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SYNOP Inlet Experiment: Bottom Current Meter Data Report for October 1987 to August 1990 Mooring Period

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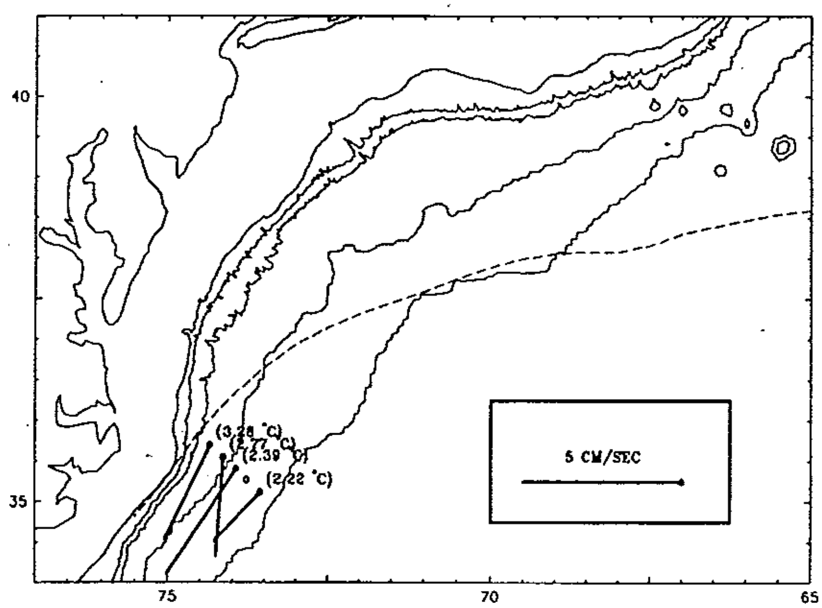
SYNOP INLET EXPERIMENT

Bottom Current Meter Data Report
for
October 1987 to August 1990 Mooring Period



GSO Technical Report No. 91-1

by

Robert S. Pickart, Xiaoshu Qian and D. Randolph Watts

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Abstract

An array of five deep current meter moorings, each 100 m above the ocean bottom, was maintained along a line extending southeast from Cape Hatteras, NC for 34 months, from October 1987 through August 1990. The transect line was part of the SYNOP (Synoptic Ocean Prediction experiment) Inlet Array, which also had a surrounding array of Inverted Echo Sounders. The line extended from approximately the 2300 m to the 3800 m isobath (roughly 100 km long), intended to measure currents in the Deep Western Boundary Current in the region where the Gulf Stream crosses over it. This report describes the array design and data processing, and presents the basic statistics for each record. The current and temperature records are also displayed in 40-hour low-passed time series plots.

Contents

List of Tables

List of Figures

1 Introduction

The Synoptic Ocean Prediction (SYNOP) experiment was a multi-institutional effort supported jointly by the National Science Foundation and Office of Naval Research to study the dynamics and predictability of the Gulf Stream. The overall goal of SYNOP was to obtain a better physical understanding of large amplitude Gulf Stream meanders by considering the current as part of a larger system which includes the cyclonic and anti-cyclonic recirculations and interactions with eddies and rings. The experiment had three major components: an extensive field program from 1987–1991, regional and basin scale numerical modeling, and analytical modeling. The field program included carefully coordinated moored arrays (Figure 1), Lagrangian float deployments, shipboard surveys and remote sensing.

This report summarizes results from the "SYNOP Inlet Array" of five deep current meters on a line near 35°30 N, 74°00 W where the Gulf Stream crosses over the deep western boundary current (DWBC). This array of five current meters, each 100 m above the bottom, was maintained from October 1987 – August 1990 by the University of Rhode Island (URI). The principal investigators were D. Randolph Watts and Robert S. Pickart and the project was funded by the Office of Naval Research. The current meter records for the "SYNOP Central Array" were processed at The University of North Carolina and are documented separately. The Inverted Echo Sounder and bottom pressure data from both the Inlet and Central Arrays were processed at URI and have been documented in three technical reports (Qian et al., 1990; Fields and Watts, 1990; Fields and Watts, 1991a).

The main objectives of the Inlet experiment were to monitor the path parameters of the Gulf Stream as it leaves the continental shelf (i.e. lateral displacement, angle, curvature) and measure the DWBC crossing under the Gulf Stream. The overall goal was to understand the predictability of the downstream Gulf Stream based on these inlet parameters and to understand the interaction of the Gulf Stream and DWBC. The deep current meter data were collected in three deployments of 8 months, 12 months, and 14 months. This report describes the array design and the data processing steps, presents the mean quantities and statistics for each deployment and for the total record length, and shows the 40 hr low-passed time series.

2 The Current Meter Array

The five Inlet deep moorings were spaced roughly 25 km apart across the DWBC, extending from 1900 m to 3800 m along the continental slope (Figure 2, Table 1). The mooring design is shown in Figure 3; in the first two deployments AANDERAA current meters (AACMs) were used, and for the third deployment Vector Averaging current meters (VACMs) were used. Table 2 lists the serial numbers of the instruments by deployment. In all cases the instruments were situated 100 m off the bottom. The AACMs recorded data once an hour and the VACMs once every 15 minutes. The first deployment lasted from October 1987 – June 1988, the second deployment from June 1988 – June 1989, and the third deployment from June 1989 – August 1990 (Figure 4; Table 1). The turnaround time for moorings was typically 1 day (i.e. the time between the last good measurement of a deployment to the first good measurement of the next deployment). Thus it is straightforward to interpolate between deployments and obtain continuous 34-month records.

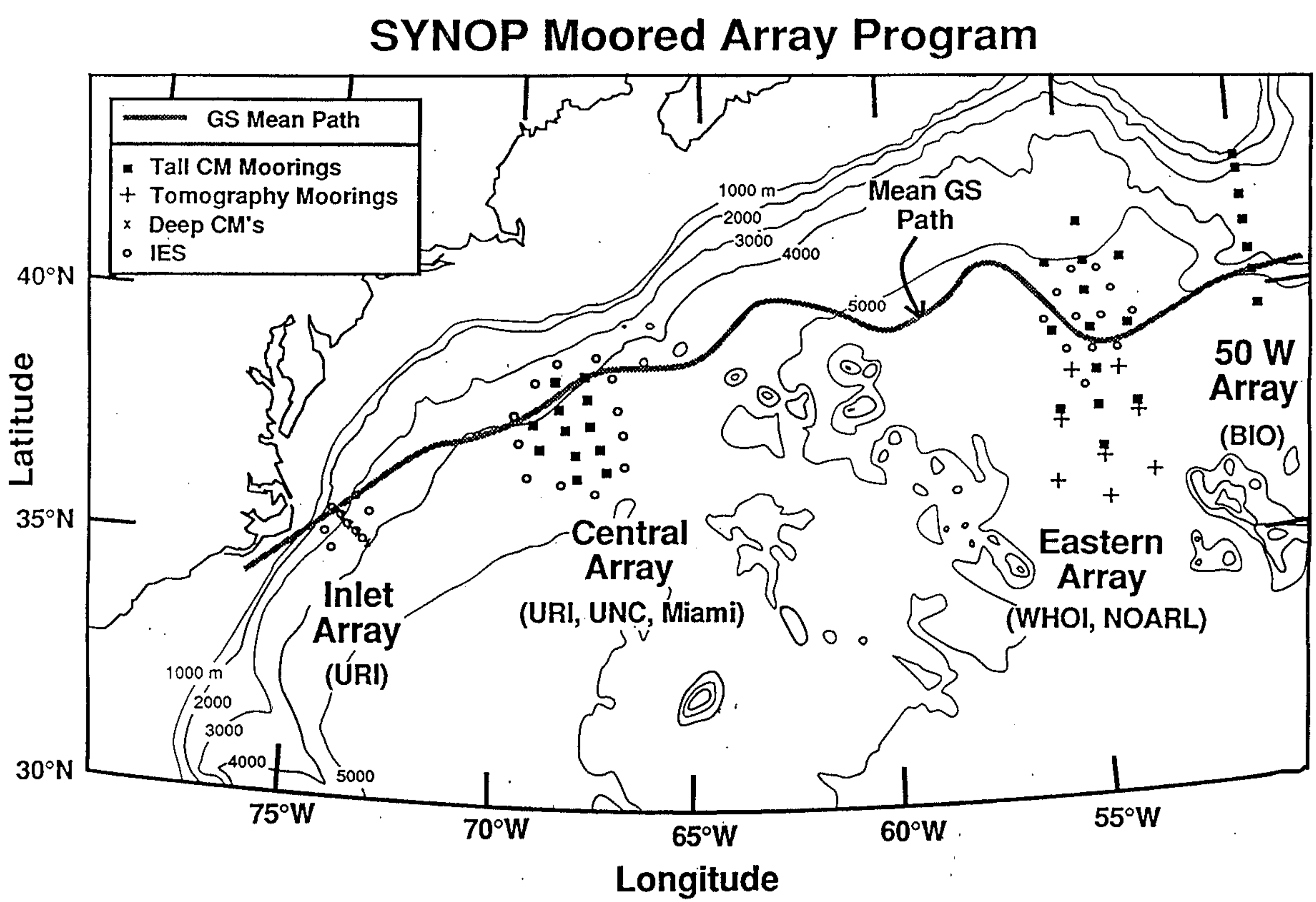


Figure 1: Moored arrays of the SYNOP experiment

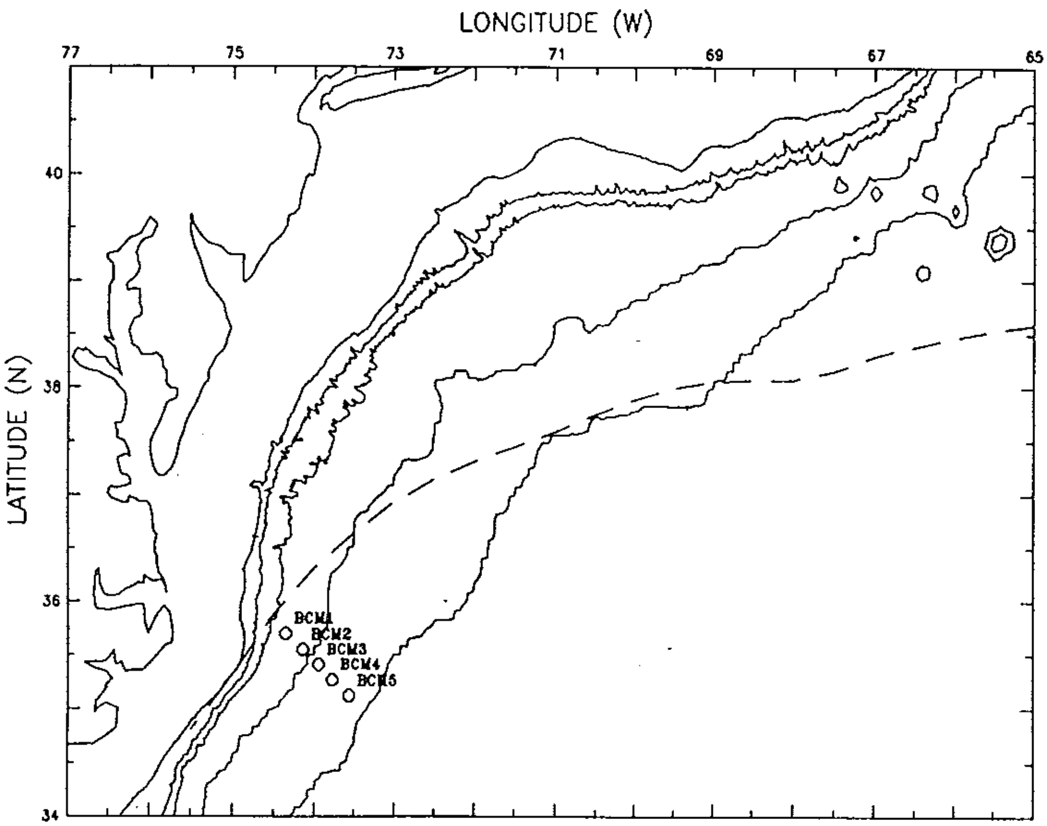


Figure 2: The SYNOP Inlet array of near bottom current meters. The dashed line is the mean path of the Gulf Stream surface front (1975-1986) from Gilman and Cornillon (1990).

