# CoastWatch Software Library and Utilities User's Guide

## Version 3.2.4 DEVELOPMENT PRERELEASE
## Revised May 7, 2012

Prepared by:
Peter Hollemans, Terrenus Earth Sciences

Modified by:
Xiaoming Liu, SP Systems, Inc.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
COASTWATCH PROGRAM

# Copyright Notice

CoastWatch Software Library and Utilities
Copyright 1998-2009, USDOC/NOAA/NESDIS CoastWatch

Permission to use, copy, modify, and distribute this software and its documentation for any purpose and without fee is hereby granted, provided that the above copyright notice appear in all copies, that both the copyright notice and this permission notice appear in supporting documentation, and that redistributions of modified forms of the source or binary code carry prominent notices stating that the original code was changed and the date of the change. This software is provided "as is" without express or implied warranty.

# Privacy Policy

On startup, this software queries network servers for up-to-date version information, at which time data is collected and stored by the server automatically concerning the computer IP address, type of operating system, version of the software, and the date and time. This information does not identify you personally. It is used to help improve the software by providing usage statistics. More details on NOAA's privacy policy may be found at http://www.noaa.gov/privacy.html.

# Obtaining a Copy

To download a copy of the CoastWatch Utilities, visit:

http://coastwatch.noaa.gov/cw_cwfv3.html

For general information on CoastWatch products and services, visit:

http://coastwatch.noaa.gov

# Providing Feedback

Email questions, comments, suggestions, and bug reports to the CoastWatch help desk at coastwatch.info@noaa.gov. In order to receive help, you should include the following information:

1. The version and operating system of the software, for example *cwf-3.2.1 on Windows XP*.
2. The type of data file and where you obtained the file, for example *CoastWatch .cwf files obtained from the SAA web site*. If the data origin is unknown, include some example data filenames.
3. If sending a bug report or asking for clarification, a description of how to reproduce your result:
   - For a command-line tool, a transcript of the terminal session during which the question or problem arose. You can cut and paste the contents of the terminal session including the command used and its output directly into the email.

- For a graphical interface tool, a list of steps to reproduce the problem. For example, *Open data file xxx, click this button, then that button.*

# Contents

**Preface** **1**

**1 Introduction** **3**

1.1 A Brief History . . . 3

1.2 Installation Notes . . . 4

1.2.1 System Requirements . . . 4

1.2.2 Downloading . . . 4

1.2.3 Installing on Windows . . . 4

1.2.4 Installing on Mac OS X . . . 5

1.2.5 Installing on Unix . . . 5

1.3 Using the Software . . . 5

1.4 Third Party Software . . . 6

**2 Common Tasks** **7**

2.1 Information and Statistics . . . 7

2.2 Data Processing . . . 8

2.3 Graphics and Visualization . . . 8

2.4 Registration and Navigation . . . 9

2.5 Network . . . 10

**3 The CoastWatch Data Analysis Tool** **11**

3.1 Getting to know CDAT . . . 11

3.2 Loading data files . . . 13

3.3 Navigating in CDAT . . . 14

3.4 Changing data image colors . . . 14

3.5 Displaying coastlines, grids, and more . . . 15
3.5.1 Types of overlays . . . 16
3.5.2 The *Overlay List* . . . 18
3.5.3 Overlay groups . . . 19
3.6 Measuring distances and data statistics . . . 20
3.6.1 Types of surveys . . . 20
3.6.2 The *Survey List* and results . . . 21
3.7 Drawing lines, shapes, and text . . . 21
3.7.1 Types of annotations . . . 21
3.7.2 The *Annotation List* . . . 22
3.8 Using composite image mode . . . 23
3.9 Correcting geographic location problems . . . 23
3.9.1 Navigation correction . . . 25
3.9.2 Navigation analysis . . . 26
3.10 Exporting images and data . . . 28
3.11 Setting color, enhancement, and units preferences . . . 29
3.11.1 Resources directory . . . 31
3.12 Connections with command line tools . . . 32

**4 Programmer's API** **35**
4.1 How to use the API . . . 35
4.2 Data I/O . . . 37
4.3 Data rendering . . . 38
4.4 Graphical user interface components . . . 39
4.5 General utility classes . . . 40
4.6 Main programs . . . 41

**A Manual Pages** **43**
A.1 cdat . . . 43
A.2 cwangles . . . 45
A.3 cwautonav . . . 48
A.4 cwcomposite . . . 57
A.5 cwcoverage . . . 60

A.6 cwdownload . . . 64
A.7 cwexport . . . 67
A.8 cwgraphics . . . 75
A.9 cwimport . . . 78
A.10 cwinfo . . . 80
A.11 cwmaster . . . 83
A.12 cwmath . . . 85
A.13 cwnavigate . . . 91
A.14 cwregister . . . 95
A.15 cwrender . . . 98
A.16 cwsample . . . 110
A.17 cwstats . . . 114
A.18 cwstatus . . . 117
A.19 hdatt . . . 119

**B CoastWatch HDF Metadata Specification 123**

B.1 Overview . . . 123
B.2 Global Metadata . . . 124
B.3 Earth Location Metadata . . . 125
B.3.1 Version 2 Affine . . . 127
B.3.2 Version 3 Affine . . . 128
B.4 Variable Metadata . . . 128
B.4.1 Calibration Values . . . 130
B.4.2 Navigation Correction . . . 130
B.5 Swath Earth Location Encoding . . . 131
B.6 GCTP Appendices . . . 136

**C Data Format Compatibility 151**

**D Miscellaneous Formats 153**

D.1 Navigation analysis XML output . . . 153
D.2 Navigation analysis CSV output . . . 155
D.3 Color palette XML format . . . 155

**E AVHRR SST Product FAQ** **157**

E.1 Data formats and archiving . . . . . 157

E.2 SST computation . . . . . 159

E.3 Cloud masking . . . . . 160

E.4 Navigation correction . . . . . 162

E.5 Map projections . . . . . 164

**F Acronyms** **167**

**G History of Changes** **169**

# List of Figures


3.1 Components of the CDAT window . . . . . 12
3.2 File Open window . . . . . 13
3.3 Color conversion tabs . . . . . 15
3.4 Color enhancement process . . . . . 16
3.5 Overlay graphics drawing order . . . . . 17
3.6 Overlay Layers tab . . . . . 17
3.7 Examples of default overlay groups . . . . . 19
3.8 Data Surveys tab . . . . . 20
3.9 Annotations tab . . . . . 22
3.10 Color Composite tab . . . . . 23
3.11 RGB composite examples . . . . . 24
3.12 Navigation Correction tab . . . . . 25
3.13 Navigation correction example . . . . . 26
3.14 Navigation Analysis panel . . . . . 27
3.15 Enhancement section in the Preferences panel . . . . . 30

B.1 A partitioning of AVHRR swath data . . . . . 132
B.2 Sampling pattern for polynomial approximation . . . . . 133
B.3 Binary tree encoding example . . . . . 134
B.4 A more complex binary tree encoding example . . . . . 134

# Preface

## Typographic Conventions

In this manual, we use the following conventions for the font and color of text. References within the document are in the standard font, but are red to emphasize that they are active links, for example a reference to a section: "see chapter 3 for information on the CoastWatch Data Analaysis Tool". External references are a `typewriter` font in magenta, such as a web site address: "`http://www.google.com` is a great search engine". Terminal commands, terminal output, file names, and verbatim character strings are in a `typewriter` font. Java class names are in *italics*. Replacement parameters in command line programs are in CAPITALS.

## Acknowledgments

We would like to acknowledge the following parties for support in creating the CoastWatch Utilities software (in no particular order):

- John Sapper of NOAA/NESDIS, CoastWatch central operations, and many other NOAA/NESDIS researchers for continued funding support and new requirements.
- The CoastWatch node managers, operations managers, and CLASS archive staff who were invaluable in providing feedback.
- CoastWatch data users who have provided critical review of the software, bug reports, and new ideas for functionality.
- The open source software community for providing high quality code libraries upon which the utilities are built.

# Chapter 1

# Introduction

The main goal of the CoastWatch Utilities software is to aid data users in working with NOAA/NESDIS CoastWatch satellite data. CoastWatch data is distributed as individual files in a scientific data format that is not recognized by standard image viewers, and the CoastWatch Utilities are useful for manipulating data and creating images from CoastWatch data for both recreational and scientific applications. CoastWatch data files contain:

1. Global file attributes that describe the date/time and location of the earth data in the file, as well as any relevant data processing details.
2. Earth data as a set of two-dimensional numerical arrays, each with a unique name. These *variables* hold the actual scientific data and accompanying attributes, such as scaling factor and units, that describe how to use the data values.

The CoastWatch Utilities allow users to selectively access and extract this information in a number of ways.

## 1.1 A Brief History

The CoastWatch Utilities have been evolving since 1998. The original software was capable of working with CoastWatch IMGMAP format data files, the standard data distribution format (limited to NOAA AVHRR data) for CoastWatch satellite data until 2003. The current utilities are capable of reading CoastWatch IMGMAP, NOAA 1b AVHRR, and CoastWatch HDF, a new format based on the NCSA Hierarchical Data Format (HDF) that has been adopted by CoastWatch for distributing earth data from a host of different satellites and sensors. Following is a sketch of the software evolution:

- Version 1: 1997. The first version created CoastWatch IMGMAP files from TeraScan Data Format (TDF), a proprietary format from SeaSpace Corporation. It was never publicly released.
- Version 2: 1998-2000. The second version was released to the CoastWatch data user community and worked with CoastWatch IMGMAP (CWF) files only. Users could convert CWF files to other formats, create GIF images, perform land and cloud masking, create data composites, and other related tasks.

- Version 3: 2001-present. The third version was designed to have a more flexible data handling capability, with support for both CoastWatch IMGMAP and the new CoastWatch HDF format. The CoastWatch Data Analysis Tool (CDAT) was integrated into the package. Additional capabilities were added for NOAA 1b AVHRR, level 2 swath style data, automatic navigational correction, ESRI shapefiles, and other improvements.

## 1.2 Installation Notes

### 1.2.1 System Requirements

**Operating system** The CoastWatch Utilities are currently available for Windows, Linux, Solaris, Mac OS X, and AIX only.

**Java version** As of version 3.2.2, the correct Java Runtime Environment (JRE) is packaged with the Windows, Linux, Solaris, and AIX versions of the CoastWatch Utilities. There is no need to install it separately – it will be placed in a subdirectory of the installation directory and will only be used by the CoastWatch Utilities.

For Mac OS X a JRE version **1.5.0 or higher** is required on the machine. Generally an up-to-date version of Mac OS X has the correct Java version. To check the current Java version, go to *Applications -> Utilities* in the Finder and start the Terminal. Type `java -version`, hit enter, and look at the first line of output. If the version does not start with 1.5.0 or greater, run *Software Update* from the  menu or visit http://www.apple.com/java to download manually.

**Disk space** A minimum of 150 Mb is required for the installed software. We recommended at least 300 Mb of space in total to allow for downloading and manipulating satellite datasets. More disk space may be required for larger datasets.

**Memory** A minimum of 128 Mb is required, while 256 Mb is recommended. More memory may be required depending on the number of concurrent processes running on the computer.

### 1.2.2 Downloading

To download, visit the CoastWatch central web site:

http://coastwatch.noaa.gov/cw_cwfv3.html

and download the package appropriate for your operating system. To install, read one of the following sections depending on your platform.

### 1.2.3 Installing on Windows

If upgrading to a new version, there is no need to uninstall the previous version – the new installation setup program will handle the details. To install the new version, simply double-click the downloaded installation package. The setup program will install the software in a user-specified directory, and add entries to the Start Menu. The User's Guide (this document) is also added to the Start Menu.

If you use the command line tools you may want to add the installed executable directory to the path for easier command line execution. On Windows XP, go to the Windows *Start Menu* and click *Control Panel -> Performance and Maintenance -> System*, select the *Advanced* tab and click the *Environment Variables* button. Edit the entry for the *Path* variable under *System variables* and add the full path to the installed executable directory, for example `C:\Program Files\CoastWatch Utilities\bin`. Other Windows versions have a similar procedure for adding a path.

### 1.2.4 Installing on Mac OS X

The Mac OS X installation package is a disk image (DMG) file that contains support for both PowerPC and Intel processors. Download the DMG file, double-click to mount it, and then double-click the installer program. When upgrading, the new version of the utilities will automatically uninstall the old version.

If you use the command line tools you may want to add the installed executable directory to your path for easier command line execution. In a Terminal session, add the following lines to the `.profile` file:

```
export PATH=${PATH}:"/Applications/CoastWatch Utilities/bin"
```

and then open a new Terminal window for the changes to take effect.

### 1.2.5 Installing on Unix

For the Linux RPM file, run the rpm command as root:

`rpm -Uvh` FILENAME.RPM

which will install or upgrade the software into `/opt/cwf` and create links to the executables in `/usr/local/bin`. For the self-installing shell script, you can install as a normal user or as root by executing the shell script and following the instructions in the graphical setup wizard. For the tar archive file (non-graphical install), extract the archive as follows:

`gunzip` FILENAME.TAR.GZ
`tar -xf` FILENAME.TAR

You may also want to add the installed executable directory to your `$PATH` environment variable for easier command line execution, for example:

`setenv PATH ${PATH}:/opt/cwf/bin` (in `.cshrc`)
`export PATH=${PATH}:/opt/cwf/bin` (in `.bashrc`)

## 1.3 Using the Software

The CoastWatch Utilities are made up of various individual tools. Graphical tools allow you to point and click, working with data interactively; the graphical tools have a built-in help system with brief

details on each key feature. To complement these, there are also command line tools that allow you to process data using a text-only command prompt or scripting language. Call any command line tool with the **--help** option to get a short synopsis of parameters. See the manual pages of Appendix A for a complete discussion on the command line parameters for both graphical and command line tools.

Functionally, the CoastWatch Utilities are designed to meet the data processing and rendering needs of many different types of data users. The individual tools have been developed from both in-house requirements and data user suggestions. The functionality of the tools may be divided into several categories based on data processing task:

**Information and Statistics** File contents, statistics computations on variables (for example min, max, mean, standard deviation), direct access to raw file and variable attributes.

**Data Processing** Data format conversions, compositing, generic variable math, data sampling.

**Graphics and Visualization** Interactive visualization/analysis, batch image rendering, ancillary graphics creation such as data coverage maps, grids, coastlines, landmasks.

**Registration and Navigation** Resampling of data from one projection to another, interactive generation of region masters, manual and automatic navigational correction, computation of solar and earth location angles.

**Network** Data download and server status.

## 1.4 Third Party Software

There are a number of other software packages than can be used to read data from CoastWatch HDF data files. They are *generic* in the sense that they can read the numerical and text data, but they cannot interpret the metadata conventions used by CoastWatch. They are well suited to advanced users who want to have more detail on HDF data file contents. You should always refer to the CoastWatch HDF metadata specification of Appendix B when using third party software with CoastWatch HDF files.

The HDF Group (THG), originally part of the National Center for Supercomputing Applications (NCSA), is the main source of information on the HDF format specification and software libraries. You can download tools for working with HDF from the main web site:

`http://www.hdfgroup.org`

Many of the tools are command line, but HDFView is a useful graphical tool.

Other non-NCSA software has been HDF-enabled by linking against the NCSA HDF libraries. Among those packages are IDL, Matlab, and OPeNDAP. A more complete list of non-NCSA software may be found at:

`http://www.hdfgroup.org/tools.html`

# Chapter 2

# Common Tasks

The first step in using the CoastWatch Utilities is to discover which tool to use for the task at hand. To help with this search, this section categorizes the tools by the most common tasks that data users perform. Use this section as a guide to the functionality of the tools, while referring to the manual pages of Appendix A for complete details on each tool's behaviour and command line options.

## 2.1 Information and Statistics

The cwinfo tool lists data file contents, including various global file attributes and the full set of earth data variables in the file. This tool is mainly useful because its output is human readable, as opposed to a raw data dump from a generic HDF tool. It also allows you to display latitude and longitude data for the data corners and center point. The **--verbose** option shows the process of identifying the file format, useful for file format debugging or when you suspect a file is corrupt.

The cwstats tool calculates statistics for each earth data variable in the file: count, valid, minimum, maximum, mean, standard deviation. This is good for assessing the data quality and checking to see that the data values fall into the expected range. Use **--sample**=0.01 to sample only 1% of the data as this saves a large amount of I/O and computation time. The *count* is the total number of data values (rows × columns), while the *valid* value is the number of data values that were not just fill values. CoastWatch satellite data does not always cover the full region of the file, since the satellite view may have clipped the edge of the region during overpass. In these cases, fill values are written for the missing data and the fill values are skipping during statistics computations. Fill values are also used to signify that data has been masked out for quality purposes (see the cwmath tool for an example of masking and section 2.2 for details on how masking can be used).

The hdatt tool is only useful for CoastWatch HDF files[1], and performs low-level reading and writing of HDF attribute data. You can use it to change an attribute value without rewriting the file, or to append an attribute value to the file. The hdatt manual page gives many good examples of when it may be required to modify or create attributes.

[1]The hdatt tool works with any HDF 4 file using the SDS interface, but is primarily intended for CoastWatch HDF files, as opposed to CoastWatch IMGMAP or any other non-HDF file format supported by the utilities.

## 2.2 Data Processing

The cwimport tool converts data into CoastWatch HDF format. Note that it is *not necessary* to convert all data into CoastWatch HDF before working with the data using the CoastWatch Utilities. In many cases, you can perform the same operations on the data in its native format, especially when the operation only reads information and performs no file modification. This is due to the design of the CoastWatch Utilities, which contains a software layer (called the *Earth Data Reader* or *EDR* layer) separating the tools from the physical input file format. The cwexport tool complements cwimport – it converts data into various simple text or binary formats. The cwexport tool benefits from the EDR layer as well, and as such can export data from CoastWatch HDF, CoastWatch IMGMAP, NOAA 1b, and others.

During satellite data processing, it is often necessary to compare data from the satellite sensor to data from in-situ measurements. The cwsample tool performs this function by taking as input a geographic latitude/longitude point or set of points and printing out the data values found at those points in the file.

Another common task in data processing is to combine data from one or more variables using a mathematical equation, or to combine data from multiple files in a data composite. The cwmath tool takes a math expression of the form $y = f(a, b, c, ...)$ where $a, b, c...$ are earth data variables in the file, and loops over each pixel in the file to compute $f$. The cwcomposite tool combines data from one earth data variable across multiple files by computing the mean, median, minimum, maximum, or latest value. You can use the cwmath and cwcomposite tools in tandem to create composite data for a given earth variable; for example to create a weekly composite of sea-surface temperature (SST), mask out all cloud contaminated SST from each file using the cwmath *mask* function, and follow by running cwcomposite on all the masked SST files to compute the mean or median.

Certain data processing tasks are beyond the capabilities of the CoastWatch Utilities. In such a case, the recommended procedure is to access and process data using either the Java Language API outlined in chapter 4, or the native C HDF libraries from NCSA (see section 1.4). IDL and Matlab also have HDF access built-in. The advantage of using the Java API provided by the CoastWatch Utilities is that metadata and file I/O operations are already implemented and generally transparent to the programmer.

## 2.3 Graphics and Visualization

The main interactive tool for displaying CoastWatch data files is the CoastWatch Data Analysis Tool (CDAT). The complexity of CDAT is such that it deserves its own section – see chapter 3 for a complete discussion of CDAT and its features. CDAT is mainly useful for creating unique plots of CoastWatch data, performing data surveys, and drawing annotations on top of the data image. In contrast, the command line tools discussed in this section are designed for the automated creation of plots and graphics from CoastWatch data from a scripting language such as Unix shell, Perl, or Windows batch files.

The cwrender tool creates images from earth data variables, using either a palette or three channel composite mode. Many rendering options are available including coast line, land mask, grid line, topographic, and ESRI shapefile overlays, custom region enlargement, and units conversion. Output formats supported include PNG, JPEG, GIF, GeoTIFF, and PDF.

The cwcoverage tool creates graphics for documentation or web pages that show the physical area that

a data file or group of files covers on the earth. The output shows an orthographic map projection with the boundary of each data file traced onto the earth and labeled. Along similar lines, the cwgraphics tool creates land, coast, and grid graphics for the region covered by a data file. The output of cwgraphics is inserted into the data file as an 8-bit data variable for later use by cwrender or alternatively to be exported via cwexport for use in custom rendering or masking routines.

## 2.4 Registration and Navigation

Earth data from two data files is said to be *in register* if every corresponding pair of pixels has the same earth location. We use the term *registration* to refer to the process of resampling data to a *master* projection. Data that has first been registered to a master can be intercompared or combined with other data registered to the same master. Standard CoastWatch map-projected data files that have been registered to the same master projection can be intercompared or combined on a pixel by pixel basis.

You can create your own master projections and CoastWatch map-projected data files using the cwmaster and cwregister tools. The cwmaster tool is an interactive tool for designing master map projections. The tool enables you to create CoastWatch HDF masters that use one of the various map projections supported by the General Cartographic Transformation Package (GCTP)[2], such as Mercator, Polar Stereographic, Orthographic, and many others. Once a master is created you can used it in the cwregister tool to resample data to the new master projection.

When earth image data is captured from a satellite and processed, there are cases in which inaccuracies in satellite position and attitude (roll, pitch, and yaw) cause coastlines to appear *shifted* with respect to the image data. We say that such data requires a *navigation correction*. Ideally the navigation correction should be applied to the satellite data while in the sensor projection before any registration to a map projection master. In reality data users often only have access to the final map-projected products. However since these map-projected products generally cover a small geographic area, acceptable navigation corrections can often be achieved by applying an offset to the image data of a few pixels in the rows direction and a few pixels in the columns direction. You can use the cwnavigate and cwautonav tools to apply navigation corrections to CoastWatch data files. The cwnavigate tool applies a manual correction, normally derived from your own observation of the data or from some preexisting database of corrections. The cwautonav tool attempts to derive and apply a correction automatically from the image data in the file.

A final tool related to registration/navigation is cwangles which computes explicit latitude, longitude, and solar angles based on metadata in the CoastWatch data file. Some data users appreciate having latitude and longitude values at each pixel rather than simply GCTP map projection parameters or swath polynomial coefficients. Such earth location data is useful when exporting CoastWatch data for use in other software packages. Note that text output from the cwexport tool (see section 2.2) can also include the latitude and longitude of each pixel without having to run cwangles.

[2]See Appendix B for a discussion of CoastWatch HDF metadata which relies on GCTP for map projection parameters.

## 2.5 Network

The cwdownload tool has a command line only interface and is recommended for advanced data users only. You can use the tool to retrieve recent data files from a CoastWatch data server, or to maintain an archive of certain data files of interest. For regular data file retrieval, the tool can be run via the Unix cron daemon or Windows Task Scheduler (located under System Tools in newer versions of Windows). Currently, only AVHRR data is handled by cwdownload. You should contact the CoastWatch Help Desk (coastwatch.info@noaa.gov) for access to a CoastWatch data server to use with cwdownload.

The cwstatus tool shows a graphical view of the status of a CoastWatch data server, and is intended for use by CoastWatch staff only. The status tool displays the current list of satellite passes, their properties, and a graphical view of the pass footprint on the earth along with a preview image.

# Chapter 3

# The CoastWatch Data Analysis Tool

## 3.1 Getting to know CDAT

The CoastWatch Data Analysis Tool (CDAT) displays 2D geographic data as a color image. CDAT converts numerical data such as sea surface temperature to a color map. You can change the way data values are converted to colors by selecting one of the various different color palettes and by changing the data enhancement range. CDAT can draw coastlines, borders, latitude/longitude grid lines, and other graphics on top of the color image. You can analyze the data and compute statistics by surveying at a single point, along a line, or within a polygon. CDAT has features for analyzing and correcting errors in the geographic position of the data. Finally, CDAT can export geographic data to a variety of image and data formats.

Figure 3.1 shows the main components of the CDAT window:

**Menu bar** – Access to file operations, tools, and the help system. The help system contains a short version of this chapter, so that if you want to quickly look up a topic, you can usually scan the help system and find it. The tools contain a preferences window that sets the default color palette, enhancement range, and units for geographic data.

**Tool bar** – Data file operations and view navigation. You can use the data file buttons to open and close files, and export data. More than one data file can be open at once, similar to tabs in a web browser. The view buttons allow you to zoom in and out and move the view center.

**File tabs** – Displays the currently open data file names, and allows you to select the desired file. To close a file, select its tab and click the *Close* button. You can flip back and forth between tabs to compare data from different files.

**Control tabs** – Access to the data view control panels.

**Data view controls** – The control panels are used to change various aspects of the data view: enhancement range, color palette, and graphics overlays. You can also use the controls to perform data surveys, turn on color composite mode, and correct the geographic position (navigation correction).

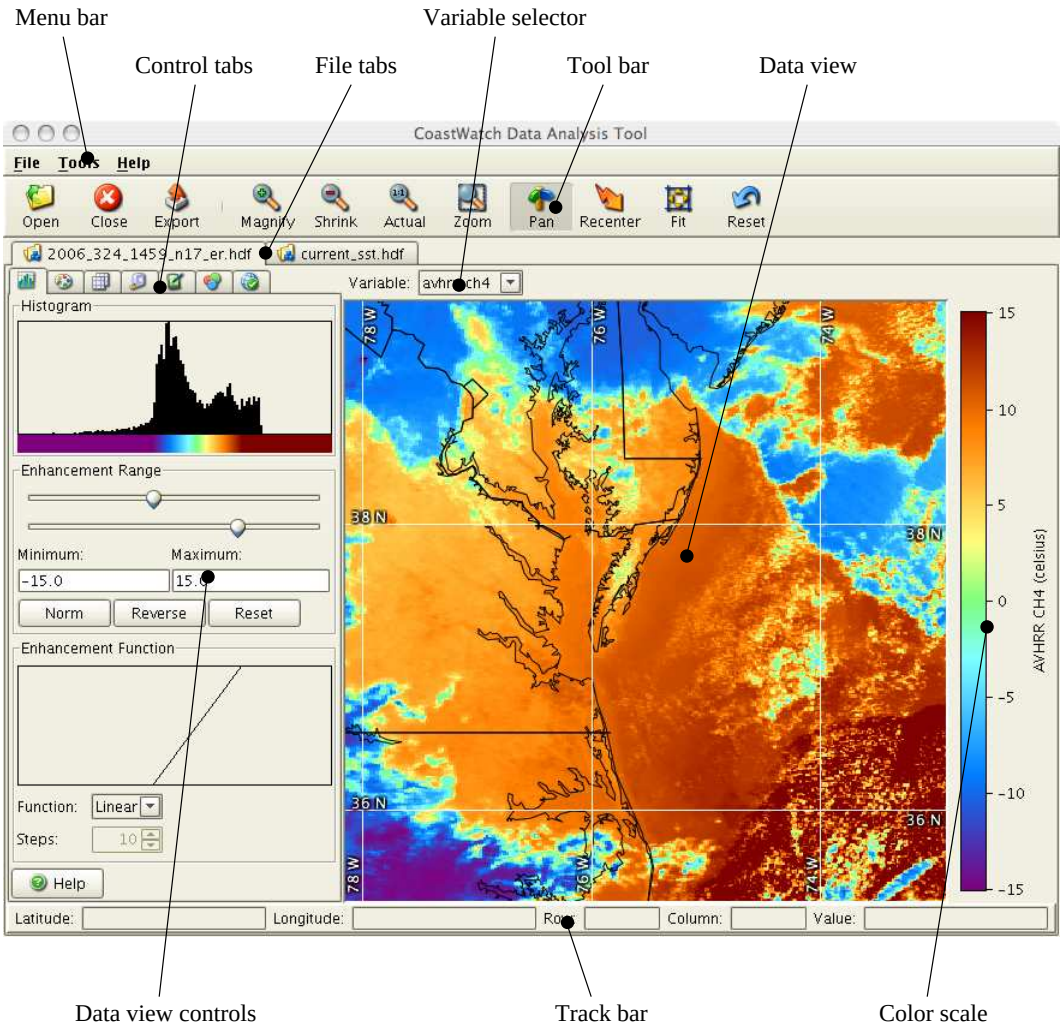



Figure 3.1: Components of the CDAT window

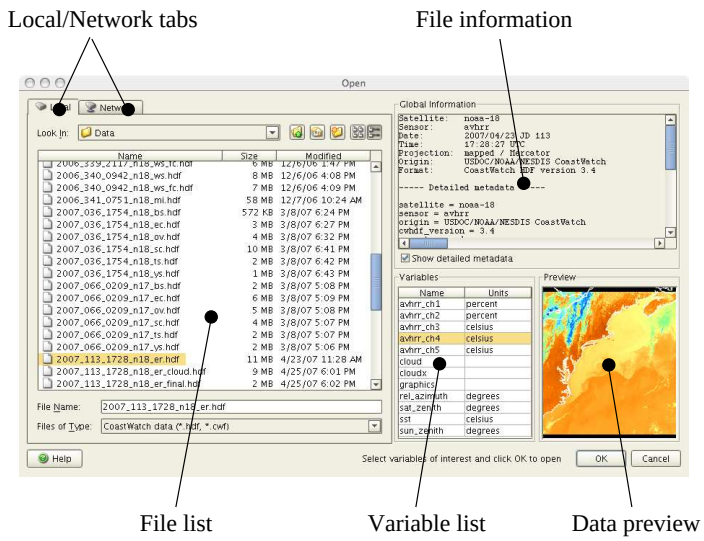



Figure 3.2: File *Open* window. Windows, Unix, and Mac will show slightly different local file choosers (left hand panel). This example shows the Unix file chooser.

**Variable selector** – Displays the currently selected variable from the data file. You can show a new variable by selecting its name from the drop-down list button.

**Data view** – The main area showing the current geographic data file. The data view can show one of several variables from a data file, for example sea surface temperature, albedo, thermal channel data, etc.

**Track bar** – Tracks mouse movement and shows the pointer location in latitude/longitude and image row/column coordinates, as well as the data variable value.

**Color scale** – Shows the relationship between color and data value. The variable name and units are also shown. The data values in the track bar are given in the units indicated by the color scale.

## 3.2 Loading data files

Click the *Open* button to open a data file, and a new *Open* window will appear for selecting the file and variables to load (see Figure 3.2). There are two tabs for loading data into CDAT: *Local* and *Network*. Local data files are files that have been downloaded and reside on the local computer, where as network data files reside on an OPeNDAP data server set up for serving CoastWatch data. Most users will use the *Local* tab in the *Open* window after downloading data from a CoastWatch web site or FTP site. Note that CDAT was originally designed to read CoastWatch HDF, CoastWatch IMGMAP, and NOAA 1b AVHRR data files, but also reads other formats as described in Appendix C. Whether using local or network data files, selecting the file name triggers the file information and variable list to change.

Generally data files contain more than one *variable*, for example sea surface temperature (SST) data files from the AVHRR sensor contain SST, cloud mask, visible and thermal channel data, and satellite viewing angles. Each *variable* holds a complete 2D geographic image, and CDAT can load any combination of variables from a data file. Once a data file is selected, you can preview the various variables be selecting the variable name in the list. To load a set of variables into CDAT, use a combination of Shift-click and Ctrl-click (or ⌘-click on Mac) and click OK. There will be a short delay as CDAT loads and analyzes the data in preparation for display. Once loaded you can change the variable displayed using the variable selector above the data view.

When a data file is first opened, all variables are displayed according to a set of default user preferences for the color palette, data enhancement range, and units based on the variable name. For example CDAT installs with preferences that indicate the variable *sst* should have the *HSL256* palette and an enhancement range of -60 to 45 Celsius. If a variable name is unknown, CDAT falls back on a grayscale palette and a range that matches the minimum and maximum data values found in the data. To change these preferences for any variable or to add new variable names to CDAT, see section 3.11 on user preferences.

## 3.3 Navigating in CDAT

CDAT displays 2D geographic data in the same way as a map, with north in the *up* direction. You can use the tool bar buttons in combination with the mouse to zoom in and out on the data view and move around within the view. Following is a list of all the actions you can perform while navigating in CDAT:

**Zoom in** – There are three ways to zoom in: (i) click the *Zoom* button to enter zoom mode and drag on the view to draw a rectangle to magnify, (ii) click the *Magnify* button to magnify the view ×2, or (iii) click the *Actual* button to make data pixels the same size as screen pixels.

**Zoom out** – To zoom out, click the *Shrink* button to shrink the view ×2.

**Move around** – There are two ways to move around within the view: (i) click the *Pan* button to enter pan mode and drag on the view to move it, or (ii) click the *Recenter* button to enter recentering mode and click the view to recenter on the mouse cursor.

**Reset** – There are two ways to reset the view, depending on the desired effect: (i) click the *Reset* button to completely reset the view so that all data is displayed, or (ii) click the *Fit* button to fit as much data as possible into the view area so that the view is completely filled (some edges of the data may be cropped off).

## 3.4 Changing data image colors

The CoastWatch Data Analysis Tool creates a color image from 2D geographic data by converting data values to colors using a color palette, enhancement range, and enhancement function. The control tabs hold two sets of controls that are used to change the way data values are converted to colors: the *Color Enhancement* tab and the *Color Palette* tab (see Figure 3.3). Figure 3.4 shows the two step process: (i) normalization of data values using an enhancement function, and (ii) conversion of

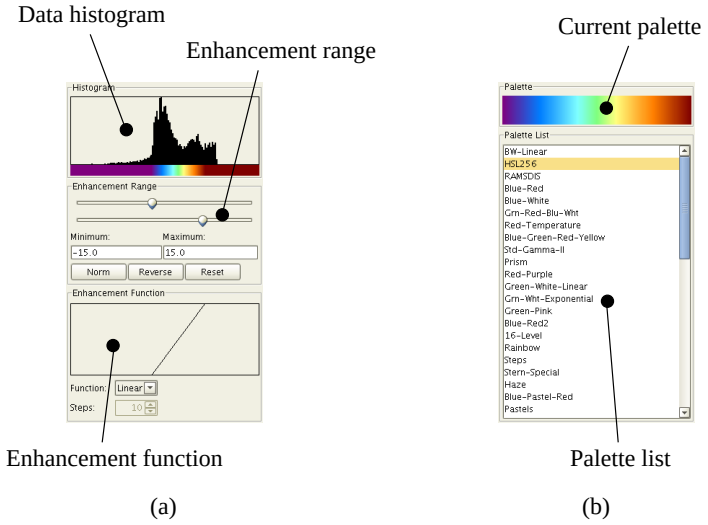



Figure 3.3: Color conversion tabs. (a) Controls for the enhancement function and range. (b) Controls for palette selection.

normalized values to colors. Typically a linear enhancement function is used so that the minimum and maximum range values map to 0 and 1 respectively, and all data values in the range are scaled linearly between 0 and 1. In contrast, a log function scales data values by powers of ten, for example if the range is [0.01..100], 0.1 scales to 0.25, 1 scales to 0.5, and 10 scales to 0.75.

The *Color Enhancement* tab has a number of controls to change the enhancement range and function. Use the sliders to change the range visually, or enter numbers into the minimum/maximum text fields and press Enter. The data histogram is a visual guide that shows where most of the data values lie – move the sliders to above and below the major histogram peaks to see the data with the best possible color contrast. To simplify setting the range, the *Normalize* button changes the range to bracket the data mean with a 1.5 standard deviation unit window, the *Reverse* button swaps the minimum and maximum range values, and the *Reset* button sets the range back to its full extents. The enhancement function can be *Linear* or *Log10* for log base 10 as described above, or *Step* which is a linear enhancement that effectively turns a normal continuously varying color palette into a palette with a discrete number of color steps.

The *Color Palette* tab shows the current color palette and list of available palettes. CDAT comes installed with a number of palettes but users can also add their own palettes in an XML text format as described in section 3.11.

## 3.5 Displaying coastlines, grids, and more

The CoastWatch Data Analysis Tool uses graphics *overlays* to show reference lines like latitude and longitude, coastlines, political borders, bathymetry, and topography, as well as mask data such as cloud masks. Overlays are arranged in *layers* like overhead projector slides – most of each layer is transparent

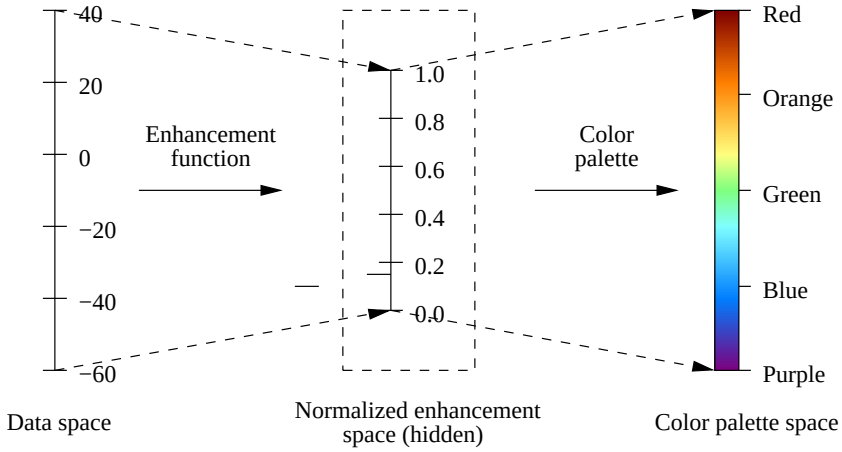



Figure 3.4: Color enhancement process. Two steps are performed, first the enhancement function is applied, and then the color palette.

except where the graphics occur and graphics from an upper layer are drawn on top of graphics from a lower layer as shown in Figure 3.5. Overlays can be added and removed, turned on and off, their layering order rearranged, and their properties modified such as color, font style, and line style. The *Overlay Layers* tab holds the overlay controls as shown in Figure 3.6.

