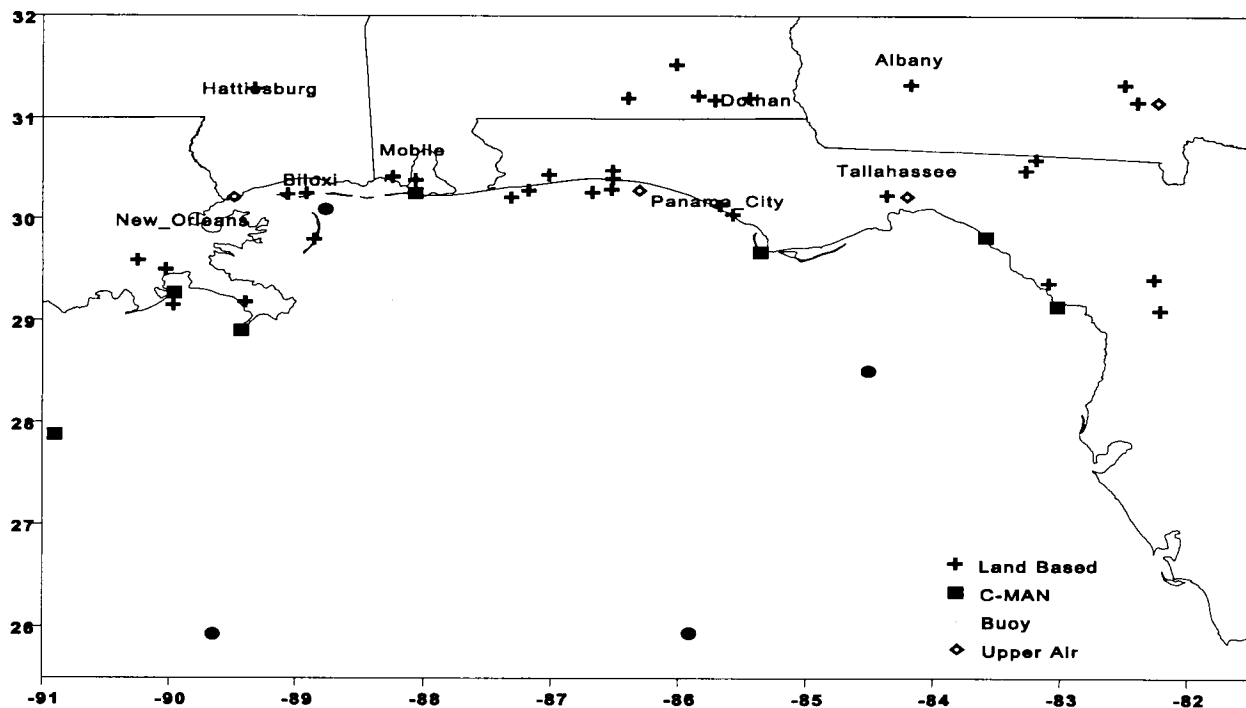




Meteorology of the Northeastern Gulf of Mexico: Data from 1995 to 1997

Final Report



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ABSTRACT

During this three-year study entitled "*Meteorology of the Northeastern Gulf of Mexico*" meteorological data for the 1995-1997 period from all available sources (National Weather Service, National Data Buoy Center, stations funded by Minerals Management Service, and other private sources) spanning the region of the Northeastern Gulf of Mexico (NEGOM) were collected. Estimates of the temporal/frequency contents and spatial scales of variation from these wind measurements were prepared. Humidity, air and sea-surface temperature measurements for the same period throughout the NEGOM were also analyzed and maps of the mean and variance fields, and estimate the temporal and spatial scales of variation were prepared. Calculations of mean and variance fields of surface wind stress and heat flux over the NEGOM were made and maps prepared of the quantities to estimate wind curl and vertical vorticity means and variability after effects of sea breezes were identified via filtering techniques. These data were used to study winter cyclogenesis and cold frontal passage in the NEGOM. Assessments were made of frontal passage and the modification of air masses affecting the local fields of temperature, humidity, pressure and other relevant meteorological parameters. Temporal and spatial variation scales were analyzed as functions of atmospheric and climatological types. Prognostic meteorological model output was also archived for the same period to supplement the observational data base for the NEGOM region. A computer-based "Expert" software system was developed that allows rapid, real-time access to the information and products developed in this study and aid in interpretation of current and forecast meteorological conditions.

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1. INTRODUCTION

BACKGROUND

There is renewed interest in oil and gas extraction activities in the Northeastern Gulf of Mexico (NEGOM). While indications are that the resources to be recovered are likely to be natural gas rather than oil, the threat of an oil spill in the NEGOM from these activities remains a great concern. Further, the National Environmental Policy Act (NEPA) mandates multidisciplinary environmental assessments of major Federal actions, such as oil and gas leases and related activities in the NEGOM. Such assessments could benefit from a meteorological database, especially in regards to oceanographic studies, oil spill trajectory estimates, air quality/plume dispersion calculations, and operational meteorological forecasts in the NEGOM.

The Minerals Management Service (MMS) contracted with ENVIRON International Corporation (ENVIRON) and its team to conduct a meteorological study of the NEGOM and to assemble and analyze such a database. ENVIRON's team was composed of Sonoma Technology Inc., AeroVironment Environmental Services, Evans Hamilton Inc., and Dr. S.A. Hsu of Louisiana State University.

The research conducted for this study resulted in a database useable for ongoing and future MMS studies in the NEGOM. In addition, the meteorological and oceanographic science communities should benefit from an improved understanding of atmospheric-oceanic interactions in this area. The database and software system products from this study may be used as a type of "handbook" to be utilized in the future by planners and analysts in the case of new industrial activities in the area, as well as on the occasion of monitoring and predicting conditions associated with non-routine or accidental hazardous events.

Knowledge acquired through the variety of analyses performed in this study will improve understanding of wind field patterns and sea breeze structures, atmospheric boundary layer behavior and structures, wind stress patterns on the sea surface and effects on ocean currents, cold air outbreaks, and boundary layer moisture fluxes across the land-sea interface. Further, the database and software products will be useful for several ongoing and proposed oceanographic studies in the NEGOM. One such study is the 1996-97 "Northeastern Gulf of Mexico Inner Shelf Circulation Study" program, designed to provide analyses of sea surface currents in the same area. It is anticipated that the raw data and products from this NEGOM meteorological study could be used to reconcile wind and stress patterns with trajectory data from "Northeastern Gulf of Mexico Inner Shelf Circulation Study" drifters and supply valuable information concerning the state of the atmosphere for any period of interest during that study.

STUDY OBJECTIVES

The objectives of this study were:

- 1) To collect wind data from available sources (National Weather Service, National Data Buoy Center, stations funded by Minerals Management Service, and other private sources) spanning the NEGOM, and estimate the temporal/frequency contents and spatial scales of variation from these measurements;
- 2) To collect humidity, and air and sea-surface temperature measurements throughout the NEGOM from these same institutions, prepare maps of the mean and variance fields, and estimate the temporal and spatial scales of variation;
- 3) To calculate mean and variance fields of surface wind stress and heat flux over the NEGOM and prepare maps of these quantities, to estimate wind curl and vertical vorticity means and variability with and without effects of sea breezes (i.e. with and without filtering techniques), and to use these data to the maximum extent possible to study winter cyclogenesis and cold frontal passage in the NEGOM;
- 4) To assess how frontal passage and the modification of air masses affect the local fields of temperature, humidity, pressure and other relevant meteorological parameters;
- 5) To estimate the transport of water-vapor and latent heat across water-land boundaries or coastlines and the properties of the atmospheric boundary layer, and to evaluate the temporal and spatial variation scales analyzed as functions of atmospheric and climatological forcing;
- 6) To collect, archive, and analyze the gridded output of a prognostic meteorological model (the Eta model) for the same time periods as the observational database.
- 7) To develop an ACCESS relational database containing both observed data, derived parameters, and gridded Eta model output for a two-year period (1996-1997).
- 8) To develop an “*expert*” *software system* to provide the users of the NEGOM meteorological database with a simple way to access and display the database and the data analysis products of the study.

The study was divided into two phases: (1) data collection followed by (2) data reduction, analysis, interpretation, and data synthesis, and report preparation.

STUDY AREA

The study area was defined as the region enclosed within the latitudes of 28°-32°N and the longitudes 82°-90°W. Figure 2-1 shows the geographical location of the study area.

DATA PERIOD

The data collection period of interest for this study was Jan 1, 1996 through December 31, 1997. 1995 observational data were also included in the ACCESS database because they were collected at the beginning of the study to test archival and analysis methods. 1995 Eta results were not available from NCAR. The ACCESS data base containing the 1995 observational data is available on magnetic tape from MMS, but 1995 observational data were not included in the NEGOMES software system.

DELIVERABLES AND PRODUCTS

In addition to this report and a prior interim report, a number of other deliverables were produced in this study. We acquired data from many agencies and processed more than 200 Gigabytes of meteorological data. From this raw data, we produced an immense relational database (Access) containing more than 5.2 Gigabytes of meteorological data. Users can easily access this data and rapidly sort and prepare reports of the data subsets utilizing MS Access97 software. The Access data set is available on magnetic tape cartridge from MMS or the National Climatic Data Center (NCDC). The ACCESS database contains all observational data and Eta model output for the study period.

In addition, we produced and delivered a software system called the North East Gulf of Mexico Expert System (NEGOMES). This software allows its users to browse the statistical and analysis products of the study. The system's graphical user interface capabilities allow users to easily access, select, sort, view, and navigate data maps and other tabular and graphical data products. The expert system also allows the user to quickly forecast and view projections of wind trajectories based on the stored wind statistics. The expert software system and supporting data are available from the MMS on a 5 CD-ROM set. The supporting NEGOMES database consists of nearly 3 Gigabytes of processed meteorological data and graphical displays that includes:

- 1996-1997 surface observation statistics;
- 1996-1997 aloft observation statistics;
- 1996-1997 gridded observation statistics;
- 1996-1997 transect data derived from observed surface data;
- 1996-1997 Eta gridded surface data;
- 1996-1997 Eta gridded 3-D data;
- 1996-1997 gridded Eta surface statistics.

2. OBSERVATIONAL DATABASE DEVELOPMENT

OVERVIEW

The study team conducted a survey of available measurement and modeling databases to compile into the MMS NEGOM meteorological database. The survey revealed that routine measurement data could be obtained only from the National Climatic Data Center (NCDC) and the National Data Buoy Center (NDBC). Meteorological data were also available from Louisiana State University for a special monitoring network on Breton Island.

NCDC was contacted to establish an agreement that NCDC would be the final repository of the MMS NEGOM meteorological database. A letter was prepared for NCDC documenting the agreement, which also explained the goals of the project, the agency funding the study, the project management staff, and a description of the data structures that would make up the final database.

Many organizations were contacted to inquire about the existence and availability of meteorological data for the study period. Ultimately, the MMS NEGOM observational meteorological database was populated using all 1995-1997 surface and upper air data in the NEGOM study area, purchased from the NCDC, 1995-1997 C-MAN and buoy data downloaded from the NDBC web site, and 1995-1996 Breton Island surface data obtained from Louisiana State University (LSU). The database was created using Microsoft® Access. This Access database was used as a basis for development of systems and programs to conduct statistical and diagnostic analyses. Recall that, while the study period is officially 1996-1997, we also collected 1995 data early in the study to test analysis and archival methods to be used later on the 1996-1997 data.

DATA ACQUISITION

Potential Routine Observational Data Sources

The following government agencies, and private companies were contacted for monitored meteorological data collected within the study area (28°N to 32°N, 82°W to 90°W) for 1995, 1996, and 1997:

- National Climatic Data Center (NCDC)
- National Data Buoy Center (NDBC)
- USGS Center for Coastal Geology
- Breton Island (National Park Service)
- Shell Oil Company
- Chevron
- Marathon
- Conoco

- Exxon
- Mobil
- Freeport-McMoran
- Amoco
- Texaco
- ORYX (Sun)
- British Petroleum
- U.S. Navy, Office of Naval Research
- U.S. Navy, Fleet Numerical, Naval Oceanographic Office
- NWS Cooperative Data
- Southern Regional Climate Center
- Neptune Sciences, Inc.
- Evans-Hamilton, Incorporated
- Ocean Weather
- University of Alabama – Dauphin Island Campus
- Pennsylvania State University
- Louisiana State University (LSU)

Only the NCDC, NDBC, and LSU were able to provide substantive and coherent meteorological data for the study region during the period of interest. The data specifically obtained are described later.

OBSERVATIONAL DATA ARCHIVAL AND DATABASE STRUCTURE

Data Acquired

Table 2-1 lists the data obtained from NCDC sites in the study area, with the date range of valid data for each. Table 2-2 lists the data obtained from NDBC sites in the study area, with the date range of valid data for each. Figure 2-1 displays the locations of all measurement sites within the analysis domain. Two sites are located outside this area: buoy 42002 to the west of 91°W, and Rawinsonde observation (RAOB) site 13889 near Jacksonville, FL.

Table 2-1.
Station data obtained from National Climatic Data Center (NCDC).

Station ID	Station Name	Station Type	Range of	Observables
13858	Eglin AFB/Valparais	Upper Air	95 - 97	RAOB
13861	Waycross/Ware Co.	Upper Air	1/95	RAOB
13889	Jacksonville International	Upper Air	95 - 97	RAOB
53813	Slidell Municipal	Upper Air	95 - 97	RAOB
93805	Tallahassee Regional	Upper Air	95 - 97	RAOB
722055	Ocala Muni (AWO8)	Land Based	95 - 97	wind, t, Td, vsb
722120	Cross City	Land Based	95 - 6/96	wind, t, Td
722130	Waycross/Ware Co.	Land Based	95 - 96	wind, t, Td, vsb
722135	Alma/Bacon	Land Based	95 - 97	wind, t, Td, p, vsb
722140	Tallahassee Regional	Land Based	95 - 97	wind, t, Td, p, vsb
722146	Gainesville Regional	Land Based	95 - 97	wind, t, Td, p, vsb
722160	Albany Municipal	Land Based	95 - 97	wind, t, Td, p, vsb
722166	Valdosta Regional	Land Based	95 - 97	wind, t, Td, p, vsb
722210	Eglin AFB/Valparais	Land Based	95 - 97	wind, t, Td, p, vsb
722215	Crestview/Bob Sikes	Land Based	95 - 97	wind, t, Td, p, vsb
722223	Pensacola Regional	Land Based	95 - 97	wind, t, Td, p, vsb
722225	Pensacola NAS	Land Based	95 - 97	wind, t, Td, p, vsb
722226	Whiting Field NAS-North	Land Based	95 - 97	wind, t, Td, p, vsb
722230	Mobile/Bates Field	Land Based	95 - 97	wind, t, Td, p, vsb
722235	Mobile Downtown	Land Based	95 - 97	wind, t, Td, vsb
722245	Panama City/Bay Co.	Land Based	95 - 97	wind, t, Td, vsb
722246	Duke Field/Eglin Aux	Land Based	95 - 97	wind, t, Td, p, vsb
722267	Troy Municipal	Land Based	95 - 97	wind, t, Td, p, vsb
722268	Dothan Municipal	Land Based	95 - 97	wind, t, Td, vsb
722269	Cairns AAF/Ozark	Land Based	95 - 97	wind, t, Td, p, vsb
722275	Andalusia/OPP Airport	Land Based	95 - 97	wind, t, Td, p, vsb
722276	Schell AHP	Land Based	95	wind, t, Td, vsb
722307	Golden Tri	Land Based	95 - 97	wind, t, Td, vsb
722309	Grand Isle	Land Based	95 - 97	wind, t, Td, vsb
722310	New Orleans Int'l Airport	Land Based	95 - 97	wind, t, Td, p, vsb
722316	New Orleans NAS	Land Based	95 - 97	wind, t, Td, p, vsb
722348	Pine Belt Regional AWOS	Land Based	95 - 97	wind, t, Td, vsb
747685	Gulfport-Biloxi	Land Based	95 - 97	wind, t, Td, p, vsb
747686	Kessler AFB/Biloxi	Land Based	95 - 97	wind, t, Td, p, vsb
747750	Tyndall AFB	Land Based	95 - 97	wind, t, Td, p, vsb
747770	Hurlbert Field	Land Based	95 - 97	wind, t, Td, p, vsb
747810	Moody AFB/Valdosta	Land Based	95 - 97	wind, t, Td, p, vsb

wind = wind speed and direction

vsb = visibility

Td = dew point temperature

p = surface pressure

t = surface air temperature

RAOB = rawinsonde observation

Table 2-2.
Station data obtained from National Data Buoy Center (NDBC).

Station ID	Station Name	Station Type	Range of	Observables
42001	Mid Gulf	Buoy	95 - 97	wind, t, p, wave
42002	West Gulf	Buoy	95 - 97	wind, t, p, sst, wave
42003	East Gulf	Buoy	95 - 9/96	wind, t, p, sst, wave
42007	OTP	Buoy	95 - 97	wind, t, p, sst, wave
42036	West Tampa	Buoy	95 - 97	wind, t, p, sst, wave, vsb
42039	Pensacola S	Buoy	95 - 97	wind, t, p, sst, wave
42040	Mobile South	Buoy	95 - 97	wind, t, p, Td, sst, wave
BURL1	Southwest Pass, LA	C-Man	95 - 97	wind, t, p
BUSL1	Bullwinkle Block 65	C-Man	8/95 - 10/96	wind, t, p, sst
CDRF1	Cedar Key, FL	C-Man	95 - 97	wind, t, p
CSBF1	Cape San Blas, FL	C-Man	95 - 97	wind, t, p, Td
DPIA1	Dauphin Island, FL	C-Man	95 - 97	wind, t, p, sst
GDIL1	Grand Isle, LA	C-Man	95 - 97	wind, t, p, sst, dp
KTNF1	Keaton Beach, FL	C-Man	95 - 97	wind, t, p

wind = wind speed and direction

t = surface air temperature

Td = dew point temperature

p = surface pressure

vsb = visibility

sst = sea surface temperature

wave = wave height, dominant period, mean period

Observational Data Screening and Validation

NCDC Data

NCDC performed extensive validation measures at their facilities before the data are made available to the public. All NCDC data were subjected to a four step quality review process that included:

- Checking the data for readability and inventorying;
- Converting the data into the DATSAV2 format;
- Processing the data through quality control programs that identify class (systematic) and sports (intermittent) errors and developing methods for correcting the data;
- Processing the data through a series of merge programs to produce a monthly file, and then a yearly file.

NDBC Data

NDBC performs extensive validation measures at their facilities before the data are made available to the public. The NDBC data were collected at remotely operating sites (buoys and C-MAN stations). NDBC routinely conducts real-time operational checks, including:

- Transmission parity error, range limit, and time continuity checks;
- Relational checks, such as examining the wind gust to wind speed ratio to check the quality of both measurements;
- Checks to ensure that the battery voltage is adequate for barometric pressure measurements.

After data arrives at NDBC, stricter range and time continuity limit checks are performed. These checks include:

- Comparison of measurements from duplicate sensors to ensure that they track together;
- A man-machine mix of quality checks, such as graphical procedures that relate wind speed and spectral wave energy;
- The use of time series plots, spectral wave curves, and computerized weather maps to detect errors.

Breton Island Data

We confirmed that the Breton Island data had been routinely subjected to Level I data validation checks by LSU. These checks are similar to those performed by NCDC on its data set.

Data Processing and Further Data Validation

We conducted additional data processing and validation to ensure that the reported data are valid and comparable to those collected by federal, state and local air pollution agencies. These procedures met the requirements and guidelines of the Environmental Protection Agency; e.g., Appendices A and B of 40 CFR 58; Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I and II (1994a, 1994b).

After the data were read from the original source media (9-track tapes, floppies, or 8-mm cassettes) and transferred to a workstation, they were processed by customized FORTRAN programs that parsed and indexed the data into the specified categories. These parsed files were then loaded into the Microsoft® Access database tables according to their categories. Various queries and screening procedures were set up in the database to identify outliers, which were flagged for review. These flagged data were reviewed by both data aides and the database manager (Level I data review).

The Level I data were output both electronically and in hard copy for further review. This second level of review (Level II) compared the data from adjacent stations for consistency (parameter-to-parameter comparisons for consistency and trends). This data review was performed by personnel familiar with the interrelationships of air quality and meteorological parameters, and potential local influences at the sites. The Level II validated data represent the "final data" produced for this project.

Observational Data Reformatting

The NCDC data did not contain decimal points when received. The decimal points were added into the data in accordance with the USAFETAC Climatic Database Users Handbook Number 4. Additionally, the NDBC data were reformatted as follows:

- Missing data codes were converted to -999 to be consistent with the NCDC data;
- The data units were changed to be consistent with the NCDC units. For example, temperatures in degrees Kelvin were converted to degrees Celsius, and visibility units in miles were converted to meters.

Observational Database Structure

The MMS NEGOM data were organized into ten Access tables by data type. This structure allows for efficient data querying for screening, validation, and reformatting, and for subsequent data analyses. The structure of the Access tables is described in Table 2-3.

Table 2-3.
Access database structure for observational data.

TABLE NAME	VARIABLES
<u>Station Information:</u>	ID, name, type, latitude, longitude, elevation, call letters
<u>Temperature and Pressure:</u>	ID, date, hour, dewpoint, temperature, sea level pressure, altimeter setting
<u>Winds:</u>	ID, date, hour, direction, speed
<u>Wind Gust:</u>	ID, date, hour, gust
<u>Sea Surface -Temperature:</u>	ID, date, hour, sea surface temperature
<u>Sea Surface - Wave:</u>	ID, date, hour, significant height, dominant period, mean period
<u>Sky Conditions:</u>	ID, date, hour, ceiling, cloud type, cloud cover
<u>Precipitation:::</u>	ID, date, hour, period of precipitation, precipitation
<u>Visibility:</u>	ID, date, hour, visibility
<u>Upper Air:</u>	ID, date, hour, (height, pressure, temperature, speed, direction, relative humidity) (repeat for each altitude) (standard encoding)

GRIDDED ETA MODEL ARCHIVE

In addition to the observational data, we also acquired from the National Center for Atmospheric Research (NCAR) the output of a prognostic meteorological model (the Eta model) for the 1996-1997 study period (NCAR, 1998). The Eta model is run twice each day by the National Center for Environmental Prediction (NCEP) to support routine NWS weather forecasting activities. NCAR is responsible for archiving the output of the twice daily Eta runs made by NCEP.

Our Access database contains gridded Eta model output at three hour intervals for the entirety of 1996 and 1997 (note: there are missing data in the Eta archived received from NCAR). These three-hourly gridded fields contain wind, temperature, and moisture information, have a horizontal spatial resolution of about 40 km, vertical resolution of tens of meters near the ground, and are available at the surface and at several aloft layers. The Eta data were organized into four Access tables by data type as shown in Table 3-2. The development of the Eta model output database is described in greater detail in Chapter 3.

ACQUIRING COPIES OF THE NEGOM METEOROLOGICAL DATABASE

The entire observational database and gridded Eta model output archives and the Access database format developed under this study has been submitted to MMS on magnetic tape cartridges along with this report. Furthermore, it has been submitted to NCDC as per our agreement. NCDC will distribute the data to interested parties as per agreement with the MMS.

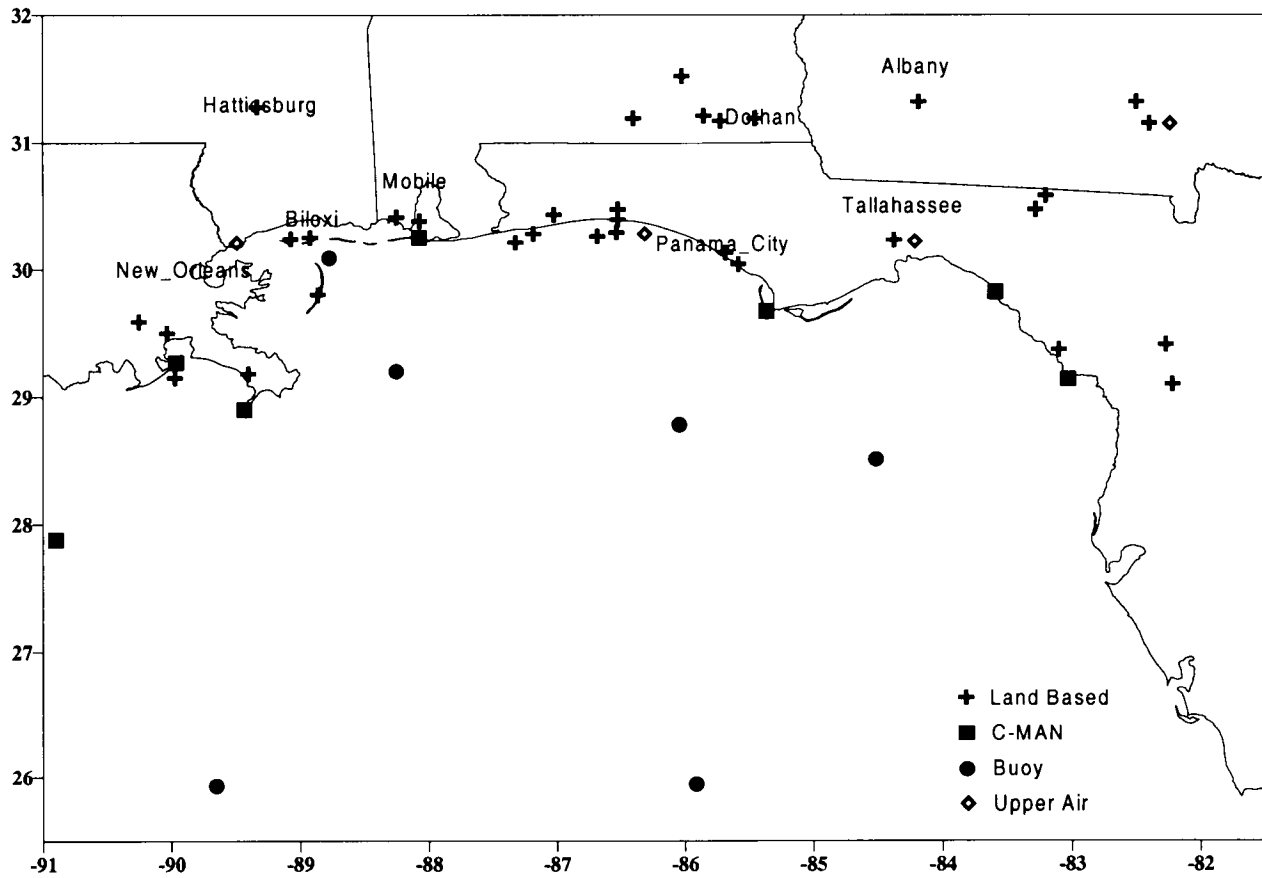


Figure 2-1. Location of land-based, buoy, C-MAN, and upper meteorological monitoring sites in the MMS NEGOM study area. (Note: coastline and state boundaries may not be accurately depicted).

3. ETA MODEL OUTPUT DATABASE DEVELOPMENT

Background

Offshore meteorological data sites are widely spaced and limited in number. Therefore, calculation of some parameters required in this study that involve spatial gradients (wind stress curl and vertical vorticity) were difficult and suspect (discussed at greater length below). Also, one of the intended uses of the data archive produced in this study is the analysis of LATEX drifter data. Ideally, concurrent gridded winds and temperatures for the entire 1996-1997 drifter program would be very useful in distinguishing between wind-driven and current-driven drifter motion. So, in addition to aiding in calculation of wind stress, wind stress curl, and vertical vorticity statistics, it was concluded that the best available gridded meteorological model output should be included within the study's data archive and in the expert system to more directly aid in the reconciliation of LATEX drifter data.

Thus, archived prognostic meteorological (weather) forecast model results were used to add spatial resolution afforded by solution of the governing primitive equations. Most recent prognostic meteorological models assimilate large volumes of observational data for initialization, so initial and early forecast fields are relatively faithful to observed conditions. For these fields, the prognostic models can be viewed as offering interpolation between observation points derived from detailed and sophisticated descriptions and solutions of the governing physics. Extraction of useful prognostic model products from model output archives has become more common in air quality/meteorological studies because it effectively capitalizes on the huge ongoing investments by U.S. government agencies in their daily forecasting simulations. Most importantly, prognostic model results should substantially enhance the information available to the users of this NEGOM database and expert data software system.

Typical output from a modern prognostic model for a two year period represents a very large volume of data (more than 65 gigabytes); the task involved manipulation, parsing, and analyses of hundreds of very large gridded model output archives.

AVAILABILITY OF PROGNOSTIC METEOROLOGICAL MODEL RESULTS FOR THE NEGOM REGION

We conducted a review of gridded meteorological model results archived by various agencies. The results of this review are summarized in Table 3-1. It was concluded that the NOAA/NCAR Eta model archives offered the greatest potential benefit to this study.

Since late 1995, NOAA's National Center for Environmental Prediction (NCEP) has been exercising the Eta model several times daily for routine weather forecasting purposes. The National Center for Atmospheric Research (NCAR) began archiving these NCEP runs in late

1997. NCAR also reconstructed Eta model output archives for the earlier NCEP runs made between October 1995 and late 1997.

The Eta model is an operational forecast model run every 12 hours to supply forecast fields out to 48 hours for the entire North American Continent, with special emphasis on precipitation forecasting. The model is initialized during a 12-hour "spinup" mode using a three-dimensional variational analysis, which assimilates wind, temperature, humidity, radiance, and precipitable water data from satellites (polar and GOES), rawinsondes, profilers, radars, and instrumented commercial aircraft. Output from the assimilation/initialization process include vertical profiles of wind, temperature, moisture, cloud water, turbulent kinetic energy, absolute vorticity, and bulk values such as precipitable water, convective available potential energy, stability and lifted indices, etc. Mixing height can be diagnosed from temperature and turbulence fields.

While the NCAR archive does include both initialization and forecast fields, only the 3-hourly initialization fields were of value to this particular study. The fields are available on a 40 km grid in a Lambert Conformal projection, with coverage across the entirety of North America and surrounding oceans (extending across the northern half of Mexico -- see Figure 7-12 for depiction of Eta's horizontal grid resolution) . This database supplies ample coverage across the northern Gulf of Mexico. Additionally the Eta archive offers vorticity fields as well; which drastically simplified the development of the various derived quantities dependent on surface wind and pressure patterns. The Eta model attempts to represent three-dimensional characterization of the atmosphere by solution of the Navier-Stokes equations of motion; which should improve our understanding of conditions in the NEGOM where there is shortage of three-dimensional data. With information extended in the vertical, certain analyses are greatly simplified yet more accurate, such as the estimation of latent heat flux across sea-land boundary (an especially difficult analysis with limited surface and sounding data), boundary layer characterization, etc. Finally, in contrast to other information sources such as satellites, there are fewer issues associated with the quality of information over/near land versus open ocean in prognostic model analysis fields, except as related to how well model grid and surface parameterizations resolve the land-sea interface.

Thus, the Eta analysis fields represent a valuable supplemental source of meteorological information within a single consistent dynamic- and energy-balanced arrangement. Spatial resolution is improved over the observation network to 40 km, and temporal resolution of 3 hours is comparable to the observation data.

USEFULNESS OF ETA MODEL OUTPUT FOR CALCULATING DERIVED QUANTITIES

One of the thrusts of the subject study, besides the compilation and statistical analysis of directly measured meteorological parameters in the northeast Gulf of Mexico, was to determine and analyze spatial and temporal patterns of several derived quantities (i.e., stress, fluxes, and boundary layer parameters). However, we found that the calculation of derived

quantities is often difficult for the Gulf due to the sparsity of necessary measurement data, particularly any parameters dependent upon humidity or spatial gradients of winds. Some parameters can be grossly calculated but may not lend themselves to a substantive level of analysis due to data sparsity and complexities associated with mid-gulf versus shoreline measurements. In particular, the determination of vorticity, stress curl, and heat fluxes are problematic. Future measurement studies aimed at this issue would likely require horizontal spacing between measurement instruments of less than 100km.

Chapter 5 discusses the manner in which the Eta model gridded output were used in this study to improve the calculation of derived surface and aloft meteorological parameters. Generally speaking, the Eta modeling output database provided us with wind and thermodynamic information with consistent temporal coverages and spatial scales on a regular orthogonal grid.

SCOPE OF ETA MODEL OUTPUT ARCHIVAL AND ANALYSIS EFFORTS

- Acquired 1996-1997 archived gridded NOAA/NCAR Eta model initialization fields
- Calculated geostrophic vorticity, wind stress curl, and boundary layer parameters for each grid point within our study domain; calculated mean and variance statistics of these parameters (see Chapter 5 for a discussion of the calculation procedures for these derived parameters).
- Archived gridded, three-hourly surface and upper level winds, temperatures, RH, mixing depth, vorticity, etc. within the NEGOM ACCESS meteorological database. Table 3-2 summarizes the structure and organization of the Eta Access database and statistics tables.
- Included this Eta model archive within the expert software system product of this study (NEGOMES).

Table 3-1.
Summary of available meteorological grid modeling archives.

SOURCE	MODEL	GRID RESOLUTION	COMMENTS
U.S. Navy	NOGAPS	240 km	'95 and '96 data only
U.S. Air Force	Relocatable Window Model	50 km	Limited Number of days in '95 & '96
NOAA	GCIP/ESOP-95	NA	Contours of Observed Data
NOAA	NMC	180 km	Monthly averages
NOAA	NGM	180 km	'95 & '96
NOAA/NCEP/NCAR	Eta	40km	'96 &'97
Purdue Univ.	Eta	80 km	'95-'97 but no surface wind data archived
NCEP/NCAR	MM5 Reanalysis	240 km	'95-'97
NOAA	Spectral Model	40 km typical	User-specific runs
ENVIRON/ASTER	RAMS	16 km	28 days, summer '93
U.S. Navy	COAMPS	40 km typical	User-specific runs

Table 3-2.
Configuration of the 1996-97 Eta ACCESS database.

Table Name	Variables on each record
Eta ID	Point ID Latitude Longitude X (easterly distance from southwest corner) Y (northerly distance from southwest corner) Level (Surface, 1000 mb, 850 mb)
Met Type	Year Julian Date Month Day Hour Season Meteorological Type
Surface Data	Point ID Year Julian date Hour Elevation above sea level Wind speed (derived) Wind direction (derived) U-component wind V-component wind Air temperature at 2 m Surface temperature Drag coefficient Specific humidity Sensible heat flux Latent heat flux Geostrophic vorticity (derived) Wind stress curl (derived) Moisture flux (derived) Ekman pumping velocity (derived) Bulk Richardson number (derived) Convective boundary layer height (derived)

Table 3-2.
Configuration of the 1996-97 Eta ACCESS database.(continued)

3D Data	Point ID Year Julian date Hour Height above sea level U-component wind V-component wind Temperature Specific Humidity
File Name	Description
Sfc-1996.mdb	1996 surface data
Sfc-1997.mdb	1997 surface data
stats-1996.mdb	1996 mean and variance of surface data
stats-1997.mdb	1997 mean and variance of surface data
Sfc-stats.mdb	1996 + 1997 mean and variance of surface data
3D-1996.mdb	1996 data at 1000 mb, 850 mb
3D-1997.mdb	1997 data at 1000 mb, 850 mb

4. METEOROLOGICAL TYPECASTING

PURPOSE

One of the goals of this project, besides the compilation and delivery of a complete three-year (1995-1997) observational database of meteorological parameters in the NEGOM, is to augment the raw database with statistical summaries of the data and to analyze the role of synoptic-scale weather features and patterns in defining regional-scale forcing. Such analyses will provide valuable resources into concurrent and future oceanographic studies, as well as the likely transport of pollutant plumes from accidental releases off-shore. In light of inter- and intra-annual meteorological variability in the NEGOM, it was useful to provide statistical measures on various temporal scales, such as season, year, and data period (1995-1997), as well as stratified by meteorological regime.

The NEGOM Expert System described in Chapter 7 not only provides a simple interface tool to access both the raw data and the statistical summaries, but also can be used in a forecast mode to estimate likely air and water parcel trajectories based upon the three-year climatology. A sequence of probable parcel paths can be determined from statistical information generated for a particular location, season, and meteorological regime that agrees most closely with current and forecast weather patterns. Caution should be exercised in using this climatological database since the period involved is quite short, and it includes an "El Nino" episode.

Understanding systematic synoptic weather analyses required us to develop procedures for identifying key meteorological patterns in the NEGOM so that (1) each day in the database can be classified into a particular regime for the purpose of generating pattern-specific statistics for the meteorological parameters, and (2) so that a user of the Expert System can select one or more of these patterns to match current and forecast conditions, thereby displaying the most appropriate statistical fields. This section describes the procedure by which ten synoptic-scale weather patterns were selected to describe the range of conditions observed during the 1995-97 data period. General guidance is also provided for users of the Expert System in choosing the most appropriate pattern from common weather and forecast charts.

PREVIOUS STUDIES OF METEOROLOGICAL CATEGORIES

The selection of weather regimes began with a review of literature sources regarding the synoptic weather types previously identified for NEGOM region. Only two studies were revealed by our search: Muller (1977) and Muller and Willis (1983)

Because there were no continuous 30-year weather observations over the Gulf, Muller (1977) employed a 30-year normal statistics from New Orleans, Louisiana as a first approximation. Using the day-to-day weather at a National Weather Service station at Moisant Airport, and on the basis of atmospheric circulation patterns, he organized the data into relatively few types to provide an environmental and economic baseline inventory for the surrounding region. The

synoptic weather situation at 0600 CST on each day from 1961 through 1990 was classified into one of eight all-inclusive synoptic weather types (see Table 4-1 and Figure 4-1). Brief descriptions of each of Mullers' eight synoptic-type are as follows (for more detail, see Muller and Willis, [1983]).

- Pacific High (PH): Following a "Pacific" cold front, this weather type is normally fair and mild with west to northwest winds. Ahead of the front, stronger southerly winds may prevail.
- Continental High (CH): This weather type is associated with polar or arctic outbreaks. North or northeasterly winds will prevail over a large section of the Gulf.
- Frontal Overrunning (FOR): This cloudy and rainy type occurs frequently when cold fronts become stationary along the Gulf coast or over the northern or central Gulf. For its effect on the Gulf, see Hsu (1992 and 1993).
- Coastal Return (CR): The wind around the high pressure over east Canada will bring southeasterly and southerly flow over the Gulf.
- Gulf Return (GR): Similar to the CR type, the wind direction is mainly from the southeast and south but the wind speed is higher due to the developing low-pressure system over north Texas.
- Frontal Gulf Return (FGR): When a cold front is approaching the Gulf from the northwest, the return flow ahead of the front becomes increasingly turbulent and stormy.
- Gulf High (GH): When a high-pressure system prevails over the Gulf, calmer weather will be the result.
- Gulf Tropical Disturbance (GTD): Any tropical weather system such as a hurricane prevails over the Gulf.

The frequency of occurrence of each weather type at New Orleans, Louisiana was compiled for a 30-year normal (i.e., from 1961 through 1990) (see Table 4-1). For brevity, four types are plotted in Figure 4-2. It can be seen that the frequency of GR peaks in April; GH in July; CH in October; and FOR in January. This sequence mirrors the progression of the seasons. From a climatological point of view, three climatic indices are presented in Figure 4-3. The Continental Index includes types CH and FOR, indicating a measure of the frequency of continental polar air masses with northerly winds and cooler, drier air. As expected, the Continental Index peaks mainly in the fall and winter. On the other hand, the Tropical Index consists of maritime tropical air, which includes types GR, FGR, GTD, GH, indicating more southerly flow with warm and moist air from the Gulf. As shown in Figure 4-3, the Tropical Index peaks during the summer and is lowest during late fall and winter, which is opposite of the Continental Index. The third index in Figure 4-3 is the Storminess Index, which includes type FOR, FGR and GTD. On the average, it is highest in mid-winter in association with frontal activity.

The following synoptic climatology derives from this review:

- (1) From May through mid-August, more than 50% of the time, the northeastern Gulf of Mexico is dominated by the tropical weather with winds mainly from the south. From mid-September through mid-February, more than 50% of the time this region is influenced by the continental weather types with winds from the north.
- (2) The march of the seasons can be represented by four major weather types over the northeastern Gulf. The Gulf Return type peaks in April for Spring, Gulf High in July for summer, Continental High in October for fall, and Frontal Overrunning in January for winter.
- (3) Climatological indices for the study area are also investigated. It is found that they can be grouped into three indices: Continental, Tropical and Storminess. As expected, the Continental Index peaks mainly in the fall and winter, Tropical Index in summer, and storminess Index in winter caused mainly by atmospheric frontal activity.

Allowing for differences in observational databases, these findings are generally consistent with earlier studies (Franceschini [1953], Mueller [1977], and Muller and Willis [1983]).

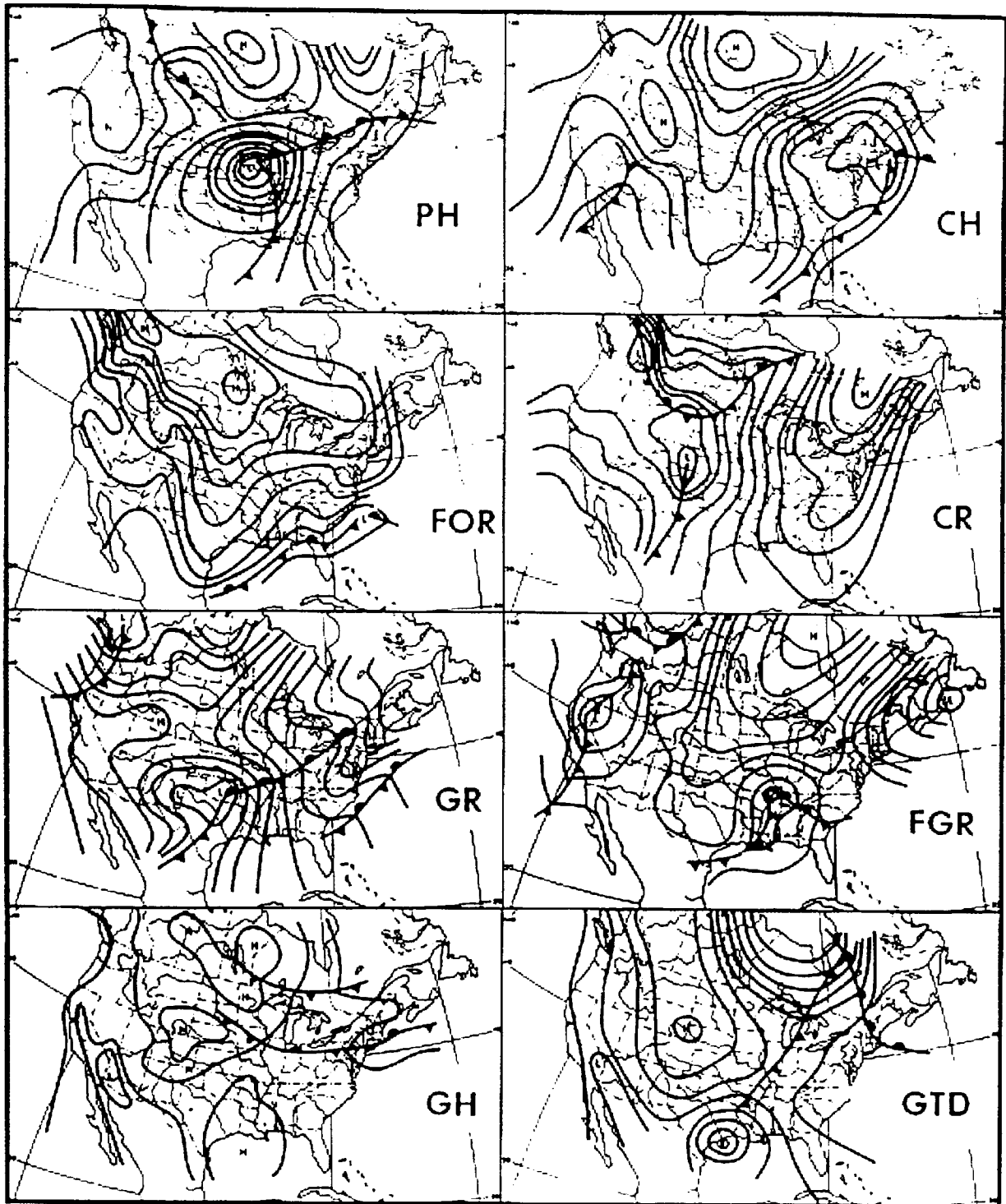


Figure 4-1. Representative examples of eight synoptic weather types for New Orleans, Louisiana (from Muller and Wax, 1977).

