Compass

Host Software
for acs/ac9 Meters

User's Guide

The user's guide is an evolving document. If you find sections that are unclear, or missing information, please let us know. Please check our website periodically for updates.

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1. Introduction

Water absorption and attenuation provide a variety of useful information about an aquatic environment. Derived data products from absorption and attenuation, when combined with those from a CTD (salinity/temperature/depth) meter, can provide even more information about parameters such as chlorophyll, visibility, etc. Compass software provides a graphical user interface that allows you to configure, collect, view, and upload data from ac9/acs instruments.

If you have not read through the Getting Started Guide we strongly recommend you read section 3 of this user's guide to get your meter up and running **before** deployment.

Required components for testing acs/ac9 meter:

1. ac meter
2. Host PC with serial adapter (if using a PC without a serial port/COM port/RS-232)
   - Many new computers and most laptops have no serial port. In this case, you'll need an adapter such as a serial–USB port adapter.
3. Power supply capable of providing 0.8 amps at 12V
4. Factory-supplied test cable
5. Factory-supplied CD, containing Compass software, device files, sample output files, ts4.cor file and user's guides.

Note

Compass does not support ac9 Plus meters.

2. System Requirements

Almost any computer capable of running Windows XP or Vista should be able to run Compass. You will need about 3MB of disk space for the Compass software; however, more is required for the data you gather (about 1MB for every two minutes of data, depending on your device). The amount of memory and the speed of your processor limit how much real-time graphing and collecting can be done without data loss.

Compass is a single executable. You can run it from anywhere, and you do not need to install it or any auxiliary software. You can install it by merely dragging it from the CD to a desired location on your hard disk.

⇨*Tip*: Copy the ac meter's .dev and .cal files from the supplied CD to a location of your choice on the host computer's hard disk.

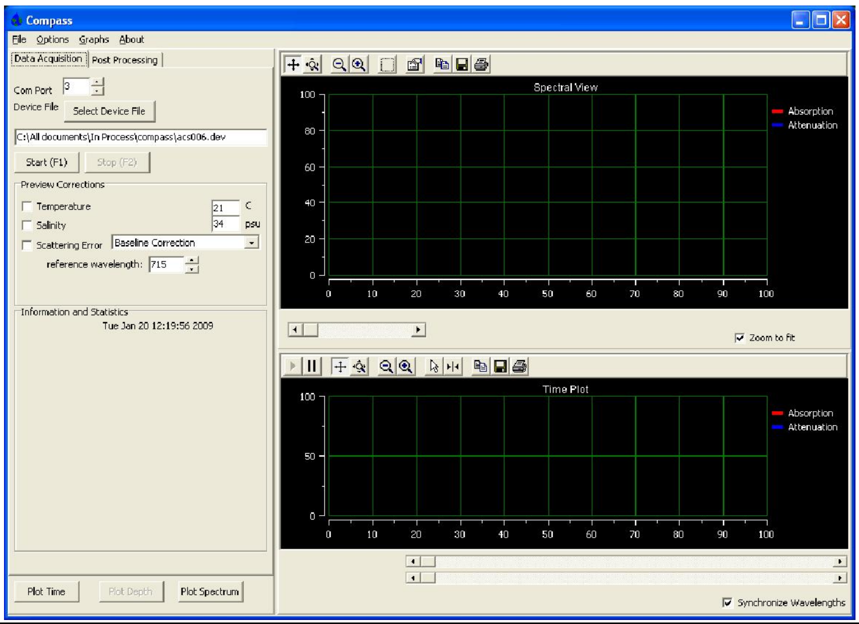
3. Setup and Operation

Note

This user's guide applies to Compass Host 2.1.
Use this document's Revision A if you're using Compass 2.0.

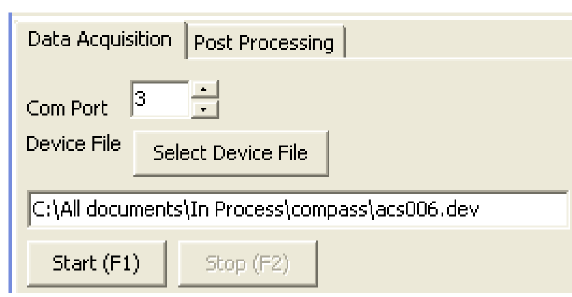
acs/ac9 meters are designed to work with the Compass host software and are easily configured for a variety of applications. We strongly recommend you read through this section to get your meter up and running **before** deployment.

1. Connect the meter to its 6-socket test cable
2. Connect the meter's test cable to an appropriate power supply.
3. Connect the test cable's data line to one of the communication ports on your computer.
4. Turn the meter power supply on.
5. Start the program by double-clicking compass.exe. The screen below will appear, displaying a spectral view showing the most recent acquisition, and a time plot, showing the data gathered at specific wavelengths over time.



6. Enter a COM port or use the up/down buttons beside it to select the appropriate COM port for meter–PC communication.

7. Click the Select Device File button, and then choose the instrument-specific device file from the CD to load. The baud rate should be automatically determined by the device file.

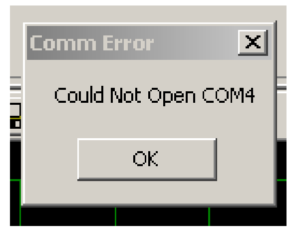


8. Click the Start button (or F1) to start data acquisition. A dialog box prompting you to save the file will appear. A default file name is automatically supplied. It indicates meter type, meter serial number, date, and time. If you do not wish to save the data, click Cancel.

The auto-generated file name convention is XXX_SSS_yyyyMMddhhmmss.dat

XXX is the meter type (either ac9 or acs)
SSS is the meter serial number
yyyy is the year
MM is the month
dd is the day
mm is the minute
ss is the second

For example: ac9_245_20081114124319 is ac9 serial number 245; data collection started 2008, November 14th, at 12:43pm, 19 seconds after the minute.



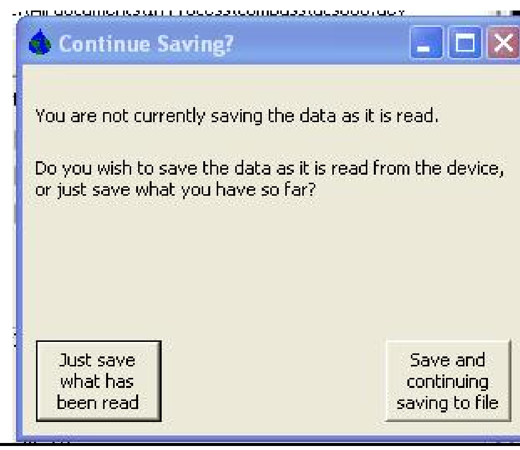
If there are communication issues,[J1] a window will pop up with a possible source of the problem. Verify

- the correct CommPort
- the correct device file
- the meter is properly plugged in and turned on.

