SAMOS netCDF Code Manual for Quality Controlled Surface Meteorological Data

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1. Introduction

The SAMOS network Common Data Format (netCDF) Code Manual for Quality Controlled (QC) Surface Meteorological Data outlines the codes used within the DAC surface meteorological data sets released to the scientific community. The code is a synthesis of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS; Slutz et al. 1985; http://www.cdc.noaa.gov/coads/), ICOADS Long Marine Reports (LMR), and International Maritime Meteorological Archive (IMMA) documentation, standard World Meteorological Organization (WMO) synoptic code, and new codes derived at Florida State University (FSU).

NetCDF was chosen to take advantage of its portability and capability to include both the data and metadata (information about the data) in a single file. Complete details regarding netCDF can be found in Appendix 1.

The SAMOS netCDF data file includes up to 36 possible parameters. In some cases, multiple measurements of the same parameter are available (e.g. sea temperature measured from a thermosalinograph and a bucket temperature) and are differentiated using sequentially numbered variable names (TS, TS2, TS3, TS4, etc.). As described in section 3, variables include not only meteorological data (temperature, pressure, etc.), but also a number of supporting variables (time of observation, platform position, movement, and flag description, etc.). A variable containing quality control (QC) flags is included to indicate the QC flags applied to the data values. Multiple variable attributes provide metadata information including data units, instruments used, instrument height, etc. (see section 2). Seventeen global attributes contain general information for all data within the netCDF file. An example of a SAMOS netCDF file is found in Appendix 2.

Most of the data that arrive at the Surface Meteorology DAC are converted to netCDF. We currently receive salinity and conductivity measurements that are not included in our public data files. The only change to the data is a simple conversion to a standard set of units. The original units are noted in a variable attribute. Any data arriving without an accurate time stamp or information on whether the time is local or UTC were discarded only after all attempts to obtain correct time information were exhausted. The data also must have position information, i.e. data lacking latitude and longitude values were discarded only after all attempts to correctly position the data failed. Furthermore, if data arrived with no units attached, only after every effort to determine their units was exhausted, were the data discarded. Data collected without a record of time, position, or units are useless to the research community. However, all original data contributions are archived in the event additional information is discovered later that would allow the inclusion of discarded data.

All data are processed through an automated quality evaluation program, samospre.f. This program verifies that oceanic platforms are not over land, data values are within a predetermined range of realistic values, and that observations are not more than 4 standard deviations from the climatological mean (da Silva, et al. 1994). The program adds an appropriate flag depending on which test the value passed or failed. The data are then processed by another automated quality evaluation program, the Spike and Stair-Step Indicator (SASSI) that uses statistics to check for spikes, steps and other suspect data. The only variables processed by SASSI are the temperatures (air, sea, wet bulb, and dew point), atmospheric pressure, relative humidity, and wind speed. Upon completion of the automated quality control, these preliminary files are made available to the public. Under the present data delivery system, preliminary files are available ~5 minute after they are received from a vessel.

After a suitable period to obtain delayed mode data, all available data for a single observation day are merged. The merged files are inspected visually using VIDAT (VIsual Data Assessment Tool), an IDL program developed at COAPS. This allows the data quality evaluator (DQE) to choose variables to plot within netCDF files and add or modify flags according to the judgment of the

DQE. Following visual inspection, these research quality files are made available to the user community.

The SAMOS DAC has now expanded beyond the WOCE parameters to provide other useful data and metadata from a wide range of oceanographic cruises. SAMOS observations are provided on a routine basis for all days when participating vessels are at sea (subject only to vessels doing classified work) or transmission failures. Many of the SAMOS cruises are in fact performed by the same ships that provided WOCE data. Unlike the WOCE standard, all data that are provided by the SAMOS DAC utilize the ICOADS 0-359.99 degrees East *units* convention for longitude.

Section 2 outlines the metadata for 36 parameters that may be collected from each vessel. The data variables and their associated metadata attributes are outlined in section 3 along with a description of the values that can be assigned to each metadata element. Note that many metadata elements have both numeric codes and text values. Unlike WOCE, the text values are included within the netCDF files, but the codes are retained to simplify the integration of these data into international marine archives (e.g., ICOADS). Section 4 covers the global attributes that primarily contain metadata that apply to a specific vessel or cruise. Throughout the manual, variables will be indicated by **bold** type and attributes will be *italicized*.

2. Variable Attributes

Up to 36 parameters may appear in a surface meteorology file for SAMOS, not including duplicate sensors. All data files will contain the **time**, **latitude**, **longitude**, **time of day**, **date**, and quality control **flag** variables. The quality control flags are single alphabetic characters that represent either problems or notable features in the data (a list of the flags, their definitions, and an example of their usage is found in section 3kk). Table 1 lists all possible variable attributes used in the SAMOS netCDF files. Note that not all of these attributes are assigned to each of the 36 possible parameters. Section 3 includes a complete variable listing with associated variable attributes.

Table 1: Variable Attributes

Attribute	Definition
actual_range	The actual, physical range of values for the parameter within the netCDF file. The range is of the same type as the data values, i.e. long or short integers or floating point numbers.
average_center	Identifies the **time** stamp associated with the mean data values as being at the start, middle, or end of an averaging period. Possible values are unknown, **time** at start of averaging period, center of averaging period, or end of averaging period.
average_length	Length of **time** (in seconds) for which the data are included into the mean. An *average_length* = 0 seconds represents an instantaneous or spot observation.
average_method	Defines whether the data value is a temporal average or an instantaneous (spot) value. Possible values are unknown, average, or instantaneous.
center_line_offset	A floating point value describing the *instrument*'s distance (to the nearest tenth of a meter) perpendicular from the center-line. Distances measured to the starboard (port) side of the center-line are positive (negative). When unknown, *center_line_offset* = -9999.
data_interval	The length of **time**, in seconds, between sequential data values.
data_precision	A floating point value to which the data collector believes the data values from the individual sensors may be accurate. For example, wind speeds are typically received in meters/second out to 5 decimals, but we know that sensors cannot resolve that level of precision. One or two decimals may be legitimate, but likely not 5.
data_type	The bit type of data being stored for each variable (e.g., long, short, float, etc.)
distance_from_bow	A floating point value describing the instrument's distance from the foremost point of the vessel above the mean water line (to the nearest tenth of a meter) measured along the center-line of the vessel at the main deck height. Distances should be positive numbers, unless sensors are mounted on a mast forward of the bow. When unknown, *distance_from_bow* = -9999.
height	The *instrument height,* in meters, above the station elevation (see Global Attributes, section 4). When unknown, *height* = -9999. NOTE: the *height* attribute for **sea temperature** is negative to represent the depth in meters below sea level.
instrument	A character attribute that contains the make, model number, manufacturer and/or type of *instrument* used to record the

	variable values. When no information on the *instrument* type is known, *instrument:* = "unknown".
last_calibration	A date associated with the *last calibration* of the deployed *instrument*. Useage of this date still needs further discussion, including how to update as sensors change, therefore it currently does not appear in our netCDF files.
long_name	An attribute for all variables that contains a descriptive name for the variable. This attribute may give information on the location of the sensor, i.e., port air temperature.
missing_value	A missing value of -9999 that is used within all variables, except **time**, **latitude**, and **longitude**, which must always exist.
mslp_indicator	An attribute only associated with **atmospheric pressure** (**P**). The indicator denotes the **P** as a value collected at the sensor *height* or adjusted to mean sea level. Possible values are unknown, adjusted to sea level, or at sensor *height*.
o*bservation_type*	This is a character attribute that indicates whether or not the values provided are directly measured by an *instrument* or derived from instrumental measurements. For, example, platform-relative winds are typically measured, but true (earth-relative) winds are always derived from the platform winds and navigation data. Possible values are unknown, measured, or calculated.
original_units	The *units* (SI, English, cgs, feet, etc.) of the variable's values when it arrived at the DAC. Again, since no data are useful without *units*, this attribute will always have a value when present.
qcindex	An integer pointer to the **flag** for the selected variable. Most variables have a *qcindex*. Exceptions include the **flag**, **history,** and coded weather and cloud parameters.
rad_direction	An attribute only associated with the **shortwave** (**RAD_SW**), **long-wave** (**RAD_LW**), **photosynthetically active radiation** (**RAD_PAR**), and **ultraviolet** (**RAD_UV**) radiation. This indicator identifies the radiation measured as being either upwelling or downwelling depending upon *instrument* orientation. Possible values include unknown, downwelling, or upwelling.
sampling_rate	The sampling rate (in Hertz) of a sensor on the vessel. Data sampled at this rate are rarely stored, but instead are used to create mean values on longer time scales. When unknown, *sampling_rate* = -9999.
special_value	A special value (set equal to -8888) is used to indicate that data were present in the original file, however the data were either: a) coded and the value listed did not fit the code range (no *qcindex* for these data) or b) an overflow value that does not fit the memory space allocated by our internal format.
ts_sensor_category	An attribute only associated with the **sea temperature** (**TS**). A coded classification of the general category of instruments used to measure **TS** on a vessel. This code is retained to ease data inclusion into international marine data archives. See **sea**