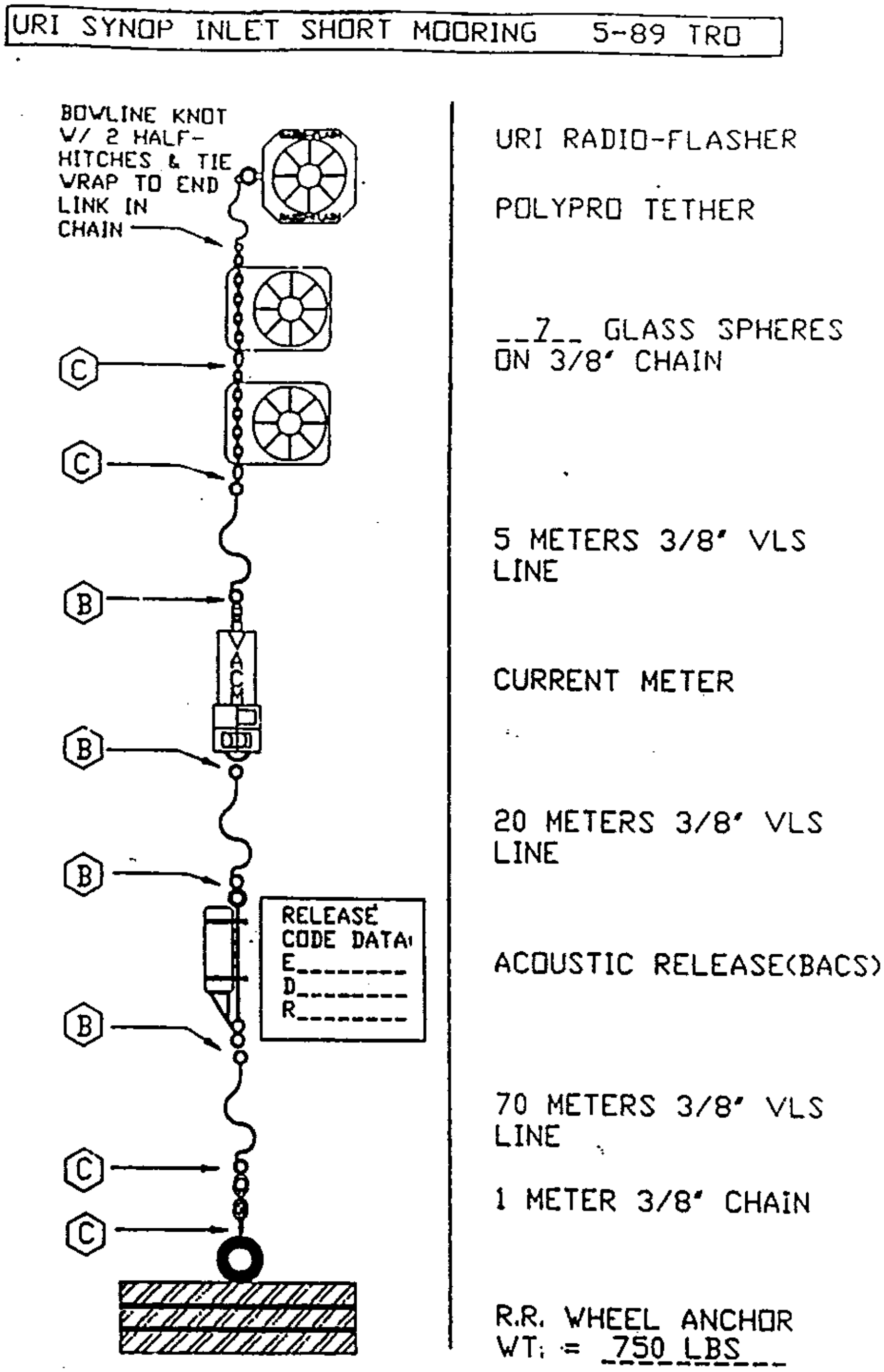


Figure 3: Moorings used in the Inlet array

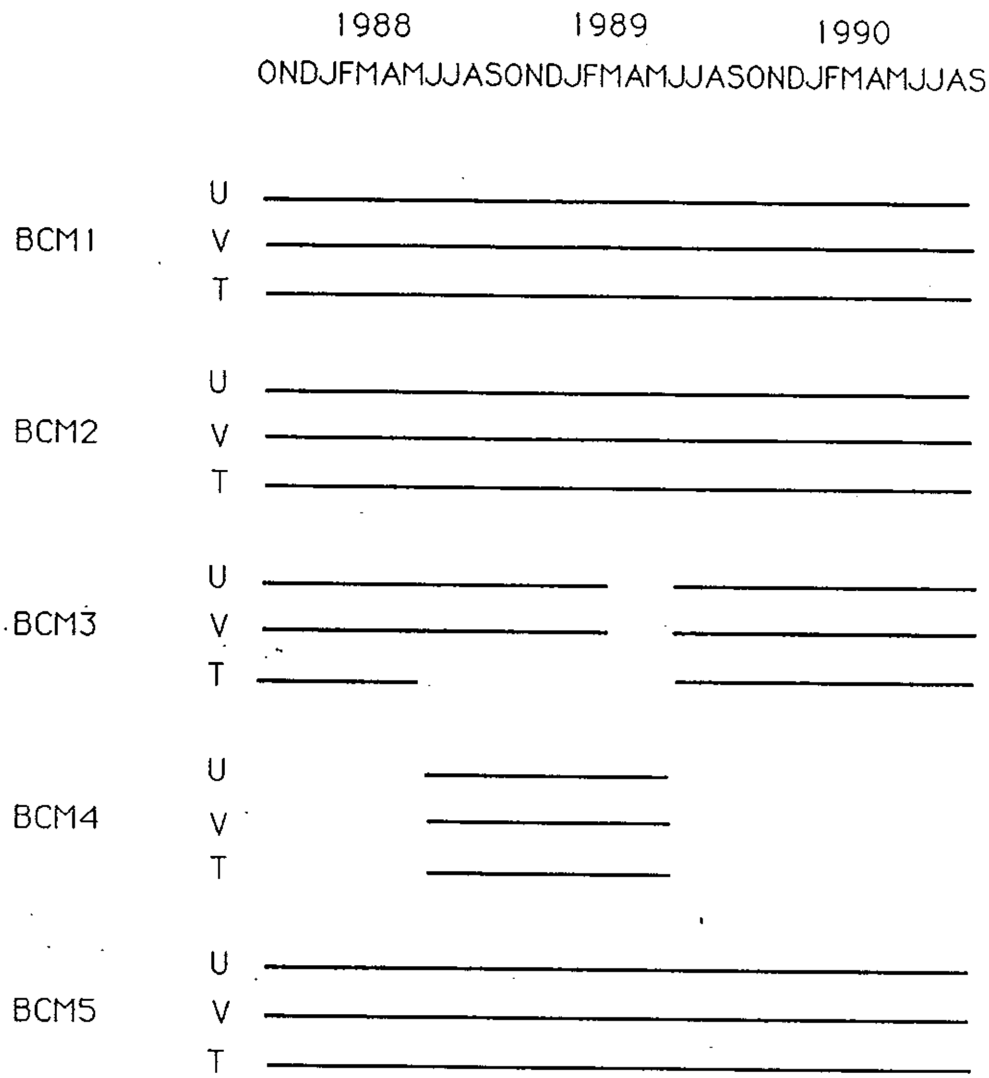


Figure 4: Time line of data coverage for each BCM site

Table 1: Mooring locations and deployment periods

	Mean Position		Mean Depth(m)		Deployment Periods		
Site	Lat (N)	Long (W)	CM	Bottom	1987 - 88	1988 - 89	1989 - 90
BCM1	35° 41.87	74° 20.49	2301	2395	Oct 13 - May 27	Jun 1 - Jun 10	Jun 12 - Sep 1
BCM2	35° 33.42	74° 07.87	2736	2830	Oct 13 - May 27	Jun 1 - Jun 10	Jun 12 - Sep 1
BCM3	35° 25.25	73° 55.99	3081	3175	Oct 13 - May 27	Jun 1 - Mar 8	Jun 12 - Sep 1
BCM4	35° 15.96	73° 46.02	3390	3484	(no data)	Jun 13- Jun 10	(no data)
BCM5	35° 07.79	73° 33.93	3661	3755	Oct 13 - May 27	Jun 1 - Jun 7	Jun 12 - Sep 2

Table 2: Instrument types and serial numbers for each deployment

	BCM1	BCM2	BCM3	BCM4	BCM5
Deployment 1	AACM/7355	AACM/7360	AACM/7361	AACM/7362	AACM/7593
Deployment 2	AACM/7358	AACM/7359	AACM/7357	AACM/7363	AACM/7356
Deployment 3	VACM/V0189	VACM/V0645	VACM/V0647	VACM/V0501	VACM/V0646

3 Data Processing

Figures 5 and 6 show flow-charts of the processing steps required to transform the raw data obtained from the current meter tapes to the final edited, 40 hr low-passed time series. Many of these steps were accomplished during the respective recovery cruises, and in one instance the processing was completed aboard ship. The AACMs measured temperature, speed and direction (in counts) which were converted to engineering units using laboratory calibrations for temperature and direction and the manufacturer calibration for speed. The laboratory calibrations for the AACMs used in this experiment were performed at the University of Rhode Island and are documented in a series of reports (Kim and Orvosh, 1988a; Kim, 1989; Kim and Orvosh, 1988b; Kim and Orvosh, 1989). Pre-calibrations and post-calibrations are compared in reports by Shay and Bane (1989) and He and Watts (1990). The VACMs also measured temperature, direction and speed; however, only the thermistors require calibration. The VACMs used in this experiment were calibrated at the Woods Hole Oceanographic Institution (WHOI) by their Buoy Group, and all of the calibrations are archived at WHOI. The direction measured by both types of current meters is magnetic north, which was converted to true north by subtracting the magnetic correction of 9.1° for this location. East (U) and north (V) velocity time series were then created from the speed and direction measurements. The 40 hr low-pass filter applied to the edited engineering data was a 2nd order Butterworth filter passed over the data forward and in reverse, to create an effective symmetric 4th order filter with −6dB cutoff at 49.9m. This particular filter was chosen for the entire SYNOP data archive in order to help standardize the different data sets. For a detailed description of the Butterworth filter see Fields et. al (1991b).

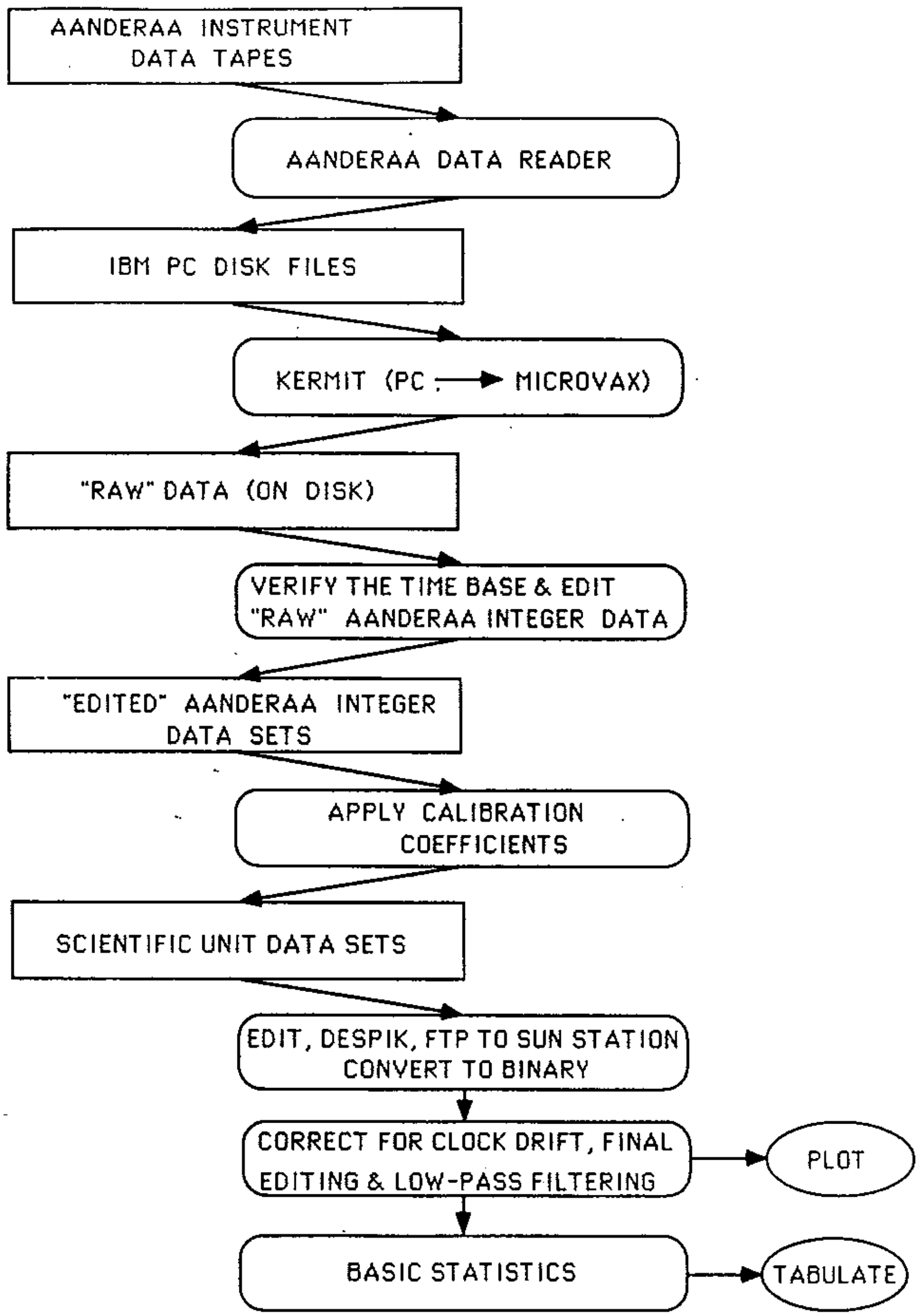


Figure 5: Flow-chart of the data processing steps for Aanderaa current meters

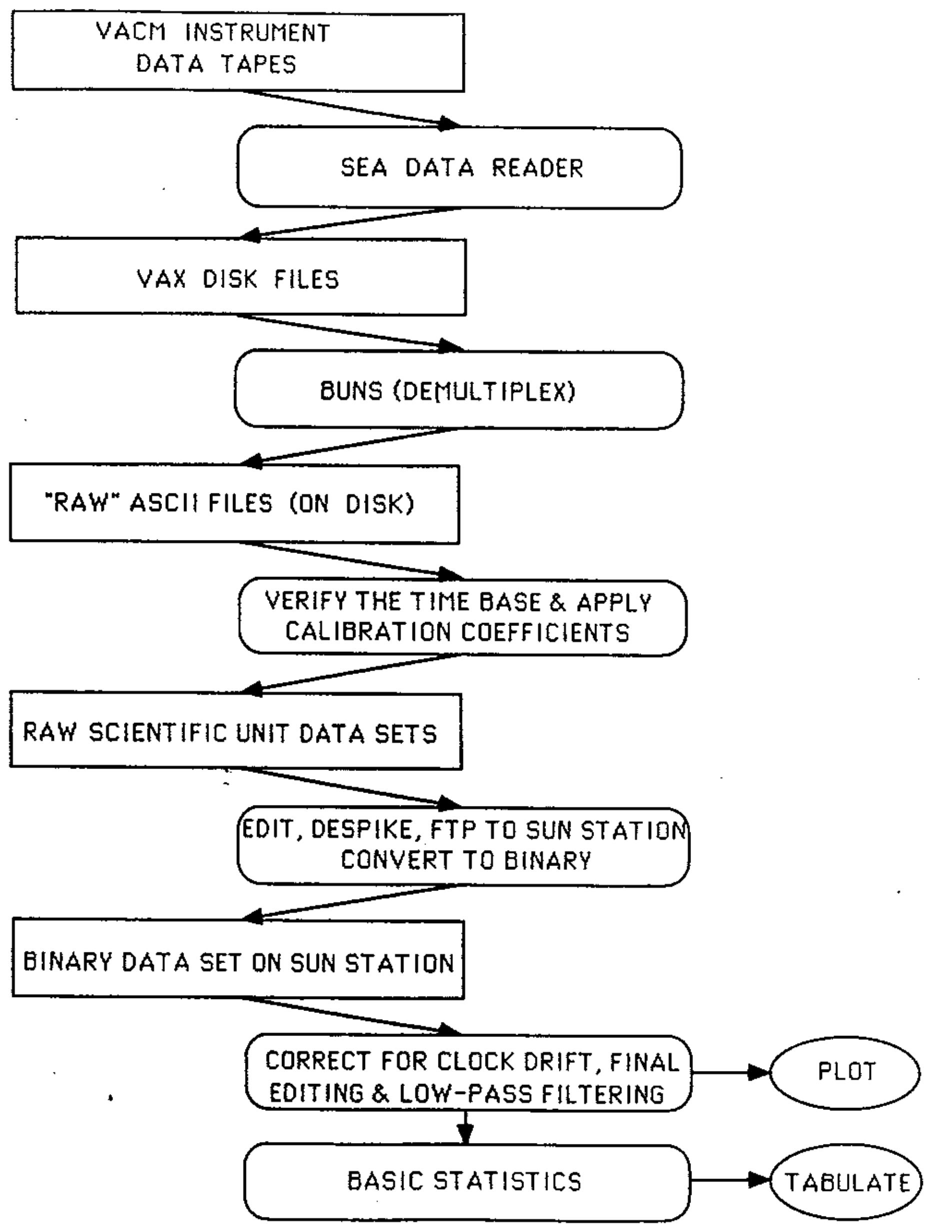


Figure 6: Flow-chart of the data processing steps for Vector Averaging current meters

4 Data Return

With the exception of BCM4 (Figure 2) the overall data return was excellent (Table 3). BCM4 failed to release after the first deployment and returned no usable data for the third deployment, so there is only one year of data at this location. The only other data loss occurred during the second deployment; BCM4 (U, V, T) is 12 days short at the start of the record, and BCM3 (U, V) is short by 94 days at the end of the record (T is missing altogether).

Wherever possible, records were merged to create continuous 34-month time series. To connect two time series a simple linear interpolation was used (as mentioned above the data gap was usually about a day). BCM1, BCM2 and BCM5 have complete 34-month records; BCM3 is nearly complete in U and V (3-month gap), but has a year gap in T (Figure 4).

5 Data Presentation

5.1 Means and Statistics

The mean current vectors and temperatures for each deployment period are displayed in Figures 7.1–7.3. The dashed line represents the mean path of the Gulf Stream surface front from 1975–1986 (Gilman and Cornillon, 1990). The 34-month means are shown in Figure 7.4 (BCM3 is a 31-month mean). Tables 4.1–4.4 list the statistics for U,V,T by individual deployment as well as full-length continuous records.

