CRUISE REPORT

RED SEA OUTFLOW EXPERIMENT – REDSOX 2

R/V *Maurice Ewing* Cruise EW-110

August 21 to September 12, 2001

1. Introduction and Objectives

The Red Sea Outflow Experiment (REDSOX) is a joint effort between the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) and the Woods Hole Oceanographic Institution (WHOI). The purpose of the program is to conduct measurements of the outflow of high salinity water from the Red Sea and its mixing with ambient waters in the Gulf of Aden. The program is funded by the United States National Science Foundation (NSF).

The main objectives of REDSOX are:

1. To describe the pathways and downstream evolution of the descending outflow plumes of Red Sea Water in the western Gulf of Aden
2. To quantify the processes that control the final depth of the equilibrated Red Sea Outflow Water, and
3. To identify the transport processes and mechanisms that advect Red Sea Outflow Water and its properties through the Gulf of Aden and into the Indian Ocean.

In order to achieve these objectives, fieldwork has been carried out during two cruises. This report describes the scientific research conducted during the second project cruise from 21 August to 12 September 2001 aboard the R/V *Maurice Ewing* (REDSOX-2). This cruise was timed to take place during the climatological period of minimum deep outflow from the Red Sea, which occurs in boreal summer. The shipboard scientific activities consisted of three main components. First, a high-resolution hydrographic and direct current survey of the Gulf of Aden was conducted to describe the three-dimensional water property distributions and circulation characteristics. Second, direct measurements of turbulent mixing were made to study the bottom stress and mixing processes in the descending plumes. Third, acoustically-tracked RAFOS floats were launched to observe the rates and pathways of Red Sea Outflow Water spreading, including some floats that were deployed in delayed release mode.

REDSOX is intended to provide the first comprehensive description of the pathways, structure, and variability of the descending outflow plumes from the Red Sea and the equilibrated Red Sea Water mass as it enters the western Indian Ocean. Analysis of the experimental data will lead to a better understanding of mixing and spreading processes in dense overflows and a more detailed knowledge of the factors that control the final watermass characteristics of these outflows.

2. Cruise Dates and Personnel

Cruise 2: R/V *Maurice Ewing*: EW-110

The second cruise was carried out aboard the R/V *Maurice Ewing* from August 21 to September 12, 2001. The cruise originated from and ended in Djibouti. The cruise track is shown in Figure 1.

Cruise Participants:

1.	Amy Bower	WHOI	Chief Scientist
2.	Hartmut Peters	RSMAS / U. Miami	Scientist
3.	Francesco Paparella	U. of Lecce, Italy	Scientist
4.	Rainer Zantopp	RSMAS / U. Miami	Senior Research Associate
5.	Deborah Glickson	WHOI	Research Associate
6.	David Fisichella	WHOI	Research Assistant
7.	Robert Jones	RSMAS / U. Miami	Technician
8.	Ewa Jarosz	Louisiana State U.	Graduate Student
9.	Erica Key	RSMAS / U. Miami	Graduate Student
10.	Silvia Matt	RSMAS / U. Miami	Graduate Student
11.	Mitchihiro Ohiwa	WHOI	Graduate Student
12.	Alison Walker	WHOI	Graduate Student
13.	Robert Wolfe	RSMAS / U. Miami	Graduate Student

3. Scientific Activities

3.1 CTD/LADCP Stations

A total of 2?? combined hydrographic (CTD; conductivity / temperature / depth) and direct current (LADCP, lowered acoustic Doppler current profiler) stations were occupied on the cruise. Appendix 1 contains the station locations, times and depths, and the stations are plotted in Figures 2 and 3. After an encounter with unidentified armed assailants on Aug. 31, 2001 (at station # 133, 18 nautical miles off the coast of Somalia), the Ewing's movements were restricted to areas more than 50 miles from any coast for reasons of security. We subsequently developed a new station grid that differed substantially from our original plan for sampling the Gulf of Aden. Rather than surveying the western gulf up to the 12-mile limits of Somalia and Yemen and east to 48E, we sampled the middle third of the gulf out to 50E.

At each station, profiles of temperature, salinity (conductivity), and dissolved oxygen concentration were collected to a depth of 2000 m or to within approximately 10 m of the bottom at shallower depths, using a Sea-Bird SBE-9plus CTD system. Water samples for calibration of the salinity and dissolved oxygen profiles were collected at about half of these stations. Current profiles were measured with a lowered 300 kHz broadband RD Instruments acoustic Doppler current profiler.

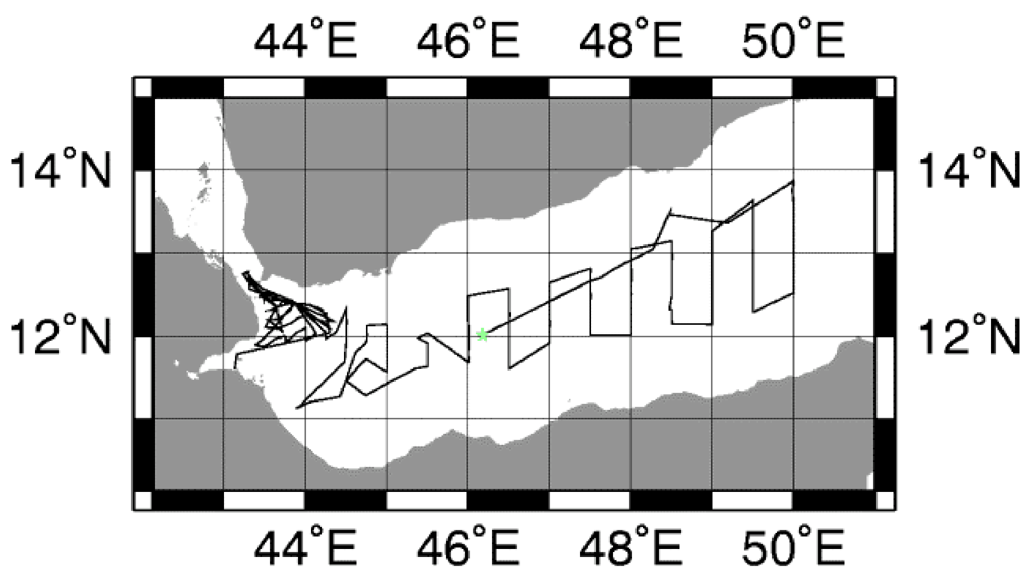

Figure 1. Cruise track of R/V *Maurice Ewing* during REDSOX-2

3.2 Mooring Deployments

3.2.1 Short-term Bottom ADCP moorings

A specialized near-bottom moored package, referred to as a "Bottom Lander", was deployed four times during the cruise for a deployment period of about one day to collect measurements of the structure and variability of the descending outflow plumes. This package consisted of a syntactic foam float holding an upward-looking 600 kHz broadband RD Instruments ADCP and a Sea-Bird SBE-37 "Microcat" temperature / conductivity / pressure recorder. The ADCP measures the velocity profile and turbulence properties within the bottom 40 m of the water column while the SBE-37 measures the water properties near the bottom. The device was deployed at the locations and times listed in Table 1 and shown in Figure 3.

Table 1: Bottom Lander Moorings

Stn. No.	Launch Date	Time (UTC)	Latitude N Deg	Latitude N min	Longitude E Deg	Longitude E min	Depth (m)	Release Date	Time (UTC)	Duration (hours)
BL-1	25-Aug-01	0328	12	20.99	43	38.51	377	26-Aug-01	0615	26.8
BL-2	26-Aug-01	1329	12	23.82	43	51.93	492	27-Aug-01	1445	*
BL-3	27-Aug-01	2218	12	46.26	43	16.60	214	28-Aug-01	2301	*
BL-4	29-Aug-01	0441	12	23.91	43	52.06	496	30-Aug-01	0458	24.3

* no data recovered

3.2.2 RAFOS Float Sound Source Moorings

One RAFOS float sound source mooring was deployed during the cruise at the location indicated in Table 2 (see also Figure 4). These sources are used to track the locations of the RAFOS floats as they drift through the area.

Table 2: Sound Source Mooring

Station	Sound Source	Launch Date	Time (Z)	Latitude N Deg	Latitude N min	Longitude E Deg	Longitude E min	Water Depth (m)	Mission Start Date
D	007	10-Sep-01	0934	13	28.439	48	28.153	1971	09-Sep-01

3.3 RAFOS Float Deployments

Acoustically tracked subsurface RAFOS floats were deployed at the locations listed in Appendix 2. The RAFOS floats were ballasted to drift at a nominal depth of 650m, which corresponds to the core of the Red Sea Water mass in the Gulf of Aden and in the Indian Ocean. The floats are programmed to drift for a period of one year and then surface to relay their data by satellite. At four locations, floats were anchored to the bottom and programmed to begin drifting after either two, four or six months. These floats are indicated as 'Dual Release' in Appendix 2.