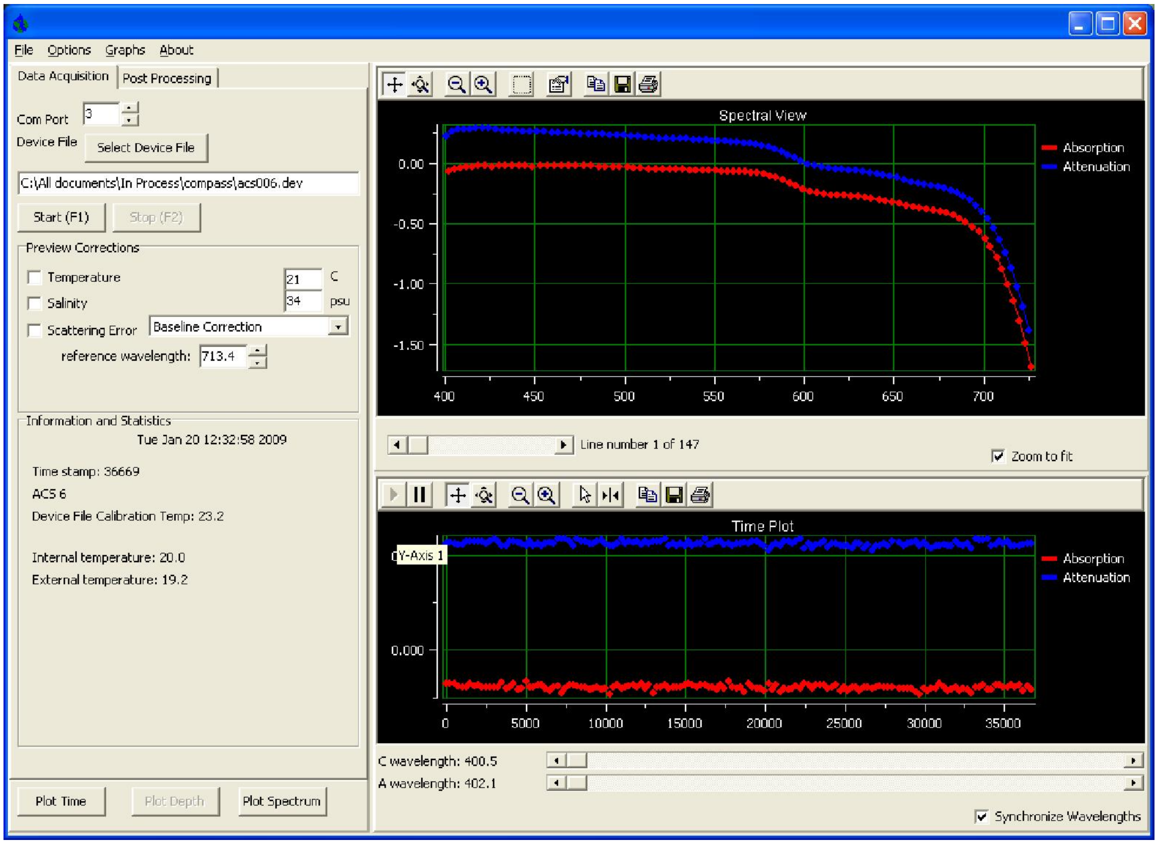
Click OK and Start again to the get the meter running.

9. Click Save in the File Dialog box to save the data as it is being collected, with no corrections applied.

Important!
If you click Cancel, you can still save data using File > Save Raw Data From Device. This allows you to either save data to the point of data collected so far, or keep saving until collection is complete.



10. View the incoming data (see Compass output below):
    - The top plot is a spectral view of the most recent wavelength.
    - The bottom is a wavelength vs. time plot. By default it shows the shortest wavelengths in the a and c channels. Move the sliders to change wavelengths. Also by default the wavelength selections follow each other, so if you move c to 532nm, the a channel will also set itself to 532nm (or whatever is closest: wavelengths commonly don't match on acs meters).
    - Additional data plots of time vs. wavelength can be created using the Graphs pull-down menu.



11. Allow the meter to run a minute or two. When you click Stop (F2), the file is saved with the filename previously specified. If you clicked Cancel at the Save pop-up box, the file is not saved.

4. Compass Reference

This section contains details about the various controls and options available in Compass. Since many of these are discussed in the previous section, there is some overlap. This section is intended as a reference for specific controls and options.

4.1 Data Acquisition Tab

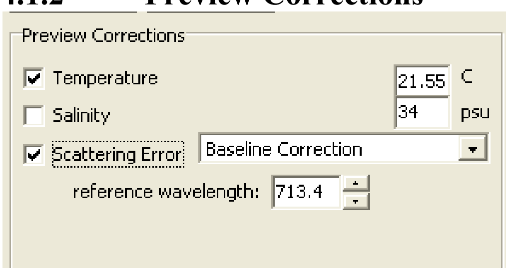
4.1.1 Instrument Setup

Com Port: Select the appropriate port for PC-to-meter communication.

Select Device File: Allows you to browse to the location of the desired device file and load it.

Start (F1): Begins data collection, saving data to the host PC.

4.1.2 Preview Corrections



Temperature: Applies a standard temperature correction. This requires the factory calibration temperature, which should be in the dev file. It is also on the meter's data calibration sheet.

Salinity: Applies a standard salinity correction.

Scattering Error: Applies a scattering error correction to the a channel. Either a baseline or a proportional correction is available. Set the reference wavelength in the box below it.

See the ac protocol document at http://www.wetlabs.com for more details.

The absorption and attenuation of light in water is dependent on the temperature of the water as well as the salinity. To account for this dependence, when recording, an absorption and attenuation correction must be applied. This is commonly referred to as the "temperature and salinity dependence correction." Additionally, reflecting tube absorption meters do not collect all of the light scattered from the source beam. This causes the instrument to overestimate the absorption coefficient. This difference is called the "scattering error" throughout this document.

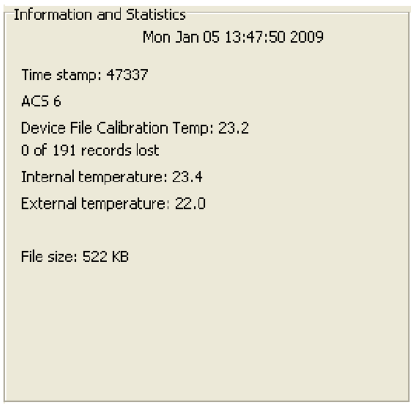
To see the effects of these corrections, check or uncheck the boxes in the Preview Corrections area. You can specify the temperature and salinity in the boxes provided. The default temperature is 21 degrees C and the default salinity is 34 psu.

Scattering error is typically estimated by assuming the absorption in the infrared wavelength is roughly zero, and then subtracting the value in the infrared from all wavelengths in the absorption channel.

Another method is the “proportional subtraction,” which assumes that it is proportionally related to the infrared value. You can choose either of these methods in the pull down boxes, and you can choose a reference wavelength of the meter as your “infrared” color.

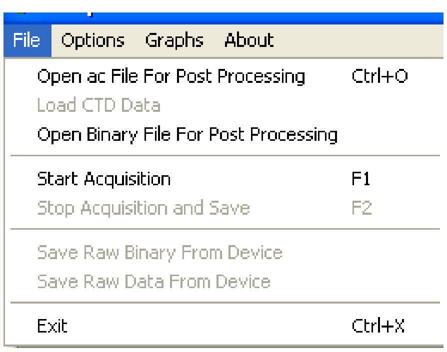
Important! Corrections selected in the Data Acquisition portion of the Compass software are NOT saved to the file. To apply corrections to your data, select the Post Processing tab. The file you just saved is still in memory and you won’t have to reload it. You can perform the same corrections here as you could in the Preview Corrections of the Data Acquisition tab.