Table 3: Data return by deployment

First Deployment

(from October 1987 to May 1988)

SITE	U	V	T	REMARK
BCM1	100%	100%	100%	
BCM2	100%	100%	100%	
BCM3	100%	100%	100%	
BCM4	0%	0%	0%	failed to release
BCM5	100%	100%	100%	

Second Deployment

(from June 1988 to June 1989)

SITE	U	V	T	REMARK
BCM1	100%	100%	100%	
BCM2	100%	100%	100%	
BCM3	75%	75%	0%	
BCM4	97%	97%	97%	
BCM5	100%	100%	100%	

Third Deployment

(from June 1989 to September 1990)

SITE	U	V	T	REMARK
BCM1	100%	100%	100%	
BCM2	100%	100%	100%	
BCM3	100%	100%	100%	
BCM4	0%	0%	0%	bad data
BCM5	100%	100%	100%	

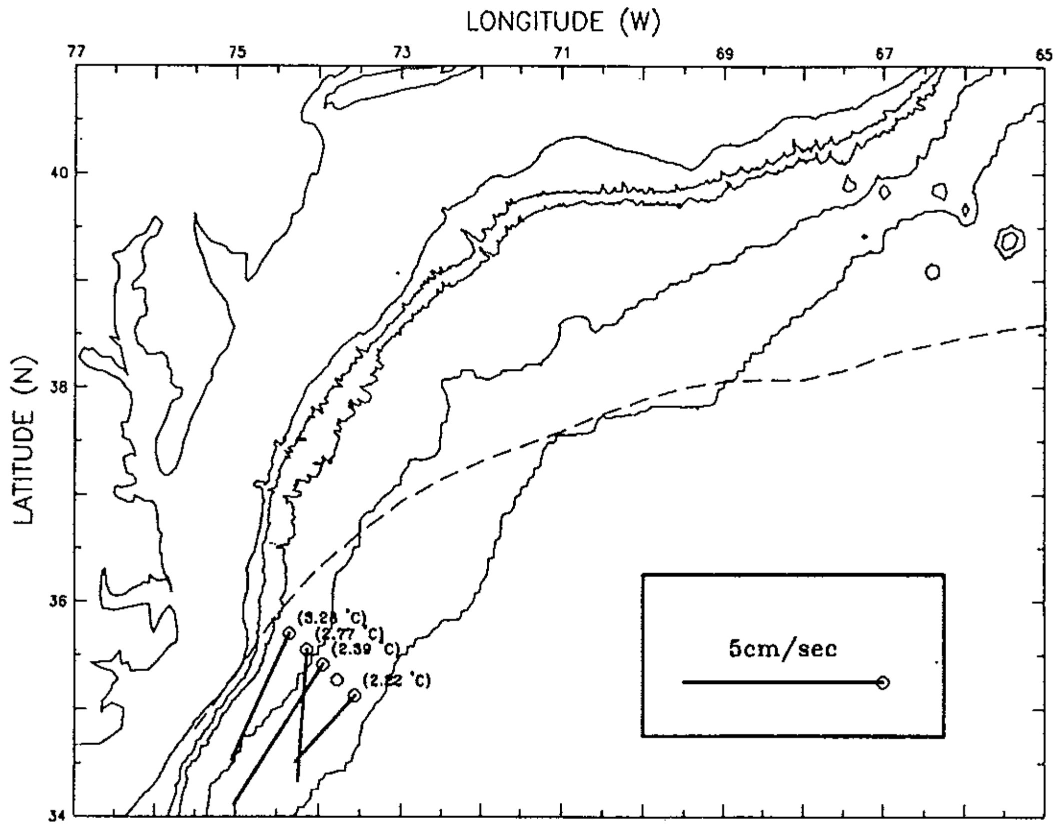


Figure 7.1: Mean current vectors and temperatures (in parentheses) for the 1st deployment. BCM4 returned no data in the 1st deployment.

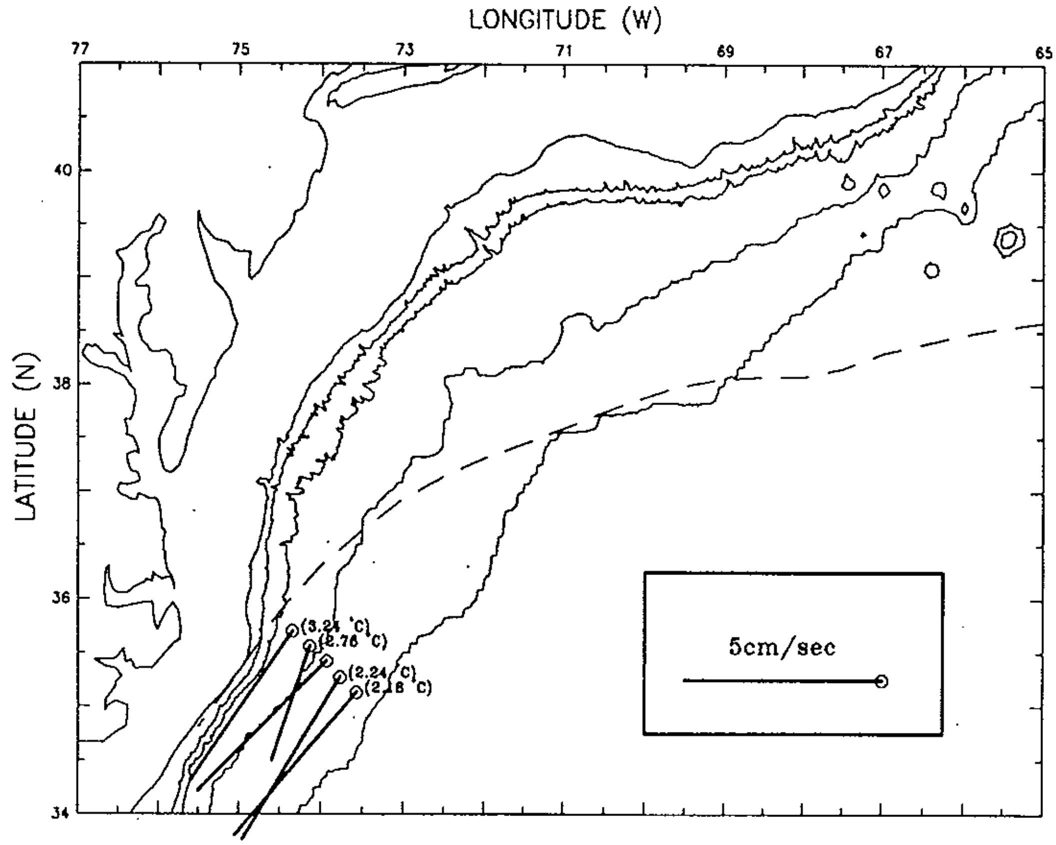


Figure 7.2: Mean current vectors and temperatures (in parentheses) for the 2nd deployment.

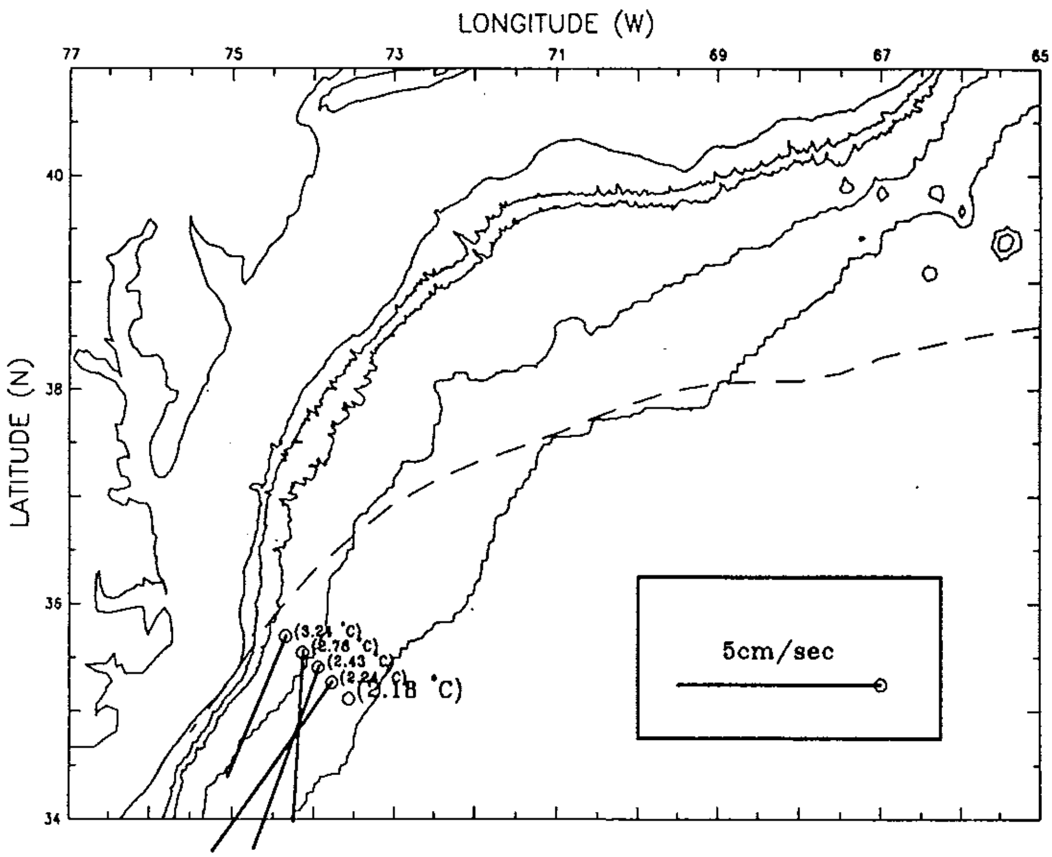


Figure 7.3: Mean current vectors and temperatures (in parentheses) for the 3rd deployment. BCM4 returned no usable data in the 3rd deployment.

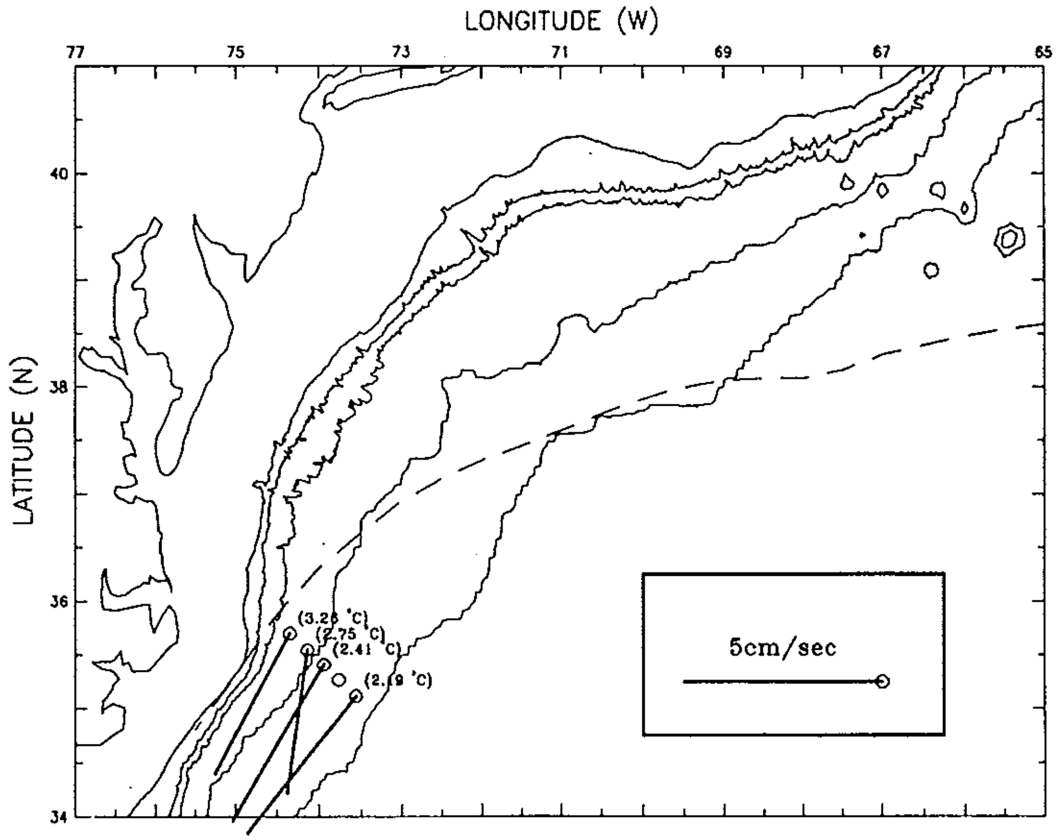


Figure 7.4: Mean current vectors and temperatures (in parentheses) for the entire deployment (BCM4 is excluded since there was only one year of data at that site).

Table 4.1: Basic statistics of the 40 hr low-passed data for the 1st deployment. Units are °C for temperature and cm/sec for velocity.

Site	Var	Min	Max	Mean	Stdv
BCM1	U	-13.790	15.714	-1.398	4.464
BCM1	V	-17.378	8.280	-2.891	5.323
BCM1	T	2.911	3.539	3.279	0.116
BCM2	U	-18.813	26.645	-0.242	8.315
BCM2	V	-28.926	15.766	-3.209	8.145
BCM2	T	2.488	3.058	2.766	0.107
BCM3	U	-16.972	13.893	-2.151	6.600
BCM3	V	-21.598	14.772	-3.207	6.719
BCM3	T	2.117	2.645	2.385	0.100
BCM5	U	-22.034	23.246	-1.419	8.913
BCM5	V	-23.983	28.211	-1.530	9.695
BCM5	T	2.168	2.323	2.215	0.036

Table 4.2: Basic statistics of the 40 hr low-passed data for the 2nd deployment. Units are °C for temperature and cm/sec for velocity.

Site	Var	Min	Max	Mean	Stdv
BCM1	U	-16.639	14.185	-2.527	4.906
BCM1	V	-16.830	12.485	-3.440	5.647
BCM1	T	2.916	3.541	3.238	0.112
BCM2	U	-18.202	18.784	-0.937	5.739
BCM2	V	-18.630	12.411	-2.620	5.508
BCM2	T	2.390	3.082	2.756	0.135
BCM3	U	-21.504	12.731	-3.153	6.119
BCM3	V	-18.182	9.784	-2.965	4.841
BCM4	U	-13.638	20.312	-2.361	5.179
BCM4	V	-16.840	21.452	-3.720	6.261
BCM4	T	2.137	2.459	2.239	0.049
BCM5	U	-20.955	29.125	-2.959	8.258
BCM5	V	-20.581	23.399	-3.279	7.923
BCM5	T	2.121	2.291	2.179	0.035

Table 4.3: Basic statistics of the 40 hr low-passed data for the 3rd deployment. Units are °C for temperature and cm/sec for velocity.

Site	Var	Min	Max	Mean	Stdv
BCM1	U	-21.535	14.097	-1.428	4.269
BCM1	V	-18.724	12.882	-3.227	5.668
BCM1	T	2.850	3.591	3.257	0.103
BCM2	U	-21.413	31.374	-0.236	6.834
BCM2	V	-35.765	18.226	-3.909	7.400
BCM2	T	2.234	3.189	2.754	0.138
BCM3	U	-21.616	21.531	-1.606	6.455
BCM3	V	-36.197	20.916	-4.170	7.410
BCM3	T	2.153	2.914	2.428	0.117
BCM5	U	-22.822	22.478	-2.920	5.940
BCM5	V	-34.725	16.651	-3.865	7.942
BCM5	T	2.139	2.324	2.197	0.035

Table 4.4: Basic statistics of the 40 hr low-passed data for the entire record length. Units are °C for temperature and cm/sec for velocity.

