMPS data is also fed into NCOM, which produces ocean currents, sea surface heights (SSH), sea surface temperatures (SST), and sea surface salinity (SSS). As a result, a combination of these three models results in a complete, downscaled, and refined model of the climatology data set for the region. (See Appendix C for a flow diagram).

In this project, we selected a 500 mi x 500 mi region around Taiwan over a three year period from January 1997 to December 1999 to demonstrate the feasibility of using downscaling technique to generate mesoscale climatology. This time interval and location were strategically chosen to demonstrate the differences produced by El Niño and La Niña, which were at 57 year extremes during that period. Figure 2.1 represents the COAMPS area for which data is being produced. The coverage is: 81 km mesh (61x61); 27 km mesh (100x100); 9 km mesh (151x151). The black outline represents 81km data, the yellow area represents 27km data and the orange outline represents 9km data. The NCOM and WAVEWATCH III coverage areas are similar to that of Figure 2.1.

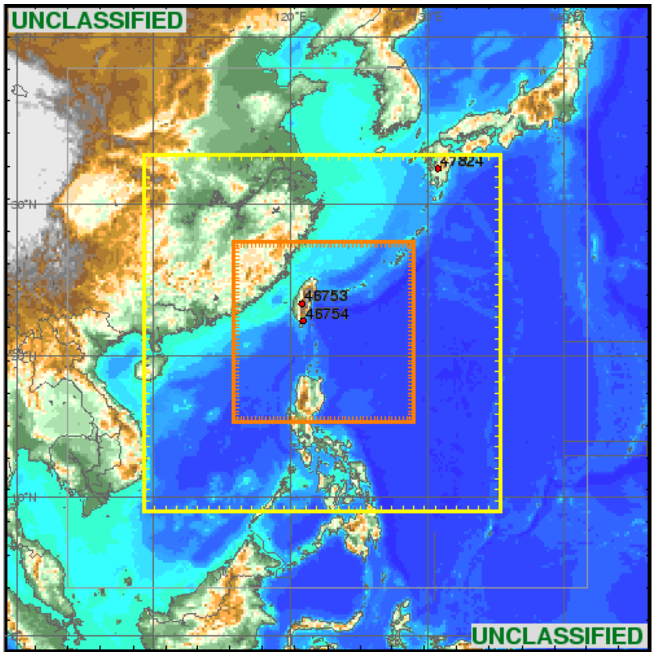


Figure 2.1 Taiwan Straits Area of High Resolution Data Production

2.3 Data Production Costs

The production process incorporates a number of costs: human time, running time, and hardware. A major disadvantage currently posed by COAMPS, NCOM, and SWAN is that they are not automatic systems; they require a human to supervise the entire procedure. A human must configure the model and continue monitoring it for any malfunctions, interruptions, or consumption of memory. Automation of these models to varying degrees have been developed. For an operational Smart Climatology On Demand system to be developed, the automation procedure must and can be developed.

The Table 2.1 below shows measures of the resources utilized to reanalyze one month of climatology data. The production of one month of data requires approximately four calendar days, and upon completion, the data requires storage space. Only one month of data consumes about 332 GB of disk space; therefore, 57 years of data will require over 227,000 GB of storage space.

Table 2.1. High resolution data productions costs

One Month of Climatology			
Model	CPU Hours (R&D Cycle)	# of CPUs	Data Size (GB)
COAMPS	48	16	167
NCOM	33	4	160
SWAN	24	4	5

The Table 2.2 below shows measures of the data space requirement. To store all data for one year is about 3 to 5 TB, and for 10 years, it will be about 50TB. With data compression, the size can be cut down. However, there is trade off when users pull the data out of the compression. The data will have to be converted again, and may lose precision depending on the type of compression scheme used. We envision that the Smart Climatology On Demand will generate the data sets on demand and be stored on on-line disks (not on tapes).

Table 2.2. High resolution data storage costs

	GB/yr	10yrs* Compressed	Grid	Level	Output Frequency
COAMPS	2,004	143	3 nests (~100x100)	30	hourly
NCOM-3	739	52	418*430	47	hourly
SWAN	60	4	5km		
Total	2,803	199			
Example of User Selected Parameters	20	0.2	~200km x 200km		COAMPS - Temp, Wind, Ceiling, Visibility, Precipation; NCOM - Temp, Sal, SS, U, V; SWAN - Wave Direction, Period, Peak, Sig Wave Height

***Compressed NetCDF (GB), compression ratio ~140.**

The high resolution reanalysis data produced for the Taiwan Straits area shown in Figure 2.1 is maintained at NRLSSC. It currently requires approximately 1 Terabyte (compressed) storage and requests for information should be directed to Mr. Fred Petry, Naval Research Laboratory, Stennis Space Center, MS.

2.4 Data Production Issues

A timeline on producing the high resolution data remains relatively flexible, for the processing time may decrease over a long period of time or increase over a short period of time. As computer speed improves in the near future, data generation time will accelerate. Data production can be delayed because of time needed for quality control, storage limitations, and network interruptions. Another disadvantage posed by the current data generation process is that the models are not run in a synchronized fashion. Neither NCOM nor SWAN can be run without information from COAMPS. Therefore, if a COAMPS model is delayed, it delays the results from NCOM and SWAN, thus extending the overall running time. Files from COAMPS are sent to an ftp site, highlighting the issue that security requirements in a network may delay model runs as well. For the eventual operational data generation, COAMPS files should be sent to NCOM and SWAN as soon as they have been generated. Hence, NCOM and SWAN can start the data generation just after a few days' COAMPS run. For the most of data production period, a single coupled modeling system with enough processing and storage to run COAMPS, NCOM, and SWAN in parallel with just a day or two lag. Currently, the entire data production in this project is a highly manual process, which requires constant monitoring, a major time delay in this project. However, there are no technology obstacles for developing an automated process.

2.5 Cold Start for Data Production

For a 10-year data generation process, it is very time consuming process. We have to run the models sequentially. However, a possible approach to the issue of the time required for data production is the idea of cold start production. Consider starting cold start runs of 12 40-day months in parallel as illustrated in Figure 2.2

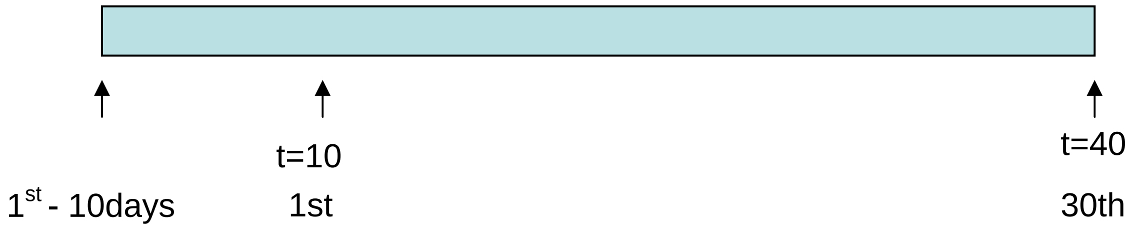
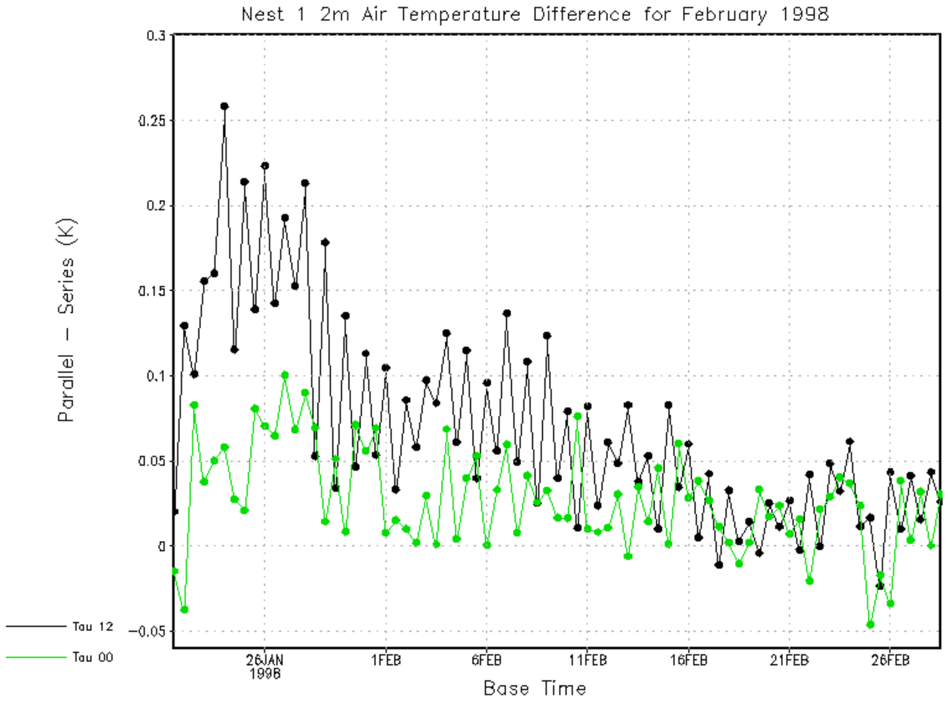


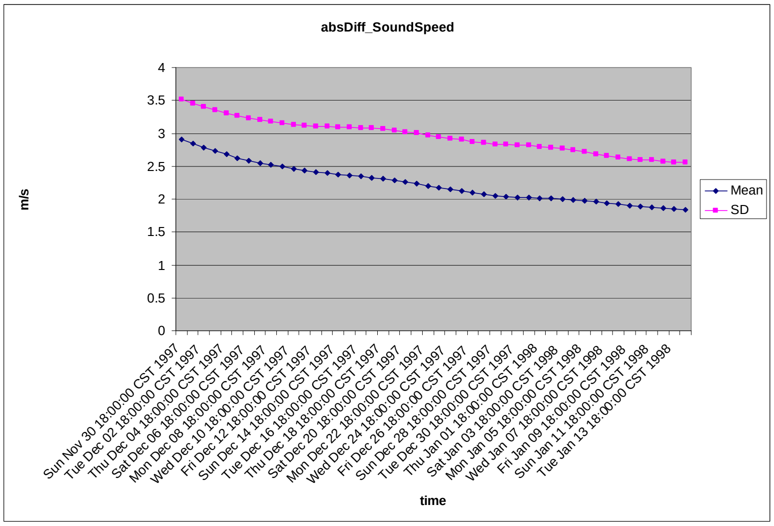
Figure 2.2

So the question becomes will the two approaches converge after a spin up? As shown in Figure 2.3, a time series comparisons of nested averaged differences between the monthly parallel and serial (continuous) runs for 2-m air temperature, cloud ceiling, low cloud amount, evaporation duct height, 10-m winds, and 20,000-ft winds marginally showed a spin-up time of fewer than five days, demonstrating the feasibility of the parallel runs (See Appendix D for more examples of convergence runs).

The cold start idea can also be applied to non-consecutive runs. For example, if users call for climatology data set for El Niño springs. It is conceivable that we can selected disjoined years and generated a data set only contains the El Niño springs.



a. 2m Air Temperature (K)



b. Abs. Sound Speed (m/s)

Figure 2.3. Examples of Cold Start Convergence

3 Smart Climatology Product Evaluation

In this section we describe some possible Smart Climatology products other than the traditional mean/bias, root means square, max/min, and frequency that can potentially be used in a future Smart Climatology On Demand system. This includes analysis techniques and an operations research modeling approach.

3.1 Composite Analysis

As NOAA continues its quest to "understand climate variability and climate change to enhance society's ability to plan and respond," it has also improved its understanding and utilization of composite analysis. Used mainly by NOAA in climate forecasts, composite analysis can determine the likelihood of a condition being beyond a specific mission threshold based on the conditional probability of a certain event, such as El Niño or La Niña, occurring.

For NOAA forecasting, composite analysis is a sampling technique that calculates the probability of an observed variable being above, near, or below normal given that an El Niño or La Niña event occurs. Since NOAA forecasts climatology for thirteen sub periods within a given 3-month period, a 3-month period of data is required to conduct the analysis.

Their current approach uses thirty years of data for some parameter, such as maximum temperature at a location, between 1971 and 2000. This is sorted in ascending order for the condition being observed for each separate month in the 3-month period and for the 3-month average itself. Each ordered set is then separated into thirds to determine the terciles, or limits that bound the above, near, and below amounts. Next all the years are compared to these terciles and the ONI's to determine how many El Niño, La Niña, and neutral periods were in each tercile. From these values, the probabilities of the parameter's departures in each tercile can be calculated, thus completing the composite analysis.

After calculating the composite analysis, the statistical significance of the probabilities must be determined by using risk analysis. First, using the previous data in which the above, near, and below normal instances were counted for the fifty years of 3-month data, a hypergeometric distribution must be created. The hypergeometric distribution can be produced from the following expression:

$$P(X = x) = f(x, n, M, N) = \frac{\binom{M}{x}\binom{N-M}{n-x}}{\binom{N}{n}}$$

The variables represent the following:

x = the number of above, near, or below events for El Niño, Normal, or La Niña events
n = the total number of El Niño, Neutral, or La Niña events
M = the total number of above, near, or below events for El Niño, Normal, and La Niña

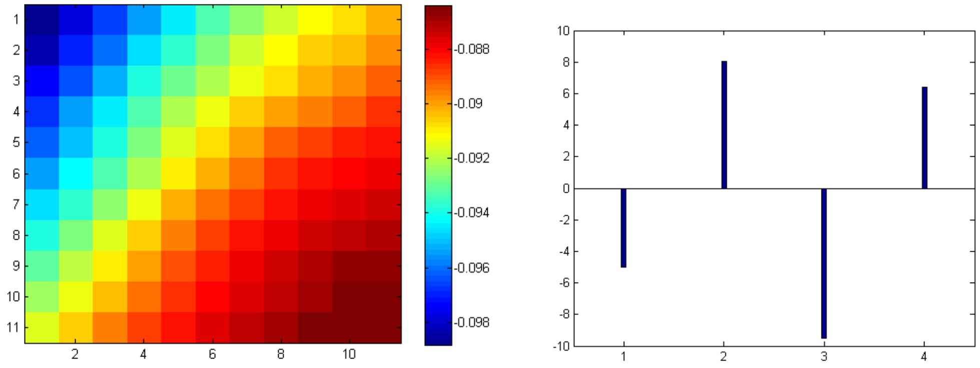
N = the total number of El Niño, Neutral, and La Niña events

The significance of a certain number of occurrences is determined if the probability is in one of the tails of the distribution, such as indicating at least a 10% significance and a 90% confidence. In order to be truly significant, a dramatically different number of possible outcomes must be calculated in confidence levels of 99%, 95%, or 90%.

Composite analysis provides a method of data analysis that offers more valid information from the low resolution data set. Rather than discovering flat LTMs, composite analysis measures the probability of the how an El Niño or La Niña will affect certain parameters. The risk analysis then assesses the statistical significance of the composite analysis probabilities. Although conducting these analyses with current NCEP/NCAR data produces more meaningful statistics, conducting these analyses with the three selected years of high resolution data using the weekly maximums of climate conditions can potentially determine the likelihoods of the worst cases of climate conditions.

3.2 Empirical Orthogonal Function (EOF)

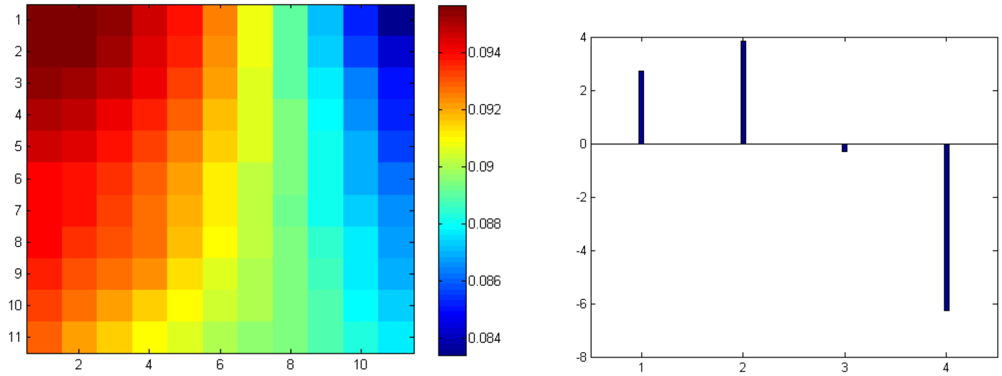
The EOF method incorporates a series of calculations to analyze the variability of a single data field. This method finds the spatial patterns of variability, their variation over time, and a measurement of each pattern's importance. While the EOF graphically portrays the spatial pattern of variability, the corresponding PC (principle component) demonstrates how the pattern varies over time in a time series. The EOF and PC produced for anomalous months can then be compared to the EOF and PC produced for the LTM.



EOF1 (VE 99.80%)

PC1 (VE 99.80%)

Figure 3.1 El Niño EOF/PC comparaison 1:4



EOF1 (VE 99.97%)

PC1 (VE 99.97%)

Figure 3.2 Long term Mean EOF/PC comparison (1-4)

However, the EOF method requires an expert to interpret the plots, which creates a disadvantage for the average user of climatology data without a background in advanced data analysis methods.

