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DATA STANDARDIZATION FOR LONG-TERM UNDERWATER ACOUSTIC OBSERVATION

OCEAN TEMPERATURE AND AMBIENT NOISE DATA IN FRAM STRAIT

by

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SUMMARY: The Fram Strait is a key region for climate research. To support the development of the Fram Strait Multipurpose Acoustic System, NERSC has conducted several acoustic field experiments in this region in the past decade. Acoustic travel times have been inverted into depth range averaged ocean sound speed and converted to ocean mean temperature. The acoustic observations have been exploited for describing acoustic ambient noise characteristic in the area (soundscape). The data collections and derived products from two experiment periods (2008-2009 and 2010-2012) have been processed and analyzed in the EU projects DAMOCLES and ACOBAR, and Norwegian Research Council project UNDER-ICE. The processed data has been prepared and formatted for distribution through NorDataNet infrastructure and the EU project INTAROS. The goal has been to define a format with ample metadata for both data discovery and appropriate data reuse of acoustic thermometry and passive acoustics datasets. This format is based on the NetCDF standard and the metadata recommendations from the Climate and Forecast (CF) convention and the OceanSITES system. This report describes the developed format and provides examples of the acoustic data collections and products.

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1. Introduction

Over the past decade, the volume of Earth Observation (EO) data has been rapidly increasing due to the launch of a series of new satellites carrying a suite of high-resolution sensors capturing important ocean, terrestrial and atmospheric parameters. The Copernicus program, with its different Sentinel missions, is a major source of new EO data with high spatial and temporal resolution. Similar advances in development of in situ sensors have taken place in the same time period. This development has resulted in vast amounts of direct measurements of environmental parameters on a regular or semi-regular basis. Alongside the technical development of new sensors, the scientific community, as well as private and public actors in environmental monitoring and assessment have recognized the growing importance of efficient data processing, analysis and management. Consequently, there is a strong need for developing standard data models - including metadata - for new types of data generated by recently deployed remote sensing and in situ sensors. Standardizing data representation and access is needed to develop scalable information systems that can capitalize on the massive amounts of data available in a timely manner.

NetCDF-CF is a widely used data standard for oceanographic in-situ data as well as for gridded products from remote sensing data and output from ice-ocean models including reanalysis [CF]. OceanSITES, which is an integral part of the Global Ocean Observing System, aims at collecting, delivering and promoting the use of high-quality data from long-term, high-frequency observations at fixed locations in the open ocean. The OceanSITES data management team has implemented a data format based on NetCDF [OceanSITES]. The U.S. Integrated Ocean Observing System (IOOS) developed IOOS metadata conventions for their data management, and this is widely used in scientific studies of coastal waters, Great Lakes, and oceans (https://ioos.noaa.gov/data/contribute-data/metadata-standards/).

However, there are no public standards and formats within acoustic thermometry. Moreover, data standards for representing energy, including underwater noise, is also missing, despite the fact that noise level has been introduced as one of eleven indicators describing Good Environmental Status (GES) in the Marine Strategic Framework Directive (MSFD) (http://ec.europa.eu/environment/index_en.htm). Consequently, there is no standardized means to discover and access to acoustic thermometry and energy information under waters.

Two experiments for long-term monitoring of underwater acoustic in Fram Strait have been carried out under the DAMOCLES (2008-2009) and ACOBAR (2010-2012) projects financed by the European Commission in the 6th and 7th Framework Programme for Research and Development. Data acquired in the experiments are processed and will be published through the NorDataNet and INTAROS projects. We develop NetCDF compliant data formats for acoustic thermometry and passive acoustic with ample metadata for data discovery and reuse based on CF-1.6, OceanSITES-Manual-1.2, IOOS Convention for Passive Acoustic Recording-1.0 [Guan, et al., 2014].

In this paper, we describe the data formats and metadata developed at NERSC to facilitate data sharing and reuse. Section 2 describes the two acoustic experiments conducted during the ACOBAR and DAMOCLES projects. Section 3 describes structure of the developed datasets, metadata and variable details as well as the metadata and data examples.

2. Long-term underwater acoustic experiments

Two underwater acoustic experiments were carried out in the central part of the Fram Strait under the DAMOCLES (September 2008 – July 2009) and ACOBAR (September 2010 – May 2012) projects for long-term ocean monitoring. Acoustic travel times between source and receiver moorings located from 130 - 300 km apart were recorded every three hours during the experiments. The recordings were processed to two different types of high-level datasets to enables various data users beyond the scientific community; depth-range averaged ocean sound speed and temperature (*WSSP_WTMP*) dataset and sound pressure and sound level (*ambientnoise*) dataset.

In this section, configurations of the acoustic systems, the acquired recordings and the characteristics are described.

2.1. DAMOCLES experiment (2008-2009)

2.1.1. Experiment configuration

The DAMOCLES experiment was carried out from September 2008 – July 2009. A source mooring (S) with a transmitter and a receiver mooring (R) were deployed in the central parts of the Fram Strait (Figure 1) [Sagen et al., 2008] [Sagen, 2016]. The transmitter sent a sweeper signal (190 - 290 Hz) for 60 s every three hours over the year-long experiment. The acoustic recordings were made by use of the Simple Tomographic Acoustic Receiver (STAR) technology, developed at Scripps Institution of Oceanography, with a four-element vertical receiving array with 96 m spacing each [Worcester et al., 2011]. Two STARs, Ra and Rb, were installed in the receiver mooring R. The four hydrophones in each STAR are labeled as hydrophone-1, 2, 3 and 4 from the closest hydrophone to the STAR controller respectively. In shallower STAR Ra, hydrophone-1 is the shallowest hydrophone and hydrophone-4 stands for the deepest one. On the other hand, deeper STAR Rb was installed upside down. Thus, hydrophone-1 was located the deepest position. Table 1 gives the water depths, mooring locations and instrument depths.

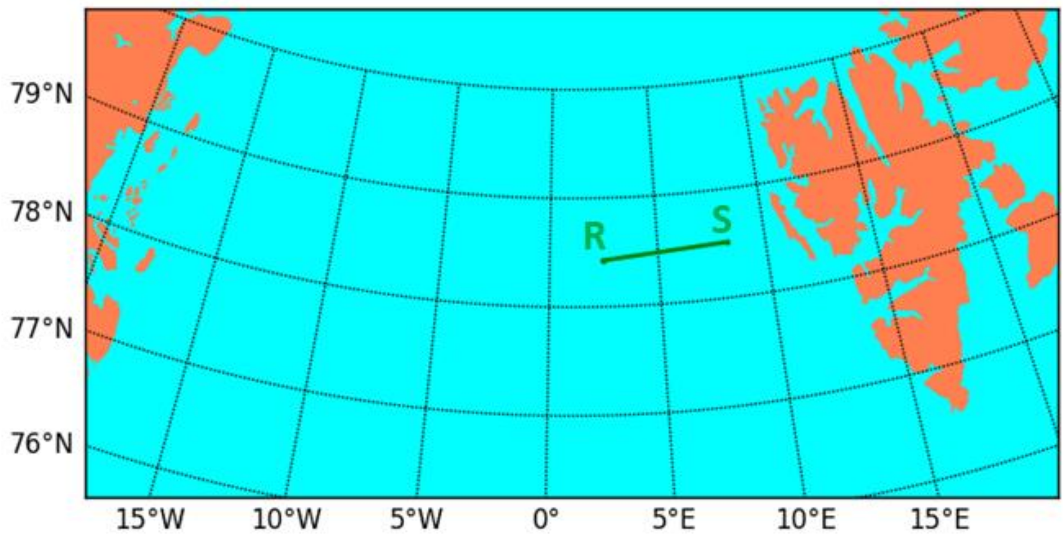

Figure 1. Two mooring positions, source mooring (S) and receiver mooring (R), under the DAMOCLES experiment. The green solid line shows the ranges for *mean_c* and *mean_t* variables in *WSSP_WTMP* dataset. Distance between S and R is 130.01 km.

Table 1. Temporal coverage and resolution, recorded time for each reception, mooring locations, corrected water depth and nominal instrument depths for the DAMOCLES experiment.

The depths for the source and receiver hydrophones represent relative distances to the sea surface when vertical motion of the hydrophone is 0 (nominal depth). In the last row, the four values are the nominal depths of hydrophone-1, 2, 3 and 4 in each STAR respectively from the left.

Temporal coverage and resolution	21 Sep. 2008 – 31 Jul. 2009 3H
Recorded time for each reception	80 s
Mooring position (lon, lat)	S (8.252, 78.511), R (2.441, 78.426)
Water depth (m)	S: 1500 R: 2500
Nominal source depth (m)	S: 378
Nominal receiver hydrophone depths (m)	Ra: 306, 402, 498, 594 Rb: 973, 877, 781, 685

2.1.2. Data acquisition

The eight receiver hydrophones were controlled to start and stop recording 10 s before and after arrival of the expected tomography signal, by the STARs every three hours during the experiment. Consequently, each recording has 80 s long with 10 s leeway before and after the expected transmission for 60 s). Two sets of recordings, which include 2173 and 2043 receptions, were obtained from each hydrophone in STARs Ra and Rb respectively. The sets of the recordings are processed to *WSSP_WTMP* dataset and *ambientnoise* dataset.

Several recordings include technical impact as overloading and saturation as shown in Figure 2 [Haugen et al., 2010]. These recordings were filtered out, and the recordings with the measurable transmission signal were then extracted for *WSSP_WTMP* dataset, described in Section 3.1. Consequently, four sets of 713 recordings from the four hydrophones in STAR Rb were obtained for the analysis.

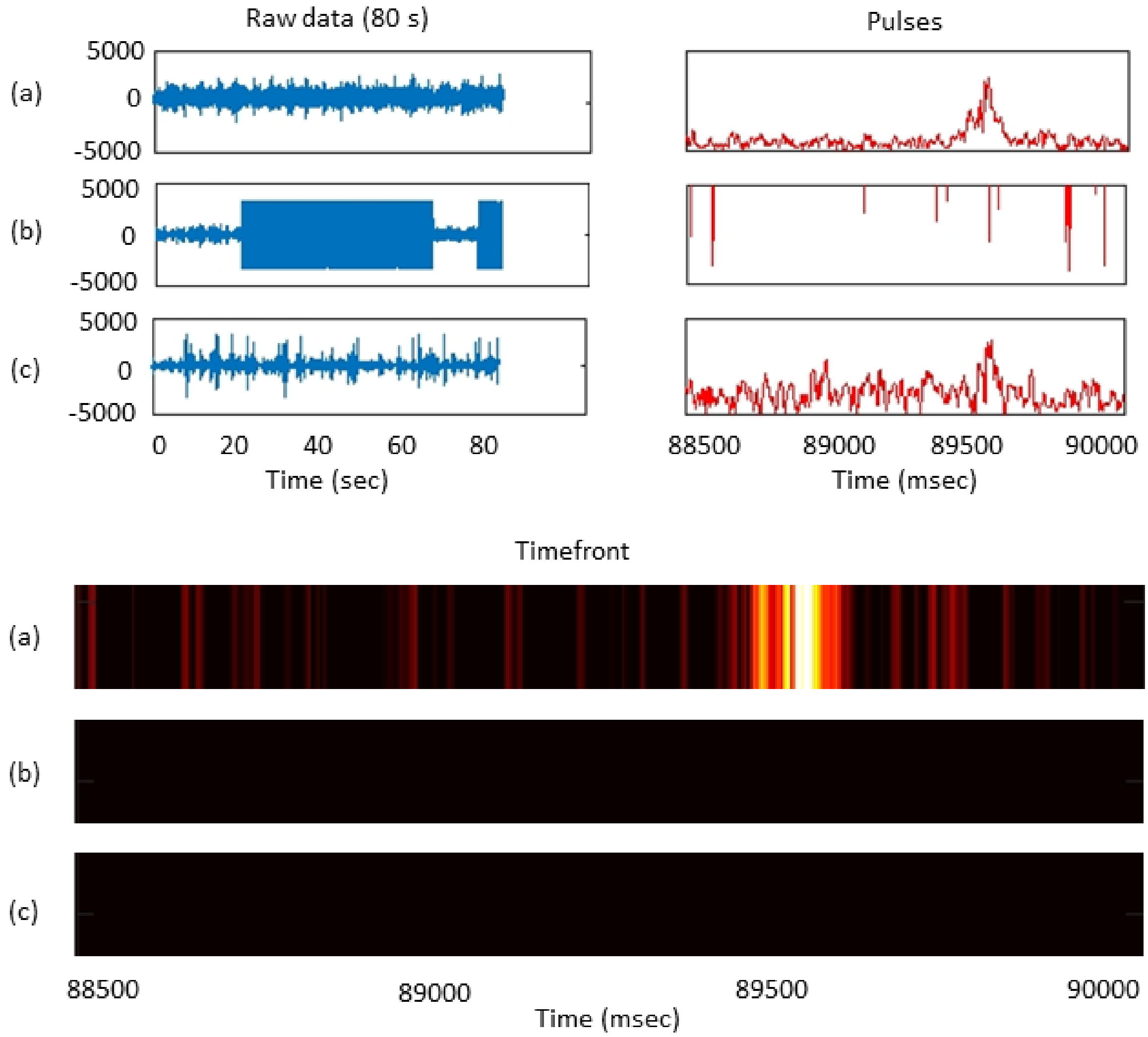

Figure 2. Examples of three different types of recordings from the DAMOCLES experiment. Upper left and right panels represent raw data and the pulse respectively, and lower panels represent time front of the recordings. (a) Reception with no evident issues and a clear pulse (b) Overloading reception (c) Reception with saturation [Haugen, 2010].

Two sequences of all recordings from hydrophone-1 and 4 were processed to *ambientnoise* dataset for each STARs. Thus, two sequences of 2173 recordings from the two hydrophones were employed to create the dataset from STAR Ra. Similarly, two sequences of 2043 recordings were used for the STAR Rb dataset. Sound pressure and sound level data are often used for soundscape analysis, while the datasets include some recordings with adverse noise as technical noise by overloading and saturation (Figure 2) and mechanical noise by cable strumming and flow noise. [Yamakawa, 2016] describes that impact of the mechanical noise is related to the instrument displacement. During the experiment, the hydrophone displacement was also recorded every hour. The measured displacement was paired with the closest-time acoustic recording to indicate quality of the recording. Total numbers of the recordings without such adverse noise for each hydrophone are shown in Table 2.