### 3.5.1 Types of overlays

Several different types of overlays can be added to the data view. In general, any overlay can have a custom color and transparency, and line overlays can have custom line style, font, and drop shadow settings.

*Grid* – Grid lines of two different types:

- *Lat/Lon* – Latitude and longitude lines. The default is to render labeled lines at regular increments based on the zoom factor, but you can customize the line increment value and labels.
- *Data reference* – Row and column lines that follow the image data. The default is to render labeled lines at regular increments based on the zoom factor, but you can set the line placement and customize the labeling.

*Coast* – Land/water boundaries including oceans, lakes, islands in lakes, and ponds in islands derived from the Global Self-consistent Hierarchical High-resolution Shorelines (GSHHS) data set: `http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html`. The resolution of the lines drawn depends on the zoom factor of the data view and ranges from 25 km (crude resolution) to 0.2 km (high resolution). Land polygons can be drawn by specifying a fill color.

*Political* – International and state border lines derived from CIA WDB-II data. As with coastline data, the resolution of the lines changes with the data view zoom. Only international borders are

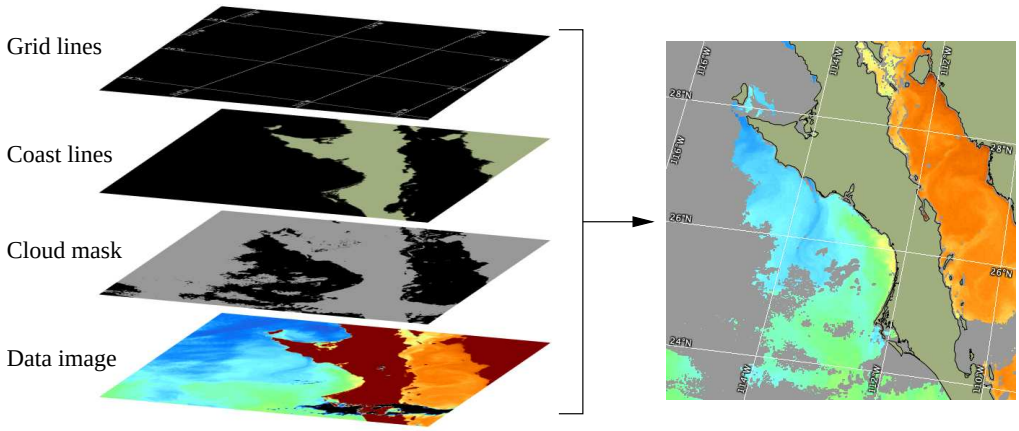



Figure 3.5: Overlay graphics drawing order.

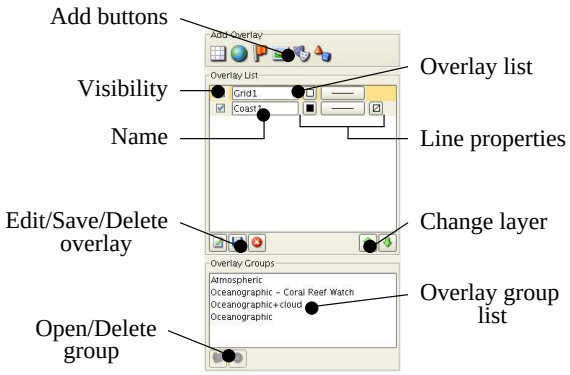



Figure 3.6: *Overlay Layers* tab

shown by default – you can add state borders manually.

*Topography* – Topographic and bathymetric lines contoured in real-time from ETOPO5 elevation data: http://www.ngdc.noaa.gov/mgg/global/etopo5.html. Only the 200 m and 2000 m bathymetric contours are shown by default. The topography levels can be modified to include any set of topographic or bathymetric contours.

*Mask* – One of three different types of masks:

- *Bitmask* – A single-color mask that uses a bitwise AND operation. A bitmask uses data values from a variable and performs a bitwise AND with each data value and an integer mask value to determine which pixels in the data view should be masked. If the results of the AND operation are non-zero, the pixel if masked otherwise is is left unmasked. Suppose that an integer data variable named "cloud" contains a value of 0 when no clouds are present, or a value of 1 when clouds are detected at a pixel. Then a bitmask with an integer mask value of 1 will cover all cloud pixels with the mask color. More complex masking can also be achieved – for example, suppose a variable named "graphics" has the fourth bit set when land is present at the pixel. Then a bitmask with an integer mask value of 8 will select out all graphics pixels with the fourth bit set in order to mask only land pixels.
- *Multilayer* – A multiple-color mask that combines a set of single-color bitmasks. A multilayer mask uses data values from a variable and colors each bit set to 1 in the data value with a different color. The idea is that if none or only a few of the bits in each data value are set, the mask will let the data show through in most locations and mask it with a bit-identifying color in others. This is useful when working with data analysis output such as cloud masking where each bit in an integer data value represents the output from a different cloud mask test. A multilayer mask can handle up to 32 different colors, one color for each bit in a 32-bit integer data value.
- *Expression mask* – A single-color mask that uses a boolean expression. An expression mask evaluates a boolean expression and masks any pixels for which the expression is true. Expression masks are slower to compute than bitmasks or multilayer masks, but are much more flexible because almost any mathematical combination of data variable values can be used. For example, an expression mask with the mask expression of "sst $<$ 5" will mask out all SST temperature data values less than 5 degrees. Any mathematical operator or constant supported by the cwmath tool can be used in the expression, as long as the variables referenced in the expression were imported when the data file was loaded.

*Shape* – Shape data lines stored in ESRI shapefile format. Shape overlays are limited in a number of ways: (i) only line and polygon shape data is rendered (no point data), (ii) shape overlays cannot be saved as part of an overlay group, and (iii) rendering may be slow for large and complex shapefiles.

### 3.5.2 The *Overlay List*

Overlays are added by clicking one of the buttons from the *Add Overlay* area of the *Overlay Layers* tab. When an overlay is first added to the data view, it's given a default set of properties (line style, line color, fill color, etc.) and appears in the *Overlay List* area. You can change any of the basic overlay properties by just clicking the property in the list, or change some of the more complex and overlay-specific properties by selecting the overlay and clicking the *Edit Properties* button (double-clicking the overlay also brings up the full property editor).

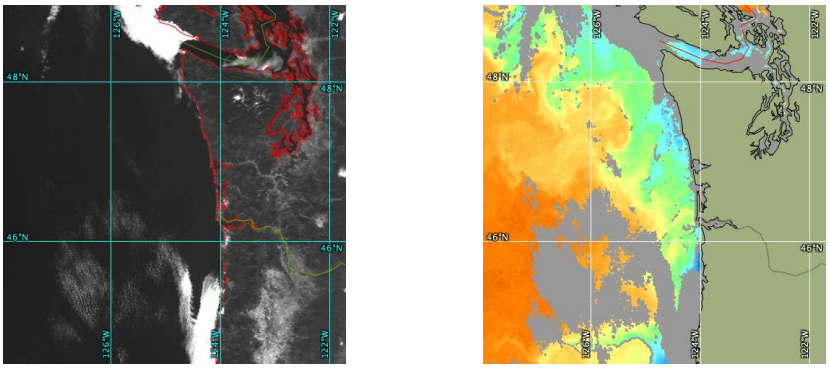



Figure 3.7: Examples of default overlay groups. The grayscale image shows the *Atmospheric* overlay group, while the color image shows *Oceanographic - Cloud Analysis*.

Since overlays are layered like overhead projector slides, their order can be changed using the *Move Up* and *Move Down* buttons. They can be set temporarily invisible with the *Visibility* check box, or deleted altogether using *Delete*.

### 3.5.3 Overlay groups

The *Overlay Groups* area of the tab lets you save and restore a set of overlays that you frequently use. Overlay groups are useful for when you've created a complex set of overlays, arranged them into the correct order, changed their properties, and want to use them again for another data file. A default set of overlay groups are provided when CDAT is installed (see Figure 3.7):

*Atmospheric* – Latitude/longitude grid lines, coast, and state/international borders for use on atmospheric data with a grayscale palette.

*Oceanographic* – Latitude/longitude grid lines, coast with filled land polygons, state and international borders for use on oceanographic data with a color palette.

*Oceanographic - Cloud Analysis* – The same overlays as Oceanographic, with extra cloud analysis overlays for NOAA NESDIS SST product users.

*Oceanographic - Coral Reef Watch* – Special overlays customized for use with Coral Reef Watch data (see the Coral Reef Watch page at `http://coralreefwatch.noaa.gov` for data and other details).

To use one of the default groups, select it in the list and click the *Open Group* button. The overlays are loaded into the overlay list on top of any existing overlays. To create a new overlay group, select a set of overlays from the *Overlay List* using Shift-click and Ctrl-click (⌘-click on Mac), then click the *Save Group* button. You can create a new overlay group by typing in a new name, or replace an existing overlay group. To remove an unwanted overlay group, select it and click *Delete Group*.

Another useful feature of overlay groups is that once created, they can be used for command line data rendering by specifying the **--group** option in the cwrender tool. Overlay groups are saved in a special directory on a per-user basis along with other user preferences as described in section 3.11.

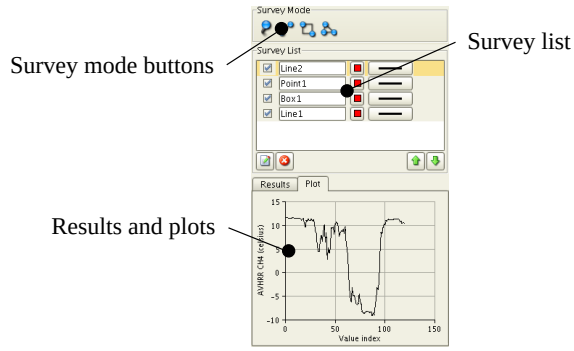



Figure 3.8: *Data Surveys* tab

## 3.6 Measuring distances and data statistics

CDAT can be used perform several different types of surveys of the current variable in the data view. The *Data Surveys* tab (Figure 3.8) allows you to manage a list of surveys and create new ones by selecting areas of the data view. Each data survey performed results in a set of data statistics, survey dimensions such as endpoints and distances, and a line or histogram plot.

### 3.6.1 Types of surveys

To perform a survey, select one of the *Survey Mode* buttons and click on the data view as follows:

*Point* (single click)
A single point survey with only the point position and data value reported but no statistics or plot. A point survey is a good way to mark a certain position and easily be able to recall its data value, such as for an ocean buoy. Point surveys are marked with a small cross.

*Line* (click/drag)
A straight line survey with the line endpoint positions, distance in kilometers, statistics, and an X-Y plot of the data values along the line. A line survey simulates an airplane or ship track of the data values, and is useful for gradient and front analysis.

*Box* (click/drag)
A rectangular box survey, with the box corner point positions, statistics, and a histogram plot of the data within the box. A box survey is useful for a clustering analysis to show groups of similar data values in an area as peaks in the histogram.

*Polygon* (click corners / double-click last corner)
A polygon survey with statistics and a histogram plot of the data within the polygon. Polygon surveys are similar to box surveys, but can help when the area has an irregular shape.

### 3.6.2 The *Survey List* and results

When you perform a data survey, a new entry is added to the *Survey List* area that shows the survey name and line properties. By default surveys are marked by thick red lines but the line color and style can easily be changed to more easily see the difference between similar surveys. Surveys can be temporarily hidden and shown again by clicking the *Visibility* check box, or deleted using *Delete*. The *Survey List* area is very similar in usage to the *Overlay List* area in the *Overlay Layers* tab (see subsection 3.5.2).

Selecting an entry in the survey list changes the *Results* and *Plot* tabs to display the results of the survey. For line surveys all data values along the line are sampled and the statistics reported. For box and polygon surveys, CDAT attempts to speed up statistics computations by only sampling 1% of the data values although this may not always be possible for smaller areas. The statistics reported are as follows:

*Sample* – For box and polygon surveys only, the number of data values sampled as a percentage of the total number of data values in the survey area.

*Count* – The total number of data values sampled.

*Valid* – The total number of data values encountered that were not marked as missing. Missing data values are skipped by the statistics computations. In many cases data values are marked as missing prior to being written to the data file for data quality reasons.

*Min* – The minimum valid data value sampled.

*Max* – The maximum valid data value sampled.

*Mean* – The mean of all valid data values sampled.

*Stdev* – The standard deviation from the mean of all valid data values sampled.

Line survey plots show the data value as a function of the pixel distance along the line. Box and polygon survey plots show a normalized histogram bin count as a function of the data value.

## 3.7 Drawing lines, shapes, and text

The CoastWatch Data Analysis Tool can be used to draw lines, boxes, circles, curves, and text on the data view. When the data view is exported to an image file, the annotations are drawn as well; annotations are an easy way to create example images for presentations that highlight features of interest in the data. The *Annotations* tab (Figure 3.9) allows you to pick the annotation mode and manage a list of annotations on the data view.

### 3.7.1 Types of annotations

To add an annotation to the data view, click one of the *Annotation Tool* buttons and add it to the data view as follows:

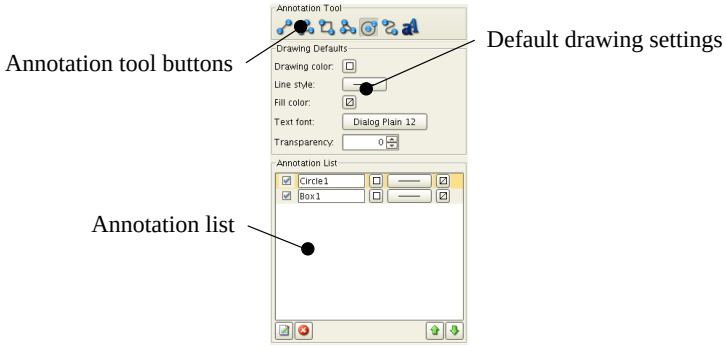



Figure 3.9: *Annotations* tab

*Line* (click/drag)
Draws a line in the current color and style.

*Polyline* (click endpoints / double-click last point)
Draws a series of connected line segments in the current color and style.

*Box* (click/drag)
Draws a rectangular box in the current color and style, and fills with the fill color.

*Polygon* (click corners / double-click last corner)
Draws an irregular polygon in the current color and style, and fills with the fill color.

*Circle* (click/drag)
Draws a circle from the center to radius point in the current color and style, and fills with the fill color.

*Curve* (click control points / double-click last point)
Uses a set of polyline control points to draw a Bezier curve in the current color and style.

*Text* (click and enter text)
Places the specified text in the current font and color. The text font size is relative to the screen, and so remains constant if the data view zoom factor is modified. The text anchor point moves with the view.

### 3.7.2 The *Annotation List*

When creating an annotation, a new entry is added to the *Annotation List* according to the current *Drawing Defaults* settings. Similar to overlays and surveys, annotation layers can be hidden/shown, deleted, rearranged, and edited (see subsection 3.5.2).

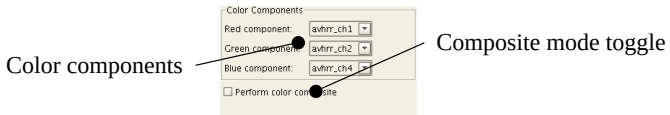



Figure 3.10: *Color Composite* tab

## 3.8 Using composite image mode

CDAT normally displays 2D geographic data as a color image by mapping the data values of a variable to colors using a color palette. Rather than using a palette, an alternative way of deriving the color values at each pixel is to treat data values from different variables as components of a color. CDAT uses the RGB color model (see `http://en.wikipedia.org/wiki/RGB`) to combine data from three different variables to form the pixel colors. The process of converting data values to color components is similar to that shown in Figure 3.4 but rather than converting the normalized value to a palette color in the second step, the normalized value is used as the intensity of red, green, or blue in the pixel color.

The *Color Composite* tab (Figure 3.10) contains controls for choosing the variables to use as components, and for turning on/off color composite mode. To create a color composite:

1. Choose three variables from those imported when the data file was opened. Set the variables as the *Red*, *Green*, and *Blue* components in the *Color Composite* tab. The best choice of variables depends on the data – satellite data channels of different wavelengths work well as long as the three channels are reasonably independent.

2. Use the variable selector (see Figure 3.1) to view each variable and set up the enhancement function in the *Color Enhancement* tab. The easiest way to set up the enhancement function is to use a grayscale palette to visually judge the scene contrast and click *Normalize* which centers the enhancement function around the mean. Then use the range sliders to fine tune the enhancement.

3. Click the *Perform color composite* check box in the *Color Composite* tab to turn composite mode on. While in composite mode you can continue to select variables and change their enhancement functions to obtain the best mixture of color components.

Figure 3.11 shows examples of RGB color composite images created using NOAA AVHRR data and Chinese FY-1D MVISR data.

## 3.9 Correcting geographic location problems

The CoastWatch Data Analysis Tool was written in part for NOAA/NESDIS researchers to use in evaluating the quality of satellite data products. One of the quality measures is computed satellite angle data (*navigation* data) including latitude, longitude, solar zenith, satellite zenith, and relative azimuth angles. Of particular interest are latitude and longitude because uncertainty in those angles determines the positional accuracy of the data. For example if the latitude and longitude of a pixel have an uncertainty of 0.01° then the pixel has a positional accuracy of ∼1 km. Small uncertainties such as these can exist when a satellite's true orientation and position are not known exactly. In this case the

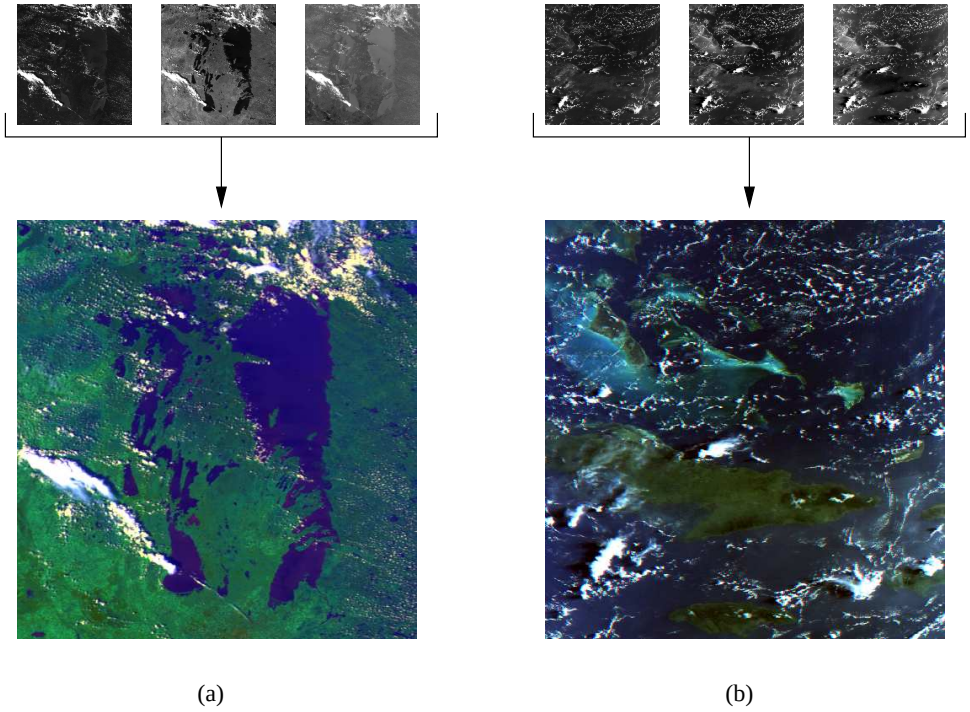



Figure 3.11: RGB composite examples. (a) NOAA-18 AVHRR false color composite using channels 1/2/4. (b) FY-1D MVISR true color composite using channels 1/9/7.

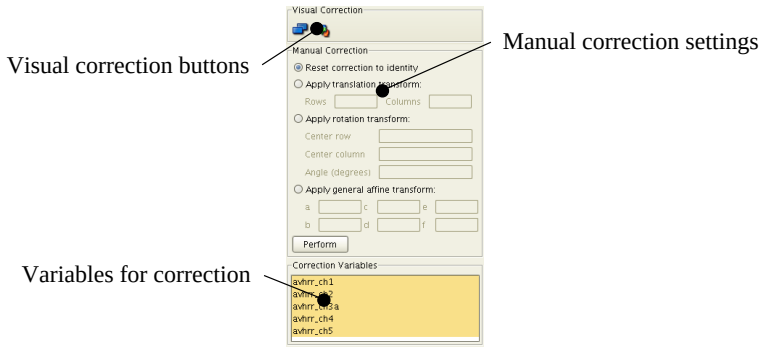



Figure 3.12: *Navigation Correction* tab

image data in CDAT may not line up correctly with coastline overlays. The image may appear to be shifted, rotated, or sheared in comparison to the coastlines. Navigation errors are not as prevalent if the data file has been produced recently, but are not uncommon in older data files or in experimental satellite data products.

There are two tools in CDAT designed for working with navigation data errors: the *Navigation Correction* tab and the *Navigation Analysis* panel. Navigation correction writes a set of correction parameters to a data file so that subsequent data access using the CoastWatch Utilities takes into account the correction. Navigation analysis allows you to examine the navigation accuracy of various points in the data file and save point position, variable data, and navigation offsets for later analysis.

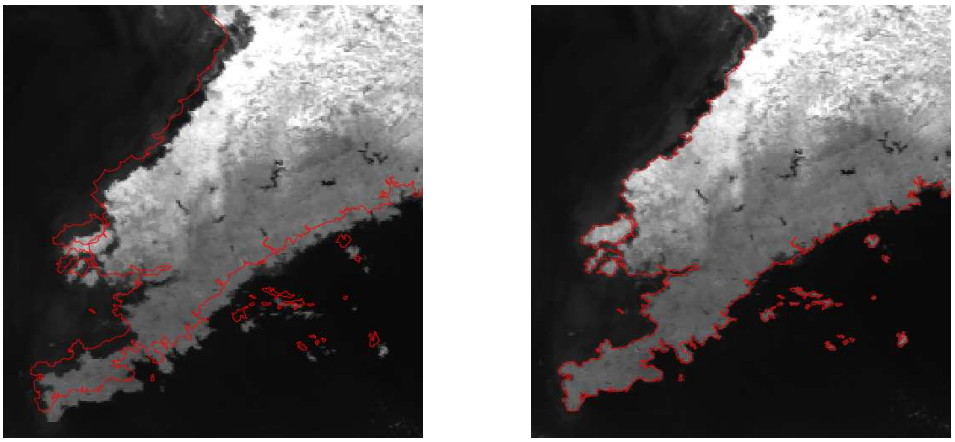
### 3.9.1 Navigation correction

The *Navigation Correction* tab (see Figure 3.12) is used to write correction parameters to a data file so that the data view image lines up correctly with actual geographic features such as coastlines. Only data files in CoastWatch IMGMAP (.cwf) and CoastWatch HDF (.hdf) format can be corrected. Also, only satellite sensor and sensor-derived variables in a data file should be corrected – not latitude/longitude data, graphics, or viewing angle data. You must select which specific variables to correct using the *Correction Variables* list (default is all variables imported when the file was opened). Navigation corrections will only be applied to the selected variables in the list. Examples of data variables that may require correction include AVHRR channel data, SST and cloud. Figure 3.13 shows an example of an uncorrected and corrected albedo image.

You can perform a navigation correction in one of two ways:

**Visually** – Click one of the *Visual Correction* buttons, either *Translation* or *Rotation*. *Translation* mode corrects the navigation by shifting the entire image in the row and column directions – click and drag anywhere on the data view to shift the origin. *Rotation* mode corrects the navigation by rotating around the center of the data view – click on an edge of the view and drag to rotate.

**Manually** – Select the type of transformation, fill in the parameters, and click *Perform* to correct the navigation. The *translation transform* is similar to the visual translation mode – it shifts the data



(a) (b)

Figure 3.13: Navigation correction example. (a) Visible channel albedo image before navigation correction. (b) Image after translation correction.

origin by some number of rows and columns. The *rotation transform* is more general than the visual rotation mode because the rotation center point row and column can be specified rather than having to use the data view center. The *general affine transform* is the most general of all (it has no visual mode counterpart) because it can be used to correct for translation, rotation, skew, and scaling problems. The affine transform is applied to the row and column coordinates of each data view pixel to translate the "desired" row and column coordinates $(R', C')$ to the "actual" coordinates $(R, C)$ in the data file:

$$\begin{bmatrix} R' \\ C' \\ 1 \end{bmatrix} = \begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} R \\ C \\ 1 \end{bmatrix}.$$

To completely remove the navigation correction on a variable, click *Reset correction to identity* and then *Perform*. Note that CoastWatch IMGMAP (.cwf) files can only store integer-valued translation corrections, not rotation or general affine corrections. CoastWatch HDF (.hdf) files have no such limitations. More information about how navigation corrections are stored in CoastWatch HDF data files can be found in Appendix B. Command line tools for performing navigation correction from a script rather than interactively are described in section 2.4, and in more detail in the cwnavigate and cwautonav manual pages.

### 3.9.2 Navigation analysis

The *Navigation Analysis* panel shown in Figure 3.14 is accessed from the *Tools* menu and enables researchers to gather statistics on navigation errors for a series of points in a data file. You can compare the known coastline geography from GSHHS coastline data to the data view image coastline to check

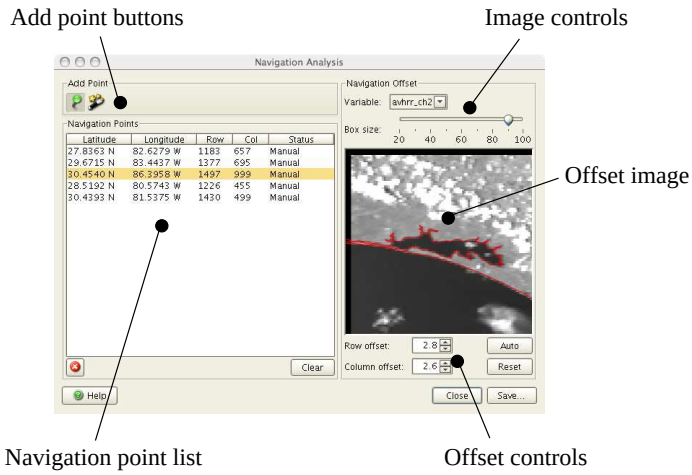



Figure 3.14: *Navigation Analysis* panel

for navigation errors. The panel shows a list of navigation points and allows you to add new points to the list, adjust the navigation offset for each point, and save the points to a data file.

There are two modes for adding new navigation points to the list, both of which work by clicking on the data view in the main CDAT window to select the point location. *Manual* mode adds a point to the list and lets the user adjust the navigation offset manually. *Automatic* mode adds a point to the list and additionally runs the image data in the box surrounding the point through an automatic navigation algorithm that attempts to: (i) classify the image data into land and water based on histogram splitting, and (ii) compute an optimal offset for the navigation box by finding the offset with maximum correlation between classified image data and pre-computed land mask data. The automatic navigation algorithm can sometimes fail to find a significant correlation at any offset in which case the *Status* column indicates *Auto failed* otherwise it indicates *Auto OK*.

Once a series of points are added to the list, the navigation offset of each point can be adjusted. Even if the automatic navigation algorithm was successful, it may be necessary to manually adjust the offsets – the algorithm is only capable of returning integer-valued offsets and some cases may require fractional offsets for the best coastline fit. To adjust the offset of a point, select the point in the list and click/drag on the offset image or use the row and column offset adjustment controls. You can change the variable shown in the offset image and the navigation box size to better see the contrast between land and water. The *Variable* and *Box size* controls also determine what data is used for automatic navigation when adding new points. Click *Auto* to re-try the automatic navigation algorithm after changing the variable or box size, or *Reset* to set the offset back to zero. Navigation points are removed from the list by clicking *Delete*, or the point list cleared entirely by clicking *Clear*.

After adding navigation points to the list and adjusting their offsets if needed, the point locations (latitude, longitude, row, column), navigation offset (row and column), variable data values, and other metadata can be saved to a text file. There are two output formats: XML (structured markup language) and CSV (comma separated value). The XML format writes out each point using XML tags and attributes and is useful for web browser display and XML readers. The CSV format writes each point as a line of comma separated values, ready for input to a spreadsheet or plotting program. Examples

of each format can be found in Appendix D.

To save navigation points, click *Save...* and choose:

- Points to save (default is all points)
- Variable data values (default is no variable data)
- Output format (default is XML)
- File name and location

Regardless of the output format, the following data is saved for each point:

**Earth location** – The latitude (-90..90) and longitude (-180..180) of the point in degrees.

**Data location** – The row and column of the point in the data file, referenced from (0,0).

**North direction** – The direction of north for the point as a unit vector with row and column components. This is useful for recovering satellite projection information at the point.

**Navigation offset** – The navigation offset of the point in the row and column directions.

**Comment** – The value of the status column indicating *Manual*, *Auto OK*, or *Auto failed*.

**Variable values** – A data value for each variable selected in the save dialog.

## 3.10 Exporting images and data

CDAT can export either the main data view (a color image with color scale and information legends) or the data file values and metadata (character, integer, floating point values). How the exported data is to be used determines the format – *color image formats* such as PNG and JPEG are commonly used for creating graphics for the web, printable materials, or presentation slides for meetings while *numerical data formats* such as HDF and ArcGIS are used for getting data into other analysis or GIS software packages.

To export the current data view to a color image, click the *Export* button and select one of the image formats: PNG (the default), GIF, JPEG, GeoTIFF, or PDF. Each format has certain characteristics:

**PNG** – A non-lossy compressed image format supported by most web browsers and image manipulation software. PNG has similar data compression characteristics to GIF and additionally supports 24-bit color images.

**GIF** – A non-lossy compressed format also supported by most web browsers and image manipulation software. The GIF files produced use LZW compression. Images stored in GIF format are run through a color quantization algorithm to reduce the color map to 256 colors or less. Although file sizes are generally smaller than PNG, image quality may be compromised by the reduced color map.

**JPEG** – A lossy compressed format that should be used with caution for images with sharp color lines such as those found in text and annotation graphics. The JPEG format generally achieves higher compression than PNG or GIF resulting in smaller image file sizes.

**GeoTIFF** – A flexible image format with support for earth location metadata. Many popular GIS packages handle GeoTIFF images and allow the user to combine a GeoTIFF base map image with other sources of raster and vector data. The GeoTIFF images generated are non-lossy uncompressed image data (unless a compression is specified in the options), and can be much larger than the corresponding PNG, GIF, or JPEG. In general the GeoTIFFs generated are 24-bit colour images, but when no overlays are used or the image color option is set, a special 8-bit paletted image file is generated and comments describing the data value scaling equation are inserting into the image description tags.

**PDF** – A standard document format for high quality publishing developed by Adobe Systems and used for output to a printer via such tools as the Adobe Acrobat Reader. In general, PDF files are slightly larger than the equivalent PNG but retain highly accurate vector graphics components such as lines and fonts.

To export data from the current data file to a numerical data format, click the *Export* button and select one of the data formats: CoastWatch HDF, binary raster, text file, or ArcGIS binary grid. Numerical data formats can hold data from one or more of the data file variables (with the exception of ArcGIS grids which only hold one variable), and either the full data file geographic extents or only the subset of the data shown in the data view. Each data format has certain characteristics:

**CoastWatch HDF** – Hierarchical Data Format (HDF) version 4 with CoastWatch metadata. HDF is a scientific data format used by CoastWatch and others to distribute satellite data. Information and access software may be found at `http://hdf.ncsa.uiuc.edu`. A description of the current CoastWatch HDF metadata standards is given in Appendix B.

**Binary raster** – A simple stream of binary data values – either 8-bit unsigned bytes, 16-bit signed integers, or 32-bit IEEE floating point values. Data values may optionally be scaled to integers using the equation integer = value/factor + offset. Each data variable may be prepended with a 72-bit dimension header: 8-bit dimension count (always 2) with 32-bit row count, 32-bit column count.

**Text file** – An ASCII text file with latitude, longitude, and data value printed – one data value per line. Each data variable may be prepended with a 1-line dimension header: dimension count (always 2), row count, column count.

**ArcGIS binary grid** – A stream of 32-bit IEEE floating point values, ready for input to ESRI's ArcGIS as a binary grid file. A header file may also be created to specify the earth location and other parameters.

## 3.11 Setting color, enhancement, and units preferences

When a data file is opened and variables are selected, CDAT shows the initial data view for each variable using a color palette, enhancement range, and units determined from the user preferences (see section 3.2 on loading data). Rather than having to customize all these items each time a data file is opened, you can set up preferences for each variable name. CDAT comes with a set of built-in preferences for a number of common variable names. To edit these preferences or add new variables, click *Preferences* from the *Tools* menu, then click *Enhancement* for the enhancement preferences (see Figure 3.15). To modify the settings for a certain variable, click the variable name in the *Variable*

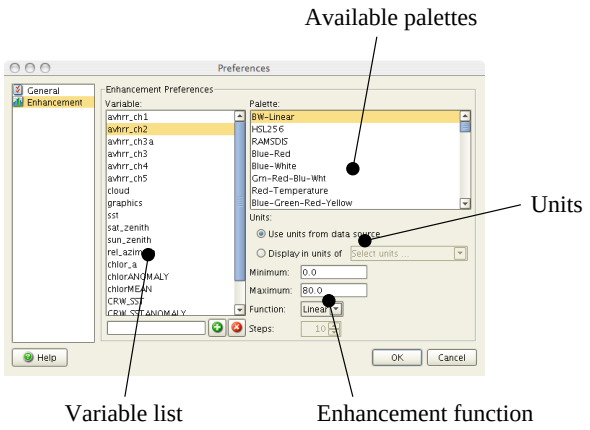



Figure 3.15: *Enhancement* section in the *Preferences* panel

list or type in a new variable name and click *Add* to add it to the list (some default preferences will be assigned to it that need to be modified). Once a variable is selected, you can change various settings:

**Palette** – Choose one of the palettes from the list. New palettes can be added to the list using an XML palette format, see subsection 3.11.1.

**Units** – Keep the same units as in the data file or choose different units to display the variable data values. CDAT normally uses the units that the data file was originally written with. For example if a sea surface temperature data variable was written with Celsius units, then CDAT uses Celsius for all numerical value readings: the data view track bar, the *Color Enhancement* tab sliders and text fields, the *Data Surveys* tab statistics and plots, and any other location that a numerical value is displayed. But if the units are set to "Display in units of fahrenheit", then all numerical readings are shown in Fahrenheit instead. If you select different data units, remember to also modify the *Minimum* and *Maximum* text fields to match those units. A number of common units are provided in the drop-down units box. If your preferred units are not shown, you can also type in the units. Most common units are supported, and base units can be combined with spaces, slashes, and exponentiation. For example, wind or ocean current speed in kilometers per hour could be written a number of ways: "km/h", "km hr^ -1", "kilometers / hour", or "kilometers per hour". For other possible unit names, see the UDUNITS package from UCAR: `http://www.unidata.ucar.edu/software/udunits/udunits-1/index.html` and `http://www.unidata.ucar.edu/software/udunits/udunits-1/udunits.txt`.

**Enhancement function** – Select the color scale minimum and maximum values and the type of function: *Linear*, *Step*, or *Log10*. See section 3.4 for a description of the *Color Enhancement* tab where these preferences are used.

After modifying any of the preferences, click *OK* the save them or *Cancel* to discard all the changes. Note that enhancement preferences only take effect the next time a data file is opened and variables loaded.

### 3.11.1 Resources directory

CDAT stores preferences for each user on the system individually. Depending on the operating system, preferences are stored in a resources directory under your home directory:

**Windows** – `C:\Documents and Settings\[User Name]\Application Data\CoastWatch`

**Mac OS X** – `~/Library/Application Support/CoastWatch`

**Unix** – `~/.coastwatch`

Preferences are normally modified using the CDAT *Preferences* panel but can also be modified by editing the XML files in the resources directory. On some operating systems it may be necessary to show hidden directories to reveal the resources directory. **Only attempt to modify the resources manually if you are familiar with editing XML files and have made a backup of any files first.** In the case of some resource file problem indicated by an error when launching CDAT, you can delete the resources directory, restart CDAT, and the resources directory will be recreated and populated with the default preferences.

The resources directory contains various files and subdirectories as follows:

`prefs.xml` – Main preferences file with general and enhancement preferences.

`opendap_servers.xml` – List of current OPeNDAP servers, accessed and edited under the *Network* tab after clicking *Open*.

`overlays/` – Directory for storing overlay groups from the *Overlay Layers* tab. Each overlay group is stored as a separate file with a `.jso` extension for "Java Serialized Object", a binary format used for saving/restoring a Java object's state. Overlay groups can be copied between computers, even between different operating systems, although some incompatibilities in overlays may exist between different CoastWatch Utilities versions.

`palettes/` – Directory for storing extra user-supplied palettes. Any files with a `.xml` extension will be considered to be palette files and read into CDAT for use in the *Color Palette* tab and *Preferences* panel. Palette files must have the format described in section D.3 for color palettes.