3.4 Underway Measurements

Meteorological Data

Meteorological measurements were continuously recorded by sensors aboard the R/V *Maurice Ewing*, including wind speed and direction, barometric pressure and relative humidity. Wind speed and direction measured during the cruise are shown in Figure 5.

Thermosalinograph

Values of surface temperature and salinity were continuously measured and logged on the ships computer using a Sea-Bird temperature-conductivity recorder installed in the ship's seawater intake line. The data are shown in Figure 6.

Shipboard Acoustic Doppler Current Profiler

Upper ocean currents were continuously measured with a 150 kHz narrow-band Acoustic Doppler Current Profiler mounted in the ship's transducer well. The depth range of good velocity data typically extended to 350 m below the vessel, depending on sea state conditions. The data are shown in Fig. 9 and described below in connection with the scientific findings of the cruise.

4. Highlights of Preliminary Scientific Findings

REDSOX-2 took place during boreal summer when the outflow of Red Sea Water has its climatological minimum. The annual variation of RSW outflow affects both the circulation in the vicinity of the Straits of Bab el Mandeb and the distribution of high-salinity water in the Gulf of Aden.The following captions highlight preliminary findings.

(a) "Near Field" - Plume Study

- There was significant outflow of RSW in the northern as well as in the southern channel on the shelf south of Bab el Mandeb (Figure 7). A preliminary estimate of the deep outflow transport through Perim Narrows based on the shipboard ADCP measurements (bottom-track mode) is 0.10 Sv during slack tide.
- Even though transports of outflowing RSW were smaller than in winter, large near-bottom velocities were encountered at some stations in the two channels. Outflow velocities appeared to be highly variable in space and time.
- At least in the northern channel, RSW appeared to equilibrate to its surroundings at shallower depths than in winter, and specifically upstream of the channel exit.

(b) Tadjura Rift

- In contrast to winter, the section along the axis of Tadjura Rift did not show signatures of high-salinity water actively flowing out of the two channels. Rather, the highest salinities occurred toward the western basin near 900 m depth (Figure 7). Salinity in the deep rift (> 1000 m) was more saline in summer compared to winter.
- The water in Tadjura Rift below 1000 m showed consistent eastward flow. The lowest part of the water column generally showed extremely low static stability, which may hint toward vertical convection. The Rift is separated from the adjacent Gulf of Aden by a sill with a depth of 1000-1100 m.

(c) "Far Field" Gulf of Aden

- A field of apparently spatially-coherent staircase structures in the stratification was found below the level of the RSW intrusion southeast of the mouth of Tadjura Rift near 11^o 30'N, 45^{o}E (Figure 8). This is where the RSW first flows over the colder, fresher Indian Ocean waters. Layers were as thick as 50 m and showed signatures of vertical convection. The stratification in the staircase field was favorable to salt fingering.
- As during REDSOX-1, energetic eddies were found in the Gulf of Aden (Figures 9 and 10). As well as could be determined from the reduced gulf survey, their horizontal scales of the eddies were generally smaller than in winter. . Surface velocities encountered at times exceeded 3 knots. In contrast to REDSOX-1, these eddies tended to be more highly surface-intensified, especially in the western Gulf.
- The spatial distribution of salinity at the level of the RSW was less homogeneous in the central and eastern Gulf of Aden during REDSOX-2 than during REDSOX-1 (Figure 9). Elevated salinities were encountered in large patches or blobs (defined by multiple stations) near 47^{o}E and as far east as 49^o-50^{o}E.

5. Release of Project Data

In accordance with the provisions specified in the cruise prospectus and application for foreign clearances, the full data results from this experiment will be provided to all clearance countries according to the following schedule:

Hydrographic Station Data, Mooring Data, and Underway Shipboard Measurements

All shipboard measurements, including underway data records and hydrographic station data, as well as the data recovered from the short-term bottom moorings in the area of the outflow plume, will be provided within 6 months of the termination of the cruise (March 15, 2002).

Subsurface Floats

Time series data and trajectories from the subsurface RAFOS floats will be provided within 18 months from the time when the last floats surface and complete their data transmissions. This is expected to occur in January 2003. Therefore we anticipate delivery of the final float data by July 2004.

6. Acknowledgements

The support and able assistance provided by the Captain and crew of the R/V *Maurice Ewing* is gratefully acknowledged, especially in light of the extraordinary events that transpired during this cruise. Special acknowledgement is extended to Robert Jones, RSMAS technician, who expertly and with good humor carried out nearly all the technical aspects of this cruise. Financial support for this research was provided by the U.S. National Science Foundation under grants to the Woods Hole Oceanographic Institution and to the University of Miami. We wish to thank the Republic of Yemen, the Republic of Djibouti, and the State of Eritrea for their cooperation on this project and for granting permission to carry out research in their territorial waters.

Appendix 1. CTD/LADCP stations occupied during REDSOX-2.

Sta. No.	Date	Time (UTC)	Latitude (Deg / Min)	Longitude (Deg / Min)	Depth (m)
001	21 08 2001	1437	12 02.25	044 17.73	1254
002	21 08 2001	1647	12 07.33	044 17.08	919
003	22 08 2001	0141	12 16.24	044 14.98	765
004	22 08 2001	0422	12 22.65	044 01.80	527
005	22 08 2001	0624	12 23.66	043 50.11	460
006	22 08 2001	0818	12 25.20	043 42.26	393
007	22 08 2001	1015	12 30.44	043 35.72	334
008	22 08 2001	1229	12 31.60	043 25.16	301
009	22 08 2001	1422	12 34.42	043 18.07	283
010	22 08 2001	1655	12 46.21	043 16.64	216
011	22 08 2001	1818	12 45.64	043 15.13	175
012	22 08 2001	1935	12 45.08	043 13.75	178
013	22 08 2001	2251	12 27.41	043 32.23	288
014	23 08 2001	0025	12 22.03	043 37.76	384
015	23 08 2001	0215	12 13.04	043 40.17	450
016	23 08 2001	0400	12 06.51	043 41.96	453
017	23 08 2001	0514	12 03.26	043 42.71	901
018	23 08 2001	0750	12 11.88	043 32.51	188
019	23 08 2001	0853	12 12.01	043 36.03	213
020	23 08 2001	1011	12 12.23	043 38.67	319
021	23 08 2001	1128	12 12.93	043 40.24	453
022	23 08 2001	1254	12 14.12	043 42.18	355
023	23 08 2001	1403	12 15.44	043 44.54	341
024	23 08 2001	1522	12 17.56	043 47.22	350
025	23 08 2001	1629	12 19.02	043 48.94	231
026	23 08 2001	1735	12 21.05	043 49.45	290
027	23 08 2001	1841	12 22.47	043 49.75	393
028	23 08 2001	1948	12 23.50	043 50.04	464
029	23 08 2001	2052	12 24.56	043 50.46	432
030	24 08 2001	0042	12 10.96	044 20.28	648
031	24 08 2001	0203	12 11.05	044 17.98	724
032	24 08 2001	0322	12 10.98	044 15.97	715
033	24 08 2001	0438	12 10.95	044 13.99	606
034	24 08 2001	0552	12 10.97	044 12.02	522
035	24 08 2001	0727	12 13.12	044 04.69	497
036	24 08 2001	0854	12 15.38	044 00.12	409
037	24 08 2001	1027	12 12.73	043 54.06	463
038	24 08 2001	1203	12 09.15	043 48.56	435
039	24 08 2001	1312	12 08.34	043 46.60	619
040	24 08 2001	1426	12 07.42	043 44.88	386
041	24 08 2001	1525	12 06.86	043 43.32	463
042	24 08 2001	1652	12 06.52	043 42.01	453
043	24 08 2001	1756	12 06.06	043 40.56	327
044	24 08 2001	1904	12 05.50	043 38.98	292
045	24 08 2001	2008	12 05.64	043 36.61	255
046	24 08 2001	2212	12 06.02	043 33.28	208
047	24 08 2001	2314	12 06.52	043 30.38	149
048	25 08 2001	0121	12 20.99	043 38.61	374
049	25 08 2001	0418	12 23.00	043 37.13	394
050	25 08 2001	0528	12 20.94	043 38.55	379
051	25 08 2001	0622	12 18.78	043 39.28	391
052	25 08 2001	0747	12 18.57	043 33.15	233
053	25 08 2001	0824	12 19.22	043 34.55	307
054	25 08 2001	0909	12 19.65	043 35.71	364

