Highlight Article

C COAST: A PC-based Program for the Analysis of Coastal Processes Using NOAA CoastWatch Data

R. L. Miller and J. DeCampo

Recent advances in computer and electronic technology now provide low-cost hardware systems for the analysis of remotely sensed data. The current emphasis on developing processing algorithms and computational techniques, however, often overshadows the critical need for real-time, affordable, data. As part of the NOAA Coastal Ocean Program, the CoastWatch program was created to provide low-cost, near real-time remotely sensed data of the coast and Great Lakes region of the United States to decision makers in the public and private sectors. Eight regional CoastWatch notes were established to distribute and archive products, in particular images of sea surface temperatures (SST), derived from AVHRR data. This paper describes a PC-based program developed specifically for the display and analysis of NOAA's CoastWatch SST processed imagery. This program, *C COAST*, provides an easy-to-use environment for both novice and advanced users to incorporate SST images into their research, educational, and management activities. Recently, many research scientists and program managers have acknowledged the complexities associated with the study and management of environmental systems. It is often difficult to characterize many Earth environments because the time and space scale relevant to important biological, chemical, and physical processes frequently render traditional methods of sampling as being inadequate to resolve many important issues and concerns. To meet program goals and objectives, many investigators and managers have adopted the use of GIS and remote sensing. Unfortunately, the widespread use of digital technology has been restricted. Initially, the use of GIS or remote sensing required expensive, dedicated systems to use digital imagery or the translation of analog (hardcopy) data into the digital domain. Miller (1993) described a robust program, *Figment*, for the analysis of digital imagery on a generic microcomputer. *Figment* provided a means to analyze and display digital imagery; however, the expense and difficulties in acquiring remotely sensed data remained a problem. During 1988, the National Oceanic and Atmospheric Administration (NOAA) established the CoastWatch program. Leshkevich et al. (1993) provide a detailed overview of the CoastWatch program. In general, the CoastWatch program was created to provide remotely sensed data to federal, state, and local decision makers that were responsible for managing the U.S. coastal zone and Great Lakes region. To be effective, the data provided by CoastWatch had to be both timely and at a level of processing that would provide usable (immediate) information. Data products, in particular sea surface temperatures, are routinely generated using NOAA's AVHRR instrument by NOAA NESDIS and distributed by the Ocean Products Center. These data provide near real-time coverage of SST of the U.S. Coasts and the Great Lakes area. Eight regional nodes (figure 1) were established by CoastWatch to distribute regional data products. Data may be accessed from a regional node by either an Internet connection, dial-up modem, or transfer by diskette. In concept, the CoastWatch program was to define, and establish the infrastructure necessary for the routine distribution of products derived from remotely sensed data.

This valuable resource of coastal data is not used to its potential.

The CoastWatch program has met the project goal of providing a repository and distribution center of digital imagery. The data are readily available, but unfortunately, many potential users do not possess the recommended computer hardware (Number 9 Revolution graphics board and supported display monitor) and software (IDIDAS, Interactive Digital Image Display and Analysis System) necessary to use CoastWatch data products. Therefore, this valuable resource of coastal data is not used to its potential.

In this paper, we describe a computer program designed specifically for the display and analysis of CoastWatch SST data. *C COAST* (Computer-based Coastal Observation and Analysis of Sea Temperatures) was developed as a collaborative effort between NASA Science and Technology Laboratory and the Southeastern CoastWatch Regional node to provide an easy-to-use program for examining CoastWatch data on low-cost microcomputers.