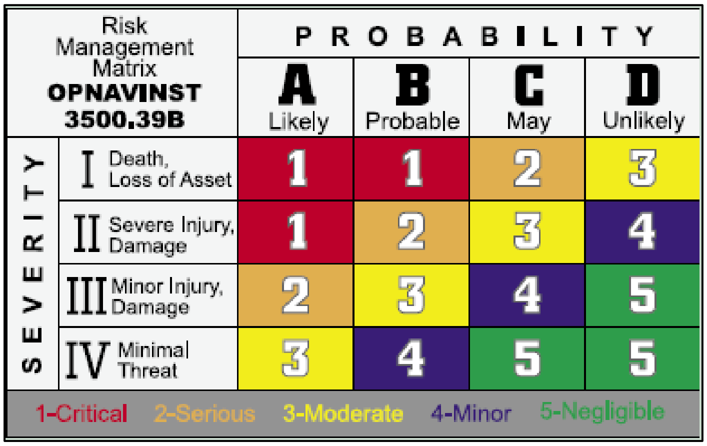
3.3 Decision Modeling for Smart Climatology

The challenges of using smart climatology in a decision making process were documented in a study by Dr. Eva Reginer of the Naval Postgraduate School (See Appendix E). The study uses an operations research/decision analysis approach to prototype the process of using smart climatology data in planning and to identify challenges and key features of a decision-relevant climatology data system. A key to the approach is the use of the value-of-information (VOI) concept which has been utilized previously in providing estimates of values of forecasts. VOI can be measured as the expected difference in consequence of two information scenarios: a baseline and an improved scenario using the enhanced data.

Specifically a model of force-on-force interactions was developed to illustrate how climatological information could be used in operational planning and how it would influence execution of operations. The scenario used is a single stage Halsey scenario. In this Halsey scenario, the relevant METOC outcomes are those that affect the ability of the Red and Blue forces to use different types of missile guidance systems- for example – less expensive (e.g. radar guided) or longer-range missiles would be more sensitive to atmospheric conditions and sea-state than more expensive (e.g. GPS-guided) or shorter-range missiles. Finally the report provides the extension of the Halsey scenario to illustrate the use and value of climatology. In order for climatology to add mission value there must be a decision that can be made based on the climatology that is not reversible later when specific forecasts become available. An example provided of a long range decision that cannot be reversed within the time horizon allowed by a forecast is the selection of a location for basing a bomber squadron.

The study pointed to the deficiency in our knowledge of the severity of the consequence. Decision makers will need to know the impact of the METOC input on the actions – the severity of the consequence or “magnitude of the consequence associated with the METOC event”. For example, consider beach landing situation by using rigid hull inflatable boats. Decision makers know that 12-ft waves will cause problems. However, it is not enough information for the decision makers to act if they were warned for 12-ft waves in 12 hours, or there was 90% chance for 12-ft waves. Decision makers need to know in addition if there was 100% chance that all boats would be capsized if waves were 12-ft, and all lives would be lost. Or was it 90% chance that boats will be capsized and 90% of Marines would lose their lives, and so on. Also, decision makers will need to know the severity of consequence if the alternatives are chosen (e.g. go/no-go, Condition 1, Condition 2, Condition 3…), what are the magnitudes of the consequences for 10-ft waves, for 8-ft waves, and so on? By the knowing the severity of the consequence gradation for all alternatives, decision science can combine the probability of the likelihood of a METOC event and its associated severities to express the impact of the METOC information to the decision makers. So, they can manage the risk of the METOC event. Modeling the consequence for METOC outcomes is a huge challenge and is not very familiar to the METOC community. In order to use operations research and decision science techniques to assess the information value of the system, it is necessary to model all available alternatives that may be selected by a decision maker using METOC information. It is also necessary to model how both METOC conditions and decisions made on the basis of METOC information affect operational consequences. Both alternatives and consequences should be modeled quantitatively. Without the alternative/consequence analysis, METOC community will continually struggle to reach the decision makers.

Figure 3.3 is a popular example of the risk management chart. For any given risk, the “probability” of an event to occur is cross-measured against the “severity” of the damage. For a likely event which would result in death and huge loss of asset, the risk is much higher than an unlikely event which would cost minimal damage.



Risk Management Matrix **OPNAVINST 3500.39B**		PROBABILITY			
		A Likely	**B** Probable	**C** May	**D** Unlikely
SEVERITY	I Death, Loss of Asset	1	1	2	3
	II Severe Injury, Damage	1	2	3	4
	III Minor Injury, Damage	2	3	4	5
	IV Minimal Threat	3	4	5	5

1-Critical 2-Serious 3-Moderate 4-Minor 5-Negligible

Figure 3.3. Risk Management Matrix (OPNAVINST 3500.39B).

METOC information including Smart Climatology information provides half of the Risk Management Matrix, namely the probability of the likelihood of a METOC event to occur. In order to use the decision science approach, the severity of each event has to be assessed first. Then, for METOC information to be useful for and relevant to decision makers, we must combine severity and probability estimates to form a risk assessment for each hazard. By combining the probability of occurrence with severity, a matrix is created where intersecting rows and columns define a Risk Assessment Matrix which is the basis for judging both the acceptability of a risk and the management level at which the decision on acceptability will be made.

4 Processing and Analyzing Smart Climatology Data

4.1 Summary of Analyses Performed

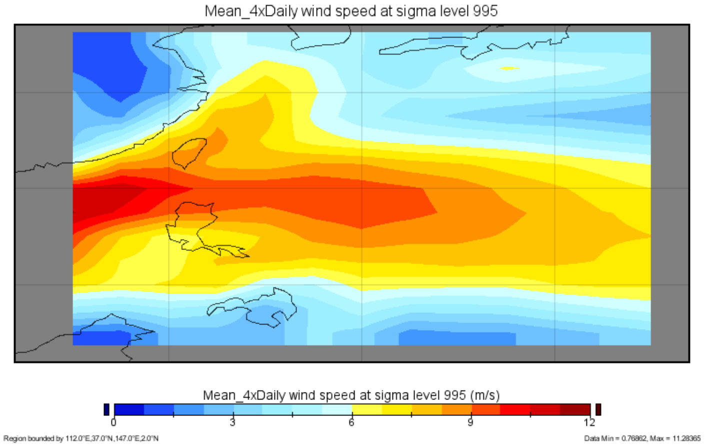
Here we summarize the analyses performed during the project. In Table 4.1 we have the data sets described on which analysis was performed.

Table 4. 1 Data Analysis Summary

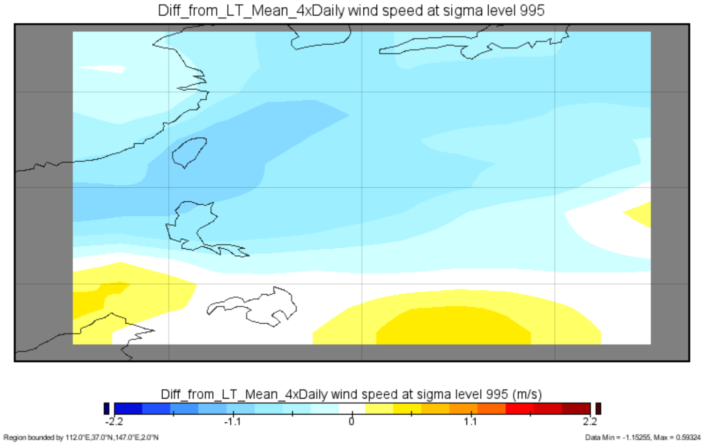
Data Set	Years	Resolutions	Parameters
WAVEWATCH III	10 years (1993-2002)	1 degree	Mean wave direction, Significant wave height, mean wave period
NCEP/NCAR	60+ years (1950-present)	2.5 degree	Surface: air temperature, pressure, relative humidity, u-wind, v-wind, 4xDaily wind speed at sigma level 995, wind speed, 4xDaily dew point at sigma level 995, dew point; Pressure: air temperature, geopotential height, relative humidity, v-wind, u-wind, wind speed
NCOM	7/97-12/99	3, 3.22, 5km	Current U&V, Sal., Sound Speed, Water Surface Elevation, Water Temp.
GNCOM	7/97-12/99	27km	Current U&V, Sal., Sound Speed, Water Surface Elevation, Water Temp.
SWAN	7/97-12/99	6, 11, 22km	Sig. Wave Ht., Mean Wave Dir., Mean Wave Period, Peak Wave Period, 10-metre winds u and v alternating components
Cold Start NCOM	45 days starting 12/97, 1/98, 2/98	3, 5km	Current U&V, Sal., Sound Speed, Water Surface Elevation, Water Temp.
MBay 2003	7/31/03-8/31/03	0.02 deg	Current U&V, Sal., Water Surface Elevation, Water Temp.
SCal 2007	6/7/07 – 7/31/07	0.03 deg	Current U&V, Sal., Sound Speed, Water Surface Elevation, Water Temp.
OAML	Monthly Climatology	10' or 30' of latitude and longitude	Water temperature

Some examples of highly representative analyses performed are illustrated in Figures 4.1. Appendix F provides a further selection and a complete set is contained in the DVD –

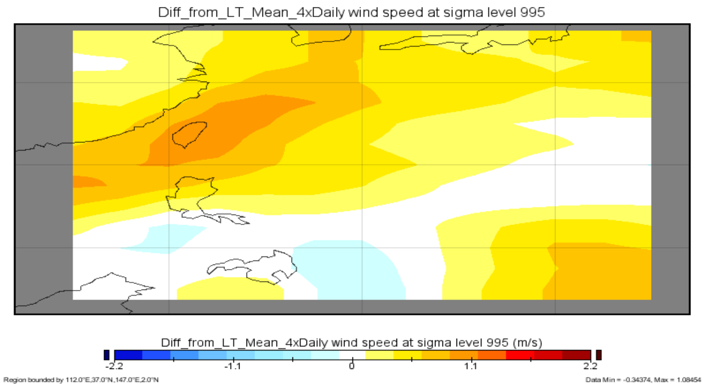
Smart Climatology Data Analysis Examples. To obtain a copy of the DVD, please contact Mr. Fred Petry, Naval Research Laboratory, Stennis Space Center, MS. fpetry@nrlssc.navy.mil.



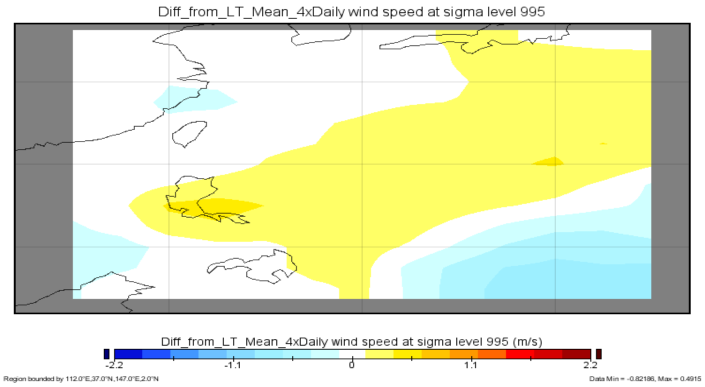
a. Long Term Mean



b. El Niño difference from Long Term Mean

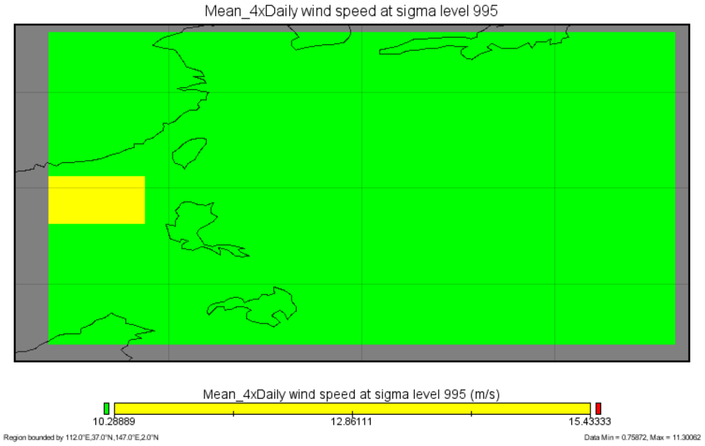


c. La Niña Mean difference from Long Term Mean

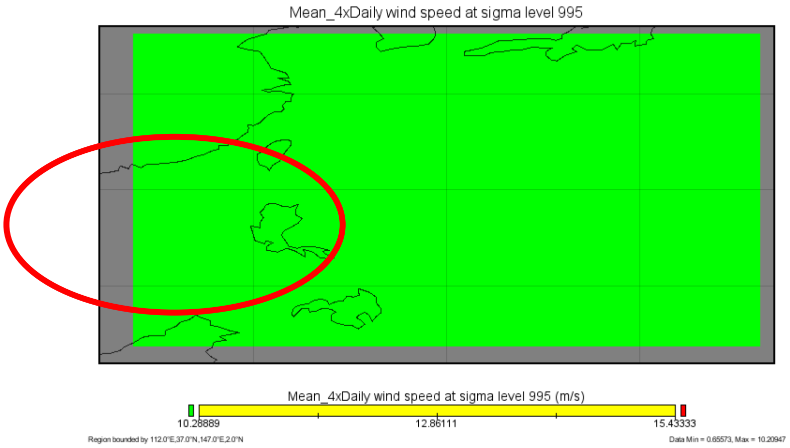


d. No Phenomena Mean difference from Long Term Mean

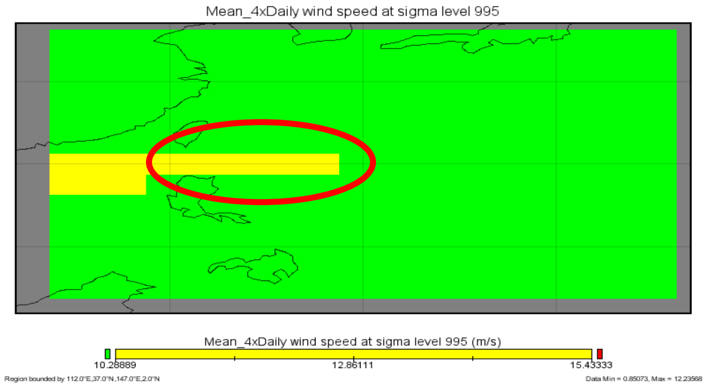
Figure 4.1. El Niño/ La Niña Means Difference from Long Term Means Surface Wind Speed – December



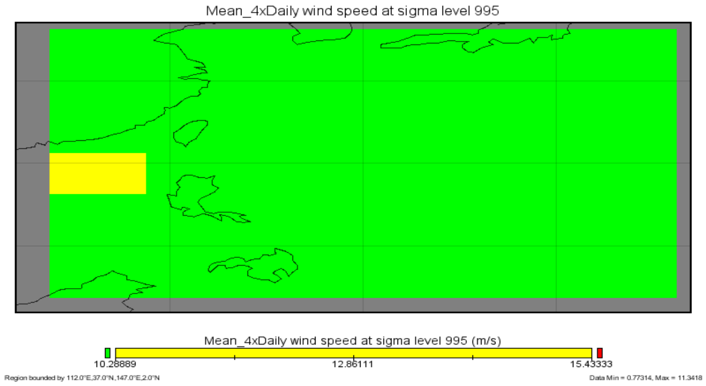
a. Long Term Means Threshold



b. El Niño Mean Threshold

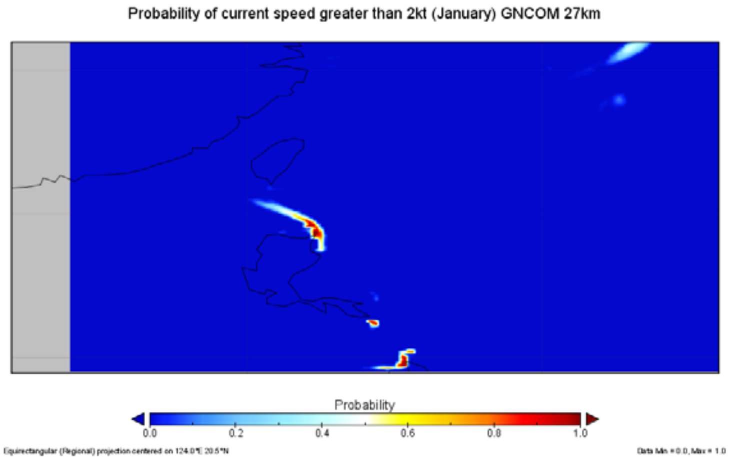


c La Niña Mean Threshold

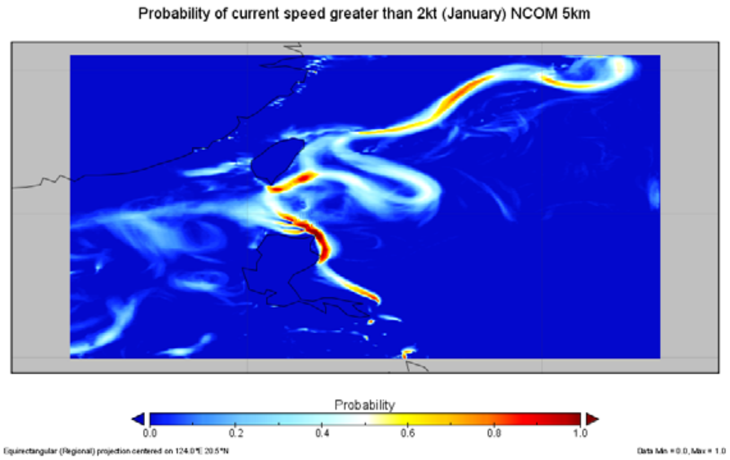


d. No Phenomena Mean Threshold

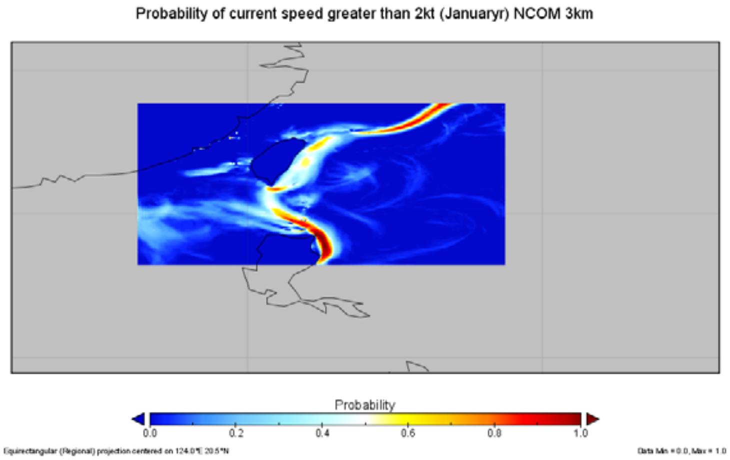
Figure 4.2 Threshold of Means - Surface Wind Speed – December
Green < 20 knots, Yellow 20-30 knots, Red > 30 knots



a. GNCOM 27 Km



b. NCOM 5Km



c. NCOM 3Km

Figure. 4.3 Frequency of Currents => 2 kts in January

4.2 Climatology Data Sets Details

The following is a discussion describing the details of the data sets used and generated within this project and some examples of conditional climatology analyses.

