Laboratoire d'Océanographie Physique et Spatiale
UMR6523 – CNRS-IFREMER-IRD-UBO
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BOCATS 2023

CTD-O_2 Data report

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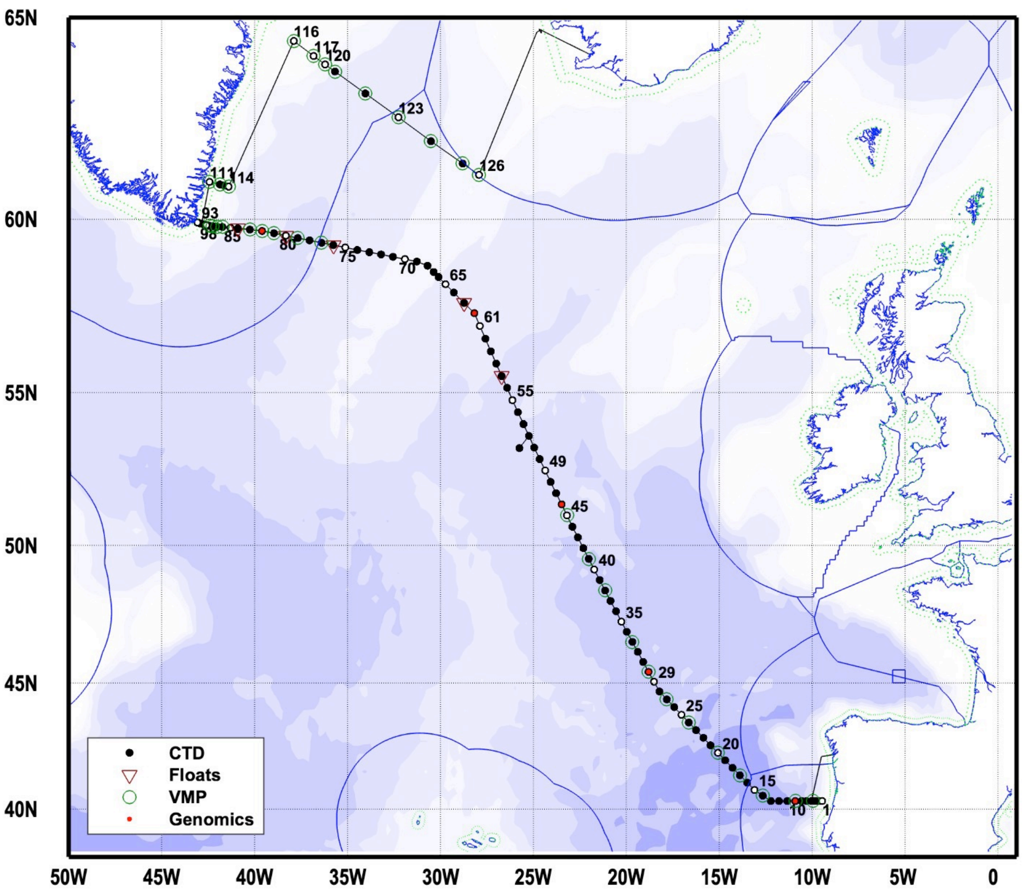
Michel Hamon and Fiz F. Pérez



EXPOCODE: 29AH20230608

GO-SHIP section A25 (OVIDE-BOCATS)

LOPS - Ifremer Centre Bretagne 1625 route de Ste-Anne CS10070 – 29280 Plouzané

Cite as: Le Bihan Caroline, Lherminier Pascale, Le Bot Philippe, Hamon Michel (2024). BOCATS 2023 CTD-O2 data report. Ifremer, LOPS. https://archimer.ifremer.fr/

Date release: November 26, 2024

ABSTRACT

BOCATS 2023 cruise focused on the 11th repetition of the OVIDE section. OVIDE (BOCATS) cruises have been run biennially since 2002, always in June-July, and the section is labelled as a high-resolution reference section in the international program GO-SHIP. BOCATS 2023 started in Vigo on June 8 and ended in Reykjavik on July 14 on the R/V Sarmiento de Gamboa. The 98 stations of the OVIDE section, from Portugal to the tip of Greenland, could be realized in totality. The core of the work consisted in acquiring surface-to-bottom hydrographic profiles of pressure, temperature, salinity and dissolved oxygen, and analyzing 14 physical and biogeochemical tracers from 11 920 samples drawn from the Niskin bottles of the CTD frame. We report here a focus on the acquisition and calibration steps of the physical variables measured specifically by the hydrographic CTD-O_2 probe.

After calibration, we find precisions for pressure, temperature, salinity and dissolved oxygen that fit the GO-SHIP international quality requirements. Pressure and temperature were calibrated at the laboratory before and after the cruise, leading to a repeatability better than 1 dbar and 0.001 °C respectively. The calibration of salinity and dissolved oxygen data is obtained by applying polynomial correcting functions that are calculated to statistically minimize the differences between the probe data and the sample data analyzed on board in the chemistry container. These chemical data are also evaluated by the comparison of replicates. After calibration, the differences in salinity and oxygen follow a zero-centered Gaussian-like distribution which standard deviation is used to evaluate the probe precision for each variable. For salinity, we find a standard deviation of 0.001, and for oxygen, 0.021 ml/l (or 1 µmol/kg). Those numbers correspond to a 68 % confidence interval and must be doubled to obtain the precision within a 95 % confidence interval.

The final dataset is available on Seanoe: https://doi.org/10.17882/95607

Table des matières

The BOCATS 2023 Cruise

1.1 Introduction

The BOCATS 2023 cruise took place on board the R/V Sarmiento de Gamboa from 8th of June to 14th of July, starting at Vigo (Spain) and finishing at Reykjavik (Island).

Figure 1: R/V Sarmiento de Gamboa

The working area is between Portugal and Greenland (see fig. 2).

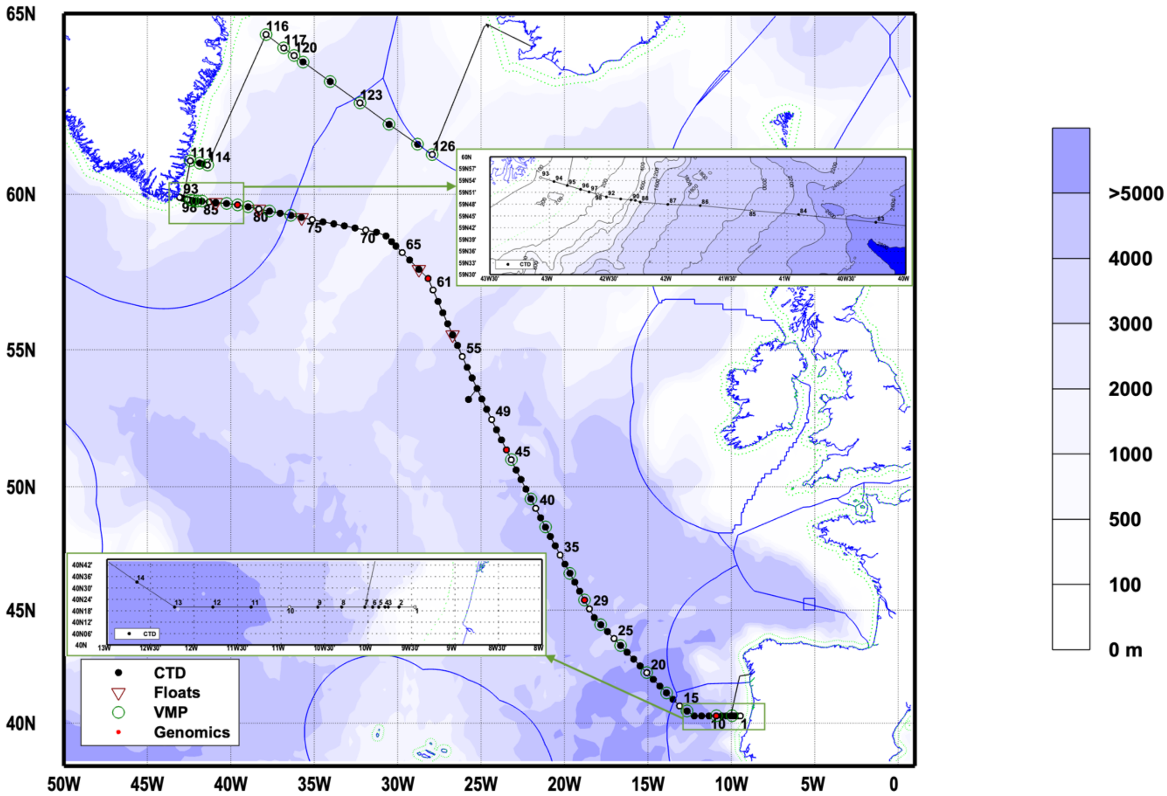


Figure 2: map of the working area, with zooms in the Iberian and Greenland areas. Blue lines delimit coasts and EEZ limits and green lines the 3 and 12 Nm national waters. Black and white dots are CTD stations (white when numbered and circled in green when the VMP was deployed), red triangles are positions of float deployments, and the stations with redpoints was sampled for genomics.

1.2 Cruise participants

Names	Organism	Responsibility on board
Fiz Fernández Pérez	IIM-CSIC	Chief scientist
Marcos Morente Fontela	CCMAR	DOC
Xose Antonio Padín Alvarez	IIM-CSIC	Sampling + genomics
Marta López Mozos	IIM-CSIC	pH + alkalinity
Sara Camaselle Vazquez	IIM-CSIC	pH + alkalinity
Maria Lopez Acosta	IIM-CSIC	Nutrients
Pilar Cameselle Salgado	IIM-CSIC	Nutrients
Daniel Fernández Román	UVIGO	VMP
Javier Lopez Fernández	UVIGO	Sampling
Aide Lasa González	UVIGO	Sampling + genomics
Jakob Ernst		Sampling
Pascale Lherminier	IFREMER	Resp. physics data (CTD, ADCP) + forecasts
Caroline Le Bihan	IFREMER	Chemistry supervision and CTD calibration
Raphael Bajon	IFREMER	CTD watch (0-4) and sampling
Aliette CHENAL	MERCATOR/CNES	CTD watch (8-12) and sampling
Ludovic Cosmes	IFREMER	CTD watch (4-8) and sampling
Philippe Le Bot	IFREMER	chemistry, O2
Michel Hamon	IFREMER	chemistry, salinity
Iago Lopez Rodriguez	CSIC	Technical resp.
Manuel Garcia Salazar	UTM	CTD watch
David Angel Fernandez Fontaiña	UTM	CTD watch
Raoul Vicente Guillot Miralles	UTM	CTD watch

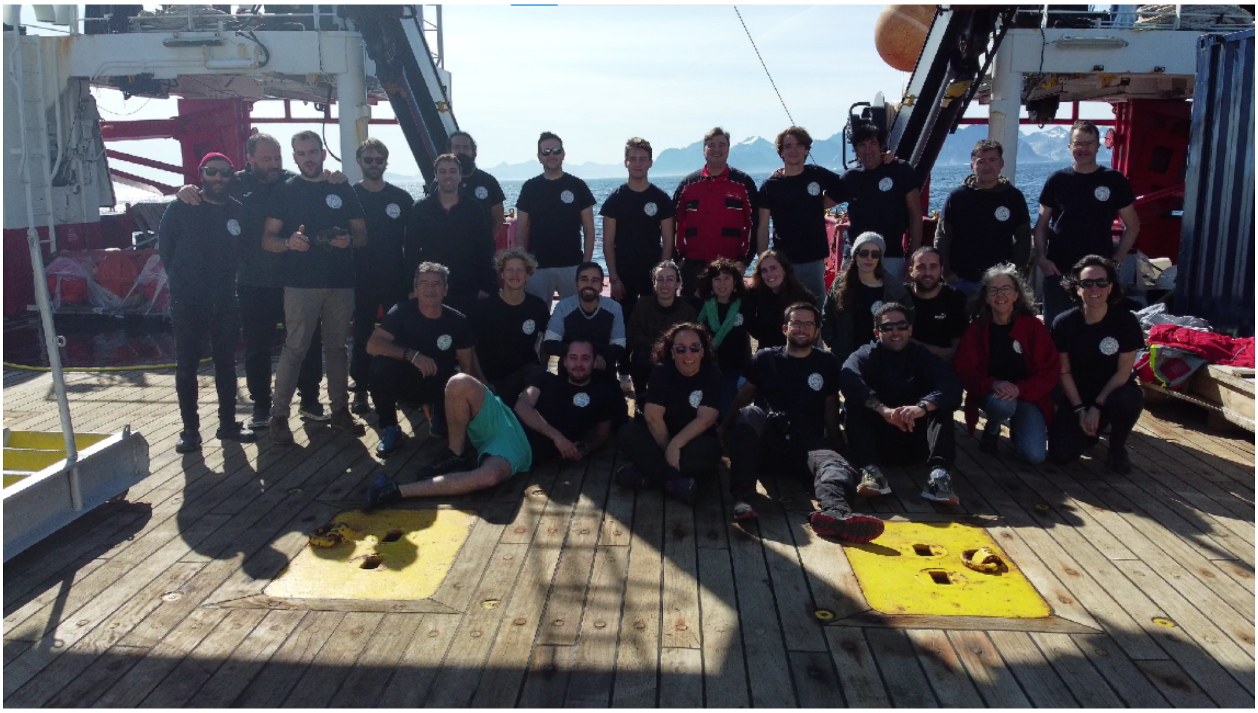


Figure 3: Scientific team and UTM crew members

1.3 Description of cruise operations

The following operations were carried out during the cruise:

- 6 stations in Vigo ria (Figure 4, data not included in this report)

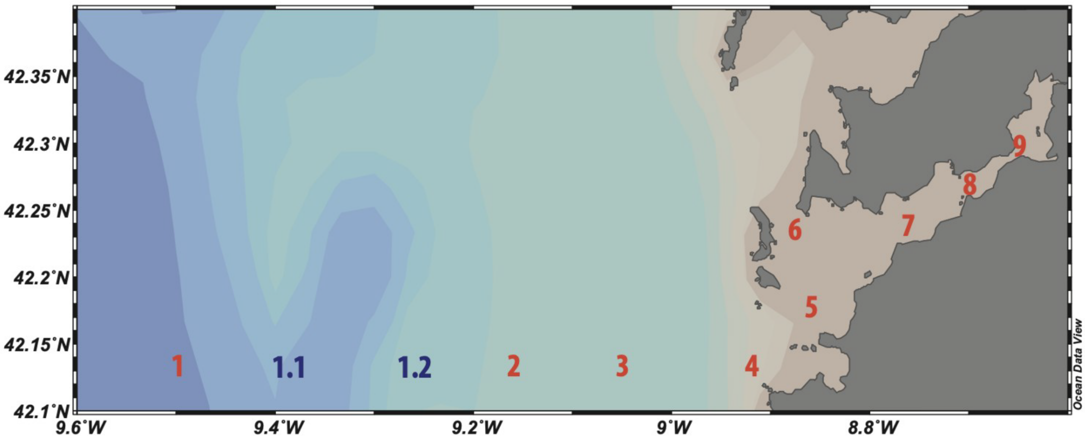


Figure 4 : stations in the Ria of Vigo

- 106 CTD stations with O_2, Salinity, pH total, alkalinity, Carbone total, nitrous oxide, Nutrients, Oxygen 18 sampling:
    - 1 test station (number 0).
    - 107 OVIDE CTD stations (1-98) with 3 casts for the station 68, 5 stations for genomics sampling (called "cast 2" of stations 10, 30, 45, 62 and 83) and 1 station in the Eriador eddy (110)
- 13 CTD stations on a short shelf-break section and on the AR24 section (northern section in Fig.2)

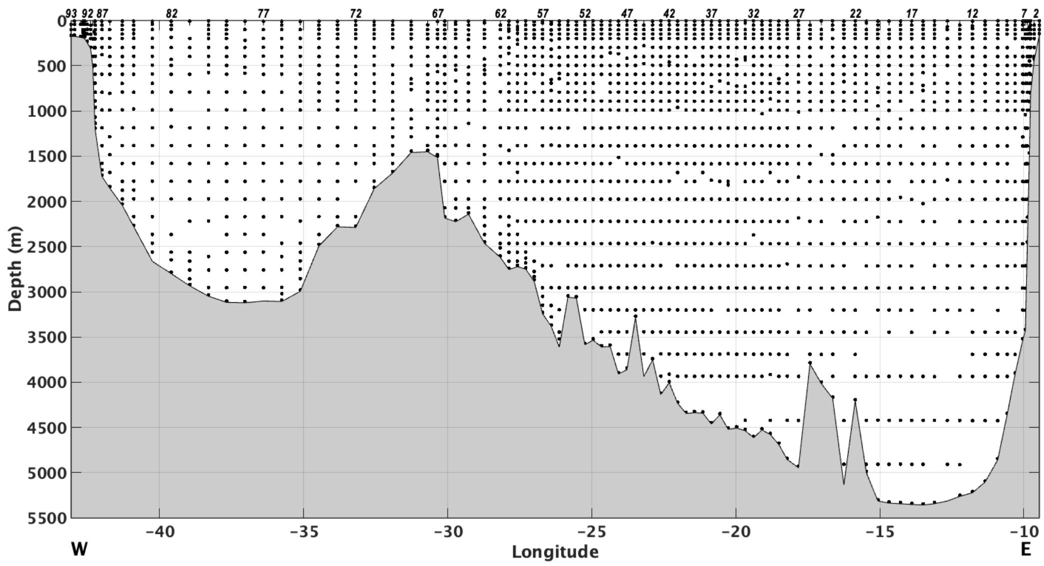


Figure 5: Synoptic chart indicating the sampling levels for CTD

- 5 Argo floats launched (Deep).
- SADCP measurements (Ship Acoustic Doppler Current Profiler, 75 and 150 kHz data acquisition).
- Underway measurements (Thermosalinometer monitoring).
- VMP

1.4 Station list

Station #	Cast #	Latitude begin	Longitude begin	Date begin	Latitude end	Longitude end	Date end	Latitude mean	Longitude mean	2023 day mean	Station durat. (min.)	CTD max depth	Bottom depth
0	1	40.33344	-10.00605	2023/06/09 16:12:49	40.33343	-10.00607	2023/06/09 18:13:20	40.333	-10.006	160.7174	121	3535	3547
1	1	40.33343	-9.45996	2023/06/09 21:27:10	40.33343	-9.45996	2023/06/09 21:36:29	40.33343	-9.45996	160.8971	9	145	154
2	1	40.33332	-9.64266	2023/06/09 23:07:37	40.33332	-9.64271	2023/06/09 23:37:00	40.33332	-9.64269	160.9738	29	423	429
3	1	40.33329	-9.7668	2023/06/10 01:06:10	40.3333	-9.76678	2023/06/10 01:46:24	40.333	-9.767	161.0599	40	801	807
4	1	40.33324	-9.80501	2023/06/10 13:59:26	40.33325	-9.80502	2023/06/10 14:58:21	40.333	-9.805	161.6034	59	1463	1477
5	1	40.33338	-9.87688	2023/06/10 05:41:32	40.33338	-9.87688	2023/06/10 07:23:31	40.333	-9.877	161.2726	102	2449	2479
6	1	40.33335	-9.946	2023/06/10 09:13:43	40.33335	-9.946	2023/06/10 11:44:07	40.333	-9.946	161.4367	150	3412	3421
7	1	40.33334	-10.03711	2023/06/10 17:33:48	40.33347	-10.03694	2023/06/10 19:52:51	40.333	-10.037	161.7801	139	3517	3527
8	1	40.33335	-10.30198	2023/06/10 21:46:45	40.33335	-10.30198	2023/06/11 00:32:20	40.333	-10.302	161.965	166	3894	3904
9	1	40.33332	-10.57693	2023/06/11 02:34:31	40.33332	-10.57695	2023/06/11 05:11:13	40.333	-10.577	162.1617	157	4341	4361
10	1	40.33338	-10.90502	2023/06/11 11:54:34	40.33337	-10.90504	2023/06/11 14:52:47	40.333	-10.905	162.5581	178	4842	4851
10	2	40.33333	-10.90502	2023/06/11 07:20:10	40.33333	-10.90501	2023/06/11 09:56:14	40.333	-10.905	162.36	156	4423	4851
11	1	40.33344	-11.34288	2023/06/11 18:02:34	40.33343	-11.34288	2023/06/11 21:12:22	40.333	-11.343	162.8177	190	5088	5099
12	1	40.33316	-11.78278	2023/06/12 00:14:21	40.33317	-11.78274	2023/06/12 03:19:24	40.333	-11.783	163.0742	185	5206	5215
13	1	40.33457	-12.2207	2023/06/12 06:49:16	40.33356	-12.22339	2023/06/12 10:05:38	40.334	-12.222	163.3524	196	5246	5261
14	1	40.55193	-12.65496	2023/06/12 13:38:31	40.55194	-12.65498	2023/06/12 16:44:02	40.552	-12.655	163.6328	186	5297	5307
15	1	40.78734	-13.09996	2023/06/12 21:51:48	40.78801	-13.10098	2023/06/13 01:20:50	40.788	-13.1	163.9836	209	5327	5338
16	1	41.08794	-13.49694	2023/06/13 05:07:25	41.08793	-13.49686	2023/06/13 08:24:15	41.088	-13.497	164.2818	197	5342	5347
17	1	41.38292	-13.88895	2023/06/13 12:26:16	41.38291	-13.88894	2023/06/13 15:31:56	41.383	-13.889	164.5827	186	5336	5346
18	1	41.68244	-14.27948	2023/06/13 19:47:50	41.68405	-14.281	2023/06/13 23:09:54	41.683	-14.28	164.895	202	5328	5338
19	1	41.98292	-14.67689	2023/06/14 02:53:53	41.98292	-14.67688	2023/06/14 06:00:37	41.983	-14.677	165.1856	187	5320	5329
20	1	42.2831	-15.06613	2023/06/14 10:02:50	42.28303	-15.06601	2023/06/14 13:24:47	42.283	-15.066	165.4888	202	5298	5306
21	1	42.57855	-15.46412	2023/06/14 18:25:24	42.58109	-15.4661	2023/06/14 21:27:11	42.58	-15.465	165.8308	182	4983	4991
22	1	42.88111	-15.85356	2023/06/15 01:05:47	42.88112	-15.85325	2023/06/15 03:34:09	42.881	-15.853	166.0972	148	4190	4200

Station #	Cast #	Latitude begin	Longitude begin	Date begin	Latitude end	Longitude end	Date end	Latitude mean	Longitude mean	2023 day mean	Station durat. (min.)	CTD max depth	Bottom depth
23	1	43.18057	-16.24574	2023/06/15 07:18:57	43.18202	-16.24689	2023/06/15 10:31:55	43.181	-16.246	166.3718	193	5117	5125
24	1	43.48023	-16.63559	2023/06/15 14:06:16	43.48022	-16.6356	2023/06/15 16:34:07	43.48	-16.636	166.639	148	4163	4173
25	1	43.78047	-17.02924	2023/06/15 21:41:35	43.78002	-17.03	2023/06/16 00:20:29	43.78	-17.03	166.9591	159	3999	4006
26	1	44.07928	-17.42313	2023/06/16 03:54:30	44.07923	-17.42281	2023/06/16 06:08:28	44.079	-17.423	167.2094	134	3782	3789
27	1	44.37704	-17.82174	2023/06/16 09:53:39	44.37703	-17.82174	2023/06/16 13:02:26	44.377	-17.822	167.4778	189	4930	4939
28	1	44.68003	-18.21453	2023/06/16 17:57:51	44.68004	-18.21451	2023/06/16 20:54:13	44.68	-18.215	167.8097	176	4838	4847
29	1	45.0352	-18.50559	2023/06/17 00:29:26	45.03521	-18.50557	2023/06/17 03:13:42	45.035	-18.506	168.0775	164	4672	4675
30	1	45.42317	-18.80074	2023/06/17 11:14:08	45.42317	-18.8009	2023/06/17 14:07:33	45.423	-18.801	168.5284	173	4563	4574
30	2	45.4236	-18.80092	2023/06/17 07:07:47	45.4236	-18.80092	2023/06/17 09:40:03	45.424	-18.801	168.3499	152	4419	4571
31	1	45.7958	-19.09068	2023/06/17 17:45:00	45.7958	-19.09066	2023/06/17 20:32:22	45.796	-19.091	168.7977	167	4512	4520
32	1	46.17531	-19.38078	2023/06/18 00:56:10	46.17532	-19.38083	2023/06/18 03:54:26	46.175	-19.381	169.1009	178	4597	4605
33	1	46.54448	-19.67029	2023/06/18 07:58:31	46.54398	-19.67311	2023/06/18 10:51:18	46.544	-19.672	169.3923	173	4520	4528
34	1	46.91693	-19.96856	2023/06/18 15:37:24	46.91695	-19.96855	2023/06/18 18:28:46	46.917	-19.969	169.7105	171	4491	4503
35	1	47.2876	-20.26376	2023/06/18 22:18:56	47.29005	-20.26293	2023/06/19 01:16:29	47.289	-20.263	169.9915	178	4504	4515
36	1	47.66618	-20.55279	2023/06/19 04:31:49	47.66618	-20.5528	2023/06/19 07:16:11	47.666	-20.553	170.2458	164	4344	4354
37	1	48.03797	-20.84799	2023/06/19 10:39:22	48.03796	-20.84796	2023/06/19 13:30:44	48.038	-20.848	170.5035	171	4446	4458
38	1	48.41274	-21.14052	2023/06/19 16:45:17	48.41275	-21.14049	2023/06/19 19:38:49	48.413	-21.141	170.7584	174	4326	4337
39	1	48.83544	-21.43043	2023/06/20 00:35:15	48.83597	-21.43081	2023/06/20 03:22:02	48.836	-21.431	171.0824	167	4321	4332
40	1	49.15795	-21.72378	2023/06/20 06:19:52	49.15795	-21.7238	2023/06/20 09:04:29	49.158	-21.724	171.321	165	4329	4342
41	1	49.54758	-22.0185	2023/06/20 12:20:09	49.54775	-22.01998	2023/06/20 15:04:49	49.548	-22.019	171.5712	165	4217	4228
42	1	49.90622	-22.30938	2023/06/20 19:30:17	49.90511	-22.31106	2023/06/20 22:06:47	49.906	-22.31	171.867	157	3990	4003
43	1	50.27674	-22.60328	2023/06/21 01:16:04	50.27693	-22.60366	2023/06/21 03:59:17	50.277	-22.603	172.1095	163	4120	4132
44	1	50.64018	-22.88552	2023/06/21 07:08:38	50.64019	-22.88553	2023/06/21 09:34:28	50.64	-22.886	172.3483	146	3737	3748
45	1	51.02908	-23.19045	2023/06/21 16:20:57	51.0291	-23.19046	2023/06/21 18:48:17	51.029	-23.19	172.7324	147	3922	3934
45	2	51.02838	-23.19055	2023/06/21 12:50:45	51.0281	-23.19012	2023/06/21 15:08:38	51.028	-23.19	172.5831	138	3850	3932
46	1	51.3994	-23.48023	2023/06/21 22:15:09	51.39925	-23.48025	2023/06/22 00:25:25	51.399	-23.48	172.9724	130	3268	3277

Station #	Cast #	Latitude begin	Longitude begin	Date begin	Latitude end	Longitude end	Date end	Latitude mean	Longitude mean	2023 day mean	Station durat. (min.)	CTD max depth	Bottom depth
47	1	51.77195	-23.7774	2023/06/22 03:43:37	51.77196	-23.77736	2023/06/22 06:13:11	51.772	-23.777	173.2072	150	3844	3854
48	1	52.14356	-24.07072	2023/06/22 09:32:12	52.14589	-24.07104	2023/06/22 12:02:30	52.145	-24.071	173.4495	150	3894	3904
49	1	52.5207	-24.36053	2023/06/22 15:12:34	52.52069	-24.36052	2023/06/22 17:27:23	52.521	-24.361	173.6805	135	3589	3599
50	1	52.89236	-24.66236	2023/06/22 21:07:03	52.89231	-24.66236	2023/06/22 23:27:27	52.892	-24.662	173.9286	140	3595	3605
51	1	53.26626	-24.95247	2023/06/23 02:42:22	53.26626	-24.95248	2023/06/23 04:54:31	53.266	-24.952	174.1586	132	3518	3528
52	1	53.63956	-25.23797	2023/06/23 08:09:18	53.63971	-25.23821	2023/06/23 10:32:32	53.64	-25.238	174.3895	143	3570	3579
53	1	54.01536	-25.5336	2023/06/23 23:46:10	54.01536	-25.5336	2023/06/24 01:45:10	54.015	-25.534	175.0317	119	3054	3062
54	1	54.38781	-25.82721	2023/06/24 05:03:02	54.38791	-25.82723	2023/06/24 07:02:25	54.388	-25.827	175.2519	119	3045	3055
55	1	54.76364	-26.12515	2023/06/24 11:13:01	54.76364	-26.12514	2023/06/24 13:39:41	54.764	-26.125	175.5183	147	3596	3608
56	1	55.14853	-26.40474	2023/06/25 20:33:02	55.14917	-26.40487	2023/06/25 23:00:22	55.149	-26.405	176.9074	147	3367	3379
57	1	55.50495	-26.70668	2023/06/26 05:09:02	55.50495	-26.70666	2023/06/26 07:14:10	55.505	-26.707	177.2581	125	3226	3235
58	1	55.88408	-26.99811	2023/06/26 10:10:57	55.88355	-26.99836	2023/06/26 12:04:02	55.884	-26.998	177.4635	113	2869	2881
59	1	56.25246	-27.29118	2023/06/26 15:15:44	56.25252	-27.2913	2023/06/26 17:04:47	56.252	-27.291	177.6738	109	2734	2742
60	1	56.6275	-27.57871	2023/06/26 20:27:18	56.62748	-27.57864	2023/06/26 22:18:57	56.627	-27.579	177.8911	112	2706	2717
61	1	57.00244	-27.87525	2023/06/27 01:26:42	57.00304	-27.87636	2023/06/27 03:18:51	57.003	-27.876	178.0991	112	2739	2751
62	1	57.37679	-28.1721	2023/06/27 06:27:47	57.37682	-28.17207	2023/06/27 08:11:51	57.377	-28.172	178.3054	104	2603	2613
62	2	57.37679	-28.17205	2023/06/27 09:15:19	57.37679	-28.17215	2023/06/27 10:48:32	57.377	-28.172	178.418	93	2602	2614
63	1	57.674	-28.72496	2023/06/27 14:12:40	57.67401	-28.72499	2023/06/27 15:53:33	57.674	-28.725	178.6272	101	2448	2458
64	1	57.96925	-29.27684	2023/06/27 19:43:45	57.96961	-29.27721	2023/06/27 21:12:43	57.969	-29.277	178.8529	89	2126	2136
65	1	58.20675	-29.72217	2023/06/28 00:46:36	58.20672	-29.72223	2023/06/28 02:22:34	58.207	-29.722	179.0657	96	2210	2222
66	1	58.4097	-30.10234	2023/06/28 05:44:54	58.40974	-30.1022	2023/06/28 07:12:15	58.41	-30.102	179.2698	87	2169	2178
67	1	58.536	-30.3553	2023/06/28 11:08:43	58.536	-30.35527	2023/06/28 12:12:39	58.536	-30.355	179.4866	64	1499	1508
68	1	58.72598	-30.69624	2023/06/29 06:15:08	58.72598	-30.69627	2023/06/29 07:14:44	58.726	-30.696	180.2812	60	1436	1447
69	1	58.84574	-31.26749	2023/07/01 01:35:03	58.84567	-31.26765	2023/07/01 02:37:25	58.846	-31.268	182.0877	62	1444	1455
70	1	58.91007	-31.90983	2023/07/01 05:43:17	58.9101	-31.90984	2023/07/01 06:53:23	58.91	-31.91	182.2627	70	1671	1681
71	1	58.97344	-32.55282	2023/07/01 10:00:22	58.97347	-32.5528	2023/07/01 11:22:05	58.973	-32.553	182.4453	82	1845	1850

Station #	Cast #	Latitude begin	Longitude begin	Date begin	Latitude end	Longitude end	Date end	Latitude mean	Longitude mean	2023 day mean	Station durat. (min.)	CTD max depth	Bottom depth
72	1	59.04106	-33.19231	2023/07/01 14:23:05	59.04105	-33.19372	2023/07/01 15:54:54	59.041	-33.193	182.6312	92	2273	2284
73	1	59.10237	-33.82426	2023/07/01 19:27:30	59.10238	-33.82429	2023/07/01 20:58:19	59.102	-33.824	182.8423	91	2266	2275
74	1	59.16362	-34.46759	2023/07/02 01:28:40	59.16388	-34.46899	2023/07/02 03:07:06	59.164	-34.468	183.0958	98	2476	2486
75	1	59.23275	-35.11732	2023/07/02 06:25:37	59.23275	-35.11733	2023/07/02 08:24:44	59.233	-35.117	183.3091	119	2979	2988
76	1	59.28476	-35.76022	2023/07/02 12:12:54	59.28491	-35.76142	2023/07/02 14:16:40	59.285	-35.761	183.5519	124	3091	3100
77	1	59.36245	-36.39497	2023/07/02 18:01:39	59.36241	-36.39508	2023/07/02 19:59:59	59.362	-36.395	183.7922	118	3087	3095
78	1	59.42747	-37.03614	2023/07/03 00:15:58	59.42794	-37.03855	2023/07/03 02:19:38	59.428	-37.037	184.054	124	3106	3116
79	1	59.49175	-37.67689	2023/07/03 05:31:53	59.49175	-37.67687	2023/07/03 07:35:27	59.492	-37.677	184.2734	124	3101	3112
80	1	59.55877	-38.30231	2023/07/03 11:13:52	59.55881	-38.30232	2023/07/03 13:13:57	59.559	-38.302	184.5097	120	3034	3042
81	1	59.6239	-38.9552	2023/07/03 16:22:52	59.62386	-38.95519	2023/07/03 18:13:54	59.624	-38.955	184.7211	111	2919	2927
82	1	59.68483	-39.59803	2023/07/03 22:40:42	59.68488	-39.59781	2023/07/04 00:32:44	59.685	-39.598	184.9838	112	2782	2793
83	1	59.72254	-40.25215	2023/07/04 07:03:00	59.72265	-40.25178	2023/07/04 08:49:13	59.723	-40.252	185.3306	106	2648	2658
83	2	59.72339	-40.25234	2023/07/04 04:26:01	59.72346	-40.2524	2023/07/04 05:57:13	59.723	-40.252	185.2164	91	2638	2657
84	1	59.75601	-40.8988	2023/07/04 12:02:15	59.75601	-40.89878	2023/07/04 13:33:27	59.756	-40.899	185.5332	91	2264	2274
85	1	59.77366	-41.29733	2023/07/04 15:46:25	59.77358	-41.29736	2023/07/04 17:08:07	59.774	-41.297	185.6856	82	2028	2037
86	1	59.79358	-41.7311	2023/07/04 19:20:14	59.79359	-41.7311	2023/07/04 20:35:31	59.794	-41.731	185.8319	75	1838	1845
87	1	59.80025	-42.00376	2023/07/04 23:46:49	59.80026	-42.00374	2023/07/05 00:56:14	59.8	-42.004	186.0149	69	1709	1722
88	1	59.80846	-42.23689	2023/07/05 02:24:13	59.80883	-42.23576	2023/07/05 03:18:24	59.809	-42.236	186.119	54	1190	1204
89	1	59.81531	-42.27582	2023/07/05 04:47:11	59.81529	-42.27582	2023/07/05 05:20:33	59.815	-42.276	186.211	33	884	900
90	1	59.81669	-42.31699	2023/07/05 08:12:16	59.8167	-42.31697	2023/07/05 08:37:45	59.817	-42.317	186.3507	25	505	522
91	1	59.82174	-42.39524	2023/07/05 10:10:39	59.82173	-42.39524	2023/07/05 10:25:27	59.822	-42.395	186.4292	15	296	308
92	1	59.83197	-42.51577	2023/07/05 12:24:52	59.83174	-42.51684	2023/07/05 12:39:14	59.832	-42.516	186.5223	14	229	236
93	1	59.91267	-43.07365	2023/07/05 16:24:45	59.91267	-43.07367	2023/07/05 16:36:33	59.913	-43.074	186.688	12	162	171
94	1	59.89613	-42.95835	2023/07/05 18:47:49	59.89612	-42.95834	2023/07/05 19:03:05	59.896	-42.958	186.7885	15	160	167
95	1	59.87848	-42.85026	2023/07/05 20:29:49	59.8785	-42.85016	2023/07/05 20:43:12	59.87849	-42.85021	186.8587	13	177	188
96	1	59.86246	-42.74517	2023/07/05 21:50:55	59.8625	-42.74517	2023/07/05 22:04:45	59.86248	-42.74517	186.9152	14	171	183

Station #	Cast #	Latitude begin	Longitude begin	Date begin	Latitude end	Longitude end	Date end	Latitude mean	Longitude mean	2023 day mean	Station durat. (min.)	CTD max depth	Bottom depth
97	1	59.85346	-42.66609	2023/07/05 22:53:38	59.8533	-42.6667	2023/07/05 23:04:24	59.85338	-42.666395	186.9577	11	177	189
98	1	59.84311	-42.59139	2023/07/05 23:55:13	59.84317	-42.59133	2023/07/06 00:08:55	59.84314	-42.59136	187.0014	14	190	201
110	1	53.42261	-25.63961	2023/06/23 16:18:43	53.42259	-25.63965	2023/06/23 18:20:15	53.423	-25.64	174.7219	122	3645	3656
111	1	60.98646	-42.43172	2023/07/07 06:20:42	60.98647	-42.4317	2023/07/07 06:34:40	60.98646	-42.43171	188.2692	14	150	157
112	1	60.92519	-41.86817	2023/07/07 09:14:32	60.92519	-41.86825	2023/07/07 09:28:10	60.92519	-41.8682	188.3898	14	156	164
113	1	60.89295	-41.61067	2023/07/07 11:15:00	60.89296	-41.61067	2023/07/07 11:50:49	60.893	-41.611	188.4812	36	831	846
114	1	60.86802	-41.39585	2023/07/07 13:59:52	60.86805	-41.39584	2023/07/07 15:22:05	60.868	-41.396	188.6118	82	1766	1777
116	1	64.46191	-37.88953	2023/07/09 04:41:37	64.46191	-37.88953	2023/07/09 05:13:23	64.462	-37.89	190.2066	32	784	795
117	1	64.1114	-36.82104	2023/07/09 10:59:02	64.1114	-36.82104	2023/07/09 11:22:01	64.1114	-36.82104	190.4656	23	398	405
120	1	63.90765	-36.18986	2023/07/09 14:23:43	63.90772	-36.18963	2023/07/09 15:31:15	63.908	-36.19	190.6233	68	1455	1466
121	1	63.74367	-35.66833	2023/07/09 17:58:16	63.74365	-35.66832	2023/07/09 19:22:04	63.744	-35.668	190.7779	84	2145	2155
122	1	63.21645	-34.03577	2023/07/10 01:33:46	63.21645	-34.03593	2023/07/10 03:23:17	63.216	-34.036	191.1031	110	2756	2766
123	1	62.63561	-32.25963	2023/07/10 10:23:55	62.63562	-32.25963	2023/07/10 12:20:04	62.636	-32.26	191.4736	116	2904	2916
124	1	62.03589	-30.51097	2023/07/10 19:04:48	62.03594	-30.51121	2023/07/10 20:30:04	62.036	-30.511	191.8246	85	2135	2144
125	1	61.46724	-28.80203	2023/07/11 03:07:46	61.46725	-28.80203	2023/07/11 04:14:33	61.467	-28.802	192.1536	67	1598	1609
126	1	61.14494	-27.97139	2023/07/11 08:52:40	61.14494	-27.97137	2023/07/11 09:35:49	61.145	-27.971	192.3849	43	954	964

1.5 Overview of the operations and main technical problems during the cruise

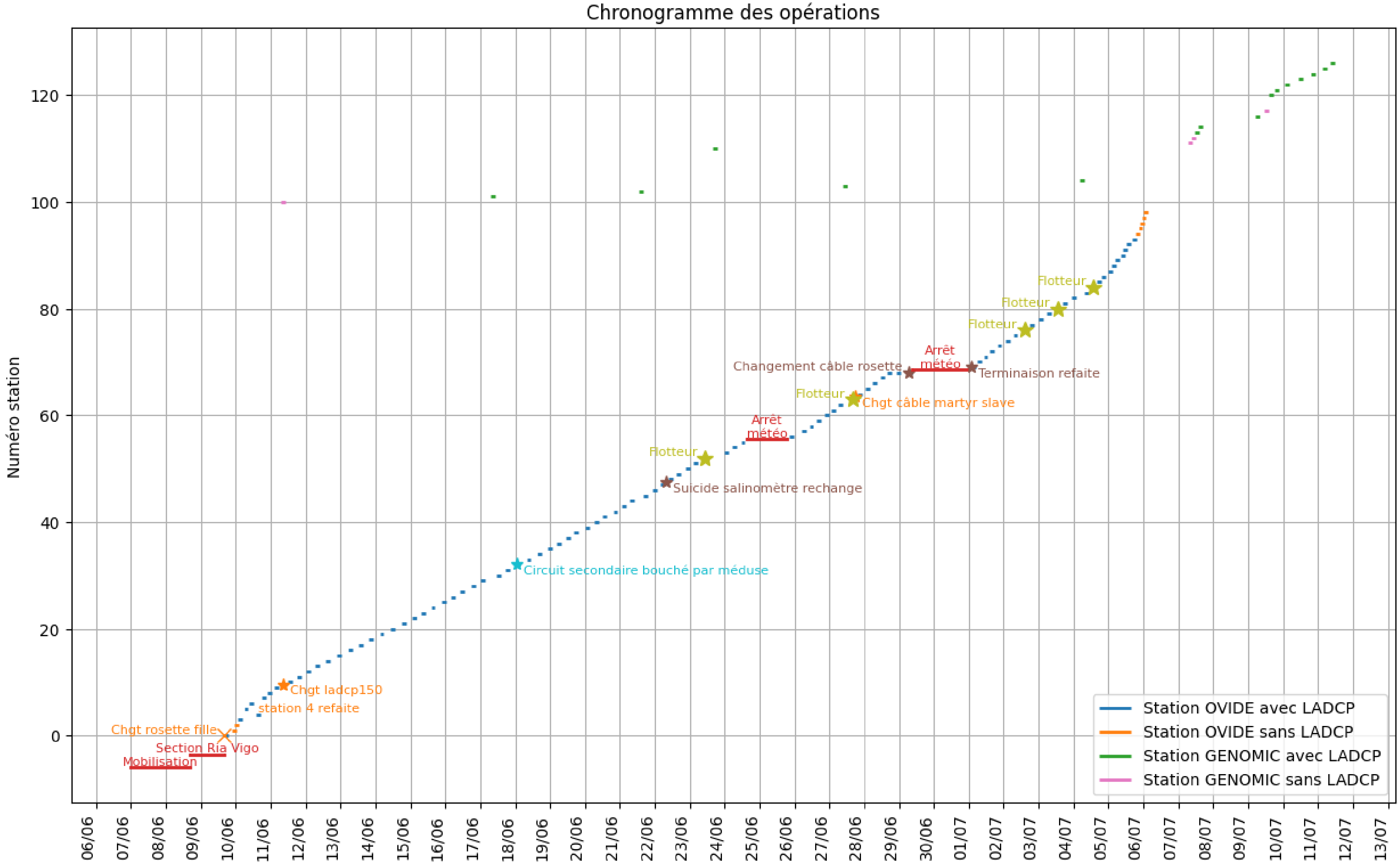


Figure 6: chronogram of the operations

Major incidents during the cruise:

- During the test station, an issue appeared on the CTD rosette motor and one of them was changed
- During the Ria's stations, the first 10 stations of the OVIDE section, and the genomic station number 100 (renamed 10 cast 2), the acquisition frequency of the probe was of 1Hz instead of 24Hz. To compensate this issue, a post processing by interpolation was realized to obtain 24Hz files.
- For station 32, a jelly fish was stuck in the secondary circuit of CTD sensors and disturbed the data.
- At the station 68, a communication issue with the rosette motor appeared. The cable between the 2 motors has been changed.
- At the beginning of the station 69, a problem of communication with the probe appeared. UTM crew made a new connection between the cable of the ship and the probe.
- The cruise was interrupted twice for the bad weather: from 24^{th} to 26^{th} and from 29^{th} to 30^{th} of June.
- We discovered that the position sent to the CTD acquisition PC was not the correct one and showed a drift in latitude and longitude as we moved northwestward (up to 8 Nm). All the positions were corrected based on the reprocessed navigation data. Note that SADCP data were not affected by this bug, and that the position at the bridge and on the screens (other than the one of CTD computer) was correct.

All operations are summarized in Figure 6 as a function of time, with station number on the Y-axis.

2 General information about data acquisition

2.1 Equipment

For hydrology acquisition, we used our LOPS frame with 28 bottles of 8 liters and a SBE911+ CTD. The frame is also equipped with 2 LADCP, electronic reversing sensors and altimeter.

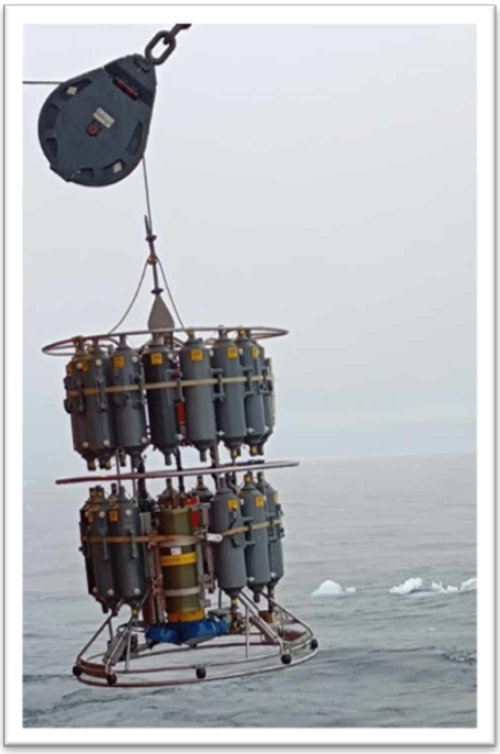


Figure 7: LOPS CTD rosette

(bottles 3 to 16 on the upper level)
(bottles 17 to 30 on the lower level)

Figure 8: Upper LADCP on CTD frame

The same Seabird 911+ CTD probe (s/n. 813) was used throughout the cruise. It was equipped with two sets of T, C, and O2 sensors. The frame was also equipped with 2 LADCP (down-looking 150 kHz and up-looking 300 kHz), 4 SIS reversing sensors (2 for Pressure measurements and 2 for Temperature measurements) and a Valeport altimeter (500 kHz) working at a frequency significantly different than the ADCP's. The LADCPs take the place of bottles 1, 2, 31 and 32.

The CTD sensors used:

	Primary sensors	Secondary sensors
Temperature (SBE3+)	s/n 2911	s/n 4594
Conductivity (SBE4c)	s/n 3194	s/n 3166
Oxygen (SBE43)	s/n 1402	s/n 526

Electronics mounted on the LOPS frame:

	top	bottom
PASH 6000 Rosette	s/n 462	s/n 460
ADCP	Upward-looking: s/n 2002 RDI 300 kHz WorkHorse (slave)	Downward-looking: s/n 23909 RDI 150 kHz WorkHorse (master) and after the station n°9, s/n 24609 RDI 150 kHz WorkHorse
IXSEA Pinger		s/n 530
Valeport altimeter		s/n 59678

SIS Reversing sensors:

	Bottle 3	Bottle 5
SIS pressure meter RPM 6000X	s/n 6664	s/n 6665
SIS thermometer RTM4002X	s/n 1752 and 1750 after station 75	s/n 1751

2.2 CTD Acquisition Protocol

The control of the CTD is carried out by 2 people: one from UTM team and one from IFREMER team.

The CTD casts start with a round trip at a depth of 30 m to remove the air bubbles in the 2 circuits of the sensors. From station 1 to 19, the operators start the data acquisition when the CTD is back near the surface; for the other stations, the acquisition started before, including the surface soak. The CTD downcast is run from the surface down to a distance of about 10 meters above the bottom. The final bottom approach is performed using the altimeter, as soon as it has 'latched' the bottom at a distance of about 90 m. During the upcast, the frame is stopped at predefined levels of closure of the 28 sampling bottles. A delay of 30 seconds at each level is respected before closing the bottle(s) and the CTD data are recorded during 8 seconds to generate the bottles files. The electro-mechanical cable is unwound and wound at a speed of 1 m/s.

The measurements of the probe are monitored on a screen with Seasave v7 software. This system allows the real time visualization of the different parameters measured and calculated on the profiles, while controlling the quality of the signal transmitted by the probe. All of the data transmitted by the probe, at the rate of 24 cycles per second, are saved on a disk.

2.3 Sampling protocol

As soon as the rosette is on board, the samples are taken from each bottle for the numerous analyses performed on board, in the order recommended by the WOCE instructions: dissolved gas (N_2O/CH_4), alkalinity, carbon isotopes ($\delta^{13}C$), alkalinity, nutrients (silicate, phosphate, nitrate and nitrite), salinity, seawater isotopes ($\delta^{18}O$, δD) and DOC. The bottles are sampled from the deepest to the shallowest levels (from bottle 3 to 30).

The salinity and oxygen samples will be used to adjust the salinity and dissolved oxygen CTD profiles. For a lot of casts, two bottles are fired at the same pressure level to have replicates. It improves the adjustment and helps to quantify the quality of the measurements.

The details of the protocols are described in appendix E and F

3 Chronological steps applied to the CTD-O2 data

3.1 Pre-cruise activity

Seabird calibration

- Calibration and ajustment of the sensors in Pressure, Temperature, Conductivity and Oxygen

Metrology laboratory Ifremer

- Calibration of the pressure and temperature sensors

3.2 During the cruise

Aquisition of the data

- Aquisition of the ".hex" files for each cast and run "Data conversion" in SBEDataProcessing (Seabird software) to obtain a file "ov21st*T1.cnv"
- Check of the chemical analysis (Salinity and Oxygen)
- Check of the corrections between the sensors measurements and the reverse thermometers and pressiometers for the temperature and pressure and the chemical data for salinity and oxygen
- A first calibration of the CTD data is done following 3.3 below

3.3 Post-cruise treatment

Data preparation

- Hydro_nett software applied to clean the data and apply hysteresis correction on oxygen data

Seabrid treatment

- Application of the seabird treatment:
  Filter, Alignctd, Celltm,Loopedit, Binavg (twice: one for upcast and one for dowcast)

Data adjustment

- Hydro_cal software applied
  - adjustements of the pressure, temperature, salinity and oxygen data
  - Data reduction

Data validation

- Hydro_val software applied to correct density inversions

4 CTD probe measurements

Before each cruise, the CTD was adjusted by Seabird for the parameters Pressure, Temperature, Conductivity and Oxygen. New coefficients are calculated for each sensor.

Independently, before and after each cruise our CTD was calibrated in the Ifremer Metrology laboratory which is under COFRAC accreditation for Pressure and Temperature calibration. For this cruise and because the metrology lab had issues with the reference equipment, only the pre-cruise calibration in temperature has been done.

4.1 Pressure measurements

The SBE9+ probe is equipped with a Paroscientific digiquartz pressure sensor which characteristics are:

Resolution: 0.001 %, i.e. 0.1 psi or 0.07 dbar
Accuracy: 0.015 % of the full scale (10000 psi), or in our case ± 1.5 psi or ± 1.0 dbar

The sensor was calibrated by Seabird 28th of November 2022 before the cruise to have new coefficients (Refer to appendix A).

On the CTD, we had only one pressure sensor, so we followed the response of the CTD pressure sensor during the cruise using two reversing pressure meter sensor (SIS RPM 6000X) mounted on bottles 3 and 5. These sensors take the measurements when the bottle closes. We compared the value of the CTD sensor and SIS sensor to detect any drift.

The SIS pressure meters have not been calibrated since we bought them, so we follow relative relation (Figure 9). Due to mechanical problems, the pressure meters did not give data at all stations. But we have enough to assess that no drift was observed in the CTD pressure sensor, so the pressure measured by the SBE 911 was not corrected.

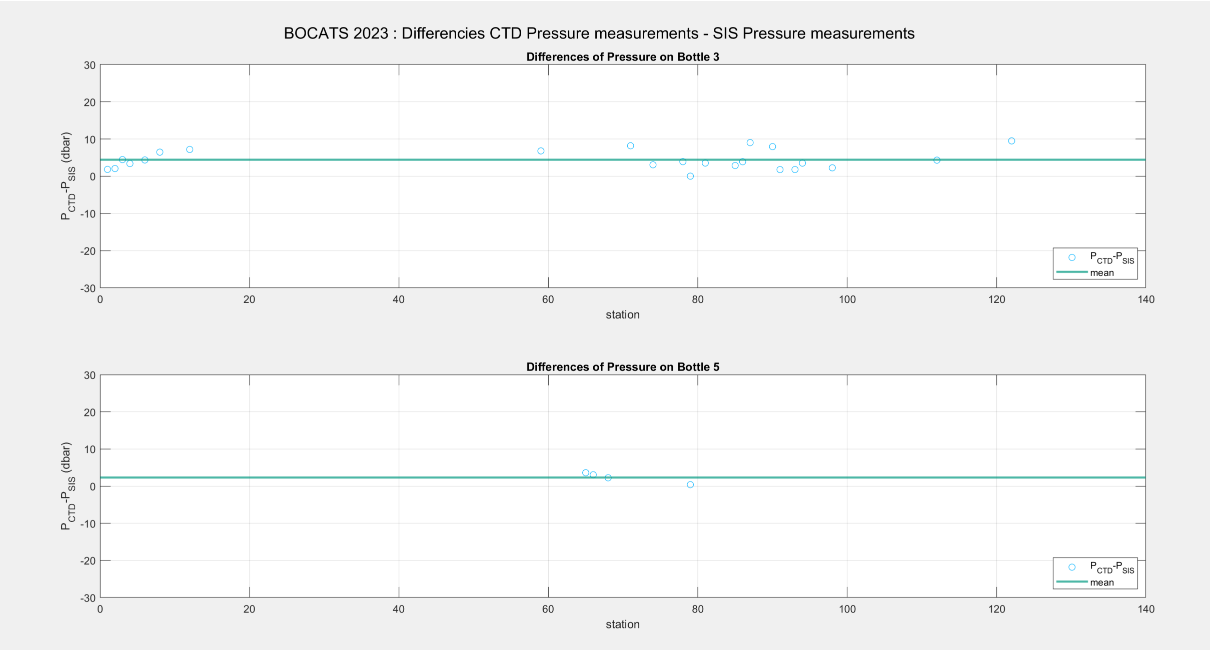


Figure 9: Monitoring of the pressure sensor drift during the cruise

4.2 Temperature measurements

Our probe is equipped with two sets of temperature sensors Seabird SBE3 which characteristics are:

Resolution: 0.0003°C
Accuracy: 0.0010°C

The sensors were calibrated by Seabird the 4th of November 2022 before the cruise to have new coefficients (Refer to appendix B).

4.2.1 Calibration of the temperature sensors at Ifremer metrology laboratory

The temperature sensors are fully immersed in a thermostatic seawater bath HART model 7BATH-045 which temperature stability is ±0.001°C. The reference temperature of the bath is provided by a Rosemount platinum resistance 25Ω thermometer, placed in close proximity to the sensors. This reference thermometer is periodically calibrated at two fixed point of the EIT90: the triple point of water and the Gallium fusion point. The traceability of the measurements to the SI (International system) is sure.

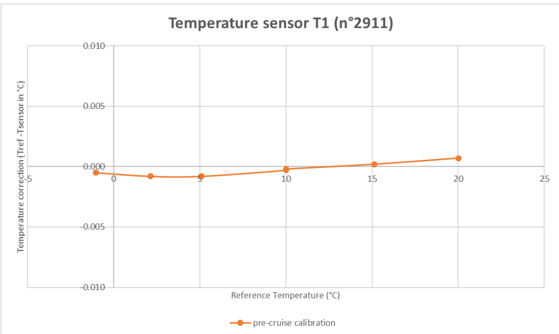


Figure 10: pre-cruise calibration of the primary Temperature sensor n°2911

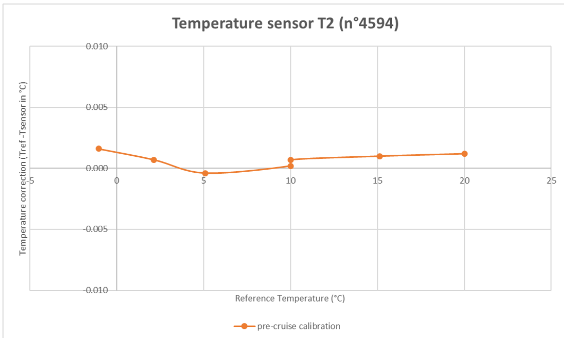


Figure 11: pre-cruise calibration of the secondary temperature sensor n°4594

The uncertainty on the temperature corrections obtained in the laboratory conditions is U = 0.014°C (with k=2)

4.2.2 Correction of the temperature measurements on the CTD profiles

The uncertainty on the correction compared with the correction itself is important so no correction on the temperature measurements was applied but the final uncertainty on the temperature measurements (in the conditions of the laboratory) needs to take in account this correction by add it linearly. The maximal calibration uncertainty obtained is 0.015°C.

<u>Remark</u>: we have to keep in mind that the major component of this budget uncertainty comes from the bath and its homogeneity. The standard deviation of the measurements during the calibration is around 0.0004°C and the repeatability is around 0.0001°C.

4.2.3 Validation of the CTD temperature measurements

During the cruise, we followed the response of the CTD temperature sensor compared with the reversing thermometers (SIS RTM 4002X) on bottle 3 and bottle 5. We compared the value of the CTD sensor and SIS sensor at the bottom to detect any drift. Like for the pressure measurements, some issues occurred during the cruise on these thermometers and a lot of their data couldn't be used.

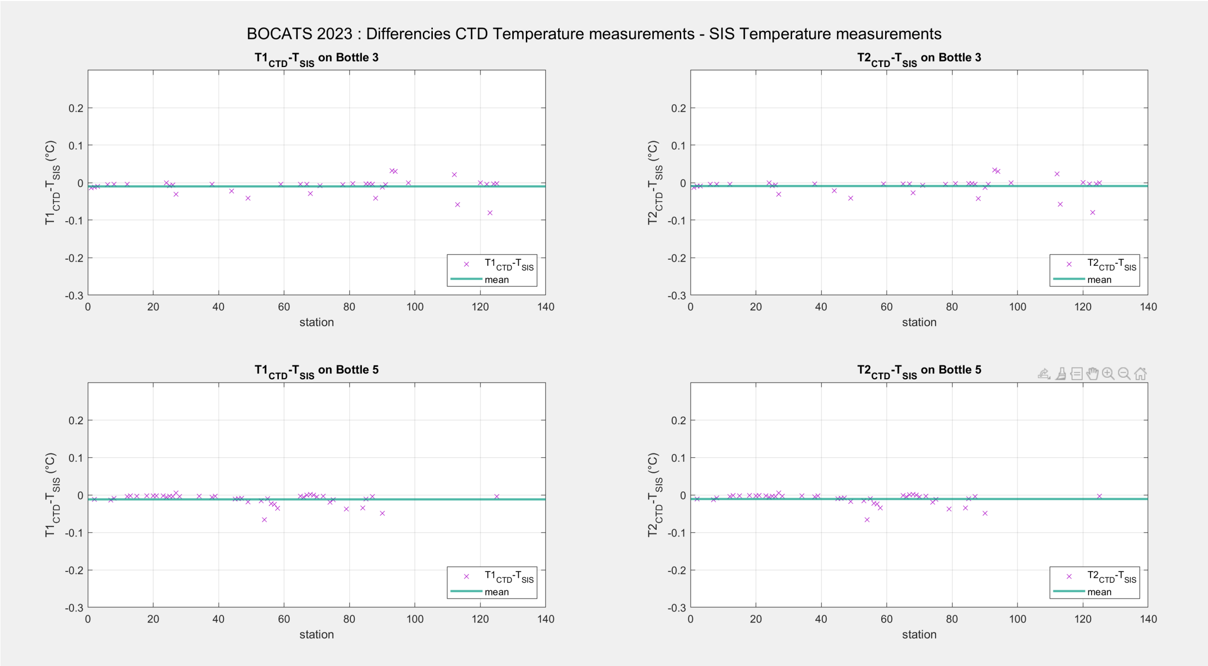


Figure 12: Monitoring of the temperature sensor drift during the cruise

Conclusion: no correction was applied to temperature measurements.

4.3 Conductivity measurements

Our probe is equipped with two sets of conductivity sensors Seabird SBE4c which characteristics are:

Resolution: 0.0004mS/cm
Accuracy: 0.0030mS/cm

The sensors were calibrated by Seabird the 27th of October 2022 before the cruise to have new coefficients (Refer to appendix C).

During the cruise, salinity samples were taken at each station to adjust the conductivity measurements of the probe.

4.4 Oxygen measurements

Two sets of oxygen sensors Seabird SBE43 are also connected to the probe which characteristics are:

Resolution: No information
Accuracy: 2% of saturation

The SBE43 sensors provide data in Volt. To convert them in ml/l, Seabird applies this formula:

$$Oxygen = \left[Soc \times \left(V + V_{offset} + tau * \frac{d_V}{d_t}\right)\right] \times \underbrace{Ox_{sol} \times (1 + A \times T + B \times T^2 + C \times T^3) \times e^{(E \times \frac{P}{K})}}_{\varphi}$$

Where:

- V = Oxygen in volt
- $\frac{d_V}{d_t}$= derivatives (volt/second)
- T = Temperature in °C
- S = Salinity
- P = Pressure in dbar
- K = Temperature in kelvin (°K = °C + 273.15)
- *tau* = Time constant
- Ox_{sol} = Oxygen solubility
- *Soc, Voffset, A, B, C, E:* sensor calibration coefficients

In practice, the term associated with tau is neglected because it adds noise when the profile is homogenous vertically (see Application note n° 64; Nov 2008). The equation becomes:

$$Oxygen = \left[Soc \times \left(V + V_{offset}\right)\right] \times \varphi$$

The sensors were adjusted by Seabird the 23th of February 2023 before the cruise to have new coefficients (Refer to appendix D).

During the cruise, oxygen samples were taken at each station to adjust the dissolved oxygen measurements of the probe.

5 Salinity and oxygen samples analysis

During the cruise, 2406 salinity samples and 2338 oxygen samples were analyzed. Some of them are replicates of two bottles at the same sampling level.

5.1 Equipment

All the salinity and dissolved oxygen samples are analyzed on board, during the cruise, in the LOPS chemical analysis container, which has Metrohm Ti Touch 916 titrator and Guildline Portasal salinometers. Air conditioning allows regulation of the room temperature (20 °C at ± 1 °C).

As soon as the collection of the cast is finished, the samples are placed in the analysis container. The samples (specially the salinity samples) are analyzed 20 to 30 hours after collection to allow them to achieve a thermal equilibrium.

Figure 13: samples boxes

Figure 14: salinity sample

Figure 15: oxygen sample

Figure 16: Metrohm Ti Touch 916 oxygen analyzer with a platinum titrode, a 20 ml burette to deliver the sodium thiosulfate and a 5ml burette to deliver the potassium iodate

Figure 17: Guildline portasal 8410A salinometer

The daily standardization of the measuring instruments (salinometers and tritrinos) was performed by Caroline LE BIHAN, all salinity analyses were performed by Michel HAMON, and oxygen analyses by Philippe LE BOT.

5.2 Salinity analysis

5.2.1 General protocol

The salinity of the samples is determined according to the equation PSS 78 (UNESCO 1981). Throughout the cruise, the temperature of the salinometer is fixed at 21°C.

For each sample, three successive rinses of the cell are performed before making three readings separated each time by a rinse.

The salinometer Guildline was connected to a PC and all the analysis were saved directly on computer with a homemade software in python 'easysal'

All salinity measurements taken during the OVIDE cruise were performed on the same Portasal salinometer (s/n: 71420 id « D »).

This salinometer was standardized using batches of standard seawater bottles (IAPSO Standard Seawater): batch P164 (Salinity = 34.994), P165 (Salinity = 34.994) and P166 (Salinity = 34.995). The standardization was verified every morning and after analysis of two casts (56 samples).

Dates of salinometer adjustment: 11th and 20th of June

5.2.2 Replicates in salinity

The replicates help to quantify the quality of the chemical data.

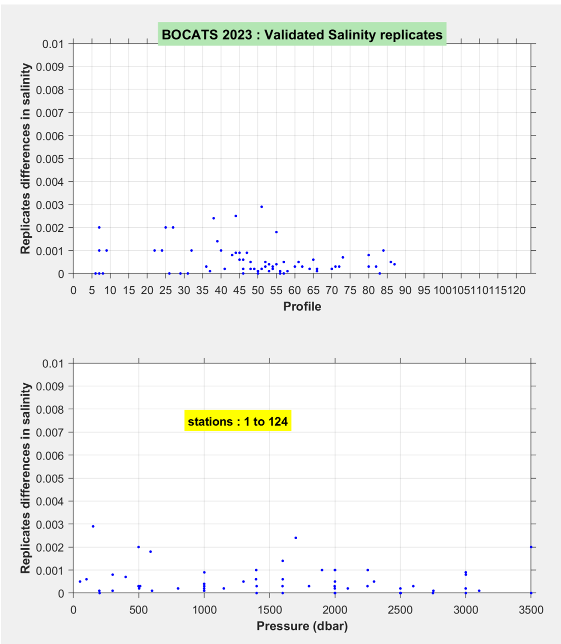


Figure 18: validated salinity replicates

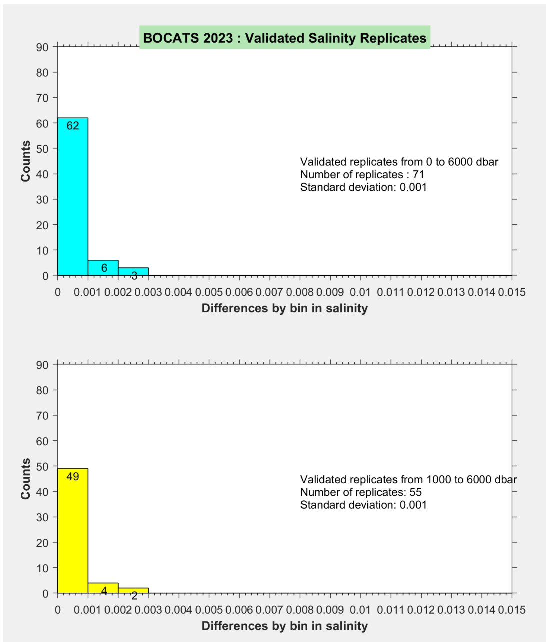


Figure 19: histogram of the validated salinity replicates

The standard deviation of salinity replicates is 0.001, used to quantify "chemical salinity error" (section 6.4.3).

5.3 Oxygen analysis

5.3.1 General protocol

The operating conditions and the analysis method (Winkler titration) comply to the recommendations of WOCE (WOCE Operations Manual, 1991).

The details of the protocol are described in appendix G

After acidification in the sampling bottle, the liberated iodine is dosed with a solution of sodium thiosulfate which normality is about 0.02 N. Its normality is determined daily, before the start of the analysis series, by comparison to a potassium iodate solution, which normality is 0.020015.

The Ti-Touch titrator (with DOSINO1 and control liquid handling Id20-2 et Id5-2) was connected to a PC and all the analysis were saved directly on computer with a homemade software in python 'easytitrino'.

5.3.2 Replicates in oxygen

The replicates help to quantify the quality of the chemical data.

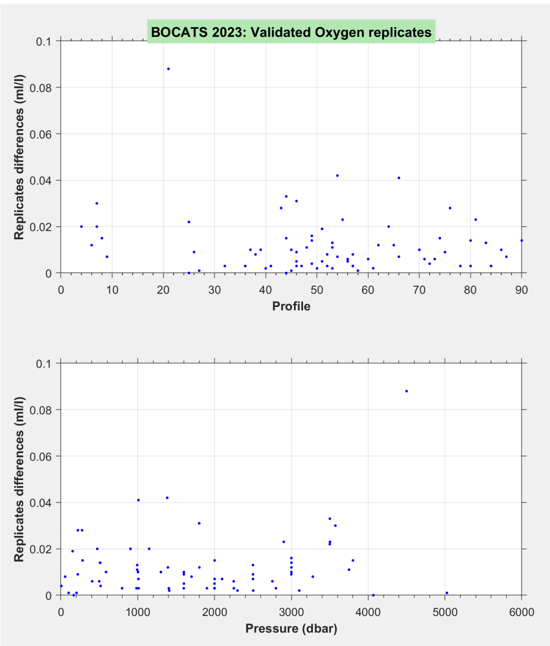


Figure 20: validated oxygen replicates

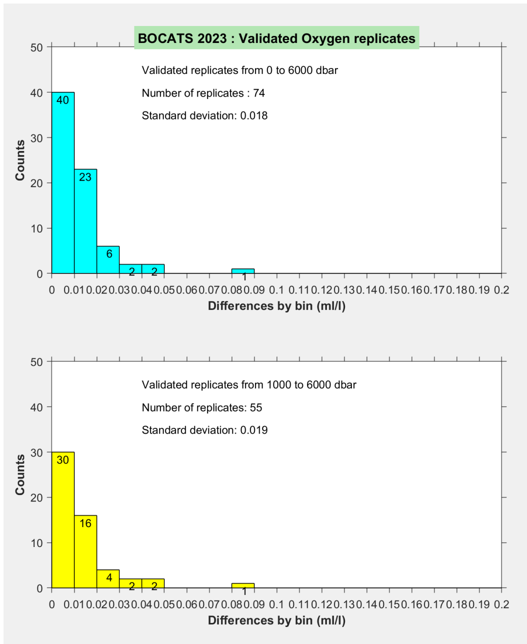


Figure 21: histogram of the validated oxygen replicates

The standard deviation of dissolved oxygen replicates is 0.018 ml/l, used to quantify "chemical oxygen error" (section 6.4.3).

6 Post-cruise treatment

During this part of data treatment, all the steps given in paragraph 3.3 will be described more precisely.

6.1 Data preparation

To clean the measurements, we use the hydro_nett software. Hydro_nett is applied to « bo23st*T1.cnv » files, obtained after decoding the probe measurements by datcnv (part of the SbeDataProcessing seabird software).

6.1.1 Data cleaning with Hydro_nett

The software is first used to correct aberrant pressure measurements in the .cnv files. Then, all measurements are cleaned using thresholds and median deviation tests, parametrized as seen in Figure 22.

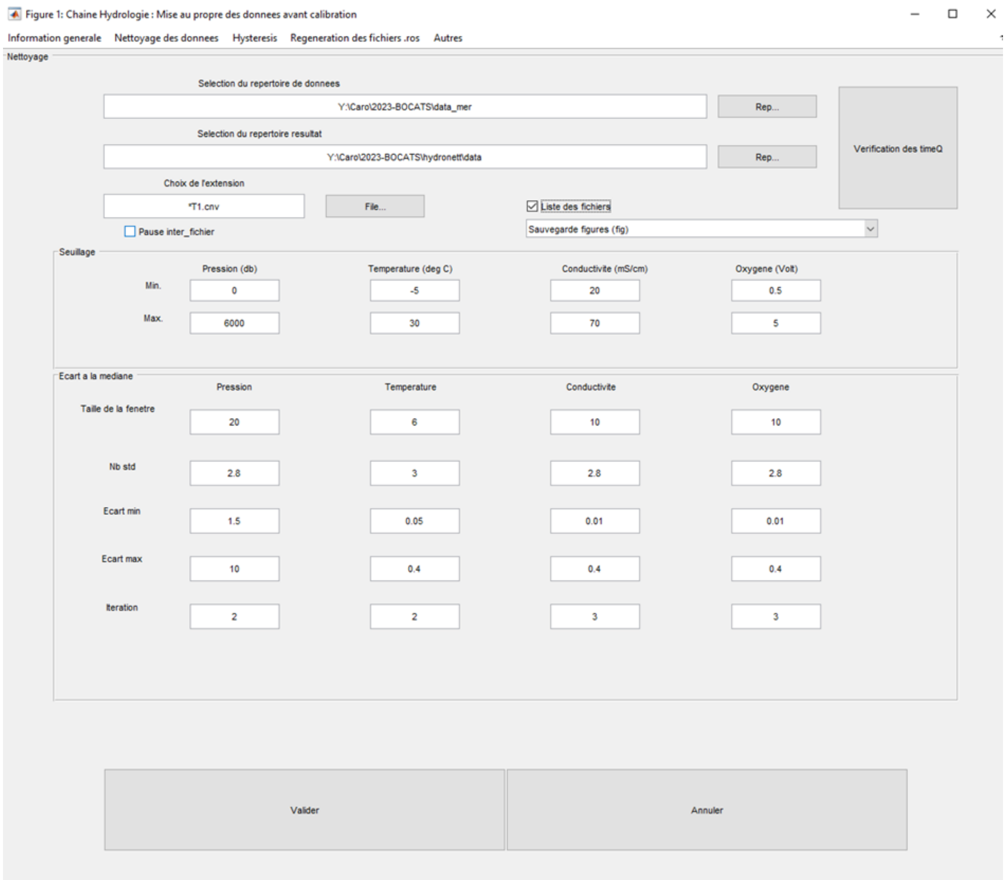


Figure 22: Hydro_nett options used for BOCATS23

6.1.2 Correction of the hysteresis on O2 measurements

The principle of hysteresis correction on the SBE 43 sensor from Seabird is described in the application note SBE 64-3 and was coded in Matlab.

The hysteresis correction depends on three coefficients: H1, H2 and H3. The default values of these coefficients are provided by Seabird.

H1 = -0.033
H2 = 5000
H3 = 1450

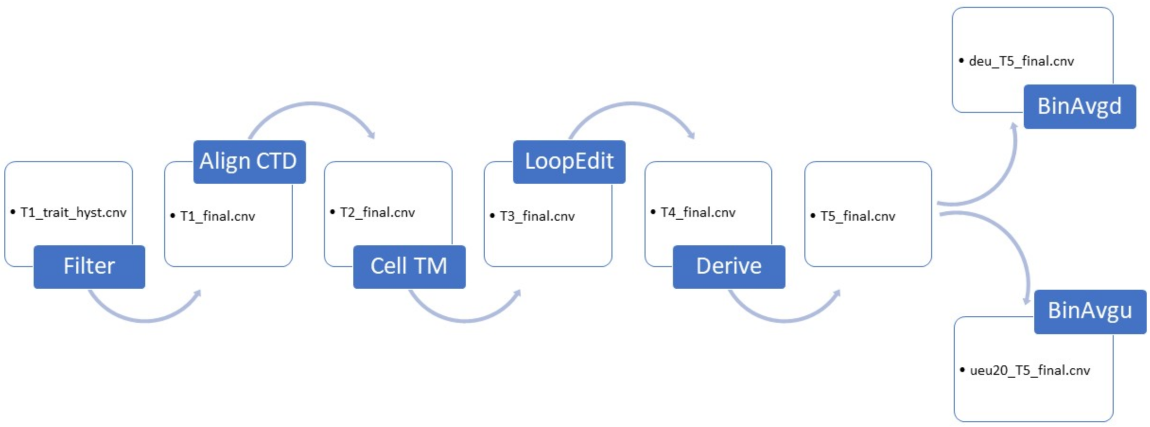
Those coefficients were used for this cruise and the resulting files are called bo23st*T1_trait_hyst.cnv.

6.1.3 Bottle file

After cleaning and correcting the pressure, temperature, conductivity and dissolved oxygen profiles from the probe (referred to as CTDO2 profiles in the following), we create a new bottle file with CTDO2 values corrected. For each station, the name of the file is « bo23st***T1corr.btl ».

6.2 Seabird treatment

Seabird developed a bunch of routines in its Seasoft V2 (SBEDataPostprocessing) software suite in order to improve the recorded probe measurements. The sequence of programs chosen by the LOPS is the result of a study performed on the 2008 CTD cruises (see C. Kermabon, M. Arhan, "Validation et Réduction des données de la sonde 9+", June 2008). The Seabird programs are applied after Hydro_nett and hysteresis correction, with the following parameters:



✧ ***Filter:*** filters on pressure measurements

Low pass filter A: 0.03s
Low pass filter B: 0.15s

✧ ***Alignctd:*** applies a delay on the primary and secondary oxygen measurements

Delay applied: 4s

- ***Cell TM:*** takes into account the effect of the thermal mass of the conductivity cell using a recursive filter

Thermal anomaly amplitude (alpha):	0.03
Thermal anomaly time constant (1/beta):	7

- ***LoopEdit:*** flags the cycles compared to the speed of the probe.

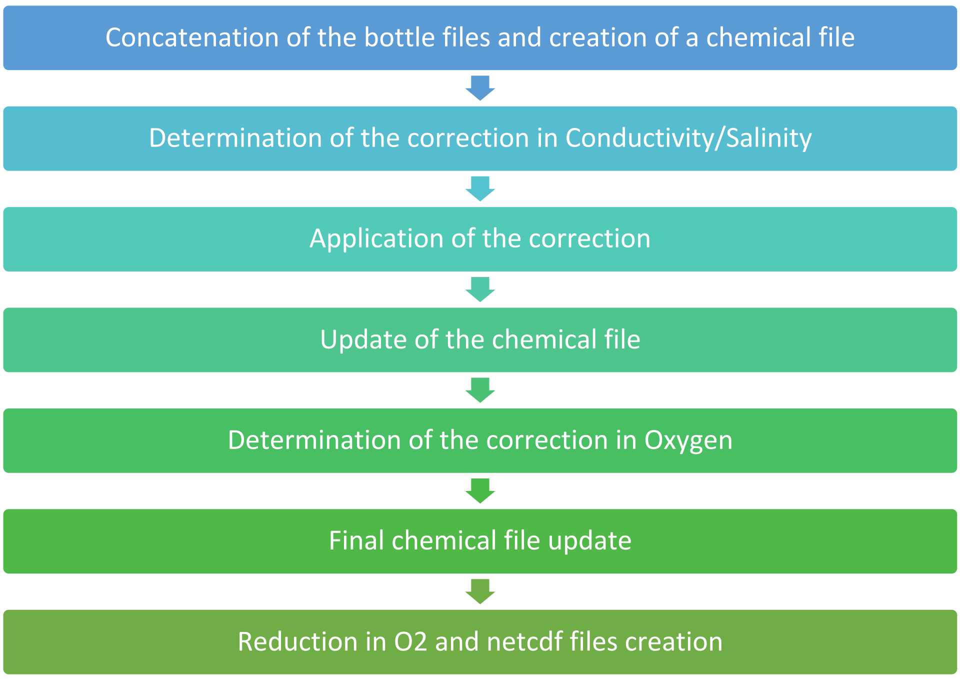
Minimum velocity type:	fixed minimum velocity
Minimum CTD velocity (m/s):	0
Remove surface soak:	Selected when acquisition begins before soaking
Exclude scans marked bad:	selected

- ***Derive***: new calculation of O2 ml/l and salinity.

- ***BinAvg:*** average the data for 1dbar and separate downcast and upcast (not used for calibration)

6.3 Data adjustment

Hydro_cal software, part of the Cadhyac software suite, is used to adjust the data of the probe by following different steps:



At this point, it is necessary to choose between primary and secondary sensors since corrections will most probably be different. For this cruise, primary sensors were chosen for their overall better quality.

6.3.1 Concatenation of the bottle files and creation of a chemical file

The goal of this part is to generate a global file for all the cruise from the bottle files of each station (obtained in the 6.1.3 paragraph) including both CTD and chemical data.

The information in this file is:

- Number of the station
- number of the sampling bottle
- probe's data average at the closure of the bottle (pressure (corrected if it was necessary), primary temperature (corrected if it was necessary), primary conductivity, primary salinity, secondary temperature (corrected if it was necessary), secondary conductivity, secondary salinity, primary oxygen measurement in Volt, secondary oxygen measurement in Volt, primary oxygen data in ml/l and secondary oxygen data in ml/l
- salinity of the sample
- oxygen and temperature of the sample

This "bottle file" is used in the following steps.

6.3.2 Determination of the correction in Conductivity/Salinity

Operating mode

The calibration procedure for the conductivity measurements given by the sensors (CO_S), written according to the recommendations of the GO-SHIP group, first involves the conversion of the chemical salinity into chemical conductivity (CO_H).

Then, the different corrections to be applied successively are calculated to minimize the differences $\Delta C = CO_H - CO_S$ (shown in Figure 23):

• Correction as a function of time to take into account a potential slow drift of the conductivity sensor.

Ccorrsta = Csonde + A2*station^2 + A1*station + A0.

• Correction as a function of the conductivity.

Ccorrcond = Ccorrsta + A2*Ccorrsta^2 + A1*Ccorrsta + A0

• Correction as a function of the pressure.

Ccorr = ***Ccorrcond*** + A5*P^5 + A4*P^4 + ... + A1*P+ A0

The selected coefficients result from successive iterations on the considered group of samples, removing outsiders at each iteration. The process is stopped when no additional sample is removed at the end of the current iteration. It follows that, at the end of the last iteration, all the differences ΔC are lower than the 2.8 * σ (σ : standard deviation of the differences) for the samples used in the calculation process.

Analysis of the initial results and choice of the polynomial correction

The conductivity differences between conductivity bottle and raw conductivity sensor without any correction or offset is plotted in different plots in function of conductivity, time and pressure.

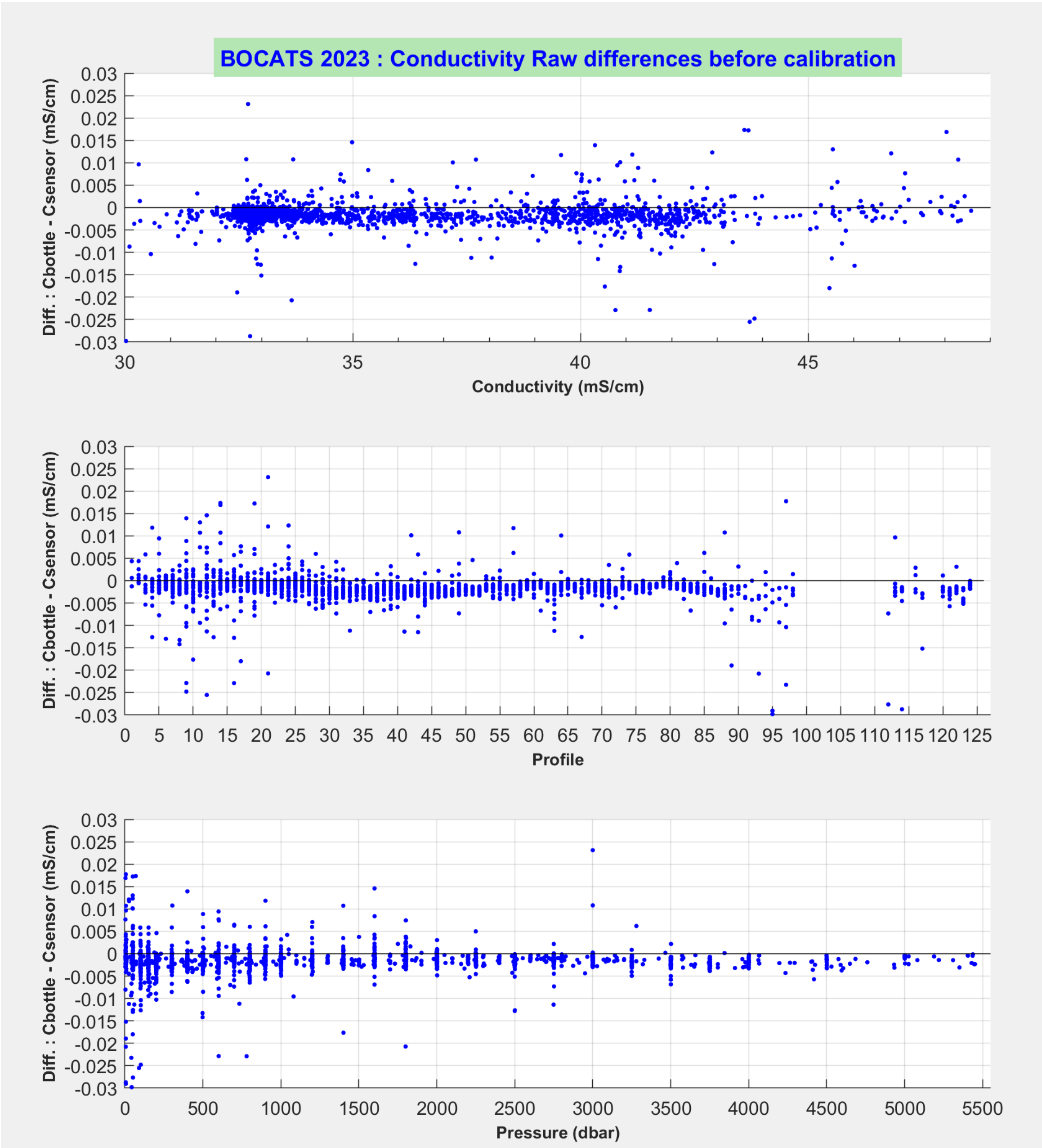


Figure 23: Conductivity raw differences

a) as a function of the conductivity,
b) as a function of the time (as the casts progress),
c) as a function of the pressure of the sampling level.

By analyzing these raw results, we applied the different corrections described in paragraph « Operating mode » successively to all the casts together:

- No correction for a potential drift of the sensor
- A degree 1 polynomial correction as a function of the conductivity
- A degree 1 polynomial correction as a function of the pressure.

Figure 24 shows the result of the adjustment of the conductivity sensor with the application of corrections. All the dots are plotted (blue dots kept as validated samples, red dots rejected) and around 85% of the samples have been kept for the determination of the conductivity correction.

Polynomial corrections applicated:

	Drift coeff		Conductivity coeff		Pressure coeff	
	A_1	A_0	A_1	A_0	A_1	A_0
Station 1-126	0	0	-0.184019	4.17919	2.8157E-4	-0.381161

Table 1: Conductivity polynomial corrections applicated

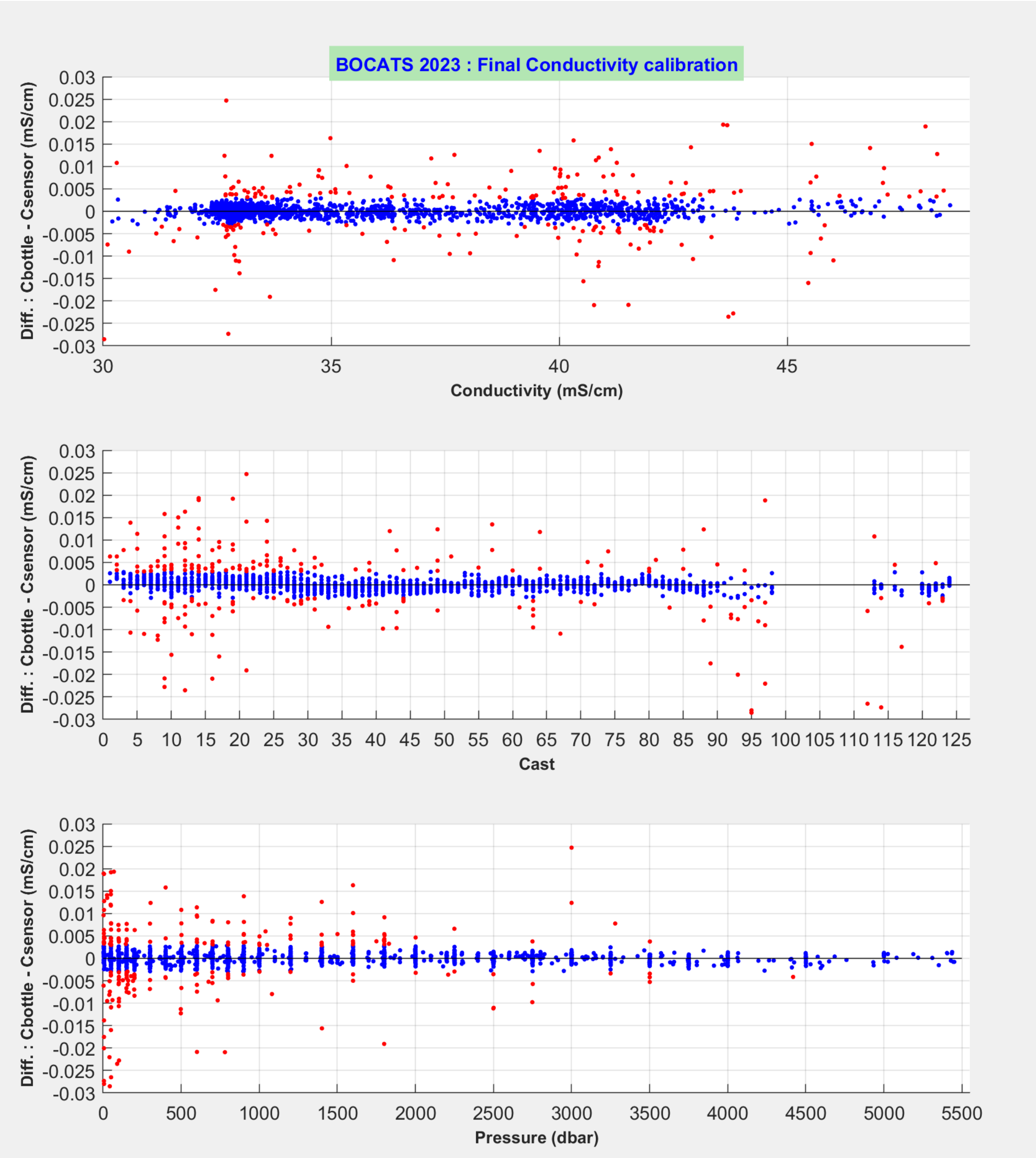


Figure 24: Final conductivity calibration
a) as a function of the conductivity,
b) as a function of the time (as the casts progress),
c) as a function of the pressure of the sampling level.

The differences between the conductivity/salinity of the validated samples and the CTD conductivity/salinity at the sampling level are categorized in these histograms:

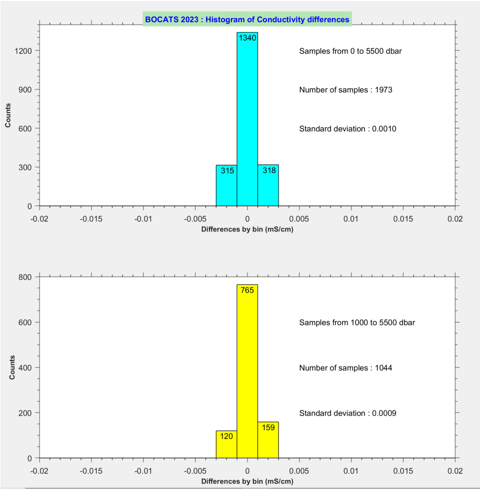


Figure 25: histogram of conductivity differences
a) for all the validated samples
b) for the validated samples at a pressure greater than 980dbar

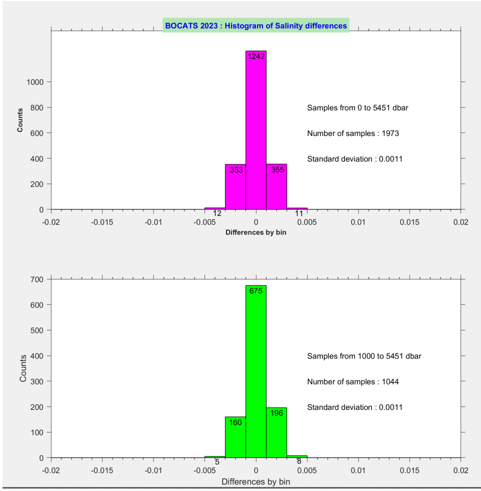


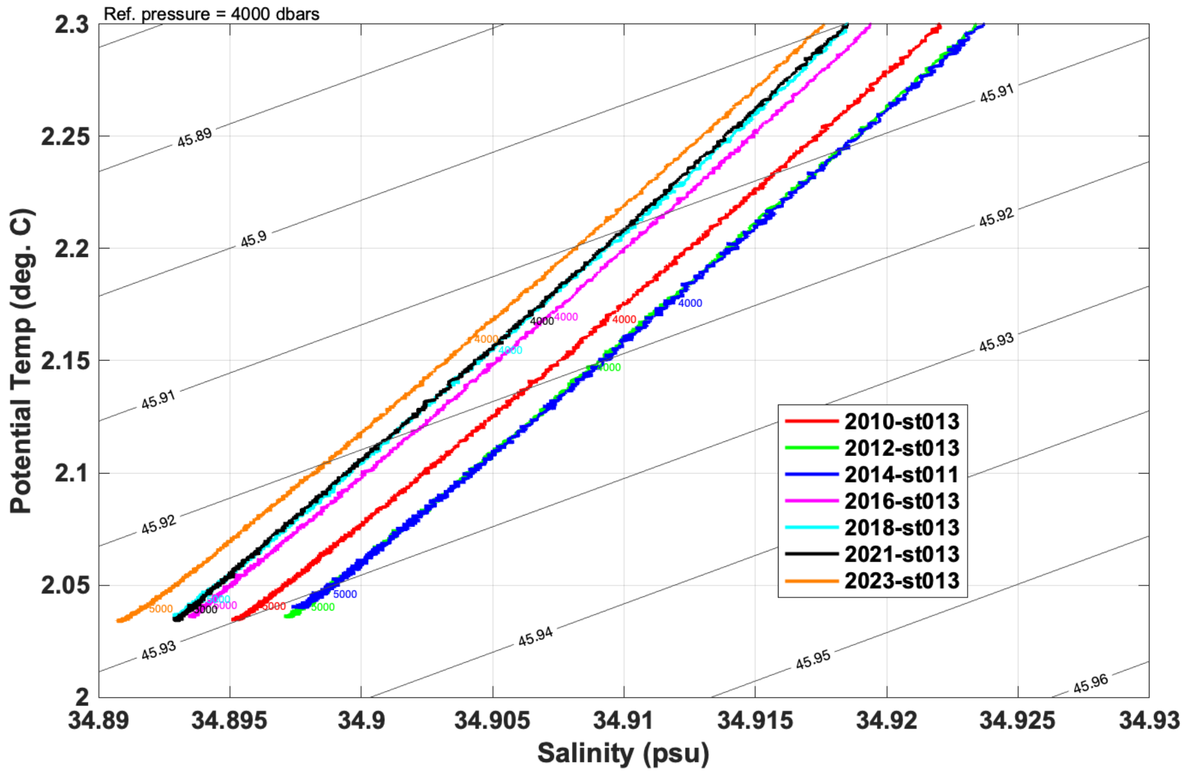
Figure 26: histogram of salinity differences
a) for all the validated samples
b) for the validated samples at a pressure greater than 980dbar

The histograms confirm that the distribution of the differences is satisfactory and confirm the quality of the adjustment.
In 60 % of cases, the differences in conductivity are lower than ± 0.001 mS/cm, while in 100.0 %, they are less than ± 0.003 mS/cm. The standard deviation in conductivity is around 0.001 mS/cm.

6.3.3 Application of the correction

The polynomial correction in conductivity calculated above is apply to all the casts of the cruise and new files are created: bo23st***corr_PTC.cnv

To check the data, the theta-S diagram is plotted for 2 stations visited biennially since 2010 (Figure 27), with a zoom on deep water for evaluating the quality and consistency of the data. Station 13 is located in the deepest part of the Iberian Abyssal Plain, where we expect a minimal variability, as observed, and station 55 is located in the Iceland Basin (in the Maury Channel), where deep water properties vary much more.
Additionally, the theta-S diagrams were plotted for all the casts of 2023 in Figure 28.



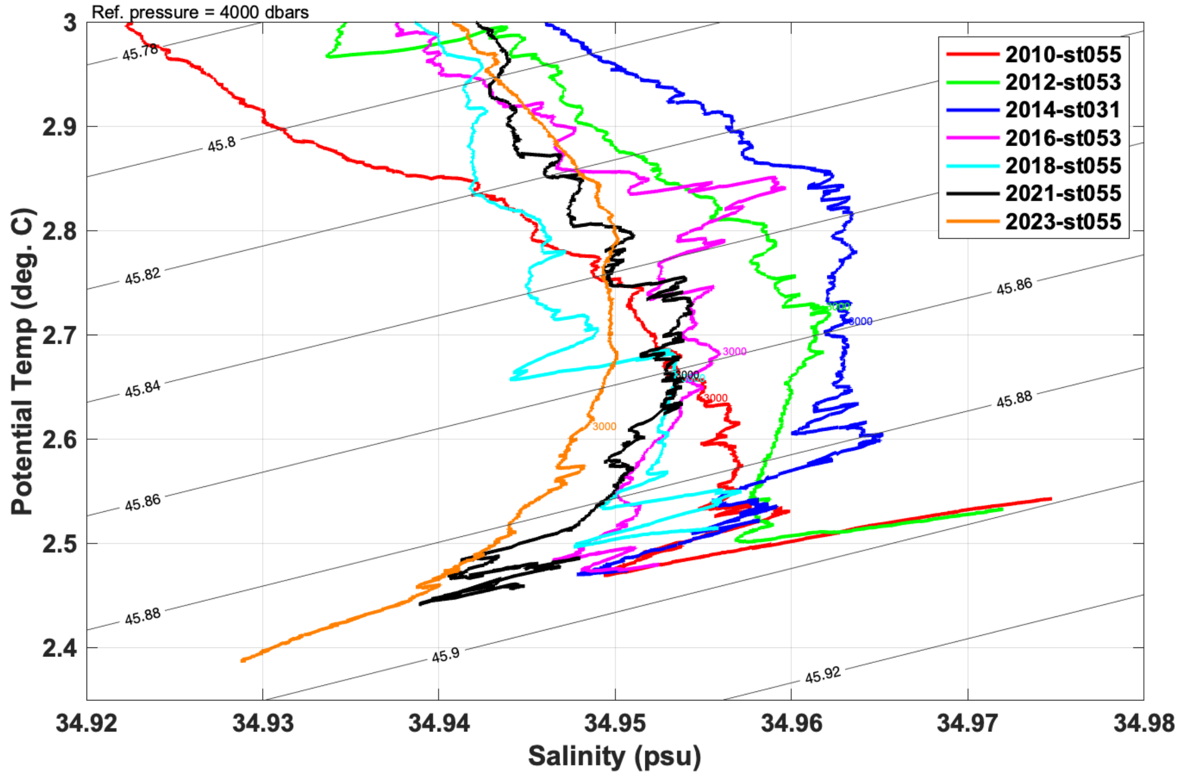


Figure 27: Theta-S comparisons for deep waters of CTD stations made at (top) 40.333°N 12.223°W in Iberian Abyssal Plain, .and (bottom) 54.762°N 26.125°W in Iceland Basin, since 2010. Numbers indicate pressure level every 1000dbar.