	temperature code table 9 based on ICOADS LMR.
units	The SI units used for describing the variable's values. Since no data are useful without units, this attribute will always have a value (when *units:* is applicable). *Units* are given for most variables. The exceptions are those variables that are coded (**WX**, **MCT**, etc.). Code tables are described under appropriate variables in section 3.
wind_direction_convention	An attribute only associated with wind directions (**DIR** and **PL_WDIR**). Possible values are oceanographic or meteorological. This refers to whether the values reported are directions FROM which the wind is blowing (meteorological) or TO which the wind is blowing (oceanographic). This parameter can also be unknown.
zero_line_reference	An attribute only associated with **platform-relative wind direction** (**PL_WDIR**). This attribute is the offset angle between the zero-line on the anemometer and the bow of the vessel (measured in degrees clockwise from the bow). For example, an anemometer with a zero-line-pointing towards the starboard side of the vessel would have a *zero_line_reference* of 90°.

3. Variables

This section outlines the 36 possible parameters that may occur in the SAMOS netCDF files. Recall that multiple values may be recorded for each parameter if the vessel is equipped with redundant sensors. Each parameter section identifies the parameter long name, variable name, and variable attributes (metadata) associated with that parameter.

a) time (**time**): *long_name, units, data_interval, observation_type, actual_range, qcindex*

The **time** is a double precision variable with *units* equal to minutes since 1-1-1980 00:00 UTC. We chose 1980 as our reference year primarily because it is the beginning of the decade that is nearest the start of the WOCE data collection. The **time** is quality controlled for non-sequential, duplicate, and unrealistic values and the **time flag** position is identified by *qcindex*.

The three attributes, *average_method, average_length* and *average_center,* provide further metadata related to time averaged data. The *average_method* indicates whether the value is an average, an instantaneous value (spot), or unknown type. The *average_length* will contain the length of the averaging period in seconds, have a value of zero when the value is instantaneous, or will be unknown. The *average_center* is either unknown, time at start of period, center of period, or end of period.

Table 2: *average_method* codes

Code	Definition
0	unknown time type
1	average (Data represent a mean observed/recorded over a fixed period of time. The location of the **time** stamp in the averaging period is denoted by *average_center*.)
2	instantaneous time (Data are recorded as instantaneous values at the **time** indicated)

Table 3: *average_center* codes:

Code	Definition
0	unknown, N/A
1	time stamp at start of averaging period
2	time stamp at center of averaging period
3	time stamp at end of averaging period

Subroutines to convert from minutes since 1-1-1980 00:00 UTC to year, month, day, hour, and minute values are provided in Appendix 3. Other codes to convert from year, month, day, hour, and minute to minutes since 1-1-1980 00:00 UTC are also available.

b) calendar date (**date**): *long_name, units, observation_type, actual_range, qcindex*

The **date** contains a four digit year (YYYY), two-digit month (MM), and two-digit date (DD) for each data record. The **date** is stored as a long integer with a format YYYYMMDD and *units* in the Universal Time Coordinate (UTC). Note: additional information about the data recording times are located in the variable attributes for **time** and **time_of_day** (see below).

c) time_of_day (**time_of_day**): *long_name, units, observation_type, actual_range, qcindex*

The **time_of_day** contains the hour (HH), minute (MM), and seconds (SS) for each data record.

The **time_of_day** is stored as a long integer of the form HHMMSS with *units* in the Universal Time Coordinate (UTC). Note: additional information about the data recording times are located in the variable attributes for **time** (see above).

d) latitude (**lat**): *actual_range, long_name, units, original_units, instrument, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, qcindex*

Platform position in *units* of degrees relative to the equator: positive degrees for north latitude, negative degrees for south latitude. Expected precision of up to 4 decimal places.

The **lat** values are quality controlled for data validity, unrealistic platform movement, and whether the oceanographic platform moves over land.

e) longitude (**lon**): *actual_range, long_name, units, original_units, instrument, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, qcindex*

Platform position is in *units* of degrees; positive 0-359.9999 degrees east longitude for all SAMOS data files. Expected precision of up to 4 decimal places.

The **lon** values are quality controlled for data validity, unrealistic platform movement, and whether the oceanographic platform moves over land.

f) platform heading (**PL_HD**): *actual_range, long_name, units, original_units, instrument, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, missing_value, special_value, qcindex*

The **platform heading** is recorded in *units* of degrees (recorded clockwise relative to true north) and represents the direction that the bow of the ship is pointing. Valid headings range from 000.0 to 359.9 degrees.

g) platform course (**PL_CRS**): *actual_range, long_name, units, original_units, instrument, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, missing_value, special_value, qcindex*

The **platform course** is recorded in *units* of degrees (recorded clockwise relative to true north) and represents the direction that the ship is moving relative to the fixed earth (e.g., a GPS derived course over the ground). Valid course values range from 000.0 to 359.9 degrees.

h) platform speed over ground (**PL_SPD**): *actual_range, long_name, units, original_units, instrument, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, missing_value, special_value, qcindex*

The **platform speed over ground** is recorded in *units* of meters per second after a conversion from the *original_units* (when necessary). This value is the speed relative to the earth and is typically measured using high resolution GPS data.

i) platform speed over water (**PL_SOW**): *actual_range, long_name, units, original_units,* *instrument, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, missing_value, special_value, qcindex*

The **platform speed over water** is recorded in *units* of meters per second after a conversion from the *original_units* (when necessary). This parameter is typically measured by a speed log and may consist of fore/aft and port/starboard components (which would be stored in separate variables).

j) platform-relative wind direction (**PL_WDIR**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, zero_line_reference, observation_type, average_method, average_center, average_length, sampling_rate, data_precision, missing_value, special_value, qcindex*

The **platform-relative wind direction** is recorded in *units* of degrees clockwise from a frame of reference aboard the vessel (typically the bow). The *wind_direction_convention* attribute indicates whether the direction is from which (meteorological) or to which (oceanographic) the wind is blowing (See Table 4). The variable attribute, *zero_line_reference,* is the offset angle between the zero-line on the anemometer and the bow of the vessel (measured in degrees clockwise from the bow) (See Table 5). The **platform-relative wind direction** values are critical in calculating true winds, and assessing errors caused by flow over the vessel or acceleration of the vessel.

Table 4: *wind_direction_convention*

Code	Convention	Definition
1	meteorological	direction from which the wind is blowing
2	oceanographic	direction to which the wind is blowing

Table 5: *zero_line_reference*

Value	Definition
000.0	Bow (Default value)
090.0	Starboard
180.0	Stern
270.0	Port

k) platform-relative wind speed (**PL_WSPD**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, observation_type, data_precision, missing_value, special_value, qcindex*

The **platform-relative wind speed** is recorded in *units* of meters per second from a frame of reference aboard the vessel. The **platform-relative wind speed** values are critical in calculating true winds, and assessing errors caused by flow over the vessel or acceleration.

l) earth-relative wind direction (**DIR**): *actual_range, long_name, units, original_units,* *instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, observation_type, data_precision, missing_value, special_value, qcindex*

The **earth-relative wind direction** is stored with *units* of degrees. The **earth-relative wind direction**, also known as the true wind direction, values increase clockwise from true north. All **DIR** are reported in the standard meteorological convention; the direction the wind is blowing from. Table 6 lists the additional direction conventions for calm and variable wind directions, although the calm and variable indicators are rarely recorded by SAMOS. They are more an artifact of bridge observations.