Table 2. Numbers of acquired recordings and recordings without adverse signals (technical and mechanical noises) for each recording set. Two values in the last column correspond to hydrophone-1 and 4 from the left respectively.

STAR ID	# of recordings	# of recordings without adverse noises (hydrophone-1 and 4)
Ra	2174	106, 112
Rb	2043	814, 846

2.2. ACOBAR experiment (2010-2012)

2.2.1. Experiment configuration

A multipurpose acoustic system was deployed under the ACOBAR experiment. The system includes three transceiver moorings (A, B and C) and an acoustic receiver mooring (D) (Figure 3). The four moorings were deployed in September 2010. Mooring C failed shortly after the deployment and the transceiver fell to the seafloor. Moorings A and D were recovered to replace their batteries in July 2011, and both moorings were then redeployed in September 2011. At this time, the arrangement of the attached hydrophones to the moorings was also modified to reduce the effects of cable strumming on the further acoustic recordings at locations A and D. The three moorings, A, B and D, were then successfully recovered in May 2012.

A STAR was installed in each transceiver mooring (A, B and C), and two STARs were included in mooring D. The upper and lower STARs in mooring D are labeled as Da and Db respectively. As well as the DAMOCLES experiment, four hydrophones in each STAR were tagged as hydrophone-1, 2, 3, and 4 from the closest hydrophone to the STAR controller. In STARs A, B, C and Da, hydrophone-1 means the shallowest hydrophone and hydrophone-4 is the deepest one. On the other hand, hydrophone-1 represents the deepest location in STAR Db since it was installed upside down. Further details about the ACOBAR experiment are given in Table 3 and [Sagen, et al., 2016].

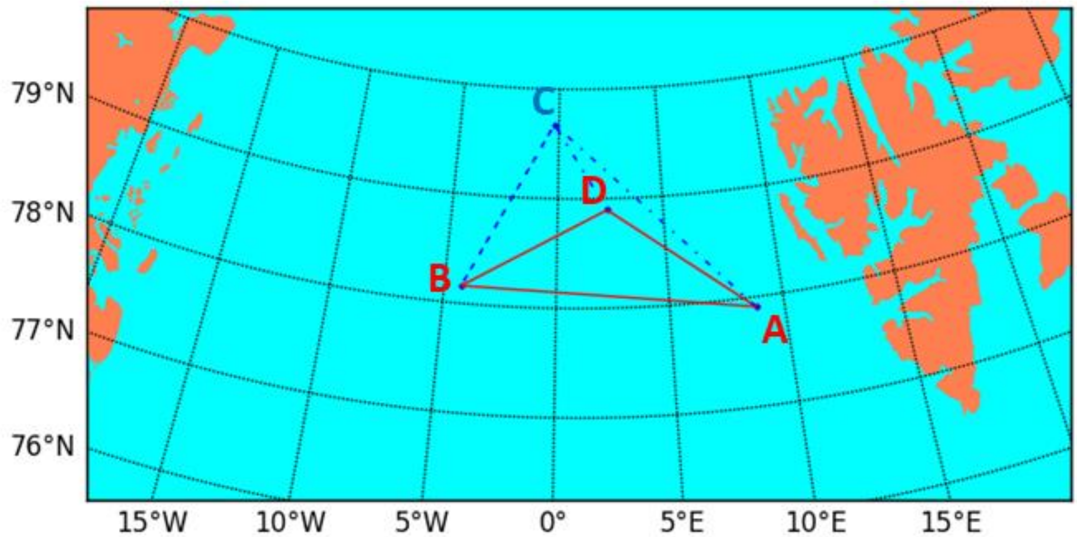

Figure 3. Four mooring positions, transmitter moorings (A, B and C) and receiver mooring (D), under the ACOBAR experiment. The location C is the position at which the anchor was dropped. The red solid lines show the ranges for *mean_c* and *mean_t* variables in *WSSP_WTMP* datasets. The distances between A-B, A-D and B-D are 301.11, 248.46 and 167.66 km respectively.

Table 3. Temporal coverage and resolution, recorded time for each reception, mooring locations, corrected water depths and nominal instrument depths for the ACOBAR experiment. Since moorings A and D were redeployed in September 2011, their positions and depths are slightly different. In the last row, the four values are the nominal depths of hydrophone-1, 2, 3 and 4 in the STAR respectively from the left. STAR A and B had a four-element receiving array with 9.6 m spacing. The four hydrophones with 96 m spacing in STAR Da and Db were modified to 9.6 m at the redeployment.

	2011	2012
Temporal coverage and resolution Recorded time for each reception	Sep. 2010 – Jul. 2011, 3H 100 s	Sep. 2011 – May 2012, 3H 100 s
Mooring position (lon, lat)	A (8.752, 77.911), B (-4.243, 78.161), C (-0.234, 79.677), D (2.346, 78.896)	A (8.747, 77.900), B (-4.243, 78.162), C (-0.234, 79.677), D (2.328, 78.895)
Water depth (m)	A: 1442 B: 2085 D: 2439	A: 1431 B: 2085 D: 2439
Nominal source depth (m)	A: 407 B: 496	A: 393 B: 496
Nominal receiver hydrophone depths (m) (hydrophone-1,2,3,4)	A: 387, 396, 406, 416 B: 476, 486, 495, 505 Da: 228, 324, 420, 516 Db: 902, 806, 710, 614	A: 373, 383, 392, 402 B: 476, 486, 495, 505 Da: 264, 274, 283, 293 Db: 954, 944, 935, 925

2.2.2. Data acquisition

A sweeper signal with 60 s long transmitted from mooring A was recorded by hydrophones controlled by three STARs in moorings B and D every three hours during the experiment. In the same manner, hydrophones commanded by STAR A, Da and Db recorded tomography signal from mooring B. The STARs were programmed to record the signal with 20 s leeway before and after the expected transmission (Figure 4 left). Thus, each recording has 100 s long. These recordings were processed to *WSSP_WTMP* datasets. The STARs in mooring A, B and D were also programmed to conduct the hydrophones to record the signal from mooring C. However, the recordings did not include the expected tomography signal because mooring C was lost shortly after the deployment (Figure 4 right). The sets of these recordings without the tomography signal were processed to *ambientnoise* datasets.

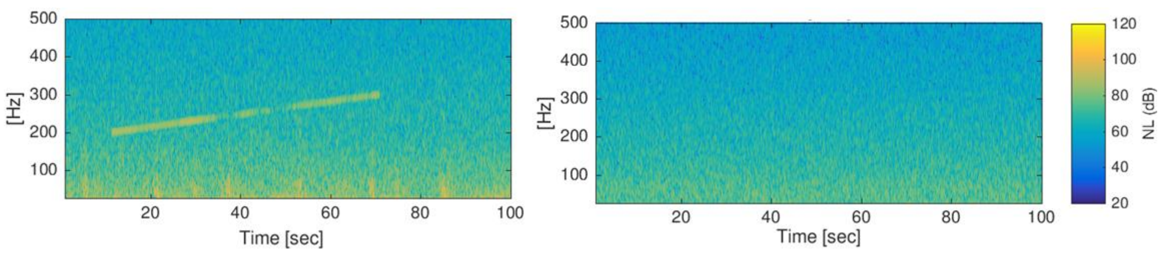

Figure 4. Recording examples from the ACOBAR experiment. The recordings have 100 s long. Left: sweeper tomography signal (190 - 290 Hz) for 60 s. The recording includes 20 s leeway before and after the signal. Right: neither tomography signal nor adverse noise.

Depth-range averaged ocean sound speed and temperature were computed using sets of the recordings with the tomography signal from source mooring A and B for each period, i.e. before and after 1 September 2011. Two STARs, Da and Db, in mooring D made recordings include same tomography signal from the source moorings. Therefore, sets of the recordings from Da only were used for the computations. Consequently, four sets of the recordings in Table 4 were used to create the *WSSP_WTMP* datasets for each year. The recordings, which do not have observable tomography signal by overloading, saturation or any other reasons, were filtered out from the computation as well as the DAMOCLES experiment. The total numbers of the recordings used for the computations are given in the last column in Table 4.

Eight sets of the recordings which do not include the tomography signal were used to create the *ambientnoise* datasets. In each set, two sequences of the recordings from hydrophone-1 and 4 were processed to sound pressure and sound level. Some recordings are contaminated by technical noise caused by overloading and saturation, and mechanical noise as cable strumming (Figure 5 upper left and upper right). As well as the DAMOCLES experiment, displacement of the hydrophone recorded every hour was paired to the closest-time acoustic recording to specify the impact of the displacement. Existence of the technical noise and/or mechanical noise, which is adverse for further soundscape analysis, is indicated in the dataset. The numbers of recordings from the two hydrophones without the adverse noise are shown in Table 5. Some recordings include anthropogenic noise, e.g. seismic air gun noise and ship engine noise (Figure 5 lower right and lower left). Especially many recordings collected in the summer are dominated by seismic air gun noise [Yamakawa, et al., 2016]. The impact of the seismic air gun is stronger below 200 Hz. Moreover, marine mammal vocalization is also recorded in some recordings. These sounds are not indicated here.

Table 4. Range, depth, temporal coverage and number of used recordings for depth and range averaged ocean water temperature estimation. The recordings in receiver D means receptions by STAR Da. The ranges are different in 2011 and 2012 because of redeployment of two moorings A and D.

Year	Source - Receiver	Range (m)	Depth (m)	Start date (DD/MM/YYYY)	End date (DD/MM/YYYY)	# of recordings
2011	A – B	0 - 331313	0 - 1000	10/09/2010	31/07/2011	843
	A – D	0 – 248455		10/09/2010	31/07/2011	1311
	B – A	0 – 331313		08/09/2010	31/07/2011	1715
	B – D	0 - 167658		09/09/2010	31/07/2011	2217
2012	A – B	0 - 301638	0 - 1000	23/09/2011	24/05/2012	566
	A – D	0 - 181855		25/09/2011	29/07/2012	1268
	B – A	0 - 301638		24/09/2011	31/05/2012	1595
	B – D	0 - 167261		24/09/2011	02/06/2012	1757

Table 5. Numbers of acquired recordings and recordings without adverse signals (technical and / or mechanical noise) for each recording set. Two numbers in the last column correspond to hydrophone-1 and 4 from left respectively.

Year	Receiver STAR ID	# of recordings	# of recordings without adverse noises (hydrophone-1 and 4)
2011	A	2892	1312, 789
	B	2856	592, 459
	Da	2888	566, 566
	Db	2889	682, 682
2012	A	2490	1430, 1430
	B	2143	398, 309
	Da	2482	1233, 1233
	Db	2481	1244, 942

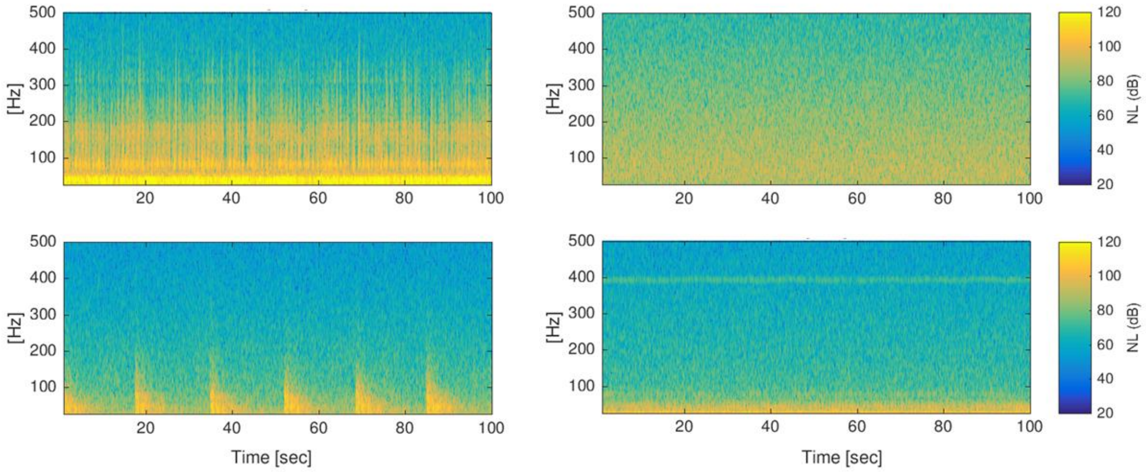

Figure 5. Power spectral density (PSD) of recordings from the ACOBAR experiment. Examples of various noise recordings. upper left: technical noise (overloaded signal), upper right: mechanical noise (hydrophone vertical displacement), lower left: seismic air gun signal, lower right: ship engine noise.

3. Datasets from the acoustic experiments

A large storage space is required to keep all the raw recordings. Moreover, expert knowledge of the mooring and instrument configuration is essential to understand the data properly, and full information are not necessary for many of the data users. Therefore, the raw recordings were processed to two high-level datasets for various data users beyond the scientific community:

- time-series depth-range averaged ocean sound speed and temperature (*WSSP_WTMP*) dataset
- time-series soundscape datasets include sound pressure and power (*ambientnoise*) dataset

In this section, the data format and metadata structure developed based on NetCDF for the acoustic thermometry and soundscape datasets are introduced.

3.1. Depth-range averaged ocean sound speed and water temperature dataset (*WSSP_WTMP)*

Travel time between two moorings was computed from the recording with the tomographic signal. It was then processed to *WSSP_WTMP* dataset as level 3 product of the acoustic tomography dataset using the inversion methodology described in [Dushaw, et al., 2016abc], [Dushaw, et al., 2017] and [Dushaw, 2017]. The *WSSP_WTMP* dataset based on NetCDF3 includes five variables as well as global metadata and dimension. The global metadata gives data discovery information, general information for the experiment and dataset, and common information for all variables. In the dataset, *time* is defined in the dimension as the common axis of the variable data arrays. The five variables with the *time* dimension in the dataset are: time-series depth-range averaged ocean sound speed (*mean_c*) and temperature (*mean_t*), smoothed mean ocean temperature (*mean_t_smooth*), and quality (*mean_t_qlty*) and quality flags (*mean_t_qc*) corresponding to each value in the *mean_t* variable. Each variable has variable metadata which are specific information for the variable as well as the data array.