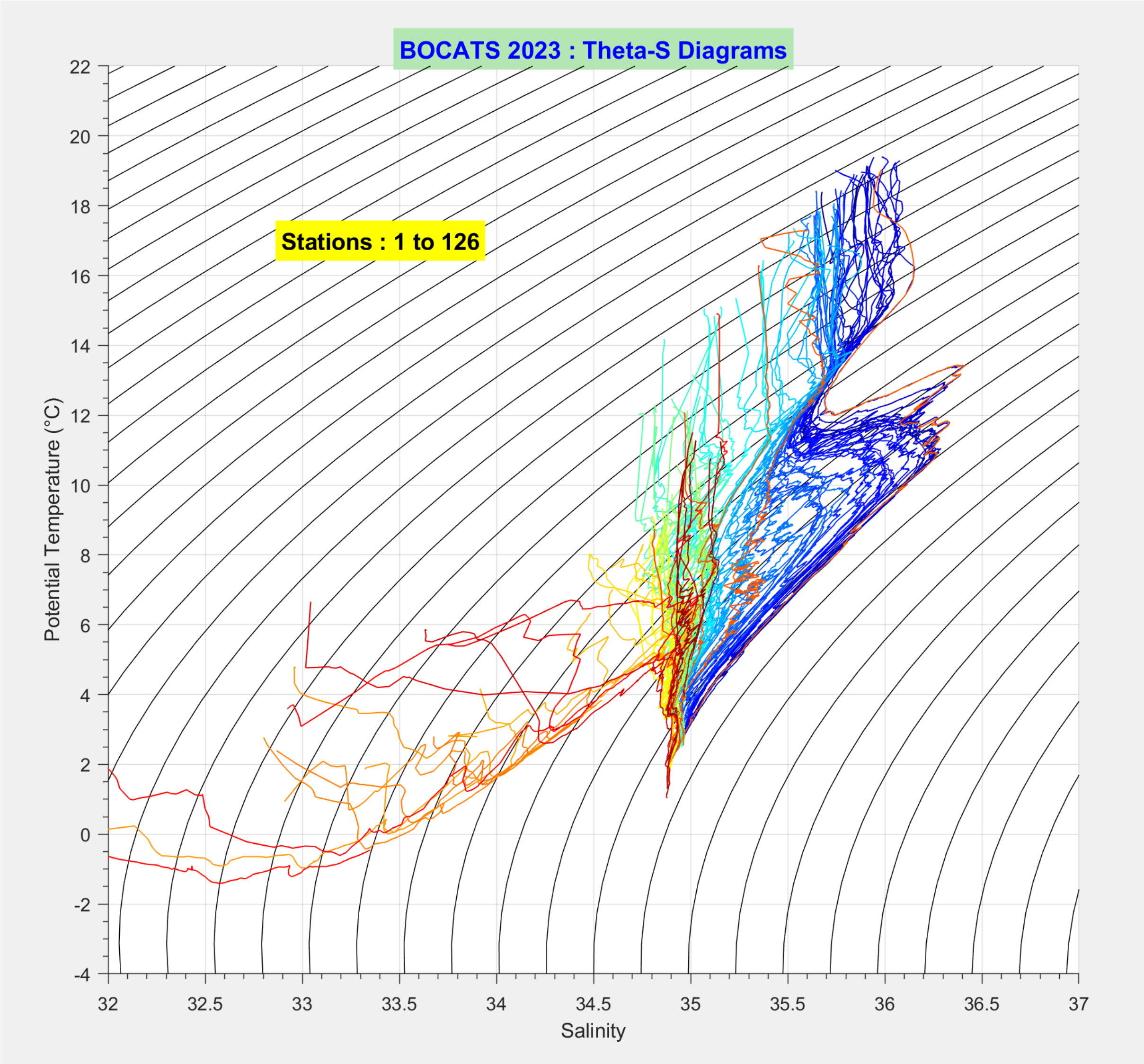


Figure 28: All Theta-S for BOCATS 2023 cruise
The color of the profiles changes gradually from blue (profile 1 to red profile 126). Isopycnals of potential density referenced to the surface are plotted in black.

6.3.4 Update of the chemical file

The chemical file created in the paragraph 6.3.1 will be updated by:

- correcting the conductivity data with the polynomial correction obtained
- preparing the file to the calculation of the better oxygen polynomial correction

Actually, the oxygen data in the file come from the bottle file of the station so taken during the upcast. These data are disturbed with turbulences during the closure of the bottles, and they are also more affected by the sensor hysteresis that is never completely corrected. The idea is to replace these data by the equivalent data **at the same density level of closure from the downcast** of the files bo23st***corr_PTC.cnv generated just above.

6.3.5 Calculation of the polynomial correction in oxygen

Operating mode

The method used to adjust the probe measurements to the chemistry measurements (OXY_C in ml/l) involves the determination of the coefficients M and B of the equation below to minimize the differences between them.

$$\frac{OXY_C}{\varphi} = OXY_S \times M + B$$

Remark: This equation is the developed equation indicated in the paragraph 4.4

where:

$$\varphi = Ox_{sol} \times (1 + A \times T + B \times T^2 + C \times T^3) \times e^{(E \times \frac{P}{K})}$$

OXY_S: data measurement of the probe in Volt

$M = Soc$

$B = V_{offset} \times Soc$

The Soc and V_{offset} coefficients (deduced from the values of M and B) of the Seabird sensor characteristics are determined for a set of samples, using successive iterations based on a principle similar to that for the conductivity.

Thus, and if necessary, a pressure polynomial correction can be calculated (from degree 0 to 5):

$$OXY_{corr} = OXY + A_0 + A_1 \times P + A_2 \times P^2 + \cdots + A_5 \times P^5$$

Analysis of the initial results and choice of the polynomial correction

The oxygen differences between oxygen bottle and oxygen sensor with hysteresis correction is plotted in different plots in function of oxygen, time and pressure (Figure 29).

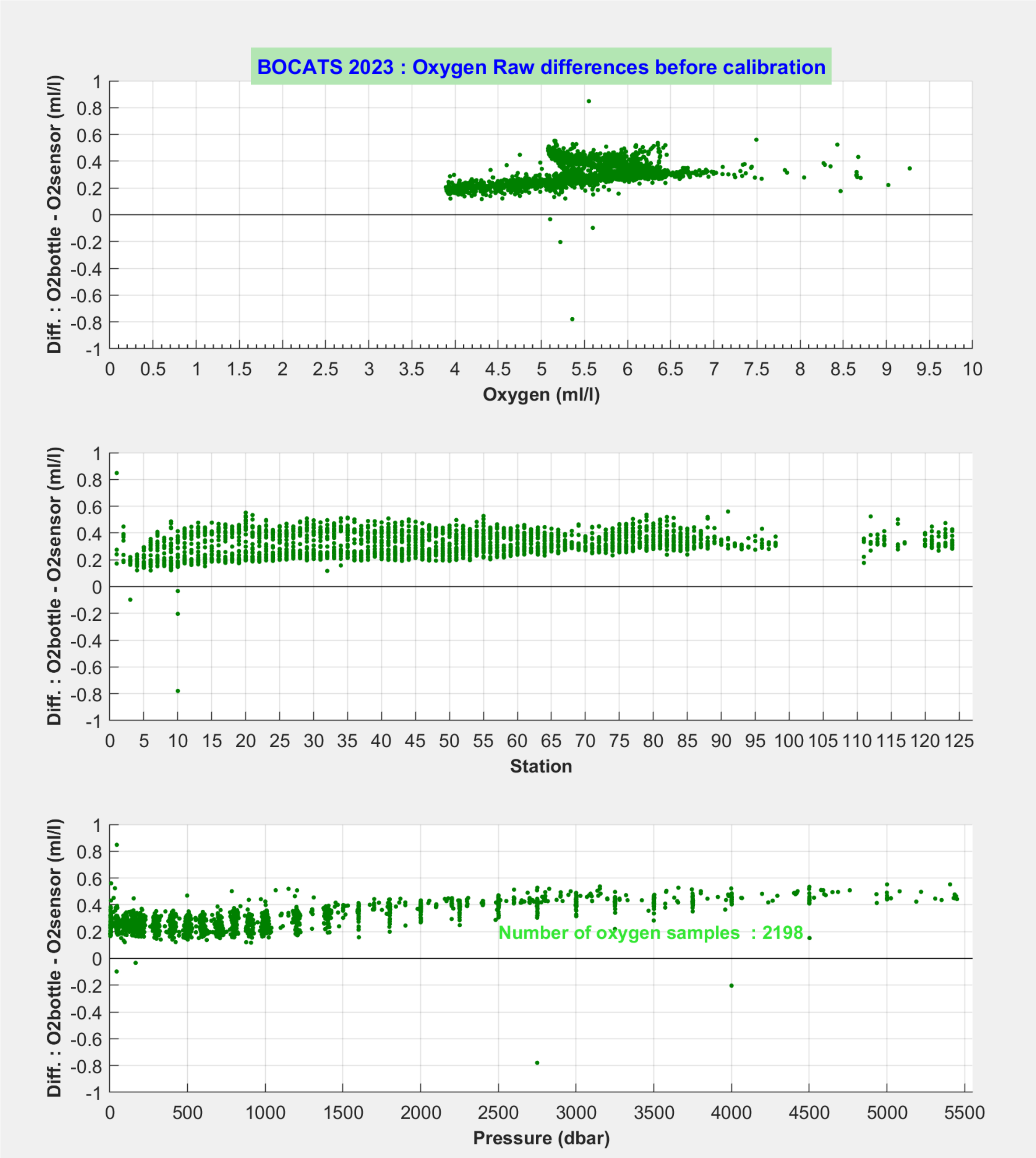


Figure 29: Oxygen raw differences

a) as a function of the oxygen,
b) as a function of the time (as the casts progress),
c) as a function of the pressure of the sampling level

By analyzing these raw results and to improve the distribution of the differences, we:

- divided the casts in 2 groups (M and B calculated for each group): 1-19 ; 20-126
- applied a polynomial pressure correction of degree 2

	Oxy coeff		Pressure coeff		
	M	B	A_2	A_1	A_0
Station 1-19	0.516793	-0.422798	-1.83568e-09	1.16228e-05	-0.00860891
Station 20-126	0.521026	-0.420501	-3.113e-09	1.74695e-05	-0.0123489

Table 2: oxygen polynomial correction applicated

Figure 30 shows the results of the adjustment of the oxygen sensor with the application of corrections. All the dots are plotted (green dots kept as validated samples, red dots rejected) and about 95% of the samples have been kept for the determination of the oxygen correction.

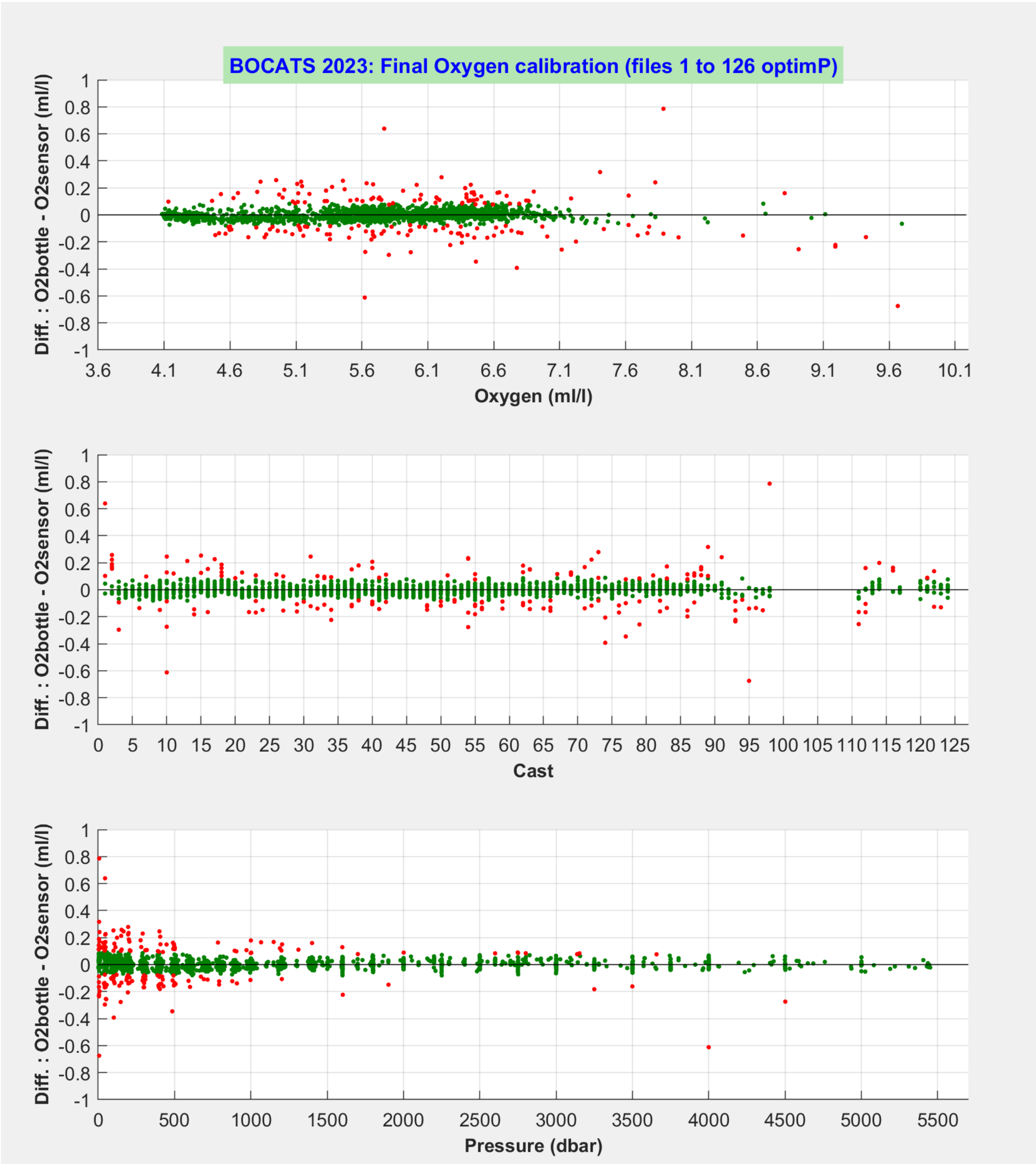


Figure 30: Final oxygen calibration

a) as a function of the oxygen,
b) as a function of the time (as the casts progress),
c) as a function of the pressure of the sampling level

The differences between the oxygen of the validated samples and the CTD adjusted oxygen measurements at the sampling level are visualized with histograms below. They confirm that the distribution of the differences is satisfactory and confirm the quality of the adjustment.
In 70 % of cases, the differences in oxygen are lower than ± 0.03 ml/l, while in 100.0 %, they are less than ± 0.08 ml/l. The standard deviation in oxygen is around 0.030 ml/l.

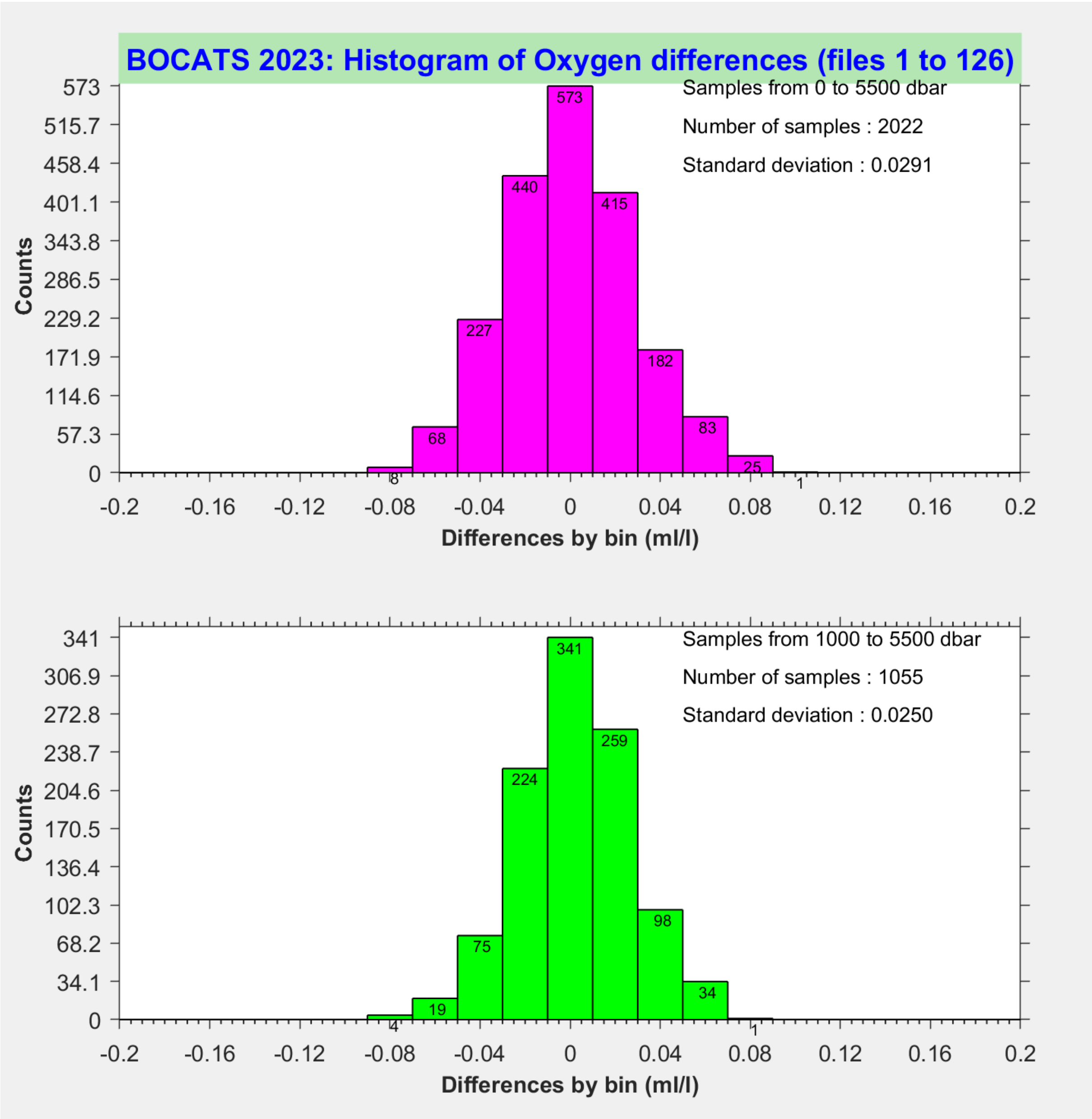


Figure 31: histogram of oxygen differences
a) for all the validated samples
b) for the validated samples at a pressure greater than 980dbar

6.3.6 Application of the correction

The polynomial corrections in oxygen calculated above are applied to all the casts of the cruise and new files are created: bo23st***corr_PTC_oxy.cnv.

To check the data, the theta-O_2 diagram is plotted for all the casts in Figure 32. Oxygen profiles are also plotted in function of pressure and a zoom of the deep waters in the Iberian Abyssal Plain (Figure 33) show a good consistency and are also in close vicinity with Saunders' (1986) value of 5.67 ml/l.

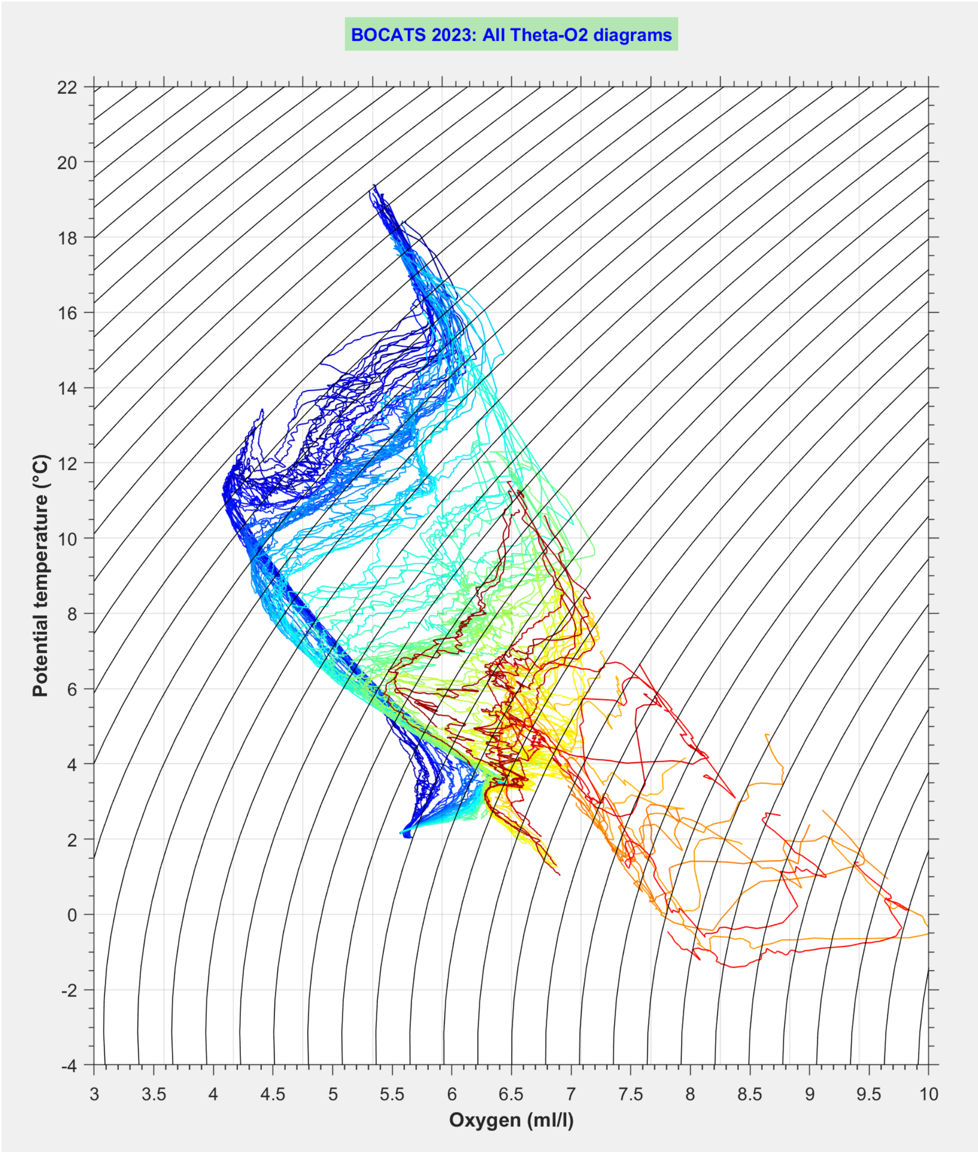


Figure 32: All Theta-O_2 for BOCATS 2023 cruise
The color of the profiles changes gradually from blue (profile 1 to red profile 126)

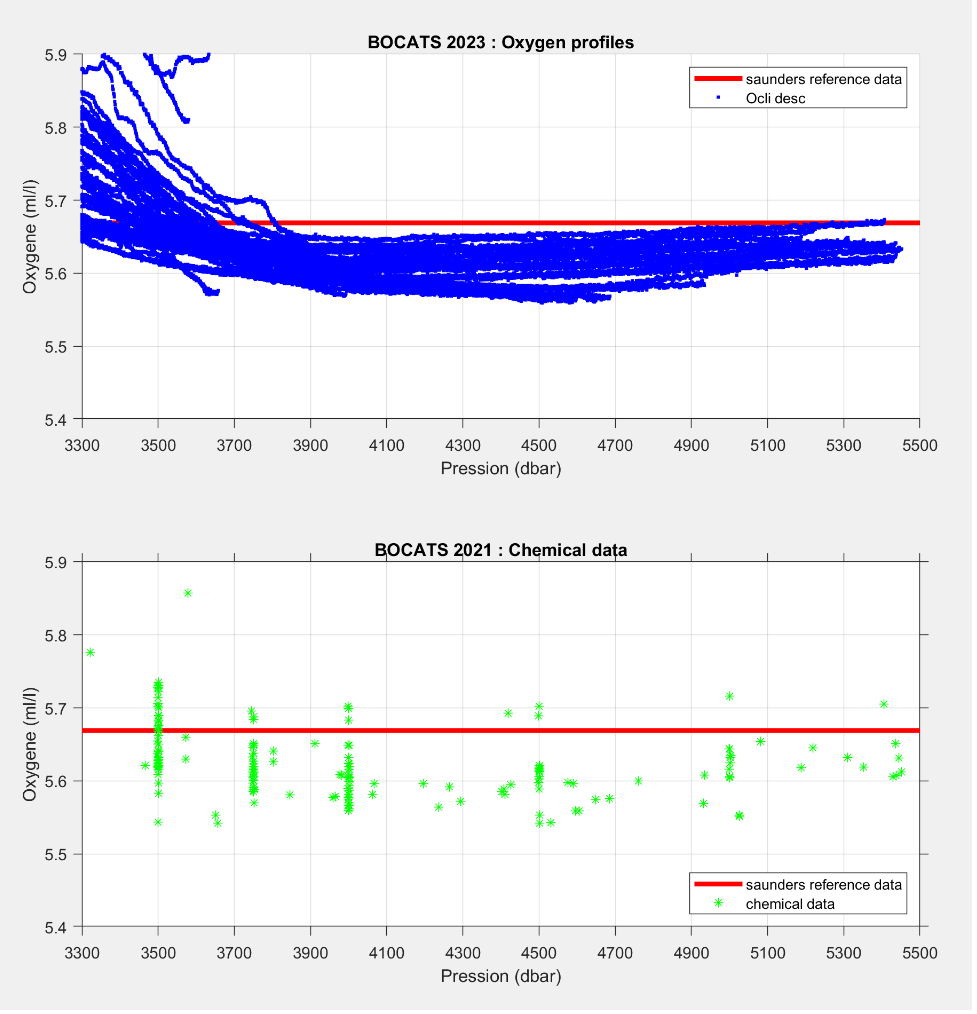


Figure 33: Dissolved oxygen measurements: profiles and bottle data for stations 1- 52 with a zoom on the North-East Atlantic Deep Water (below 3300 dbar):
a) continuous measurements on the probe downcast profiles,
b) chemical measurements obtained on the samples.
The red line represents the reference value proposed by Saunders (1986) in the Northeast Atlantic.

6.3.7 Final update of the chemical file

The chemical file updated in the paragraph 6.3.4 is updated again by correcting the oxygen data with the polynomial correction obtained.

This final chemical file contains:

- Number of the station
- Number of the bottle
- Pressure measurement adjusted
- Temperature measurement adjusted
- Salinity measurements adjusted
- Oxygen measurements in ml/l adjusted
- Oxygen measurements in µmol/kg adjusted
- Potential temperature calculated
- Potential density calculated
- Immersion
- Salinity of the samples
- Oxygen in ml/l of the samples
- Oxygen in µmol/kg of the samples

For each indication, a quality flag is indicated (refer Appendix H).

6.3.8 Reduction in O2 and netcdf files creation

All of the calibration part of the data processing is done based on the total probe measurements at 24 Hz. The data are then reduced to one measurement per decibar.

The elimination of non-validated cycles and the data reduction was carried out using the parameter gradients as elimination criteria:

$$\frac{|ParamCycle_N - ParamCycle_{N-1}|}{PressionCycle_N - PressionCycle_{N-1}}$$

A cycle is validated if the values of the gradients are lower than the selected thresholds. Initially, a determination of the gradient histograms allows us to choose threshold values beyond which the parameters will be rejected. After removal of non-validated cycles, the decimation of the data is performed by calculating, for each integer pressure value, the mean of the parameters on a 1 dbar-layer centered on this value.
The set of criteria used to reduce the probe measurements is described in the document: "Validation et Réduction des données de la sonde SBE9+", C. Kermabon, M. Arhan, Nov 2008.
The options used for the cruise are shown below:
Threshold values for stations:

- Echant. 1
- Nb val min 6
- Threshold P 0.5
- Threshold T, C surface 0.6
- Threshold T, C bottom 0.2
- Threshold O_2 (Volt) surf 1.8
- Threshold O_2 (Volt) fond 2.0

The downcast and upcast files were generated in netcdf format.
bo23d***_cli.nc for the downcasts
bo23a***_cli.nc for the upcasts
Those files are used as inputs for the following final validation

6.4 Data final validation

Hydro_val software, part of the Cadhyac software suite, is used:

- to validate the oxygen data of the probe
- to analyze the density inversions in order to flag the corresponding T, S, O2 data as bad, if necessary, and replace them by interpolated value later on.

6.4.1 Validation of the Oxygen profiles

The software flags as 'bad' (QC = 4), the small number of oxygen peaks which were not eliminated during the data reduction by testing the difference with the median over a centered window of N points. This is only done in the deep part of the profile since the variability above is too high.

The data is invalidated if these 2 conditions are present:

- Data pressure > Minimal pressure (data above minimal pressure are not changed)
- $|Median - oxygen\ data| \geq standard\ deviation\ number \times std$
  With,
  $$Minimal\ difference \leq standard\ deviation\ number \times std \leq Maximal\ difference$$

The number of iterations and the parameter values are indicated in Table 3.

	Downcast	upcast
Minimal pressure:	2800	2800
Size of the window N:	80	80
Minimal difference:	0.005	0.005
Maximal difference:	1	1
Standard deviation number:	2.7	3.4
Iteration:	3	3

Table 3: options for validation of the oxygen profiles

6.4.2 Density inversions

By superposing the reduced file, the adjusted file at 24 Hz and the file before loopedit at 24 Hz on the same graph, we can detect density inversions related to the drag of the probe.

We can see on the graph below (figure 46) that the peak at 407 and 408 dbar in T and C corresponds to the measurements recorded by the probe 3 dbar previously. This crossed water (blue arrows) was drawn in by the frame and pollutes the sensors when the probe slows down. These inversions are not at all physical: they must be identified and the quality flag is set to 4 (QC = 4) for all the parameters. During the transfer to the.clc.nc files (intermediate format before the multi-cast format), a linear interpolation will be performed at these locations.

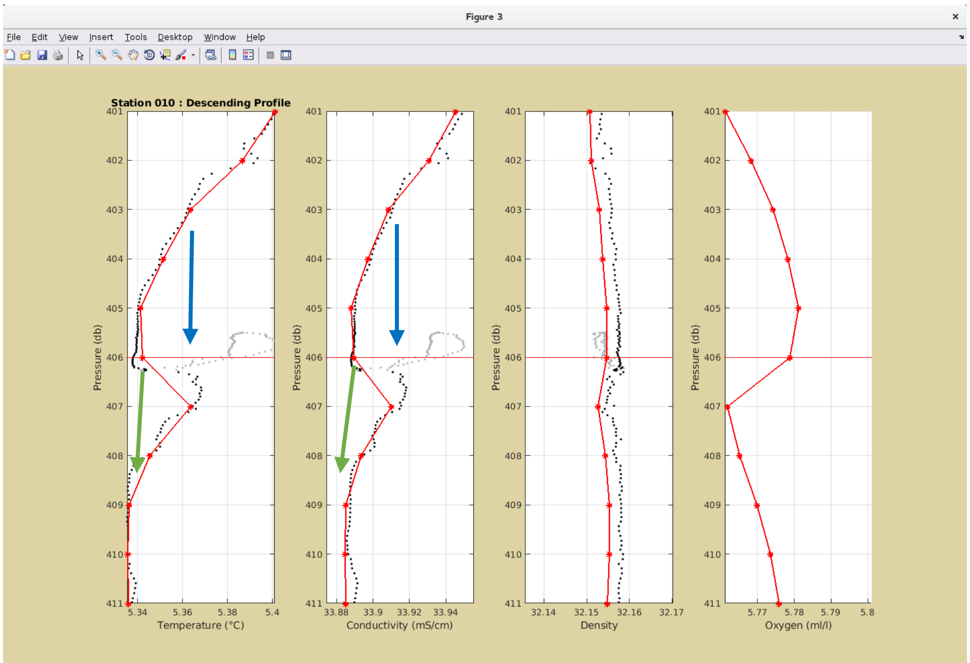


Figure 34: example of invalidation of density inversions
The reduce profile is shown in red
The adjusted data at 24 Hz in black
The data at 24Hz before loopedit in grey.

After all those corrections in the "cli" netcdf files, "clc" netcdf files are generated to fill the missing levels with interpolated points (flagged 8) if gaps are not bigger than 10 dbar. Derived parameters like potential temperature, density … are then added in those "clc" files, which are finally concatenated in the multi-station netcdf filed that we called bo23_PRES.nc.

6.4.3 Correction of the flags of oxygen bottle data

Using downcast CTD O_2 data at the same pressure or density than the bottle samples to compare with oxygen sample measurements have several advantages:

- we gain precision since the rosette has less influence on the data when it's moving downward.
- we reduce the impact of the hysteresis effect on the oxygen sensor that is never totally corrected (indeed, the influence of the pressure on O_2 measurements is weaker during the downcast than during the upcast).

However, the drawback is that we also don't consider the changes in the water column between the upcast and the downcast. In the upper water column, those changes are mainly due to internal waves that heave the water masses up and down by several tens of meters (Saout-Grit et al., 2015), particularly in the upper water column. Consequently, we used the new feature of CADHYAC consisting in selecting the downcast data at the same density than the upcast bottle level (what we call hereafter the "bottle density level").

For the OVIDE-BOCATS data, this is not really an issue for the calibration, since we have many samples, and the chemical data that don't match the CTD-O2 data are simply discarded from the calibration. Among the 2198 samples, only 174 were moved out by the calibration because of a too large discrepancy with the probe data. However, the side effect is that these chemical data were flagged bad, although only 65 were actually further than 3 standard deviations from the profile if we consider either the upcast data or the downcast data at the same pressure.

Since chemical data are distributed and widely used (particular by biogeochemists), it is important to flag the chemical data the best we can. This is why CTD-O2 data and flags of chemical oxygen data are corrected after calibration in the final chemical database by associating the sample measurement to its best match with CTD data between (i) the downcast point adjusted in pressure (ii) the downcast point adjusted in density and (iii) the upcast point at the effective level where the bottle was closed. This way, 109 chemical oxygen data were rehabilitated, leaving only 65 chemical data flagged bad.

This processing improved also greatly the histogram of the difference between CTD and chemical data (Figure 35), with a standard deviation down to 0.9 instead of 1.3 $\mu mol.kg^{-1}$, better than the 1 $\mu mol.kg^{-1}$ value found for replicates in section 5.3.2. Since we need to include the bias of 0.1 $\mu mol.kg^{-1}$ (mainly due to the hysteresis effect), an accuracy of 1 $\mu mol.kg^{-1}$ could then be claimed on oxygen CTD data.

Note finally that those correction don't affect the calibration results and that the CTD-O_2 oxygen profiles were not corrected. The above changes appear:

- in the csv and excel sheet of the chemical data.
- in the chemical data of the multi-station netcdf file: variables CHPOXYLP, CHOXYLB_QC, CHPOXYKP and CHOXYKB_QC were updated, with previous values saved in CHPOXYLPD, CHOXYLBD_QC, CHPOXYKPD, CHOXYKBD_QC respectively.

Chemical data in the individual "cli" and "clc" netcdf files were unchanged.

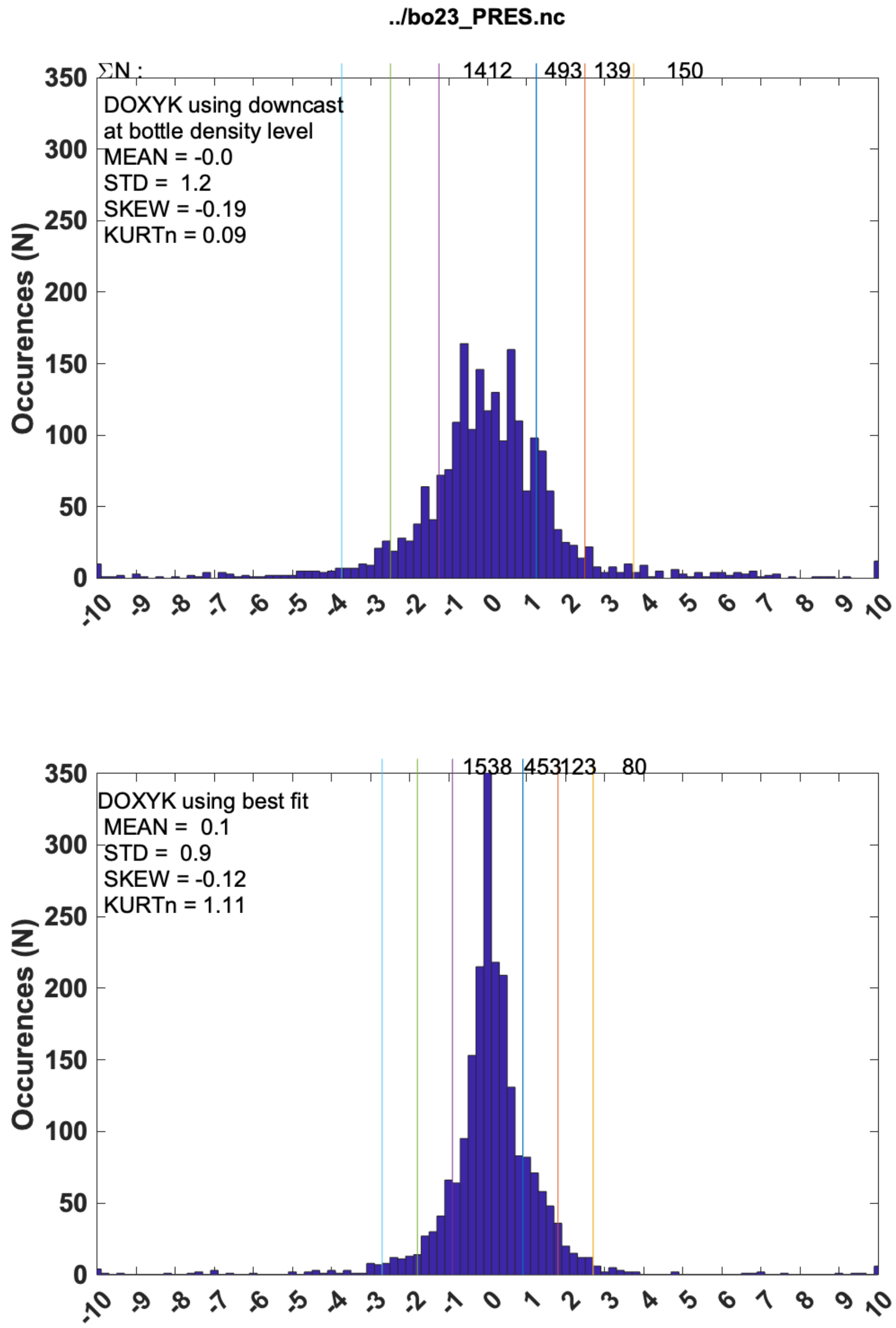


Figure 35: Histogram of the oxygen difference between the chemical measurements flagged good and the probe data, in µmol.kg-1: [top] using only downcast data at the bottle density level (same than in Figure 31 (top) but in µol/kg), [bottom] using the best match between chemical and probe data by using either upcast data, downcast data at the bottle pressure level or downcast data at the bottle density level

7 Precision of the BOCATS 2023 measurements

The calibration of the CTD measurements ends with the determination of the quality of the different types of measurements (probe and chemistry) by giving in the table below the accuracies for the different measurements of the cruise coming from a statistical treatment or directly from the constructor.

As a reminder, the accuracy for the different CTD sensors are evaluated in section 4 and 6.4.3, and the accuracy of chemical parameters are evaluated with the replicates in section 5.

Probe Param	Value	Unit	Chemical Param	Value	Unit
PRES	1	dbar			
TEMP	0.001	°C			
COND	0.001	mS/cm			
PSAL	0.001		CHPSALB	0.001	
OXYL	0.021	ml/l	CHOXYLB	0.018	ml/l
OXYK	1	µmol/kg	CHOXYKB	0.8	µmol/kg
			CHTMPOB	0.5	°C

Table 4: quality data measurements obtained for BOCATS 2021 cruise

PRES: accuracy of the sensor given by the manufacturer

TEMP: accuracy of the sensor given by the manufacturer

COND: standard deviation of the differences Conductivity probe / Conductivity from the sample

PSAL: standard deviation of the differences Salinity probe / Salinity from the sample

CHPSALB: standard deviation of the replicates validated in salinity

OXYL: standard deviation of the differences Oxygen probe / Oxygen from the sample in ml/l

CHOXYLB: standard deviation of the replicates validated in oxygen (ml/l)

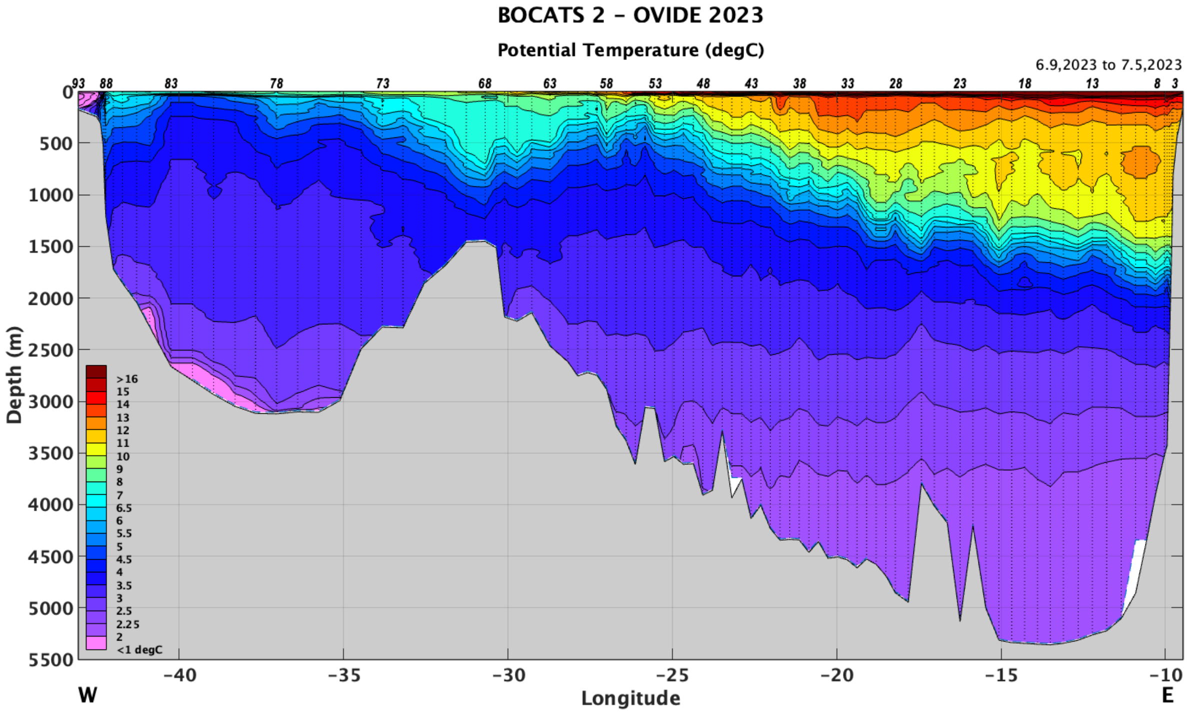
OXYK: standard deviation of the differences Oxygen probe / Oxygen from the sample in µmol/kg

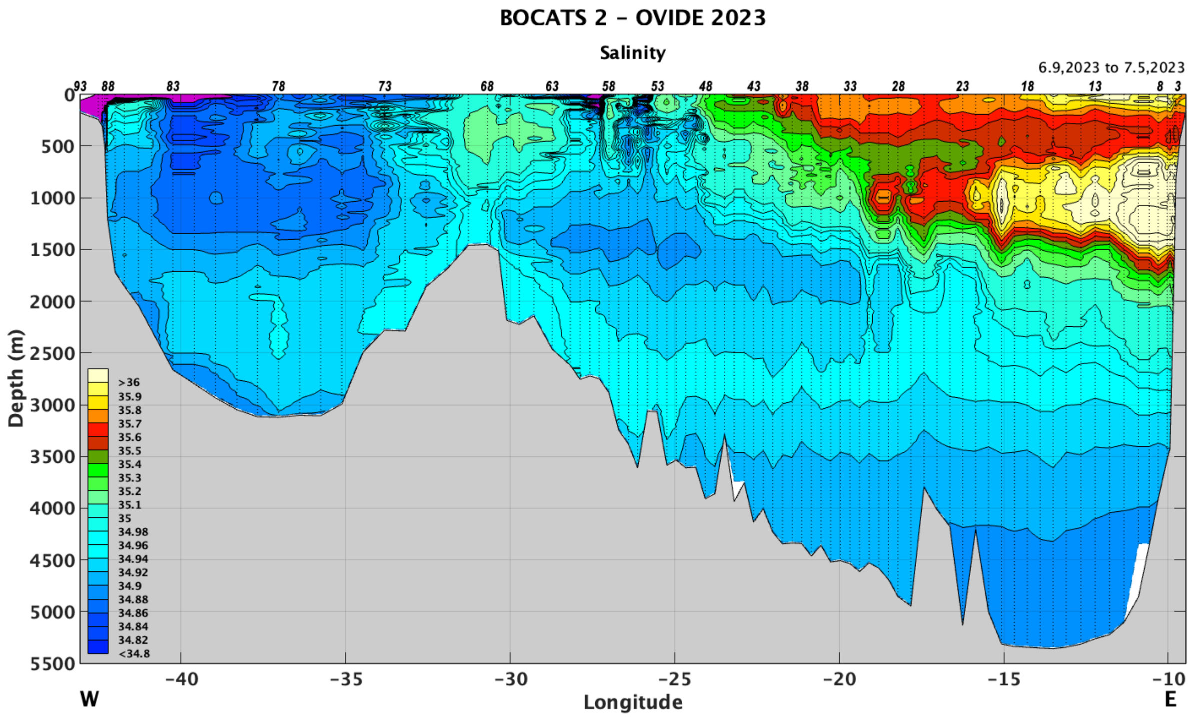
CHOXYKB: standard deviation of the replicates validated in oxygen (µmol/kg)

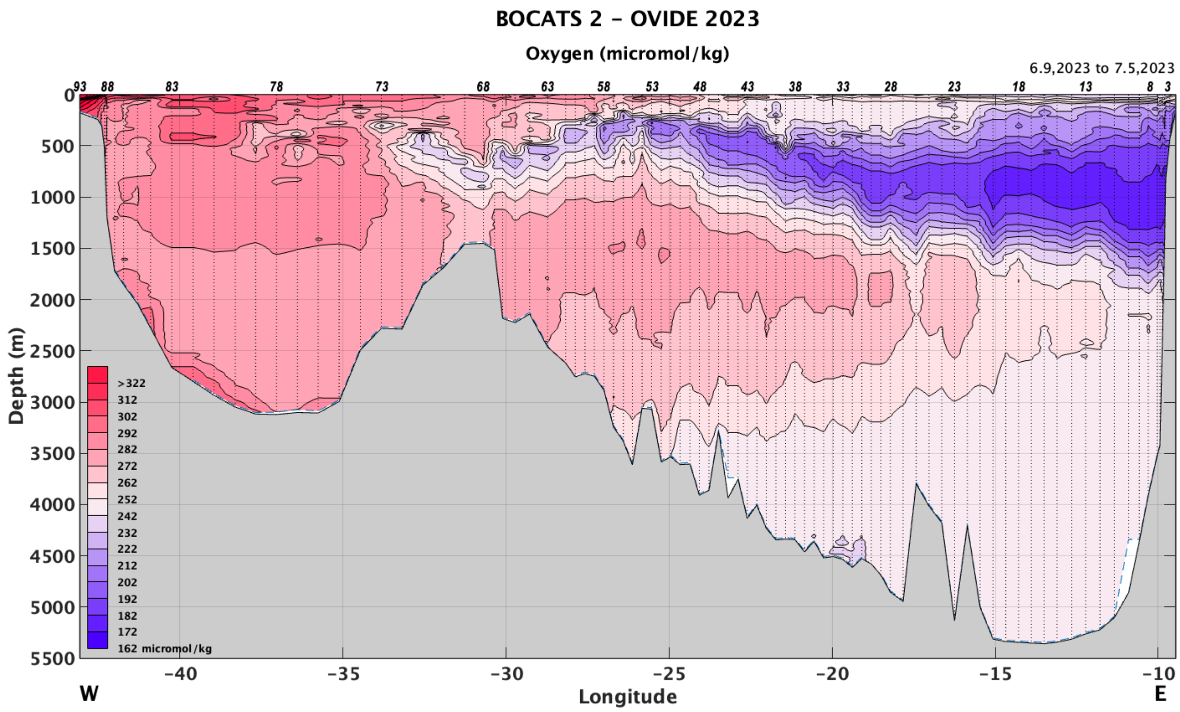
CHTMPOB: accuracy of the thermometer used for the oxygen sampling

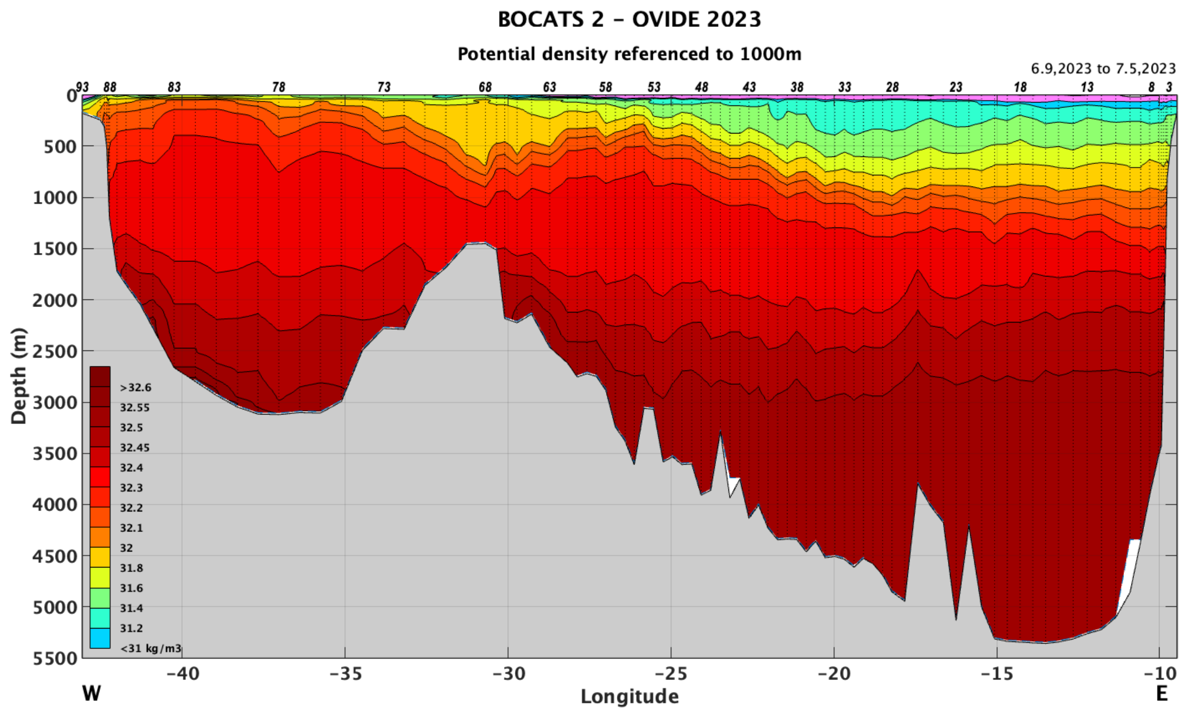
8 Sections

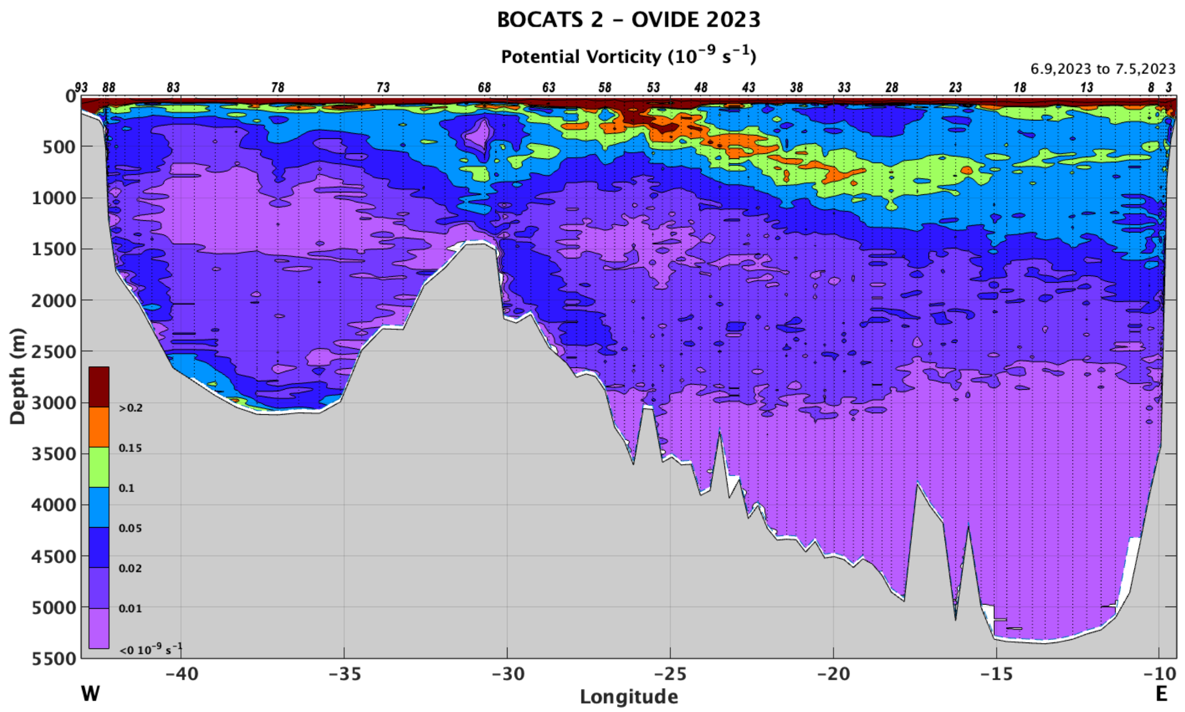
Following figures present the A25 (BOCATS-OVIDE) section for the different parameters.






BOCATS 2 - OVIDE 2023
Oxygen (micromol/kg)
6.9,2023 to 7.5,2023
93 88 83 78 73 68 63 58 53 48 43 38 33 28 23 18 13 8 3
Depth (m)
>322
312
302
292
282
272
262
252
242
232
222
212
202
192
182
172
162 micromol/kg
Longitude
W
E


BOCATS 2 - OVIDE 2023
Potential density referenced to 1000m
6.9,2023 to 7.5,2023
93 88 83 78 73 68 63 58 53 48 43 38 33 28 23 18 13 8 3
Depth (m)
>32.6
32.55
32.5
32.45
32.4
32.3
32.2
32.1
32
31.8
31.6
31.4
31.2
<31 kg/m3
Longitude
W
E



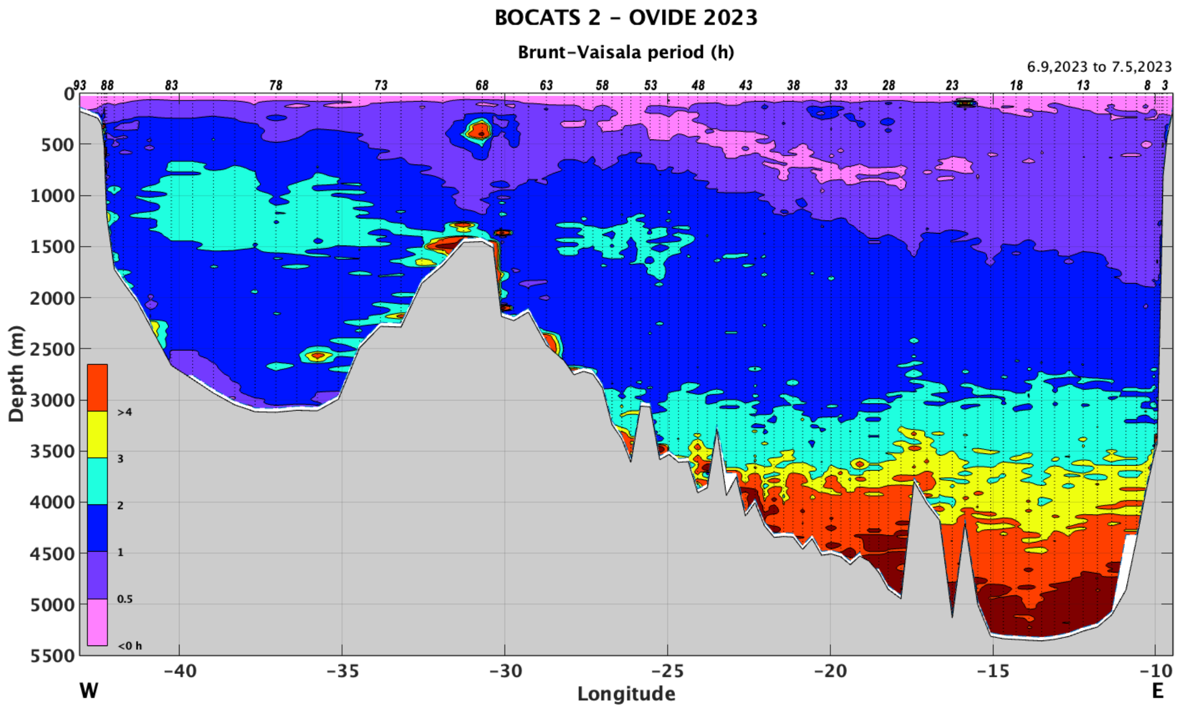


Figure 36: Section A25-OVIDE: potential temperature, practical salinity, dissolved oxygen, potential density referenced at 1000dbar, potential vorticity (here approximated at f/gN^2, without the relative vorticity), Brünt-Vaïsala frequency (N^2) converted in period (= $2\pi/N$).*

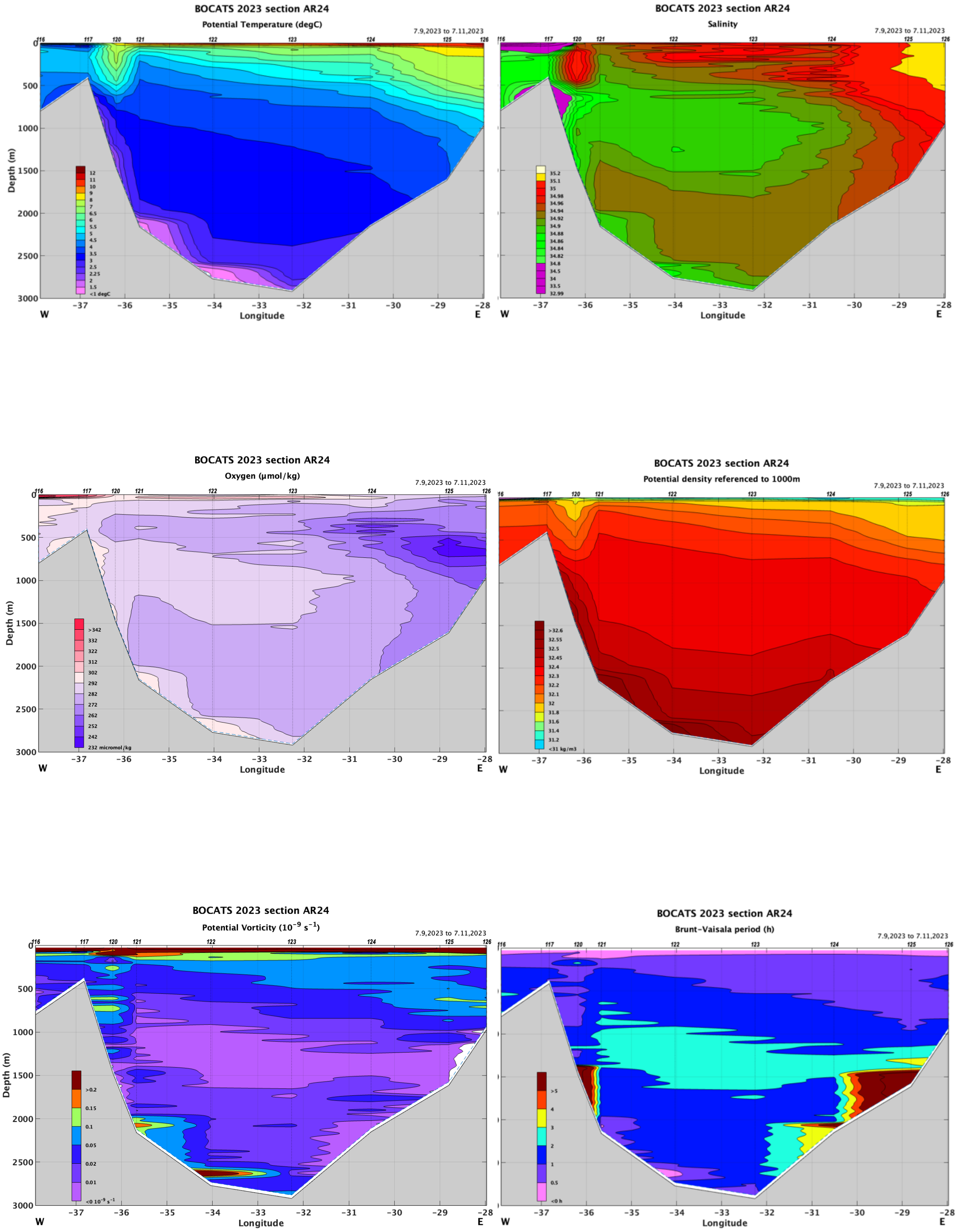


Figure 37: Section AR24 (Irminger Sea, 64.5°N ⇨ 61°N, see Figure 2); same parameters than Figure 36

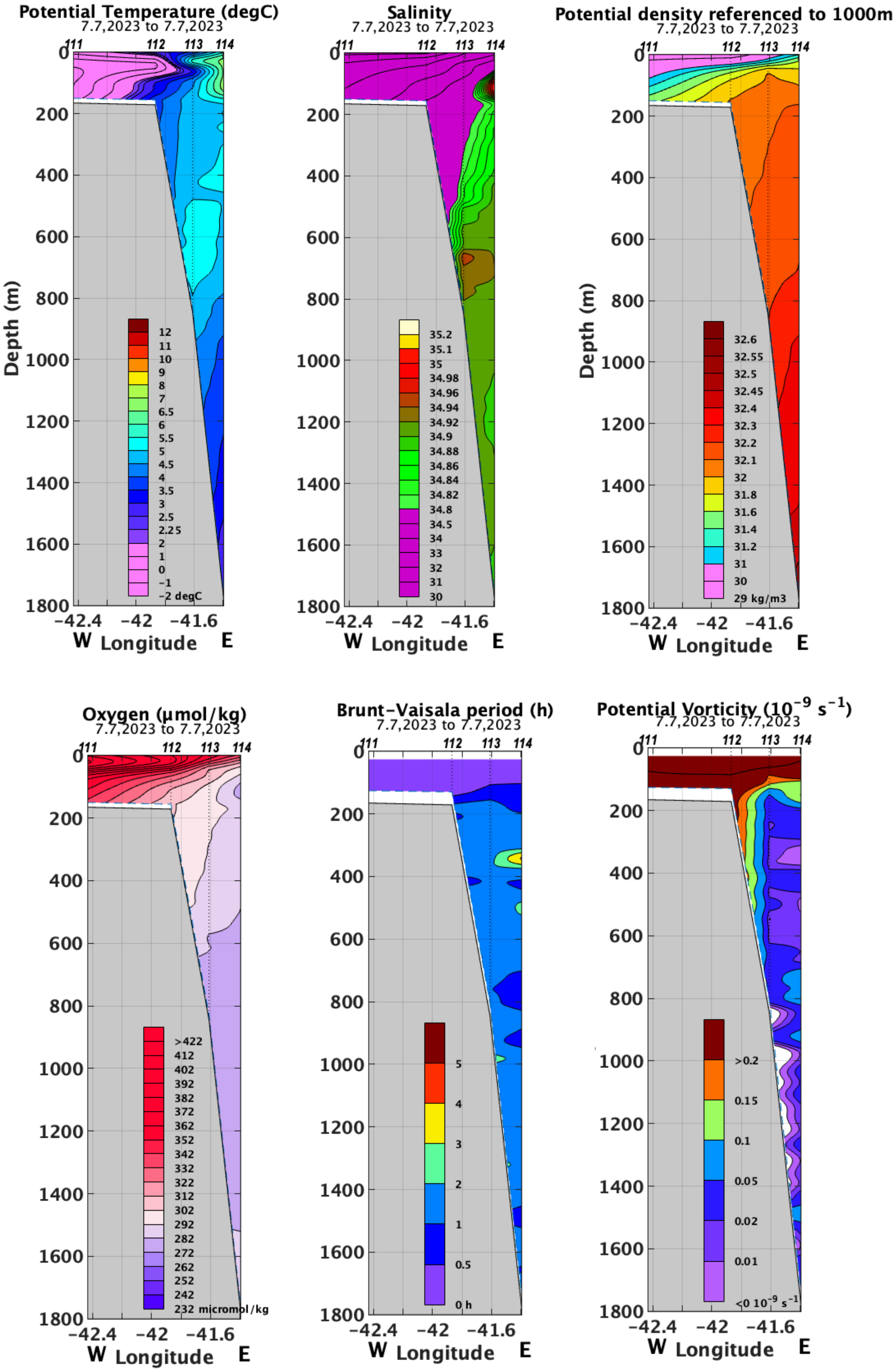


Figure 38: Section on the Greenland shelf at 61°N; same parameters than Figure 36

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10 Acknowledgments

This work received funding from the European Union's programme EuroGO-SHIP under grant agreement No 101094690, and from Ifremer. The cruise was supported by the BOCATS2 (PID2019-104279GB-C21) project funded by MCIN/AEI/10.13039/501100011033. We are very grateful to the captain and crew of the Sarmiento de Gamboa for their hard work.

Figure table

Appendix

A. Seabird pressure sensor of the 813 probe calibration

Sea-Bird GmbH
Sea-Bird GmbH
Postfach 1167
87401 Kempten
Germany

+49 831 9 60994 701
seabird.eu@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0813
CALIBRATION DATE: 28-Nov-22

SBE 9plus PRESSURE CALIBRATION DATA
10000 psia S/N 98623

DIGIQUARTZ COEFFICIENTS:

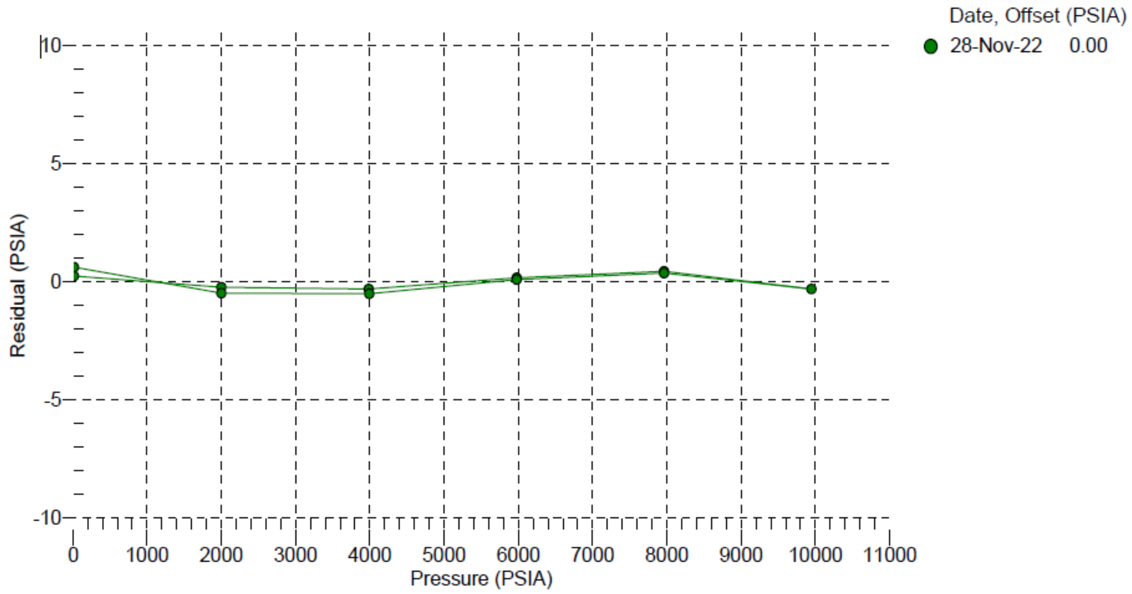
```
C1 =  -4.480765e+004
C2 =  -5.250438e-001
C3 =   1.424300e-002
D1 =   3.732300e-002
D2 =   0.000000e+000
T1 =   3.039466e+001
T2 =  -4.630908e-004
T3 =   4.384490e-006
T4 =   1.785720e-009
T5 =   0.000000e+000
```

AD590M, AD590B, SLOPE AND OFFSET:

```
AD590M =    1.28893e-002
AD590B =   -8.41874e+000
Slope  =    1.00006
Offset =   -3.0175  (dbars)
```

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
13.540	32915.80	21.7	18.141	13.765	0.225
1999.546	33635.60	21.7	2003.570	1999.304	-0.242
3987.387	34338.80	21.8	3991.225	3987.067	-0.320
5974.498	35025.60	21.8	5978.697	5974.649	0.151
7961.737	35697.00	21.8	7966.100	7962.162	0.425
9950.279	36354.00	21.8	9953.808	9949.980	-0.299
7962.056	35697.10	21.8	7966.365	7962.427	0.371
5974.808	35025.70	21.8	5978.943	5974.895	0.087
3987.783	34338.90	21.9	3991.429	3987.272	-0.511
1999.964	33635.70	21.9	2003.738	1999.472	-0.492
13.540	32916.00	21.9	18.525	14.148	0.608

Residual (PSIA) = corrected instrument pressure - reference pressure



1

B. Seabird temperature sensor of the 813 probe calibration

Sea-Bird GmbH

Sea-Bird GmbH
Postfach 1167
87401 Kempten
Germany

+49 831 9 60994 701
seabird.eu@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2911
CALIBRATION DATE: 04-Nov-22

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

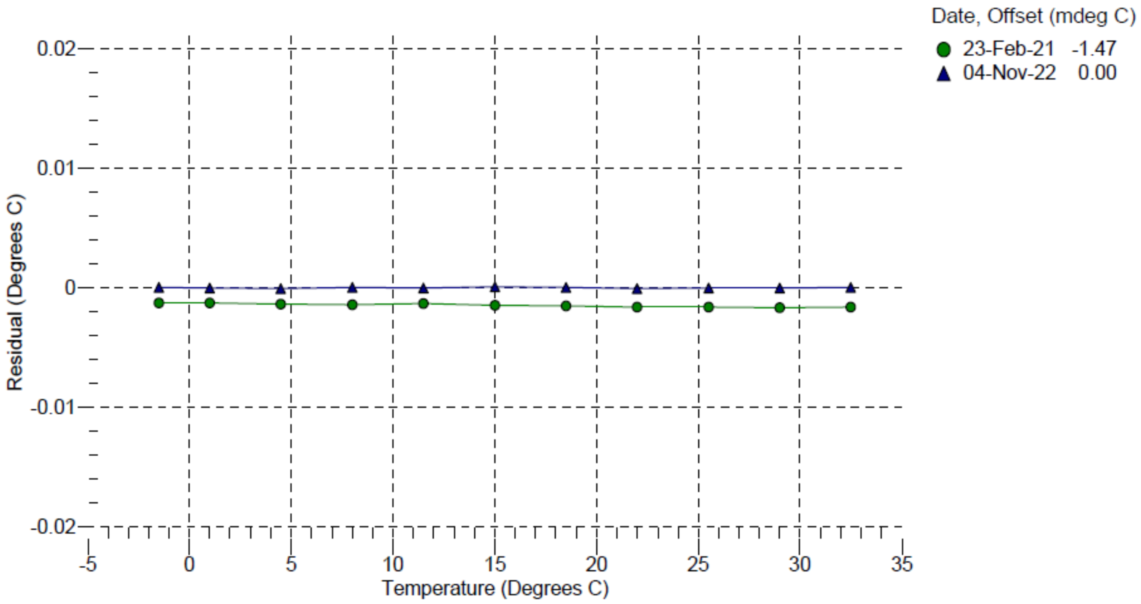
COEFFICIENTS:
g = 4.36422727e-003
h = 6.58390511e-004
i = 2.44014993e-005
j = 2.18374573e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	2933.514	-1.5000	0.00005
1.0000	3098.769	1.0000	-0.00004
4.5000	3341.254	4.4999	-0.00006
8.0000	3597.038	8.0000	0.00002
11.5000	3866.452	11.5000	-0.00000
15.0000	4149.846	15.0001	0.00009
18.5000	4447.519	18.5000	0.00002
22.0000	4759.798	21.9999	-0.00006
25.5000	5086.993	25.5000	-0.00002
29.0000	5429.380	29.0000	-0.00003
32.5000	5787.248	32.5000	0.00004

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



1

C. Seabird Conductivity sensor of the 813 probe calibration

Sea-Bird GmbH

Sea-Bird GmbH
Postfach 1167
87401 Kempten
Germany

+49 831 9 60994 701
seabird.eu@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 3194
CALIBRATION DATE: 27-Oct-22

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -1.01556512e+001
h =   1.40617900e+000
i =  -9.15978403e-005
j =   7.92315570e-005