055	25 08 2001	0955	12 20.47	043 37.40	313
056	25 08 2001	1056	12 21.03	043 38.57	381
057	25 08 2001	1200	12 21.42	043 39.31	317
058	25 08 2001	1259	12 22.02	043 40.48	318
059	25 08 2001	1408	12 23.95	043 41.69	349
060	25 08 2001	1513	12 25.16	043 42.20	424
061	25 08 2001	1616	12 26.12	043 42.71	304
062	26 08 2001	0540	12 21.01	043 38.45	379
063	26 08 2001	0812	12 24.58	043 51.98	466
064	26 08 2001	0932	12 23.92	043 52.02	497
065	26 08 2001	1036	12 22.85	043 52.10	426
066	26 08 2001	1152	12 23.53	043 49.99	473
067	26 08 2001	1357	12 23.89	043 52.03	497
068	26 08 2001	1518	12 23.71	043 53.95	518
069	26 08 2001	1703	12 23.44	043 57.40	539
070	26 08 2001	1826	12 22.69	044 01.74	549
071	26 08 2001	1959	12 20.92	044 08.29	660
072	26 08 2001	2134	12 18.20	044 13.39	707
073	26 08 2001	2239	12 15.75	044 13.24	524
074	26 08 2001	2345	12 15.94	044 14.07	626
075	27 08 2001	0049	12 16.18	044 15.00	802
076	27 08 2001	0217	12 13.59	044 14.07	596
077	27 08 2001	0341	12 11.03	044 17.97	731
078	27 08 2001	0447	12 10.97	044 15.97	722
079	27 08 2001	0610	12 10.98	044 13.99	617
080	27 08 2001	0707	12 11.00	044 12.06	524
081	27 08 2001	0836	12 05.21	044 18.01	1175
082	27 08 2001	1331	12 23.92	043 51.99	492
083	27 08 2001	2243	12 46.27	043 16.61	215
084	27 08 2001	2327	12 45.61	043 15.08	179
085	28 08 2001	0008	12 45.08	043 13.80	180
086	28 08 2001	0206	12 46.29	043 16.61	214
087	28 08 2001	0248	12 45.64	043 15.14	179
088	28 08 2001	0333	12 45.13	043 13.76	180
089	28 08 2001	0446	12 46.31	043 16.63	212
090	28 08 2001	0529	12 45.63	043 15.05	180
091	28 08 2001	0617	12 45.05	043 13.75	181
092	28 08 2001	0749	12 46.30	043 16.61	214
093	28 08 2001	0828	12 45.61	043 15.04	182
094	28 08 2001	0911	12 45.08	043 13.74	181
095	28 08 2001	1035	12 46.36	043 16.64	212
096	28 08 2001	1053	12 46.34	043 16.60	213
097	28 08 2001	1138	12 45.65	043 15.03	183
098	28 08 2001	1221	12 45.07	043 13.73	181
099	28 08 2001	1343	12 46.40	043 16.53	216
100	28 08 2001	1447	12 45.65	043 15.01	184
101	28 08 2001	1540	12 45.12	043 13.77	180
102	28 08 2001	1712	12 46.28	043 16.61	212
103	28 08 2001	1753	12 45.59	043 15.03	184
104	28 08 2001	1834	12 45.10	043 13.73	181
105	28 08 2001	1956	12 46.21	043 16.56	212
106	28 08 2001	2050	12 45.55	043 15.06	183
107	28 08 2001	2134	12 45.03	043 13.75	180
108	29 08 2001	0342	12 23.86	043 52.04	497
109	29 08 2001	0830	11 58.83	043 30.04	915
110	29 08 2001	1016	11 53.50	043 23.01	1298
111	29 08 2001	1203	11 52.37	043 29.96	892
112	29 08 2001	1350	11 57.83	043 37.51	1659
113	29 08 2001	1554	12 00.03	043 45.01	1587

114	29 08 2001	1746	11 54.97	043 44.98	875
115	29 08 2001	1936	12 01.94	043 52.40	1186
116	29 08 2001	2152	12 06.11	044 00.00	953
117	29 08 2001	2337	11 56.54	044 00.01	898
118	30 08 2001	0122	12 02.01	044 07.51	1315
119	30 08 2001	0828	12 02.53	044 15.01	1276
120	30 08 2001	1000	11 57.99	044 15.02	932
121	30 08 2001	1140	12 02.77	044 22.47	1410
122	30 08 2001	1440	12 19.97	044 29.92	553
123	30 08 2001	1551	12 15.00	044 30.04	751
124	30 08 2001	1712	12 10.03	044 30.00	756
125	30 08 2001	1907	12 02.52	044 30.01	1385
126	30 08 2001	2032	11 56.05	044 29.83	805
127	30 08 2001	2245	11 41.37	044 28.70	831
128	31 08 2001	0035	11 34.27	044 21.38	783
129	31 08 2001	0219	11 26.78	044 13.80	688
130	31 08 2001	0400	11 19.97	044 06.16	586
131	31 08 2001	0544	11 12.18	043 58.22	570
132	31 08 2001	0650	11 08.37	043 55.45	599
133	31 08 2001	0748	11 07.52	043 53.14	414
134	31 08 2001	1426	11 47.98	044 36.62	899
135	31 08 2001	1604	11 52.68	044 42.19	912
136	31 08 2001	1734	11 56.69	044 44.97	909
137	31 08 2001	1857	11 59.25	044 45.01	1181
138	31 08 2001	2019	12 02.19	044 45.06	1290
139	31 08 2001	2154	12 07.48	044 45.06	1217
140	01 09 2001	0031	12 08.43	045 00.05	727
141	01 09 2001	0147	12 04.26	044 59.86	1022
142	01 09 2001	0315	11 58.91	044 59.97	1203
143	01 09 2001	0549	11 53.34	044 59.87	937
144	01 09 2001	0745	11 44.12	044 59.88	1143
145	01 09 2001	0951	11 33.96	044 59.97	1457
146	01 09 2001	0951	11 38.40	044 52.47	1176
147	01 09 2001	1414	11 43.65	044 44.29	1007
148	01 09 2001	1616	11 35.65	044 36.97	923
149	01 09 2001	1812	11 27.42	044 29.99	880
150	01 09 2001	1959	11 21.93	044 37.00	979
151	01 09 2001	2144	11 17.00	044 44.18	1115
152	02 09 2001	0000	11 21.76	044 53.11	1273
153	02 09 2001	0201	11 26.82	045 02.34	1505
154	02 09 2001	0412	11 31.64	045 11.66	1581
155	02 09 2001	0620	11 36.53	045 20.92	1677
156	02 09 2001	0816	11 38.07	045 30.01	1429
157	02 09 2001	1037	11 47.94	045 30.01	1520
158	02 09 2001	1239	11 54.97	045 29.96	1097
159	02 09 2001	1405	11 57.00	045 25.49	1131
160	02 09 2001	1528	11 58.21	045 22.99	1067
161	02 09 2001	1652	11 59.99	045 25.04	1052
162	02 09 2001	1816	12 01.00	045 28.05	1086
163	02 09 2001	1931	12 01.97	045 30.02	1092
164	02 09 2001	2109	11 58.22	045 35.52	974
165	03 09 2001	0045	11 41.01	045 59.95	1881
166	03 09 2001	0330	11 50.99	046 00.10	1206
167	03 09 2001	0600	12 00.60	046 00.23	1488
168	03 09 2001	0750	12 10.98	045 59.97	1206
169	03 09 2001	0955	12 20.99	046 00.04	1463
170	03 09 2001	1155	12 28.96	045 59.98	1502
171	03 09 2001	1626	12 34.49	046 30.00	1818
172	03 09 2001	1839	12 27.00	046 30.04	1759

