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DRIFTER OBSERVATIONS IN THE NORDIC SEAS (1991-1995) DATA REPORT

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Director

Drifter Observations in the Nordic Seas (1991-1995): Data Report

P.-M. Poulain, P. Zanasca and A. Warn-Varnas

Executive Summary: This memorandum describes the data acquired during the SACLANTCEN Nordic Seas Drifter Programme for subsequent scientific analyses.

The drifter programme was a part of the Greenland-Iceland-Norwegian (GIN) Sea Project the aim of which was to develop an understanding of the complex physical processes causing variability at large, meso- and fine scales. It studied the characteristics and the variability of the near-surface ocean current and temperature in the Nordic seas in support of acoustic ASW and MCM operations.

The majority of drifters were deployed from NRV *Alliance* during hydrographic surveys, providing unique measurements of current and temperature in the complex Iceland-Faeroes frontal structures which were combined with other oceanographic measurements for nowcasting and forecasting of ocean variability.

After their use in the regional frontal zones where they were deployed, the drifters were dispersed by prevailing surface currents to sample most of the ice-free Nordic seas. They provided the first basin scale, accurate, near surface data set from which many important circulation characteristics were discovered, quantified and interpreted. The results of the drifter experiment demonstrate that drifter measurements can be a practical and cost effective alternative to the extensive use of stationary current meters. It is also an advantage of satellite tracked drifters that one need not stay in an area to obtain the oceanographic information. In addition, the drifter temperature measurements have been used *in situ* to validate satellite remotely sensed data.

Drifter Observations in the Nordic Seas (1991-1995): Data Report

P.-M. Poulain, P. Zanasca and A. Warn-Varnas

Abstract: During the period June 1991 to August 1993, 107 Argos tracked drifters drogued to 15 m depth were released in the Nordic seas (or Greenland-Iceland-Norwegian [GIN] sea) to study the variability of the near-surface circulation and temperature fields at scales ranging from a few kilometres (mesoscale) to thousands of kilometres (basin-wide large scale).

An additional data set, extending to April 1995, is described in this report. Full details of the data acquisition systems and data processing are provided to serve as a reference for the analyses published in the scientific literature. Graphics are included in the Annexes to illustrate drifter performance, position and temperature data, and Eulerian statistics.

These drifter measurements comprise the first basin scale, accurate near-surface velocity and temperature *in situ* data over the ice-free Nordic seas. The data from these drifters describe the major circulation features of a large inhospitable ocean area which has an important role in crucial issues such as global heat budget, fisheries and defence.

At smaller scales, the drifter observations were used, in conjunction with hydrographic data, to study the mesoscale structure and dynamics of the complex circulation patterns in the Iceland-Faeroe Frontal zone. The drifter sea surface temperature measurements were also used to validate satellite sea surface temperature data.

Contents

1 Introduction

Several years ago, low cost, Argos tracked, Lagrangian mixed-layer drifters which could easily be deployed from ships of opportunity were developed by the World Climate Research Programme for long term sampling of the upper ocean environment (WCRP-26, 1988). This development afforded an opportunity for SACLANTCEN to begin a comprehensive measurement program of surface currents and sea surface temperature (SST) in support of acoustic Anti-Submarine Warfare (ASW) and Mine Counter Measure (MCM) operations in the Nordic seas. Lagrangian drifters provide a broad, basin-scale, coverage of mesoscale surface circulation and SST structures that can be used to complement ocean acoustic measurements and predictions of operational ocean acoustic environmental models and to study the movement characteristics of water masses. Drifter data are also used to validate satellite sensed oceanic parameters.

Drifter deployments began in June 1991 and by August 1993, 107 drifters had been released from various research vessels and volunteer observing ships. By April 1995, approximately 31,000 days of drifter data had been acquired through Service Argos. This memorandum describes the drifter data obtained from June 1991 to April 1995. The drifter position data were used to construct a velocity data set, from which maps and statistics of the near surface circulation were made. A detailed description of the Nordic seas circulation as measured by the surface drifters can be found in Poulain *et al* (1995). The direct measurements of near-surface currents provided by the drifters deployed in the Iceland-Faeroe Frontal zone complemented extensive sets of hydrographic data that were used to diagnose the frontal dynamics and carry out forecasting exercises of ocean variability (Miller, Arango *et al* 1995 and Miller, Poulain *et al* 1995). The drifter SST data have also been used as ground-truth observations to calibrate satellite SST retrievals (Essen *et al* 1995).

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Data acquisition systems

2.1 DRIFTER HARDWARE

The drifter used in this study is the WOCE/TOGA Lagrangian Drifter (Sybrandy and Niiler, 1991), manufactured by Clearwater Instrumentation, Watertown, Massachusetts, USA (Figs. 1a 1b and 1c). The top flotation element is a small fiberglass sphere (33 cm diameter) housing an Argos transmitter and controller (Telonics ST-5), alkaline battery packs, drogue-presence sensor (sea-water switch and/or strain gauge) and a thermistor for measuring SST. Attached to the surface float is a thin resilient tether terminating in a holey-sock drogue, centered at 15 m nominal depth. The tether is a 0.40 cm steel wire oceanographic cable coated with polyethylene to a diameter of 0.56 cm. A subsurface flotation sphere (20 cm diameter) is attached to the tether about 3 m below the surface to dampen the rapid movement of the drogue assembly, caused by breaking wind waves. The upper segment of tether, between the surface and subsurface spheres, is protected by heavy steel-mesh reinforced hose (1.9 cm diameter). The tether connections to the surface and subsurface floats and to the drogue are protected with cast rubber stress reliefs (carroting).

The sea anchor for the WOCE/TOGA drifter is an eight section holey sock drogue made of Cordura nylon, a plastic-backed fray resistant cloth. The tether is attached to the drogue with a "taut-cross" hub from which extend six radials of the same oceanographic wire as the tether. The size of the drogue (6.41 m by 0.92 m) was chosen such that the drag coefficient times the total frontal area of the drogue divided by the sum of the products of the frontal areas and drag coefficients of the tether and floats, the drag area ratio, R, is about 39 (Fig. 1a). With an R of about 39, the downwind slip of the drogue through water is expected to be less than 0.1% of the wind speed (Niiler *et al* 1995). The climatological winter months' mean resultant wind speed in the area of drifter data is less than 4 m/s (Hopkins, 1991), it follows that the monthly mean wind-induced slip velocity is less than 0.4 cm/s. The drifter data were not corrected for bias introduced by wind produced slip.

The transmission period of the ST-5 transmitter is 90 ± 6 s. The controller samples the thermistor once a minute and calculates an average temperature every 15 minutes. At the time of drifter manufacture, the SST sensor was calibrated to ±0.1°C in the range of -5 to 40°C. The temperature data is transmitted by the ST-5 with 0.1°C accuracy and 0.05°C resolution.

Drogue presence is monitored by timing the submergence of the surface float with a sea-water switch. While the drogue is attached, drag causes the surface sphere to be submerged occasionally. If the drogue has been lost, the surface sphere remains at the surface and is not submerged by waves. When the surface float submerges, the contacts on the top of the sphere are shorted out by the sea water. The ST-5 controller measures the length of time the contacts are shorted and accumulates these values over a 30 minute time period. The submergence number is updated every 30 minutes.

By mid-1992, it became apparent that the sea-water switch on a number of drifters (Table 1) failed to activate, losing thereby its role as an indicator of drogue separation. Drifters deployed after October 1992 (Table 1) were equipped with a strain gauge transducer mounted on the inside of the surface float as a second drogue-presence indicator. Tension on the tether causes small deflections in the fiberglass shell of the surface sphere which are physically transmitted to a small flat square of semiconductor glued to the inside of the sphere adjacent to the tether attachment point. Strain on the sensor causes small changes in resistance in a Wheatstone bridge and this signal i amplified by a signal conditioner which is periodically interrogated by the ST-5 controller. Strain data are sampled every second and their statistics over a 30 minute interval are transmitted. The maximum and minimum values from the previous 30 minute time period are used to divide the strain range into four bins. This dynamic allocation was employed to account for the possibility that a higher sea state would result in a larger range of strain measurements than quiet conditions. The frequency of measurements in the four ranges of strain together with the highest and interval value of the strain measurements are transmitted by the ST-5.

Battery level is also telemetered by the ST-5. For the majority of the drifters, the transmitter reports a non-zero number if battery voltage falls below working levels. A zero value indicates that the battery level is adequate. Some drifters (Table 1) reported the battery level in volts and slow battery discharge can be detected (typically 0.4 volts per month at uninterrupted 90 s transmission periods).

In order to take advantage of a special scientific tariff for Argos tracking and data telemetry in which costs are reduced by a third if transmissions are only active for 24 hours in a 72 hour window, the ST-5 was programmed to transmit according to the following duty cycles (Table 1): (1) The majority of drifters transmitted for 8 hours in every 24 hour period; (2) some drifters deployed in August 1993 had continuous transmissions for 90 days, followed by a cycle with transmissions enabled for 24 hours and disabled for 48 hours in every 3 day time period (Fig. 2).

2.2 ARGOS TRACKING AND DATA TELEMETRY

The Argos Data Collection and Location System (DCLS) installed on the National Oceanographic and Atmospheric Administration (NOAA) polar-orbiting Tiros-N satellites, receives and processes all transmissions of the Argos transmitters visibile during orbit. The satellite orbit is sun-synchronous and has a duration of approximately 101 minutes (14 orbits per day). With the DCLS on two NOAA satellites (with an offset of 75° between orbital planes) the mean number of passes per 24 hours over a site near latitudes 65°N and 75°N is 22 and 28, respectively. Each time a satellite passes over a telemetry ground station of the Argos ground system, the DCLS downlinks the recorded data.

Platform location is determined by calculation of the Doppler effect on received frequencies. A given Doppler frequency shift corresponds to a field in the form of a half-cone with the satellite at its apex. The intersection of the various location cones obtained during the satellite overpass with the sea surface gives two possible positions for the transmitter. This ambiguity is removed using additional information, such as previous location and range of possible speeds. Prior to position calculation geometric tests are carried out to eliminate platforms for which an acceptable degree of accuracy cannot be guaranteed. The main causes of rejection are: (1) excessive erroneous frequency shift, (2) unsatisfactory convergence due to noisy platform oscillator and (3) unacceptable distance from ground track (platforms too close and too far from the ground track cannot be located accurately). The mean number of locations per day in the 60 – 80°N latitude band varies between 10 and 20. We have calculated the distribution of the number of locations per day (Fig. 3) from all the drifters with transmission over a third of a day. The mean is 7 and the most frequent number is 9 fixes over the 8 hour window. The distribution of the number of all fixes with good data collection (including those without location) per day is also depicted in Fig. 3. The mean is 9 and the most probable value is 11 fixes per day. These relatively high statistics show that the sampling rate of the Argos DCLS is optimum for the high latitudes of the Nordic seas. The location accuracy is provided by Service Argos by means of location classes: Classes 3, 2 and 1 correspond to an accuracy better than 150 m, 350 m and 1000 m, respectively.

Drifter data can be obtained *via* the Argos on-line consulation service using, for example, the normal telephone network. In this way the data is available within a few hours from the time of measurement. With our approval, the position and SST drifter data were disseminated in *quasi* real time on the Global Telecommunications System (GTS) to be readily available for injection into weather forecast models of various national meteorological centers. At the end of each month, Service Argos copies the month-long data set onto floppy disks which are mailed to the user.

2.3 DEPLOYMENTS

Most drifters were deployed in their deployment cartons. Because the deployment box is sealed with tape that readily dissolves in water and the on/off magnet is secured with the same paper tape, the box rapidly disintegrates in water releasing the drifter and turning on the Argos transmitter, within an hour from deployment. Drifters were generally carried by two able-bodied seamen and thrown over the side away from ship-generated turbulence while proceeding at normal ship speed. All of the drifters deployed from NRV *Alliance* were checked for good transmission prior to deployment using a portable Telonics receiver by partially opening the deployment box and removing the magnet.

The majority of drifters were released from three deployment sites (Fig. 4). Seasonal releases were made northeast, east (in cold/low-salinity modified Arctic waters) and southeast (in warm/high-salinity North Atlantic waters) off Iceland by scientists of the Marine Research Institute in Reykjavik, Iceland. In August 1991, March and October 1992 and August 1993, drifters were deployed from the NRV *Alliance* during Iceland-Faeroe Front surveys. Seasonal and monthly releases were made in the Norwegian Coastal Current system northwest of Bergen in southwestern Norway by the Norwegian Coast Guard. Several efforts were made to seed the Greenland basin (by German and Norwegian scientists in June 1991 and August 1992, respectively), but ice conditions prevented a regular deployment scheme.

Table 1. Life statistics of the Nordic seas drifters, including drifter identification number; time, latitude and longitude of deployment and of last good fix; bucket temperature at deployment; the geographical area covered given by the latitude and longitude extrema; times of drogue loss and last good temperature; life times of drifter, of attached drogue and of temperature sensor; type of death and comments. All times are Universal Time (UT) and are expressed in modified Julian days referred to 1991 (see conversion tables in Annex A).

TABLE 1 : NORDIC SEAS DRIFTER LIFE STATISTICS (1)

DRIFTER	DEPLOYMENT				LAST FIX			MIN	MAX	MIN	MAX	DROGUE	LAST	LIFE	LIFE	LIFE	TYPE	COMMENTS
ID	TIME	LAT	LON	TEMP	TIME	LAT	LON	LAT	LAT	LON	LON	LOST	TEMP	TIME	DROG	TEMP	DEATH	
2458	656.689	64.328	-12.560	5.18	766.850	70.698	22.075	61	71	-13	23	722.885		110.161	66.196	110.161	1	SG, ISP, D1
2459	656.716	64.376	-12.633	5.04	799.773	66.828	12.879	61	67	-13	13	778.741		143.057	122.025	143.057	1	SG, ISP, D1
2460	656.755	64.435	-12.724	5.14	766.973	70.353	21.136	61	71	-14	22	720.840		110.218	64.085	110.218	1	SG, ISP, D1
2461	658.871	64.342	-12.500	4.89	767.115	70.108	18.698	61	71	-13	19	739.500		108.244	80.629	108.244	1	SG, ISP, D1
2462	659.120	63.833	-12.500	7.82	765.168	70.125	16.524	61	71	-13	17	739.100		106.048	79.980	106.048	2	SG, ISP, D1
2463	962.264	64.401	-12.306	6.42	962.264	64.401	-12.306	62	64	-13	-11			0.000	0.000	0.000	3	SG, D1
2464	879.267	61.750	3.250		1426.488	70.782	35.767	60	75	-1	38		1407.429	547.221	547.221	528.162	3	SG, D1
2465	962.290	64.401	-11.999	6.63	1394.381	70.177	1.639	61	72	-14	12	1124.310		432.091	162.020	432.091	3	SG, D1
2466	962.247	64.333	-12.153	7.95	1485.573	72.474	26.525	61	73	-13	25	1376.601		523.326	414.354	523.326	3	SG, D1
2467	881.365	64.033	-14.467	7.00	1462.571	71.267	25.474	59	72	-15	26	1122.887	916.837	581.207	241.522	35.472	3	SG, D1
5580	844.399	61.750	3.250	6.80	844.513	61.736	3.262	63	65	-15	-13		844.450	0.114	0.114	0.051	3	SG, D1
5581	962.191	64.465	-11.837	6.22	1320.522	71.667	10.757	61	72	-12	12		1319.780	358.331	358.331	357.589	3	SG, D1
5582	962.313	64.399	-11.692	6.40	1489.650	70.476	55.223	61	73	-12	56	1124.590		527.336	162.277	527.336	3	SG, D1
5583	878.639	65.000	-12.817	1.80	1499.536	72.987	14.995	62	74	-14	16	1162.543		620.897	283.904	620.897	3	SG, D1
5584	815.944	61.750	3.250	6.50	843.261	64.147	9.247	60	65	2	10			27.316	27.316	27.316	2	SG, D1
5585	878.813	65.000	-11.667	2.50	1240.300	65.283	-6.179	61	70	-13	2	1165.237	1165.237	361.488	286.425	286.424	3	SG, D1
5586	962.166	64.464	-12.154	6.13	1393.107	71.365	45.487	62	74	-13	46	1114.180	1380.628	430.941	154.995	418.462	3	SG, D1
5587	962.220	64.329	-11.850	9.39	1130.258	67.505	8.264	61	68	-12	9	1085.100	1085.082	168.038	122.880	122.861	3	SG, D1
5588	877.990	66.367	-13.567	2.30	1557.243	71.143	9.746	62	73	-15	16	1447.350		679.253	569.360	679.253	3	SG, D1
5589	784.502	61.750	3.250	7.80	961.722	68.851	16.291	60	70	1	17			177.220	177.220	177.220	1	SG, D1
8330	418.802	67.750	-12.967	-0.91	1142.867	74.319	18.145	62	75	-14	20	1122.200	810.177	724.065	703.398	391.375	3	D1
8331	331.349	64.033	-14.467	6.08	602.588	76.107	20.175	61	77	-15	21			271.239	271.239	271.239	5	D1
8332	227.700	65.925	-11.549		365.864	66.356	12.316	62	67	-12	13	318.992	316.673	138.164	91.292	88.973	3	D1
8333	422.951	64.167	-12.917	6.33	575.278	64.746	1.330	60	65	-13	2		442.298	152.326	152.326	19.346	3	D1
8334	447.103	63.767	-8.487	6.20	885.816	69.509	32.618	61	72	-9	34	790.780	721.754	438.714	343.677	274.651	1	D1
8335	330.500	63.384	4.781		739.990	74.751	43.224	62	76	3	49	716.980	739.910	409.490	386.480	409.410	3	D1
8629	311.494	63.360	5.437		550.784	71.063	26.147	62	72	2	27		424.834	239.290	239.290	113.340	3	D1
8630	158.294	75.500	-4.217		307.525	75.009	-5.299	73	76	-10	-2		211.655	149.231	149.231	53.361	3	D1
8631	157.080	73.073	-8.070		977.205	73.391	36.888	69	76	-9	49	315.235	281.441	820.125	158.155	124.361	3	D1

PRESUMED TYPES OF DEATH: 0=ALIVE, 1=GROUNDED, 2=PICKED-UP, 3=BATTERY, 5=SINKING
COMMENTS: SG=STRAIN GAUGE, ISP=INITIAL SUBMERGENCE PROBLEMS, D1=8H-ON/16H-OFF DUTY CYCLE

TABLE 1 : NORDIC SEAS DRIFTER LIFE STATISTICS (2)

DRIFTER	DEPLOYMENT				LAST FIX			MIN	MAX	MIN	MAX	DROGUE	LAST	LIFE	LIFE	LIFE	TYPE	COMMENTS
ID	TIME	LAT	LON	TEMP	TIME	LAT	LON	LAT	LAT	LON	LON	LOST	TEMP	TIME	DROG	TEMP	DEATH	
8632	512.628	63.433	-21.217	7.30	540.795	64.357	-22.060	62	65	-24	-20			28.166	28.166	28.166	1	D1
8633	239.035	64.493	-11.533		849.401	70.621	21.661	63	72	-12	23	721.160		610.366	482.125	610.366	1	D1
8634	323.510	64.124	8.597		323.516	64.124	8.597	63	65	-12	-10			0.006	0.006	0.006	3	D1
8635	158.419	76.087	-4.290		177.788	75.742	-4.941	74	77	-6	-3		177.506	19.369	19.369	19.087	3	D1
8636	157.283	74.002	-6.202		297.669	76.623	-0.550	72	77	-7	6			140.386	140.386	140.386	3	D1
8637	494.170	63.433	-21.217	6.30	684.466	66.347	-30.157	62	67	-31	-20			190.296	190.296	190.296	4	D1, RD
8638	418.889	67.500	-13.267	-0.91	1097.118	67.885	10.715	58	70	-16	13	867.300	738.223	678.229	448.411	319.334	3	D1
8639	327.480	67.490	-13.270	1.43	873.784	70.328	21.553	65	73	-14	22	432.648		546.304	105.168	546.304	1	D1
8640	239.297	64.190	-12.207		380.575	63.324	7.780	59	65	-13	8	371.636	317.639	141.278	132.339	78.342	1	D1
8641	327.300	67.000	-13.810	4.49	1358.340	68.274	-6.031	64	73	-16	2	952.700	435.605	1031.040	625.400	108.305	3	D1
8642	327.535	67.750	-12.967	1.57	891.794	69.432	33.504	62	72	-15	35	434.618	388.877	564.259	107.083	61.342	1	D1
14382	458.625	63.433	-21.217	5.60	633.807	64.219	-39.978	62	67	-40	-20			175.182	175.182	175.182	1	D1
14383	238.190	65.466	-11.407		1039.539	69.318	48.397	61	75	-12	52	719.525	390.529	801.349	481.335	152.339	3	D1
14384	448.646	64.062	-6.410	2.41	963.692	70.641	3.329	62	71	-7	10	871.900	741.946	515.046	423.254	293.300	3	D1
14385	419.031	67.250	-13.570	-0.91	788.218	70.339	-11.547	65	71	-14	-4	0.000	419.032	369.187	369.187	0.001	3	D1
14386	418.601	68.000	-12.650	-0.36	796.709	67.743	-21.839	66	71	-23	-7	0.000	739.765	378.108	378.108	321.164	3	D1
14387	419.160	67.000	-13.790	-0.43	1041.223	66.140	1.532	63	69	-14	4	803.520	656.489	622.063	384.360	237.329	3	D1
14388	311.476	63.360	5.200		911.634	69.333	34.396	62	75	3	35	479.790	380.784	600.158	168.314	69.308	1	D1
14389	327.344	67.250	-13.567	1.42	910.719	69.451	34.496	65	79	-14	37	611.578	375.657	583.375	284.234	48.313	1	D1
14390	327.684	68.000	-12.650	1.51	534.536	69.592	-12.557	66	70	-13	-7		423.611	206.852	206.852	95.927	3	D1, *
14391	331.282	63.867	-14.133	6.33	331.663	63.900	-14.015	62	64	-15	-13	331.282	331.283	0.381	0.000	0.001	3	D1
14392	158.747	77.320	-1.502		161.888	77.020	-4.915	76	78	-5	0	158.747		3.141	0.000	3.141	4	D1
14393	311.512	63.360	5.613		398.797	67.603	15.146	65	68	10	16	311.512	398.728	87.285	0.000	87.216	1	D1, **
14394	156.599	72.000	-6.785		345.875	71.800	-13.295	70	73	-15	-5			189.276	189.276	189.276	3	D1
14395	331.174	63.633	-13.667	8.16	930.630	69.885	-1.673	61	71	-14	9	738.000	332.718	599.456	406.826	1.544	3	D1
14396	231.180	64.917	-10.324		363.403	68.304	13.577	62	69	-11	14	308.512	246.509	132.223	77.332	15.329	1	D1, ***
14397	156.461	71.150	-5.950		396.756	70.994	27.271	69	73	-7	28	281.762	210.733	240.295	125.301	54.272	1	D1
14398	228.521	64.834	-10.665		550.855	70.964	28.860	61	73	-11	29	415.897	312.870	322.334	187.376	84.349	2	D1
14399	159.003	78.043	-4.910		159.581	77.957	-4.965	76	79	-5	-3	159.003	159.004	0.577	0.000	0.001	4	D1

PRESUMED TYPES OF DEATH: 0=ALIVE, 1=GROUNDED, 2=PICKED-UP, 3=BATTERY, 4=ICE

COMMENTS: D1=8H-ON/16H-OFF DUTY CYCLE, RD=RE-DEPLOYED, *=1ST TRANS. AT TIME 404.35 , **=1ST TRANS. AT TIME 352.57, ***=DROGUED TO 65 M

TABLE 1 : NORDIC SEAS DRIFTER LIFE STATISTICS (3)

DRIFTER	DEPLOYMENT				LAST FIX			MIN	MAX	MIN	MAX	DROGUE	LAST	LIFE	LIFE	LIFE	TYPE	COMMENTS
ID	TIME	LAT	LON	TEMP	TIME	LAT	LON	LAT	LAT	LON	LON	LOST	TEMP	TIME	DROG	TEMP	DEATH	
14400	423.238	64.033	-14.467	6.45	424.560	63.886	-14.173	62	65	-15	-13		423.239	1.321	1.321	0.001	3	D1
14401	158.563	76.750	-4.447		160.928	76.714	-3.961	75	77	-5	-2	158.563	159.937	2.365	0.000	1.374	4	D1
15888	626.321	61.750	3.250		882.614	73.601	47.245	60	74	2	52		873.479	256.293	256.293	247.158	3	ISP, D1
15889	597.552	75.998	-0.003		635.918	75.816	-5.939	74	77	-6	1			38.366	38.366	38.366	3	ISP, D1
15890	661.493	64.014	-10.516	6.50	913.675	72.119	31.649	61	73	-11	32		718.666	252.182	252.182	57.173	3	ISP, D1
15891	597.650	75.669	-0.991		662.023	75.334	-8.269	74	77	-9	1			64.373	64.373	64.373	4	ISP, D1
15892	597.753	75.329	-2.013		641.058	76.180	-4.298	74	77	-5	1		638.103	43.305	43.305	40.350	4	ISP, D1
15893	662.583	63.998	-9.501	5.55	1401.725	70.373	31.086	62	73	-10	34	795.650		739.142	133.067	739.142	1	ISP, D1
15894	597.860	74.999	-3.002		677.923	75.093	-9.658	73	76	-10	-2			80.063	80.063	80.063	4	ISP, D1
15895	658.897	64.251	-12.498	6.65	1187.120	72.775	32.232	62	74	-13	33		1183.110	528.223	528.223	524.213	2	ISP, D1
15896	660.456	63.998	-11.537	7.91	1155.667	70.493	44.139	61	72	-12	45			495.211	495.211	495.211	3	ISP, D1
15897	658.976	64.158	-12.471	7.97	794.026	70.154	18.666	60	71	-13	19	776.111		135.050	117.135	135.050	1	ISP, D1
15898	600.722	76.000	-4.604		676.024	75.499	-8.367	73	77	-9	-3			75.302	75.302	75.302	4	ISP, D1
15899	660.361	64.325	-11.513	4.84	1286.671	66.205	-14.662	61	77	-17	25	937.700	1286.513	626.310	277.339	626.152	1	ISP, D1
15900	585.747	63.633	-13.667	9.20	656.332	63.621	-5.831	62	65	-14	-4			70.585	70.585	70.585	3	ISP, D1
15901	659.656	71.000	-13.317	2.20	723.863	68.982	-22.027	67	72	-23	-11		670.957	64.206	64.206	11.301	3	ISP, D1
15902	587.007	65.000	-12.000	7.10	1481.146	71.659	37.031	62	77	-13	38	765.500		894.139	178.493	894.139	3	ISP, D1
15903	589.438	66.500	-12.000	7.50	744.587	65.562	9.608	60	67	-13	10		743.774	155.149	155.149	154.336	3	ISP, D1
15904	591.195	68.000	-12.650	6.90	1035.521	65.694	11.584	64	70	-15	12	760.340		444.326	169.145	444.326	1	ISP, D1
15905	778.927	66.367	-13.000	1.20	1062.532	67.045	9.847	61	68	-14	10		817.116	283.605	283.605	38.189	3	ISP, D1
15906	652.797	61.750	3.250		994.083	68.834	37.264	60	73	1	42	861.100		341.287	208.303	341.287	1	ISP, D1
15907	585.997	64.033	-14.467	10.40	594.897	64.008	-13.628	62	65	-15	-12			8.900	8.900	8.900	2	ISP, D1
15908	600.827	76.499	-2.004		648.205	70.552	-18.615	69	77	-21	-1	630.300	628.326	47.378	29.473	27.499	4	ISP, D1
15909	659.090	63.919	-12.500	7.73	1214.898	73.426	-8.787	60	79	-13	17	1106.190	1214.242	555.808	447.100	555.152	4	ISP, D1
15910	559.946	61.748	3.253		852.310	65.708	-28.206	59	80	-29	17	775.300	822.298	292.363	215.354	262.351	4	ISP, D1
15911	781.451	63.650	-13.667	7.40	942.590	64.896	0.246	61	66	-14	1			161.138	161.138	161.138	3	ISP, D1
15912	590.993	67.500	-13.267	6.60	1514.342	75.646	49.816	60	76	-14	51	847.300	1514.283	923.349	256.307	923.290	4	ISP, D1
15913	659.507	70.577	-13.423	2.00	739.836	70.464	-18.237	69	72	-19	-12			80.329	80.329	80.329	3	ISP, D1
15914	660.958	64.499	-11.023	6.03	1470.174	70.218	51.274	62	75	-12	52			809.216	809.216	809.216	3	ISP, D1