Table 6: Wind Directions

Direction	Definition
000.0	Calm winds
000.1 – 360.0	Direction in degrees
361.0	Variable wind direction

m) earth-relative wind speed (**SPD**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

The **earth-relative wind speed** is recorded in *units* of meters per second after possible conversion from the *original_units*.

NOTE: EARTH-RELATIVE WIND SPEED AND DIRECTION ARE EITHER CALCULATED BY THE DATA PROVIDER AND CHECKED BY THE DAC, OR THEY ARE CALCULATED BY THE DAC. A comment in the *instrument* attribute will be included when they are calculated by the DAC.

n) atmospheric pressure (**P**): *actual_range, long_name, units, original_units, mslp_indicator, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

Atmospheric pressure is recorded in *units* of hectopascals. The possible *original_units* of the pressure data are listed in Table 7 and Table 8 outlines the codes for the *mslp_indicator*.

Table 7: atmospheric pressure *original_units*

Code	Definition
0	hectopascals (millibars)
1	bars
2	millimeters of mercury
3	inches of mercury
4	pascals
5	high resolution (0.01 mb)
6	kilopascals

Table 8: *mslp_indicator*

Code	Definition
0	unknown
1	adjusted to sea level
2	at sensor height

o) air temperature (**T**):
p) wet-bulb temperature (**TW**):
q) dew point temperature (**TD**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

All **air temperatures** are recorded in *units* of degrees Celsius after a conversion from the *original_units* (when necessary). The **air temperature** is quality controlled by the SAMOS prescreener for data out of realistic bounds and data that are greater than 4 standard deviations from climatological means. Spikes and steps are also checked for using the automated quality control program SASSI.

All **wet bulb temperature** data are recorded in *units* of degrees Celsius after a conversion from the *original_units* (typically Celsius or Fahrenheit). The **wet bulb temperature** is also quality controlled for data out of realistic bounds and greater than 4 standard deviations from climatological means by the SAMOS prescreener as well as for spikes and steps using SASSI. The SAMOS prescreener also checks that the **wet bulb temperature** is less than or equal to the **air temperature** (a physical constraint), if not, the data are D-flagged (See Table 23).

All **dew point temperatures** are recorded in *units* of Celsius after a conversion from the *original_units* (typically Celsius or Fahrenheit). The **dew point temperature** is also quality controlled for spikes and steps using SASSI. The SAMOS prescreener also checks that **the dew point temperature** is less than or equal to the **wet bulb temperature** (physical constraint), if not, the data are D-flagged (See Table 23). The SAMOS prescreener also checks for data that are out of a realistic range of bounds and that the data are not greater than 4 standard deviations from the climatological mean.

r) sea temperature (**TS**): *actual_range, long_name, units, original_units, instrument, ts_sensor_category, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

The **sea temperature** is recorded in *units* of degrees Celsius after conversion from the *original_units* (when necessary). NOTE: The sensor *height* is recorded in meters and has a negative value for all non-missing values to indicate that sensors are located below the sea surface. The specific *instrument* type used to measure the **sea temperature** is stored in *instrument* while the general instrument type is recorded using the codes in Table 9 referring to the *ts_sensor_category*. The SAMOS prescreener checks the data for values that fall outside of a latitude dependent range of bounds and for data are greater than 4 standard deviations from the climatological mean. SASSI also checks the data for spikes and steps.

Table 9: General instrument types used to record sea temperature (*ts_sensor_category)*

Code	Definition
0	unknown
1	condenser inlet (intake)
2	trailing thermistor
3	hull contact sensor
4	through hull sensor
5	radiation thermometer
6	bait tanks thermometer
7	others
8	bucket
9	implied bucket (an HSST SID or any match)
10	reversing thermometer
11	other electronic sensor
12	thermosalinograph

s) relative humidity (**RH**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

The **relative humidity** is recorded in *units* of percent. The data are checked by the prescreener for values that fall outside of a realistic range of bounds. SASSI checks the data for spikes and steps.

t) specific humidity (**Q**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

Specific humidity is recorded in *units* of grams per kilogram and the codes for *original_units* are found in Table 10. The data are checked by the prescreener for values that fall outside of a realistic range of bounds. SASSI checks the data for spikes and steps.

Table 10: Possible original specific humidity units.

Code	Definition
0	$g*kg^{-1}$
1	$kg*kg^{-1}$

u) precipitation (**PRECIP**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

The **precipitation** is recorded in *units* of millimeters and Table 11 lists the possible **precipitation** *original_units*. Note that the precipitation typically represents the total height of the water in the precipitation gauge at the recording time (contrast this with rain rate below).

Table 11: Possible precipitation *original_units*

Code	Definition
0	inches

1	tenths
2	hundredths
3	centimeters
4	millimeters
5	high resolution (< 0.1 millimeter)

v) rain rate (**RRATE**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

The **rain rate** is recorded in *units* of millimeters per minute and is typically derived from the accumulated amount of precipitation (**PRECIP**) and the amount of time between sequential observations. The *original_units* are listed in Table 12. The SAMOS prescreener checks the data for values that fall out of a realistic range of **rain rates**.

Table 12: Rain rate *original_units*

Code	Definition
0	inches per minute
1	tenths of an inch per minute
2	hundredths of an inch per minute
3	centimeters per minute
4	millimeters per minute
5	high resolution (< 0.1 millimeter per minute)

w) short-wave atmospheric radiation (**RAD_SW**):
x) long-wave atmospheric radiation (**RAD_LW**):
y) ultraviolet atmospheric radiation (**RAD_UV**):
z) photosynthetically active radiation (**RAD_PAR**): *actual_range, long_name, units, original_units, rad_direction, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

Short-wave radiation will be stored in *units* of watts/m^2. The original radiation units are encoded based on Table 13 and the *rad_direction* is listed in Table 14. Radiation values are checked for values that fall out of a realistic range by the SAMOS prescreener.

Table 13: Possible radiation *original_units*

Code	Definition
0	watts/meter^2
1	calories*centimeters^{-2}*minute^{-1}
2	Langley
3	other
4	kilowatts*meter^{-2}

Table 14: *rad_direction* types

Code	Definition
0	unknown
1	downwelling
2	upwelling

The **long-wave atmospheric radiation** will be stored in *units* of watts/m^2. Refer to table 14 for *rad_direction* identifiers. The prescreener checks for values that fall outside of a realistic range.

The **ultraviolet radiation** will be stored in *units* of watts/m^2 and refer to Table 17 for *rad_direction* identifiers. The values are checked, by the prescreener, for values that fall outside of a realistic range.

The **photosynthetically active radiation** will also be stored in *units* of watts/m^2 and refer to Table 17 for *rad_direction* identifiers. The prescreener checks for values that fall outside of a realistic range of values.

aa) net atmospheric radiation (**RAD_NET**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

The **net atmospheric radiation** is the difference between downwelling and upwelling atmospheric radiation. The *units* will be watts/m^2 and positive (negative) values will indicate net incoming (outgoing) atmospheric radiation. This value will only be provided when the vessel is equipped with a net radiometer.

bb) visibility (**VIS**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

Visibility will be recorded in units of meters and will only be provided for vessels with automated visibility sensors.

cc) ceiling (**CEIL**): *actual_range, long_name, units, original_units, instrument, height, distance_from_bow, centerline_offset, average_method, average_center, average_length, sampling_rate, data_precision, observation_type, missing_value, special_value, qcindex*

Ceiling will be recorded in units of meters and will only be provided for vessels with automated ceiliometers.