4.2.1 NCEP/NCAR Reanalysis

- Monthly means of wind speed at sigma level 995 as shown in Figure 4.1.a.
- Differences of monthly means by phenomena from long term mean (wind speed at sigma 995) as shown in Figure 4.1.b-d.
- Monthly wind speed means for long term and all phenomena.
- Monthly surface wind u and v means for long term, EN, LN, NP. Slides made for each month. Comparisons of wind speed against thresholds are shown in Figure 4.2.
- Monthly long term means of wind speeds compared against NCDC climatology.
- Monthly means of surface winds lat/lon spreadsheets made for Fred to test statistical significance.
- Means of wind speed (daily, weekly, monthly) maximums spreadsheets.

4.2.2 NCEP and WAVEWATCH III

- Data loaded into classified VNE-NCS for AREPS comparisons.
- Various statistics runs on air temperature and dew point used to identify candidates for AREPS comparisons.
- AREPS runs were performed by the War College. Comparison between OAML data and the NCEP/WW3 means for long term, El Niño, La Niña, and no phenomena.

4.2.3 Data Resolution Comparison Spreadsheets

- NCOM water temperature and salinity
- Tiled means for Aug-97 Tau=0,12 for 27km vs 5km, 27km vs 3.22km, 27km vs 3km, 5km vs 3km. Spreadsheets.
- NCOM current speed, salinity, significant wave height, water temperature, and salinity
- Tiled means for Oct-97 Tau=0,12 for 27km vs 5km, 27km vs 3.22km, 27km vs 3km, 5km vs 3km. Spreadsheets.
- NCEP air temperature at surface and 500mb level
- Daily, weekly, and monthly max statistics spreadsheets.
- WW3 global significant wave height
- Daily, weekly, and monthly max statistics spreadsheets.
- SWAN significant wave height
- Tiled means for Oct-97 Tau=0,12, 22km vs 11km, 22km vs 6km, 11km vs 6km. Spreadsheets.

4.2.4 Thermoclines

- Thermoclines are calculated as the center depth of the negative most sound speed gradient of each water column in a 3D grid of sound speeds. This may not be the best way to calculate thermoclines.
- Monthly means (long term, EN, LN, NP) of the maximum absolute differences of thermocline depths between GNCOM 27km and NCOM 3.22km.

4.2.5 Cold Start Differences Spreadsheets

- NCOM EAS 5km Cold Start 9712 (45 days)
- Daily Scalar Means (Diff, Abs Diff, Abs % Diff) X (sound speed, water temperature) X 1.(all levels, levels 0-2m, all levels masked <= 100m, all levels masked <= 200m); 2. (levels 0-2m masked <= 50m); 3. (levels 0-2m masked <= 100m); 4. (sound speed, water temperature) X (200m, 500m)
- Daily Scalar Mean Diff water temperature coldstart – OAML vs NCOM – coldstart .1 for all levels; 2. for levels <= 200m
- NCOM EAS 5km Cold Start 9801&2 (45 days)
- Daily Scalar Means (Abs Diff) X (sound speed, water temperature) X (all levels)
- Daily Scalar Means (Diff) X (water temperature) X (all levels)
- Daily Scalar Mean Diff water temperature coldstart – OAML vs NCOM – coldstart for all levels
- NCOM EAS 3km Cold Start 9712 (45 days)
- Daily Scalar Means (Diff, Abs Diff, Abs % Diff) X (sound speed, water temperature) X (all levels)
- Daily Scalar Means (Abs Diff) X (sound speed) X (level = 0m)
- NCOM EAS 3km Cold Start 9801&2 (45 days)
- Daily Scalar Means (Diff, Abs Diff, Abs % Diff) X (sound speed, water temperature) X (all levels)
- Monterey Bay Wdata and free comparisons
- Daily Scalar Means Spreadsheets (Diff, Abs Diff, Abs % Diff) X (current speed, water temperature, salinity) X (all levels)
- Plots of mean differences (current speed, salinity, water temperature)
- Southern Cal Wdata and free comparisons
- Daily Scalar Means Spreadsheets (Diff, Abs Diff, Abs % Diff) X (current speed, water temperature, salinity) X (all levels)
- Plots of mean differences (current speed, salinity, water temperature)
- Plots of mean differences for last 15 days (current speed, salinity, water temperature)

4.2.6 Information

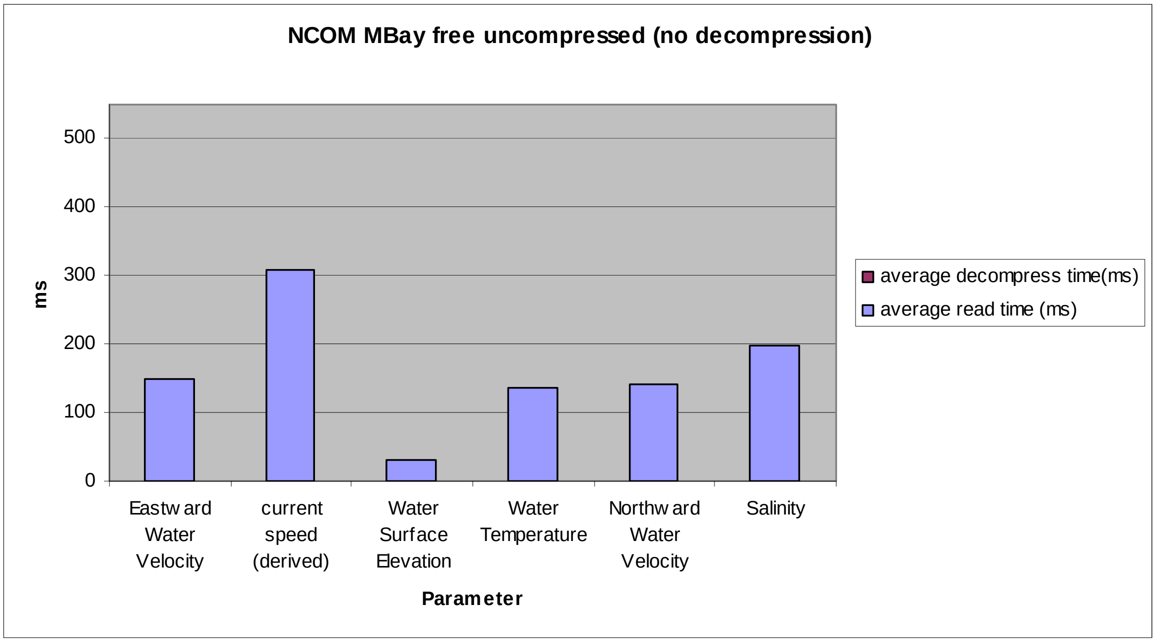
- Phenomena Filtering
- Filtered by Phenomena (El Niño, La Niña, No Phenomenon) : Not filtered by phenomena
- Means (min, max, mean, standard deviation, count)
- Statistics are calculated for each cell (lat, lon, vertical) in a set of grids.
- Scalar Means: Statistics are calculated over all cells in a set of grids.

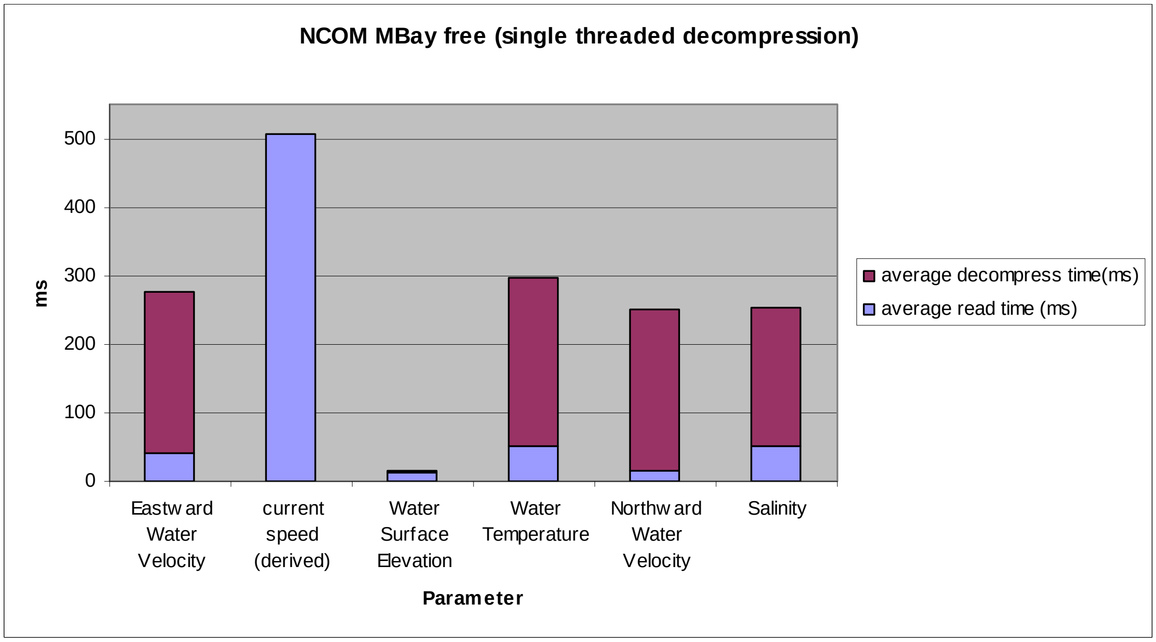
- Tiled Means: The resolution of the coarser grid determines the tiling of the area. Minimums or maximums of the finer grid are calculated for each vertical level and used to form a resulting grid. These resulting grids are used in further processing.
- Differences: Simple differences between a and b: (a – b); Absolute Difference- The absolute value of the difference between a and b. |a – b|; Absolute Percent Difference- The absolute value of the differences between a and b divided by a. Undefined (NaN) for a = 0. |a – b| / a
- Time Periods; Daily: By day (24 hour period starting at 00:00 GMT): Month: By Month (ex. Januarys): Month and Year (ex. Jan 97, Jan 98): Span of months (ex. Jan – Jul)
- Time Periods for Extremes (min, max): By day (24 hour period starting at 00:00 GMT). By week. (Actually, 6 day periods. Ignores the 31st of the month and February gets a short week. Weeks start at the beginning of each month GMT time and excluding partial week at end of month): By Month (ex. Januarys). Notation: X - Cartesian product: (a, b) X (1, 2) produces a1, a2, b1, b2.
- Masked Data: Area masks are made by applying criteria to a data grid. These masks are used to subset the grids to an area that is difficult to define by bounding boxes. A mask made by selecting grid cells containing data for 50 meters should roughly provide a subset containing near shore data.

4.3 Computational Techniques

We considered several issues relative to processing and analyzing the environmental data produced during the Smart Climatology project. In particular we needed to consider concurrency for processing as single threaded execution does not utilize the multiple cores found in current computers. So on a four core machine only 25% of CPU capacity is used. Specifically we analyzed utilization for data decompression, overlapping of I/O and processing and for the statistics computations.

First let us describe concurrent decompression. Lossless Predictive Audio Compression (LPAC) is used in memory compression where 3D data are compressed by 2D levels. We found that sequential decompression is quite slow (can be several seconds per grid) and so we began to decompress several levels concurrently. This utilizes more of the machine capability but we found that LPAC seems to be limited because of its memory allocation scheme. Four cores are not four times faster than one core, instead approximately 2.5 to 3 times faster. See the comparisons shown in Figure 4.4.


NCOM MBay free uncompressed (no decompression)
ms
500
400
300
200
100
0
Eastward Water Velocity
current speed (derived)
Water Surface Elevation
Water Temperature
Northward Water Velocity
Salinity
Parameter
average decompress time(ms)
average read time (ms)


NCOM MBay free (single threaded decompression)
ms
500
400
300
200
100
0
Eastward Water Velocity
current speed (derived)
Water Surface Elevation
Water Temperature
Northward Water Velocity
Salinity
Parameter
average decompress time(ms)
average read time (ms)

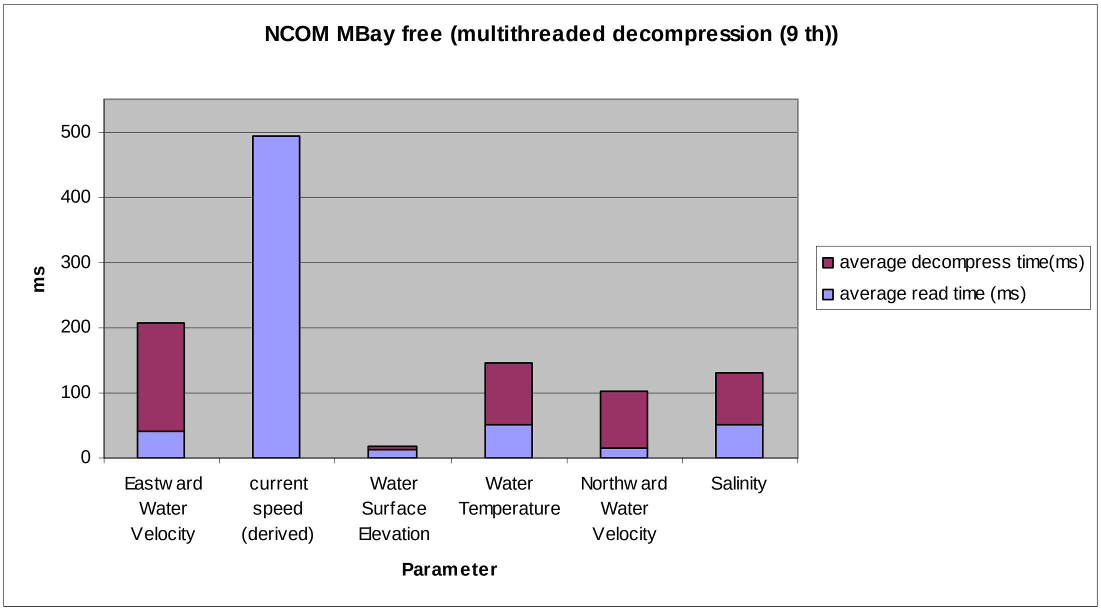


Figure 4.4 Read Vs. Compression Data for Monterey Bay Data

For overlapping I/O and processing, the reading of a grid and its decompression was overlapped with the statistics processing. We found that derived grids may require multiple read and decompression stages but that processing can occur while disk reads are pending. Decompression and I/O overlapping use Java 5 ExecutorService to manage a thread pool for parallel execution.

Statistics calculations such as mean, min, maximum, and standard deviation were calculated for each element in the grid. Utilizing parallel execution allowed multiple elements to be processed at once (one per core). This yields greater CPU utilization (near 100%). The program used fork/join and ParallelArray features that will be supported in the future in Java 7. 3D arrays are wrapped with a ‘java.util.collections’. An array of index types are made and passed to the ParallelArray. Procedures are then applied across the array of indices (in parallel). The map interface implementation and utilities for ParallelArray are available as a library.

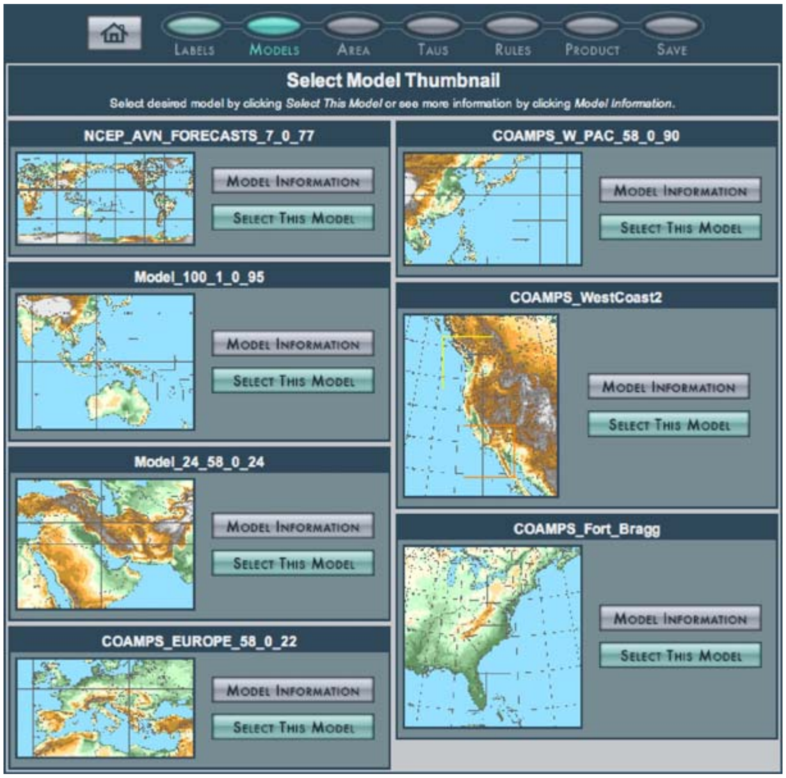
5 Effective Dissemination of Data and Products in a Net-centric Environment / Reach-back Mode

In the currently available environment, the access to information is hindered by a series of manual processes. Data access via the internet is substantially limited. Data is often requested by telephone or email and received days to weeks later by CD or paper. In modern warfare, the amount of information and the speed of command have increased drastically, and manual data dissemination processes are not advanced enough to keep up with modern day technology. In order to maintain efficacy, manual processes must be replaced by automated electronic and digital information gathering processes. Through automated processes, naval officers are more aware of their surroundings and better prepared. The delay between the data request and the data retrieval is minimized, yet a human is still kept in the procedure to evaluate the data and make decisions. Following is an overview of the different options available for effective data dissemination.