The file names for nine *WSSP_WTMP* datasets, one from the DAMOCLES experiment and eight datasets from the ACOBAR experiment in Table 4, are structured as:

<dataLocation>_<ProjectName>_<sourceMooringID>-<receiverMooringID>_<startDate>-<endDate>_<parameterName1>_<parameterName2>

e.g. `ARCTIC_DAMOCLES_S-R_20080921-20090731_WSSP_WTMP.nc`

includes depth-range averaged sound speed and temperature between mooring S and R from the DAMOCLES experiment. The dataset covers from 21 September 2008 to 31 July 2009.

e.g. `ARCTIC_ACOBAR_A-Da_20100910-20110731_WSSP_WTMP.nc`

includes depth-range averaged sound speed and temperature between mooring A and D from 10 September 2010 to 31 July 2011.

3.1.1. Dataset format and structure

Structure of the *WSSP_WTMP* dataset based on NetCDF-3 is exampled in Figure 6.

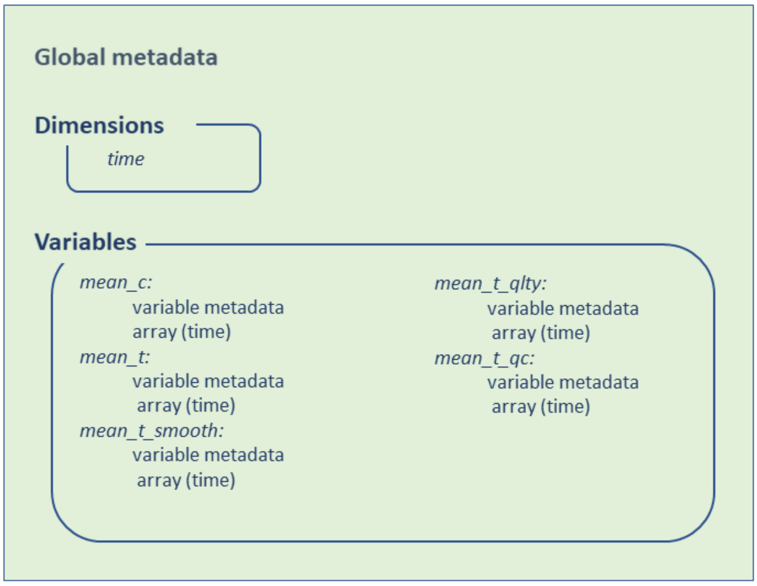

Figure 6. Structure of the *WSSP_WTMP* dataset. Standard information about the experiment, common information for all variables and data discovery information are listed in "Global metadata". Common axis (*time*) for all variables is given in "Dimensions". Five variables i.e. *mean_c, mean_t, mea_t_smooth, mean_t_qlt* and *mean_t_qc*, are in "Variables". Specific variable metadata and the data array are given under each variable.

3.1.2. Metadata specification

Metadata in the *WSSP_WTMP* dataset are compliant with CF-1.6 [CF], OceanSITES-Manual-1.2 [OceanSITES, 2010]. Specific metadata developed for the dataset is listed follows:

Global metadata

S_to_R_range	distance between source and receiver moorings
S_to_R_range_unit	unit of *S_to_R_range*
geospatial_lat_receiver	latitude of receiver mooring
geospatial_lon_receiver	longitude of receiver mooring
geospatial_lat_source	latitude of source mooring
geospatial_lon_source	longitude of source mooring
geospatial_lat_units	units of geospatial_lat_receiver and geospatial_lat_source metadata
geospatial_lon_units	units of geospatial_lon_receiver and geospatial_lon_source metadata
geospatial_vertical_positive	indicates which vertical direction is positive
geospatial_vertical_units	units of vertical coordinates
label_R	label of receiver mooring
label_S	label of source mooring

Variable metadata

geospatial_range	geospatial horizontal range. Suppose that source mooring location is origin (0 m). The geospatial horizontal range is a distance from the source mooring to the receiver mooring.
vertical_depth	vertical depth range. Suppose that sea surface is 0 m. The vertical depth is a distance from sea surface to the deepest estimation depth.

Example:

```
netcdf ARCTIC_DAMOCLES_S-R_20080921-20090731_WSSP_WTMP {
dimensions:
      time = 713 ;
variables:
float mean_c(time) ;
      mean_c:geospatial_range = "0 to 130012 m range average" ;
      mean_c:long_name = "range_and_depth_average_sound_velocity" ;
      mean_c:standard_name = "speed_of_sound_in_sea_water" ;
      mean_c:units = "m s-1" ;
      mean_c:valid_range = 1458.07773172562, 1466.17051294744 ;
      mean_c:vertical_depth = "0 to 1000 m depth average" ;
float mean_t(time) ;
      mean_t:geospatial_range = "0 to 130012 m range average" ;
      mean_t:long_name = "range_and_depth_average_sea_water_temperature" ;
      mean_t:standard_name = "sea_water_temperature" ;
      mean_t:units = "degreeC" ;
      mean_t:valid_range = 0.221934717905686, 2.02033054497521 ;
      mean_t:vertical_depth = "0 to 1000 m depth average" ;
byte mean_t_qc(time) ;
      mean_t_qc:comments = "If mean_t_qlty < 2.0, it is a Probably_good_data.
       Otherwies, it is a Bad_data." ;
      mean_t_qc:conventions = "Table 2 in OceanSITES Data Format Reference Manual"
       ;
      mean_t_qc:flag_meanings = "No_QC_was_performed Good_data Probably_good_data
       Bad_data_that_are_potentially_correctable Bad_data Value_changed" ;
      mean_t_qc:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
      mean_t_qc:long_name =
       "range_and_depth_average_sea_water_temperature_status_flag" ;
      mean_t_qc:standard_name = "status_flag" ;
      mean_t_qc:valid_range = 0., 5. ;
float mean_t_qlty(time) ;
      mean_t_qlty:comment = "Quality is defined as (|x_i - v_i| / std), where x_i
       is the mean_t data point, v_i is the mean_t_smooth data point and std is
       the standard deviation. std = sqrt(sum(x_i - v_i)^2 / N). (i = time(i), N
       = number of the data points) i.e. it represents an absolute value of the
       Z-score." ;
      mean_t_qlty:long_name =
       "range_and_depth_average_sea_water_temperature_quality" ;
      mean_t_qlty:units = "1" ;
      mean_t_qlty:valid_range = 0.00164473383602297, 6.1997082620089 ;
float mean_t_smooth(time) ;
      mean_t_smooth:comment = "70 m degreeC was formed most from the inversion.
       The smoothed time-series has estimated accuracy of 20 m degreeC. Shown in
       technical report." ;
      mean_t_smooth:geospatial_range = "0 to 130012 m range average" ;
      mean_t_smooth:long_name =
       "range_and_depth_average_smoothed_sea_water_temperature" ;
```

```
      mean_t_smooth:quality_control_indicator = 2. ;
      mean_t_smooth:quality_control_indicator_conventions = "Table 2 in OceanSITES
        Data Format Reference Manual" ;
      mean_t_smooth:standard_name = "sea_water_temperature" ;
      mean_t_smooth:units = "degreeC" ;
      mean_t_smooth:valid_range = 0.303636682375187, 1.96774804326306 ;
      mean_t_smooth:vertical_depth = "0 to 1000 m depth average" ;
double time(time) ;
      time:calendar = "julian" ;
      time:comments_units = "day 1 is 2008-01-01T00:00:00Z" ;
      time:long_name = "time" ;
      time:standard_name = "time" ;
      time:units = "days since 2007-12-31T00:00:00Z" ;
      time:valid_range = 265.007847222267, 578.882847222267 ;

// global metadata:
     :Conventions = "CF-1.6 OceanSITES-Manual-1.2" ;
     :S_to_R_range = 130012 ;
     :S_to_R_range_unit = "m" ;
     :acknowledgment = "This work has been financed by the European Commission in
       the 7th Framework Programme for Research and Development the ACOBAR
       projects (Project No.212887) and the Research Council of Norway through
       the UNDER-ICE project (Project No. 226373).B. Dushaw was also supported by
       ACOBAR and by ONR grants N00014-12-1-0183 and N00014-15-1-2186." ;
     :contributor_email = "brian.dushaw@nersc.no, hanne.sagen@nersc.no,
       torill.hamre@nersc.no, asuka.yamakawa@nersc.no" ;
     :contributor_name = "Brian Dushaw, Hanne Sagen, Torill Hamre, Asuka Yamakawa"
       ;
     :creator_email = "brian.dushaw@nersc.no" ;
     :creator_name = "Brian Dushaw" ;
     :data_assembly_center = "CONSORTIA/INSTITUTIONS>>>>NERSC>Nansen Environmental
       and Remote Sensing Centre>http://www.nersc.no/main/index2.php" ;
     :date_created = "2017-12-14T09:57:25Z" ;
     :date_modified = "2017-12-14T09:57:25Z" ;
     :geospatial_lat_receiver = 78.4259 ;
     :geospatial_lat_source = 78.5106 ;
     :geospatial_lat_units = "degree_north" ;

     :geospatial_lon_receiver = 2.4412 ;
     :geospatial_lon_source = 8.2516 ;
     :geospatial_lon_units = "degree_east" ;
     :geospatial_vertical_positive = "down" ;
     :geospatial_vertical_units = "EPSG:5831" ;
     :history = "2017-12-14T09:57:25Z creation; 2017-12-14T09:57:25Z last update";
     :id = "NERSC_ARCTIC_DAMOCLES_-_20080921-20090731_WSSP_WTMP" ;
     :institution = "Nansen Environmental and Remote Sensing Center (NERSC)" ;
     :instrument = "source S : Teledyne Webb Research sweeper source (190 - 290
       Hz) to receiver R: Simple Tomographic Acoustic Receiver (STAR)/4
       hydrophones" ;
     :iso_topic_category = "oceans" ;
     :keywords = "EARTH SCIENCE>OCEANS>OCEAN TEMPERATURE>WATER TEMPERATURE>, EARTH
       SCIENCE>OCEANS>OCEAN ACOUSTICS>ACOUSTIC TOMOGRAPHY>, EARTH
       SCIENCE>OCEANS>OCEAN ACOUSTICS>ACOUSTIC VELOCITY>" ;
     :keywords_vocabulary = "GCMD Science Keywords" ;
     :license = "This data is made freely available by NERSC. User must display
       this citation in any publication or product using data: <These data were
       collected and produced by the ACOBAR project (ref. Hanne Sagen and Brian
       Dushaw at NERSC)> and made freely available by NERSC." ;
     :naming_authority = "no.nersc.damocles" ;
     :processing_level = "Data manually reviewed" ;
     :processing_level_conventions = "Table.3 in OceanSITES Data Format Reference
       Manual" ;
     :project = "DAMOCLES" ;
```

```
    :references = "https://www.nersc.no/project/damocles ;Sagen, H., Dushaw, B.,
      Skarsoulis E., et al., Time series of temperature in Fram Strait
      determined from the 2008-2009 DAMOCLES acoustic tomography measurements
      and an ocean model, Journal of Geophysical Research - Oceans, 2016;121(7),
      DOI:10.1002/2015JC011591; Dushaw, B., Sagen, H., Beszczynska-Moller, A.,
      Sound speed as a proxy variable to temperature in Fram Strait, Journal of
      the Acoustical Society of America, 2016;140(1), DOI:10.1121/1.4959000;
      Dushaw, B., Sagen, H., Beszczynska-Moller, A., On the effects of small-
      scale variability on acoustic propagation in Fram Strait: The tomography
      forward problem, Journal of the Acoustical Society of America,
      2016;140(2), DOI:10.1121/1.4961207; Dushaw, B., Sagen, H., A comparative
      study of moored/point and acoustic tomography/integral observations of
      sound speed in fram strait using objective mapping techniques, Journal of
      Atmospheric and Oceanic Technology, 2016;33(10), DOI:10.1175/JTECH-D-15-
      0251.1." ;
    :sea_name = "Arctic Ocean" ;
    :source = "Acoustic Tomography" ;
    :summary = "Range and depth averaged ocean sound speed and temperature
      obtained from the DAMOCLES acoustic tomography experiment in Fram Strait.
      Sound speed is estimated using travel times from a single track between S
      (source at 378.0 m) and R (hydrophone(s) at 685  781  877  973 m
      depth(s)), separated by 130.012 km. A total of 713 receptions were
      obtained over 314 days from Sep 2008 - Jul 2009. For the procedure to
      compute temperature from estimated sound speed see cited reference." ;
    :time_coverage_end = "2009-07-31T21:11:18Z" ;
    :time_coverage_resolution = "P3H" ;
    :time_coverage_start = "2008-09-21T00:11:18Z" ;
    :title = "DAMOCLES: Range and depth average sea water temperature from
      acoustic tomography measurements in the Fram Strait _ 21/09/2008-
      31/07/2009" ;
}
```

3.1.3. Dimensions

time axis in Julian day and time is defined in Dimensions. The time coverage is given in `time_coverage_start` and `time_coverage_end` in the Global metadata.

