

Title: Ocean Turbulence Mast Data Archive

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The Ocean Turbulence Mast project during SHEBA maintained clusters of instruments designed to measure turbulent fluxes of momentum, heat, and salt at multiple levels in the boundary layer under the drifting ice floe. Each turbulence instrument cluster (TIC) included three mechanical rotor current meters (Smith partially ducted rotor design) arranged as an orthogonal triad, tilted with respect to horizontal so that all rotors sensed roughly equal parts of the mean flow velocity. The current meter triad was mounted near to Sea-Bird Electronics SBE03 temperature sensors and SBE04 conductivity sensors, except for one cluster that included a SBE07 microstructure open electrode conductivity meter. The clusters were mounted on stainless rods that made up a rigid mast. Included on the mast was a highly modified SBE09 CTD unit equipped with compass and pressure sensor. Frequency data from each cluster was collected by the SBE09 and multiplexed to a surface SBE 11 deck unit, interfaced to a computer, at a sampling rate of 6 per second. The clusters were spaced 4 m apart on the mast, which could be lowered as a unit to any level in the upper 100 m of the ocean. Typically the uppermost cluster was situated about 4 m below the ice/ocean interface under the main SHEBA floe, which was about 2 m thick.

The experiment was divided roughly in half, with two different locations forced by a severe deformation event in March, 1998. The original site 1 was situated about 300 m off the starboard of the *Des Grosiellier*. After the breakup in March, the ocean camp was shifted to a new site farther into the SHEBA floe. In anticipation of summer biofouling requiring pulling the mast for cleaning, and inevitable equipment loss (after spending months in salt water), the number of clusters was reduced from four to two for site 2. The two clusters were still spaced 4 m apart, with the mast raised later in the summer so that the uppermost cluster was nominally 2 m below the ice/water interface. The reduction freed up a frequency channel for the μ C instrument, which was then added to cluster 2 so that it had both types of conductivity sensors.

The master directory data_submission contains 3 subdirectories: **conv_data_structures; realizations; mfiles.**

conv_data_structures directory:

Each file contains an array of matlab data structures, and corresponds in numbering to the original binary files as transmitted from the SeaBird deck box to the recording computer. The prefix "A" or "B" refers to the SBE 9+ system used to collect the data. There were two SBE 9 instruments with slightly different characteristics, and output data streams. System A was used early in the project, and then again beginning in late July, 1998, when a bulkhead connector on the B instrument failed. The files are numbered sequentially despite the prefix. The following steps were used to reduce the data to usable form.

Step 1: The binary files were decoded into frequencies for each channel (binary numbers for the compass data) as an intermediate step using a matlab function `fetch_raw_file.m`. The original binary files and corresponding frequency files are not included here, but can be made available upon request.

These files comprise the basic turbulence mast data set. Some files with obvious problems or short durations are not included (e.g. A001 to A006).

realizations directory:

Step 3: The usual method for estimating turbulent fluxes assumes the "frozen field hypothesis" and calculates the covariance of the velocity components (and scalar deviatory fields with the vertical velocity). This involves several steps in analysis of the data from the "raw" calibrated files.

The basic unit in this phase is a flow "realization" of duration 15 minutes. The data files from Step 2 are divided into 15 minute segments (900 samples for scan_average =6; 450 for scan_average=12). The routine `turb_realize.m` divides the data file for each cluster (e.g. A900C.mat, cluster 1) into 15 minute segments, then for each segment:

- Rotates the velocity from the measurement reference frame into a streamline reference frame so the mean flow is aligned with the u direction, w is vertical (pos up) and v is the cross-stream component so as to form a right-handed system. It is assumed that the vertical velocity over the 15 min period is zero, so that $\langle w \rangle$ and $\langle v \rangle$ are zero; $\langle u \rangle$ is the mean current speed. See the subfunction `u_streamline`. In any mechanical current measuring system there is a threshold velocity below which the rotors stop turning. For each velocity component, the routine determines the no. of samples for which the velocity is nonzero and forms a ratio with the total no of samples, $r\{u,v,w\}$. It then determines a quality flag as follows:

flg=0 : $r_u < 0.9 \mid r_w < 0.9$ no valid vertical fluxes

flg=1: $r_u > 0.9 \ \& \ r_w > 0.9 \ \& \ r_v > 0.9$, 3-d currents considered valid

flg=2: $r_u > 0.9 \ \& \ r_w > 0.9 \ \& \ r_v < 0.9$ in this case the w is ok, but terms with v are not, so for example, $\langle w'T' \rangle$ would be valid.

Any segments with flg=0 are dropped from further consideration.

- Early in the project (Oct, early Nov), data from the upper two clusters on the ocean turbulence mast were occasionally susceptible to electronic noise in the T and C frequencies, apparently generated by the neighboring ocean profiling winch. The routine uses a histogram based algorithm to remove this noise (subfunction `remove_noise3`); however, it is not always successful, and caution should be exercised in interpreting fluxes derived from these data, by for example, comparing the `turb_realize` results with the untreated data, as described below.
- Calculates average values of T, S, speed, current heading (magnetic), depth, θ which is the angle through which the measurement frame is rotated to bring the vertical velocity to zero. This should be within a few degrees of 45, and serves a later quality check.
- Calculates variance and covariance quantities: $\langle u'u' \rangle$, $\langle v'v' \rangle$, $\langle w'w' \rangle$, $\langle u'w' \rangle$, $\langle v'w' \rangle$, $\langle T'T' \rangle$, $\langle w'T' \rangle$, $\langle S'S' \rangle$, $\langle w'S' \rangle$. It should be noted that S' quantities are somewhat suspect, since the ducted design of the SBE 04 conductivity meters tends to cause significant flow disturbance at higher frequencies. The result seems to be to underestimate the actual covariance with w by about 25%. The μ C (SBE 07) instrument has better high frequency

response, but the records tend to be spiky with sudden significant shifts. In my experience, it is necessary to visually inspect every μC time series before accepting the covariance statistics as valid flux estimates. This has not been done here.