4.1.3 Information and Statistics



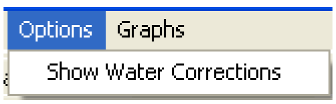
- Date and time according to the host computer.
- Time stamp: The time in milliseconds since the device has been running, according to the device.
- Device File Calibration Temp: The factory calibration temperature, according to the device file.
- x of n records lost: Every data record is verified for checksum, consistent serial number and number of wavelengths read. If anything doesn’t match correctly, it will be marked as a bad record and noted here. In the case of an ac9, records come in groups of ten, so these both should be multiples of ten.
- Internal Temperature: The temperature read from the internal thermistor.
- External Temperature: acs only. The temperature from the external thermistor.
- File Size: size of processed data file being saved to host PC.

4.2 Menus

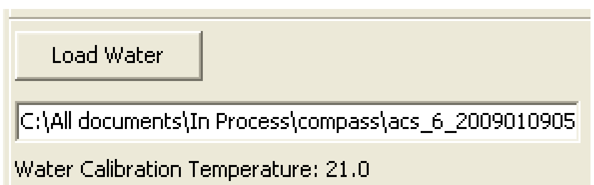


Open ac File For Post Processing	Opens a previously saved data file for display.
Load CTD Data	Opens a CTD file and merges it with the data. Only available after opening a data file.
Open Binary File For Post Processing	Opens a raw binary file in the post processing tab. Performs all device file corrections, then allows further processing.
Start Acquisition	Clears data, loads the provided device file, attempts to communicate with the meter, and prompts for a file name to save data to.

Stop Acquisition and Save	Stops data acquisition.
Save Raw Binary From Device	Saves the raw binary data stream from the ac meter. Only available after collecting some data.
Save Raw Data From Device	Saves the data with applied device file corrections without stopping the meter. If you don't save the data after initially starting, you can use this to save your data, and a dialog will prompt you if you wish to continue saving or just save up to that point. If you are saving to a file as you are collecting data, it will only save the data up to the point of collection, with a dialog warning of this action. If you have already finished collecting data (selected Stop), it will save the data collected.
Exit	Quits the Compass program.



Show water corrections	If checked, provides area to load water calibration files (.wcf)



Plot Spectra	Allows incoming spectral data to be viewed in a separate window.
Plot Time	Displays wavelength vs. time.
Plot Depth	Available when CTD data is loaded for post processing. Displays wavelength vs. depth.

Section 4.3.2 contains additional details about plotting capabilities.

4.2.1 Plot Window Controls

Each plot window has a toolbar that allows for a variety of changes to the way data is plotted. Changes to the plot will not affect the data recording. In addition to the toolbar options, you can click on the numbers of either axis and change the values by dragging.

	Resume	Resume tracking. If the triangle is green, this button may be used to pressed to resume tracking.
	Pause	Pause tracking. This stops the scrolling of the X-axis.
	Axes Scroll	Drag either axis up or down, right or left.
	Axes Zoom	Zoom the axis up or down, right or left. Allows user to scale the axes for coarser or finer plotting.
	Zoom Out	Decrease the zoom by 2x.
	Zoom In	Increase the zoom by 2x.
	Zoom Box	Draw a box on the plotting area and zoom all axes around selected area.
	Copy	Send a copy of the current plot to the host PCs clipboard.
	Properties	Displays numerous properties of plot window.
	Copy to Clipboard	Copies the current plot to the host PC's clipboard.
	Save	Saves an image of the current plot as a bmp, jpg, or png file.
	Print	Send a snapshot of the data plot to a printer.

Time view plot only:

	Grab Range	The select arrow allows you to click on a single point to view that spectrum.
	Select Arrow	The grab range button will put two lines on the plot, which you can slide around. It will also put a Grab button on the bottom of the graph.

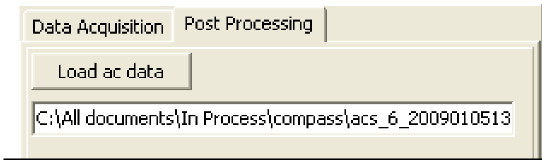
4.3 Post Processing Tab

An ac meter is commonly part of a package of other instruments. The most important external instrument is a CTD, which measures salinity (by way of conductivity), temperature, and depth (by way of pressure). Using a CTD allows you to more closely track the temperature and salinity in the water you are sampling, rather than being required to haphazardly determine the temperature and salinity.

You can either use ac data generated by this program, by WETView, or WET Labs Archive file Processing software, (WAP). If you use Compass, you can either load a saved file, or after data acquisition, just click on the Post Processing tab, and the data you've acquired will still be in the computer's memory.

The details of using WAP is beyond the scope of this document. For more information, refer to www.wetlabs.com for WAP documentation. Once you've created a file, however, WAP output is the same as the "raw" output format of Compass. The device file is used as a header, and the data follows, one row at a time, with a time stamp in the first column, and the data follows by wavelength in the order the device outputted.

WET Labs highly recommends using a CTD with your ac meter for the best quality post processing corrections. Using Compass, you can load CTD data in the Post Processing tab, and the pull-down menu allows you to select the CTD data, constant values, and the acs external temperature probe.



Click the Load ac data button to select an ac meter data file for processing.

Data loaded from a meter is saved on the host computer. Selecting the Save button will generate a file with header information as shown below, which includes the corrections chosen.

This file was created from the following files:

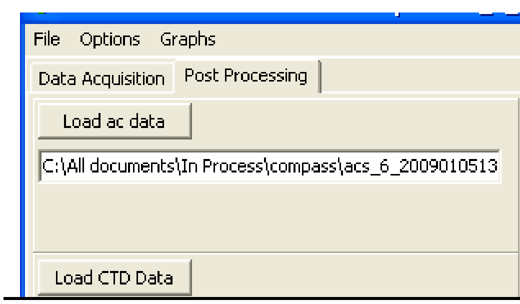
ACS file: C:\Documents and Settings\ Desktop\ac files\sample files\acs.dat
CTD file: C:\Documents and Settings\ Desktop\ac files\sample files\ctd.dat
No Water file used.

Factory Calibration temperature: 23.5
Field Water Calibration temperature: 21.3
Using CTD file for temperature.
Using CTD file for salinity.
Temperature correction applied.
Salinity correction applied.

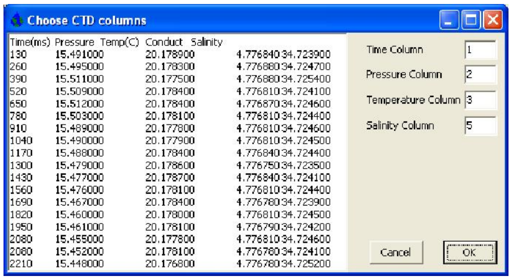
Scattering correction by proportional subtraction applied at 714.5.

88 ; number of wavelengths

Time(ms)	c400.3	c403.9	c407.3	c410.7	c413.9
0	0.281476	0.266194	0.273157	0.263257	0.255117
520	0.268066	0.244964	0.263327	0.254927	0.259607
910	0.273726	0.273324	0.264417	0.263747	0.269637



Select the Load CTD Data button to select the CTD data file for processing. CTD data may be delimited by spaces, tabs, or commas. See Appendix D for more details.