PRESUMED TYPES OF DEATH: 0=ALIVE, 1=GROUNDED, 2=PICKED-UP, 3=BATTERY, 4=ICE
COMMENTS: ISP=INITIAL SUBMERGENCE PROBLEMS, D1=8H-ON/16H-OFF DUTY CYCLE

TABLE 1 : NORDIC SEAS DRIFTER LIFE STATISTICS (4)

DRIFTER	DEPLOYMENT				LAST FIX			MIN	MAX	MIN	MAX	DROGUE	LAST	LIFE	LIFE	LIFE	TYPE	COMMENTS
ID	TIME	LAT	LON	TEMP	TIME	LAT	LON	LAT	LAT	LON	LON	LOST	TEMP	TIME	DROG	TEMP	DEATH	
15915	590.757	67.000	-13.833	8.50	988.107	80.539	5.357	61	81	-15	17			397.350	397.350	397.350	4	ISP, D1
15916	778.042	68.000	-12.667	-0.50	1338.215	71.613	26.477	61	72	-15	29	1106.400		560.173	328.358	560.173	3	ISP, D1
15917	661.510	68.000	8.000		1014.837	79.515	6.578	66	80	1	16		995.850	353.327	353.327	334.339	3	ISP, D1
15918	661.370	64.335	-10.505	5.26	749.615	63.899	3.677	61	65	-11	4			88.245	88.245	88.245	3	ISP, D1
15919	601.417	61.750	3.252		1279.547	77.623	5.066	60	78	-3	13			678.130	678.130	678.130	3	ISP, D1
15920	659.007	64.082	-12.502	7.90	832.141	79.711	6.017	60	80	-13	16			173.134	173.134	173.134	4	ISP, D1
15921	659.066	63.993	-12.503	7.98	1064.995	79.610	10.810	61	80	-13	17	854.100	1060.080	405.929	195.034	401.014	1	ISP, D1
15922	778.538	67.000	-13.833	0.90	1051.698	65.673	-7.680	64	68	-15	-5	819.620	802.802	273.160	41.082	24.264	3	ISP, D1
15923	690.365	61.750	3.250		703.675	63.204	7.864	60	64	2	8			13.310	13.310	13.310	2	ISP, D1
15924	780.128	65.000	-11.667	1.40	819.754	61.860	-3.994	60	66	-12	-2	819.620	780.129	39.625	39.492	0.001	3	ISP, D1
15925	781.691	64.033	-14.467	5.70	1333.847	70.922	-2.511	62	72	-15	2			552.156	552.156	552.156	3	ISP, D1
15926	662.513	64.312	-9.499	4.94	826.455	70.934	23.340	62	71	-10	24	806.700		163.942	144.187	163.942	2	ISP, D1
15927	585.885	63.867	-14.133	10.40	683.831	62.686	1.603	61	65	-15	2		609.185	97.946	97.946	23.299	3	ISP, D1
20321	961.207	64.370	-11.960	6.60	1023.698	61.877	-4.384	60	65	-12	-3			62.491	62.491	62.491	5	SG, D2, BV
20323	961.216	64.337	-11.962	7.85	994.441	63.485	-6.981	62	65	-12	-5			33.225	33.225	33.225	5	SG, D2, BV
20324	961.240	64.353	-12.001	7.18	1124.785	65.859	0.983	62	67	-13	2	1119.212		163.545	157.972	163.545	3	SG, D2, BV
20326	961.231	64.353	-12.076	7.56	1004.293	62.070	-3.578	61	65	-13	-1			43.061	43.061	43.061	5	SG, D2, BV
20328	961.249	64.353	-11.925	6.66	1053.630	66.046	0.864	61	67	-12	2			92.381	92.381	92.381	5	SG, D2, BV
20329	961.199	64.370	-12.036	6.58	1003.858	63.537	-5.225	61	65	-13	-3			42.659	42.659	42.659	5	SG, D2, BV
20333	961.226	64.337	-12.039	8.20	1114.186	63.602	-1.552	62	65	-13	1			152.960	152.960	152.960	5	SG, D2, BV

PRESUMED TYPES OF DEATH: 0=ALIVE, 1=GROUNDED, 2=PICKED-UP, 3=BATTERY, 4=ICE, 5=SINKING

COMMENTS: SG=STRAIN GAUGE, ISP=INITIAL SUBMERGENCE PROBLEMS, BV= BATTERY VOLTAGE REPORTED, D1=8H-ON/16H-OFF DUTY CYCLE
D2=90 DAYS CONTINUOUS TRANSMISSIONS FOLLOWED BY 1-DAY-ON/2-DAY-OFF DUTY CYCLE

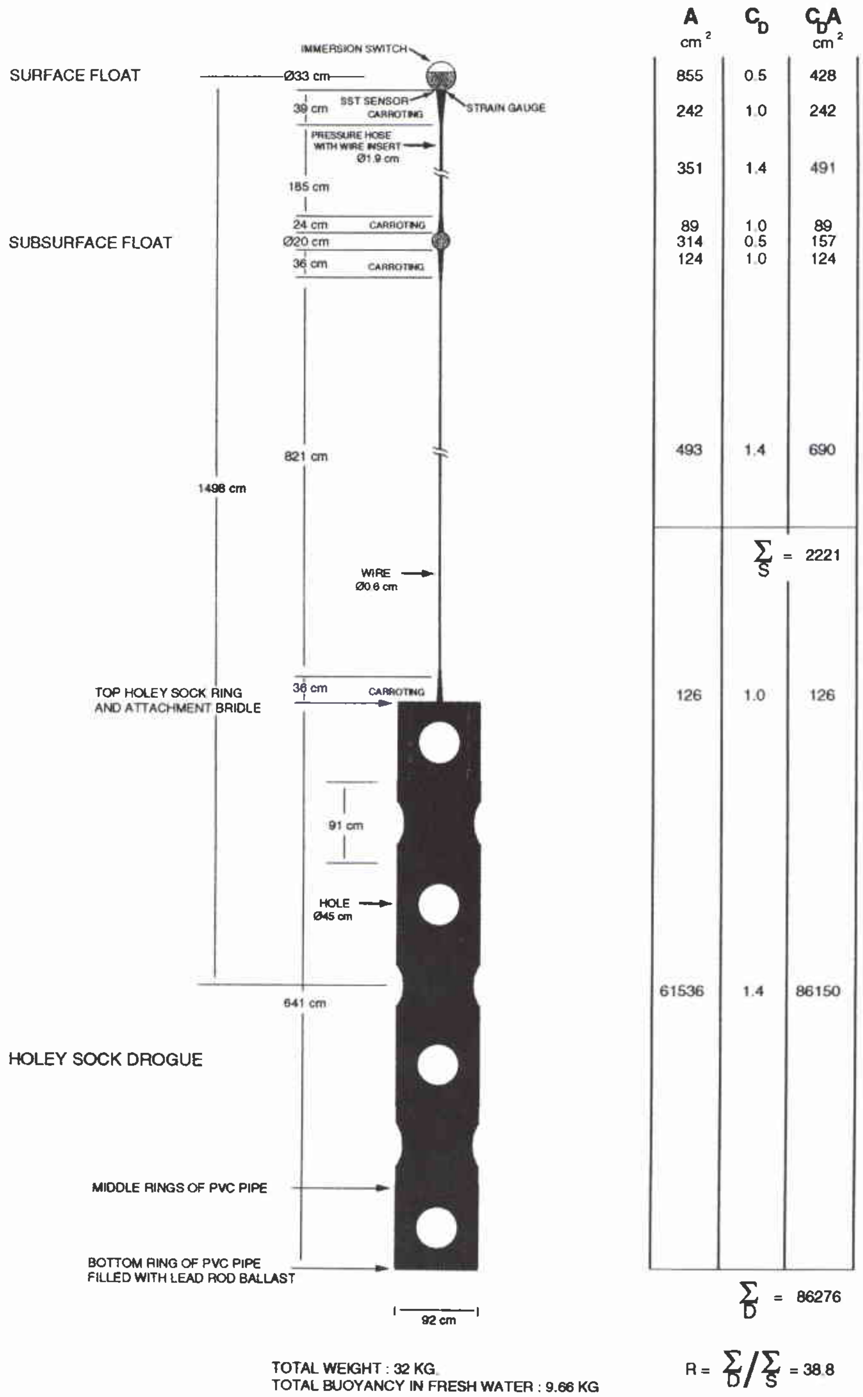

Figure 1 *Schematic diagram of the WOCE/TOGA Lagrangian drifter with computation of drag area ratio (a). Photograph of a WOCE/TOGA drifter recovered after 8 months in the Norwegian coastal current: (b) Global view with Holey sock drogue in the foreground; (c) Detailed view of the surface and sub-surface spheres. The SST sensor is apparent on the surface float.*

Figure 1b

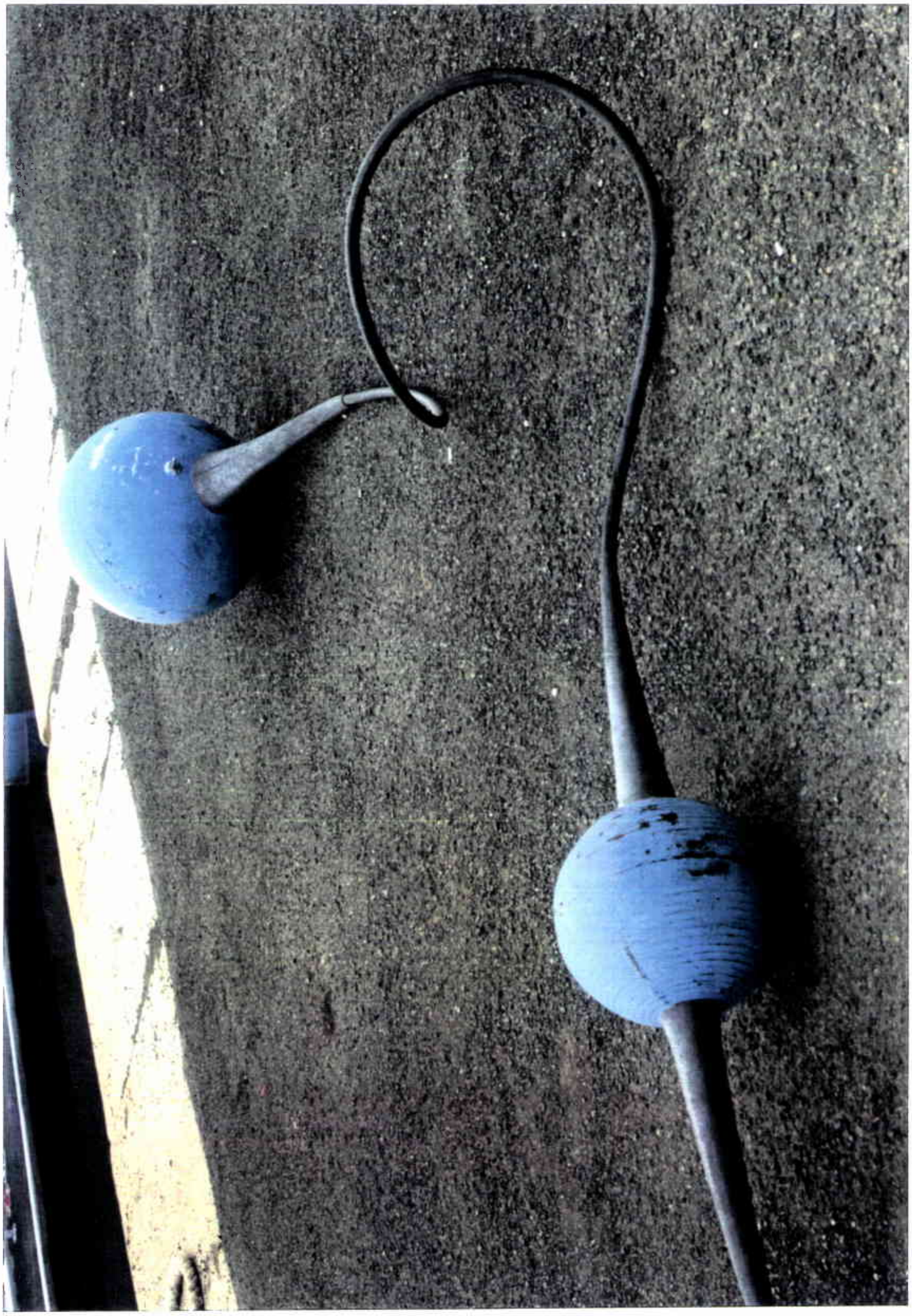

Figure 1c

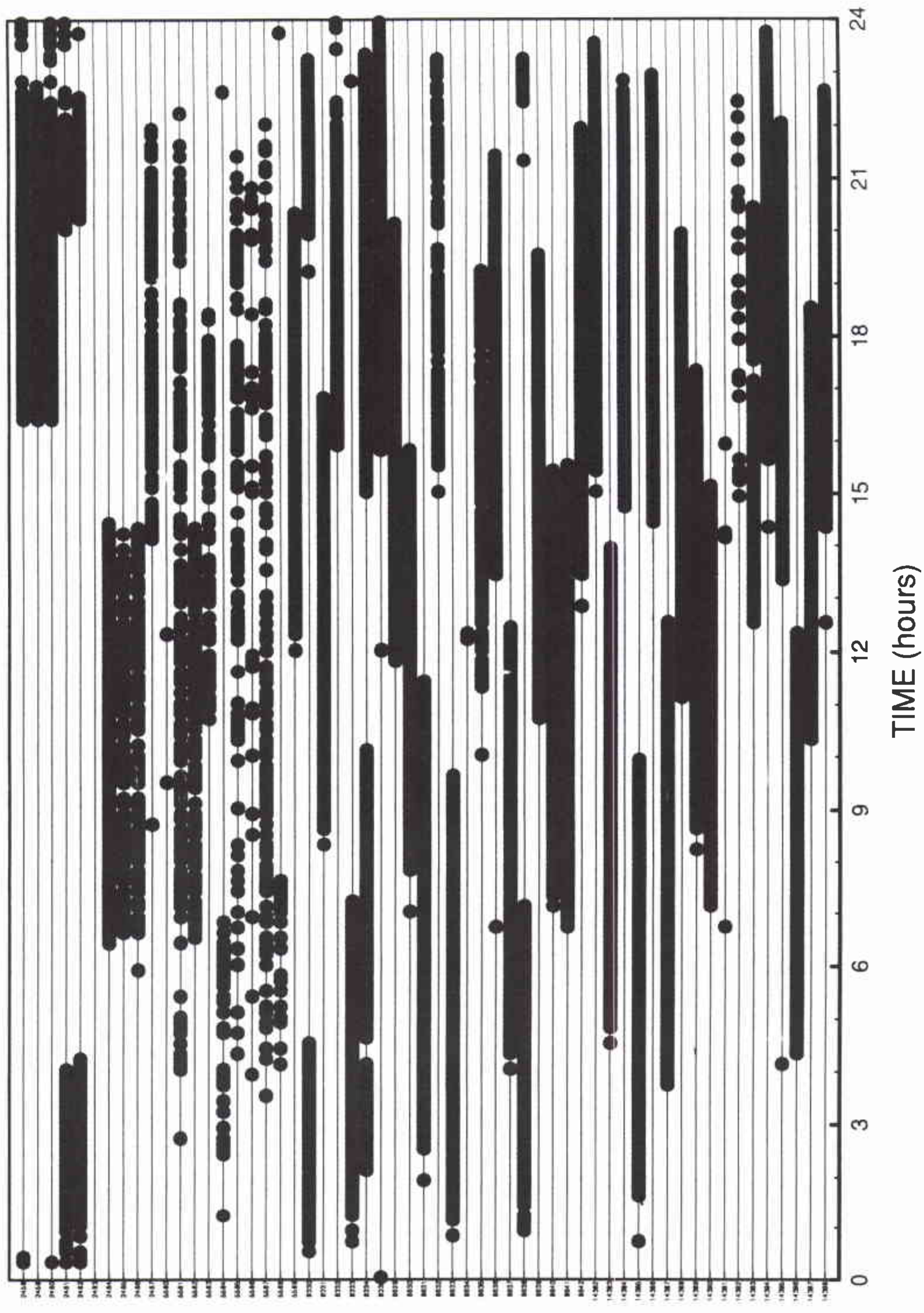

Figure 2 *Transmission time windows for all the drifter numbers shown in vertical scale, i.e., periods of the day for which transmissions were received at least once during the entire drifter life.*

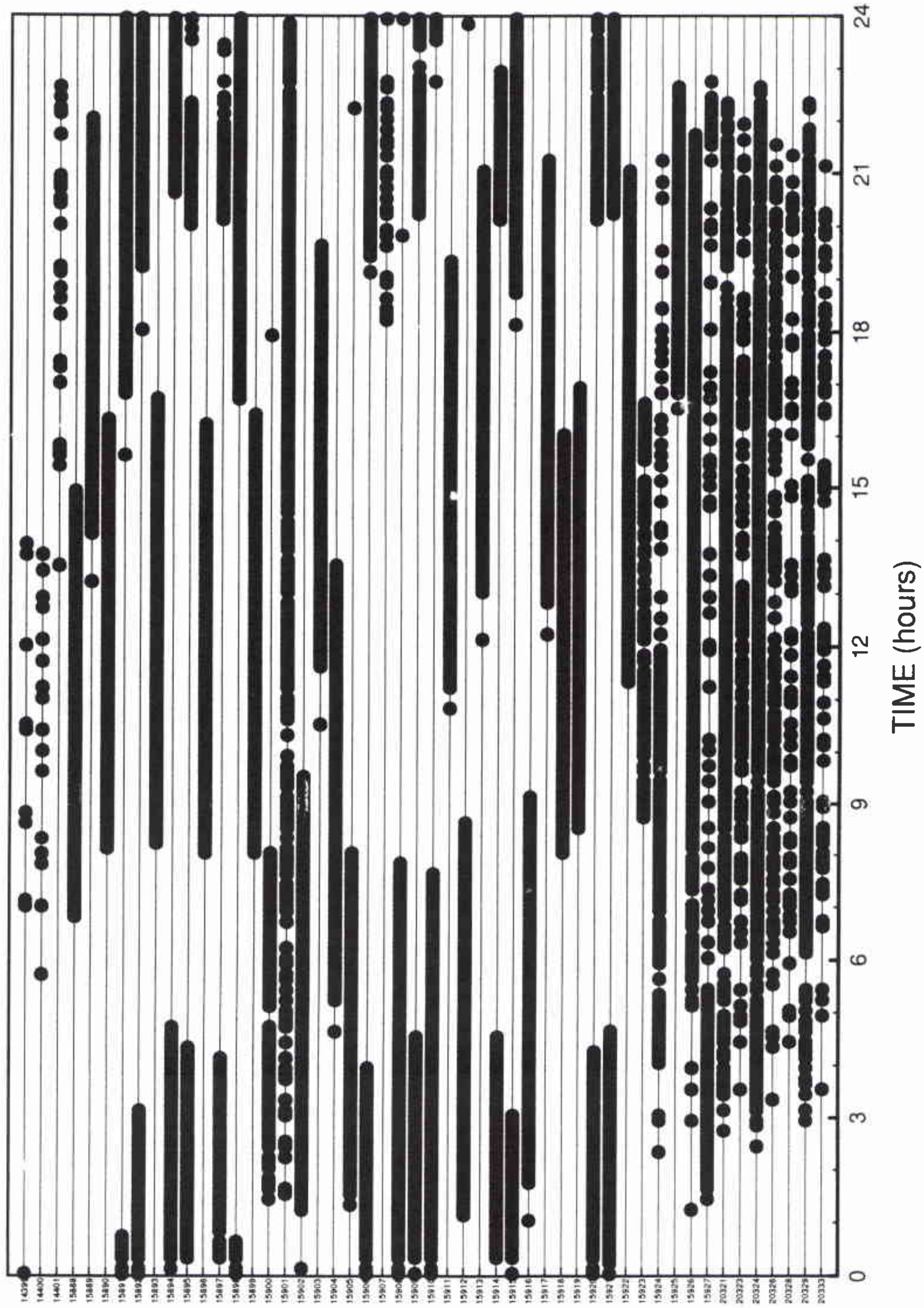

Figure 2 *(cont.)*

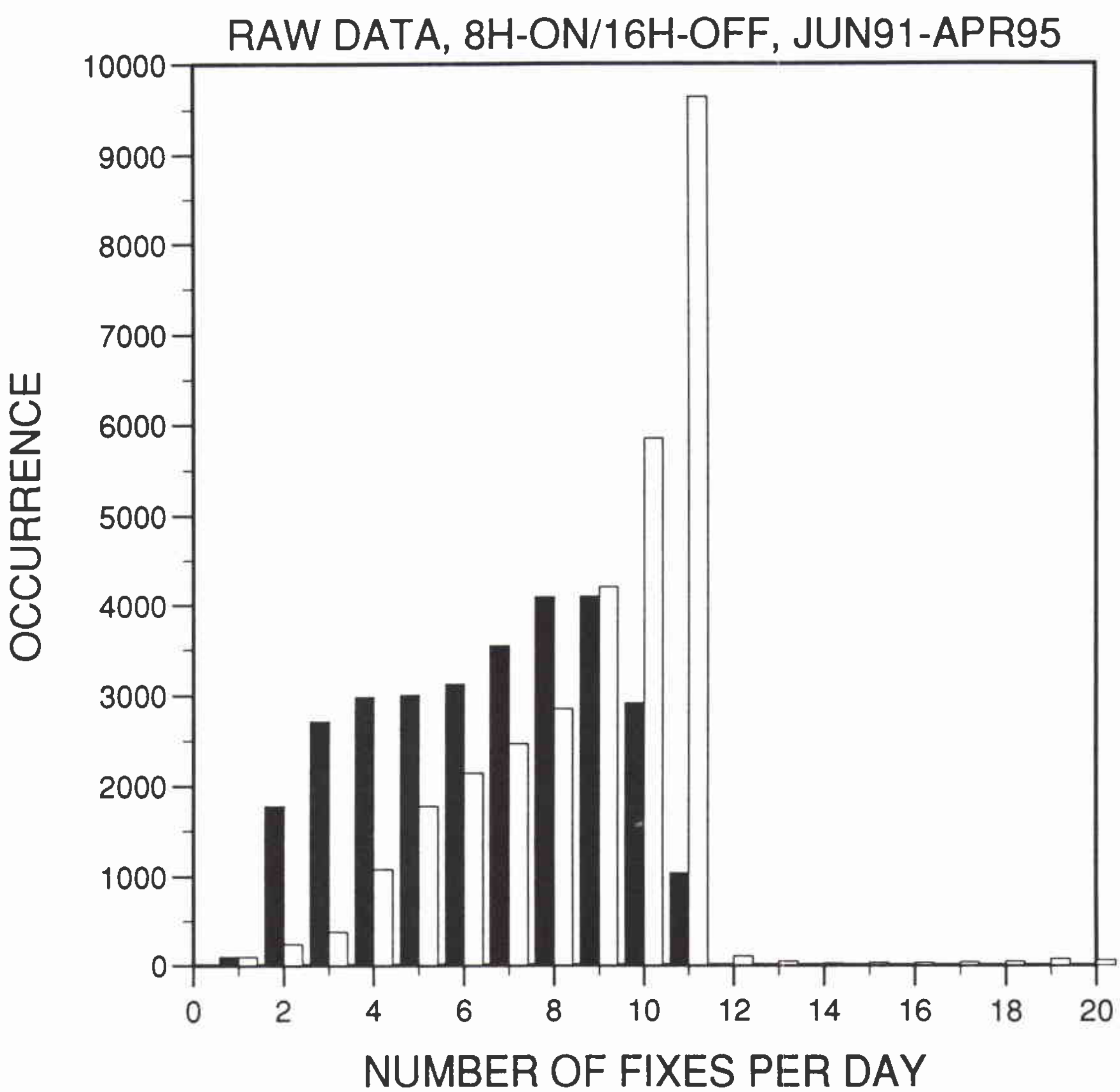

Figure 3 *Histogram of the number of position (solid black columns) and sensor data (open columns) fixes per day.*

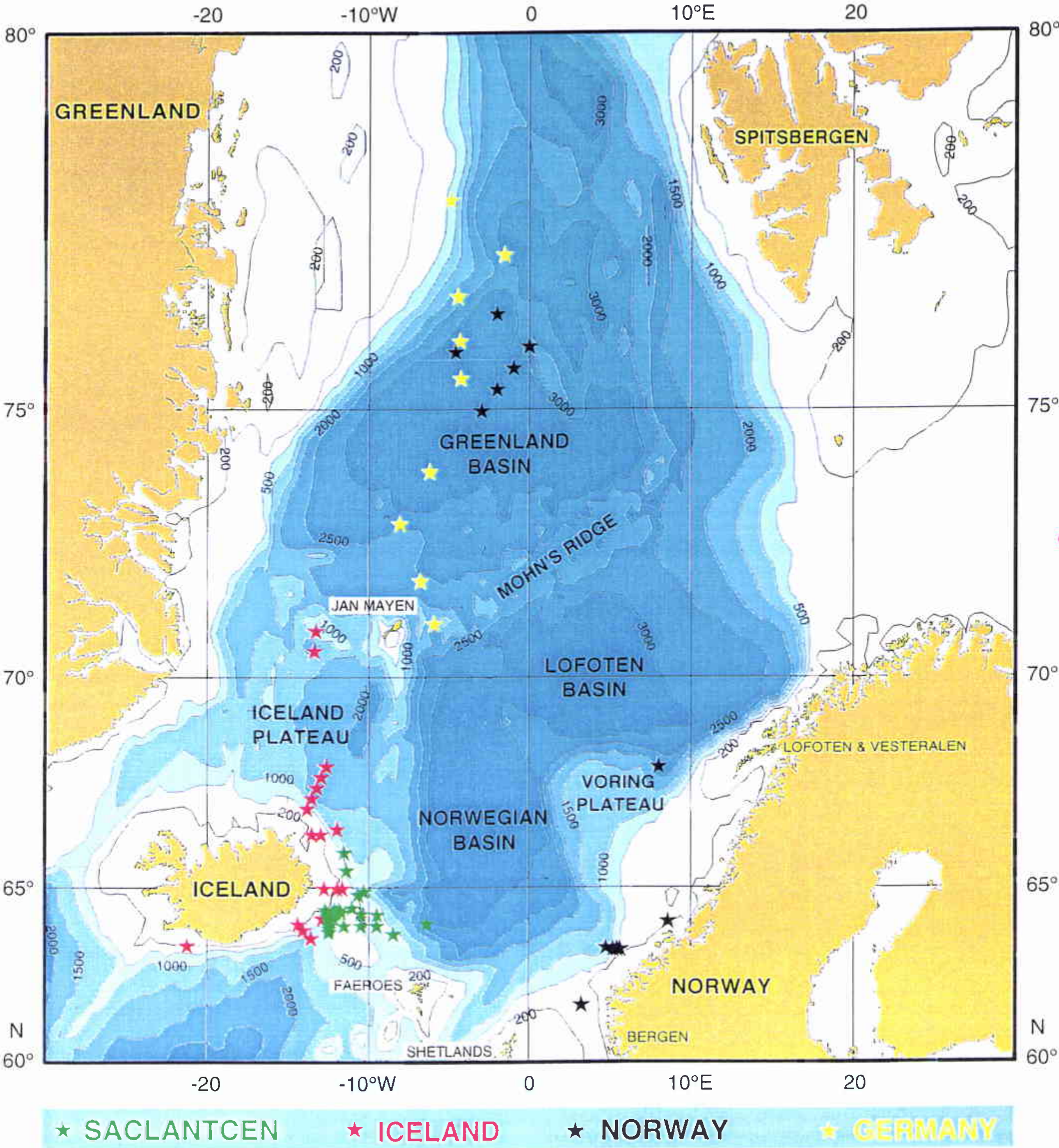

Figure 4 *Bathymetry of the Nordic seas with sites of drifter deployments (star symbols).*

3

Data processing

3.1 WEEKLY ROUTINE PROCESSING AND DISPLAYING

The Argos data base in Toulouse, France was interrogated on an *ad hoc* basis *via* the telephone network to obtain recent drifter positions and SST data. Various maps showing the drifter latest position and SST together with a segmeted tail corresponding to the four previous weekly displacements, were routinely produced (Fig. 5). They were used to monitor drifter movements (especially during sea trials) and to optimize additional seeding of drifters based on existing drifter numbers and positions.