Site	Var	Min	Max	Mean	Stdv
BCM1	U	-21.535	15.714	-1.814	4.579
BCM1	V	-18.724	12.882	-3.230	5.591
BCM1	T	2.850	3.591	3.255	0.110
BCM2	U	-21.413	31.374	-0.488	6.840
BCM2	V	-35.765	18.226	-3.296	6.991
BCM2	T	2.234	3.189	2.757	0.131
BCM3	U	-21.616	21.531	-2.191	6.427
BCM3	V	-36.197	20.916	-3.586	6.605
BCM3	T	2.117	2.914	2.414	0.113
BCM5	U	-22.822	29.125	-2.607	7.548
BCM5	V	-34.725	28.211	-3.148	8.396
BCM5	T	2.121	2.324	2.194	0.038

5.2 Time Series

The time series at each site are displayed in Figures 8.1–8.5. In each figure the top panel shows temperature (T), the middle panel shows east velocity (U) and north velocity (V), and the bottom panel shows the vector stick plot. For presentation purposes the stick plots have been subsampled every 12 hours. The data are displayed versus yearday as well as calendar month; the deployment number (1, 2 or 3) is labelled at the top. The gaps are either data loss (see above) or turnaround time between deployments. For comparison purposes the velocity and temperature scales are the same in each graph.

Figure 9 contains the vector stick plots for each site displayed in stack form; this allows for direct comparison of the currents across the array (the velocity scale is the same for each site). Figure 10 stacks the temperatures at all five sites on the same time axis as in Figure 9.

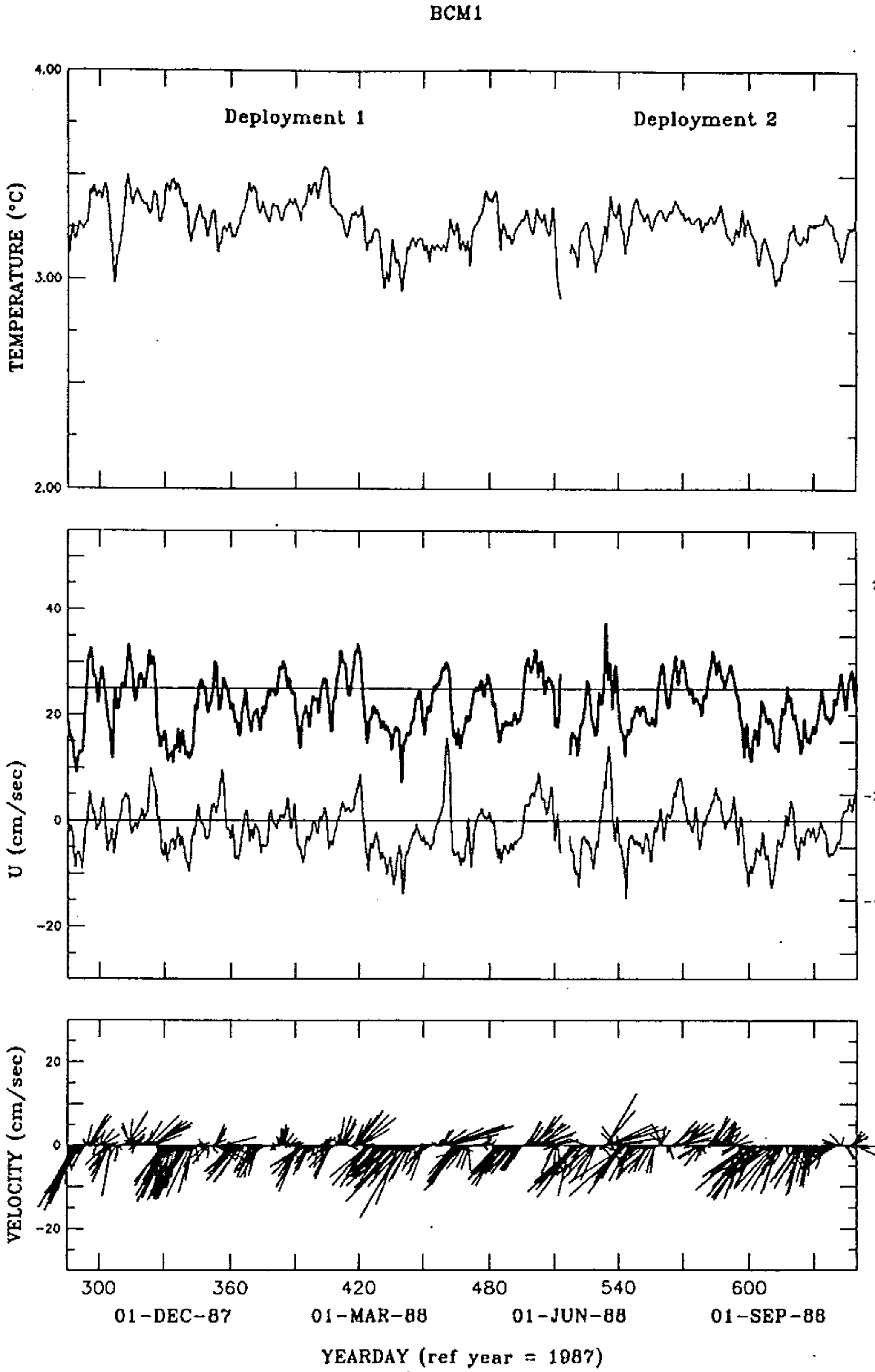
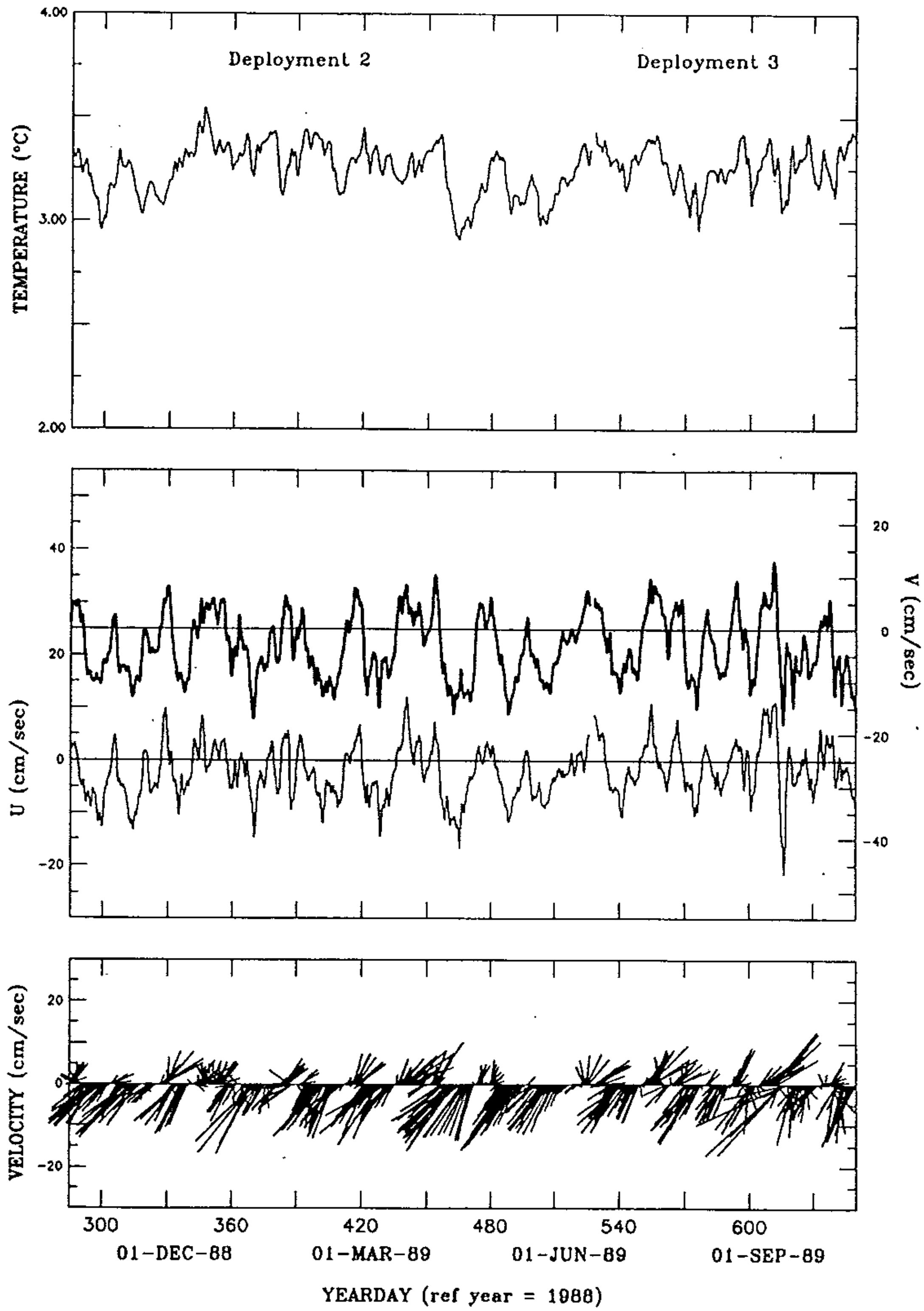
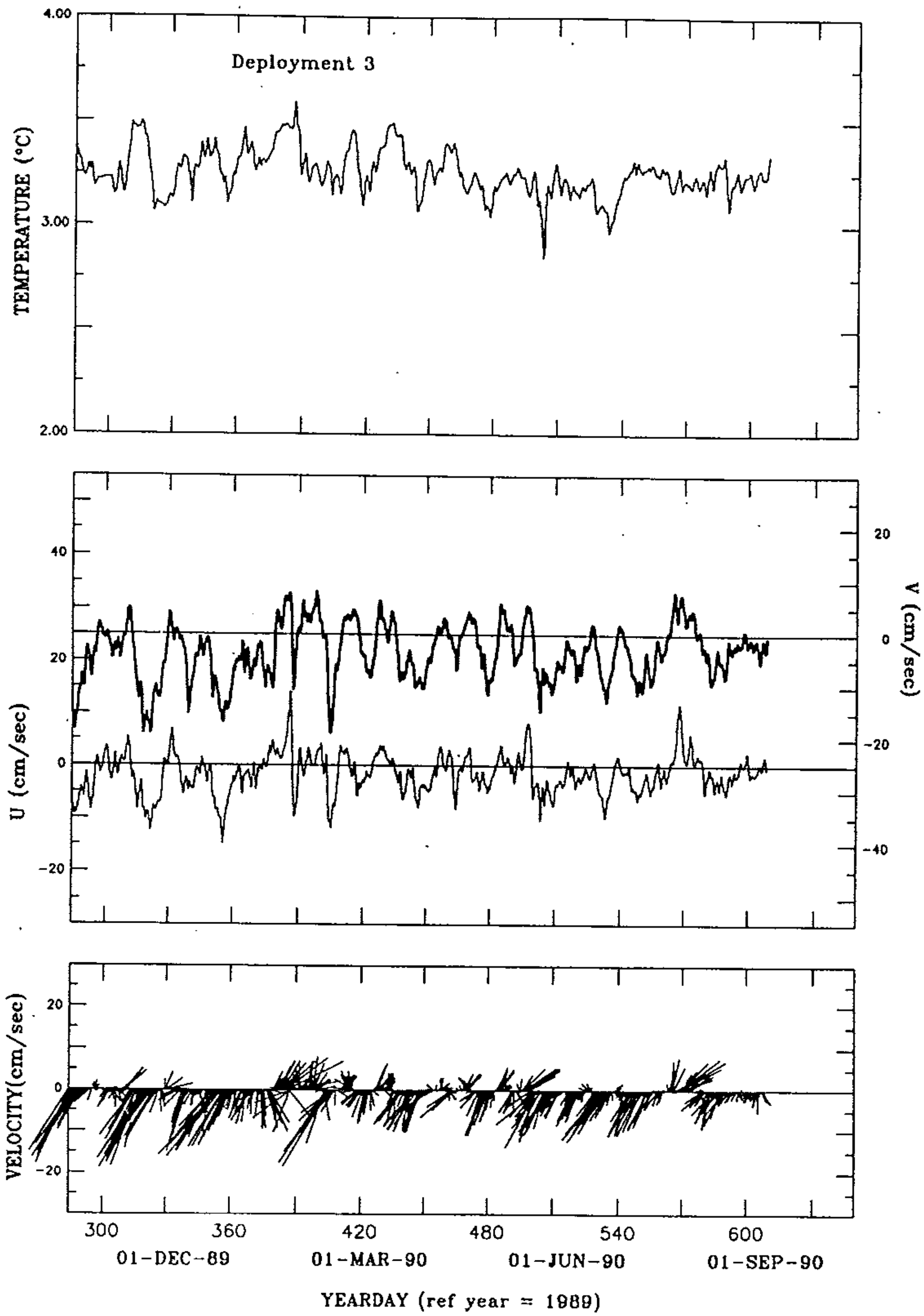


Figure 8.1: 40 hr low-passed time series at BCM1. The entire record length is shown (there is a short break between deployments). The top panel is temperature, the middle panel east (U) and north (V) velocity, and the bottom panel vector stick plot.

BCM1 (continued)



BCM1 (continued)