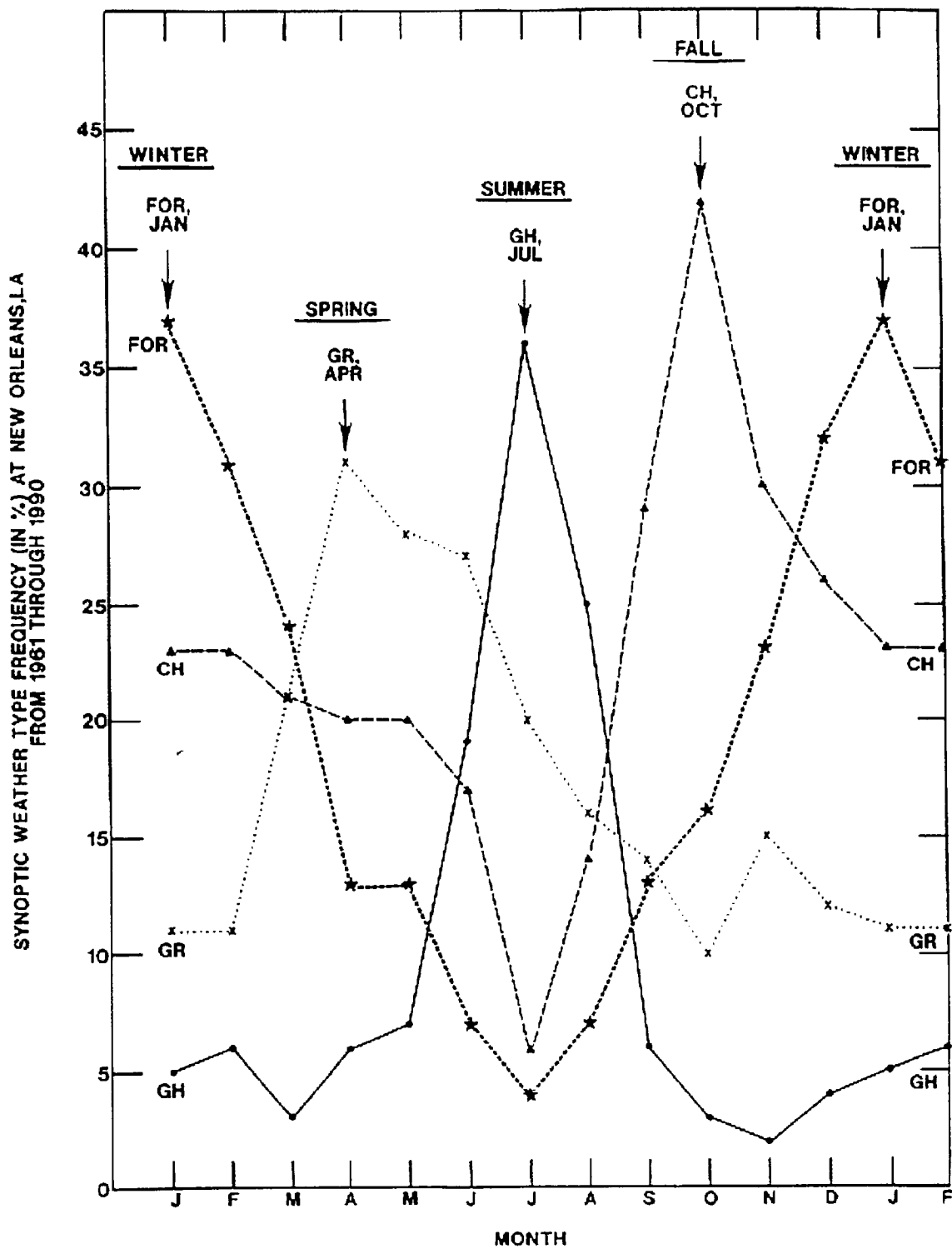


Figure 4-2. The frequency of occurrence for four weather types over New Orleans, Louisiana from 1961 through 1990 based on the data provided by the Louisiana Office of State Climatology.

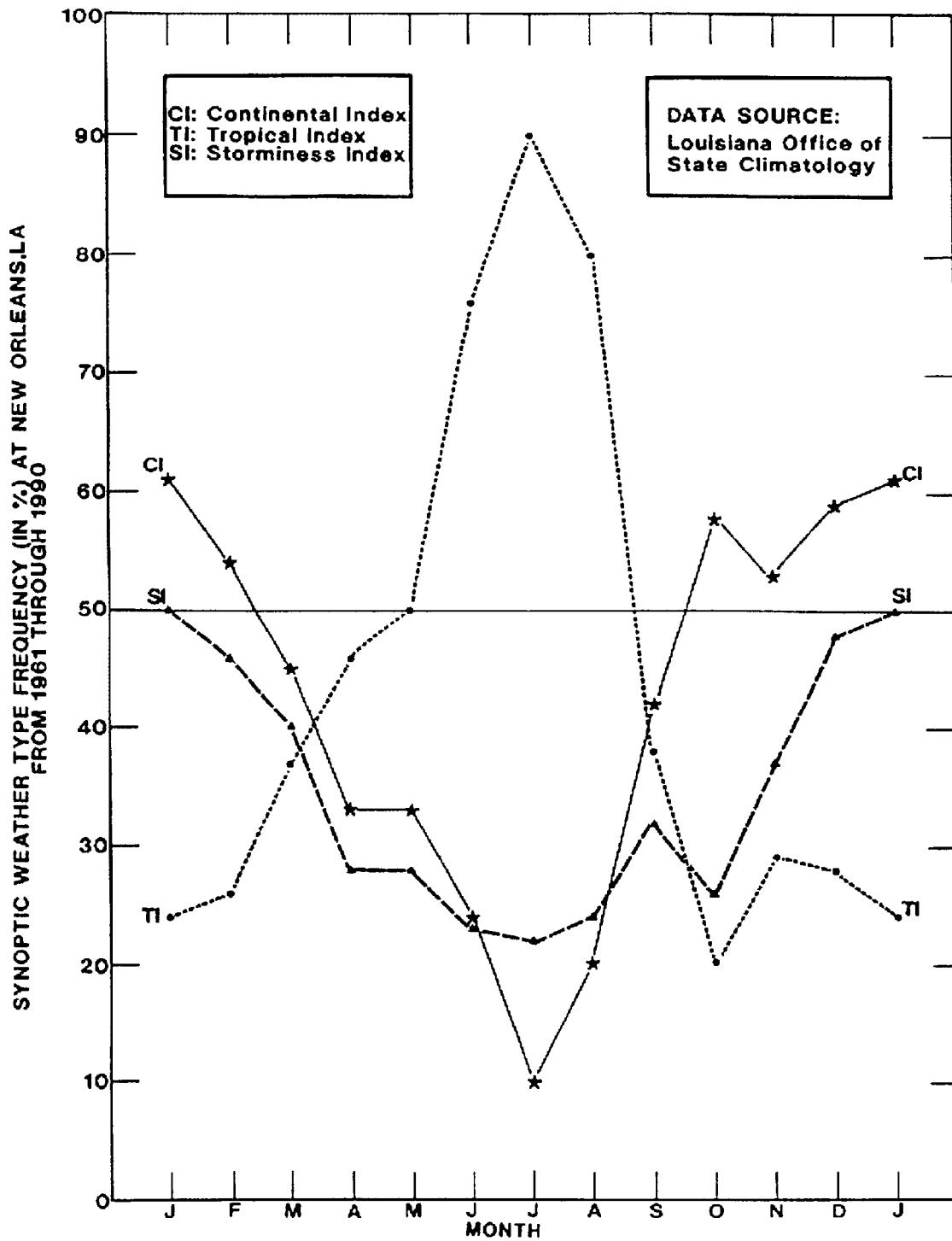


Figure 4-3. The frequency of occurrence for Continental Index (weather types CH + FOR), Tropical Index (GR + FGR + GTD + GH), and Storminess Index (FOR + FGR + GTD).

Table 4-1.

Synoptic weather type frequency (in percent) at New Orleans, Louisiana from 1961 through 1990 (Data Source: Louisiana Office of State Climatology).

Month	PH	CH	FOR	CR	GR	FGR	GH	GTD
Jan	4	23	37	7	11	13	5	0
Feb	6	23	31	7	11	16	6	0
Mar	6	21	24	9	21	16	3	0
Apr	5	20	13	10	31	15	6	0
May	4	20	13	12	28	15	7	1
Jun	0	17	7	15	27	11	19	5
Jul	0	6	4	16	20	8	36	10
Aug	0	14	7	21	16	8	25	9
Sep	1	29	13	19	14	7	6	12
Oct	3	42	16	16	10	8	3	2
Nov	4	30	23	12	15	13	2	1
Dec	4	26	32	6	12	16	4	0
Annual	3	23	18	13	18	12	10	3

Note: PH stands for Pacific High weather type
 CH for Continental High
 FOR for frontal overrunning
 CR for Coastal Return
 GR for Gulf Return
 FGR for Frontal Gulf Return
 GH for Gulf High, and
 GTD for Gulf Tropical Disturbance (see Muller and Wax, 1977).

REVISED CATEGORIES

A preliminary classification was performed for the year 1994 using Muller's weather typing scheme. Through this effort, it was realized that Muller's eight weather types, which were focused on New Orleans, needed to be refined to more specifically address surface wind and pressure gradient patterns in the NEGOM. Specifically, the following changes were developed:

- The Coastal Return classification was redefined as a regime dominated by high pressure over or off-shore of the eastern U.S. -- Eastern Continental High and Bermuda High;
- The Frontal Overrunning classification was separated into three regimes dominated by low pressure over the eastern U.S. -- Eastern Low, Gulf Front East/West, and Gulf Front North/South;
- The Gulf High classification was separated into two regimes dominated by high pressure over the Gulf -- Gulf High and No Gradient (the difference being defined in terms of the location and breadth of the central highest pressure).

- The Frontal Gulf Return classification was dropped as it is covered by the Gulf Return category.
- The names of the remaining original classifications were changed to be more descriptive in terms of the dominant system defining each regime.

These changes resulted in ten new synoptic weather types. Two project team members then independently reviewed NWS daily weather maps for each day of the three year (1995-1997) NEGOM database, and assigned each day to a specific classification based on pressure contour maps and wind flow patterns at 1200 UTC (0600 CST). After reconciliation of the two independent reviews, the criteria or “rules” defining each of the ten regimes were amended and solidified. The review confirmed that ten synoptic patterns would adequately represent the various surface conditions in the Northeast Gulf provided that an accurate and comprehensive description of each was available to future users of the Expert System. Examples of these final ten synoptic patterns are shown in the attached figures (4-4 through 4-13).

Another important step was to define each synoptic category in terms of the key synoptic features that are routinely and easily identifiable to the database users. Therefore, we identified the key features in terms of isobar orientation commonly plotted on surface weather charts. The criteria for each synoptic feature are described below and are included, in brief, in the figure captions shown in Figure 4-14. These general guidelines will allow expert software system users to distinguish, based on routinely available weather maps, between the position and orientation of synoptic high and low pressure systems that influence the wind flow in the NEGOM.

Midwest Continental High (Figure 4-4): A high-pressure system is generally centered west of the Mississippi River and north of the Texas/Mexico border. In the Northeast Gulf the isobars under this pattern are orientated from the northeast to the southwest. Winds in the Northeast Gulf under this pattern are from the north by northwest with anti-cyclonic curvature following the flow.

Eastern Continental High (Figure 4-5): A high pressure system is generally centered east of the Mississippi River and west of the eastern seaboard and from just north of the Northeast Gulf Coast to the US/Canada border. In the Northeast Gulf the isobars under this pattern are orientated from the east to the west. Winds in the Northeast Gulf under this pattern are from the northeast with anti-cyclonic curvature following the flow.

Bermuda High (Figure 4-6): A high-pressure system is generally centered in the Atlantic Ocean from Florida to Maine. In the Northeast Gulf the isobars under this pattern are orientated from the south to the north or from the southeast to the northwest. Winds in the Northeast Gulf are from the east by southeast under this synoptic pattern, with anti-cyclonic curvature following the flow. This pattern often coexists with a **Midwest Low**. If this is the

case, the user must decide which pattern is closest to the Northeast Gulf and select that pattern.

Midwest Low (Figure 4-7): A low-pressure system is generally located east of the Rockies with or without a north/south orientated front located west of New Orleans. In the Northeast Gulf the isobars under this pattern are orientated from the south to the north. Winds in the Northeast Gulf under this synoptic pattern are from the southeast with cyclonic curvature following the flow. This pattern often coexists with a **Bermuda High**. If this is the case, the user must decide which pattern is closest to the Northeast Gulf and select that pattern.

Gulf Front or Trough N/S (Figure 4-8): A north/south-orientated front or trough exists between New Orleans and Tampa. Winds in the Northeast Gulf to the west of the front are northwesterly and winds to the east of the front are southeasterly under this pattern. This pattern may often be accompanied by other patterns such as the **Midwest Low** or **Bermuda High**. If the winds on both sides of the front are from the same direction (indicating a weak front or trough), and the wind directions are consistent with the other accompanying pattern, then the **Gulf Front or Trough N/S** pattern should be ignored and the other accompanying pattern should be chosen.

Gulf Front or Trough E/W (Figure 4-9): An east/west-orientated front or trough is located in the Northeast Gulf region within 50 km of the coastline. Winds are northerly on the northern side of the front and southerly on the southern side of the front. Other patterns may often coexist with this pattern. If the winds on both sides of the front are from the same direction (indicating a weak front or trough), and the wind directions are consistent with the other observed synoptic pattern, then the **Gulf Front or Trough E/W** pattern should be ignored and the other accompanying pattern should be chosen.

East Coast Low (Figure 4-10): A low-pressure system is generally located east of the Mississippi River with east/west-orientated isobars over the Northeast Gulf region and no front over the Northeast Gulf. Winds in the Northeast Gulf are westerly under this synoptic pattern with cyclonic curvature following the flow.

Gulf High (Figure 4-11): High surface pressure is centered in the Gulf, south of the Northeast Gulf Coast from Florida to Texas, and usually associated with a weak pressure gradient. Winds in the Northeast Gulf have a southerly component under this pattern, and are generally weak and anti-cyclonic.

No Gradient (Figure 4-12): No other patterns are present and no surface pressure gradient is evident in the Northeast Gulf region. Winds in the Northeast Gulf are calm or light and variable under this pattern.

Hurricane, Tropical Storm, or Depression (Figure 4-13): A hurricane, tropical storm or tropical depression exists in the Gulf region. Winds in the Northeast Gulf are variable.

When choosing a synoptic pattern NEGOMES users should use the wind observations as a guideline. For example, if the user suspects that an eastern continental high is present, but the winds in the Gulf are not northerly, as expected, but from a significantly different direction, then the user should attempt to find another category appropriate to the wind direction and pressure pattern. If, however, the user suspects that the synoptic category is an eastern continental high and northerly winds are observed, then the user should choose the Eastern Continental High with confidence.

As mentioned above in the synoptic pattern description, there are times when more than one pattern may be present, in which case the user must choose the feature that has the greater influence on the winds in the Northeast Gulf. For example, an east/west-orientated front may exist over the Northeast Gulf region with a strong continental high located east of the Mississippi and to the north of the Gulf. If the high pressure system dominates the pressure pattern and the wind flow, and if the front has little influence on the wind (i.e., no wind shift across the frontal boundary), it is appropriate to classify the pattern as the Eastern Continental High and not the Gulf Front or Trough E/W.

At times it was difficult to decide which pattern is having a greater influence on the winds in the northeast Gulf. Under these circumstances we favored the upstream feature (generally the feature to the west) rather than the downstream feature (generally to the east). For example, if the Midwest Low and the Bermuda High were simultaneously observed and both appeared to be having an equal influence on the winds in the northeast Gulf, then we chose the upstream Midwest Low rather than the Bermuda High.

After categorization of the synoptic condition we estimated transport times. The estimation of transport times required an estimation of wind speeds over the northeast Gulf. Because the wind speeds could not be estimated from the synoptic patterns alone, the surface pressure gradients were used. Guidelines for wind speeds based on the surface pressure gradients were estimated using geostrophic balances and logarithmic vertical wind profiles, and are shown in the Table 4-2. For example, with a surface pressure gradient of 4 mb per 400 km, the surface wind speed at 10 meters over the water is about 10 m/sec. Likewise, a surface pressure gradient of 4 mb per 800 km would result in a 10 meter wind speed of about 5 m/sec.

Table 4-2.
Relationship between isobar spacing and 10-m geographic wind speed.

Distance (km) between 4 mb isobar contours	Wind Speed (m/sec)
200	20
400	10
600	7
800	5
1000	4
1500	3
2000	2

DAILY TYPECASTING FOR 1995-1997

Results of synoptic typecasting for each day of the three year period 1995-97 are shown in Table 4-3. Cumulative days for each of the ten categories are given for each season and for the entire year. Overall, daily synoptic meteorology was found to be dominated during this period by the three high pressure categories (Midwest, eastern and Bermuda high), followed in order by no-gradient, the frontal categories, and finally by the various lows (Midwest, eastern, and tropical). The daily assignments were used in the calculation of statistics by meteorological category, season, and year.

Table 4-3.
Frequency of occurrence (days) for each synoptic category by season and year.

Period	MCH	ECH	BH	MLOW	GFNS	GFEW	ELOW	GH	NG	TS
Spring 95	20	23	18	4	11	2	2	5	4	1
Summer 95	10	24	30	0	5	0	1	5	14	2
Fall 95	7	32	11	1	7	4	1	5	15	9
Winter 95	21	34	15	1	7	3	2	2	5	2
1995	58	113	74	6	30	9	6	17	38	14
Spring 96	14	18	26	1	9	4	4	8	6	1
Summer 96	9	24	25	0	6	3	0	5	19	0
Fall 96	4	23	18	2	3	7	3	12	20	0
Winter 96	9	37	18	0	7	6	2	5	7	1
1996	36	102	87	3	25	20	9	30	52	2
Spring 97	12	27	16	3	12	4	1	7	8	0
Summer 97	4	28	14	2	8	6	4	17	8	0
Fall 97	6	21	6	0	6	11	5	2	31	4
Winter 97	20	32	7	4	10	6	6	1	6	0
1997	42	108	43	9	36	27	16	27	53	4

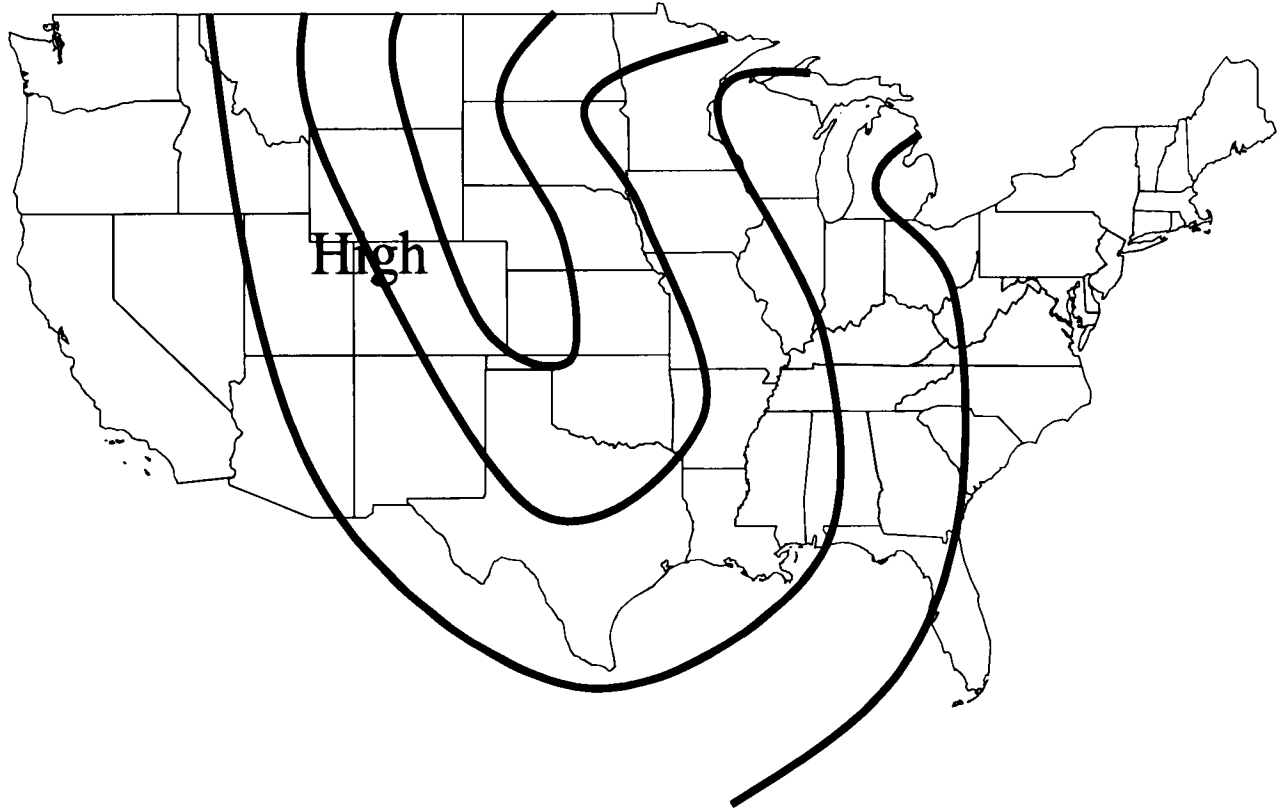


Figure 4-4. Midwest Continental High (MCH), high pressure generally centered west of the Mississippi River and north of the Texas/Mexico border. In the Northeast Gulf the isobars are approximately orientated northeast to southwest and winds are from the north by northwest. The highest frequencies of occurrence for this type are in the Spring and Summer

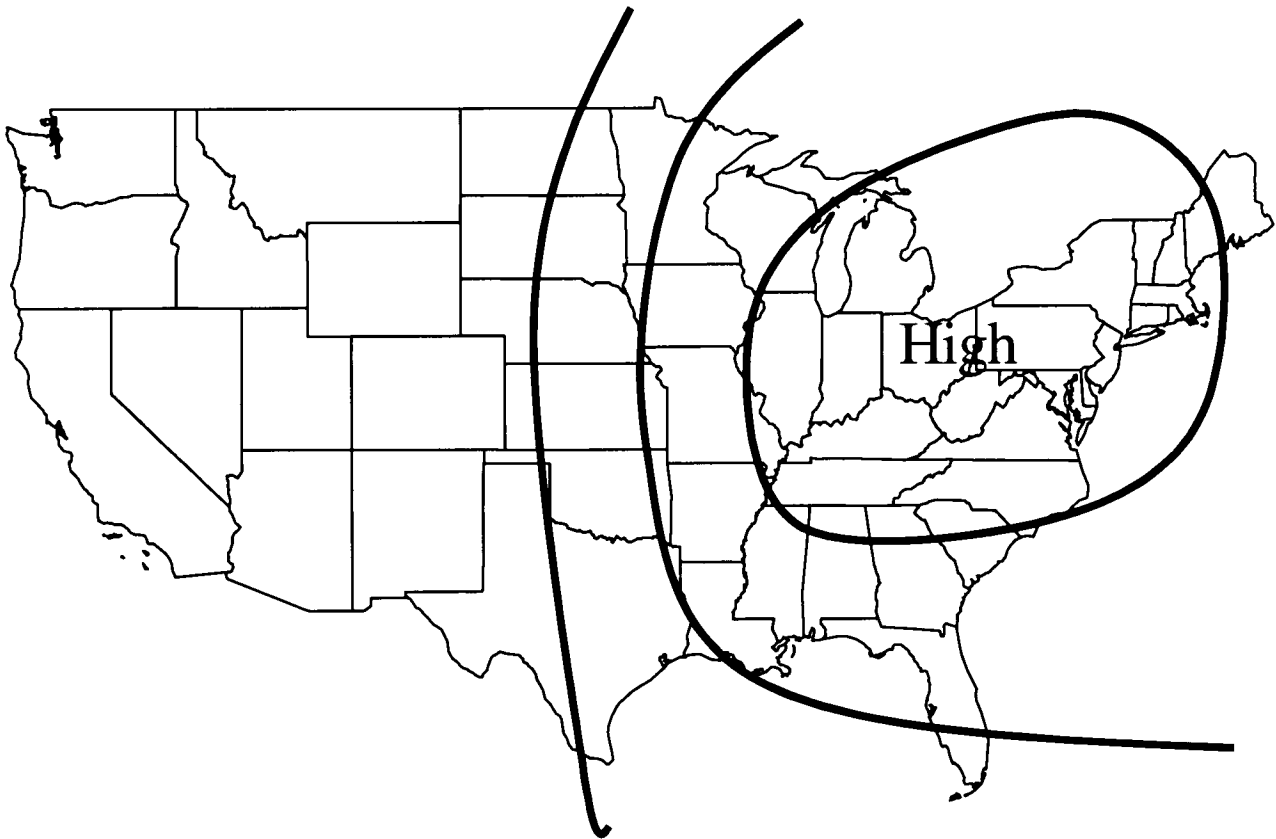


Figure 4-5. Eastern Continental High (ECH), high pressure generally centered east of the Mississippi River and west of the eastern seaboard and from just north of the Gulf Coast to the US/Canada border. In the Northeast Gulf the isobars are approximately orientated east to west and winds are from the northeast. The highest frequencies of occurrence for this type are in the Winter.

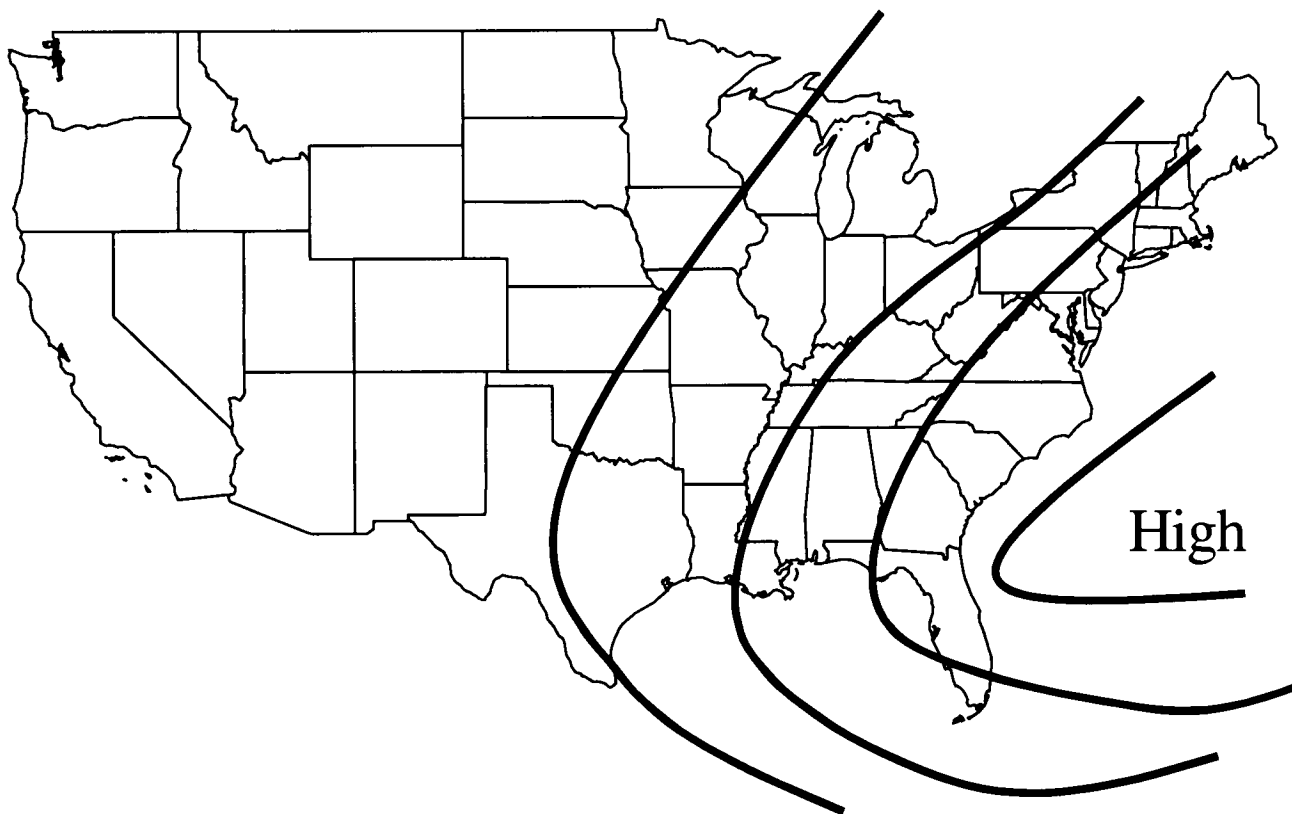


Figure 4-6. Bermuda High (BH), high pressure generally centered in the Atlantic Ocean from Florida to Maine. In the Northeast Gulf the isobars are approximately orientated southeast to northwest or south to north and winds are from the southeast. The highest frequencies of occurrence for this type are in the Spring and Summer

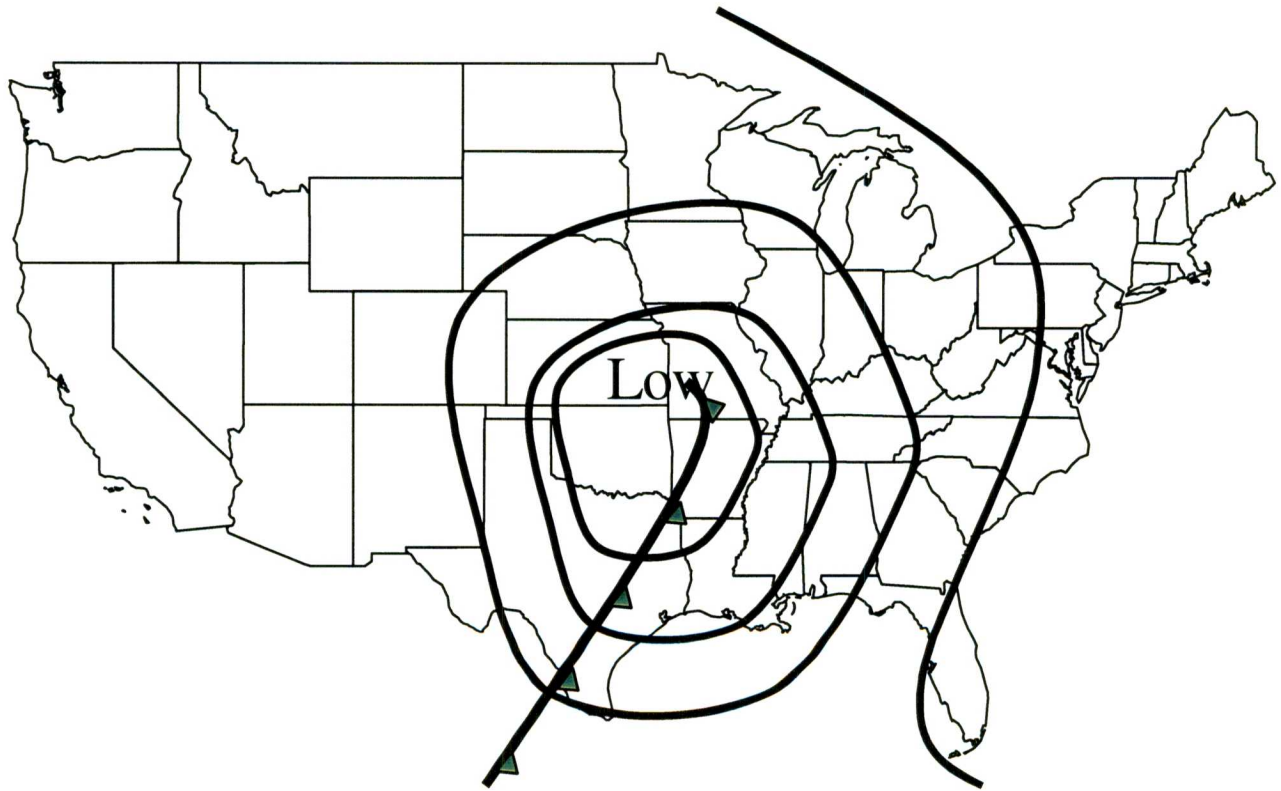


Figure 4-7. Midwest Low (MLOW), low centered east of the Rockies with or without a north/south-orientated front west of New Orleans. In the Northeast Gulf the isobars are orientated south to north and the wind has a southerly component. The highest frequencies of occurrence for this type are in the Winter and Spring

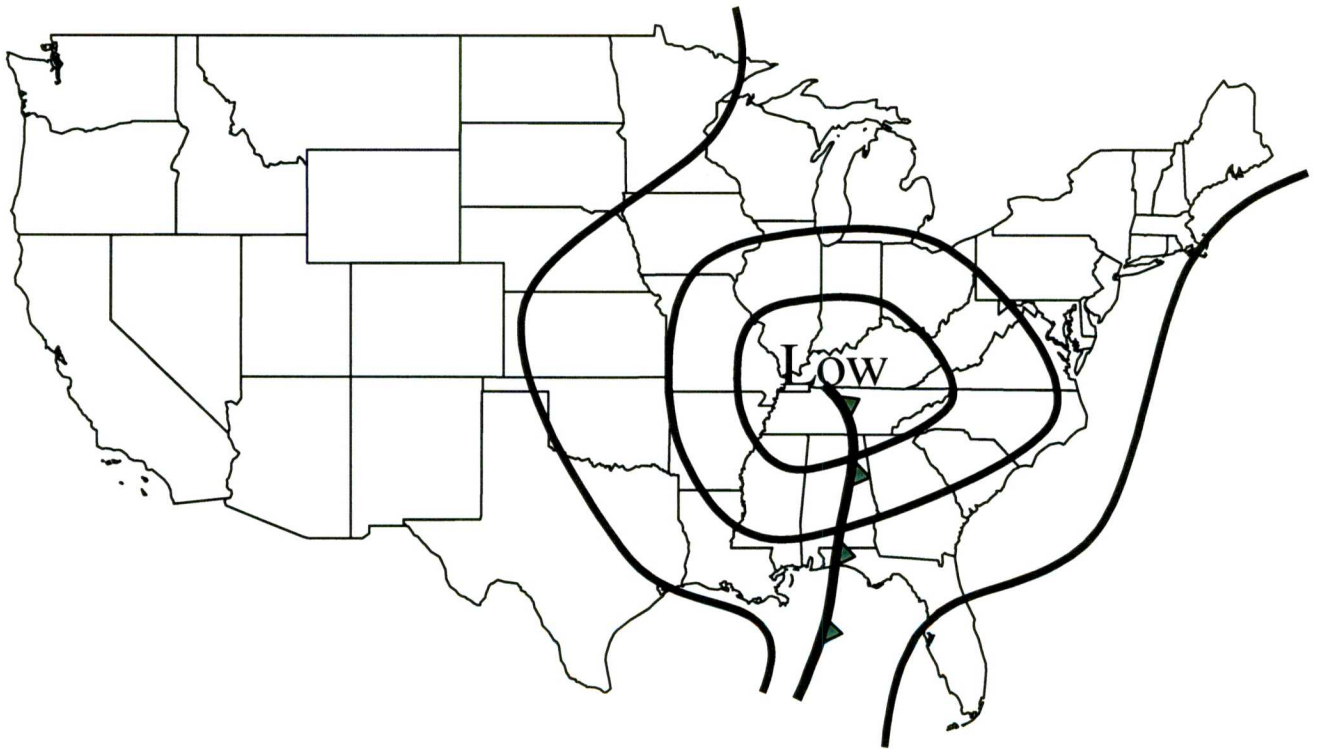


Figure 4-8. Gulf front or trough N/S (GFNS), north/south-orientated front or trough between New Orleans and Tampa. In the Northeast Gulf winds to the west of the front are northwesterly and winds to the east of the front are southeasterly. The highest frequencies of occurrence for this type are in the Spring

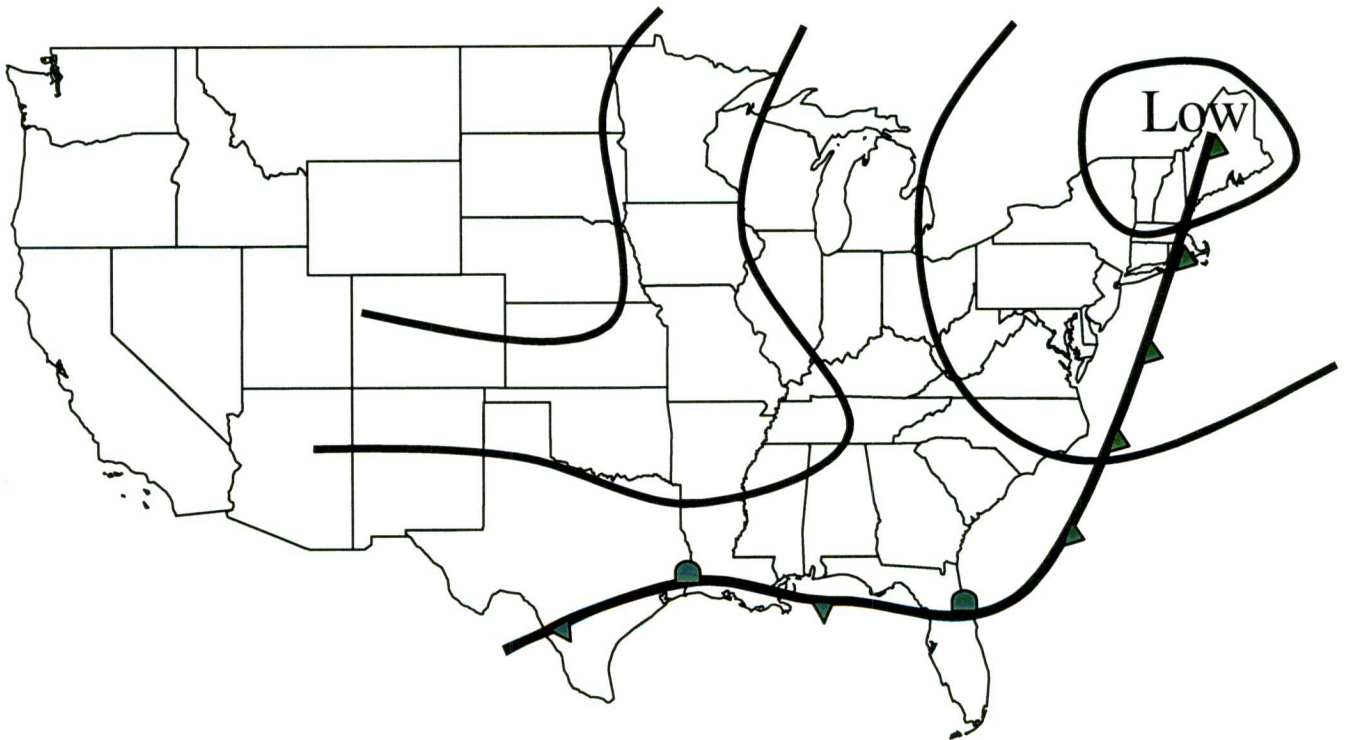


Figure 4-9. Gulf front or trough E/W (GFEW), east/west-orientated front or trough located in the Gulf region. In the Northeast Gulf winds are northerly on the northern side of the front and southerly on the southern side of the front. The wind directions are highly variable. The highest frequencies of occurrence for this type are in the Fall



Figure 4-10. East Coast Low (ELOW), low pressure system east of the Mississippi River with west/east-orientated isobars over the Gulf region and no front over the Gulf. In the Northeast Gulf the wind has a westerly component. The frequencies of occurrence for this type are similar in all seasons

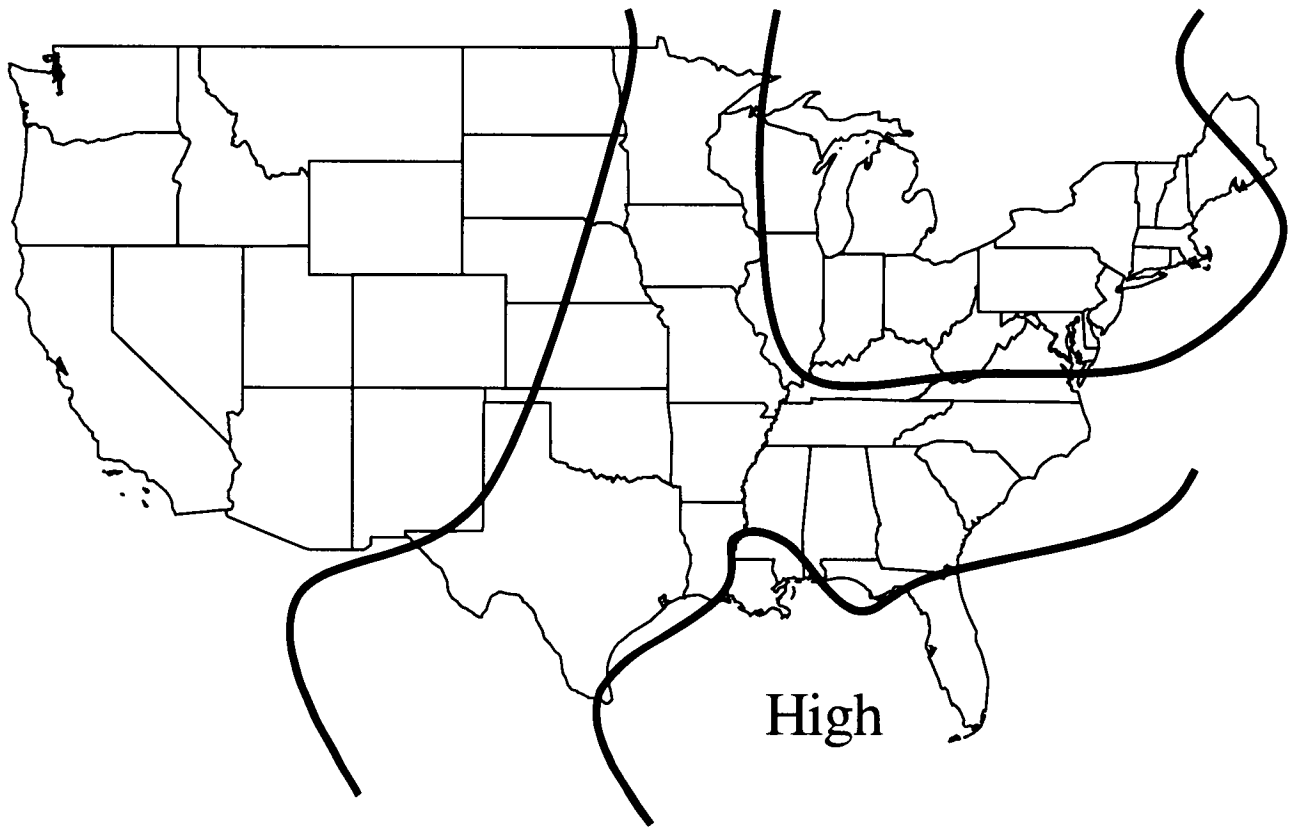


Figure 4-11. Gulf High (GH), high surface pressure centered in the Gulf, south of the Northeast Gulf from Florida to Texas. In the Northeast Gulf winds have a southerly component. The highest frequencies of occurrence for this type are in the Summer and Fall.

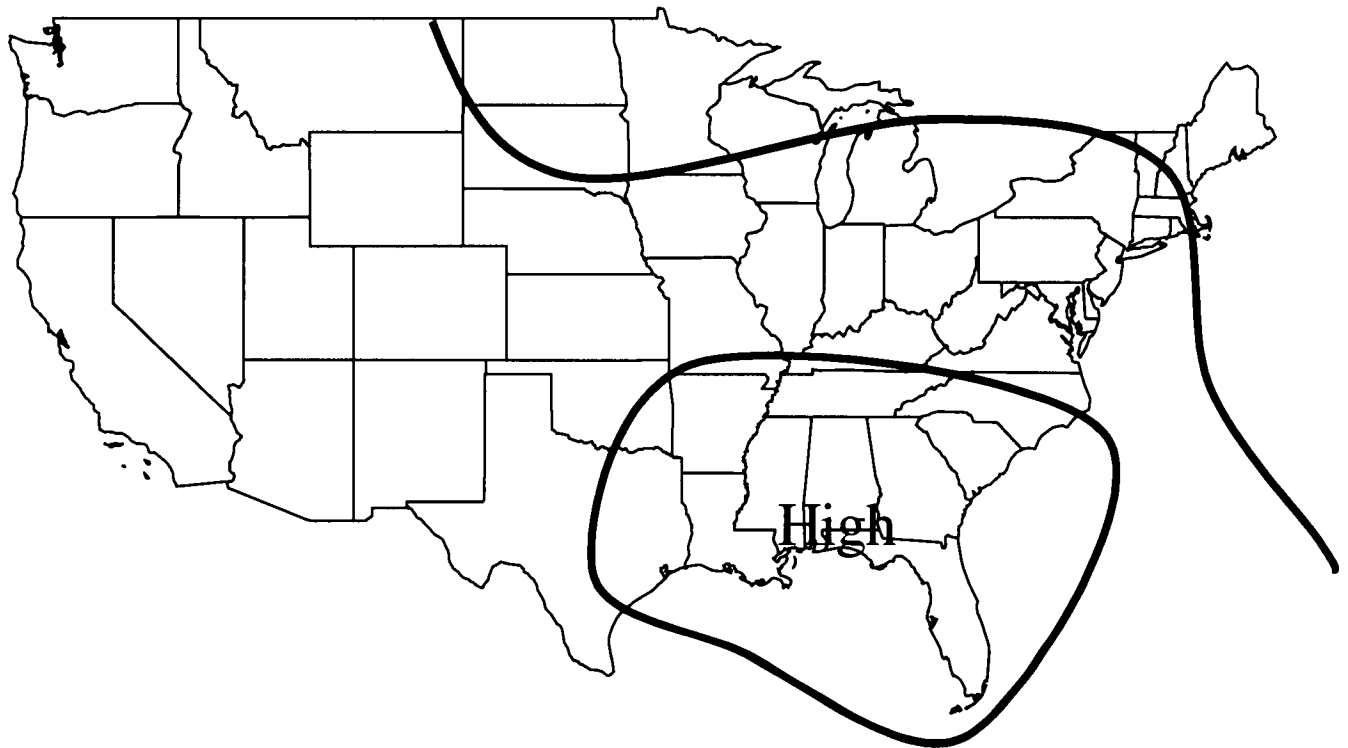


Figure 4-12. No Gradient (NOGRAD), no surface pressure gradient in the Gulf region. In the Northeast Gulf winds are calm or light and variable. The highest frequencies of occurrence for this type are in the Summer and Fall.