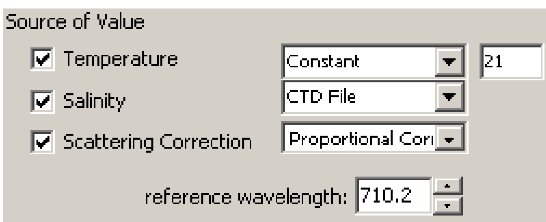


Once a file is selected, the window at left appears, showing the columns to be processed.

Note: The time stamps of the CTD and ac file must start at the same time. Both files can use milliseconds, or Julian time, but they must be the same.

Compass will merge by time, using a nearest-neighbor algorithm. Compass merges to the ac data—if the sampling rate of the ac meter is higher than the CTD meter, the CTD data is filled in with the nearest neighbors. If the sampling rate of the CTD meter is higher, the extra resolution is not averaged but ignored.

The default order of the CTD columns is time, pressure, temperature, conductivity, and salinity. It is also possible to have a header above these indicating the purpose of these columns. However, this is not a universal standard, and a window will appear to prompt you to specify which column corresponds to which value, with the beginning of the file displayed.



- You can then choose to use the values from a CTD file or use constants for temperature and salinity.
- You can choose between a proportional algorithm or a baseline subtraction for scattering correction, and what reference wavelength to use for scattering correction.

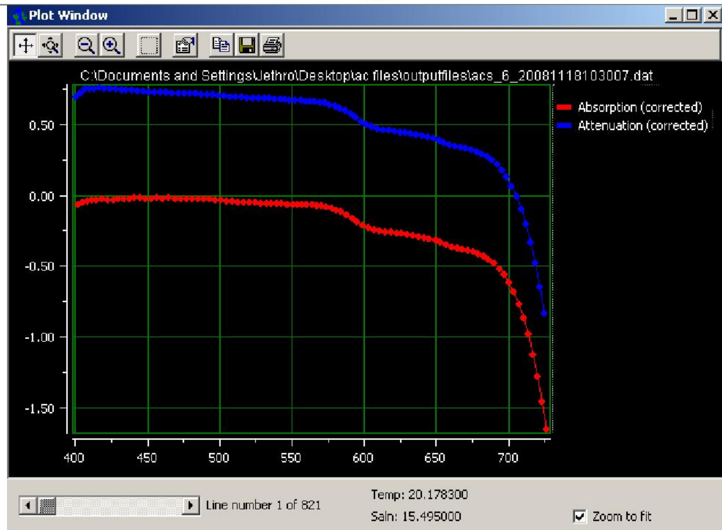
Refer to the ac9 Protocol document or Appendix D of this user's guide for details on algorithms used.

If you're satisfied with the corrections, click Save, and you will be prompted for a file name. The format of this file is not compatible with WETView and you'll be unable to open it in that or other programs expecting that format. However, the new header indicates all options chosen, and if you are using an ac9, the wavelengths are put in the proper order, making it easier to import into Excel or Matlab.

4.3.2 Additional Graphs

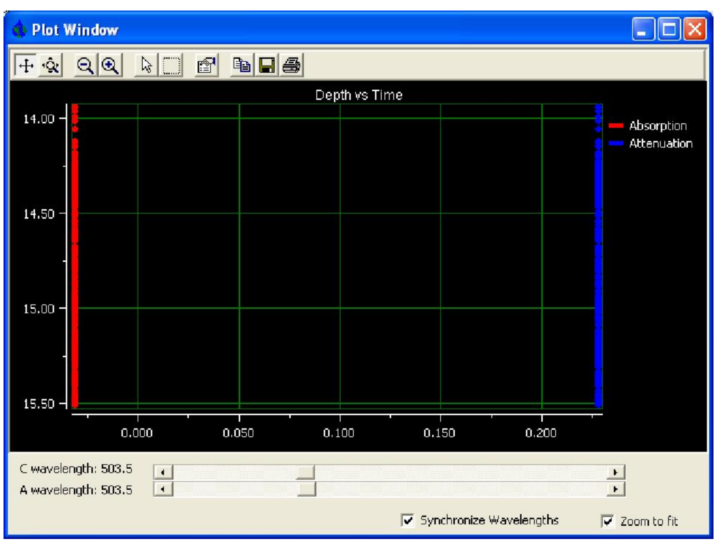
At the bottom left of the Compass window are three buttons that open new graph windows for simultaneously viewing multiple spectra or different wavelengths.

Note that the depth plot is unavailable unless you also load a CTD file.

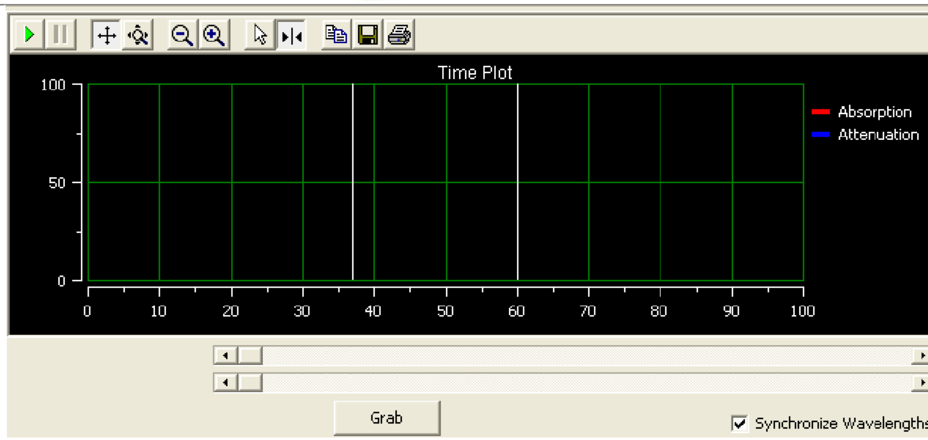


The spectral plot window shows a given spectrum vs. wavelength. The Line Number lists where it occurs in the file. You can choose which line to view by moving this slider. If you have loaded a CTD file, the temperature and salinity are also listed.

The depth plot window displays a given wavelength plotted vs. the depth found in the CTD file (only available if you have loaded a CTD data file). The c and a wavelengths are displayed on the lower left of the graph, and can be changed by moving the sliders around.

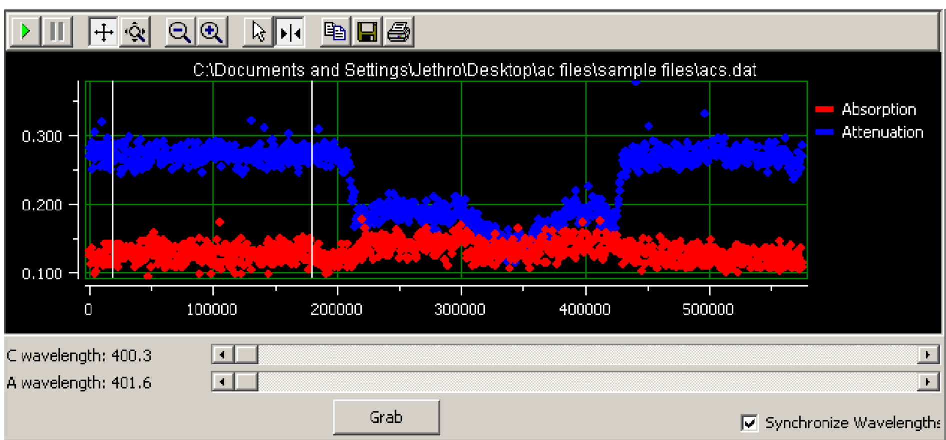


Use the sliders to change the wavelengths displayed in the depth and time plot windows. If Synchronize Wavelengths is checked, both sliders will move together, keeping the two wavelengths as close as reasonably possible. If you uncheck Synchronize Wavelengths, the sliders can be moved independently.