3.2 REDUCTION AND EDITING

Data reduction

Drifter position and sensor data was obtained from Service Argos once a month. The data for each drifter were read, reduced and written into individual files (B-files) which were updated monthly as long as the drifter provided good data. The sensor data were processed and reduced in the following way. The sensor data (i.e., time, submergence, voltage, temperature and strain gauge) records telemetered during a single satellite overpass were decompressed, that is, each record was repeated by a number of times equal to a given compression index and the repeated records were shifted back in time by successive 90 s increments. The data were then sorted in increasing sequential order and the median values were estimated. These median statistics were assigned to the drifter location and were written into the output raw file. Note that the median sensor and the position times vary according to the time distribution of sensor fixes during the satellite pass. For the passes with good sensor data but for which no drifter location was provided by Service Argos, the output raw latitude and longitude were assigned with the 999.999 default value.

During the reading and reduction process, the data were converted into modified Julian days referred to the year 1991 (Annex A) and longitudes west of the Greenwich meridian were converted into negative east longitudes. The deployment coordinates (time, latitude, longitude and bucket SST) were added to the drifter time series as the initial record. A location class 4 (accuracy better than 100 m determined by ship GPS navigation system) was assigned to this record. The raw data time series for drifter 8641 (the one with the longest life) are presented in Fig. 6 in which data spikes are evident. The location classes and the distribution of fixes during the day are also displayed. The 8 hour transmission window is striking. A slight shift of the transmitter internal clock is evident, amounting to about 1 hour 26 minutes in 1031 days (or 5 s per day).

Determination of time of last good fix and type of death

The type of dysfunction or the circumstances of the termination receipt of good quality oceanographic data have been carefully investigated by examining the suspect records in the context of their proximity to the coast line or to the ice edge, the values of voltage and submergence, and the probability that they were picked up by seafarers. Thus, the time for the last good fix was determined and the type of death was classified into one of four categories: Grounded; Picked-up; Battery failure; Ice edge/Sinking (Table 1).

Determination of time of drogue loss

The sea-water switch on the surface flotation sphere provides submergence data which are used to determine whether or not the holey-sock drogue is attached. Typical values of submergence time for a drogued drifter vary around 5 minutes per half hour time period, depending on the sea state (Fig. 6). Upon drogue separation, the submergence time falls down abruptly to about zero, giving a clear indication of drogue loss.

The strain gauge showed a dramatic reduction of voltage range at the same time as the sea-water switches began to indicate near zero submergence. This complementary drogue indicator data confirm that even if the submergence switch does not function correctly at deployment, perhaps due to an accumulated film during storage and transport, data acquired are reliable after activation. An example is shown in Fig. 7 where the strain gauge voltage statistics and the submergence values for drifter 2460 are plotted *versus* time. The sea-water switch which did not operate for about 9 days after deployment yields non-zero submergence counts between days 665 and 720. The range in strain gauge voltage, depicted by the minimum and maximum values, shows an abrupt reduction at exactly the same time that submergence registers zero.

The submergence counts and the strain gauge voltage range have been used to determine the time of drogue separation for all drifters. For a few ambiguous cases (drifters 2466, 2467, 5586, 20324, 20333), the time of drogue loss was estimated or confirmed from correlation analyses between the drifter and the surface wind speeds. About half of the drifters (55 out of 107) lost their drogue before the end of their life.

Location data editing

As discussed above, Service Argos provides quality indices, designated location classes, for all locations determined. Being probabilistic, these indices do not preclude the occurrence of occasional large errors. An editing procedure derived from statistical tests for the full sequence of data values was applied, based upon speed between consecutive locations.

The raw data in the period between deployment and last good fix times were processed as follows:

1) For each drifter, a range of physically possible values of latitude and longitude are defined. Data points outside this range are flagged with a time equal to 999.999.

2) The records are arranged in ascending temporal sequence. Velocity components are estimated for each satellite separately by finite differencing successive positions.

3) Only velocities computed from the data points inside the same 8-hour transmission window are considered velocities corresponding to a time difference in excess of 16 hours are excluded. Suspected outlier velocity points are searched using Chauvenet's criterion. Assuming that the underlying basic velocity distribution is Gaussian, this statistical test rejects observations that are more than c times the standard deviation from the mean. The value of c satifies $NP(-c) = 0.5$ where N is the total number of observations and P is the cumulative distribution function of the Gaussian distribution (Hawkins, 1980). Thus, on average, half an observation is rejected, regardless of N. The Chauvenet limits obtained for the two components of velocity are then averaged. The velocity observations exceeding these averaged limits are considered to be unreliable.

4) Since an unreliable velocity observation corresponds to two position points, deciding which point of the pair is the flawed location is not trivial. This choice is usually made by considering the location classes. The point with the lowest location quality index is chosen as the flawed observation. In the case of a pair of points with identical classes, the previous and successive velocity magnitudes are used. If the previous (successive) velocity magnitude is larger than the successive (previous) one, the first (second) point is considered flawed.

5) When a latitude or longitude point is considered flawed, the corresponding time

is assigned the 999.999 value. The statistical editing process is then iterated (operations 2 to 5) excluding the records flagged by a 999.999 time value.

Iteration procedure stops when one of the following conditions is fulfilled: (a) Three consecutive iteration loops result in no reduction of the number of edited points. (b) The difference between the mean speed (i.e., the magnitude of the mean velocity vector) computed from the present and previous edited velocity distributions, is inferior to 0.05 (value determined experimentally).

It is important to note that if one of the Chauvenet limits happens to be (or comes) within the drifter velocity resolution, then the rejection limit is substituted by the constant resolution value for the rest of the iterative procedure. This is necessary to stop the loop process for some velocity distributions (usually with a relatively small number of points) which would have removed the entire set of observations. The velocity resolution was estimated by taking into account the position resolution provided by Argos (one thousandth of a degree) and the minimum time separation between fixes by the same satellite (about 100 minutes). It is about 1.85 cm s^{-1}.

At the end of the statistical editing process, the data of the different satellites are recombined into a single sequence series. Records with identical times are reduced, retaining only the data stream corresponding to the highest location class, or to the location more similar to the adjacent data points. Those records with time not substituted by the 999.999 value are written in a position edited file (named P-file) containing the position time, latitude, longitude and location class.

When the position time series are scrutinized, remaining spikes are removed using a manual interactive program which flags the corresponding records with a time equal to 999.999 in the P-file.

Determination of time of last good temperature

The time of last good temperature was estimated by examining the temperature records and comparing them to typical climatological values in the sea area. Continuous unacceptable range temperatures were edited out by assigning the temperature cut-off time before the anomalous values start. Failure of the temperature sensor was generally indicated by temperature values near -3.0°C.

Temperature editing

For each satellite, the temperature gradients are computed from successive fixes within the same 8-hour transmission time period. Using Chauvenet's criterion and the comparison with the neighboring gradient magnitudes, temperature points are edited iteratively. When only one temperature record is available in the 8-hour window, this value is compared to the mean temperature during the preceding and subsequent 8-hour time periods, and rejected if both variations exceed of 0.15°C (threshold value obtained experimentally and equal to three times the temperature resolution).

At the end of the temperature editing process, the data corresponding to the different satellites are combined and records with identical times are reduced. The temperature time series are edited manually and all sensor data records (time, submergence, temperature and battery voltage) are written in a sensor edited file (called S-file) where the flawed temperature values are substituted by 999.999.

3.3 *INTERPOLATION AND FILTERING*

The despiked data were interpolated onto regular intervals using an optimum analysis technique known as Kriging (Hansen and Herman,1989; Hansen and Poulain, 1995). The Kriging used here employed an analytic function fit to a structure function computed from the entire despiked data set. The structure function is defined as

$$S_{ij} = 0.5\langle(\boldsymbol{x}_i - \boldsymbol{x}_j)^2\rangle, \tag{1}$$

where $\boldsymbol{x}_i$ and $\boldsymbol{x}_j$ are the observations (latitude, longitude or temperature) of the same drifter at times t_i and t_j, and $\langle\rangle$ represents an ensemble mean. Empirical values of the location and temperature structure functions were computed separately for both the drogued and undrogued drifter data sets. Assuming stationary statistics, the ensemble mean was substituted by a time average procedure in which the squared differences of the observations were binned into one hour lag intervals and averaged. The results are presented in Fig. 8 for time lags up to 10 days. The number of pairs of observations considered is also depicted. Due to the 8-hour-on/16-hour-off transmitter duty cycle, very few data pairs exist for lags included between 8 and 16 hours, 32 and 40 hours, etc.

To provide structure function values at all possible lags needed for the interpolations, the empirical values must be modelled by a conditionally negative definite function. We used a fractional Brownian motion model (Hansen and Poulain, 1995)

$$\hat{S} = \alpha\tau^{\beta}, \tag{2}$$

in which τ denotes time lag (in days) and the parameters α and β are determined from the empirical data. The fitting of the above model was only applied for those time lags with many observation pairs (more than 3000 location pairs and more than 5000 temperature pairs) to avoid data gaps created by the intermittent transmission mode. The parameter β was varied from 1 to 2 by increments of 0.01 and for each value, α was obtained by least squares fitting. The pair of parameters corresponding to the maximum explained variance was selected. These parameter values are listed in Table 2. The corresponding model analytical functions are depicted in Fig. 8 (dotted curve).

By looking at the edited trajectories, it became evident that strong tidal motions were partially sampled by the drifters. Knowing that the semi-diurnal tide (M2 and S2) is predominant in the southern Nordic seas (Perkins *et al* 1994), a tidal term was added to the location structure function model, that is

$$\hat{S} = \alpha\tau^{\beta} + \gamma(1 - cos4\pi\tau). \qquad (3)$$

The coefficient γ was not determined from the empirical data because semidiurnal oscillations are barely seen in the structure functions (Fig. 8) and was given the constant value of 1. Changing the value of this parameter does not change the Kriging characteristics. The diurnal variability in both the location and SST was not modelled in the structure function because the 8-hour transmission window is too small to resolve the amplitude characteristics of the diurnal oscillations.

The edited drifter data were interpolated at regular 2-hour intervals using the Kriging technique with the above structure function models. Following experimentation, 20 observations were selected, 10 preceeding and 10 following each interpolation point, to carry out the Kriging interpolation technique. When data are few, as at the beginning or end of a drifter life, or where data intermittent, interpolations were done with as few as a single observation on either side of the interpolation time. Both the interpolated value and an estimate of its accuracy were computed. The interpolated positions and SST were then low-pass filtered with a designed filter cut-off period at 36 hours (-3 dB at 36 hours and -49 dB at 27 hours) in order to remove high frequency current components, especially the strong tidal and inertial currents. The low-pass time series were finally subsampled every 6 hours and the velocity was computed by finite centered differencing the 6-hourly interpolated/filtered position data. The processed data files (called K-files) contain 6-hourly values of position, velocity and temperature. The velocity for the first and last records of each drifter, the temperature after failure of the SST sensor, and all the variables during temporary grounding, were assigned the 999.999 default value. If the time difference between the interpolated point and the closest edited observation is larger than 3 days, the corresponding velocity was assigned 999.999 in order to avoid meaningless interpolated velocity estimates in large data gaps.

Table 2 Values of the model structure function parameters determined from the empirical latitude, longitude and temperature structure functions, for both drogued and undrogued data.

TABLE 2 : STRUCTURE FUNCTION MODELS

$$S = \alpha \tau^{\beta} + \gamma (1 - \cos 4 \pi \tau)$$

		α	β	γ
LATITUDE				
	DROGUED	0.00504	1.53	1
	UNDROGUED	0.00998	1.36	1
LONGITUDE				
	DROGUED	0.03780	1.54	1
	UNDROGUED	0.09108	1.47	1
TEMPERATURE				
	DROGUED	0.03195	1.02	0
	UNDROGUED	0.06641	0.87	0

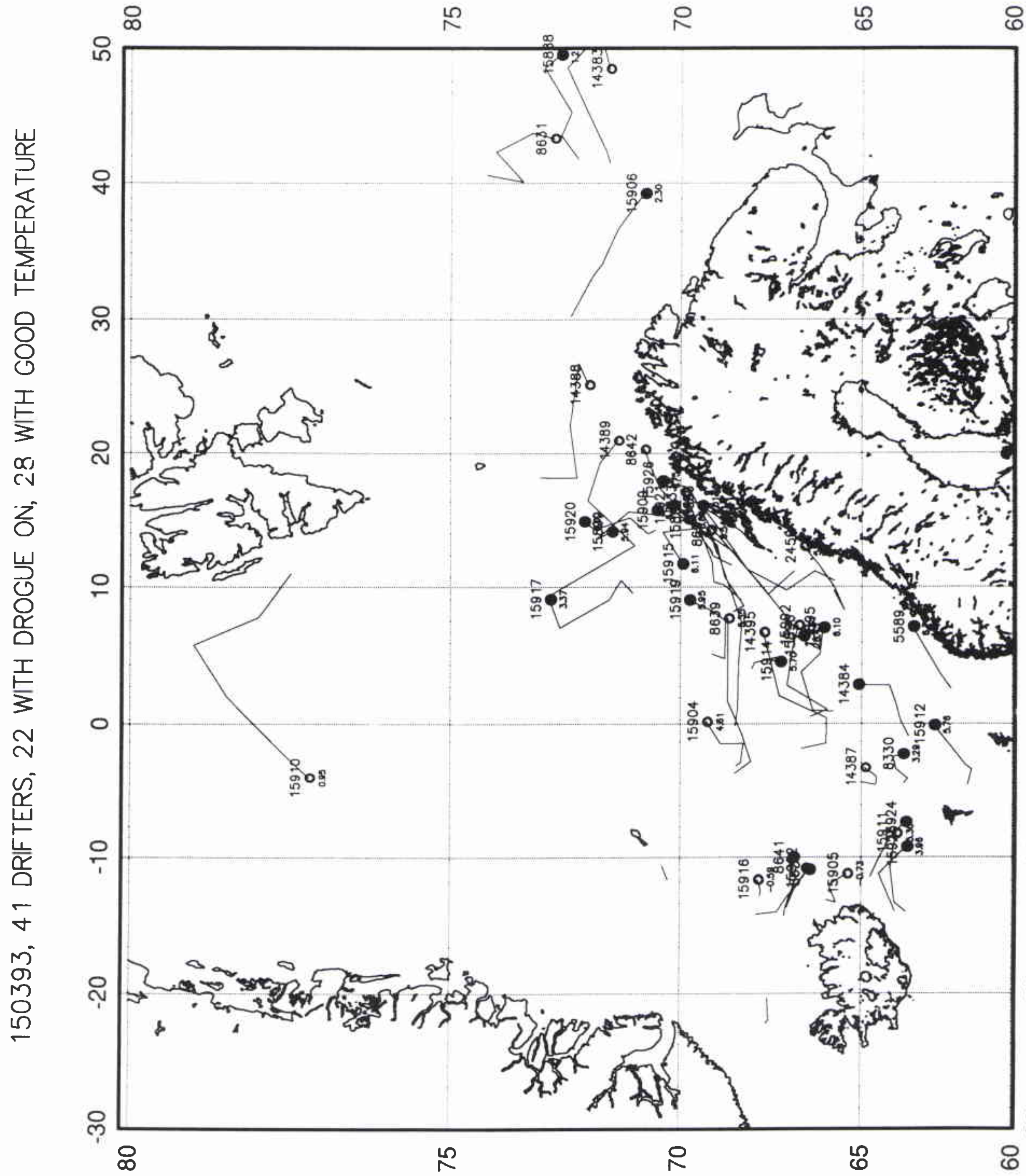

Figure 5 *Drifter location and SST on 15 March 1993 along with four previous weekly displacements. The solid black and open circle symbols correspond to drogued and undrogued drifters, respectively. The drifter ID number and SST (°C)are posted above and below the location symbol, respectively.*

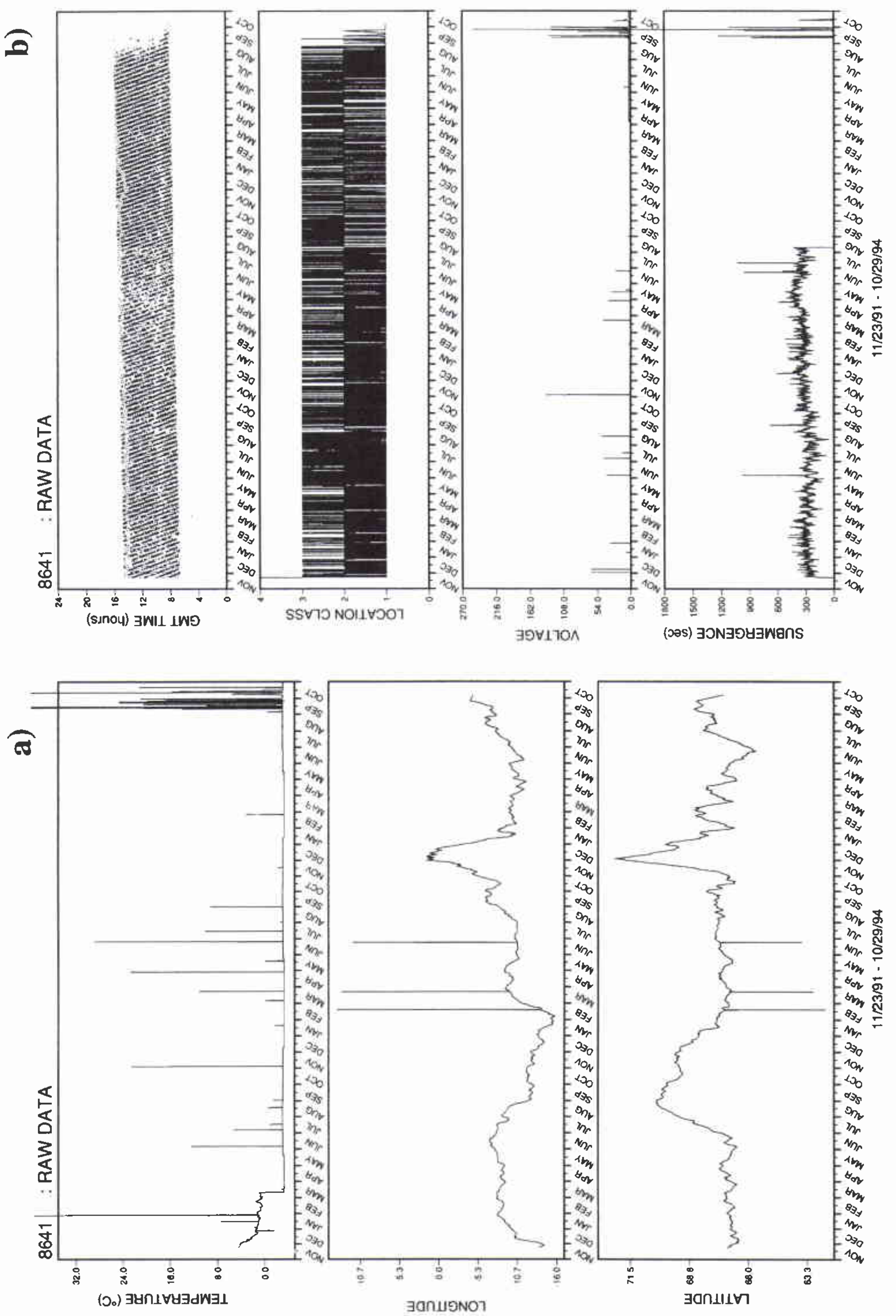

Figure 6 *Raw data time series for drifter 8641. (a) Latitude, longitude and temperature. (b) Submergence time, battery voltage indicator, location class and distribution of data received during an 8h period (cross and dot symbols for NOAA11 and NOAA12 satellites, respectively).*

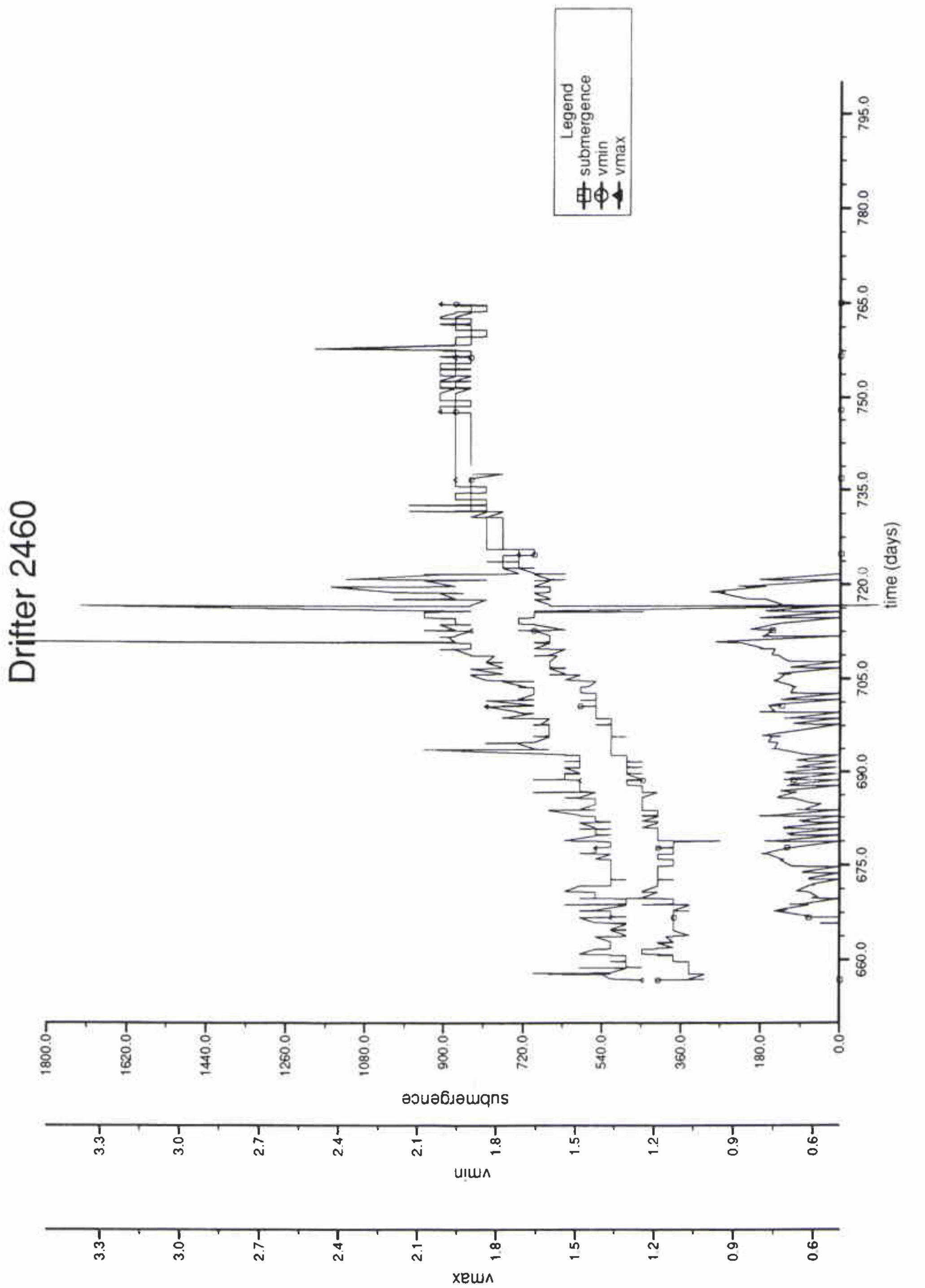

Figure 7 *Submergence counts and strain gauge voltage statistics for drifter 2460.*