NOTE: The coded values for WX, TCA, LMCA, ZCL, LCT, MCT, and HCT (below) are rarely recorded by SAMOS systems, but we retain these variables in anticipation of future sensor improvements.

dd) present weather (**WX**): *actual_range, long_name, units, observation_type, instrument,* *missing_value, special_value*

The codes for the **present weather** are available in Table 15 and are from ICOADS data (Slutz et al. 1985).

Table 15: Present weather codes

Code	Definition
00 – 19	*indicate no precipitation at site (e.g., ship, buoy, etc.) at time of observation*
00	cloud development not observed
01	clouds generally dissolving or becoming less developed
02	state of the sky unchanged
03	clouds generally forming or developing
04	visibility reduced by smoke
05	haze
06	widespread dust in suspension in the air, not raised by wind at or near the station at time of observation
07	dust or sand raised by wind at or near the station at time of observation, but no well-developed dust whirls or sand whirls and no dust storm or sandstorm seen
08	well developed dust whirls or sand whirls seen at or near the station during the preceding hour or at time of observation, but no dust storm or sandstorm
09	dust storm or sandstorm within sight at time of observation, or at the station during the preceding hour
10	light fog (visibility 1,100 yards or more); synonymous with European term "mist”
11	patches of shallow fog or ice fog at the station, not deeper than about 10 meters
12	more or less continuous shallow fog or ice fog at the station, not deeper than about 10 meters
13	lightning visible, no thunder heard
14	precipitation within sight, not reaching the surface of the sea
15	precipitation within sight, reaching the surface of the sea, but more than 5 kilometers from the station
16	precipitation within sight, reaching the surface of the sea, near to, but not at the station
17	thunderstorm, but no precipitation at time of observation
18	squalls at or within sight of the station during the preceding hour or at time of observation
19	funnel cloud or waterspout at or within sight of the station during the preceding hour or at time of observation
20 - 29	*refer to phenomena that occurred at the site during the preceding hour but not at time of observation*
20	drizzle (not freezing) or snow grains
21	rain (not freezing)
22	snow
23	rain and snow or ice pellets, type (a)
24	freezing drizzle or freezing rain
25	shower of rain
26	shower of snow, or of rain and snow
27	shower of hail (ice pellets, type (b), snow pellets), or of rain and hail
28	fog or ice fog
29	thunderstorm (with or without precipitation)

30 - 99	*refer to phenomena occurring at the site at time of observation*
30	slight or moderate dust storm or sandstorm has decreased during the preceding hour
31	slight or moderate dust storm or sandstorm with no appreciable change during the preceding hour
32	slight or moderate dust storm or sandstorm has begun or has increased during the preceding hour
33	severe dust storm or sandstorm has decreased during the preceding hour
34	severe dust storm or sandstorm with no appreciable change during the preceding hour
35	severe dust storm or sandstorm has begun or has increased during the preceding hour
36	slight or moderate drifting snow generally low (below eye-level, less than 6 feet)
37	heavy drifting snow generally low (below eye level, less than 6 feet)
38	slight or moderate blowing snow generally high (above eye-level, 6 feet or more)
39	heavy blowing snow generally high (above eye level, 6 feet or more)
40	fog or ice fog at a distance at time of observation, but not at the station during the preceding hour, the fog or ice fog extending to a level above that of the observer
41	fog or ice fog in patches
42	fog or ice fog (sky visible) has become thinner during the preceding hour
43	fog or ice fog (sky invisible) has become thinner during the preceding hour
44	fog or ice fog (sky visible) with no appreciable change during the preceding hour
45	fog or ice fog (sky invisible) with no appreciable change during the preceding hour
46	fog or ice fog (sky visible) has begun or has become thicker during the preceding hour
47	fog or ice fog (sky invisible) has begun or has become thicker during the preceding hour
48	fog, depositing rime, sky visible
49	fog, depositing rime, sky invisible
50 - 99	*indicate precipitation at the site at time of observation*
50	drizzle, not freezing, intermittent, slight at time of observation
51	drizzle, not freezing, continuous, slight at time of observation
52	drizzle, not freezing, intermittent, moderate at time of observation
53	drizzle, not freezing, continuous, moderate at time of observation
54	drizzle, not freezing, intermittent, heavy (dense) at time of observation
55	drizzle, not freezing, continuous, heavy (dense) at time of observation
56	drizzle, freezing, slight
57	drizzle, freezing, moderate or heavy (dense)
58	drizzle and rain, slight
59	drizzle and rain, moderate or heavy
60	rain, not freezing, intermittent, slight at time of observation
61	rain, not freezing, continuous, slight at time of observation
62	rain, not freezing, intermittent, moderate at time of observation
63	rain, not freezing, continuous, moderate at time of observation
64	rain, not freezing, intermittent, heavy at time of observation
65	rain, not freezing, continuous, heavy at time of observation
66	rain, freezing, slight

67	rain, freezing, moderate or heavy
68	rain or drizzle and snow, slight
69	rain or drizzle and snow, moderate or heavy
70	intermittent fall of snowflakes, slight at time of observation
71	continuous fall of snowflakes, slight at time of observation
72	intermittent fall of snowflakes, moderate at time of observation
73	continuous fall of snowflakes, moderate at time of observation
74	intermittent fall of snowflakes, heavy at time of observation
75	continuous fall of snowflakes, heavy at time of observation
76	ice prisms (with or without fog)
77	snow grains (with or without fog)
78	isolated star-like snow crystals (with or without fog)
79	ice pellets, type (a) (sleet, U.S. definition)
80	rain shower, slight
81	rain shower, moderate or heavy
82	rain shower, violent
83	shower of rain and snow mixed, slight
84	shower of rain and snow mixed, moderate or heavy
85	snow shower, slight
86	snow shower, moderate or heavy
87	slight showers of snow pellets or ice pellets, type (b), with or without rain or rain and snow mixed
88	moderate or heavy showers of snow pellets or ice pellets, type (b), with or without rain or rain and snow mixed
89	slight showers of hail, with or without rain or rain and snow mixed, not associated with thunder
90	moderate or heavy showers of hail, with or without rain or rain and snow, mixed, not associated with thunder
91	slight rain at time of observation, thunderstorm during preceding hour but not at time of observation
92	moderate or heavy rain at time of observation, thunderstorm during preceding hour but not at time of observation
93	slight snow, or rain and snow mixed, or hail, at time of observation with thunderstorm during the preceding hour but not at time of observation
94	moderate or heavy snow, or rain and snow mixed, or hail, at time of observation with thunderstorm during the preceding hour but not at time of observation
95	thunderstorm, slight or moderate, without hail, but with rain and/or snow at time of observation
96	thunderstorm, slight or moderate, with hail at time of observation
97	thunderstorm, heavy, without hail but with rain and/or snow at time of observation
98	thunderstorm combined with dust storm or sandstorm at time of observation
99	thunderstorm, heavy, with hail at time of observation

ee) total cloud amount (**TCA**): *actual_range, long_name, units, original_units, instrument, observation_type, missing_value, special_value*

The *units* for **total cloud amounts** are oktas and the codes for cloud amounts are located in Table 16 and are from the ICOADS data (Slutz et al. 1985). For the total cloud amount, codes 0 to 9 show the fraction, in oktas, of the celestial dome covered by all clouds. Table 17 gives the relationship between oktas and tenths (if the *original_units* are in tenths). The *original_units* will be noted using codes in Table 18.

Table 16: cloud amounts

Code	Definition
0	clear
1	1 okta or less, but not zero
2 – 6	2 – 6 oktas
7	7 oktas or more, but not 8 oktas
8	8 oktas
9	sky obscured or cloud amount cannot be estimated

ff) low/middle cloud amount (**LMCA**): *actual_range, long_name, units, original_units, instrument, observation_type, missing_value, special_value*

The codes for the **low/middle cloud amounts** (Table 19) are also from the ICOADS data (Slutz et al. 1985). For the **low/middle cloud amount**, the codes show the fraction, in oktas, of the celestial dome covered by all the low clouds and, if no low clouds are present, the fraction of the celestial dome covered by all the middle clouds.

