

## **Cruise report**

**The impact of localized VERTical MIXing over the nutricline  
on plankton diversity, primary production and ecosystem  
structure**

## **VERMIX**

*R/V DANA 12 - 31 July 2016*

R/V DANA Cruise ID. 2322

Cruise leader Katherine Richardson, University of Copenhagen

Cruise area Skagerrak/Nordsøen

Port of departure Hirtshals 12 July 2016

Port of arrival Hirtshals 31 July 2016

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\*First half of cruise only (12 - 21 July 2016)

\*\* Second half of cruise only (22-31 July 2016)

Scientific goals of the cruise

1. To identify regions of vertical mixing across the nutricline in a region of the seasonally stratified North Sea.
2. To quantify the influence of vertical mixing over the nutricline on phytoplankton photosynthesis in the Deep Chlorophyll Maximum (DCM).
3. To quantify the influence of vertical mixing over the nutricline on diversity of phytoplankton in the DCM.
4. To identify potential differences in the distribution and/or productivity of zooplankton in regions experiencing vertical mixing over the nutricline compared to regions where mixing is not occurring.
5. To assess the usefulness of stable isotopes to identify differences in plankton food web structure.
6. To investigate the potential role of small and mesoscale oceanographic features in controlling phytoplankton diversity.
7. To map the occurrence of photoinhibition in natural phytoplankton populations.

Cruise summary

The course of the cruise followed the cruise plan with two exceptions: owing to failure of the fast repetition rate fluorometer on the first station, a replacement instrument was flown to Denmark. Collection of the instrument required a pause in the sampling program in order to sail in to Thyberøn. Fortunately, this harbor visit could be combined with the need for an unplanned change in the ship's personnel. In addition, some working time was lost due to problems with the hydraulics and winches on the hydrography deck. These problems were solved in harbor (Hirtshals) between the two cruise legs.

The weather conditions were good except for windy conditions during the first week. Stations were located in the Skagerrak/North Sea area along five North-South directed transects with a distance between stations of 10 km. On two Focus Transects, i.e., transect two and four, the distance between stations was shorter (down to ~ 1 km) for resolving the characteristics of the spatial variability. In general, measurements at the stations included one or several CTD-casts where water samples were collected from Niskin bottles mounted on the rosette. Stations activities also included measurements of turbulence and microstructure profiles with a VMP-250, sampling with plankton net and WP2-net for zooplankton. Sampling with multi-net took place during nighttime at stations previously visited during the day. Acoustic signals were retrieved from the water column in order to determine distributions of sound-reflecting particles (fish and zooplankton) to be ground-truthed with the zooplankton samples. Three continuous transects of the upper 50 m were made with an underway CTD. A sediment trap mooring collected particulate material for about 24 hours at three stations. Acoustic measurements were made of zooplankton size distributions and an acoustic doppler current profiler (ADCP) was measuring continuously during most of the cruise. Two time series-stations were occupied for 24-36 hours where measurements were carried out at hourly intervals.

Water samples were taken for determination of primary production ( $^{14}\text{C}$  measurements carried out on board), photosynthetic electron transport capacity (Fv/Fm), chlorophyll and nutrient concentrations. In addition, phytoplankton samples were taken for molecular genetic and microscopic analyses on shore.

## Summary of cruise activities:

<b>Stations and transects</b>	<b>Number</b>
CTD stations	132
Transects	5
<b>Specific activities</b>	<b>Number of casts</b>
CTD casts	228
Turbulence casts	118
Multinet casts	53
Plankton net casts	143
WP2 casts	22
Sediment trap moorings	3
U-CTD sections	3