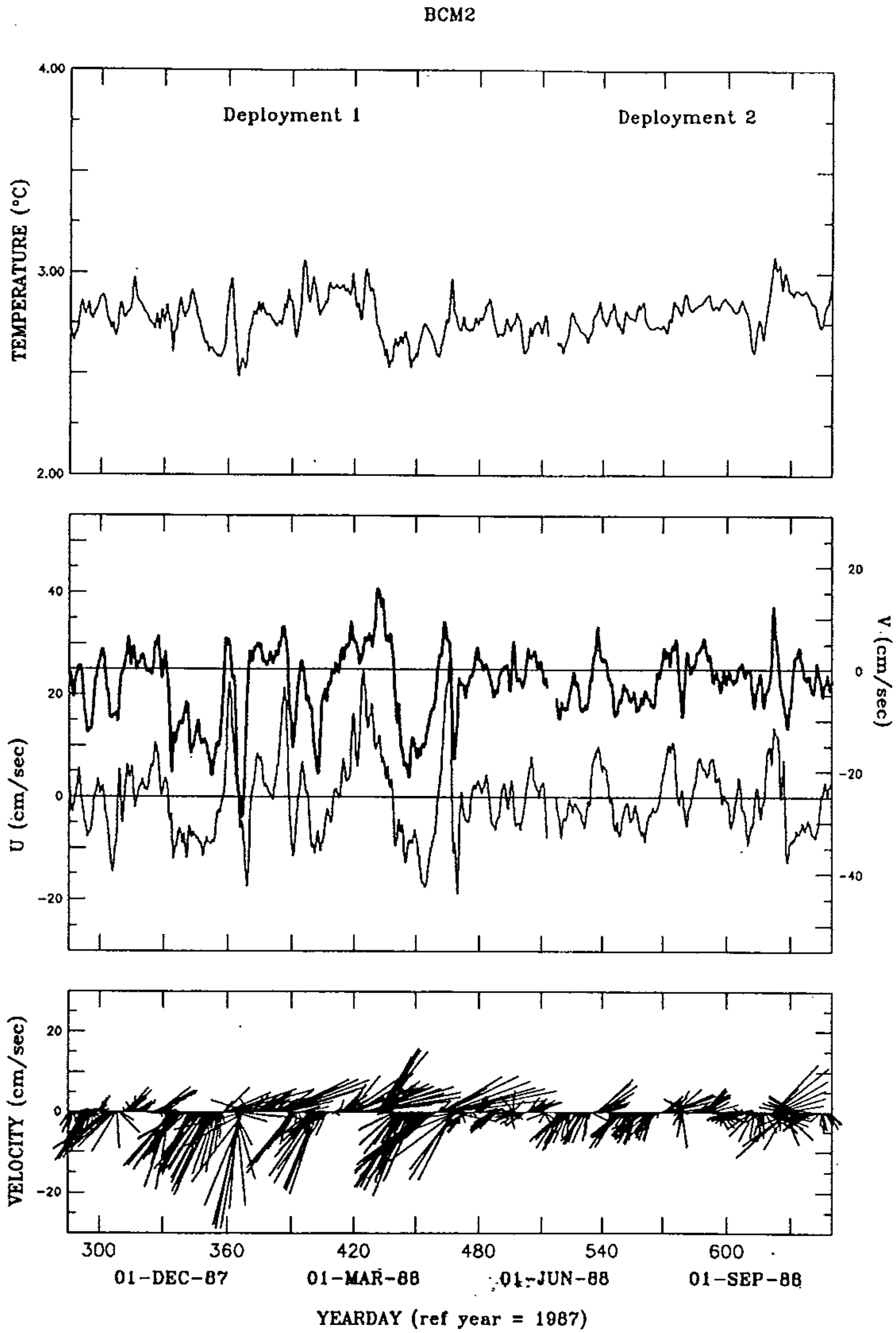
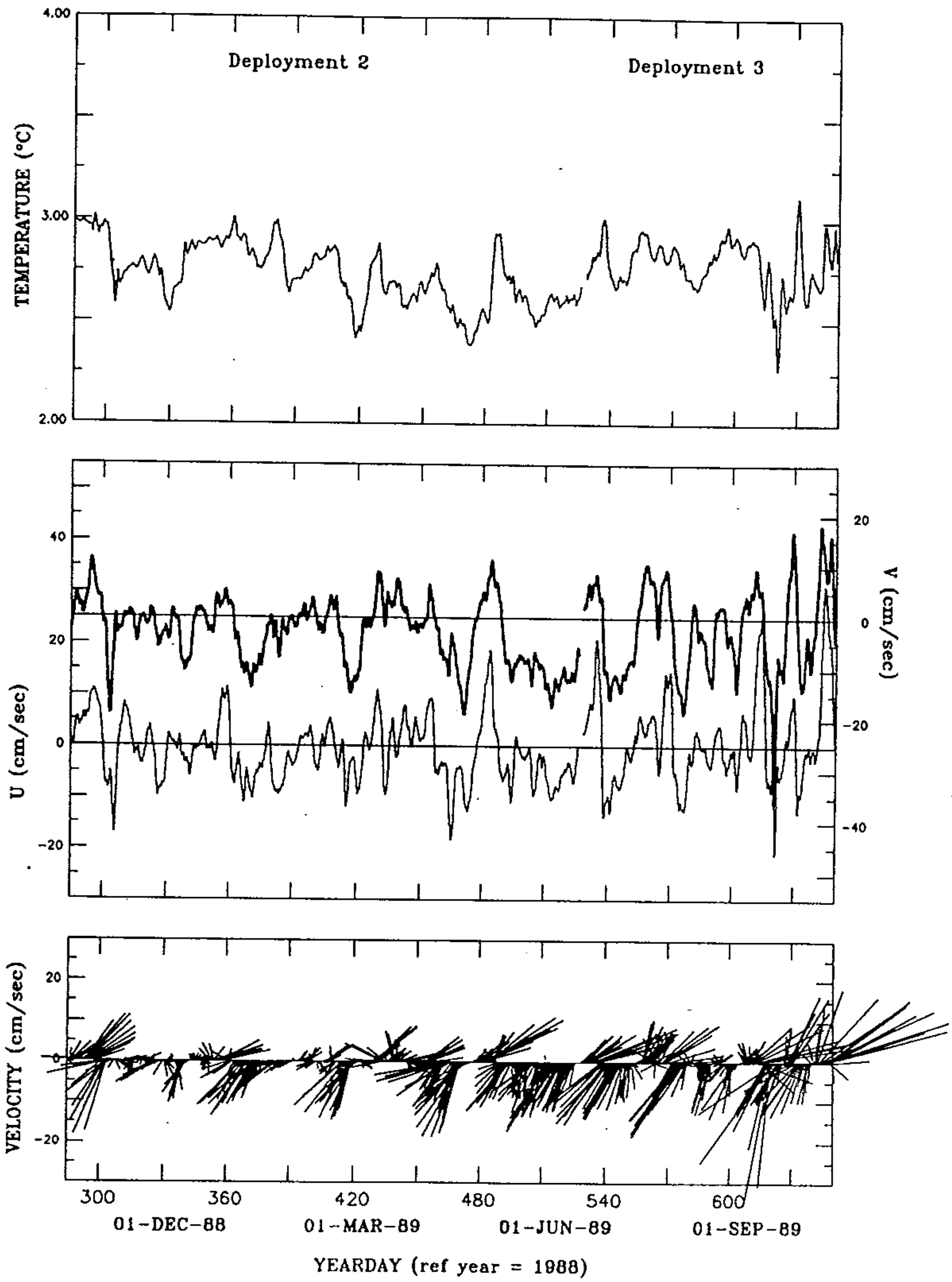
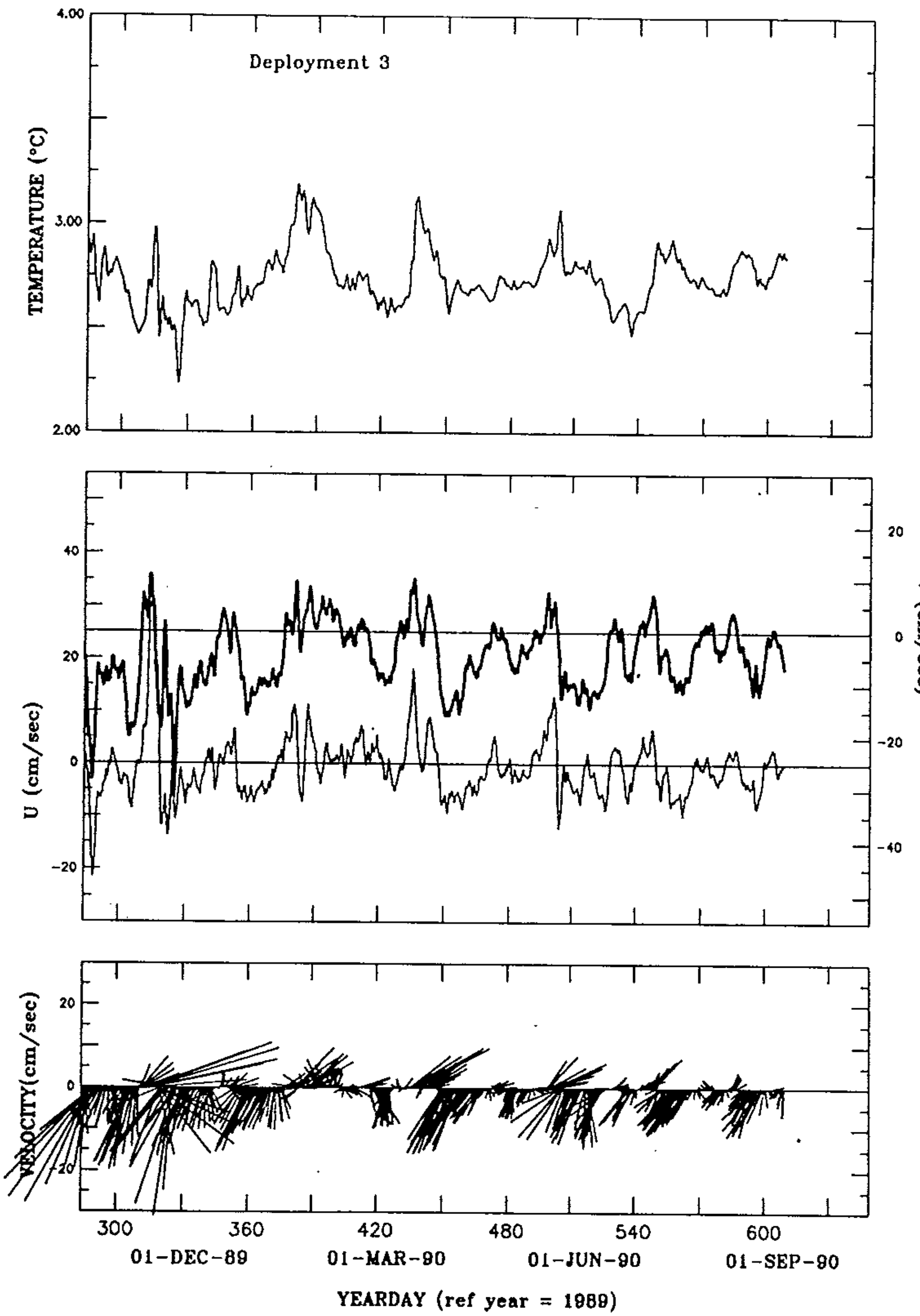


Figure 8.2: 40 hr low-passed time series at BCM2.

BCM2 (continued)



BCM2 (continued)



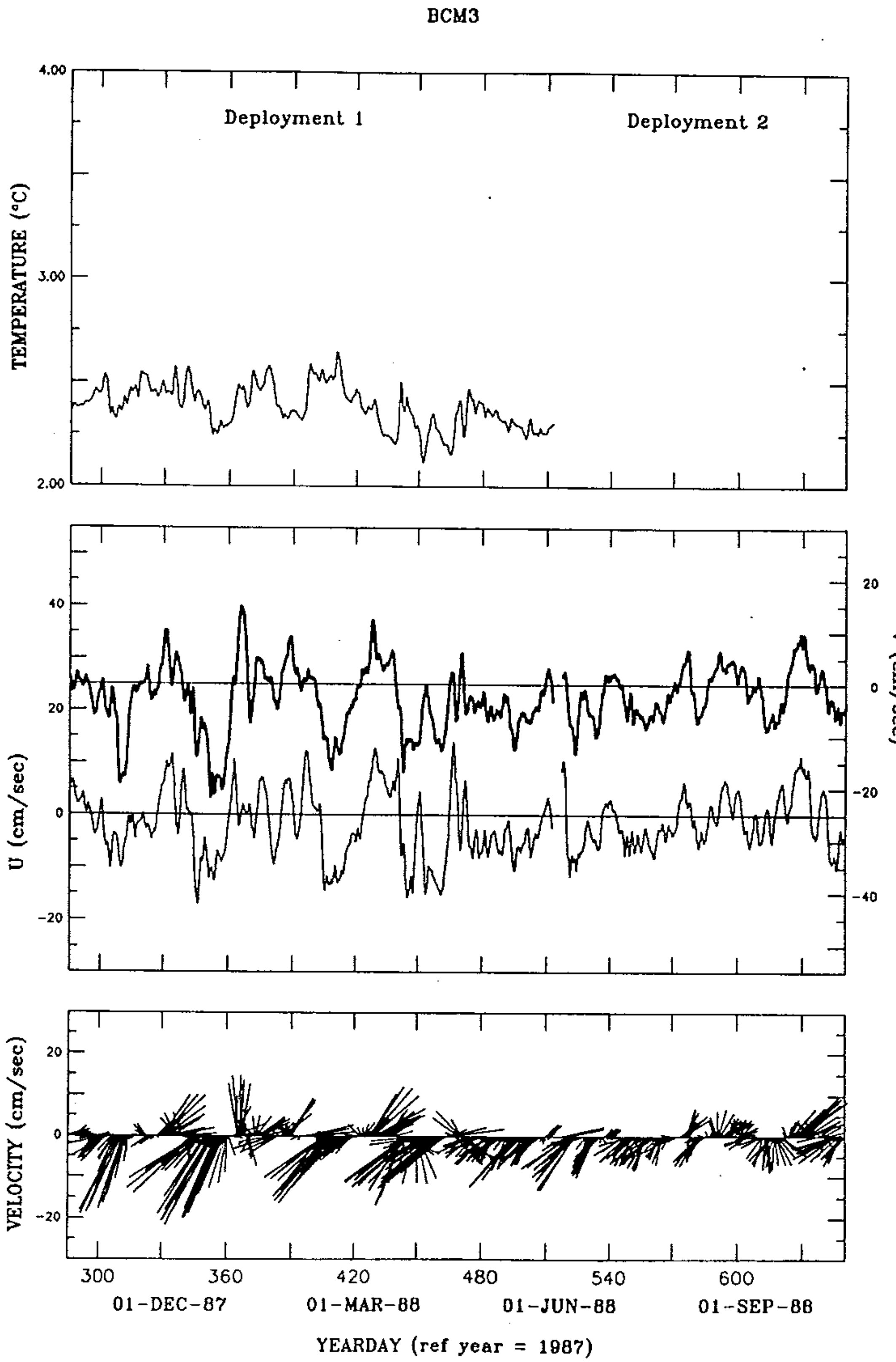
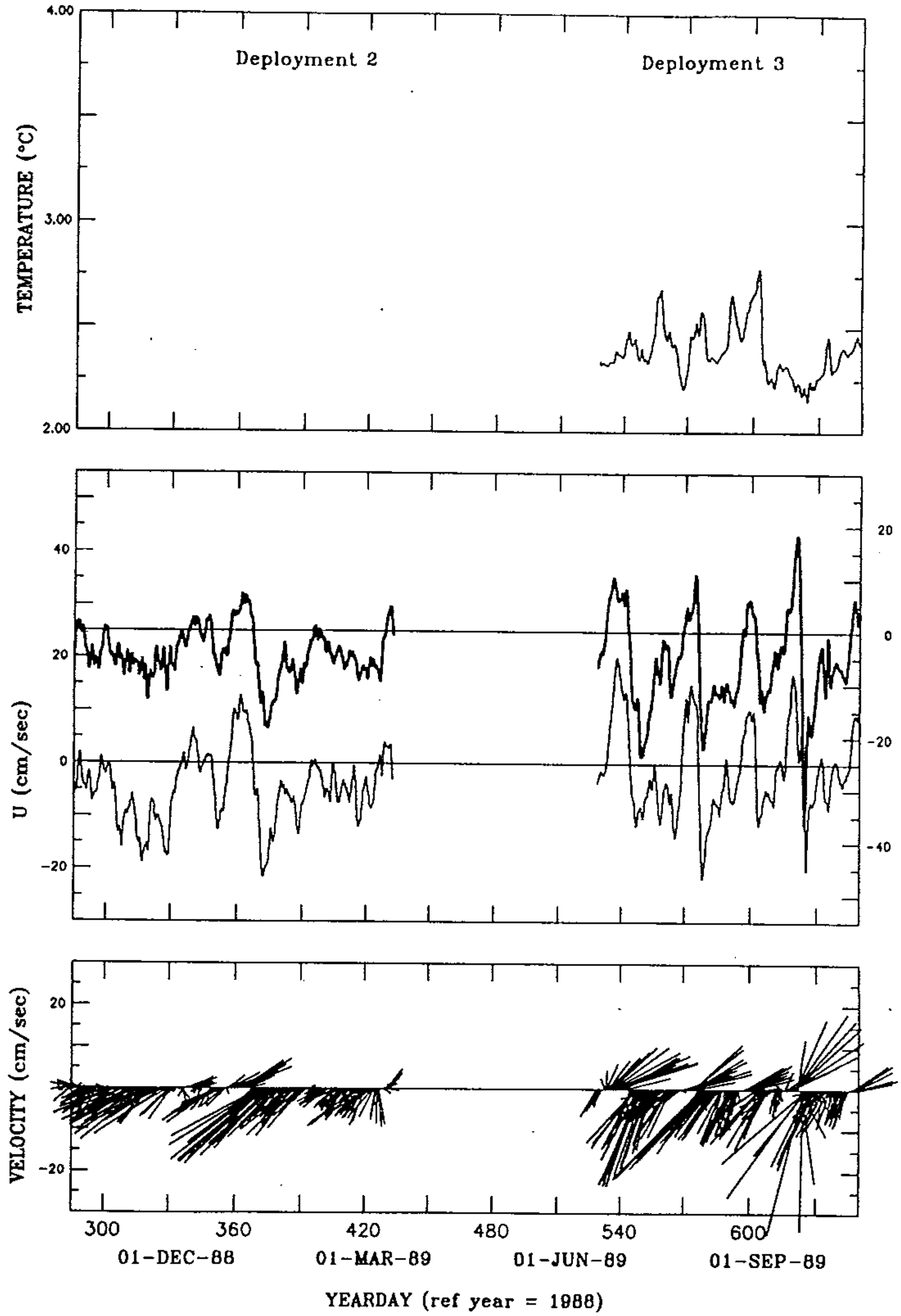
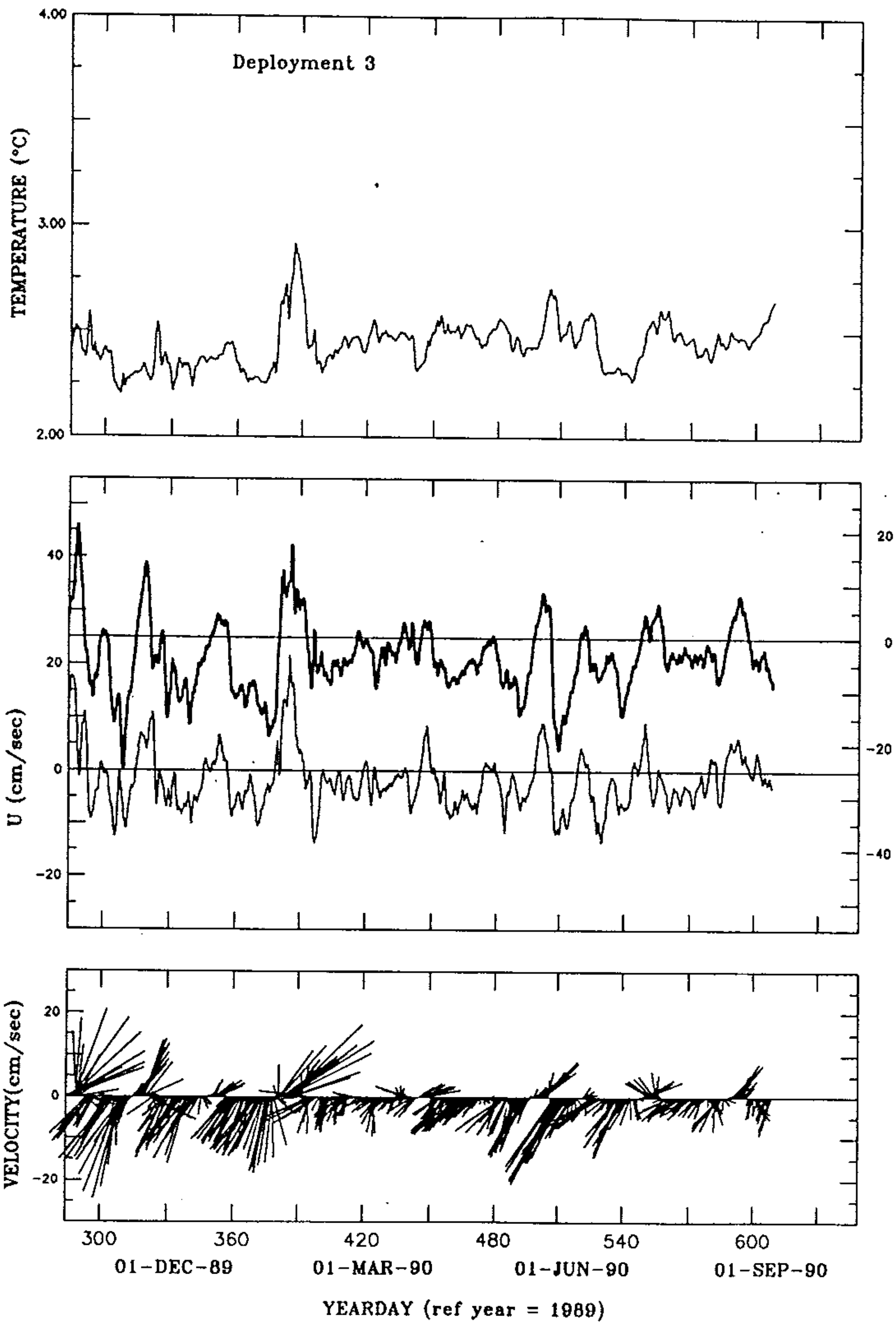