CPcor =  -9.5700e-008  (nominal)
CTcor =   3.2500e-006  (nominal)
```

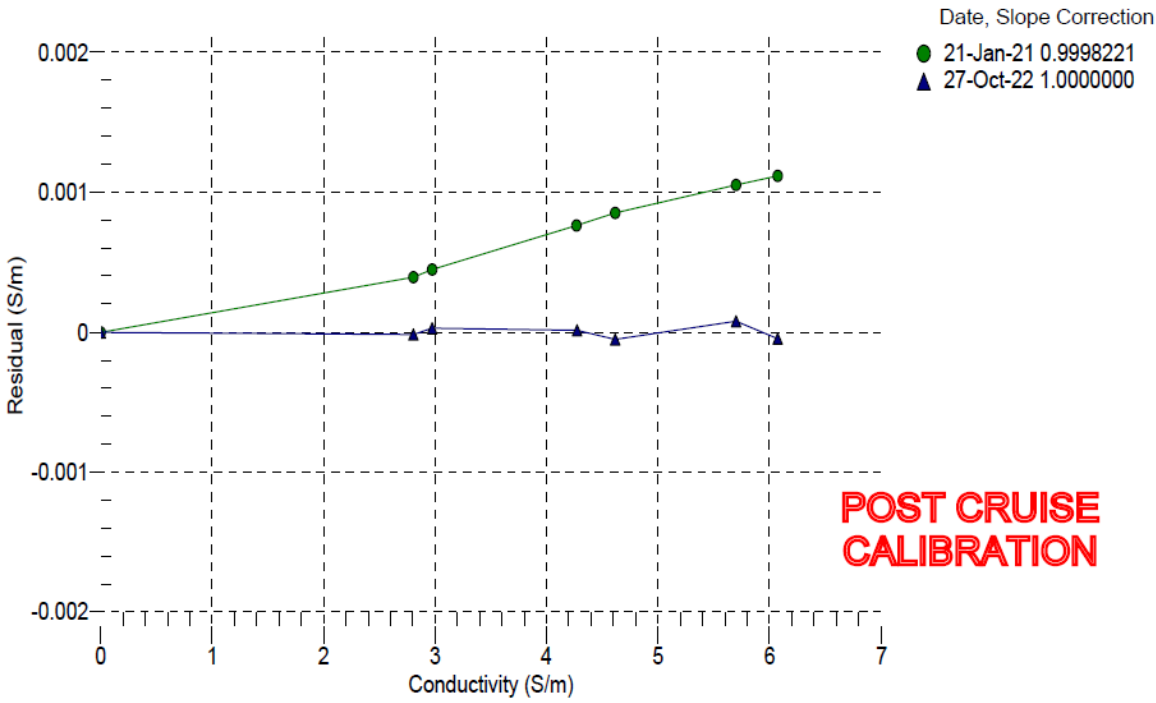
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.68710	0.00000	0.00000
-1.0000	34.8074	2.80393	5.20862	2.80391	-0.00002
1.0000	34.8077	2.97530	5.32407	2.97533	0.00003
15.0000	34.8091	4.27082	6.12627	4.27084	0.00001
18.5000	34.8096	4.61758	6.32360	4.61752	-0.00005
29.0000	34.8066	5.70091	6.90375	5.70098	0.00008
32.5001	34.7998	6.07345	7.09213	6.07340	-0.00005

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) /10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



1

D. Seabird oxygen sensor of the 813 probe calibration

SEA·BIRD SCIENTIFIC

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 1402
CALIBRATION DATE: 23-Feb-23

SBE 43 OXYGEN CALIBRATION DATA

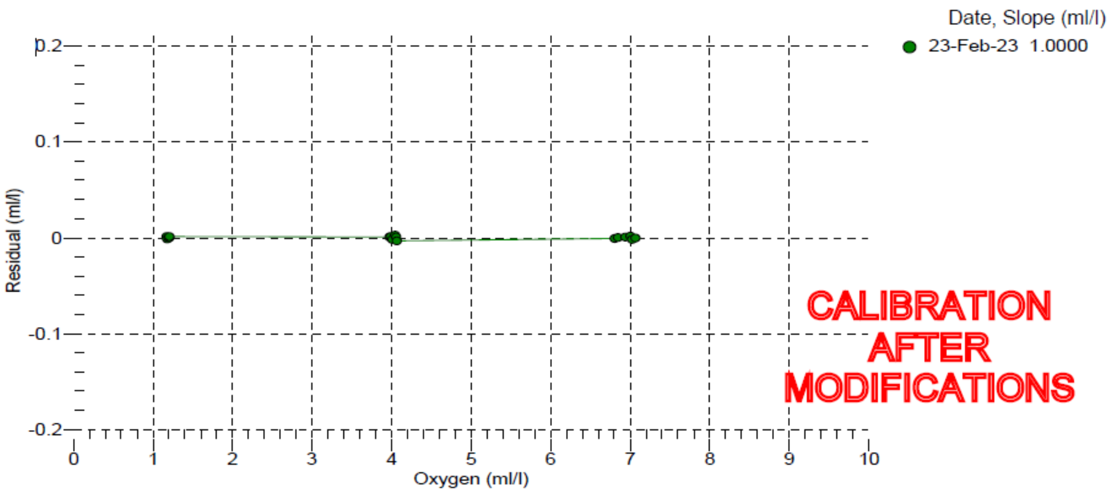
COEFFICIENTS:
Soc = 0.5119
Voffset = -0.4761
Tau20 = 1.03

A = -4.8098e-003
B = 2.0704e-004
C = -3.1285e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.17	2.00	0.00	0.715	1.17	0.00
1.18	6.00	0.00	0.746	1.18	-0.00
1.18	12.00	0.00	0.792	1.18	-0.00
1.20	20.00	0.00	0.859	1.20	-0.00
1.21	26.00	0.00	0.908	1.21	0.00
1.21	30.00	0.00	0.942	1.21	0.00
3.97	2.00	0.00	1.286	3.97	0.00
3.98	6.00	0.00	1.390	3.99	0.00
4.01	12.00	0.00	1.550	4.01	-0.00
4.04	20.00	0.00	1.768	4.04	0.00
4.06	26.00	0.00	1.932	4.06	0.00
4.07	30.00	0.00	2.044	4.06	-0.00
6.81	2.00	0.00	1.862	6.80	-0.00
6.85	6.00	0.00	2.047	6.85	0.00
6.94	12.00	0.00	2.335	6.94	0.00
7.00	30.00	0.00	3.178	7.01	0.00
7.02	20.00	0.00	2.718	7.02	-0.00
7.07	26.00	0.00	3.010	7.07	-0.00

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)
Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)
Oxygen (ml/l) = Soc * (V + Voffset) * $(1.0 + A * T + B * T^2 + C * T^3)$ * Oxsol(T,S) * exp(E * P / K)
Residual (ml/l) = instrument oxygen - bath oxygen



1

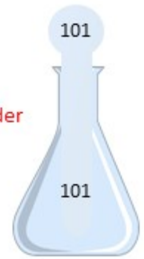
E. Salinity sampling protocol

F. Oxygen sampling protocol

User's guide for dissolved oxygen sampling

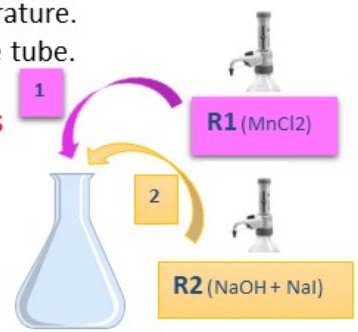
1. Put the gloves.
2. Purge the reagent distributors of R1 and R2 to be sure that there is no bubbles in the tubes.
3. Take :
   - ✓ A flask in the box and check that the number on the flask and on the cap are in agreement.
   - ✓ The sampling tube.
   - ✓ The thermometer.

Take the flask in increasing order please



4. Give the number information to the secretary.
5. Start the sampling :
   - ✓ Install the sampling tube on the tap.
   - ✓ Drain the tube and be sure that no bubbles are present.
   - ✓ Pinch the tube and inside it to the bottom of the flask a little inclined.
   - ✓ Release the tube carefully to not create a vortex or bubbles.
   - ✓ Let overflow the water (3 times the volume of the flask) and take the temperature.
   - ✓ Pinch again the tube to reduce the flow (don't stop the flow) and get out the tube.
   - ✓ Stop the flow of the niskin bottle.
6. Inject the reagents R1 (pink) <u>then</u> R2.

⚠ The order of the reagents is important!!!!



7. Close the flask and start the agitation during 30 seconds minimum.
8. Apply the same protocol for the others samples of the station.

<u>At the end of the station</u> : shake again very softly all the samples of the station and add distilled water in the top of the flasks.

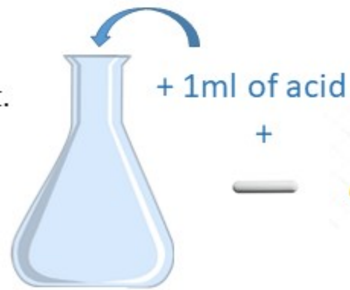
Créé par CLB le 09/01/2020

G. Oxygen sampling analysis

User's guide for dissolved oxygen analysis

1. Put the gloves and check that the method on the titrator is « oxy3 ».
2. Check on the container's PC that the software esaytitrino has been launched.
3. Put out the excess of water.

4. Open the flask and rinse the bottom of the cap with distilled water.
   (to be sure to have all the precipitate for the analysis)
5. Add the acid (R3) <u>then</u> the bar magnet.



⚠ The order acid then stirrer is really important.

6. Put in the titrod and the anti diffusion tube in the flask on the magnetic stirrer.

⚠ The anti diffusion tube must always be behind the titrode and never be glue on it.

7. Push on « START » then write
   - the station number,
   - The flask number,
   - The flask volume. (confirm by « Entrée » each time)

Créé par CLB le 09/01/2020

H. Quality Flag

During Cadhyac treatment, each data will be marked with a quality flag:

1	good
4	bad
9	no data

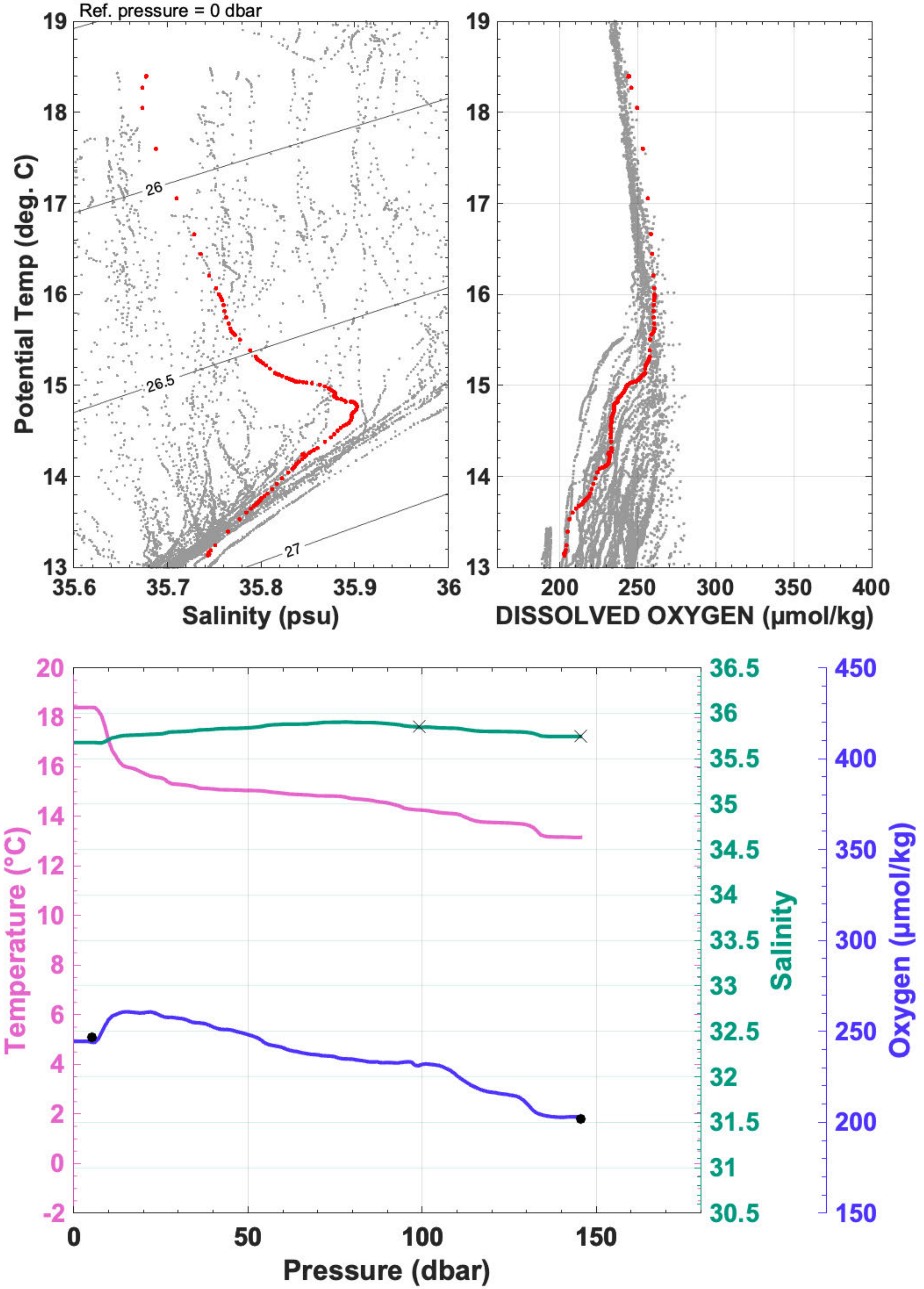
During the generation of the clc file, some flags can appear:

2	probably good
8	interpolated

Figures of the CTD and associated bottle data