Scientific equipment

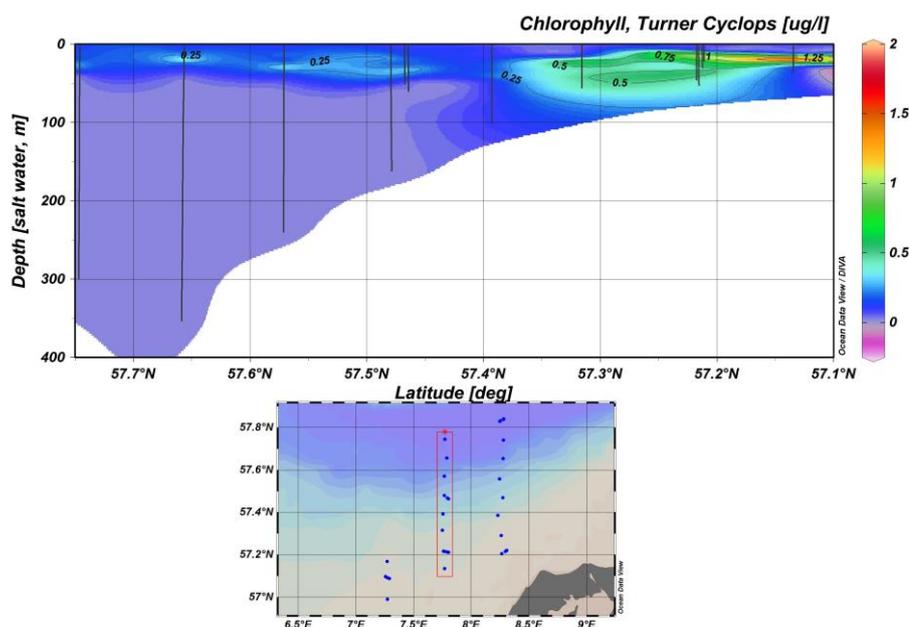
A CTD equipped with fluorometer and oxygen sensors was mounted on a rosette with 12 Niskin bottles. ADCP-data was obtained from the ship-mounted instrument (75 kHz). Continuous intake of surface water measured temperature, salinity and fluorescence. The echo sounder on the ship provided information about bathymetry along the transects. The Underway CTD (U-CTD) was applied in yo-yo mode along three transects where it continuously measured temperature, salinity and pressure in the upper 50 m. Several casts with a VMP-250 (Rockland Science) turbulence profiler was conducted at the CTD-stations and at time series stations the profiler was applied continuously for up to four hours. Plankton net and WP2 were taken after CTD casts at selected stations. Multinet was used at stations during nighttime.

### Water samples

Water samples for nutrients ( $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{NH}_4^+$ , Si,  $\text{PO}_4^{3-}$ ), TN, TP, chlorophyll a, fractionated chlorophyll a were taken regularly at several depths at the CTD stations. Water samples for stable nitrogen isotopes were taken at selected stations. Samples for phytoplankton identification and samples for e-DNA were taken at selected stations and depth levels. Water samples were analyzed for Fv/Fm and incubations were made for calculating primary production.

### Preliminary results

Preliminary results from the CTD, turbulence profiler and the Fv/Fm were analyzed during the cruise. An example is shown below from transect two across the slope towards the deeper part of the Norwegian Trench. Measurements of fluorescence indicate increased chlorophyll concentration above the more shallow part of the transect (chlorophyll a values are preliminary and will be calibrated against measurements of chlorophyll a from water samples).



*Figure shows the preliminary un-calibrated chlorophyll a concentration along transect 2. CTD stations and transects*

CTD stations were numbered in succession. The station ID also identified the transect number. For example, station number 12 was located along transect number 2 and the station ID then became 2.12. The CTD station list below includes the starting position and time of the first CTD cast at that station. Several CTD cast were made at some stations and in that case the CTD-cast was identified by its activity number.