173	03 09 2001	2110	12 17.01	046 30.03	2098
174	03 09 2001	2342	12 07.02	046 29.95	2121
175	04 09 2001	0218	11 57.06	046 29.93	1291
176	04 09 2001	0428	11 46.98	046 29.95	2001
177	04 09 2001	0659	11 36.52	046 29.99	1993
178	04 09 2001	1149	11 54.98	046 59.99	2000
179	04 09 2001	1418	12 04.02	047 00.03	1982
180	04 09 2001	1650	12 14.03	047 00.03	1985
181	04 09 2001	1924	12 24.00	047 00.15	2440
182	04 09 2001	2148	12 31.45	047 00.10	2159
183	05 09 2001	0001	12 38.99	047 00.07	1994
184	05 09 2001	0414	12 48.94	047 30.05	2025
185	05 09 2001	0625	12 41.09	047 30.01	2246
186	05 09 2001	0852	12 31.02	047 30.01	1990
187	05 09 2001	1131	12 21.06	047 29.94	2001
188	05 09 2001	1408	12 10.96	047 29.98	1300
189	05 09 2001	1618	12 01.05	047 29.92	1876
190	05 09 2001	2050	12 00.99	047 59.96	2290
191	05 09 2001	2328	12 10.93	048 00.00	2257
192	06 09 2001	0200	12 20.96	047 59.97	1926
193	06 09 2001	0427	12 30.96	048 00.00	1634
194	06 09 2001	0705	12 40.92	048 00.14	2467
195	06 09 2001	0933	12 50.97	047 59.94	1917
196	06 09 2001	1217	13 03.00	047 59.97	2173
197	06 09 2001	1647	13 08.98	048 29.94	1587
198	06 09 2001	1903	12 59.03	048 30.04	2190
199	06 09 2001	2128	12 49.05	048 30.01	2737
200	07 09 2001	0017	12 39.02	048 29.94	2416
201	07 09 2001	0246	12 28.96	048 30.05	2217
202	07 09 2001	0610	12 18.95	048 29.97	2105
203	07 09 2001	0827	12 08.94	048 30.05	2280
204	07 09 2001	1303	12 08.51	048 59.99	2338
205	07 09 2001	1518	12 17.00	048 59.96	2364
206	07 09 2001	1744	12 27.04	048 59.99	2591
207	07 09 2001	2008	12 36.97	048 59.98	2642
208	07 09 2001	2235	12 47.01	048 59.97	2148
209	08 09 2001	0100	12 57.00	048 59.98	2323
210	08 09 2001	0326	13 07.04	048 59.96	2084
211	08 09 2001	0545	13 15.91	048 59.99	2604
212	08 09 2001	1041	13 37.97	049 29.96	2118
213	08 09 2001	1352	13 20.97	049 29.99	2554
214	08 09 2001	1653	13 05.03	049 29.99	3297
215	08 09 2001	1950	12 49.01	049 29.99	2322
216	08 09 2001	2248	12 33.04	049 30.02	2338
217	09 09 2001	0144	12 17.53	049 30.01	2384
218	09 09 2001	0557	12 31.32	049 59.95	2399
219	09 09 2001	0853	12 47.46	050 00.01	2266
220	09 09 2001	1155	13 03.96	050 00.04	2504
221	09 09 2001	1456	13 20.00	049 59.98	2553
222	09 09 2001	1757	13 36.05	050 00.05	1934
223	09 09 2001	2054	13 52.00	050 00.00	2348
224	10 09 2001	0653	13 27.94	048 27.98	1972
225	11 09 2001	0732	11 31.83	045 11.96	1577
226	11 09 2001	0817	11 32.69	045 12.74	1565
227	11 09 2001	0850	11 33.28	045 13.34	1557

Appendix 2. Float releases

										Properties at 650 dbar		
Float#	ARGOS ID	Launch Date	Time (Z)	Latitude	Longitude	Station No.	Water Depth	Dual Re.	Mission Start Date	theta	salinity	sigma-theta
210	22868	03-Sep-01	2042	12 24.024	47 00.196	181	2442	N	04-Sep-01	13.262	36.250	27.308
211	22869	06-Sep-01	1334	13 03.081	48 00.046	196	2100	N	06-Sep-01	11.496	35.880	27.369
212	24247	01-Sep-01	1655	11 35.648	44 36.862	148	912	N	01-Sep-01	13.766	36.396	27.316
213	24248	01-Sep-01	2245	11 16.950	44 44.209	151	1114	N	02-Sep-01	15.895	37.047	27.348
214	24249	06-Sep-01	0538	12 30.753	48 00.408	193	1634	N	06-Sep-01	11.690	35.856	27.314
215	24250	05-Sep-01	2208	12 01.038	48 00.052	190	2290	N	06-Sep-01	12.081	35.926	27.293
216	25188	31-Aug-01	1810	11 56.726	44 44.930	136	910	N	01-Sep-01	14.621	36.660	27.336
217	25189	01-Sep-01	0430	11 58.811	44 59.998	142	1202	N	01-Sep-01	13.910	36.452	27.329
218	25190	27-Aug-01	0941	12 05.215	44 18.109	81	1200	N	27-Aug-01	15.164	36.880	27.386
219	25191	29-Aug-01	2028	12 01.957	43 52.362	115	1187	N	28-Aug-01	17.463	37.587	27.389
220	25192	04-Sep-01	1307	11 54.986	47 00.051	178	2100	N	04-Sep-01	13.440	36.303	27.312
221	25660	05-Sep-01	0124	12 38.936	47 00.156	183	1995	N	05-Sep-01	12.118	35.894	27.261
222	26323	05-Sep-01	1732	12 01.062	47 29.956	189	2300	N	05-Sep-01	13.214	36.258	27.293
223	26324	03-Sep-01	1257	12 28.973	45 59.978	170	1500	N	03-Sep-01	12.917	36.287	27.408
224	26325	03-Sep-01	0208	11 41.000	46 00.084	165	1881	N	03-Sep-01	12.596	36.093	27.321
225	26326	03-Sep-01	0635	12 00.515	46 00.307	167	1515	N	03-Sep-01	12.848	36.264	27.407
226	26327	01-Sep-01	2233	11 16.983	44 44.155	151	1114	Y	01-Nov-01	15.895	37.047	27.348
227	26328	01-Sep-01	2243	11 16.956	44 44.176	151	1114	Y	01-Jan-02	15.895	37.047	27.348
228	28569	29-Aug-01	2035	12 01.961	43 52.308	115	1187	Y	01-Nov-01	17.463	37.587	27.389
229	28570	29-Aug-01	2032	12 01.965	43 52.336	115	1187	Y	01-Jan-02	17.463	37.587	27.389
230	28571	29-Aug-01	2040	12 01.968	43 52.283	115	1187	Y	01-Mar-02	17.463	37.587	27.389
231	28572	01-Sep-01	0711	11 58.915	45 00.161	142	1202	Y	01-Nov-01	13.910	36.452	27.329
232	28573	27-Aug-01	1003	12 05.192	44 18.192	81	1200	Y	01-Jan-02	15.164	36.880	27.386
233	28574	27-Aug-01	1009	12 05.163	44 18.225	81	1200	Y	01-Mar-02	15.164	36.880	27.386
234	18559	01-Sep-01	1202	11 58.912	45 00.017	142	1202	Y	01-Jan-02	13.910	36.452	27.329
235	18560	01-Sep-01	1202	11 58.819	44 59.998	142	1202	Y	01-Mar-02	13.910	36.452	27.329
236	18561	27-Aug-01	1200	12 05.218	44 18.160	81	1200	Y	01-Nov-01	15.164	36.880	27.386

