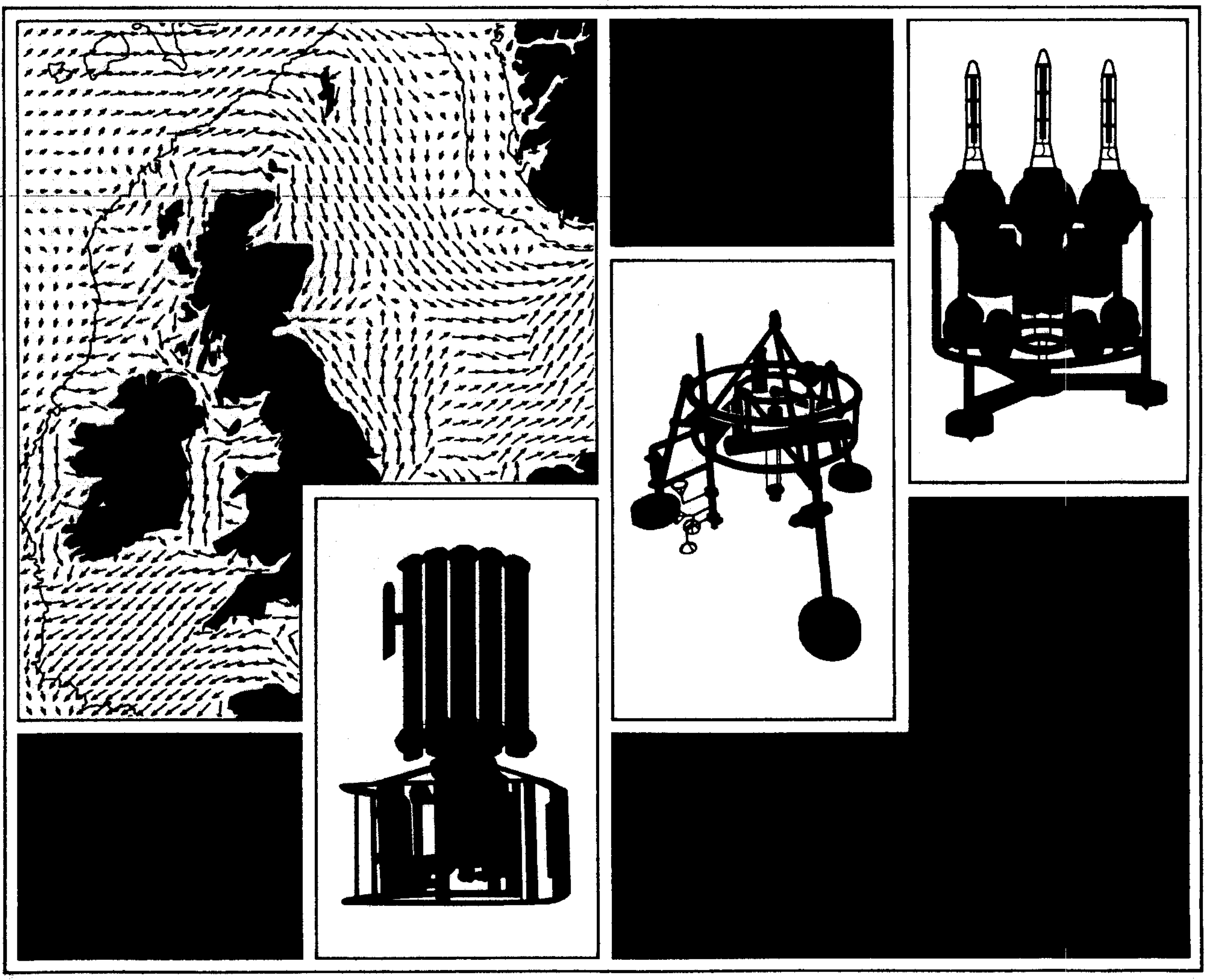
Proudman Oceanographic Laboratory

H.F. Radar (OSCR) surface current measurements in the North Channel, July 1993 - August 1994

RJ Player

Report No. 40 1995



Natural Environment Research Council

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REPORT NO. 40

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ABSTRACT

This report describes the H.F. Radar (OSCR) experiment in the North Channel, July 1993 - August 1994.

It includes descriptions of the OSCR sites at Portpatrick and Crammag Head, the area covered, problems encountered, and the initial data return and results. It also includes plots of the wind recorded at Orlock Point, Northern Ireland over the same period.

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1.0 Introduction

Between July 1993 and October 1994 an experiment was conducted to determine the volume flux through the North Channel of the Irish Sea, between Scotland and Northern Ireland. This formed part of a study of shelf edge and shelf sea exchange rates, contributing to the shelf edge (SES) and modelling (NORMS) components of the Land Ocean Interaction Study (LOIS) Community Research Programme.

H.F. Radar was used continually from July 1993 to August 1994, to measure sea surface currents in the North Channel, as part of the LOIS programme. The radar experiment was initially devised to coincide with a series of releases of Technetium from the Sellafield Nuclear Fuel Reprocessing Plant on the Cumbrian Coast, as an additional aid to monitoring the water transport through the Channel, although the Technetium release has since been delayed.

The H.F. Radar used was the Ocean Surface Current Radar Mk2 (OSCR II) owned by the Natural Environment Research Council, and maintained at Southampton University on their behalf. The deployment, day to day monitoring and troubleshooting of the deployment was carried out by Southampton University.

This report describes the deployment, data collected, analysis and initial results, together with the problems encountered. Further results will be presented later. See also reference [4].

A year long deployment of an Acoustic Doppler Current Profiler (ADCP) co-incided with the H.F. Radar deployment, and a report of the moorings and data collected is presented in [5].

Challenger Cruises 106 and 107 also recorded information on vertical and horizontal temperatures and current gradients in the North Channel area during September and November 1993 [6].

This work was carried out under a Special Topic Award from the Natural Environment Research Council, and partly funded under contract to the UK Department of the Environment, as a contribution to its co-ordinated programme of marine research for the North East Atlantic.

2.0 How OSCR works

The technique of using the Doppler shift of returning electro-magnetic waves from the sea surface to measure surface currents is well documented elsewhere ([1],[2] and [3]), but a brief description of OSCR hardware and routine operation is given here. The current version of the OSCR system has an updated range-gating system which can pinpoint the sea surface area required, rather than a specific range along a specific radar beam, and is known as OSCR II.

Each H.F. Radar unit consists of 1 transmit antenna, with 3 additional antennae set up in an array to direct the signal forward to the sea surface in the required direction. There are 16 receive transmit antennae set up in a straight, level line, over a horizontal distance of 84.4m. Additionally, there is also the site computer and tape deck, and outside communication hardware, which can be a telephone line connected to the Public Service Telephone Network and/or a radio link to communicate with another site if needed.

At each recording time, the transmit antenna sends out an amplified signal of 500 Watts over the sea surface, and the receive antennae pick up the return signal. A multiplexer splits the signals up and sends them to the computer where range-gating software decodes the signal from each particular position (cell) on the sea surface. Data for all cells is recorded every ⅓ of a second, over 5 minutes, and represents a 1 km^2 area (footprint) of the sea surface. For each cell this is then averaged, to improve the signal to noise ratio, and put through a Fast Fourier Transform to produce an energy spectrum. The current speed is calculated from the Doppler shift in the spectrum's Bragg peaks, and is accurate to $\pm$ 4 cm/sec [7]. The spectral analysis assigns a quality code to the data, according to the clarity and interpretation of the spectral signal and Bragg peaks, and this is used as a guide in subsequent data processing.

The speed calculated is a radial measurement either towards or away from the radar site. Therefore to get an accurate vector current, two radar sites are needed, to record measurements whose respective bearings are (preferably) more than 30° apart, and the data combined to form the vector.

The two OSCR sites are known as the master and slave sites, the distinction between the two being that the master automatically collects the data from the slave (using either UHF radio or a telcommunication line) and combines the data into vectors on site, with the master computer storing the vector data. Thus only the master needs to be contacted by telephone to monitor the deployment.

Data for each site were recorded at 20 minute intervals, the slave staggered 5 minutes after the master, to prevent signal interference between sites.

3.0 Area and sites used

The two sites used to carry out the radar deployments were Portpatrick and Crammag Head, on the Dumfries and Galloway Coast, approximately 20 km apart, set up with a maximum range of 44 km. The survey area included the Beaufort Dyke, which goes down to a depth of 300 m (Figure 1).

3.1 Portpatrick

Location 54.84° N 5.12° W. on a grass covered sheer granite cliff top, approximately 25 m above m.s.l. with a good view of the sea area.

Set up as the master site, the 4 transmit antennae were set up in the MOD compound at Cove Hill, overlooking Portpatrick. The trailer housing the OSCR computer was also within the compound, but the 16 receive antennae were located in a public area on the cliff top outside the compound. There was also a radio transmitter to link to the slave site at Crammag Head.

Nearby, (300 m south) on the cliff top, was a radio station transmitting on 2.8 Mhz, and on the surrounding golf course 4 large communication towers were situated. These were presumed to be attached to the nearby MOD West Freugh Airbase test site. There are also several other large communications towers in the surrounding area.

3.2 Crammag Head

Location 54.67°N 4.96°W on grass covered granite, approximately 20 m above m.s.l., with a gradual rocky drop down to the sea, and a good view of the sea area.

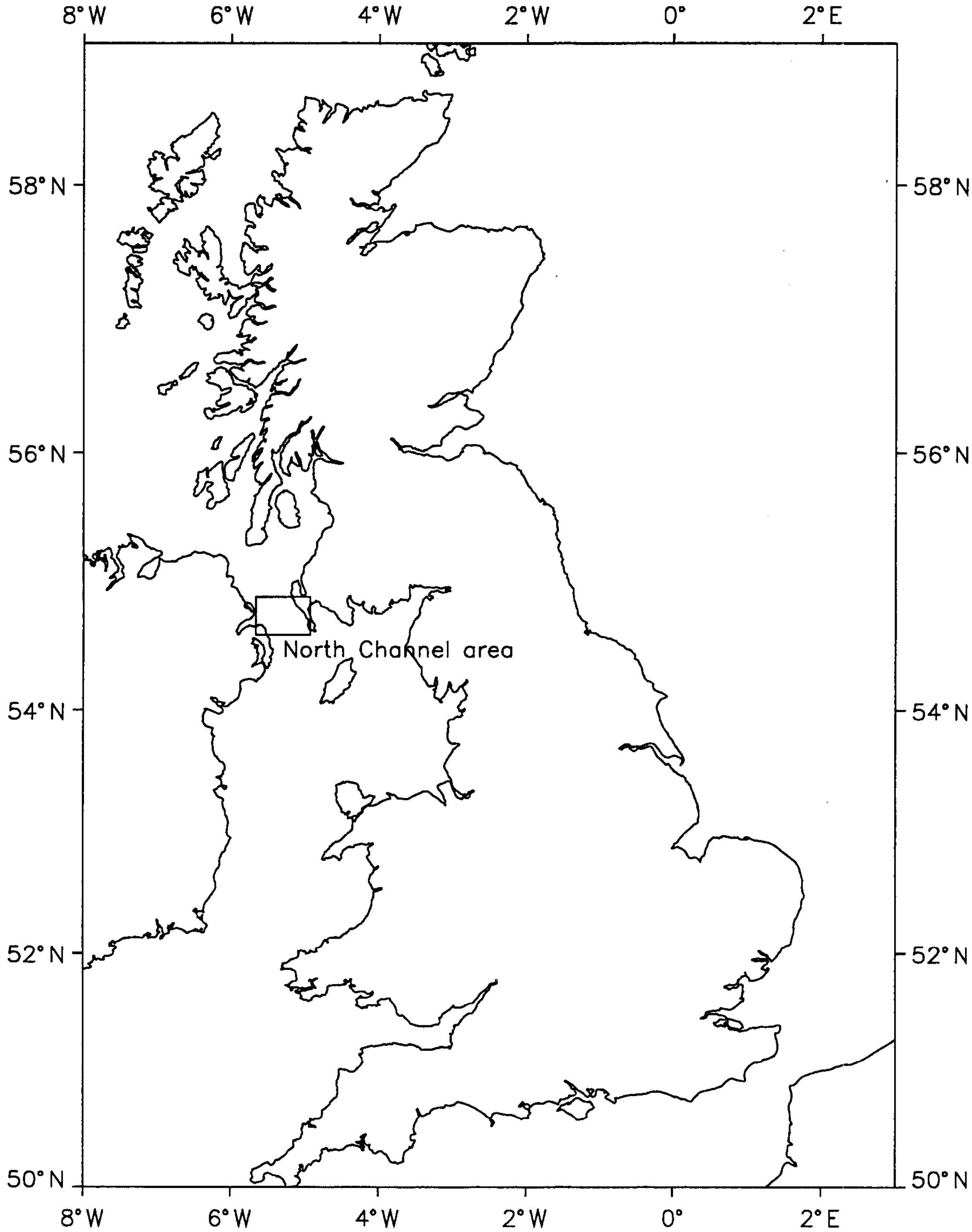
Set up as the slave site, the transmit and receive antennae were set up in a field on Slockmill Farm, Drummore, in a very remote location, and the OSCR equipment was moved there courtesy of the farmers tractor and trailer. The OSCR computer was housed in a small lighthouse, of which the farmer was also the keeper. Although the lighthouse was powered by carbide, mains power was also provided from the farm. Since the field was used for livestock, a 12 v electric fence was set up around the antennae to prevent damage to the equipment.

4.0 Deployment configuration

The master and slave sites were set up with boresites of 242° and 308° respectively, where the boresite is the angle perpendicular to the line of the 16 receive antennae.

Transmission frequency was 27 MHz, with a maximum range of 44 km, and 652 cells were set up to cover the desired area. See Appendix A for a diagram of the cells used.

Figure 1 Map of area



5.0 Data collected

Data were collected by Southampton University at regular intervals, and supplied to POL where possible in data sets of 30 days duration. Table 1 gives further details.

Table 1 Datasets received and processed

Dataset *	Data span	Max. number data values	Analysed cells	% time operational #	% data return @
25	02 Jul 93 - 22 Jul 93	1447	635	99/69	88/57
26	22 Jul 93 - 21 Aug 93	2160	647	99/85	94/71
27	21 Aug 93 - 20 Sep 93	2160	645	97/89	87/44
28	20 Sep 93 - 20 Oct 93	2160	649	98/96	94/83
29	20 Oct 93 - 19 Nov 93	2160	652	99/95	94/80
30	19 Nov 93 - 19 Dec 93	2160	652	99/77	91/61
31	19 Dec 93 - 18 Jan 94	2160	572	97/36	90/27
32	18 Jan 94 - 17 Feb 94	2160	622	99/59	91/41
33	17 Feb 94 - 19 Mar 94	2160	548	97/24	90/20
34	19 Mar 94 - 14 Apr 94	1883	0	99/12	92/9
35	14 Apr 94 - 14 May 94	2160	563	99/28	91/24
36	14 May 94 - 13 Jun 94	2160	602	99/58	93/47
37	13 Jun 94 - 13 Jul 94	2160	630	99/95	86/73
38	13 Jul 94 - 12 Aug 94	2160	631	99/96	90/80
39	25 Jul 94 - 24 Aug 94	2160	644	99/99	92/84

* Data set number in POL OSCR database.

\# % of time that the system was operational (Master/Slave)

@ % of valid data after filtering/editing (Master/Slave)

6.0 Data processing

The analysis of the data sets was carried out on a Silicon Graphics 4000 Indigo Workstation running a Unix operating system. All processing software is written in Fortran 77 and graphics software in PV-Wave graphics language.

6.1 Data screening

Each data value has an associated data flag. Data calculated as invalid has its associated flag altered and subsequent processing then ignores it. Several techniques were used to determine invalid data.

1) Each dataset was filtered to remove data where the calculated currents appeared to 'jam' at any particular time (see 7.0 Operational problems).

a) Data values were combined into a histogram, and where any data value occurred for more than 20% of the available data, the values were flagged.

b) Where the 10 highest values in the histogram exceeded 1.0/1.3 m/s for master/slave respectively, and occurred for more than 5% of the data, the data values were flagged. The slave tolerance used was higher, due to the slave radial recording directions being more in line with the prevailing current, and therefore generally measuring higher speeds.

2) Residuals were produced using harmonic analysis (see 6.2 Tidal analysis), and these were screened to reflag observed data where the corresponding residual speed exceeded approximately 3.5 times the residual standard deviation for that dataset and site. The tolerance values used for each data set are shown in Table 2.

3) Manual graphical editing was also carried out for remaining obvious anomolies remaining in the data.

It is possible that techniques 1) and 2) allowed some otherwise genuine values to be flagged.

6.2 Tidal Analysis

Each dataset was processed using harmonic tidal analysis software. Where each cell had more than 324 values, it was analysed as a single time series, using equilbrium constants as the reference constant set. The program then produced vector tidal constituents for each cell, and radial residuals, which could then be combined into vector residuals.

6.3 Initial results

Graphical constituent output for Z0 and M2 for each dataset are presented in Appendix B.

The data sets were also combined into a single large time series for each cell, and again analysed, and the Z0 and M2 constituents presented in Appendix C.

Table 2 Residual tolerances applied

Data span	Master residual tolerance (m/s)	Slave residual tolerance (m/s)
02 Jul 93 - 22 Jul 93	0.6	1.0
22 Jul 93 - 21 Aug 93	0.5	0.75
21 Aug 93 - 20 Sep 93	0.6	1.0
20 Sep 93 - 20 Oct 93	0.5	0.75
20 Oct 93 - 19 Nov 93	0.5	0.75
19 Nov 93 - 19 Dec 93	0.6	1.0
19 Dec 93 - 18 Jan 94	0.6	1.0
18 Jan 94 - 17 Feb 94	0.6	1.1
17 Feb 94 - 19 Mar 94	0.7	1.0
19 Mar 94 - 14 Apr 94	0.6	3.0 #
14 Apr 94 - 14 May 94	0.6	0.75
14 May 94 - 13 Jun 94	0.6	0.75
13 Jun 94 - 13 Jul 94	0.6	0.75
13 Jul 94 - 12 Aug 94	0.6	0.75
25 Jul 94 - 24 Aug 94	0.6	0.75

Too little data for analysis, therefore no residual data available.

7.0 Operational Problems

1) Various software problems were encountered, ranging from being unable to read the supplied data tapes, to data formats that had not previously been encountered. Also, information files were not always accurate, but these problems were generally easily identifiable, and overcome fairly easily.

2) Signal interference occurred at both sites, but was more noticable at Portpatrick. This was assumed to be because of the large amount of communication equipment in the surrounding area causing the interference. The interference became apparent when high numbers of cells at any one time all had exactly the same value, and which was outside normal current speeds. At Portpatrick, the interference was usually confined to the hours of 0800 - 1400 on the days when it occurred, but at Crammag head, it occurred more randomly, but far less often. With no equipment available to test for outside interference, it was difficult to investigate further.

Variation of valid data collection with time of day is shown in Appendix D.

3) Power failures occurred frequently at the Crammag Head site, due to the intermittent power supply from the farm. Additionally, the system often failed to recover from the power failure, resulting in further loss of data.

4) The UHF radio transmitter that connected the two sites failed early on, therefore no vector data was available to POL until a complete dataset was taken back to Southampton University, put into the correct format, and then sent to POL, where POL software combined it into vector format. Also full remote monitoring of the slave site was unavailable, due to the master being unable to contact the slave site for data, and together with 3) above accounted for most of the slave site loss of data for the deployment.

5) System performance of the H.F. radar system is shown in Appendix E.

7.1 Log of events

02/06/93	System setup.
03/08/93	Master modem failed.
01/09/93	Slave site not collecting data for many cells. Master modem now replaced by slave modem. Slave tranmit antenna bent in two, but electric fence still intact. Southampton University personnel hurt by bull in farmer's field.
07/09/93	Slave antenna now repaired after a visit by Southampton personnel. Also power amplifier not plugged in. Slave site now reported ok. Master 'disc error' at Portpatrick, reason unknown.
13/09/93	Master UHF radio transmitter starts to fail, unable to remotely check slave site.
/09/93	Electrical storm damage to mobile phone, receiver for the master UHF radio link, and the modem converter.
/12/93	Slave site hung after power failure resulting in data loss.
/01/94	Master has tape rewind problem.
09/02/94	Interference from Portpatrick radio station suspected by Southampton University.
/02/94	Slave UHF unit sent for repair
05/02/94	Slave system 'hung' until 17/02/94.
14/04/94	Master trailer lined with foil in an effort to eliminate interference.
04/05/94	Slave often losing up to 50% data, possibly due to watchdog failure. Master antennae blown over, due to rusting shackles, to be replaced.
06/06/94	Master watchdog moved to slave site. Slave tape deck and watchdog removed for repair. Master now has loan watchdog.
12/07/94	Antenna 14 at master site failed.
24/08/94	System dismantled.

8.0 Wind data used

Wind data from Orlock Point, Northern Ireland, were used to determine the wind conditions, and are presented in Appendix H.

9.0 Acknowledgments

The author would like to thank Rob Palmer, formerly of Southampton University for his patience in deploying and operating the OSCR hardware, and the Meteorological Office, Bracknell for supplying wind data for the experiment. Also to John Howarth, of POL for his guidance in dealing with the data.

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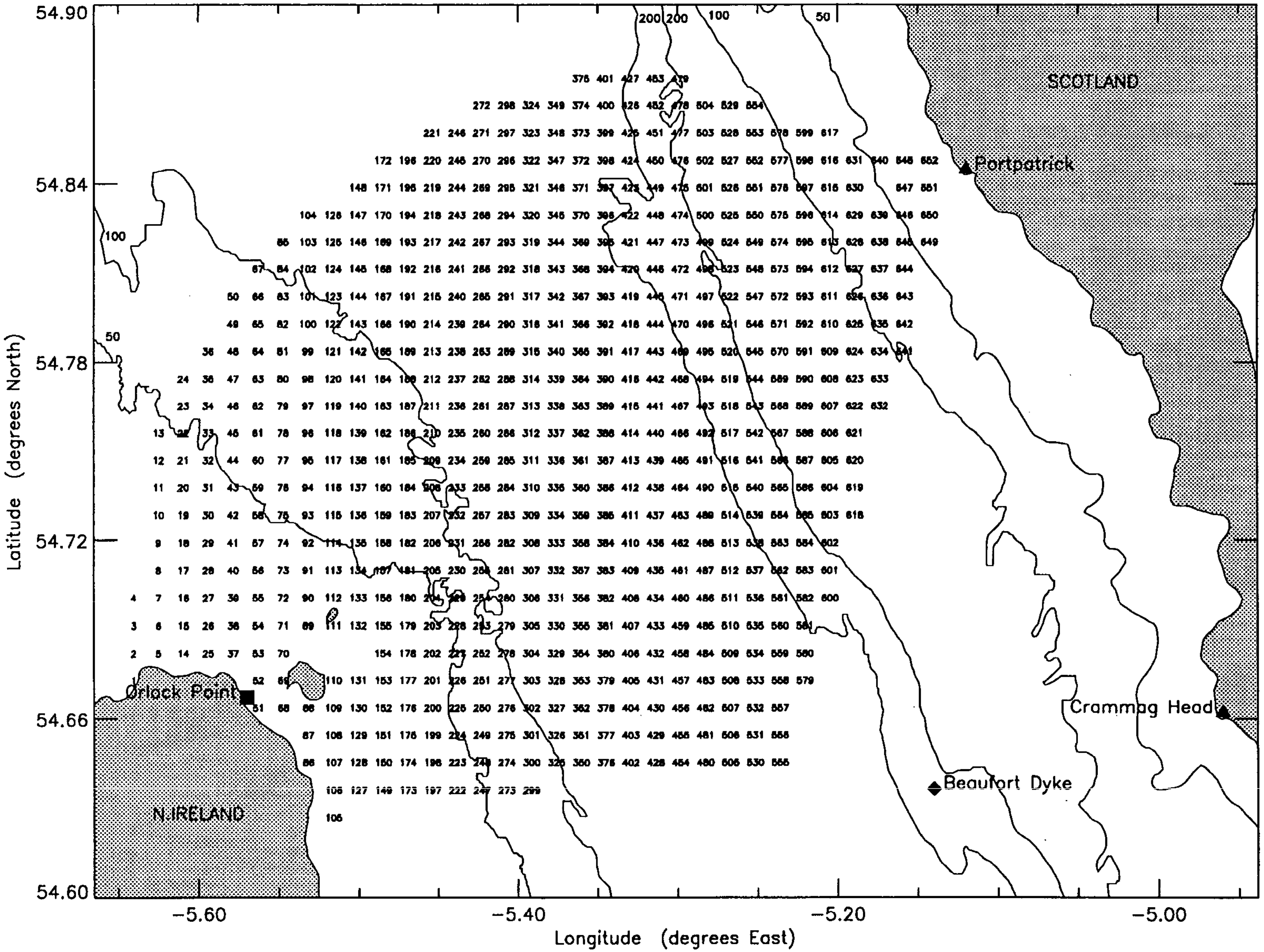
Journal of Physical Oceanography, 1987, **17**(2), 231-245.

Appendix A Diagram of cell positions

Cell positions



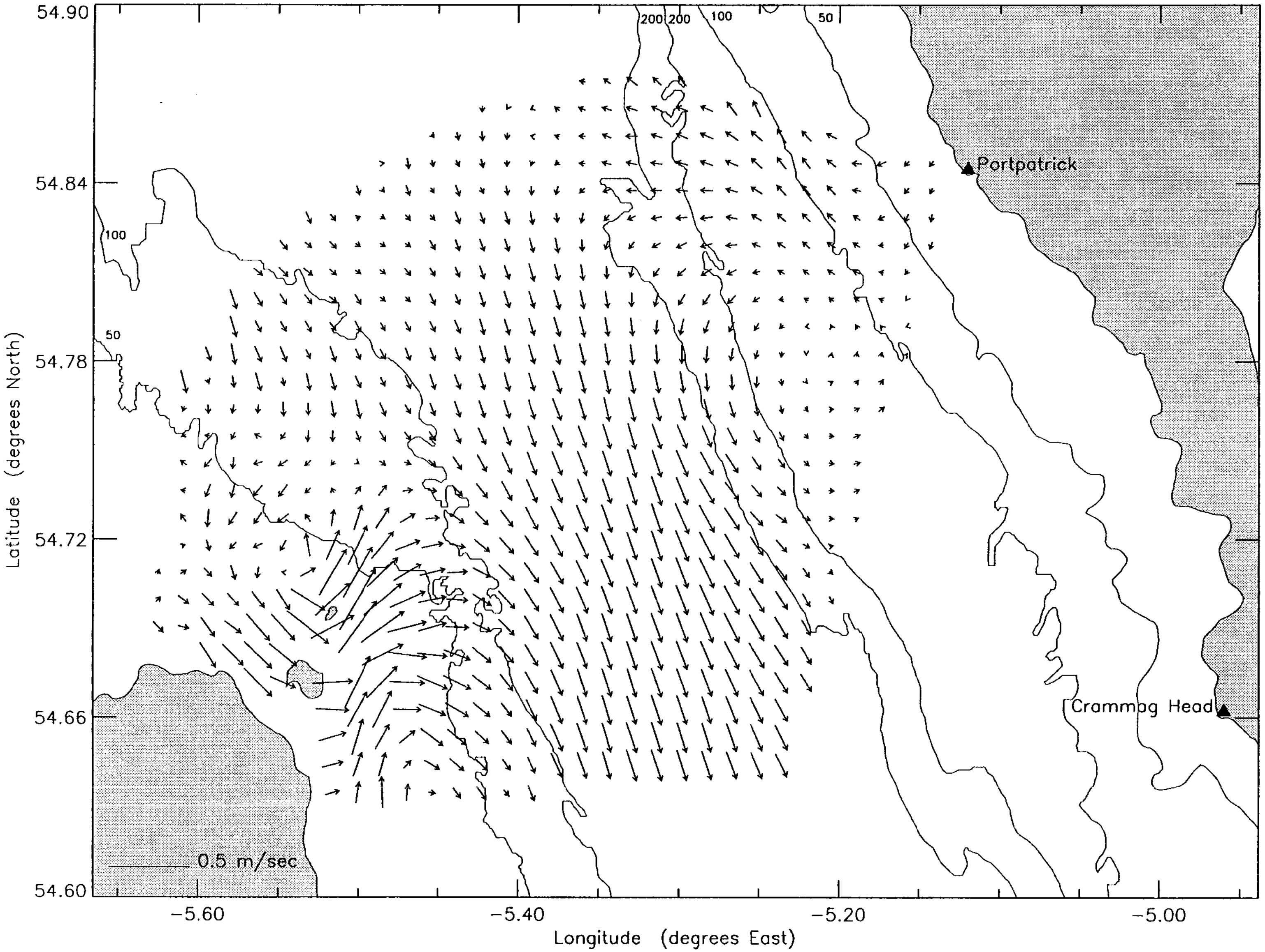
Appendix B Z0 and M2 constituents for each dataset

The Z0 plots show the mean current speed and direction over the specified period.