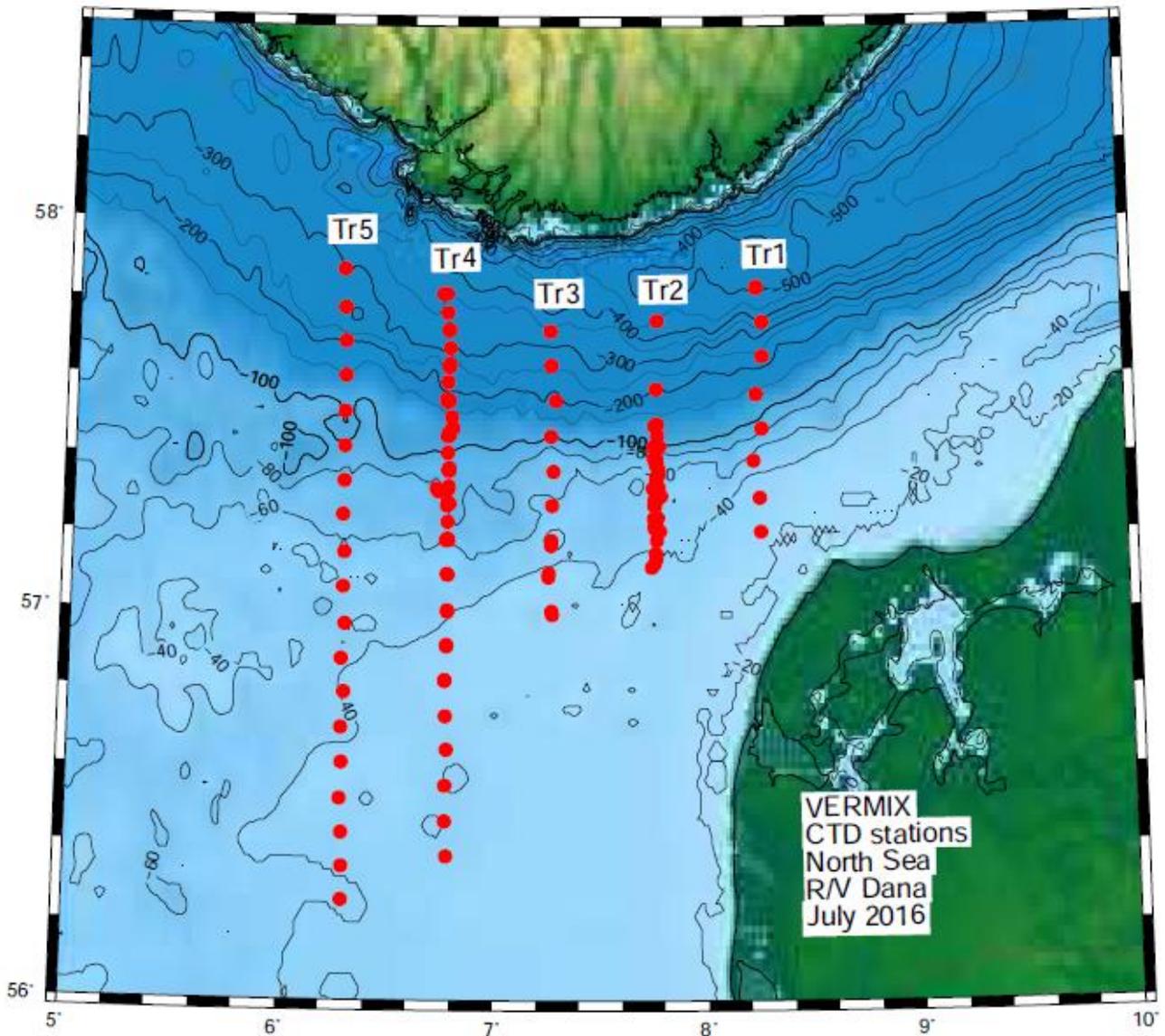


Figure of CTD stations along the five transects.