If the data arriving at the DAC use tenths as *original_units* to describe cloud cover, the conventions in Table 17 will be used to convert from tenths to oktas. The *original_units* will be noted using the codes in Table 18.

Table 17: Relationship between tenths and oktas

Tenths	Oktas
0	0
1	1
2, 3	2
4	3
5	4
6	5
7, 8	6
9	7
10	8

Table 18: cloud amount *original_units*

Code	Definition
1	oktas
2	tenths

gg) cloud height (**ZCL**): *actual_range, long_name, units, original_units, observation_type, missing_value, special_value*

Cloud height is recorded using the standard 0-10 synoptic code. Table 19 shows the height ranges and codes for measurements in feet or meters. This parameter differs from an actual ceiling height measured by a ceiliometer.

Table 19: Cloud height codes. Approximate height of lowest cloud base*

Code	Feet	Meters
0	0 – 149	0 - 49
1	150 – 299	50 – 99
2	300 – 599	100 – 199
3	600 – 999	200 – 299
4	1000 – 1999	300 – 599
5	2000 – 3499	600 – 999
6	3500 – 4999	1000 – 1499
7	5000 – 6499	1500 – 1999
8	6500 – 7999	2000 – 2499
9	≥8000 or no clouds	≥2500 or no clouds
10	Indicates cloud height cannot be determined due to darkness or other reasons	Indicates cloud height cannot be determined due to darkness or other reasons

*Adapted from Table 9 of the ICOADS data documentation (Slutz et al. 1985)

hh) low cloud type (**LCT**): *actual_range, long_name, units, original_units, observation_type, missing_value, special_value*

Table 20: Low cloud type codes extracted from the ICOADS data documentation (Slutz et al. 1985). The codes show observed characteristics of clouds of the types stratocumulus, stratus, cumulus, cumulonimbus, and their variations.

Code	Cloud Types
0	no stratocumulus, stratus, cumulus, or cumulonimbus
1	cumulus with little vertical extent and seemingly flattened, or ragged cumulus other than of bad weather, or both
2	cumulus of moderate or strong vertical extent, generally with protuberances in the form of domes or towers, either accompanied or not by other cumulus or by stratocumulus, all having their base at the same level.
3	cumulonimbus the summits of which, at least partially, lack sharp outlines but are neither clearly fibrous (cirriform) nor in the form of an anvil; cumulus, stratocumulus, or stratus may also be present
4	stratocumulus formed by the spreading out of cumulus; cumulus may also be present
5	stratocumulus not resulting from the spreading out of cumulus
6	stratus in a more or less continuous sheet or layer, or in ragged shreds, or both, but no stratus fractus of bad weather
7	stratus fractus of bad weather (generally existing during precipitation and a short time before and after) or cumulus fractus of bad weather, or both (pannus), usually below altostratus or nimbostratus
8	cumulus and stratocumulus other than that formed from the spreading out of cumulus; the base of the cumulus is at a different level from that of the stratocumulus
9	cumulonimbus, the upper part of which is clearly fibrous (cirriform), often in the form of an anvil; either accompanied or not by cumulonimbus without anvil or fibrous upper part, by cumulus, stratocumulus, stratus, or pannus
10	low clouds not visible, owing to darkness, fog, blowing dust or sand, or other similar phenomena

ii) middle cloud type (**MCT**): *actual_range, long_name, units, original_units,* *observation_type, missing_value, special_value*

Table 21: Middle cloud type codes extracted from the ICOADS data documentation (Slutz et al. 1985). The codes show observed characteristics of clouds of the types altocumulus, altostratus, and nimbostratus.

Code	Cloud Types
0	no altocumulus, altostratus, or nimbostratus
1	altostratus, the greater part of which is semi-transparent; through this part the sun or moon may be weakly visible, as through ground glass
2	altostratus, the greater part of which is sufficiently dense to hide the sun or moon, or nimbostratus
3	altocumulus, the greater part of which is semi-transparent; the various elements of the cloud change only slowly and are all at a single level
4	patches (often in the form of almonds or fishes) of altocumulus, the greater part of which is semi-transparent; the clouds occur at one or more levels and the elements are continually changing in appearance
5	semi-transparent altocumulus in bands, or altocumulus in one or more fairly continuous layers (semi-transparent or opaque), progressively invading the sky; these altocumulus clouds generally thicken as a whole
6	altocumulus resulting from the spreading out of cumulus (or cumulonimbus)
7	altocumulus in two or more layers, usually opaque in places, and not progressively invading the sky; or opaque layer of altocumulus, not progressively invading the sky; or altocumulus together with altostratus or nimbostratus
8	altocumulus with sproutings in the form of small towers or battlements; or altocumulus having the appearance of cumuliform tufts
9	altocumulus of a chaotic sky, generally at several levels
10	middle clouds not visible, owing to darkness, fog, blowing dust or sand, or other similar phenomena, or more often because of the presence of a continuous layer of lower clouds

jj) high cloud type (**HCT**): *actual_range, long_name, units, original_units, observation_type, missing_value, special_value*

Table 22: High cloud type codes extracted from the ICOADS data documentation (Slutz et al. 1985). The codes show observed characteristics of clouds of the types cirrus, cirrocumulus and cirrostratus.

Code	Cloud Types
0	no cirrus, cirrocumulus or cirrostratus
1	cirrus in the form of filaments, strands, or hooks, not progressively invading the sky
2	dense cirrus, in patches or entangled sheaves, which usually do not increase and sometimes seem to be the remains of the upper part of a cumulonimbus, or cirrus with sproutings in the form of small turrets or battlements, or cirrus having the appearance of cumuliform tufts
3	dense cirrus, often in the form of an anvil, being the remains of the upper parts of cumulonimbus
4	cirrus in the form of hooks or of filaments, or both, progressively invading the sky; they generally become denser as a whole
5	cirrus (often in bands converging towards one point or two opposite points of the horizon) and cirrostratus, or cirrostratus alone; in either case, they are progressively invading the sky, and generally growing denser as a whole, but

	the continuous veil does not reach 45 degrees above the horizon
6	cirrus (often in bands converging towards one point or two opposite points of the horizon) and cirrostratus, or cirrostratus alone; in either case, they are progressively invading the sky, and generally growing denser as a whole; the continuous veil extends more than 45 degrees above the horizon, without the sky being totally covered
7	veil of cirrostratus covering the celestial dome
8	cirrostratus not progressively invading the sky and not completely covering the celestial dome
9	cirrocumulus alone, or cirrocumulus accompanied by cirrus or cirrostratus, or both, but cirrocumulus is predominant
10	high clouds not visible, owing to darkness, fog, blowing dust or sand, or other similar phenomena, or more often because of the presence of a continuous layer of lower clouds

kk) quality control flags (**flag**): *long_name*

The quality control flags (Table 23) are single alphabetic characters for each data value. The quality control flags for multiple variables are combined in a single string and stored in the **flag** variable. The **flag** variable as a result is a character string that has a length equal to the number of variables that underwent quality control. Only those variables with a *qcindex* have flag values (the *qcindex* is an integer pointer to the **flag** for a selected variable), i.e. not all meteorological variables are quality controlled.

A more detailed description of the quality evaluation process can be found at:
http://www.coaps.fsu.edu/woce/docs/qchbook/qchbook.htm

As an example of the usage of the **flag** variable, assume that a SAMOS netCDF file contains only **time**, **latitude**, **longitude**, **atmospheric pressure**, and **air temperature** data along with a **flag** variable. Based on the fact that all of the variables have a *qcindex*, all five variables will be quality controlled and each will have a unique *qcindex*. If the values for the first record of all five variables pass all quality control checks, then the first record of the **flag** variable will contain "ZZZZZ"; i.e. the **flag** variable contains QC flags for each variable in the *qcindex* for each variable, in this example 5 flags. However, if the second record contains a non-sequential **time**, but good **latitude** and **longitude** values, an **atmospheric pressure** value of 1090 mb, and an **air temperature** that is 6 standard deviations from the climatology, then the second record of **flag** will contain "CZZBG". The *qcindex* allows access to the flags for any variable. For example, the flag for the second record for **atmospheric pressure** (*qcindex*=4) is a "B" indicating the **atmospheric pressure** value is out of the realistic range of bounds.