5.1 Environmental Visualization (EVIS)

The EVIS Project's main purpose is to demonstrate how METOC information can be pulled by decision makers or tactical analysts in a Netcentric Web Service environment. The project developed and evaluated the web service oriented capability to support air strike and amphibious warfare operations that delivers tactically relevant by thresholding meteorology and oceanographic information to forecasters and warfighters. EVIS delivers relevant information that includes the effects of the atmosphere on mission areas as well as on weapons and sensors. This capability has been derived from an information interaction model, which is a description of the information delivery requirements of warfighters. The model is based on cognitive and systems analyses of workflow during air strike briefing preparation. EVIS requires a human (a forecaster) to play a distinct role in the decision-making system. The human acts as an agent for the decision makers to request data and to interpret data because decision makers must evaluate the weather conditions beyond a basic stop light chart. EVIS enables them or the forecaster to quickly assess the data with more detail by accessing a hyperlinked METOC graphic for each mission or system affected by the weather.

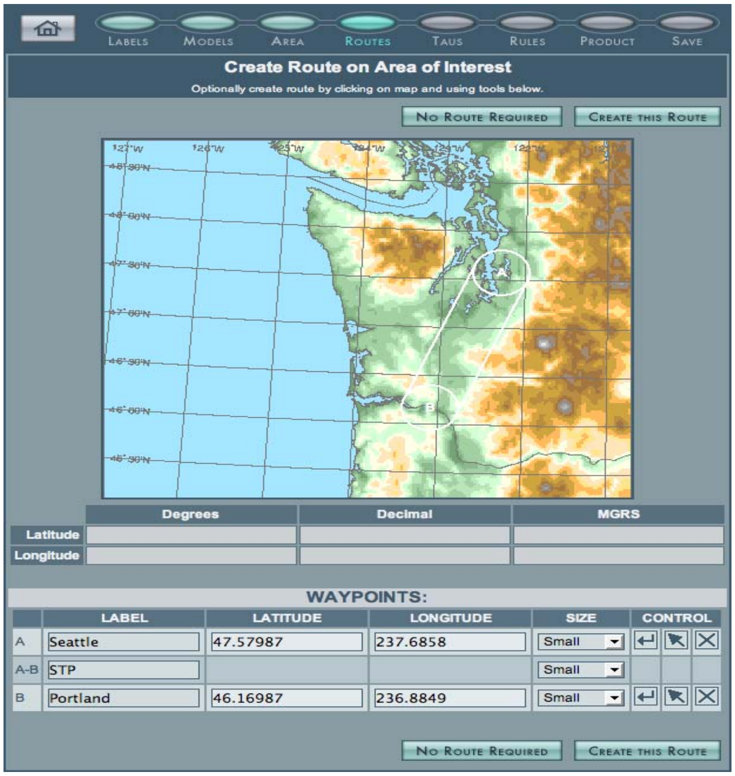
A similar capability was developed by the Navy Integrated Tactical Environmental System (NITES), whose Joint Thresholding Segment (JTS) delivers the similar thresholding capability. EVIS and JTS were examined by this project is because they can be adapted for delivering smart climatology information in a thresholding manner. Depending on the thresholds defined by the requesters, Smart Climatology can deliver the customized climatology information to the users. Following are images of the inputs that are required by EVIS.



Select Model Thumbnail

Select desired model by clicking *Select This Model* or see more information by clicking *Model Information*.

Figure 5.1. Select area of interest



Create Route on Area of Interest

Optionally create route by clicking on map and using tools below.

	Degrees	Decimal	MGRS
Latitude			
Longitude			

WAYPOINTS:

	LABEL	LATITUDE	LONGITUDE	SIZE	CONTROL
A	Seattle	47.57987	237.6858	Small	
A-B	STP			Small	
B	Portland	46.16987	236.8849	Small	

Figure 5.2 Add routes on area of interest

EVIS also depends greatly on a series of mission rules. These rules set environmental limits on missions and weapon systems to ensure operational success. Rules are also needed for automated systems, for they require a core of rules on which to base their results. From these rules, the EVIS system is able to produce a spreadsheet like product that lists a series of parameters for certain types of missions and operations and identifies the risk of each based on the predicted conditions. The design of the EVIS system includes a human user in the loop. Thought the system can be automated, the request and QC tasks have to be developed separately and carefully. Through task and workflow analyses and timelines, EVIS ensures that the most accurate, up-to-date forecasts are provided, since the user interface is ideally designed for a decision-maker. The decision maker also possesses the advantage of obtaining a forecasting visualization designed for a specific mission without long delays. Figure 5.3 illustrates the selection of rules.

Select Rules

Available rules computed from basetime and tau selection. Rollover Condensed Impact for Full Impact.

AVAILABLE RULES

☐ ⊟ RECON (HIGH) [2]

	ID	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE
☑	16	High Cloud Cover	Very High - Low Cloud Cover	50.0 %	60.0 %
☐	17	Low Visibility	Surface Visibility	5600.0 M	4800.0 M

☐ ⊞ RECON (GROUND) [1]

☐ ⊞ AERIAL REFUEL [1]

☑ ⊟ UAV (DRONES) [3]

	ID	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE
☑	19	Low Ceiling	Cloud Ceiling	6000.0 FT	4000.0 FT
☑	20	Low Visibility	Surface Visibility	5600.0 M	4800.0 M
☑	21	High Winds	20 Meter Wind Speed	40.0 KT	60.0 KT

☐ ⊞ AIR LAUNCH/RECOVERY [2]

☐ ⊞ RECON (LOW) [1]

☐ ⊞ CLOSE AIR SUP [2]

☐ ⊟ HIGH ALTITUDE ISR [1]

	ID	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE
☐	43	High Cloud Cover	Very High - Low Cloud Cover	40.0 %	60.0 %

☐ ⊞ BOMBING [5]

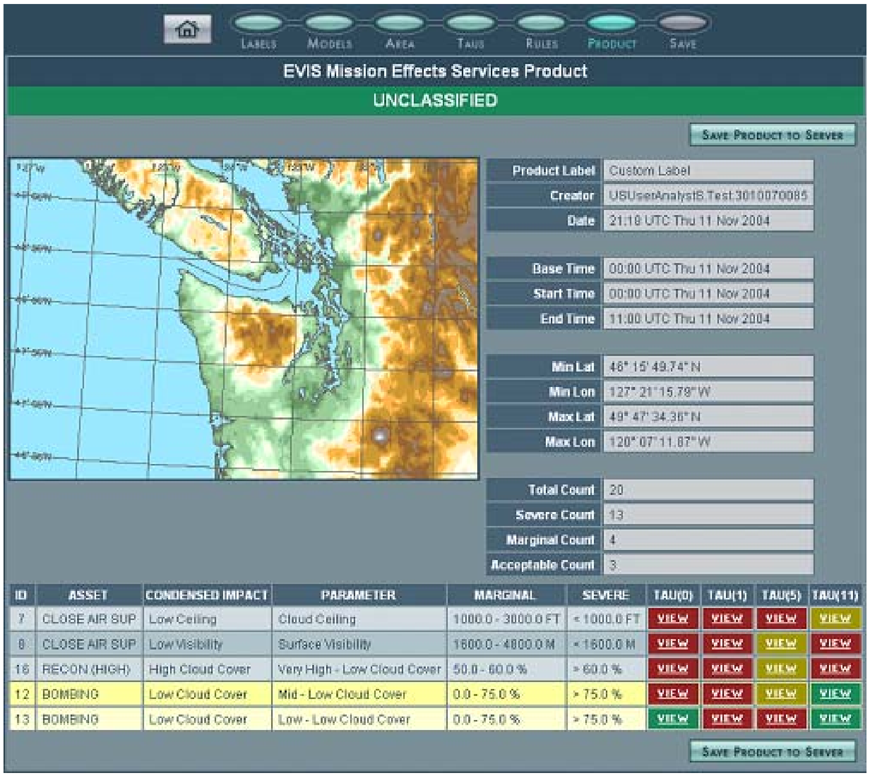
☐ ⊞ CARRIER [5]

UNAVAILABLE RULES

⊞ UAV (DRONES) [1]

Figure 5.3 Choose and edit threshold rules.

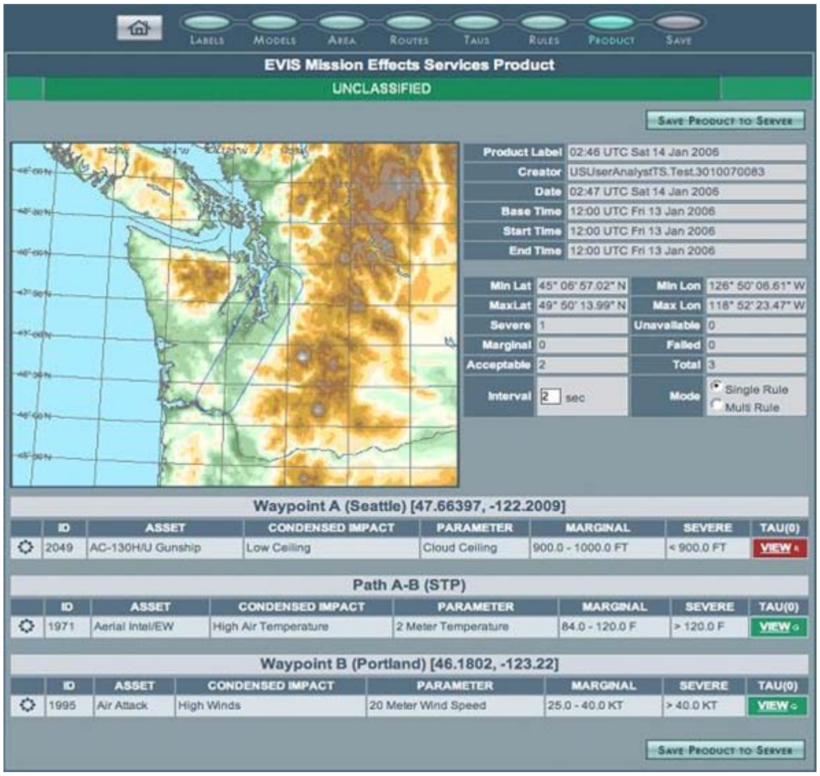
The METOC data currently used by EVIS to produce its environmental thresholds and visualizations comes directly from the Tactical Environmental Database Server (TEDS) and eventually from VNE-NCS (Virtual Natural Environment Net Centric Services), a web served version of TEDS. A server, the EVIS Data Facing System, holds the data at a forecast center and receives data requests and provides the data to rule-based systems. In addition to easy data access, EVIS system architecture allows it to define and tailor rules, threshold data, and deliver geographic maps that depict the thresholds. The following graphics depict the final products created by EVIS.



Product Label	Custom Label
Creator	USUserAnalystB.Test.3010070085
Date	21:19 UTC Thu 11 Nov 2004
Base Time	00:00 UTC Thu 11 Nov 2004
Start Time	00:00 UTC Thu 11 Nov 2004
End Time	11:00 UTC Thu 11 Nov 2004
Min Lat	46° 15' 49.74" N
Min Lon	127° 21' 15.79" W
Max Lat	49° 47' 34.36" N
Max Lon	120° 07' 11.87" W
Total Count	20
Severe Count	13
Marginal Count	4
Acceptable Count	3

ID	ASSET	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE	TAU(0)	TAU(1)	TAU(5)	TAU(11)
7	CLOSE AIR SUP	Low Ceiling	Cloud Ceiling	1000.0 - 3000.0 FT	< 1000.0 FT	VIEW	VIEW	VIEW	VIEW
8	CLOSE AIR SUP	Low Visibility	Surface Visibility	1600.0 - 4800.0 M	< 1600.0 M	VIEW	VIEW	VIEW	VIEW
16	RECON (HIGH)	High Cloud Cover	Very High - Low Cloud Cover	50.0 - 60.0 %	> 60.0 %	VIEW	VIEW	VIEW	VIEW
12	BOMBING	Low Cloud Cover	Mid - Low Cloud Cover	0.0 - 75.0 %	> 75.0 %	VIEW	VIEW	VIEW	VIEW
13	BOMBING	Low Cloud Cover	Low - Low Cloud Cover	0.0 - 75.0 %	> 75.0 %	VIEW	VIEW	VIEW	VIEW

Figure 5.4. View and edit the threshold product.



Product Label	02:46 UTC Sat 14 Jan 2006
Creator	USUserAnalystTS.Test.3010070083
Date	02:47 UTC Sat 14 Jan 2006
Base Time	12:00 UTC Fri 13 Jan 2006
Start Time	12:00 UTC Fri 13 Jan 2006
End Time	12:00 UTC Fri 13 Jan 2006

Min Lat	45° 06' 57.02" N	Min Lon	126° 50' 06.61" W
MaxLat	49° 50' 13.99" N	Max Lon	118° 52' 23.47" W
Severe	1	Unavailable	0
Marginal	0	Failed	0
Acceptable	2	Total	3
Interval	2 sec	Mode	● Single Rule ○ Multi Rule

Waypoint A (Seattle) [47.66397, -122.2009]

	ID	ASSET	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE	TAU(0)
⚙	2049	AC-130H/U Gunship	Low Ceiling	Cloud Ceiling	900.0 - 1000.0 FT	< 900.0 FT	VIEW

Path A-B (STP)

	ID	ASSET	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE	TAU(0)
⚙	1971	Aerial Intel/EW	High Air Temperature	2 Meter Temperature	84.0 - 120.0 F	> 120.0 F	VIEW

Waypoint B (Portland) [46.1802, -123.22]

	ID	ASSET	CONDENSED IMPACT	PARAMETER	MARGINAL	SEVERE	TAU(0)
⚙	1995	Air Attack	High Winds	20 Meter Wind Speed	25.0 - 40.0 KT	> 40.0 KT	VIEW

Figure 5.5 Route threshold product

The EVIS system design can provide the user with detailed, accessible information incorporated in both text and graphics in a timely manner. The decision maker can easily assess the given information and make a quick and precise decision. This data dissemination process has proven to make a difference in war gaming scenarios. The use of an EVIS system was compared to the lack of an EVIS system in a demonstration at the METOC Advance Concepts Lab in North Island, CA. During a strike planning simulation, forecasters were instructed to provide mission effects information to warfighters. The forecaster using an EVIS system was able to disseminate the data faster and in an organized format.

5.2 JMBL (Joint METOC Broker Language)

In order to create a completely automated end-to-end Smart Climatology system, machines within the network must be able to communicate with each other without human interference. However, all the machines involved in the process must use the same computer language in order to communicate, yet realistically different programs and applications are written in different languages. A Web Service enables various Web-enabled programs to function together despite the language barrier. Essentially, it serves as a translator, but instead of converting one language to another, a common language or means of communication shared amongst the applications is discovered to allow the machines to operate, thus enabling faster and more accurate data delivery. In order to "tightly couple" the machines, the web server providing the data must contain a Web Service interface written in text, which is language and platform independent so that all other machines and applications can interpret it. The text defines a Web Service contract in which the types of requests and responses are specified; however, any computer is capable of defining its own contract.

The main purpose of JMBL (the Joint METOC Broker Language) is to standardize all the Web service contracts within the Navy (and DoD as well) and to allow the easy exchange of METOC data for all Navy personnel. It establishes one Web Service based on jointly defined XML schemas, or specifications within the contract that describe the requests and responses given and received by the Web Service, within one WSDL (Web Service Description Language), or the container of all the schemas. The following diagram explains how a JMBL WSDL is organized. The boxes labeled "XSD" represent schemas.