3.1.4. Variables

Examples of five variables with the *time* axis are shown in Figure 7.

mean_c (time) variable is time-series range-depth averaged sound speed in ocean waters (m/s) during the yearlong acoustic experiments. The range and depth are given in the variable metadata (`geospatial_range` and `vertical_depth`). The horizontal axis represents *time* dimension. Each data point was calculated based on signal transmission times recorded by the four hydrophones in STAR [Dushaw, et al., 2016 (a)(b)(c)], [Sagen, et al., 2016], [Dushaw, et al., 2017], [Dushaw, 2017].

mean_t (time) is time-series depth-range averaged ocean water temperature in degree C computed based on the *mean_c* variable [Dushaw, et al., 2016 (a)(b)(c)], [Sagen, et al., 2016], [Dushaw, et al., 2017], [Dushaw, 2017]. The range and depth are given as `geospatial_range` and `vertical_depth` in the variable metadata. The horizontal axis represents the *time* dimension.

mean_t_qlty (time) represents quality of the *mean_t* variable. It is computed as $|x(i) - v(i)| / std$, where $x(i)$ and $v(i)$ are data points of *mean_t* and *mean_t_smooth* at time i respectively, and std is the standard deviation, i.e. the variable is equal to absolute value of the Z-score.

mean_t_qc (time) shows quality flag of the *mean_t* values. Each point is quantified based on the *mean_t_qlty* variable, i.e. if $mean\_t\_qlty < 3 \times std$, then the data are probably good (2), otherwise bad data (4). The flag values are compliant with Table 2 in OceanSITES Data Format Reference Manual [OceanSITES, 2014].

mean_t_smooth (time) is smoothed values of *mean_t*. 70 m degree C was formed most from the inversion. The smoothed time-series has estimated accuracy of 20 m degree. The details are described in [Dushaw, et al., 2017]. All data points keep good quality as shown in `quality_control_indicator`.

Figure 7. Examples of five variables in the *WSSP_WTMP* dataset, ARCTIC_DAMOCLES_S-R_20080921-20090731_WSSP_WTMP.nc. The panels are time-series range-depth averaged sound speed in ocean waters (*mean_c*), time-series depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

3.2. Soundscape dataset (*ambientnoise*)

The *ambientnoise* dataset, which includes year-long sound pressure and sound power, was created based on sets of the recordings made by each STAR in Table 2 and 5. Voluminous full information is not required for many of data users as decision makers. According to the Marine Strategy Framework Directive (MSFD Technical Subgroup on Underwater Noise, 2014), the distribution, in the form of percentiles, of the cumulative probability density function is required to establish the statistical significance of any trend. Therefore, 10- and 90- percentiles represent potential minimum and maximum values excluded outliers and 50- percentile indicates realistic mean value which is not affected by outliers are provided in the dataset. NetCDF-4, which supports hierarchical groups within a dataset, was adopted. The dataset was created for each station (mooring) and includes group(s) for each instrument (STAR). Thus, datasets created from mooring R in the DAMOCLES experiment and mooring D in the ACOBAR experiment include two groups since the moorings had two STARs. On the other hand, datasets from mooring A and B in the ACOBAR project contain one group. Consequently, a total of seven *ambientnoise* datasets are provided from the two experiments. Each group contains group metadata, dimensions and variables. The group metadata provides the STAR information. The dimensions present axes of variable data matrix in the group. Three variables are defined in the variables; time-series sound power variable (*snd_power*), time-series sound pressure variable (*snd_pressuer*) obtained from hydrophones-1 and 4 and their quality flag values (*snd_qc*). In the variables, specific variable information and the data matrix are included for each variable.

The file names for the *ambientnoise* datasets are structured as:

<dataLocation>_<ProjectName>_<MooringID><ExperimentYear>_<startDataDate>-
<endDataDate>_<parameterName1>_L2

e.g. `ARCTIC_ACOBAR_A2012_20110924-20120731_ambientnoiseL2.nc`

includes sound pressure and sound power at location A from ACOBAR 2011 experiment. It includes data from 24 September 2011 to 31 July 2012.

3.2.1. Data format and structure

Figure 8 shows the structure of the *soundscape* dataset based on NetCDF-4.

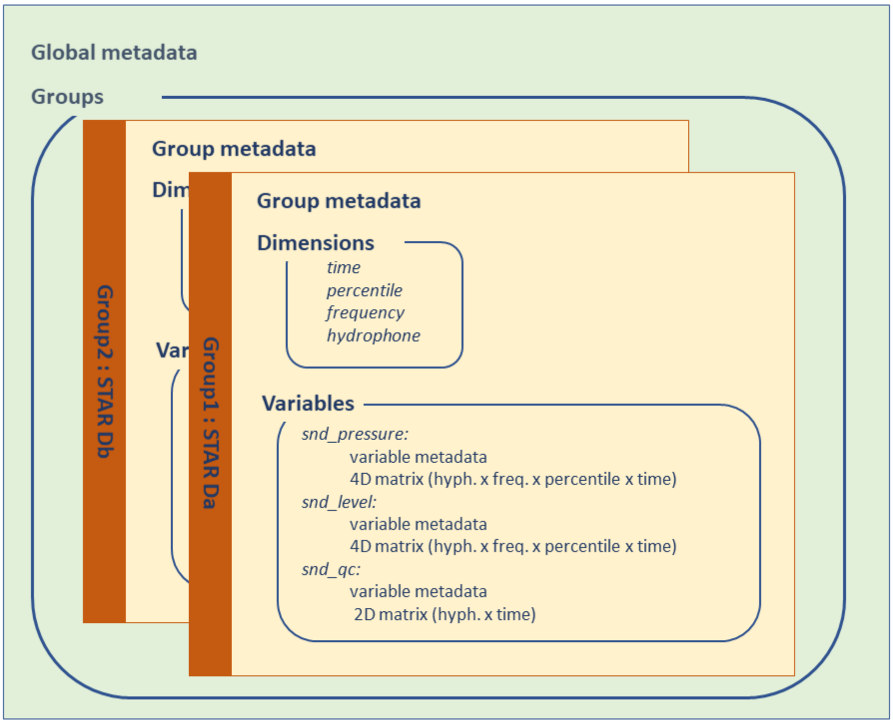

Figure 8. Structure of the *ambientnoise* dataset from ACOBAR mooring D. It includes two groups for two SATRs in the mooring, as well as global metadata. Data discovery information and standard information for the experiment and common information for all groups are listed in the global metadata. Each group consists of group metadata, dimensions and variables. The group metadata provides specific information for the instrument (STAR). The dimension includes four variables; *time, percentile, frequency* and *hydrophone*, which represent axes of data matrices in the group. The group has three variables; *snd_power, snd_pressure* and *sp_qc.* Each variable consists of variable metadata and a data matrix.

3.2.2. Metadata specification

Metadata in the *ambientnoise* dataset are compliant with CF-1.6 [CF], OceanSITES-Manual-1.2 [OceanSITES, 2010], and IOOS Convention for Passive Acoustic Recording-1.0 [Guan, et al., 2014]. Specific metadata developed for the dataset is listed follows:

Global metadata

platform_name	name of mooring equipped with the hydrophones.

Group metadata

nominal_geospatial_vertical_depth	depth of each hydrophone relative to the sea surface when vertical motion of the hydrophone is 0
nominal_geospatial_vertical_depth_unit	unit of *nominal_geospatial_vertical_depth*

actual_maximum/minimum_hydrophone_depth	actual maximum / minimum vertical depth of the hydrophone from the sea surface
actual_maximum/minimum_hydrophone_depth_unit	unit of *actual_maximum/minimum_hydrophone_depth*
hydrophone_id	hydrophone IDs (The hydrophone closest to the controller is numbered 1 and the farthest from the instrument is numbered 4.)

Example:

```
netcdf ARCTIC_ACOBAR_D2012_20110924-20120730_ambientnoiseL2 {

// global attributes:
    :Conventions = "CF-1.6 ACDD-1.3 OceanSITES-Manual-1.2 IOOS-Convention-
      for_Passive_Acoustic_Recording-1.0" ;
    :acknowledgment = "Collection of the data was financed by the European
      Commission in the 7th Framework Programme for Research and Development the
      ACOBAR projects (Project No.212887) and the Research Council of Norway
      through the UNDER-ICE project (Project No. 226373).The standardization of
      the data files has been carried out under the founding from NorDataNet
      (Project No. 245967/F50). " ;
    :cmd_data_type = "point, timeSeries" ;
    :contributor_email = "asuka.yamakawa@nersc.no, hanne.sagen@nersc.no,
      torill.hamre@nersc.no" ;
    :contributor_name = "Asuka Yamakawa, Hanne Sagen, Torill Hamre" ;
    :contributor_role = "Polar Acoustics and Oceanography Group at NERSC
      collected the acoustic data. Scientific Data Management Group at NERSC
      processed and produced the data." ;
    :creator_address = "Thormøhlens gate 47" ;
    :creator_city = "Bergen" ;
    :creator_country = "Norway" ;
    :creator_email = "hanne.sagen@nersc.no" ;
    :creator_name = "Polar Acoustics and Oceanography Group, Nansen Environmental
      and Remote Sensing Centre (NERSC)" ;
    :creator_phone = "+47 55 20 58 00" ;
    :creator_sector = "Academic" ;
    :creator_state = "Hordaland" ;
    :creator_url = "https://www.nersc.no" ;
    :creator_zipcode = "5006" ;
    :data_assembly_center = "CONSORTIA/INSTITUTIONS>>>>NERSC>Nansen Environmental
      and Remote Sensing Center>http://www.nersc.no" ;
    :date_created = "2019-02-05T08:22:10Z" ;
    :date_modified = "2019-02-05T08:22:10Z" ;
    :featureType = "timeSeries" ;
    :geospatial_lat = 78.895 ;
    :geospatial_lat_units = "degree_north" ;
    :geospatial_lon = 2.328 ;
    :geospatial_lon_units = "degree_east" ;
    :history = "2019-02-05T08:22:10Z creation; 2019-02-05T08:22:10Z last update"
      ;
    :id = "NERSC_ARCTIC_ACOBAR_C-D_20110924-20120730_ambient_noise_L2" ;
    :institution = "Nansen Environmental and Remote Sensing Center (NERSC)" ;
    :iso_topic_category = "oceans" ;
    :keywords = "EARTH SCIENCE>OCEANS>OCEAN ACOUSTICS>, EARTH
      SCIENCE>OCEANS>OCEAN ACOUSTICS>AMBIENT NOISE> " ;
    :keywords_vocabulary = "GCMD Science Keywords" ;
    :license = "This data is made freely available by NERSC. User must display
      this citation in any publication or product using data: <These data were
```

```
        collected and produced by the ACOBAR project (ref. Hanne Sagen at NERSC)>
        and made freely available by NERSC." ;
      :naming_authority = "no.nersc.acobar" ;
      :place = "Fram_Strait" ;
      :platform = "moored_buoy" ;
      :platform_detail = "2 STAR(s) were installed in the platform. Each STAR
        included 4 hydrophones." ;
      :platform_name = "ACOBAR D" ;
      :platform_vocabulary = "http://mmisw.org/ont/ioos/platform" ;
      :project = "ACOBAR" ;
      :publisher_address = "Thormohlens gate 47" ;
      :publisher_city = "Bergen" ;
      :publisher_country = "Norway" ;
      :publisher_email = "hanne.sagen@nersc.no" ;
      :publisher_name = "Polar Acoustics and Oceanography Group, Nansen
        Environmental and Remote Sensing Centre (NERSC)" ;
      :publisher_phone = "+47 55 20 58 00" ;
      :publisher_state = "Hordaland" ;
      :publisher_url = "https://www.nersc.no" ;
      :publisher_zipcode = "5006" ;
      :references = "https://www.nersc.no/project/acobar ;http://www.damocles-
        eu.org/Sagen, H., Geyer, F., Stette, M., Sandven S., Dzieciuch, M. and
        Worcester, F. P., Acoustic Technology for Observing the Internal of the
        Arctic Ocean, 2013; EU DG Environment 2013 71 s., Yamakawa, A., Sagen, H.,
        Babiker, M., Worcester, F. P. and Furevik, B.,Soundscape Characterization
        and the Impact of Environmental Factors in the Central Part of the Fram
        Strait, Proc. of the Acoustic and environmental variability, fluctuations
        and coherence, 2016; ISBN 978-1-906913-26-7. p. 187-194, Yamakawa, A.,
        Sagen, H., Babiker, M., Worcester, F. P. and Furevik, B., Impact of
        anthropogenic and environmental factors on the underwater soundscape in
        Fram Strait, Proc. of Underwater Acoustics Conference & Exhibitions, 2017;
        p.293-298,
        http://www.uaconferences.org/docs/Past_Proceedings/UACE2017_Proceedings.pd
        f " ;
      :sea_name = "Fram Strait" ;
      :source = "underwater observation" ;
      :standard_name_vocabulary = "CF Standard Name version 57" ;
      :summary = "Time averaged sound pressure obtained from the ACOBAR acoustic
        experiment in Fram Strait. The data were were obtained over 310 days every
        3 hours from Sep 2011 - Jul 2012. 10-, 50- and 90- percentiles of the
        sound pressure and power for each frequency (0-500 Hz) were computed." ;
      :time_coverage_duration = "P" ;
      :time_coverage_end = "2012-07-30T21:13:40Z" ;
      :time_coverage_resolution = "P3H" ;
      :time_coverage_start = "2011-09-24T18:13:40Z" ;
      :title = "ACOBAR: Ambient noise in water _ 24/09/2011-30/07/2012" ;

group: STAR_Da {
  dimensions:
      time = 2482 ;
      frequency = 513 ;
      percentile = 3 ;
      hydrophone = 2 ;
  variables:
      double time(time) ;
             time:calendar = "gregorian" ;
             time:long_name = "time" ;
             time:standard_name = "time" ;
             time:units = "days since 1-1-1 0:0:0" ;
             time:valid_range = 734770.759490741, 735080.884490741 ;
      double frequency(frequency) ;
             frequency:frequency_resolution = 0.9747 ;
             frequency:long_name = "sound_frequency" ;
```

```
        frequency:standard_name = "sound_frequency" ;
        frequency:units = "Hz" ;
        frequency:valid_range = 0., 500. ;
    float percentile(percentile) ;
        percentile:comments = "10- 50- and 90- percentiles are common for
          use." ;
        percentile:long_name = "percentile" ;
        percentile:standard_name = "percentile" ;
        percentile:units = "Percent" ;
        percentile:valid_range = 0., 100. ;
    char hydrophone(hydrophone) ;
        hydrophone:comments = "hydrophone ID in the STAR." ;
        hydrophone:long_name = "hydrophone_ID" ;
        hydrophone:standard_name = "hydrophone_ID" ;
    float snd_pressure(hydrophone, percentile, time, frequency) ;
        snd_pressure:coverage_content_type = "physicalMeasurement" ;
        snd_pressure:long_name = "10-, 50-, 90-
          percentiles_sound_pressure_in_water" ;
        snd_pressure:standard_name = "sound_pressure_in_water" ;
        snd_pressure:units = "Pa" ;
        snd_pressure:valid_range = 667.835280085503, -958236008.194806 ;
    float snd_power(hydrophone, percentile, time, frequency) ;
        snd_power:coverage_content_type = "physicalMeasurement" ;
        snd_power:long_name = "10-, 50-, 90-
          percentiles_sound_intensity_in_water" ;
        snd_power:standard_name = "sound_intensity_in_water" ;
        snd_power:units = "dB" ;
        snd_power:valid_range = 23.4493224648876, 141.924537603436 ;
    byte snd_qc(hydrophone, time) ;
        snd_qc:comments = "Mechanical noise was detected by the hydrophone
          displacement with threshold 2.5, 2.5 m. 2 stands for recording
          without mechanical noise. 4 means recording incl. mechanical /
          electronic noise. When hydrophone displacement information is
          missing, the corresponding recording takes flag_value 0." ;
        snd_qc:coverage_content_type = "qualityInformation" ;
        snd_qc:flag_meanings = "No_QC_was_performed Good_data
          Probably_good_data Bad_data_that_are_potentially_correctable
          Bad_data Value_changed" ;
        snd_qc:flag_values = 0UB, 1UB, 2UB, 3UB, 4UB, 5UB ;
        snd_qc:long_name = "quality_flag" ;
        snd_qc:quality_control_indicator_conventions = "Table 2 in OceanSITES
          Data Format Reference Manual" ;
        snd_qc:standard_name = "status_flag" ;

  // group attributes:
        :acoustic_sampling_end_date = "2012-07-30T21:13:40Z" ;
        :acoustic_sampling_start_date = "2011-09-24T18:13:40Z" ;
        :acoustic_sampling_temporal_resolution = "P3H" ;
        :geospatial_vertical_positive = "down" ;
        :geospatial_vertical_units = "EPSG:5831" ;
        :hydrophone_id = "hydrophone_1, hydrophone_4" ;
        :hydrophone_type = "pressure sensor" ;
        :instrument = "hydrophone_pressure_sensor, AD_converter" ;
        :instrument_id = "STAR_S/N_Da" ;
        :instrument_other_info = "Simple Tomographic Acoustic Receiver (STAR)
          /4 hydrophones developed by Scripps Institution of Oceanography" ;
        :nominal_geospatial_vertical_depth = "263.9 292.7 " ;
        :nominal_geospatial_vertical_depth_unit = "m" ;
        :processing_level = "Data verified against model or other contextual
          information" ;
        :processing_level_conventions = "Table.3 in OceanSITES Data Format
          Reference Manual" ;
        :sample_rate = 1000. ;
```

```
            :summary = "Passive acoustic data were recorded with 2 hydrophone(s)
              and a total of 2482 receptions were obtained from each hydrophone.
              Each observed acoustic data records 100 s with sampling rate
              1000Hz.10-, 50- and 90- percentiles of sound pressure and power
              were calculated for each reception using 50 % overlapping Hanning
              window with a window length of 1024 samples.Noise by cable
              strumming is included." ;
   } // group STAR_Da

 group: STAR_Db {
      …
 }
```