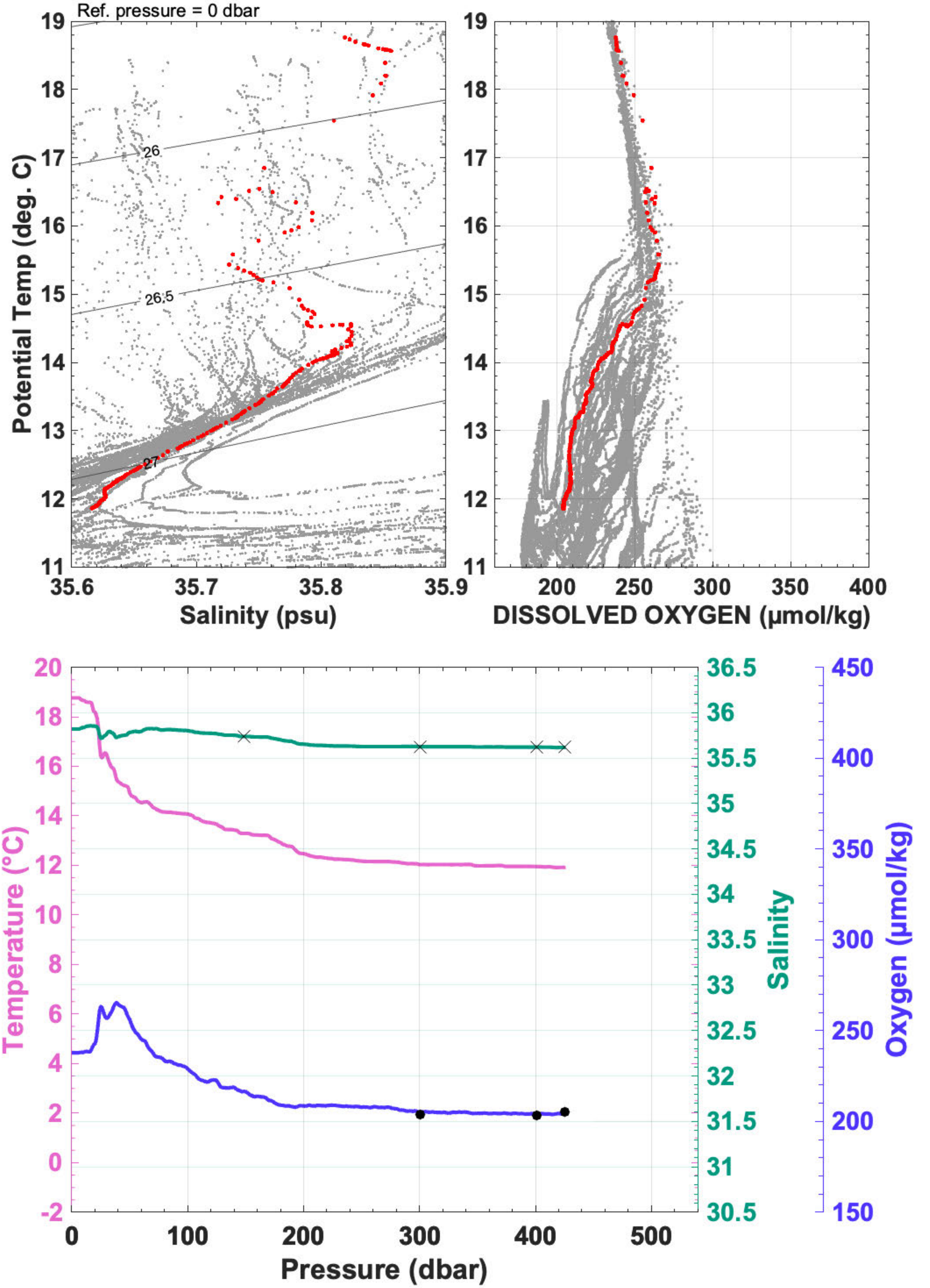
The following pages present plots showing (top-left) $\boldsymbol{\theta}$-S diagram, (top-right) $\boldsymbol{\theta}$-Ox diagram and (bottom) profiles of CTD temperature, salinity and dissolved oxygen as a function of pressure, along with bottle data (points). On top figures, all stations are plotted in grey while the specified station appears in red.

STATION 1



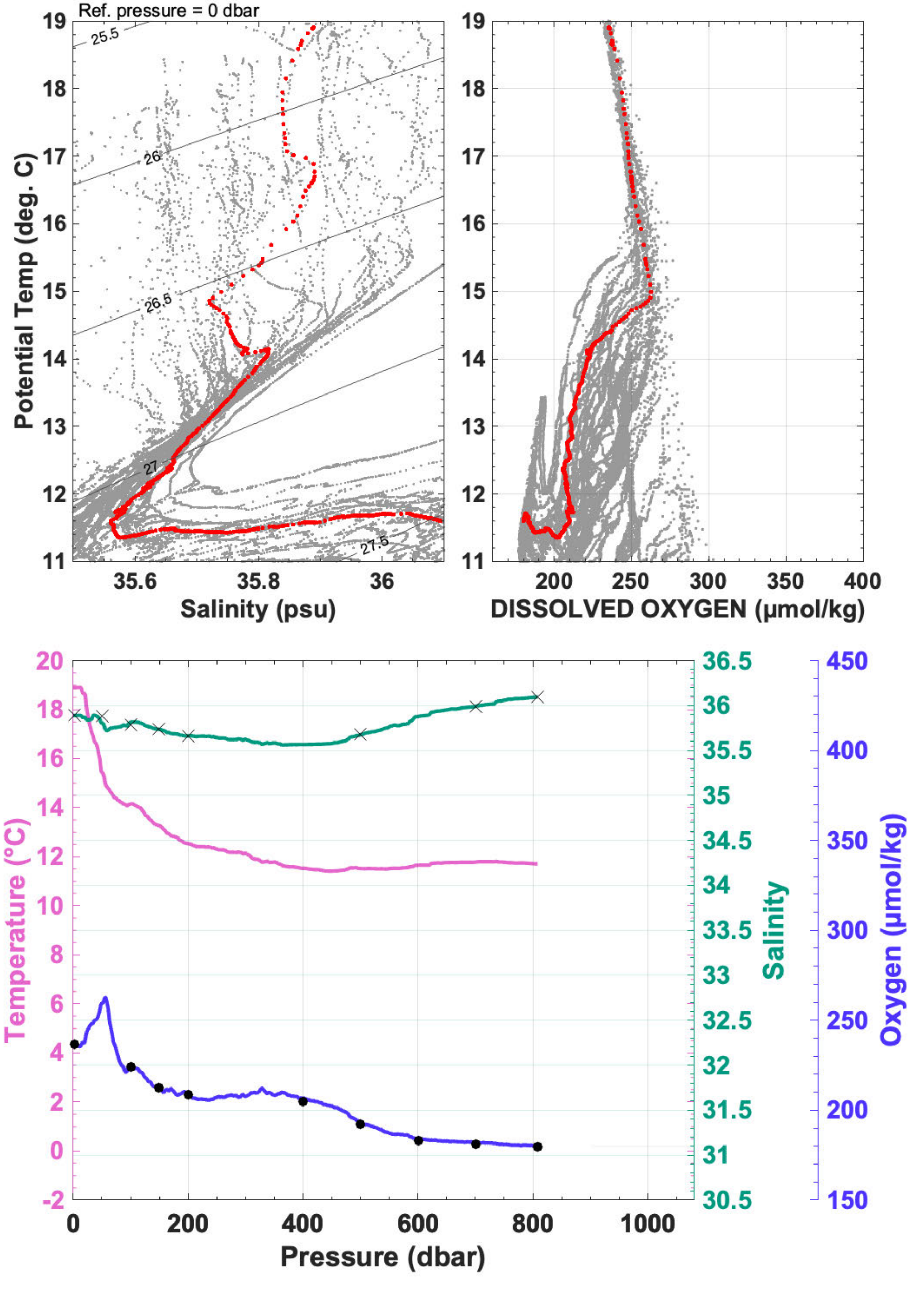
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 2



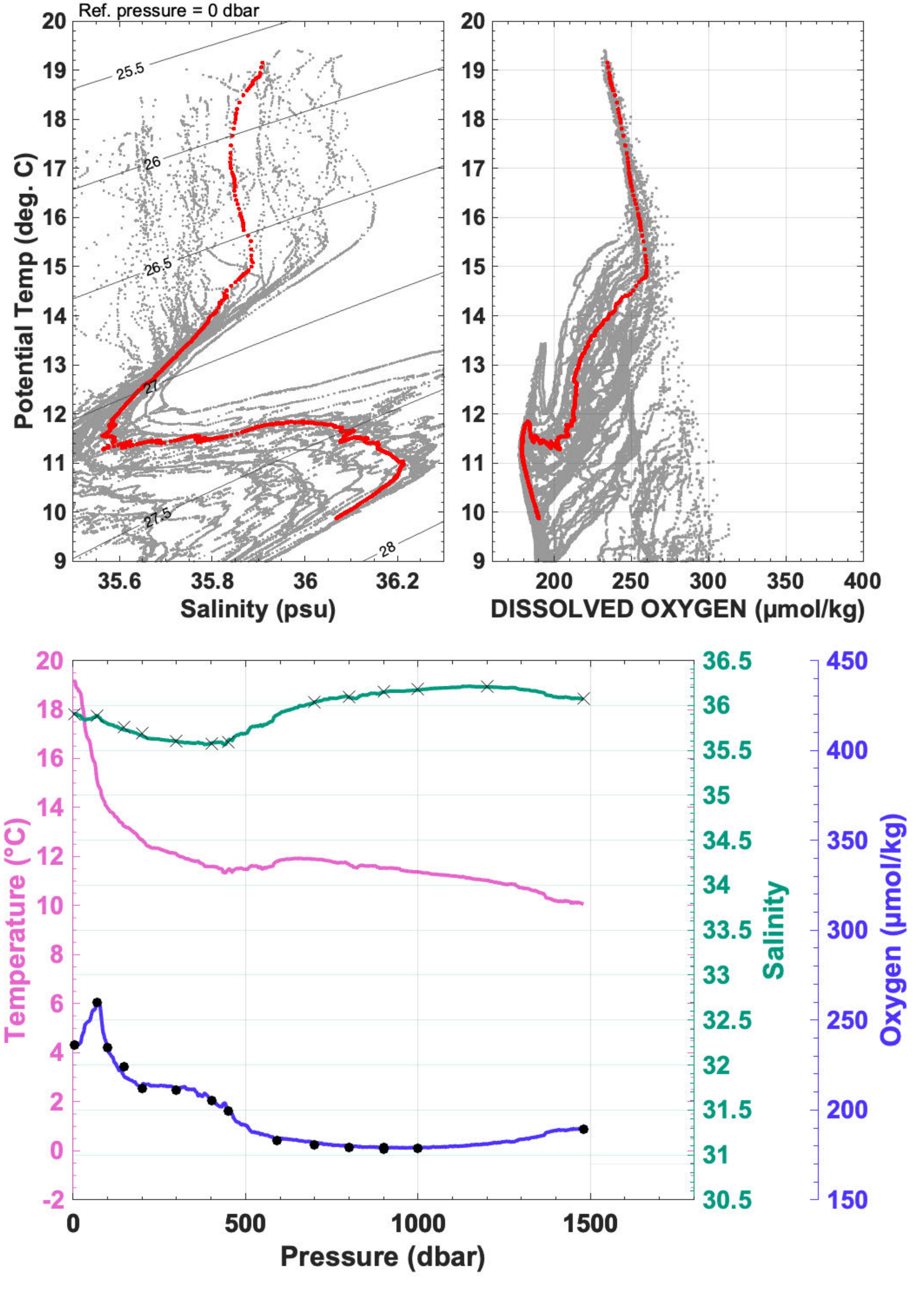
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 3



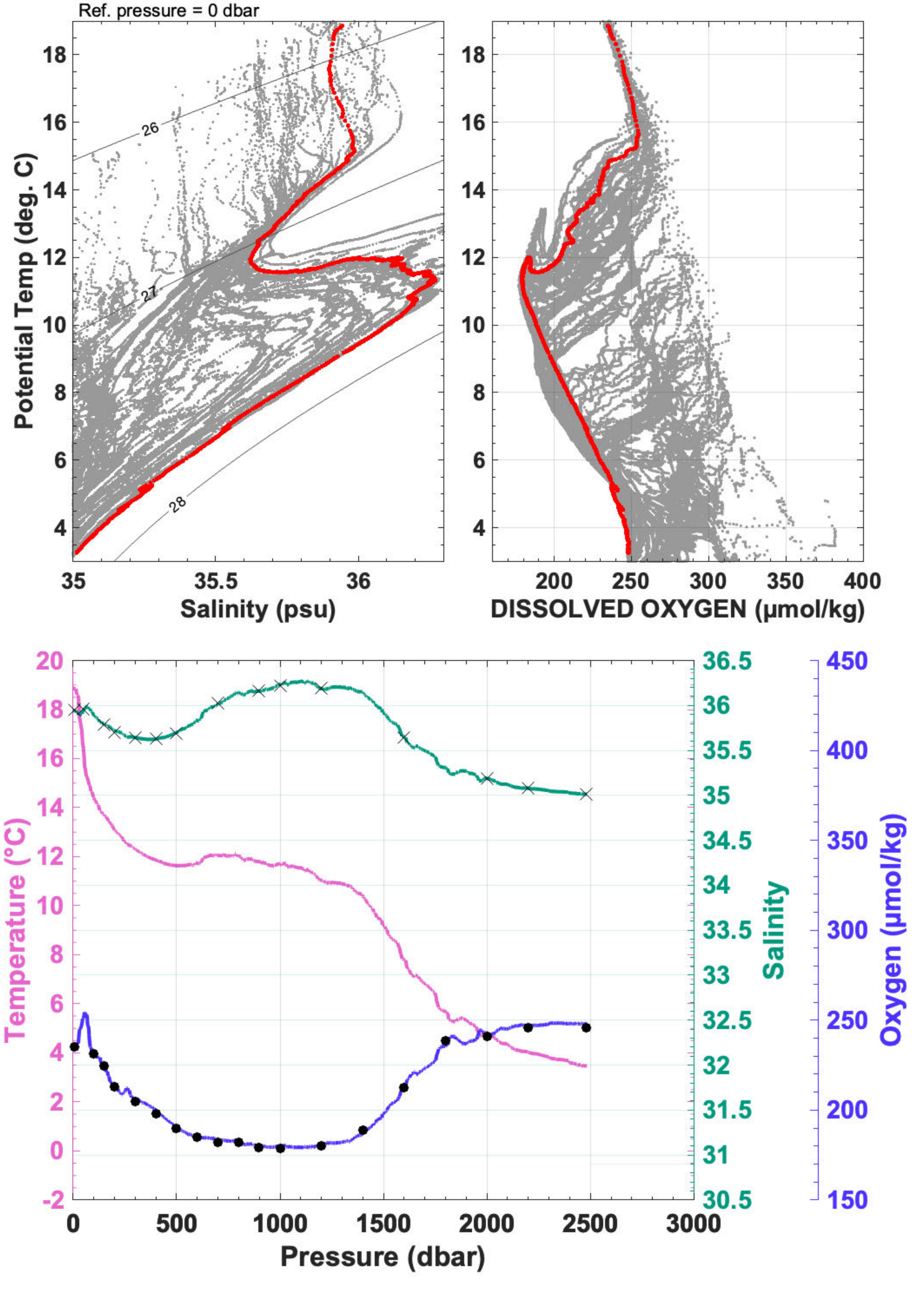
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
27.5
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 4



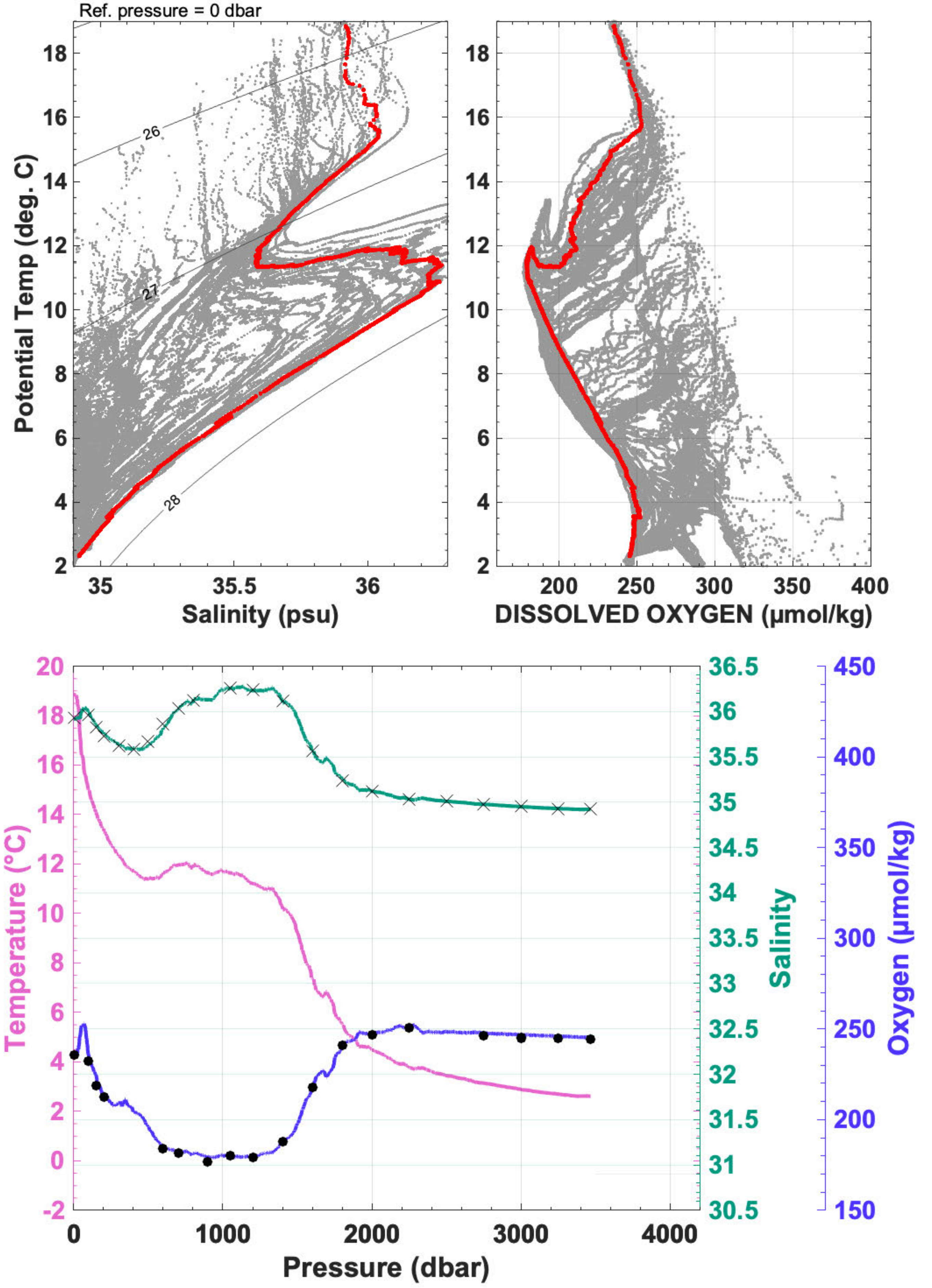
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 5



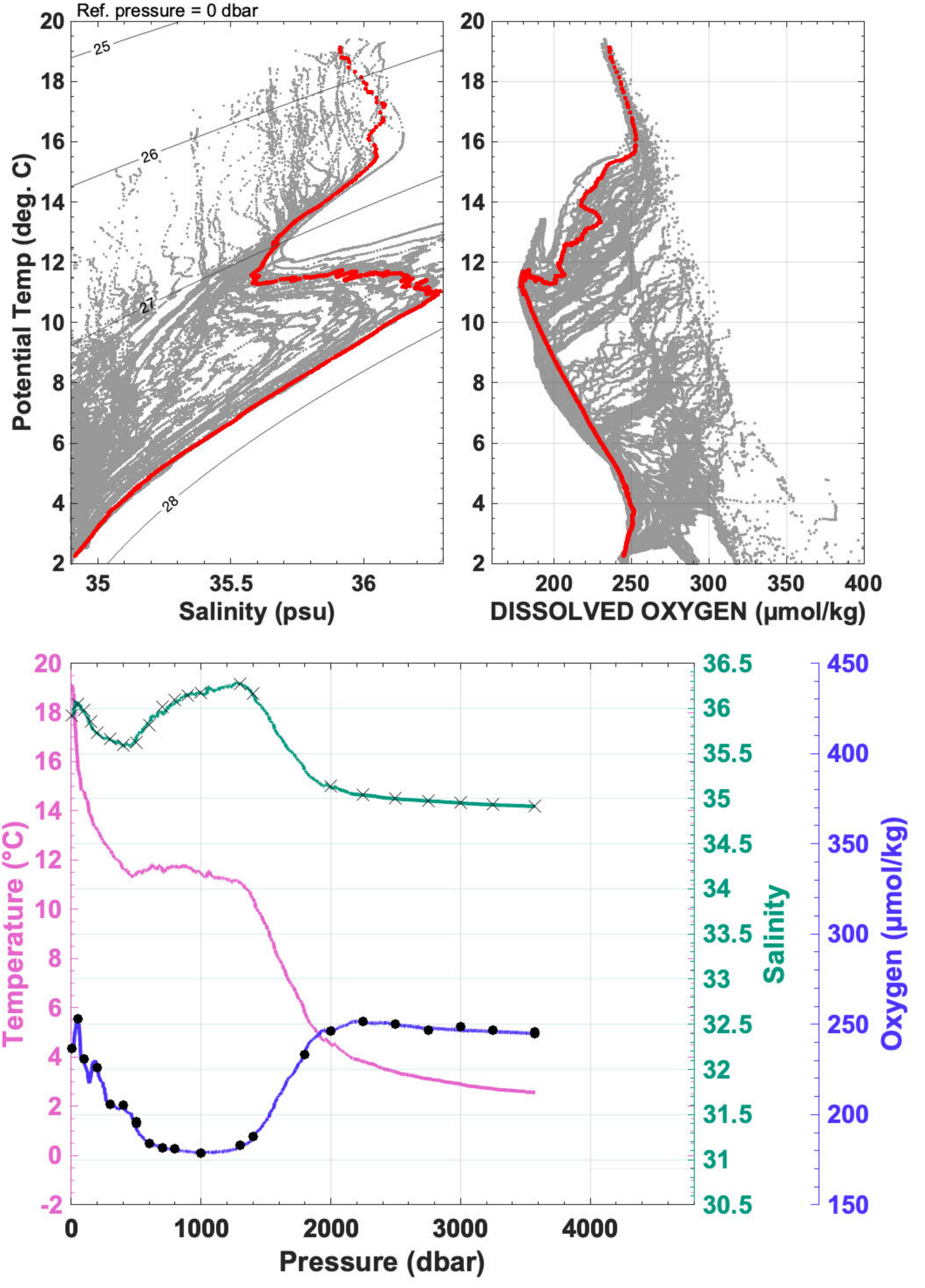
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
27
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 6



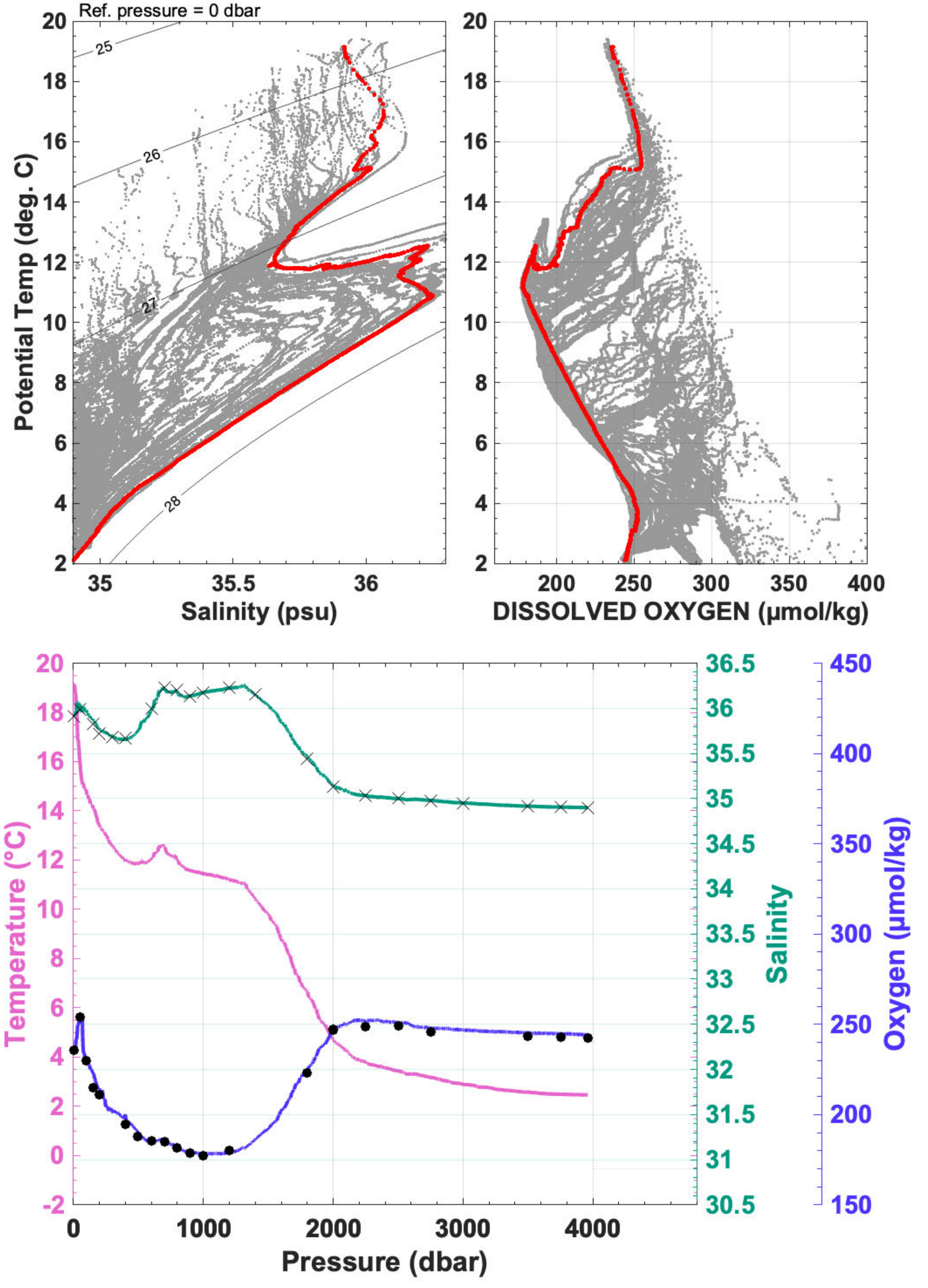
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
27
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 7



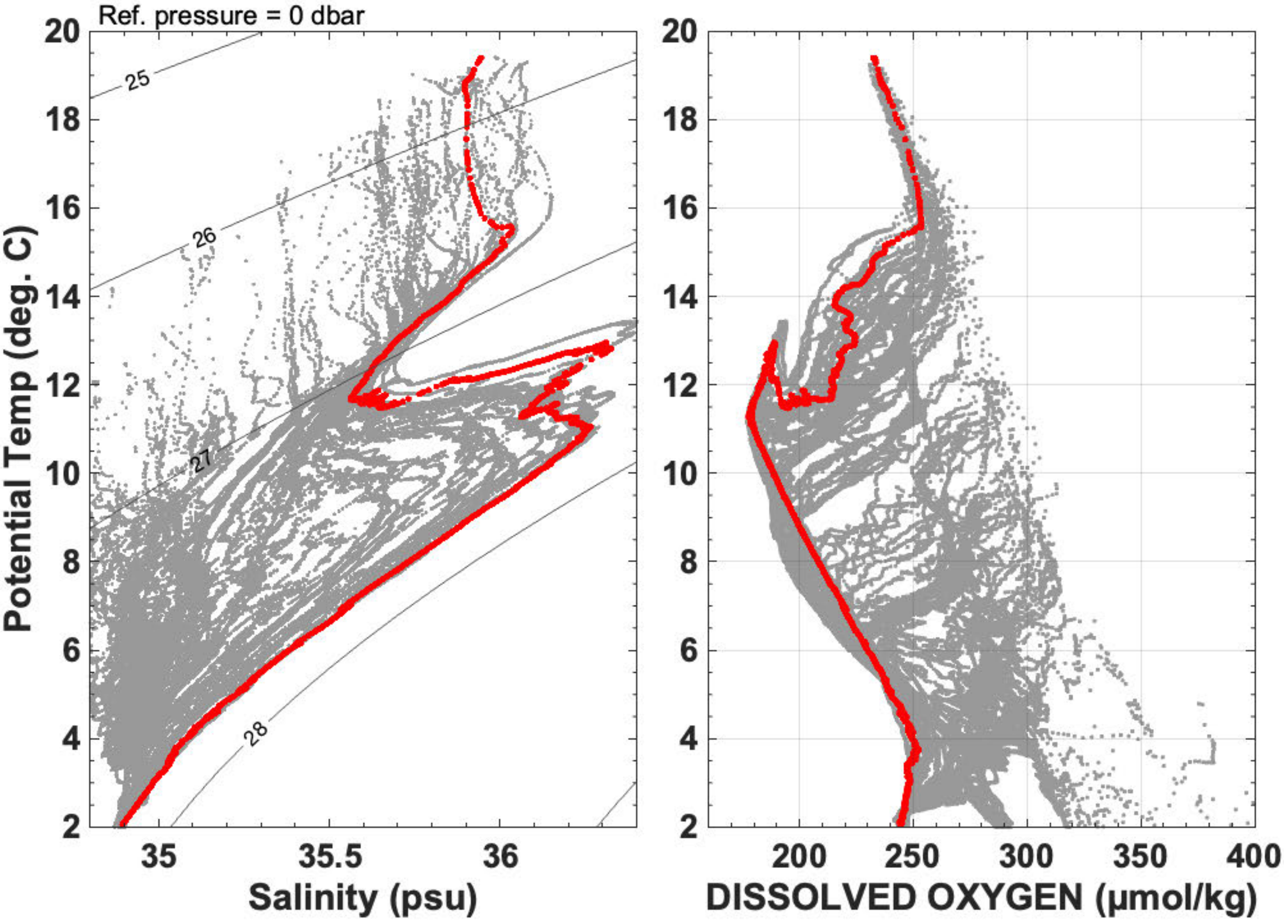
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 8

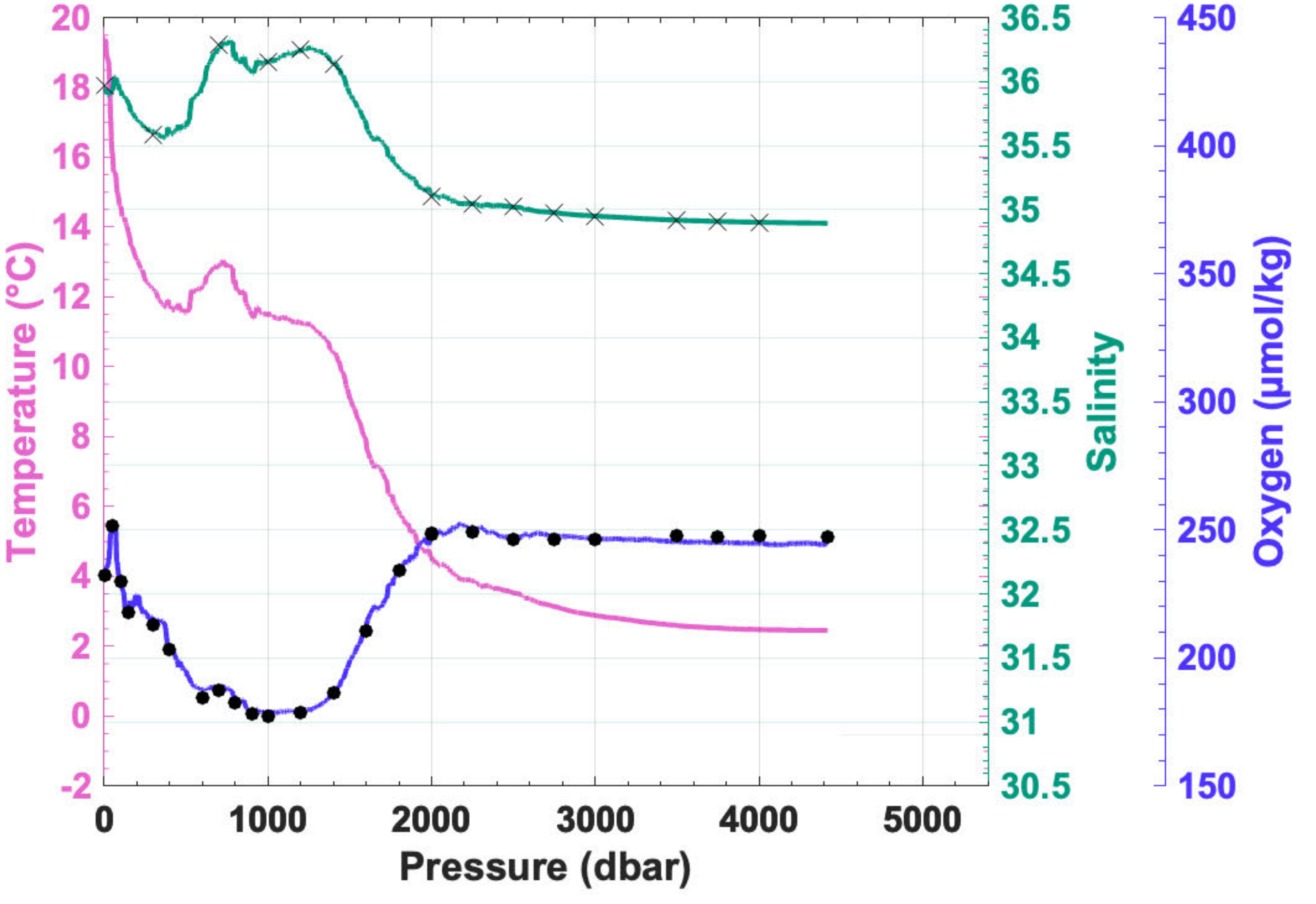


Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
35
35.5
36
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
1000
2000
3000
4000

STATION 9

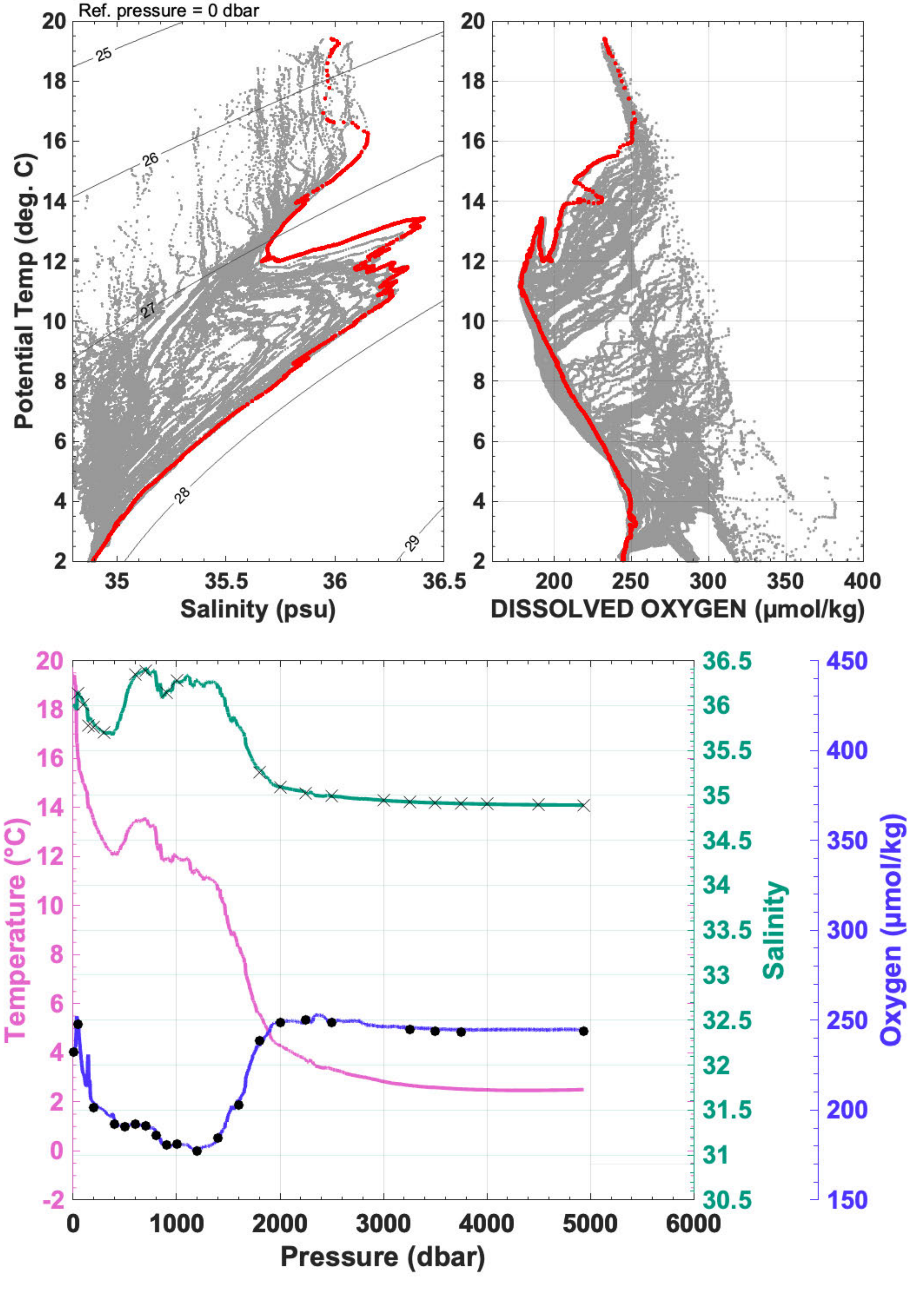


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25
26
27
28
DISSOLVED OXYGEN (µmol/kg)



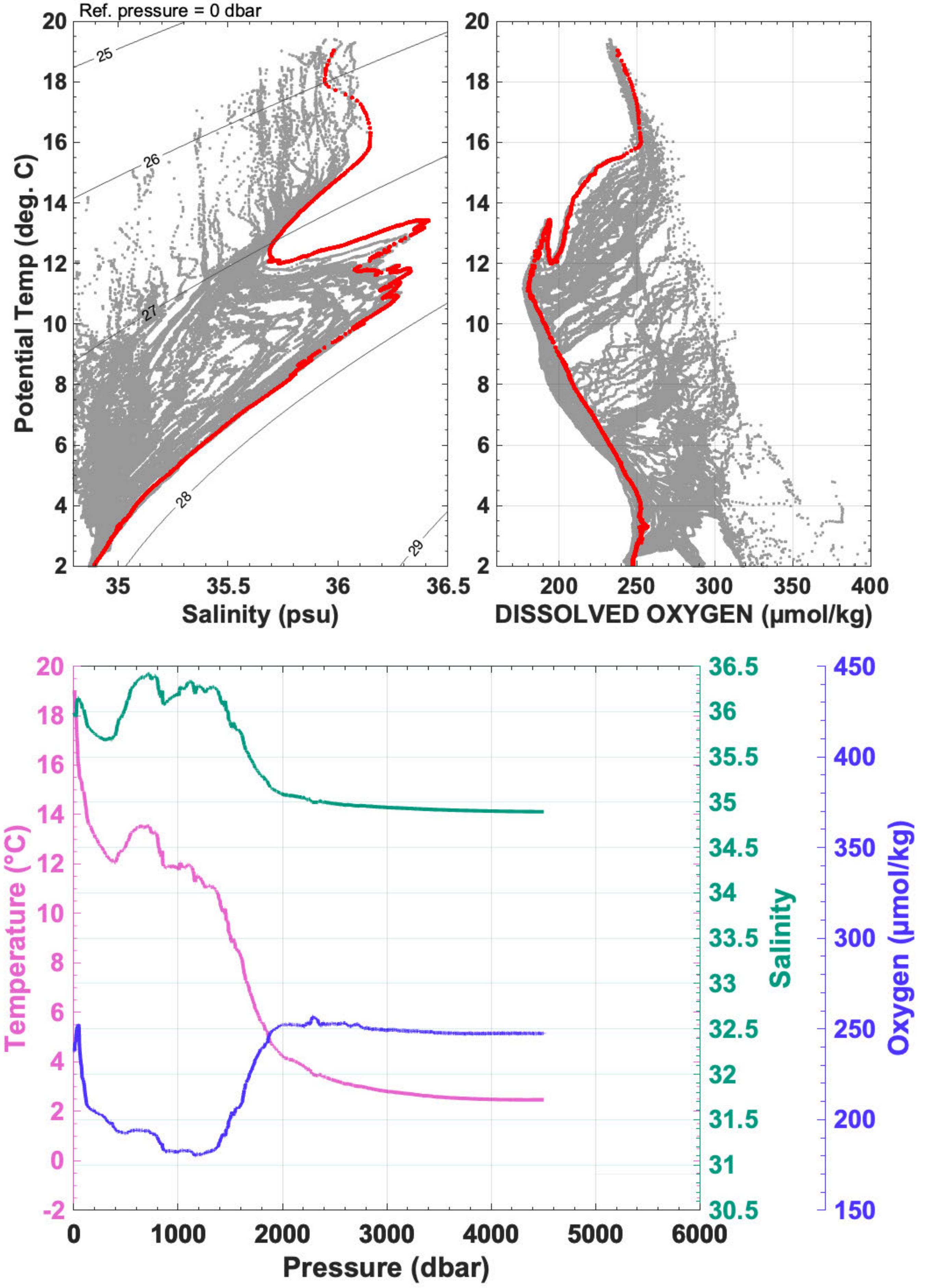
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 10

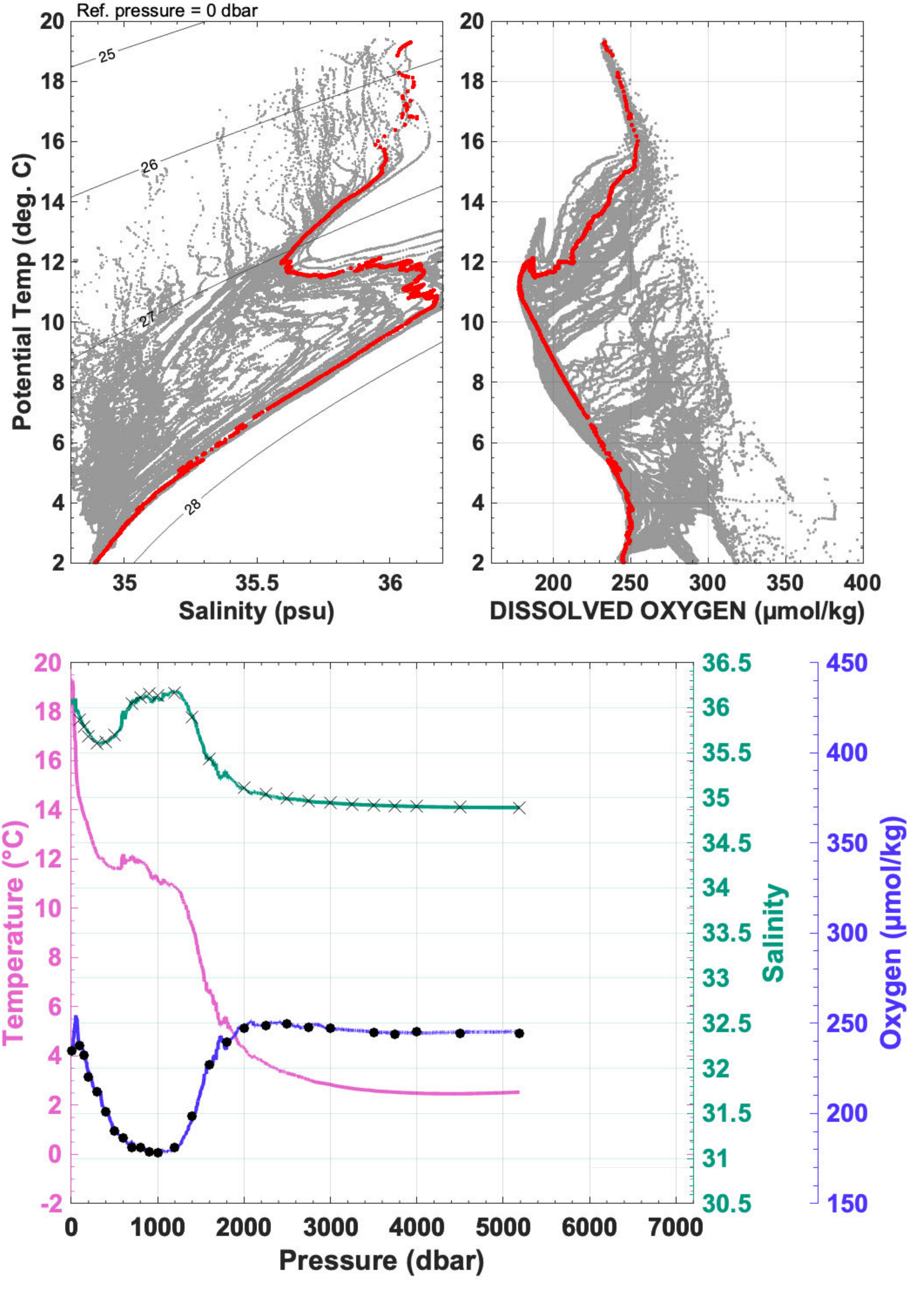


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 10 CAST 2

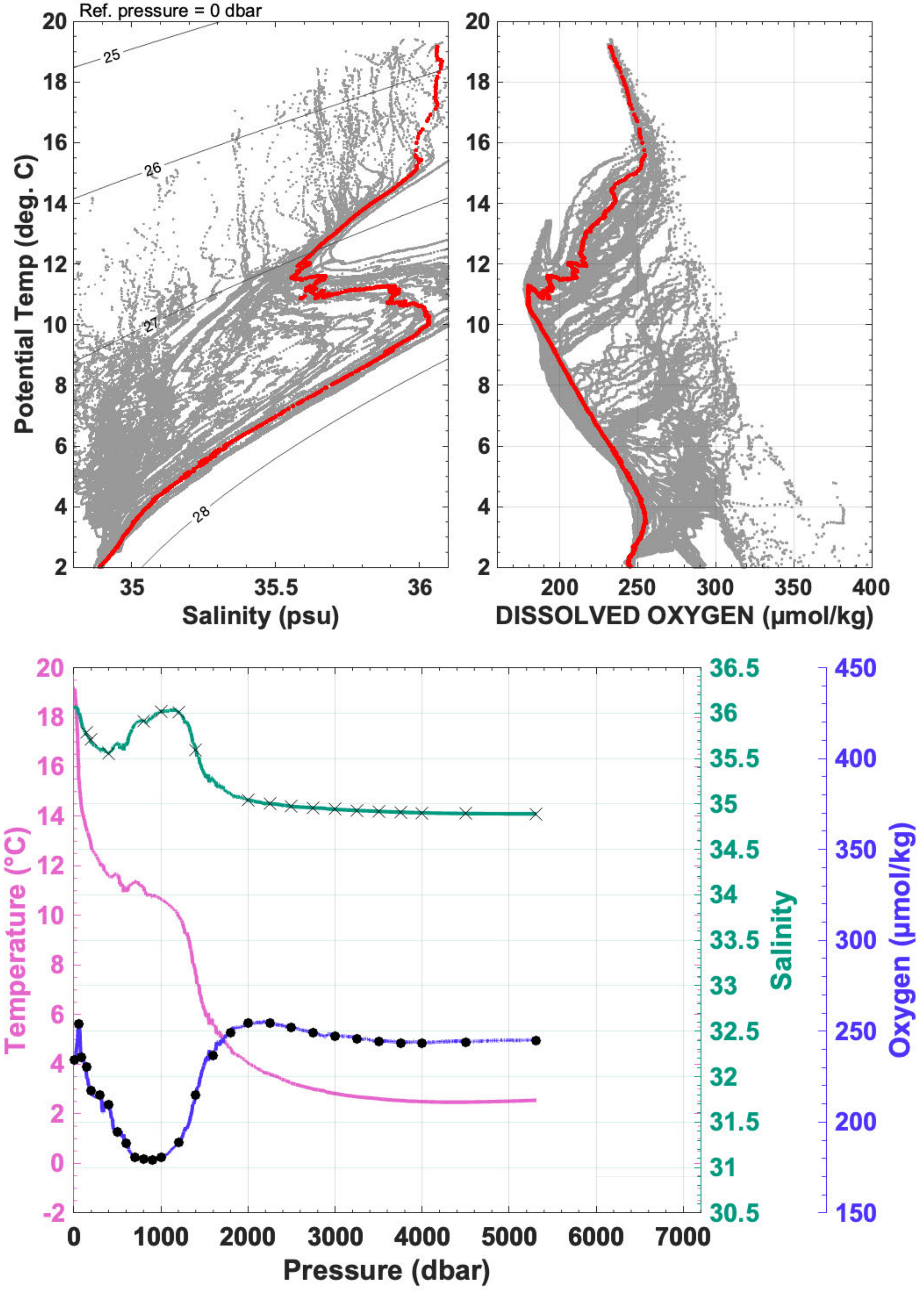


STATION 11



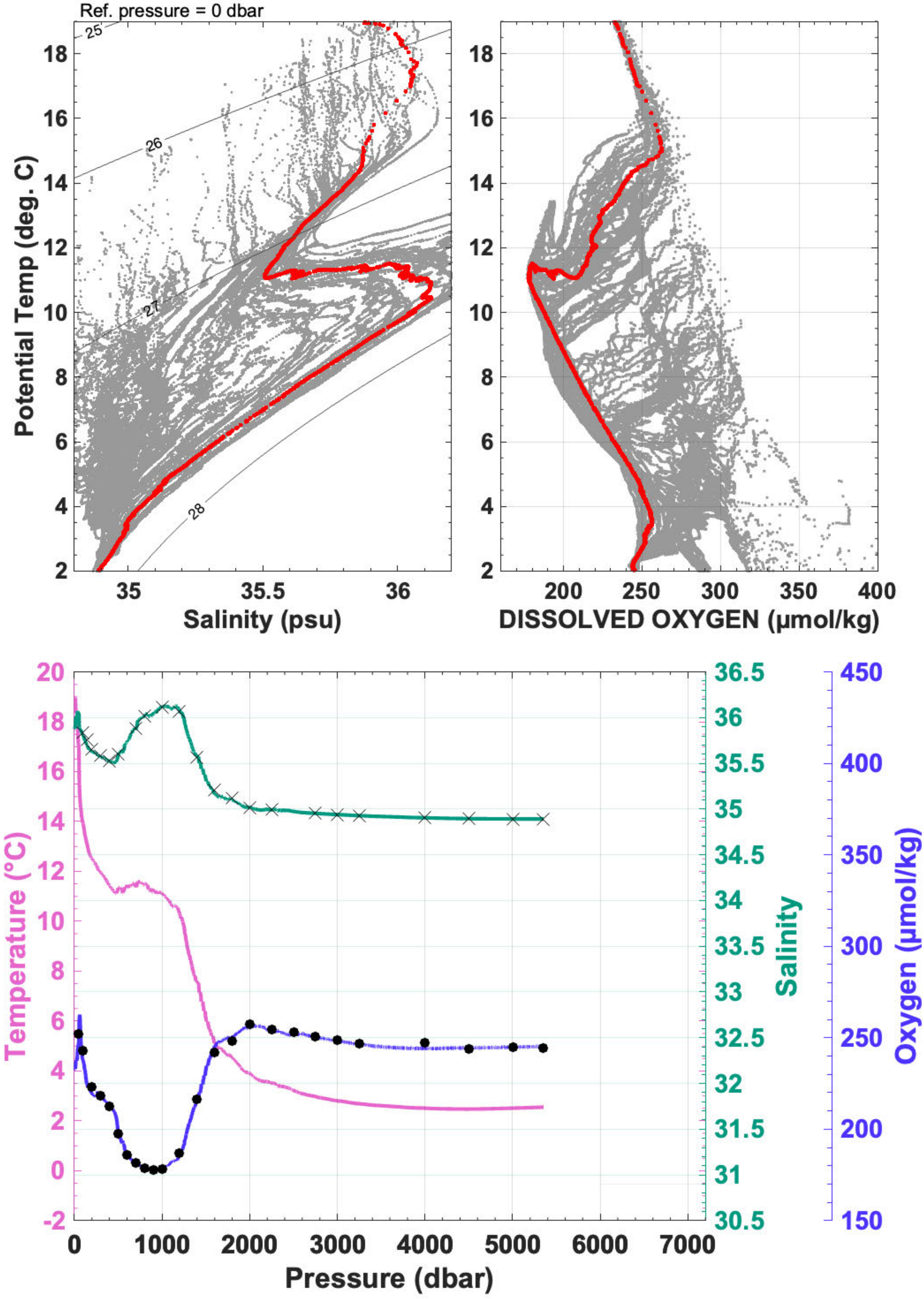
Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 12



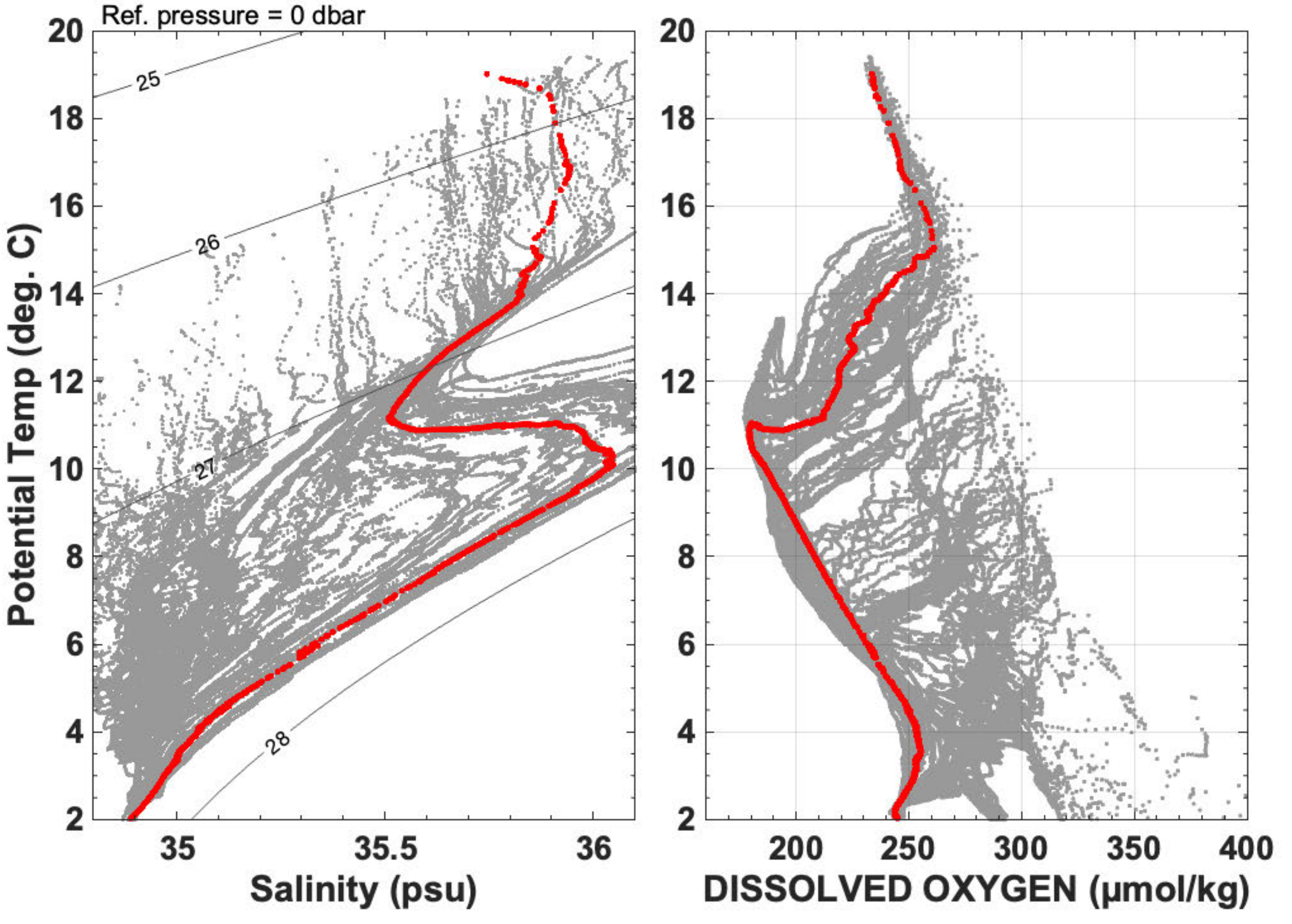
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 13

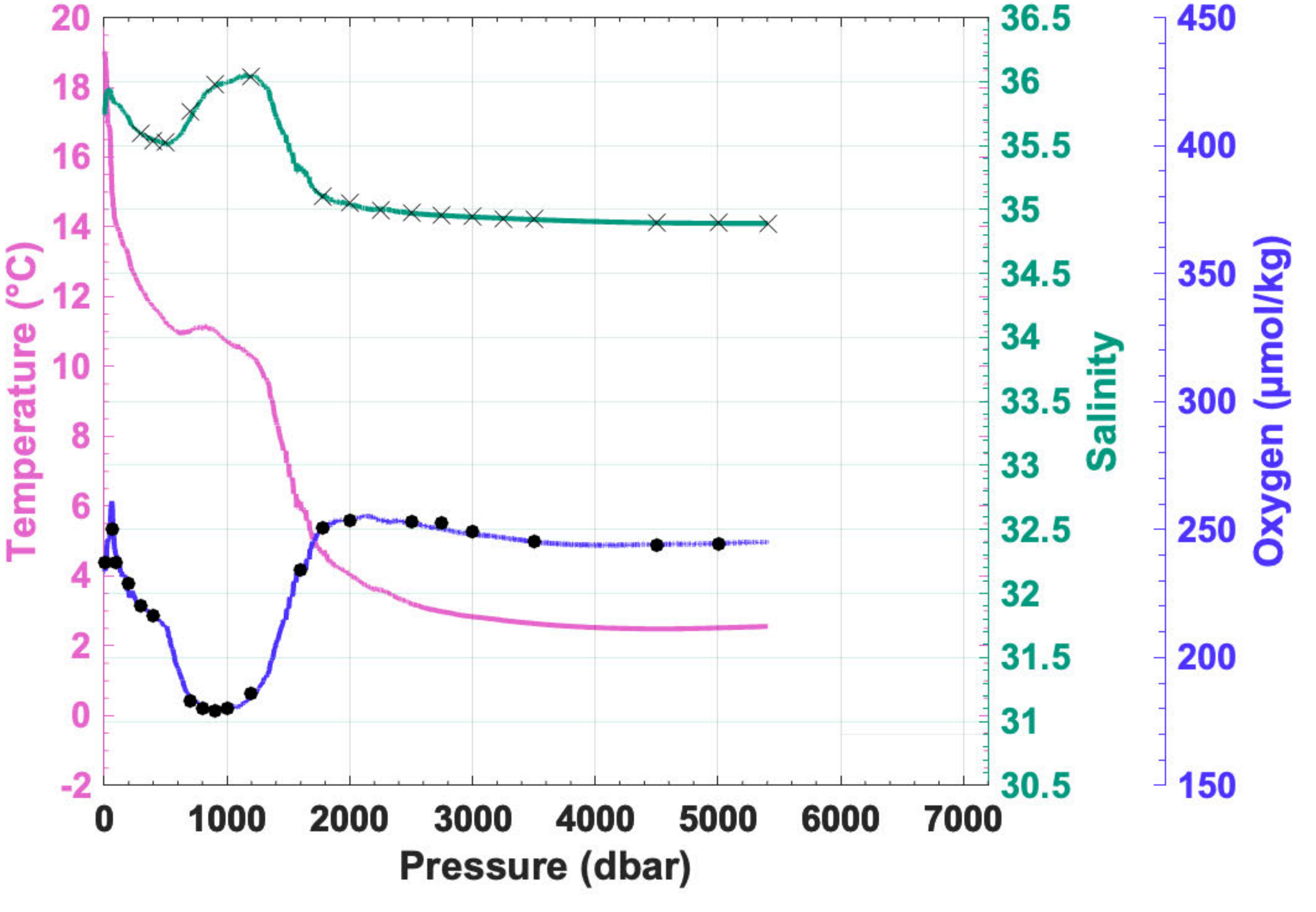


Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 14

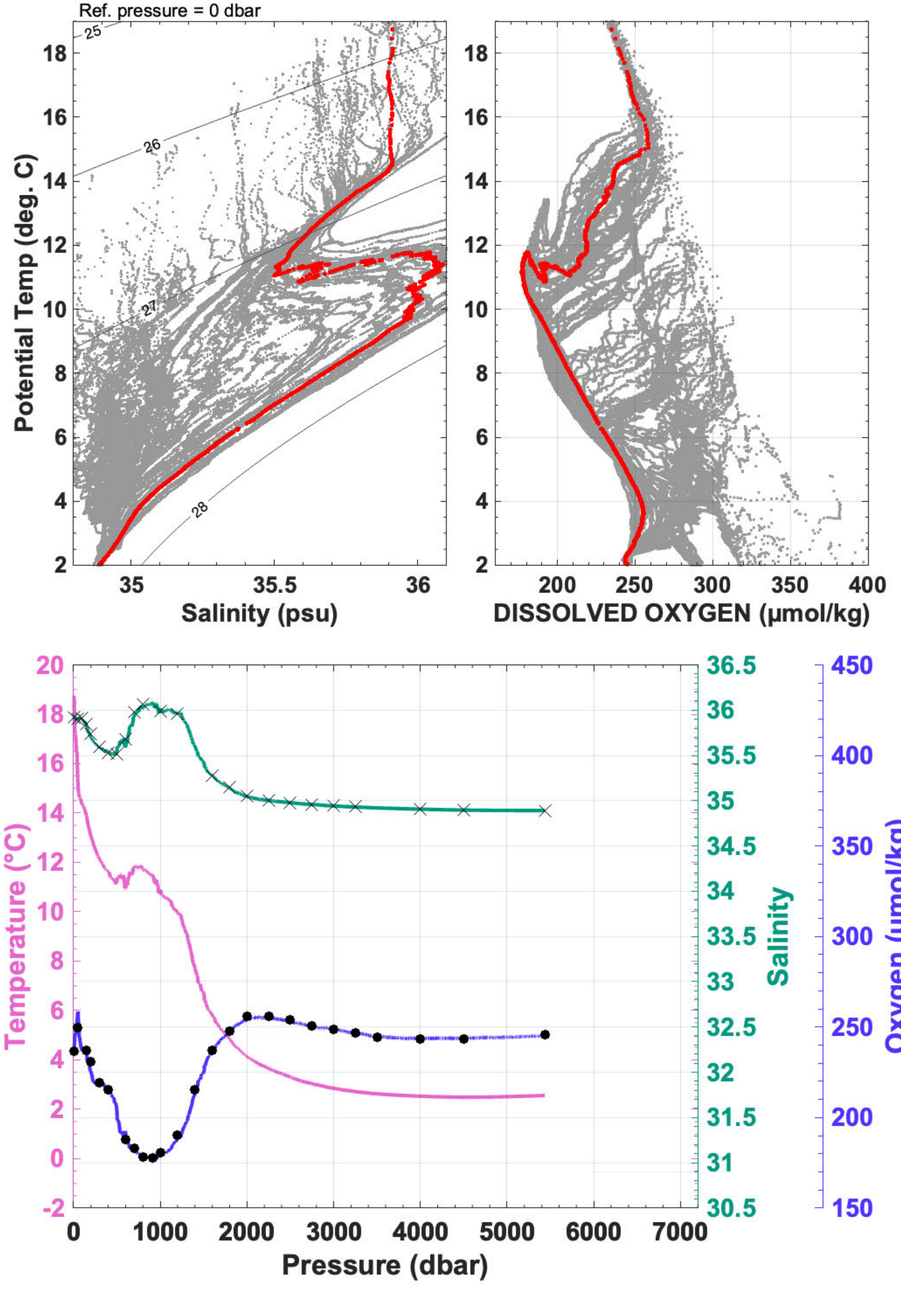


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



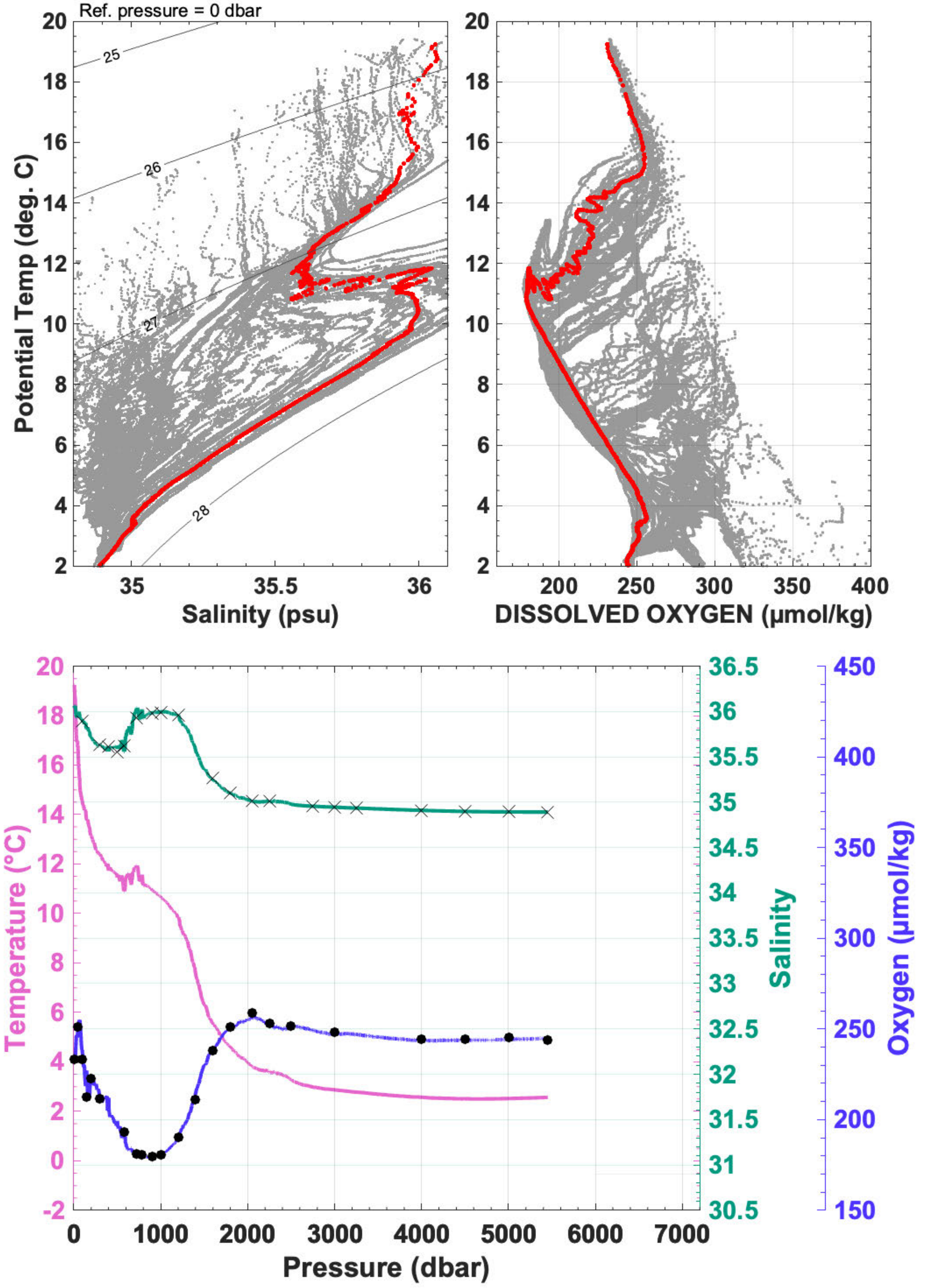
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 15



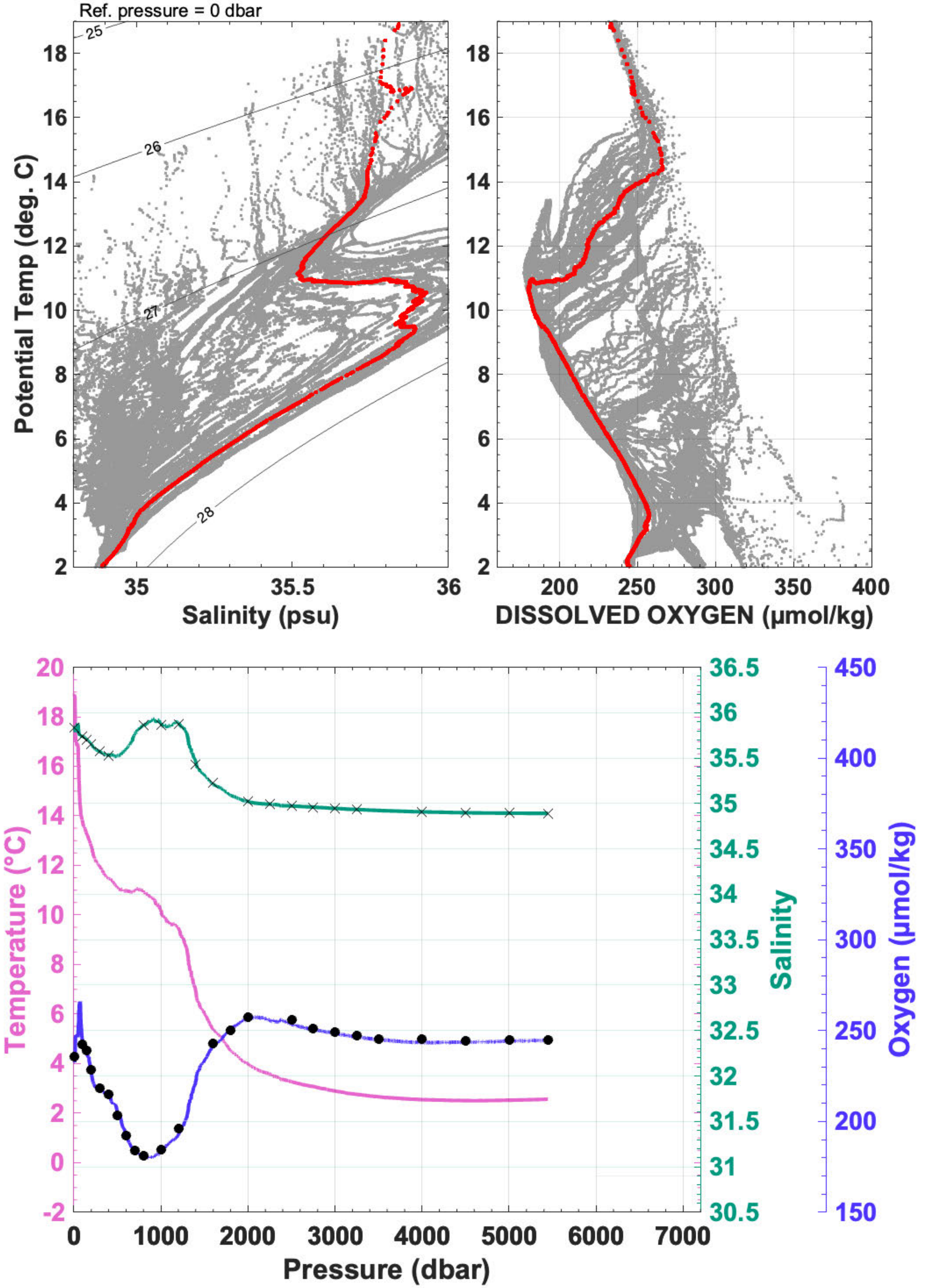
Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 16



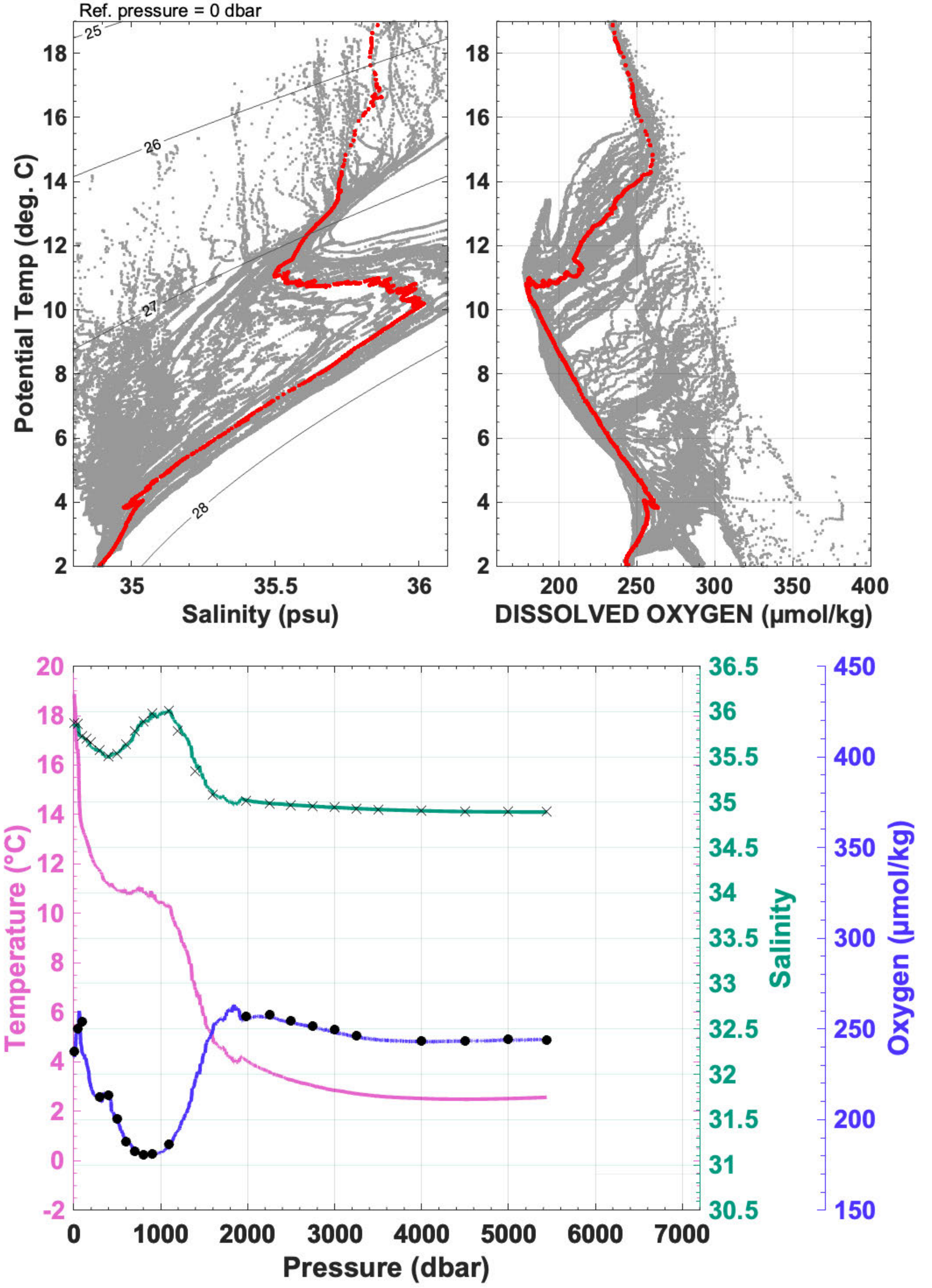
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
25
26
27
28
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 17



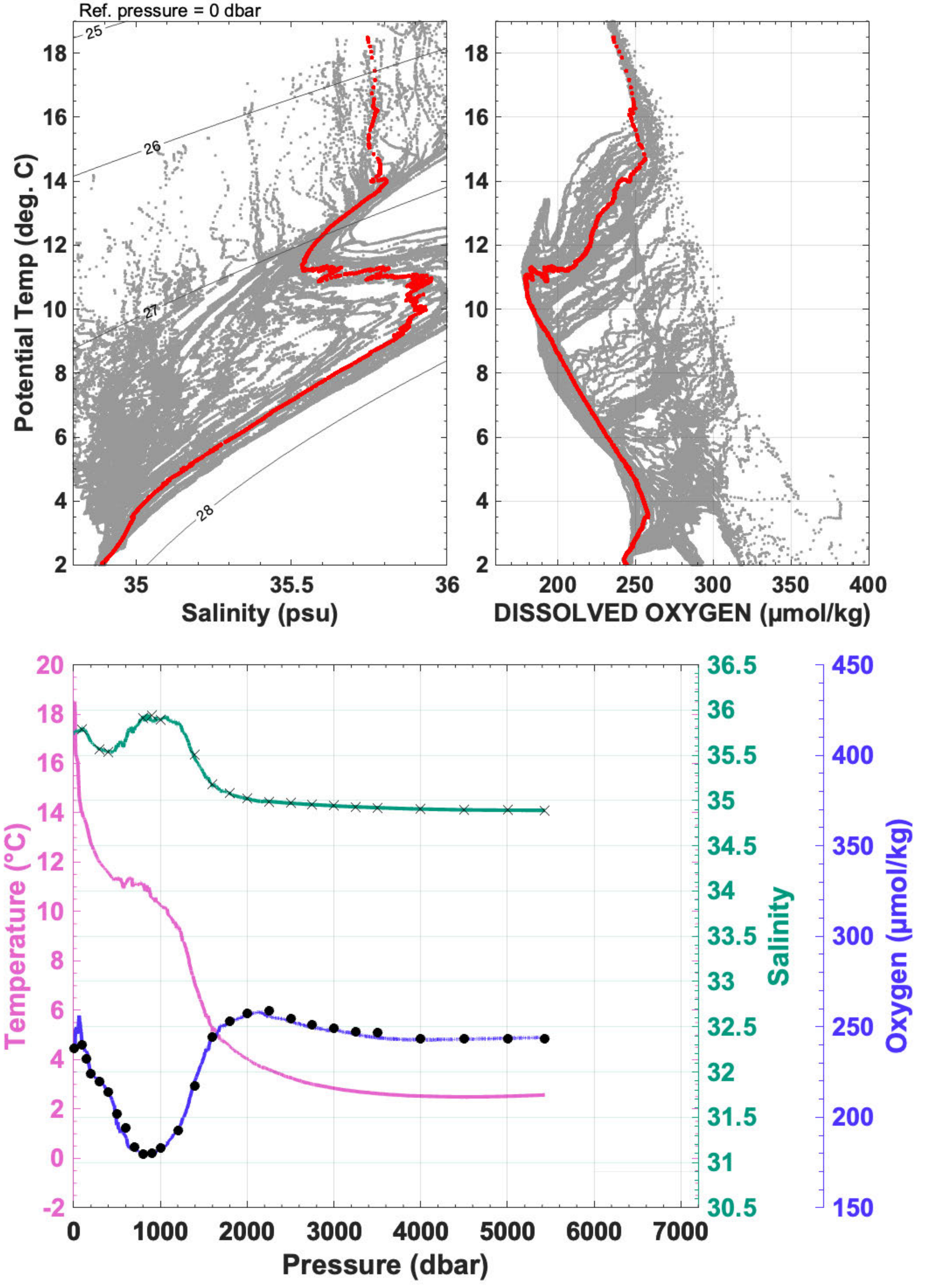
Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
2
4
6
8
10
12
14
16
18
35
35.5
36
Salinity (psu)
200
250
300
350
400
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
-2
0
2
4
6
8
10
12
14
16
18
20
Salinity
30.5
31
31.5
32
32.5
33
33.5
34
34.5
35
35.5
36
36.5
Oxygen (µmol/kg)
150
200
250
300
350
400
450
0
1000
2000
3000
4000
5000
6000
7000
Pressure (dbar)

STATION 18



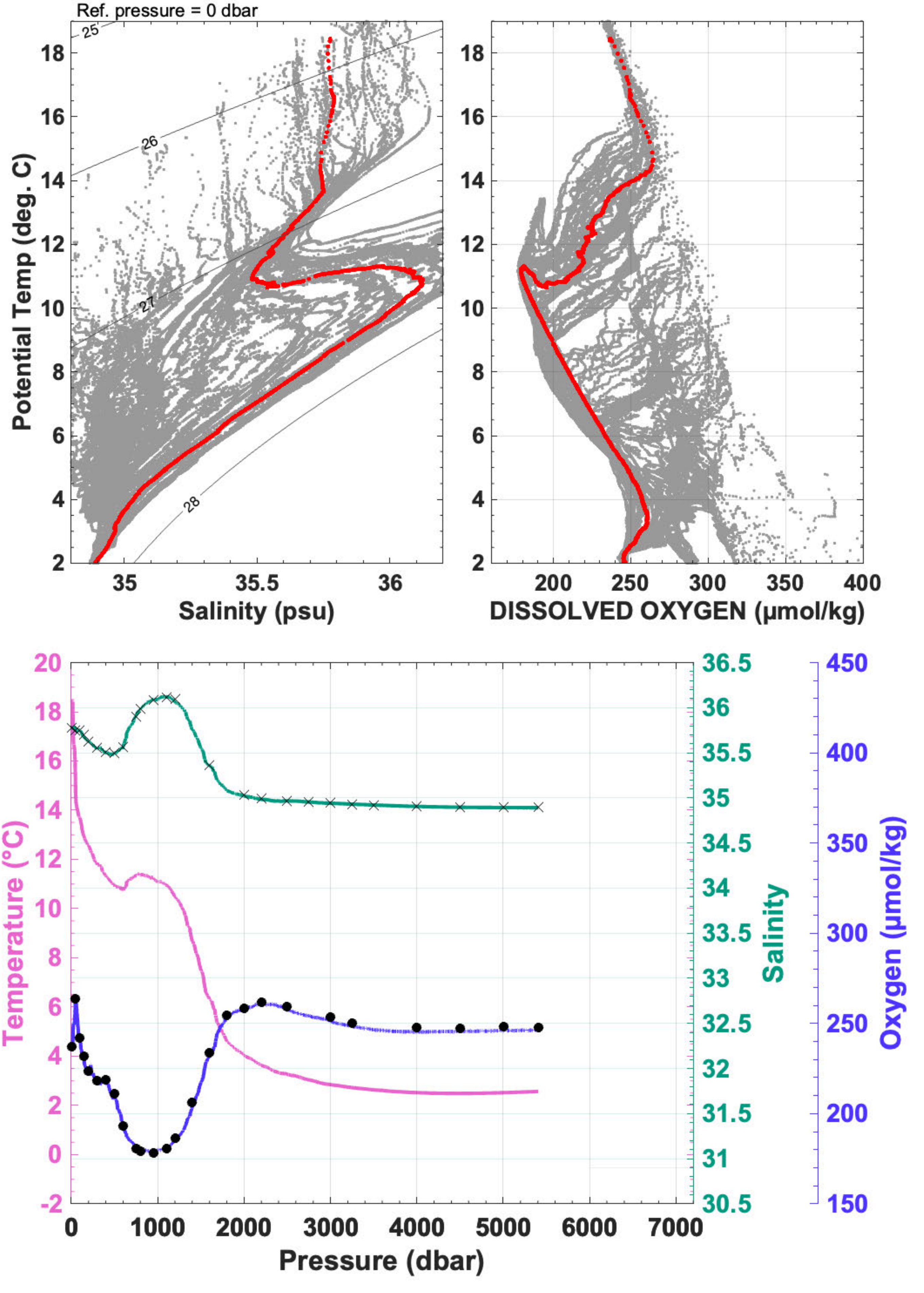
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 19



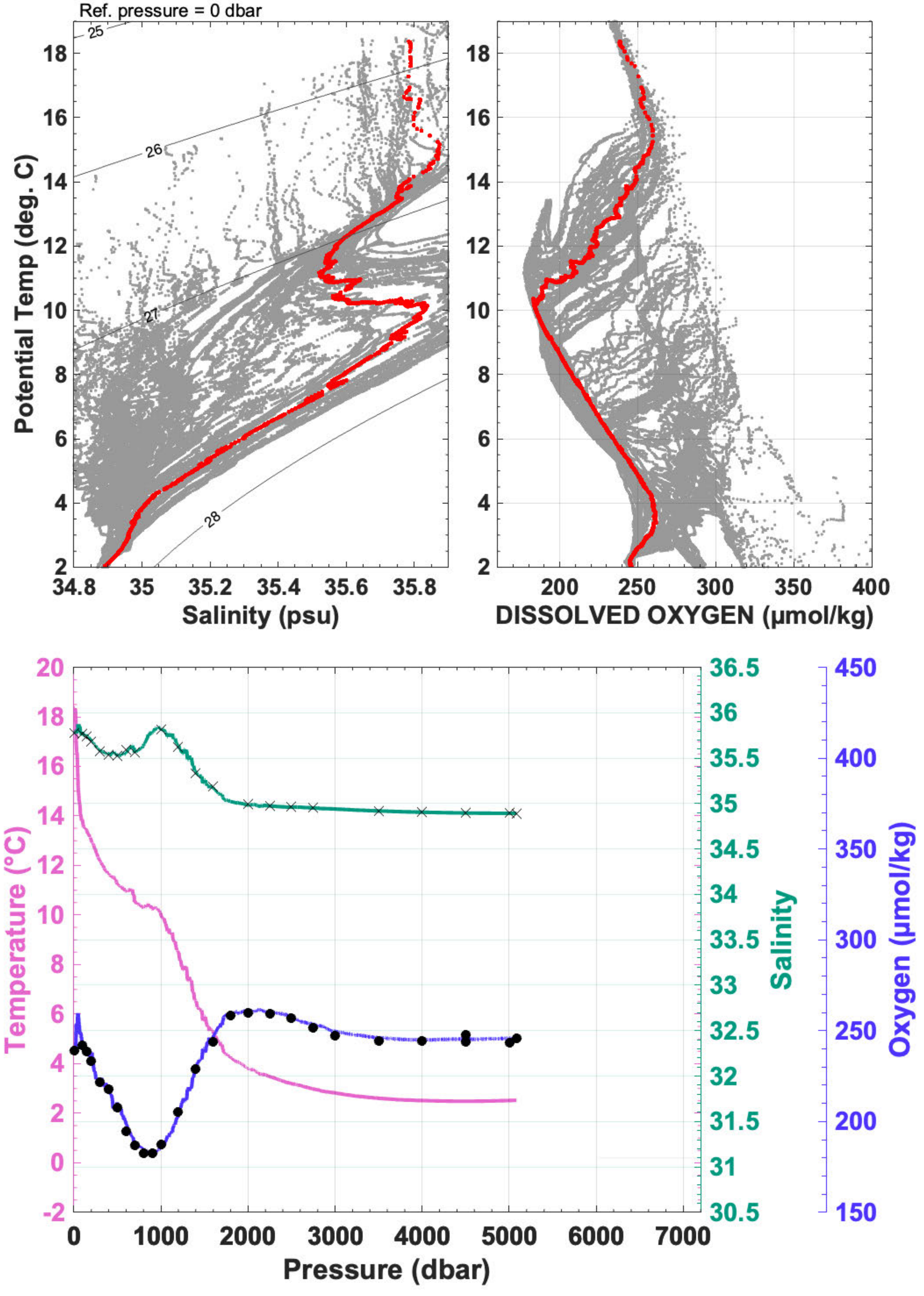
Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 20



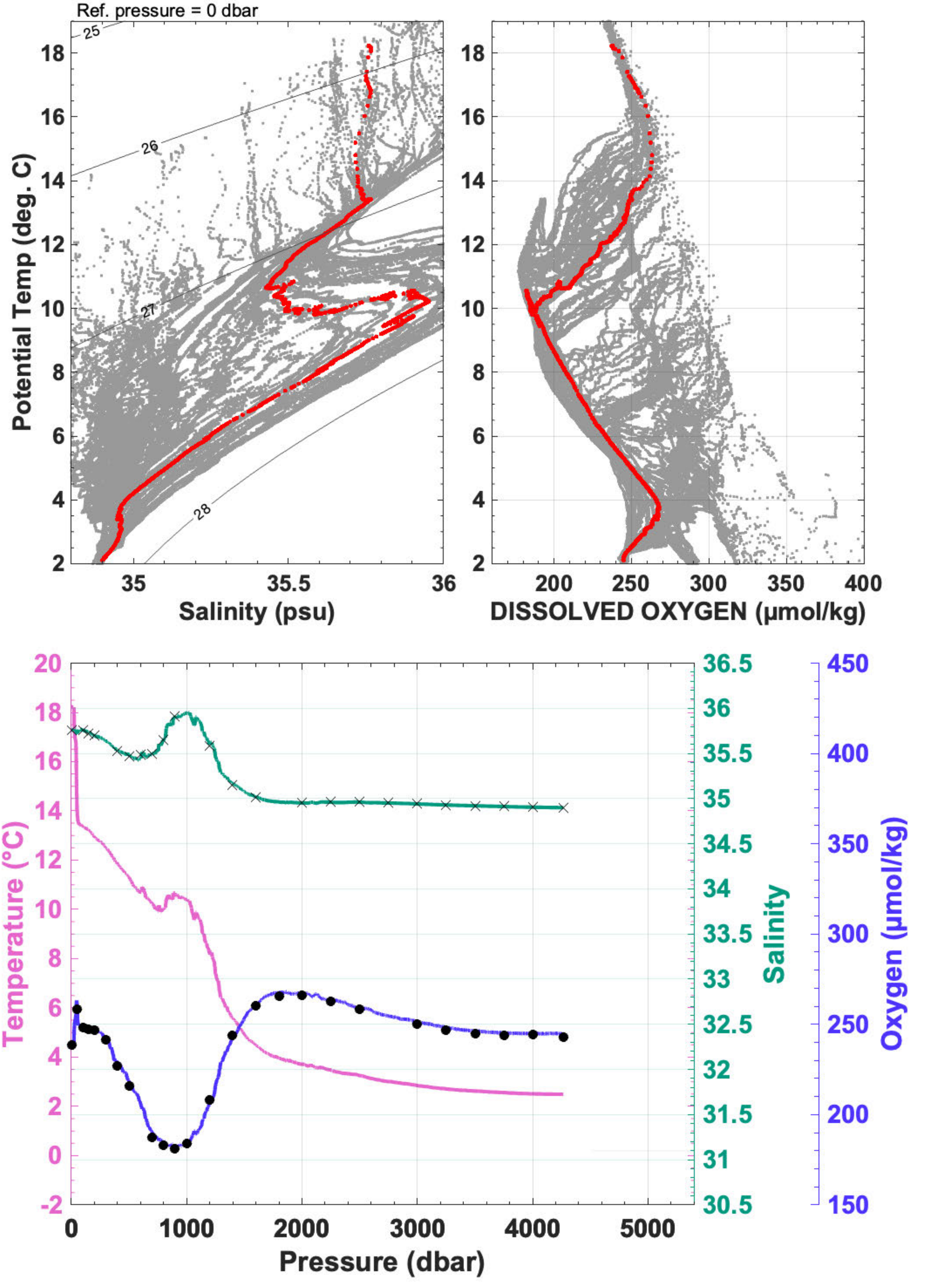
Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 21



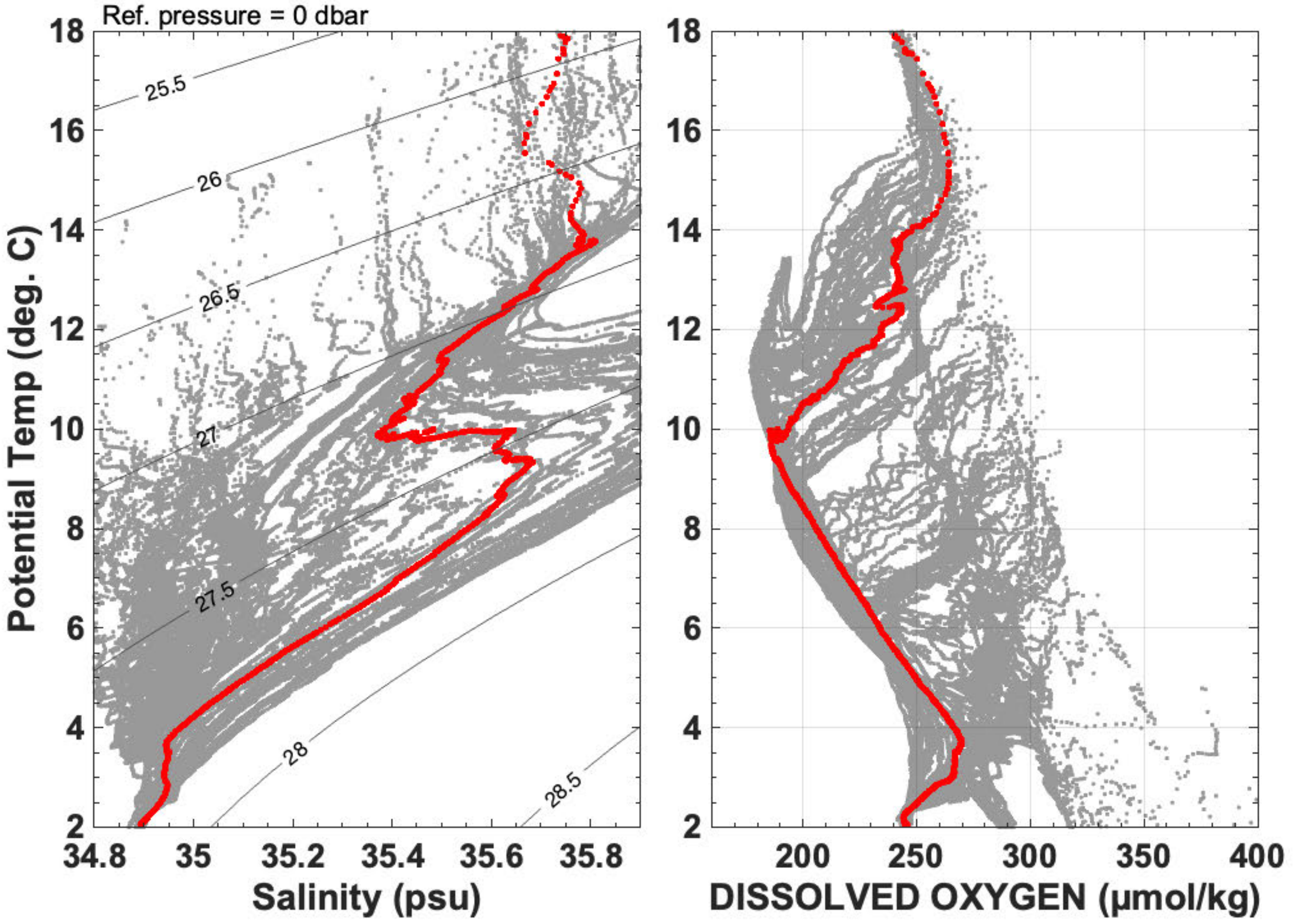
Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 22

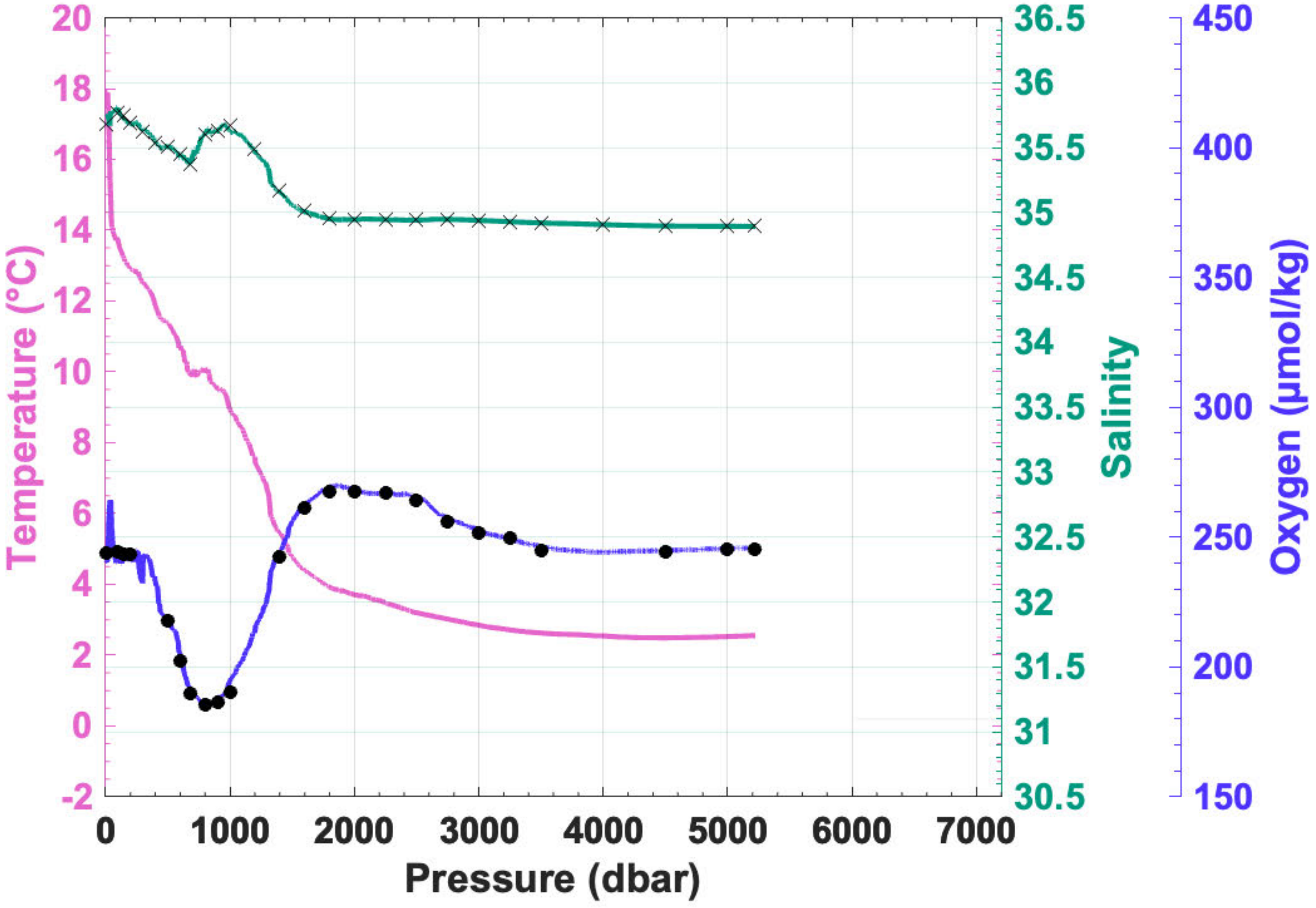


Ref. pressure = 0 dbar
25
26
27
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 23

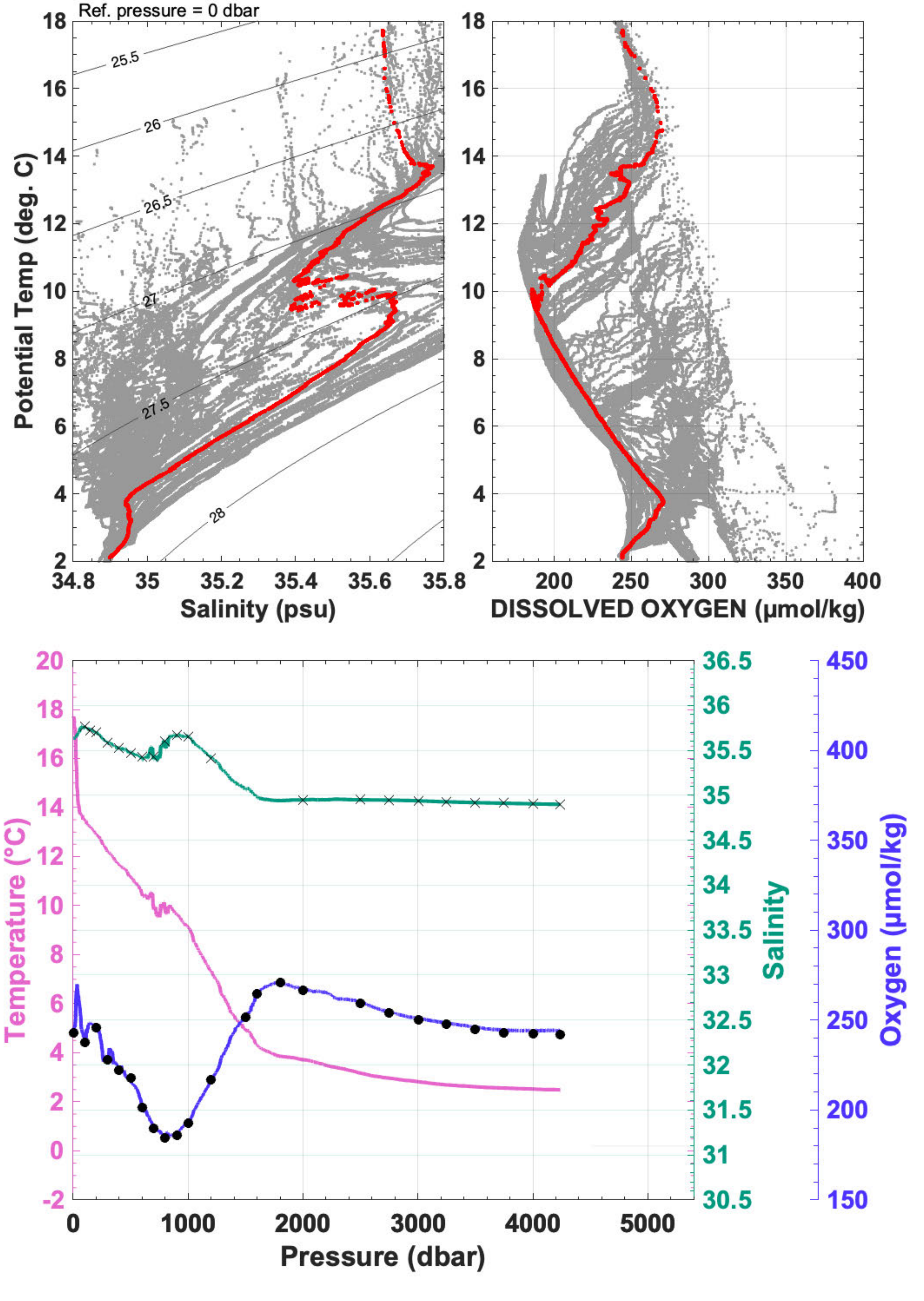


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
28.5
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



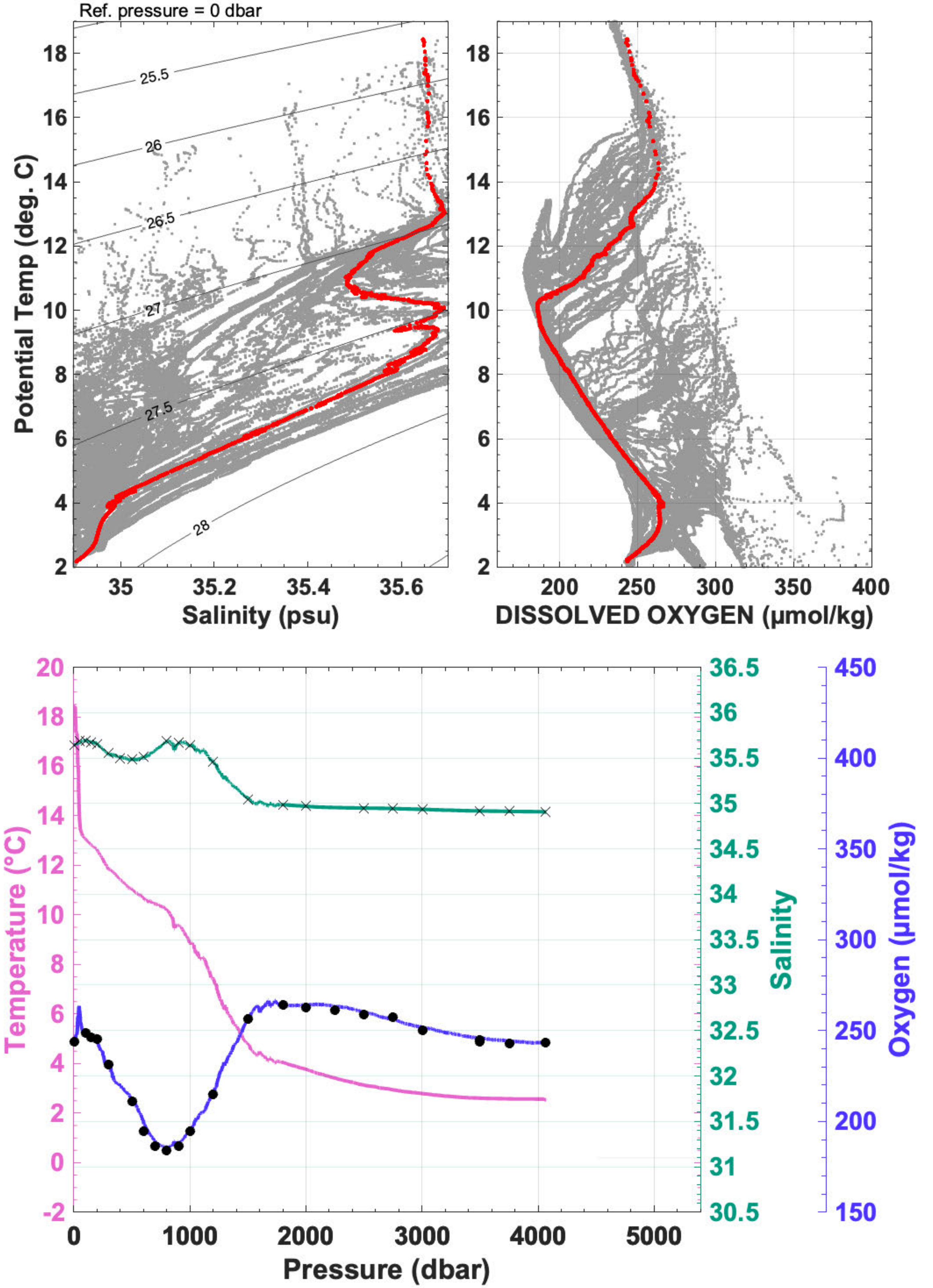
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 24



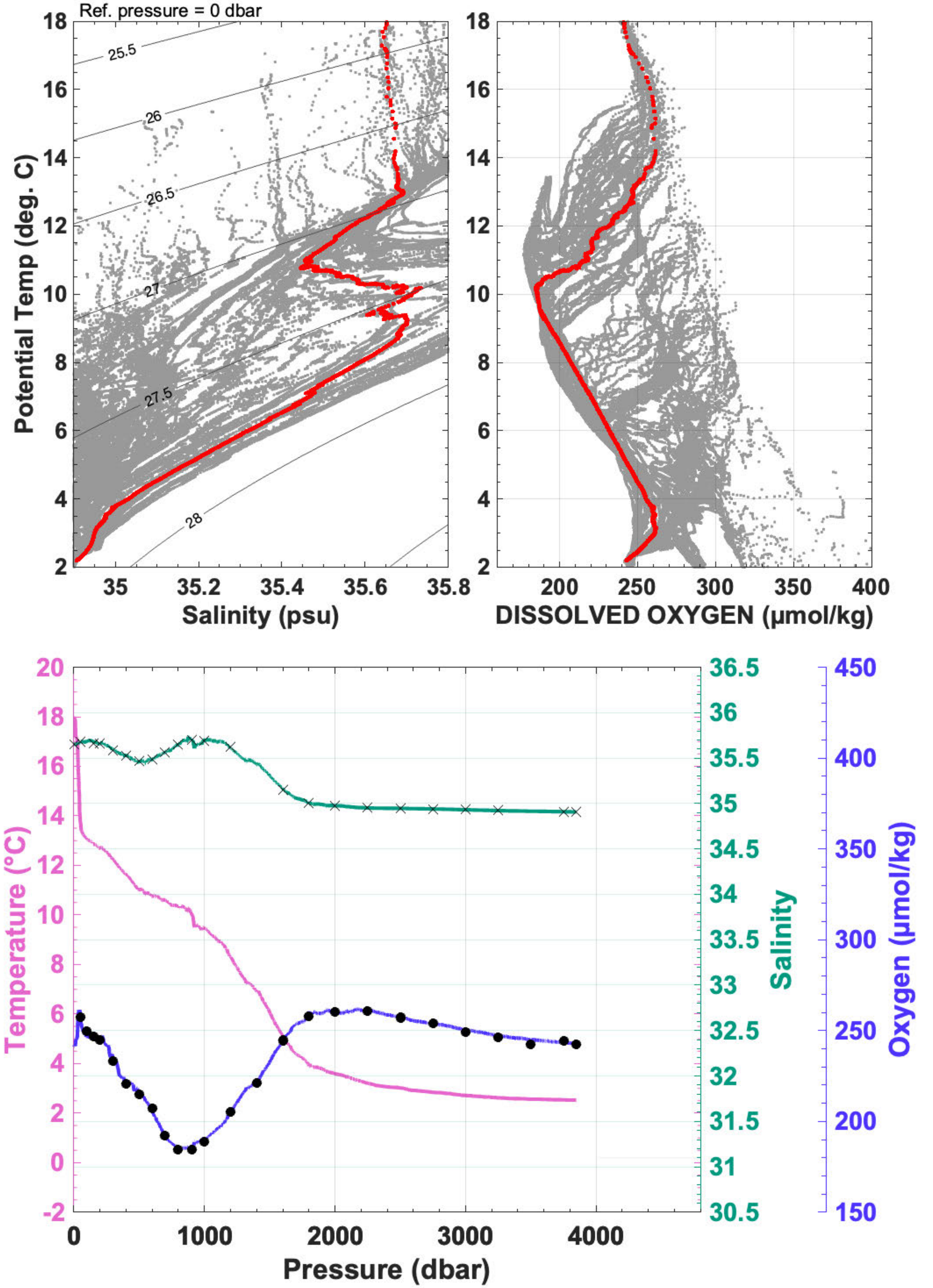
Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 25



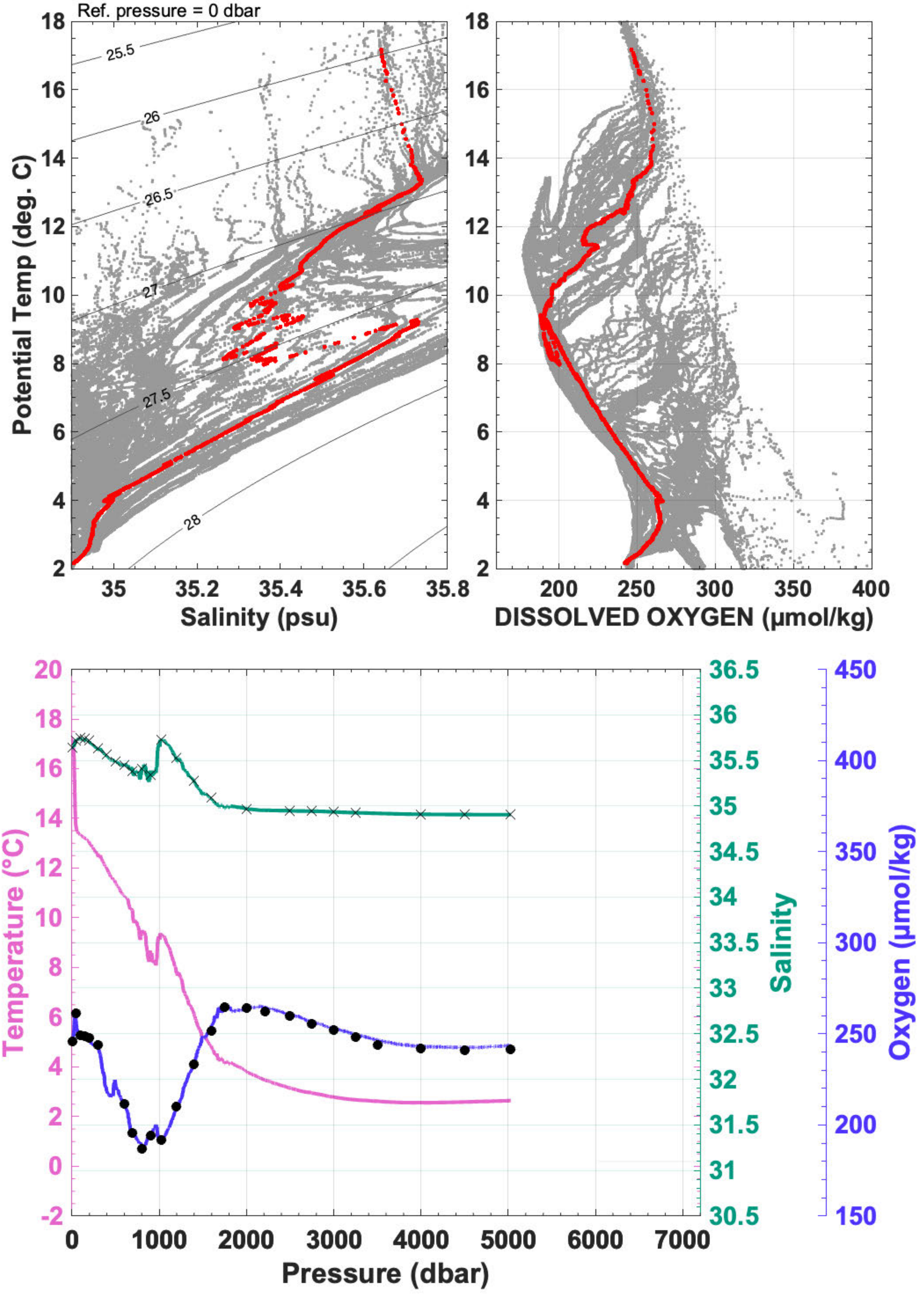
Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 26



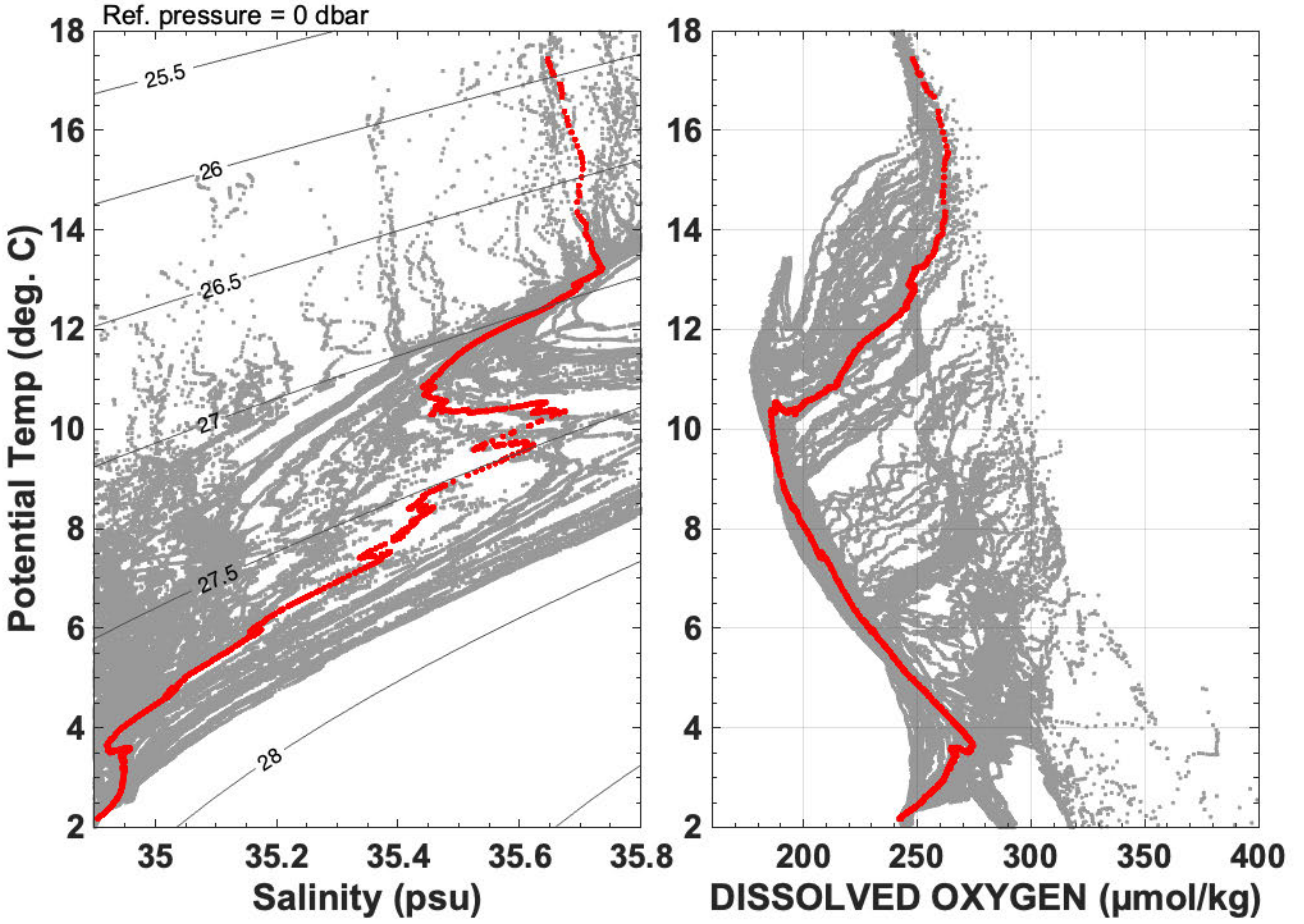
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 27

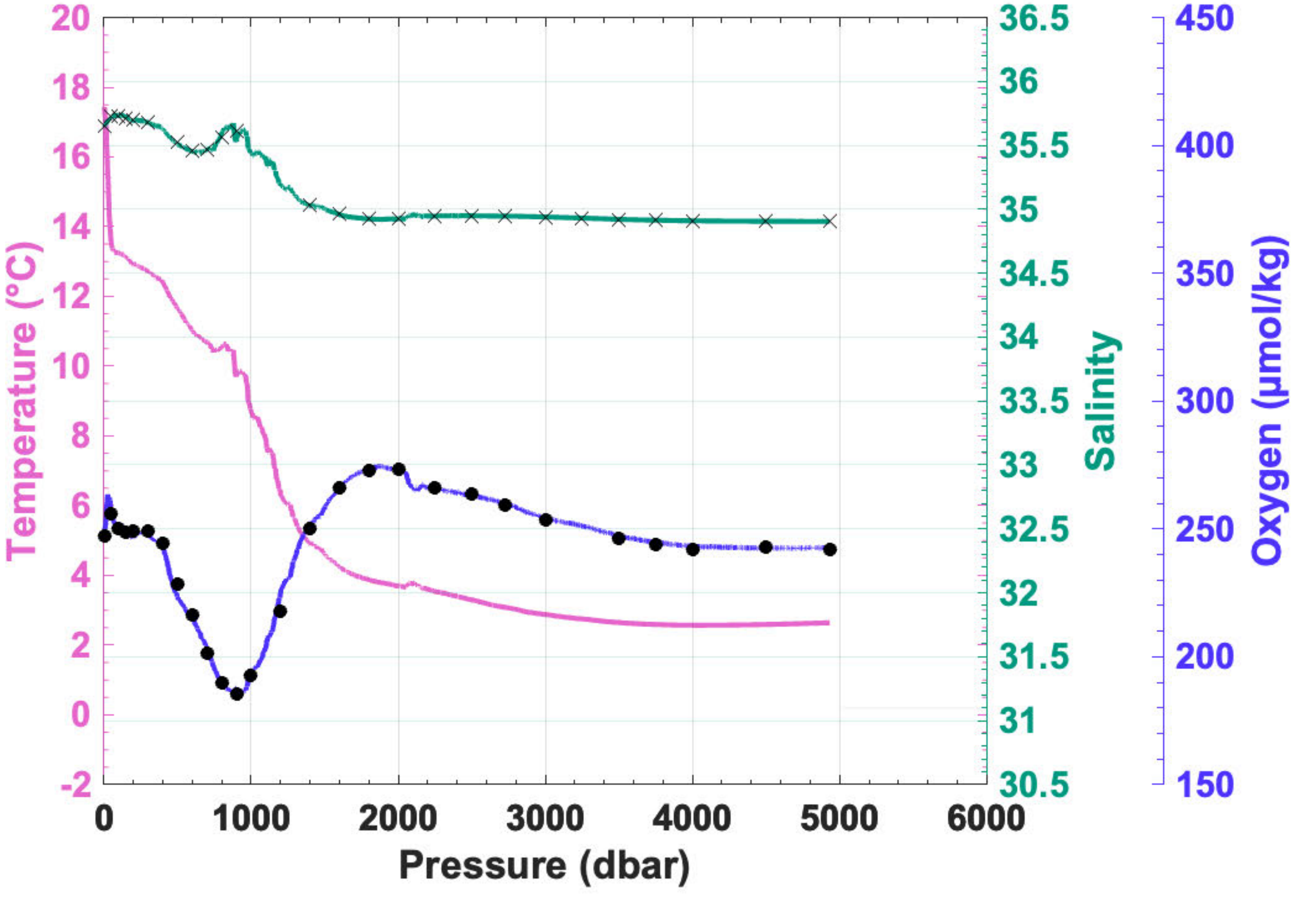


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 28

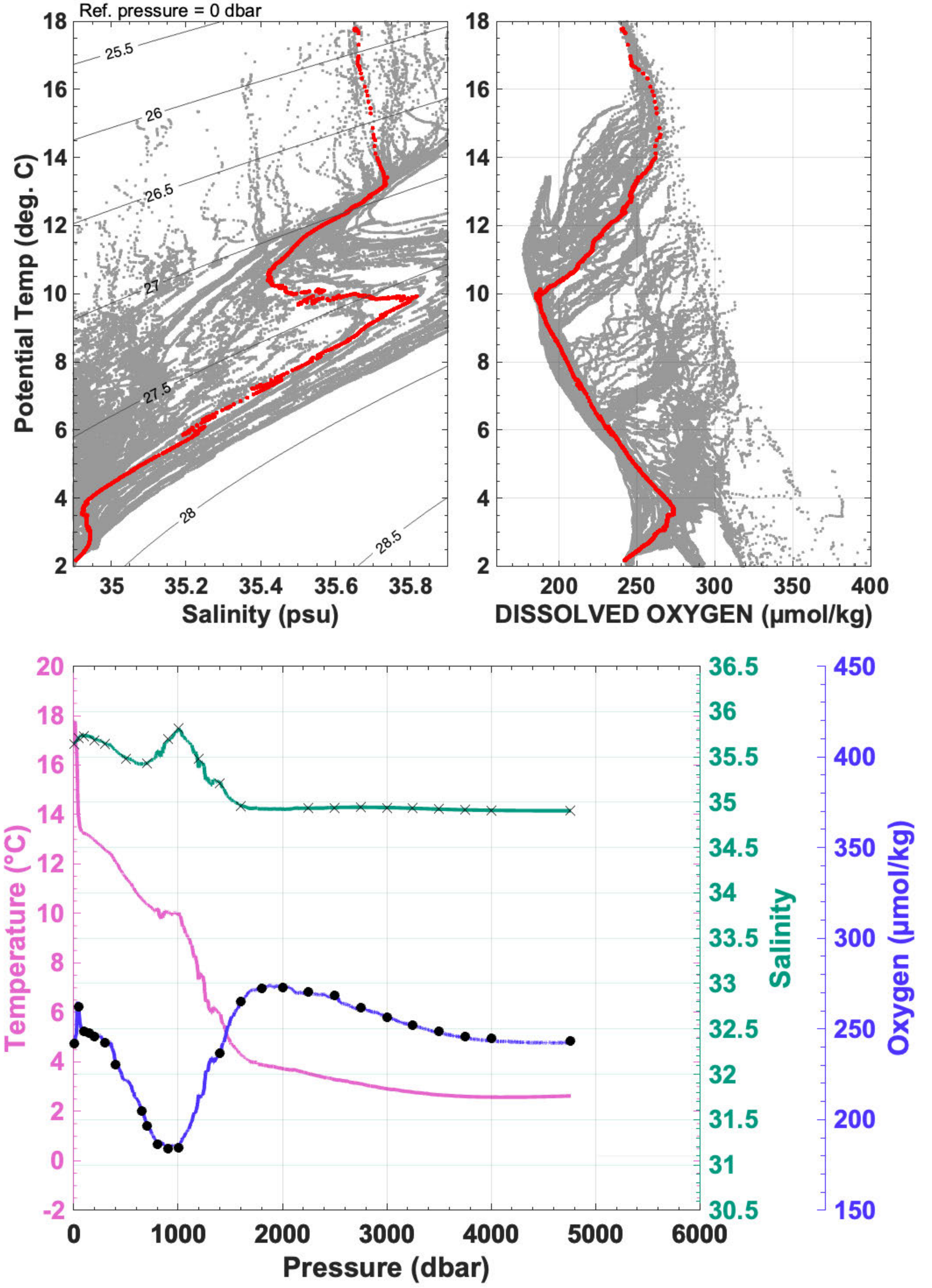


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



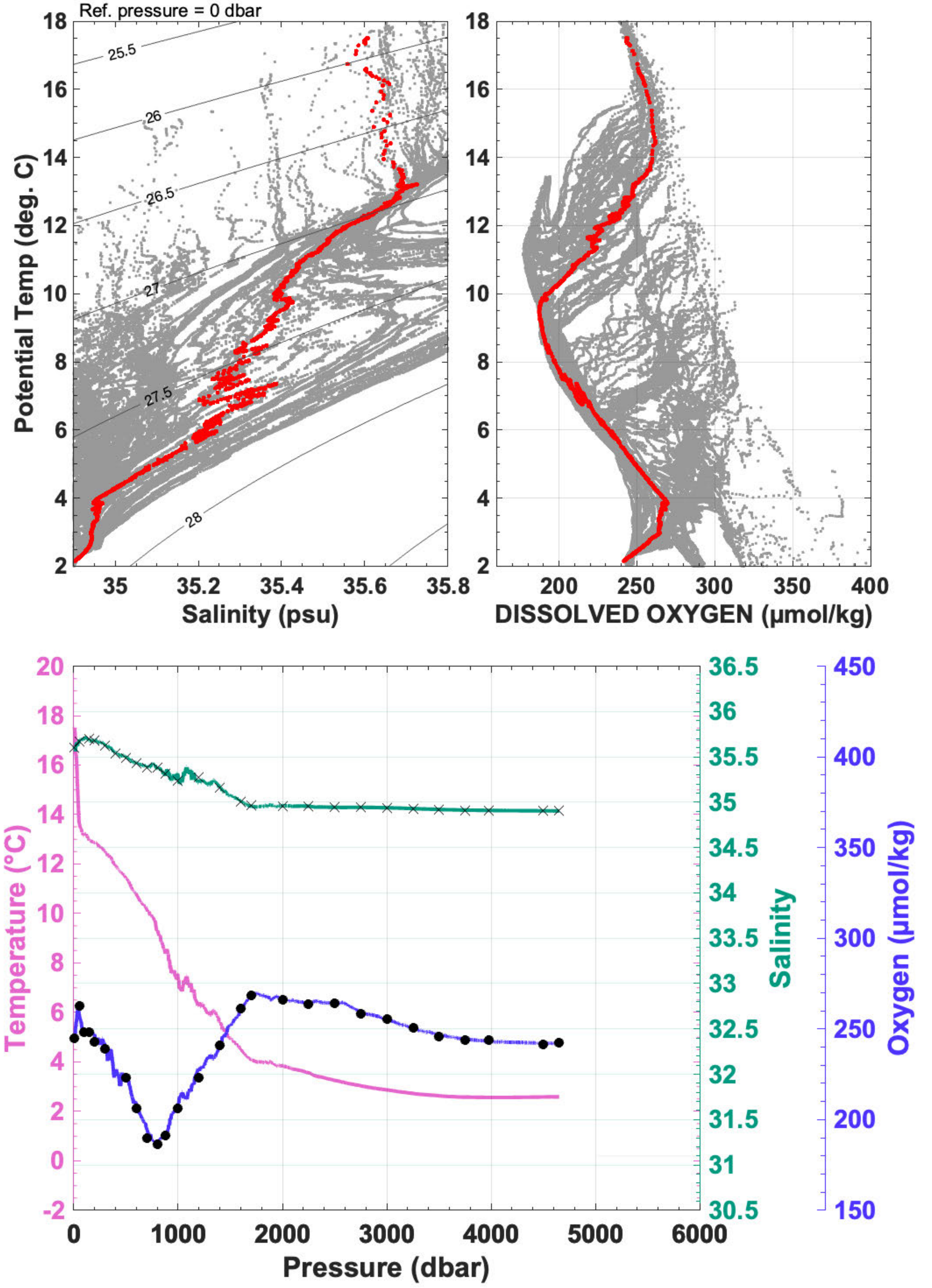
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 29