Figure 8.3: 40 hr low-passed time series at BCM3.

BCM3 (continued)



BCM3 (continued)



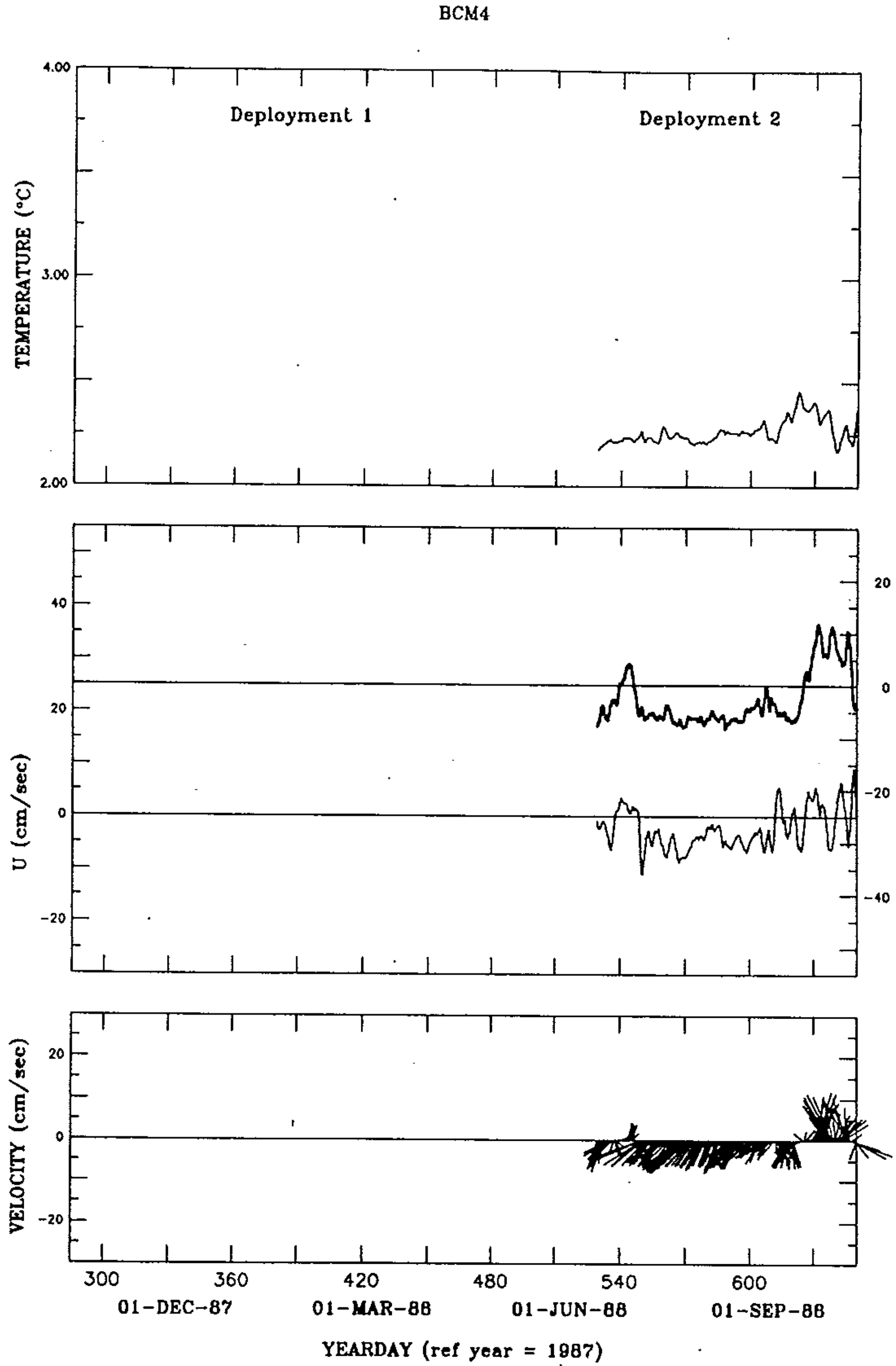
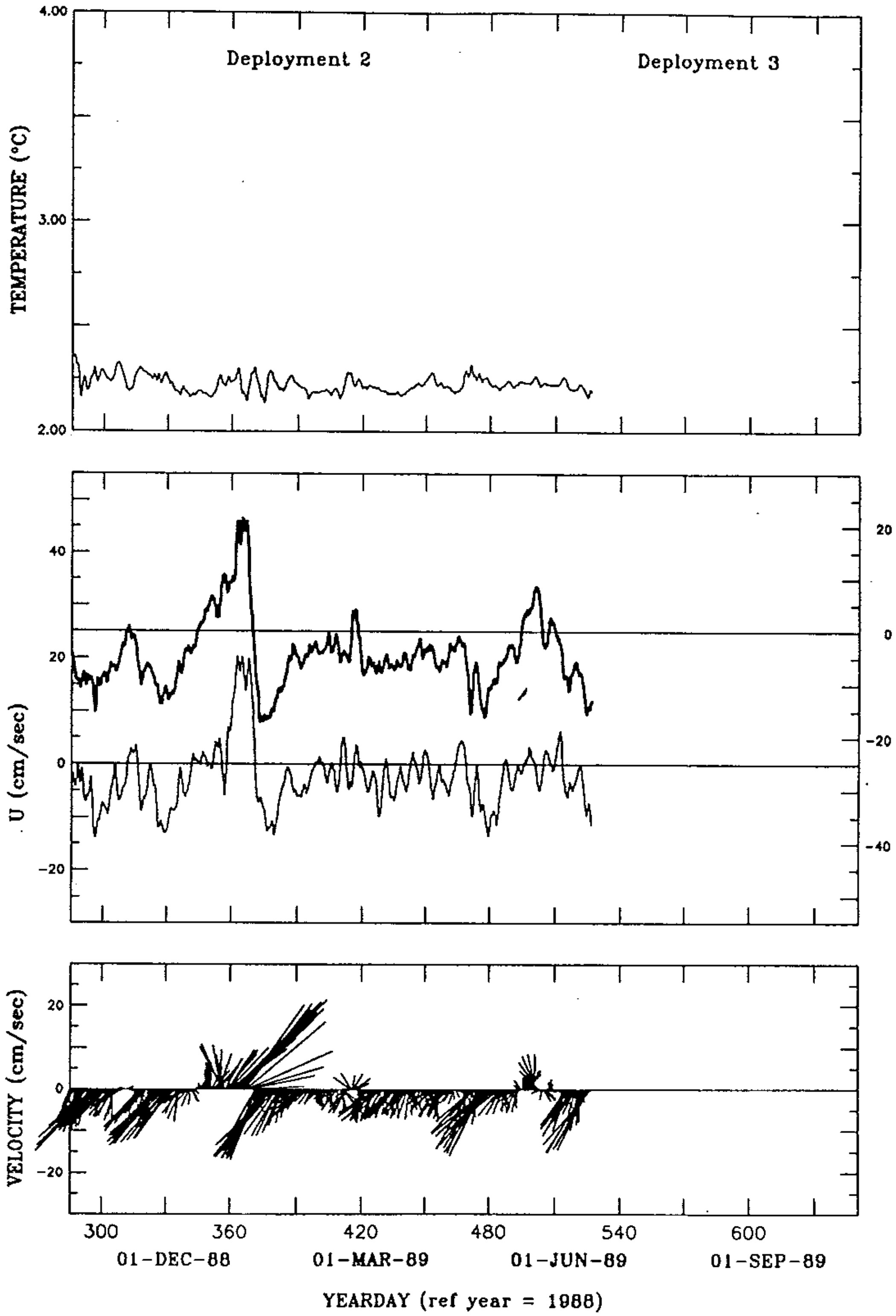


Figure 8.4: 40 hr low-passed time series at BCM4.

BCM4 (continued)