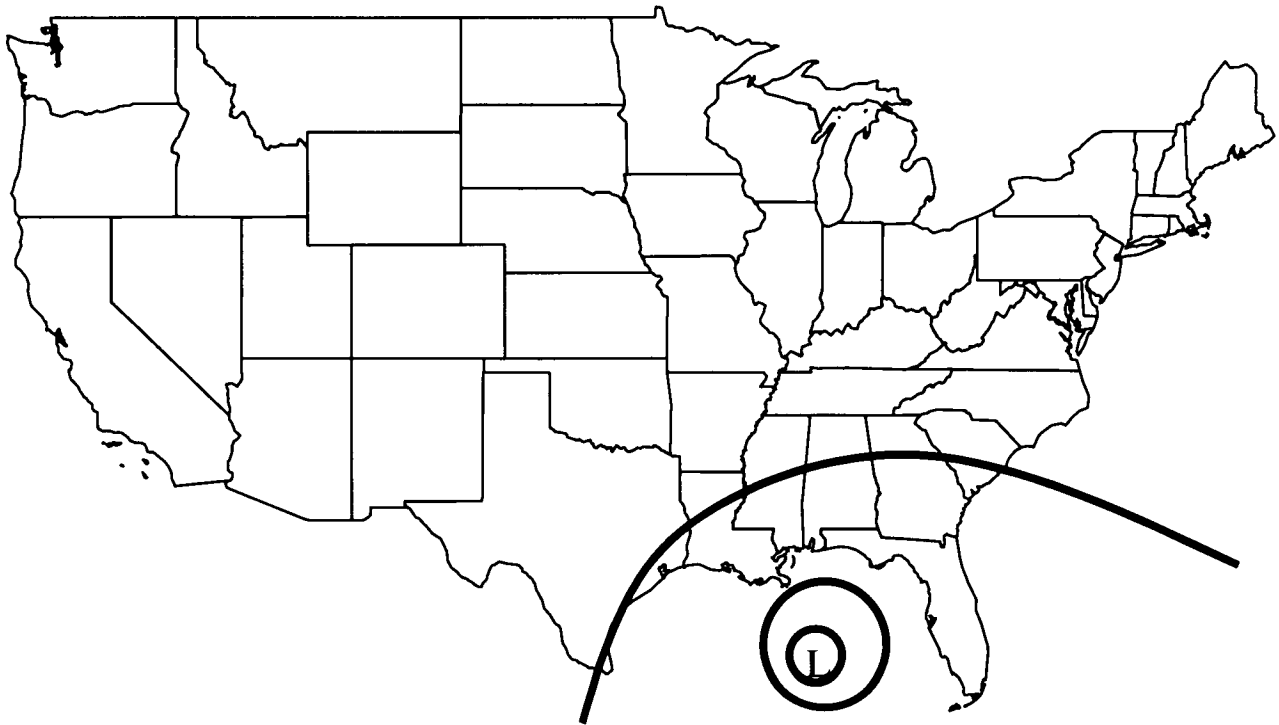


Figure 4-13. Hurricane, Tropical Storm, or Depression (TS), a tropical storm in the Gulf region. In the Northeast Gulf winds are variable. The highest frequencies of occurrence for this type are in the Fall.

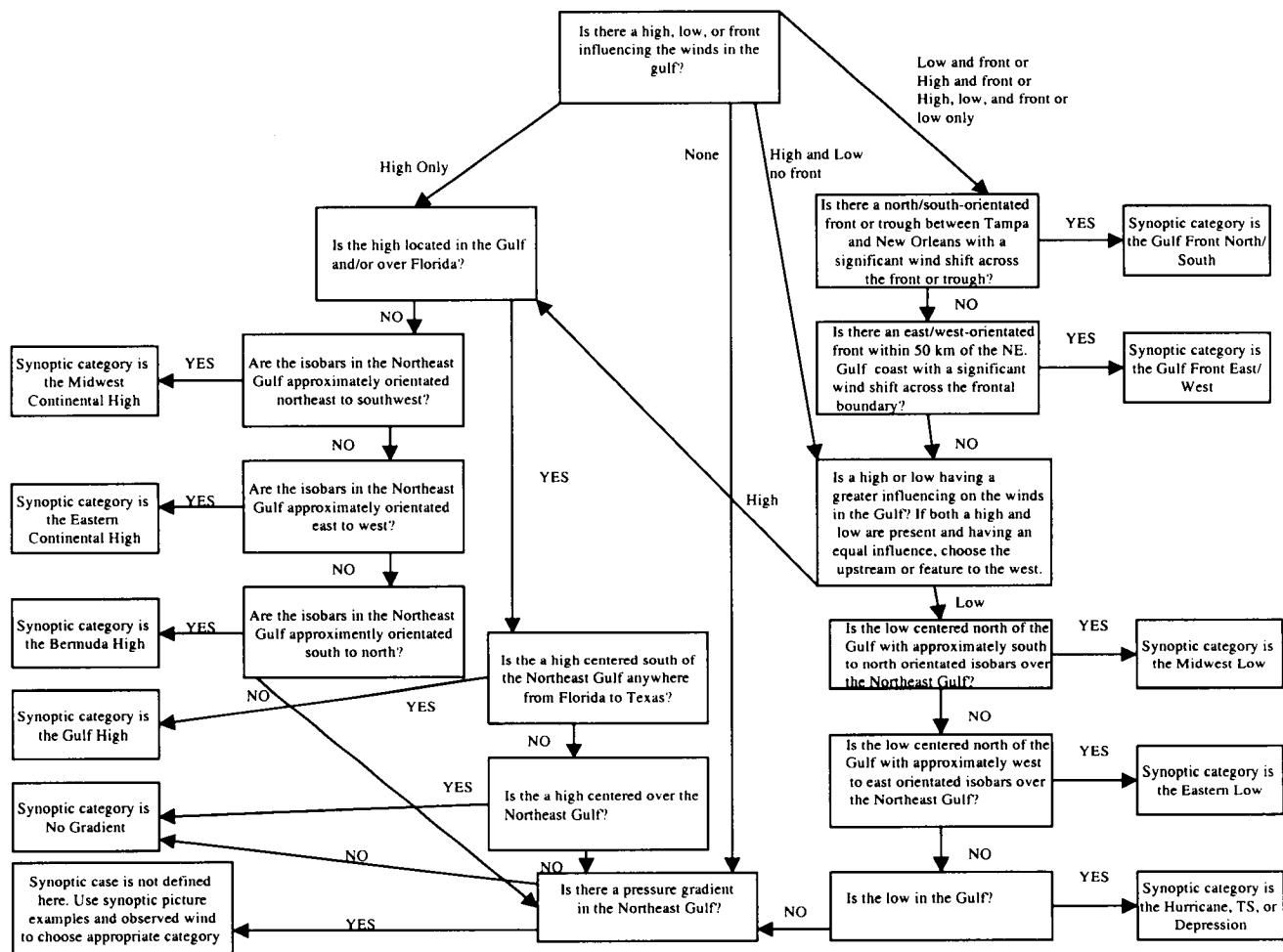


Figure 4-14. Decision tree flowchart describing the general methodology used to select a synoptic category.

5. METEOROLOGICAL DATA REDUCTION AND ANALYSIS

OVERVIEW

After compilation of a historical three-year observational database, we conducted various analyses of directly measured and derived quantities that may ultimately be useful to multi-disciplinary scientific studies, forecasters, and engineers. These analysis products were developed using the three-year observational database. In addition, we also collected and archived the output of a prognostic meteorological grid model, the Eta model. This output was extracted from NCAR's Eta model archives. No attempt was made in this study to reconcile any differences between the two separate data bases (i.e., the observational and Eta model databases).

The general tasks performed were:

- Means and variances, stratified by season, meteorological regime, year, and total data period (1995-97) were determined for directly measured quantities such as winds, temperature (air and/or sea, depending on the site), humidity, and pressure.
- Means and variances, stratified by season, meteorological regime, year, and total data period (1995-97) were determined for quantities derived from directly measured parameters (where data allowed); these included heat flux, boundary layer depth, boundary layer stability, moisture and latent heat flux across the land-sea boundary, stress, stress curl, and Ekman pumping velocity.
- Time series of winds and temperature for all marine sites and selected coastal stations were generated for the entire data period. All time series data were reduced and analyzed using accepted, state-of-the-art time series techniques, including the calculation of frequency spectra and autocorrelation functions. These same analysis techniques were applied to filtered versions of the raw time series that removed significant diurnal modes such as sea breeze circulations.
- Using all available data, distribution maps were prepared for mean and variance wind patterns, mean and variance wind stress, mean and variance air and sea surface temperature, and mean and variance humidity. Distribution maps were stratified by season, meteorological category, year, and total data period.
- Vertical vorticity and wind stress curl were estimated, mapped, and interpreted under different thermal stratification conditions.
- Bulk formulae were utilized to estimate surface layer water and latent heat transport across the sea-land boundary; statistics of these fluxes were calculated for various temporal and meteorological regime stratifications.

- The basic properties and stability associated with the atmospheric boundary layer were estimated using theoretical relationships (bulk parameterization); statistics of these parameters were developed for various stratifications (season, meteorological category, etc.) that allowed for their variations to be determined as a function of atmospheric forcing.

Some of the meteorological parameter statistics were directly calculated from the observational database that we assembled; the *observed parameters* included:

- wind speeds and velocity
- surface temperature
- sea-surface temperature
- humidity
- pressure.

Other parameters, called derived parameters were calculated from observed parameters for offshore (overwater) sites. The *derived parameters* included:

- humidity at buoy sites
- wind stress
- wind stress curl
- heat fluxes
- moisture fluxes
- boundary layer depths
- boundary layer stability
- Ekman pumping velocity.

In addition, most of these parameters are also predicted by the Eta model, so statistics were calculated for both observed and derived parameters using the gridded Eta model output.

Next we discuss the statistical calculation and sorting methods for all parameters, including observed, derived, and predicted parameters. Then we discuss the issues with and calculation methods for the derived parameters.

STATISTICAL ANALYSES

Statistical Data Summaries

Summaries of statistical sample mean and sample variance for observed and derived meteorological parameters were prepared for each surface observing site listed in Table 2-2 and Table 2-3. For the Eta model output, statistics were calculated at each model grid node (See Figure 5-1).

Sample mean is defined as follows:

$$\mu_p = \frac{1}{N_p} \sum_{i=1}^{N_p} p_i$$

where:

μ_p	=	mean of parameter p sample set
N_p	=	number of samples for parameter p
p_i	=	value of sample I for parameter p.

Sample variance is defined as follows:

$$\sigma_p^2 = \frac{1}{N_p} \sum_{i=1}^{N_p} (p_i - \mu_p)^2$$

where:

σ_p	=	variance of parameter p sample set
N_p	=	number of samples for parameter p
p_i	=	value of sample I for parameter p
μ_p	=	mean of parameter p sample set.

Observed data were segregated and organized into five Access database tables:

1. By site
2. By site and meteorological type
3. By site and season (winter = December-February; spring = March-May; summer = June-August; fall = September-November)
4. By site and meteorological type and season
5. By site and season and year

The sample mean and variance statistics were computed using all of the data in each of the above five tables for the following observed and derived parameters:

- temperature (C)
- barometric sea-level pressure (mb)
- relative humidity (%)
- wind speed (m/s)
- magnitude of u and v components of the wind vector (m/s)
- wind direction (degrees from north)
- sea surface temperature (C)¹
- surface heat flux (W/m²)¹
- convective PBL depth (m)¹

- bulk Richardson number¹
- horizontal moisture flux across the land-sea boundary²
- horizontal latent heat flux across the land-sea boundary²
- wind stress³
- stress curl⁴
- Ekman pumping⁴

Notes:

¹ Only sites with sea surface temperature (buoy and C-MAN)

² Coastal sites only

³ Buoy sites only

⁴ Transects only

Access data tables were prepared of the mean and variance of each parameter and each of the five data groups listed above. Also tabulated were the number of non-missing values used in the statistical calculations, and number of possible values (based on hourly sampling). The number of possible hourly values was computed as twenty-four times the number of days in the table cell. Thus, for the first table (by site), the number of possible hourly data points in the 1996-1997 data period was 17,544.

Since the number of statistical tables we have produced is very large, they are not presented in hard copy form in this report. The companion Access database and expert system contain all the data and can be easily downloaded and viewed on a PC type computer. However, we present an example of a station statistics table in Table 5-1.

Spatial Interpolation Of Observed Data Statistics

Meteorological data for the study region are available at a very limited number of irregularly spaced observing locations. A spatial interpolation procedure was employed to estimate values of temperature, sea surface temperature, relative humidity, wind speed/direction, and wind stress over a regularly spaced array of grid nodes consisting of 19 nodes in the east-west direction and 13 nodes in the north-south direction. The grid was equally spaced in a latitude-longitude coordinate system with east-west and north-south spacings of 0.5 degrees each (approximately 900 km by 700 km). Given the sparse coverage of data sites, spatial interpolation was performed using a standard software package for “Kriging” interpolation; interpolation weights were automatically applied to each data point based on a variogram developed by the software describing the spatial variability in the data. This approach is well-suited to and commonly applied to interpolation irregularly-spaced environmental data sets. A linear model was used for the variogram with scale factor $C = 6.67$ and length parameter $A = 4.12$. The variogram was assumed to be isotropic with no nugget effect. “Ordinary” Kriging was used (i.e., no drift was specified). Calculations were carried out with a PC-based spatial mapping software package (*Surfer* 6.0, Golden Software Inc.). A data completeness criterion of 50% of all possible hours (assuming measurements made every hour) was applied: any sites not meeting this criterion were excluded from the spatial interpolation.

Table 5-1.

Example of a station statistics table: (this case shows statistics for station 42001, for all years, ECH meteorology types and the winter season).

Meteorological Parameter	Mean	Variance	Sample Size
Air Temperature (°C)	22.93	5.61	929
Sea Temperature (°C)	23.03	1.10	929
Pressure (mb)	1021.00	15.86	929
Wind Speed (m/s)	7.41	5.71	929
U Winds (m/s)	-5.70	8.29	929
U Winds (m/s)	-1.46	17.72	929
Surface Heat Flux (W/m2)	35.54	638.42	852
Bulk Richardson Number	.02	1.07	928
Planetary Boundary Layer (m)	546	15854	852
Wind Stress (kg/m2s)	.0980	.0049	752
Drag Coefficient	.0012	.0000	752

A typical example of gridded mean winds is shown in Figure 5-2. The balance of the gridded mean fields plots are provided as part of the Expert software system.

Time Series Analysis Methods

Time series of hourly scalar wind speed, magnitude of the north-south wind component, and surface temperature observations collected at sixteen marine, coastal, and inland locations listed in Table 5-2 were analyzed for their statistical behavior.

Table 5-2.
Surface meteorological data sites used in the
time series analysis for the 1995-1997 data period.

Site	Location	% Non-Missing Values (based on wind speed)
Buoy 42001	Mid Gulf	89
Buoy 42002	West Gulf	92
Buoy 42007	OTP	99
Buoy 42036	West Tampa	76
Buoy 42039	Pensacola S	99
Buoy 42040	Mobile South	99
Land Based 722210	Eglin AFB/Valparais	85
Land Based 722225	Pensacola NAS	94
Land Based 747686	Kessler AFB/Biloxi	88
Land Based 747750	Tyndall AFB	89
C-MAN Buoy BURL1	Southwest Pass, LA	96
C-MAN Buoy CDRF1	Cedar Key, FL	99
C-MAN Buoy DPIA1	Dauphin Island, FL	96
C-MAN Buoy GDIL1	Grand Isle, LA	99
C-MAN Buoy KTNF1	Keaton Beach, FL	99
BRETON	Breton Island	69

Since the time series analysis methods used here assume complete data, missing values were first filled in with means computed for the season and hour corresponding to the time of each missing observation. Assuming normally distributed data, this procedure avoids introduction of biases in the mean diurnal pattern. Furthermore, for sparse, randomly occurring missing values, biases in spectral analyses should be minimal. Therefore, sites in Table 5-2 represent locations with data completeness of at least 70 percent; sites with more extensive missing data were not included in the analysis although this requirement was relaxed somewhat at the buoy sites to avoid losing data from these critical locations.

Autocorrelation functions and periodograms were computed for both the raw time series and a filtered series in which the 24-hour diurnal cycle has been removed using a Buys-Ballot filter. The Buys-Ballot filter simply subtracts the mean diurnal cycle from the raw time series. In other words, a time series consisting of a repeated sequence of 24 values corresponding to the mean for each hour of the day is subtracted from the raw time series to create the filtered series.

Autocorrelations for lags $n=1,2,\dots, N/2$ hours where N is the length of the time series were computed and plotted using the S-PLUS *acf* function.

Smoothed periodograms were computed using the S-PLUS *spectrum* function. This function first removes any trend from the raw time series (using a least squares fit) and rescales to a zero mean. A split cosine data taper of ten percent is then applied to each end of the detrended series. A mixed radix fast Fourier transform algorithm is then applied to the series to estimate the raw periodogram which is smoothed by applying a sequence of running averages (a sequence of two modified Daniell windows of length 25 and 27). The smoothed periodogram is expressed in decibels.

We generated the time series analysis plots for each of the sixteen stations listed in Table 5-2. Sample time-series statistics plot are presented in Figure 5-3 and 5-4; Figure 5-3 shows the results for a site that is influenced by diurnal land-sea breeze flow reversal; Figure 5-4 is for an offshore site beyond the furthest extent of land-sea breeze influences. The balance of the time series figures are available in the Appendices B and C, and in the NEGOMES Expert Software System which is a companion deliverable of this study.

ISSUES ASSOCIATED WITH DERIVED QUANTITIES

One of the thrusts of the subject study, besides the compilation and statistical analysis of directly measured meteorological parameters in the northeast Gulf of Mexico, was to determine and analyze spatial and temporal patterns of several derived quantities (i.e., stress, fluxes, and boundary layer parameters). As described above, the calculation of derived quantities was often difficult for the Gulf due to the sparsity of necessary measurement data, particularly any parameters dependent upon humidity or spatial gradients of winds. Some parameters could have been grossly calculated but did not lend themselves to a substantive level of analysis due to data sparsity and complexities associated with mid-gulf versus shoreline measurements; in particular, the determination of vorticity and stress curl were problematic.

This section presents a review of the specific problem areas, and closes with our final diagnostic approach of applying parametric relationships to the existing surface observation database. The importance of obtaining archived gridded meteorological model output is also stressed; these are regarded as a highly valuable resource to provide the data coverage and variables needed for an adequate assessment of derived parameters.

Humidity-based Parameters

Most derived quantities that characterize the boundary layer depend on surface-level humidity measurements. The number of data buoys measuring dew point in the northeastern Gulf was recently increased in the last half of 1997. Nevertheless, surface humidity data were routinely available from only a single buoy in the Gulf of Mexico for the database years of 1995-97. It was therefore essential to identify available methodologies from which to derive either

humidity or, alternatively, related boundary layer parameters directly. We identified three possible resources (Emery, 1998): (1) satellite soundings of moisture, (2) recently developed empirical relationships between surface layer temperature and moisture fluxes, and (3) archived NWS Eta prognostic meteorological model fields.

In order to utilize satellite data, potentially significant additional resources would have been needed to procure vertical sounder archives and process the data for the 3 year database. In return, a rather high spatial (20 km), but low temporal (6-hourly), resolution surface humidity database could have been developed for much of the northeastern Gulf. The Eta model initialization archives included 3-hourly analysis fields on a 40 km grid in a Lambert Conformal projection grid, with coverage across the entirety of North America and surrounding oceans (extending across the northern half of Mexico). The major drawback to this source of information was the enormity of the data volume; as with the satellite data described above. Significant resources were used to procure the Eta archives and process the data for the 1996-97 MMS database, but the usefulness of the Eta model information far surpassed that of the surface observation dataset.

Hsu (1998) presents a compelling relationship between air and sea-surface temperature differences and the Bowen ratio (the ratio of sensible to latent heat flux from the surface) in the Gulf of Mexico during unstable conditions. Based upon theoretical considerations, the air-sea temperature difference can be linked to the latent heat flux to some extent. Using data from Buoy 42040 during a cold air outbreak in December 1996, Hsu finds a linear correlation between the air-sea temperature difference and the air-sea mixing ratio difference with a high correlation coefficient of 0.98; these findings are then extended to a non-linear relationship between air-sea temperature difference and the Bowen ratio under unstable conditions and seems to also work reasonably well under neutral and weakly stable conditions. This relationship was extended to additional buoy data from four sites between 1993 and 1997. Different coefficients are derived for near shore areas as well, based on data from the Dauphin Island C-MAN site.

Once the Bowen ratio is known, surface humidity may be calculated, and heat fluxes, surface layer stability, and boundary layer depth can be determined at each site containing air and sea-surface temperature data. This approach, therefore, is limited to estimations of humidity based on available hourly buoy temperature data at each site, and did not improve the spatial or temporal resolution beyond those of the temperature observations. Nevertheless, we pursued the latest developments of Hsu (1998) in relating sea-air temperature differences to the Bowen ratio, as it appeared to be a promising technique to derive boundary layer quantities that would otherwise require knowledge of humidity at each measurements site.

Wind-based Parameters

We identified several problems associated with determining some of the derived quantities from the wind observations. Particularly, we investigated the feasibility of using pressure measurements at buoys and C-MAN sites to define rhomboid patterns (i.e., parallelograms

with oblique angles and unequal adjacent sides) from which the pressure Laplacian may be calculated and geostrophic vorticity and stress curl can be derived. Originally, only two rhomboids could be defined that had a sufficient number of measurement sites to calculate these quantities. This problem was remedied in part by procuring data from three additional buoys located along the 28°N parallel.

A Laplacian, being a second-order spatial derivative, requires a rhomboidal configuration of at least 5 measurement sites. A simple differencing formula suggested by Hsu (1992) was initially planned to be used in this project; however, its simplicity rests in the assumption that the various sites are about equally spaced, and that the sites are aligned orthogonally. In the current study, the distances between sites were quite variable for the few highly non-orthogonal rhomboids that could be constructed. To understand the sensitivity of the rhomboid approach to which differencing technique is used, vorticity was calculated using the formula initially chosen (Hsu, 1992), and then with a revised formula to account for the large disparity among inter-site distances (although it still did not account for the non-orthogonality in each rhombus). An example of the results are shown in Table 5-3 for a particular time for two rhomboids. Note that both the Laplacian and vorticity values change by an order of magnitude, and the signs flip, denoting a change from cyclonic to anticyclonic vorticity.

Furthermore, there was no consistent “scale” of the derived quantities among each rhombus. For example, one rhombus may characterize the scale of vorticity across 40,000 km², whereas another might extend over several more orders of magnitude, while containing a portion of the first area. The fact that the vorticity from the smaller rhombus was consistently higher than the vorticity from the larger rhombus indicated that rhombus scale was playing a role in the calculations. Similar differences were noted in the seasonal and annual averages. However, for the seasonal calculations, an additional problem of data availability arose. For the three years of hourly pressure data, only 10-25% of the total number of hours contained sufficient data at all sites to calculate the two-dimensional spatial gradients.

A simplification to the rhombus methodology was also presented in the analyses of Hsu (1992), in which it was determined that an equally robust metric could be based on simply the temperature (pressure) difference between a single shoreline site and a deep water buoy (i.e., a transect methodology). This stems from the fact that in the winter season, the along-shore component of temperature difference is quite small compared to the large temperature differences orthogonal to the shore, especially between deep water and the shoreline. It was realized that a similar analysis could be carried out for the NEGOM, however, transects needed to be developed that run orthogonal to the gulf shelf break both east and west of the Desoto Canyon area due to its influence on atmospheric baroclinicity. It was also suggested that transects be developed to characterize outer gulf and near-shore vorticity separately. The transects methodology was fully adopted in lieu of the use of fully two-dimensional rhomboids in calculating Laplacian fields; we worked closely with Dr. Hsu in developing the most appropriate transects as a function of sub-surface topography and data availability.

Hence, while Laplacian calculations were made from the buoy data alone, the quality of the results remained highly uncertain and dependent upon the methodology employed. Also, spatial and temporal coverage was greatly limited. It became obvious from these tests that an improved set of wind information on a more regular grid would be a valuable component of the NEGOM meteorological database, certainly in regards to the reconciliation of stress estimates with currents and transport patterns of LATEX drifters in 1996-97.

Table 5-3.
 Example of Laplacian and vorticity calculations using
 two differencing methodologies at 1200 LST, July 14, 1996.

Rhombus centered on site	Initial Laplacian	Revised Laplacian	Initial Vorticity	Revised Vorticity
42007	5.4×10^{-8}	-2.8×10^{-8}	6.1×10^{-4}	-2.7×10^{-4}
42040	4.8×10^{-10}	-1.7×10^{-9}	5.4×10^{-6}	-2.0×10^{-5}

Usefulness of Eta Model Output for Estimating Derived Parameters

As has been described, the derivation of wind stress, heat flux, boundary layer parameter estimates from observed data alone was complicated by the scarcity of stations. For example, many of the diagnostic calculations listed above were derived from meteorological data taken at buoy and C-MAN stations located in the NEGOM. The locations of these sites are presented in Figure 2-1. Furthermore, the derivations of certain parameters required measurements of parameters that are not always reported by Buoy or C-Man stations. (The methodology to derive these quantities using alternative approaches is described later in this section).

The Eta model fields archived by NCAR (described earlier) offered a very attractive source of surface (and aloft) information. Since these output are gridded, they drastically simplify the development of the various derived quantities dependent on spatial surface wind and pressure patterns. Wind and thermodynamic output have consistent temporal coverage and are resolved on a regular 40 km orthogonal grid. Since the Eta model initializations assimilated much of the observed data in the area, the Eta model analysis output can be viewed as a very sophisticated spatial and temporal data interpolation scheme.

Eta model output fields are generated on a finer spatial (and in some cases time) scales than available from a monitoring network. This is very useful when it is necessary to extrapolate analyses beyond the spatial limits of the monitoring network, or to interpolate analyses to finer scales within the network. This is particularly true in the vertical, where modeled fields allow for much more spatial and temporal detail in the vertical than available from measurements. Moreover, the theoretical expressions employed by Eta models automate the estimation of

some derived parameters, particularly in defining the structures and variations of the atmospheric boundary layer, heat and mass fluxes, and sea breeze circulations.

METHODOLOGY FOR CALCULATING DERIVED PARAMETERS FROM OBSERVED DATA

The first and most critical step in the process of calculating the various derived parameters was to ensure that all over-water sites possessed hourly humidity data when sufficient temperature and pressure data were available. This step drew from the relationships developed by Hsu (1998) that link air-sea temperature differences to the Bowen ratio. Once Bowen ratio was known, it was a rather simple matter to determine humidity parameters. Two basic humidity measures were calculated in this way: specific humidity was calculated since it was needed for other derivations such as heat flux; and dewpoint temperature was needed to fill in missing humidity values for buoy and C-MAN sites in the raw observational database.

At over-water sites without humidity measurements, the Bowen ratio was first calculated for all hours with valid air and sea-surface temperature (T and T_s in $^{\circ}\text{C}$, respectively):

$$B = a(T_s - T)^b$$

where the constants $a = 0.077$, $b = 0.70$ for buoy sites, and $a = 0.087$, $b = 0.74$ for C-MAN sites (as determined by Hsu, 1998). The ambient specific humidity q_a was determined from a relationship defining surface latent heat flux as a function of moisture and temperature differences between the sea and air surface:

$$q_a = q_s + \frac{T - T_s + 0.01z}{2500B} \quad (\text{g/g})$$

where z is measurement probe height (5 m for buoys 42039, 42040, and 42036, and 10 m for all other buoys and C-MAN sites). The sea-surface specific humidity was assumed to be saturated, and is therefore a function of ambient pressure p (mb) and sea-surface temperature only:

$$q_s = 0.62 \frac{e_s}{p}, \quad e_s = 6.1 \times 10^3 \left(\frac{7.5T_s}{257.2 + T_s} \right)$$

Specific humidity was determined as well for all land sites that report dewpoint T_d ($^{\circ}\text{C}$), using equations similar to above:

$$q_a = 0.62 \frac{e}{p}, \quad e = 6.1 \times 10^4 \left(\frac{7.5 T_d}{257.2 + T_d} \right)$$

The horizontal moisture flux orthogonal to the coastline F_q was determined at selected coastal sites based on the north-south component of the observed wind v (m/s) and the water vapor concentration c_w (kg/m³):

$$F_q = v \cdot c_w \quad (\text{kg m}^{-2} \text{s}^{-1})$$

where

$$c_w = 1.2 q_a \left(\frac{273 p}{1013.25 T} \right)$$

The 1.2 factor in the equation above represents a standard atmospheric density, which was used throughout these analyses wherever density was needed. The range of this value is not large under most circumstances, and is relatively small compared to the uncertainty associated with the assumptions necessarily made in these analyses. The horizontal latent heat flux F_h (J/kg) was calculated from F_q by simply multiplying the latter by the latent heat of vaporization (2.5×10^6 J/kg).

The total surface heat flux H was only determined for conditions in which the sea surface was warmer than the ambient air temperature. The equation utilized the Bowen ratio previously calculated, and therefore heat flux was only determined for over-water sites:

$$H = 1.2 c_p c_T V (T_s - T) \left(1 + \frac{0.07}{B} \right) \quad (\text{Wm}^{-2})$$

where c_p is the specific heat of dry air at constant pressure (1004 J K⁻¹ kg⁻¹), c_T is the bulk heat transfer coefficient under convective conditions (taken from Hsu [1997]), and V is total wind speed (m/s). From this, the convective boundary layer depth was estimated for offshore sites using an empirical relationship developed by Hsu (1997):

$$CBL = 369 + 6004 \left(\overline{w'\theta'_v} \right) \quad (m)$$

where

$$\overline{w'\theta'_v} = \frac{H}{1.2 c_p} \quad (m K/s)$$

There are a number of parameters to represent the stability regime of the surface boundary layer. We used the bulk Richardson number since it could be directly determined from wind speed and surface-to-probe gradients in temperature:

$$R_b = \frac{g z}{V^2 T_s} (T_s - T)$$

where g is the gravitational acceleration constant (9.8 m/s^2) and T_s must be expressed in units of K in the denominator.

Calculation of wind stress required the knowledge of a drag coefficient. Since the focus of the current study was on wind stress on the ocean surface, we limited the calculation of wind stress to over-water stations. As pointed out by Hsu (1995), it is difficult to define the drag coefficient, or alternatively the friction velocity u^* , because they depend on more unknown variables than there are equations to interrelate them. Therefore, Hsu developed a parameterization for the over-water drag coefficient C_d based on wave information that is routinely available from buoy sites. Effectively, the significant wave height H_s (m) and the dominant wave period T_p (s) were used as surrogates for a space- and time-variable surface roughness length. The resulting equation was:

$$C_d = \left[\frac{0.4}{11 - \ln \left[\frac{H_s}{\left(\frac{g T_p}{2\pi V} \right)^{2.6}} \right]} \right]^2$$

The vertical component of the wind stress tensor was then determined for all over-water stations from the following relationship:

$$\tau = 1.2 C_d V^2$$

The wind stress curl may be determined by combining the horizontal components of the vertical stress with the geostrophic vorticity equation. Evaluating vorticity requires the

calculation of a pressure (or temperature) Laplacian, and as discussed above, this second-order two-dimensional spatial derivative requires at least five data points. We elected to evaluate the vorticity using a transect method, which reduced the number of data points to three, aligned along a direction that usually yields the largest gradient (i.e., orthogonal to the gulf shore line). This approach maximized the total number of possible configurations as well as the coverage of stress curl estimates over the Gulf.

Hsu (1992) utilized a Laplacian of temperature to diagnose geostrophic vorticity during wintertime cold-air outbreaks over the central and western Gulf. Since our focus was more broad in determining stress curl for all seasons of the three-year database, we elected to use pressure so that diurnal temperature tides at land sites were not introduced (although a slight diurnal pressure wave of usually less than 1-2 mb was typically present). The large land-based temperature variation over the day was often sufficient to cause a semi-diurnal reversal in the geostrophic vorticity for all scales of transects. We did not see this when using pressure.

Transects were defined by three sites that are roughly equally spaced along a consistent direction. In this way, the one-dimensional pressure Laplacian was simplified using pressure from the three sites and an average separation distance D (m):

$$\nabla^2 p = \frac{1}{D^2} (p_1 + p_2 - 2p_0)$$

where p_1 and p_2 are pressures (Pa) at the transect endpoints, and p_0 is the pressure at the central (usually coastal) site. The wind stress curl was then determined from

$$\nabla \times \tau = \frac{C_d V_0}{f} \nabla^2 p$$

Here, the drag coefficient was taken from the buoy site defining the deep water endpoint of the transect, or the nearest buoy to the transect if no data were available. The total wind speed V_0 (m/s) was taken from the central site in the transect, and the Coriolis parameter f was set to $7.3 \times 10^{-5} \text{ s}^{-1}$, which represents the value at 30°N . From the stress curl, it was a simple matter of deriving the Ekman pumping velocity:

$$W_e = \frac{\nabla \times \tau}{\rho_w f}$$

assuming the density of seawater ρ_w is about 1030 kg/m^3 .

Transect Definitions

Several transects were defined for the calculation of pressure Laplacian. The general rules in developing these were: (1) three sites define a transect, one in the outer Gulf, one near shore, and one inland; (2) the spacing between each of the three sites should be fairly uniform; and (3) the three sites should form a straight line orthogonal to the shoreline. Two sets of transects were defined, coastal and deep water, with the central point of the former located on or near the coast (typically C-MAN sites) and the Gulf point located near the shelf break, and the central point of the latter at the shelf break and the Gulf point at a “deep water” buoy. Many more transects were defined than were feasible when calculating actual hourly pressure Laplacian values, because some of the land based endpoint sites contained significant data gaps. Since no viable alternatives were found, these transects were dropped from the analysis. Figures 5-5 and 5-6 present the locations of the deep water and coastal transects, respectively. Note that in the figures, dashed lines represent original transect definitions that had to be dropped due to data sparsity. Table 5-4 provides a listing of stations defining each transect in these analyses, by station ID.

CALCULATION OF DERIVED PARAMETERS FROM ETA MODEL OUTPUT

After Eta model output was obtained from NCAR, data were extracted for the study region and selected output parameters. The extracted data were reorganized into Access data tables, and indexed by meteorological type and season. To be consistent with the derived quantities in the observational database, several variables were derived from the Eta analyses, including bulk Richardson number (stability measure of the boundary layer), convective boundary layer depth, vorticity, wind stress curl, and Ekman pumping velocity. Since the Eta fields contain only the east-west (u) and north-south (v) components of the winds, the total wind speed and direction were first calculated and supplied to the data tables. Surface fluxes of sensible and latent heat were also supplied in the Eta fields. The surface moisture flux at each grid point was calculated from the surface latent heat flux by simply multiplying by the latent heat of vaporization.

The bulk Richardson number was estimated using an equation similar to that used for the observational database, but using vertical gradients specific to the Eta output. In essence, the value of height z in the equation was increased from 10 to 50 to account for the fact that the Eta model provides temperatures at 2 m above the surface and wind speeds at 10 m (zero wind speed is assumed at the surface). Also, the convective boundary layer heights were determined using the same equation as developed for the observational database, with values of total surface heat flux (latent + sensible) taken directly from the Eta output fields.

The calculation of wind stress curl from the Eta wind fields was significantly improved relative to the observational database. First, the geostrophic vorticity field was explicitly calculated from the full two-dimensional pressure Laplacian. At each grid node, vorticity was calculated from

$$\xi = \frac{1}{1.2 f} \nabla^2 p$$

where atmospheric density (1.2 kg/m³), coriolis (f), and pressure (p) were defined previously. The Laplacian was calculated using simple difference equations, where for point (i,j),

$$\nabla^2 p = \frac{1}{\Delta x^2} (p_{i-1,j} + p_{i+1,j} + p_{i,j-1} + p_{i,j+1} - 4p_{i,j})$$

where Δx is the grid point spacing (40 km). Since the values for pressure must be available at points $i+1$, $i-1$, $j+1$, and $j-1$ in the above equation, the derived vorticity along the border of the domain was marked as missing.

Wind stress curl was calculated similarly to the observational data,

$$\nabla \times \tau = 1.2 C_d V \xi$$

where the drag coefficient at each point was provided in the model output fields. Finally, Ekman pumping velocity was estimated using the stress curl as described for the observational database.

Within the Eta output data there were occasional periods of missing data. These data were given a value of -999. If a missing value was required in the computation of a derived variable, that missing value was propagated to the derived variable. After all derived variables were calculated for the entire 1996-97 period, summary mean and variance statistics were computed for all model and derived surface variables using the same stratifications as for the observed database (e.g., by site, by season, by meteorological type, etc.). Although no statistics were derived for the upper air data, the 3-hourly 1000 and 850 mb winds, temperature, and humidity are available in the Eta database for every grid point in the NEGOM domain.

Table 5-4.
List of deep and coastal transects, and site IDs that define each.

Transect ID	Outer Water Site	Coastal Site	Inland Site
Deep Water			
1D	42001	42040	722267
2D	42003	42039	722267
3D	42003	42036	722135
Coastal			
1C	BUSL1	GDIL1	747685
2C	BUSL1	BURL1	42007
3C	42040	722225	722275
4C	42039	722210	722267
5C	42039	722245	722269
6C	42039	CSBF1	722140
7C	42036	CSBF1	722269
8C	42036	KTNF1	722135
9C	42036	CDRF1	722146

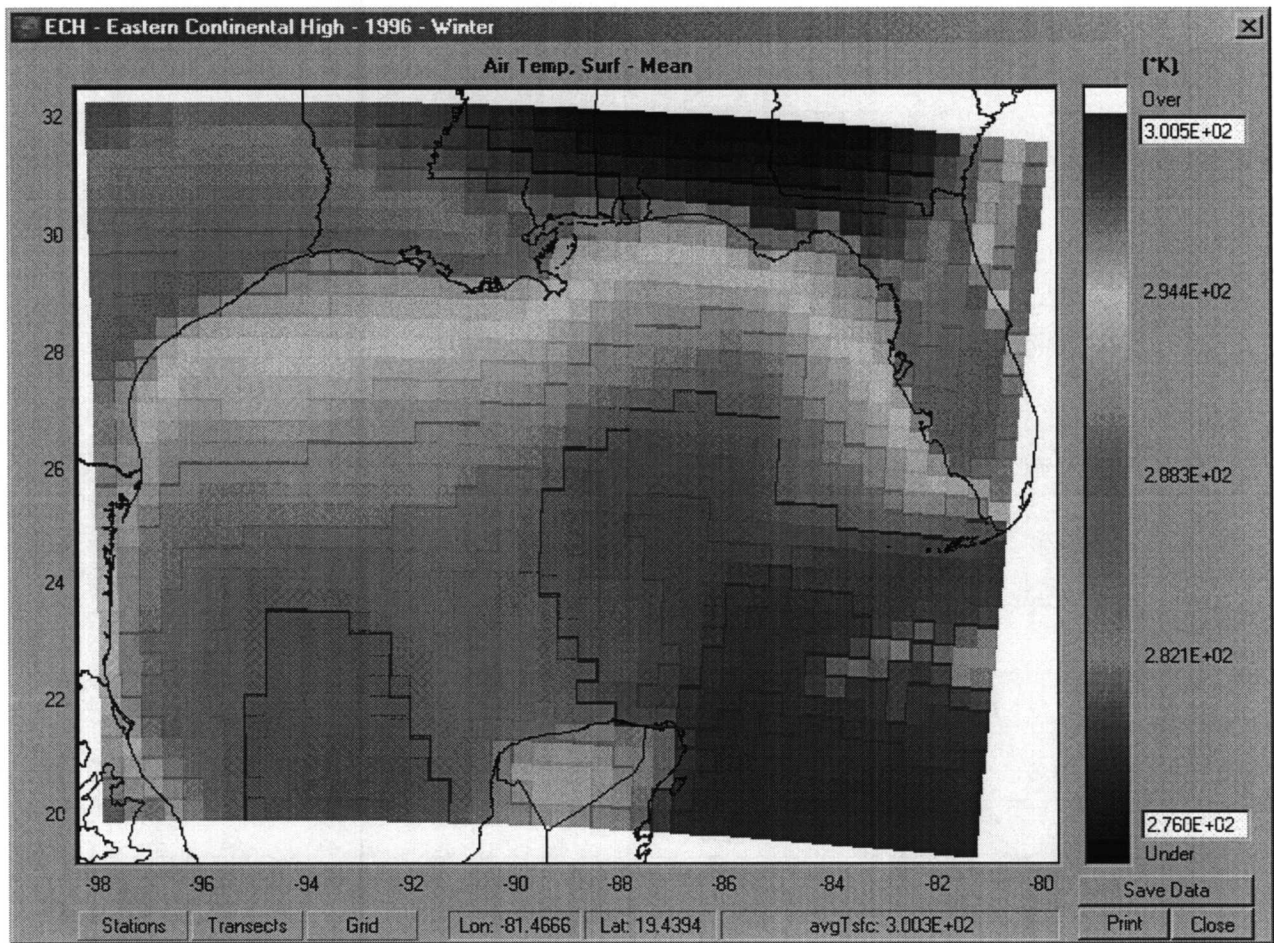


Figure 5-1. An example of a gridded Eta model statistics map (this example shows gridded mean surface temperatures for 1996 and the ECH type meteorology). Each colored square represents the data for one grid square.

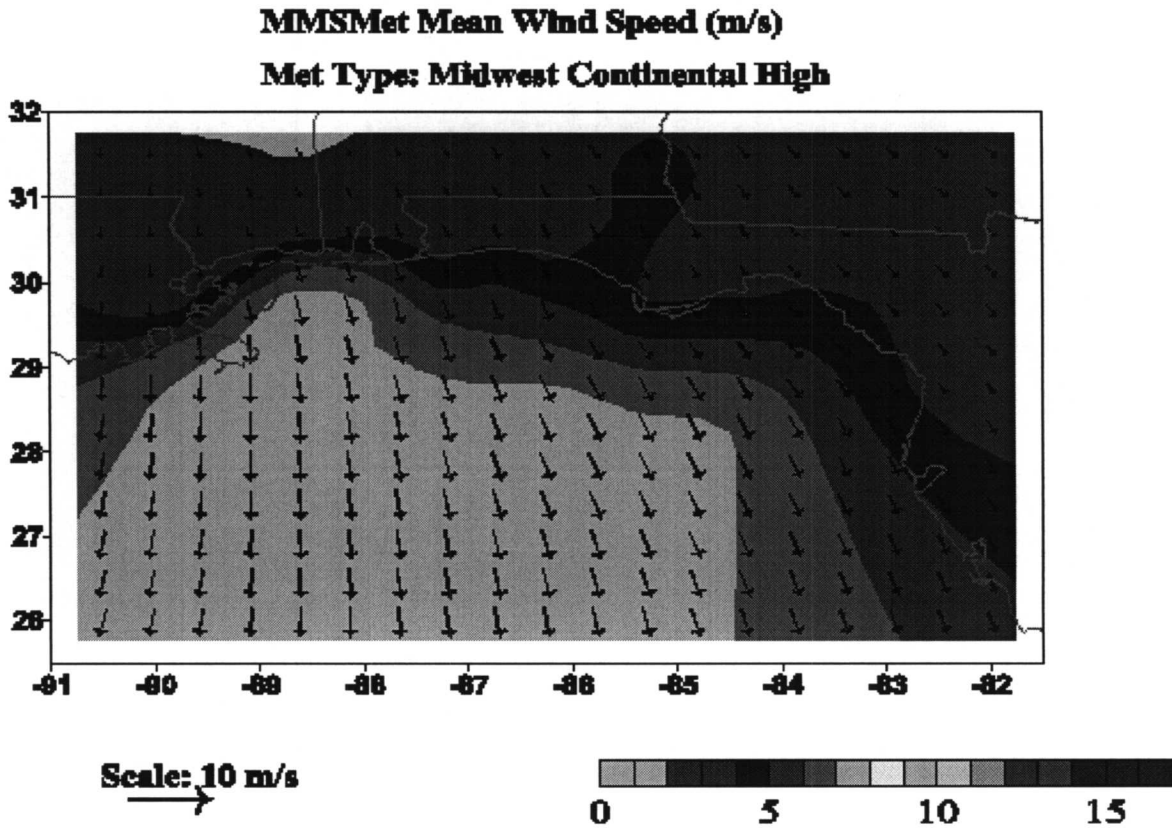


Figure 5-2. Example of gridded mean winds (vectors and contoured speed) for the Midwest Continental High category over the entire data period (1995-1997). The mean wind velocity in each grid square is depicted by an arrow whose length is proportional to mean speed and whose direction is the vector averaged wind direction.