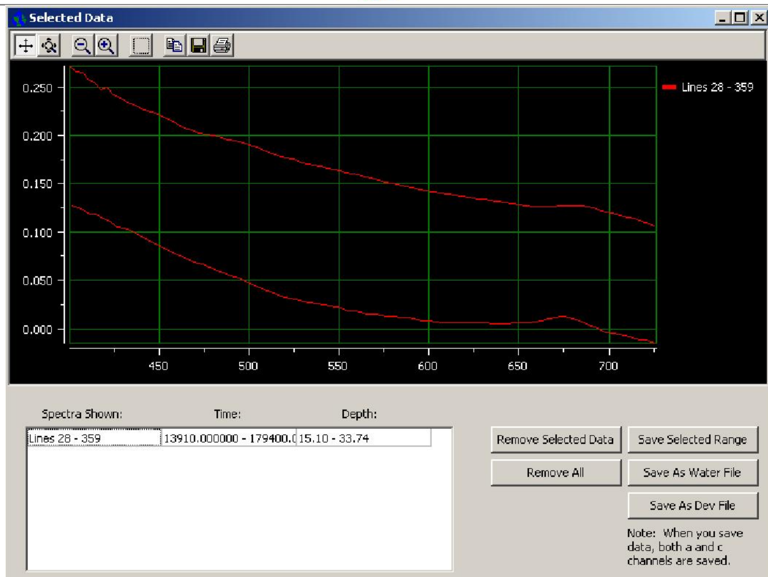


The Time Plot window shows given wavelengths (labeled on the lower left) vs. time.

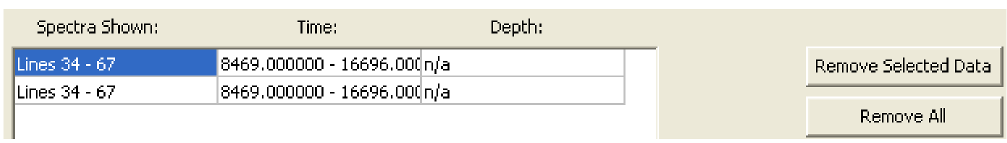
Additional features: The select arrow allows you to click on a single point to view that spectrum. The grab range button will put two white lines on the plot, which you can slide around. It will also put a Grab button on the bottom of the graph.



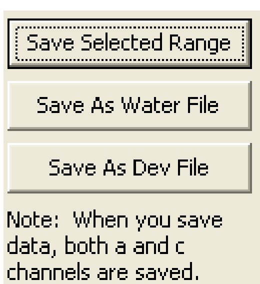
Clicking the now visible Grab button will bring up a new window with the data you have selected averaged into one line.



If you "grab" more than one data range, they will all appear on this one plot.



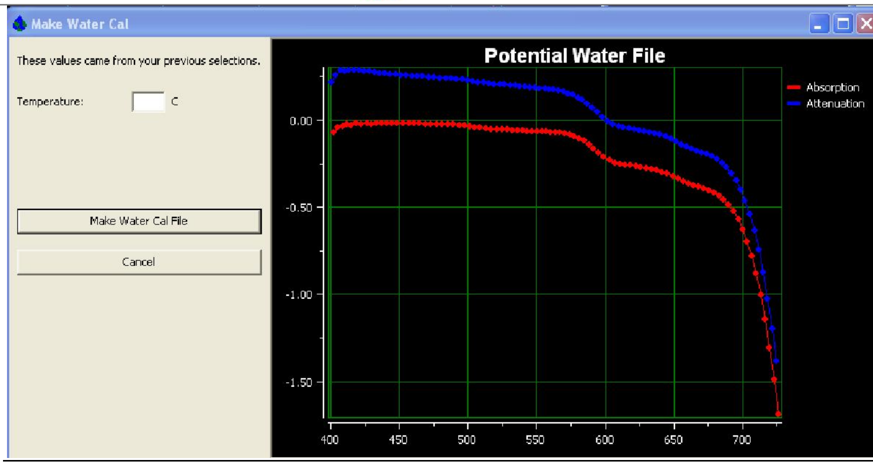
Select Remove Selected Data or Remove All to edit selected data ranges.



Save Selected Range brings up a dialog box that allows you to save a selected number of lines of data, corrected as per the boxes on the "Post Processing" tab, in the Compass format, cropped down to the range selected.[J2]

Save as Water File brings up a second window to enter temperature values and thus generate a water calibration file (See below). Data will be averaged to one line before being saved in a water file format. Creating water files can be used to correct for instrument drift; see the ac protocol document for details.

Save as Dev File brings up a dialog box that allows you to create a device file for the meter using the averaged data with the corrections applied listed on the Post Processing tab.[J3] Traditionally device files were used to correct for instrument drift; we recommend you use water calibration files instead. The ability to create device files is included for those who have been maintaining their own history of device files.



We hope you find Compass useful and we will strive to fix any bugs found and continue to add enhancements. For any concerns, suggestions, or bug reports, email jethro@wetlabs.com.

Appendix A: Compass Device Files

The Compass program requires a device file to find information to be able to read from the sensor. If there are any errors in the device file, the program will this. Note that WETView device files are compatible with Compass device files, and vice versa.

Identifier
The first line in the device file is identifies it as an acs or an ac9.

Serial number
For an ac9, this is the serial number, given as a hexadecimal number. For an acs, the serial number is given as a hexadecimal number with 53000000 added to it.

Structure version number
This is unused in Compass.

Temperature calibrations
This line should look like:
Tcal: 23.2 C, Ical: 24.7 C. July 21, 2008.

Compass attempts to parse this line for the temperature calibration. If it fails, it uses a temperature calibration of 0. A dialog box will ask for the proper calibration value. Editing this value in the calibration file will generally allow Compass to parse it.

Depth calibration
If your meter has a depth sensor, the first number will be a multiplier, and the second number will be an offset, to be used to determine the depth from the built in depth sensor. If your meter does not have a depth sensor, both these values will be 0. Compass does not support the built-in depth sensor at this time.

Baud rate
This is the baud rate at which your device operates. It should be 115200 for an acs meter and 19200 for an ac9.

Path length
This is the path length of the tubes for the ac meter in meters. Almost all ac meters have 25cm path lengths, though a few are 10 cm.

Output wavelengths
This is the number of output wavelengths at which absorption and attenuation are measured. What the wavelengths actually are follows. This only appears on an acs. On an ac9, there are always nine measured wavelengths of light.

Number of temperature bins
This is the number of temperature bins per wavelength. The temperature bins follow on the next line, and the actual offsets by temperature follow.