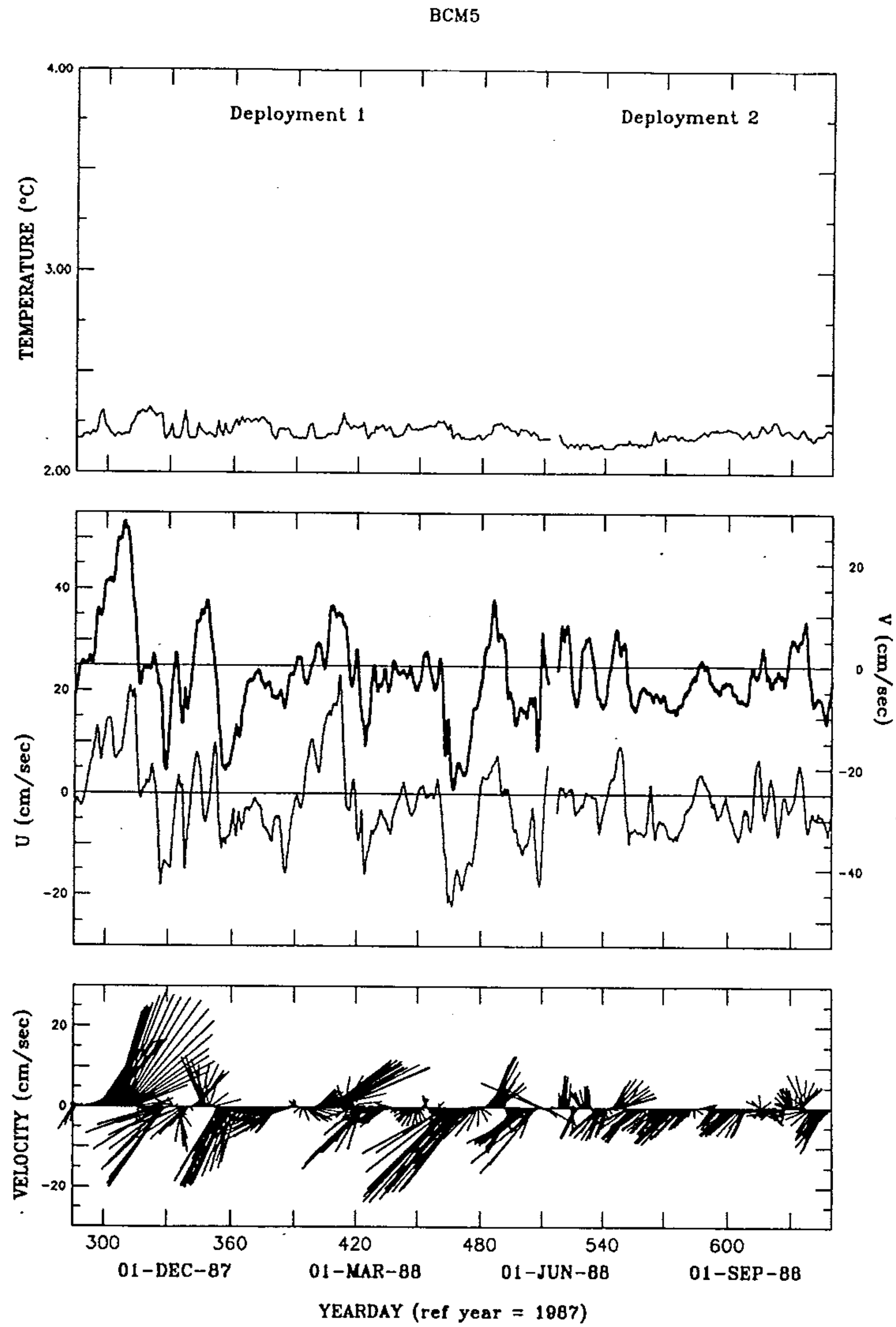
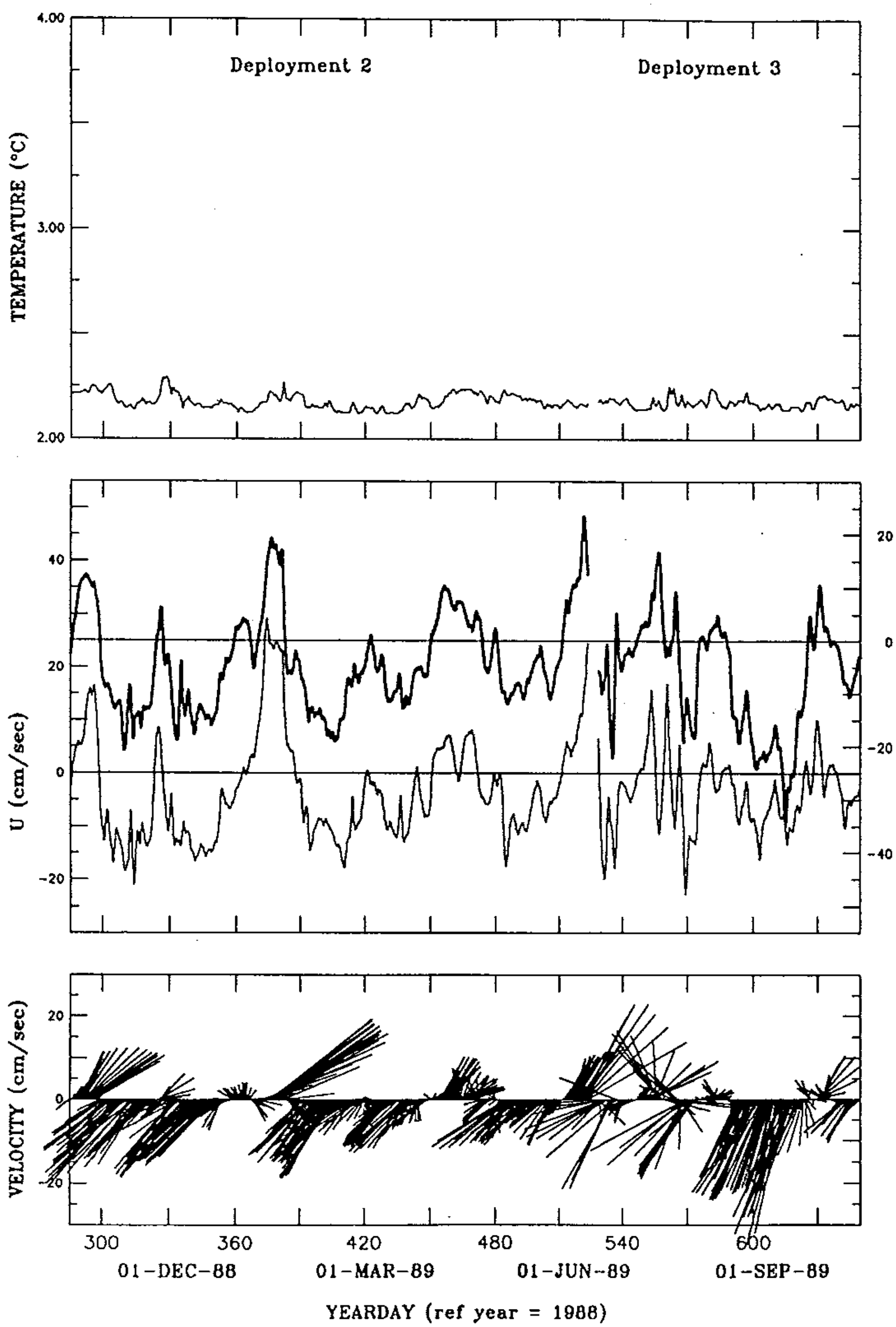
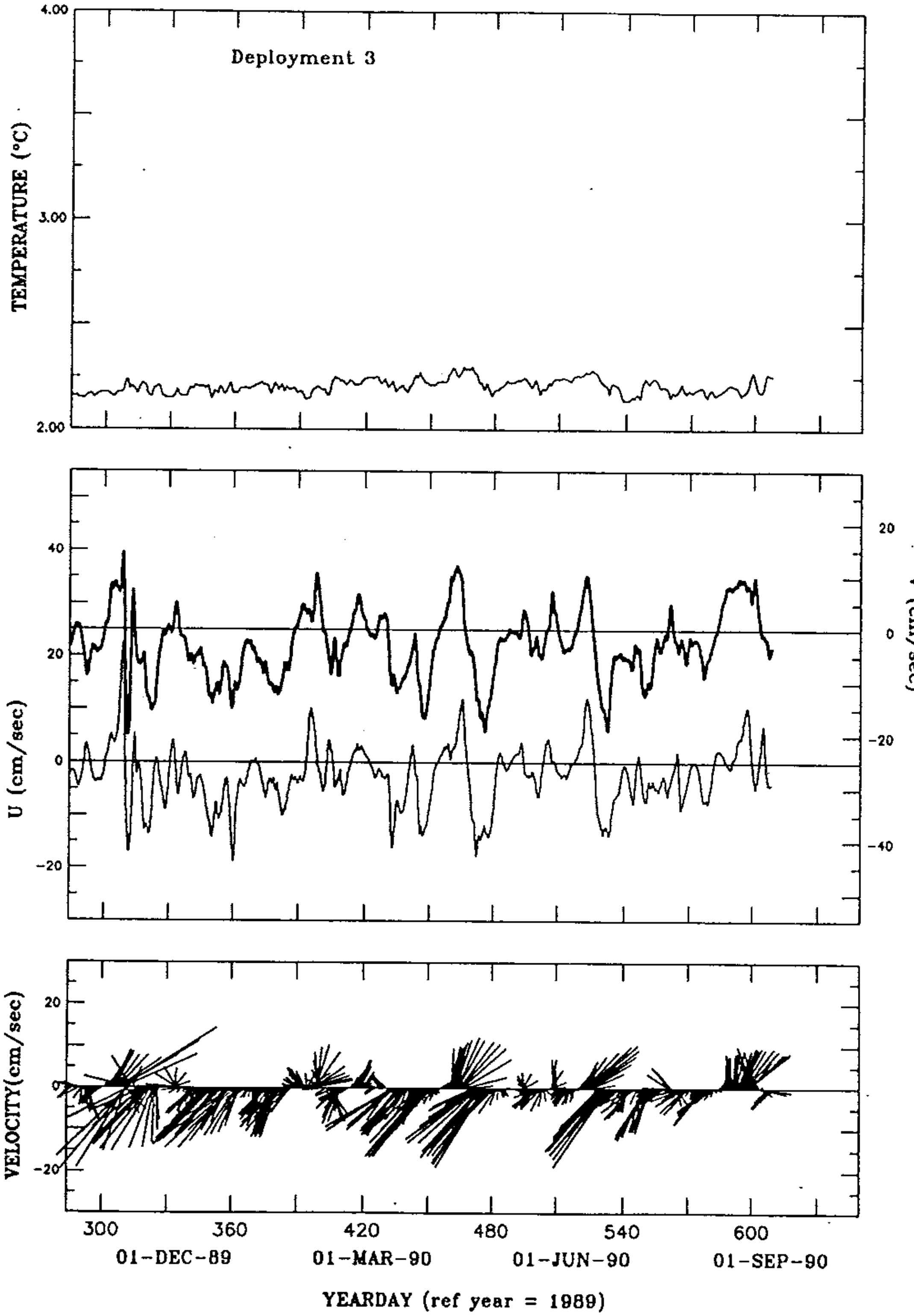


Figure 8.5: 40 hr low-passed time series at BCM5.

BCM5 (continued)



BCM5 (continued)



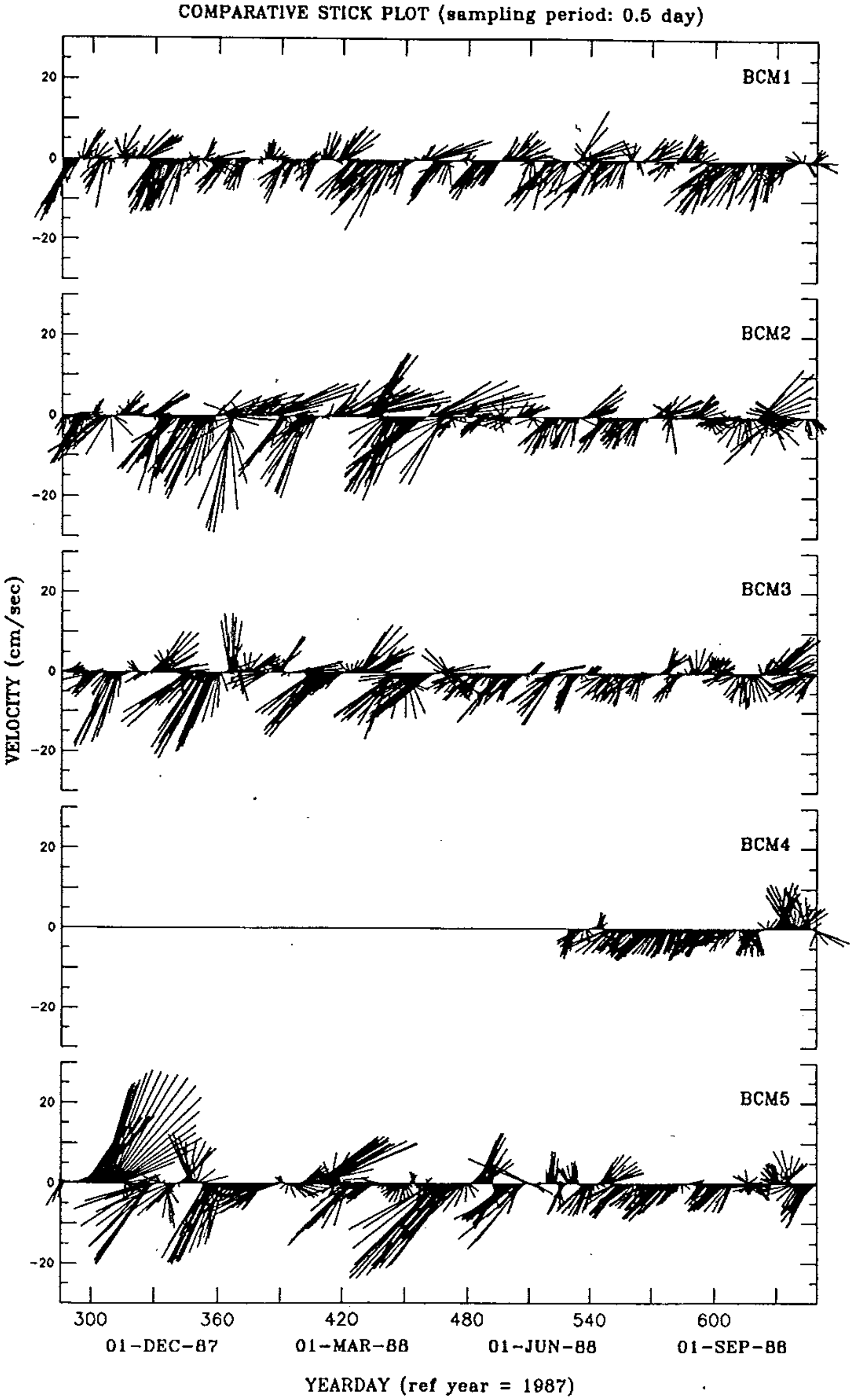
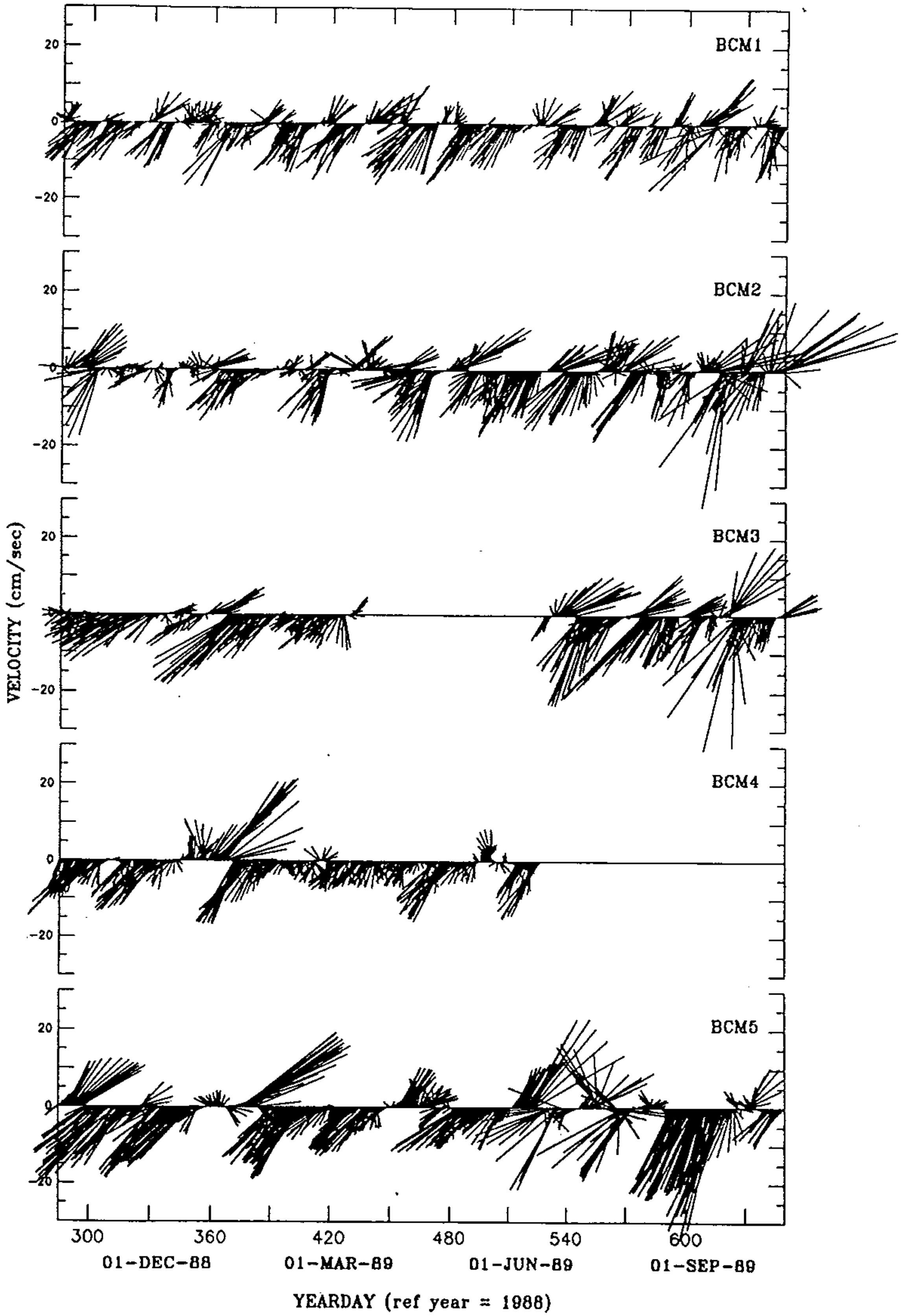
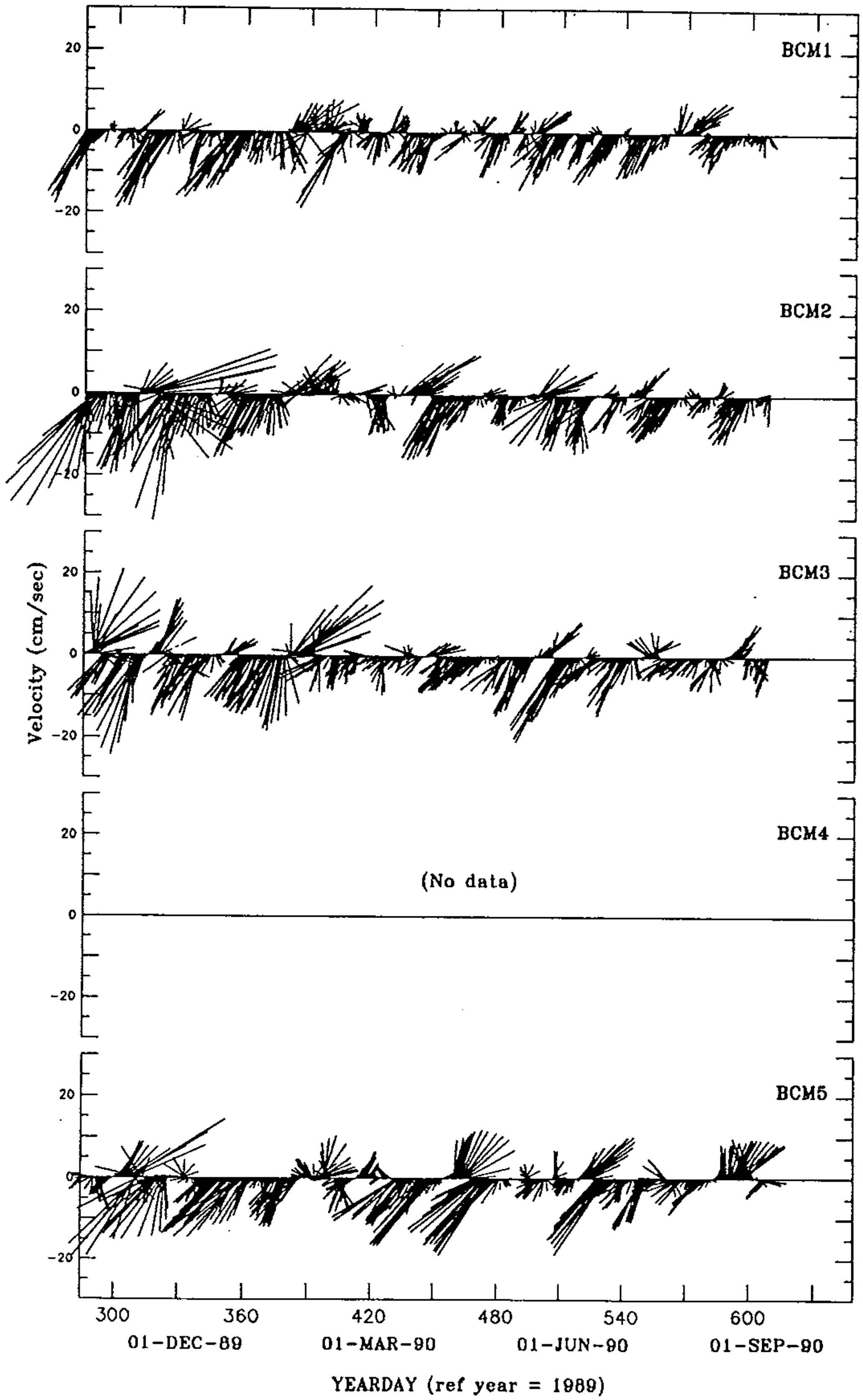