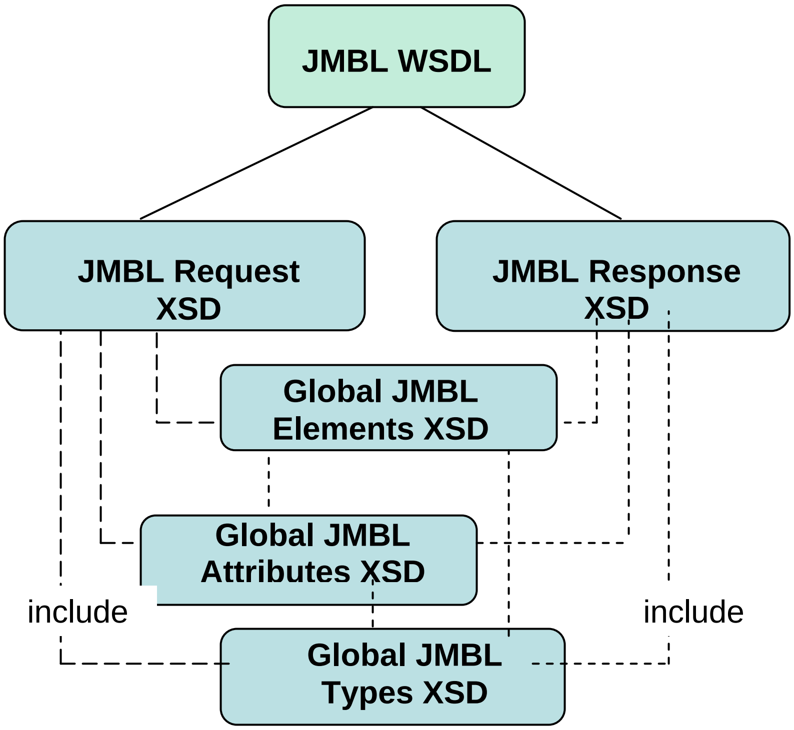


Figure 5.6. Conceptual View of JMBL WSDL and Schemas

JMBL standardizes all METOC Web Services with one WSDL. The WSDL consists of the declarations specifying the types of requests a Web Service will recognize and the types of responses it will produce. The request and response schemas are linked to other global schemas including global JMBL elements, attributes, and type schemas, which define global data sets and structures. Together they compose a standard for all Web Services allowing them to be easily accessed by any authorized client.

The use of JMBL eases the data dissemination process and reduces the time needed to deliver information. JMBL will also enable clients to simply fill out only one request for data that can access all METOC databases. JMBL focuses on service-oriented architectures, in which its main objective is to serve the warfighter needs within the time constraints. If a warfighter must visit multiple sites for a few sets of data or get familiarized with multiple user interfaces, a mission may be in jeopardy. Therefore, having all data sets in compatible formats will increase agility and a mission's success rate.

5.3 VNE NCS (Virtual Natural Environment Net Centric Services)

Formerly known as TEDS (Tactical Environmental Data Server), VNE NCS (Virtual Natural Environment Net Centric Services) serves the purpose of managing and transporting METOC and Environmental data to warfighters, Tactical Decision Aids (TDA), and weapons systems. VNE NCS data cache provides access to the 4-dimensional, user-specified Virtual

Natural Environment (VNE). Through its design, VNE NCS strives to improve data management, transport, and representation. With warfare on a gradual progression towards network centric philosophy, VNE NCS attempts to standardize METOC databases and extraction routines. All of the information provided will come from a common geospatial and temporal information source; thus, all collaborative planning can be done by different agencies but with the same datasets.

VNE-NCS is composed of nodes or gateways which act as the data broker between data producers and data consumers in a web-centric environment. One gateway represents one entire platform, either a data producer or a data consumer. The following diagrams depict how VNE-NCS permits direct data access between battle groups and data producers:

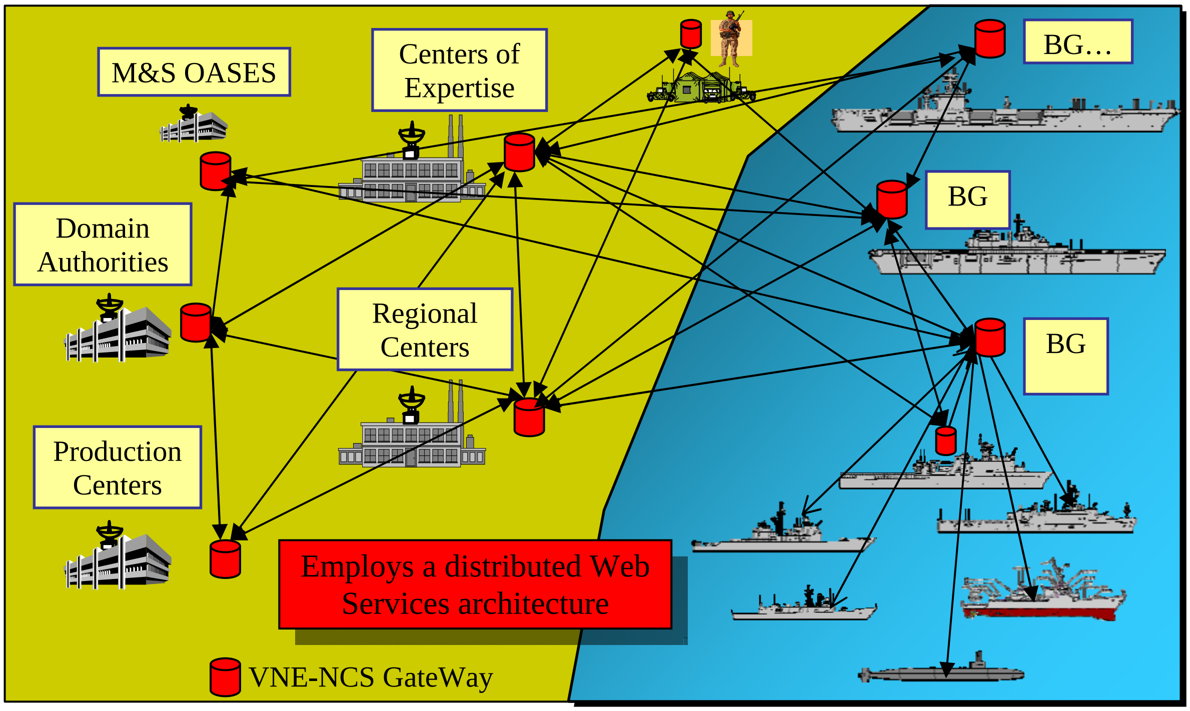


Figure 5.7. Many-to-Many Topology of Distributed Web Services Architecture.

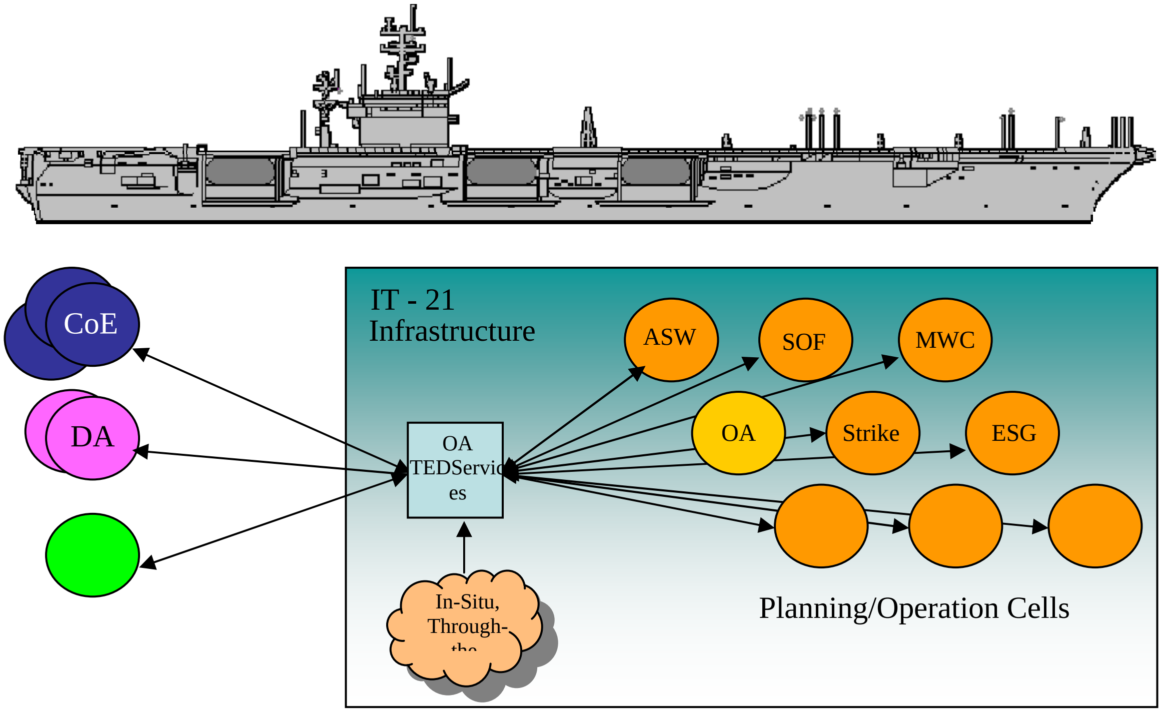


Figure 5.8. VNE-NCS GateWay with Bandwidth Management and Forward Deployed Data Caching

VNE-NCS contains a number of key features including simplified data management, bi-directional data transport, and consistent data representation. The data is ordered according to its relevance to the mission, and it is held within a light-weight, forward-deployed “data cache.” Also, data is transported efficiently and bi-directionally between the consumer and the data producer. And finally the data is represented in a uniform format, thus speeding up the compression process and allowing broken HTTP/HTTPS communication sessions to be resumed. In addition, VNE-NCS decreases the amount of time needed to extract data and the amount of hard drive space a model produced from the data occupies.

5.4 IWB (Integrated Web Services Broker)

The internet contains copious amounts of METOC data; however, searching for that information may be an unwieldy process. Finding, browsing, downloading, and evaluating the data may not only be challenging but also time-consuming. The Integrated Web Services Broker (IWB), formerly known as the Advanced METOC Broker (AMB), is designed to eliminate these burdens and ease the process of finding METOC data on the internet. IWB’s main purpose is to automate the search for METOC data and web services. The Registry Crawler, a component of IWB, is constantly patrolling the internet for evolving and brand new METOC web services. When an updated or new METOC web service is encountered, IWB automatically adds it to their database and incorporates it in future data searches. The Registry Crawler uses keyword matches to find the appropriate METOC Web Services.

When a match is found, the Registry Crawler finds the web service's WSDL (Web Service Description Language) and downloads it to the hard drive. The WSDL is scanned for key words and the METOC data from the web service is retrieved.

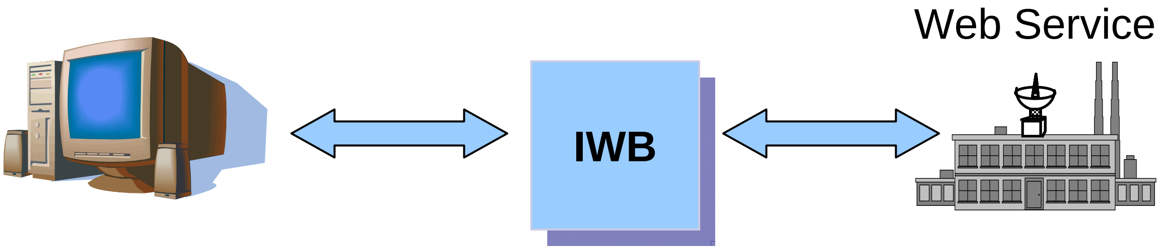


Figure 5.9 Finding new METOC Web Services with IWB

In addition to finding relevant information, the IWB is completely automated and provides confidence levels on the data based on the source. As a result, the human labor as well as the extensive time consumption would be reduced. The following Figure 5.10 depicts how the overall IWB operates.

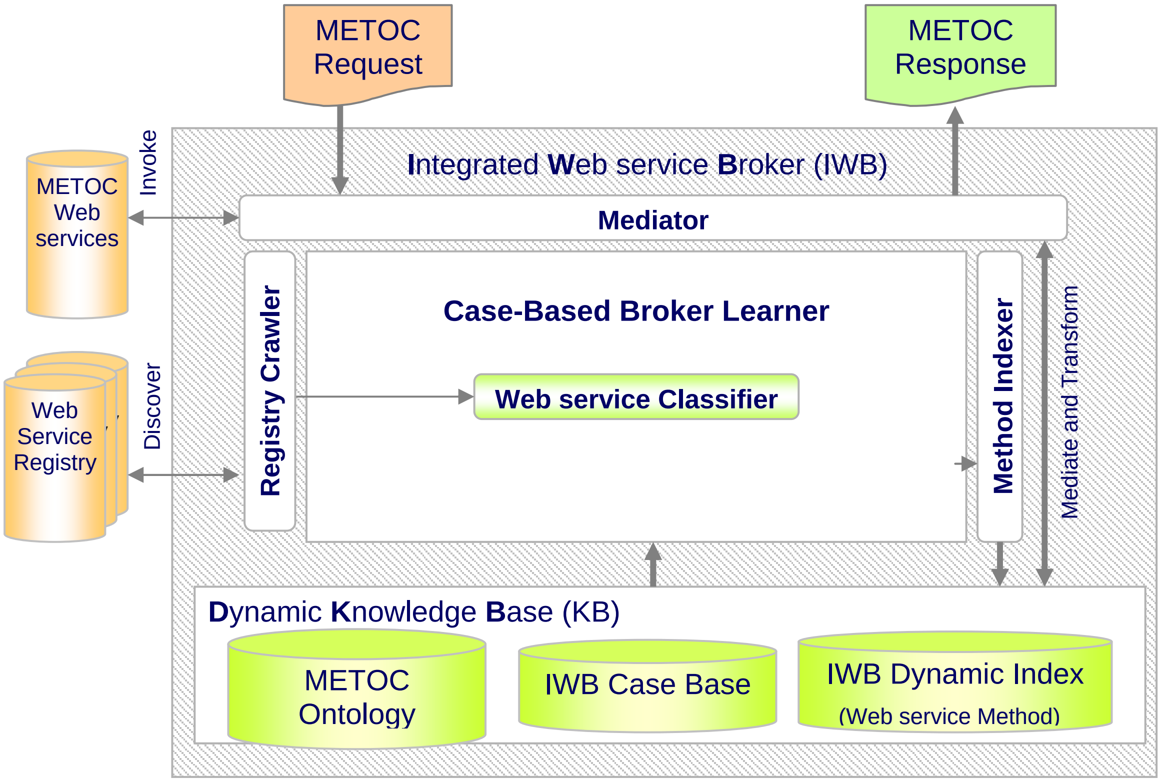


Figure 5.10. IWB Organization

As a METOC request is placed to the IWB, it is initially relayed to the mediator which guides the request through the IWB in order to output a legitimate response. It makes sure that requests are made in a format understood by the Web services and that responses are given in a format understood by the client. First the key words, or the concepts addressed, are Dynamic Knowledge Base in which the request is essentially "understood" by the IWB. Then it is searched within the index of Web services, and the information is relayed back to the client as the METOC response. This process requires about three seconds to complete and outputs accurate and vital information.

6 Summary and Recommendations for Smart Climatology On Demand

6.1 Summaries

6.1.1 Climate Anomalies and Effects

Climate can be defined as a region's general METOC conditions over time. However, climate changes constantly, it is not a static condition. It is true that the 30-year mean represents the average METOC condition of a region, but it does not represent the range of climatic variations. Climate anomalies and long term trend are prominent features. It is the goal of the Smart Climatology to convey the anomaly information to the user along with its average conditions; or simply put Smart Climatology is "conditional climatology". We must provide contextual information and data for interpretation of climatology statistics delivered.

6.1.2 Data Resolution

For climatology data used in tactical decisions (e.g. expeditionary warfare), climate information derived from high resolution data is necessary. The coarse data may provide information over the entire region; however, it will not satisfy the needs of Navy mission planners. Figures 1.9 and 1.10 have shown that different decision recommendations would be the result if we based the decision on METOC conditions presented in the coarse resolution data instead of the high resolution data, and vice versa.

6.1.3 Smart Climatology On Demand System

This RTP project explores the feasibility of a smart climatology system which can produce conditional (i.e. stratified by conditions) climatology on demand. If a high resolution climatology data set is needed, how fast can we produce such a data set for the users? In our projection, if we formally establish an operational Smart Climatology System, we can produce a high-resolution data set (with 3km resolution for 10-20 years length) within two months (one to two months depending on the size of the area and length of the period). We can start with the large-scale re-analysis data set (e.g. NCEP/NCAR reanalysis since 1948), using coupled ocean/atmosphere mesoscale model to downscale the resolution to 3km. Using a cold-start 40-day month method, we can produce a 10-year run or a 10-stratified-year run for a specific region. One critical feature of this approach is that we use the operational mesoscale numerical models for data generation purpose. This means that the "system" is always updated as the operational mesoscale prediction system is updated/improved. We should not generate the area climatology data sets and put them on the shelf for future use. The climate changes; the climate anomaly changes; the numerical model improves; and the data assimilation system improves with time. A previously generated climatology data set may not be the state-of-the-art data set when needed. It is better to generate the smart climatology data set on demand, and to use state-of-the-art system and knowledge to generate the data set.

Several METOC projects have experimented with "request & reply" METOC data from web services through service-oriented architecture. The conclusion of these projects is that they are very well suited for use in a smart climatology system. The distributed nature of a system fits perfectly with the current METOC data production centers. The mechanics of the procedures can certainly be automated. On top of the automation, we recommend the "human in the loop" CONOPS for the purposes of interpretation of the requests, selection of the seasons, decisions of the resolutions, and quality control of the output.

6.1.4 Analysis Tool Set

Climatology Statistics: The routine long-term average climatological parameters (or statistics) are routinely requested by the users. These statistics though can't provide much insight to the regional climatology; however they still provide useful information. These statistics include mean, standard deviation, max/min, periods (e.g. rain days), and frequency (e.g. How often an event does (or does not) occur?).

Anomalies: Since El Niño/La Niña anomalies have such a drastic influence on climatic conditions that the ENSO like information and conditional climatology must be provided to the users. The climatological statistics must reflect the stratification of the anomaly. This is particularly true if climatology information is required adjacent to Pacific and Atlantic oceans. There are other climatic indices which can be used to stratify the climatology statistics; however, some of these indices are very transient in nature and behave differently if overlapped by other indices. These transient indices are very difficult to use as a condition to stratify the climatology data sets. For example, the Madden-Julian Oscillation (MJO) is an equatorial traveling pattern of anomalous rainfall that is planetary in scale. The anomalous rainfall is usually first evident over the western Indian Ocean, and remains evident as it propagates over the very warm ocean waters of the western and central tropical Pacific. Each cycle lasts approximately 30–60 days. For a given area and a given season, we can stratify the condition with or without MJO. The MJO features and characteristics should be conveyed to the users so they would understand the range of climatic conditions.