3.2.3. Dimensions

Four axis variables are defined in each group; ***time*** axis is given in Gregorian calendar and time. It represents every 3 hours during the experiment period. ***frequency*** axis represents from 0 to 500 Hz at intervals of 0.9747 Hz. ***percentile*** axis with length 3 shows10-, 50- and 90- percentiles of the data values. ***hydrophone*** axis with length 2 denotes hydrophone-1 and hydrophone-4.

3.2.4. Variables

snd_pressure ***(hydrophone, percentile, time, frequency)*** variable contains percentiles of time-seriese sound pressure. Hydrophone signal (0 - 500 Hz) was amplified, applied bandpass filter, and sampled using 16-bit delta-sigma converters at a 1000 Hz rate. The sound pressure of each signal was calculated with the Short Time Fourier Transform (STFT). 50 % overlapping Hanning window with a window length of 1024 samples were chosen as the best parameter by trial and error. The sound pressure for each recording is represented by a 2D matrix with time (0 -80 or 100 s) and frequency (0 - 500 Hz). The size of the 2D matrix (recording time x frequency (0-500 Hz)) is reduced to a 2D matrix with (3 (10-, 50-, 90- percentiles) x frequency) by providing the three percentiles. The sound pressures for 0.9766 Hz from 0 to 500 Hz are obtained for each recording because of the specified window length. A 3D matrix (percentile x time x frequency) holding 1 year of the data with a temporal resolution of 3 hours, is then constructed by stacking the 2D matrices from the hydrophone. Since the datasets include data from two hydrophones in each STAR, a 4D matrix is constructed by adding one more axis to represent multiple hydrophones. Consequently, the 4D matrix with *hydrophone, percentile, time and frequency* axes is stored and provided as sound pressure variable (*snd_pressure*) with the unit (Pa) in the produced dataset. The recordings from DAMOCLES experiment include a sweeping source signal, while it does not make a problem for the quality of the dataset because not arithmetic mean but percentiles are provided here. Figure 9 represents the 10-, 50- and 90-percentile sound pressure from hydrophone-1 in ARCTIC_ACOBAR_A2012_20110924-20120731_ambientnoiseL2 dataset.

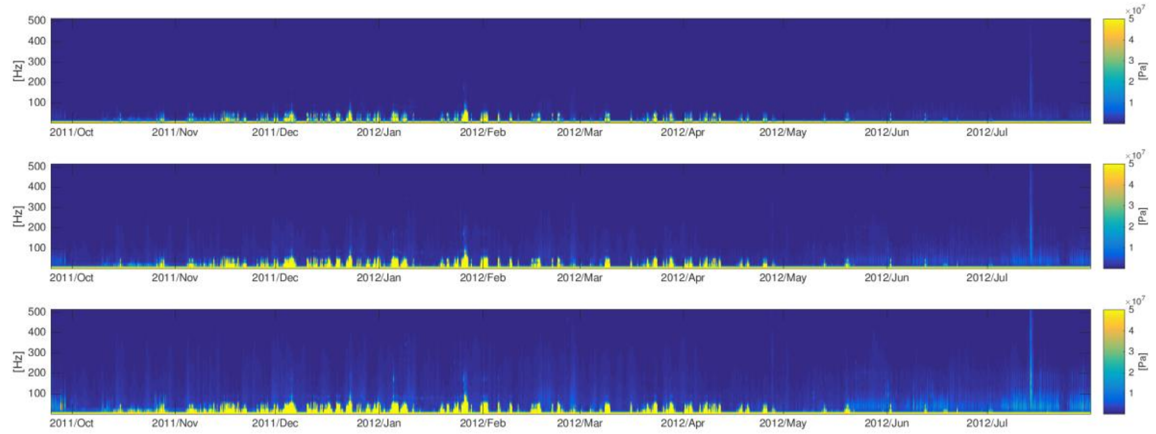

Figure 9. Sound pressure in Pa (*snd_pressure*) from hydropohon-1, in ARCTIC_ACOBAR_A2012_20110924-20120731_ambientnoiseL2 dataset. From the top panel, 10-, 50- and 90- percentiles respectively. The horizontal axis (*time*) is common for all parameters.

snd_power (*hydrophone, percentile, time, frequency*) variable is created based on the *snd_pressure* variable by converting the sound pressure (P) into the sound power (dB). Structure of the matrix is same as the *snd_pressure* matrix. Examples of the matrix are shown in Figure 10.

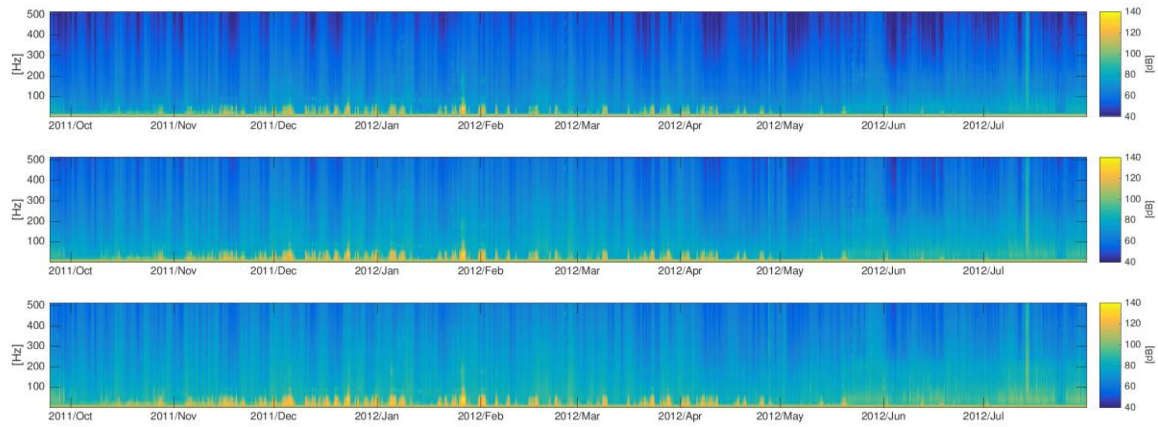

Figure 10. Sound level in dB (*snd_power*) from hydrophone-1, in ARCTIC_ACOBAR_A2012_20110924-20120731_ambientnoiseL2. From the top panel, 10-, 50- and 90- percentiles respectively. The horizontal axis (*time*) is common for all parameters.

snd_qc (*hydrophone, time*) represents data quality. Some recordings include technical noise caused by overloading and saturation as Figure 2 (b) (c) and mechanical noise by the hydrophone displacement as Figure 5 (upper left and right). These recordings are adverse for further soundscape analysis. [Yamakawa, 2019] describes means to determine the existence of the mechanical noise with corresponding hydrophone displacement. The *snd_qc* variable, which takes a numeric code, indicates appropriateness of the data for soundscape assessment. According to [OceanSITES, 2014], recording without the adverse noise takes a value of 2 (termed probably good data), otherwise it is assigned a value of 4 (bad data). If hydrophone displacement is not observed, a value of 0 (unknown) is assigned. It is a common variable for all percentiles of the *snd_pressure* and *snd_power* variables. Figure 11 shows an example of *snd_qc*.

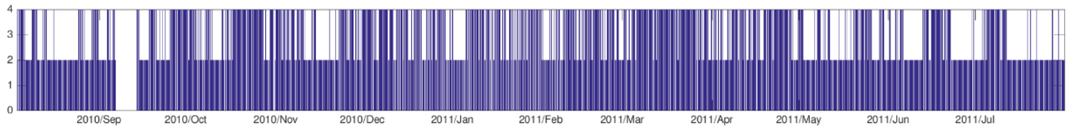

Figure 11. Quality flag value of hydrophone-1 in ARCTIC_ACOBAR_A2012_20110924-20120731_ambientnoiseL2. The *snd_qc* variable is common for *snd_power* and *snd_pressure*. The horizontal axis (*time*) corresponds to that of *snd_pressure* and *snd_power* variables for all percentile.

4. Supporting DAMOCLES and ACOBAR NERSC Reports

- S. A. Haugen, H. Sagen, S. Sandven, M. Dzieciuch, P. Worcester, E. Skarsoulis, G. Piperakis, and M. Kalogerakis, 2010. Results from the Fram Strait acoustic tomography experiment and system evaluation, DAMOCLES Report D8.2-06, Nansen Environmental and Remote Sensing Canter, Bergen, Norway, 105 pp.
- H. Sagen, D. Dumont, A. Beszczynska-Möller, S.A. Haugen, S. Sandven, 2010. Developing Arctic Modelling and Observing Developing Arctic Modelling and Observing Capabilities for Long Capabilities for Long-term Environment Studies term Environment Studies - D4.1-06 - Report describing the validation experiment of FRAM strait model, https://www.nersc.no/sites/www.nersc.no/files/DAMOCLES_D4.1-06-NERSC.pdf
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Appendix-A

Examples of five variables in *WSSP_WTMP* datasets are shown as follows.

Figure 12-1. Data from ARCTIC_ACOBAR_A-B_20100910-20110731_WSSP_WTMP.nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

Figure 12-2. Data from ARCTIC_ACOBAR_A-B_20110923-20120524_WSSP_WTMP.nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

Figure 12-3. Data from ARCTIC_ACOBAR_A-D_20100910-20110731_WSSP_WTMP.nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

Figure 12-4. Data from ARCTIC_ACOBAR_A-D_20110925-20120729_WSSP_WTMP.nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

Figure 12-5. Data from ARCTIC_ACOBAR_B-A_20100908-20110731_WSSP_WTMP. nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

Figure 12-6. Data from ARCTIC_ACOBAR_B-A_20110924-20120531_WSSP_WTMP. nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