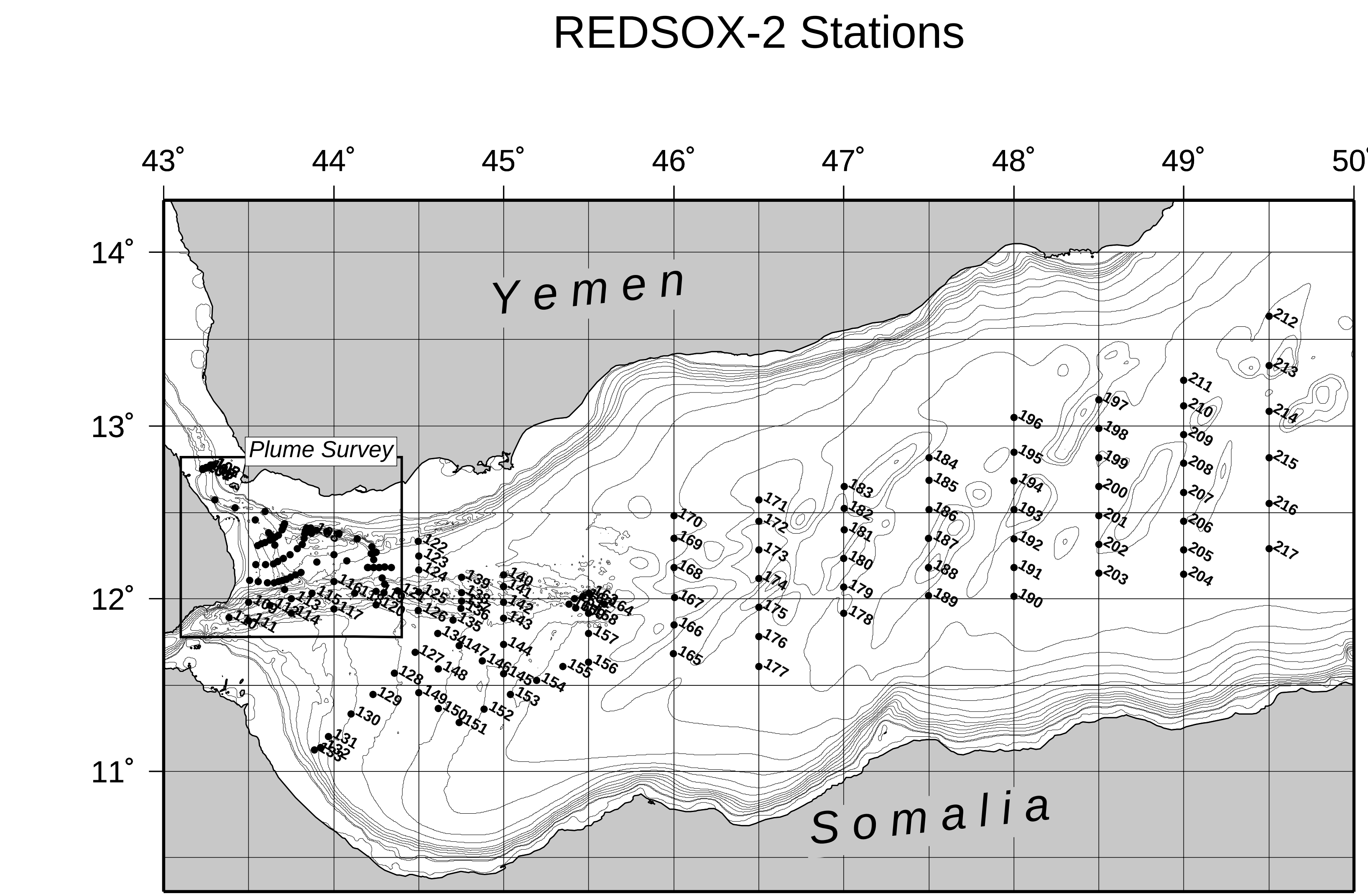

Figure 2: Location of the CTD/LADCP stations during during REDSOX-2 in the Gulf of Aden. An extended view of the plume survey is shown in Fig. 3.

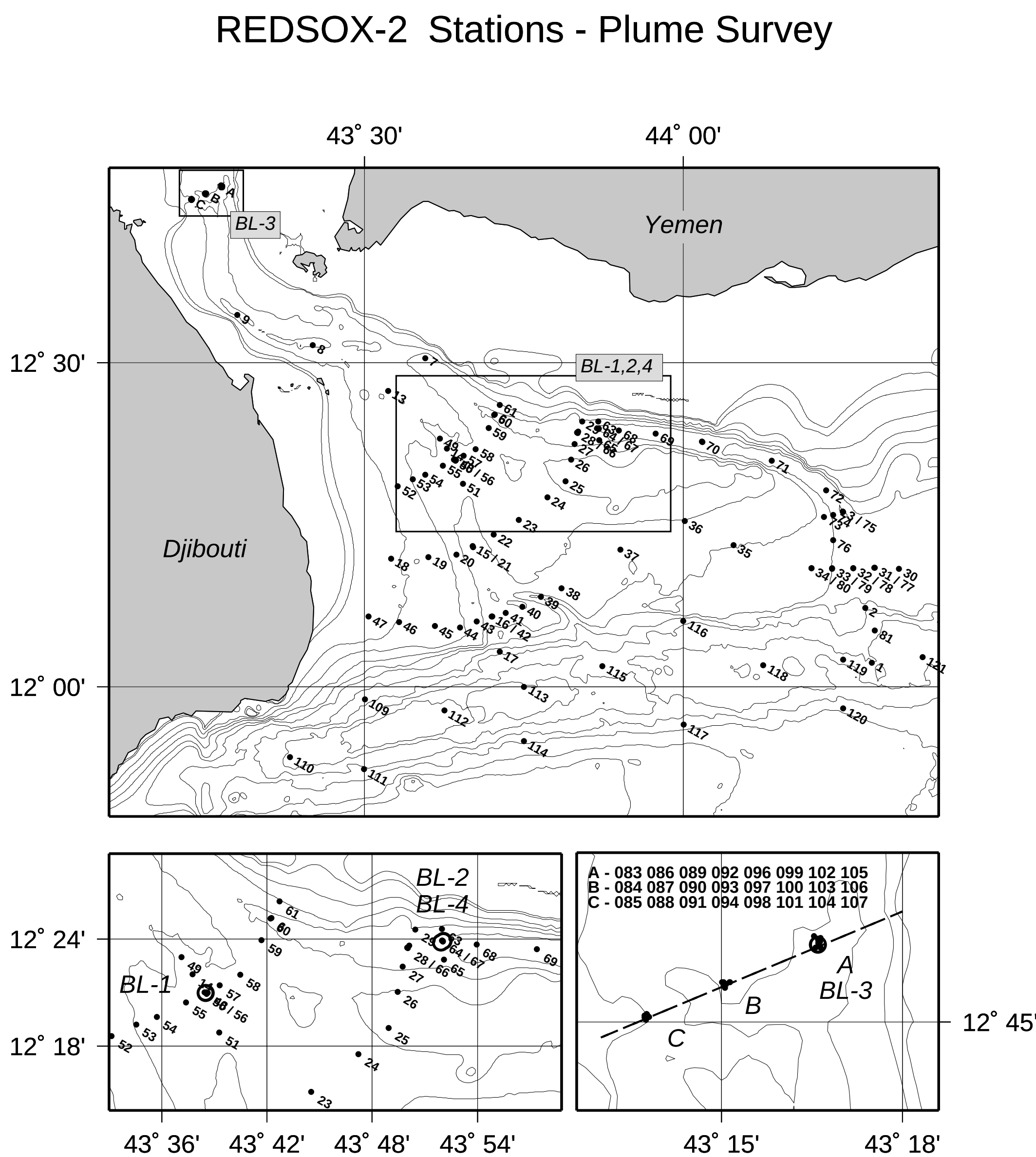

Figure 3: Expanded view of the CTD/LADCP stations during the plume survey (stations 1-108) and in Tadjura Rift (stations 109-125) in the western Gulf of Aden. Additional enlargements cover bottom lander sites BL1, BL2 and BL3 in the center of the plume region (bottom left) and BL3 in the Perim Narrows (bottom right). Bottom lander sites are marked by open circles. The dashed line through the BL3 site indicates repeated shipboard ADCP sections.