Appendix B: ac-9 Files

ac-9 Configuration File

Configuration files (with file extension .DEV) give calibration and other information specific to a particular unit. These files are tab-delimited text files and have the following format:

Line 1	Device name.
Line 2	Serial number: the serial number of the device that was used to collect the data.
Line 3	Version number of the following structure. This should be "2."
Line 4	Reserved for future use.
Line 5	Calibrations for depth meter: there are two values, the first is an offset and the second is a multiplier.
Line 6	RS-232 baud rate that the instrument uses
Line 7	Optical path length through water (in meters).
Line 8	Number of temperature compensation bins.
Line 9	Several values (the count is given in the preceding line); each value is the average temperature of the temperature bin.
Line 10–27	Each line describes one channel of the instrument; the first three fields are: label for identifying the channel color for plotting clean water calibration constant (offset) The rest of the line contains temperature compensation values that correspond to the temperature bins given in the previous line.
Line 28	Reserved for future use
Line 29	Extra capabilities mask. This is a list of capabilities that the meter may have in addition to the standard product. Currently, only one such capability exists: an external temperature sensor. If the first number on this line is non-zero, the meter supports such a sensor.

ac-9 Raw Data File

Below is one record of raw data that was captured from the device. It has been converted to hexadecimal, formatted and commented. Note that the two-byte and four-byte values are byte-reversed. That is, the bytes within a word are read from right to left. This reflects the way the Intel 386 and 486 processors store values in memory.

`00FF00FF`	registration word
`7A02`	record length, from this word through checksum
`21010000`	serial number
`0000`	status
`DB13`	sample rate
`1600`	depth
`34FF`	external temperature
`6410 171E 89 2D20 0F 0319 1B …`	first sample, time and data
`7510 171E CB 2C20 EE 0119 A3 …`	second sample, time and data
`8510 161E 84 2E20 0A 0119 F2 …`	o
`9510 131E F1 2920 DE FE18 DF …`	o
`A510 151E 9B 2B20 BC 0119 51 …`	o

```
B510 151E 7A 2B20 BA 0119 9A …
C510 161E 5D 2C20 99 0019 49 …
D510 141E F5 2B20 85 0019 B1 …
E510 121E 3F 2820 76 FF18 11 …
F610 141E 05 2A20 5E 0019 35 …   tenth sample, time and data
7804 C8 B604 C0 A603 66 …        3 references and temperature
9701                             temperature
65D00000                         checksum (FF00FF00 through refs)
00000000                         padding (4 null bytes)
```

Registration word	= 00FF00FF hex
Record length	= 7A02 hex = 634 bytes
Serial number	= 00000121 This is the thirty-third ac-9 meter produced. Production numbers begin with 0100 hex.
Status	= 0000 Zero indicates normal operation.
Sample rate	= 14F9 hex = 5083 This is a count of the time used to take one sample. It is scaled by 0.0000316 to match the hardware's clock rate, then inverted to give samples per second: 1 / (5083 * 0.0000316) = 6.226
Depth	= 0016 hex = 22 This reflects the voltage read from the depth sensor. It is scaled and offset by the values from the configuration file. 22 * 0.3 + 5.3 = 11.9 meters
External Temp	= 34FF hex This word is ignored for this meter because the meter does not have an external temperature probe in it. This is determined by the last line of the configuration file: the value is zero.

For the purpose of this discussion, we skip to the third-from-last line of the data record. This is the reference line, and values here will be used in the computation of the absorption values for each channel.

Reference a610	= 7804 C8 hex = 13108344 This is the reference value for the first channel (ab610). This is a 24-bit value indicating the output from an analog to digital converter. This represents a fraction of the input voltage. To convert from counts to this fraction, the value is divided by 2^{24} (16777216). 13108344/16777216 = 0.7813
Temperature	= 0F01 hex = 271 The temperature is given as a reading from a thermistor. The manufacturer of the thermistor provides a table correlating the reading (counts) to temperature. That table fits the polynomial equation given above. Using 407 counts, we get: 10.61831 + 0.045113 * 271 + -4891.32 * 1/271 + 208130.2 * $1/271^2$ + 1171473 * $1/271^3$ = 7.69 deg C
Absorption 610	= 171E 89 hex = 8986135 This is the signal value for the first channel (a610). This 24-bit value is

converted to raw voltage in the same manner as for reference values.

8986135 / 16777216 = 0.5356 VDC

Raw absorption is computed from the signal and reference values as described above:

$$a_{raw} = \frac{-\ln\left(\frac{E_{sig}}{E_{ref}}\right)}{Z}$$

The device's optical path length is read from the configuration file.

$$a_{raw} = \frac{-\ln\left(\frac{0.5356}{0.7813}\right)}{0.25} = 1.5103 \text{ meter}^{-1}$$

The temperature correction is then applied using the temperature from the reference line and the channel's correction table from the configuration file. The approximate correction value is linearly interpolated from the table. First, the correct temperature bin is determined by finding the two bin temperatures, T_0 and T_1, that bracket the current temperature. Then, using the values, Δ_{Tn} and Δ_{Tn+1}, from the table,

$$\Delta_T = \Delta_{Tn} + \frac{(T - T_0)}{(T_1 - T_0)} * (\Delta_{Tn+1} - \Delta_{Tn})$$

where,

Δ_T=compensation constant

T=current temperature, 7.69

T_0=first bin temperature, 5.5233

T_1=second bin temperature, 8.4553

Δ_{Tn}=first value, 0.1411

Δ_{Tn+1}=second value, 0.1028

Using these values,

$$\Delta_T = 0.1411 + \frac{(7.69 - 5.5233)}{(8.4553 - 5.5233)} * (0.1028 - 0.1411) = 0.1127\text{m}^{-1}$$

Subtracting this from the raw absorption,

$$\begin{aligned} a' &= a_{raw} - \Delta_T \\ &= 1.5103 - 0.1127 \\ &= 1.3976 \end{aligned}$$

Finally, adding in the calibration offset for a610,

$$a = a' + C$$
$$= 1.3976 + 7.6242$$
$$= 9.0218$$

Checksum = 65D00000 = 53349

The checksum is the sum of all the bytes of the record, beginning with the registration word and ending with the temperature. For this record, the checksum is 53349. This is used to verify that the record was received correctly by WETView.

Padding = 00000000

These four null bytes separate records. They are ignored. The advantage of having them is that if a character is lost in transmission, WETView will read one byte past the end of the corrupted record. If there were no padding bytes, the first byte of the next record would have been read, corrupting that record as well. With the padding bytes, however, if a character is lost in transmission, then WETView will read one byte past the end of the record, which will be a padding byte, and it can be safely discarded. The next record will be read correctly.

Appendix C: ac-s Files

acs Configuration File

ac-s device files (with file extension .dev) give calibration and other information specific to a particular meter. These files are tab-delimited text files and have the following format:

Line 1	Device name.
Line 2	Serial number. The serial number of the device that was used to collect the data.
Line 3	Version number of the following structure. This should be “3” or greater.
Line 4	Reserved for future use.
Line 5	Calibrations for depth meter: there are two values, the first is an offset and the second is a multiplier.
Line 6	Serial port baud rate the instrument uses.
Line 7	Optical path length through water (in meters).
Line 8	Number of output wavelengths.
Line 9	Number of temperature compensation bins.
Line 10	Several values (the count is given in the preceding line); each value is the average temperature for each temperature bin.
Lines 11–varies *(dependent on value in line 8)*	Each line describes one wavelength pair of the instrument; the first five fields are: label for identifying the c wavelength label for identifying the a wavelength color for plotting within WETView clean water calibration constant for attenuation, c clean water calibration constant for absorption, a The rest of the line contains temperature compensation values that correspond to the temperature bins given in the previous line. The first *n* values are for c, the next *n* values are for a, where *n* is the number of temperature bins.
Varies	Reserved for future use.