CTD stationlist

<b>Activity</b>	<b>timeStart</b>	<b>posLatStart</b>	<b>posLonStart</b>	<b>Depth</b>	<b>Station ID</b>
1	2016-07-12T13:51:51	57.12.243 N	008.15.587 E	31.8	1 1.1
6	2016-07-12T16:57:22	57.17.454 N	008.15.337 E	37.1	2 1.2
7	2016-07-12T17:53:51	57.23.158 N	008.13.591 E	55.5	3 1.3
10	2016-07-12T19:19:19	57.28.109 N	008.16.022 E	92.7	4 1.4
12	2016-07-13T04:21:52	57.33.414 N	008.14.473 E	161.6	5 1.5
14	2016-07-13T06:27:35	57.39.232 N	008.16.271 E	240.0	6 1.6
16	2016-07-13T08:17:09	57.44.497 N	008.16.312 E	432.4	7 1.7
18	2016-07-13T10:15:52	57.49.946 N	008.14.816 E	33.2	8 1.8
24	2016-07-13T16:29:44	57.44.734 N	007.46.113 E	464.3	9 2.9
27	2016-07-13T20:50:32	57.49.754 N	008.14.709 E	516.7	11 1.11
34	2016-07-14T04:22:38	57.34.225 N	007.45.819 E	247.2	12 2.12
36	2016-07-14T06:20:17	57.28.774 N	007.45.698 E	165.2	13 2.13
42	2016-07-14T09:19:09	57.23.583 N	007.45.083 E	106.4	14 2.14
44	2016-07-14T10:28:10	57.18.922 N	007.44.798 E	61.7	15 2.15
46	2016-07-14T11:41:17	57.13.037 N	007.45.285 E	55.7	16 2.16
51	2016-07-14T13:43:39	57.08.080 N	007.45.786 E	43.9	17 2.17
53	2016-07-14T16:18:25	56.59.484 N	007.16.161 E	33.1	18 3.18
54	2016-07-14T17:37:11	57.05.857 N	007.15.216 E	36.9	19 3.19
57	2016-07-14T19:41:43	57.10.157 N	007.15.871 E	58.8	20 3.20
59	2016-07-15T04:15:22	57.12.969 N	007.45.971 E	56.5	21 2.21
64	2016-07-15T17:45:11	57.06.771 N	007.44.480 E	41.5	22 2.22
67	2016-07-15T19:12:28	57.08.950 N	007.45.579 E	45.3	23 2.23
75	2016-07-16T04:13:44	57.10.922 N	007.45.949 E	52.5	25 2.25
80	2016-07-16T06:36:39	57.12.348 N	007.46.849 E	54.1	26 2.26
84	2016-07-16T07:43:41	57.14.415 N	007.46.225 E	51.7	27 2.27
88	2016-07-16T08:56:48	57.16.184 N	007.45.429 E	54.4	28 2.28
92	2016-07-16T10:54:52	57.16.301 N	007.45.214 E	54.2	29 2.29
96	2016-07-16T12:06:17	57.16.976 N	007.45.463 E	58.3	30 2.30
102	2016-07-16T13:53:51	57.18.229 N	007.46.419 E	61.1	31 2.31
109	2016-07-16T16:29:49	57.19.061 N	007.46.521 E	60.9	32 2.32
115	2016-07-16T18:05:15	57.20.109 N	007.45.761 E	68.9	33 2.33
121	2016-07-16T19:16:21	57.20.983 N	007.46.294 E	71.8	34 2.34
123	2016-07-16T21:01:45	57.28.528 N	007.45.318 E	163.1	35 2.35
132	2016-07-17T04:27:47	57.21.770 N	007.46.442 E	73.2	36 2.36
140	2016-07-17T06:41:18	57.22.750 N	007.46.000 E	86.6	37 2.37
145	2016-07-17T08:04:17	57.23.477 N	007.45.861 E	104.8	38 2.38
153	2016-07-17T10:58:12	57.25.365 N	007.46.685 E	121.6	39 2.39
159	2016-07-17T12:37:59	57.27.053 N	007.46.110 E	141.6	40 2.40
167	2016-07-17T14:56:51	57.28.801 N	007.46.095 E	165.9	41 2.41
170	2016-07-17T21:50:44	57.07.296 N	007.45.279 E	40.6	42 2.42
178	2016-07-18T04:33:04	57.00.027 N	007.15.994 E	33.8	43 3.43
185	2016-07-18T06:25:55	57.05.286 N	007.15.107 E	34.0	44 3.44
193	2016-07-18T08:24:03	57.10.921 N	007.15.924 E	60.7	45 3.45
200	2016-07-18T10:34:48	57.16.312 N	007.16.127 E	62.0	46 3.46
207	2016-07-18T12:25:27	57.21.543 N	007.16.474 E	92.5	47 3.47
212	2016-07-18T14:08:44	57.26.956 N	007.15.749 E	131.3	48 3.48
<b>Activity</b>	<b>timeStart</b>	<b>posLatStart</b>	<b>posLonStart</b>	<b>Depth</b>	<b>Station ID</b>