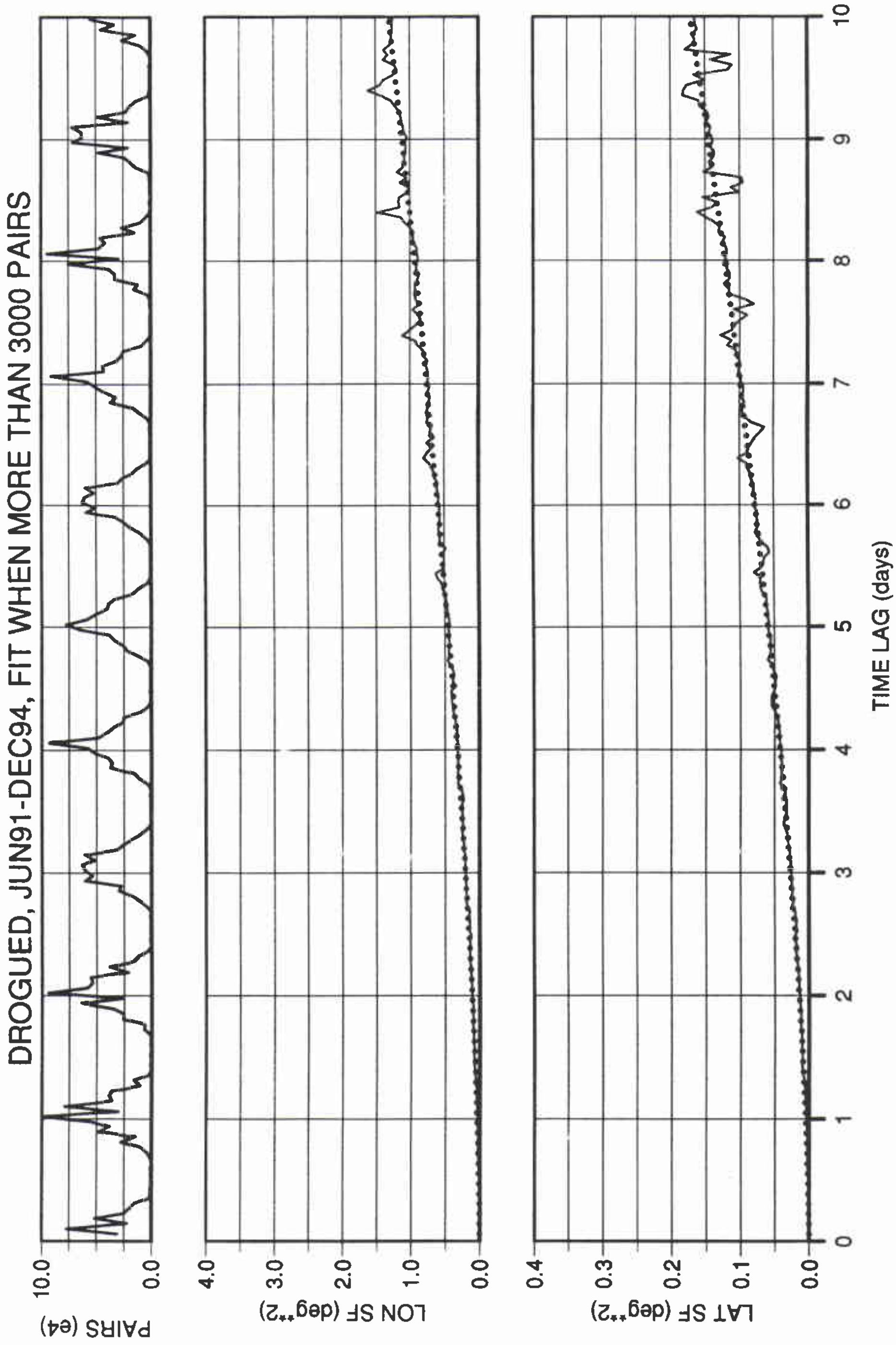

Figure 8 *Empirical structure functions for drogued (a) and undrogued (b) position data and for drogued (c) and undrogued (d) temperature data, as a function of time lag. The number of data pairs is also shown. The model analytical best fit functions are represented by dotted lines.*

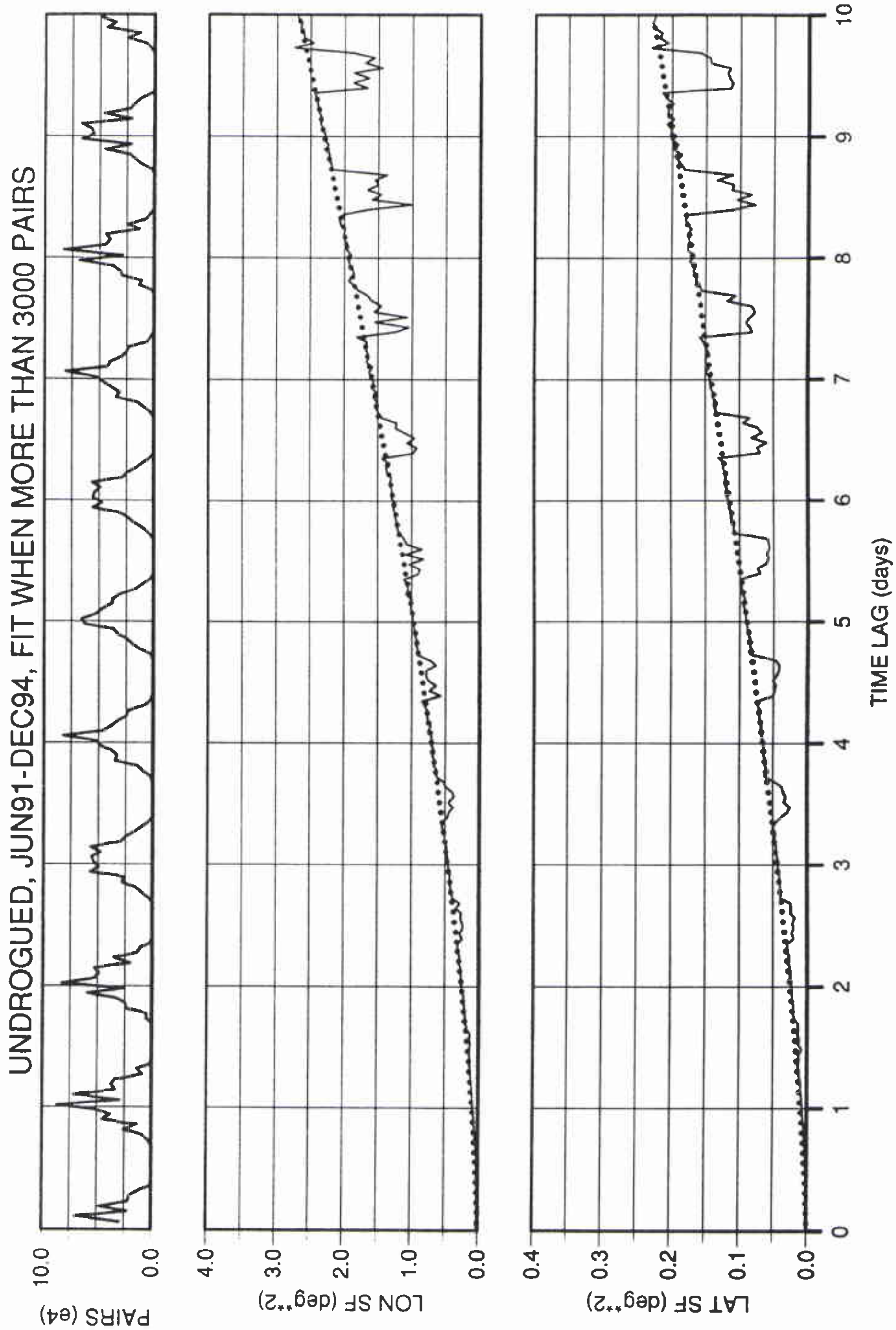
UNDROGUED, JUN91-DEC94, FIT WHEN MORE THAN 3000 PAIRS
PAIRS (e4)
LON SF (deg**2)
LAT SF (deg**2)
TIME LAG (days)

Figure 8b

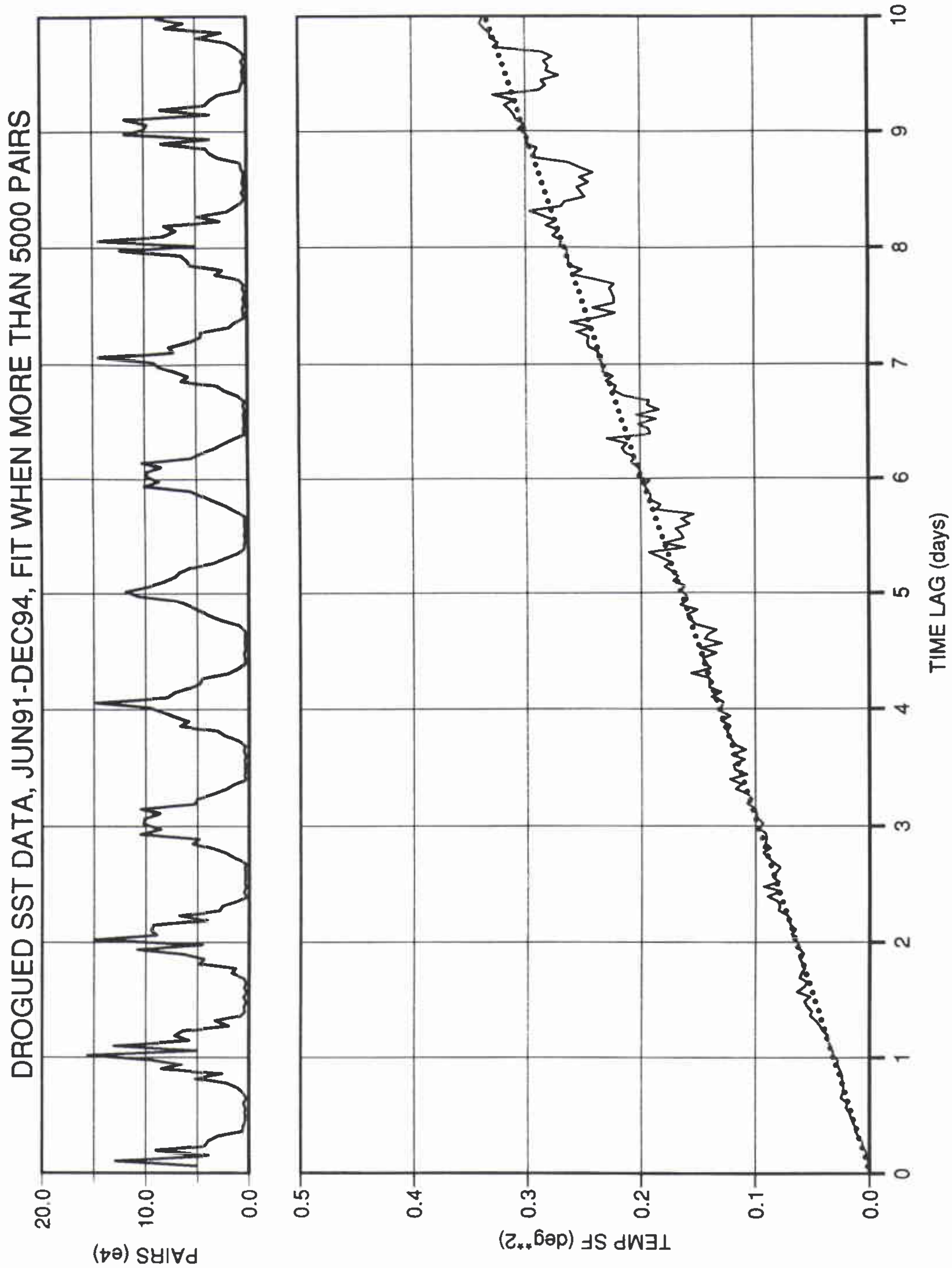
DROGUED SST DATA, JUN91-DEC94, FIT WHEN MORE THAN 5000 PAIRS
PAIRS (e4)
20.0
10.0
0.0
TEMP SF (deg**2)
0.5
0.4
0.3
0.2
0.1
0.0
TIME LAG (days)
0
1
2
3
4
5
6
7
8
9
10

Figure 8c

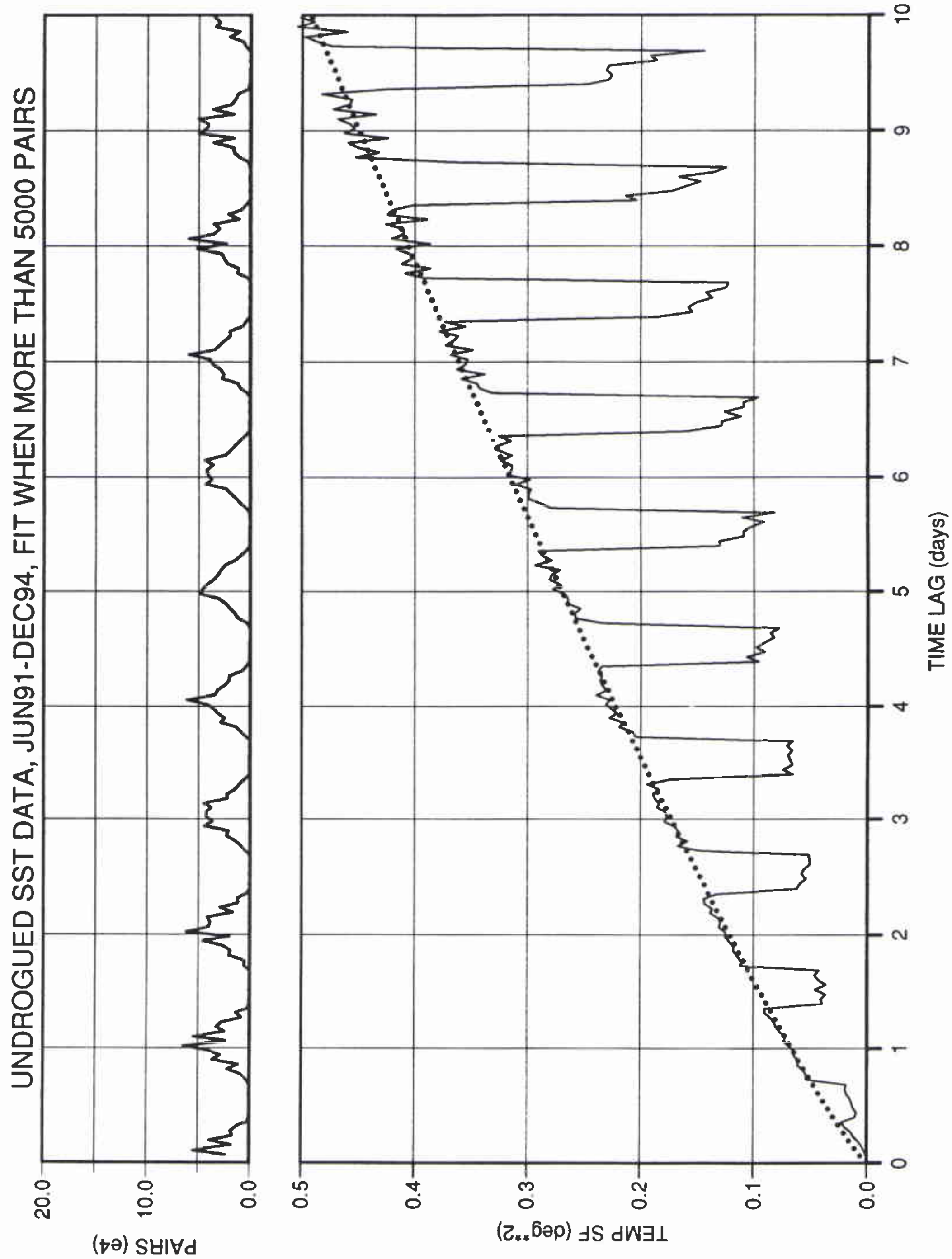
UNDROGUED SST DATA, JUN91-DEC94, FIT WHEN MORE THAN 5000 PAIRS
PAIRS (e4)
20.0
10.0
0.0
TEMP SF (deg**2)
0.5
0.4
0.3
0.2
0.1
0.0
TIME LAG (days)
0
1
2
3
4
5
6
7
8
9
10

Figure 8d

4

Data presentation

The drifter data are presented in the figures of Annexes B and C. Information on drifter performance, survivability and time distribution of drifter data is given in Annex B. Annex C includes graphics showing the ensemble of drifter trajectories (all data, drogued data and temperature data). The spatial distribution of data is displayed as the number of observations in 4° latitude by 2° longitude boxes. The velocity and temperature statistics (mean and variance) in these bins are also presented.

The complete set of graphics with the edited and interpolated data time series for each drifter separately, together with a graphical representation of its interpolated trajectory (Annex D), is available upon request from SACLANTCEN.

The SACLANTCEN Nordic seas data (raw Service Argos retrievals and the edited and interpolated drifter data sets) have been forwarded to the WOCE/TOGA Drifter Data Center, at MEDS, Canada, for dissemination to the scientific community.

5

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References

Essen, H.-H., Nacini, E. and Poulain, P.-M. (1995). Comparison of satellite-retrieved sea-surface temperatures with drifter- and ship-borne measurements. SACLANTCEN SM-297, La Spezia, Italy, SACLANT Undersea Research Centre.

Hansen, D.V. and Herman, A. (1989). Temporal sampling requirements for surface drifting buoys in the tropical Pacific. *Journal of Atmospheric and Oceanic Technology*, **6**: 599-607.

Hansen, D.V., and Poulain, P.-M. (1995). Processing of WOCE/TOGA drifter data. *Journal of Atmospheric and Oceanic Technology*, **12**: submitted.

Hawkins, D.M. (1980). Identification of outliers. London Chapman and Hall.

Hopkins, T.S. (1991). The GIN Sea - A synthesis of its physical oceanography and literature reviews 1972-1985. *Earth-Science Reviews*, **30**: 175-318.

Miller, A.J., Arango, H.G., Robinson, A.R., Leslie, W.G., Poulain, P.-M. and Warn-Varnas, A. (1995). Quasigeostrophic forecasting and physical processes of Iceland-Faeroe frontal variability. *Journal of Physical Oceanography*, **25**: 1273-1295.

Miller, A.J., Poulain, P.-M., Robinson, A.R., Arango, H.G., Leslie, W.G. and Warn-Varnas, A. (1995). Quantitative skill of quasigeostrophic forecasts of a baroclinically unstable Iceland- Faeroe Front. *Journal of Geophysical Research*, **100**: 10833-10849.

Niiler, P.P., Sybrandy, A.S., Bi, K., Poulain, P.-M. and Bitterman, D. (1995). Measurements of the water following capability of holey-sock and TRISTAR drifters. *Journal of Atmospheric and Oceanic Technology*, **12**: accepted.

Perkins, H., Sherwin, T.J. and Hopkins, T.S. (1994). Amplification of tidal currents by overflow on the Icelan-Faeroe Ridge. *Journal of Physical Oceanography*, **24**: 721-735.

Poulain, P.-M., Warn-Varnas, A. and Niiler, P.P. (1995). New surface of the Nordic Seas as measured by Lagrangian drifters. *Journal of Geophysical Research*: accepted.

Sybrandy, A.L. and Niiler, P.P. (1991). WOCE/TOGA Lagrangian drifter construction manual. SIO Ref. 91/6, WOCE Report 63, San Diego, California, Scripps Institution of Oceanography.

WCRP-26 (1988). Report of the First Meeting of the Surface Velocity Programme Planning Committee, SVP-1, and TOGA Pan-Pacific Surface Current Study. WMO/TD 323, WOCE Report 24/88, Wormley, United Kingdom, WOCE International Project Office.

A

1991 day conversion tables

All times in the Nordic seas drifter data set are Universal Time (UT) and are expressed in modified Julian days referred to year 1991 (first year of the program). This annex contains the date conversion tables for years 1991 to 1995.

MODIFIED JULIAN DAY
Year 1991 (referred to 1991)

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29	0	88	119	149	180	210	241	272	302	333	363
30	30	0	89	120	150	181	211	242	273	303	334	364
31	31	0	90	0	151	0	212	243	0	304	0	365

MODIFIED JULIAN DAY
Year 1992 (referred to 1991)

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	366	397	426	457	487	518	548	579	610	640	671	701
2	367	398	427	458	488	519	549	580	611	641	672	702
3	368	399	428	459	489	520	550	581	612	642	673	703
4	369	400	429	460	490	521	551	582	613	643	674	704
5	370	401	430	461	491	522	552	583	614	644	675	705
6	371	402	431	462	492	523	553	584	615	645	676	706
7	372	403	432	463	493	524	554	585	616	646	677	707
8	373	404	433	464	494	525	555	586	617	647	678	708
9	374	405	434	465	495	526	556	587	618	648	679	709
10	375	406	435	466	496	527	557	588	619	649	680	710
11	376	407	436	467	497	528	558	589	620	650	681	711
12	377	408	437	468	498	529	559	590	621	651	682	712
13	378	409	438	469	499	530	560	591	622	652	683	713
14	379	410	439	470	500	531	561	592	623	653	684	714
15	380	411	440	471	501	532	562	593	624	654	685	715
16	381	412	441	472	502	533	563	594	625	655	686	716
17	382	413	442	473	503	534	564	595	626	656	687	717
18	383	414	443	474	504	535	565	596	627	657	688	718
19	384	415	444	475	505	536	566	597	628	658	689	719
20	385	416	445	476	506	537	567	598	629	659	690	720
21	386	417	446	477	507	538	568	599	630	660	691	721
22	387	418	447	478	508	539	569	600	631	661	692	722
23	388	419	448	479	509	540	570	601	632	662	693	723
24	389	420	449	480	510	541	571	602	633	663	694	724
25	390	421	450	481	511	542	572	603	634	664	695	725
26	391	422	451	482	512	543	573	604	635	665	696	726
27	392	423	452	483	513	544	574	605	636	666	697	727
28	393	424	453	484	514	545	575	606	637	667	698	728
29	394	425	454	485	515	546	576	607	638	668	699	729
30	395	0	455	486	516	547	577	608	639	669	700	730
31	396	0	456	0	517	0	578	609	0	670	0	731

MODIFIED JULIAN DAY
Year 1993 (referred to 1991)

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	732	763	791	822	852	883	913	944	975	1005	1036	1066
2	733	764	792	823	853	884	914	945	976	1006	1037	1067
3	734	765	793	824	854	885	915	946	977	1007	1038	1068
4	735	766	794	825	855	886	916	947	978	1008	1039	1069
5	736	767	795	826	856	887	917	948	979	1009	1040	1070
6	737	768	796	827	857	888	918	949	980	1010	1041	1071
7	738	769	797	828	858	889	919	950	981	1011	1042	1072
8	739	770	798	829	859	890	920	951	982	1012	1043	1073
9	740	771	799	830	860	891	921	952	983	1013	1044	1074
10	741	772	800	831	861	892	922	953	984	1014	1045	1075
11	742	773	801	832	862	893	923	954	985	1015	1046	1076
12	743	774	802	833	863	894	924	955	986	1016	1047	1077
13	744	775	803	834	864	895	925	956	987	1017	1048	1078
14	745	776	804	835	865	896	926	957	988	1018	1049	1079
15	746	777	805	836	866	897	927	958	989	1019	1050	1080
16	747	778	806	837	867	898	928	959	990	1020	1051	1081
17	748	779	807	838	868	899	929	960	991	1021	1052	1082
18	749	780	808	839	869	900	930	961	992	1022	1053	1083
19	750	781	809	840	870	901	931	962	993	1023	1054	1084
20	751	782	810	841	871	902	932	963	994	1024	1055	1085
21	752	783	811	842	872	903	933	964	995	1025	1056	1086
22	753	784	812	843	873	904	934	965	996	1026	1057	1087
23	754	785	813	844	874	905	935	966	997	1027	1058	1088
24	755	786	814	845	875	906	936	967	998	1028	1059	1089
25	756	787	815	846	876	907	937	968	999	1029	1060	1090
26	757	788	816	847	877	908	938	969	1000	1030	1061	1091
27	758	789	817	848	878	909	939	970	1001	1031	1062	1092
28	759	790	818	849	879	910	940	971	1002	1032	1063	1093
29	760	0	819	850	880	911	941	972	1003	1033	1064	1094
30	761	0	820	851	881	912	942	973	1004	1034	1065	1095
31	762	0	821	0	882	0	943	974	0	1035	0	1096

MODIFIED JULIAN DAY
Year 1994 (referred to 1991)

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1097	1128	1156	1187	1217	1248	1278	1309	1340	1370	1401	1431
2	1098	1129	1157	1188	1218	1249	1279	1310	1341	1371	1402	1432
3	1099	1130	1158	1189	1219	1250	1280	1311	1342	1372	1403	1433
4	1100	1131	1159	1190	1220	1251	1281	1312	1343	1373	1404	1434
5	1101	1132	1160	1191	1221	1252	1282	1313	1344	1374	1405	1435
6	1102	1133	1161	1192	1222	1253	1283	1314	1345	1375	1406	1436
7	1103	1134	1162	1193	1223	1254	1284	1315	1346	1376	1407	1437
8	1104	1135	1163	1194	1224	1255	1285	1316	1347	1377	1408	1438
9	1105	1136	1164	1195	1225	1256	1286	1317	1348	1378	1409	1439
10	1106	1137	1165	1196	1226	1257	1287	1318	1349	1379	1410	1440
11	1107	1138	1166	1197	1227	1258	1288	1319	1350	1380	1411	1441
12	1108	1139	1167	1198	1228	1259	1289	1320	1351	1381	1412	1442
13	1109	1140	1168	1199	1229	1260	1290	1321	1352	1382	1413	1443
14	1110	1141	1169	1200	1230	1261	1291	1322	1353	1383	1414	1444
15	1111	1142	1170	1201	1231	1262	1292	1323	1354	1384	1415	1445
16	1112	1143	1171	1202	1232	1263	1293	1324	1355	1385	1416	1446
17	1113	1144	1172	1203	1233	1264	1294	1325	1356	1386	1417	1447
18	1114	1145	1173	1204	1234	1265	1295	1326	1357	1387	1418	1448
19	1115	1146	1174	1205	1235	1266	1296	1327	1358	1388	1419	1449
20	1116	1147	1175	1206	1236	1267	1297	1328	1359	1389	1420	1450
21	1117	1148	1176	1207	1237	1268	1298	1329	1360	1390	1421	1451
22	1118	1149	1177	1208	1238	1269	1299	1330	1361	1391	1422	1452
23	1119	1150	1178	1209	1239	1270	1300	1331	1362	1392	1423	1453
24	1120	1151	1179	1210	1240	1271	1301	1332	1363	1393	1424	1454
25	1121	1152	1180	1211	1241	1272	1302	1333	1364	1394	1425	1455
26	1122	1153	1181	1212	1242	1273	1303	1334	1365	1395	1426	1456
27	1123	1154	1182	1213	1243	1274	1304	1335	1366	1396	1427	1457
28	1124	1155	1183	1214	1244	1275	1305	1336	1367	1397	1428	1458
29	1125	0	1184	1215	1245	1276	1306	1337	1368	1398	1429	1459
30	1126	0	1185	1216	1246	1277	1307	1338	1369	1399	1430	1460
31	1127	0	1186	0	1247	0	1308	1339	0	1400	0	1461

MODIFIED JULIAN DAY
Year 1995 (referred to 1991)

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1462	1493	1521	1552	1582	1613	1643	1674	1705	1735	1766	1796
2	1463	1494	1522	1553	1583	1614	1644	1675	1706	1736	1767	1797
3	1464	1495	1523	1554	1584	1615	1645	1676	1707	1737	1768	1798
4	1465	1496	1524	1555	1585	1616	1646	1677	1708	1738	1769	1799
5	1466	1497	1525	1556	1586	1617	1647	1678	1709	1739	1770	1800
6	1467	1498	1526	1557	1587	1618	1648	1679	1710	1740	1771	1801
7	1468	1499	1527	1558	1588	1619	1649	1680	1711	1741	1772	1802
8	1469	1500	1528	1559	1589	1620	1650	1681	1712	1742	1773	1803
9	1470	1501	1529	1560	1590	1621	1651	1682	1713	1743	1774	1804
10	1471	1502	1530	1561	1591	1622	1652	1683	1714	1744	1775	1805
11	1472	1503	1531	1562	1592	1623	1653	1684	1715	1745	1776	1806
12	1473	1504	1532	1563	1593	1624	1654	1685	1716	1746	1777	1807
13	1474	1505	1533	1564	1594	1625	1655	1686	1717	1747	1778	1808
14	1475	1506	1534	1565	1595	1626	1656	1687	1718	1748	1779	1809
15	1476	1507	1535	1566	1596	1627	1657	1688	1719	1749	1780	1810
16	1477	1508	1536	1567	1597	1628	1658	1689	1720	1750	1781	1811
17	1478	1509	1537	1568	1598	1629	1659	1690	1721	1751	1782	1812
18	1479	1510	1538	1569	1599	1630	1660	1691	1722	1752	1783	1813
19	1480	1511	1539	1570	1600	1631	1661	1692	1723	1753	1784	1814
20	1481	1512	1540	1571	1601	1632	1662	1693	1724	1754	1785	1815
21	1482	1513	1541	1572	1602	1633	1663	1694	1725	1755	1786	1816
22	1483	1514	1542	1573	1603	1634	1664	1695	1726	1756	1787	1817
23	1484	1515	1543	1574	1604	1635	1665	1696	1727	1757	1788	1818
24	1485	1516	1544	1575	1605	1636	1666	1697	1728	1758	1789	1819
25	1486	1517	1545	1576	1606	1637	1667	1698	1729	1759	1790	1820
26	1487	1518	1546	1577	1607	1638	1668	1699	1730	1760	1791	1821
27	1488	1519	1547	1578	1608	1639	1669	1700	1731	1761	1792	1822
28	1489	1520	1548	1579	1609	1640	1670	1701	1732	1762	1793	1823
29	1490	0	1549	1580	1610	1641	1671	1702	1733	1763	1794	1824
30	1491	0	1550	1581	1611	1642	1672	1703	1734	1764	1795	1825
31	1492	0	1551	0	1612	0	1673	1704	0	1765	0	1826

B

Drifter performance statistics

The statistics of the drifter system performances are presented in the tables and figures included in this Annex. The time distribution of the drifter data is represented in different ways: (1) Bar diagram showing the life times of all drifters; (2) the distribution of the number of active drifters as a function of time; and (3) the distribution of the number of drifter-days per month, also including the separation of drifter data in the Nordic and Barents seas. Longevity characteristics are displayed in a life time histogram and in a survivability plot.