Table 23: Definitions of SAMOS quality control flags.

A	Original data had unknown units. The units shown were determined using a climatology or some other method.
B	Original data were out of physically realistic range bounds outlined.
C	Time data are not sequential or date/time not valid.
D	Data failed T≥Tw≥Td test. In the free atmosphere, the value of the temperature is always greater than or equal to the wet-bulb temperature, which in turn is always greater than or equal to the dew point temperature.
E	Data failed resultant wind re-computation check. When the data set includes the

	platform's heading, course, and speed along with the platform relative wind speed and direction, a program re-computes the earth relative wind speed and direction and compares the computed values to the reported earth relative wind speed and direction. A failed test occurs when the wind direction difference is > 20 degrees or the wind speed difference is >2.5m/s.
F	Platform velocity unrealistic. Determined by analyzing latitude and longitude positions as well as reported platform speed data.
G	Data are greater than 4 standard deviations from the COADS climatological means (da Silva et al. 1994). The test is only applied to pressure, temperature, sea temperature, relative humidity, and wind speed data.
H	Discontinuity found in data.
I	Interesting feature found in data. More specific information on the feature is contained in the data reports. Examples include: hurricanes passing stations, sharp seawater temperature gradients, strong convective events, etc.
J	Data are of poor quality by visual inspection, DO NOT USE.
K	Data suspect/use with caution – this flag applies when the data look to have obvious errors, but no specific reason for the error could be determined.
L	Oceanographic platform passes over land or fixed platform moves dramatically.
M	Known instrument malfunction.
N	Signifies that the data were collected while the vessel was in port. Typically these data, though realistic, are significantly different from open ocean conditions.
O	Original units differ from those listed in the *original_units* variable attribute. See quality control report for details.
P	Position of platform or its movement are uncertain. Data should be used with caution.
Q	Questionable - data arrived at DAC already flagged as questionable/uncertain.
R	Replaced with an interpolated value. Done prior to arrival at the DAC. Flag is used to note condition. Method of interpolation is often poorly documented.
S	Spike in the data. Usually one or two sequential data values (sometimes up to 4 values) that are drastically out of the current data trend. Spikes occur for many reasons including power surges, typos, data logging problems, lightning strikes, etc.
T	Time duplicate
U	Data failed statistical threshold test in comparison to temporal neighbors. This flag is output by automated Spike and Stair-Step Indicator (SASSI) procedure developed by the DAC.
V	Data spike as determined by SASSI.
X	Step/discontinuity in data as determined by SASSI
Y	Suspect values between X-flagged data (from SASSI)
Z	Data passed evaluation.

Table 24: Range Bounds used in determining the use of flag B.

Variable	Lower Bound	Upper Bound	Units	Other
time	1-1-1980	12-31-2020		

latitude	-90	90	degrees	
longitude	0	359.9999	degrees	
platform heading	0	359.9	degrees	
platform course	0	359.9	degrees	
platform speed	0	15	$m*s^{-1}$	research vessels
wind direction	0	360	degrees	
wind speed	0	40	$m*s^{-1}$	
pressure	950	1050	mb (hPa)	sea level
air temperature* wet bulb temperature* dew point temperature*	-30	15	°Celsius	polar (60° - pole)
	-10	40	°Celsius	midlats (30° - 60°)
	10	40	°Celsius	tropics (0° - 30°)
sea temperature*	-2	15	°Celsius	polar
	-2	30	°Celsius	midlats
	15	35	°Celsius	tropics
relative humidity	0	100	percent	
specific humidity	0	48	g/kg	
rain rate	0	150	$mm*hr^{-1}$	
radiation	0	1400	$W*m^{-2}$	

*latitude dependent bounds checks

ll) history (**history**): *long_name*

The **history** provides tracking notes and times when the file passed through various stages of the SAMOS quality evaluation procedures. This includes the process version, date the process was run, and the flag changes made by the processes.

An example of a SAMOS netCDF file is located in Appendix 2. All data that are included in SAMOS have the 0-359.9999 degrees East *units* convention for longitude.

4. Global Attributes

The global attributes in the SAMOS DAC netCDF files include parameters that apply to all the variables in the file or to the file in general. Again, a mix of data and metadata are included.

a) *title*

A descriptive title highlighting the platform name, location, and special instrument characteristics of the platform. Often used to title plots of the data from the netCDF file. Ex: " KNORR Meteorological Data "

b) *site*

This attribute will contain either the alphanumeric R/V name or buoy number or location name.

c) *elev*

Stores the geographic elevation of the site in meters above sea level. This value is zero for ships and buoys.

d) *ID*

The ship/platform identification, call sign, or WMO number.

e) *IMO*

International Maritime Organization number that uniquely identifies a vessel throughout its operational life.

f) *platform*

Instrument system that recorded the data. For example: IMET, PAM, ATLAS, unspecified tower, bridge report, hand held instruments, etc.

g) *platform_version*

The version number of the data logging software used by the SAMOS "*platform*"

h) *facility*

The institution or country that collected the data or is the primary holder of the data. For example: NOAA, PMEL, WHOI, University of Washington, Chile, etc.

i) *data_provider*

Individual at the *facility* responsible for the distribution of the data to FSU DAC (typically the PI, data manager, or vessel technician responsible for the SAMOS data collection).

j) *fsu_version*

The current process version number of the data in the file. Identifies which stages of quality control the data have undergone.

k) *receipt_order*

Identifies the order in which multiple files may have been received at the DAC for the same observation day. Multiple *receipt_orders* are likely to occur in preliminary SAMOS netCDF files.

l) *start_date_time*

The first date and time of the data in the file. Coded as YYYY/MM/DD – hh:mm UTC where YYYY Four digit year (ex. 1992), MM Month (1 - 12), and DD Day number (1 - 31).

m) *end_date_time*

The last date and time of the data in the file. Coded the same as *start_date_time*.

n) *EXPOCODE*

Identifier for all WOCE cruises created by the WOCE Hydrographic Programme Office and obtained from the WOCE DIU at the University of Delaware. This identifier is appended to help match our data files to other oceanographic data sets.

o) *Cruise_id*

A unique identifier used, typically by the facility, in identifying which cruise of the year the data collection took place.

p) *Data_modification_date*

Computer clock time when the data were modified by either a quality control program or the data quality evaluator (DQE).

q) *Metadata_modification_date*

Computer clock time when the metadata were modified, i.e., we were notified that an instrument had been calibrated. It has the form of 'DD-MM-YYYY hh:mm:ss time zone'.

r) *contact_info*

Center for Ocean-Atmospheric Prediction Studies (COAPS), The Florida State University, Tallahassee, FL, 32306-2840, USA.

s) *contact_email*

samos@coaps.fsu.edu

5. References

da Silva, A. M., C. C. Young, and S. Levitus, 1994: Atlas of Surface Marine Data, Volumes 1: Algorithms and Procedures. NOAA Atlas Series, U.S. Dept. of Commerce, NOAA, NESDIS, Data, and Information Service : For sale by the U.S. G.P.O., Supt. of Docs.

Slutz, R.J., S.J. Lubker, J.D. Hiscox, S.D. Woodruff, R.L. Jenne, D.H. Joseph, P.M. Steurer, and J.D. Elms, COADS (Comprehensive Ocean-Atmosphere Data Set) Release 1, pp. 300, CIRES University of Colorado, 1985.

Appendix 1

Unidata netCDF

The Unidata network Common Data Form (netCDF) is an interface for scientific data access and a freely-distributed software library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The current netCDF software provides common C, FORTRAN77, FORTRAN90, and C++, and perl interfaces for applications and data. It has been tested on various common platforms.

netCDF files are self-describing, network-transparent, directly accessible, and extendible. `Self-describing' means that a netCDF file includes information about the data it contains. `Network-transparent' means that a netCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers. `Direct-access' means that a small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data. `Extendible' means that data can be appended to a netCDF dataset without copying it or redefining its structure.

netCDF is useful for supporting access to diverse kinds of scientific data in heterogeneous networking environments and for writing application software that does not depend on application-specific formats. A variety of analysis and display packages have been developed to analyze and display data in netCDF form.