221	2016-07-18T16:55:16	57.32.430 N	007.17.172 E	246.7	49	3.49
233	2016-07-19T04:51:38	57.37.858 N	007.15.792 E	299.6	50	3.50
239	2016-07-19T06:53:13	57.43.145 N	007.15.508 E	360.2	51	3.51
247	2016-07-19T10:49:00	57.48.834 N	006.45.673 E	359.4	52	4.52
253	2016-07-19T13:27:44	57.43.278 N	006.46.499 E	321.5	53	4.53
255	2016-07-19T15:23:03	57.37.573 N	006.46.545 E	313.4	54	4.54
260	2016-07-19T17:39:06	57.32.652 N	006.45.934 E	171.8	55	4.55
271	2016-07-20T04:53:41	57.26.935 N	006.46.233 E	124.2	56	4.56
275	2016-07-20T06:33:02	57.21.716 N	006.46.448 E	95.6	57	4.57
283	2016-07-20T08:40:54	57.16.539 N	006.46.869 E	71.6	58	4.58
288	2016-07-20T10:53:04	57.10.930 N	006.45.927 E	65.7	59	4.59
292	2016-07-20T18:56:17	57.25.312 N	007.45.061 E	120.1	61	2.61
305	2016-07-21T11:34:25	57.17.248 N	007.45.347 E	58.0	62	2.62
317	2016-07-21T17:56:05	57.25.554 N	007.45.652 E	123.5	63	2.63
320	2016-07-21T21:56:04	57.17.762 N	007.47.183 E	58.5	64	2.64
324	2016-07-22T18:31:58	57.17.204 N	007.45.983 E	57.5	65	2.65
327	2016-07-22T19:53:39	57.12.690 N	007.45.440 E	54.7	66	2.66
329	2016-07-22T20:43:06	57.14.323 N	007.45.119 E	51.5	67	2.67
331	2016-07-22T21:43:46	57.18.889 N	007.45.451 E	60.4	68	2.68
333	2016-07-22T22:32:24	57.20.723 N	007.45.843 E	71.9	69	2.69
335	2016-07-22T23:19:00	57.22.546 N	007.45.721 E	83.8	70	2.70
337	2016-07-23T00:11:55	57.25.131 N	007.45.521 E	118.2	71	2.71
338	2016-07-23T06:14:49	56.49.387 N	006.45.935 E	37.0	72	4.72
349	2016-07-23T11:36:39	56.54.547 N	006.46.334 E	39.4	73	4.73
352	2016-07-23T12:51:01	56.59.920 N	006.46.504 E	45.6	74	4.74
354	2016-07-23T13:55:20	57.05.593 N	006.46.537 E	57.9	75	4.75
356	2016-07-23T15:08:48	57.10.943 N	006.46.698 E	65.6	76	4.76
358	2016-07-23T16:19:40	57.16.274 N	006.46.140 E	71.5	77	4.77
360	2016-07-23T17:26:03	57.21.571 N	006.46.666 E	96.2	78	4.78
362	2016-07-23T18:38:20	57.27.060 N	006.46.706 E	126.4	79	4.79
364	2016-07-23T19:57:15	57.32.241 N	006.46.134 E	172.8	80	4.80
368	2016-07-24T04:18:45	57.28.166 N	006.47.720 E	128.3	81	4.81
372	2016-07-24T06:30:15	57.37.765 N	006.46.683 E	319.8	82	4.82
377	2016-07-24T09:08:12	57.43.340 N	006.46.429 E	321.6	83	4.83
380	2016-07-24T10:45:33	57.48.812 N	006.44.718 E	356.2	84	4.84
385	2016-07-24T14:23:12	57.52.549 N	006.16.149 E	307.2	85	5.85
389	2016-07-24T17:00:14	57.46.637 N	006.16.473 E	280.7	86	5.86
391	2016-07-24T18:32:29	57.41.485 N	006.16.776 E	267.2	87	5.87
393	2016-07-24T19:59:58	57.36.177 N	006.16.885 E	154.6	88	5.88
397	2016-07-25T03:24:26	57.28.176 N	006.47.507 E	128.1	89	5.89
400	2016-07-25T06:19:32	57.30.651 N	006.16.781 E	92.4	90	5.90
404	2016-07-25T07:44:44	57.25.336 N	006.16.844 E	88.8	91	5.91
407	2016-07-25T09:28:35	57.19.992 N	006.16.865 E	76.9	92	5.92
410	2016-07-25T10:48:37	57.14.817 N	006.16.623 E	73.9	93	5.93
413	2016-07-25T12:36:34	57.09.030 N	006.17.161 E	68.7	94	5.94
416	2016-07-25T14:18:19	57.03.694 N	006.16.944 E	63.3	95	5.95
421	2016-07-25T16:14:58	56.58.008 N	006.17.565 E	55.2	96	5.96
<b>Activity</b>	<b>timeStart</b>	<b>posLatStart</b>	<b>posLonStart</b>	<b>Depth</b>	<b>Station ID</b>	