ACS Meter
53000002 ; Serial number
unused ; structure version number
Tcal: 23.2 C, Ical: 24.7 C. July 21, 2008
0 0 ; Depth calibration
115200 ; Baud rate
0.25 ; Path length (meters)
80–90 ; output wavelengths
63 ; number of temperature bins

					7.632727	8.171312	8.706667	9.219706	9.727826…
C398.6	A397.5	8	1.691751	-0.80038		0.018293	0.017729	0.017763	0.016839…
C402.2	A400.9	10	1.770073	-0.41443		0.018396	0.018062	0.017715	0.016939…
C405.7	A404.5	11	1.81221	-0.09669		0.018499	0.018026	0.017409	0.016157…
C409.4	A408.2	12	1.82833	0.132231		0.015788	0.015389	0.014772	0.013682…
C413.0	A411.8	13	1.84002	0.285005		0.018766	0.01837	0.018024	0.016658…
C417.0	A415.7	15	1.850093	0.382613		0.016909	0.01643	0.015824	0.015166…
C420.9	A419.6	16	1.856859	0.453001		0.016226	0.015822	0.015416	0.014600…
⋮									
C730.6	A730.7	106	-0.28523	0.017783		0.004847	0.004845	0.004855	0.004802
C734.2	A734.4	107	-0.50568	-0.17825		0.004823	0.004771	0.004818	0.004686
C737.9	A737.9	109	-0.676	-0.32109		0.004798	0.004803	0.004837	0.004833
C741.5	A741.4	110	-0.78822	-0.40855		0.004683	0.004676	0.004701	0.004667
C745.2	A744.9	111	-0.85581	-0.45682		0.004321	0.00431	0.004344	0.004257
C748.8	A748.6	112	-0.89734	-0.47902		0.004134	0.004146	0.004179	0.004176
C752.3	A752.0	114	-0.91907	-0.48634		0.004145	0.004146	0.004201	0.004071
C755.5	A755.5	115	-0.93167	-0.48493		0.003956	0.00395	0.003961	0.003925
0	0	0	0	0	0	0	0	0	0

ac-s Raw Data

Below is one record of raw data that was captured from the device. It has been converted to hexadecimal, formatted and commented.

ff00ff00	Packet registration
02D0	Record length of full packet (not including chksum) = 720
04	Packet Type 03 and above designates an ac-s meter
01	unused by ac-s
53	meter type—53 indicates an ac-s
000002	serial number
4e1a	sample to sample delta time in 25 microsecond counts (0.49985 sec)
01ba	Reserved
02a1	Reserved
7ae4	raw external temp counts = 26.82 °C
b9d7	raw internal temp counts = 27.93 °C
01d5	Reserved
02b0	Reserved
00071b02	time in milliseconds since power up (465666 = 7.761 mins)
01	Reserved
56	Number of output wavelengths = 80–90 decimal (86 in this example)
0405	raw $cref_1$ counts
0363	raw $aref_1$ counts

04f4	raw $csig_1$ counts
0310	raw $asig_1$ counts
0498	raw $cref_2$ counts
20bb	raw $cref_{86}$ counts
19bf	raw $aref_{86}$ counts
2c49	raw $csig_{86}$ counts
2c1c	raw $asig_{86}$ counts
2243	Checksum
00	pad byte

Registration word	= FF00FF00 hex
Record length	= 02D0 hex = 720 bytes
Packet type	= 04 (Reserved for future use.)
Reserved	= 01
Meter Type	= 53
Serial Number	= 000002 This is the second ac-s meter produced (production numbers begin with 0000 hex).
Status	= 4E1A Sample to sample delta time in 25 us counts (0.49985 sec)
Reserved	<2 undefined bytes> (Reserved for future use.)
Reserved	<2 undefined bytes> (Reserved for future use.)
External Temperature	= 7AE4 hex = 31460 The external temperature is derived from a voltage drop across a thermistor. The temperature is calculated from a polynomial to convert counts to temperature. The polynomial to convert counts to temperature is: $y = a \times counts^3 + b \times counts^2 + c \times counts + d$ where a = -7.1023317 E-13, b = 7.09341920 E-8, c = -3.87065673 E-3, and d = 95.8241397 which yields an external temperature of 22.14ºC
Internal Temperature	= B9D7 hex = 47575 The internal temperature is derived from a voltage drop across a thermistor. The temperature is calculated from an equation to convert the thermistor resistance to temperature. The equation for converting the raw A/D counts to volts is: volts = (5 × counts / 65535) which yields 3.6297 The volts are then converted to resistance using the equation: resistance = 10,000×volts/(4.516 – volts) which yields 40,956.7 ohms The equation to convert resistance to temperature is: $temp = \frac{1}{a + b \times \ln(res) + c \times (\ln(res))^3} - 273.15$

where a = 0.00093135, b = 0.000221631, and c = 0.000000125741

which yields

$$T = \frac{1}{a + b\ln 40956 + c(\ln 40956)^3} - 273.15 = 17.91\ ^{o}\mathrm{C}$$

Reserved	<4 undefined bytes> Reserved for future use.

Appendix D: CTD File Format

```
Julian_Day__ Pres(dbar)    Temp(C)    Cond(S/m)     Sal(PSU)
319.34565440 1.846000      9.454500   3.268330      29.976800
319.34565637 1.852000      9.455400   3.268480      29.977500
319.34565637 1.861000      9.455300   3.268520      29.978100
```

Compass accepts up to 2 lines of header information on CTD files. Columns may be added and they may be delimited by spaces, tabs, or commas.

Appendix E: Algorithms

The algorithms used are given in the ac protocol document in chapter 5. The initial parsing of the raw binary data is quite standard and follows the exact algorithms as the WETView software.

To perform the temperature calibrations, we use the formulas:

$$a_{mts} = a_m - [\ \Psi_t * (t - t_r) + \Psi_{sa} * S]$$
$$c_{mts} = c_m - [\ \Psi_t * (t - t_r) + \Psi_{sc} * S]$$

where:
a_m is the measured absorption
a_{mts} is the absorption corrected for temperature and salinity
c_m is the measured attenuation
c_{mts} is the attenuation corrected for temperature and salinity
t is the temperature
S is the salinity

The temperature and salinity are either the given constants, or the corresponding temperature and salinity in the given CTD file.

t_r is the temperature when the calibration was performed at the factory, given in the device file, or entered in the case that the temperature could not be parsed by Compass.

If only temperature is applied, the Ψ_{sc} * S term is not applied. Similarly, if only salinity is applied, the $\Psi_t * (t - t_r)$ is not applied.

The Ψ_t terms are dependent on wavelength and type of device (acs or ac9). In the case of the ac9, the Ψ_t comes from a lookup table.

Wavelength (λ)	Pure water (ψ_T)
412	0.0001
440	0.0000
488	0.0000
510	0.0002
520	0.0001
532	0.0001
555	0.0001
560	0.0000
650	-0.0001
676	-0.0001
715	0.0029

Source: Pegau et *al*., Applied Optics, Vol. 36 No. 24, 1997.