You can obtain a copy of the latest released version of netCDF software using a WWW browser or anonymous FTP from

ftp://ftp.unidata.ucar.edu/pub/netCDF/netCDF.tar.Z

Included in this distribution are: the C source for the netCDF data access library, sources for the FORTRAN and C++ interfaces, documentation for the netCDF library and utilities in the form of a netCDF User's Guide, source for the netCDF utilities ncdump and ncgen, and test programs to verify the correct implementation of the netCDF library.

More information about netCDF, including a Frequently Asked Questions list and access to on-line documentation, is available from the URL

http://www.unidata.ucar.edu/packages/netCDF/

A mailing list, netCDF group@unidata.ucar.edu, exists for discussion of the netCDF interface and announcements about netCDF bugs, fixes, and enhancements. For information about how to subscribe, see the URL

http://www.unidata.ucar.edu/packages/netCDF/mailing-lists.html

An archive of past postings to the netCDFgroup mailing list is available for searching from the netCDF home page.

Questions about netCDF may be sent to support@unidata.ucar.edu.

Appendix 2

Sample listing of the contents of a SAMOS netCDF file created by the FSU DAC. This file is stored in a binary format but the listing presented here can be created using a netCDF utility called "ncdump" (refer to information provided by Unidata, Appendix 1). All arrays are indexed by the time.

```
netcdf KCEJ_20050831v01101 {
dimensions:
	time = UNLIMITED ; // (1 currently)
	f_string = 13 ;
	h_string = 236 ;
	h_num = 50 ;
variables:
	long time(time) ;
		time:long_name = "time" ;
		time:units = "minutes since 1-1-1980 00:00 UTC" ;
		time:data_interval = 60 ;
		time:observation_type = "measured" ;
		time:actual_range = 13498560, 13498560 ;
		time:qcindex = 1 ;
	float lat(time) ;
		lat:actual_range = -58.76649f, -58.76649f ;
		lat:long_name = "latitude" ;
		lat:units = "degrees (+N)" ;
		lat:original_units = "degrees (+N)" ;
		lat:instrument = "Best of Pcode GPS, Northstar 951 WASS, Northstar80" ;
		lat:observation_type = "measured" ;
		lat:average_method = "unknown" ;
		lat:average_center = "unknown" ;
		lat:average_length = -9999s ;
		lat:sampling_rate = -9999.f ;
		lat:data_precision = 0.0001f ;
		lat:qcindex = 2 ;
	float lon(time) ;
		lon:actual_range = 281.0018f, 281.0018f ;
		lon:long_name = "longitude" ;
		lon:units = "degrees (+E)" ;
		lon:original_units = "degrees (-W/+E)" ;
		lon:instrument = "Best of Pcode GPS, Northstar 951 WASS, Northstar80" ;
		lon:observation_type = "measured" ;
		lon:average_method = "unknown" ;
		lon:average_center = "unknown" ;
		lon:average_length = -9999s ;
		lon:sampling_rate = -9999.f ;
		lon:data_precision = 0.0001f ;
		lon:qcindex = 3 ;
	float PL_HD(time) ;
		PL_HD:actual_range = 0.5f, 0.5f ;
		PL_HD:long_name = "platform heading" ;
		PL_HD:units = "degrees (clockwise towards true north)" ;
		PL_HD:original_units = "degrees (clockwise from true north)" ;
		PL_HD:instrument = "Sperry (ship\'s instrument)" ;
		PL_HD:observation_type = "measured" ;
```

```
        PL_HD:average_method = "unknown" ;
        PL_HD:average_center = "unknown" ;
        PL_HD:average_length = -9999s ;
        PL_HD:sampling_rate = -9999.f ;
        PL_HD:data_precision = 1.f ;
        PL_HD:missing_value = -9999.f ;
        PL_HD:special_value = -8888.f ;
        PL_HD:qcindex = 4 ;
    float PL_CRS(time) ;
        PL_CRS:actual_range = 358.f, 358.f ;
        PL_CRS:long_name = "platform course" ;
        PL_CRS:units = "degrees (clockwise towards true north)" ;
        PL_CRS:original_units = "degrees (clockwise from true north)" ;
        PL_CRS:instrument = "Best of Pcode GPS, Northstar 951 WASS, Northstar80";
        PL_CRS:observation_type = "measured" ;
        PL_CRS:average_method = "unknown" ;
        PL_CRS:average_center = "unknown" ;
        PL_CRS:average_length = -9999s ;
        PL_CRS:sampling_rate = -9999.f ;
        PL_CRS:data_precision = 1.f ;
        PL_CRS:missing_value = -9999.f ;
        PL_CRS:special_value = -8888.f ;
        PL_CRS:qcindex = 5 ;
    float DIR(time) ;
        DIR:actual_range = 262.2f, 262.2f ;
        DIR:long_name = "earth relative wind direction" ;
        DIR:units = "degrees (clockwise from true north)" ;
        DIR:original_units = "degrees (clockwise from true north)" ;
        DIR:instrument = "Calculated on ship from relative wind and GPS" ;
        DIR:observation_type = "calculated" ;
        DIR:distance_from_bow = 0.7f ;
        DIR:centerline_offset = 0.f ;
        DIR:height = 10.3f ;
        DIR:average_method = "average" ;
        DIR:average_center = "time at end of period" ;
        DIR:average_length = 60s ;
        DIR:sampling_rate = 0.0667f ;
        DIR:data_precision = 0.1f ;
        DIR:missing_value = -9999.f ;
        DIR:special_value = -8888.f ;
        DIR:qcindex = 6 ;
    float PL_SPD(time) ;
        PL_SPD:actual_range = 10.66f, 10.66f ;
        PL_SPD:long_name = "platform speed over ground" ;
        PL_SPD:units = "meter second-1" ;
        PL_SPD:original_units = "meter second-1" ;
        PL_SPD:instrument = "Best of Pcode GPS, Northstar 951 WASS, Northstar80";
        PL_SPD:observation_type = "measured" ;
        PL_SPD:average_method = "unknown" ;
        PL_SPD:average_center = "unknown" ;
        PL_SPD:average_length = -9999s ;
        PL_SPD:sampling_rate = -9999.f ;
        PL_SPD:data_precision = 1.f ;
        PL_SPD:missing_value = -9999.f ;
```

```
		PL_SPD:special_value = -8888.f ;
		PL_SPD:qcindex = 7 ;
	float SPD(time) ;
		SPD:actual_range = 6.49f, 6.49f ;
		SPD:long_name = "earth relative wind speed" ;
		SPD:units = "meter second-1" ;
		SPD:original_units = "meter second-1" ;
		SPD:instrument = "Calculated on ship from relative wind and GPS" ;
		SPD:observation_type = "calculated" ;
		SPD:distance_from_bow = 0.7f ;
		SPD:centerline_offset = 0.f ;
		SPD:height = 10.3f ;
		SPD:average_method = "average" ;
		SPD:average_center = "time at end of period" ;
		SPD:average_length = 60s ;
		SPD:sampling_rate = 0.0667f ;
		SPD:data_precision = 0.1f ;
		SPD:missing_value = -9999.f ;
		SPD:special_value = -8888.f ;
		SPD:qcindex = 8 ;
	float P(time) ;
		P:actual_range = 1022.16f, 1022.16f ;
		P:long_name = "atmospheric pressure" ;
		P:units = "millibar" ;
		P:original_units = "millibar" ;
		P:instrument = "DB-1A (BPR104)" ;
		P:mslp_indicator = "adjusted to sea level" ;
		P:observation_type = "measured" ;
		P:distance_from_bow = 1.5f ;
		P:centerline_offset = -0.4f ;
		P:height = 10.3f ;
		P:average_method = "average" ;