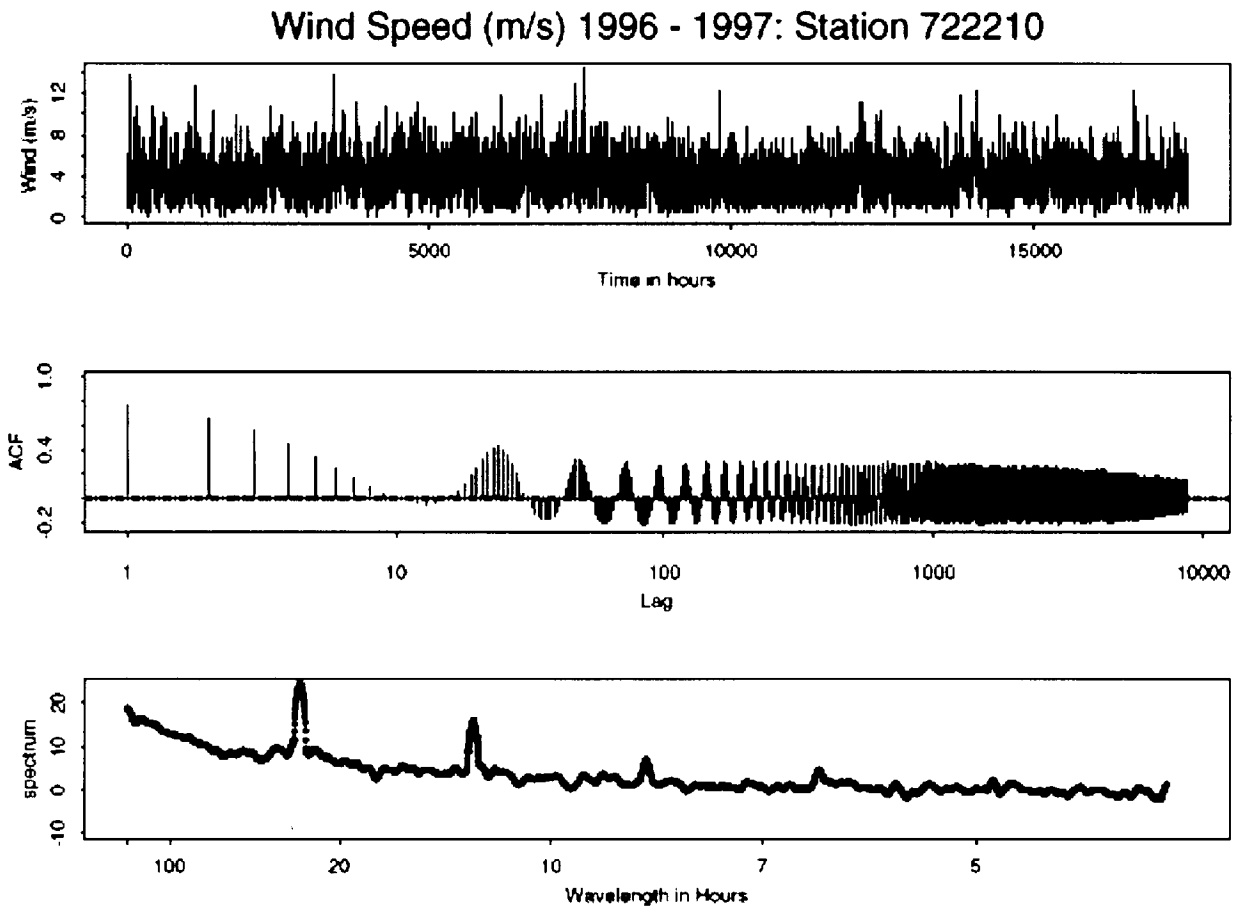


Figure 5-3. Example of time series plots of temperature for the Elgin AFB/Valparais site. Note the power spectrum peaks at 12 and 24 hours, reflecting diurnal, land-sea breeze influences. (ACF is an abbreviation for autocorrelation function which is a measure of the correlation between the successive observations of a parameter at one site as a function of lag time).

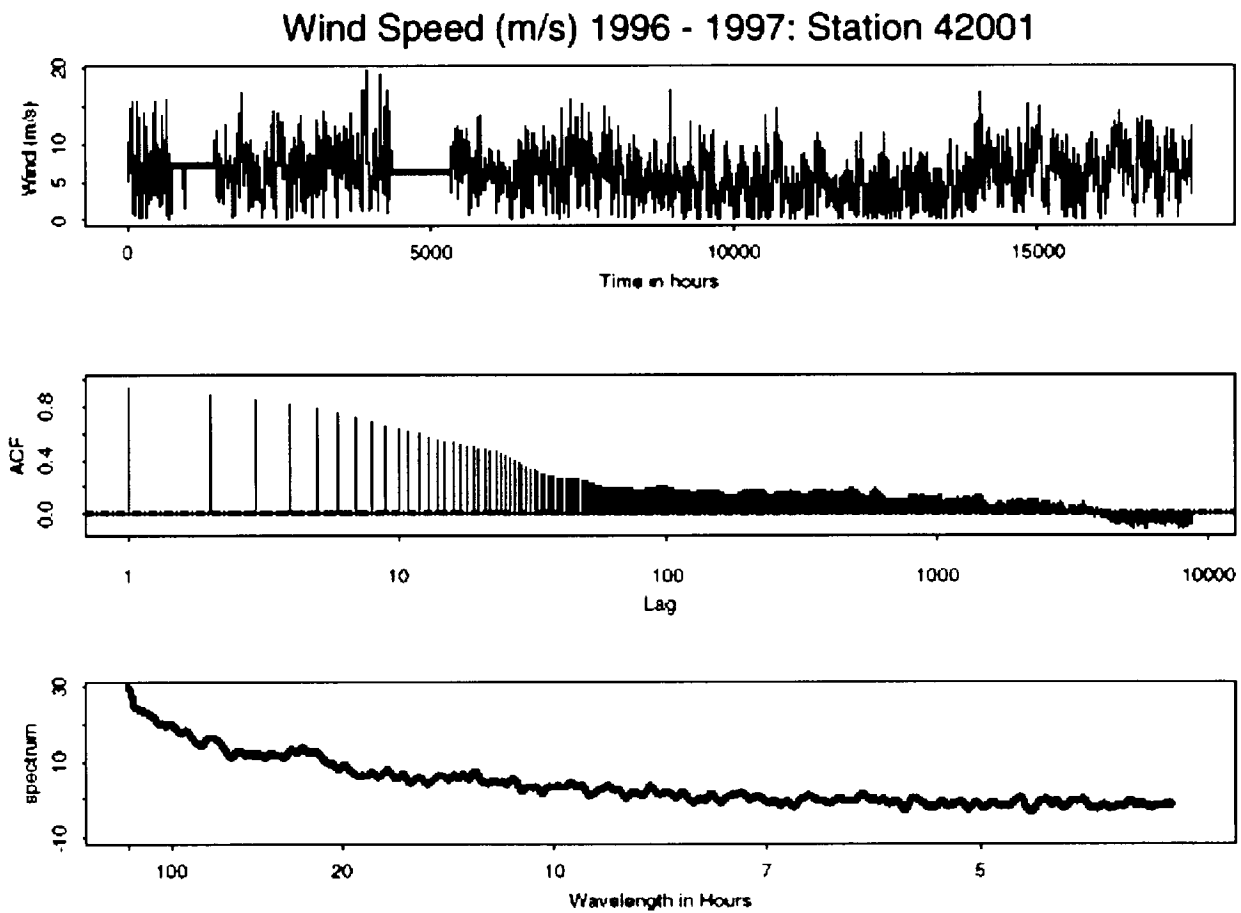


Figure 5-4. Example of time series plots of temperature for the Mid Gulf site. Note the absence of power spectrum peaks at 12 and 24 hours, no reflecting diurnal, land-sea breeze influences. (ACF is an abbreviation for autocorrelation function which is a measure of the correlation between the successive observations of a parameter at one site as a function of lag time).

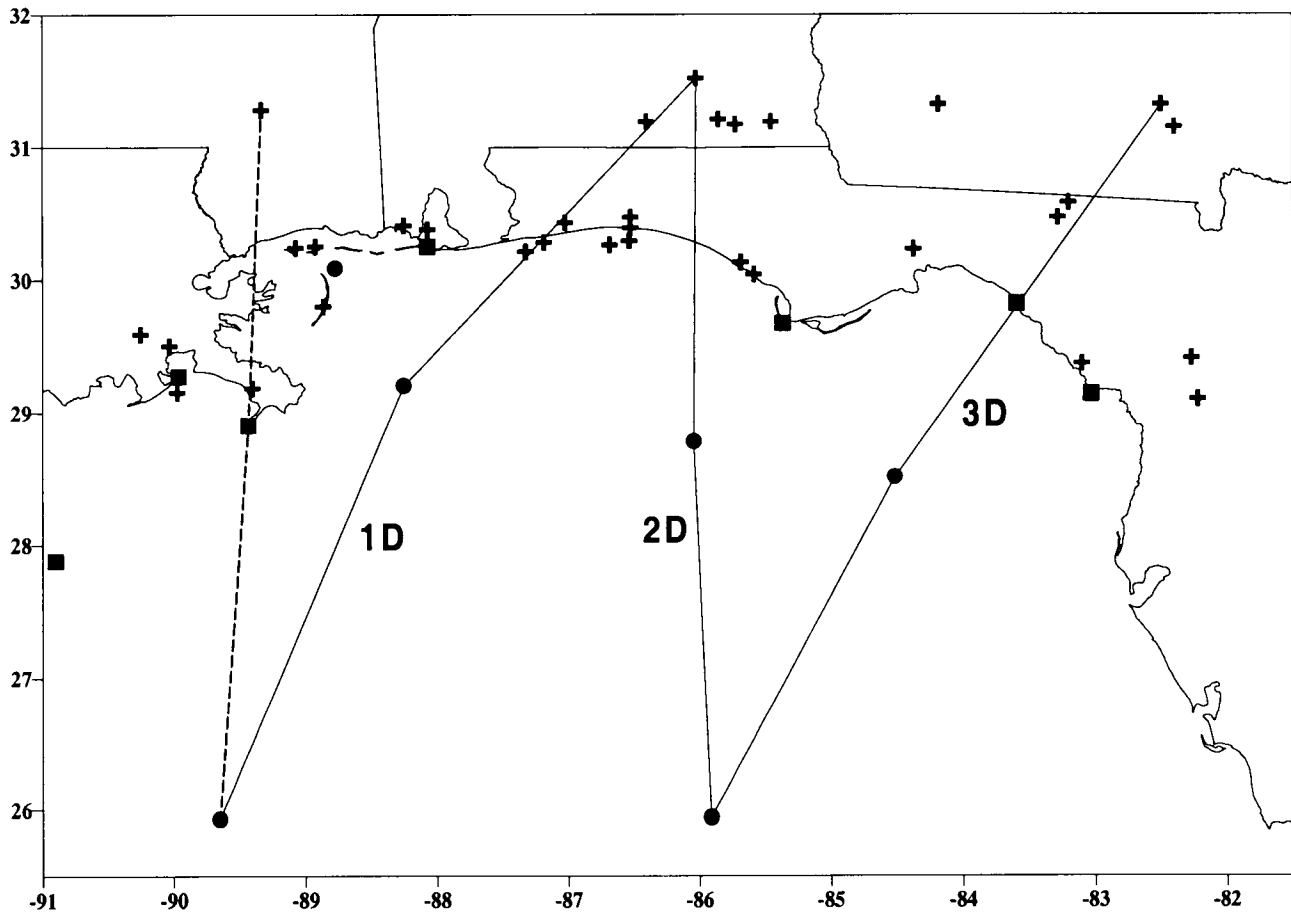


Figure 5-5. Location of deep water transects in the NEGOM. Dashed line represents original definition that was dropped from the analysis due to lack of observation data. (Note: + indicates land-based stations, squares are C-MAN stations, circles are buoys, and diamonds are upper air sites.)

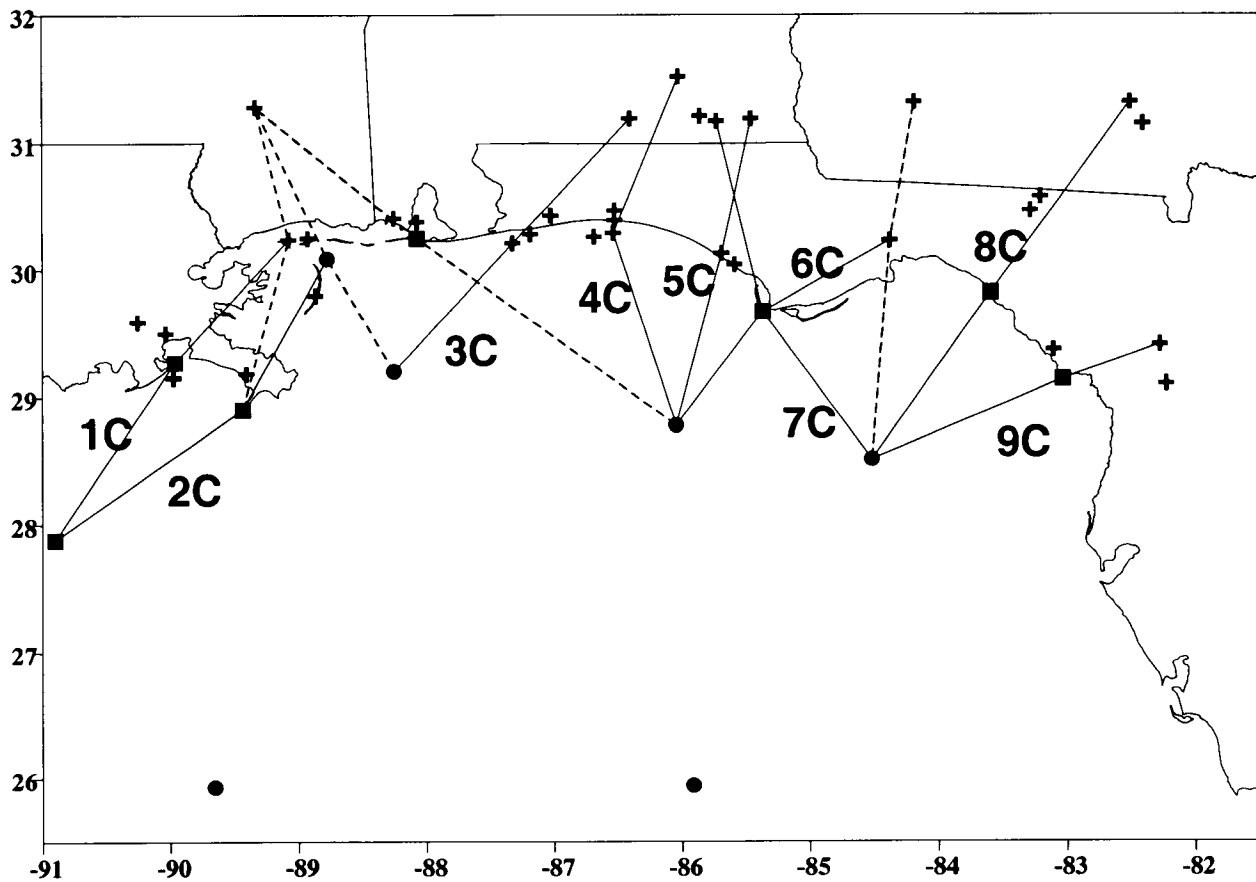


Figure 5-6. Location of coastal water transects in the NEGOM. Dashed line represents original definition that was dropped from the analysis due to lack of observation data.
 (Note: + indicates land-based stations, squares are C-MAN stations, circles are buoys, and diamonds are upper air sites.)

6. SYNTHESIS AND CONCEPTUAL MODELS

OVERVIEW

In Chapter 4 we describe 10 prevalent weather types that encompass the bulk of meteorological conditions in the study area. These weather types were designed so that investigators can determine the dominant synoptic weather pattern currently affecting or forecasted to affect weather conditions in the region, and then determine the climatologically-averaged conditions that accompany such patterns. The observational and Eta model Access databases have been organized so that data or the data statistics can be retrieved by weather type (as well as by season).

The weather typing approach is also a convenient starting point for developing a conceptual understanding of surface meteorological phenomena in the NEGOM. Firstly, general flow patterns and tendencies can be more easily discerned when grouped by the forcing synoptic- and mesoscale pressure and frontal patterns. Secondly, physical reasoning is easily applied in understanding the differences in meteorological statistics between weather types. For example, the “No Gradient” category can be expected to exhibit lower average wind speeds, higher average temperatures, and greater wind direction variability than most other categories because physical reasoning suggests more chaotic light winds, higher pressure, and subsidence in this category. Third, since frontal passage is an integral component of our weather typing scheme, frontal passages can be described as sequences of weather types; so corresponding meteorological parameter statistics by weather type can be assembled to assess how frontal passage, air mass evolution, and cyclogenesis affect local fields in the NEGOM.

In this chapter, we present discussions of the consistency and correlations between conceptual models of the conditions associated with each weather type by season, and the statistics calculated on the observed database by weather type and season. For this investigation, the seasons were defined as follows:

- Winter months -- December, January, and February
- Spring months -- March, April, and May
- Summer months -- June, July, and August
- Fall months -- September, October, and November

DISCUSSION OF FREQUENCY OF WEATHER TYPES BY SEASON

Table 6-1 summarizes the annual and seasonal frequency of occurrence of each meteorological pattern type for the period 1996-1997. Review of these statistics reveals the following notable characteristics:

- The East Continental High pressure pattern (ECH) was, by far, the most frequent pattern during all seasons.

- The high pressure patterns (ECH, MCH, BH, NG, plus GH) dominated 80% of the year; the fall and winter had the lowest total frequencies (78%) and the spring had the highest (89%).
- The No Gradient (NG) pattern frequency peaked in the fall.
- The Gulf High (GH) pattern frequency peaked in the summer.
- The East-West frontal pattern (GFEW) occurred most frequently in the fall.
- The North-South frontal pattern (GFNS) occurred most frequently in the spring.
- The Mid-continental low pressure (MLOW) and Eastern low pressure (ELOW) patterns rather infrequently affected the weather in the NEGOM.
- The tropical storm (TS) pattern occurred very infrequently in all seasons, especially in the summer season.

Generally speaking, the statistics confirm that the NEGOM was dominated by fair weather conditions, which was infrequently punctuated in all season by frontal passage. Tropical storms are infrequent, and did not occur once during the summer months of both years (which seems counter-intuitive).

Most of these findings are consistent with expectation based on common-sense meteorological reasoning and longer-term historical climatology. However, it must be remembered that a strong El Nino event marked the second half of 1997, and the related eastern movement of the Southern Oscillation in the Pacific was signaled in late 1996. El Nino events are known to suppress western Atlantic tropical storm development in the summer and fall months following onset.

Table 6-1.
1996-1997 annual and seasonal frequencies of
occurrence for each meteorological regime defined in Section 4.

MET. TYPE	ANNUAL FREQ. (%)	SPRING FREQ. (%)	SUMMER FREQ. (%)	FALL FREQ. (%)	WINTER FREQ. (%)
MCH	11	14	7	5	16
ECH	29	25	29	24	38
BH	18	23	23	13	14
MLOW	2	2	1	1	2
GFNS	8	12	8	5	9
GFEW	6	4	4	10	7
ELOW	3	3	2	4	4
GH	8	8	12	8	3
NG	14	8	15	28	7
TS	1	1	0	2	1

DISCUSSION OF STATISTICAL DIFFERENCES BETWEEN SEASONS

Table 6-2 provides a summary of the mean and variability of key meteorological parameters in the NEGOM for 1996-97 by season. Review of these results lead to the following points:

- Winds are strongest in the winter, and lighter and more variable in the summer.
- Generally winds are from the east, yet progressively turn from southerly in the summer to northeasterly in the winter.
- Surface air temperature follows the expected season patterns.
- Annually, sea-surface temperature (SST) are greater than air temperatures (unstable regime). In spring and summer, SST is less than the air temperature (stable regime), but in the fall and winter, unstable conditions prevail as off-shore flow moves cooler continental air over the Gulf.
- Geostrophic vorticity is slightly positive annually, suggesting the dominance of cyclonic curvature of surface-level winds; negative vorticity (anti-cyclonic curvature) is evident in spring and summer, likely due to the dominance of high pressure regimes.

- Variability in vorticity is larger in the winter, possibly due to the larger frequency of transient systems moving through the area, while it is least variable in the summer with the establishment of constant and stationary high pressure systems.
- Wind stress curl follows the vorticity patterns since the two are directly related.

It is important to note that the mean vorticity and wind stress curl reported in these tables are rather low (about 1 order of magnitude smaller than the rotational rate of the Earth, or the coriolis effect). This suggests that the means for each meteorological type are influenced by both cyclonic and anti-cyclonic regimes on a day-to-day basis. Since they are near-zero, the vorticity means are probably not statistically significant, and so the reader should not place much significance on the actual values.

Table 6-2.

Annual and seasonal mean and variability (standard deviation) of key observed and derived meteorological variables from coastal and ocean-based observation sites and Eta grid points.

OBSERVED/DERIVED PARAMETER	ANNUAL MEAN/SD	SPRING MEAN/SD	SUMMER MEAN/SD	FALL MEAN/SD	WINTER MEAN/SD
Wind Speed (m/s)	5.3 / 2.4	5.6 / 2.5	4.2 / 2.1	5.6 / 2.5	6.1 / 2.6
Wind Direction (deg)	90 / 59	112 / 55	169 / 66	64 / 57	43 / 57
Surf. Temp. (deg. C)	23.8 / 3.1	22.7 / 3.5	29.7 / 1.5	25.1 / 4.1	17.5 / 3.5
Humidity (%)	77 / 10	80 / 11	77 / 7	75 / 11	78 / 13
SST (deg. C)	24.4 / 2.0	22.5 / 2.5	29.2 / 1.3	25.7 / 2.9	19.5 / 1.4
Wind Stress Curl from Eta ¹	0.6 / 25.0	-0.2 / 19.3	0.2 / 12.1	1.1 / 24.3	1.4 / 44.3
Vorticity from Eta ²	0.6 / 83.5	-3.9 / 77.9	-1.6 / 69.1	5.3 / 76.7	2.7 / 110.8

¹Values in units of $10^{-7} \text{ kg m}^{-2} \text{ s}^{-2}$

²Values in units of 10^{-6} s^{-1}

DISCUSSION OF STATISTICAL DIFFERENCES BETWEEN WEATHER TYPES

Table 6-3 provides a summary of the mean and variability of key meteorological parameters in the NEGOM for 1996-97 by meteorological pattern type. Review of these results lead to the following points:

- The strongest winds are associated with the low pressure regimes and transient systems, e.g., the GFNS and the more quick-moving high pressure systems such as MCH.
- The wind directions faithfully reflect the typing procedure (since the approach relied heavily upon recognizing the patterns in wind directions); the frontal and No Gradient

types are associated with the largest variability in direction, while the Tropical Storm type has lower than expected variability (potentially a result of the very few TS cases in the database).

- Surface air temperatures by meteorological type generally reflect the seasons in which each type dominate; the maximum variability is seen for MCH, and is probably related to the fact that under this condition offshore flow is bringing post-frontal continental air into the NEGOM, the temperature of which varies significantly by season (this is consistent with the temperature variability shown by type and season, provided in Appendix A). Less variance is seen for on-shore types and TS, due to consistent temperatures within the tropical maritime air mass.
- Humidity is lower for off-shore flow regimes, and higher for on-shore regimes as well as those types that occur in single seasons.
- Negative vorticity (anti-cyclonic curvature) is associated with high pressure regimes (GH, NG, BH), but also includes MLOW; positive vorticity is seen for low-pressure regimes but also includes MCH and ECH. The highest variability is associated with the most transient systems.

While the meteorological categories were defined by the presence and influence of high and low pressure systems in or near the NEGOM, the actual flow patterns in the NEGOM were often characterized by curvature in opposite sense to the pressure regime. For example, in the MLOW case, a low pressure center is located over the mid-U.S., with a front extending southward approaching the Gulf. Air flow in the NEGOM often curves anti-cyclonically (from easterly to southeasterly) well ahead of such fronts; furthermore, MLOW commonly exists with the BH condition. Also, for MCH and ECH categories, high pressure systems induce off-shore flow that often curves cyclonically from northerly to westerly once well beyond the coastline.

The reader is referred to Appendix A for additional detail, where these statistics by meteorological pattern are further broken down by season.

Table 6-3.

Annual mean and variability (standard deviation) by meteorological type of key observed and derived meteorological variables from coastal and ocean-based observation sites and Eta grid points.

PARAMETER	METEOROLOGICAL TYPE									
	MCH	ECH	BH	MLOW	GFNS	GFEW	ELOW	GH	NG	TS
Wind Speed (m/s)	6.5 / 2.8	5.5 / 2.5	5.4 / 2.2	5.9 / 2.8	6.7 / 3.1	4.8 / 2.5	6.4 / 2.7	4.8 / 2.1	3.5 / 1.8	8.6 / 3.0
Wind Direction (deg.)	347 / 51	68 / 53	147 / 49	162 / 54	296 / 77	141 / 79	291 / 47	213 / 51	172 / 77	30 / 46
Surf. Temp. (deg. C)	18.7 / 4.5	23.3 / 3.9	24.7 / 2.3	24.8 / 2.0	22.1 / 3.1	25.8 / 2.3	23.4 / 2.7	25.4 / 2.4	26.7 / 2.8	27.0 / 1.2
Humidity (%)	69 / 14	74 / 12	86 / 8	88 / 8	80 / 13	83 / 8	71 / 11	83 / 9	75 / 10	82 / 5
SST (deg. C)	22.1 / 2.1	24.3 / 2.3	23.8 / 1.9	23.5 / 2.2	22.7 / 1.6	25.5 / 1.8	24.3 / 1.5	25.0 / 1.8	26.9 / 1.9	26.8 / 0.7
Wind Stress Curl from Eta ¹	2.5 / 62.8	0.6 / 20.2	-0.3 / 22.1	-1.0 / 10.7	1.5 / 23.9	0.9 / 12.4	0.5 / 31.4	-0.5 / 13.4	0.2 / 22.9	5.4 / 32.0
Vorticity from Eta ²	8.2 / 116.4	4.0 / 73.2	-5.9 / 73.2	-6.3 / 83.5	9.2 / 105.5	5.2 / 77.3	1.7 / 118.3	- / 11.0/80.9	-5.5 / 75.4	29.3 / 90.1

¹Values in units of $10^{-7} \text{ kg m}^{-2} \text{ s}^{-2}$

²Values in units of 10^{-6} s^{-1}

DISCUSSION OF TIME-SERIES STATISTICAL DIFFERENCES BETWEEN SITES

Time series were conducted for the sixteen stations listed in Table 5-2 to discern diurnal patterns in the data. Two scalar parameters that would likely be influenced by diurnal oscillations were selected for analysis -- surface temperature and wind velocity component (the component orthogonal to the coast line). Although wind direction is also likely affected, time series analyses for this parameter were not feasible as this is a vector quantity. The results of these analyses are graphically depicted in the figures in Appendix B. We summarize key features of these results in Table 6-4.

Two obvious conclusions can be drawn from these results. First, the effects of land-sea breeze recirculation and flow reversals are not felt far offshore; certainly less than 80 km and probably no further than about 50 km. This finding is consistent with prior analyses of coastal meteorology in the Gulf of Mexico. Second, the land-sea breeze effect is much less pronounced offshore Louisiana; probably due to the predominance of swamps and a poorly defined coastline.

As discussed in Chapter 5, we also filtered the observed meteorological data to remove the diurnal signals. This was accomplished using a 12 block averaging method. The effectiveness of this filtering can be seen in the filtered results for selected stations that exhibited strong diurnal, as shown in the figures of Appendix C. These results confirm that the 12-hour block filtering effectively removed the diurnal land-sea breeze components of the data stream. Thus, the filtered data are available for use by investigators that wish to examine meteorological conditions absent diurnal influences.

Table 6-4.
Diurnal land-sea breeze influences at surface meteorological
data sites based on interpretation of time series analysis for the 1995-1997 data period.

Site	Location	Approximate Distance from Shoreline (km)	Discernable Diurnal Influence (wind speed/temps.)
Buoy 42001	Mid Gulf	300	none/none
Buoy 42002	West Gulf	250	none/none
Buoy 42007	OTP	25	weak/weak
Buoy 42036	West Tampa	150	none/none
Buoy 42039	Pensacola S	80	none/none
Buoy 42040	Mobile South	80	none/none
Land Based 722210	Eglin AFB/Valparais	< 10	strong/strong
Land Based 722225	Pensacola NAS	< 10	strong/strong
Land Based 747686	Keesler AFB/Biloxi	< 10	strong/strong
Land Based 747750	Tyndall AFB	< 10	strong/strong
C-MAN Buoy BURL1	Southwest Pass, LA	< 10	very weak/weak
C-MAN Buoy CDRF1	Cedar Key, FL	< 10	weak/moderate
C-MAN Buoy DPIA1	Dauphin Island, FL	< 10	very weak/moderate
C-MAN Buoy GDIL1	Grand Isle, LA	< 10	very weak/moderate
C-MAN Buoy KTNF1	Keaton Beach, FL	< 10	moderate/moderate
BRETON	Breton Island	25	none/weak

ANALYSIS OF FRONTAL PASSAGES AND CYCLOGENESIS

During the 1996-97 period, about a dozen cyclogenesis events occurred in the northern Gulf of Mexico, during which times low pressure centers rapidly deepened over the Gulf and exited to the northeast. These cases were found to occur between late fall and early spring. About another dozen or so events also occurred during this period in which low pressure centers over the Gulf coast states (Arkansas, Louisiana, Mississippi, Alabama, and Georgia) intensified via the strong baroclinic zones that set up along associated frontal systems extending southward into the Gulf.

A comprehensive description of the role that the NEGOM plays in frontal passage and cyclogenesis is not feasible on a case-by-case basis because of the unique characteristics of each event. The most significant of these characteristics include:

- the role of larger-scale synoptic forcings;
- orientation of the frontal systems (north-south vs. east-west);
- type of fronts (warm, cold, stationary);
- speed of the low/frontal systems, and the tendency for stalling/stationarity; and
- locations within the NEGOM.

However, a more generalized description (or conceptual model) of NEGOM cyclogenesis has been developed by reviewing the events occurring in the 1996-97 period to characterize the process as a progression or sequence of the meteorological types identified in Section 4. A specific example of a representative frontal passage/cyclogenesis event has been selected as a model to establish the temporal progression of meteorological types. The period analyzed was January 4-10, 1997.

Two conditions appear to be necessary for cyclogenesis to occur in this region: (1) a strong cold-core upper level low or trough above or just to the west of the Gulf; and (2) a preexisting front (commonly a stationary front aligned east-west near the NEGOM coast) defining the boundary between cold continental air and warm tropical maritime air, often associated with a weak surface low pressure center. The following sequence of events for January 4-10, 1997 was found to be typical of cyclogenesis in the NEGOM:

- January 4 (Bermuda High): In the NEGOM winds are light from the south and southeast and temperatures are in the low 70's over the water; a strong frontal system is approaching the Mississippi Valley, extending to the southwest from a very deep low pressure system over the upper midwest.
- January 5 (Midwest Low): As the low enters the Great Lakes area its northeast-southwest oriented front approaches the NEGOM with a preceding heavy squall line; anti-cyclonic curvature increases for the southerly winds over the NEGOM.
- January 6 (Gulf Front East-West): The front stalls over the NEGOM as the low pressure center exits the northeast U.S.; the front aligns east-west just south of the

NEGOM coastline and is associated with a 15 degree (F) temperature gradient. Winds are southerly to the south of the front and northerly to the north of the front.

- January 7 (Gulf Front East-West): The front remains stationary over the NEGOM, but a wave (weak low pressure system) forms on the front south of Texas preceding a very deep and low-latitude upper air trough over the southwestern U.S.; southerly winds strengthen to 15 knots south of the front and heavy precipitation falls along the Gulf coast.
- January 8 (Gulf Front East-West): The stationary front moves slightly south, leading to northeast winds over much of the NEGOM under the East Coast High regime, and the weak low pressure wave retrogrades to the west in response to the amplifying upper-level trough now centered over the southern Rocky Mountains; heavy precipitation in the southeast U.S. continues.
- January 9 (Gulf Front North-South): The low pressure wave suddenly deepens and moves eastward into the NEGOM, driven by the advancing upper level trough now over Mississippi Valley; this reorients the front to a north-south configuration, and a 25-degree (F) temperature gradient across the front increases the baroclinicity of the storm system. Winds are southerly to the east of the front, and are northwesterly to the west of the front. The heaviest precipitation moves to the eastern seaboard.
- January 10 (Gulf High or No Gradient): As the frontal system exits into the Atlantic, more quiescent conditions prevail over the NEGOM; winds are light and variable with a tendency for northwesterly directions, temperatures range in the high 50's and low 60's over the Gulf waters.

7. DESCRIPTION OF AND USER'S GUIDE TO THE EXPERT SOFTWARE SYSTEM (NEGOMES)

OVERVIEW

The MMS NEGOM Expert Software System (NEGOMES) is a graphical-user-interfaced (GUI) software package written in VisualBasic v6.0. NEGOMES allows the various meteorological observations and statistics, derived parameters, gridded ETA model output and other products of this study to be easily accessed and viewed. NEGOMES automates the process of navigating through the multitude of ACCESS data tables, statistical tables, and graphics files. The point-and-click windows style screens are arranged with buttons, drop-down menus, and dialogue boxes that most personal computer (PC) users are familiar with, and guide the user through selections to the desired data tables or plots. The NEGOMES includes user-interactive screens that allow for the construction of parcel trajectories under specific meteorological conditions and seasons, based on statistically-derived wind information. *The Help function within the NEGOMES software package also includes much of the same information presented in this section.*

NEGOMES software and its associated databases are disseminated on a set of 5 CDROMs available from the MMS. The associated NEGOMES database is comprised of nearly 3 Gigabytes of information that includes:

- 1996-1997 surface observation statistics
- 1996-1997 aloft observation statistics
- 1996-1997 gridded observation statistics
- 1996-1997 transect data derived from observed surface data
- 1996-1997 Eta gridded surface data
- 1996-1997 Eta gridded 3-D data
- 1996-1997 gridded Eta surface statistics

NOTE: When running NEGOMS, users should be sure to insert into their computer CD drive the CDROM containing the data appropriate for the NEGOMS data display requested.

NEGOMES FUNCTIONS

A NEGOMES user can select from a number of functions:

- View ACCESS database containing observational data
- View ACCESS database containing Eta meteorological model output fields
- View tabulated observed parameter statistics for user-selected measurement stations
- View time-series plots or surface wind-rose plots for user-selected measurement stations

- View maps of gridded observed parameters statistics
- View maps of gridded Eta model surface or 3-D output
- View maps of gridded Eta model output statistics
- View tabulated statistics of derived parameters along transects
- Perform trajectory evaluation for hypothetical air parcel releases
- Print or export certain viewed tables, maps, or data files.

The users can select to view data, tables or products derived from the entire two-year NEGOMS database or for an individual year (1996 or 1997), an individual season, or an individual weather type. The users can easily navigate from one screen to another and direct the flow to the program by point-and-click action on buttons and pull-down menus. The user can select stations or geographical locations by direct entry of station names, entry of Latitude/Longitude coordinates, and pointing-and-clicking on map locations.

Viewing the ACCESS database required that a copy of ACCESS '97 also be installed on the host computer.

NEGOMES OPERATION

After launching the NEGOMES software session, the user should load the data CDROM appropriate his/her requests. Figure 7-1 displays a flowchart of the NEGOMES, indicating the screens that are presented as one progresses through various paths, beginning with initial selections in the Main Menu Screen. The purposes and operations of each individual screen are described next. Description of the technical concepts, parameters, statistical measures, data products, and data stratifications referred to in this section are provided in Chapters 1 through 5.

SUMMARY

The NEGOMES main program screen allows users to access various statistical data produced during the Northeast Gulf of Mexico study. To view graphical and tabular data and statistics, simply: (1) click on the appropriate button and then, (2) select the data you wish to view from the selection screen that appears next. The Perform Trajectory Evaluation button takes users to an interactive program that allows various trajectory scenarios to be plotted using data from the study.

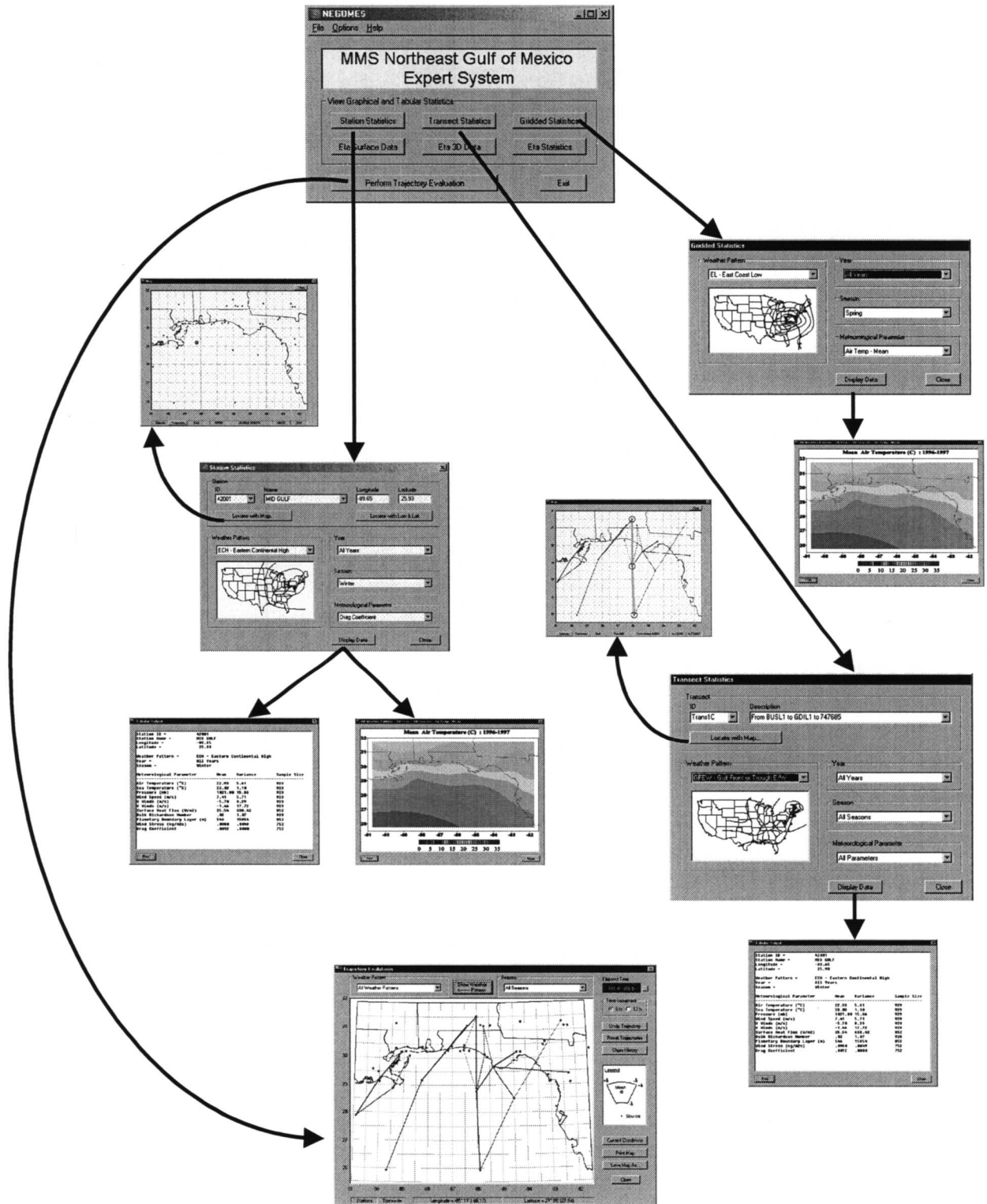


Figure 7-1a. Flow chart depicting the sequencing of various screens within the MMS NEGOMES (observed data).

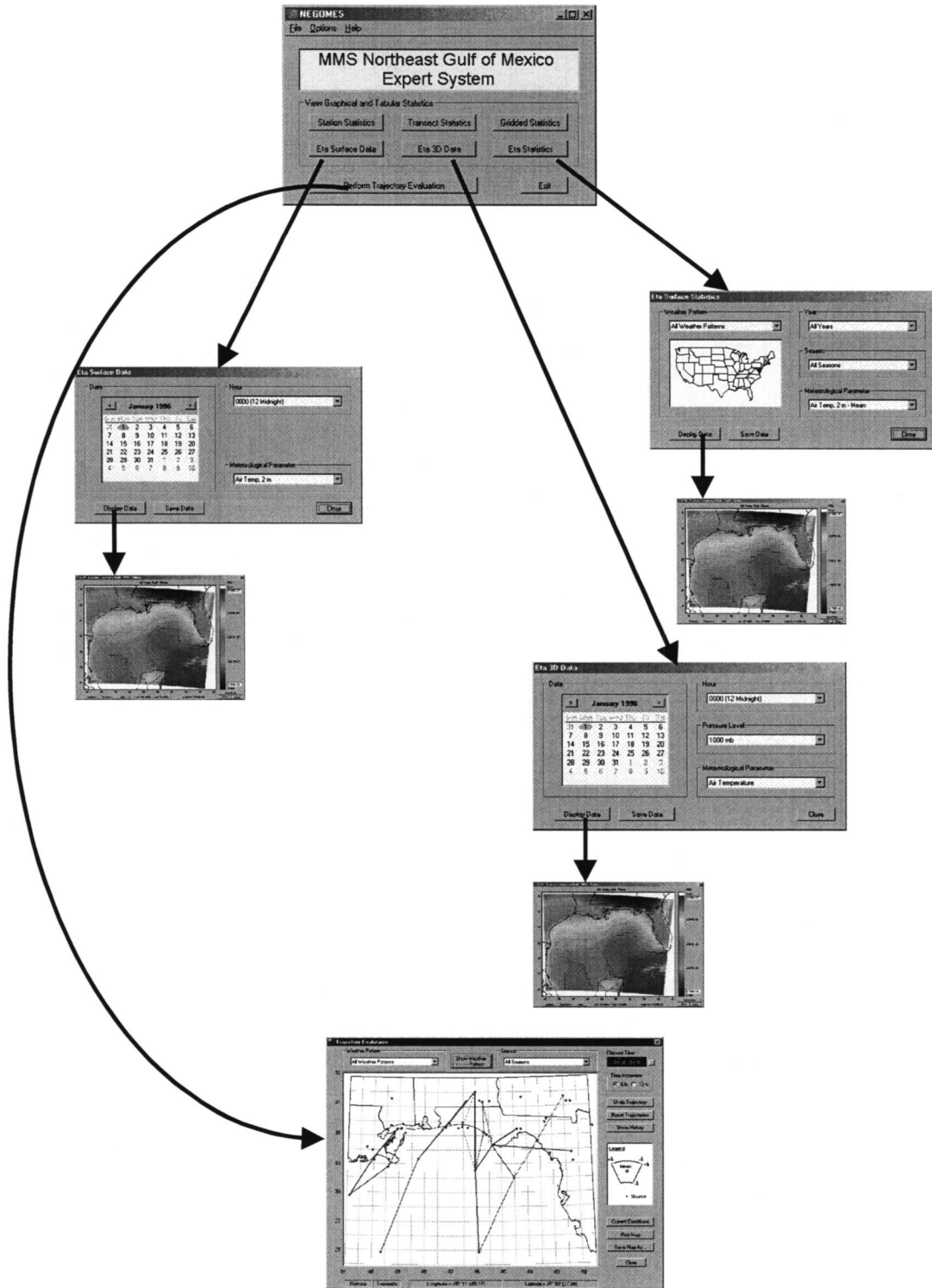


Figure 7-1b. Flow chart depicting the sequencing of various screens within the MMS NEGOMES (Eta model data).