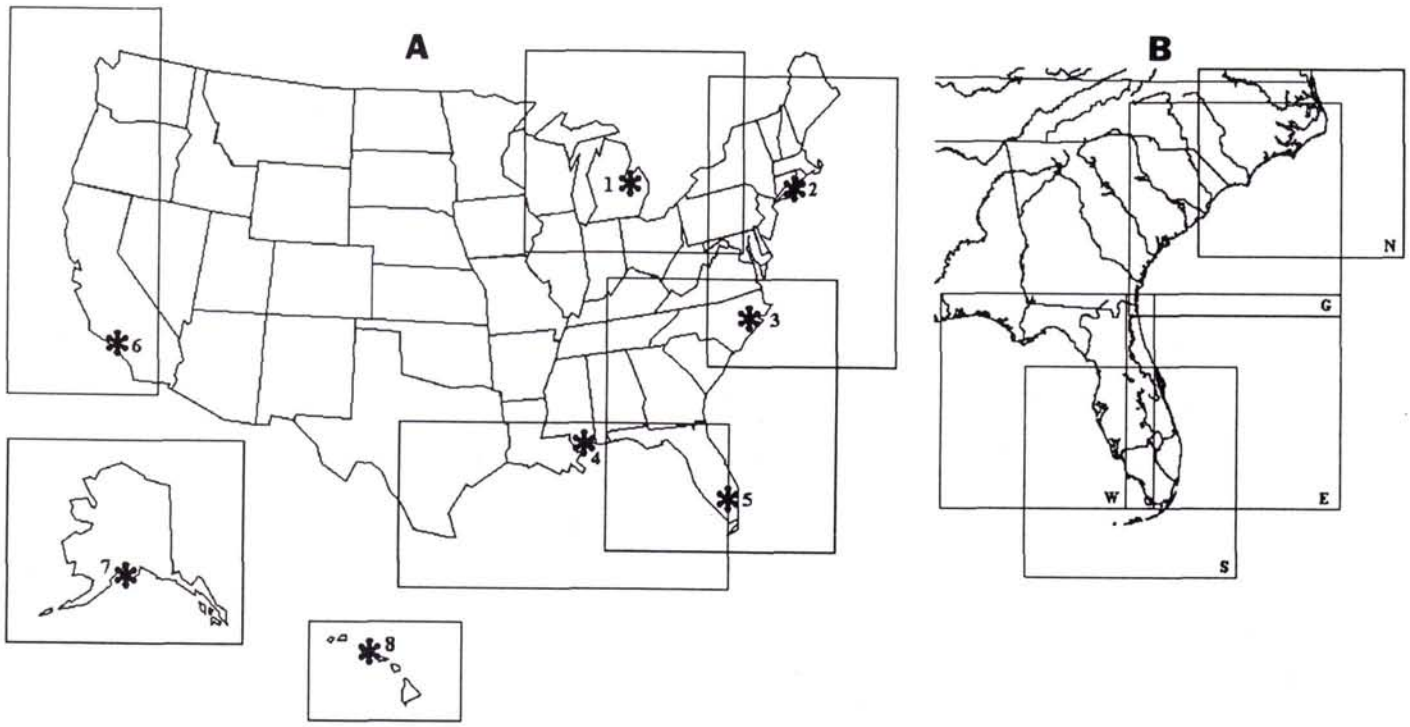

Figure 1. A. Location of CoastWatch region nodes: 1. Ann Arbor, Mich.; 2. Narragansett, R.I.; 3. Beaufort, N.C.; 4. Bay St. Louis, Missouri; 5. Miami, Fla.; 6. La Jolla, Cal.; 7. Anchorage, Alas.; Honolulu, Haw. B. Each regional node maintains images of subregions. For example, the Beaufort, N.C. node produces five subregion scenes as shown here.

We describe the design and use of *C COAST*, the equipment required, and future directions planned for the development of affordable computer software for the analysis of remotely sensed digital imagery.

C COAST was modeled after the design principles of *Figment* (Miller, 1993). Briefly, *C COAST* was designed to provide easy-to-use access of CoastWatch SST data on a PC-based microcomputer, to have minimal computer hardware requirements, and to provide a logical and affordable upgrade path to other existing and future digital remote sensing data (e.g., SeaWiFS). *C COAST* was also to provide a bridge between both novice and sophisticated users of remotely sensed data, thus providing an effective research, management, and educational tool.

The major design criterion was to develop a program that would operate on the large number of PC-based microcomputers installed without requiring the user to invest significant funds for dedicated display hardware. Image display and processing of digital imagery imply visualization of data at a screen (pixel, or picture element) and color resolutions that would provide a user the ability to discern features as necessary for their work. Therefore, the required screen and color resolutions will, by necessity, vary as a function of both the input data, sophistication of the user, and analytical questions addressed. Until recently, these requirements could only be nominally met by expensive computer systems.