424	2016-07-25T17:42:55	56.52.593 N	006.16.691 E	50.1	97	5.97
434	2016-07-26T04:26:54	56.47.464 N	006.17.523 E	50.1	98	5.98
437	2016-07-26T06:06:43	56.42.009 N	006.16.821 E	50.5	99	5.99
441	2016-07-26T07:37:36	56.36.633 N	006.17.153 E	45.7	100	5.100
445	2016-07-26T09:06:30	56.31.067 N	006.16.775 E	37.9	101	5.101
448	2016-07-26T10:24:10	56.25.832 N	006.17.361 E	41.5	102	5.102
451	2016-07-26T11:39:00	56.20.630 N	006.17.569 E	46.8	103	5.103
454	2016-07-26T13:18:40	56.15.436 N	006.17.596 E	43.5	104	5.104
457	2016-07-26T15:24:00	56.22.220 N	006.46.680 E	40.4	105	4.105
460	2016-07-26T16:43:40	56.27.613 N	006.46.227 E	43.8	106	4.106
464	2016-07-26T18:43:29	56.33.116 N	006.46.230 E	40.9	107	4.107
466	2016-07-26T19:43:23	56.38.662 N	006.46.549 E	41.8	108	4.108
472	2016-07-27T04:10:05	56.43.822 N	006.46.187 E	41.7	109	4.109
475	2016-07-27T06:11:40	56.49.232 N	006.45.888 E	37.5	110	4.110
479	2016-07-27T07:29:39	56.54.818 N	006.46.331 E	43.1	111	4.111
481	2016-07-27T08:32:31	57.00.145 N	006.46.473 E	45.5	112	4.112
484	2016-07-27T10:10:07	57.05.771 N	006.46.291 E	59.2	113	4.113
487	2016-07-27T11:19:58	57.11.219 N	006.46.364 E	65.8	114	4.114
489	2016-07-27T12:17:20	57.13.772 N	006.46.392 E	68,0	115	4.115
491	2016-07-27T13:12:46	57.16.755 N	006.46.409 E	73.2	116	4.116
493	2016-07-27T14:02:52	57.19.237 N	006.46.635 E	82.1	117	4.117
496	2016-07-27T15:03:35	57.22.069 N	006.46.705 E	96.7	118	4.118
498	2016-07-27T16:11:17	57.24.389 N	006.46.271 E	116.3	119	4.119
501	2016-07-27T17:21:50	57.27.394 N	006.46.481 E	122.6	120	4.120
503	2016-07-27T18:32:55	57.29.875 N	006.47.353 E	166.4	121	4.121
505	2016-07-27T19:37:31	57.32.460 N	006.46.754 E	174.4	122	4.122
510	2016-07-28T04:18:12	57.35.246 N	006.46.164 E	201,0	123	4.123
513	2016-07-28T06:24:45	57.38.039 N	006.46.667 E	320.1	124	4.124
515	2016-07-28T07:46:36	57.40.491 N	006.46.792 E	301.8	125	4.125
518	2016-07-28T09:14:33	57.43.241 N	006.46.493 E	321.9	126	4.126
523	2016-07-28T11:22:04	57.45.951 N	006.45.944 E	339.3	127	4.127
529	2016-07-29T05:16:14	57.18.893 N	006.43.146 E	84,0	129	4.129
530	2016-07-29T06:23:06	57.18.714 N	006.46.411 E	82,0	130	4.130
567	2016-07-30T03:48:14	57.18.444 N	006.43.691 E	81,0	131	4.131
568	2016-07-30T04:57:14	57.18.787 N	006.46.015 E	82.8	132	4.132

Time series stations, sediment traps and UCTD sections.