Some users have asked "How can I modify an existing color palette and use that in CDAT?" To do this, you can extract it from the `lib/cwf.jar` file in the CoastWatch Utilities installation directory using the Java jar command in a command line session, for example:

```
jar xf <path to CW utils>/lib/cwf.jar noaa/coastwatch/render/HSL256.xml
```

which will extract the HSL256 palette XML file to a `noaa` subdirectory (do this command in some scratch working directory, not in the `lib/` directory). Then modify the palette file RGB color triplets, rename the file, change the `<palette name="...">` inside the file to match, and copy the new XML file into the `palettes/` directory. After restarting CDAT the new palette should appear in the *Color Palette* tab.

## 3.12 Connections with command line tools

The CoastWatch Data Analysis Tool can be used on conjunction with the CoastWatch Utilities command line tools (described in chapter 2 and Appendix A) in a number of ways:

**Visualization** – CDAT can be used to set up a plot's characteristics for use with the cwrender tool. You can manually transfer settings from CDAT to the rendering command line:

- Variable being displayed → **--enhance**
- Enhancement min/max text fields and function → **--range**, **--function**
- Selected color palette → **--palette**
- Overlay layers → **--coast**, **--grid**, **--political**, **--bath**, **--group** and others
- Units preferences → **--units**
- Region shown in data view → **--magnify**
- Color composite variables → **--composite**

Note that custom palettes and overlay groups stored in the user's resource directory (subsection 3.11.1) can also be used by cwrender.

**Statistics** – To perform a similar box data survey from a script as was performed using the *Data Surveys* tab *Box* mode (section 3.6), you can either (i) hover the mouse cursor over the center of the box and note the latitude and longitude value to use in the **--region** option to the cwstats tool, or (ii) note the box corner row and column values from the survey results for the **--limit** option.

**Sampling** – To perform a similar point data survey from the command line as was performed using the *Data Surveys* tab *Point* mode, you can note the latitude and longitude values in the point survey results and use them for the **--sample** option in the cwsample tool. Multiple variables in a data file can be sampled at once using cwsample, rather than CDAT which only surveys the displayed variable.

**Navigation** – After using the *Navigation Analysis* panel (subsection 3.9.2) to determine the best navigation correction for the data file, you can apply/reset the navigation correction using the cwnavigate tool. If you save a number of navigation points that would likely be good for future navigation efforts, their latitude/longitude coordinates could be used as input to the cwautonav tool.

**Export** – The CDAT *Export* button (section 3.10) has almost the same functionality as the cwrender and cwexport tools combined. The *Format* box in the CDAT *Export* window has the same color image formats as the **--format** option in cwrender, and the same numerical data formats as **--format** in cwexport. CDAT export options map to the command line as follows:

- Color image options → **--nolegends**, **--tiffcomp**, **--worldfile**, **--noantialias**, **--imagecolors** in cwrender
- Numerical data options → **--header**, **--match**, **--missing**, **--scale**, **--range**, **--byteorder**, **--size**, **--nocoords**, **--reverse** in cwexport

**File information** – The file information shown clicking *Tools* — *File Information* in CDAT is the same as that reported by the cwinfo tool.

**Data formats** – The same data formats read by CDAT (including network data via OPeNDAP) can be read by most of the command line tools. See Appendix C for more details on data format compatibility between tools.

# Chapter 4

# Programmer's API

## 4.1 How to use the API

Developers may want to use some of the same code used by the CoastWatch Utilities to read and write data, render images, or perform some variation on the existing functionality. Since the CoastWatch Utilities are written almost entirely in Java (conforming to the Java 5 language spec), the Java Application Programming Interface (API) documentation is available in the standard Javadoc-generated HTML web page format, included with the CoastWatch Utilities distribution package as the compressed `doc/api.zip` file in the installation directory. Users of the graphical installers on Windows, Mac, and some Unix versions have to manually check off the "Source code and API docs" when the package is installed in order to get the API zip file (you also get the full source code `src.zip` file whose Java code files serve as examples of using the API). Unzipping the API file creates a new directory with an `index.html` file to use as the starting point for all API documentation. The Javadoc is fairly verbose and can be used as a reference for all Java classes in the software, along with this chapter which provides a high-level overview of the main classes.

In order to effectively develop your own Java code that uses the CoastWatch API and link it to the CoastWatch libraries, you should be familiar with using the Java compiler, JAR files, how to navigate through Javadoc pages, and possibly be familiar with automated code compiling tools such as Ant. There are a number of directories and files in the installation that are of use to developers:

`lib/` – Contains the main `cwf.jar` file of CoastWatch Utilities code, plus all JAR files required by the CoastWatch code. The major dependencies are as follows:

- Alloy Look and Feel (used for Unix GUI only):
  `alloy.jar`
- GeoTools (shapefile support):
  `geoapi-1.1.0alpha.jar`
  `gt2-main-nojai.jar`
  `gt2-shapefile.jar`
  `JTS-1.4.jar`
- GIF encoding:
  `neuquant.jar` (neural net color quantization)

`gifencoder.jar` (actual format encoder)
`kd.jar` (KD-tree color quantization)

- PDF encoding:
  `itext-1.2.jar`
- XML parsing:
  `jaxen-full.jar`
  `saxpath.jar`
- C-style print formatting:
  `hb16.zip`
- Command line argument parsing:
  `jargs.jar`
- Java Advanced Imaging CODEC (mainly for GeoTIFF encoding):
  `jai_codec.jar`
- Mathematical expression parsing:
  `jep-2.24.jar`
- Plotting symbols:
  `PlotPackage.jar`
- Java matrix manipulation:
  `Jama-1.0.1.jar`
- HDF native library stubs:
  `jhdf.jar`
- Unidata UDUNITS support:
  `udunits.jar`
- NetCDF Java support:
  `bzip2.jar`
  `commons-httpclient-2.0.1.jar`
  `commons-logging.jar`
  `dods-1.1.7.jar`
  `gnu-regexp-1.1.4.jar`
  `grib.jar`
  `jdom-b9.jar`
  `jpeg2000.jar`
  `netcdf-2.2.jar`
  `visad.jar`
- Terrenus HRPT interfaces for NOAA1b instrument data:
  `hrpt.jar`

`lib/aix,linux,macosx,solaris,win32/` – Native libraries for various operating systems. C language code has been compiled to native binary libraries and linked to Java via JNI in cases where no Java libraries existed. Native libraries include HDF 4 file I/O, CoastWatch IMGMAP (.cwf) file I/O, and GCTP map projection coordinate transformations.

To use the API, you *must* have the `cwf.jar` file in your Java class path to compile and run custom code, for example on Unix:

```
javac -classpath ~/cwf/lib/cwf.jar MyCode.java
java -classpath  .:~/cwf/lib/cwf.jar MyCode
```

Depending on what CoastWatch classes are used in the `MyCode.java` code, other JAR files as listed above may also need to be in the Java class path, and as well native library directories may need to be in the dynamic link path. For example using a Unix bash shell under Mac OS X, this code fragment sets up the environment for compiling and running with the CoastWatch Utilities:

```
cwfroot="/Applications/CoastWatch Utilities 3.2.2"
CLASSPATH="."
for fname in "$cwfroot"/lib/*.jar "$cwfroot"/lib/*.zip ; do
  CLASSPATH=${CLASSPATH}:"$fname"
done
export CLASSPATH
export DYLD_LIBRARY_PATH="$cwfroot"/lib/macosx
```

If you prefer to use a GUI development environment such as Eclipse or JBuilder, then the GUI will have settings to store the class and native library paths for the current project. CoastWatch Utilities development is currently performed using Ant for the build/test cycle and ej-technologies install4j product (see www.ej-technologies.com) for building multi-platform installation packages and launching the various Java programs.

The rest of this chapter is dedicated to describing the main packages available in the API as follows:

*noaa.coastwatch.io* – I/O classes for satellite and other geographic data formats.

*noaa.coastwatch.render* – Utility classes for transforming geographic data into images.

*noaa.coastwatch.gui* – Graphical classes for custom user interface components.

*noaa.coastwatch.util* – General utility classes for working with geographic data arrays and performing numerical operations.

*noaa.coastwatch.tools* – Main program classes for all GUI and command line tools.

## 4.2 Data I/O

The *noaa.coastwatch.io* package contains a number of classes for performing I/O with satellite and geographic data formats. The superclasses and static method classes for most of the functionality are as follows:

*EarthDataReader*
: Reads various formats of geographic data. The data reader classes read global information about the data file such as the date and time of the data, what sensor or model it came from, what organization gathered/processed the data, and how to transform data array coordinates into geographic locations on the earth. The reader classes also report back on a list of n-dimensional "variables" that hold numerical data. The *CWFReader*, *HDFReader*, *NOAA1bReader*, and *OpendapReader* are all examples of *EarthDataReader* classes.

*EarthDataWriter*
: Writes various formats of geographic data. Just as the data reader classes read global information and variables, the data writers construct from some global information and set of variables, and then write out the numerical data to a specific format. The *BinaryWriter*, *HDFWriter*, and *TextWriter* are all examples of *EarthDataWriter* classes.

*EarthImageWriter*
: Writes various color image formats of geographic data. Unlike the data writer classes, the *EarthImageWriter* (i) has no subclasses and (ii) only writes color pixel data to an output file rather than numerical data. Image formats include PNG, JPEG, GeoTIFF, GIF, and PDF. The *EarthImageWriter* makes use of *GeoTIFFWriter*, *GIFWriter*, and *WorldFileWriter* to perform parts of its job.

*CachedGrid*
: Reads 2D numerical data using a least-recently-used caching strategy. Data format specific subclasses of *CachedGrid* form the basis of most of the high-performance I/O operation in the CoastWatch Utilities. *CWFCachedGrid*, *HDFCachedGrid*, and *NOAA1bCachedGrid* are all subclasses. The *OpendapGrid* class is not part of the *CachedGrid* hierarchy but performs some similar operations for OPeNDAP data sources.

*EarthDataReaderFactory*
: Perhaps one of the most useful classes, the reader factory has one static method, *create()*, that takes a data file name, automatically identifies the file format, and returns an *EarthDataReader* object. The reader factory has a special property: it can be extended to read data formats that are not supported by the standard CoastWatch Utilities distribution. To add your own data format support to CDAT and the CoastWatch Utilities command line tools, simply subclass *EarthDataReader*, place the compiled code into a JAR file in the `lib/` directory, and add the name of your subclass to the `extensions/reader.properties` file. Most tools in the package use *EarthDataReaderFactory.create()* for data reading, so your custom data format will be easy to incorporate into most tool operations. In case of problems with automatic file identification, use the cwinfo tool with **-v** option to print verbose messages during the file identification process.

## 4.3 Data rendering

The *noaa.coastwatch.render* package is the heart of all rendering operations: converting 2D numerical geographic data arrays to a color image (palettes, enhancement functions), drawing line, symbol, and text overlays, and drawing legends (logos, icons, text, color scales) The main classes are as follows:

*EarthDataView*
: Renders 2D geographic data to a color image. The data view classes take numerical data and convert it to colors using various schemes: *ColorEnhancement* uses a color palette and enhancement function where as *ColorComposite* uses three enhancement functions, one each for the red, green and blue components of the output color.

*EarthDataOverlay*
: Renders line, mask, symbol, and text overlays for an *EarthDataView* object. There are more than a dozen concrete overlay classes for all different purposes: *MaskOverlay*, *TextOverlay*, *CoastOverlay*, *TopographyOverlay*, *LatLonOverlay*, and so on. Each overlay class draws graphics to the view by

implementing the *render()* method and in some cases uses only the data view properties and other cases uses supplementary data such as coastline segment data or topographic elevation data.

*Legend*
: Renders legends for plots with information such as color scaling, date and time of the data, geographic location and projection. The two classes of legends are *DataColorScale* and *EarthPlotInfo*, mainly to accompany the output from an *EarthDataView*.

*Feature*
: Stores the geometry of some geographic feature, along with a set of attributes attached to the feature. The concrete feature classes are *PointFeature*, *LineFeature*, and *PolygonFeature* to handle those major feature types.

*FeatureSource*
: Reads or creates a set of features from some geographic data source. There are many concrete feature sources for various data including *BinnedGSHHSReader* for reading GSHHS coastline polygon data, *ContourGenerator* for generating contour line features from numerical data, and inner classes of *ESRIShapefileReader* for extracting features from ESRI shapefile format files.

*PointFeatureSymbol*
: Draws symbol graphics, mainly for use with an *EarthDataView* in the context of a *PointFeatureOverlay*. The *ArrowSymbol* and *WindBarbSymbol* are examples of concrete symbol classes for drawing vector wind and current fields.

*EnhancementFunction*
: Specifies the functional form for mapping data values to a normalized range of [0..1] for use with a *Palette* in a *ColorEnhancement*. *LinearEnhancement*, *StepEnhancement*, and *LogEnhancement* are all types of functions. The *EnhancementFunctionFactory* is useful for creating enhancement functions from a text specification and range.

*Palette*
: Holds a set of colors for use in a *ColorEnhancement*. The *PaletteFactory* is useful for obtaining one of many predefined palettes, mostly derived from IDL but also some special-purpose CoastWatch palettes.

## 4.4 Graphical user interface components

The *noaa.coastwatch.gui* package is the largest and most complex package in the CoastWatch Utilities, and provides all the GUI components for the CoastWatch Data Analysis Tool, CoastWatch Master Tool (cwmaster), and CoastWatch Status Tool (cwstatus) using Java Swing for platform-dependent look and feel. There are far too many classes to describe here, but the following are some of the more general and re-usable classes:

*HTMLPanel*
: Displays an HTML web page and allows for hyperlinks and page navigation (forward, back, top, etc). The panel is the basis of the *Help and Support* menus in the graphical tools.

*EarthDataViewController*
: Displays the contents of a *noaa.coastwatch.io.EarthDataReader* object in a panel and provides

various other control panels for users to control the data view. The controller is the basis for each tab in CDAT.

*MapProjectionChooser*
: Lets you choose the specifications of a GCTP-style map projection. This panel is used in the CoastWatch Master Tool.

*EarthDataChooser*
: A panel and dialog for choosing *noaa.coastwatch.io.EarthDataReader* objects using either network or local file access and showing a variable preview image.

*LightTable*
: A general purpose drawing class that displays rubber band style graphics on top of another component for use in interactive drawing input. This class is responsible for the rubber banding in CDAT during a zoom operation, or while drawing annotations and surveys.

*PaletteChooser*
: Presents a list of *noaa.coastwatch.render.Palette* objects and lets you select one of them, showing a preview of the selected palette.

*FullScreenWindow*
: Displays a component in a full screen window with a toolbar. This class is used in CDAT for displaying the data view in full screen mode.

## 4.5 General utility classes

The *noaa.coastwatch.util* package provides a number of general utility classes for working with geographic data:

*EarthLocation*
: Holds a latitude and longitude value and allows for intelligently incrementing the values, formatting them to standard string representations, shifting datums, and computing the physical distance to other locations.

*DataLocation*
: Holds an n-dimensional index for use in addressing a value in an *DataVariable*.

*EarthTransform*
: Converts *DataLocation* objects to and from *EarthLocation* objects in order to tie data to a physical geographic space. *MapProjection*, *SwathProjection*, and *SensorScanProjection* are all examples of transforms.

*Function*
: Maps a set of variables to a function value such that $y = f(x_1, x_2, x_3, ...)$. *LagrangeInterpolator*, *BivariateEstimator*, and *noaa.coastwatch.render.EnhancementFunction* are examples of concrete *Function* classes.

*DataVariable*
: Holds an n-dimensional array of data and allows for get/set of values, units conversion, value formatting, and statistics. The variable has two concrete classes with specialized methods for their rank: *Line* for 1D data, and *Grid* for 2D data.

*EarthDataInfo*
: Holds information about a geographic dataset including the data source, the date and duration of data recording (possible more than one), and the *EarthTransform* object.

*LandMask*
: Consults a land mask database to return true or false for the query: "Is there land at location (lat,lon)?".

*Statistics*
: Computes statistics for a set of data values including the minimum, maximum, mean, standard deviation, median, and average deviation. This class is used for all statistics computations in the CoastWatch Utilities.

*GridResampler*
: Computes a resampling of 2D *Grid* data from one *EarthTransform* to another. There are two algorithms for resampling used by the concrete *InverseGridResampler* and *MixedGridResampler* classes.

## 4.6 Main programs

The main program classes in the *noaa.coastwatch.tools* package include all the command line tools, graphical tools, and some supporting classes for preferences and user resources. The main programs' source code are a reference for using the top-level API classes. See Appendix A for the full manual pages for all main programs, and chapter 2 for a category-based guide to using the programs.

# Appendix A

# Manual Pages

## A.1 cdat

### Name

cdat - performs visual Earth data analysis.

### Synopsis

cdat [OPTIONS] input
cdat [OPTIONS]

**Options:**

-h, --help
-s, --splash
--version

### Description

The CoastWatch Data Analysis Tool (CDAT) allows users to view, survey, and save Earth datasets. Detailed help on the usage of CDAT is available from within the utility using the menu bar under *Help | Help and Support* .

## Parameters

**Main parameters:**

**input** The input data file name. If specified, the data file is opened immediately after CDAT starts.

**Options:**

**-h, --help** Prints a brief help message.

**-s, --splash** Shows the splash window on startup. The splash window shows the version, author, and web site information.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.

## Examples

The following shows the use of CDAT to view data from a CoastWatch IMGMAP file:

```
phollema@localhost:<~/cwatch/satdata/2002_319_2144_n16_wl> cdat
  2002_319_2144_n16_wl_c2.cwf
```

## A.2 cwangles

### Name

cwangles - computes Earth location and solar angles.

### Synopsis

cwangles [OPTIONS] input

**Options:**

-f, --float
-d, --double
-h, --help
-l, --location
-s, --scale=FACTOR/OFFSET
-u, --units=TYPE
-v, --verbose
-z, --sunzenith
--version

### Description

The angles tool computes Earth location and solar angles for an Earth data file. Angles may be computed as scaled integer or floating point values, and in radians, degrees, or cosine. The Earth location values computed refer to the center of each pixel.

### Parameters

**Main parameters:**

**input** The input data file name.

**Options:**

**-f, --float** Specifies that data should be stored as 32-bit floating point values with no scaling. The default is to store as 16-bit signed integers with a scaling factor of 0.01.

**-d, --double** Specifies that data should be stored as 64-bit floating point values with no scaling. The default is to store as 16-bit signed integers with a scaling factor of 0.01.

**-h, --help** Prints a brief help message.

**-l, --location** Specifies that Earth location latitude and longitude data should be computed.

**-s, --scale=FACTOR/OFFSET** The data scale factor and offset. Data values are scaled to integers using the factor and offset under the equation:

```
integer = value/factor + offset
```

The default factor is 0.01 and offset is 0. This option is ignored if **--float** or **--double** is used.

**-v, --verbose** Turns verbose mode on. The current status of data computation is printed periodically. The default is to run quietly.

**-u, --units=TYPE** The units type. Valid units are 'deg' for degrees, 'rad' for radians, or 'cos' for cosine of the angle. The default is to compute angles in degrees.

**-z, --sunzenith** Specifies that solar zenith angle data should be computed.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- No angle computations specified.

## Examples

The following shows the computation of latitude and longitude data for a CoastWatch HDF product file:

```
phollema@localhost:<~/cwatch/satdata/angles_test> cwangles
  --float --location 2002_361_1049_n16_ax.hdf

cwangles: Reading input 2002_361_1049_n16_ax.hdf
cwangles: Creating latitude variable
cwangles: Creating longitude variable
cwangles: Calculating angles
cwangles: Computing row 0
cwangles: Computing row 100
cwangles: Computing row 200
cwangles: Computing row 300
```

```
cwangles: Computing row 400
cwangles: Computing row 500
cwangles: Computing row 600
cwangles: Computing row 700
cwangles: Computing row 800
cwangles: Computing row 900
cwangles: Computing row 1000
```

Another example below shows the computation of solar zenith angle, stored as the cosine and scaled to integer data by 0.0001:

```
phollema@localhost:<~/cwatch/satdata/angles_test> cwangles -v
  --sunzenith --units cos --scale 0.0001/0 test_angles.hdf

cwangles: Reading input test_angles.hdf
cwangles: Creating sun_zenith variable
cwangles: Calculating angles
cwangles: Computing row 0
cwangles: Computing row 100
cwangles: Computing row 200
cwangles: Computing row 300
cwangles: Computing row 400
cwangles: Computing row 500
cwangles: Computing row 600
cwangles: Computing row 700
cwangles: Computing row 800
cwangles: Computing row 900
cwangles: Computing row 1000
cwangles: Computing row 1100
cwangles: Computing row 1200
```

## A.3 cwautonav

### Name

cwautonav - automatically determines a navigation correction based on Earth image data.

### Synopsis

cwautonav [OPTIONS] locations-file variable input

**Options:**

-c, --correlation=FACTOR
-f, --fraction=FRACTION
-h, --help
-H, --height=PIXELS
-m, --match=PATTERN
-M, --minboxes=N
-s, --search=LEVEL
-S, --separation=DISTANCE
-t, --test
-v, --verbose
-w, --width=PIXELS
--version

### Description

The autonavigation tool automatically determines a navigation correction based on Earth image data. The algorithm is as follows:

- **Step 1** - The user supplies a number of boxes of coastal data to use for navigation. The boxes are specified by the latitude and longitude of each box center in a text file separate from the Earth data file. The box dimensions are controlled by command line options.
- **Step 2** - Each box is run through an offset estimation algorithm. The algorithm first attempts to separate the pixels within a given box into two classes: land and water. If the classes are sufficiently separable, an image correlation is run by "shifting" the image data around to find the maximum correlation between land/water classes and a precomputed land mask database.
- **Step 3** - All navigation boxes with successful offset estimates are used to compute the mean offset for the entire input file. All user-specified variables in the input file are then corrected with the mean offset.

Note that because of the autonavigation algorithm design, there are a number of **limitations** :

- **Coastline features** - The algorithm relies partly on the user being able to specify navigation boxes containing "wiggly" coastline features such as peninsulas and bays. A flat coastline can cause the algorithm to generate inaccurate offset estimates.
- **Distinct classes** - Image data in the navigation boxes must be separable into distinct land and water classes. If the image data contains cloud, or if the land and water pixels do not differ significantly (too similar in visible or thermal radiance), then the class separation step will fail for some boxes.
- **Large areas** - The mean offset generated from the set of successful offset estimates in Step 3 may not model the actual navigation correction for data files that cover a large physical area. If the offsets differ significantly for navigation boxes at a great distance from each other, then the user should treat a number of subsets of the data file separately.
- **Rotation or scaling** - An offset correction cannot model the actual navigation correction if the data requires a rotation or scale correction.

Note that satellite channel data or channel-derived variables should be corrected with navigation but GIS-derived variables such as coastline and lat/lon grid graphics should not be corrected. Applying a navigation correction simply establishes a mapping between desired and actual data coordinates -- it does not change the gridded data values themselves. Once a data file has been autonavigated successfully, other CoastWatch tools in this package will take the correction into account when reading the data.

See the **cwnavigate** tool in this package for details on how to set a navigation correction manually, or to reset the existing navigation.

## Parameters

**Main parameters:**

**locations-file** The file name containing a list of navigation box centers. The file must be a text file containing center points as latitude / longitude pairs, one line per pair, with values separated by spaces or tabs. The points are specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180].

**variable** The variable name to use for image data.

**input** The input data file name. The navigation corrections are applied to the input file in-situ. For CoastWatch HDF files, the corrections are applied to individual variables. For CoastWatch IMGMAP files, corrections are applied to the global attributes and the **--match** option has no effect. No other file formats are supported.

**Options:**

**-c, --correlation=FACTOR** The minimum allowed image versus land mask correlation factor in the range [0..1]. If the image data matches the precomputed land mask to within the specified correlation factor, the navigation is considered to be successful. The default correlation factor is 0.95. Caution should be used in lowering this value, as it has a significant impact on the quality of navigation results.

**-f, --fraction=FRACTION** The minimum allowed class fraction in the range [0..1]. The class fraction is the count of land or water pixels from the class separation stage, divided by the total number of pixels in the navigation box. If the fraction of either land or water pixels is too low, the image data is rejected. The default minimum fraction is 0.05.

**-h, --help** Prints a brief help message.

**-H, --height=PIXELS** The navigation box height. By default, each navigation box is 100 pixels in height.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will have the navigation correction applied. By default, no pattern matching is performed and all variables are navigated.

**-M, --minboxes=N** The minimum number of successful navigation boxes needed to apply the navigation correction. The default is 2.

**-s, --search=LEVEL** The search level starting from 0. This option should only be used if the magnitude of the navigation correction is likely to be half or more the size of the navigation box, as it can significantly increase the algorithm running time. In these cases, the offset estimation can often fail because the image data is so far off the correct geographic features that the class separation and image correlation steps are meaningless. When this option is specified, an area of (n+1)ˆ2 times the size of the navigation box is searched, where n is the search level. By default, only image data within the navigation box is used (n = 0).

**-S, --separation=DISTANCE** The minimum allowed class separation distance in standard deviation units. Typical values are in the range [1..4]. The greater the distance, the more distinct the land and water classes are. The default distance is 2.5.

**-t, --test** Turns on test mode. All operations that compute the navigation correction are performed, but no actual correction is applied to the input file. By default, test mode is off and the input file is modified if a correction can be computed.

**-v, --verbose** Turns verbose mode on. Details on offset estimation and navigation correction are printed. The default is to run with minimal messages.

**-w, --width=PIXELS** The navigation box width. By default, each navigation box is 100 pixels in width.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.

## Examples

The following example shows an automatic correction of an East Coast CWF (IMGMAP format) file containing AVHHR channel 2 data. A total of 3 navigation boxes are specified in a text file, and the size of each box set to 60 by 60 pixels. The output shows that 2 of the 3 boxes were successful and a final navigation correction of (rows, cols) = (-3, 1) was applied to the file.

```
phollema@damdog<~/cwatch/satdata/level3> cwautonav -v --width 60
  --height 60 navbox.txt avhrr_ch2 2004_064_1601_n17_er_c2.cwf
cwautonav: Reading input 2004_064_1601_n17_er_c2.cwf
cwautonav: Testing box at 37.0503 N, 76.2111 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.33
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 44.2783 N, 66.1377 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.436
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.965 at
  offset = (-3, 1)
cwautonav: Box offset = (-3, 1)
cwautonav: Testing box at 45.1985 N, 65.9262 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.814
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.987 at
  offset = (-3, 1)
cwautonav: Box offset = (-3, 1)
cwautonav: Mean offset = (-3, 1)
cwautonav: Applying navigation correction
```

The next example below shows the import and automatic correction of multiple CWF files from the Gulf of Mexico. The AVHRR channel 1, channel 2, SST, and cloud mask variables are first imported to an HDF file. The automatic correction then runs using only data from AVHRR channel 2 which provides high contrast between land and water during the day. The final correction is applied to all variables in the input file. This combination of import and autonavigation is a convenient way of correcting a set of older CWF data files all at once, using just data from AVHRR channel 2.

```
phollema@damdog<~/cwatch/satdata/level3> cwimport -v
  --match '(avhrr.*|sst|cloud)' 2004_313_1921_n16_mr*.cwf
  2004_313_1921_n16_mr.hdf
cwimport: Reading input 2004_313_1921_n16_mr_c1.cwf
cwimport: Creating output 2004_313_1921_n16_mr.hdf
cwimport: Converting file [1/4], 2004_313_1921_n16_mr_c1.cwf
cwimport: Writing avhrr_ch1
cwimport: Converting file [2/4], 2004_313_1921_n16_mr_c2.cwf
```

```
cwimport: Writing avhrr_ch2
cwimport: Converting file [3/4], 2004_313_1921_n16_mr_cm.cwf
cwimport: Writing cloud
cwimport: Converting file [4/4], 2004_313_1921_n16_mr_d7.cwf
cwimport: Writing sst

phollema@damdog<~/cwatch/satdata/level3> cwautonav -v --width 60
  --height 60 navbox2.txt avhrr_ch2 2004_313_1921_n16_mr.hdf
cwautonav: Reading input 2004_313_1921_n16_mr.hdf
cwautonav: Testing box at 26.7734 N, 82.1731 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.239
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.945 at
  offset = (-2, 1)
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient correlation
cwautonav: Box failed
cwautonav: Testing box at 29.1666 N, 83.0324 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.54
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.985 at
  offset = (-2, 1)
cwautonav: Box offset = (-2, 1)
cwautonav: Testing box at 29.9141 N, 84.3543 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 4.514
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.976 at
  offset = (-2, 0)
cwautonav: Box offset = (-2, 0)
cwautonav: Testing box at 30.3258 N, 88.1352 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.006
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.954 at
  offset = (-3, 0)
cwautonav: Box offset = (-3, 0)
cwautonav: Testing box at 27.8423 N, 82.5433 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.59
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.953 at
  offset = (-2, 1)
cwautonav: Box offset = (-2, 1)
cwautonav: Mean offset = (-2.25, 0.5)
cwautonav: Applying navigation correction
```

Another example below shows the correction of a Hawaii AVHRR HDF file using many 15 by 15 pixel navigation boxes distributed throughout the islands. AVHRR channel 2 data is used to compute the optimal offset, and the final correction is applied only to AVHRR sensor bands and derived variables.

```
phollema@damdog<~/cwatch/satdata/level3> cwautonav -v
  --match '(avhrr.*|sst|cloud)' --width 15 --height 15
  navbox3.txt avhrr_ch2 2005_042_0051_n16_hr.hdf
cwautonav: Reading input 2005_042_0051_n16_hr.hdf
cwautonav: Testing box at 21.7885 N, 160.2259 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.537
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.9856 N, 160.0938 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.395
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.6033 N, 158.2847 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.562
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.7144 N, 157.9678 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.982
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.0961 N, 157.3207 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.517
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.2448 N, 157.2547 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.252
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.2076 N, 156.9774 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.236
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.973 at
  offset = (-2, 0)
cwautonav: Box
  offset = (-2, 0)
cwautonav: Testing box at 21.1581 N, 156.7001 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.293
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.9225 N, 157.0698 W
```

```
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.448
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.7115 N, 156.9642 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.506
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.3067 N, 158.1130 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.601
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.3067 N, 157.6508 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.593
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.5374 N, 156.7001 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 5.142
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.978 at
  offset = (-2, 0)
cwautonav: Box
  offset = (-2, 0)
cwautonav: Testing box at 20.5499 N, 156.5680 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.834
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.947 at
  offset = (-2, -1)
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient correlation
cwautonav: Box failed
cwautonav: Testing box at 20.5996 N, 156.4360 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.285
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.8108 N, 156.5152 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.092
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.9349 N, 156.4756 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.629
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.969 at
  offset = (-2, -1)
```

```
cwautonav: Box
  offset = (-2, -1)
cwautonav: Testing box at 20.8357 N, 156.1190 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.46
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.2635 N, 155.8813 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.522
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.964 at
  offset = (-2, 0)
cwautonav: Box
  offset = (-2, 0)
cwautonav: Testing box at 19.5140 N, 154.7985 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.64
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.7392 N, 155.0230 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.833
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.7267 N, 155.1022 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.688
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 18.9119 N, 155.6965 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.378
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.8642 N, 155.9342 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.583
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.0375 N, 155.8813 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.638
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 22.0349 N, 159.7901 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.919
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
```

```
cwautonav: Box failed
cwautonav: Testing box at 22.1826 N, 159.3279 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.496
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Mean offset = (-2, -0.25)
cwautonav: Applying navigation correction
```

## A.4 cwcomposite

### Name

cwcomposite - combines a time series of Earth data.

### Synopsis

cwcomposite [OPTIONS] input [input2 ...] output
cwcomposite [OPTIONS] {-i, --inputs=FILE} output

**Options:**

-c, --coherent=VARIABLE1[/VARIABLE2[...]]
-h, --help
-m, --match=PATTERN
-M, --method=TYPE
-p, --pedantic
-v, --verbose
-V, --valid=COUNT
--version

### Description

The composite tool combines a time series of Earth data. Data variables are combined on a pixel-by-pixel basis using one of several statistical or temporal methods: mean, median, minimum, maximum, explicit or latest. The input files must have matching Earth transforms but may have different dates. The composite tool may be used, for example, to combine a number of sea-surface-temperature datasets into one in order to obtain a mean SST for a certain region and help eliminate cloud. Another use is to combine datasets from different regions that are registered to the same Earth transform to create a mosaic. The output dataset is constructed using metadata from each input dataset so that it properly reflects the different input dataset dates and other metadata.

### Parameters

**Main parameters:**

**input [input2 ...** ] The input data file names. At least one input file is required, unless the **--inputs** option is used. If multiple files are specified, they must have matching Earth transforms.

**-i, --inputs=FILE** The file name containing a list of input data files. The file must be an ASCII text file containing input file names, one per line. If multiple files are listed, they must have matching Earth transforms. If the inputs file name is '-', input is read from standard input.

**output** The output data file name.

**Options:**

**-c, --coherent=VARIABLE1[/VARIABLE2[...]** ]Turns on coherent mode (only valid with **--method latest or --method explicit** ). In coherent mode, the output values for all variables at a given pixel location are guaranteed to originate from the same input file. The specified variable list is used to prioritize variables to check for a valid latest/last value. If there are no valid values for the first variable at a given location, then the next variable is checked and so on until the latest/last valid value is found. This mode is useful for when data variables and their respective quality flags should be kept together during a composite operation. Without this option, the 'latest' and 'explicit' composite methods may select the latest/last valid data value from one input file, and the latest/last valid quality flag from another input file for a given location.

**-h, --help** Prints a brief help message.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be present in the output. By default, no pattern matching is performed and all variables are combined.

**-M, --method=TYPE** The composite method. Valid methods are 'mean', 'median', 'min', 'max', 'explicit' and 'latest'. The default is to calculate the mean.

**-p, --pedantic** Turns pedantic mode on. In pedantic mode, metadata from each input file is combined exactly such that composite attributes in the output file may contain repeated values. When pedantic mode is off, composite attributes are collapsed so that only unique values appear. By default, pedantic mode is off.

**-v, --verbose** Turns verbose mode on. The current status of data combination is printed periodically. The default is to run quietly.

**-V, --valid=COUNT** The minimum number of valid values required to form an aggregate function. By default, only one value per pixel is required. If the actual number of valid values is below this threshold, the output value is set to invalid.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Input file Earth transforms do not match.
- No matching variables found.
- Unsupported composite method.

## Examples

The following shows the combination of several Earth datasets into one using the 'latest' composite method:

```
 phollema@localhost:<~/cwatch/satdata/hdf> cwcomposite -v
   --method latest 2003_097_1428_n17_wi_na.hdf
   2003_097_1607_n17_wi_na.hdf 2003_097_1751_n17_mo_na.hdf
   2003_097_1931_n17_mo_na.hdf 2003_097_n17_na.hdf

cwcomposite: Reading input 2003_097_1428_n17_wi_na.hdf
cwcomposite: Adding avhrr_ch1 to composite variables
cwcomposite: Adding avhrr_ch2 to composite variables
cwcomposite: Adding avhrr_ch4 to composite variables
cwcomposite: Reading input 2003_097_1607_n17_wi_na.hdf
cwcomposite: Reading input 2003_097_1751_n17_mo_na.hdf
cwcomposite: Reading input 2003_097_1931_n17_mo_na.hdf
cwcomposite: Creating output 2003_097_n17_na.hdf
cwcomposite: Writing avhrr_ch1
cwcomposite: Writing avhrr_ch2
cwcomposite: Writing avhrr_ch4
```

## A.5 cwcoverage

### Name

cwcoverage - creates an Earth data coverage map.

### Synopsis

cwcoverage [OPTIONS] input1 [input2 ...] output
cwcoverage [OPTIONS] output

**General options:**

-h, --help
-v, --verbose
--version

**Output content and format options:**

-a, --noantialias
-b, --background=COLOR
-c, --center=LATITUDE/LONGITUDE
-f, --foreground=COLOR
-s, --size=PIXELS

**Dataset boundary options:**

-H, --highlight=PATTERN
-l, --labels=LABEL1/LABEL2/...
-m, --map=OUTPUT
-x, --box=COLOR

**Ground station options:**

-C, --stationcolor=COLOR
-e, --elevation=DEGREES
-E, --height=KILOMETERS
-L, --stationlabels=LABEL1/LABEL2/...
-S, --stations=LAT1/LON1/LAT2/LON2/...

## Description

The coverage tool creates an Earth data coverage map by accessing a number of user-specified Earth data sets and tracing the boundaries onto an orthographic map projection. The map is output as a PNG graphics file. Approximate satellite ground station coverage boundaries may also be added to the map.

## Parameters

**Main parameters:**

**input1 [input2 ...]** The input data files name(s). If none are specified, the output PNG image contains only map graphics and possibly ground station circles (see the **--stations** option).

**output** The output PNG file name.

**General options:**

**-h, --help** Prints a brief help message.

**-v, --verbose** Turns verbose mode on. The current status of data rendering is printed periodically. The default is to run quietly.

**--version** Prints the software version.

**Output content and format options:**

**-a, --noantialias** Turns off line antialiasing. By default, the edges of lines are smoothed using shades of the drawing color. The use of this option can significantly reduce the size of the output file, while sacrificing visual quality.

**-b, --background=COLOR** The map background color. The color is specified by name or hexadecimal value. The default is black.

**-c, --center=LATITUDE/LONGITUDE** The map center location. By default, the center location is determined from the data sets.