The M2 plots show the amplitude and direction of the major axis for that constituent. The directions are ambiguous by 180° depending on the phases for that constituent.

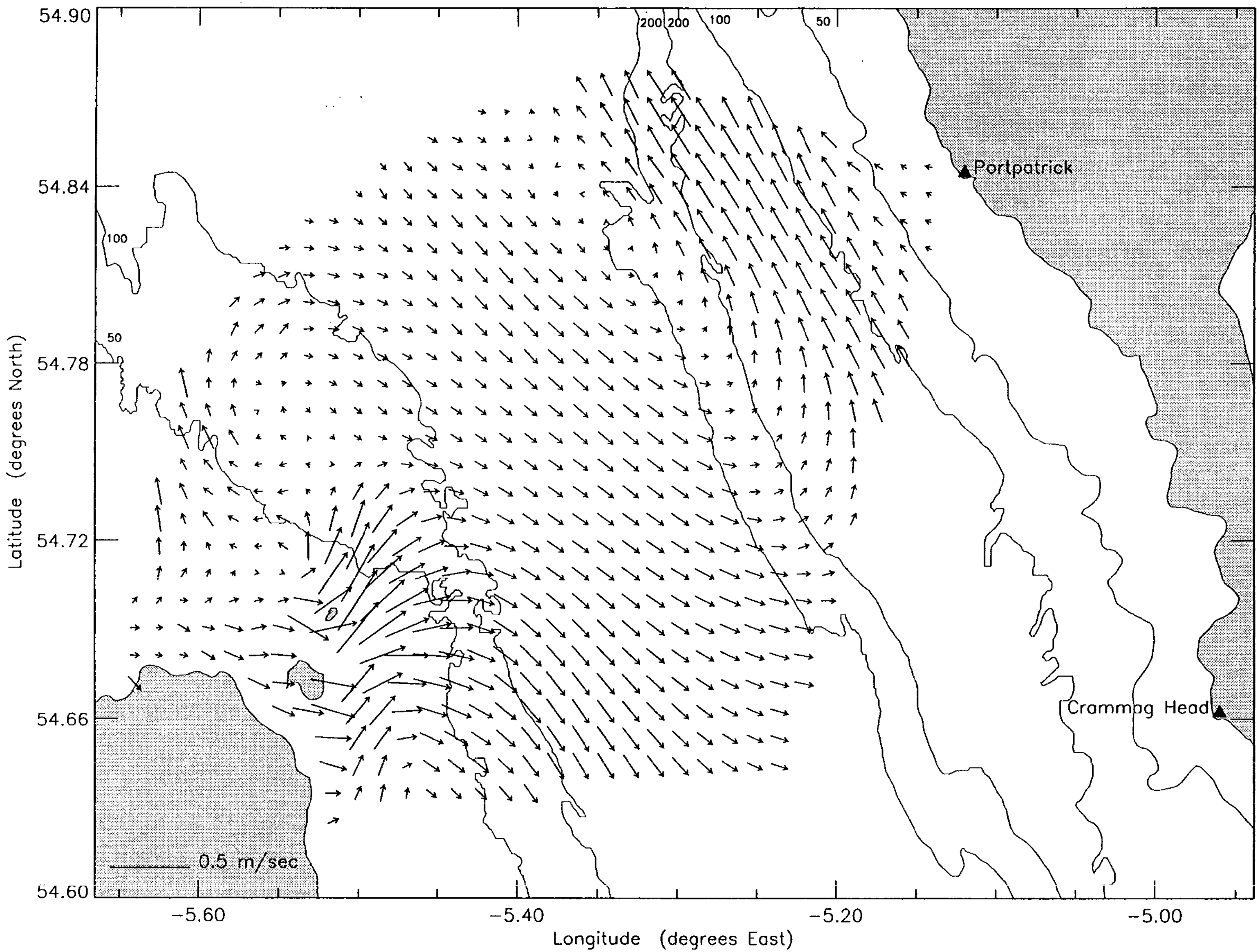
2 - 22/7/93

Constituent Z0



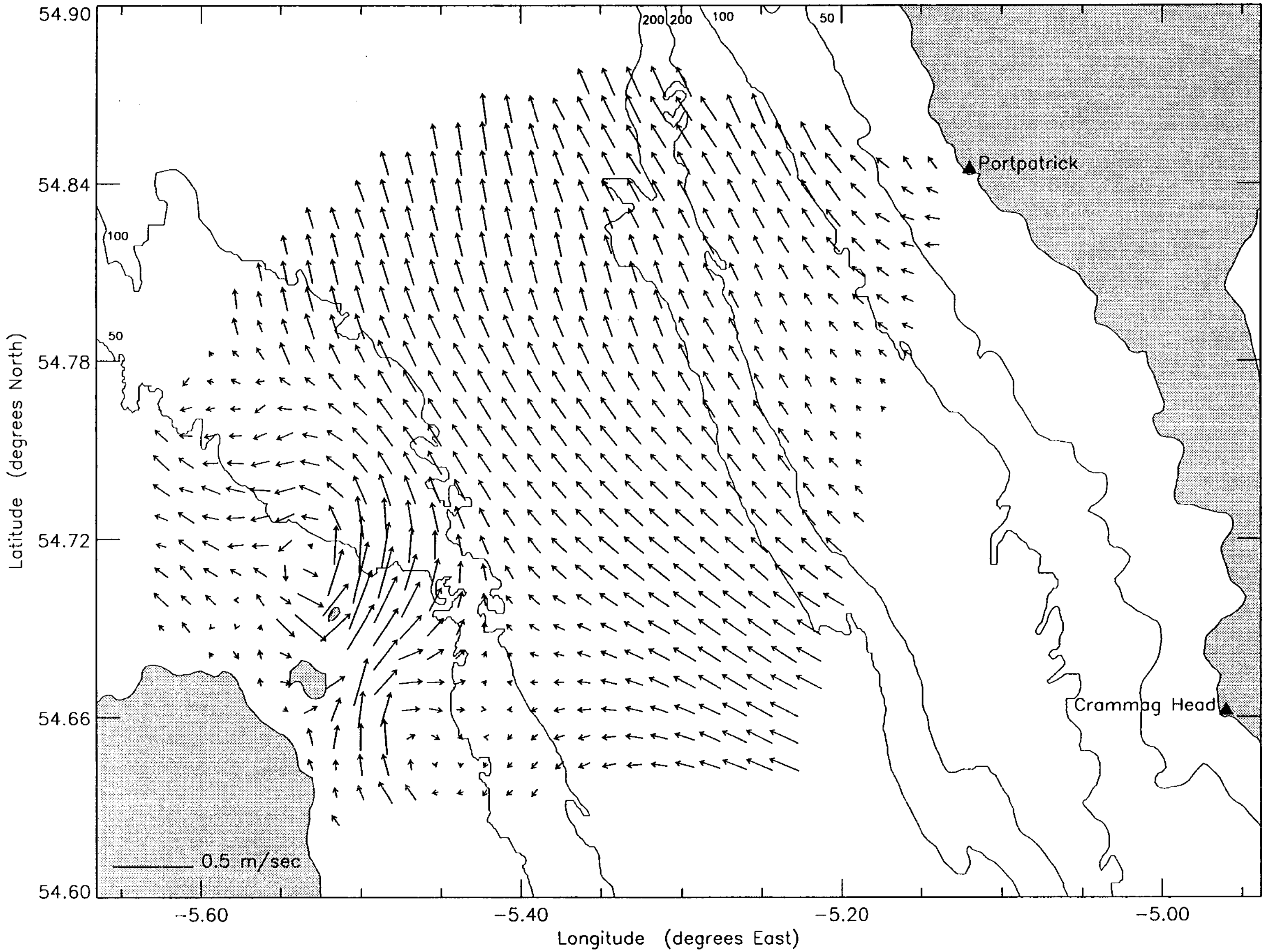
22/7 – 21/8/93

Constituent Z0



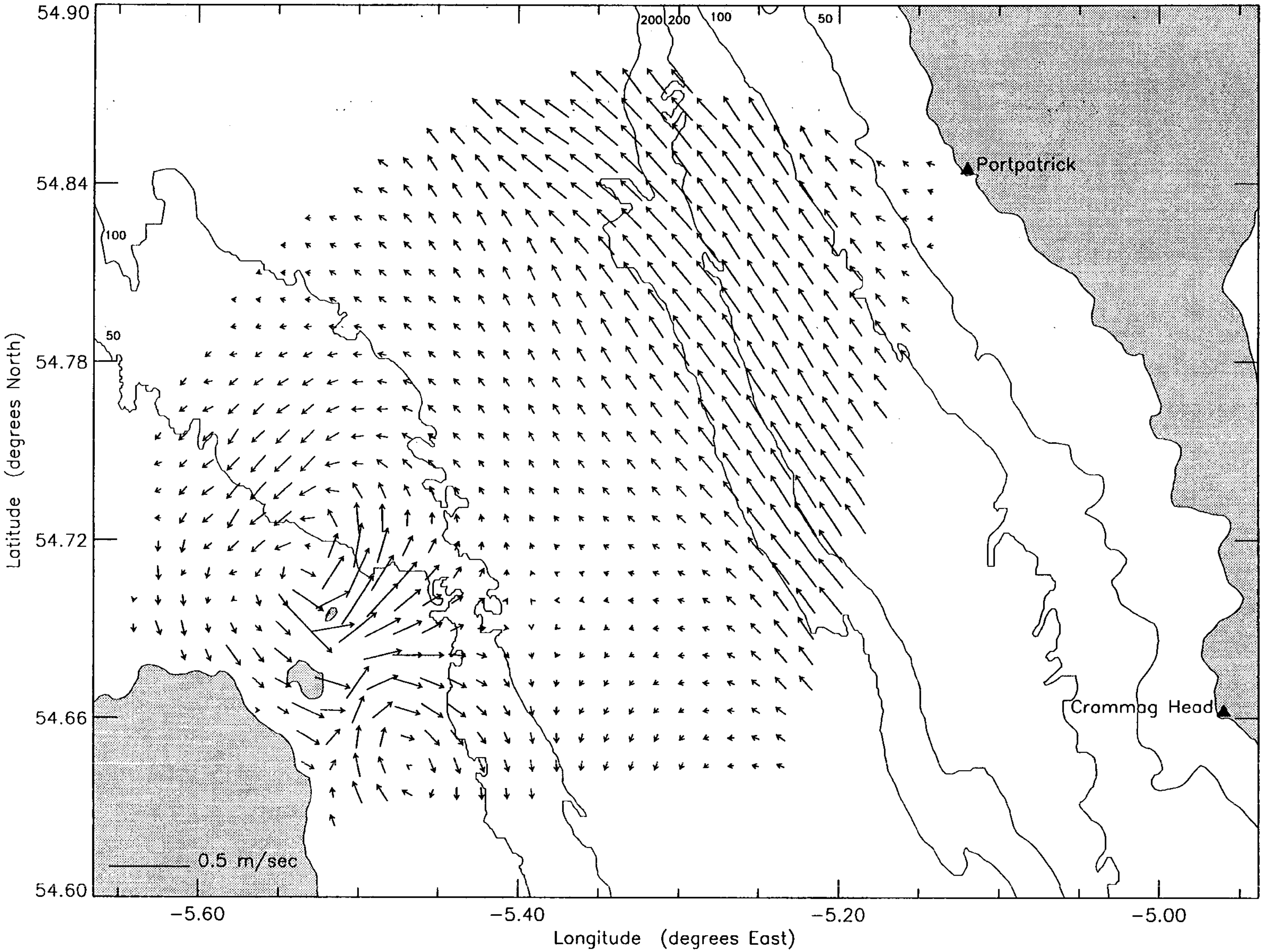
21/8 - 20/9/93

Constituent Z0



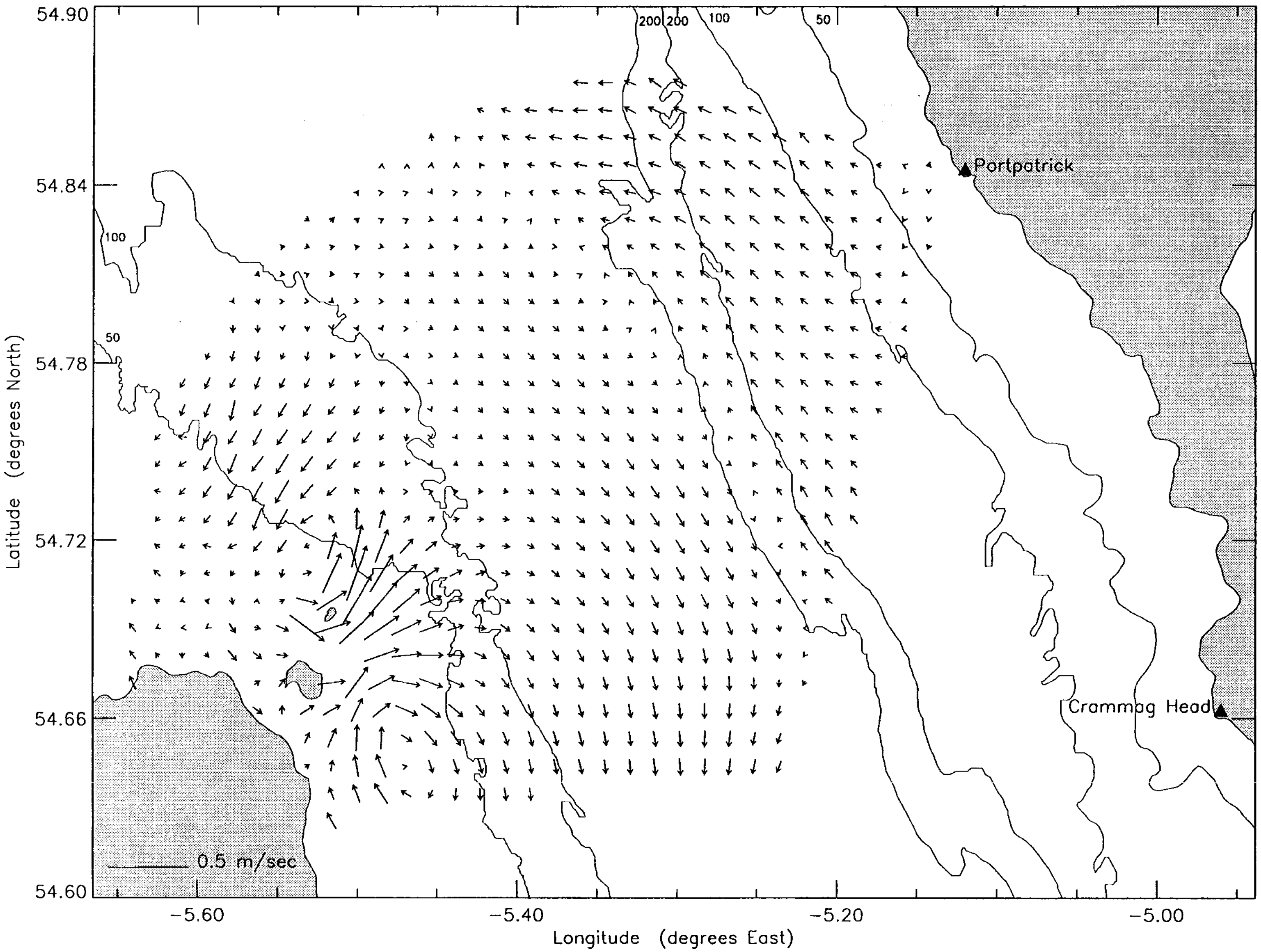
20/9 – 20/10/93

Constituent Z0



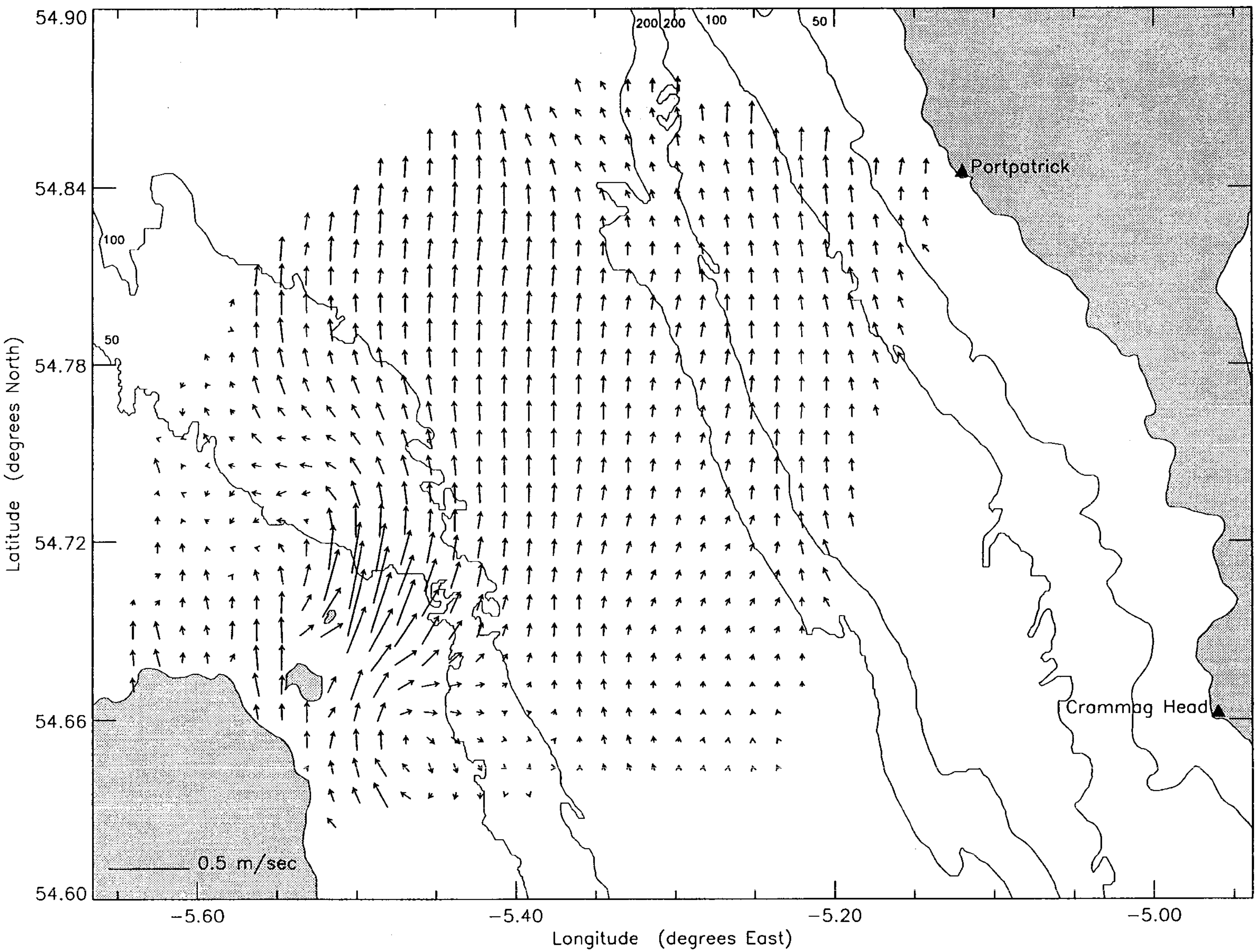
20/10 – 19/11/93

Constituent Z0



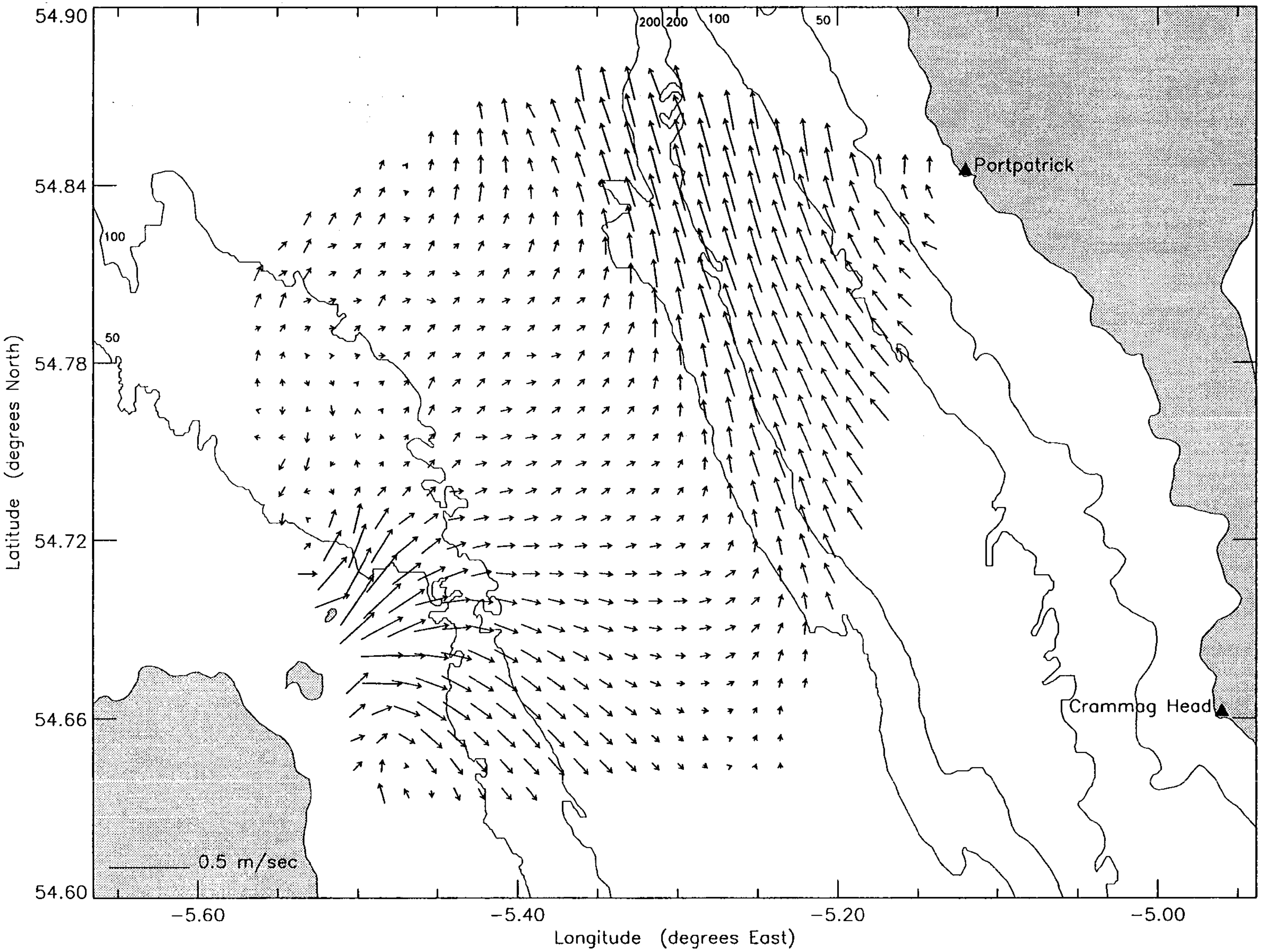
19/11 – 19/12/93

Constituent Z0



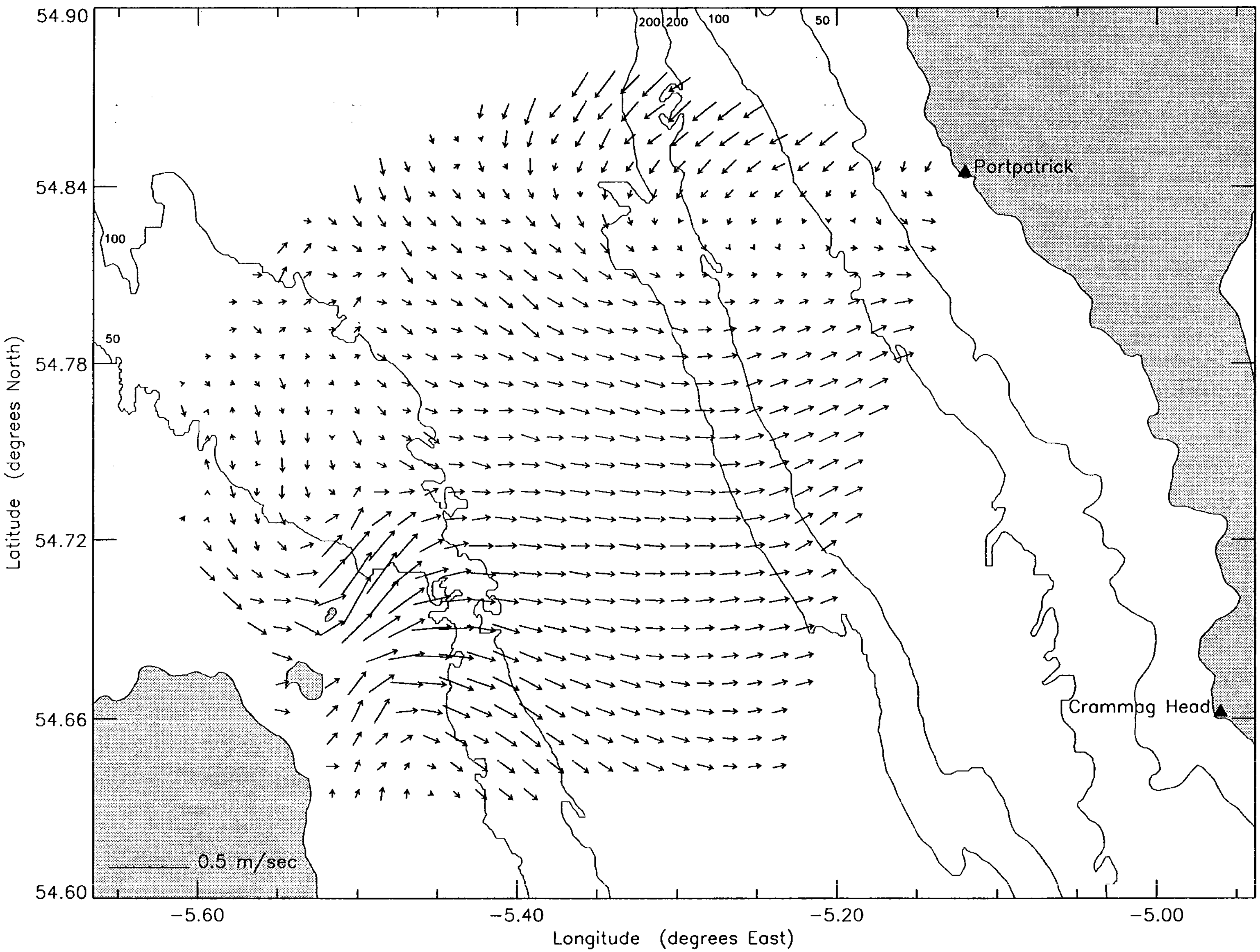