Table B1 Drifter performance statistics: Maximum life time, half-life and number of drifter-days.

TABLE B1: DRIFTER PERFORMANCE STATISTICS

MAXIMUM LIFE TIME			
	DRIFTING TRANSMITTER:	1031 DAYS	
	DRIFTING DROGUED:	809 DAYS	
	DRIFTING GOOD SST SENSOR:	923 DAYS	
HALF-LIVES			
	DRIFTING TRANSMITTER:	191 DAYS	
	DRIFTING DROGUED:	157 DAYS	
	DRIFTING GOOD SST SENSOR:	114 DAYS	
NUMBER OF DRIFTER-DAYS (OR DRIFTER-YEARS)			
	DRIFTING TRANSMITTER:	30986 DAYS	85 YEARS
	DRIFTING DROGUED:	20845 DAYS	57 YEARS
	DRIFTING UNDROGUED:	10141 DAYS	28 YEARS
	DRIFTING GOOD SST SENSOR:	21979 DAYS	60 YEARS

Table B2 Days, years and percentage of drifter presence in the Nordic and Barents seas.

TABLE B2: DRIFTER DATA IN THE NORDIC AND BARENTS SEAS

NORDIC SEAS (WEST OF 20E)			
NUMBER OF DRIFTER-DAYS (OR DRIFTER-YEARS)			
DRIFTING TRANSMITTER:	26748 DAYS	73 YEARS	86%
DRIFTING DROGUED:	18964 DAYS	52 YEARS	91%
DRIFTING UNDROGUED:	7785 DAYS	21 YEARS	77%
DRIFTING GOOD SST SENSOR:	19625 DAYS	54 YEARS	89%
BARENTS SEA (EAST OF 20E)			
NUMBER OF DRIFTER-DAYS (OR DRIFTER-YEARS)			
DRIFTING TRANSMITTER:	4238 DAYS	12 YEARS	14%
DRIFTING DROGUED:	1882 DAYS	5 YEARS	9%
DRIFTING UNDROGUED:	2356 DAYS	6 YEARS	23%
DRIFTING GOOD SST SENSOR:	2348 DAYS	6 YEARS	11%

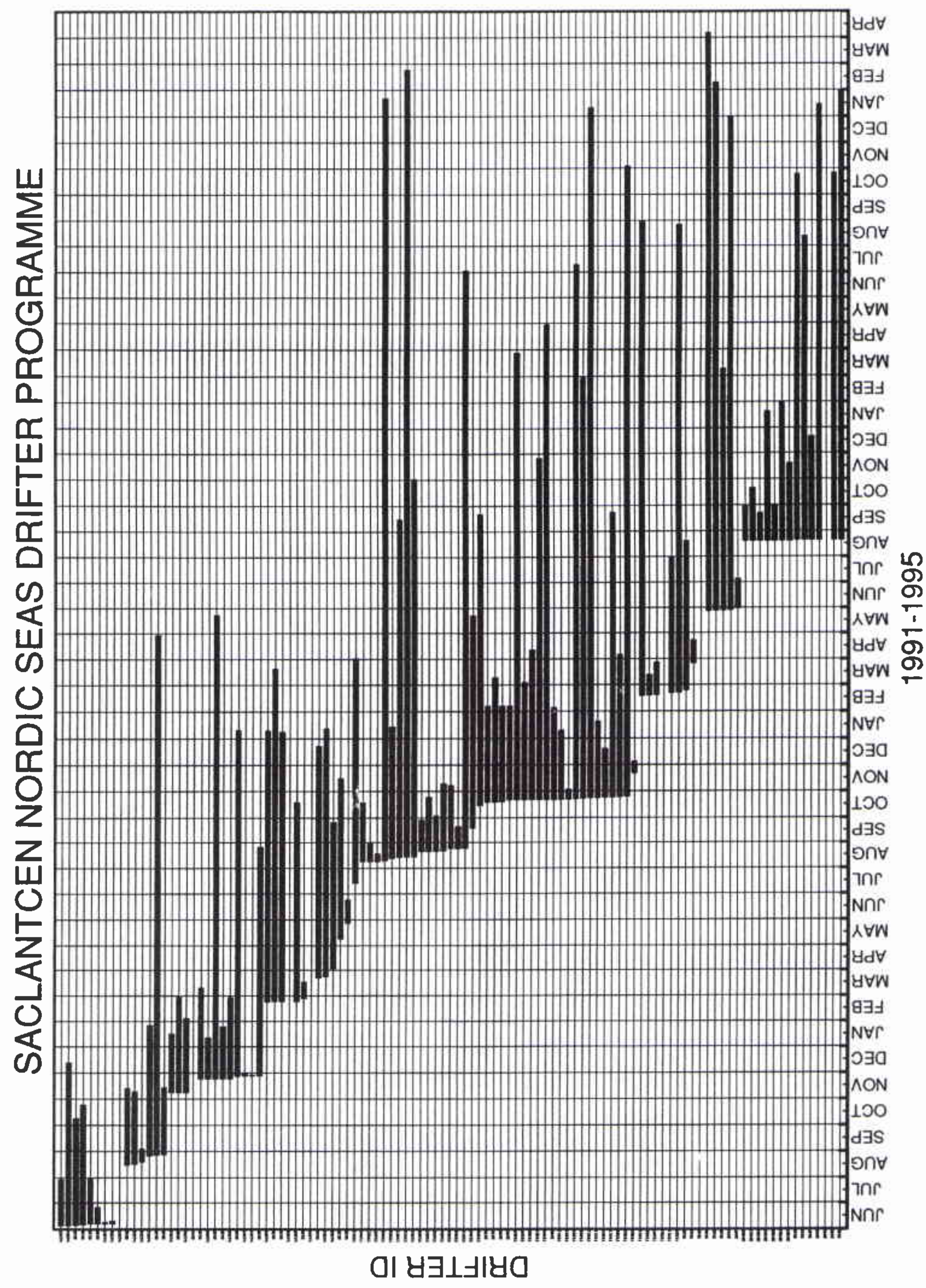

Figure B1 *Horizontal bar diagram showing the life times of all the drifters between June 1991 and April 1995.*

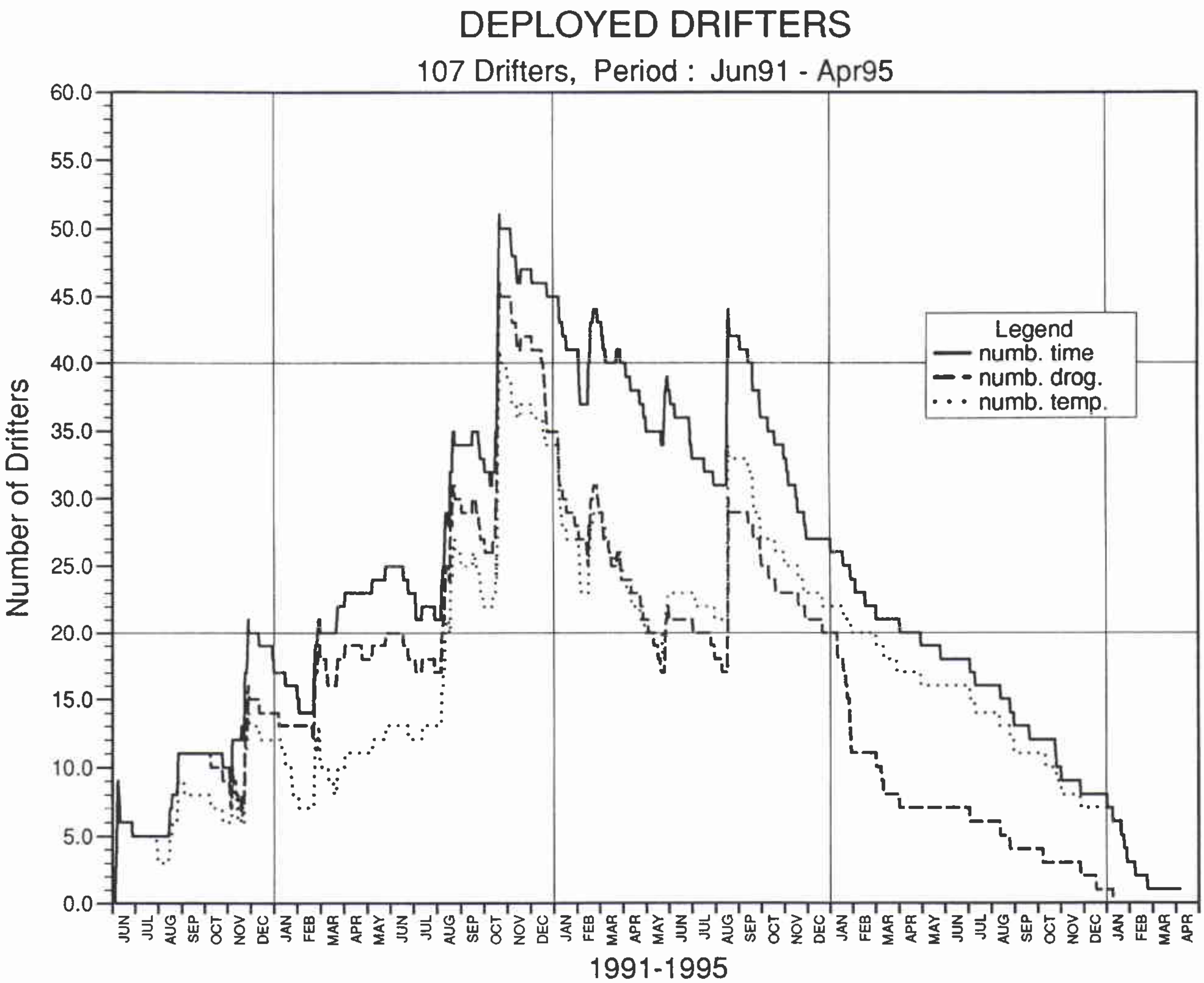

Figure B2 *Total number of simultaneous drifters alive (solid), with drogue attached (dashed) and with good SST sensor (dotted) as a function of time. The distribution has two major peaks in October 1992 (51 drifters) and in August 1993 (44 drifters) corresponding to the major deployments carried out during the GIN92 and GIN93 Iceland-Faeroe Front surveys, respectively.*

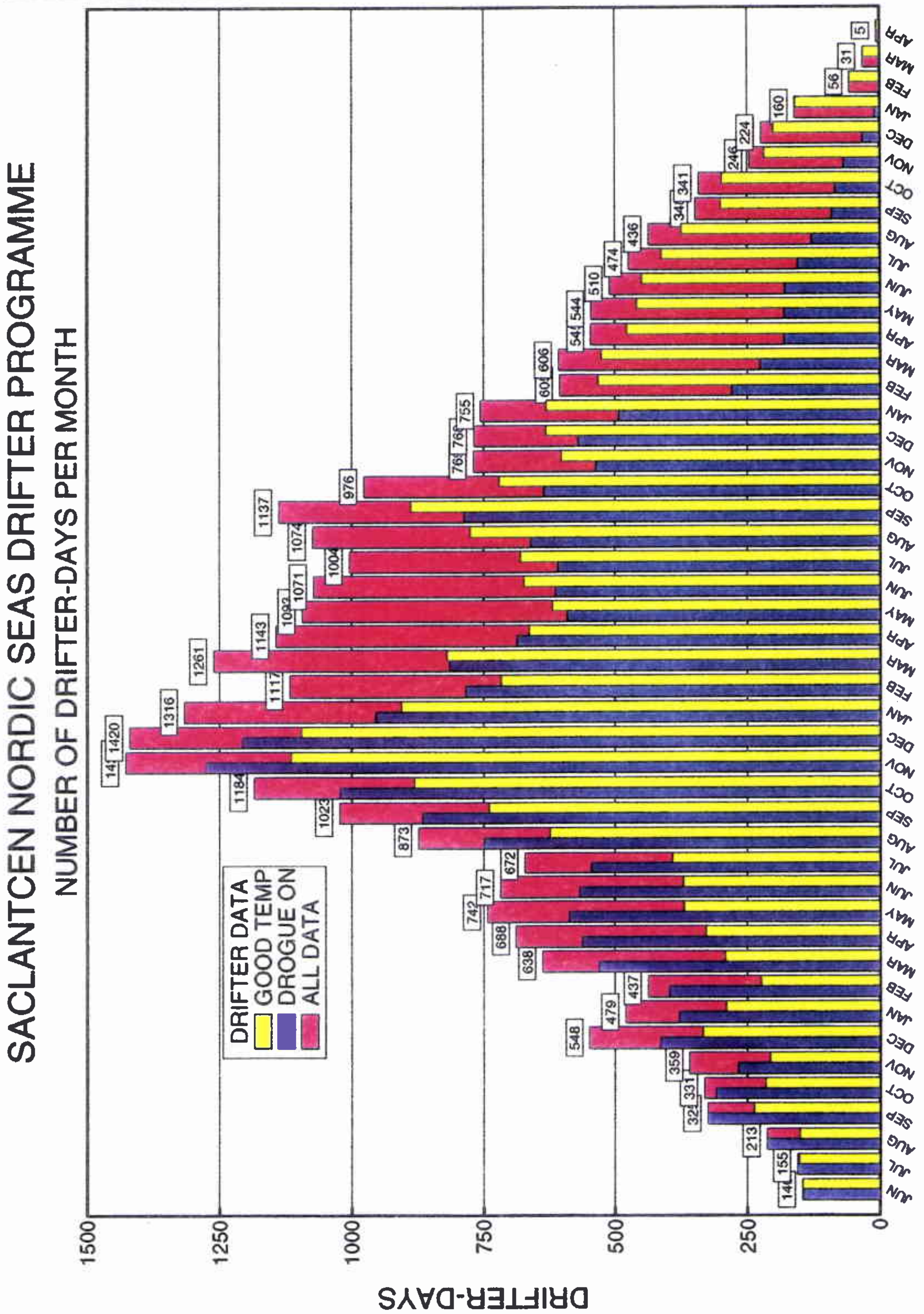

Figure B3 *Vertical bar diagram showing the distribution of the number of drifter-days (red), drogued drifter-days (blue) and SST-drifter-days (yellow) per month. The maximum density of data was reached in November-December 1992 with more than 1400 drifter-days per month.*

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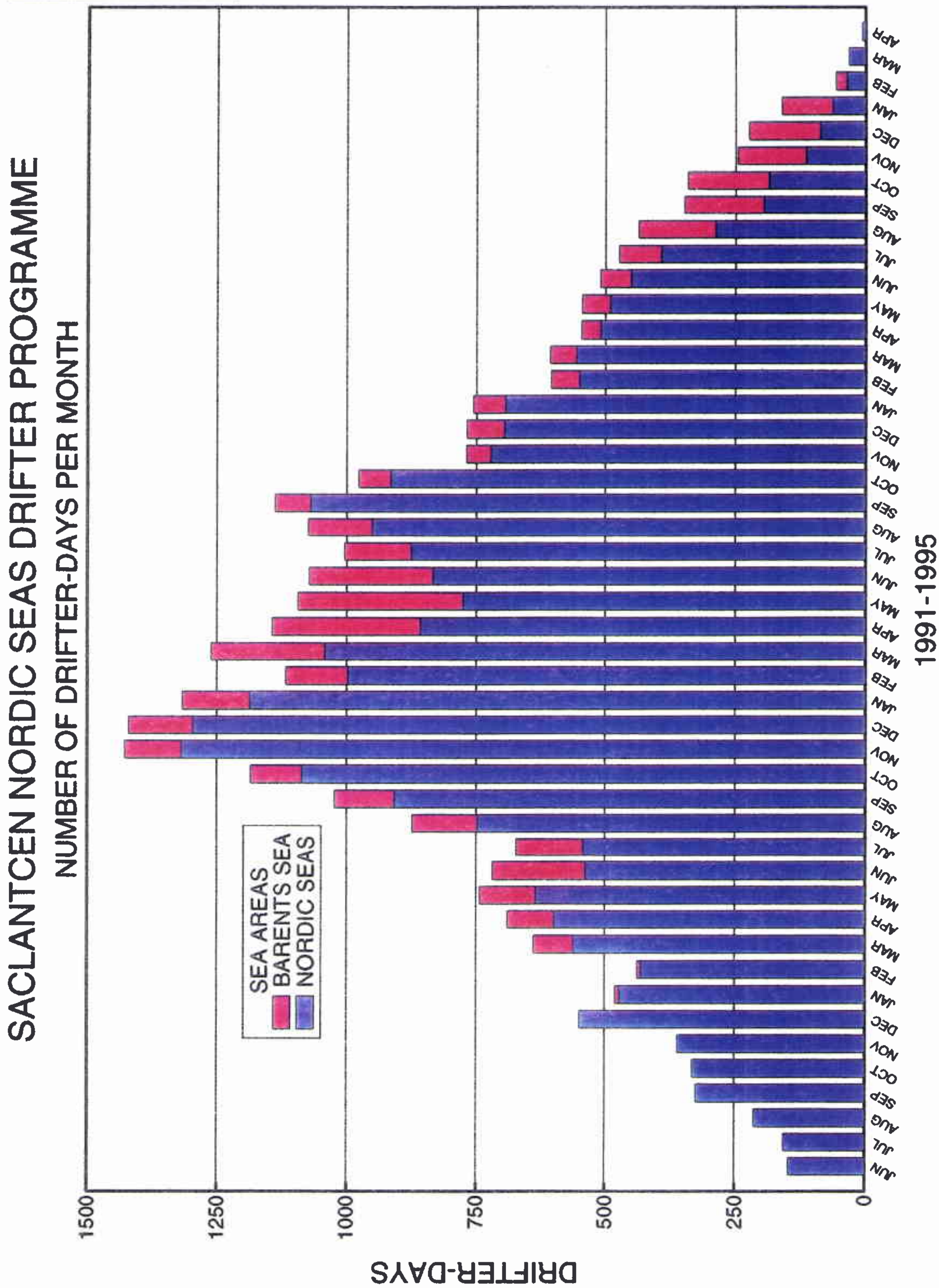

Figure B4 *Time distribution of the number of drifter-days per month in the Nordic seas (blue) and Barents sea (red) basins. The longitudinal limit between the two basins was chosen as 20° E: (a) All drifter data, (b) drogued drifter data, (c) undrogued drifter data and (d) drifter temperature data.*

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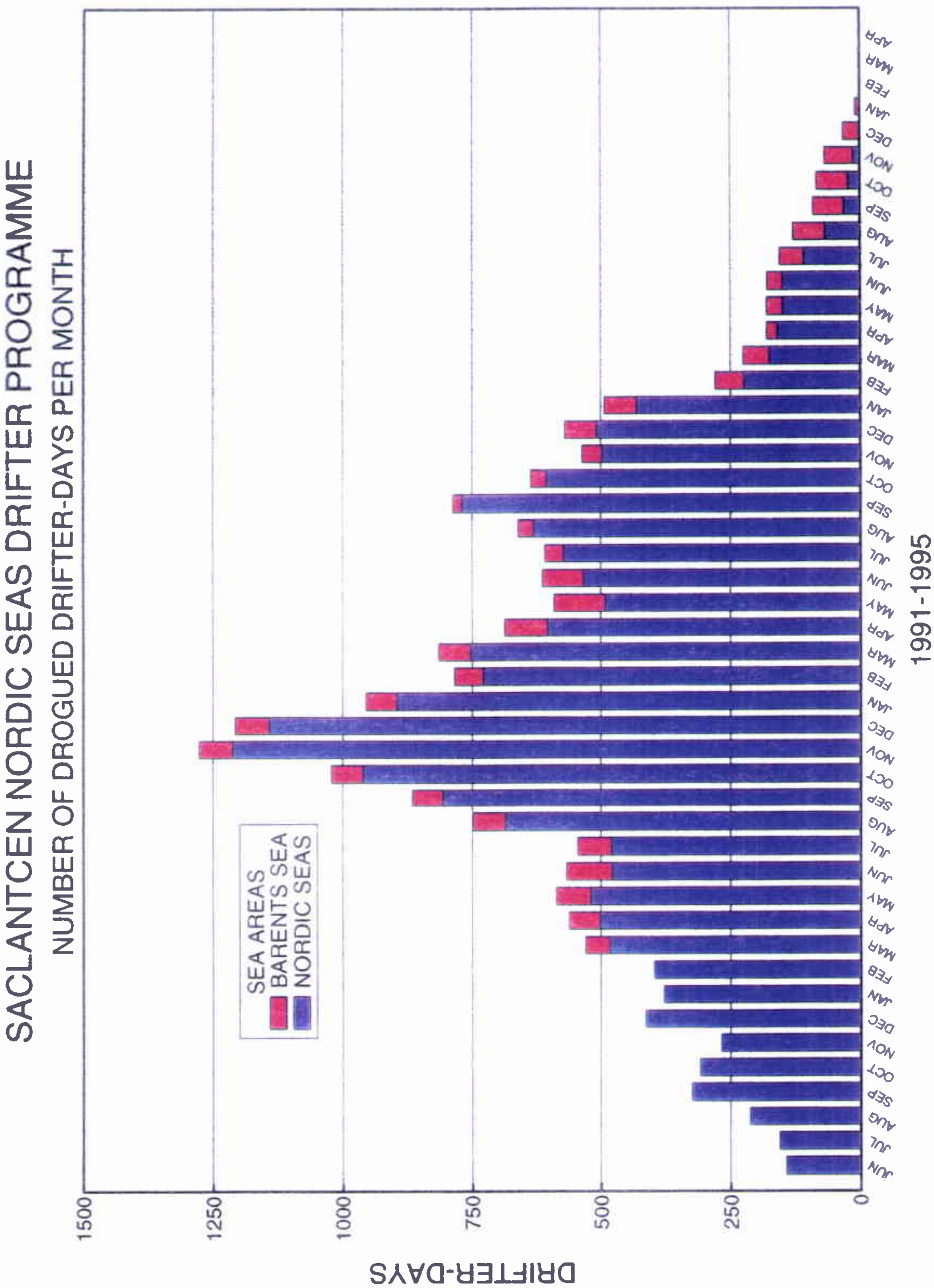
SACLANTCEN NORDIC SEAS DRIFTER PROGRAMME
NUMBER OF DROGUED DRIFTER-DAYS PER MONTH
SEA AREAS
BARENTS SEA
NORDIC SEAS
1991-1995
DRIFTER-DAYS
0
250
500
750
1000
1250
1500
JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR

Figure B4b

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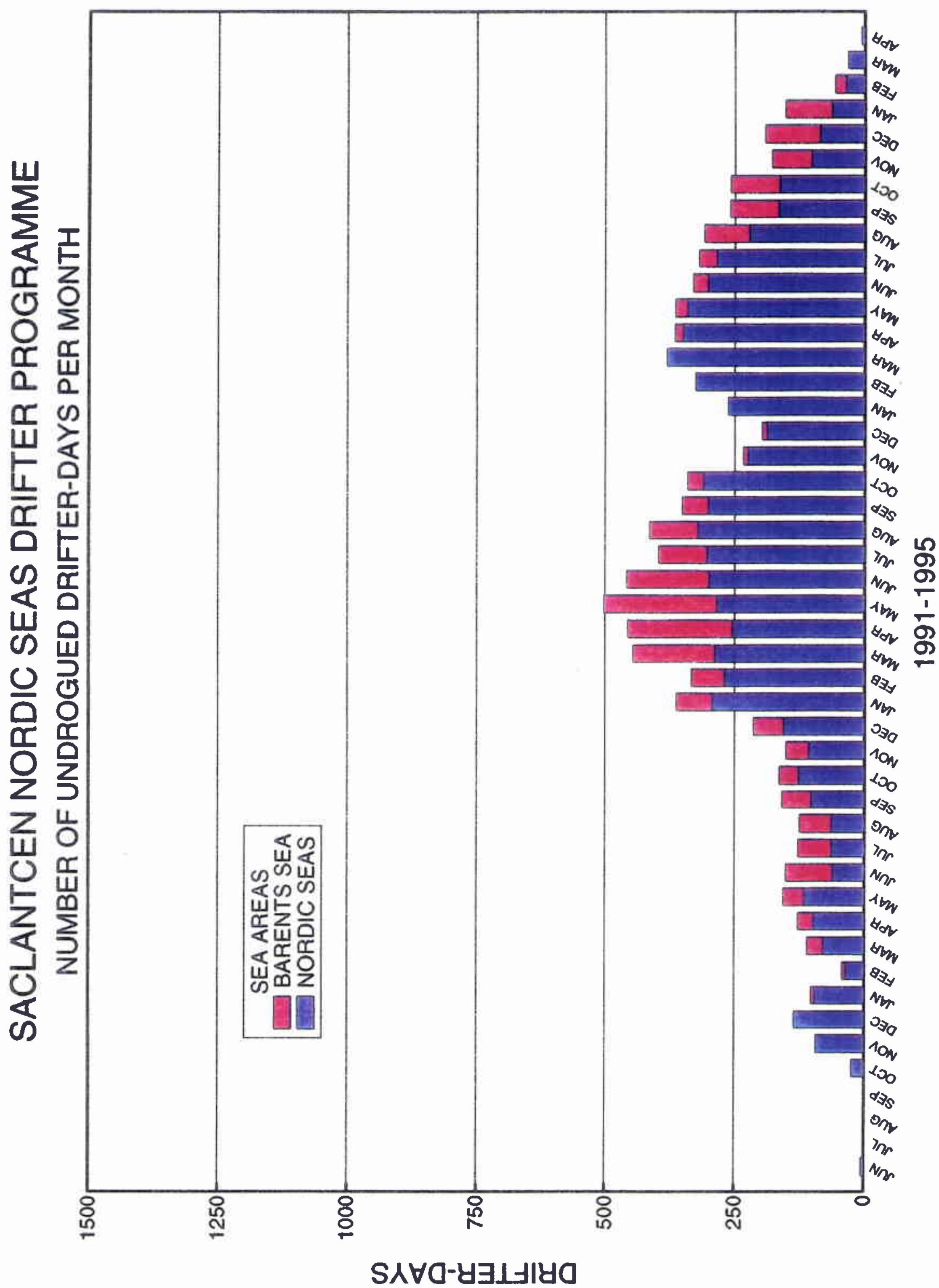
SACLANTCEN NORDIC SEAS DRIFTER PROGRAMME
NUMBER OF UNDROGUED DRIFTER-DAYS PER MONTH
SEA AREAS
BARENTS SEA
NORDIC SEAS
1500
1250
1000
750
500
250
0
DRIFTER-DAYS
1991-1995

Figure B4c

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Report no. changed (Mar 2006): SM-299-UU

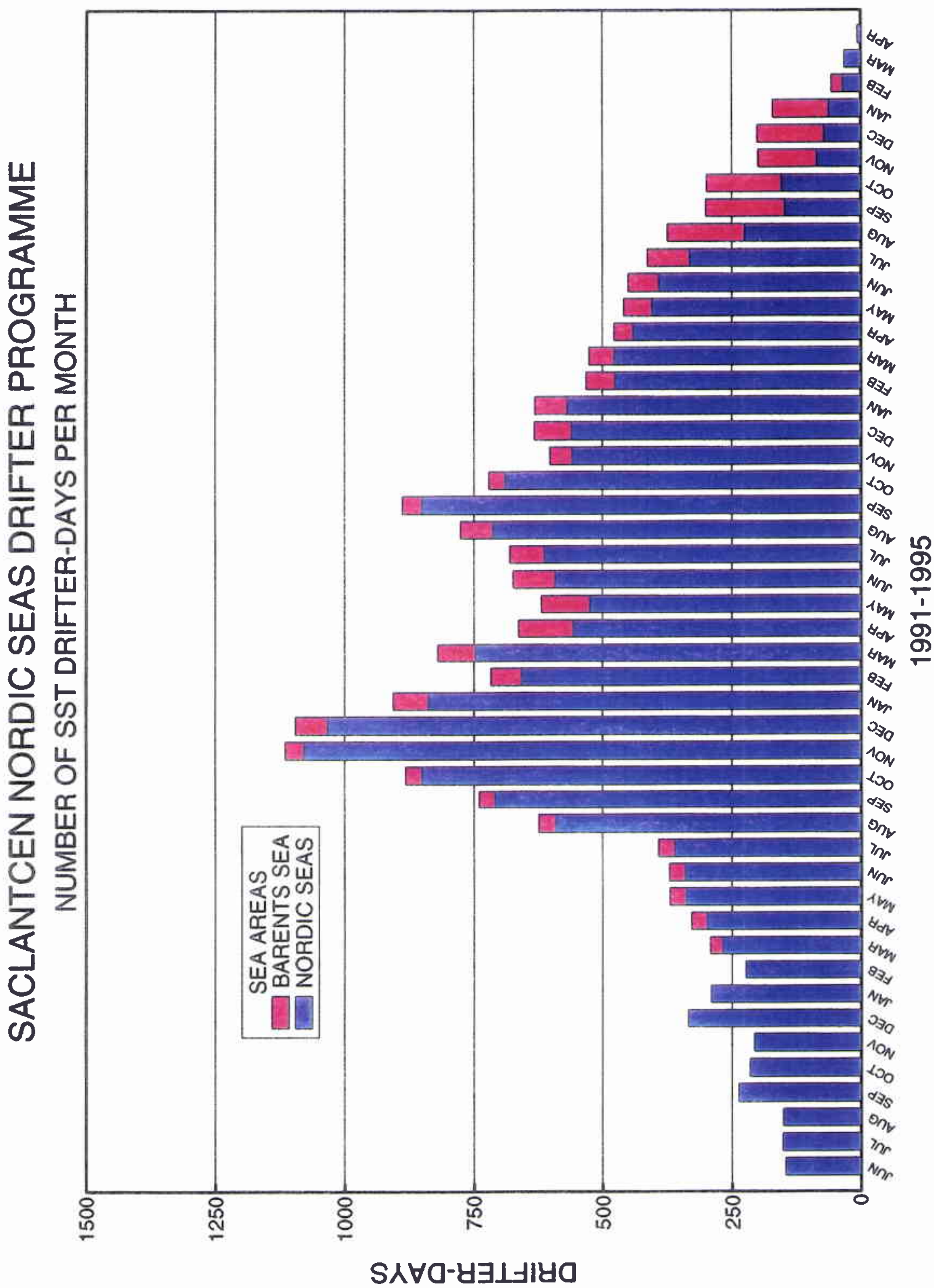

Figure B4d

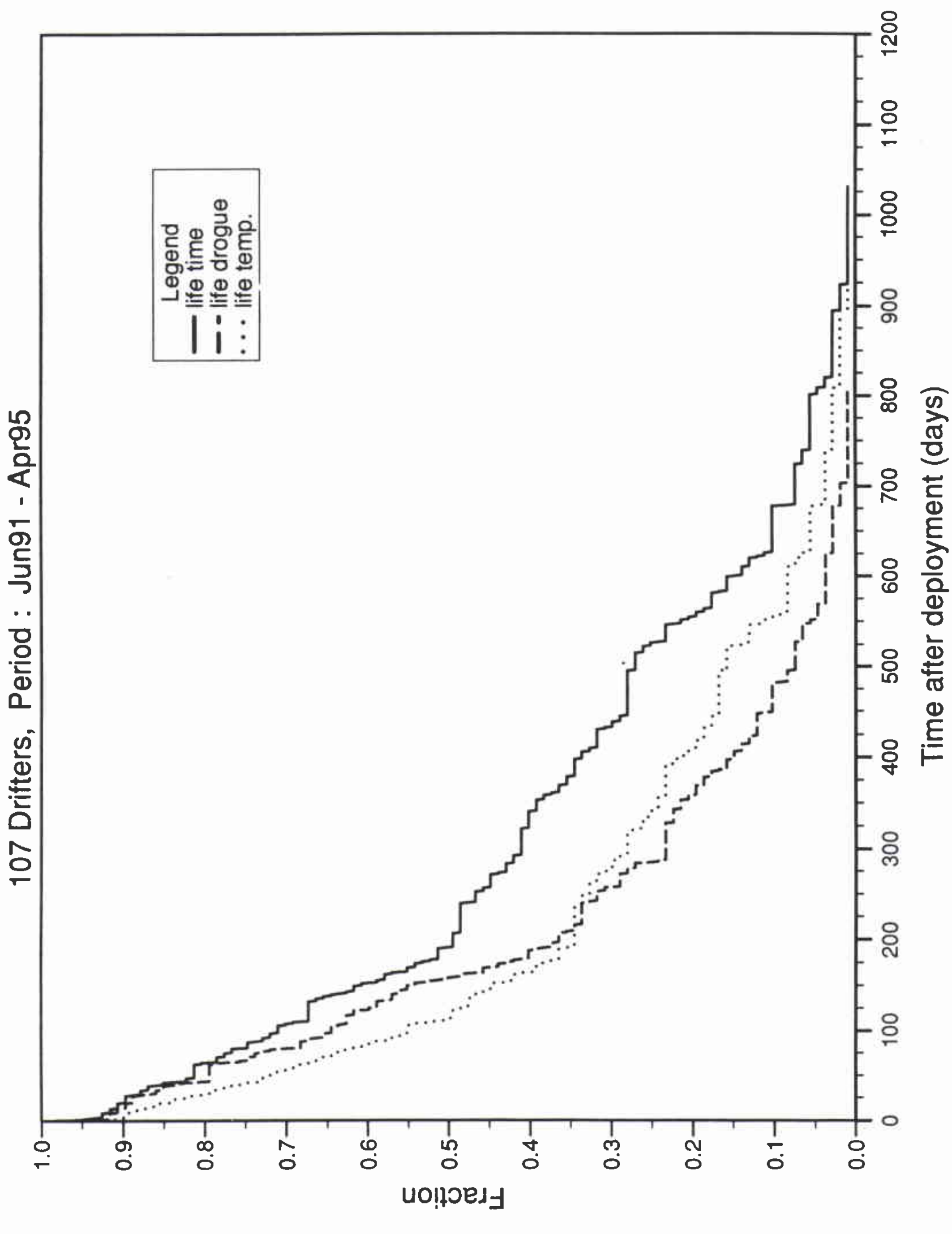

Figure B5 *Drifter survivability plot showing the fraction of deployed drifters still transmitting (and freely drifting with the currents) (solid), with drogue attached (dashed) and with good SST sensor (dotted) as a function of time after deployment. The times corresponding to a fraction of 0.5 are the mean half lives, i.e., 191 days (drifting transmitter), 157 days (drifting drogue) and 114 days (drifting good temperature sensor).*

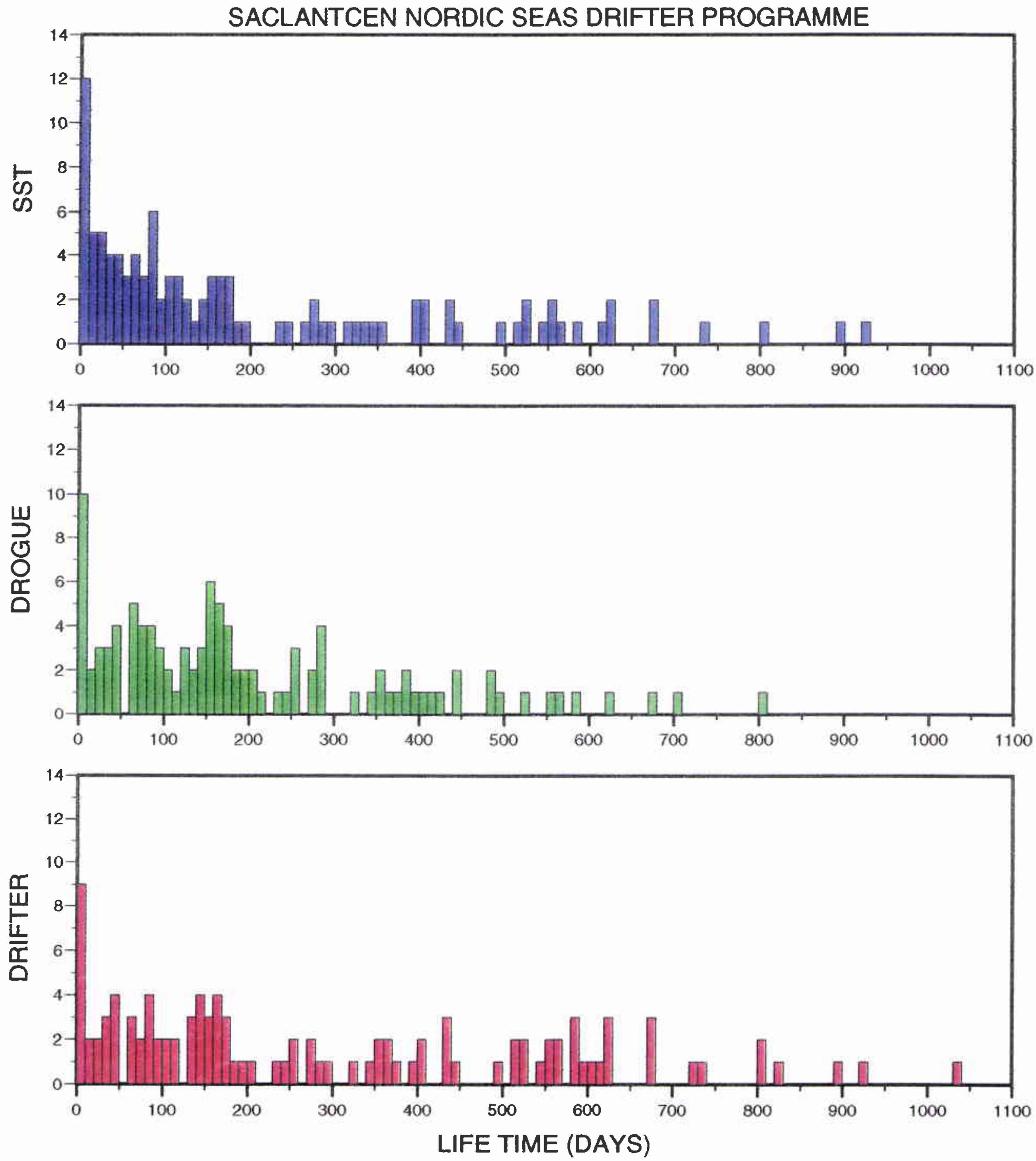

Figure B6 *Histogram of drifting transmitter (red), drogue (green) and SST sensor (blue) life times.*

C

Composite maps and Eulerian statistics

This section includes geographical maps with various representations of the global data set. Composite "spaghetti" diagrams (Total displacements, trajectories of drogued and/or undrogued drifters, trajectories of SST drifters) are presented. Eulerian statistics have been calculated by averaging the velocity and temperature observations in bins of 4° latitude by 2° longitude. The number of observations, the mean value and the variance are shown. For the velocity data, the statistics are represented as mean velocity vectors and principal axes of variance; whereas for the temperature data, the mean and variance are simply posted. The principal axes of velocity variance have been computed as follows: Their length is equal to twice the roots λ_1 and λ_2 of

$$((\langle u'^2 \rangle - \lambda)((\langle v'^2 \rangle - \lambda) \; - \langle u'v' \rangle^2 \; = \; 0, \qquad (C1)$$

where u' and v' are the residual velocity components. The direction of the major axis, θ, is related to $\langle u'v' \rangle$ by

$$0.5 \; tan(2\theta) = \frac{\langle u'v' \rangle}{(\langle v'^2 \rangle - \langle u'^2 \rangle)}. \qquad (C2)$$

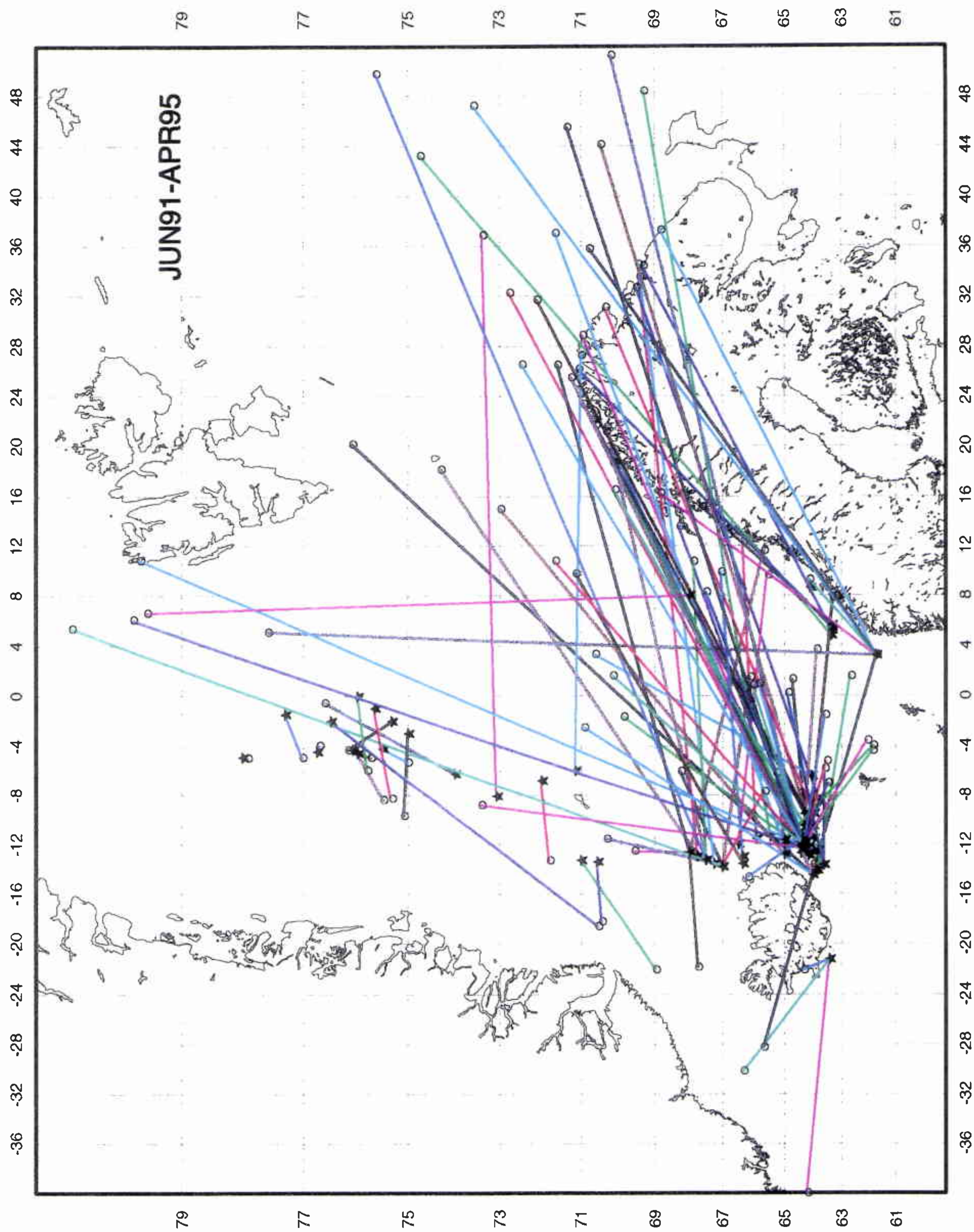

Figure C1 *Total displacement vectors connecting the deployment site (start symbol) to the location of last good fix (circle symbol). The vectors are arbitrarily color coded.*

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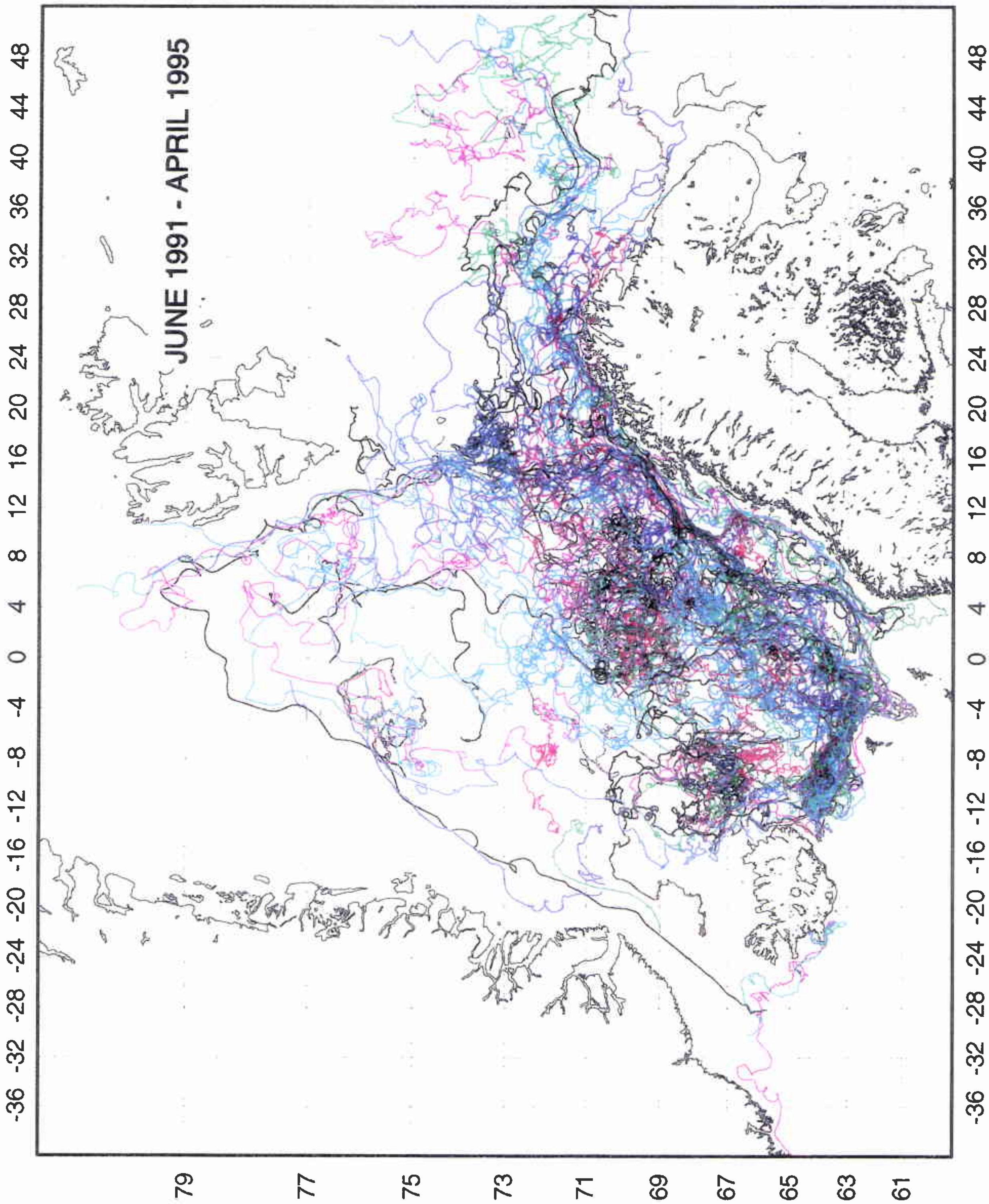

Figure C2 *Drifter trajectories corresponding to (a) all the drifter data, (b) the drogued drifter data and (c) the SST drifter data. The trajectories are arbitrarily color coded.*

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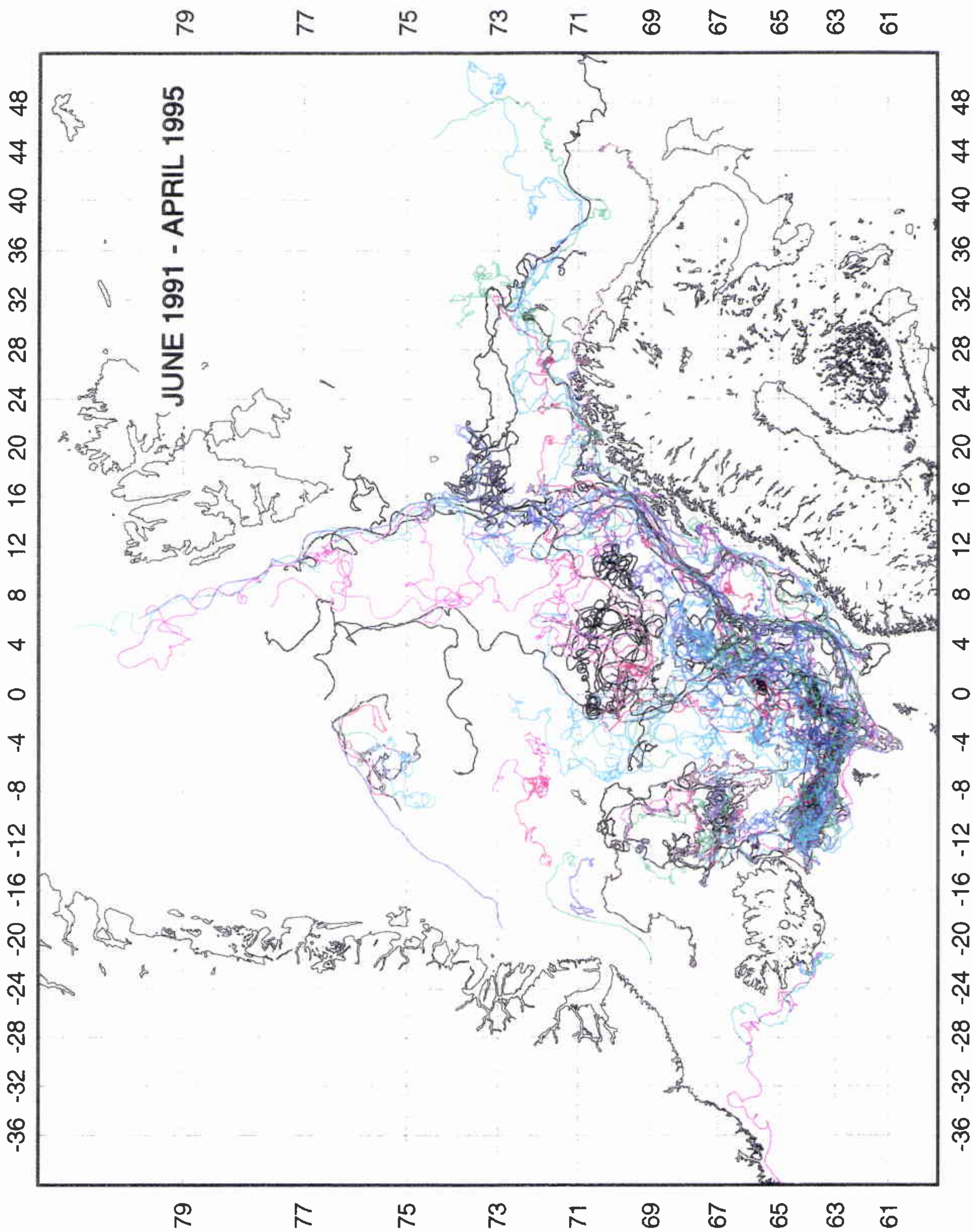
JUNE 1991 - APRIL 1995
79 77 75 73 71 69 67 65 63 61
48 44 40 36 32 28 24 20 16 12 8 4 0 -4 -8 -12 -16 -20 -24 -28 -32 -36