**-f, --foreground=COLOR** The map foreground color. The color is specified by name or hexadecimal value. The default is a gray of 63% RGB intensity.

**-s, --size=PIXELS** The coverage map size in pixels. By default, the map size is 512 pixels.

**Dataset boundary options:**

**-H, --highlight=PATTERN** The highlighted input file matching pattern. By default, all input files are highlighted with the box boundary fill and color. With this option, only input files whose names match the pattern are highlighted. The remaining non-matching input file boundaries are drawn using the foreground color.

**-l, --labels=LABEL1/LABEL2/...** The labels for each input file. Labels are drawn at the center point of each dataset boundary. By default, no labels are drawn.

**-m, –map=OUTPUT** The output file for HTML image map output. The output file contains an HTML fragment with an image map and area polygons for each input file, similar to the following:

```
<map name="coverage_map">
  <area shape="poly" id="region_0" coords="111,64,170,63,179,132,108,134,111,64" />
  <area shape="poly" id="region_1" coords="75,106,132,109,133,179,66,174,75,106" />
  <area shape="poly" id="region_2" coords="121,124,183,121,192,188,119,191,121,124" />
</map>
```

The map may be used in an HTML document in conjunction with the output PNG coverage image to provide users with a clickable interface for area of interest selection.

**-x, --box=COLOR** The box boundary and fill color. The color is specified by name or hexadecimal value. The default is a color close to cyan.

**Ground station options:**

**-C, --stationcolor=COLOR** The ground station circle color. This option is only used in conjunction with the **--stations** option. By default, the box color is used (see the **--box** option).

**-e, --elevation=DEGREES** The minimum elevation of the ground station antenna above the horizon in degrees. This option is only used in conjunction with the **--stations** option. By default, the antenna elevation is set to 5 degrees, which approximates a NOAA HRPT tracking station with a 1.7 m diameter dish.

**-E, --height=KILOMETERS** The orbital height of the theoretical satellite above the Earth surface in kilometers. This option is only used in conjunction with the **--stations** option. By default, the satellite orbital height is set to 846.5 km which approximates a NOAA polar orbiter.

**-L, --stationlabels=LABEL1/LABEL2/...** The ground station labels. This option is only used in conjunction with the **--stations** option. When specified, each ground station location is labelled with its corresponding label. By default, no labels are drawn.

**-S, --stations=LAT1/LON1/LAT2/LON2/...** A list of ground station locations. For each ground station, a circle is drawn on the Earth, centered at the ground station. The circle shows the approximate area that a theoretical satellite can view from orbit while in sight of the station, ie: the ground station's real-time coverage area. See the **--height** and **--elevation** options to control the orbital parameters of the theoretical satellite. Note that the swath width of the satellite sensor is not taken into account in drawing the circle, so the area should be used as a conservative estimate of satellite coverage.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Unrecognized color name.
- Invalid map center or station location.
- Mismatch between label and file or station count.

## Examples

As an example, the following command shows the creation of a coverage plot of the ER and SR CoastWatch regions covering the US East coast:

```
phollema@damdog<~/cwatch/satdata/hdf> cwcoverage -v --labels ER/SR
  2004_155_1147_n15_er.hdf 2004_155_1147_n15_sr.hdf east_coast.png

cwcoverage: Reading input 2004_155_1147_n15_er.hdf
cwcoverage: Reading input 2004_155_1147_n15_sr.hdf
cwcoverage: Writing east_coast.png
```

## A.6 cwdownload

### Name

cwdownload - downloads data from a CoastWatch server.

### Synopsis

cwdownload [OPTIONS] host

**General options:**

-c, --script=PATH
-d, --dir=PATH
-f, --force
-h, --help
-t, --test
-T, --timeout=SECONDS
--version

**Data file selection options:**

-a, --age=HOURS
-C, --coverage=PERCENT
-G, --station=PATTERN
-p, --projection=TYPE
-r, --region=PATTERN
-s, --satellite=PATTERN
-S, --scenetime=PATTERN

### Description

The download tool retrieves a set of user-specified data files from a CoastWatch data server. Data files may be selected based on satellite, scene time, region, ground station, and other parameters. Without any command line options, all data files on the server are retrieved. The command line options are used to filter the list of data files. Multiple options are used in conjunction, for example if both **--satellite** and **--scenetime** are specified, only files matching the specified satellites and scene times will be retrieved. The download tool has a built-in facility for avoiding redundant file downloads. Unless the **--force** option is used, files are only downloaded if no file with the same name already exists in the local directory. The **--test** option may be used for testing file download options without downloading any actual data.

## Parameters

**Main parameters:**

**host** The CoastWatch server host name. There is no default host name.

**General options:**

**-c, --script=PATH** ADVANCED USERS ONLY. The query script path. The default is /ctera/query.cgi.

**-d, --dir=PATH** The download directory path. The default is to download to the current directory.

**-f, --force** Turns on forced mode. When forced mode is in effect, no check is performed to determine if the file already exists in the download directory. The default is to check if a file of the same name exists, and if so skip the download for that particular file.

**-h, --help** Prints a brief help message.

**-t, --test** Turns on test mode. When the test mode is in effect, the data files are selected based on the specified command line parameters but no actual data is downloaded. The default is to perform the data download. Test mode may be used to determine if a certain set of command line parameters have the desired effect without having to wait for data files to transfer.

**-T, --timeout=SECONDS** The network timeout in seconds. If the network becomes unresponsive for the timeout period, the download is aborted. If there is a file currently in the process of downloading when the timeout occurs, the partial file is deleted. The default timeout is 30 seconds.

**--version** Prints the software version.

**Data file selection options:**

**-a, --age=HOURS** The maximum age of the data in hours. Datasets contain a time stamp for the date and time that the data was taken by the sensor. Only datasets created more recently than the specified number of hours ago are retrieved, based on the clock on the host computer running the download. The default is to download regardless of date and time.

**-C, --coverage=PERCENT** The minimum data coverage in percent. Mapped regions may have less than 100% coverage when the edge of the satellite pass intersects the region area. The default minimum coverage is 0. The use of this option implies **--projection mapped** .

**-G, --station=PATTERN** The ground station matching pattern. Multiple ground stations may be specified with a regular expression, for example '(wi|mo|hi)' for the wi, mo, and hi stations. The default is to download all ground stations.

**-p, --projection=TYPE** The data projection type. Valid values are 'mapped' and 'swath'. Mapped datasets are those that have possibly been reduced in resolution, and registered to a standard map projection. Swath datasets are generally at the full sensor resolution and unregistered sensor scan projection. By default, all types of datasets are downloaded.

**-r, --region=PATTERN** The region code matching pattern. Multiple regions may be specified with a regular expression, for example '(er|sr|gr)' for the 'er', 'sr', and 'gr' regions. The default is to download all regions. The use of this option implies **--projection mapped** .

**-s, --satellite=PATTERN** The satellite name matching pattern. For example, 'noaa-16'. Multiple satellites may be specified with a regular expression, for example 'noaa-1[56]' for NOAA-15 and NOAA-16. The default is to download data from all satellites.

**-S, --scenetime=PATTERN** The scene time matching pattern. Valid times are 'day', 'night', and 'day/night'. Multiple times may be specified with a regular expression, for example '(day|night)' for day and night. The default is to download all scene times.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Cannot contact data server.
- Invalid or write-protected download directory.
- Error transferring data file.

## Examples

The following shows a download command that retrieves any NOAA-16 daytime data files for the East Coast north and south regions captured at Wallops Island to the /cwatch/satdata directory from the fictitious server foobar.noaa.gov:

```
phollema@localhost:<~> cwdownload --satellite noaa-16 --scenetime day
  --region '(er|sr)' --station wi --dir ~/cwatch/satdata foobar.noaa.gov

cwdownload: Contacting foobar.noaa.gov
cwdownload: Retrieving 2002_197_1719_n16_er.hdf
cwdownload: Retrieving 2002_197_1719_n16_sr.hdf
cwdownload: Retrieving 2002_197_1900_n16_er.hdf
cwdownload: Retrieving 2002_197_1900_n16_sr.hdf
cwdownload: Transferred 31715 kb in 4 files
```

## A.7 cwexport

### Name

cwexport - translates Earth data into external file formats.

### Synopsis

cwexport [OPTIONS] input output

**General options:**

-f, --format=TYPE
-h, --help
-H, --header
-m, --match=PATTERN
-M, --missing=VALUE
-v, --verbose
--version

**Binary raster specific options:**

-c, --scale=FACTOR/OFFSET
-o, --byteorder=ORDER
-r, --range=MIN/MAX
-s, --size=TYPE

**ASCII text specific options:**

-d, --dec=DECIMALS
-D, --delimit=STRING
-n, --nocoords
-R, --reverse

**NetCDF specific options:**

-S, --dcs
-C, --cw

## Description

The export tool translates Earth data into external formats as described below. In all cases, 2D data sets are exported in row major order starting from row 0. For example, if the Earth data values form the 2D array:

```
 0  1  2  3
 4  5  6  7
 8  9 10 11
12 13 14 15
```

then values are output in the order:

```
0 1 2 3 4 5 6 7 ...
```

In the general case, multiple variables may be exported to the same data file. The use of the **--match** option may be used to select a specific variable or subset of variables.

**Binary raster:**

The output is a stream of binary data values – either 8-bit unsigned bytes, 16-bit signed integers, or 32-bit IEEE floating point values. For 8- and 16-bit output, data values may be scaled to integers using a minimum and maximum or by using a scaling factor and offset. For minimum/maximum scaling, integer data is calculated from data values using the equation:

```
integer = type_min + type_range*((value - min) / (max - min))
```

where type_min is 0 for 8-bit and -32768 for 16-bit, and type_range is 255 for 8-bit and 65535 for 16-bit. For scaling factor and offset, the following equation is used:

```
integer = value/factor + offset
```

In both cases, the results are rounded to the nearest integer and out of range values are assigned the missing value.

**ASCII text:**

The output is an ASCII text file with latitude, longitude, and data value printed -- one data value per line.

**ArcGIS binary grid:**

The output is a stream of 32-bit IEEE floating point values, ready for input to ArcGIS applications as a binary grid file. A header file may also be created to specify the Earth location and other parameters. In the case of the ArcGIS format, only one variable is allowed per binary grid file. If an attempt to export multiple variables is made, only the first variable is actually written.

**NetCDF:**

The output is a NetCDF-3 dataset with CF 1.4 convention metadata. The formatting follows as much as possible the recommendations and examples in the document "Encoding CoastWatch Satellite Data in NetCDF using the CF Metadata Conventions", Peter Hollemans, February 2010. In some cases, the source data for some attributes may not be available, in which case the output NetCDF may need to be modified and extended.

## Parameters

**Main parameters:**

**input** The input data file name.

**output** The output data file name. Unless the **--format** option is used, the output file extension indicates the desired output format: '.raw' for binary, '.txt' for text, '.flt' for ArcGIS, and '.nc' for NetCDF.

**General options:**

**-f, --format=TYPE** The output format. The current formats are 'bin' for binary raster, 'text' for ASCII text, 'arc' for ArcGIS binary grid, 'netcdf' for NetCDF, or 'auto' to detect the format from the output file name. The default is 'auto'.

**-h, --help** Prints a brief help message.

**-H, --header** Specifies that a header should be written with the output data. The header is written before any data and is different depending on the output format:

- Binary: The header consists of one byte specifying the number of dimensions followed by a series of 32-bit signed integers specifying the dimension lengths.
- Text: The header is one line consisting of an integer specifying the number of dimensions followed by a series of integers specifying the dimension lengths.
- ArcGIS: The header is a separate file used by ArcGIS applications to determine the dimensions of the data, the geographic position and resolution, and other parameters. The header file name is created by replacing any '.' followed by an extension in the output file name with '.hdr'
- NetCDF: Not applicable, all metadata in NetCDF is written into the dataset itself.

By default no header is written.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be exported. By default, no pattern matching is performed and all variables are exported.

**-M, --missing=VALUE** The output value for missing or out of range data. The default missing value is different depending on the output format:

- Binary: The default is 0 for 8-bit unsigned bytes, -32768 for 16-bit signed integers, and the IEEE NaN value for floating point.
- Text: The default is to print 'NaN' for missing values.
- ArcGIS: The missing value is fixed at -3.4e38 and the **--missing** option is ignored.
- NetCDF: Not applicable, the missing values for variable data are copied from the input data source.

**-v, --verbose** Turns verbose mode on. The current status of data conversion is printed periodically. The default is to run quietly.

**--version** Prints the software version.

**Binary raster specific options:**

**-c, --scale=FACTOR/OFFSET** The data scale factor and offset. Data values are scaled to integers using the factor and offset (see the equation above). The default factor is 1 and offset is 0.

**-o, --byteorder=ORDER** The output byte order. Valid choices are 'host' for the host byte order, 'msb' for most significant byte first, or 'lsb' for least significant byte first. The default is the host byte order.

**-r, --range=MIN/MAX** The data scaling range. Data values are mapped to integers using the minimum and maximum values (see the equation above). There is no default range.

**-s, --size=TYPE** The binary value size. Valid choices are 'byte' for 8-bit unsigned bytes, 'short' for 16-bit signed integers, or 'float' for 32-bit IEEE floating point values. The default is 32-bit floats.

**ASCII text specific options:**

**-d, --dec=DECIMALS** The number of decimal places for printed geographic coordinate values. The default is 6 decimals.

**-D, --delimit=STRING** The value delimiter string. By default, values are separated with a single space character.

**-n, --nocoords** Turns geographic coordinate printing off. By default, each line has the form 'latitude longitude value' but with no coordinates, each line simply contains the data value.

**-R, --reverse** Specifies that coordinates should be printed in reverse order, 'longitude latitude'. The default is 'latitude longitude'.

**NetCDF specific options:**

**-S, --dcs** Turns on writing of ocean color Data Content Standard metadata. The default is to write only CF-1.4 metadata. DCS metadata is written as a set of global NetCDF attributes with the namespace prefix 'dcs'. Only the minimal set of 15 required attributes are written. Since the NetCDF file will generally contain more than one variable, the required DCS attributes observedProperty and observedPropertyAlgorithm are set to 'Unknown' and must be modified manually.

**-C, --cw** Turns on writing of CoastWatch HDF-style metadata. The default is to write only CF-1.4 metadata. CoastWatch metadata is written as a set of global- and variable-level NetCDF attributes with the namespace prefix 'cw'. Only a very small subset of the original CoastWatch HDF metadata is written, those attributes that have no CF-1.4 equivalent.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid variable name.
- Unrecognized format, size, or byte order.

## Examples

The following shows the export of AVHRR channel 1 data from a CoastWatch HDF file with the default 32-bit IEEE floating point value format, host byte order, no header, in verbose mode:

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --match 'avhrr_ch1' 2002_216_1853_n16_gr.hdf 2002_216_1853_n16_gr.ch1

cwexport: writing 'avhrr_ch1'
```

The example below shows the export of AVHRR channels 1, 2, and 4 to the same output file from a CoastWatch HDF file using 8-bit unsigned byte format, no header, in verbose mode. Range scaling is used to scale all values between -30 and 30 prior to conversion to byte values in the range 0 to 255. Note that some values may fall outside the range and be clipped, especially albedo values which can range up to 100. The clipped values are assigned the default missing value, which for byte data is 0.

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --match 'avhrr_ch[124]' --size byte --range -30/30
  2002_216_1853_n16_gr.hdf 2002_216_1853_n16_gr.ch124
```

```
cwexport: writing 'avhrr_ch1'
cwexport: writing 'avhrr_ch2'
cwexport: writing 'avhrr_ch4'
```

The example shows the export of AVHRR channel 4 data to an ASCII text file from a CoastWatch IMGMAP file in verbose mode. The geographic coordinates are printed in the order longitude, latitude, and delimited with a comma character. Any missing values are denoted with the value -999. A one line dimension header is prepended to the dataset.

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --match 'avhrr_ch4' --format text --reverse --delimit ','
  --missing -999 --header 2002_214_2057_n16_wv_c4.cwf
  2002_214_2057_n16_wv_c4.txt

cwexport: writing 'avhrr_ch4'
```

The first few lines of the resulting text file are as follows:

```
2,512,512
-127.777901,51.212974,13
-127.768008,51.212974,13.75
-127.758116,51.212974,13.75
-127.748224,51.212974,13.1
-127.738332,51.212974,13.1
-127.728439,51.212974,13
-127.718547,51.212974,8.95
-127.708655,51.212974,7.45
-127.698763,51.212974,7.45
```

The example below shows the export of AVHRR channel 2 data to an ArcGIS binary grid file from a CoastWatch IMGMAP file, verbose mode on. The binary grid data is written to a '.flt' file and the header data to a '.hdr' file.

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --format arc --match 'avhrr_ch2' --header
  2002_214_2057_n16_wv_c2.cwf 2002_214_2057_n16_wv_c2.flt

cwexport: writing 'avhrr_ch2'
```

The header file contents are as follows:

```
nrows 512
ncols 512
xllcorner -14208797.57
yllcorner 6088966.68
cellsize 1099.96
nodata_value 1.4E-45
byteorder MSBFIRST
```

A final example shows the export of SST and cloud data to a NetCDF dataset:

```
phollema@Bean cwexport -v --match '(sst|cloud)'
  2010_040_1636_m02_wj.hdf 2010_040_1636_m02_wj.nc"

cwexport: Creating output 2010_040_1636_m02_wj.nc
cwexport: Writing cloud
cwexport: Writing sst
```

A dump of the file contents:

```
netcdf 2010_040_1636_m02_wj {
dimensions:
  time = 1 ;
  level = 1 ;
  row = 1024 ;
  column = 1024 ;
variables:
  int coord_ref ;
    coord_ref:grid_mapping_name = "mercator" ;
    coord_ref:longitude_of_projection_origin = 0. ;
    coord_ref:standard_parallel = 0. ;
    coord_ref:false_easting = 0. ;
    coord_ref:false_northing = 0. ;
    coord_ref:semi_major_axis = 6378137. ;
    coord_ref:inverse_flattening = 298.257223653 ;
    coord_ref:longitude_of_prime_meridian = 0. ;
  double x(column) ;
    x:standard_name = "projection_x_coordinate" ;
    x:units = "m" ;
  double y(row) ;
    y:standard_name = "projection_y_coordinate" ;
    y:units = "m" ;
  double lat(row, column) ;
    lat:standard_name = "latitude" ;
```

```
      lat:units = "degrees_north" ;
    double lon(row, column) ;
      lon:standard_name = "longitude" ;
      lon:units = "degrees_east" ;
    double time(time) ;
      time:standard_name = "time" ;
      time:units = "seconds since 1970-01-01 00:00:00 UTC" ;
    double level(level) ;
      level:standard_name = "height" ;
      level:units = "m" ;
      level:positive = "up" ;
    byte cloud(time, level, row, column) ;
      cloud:missing = 0b ;
      cloud:valid_range = 0, 255 ;
      cloud:coordinates = "lat lon" ;
      cloud:cell_methods = "area: mean" ;
      cloud:grid_mapping = "coord_ref" ;
    short sst(time, level, row, column) ;
      sst:scale_factor = 0.01 ;
      sst:add_offset = -0. ;
      sst:missing = -32768s ;
      sst:units = "celsius" ;
      sst:coordinates = "lat lon" ;
      sst:cell_methods = "area: mean" ;
      sst:grid_mapping = "coord_ref" ;
      sst:source = "nonlinear_split_window linear_triple_window_modified" ;

  // global attributes:
    :Conventions = "CF-1.4" ;
    :source = "METOP2_AVHRR " ;
    :institution = "USDOC/NOAA/NESDIS CoastWatch" ;
    :history = "[2010-03-13 09:46:43 IST cwf-3.2.4-pre-build169 phollema] cwexport -v --match (sst|clou
  }
```

## A.8 cwgraphics

### Name

cwgraphics - creates Earth data annotation graphics.

### Synopsis

cwgraphics [OPTIONS] input
cwgraphics [OPTIONS] input output

**Options:**

-c, --coast=PLANE
-g, --grid=PLANE
-h, --help
-l, --land=PLANE
-p, --political=PLANE
-v, --verbose
-V, --variable=NAME
--version

### Description

The graphics tool creates Earth data annotation graphics in the form of a byte-valued variable. Each output byte in the new variable contains 8 bits, one for each of 8 possible graphics planes numbered 1 to 8 from the least significant bit to the most significant bit. The graphics planes are independent of one another and encode a bitmask for graphical data annotation, where a bit value of 0 is interpreted as 'off' and a bit value of 1 as 'on'. In this way, 8 separate binary bitmasks may be encoded into one byte value. For example a pixel with graphics planes 2, 3, and 4 on is encoded as:

```
Binary value  = 00001110
Decimal value = 14
```

Following the standard convention for graphics planes in CoastWatch product files, the default behaviour places latitude/longitude grid graphics in plane 2, coast line graphics in plane 3, and land mask graphics in plane 4. Coast lines are derived from GSHHS coast line data, and land polygons are filled GSHHS polygons (see http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html). The default output variable name is 'graphics'. These defaults may be changed using command line options to alter the planes used for each type of annotation, to exclude or add some types of annotation, and to change the output variable name.

Once the graphics planes are created, they may be used as overlay graphics for rendered Earth data images. The graphics byte data may be exported using the cwexport tool for use in other software packages, or may be used in the cwrender tool with the **--bitmask** option.

## Parameters

**Main parameters:**

**input** The input data file name.

**output** The output file name. If the output file name is not specified, the input file name is used and the new variable must not already exist in the input file.

**Options:**

**-c, --coast=PLANE** The coast line graphics plane. The default is plane 3. If the plane value is 0, no coast graphics are rendered.

**-g, --grid=PLANE** The grid line graphics plane. The default is plane 2. If the plane value is 0, no grid graphics are rendered.

**-h, --help** Prints a brief help message.

**-l, --land=PLANE** The land mask graphics plane. The default is plane 4. If the plane value is 0, no land graphics are rendered.

**-p, --political=PLANE** The political line graphics plane. There is no default plane for political lines, as they are normally excluded from rendering.

**-v, --verbose** Turns verbose mode on. The current status of data rendering is printed periodically. The default is to run quietly.

**-V, --variable=NAME** The output variable name. The default name is 'graphics'.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Output variable already exists in input file.

## Examples

The following shows the creation of a standard set of graphics planes using cwgraphics. The file being acted upon is a CoastWatch HDF file created using the graphical cwmaster tool:

```
phollema@localhost:<~/cwatch/satdata/hdf> cwgraphics -v bc_coast.hdf
cwgraphics: Reading input bc_coast.hdf
cwgraphics: Creating graphics variable
cwgraphics: Rendering overlay at plane 2
cwgraphics: Rendering overlay at plane 3
cwgraphics: Rendering overlay at plane 4
```

Another example below shows the alteration of the default options. Only coast line and political line graphics are rendered to plane 1, and the output variable is named 'geography':

```
phollema@localhost:<~/cwatch/satdata/hdf> cwgraphics -v --land 0
  --grid 0 --coast 1 --political 1 --variable geography bc_coast.hdf
cwgraphics: Reading input bc_coast.hdf
cwgraphics: Creating geography variable
cwgraphics: Rendering overlay at plane 1
cwgraphics: Rendering overlay at plane 1
cwgraphics: Rendering overlay at plane 1
```

## A.9 cwimport

### Name

cwimport - translates Earth data into CoastWatch HDF.

### Synopsis

cwimport [OPTIONS] input1 [input2 ...] output

**Options:**

-c, --copy
-h, --help
-m, --match=PATTERN
-v, --verbose
--version

### Description

The import tool translates Earth data into CoastWatch HDF format. Multiple input files may be specified, but must have matching Earth transforms and dates. The utility loops over all input files and creates a single CoastWatch HDF output file. The utility does not handle multiple variables with the same name -- if a variable in an input file is encountered with the same name as an existing variable from a previous input file, the new variable is skipped. Options are available to alter verbosity and variable name matching.

### Parameters

**Main parameters:**

**input1 [input2 ...** ] The input data file name(s). At least one input file is required. If multiple files are specified, they must have matching dates and Earth transforms. The currently supported input formats are CoastWatch HDF, CoastWatch IMGMAP, TeraScan HDF, and NOAA 1b format GAC/LAC/HRPT AVHRR.

**output** The output data file name.

**Options:**

**-c, --copy** Turns on copy mode. In copy mode, variables from the input files are copied into an existing output file. The default is to create a new output file and populate it with data. Copy mode is especially useful for copying variables from one CoastWatch HDF file to another.

**-h, --help** Prints a brief help message.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be imported. By default, no pattern matching is performed and all variables are imported.

**-v, --verbose** Turns verbose mode on. The current status of data conversion is printed periodically. The default is to run quietly.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Input file dates or Earth transforms do not match.

## Examples

The following shows the import of several .cwf files to CoastWatch HDF with verbose mode on:

```
phollema@localhost:<~/cwatch/satdata> cwimport --verbose
  2002_214_2057_n16_wv_*.cwf 2002_214_2057_n16_wv.hdf

cwimport: Reading file [1/2], 2002_214_2057_n16_wv_c2.cwf
cwimport: Writing avhrr_ch2
cwimport: Writing graphics
cwimport: Reading file [2/2], 2002_214_2057_n16_wv_c4.cwf
cwimport: Writing avhrr_ch4
cwimport: Writing graphics
cwimport: Variable 'graphics' already exists, skipping
```

## A.10 cwinfo

### Name

cwinfo - prints earth data file information.

### Synopsis

cwinfo [OPTIONS] input

**Options:**

-h, --help
-t, --transform
-c, --coord
-v, --verbose
--version

### Description

The information utility dumps earth data information in a display-friendly format. The global earth information is printed such as satellite name, sensor, date, and earth transform information. The name of each variable is printed along with its data type, dimensions, scaling factor, and so on. For more detailed printing of generic HDF file contents, use the HDF hdp command.

When the **--transform** option is used, various additional earth transform information is printed. Let nc and nr be the x and y coordinate dimensions respectively, and mc=(nc-1)/2, mr=(nr-1)/2 be the midpoint coordinates. Note that indexing is zero-based and coordinates refer to the pixel center. Then the following information is computed:

- Pixel width at (mc,mr)
- Pixel height at (mc,mr)
- Total width from (0,mr) to (nc-1,mr)
- Total height from (mc,0) to (mc,nr-1)
- Center lat/lon at (mc,mr)
- Upper-left lat/lon at (0,0)
- Upper-right lat/lon at (mc-1,0)
- Lower-left lat/lon at (0,mr-1)
- Lower-right lat/lon at (mc-1,mr-1)

When the **--coord** option is used, Common Data Model coordinate systems are printed if available. Generally this style of coordinate system information is only available for files read by the NetCDF Java library.

## Parameters

**Main parameters:**

**input** The input data file name.

**Options:**

**-h, --help** Prints a brief help message.

**-t, --transform** Specifies that additional earth transform information should also be printed. The default is to show only global and variable information.

**-c, --coord** Specifies that Common Data Model coordinate system information should also be printed. The default is to show only global and variable information.

**-v, --verbose** Turns verbose mode on. The current status of automatic file identification is printed. This output is useful when trying to understand why a certain file is not being recognized by this and other tools. The default is to run quietly.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.

## Examples

The following shows an information dump of a CoastWatch HDF file from the West Coast:

```
phollema@localhost:<~/cwatch/satdata> cwinfo 2002_197_1100_n16_wn.hdf

Contents of file 2002_197_1100_n16_wn.hdf

Global information:
  Satellite:        noaa-16
```

```
  Sensor:           avhrr
  Date:             2002/07/16 JD 197
  Time:             11:00:08 UTC
  Pass type:        night
  Projection type:  mapped
  Map projection:   mercator
  Map affine:       0 -1469.95 1469.95 0 -15012623.67 6367109.52
  Origin:           USDOC/NOAA/NESDIS CoastWatch

Variable information:
  Variable       Type    Dimensions  Units          Scale     Offset
  avhrr_ch3      short   1024x1024   temp_deg_c     0.01      0
  avhrr_ch4      short   1024x1024   temp_deg_c     0.01      0
  avhrr_ch5      short   1024x1024   temp_deg_c     0.01      0
  sst            short   1024x1024   temp_deg_c     0.01      0
  cloud          byte    1024x1024   -              -         -
  sat_zenith     short   1024x1024   -              0.0001    0
  graphics       byte    1024x1024   -              -         -
```

## A.11 cwmaster

### Name

cwmaster - creates map projection master datasets.

### Synopsis

cwmaster [OPTIONS] input
cwmaster [OPTIONS]

**Options:**

-h, --help
-s, --splash
--version

### Description

The master utility creates map projection master data sets using a graphical user interface. A master projection specifies the translation between grid row and column coordinates and Earth latitude and longitude coordinates. A number of common map projections are available such as Mercator, Transverse Mercator, Polar Stereographic, Orthograpic, Lambert Conformal Conic, and so on. Detailed help on the usage of cwmaster is available from within the utility using the menu bar under *Help | Help and Support* .

### Parameters

**Main parameters:**

**input** The input data file name. If specified, the data file is opened and used as the initial map projection master.

**Options:**

**-h, --help** Prints a brief help message.

**-s, --splash** Shows the splash window on startup. The splash window shows the version, author, and web site information.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.
- Input file does not contain a map projection.

## Examples

The following shows the use of cwmaster to load master parameters from a CoastWatch IMGMAP file:

```
phollema@localhost:<~/cwatch/satdata/2002_319_2144_n16_wl> cwmaster
  2002_319_2144_n16_wl_c2.cwf
```

## A.12 cwmath

### Name

cwmath - combines Earth data using a mathematical expression.

### Synopsis

cwmath [OPTIONS] input
cwmath [OPTIONS] input1 [input2 ...] output

**Options:**

-c, --scale=FACTOR/OFFSET
-e, --expr=EXPRESSION
-h, --help
-l, --longname=STRING
-s, --size=TYPE
-t, --template=VARIABLE
-u, --units=STRING
-v, --verbose
--version

### Description

The math tool combines Earth data using a mathematical expression. The expression takes the form:

```
variable = formula
```

where the variable is the output variable to create and the formula is a mathematical combination of input variables. The formula may contain a number of standard operators, for example addition and subtraction, as well as functions such as sine and cosine and numerical and symbolic constants. The supported operators and functions are as follows:

| Operator | Symbol |
|---|---|
| Power | ^ |
| Boolean Not | ! |
| Unary Plus, Unary Minus | +x, -x |
| Modulus | % |
| Division | / |
| Multiplication | * |
| Addition, Subtraction | +, - |
| Less or Equal, More or Equal | <=, >= |
| Less Than, Greater Than | <, > |
| Not Equal, Equal | !=, == |
| Boolean And | && |
| Boolean Or | \|\| |

| Function | Calling sequence |
|---|---|
| Sine | sin (x) |
| Cosine | cos (x) |
| Tangent | tan (x) |
| Arc Sine | asin (x) |
| Arc Cosine | acos (x) |
| Arc Tangent | atan (x) |
| Hyperbolic Sine | sinh (x) |
| Hyperbolic Cosine | cosh (x) |
| Hyperbolic Tangent | tanh (x) |
| Inverse Hyperbolic Sine | asinh (x) |
| Inverse Hyperbolic Cosine | acosh (x) |
| Inverse Hyperbolic Tangent | atanh (x) |
| Natural Logarithm | ln (x) |
| Logarithm base 10 | log (x) |
| Angle | angle (x) |
| Absolute Value / Magnitude | abs (x) |
| Random number (between 0 and 1) | rand () |
| Modulus | mod (x) |
| Square Root | sqrt (x) |
| Sum | sum (x1, x2, ...) |
| if (condition is true) then return (x1) else return (x2) | select (condition, x1, x2) |
| Hexadecimal decoder | hex (string) |
| if (b (BITWISE OR) mask == 0) then return (x) else return (Not-a-Number) | mask (x, b, mask) |
| Bitwise And | and (x1, x2) |
| Bitwise Or | or (x1, x2) |
| Bitwise Xor | xor (x1, x2) |
| Bitwise Not | not (x) |

| Constant | Value |
|---|---|
| e | 2.7182818... |
| pi | 3.1415927... |
| nan (Not-a-Number) | NaN |

Note that boolean expressions are evaluated to be either 1 or 0 (true or false respectively).

## Parameters

**Main parameters:**

**input** The single input and output data file. In the case that a single input file is specified and no output file, data is read from and written to the same file. The new variable created by the expression must not already exist in the input file.

**input1 [input2...]** The input data file name(s). If multiple input files are specified, variables on the right hand side of the expression (or used in the **--template** option) must be prefixed by the string 'file<N>_' where <N> is replaced with the index of the input file which contains the variable and input file indexing starts at 1. For example, to reference the variable 'avhrr_ch4' in the second input file, use 'file2_avhrr_ch4' in the expression.

**output** The output data file name. If specified and the file does not already exist, it will be created using metadata from the first input file. If it does exist, it will be opened and checked for a compatible Earth transform and the new variable data will be added to the file. The new variable created by the expression must not already exist in the output file. The output file can be one of the input files if needed.

**Options:**

**-c, –scale=FACTOR/OFFSET** The output variable scale and offset. The scaling is used to store floating-point values as integers using the equation:

```
integer = value/factor + offset
```

The default is '0.01,0'. This option is ignored if **--size** is 'float'.

**-e, --expr=EXPRESSION** The mathematical expression. See above for the expression syntax and supported operators and functions. If no expression is specified, the user will be prompted to enter an expression at the keyboard. The latter method is recommended for operating systems such as Microsoft Windows in which the command line shell can mangle some expression characters such as the equals sign.

**-h, --help** Prints a brief help message.

**-l, --longname=STRING** The output variable long name. The long name is a verbose string to describe the variable in common terms. For example, the variable named 'sst' might have the long name 'sea surface temperature'. The default is to use the output variable name as the long name.

**-s, --size=TYPE** The output variable value size. Valid choices are 'byte' or 'ubyte' for 8-bit signed or unsigned bytes, 'short' or 'ushort' for 16-bit signed or unsigned integers, and 'float' for 32-bit floating-point values with no scaling. The default is 'short'.

**-t, --template=VARIABLE** The output template variable. When a template is used, the output variable size, scaling, units, long name, and missing value are all determined from the template variable. Any of these properties set from the command line override the corresponding template property. There is no default template variable.

**-f, --full-template** Turns on full template attribute mode. All attributes from the template variable (except for those overridden at the command line) are copied to the output variable. By default only the minimal set of attributes is written.

**-u, --units=STRING** The output variable units. For example if the output variable data is based on temperature in Celsius, the variable units might be 'celsius'. There is no default units value.

**-v, --verbose** Turns verbose mode on. The current status of computation is printed periodically. The default is to run quietly.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Invalid mathematical expression.
- Output variable already exists in input file.
- Invalid scale or size specified.
- Unsupported variable rank detected.
- Invalid expression variable name.

## Examples

The following shows the correction of AVHRR channel 2 data for solar zenith angle. The output variable is named 'avhrr_ch2_corr' and is written to the input file:

```
phollema@localhost:<~/cwatch/satdata/hdf> cwmath -v --units
  "percent" --longname "AVHRR channel 2 corrected"
  --expr "avhrr_ch2_corr = avhrr_ch2/cos(sun_zenith*pi/180)"
```

```
  2003_104_1513_n17_er.hdf

cwmath: Reading input 2003_104_1513_n17_er.hdf
cwmath: Creating avhrr_ch2_corr variable
cwmath: Computing row 0
cwmath: Computing row 100
cwmath: Computing row 200
cwmath: Computing row 300
...
```

Another example below shows the computation of Normalized Difference Vegetation Index (NDVI):

```
phollema@localhost:<~/cwatch/satdata/hdf> cwmath -v --longname
  "Normalized Difference Vegetation Index"
  --expr "ndvi = (avhrr_ch2 - avhrr_ch1)/(avhrr_ch2 + avhrr_ch1)"
  2003_104_1513_n17_er.hdf

cwmath: Reading input 2003_104_1513_n17_er.hdf
cwmath: Creating ndvi variable
cwmath: Computing row 0
cwmath: Computing row 100
cwmath: Computing row 200
cwmath: Computing row 300
...
```

In order to demonstrate the use of the 'mask' function, the example below shows the masking of the 'sst' variable using the 'cloud' variable. Note that a hexadecimal value is used to determine which values from the cloud mask are used in the masking procedure. Since the cloud data is represented by 8-bit bytes, the hexadecimal mask value need only specify two hexadecimal digits. In this case, the value '0x6f' represents bits 1, 2, 3, 4, 6, and 7 (for all cloud mask bits, the value would be '0xff'):

```
phollema@localhost:<~/cwatch/satdata/hdf> cwmath -v --template sst
  --expr 'sst_masked = mask (sst, cloud, hex ("0x6f"))'
  2003_104_1513_n17_er.hdf

cwmath: Reading input 2003_104_1513_n17_er.hdf
cwmath: Creating sst_masked variable
cwmath: Computing row 0
cwmath: Computing row 100
cwmath: Computing row 200
cwmath: Computing row 300
...
```

A final example below shows how the tool may be used to compute complex formulas using a Unix Bourne shell script. The example computes the theoretical AVHRR channel 3b albedo at night for NOAA-17 using actual channel 3b temperatures and channel 3b emission temperatures estimated from channel 4 and 5:

```
#!/bin/sh

input=$1
T3E_A=6.82947
T3E_B=0.97232
T3E_C=1.66366
ZERO_C=273.15
t3="(avhrr_ch3 + $ZERO_C)"
t4="(avhrr_ch4 + $ZERO_C)"
t5="(avhrr_ch5 + $ZERO_C)"
t3e="($T3E_A + $T3E_B*$t4 + $T3E_C*($t4 - $t5))"
planck_c1=1.1910427e-5
planck_c2=1.4387752
w3=2669.3554
c3b_a=1.702380
c3b_b=0.997378
rad3="(($planck_c1*($w3^3)) / (e^(($planck_c2*$w3)/($c3b_a + $c3b_b*$t3)) - 1.0))"
rad3e="(($planck_c1*($w3^3)) / (e^(($planck_c2*$w3)/($c3b_a + $c3b_b*$t3e)) - 1.0))"
alb3="(100*(1 - $rad3/$rad3e))"
cwmath -v --longname "AVHRR channel 3 albedo" --units "percent" \
  --expr "avhrr_ch3_albedo=$alb3" $input
```

## A.13 cwnavigate

### Name

cwnavigate - adds navigation corrections to Earth data.

