File Formats Used for CODAR Radial Data

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INTRODUCTION
The following is a detailed summary of the various file formats encountered by scientists working on the nationwide CODAR network. The focus is currently on radial data collected by Coastal Ocean RADAR (CODAR) SeaSonde instruments from the following institutions:

Rutgers University (Rutgers)
University of California at Santa Barbara (UCSB)
Naval Postgraduate School (NPS)
Universidad Autónoma de Baja California (UABC)
Texas A&M (TexAM)
University of Maine (UMaine)
Scripps Institution of Oceanography (SIO)

Working with datasets from institutions above has exposed a variety of formats currently in use by the CODAR community. It is recognized that there are likely other formats in use by the community that haven't been accounted for here. However, as more institutions participate in the network, it will be necessary to update this document with any new formats encountered.

Scientists at Scripps, the ROADNet project and Kent Lindquist of Lindquist Consulting have been working on a collaborative effort to build a nationwide network of CODAR sensors. Institutions listed above are providing data support. Technical support is also being provided by individuals from each institution, specifically:

Josh Kohut   (Rutgers)
Brian Emery   (UCSB)
Mike Cook   (NPS)
Reginaldo Durazo   (UABC)
John Perez   (TexAM)
Karl Schlenker   (UMaine)

In addition, collaboration with Bill Rector at CODAR Ocean Sensors has helped clarify the contents in radial files as well as shape metadata to be contained in future versions. In building this network it is necessary to understand what the various file formats are so that information from the files can be extracted in a consistent and controlled manner. This report is the beginning of an effort to document each format in as much detail as possible.

OVERVIEW
Radial files ultimately have one source, the SeaSonde software package. As sensors process data, a radial file is produced every hour for standard sites or every 4 hours for long-range sites. This file is a CODAR format radial file or, for brevity in this document, a **CODAR format** file. Variations in the CODAR format arise from different versions of

the SeaSonde software. Three versions of the SeaSonde software are represented in the datasets considered:

SeaSonde 4.3
SeaSonde 4.4
SeaSonde 10

Until the introduction of SeaSonde 10, the CODAR format was generally the same with modifications only to the header and trailer of the file. Data was always reported in a *range/bin format*. This style makes it difficult to work with and share data as additional processing is needed to report data in the conventional latitude, longitude, u & v format (or *lluv format*). With the release of SeaSonde 10, files are still available in range/bin format but CODAR has responded to users' requests by also providing output in lluv format. Future releases of SeaSonde software will only output lluv format although there are tools to convert between lluv and range/bin formats.

Over the years, Mike Cook has been responding to users' processing needs by developing and maintaining a MATLAB toolbox called HFRadarmap. The toolbox is designed for post-processing of the CODAR (range/bin) format radial files and introduces another widely accepted file format called **HF format**. The HF format has remained stable at least over versions 3.2 through 4.1 of HFRadarmap which correspond to release dates of December 2002 and September 2004, respectively. However, users of the toolbox may modify it to produce custom output. Given the freedom available in user customization, individual modification of the HF format will likely need to be associated with institutions or users rather than considering the modified file a true version of the HF format.

To summarize:
- CODAR format radial files are in range/bin format up though SeaSonde 4.4
- lluv format files are introduced in addition to range/bin format in SeaSonde 10
- CODAR format changes for range/bin data are only observed in the header and trailer of the file
- HF format radial files report data in lluv format, but are not equivalent to the CODAR lluv format file.

NOTE: regardless of the radial file format, there is no information *in* the file indicating that ideal or measured beam patterns were used to produce the radial file. As this information makes its way into the metadata reported in the file, it will also be beneficial to indicate the version of measured beam pattern used. Currently, the only way to know if a measured or ideal pattern is being used is by the fourth character in the filename:

's'	ideal pattern processed from CSS files
'z'	measured pattern from CSS files
'p'	measured pattern from CSA file
'_' or ' '	ideal pattern from CSA file

CODAR RANGE/BIN FORMAT RADIAL FILES

As mentioned above, the range/bin format has only changed in the way metadata is reported in the header and trailer of the file. The following is the radial file format documentation from CODAR Ocean Sensors:

Radial Vector Description:
Each radial vector describes the measurable portion of a current vector in relation to the SeaSonde site.