Figure C2b

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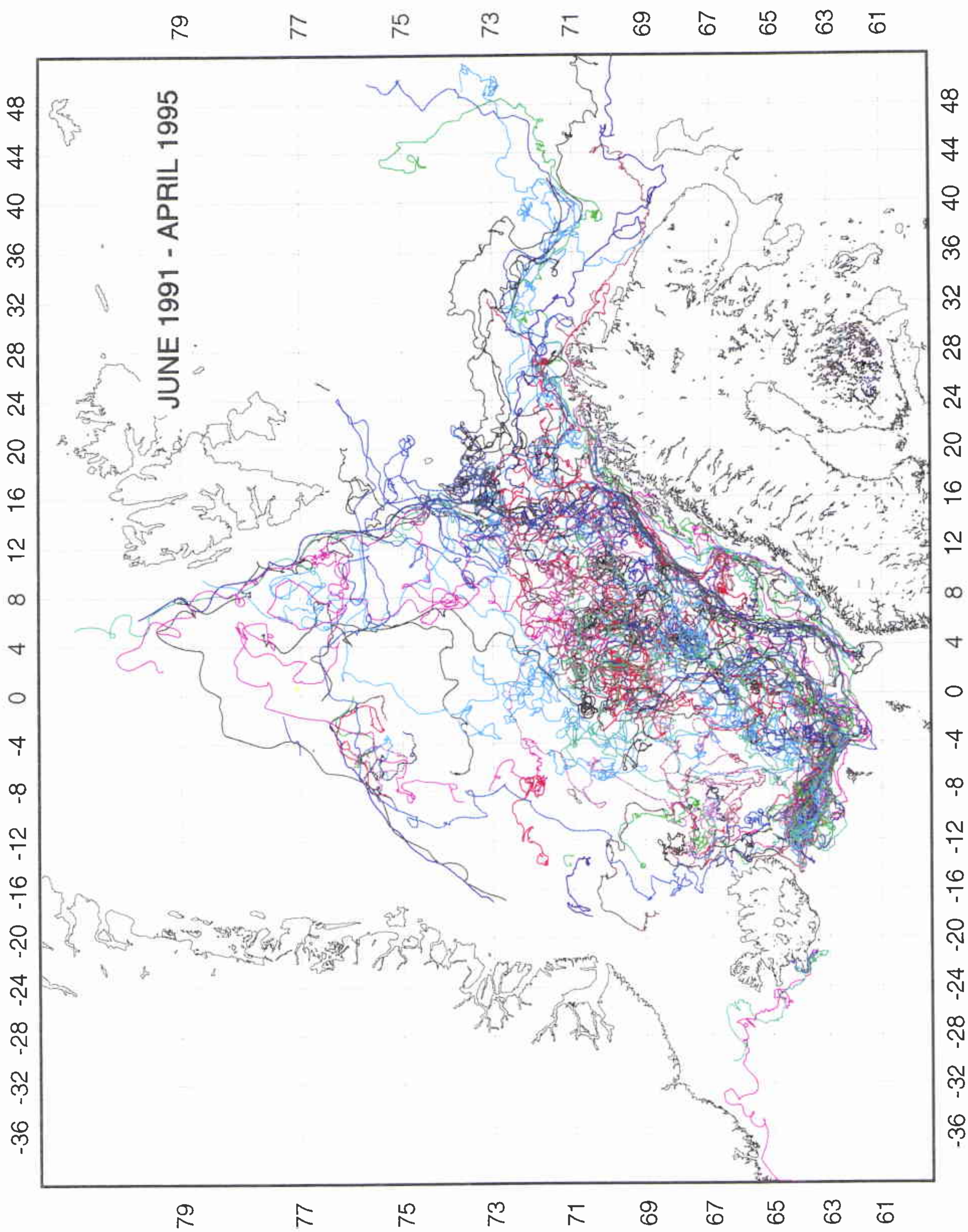
JUNE 1991 - APRIL 1995
79 77 75 73 71 69 67 65 63 61
-36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40 44 48

Figure C2c

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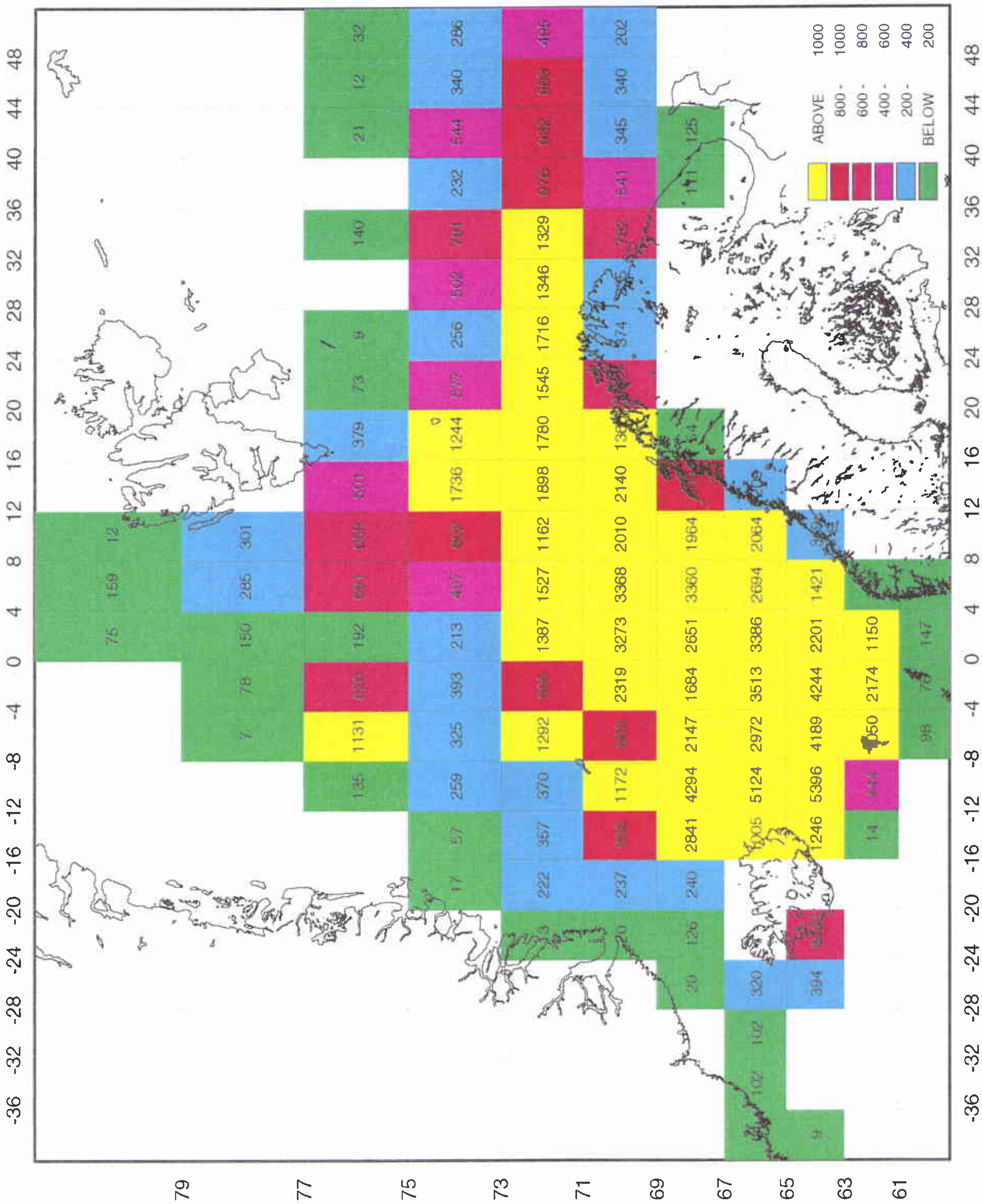

Figure C3 *Number of 6-hourly drifter data in 4° latitude by 2° longitude bins for (a) the whole duration of the drifter program (June 1991 to April 1995) and for the individual years: (b) 1991, (c) 1992, (d) 1993, (e) 1994 and (f) 1995. The values are posted and color coded.*

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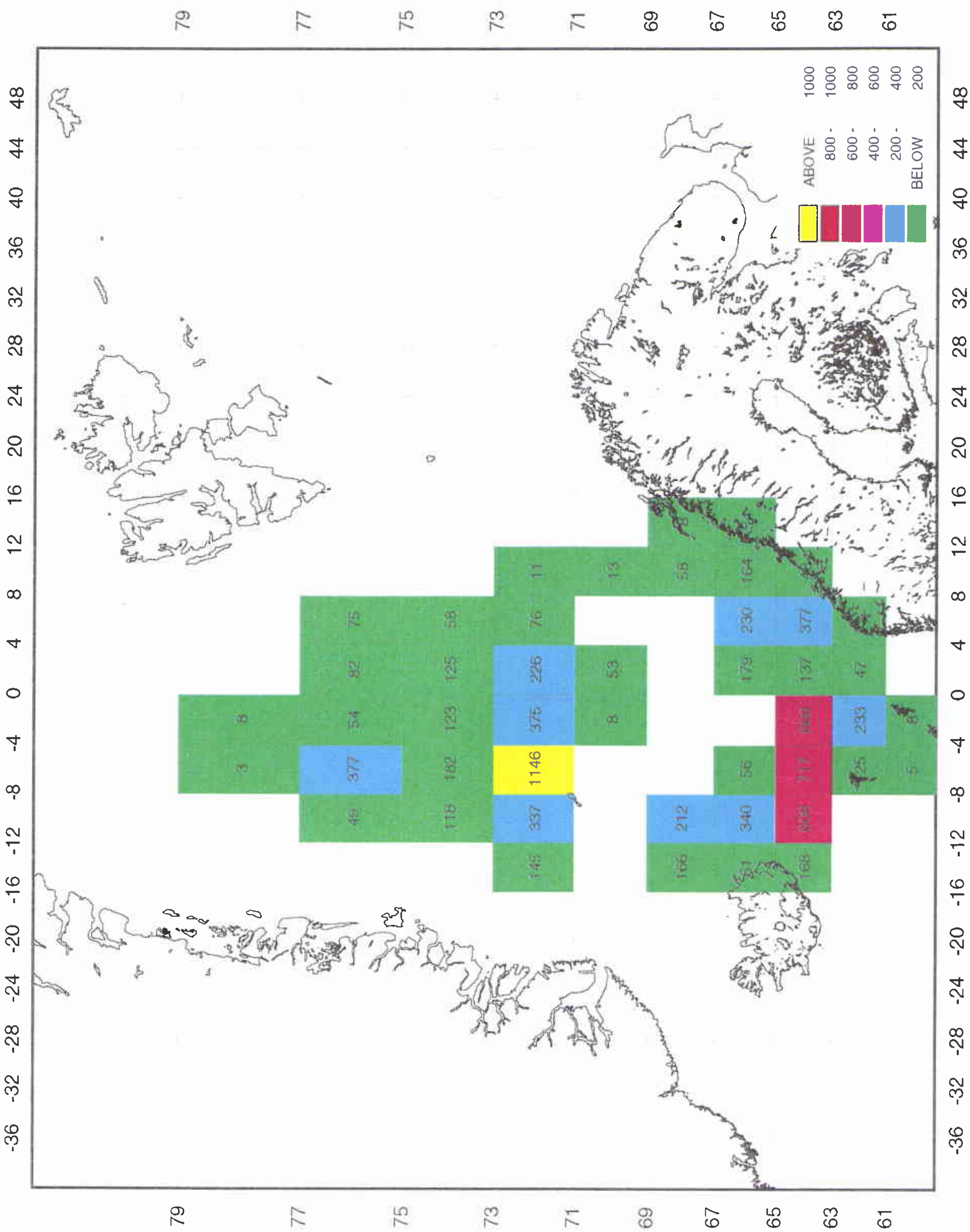

Figure C3b

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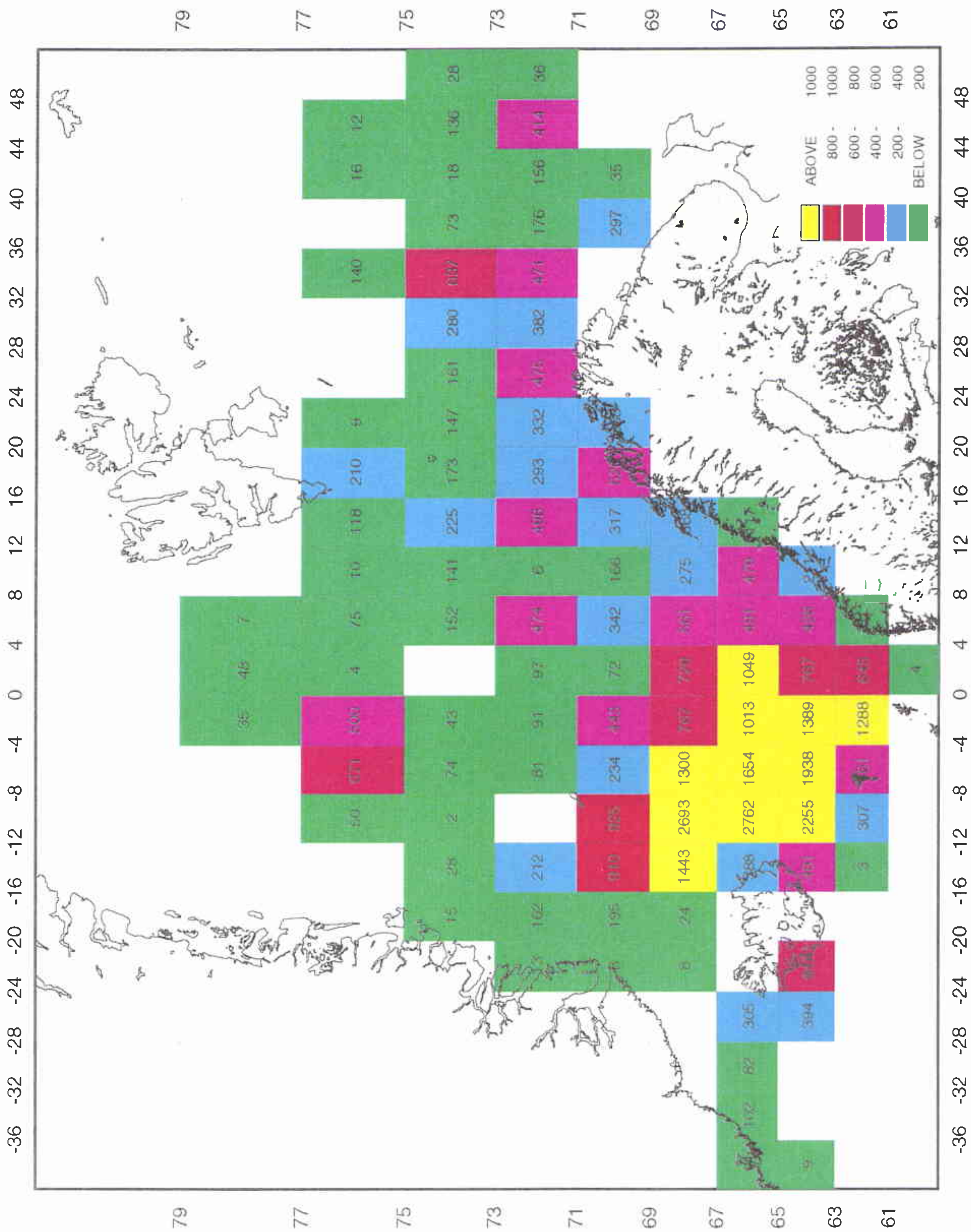

Figure C3c

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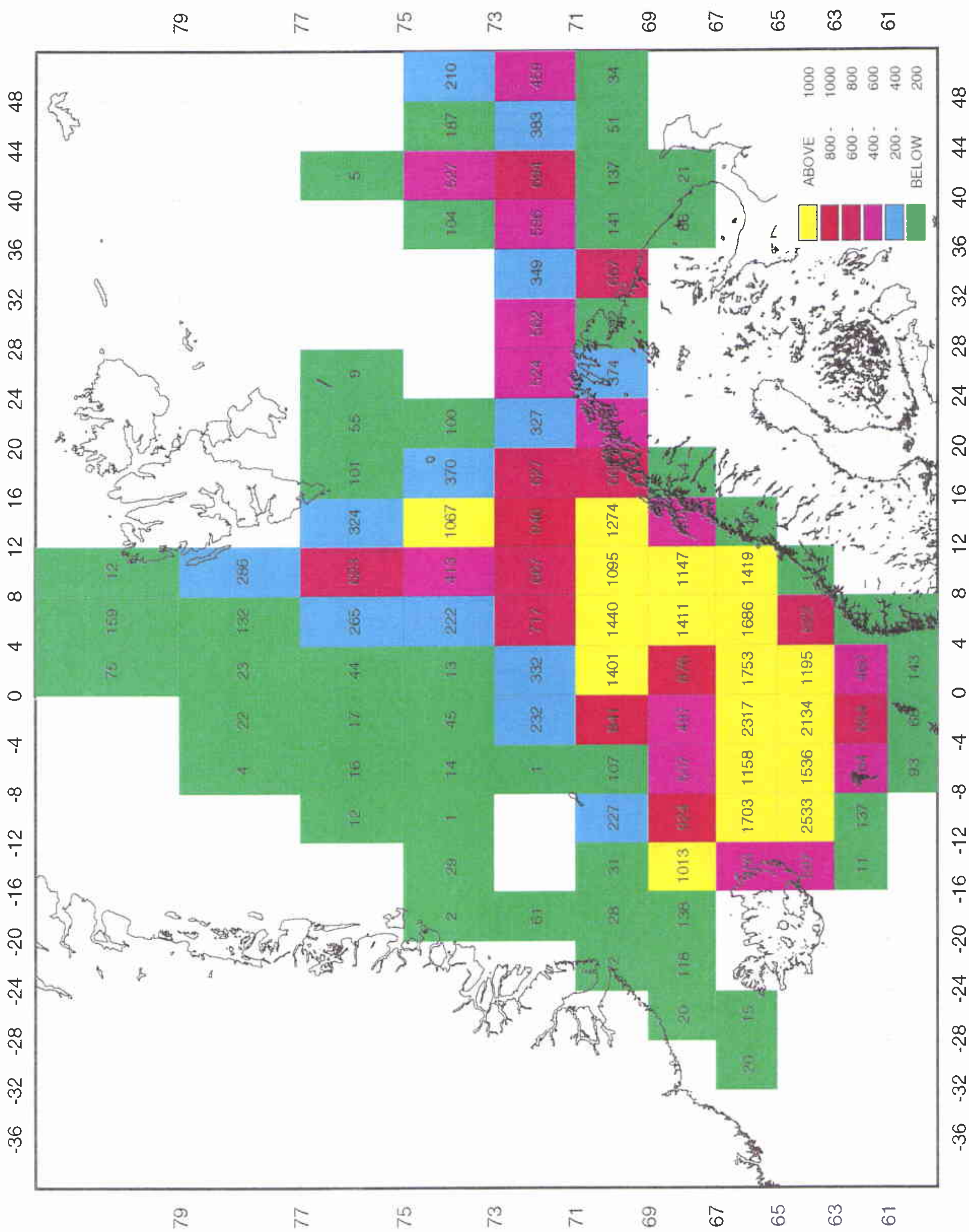

Figure C3d

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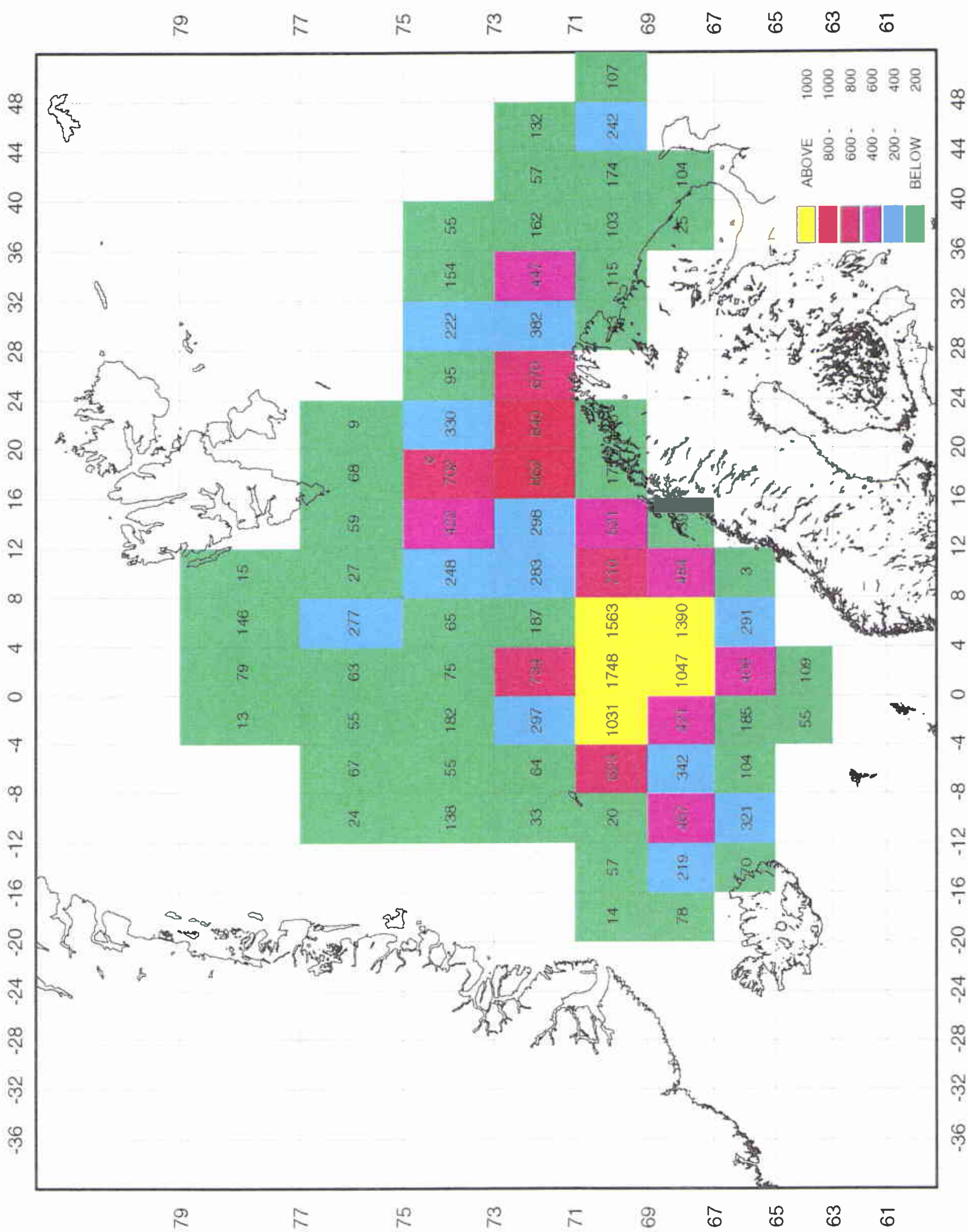
ABOVE 1000
800 - 1000
600 - 800
400 - 600
200 - 400
BELOW 200

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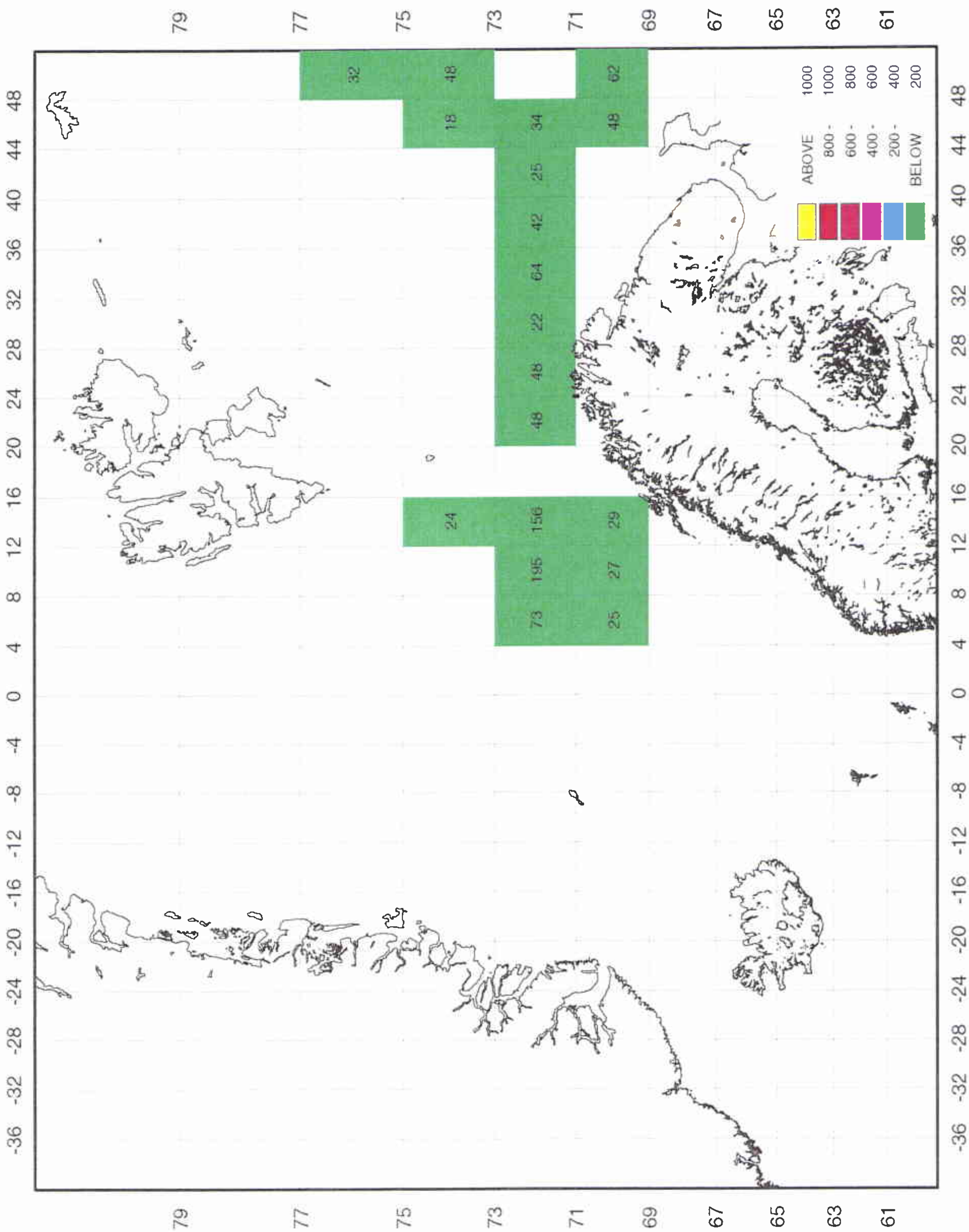
79
77
75
73
71
69
67
65
63
61
48
44
40
36
32
28
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
32
48
62
18
34
48
25
42
64
22
48
48
24
156
29
195
27
73
25
ABOVE 1000
800 - 1000
600 - 800
400 - 600
200 - 400
BELOW 200