19/12/93 – 18/1/94

Constituent Z0



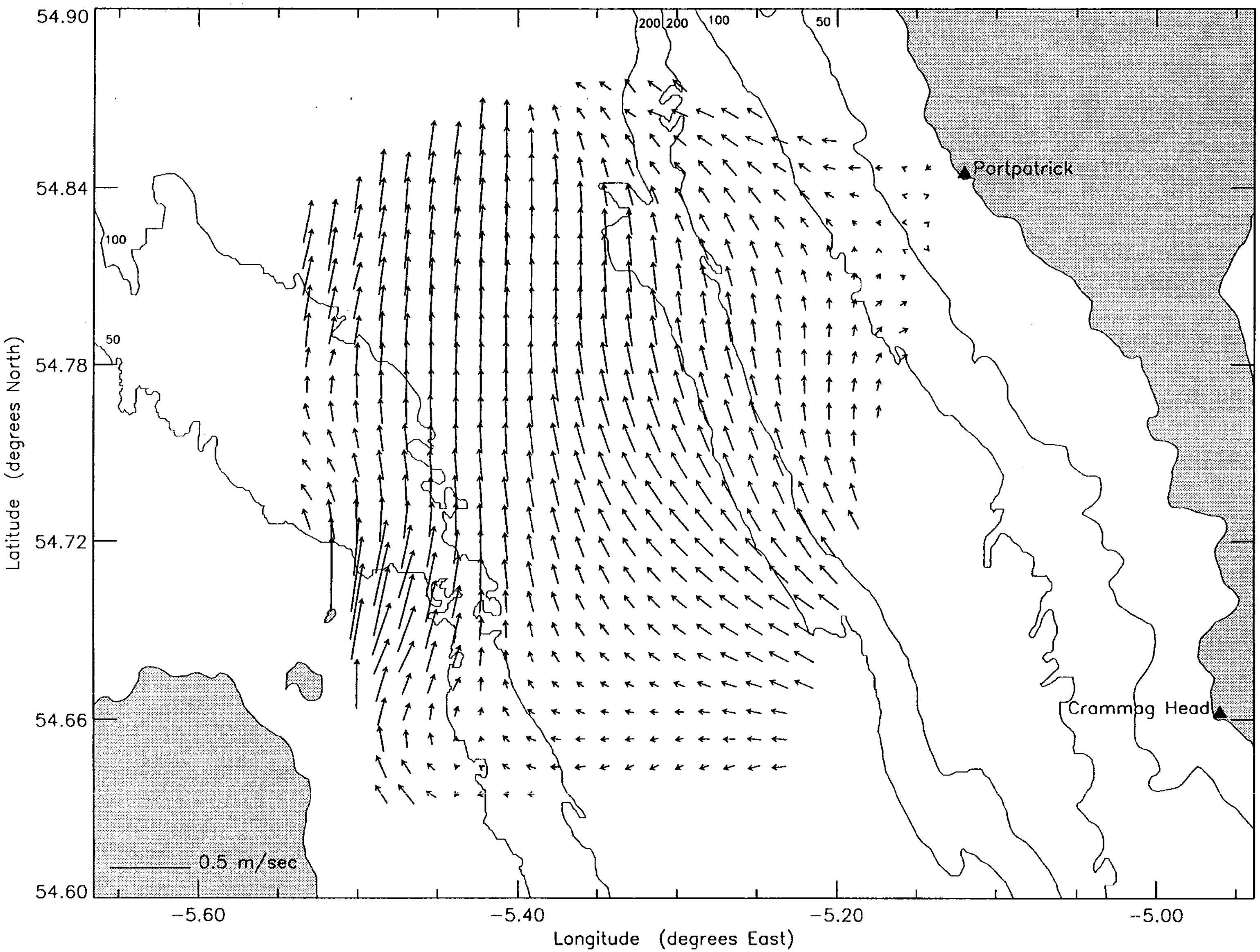
18/1 – 17/2/94

Constituent Z0



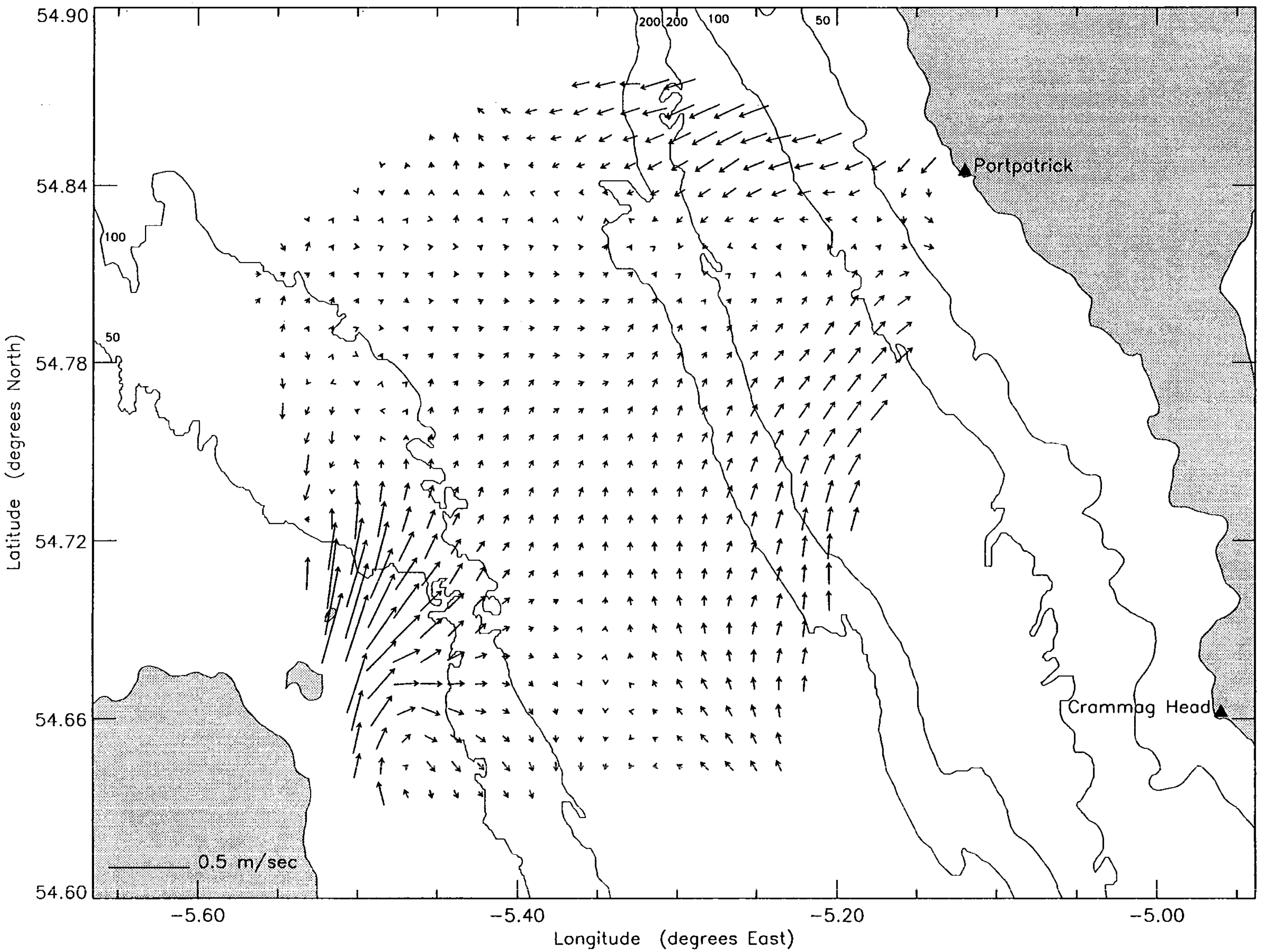
17/2 – 19/3/94

Constituent Z0



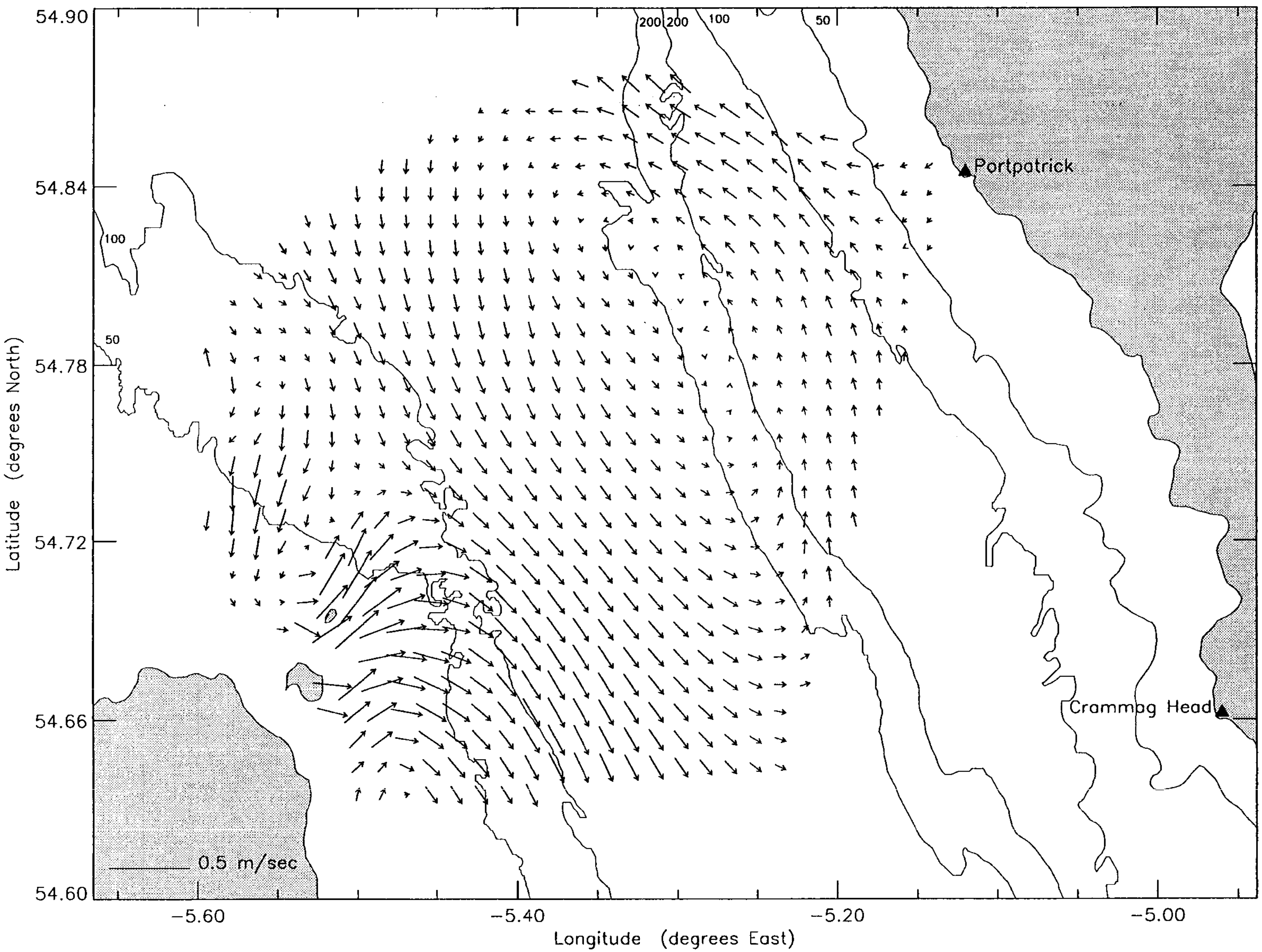
14/4 – 14/5/94

Constituent Z0



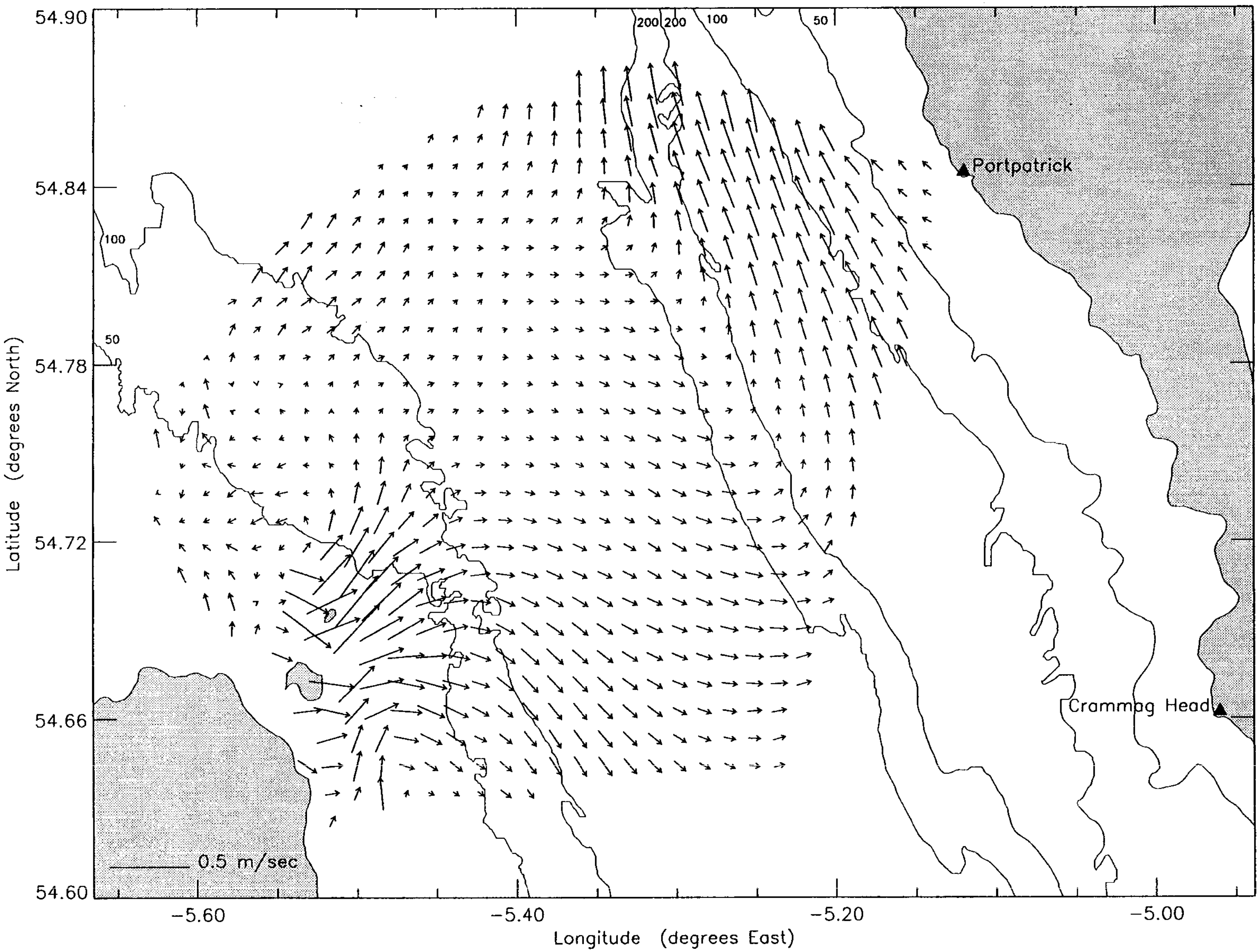
14/5 – 13/6/94

Constituent Z0



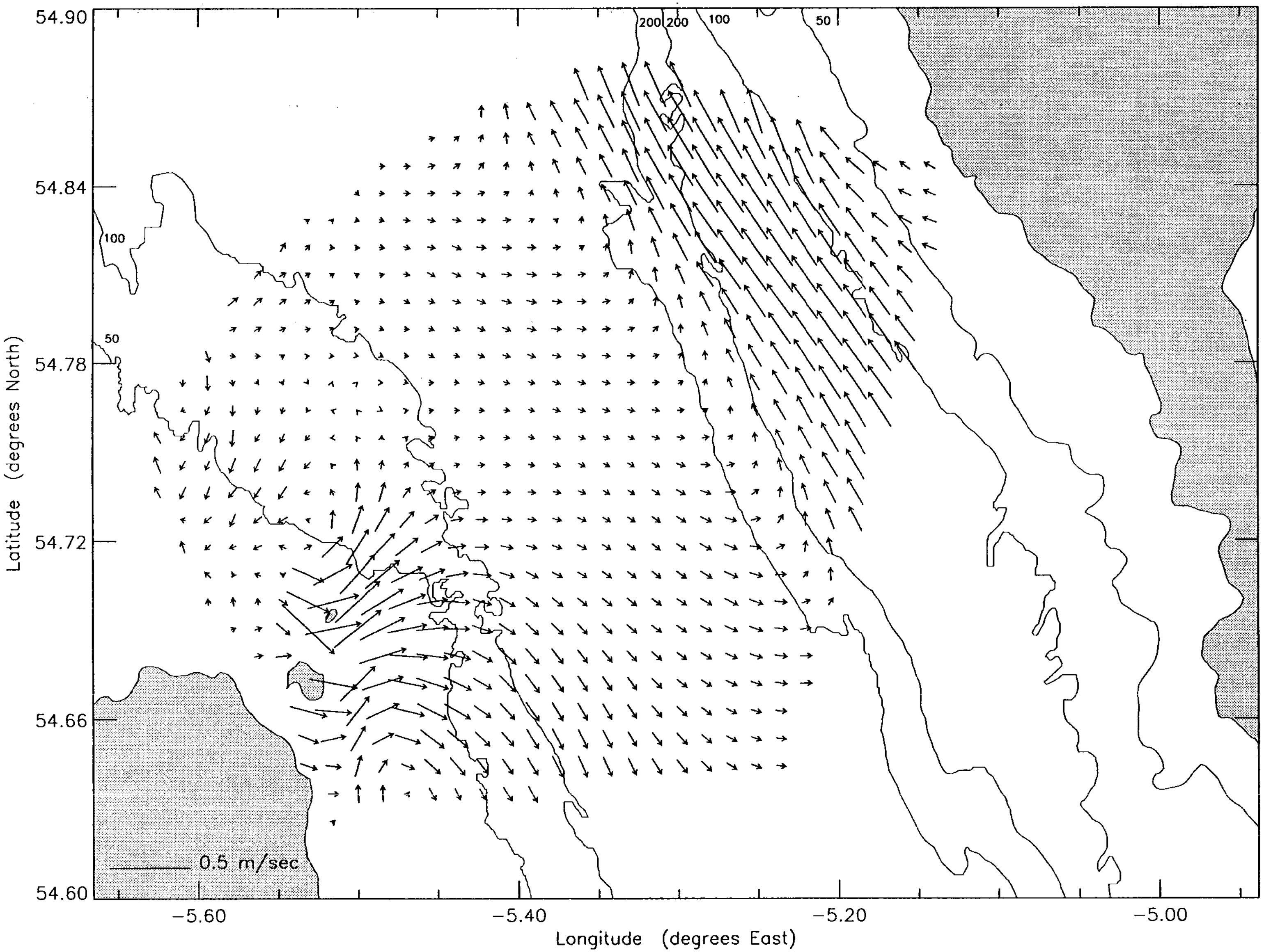
13/6 – 13/7/94

Constituent Z0



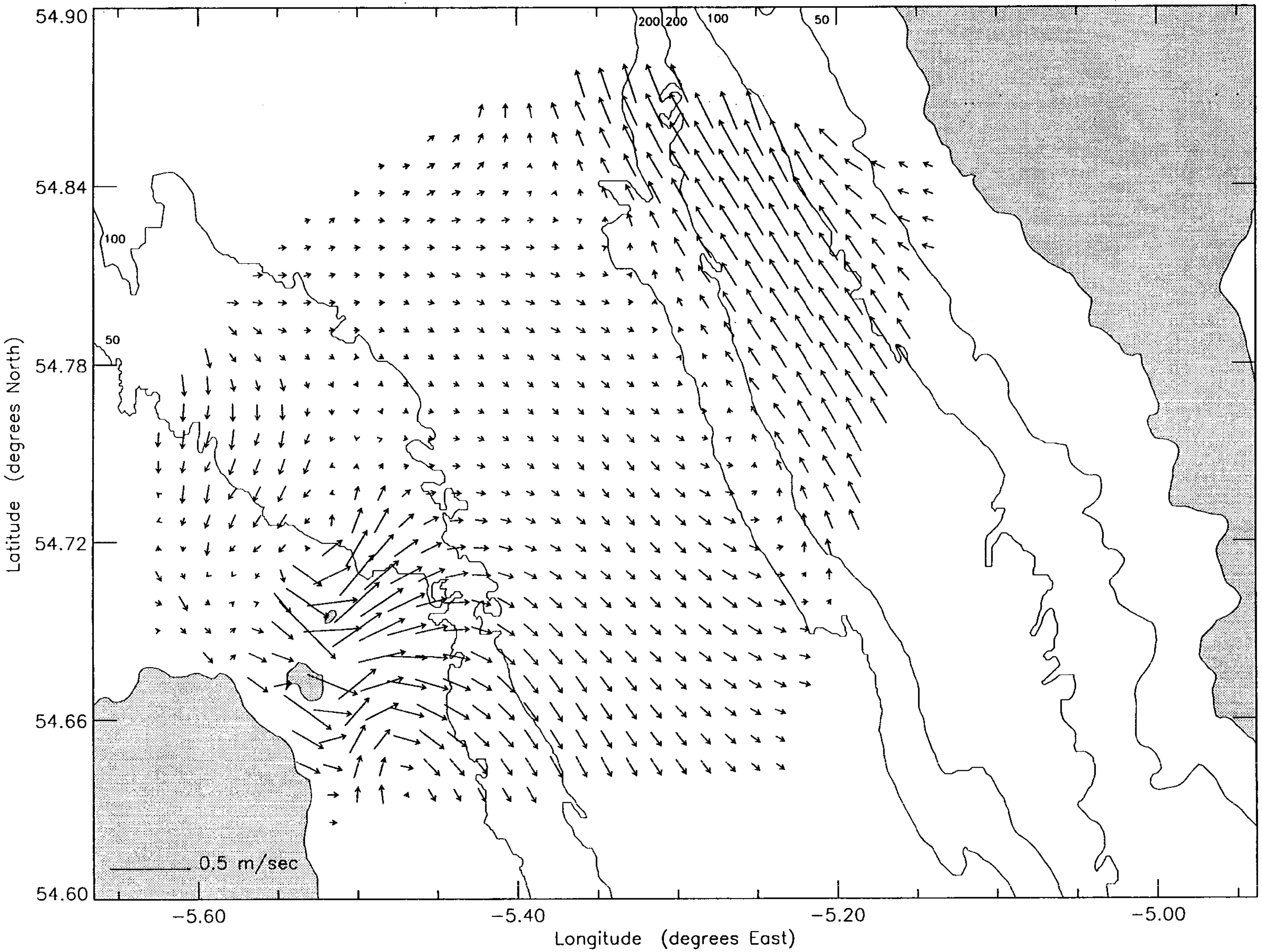
13/7 – 12/8/94

Constituent Z0



25/7 - 24/8/94

Constituent Z0



2 - 22/7/93

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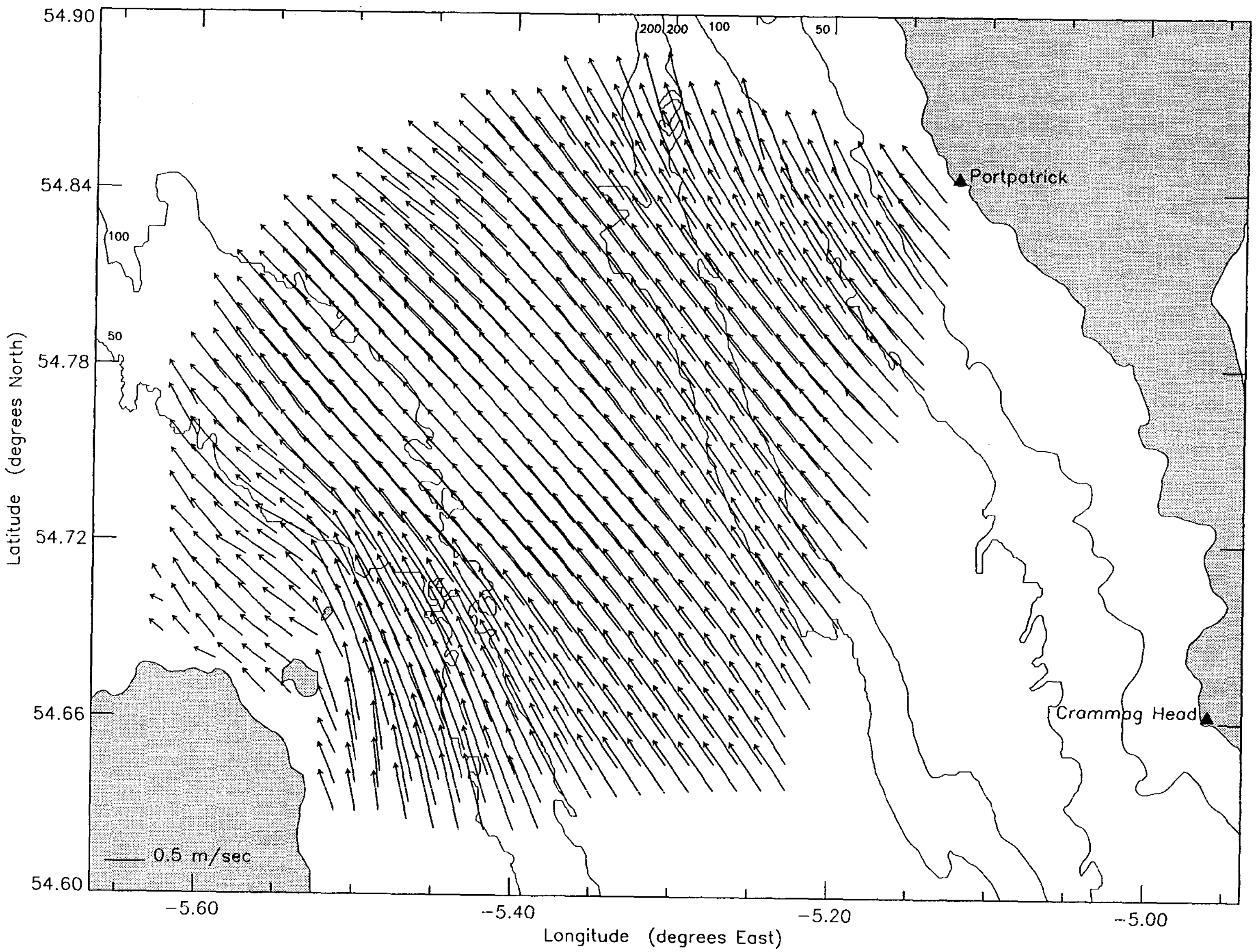
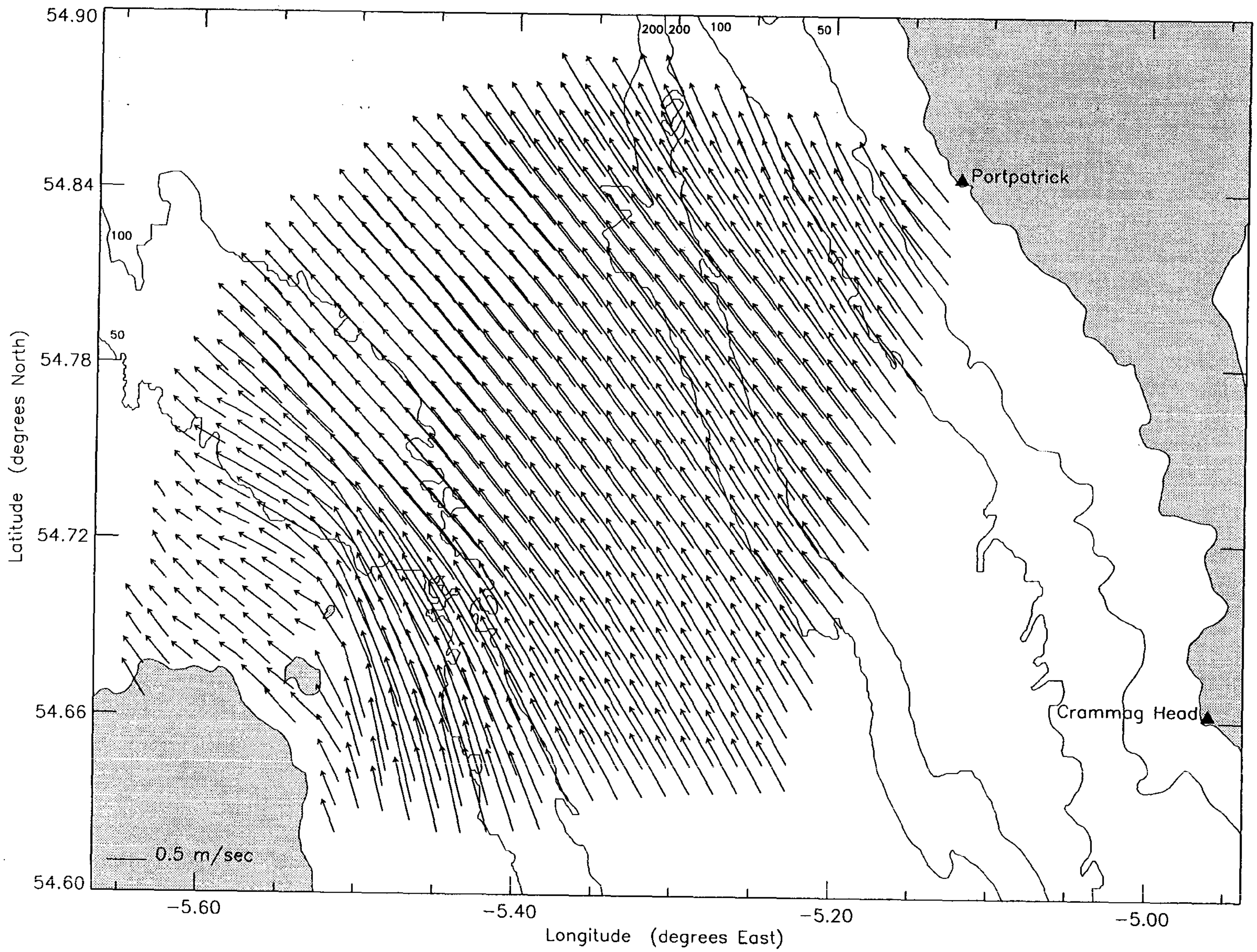