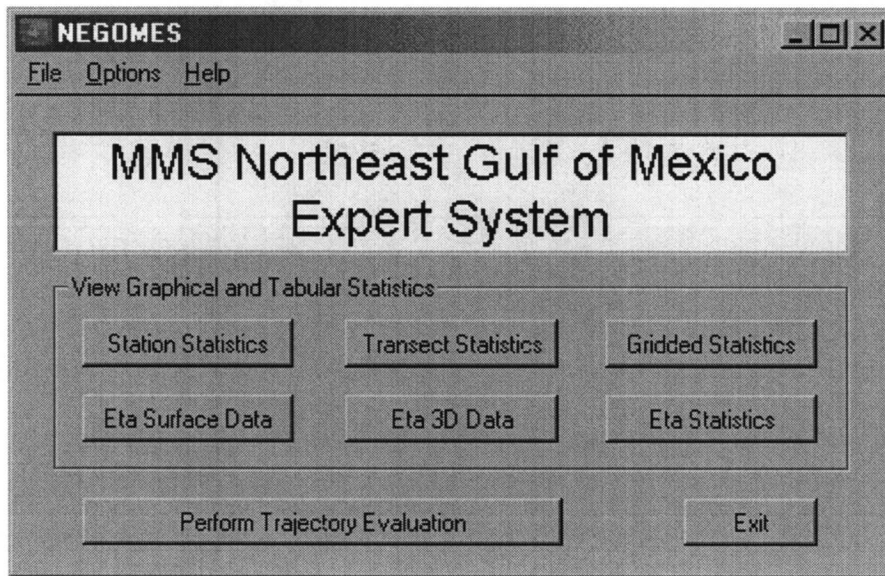


Figure 7-2. Main Program Screen

HOW TO USE THE NEGOMES MAIN PROGRAM SCREEN

Viewing the MMS Database

Select File | MMS Database from the menu bar to open Microsoft Access and load the MMS database file. If your system does not have Microsoft Access '97 installed, you will not be able to view the database file directly. The user should select and load the CDROM containing the observational data appropriate for his/her data request (data content is printed on the CDROM labels).

Viewing the Eta Database

Select File | Eta Database from the menu bar to open Microsoft Access and load the Eta database file. If your system does not have Microsoft Access '97 installed, you will not be able to view the database file directly. The user should select and load the CDROM containing the Eta output appropriate for his/her data request (data content is printed on the CDROM labels).

Exiting NEGOMES

Select File | Exit from the menu bar, or click the "X" button in the top right corner of the main screen to exit the program.

Changing Settings

Select Options | Settings from the menu bar to view the Settings screen. This screen is used to set the location of files needed to run NEGOMES.

Viewing General Program Information

Select Help | About from the menu bar to open the splash screen that is seen at startup.

Locating Help Information

Select Help | Using from the menu bar to open the NEGOMES.HTML file you are currently reading. To print out the User's Guide, just right-click and select Print from the pop-up menu.

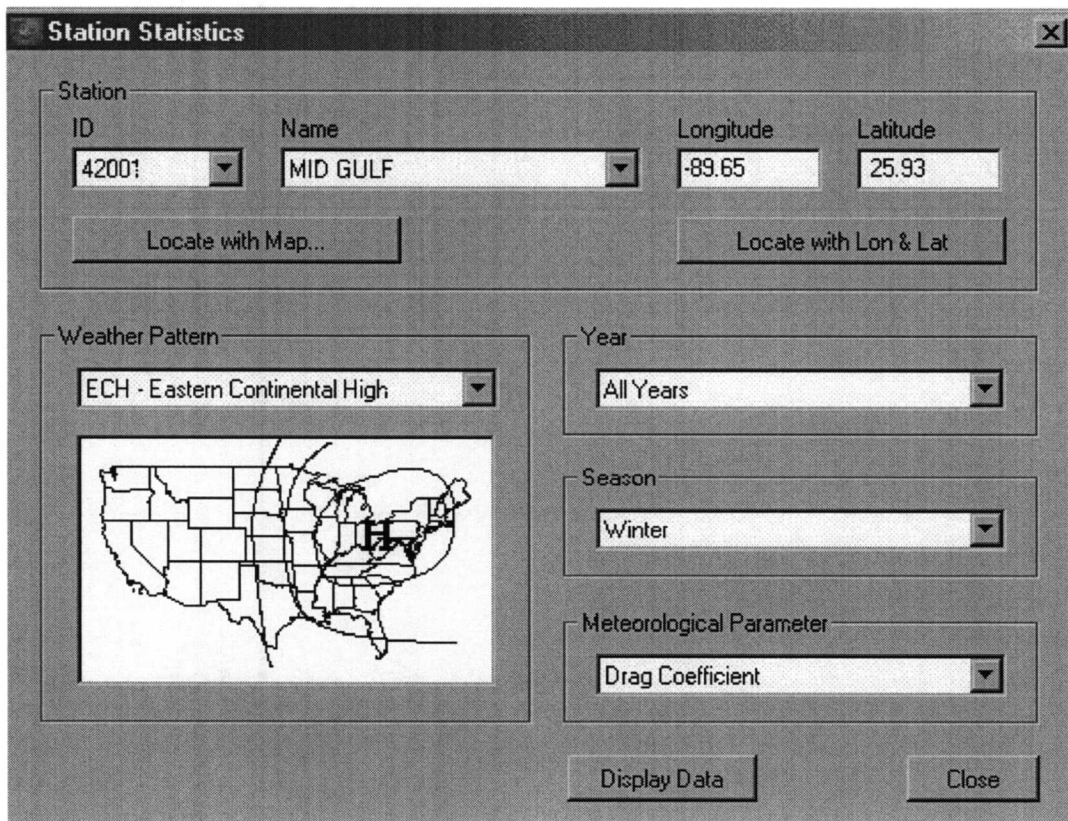


Figure 7-3. Station Statistics Screen

SUMMARY/STATION STATISTICS

The Station Statistics screen is used to retrieve a specific monitoring station's data set. The specified data set is viewed by clicking the Display Data button. The display can be viewed as a tabular summary of data values, a time series image, or as a wind rose image. The displays available are based on the selection of Weather Pattern, Year, and Season.

Certain combinations of Station, Weather Pattern, Year, and Season have either no data or insufficient statistical information available. In these situations, the Meteorological Parameter selection box will indicate "No Data Available."

HOW TO USE THE STATION STATISTICS SCREEN

Selecting a Station

Use one of the following three options to select a station:

- 1) Choose either a Station ID or a Station Name from the appropriate drop-down selection box. When one of these displays is changed, the remaining station information is automatically updated.
- 2) Manually enter longitude and latitude values and click on the Locate with Lon & Lat button. NEGOMES will then determine the closest station to these values and will display the pertinent information for this station. Longitude and latitude coordinates are expressed as degrees north latitude and degrees east longitude (e.g., buoy 42001 coordinates are -89.65 degrees longitude and 25.93 degrees latitude).
- 3) Click on the Locate with Map button. The Map screen appears, displaying the MMS monitoring stations as red dots on a map of the Gulf of Mexico (see "Selecting a Station Using the Map Screen"). Select the appropriate station location on the Map screen, which will return you to the Station Statistics screen. All station information will be updated to reflect the station selected.

Note: Due to missing data and/or sample size limitations, statistics may be unavailable for certain combinations of season, year, or parameter. In these case, the parameter selection box will be blank. For example, certain weather types occur very infrequently or not occur at all during some seasons, so statist

Selecting a Weather Pattern

Ten major weather patterns have been identified in the Gulf of Mexico. Statistics have been gathered on each weather pattern and for all weather patterns combined. Choose a weather pattern using the drop-down selection box. The displayed image of the United States will then be updated to show the main characteristics of the chosen weather pattern.

Selecting a Year

Statistics have been gathered in the Northeast Gulf of Mexico for 1996 and 1997 and for both years combined. Select a year (or all years) by using the drop-down selection box.

Selecting a Season

Statistics have been gathered in the Northeast Gulf of Mexico for each of the four seasons and for all seasons combined. Select a season (or all seasons) by using the drop-down selection box.

Selecting a Meteorological Parameter

Select the meteorological parameter to be viewed by using the drop-down selection box. Wind speed and time series statistics are displayed in graphical images. Other parameters are presented in a tabular data format. Select All Parameters to display variables that are only presented in a tabular data format. The contents of the drop-down selection box change according to the selected station, weather pattern, year, and season. Certain combinations have no statistics available. In these cases, the Meteorological Parameter drop-down selection box will display the message "No Data Available" and the Display Data button will be disabled.

Displaying Station Statistics

After selecting a value for all of the selection options, click on the Display Data button to open a screen with the statistics displayed either as a graphical image, or in a tabular data format. To see another set of statistics, the user can leave the display screen open, change the selection parameters, and click on the Data Display button again. Note: time-series displays are available for only the 16 stations listed in Table 5-2.

Exiting the Station Statistics Screen

Click the Close button at the bottom of the screen, or click the "X" button in the top right corner of the Station Statistics screen to exit the screen

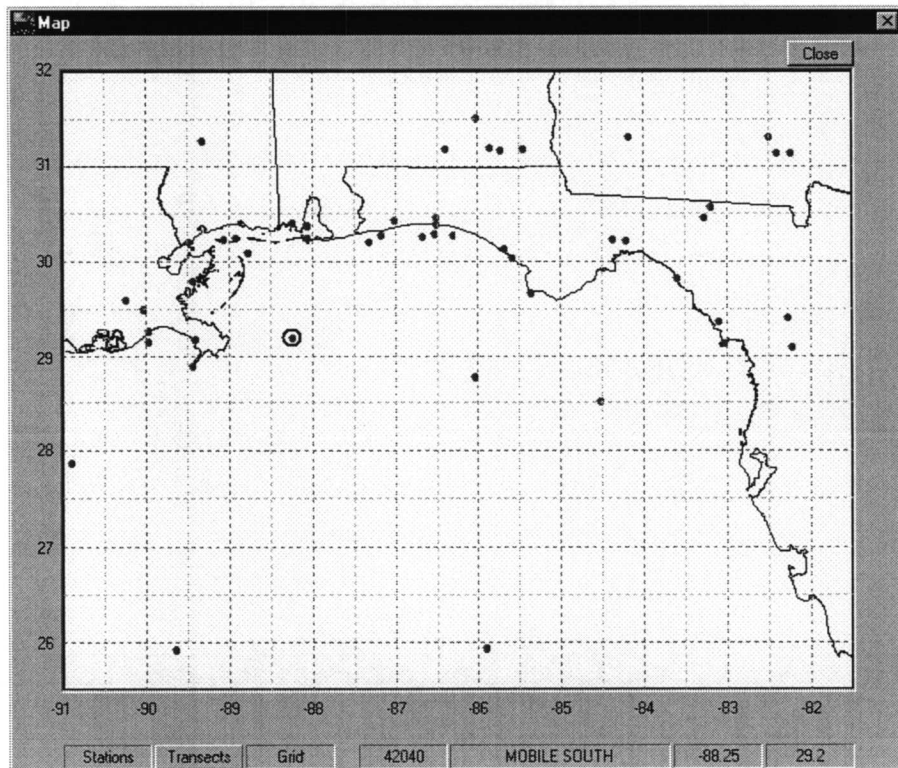


Figure 7-4. Selecting a Station Using The Map Screen

SUMMARY

The Map screen enables the user to select a particular monitoring station in the Northeast Gulf of Mexico Study. Using the mouse, the user selects a red dot which represents a station. When the Close button is clicked, the user is returned to the Select Statistics screen and the information regarding the newly selected station is updated.

HOW TO SELECT A STATION USING THE MAP SCREEN

Display Stations

Stations are indicated by red dots on the map. The station display can be turned off by toggling the Stations button in the lower left corner of the Map screen.

Display Transects

Transects are indicated by colored lines that connect the red dots on the map. The transect display can be turned off by toggling the Transects button in the lower left corner of the Map screen.

Display Grid Lines

Latitude and longitude grid lines are indicated by dashed lines. The grid line display can be turned off by toggling the Grid button in the lower left corner of the Map screen. Longitude and latitude coordinates are expressed as degrees north latitude and degrees east longitude (e.g., buoy 42001 coordinates are -89.65 degrees longitude and 25.93 degrees latitude).

Reading the Status Bar

The status bar at the bottom of the Map screen is divided into four sections: (1) station ID, (2) station name, (3) longitude, and (4) latitude. The status bar displays information for the station currently selected on the map.

Exiting the Map Screen

Click the Close button or click the "X" button in the top right corner of the Map screen to exit the screen.

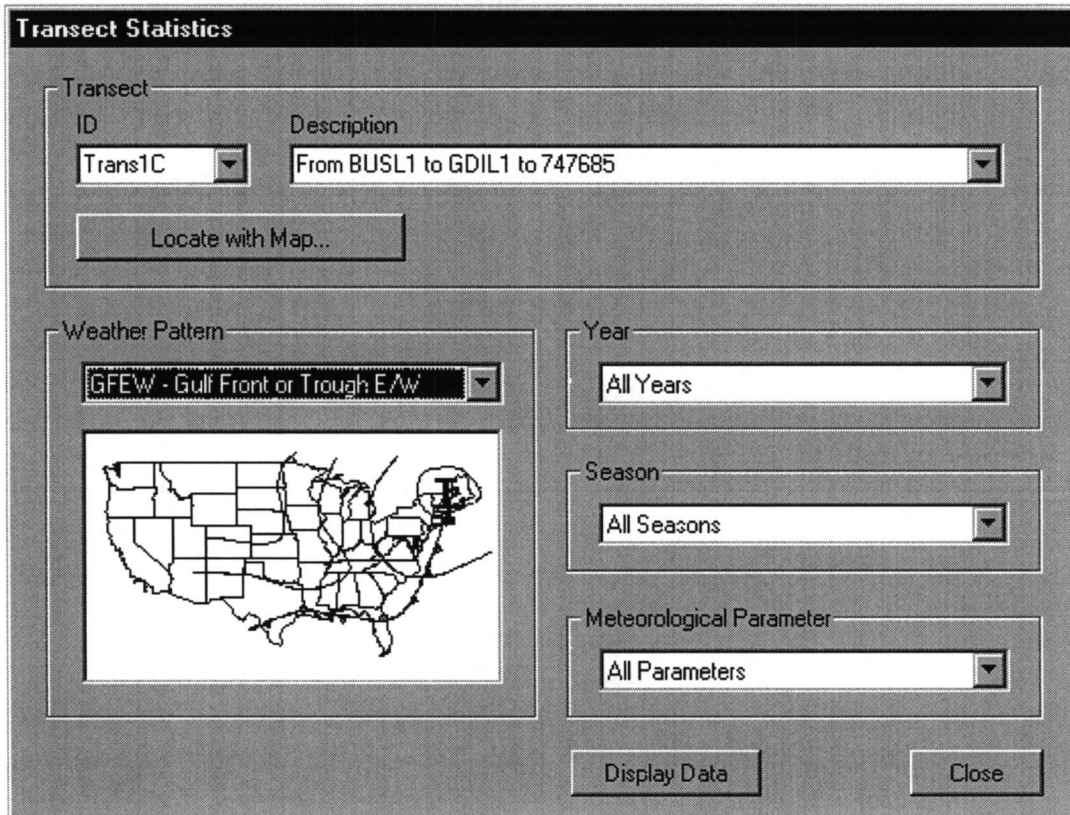


Figure 7-5. Transect Statistics Screen

SUMMARY

The Transect Statistics screen is used to select a data set describing statistical information retrieved from a particular monitoring station. The data set is then viewed by clicking the Display Data button.

HOW TO USE THE TRANSECT STATISTICS SCREEN

Selecting a Transect

Use one of the following two options to select a transect:

- 1) Choose a Transect ID or a Transect name from the drop-down selection boxes provided.
- 2) Use a map to select a transect. Click the Locate with Map button to display the available stations as red dots on a map of the Gulf of Mexico. After making a selection from the Map screen, the user is returned to the Transect Statistics screen and all transect information is updated to reflect the transect selected.

Selecting a Weather Pattern

Ten major weather patterns have been identified in the Gulf of Mexico. Statistics have been gathered on each of these weather patterns as well as on all weather patterns combined. Choose a weather pattern using the drop-down selection box. After the weather pattern is updated, the image of the United States is updated to show the main characteristics of the chosen weather pattern.

Selecting a Year

Statistics have been gathered in the Northeast Gulf of Mexico for 1996 and 1997 and for both years combined. Select a year (or all years) by using the drop-down selection box.

Selecting a Season

Statistics have been gathered in the Northeast Gulf of Mexico for the four seasons, as well as for all seasons combined. Select a season (or all seasons) by using the drop-down selection box.

Selecting a Meteorological Parameter

Select which meteorological parameter you wish to view by choosing the parameter from the Meteorological Parameter drop-down selection box. The contents of the drop-down selection box change according to the selected transect, weather pattern, year, and season. For some combinations of these no statistics exist. In these cases, the Meteorological Parameter drop-down selection box will display the message "No Data Available" and the "Display Data" button will be disabled.

Displaying Transect Statistics

After selecting a value for all of the selection options, click on the Display Data button to open a screen with the statistics displayed as either a graphical image or in a tabular data format. To see another set of statistics, the user can leave the display screen open, change the selection parameters, and click on the Data Display button again.

Exiting the Transect Statistics Screen

Click the Close button at the bottom of the screen to exit the Transect Statistics screen. The user will be returned to the Main Program screen.

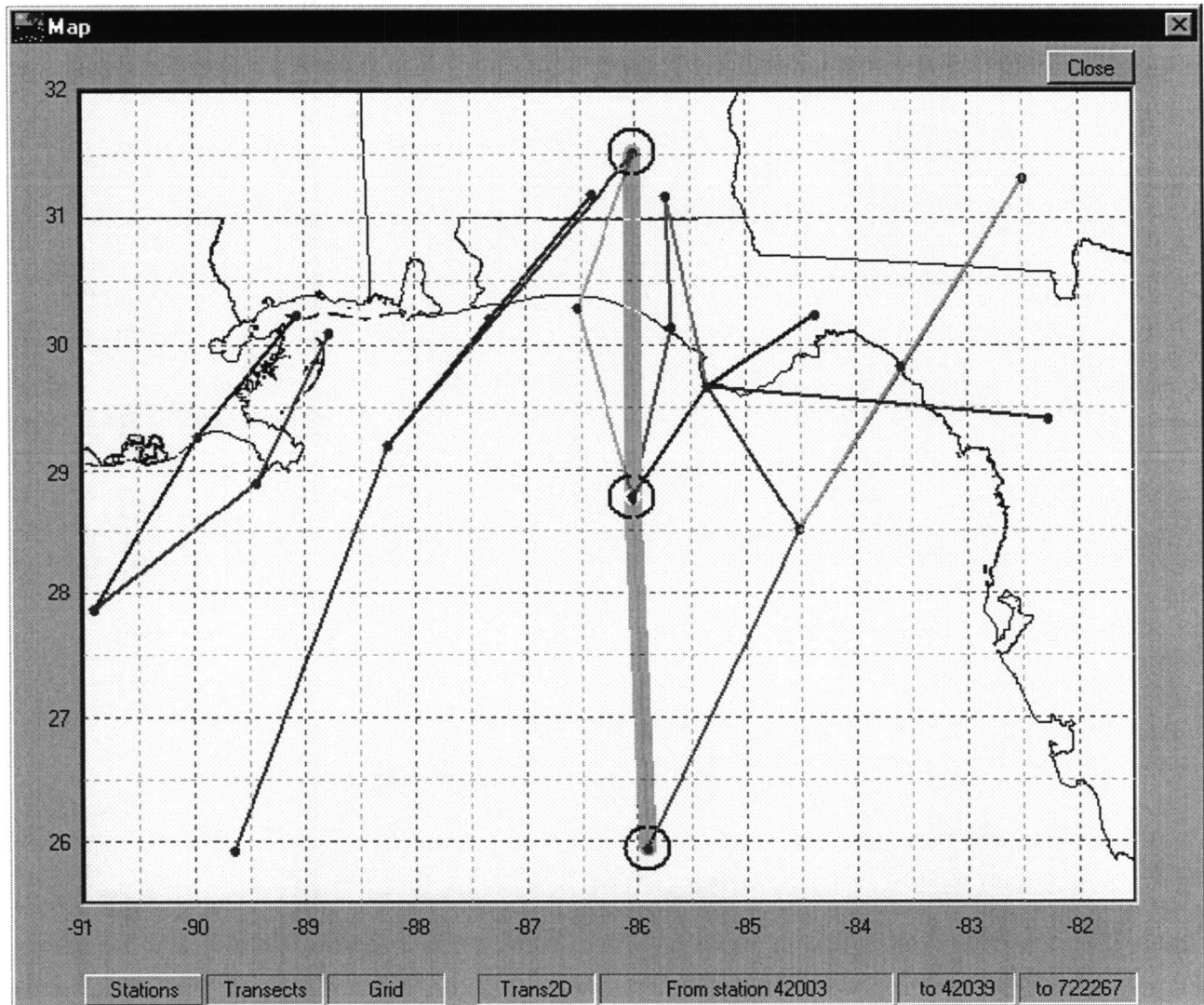


Figure 7-6. Selecting a Transect Using The Map Screen

SUMMARY

The Map screen can be used to select a particular transect (group of three monitoring stations) in the Northeast Gulf of Mexico Study. Using the mouse, the user selects a colored line which represents a transect. When the Close button is clicked, the user is returned to the Transect Statistics screen, and the information regarding the newly selected transect is updated.

HOW TO LOCATE TRANSECTS USING THE MAP SCREEN

Display Stations

Stations are indicated by red dots on the map. The station display can be turned off by toggling the Stations button in the lower left corner of the Map screen.

Display Transects

Transects are displayed by colored lines that connect the red dots on the map. The transect display can be turned off by toggling the Transects button in the lower left corner of the Map screen.

Display Grid Lines

Latitude and longitude grid lines are indicated by dashed lines. The grid line display can be turned off by toggling the Grid button in the lower left corner of the Map screen.

Reading the Status Bar

The status bar at the bottom of the screen is divided into four sections: transect ID, transect description, and the two station end points of the transect. The Status bar displays information for the transect currently selected on the map.

Exiting the Map Screen

Click the Close button or click the "X" button in the top right corner of the Map screen to exit the screen.

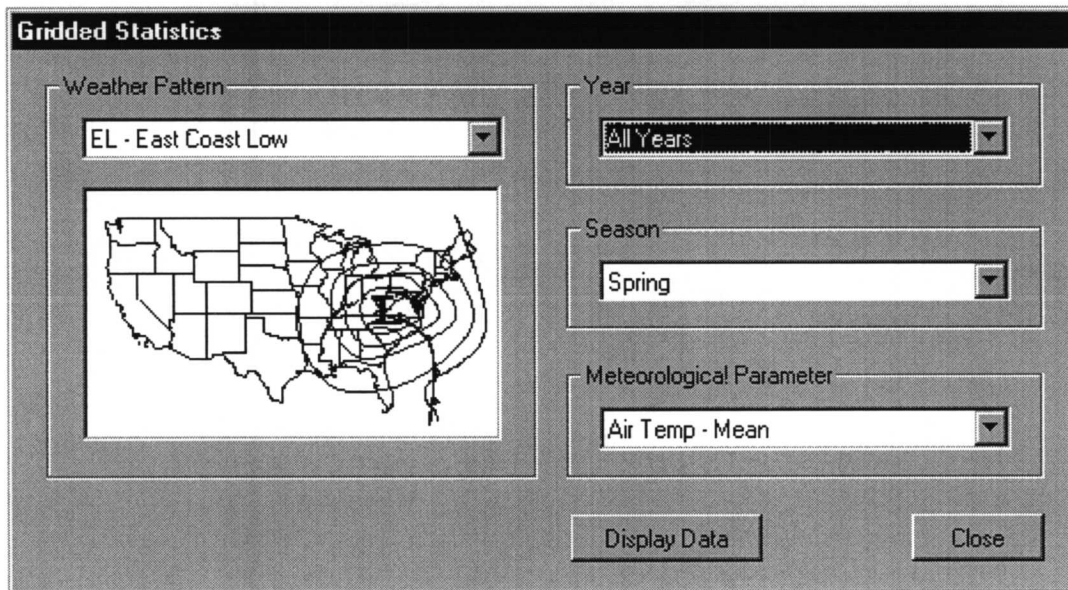


Figure 7-7. Gridded Statistics Screens

SUMMARY

The Gridded Statistics screen is used to select a data set describing statistical information retrieved from a particular grid point. View the data set by clicking the Display Data button.

HOW TO USE THE GRIDDED STATISTICS SCREEN

Selecting a Weather Pattern

Ten major weather patterns have been identified in the Gulf of Mexico. Statistics have been gathered on each weather pattern and for all weather patterns combined. Choose a weather pattern using the drop-down selection box. The displayed image of the United States will then be updated to show the main characteristics of the chosen weather pattern.

Selecting a Year

Statistics have been gathered in the Northeast Gulf of Mexico for 1996 and 1997 and for both years combined. Select a year (or all years) by using the drop-down selection box.

Selecting a Season

Statistics have been gathered in the Northeast Gulf of Mexico for the four seasons, as well as for all seasons combined. The user can select a season (or all seasons) by using the drop-down selection box.

Selecting a Meteorological Parameter

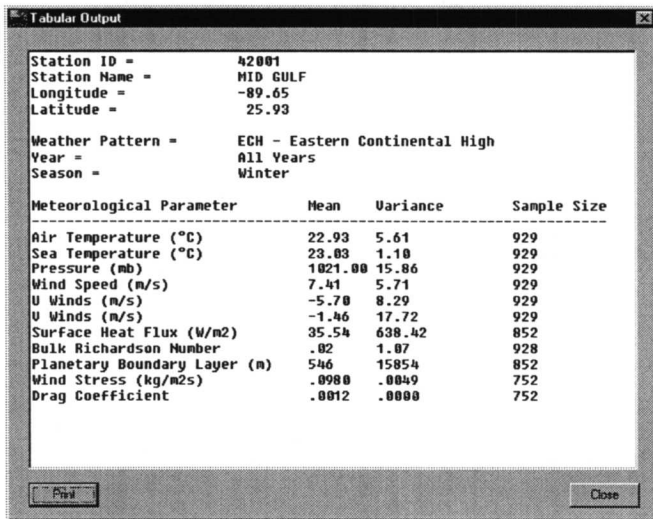
Select the meteorological parameter to be viewed by using the drop-down selection box. The contents of the drop-down selection box change according to the selected station, weather pattern, year, and season. Certain combinations have no statistics available. In these cases, the Meteorological Parameter drop-down selection box will display the message "No Data Available," and the Display Data button will be disabled.

Displaying Gridded Statistics

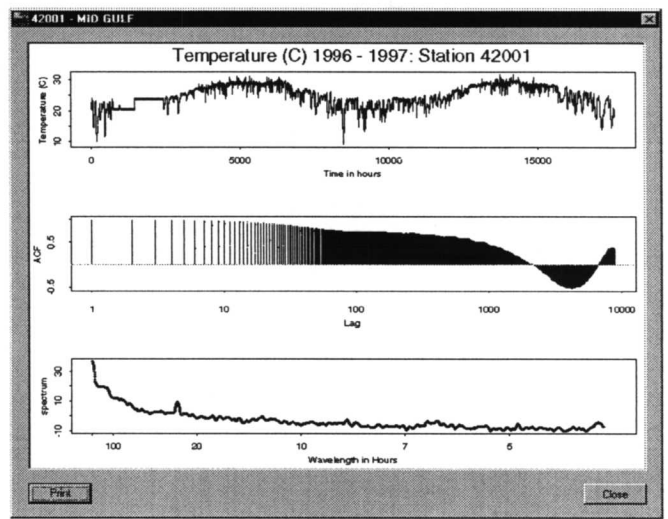
After selecting a value for all of the selection options, click on the Display Data button to open a screen with the statistics displayed as a graphical image. To see another set of statistics, the user can leave the display screen open, change the selection parameters, and click on the Data Display button again.

Exiting the Gridded Statistics Screen

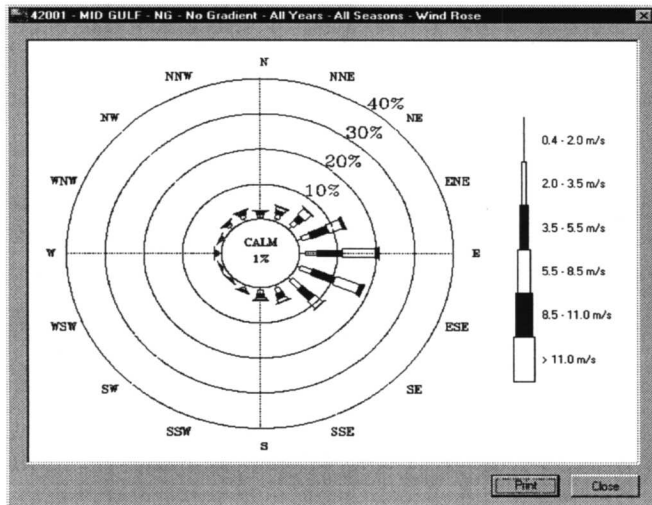
Click the Close button at the bottom of the screen to exit the screen.



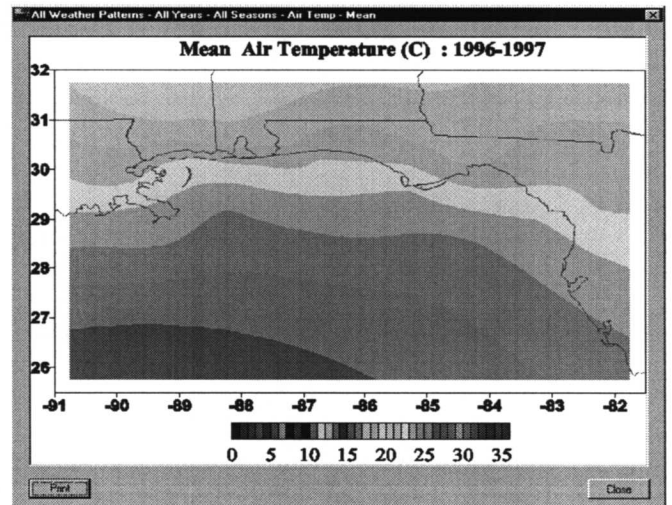
a) Tabular Data



b) Time Series



c) Wind Rose



d) Gridded Data

Figure 7-8. Data Display Screens (accessible from the station gridded statistics screens by clicking the display data button -- note: time-series are not available for all stations; when time series and wind rose data are available, they are listed in the Meteorological Parameter drop-down list as "TS" and "Wind Rose.").

SUMMARY

The Data Display Screens present data in tabular or graphical format. Multiple display screens can be open at one time.

HOW TO USE THE DATA DISPLAY SCREENS

Printing a Data Display Screen

Print the information displayed on a selected screen by clicking the Print button. The image or tabular data display will be sent to the default printer, using the default printer settings.

Closing a Data Display Screen

Click the Close button at the bottom of the screen, or click the "X" button in the top right corner of the screen to close a particular display screen.

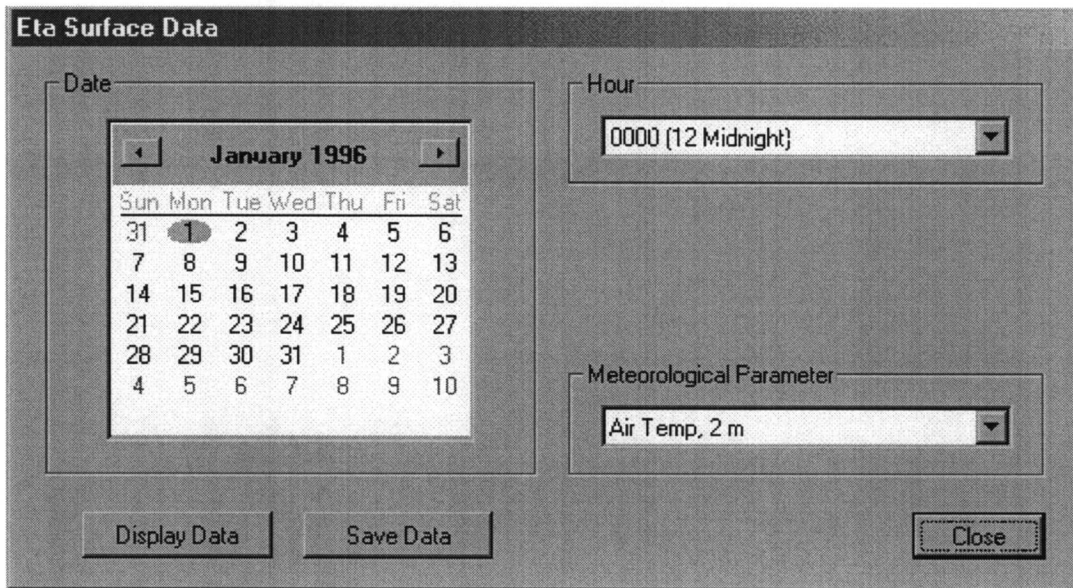


Figure 7-9. Eta Surface Data Screen

SUMMARY

The Eta Surface Data screen is used to select a data set describing surface information for a particular date, time, and meteorological parameter. View a color contour or wind direction plot of the data set by clicking the Display Data button. Save the data set to a comma separated value (.csv) file by clicking the Save Data button and specifying a filename.

HOW TO USE THE ETA SURFACE DATA SCREEN

Selecting a Date

Eta model data have been generated for 1996 and 1997. Select a month by clicking on the arrow buttons and a day by clicking on a date on the calendar.

Selecting a Time

Eta model data have been generated at three-hour intervals. The user can select a time by using the Hour drop-down selection box.

Selecting a Meteorological Parameter

Select the meteorological parameter to be viewed or saved by using the drop-down selection box. Selecting Wind Direction will produce an arrow plot which is color coded by wind speed. Selecting any other parameter will generate a color contour plot when the Display Data button is clicked.

Exiting the Eta Surface Data Screen

Click the Close button at the bottom of the screen to exit the screen.

The screenshot shows a software interface titled "Eta 3D Data". It features a "Date" section with a calendar for "January 1996" where the 1st is selected. To the right, there are three dropdown menus: "Hour" set to "0000 (12 Midnight)", "Pressure Level" set to "1000 mb", and "Meteorological Parameter" set to "Air Temperature". At the bottom, there are three buttons: "Display Data", "Save Data", and "Close".

Figure 7-10. Eta 3-D Data Screen

SUMMARY

The Eta 3D Data screen is used to select a data set describing model information for a particular date, time, pressure level, and meteorological parameter. View a color contour or

wind direction plot of the data set by clicking the Display Data button. Save the data set to a comma separated value (.csv) file by clicking the Save Data button and specifying a filename.

HOW TO USE THE ETA 3D DATA SCREEN

Selecting a Date

Eta model data have been generated for 1996 and 1997. Select a month by clicking on the arrow buttons and a day by clicking on a date on the calendar.

Selecting a Time

Eta model data have been generated at three-hour intervals. The user can select a time by using the drop-down selection box.

Selecting a Pressure Level

Eta model data have been generated for four pressure levels: 1000, 950, 900, and 850 mb. The user can select a pressure level by using the drop-down selection box.

Selecting a Meteorological Parameter

Select the meteorological parameter to be viewed or saved by using the drop-down selection box. Selecting "Wnd Direction" will produce an arrow plot which is color coded by wind speed. Selecting any other parameter will generate a color contour plot when the Display Data button is clicked.

Exiting the Eta 3D Data Screen

Click the Close button at the bottom of the screen to exit the screen.

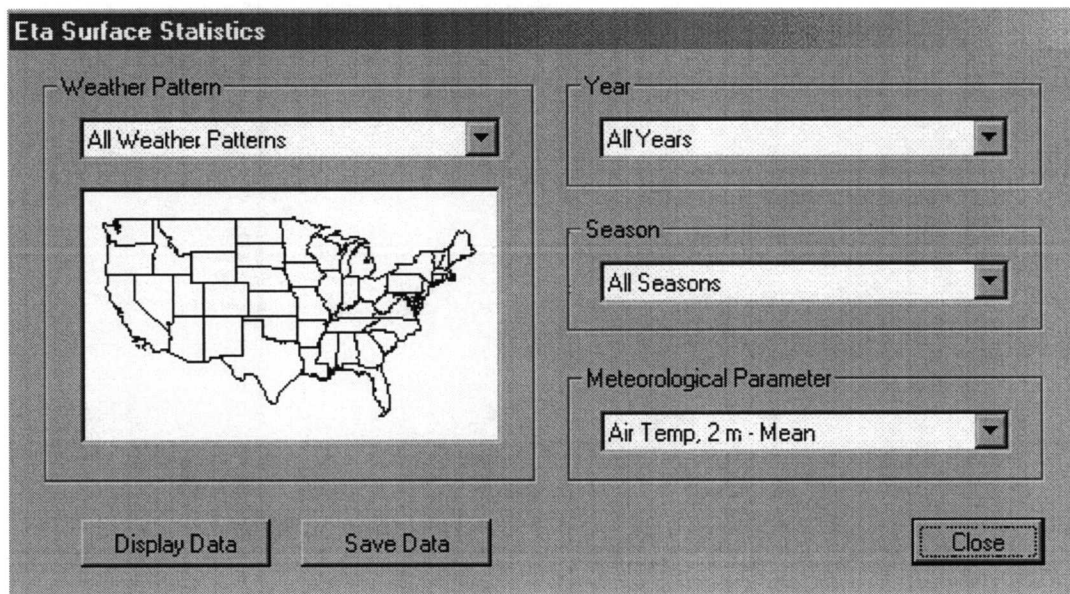


Figure 7-11. Eta Surface Statistics Screen

SUMMARY

The Eta Surface Statistics screen is used to select a data set describing surface statistics for a particular weather pattern, year, season, and meteorological parameter. View a color contour or wind direction plot of the data set by clicking the Display Data button. Save the data set to a comma separated value (.csv) file by clicking the Save Data button and specifying a filename.

HOW TO USE THE ETA SURFACE STATISTICS SCREEN

Selecting a Weather Pattern

Ten major weather patterns have been identified in the Gulf of Mexico. Statistics have been gathered on each weather pattern and for all weather patterns combined. Choose a weather pattern using the drop-down selection box. The displayed image of the United States will then be updated to show the main characteristics of the chosen weather pattern.

Selecting a Year

Eta model data statistics have been generated for 1996 and 1997, as well as for both years combined. Select a year (or all years) by using the drop-down selection box.

Selecting a Season

Eta model data statistics have been generated for the four seasons, as well as for all seasons combined. The user can select a season (or all seasons) by using the drop-down selection box.

Selecting a Meteorological Parameter

Select the meteorological parameter to be viewed or saved by using the drop-down selection box. Selecting "Wind Direction" will produce an arrow plot which is color coded by wind speed. Selecting any other parameter will generate a color contour plot when the Display Data button is clicked.

Exiting the Eta Surface Statistics Screen

Click the Close button at the bottom of the screen to exit the screen.

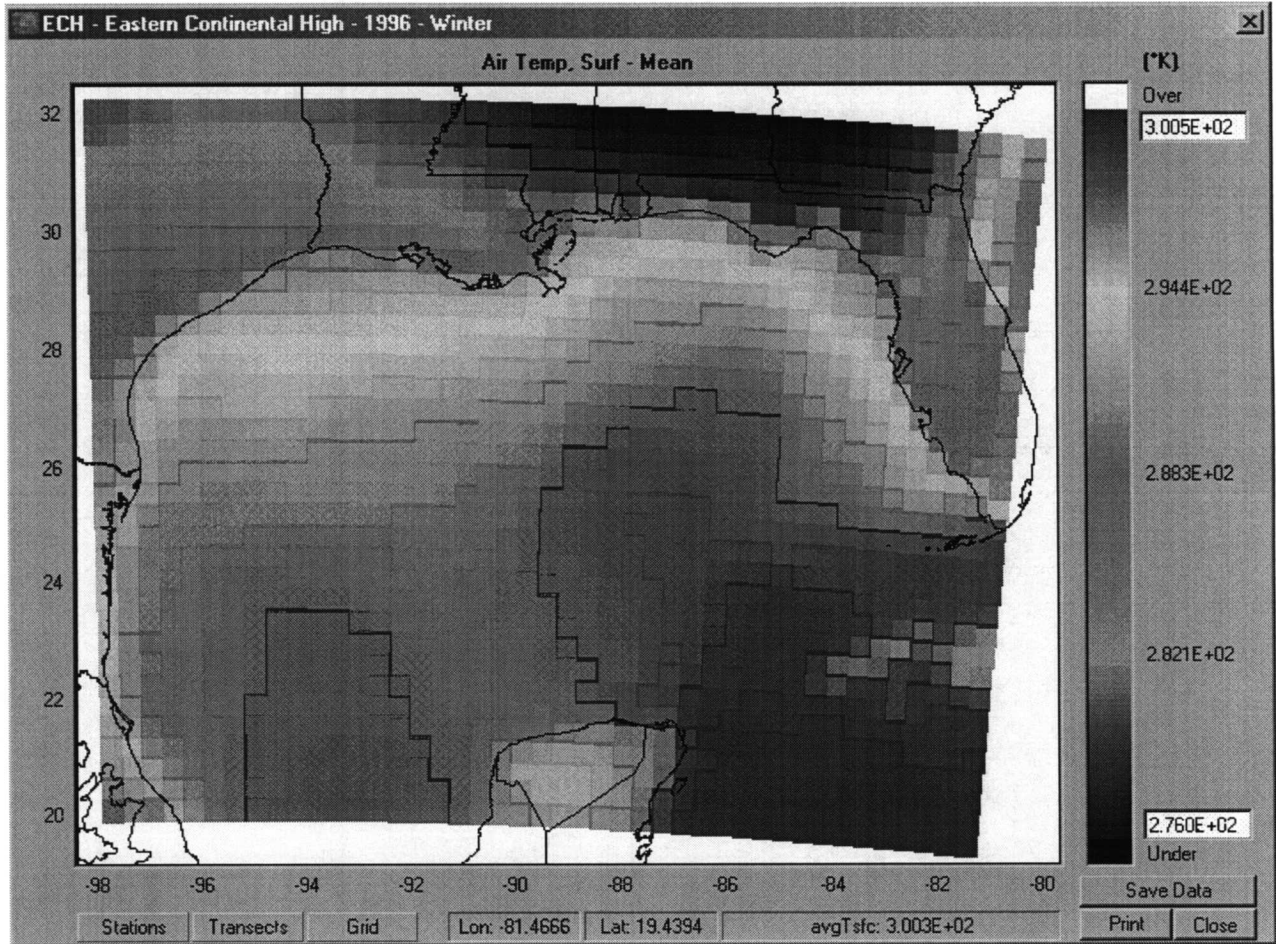


Figure 7-12. Eta Data Display Screen

SUMMARY

The Eta Data Display Screen presents data in graphical format as color contours or wind direction arrows. Only one display screen may be open at one time.

HOW TO USE THE ETA DATA DISPLAY SCREEN

Changing a Data Scale

The upper and lower bounds of the color scale may be adjusted by entering new values in the text boxes at either end of the legend. Initially these are automatically set to the maximum and minimum values found in the data set.

Display Stations

Stations are indicated by red dots on the map. The station display can be turned off by toggling the Stations button in the lower left corner of the Map screen.

Display Transects

Transects are indicated by colored lines that connect the red dots on the map. The transect display can be turned off by toggling the Transects button in the lower left corner of the Map screen.

Display Grid Lines

Latitude and longitude grid lines are indicated by dashed lines. The grid line display can be turned off by toggling the Grid button in the lower left corner of the Map screen.

Reading the Status Bar

The status bar at the bottom of the Map screen is divided into three sections: (1) longitude, (2) latitude, and (3) data field name and value. The status bar displays information for the Eta model grid cell currently selected on the map.

Save the Data to a File

Save the data set to a comma separated value (.csv) file by clicking the Save Data button and specifying a filename.

Printing a Data Display Screen

Print the information displayed on a selected screen by clicking the Print button. The image or tabular data display will be sent to the default printer, using the default printer settings.

Closing a Data Display Screen

Click the Close button at the bottom of the screen, or click the "X" button in the top right corner of the screen to close a particular display screen.