REDSOX-2 Float Launches

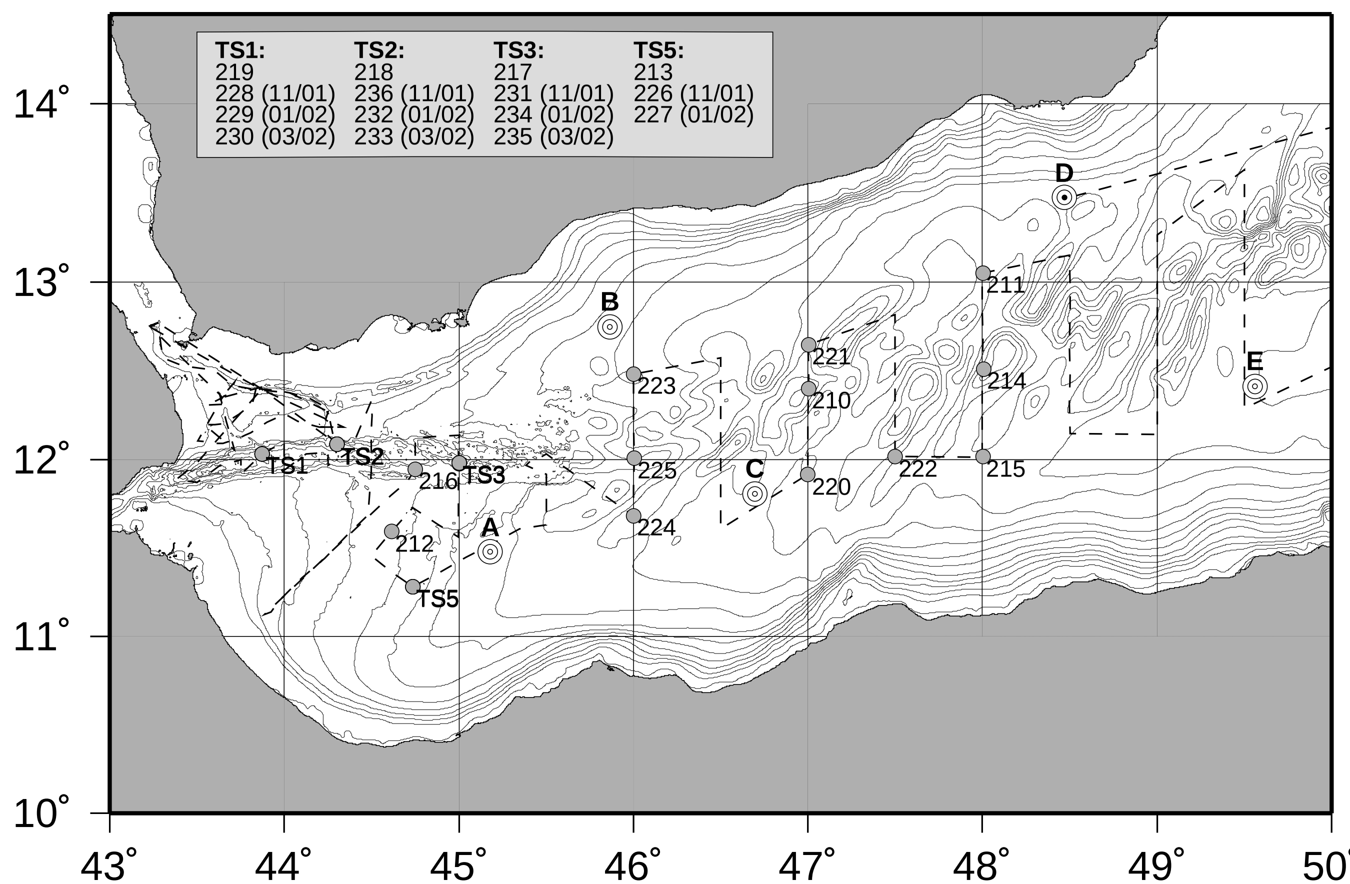

Figure 4: Launch locations of 650-m RAFOS floats during REDSOX-2 (numbered); timed-release floats were deployed at 4 time series stations (TS1–TS4). Locations of 780-Hz sound sources (lettered); sources A, B, C, and E having been deployed during REDSOX-1 while sound source D was deployed during REDSOX-2.

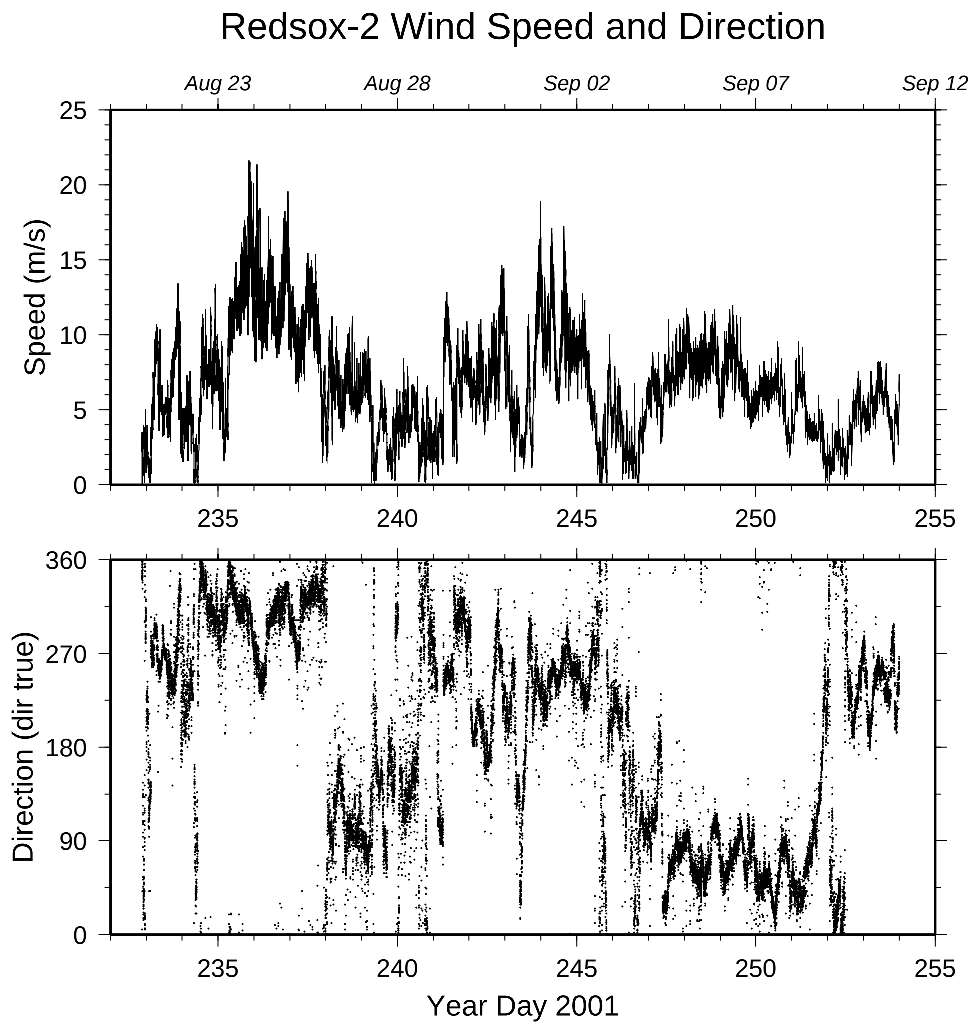

Figure 5: Wind speed (top) and direction (bottom) as recorded by the meteorological sensors on the R/V *Maurice Ewing* during REDSOX-2.

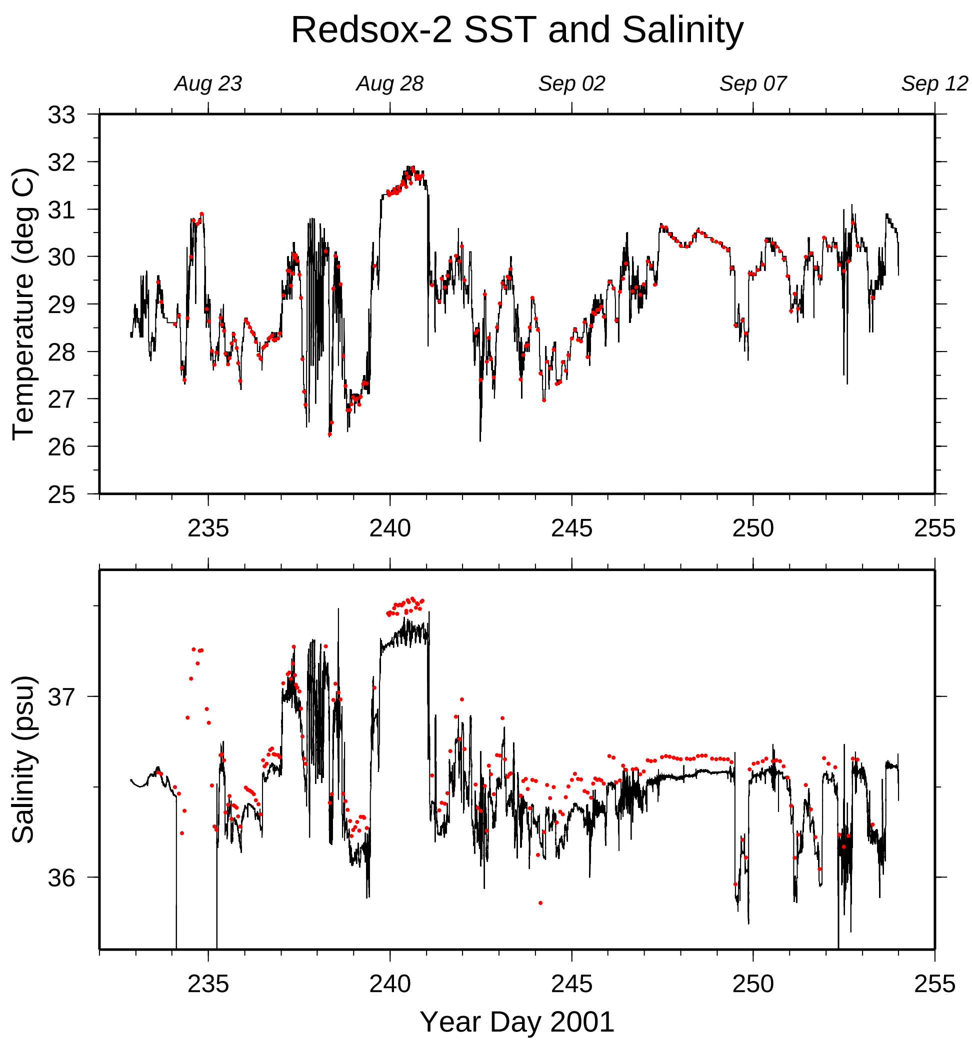

Figure 6: Sea surface temperature (top) and salinity (bottom) as recorded by the thermosalinograph on the R/V *Maurice Ewing* during REDSOX-2. Near-surface CTD data (dots) indicate a mean offset of the thermosalingraph salinity of -0.12 psu.