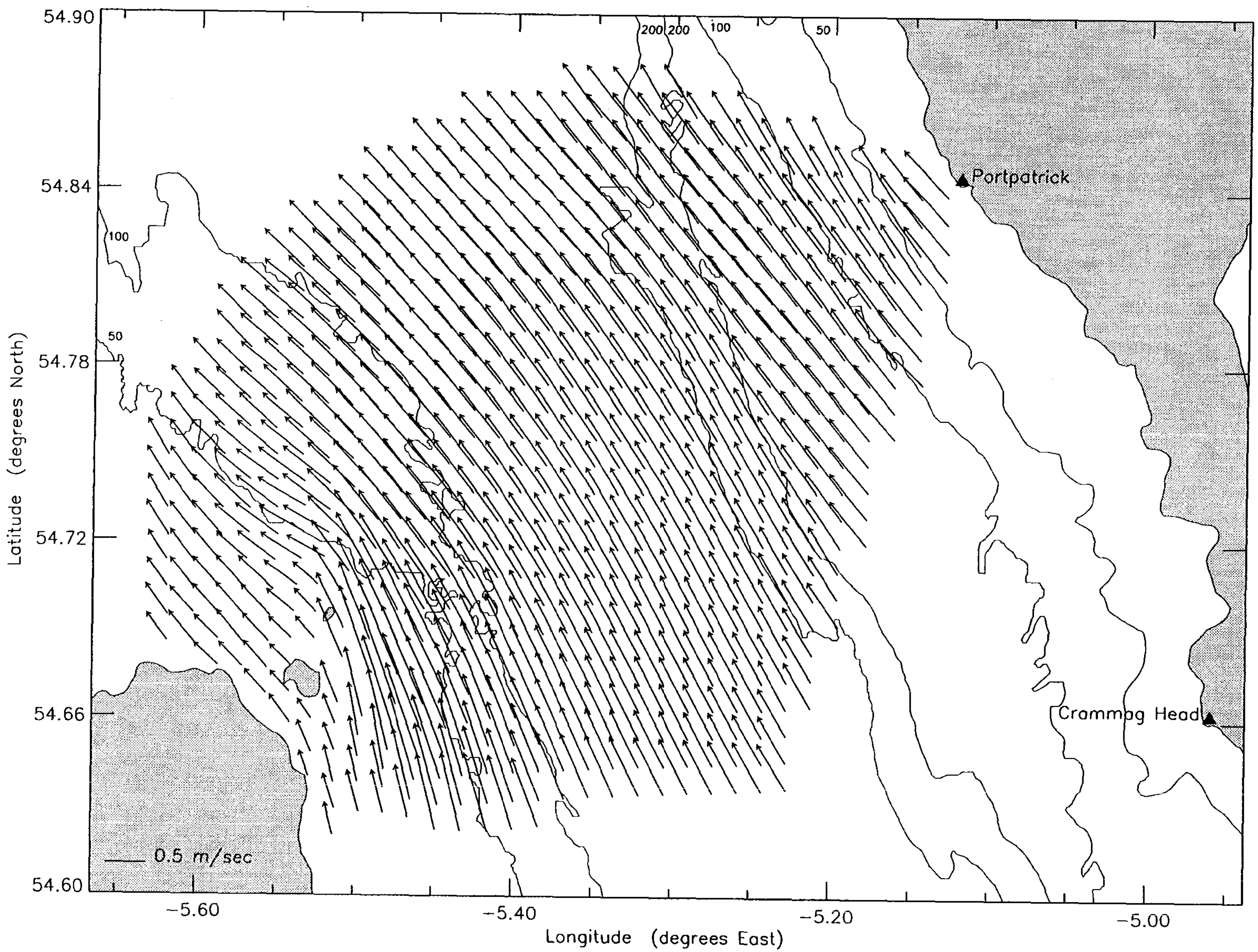
22/7 - 21/8/93

Constituent M2



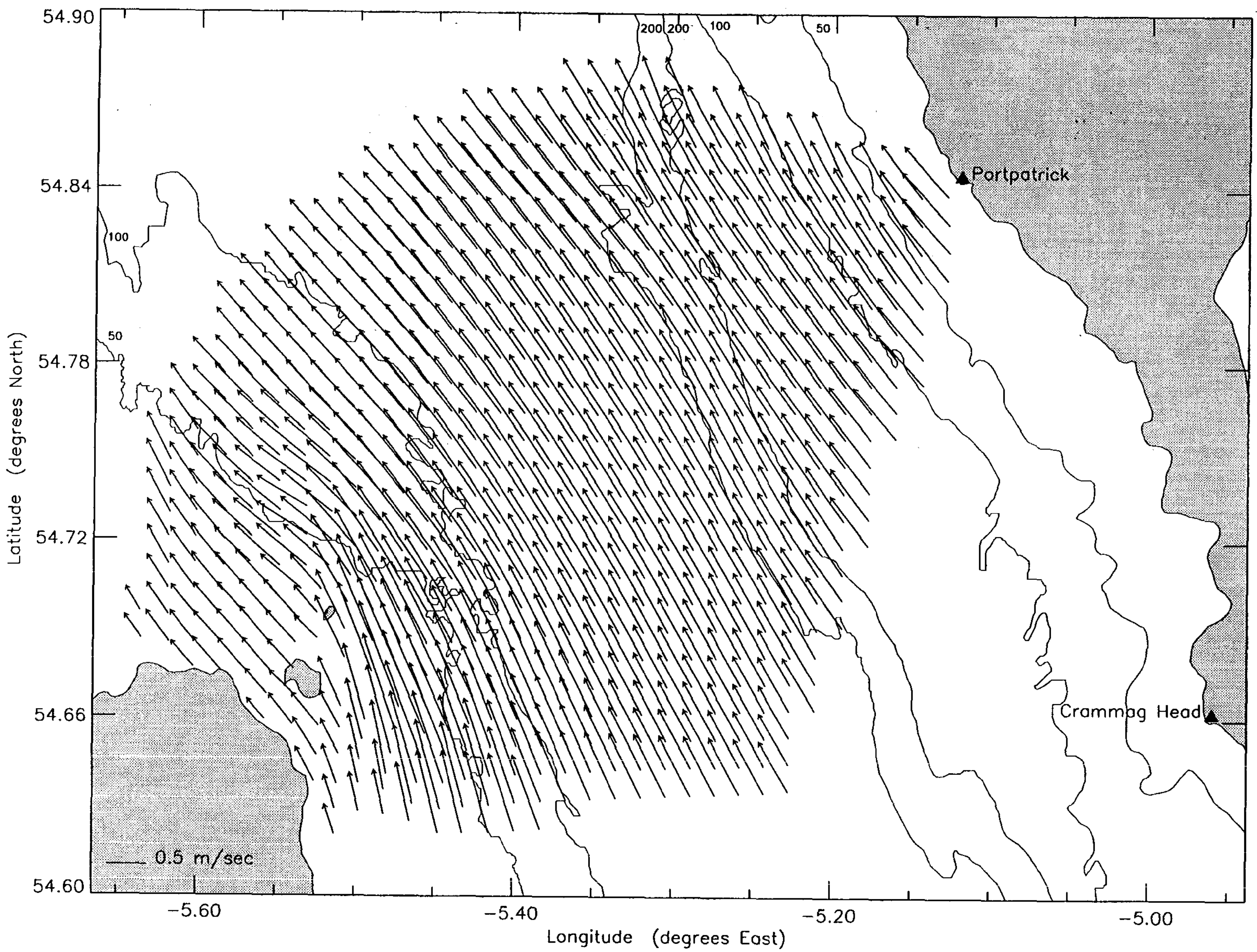
21/8 – 20/9/93

Constituent M2



20/9 - 20/10/93

Constituent M2



20/10 – 19/11/93

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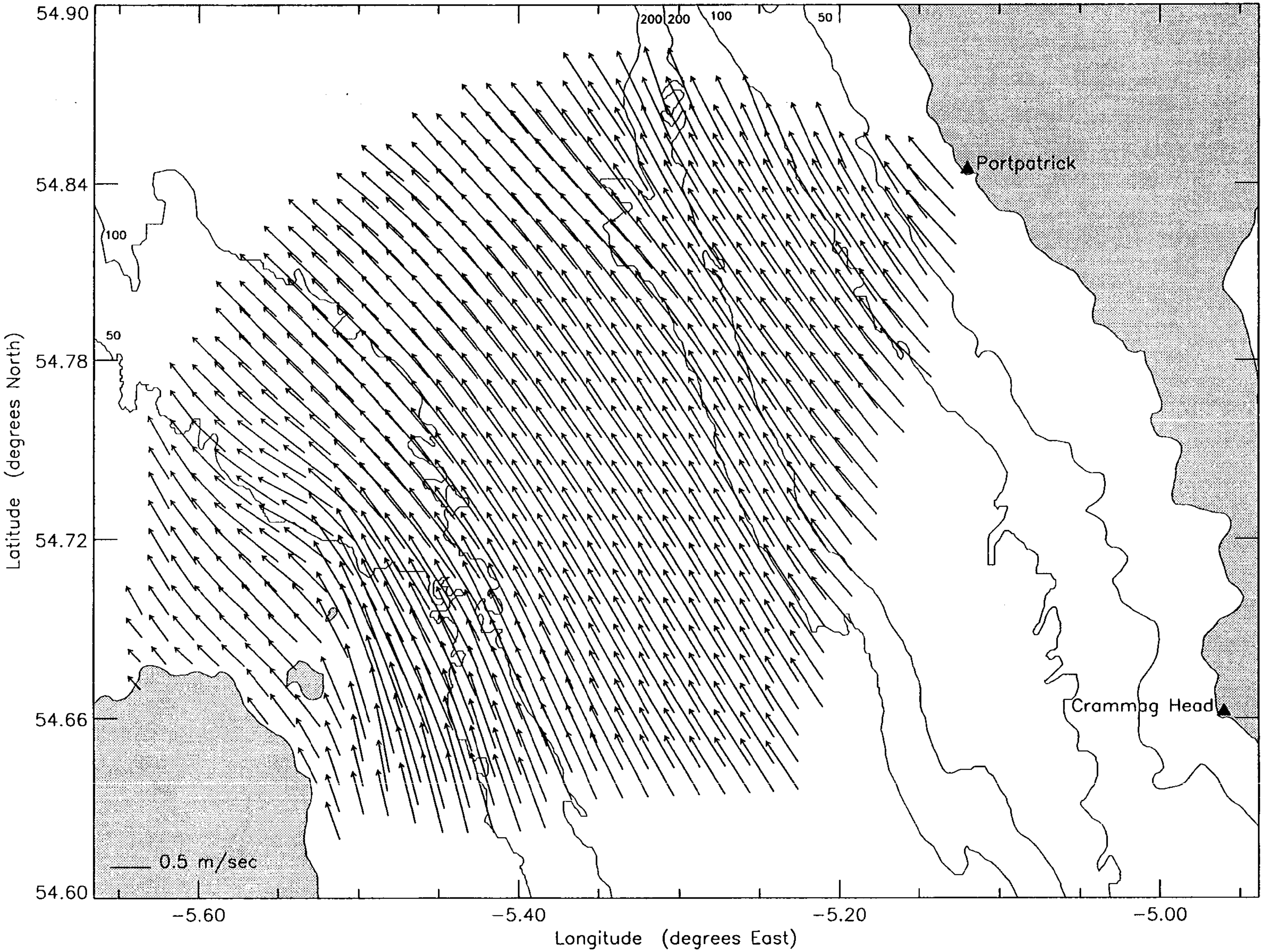

19/11 - 19/12/93

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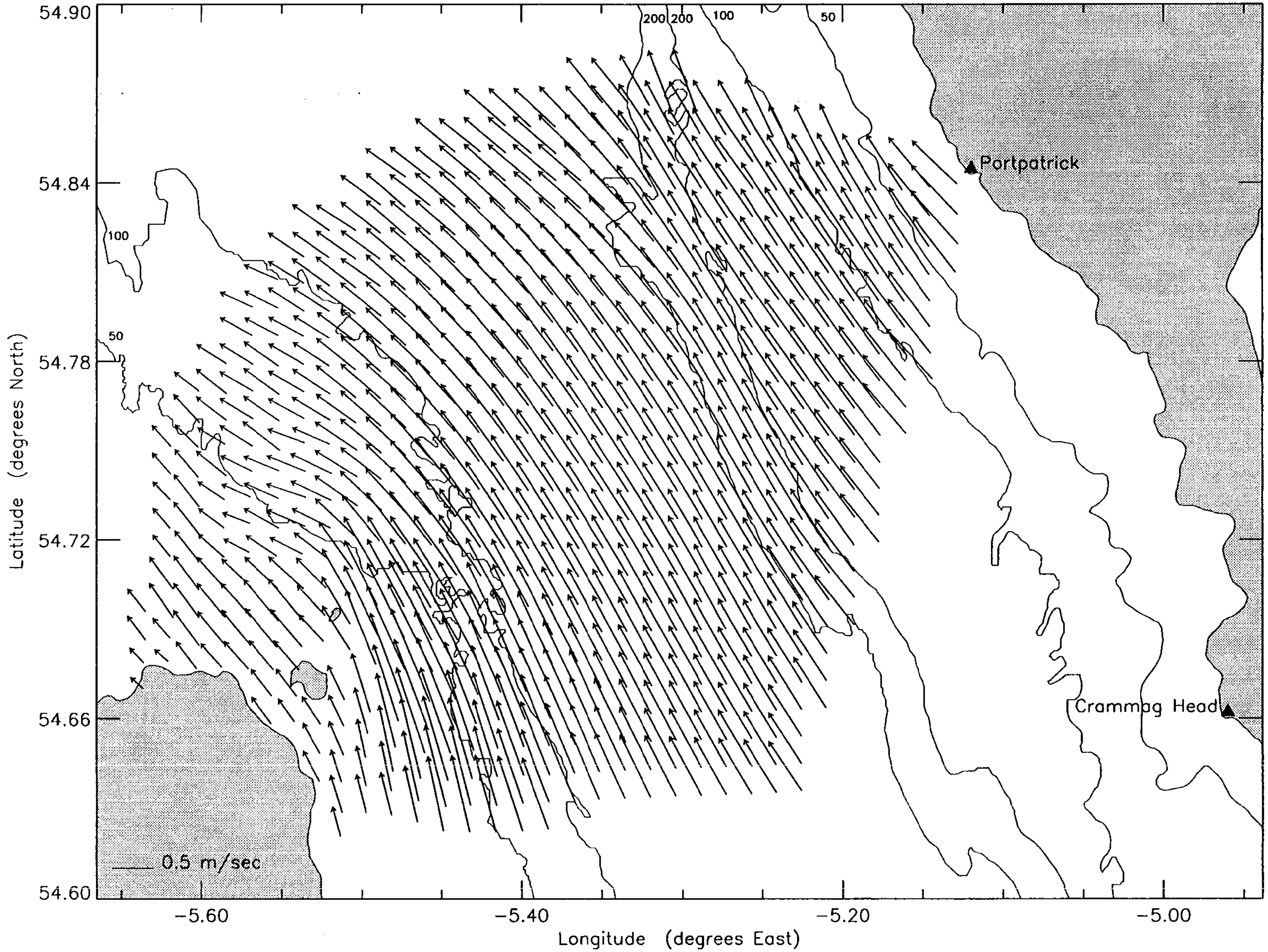
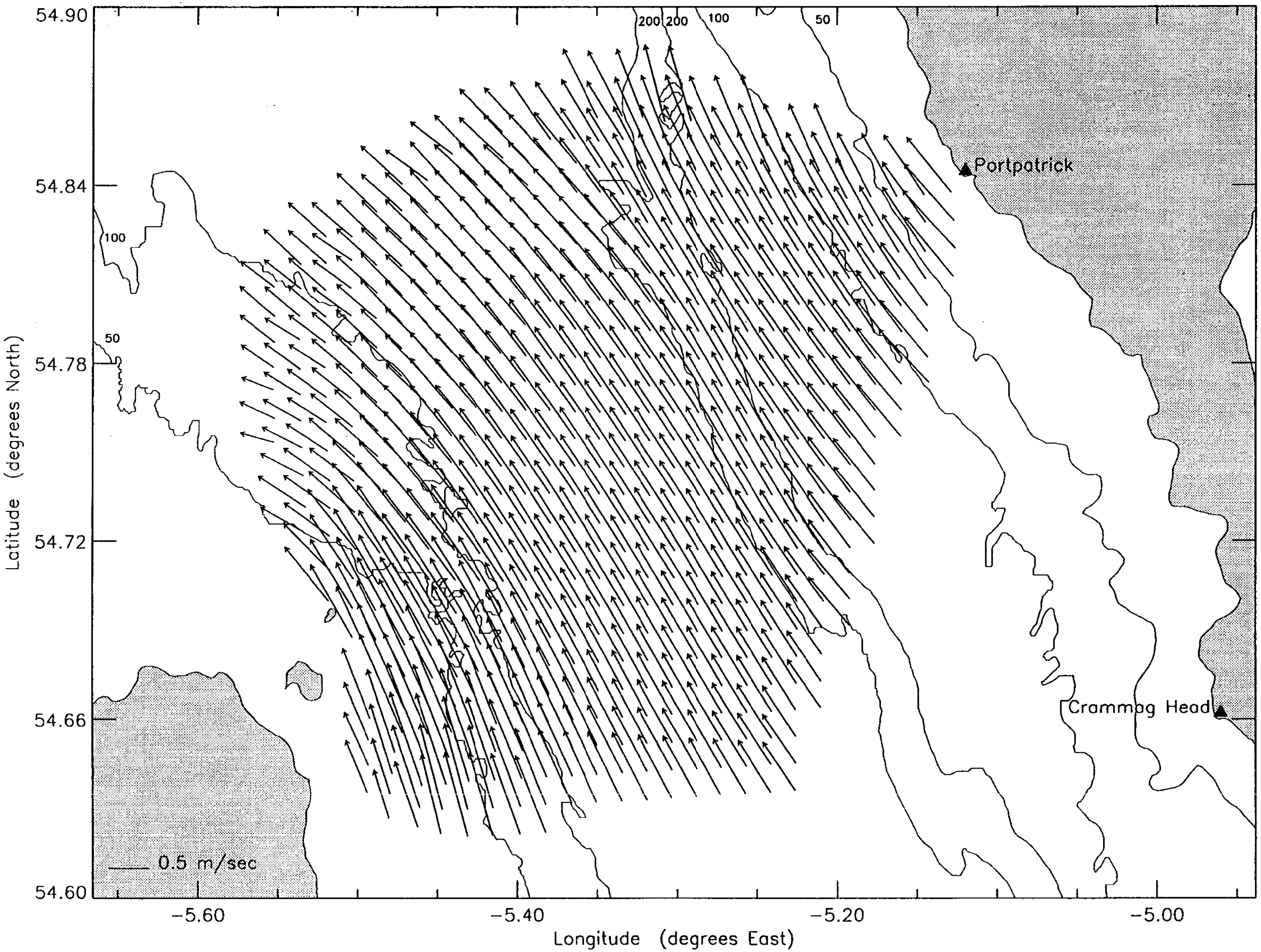
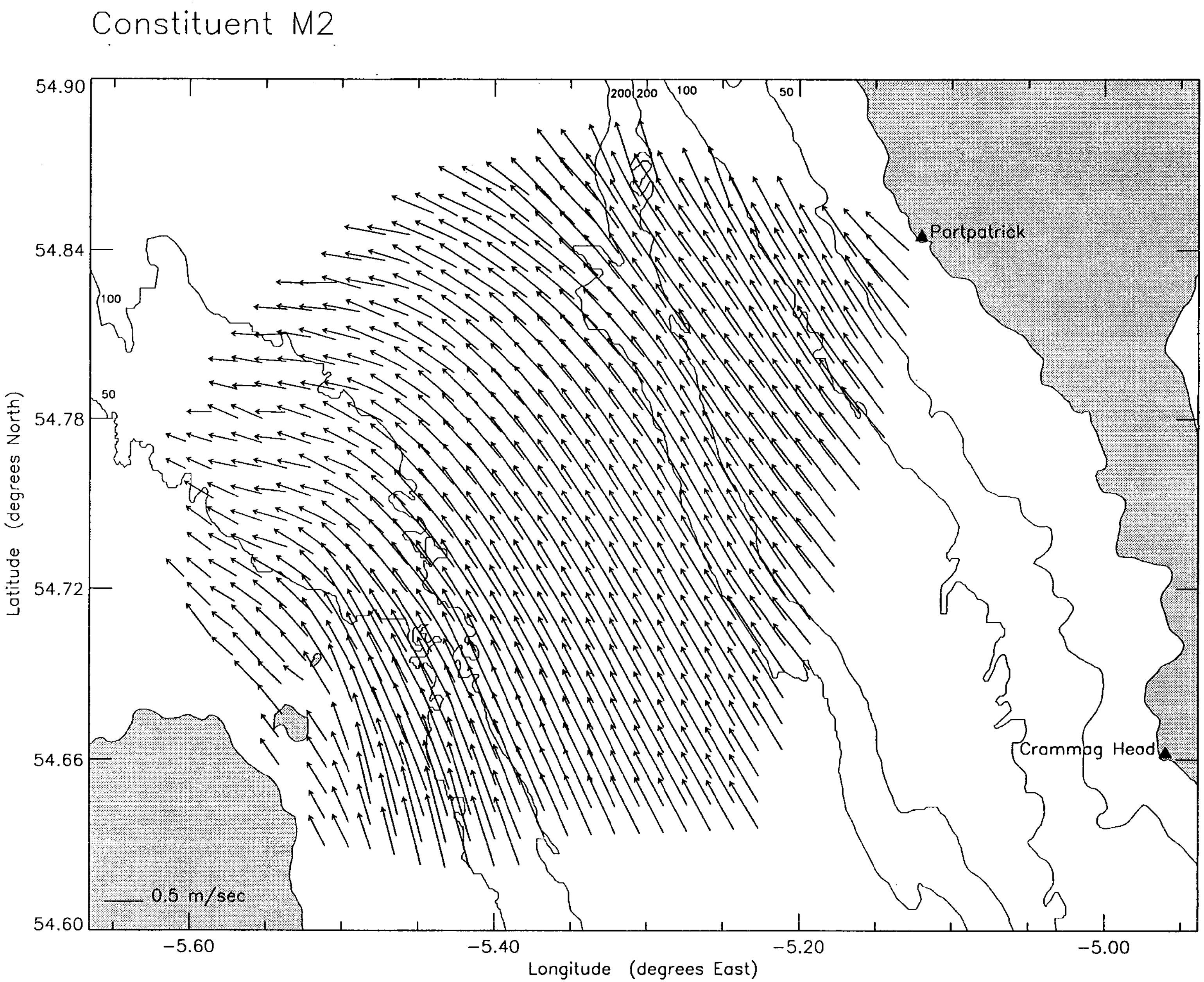


19/12/93 - 18/1/94

Constituent M2

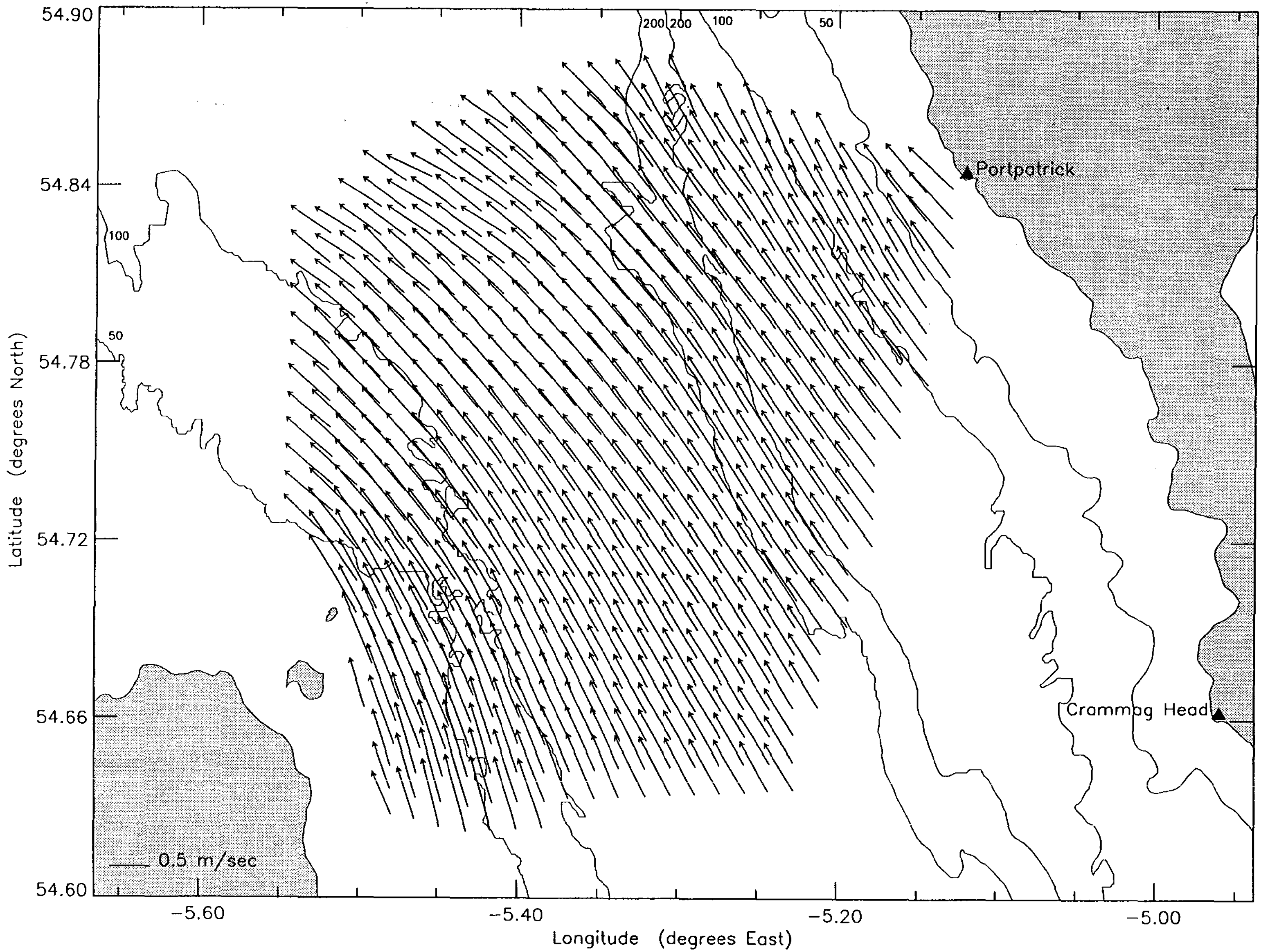


18/1 - 17/2/94


Constituent M2
54.90
54.84
54.78
54.72
54.66
54.60
Latitude (degrees North)
-5.60
-5.40
-5.20
-5.00
Longitude (degrees East)
200
200
100
50
100
50
Portpatrick
Crammag Head
0.5 m/sec