### Synopsis

cwnavigate [OPTIONS] {-t, --trans=ROWS/COLS} input
cwnavigate [OPTIONS] {-r, --rotate=ANGLE} input
cwnavigate [OPTIONS] {-a, --affine=A/B/C/D/E/F} input
cwnavigate [OPTIONS] {-R, --reset} input

**Options:**

-h, --help
-m, --match=PATTERN
-v, --verbose
--version

### Description

The navigation tool adds navigation corrections to 2D variables in an Earth data file by setting navigation transform parameters. The most basic navigation transform consists of additive translation in the row and column data coordinates. As an example of translation, the following diagram shows coastlines in the Earth image data as a '.' (period) symbol and coastlines derived from a GIS database as a '*' (star). Translation has been used to correct the position of the image data:

```
  ***                              ***
... ***         *****                ***         *****
  ... ***     **...                    ***     **
    ... *   .**          ---->           *    **
      . *  **                            *  **
      . ****        row trans = 1        ****
      ....          col trans = -2
```

A more generic navigation transform consists of a translation combined with a rotation or shear. To represent generic navigation transforms, an affine transform matrix is used to convert "desired" data coordinates to "actual" data coordinates as follows:

```
|row'|   |a  c  e|  |row|
|    |   |       |  |   |
|col'| = |b  d  f|  |col|
|    |   |       |  |   |
| 1  |   |0  0  1|  | 1 |
```

where [a..f] are the affine transform matrix coefficients and (row',col') is the actual data coordinates at which the desired data value for (row,col) may be found.

To apply a navigation transform to a 2D variable, the existing navigation transform is read and the new transform is applied to it using matrix multiplication to create a combined transform. As an example, suppose that T1 is the initial navigation transform. The application of an additional transform T2 results in a new transform that is equivalent to:

```
T2 (T1 (row, col))
```

A navigation transform can be applied to a subset of 2D variables, or all variables in the file. Note that satellite channel data or channel-derived variables should be corrected with navigation but GIS-derived variables such as coastline and lat/lon grid graphics should not be corrected. Setting the navigation transform simply establishes a mapping between desired and actual data coordinates -- it does not change the gridded data values themselves. Once a navigation transform has been set, other CoastWatch tools in this package will take the transform into account when reading the data.

## Parameters

**Main parameters:**

**-t, --trans=ROWS/COLS** The translation transform to apply. The actual row and column coordinates are calculated by adding the specified row and column translation to the desired coordinates.

**-r, --rotate=ANGLE** The rotation transform to apply. The actual row and column coordinates are calculated by rotating the desired row and column coordinates about the data center by the specified angle in degrees. Positive angles rotate counter-clockwise while negative angles rotate clockwise.

**-a, --affine=A/B/C/D/E/F** The explicit affine transform to apply. The coefficients are used to form the affine transform matrix (see the Description section above) which is applied to the existing transform using matrix multiplication.

**-R, --reset** Specifies that the existing navigation transform should be reset to the identity. Under the identity transform, no navigation correction is performed.

**input** The input data file name. The navigation corrections are applied to the input file in-situ. For CoastWatch HDF files, the corrections are applied to individual variables. For CoastWatch IMGMAP files, corrections are applied to the global attributes and the **--match** option has no effect. No other file formats are supported.

**Options:**

**-h, --help** Prints a brief help message.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be navigated. By default, no pattern matching is performed and all variables are navigated.

**-v, --verbose** Turns verbose mode on. The status of navigation correction is printed periodically. The default is to run quietly.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.
- Unsupported navigation correction.

## Examples

The following example shows the navigation correction of a NOAA-15 CoastWatch HDF data file from the Gulf of Mexico:

```
phollema@localhost:<~/cwatch/satdata> cwnavigate --trans -3/3 -v
  --match '(avhrr.*|cloud|sst)' 2002_328_1326_n15_ml.hdf

cwnavigate: Reading input 2002_328_1326_n15_ml.hdf
cwnavigate: Applying navigation correction to avhrr_ch1
cwnavigate: Applying navigation correction to avhrr_ch2
cwnavigate: Applying navigation correction to avhrr_ch4
cwnavigate: Applying navigation correction to cloud
cwnavigate: Applying navigation correction to sst
```

Another example below shows the navigation correction of a NOAA-15 CoastWatch IMGMAP data file from the US east coast:

```
phollema@localhost:<~/cwatch/satdata> cwnavigate --trans -2/1 -v
  2002_326_1330_n15_er_c2.cwf
```

```
cwnavigate: Reading input 2002_326_1330_n15_er_c2.cwf
cwnavigate: Applying navigation correction
```

## A.14 cwregister

### Name

cwregister - resamples gridded Earth data to a master projection.

### Synopsis

cwregister [OPTIONS] master input output

**Options:**

-h, --help
-m, --match=PATTERN
-M, --method=TYPE
-O, --overwrite=TYPE
-p, --polysize=KILOMETERS
-r, --rectsize=WIDTH/HEIGHT
-v, --verbose
--version

### Description

The register tool resamples gridded Earth data to a master projection. A master projection specifies the translation between grid row and column coordinates and Earth latitude and longitude coordinates. The master projection file is any valid Earth data file from which a set of row and column dimensions and Earth transform parameters may be extracted. This includes standard CoastWatch product files as well as master files created using the **cwmaster** tool.

### Parameters

**Main parameters:**

**master** The master projection file name. Note that the master file is not altered in any way. It is simply accessed in order to determine grid and Earth transform parameters.

**input** The input data file name.

**output** The output data file name.

**Options:**

**-h, --help** Prints a brief help message.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables in the input file matching the pattern will be registered. By default, no pattern matching is performed and all variables are registered.

**-M, --method=TYPE** The registration resampling method. Valid methods are 'inverse' and 'mixed'. The inverse resampling method divides the destination into rectangles of bounded physical size (see the **--polysize** option), and computes polynomial approximations for the coordinate transforms on each rectangle in order to determine a source coordinate for each destination coordinate. This is the default method and recommended when the source coordinate transform is smooth and continuous in the destination coordinate space such as with AVHRR LAC swath data. The mixed resampling method divides the source into rectangles of certain dimensions (see the **--rectsize** option), computes polynomials on each rectangle similar to the inverse method, and follows with a single pixel interpolation. This method is recommended when the source coordinate transform is discontinuous at regular intervals in the destination coordinate space, such as with MODIS swath data.

**-O, --overwrite=TYPE** ADVANCED USERS ONLY. Sets the overwrite policy for 'mixed' mode resampling: either 'always' (the default), 'never', or 'closer'. If during resampling, more than one source pixel maps to a single destination pixel, this option is used to determine if the new value should overwrite the old value. By default, the new value always overwrites the destination pixel (the 'always' mode). If 'never' is specified, the first written value is never overwritten. If 'closer' is specified, the destination pixel is only overwritten if the source pixel is closer in physical location to the destination than any previous source pixel.

**-p, --polysize=KILOMETERS** The polynomial approximation rectangle size in kilometers. This option is only used by the inverse resampling method (see the **--method** option). The inverse resampling method employs a polynomial approximation to speed up the calculation of data locations. The polynomial rectangle size determines the maximum allowed size of the resampling rectangles in the destination. The default polynomial size is 100 km, which introduces an error of less than 0.15 km for AVHRR LAC data.

**-r, --rectsize=WIDTH/HEIGHT** The polynomial approximation rectangle size in pixels. This option is only used by the mixed resampling method (see the **--method** option). The mixed resampling method employs a polynomial approximation to speed up the calculation of data locations. The polynomial rectangle size determines the exact dimensions of the resampling rectangles in the source. The default polynomial rectangle size is 50/50, which introduces only a small error for AVHRR LAC data.

**-v, --verbose** Turns verbose mode on. The current status of data conversion is printed periodically. The default is to run quietly.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid master, input or output file names.

- Unsupported master or input file format.

## Examples

The following shows the registration of NOAA-17 AVHRR channel 2 swath data to a southern California master:

```
phollema@localhost:<~/cwatch/satdata/2002_318_1826_n17_mo> cwregister
  -v --match avhrr_ch2 ws_master.hdf 2002_318_1826_n17_mo.hdf
  2002_318_1826_n17_ws.hdf

cwregister: Reading master ws_master.hdf
cwregister: Reading input 2002_318_1826_n17_mo.hdf
cwregister: Creating output 2002_318_1826_n17_ws.hdf
cwregister: Adding avhrr_ch2 to resampled grids
GridResampler: Found 1 grid(s) for resampling
GridResampler: Resampling 4788x2048 to 1024x1024
GridResampler: Creating location estimators
GridResampler: Computing row 0
GridResampler: Computing row 100
GridResampler: Computing row 200
GridResampler: Computing row 300
GridResampler: Computing row 400
GridResampler: Computing row 500
GridResampler: Computing row 600
GridResampler: Computing row 700
GridResampler: Computing row 800
GridResampler: Computing row 900
GridResampler: Computing row 1000
cwregister: Closing files
```

## A.15 cwrender

### Name

cwrender - performs Earth data visualization.

### Synopsis

cwrender {-c, --composite=RED/GREEN/BLUE} [OPTIONS] input output
cwrender {-e, --enhance=VARIABLE1[/VARIABLE2]} [OPTIONS] input output

**General options:**

-h, --help
-v, --verbose
--version

**Output content and format options:**

-a, --noantialias
-f, --format=TYPE
-i, --indexed
-I, --imagecolors=NUMBER
-l, --nolegends
-m, --magnify=LATITUDE/LONGITUDE/FACTOR
-o, --logo=NAME
-s, --size=PIXELS | full
-T, --tiffcomp=TYPE
-W, --worldfile=FILE

**Plot overlay options:**

-A, --bath=COLOR[/LEVEL1/LEVEL2/...]
-b, --bitmask=VARIABLE/MASK/COLOR
-C, --coast=COLOR[/FILL]
-d, --cloud=COLOR
-g, --grid=COLOR
-H, --shape=FILE/COLOR[/FILL]
-L, --land=COLOR
-p, --political=COLOR
-S, --nostates
-t, --topo=COLOR[/LEVEL1/LEVEL2/...]
-u, --group=GROUP

-w, --water=COLOR
-X, --exprmask=EXPRESSION/COLOR

**Color enhancement options:**

-E, --enhancevector=STYLE/SYMBOL[/SIZE]
-F, --function=TYPE
-k, --background=COLOR
-M, --missing=COLOR
-P, --palette=NAME
-r, --range=MIN/MAX
-U, --units=UNITS

**Color composite options:**

-B, --bluerange=MIN/MAX
-G, --greenrange=MIN/MAX
-R, --redrange=MIN/MAX
-x, --redfunction=TYPE
-y, --greenfunction=TYPE
-z, --bluefunction=TYPE

## Description

### Overview

The render tool performs Earth data visualization by converting 2D data sets in the input file to color images. The data values are converted from scientific units to a color using either an enhancement function and color palette or by performing a color composite of three data variables -- one for each of the red, green, and blue color components. The resulting Earth data plot may have legends displaying the color scale, data origin, date, time, projection info, as well as data overlays showing latitude/longitude grid lines, coast lines, political boundaries, masks, and shapes.

### Overlay colors

Overlay colors may be specified using simple color names such as 'red', 'gray', 'cyan', 'blue', and 'green'. Overlays may be made to appear slightly transparent (allowing the color behind to show through) by following the color name with a colon ':' and a transparency value in percent, for example 'red:50' would make the overlay red with a 50% transparency. Transparency values range from 0 (completely opaque) to 100 (completely transparent).

Colors may also be specified using explicit hexadecimal notation for red/green/blue color components and optional alpha component as follows:

```
0xAARRGGBB
```

```
^ ^ ^ ^
| | | ----- Blue              \
| | ------- Green             |---- Range: 00 -> ff
| --------- Red               |
----------- Alpha (optional)  /
```

Note that the prepended '0x' denotes a hexadecimal constant, and must be used even though it is not part of the color component values. As an example, the simple color names above may be specified as hexadecimal values:

```
0xff0000    red
0x555555    gray
0x00ffff    cyan
0x0000ff    blue
0x00ff00    green
0x80ff0000  red, 50% transparent
```

**Rendering order**

The data view itself (not including the legends) is rendered in such a way that overlays may overlap each other. For example, latitude/longitude grid lines may fall on top of land polygons because the grid overlay is rendered after the coastline overlay. Knowing the order in which the data and overlays are rendered may answer some questions if the data view doesn't look the way the user expects. The data view is rendered in the following order:

1. Before any overlay or data, the data view is filled with a background color (normally white) for vector plots or a missing color (normally black) for color enhancement or color composite plots.
2. Color vectors or image pixels are rendered to the data view. The background or missing color will show though where no vectors or pixels were rendered.
3. Data overlays are rendered to the view in the following order (see the description of each option below):
   - Cloud mask (**--cloud** )
   - Bit masks (**--bitmask** ), possibly more than one
   - Expression masks (**--exprmask** ), possibly more than one
   - Water mask (**--water** )
   - Bathymetric contours (**--bath** )
   - Land mask (**--land** )
   - Coastline and filled land polygons (**--coast** )
   - Political lines (**--political** )
   - Topography contours (**--topo** )

- Shape files (**--shape** ), possibly more than one
- Latitude/longitude grid lines (**--grid** )
- Overlay groups (**--group** )

## Parameters

**Main parameters:**

**-c, --composite=RED/GREEN/BLUE** Specifies color composite mode using the named variables. The data variable values are converted to colors using an individual linear enhancement function for each variable. The data values are scaled to the range [0..255] and used as the red, green, and blue components of each pixel's color. Either this option or **--enhance** must be specified, but not both.

**-e, --enhance=VARIABLE1[/VARIABLE2]** Specifies color enhancement mode using the named variable(s). The data variable values are converted to colors using an enhancement function and color palette. Either this option or **--composite** must be specified, but not both. If one variable name is specified, the plot shows color-enhanced image data. If two variable names are specified, the plot shows color-enhanced vectors whose direction is derived using the two variables as vector components. See the **--enhancevector** and **--background** options for settings that are specific to vector plots.

**input** The input data file name.

**output** The output image file name. Unless the **--format** option is used, the file extension indicates the desired output format: '.png', '.jpg', '.tif', or '.pdf'.

**General options:**

**-h, --help** Prints a brief help message.

**-v, --verbose** Turns verbose mode on. The current status of data rendering is printed periodically. The default is to run quietly.

**--version** Prints the software version.

**Output content and format options:**

**-a, --noantialias** Turns off line and font antialiasing. By default, the edges of lines and fonts are smoothed using shades of the drawing color. It may be necessary to turn off antialiasing if the smoothing is interfering with the readability of annotation graphics, such as in the case of very small fonts. This option only effects raster image output formats such as PNG, GIF and JPEG.

**-f, --format=TYPE** The output format. The current formats are 'png' for Portable Network Graphics, 'gif' for Graphics Interchange Format, 'jpg' for Joint Picture Experts Group, 'tif' for Tagged Image File Format with geolocation tags (GeoTIFF), 'pdf' for Portable Document Format, or 'auto' to detect the format from the output file name. The default is 'auto'. The correct choice of output format is governed by the desired use of the rendered image as follows:

- **PNG** is a non-lossy compressed image format supported by most web browsers and image manipulation software. It has similar data compression characteristics to GIF and additionally supports 24-bit color images.
- **GIF** is a non-lossy compressed format also supported by most web browsers and image manipulation software. The GIF files produced use LZW compression. Images stored in GIF format are run through a color quantization algorithm to reduce the color map to 256 colors or less. Although file sizes are generally smaller than PNG, image quality may be compromised by the reduced color map.
- **JPEG** is a lossy compressed format that should be used with caution for images with sharp color lines such as those found in text and annotation graphics. The JPEG format generally achieves higher compression than PNG or GIF resulting in smaller image file sizes.
- **GeoTIFF** is a flexible image format with support for Earth location metadata. Many popular GIS packages handle GeoTIFF images and allow the user to combine a GeoTIFF base map image with other sources of raster and vector data. The GeoTIFF images generated are non-lossy uncompressed image data (unless a compression is specified using **--tiffcomp** ), and can be much larger than the corresponding PNG, GIF, or JPEG. Since GeoTIFF images are generally destined for import into a GIS system, the use of this format turns on the **--nolegends** option. In general the GeoTIFFs generated are 24-bit colour images, but when no overlays are specified or the **--indexed** or **--imagecolors** options are used, a special 8-bit paletted image file is generated and comments describing the data value scaling are inserting into the image description tags.
- **PDF** is a standard for high quality publishing developed by Adobe Systems and is used for output to a printer via such tools as the Adobe Acrobat Reader. In general PDF files are slightly larger than the equivalent PNG but retain highly accurate vector graphics components such as lines and fonts.

**-i, --indexed** Short for **--imagecolors 256** . See the **--imagecolors** option below.

**-I, --imagecolors=NUMBER** The number of colors to use for the index color model of the data image, up to 256. Normally the data image uses an unlimited number of colors because this achieves the best visual rendering quality. But in some cases it may be desirable to make the output file smaller by limiting the number of colors to <=256 values and using a index color model so that each data pixel can be represented as 8-bit bytes. This option can only be used with PNG, GIF, GeoTIFF, and PDF output formats, and only with color enhancements, not color composites. While in index color mode, antialiasing is turned off.

**-l, --nolegends** Turns the plot legends off. By default, the Earth data view is shown in a frame on the left and to the right color scale and plot information legends are drawn. With no legends, the Earth data is simply rendered by itself with no frame, borders, or legends.

**-m, --magnify=LATITUDE/LONGITUDE/FACTOR** The magnification center and factor. The data view is set to the specified center and pixel magnification factor. The center position is specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180] and the magnification factor as a fractional number (0..1] where factors > 1 magnify and factors < 1 shrink. By default, the data view shows the entire data field with an optimal magnification factor to fit the desired view size (see **--size** ).

**-o, --logo=NAME** The logo used for plot legends. The current predefined logo names are 'noaa3d' (the default), 'nasa3d', 'nws3d', 'doc3d', and their corresponding non-3D versions 'noaa', 'nasa',

'nws', and 'doc'. The predefined logos are named for their respective government agencies: NOAA, NASA, National Weather Service (NWS), and Department of Commerce (DOC). The user may also specify a custom logo file name, which can be any PNG, GIF, or JPEG file.

**-s, --size=PIXELS | full** The Earth data view size in pixels. The data view is normally accompanied by a set of legends unless the **--nolegends** option is used. By default, the view size is 512 pixels, plus the size of any legends. If 'full' is specified rather than a size in pixels, the view size is set to match the actual full extent of the data, ie: full resolution.

**-T, --tiffcomp=TYPE** The TIFF compression algorithm. The valid types are 'none' for no compression (the default), 'deflate' for ZIP style compression, and 'pack' for RLE style PackBits compression. This option is only used with GeoTIFF output.

**-W, --worldfile=FILE** The name of the world file to write. A world file is an ASCII text file used for georeferencing images that contains the following lines:

- Line 1: x-dimension of a pixel in map units
- Line 2: rotation parameter
- Line 3: rotation parameter
- Line 4: NEGATIVE of y-dimension of a pixel in map units
- Line 5: x-coordinate of center of upper left pixel
- Line 6: y-coordinate of center of upper left pixel

World files may be written for any GIF, PNG, or JPEG image. The use of this option turns on the **--nolegends** option. The convention used in GIS is to name the world file similarly to the image file, but with a different extension. GDAL expects world files with a ".wld" extension, where as ESRI applications expect ".pgw" for PNG, ".gfw" for GIF, and ".jgw" for JPEG. Users should name their world files accordingly.

**Plot overlay options:**

**-A, --bath=COLOR[/LEVEL1/LEVEL2/...]** The bathymetric contour color and levels. The color is specified by name or hexadecimal value (see above). Bathymetric contours are generated for the specified integer levels in meters. If no levels are specified, contours are drawn at 200 m and 2000 m. The default is not to render bathymetric contours.

**-b, --bitmask=VARIABLE/MASK/COLOR** Specifies that a mask should be rendered on top of the data image whose pixels are obtained by a bitwise AND with the mask value. The named variable is used to mask the Earth data with the specified color and mask. The color is a name or hexadecimal value (see above). The mask is a 32-bit integer hexadecimal value specifying the mask bits. The bitmask is formed by bitwise ANDing the data value and mask value. If the result of the operation is non zero, the pixel is colored with the bitmask color. This option is useful for overlaying graphics on the data image when the graphics are stored as an integer valued variable in the data set. Such variables include cloud and land mask graphics. Multiple values of the **--bitmask** option may be given, in which case the masks are applied in the order that they are specified.

**-C, --coast=COLOR[/FILL]** The coast line color and optional fill color. The colors are specified by name or hexadecimal value (see above). The default is not to render coast lines.

**-d, --cloud=COLOR** The cloud mask color. The color is specified by name or hexadecimal value (see above). Cloud masking requires that a 'cloud' variable exists in the input file. The default is not to render a cloud mask.

**-g, --grid=COLOR** The latitude/longitude grid line color. The color is specified by name or hexadecimal value (see above). The default is not to render grid lines.

**-H, --shape=FILE/COLOR[/FILL]** The name and drawing/fill colors for a user-supplied shape file. The colors are specified by name or hexadecimal value (see above). The only file format currently supported is ESRI shapefile format, and only line and polygon data (no point data). The fill color is optional and is used to fill polygons if any are found in the file. Multiple values of the **--shape** option may be given, in which case the shape overlays are rendered in the order that they are specified.

**-L, --land=COLOR** The land mask color. The color is specified by name or hexadecimal value (see above). Land masking requires that a 'graphics' variable exists in the input file with a land mask at bit 3 where bit numbering starts at 0 for the least significant bit. The default is not to render a land mask. For an alternative to the **--land** option, try using the **--coast** option with a fill color.

**-p --political=COLOR** The political boundaries color. The color is specified by name or hexadecimal value (see above). The default is not to render political boundaries.

**-S, --nostates** Turns off state boundary rendering. The default when **--political** is specified is to render international and state boundaries. With this option is specified, only international boundaries are rendered.

**-t, --topo=COLOR[/LEVEL1/LEVEL2/...]** The topographic contour color and levels. The color is specified by name or hexadecimal value (see above). Topographic contours are generated for the specified integer levels in meters. If no levels are specified, contours are drawn at 200 m, 500 m, 1000 m, 2000 m, and 3000 m. The default is not to render topographic contours.

**-u, --group=GROUP** The overlay group name to render. Overlay groups are a concept from the CoastWatch Data Analysis Tool (CDAT). CDAT users can save a set of preferred overlays as a group and then restore those overlays when viewing a new data file. The same group names saved from CDAT are available to be rendered here. This is an extremely useful option that allows users to design a set of overlays graphically and adjust the various overlay properties beyond what can be achieved using the command line options for cwrender. If specified, this option will cause all overlays in the group to be drawn on top of any other overlays specified by command line options.

**-w, --water=COLOR** The water mask color. The color is specified by name or hexadecimal value (see above). Water masking is performed similarly to land masking (see the **--land** option), but the sense of the land mask is inverted. The default is not to render a water mask.

**-X, --exprmask=EXPRESSION/COLOR** Specifies that a mask should be rendered on top of the data image whose pixels are obtained by evaluating the expression. The color is specified by name or hexadecimal value (see above). An expression mask is a special type of multipurpose mask similar to a bitmask (see the **--bitmask** option above) but which allows the user to specify a mathematical expression to determine the mask. If the result of the expression is true (in the case of a boolean result) or non-zero (in the case of a numerical result), the data image is masked at the given location with the given color. Multiple values of the **--exprmask** option may be given, in which case the masks are applied in the order that they are specified. The syntax for

the expression is identical to the right-hand-side of a **cwmath** expression (see the **cwmath** tool manual page).

**Color enhancement options:**

**-E, --enhancevector=STYLE/SYMBOL[/SIZE]** The color-enhanced vector specifications. This option is only used if two variable names are passed to the **--enhance** option. The vector style may be either 'uvcomp' or 'magdir'; the default is 'uvcomp'. In uvcomp mode, the variables that are passed to the **--enhance** option are taken to be the U (x-direction) and V (y-direction) components of the vector. In magdir mode, the first variable is taken to be the vector magnitude, and the second to be the vector direction in degrees clockwise from north. The vector symbol may be either 'arrow' to draw arrows in the direction of the vector, or 'barb' to draw WMO wind barbs; the default is 'arrow'. If wind barbs are used, the feathered end of the barb points in the direction of the wind. Lastly, the size of the vector symbols in pixels may be specified; the default size is 10.

**-F, --function=TYPE** The color enhancement function. Data values are mapped to the range [0..255] by the enhancement function and range, and then to colors using the color palette. The valid enhancement function types are 'linear', 'stepN', 'log', 'linear-reverse', 'stepN-reverse', and 'log-reverse' where N is the number of steps in the function, for example 'step10'. The reverse functions are equivalent to the non-reversed functions but map data values to the range [255..0] rather then [0..255]. By default, the enhancement function is 'linear'. A log enhancement may be necessary when the data value range does not scale well with a linear enhancement such as with chlorophyll concentration derived from ocean color data.

**-k, --background=COLOR** The color for the background of vector plots. The color is specified by name or hexadecimal value (see above). The default background color is white.

**-M, --missing=COLOR** The color for missing or out of range data values. The color is specified by name or hexadecimal value (see above). The default missing color is black.

**-P, –palette=NAME** The color palette for converting data values to colors. The color palettes are dervied in part from the Interactive Data Language (IDL) v5.4 palettes and have similar names. The valid color palette names are as follows (line indexes are simply for reference):

```
0  BW-Linear
1  HSL256
2  RAMSDIS
3  Blue-Red
4  Blue-White
5  Grn-Red-Blu-Wht
6  Red-Temperature
7  Blue-Green-Red-Yellow
8  Std-Gamma-II
9  Prism
10 Red-Purple
11 Green-White-Linear
12 Grn-Wht-Exponential
```

```
13 Green-Pink
14 Blue-Red2
15 16-Level
16 Rainbow
17 Steps
18 Stern-Special
19 Haze
20 Blue-Pastel-Red
21 Pastels
22 Hue-Sat-Lightness-1
23 Hue-Sat-Lightness-2
24 Hue-Sat-Value-1
25 Hue-Sat-Value-2
26 Purple-Red-Stripes
27 Beach
28 Mac-Style
29 Eos-A
30 Eos-B
31 Hardcandy
32 Nature
33 Ocean
34 Peppermint
35 Plasma
36 Rainbow2
37 Blue-Waves
38 Volcano
39 Waves
40 Rainbow18
41 Rainbow-white
42 Rainbow-black
43 NDVI
44 GLERL-Archive
45 GLERL-30-Degrees
46 Chlora-1
47 Chlora-anom
48 Spectrum
49 Wind-0-50
50 CRW_SST
51 CRW_SSTANOMALY
52 CRW_HOTSPOT
53 CRW_DHW
54 StepSeq25
```

By default, the 'BW-Linear' palette is used which is a gray scale color ramp from black to white.

**-r, --range=MIN/MAX** The color enhancement range. Data values are mapped to colors using the minimum and maximum values and an enhancement function. By default, the enhancement

range is derived from the data value mean and standard deviation to form an optimal enhancement window of 1.5 standard deviation units around the mean.

**-U, --units=UNITS** The range and color scale units for the enhancement variable(s). By default, the user must specify the values for the **--range** option in the standard units indicated in the data. If the user prefers a different set of units to be used, they may be specified here. Many common units are accepted (and various forms of those units), for example 'kelvin', 'celsius' and 'fahrenheit' for temperature data, 'knots', 'meters per second' or 'm/s' for windspeed, and 'mg per m^-3' or 'kg/m-3' for concentration. For other possible unit names, see the conventions used by the Unidata UDUNITS package and its supported units file.

**Color composite options:**

**-B, --bluerange=MIN/MAX** The blue component enhancement range, see **--redrange** .

**-G, --greenrange=MIN/MAX** The green component enhancement range, see **--redrange** .

**-R, --redrange=MIN/MAX** The red component enhancement range. Data values are mapped to the range [0..255] using the minimum and maximum values and an enhancement function. By default, the enhancement range is derived from the data value mean and standard deviation to form an optimal enhancement window of 1.5 standard deviation units around the mean.

**-x, --redfunction=TYPE** The red component enhancement function. Data values are mapped to the range [0..255] by the enhancement function and range, and then the pixel color is created by compositing the red, green, and blue mapped values into one 32-bit integer color value. See the **--function** option for valid function types. By default, the red, green, and blue enhancements are linear.

**-y, --greenfunction=TYPE** The green component enhancement function, see **--redfunction** .

**-z, --bluefunction=TYPE** The blue component enhancement function, see **--redfunction** .

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid variable name.
- Unrecognized format.
- Unrecognized color name.
- Invalid palette name.
- Invalid magnification center.

## Examples

As an example of color enhancement, the following command shows the rendering of AVHRR channel 2 data from a CoastWatch HDF file to a PNG image, with coast and grid lines in red and the default linear black to white palette. We allow the routine to calculate data statistics on channel 2 for an optimal enhancement range:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --enhance avhrr_ch2 --coast red --grid red 2002_288_1435_n17_er.hdf
  2002_288_1435_n17_er_ch2.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
cwrender: Normalizing color enhancement
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.LatLonOverlay
cwrender: Writing output 2002_288_1435_n17_er_ch2.png
```

For a color composite of the same file, the following command shows the rendering of AVHRR channels 1, 2, and 4 to a PNG image. Again, we allow the routine to calculate statistics for optimal enhancement ranges. Note that the final enhancement function is reversed in order to map warm AVHRR channel 4 values to dark and cold values to bright:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --composite avhrr_ch1/avhrr_ch2/avhrr_ch4
  --bluefunction reverse-linear --coast black --grid gray
  2002_288_1435_n17_er.hdf 2002_288_1435_n17_er_ch124.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
cwrender: Normalizing red enhancement
cwrender: Normalizing green enhancement
cwrender: Normalizing blue enhancement
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.LatLonOverlay
cwrender: Writing output 2002_288_1435_n17_er_ch124.png
```

A further example below shows the rendering of AVHRR derived sea-surface-temperature data from the same file with a cloud mask applied. The color enhancement uses a blue to red color palette and an explicit range from 5 to 20 degrees Celsius:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --enhance sst --coast white --grid white --palette HSL256
```

```
  --range 5/20 --cloud gray 2002_288_1435_n17_er.hdf
  2002_288_1435_n17_er_sst.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.BitmaskOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.LatLonOverlay
cwrender: Writing output 2002_288_1435_n17_er_sst.png
```

An example usage of the **--magnify** option is shown below to create a plot of cloud masked sea-surface-temperature data off Nova Scotia:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --enhance sst --coast white --grid white --palette HSL256
  --range 5/20 --cloud gray --magnify 43/-66/1
  2002_288_1435_n17_er.hdf 2002_288_1435_n17_er_sst_mag.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.BitmaskOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.LatLonOverlay
cwrender: Writing output 2002_288_1435_n17_er_sst_mag.png
```

## Known Bugs

When using the **--coast** option with a fill color and output is to a PDF file, lakes may contain a thin stripe of land in some places. In this case, use the **--land** for land filling instead.

When using the **--coast** option with a fill color, map projection discontinuities or swath projection edges may not be filled correctly.

## A.16 cwsample

### Name

cwsample - extracts data values at specified Earth locations.

### Synopsis

cwsample {-s, --sample=LATITUDE/LONGITUDE} [OPTIONS] input output
cwsample {-S, --samples=FILE} [OPTIONS] input output

**Options:**

-d, --dec=DECIMALS
-D, --delimit=STRING
-h, --help
-H, --header
-i, --imagecoords
-m, --match=PATTERN
-M, --missing=VALUE
-n, --nocoords
-R, --reverse
-V, --variable=NAME1[/NAME2/...]
--version

### Description

The sampling tool extracts data values at specified Earth locations from 2D data variables. A sample point may be specified on the command line using geographic coordinates, or multiple sample points may be specified using a data file. A number of 2D data variables may be sampled simultaneously. The sampled values are printed as ASCII text to the output file, one line per sample point. Various options are available to modify the output decimals places, delimiters, and so on.

### Parameters

**Main parameters:**

**-s, --sample=LATITUDE/LONGITUDE** The sample point for a single sampling operation. The point is specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180].

**-S, --samples=FILE** The file name containing a list of sample points for performing multiple sampling operations. The file must be an ASCII text file containing sample points as latitude /

longitude pairs, one line per pair, with values separated by spaces or tabs. The points are specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180].

**input** The input data file name.

**output** The output text file name. If the output file name is '-', output is sent to standard output (normally the terminal).

**Options:**

**-d, --dec=DECIMALS** The number of decimal places for printed geographic coordinate values. The default is 6 decimals.

**-D, --delimit=STRING** The value delimiter string. By default, values are separated with a single space character.

**-h, --help** Prints a brief help message.

**-H, --header** Specifies that a one line header should be written. The header is written before any data and consists of the output column names. By default no header is written.

**-i, --imagecoords** Specifies that image coordinates (row and column) should be printed for each output line. The default is to print only geographic coordinates.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be sampled. By default, no pattern matching is performed and all variables are sampled unless the **--variable** option is used. Note that either **--variable** or **--match** may be specified, but not both.

**-M, --missing=VALUE** The output value for missing or out of range data. The default is to print 'NaN' for missing values.

**-n, --nocoords** Turns geographic coordinate printing off. By default, each output line has the form 'latitude longitude value(s)' but with no coordinates, each line simply contains the data value(s).

**-R, --reverse** Specifies that coordinates should be printed in reverse order, 'longitude latitude'. The default is 'latitude longitude'.

**-V, --variable=NAME1[/NAME2/...** ] The variable names to sample. If specified, the variable sample values are printed in columns in exactly the same order as they are listed. This option is different from the **--match** option because it (i) specifies the column order, where as **--match** orders the columns as the variables are encountered in the file, and (ii) does not support pattern matching; all variable names must be specified exactly. Without this option or the **--match** option, all variables are sampled. Note that either **--variable** or **--match** may be specified, but not both.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid sample coordinates file format.

## Examples

In the example below, a sample points file named sample_locs.txt was set up to follow the 93 W longitude line at regular 0.2 degree intervals as follows:

```
28 -93
28.2 -93
28.4 -93
28.6 -93
28.8 -93
29 -93
29.2 -93
29.4 -93
29.6 -93
29.8 -93
30 -93
```

and a Gulf of Mexico data file sampled for SST and cloud data along this line with output to the terminal screen:

```
phollema@localhost:<~/cwatch/satdata> cwsample --header
  --match '(sst|cloud)' --samples sample_locs.txt
  2002_325_1546_n17_mr.hdf -

latitude longitude sst cloud
28 -93 25.24 0
28.2 -93 25.24 0
28.4 -93 24.78 0
28.6 -93 23.84 0
28.8 -93 22.72 0
29 -93 21.37 0
29.2 -93 20.06 0
29.4 -93 19.29 0
29.6 -93 18.16 0
29.8 -93 17.57 6
```

```
30 -93 17.48 22
```

Another example shows the sampling of one SST value as in the case of comparison with a single buoy measurement with output to the terminal screen:

```
phollema@localhost:<~/cwatch/satdata> cwsample --header
  --match sst --sample 28.8/-93 2002_325_1546_n17_mr.hdf -

latitude longitude sst
28.8 -93 22.72
```

## A.17 cwstats

### Name

cwstats - calculates Earth data file statistics.

### Synopsis

cwstats [OPTIONS] input

**Options:**

-h, --help
-i, --region=LAT/LON/RADIUS
-l, --limit=STARTROW/STARTCOL/ENDROW/ENDCOL
-m, --match=PATTERN
-s, --stride=N
-S, --sample=FACTOR
--version

### Description

The statistics utility calculates a number of statistics for each variable in an Earth data file:

- Count - the count of total data values sampled.
- Valid - the number of valid (not missing) data values.
- Min - the minimum data value.
- Max - the maximum data value.
- Mean - the average data value.
- Stdev - the standard deviation from the mean.
- Median - the median data value.

To speed up the statitics calculations, a subset of the data values in each variable may be specified using either the **--stride** or **--sample** options, and the **--limit** option. The **--match** option may also be used to limit the statistics calculations to a subset of the variables.

### Parameters

**Main parameters:**

**input** The input data file name.

**Options:**

**-h, --help** Prints a brief help message.

**-i, --region=LAT/LON/RADIUS** The sampling region for each two-dimensional variable. The region is specified by the center latitude and longitude in degrees, and the radius from the center in kilometers. Only data within the rectangle specified by the center and radius is sampled. By default, all data is sampled. Either the **--region** option or the **--limit** option may be specified, but not both.