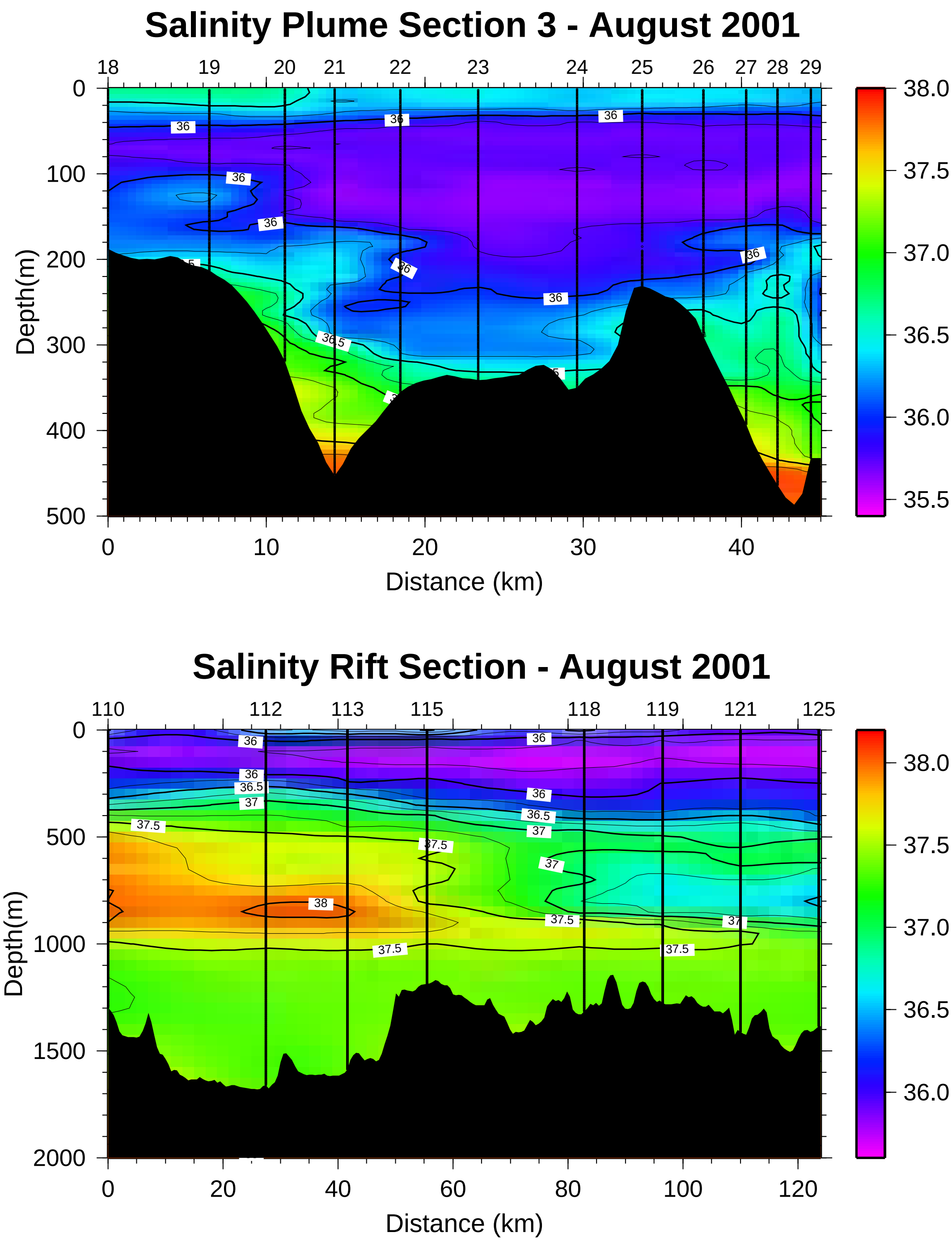

Figure 7: (Top) Salinity section across the two main outflow channels from the Red Sea. The station numbers comprising the section are shown at the top (see Figs. 2 and 3 for station locations. (Bottom) Salinity section along the Tadjura Rift.

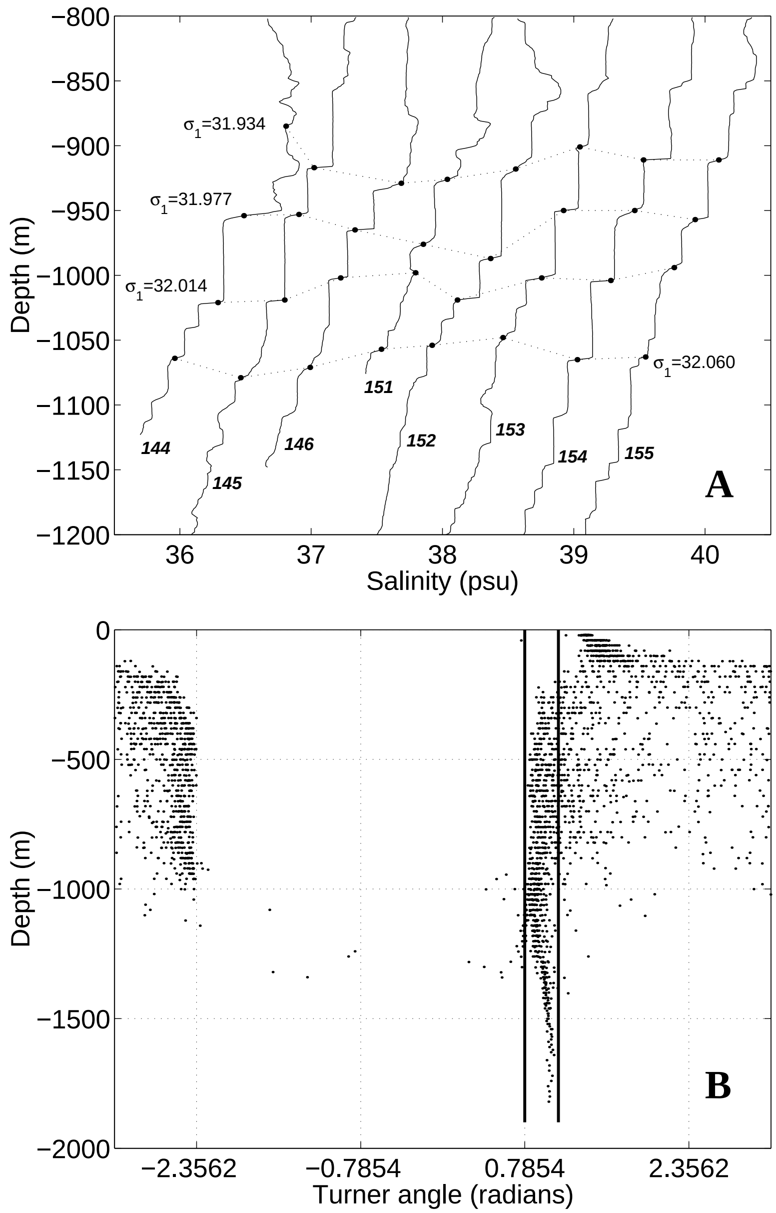

Figure 8: (Top) Salinity profiles below the spreading Red Sea Water from a cluster of stations near 11.5°N, 45°E showing a pronounced staircase structure. The staircase was likely caused by salt finger activity. Some of the sharpest steps lay along potential density surfaces (shown as dotted lines). (Bottom) The Turner angle for the stations 120–169 shows a large number of data points in a region favorable to salt fingering (vertical lines at density ratios 1 and 2, respectively). The Turner angle is $Tu = \mathrm{atan}(\Delta T, \Delta S)$, where ΔT and ΔS are, respectively, vertical temperature and salinity differences measured in density units.