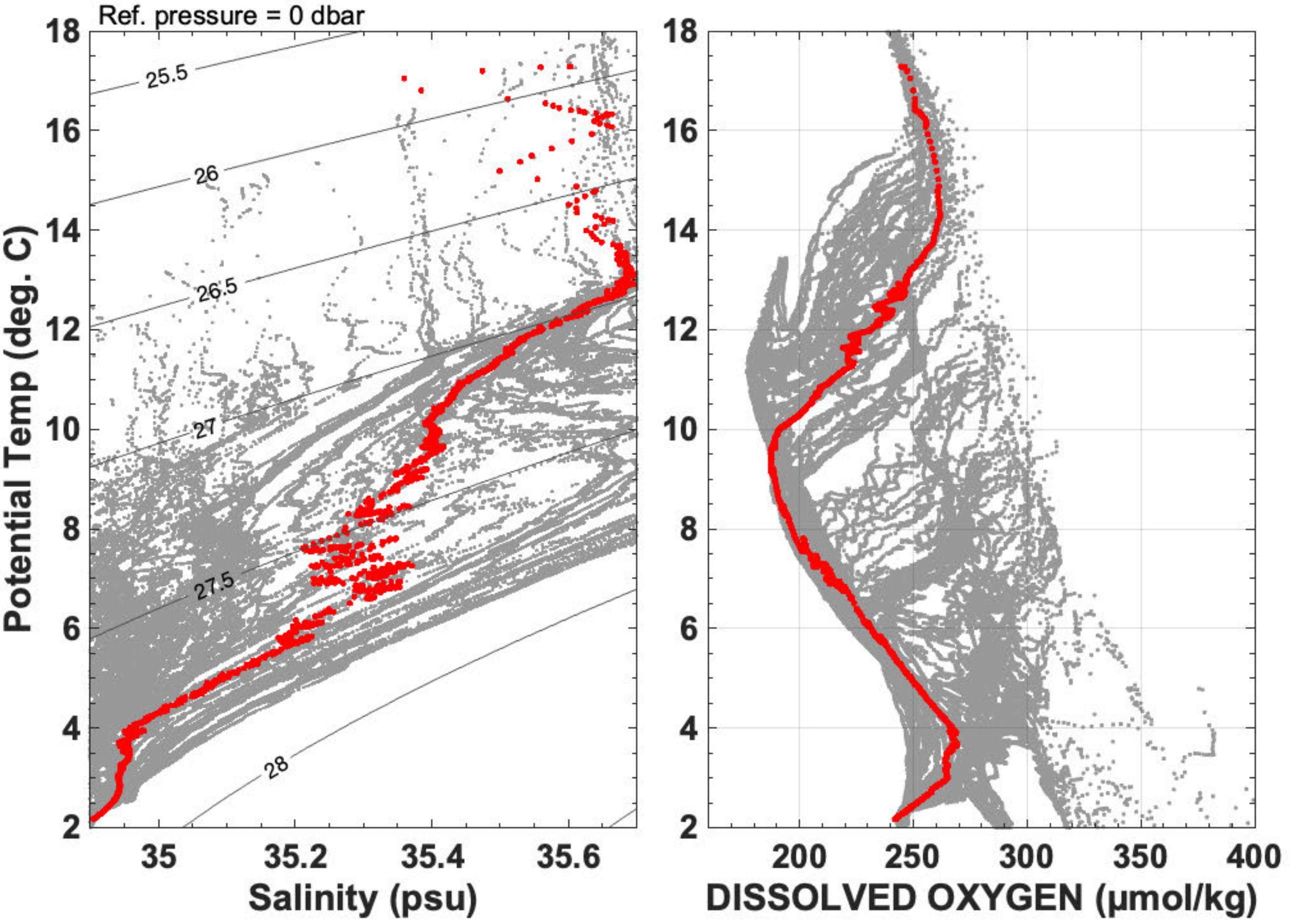
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
27.5
28
28.5
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

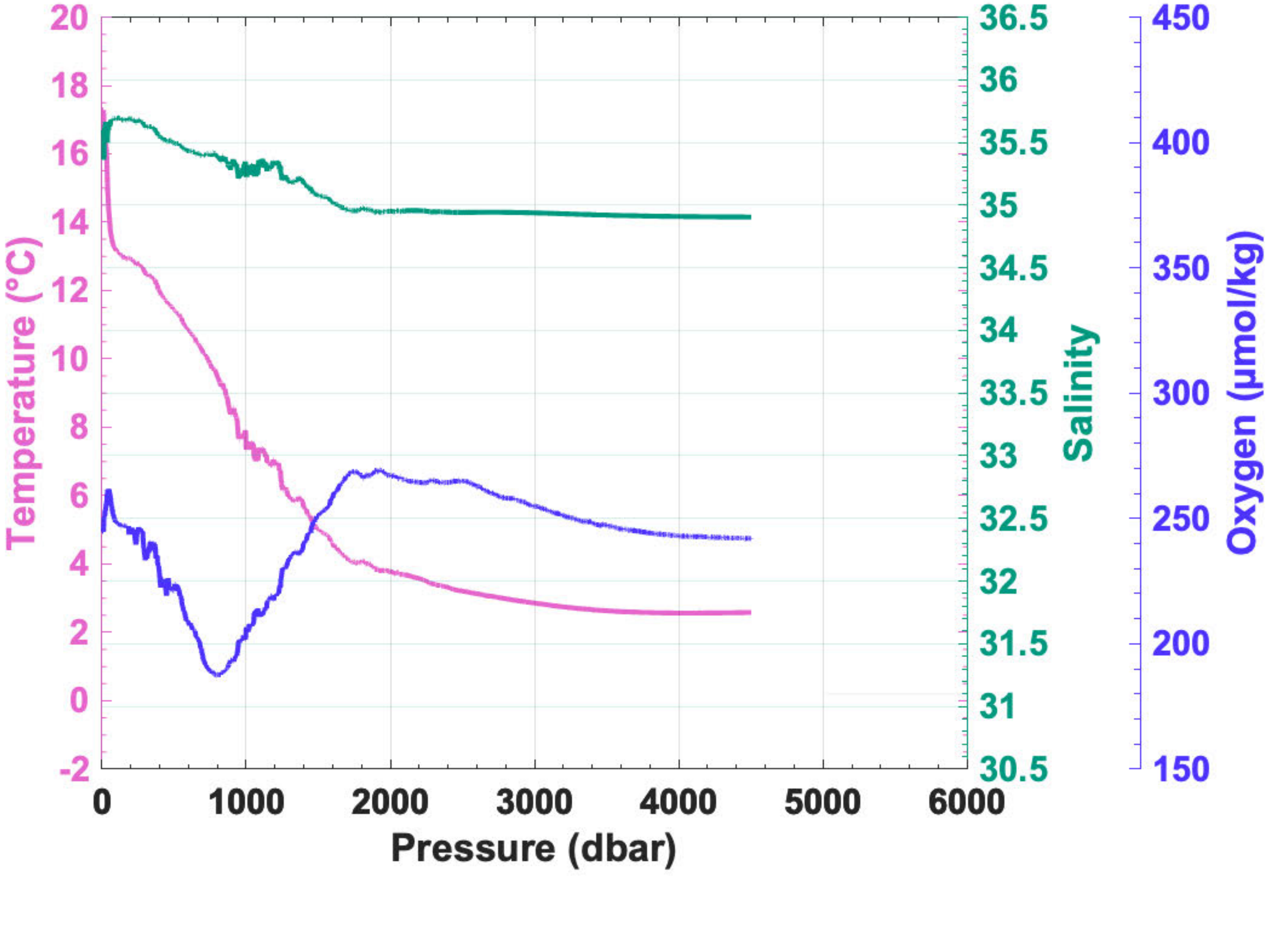
STATION 30



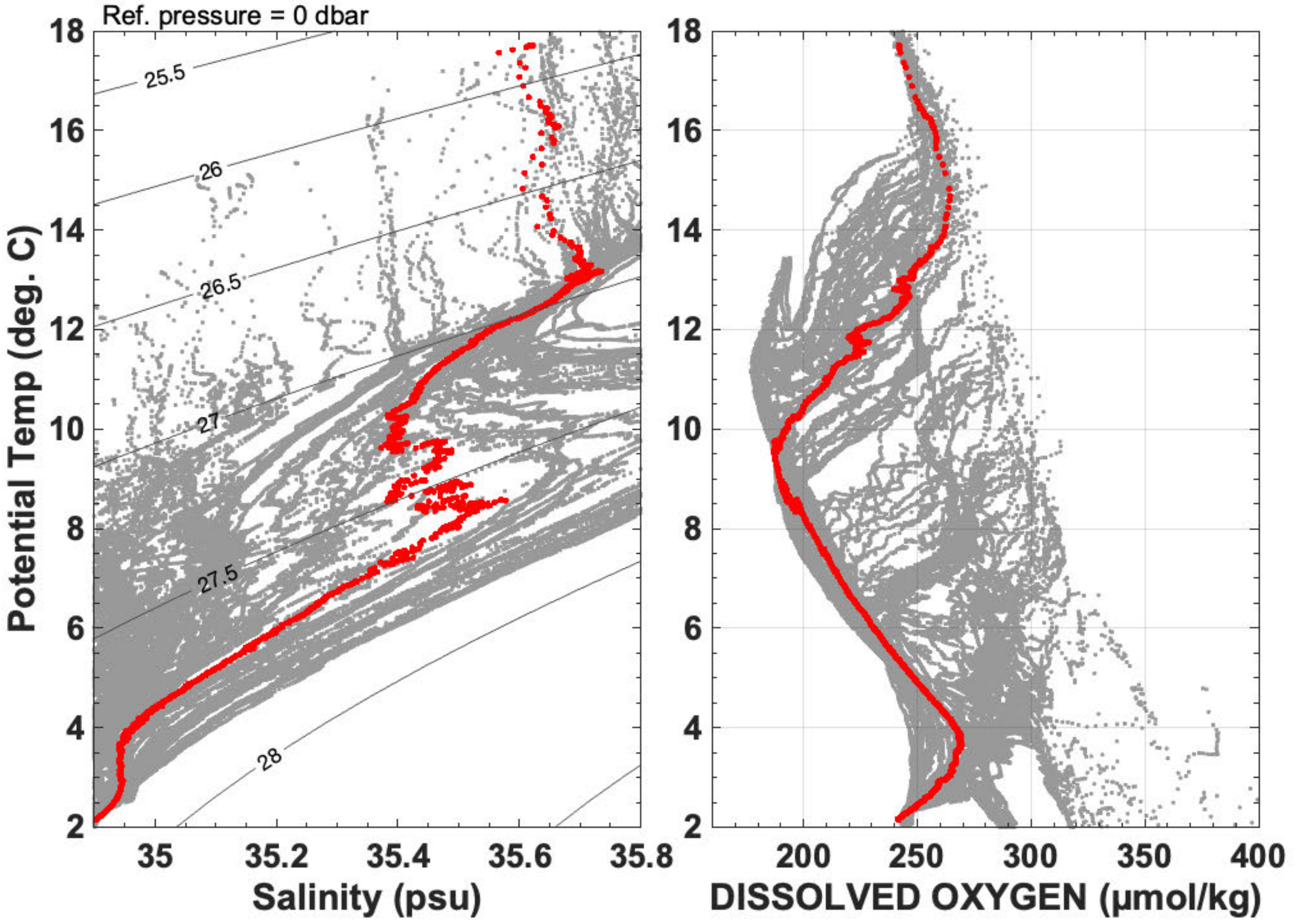
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 30 CAST 2

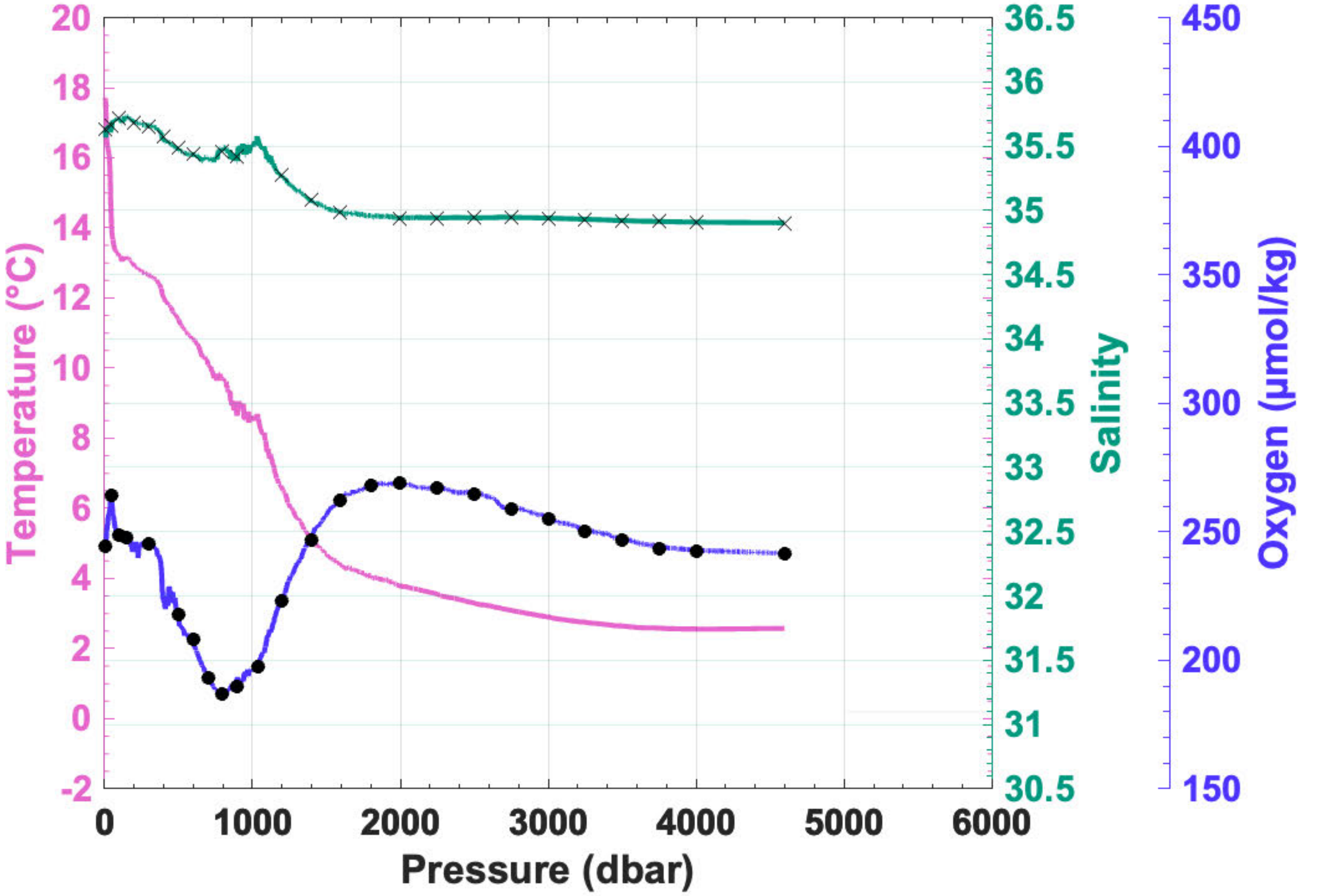




STATION 31

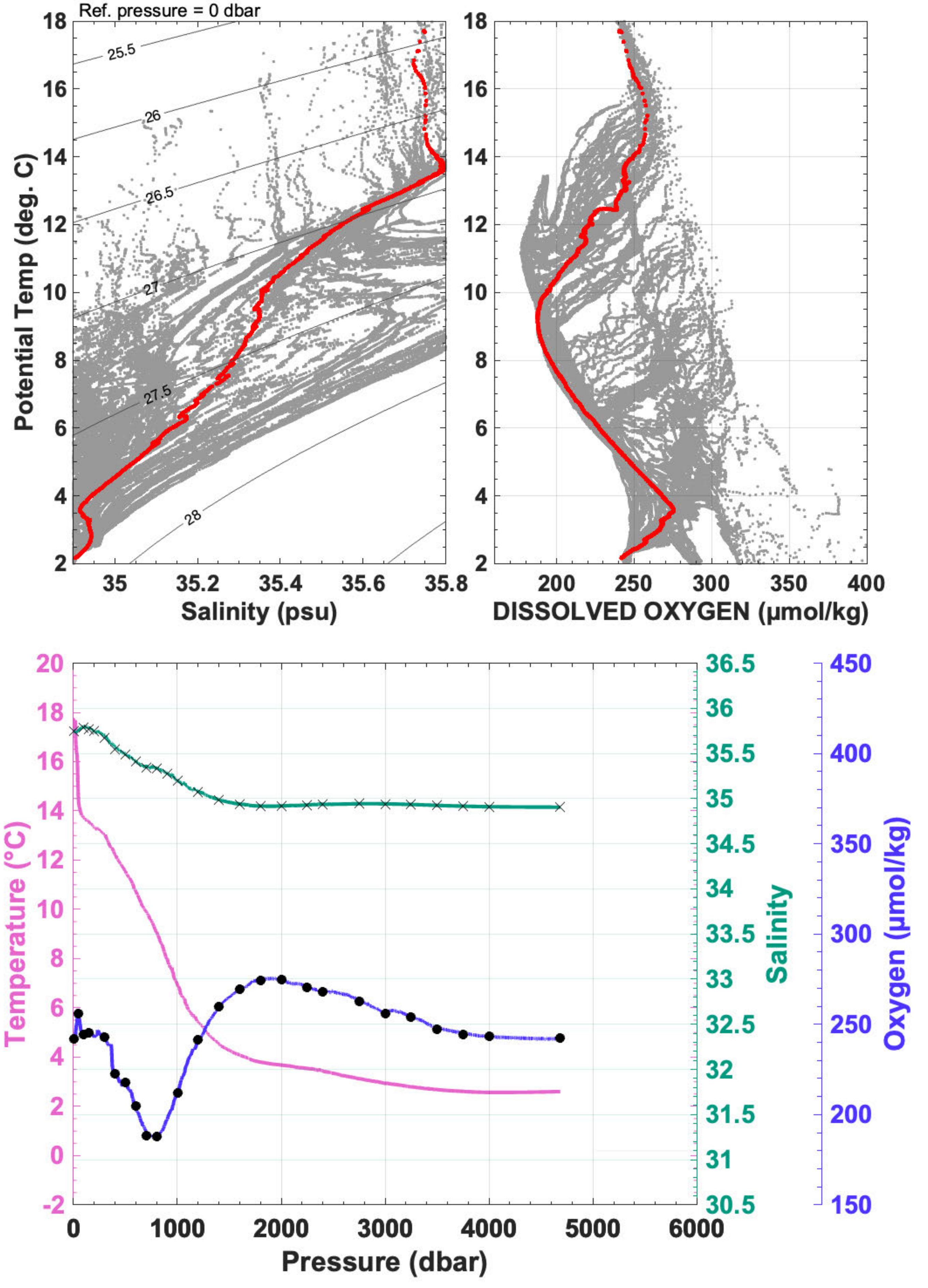


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)



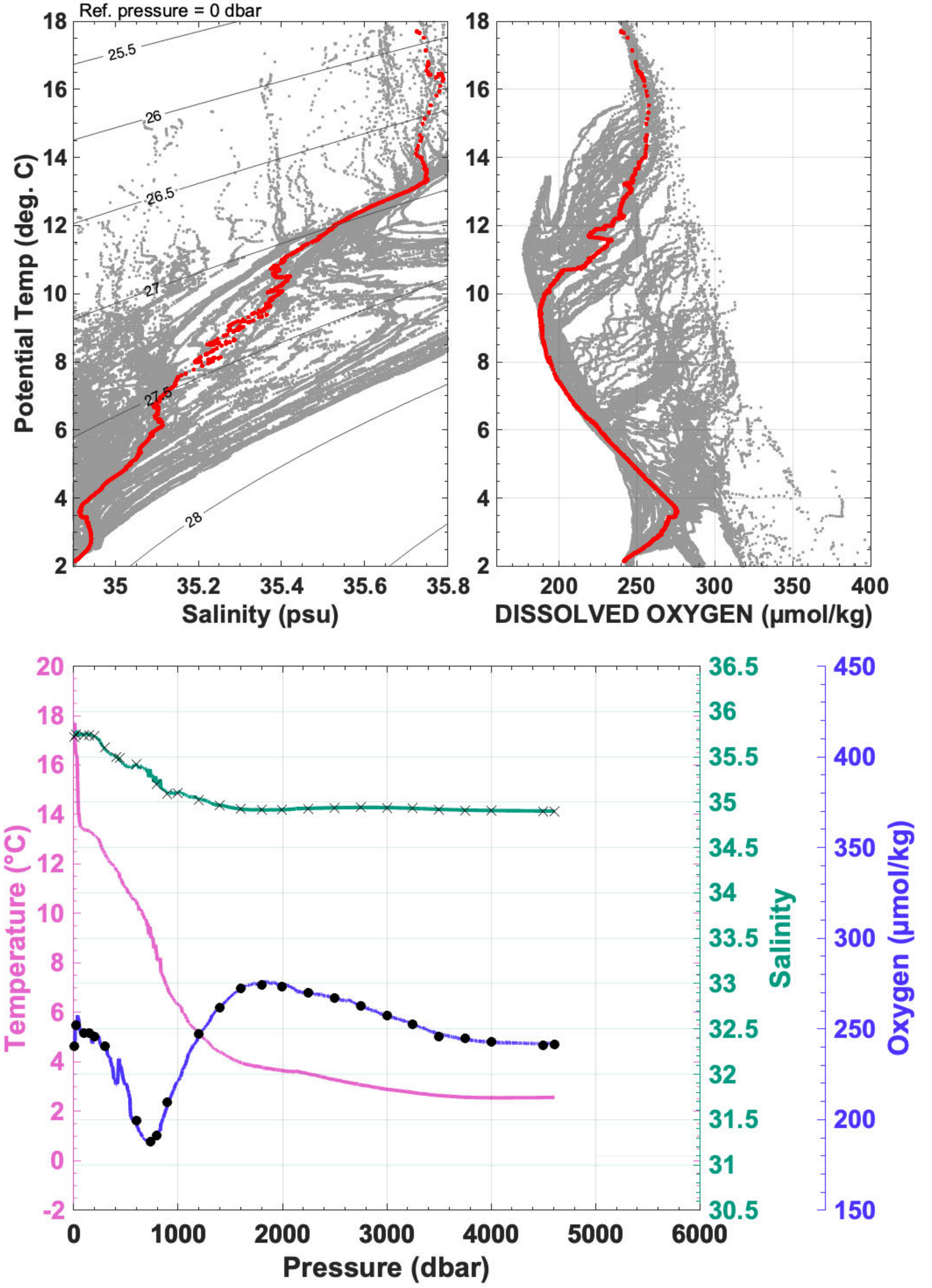
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 32

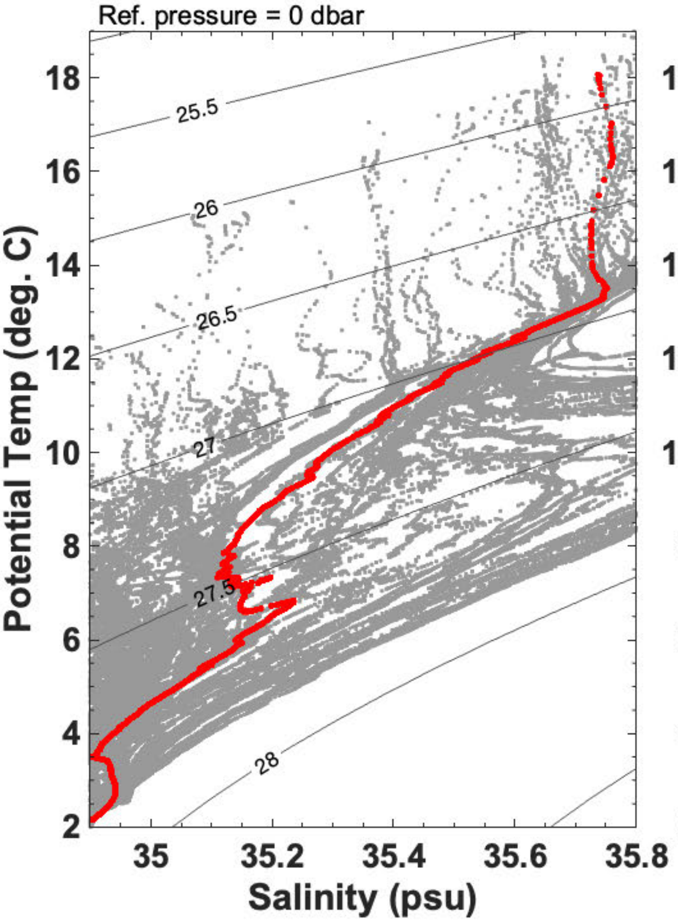


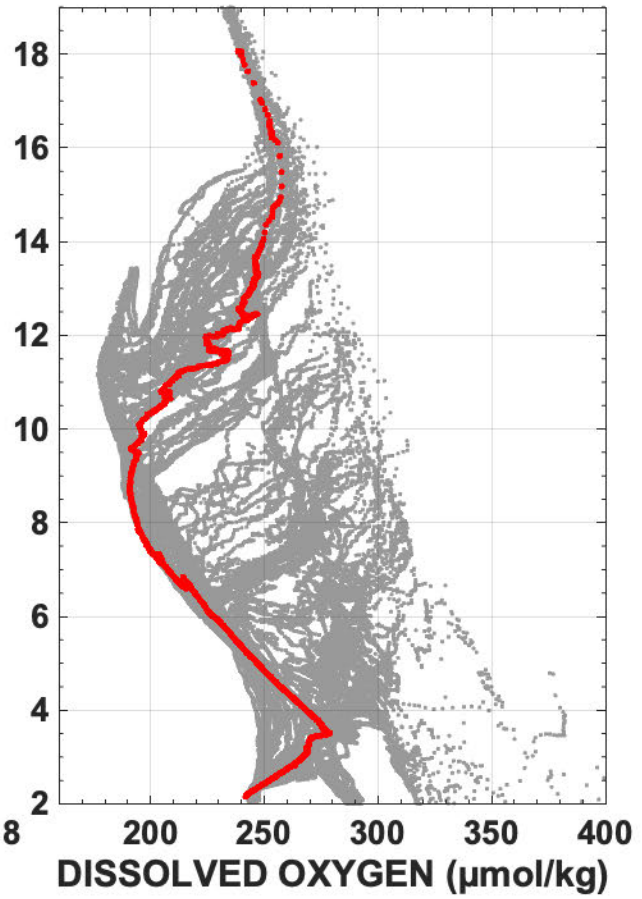
Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

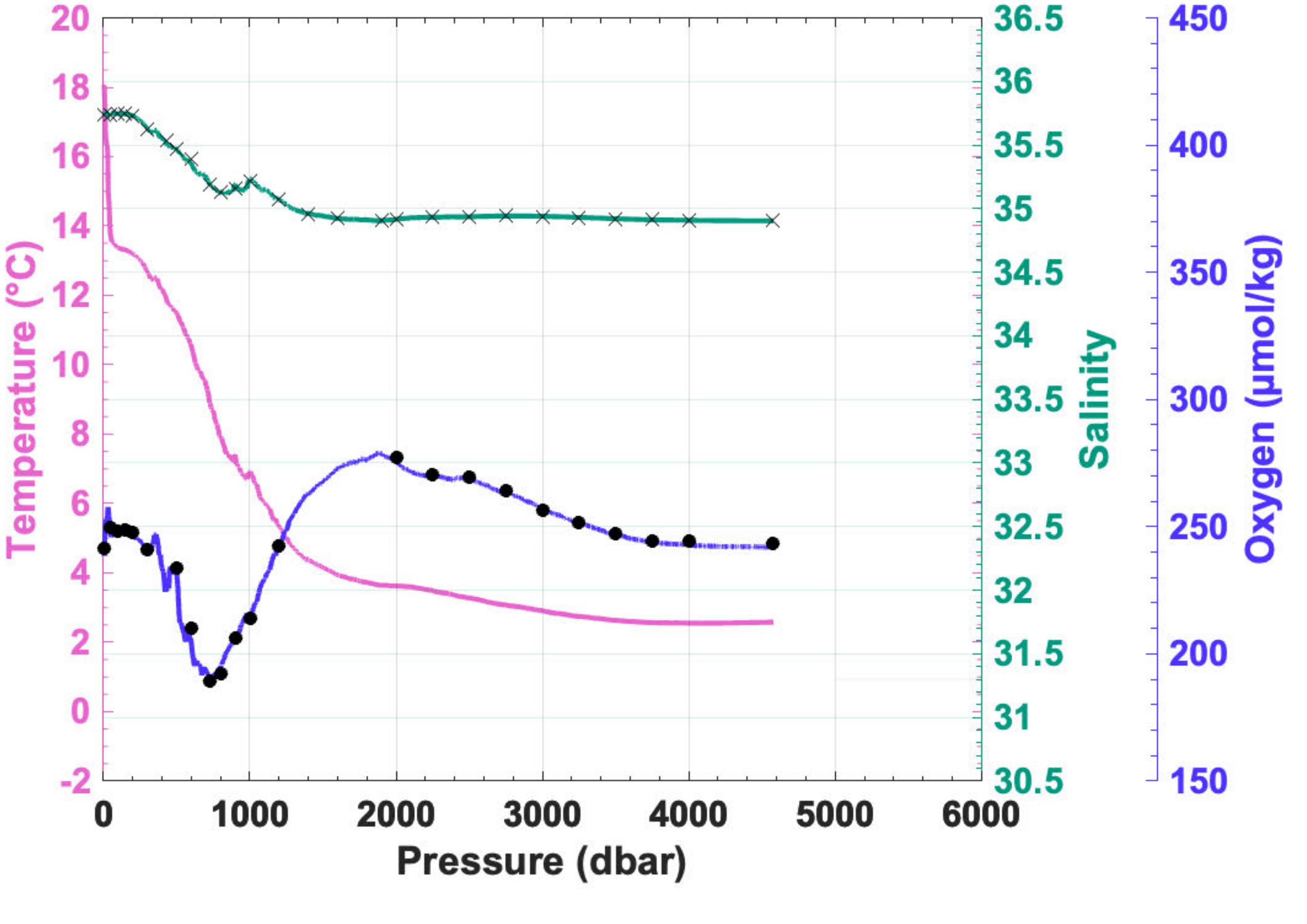
STATION 33


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

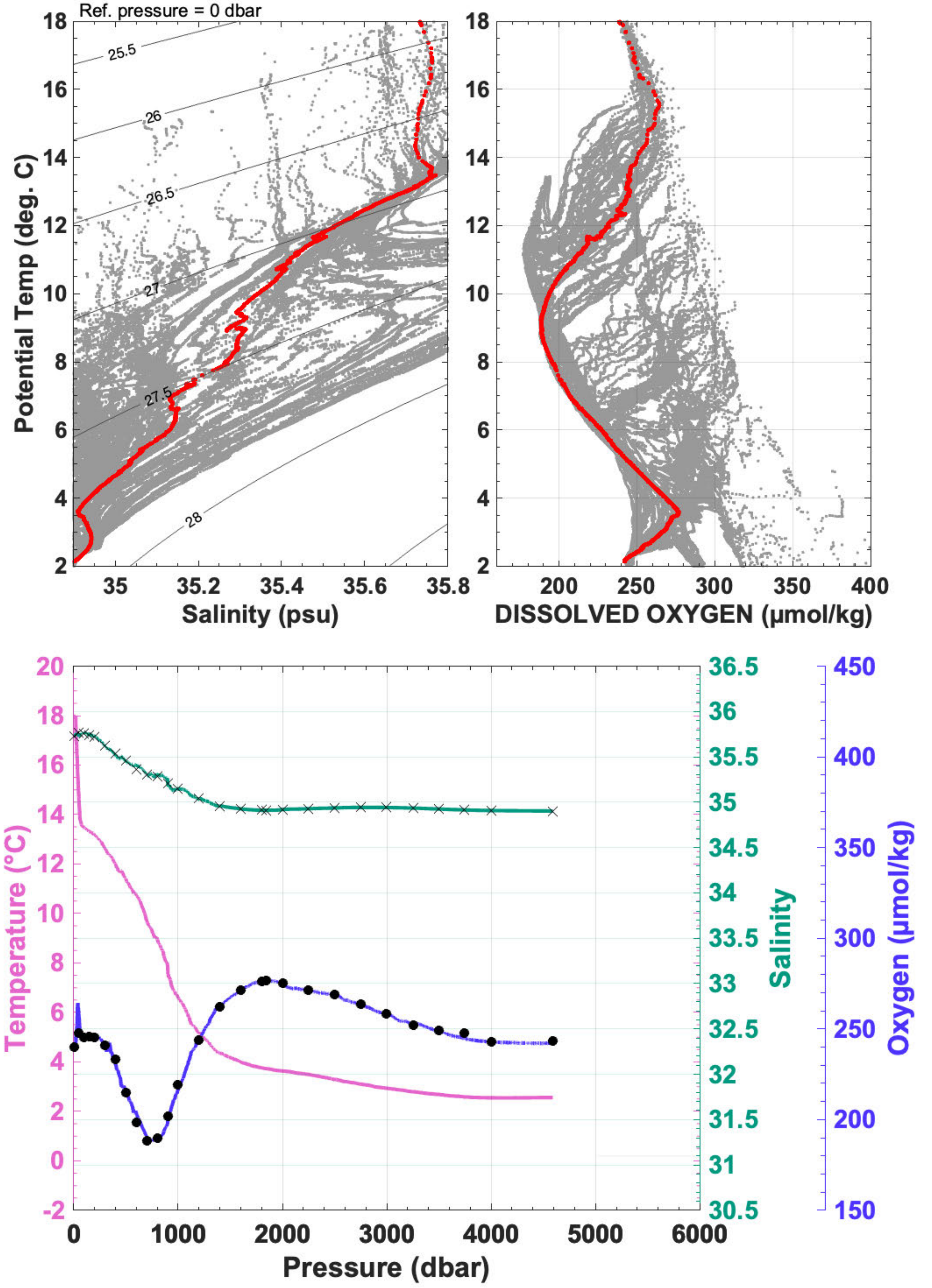
STATION 34


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)


DISSOLVED OXYGEN (µmol/kg)

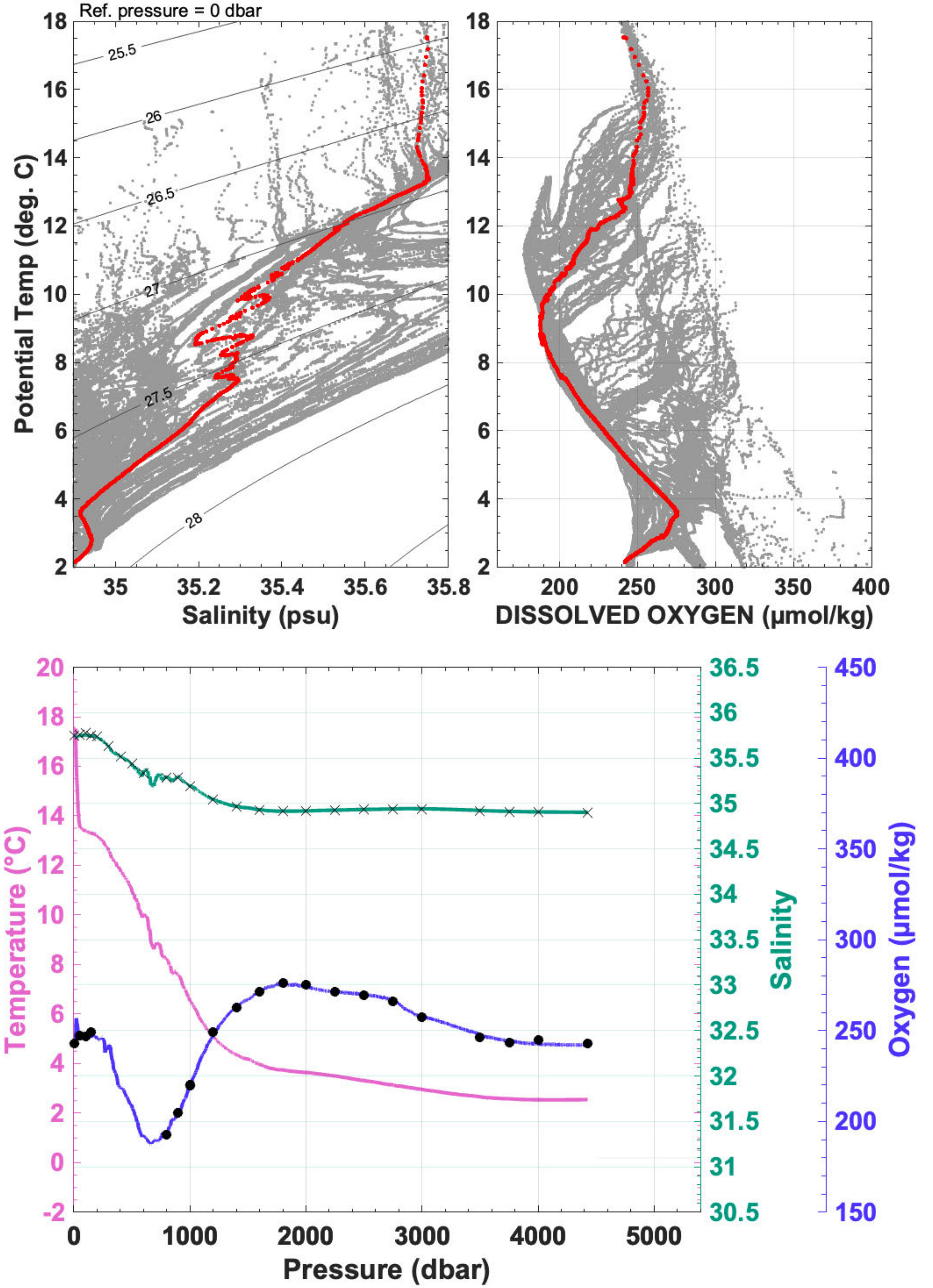

Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 35



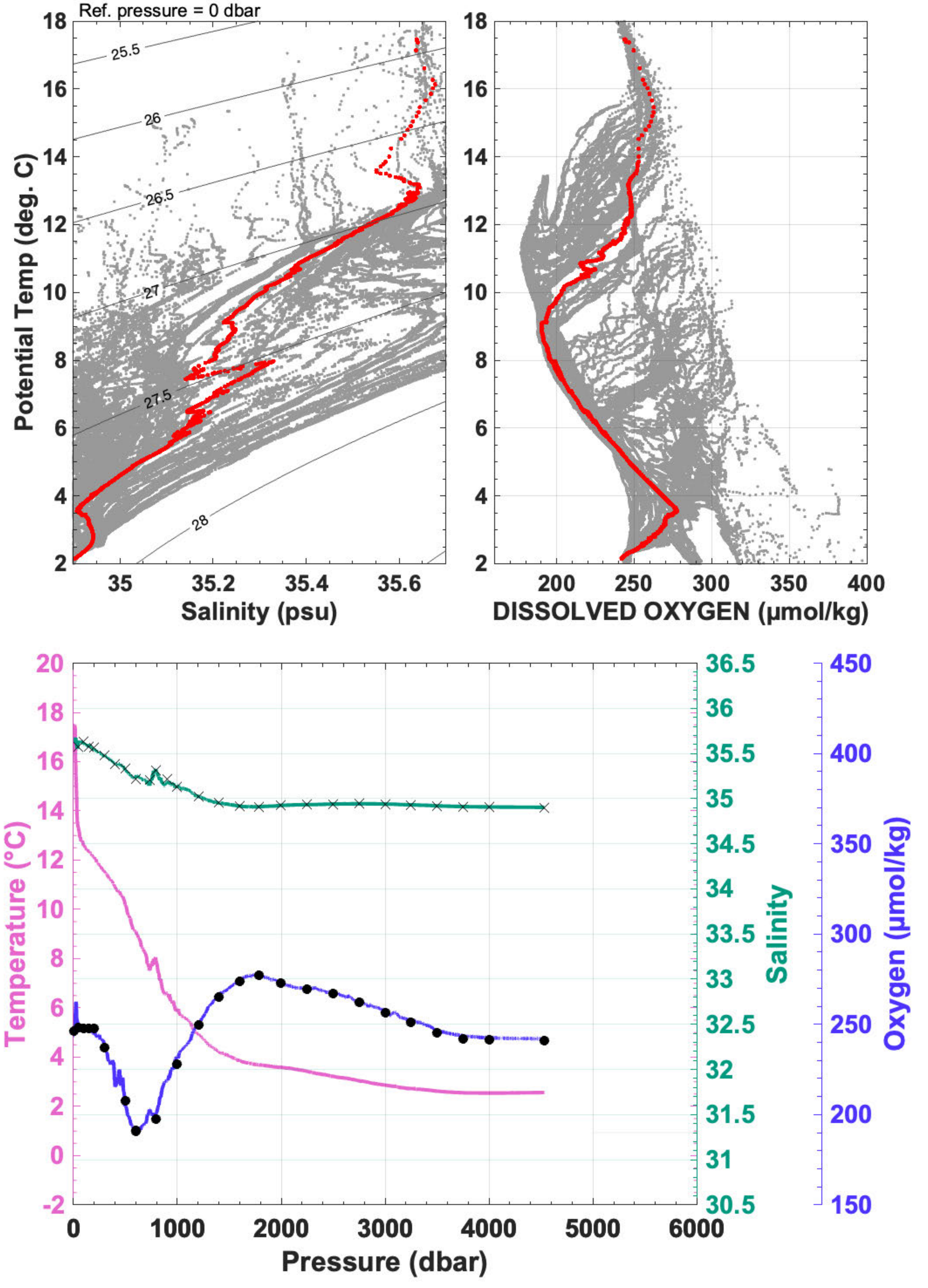
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
25.5
26
26.5
27
27.5
28
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 36

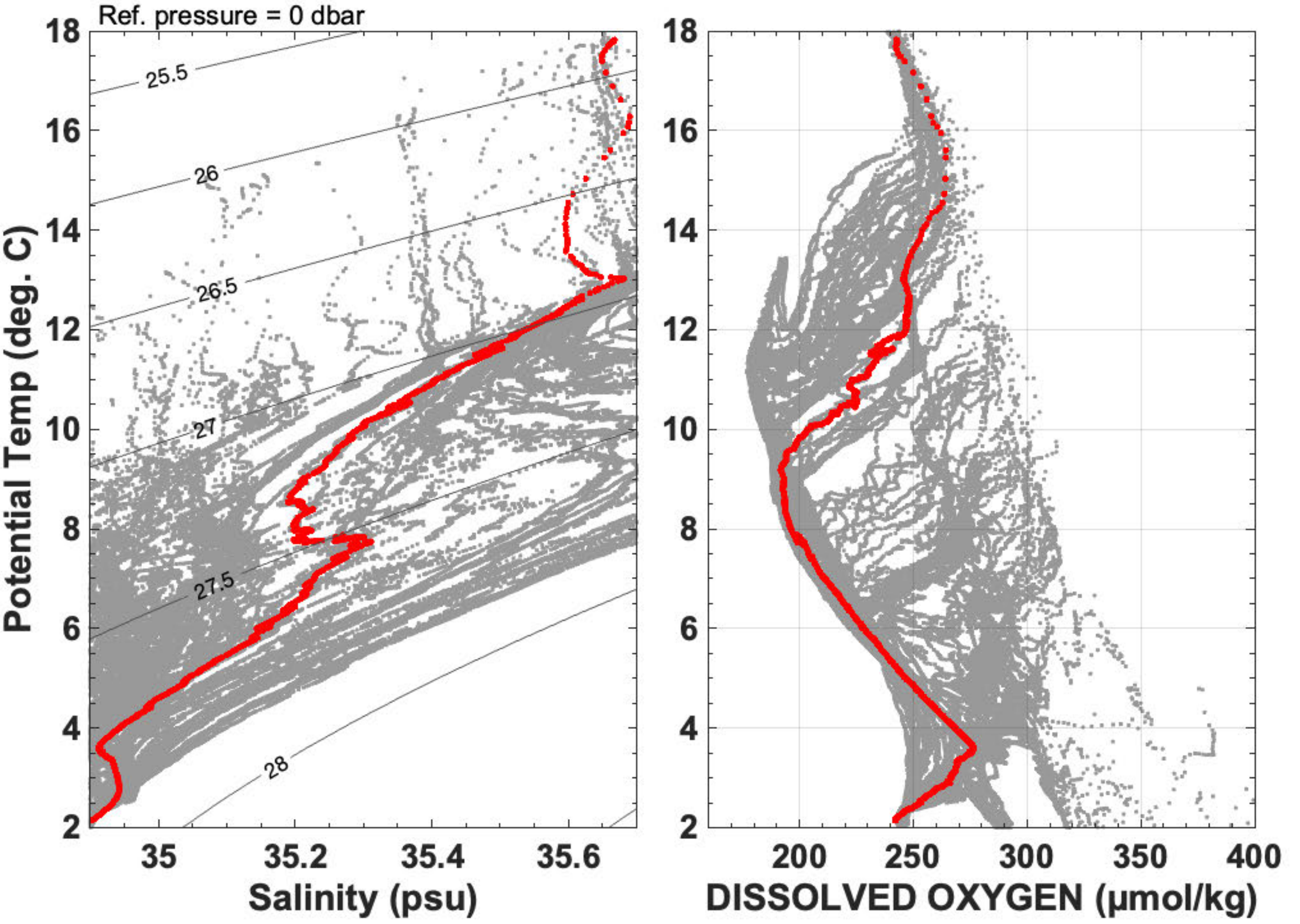


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

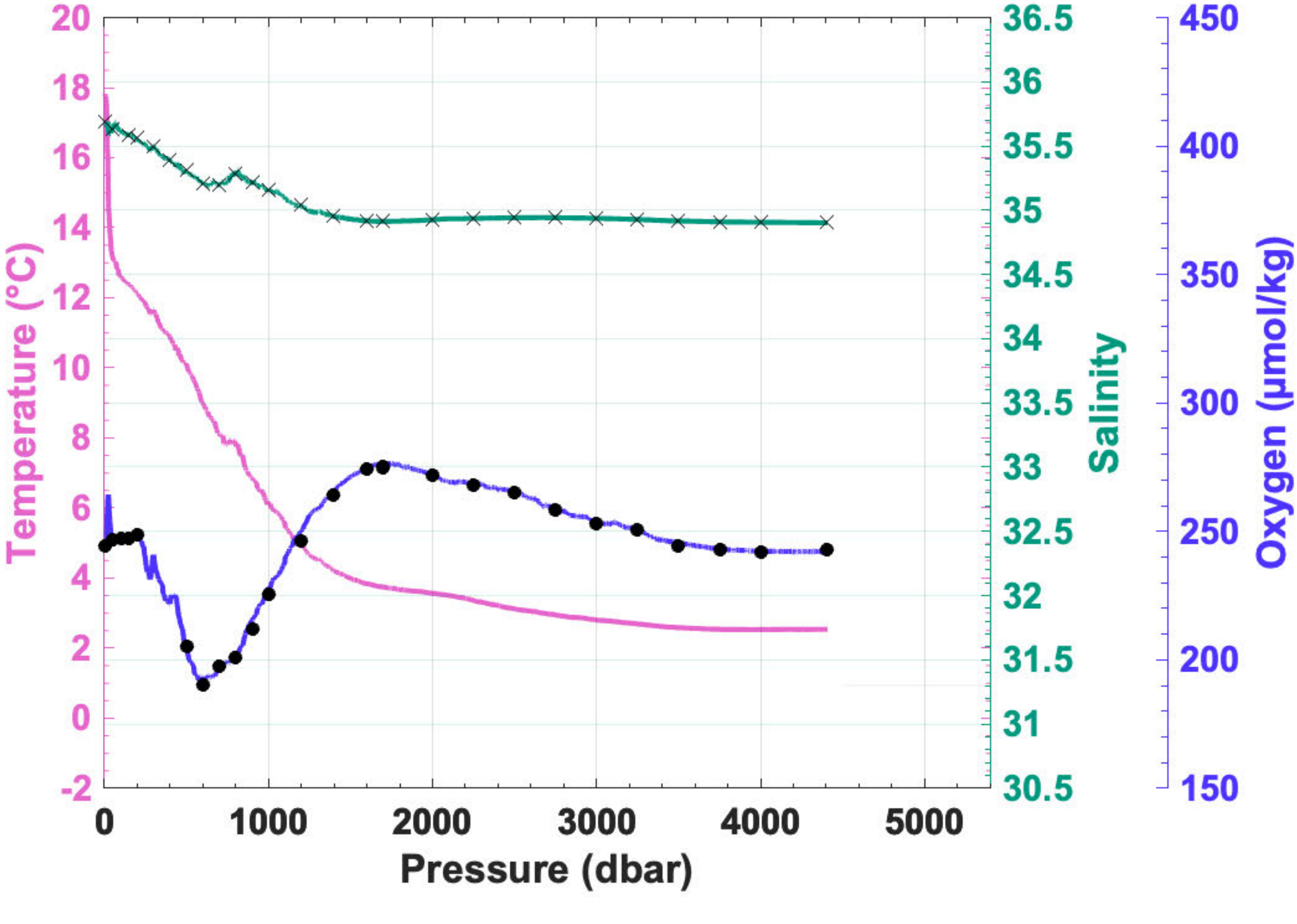
STATION 37


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 38

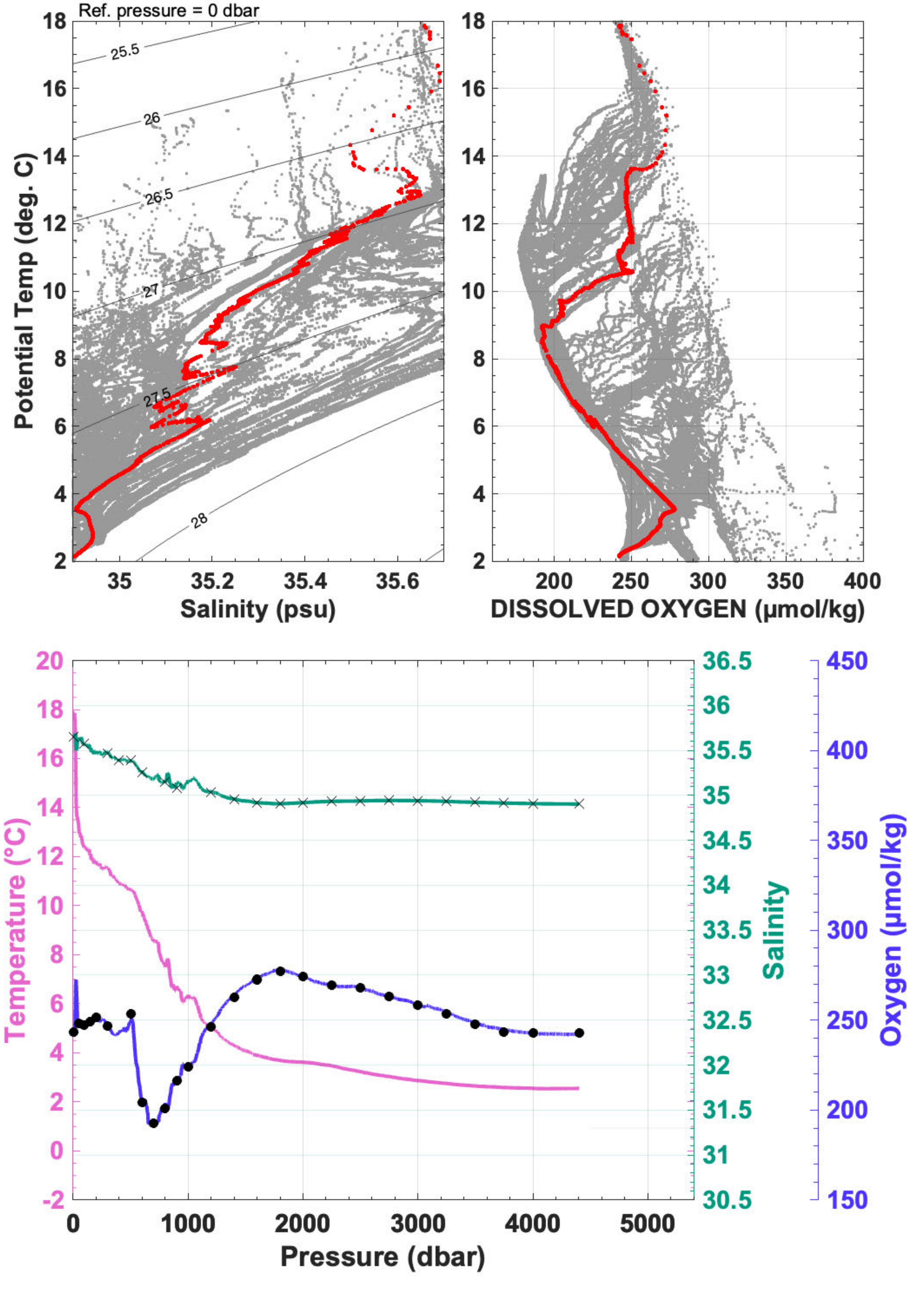


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)

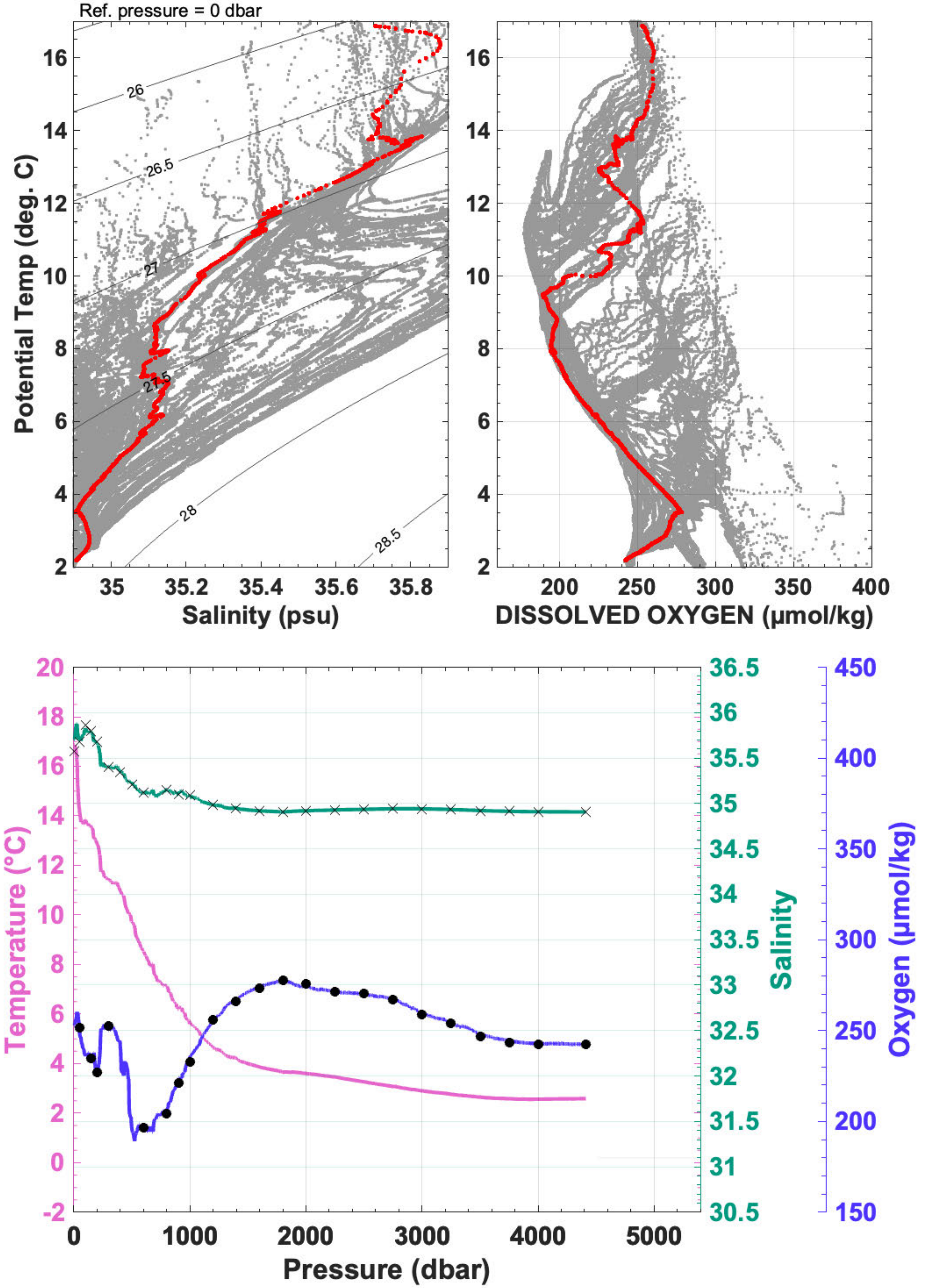


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

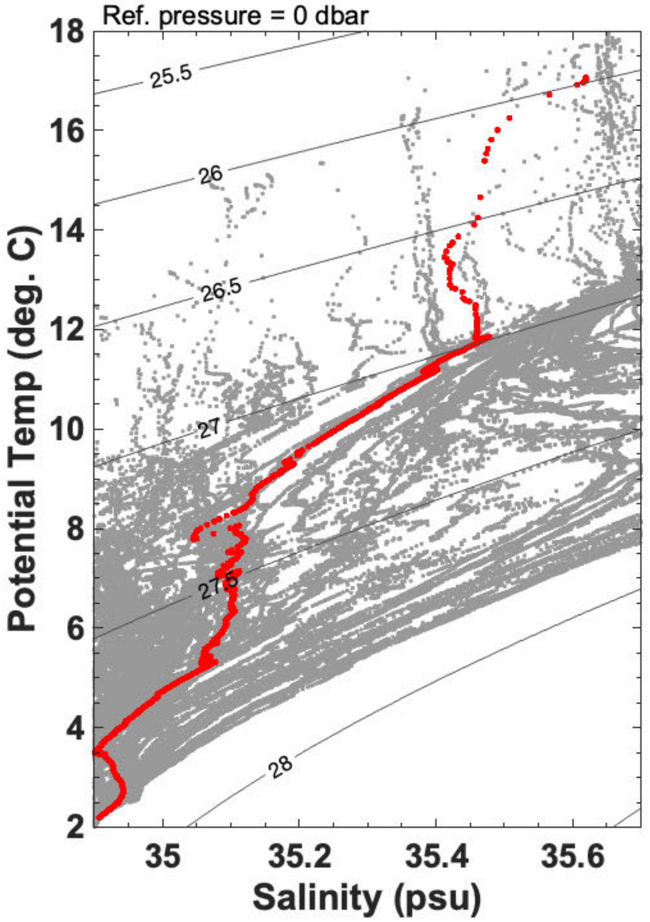
STATION 39


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

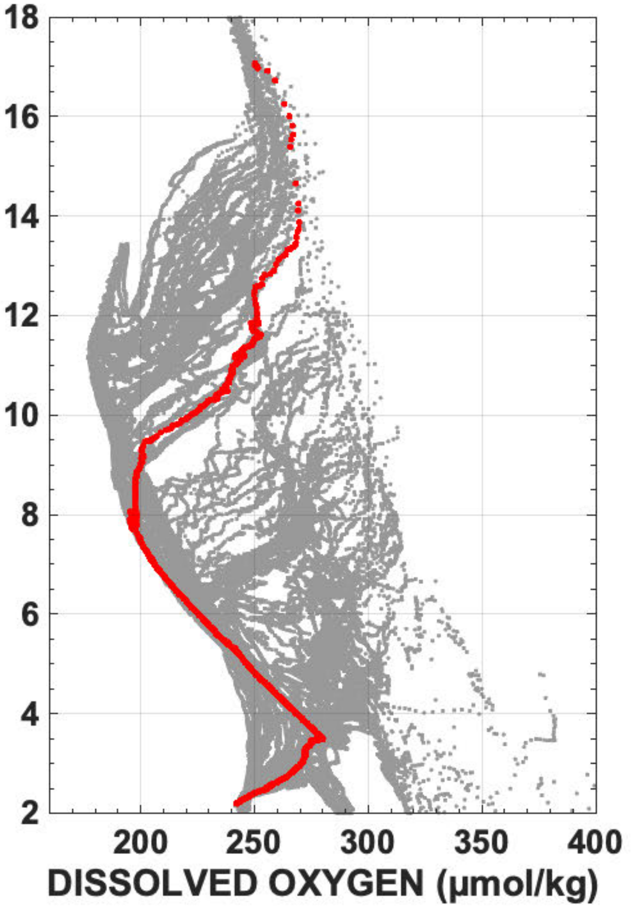
STATION 40


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
27.5
28
28.5
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

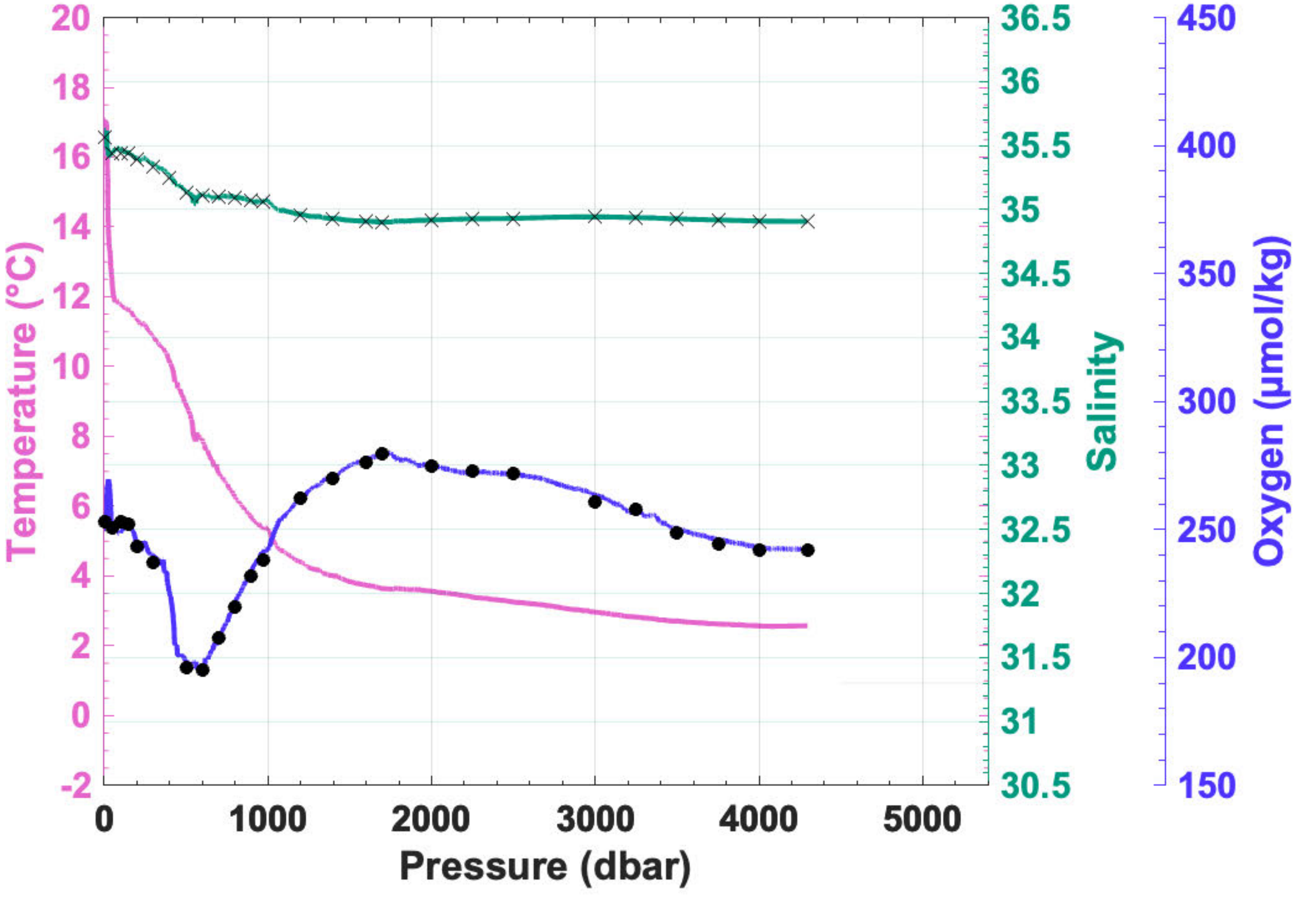
STATION 41



Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
27.5
28

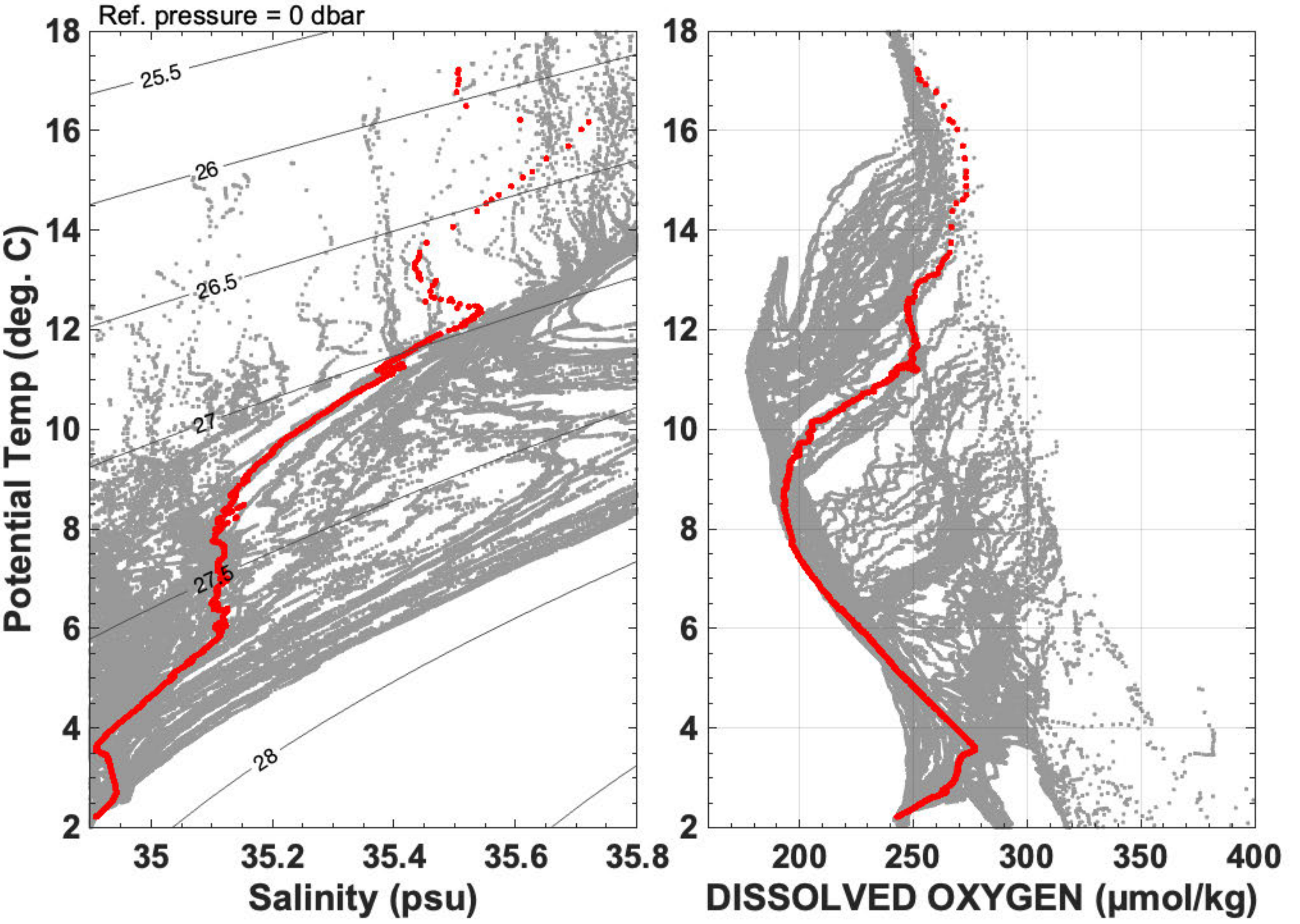


DISSOLVED OXYGEN (µmol/kg)

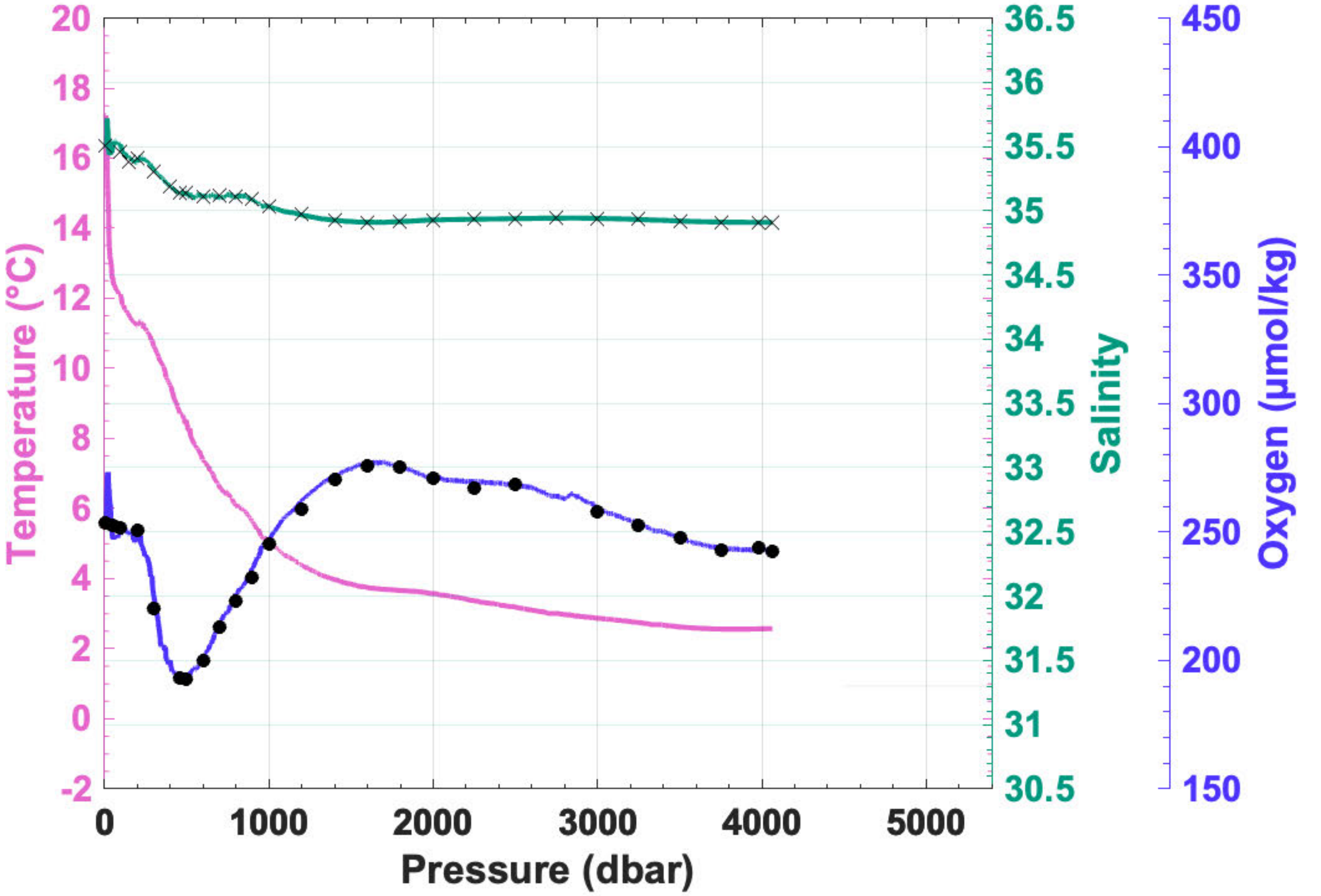


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 42

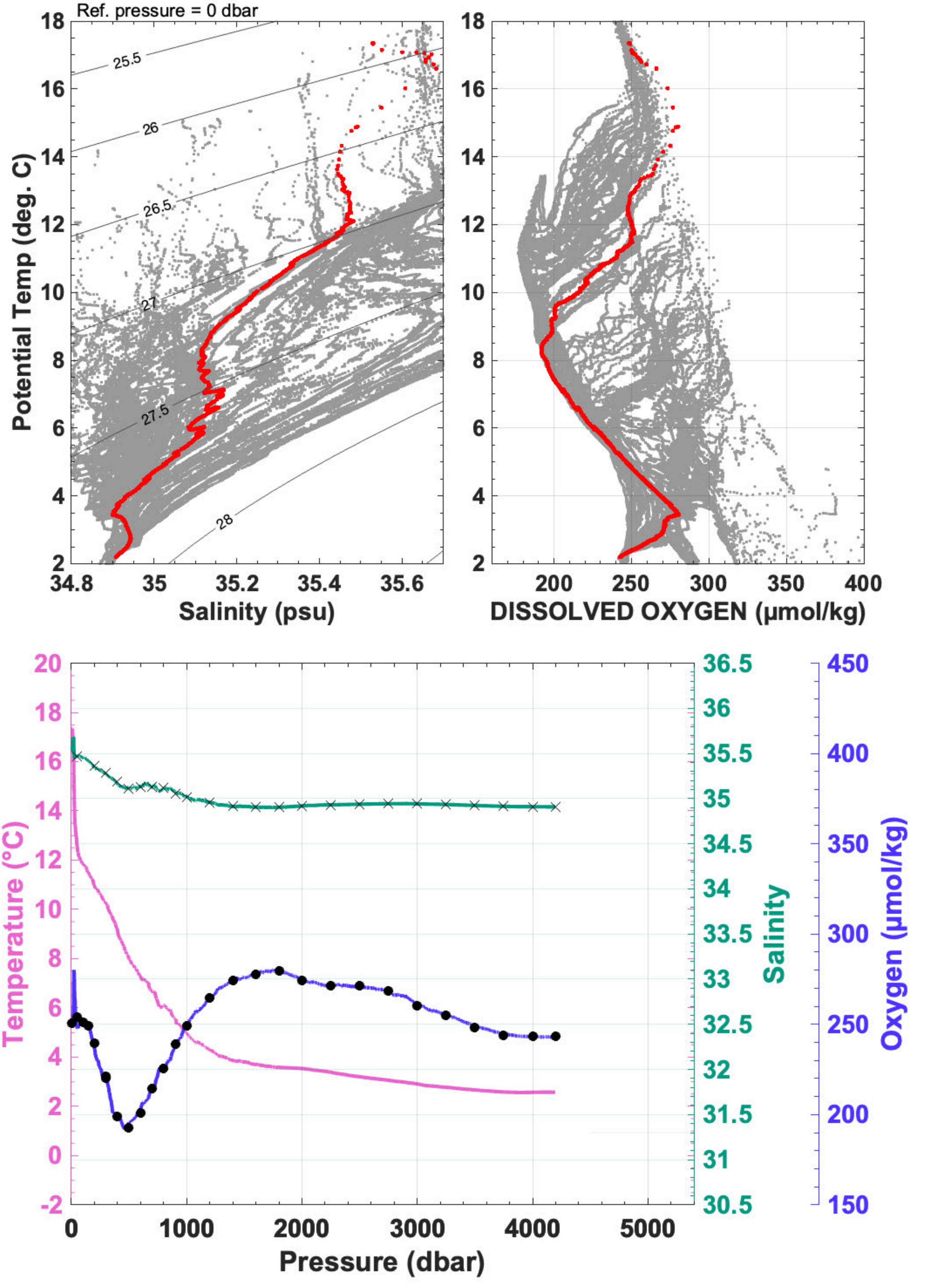


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



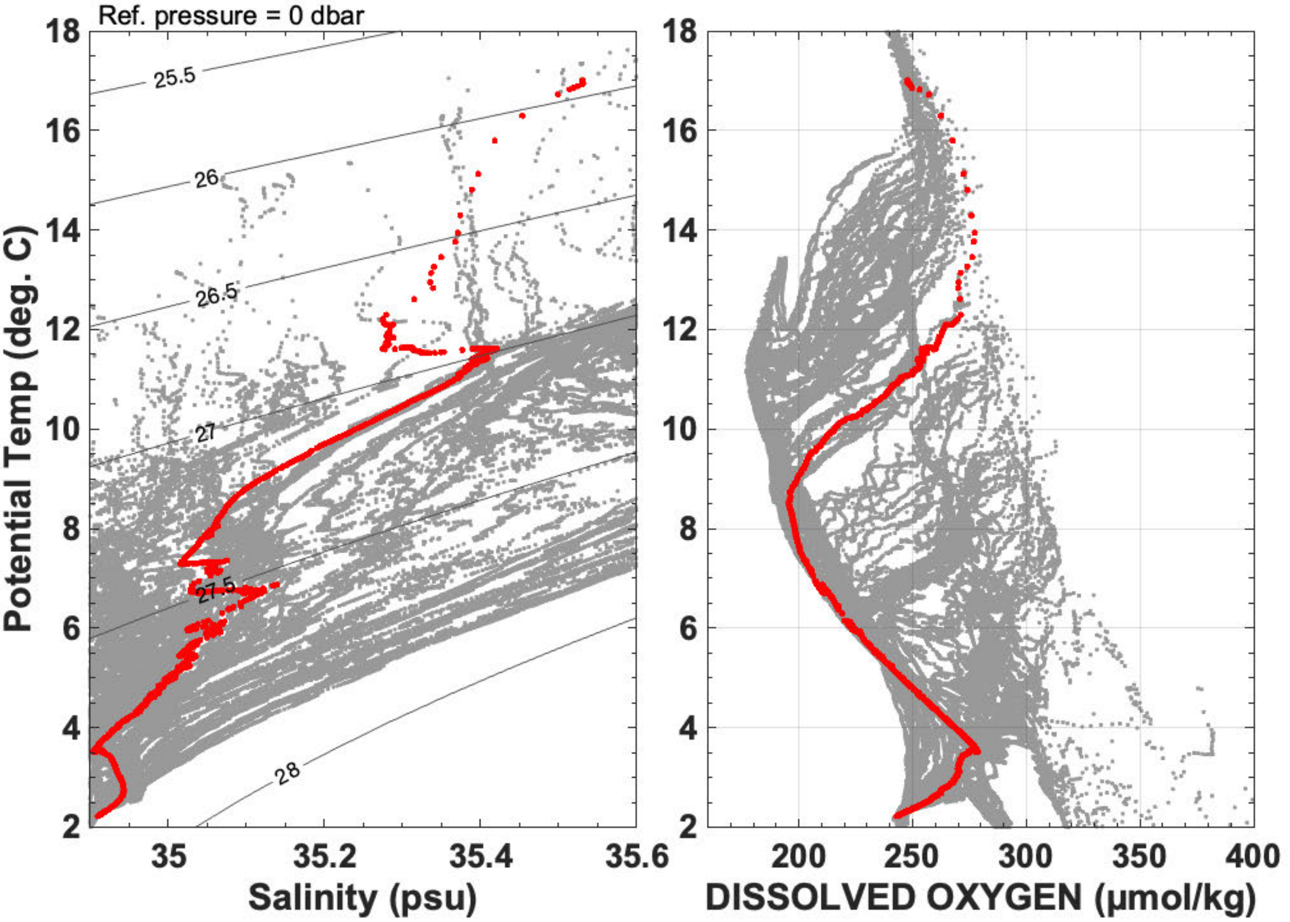
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 43

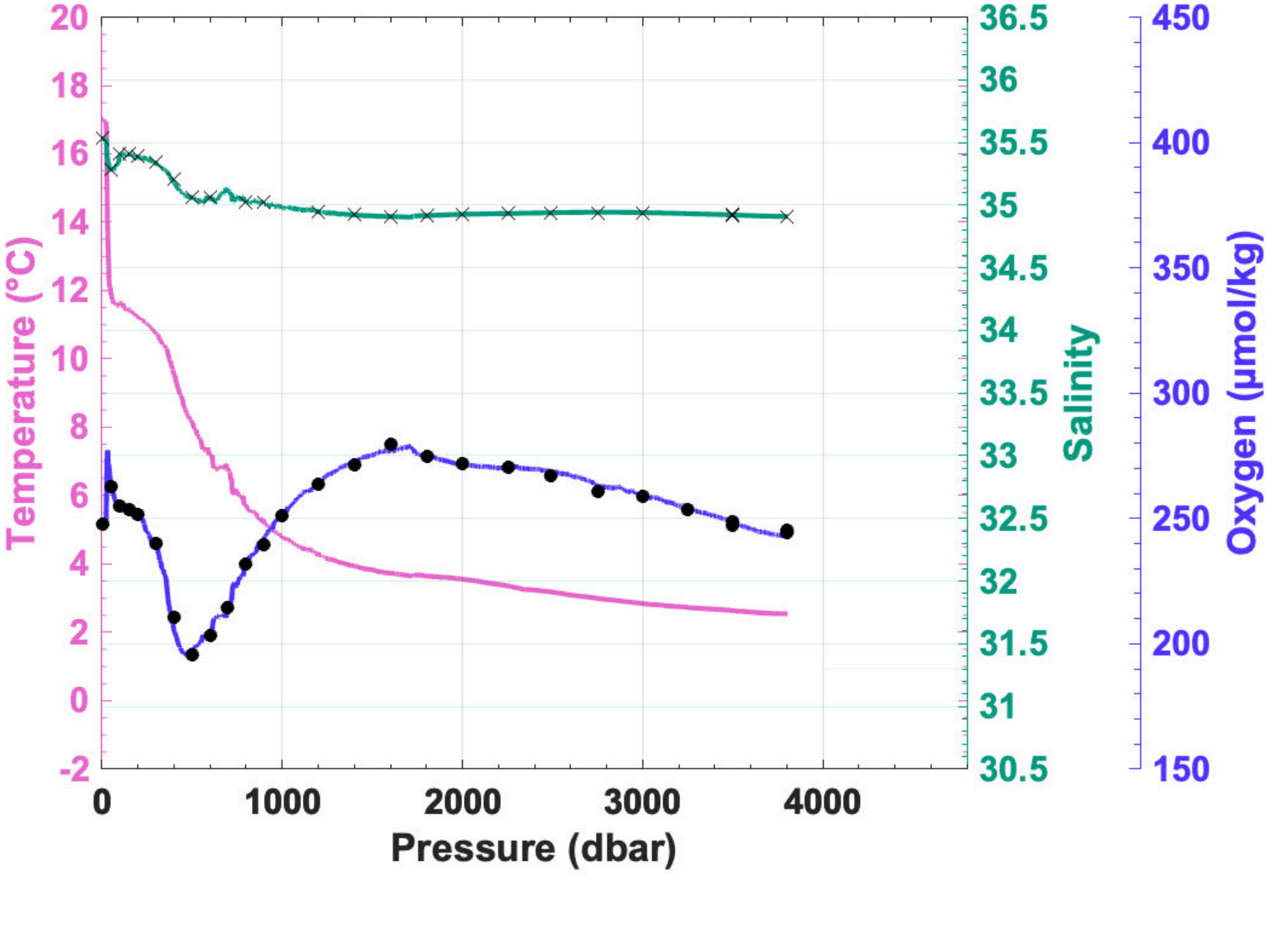


Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
18
16
14
12
10
8
6
4
2
34.8
35
35.2
35.4
35.6
Salinity (psu)
200
250
300
350
400
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
20
18
16
14
12
10
8
6
4
2
0
-2
Salinity
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
Oxygen (µmol/kg)
450
400
350
300
250
200
150
0
1000
2000
3000
4000
5000
Pressure (dbar)

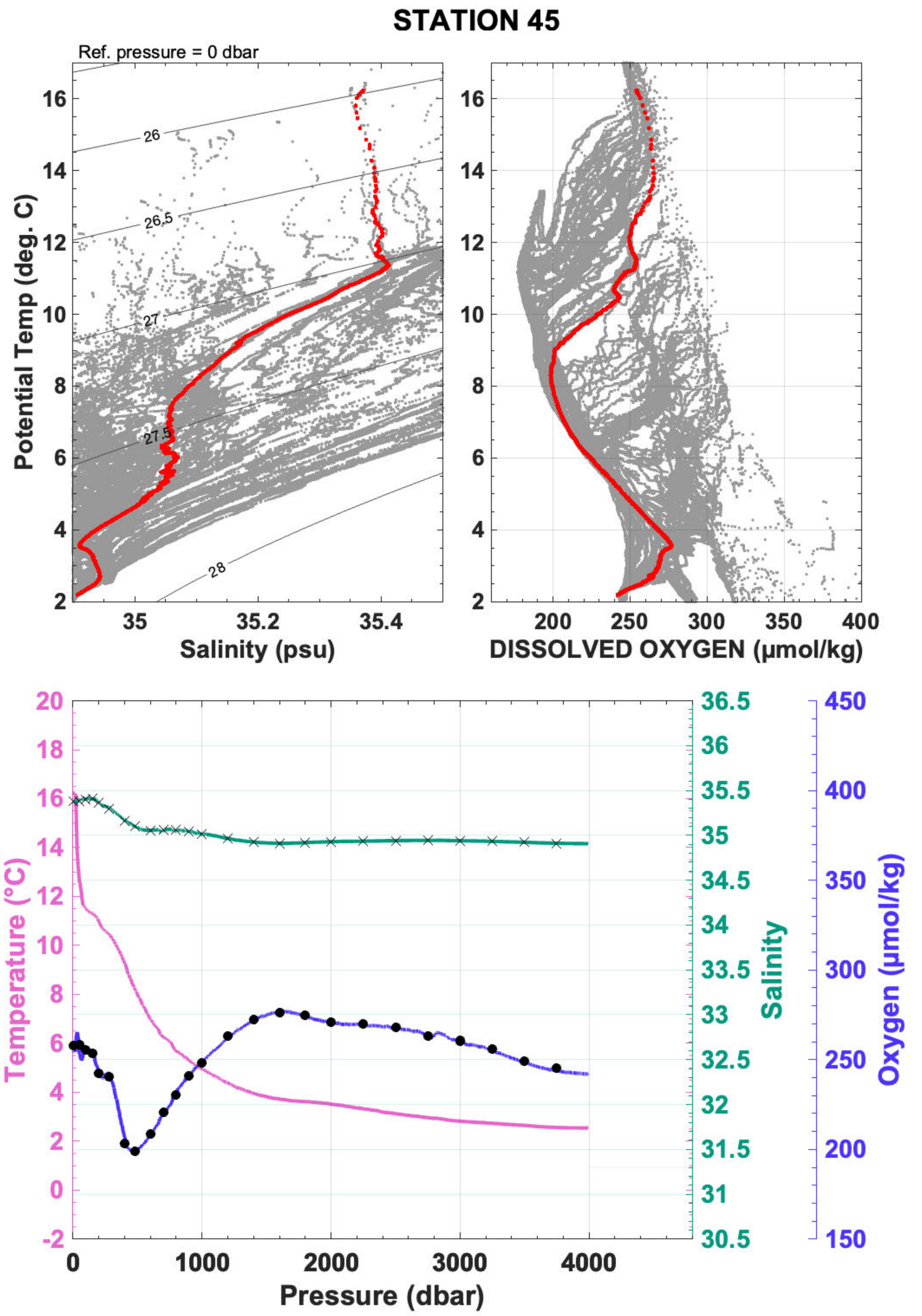
STATION 44



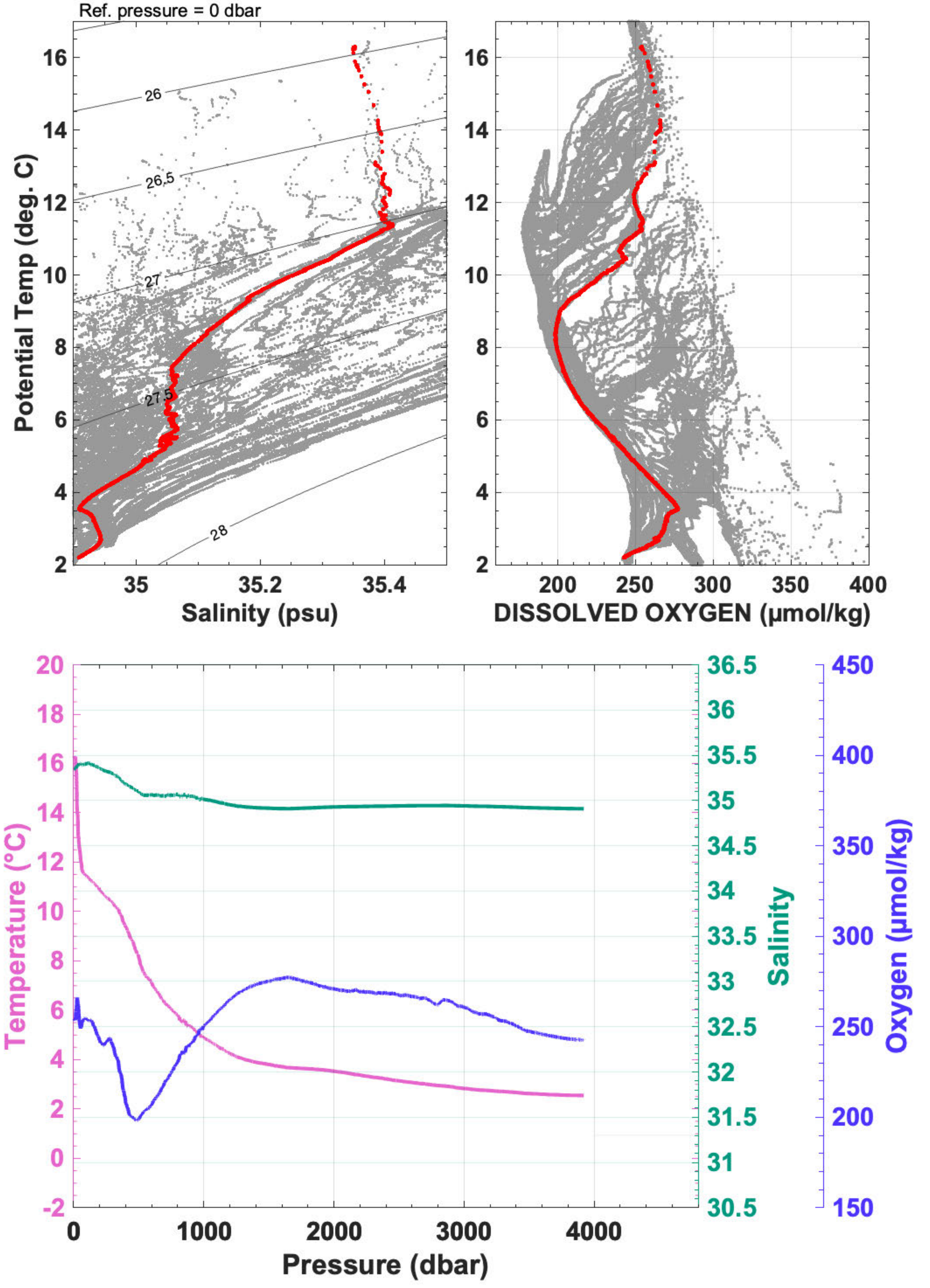
Ref. pressure = 0 dbar
25.5
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



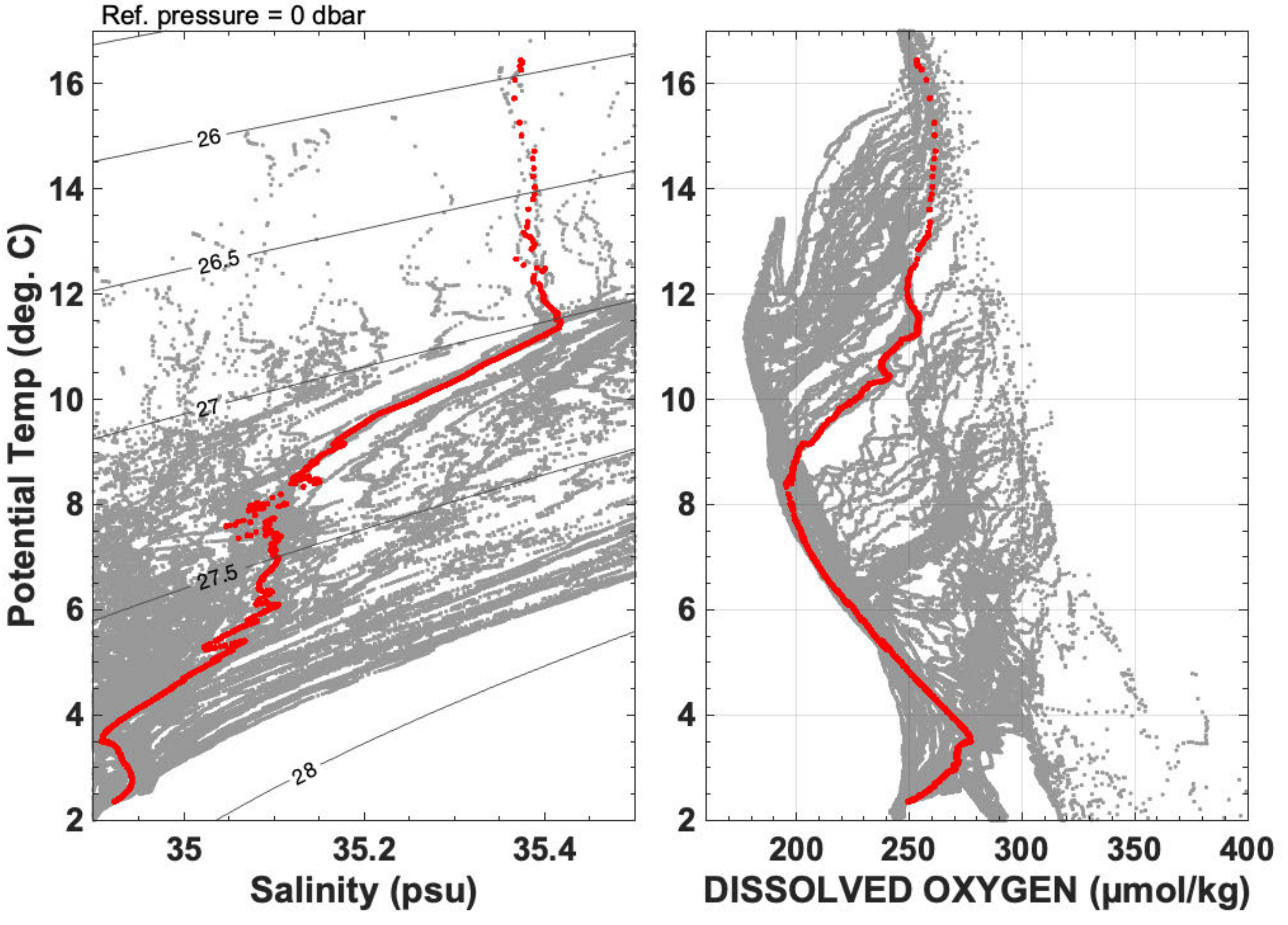
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)


STATION 45
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

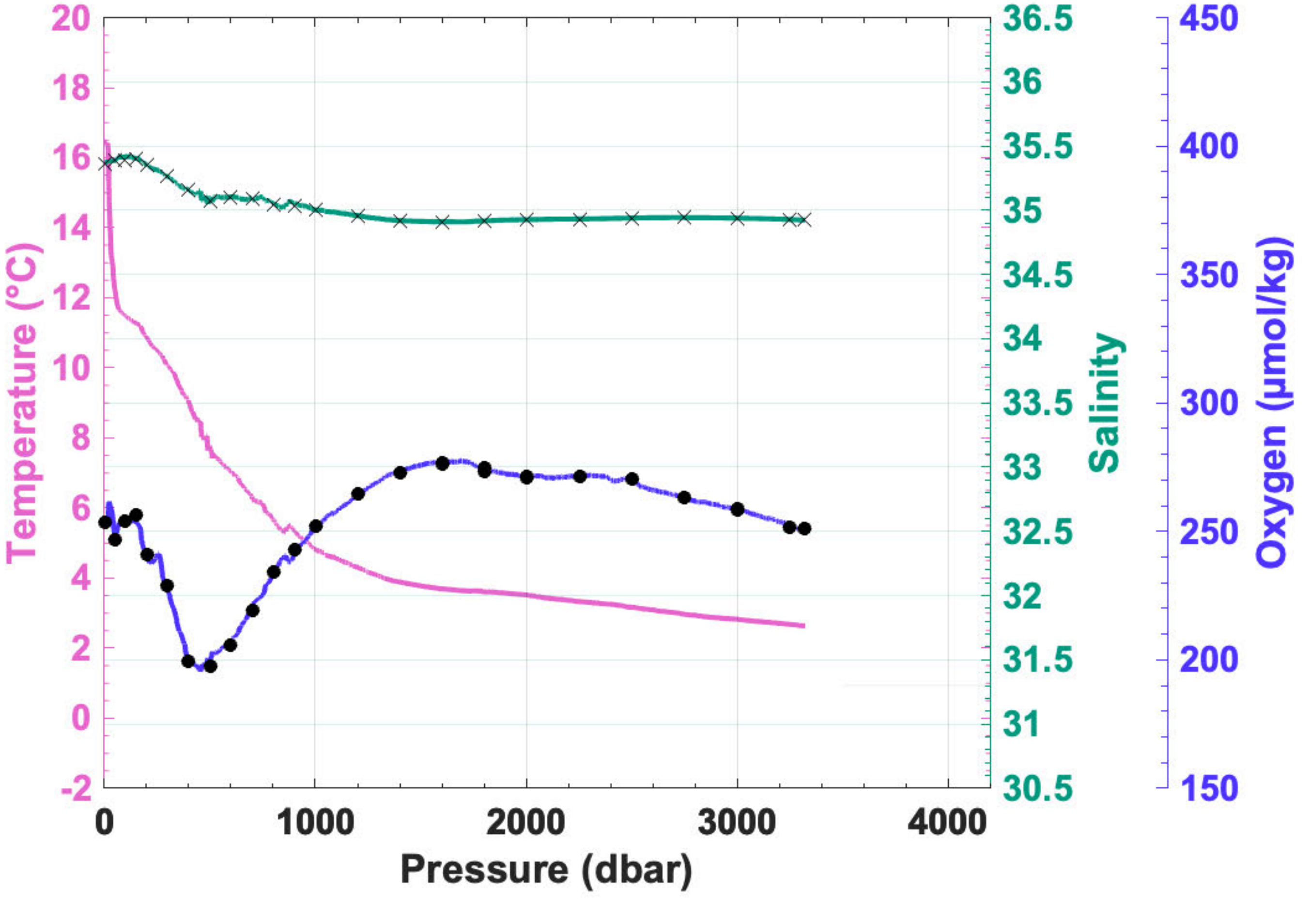
STATION 45 CAST 2



STATION 46

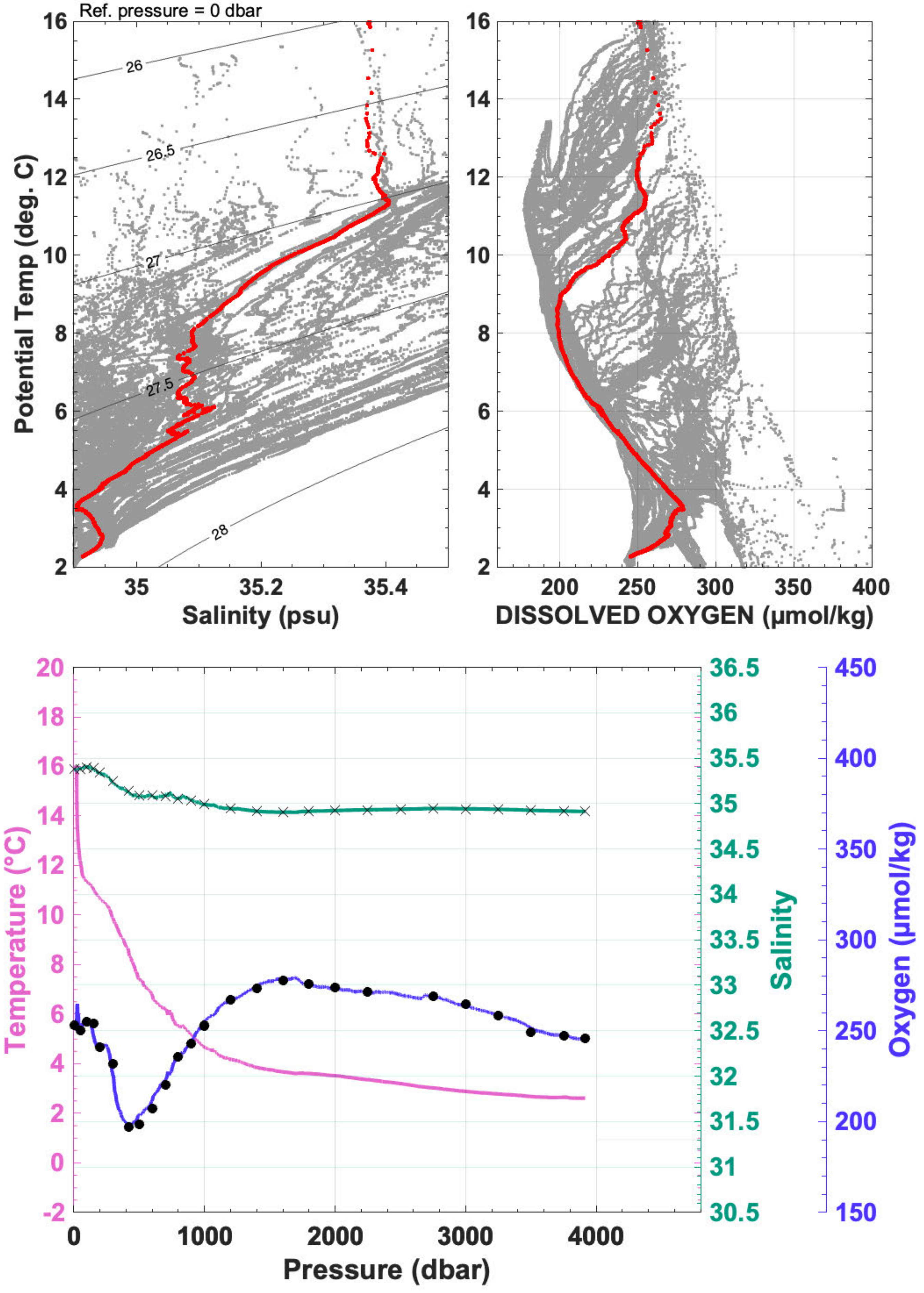


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)

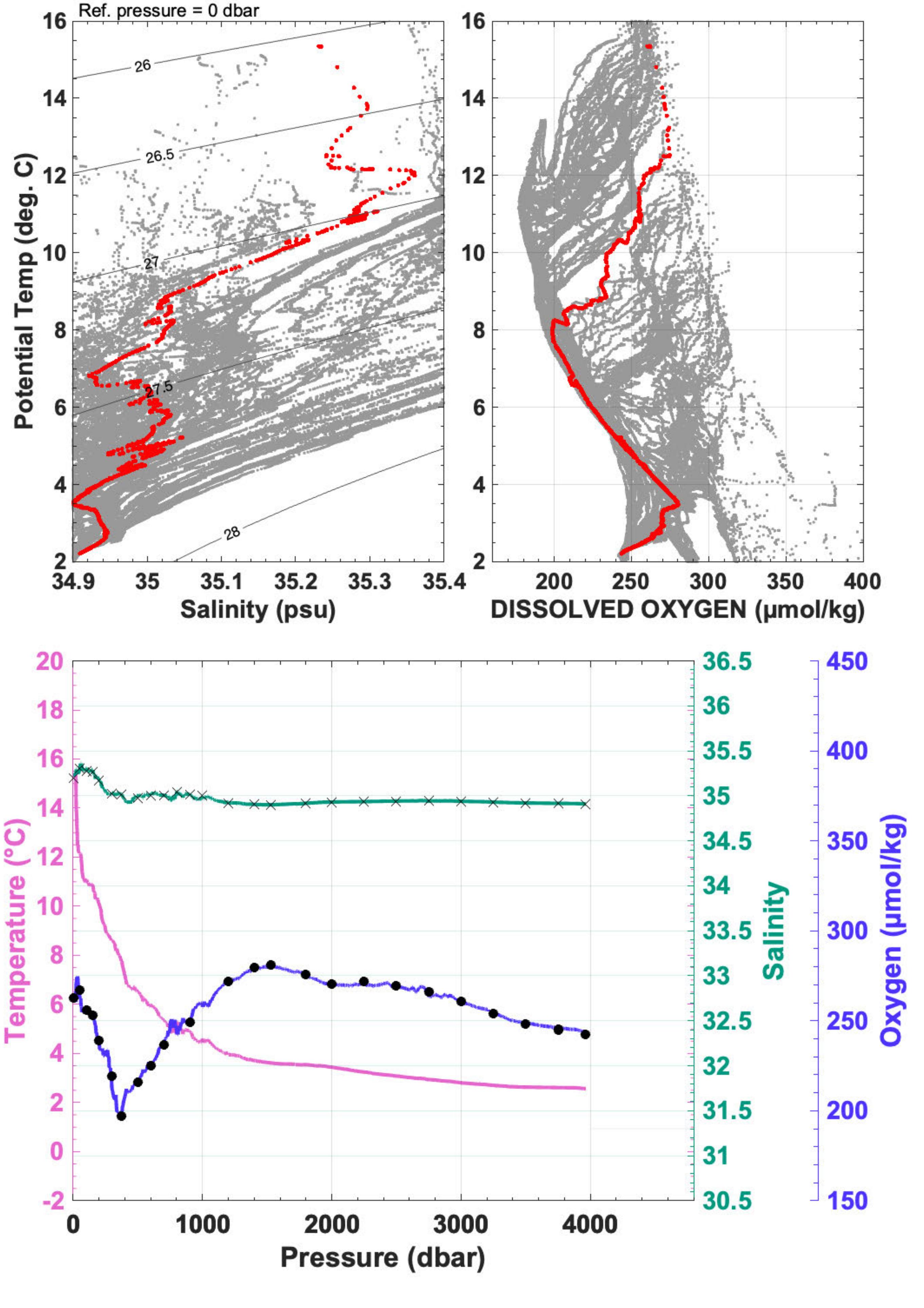


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 47

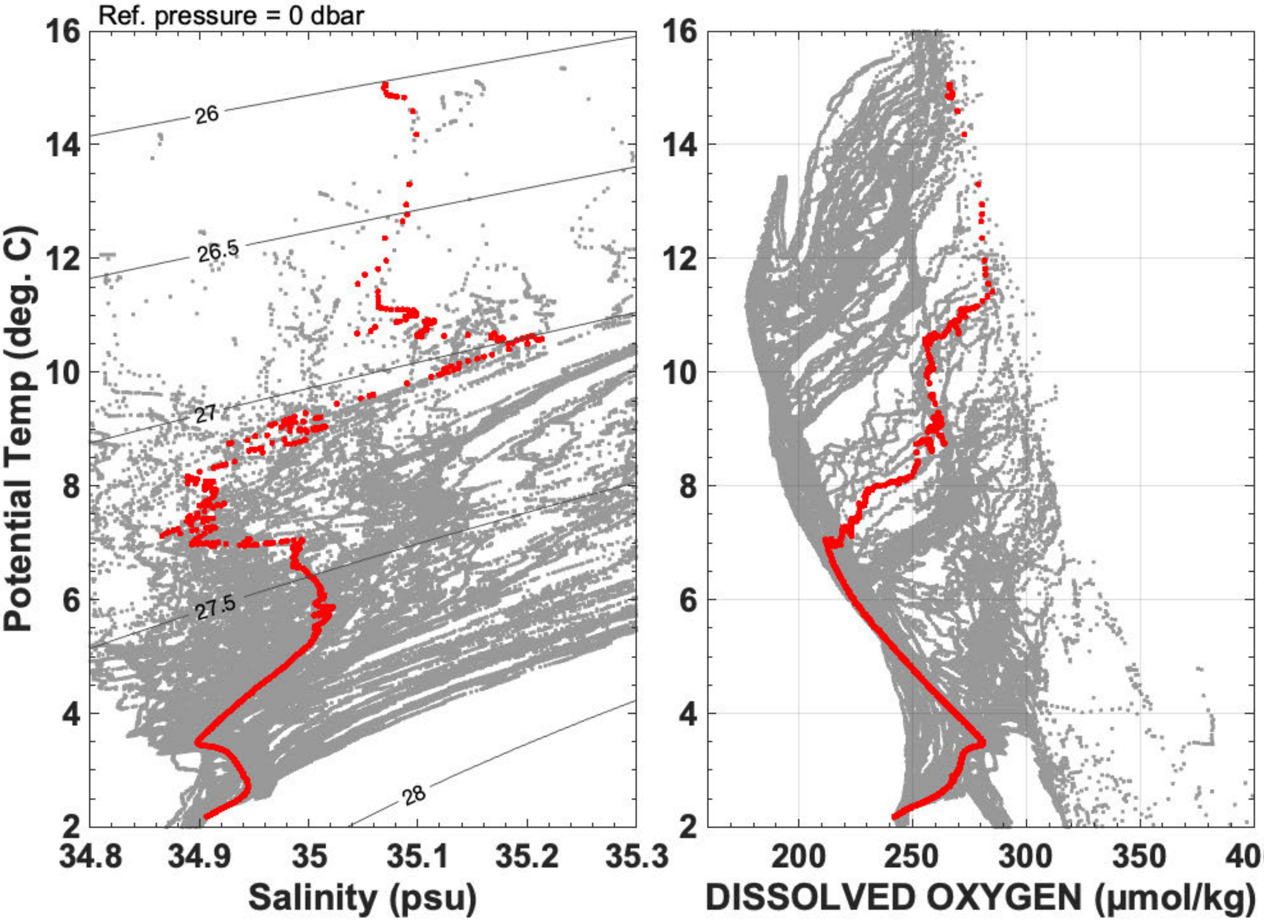

Ref. pressure = 0 dbar
26
26.5
27
27.5
28
16
14
12
10
8
6
4
2
Potential Temp (deg. C)
35
35.2
35.4
Salinity (psu)
200
250
300
350
400
DISSOLVED OXYGEN (µmol/kg)
20
18
16
14
12
10
8
6
4
2
0
-2
Temperature (°C)
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
Salinity
450
400
350
300
250
200
150
Oxygen (µmol/kg)
0
1000
2000
3000
4000
Pressure (dbar)

STATION 48

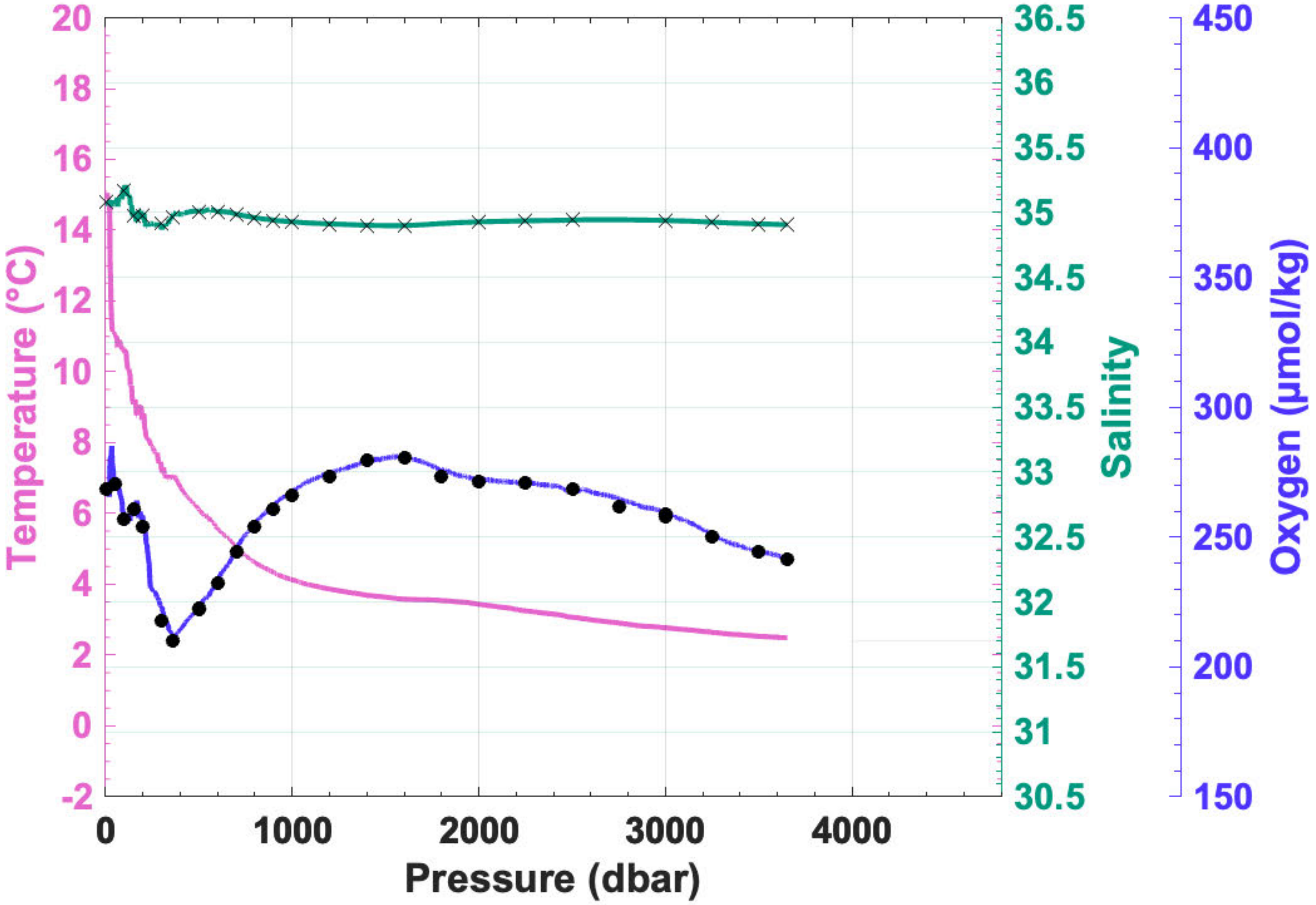


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 49

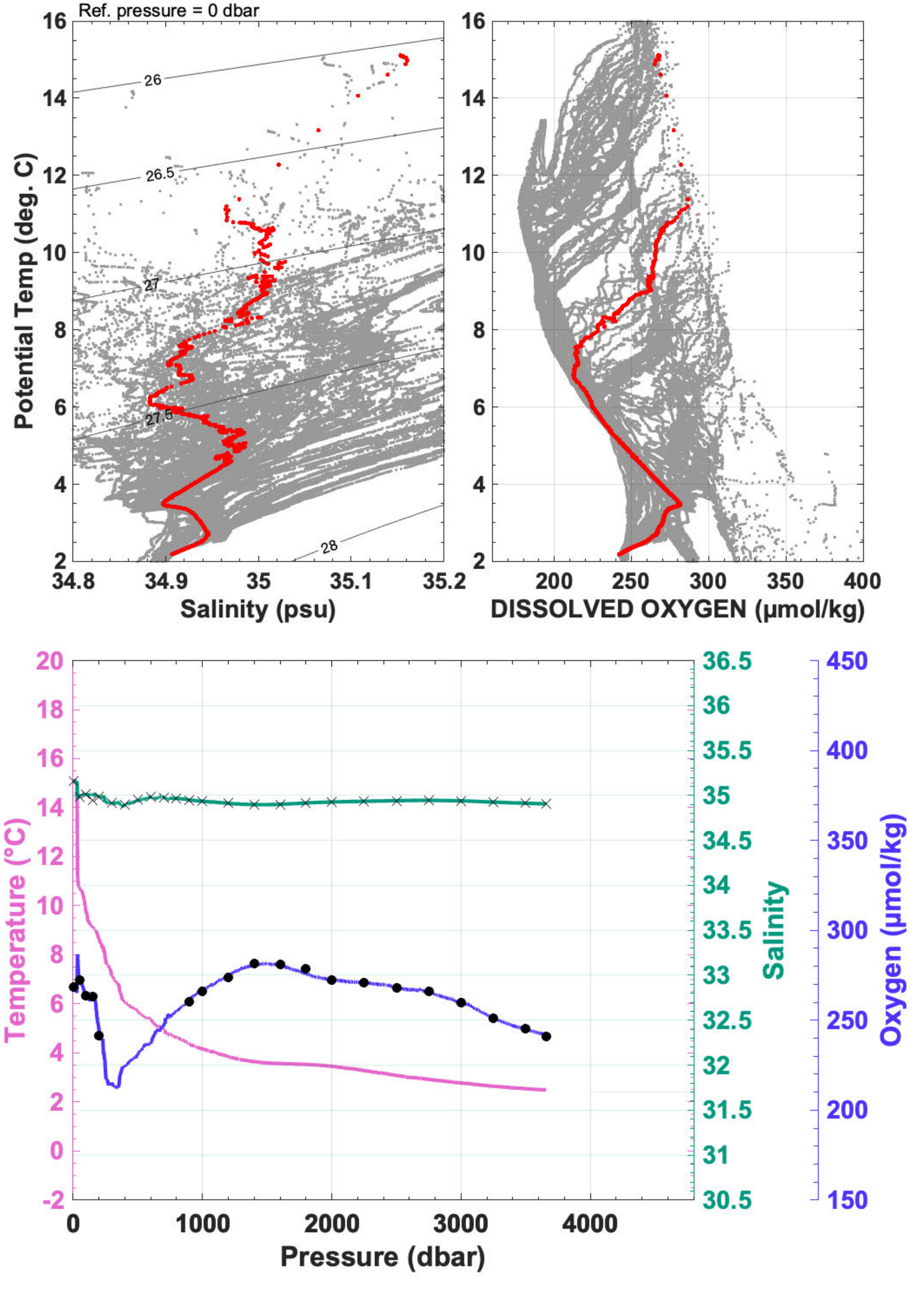


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)

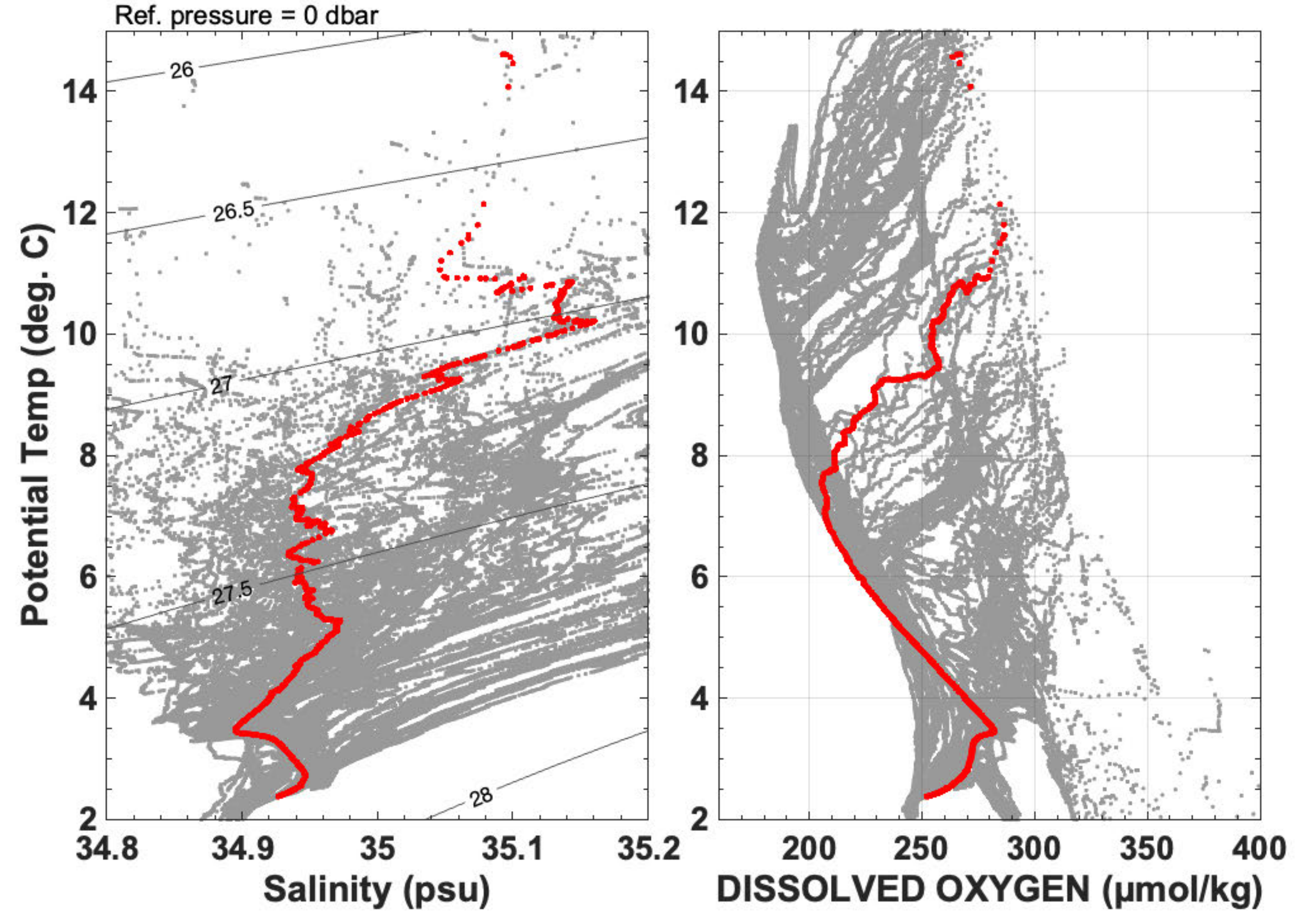


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

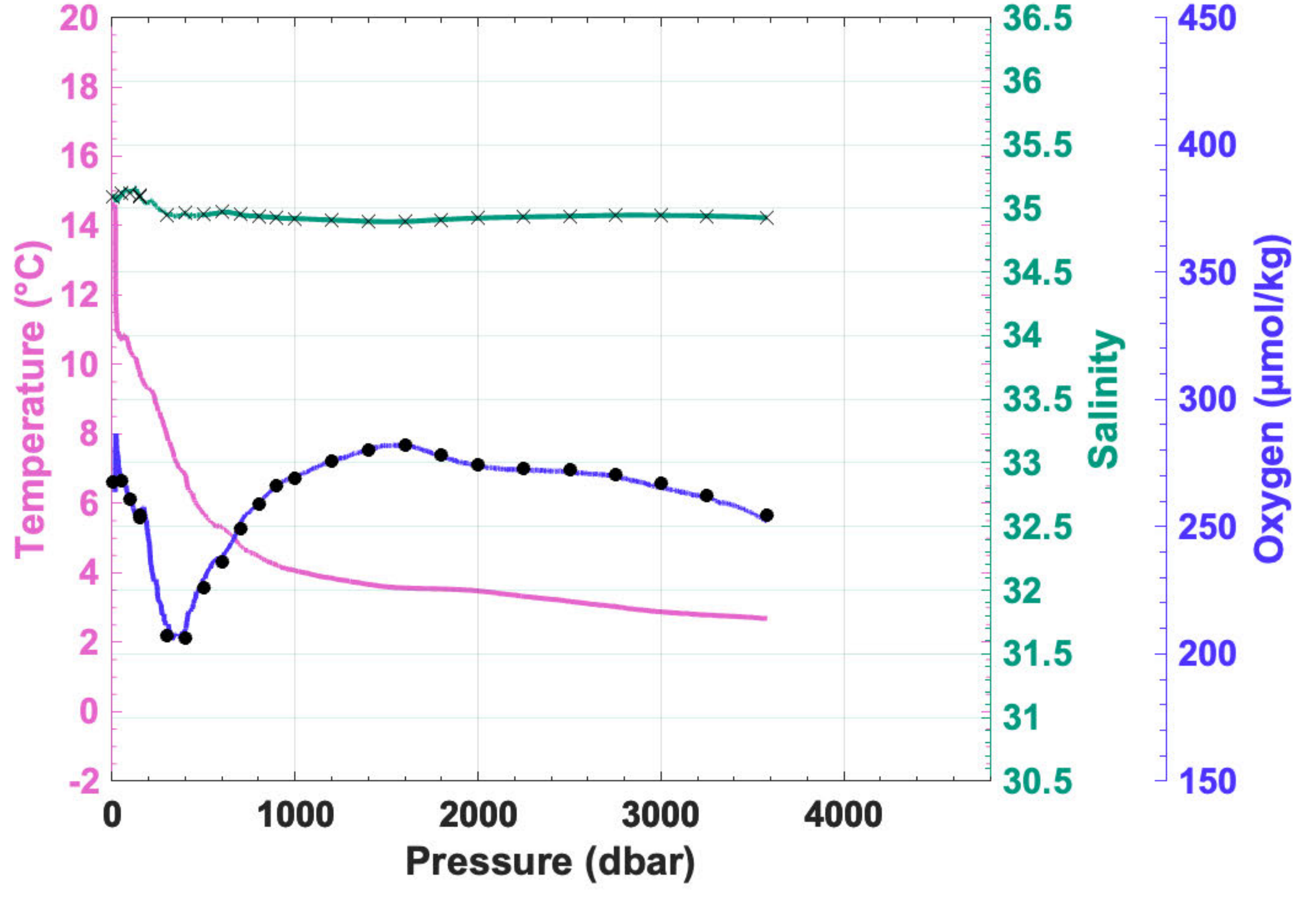
STATION 50


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 51

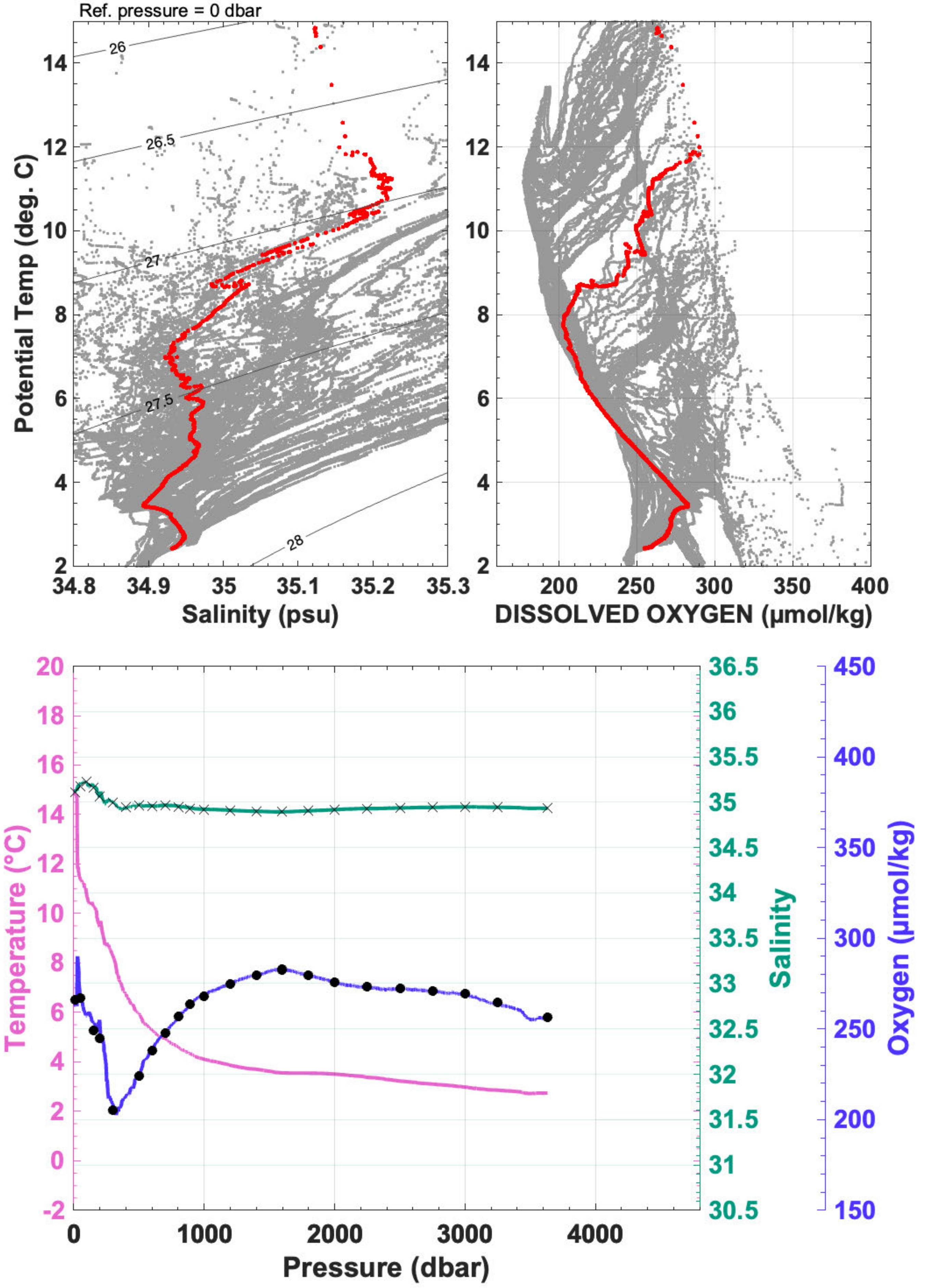


Ref. pressure = 0 dbar
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



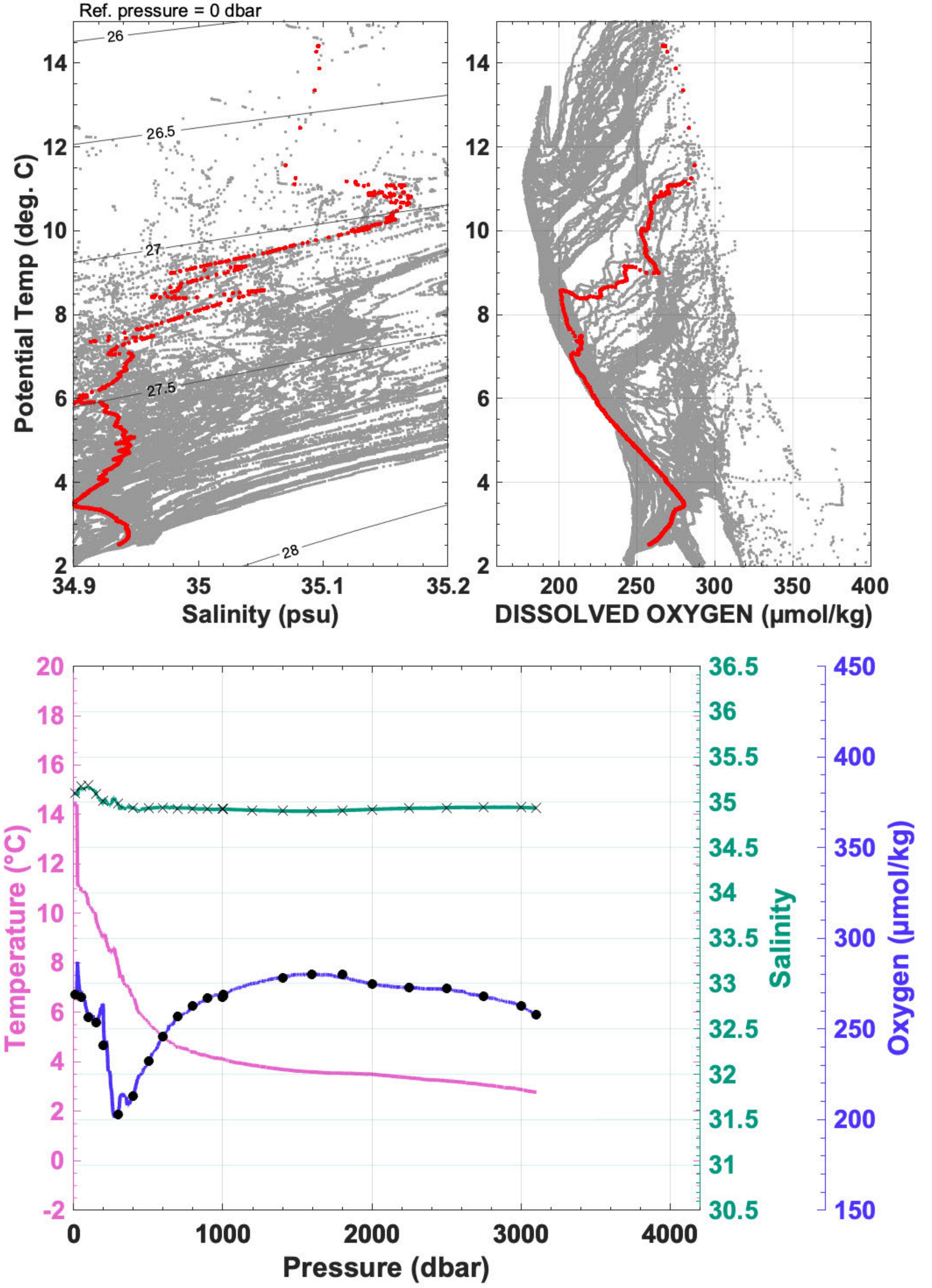