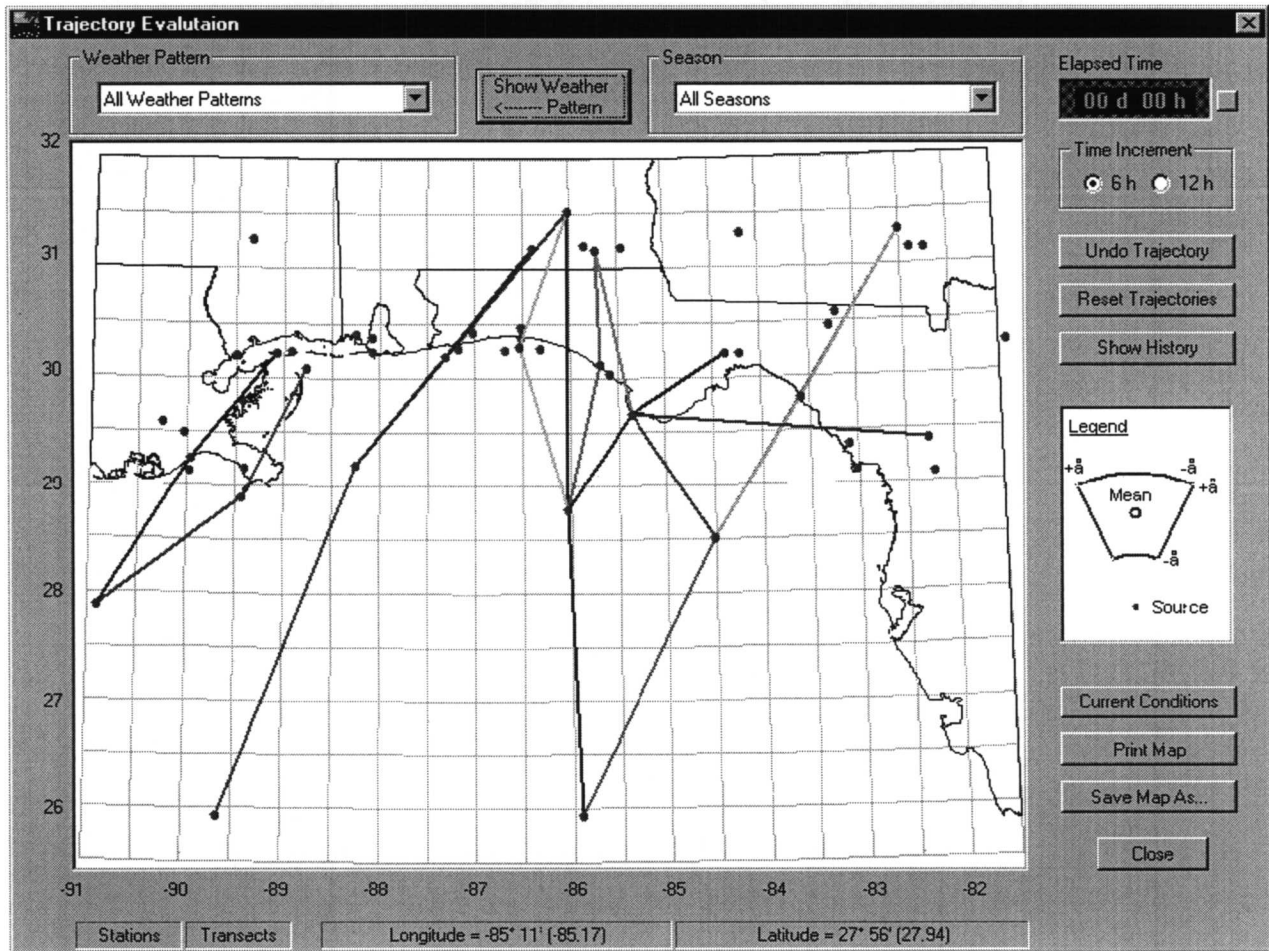


Figure 7-13. Trajectory Evaluation Screen

SUMMARY

The Trajectory Evaluation screen allows the user to plot trajectories in the Northeast Gulf of Mexico region and see the potential transport direction. The trajectories are plotted based on statistics gathered for various weather patterns and seasons in each grid square. By plotting the trajectories one after another, the user can get an idea of the possible distance a particle can travel in specific weather conditions. The resulting plot can be saved to a file as well as printed.

HOW TO USE THE TRAJECTORY EVALUATION SCREEN

Selecting a Weather Pattern

Ten major weather patterns have been identified in the Gulf of Mexico. Statistics have been

gathered on each weather pattern and for all weather patterns combined. Choose a weather pattern using the drop-down selection box. The displayed image of the United States will then be updated to show the main characteristics of the chosen weather pattern.

Selecting a Season

Statistics have been gathered in the Northeast Gulf of Mexico for each of the four seasons and for all seasons combined. Select a season (or all seasons) by using the drop-down selection box.

Selecting a Time Increment

Select the appropriate Time Increment button on the right side of the screen to draw trajectories in either 6 hour or 12 hour increments. Be sure to select the desired time increment before clicking on the map to plot a trajectory.

Plotting Trajectories

After selecting the desired weather pattern season, and time increment, draw a trajectory by clicking on the map where you would like the trajectory to start. If a point outside the map region is clicked, no trajectory will be plotted.

Removing Trajectories

Remove the last trajectory drawn by clicking the Undo Trajectory button located on the right side of the screen. Clicking this button numerous times will undo trajectories one at a time in reverse order. Click the Reset Trajectories button located on the right side of the screen to remove all trajectories.

Viewing Detailed Information About the Trajectories Drawn on the Screen

The Trajectory Evaluation screen is too small to display all of the information about the trajectories. To determine the weather pattern and season used to draw a trajectory, click the Show History button on the right side of the screen. The information for all trajectories will be shown in a window.

Tracking Elapsed Time

The Elapsed Time display at the top right side of the screen shows a summation of the time corresponding to each trajectory. To reset the elapsed time to 0, click the button to the right of the display.

Saving Trajectories

Save a trajectory image to a bit map file by clicking the Save Map As button on the lower right side of the screen. A dialog box will prompt the user for a file name. The trajectory history information will be saved with the image.

Printing Trajectories

Print a trajectory image by clicking the Print Map button on the lower right side of the

screen. The default printer setting will be used to print the image. The trajectory history information will also be printed with the image.

Viewing Current Weather Conditions

Click the Current Conditions button on the bottom right side of the screen to obtain assistance in selecting a weather pattern based on the current weather conditions. If the user has an Internet browser installed, the browser will be started and a URL of a weather site will be loaded so the user can compare the available weather patterns to the current weather pattern. The user will be able to switch between the NEGOMES program and the browser window if both windows cannot fit on the monitor screen.

Viewing Stations and Transects on the Map

Click the Stations toggle button on the bottom left side of the screen to view the location of the monitoring stations. The stations are indicated by red dots on the map. Click the Transects toggle button at the bottom left side of the screen to view the location of the transects. The transects appear as colored lines on the map.

Exiting the Trajectory Evaluation Screen

Click the Close button at the bottom of the screen, or click the "X" button in the top right corner of the Trajectory Evaluation screen to exit the screen. The user will be returned to the Main Program screen.

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State University, Baton Rouge.

APPENDIX A

Seasonal mean and variability (standard deviation) by meteorological type of key observed and derived meteorological variables from coastal and ocean-based observation sites and Eta grid points. The following parameters and units are provided:

- Wind Speed (m/s)
- Wind Direction (deg)
- Surface Temp. (C)
- Humidity (%)
- SST (C)
- Wind Stress Curl from Eta (in units of $10^{-7} \text{ kg m}^{-2} \text{ s}^{-2}$)
- Vorticity from Eta (in units of 10^{-6} s^{-1})

	WINTER	MCH	ECH	BH	MLOW	GFNS	GFEW	ELOW	GH	NG	TS
Wind Speed:	7.6 / 2.8	5.9 / 2.3	5.4 / 2.3	6.7 / 2.2	7.5 / 3.3	5.3 / 2.5	6.9 / 3.2	4.9 / 2.3	3.7 / 2.1	NA / NA	NA / NA
Wind Direction:	344.0 / 44.7	62.0 / 46.9	144.2 / 50.6	172.8 / 55.0	304.7 / 79.3	110.6 / 68.4	297.3 / 47.6	231.4 / 57.2	325.3 / 89.8	NA / NA	NA / NA
Surface Temperature:	13.4 / 4.4	6.4 / 4.1	20.7 / 2.1	21.6 / 1.1	18.4 / 3.7	20.2 / 2.3	16.6 / 3.2	18.6 / 3.6	15.7 / 4.1	NA / NA	NA / NA
Humidity:	69.6 / 13.9	3.5 / 14.2	87.5 / 9.7	86.1 / 10.5	81.5 / 13.6	90.2 / 8.6	65.6 / 12.3	80.6 / 15.9	73.7 / 16.3	NA / NA	NA / NA
SST:	19.0 / 1.5	9.2 / 1.3	19.8 / 1.3	19.5 / 0.3	19.7 / 1.2	19.9 / 1.2	18.9 / 1.5	19.7 / 1.4	18.8 / 1.2	NA / NA	NA / NA
Vorticity:	14.8 / 166.4	3.9 / 81.9	-7.4 / 84.7	-15.8 / 107.6	13.2 / 133.4	6.1 / 74.2	7.2 / 233.3	-10.5 / 97.8	-3.3 / 113.2	NA / NA	NA / NA
Wind Stress Curl:	3.9 / 108.5	0.7 / 25.1	-0.2 / 24.1	-1.4 / 9.6	2.5 / 37.7	2.3 / 28.1	2.7 / 65.2	-0.5 / 30.3	1.6 / 59.1	NA / NA	NA / NA

	SPRING	MCH	ECH	BH	MLOW	GFNS	GFEW	ELOW	GH	NG	TS
Wind Speed:	6.7 / 2.9	5.2 / 2.4	5.6 / 2.1	5.6 / 2.7	6.6 / 3.2	5.9 / 3.2	7.5 / 3.5	4.9 / 1.9	3.8 / 1.7	8.9 / 2.5	8.9 / 2.5
Wind Direction:	351.2 / 55.0	67.3 / 57.1	140.8 / 43.6	54.7 / 56.2	288.6 / 84.0	117.9 / 73.6	289.9 / 49.6	202.4 / 41.0	135.1 / 64.1	61.0 / 49.6	61.0 / 49.6
Surface Temperature:	19.0 / 5.2	21.9 / 4.5	24.1 / 2.6	23.6 / 1.9	21.7 / 2.3	24.3 / 2.6	19.9 / 3.3	24.9 / 2.6	23.9 / 3.9	19.5 / 1.5	19.5 / 1.5
Humidity:	65.4 / 15.0	73.0 / 13.8	89.9 / 7.3	89.7 / 6.4	84.8 / 13.7	88.8 / 7.9	70.3 / 11.3	86.3 / 9.6	79.5 / 14.8	91.4 / 2.2	91.4 / 2.2
SST:	21.1 / 2.4	22.3 / 2.9	22.8 / 2.5	22.0 / 2.0	21.2 / 1.0	22.9 / 2.4	21.0 / 1.4	23.5 / 2.4	23.6 / 2.8	19.6 / 0.2	19.6 / 0.2
Vorticity:	3.1 / 95.8	-0.3 / 74.2	-7.3 / 68.7	-8.2 / 81.0	4.9 / 97.3	-0.4 / 93.8	0.5 / 78.0	-14.2 / 77.5	-14.3 / 63.4	30.4 / 94.8	30.4 / 94.8
Wind Stress Curl:	0.4 / 17.5	-0.1 / 16.0	-0.3 / 32.7	-1.5 / 11.4	0.7 / 16.9	0.2 / 5.1	-0.4 / 39.5	-0.9 / 9.2	-0.8 / 8.3	-2.2 / 19.5	-2.2 / 19.5

	SUMMER	MCH	ECH	BH	MLOW	GFNS	GFEW	ELOW	GH	NG	TS
Wind Speed:	4.0 / 1.9	4.3 / 2.2	4.2 / 1.9	NA / NA	4.6 / 2.1	4.3 / 2.2	4.7 / 2.0	4.7 / 2.0	3.4 / 1.6	7.3 / 3.2	7.3 / 3.2
Wind Direction:	342.5 / 66.0	83.3 / 64.8	173.8 / 59.2	NA / NA	246.9 / 57.3	221.0 / 81.5	270.7 / 49.0	209.3 / 52.5	177.0 / 75.1	224.5 / 53.0	224.5 / 53.0
Surface Temperature:	30.1 / 1.3	29.0 / 1.9	30.1 / 1.1	NA / NA	27.6 / 1.9	29.6 / 1.5	30.1 / 1.8	30.0 / 1.2	30.2 / 1.2	29.3 / 1.2	29.3 / 1.2
Humidity:	72.6 / 9.6	75.4 / 8.1	78.8 / 4.8	NA / NA	72.0 / 9.7	80.0 / 7.0	76.3 / 7.4	81.1 / 6.2	75.4 / 6.0	80.9 / 5.5	80.9 / 5.5
SST:	29.6 / 0.9	28.8 / 1.5	29.4 / 0.9	NA / NA	27.2 / 1.4	29.2 / 1.2	29.4 / 1.4	29.1 / 1.3	29.6 / 1.1	28.1 / 0.8	28.1 / 0.8
Vorticity:	-6.3 / 63.7	4.5 / 64.0	-2.8 / 65.8	NA / NA	1.3 / 74.1	3.1 / 76.4	-6.2 / 76.8	-9.8 / 72.5	-4.2 / 69.1	-0.5 / 80.4	-0.5 / 80.4
Wind Stress Curl:	0.1 / 3.0	0.5 / 12.2	-0.3 / 5.6	NA / NA	-0.2 / 6.9	0.3 / 9.1	-0.3 / 6.4	-0.1 / 5.7	0.2 / 21.1	2.0 / 21.2	2.0 / 21.2

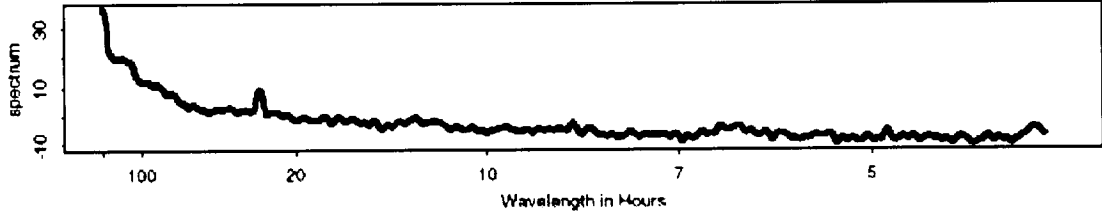
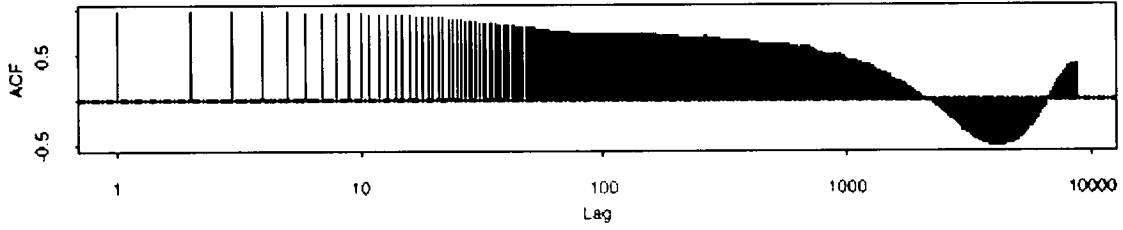
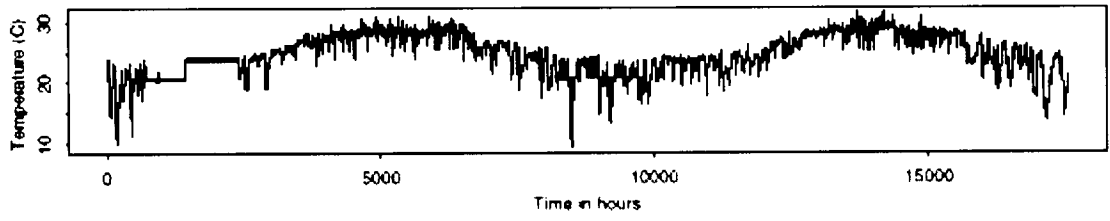
	FALL	MCH	ECH	BH	MLOW	GFNS	GFEW	ELOW	GH	NG	TS
Wind Speed:	5.2 / 2.7	6.1 / 2.7	5.9 / 2.1	6.0 / 2.8	6.4 / 2.9	4.4 / 2.2	8.0 / 2.3	4.4 / 1.9	3.4 / 1.7	13.3 / 2.1	13.3 / 2.1
Wind Direction:	351.2 / 52.0	66.3 / 44.6	146.5 / 46.9	167.9 / 51.0	306.0 / 72.6	116.1 / 89.1	309.7 / 35.3	223.5 / 61.9	230.8 / 80.5	36.0 / 18.4	36.0 / 18.4
Surface Temperature:	22.9 / 4.8	24.3 / 4.7	26.7 / 2.9	26.7 / 2.2	25.3 / 3.4	26.2 / 3.2	21.6 / 3.2	27.6 / 2.7	27.2 / 4.0	23.9 / 0.8	23.9 / 0.8
Humidity:	68.6 / 12.9	73.2 / 10.9	83.0 / 9.4	85.3 / 8.4	77.4 / 11.0	80.2 / 10.5	62.5 / 16.1	84.6 / 6.8	72.4 / 12.1	87.3 / 3.6	87.3 / 3.6
SST:	24.9 / 2.9	25.3 / 3.0	25.6 / 2.8	25.8 / 2.8	26.1 / 2.6	26.0 / 2.9	23.5 / 1.3	26.5 / 2.8	27.3 / 2.9	25.9 / 0.1	25.9 / 0.1
Vorticity:	7.4 / 82.3	6.4 / 73.2	-3.0 / 70.0	-2.0 / 81.6	11.3 / 87.4	9.9 / 72.0	15.3 / 109.6	-5.2 / 74.6	-3.2 / 74.5	147.5 / 124.2	147.5 / 124.2
Wind Stress Curl:	2.9 / 58.4	1.0 / 24.7	-0.1 / 13.1	-0.3 / 10.0	1.3 / 17.9	0.9 / 8.5	0.8 / 38.0	0.1 / 5.6	0.1 / 1.5	22.9 / 76.7	22.9 / 76.7

A-3

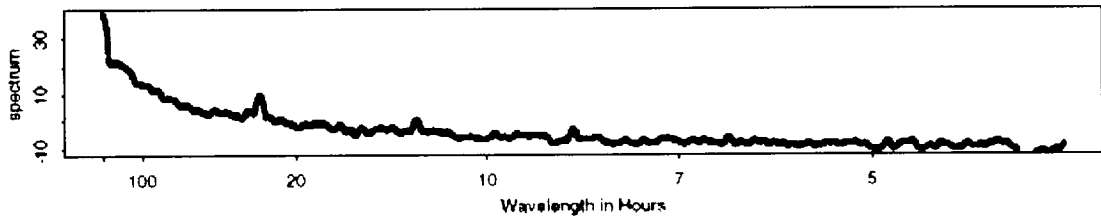
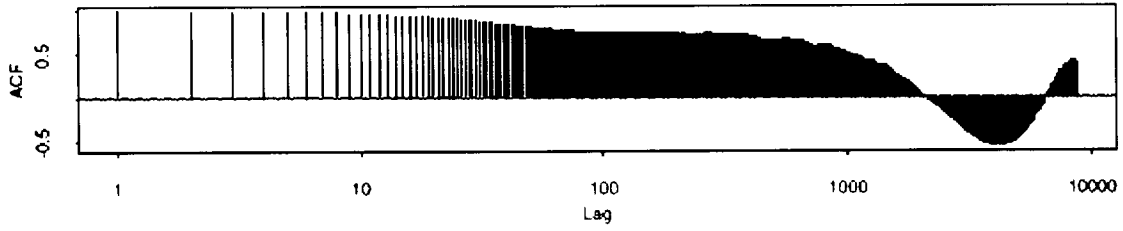
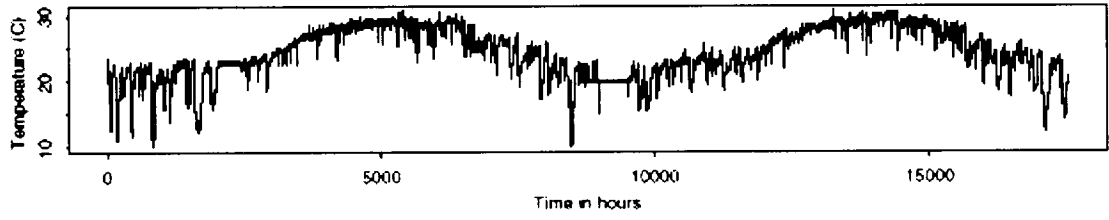
APPENDIX B

**Time Series Analyses for Wind Speed and Temperature for
16 Selected NEGOM Offshore and Coastal Observation Stations.**

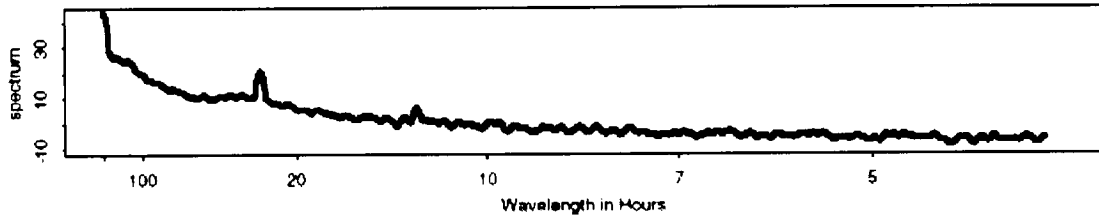
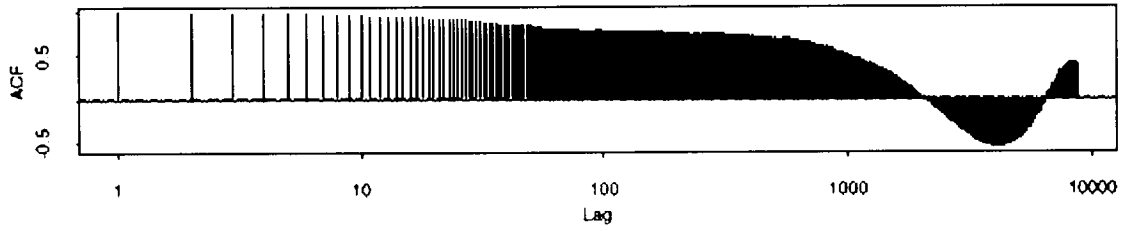
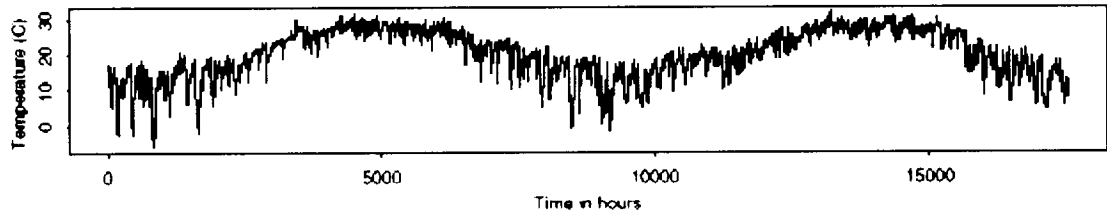
Temperature (C) 1996 - 1997: Station 42001



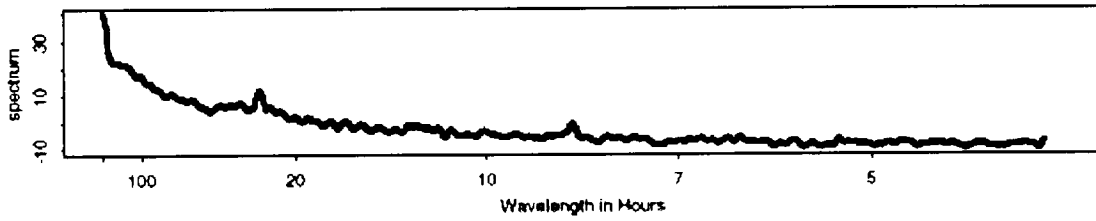
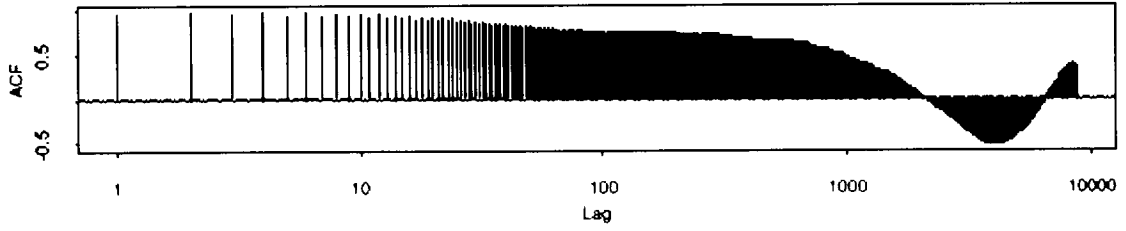
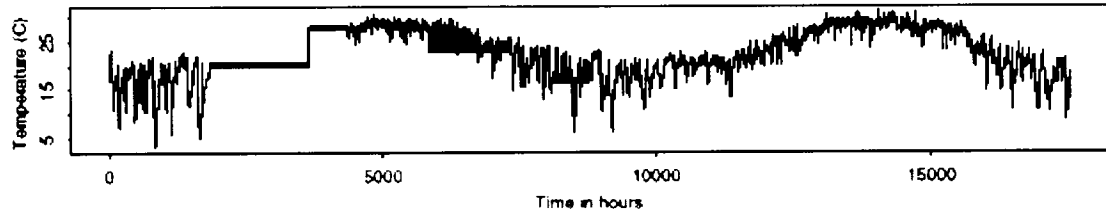
Temperature (C) 1996 - 1997: Station 42002



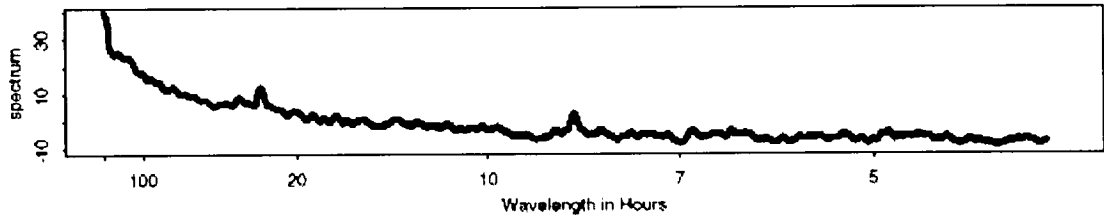
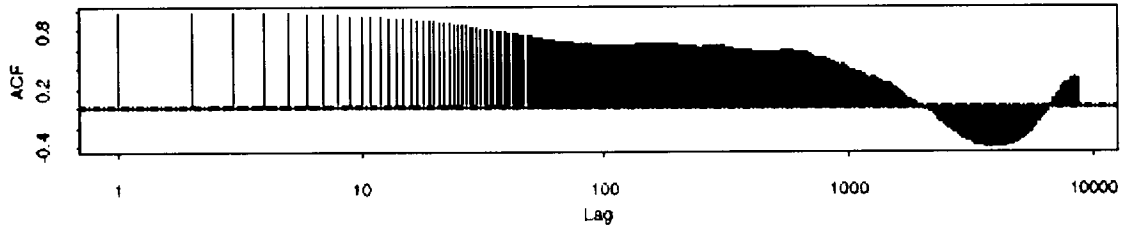
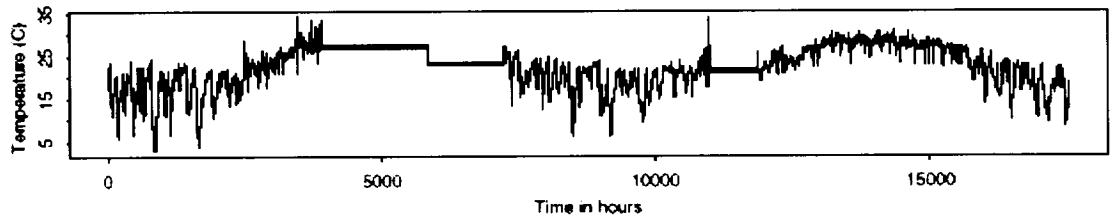
Temperature (C) 1996 - 1997: Station 42007



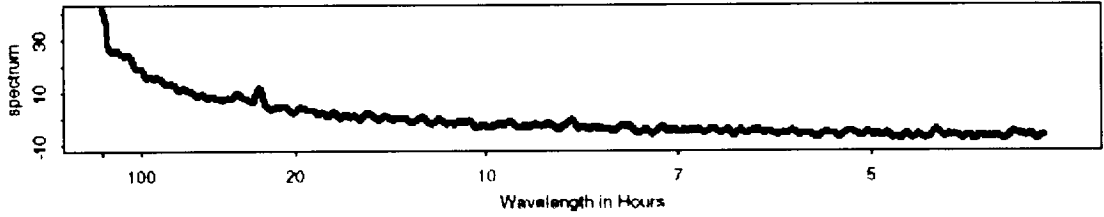
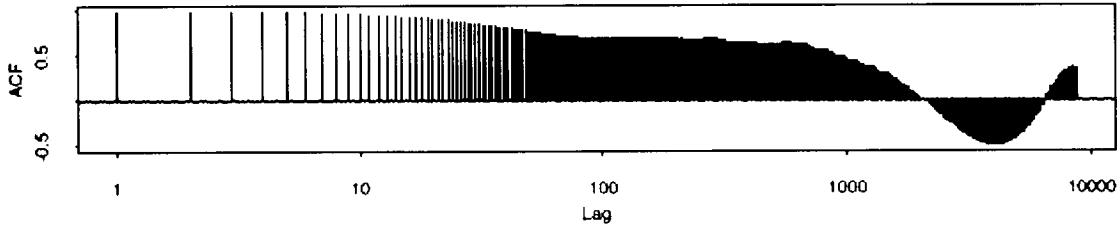
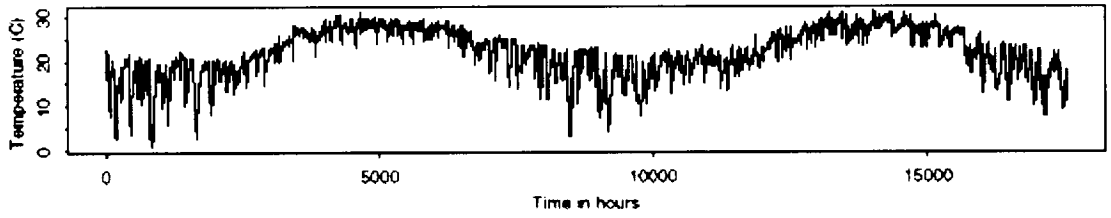
Temperature (C) 1996 - 1997: Station 42036



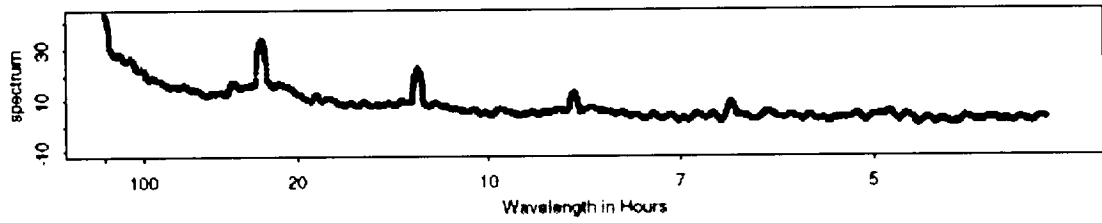
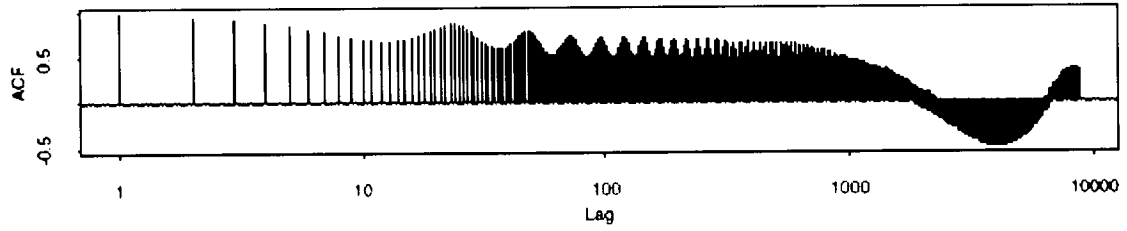
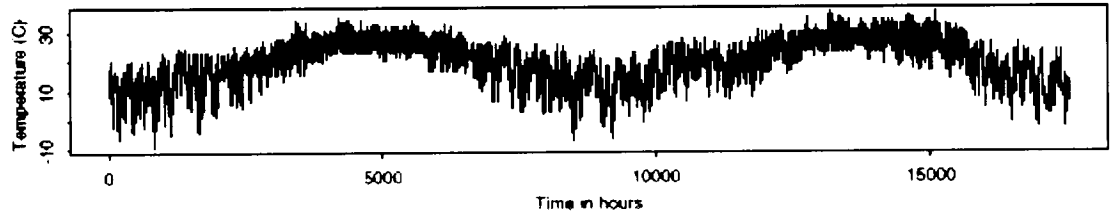
Temperature (C) 1996 - 1997: Station 42039



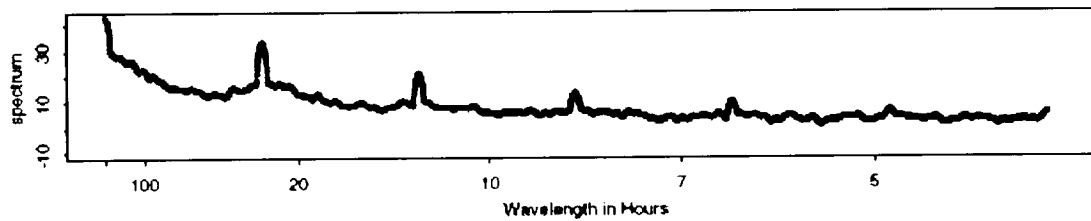
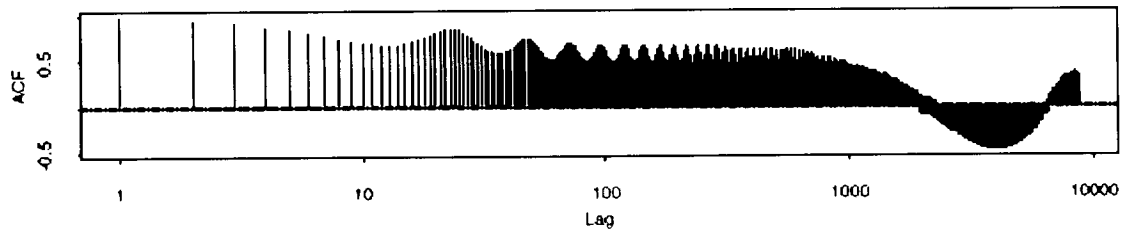
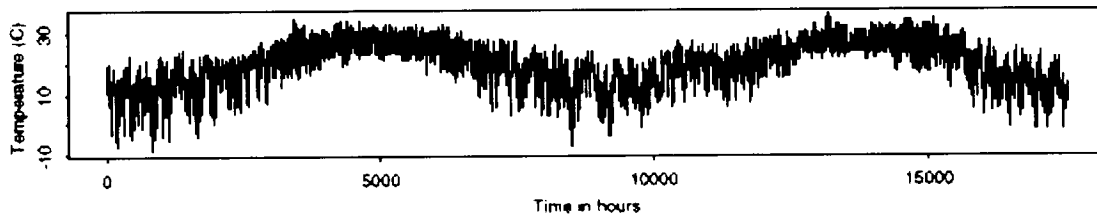
Temperature (C) 1996 - 1997: Station 42040



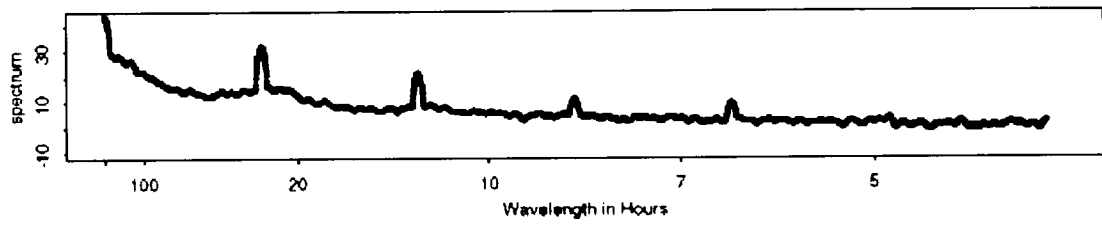
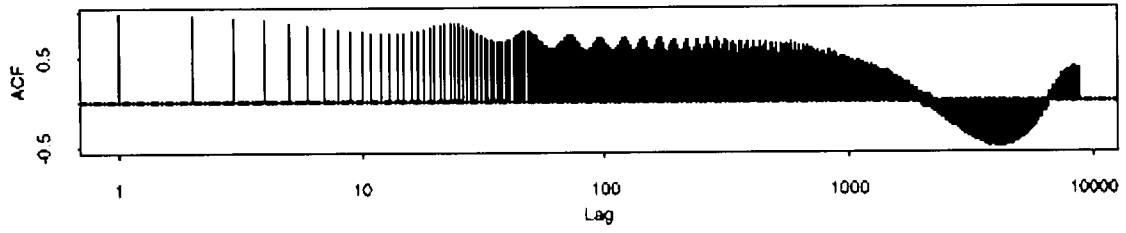
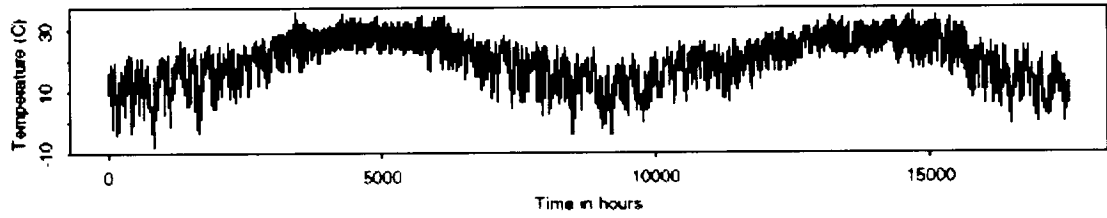
Temperature (C) 1996 - 1997: Station 722210



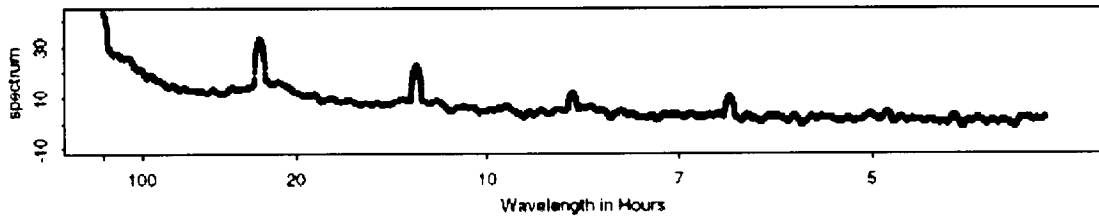
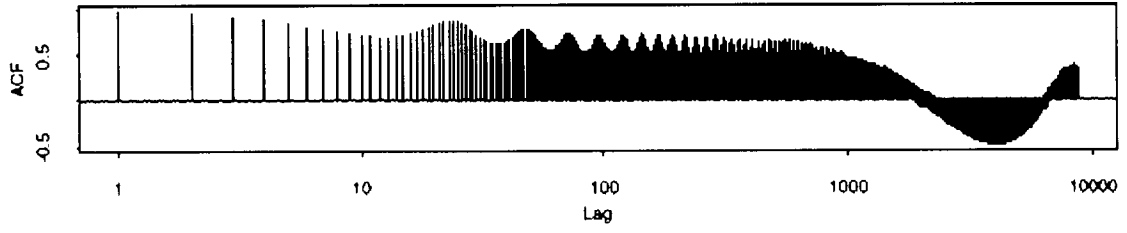
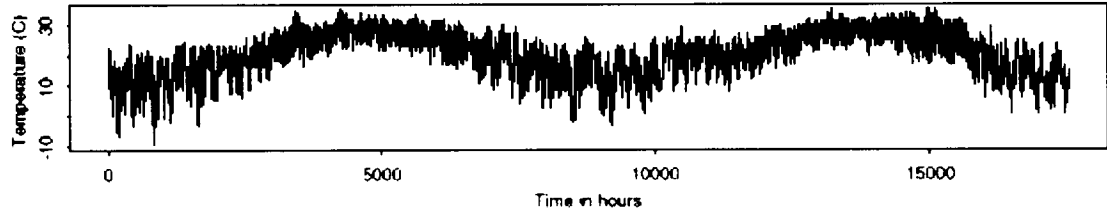
Temperature (C) 1996 - 1997: Station 722225



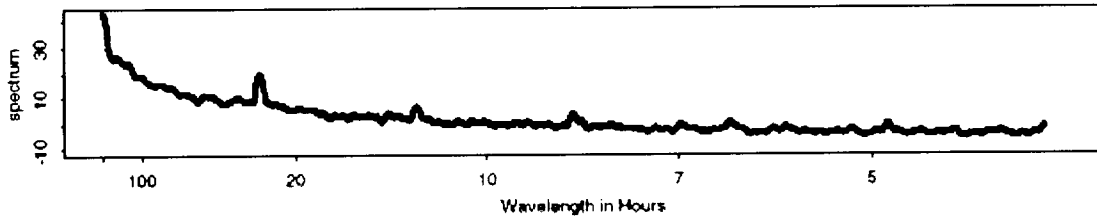
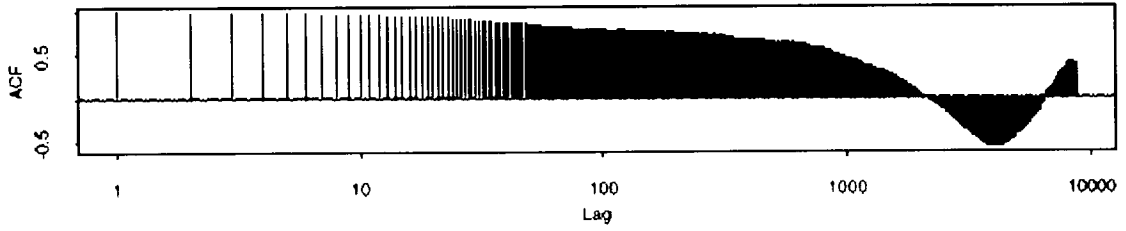
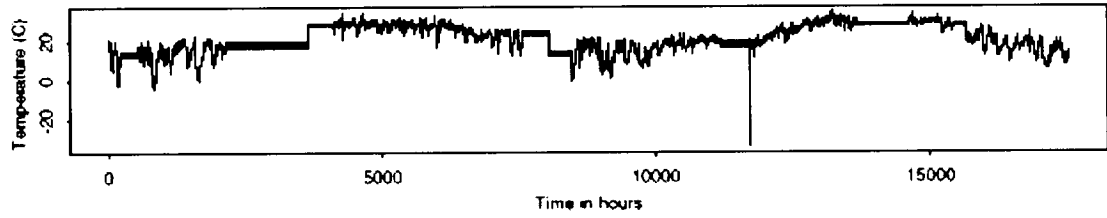
Temperature (C) 1996 - 1997: Station 747686



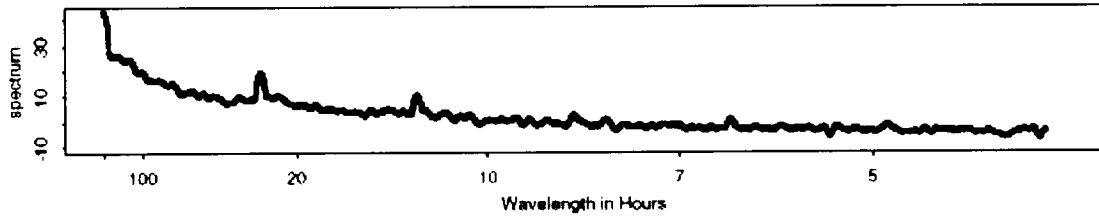
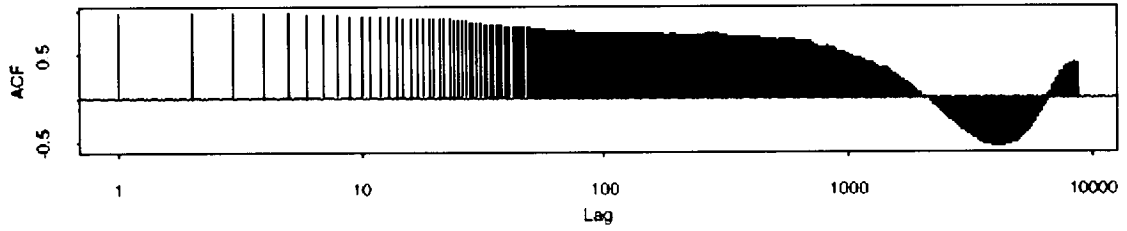
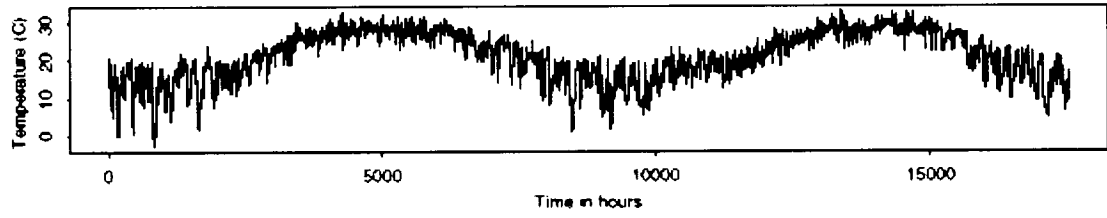
Temperature (C) 1996 - 1997: Station 747750