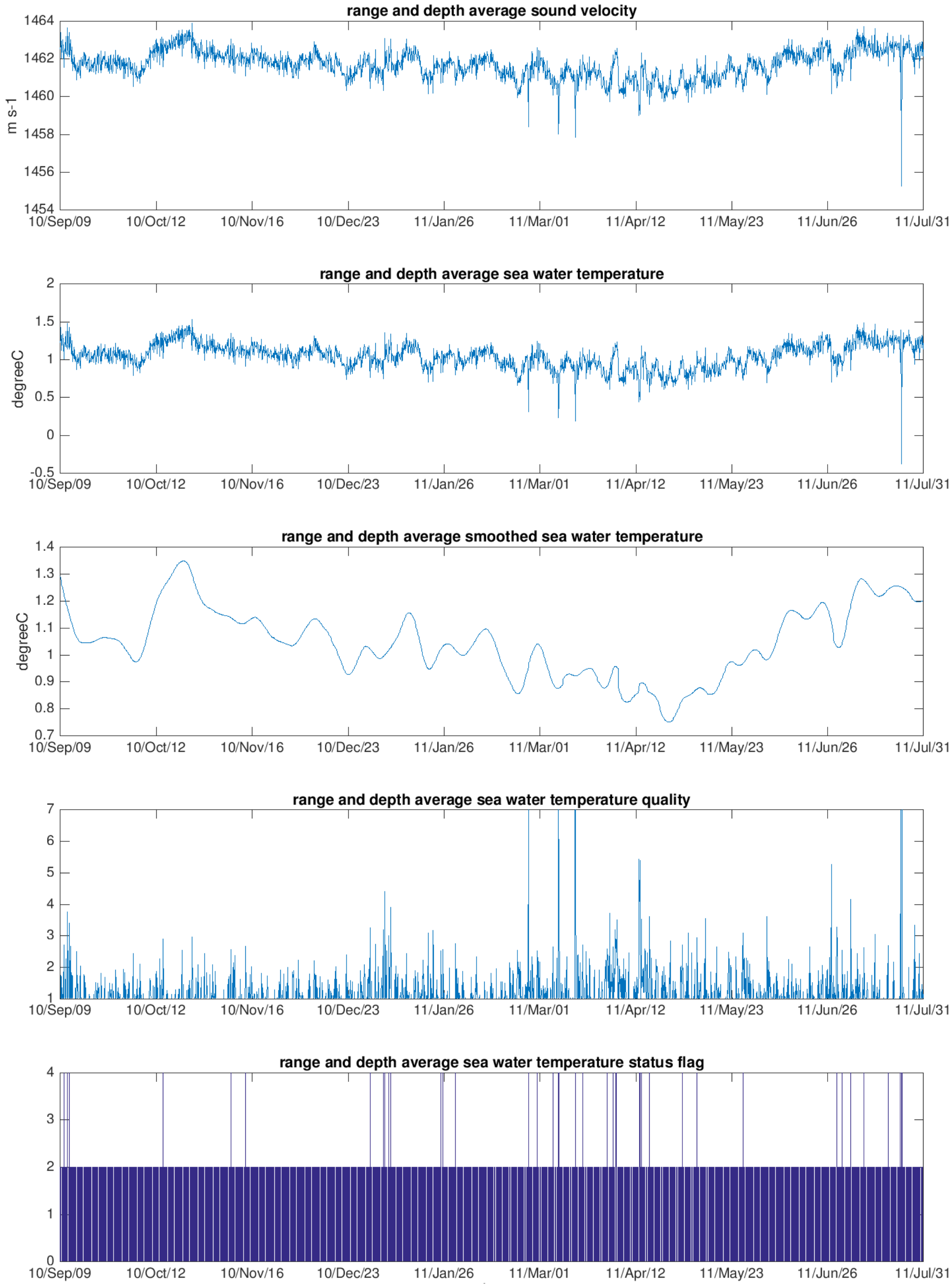

Figure 12-7. Data from ARCTIC_ACOBAR_B-D_20100909-20110731_WSSP_WTMP.nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

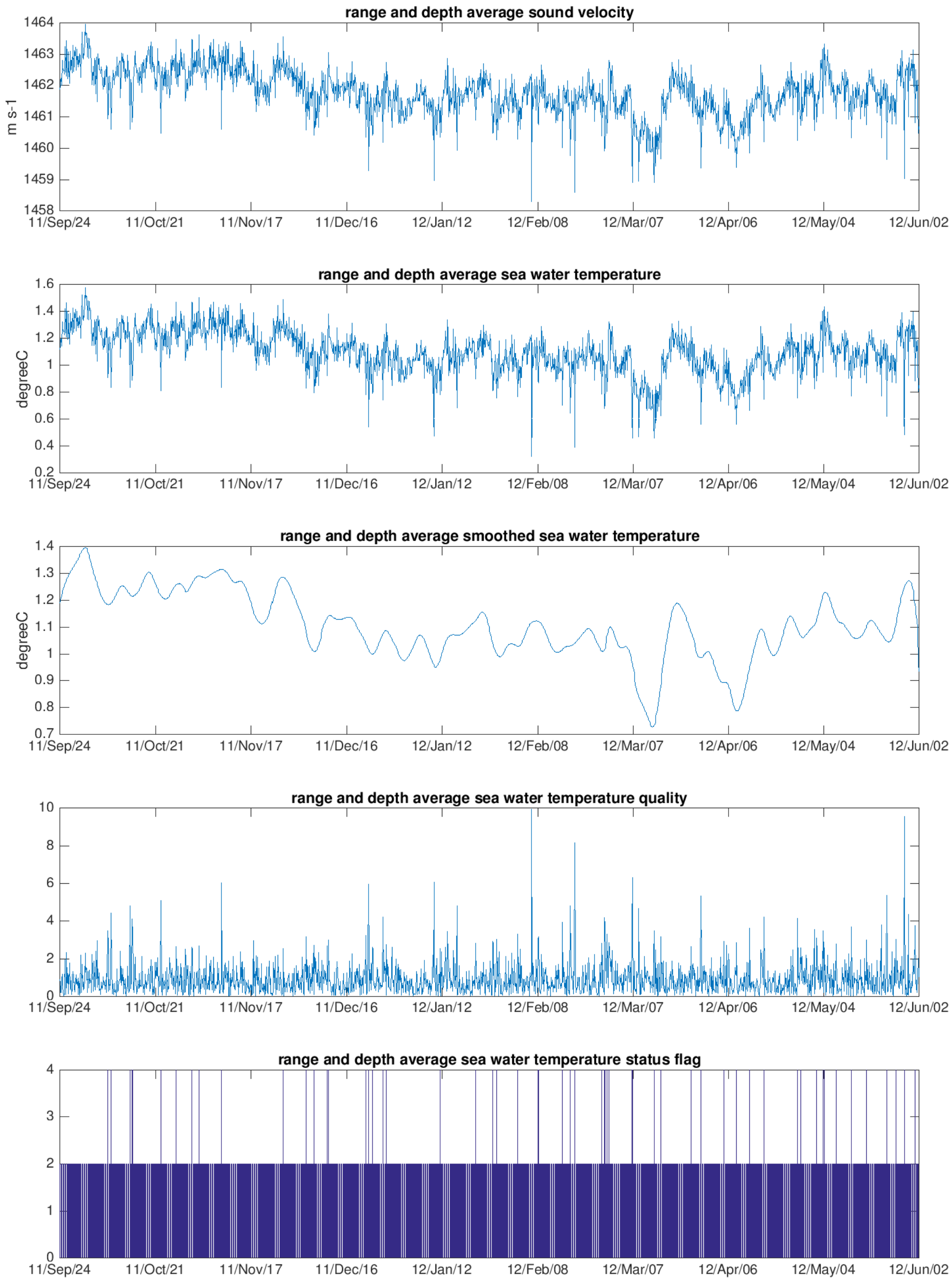

Figure 12-8. Data from ARCTIC_ACOBAR_B-D_20110924-20120602_WSSP_WTMP.nc. The panels are range-depth averaged sound speed in ocean waters (*mean_c*), depth-range averaged ocean water temperature (*mean_t*), smoothed values of *mean_t* (*mean_t_smooth*) and quality of *mean_t* (*mean_t_qlty*) from the top respectively.

Appendix-B

Examples of three variables in *soundscape* datasets are shown as follows.

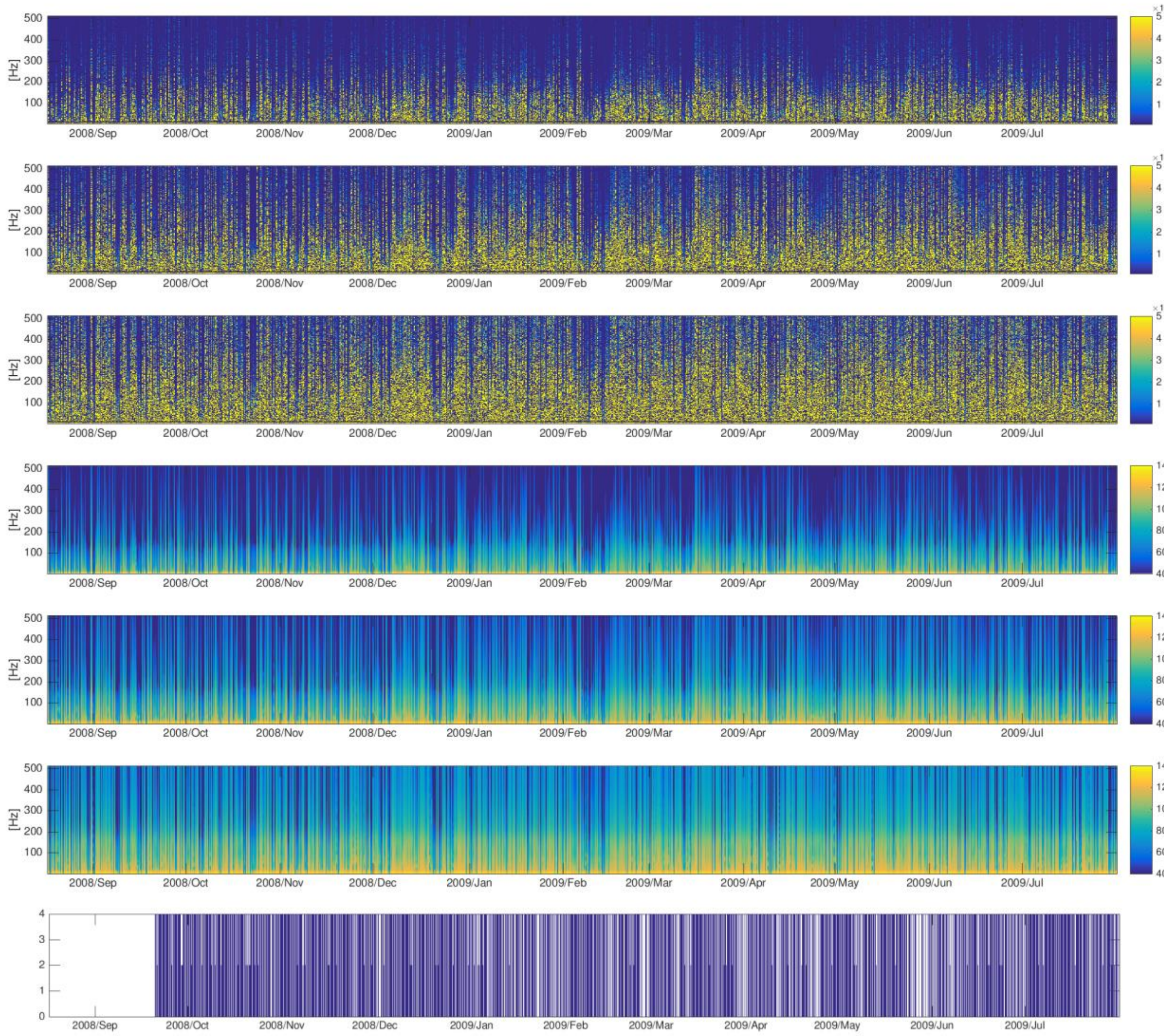

Figure 13-1. Data from hydrophone-1 in STAR Ra, ARCTIC_DAMOCLES_R_20080816-20090731_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

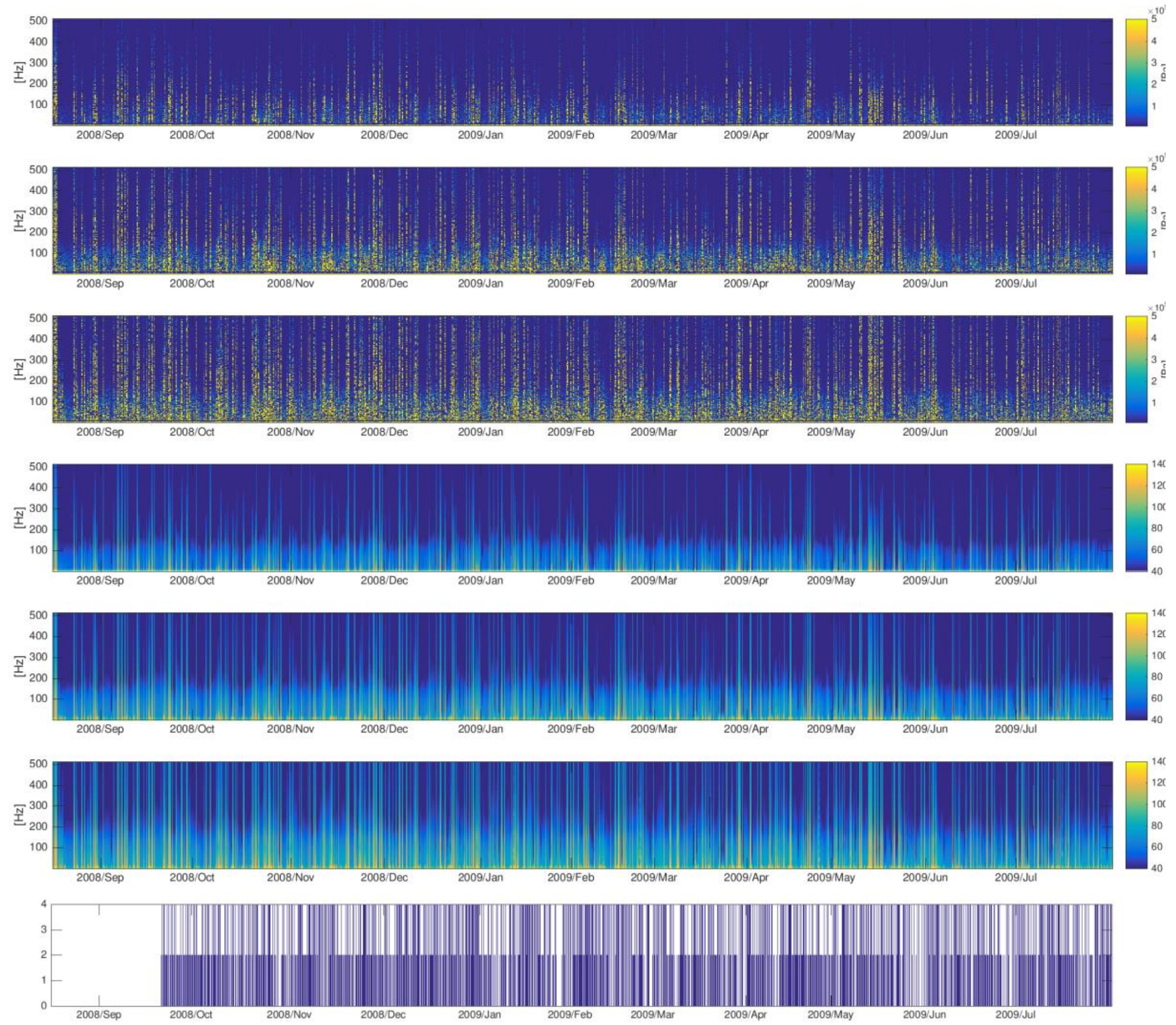

Figure 13-2. Data from hydrophone-1 in STAR Rb, ARCTIC_DAMOCLES_R_20080816-20090731_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