The development of the microprocessor has redefined the world of computers. For example, there has been a rapid evolution in the computational power and storage capacity of computers; microcomputers defined by their limited capabilities five years ago now rival mini- to mainframe computers of vintage. With increasing power and capacity, there has been a commensurate decrease in price in most computer systems. Given the appropriate software, the computer systems used routinely by most offices and students can also provide a powerful and robust platform for displaying and processing digital, remotely sensed data.

The current de-facto standard of PC-based microcomputers (IBM compatibles) is based on the ISA (Industry Standard Architecture) bus. Within this environment numerous standards, and limitations, emerge. Programs designed to operate within this environment are limited to their size (640 k), unless additional hardware requirements (e.g., expanded or extended memory) are levied against the user. Fortunately, the precipitously rapid decline in the cost of volatile memory minimizes this concern. However, a large number of computer users that would benefit from the ability to analyze remotely sensed data, routinely use a baseline (640 to 1024 k) computer in their work.

To address these issues, *C COAST* was developed to operate efficiently within the 640 k memory limitation. Due to the graphics nature of image processing, *C COAST* also requires that the system contains a mouse or analog pointing device. Perhaps the most important or critical hardware requirement relates to the display technology.

Recent developments have provided a migration from monochrome to 16, 256 and now over 32,000 colors displayed simultaneously at screen resolutions of up to 1024 (horizontal) by 768 (vertical) pixels. It is important to note that most dedicated image processing systems are limited to 256 colors at a screen resolution of 1024 by 1024. The PC-based hardware defined by the SAGA (Super Video Graphics Array) provides the color/screen resolutions described above and is now standard on most microcomputers. *C COAST* capitalizes on the capabilities of the SAGA and provides graphics support that rivals most dedicated image processing systems. The minimum computer configuration required to operate *C COAST* is listed in Table 1.

C COAST was developed to be an easy-to-use program. To achieve this goal, *C COAST* employs a desktop interface containing pull-down menus, and pop-up, movable, scrollable, and resizeable windows (Figure 2). The design and operation of the desktop is intuitive and is consistent with the graphical interface of numerous PC-based programs. The desktop is generated within the text video mode to reduce memory requirements. Windows adhere to the CUA (Common User Access) standard. In this way, users can perform most *C COAST* functions without extensive training. The desktop environment is used for file access and maintenance.

Up to five CoastWatch files may be accessed at any time. To minimize requirements, data files acquired from a CoastWatch regional node are maintained in their original compressed form. Upon accessing a file, *C COAST* prompts the user to input a range of temperatures to which the input data are binned. That is, CoastWatch data files are stored as a compressed file and a 1024 byte header. The header provides descriptive information and is used by *C COAST* to provide information (within an annotated window) of a data file upon request. CoastWatch uses a proprietary compression algorithm.

TABLE 1. SYSTEM REQUIREMENTS TO OPERATE *C COAST*

Required:	
Computer	IBM compatible (286 (AT) or greater)
Memory (volatile)	640 k conventional
Memory (static)	up to a maximum of 20 mb (required for temporary storage of data files being observed)
Pointing Device	Microsoft compatible mouse
Display	SVGA (super VGA) capable of a minimum resolution of 640 by 400 at 256 colors; display monitor capable of displaying SVGA resolution selected
Software	DOS 3.3 or higher
Recommended:	
Memory (volatile)	additional memory configured as expanded (LIM 4.0) memory to improve performance of various display options
Memory (static)	high capacity for archival storage of Coast-Watch files; removable cartridge storage (e.g., Bernoulli, Floptical) is highly recommended

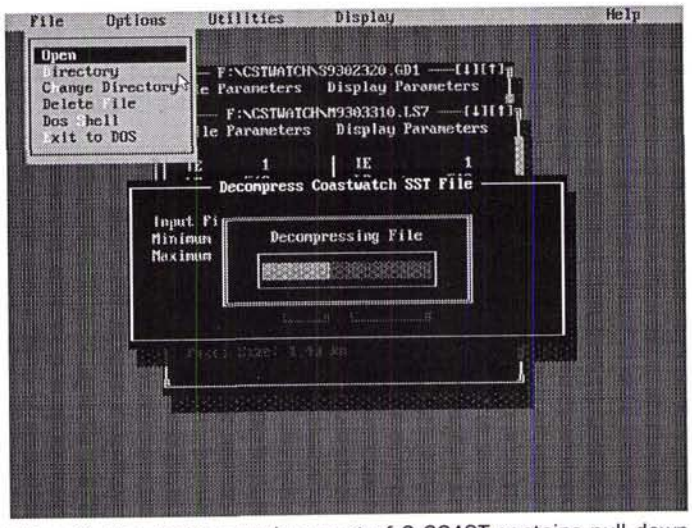

Figure 2. The desktop environment of *C COAST* contains pull-down menus and pop-up windows that are consistent with the graphical user interfaces found on many computer systems.