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 52



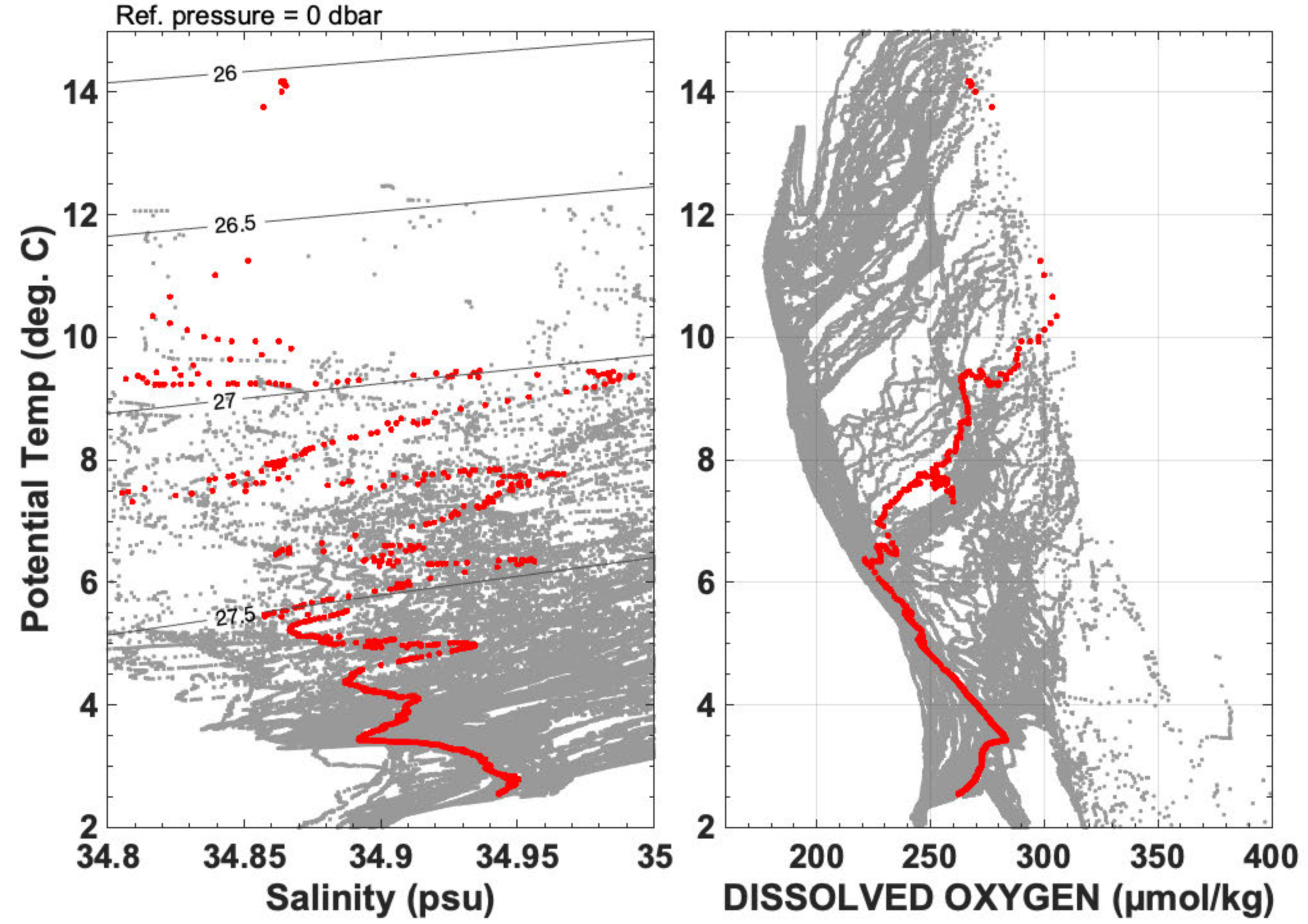
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
26
26.5
27
27.5
28
34.8
34.9
35
35.1
35.2
35.3
200
250
300
350
400
2
4
6
8
10
12
14
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
1000
2000
3000
4000
-2
0
2
4
6
8
10
12
14
16
18
20
30.5
31
31.5
32
32.5
33
33.5
34
34.5
35
35.5
36
36.5
150
200
250
300
350
400
450

STATION 53

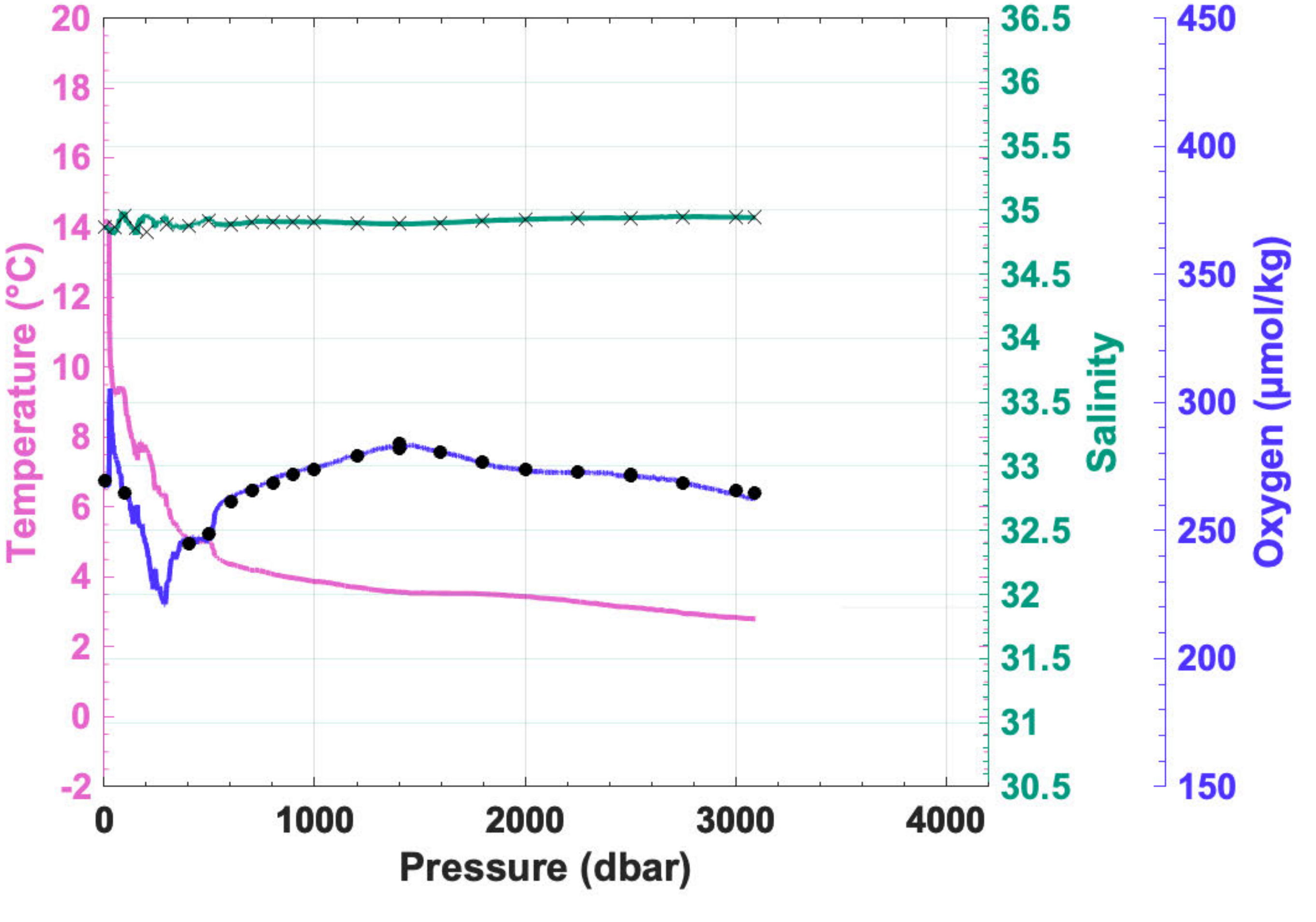


Ref. pressure = 0 dbar
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 54

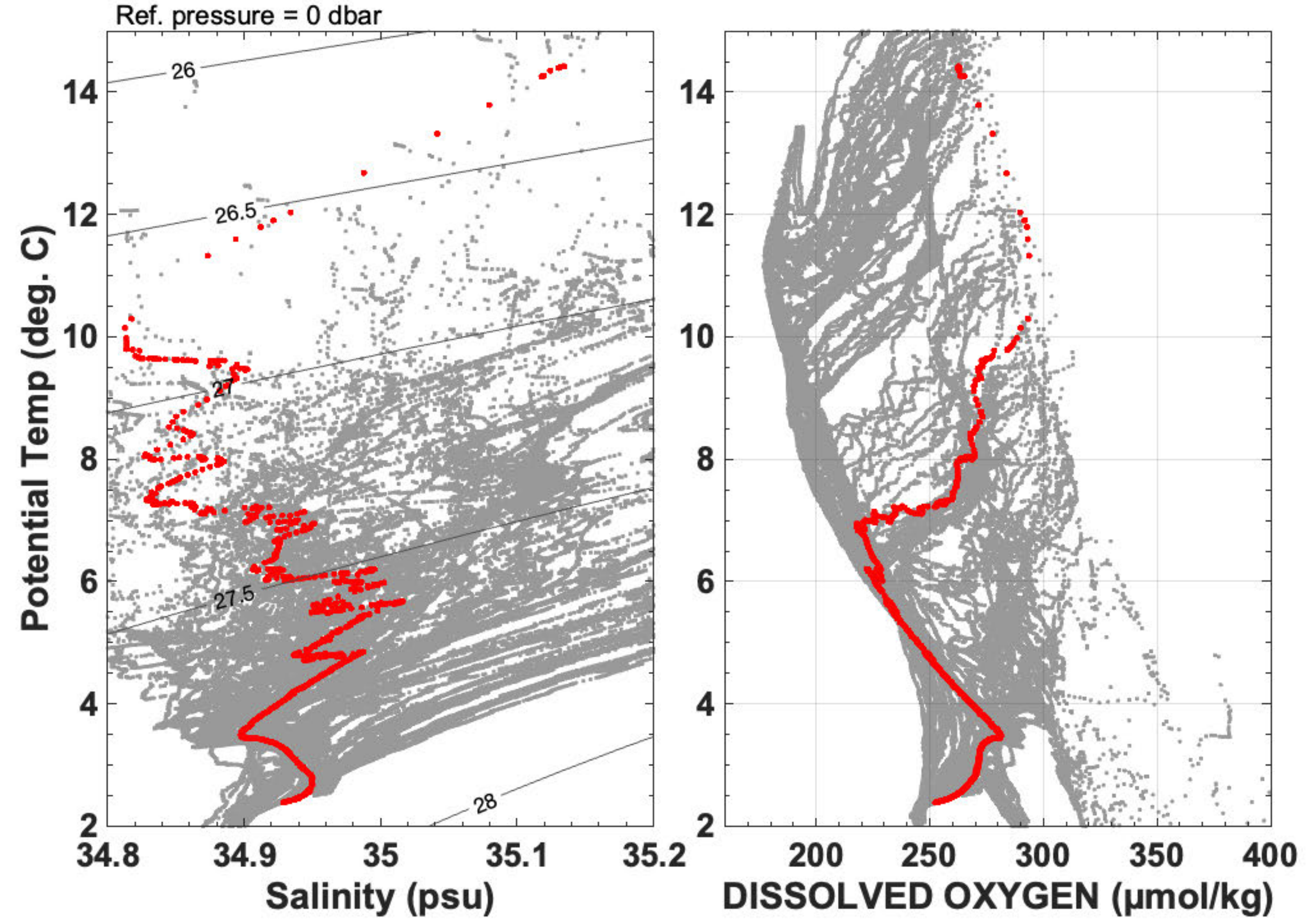


Ref. pressure = 0 dbar
26
26.5
27
27.5
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (μmol/kg)

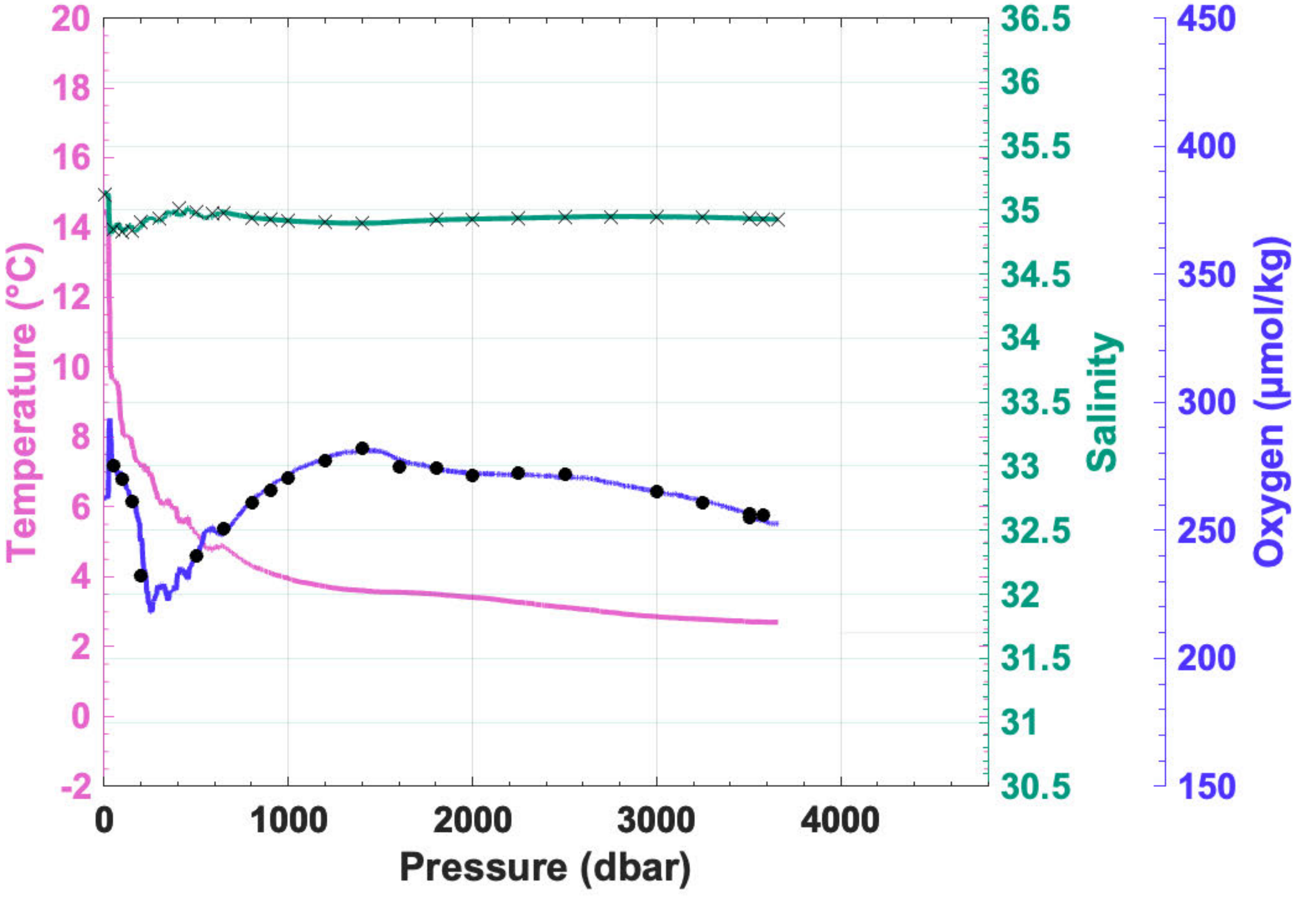


Temperature (°C)
Salinity
Oxygen (μmol/kg)
Pressure (dbar)

STATION 55

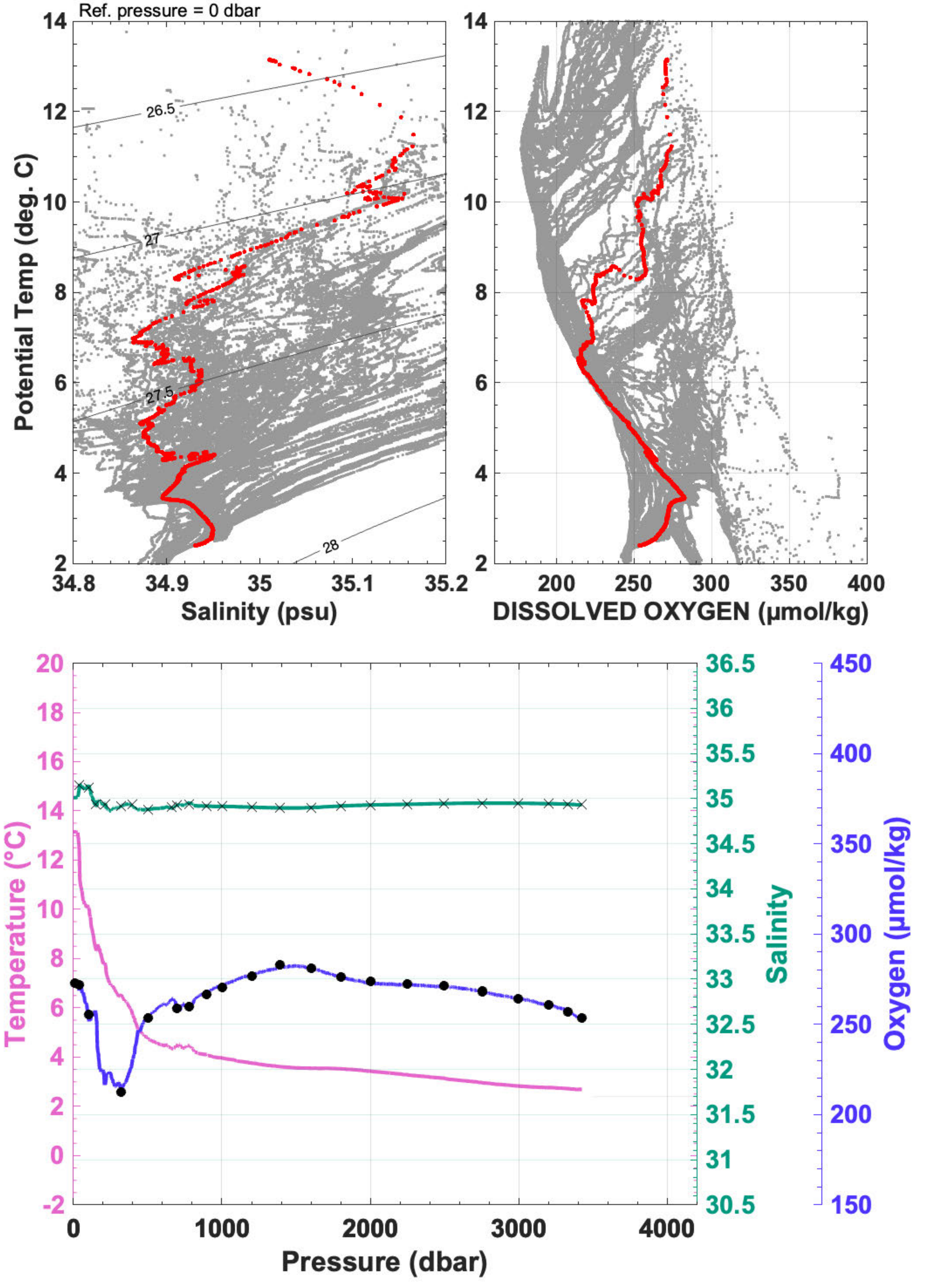


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
26
26.5
27
27.5
28



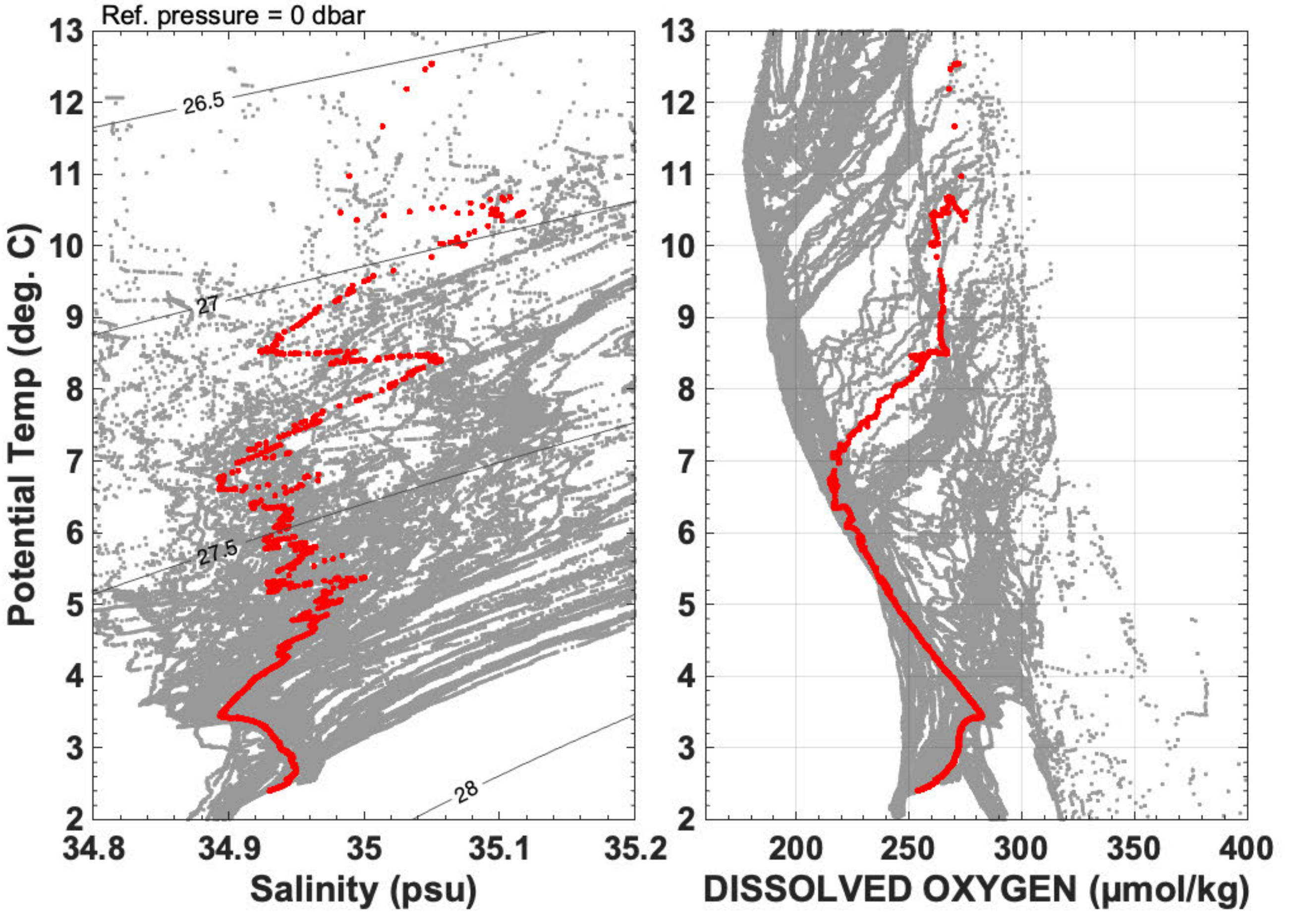
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 56

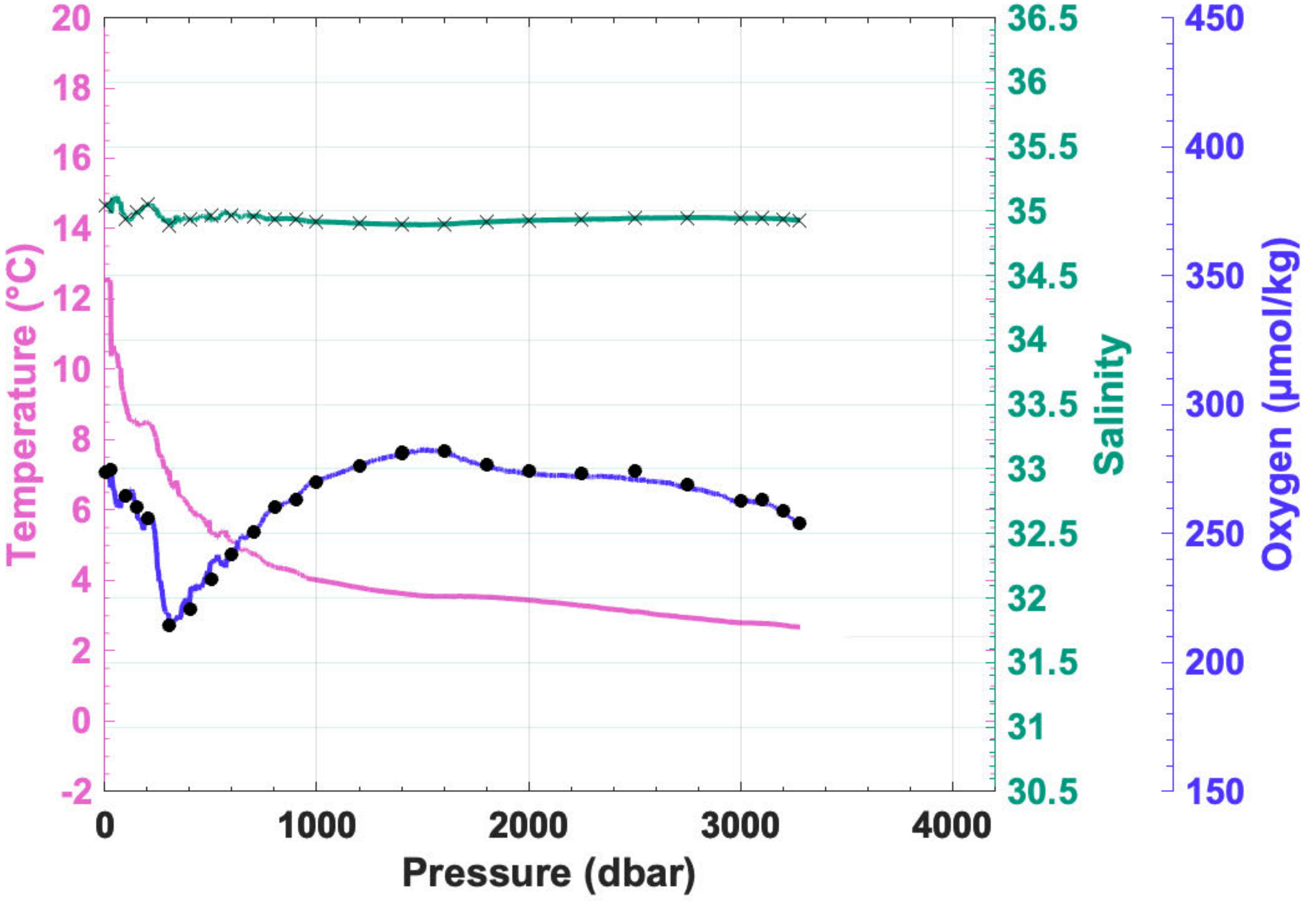


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 57

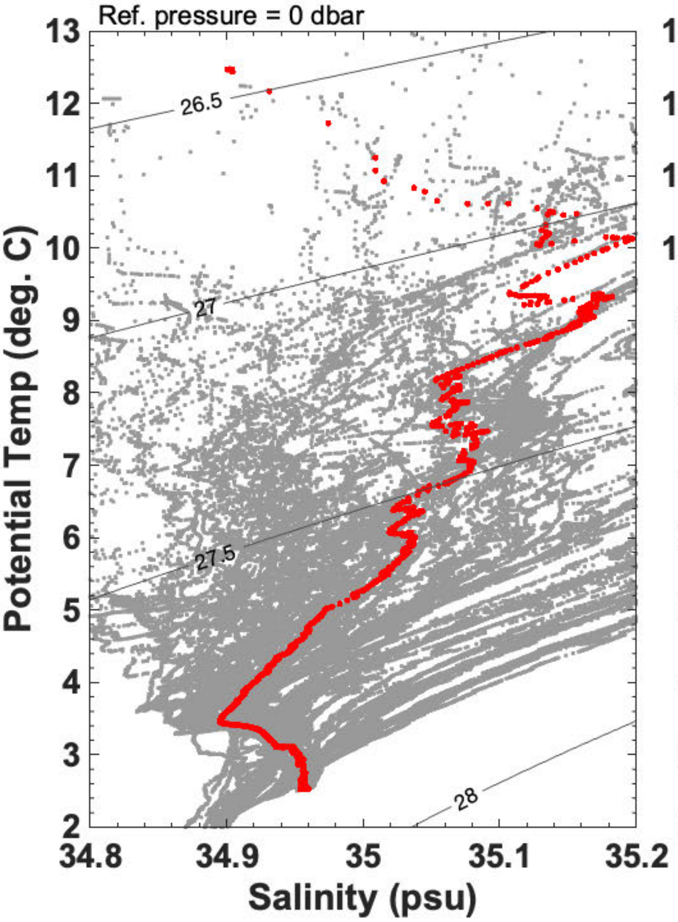


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)

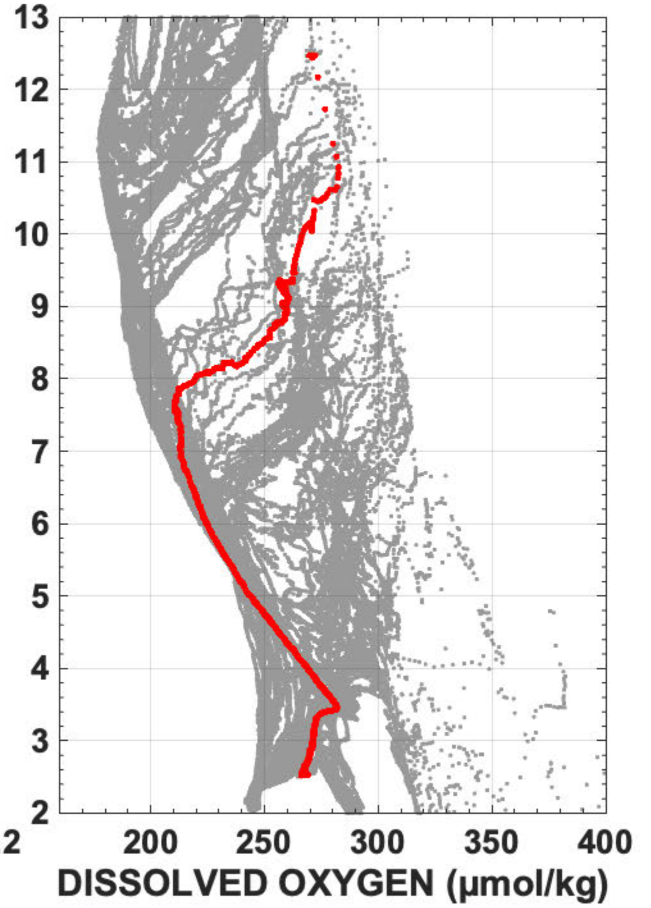


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

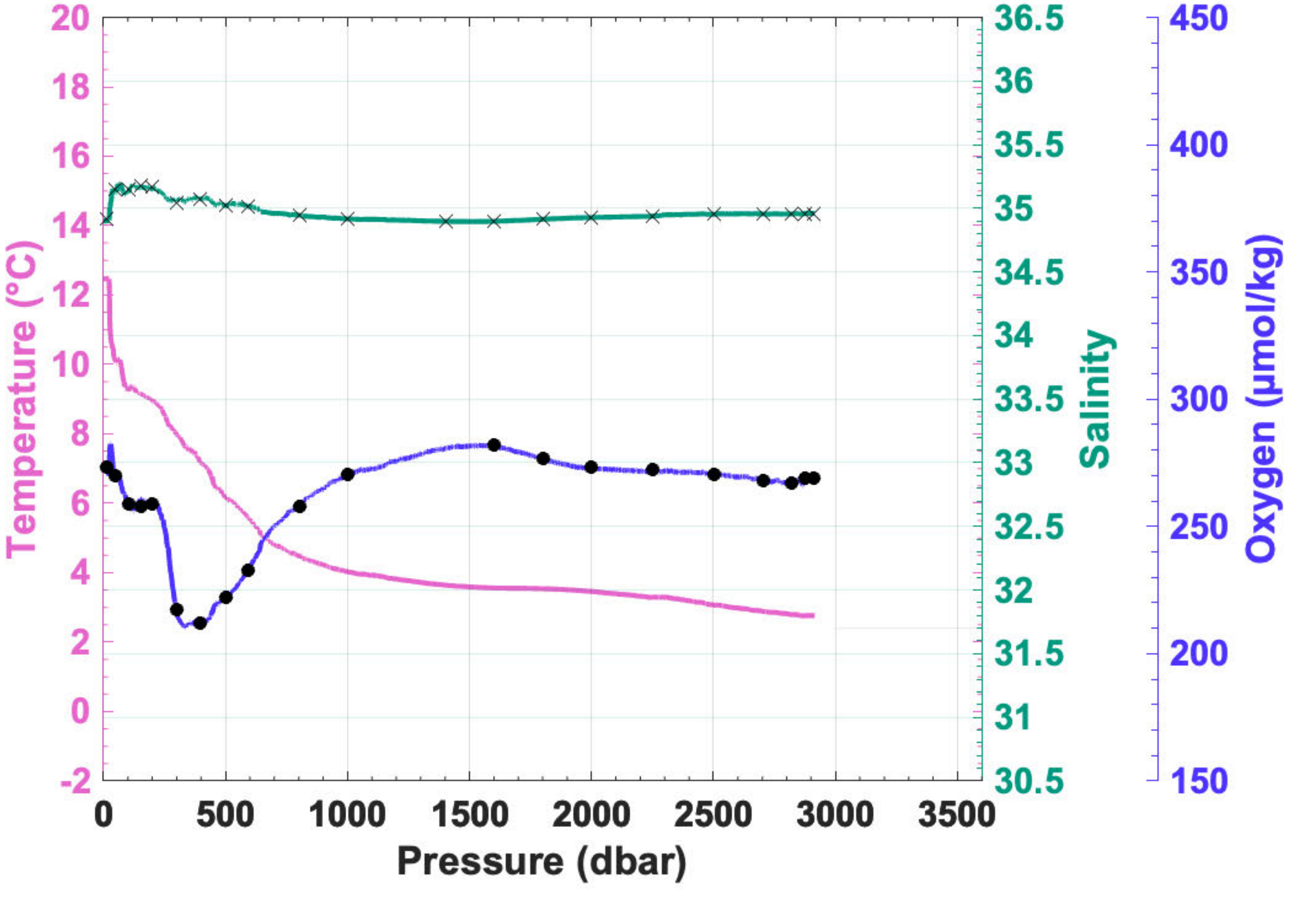
STATION 58



Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
28

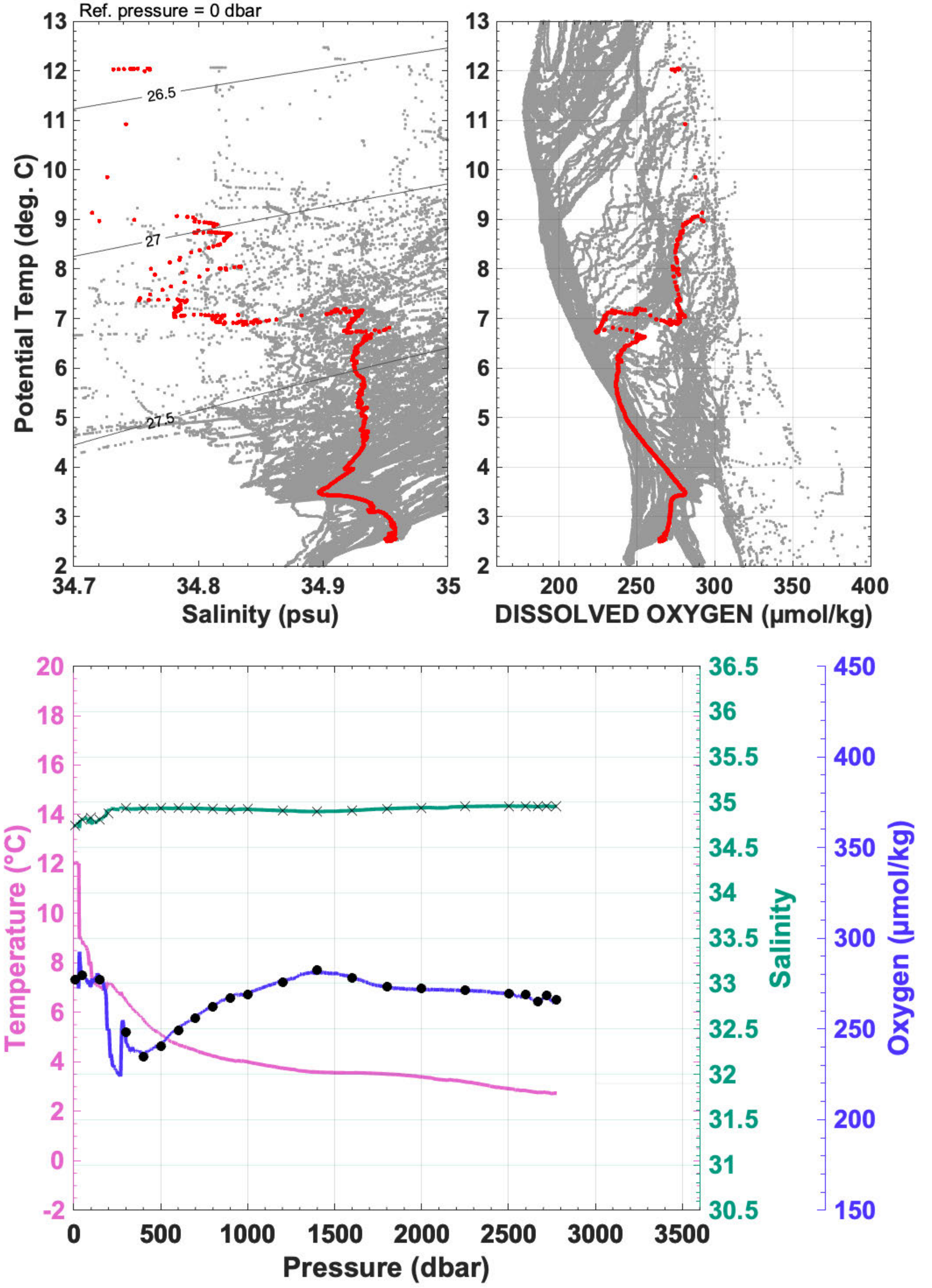


DISSOLVED OXYGEN (µmol/kg)

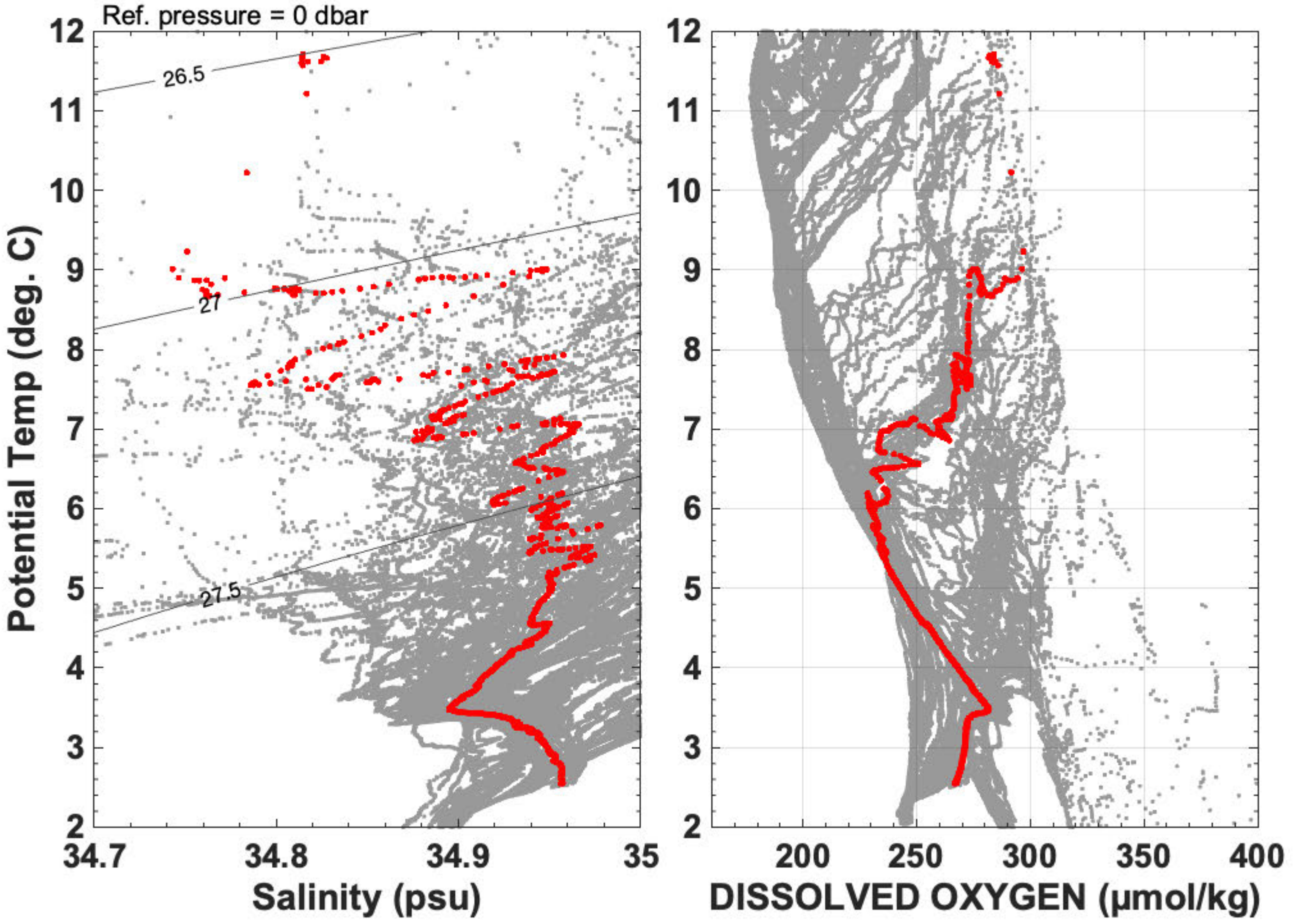


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

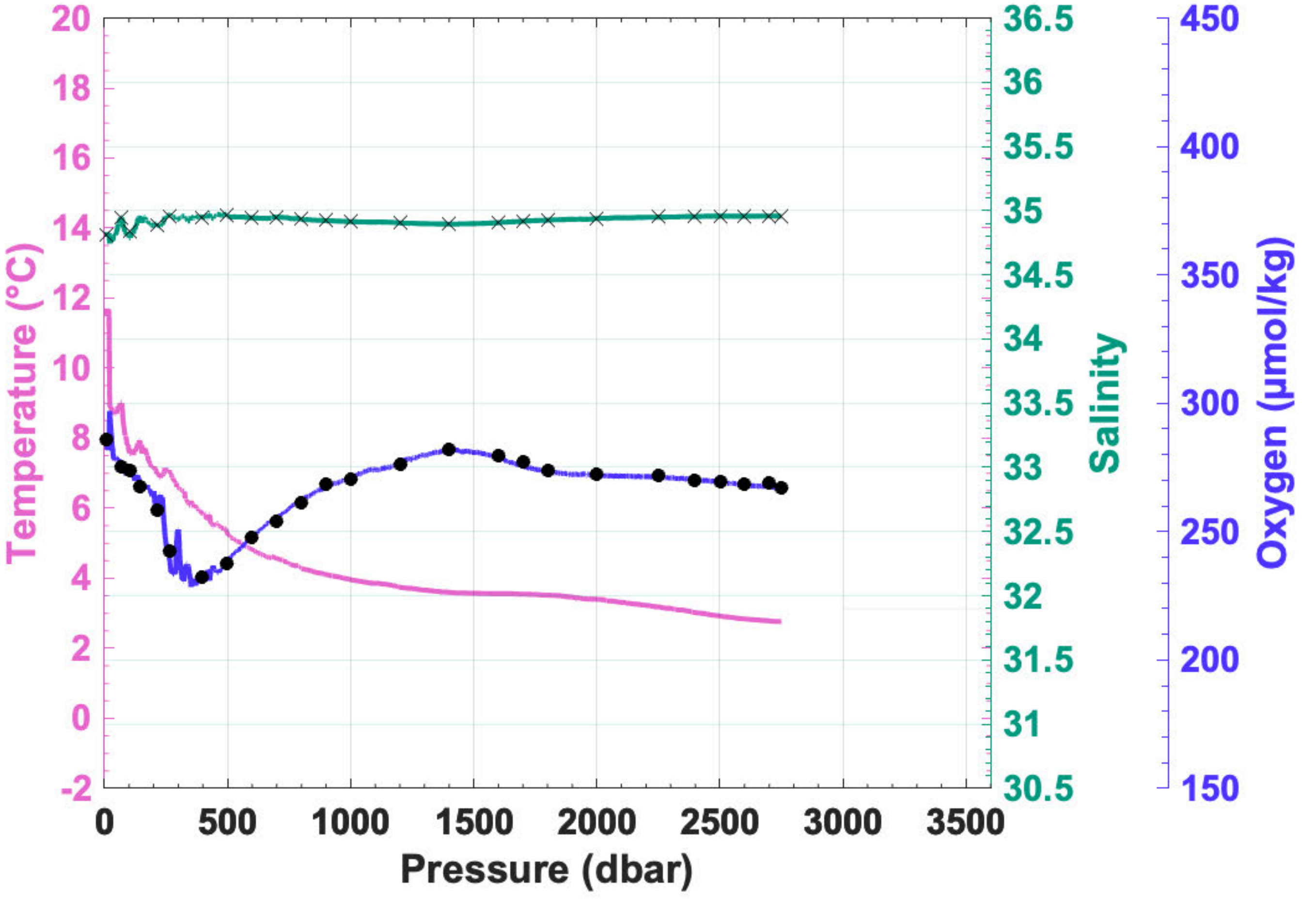
STATION 59


Ref. pressure = 0 dbar
26.5
27
27.5
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 60

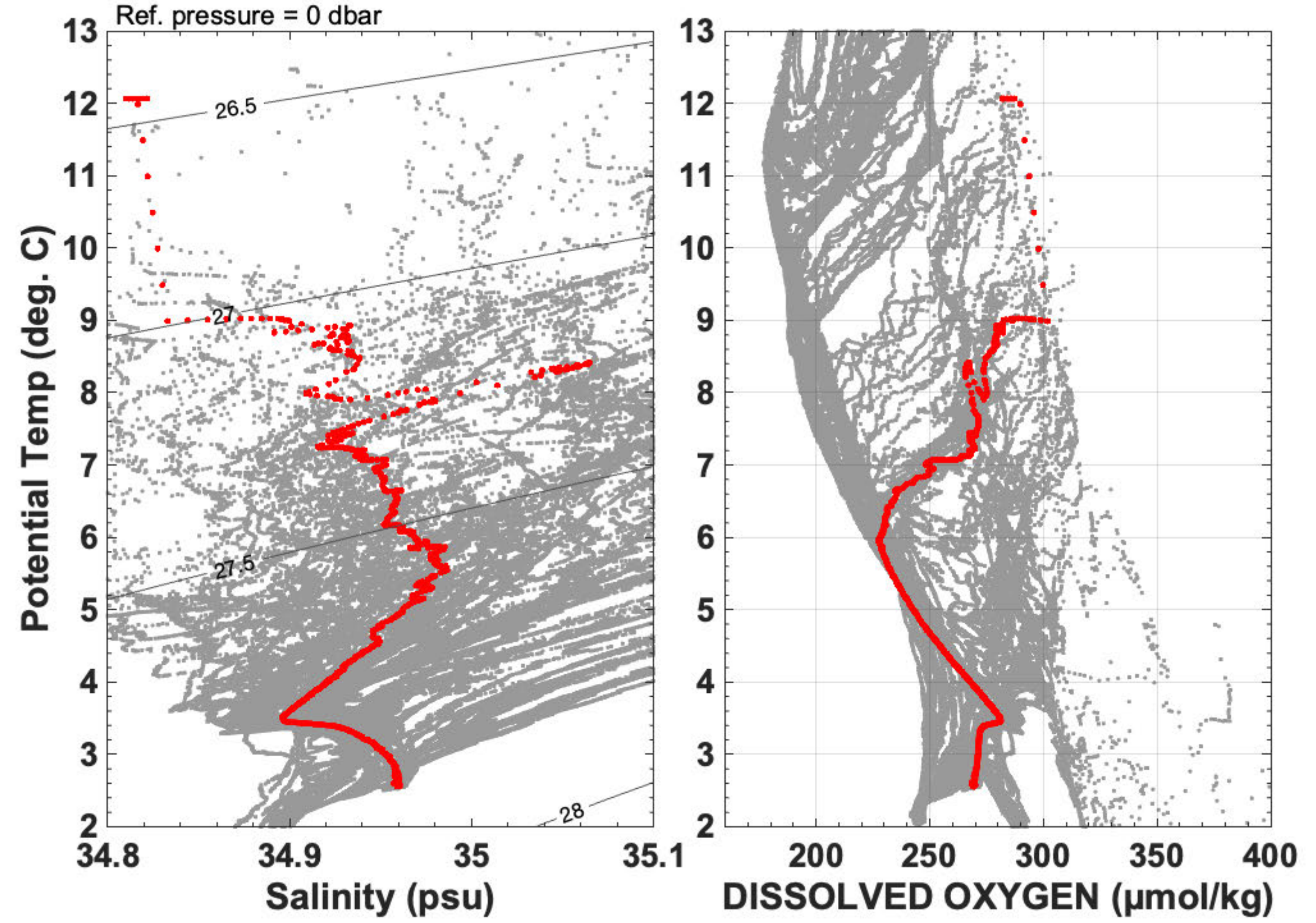


Ref. pressure = 0 dbar
26.5
27
27.5
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)

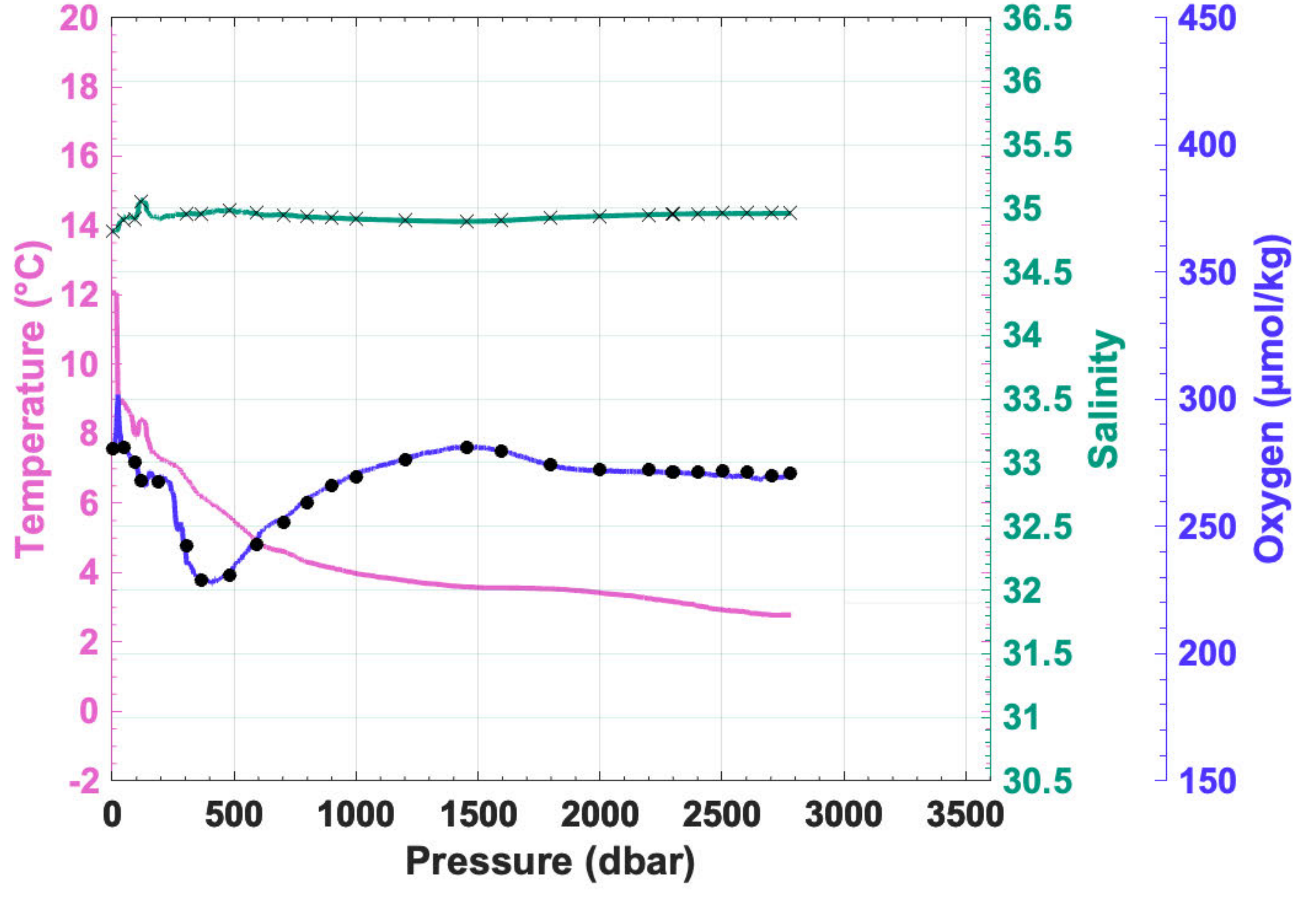


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 61

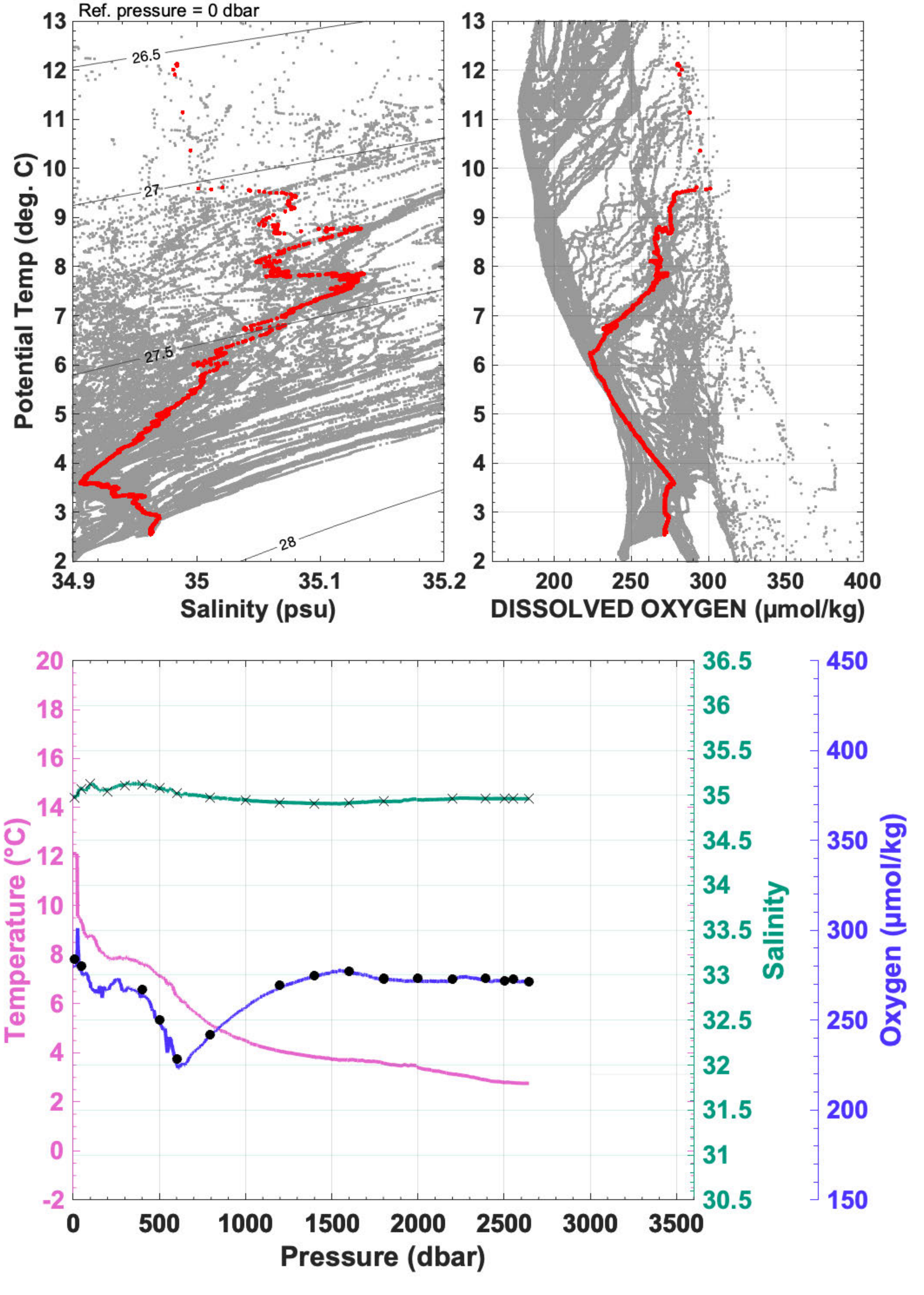


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)



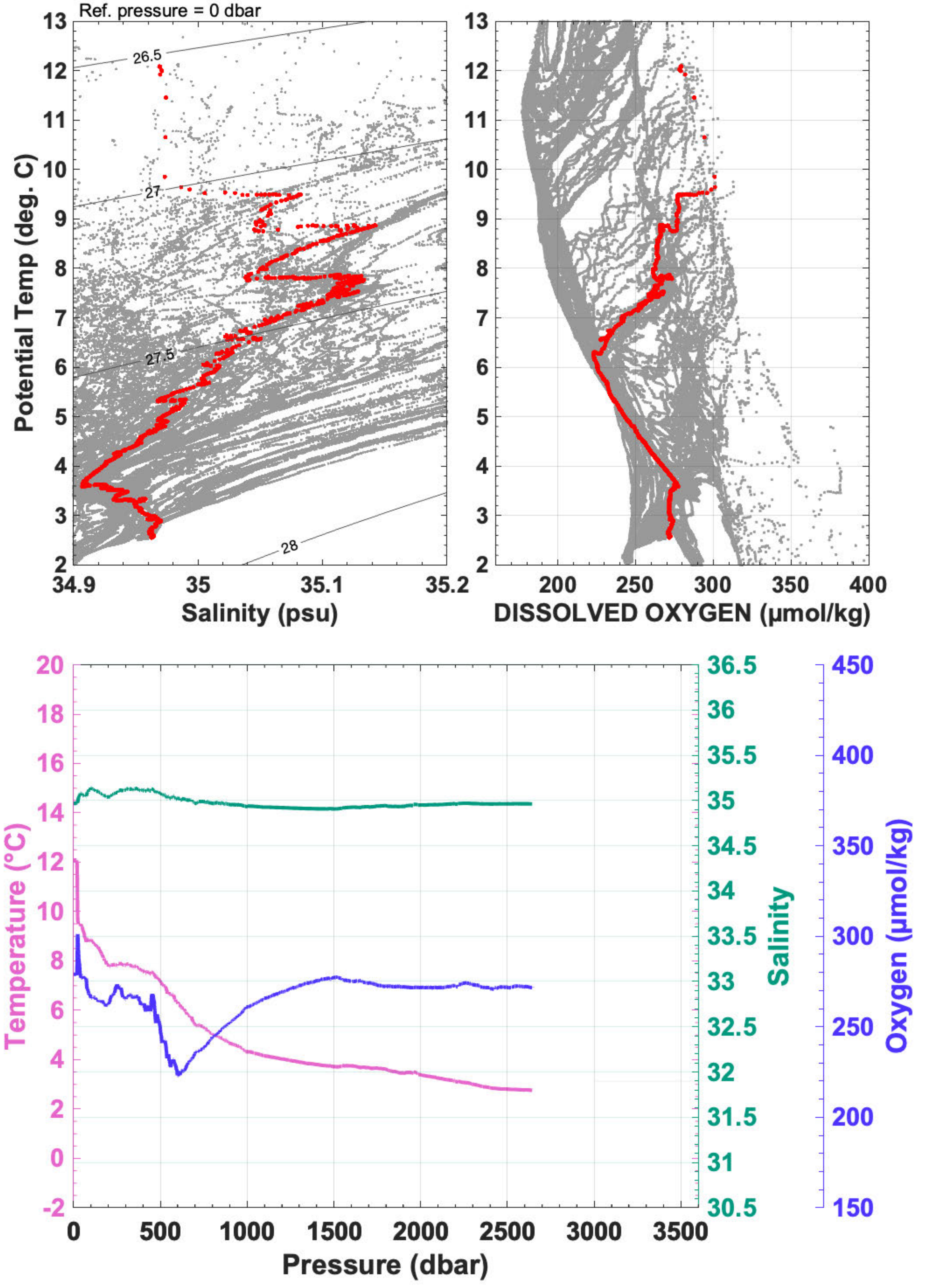
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 62

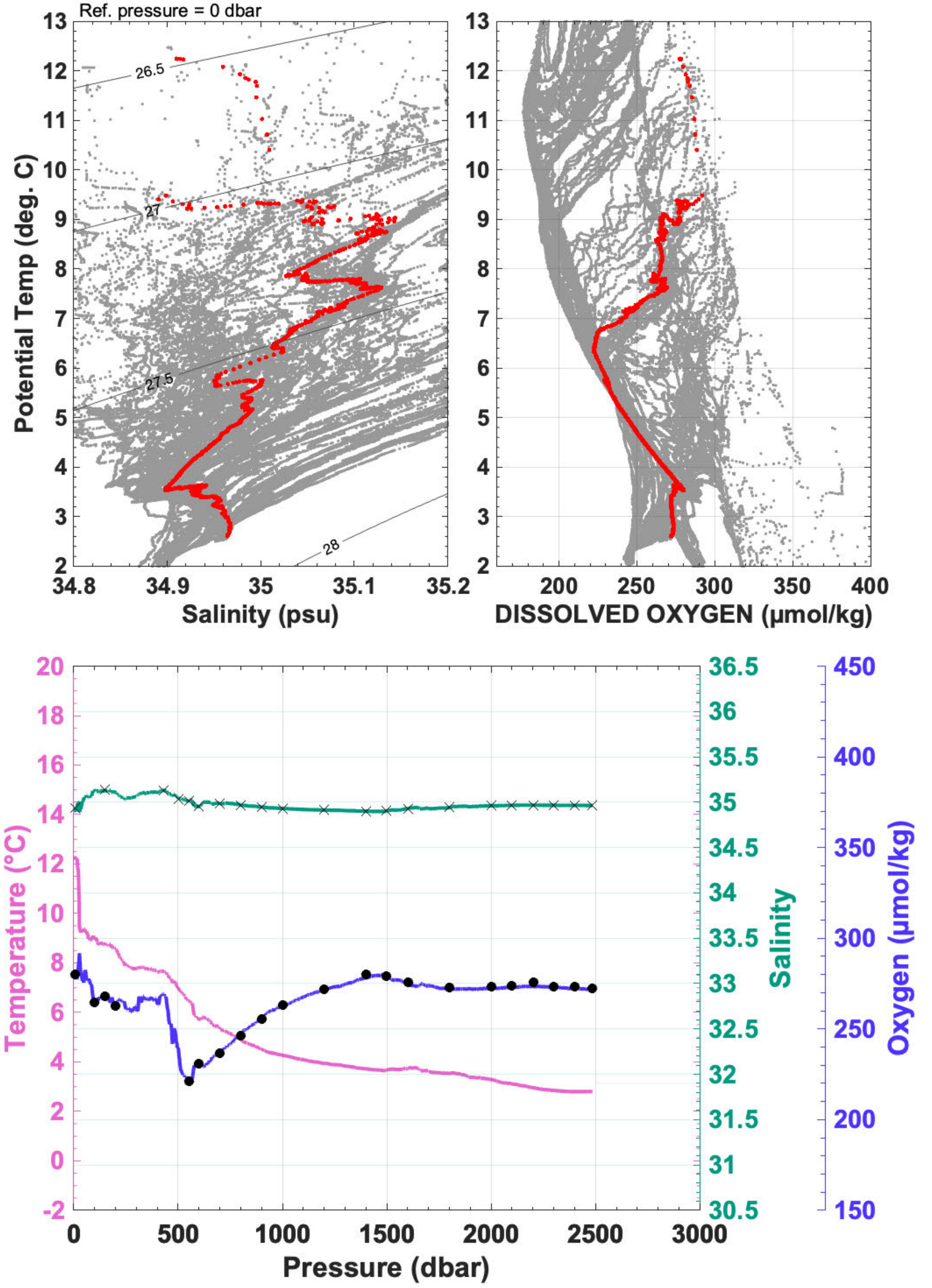


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 62 CAST 2

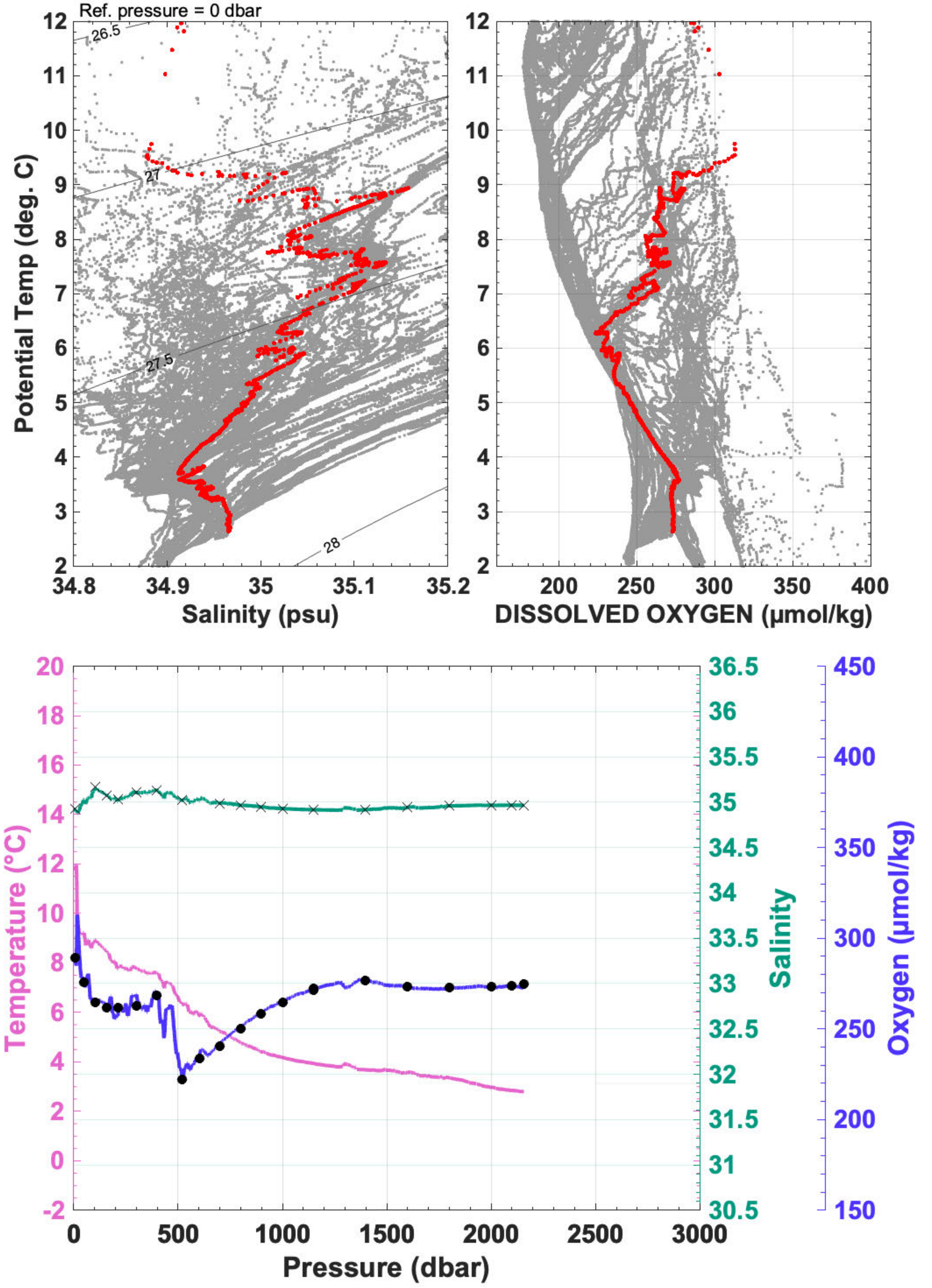


STATION 63

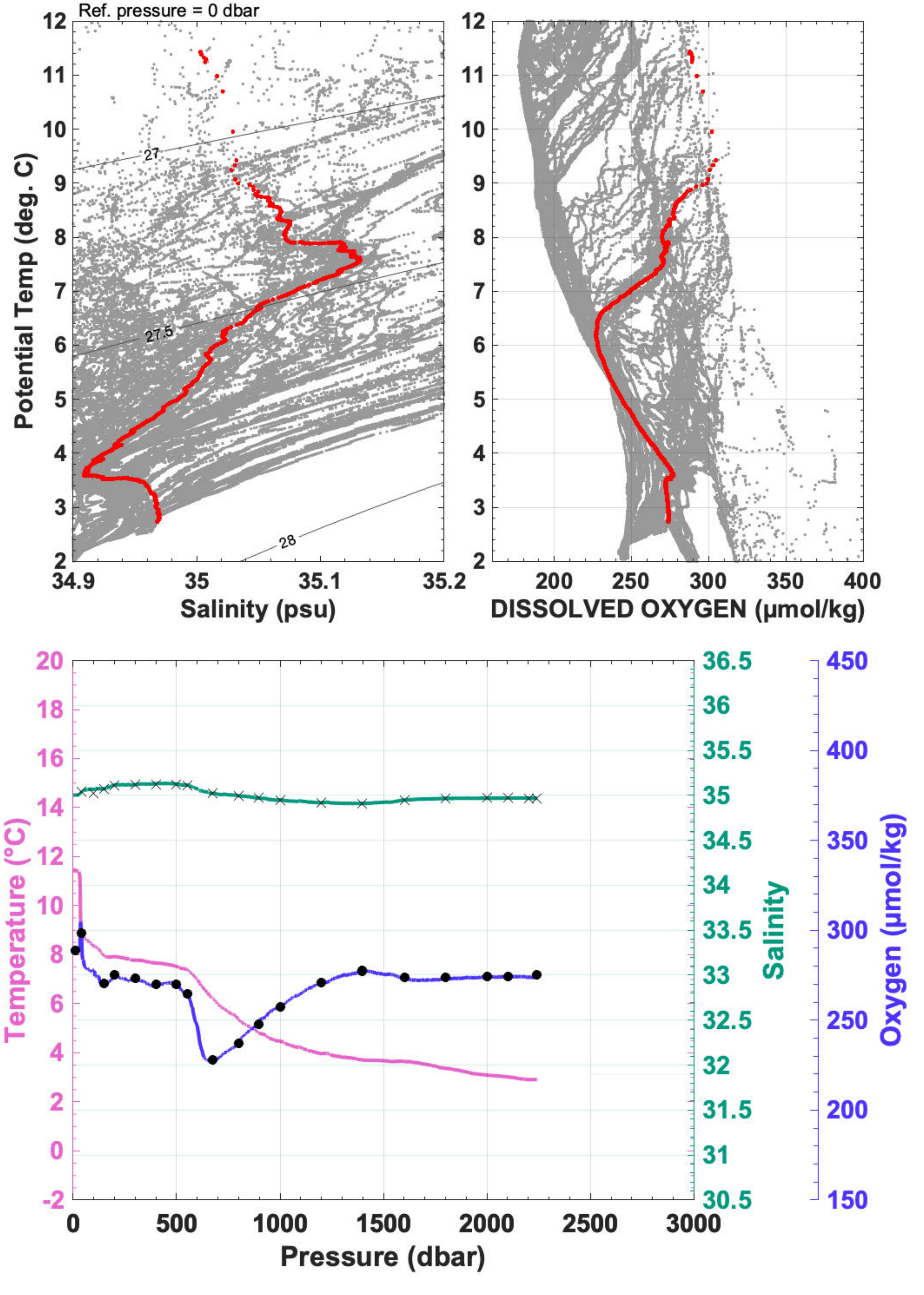


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
28
34.8
34.9
35
35.1
35.2
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
500
1000
1500
2000
2500
3000

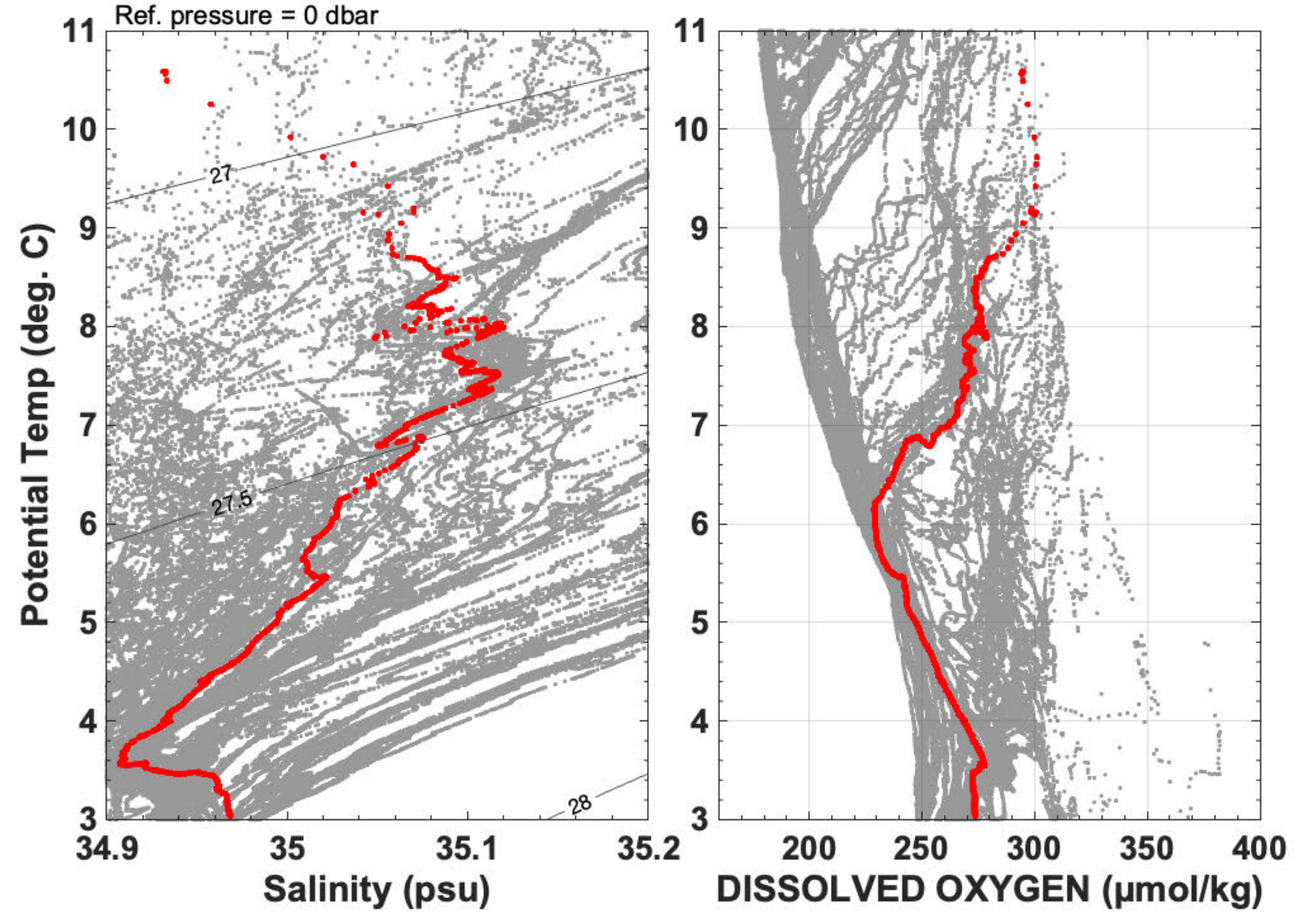
STATION 64

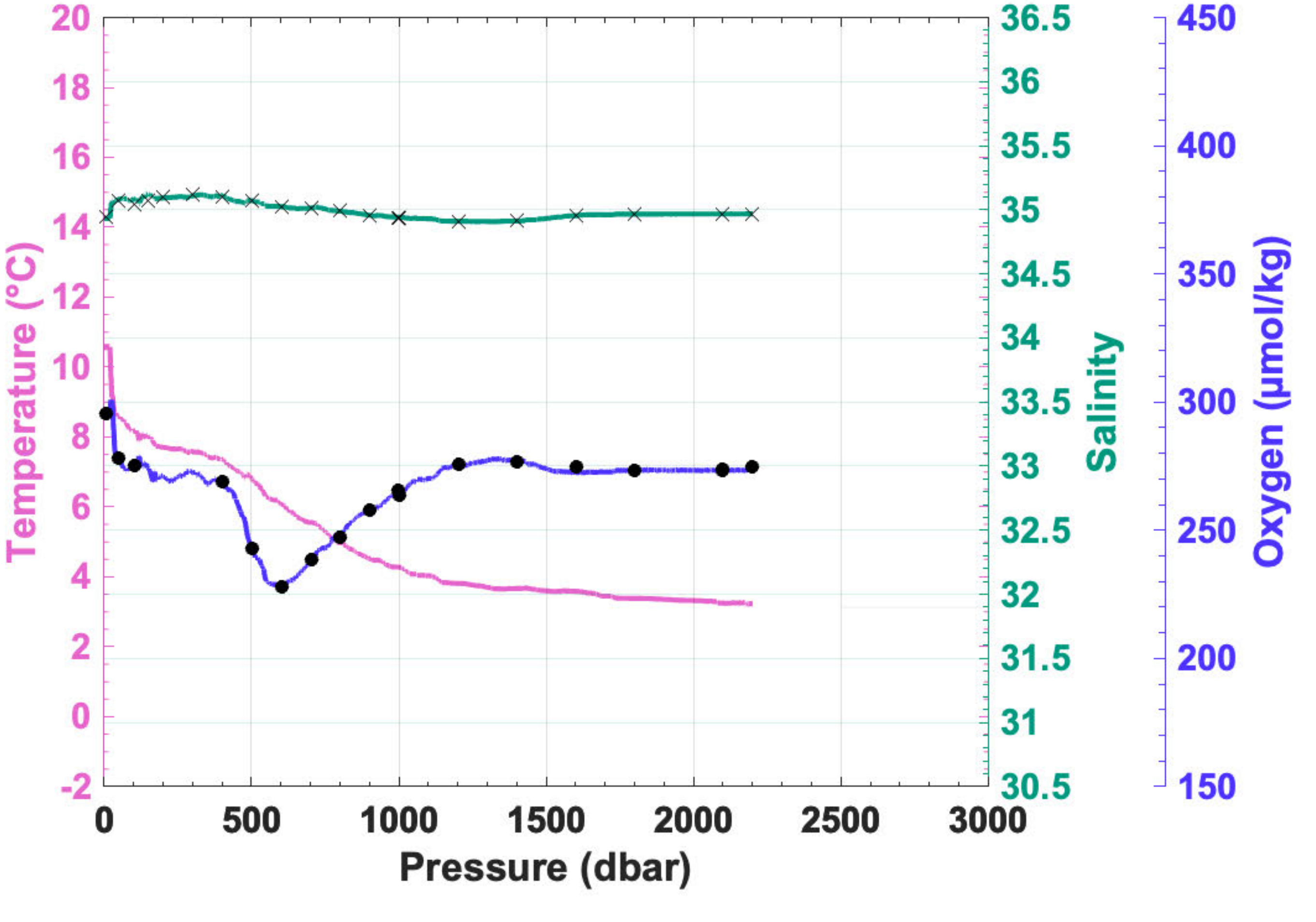

Ref. pressure = 0 dbar
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 65

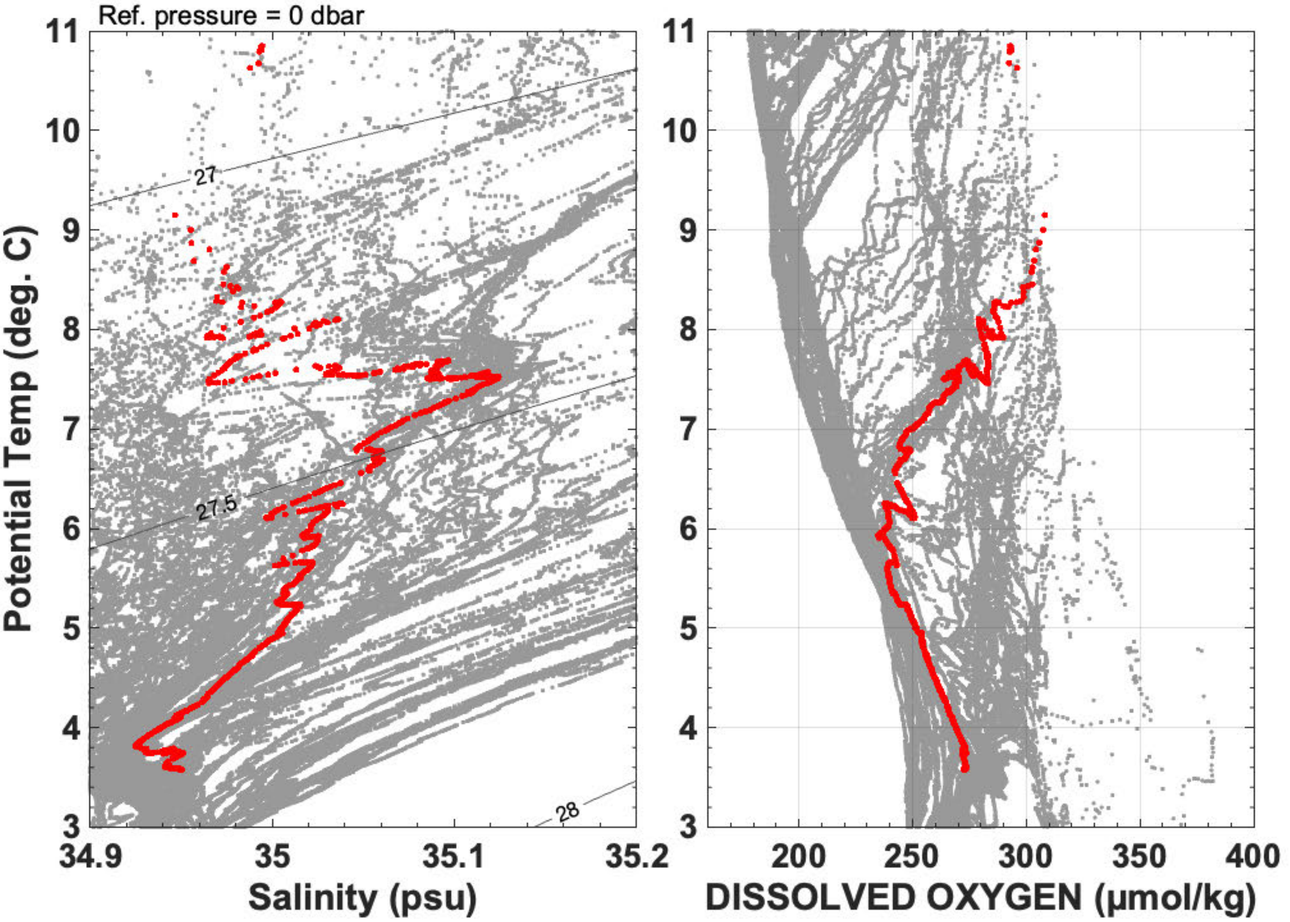

Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 66

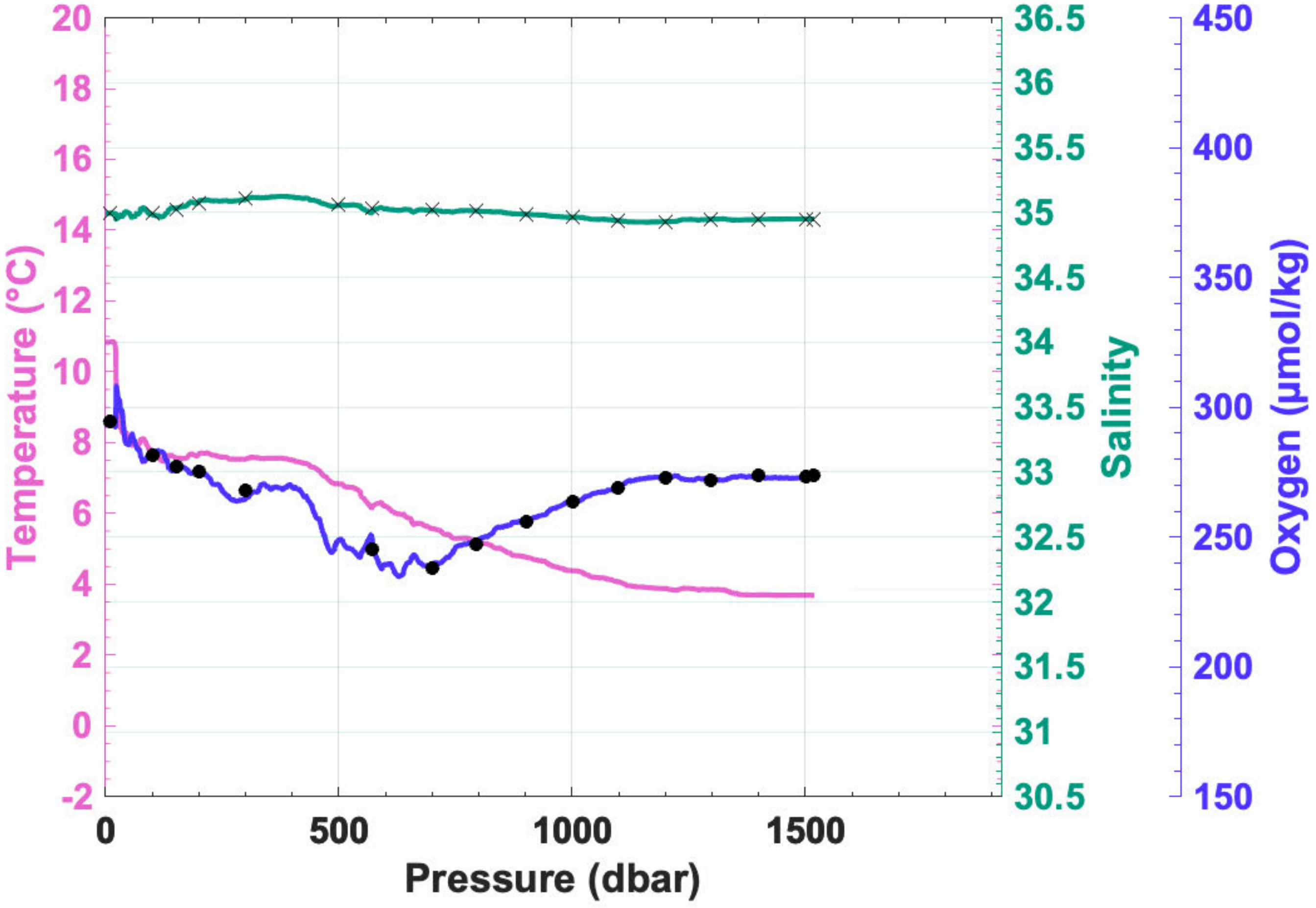

Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 67

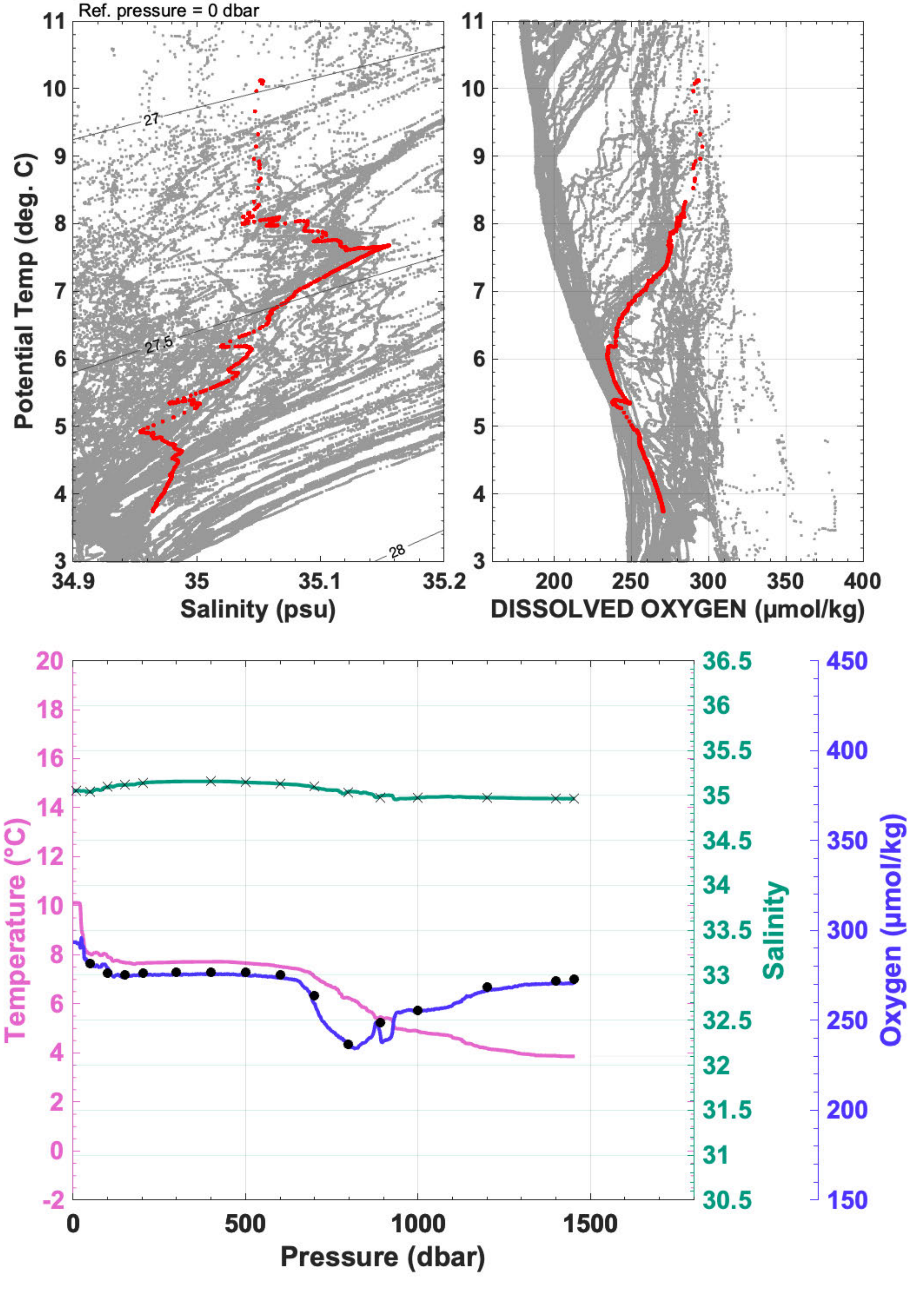


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
34.9
35
35.1
35.2
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400



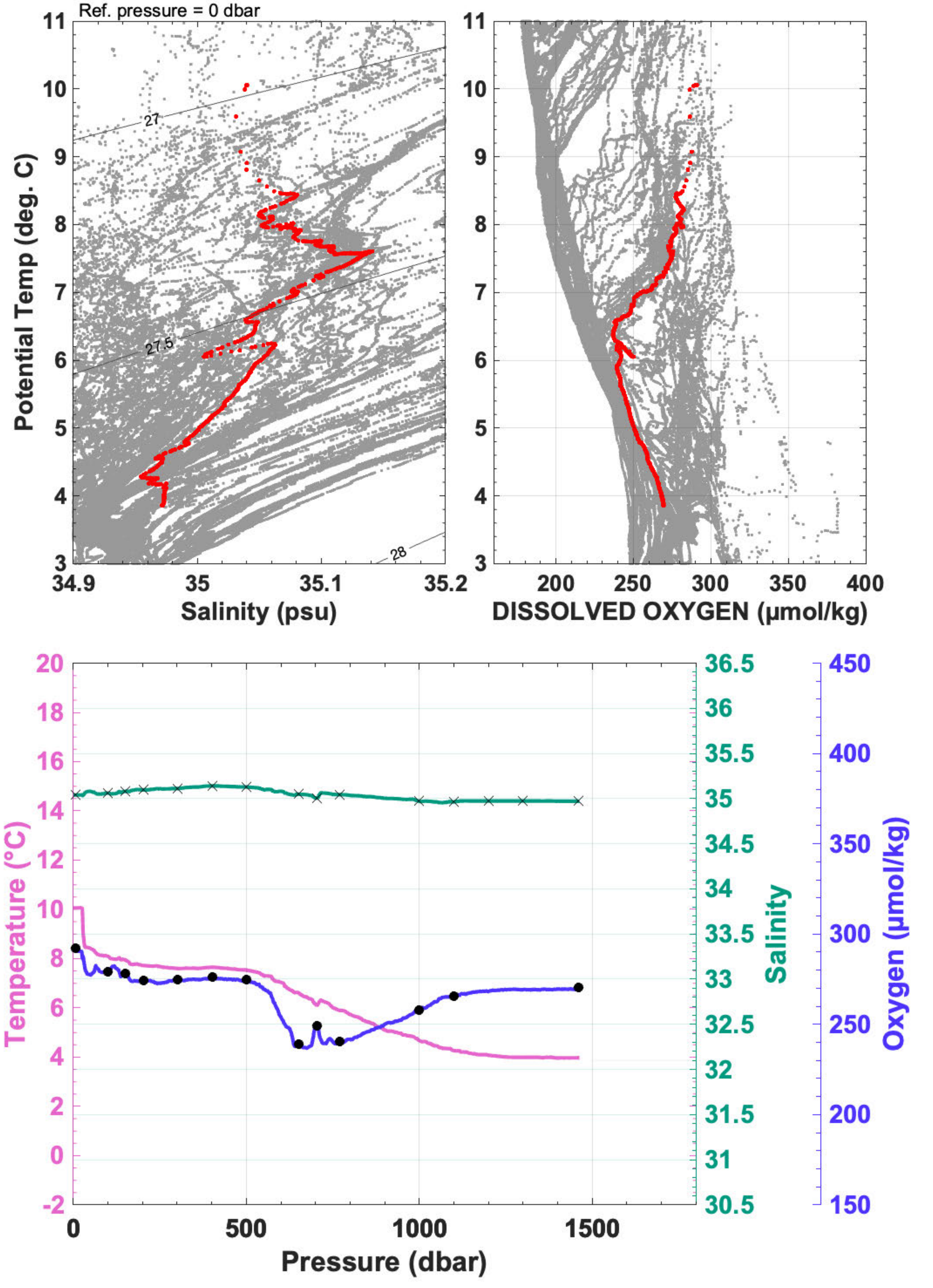
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
500
1000
1500

STATION 68

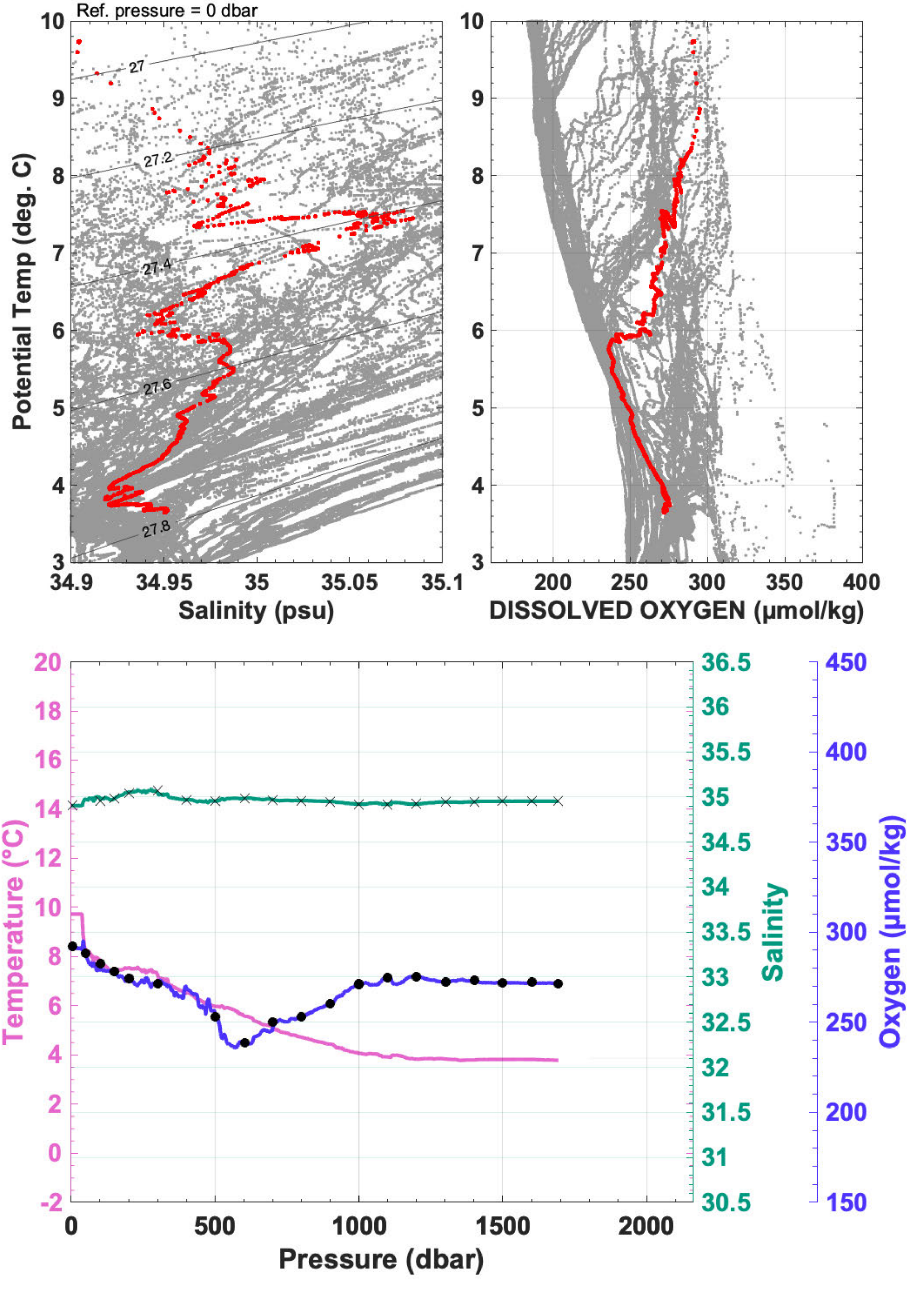


Ref. pressure = 0 dbar
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 69

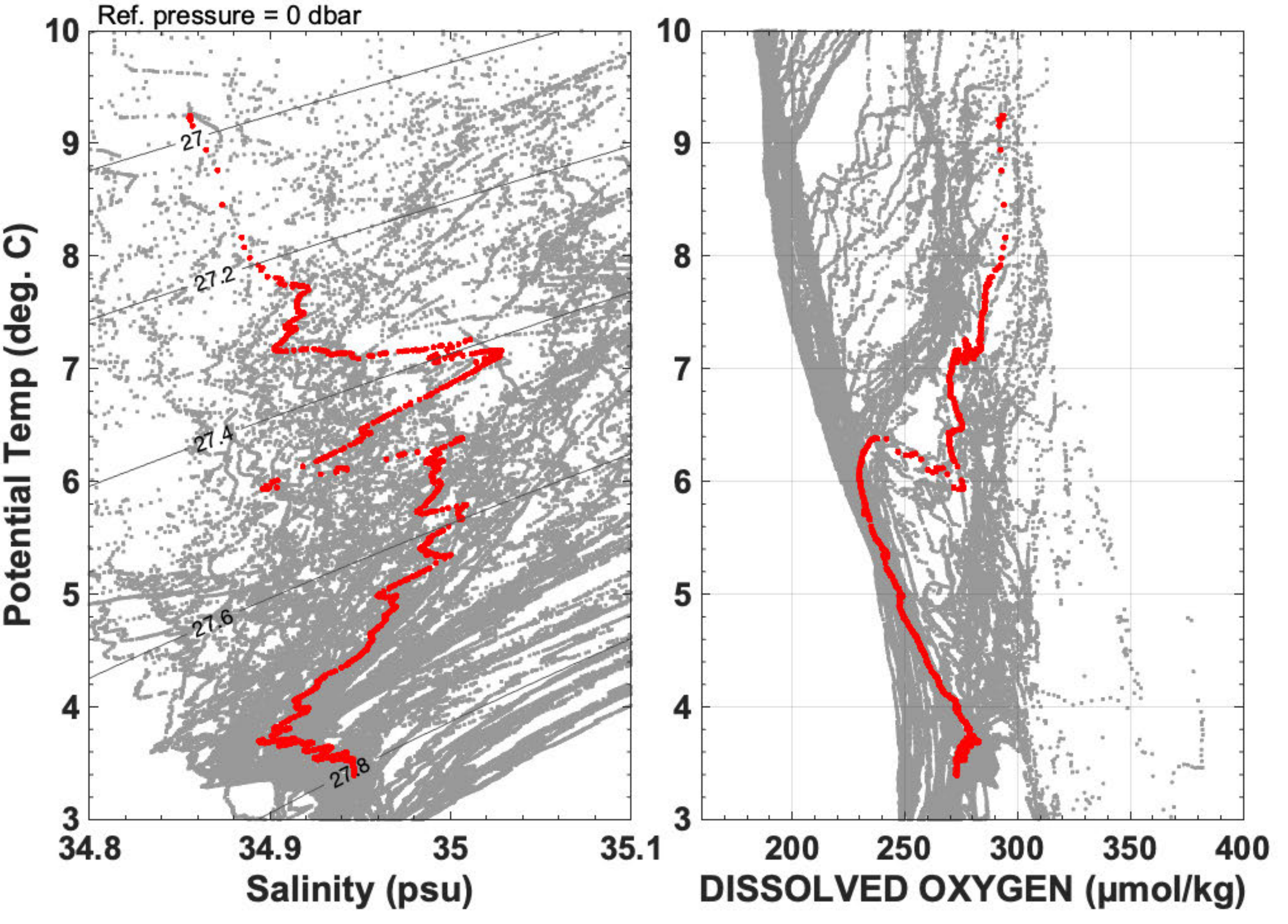

Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 70

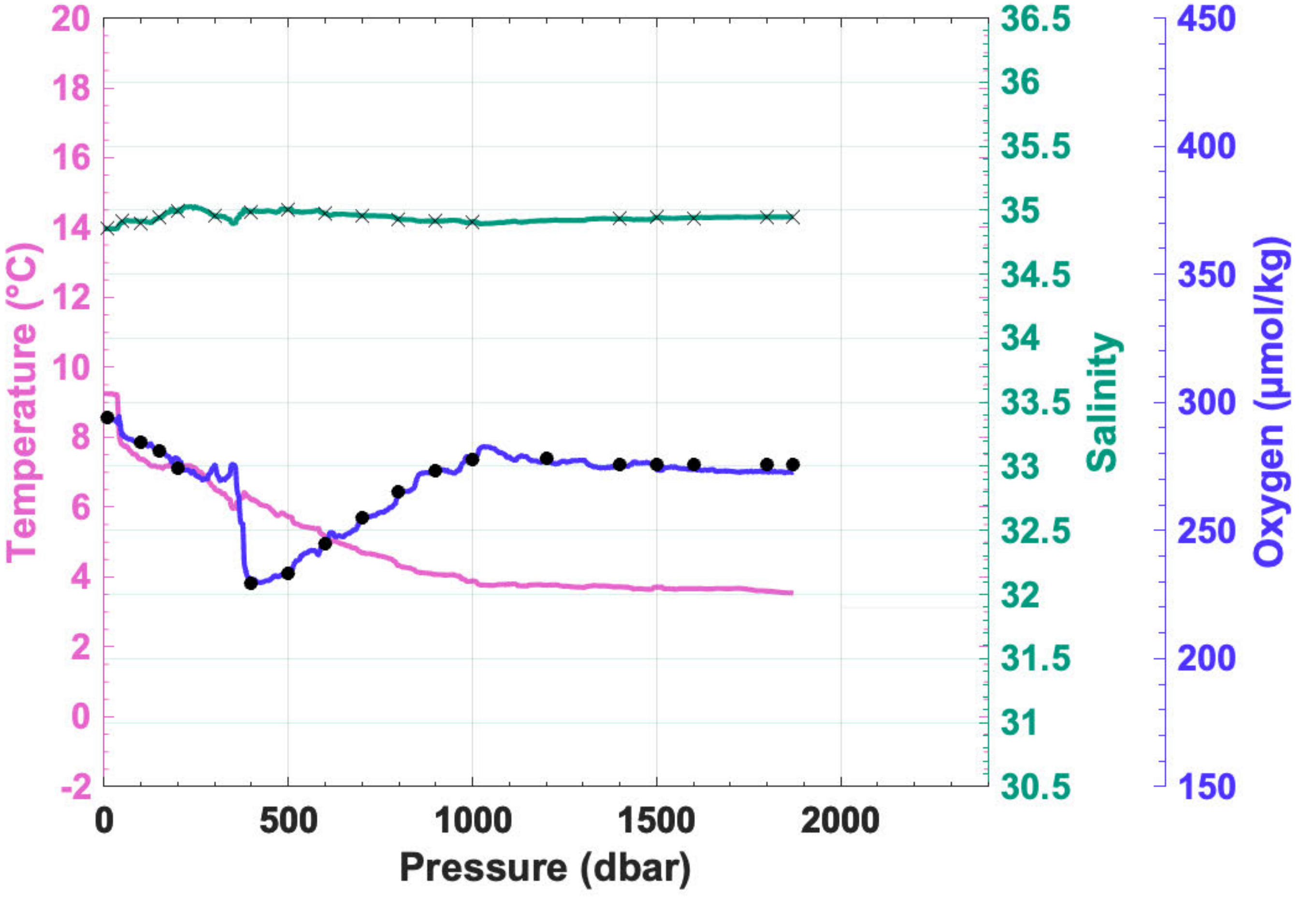


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
27.8
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 71

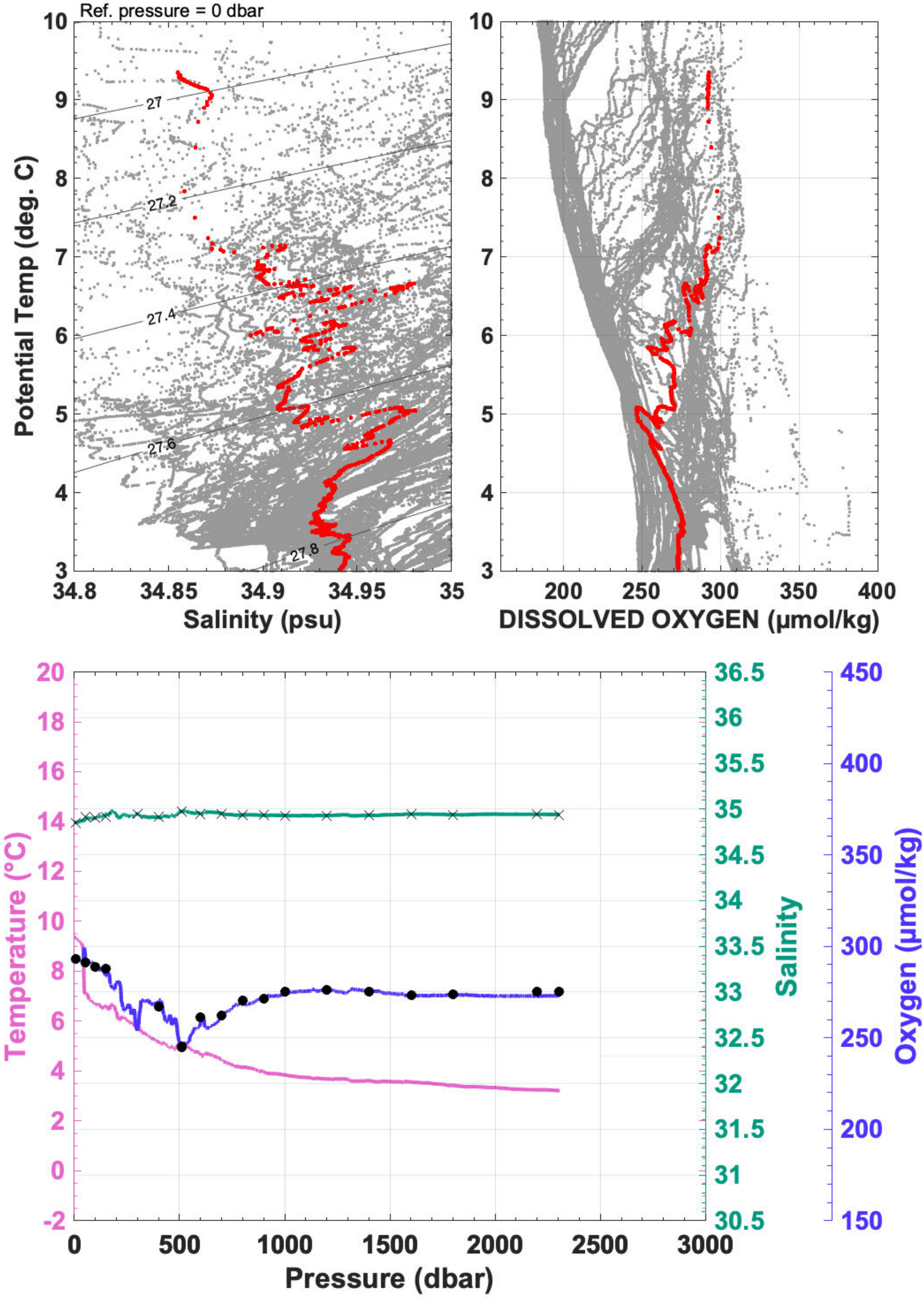


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27.
27.2
27.4
27.6
27.8
10
9
8
7
6
5
4
3
34.8
34.9
35
35.1
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400

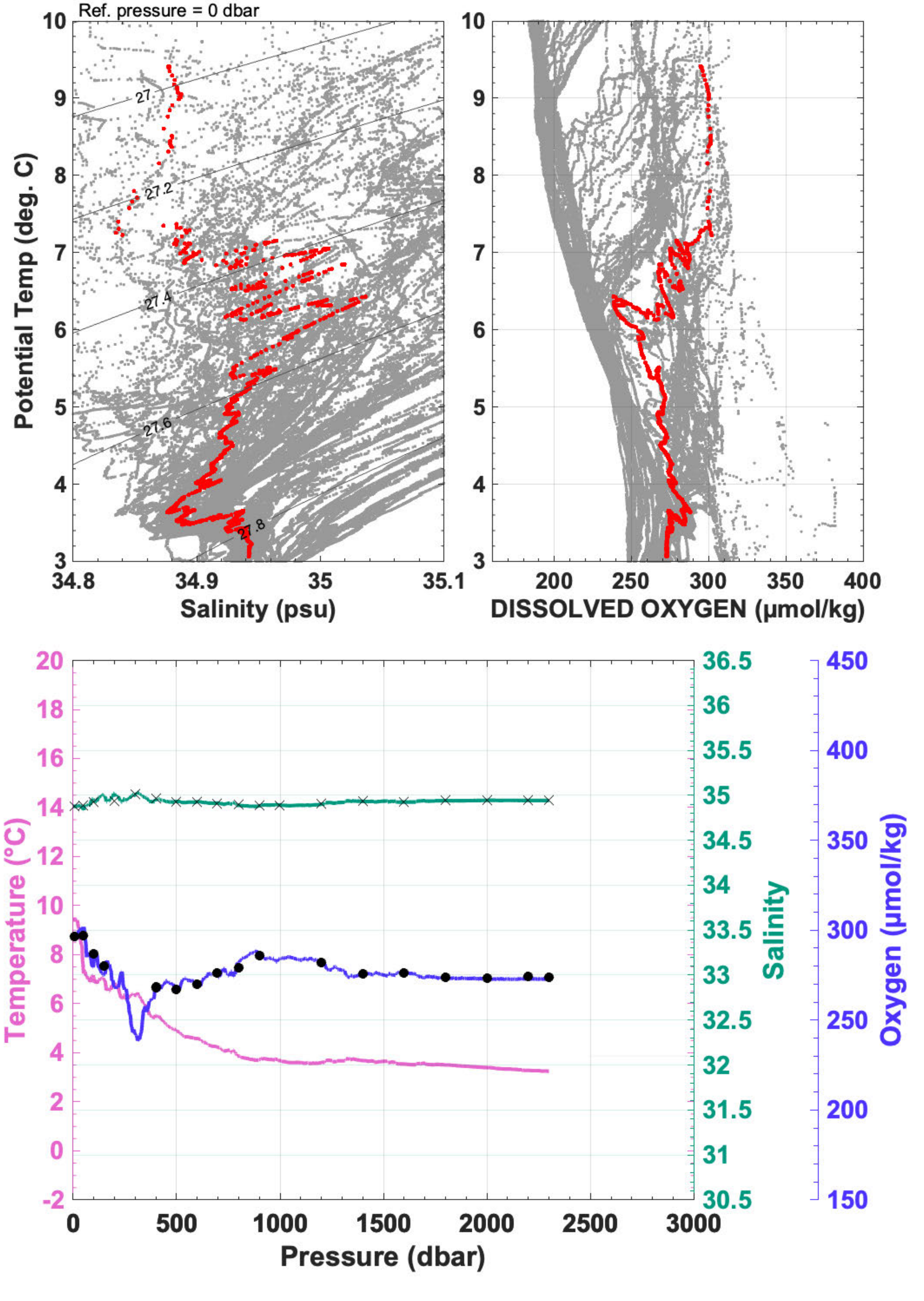


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
20
18
16
14
12
10
8
6
4
2
0
-2
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
450
400
350
300
250
200
150
0
500
1000
1500
2000

STATION 72

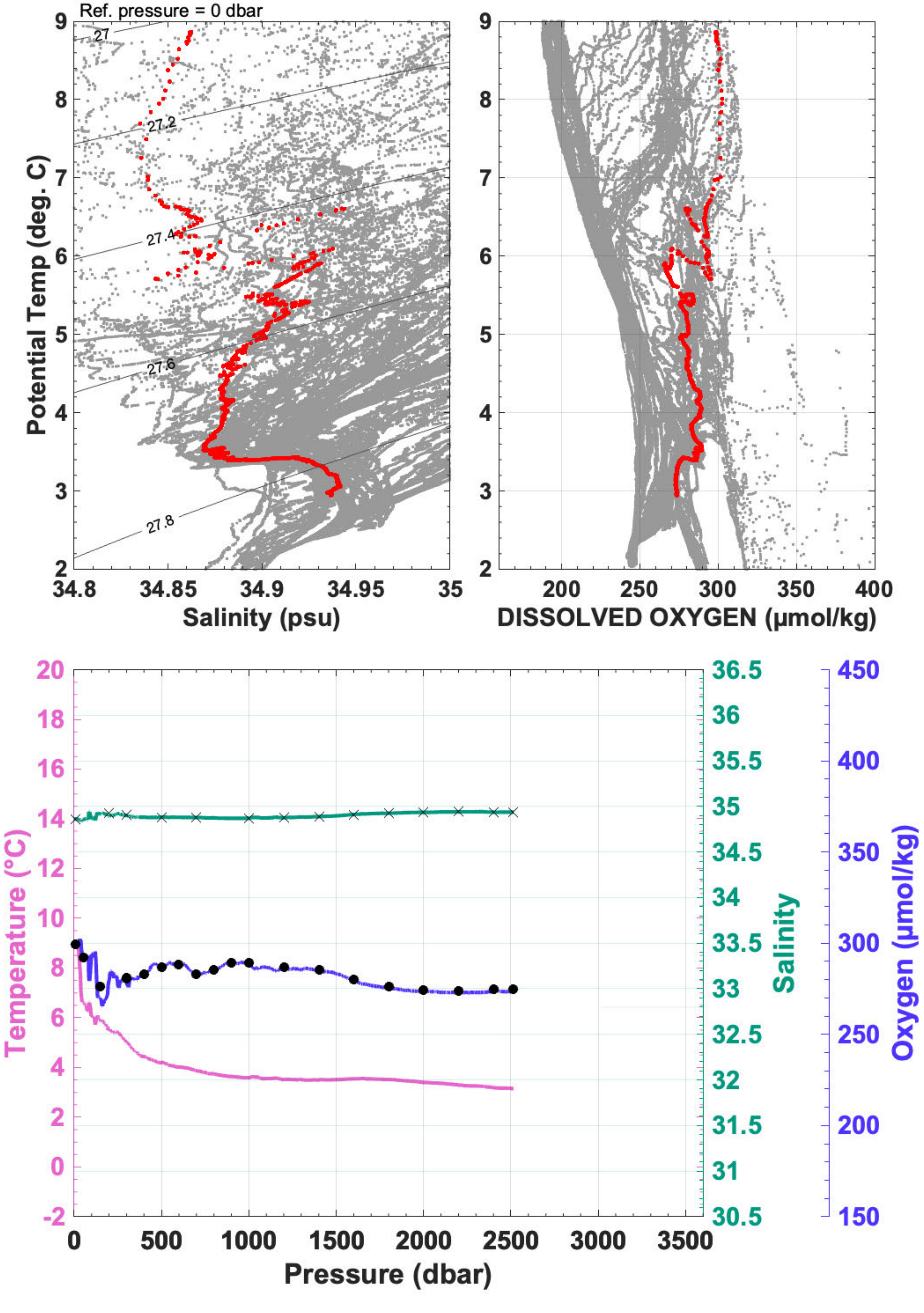

Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
27.8
34.8
34.85
34.9
34.95
35
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
500
1000
1500
2000
2500
3000

STATION 73



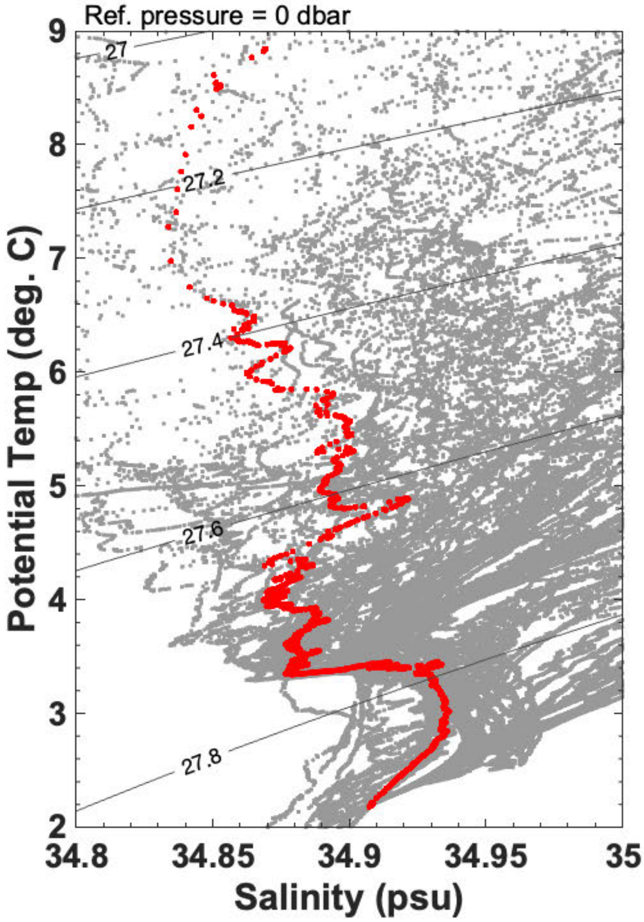
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
27.8
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 74