**-l, --limit=STARTROW/ENDROW/STARTCOL/ENDCOL** The sampling limits for each two-dimensional variable in image coordinates. Only data between the limits is sampled. By default, all data is sampled. Either the **--region** option or the **--limit** option may be specified, but not both.

**-m, --match=PATTERN** The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern are included in the calculations. By default, no pattern matching is performed and all variables are included.

**-s, --stride=N** The sampling frequency for each variable dimension. The default is to sample all data values (stride = 1).

**-S, --sample=FACTOR** The sampling factor for each variable. The sampling factor is a value in the range [0..1] that specifies the number of data values sampled as a fraction of the total number of data values. To sample 1 percent of all data values, the sample factor would be 0.01. The default is to sample all data values (factor = 1).

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.
- Error reading input data values.

## Examples

The following shows a statistics calculation on a CoastWatch HDF file from the Great Lakes:

```
phollema@localhost:<~/cwatch/satdata> cwstats 2002_197_1719_n16_gr.hdf

Variable       Count     Valid     Min       Max       Mean       Stdev
```

```
avhrr_ch1      1048576   483728    3.49      74.36     13.059646  11.371605
avhrr_ch2      1048576   483728    1.97      71.35     18.520041  9.844144
avhrr_ch3a     1048576   483728    0.53      52.84     14.664213  8.88201
avhrr_ch4      1048576   483728    -44.8     31.55     11.052207  13.683309
avhrr_ch5      1048576   483728    -45.48    27.05     7.978351   13.185983
sst            1048576   483728    -44.51    51.43     20.166333  16.714169
cloud          1048576   1048576   0         127       23.24175   37.179013
sat_zenith     1048576   483728    0.36      0.7       0.466376   0.077153
sun_zenith     1048576   483728    0.87      0.95      0.907019   0.022209
rel_azimuth    1048576   483728    -0.58     -0.33     -0.465731  0.058149
graphics       1048576   1048576   0         14        6.84576    2.931459
```

## A.18 cwstatus

### Name

cwstatus - shows the status of a CoastWatch data server.

### Synopsis

cwstatus [OPTIONS]
cwstatus [OPTIONS] host

**Options:**

-c, --script=PATH
-h, --help
-s, --splash
-o, --operator
--version

### Description

The status utility shows the status of a CoastWatch data server using a graphical user interface. The incoming, unprocessed, processing, and online data are shown and continually updated as the server is processing data. Individual passes with coverage area and preview image may be selected from a list. The status utility is designed for use by research personnel and system operators to monitor a CoastWatch data processing server and select data of interest. Detailed help on the usage of cwstatus is available from within the utility using the menu bar under *Help* | *Help and Support* .

### Parameters

**Main parameters:**

**host** The CoastWatch server host name. There is no default host name. If specified, the host is contacted and polled for its status immediately after the status utility starts. Otherwise, the user must connect to the server manually using *File* | *New server* on the menu bar.

**Options:**

**-c, --script=PATH** ADVANCED USERS ONLY. The query script path. The default is /ctera/query.cgi.

**-h, --help** Prints a brief help message.

**-s, --splash** Shows the splash window on startup. The splash window shows the version, author, and web site information.

**-o, --operator** Specifies that operator messages should be displayed. By default, errors on the server are not of interest to normal users and are not displayed. Operator messages take the form of a special message box that appears when an error occurs.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.

## Examples

The following command shows the startup of the status monitor for the fictitious server foobar.noaa.gov:

```
phollema@localhost:<~/cwatch/satdata> cwstatus foobar.noaa.gov
```

## A.19 hdatt

### Name

hdatt - reads or writes HDF file attributes.

### Synopsis

hdatt [OPTIONS] input
hdatt {-n, --name=STRING} [OPTIONS] input
hdatt {-n, --name=STRING} {-l, --value=STRING1[/STRING2/...]} [OPTIONS] input

**Options:**

-h, --help
-t, --type=TYPE
-V, --variable=STRING
--version

### Description

The attribute tool reads or writes HDF file attributes using the HDF Scientific Data Sets (SDS) interface. The two modes work as follows:

**Read mode** In read mode, the tool can read from either the global attribute set (the default), or the attribute set specific to a variable (when then **--variable** option is specified). It can read either all attribute values in the set (the default), or just a single attribute value (when the **--name** option is specified).

**Write mode** Write mode is specified by the use of the **--value** option, which provides a value for a named attribute. In write mode, the user is required to supply an attribute name and value, and optionally a type. If no type is specified, the type defaults to 'string' (see the **--type** option below for the meanings of various type names). Attributes may be written to the global attribute set (the default), or to specific variables in the data file using the **--variable** option.

**Note:** The attribute tool is currently limited to reading and writing only the signed HDF data types. In read mode, unsigned HDF attribute data are read correctly, but the value displayed as if it were signed.

## Parameters

**Main parameters:**

**-n, --name=STRING** The name of the attribute to read or write.

**-l, --value=STRING1[/STRING2/...** ] The value(s) for the named attribute. If specified, this places the tool into write mode, and **--name** must specify an attribute name. If an attribute already exists, its value is overwritten with the new value. If an attribute with the name does not exist, it is created and the new value assigned to it. By default if this option is not used, the tool is in read mode.

**input** The input data file name.

**Options:**

**-t, --type=TYPE** The attribute data type (write mode only). The valid types and their HDF equivalents are as follows:

| Type name | HDF type |
|---|---|
| string | DFNT_CHAR8 |
| byte | DFNT_INT8 |
| short | DFNT_INT16 |
| int | DFNT_INT32 |
| long | DFNT_INT64 |
| float | DFNT_FLOAT32 |
| double | DFNT_FLOAT64 |

**-V, --variable=STRING** The variable to read or write the attribute data. By default, the attribute is read from or written to the global attribute set.

**--version** Prints the software version.

## Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid variable name.
- Invalid attribute name in read mode.
- Invalid attribute type in write mode.
- Value does not convert to the specified attribute data type.

## Examples

As an example of read mode, the following command reads and prints all the global attribute data from a CoastWatch HDF file:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt 2005_095_1522_n17_er.hdf
satellite = noaa-17
sensor = avhrr
origin = USDOC/NOAA/NESDIS CoastWatch
cwhdf_version = 3.2
pass_type = day
pass_date = 12878
start_time = 55371.0
projection_type = mapped
projection = Mercator
gctp_sys = 5
gctp_zone = 0
gctp_parm = 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
gctp_datum = 12
et_affine = 0.0 -1470.0 1470.0 0.0 -8804259.100925786 5723777.271647277
rows = 1401
cols = 1302
polygon_latitude = 45.83810150571052 45.83810150571052 45.83810150571052
  45.83810150571052 45.83810150571052 42.51315402540104 38.99999999998719
  35.30179546333813 31.424886223357582 31.424886223357582 31.424886223357582
  31.424886223357582 31.424886223357582 35.30179546333813 38.99999999998719
  42.51315402540104 45.83810150571052
polygon_longitude = -79.09000515710031 -74.79500257855015 -70.5 -66.20499742144985
  -61.90999484289969 -61.90999484289969 -61.90999484289969 -61.90999484289969
  -61.90999484289969 -66.20499742144985 -70.5 -74.79500257855015 -79.09000515710031
  -79.09000515710031 -79.09000515710031 -79.09000515710031 -79.09000515710031
history = cwimport product.tshdf product.hdf
```

To dump only a single attribute:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name satellite
  2005_095_1522_n17_er.hdf
noaa-17
```

or a single attribute from a specific variable:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name units
  --variable avhrr_ch3a 2005_095_1522_n17_er.hdf
```

```
albedo*100%
```

As an example of write mode, suppose that we wanted to save the date when the file was originally downloaded from the server:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name download_date
  --value "Mon Apr 11 18:20:15 PDT 2005" 2005_095_1522_n17_er.hdf
```

Now suppose we wanted to assign an integer quality value of 65% to the file based on some test that was performed on the file data:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name quality_value
  --value 65 --type int 2005_095_1522_n17_er.hdf
```

Finally, suppose that we wanted to change the units and scaling factor / offset of a variable, originally in degrees Celsius and scaled by 0.01, to degrees Fahrenheit:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name units
  --value "deg F" --variable sst 2005_095_1522_n17_er.hdf
phollema@damdog<~/cwatch/satdata/level3> hdatt --name scale_factor
  --value 0.018 --type double --variable sst 2005_095_1522_n17_er.hdf
phollema@damdog<~/cwatch/satdata/level3> hdatt --name add_offset
  --value -1777.777777 --type double --variable sst
  2005_095_1522_n17_er.hdf
```

# Appendix B

# CoastWatch HDF Metadata Specification

## B.1 Overview

CoastWatch HDF format may be used to store almost any scientific data that has an associated set of Earth locations, including satellite data and output from numerical models. The term *metadata* refers to information describing data. HDF stores metadata as a set of attribute name and value pairs. For example, if a dataset is derived from a satellite called NOAA-16, it is useful to store the attribute name `satellite` and value `noaa-16` along with the data to denote its origin. Along these lines, the CoastWatch metadata standards have been written to help developers write software to read and write data and its associated metadata in a consistent fashion. This document describes the standard and can be used as a reference guide to the HDF attribute names and values in CoastWatch HDF files. A number of overall conventions are used for storing data:

1. Multiple 2D data grids are stored in one HDF file using the HDF Scientific Data Sets (SDS) model. A standard CoastWatch HDF file contains data for one region only.

2. A standard set of global attributes is encoded with the data, describing the date and time, Earth locations, data source or satellite/ sensor, and so on from which the data originated.

3. A standard set of variable attributes is encoded with each variable, describing the variable units, scaling factor, and so on as well as any other important information.

As the requirements for the CoastWatch HDF format evolve, new metadata specifications are added, thus new metadata *versions* support features that older versions do not. An effort is made with each new metadata version to maintain compatibility with older versions:

**Version 2.4** The original metadata version supported by the CWF utilities version 2.3 and 2.4 and CDAT 0.6 and 0.7. CoastWatch HDF was originally designed to store projection-mapped satellite data only, and had a very limited set of metadata.

**Version 3.1** Support was added for multiple metadata versions, unmapped swath data, per-variable navigation transforms, and the interpretation of the `et_affine` attribute was changed.

**Version 3.2** Support was added for non-satellite derived data, composite datasets from multiple time ranges, raster pixel types, region codes and names, temporal extents, vector direction variables, polygon outlines, and various other features.

**Version 3.3** Support was added for satellite sensor scan projection type.

**Version 3.4** Units strings were standardized to use Unidata UDUNITS style. Vector direction variables now have a convention attribute.

## B.2 Global Metadata

The following table lists the standard set of global attributes for CoastWatch HDF:

| Attribute name | HDF type | Description | Since version |
|---|---|---|---|
| `cwhdf_version`† | CHAR8 | The metadata version. The version is written as a string attribute but should be interpreted as a fractional number, for example 2.3 or 3.1. If absent, version 2.4 is assumed. | 3.1 |
| `satellite`‡ | CHAR8 | If data is from a satellite, the satellite name, for example `noaa-16`, `goes-8`, `orbview-2`. | 2.4 |
| | CHAR8 | If the data is a composite, multiple values are newline-separated. | 3.2 |
| `sensor`‡ | CHAR8 | If data is from a satellite, the satellite sensor name, for example `avhrr`, `seawifs`. | 2.4 |
| | CHAR8 | If the data is a composite, multiple values are newline-separated. | 3.2 |
| `data_source`‡ | CHAR8 | If data is not from a satellite, the data source, for example the instrument used to collect the data or the model used to generate the data. If the data is a composite, multiple values are newline-separated. | 3.2 |
| `composite` | CHAR8 | The composite flag, `true` if the data is derived from multiple datasets, or `false` if not. If true, then the `pass_date`, `start_time`, and `temporal_extent` attributes may contain arrays of values, and the `satellite`, `sensor`, `data_source`, `orbit_type`, `pass_type`, and `origin` attributes may have multiple newline-separated values. If absent, it is assumed that the data is not a composite. | 3.2 |

| Attribute name | HDF type | Description | Since version |
|---|---|---|---|
| `pass_date`† | INT32 | The date of data recording in days since January 1, 1970. | 2.4 |
| | INT32[ ] | If the data is a composite, the dates of data recording in days since January 1, 1970. Date and time data must be stored in sorted order from least recent to most recent. | 3.2 |
| `start_time`† | FLOAT64 | The start time of the data recording in seconds since 00:00:00 UTC. | 2.4 |
| | FLOAT64[ ] | If the data is a composite, the start times of data recording in seconds since 00:00:00 UTC. | 3.2 |
| `temporal_extent` | FLOAT64[ ] | The time duration in seconds between the start of data recording and the end of data recording. Multiple values may be present if the data is a composite. If absent, it is assumed that each data recording is instantaneous. | 3.2 |
| `pass_type` | CHAR8 | The satellite pass temporal type: `day`, `night`, `day/night`. | 2.4 |
| | CHAR8 | If the data is a composite, multiple values are newline-separated. | 3.2 |
| `orbit_type` | CHAR8 | If the data is from an orbiting satellite that crosses the equator in a northward or southward direction, the orbit type as `ascending` or `descending` respectively. If the data is a composite, multiple values are newline-separated. | 3.2 |
| `origin`† | CHAR8 | The original data source as an agency or organization name, for example `USDOC/NOAA/NESDIS CoastWatch`. | 2.4 |
| | CHAR8 | If the data is a composite, multiple values are newline-separated. | 3.2 |
| `history`† | CHAR8 | A newline-separated list of utilities and command line parameters used to create the file and perform processing. | 2.4 |

†This attribute is required. Other attributes are optional.
‡Either `satellite` and `sensor`, or `data_source` are required, but not both.

## B.3 Earth Location Metadata

In addition to the standard global attributes listed above, a number of Earth location attributes are also present. Prior to version 3.1, only mapped data was supported. For mapped data, all map projection calculations are performed using the General Cartographic Transformation Package (GCTP) from the USGS National Mapping Division. A number of global attributes are dedicated to storing GCTP related parameters. For documentation on the allowed values of GCTP parameters, see section B.6. The table below lists the standard set of global attributes for Earth location metadata:

| Attribute name | HDF type | Description | Since version |
|---|---|---|---|
| `projection_type` † | CHAR8 | The projection type: `mapped`, `swath`, or `sensor_scan`. Mapped data is formatted to a well-known map projection and accompanied by GCTP map projection parameters. Swath data is data that is not in a standard map projection, but is accompanied by Earth location data for each pixel (see section B.5 on swath data). Sensor scan data is similar to swath in that it cannot be described by a set of map projection parameters, but it can be described by a set of sensor-specific parameters and does not require Earth locations to be stored for each pixel. | 3.1 |
| `projection`‡ | CHAR8 | For mapped data, a descriptive projection name, for example `mercator`, `geographic`, `polar stereographic`. | 2.4 |
| `gctp_sys`‡ | INT32 | For mapped data, the GCTP projection system code. | 2.4 |
| `gctp_zone`‡ | INT32 | For mapped data, the GCTP zone for UTM projections. | 2.4 |
| `gctp_parm`‡ | FLOAT64[ ] | For mapped data, the GCTP projection parameters (15). | 2.4 |
| `gctp_datum`‡ | INT32 | For mapped data, the GCTP spheroid code. | 2.4 |
| `et_affine`‡ | FLOAT64[ ] | For mapped data, the map affine transform (6). | 2.4 |
| `sensor_code`* | INT32 | For sensor scan data, the sensor code. The only code currently available is 0, which indicates a geostationary satellite. | 3.3 |
| `sensor_parm`* | FLOAT64[ ] | For sensor scan data, the sensor parameters. For a geostationary satellite (`sensor_code=0`):<br>1. Subpoint latitude in degrees (geocentric).<br>2. Subpoint longitude in degrees.<br>3. Distance of satellite from center of Earth in kilometers.<br>4. Scan step angle in row direction in radians.<br>5. Scan step angle in column direction in radians. | 3.3 |
| `rows`† | INT32 | The number of rows of data. | 2.4 |
| `cols`† | INT32 | The number of columns of data. | 2.4 |
| `polygon_latitude` | FLOAT64[ ] | Latitude components of the bounding polygon with initial element repeated. | 3.2 |
| `polygon_longitude` | FLOAT64[ ] | Longitude components of the bounding polygon with initial element repeated. | 3.2 |

| Attribute name | HDF type | Description | Since version |
|---|---|---|---|
| `raster_type` | CHAR8 | One of `RasterPixelIsArea` or `RasterPixelIsPoint` to capture the same distinction as the GeoTIFF global attribute `GTRasterTypeGeoKey`. If pixels represent point data, then extra SDS variables `latitude` and `longitude` in the dataset localize the point within the pixel area which otherwise defaults to the pixel center. If absent, pixels are assumed to represent area data. | 3.2 |
| `region_code` | CHAR8 | The data processing region code as a short abbreviation. | 3.2 |
| `region_name` | CHAR8 | The data processing region name in full. | 3.2 |
| `station_code` | CHAR8 | The data capture ground station as a short abbreviation. | 3.2 |
| `station_name` | CHAR8 | The data capture ground station name in full. | 3.2 |

†This attribute is required. Other attributes are optional.
‡Required for mapped data only.
*Required for sensor scan data only.

### B.3.1 Version 2 Affine

The `et_affine` attribute is used by CoastWatch software to translate between map (x,y) coordinates in meters and image (row,col) coordinates. GCTP is used to translate between (lat,lon) in degrees and map (x,y) in meters. With this two-step process, the translation between image (row,col) and Earth location (lat,lon) is very flexible and can be expressed partly as a linear coordinate transform. The six affine transform parameters are used in a matrix equation as follows. Let $a..f$ be the `et_affine` attribute array values 0..5, $(X, Y)$ be map coordinate easting and northing in meters, and $(R, C)$ be 1-relative row and column image coordinates, then:

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & e \\ c & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C \\ R \\ 1 \end{bmatrix}$$

or alternatively:

$$\begin{aligned} X &= aC + bR + e \\ Y &= cC + dR + f \end{aligned}$$

The inverse operation may be performed by inverting the affine transform:

$$\begin{aligned} \alpha &= ad - bc \\ a' &= d/\alpha \\ b' &= -b/\alpha \\ c' &= -c/\alpha \\ d' &= a/\alpha \\ e' &= -(a'e + b'f) \\ f' &= -(c'e + d'f) \end{aligned}$$

$$\begin{bmatrix} C \\ R \\ 1 \end{bmatrix} = \begin{bmatrix} a' & b' & e' \\ c' & d' & f' \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix}$$

or alternatively:

$$\begin{aligned} C &= a'X + b'Y + e' \\ R &= c'X + d'Y + f' \end{aligned}$$

### B.3.2 Version 3 Affine

The conventions of the `et_affine` attribute are slightly different in version 3 metadata. The affine transform is stored and used (in matrix form) as:

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} R \\ C \\ 1 \end{bmatrix}$$

or alternatively:

$$\begin{aligned} X &= aR + cC + e \\ Y &= bR + dC + f \end{aligned}$$

where $(R, C)$ are 0-relative, **not** 1-relative image coordinates. Deriving the inverse transform is similarly changed.

## B.4 Variable Metadata

The following table shows the standard set of variable attributes for CoastWatch HDF. Some attribute groups are created by HDF SD convenience functions in order to make data more readable and usable by generic HDF viewing programs. A <*var*> in the *HDF Type* indicates that the attribute type is the same as the variable data type.

| Attribute name | HDF type | Description | Since version |
|---|---|---|---|
| `long_name`† | CHAR8 | *Written by SDsetdatastrs.* A descriptive variable name, for example `AVHRR channel 4`, `sea surface temperature`. | 2.4 |
| `units`† | CHAR8 | *Written by SDsetdatastrs.* A descriptive units name in the conventions used by the Unidata UDUNITS package and its supported units file. Many common units are acceptable (and various forms of those units), for example `kelvin`, `celsius` and `fahrenheit` for temperature data, `knots`, `meters per second` or `m/s` for wind-speed, `mg per m^-3` or `kg/m-3` for concentration, `percent` or `%` for reflectance, and `degrees` or `radians` for angles. | 2.4, updated in 3.4 |
| `format`† | CHAR8 | *Written by SDsetdatastrs.* A FORTRAN-77 style format string, for example `F7.2`. | 2.4 |
| `coordsys`† | CHAR8 | *Written by SDsetdatastrs.* A descriptive coordinate system name, the same as the global `projection` attribute. | 2.4 |
| `_FillValue` | <*var*> | *Written by SDsetfillvalue.* The value used to fill in for missing or unwritten data. | 2.4 |
| `scale_factor`‡ | FLOAT64 | *Written by SDsetcal.* The calibration scale factor. | 2.4 |
| `scale_factor_err`‡ | FLOAT64 | *Written by SDsetcal.* The calibration scale error. | 2.4 |
| `add_offset`‡ | FLOAT64 | *Written by SDsetcal.* The calibration offset. | 2.4 |
| `add_offset_err`‡ | FLOAT64 | *Written by SDsetcal.* The calibration offset error. | 2.4 |
| `calibrated_nt`‡ | INT32 | *Written by SDsetcal.* The HDF data type code for uncalibrated data. | 2.4 |
| `C_format`† | CHAR8 | A C style format string, for example `%7.2f`. | 2.4 |
| `missing_value` | <*var*> | The value used to fill in for missing or unwritten data; same as `_FillValue`. | 2.4 |
| `fraction_digits`† | INT32 | The number of significant digits after the decimal place for calibrated or floating-point variable data. This is an alternative to the C or FORTRAN notation for value formatting and is independent of the programming language. | 3.1 |
| `nav_affine` | FLOAT64[ ] | The navigation correction affine transform. If absent, an identity transform is assumed. | 3.1 |
| `direction_variable` | CHAR8 | The name of the associated SDS variable for vector direction. Any variable with this attribute is assumed to be the magnitude component of a vector field, for which the named variable is the direction component. The direction component is encoded as degrees clockwise from north. | 3.2 |

| Attribute name | HDF type | Description | Since version |
|---|---|---|---|
| `direction_convention` | CHAR8 | When this SDS variable is the direction component of a vector, the convention for the direction is either `DirectionIsTo` or `DirectionIsFrom` to indicate that the direction indicates where to vectors are pointing to, or pointing from. For example, wind direction is normally quoted as where the wind is coming from, where as ocean currents are quoted as where the current is moving towards. This attribute is only required for direction component SDS variables (see the `direction_variable` attribute). | 3.4 |
| `quality_flag` | CHAR8 | The name of the associated SDS variable that contains quality flag information. | 3.2 |
| `quality_mask` | INT64 | The value to use as a mask in a bitwise AND operation to isolate the quality bits in the SDS variable named by the `quality_flag` attribute. | 3.2 |
| `flag_bits` | CHAR8 | The newline-separated list of flag descriptions for each bit from least significant to most significant. This is generally only required if this SDS variable contains quality flag information for another SDS variable. Any unused bits are denoted by `Unused`. | 3.2 |

† This attribute is required. Other attributes are optional.
‡ Required for calibrated data only.

### B.4.1 Calibration Values

The calibration attributes are used to read and write variable data as follows:

$$\begin{array}{lcll} float & = & \texttt{scale_factor}(int - \texttt{add_offset}) & \text{(on read)} \\ int & = & float/\texttt{scale_factor} + \texttt{add_offset} & \text{(on write)} \end{array}$$

where $float$ and $int$ are the floating-point and integer values respectively. See the HDF User's Guide for more details on data calibration. If no calibration data is found, the data is assumed to be already calibrated.

### B.4.2 Navigation Correction

The navigation correction transform has 6 coefficients, similar to the global `et_affine` attribute, and is used (in matrix form) as:

$$\begin{bmatrix} R' \\ C' \\ 1 \end{bmatrix} = \begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} R \\ C \\ 1 \end{bmatrix}$$

where$a..f$ are the `nav_affine` matrix coefficients in order and $(R', C')$ are the actual image coordinates at which the desired data value for $(R, C)$ may be found.

## B.5 Swath Earth Location Encoding

There are currently two methods for specifying Earth location data for CoastWatch HDF swath files:

1. **Explicit encoding:** Two standard 2D HDF SDS variables named `latitude` and `longitude` are written to the file. Each variable must be accompanied with appropriate metadata as outlined above. The latitude and longitude data must not have any values set to the missing or fill value, or problems may occur in performing Earth coordinate transformations.

2. **Polynomial encoding:** A number of 1D HDF SDS variables named *swath_struct*, *swath_bounds*, *swath_lat*, and *swath_lon* are used to define data structures for use in a polynomial approximation algorithm that supports an efficient and accurate estimation of latitude and longitude values for the swath data.

The polynomial encoding option is described in this section. The polynomial approximation scheme is given, along with details on the required HDF variables.

The easiest approach to swath Earth location encoding is to simply record latitude and longitude values for every data value in the swath. For a typical AVHRR swath size of 2048×5000, this can add about 80 Mb of extra data to a file using 32-bit floating point values. To convert a data (row,col) coordinate to geographic (lat,lon) coordinate, an application simply reads the (lat,lon) data at the specified coordinate from the file. This method requires either a large amount of file I/O or a large amount of memory, depending on how much of the Earth location data is read at once. It also does not lend itself to an efficient reverse lookup algorithm for converting an arbitrary (lat,lon) back to (row,col).

In order to support swath data in CoastWatch HDF files but avoid the overhead of storing the Earth locations, a polynomial approximation scheme is used. The approximation scheme also lends itself to an efficient reverse lookup algorithm. The approximation divides the data into a number of rectangular partitions of varying size in rows and columns but bounded physical size in kilometres. For a typical AVHRR swath whose resolution is lowest at the left and right edge of the image data, the rectangular partitioning may look something like Figure B.1.

The approximation derives a set of bivariate polynomials on each partition for latitude and longitude estimation. To convert a (row,col) coordinate to (lat,lon), the partitions are first searched for the one containing the data coordinate. Using the polynomials for that partition, latitude and longitude are calculated for the data coordinate using the polynomial coefficients. By bounding the physical size of each partition, it is possible to bound the error in latitude and longitude estimation. For a typical AVHRR pass, it has been found that a 100 km maximum partition size yields a maximum error of approximately 50 m in Earth location.

The polynomial approximation scheme used is as follows. For each partition, nine latitude and longitude values are sampled in a 3×3 grid pattern as shown in Figure B.2. The (row,col) coordinates and (lat,lon) data values are used to derive two independent sets of 9 polynomial coefficients, one set for latitude and one set for longitude. These coefficients, denoted $a_0..a_8$ and $b_0..b_8$ can be used to recover the latitude and longitude values using the formulae:

$$\begin{aligned} lat(x,y) &= a_0 + a_1x + a_2x^2 + a_3y + a_4xy + a_5x^2y + a_6y^2 + a_7xy^2 + a8x^2y^2 \\ lon(x,y) &= b_0 + b_1x + b_2x^2 + b_3y + b_4xy + b_5x^2y + b_6y^2 + b_7xy^2 + b_8x^2y^2 \end{aligned}$$

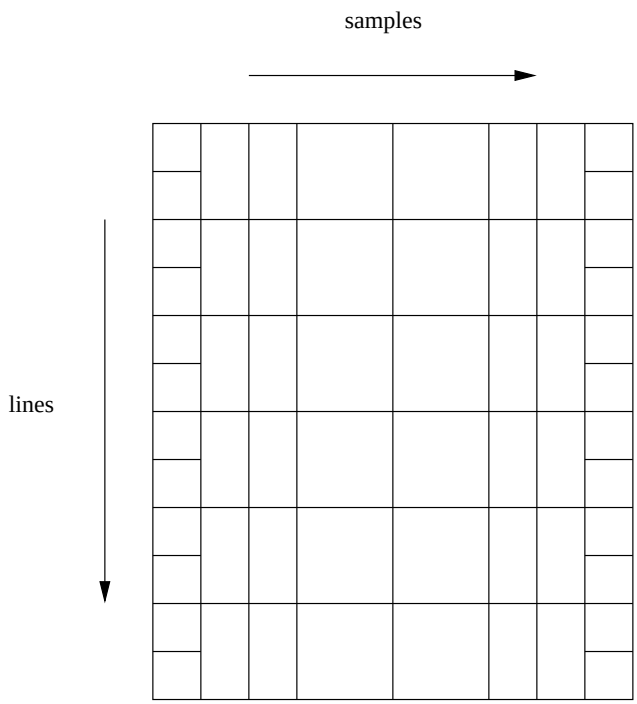



Figure B.1: A partitioning of AVHRR swath data. Each partition has a bounded physical size in the lines and samples directions.

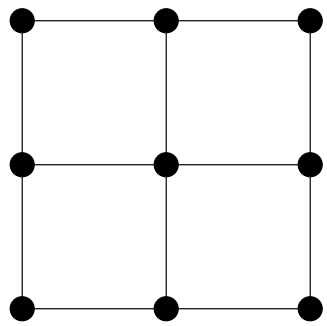


Figure B.2: Sampling pattern for polynomial approximation. Each • symbol is a sampling point for latitude and longitude.

where $x$ is the image row and $y$ is the image column. Note that the polynomial approximation also acts to interpolate (lat,lon) coordinates between integer data coordinates, since there are no requirements on $x$ and $y$ to be integers in the above equations. This is important for the accuracy of the reverse-lookup algorithm described later.

Since each partition is associated with its own set of coefficients, a simple algorithm to search for the appropriate partition for a data (row,col) coordinate is to loop through all partitions, checking the row and column bounds on each partition until one containing the desired (row,col) coordinate is found. If there are $n$ partitions, then the loop will perform $O(n)$ (where $O()$ denotes an *order of* upper bound relationship) partition bound checks. In order to avoid this, a binary tree is used to arrange the partitions in a hierarchical structure. The set of partitions with polynomial coefficients form the leaves of the tree. The relationship between parent and child nodes is such that each child is a binary sub-partition of the parent. In this way, a search through $n$ partitions is replaced by a search down the binary tree through $O(\log n)$ partitions until a leaf is encountered. For encoding purposes, a binary tree structure may be encoded uniquely using a preorder traversal of its nodes. A `0` is used to encode a left child, and a `1` for a right child (the root is not recorded because we assume that the preorder traversal starts at the root). Figure B.3 shows the binary tree for the encoding `000111`. A more complex example in Figure B.4 show the binary tree for the encoding `000111001101`.

For a complete encoding of the swath including the polynomial coefficients for each leaf partition, all partition boundaries, and the binary tree structure, the following HDF variables are used:

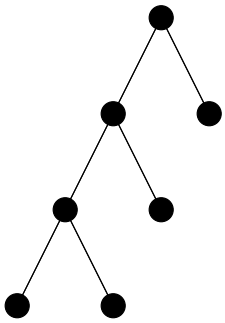


Figure B.3: Binary tree encoding example. The tree is encoded under a preorder traversal by the binary string `000111`.

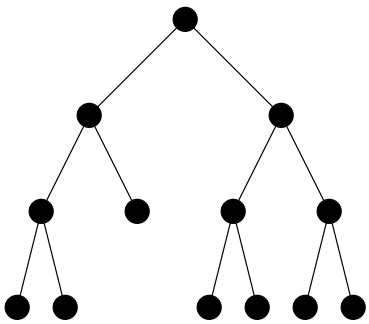


Figure B.4: A more complex binary tree encoding example. The tree is encoded under a preorder traversal by the binary string `000111001101`.

| Variable name | HDF type | Description |
|---|---|---|
| `swath_struct` | INT8 | A preorder encoding of the binary tree. The encoding bits are zero-padded at the end to the nearest byte. |
| `swath_bounds` | FLOAT64 | Upper-left and lower-right (row,col) bounds for each partition. All partition bounds are recorded, including all leaf and non-leaf partitions in the tree. |
| `swath_lat` | FLOAT64 | Latitude polynomial coefficients for each leaf partition. There are 9 coefficients stored for each partition. |
| `swath_lon` | FLOAT64 | Longitude polynomial coefficients for each leaf partition. There are 9 coefficients stored for each partition. |

This encoding may be used to re-create the tree structure and populate the tree with partition bound and polynomial information. For a typical AVHRR pass which might require 80 Mb of data if all (lat,lon) coordinates were pre-computed, this encoding only requires about 500 kb using a maximum partition size of 100 km.

Finally, the reverse-lookup algorithm to convert (lat,lon) coordinates back to (row,col) is as follows. Define the following symbols:

Let $T$ be a tolerance distance in kilometers.
Let $\overrightarrow{C}_g^{in}$ be the input geographic (lat,lon) coordinate.
Let $\overrightarrow{C}_d^{out}$ be the output data (row,col) coordinate.
Let $D_{\overrightarrow{C}_g}(\overrightarrow{C}_d)$ be a function that computes the physical distance in kilometers between geographic coordinate $\overrightarrow{C}_g$ and data coordinate $\overrightarrow{C}_d$.
Let $N_r$ and $N_c$ be the total number of rows and columns.
Let $\overrightarrow{\nabla}_d$ be the gradient operator in data coordinates, $\overrightarrow{\nabla}_d = (\frac{\partial}{\partial r}, \frac{\partial}{\partial c})$.

Now, initialize $\overrightarrow{C}_d^{out}$ and iterate until the tolerance is satisfied:

$\overrightarrow{C}_d^{out} = (N_r/2, N_c/2)$
$d = D_{\overrightarrow{C}_g^{in}}(\overrightarrow{C}_d^{out})$
while $d > T$ {
  $\overrightarrow{u} = \overrightarrow{\nabla}_d D_{\overrightarrow{C}_g}(\overrightarrow{C}_d)$
  $\hat{u} = \overrightarrow{u}/|\overrightarrow{u}|$
  $\overrightarrow{C}_d^{out} = \overrightarrow{C}_d^{out} - d\hat{u}$
  $d = D_{\overrightarrow{C}_g^{in}}(\overrightarrow{C}_d^{out})$
}

This algorithm is particularly well suited to be used with a polynomial approximation scheme for (lat,lon) because it can provide sub-pixel accuracy in the (row,col) coordinate. For example as part of

a data resampling algorithm, once a fractional data coordinate is obtained for a given (lat,lon), nearest neighbour or bilinear interpolation may then be used to provide a smooth data resampling.