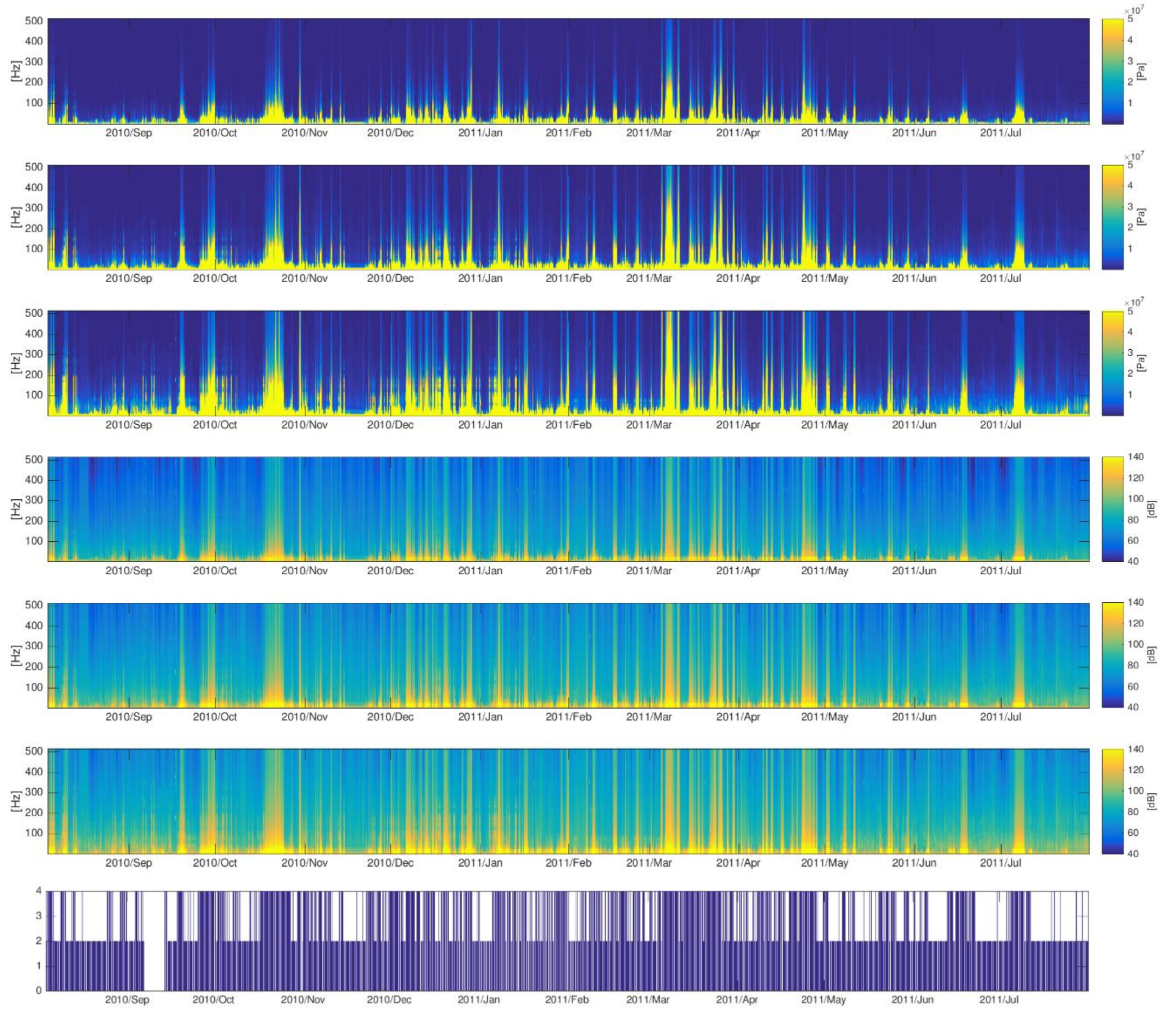

Figure 13-3. Data from hydrophone-1 in ARCTIC_ACOBAR_A2011_20100803-20110731_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

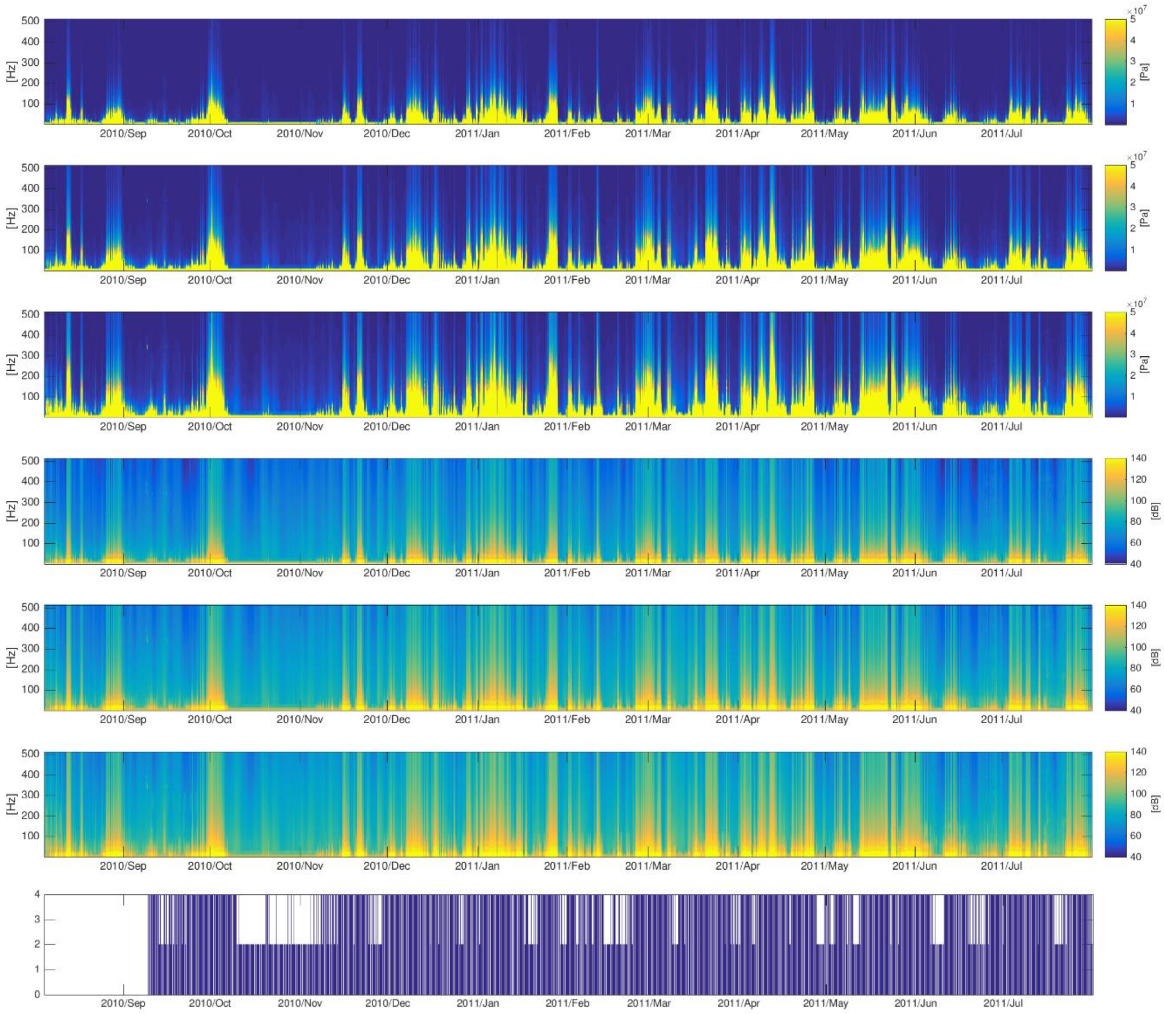

Figure 13-4. Data from hydrophone-1 in STAR Da, ARCTIC_ACOBAR_D2011_20100804-20110731_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

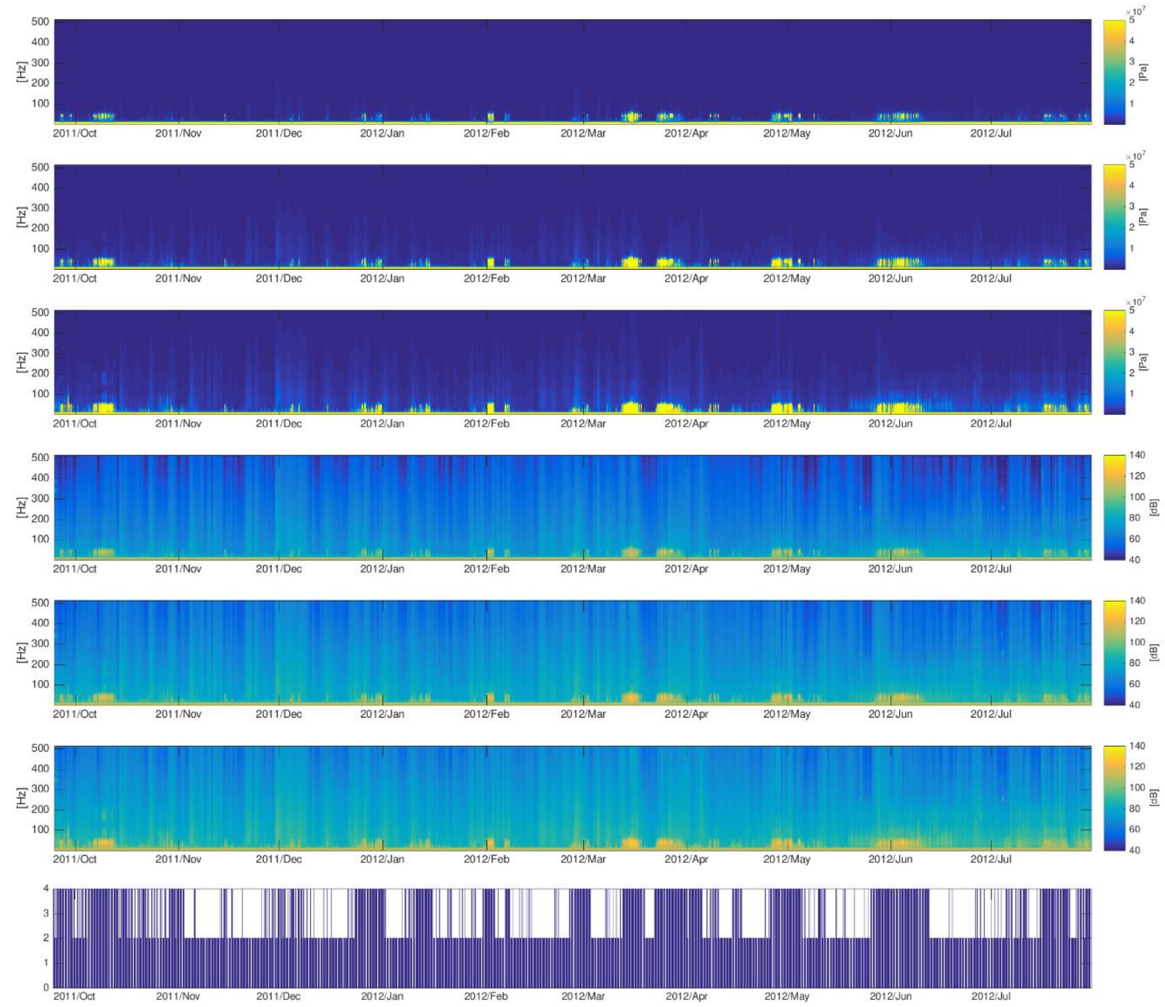

Figure 13-5. Data from hydrophone-1 in STAR Da, ARCTIC_ACOBAR_D2012_20110924-20120730_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