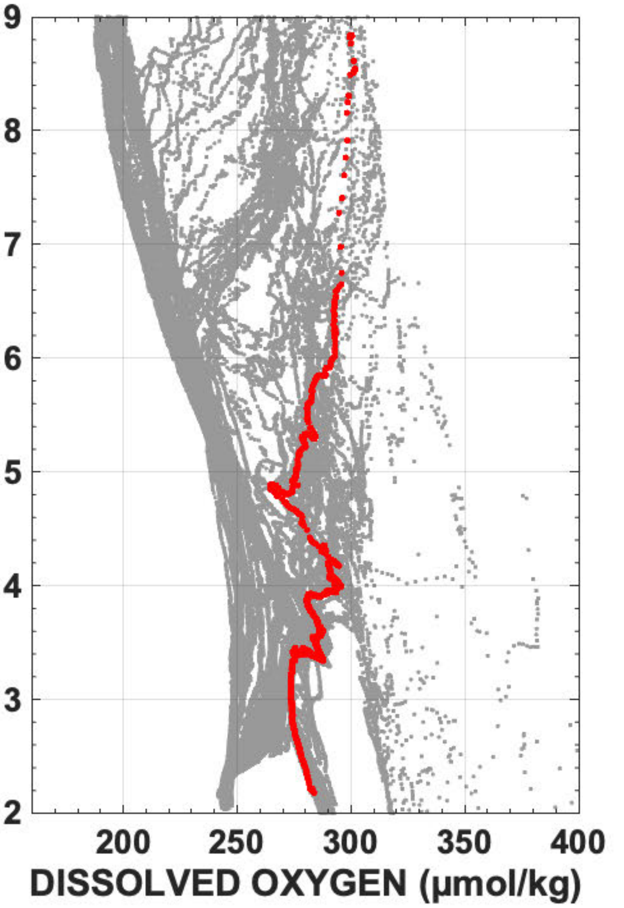


Ref. pressure = 0 dbar
27
27.2
27.4
27.6
27.8
Potential Temp (deg. C)
Salinity (psu)
34.8
34.85
34.9
34.95
35
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
500
1000
1500
2000
2500
3000
3500

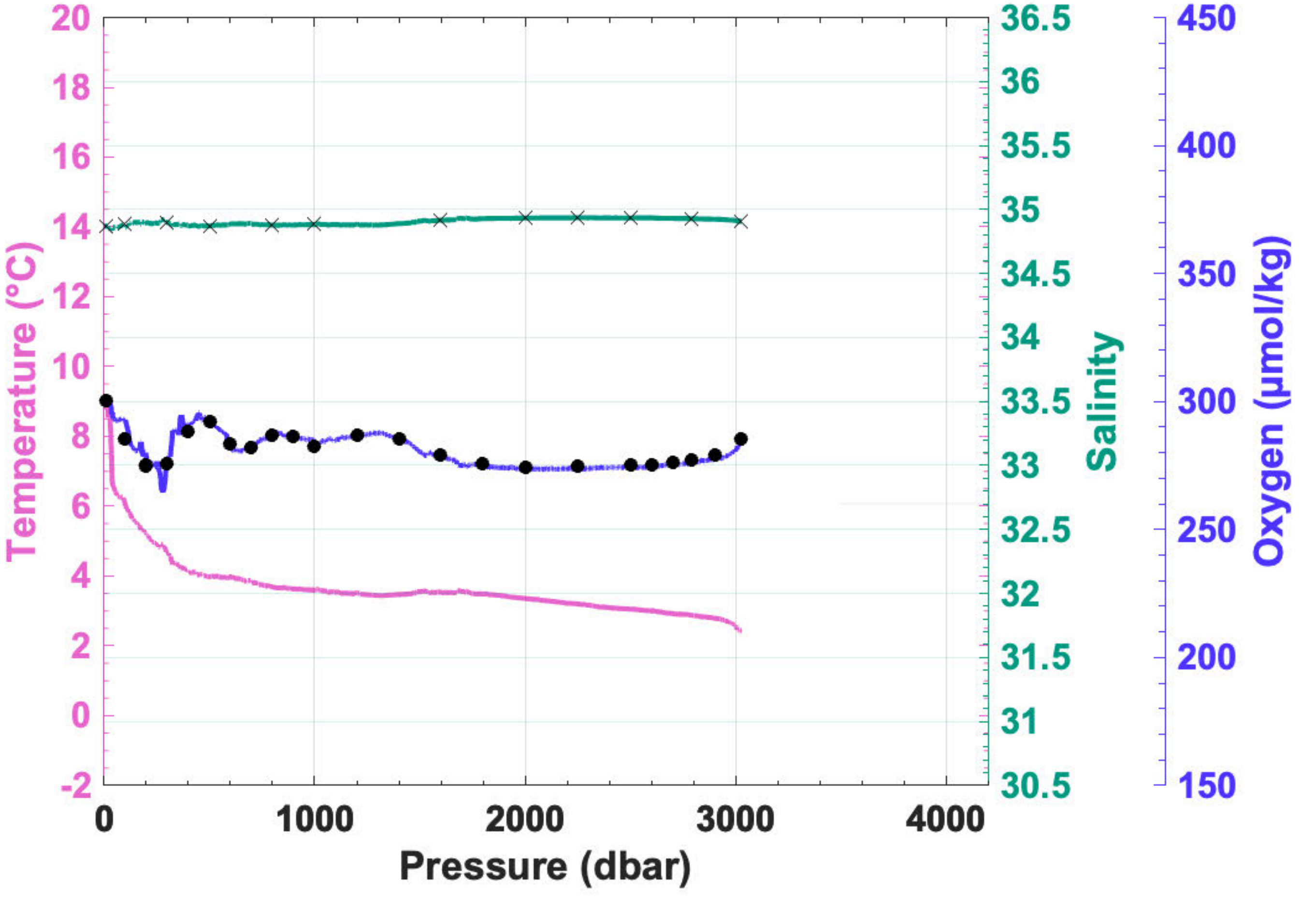
STATION 75



Ref. pressure = 0 dbar
27
27.2
27.4
27.6
27.8
9
8
7
6
5
4
3
2
Potential Temp (deg. C)
34.8
34.85
34.9
34.95
35
Salinity (psu)

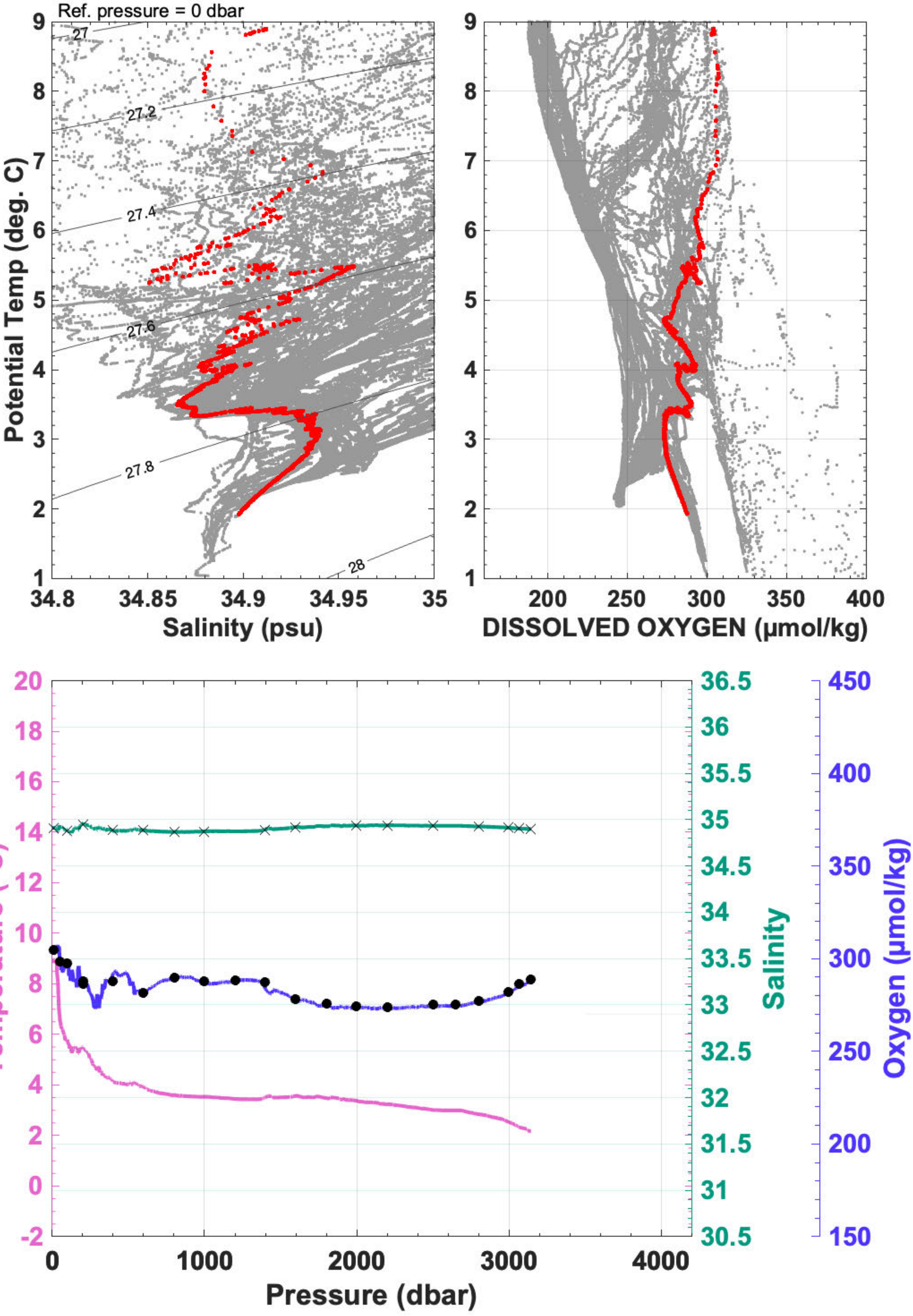


9
8
7
6
5
4
3
2
200
250
300
350
400
DISSOLVED OXYGEN (µmol/kg)



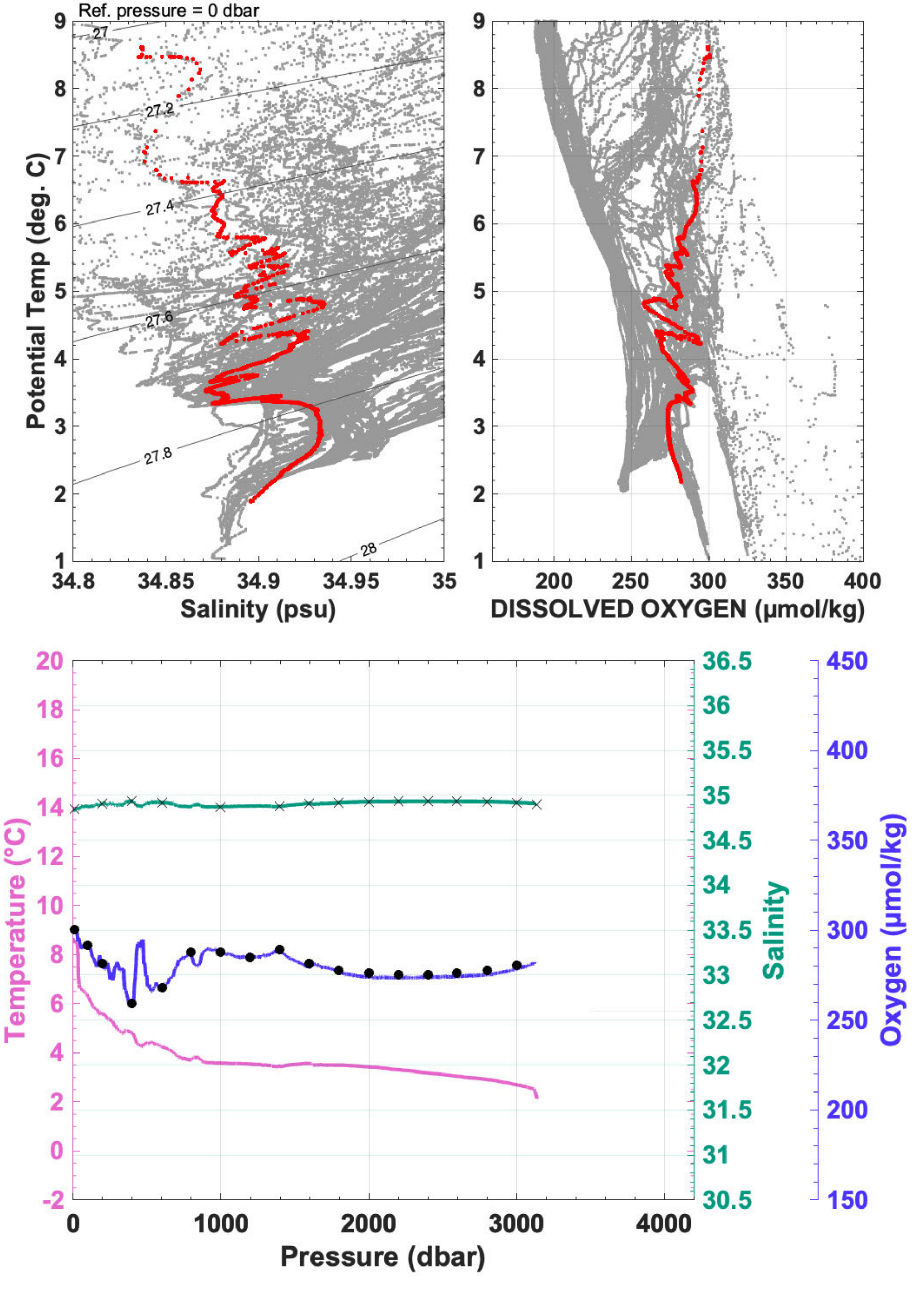
Temperature (°C)
20
18
16
14
12
10
8
6
4
2
0
-2
Salinity
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
Oxygen (µmol/kg)
450
400
350
300
250
200
150
0
1000
2000
3000
4000
Pressure (dbar)

STATION 76



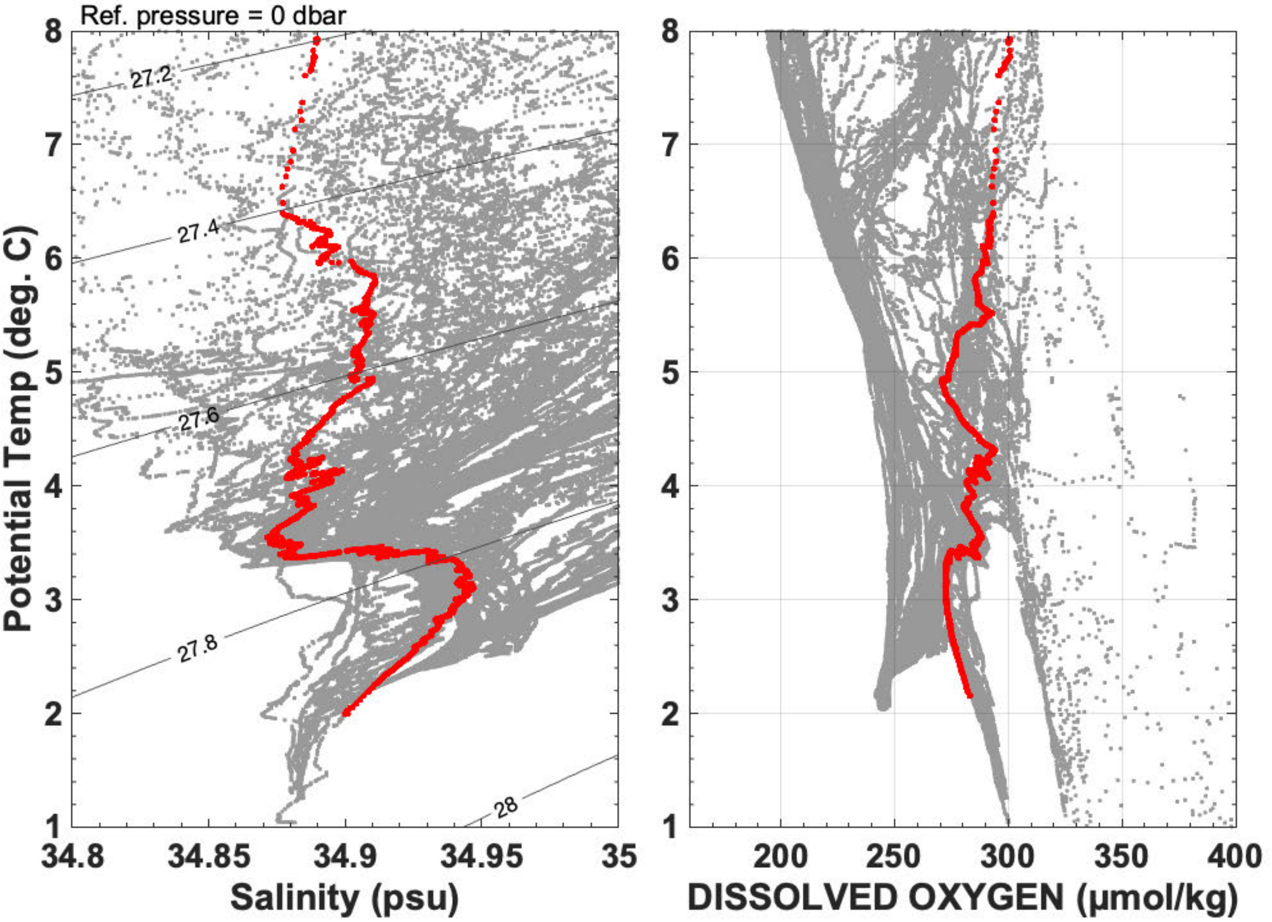
Ref. pressure = 0 dbar
27
27.2
27.4
27.6
27.8
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 77

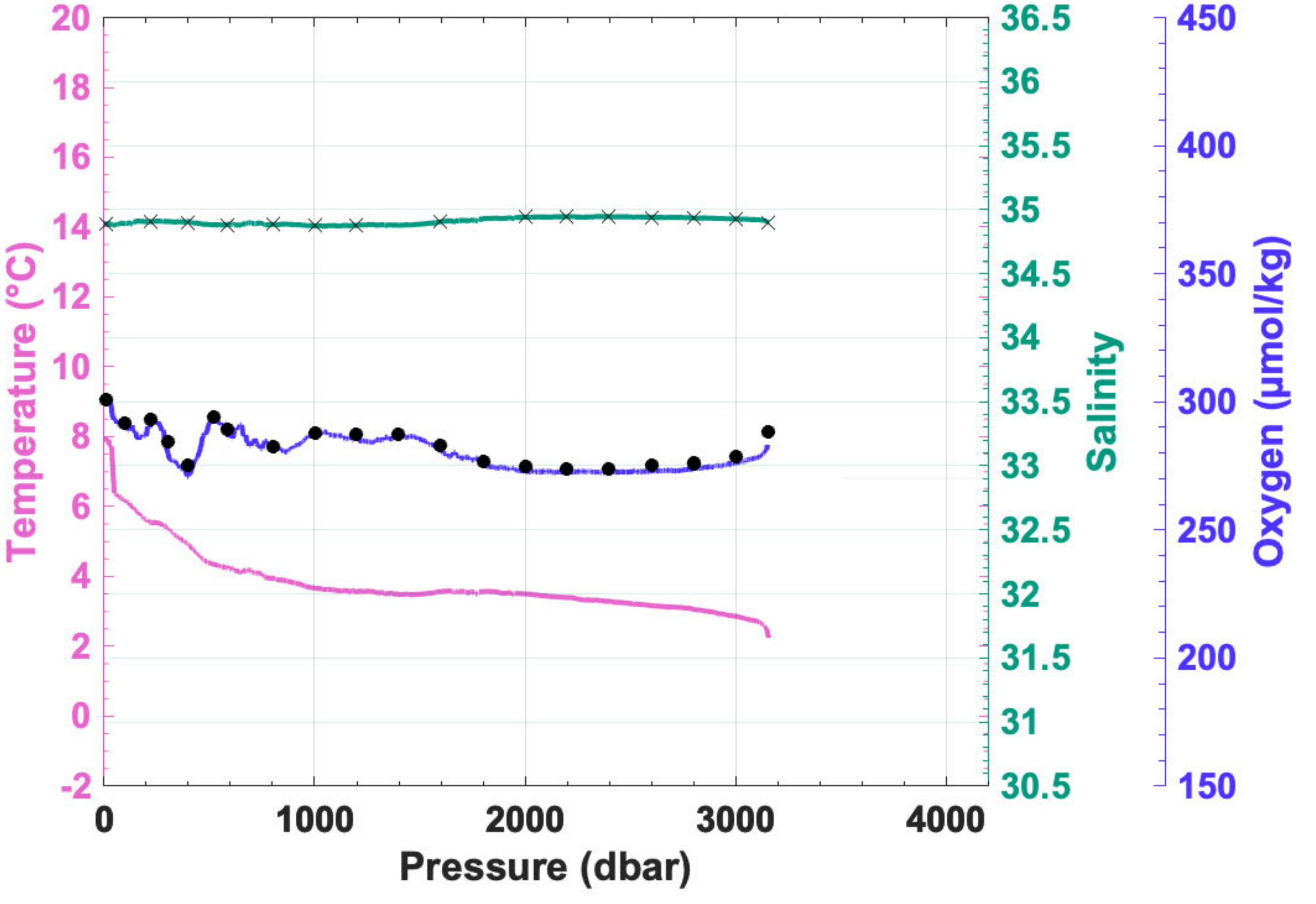


Ref. pressure = 0 dbar
27
27.2
27.4
27.6
27.8
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 78

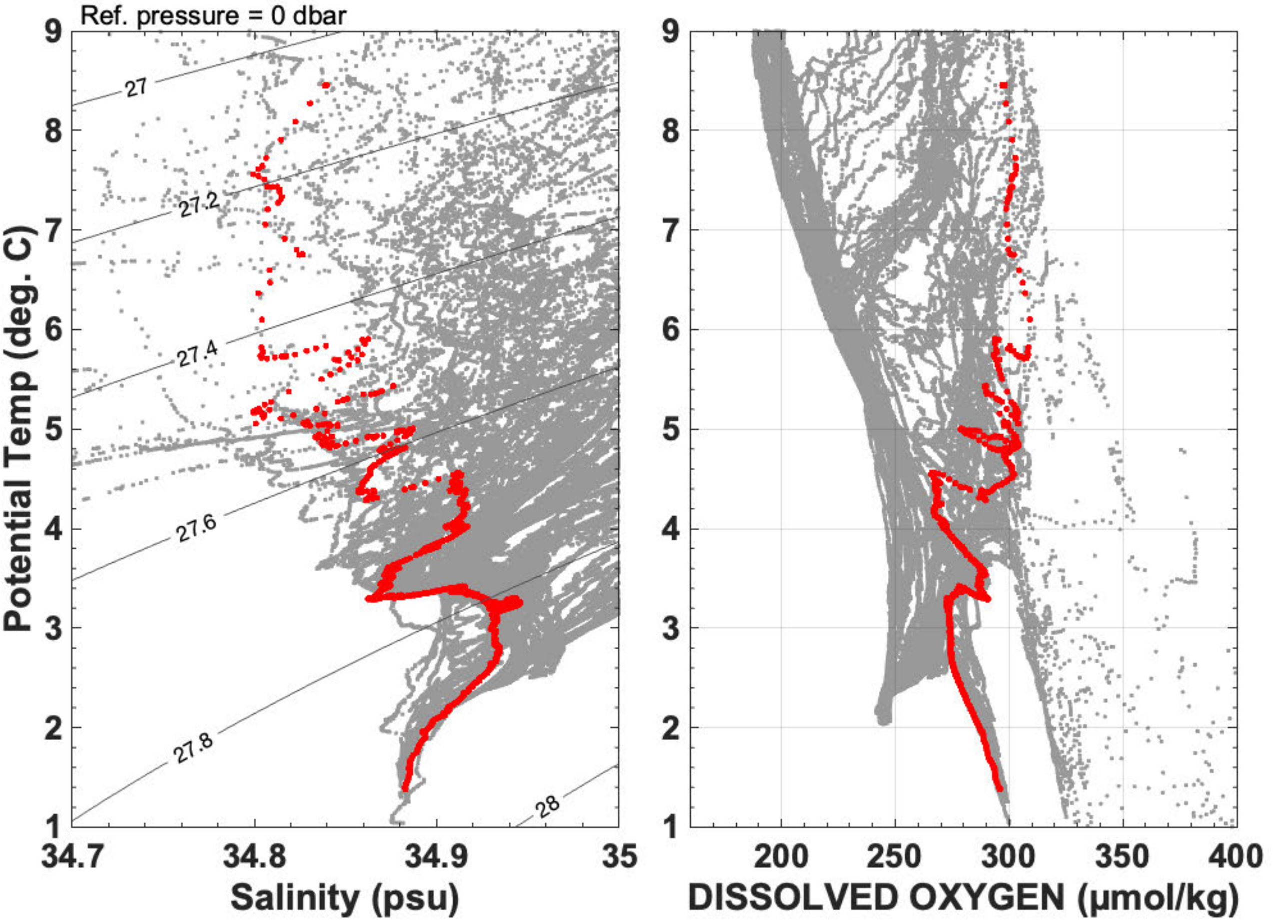


Ref. pressure = 0 dbar
27.2
27.4
27.6
27.8
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)

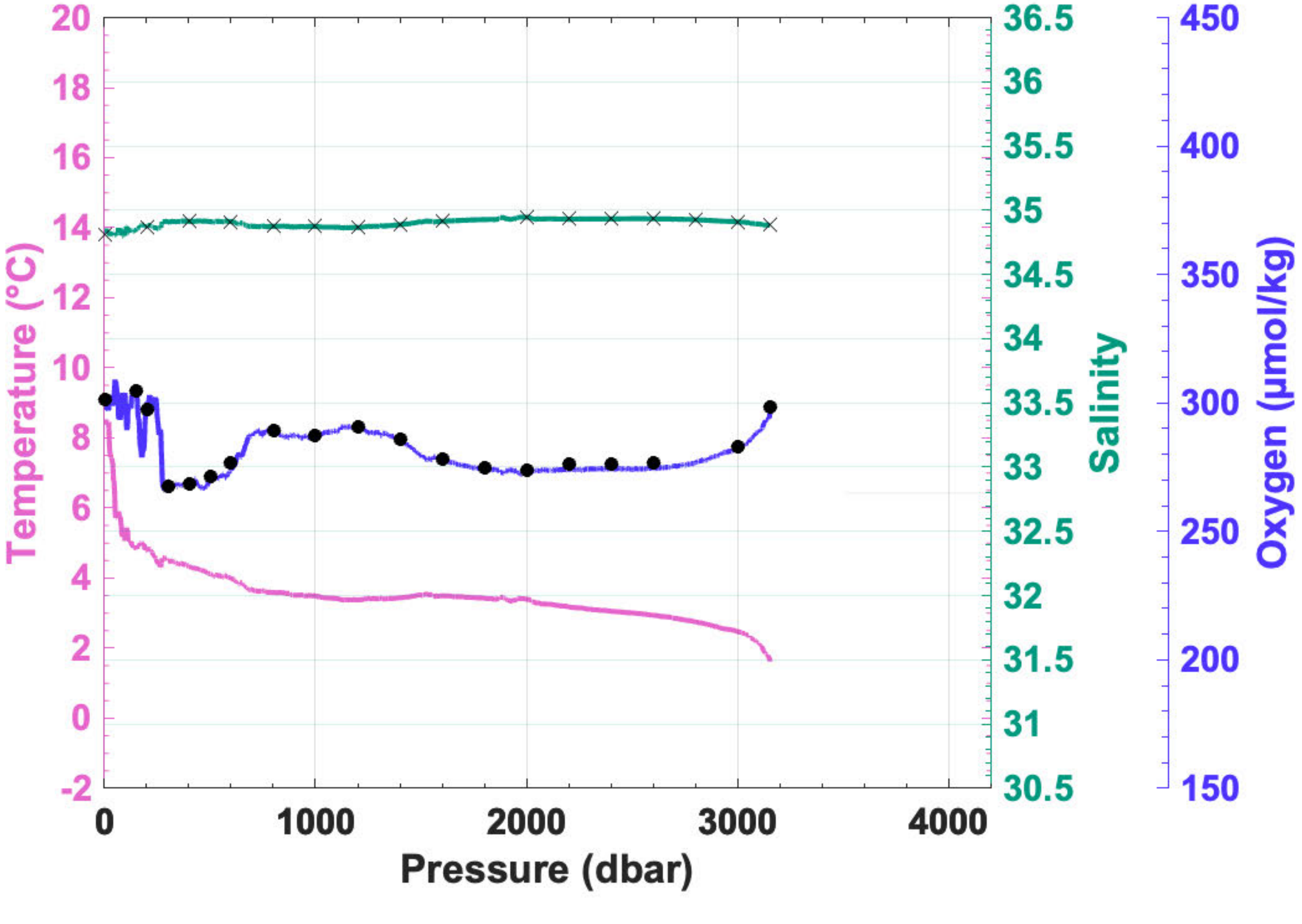


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 79

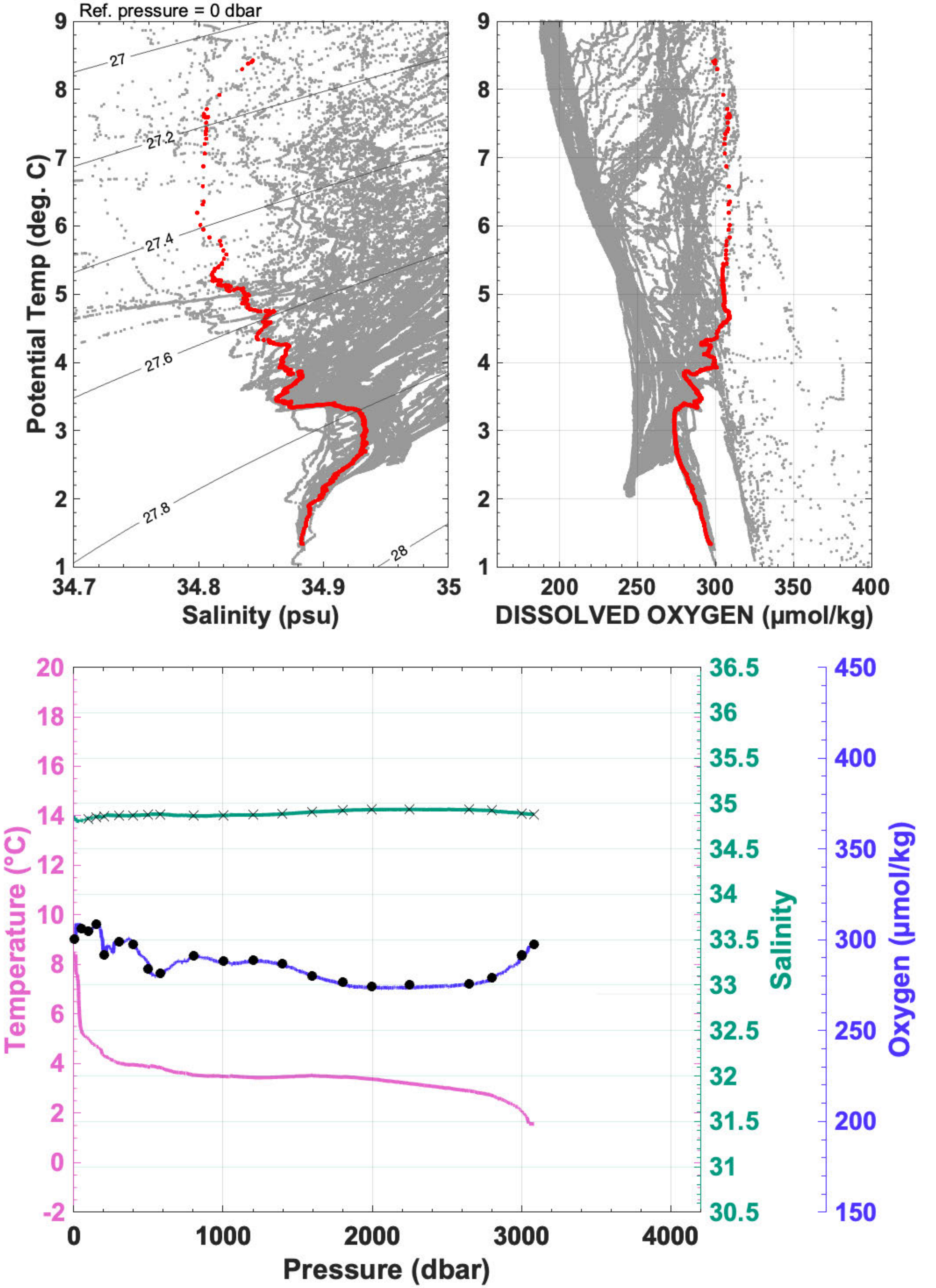


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
27.8
28
DISSOLVED OXYGEN (µmol/kg)



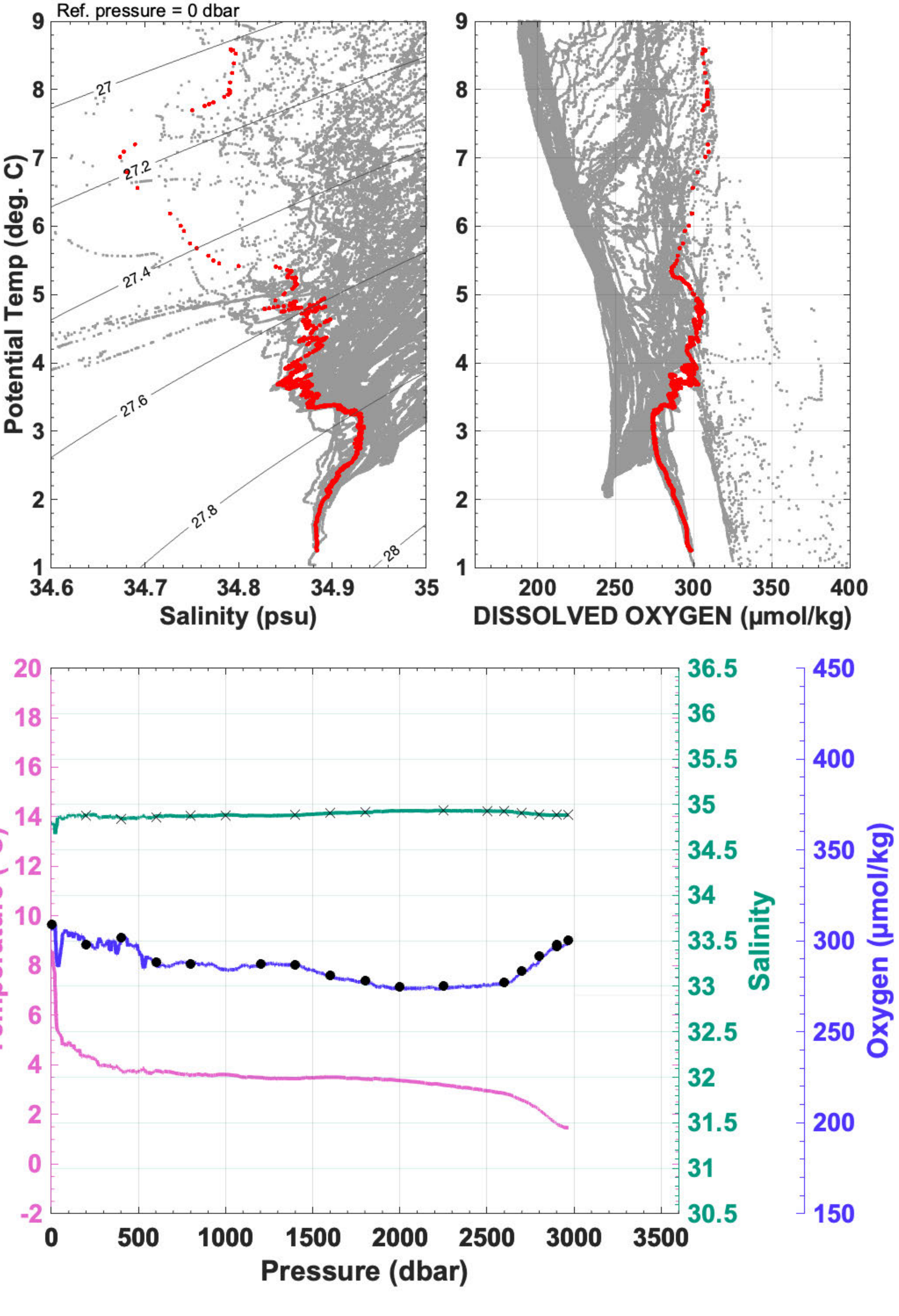
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 80



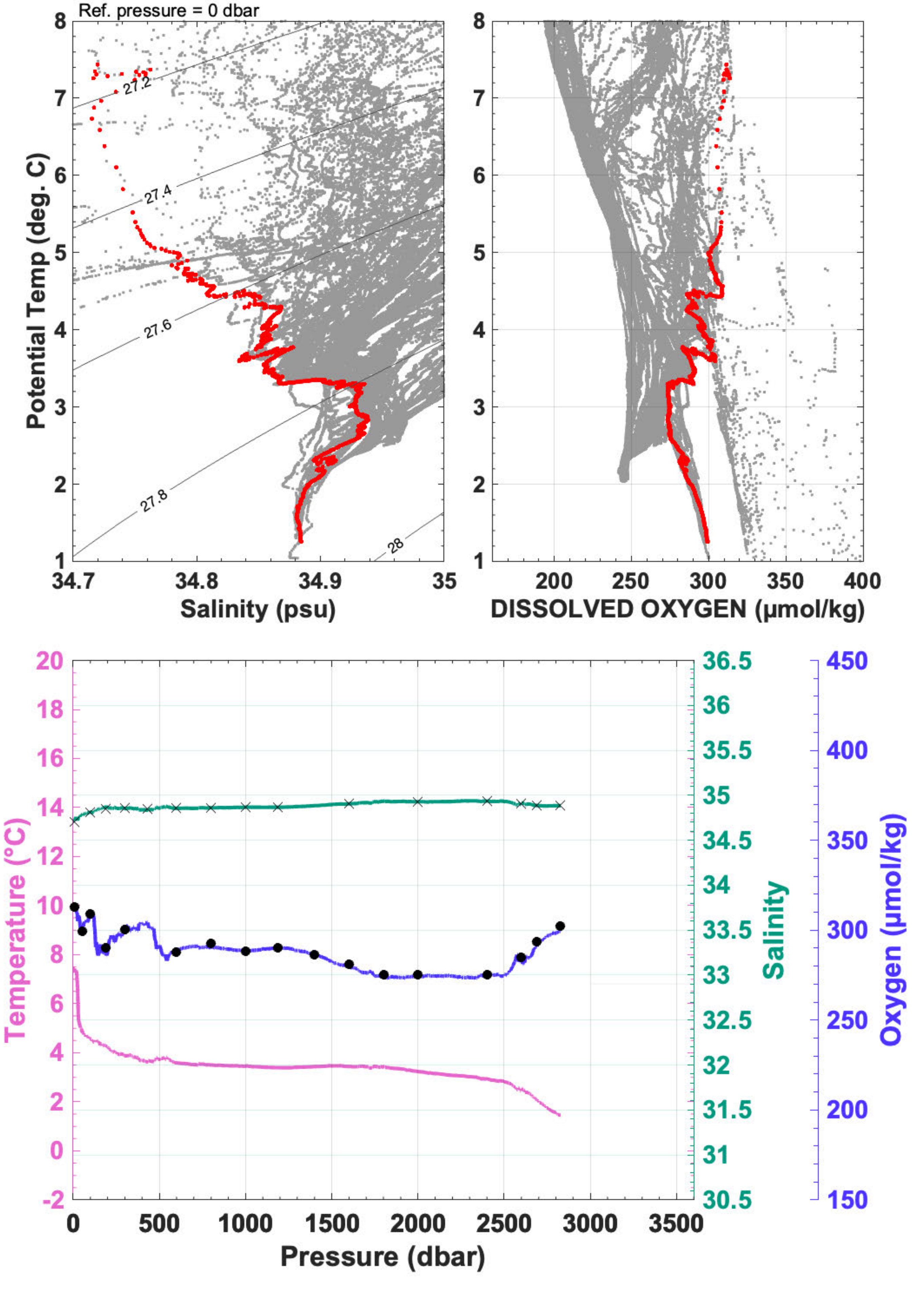
Ref. pressure = 0 dbar
27
27.2
27.4
27.6
27.8
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 81



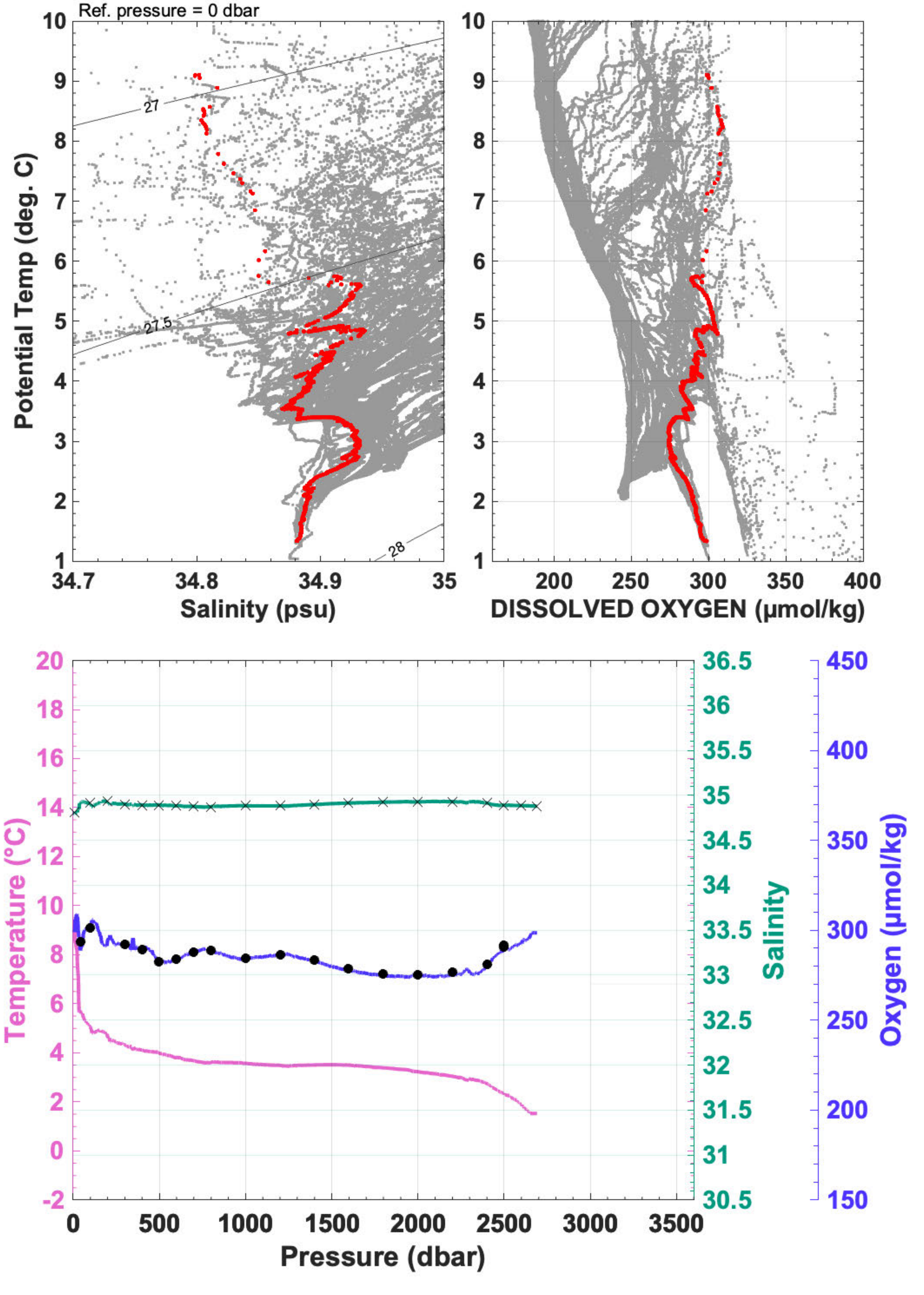
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
27
27.2
27.4
27.6
27.8
28
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 82



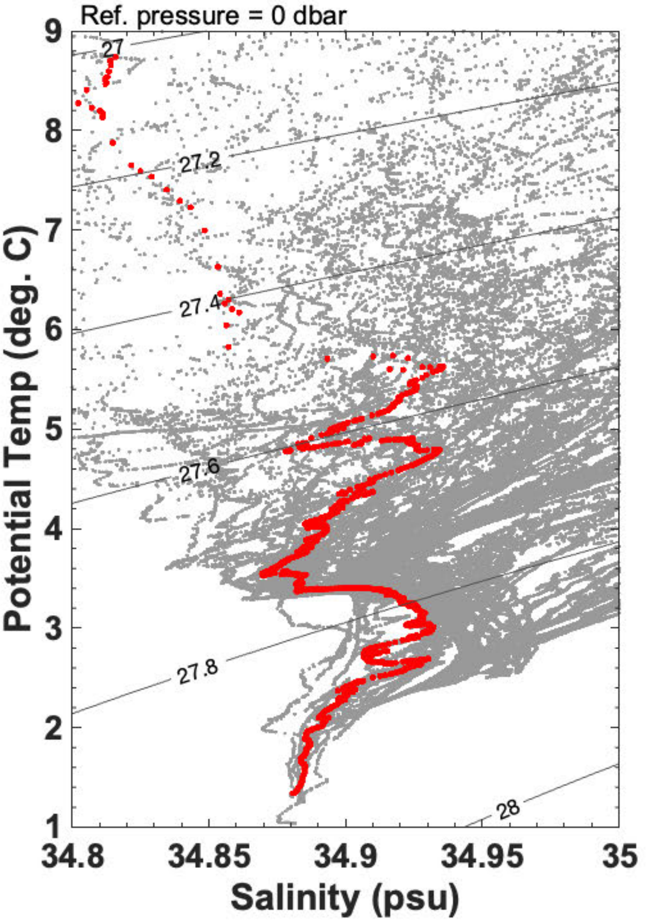
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27.2
27.4
27.6
27.8
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

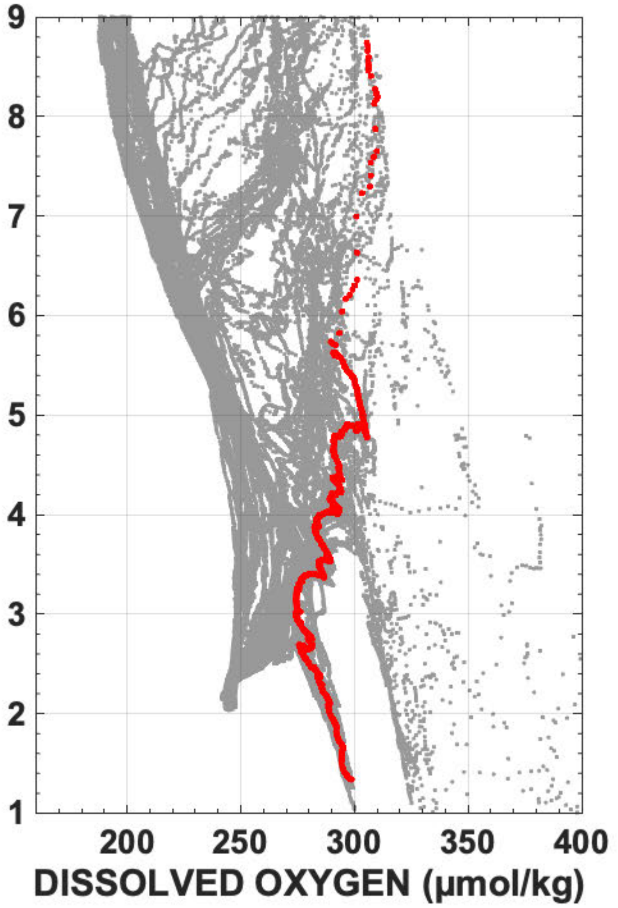
STATION 83

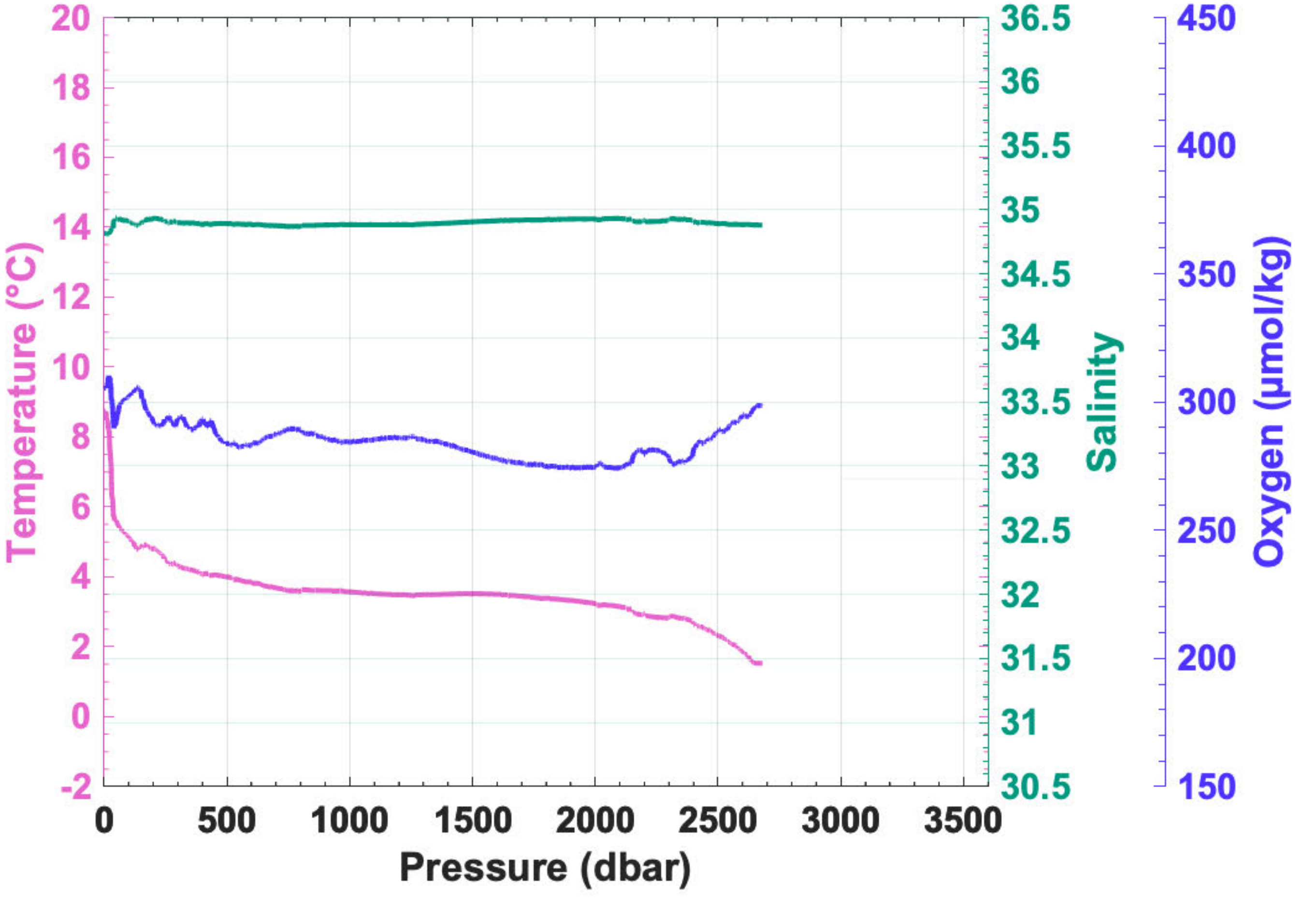


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

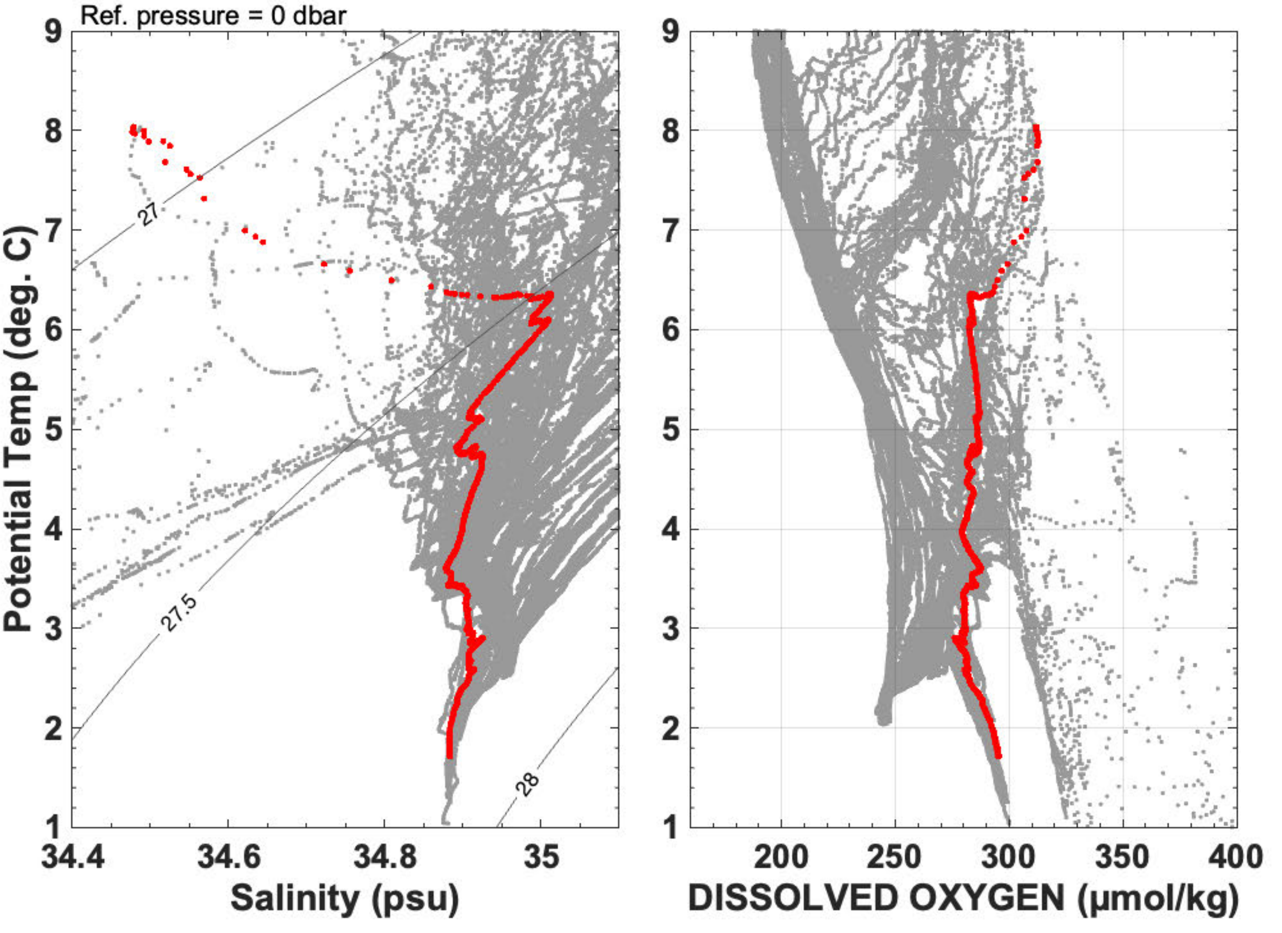
STATION 83 CAST 2



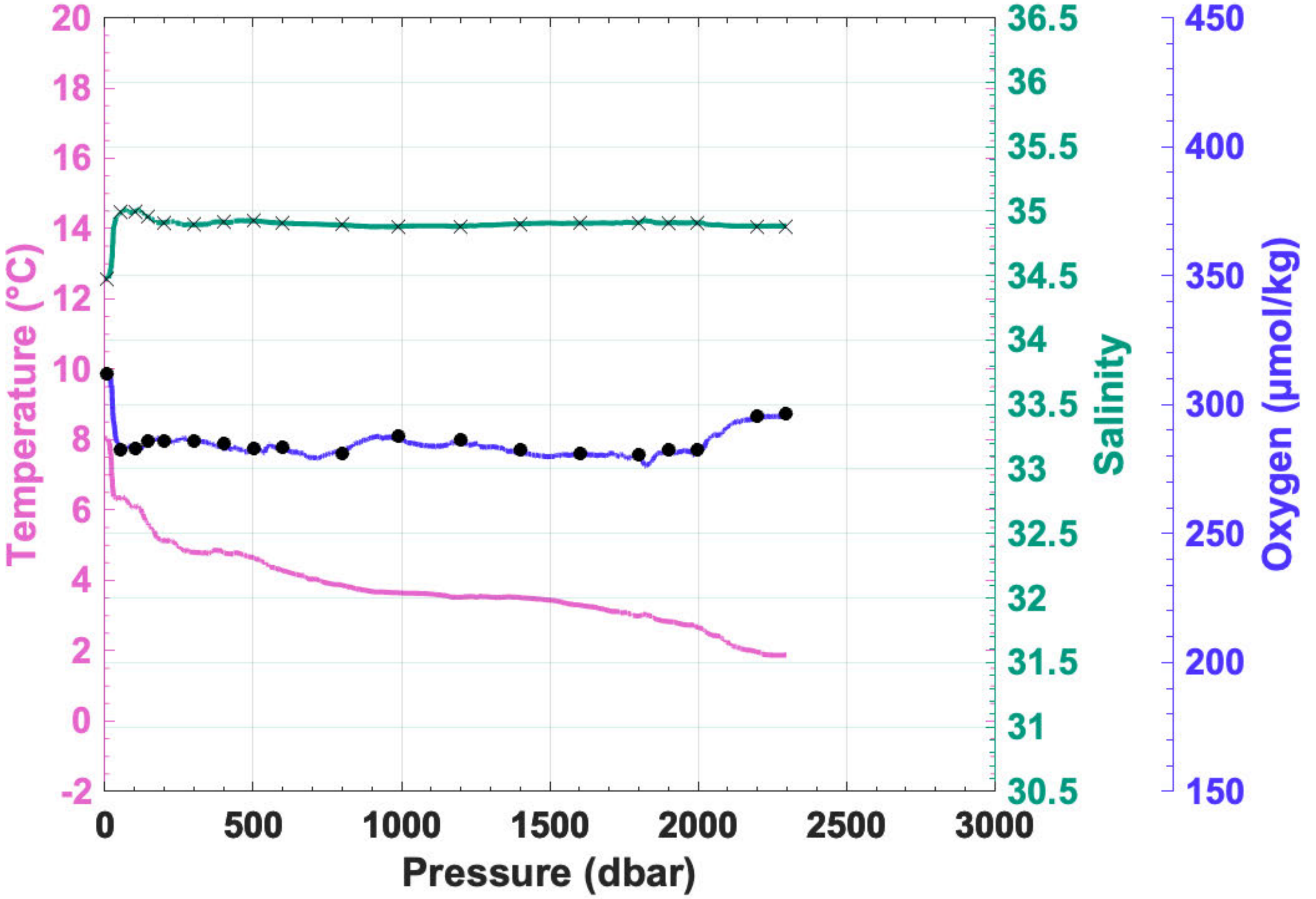




STATION 84

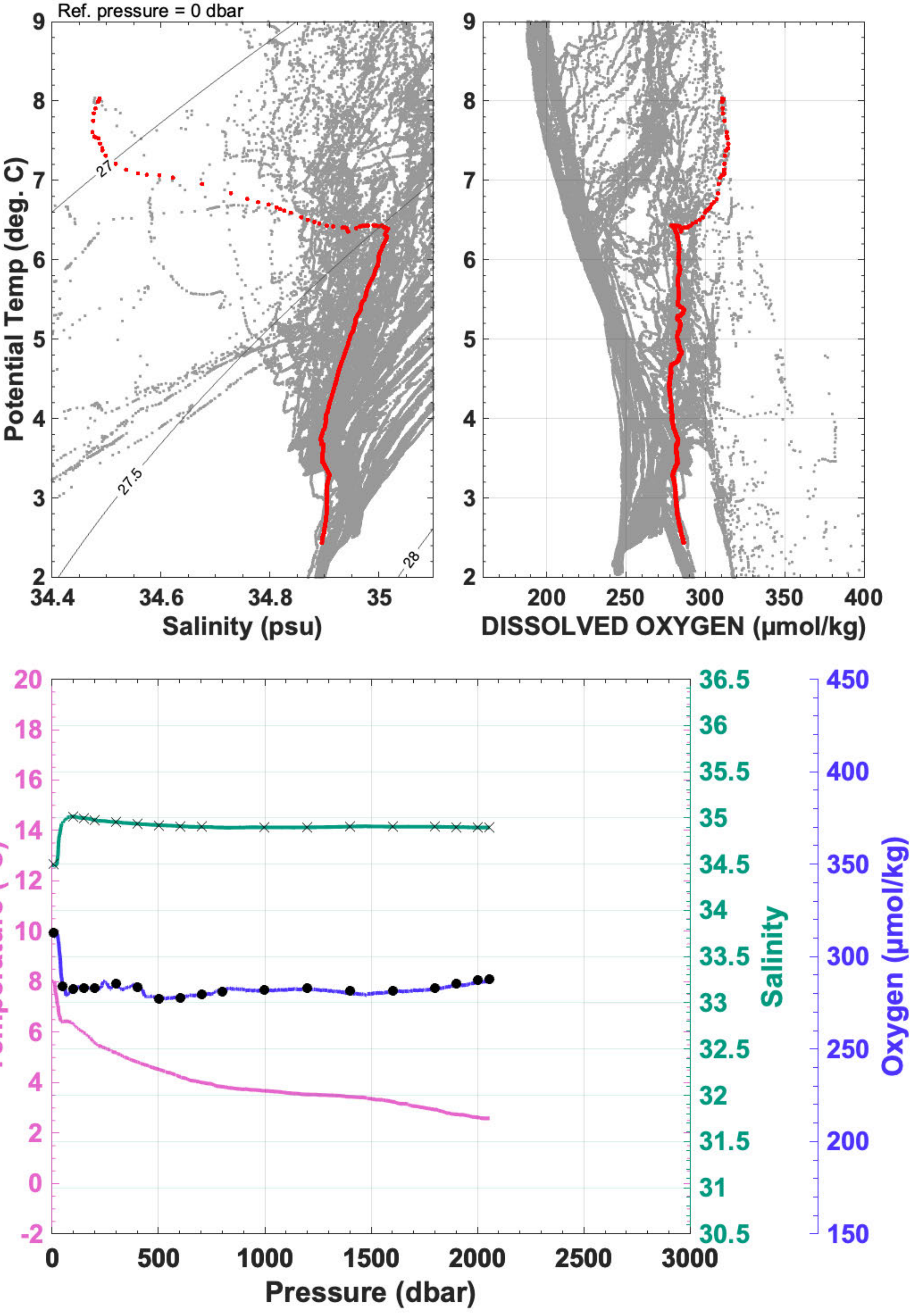


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)

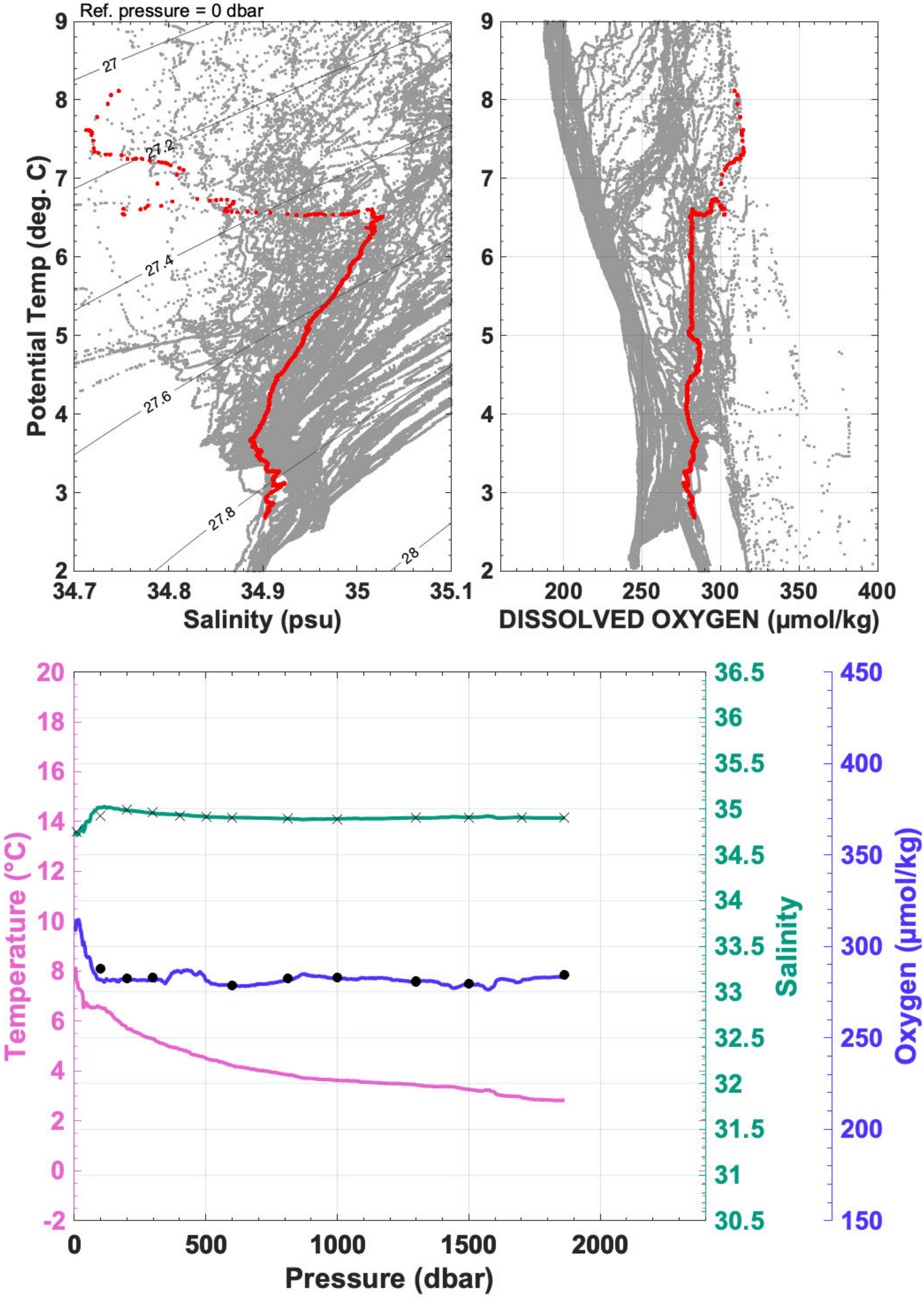


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 85

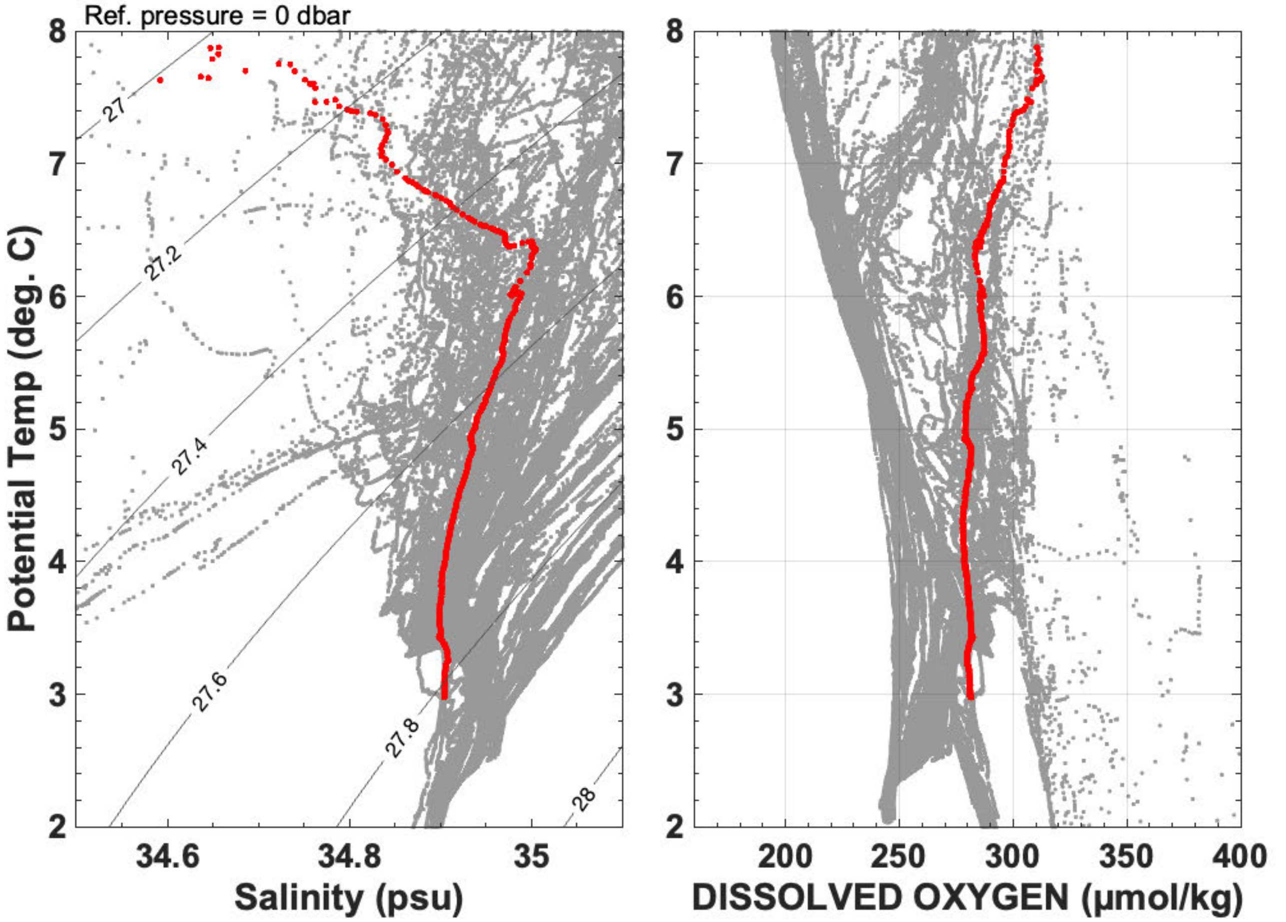

Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 86

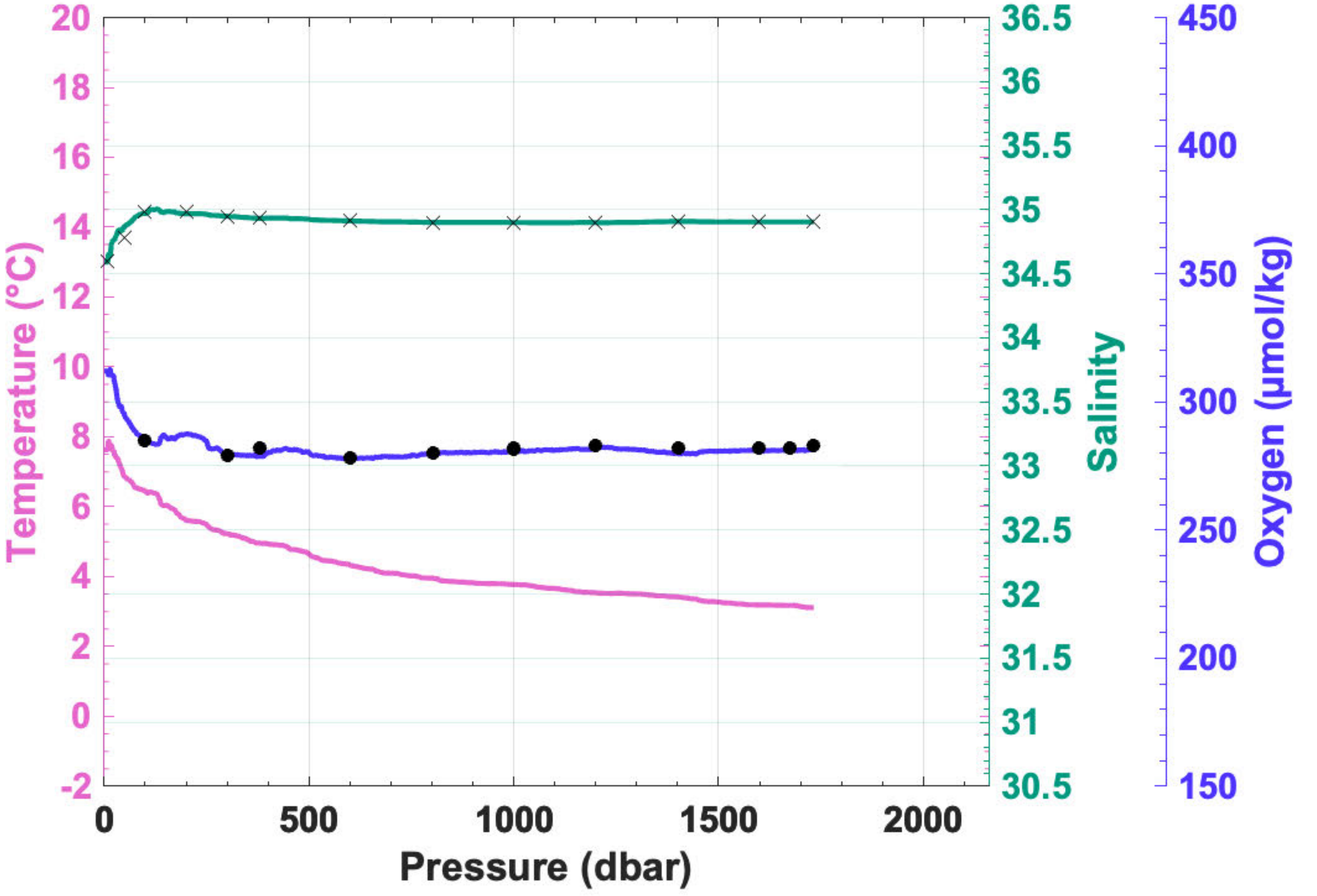


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
27.8
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 87

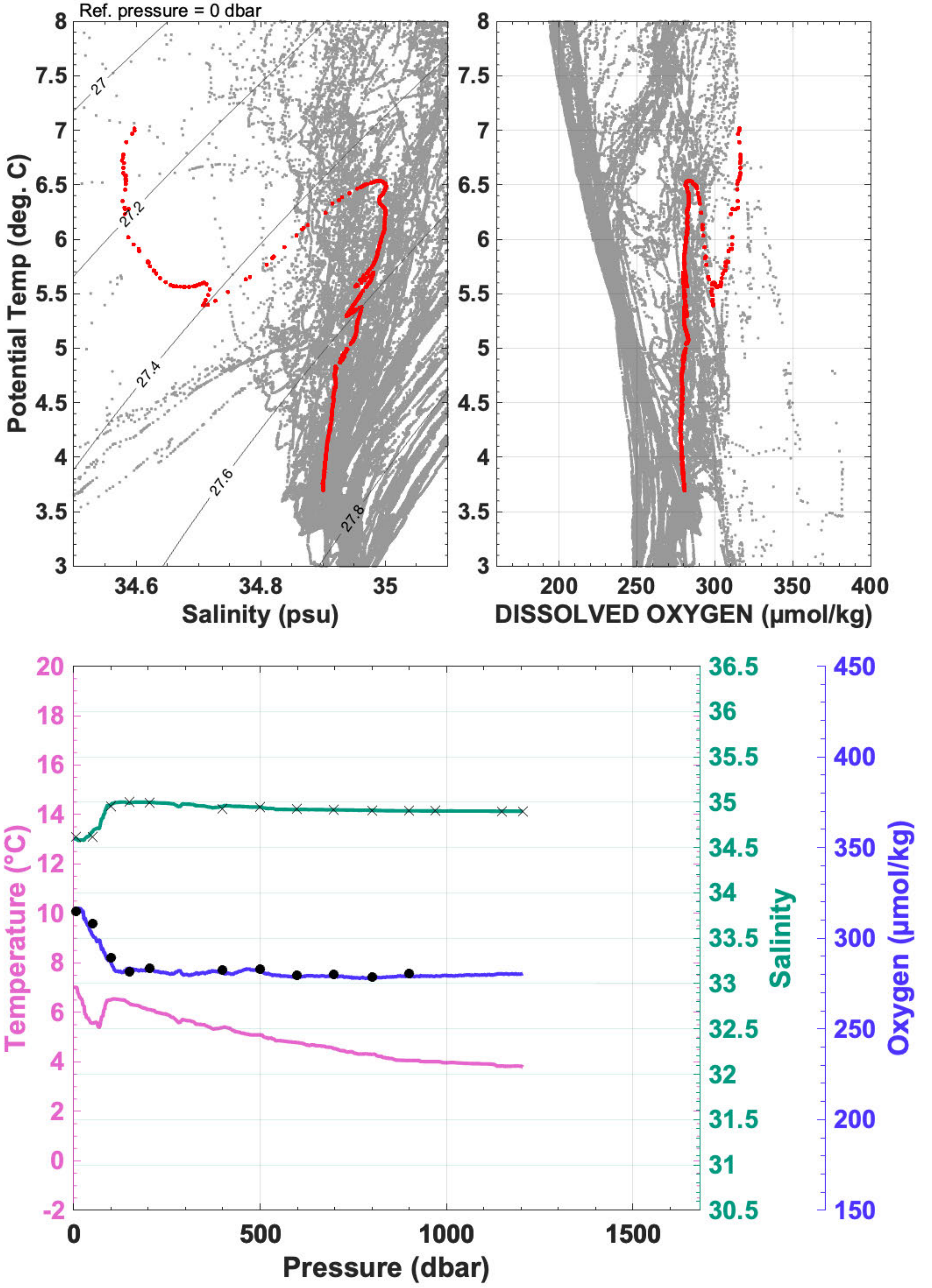


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
27.8
28
DISSOLVED OXYGEN (µmol/kg)



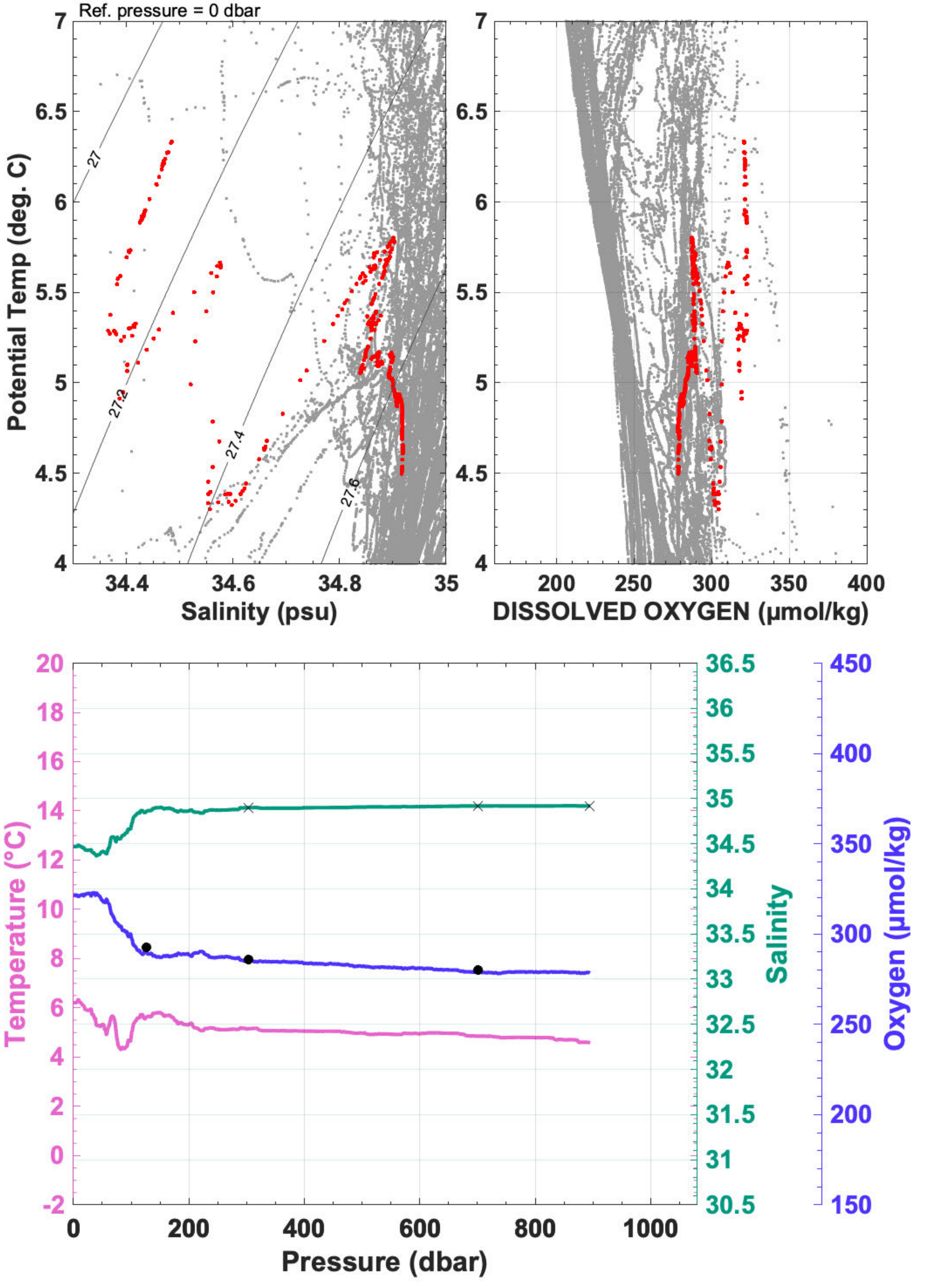
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 88



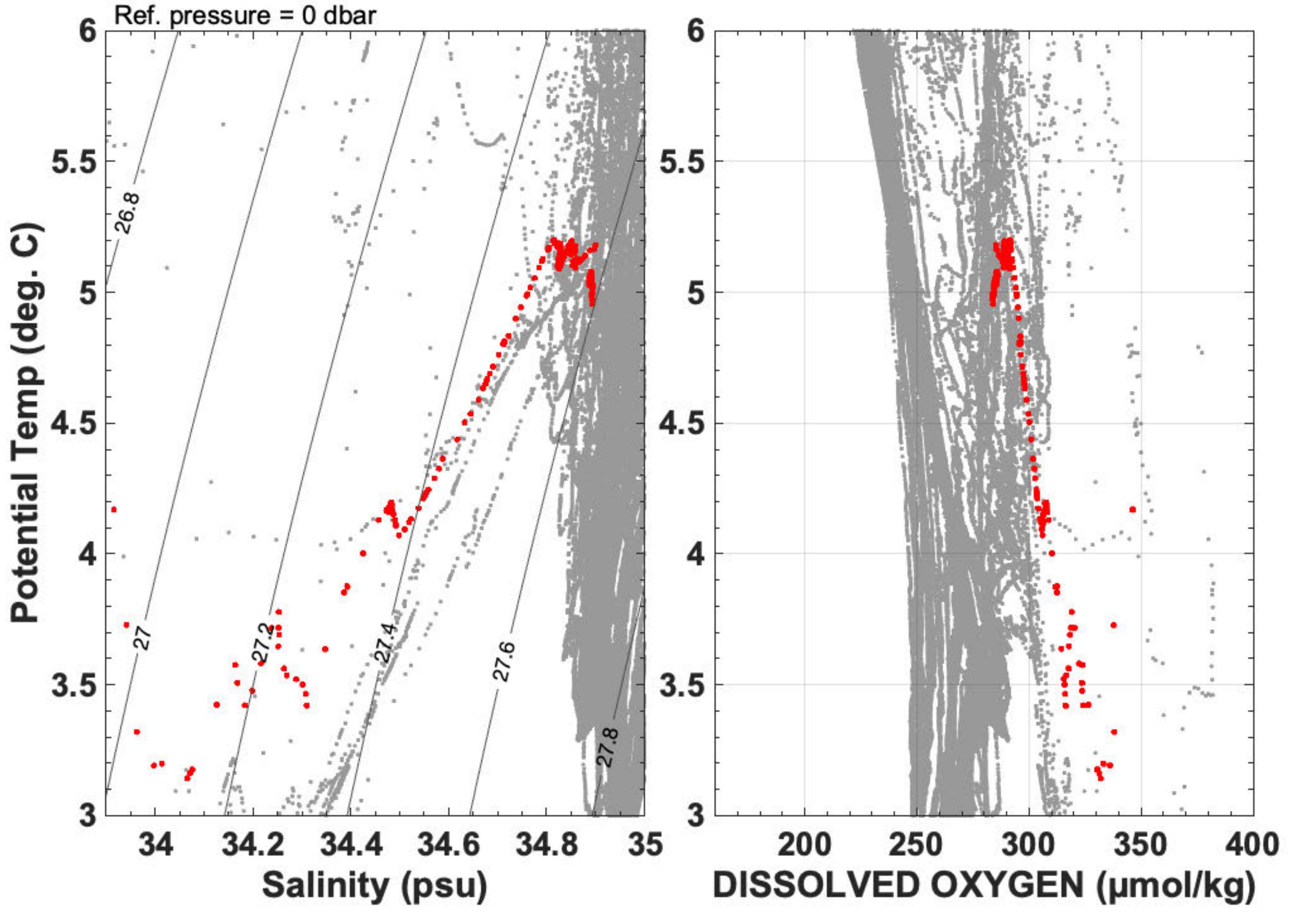
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
27
27.2
27.4
27.6
27.8
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

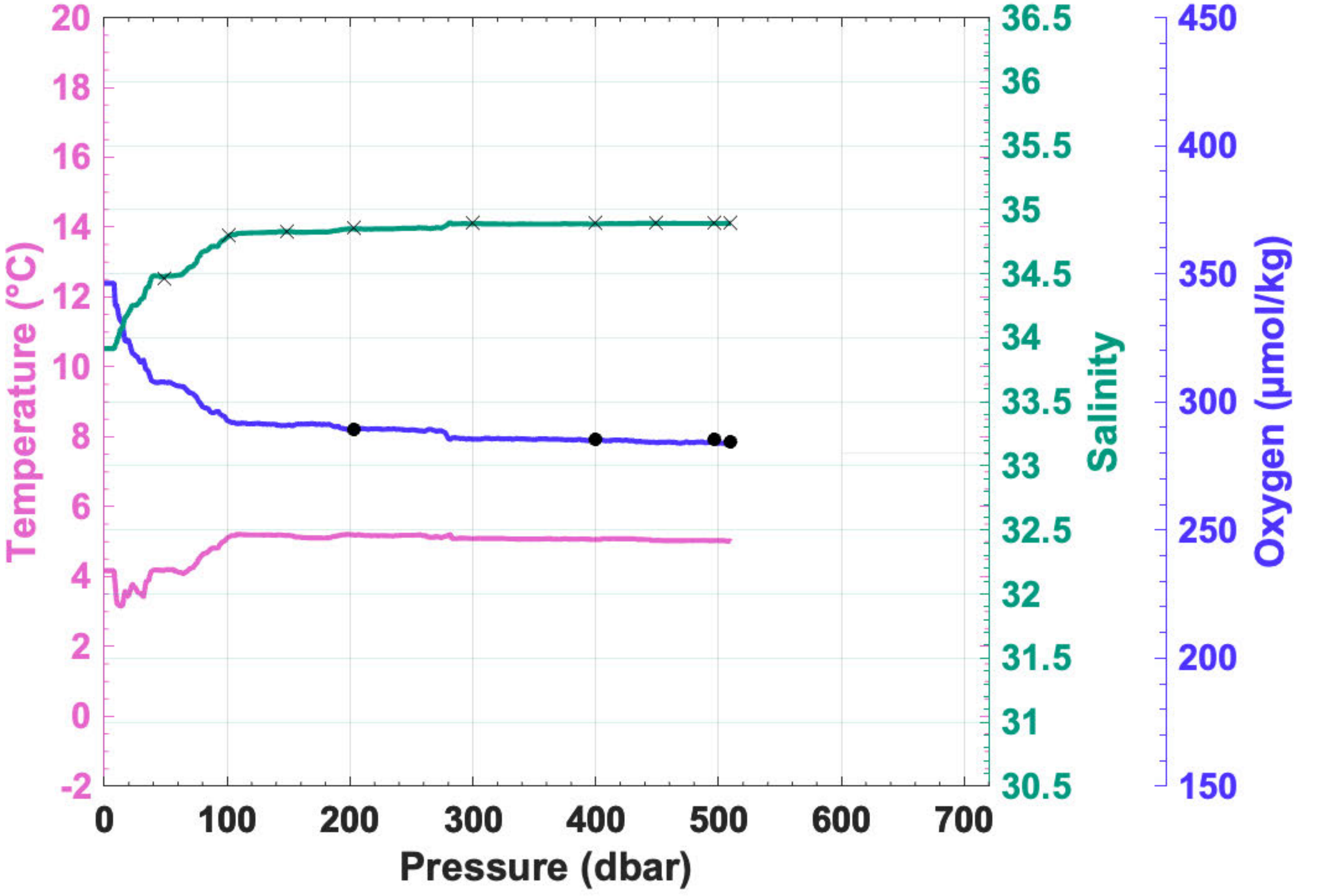
STATION 89



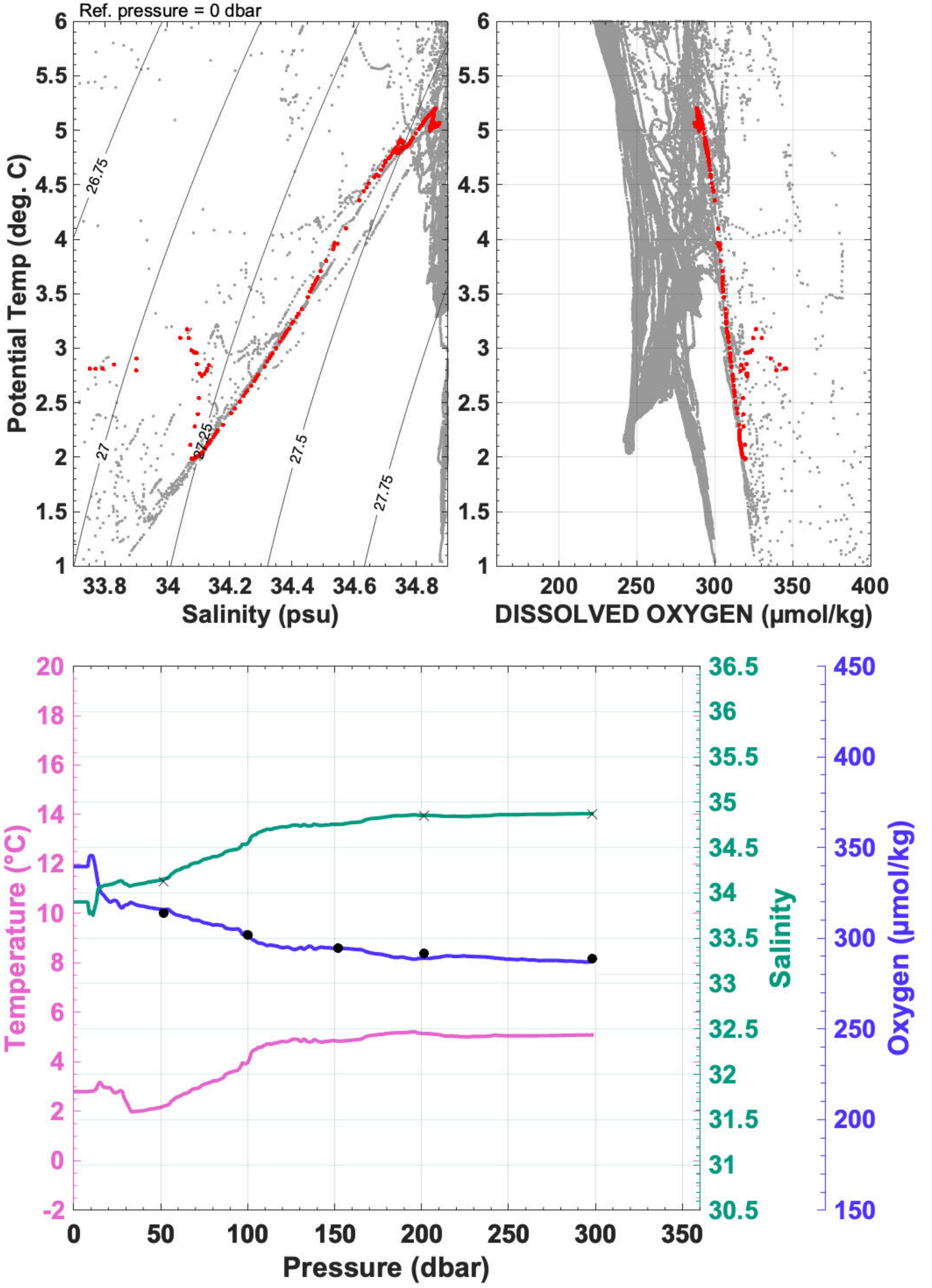
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.2
27.4
27.6
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 90


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.8
27
27.2
27.4
27.6
27.8
DISSOLVED OXYGEN (µmol/kg)

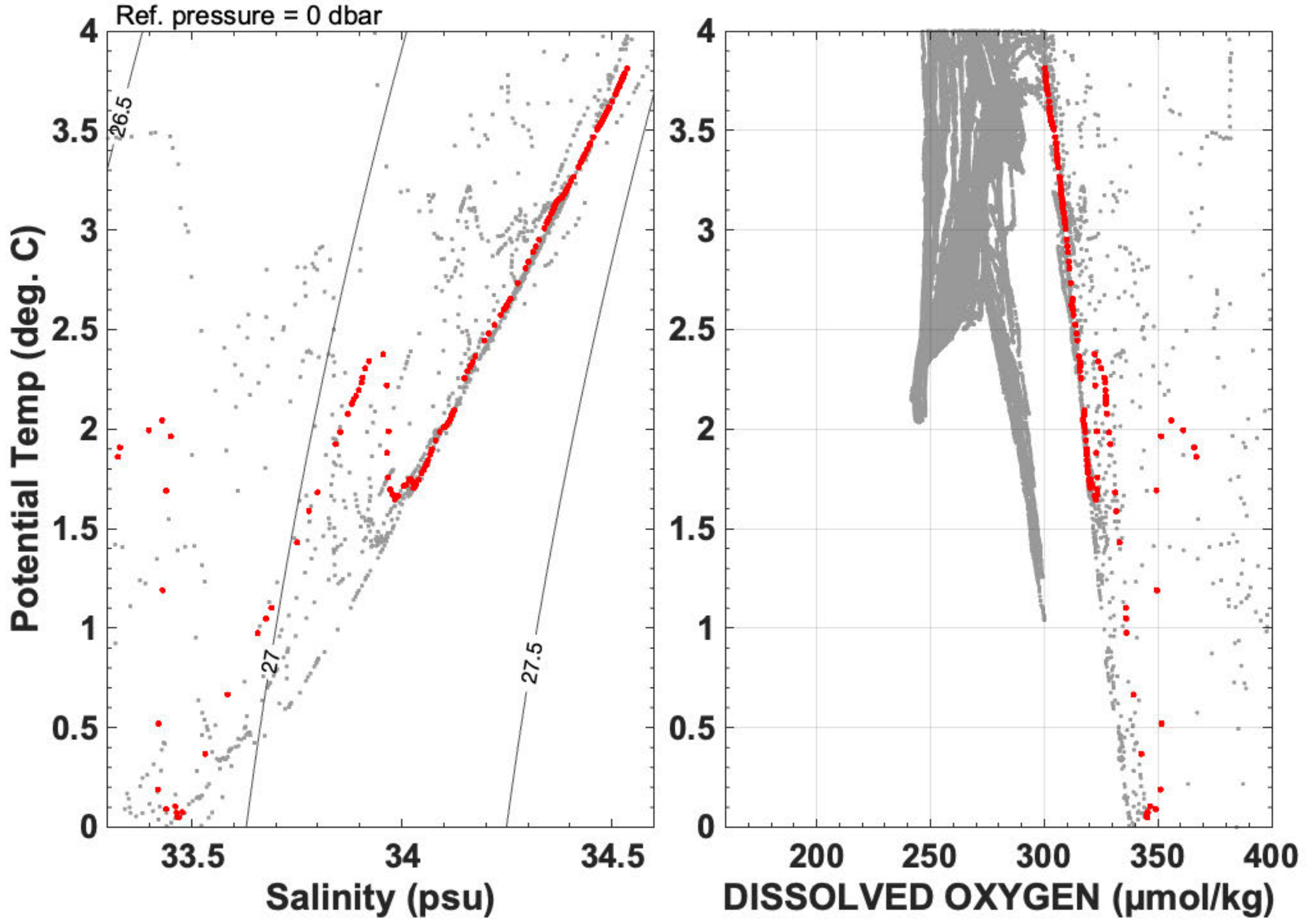

Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 91

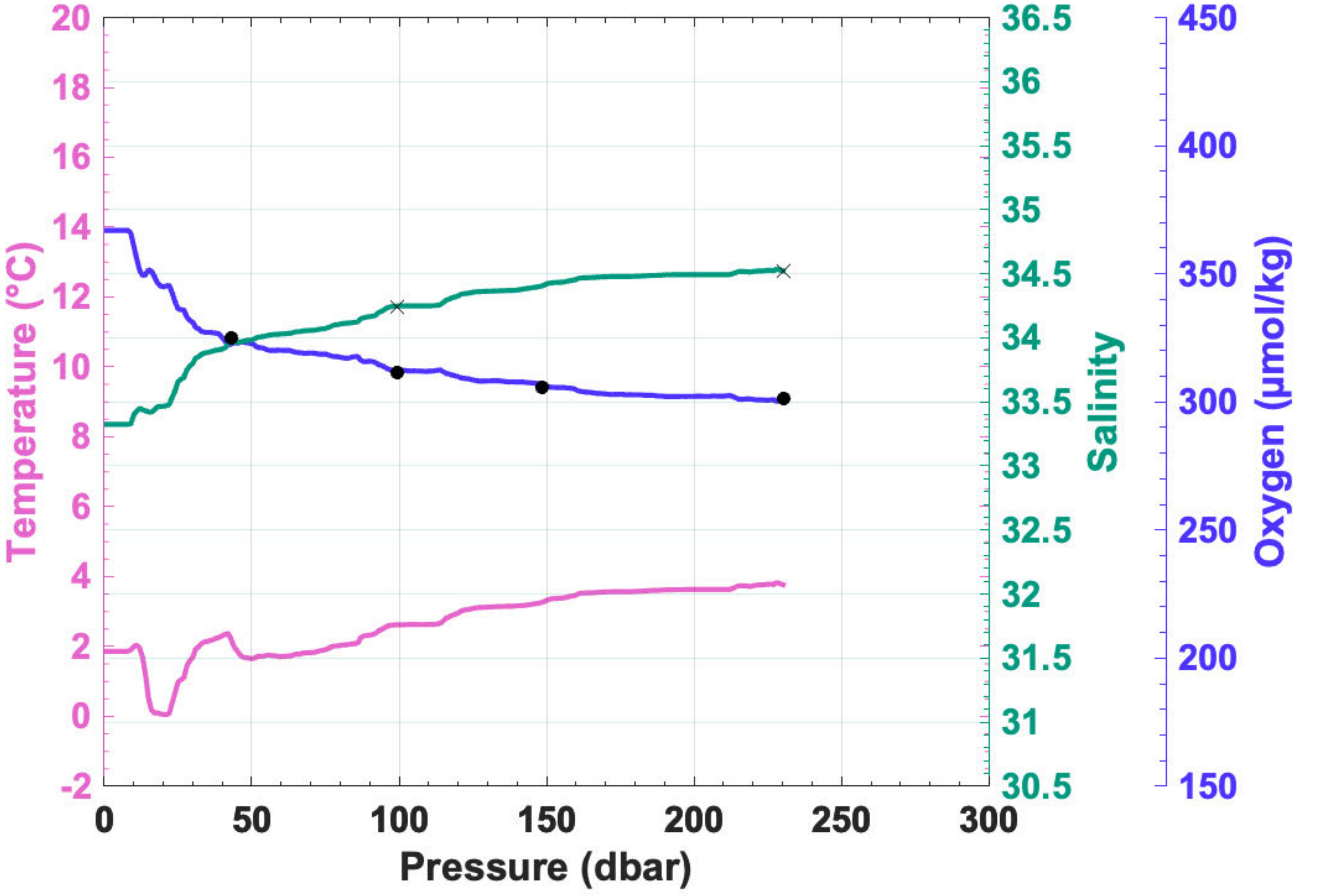


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.75
27
27.25
27.5
27.75
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 92

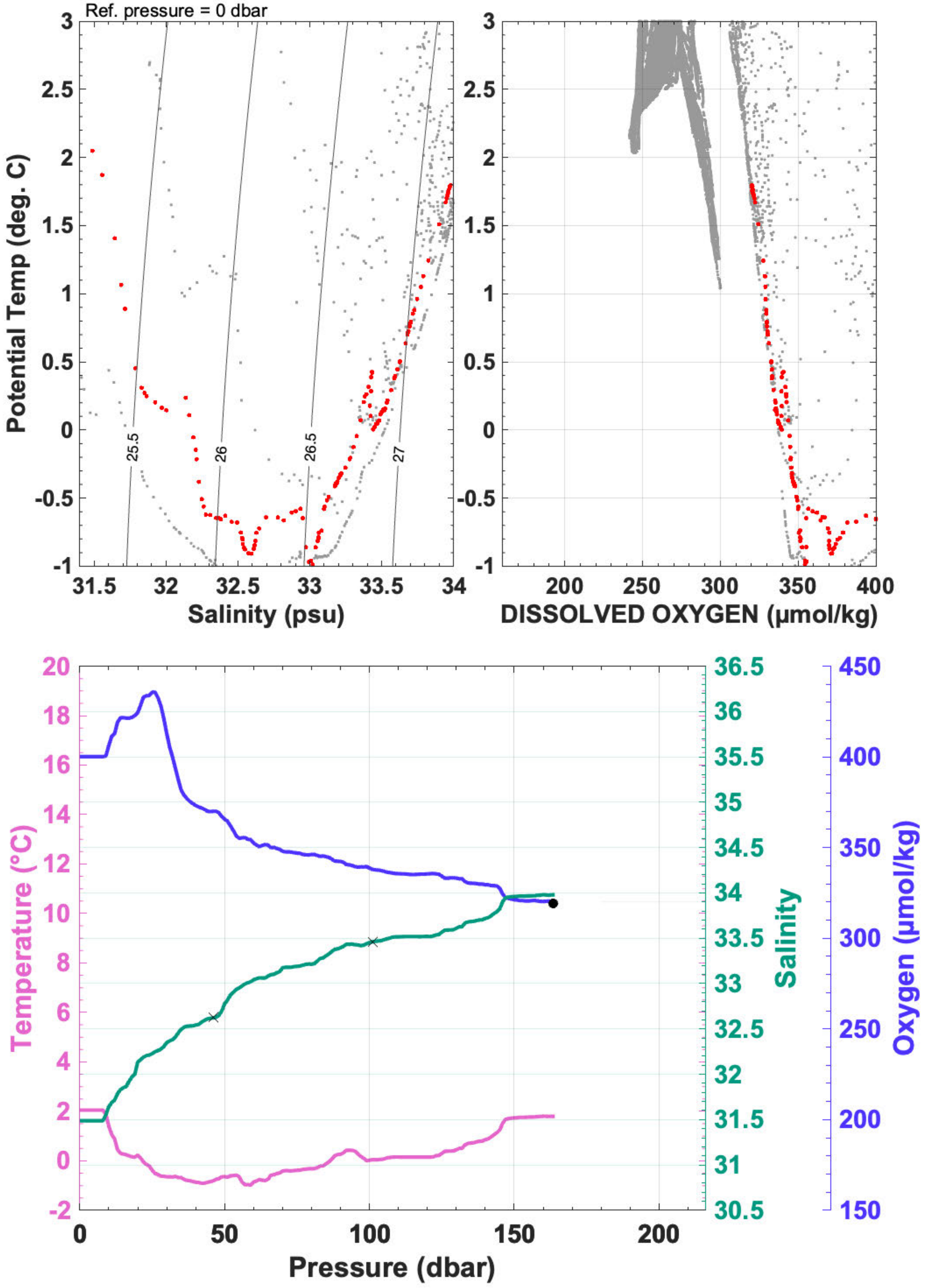


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
DISSOLVED OXYGEN (µmol/kg)



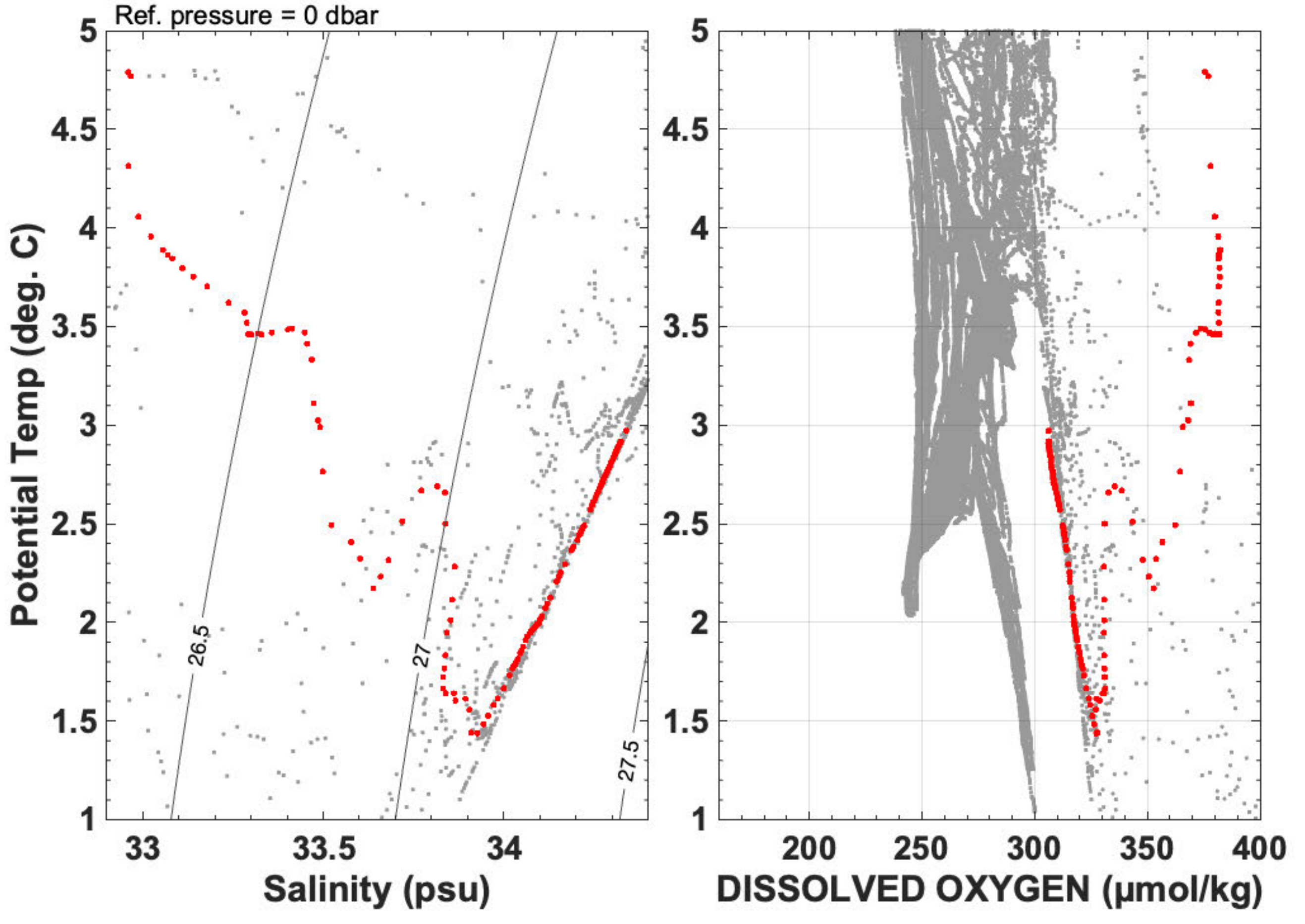
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 93

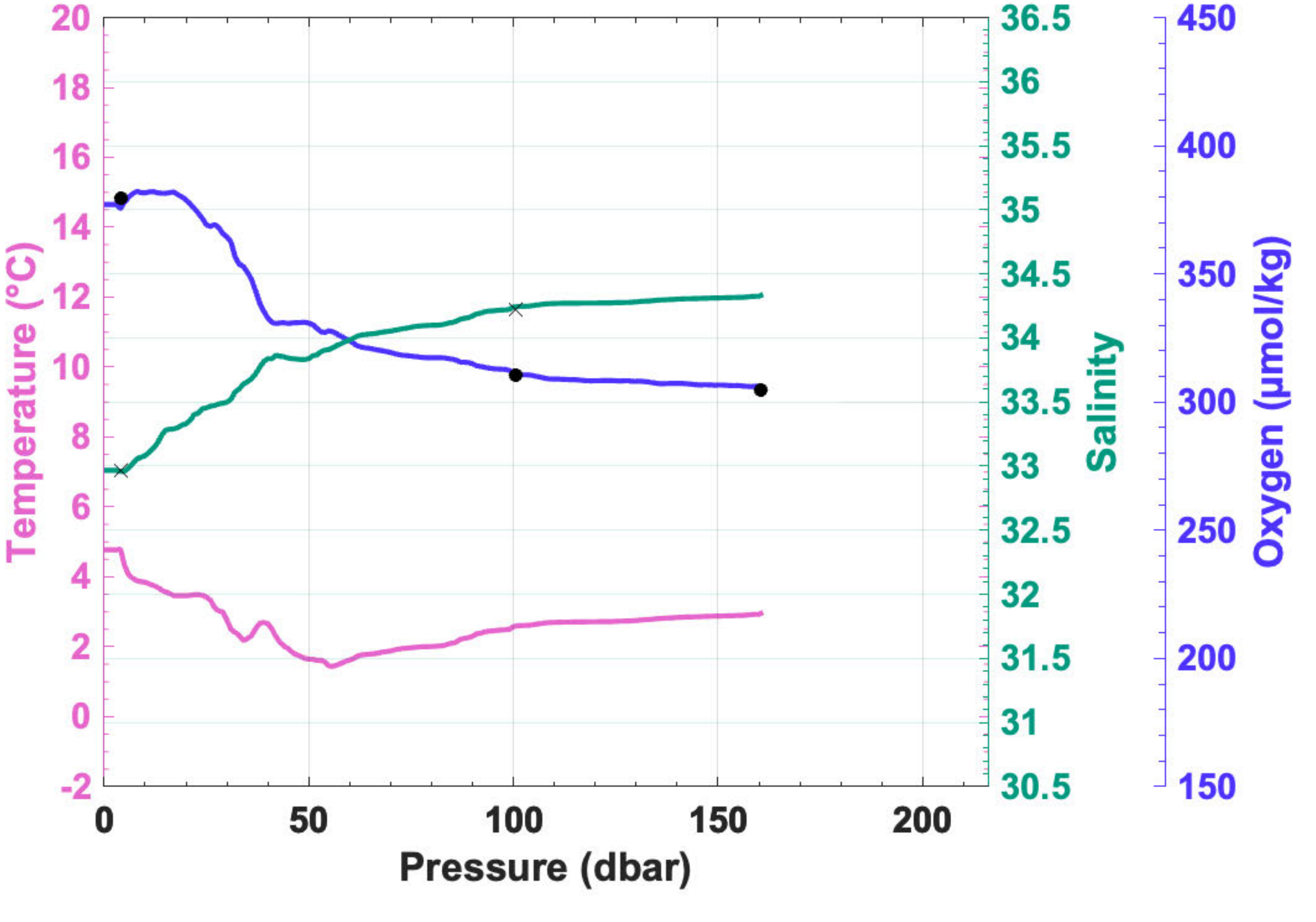


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25.5
26
26.5
27
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 94

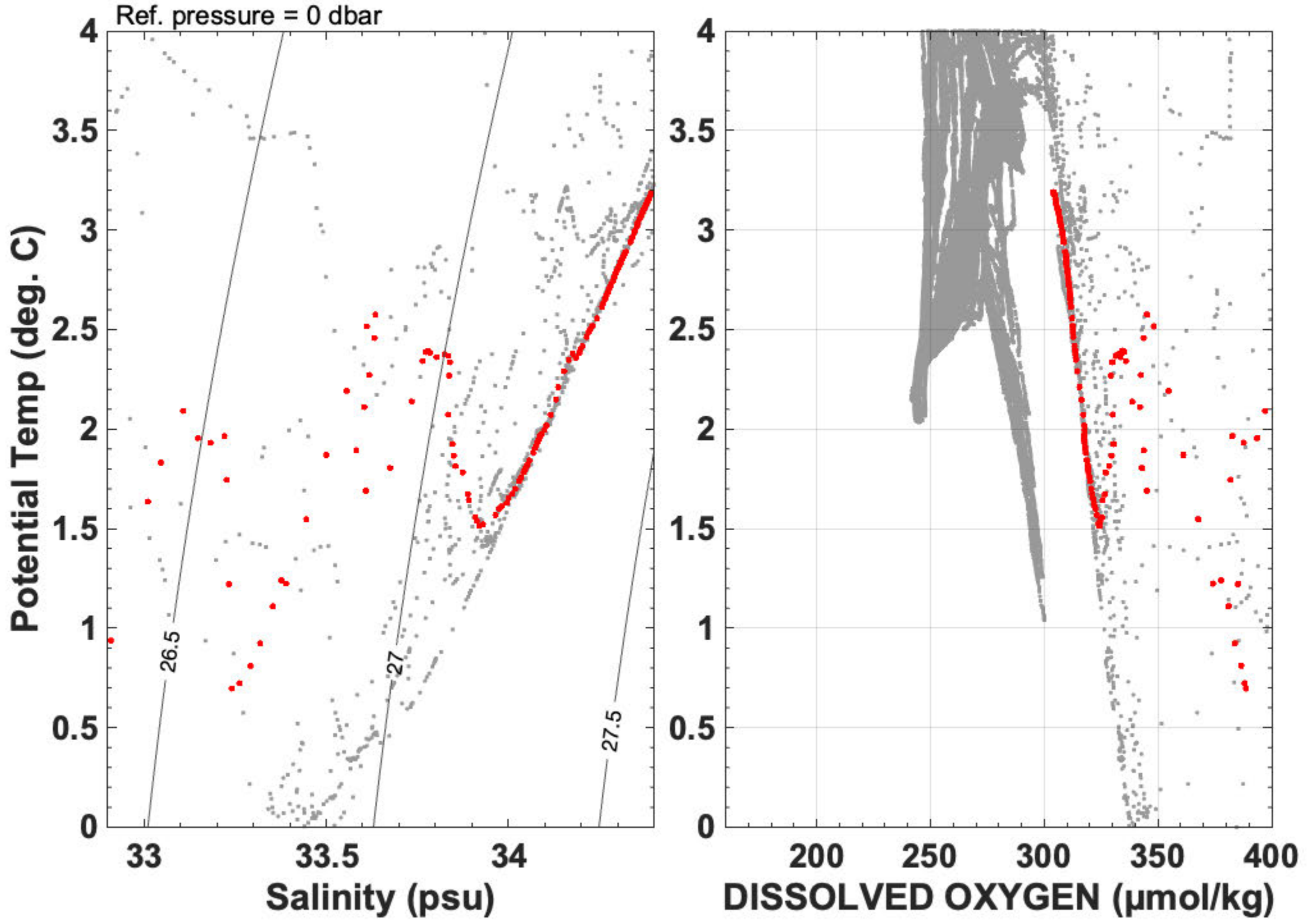


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
DISSOLVED OXYGEN (µmol/kg)

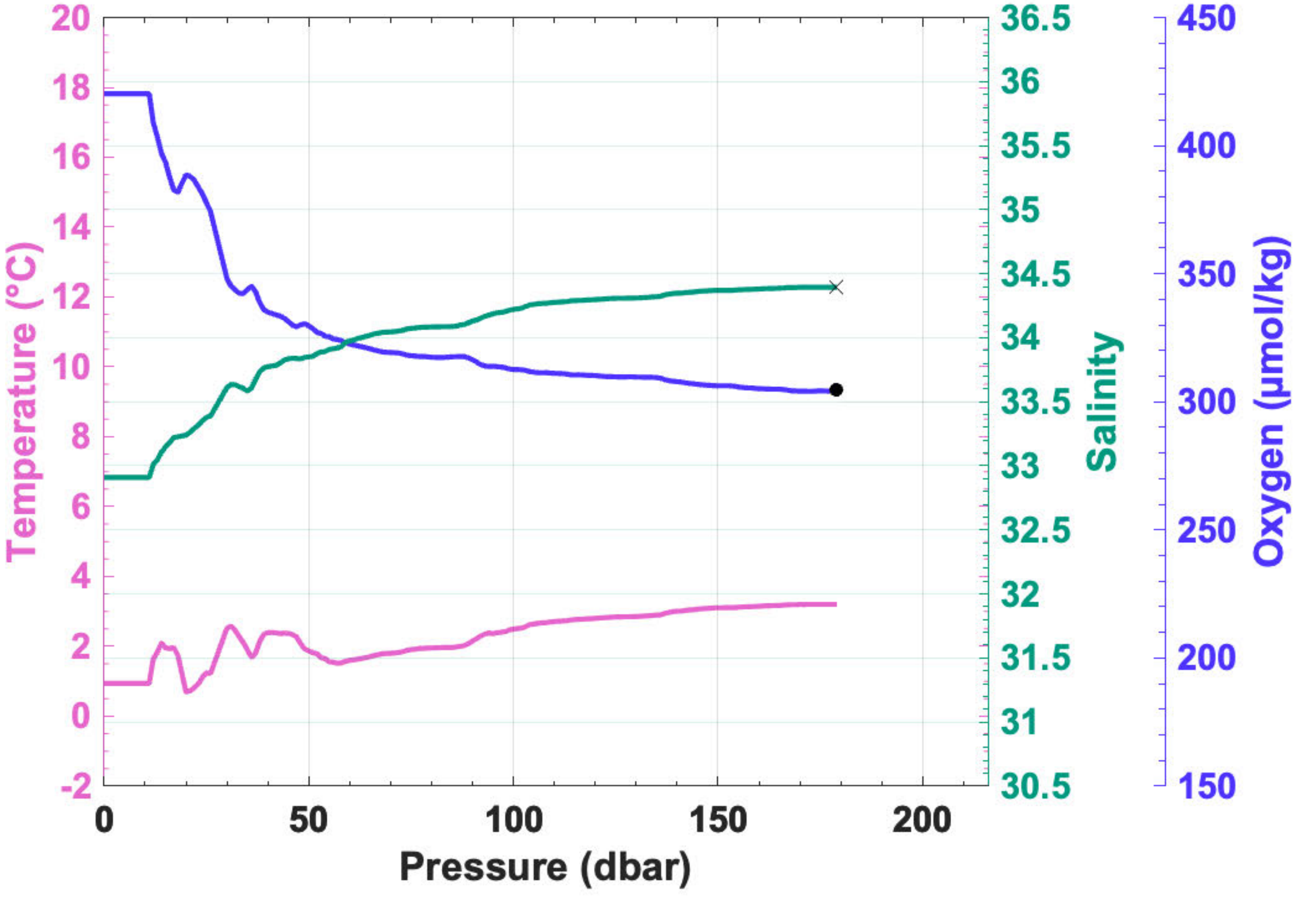


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 95

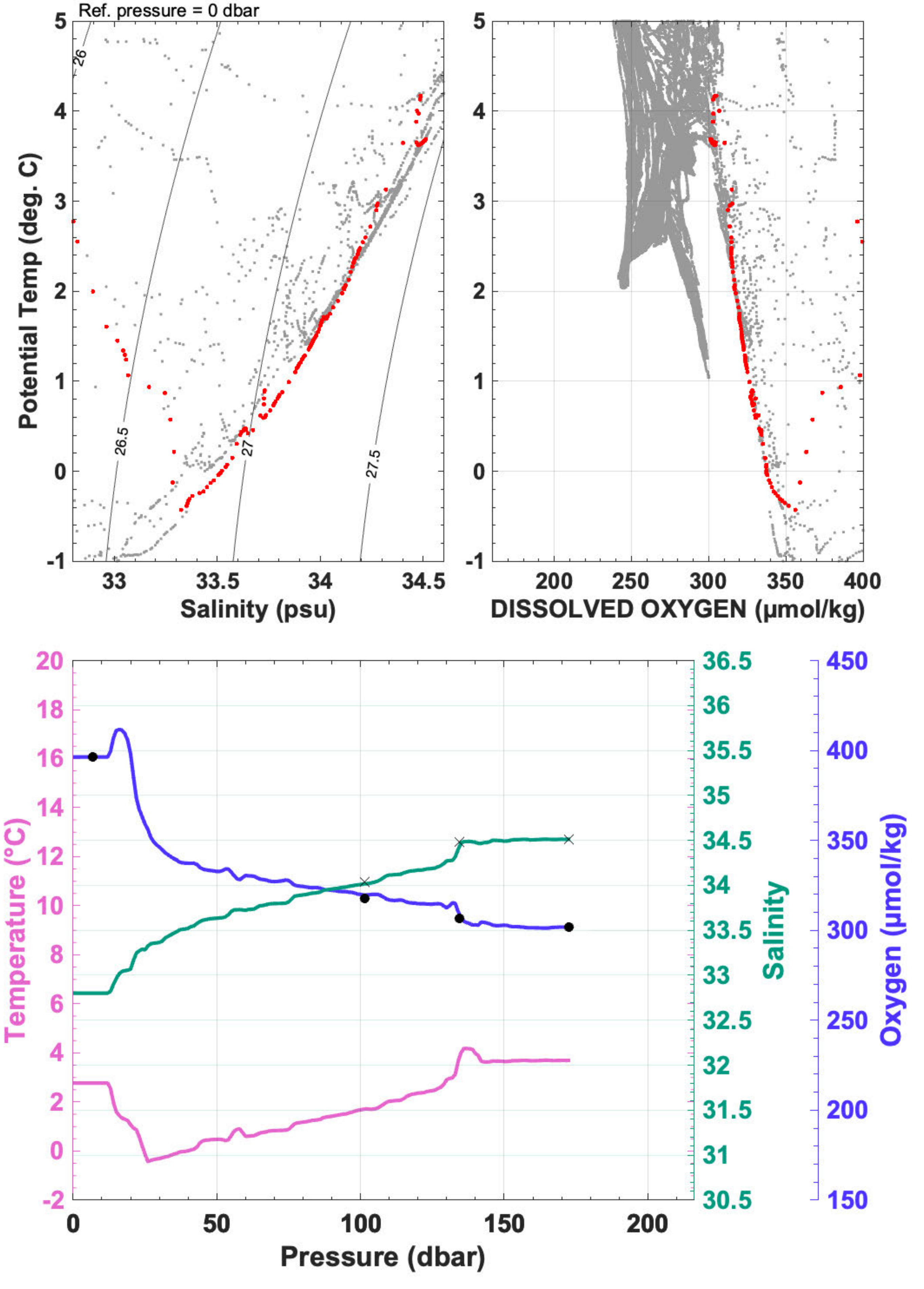