## B.6 GCTP Appendices

```
Function Description
********************

gctp - Initializes projection transformation parameters and performs
transformations.

SYNTAX

  FUNCTION gctp (incoor, insys, inzone, inparm, inunit, indatum, ipr,
  efile, jpr, pfile, outcoor, outsys, outzone, outparm, outunit,
  outdatum, fn27, fn83, iflg)

  double incoor[2];
  long *insys;
  long *inzone;
  double inparm[15];
  long *inunit;
  long *indatum;
  long *ipr;
  char efile[];
  long *jpr;
  char pfile[];
  double outcoor[2];
  long *outsys;
  long *outzone;
  double outparm[15];
  long *outunit;
  long *outdatum;
  char fn27[];
  char fn83[];
  long *iflg;

PARAMETERS

* incoor (input, double, length(2))

  Array of two input coordinates (X-Y, Longitude-Latitude,
  Northing-Easting, etc) to be translated. The nature of the
  coordinates is defined by insys, inzone, and inunit. The east-west
  dimension (X, Longitude, Easting) is first followed by the
  north-south (Y, latitude, Northing).
```

```
* insys (input, long)

  Defines the input projection system. Valid codes are:
  = 0: GEO (Geographic)
  = 1: UTM (Universal Transverse Mercator)
  = 2: SPCS (State Plane Coordinates)
  = 3: ALBERS (Albers Conical Equal Area)
  = 4: LAMCC (Lambert Conformal Conic)
  = 5: MERCAT (Mercator)
  = 6: PS (Polar Stereographic)
  = 7: POLYC (Polyconic)
  = 8: EQUIDC (Equidistant Conic)
  = 9: TM (Transverse Mercator)
  = 10: STEREO (Stereographic)
  = 11: LAMAZ (Lambert Azimuthal Equal Area)
  = 12: AZMEQD (Azimuthal Equidistant)
  = 13: GNOMON (Gnomonic)
  = 14: ORTHO (Orthographic)
  = 15: GVNSP (General Vertical Near-Side Perspective)
  = 16: SNSOID (Sinusoidal)
  = 17: EQRECT (Equirectangular)
  = 18: MILLER (Miller Cylindrical)
  = 19: VGRINT (Van der Grinten)
  = 20: HOM (Hotine Oblique Mercator--HOM)
  = 21: ROBIN (Robinson)
  = 22: SOM (Space Oblique Mercator--SOM)
  = 23: ALASKA (Modified Stereographic Conformal--Alaska)
  = 24: GOOD (Interrupted Goode Homolosine)
  = 25: MOLL (Mollweide)
  = 26: IMOLL (Interrupted Mollweide)
  = 27: HAMMER (Hammer)
  = 28: WAGIV (Wagner IV)
  = 29: WAGVII (Wagner VII)
  = 30: OBLEQA (Oblated Equal Area)

* inzone (input, long)

  Input zone for UTM and State Plane projection systems. The UTM
  Coordinate System (insys = 1) and State Plane Coordinate System
  (insys = 2) use zone codes instead of specific projection parameters
  (See Appendix B--UTM and Appendix C--State Plane). For Southern
  Hemisphere UTM, use a negative zone code. Inzone will be ignored for
  all other projections.

* inparm (input, double, length(15))

  Array of fifteen projection parameters. These parameters are
```

```
  required to define each map projection.  (See Appendix A)

* inunit (input, long)

  Unit code for input coordinates. Valid unit codes are:
  = 0: radians
  = 1: U.S. feet
  = 2: meters
  = 3: seconds of arc
  = 4: degrees of arc
  = 5: International feet
  = 6: Table supplying the unit code, which is legislated
       for the State zone selected

* indatum (input, long)

  Input spheroid code. This identifies the semi-major axis and
  eccentricity that is to be used in the transformation process. If a
  negative spheroid code is entered, inparm elements 1 and 2 are to be
  used (See Appendix A). Supported spheroids include:
  = 0: Clarke 1866 (default)
  = 1: Clarke 1880
  = 2: Bessel
  = 3: International 1967
  = 4: International 1909
  = 5: WGS 72
  = 6: Everest
  = 7: WGS 66
  = 8: GRS 1980
  = 9: Airy
  = 10: Modified Everest
  = 11: Modified Airy
  = 12: WGS 84
  = 13: Southeast Asia
  = 14: Australian National
  = 15: Krassovsky
  = 16: Hough
  = 17: Mercury 1960
  = 18: Modified Mercury 1968
  = 19: Sphere of Radius 6370997 meters

  Note: State Plane projection (insys = 2) only supports Clarke 1866
  (indatum = 0) and GRS 1980 (indatum = 8) spheroids corresponding to
  datums NAD27 and NAD83 respectively (See Appendix B).

* ipr (input, long)

  Error message print flag. If ipr is zero, error messages will be
```

```
  printed to the terminal. If ipr is one, error messages will be
  printed to efile. If ipr is two, error messages will be printed to
  both the terminal and efile. If ipr is something else, error
  messages will not be printed.

* efile (input, character, length(*))

  The file which will contain the output error messages. efile need
  not be opened at this time.

* jpr (input, long)

  Projection parameter print flag. If jpr is zero, projection
  parameters will be printed to the terminal. If jpr is one,
  projection parameters will be printed to pfile. If jpr is two,
  projection parameters will be printed to both the terminal and
  pfile. If jpr is something else, the projection parameters will not
  be printed. As specified by jpr, Projection parameters are printed
  each time the input projection parameters (insys, inzone, inparm,
  inunit, indatum, outsys, outzone, outparm, outunit, and outdatum)
  change.

* pfile (input, character, length(*))

  The file which will contain the output projection parameter
  messages. pfile need not be opened at this time.

* outcoor (output, double, length(2))

  Array of two transformed coordinates. See incoor for an explanation.

* outsys (input, long)

  Defines the output projection system. See insys.

* outzone (input, long)

  Output zone for UTM and State Plane projection systems. The UTM
  Coordinate System (outsys = 1) and State Plane Coordinate System
  (outsys = 2) use zone codes instead of specific projection
  parameters (See Appendix B--UTM and Appendix C--State Plane). For
  Southern Hemisphere UTM, use a negative zone code. Outzone will be
  ignored for all other projections.

* outparm (input, double, length(15))

  Array of fifteen projection parameters. These parameters are
  required to define each map projection.  (See Appendix A)
```

```
* outunit (input, long)

  Unit code for output coordinates. See inunit.

* outdatum (input, long)

  Output spheroid code. See indatum.

* fn27 (input, character, length(*))

  Name of the file which contains the NAD 1927 State Plane zone
  parameters.

* fn83 (input, character, length(*))

  Name of the file which contains the NAD 1983 State Plane zone
  parameters.

* iflg (output, long)

  Error flag after transformation. The error number returned will
  correspond to the specific error.

DESCRIPTION

  This routine initializes the proper projection parameters when
  initialization is required. The proper informational and error
  message handling is initialized. Then, the incoor coordinates are
  converted from the insys map projection to the outsys map projection
  and are returned in outcoor.

RETURN VALUE

  gctp() has no return value.


Projection Transformation Package Projection Parameters
*******************************************************

  ------------------------------------------------------------------------------
                          |                    Array Element                  |
   Code & Projection Id   |---------------------------------------------------
                          |   1  |   2  |  3   |  4   |   5   |    6    |7 | 8|
  ------------------------------------------------------------------------------
   0 Geographic           |      |      |      |      |       |         |  |  |
   1 U T M                |Lon/Z |Lat/Z |      |      |       |         |  |  |
   2 State Plane          |      |      |      |      |       |         |  |  |
```

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 Albers Equal Area | SMajor | SMinor | STDPR1 | STDPR2 | CentMer | OriginLat | FE | FN |
| 4 Lambert Conformal C | SMajor | SMinor | STDPR1 | STDPR2 | CentMer | OriginLat | FE | FN |
| 5 Mercator | SMajor | SMinor | | | CentMer | TrueScale | FE | FN |
| 6 Polar Stereographic | SMajor | SMinor | | | LongPol | TrueScale | FE | FN |
| 7 Polyconic | SMajor | SMinor | | | CentMer | OriginLat | FE | FN |
| 8 Equid. Conic A | SMajor | SMinor | STDPAR | | CentMer | OriginLat | FE | FN |
| Equid. Conic B | SMajor | SMinor | STDPR1 | STDPR2 | CentMer | OriginLat | FE | FN |
| 9 Transverse Mercator | SMajor | SMinor | Factor | | CentMer | OriginLat | FE | FN |
| 10 Stereographic | Sphere | | | | CentLon | CenterLat | FE | FN |
| 11 Lambert Azimuthal | Sphere | | | | CentLon | CenterLat | FE | FN |
| 12 Azimuthal | Sphere | | | | CentLon | CenterLat | FE | FN |
| 13 Gnomonic | Sphere | | | | CentLon | CenterLat | FE | FN |
| 14 Orthographic | Sphere | | | | CentLon | CenterLat | FE | FN |
| 15 Gen. Vert. Near Per | Sphere | | Height | | CentLon | CenterLat | FE | FN |
| 16 Sinusoidal | Sphere | | | | CentMer | | FE | FN |
| 17 Equirectangular | Sphere | | | | CentMer | TrueScale | FE | FN |
| 18 Miller Cylindrical | Sphere | | | | CentMer | | FE | FN |
| 19 Van der Grinten | Sphere | | | | CentMer | OriginLat | FE | FN |
| 20 Hotin Oblique Merc A | SMajor | SMinor | Factor | | | OriginLat | FE | FN |
| Hotin Oblique Merc B | SMajor | SMinor | Factor | AziAng | AzmthPt | OriginLat | FE | FN |
| 21 Robinson | Sphere | | | | CentMer | | FE | FN |
| 22 Space Oblique Merc A | SMajor | SMinor | | IncAng | AscLong | | FE | FN |
| Space Oblique Merc B | SMajor | SMinor | Satnum | Path | | | FE | FN |
| 23 Alaska Conformal | SMajor | SMinor | | | | | FE | FN |
| 24 Interrupted Goode | Sphere | | | | | | | |
| 25 Mollweide | Sphere | | | | CentMer | | FE | FN |
| 26 Interrupt Mollweide | Sphere | | | | | | | |
| 27 Hammer | Sphere | | | | CentMer | | FE | FN |
| 28 Wagner IV | Sphere | | | | CentMer | | FE | FN |
| 29 Wagner VII | Sphere | | | | CentMer | | FE | FN |
| 30 Oblated Equal Area | Sphere | | Shapem | Shapen | CentLon | CenterLat | FE | FN |

Array elements 9-15 Continued on page 2

Projection Transformation Package Projection Parameters elements 9-15 continued from page 1:

| Code & Projection Id | Array Element | | | | |
|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 |
| 0 Geographic | | | | | |
| 1 U T M | | | | | |

```
 2 State Plane          |     |    |     |    |    |
 3 Albers Equal Area    |     |    |     |    |    |
 4 Lambert Conformal C  |     |    |     |    |    |
 5 Mercator             |     |    |     |    |    |
 6 Polar Stereographic  |     |    |     |    |    |
 7 Polyconic            |     |    |     |    |    |
 8 Equid. Conic A       |zero |    |     |    |    |
   Equid. Conic B       |one  |    |     |    |    |
 9 Transverse Mercator  |     |    |     |    |    |
10 Stereographic        |     |    |     |    |    |
11 Lambert Azimuthal    |     |    |     |    |    |
12 Azimuthal            |     |    |     |    |    |
13 Gnomonic             |     |    |     |    |    |
14 Orthographic         |     |    |     |    |    |
15 Gen. Vert. Near Per  |     |    |     |    |    |
16 Sinusoidal           |     |    |     |    |    |
17 Equirectangular      |     |    |     |    |    |
18 Miller Cylindrical   |     |    |     |    |    |
19 Van der Grinten      |     |    |     |    |    |
20 Hotin Oblique Merc A |Long1|Lat1|Long2|Lat2|zero|
   Hotin Oblique Merc B |     |    |     |    |one |
21 Robinson             |     |    |     |    |    |
22 Space Oblique Merc A |PSRev|LRat|PFlag|    |zero|
   Space Oblique Merc B |     |    |     |    |one |
23 Alaska Conformal     |     |    |     |    |    |
24 Interrupted Goode    |     |    |     |    |    |
25 Mollweide            |     |    |     |    |    |
26 Interrupt Mollweide  |     |    |     |    |    |
27 Hammer               |     |    |     |    |    |
28 Wagner IV            |     |    |     |    |    |
29 Wagner VII           |     |    |     |    |    |
30 Oblated Equal Area   |Angle|    |     |    |    |
---------------------------------------------------
```

where

```
Lon/Z     Longitude of any point in the UTM zone or zero.  If zero,
          a zone code must be specified.
Lat/Z     Latitude of any point in the UTM zone or zero.  If zero, a
          zone code must be specified.
SMajor    Semi-major axis of ellipsoid.  If zero, Clarke 1866 in meters
          is assumed.
SMinor    Eccentricity squared of the ellipsoid if less than zero,
          if zero, a spherical form is assumed, or if greater than
          zero, the semi-minor axis of ellipsoid.
Sphere    Radius of reference sphere.  If zero, 6370997 meters is used.
STDPAR    Latitude of the standard parallel
STDPR1    Latitude of the first standard parallel
```

```
STDPR2    Latitude of the second standard parallel
CentMer   Longitude of the central meridian
OriginLat Latitude of the projection origin
FE        False easting in the same units as the semi-major axis
FN        False northing in the same units as the semi-major axis
TrueScale Latitude of true scale
LongPol   Longitude down below pole of map
Factor    Scale factor at central meridian (Transverse Mercator) or
          center of projection (Hotine Oblique Mercator)
CentLon   Longitude of center of projection
CenterLat Latitude of center of projection
Height    Height of perspective point
Long1     Longitude of first point on center line (Hotine Oblique
          Mercator, format A)
Long2     Longitude of second point on center line (Hotine Oblique
          Mercator, format A)
Lat1      Latitude of first point on center line (Hotine Oblique
          Mercator, format A)
Lat2      Latitude of second point on center line (Hotine Oblique
          Mercator, format A)
AziAng    Azimuth angle east of north of center line (Hotine Oblique
          Mercator, format B)
AzmthPt   Longitude of point on central meridian where azimuth occurs
          (Hotine Oblique Mercator, format B)
IncAng    Inclination of orbit at ascending node, counter-clockwise
          from equator (SOM, format A)
AscLong   Longitude of ascending orbit at equator (SOM, format A)
PSRev     Period of satellite revolution in minutes (SOM, format A)
LRat      Landsat ratio to compensate for confusion at northern end
          of orbit (SOM, format A -- use 0.5201613)
PFlag     End of path flag for Landsat:  0 = start of path,
          1 = end of path (SOM, format A)
Satnum    Landsat Satellite Number (SOM, format B)
Path      Landsat Path Number (Use WRS-1 for Landsat 1, 2 and 3 and
          WRS-2 for Landsat 4, 5 and 6.)  (SOM, format B)
Shapem    Oblated Equal Area oval shape parameter m
Shapen    Oblated Equal Area oval shape parameter n
Angle     Oblated Equal Area oval rotation angle
```

NOTES

```
Array elements 14 and 15 are set to zero
All array elements with blank fields are set to zero
All angles (latitudes, longitudes, azimuths, etc.) are entered in packed
     degrees/ minutes/ seconds (DDDMMMSSS.SS) format
```

The following notes apply to the Space Oblique Mercator A projection.

A portion of Landsat rows 1 and 2 may also be seen as parts of rows 246 or 247. To place these locations at rows 246 or 247, set the end of path flag (parameter 11) to 1--end of path. This flag defaults to zero.

When Landsat-1,2,3 orbits are being used, use the following values for the specified parameters:

Parameter 4 099005031.2
Parameter 5 128.87 degrees - (360/251 * path number) in packed DMS format
Parameter 9 103.2669323
Parameter 10 0.5201613

When Landsat-4,5 orbits are being used, use the following values for the specified parameters:

Parameter 4 098012000.0
Parameter 5 129.30 degrees - (360/233 * path number) in packed DMS format
Parameter 9 98.884119
Parameter 10 0.5201613

## UTM Zone Codes

**********

The Universal Transverse Mercator (UTM) Coordinate System uses zone codes instead of specific projection parameters. The table that follows lists UTM zone codes as used by GCTPc Projection Transformation Package.

| Zone | C.M. | Range | Zone | C.M. | Range |
|---|---|---|---|---|---|
| 01 | 177W | 180W-174W | 31 | 003E | 000E-006E |
| 02 | 171W | 174W-168W | 32 | 009E | 006E-012E |
| 03 | 165W | 168W-162W | 33 | 015E | 012E-018E |
| 04 | 159W | 162W-156W | 34 | 021E | 018E-024E |
| 05 | 153W | 156W-150W | 35 | 027E | 024E-030E |
| 06 | 147W | 150W-144W | 36 | 033E | 030E-036E |
| 07 | 141W | 144W-138W | 37 | 039E | 036E-042E |
| 08 | 135W | 138W-132W | 38 | 045E | 042E-048E |
| 09 | 129W | 132W-126W | 39 | 051E | 048E-054E |
| 10 | 123W | 126W-120W | 40 | 057E | 054E-060E |
| 11 | 117W | 120W-114W | 41 | 063E | 060E-066E |
| 12 | 111W | 114W-108W | 42 | 069E | 066E-072E |

| | | | | | |
|---|---|---|---|---|---|
| 13 | 105W | 108W-102W | 43 | 075E | 072E-078E |
| 14 | 099W | 102W-096W | 44 | 081E | 078E-084E |
| 15 | 093W | 096W-090W | 45 | 087E | 084E-090E |
| 16 | 087W | 090W-084W | 46 | 093E | 090E-096E |
| 17 | 081W | 084W-078W | 47 | 099E | 096E-102E |
| 18 | 075W | 078W-072W | 48 | 105E | 102E-108E |
| 19 | 069W | 072W-066W | 49 | 111E | 108E-114E |
| 20 | 063W | 066W-060W | 50 | 117E | 114E-120E |
| 21 | 057W | 060W-054W | 51 | 123E | 120E-126E |
| 22 | 051W | 054W-048W | 52 | 129E | 126E-132E |
| 23 | 045W | 048W-042W | 53 | 135E | 132E-138E |
| 24 | 039W | 042W-036W | 54 | 141E | 138E-144E |
| 25 | 033W | 036W-030W | 55 | 147E | 144E-150E |
| 26 | 027W | 030W-024W | 56 | 153E | 150E-156E |
| 27 | 021W | 024W-018W | 57 | 159E | 156E-162E |
| 28 | 015W | 018W-012W | 58 | 165E | 162E-168E |
| 29 | 009W | 012W-006W | 59 | 171E | 168E-174E |
| 30 | 003W | 006W-000E | 60 | 177E | 174E-180W |

Obtained from Software Documentation for GCTP General Cartographic Transformation Package: National Mapping Program Technical Instructions, U.S. Geological Survey, National Mapping Division, Oct 1990,

Note: The following source contains UTM zones plotted on a world map:

Snyder, John P. Map Projections--A Working Manual: U.S. Geological Survey Professional Paper 1395 (Supersedes USGS Bulletin 1532), United States Government Printing Office, Washington D.C. 1987. p. 42.

## State Plane Zone Codes
**********

State Plane Coordinate System uses zone codes instead of specific projection parameters. The table that follows lists State Plane zone codes as used by the GCTPc Projection Transformation Package.

| Jurisdiction Zone name or number | Zone Code | Zone Code |
|---|---|---|
| Alabama | | |
| East | 0101 | 0101 |
| West | 0102 | 0102 |
| Alaska | | |
| 01 through 10 | 5001 | 5001 |

| | | |
|---|---|---|
| thru | 5010 | 5010 |
| Arizona | | |
| East | 0201 | 0201 |
| Central | 0202 | 0202 |
| West | 0203 | 0203 |
| Arkansas | | |
| North | 0301 | 0301 |
| South | 0302 | 0302 |
| California | | |
| 01 through 07 | 0401 | 0401 |
| thru | 0407 | 0406 |
| Colorado | | |
| North | 0501 | 0501 |
| Central | 0502 | 0502 |
| South | 0503 | 0503 |
| Connecticut | 0600 | 0600 |
| Delaware | 0700 | 0700 |
| District of Columbia | 1900 | 1900 |
| Florida | | |
| East | 0901 | 0901 |
| West | 0902 | 0902 |
| North | 0903 | 0903 |
| Georgia | | |
| East | 1001 | 1001 |
| West | 1002 | 1002 |
| Hawaii | | |
| 01 through 05 | 5101 | 5101 |
| thru | 5105 | 5105 |
| Idaho | | |
| East | 1101 | 1101 |
| Central | 1102 | 1102 |
| West | 1103 | 1103 |
| Illinois | | |
| East | 1201 | 1201 |
| West | 1202 | 1202 |
| Indiana | | |
| East | 1301 | 1301 |
| West | 1302 | 1302 |
| Iowa | | |
| North | 1401 | 1401 |
| South | 1402 | 1402 |
| Kansas | | |
| North | 1501 | 1501 |
| South | 1502 | 1502 |
| Kentucky | | |
| North | 1601 | 1601 |
| South | 1602 | 1602 |
| Louisiana | | |

| | | |
|---|---|---|
| North | 1701 | 1701 |
| South | 1702 | 1702 |
| Offshore | 1703 | 1703 |
| Maine | | |
| East | 1801 | 1801 |
| West | 1802 | 1802 |
| Maryland | 1900 | 1900 |
| Massachusetts | | |
| Mainland | 2001 | 2001 |
| Island | 2002 | 2002 |
| Michigan | | |
| East(TM) | 2101 | ---- |
| Central(TM) | 2102 | ---- |
| West(TM) | 2103 | ---- |
| North(Lam) | 2111 | 2111 |
| Central(Lam) | 2112 | 2112 |
| South(Lam) | 2113 | 2113 |
| Minnesota | | |
| North | 2201 | 2201 |
| Central | 2202 | 2202 |
| South | 2203 | 2203 |
| Mississippi | | |
| East | 2301 | 2301 |
| West | 2302 | 2302 |
| Missouri | | |
| East | 2401 | 2401 |
| Central | 2402 | 2402 |
| West | 2403 | 2403 |
| Montana | ---- | 2500 |
| North | 2501 | ---- |
| Central | 2502 | ---- |
| South | 2503 | ---- |
| Nebraska | ---- | 2600 |
| North | 2601 | ---- |
| South | 2602 | ---- |
| Nevada | | |
| East | 2701 | 2701 |
| Central | 2702 | 2702 |
| West | 2703 | 2703 |
| New Hampshire | 2800 | 2800 |
| New Jersey | 2900 | 2900 |
| New Mexico | | |
| East | 3001 | 3001 |
| Central | 3002 | 3002 |
| West | 3003 | 3003 |
| New York | | |
| East | 3101 | 3101 |
| Central | 3102 | 3102 |

| | | |
|---|---|---|
| West | 3103 | 3103 |
| Long Island | 3104 | 3104 |
| North Carolina | 3200 | 3200 |
| North Dakota | | |
| North | 3301 | 3301 |
| South | 3302 | 3302 |
| Ohio | | |
| North | 3401 | 3401 |
| South | 3402 | 3402 |
| Oklahoma | | |
| North | 3501 | 3501 |
| South | 3502 | 3502 |
| Oregon | | |
| North | 3601 | 3601 |
| South | 3602 | 3602 |
| Pennsylvania | | |
| North | 3701 | 3701 |
| South | 3702 | 3702 |
| Rhode Island | 3800 | 3800 |
| South Carolina | ---- | 3900 |
| North | 3901 | ---- |
| South | 3902 | ---- |
| South Dakota | | |
| North | 4001 | 4001 |
| South | 4002 | 4002 |
| Tennessee | 4100 | 4100 |
| Texas | | |
| North | 4201 | 4201 |
| North Central | 4202 | 4202 |
| Central | 4203 | 4203 |
| South Central | 4204 | 4204 |
| South | 4205 | 4205 |
| Utah | | |
| North | 4301 | 4301 |
| Central | 4302 | 4302 |
| South | 4303 | 4303 |
| Vermont | 4400 | 4400 |
| Virginia | | |
| North | 4501 | 4501 |
| South | 4502 | 4502 |
| Washington | | |
| North | 4601 | 4601 |
| South | 4602 | 4602 |
| West Virginia | | |
| North | 4701 | 4701 |
| South | 4702 | 4702 |
| Wisconsin | | |
| North | 4801 | 4801 |

```
     Central               4802     4802
     South                 4803     4803
Wyoming
     East                  4901     4901
     East Central          4902     4902
     West Central          4903     4903
     West                  4904     4904
Puerto Rico                5201     5200
Virgin Islands             ----     5200
     St. John, St. Thomas  5201     ----
     St. Croix             5202     ----
American Samoa             5300     ----
Guam                       5400     ----
```

Obtained from Software Documentation for GCTP General Cartographic Transformation Package: National Mapping Program Technical Instructions, U.S. Geological Survey, National Mapping Division, Oct 1990,

Note: Equations for State Plane zones are given in:

Clarie, Charles N, State Plane Coordinates by Automatic Data Processing, U.S. Department of Commerce, Environmental Science Services Administration, Coast and Geodetic Survey, United States Government Printing Office, Publication 62-4, 1973.

# Appendix C

# Data Format Compatibility

Many of the tools automatically detect the input file format and perform the same operation for a number of different formats, for example CoastWatch IMGMAP files and CoastWatch HDF files. The following table shows the file format compatibility of the various tools:

| Tool | Input formats | Output formats |
|---|---|---|
| cdat | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | CWHDF, Binary, Text, ArcGIS, PNG, GIF, JPEG, PDF, GeoTIFF |
| cwangles | CWHDF/NC | – |
| cwautonav | CWHDF/NC, CWF | – |
| cwcomposite | CWHDF/NC, CWF, TSHDF, OPeNDAP | CWHDF |
| cwcoverage | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | PNG |
| cwdownload | – | – |
| cwexport | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | Binary, Text, ArcGIS |
| cwgraphics | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | CWHDF |
| cwimport | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | CWHDF |
| cwinfo | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | – |
| cwmaster | CWHDF/NC, CWF, TSHDF | CWHDF |
| cwmath | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | CWHDF |
| cwnavigate | CWHDF/NC, CWF | – |
| cwregister | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | CWHDF |

| Tool | Input formats | Output formats |
|---|---|---|
| cwrender | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | PNG, GIF, JPEG, PDF, GeoTIFF |
| cwsample | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | Text |
| cwstats | CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP | – |
| cwstatus | – | – |

where:

**CWHDF/NC** HDF 4 and netCDF 3 with CoastWatch HDF or CF metadata (.hdf, .nc). CF metadata support is still experimental.

**CWF** CoastWatch format (.cwf) files that contain AVHRR SST, cloud, channel, angle, and graphics data. These files were produced by CoastWatch up to 2004.

**TSHDF** SeaSpace TeraScan files that have been converted to HDF using tdftohdf. Only the `rectangular`, `polarstereo`, `mercator`, and `emercator` projections are supported, along with `sensor_scan` if latitude and longitude angles have been included in the file.

**N1B** NOAA 1b AVHRR data, format versions 1 through 5, GAC or LAC resolutions, 8-bit, 10-bit, and 16-bit sensor word sizes with or without archive header.

**OPeNDAP** OPeNDAP datasets with CoastWatch HDF or CF metadata, map projection files only. CF metadata support is still experimental. Swath datasets and `RasterPixelIsPoint` mode are not supported.

**Binary** Raw binary format. See individual manual pages for a description of the binary file contents.

**Text** Standard ASCII text format. See individual manual pages for a description of the text file contents.

**ArcGIS** ESRI ArcGIS binary grid format (32-bit IEEE floats) with accompanying header file.

**PNG** Portable Network Graphics with optional world file.

**GIF** Graphics Interchange Format with optional world file.

**JPEG** Joint Photographic Experts Group with optional world file.

**PDF** Adobe Portable Document Format

**GeoTIFF** Tagged Image File Format with georeferencing tags.

# Appendix D

# Miscellaneous Formats

## D.1 Navigation analysis XML output


```
<?xml version="1.0"?>

<pointList
  xmlns="http://coastwatch.noaa.gov"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://coastwatch.noaa.gov http://coastwatch.noaa.gov/xml/pointlist.xsd">

  <dataset
    name="2006_340_0942_n18_ws.hdf"
    format="CoastWatch HDF version 3.4"/>

  <point>
    <earthLoc lat="34.442345084532306" lon="-120.5162100165965"/>
    <dataLoc row="702.0" col="586.0"/>
    <northDir row="-1.0" col="0.0"/>
    <navOffset row="0.0" col="0.0"/>
    <comment value="Manual"/>
    <varValue name="avhrr_ch3" value="13.34" units="celsius"/>
    <varValue name="avhrr_ch4" value="13.75" units="celsius"/>
    <varValue name="avhrr_ch5" value="13.19" units="celsius"/>
    <varValue name="sat_zenith" value="27.41" units="degrees"/>
  </point>

  <point>
    <earthLoc lat="33.71715205953104" lon="-118.35055152964117"/>
    <dataLoc row="768.0" col="750.0"/>
    <northDir row="-1.0" col="0.0"/>
    <navOffset row="0.0" col="0.0"/>
    <comment value="Manual"/>
```

```
    <varValue name="avhrr_ch3" value="13.66" units="celsius"/>
    <varValue name="avhrr_ch4" value="13.38" units="celsius"/>
    <varValue name="avhrr_ch5" value="13.32" units="celsius"/>
    <varValue name="sat_zenith" value="12.86" units="degrees"/>
  </point>

  <point>
    <earthLoc lat="37.96232720746668" lon="-122.93276796240643"/>
    <dataLoc row="373.0" col="403.0"/>
    <northDir row="-1.0" col="0.0"/>
    <navOffset row="0.0" col="0.0"/>
    <comment value="Auto failed"/>
    <varValue name="avhrr_ch3" value="10.77" units="celsius"/>
    <varValue name="avhrr_ch4" value="11.06" units="celsius"/>
    <varValue name="avhrr_ch5" value="10.36" units="celsius"/>
    <varValue name="sat_zenith" value="43" units="degrees"/>
  </point>

  <point>
    <earthLoc lat="32.67355292893255" lon="-117.21490134745726"/>
    <dataLoc row="862.0" col="836.0"/>
    <northDir row="-1.0" col="0.0"/>
    <navOffset row="0.0" col="0.0"/>
    <comment value="Auto OK"/>
    <varValue name="avhrr_ch3" value="13.97" units="celsius"/>
    <varValue name="avhrr_ch4" value="14.11" units="celsius"/>
    <varValue name="avhrr_ch5" value="13.7" units="celsius"/>
    <varValue name="sat_zenith" value="3.22" units="degrees"/>
  </point>

  <point>
    <earthLoc lat="33.992583436357236" lon="-119.92197445615143"/>
    <dataLoc row="743.0" col="631.0"/>
    <northDir row="-1.0" col="0.0"/>
    <navOffset row="0.0" col="0.0"/>
    <comment value="Auto failed"/>
    <varValue name="avhrr_ch3" value="12.17" units="celsius"/>
    <varValue name="avhrr_ch4" value="12.4" units="celsius"/>
    <varValue name="avhrr_ch5" value="11.91" units="celsius"/>
    <varValue name="sat_zenith" value="23.27" units="degrees"/>
  </point>

</pointList>
```

## D.2 Navigation analysis CSV output

Note that long lines are wrapped and continuation lines indented. In the actual output, each point is on a single line.

```
"LAT","LON","ROW","COL","ROW_NORTH","COL_NORTH","ROW_OFFSET","COL_OFFSET",
  "COMMENT","AVHRR_CH3","AVHRR_CH4","AVHRR_CH5","SAT_ZENITH"
34.442345084532306,-120.5162100165965,702.0,586.0,-1.0,0.0,0.0,0.0,
  "Manual",13.34,13.75,13.19,27.41
33.71715205953104,-118.35055152964117,768.0,750.0,-1.0,0.0,0.0,0.0,
  "Manual",13.66,13.38,13.32,12.86
37.96232720746668,-122.93276796240643,373.0,403.0,-1.0,0.0,0.0,0.0,
  "Auto failed",10.77,11.06,10.36,43
32.67355292893255,-117.21490134745726,862.0,836.0,-1.0,0.0,0.0,0.0,
  "Auto OK",13.97,14.11,13.7,3.22
33.992583436357236,-119.92197445615143,743.0,631.0,-1.0,0.0,0.0,0.0,
  "Auto failed",12.17,12.4,11.91,23.27
```

## D.3 Color palette XML format

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!DOCTYPE palette SYSTEM "http://coastwatch.noaa.gov/xml/palette.dtd">

<palette name="HSL256" length="256">
  <color r="128" g="0" b="127" />
  <color r="125" g="3" b="130" />
  <color r="123" g="5" b="132" />
  <color r="120" g="8" b="135" />
  <color r="118" g="10" b="137" />

(... lines omitted ...)