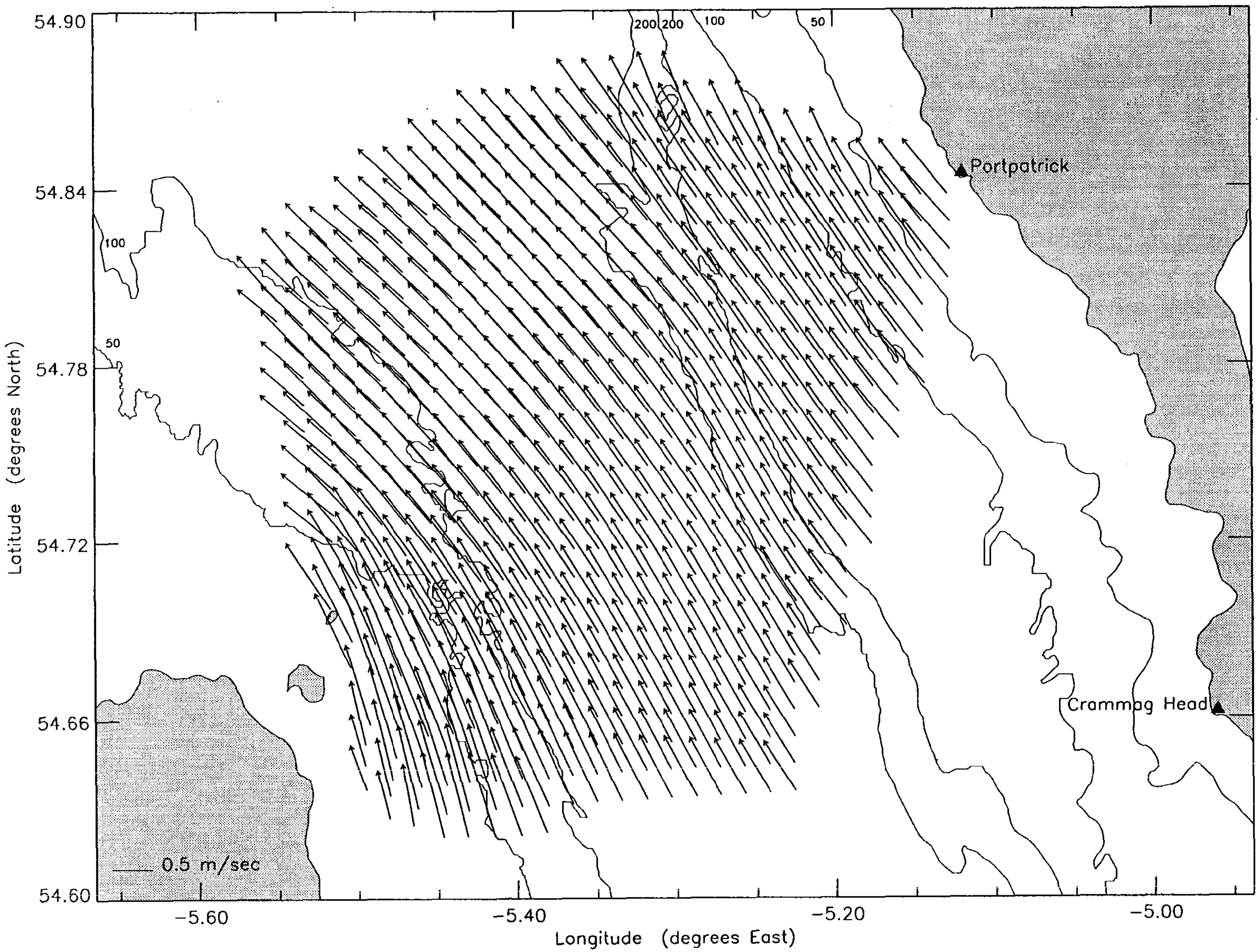
17/2 – 19/3/94

Constituent M2



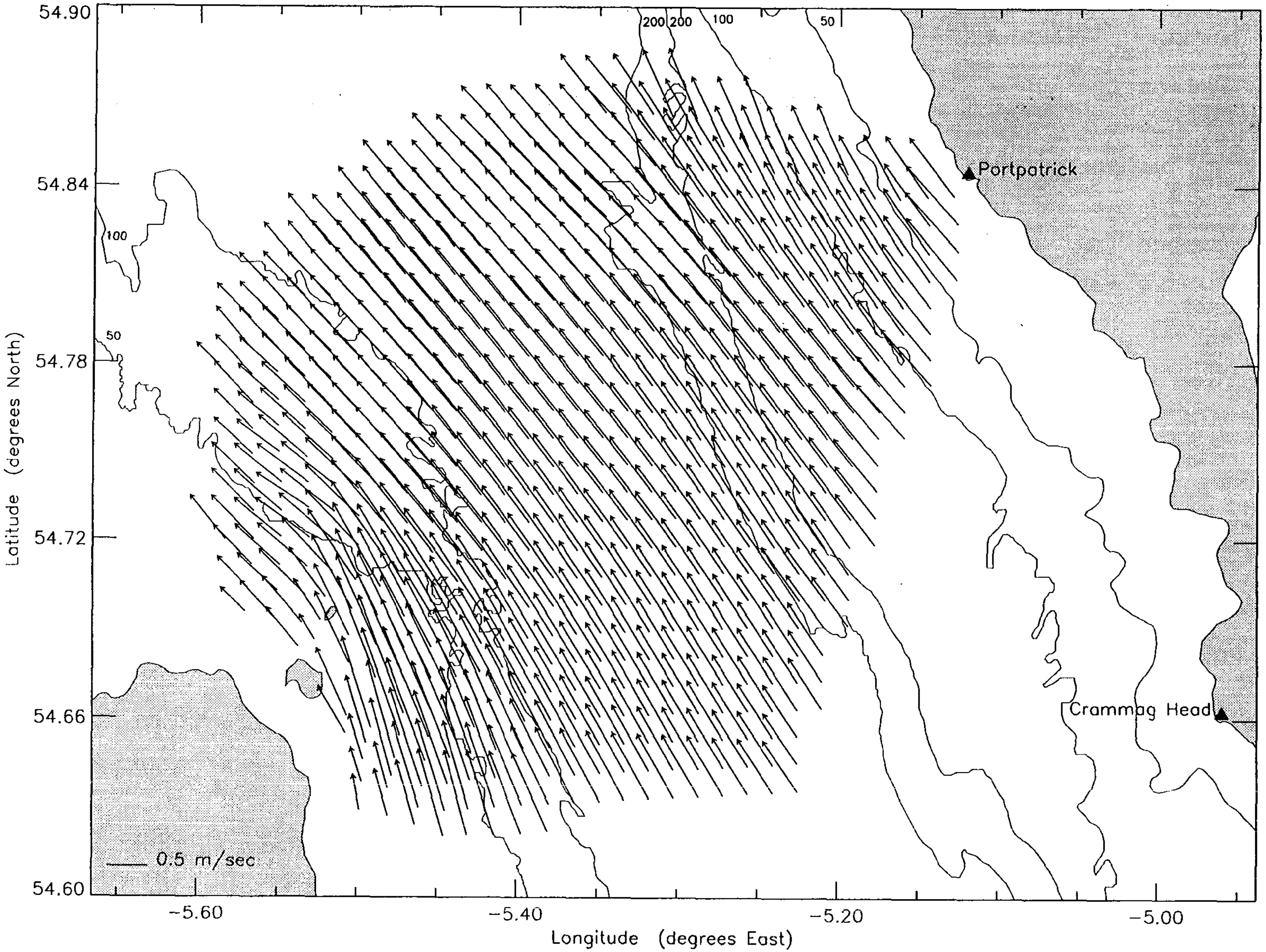
14/4 – 14/5/94

Constituent M2

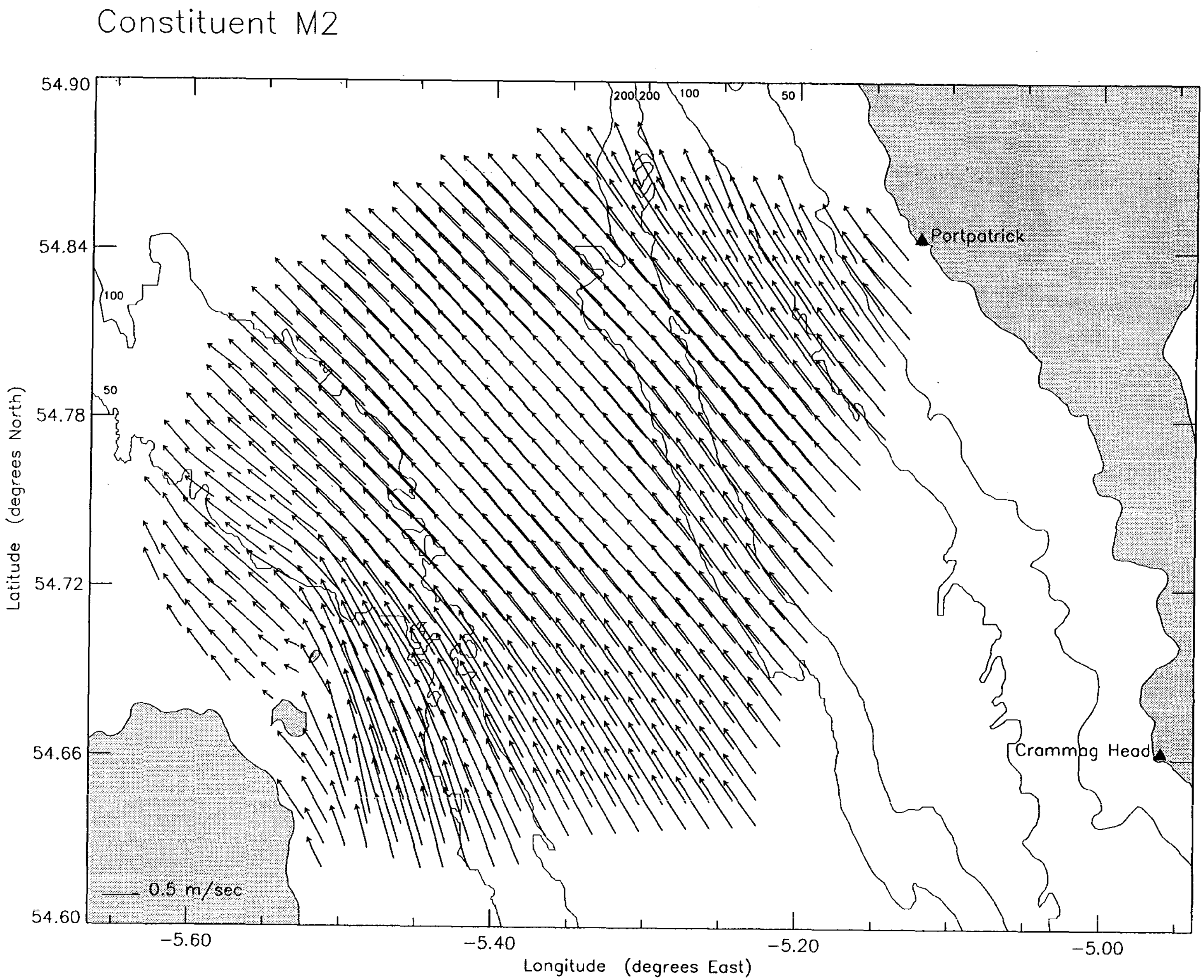


14/5 – 13/6/94

Constituent M2

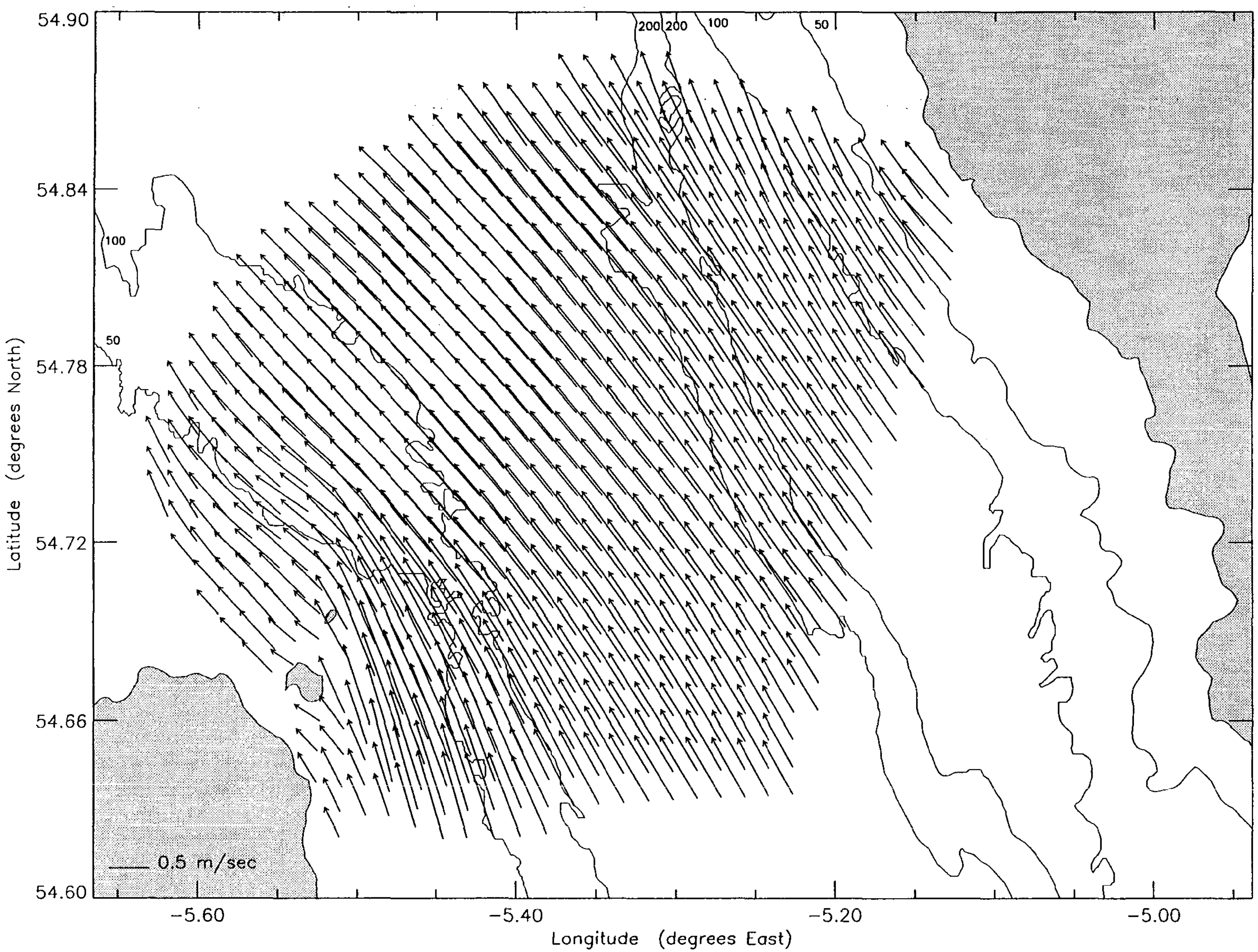


13/6 - 13/7/94

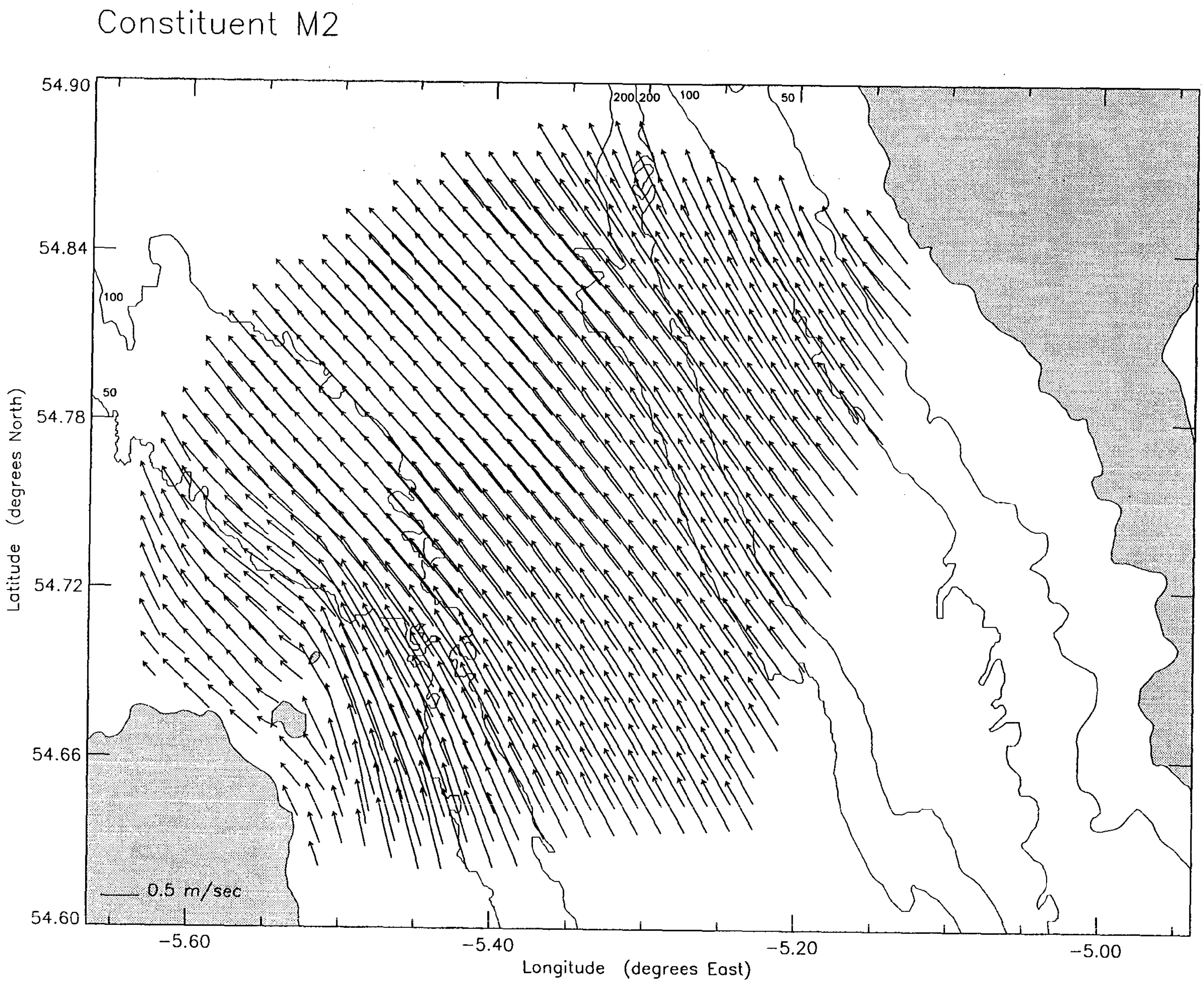

Constituent M2
54.90
54.84
54.78
54.72
54.66
54.60
Latitude (degrees North)
-5.60
-5.40
-5.20
-5.00
Longitude (degrees East)
200
200
100
50
100
50
Portpatrick
Crammag Head
0.5 m/sec

13/7 – 12/8/94

Constituent M2



25/7 - 24/8/94

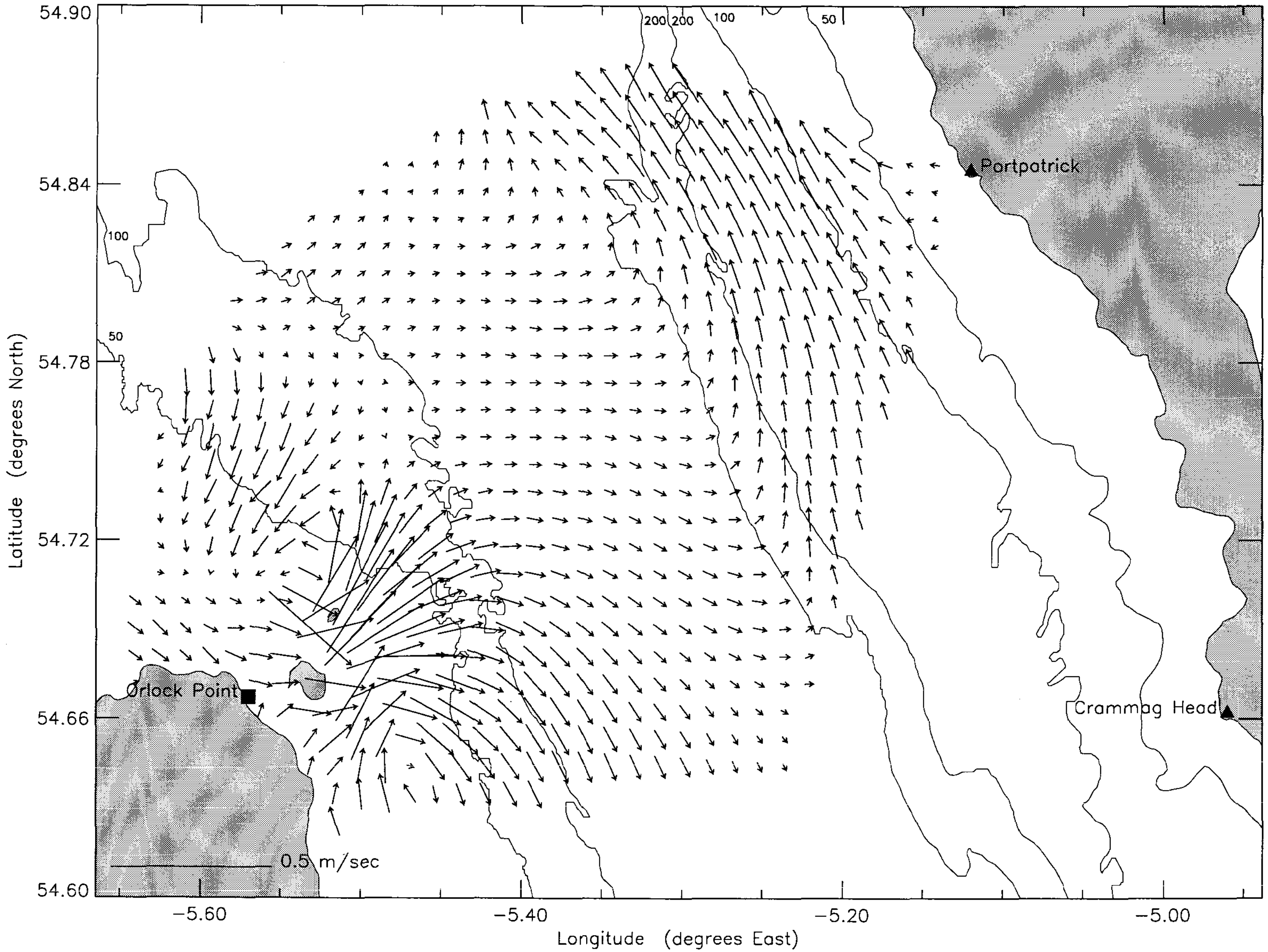

Constituent M2
54.90
54.84
54.78
54.72
54.66
54.60
Latitude (degrees North)
-5.60
-5.40
-5.20
-5.00
Longitude (degrees East)
200
200
100
50
100
50
0.5 m/sec

Appendix C Z0 and M2 constituents for combined deployments

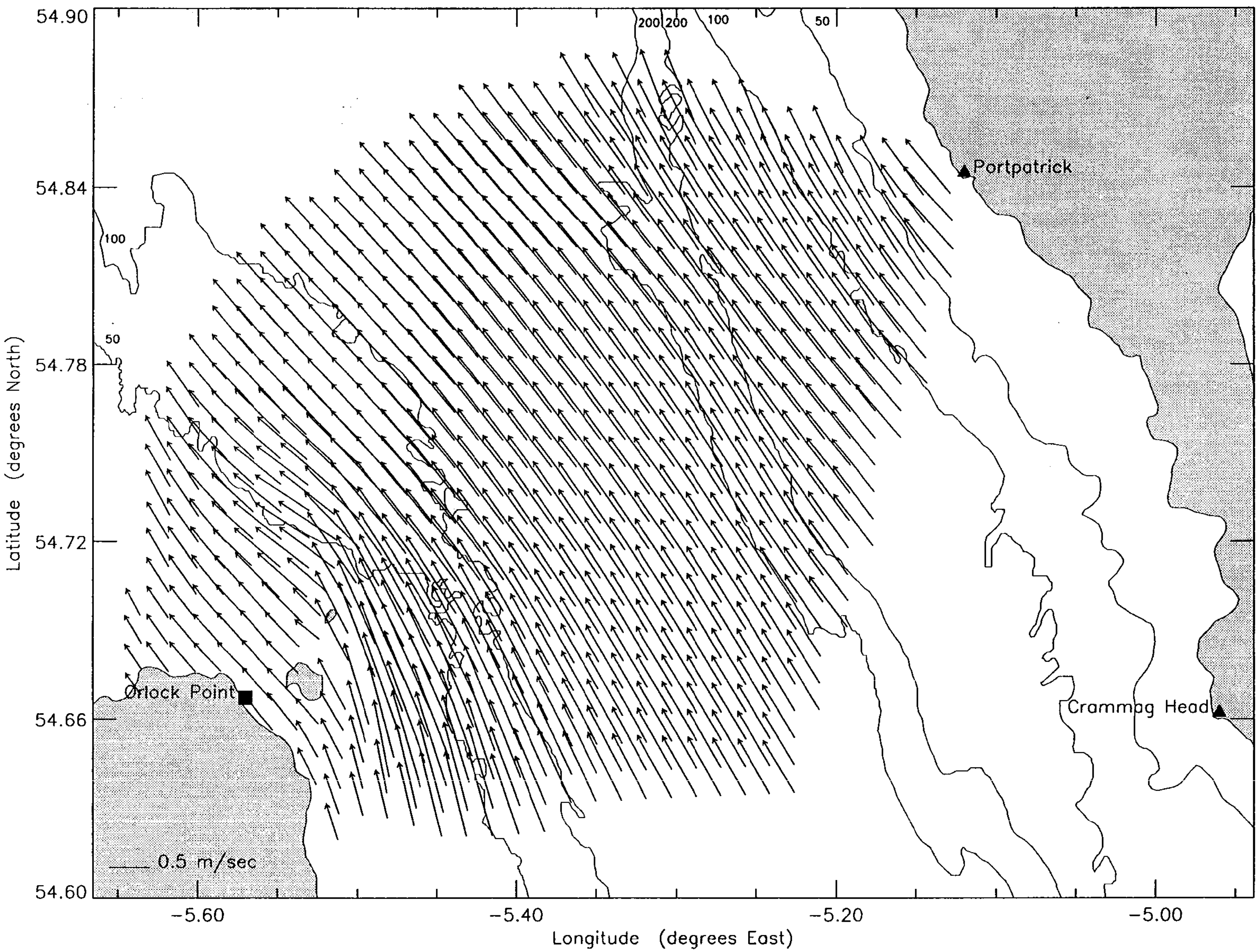
The Z0 plot shows the mean current speed and direction over the 15 month period.