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
DISSOLVED OXYGEN (µmol/kg)

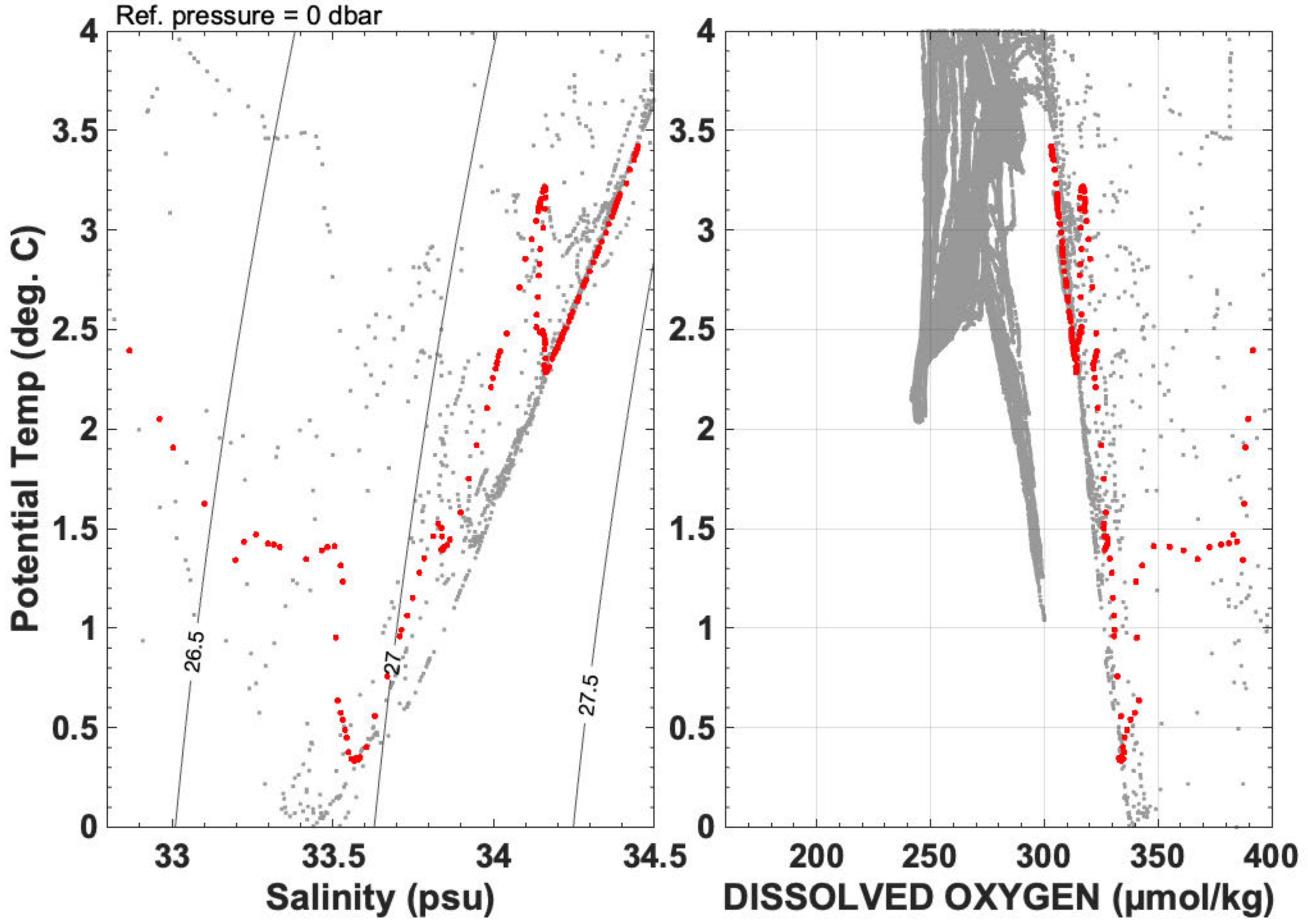


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

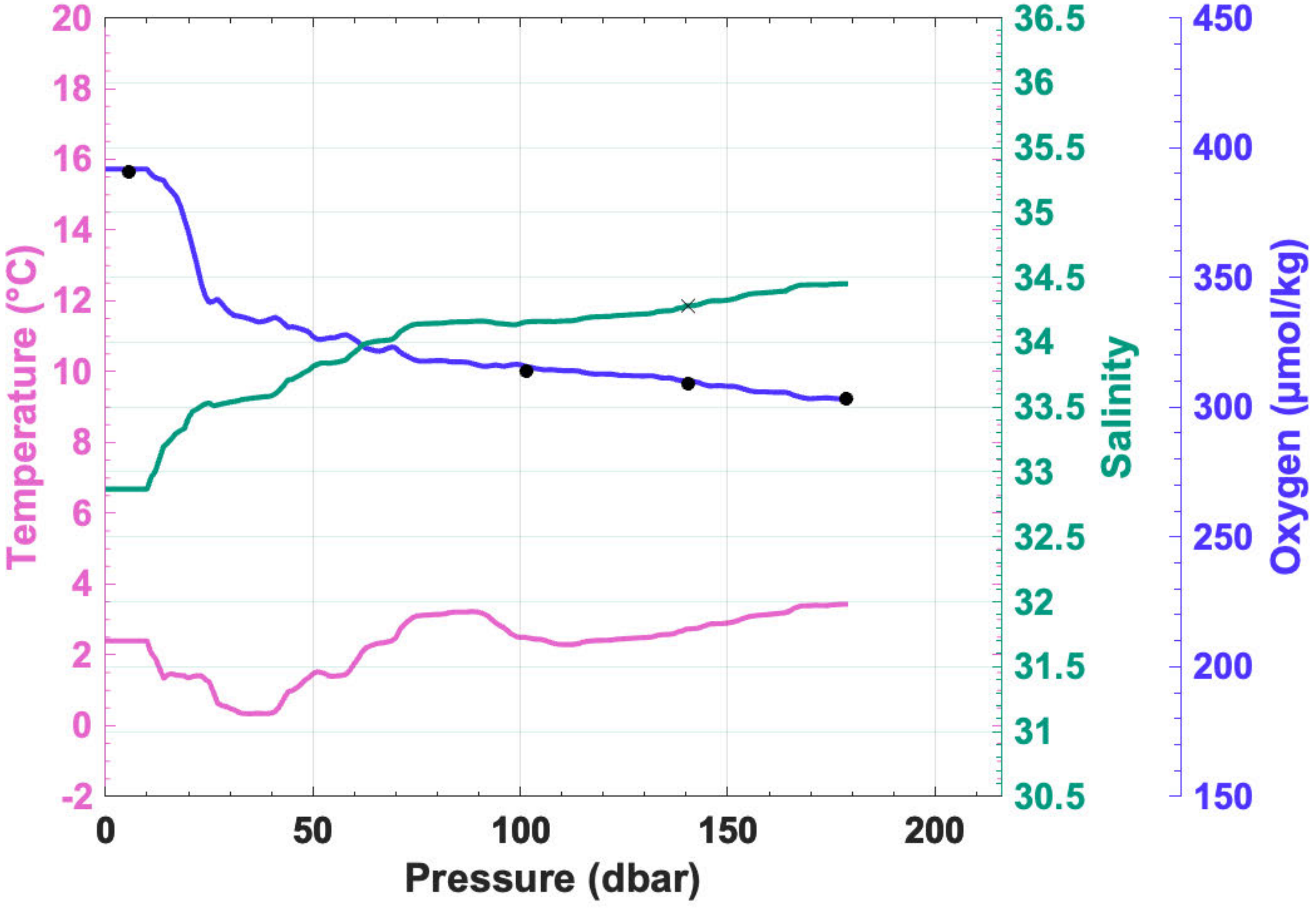
STATION 96


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 97

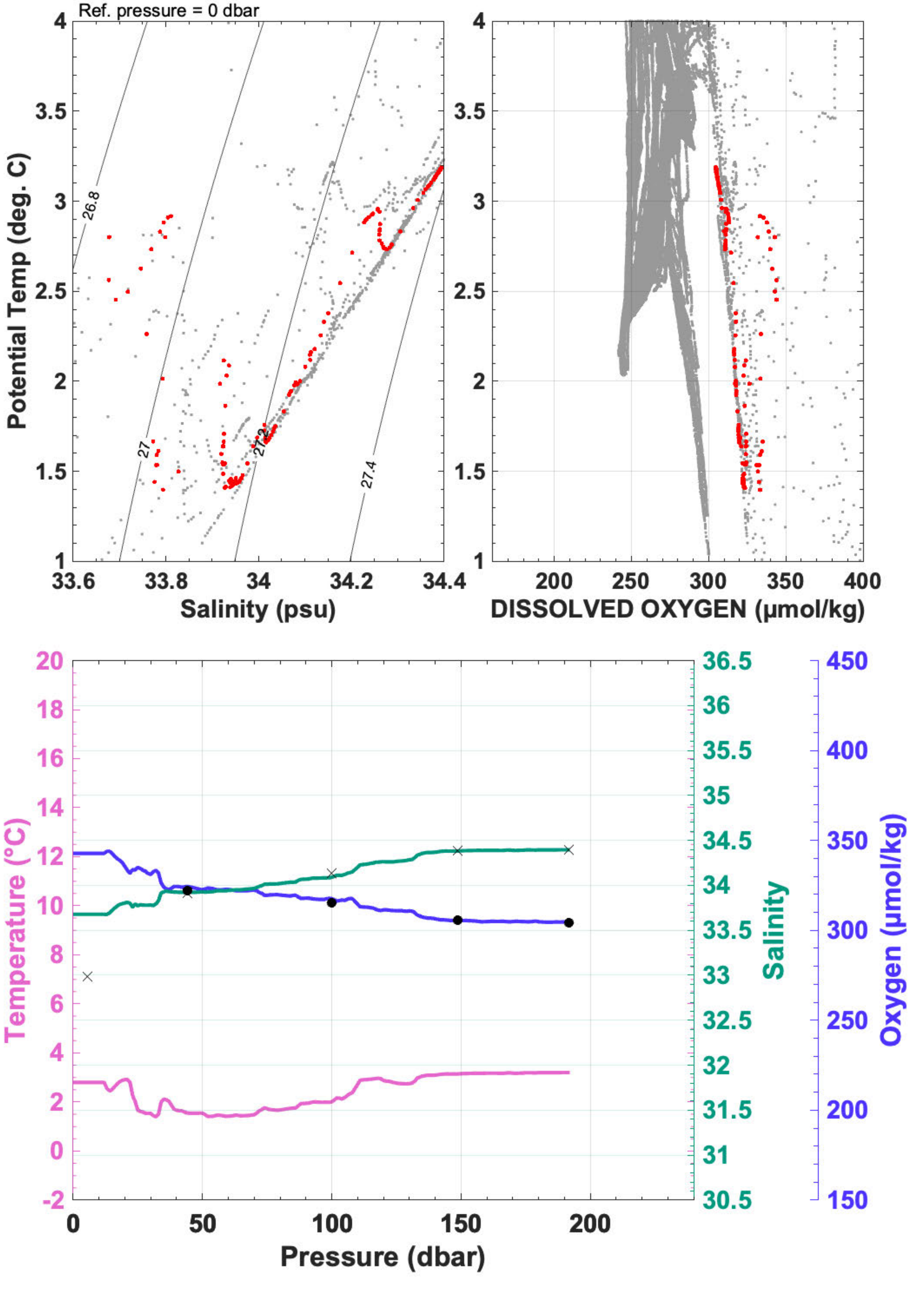


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.5
27
27.5
DISSOLVED OXYGEN (µmol/kg)

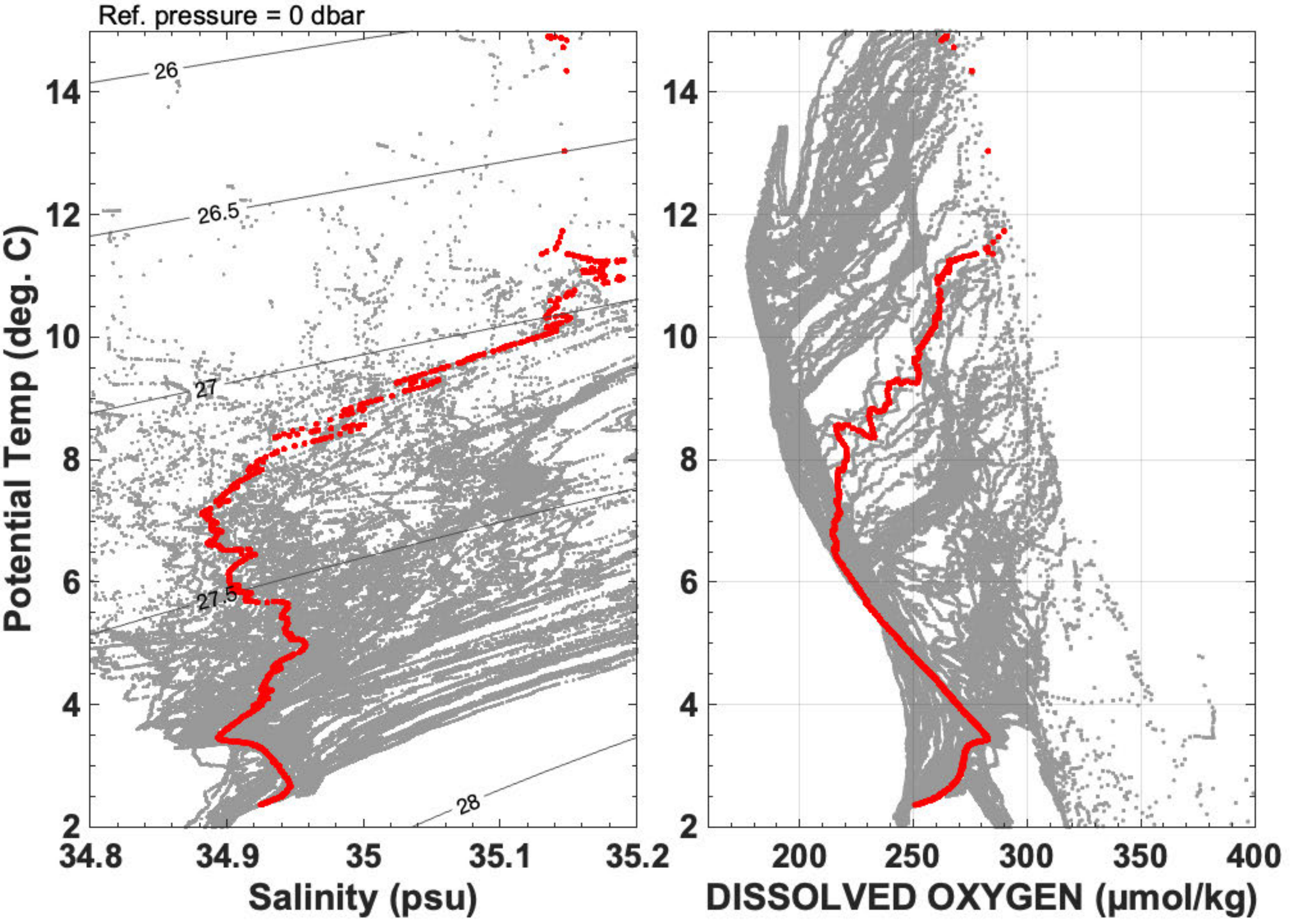


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

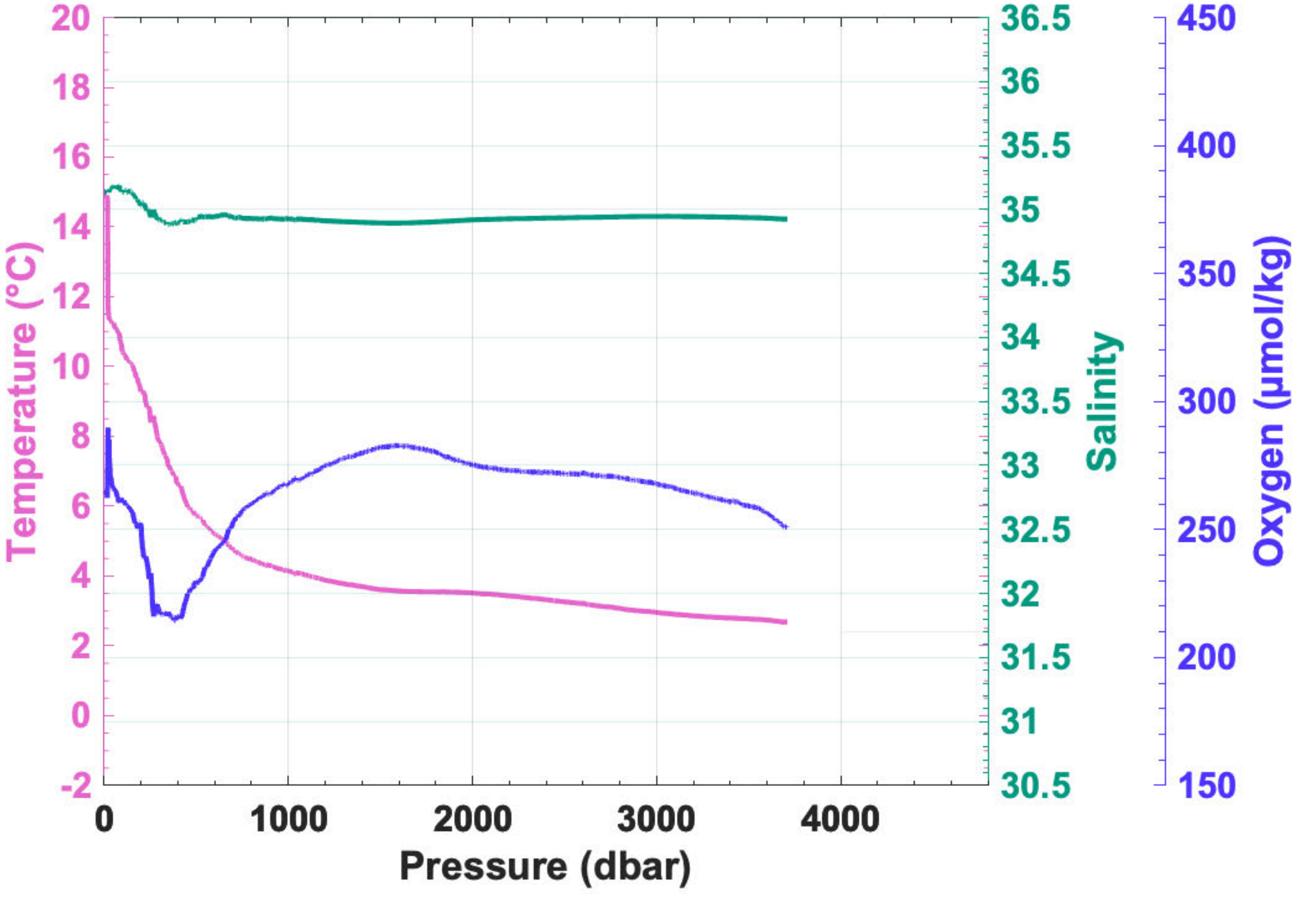
STATION 98


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.8
27
27.2
27.4
DISSOLVED OXYGEN (μmol/kg)
Temperature (°C)
Salinity
Oxygen (μmol/kg)
Pressure (dbar)

STATION 110

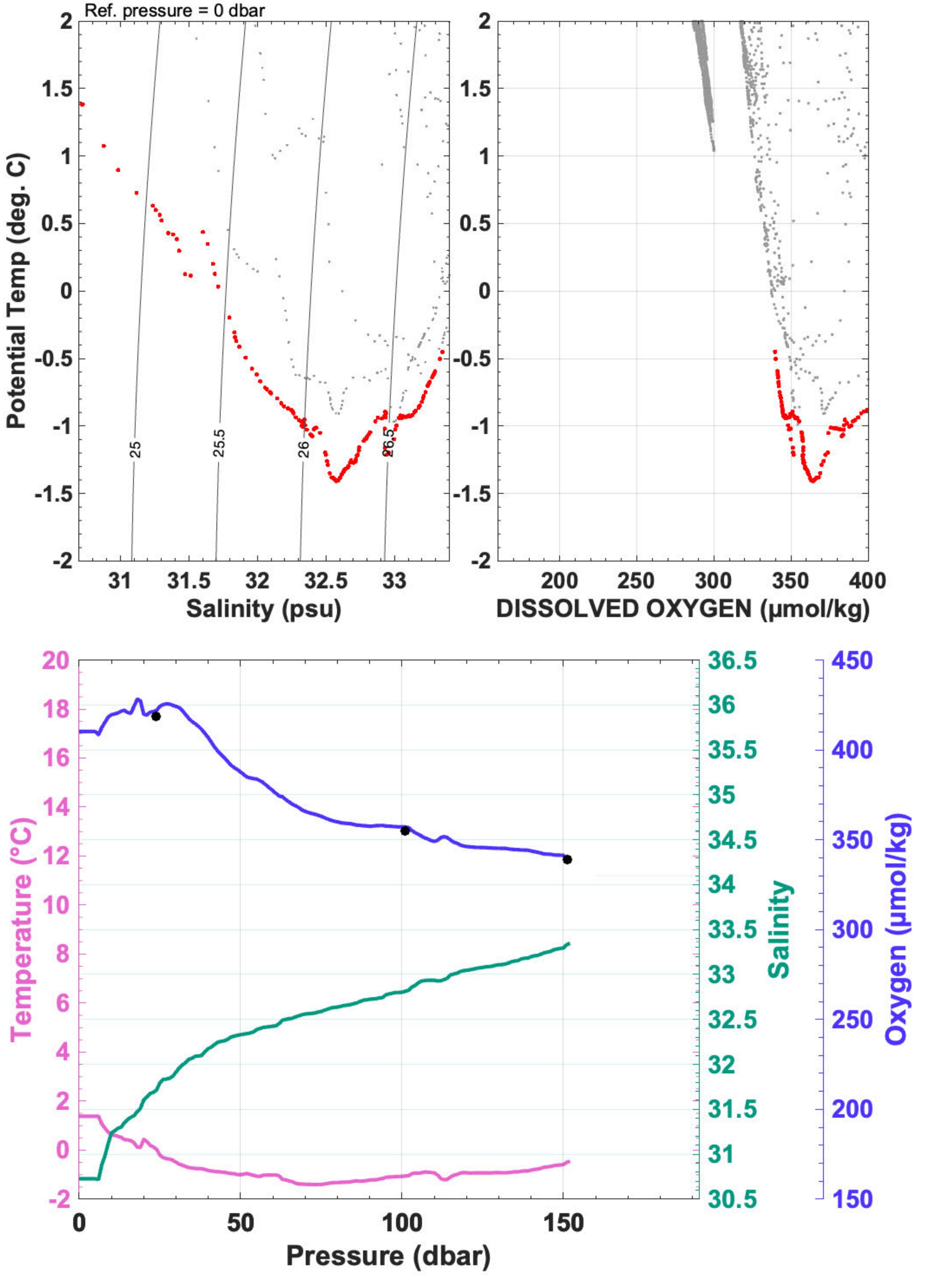


Ref. pressure = 0 dbar
26
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



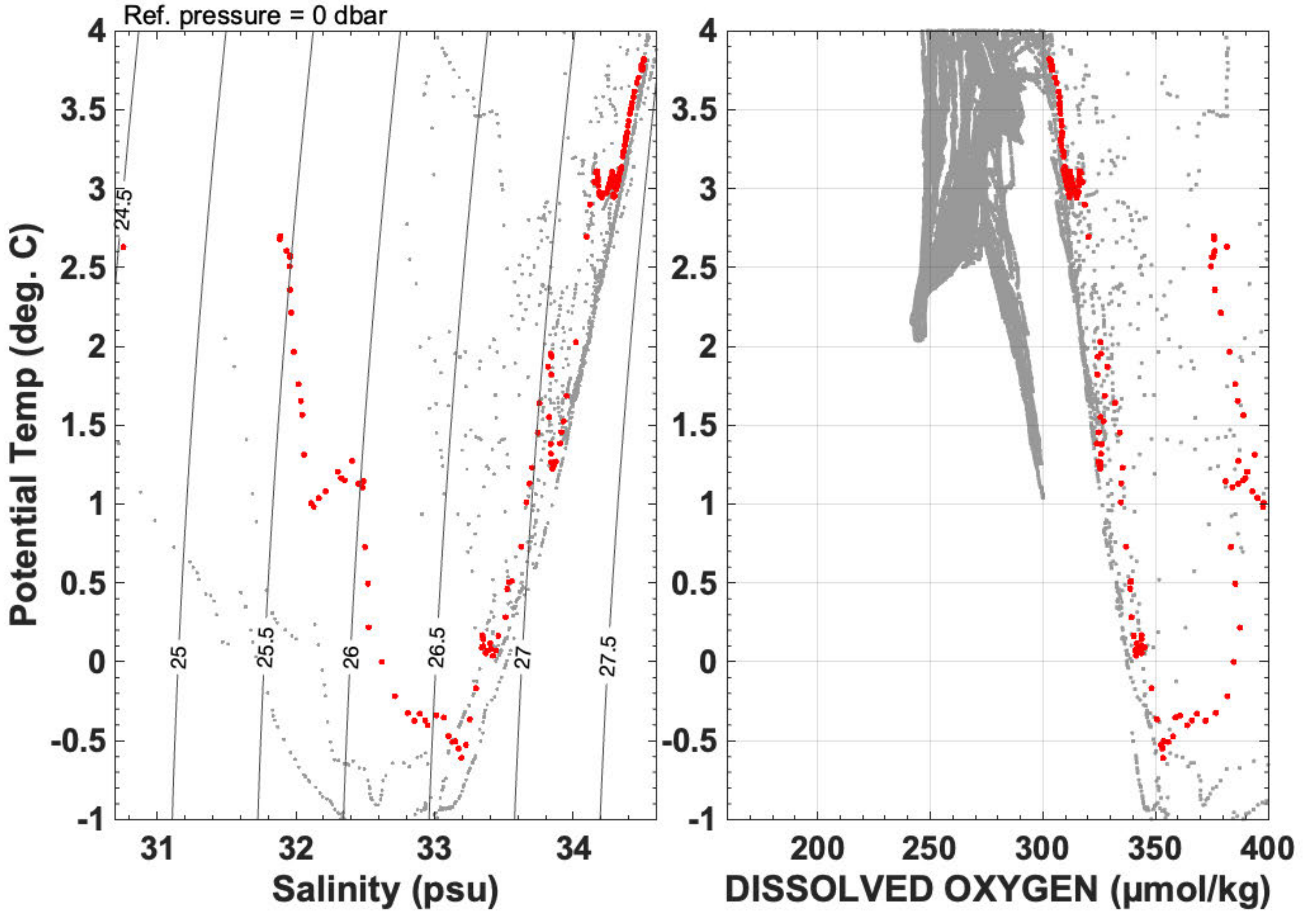
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 111

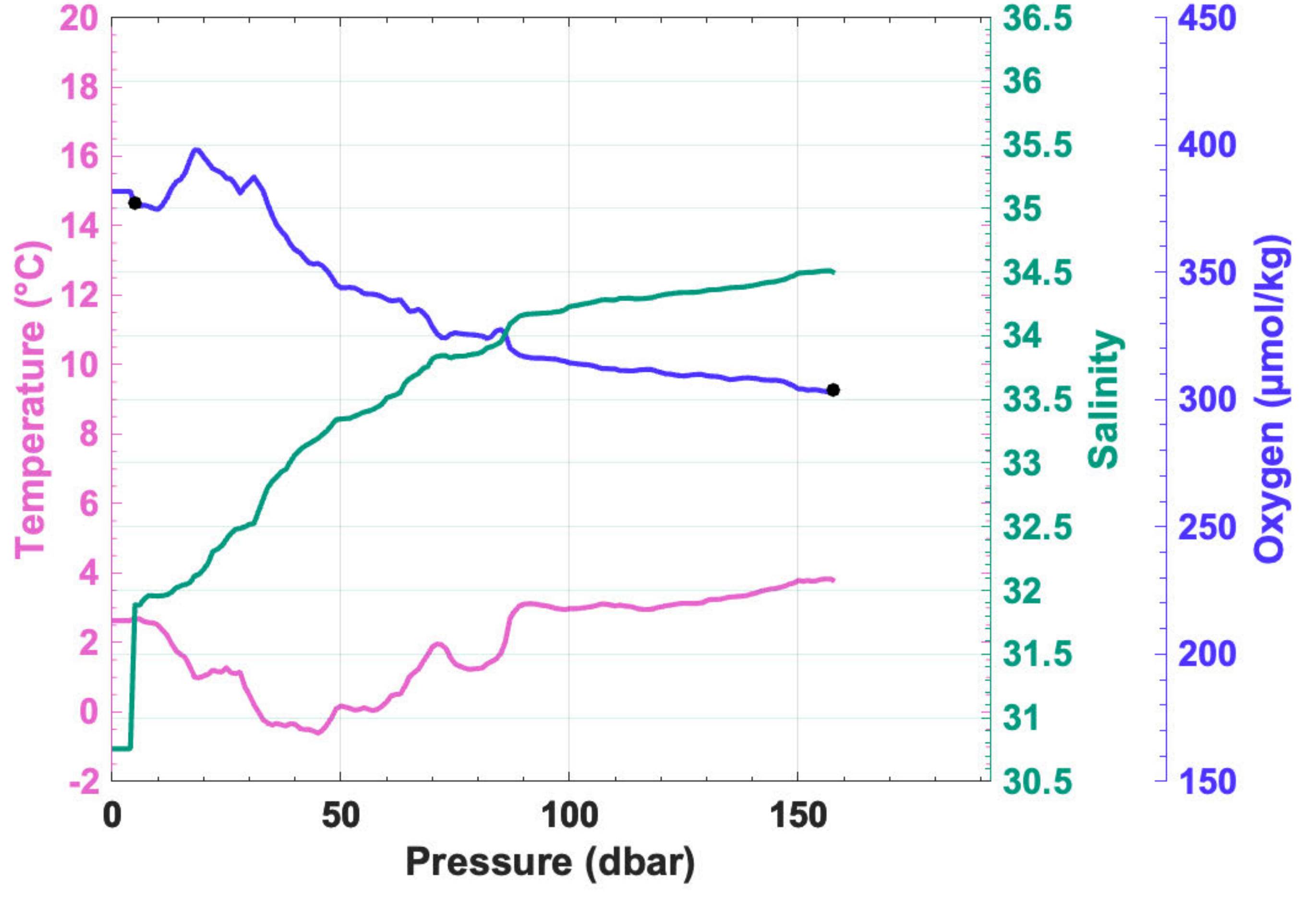


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
25
25.5
26
26.5
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 112

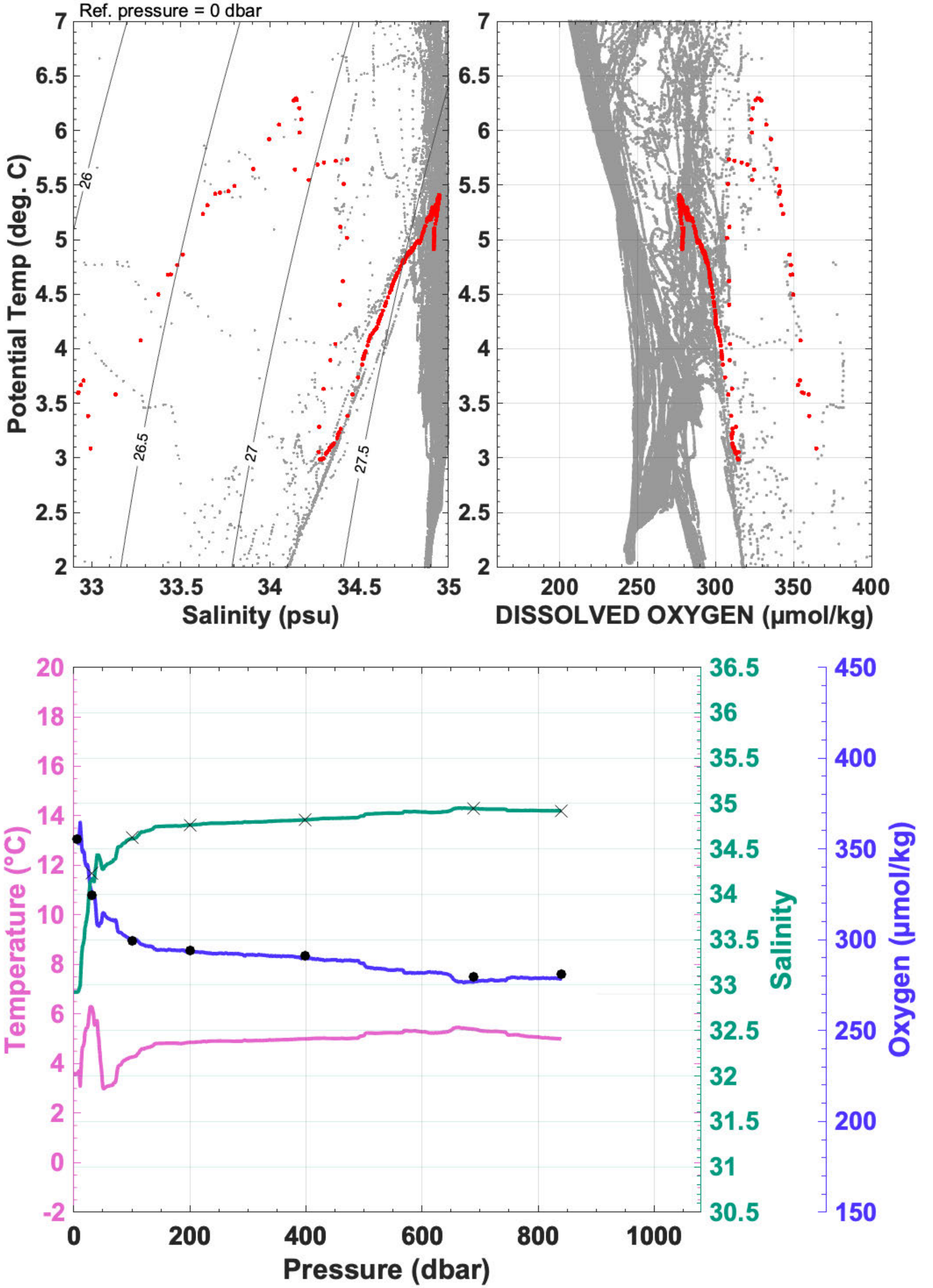


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
24.5
25
25.5
26
26.5
27
27.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
31
32
33
34
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400



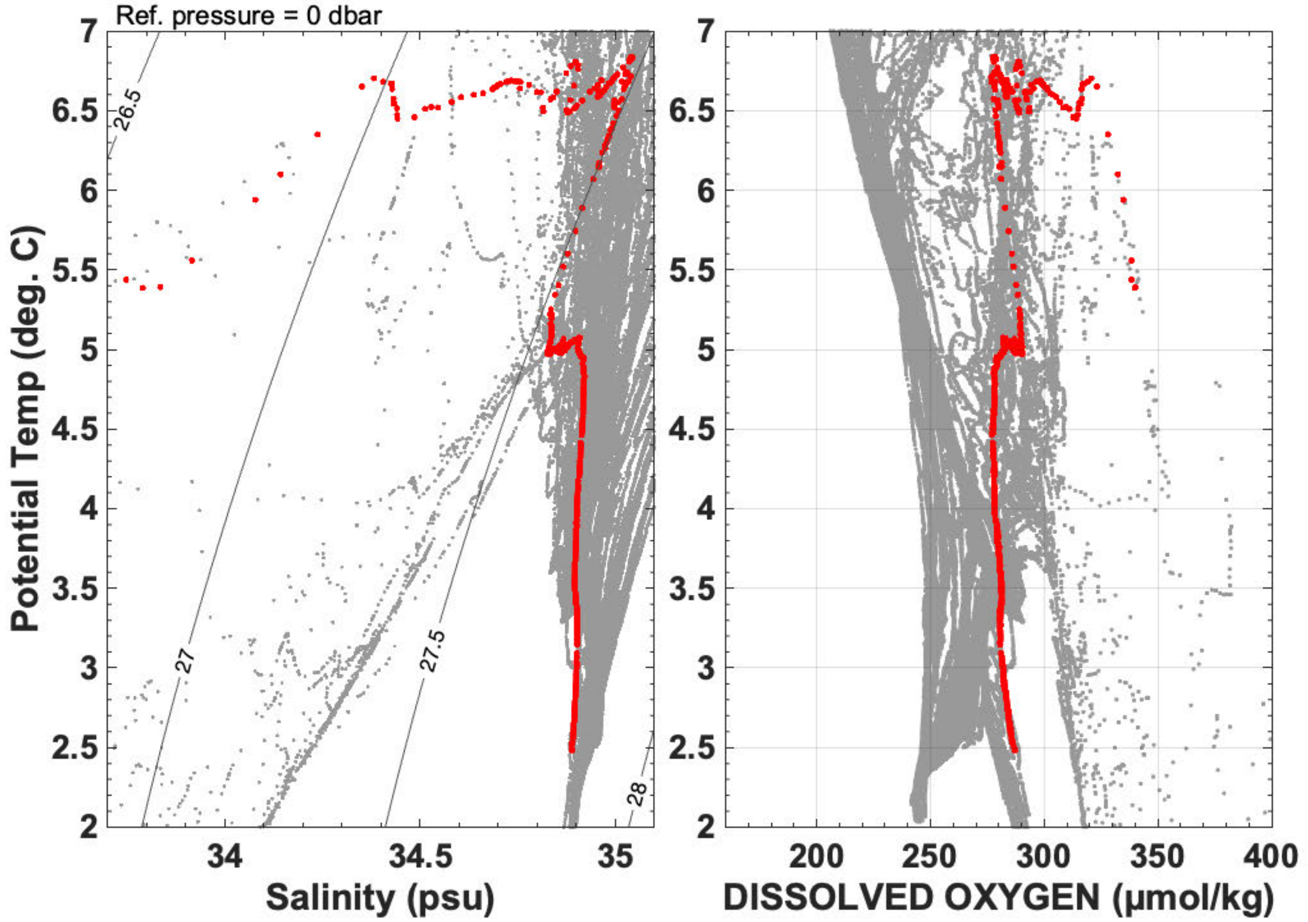
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
20
18
16
14
12
10
8
6
4
2
0
-2
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
450
400
350
300
250
200
150
0
50
100
150

STATION 113

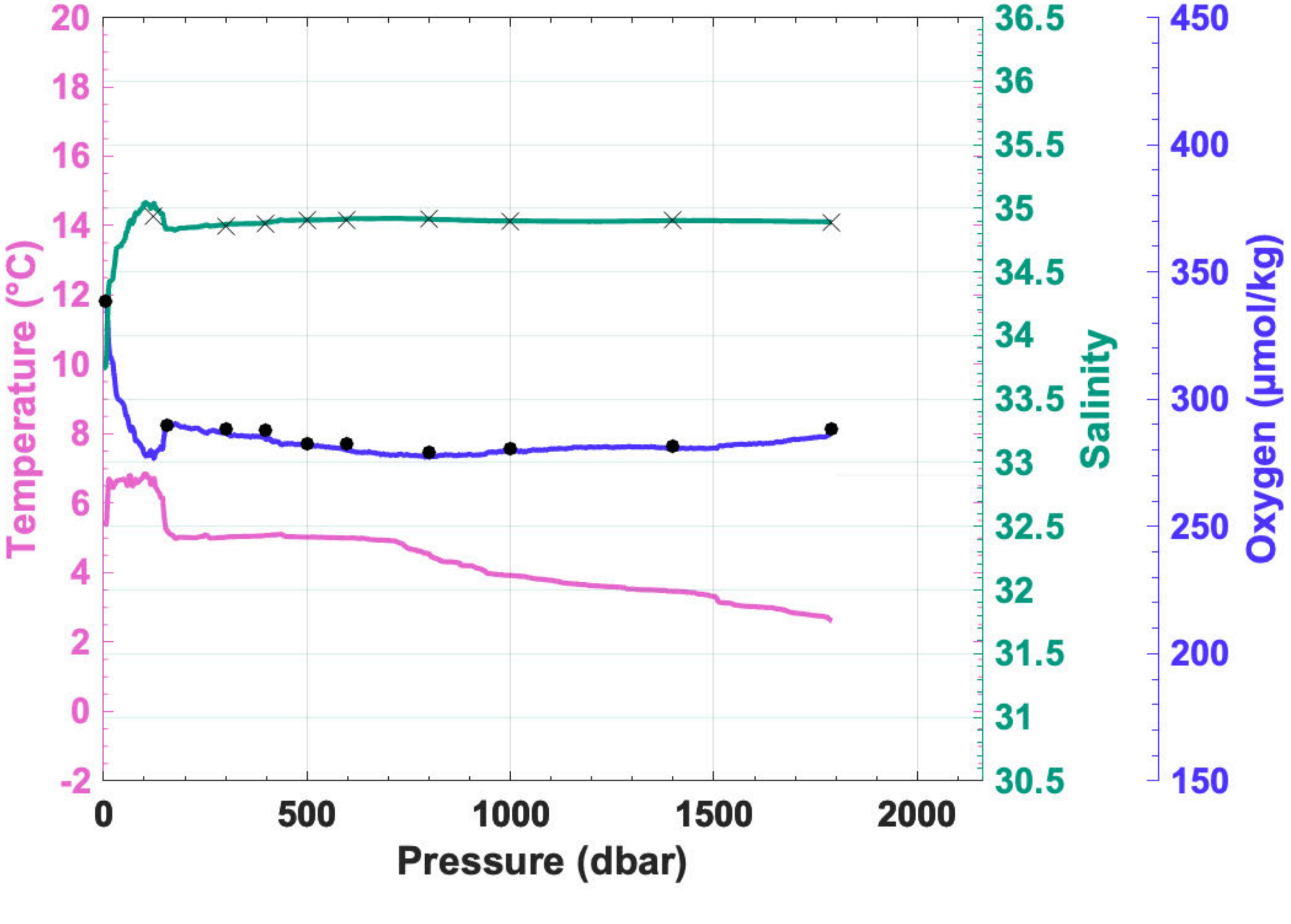


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
26
26.5
27
27.5
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 114

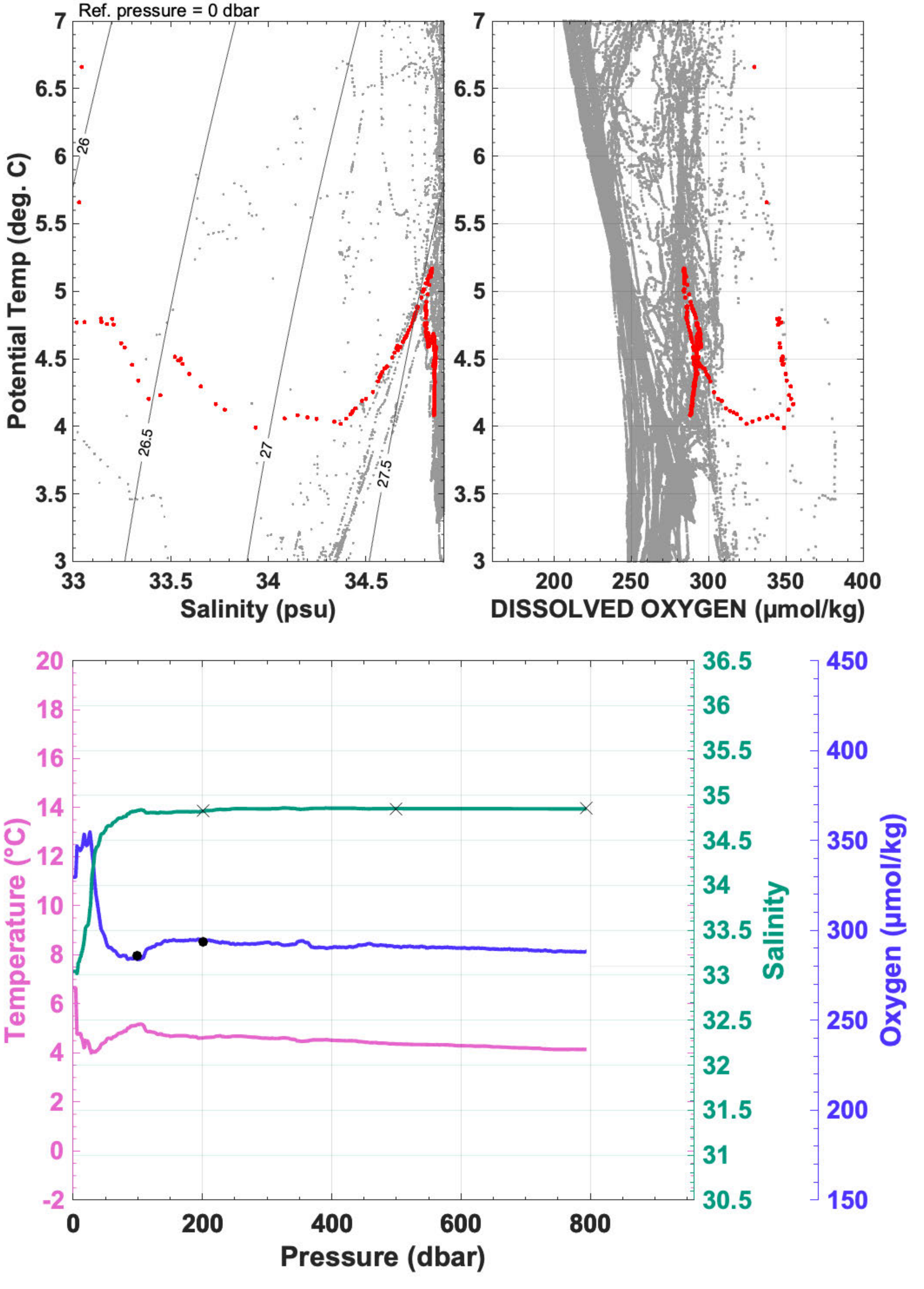


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
26.5
27
27.5
28
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
34
34.5
35
200
250
300
350
400



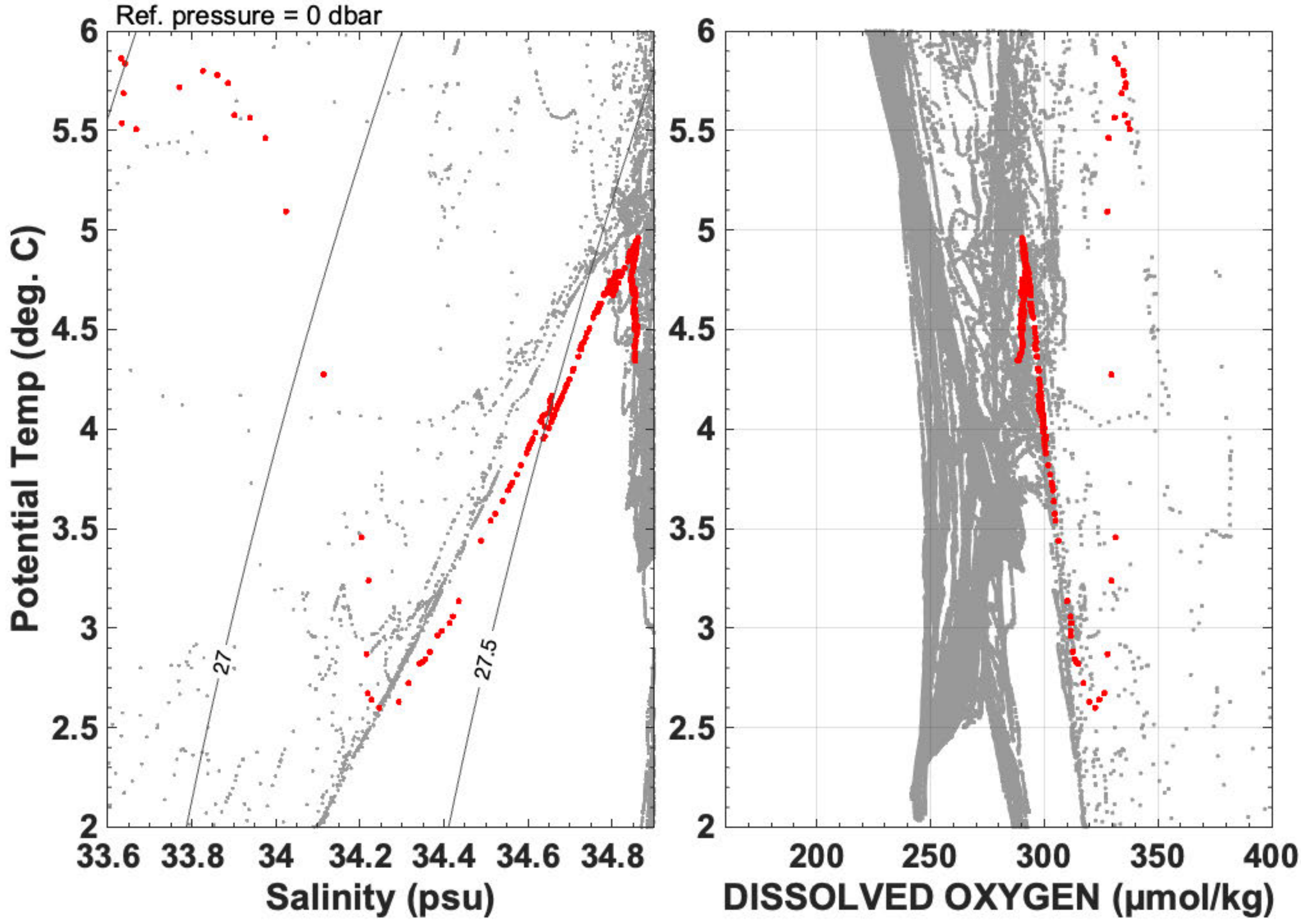
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
20
18
16
14
12
10
8
6
4
2
0
-2
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
450
400
350
300
250
200
150
0
500
1000
1500
2000

STATION 116

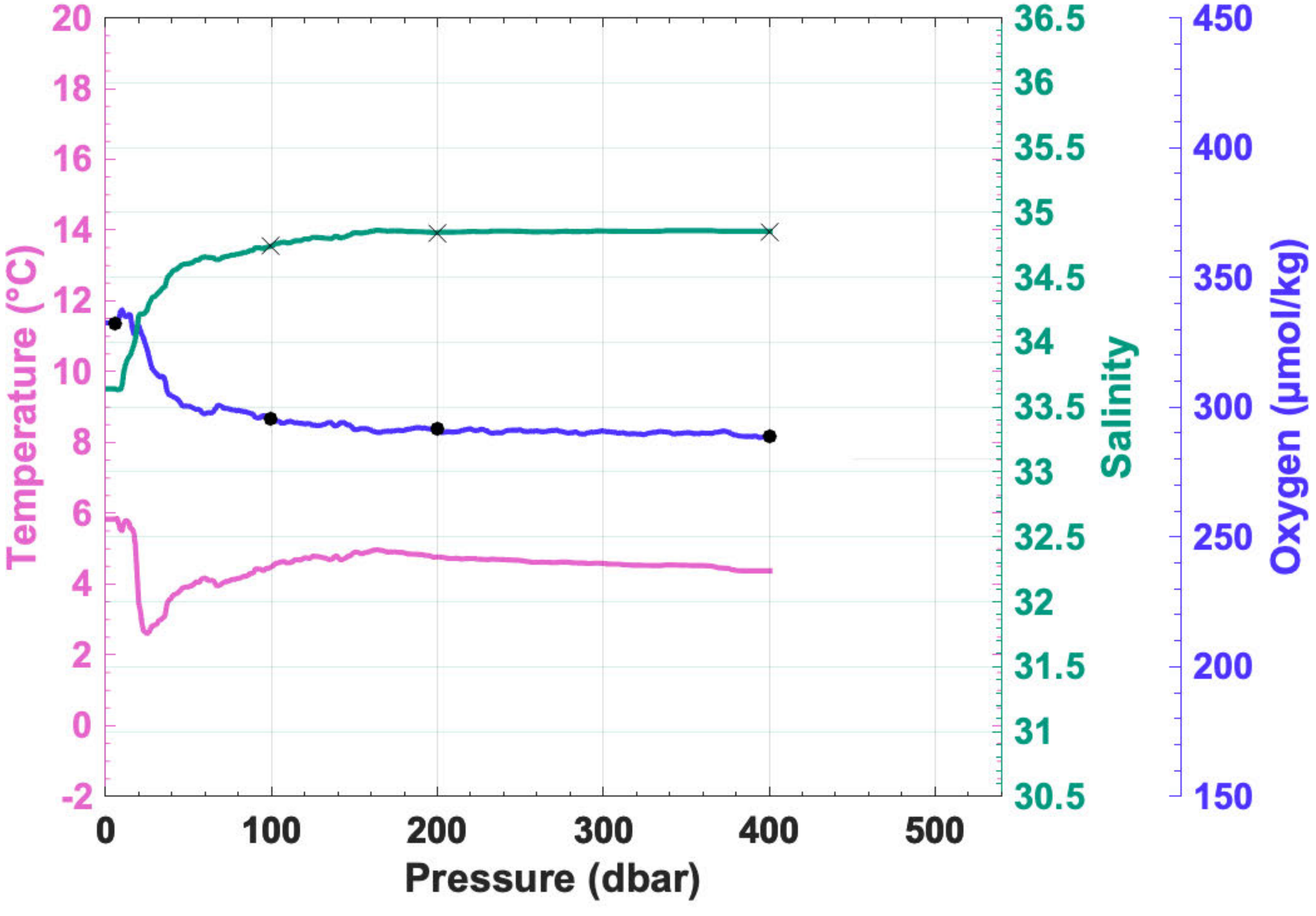


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 117

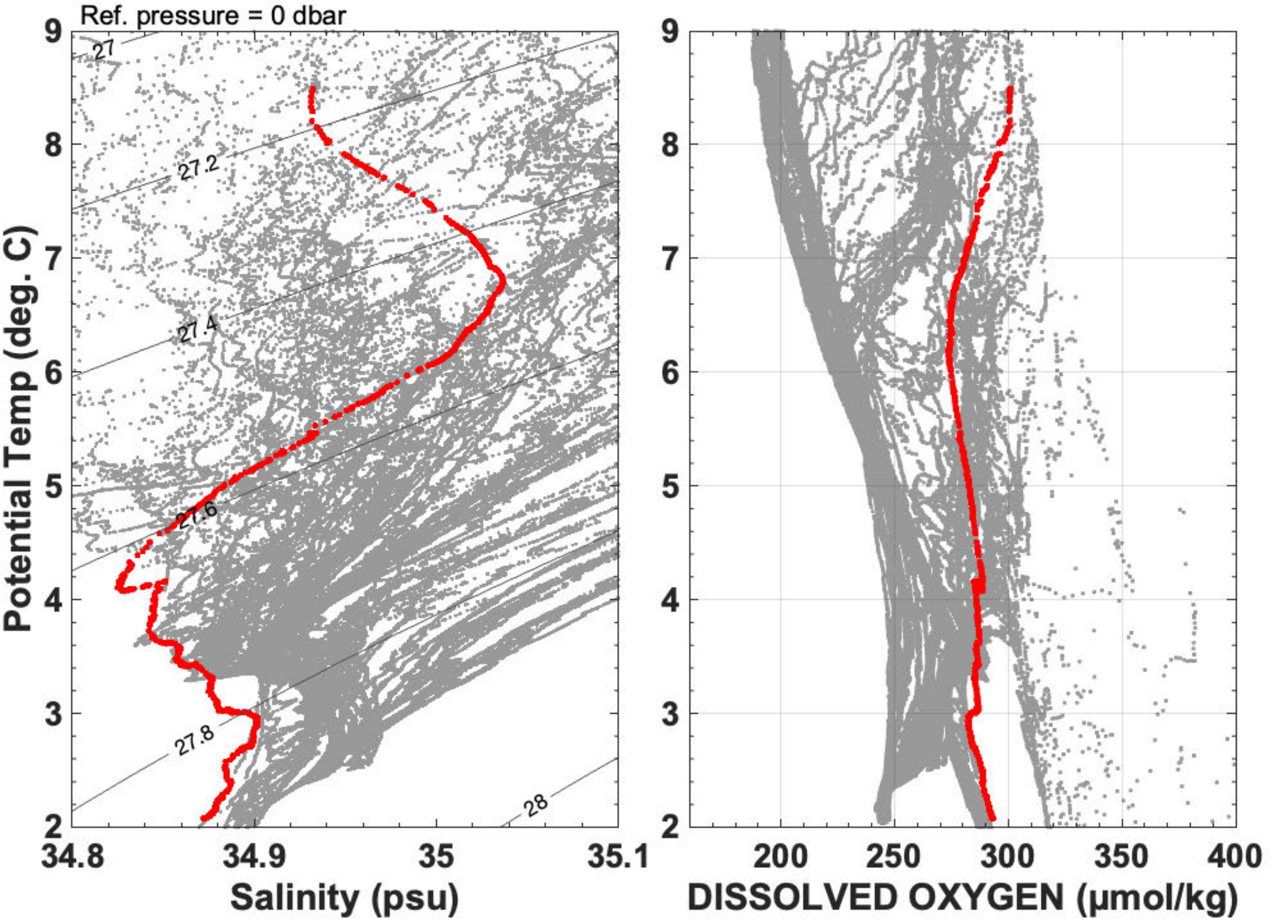


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
DISSOLVED OXYGEN (µmol/kg)

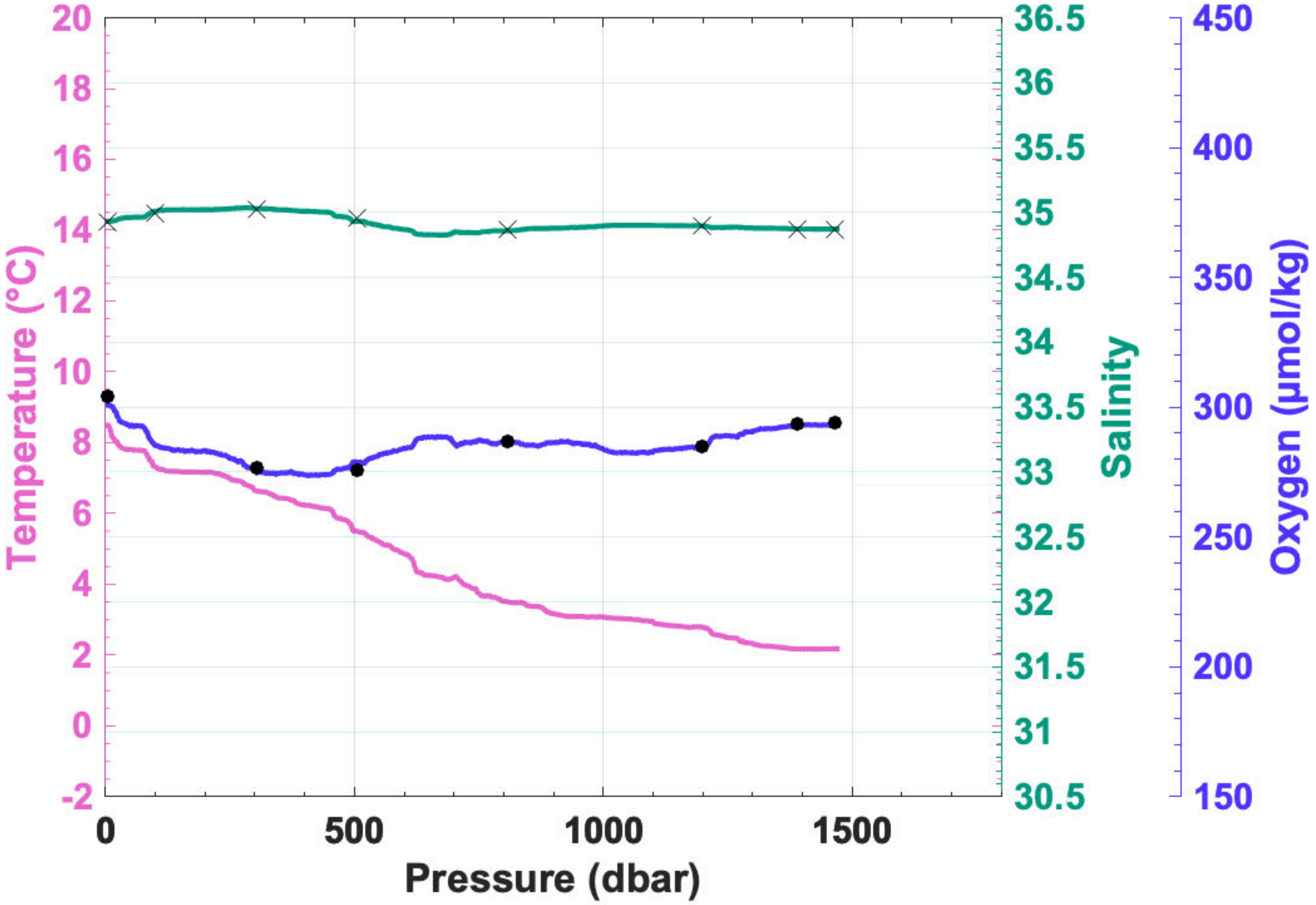


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 120

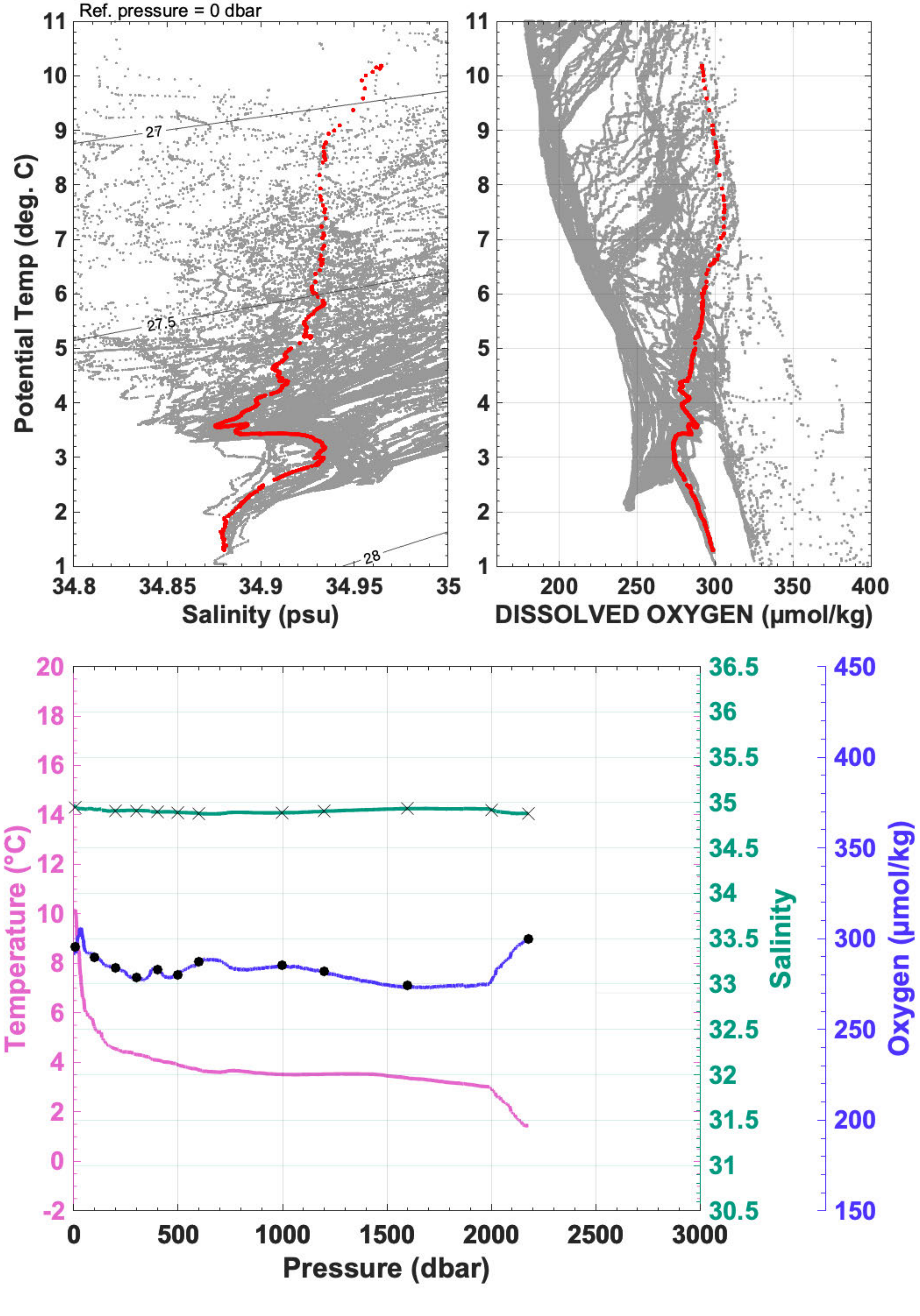


Ref. pressure = 0 dbar
27
27.2
27.4
27.6
27.8
28
Potential Temp (deg. C)
Salinity (psu)
DISSOLVED OXYGEN (µmol/kg)



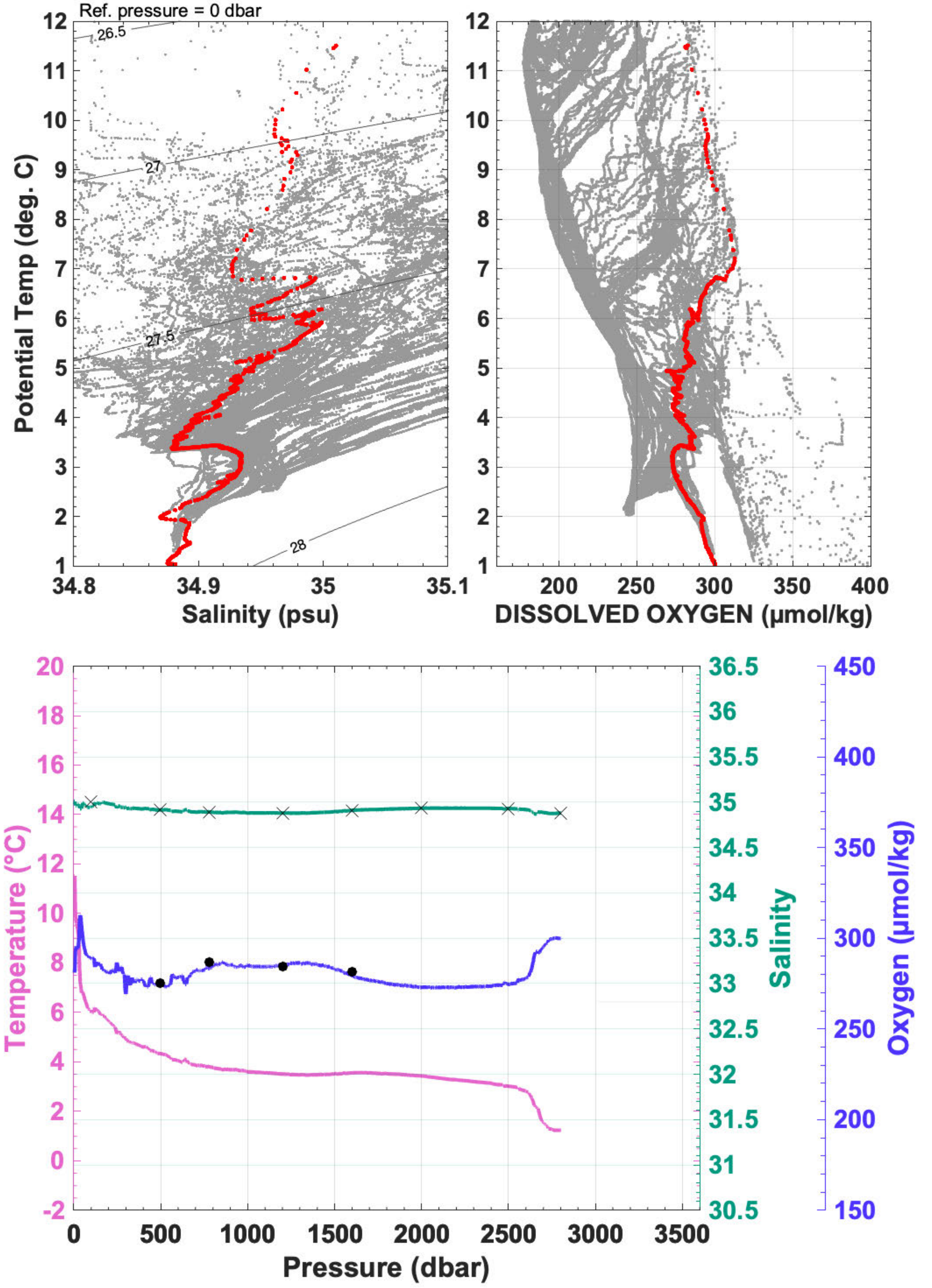
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 121



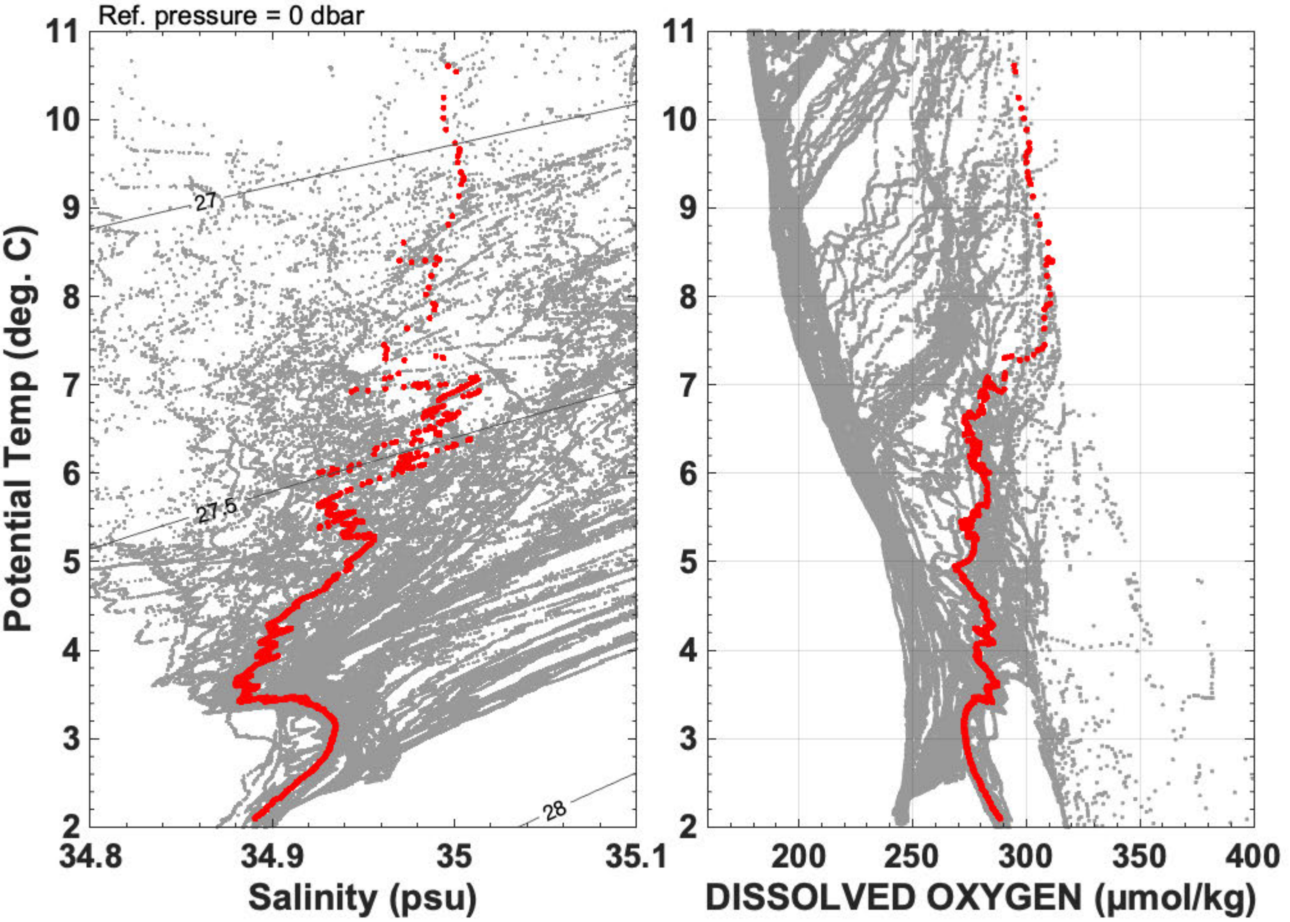
Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 122

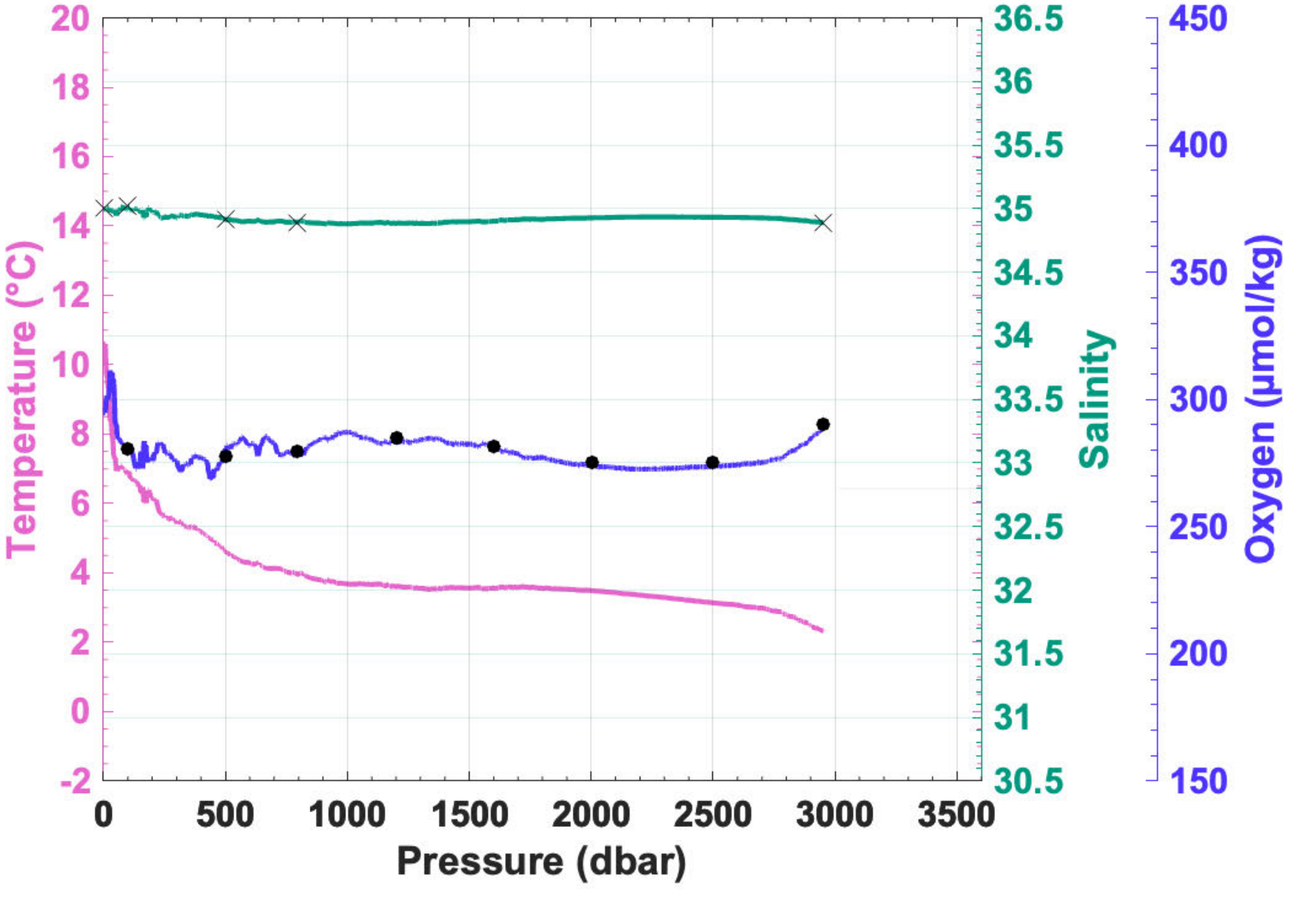


Ref. pressure = 0 dbar
26.5
27
27.5
28
Potential Temp (deg. C)
Salinity (psu)
34.8
34.9
35
35.1
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

STATION 123

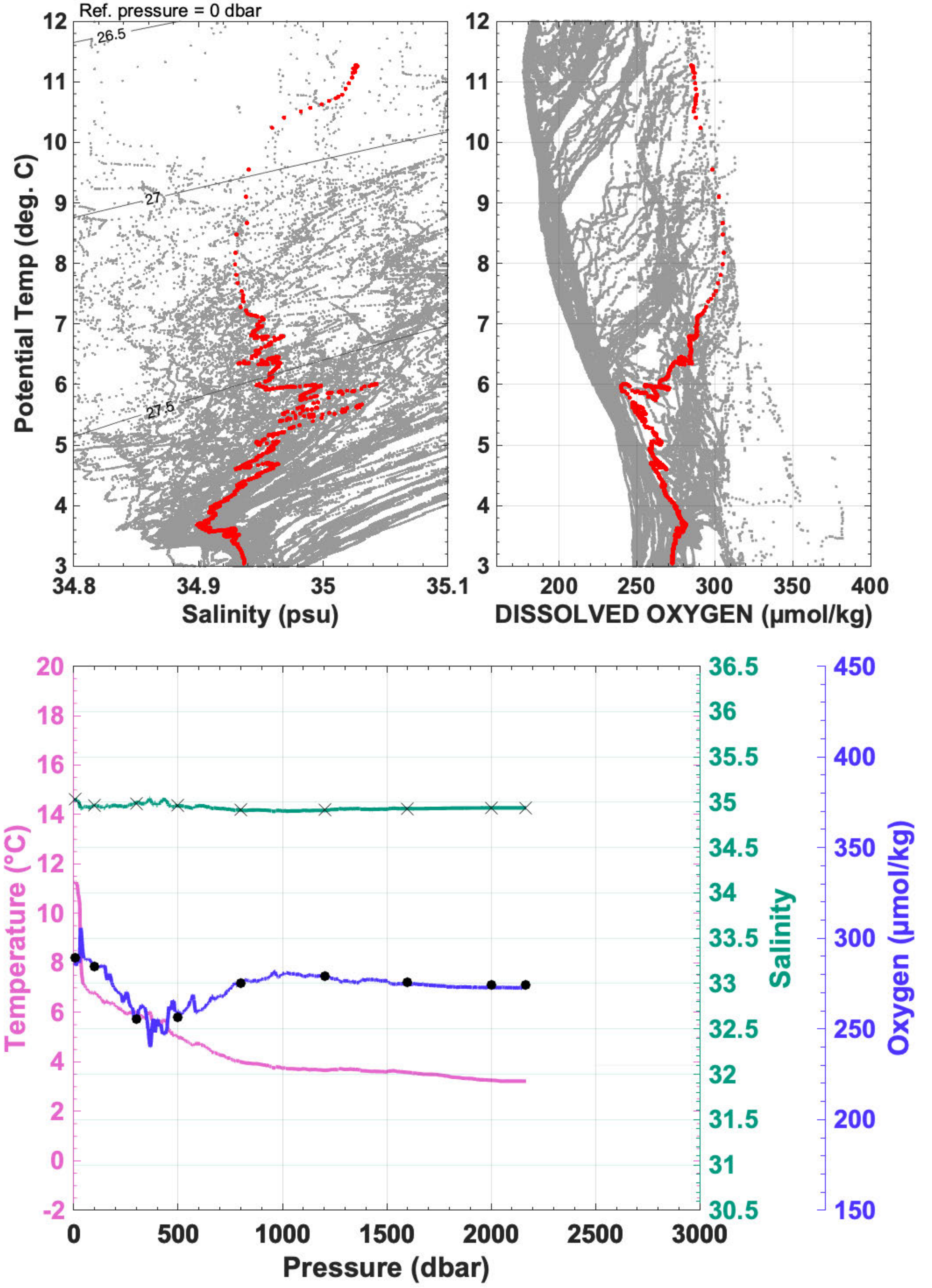


Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
27
27.5
28
DISSOLVED OXYGEN (µmol/kg)

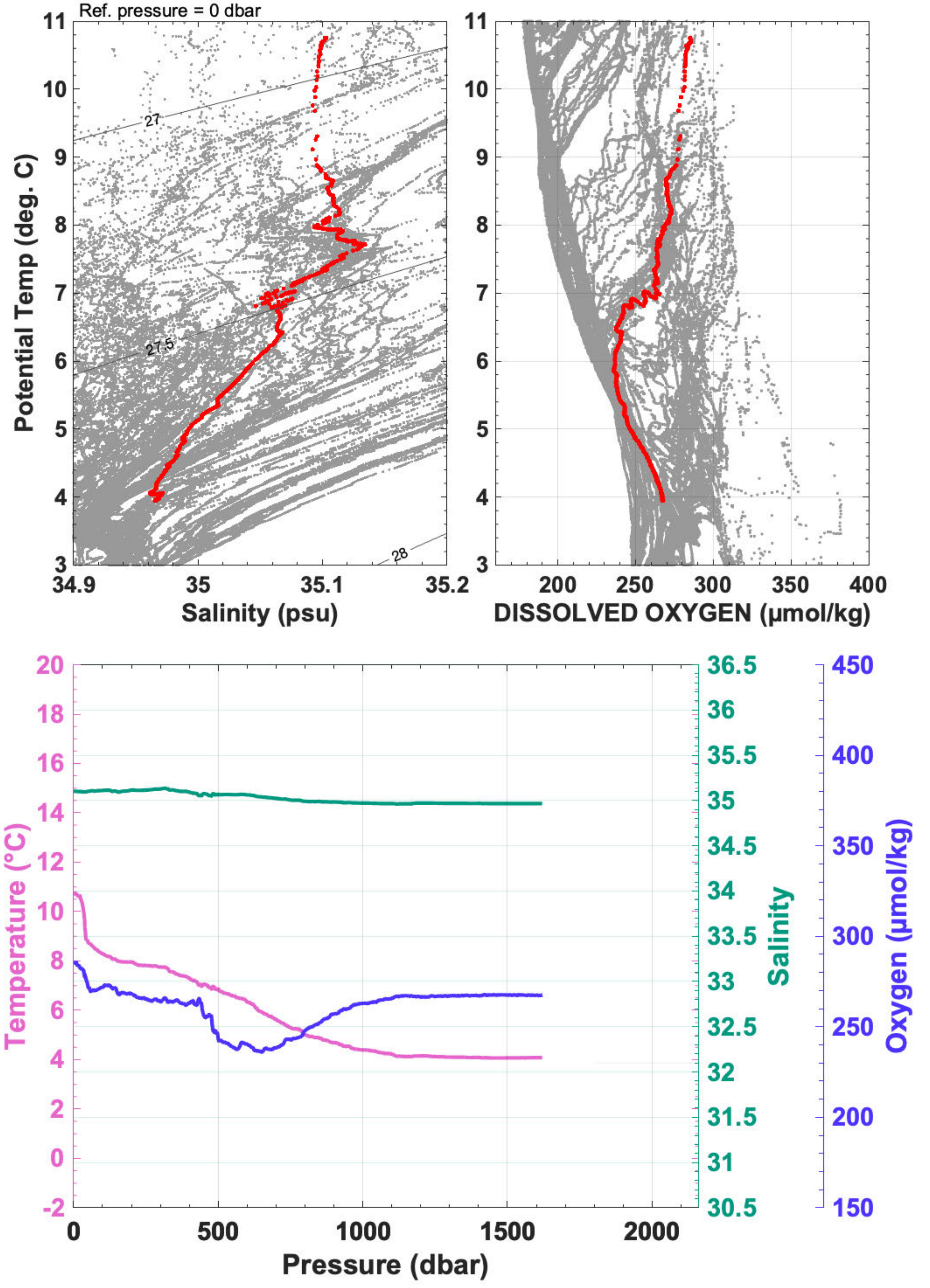


Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)

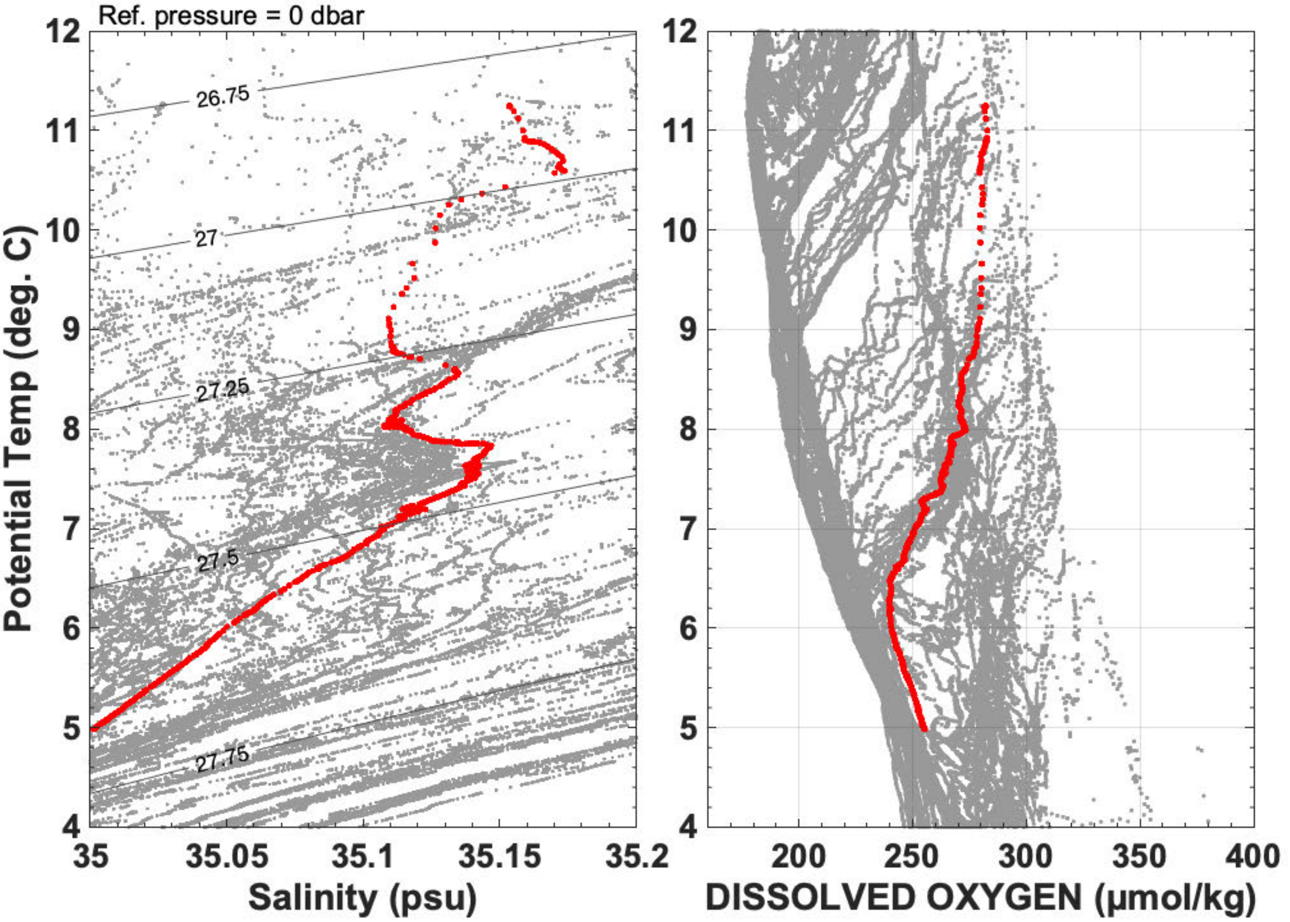
STATION 124


Ref. pressure = 0 dbar
26.5
27
27.5
Potential Temp (deg. C)
Salinity (psu)
34.8
34.9
35
35.1
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400
Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
0
500
1000
1500
2000
2500
3000

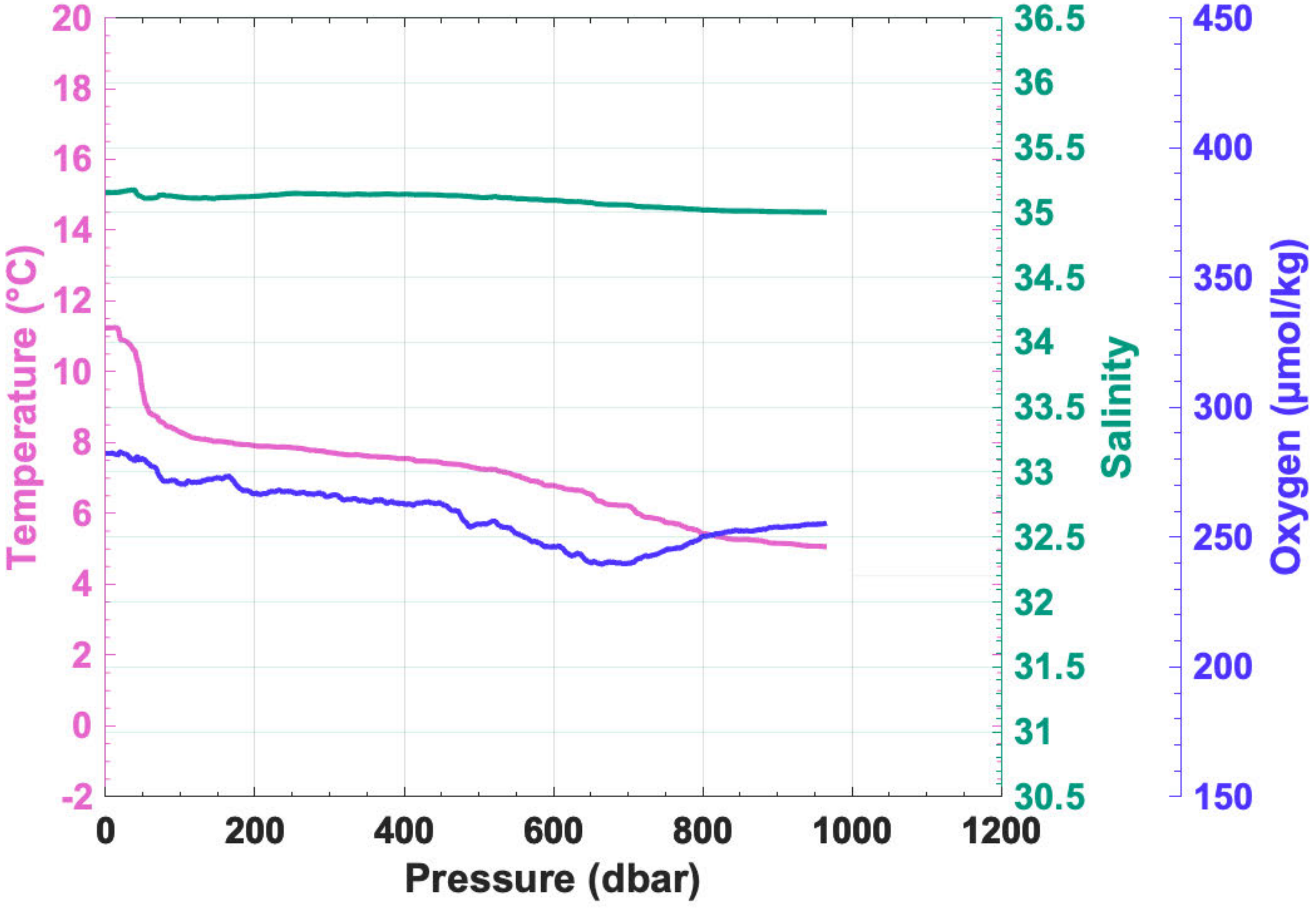
STATION 125


Ref. pressure = 0 dbar
Potential Temp (deg. C)
11
10
9
8
7
6
5
4
3
27
27.5
28
34.9
35
35.1
35.2
Salinity (psu)
200
250
300
350
400
DISSOLVED OXYGEN (µmol/kg)
Temperature (°C)
20
18
16
14
12
10
8
6
4
2
0
-2
Salinity
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
Oxygen (µmol/kg)
450
400
350
300
250
200
150
0
500
1000
1500
2000
Pressure (dbar)

STATION 126



Ref. pressure = 0 dbar
Potential Temp (deg. C)
Salinity (psu)
26.75
27
27.25
27.5
27.75
12
11
10
9
8
7
6
5
4
35
35.05
35.1
35.15
35.2
DISSOLVED OXYGEN (µmol/kg)
200
250
300
350
400



Temperature (°C)
Salinity
Oxygen (µmol/kg)
Pressure (dbar)
20
18
16
14
12
10
8
6
4
2
0
-2
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
450
400
350
300
250
200
150
0
200
400
600
800
1000
1200