Figure 9: Comparison of the 40 hr low-passed stick plots from all sites

COMPARATIVE STICK PLOT (Continued)



COMPARATIVE STICK PLOT (Continued)



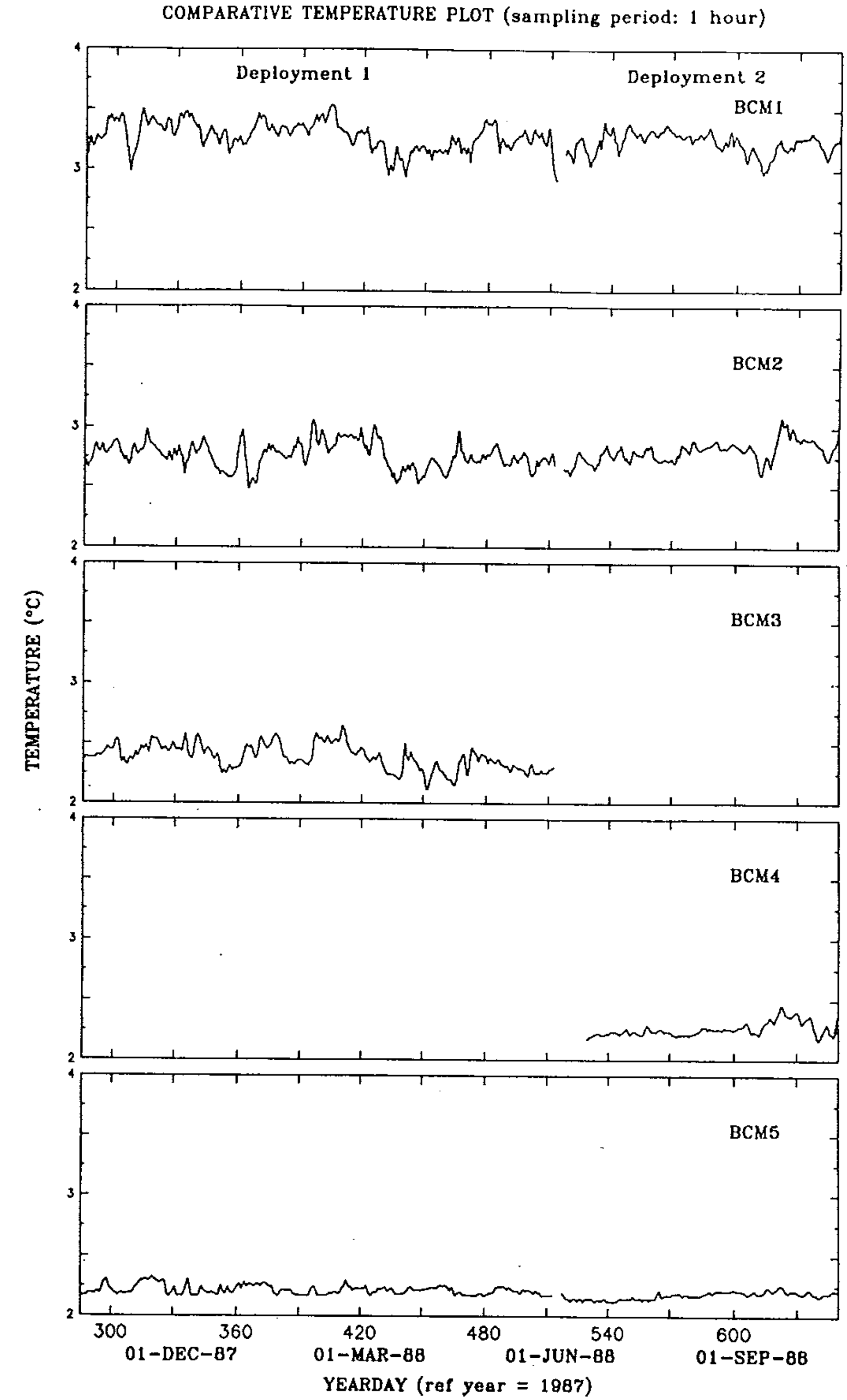
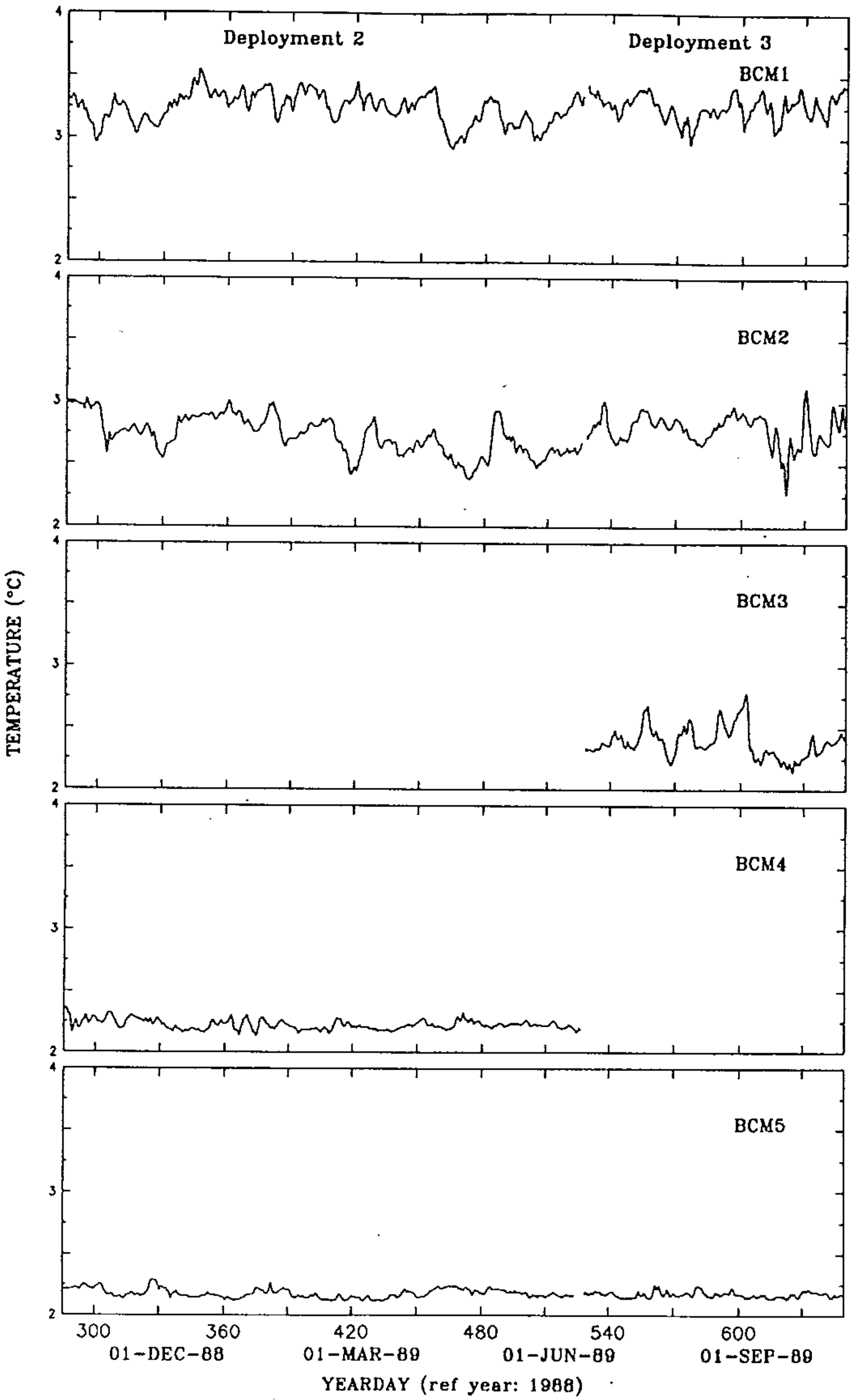
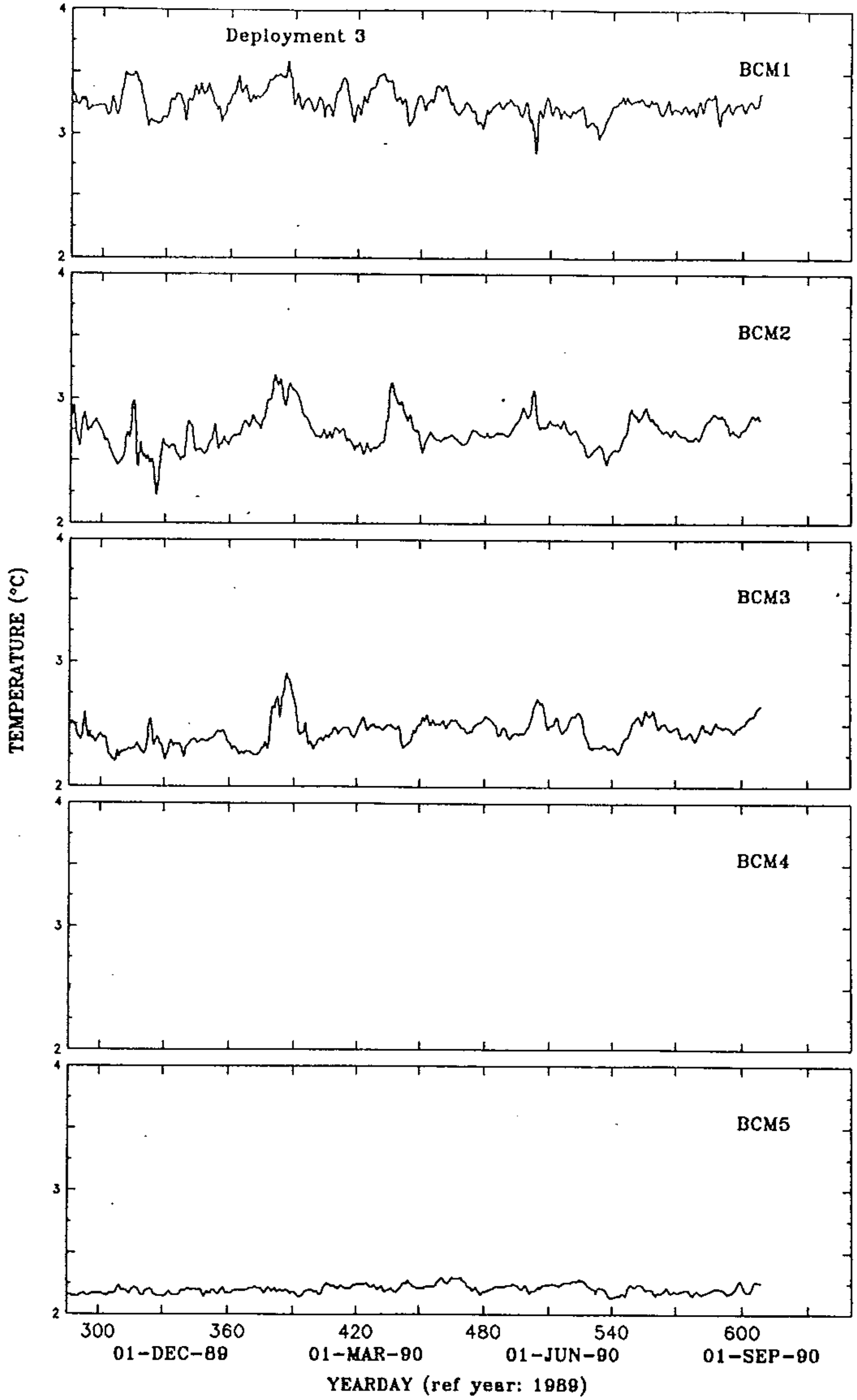


Figure 10: Comparison of the 40 hr low-passed temperature plots from all sites

COMPARATIVE TEMPERATURE PLOT (continued)



COMPARATIVE TEMPERATURE PLOT (continued)



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An array of five deep current meter moorings, each 100 m above the ocean bottom, was maintained along a line extending southeast from Cape Hatteras, NC for 34 months, from October 1987 through August 1990. The transect line was part of the SYNOP (Synoptic Ocean Prediction experiment) Inlet Array, which also had a surrounding array of Inverted Echo Sounders. The line extended from approximately the 2300 m to the 3800 m isobath (roughly 100 km long), intended to measure currents in the Deep Western Boundary Current in the region where the Gulf Stream crosses over it. This report describes the array design and data processing, and presents the basic statistics for each record. The current and temperature records are also displayed in 40-hour low-passed time series plots.

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