Figure C3f

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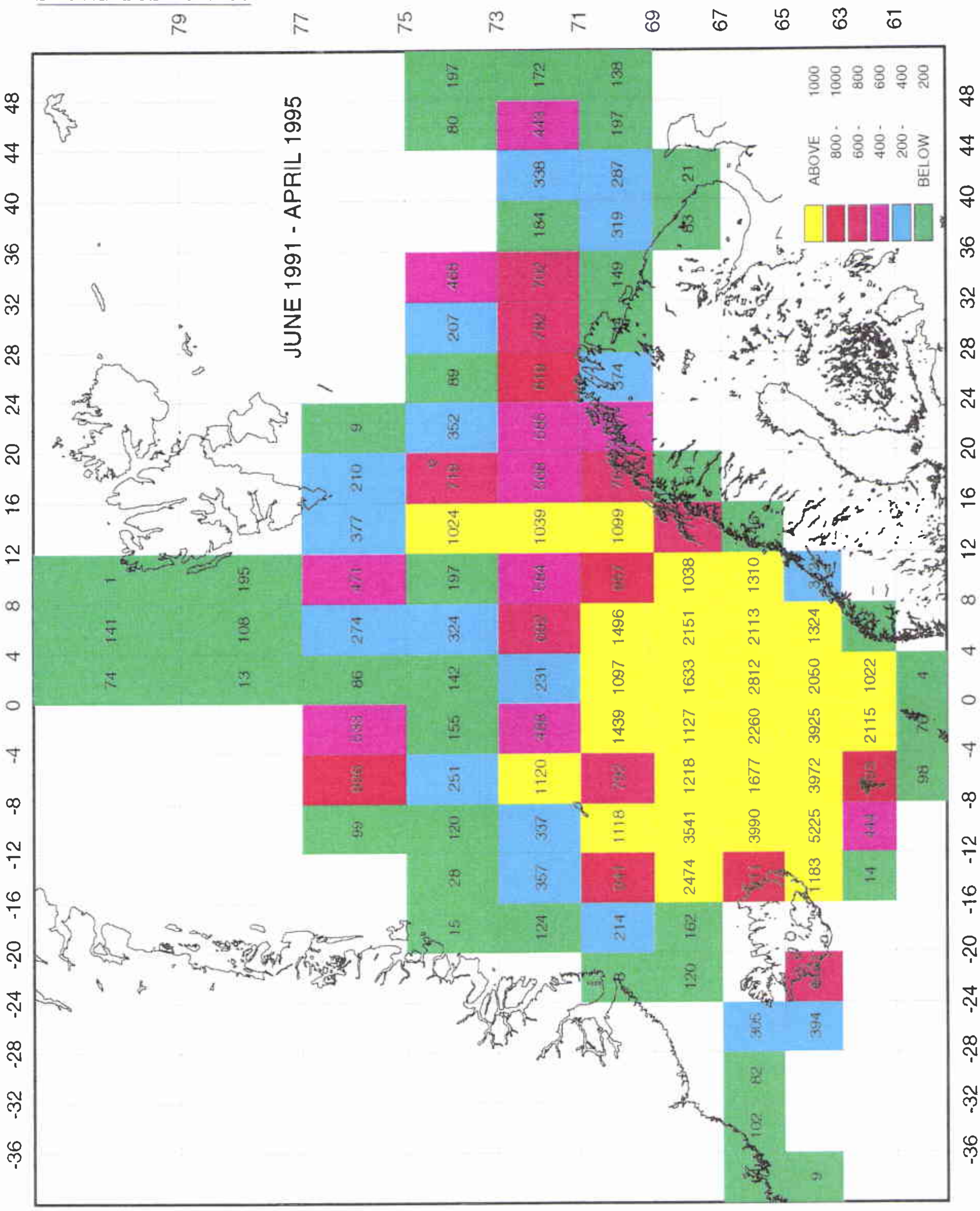

Figure C4 *Eulerian velocity statistics in bins of 4° latitude by 2° longitude, as computed from the drogued interpolated/filtered drifter observations. (a) Number of 6-hourly velocity observations, (b) mean velocity vector and (c) principal axes of residual variability. The mean and variance statistics are only plotted in those bins with more than 50 observations. The number of observations, the mean speed and the major axis half-length are also color coded.*

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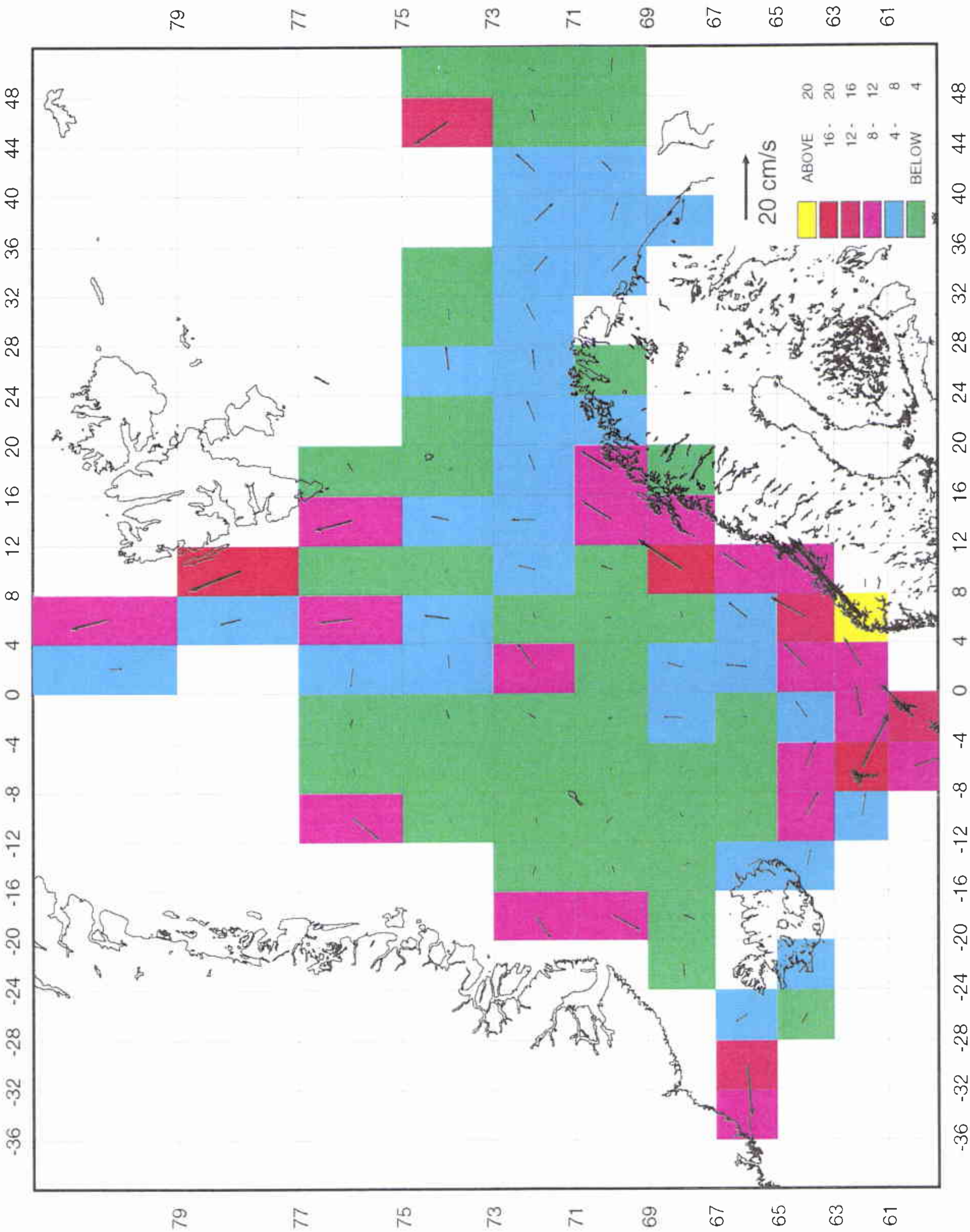
20 cm/s
ABOVE 20
16 - 20
12 - 16
8 - 12
4 - 8
BELOW 4
79
77
75
73
71
69
67
65
63
61
48
44
40
36
32
28
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
-32
-36

Figure C4b

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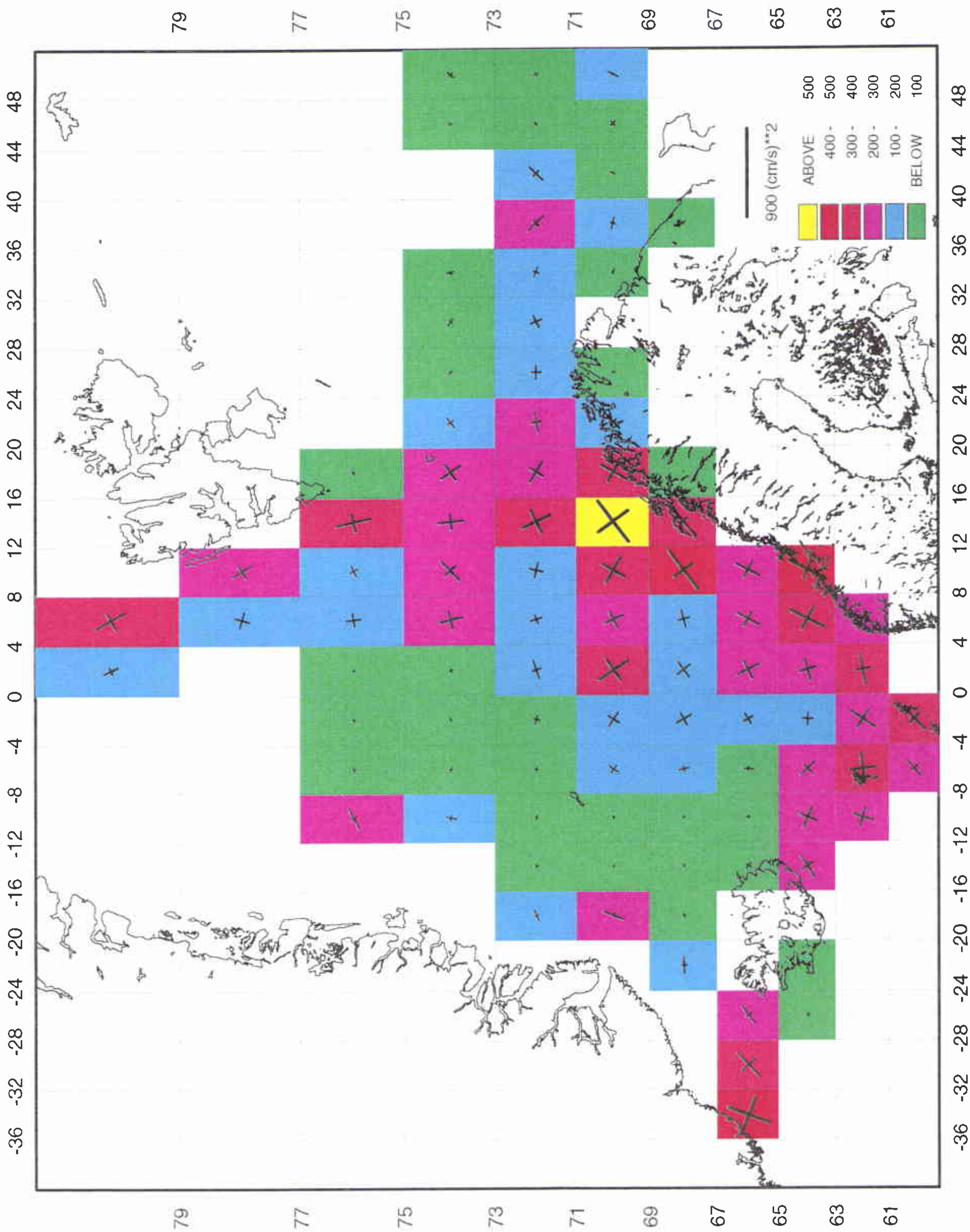
79 77 75 73 71 69 67 65 63 61
48 44 40 36 32 28 24 20 16 12 8 4 0 -4 -8 -12 -16 -20 -24 -28 -32 -36
900 (cm/s)**2
ABOVE 500
400 - 500
300 - 400
200 - 300
100 - 200
BELOW 100

Figure C4c

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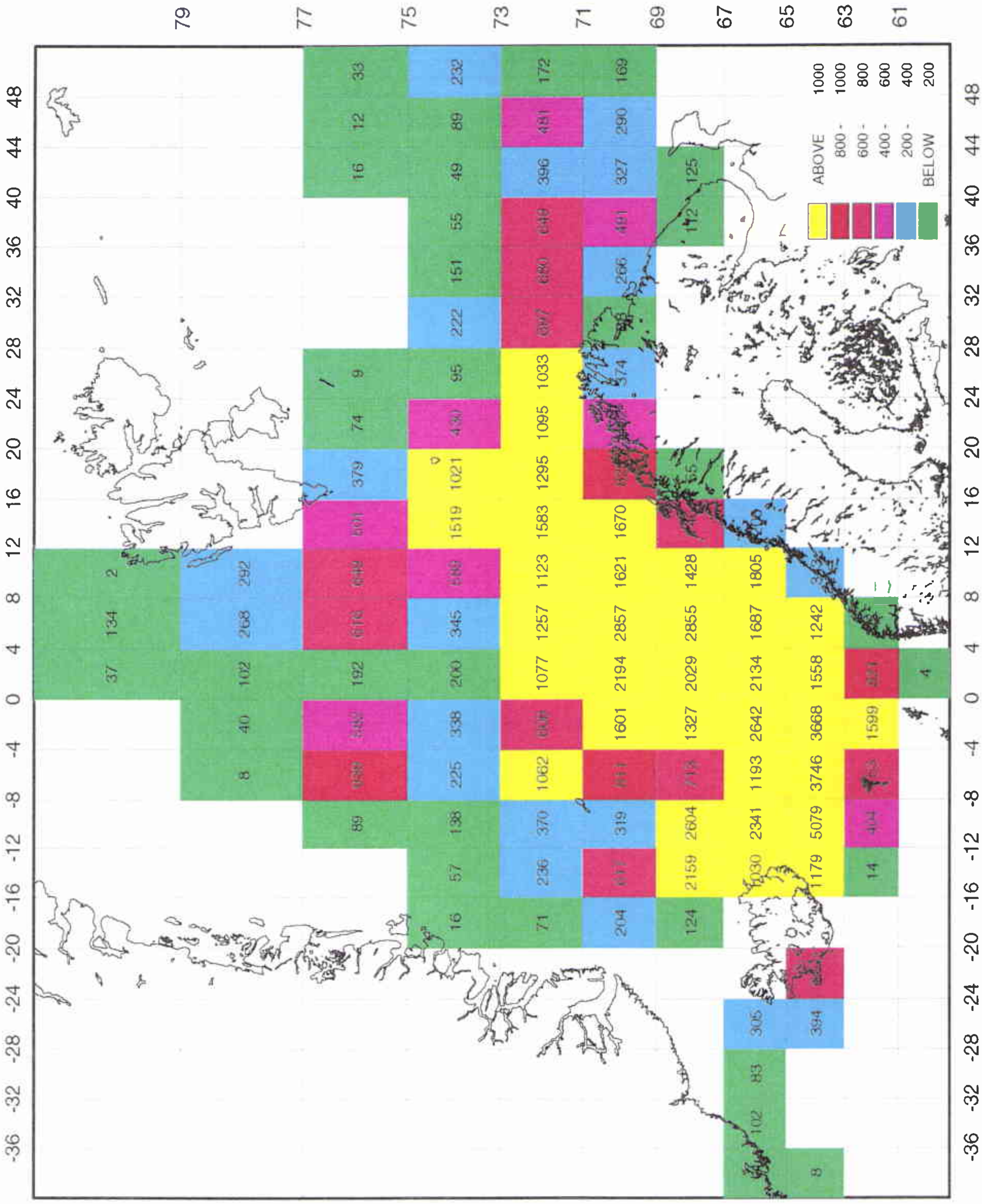

Figure C5 *Eulerian temperature statistics in bins of 4° latitude by 2° longitude, as computed from the interpolated/filtered drifter observations. (a) Number of 6-hourly SST observations, (b) mean temperature and (c) temperature variance. The mean and variance statistics are only plotted in those bins with more than 50 observations. The number of observations, the mean temperature and its variance are also color coded.*

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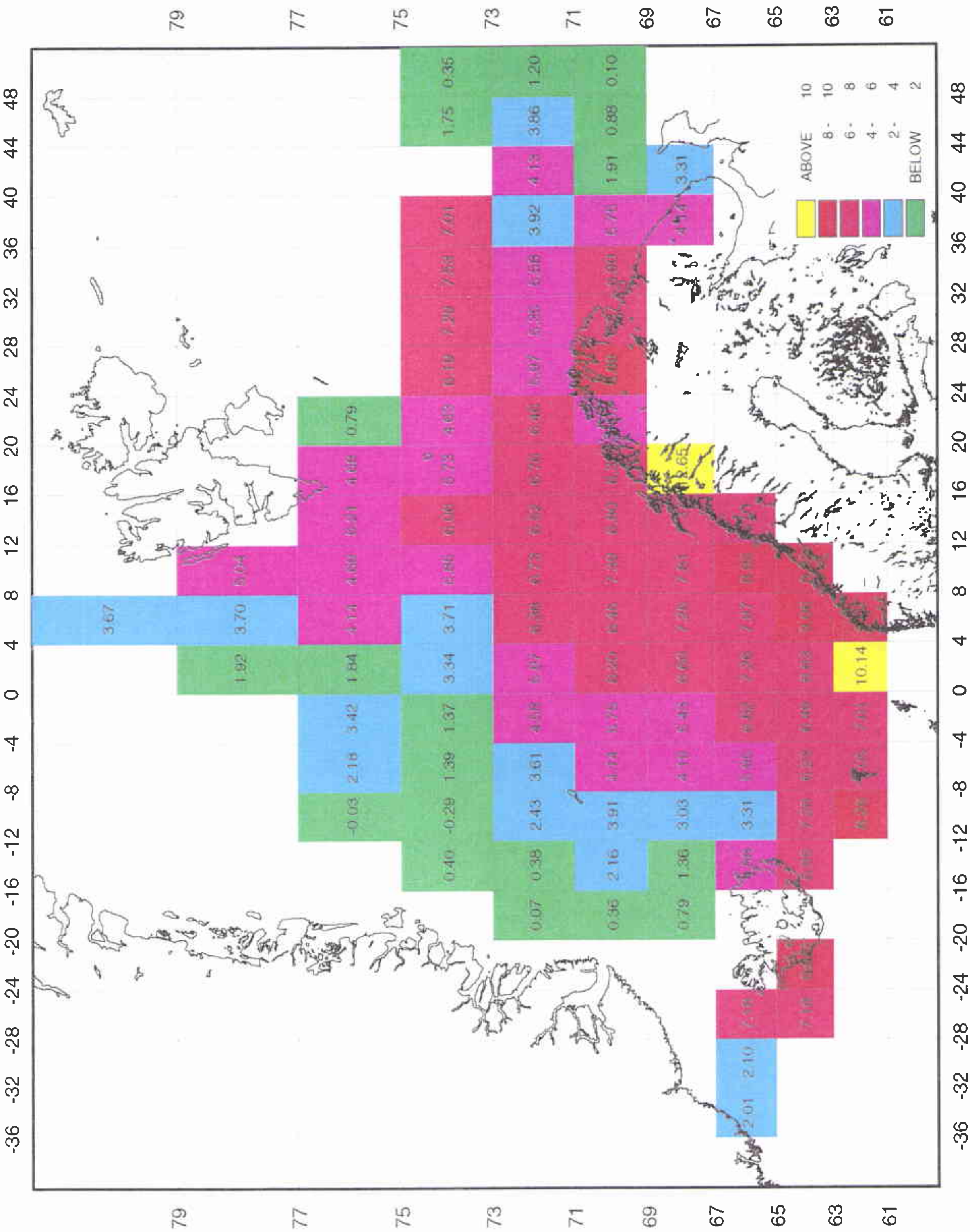

Figure C5b

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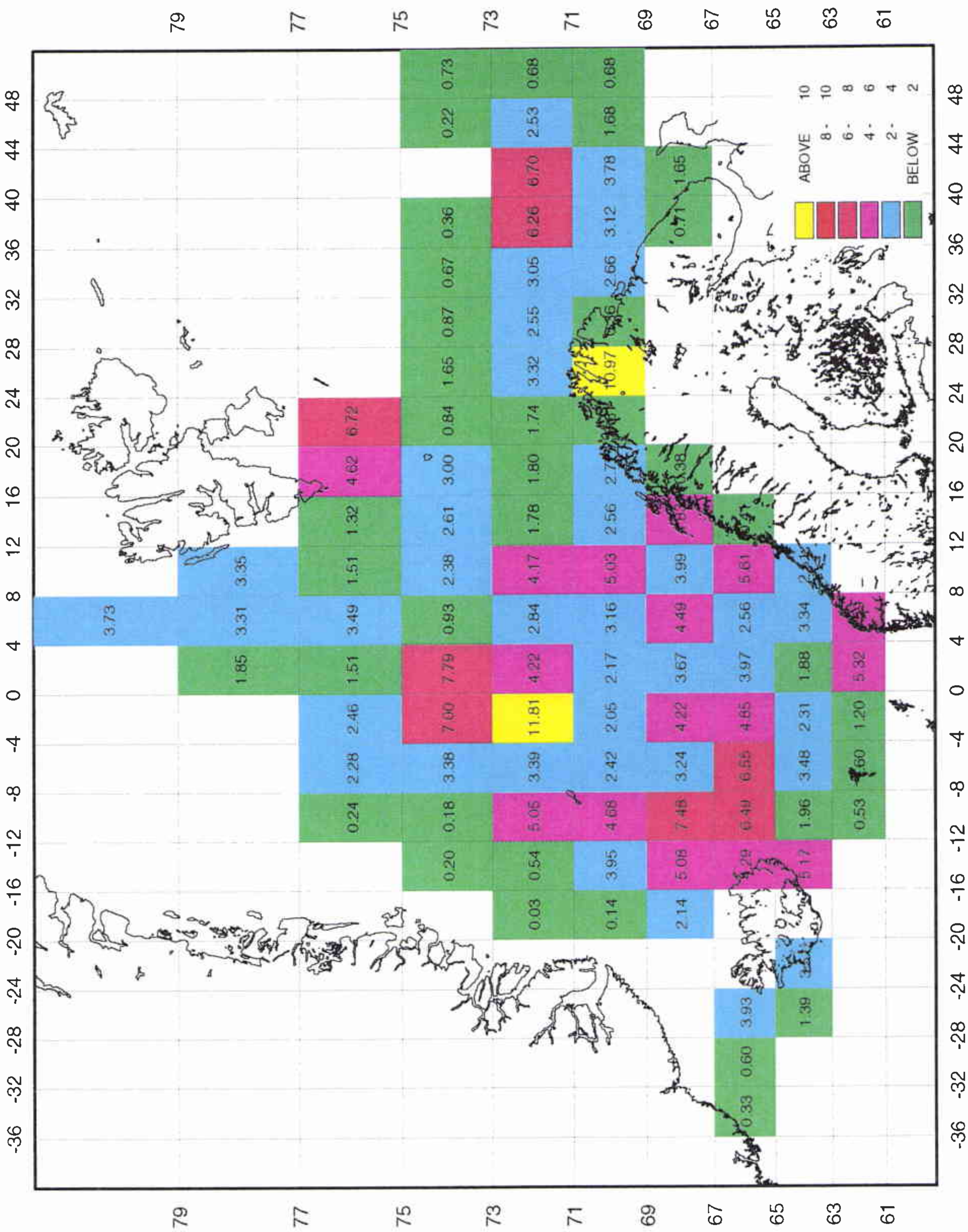

Figure C5c

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Author(s)

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Title

Drifter observations in the Nordic Seas (1991-1995): Data report

Abstract

During the period June 1991 to August 1993, 107 Argos tracked drifters drogued to 15 m depth were released in the Nordic seas (or Greenland-Iceland-Norwegian [GIN] sea) to study the variability of the near-surface circulation and temperature fields at scales ranging from a few kilometres (mesoscale) to thousands of kilometres (basin-wide large scale).

An additional data set, extending to April 1995, is described in this report. Full details of the data acquisition systems and data processing are provided to serve as a reference for the analyses published in the scientific literature. Graphics are included in the Annexes to illustrate drifter performance, position and temperature data, and Eulerian statistics.

These drifter measurements comprise to first basin scale, accurate near-surface velocity and temperature *in situ* data over the ice-free Nordic seas. The data from these drifters describe the major circulation features of a large inhospitable ocean area which has an important role in crucial issues such as global heat budget, fisheries and defence.

At smaller scales, the drifter observations were used, in conjunction with hydrographic data, to study the mesoscale structure and dynamics of the complex circulation patterns in the Iceland-Faeroe Frontal zone. The drifter sea surface temperature measurements were also used to validate satellite sea surface temperature data.

Time series and trajectories to accompany this report are available in the form of an unpublished data report (Annex D to this report) on request (email library@saclantc.nato.int).

Keywords

Drifter observations – Nordic Seas – Greenland-Iceland-Norwegian Sea – GIN Sea – Iceland-Faeroe

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