  <color r="140" g="12" b="0" />
  <color r="137" g="10" b="0" />
  <color r="135" g="7" b="0" />
  <color r="132" g="5" b="0" />
  <color r="130" g="2" b="0" />
  <color r="128" g="0" b="0" />
</palette>
```

# Appendix E

# AVHRR SST Product FAQ

This list of frequently asked questions is designed to answer some of the more in-depth user questions received about AVHRR sea surface temperature products. The NOAA CLASS archive (http://www.class.noaa.gov) holds a long series of CoastWatch AVHRR SST products from 1990 to the present. The data is available in close to its original AVHRR LAC pixel resolution (1.1 km) in various projections depending on region including Mercator and polar stereographic. CoastWatch IMGMAP (.cwf) products are available prior to November 10, 2003 as a set of high/medium/low resolution regions with various AVHRR channels, SST, cloud, and sensor angle data split into separate files for a given AVHRR pass. CoastWatch HDF (.hdf) products are available from November 10, 2003 to the present as high resolution regions with all AVHRR channel data, derived data, and angles in one file for a given AVHRR pass. The questions and answers below deal with both CWF and HDF files.

## E.1 Data formats and archiving

**What are all the various categories of CoastWatch data files on CLASS?**

There are many CoastWatch products on CLASS to search through – following is a guide to the categories:

**CW_SWATH**
: CoastWatch HDF capture station swath files produced starting November 10, 2003 to the present. The swath files contain data in the original AVHRR sensor scan projection before registration to a Mercator or polar stereographic map. Swath files are equivalent to NOAA 1b HRPT data but with SST and cloud data computed, and AVHRR channels calibrated.

**CW_REGION**
: CoastWatch HDF regional node files produced starting November 10, 2003 to the present. Each HDF region file contains data from the swath files registered to a map projection.

**CWALA, CWCAR, CWGRL, CWGOM, CWHAW, CWNOE, CWSOE, CWWEC**
: CWF files produced before November 10, 2003 for the Alaska, Caribbean, Great Lakes, Gulf of Mexico, Hawaii, Northeast, Southeast, and West Coast regions.

**Why do I get all sorts of error messages when I run cwinfo with the -v option?**

The **-v** option for the cwinfo tool tells it to print the status of file identification. The code steps through a number of file formats before it finds the one that works, prints the file information, and then exits with a zero status code (zero indicates nothing went wrong). Leave off the **-v** option if you only want to see normal output and no error messages. The tool prints the file identification tests as Java code *exceptions* just as a convenience so that programmers can check the line numbers in the code for where the identification failed, which is good for debugging, but not intended for the average user.

**When I run the CoastWatch tools on some files from CLASS, I get error messages. Is there something wrong with the files?**

We have had reports of data files obtained from the CLASS archive that are truncated or corrupt in some way. Users report that CoastWatch tools crash, report error messages, or simply don't recognize the file format. In some cases you can re-download the file and try accessing it again, because the error occurred during transmission from CLASS to your local machine. CLASS can provided a digital signature file in order to check that the downloaded file was not corrupted during transmission (see the options in the CLASS shopping cart). In other cases, the files are corrupt in the archive itself, and should be reported to CLASS as being invalid.

**Not all the HDF files I access contain an SST or cloud variable. Why is that?**

Some NOAA-12 data files covering Hawaii do not have SST and cloud computed because of a special arrangement with Hawaii data users who wanted AVHRR channel data when no NOAA-12 operational SST equation was available. There are also some NOAA-15 data files covering various US regions that do not have SST and cloud due to a processing system bug that was corrected by reprocessing the data (although some files were missed by the reprocessing). In general, all AVHRR SST products should contain SST and cloud data. If they don't, report the data file to CLASS.

**Why does the graphics variable in some CWF files not have any data in it?**

Some full regional panel CWF data files such as the ER region for the East Coast do not contain any graphics data. This is due to a problem with the processing system for those files. There is a *placeholder* for graphics data in CWF files which in some cases contains graphics for the smaller 512×512 CWF files, but in some larger region CWF files it contains all zeroes.

An easy way to create the missing graphics is to import a CWF SST file into HDF with cwimport (make sure to use `--match sst` so that the graphics aren't imported as well) and run the cwgraphics tool on it to create and insert coast/land/grid graphics into the HDF file.

## E.2 SST computation

**Can I use the AVHRR SST products for front analysis?**

CoastWatch AVHRR SST data can be used for SST front detection and is useful for small areas due to its relatively high spatial resolution. See the follow paper for one such front detection algorithm:

> Ullman, D.S., and P.C. Cornillon, 2000: Evaluation of Front Detection Methods for Satellite-Derived SST Data Using In Situ Observations. *J. Atmos. Oceanic Technol.*, 17, 1667-1675.

**Why are there so many SST algorithms for the CWF data files on CLASS?**

The different SST algorithms listed under "Datatype" on CLASS go hand-in-hand with the file naming convention – each SST algorithm used has a different code as the last two characters before the `.cwf` extension. To search for any available SST, select all of the possible SST products. Generally only one SST product will have been produced for a given satellite pass, but various algorithms have been used over the time period of the CWF file production so they all appear in the Datatype check boxes.

The naming of the SST algorithms may be confusing for new users. "MCSST" stands for multi-channel but really *any* SST algorithm used by CoastWatch uses multiple channels to compute the SST. Sometimes SST is called "moisture corrected" because that's how *all* of the SST algorithms work – they generally use channel 4 and correct it for moisture in the atmosphere using thermal channel difference terms ($ch_4 - ch_5$, $ch_3 - ch_5$, $ch_3 - ch_4$), either in a linear combination or non-linear combination. The most accurate algorithm and coefficients to run at a given time is determined by NESDIS researchers who call it the "operational algorithm" which changes from satellite to satellite and time period to time period.

The results of an SST data search on CLASS should return a single SST product file per satellite pass whose data is SST – only advanced users comparing AVHRR channel data to SST results should be concerned with which algorithm was used, or those who need to provide such details with a publication.

As an added note, CoastWatch HDF files are not searchable by SST algorithm because only one SST algorithm is available per region: the most accurate one according to comparison with buoy measurements. HDF products contain SST in the `sst` HDF variable, and the SST algorithm used is documented by the `sst_equation` attribute attached to the variable. Some older HDF files may be missing this attribute due to a bug in the processing software.

**What happens when the solar terminator passes close to the center of a scene, which SST algorithm is used?**

NOAA series polar orbiting satellites (for example NOAA-14, NOAA-15, NOAA-16 and so on) are launched into a sun synchronous polar orbit which results in the satellite passing over low and mid latitude regions at roughly the same time every day (as opposed to polar regions where it passes over every 100 minutes). That time is initially set up to be once for daytime (sunlight hours) and once for nighttime (complete darkness). Some satellites such as NOAA-15 have slipped over time and pass over a region when the region is partially lit and partially dark because the sun has set and the satellite is viewing the solar terminator. In these cases, the SST algorithm used is switched between a daytime algorithm and a nighttime algorithm depending on the sun angle at each pixel. For CoastWatch data,

either in CWF or HDF format, the algorithm is switched when the solar zenith angle is 85°. For $sz \leq 85°$, the pixel undergoes a daytime SST algorithm, and for $sz > 85°$ a nighttime SST algorithm. Note that the cloud masking algorithm (mentioned below) uses a different threshold: 80° rather than 85°.

**Why can I see a discontinuity in the SST values in some mixed day/night scenes?**

See the question above. When the SST algorithm switches in the middle of a mixed day/night scene, the SST values computed often show a slight discontinuity at the threshold because the different algorithms use different coefficients and possibly use different thermal AVHRR channels. The discontinuity is more pronounced in cloudy data, data that should be masked anyway.

## E.3 Cloud masking

**What cloud mask tests were used for day and night scenes?**

The cloud mask tests are different for day and night as follows:

**Daytime**

Bit 1: Reflective Gross Cloud Test
Bit 2: Reflectance Uniformity Test
Bit 3: Reflectance Ratio Cloud Test
Bit 4: Channel 3 Albedo Test
Bit 5: Thermal Uniformity Test
Bit 6: Four Minus Five Test
Bit 7: Thermal Gross Cloud Test

**Nighttime**

Bit 1: Thermal Gross Cloud Test
Bit 2: Thermal Uniformity Test
Bit 3: Uniform Low Stratus Test
Bit 4: Four Minus Five Test
Bit 5: Cirrus Test
Bit 6: Channel 3B Albedo Test (CLAVR-x, HDF only)
Bit 7: Channel 3B Albedo Uniformity Test (CLAVR-x, HDF only)

where bit 1 is the least significant bit, and bit 8 is the most significant. The CWF data files use only CLAVR-1 cloud mask tests as described in:

> Stowe, L.L., P.A. Davis, and E.P. McClain, 1999: Scientific Basis and Initial Evaluation of the CLAVR-1 Global Clear/Cloud Classification Algorithm for the Advanced Very High Resolution Radiometer. *J. Atmos. Oceanic Technol.*, 16, 656-681.

The HDF files use mainly CLAVR-1 tests but also two CLAVR-x tests at night, described in:

> Jelenak, A. and A.K. Heidinger: Validation of CLAVR-x cloud detection over ocean using AVHRR GAC sea surface temperature. Proceedings of SPIE – Volume 5658 Applications

with Weather Satellites II, W. Paul Menzel, Toshiki Iwasaki, Editors, January 2005, pp. 292-298.

and have modified versions of the RGCT, RUT, and RRCT during the day that take advantage of CLAVR-x style thresholds rather than static thresholds for these tests.

**What happens with the cloud mask when a scene contains the solar terminator?**

For data users interested in SST masking, the intended use for the cloud mask data is that regardless of scene time (day, night, or mixed day/night), the cloud mask should be treated as zero = clear, non-zero = cloudy. If a scene contains the solar terminator then the set of cloud mask tests is switched at a solar zenith angle of 80°, but the zero/non-zero rule still applies. If you need more information about exactly which tests were used at each pixel, you can use the solar zenith angle data for the pixel. For $sz \leq 80°$, the pixel has daytime cloud mask tests, and for $sz > 80°$ it has nighttime tests (although see the answer to the next question below about cloud test bit mixing).

The CWF and HDF files have the same behaviour with respect to cloud mask test switching. The HDF files always contain the solar zenith angle data for day or mixed day/night scenes, but are missing the solar zenith angle for night scenes to decrease the file size, and because solar zenith angle data is largely useless at night. CWF SST and cloud mask data files may in some cases be accompanied by corresponding solar zenith angle files (datatype ZA on CLASS) but not always as their production was based on the data requirements at the time. In most cases the scene time of CWF files and hence which set of cloud mask tests were used can be determined from the scene time output line from the cwinfo tool.

**Why can I see a discontinuity in the cloud mask data in some mixed day/night scenes?**

See the question above for a partial explanation. A different set of cloud mask tests are used for day pixels versus night pixels, so the cloud mask data pixels have different bits set depending on which side of the discontinuity they lie. There is no one-to-one correspondence between day and night cloud tests.

In addition to a cloud mask data discontinuity at the solar zenith, in some cases the change from day to night tests is not "clean", rather there are some pixels on the day side of the $sz = 80°$ line that appear to have bits set the same as the night side of the line and vice-versa. There are two issues that contribute to this:

1. The solar zenith angles are rounded to the nearest 1/100th of a degree when written to an HDF file (or either 1/100th or 1/128th for a CWF file depending on the compression used) so a few pixels with values of, for example, 80.003° will be rounded down to 80° even though they underwent processing with the nighttime cloud tests.

2. The cloud tests in some cases use neighborhood functions. The uniformity tests use a 2×2 box of data pixels to the right and below a given pixel in the array to check for a condition being true, and the result of the uniformity test flags all pixels in the 2×2 box with the test results, regardless of whether all those pixels are day or night. Both day and night have uniformity tests, so the results of uniformity tests at the day/night boundary are mixed. The mixing is generally acceptable because the results are intended to be used for SST masking, not cloud type evaluation and the mixing only occurs in cloudy conditions, not clear SST conditions.

## E.4 Navigation correction

**What does navigation correction actually do, rewrite all the data in the file?**

No, it only adds metadata to the file header to advise the CoastWatch Utilities software of how to read the data. Think of navigation correction like this. The file metadata says "this file starts at a certain latitude/longitude and has a certain number of rows, columns, and pixel size". That metadata sets the physical area for the file and cannot be changed by the navigation correction. Performing a navigation correction on the file sets up extra metadata in the header that says "for this variable (for example SST), when the user requests the pixel data at (0,0), give them the data from $(0+x,0+y)$" where $x$ and $y$ are the navigation correction offsets.

**Have the CoastWatch products on CLASS been autonavigated to correct the coastlines, and if so how accurate is the navigation?**

The CW_REGION and CW_SWATH files have been autonavigated, but the older CWF files listed under other regional node categories have not. The autonavigation is accurate to $\pm 1$ pixel when it runs successfully, which is about 90% of the time. If navigation accuracy is a major concern, products should be checked by hand and corrected if needed. Starting in 2007, both swath and mapped HDF products contain two extra global HDF attributes to indicate the success/failure of the autonavigation algorithm: `autonav_performed` which indicates `true` or `false`, and `autonav_quality` which is an integer attribute written when the autonavigation is successful to give an indication of the quality of the navigation as low (0), medium (1), or high (2).

**Was the cwautonav tool used for autonavigating the 2003 and later HDF files?**

No, the CoastWatch data processing system for AVHRR uses the SeaSpace TeraScan software for autonavigation, which employs a similar algorithm to cwautonav. The cwautonav tool was added to the CoastWatch software in 2004, mainly to aid users in working with the older CWF data files.

**Is the autonavigation performed by the CoastWatch AVHRR processing system more accurate than cwautonav?**

Yes, the best spatial accuracy is achieved by correcting navigation problems during HDF file production rather than using cwautonav after production. The source of most navigation errors with NOAA satellites is an inaccuracy in the on-board clock and an uncertainty in the roll of the satellite. Those errors translate respectively to a shift in the scan line direction and sample direction when viewing the image data in its original sensor scan geometry. The AVHRR processing system makes the correction while in sensor scan geometry, and then registers the data to a map projection. Once in a map projection, you cannot correct the navigation perfectly using a simple x and y shift, except in small areas. Generally CoastWatch regional data files cover only small areas of about 500-1000 km in radius, so correcting with an x and y shift works well enough in most cases.

**How can I perform autonavigation of the pre-2003 CWF files?**

The best way to perform navigation of CWF files is to import multiple CWF files to an HDF file with cwimport, then run the cwautonav tool on the new HDF file. That way, you only have to run the navigation once and the results are applied to all the variables in the HDF file selected for navigation (see the question below about variables that should be navigated). Use the cwautonav command line tool with the default options. The key to successful autonavigation is to choose many navigation boxes with feature-rich coastline segments (rather than a flat coastline with no curves). Use AVHRR visible channel 2 for navigation when possible, as channel 2 data provides the most contrast between land and water. At night, you can fall back on AVHRR channel 4, channel 3, or SST since SST is very similar to channel 4.

**After manually navigating a CoastWatch data file in CDAT, how can I access the navigation offsets?**

For CWF files that have been manually navigated, there is no way to extract the navigation metadata directly from the file using the most recent version (3.x) of the CoastWatch Utilities. You *can* use version 2.3 of the package, by running the cwfatt tool (see the user's guide in that version) and ask it to print the `horizontal_shift` and `vertical_shift` attributes. You can then apply them to other CWF files from the same date/time using the cwfnav tool (also in the version 2.3 package) as shown by example in the user's guide. Be careful about mixing version 2 (cwfnav) and version 3 (cwnavigate) command-line navigation tools – they use different conventions for the navigation offset. A positive translation offset in the version 2 tool is a negative translation offset in the version 3 tool and vice-versa. However once the offsets are set (using either the old or new tools), CDAT will know how to interpret them correctly. Note that navigating a CWF file and then converting to HDF to get the navigation metadata won't work – when the import to HDF is done, the navigation is taken into account by shifting the image data, so the HDF file will not contain the navigation metadata.

For HDF files that have been manually navigated, you can extract the navigation metadata using the hdatt tool by asking for the `nav_affine` attribute for a specific variable since HDF files stored navigation metadata individually for each variable. See Appendix B for a description of HDF navigation metadata. An alternative to hdatt is the hdp command in the HDF Group software.

**Why do the HDF files contain floating-point navigation corrections, but CWF files only contain integer corrections?**

The floating-point values in the HDF files are a feature of the new file format. CWF files can only contain integer-valued translation offsets, where as HDF files can contain float-valued affine transform coefficients which are much more flexible and can represent rotation, scale, shear, and translation transformations. The CoastWatch Utilities software uses whatever offsets it can find in the file and converts them internally to floats. When writing navigation corrections to CWF files, the translation offsets are rounded to integers and an error occurs if the affine transform represents anything but a simple translation.

**Should navigation corrections in CDAT, cwautonav, and cwnavigate be applied to all variables in an HDF file?**

No, only certain variables should have navigation corrections applied, namely those from the AVHRR sensor and sensor data derived variables. Graphics, solar zenith, satellite zenith, and relative azimuth angles should *not* be corrected. AVHRR channel data, SST, and cloud *should* be corrected. If you're using the command line tools, you can use the following option to match only the sensor type data: `--match "avhrr_ch.*|sst|cloud"`.

**Are there any other autonavigation algorithms that I can use for CoastWatch data?**

Randy Ferguson et. al. (NOAA, National Centers for Coastal Ocean Science, Center for Coastal Fisheries and Habitat Research) have written a research paper on their experience with automatic registration of daytime CoastWatch SST data:

Ferguson. R.L., C. Krouse, M. Patterson, and J.A. Hare. Automated Thematic Registration of NOAA, CoastWatch, and AVHRR Images. *Photogrammetric Engineering & Remote Sensing.* Vol. 72, No. 6, June 2006, pp. 677-685.

## E.5 Map projections

**What is the spheroid used for the CWF data files?**

The answer is complicated. Running the cwinfo tool on a CWF file reveals that the files use a WGS-72 spheroid which has a semi-major axis of 6378135 m and inverse flattening of 298.26. The reality is that the CWF files were registered to a Mercator or polar stereographic map projection using a sphere of radius 6371200 m, but the NOAA 1b file (the source of the AVHRR data) used a WGS-72 spheroid for the geographic coordinates with geodetic latitudes but the geodetic latitudes were not converted (datum shifted) to geocentric when the data was registered. If the data is regarded as having a spherical earth model when imported into a GIS system, the coastlines at all points in the image are completely wrong in the north-south direction. However assuming WGS-72, you'll find that if you match the center points of the CWF files based on coastlines, the image data will match the coastlines reasonably well except at the corners and edges where a 1-2 pixel error occurs.

**Are the land mask and other graphics the same for all data files?**

No. All the HDF files for a given region (for example the ER region) have the same land mask and graphics in each file because they all cover the same physical area. However, when the switch from CWF files to HDF files occurred in 2003, the map projections were upgraded to use a true WGS-84 spheroid rather than the mixed spheroid model as discussed above. Thus, CWF files all have a slightly different land mask and graphics data compared to their corresponding HDF files, because they represent a slightly different physical area. This means that pixel (0,0) in a CWF file is not at the same latitude/longitude as pixel (0,0) in the corresponding HDF file.

**Which CWF file regions correspond most closely to the new HDF file regions?**

The rough correspondence is as follows (note that some HDF regions have no corresponding CWF region):

| HDF region | CWF node and region |
|---|---|
| Alaska North | CWALA Northern Alaska |
| Alaska Sitka | CWALA Vancouver |
| Alaska South | CWALA Southern Alaska |
| Alaska West | CWALA Western Alaska |
| Caribbean East | CWCAR East Caribbean Synoptic |
| Caribbean West | CWCAR West Caribbean Synoptic |
| East Coast Bermuda | none |
| East Coast North | CWNOE Full Regional Panel |
| East Coast South | CWSOE Full Regional Panel |
| Great Barrier Reef | none |
| Great Lakes | CWGRL Full Regional Panel |
| Great Salt Lake | none |
| Gulf of Mexico | CWGOM Full Regional Panel |
| Hawaii | CWHAW Synoptic |
| West Coast Acapulco | none |
| West Coast Baja | CWWEC Baja Mexico Synoptic |
| West Coast North | CWWEC Northwest |
| West Coast South | CWWEC Southwest |

**When converting the Alaska HDF products to an ArcGIS binary grid, why do I end up with the data looking like it's on the wrong side of the earth?**

The CoastWatch HDF files and ArcGIS use different conventions for specifying the rotation angle of the central meridian. For the Alaska products, use the following projection string:

```
PROJCS['WGS_1984_Stereographic_North_Pole',
  GEOGCS['GCS_WGS_1984',
    DATUM['D_WGS_1984',SPHEROID['WGS_1984',6378137.0,298.257223563]],
    PRIMEM['Greenwich',0.0],
    UNIT['Degree',0.0174532925199433]
  ],
  PROJECTION['Stereographic_North_Pole'],
  PARAMETER['False_Easting',<insert value>],
  PARAMETER['False_Northing',<insert value>],
  PARAMETER['Central_Meridian',<insert value>],
  PARAMETER['Standard_Parallel_1',60.0],
  UNIT['Meter',1.0]
]
```

and insert values for the central meridian, false easting, and false northing. The central meridian can be determined from the center point longitude reported by running `cwinfo -t`, and the false easting

and northing can be computed from the `.hdr` file values for `xllcorner` and `yllcorner` as follows:

$$\begin{bmatrix} false\ east \\ false\ north \end{bmatrix} = \begin{bmatrix} 1-\cos t & -\sin t \\ \sin t & 1-\cos t \end{bmatrix} \begin{bmatrix} xllcorner \\ yllcorner \end{bmatrix}$$

where $t$ is the central meridian angle.

# Appendix F

# Acronyms

**API** Application Programming Interface

**AVHRR** Advanced Very High Resolution Radiometer

**CDAT** CoastWatch Data Analysis Tool

**CLASS** Comprehensive Large Array-data Stewardship System

**CWF** CoastWatch Format

**DMG** Disk Image

**ESRI** Environmental Systems Research Institute

**FAQ** Frequently Asked Question(s)

**FY** Feng Yun

**GAC** Global Area Coverage

**GCTP** General Cartographic Transformations Package

**GeoTIFF** Geographic Tagged Image File Format

**GIF** Graphics Interchange Format

**GIS** Geographic Information System

**GMT** Greenwich Mean Time *or* Generic Mapping Tools

**GSHHS** Global Self-consistent, Hierarchical, High-resolution Shorelines

**GUI** Graphical User Interface

**HDF** Hierarchical Data Format

**HRPT** High Resolution Picture Transmission

**IDL** Interactive Data Language

**IMGMAP** Image Map

**JPEG** Joint Picture Experts Group

**JRE** Java Runtime Environment

**JNI** Java Native Interface

**LAC** Local Area Coverage

**MVISR** Multichannel Visible and Infrared Scan Radiometer

**NAD** North American Datum

**NCSA** National Center for Supercomputing Applications

**NDVI** Normalized Difference Vegetation Index

**NESDIS** National Environmental Satellite, Data, and Information Service

**NetCDF** Network Common Data Form

**NOAA** National Oceanic and Atmospheric Administration

**OPeNDAP** Open-source Project for a Network Data Access Protocol

**PDF** Portable Document Format

**PNG** Portable Network Graphics

**RGB** Red/Green/Blue

**SAA** Satellite Active Archive (now part of CLASS)

**SDS** Scientific Data Set

**SST** Sea Surface Temperature

**TDF** TeraScan Data Format

**THG** The HDF Group

**UTC** Coordinated Universal Time

**UTM** Universal Transverse Mercator

**WGS** World Geodetic System

**XML** Extensible Markup Language

# Appendix G

# History of Changes

## Version 1, 1997/10/01 (internal release)

## Version 2, 1998/09/09 (first public release)

## Version 2.2, 1999/01/19

- cwf.c:
  Fixed file close bug in decompression routine
  Added more NOAA satellite codes (NOAA-15, -16, -17)
- Created composite program, cwfcomp
- cwftoarc.c:
  Corrected lower-left pixel position and cell size
  Added binary output option
  Added polar projection conversion
  Added projection specifications note
- cwftogif.c:
  Changed IR default min
  Changed brightness temperature legend
- cwproj.c:
  Modified polar projection calculation for Alaska file bugs

## Version 2.3, 1999/10/18

- cwfcomp.c:
  Added -b option to allow badval specification

Changed output file date to match last file

- cwf.c:
  Added f to various float constants
  Added test for near-zero IR values
  Simplified round function
  Fixed bug in cw_compress for files with cols < 512
  Added calibration guess for older WCRN files
- cwfnav.c:
  Fixed usage message
- cwftogif.c cwftohdf.c cwftonc.c cwftoraw.c cwfval.c cwproj.c:
  Simplified round function
- cwproj.c:
  Added corrections for WCRN's linear files
- cwftogif.c:
  Modified graphics plane layering, reformatted and commented
  Added ramsdis color palette for CH4 IR
- cwftohdf.c: Completely rewritten
- Created new HDF information routine: hdfinfo
- Created new landmasking routine, cwflmask
- Updated Makefile for new HDF and netCDF releases

## Version 2.4, 2001/06/21 (internal release)

- Changed Makefile to include cwproj.c in libcwf.a
- Created cwflmaskdb routine
- cwproj.c: Modified for linear lat/lon header errors
- Fixed hdfinfo and cwftohdf usage messages
- cwf.c: Added orbit_type "both" and channel_number "sst_multi"
- cwftohdf.c: Added orbit_type "both" and channel_number "sst_multi"
- cwf.c: Added flat file support, reading only
- Moved cwftohdf to cwftocwhdf
- Moved hdfinfo to cwhdfinfo
- Fixed CWclone bug in hcwf library
- Added Julian day printing to cwhdfinfo

## Version 3.1.0, 2001/07/19

- Implemented in Java using Java native interface to CWF and GCTP code.
- Now uses HDF4 via the HDF JNI calls.
- Now supports swath data.

## Version 3.1.1, 2002/10/17

- Added rendering.
- Compiled shared libraries for Windows and Solaris.

## Version 3.1.2, 2002/12/30

- Optimized coordinate translation code, rendering now runs 20% faster.
- Modified rendering normalization for viewable data only.
- Added grid overlay label drop shadows for better label legibility.
- Removed miter problems in shape drawings and coast lines.
- Added gridded dataset tile read/write caching for improved memory performance.
- Added NDVI palette.
- Corrected bitmask rendering for PDF files.
- Added registration tool for mapping between projections.
- Added generic bitmask rendering.
- Added navigation, master, sampling tools.
- Modified download tool command line parameters for regular expression matching.
- Added angle calculation tool.
- Improved coastline selection and rendering performance using binned GMT HDF dataset.

## Version 3.1.3, 2003/03/31

- Added new tool for server status monitoring.
- Optimized download and status tools for database usage and updated command line options.
- Added GeoTIFF output for mapped projection data to cwrender.

- Added NOAA 1b GAC/LAC AVHRR input.
- Fixed various bugs and made performance improvements.
- Updated Unix startup script for headless operations.

## Version 3.1.4, 2003/05/16

- Added two new tools: cwmath and cwcomposite.
- Added MacOS X support in the dynamic JNI libraries and wrapper script.
- Fixed dateline crossing navigation problems in NOAA 1b readers – still needs refinement for near-polar areas.
- Added basic GSHHS polygon rendering code to BinnedGSHHSReader – still needs refinement for bin boundaries and polygons broken by projection distortion.
- Added support for rendering progress to EarthDataView in preparation for CDAT operations.
- Added GLERL palettes "GLERL-Archive" and "GLERL-30-Degrees" palettes to the rendering tool and "NDVI" palette.
- Added "--age" option to download tool for specifying the desired maximum age of the data in hours.
- Added file chooser filters for ".hdf" and ".cwf" files in the cwmaster tool for easier use.
- Added 3D logos to rendering output.

## Version 3.1.5, 2003/09/03

- Extended GeoTIFF output in cwrender to generate a paletted file when no overlays are used, and such that the ImageDescription TIFF tag contains a mapping equation from palette index to data value.
- Corrected cwimport so that the "pass_type" attribute is correctly written when the metadata version is $< 3$.
- Corrected the text output from cwexport to write "NaN" for invalid values.
- Corrected a 0.5 pixel offset problem in image overlay rendering.
- Added land polygon filling algorithms for cwmaster (by default) and cwrender (by using --coast).
- Added --operator option in cwstatus for verbose operator messages.
- Added bitwise or/and functions in cwmath.
- Added new "cwgraphics" tool to generate standard CoastWatch graphics overlays.
- Modified cwdownload to more gracefully handle connection errors and network timeouts.

## Version 3.1.6, 2003/12/06

- Fixed space in resource path problem in Windows.
- Added support for AIX and IRIX.
- Added a resize bar for cwstatus between the online data list and data coverage / data preview panels.
- Added the cwcoverage tool for showing region coverage plots (need to add ground station coverage circle feature).

## Version 3.1.7, 2004/06/19

- Updated TeraScan HDF import for equirectangular projections and spheroid detection.
- Changed EarthVectorReader to EarthVectorSource.
- Moved file path creation to IOServices.
- Created ContourGenerator and TopographyOverlay classes and added contouring to cwrender.
- Changed command line tools to split multi-parameter options on regular expression, including ',' and '/'.
- Added splash screen for cwmaster and cwstatus.
- Added support in CWHDFReader for explicit lat/lon data rather than polynomial coefficients.
- Changed use of Vector in many classes to ArrayList for better performance.
- Added support for unsigned HDF and CWF variable data.
- Modified data color scale in cwrender for better log scale behaviour.
- Modified cwmaster and cwstatus batch files to run with the Windows look and feel.
- Fixed automatic center calculation problem in cwcoverage.
- Fixed rounding problem in EarthDataViewPanel.TrackBar.
- Added build file for ant.
- Now using the Java install4j wizard to create installation packages.
- Re-coded and extended the CoastWatch Data Analysis Tool to work with the Java API. In addition to its 0.7a version, CDAT now has annotation and navigation capabilities, online help, GeoTIFF output, topography overlays, generic bitmask overlays, overlay groups, support for swath files, and more. CDAT is now an integrated part of the package.
- Modified the cwstatus menus to allow users to connect to a different server.
- Removed the cwrender preview option – it was causing problems with headless operations.

- Updated online documentation in cwstatus and cwmaster.
- Replaced palette and RGB database files with XML versions.
- Added the --template option to cwmath so that users may use an existing variable as a template for the new variable rather than having to specify all of its properties.
- Added an update agent to graphical tools that informs the user if a software update is available.

# Version 3.1.8, 2004/11/25

## Updates

- Extended data caching in I/O routines to handle arbitrary size data arrays. Previously, some utilities would memory-thrash when faced with a large column count.
- Renamed various SatelliteXXX classes to EarthXXX to mirror more generality in metadata.
- Updated I/O for new metadata specifications, including multiple time periods and composite attributes.
- Modified the default metadata version to 3.2. Now by default, new files created with the utilities are no longer compatible with the older CDAT version 0.7a and earlier.
- Updated coastline data files to GSHHS v1.3 and corrected known polygon fill problems on the US East Coast, Africa, and South America.
- Updated ETOPO5 topography database and corrected problems with contours fills producing strange bullseye artifacts.
- Added a --timeout option to cwdownload to allow the user to select a network timeout value.
- Added a --transform option to cwinfo to print Earth transform information.
- Modified the behaviour of cwcomposite to append dataset metadata together rather than simply use the last file's global metadata (time, satellite, etc). The --pedantic option was also added to allow exact tracking of source dataset metadata.
- Added a --inputs option to cwcomposite to allow the user to specify a list of files in a text file rather than on the command line.
- Recompiled the HDF library for Linux to allow up to 256 open files. This allows the cwcomposite to handle more than 31 input datasets which was the previous limit.
- Modified cwmath to allow multiple input files, and output to an existing file that is not an input file.
- Updated to new install4j installation package wizard to fix various bugs and allow the user to select components during a graphical installation.
- Added various option to cwcoverage tool for plotting ground station coverage circles.

### Bug fixes

- Fixed stall problem in cwdownload when data server is unavailable or not responding within a certain timeout period.
- Fixed spelling problems with GCTP sinusoidal projection.
- Fixed swath reverse-lookup problems for non-AVHRR data.
- Fixed registration problems with partially swath-covered partitions in the output dataset.
- Fixed bitmask overlay navigation problem in CDAT.
- Fixed font problems in overlay group loading in CDAT on MacOS X.
- Fixed small polygons bug in CDAT coastline overlay.
- Fixed legend bounding rectangle line style problems in output from CDAT and cwrender.
- Fixed bitmask overlay rendering problems in CDAT on MacOS X.
- Fixed step color scale problems in image file output from CDAT.
- Fixed printing problems in cwinfo and cwstats.
- Fixed CDAT data view size change when many files are opened.
- Fixed CDAT data view so that if multiple file tabs are open and the user switches tabs, the data view does not continue to render to the wrong tab.
- Fixed CDAT problem with allowing multiple overlay property control dialogs.
- Fixed CDAT problem with contour level deletion causing a stall.
- Fixed stall problems in CDAT related to delayed rendering.
- Fixed stall problems in cwstatus when server is not responding.

## Version 3.1.9, 2004/04/07

### Updates

- Updated NOAA 1b AVHRR reading for version 3 format.
- Added support in metadata and CW HDF reading/writing for sensor scan geometry geostationary satellite data.
- Added LZW compressed GIF output for CDAT and cwrender.
- Added mixed resampling method to cwregister for handling discontinuities in the source data, such as in MODIS sensor data.
- Added cwautonav tool for estimating navigational corrections using image data.

- Added transparent overlay color rendering in CDAT and cwrender, specifically for overlaying user-specified polygon data without obscuring the background image.
- Modified graphical tools to output error messages that would normally go to the terminal to a dialog. Now users will be able to see "uncaught" exceptions and decide to ignore them or file a bug report.
- Added standard palettes specific to chlorophyll data.
- Added basic ESRI shapefile rendering support in CDAT and cwrender.
- Reformatted all tool manual pages and usage notes for clarity, as well as adding the equivalent one-letter options for all word-length options.
- Added general settings section in CDAT user preferences, initially for lat/lon format preferences.
- Modified all tools to clean up partially written data files after unexpected errors have occurred.
- Modified cwexport and cwrender to detect the desired file format based on the output file extension.
- Added --nostates (don't plot state border, just international borders) and --logo (plot a user-specified logo) options to cwrender.
- Added --imagecoords (print image row and column coordinates) to cwsample.
- Added log scale enhancements to CDAT.
- Updated graphical tool icons, menus, help pages, and Unix look-and-feel.
- Modified drop shadow rendering in CDAT and cwrender for better text readability.
- Added --projection option to cwdownload to allow the user to download only mapped or swath data files.

## Bug fixes

- Fixed overflow problem when writing HDF attribute data beyond 65535 values long.
- Fixed registration problem with navigationally corrected data.
- Fixed inappropriate missing value problem in ESRI ArcGIS grid and raw float output.
- Fixed "almost equals" problem with map projection parameter comparisons.
- Fixed background fill problem in CDAT data view when performing navigation.
- Fixed CDAT image saving bug; data view changed or became unusable after saving.
- Fixed problem with CDAT leaving files open even when user has closed file.
- Fixed PDF page size problem.

# Version 3.2.0, 2005/10/08

## Updates

- Added RasterPixelIsPoint style Earth location code for wind data.
- Improved speed of NOAA 1b reading by caching scan lines rather than tiles, as this reflects the actual file organization.
- Added support for OPeNDAP-accessible datasets with CoastWatch HDF metadata.
- Updated to perform datum shifting between Earth transforms of different datums.
- Changed "datum" terminology to "spheroid" in various locations.
- Added support for abstract GIS features to help in ESRI shapefile processing.
- Added spectrum and wind palettes for cwrender and CDAT.
- Added --limits option in cwstats.
- Added check for incompatible overlay group files in CDAT.
- Added support in cwrender for overlay group rendering, world files, vector data rendering, and units conversion.
- Updated CDAT to have a special interface for opening OPeNDAP connections and datasets, moved file information to a full size window, and added 1:1 toolbar button.
- Added various detailed control options in cwautonav.
- Added hdatt tool for direct manipulation of HDF attribute information.

## Bug fixes

- Corrected NOAA 1b longitude interpolation in polar regions.
- Modified to ignore coordinate variables in HDF files (for compliance with CF metadata conventions).
- Relaxed NOAA 1b format description check for varying descriptions in CLASS data files.
- Fixed unreliable convergence problem in swath Earth location reverse lookup algorithm.
- Fixed dropouts between rectangles in mixed resampling method for cwregister.
- Fixed Earth context element in output from cwrender to not draw coverage polygon when area is larger than orthographic projection area.
- Fixed problem with minimized window icons in graphical tools.
- Modified cwmaster so that map projections that support only sphere Earth models cannot be saved with an ellipsoid model.
- Modified the default locale for number formatting and printing to English/US to resolve problems with inconsistent parsing of numbers formatted in other countries.

# Version 3.2.1, 2006/11/21

## Updates

- Updated GUI code for better Mac OS X integration.
- Added help buttons in some areas of CDAT to aid users in getting context-specific help.
- Added color scale legend beside data view in CDAT in response to user suggestions.
- Added warning message in CDAT before applying navigation to make sure user understands that the data file is being modified.
- Changed "Save As" in CDAT to "Export" to avoid confusion. The data file should be thought of as read-only and the save formats as export formats.
- Changed the order of operations for exporting data in CDAT to simplify the number of steps users need to perform.
- Added continuous enhancement updates in CDAT for visual appeal.
- Updated icons for data view controls in CDAT.
- Added drag-and-drop support in CDAT for opening data files.
- Updated all dialog box buttons in CDAT to more closely match platform defaults.
- Factored code for earth transforms to allow for both native C and Java map projection implementations in the future.
- Added support in CDAT and cwrender for expression masking.
- Added support in CDAT for preferred units.
- Added support in CDAT and cwrender for saving image files with indexed 8-bit palettes.
- Added support in CDAT and cwrender for saving world files.
- Changed splash screen to not display by default for GUI tools. This was causing users to think that startup was abnormally slow.
- Added support in NOAA 1b reading code for version 4 and 5 file formats, 8-bit and 16-bit sensor word sizes, MetOp data files, and files with missing scan lines.
- Added support for user file formats via the extensions/ directory.
- Added TIFF file compression in CDAT and cwrender.
- Added code for the Earth Data Access Client (EDAC) for for use by the CoastWatch East Coast Node (ECN).
- Added support in TeraScan HDF I/O code for importing a user-specified set of attributes.
- Updated GSHHS reading code to handle binned political line data, and replaced databases in TeraScan vector format with new HDF binned data from GMT. This speeds up the access and rendering of state and international lines considerably.

- Enhanced color scale in cwrender and CDAT to correctly show log scale ticks above the highest power of ten on the scale. This helps with chlorophyll plotting when users scale between non-power-of-ten minimum and maximum.
- Added CDAT and cwrender palettes for Coral Reef Watch data.
- Added the --coherent option to cwcomposite based on CoastWatch central processing request. See the manual page for details.
- Updated look and content of application help files for CDAT, cwmaster, and cwstatus to be easier to read and navigate.
- Added ubyte/ushort types, and xor/not functions to cwmath.
- Added the --overwrite option to cwregister based on CoastWatch central processing request. See the manual page for details.
- Added the ability in cwrender to accept multiple --shape and --bitmask options. This makes rendering much more flexible.
- Added the --variable option to cwsample. It was confusing to users to have only --match and not be able to depend on the ordering of columns in the output text file.
- Added the --region option to cwstats that takes a center point and radius for sampling.
- Modified the base directory for user preferences to be operating system specific. The base directory was causing problems because different operating systems expect software to place customization directories in different locations. See the help files in CDAT for the new locations.
- Standardized on coastwatch.info@noaa.gov as the destination for all support emails.

## Bug fixes

- Fixed error with log enhancement normalization by disabling the Normalize button for log enhancements.
- Fixed status dialog problem in CDAT when loading variables with long names from files with short names.
- Fixed color, stroke, and font swatch rendering in CDAT for Mac OS X.
- Fixed problem with writing ArcGIS files from CDAT and cwexport. Header file accuracy was being impacted by writing to only two decimal places.
- Fixed problem when reading OPeNDAP files with 2D data of odd dimensions.
- Fixed error with retrieving chunks lengths while reading netCDF files, since netCDF has no chunking or compression support.
- Fixed null line color errors in CDAT overlays.
- Fixed problem with rendering text shadows for black grid lines in CDAT and cwrender.

- Fixed problem with lat/lon separator characters in cwautonav. Now the documentation and implementation match.
- Fixed cwdownload to delete partial files when a transfer error occurs.
- Fixed the lack of equation description in log-enhanced GeoTIFF output from cwrender and CDAT.
- Fixed error when working with geographic projection data that crosses the date line.

# Version 3.2.2, 2007/11/06

## Updates

### Graphical tools

- Improved visibility of shape drawing in CDAT during zoom and annotation operations.
- Added full screen data view mode in CDAT.
- Added navigation analysis panel in CDAT.
- Added data reference grid overlays for drawing lines at regular image row and column spacings.
- Added a warning dialog in CDAT when navigation correction is about to modify a data file.
- Improved file open/save functionality in the CoastWatch Master Tool (cwmaster).

### File formats and I/O

- Added support for reading NOAA/NESDIS AVHRR Clear-Sky Processor for Oceans (ACSPO) HDF data files.
- Modified ArcGIS binary grid header writer to include "nbits" value.
- Added support for reading NOAA 1b High Resolution Infrared Radiation Sounder (HIRS) data from NOAA KLMNN' satellites.
- Modified CoastWatch HDF writing to handle writing explicit lat/lon values for earth location data.
- Modified netCDF file reading to handle data with greater than two dimensions as a set of 2D arrays.
- Added "scan_time" variable to NOAA 1b file variables.
- Modified NOAA 1b file reading to read only the largest contiguous run of valid scan lines.
- Added support for reading erroneous NOAA-15 data files from CLASS that indicate the wrong file version in the header.
- Added checks for spheroid compatibility in GCTP map projections.

**Command line tools**

- Added step sequential color palette for East Coast Node chlorophyll data.
- Added version printing option "--version" to all command line tools.
- Added the "--copy" option to cwimport so that entire variables can be copied from one file to another.
- Added median value computation results to the output of the cwstats command.

### Bug fixes

- Fixed problem with overlay groups not updating between CDAT tabs.
- Fixed problem with directory refresh on file open in CDAT.
- Fixed problems with box surveys in CDAT that were not correctly surveying very small boxes of pixels.
- Fixed some problems with earth location reverse lookup in full orbit swath datasets.

## Version 3.2.3, 2009/03/31

### Updates

- Added support for NOAA 1b KLMN data files with AMSU-A, AMSU-B, and MHS sensor data.
- Added informational "Reading file information" message when opening large files in CDAT.
- Updated to use the netCDF Java library 2.2.22 for improved GRIB 2 file support.
- Improved expression parsing in cwmath to allow for symbol characters in variable names, such as minus signs.
- Added geometric mean composite and explicit command line ordering options in cwcomposite tool.
- Added 64-bit IEEE floating point output option in cwangles tool.
- Created tool to automatically test command line tools and options (work in progress).

### Bug fixes

- Corrected problem with reading CoastWatch HDF swath geolocation data. This was causing an error when displaying or working with CoastWatch HDF swath projection data files.
- Regenerated HDF land mask files for use with autonavigation. The cwautonav tool was failing when encountering navigation points with latitude $> 45$ degrees.

- Fixed problem with ACSPO HDF file buoy data variables being read and displayed in CDAT.
- Fixed problem with full orbit FRAC data files from Metop. Opening a full orbit file was resulting in a very long wait and CDAT becoming unresponsive.
- Fixed out of memory problems with opening and closing many large files in CDAT.
- Fixed unsupported file format error when reading TOVS data files with no archive header.
- Corrected ACSPO file I/O routines to read both orbit and granule metadata conventions.
- Corrected overflow error in cwdownload byte count for large file transfers.

## Version 3.2.4, 2010/10/31

### Updates

- A
- B

### Bug fixes

- C
- D

# Bibliography


[1] General Cartographic Transformation Package. http://edcwww.cr.usgs.gov/pub/software/gctpc.

[2] Global Self-consistent, Hierarchical, High-resolution Shoreline Database. http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html.

[3] Interactive Data Language. http://www.rsinc.com.

[4] Matlab. http://www.mathworks.com.

[5] NCSA HDF. http://hdf.ncsa.uiuc.edu.

[6] Open-source Project for a Network Data Access Protocol (OPeNDAP). http://www.opendap.org.

[7] Unidata UDUNITS package. http://my.unidata.ucar.edu/content/software/udunits/index.html.

[8] *HDF Reference Manual, Version 4.1r2*. University of Illinois at Urbana-Champaign, June 1998.

[9] *HDF User's Guide, Version 4.1r2*. University of Illinois at Urbana-Champaign, June 1998.