At decompression, *C COAST* decompresses the original CoastWatch SST file into 256 digital values (8 bits), binned according to the minimum and maximum range of SST (°C) specified by the user. The decompressed file is maintained as a temporary file, linked both to a file description window within the desktop and the original decompressed file. Upon exiting *C COAST* or closing the file window, the temporary file is deleted. Thus the overall system requirements that are required to operate *C COAST* are significantly reduced.

Once a file is opened, the power of *C COAST* is revealed when the image is displayed graphically. Standard CoastWatch SST files are 512 by 512 pixels and, as performed by *C COAST*, can be ginned (floating point SST values partitioned into separate groups) into 256 discrete temperature values. For example, the default temperature range of 0 to 30 °C yields a temperature resolution of about 0.12 °C. A single file may be "opened" using several ranges of temperatures. This capability can yield high contrast images that detail select features (Figure 3).

C COAST was to provide a bridge between both novice and sophisticated users of remotely sensed data.

Once displayed, *C COAST* provides a second menu interface, a graphical menu with push- buttons

and pop-up windows (Figure 3). Once displayed, the user may interactively annotate, edit, or extract information from the image (Figure 4). For example, simple descriptive statistics can be extracted by interactively drawing a line or box. Similarly, pixel location (latitude and longitude) and sea surface temperature can be examined by selecting the appropriate menu option and roaming with the mouse cursor. Images created may be saved as a PCX file. As a widely accepted graphics file format, PCX offers a means to use other PC-based programs to provide, for example, file conversion to other graphic file formats, additional annotation or editing, and hard copy images. A functional description of the options available within *C COAST* are given in Table 2. In general, *C COAST* provides the tools necessary to display, visually enhance, edit, annotate, and extract statistical information from CoastWatch data. Coupled with the frequent availability of CoastWatch data, these capabilities provide to *C COAST* users the ability to routinely analyze coastal processes or monitor coastal environmental problems.

Users can perform most *C COAST* functions without extensive training.

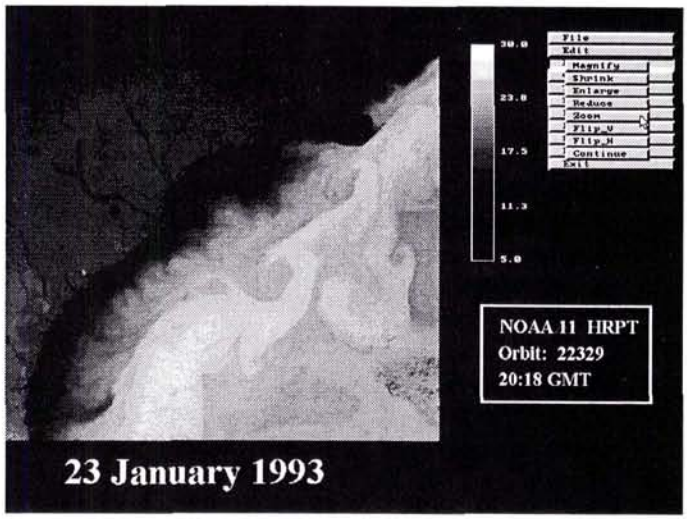

Figure 3. The graphics environment of *C COAST* provides push button menus and full annotation capabilities. Note: Images were converted to gray scale for publication. In practice, images may be displayed using 256 individual colors selected from several default or user generated palettes.

To understand the principles of fundamental processes operating in environmental systems, synoptic data acquired over a broad spectrum of time and space scales must be acquired. This data is most readily afforded by remote sensing instruments. A major global effort is in place to develop and launch a series of satellite-borne instruments to view the Earth as a system. These instruments will examine both land and ocean processes through multispectral analysis. For example, the U.S. government is designing a research program to examine Earth science and Earth missions, a Mission to Planet Earth. A key element of this program must be the use of remote sensing and GIS technology.