The *radial velocity* is measurable portion of the current velocity moving towards or away from the SeaSonde. Current velocities, which run perpendicular to the SeaSonde, will have a zero radial vector component, while current velocities, which run directly towards or away from the SeaSonde, will have a 100 percent radial vector component. A positive radial velocity is moving towards the SeaSonde, while a negative radial velocity is moving away from the SeaSonde.

The *radial bearing angle* indicates the direction out from the SeaSonde to where the radial vector is located.

The *radial range cell* minus one multiplied by the distance between range cells plus the first range cell distance indicates how far away the radial vector is located.

Values may be in Exponent format where 'E+n' means 10 to the nTH. Example 1.2E+3 is 1200

File Contents:
Line 1: First 48 characters: Long Textual Date of Radial
Line 1: After 48th character: Seconds from year 1904 after adding 2^32. *Actually, this is the seconds from year 1904 represented as the 2's complement of 2^{32} or [seconds since 1904] – 2^{32}, reference Bill Rector) .
Line 2: Site Latitude and Longitude formatted as 00°00.000N,000°00.000E
Line 3: Parameter 1: Distance in kilometers to first range cell
Line 3: Parameter 2: Distance in kilometers between range cells
Line 3: Parameter 3: *Reference Angle* degrees counter-clockwise from East. Typically, this will be 90.0 degrees, which is North.
Line 3: Parameter 4: Time Coverage in hours of Radial Data
Line 4: *Number of Range Cells*
> **Repeat** for *Number of Range Cells*
>> **Line N: Parameter 1:** *Number of Vectors* for this Range cell
>> **Line N: Parameter 2:** Current Range Cell Index
>> -- *Bearings* in degrees counter clockwise from *Reference angle*
>> **Repeat** for *Number of Vectors*
>> **Line N:** Bearing values in degrees up to 7 per line
>> **End Repeat**
>> -- *Velocities* in cm/s.
>> **Repeat** for *Number of Vectors*
>> **Line N:** Velocity values in cm/s up to 7 per line
>> **End Repeat**
>> -- *Uncertainties*
>> **Repeat** for *Number of Vectors*
>> **Line N:** Standard Deviation values in cm/s up to 7 per line
>> **End Repeat**
> **End Repeat**
End File

There has been one anomaly observed in the way standard deviation values may be reported. Normally, data is reported in scientific notation. However, for standard deviation data produced from OS's prior to 9.22 and seasonde software prior to 4.4f6, occasionally data will be reported as NAN(001).

There appears to be no documentation for the way in which the header has been modified over different versions of SeaSonde software and there is no documentation at all on the trailer. The following notes on variations in the formats are from direct comparison of files.

General Variations
End-of-Line indicators
   SeaSonde <10   ASCII 13 (return)
   SeaSonde 10[*]   ASCII 10 (linefeed)

[*]Unless the file has been converted for processing on an OS9 central site, in which case the line ending will be ASCII 13.

Header Variations
Line 1 Time formats
   Files from Rutgers, UCSB & SIO indicate that there are two variations in the time format;
```
2:00 PM    Friday,   October  8, 2004  GMT        -1114878496
13:00:00 Saturday, September 25, 2004 GMT        -1116005296
```

   And that the variations are correlated with SeaSonde versions as follows;
   SeaSonde 4.3/ 4.4   military time (HH:MM:SS)
   SeaSonde 10   civilian time (HH:MM AM/PM)

   However, Mike Cook notes that there can be any combination of the following (from codar2HFR.m);
   hh:mm:ss or hh:mm
   Civilian time or Military time
   No Time zone or Time Zone reported (not always GMT)

   GMT has also been observed after the time (as well as after the year) for early data from a UMaine site, CSTM.

Line 2 Latitude and Longitude formatting – degree minute separator symbol
   Examples:
```
32¡24.844'N,117¡14.624'W     ASCII 161
40°33.701'N,73°52.959'W      ASCII 176
36û56.953'N,122¡03.966'W     ASCII 251
```

   Latitude and Longitude formatting – Separator between latitude and longitude
   Examples
```
40°33.701'N,73°52.959'W
```