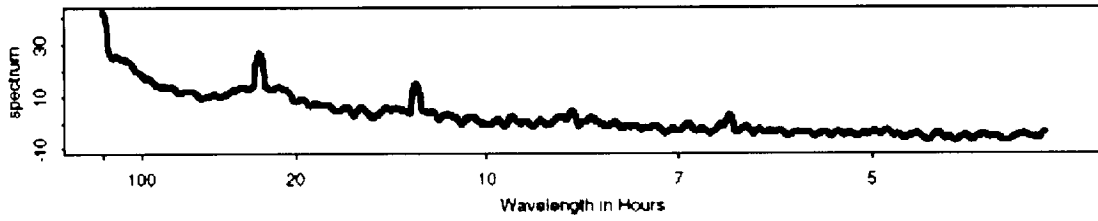
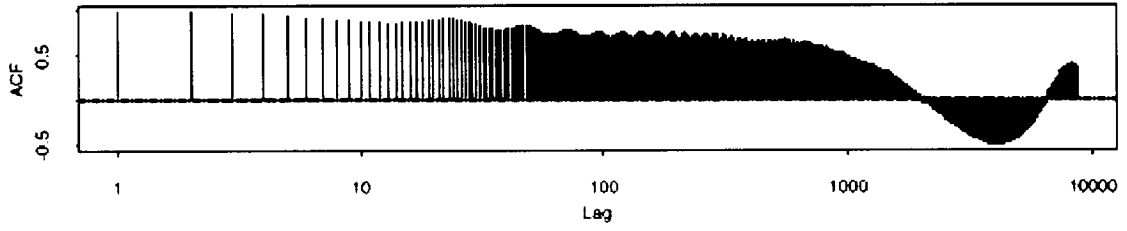
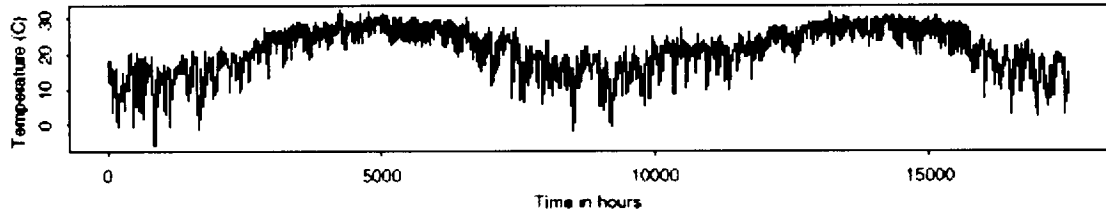
Temperature (C) 1996 - 1997: Station BRETON



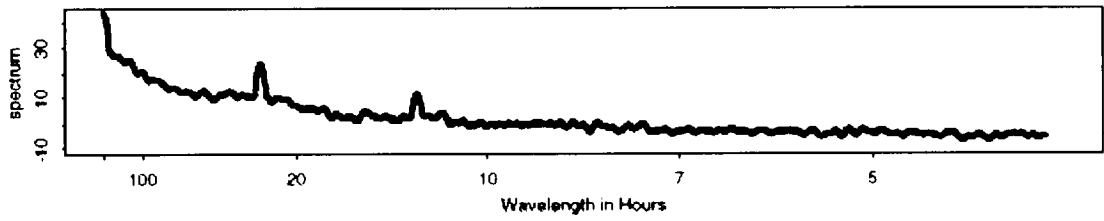
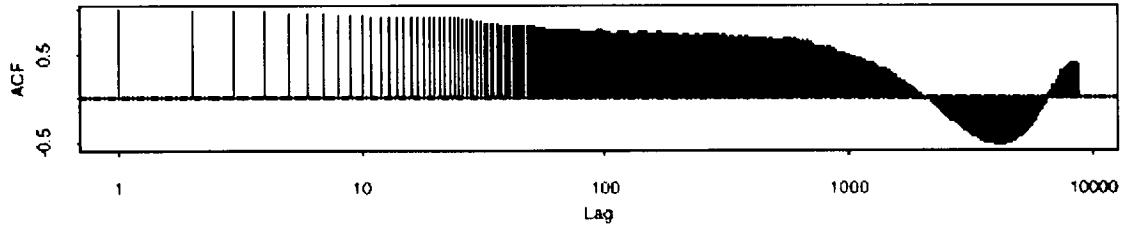
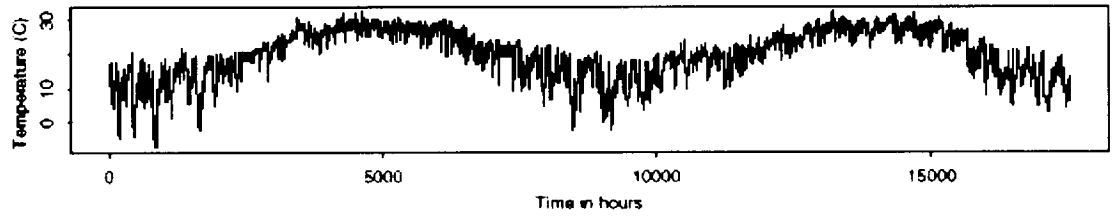
Temperature (C) 1996 - 1997: Station BURL1



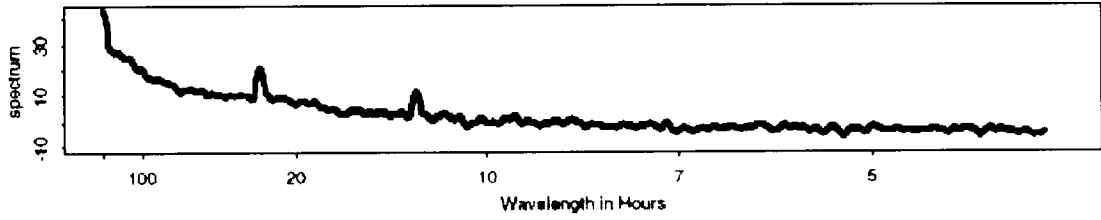
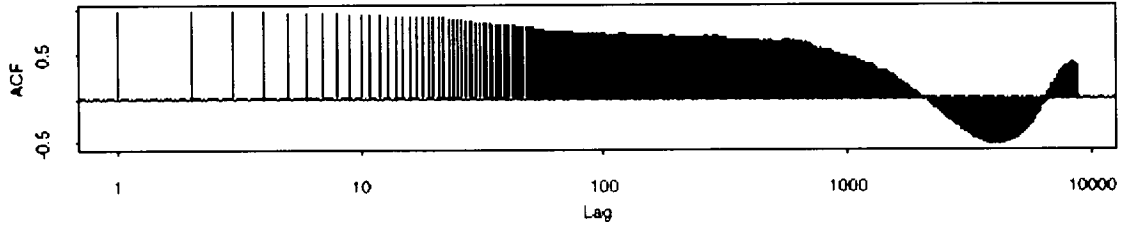
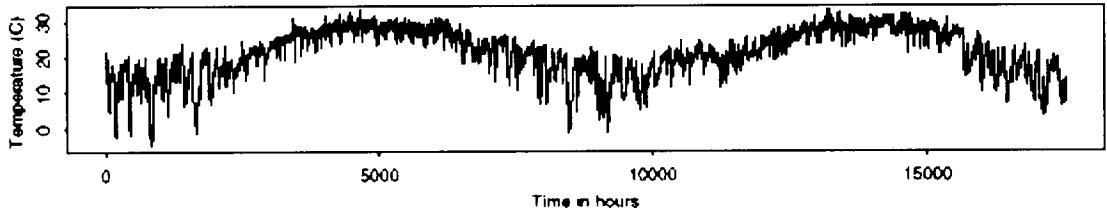
Temperature (C) 1996 - 1997: Station CDRF1



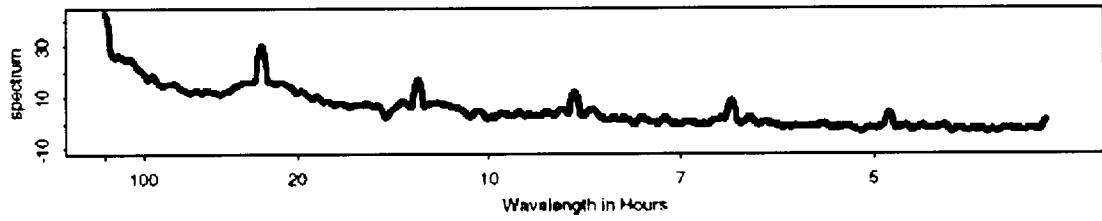
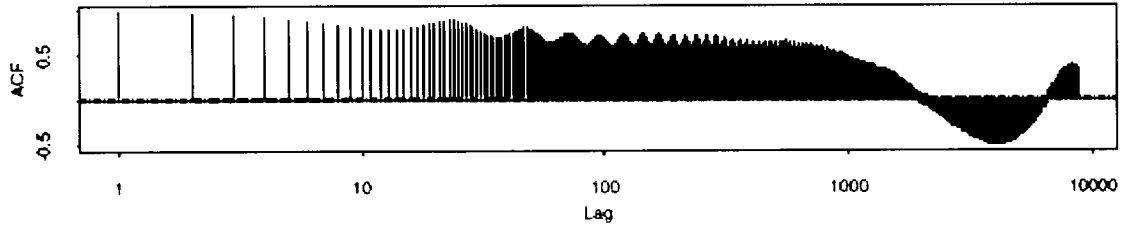
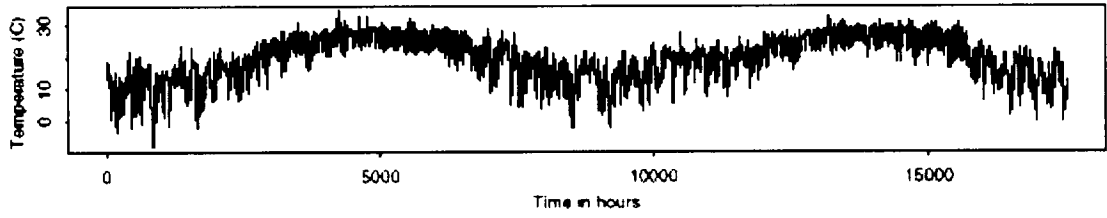
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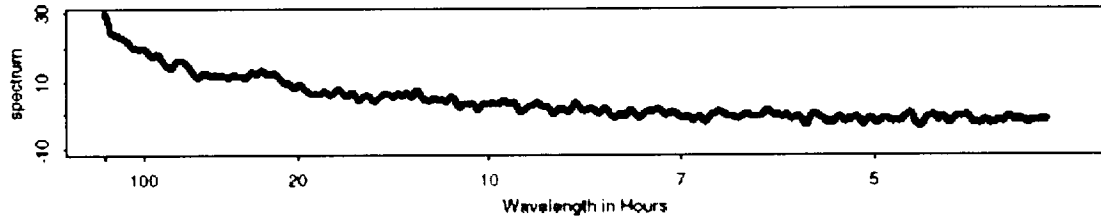
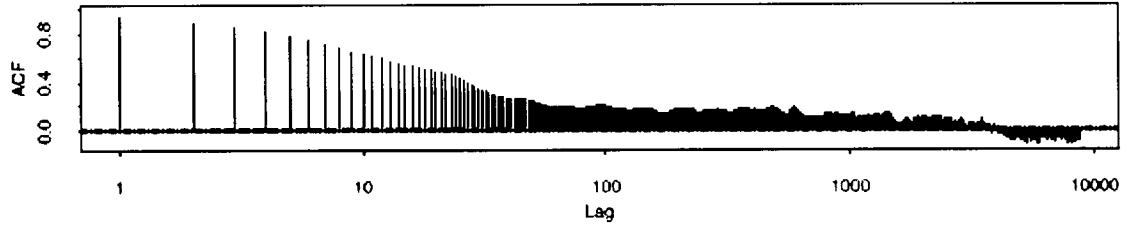
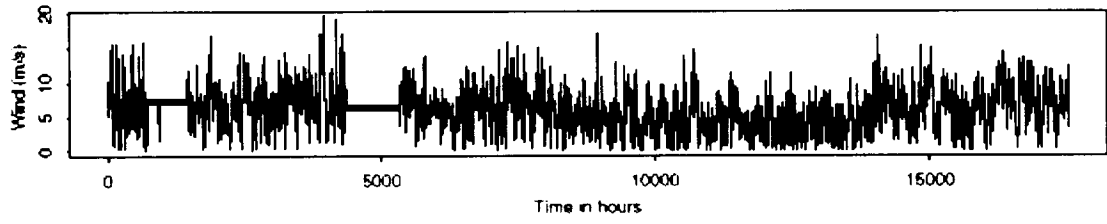
Temperature (C) 1996 - 1997: Station GDIL1



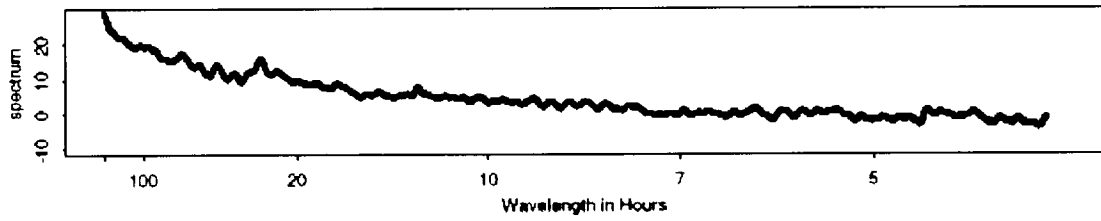
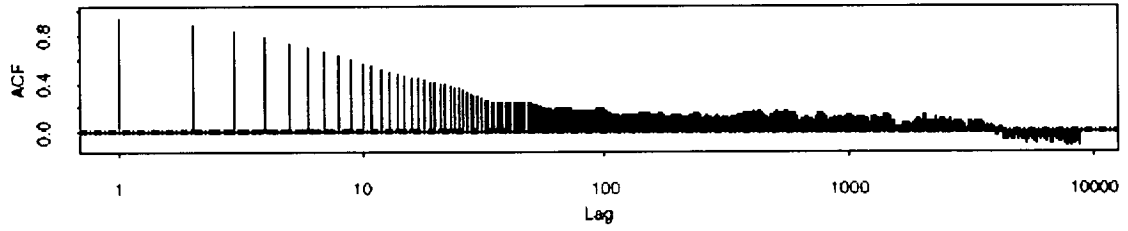
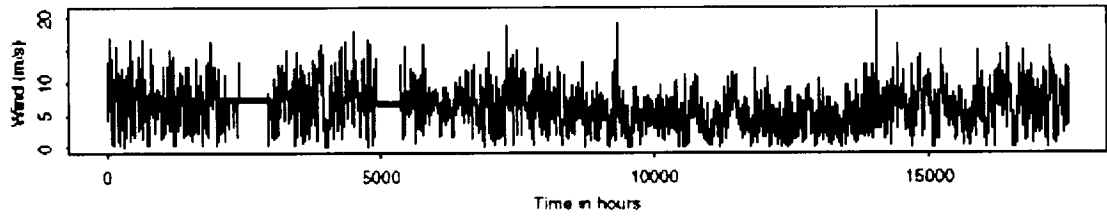
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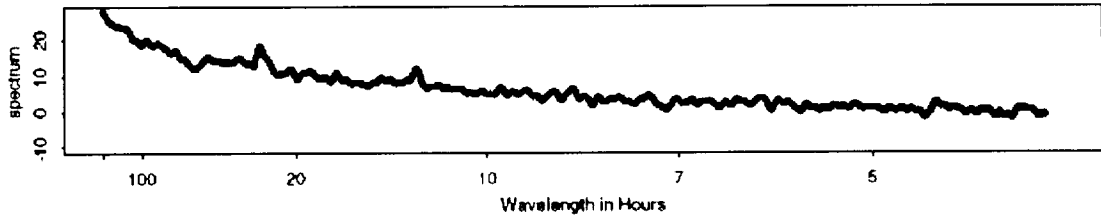
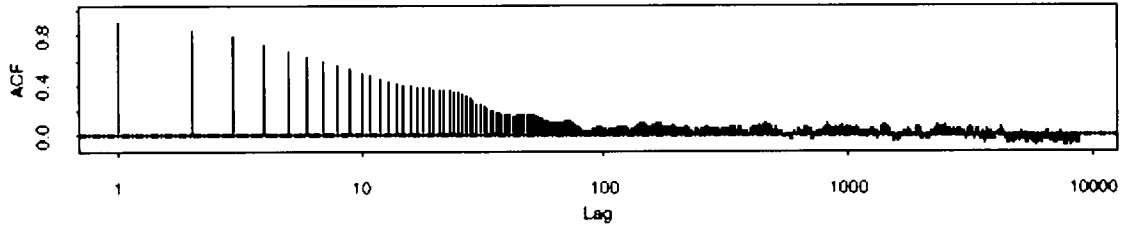
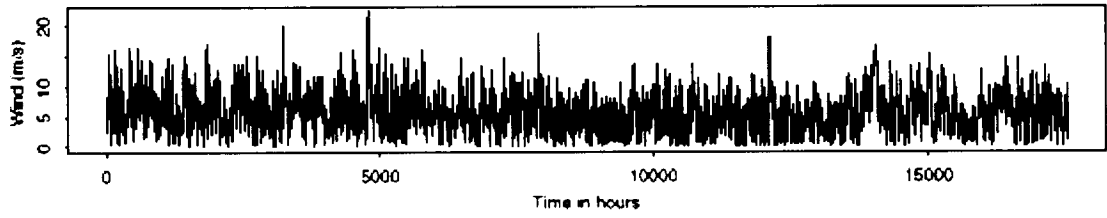
Wind Speed (m/s) 1996 - 1997: Station 42001



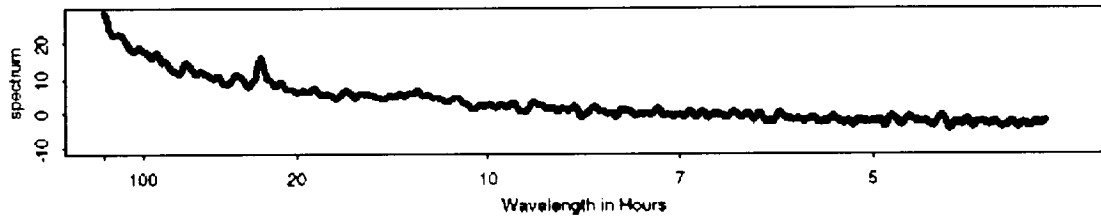
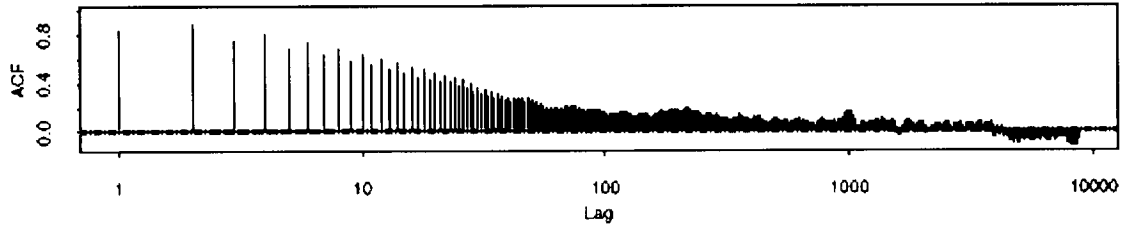
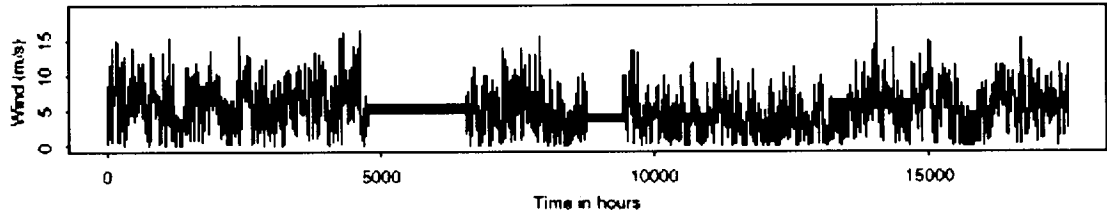
Wind Speed (m/s) 1996 - 1997: Station 42002



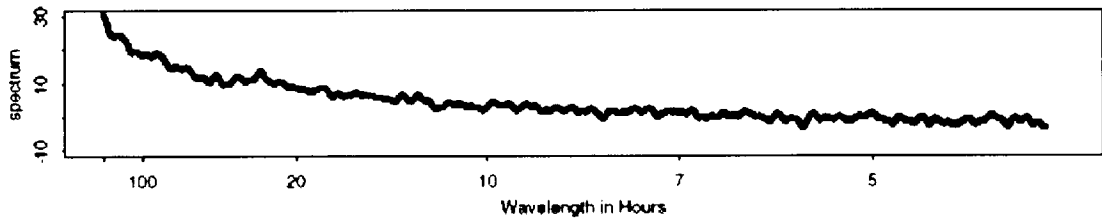
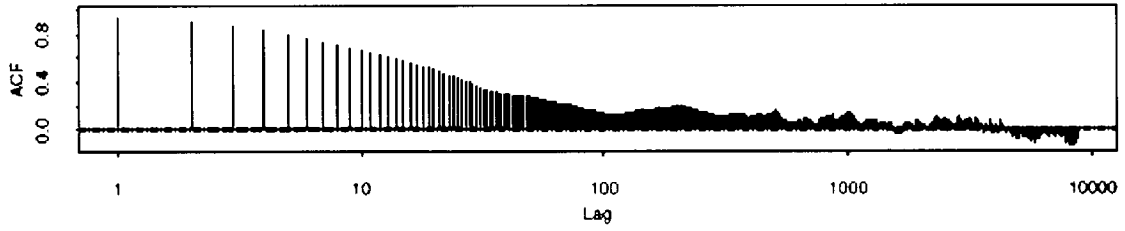
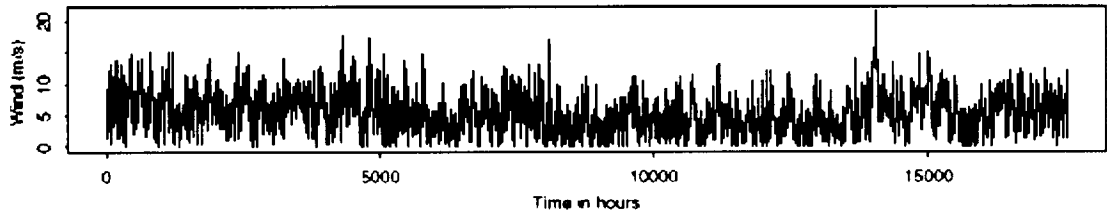
Wind Speed (m/s) 1996 - 1997: Station 42007



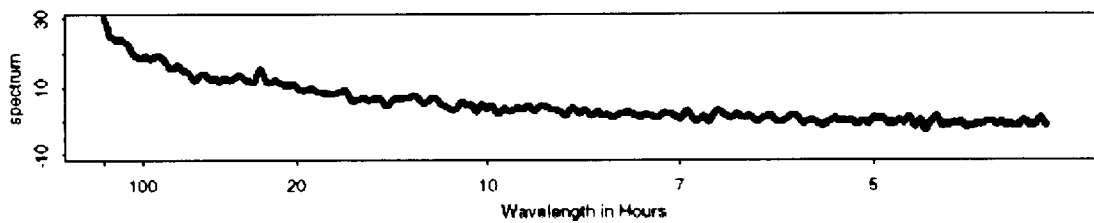
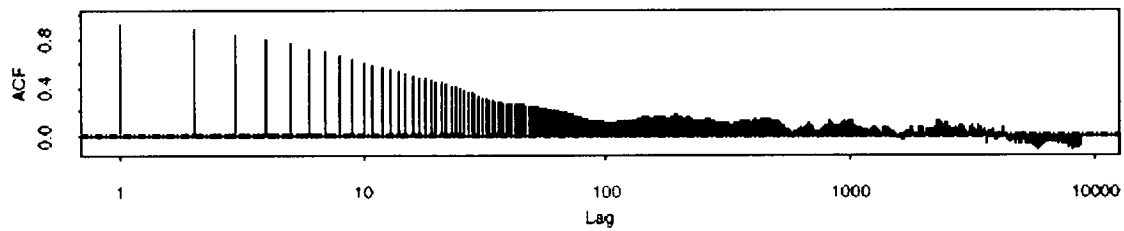
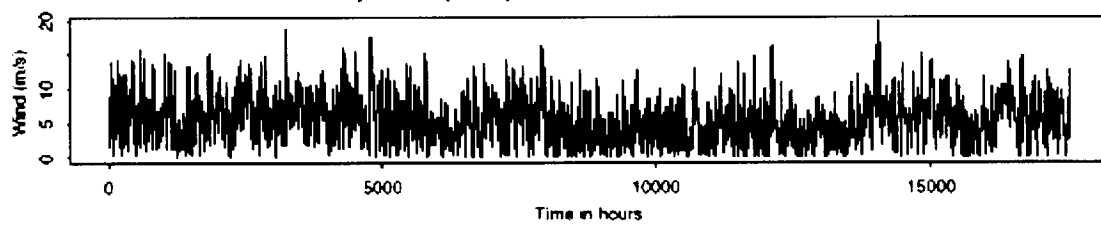
Wind Speed (m/s) 1996 - 1997: Station 42036



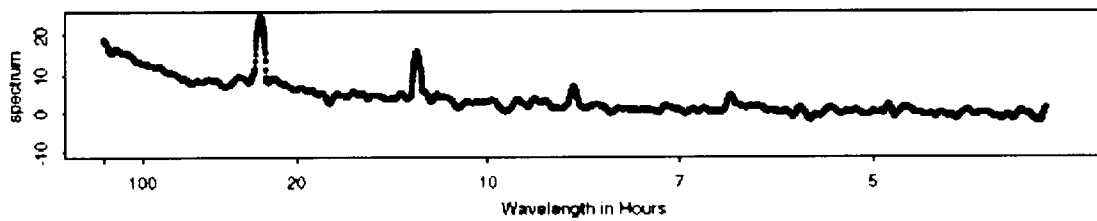
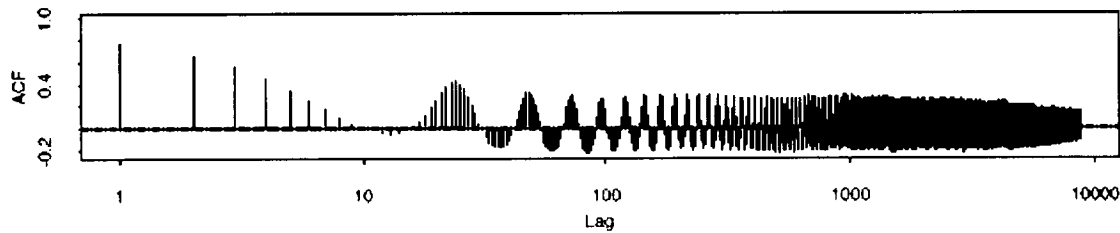
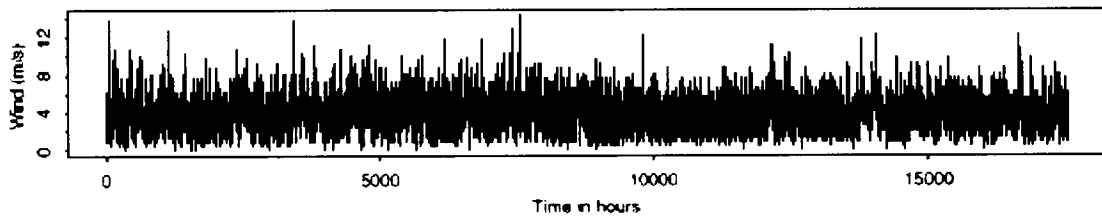
Wind Speed (m/s) 1996 - 1997: Station 42039



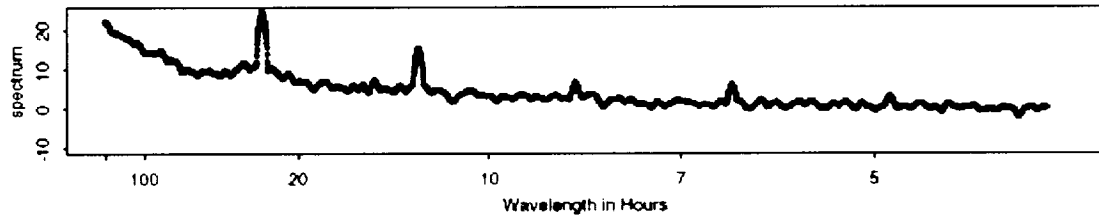
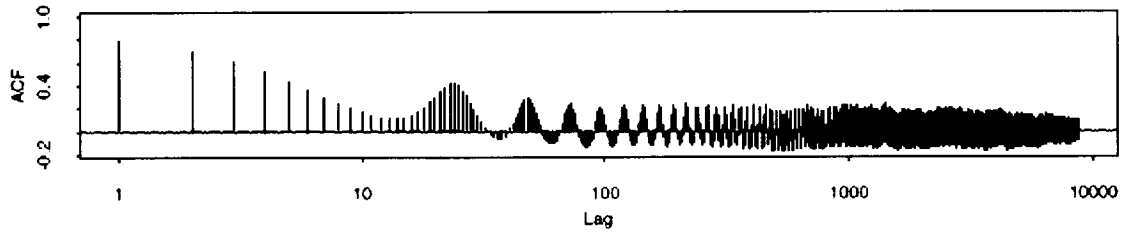
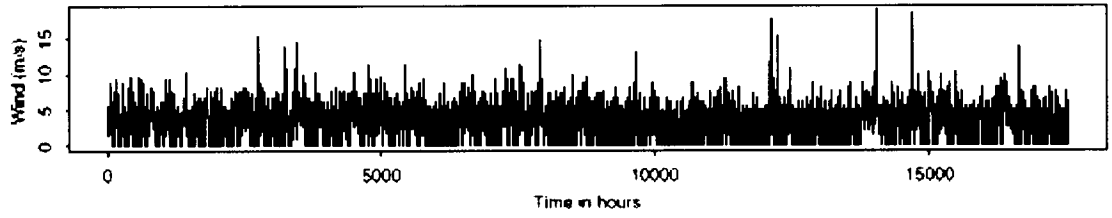
Wind Speed (m/s) 1996 - 1997: Station 42040



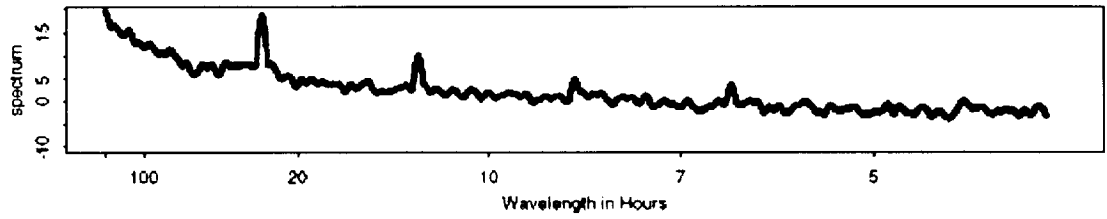
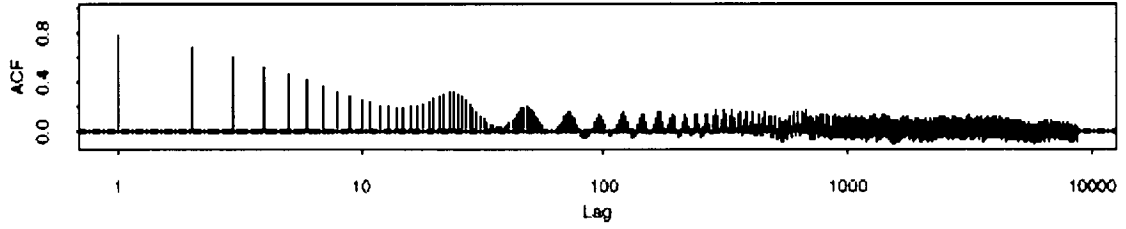
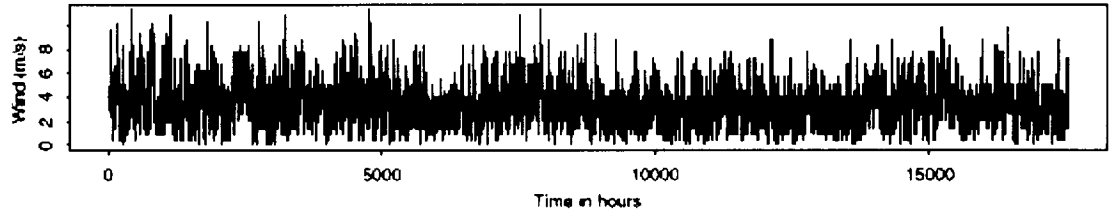
Wind Speed (m/s) 1996 - 1997: Station 722210



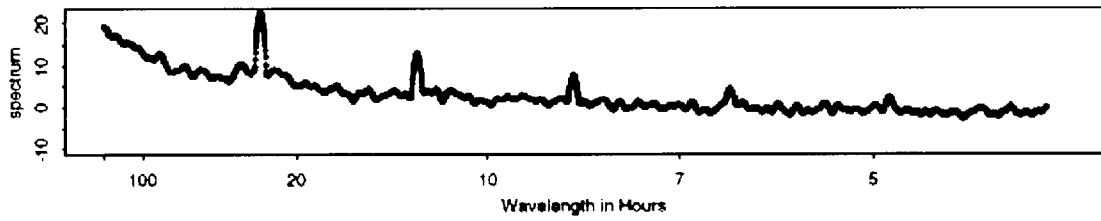
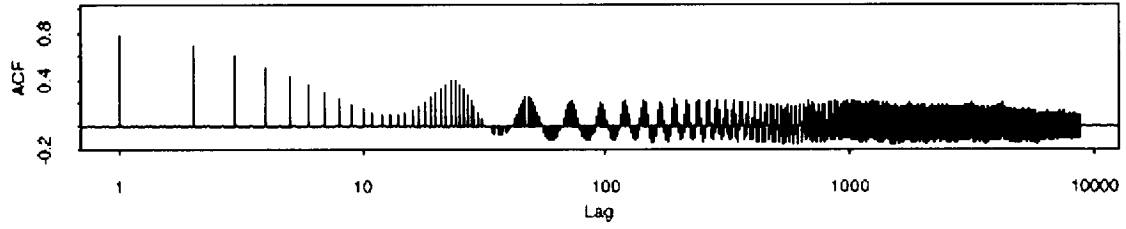
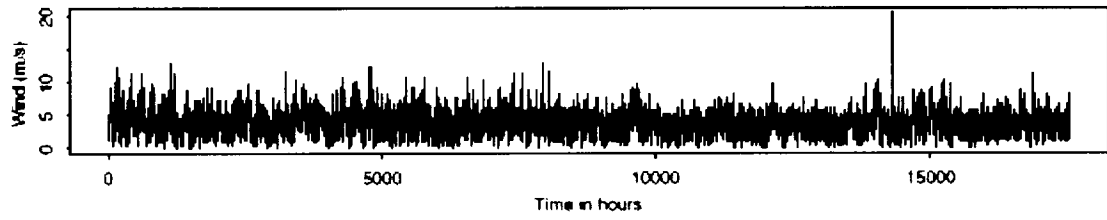
Wind Speed (m/s) 1996 - 1997: Station 722225



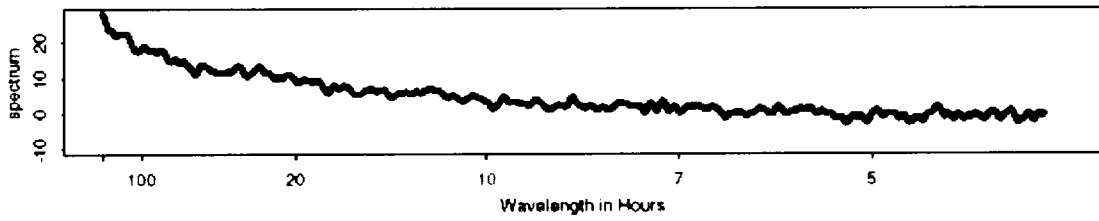
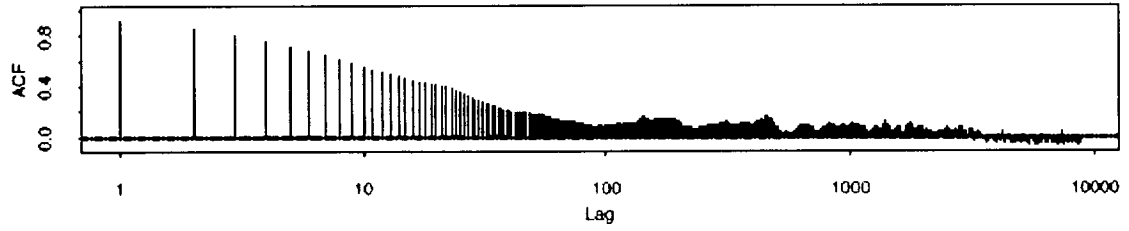
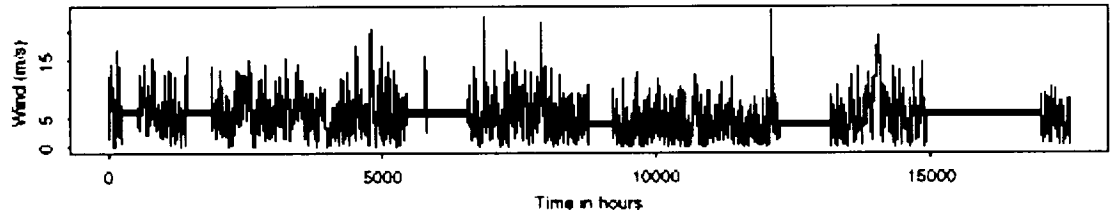
Wind Speed (m/s) 1996 - 1997: Station 747686



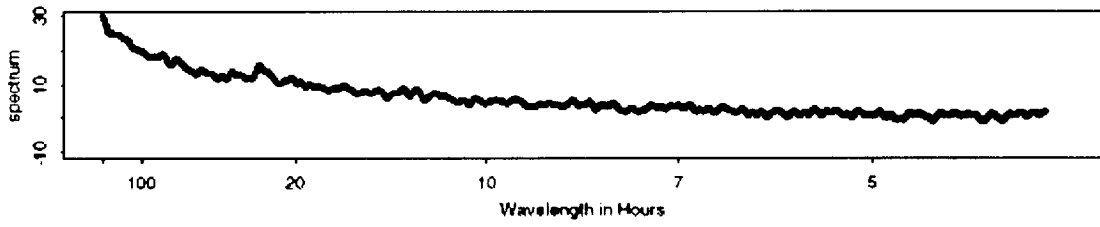
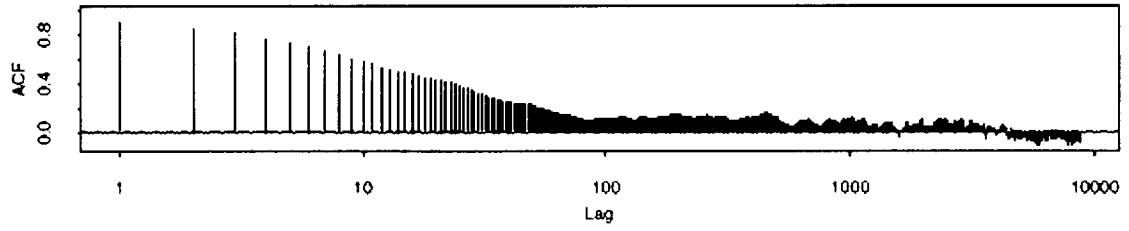
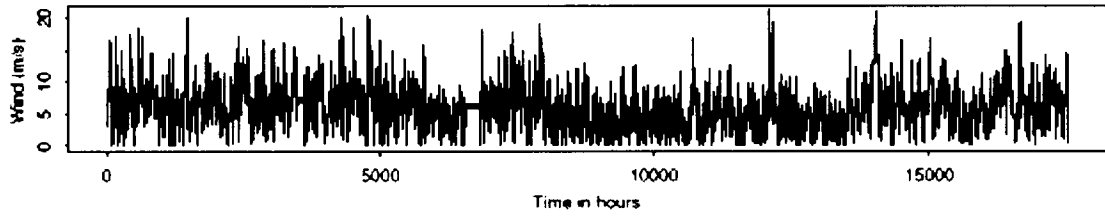
Wind Speed (m/s) 1996 - 1997: Station 747750



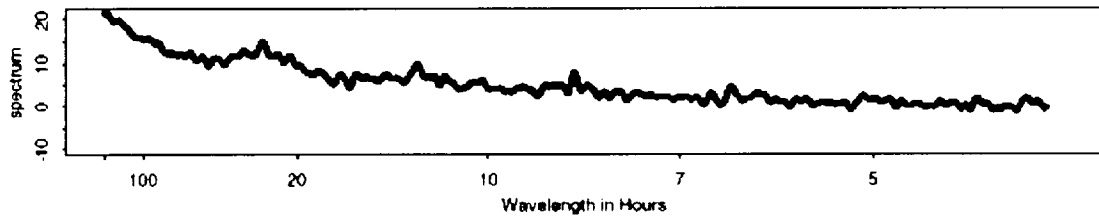
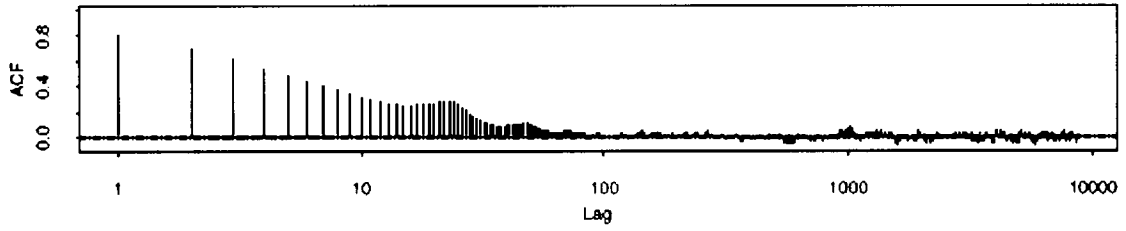
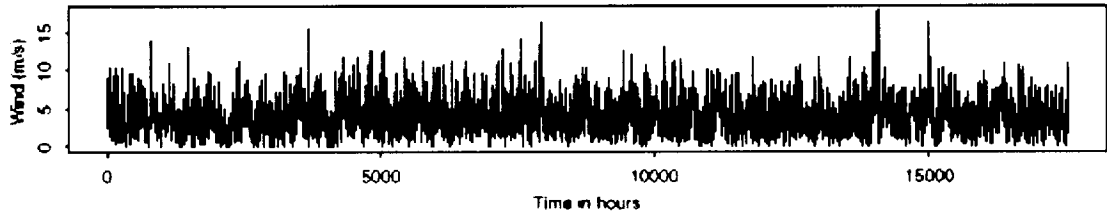
Wind Speed (m/s) 1996 - 1997: Station BRETON



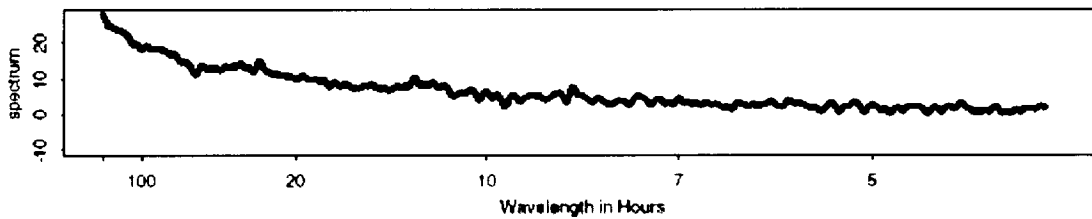
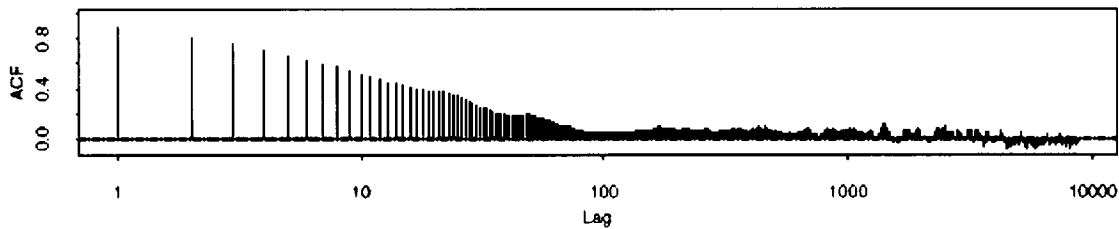
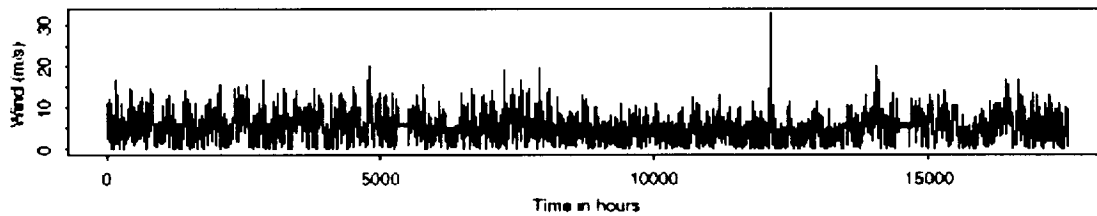
Wind Speed (m/s) 1996 - 1997: Station BURL1