		P:average_center = "time at end of period" ;
		P:average_length = 1s ;
		P:sampling_rate = 10.f ;
		P:data_precision = 0.1f ;
		P:missing_value = -9999.f ;
		P:special_value = -8888.f ;
		P:qcindex = 9 ;
	float T(time) ;
		T:actual_range = 1.87f, 1.87f ;
		T:long_name = "air temperature" ;
		T:units = "celsius" ;
		T:original_units = "celsius" ;
		T:instrument = "Rotronic MP100 (HRH106)" ;
		T:observation_type = "measured" ;
		T:distance_from_bow = 1.5f ;
		T:centerline_offset = -0.8f ;
		T:height = 10.3f ;
		T:average_method = "average" ;
		T:average_center = "time at end of period" ;
		T:average_length = 60s ;
		T:sampling_rate = 0.1f ;
		T:data_precision = 0.01f ;
```

```
        T:missing_value = -9999.f ;
        T:special_value = -8888.f ;
        T:qcindex = 10 ;
float RH(time) ;
        RH:actual_range = 94.19f, 94.19f ;
        RH:long_name = "relative humidity" ;
        RH:units = "percent" ;
        RH:original_units = "percent" ;
        RH:instrument = "Rotronic MP100 (HRH106)" ;
        RH:observation_type = "measured" ;
        RH:distance_from_bow = 1.5f ;
        RH:centerline_offset = -0.8f ;
        RH:height = 10.3f ;
        RH:average_method = "average" ;
        RH:average_center = "time at end of period" ;
        RH:average_length = 60s ;
        RH:sampling_rate = 0.1f ;
        RH:data_precision = 0.1f ;
        RH:missing_value = -9999.f ;
        RH:special_value = -8888.f ;
        RH:qcindex = 11 ;
float TS(time) ;
        TS:actual_range = 3.83f, 3.83f ;
        TS:long_name = "sea temperature" ;
        TS:units = "celsius" ;
        TS:original_units = "celsius" ;
        TS:instrument = "Falmouth Science Inc. OTM-S-212 (OTM1328)" ;
        TS:ts_sensor_category = 12s ;
        TS:observation_type = "measured" ;
        TS:distance_from_bow = 0.f ;
        TS:centerline_offset = 0.f ;
        TS:height = -5.f ;
        TS:average_method = "average" ;
        TS:average_center = "time at end of period" ;
        TS:average_length = 1s ;
        TS:sampling_rate = 4.f ;
        TS:data_precision = 0.01f ;
        TS:missing_value = -9999.f ;
        TS:special_value = -8888.f ;
        TS:qcindex = 12 ;
float RAD_SW(time) ;
        RAD_SW:actual_range = -0.2f, -0.2f ;
        RAD_SW:long_name = "short wave atmospheric radiation" ;
        RAD_SW:units = "watts meter-2" ;
        RAD_SW:original_units = "watts meter-2" ;
        RAD_SW:instrument = "Eppley PSP (SWR003)" ;
        RAD_SW:rad_direction = "downwelling" ;
        RAD_SW:observation_type = "measured" ;
        RAD_SW:distance_from_bow = 1.5f ;
        RAD_SW:centerline_offset = -0.1f ;
        RAD_SW:height = 10.9f ;
        RAD_SW:average_method = "average" ;
        RAD_SW:average_center = "time at end of period" ;
        RAD_SW:average_length = 60s ;
```

```
		RAD_SW:sampling_rate = 0.5f ;
		RAD_SW:data_precision = 0.1f ;
		RAD_SW:missing_value = -9999.f ;
		RAD_SW:special_value = -8888.f ;
		RAD_SW:qcindex = 13 ;
	long date(time) ;
		date:long_name = "calender date" ;
		date:units = "YYYYMMDD UTC" ;
		date:observation_type = "measured" ;
		date:actual_range = 20050831, 20050831 ;
		date:qcindex = 1 ;
	long time_of_day(time) ;
		time_of_day:long_name = "time of day" ;
		time_of_day:units = "hhmmss UTC" ;
		time_of_day:observation_type = "measured" ;
		time_of_day:actual_range = 0, 0 ;
		time_of_day:qcindex = 1 ;
	char flag(time, f_string) ;
		flag:long_name = "quality control flags" ;
		flag:A = "Units added" ;
		flag:B = "Data out of range" ;
		flag:C = "Non-sequential time" ;
		flag:D = "Failed T>=Tw>=Td" ;
		flag:E = "True wind error" ;
		flag:F = "Velocity unrealistic" ;
		flag:G = "Value > 4 s. d. from climatology" ;
		flag:H = "Discontinuity" ;
		flag:I = "Interesting feature" ;
		flag:J = "Erroneous" ;
		flag:K = "Suspect - visual" ;
		flag:L = "Ocean platform over land" ;
		flag:M = "Instrument malfunction" ;
		flag:O = "Multiple original units" ;
		flag:P = "Movement uncertain" ;
		flag:Q = "Pre-flagged as suspect" ;
		flag:R = "Interpolated data" ;
		flag:S = "Spike - visual" ;
		flag:T = "Time duplicate" ;
		flag:U = "Suspect - statistial" ;
		flag:V = "Spike - statistical" ;
		flag:X = "Step - statistical" ;
		flag:Y = "Suspect between X-flags" ;
		flag:Z = "Good data" ;
	char history(h_num, h_string) ;
		history:long_name = "file history information" ;

// global attributes:
		:title = "KNORR Meteorological Data" ;
		:site = "KNORR" ;
		:elev = 0s ;
		:ID = "KCEJ" ;
		:IMO = "007738618" ;
		:platform = "IMET - CALLIOPE" ;
		:platform_version = "001" ;
```

```
                :facility = "Woods Hole Oceanographic Institution" ;
                :data_provider = "Barrie Walden" ;
                :fsu_version = "011" ;
                :receipt_order = "01" ;
                :start_date_time = "2005/ 8/31 --  0: 0  UTC" ;
                :end_date_time = "2005/ 8/31 --  0: 0  UTC" ;
                :EXPOCODE = "EXPOCODE undefined for now" ;
                :Cruise_id = "Cruise_id undefined for now" ;
                :Data_modification_date = "30- 8-2005 20:13:48 EDT" ;
                :Metadata_modification_date = "30- 8-2005 20:13:48 EDT" ;

data:

 time = 13498560 ;

 lat = -58.76649 ;

 lon = 281.0018 ;

 PL_HD = 0.5 ;

 PL_CRS = 358 ;

 DIR = 262.2 ;

 PL_SPD = 10.66 ;

 SPD = 6.49 ;

P = 1022.16 ;

 T = 1.87 ;

 RH = 94.19 ;

 TS = 3.83 ;

 RAD_SW = -0.2 ;

 date = 20050831 ;

 time_of_day = 0 ;

 flag =
  "ZZZZZZZZZZZZB" ;

 history =
  "NETCDF file created Wed Aug 31 00:13:42 UTC 2005   ",
  "Prescreened on 30- 8-2005 20:13:48 EDT with code version samos0.2",
  "# flag changes by pre:    0    0    0    0    0    0    0    0    0    0    0    0    1",
  "",
  "" ;
}
```

Appendix 3

The following links (from http://www.coaps.fsu.edu/woce/html/wcdtools.htm) are subroutines that can be used to convert the time values from the DACs netCDF files to four-digit year, month, day, hour, and minute values (Invtime) and from four-digit year, month, day, hour, and minute values to the time values in the DACs minute time convention (Convtime). The routine processes individual time values (time stamp), but could be easily modified to handle an entire time array. They are available in FORTRAN, IDL, and C.

FORTRAN
invtime.f
convtime.f

IDL
invtime.pro
convtime.pro

C
invtime.c
convtime.c

The Invtime codes can be acquired electronically from our ftp site via the following commands:

```
ftp wocemet.fsu.edu
login anonymous
cd pub/src
get (invtime.f, invtime.pro, invtime.c)
```

Any problems that occur while using the code can be addressed to samos@coaps.fsu.edu