- Produce a $n \times 5$ matrix of 5 data vectors: T, S, u, v, w , where n is the number of samples in the 15-min period. The data are cross-referenced to the original file name and the beginning and ending indices in the .hdr structure.

The routine `adjust_F.m` operates on the structure produced by `turb_realize.m` to correct several known data defects, then it adjusts the compass reading to magnetic heading, and finally corrects the depth (pressure) reading for changes in atmospheric pressure. Note that the temperature and conductivity values are based on the pre- and post-cruise calibration values provided by SBE. With the slowly changing properties of the Arctic well mixed layer, we were able to cross calibrate the various sensors with the SBE9+ profiler to much higher relative accuracy than was provided by the manufacturer's calibrations. The following table is supplied as a courtesy only, and should be verified/ revised by an investigator interested in minute T/S differences. **These corrections have not been applied to the data in the `Fmon.mat` files.**

Table 1: Field Determined Temperature Corrections

Day of 1997	280	326.7	374.5	430	456.85	485	637
Cluster 1	-0.0014	-0.0007	0.0005	0.0014	0.0014	0.0015	0.0034
Cluster 2	-0.0002	0.0006	-0.0073	- 0.0073	0	0	0
Cluster 3	0	0	0	0	—	—	—
Cluster 4	0.0025	0.0038	0.0041	0.0048	—	—	—
Profiler	0.0001	0.0022	0.0026	0.0019	-0.0017	-0.0020	- 0.0008

Table 2: Field Determined Salinity Corrections

Day of 1997	280	326.7	374.5	430	450	484 ^a	640
Cluster 1 ^b	—	—	—	—	-0.0090	-0.0117	-0.0070
Cluster 2	-0.0011	-0.0012	0.0069	0.0066	0	0	0
Cluster 3	0	0	0	0	—	—	—
Cluster 4	-0.0068	-0.0113	-0.0169	-0.0146	—	—	—
Profiler	0.0004	0.0012	-0.0252	-0.0312	-0.0224	-0.0003	-0.0033

a. For the period 520 to 524, the correction varies linearly from 484 values to zero.

b. At Site 1, Cluster 1 was equipped with an open electrode microstructure conductivity sensor, unreliable for mean conductivity values because of rapid sensor calibration drift.

The routine `flux_allmonths.m` arranges the 15-min records in structure arrays month by month, so for example, the mat file `realizations/Fsep.mat` contains all of the 15 minute structures for the month of September, 1998, for each cluster (where cluster 3 is the same as cluster 2, except with salinity calculated from the μC conductivity). For someone unfamiliar with matlab structured arrays (akin to C+ structures), the following exercise may help clarify their role. From the **mfiles** directory:

```
>> load ../realizations/Fsep
```

```
>> whos
```

Name	Size	Bytes	Class
F1	823x1	20655468	struct array
F2	1646x1	40352328	struct array
F3	1646x1	40352328	struct array

```
Grand total is 11815420 elements using 101360124 bytes
```

```
>> f=F2(1000);
```

```
>> f
```

```
f =
```

```
    hdr: [1x1 struct]
```

```
  cluster: 2
```

```
    time: 262.4546
```

```
    flg: 1
```

```
  dmn: [-1.6011 29.8015 0.2754 1.1935 7.3390 0.8186] T, S, spd (m/s), maghdg (rad), depth,  $\theta$ 
```

```
  trb: [1x9 double] <u'u>, <v'v>, <w'w>, <u'w>, <v'w>, <T'T>, <w'T>, <S'S>, <w'S>
```

```
  data: [900x5 double] T, S, u, v, w [velocity units m/s]
```

```
>> f.hdr
```

```
ans =
```

```
  filenumber: 900
```

```
  comment: [1x51 char]
```

```
interface_flag: 1
```

```
scan_average: 6
```

```
no_clusters: 3
```

```
record_size: 73
```

```
no_records: 62893
```

```
  Tsn: [7x1 double]
```

```
  Csn: [7x1 double]
```

```
  bearing: [7x1 double]
```

```
  depth: [7x1 double]
```

```
start_time: [262.1682 1998 1.0043]
```

```
  filename: 'A900C'
```

```
  index_orig: [24301 25200]
```

```
>> load ../conv_data_structures/A900C
```

```
>> idx=f.hdr.index_orig[1]:f.hdr.index_orig[2];
```

```
>> subplot(21 1);plot(f.data[:,3:5]);grid on
```

```
>> uorig=[B(2).um(idx) B(2).vm(idx) B(2).wm(idx)];  
>> subplot(2 1 2);plot(uorig);grid on  
>> xlabel('Sample');ylabel('cm s^{-1}');subplot(2 1 1);ylabel('m s^{-1}');
```