Thresholding: Thresholding is a common way to express the "threat" area by a METOC event. The joint Integrated Weather Effects Decision Aid (IWEDA) effort is making strides in combining all METOC thresholding rules for all three services. A convenient way to express the climate conditions with respect to operations is the thresholding stop-light expressions.

Tool Set to be Selected by the Users: The analysis tool set should reside at the data production centers. Analyses and stratification of the data sets can be performed at the data production center after data sets are generated. Analysis results then should be stored at data production centers for queries by users.

Reaching to the Decision Makers: In the concept of Battlespace ON Demand (BOND), the third tier decision makers will need the METOC performance information to help them make decisions. While we worked through an example of how a decision science approach can be applied to deliver climate/METOC information to the decision makers, we realized that METOC information alone (or by itself) is not enough for the decision makers to act. It is necessary, but not sufficient. In addition to the probability of an METOC event to occur, the decision makers need to know the impact of the METOC input on the actions – the "**magnitude of the consequence associated with the METOC event"** of each METOC event and the magnitudes of the impact on all the alternatives of the decision.

Smart climatology Information Request and Dissemination:

Long interviews with FNMOD led us to conclude that the climatology data or information should not be directly accessed by the decision makers. FNMOD or METOC staff should be in the loop to

- Interpret the request,
- Stratify the data sets for Smart or Conditional Climatology,
- Advise on the contextual information, and
- Alert the decision makers of the magnitude of consequences.

In the concept of Smart Climatology On Demand, we recommend that FNMOD SME's should first examine the targeted region and season and determine what time period (or periods) should be included in the climatological statistics for that particular case. The reason for these pre-database generation analyses is to include the time period which contains climatic anomalies or extremes.

Certainly, the mechanics of data request from the FNMOD or METOC staff, stratified climatology data set generation, delivery of data sets and associated statistics back to FNMOD or METOC staff can be automated.

6.2 Recommendations

6.2.1 Smart Climatology Data Generation

We can summarize the characteristics of a "Smart Climatology On Demand" system as comprised of

- State-of-the-art mesoscale numerical environmental prediction system or an operational mesoscale environmental prediction system capable of generating high-resolution data sets on demand (e.g. operational COAMPS/NCOM/SWAN mesoscale prediction system),
- The global reanalysis data set (e.g. NCEP/NCAR reanalysis data set since 1948),
- User interface for data request and reply, and
- Automation of these processes and effective availability in a service–oriented architecture via Web Services.

The data base for the Smart Climatology On Demand system should have

- A conditional high resolution climate data base generated on demand for a given request,
- A data analysis system (a set of analysis tools) which can analyze the data retrieved from the database and perform analysis, and
- Climate statistics including conditional statistics for the average, anomaly, and extreme (or expected ranges) conditions.

For an operational system the following steps will be required:

- CONOPS establishment,
- Operational system set up for generation of climatology databases,
- Operational resources identification (computational resources, storage requirements, distribution methods),
- Statistical analysis package to be implemented, and
- Web display package to be implemented.

6.2.2 CONOPS Recommendation

We recommend that mission planners continue to request climatology data/information through FNMOD. The mechanics of data request from the FNMOD, data generation, staging the data at server site, and product retrieval and display can be automated. FNMOD will perform three major functions:

- Request Interpretation: All requests for climatic data should be “screened”. More than often, the requesters are 1) not aware of the METOC capability, 2) not familiar with the products, and 3) not familiar with the information content or limitations residing in product. It is much more efficient for FNMOD to screen the requests and provide appropriate products for the users. FNMOD is familiar with the process.

- Database Stratification: Climatology for a local region is subject to multiple climate regimes and conditions. FNMOD can stratify these climatic conditions for the users before they order the datasets. Also the contextual information associated with these stratifications should be provided to the users as well.

- Product Interpretation: All content information and limitations should be accompanying the data/products provided to the requesters. This is not a new task for FNMOD. It has been the practice that the FNMOD provides interpretation for the users.

- Figure 6.1 outlines the flow diagram for the CONOPS.

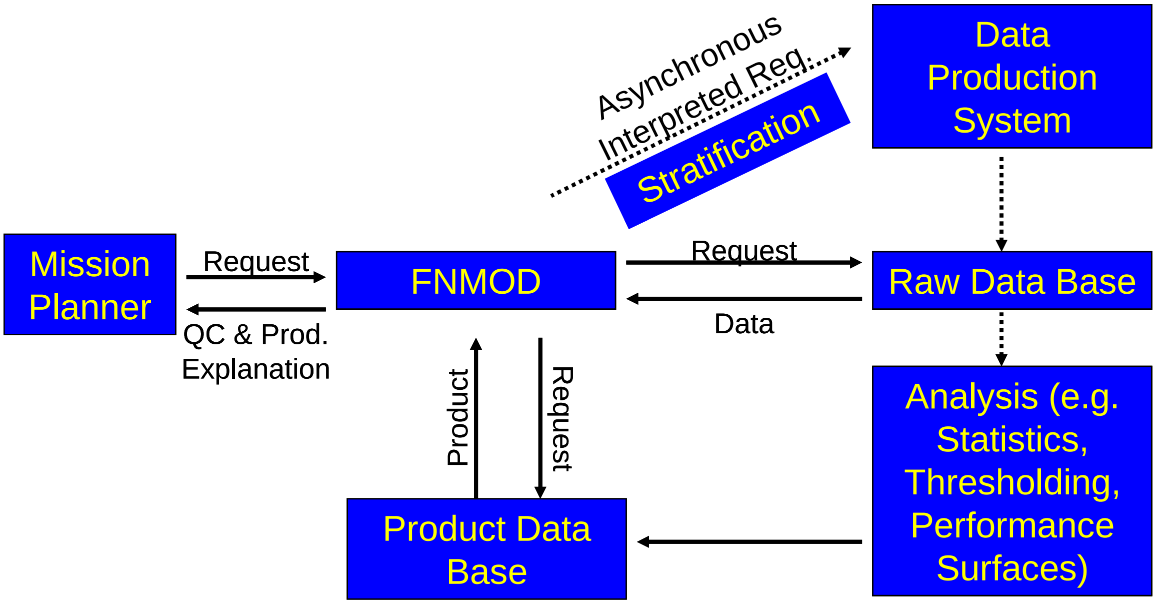


Figure 6.1: System Workflow Diagram

6.2.3 Decision Making

As discussed in Decision Modeling for Smart Climatology (Section 3.3), if METOC community needs to reach the decision makers, we have to express the cost/benefit ratio in their language or in their frame of mind (i.e. what is their priority?) In other words, why would the mission planners care about the climate conditions? It is vital for the METOC community to study the magnitudes of the consequence associated with the climatic anomalies or METOC events. Of course, it is an impossible task to study all the decisions against all possible METOC events, and analyze the consequence of each combination. However, we recommend that we should start to make an effort toward decision science. This project recommends that we study these severities of consequence by opportunities. When a decision maker/mission planner/user asks for climate or METOC information, we should take that opportunity to engage with them in an informal (but documented) assessment of the severity or the magnitude of the consequence or alternative consequences associated with that METOC event (How wet is wet enough for you to re-consider your action choice?). Over a sustained period, in a rather small effort, we should be able to establish a knowledge base for assessing the METOC impact on operations.

7 Acknowledgement

We gratefully acknowledge the support of our research sponsors, the Oceanographer of the Navy through the program office at PEO C4I&Space PMW-120 (PE 06033207N). We are also indebted to the following individuals for carrying out various tasks: Daniel Geiszler (SAIC) for generating most of the COAMPS data sets used in this study, Germana Peggion (University of New Orleans) for generating most of the NCOM data sets used in this study, Robert Owens (QinetiQ North America) for developing data conversion and analysis software, performing data download, conversion, and dataset construction tasks, and executing analysis runs and creating plots and spreadsheets from the results.

We also want to acknowledge our partners who have pointed us in the right direction and helped us shaping the concept and provided ample background information. At FNMOD, LCDR Tony Boyter was the most gracious host. He allowed us to interview FNMOD personnel for crucial information regarding what do the METOC customers want and how do they want it. At Naval War College, LCDR Michael Rocheleau and Professor Craig Koerner gave us a glimpse of what and how the climatological information is used by a customer. Also, LCDR Rocheleau and his team provided us some key with/without experiments on several of METOC products. Special thanks to Dr. Eva Regnier at Naval Postgraduate School and Dr. James Hansen at Naval Research Laboratory for introducing METOC issues associated with Decision Science and the concept of Risk Management Matrix. We owe special thanks also to Professor Tom Murphree at the Naval Postgraduate School for allowing us to use two of the long-term climatic trend figures and contributing challenging ideas to our study.

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NCAR: http://www.ucar.edu/org/about-us.shtml
SODA: http://www.met.rdg.ac.uk/~swr02ldc/SODA.html
NCEP/NCAR 1: http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml
NCEP/NCAR 2:www.ncep.noaa.gov/
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Decision Modeling for Smart Climatology by Eva Regnier, 2008, Naval Postgraduate School Technical Report (NPS-64-08-001), 55pp. For a copy, please email to Ted Tsui at Naval Research Laboratory, Monterey, CA

8 APPENDICES

8.1 Appendix A: Examples of Climatic Data Sources

National Oceanographic and Atmospheric Agency (NOAA) National Climatic Data Center (NCDC), Asheville, NC

NCDC is the world's largest active archive of weather data. NCDC produces numerous climate publications and responds to data requests from all over the world. NCDC operates the World Data Center for Meteorology which is co-located with NCDC, and the World Data Center for Paleoclimatology which is located in Boulder, Colorado. NCDC supports a three tier national climate services support program - the partners include: NCDC, Regional Climate Centers, and State Climatologists.

More climate data is also openly available from a gateway to data for the geosciences, the Community Data Portal (CDP), a collection of earth science datasets from NCAR, UCAR, UOP, and participating organizations. The statistics of what is available include 8000+ Collections; 1,169,041 Files; 6.3TB Total Size.

The climate data nested collections that are provided include the following:

- Arctic Regional Climate Model Intercomaprison Project (ATLAS)
- Asian Pacific Regional Aerosol Characterization Experiment (ACE-ASIA)
- Arctic Regional Climate Model Intercomaprison Project (ATLAS)
- Asian Pacific Regional Aerosol Characterization Experiment (ACE-ASIA)
- Carbon Data-Model Assimilation (CDAS)
- CCM2 T170 Precipitation, Cloud Fraction and Wind
- CCM2 T170 Total Precipitable water
- CCM3 T170 Cloud and Precipitation Simulation
- Center for Ocean-Land Atmosphere Studies (COLA) Climate Modeling Data Sets
- Climate Analysis Section (CAS) Climate Indices
- Climate Analysis Section (CAS) Satellite Data
- Climate Analysis Section (CAS) Surface Data
- Climate System Model Visualizations
- Climatological and Monthly-Mean Grids Datasets 270 - 299
- Climatology Interdisciplinary Data Collection (CIDC)
- Community Climate System Model (CCSM)
- Coupled Ocean Atmosphere and European Climate (COAPEC)
- Daily Surface Weather Data and Climatological Summaries (DAYMET)
- Data Support Section (DSS) Climatological Data
- Data Support Section (DSS) Ship Data
- Data Support Section (DSS) Special Meteorological Analyses
- Earth Radiation Budget Experiment (ERBE)
- Effective Atmospheric Angular Momentum (EAAM)
- El Nino Visualization

- European Centre for Medium-Range Weather Forecasting (ECMWF) Datasets (Climatologies)
- GIS Climate Change Scenario Project
- Global Ocean Surface Temperature Atlas Plus (GOSTAplus)
- Greenhouse Gases and Sulfate Aerosols
- Intergovernmental Panel on Climate Change (IPCC)
- International Satellite Cloud Climatology Project D1 dataset
- International Satellite Cloud Climatology Project D2 dataset
- International Satellite Cloud Climatology Project Data - C2 (ISCCPD-C2)
- International Satellite Land Surface Climatology Project (ISLSCP)
- Met Office - GISST/MOHMATN4/MOHSST6 - Global Ice coverage and SST (1856-Present)
- Met Office - HadISST 1.1 - Global sea-Ice coverage and SST (1870-Present)
- Monthly Mean Raobs
- National Centers for Environmental Prediction (NCEP) Climate Data
- NCEP/NCAR Reanalysis Data
- NCAR Historical Vasualizations
- Network for the Detection of Stratospheric Change (NDSC)
- Pan American Climate Studies (PACS)
- Parallel Climate Model (PCM)
- Portable Unified Model (PUM) software from the Met Office
- Satellite Observed Ozone Data
- Sea Ice and CO2 Levels
- Stratospheric Circulation Simulation
- Sulfate Aerosol Evolution
- Surface Heat Budget of the Arctic Ocean Project (SHEBA)
- Surface Radiation Budget (SRB)
- Temperature Differences Due to CO2
- UGAMP Ozone Climatology
- Upper Troposphere and Lower Stratosphere distribution of ozone (UTLS-OZONE)
- Vegetation/Ecosystem Modeling and Analysis Project (VEMAP)
- Whole Atmosphere Community Climate Model (WACCM)
- World Land Surface Temperature Atlas (1992-1993)

National Oceanographic and Atmospheric Agency (NOAA) the Climate Prediction Center (CPC), Washington DC.

NOAA/CPC is responsible for issuing seasonal climate outlook maps for one to thirteen months in the future. In addition, the CPC issues extended range outlook maps for 6-10 and 8-14 days as well as several special outlooks, such as degree day, drought and soil moisture, and a forecast for daily ultraviolet (UV) radiation index. Many of the outlook maps have an accompanying technical discussion.

The CPC's outlook and forecast products complement the short range weather forecasts issued by other components of the National Weather Service (e.g. local Weather Forecast

Offices, and National Centers for Environmental Prediction). These weather and climate products comprise the National Weather Service's Suite of Forecast Products.

- One-Month to Three-Month Climate Outlooks: The CPC issues maps showing the probabilities of temperature, precipitation and sea surface temperatures (SSTs) deviation from normal for the next month and three month periods. These outlooks are issued from 2 weeks to 13 months in advance, for the lower 48 states and Hawaii and other Pacific Islands. In addition, seasonal climate outlooks show average temperature (degrees Fahrenheit) and precipitation (inches) for the lower 48 states by climate regions, and probability of exceedance outlook.

- Extended Range Outlooks: CPC issues 6-10 Day and 8-14 Day Outlook maps showing probabilities of temperature and precipitation departing from normal, with an accompanying technical discussion. An excessive Heat Index Outlook (April-September) and Wind Chill Index Outlook (October-March) for 6-10 days are made every day.

- Special Outlook Products: CPC also issues a Palmer Drought Outlook, Weekly Degree Day Outlook, 14-day Calculated Soil Moisture Outlook, Probability of Exceedance Outlook, daily UV Index Forecast, Atlantic and East Pacific Hurricane Outlooks and verification of seasonal outlooks.

Columbia University, New York, NY

Based at Columbia University the International Research Institute for the Climate and Society (IRI)/Lamont-Doherty Earth Observatory (LDEO) Climate Data Library contains over 300 datasets from a variety of earth science disciplines and climate-related topics. It is a powerful tool that offers the following capabilities at no cost to the user:

- access any number of datasets;
- create analyses of data ranging from simple averaging to more advanced EOF analyses;
- monitor present climate conditions with maps and analyses at the Map Room site which provides a collection of maps and analyses used to monitor climate conditions;
- create visual representations of data, including animations;
- download data in a variety of commonly-used formats, including GIS-compatible formats
- monitor El Niño-Southern Oscillation (ENSO) and provides ENSO information.

National Center for Atmospheric Research (NCAR), Boulder, CO

NCAR has developed the Global Climatology Analysis Tool (GCAT) which is capable of generating fine-scale (3.3km) climatological analyses anywhere around the globe. For example, in a given month, analyses for each of the past 40 years are generated. Uncertainty in the mean analyzed meteorological fields is derived from the ensemble and, for risk assessment, can be input into plume models, such as the DOD HPAC application.

Specifically by applying:

- NCAR's MM5-based Real-Time Four-Dimensional Data Assimilation (RT-FDDA) system;
- the NCEP-NCAR Reanalysis Project (NNRP) 2.5 degree, 60+ years gridded model dataset for lateral boundary conditions; and
- 3) observations from the NCAR ADP historical repository,

GCAT creates a set of probabilistic forecasts and plume products to support the National Ground Intelligence Center's (NGIC) mission for Chemical, Nuclear, Biological and Radiological (CNBR) consequence analysis. GCAT uses the climatological information generated from RT-FDDA, and couples it to the Second order Closure Integrated PUFF (SCIPUFF) dispersion model, which is part of the Defense Threat Reduction Agency's (DTRA) Hazard Prediction and Assessment Capability (HPAC) toolset. This automated system takes advantage of the Linux cluster technology to perform the necessary climatological and plume-modeling computations. Outputs consist of data files and images that can be downloaded through a web interface.

Mesoscale analyses of current climates can be used for many purposes, including the optimal siting of wind-energy farms and airports, calculating the most probable direction of the transport of hazardous material at some future date and time, and scheduling the time and season for events that require specific meteorological conditions. To construct such climatographies for the many areas of the world where there are few routine four-dimensional (4D) observations of the atmosphere, RAL has developed a Climate Four-Dimensional Data Assimilation (Climate-FDDA) system that uses MM5/WRF to downscale present-day climates from archived global analyses.