The M2 plot shows the amplitude and direction of the major axis for that constituent. The directions are ambiguous by 180° depending on the phases for that constituent.

Constituent ZO



Constituent M2

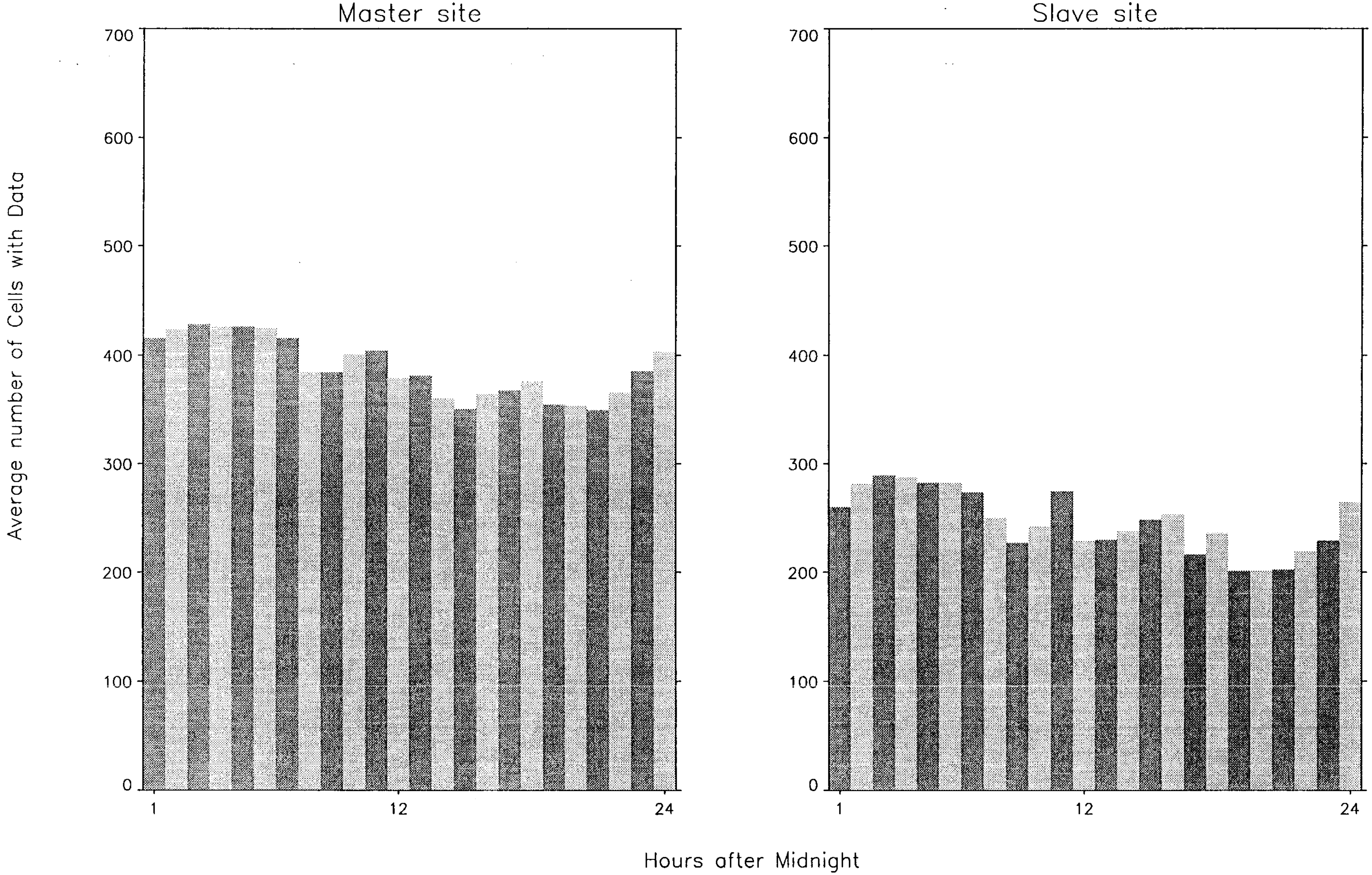


Appendix D Variation of data capture with time of day for each dataset

1 hour after midnight indicates the period 0000 -> 0059 hours GMT inclusive etc.

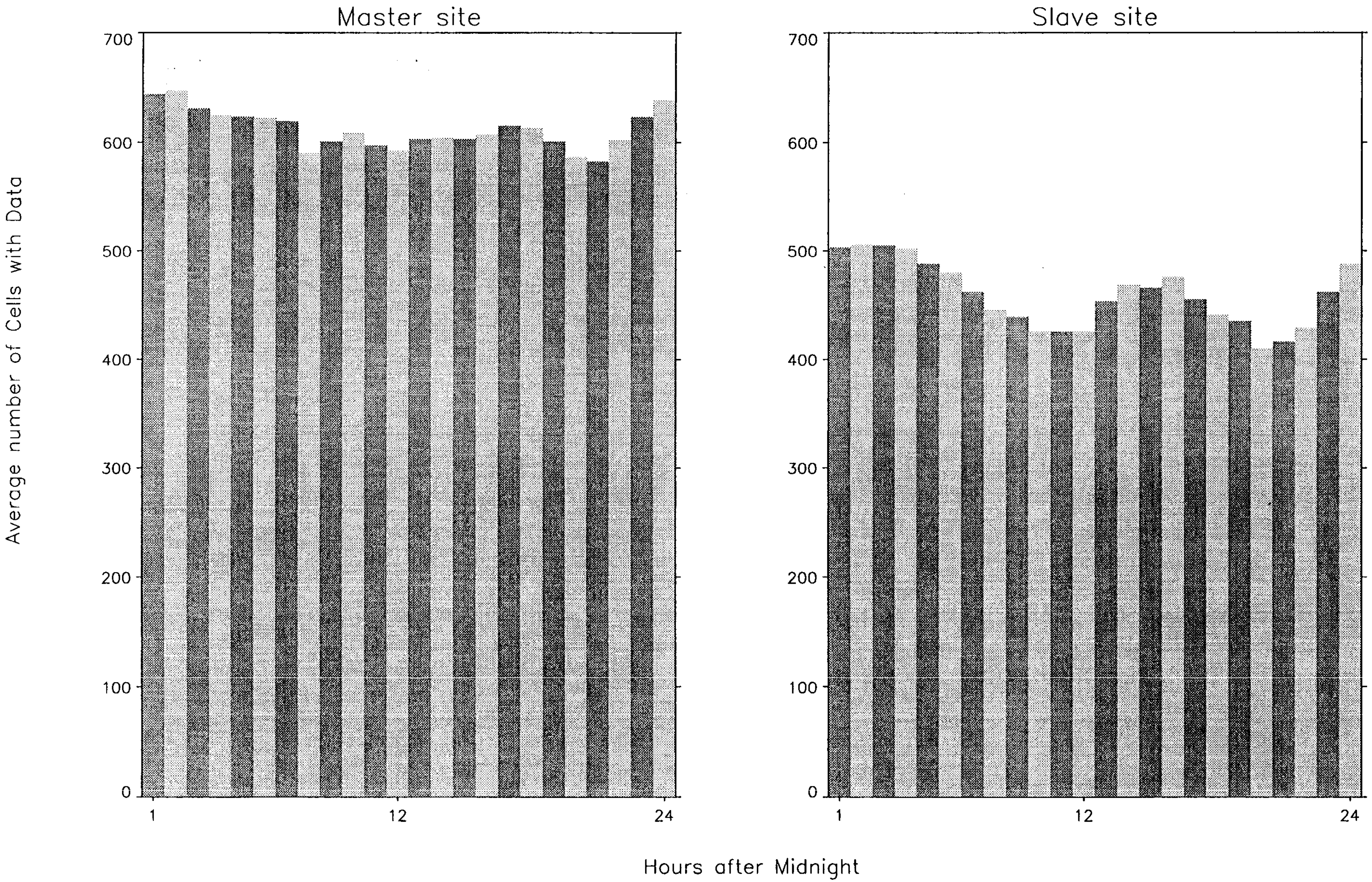
2 – 22/7/93

Data Variation with time of Day



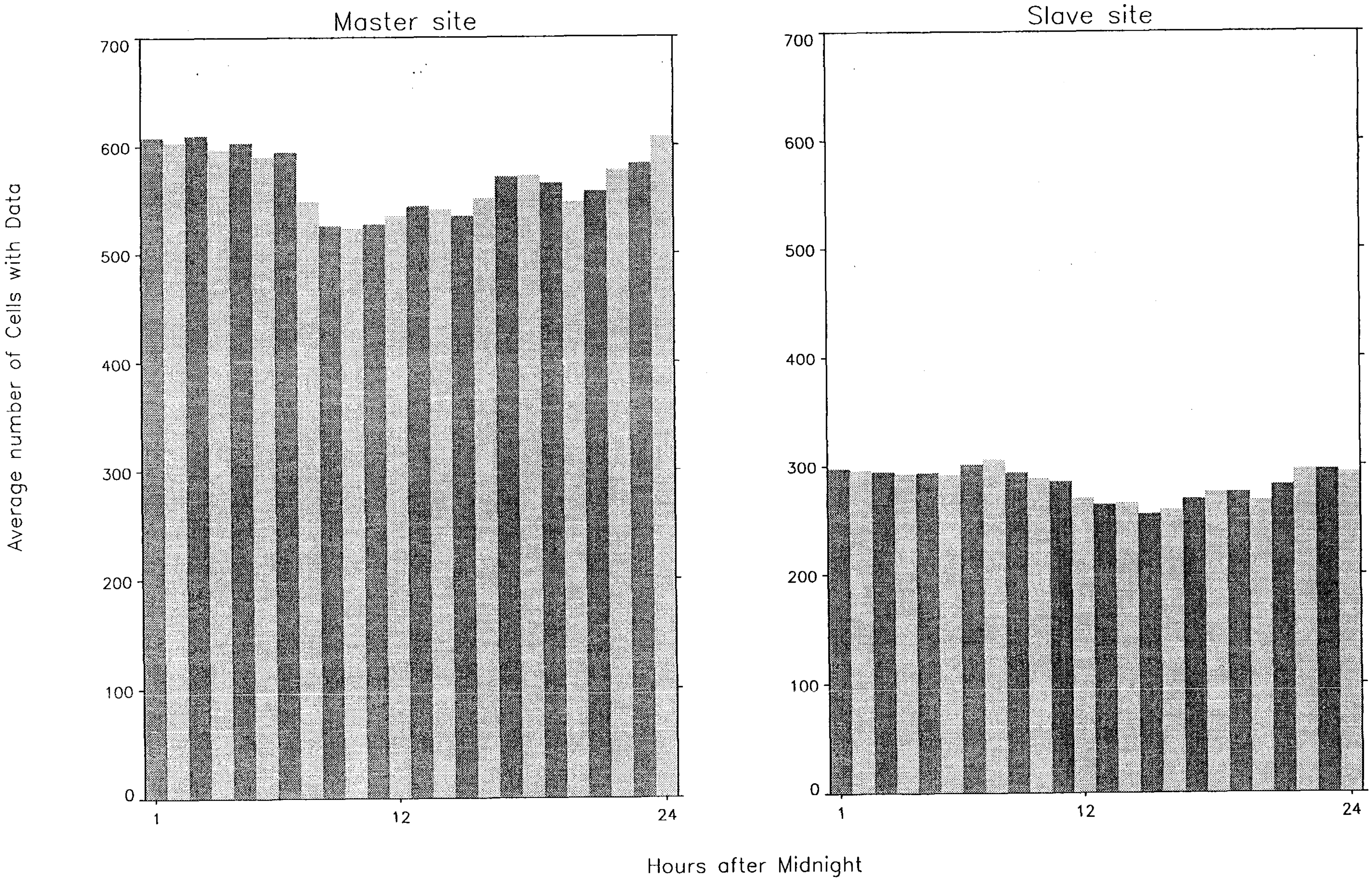
22/7 - 21/8/93

Data Variation with time of Day



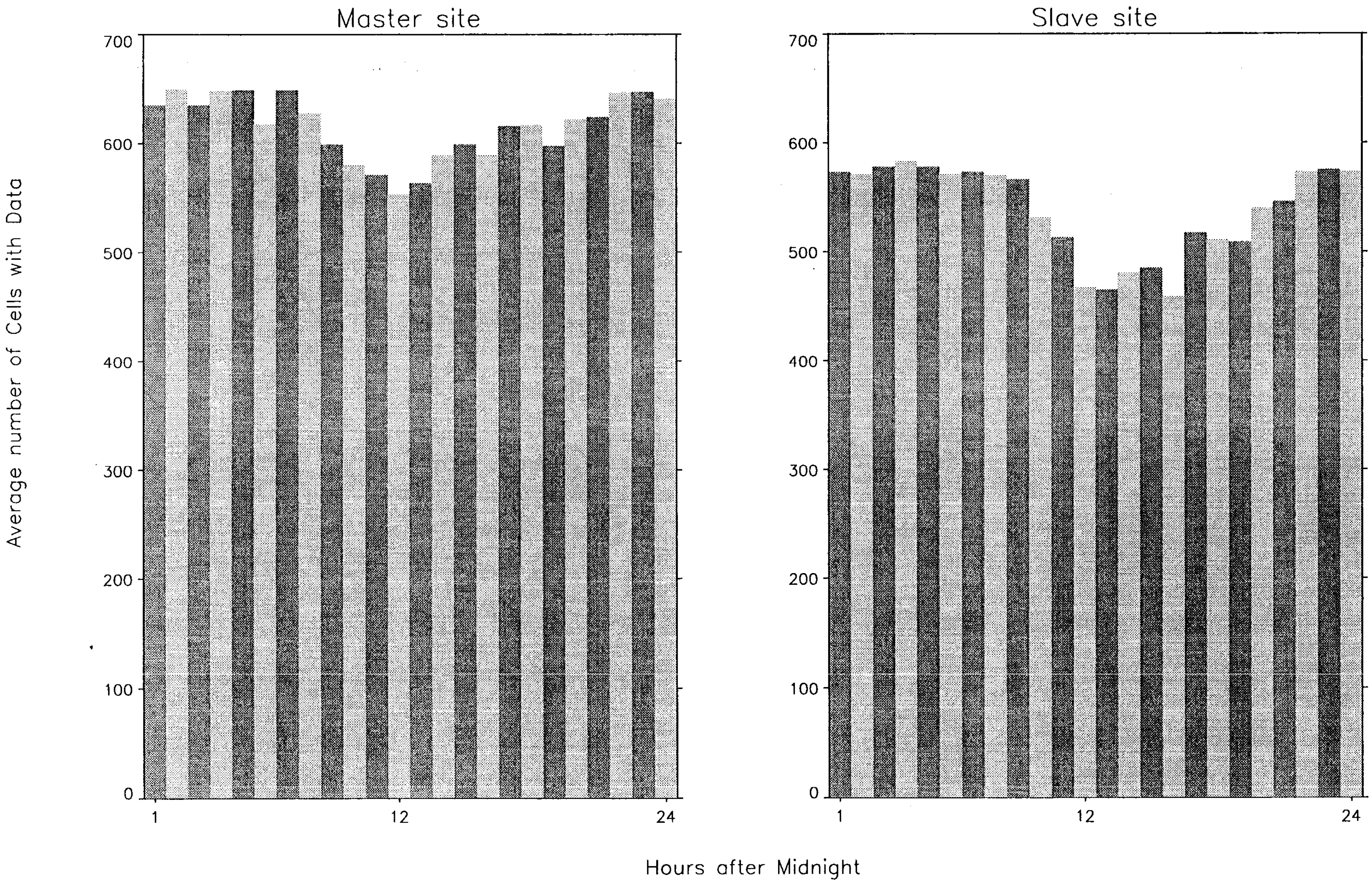
21/8 – 20/9/93

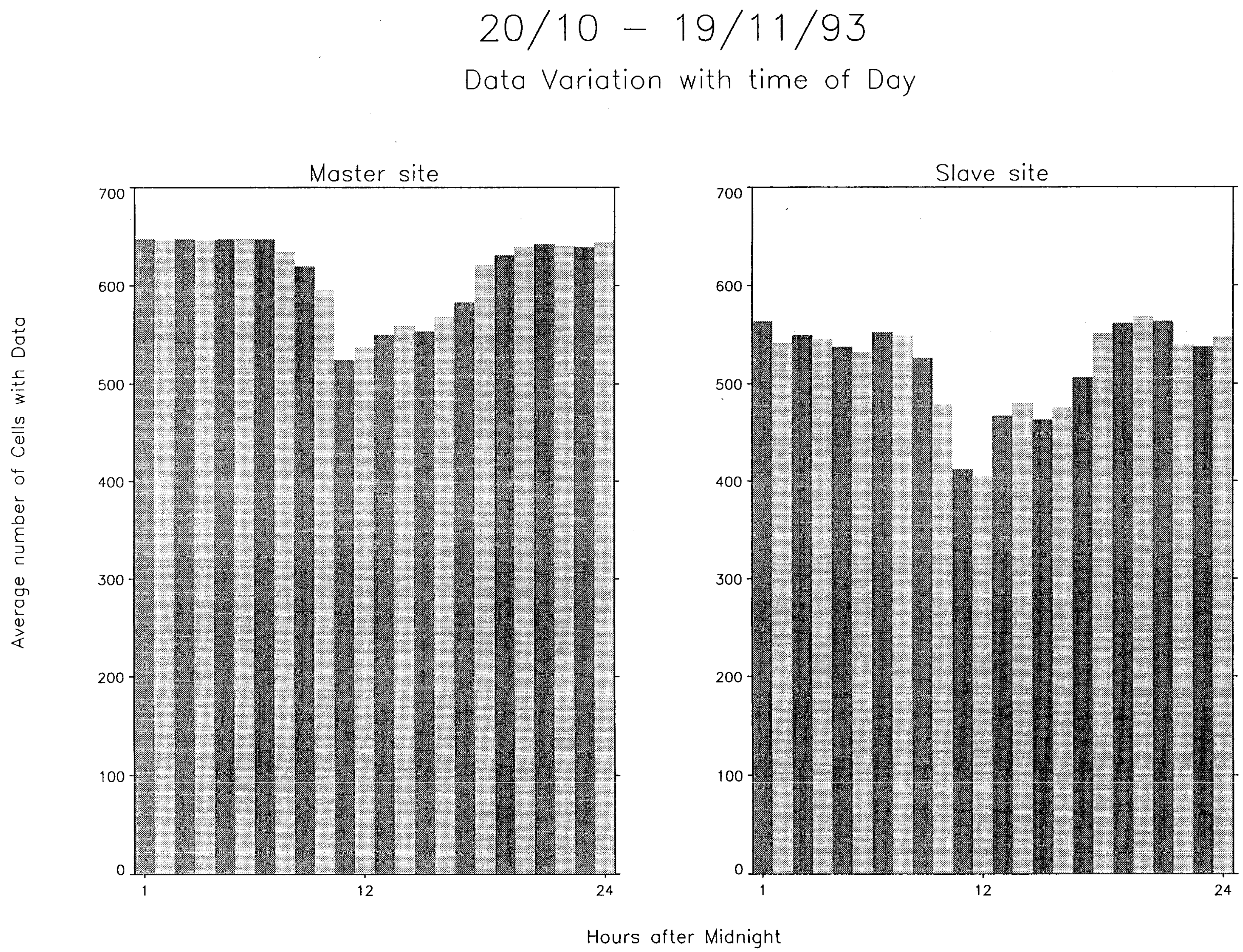
Data Variation with time of Day

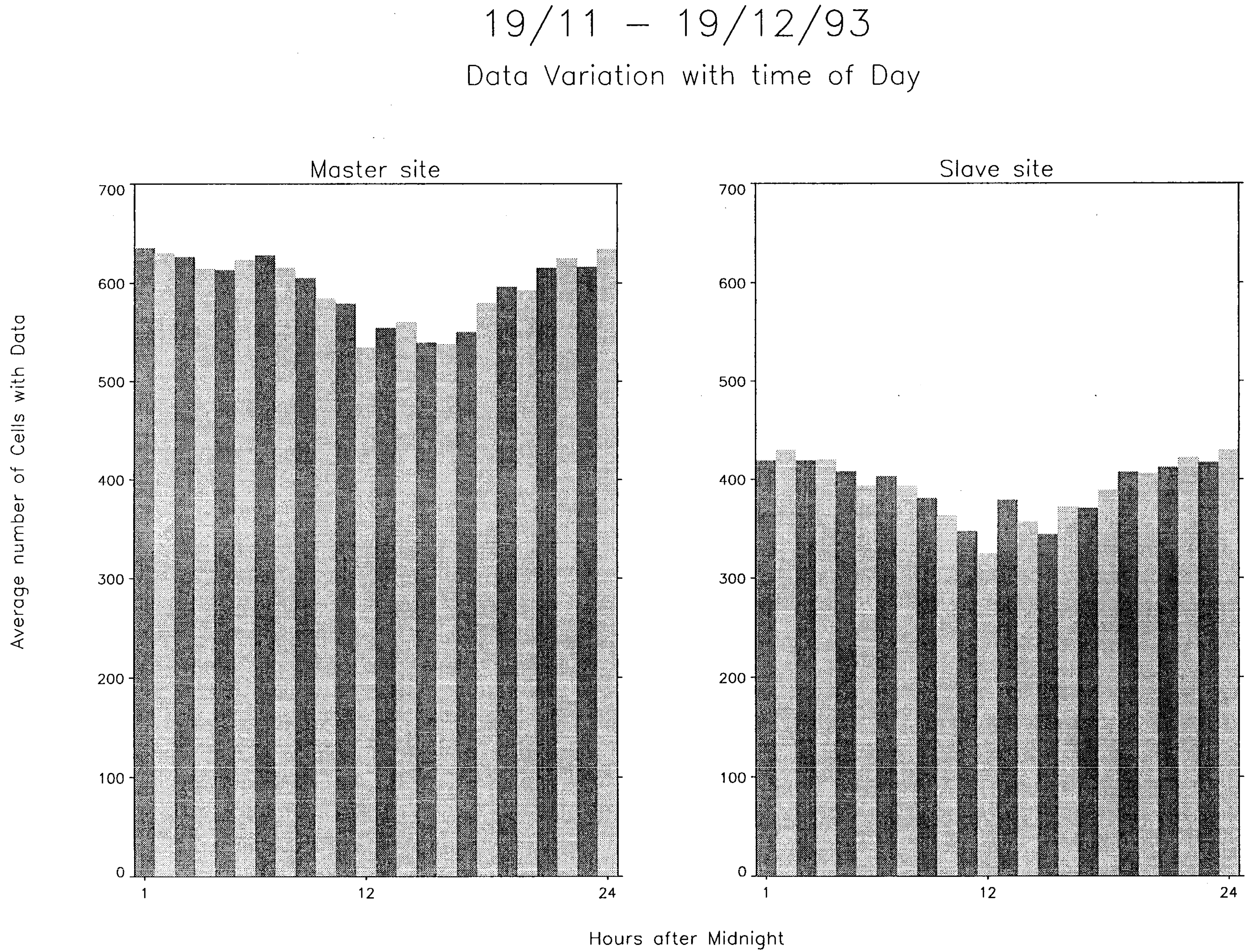


20/9 - 20/10/93

Data Variation with time of Day

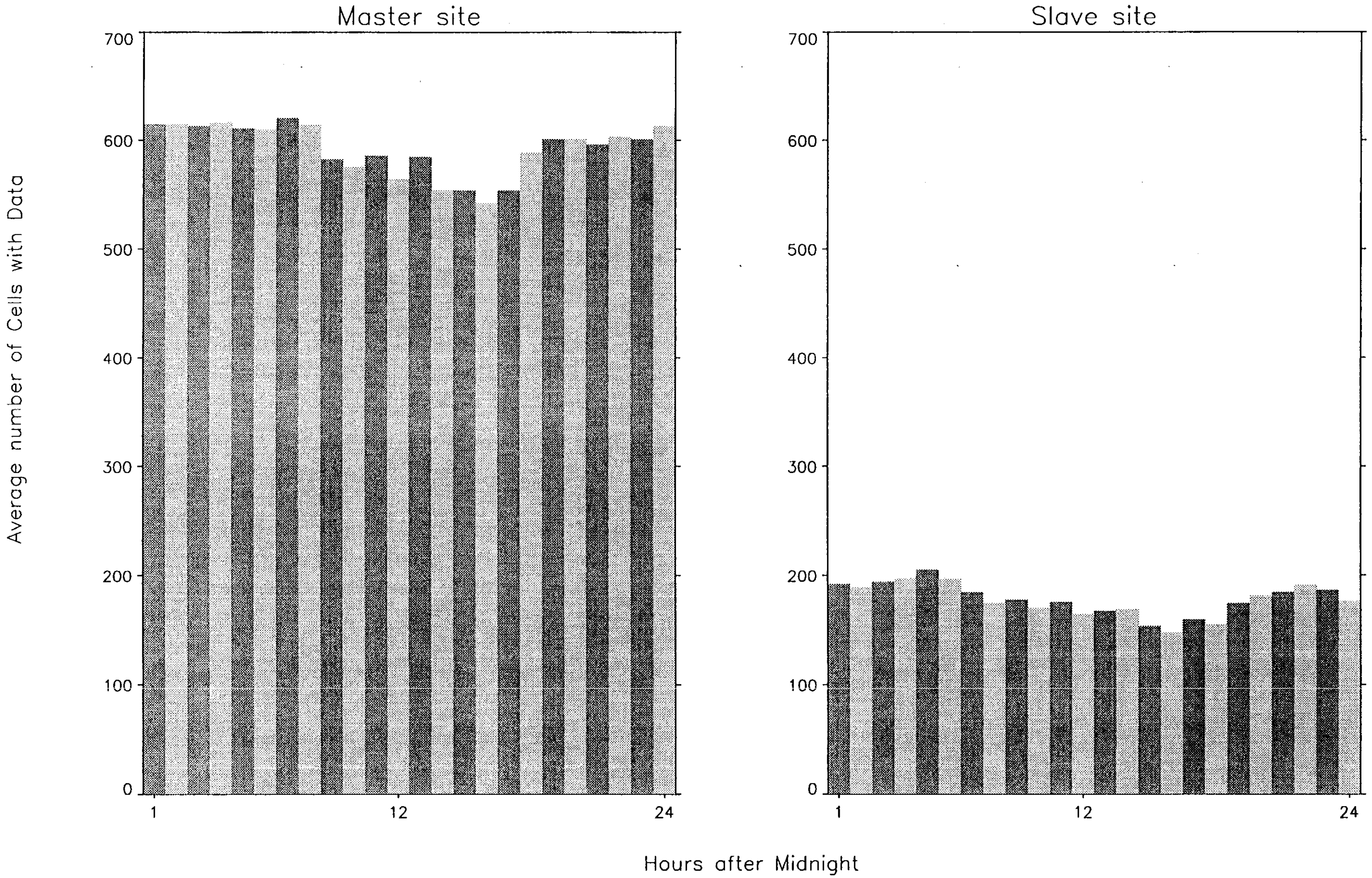



20/10 - 19/11/93
Data Variation with time of Day
Master site
Slave site
Average number of Cells with Data
700
600
500
400
300
200
100
0
1
12
24
Hours after Midnight