CTD casts, turbulence profiles and water samples were taken repeatedly at hourly intervals at the two time series stations. Three moorings with sediment traps were sampled during the cruise. UCTD transects were located at subsections of transect 2 and 4.

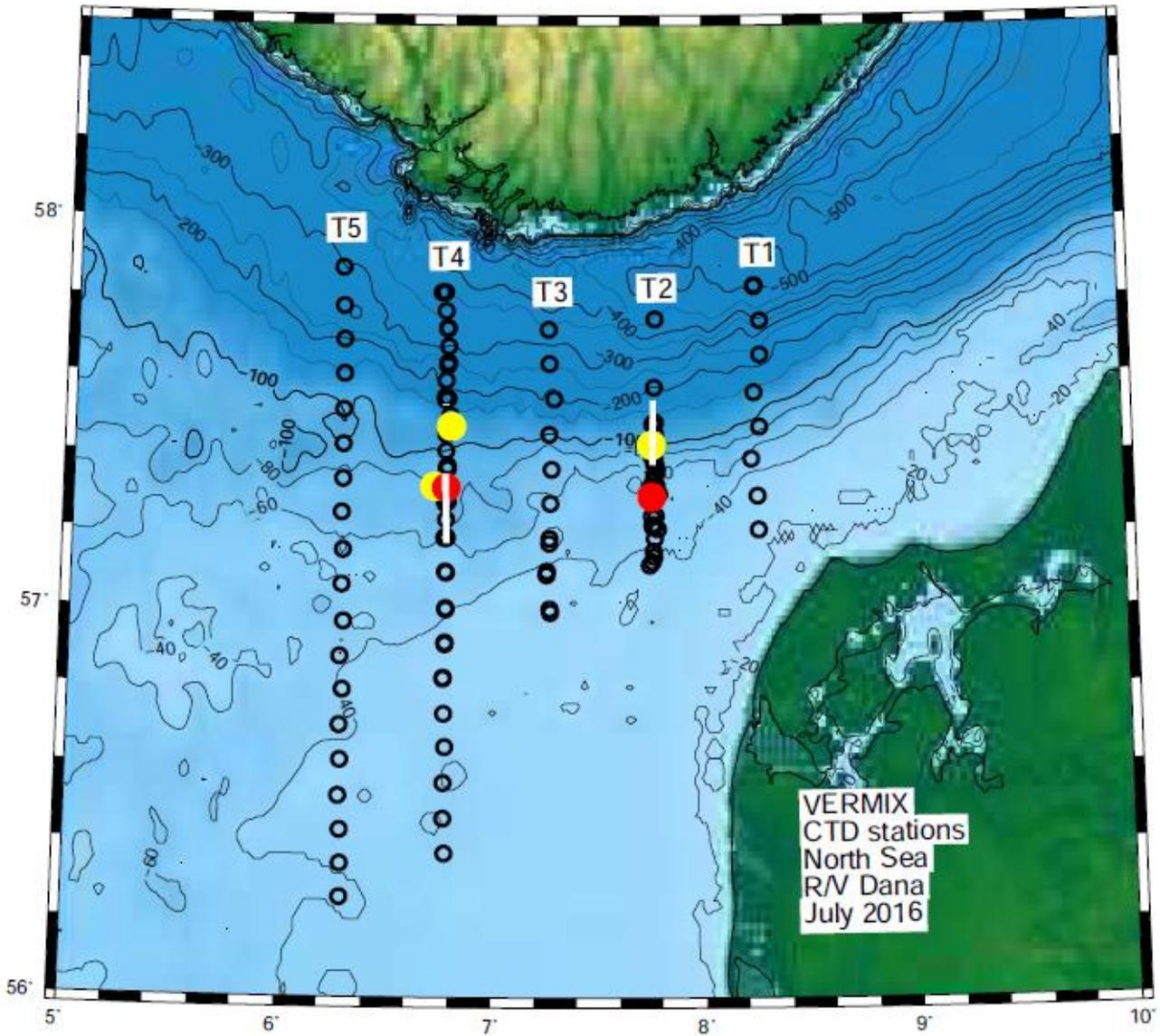


Figure showing locations of Time series stations (red bullets), sediment trap moorings (yellow bullets) and sections where UCTD measured continuously in the upper 50 m (white lines). Open circles show the locations of all CTD stations.