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```
40°25.992'N 073°59.026'W
```

Latitude and Longitude formatting – degrees/minutes vs. decimal degrees
All sites use degrees and minutes with some variation of the formatting noted
above EXCEPT

smr1 `34 25.221`<mark>`¡`</mark>`N,119 36.231`<mark>`¡`</mark>`W`
Degree minute separator is a space and ¡ is used where normally
the minute indicator (`'`) is used

Rfg1 <mark>`34.4612`</mark><mark>`¡`</mark>`N,`<mark>`120.0767`</mark><mark>`¡`</mark>`W`
Lat/lon is reported in decimal degrees and, again, single quote
(`'`) normally precedes hemisphere designator.

Variations in the header are not correlated with versions of SeaSonde software. This is
due to the fact that line 1 is dependent upon the operating system and line 2 comes from
unformatted user input into the header file. ASCII variations also result from alteration
as files are transferred via FTP or moved to different OS platforms. For this reason, the
header should not be used to delineate further CODAR format versions. Instead,
variations in the header should be delt with on an individual user/institution basis.

Trailer Variations
The trailer only varies in the fields included. For the majority of fields, data reported
appears to be in the same format across all files. Below is a table of all fields observed
and which versions of SeaSonde software contain them. Numbers indicate order of
appearance in the trailer. If the *Currents* field is included (it has only been observed to be
absent from UABC data), it is second in order of appearance.

Trailer Fields	SeaSonde 4.3/4.4	SeaSonde 10
RadialMerger		1
RadSmoothing		3
MinRadVectorPts		4
SpectraToRadial		5
Currents	(2)	
NumMergeRads	1	2
CenterFreqMHz	2	6
DopplerFreqHz	3	7
LimitMaxCurrent	4	8
AverFirmssPts	5	9
FactorDownPeakLimit	6	10
UseSecondOrder	7	11
FactorDownPeakNull	8	12
FactorAboveNoise	9	13
AmpAdjustFactors	10	14
MusicParams	11	15

Explainations for the above fields are provided below (from Bill Rector):

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RadialMerger	Version of the RadialMerger tool used. It collection short time radials (standard 10mins) over the (standard 60min) period and merges them into the output radial.
RadSmoothing	The analysis options value of whether radial smoothing/interpolation was on (1) or off (0).
MinRadVectorPts	The analysis options value of the minimum RadialMerger vectors filter. Must have a least this many vectors across the short time radials at the same bearing & range to be outputted to the merged radial file.
SpectraToRadial	Version number of the SpectraToRadial tool (OS X equiv of Currents tool)
Currents	Version number of the Currents tool on OS9 which processes a Cross Spectra (CSS) into a short time radial.
NumMergeRads	The number of short time radials merged into the output by RadialMerger tool. On a standard system with complete time coverage this would be seven.
CenterFreqMHz	The center freq in MHz of the system.
DopplerFreqHz	The doppler cell spacing of the Cross Spectra which is the number of doppler cells over the sweep rate. This is used to determine the Bragg positions and the radial velocities.
LimitMaxCurrent	The header value Maximum current limit. There will be no velocities in the file larger than this. The SpectraToRadial will filter out any velocties larger than this.
AverFirmssPts	The header value Averaging point for First Order Determination. The cross spectra doppler is smoothed by this in order to determine the Bragg first order region.
FactorDownPeakLimit	The header value FactorDownPeakLimit for First Order Determination. This is used on the cross spectra to determine the Bragg first order region.
UseSecondOrder	The header value UseSecondOrder for First Order Determination. This is used on the cross spectra to determine the Bragg first order region.
FactorDownPeakNull	The header value FactorDownPeakNull for First Order Determination. This is used on the cross spectra to

determine the Bragg first order region.

FactorAboveNoise   The header value FactorAboveNoise for First Order Determination. This is used on the cross spectra to determine the Bragg first order region.

AmpAdjustFactors   The amplitude adjustment factors (two, one for each antenna loop) used to manually adjust for loop antenna anomalies.

MusicParams   The three MUSIC processing parameters used by SpectraToRadial. See the MUSIC processing algorithm.

CODAR LLUV FORMAT RADIAL FILES

HF FORMAT RADIAL FILES

The HF format has not changed over versions 3.2 through 4.1 of HFRadarmap which correspond to release dates of December 2002 and September 2004, respectively. Within HFRadarmap, each function (script) has its own version so that changes in individual functions can be tracked. A single function is responsible for converting CODAR range/bin format radial files to HF format files, namely codar2HFR.m (or codar2HFR). Over versions 3.2 through 4.1 of HFRadarmap, codar2HFR has gone through versions 2.2 through 5.1. The following is an example of HF format file format:

```
%time: 2002 10 03 02 00 00 GMT
%site: UABC
%radarpos: -117.075800 32.376433
%datasource: SIO, Mark Otero
%procprog: codar2HFR.m, v.2.2: 031013 18:02:39
%lobe1dir:
%firstbin: 0.999000
%binres: 0.999000
%centerfreq: 25.324926376
%avetime: 1.250000
%nummergerads: 7
%samplelength:
%antpatt:
%interp: 0
%musicparms: 20.00    10.0    3.0
%  Lon       Lat       U       V    Uncert   Rad Speed
% (deg)     (deg)    (cm/s)  (cm/s)          (cm/s)
-117.0803  32.3846   -6.42   13.78  18.9    15.20

        .         .         .         .         .         .
        .         .         .         .         .         .
        .         .         .         .         .         .
```

Only one minor variation is noted among HF format files and that is in the fifth line of the header. Somewhere between version 4.0 & 5.1 of codar2HFR, the colon after the version changed to a semicolon.

```
Ex.
%procprog: codar2HFR.m, v.2.2: 031013 18:02:39
%procprog: codar2HFR.m, v.5.1; 041019 05:02:33
```

Explainations and general format descriptions for each header line follow below:

time:	Center of time average of radial current data (hours).
site:	4 character radial site indicator (from file name).
radarpos:	Position (lon / lat) of radar site (decimal degrees).
datasource:	Governing institution and name of program user.
procprog:	Name & version of codar2HFR.m, and date/time program run.
lobe1dir:	Lobe 1 angle as measured positive from true north.
firstbin:	Distance to first bin (kilometers).
binres:	Bin resolution (kilometers).
centerfreq:	Operating frequency (MHz).
avgtime:	Average time (hours).
nummergerads:	Number radial files merged.
samplelength:	Length of fft (seconds).
antpatt:	Antenna pattern used : ideal or measured
interp:	Integer describing interpolation scheme used, 0 for no interpolation. Numbers that follow will describe the parameters needed for the particular interpolation scheme used.
musicparams:	Music parameters used in determining radial direction.

Three fields, lobe1dir, samplelength & attpatt, are included in the header in anticipation of their use but have not been used yet (always blank). All fields except datasource, procprog & interp are obtained from the CODAR range/bin format file or filename. procprog comes from a hard-coded line in codar2HFR while datasource comes from 2 arguments input by the user. Parameters from the interpolation file provide information for the interp field, if used.

RECOMMENDATIONS & IMPLEMENTATIONS

Having reviewed the variations in CODAR radial file formats, it is necessary to synthesize the information into versions for each file type, i.e. How many versions of the CODAR range/bin format radial file are there? or How many versions of the HF format are there? Going by any differences at all between files will likely lead to a situation where nearly every institution (if not site) will constitute its own 'version' of a file type. Recommendations and implementations for delineating versions of each file type are discussed below.

CODAR range/bin Format Radial Files

The header is the only region of the file containing variation that does not correlate with different versions of SeaSonde software. This is due to variations in user input and operating systems. All other variations are associated with different versions of SeaSonde software. It is therefore suggested that there be a minimum of two or maximum of three recognized versions of CODAR range/bin format radial files (for versions of SeaSonde software considered thus far).

Two-version model: In this model, the only differences between SeaSonde 10 and all previous versions of SeaSonde software are recognized. The differences are only in the end-of-line indicators. A script which searches for all possible trailer fields and uses any field that is found would handle trailer differences.

Three-version model: In this model, differences are recognized in the trailer so that the three versions are made up of radial files generated by SeaSonde 4.3/4.4 and SeaSonde 10.

The three-version model described above has been adopted for the current development stage of the network. The three formats are:

      hfrss10rb   SeaSonde 10 range bin files
      hfrss4   SeaSonde 4.X files, with Currents field in trailer
      hfrss4nCV   SeaSonde 4.X files, without Currents field in trailer

HF Format

There appears no justification for establishing more than one version of the HF format at this point. Only one minor variation is observed in the `procprog` field (line 5) of the header where a colon changes to a semicolon. The recommendation is to have one HF format version until either older files that may be different are encountered (processed with HFRadarmap version prior to 3.2) or a change is made in future releases of HFRadarmap.

At the current stage of development, there does not seem to be a need for supporting HF Format radial files since CODAR format radial files form the basis of HF Radar measurements and provide common ground for developement.