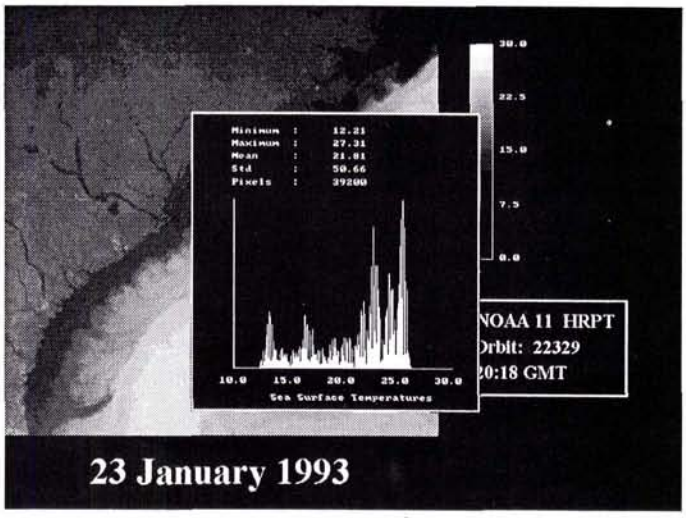

Figure 4. Users may interactively extract descriptive statistics or position information.

There are several critical components of any program that adopts remote sensing: such as the technology necessary to acquire data and the technology necessary to process and analyze digital data (i.e., image processing). We have shown that these two components are addressed by the acquisition of SST data by the NOAA CoastWatch program and the development of a robust, affordable, image processing program *C COAST*. In particular, the near daily access of CoastWatch data will provide the information necessary to analyze and monitor many dynamic coastal processes.

The combination of CoastWatch and *C COAST* also provides numerous opportunities for college and secondary education students to learn the principles of remote sensing, image analysis, and various coastal processes. To fully realize the potential of an orbiting Earth observing system, a new cadre of scientists and technicians must be trained in the science and technology of remote sensing and image processing. To do so requires low-cost powerful systems.

C COAST is in use at all regional CoastWatch nodes and at select test sites [For more information or a copy of *C COAST* and a Users Manual, contact: Mr. Tom Leming, NOAA/National Marine Fisheries Service, CoastWatch Node Manager,

TABLE 2. FUNCTIONAL DESCRIPTION OF OPTIONS AVAILABLE WITHIN *C COAST*'S DESKTOP AND GRAPHICS ENVIRONMENT.

Desktop: Name	*Description*
File	Access a CoastWatch file, list files, change to an existing directory, delete a file, shell to DOS, and exit *C COAST*
Options	Create a movie script (generate dist of graphic files that will be played in succession to emulate the playing of a movie), alter default parameters for system startup
Utilities	Display file information, delete desktop windows, generate user-defined color palettes
Display	Display file associated with current file window
Help	Context sensitive help, system information, brief description of *C COAST*
Graphics Environment:	
File	Capture current image as a PCX file
Edit	Perform basic editing functions such as copy, move, cut, and paste
Display	Magnify, shrink, flip (horizontal and vertical), and interactive zoom
Color	Select current palette, display color bar, and highlight all pixels of a given temperature
Text	Annotate image, select active font, select color of text
Draw	Draw rectangles, lines, and polygons
Function	Change function (mapping of SST to a color), plot function, initialize function (linear mapping of SST to color index (0-225))
Parameters	Extract current value of all system parameters
Statistics	Extract descriptive statistics (e.g., minimum, maximum, mean) from an area of the image defined by a line, rectangle, or polygon
Position	Interactively determine Earth position (latitude, longitude) of a pixel or the distance (km) between two pixels

Stennis Space Center, MS 39529]. In addition to testing program stability, current users will help define both the character and capabilities of *C COAST*. It is planned that after testing and full program development, an operational version of *C COAST* will be available from CoastWatch.

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Authors

Richard L. Miller is with NASA, Earth Observation Projects Office, JA20 Building 1000, Stennis Space Center, MS 29519; J. DeCampo is with NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort Laboratory, Beaufort, NC 28516.

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