The Climate-FDDA system is able to generate a 4D description of the diurnal and seasonal evolution of atmospheric processes, with a focus on the boundary layer. Unlike point measurements, the gridded fields define coherent multi-dimensional realizations of complete physical systems. Not only does the Climate-FDDA system define mean values of variables as a function of season and time of day, extremes are also estimated, and example days are produced.

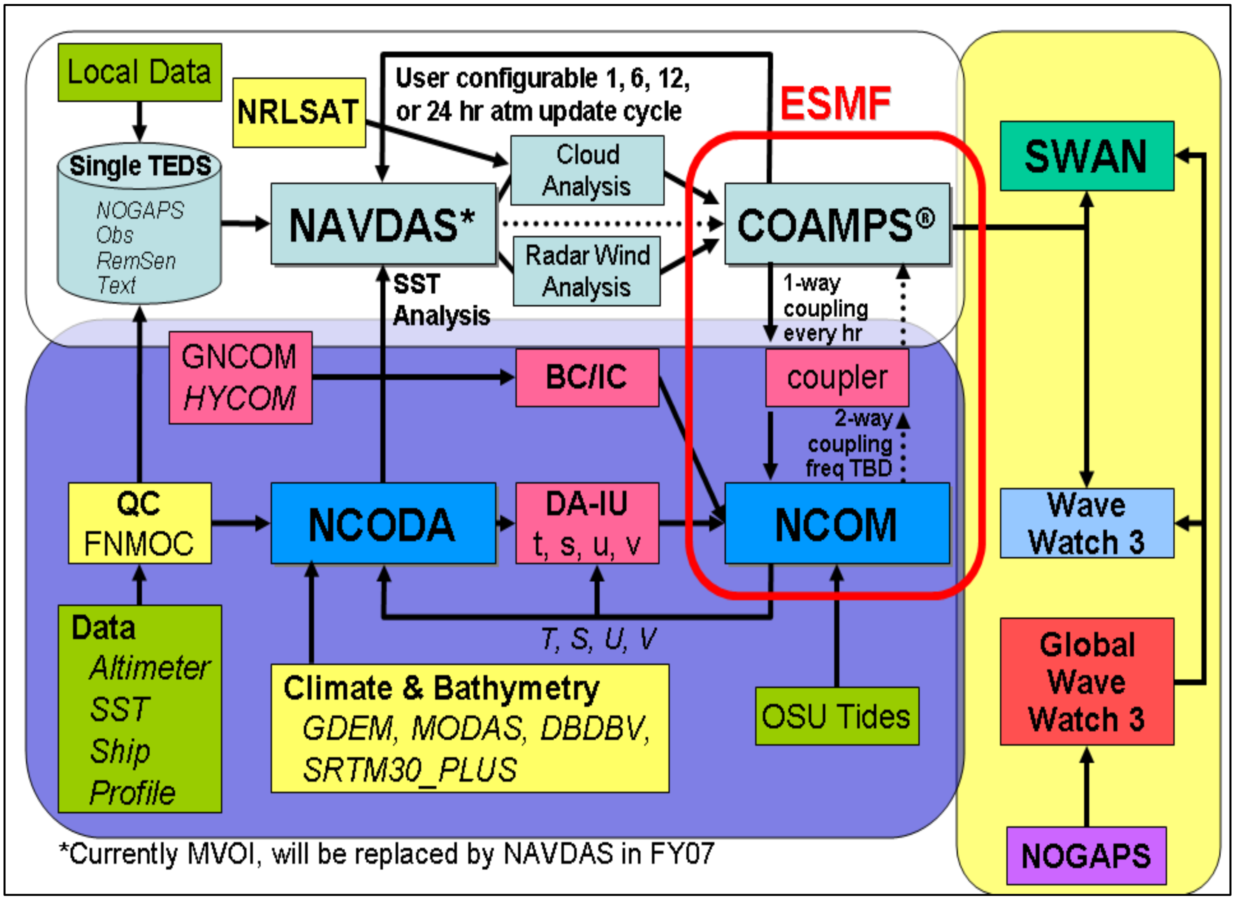
As an example of one Climate-FDDA application, a calculation can be made of the probability that 30-m above-ground-level winds will exceed 10 m s-1 in the month of February in southern Europe, where such an analysis would be valuable for wind-energy prospecting. These statistics are based on a 20-year downscaling from the NCEP-NCAR Reanalysis Project global data set.

8.2 Appendix B: Climatology Data Sets Available through FNMOD

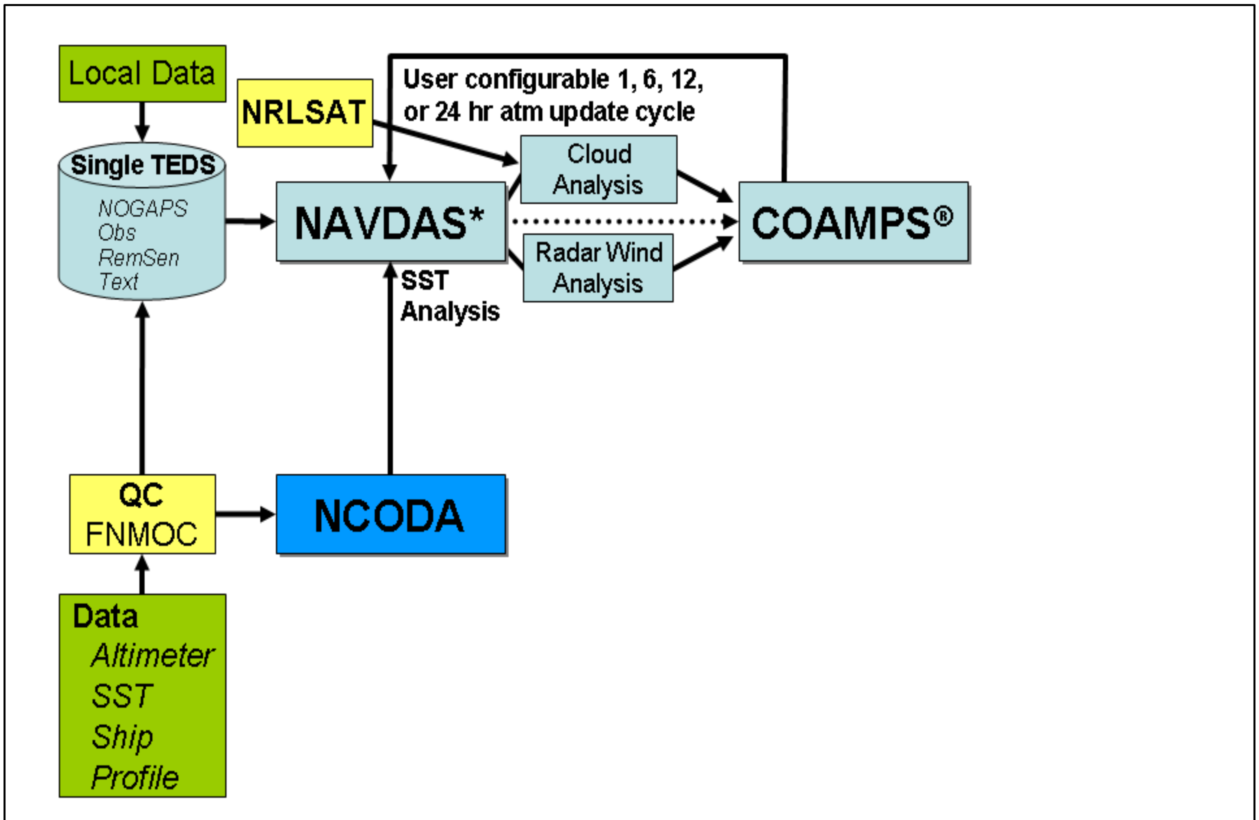
Available Climatology Data Sets				
Name	**Abbrev**	**Model Type**	**Resol**	**Time Span**
U. S. Navy Operational Global Atmospheric Prediction System	NOGAPS	Atmospheric	1º	Jan 97 - present
U. S. Navy Operational Global Atmospheric Prediction System	NOGAPS	Atmospheric	0.5º	Jan 04 - present
Derived Atmospheric Fields	DAF	Atmospheric	1º	Apr 99 - present
Navy Multivariate Optimum Interpolation Analysis	MVOI	Atmospheric	1º	Sept 04 - present
Wave Action Model	WAM	Oceanographic	1º	Jan 97 - Aug 01
Wave Watch 3rd Revision	WAVEWATCH III	Oceanographic	1º	Aug 01 - present
Optimum Thermal Interpolation System	OTIS	Oceanographic		Oct 99 - Sept 04
Navy Coupled Ocean Data Assimilation	NCODA	Oceanographic		Oct 04 - present
Thermal Ocean Prediction System	TOPS	Oceanographic		Jan 97 - present
Global Ocean Data Assimilation Experiment	GODAE	Oceanographic		
Global Wave Watch 3rd Revision - 10 Year Reanalysis	WAVEWATCH III	Oceanographic Reanalysis		Jan 93 - Dec 02
Mediterranean Wave Watch 3rd Revision - 10 Year Reanalysis	WAVEWATCH III	Oceanographic Reanalysis		Jan 93 - Dec 03
Arabian Sea/Gulf SWAN 10 Year Reanalysis	SWAN	Oceanographic Reanalysis		Jan 93 - Dec 04
Taiwan SWAN 3 year Reanalysis	SWAN	Oceanographic Reanalysis	0.2º	Jan 1997 – Dec 1999
Taiwan SWAN 3 year Reanalysis	SWAN	Oceanographic Reanalysis	0.1º	Jan 1997 – Dec 1999
Taiwan SWAN 3 year Reanalysis	SWAN	Oceanographic Reanalysis	0.05º	Jan 1997 – Dec 1999
Surface Marine Gridded Climatology	SMGC	Marine Climatology	1º	Jan 1854 - Dec 1997
Global Marine Climatic Atlas	GMCA	Marine Climatology	1º	Jan 1854 - Dec 1998
Comprehensive Oceanographic and Atmospheric Data Set	COADS	Marine Climatology	1º	1854 - 1997
Worldwide Surface Climate Summaries		Surface Climatology		Jan 1854 - Dec 1999
Middle East Climate Graphs		Surface Climatology		
US Navy Local Climatological Data		Surface Climatology		
Historical Electromagnetic Propagation Conditions		Ducting Climatology		
Upper Air National Centers for Environmental Prediction Reanalysis		Upper Air Climatology		

8.3 Appendix C: Software Components and Data Flow for Smart Climatology

Software Components:

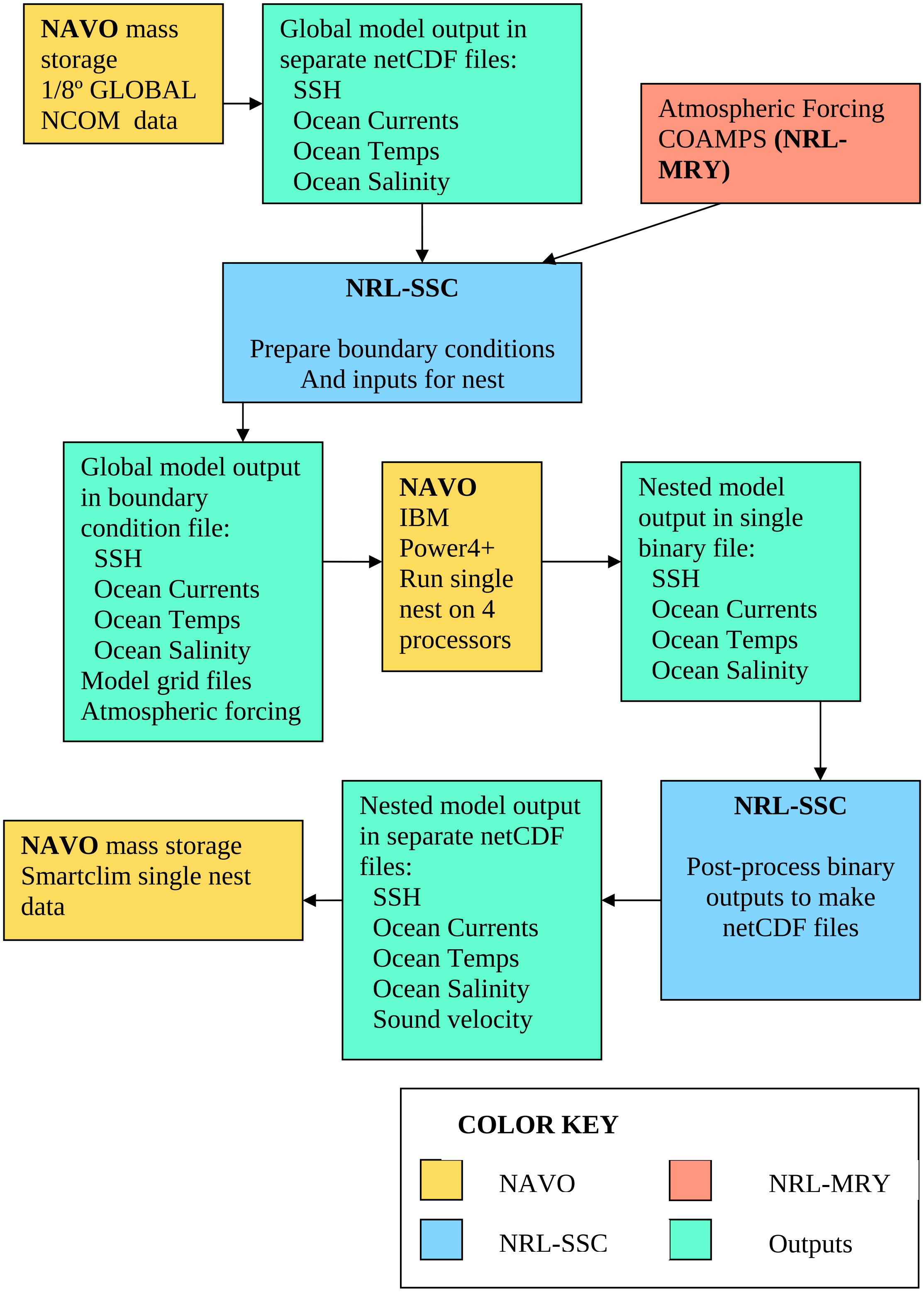


Data Flow for the Air-Ocean Coupled System: Part I - COAMPS-OS



*Currently MVOI, will be replaced by NAVDAS in FY07

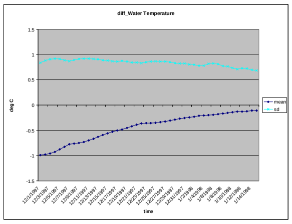
Data Flow for the Air-Ocean Coupled System: Part II – NCOM and SWAN

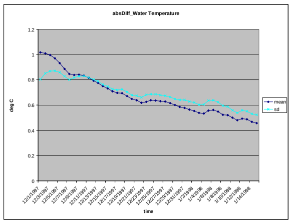


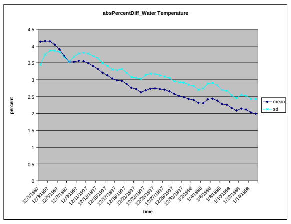
8.4 Appendix D: Cold Start and Sequential Run Comparison

Cold Start vs NCOM

Water Temperature (0, 1, 2m levels)

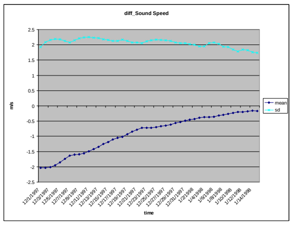


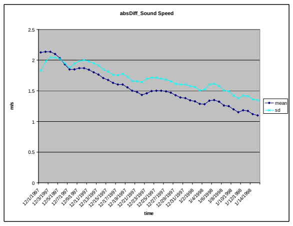


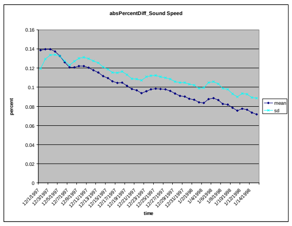


Cold Start vs NCOM

Sound Speed (0, 1, 2m levels)







Cold Start data for 45 days beginning 12/97; Data is 5km resolution.
19971200 NCOM cold start compared with the original NCOM data.
Differences between grids spanning 24 hour periods.

Top Left: diff = original - coldstart
Top Right: absDiff = | original - coldstart |
Bottom: absPercentDiff = (absDiff / original) * 100

8.5 Appendix E: Decision Modeling for Smart Climatology

Dr. Eva Regnier, Associate Professor of Decision Science in Defense Resources Management Institute (DRMI) and Visiting Associate Professor of Operations Research, Naval Postgraduate School, Monterey, CA, participated in the Smart Climatology project. She has documented the process of using smart climatology (or METOC) information in mission planning, and identifies challenges and key features of decision-relevant climatology data system.