19/11 - 19/12/93
Data Variation with time of Day
Master site
Slave site
Average number of Cells with Data
0
100
200
300
400
500
600
700
1
12
24
Hours after Midnight

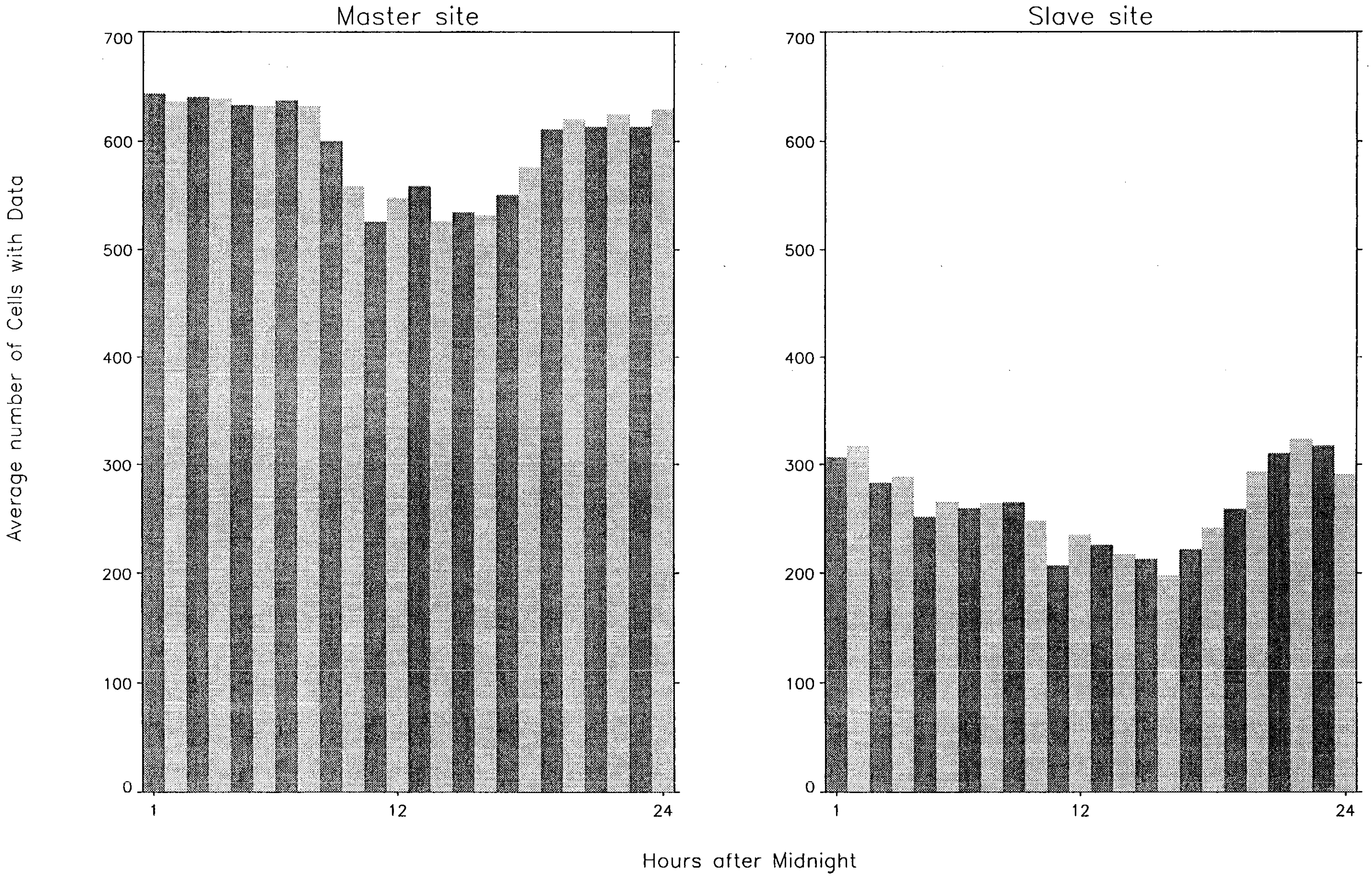
19/12/93 – 18/1/94

Data Variation with time of Day



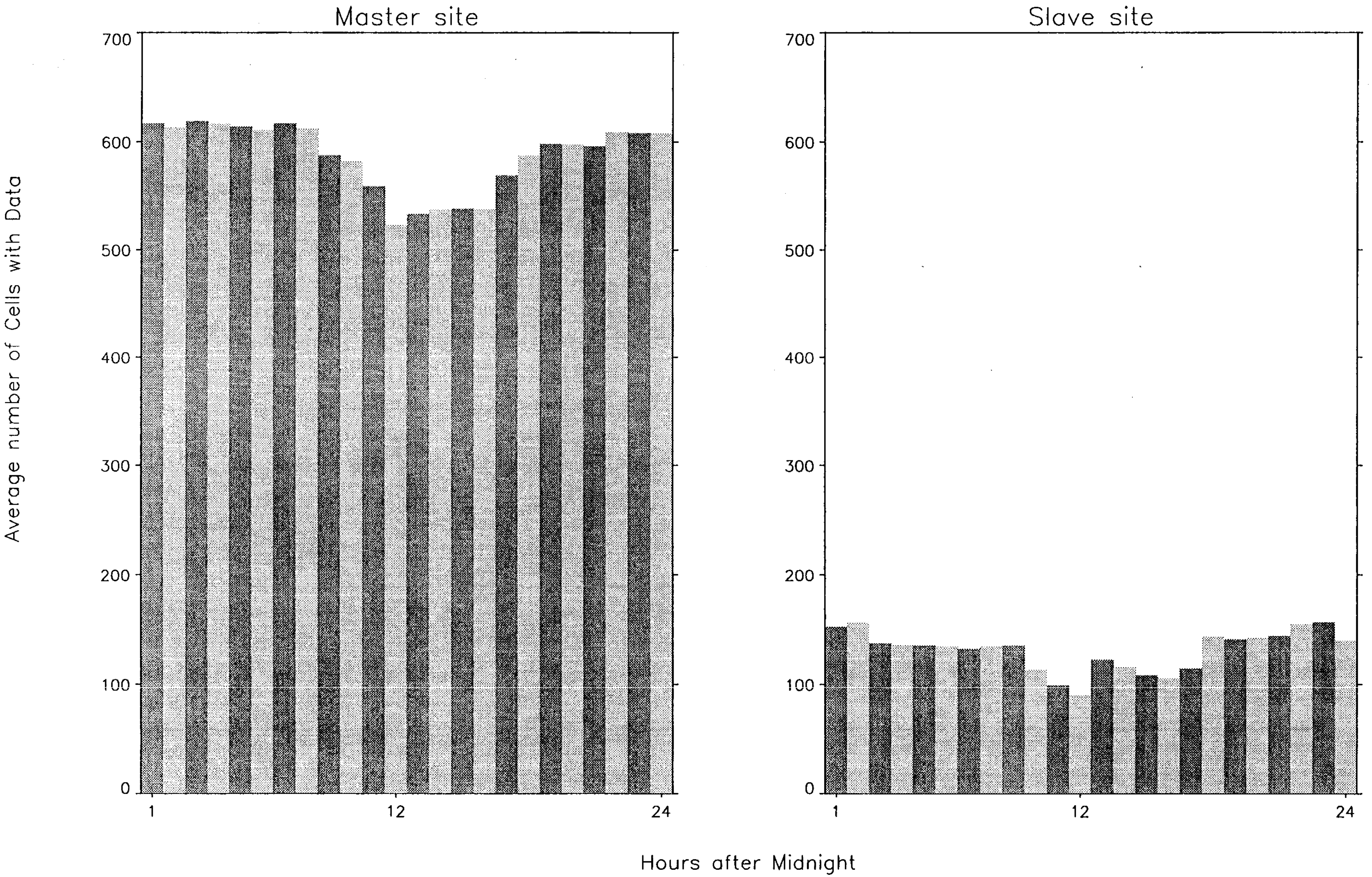
18/1 - 17/2/94

Data Variation with time of Day



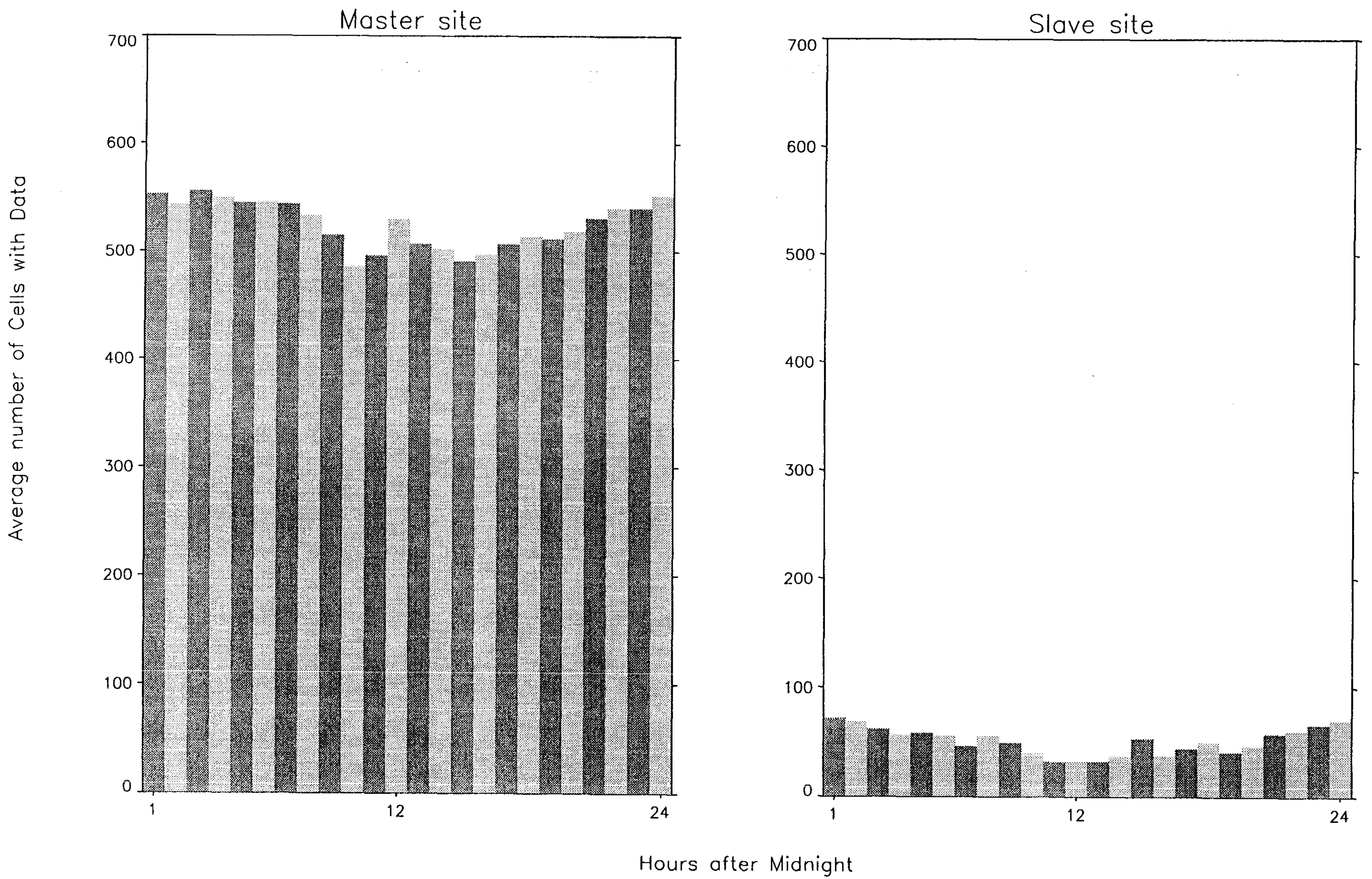
17/2 – 19/3/94

Data Variation with time of Day



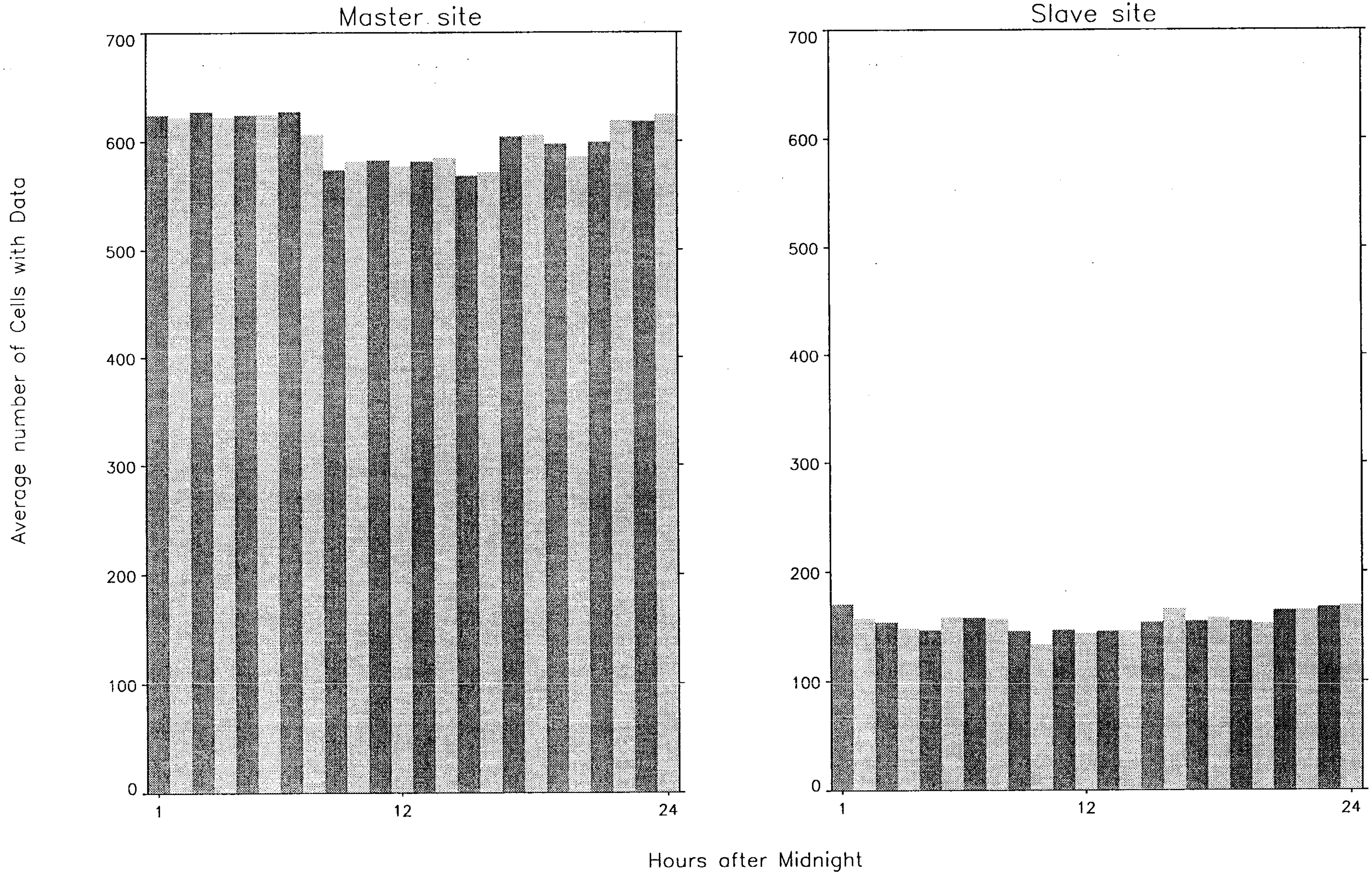
19/3 – 14/4/94

Data Variation with time of Day



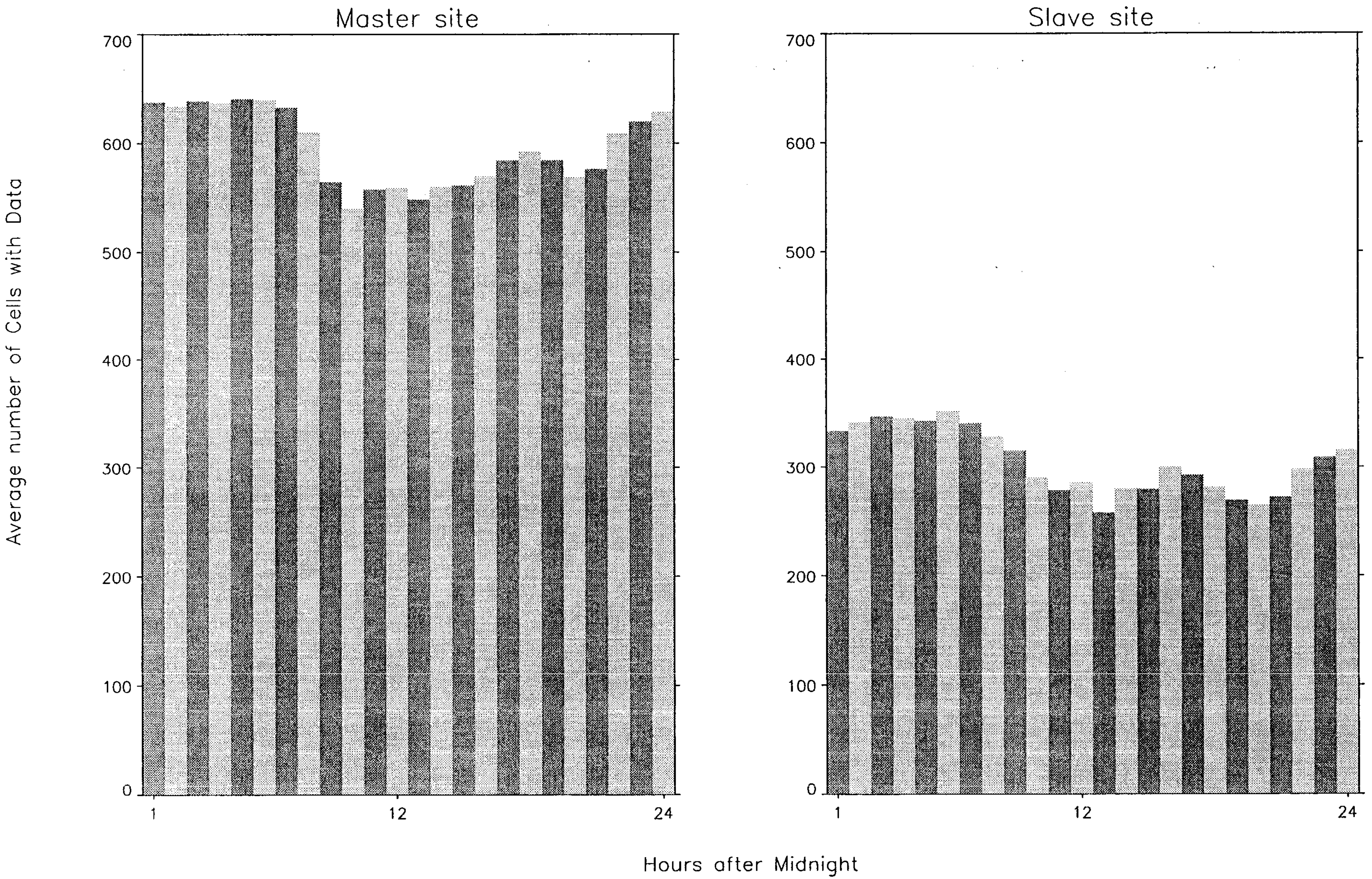
14/4 – 14/5/94

Data Variation with time of Day



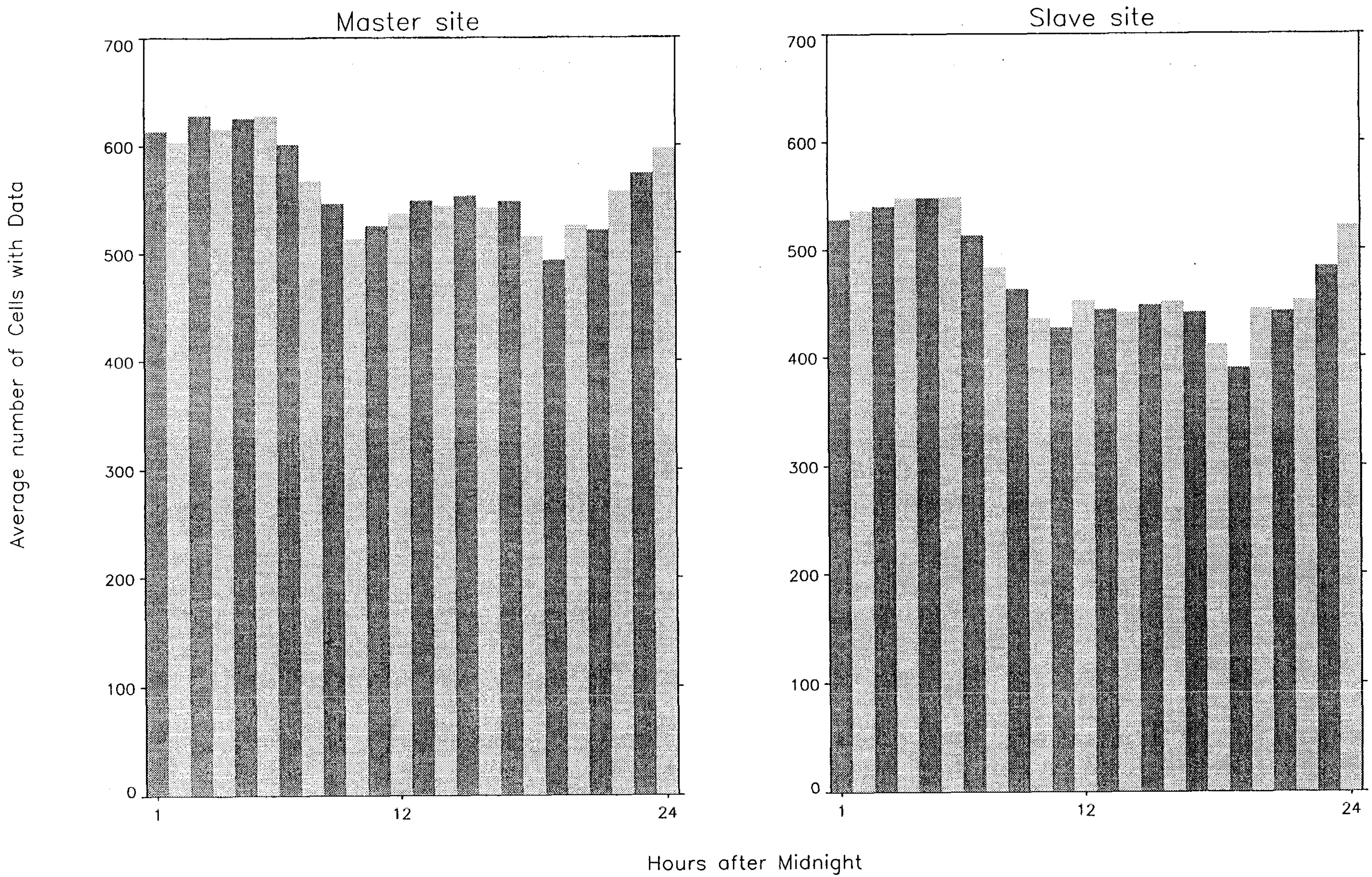
14/5 – 13/6/94

Data Variation with time of Day



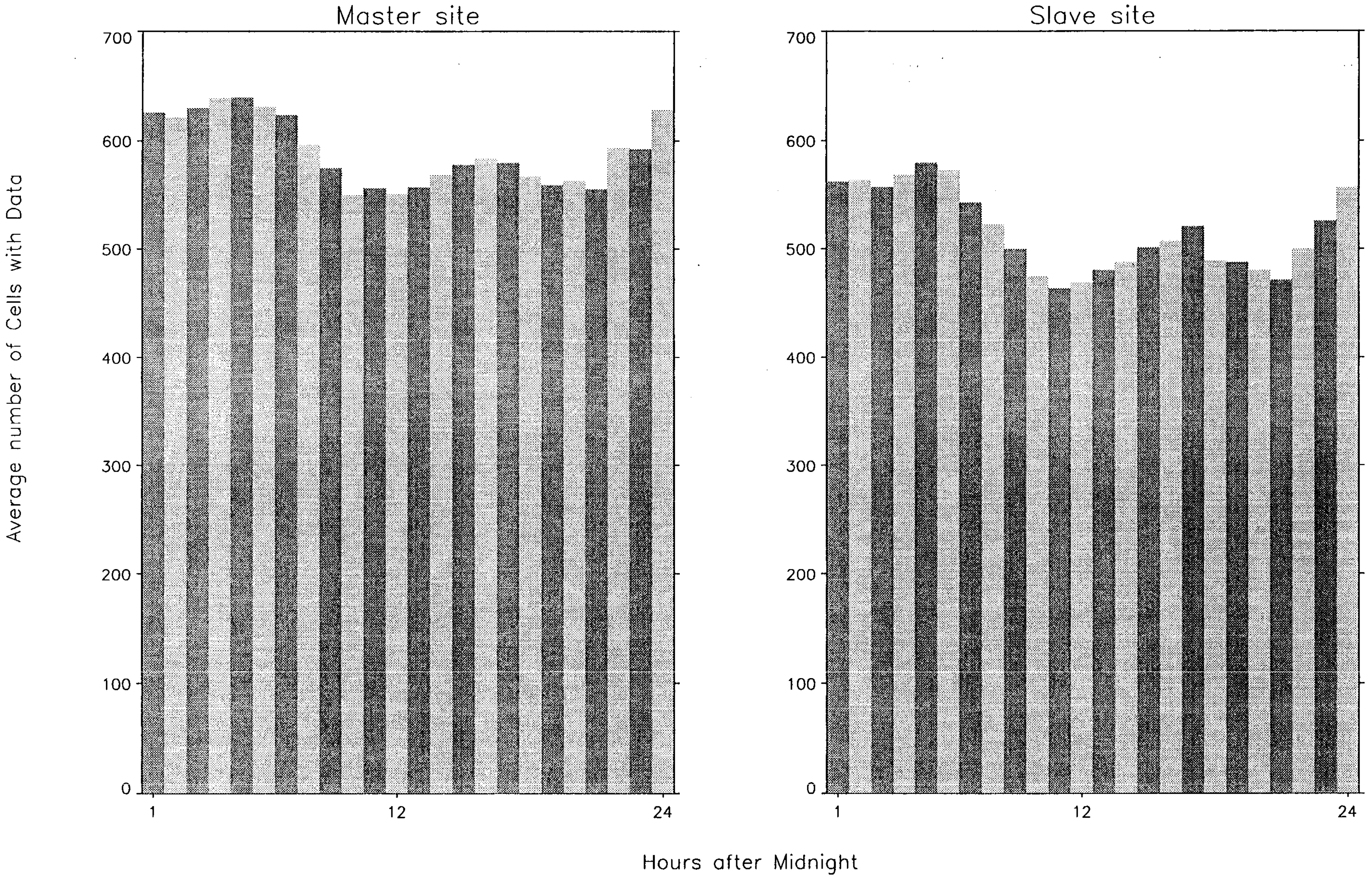
13/6 – 13/7/94

Data Variation with time of Day



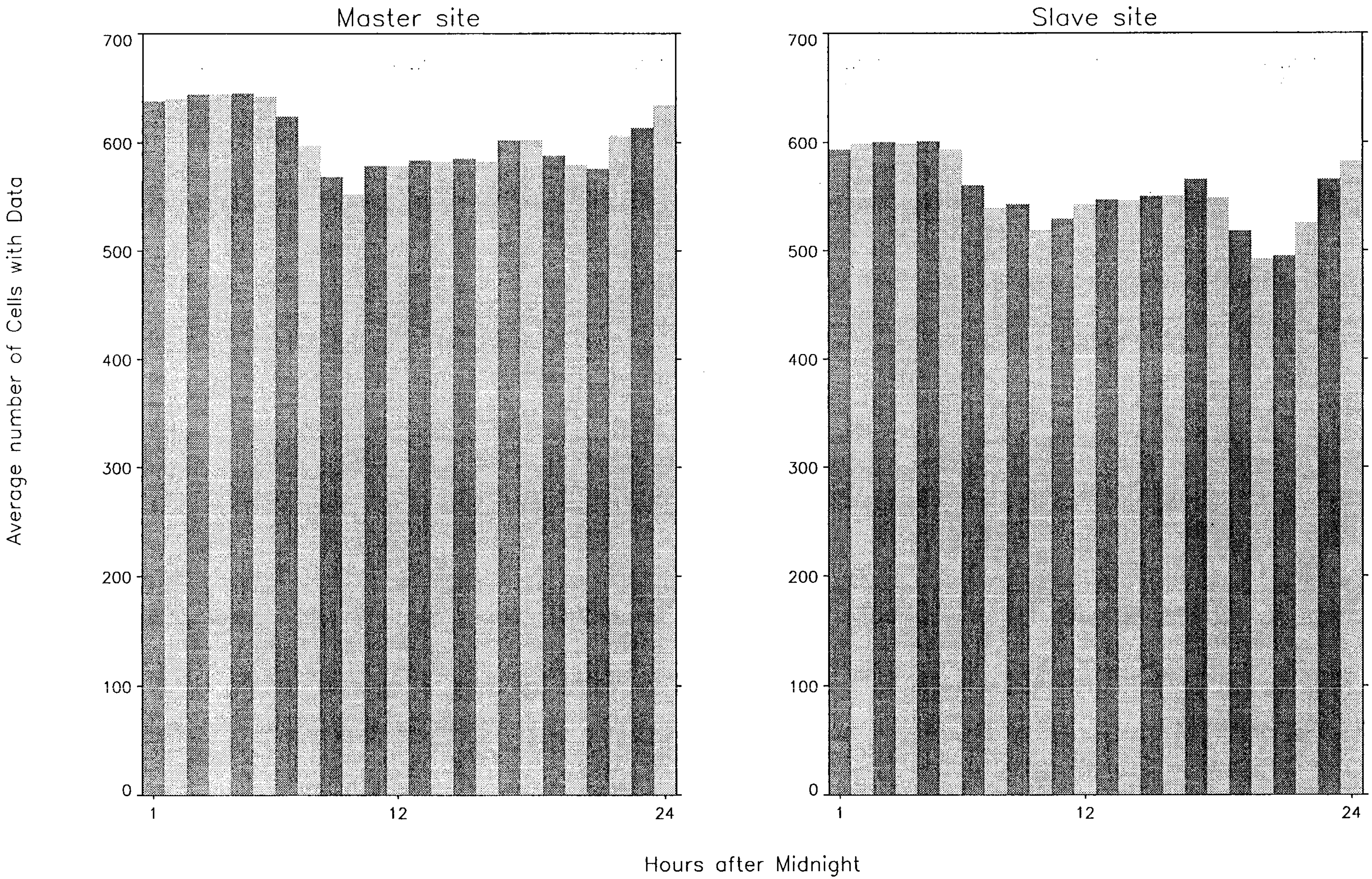
13/7 – 12/8/94

Data Variation with time of Day



25/7 - 24/8/94

Data Variation with time of Day

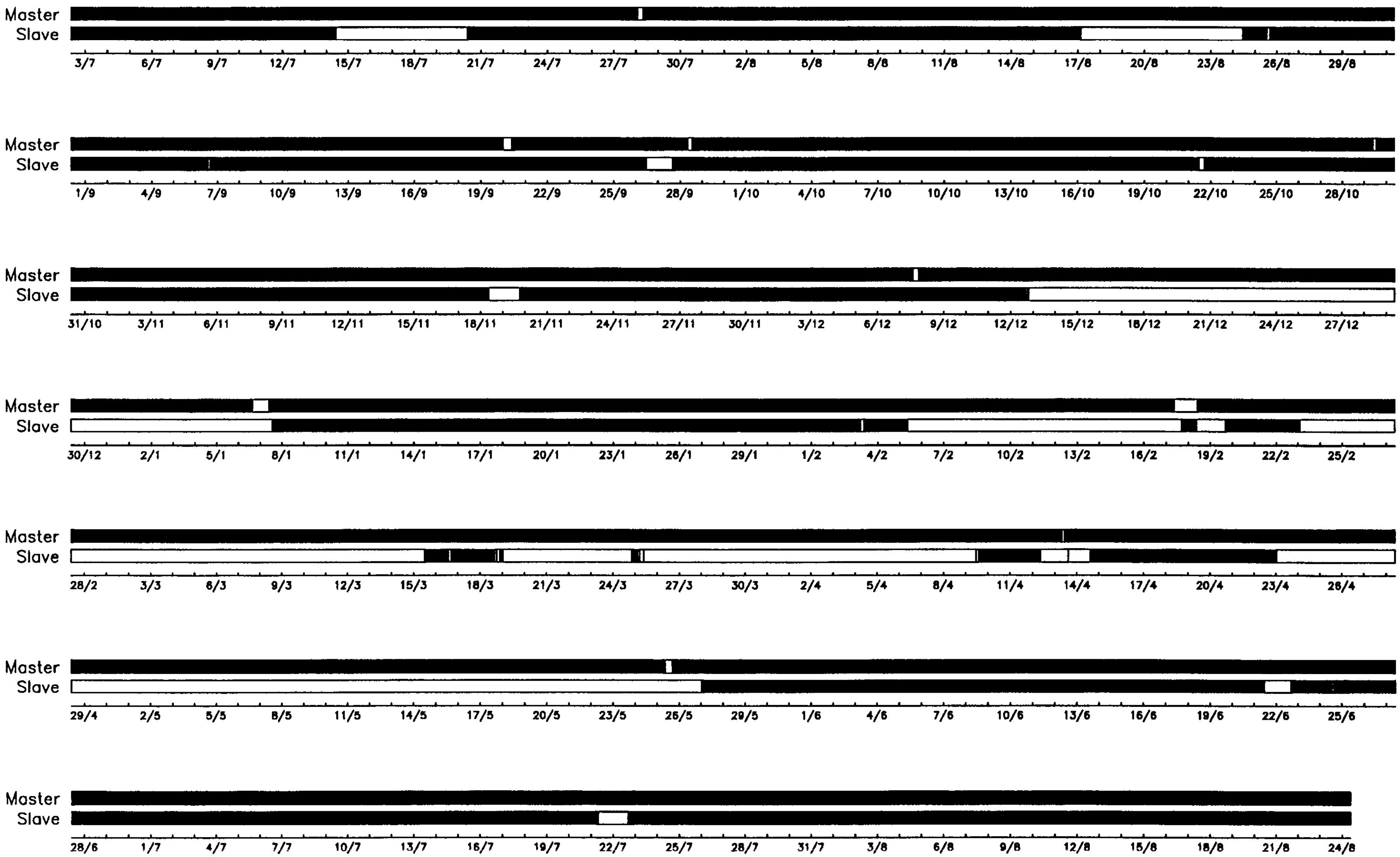


Appendix E   System performance during the deployment

White infill indicates where the OSCR system was not working, generally due to hardware failure.

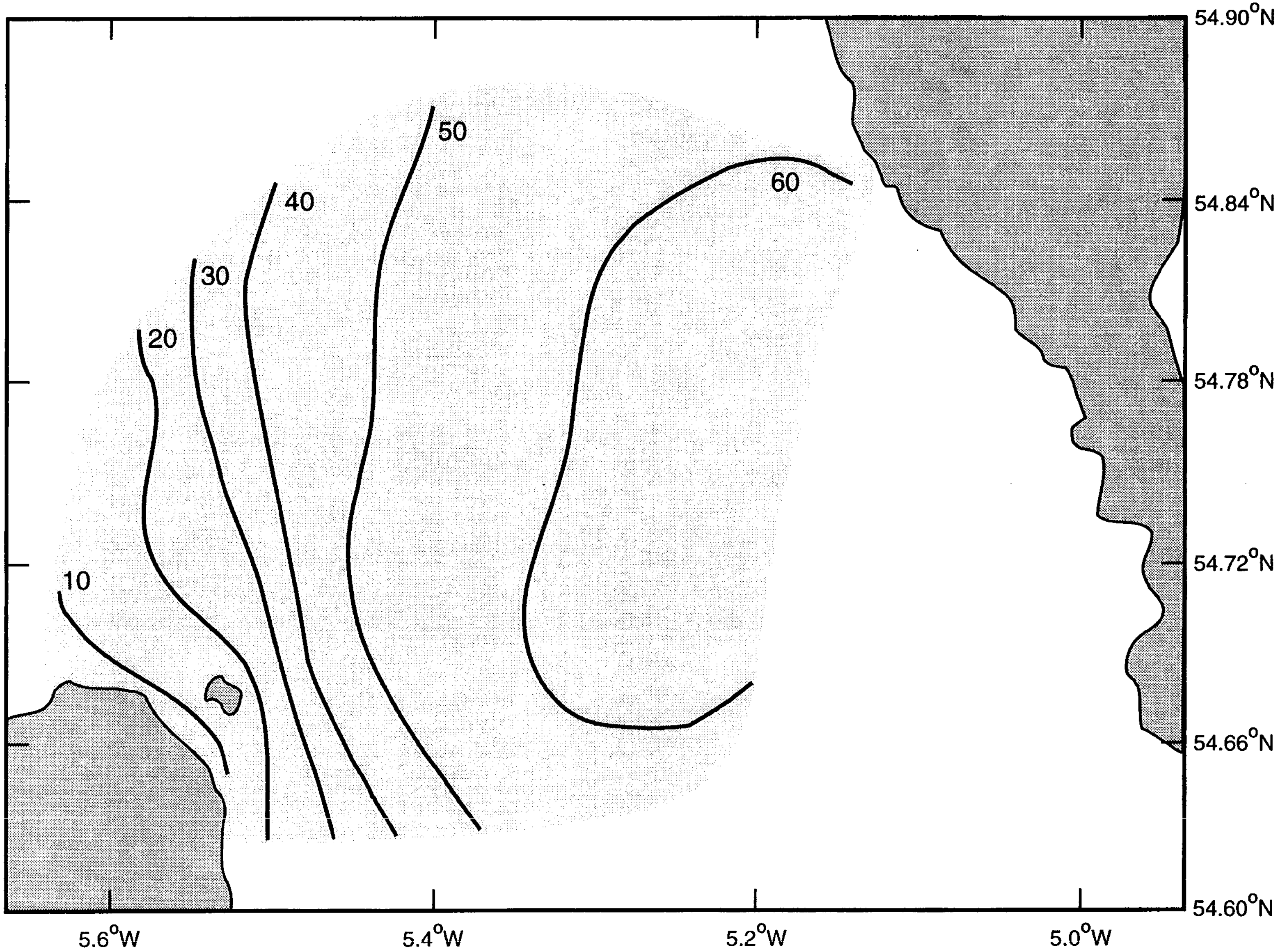
Bold infill indicates when the relevent OSCR system was up and running, although all the data possible may not be being recorded.