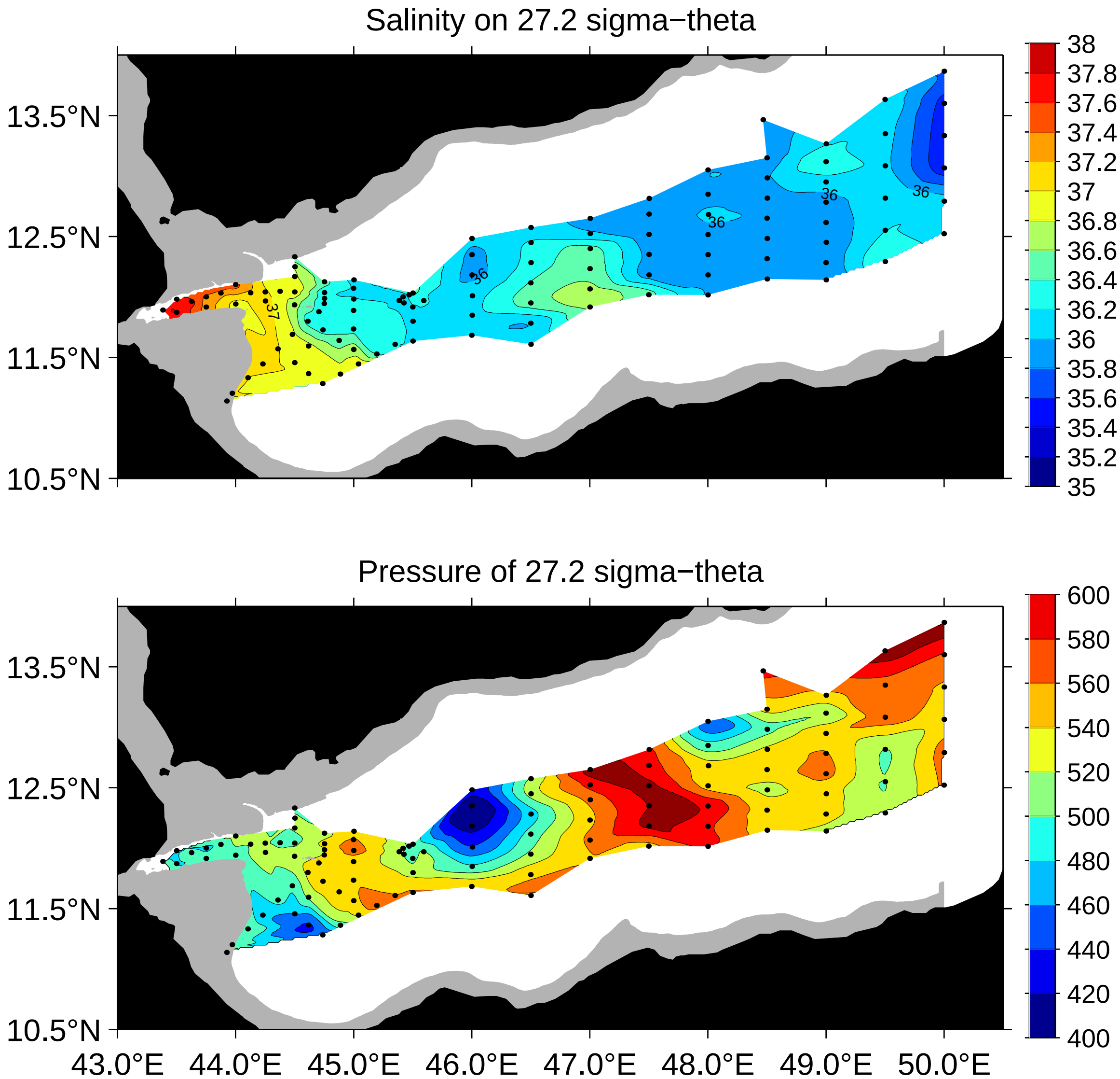

Figure 9: (Top) Horizontal distribution of salinity in the Gulf of Aden at the main spreading level of Red Sea Water (density layer $27.15 < \sigma_\theta < 27.25$). (Bottom) Same as top, but showing the mean pressure in dbar of that layer.

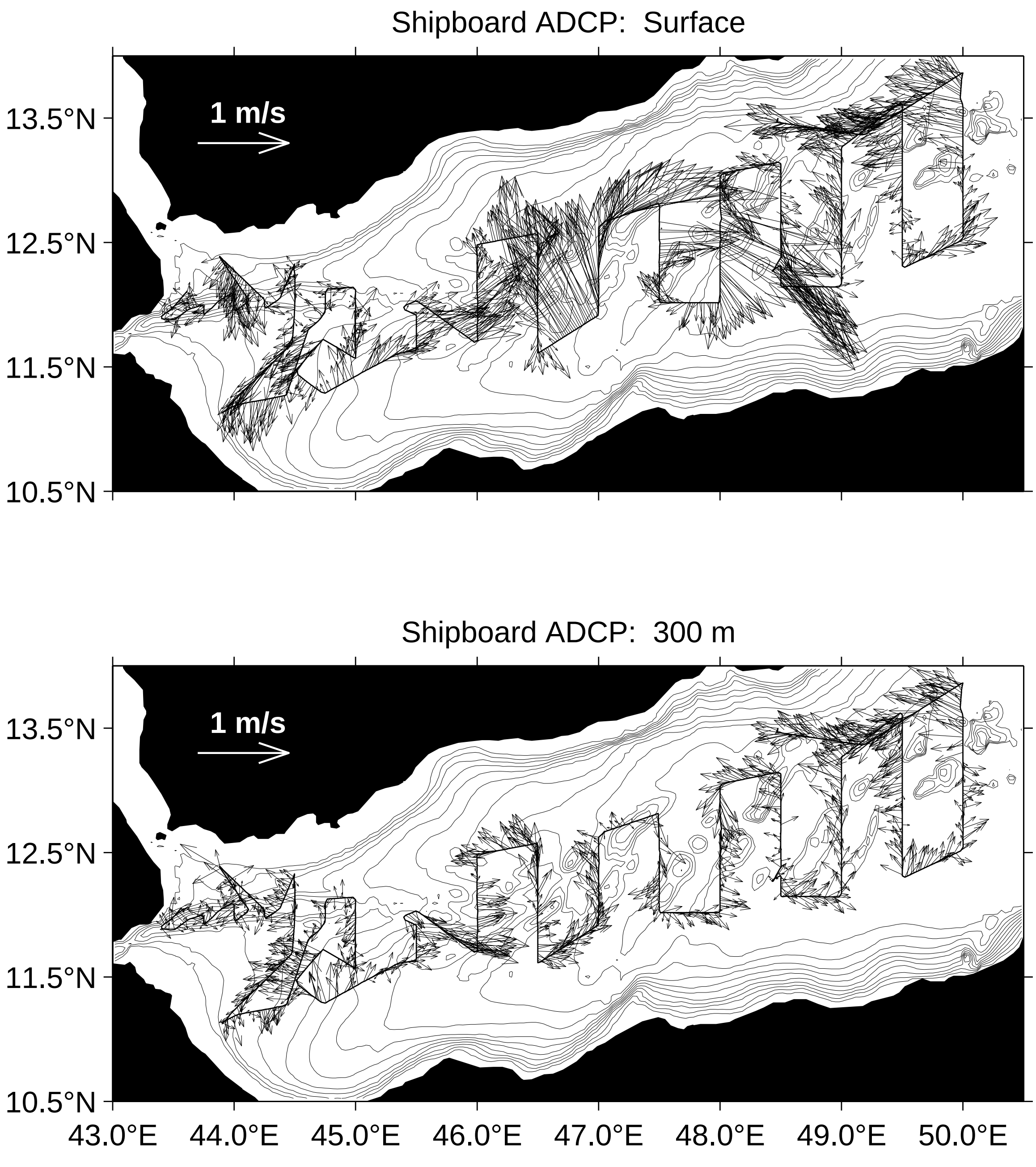

Figure 10: (Top) Surface current vectors measured by the shipboard acoustic Doppler current profiler, showing strong eddy fields in the Gulf of Aden during REDSOX-2. (Bottom) Current vectors at 300 m depth.