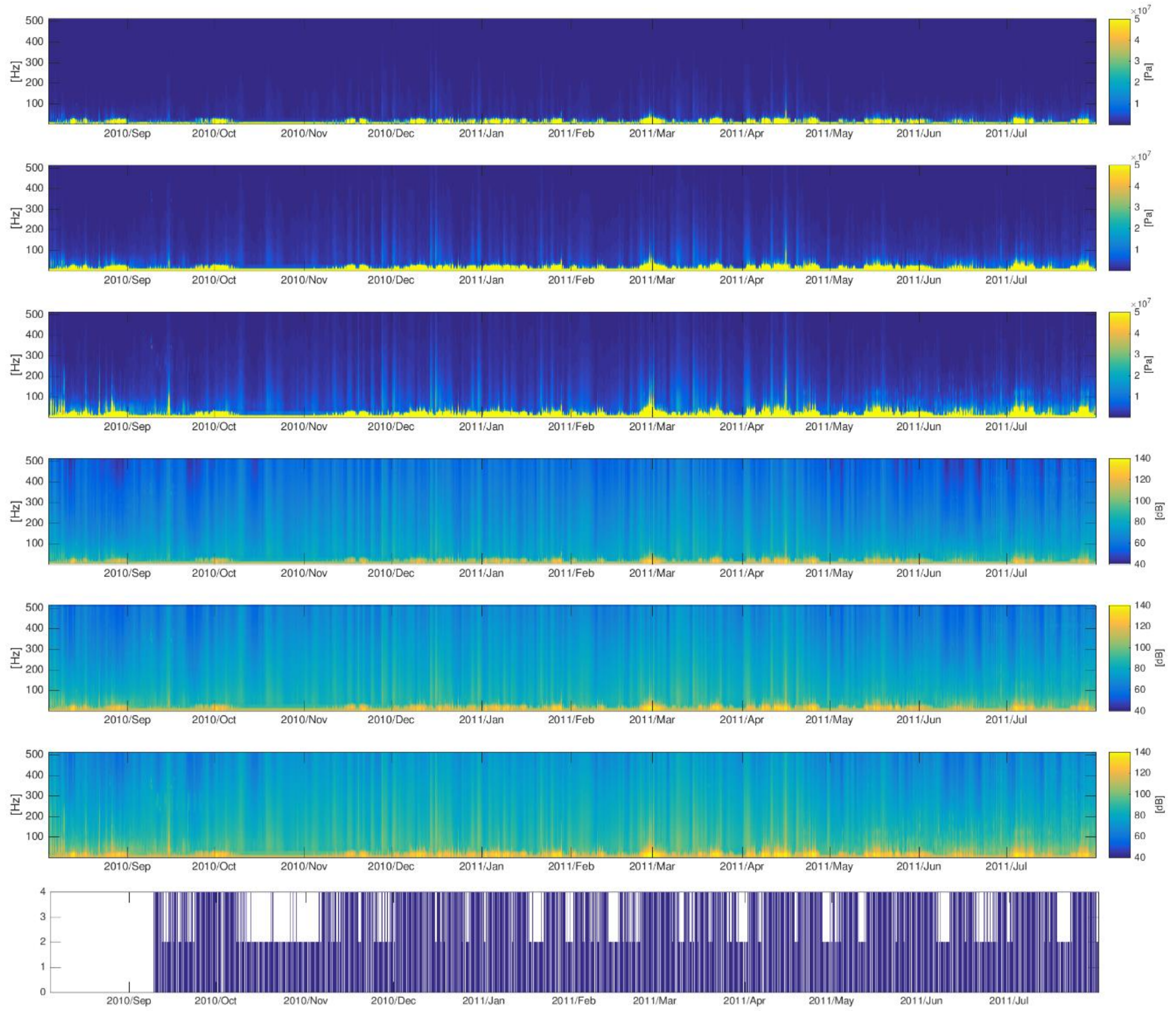

Figure 13-6. Data from hydrophone-1 in STAR Db, ARCTIC_ACOBAR_D2011_20100804-20110731_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

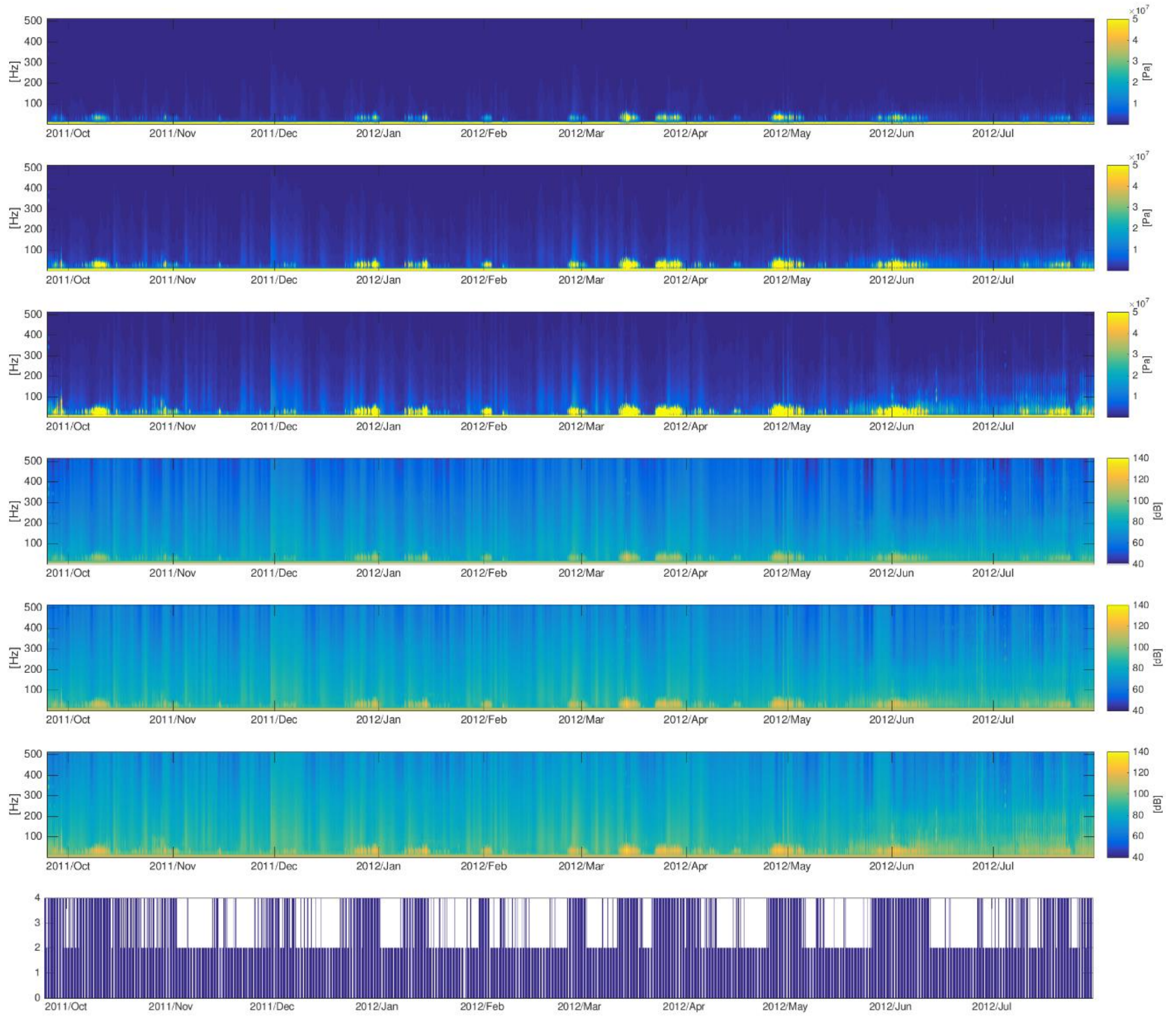

Figure 13-7. Data from hydrophone-1 in STAR Db, ARCTIC_ACOBAR_D2012_20110924-20120730_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

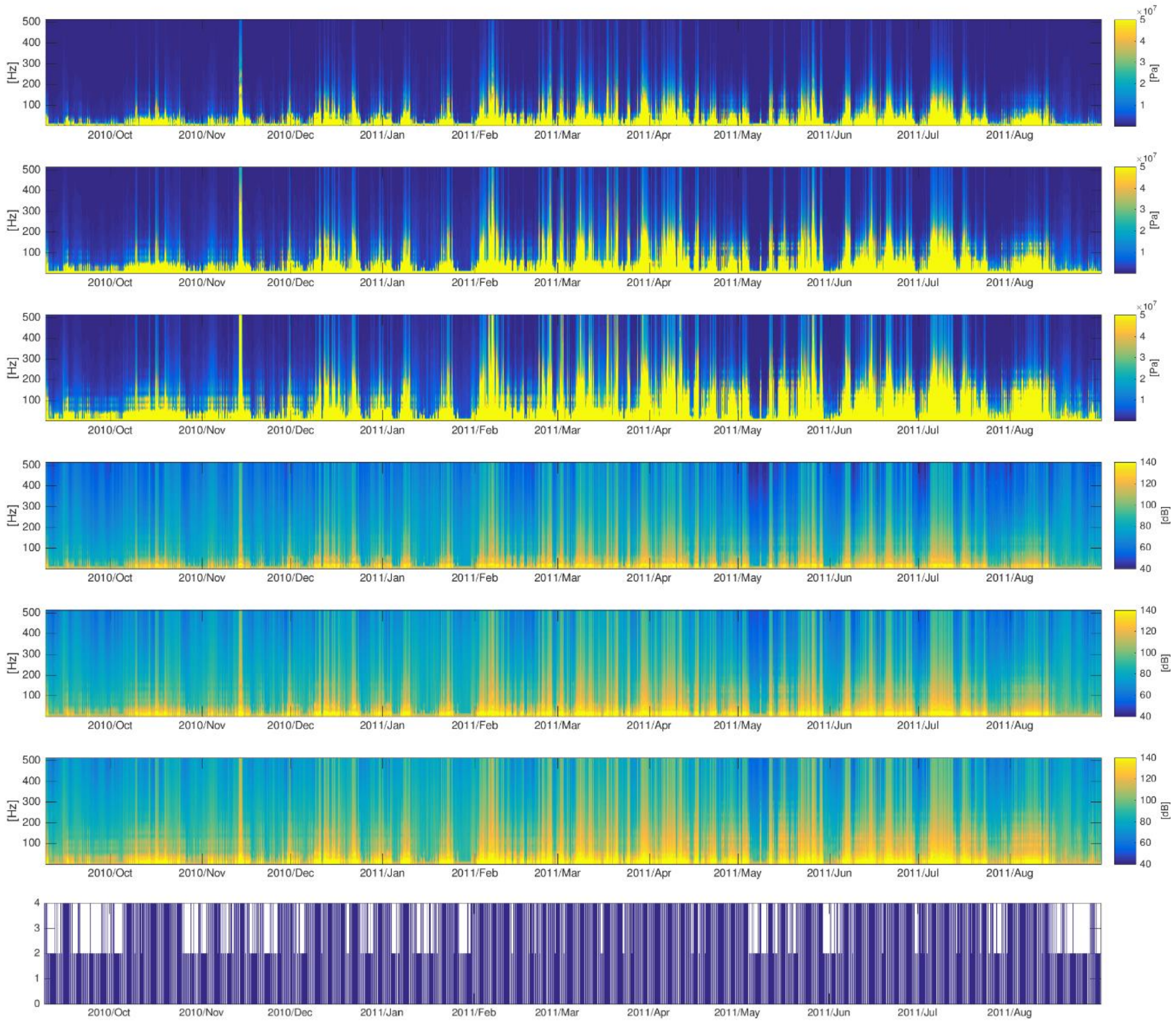

Figure 13-8. Data from hydrophone-1 in ARCTIC_ACOBAR_B2011_20100909-20110831_ambientnoiseL2.nc From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.

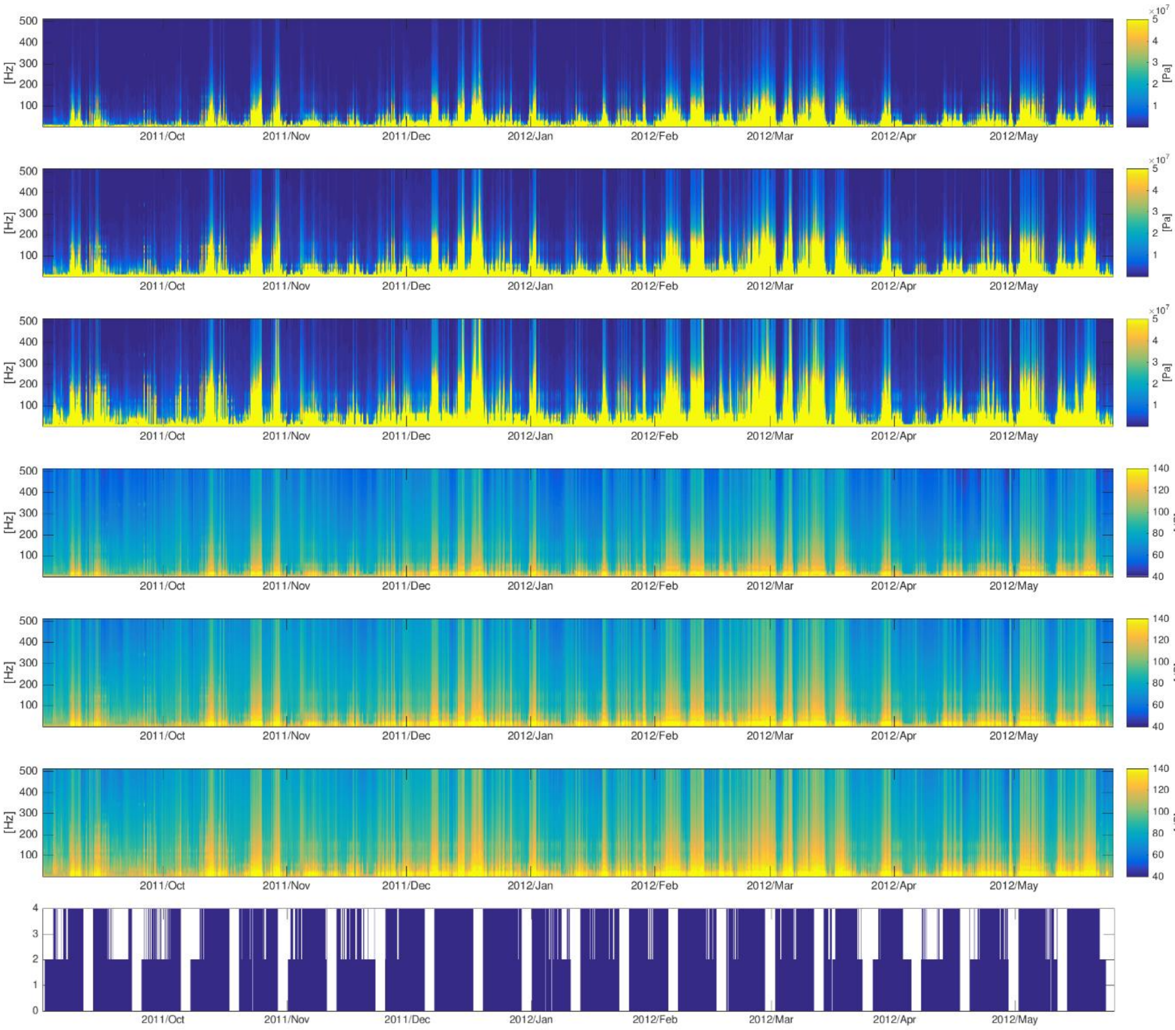

Figure 13-9. Data from hydrophone-1 in ARCTIC_ACOBAR_B2012_20110901-20120525_ambientnoiseL2.nc. From the top, 10-, 50- and 90- percentiles of sound pressure, 10-, 50-, and 90- percentiles of sound power and quality flag.