If the wavelengths do not appear in the above lookup table, the following formula is used:

$$\psi_T = \Sigma \{M_T(M/\sigma)\exp -[(\lambda - \lambda_c)^2 / 2\sigma^2]\}$$

Where λ is the wavelength we are seeking to determine for ψ_T. The values used in the above formula are given in the table below. Note that for a single wavelength, we do indeed sum over the entire table, with only λ staying constant.

Magnitude (M)	Width (σ)	Central wavelength (λ_c)	Temperature percentage multiplier (M_T)
.18	18	453	0.0045
.17	15	485	0.002
.52	14	517	0.0045
1.4	20	558	0.002
4.6	17.5	610	0.0045
2.1	15	638	-0.004
4.3	17	661	0.002
9.6	22	697	-0.001
1.6	6	740	0.0045
34	18	744	0.0062
18	20	775	-0.001
42	25	795	-0.001

Source: Pegau et *al*., Applied Optics, Vol. 36 No. 24, 1997.

To perform salinity corrections for an ac9, we use the values from "Hyperspectral temperature and salt dependencies of absorption by water and heavy water in the 400-650nm spectral range," Sullivan et *al*., Applied Optics, Vol. 45 No. 21, 2006.

For performing temperature and salinity corrections for an acs, we use the temperature and salinity slope values from Sullivan et *al*. linearly interpolated to every 0.1 nm. These values are included in a file labeled `TS4.cor` on the CD that ships with your meter.

If you are using a water blank file, note that while the temperature correction is not applied to the saved file, it is applied to the water file when the loaded data is being corrected in Compass. Compass then subtracts the correct file from the data.

$a_{mtso} = a_{mts}(\lambda) - a_{offset}(\lambda)$

$c_{mtso} = c_{mts}(\lambda) - c_{offset}(\lambda)$.

Scattering correction by baseline subtraction is $a(\lambda) = a_{mtso}(\lambda) - a_{mtso}(\lambda_{ref})$

Scattering correction by proportional subtraction removes an amount from each wavelength using this equation:

$$a_t(\lambda) = a_{mtso}(\lambda) - \frac{a_{mtso}(\lambda_{ref})}{[c_{mtso}(\lambda_{ref}) - a_{mtso}(\lambda_{ref})]} * [c_{mtso}(\lambda) - a_{mtso}(\lambda)].$$

All corrections are applied before doing the scattering corrections. If temperature and/or salinity corrections are not performed previously, then the temperature/salinity corrections will not be applied in the formulas for scattering error.
None of the data is smoothed before doing scattering corrections. Because of this, noise in your data caused by particles in one chamber can cause the proportional scattering method to propagate errors.

Scattering corrections are only applied to the absorption, not the attenuation.

Appendix F: Water Calibration File Formats for ac9 and acs

```
Water cal file format, ending in .wcf.
Compass Release Candidate 1
Water Calibration File: 1.0
This file was created on Thu Jan 08 14:58:45 2009
Serial Number: 245
Water Calibration Temperature: 19.7
Number of wavelengths: 9

0  c412  c440  c488  c510  c532  c555  c650  c676  c715  a412  a440  a488  a510  a532  a555
a650  a676  a715
0  0.3025097437  0.2663650113  0.2232617636  -0.2525666955  -0.3237668821  -0.8787422278  -
0.05388026053  0.09178817827  -0.643113333  0.03584636102  0.0299225855  0.0254905912
0.3765493366  0.4350427777  0.3377746078
```

```
Compass Release Candidate 1
Water Calibration File: 1.0
This file was created on Fri Jan 09 05:22:31 2009
Serial Number: 1818589289
Water Calibration Temperature: 21
Number of wavelengths: 89
0c400.5 c403.7  c407.1  c410.3  c413.4  c417.1  c420.6  c424.4  c428.3  c431.8  c435.5  c439.3
    c443.2  c447.2  c451.1  c455    c459.2  c463.1  c467.1  c471.3  c475.4  c479.7  c483.9  c487.8
    c491.8  c495.6  c499.6  c503.5  c507.3  c511.4  c515.4  c519.4  c523.2  c526.8  c531    c534.4
    c538    c541.8  c545.2  c548.8  c552.2  c556    c559.1  c562.7  c566.2  c569.6  c573    c576.4
    c580    c583.4  c587.1  c590.8  c594.4  c598.1  c601.8  c605.6  c609.7  c613.3  c617.4  c621
    c624.9  c628.7  c632.5  c636.3  c640.2  c644    c647.9  c651.7  c655.5  c659.5  c663.2  c666.9
    c670.6  c674.4  c678    c681.5  c685.1  c688.5  c692.1  c695.5  c698.9  c702.1  c705.5  c708.9
    c712.1  c715.3  c718.5  c721.7  c724.8  a402.1  a405.3  a408.5  a411.7  a415    a418.5  a422.4
    a426.3  a429.7  a433.6  a437.3  a440.9  a444.6  a448.6  a452.7  a456.9  a460.8  a464.7  a469
    a472.9  a477.5  a481.3  a485.5  a489.2  a493.4  a497.2  a501.2  a505    a509    a513    a517
    a521    a524.8  a528.5  a532.3  a536    a539.6  a543.2  a546.6  a550.4  a553.8  a557.4  a560.4
    a563.9  a567.1  a570.5  a573.9  a577.3  a580.8  a584.4  a588.1  a591.7  a595.4  a599.1  a603.1
    a607    a610.7  a614.7  a618.5  a622.4  a626    a630    a633.7  a637.5  a641.5  a645.3  a649.3
    a653    a656.8  a660.8  a664.4  a668.2  a672.1  a675.8  a679.3  a683    a686.4  a690    a693.7
    a697.3  a700.5  a703.6  a707.1  a710.2  a713.4  a716.6  a719.8  a723.2  a726.4
    0   0.2221527973    0.251379441 0.279252422 0.2826879233    0.2821031966    0.2890712977
    0.2856252025    0.2836021823    0.2774181566    0.2771636669    0.27320107  0.2693807039
    0.2654577985    0.2620501461    0.2585716273    0.2563488979    0.2531700841    0.2514267778
    0.2495091942    0.2464223177    0.2453556571    0.2422091426
```

Line 1	Compass identifier and version number.
Line 2	Water calibration file format version number, to allow for future changes.

Line 3	Time and date stamp, for human readable use (future plans include a machine-readable date/time).
Line 4	Serial number. Must add 53000000 and be in hexadecimal for an acs, same as device files. Must be decimal for ac9 files, same as device files. Used to prevent device mismatch.
Line 5	Water calibration temperature. This is the temperature entered when creating a device file.
Line 6	Number of wavelengths. Again, used to prevent device mismatch.
Line 7	c and a channels of the wavelengths. While this line is not used to verify device mismatch, if a user is to attempt to create a water cal file, this line must exist, and the wavelengths must appear in this order. The first value is unused, then the c channel wavelengths in ascending order, then the a wavelengths in ascending order.
Line 8	The averaged (mean) values of the data used to create this water file.

Revision History

Revision	Date	Revision Description	Originator
A	1/21/09	New document (DCR 643)	J. Bell
B	5/19/10	Add CTD file description, Compass software release 2h (DCR 708)	J. Bell