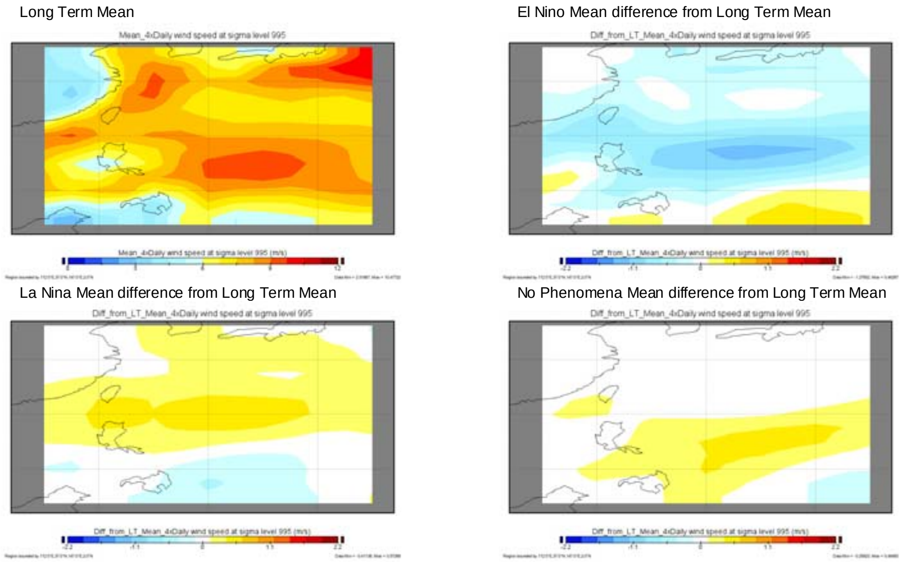
Her report listed below can be obtained through Naval Postgraduate School or requested through Ted Tsui, Naval Research Laboratory, Monterey, CA. The distribution of this unclassified report is unlimited:

> Regnier 2008, Decision Modeling for Smart Climatology, Naval Postgraduate School Technical Report NPS-64-08-0001, 56pp.

8.6 Appendix F: Selected Data Illustrations

The complete product data sets are stored on a DVD. For a copy of the DVD, please direct your request to Mr. Fred Petry, Naval Research Laboratory, Stennis Space Center, MS. fpetry@nrlssc.navy.mil.

February Means – Differences - Wind Speed



Long Term Mean

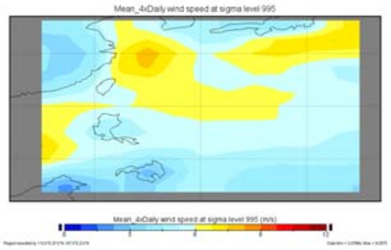
El Nino Mean difference from Long Term Mean

La Nina Mean difference from Long Term Mean

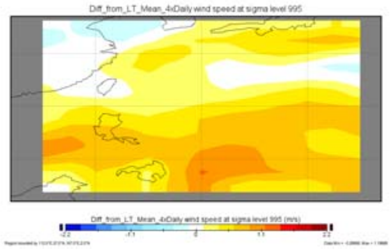
No Phenomena Mean difference from Long Term Mean

July Means – Differences - Wind Speed

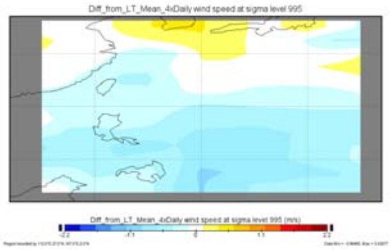
Long Term Mean



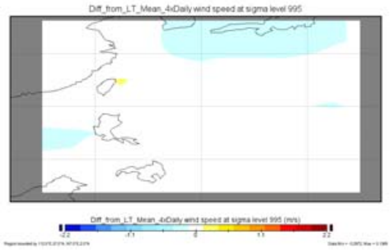
El Nino Mean difference from Long Term Mean



La Nina Mean difference from Long Term Mean

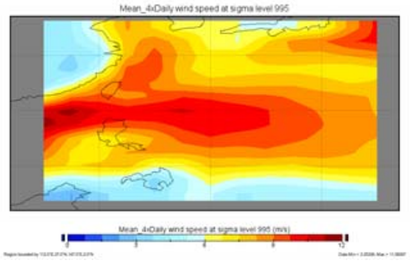


No Phenomena Mean difference from Long Term Mean

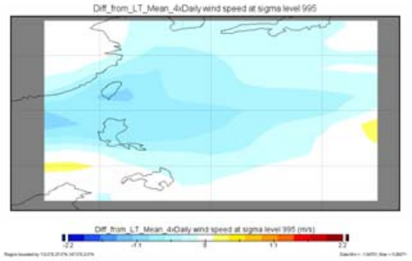


December Means – Differences - Wind Speed

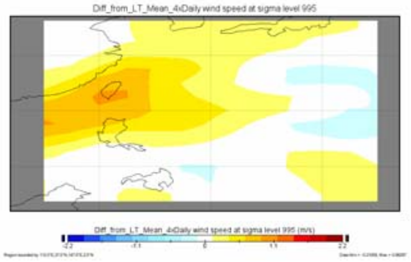
Long Term Mean



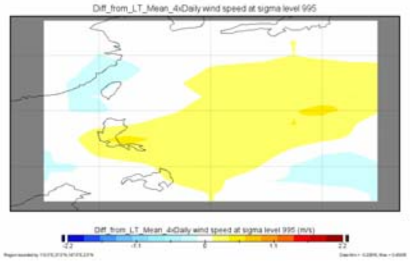
El Nino Mean difference from Long Term Mean



La Nina Mean difference from Long Term Mean

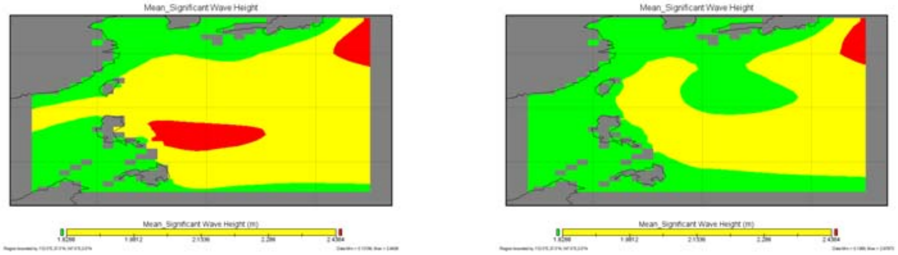


No Phenomena Mean difference from Long Term Mean



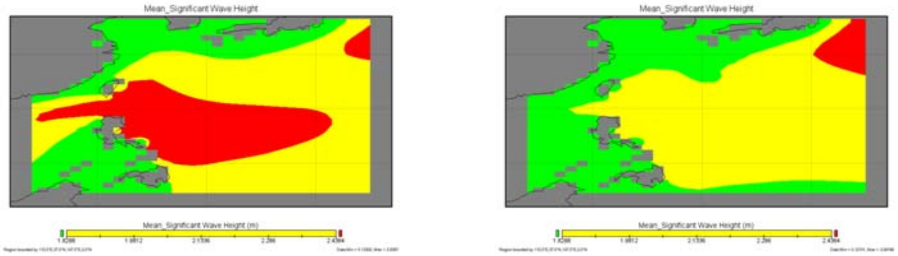
February Means - Threshold - Significant Wave Height

Green < 6 feet, Yellow 6-8 feet, Red > 8 feet



Long Term Mean Threshold

El Nino Mean Threshold

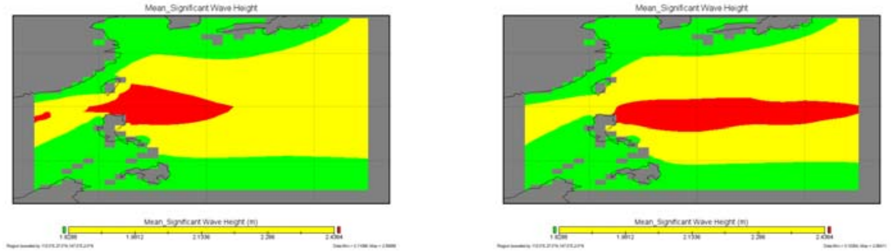


La Nina Mean Threshold

No Phenomena Mean Threshold

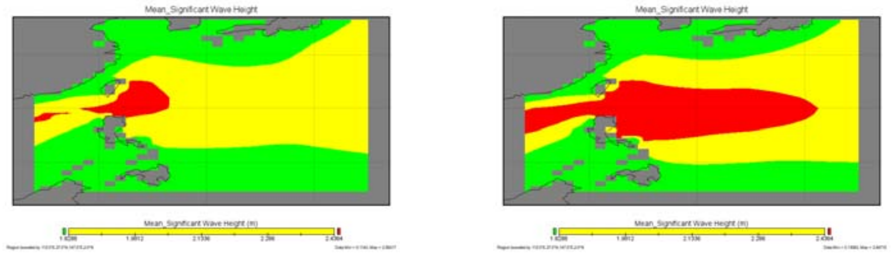
November Means - Threshold - Significant Wave Height

Green < 6 feet, Yellow 6-8 feet, Red > 8 feet



Long Term Mean Threshold

El Nino Mean Threshold



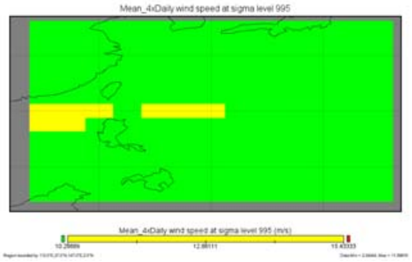
La Nina Mean Threshold

No Phenomena Mean Threshold

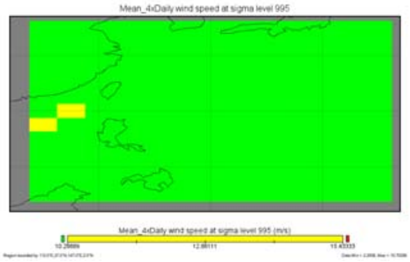
December Means - Threshold - Wind Speed

Green < 20 knots, Yellow 20-30 knots, Red > 30 knots

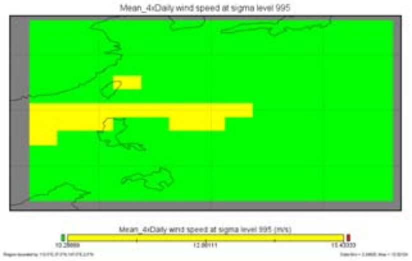
Long Term Mean Threshold



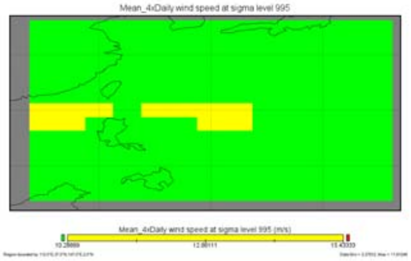
El Nino Mean Threshold



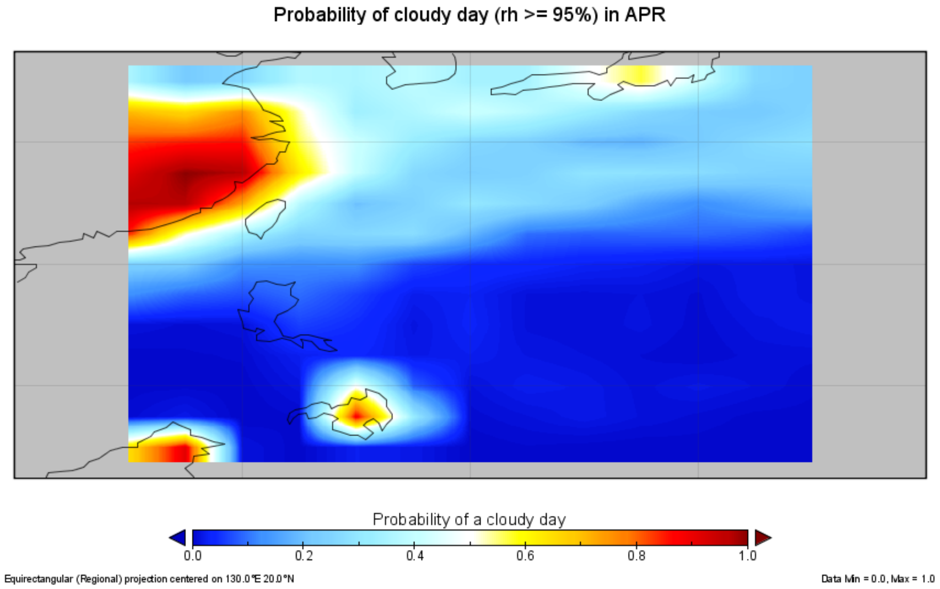
La Nina Mean Threshold



No Phenomena Mean Threshold



Occurrence (Frequency) Calculations



Data: NCEP/NCAR Reanalysis surface relative humidity for 1950-2006. Data occurs every 6 hours.

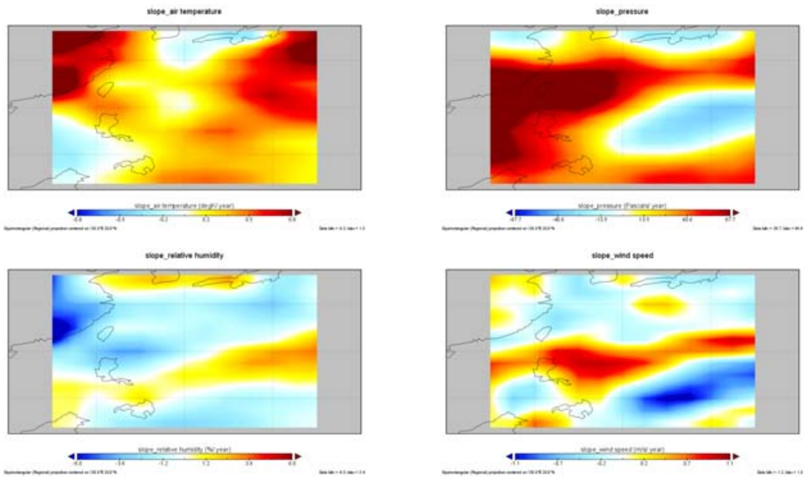
Criteria: cloudy day - a day with one or more data points >= 95% rh

Calculation: The data are partitioned into days (based on GMT) and the cloudy day criteria is applied resulting in a derived dataset of one grid per day coded as a 0 value for not cloudy and a 1 value for a cloudy day. The monthly mean of the derived data is then calculated. Each grid cell is independently calculated.

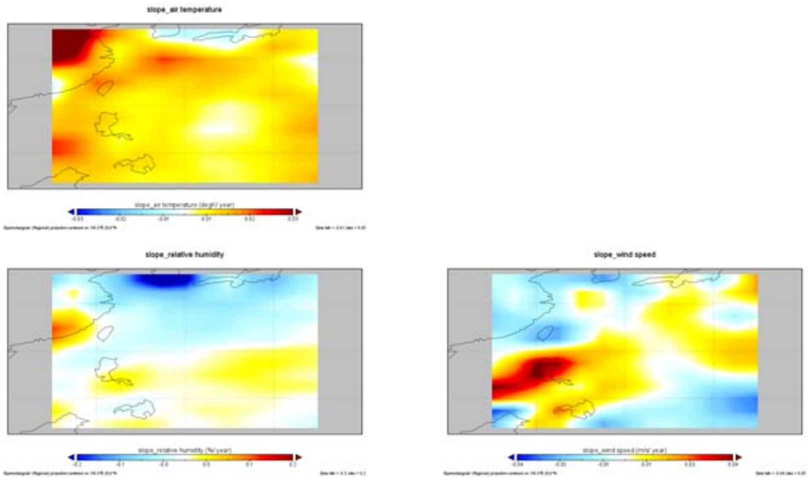
Notes: The calculation for the day partition actually calculates the frequency of occurrence of the criteria. The frequency was then post-processed into a simple occurrence for this example.

Interpretation: The plot depicts the probability of having a cloudy day for the given month.

February Trends



February Trends
NCEP 1950-2006

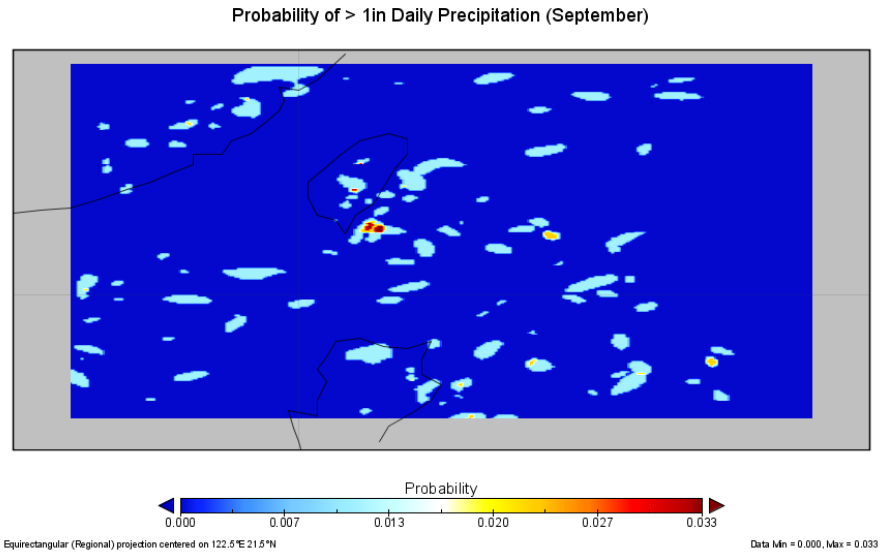


Top: NCEP/NCAR Reanalysis surface 1997-1999; Bottom: NCEP/NCAR Reanalysis surface 1950-2006

Calculation: The data are partitioned into months. For each month a linear regression calculation is performed on the data. Each grid cell is independently calculated.

Interpretation: The slope of the line fitted to the data indicates the trend in the data.

Probability of Precipitation



Data: COAMPS 1997-1999 (6hr data)

Criteria: daily precipitation > 1.0in

Calculation: The data are partitioned into days (based on GMT) and the precipitation amounts are summed. The criteria are then applied to the daily sums to determine occurrence. The monthly mean of the occurrences is then calculated. Each grid cell is independently calculated.

Interpretation: The plot depicts the probability of having days with greater than 1in of rain.