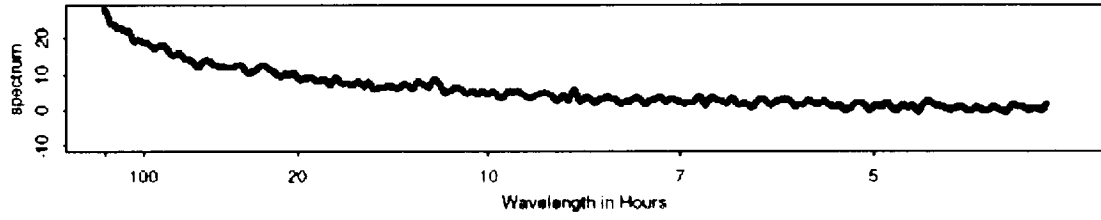
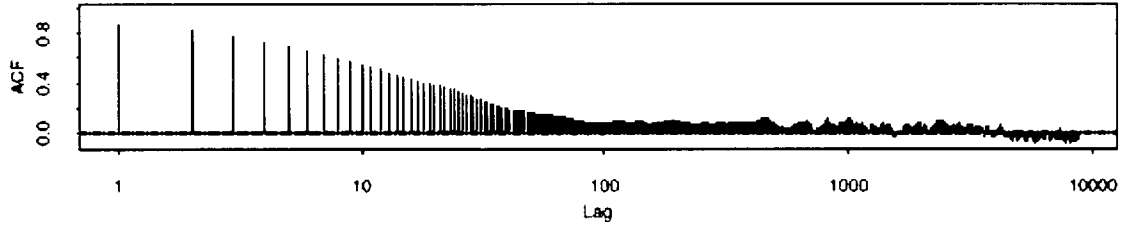
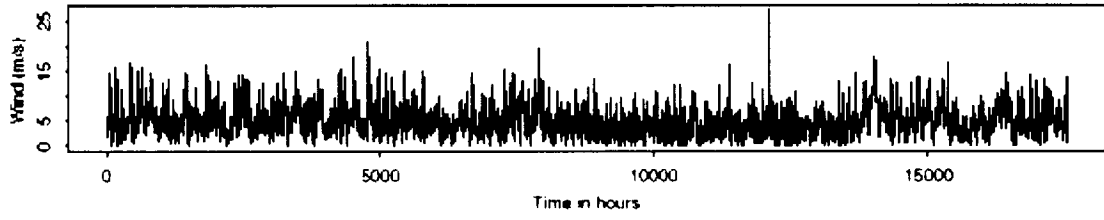
Wind Speed (m/s) 1996 - 1997: Station CDRF1



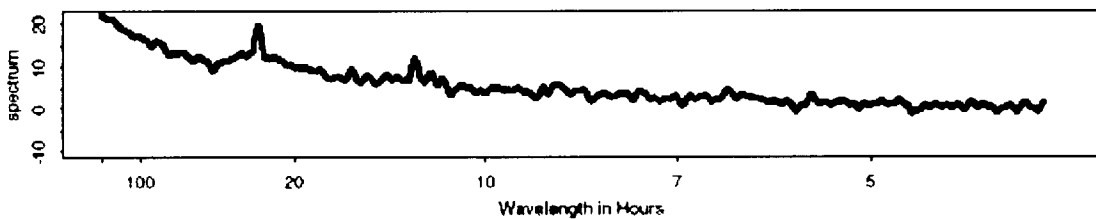
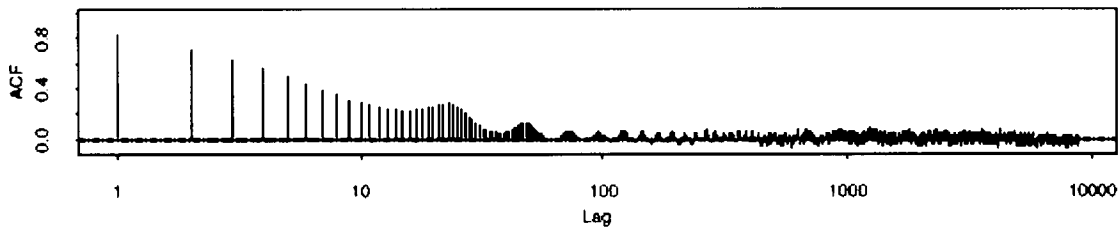
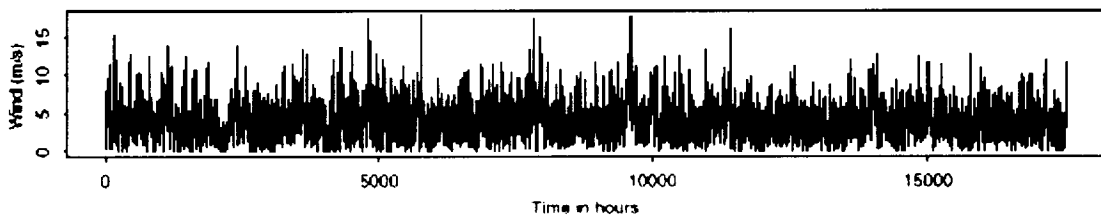
Wind Speed (m/s) 1996 - 1997: Station DPIA1



Wind Speed (m/s) 1996 - 1997: Station GDIL1



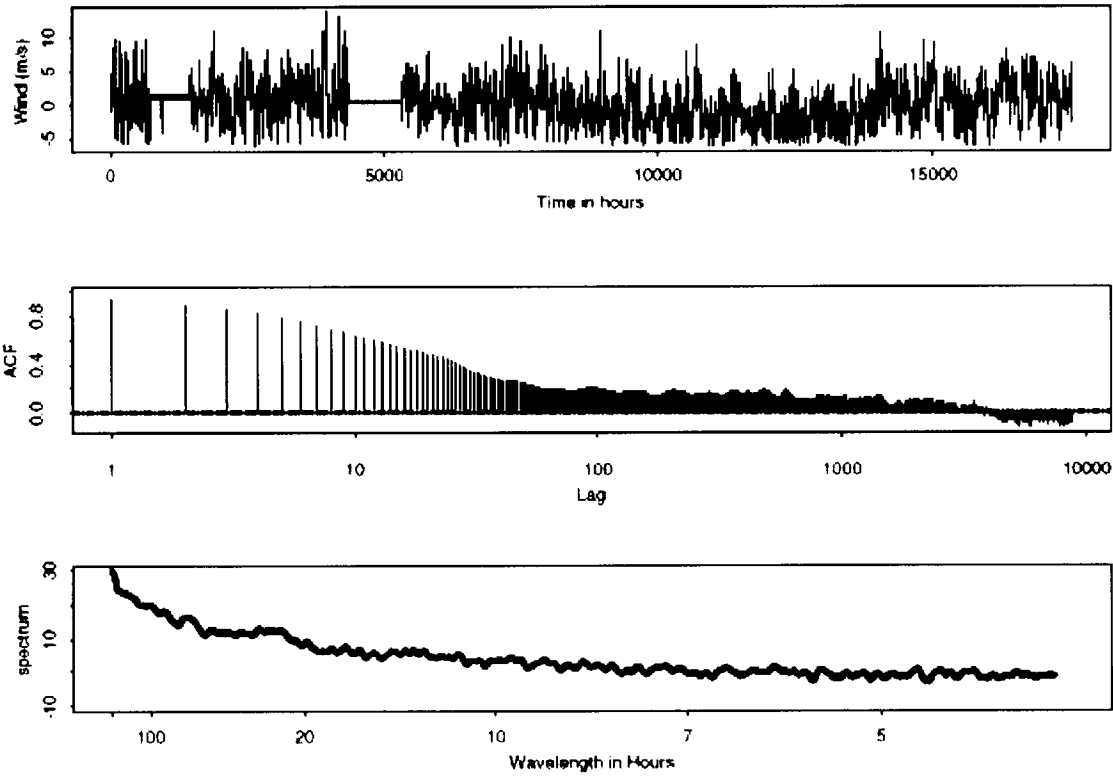
Wind Speed (m/s) 1996 - 1997: Station KTNF1



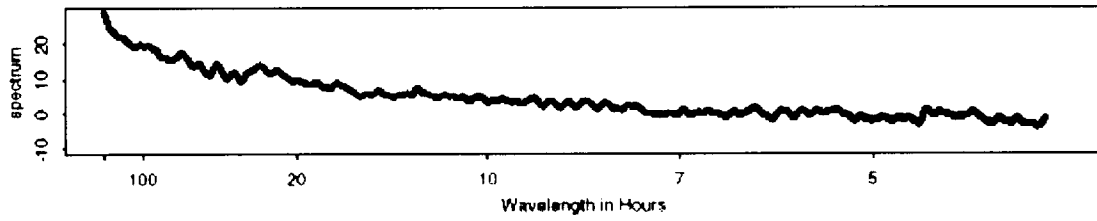
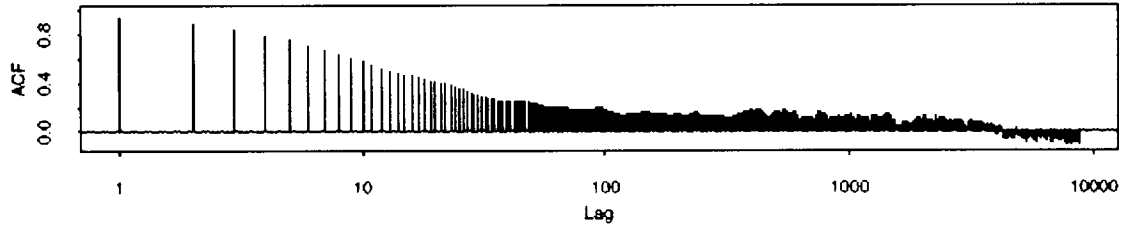
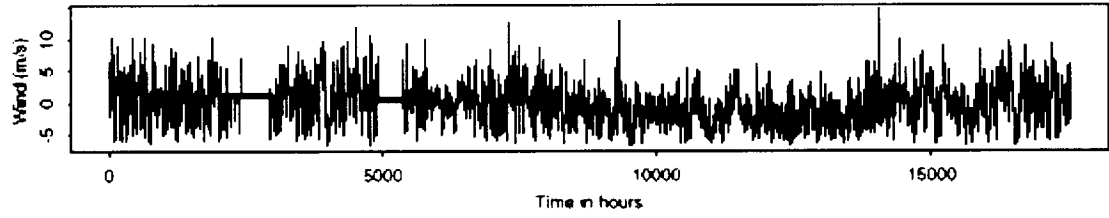
APPENDIX C

**Filtered (12-hour Block Filter) Time Series Analyses for
Wind Speed for 16 Selected NEGOM Offshore and Coastal Observation Stations.**

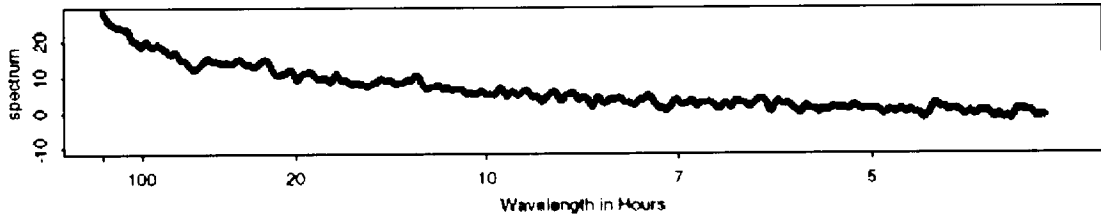
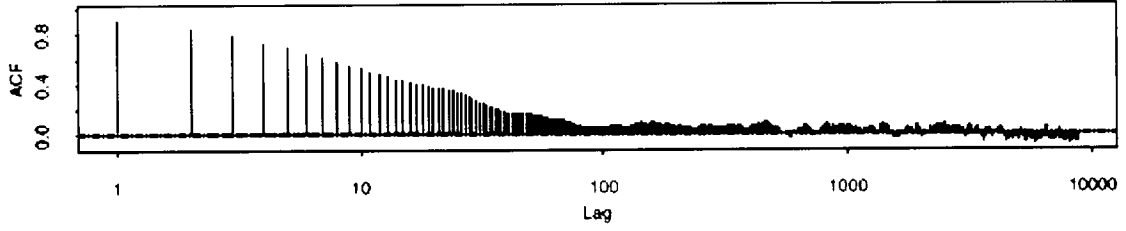
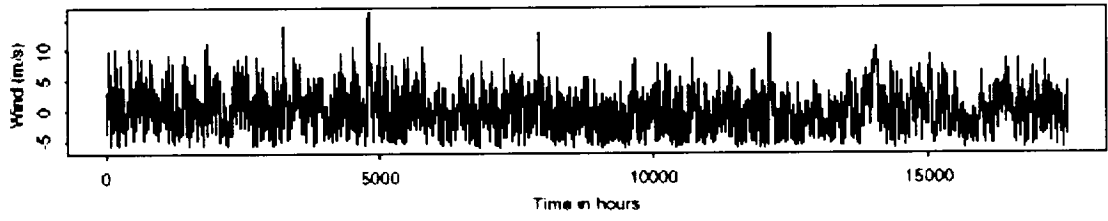
Filtered Wind Speed (m/s) 1996 - 1997: Station 42001



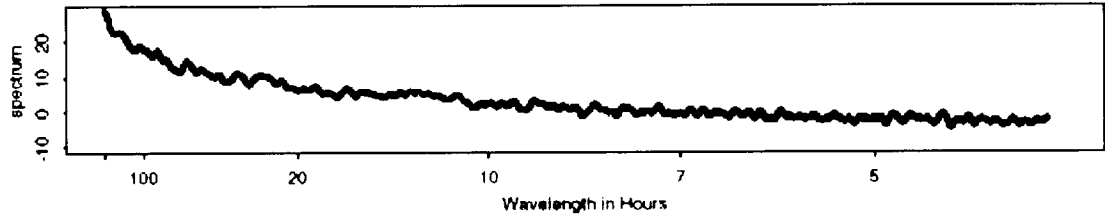
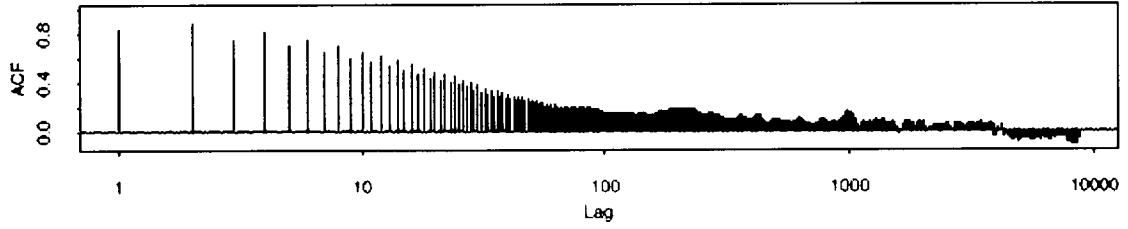
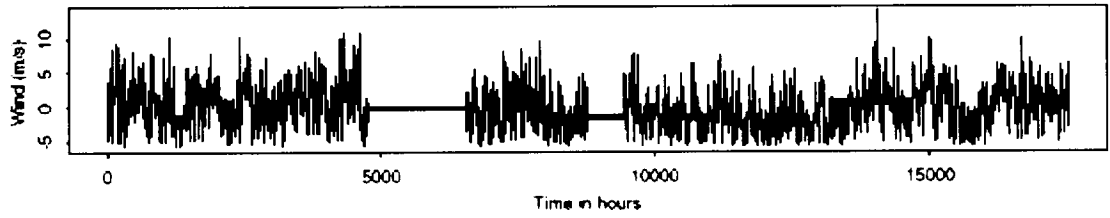
Filtered Wind Speed (m/s) 1996 - 1997: Station 42002



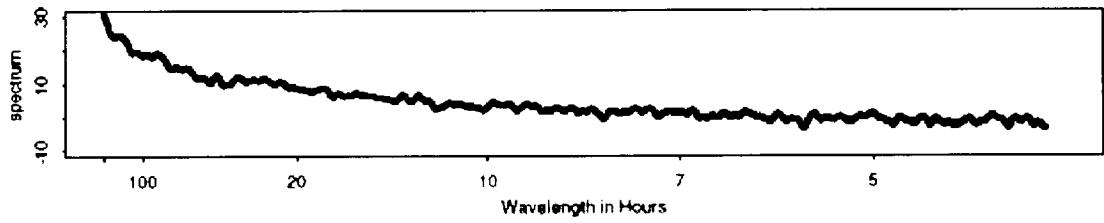
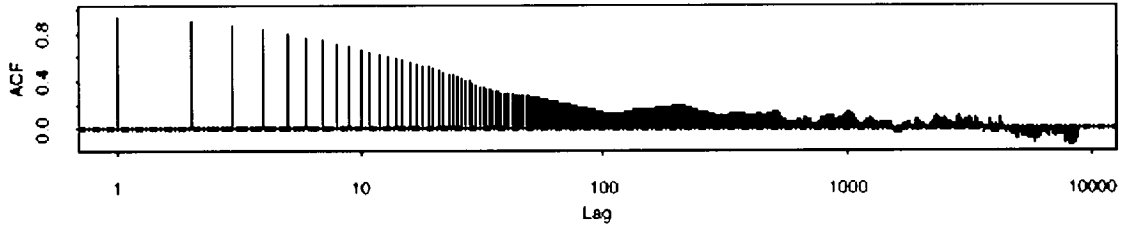
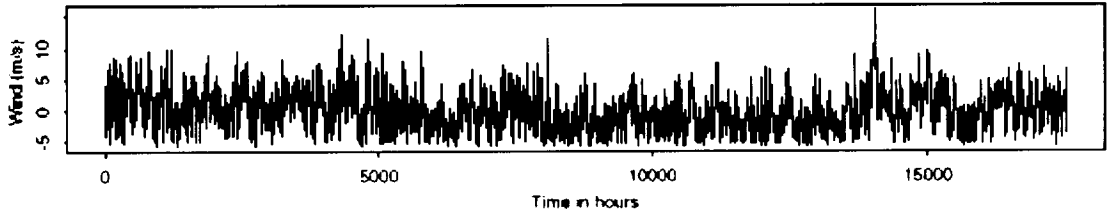
Filtered Wind Speed (m/s) 1996 - 1997: Station 42007



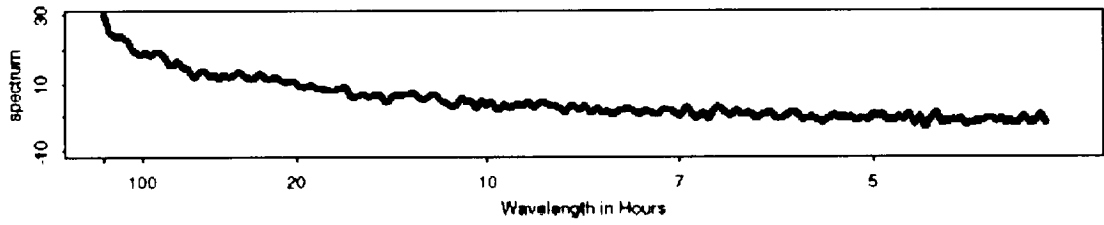
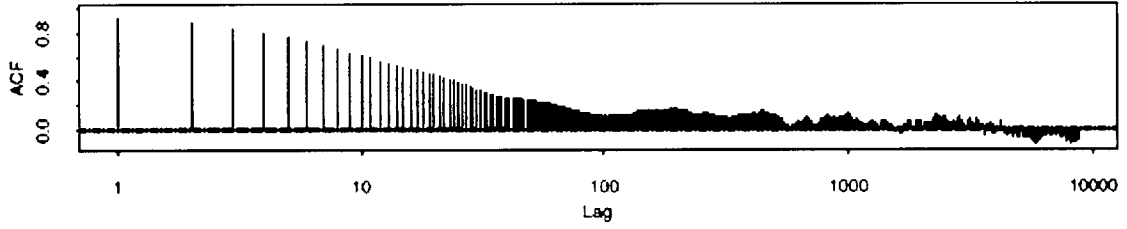
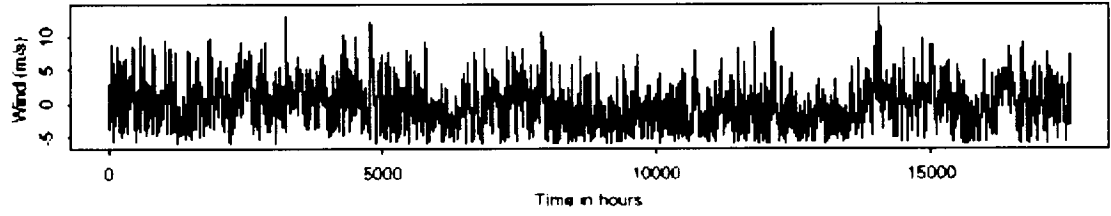
Filtered Wind Speed (m/s) 1996 - 1997: Station 42036



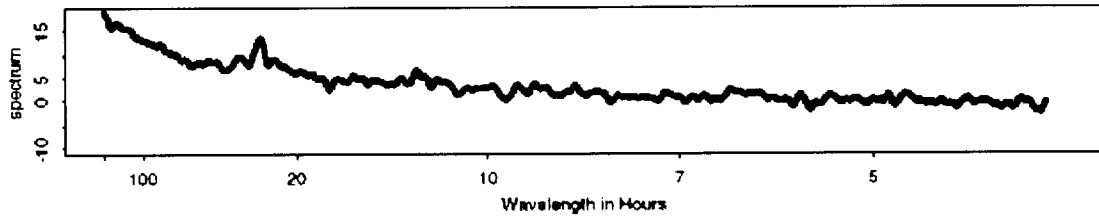
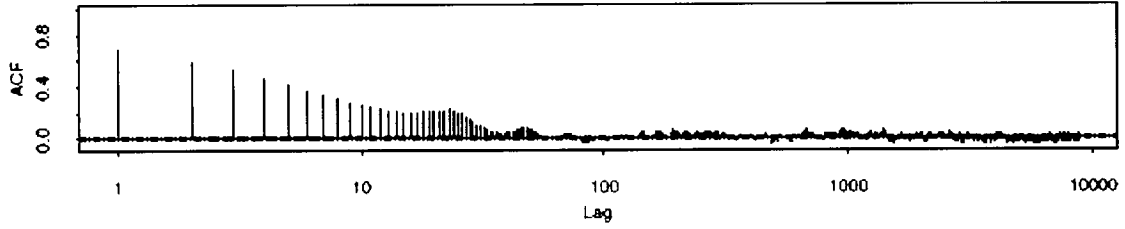
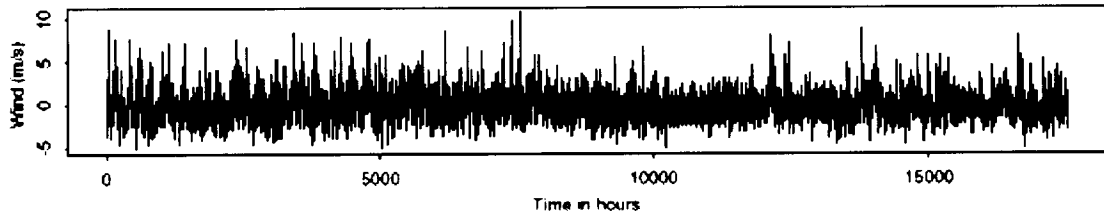
Filtered Wind Speed (m/s) 1996 - 1997: Station 42039



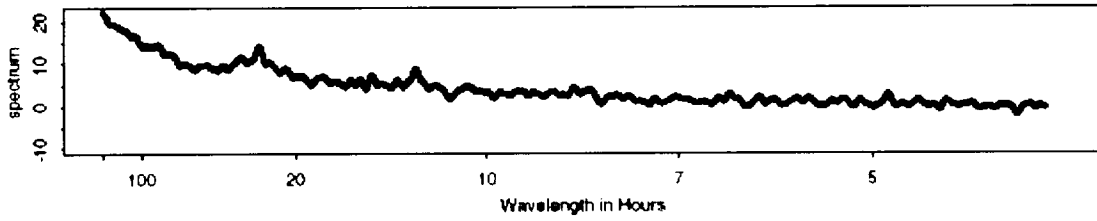
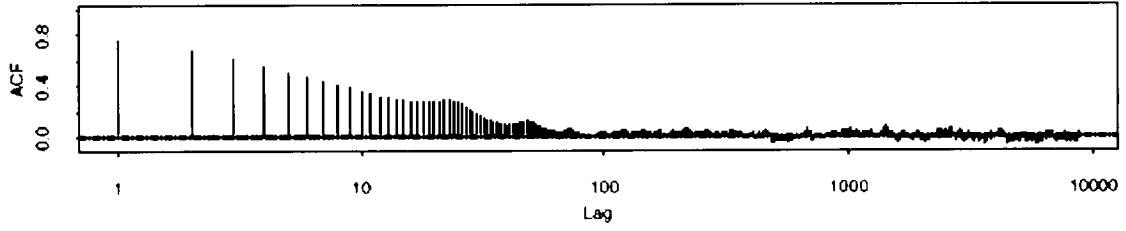
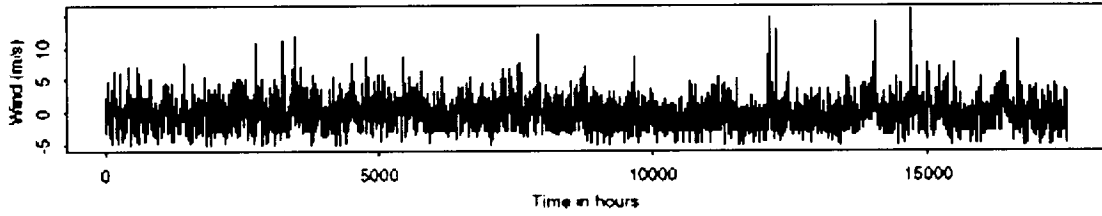
Filtered Wind Speed (m/s) 1996 - 1997: Station 42040



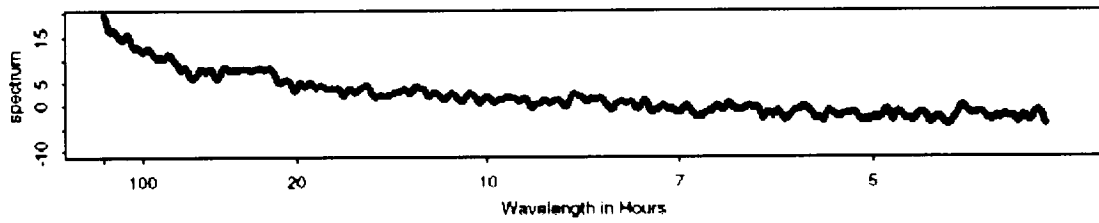
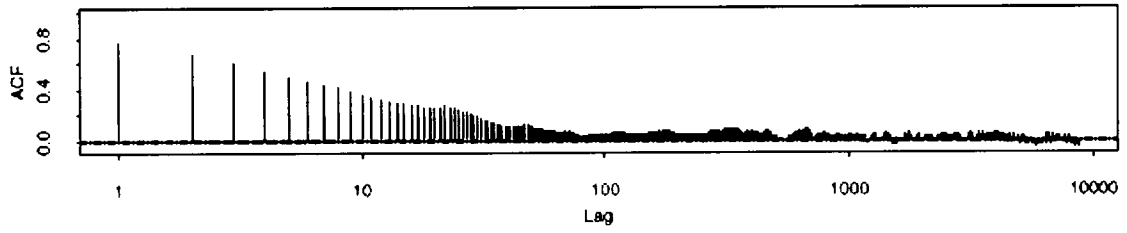
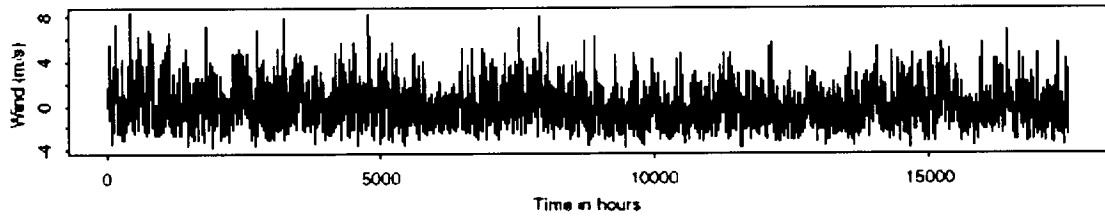
Filtered Wind Speed (m/s) 1996 - 1997: Station 722210



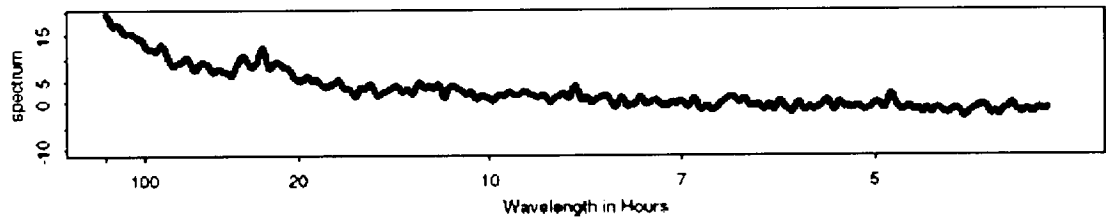
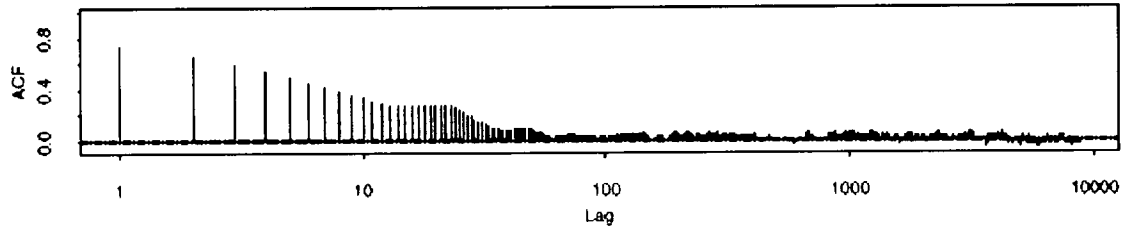
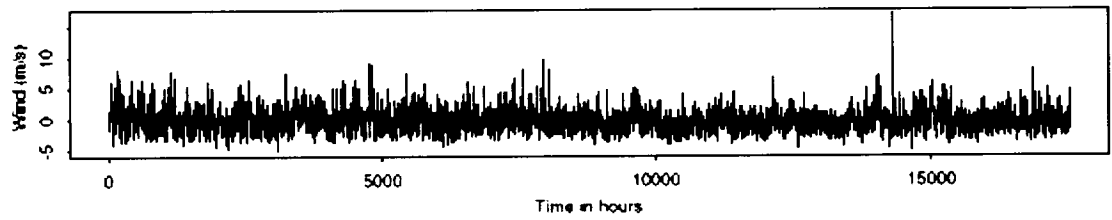
Filtered Wind Speed (m/s) 1996 - 1997: Station 722225



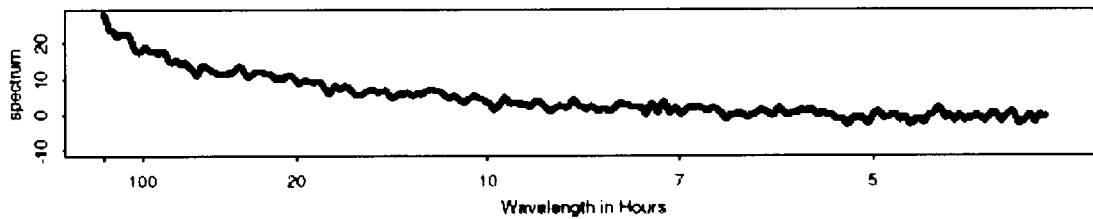
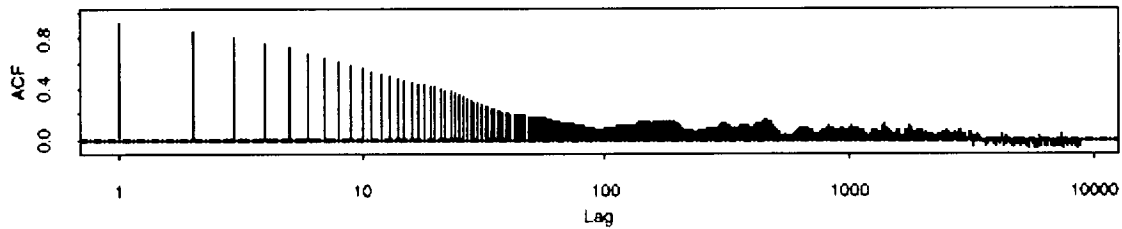
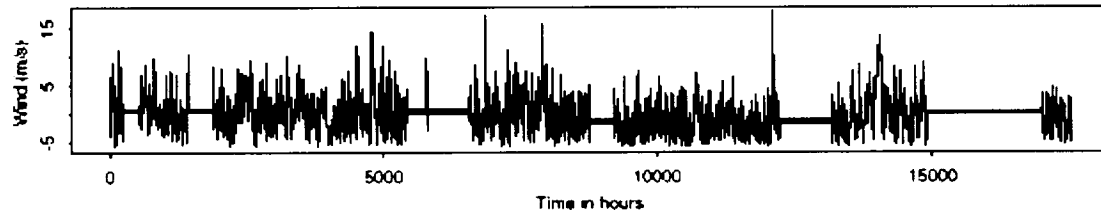
Filtered Wind Speed (m/s) 1996 - 1997: Station 747686



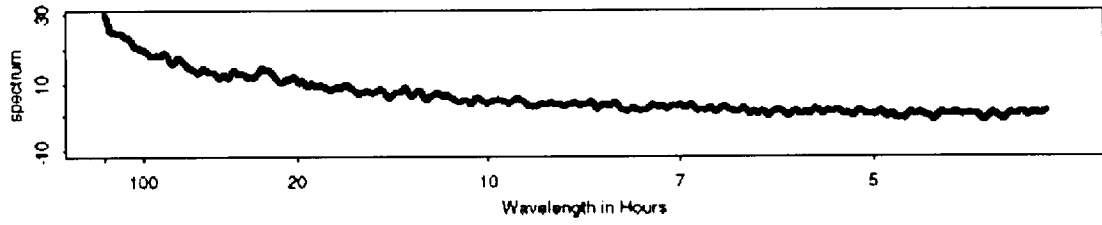
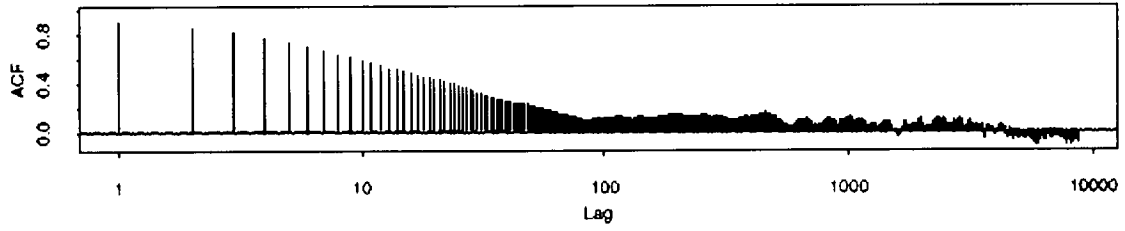
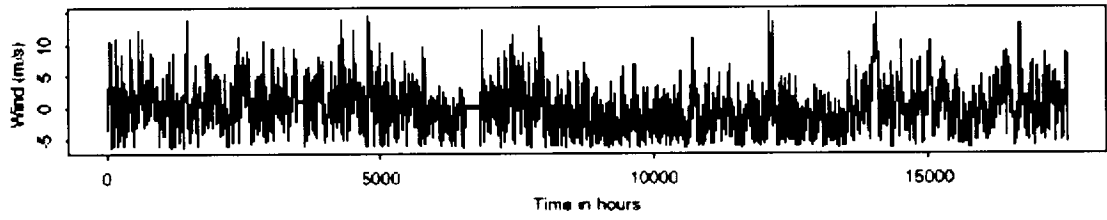
Filtered Wind Speed (m/s) 1996 - 1997: Station 747750



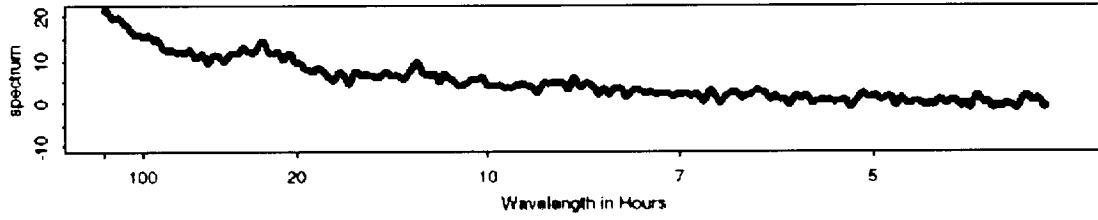
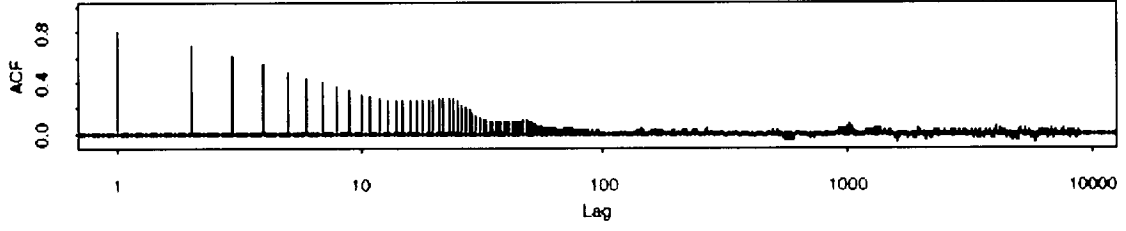
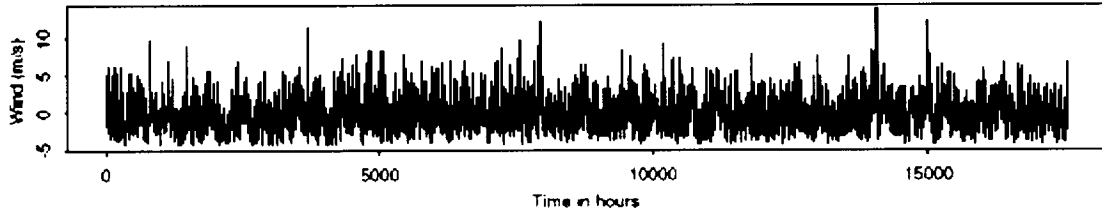
Filtered Wind Speed (m/s) 1996 - 1997: Station BRETON



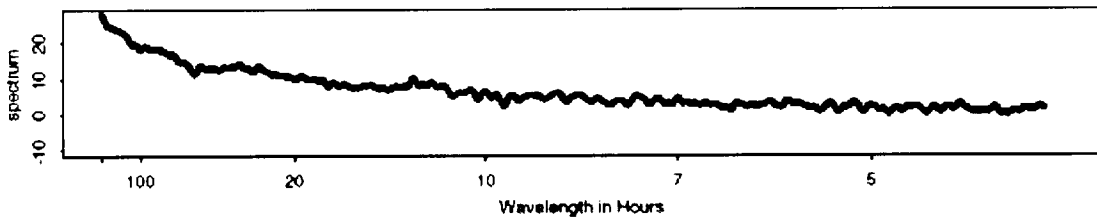
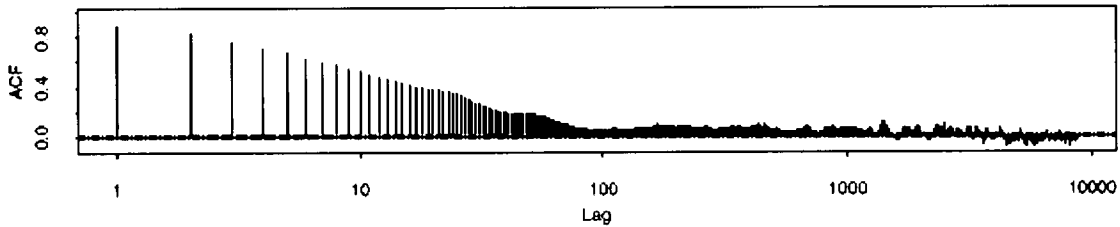
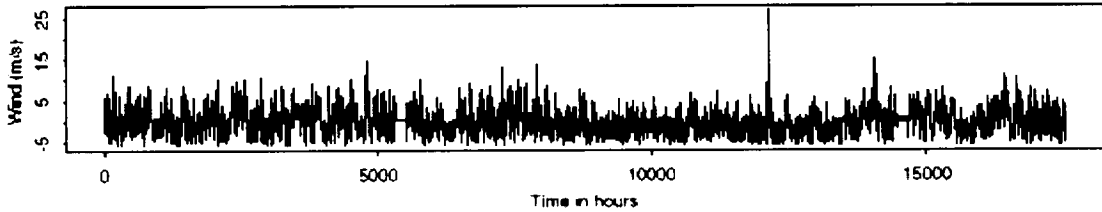
Filtered Wind Speed (m/s) 1996 - 1997: Station BURL1



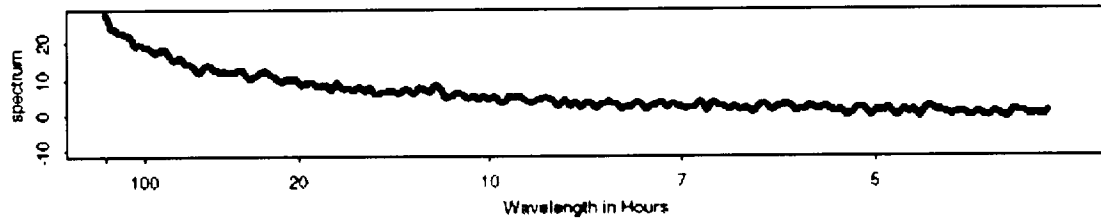
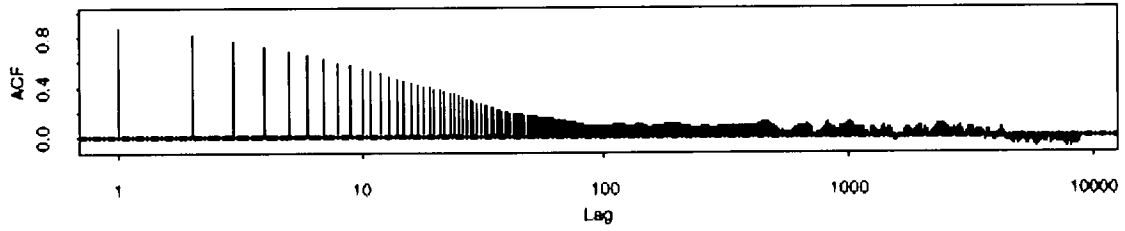
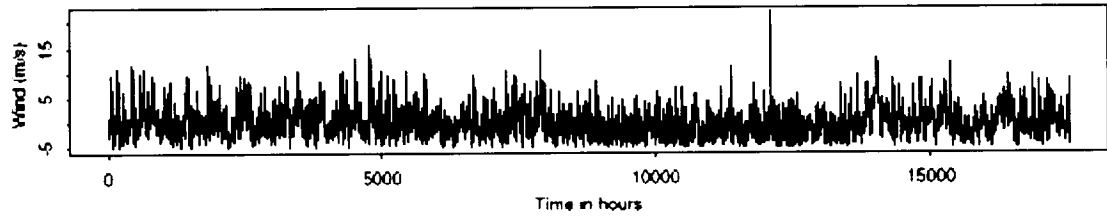
Filtered Wind Speed (m/s) 1996 - 1997: Station CDRF1



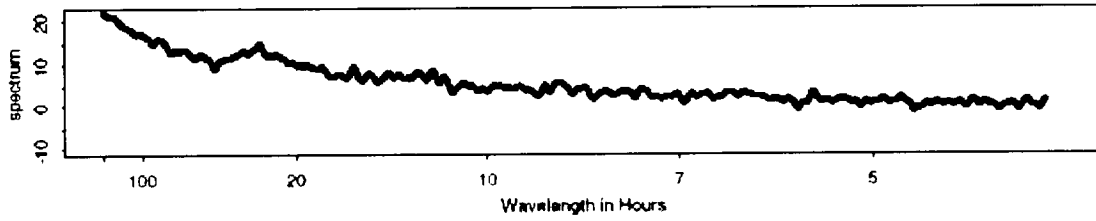
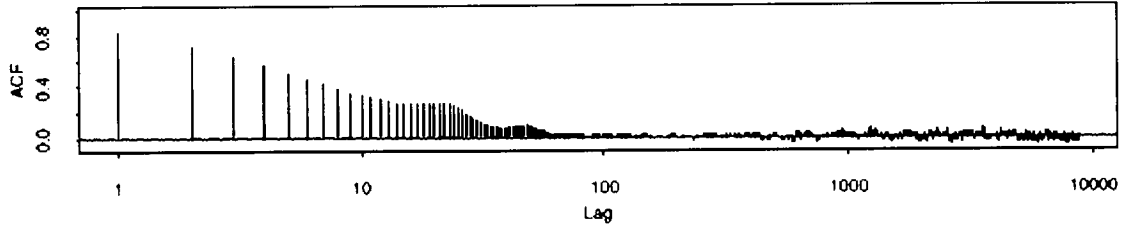
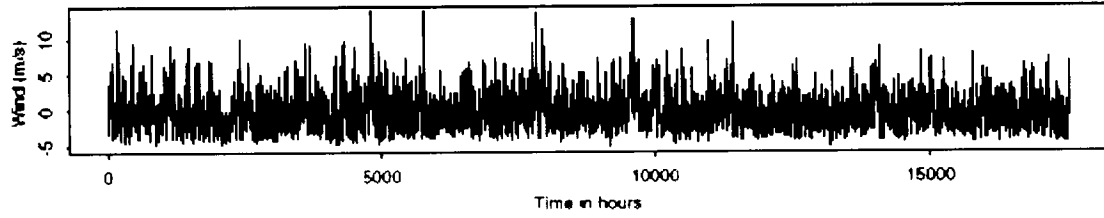
Filtered Wind Speed (m/s) 1996 - 1997: Station DPIA1



Filtered Wind Speed (m/s) 1996 - 1997: Station GDIL1



Filtered Wind Speed (m/s) 1996 - 1997: Station KTNF1





The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.



The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The **MMS Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.