System performance 2/7/93 – 24/8/94



Appendix F Combined data return with distance from radar sites

This illustrates the percentage of data return for both sites combined.
ie. 60 indicates where data for that area worked for 60% of the time at both sites simultaneously.

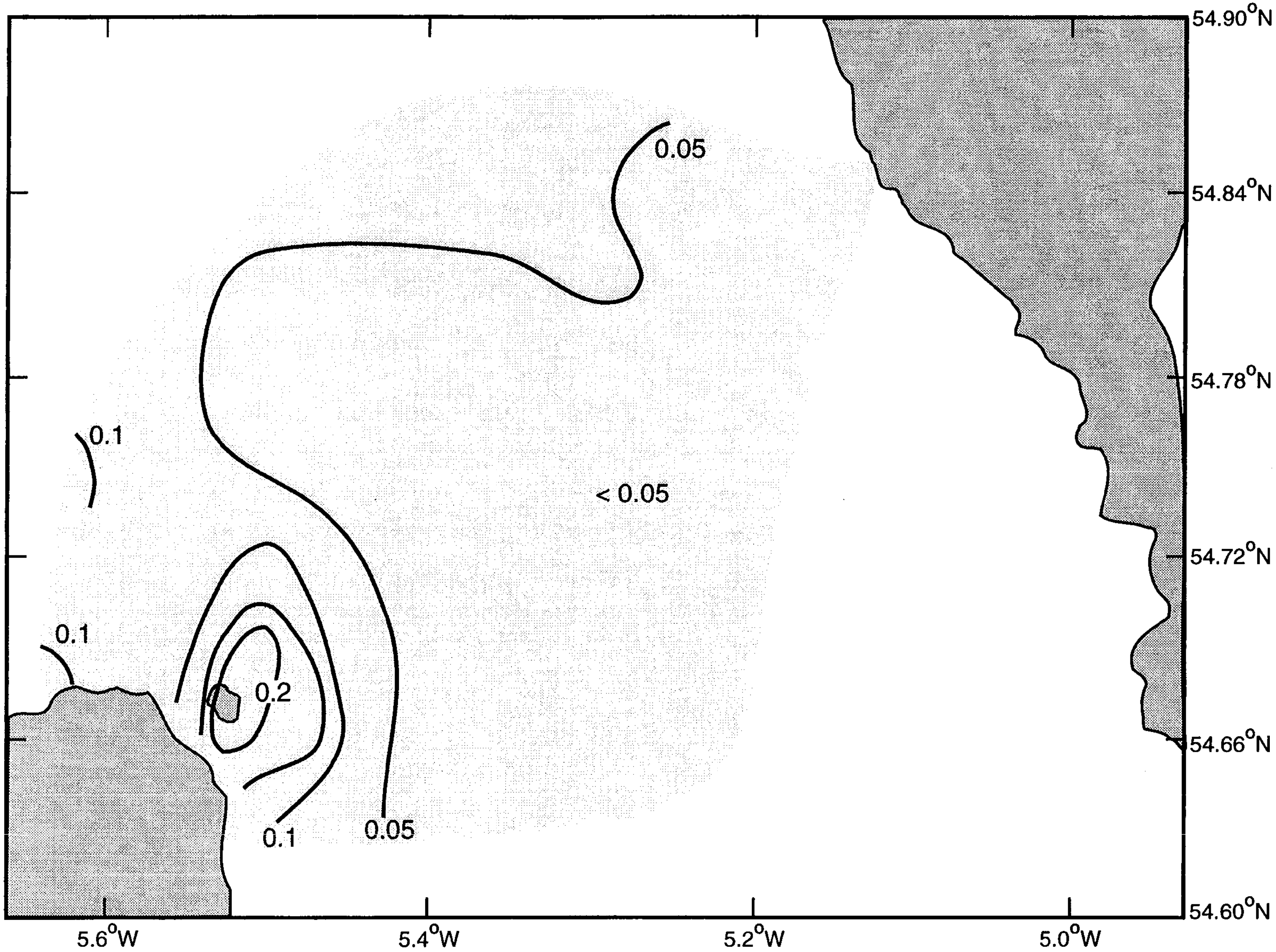


54.90°N
54.84°N
54.78°N
54.72°N
54.66°N
54.60°N
5.6°W
5.4°W
5.2°W
5.0°W
10
20
30
40
50
60

Appendix G Residual variance for combined sites

This illustrates the residual variance for data recorded at both sites simultaneously.

Units are m^2s^{-2}.

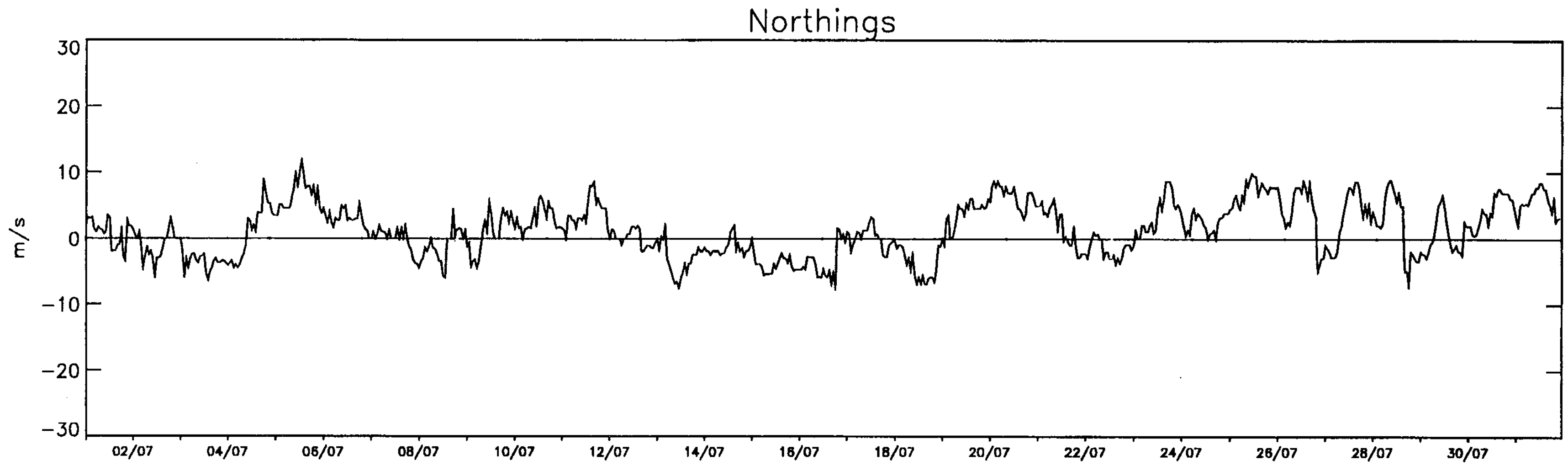


54.90°N
54.84°N
54.78°N
54.72°N
54.66°N
54.60°N
5.6°W
5.4°W
5.2°W
5.0°W
0.05
0.1
< 0.05
0.1
0.2
0.1
0.05

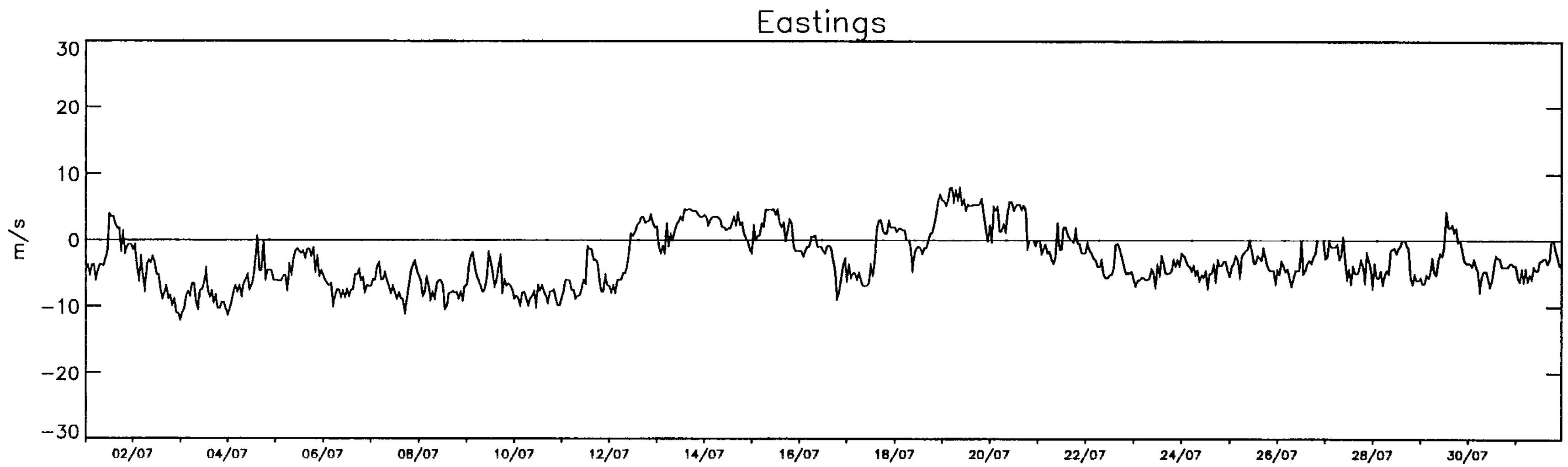
Appendix H Wind data diagrams

These are presented as Northings and Eastings, in monthly blocks, for the complete period.

July 1993

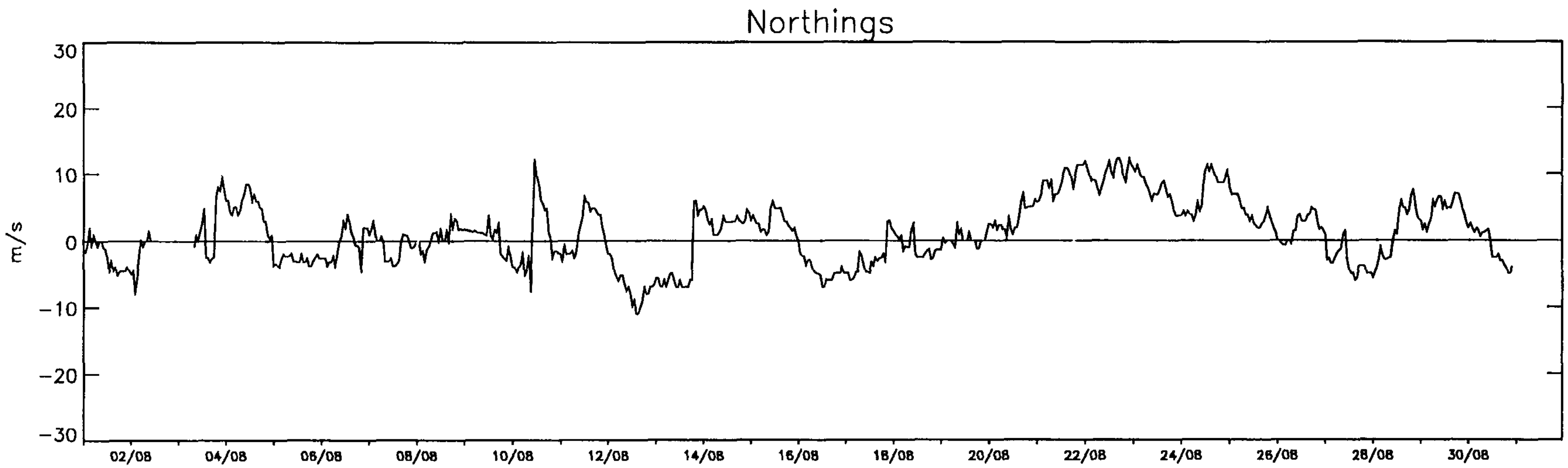


Northings
30
20
10
0
−10
−20
−30
m/s
02/07
04/07
06/07
08/07
10/07
12/07
14/07
16/07
18/07
20/07
22/07
24/07
26/07
28/07
30/07

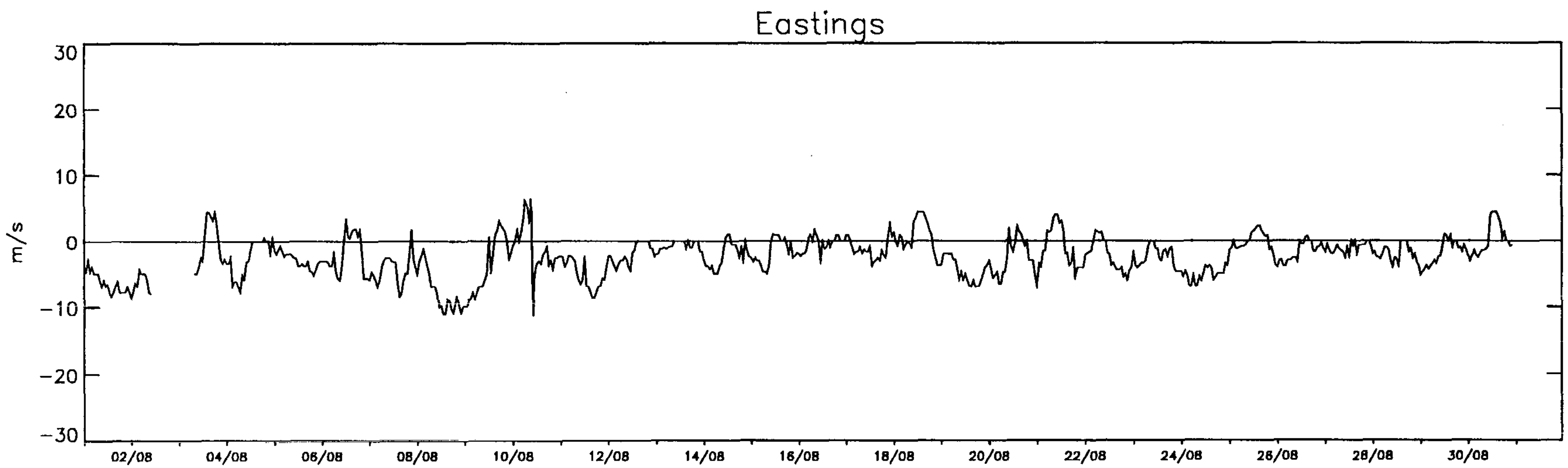


Eastings
30
20
10
0
−10
−20
−30
m/s
02/07
04/07
06/07
08/07
10/07
12/07
14/07
16/07
18/07
20/07
22/07
24/07
26/07
28/07
30/07

August 1993

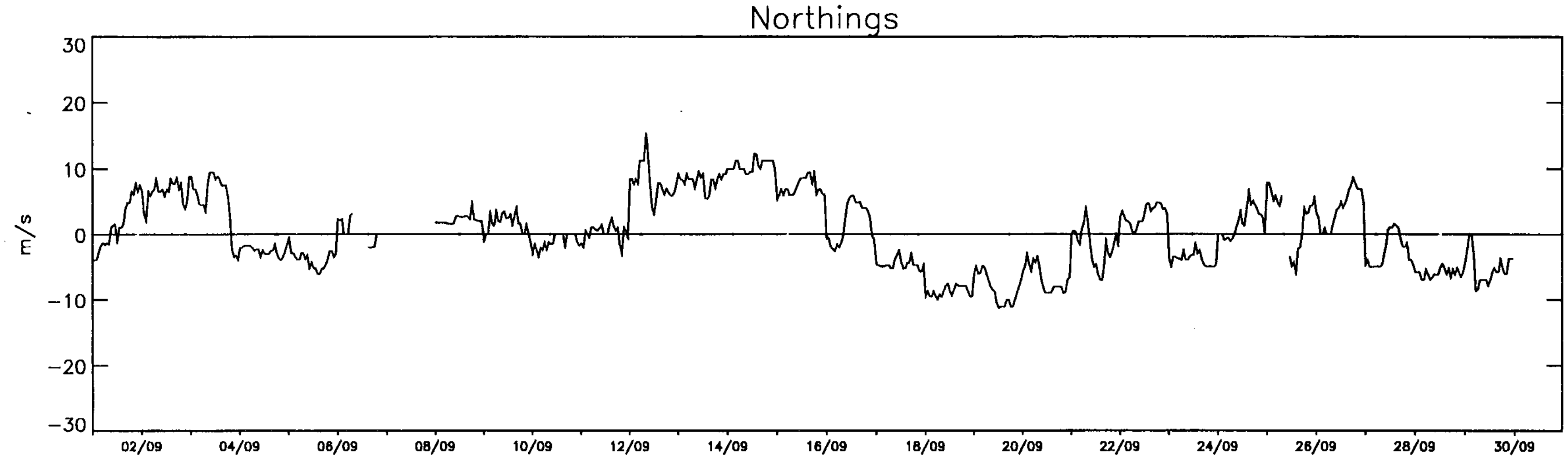


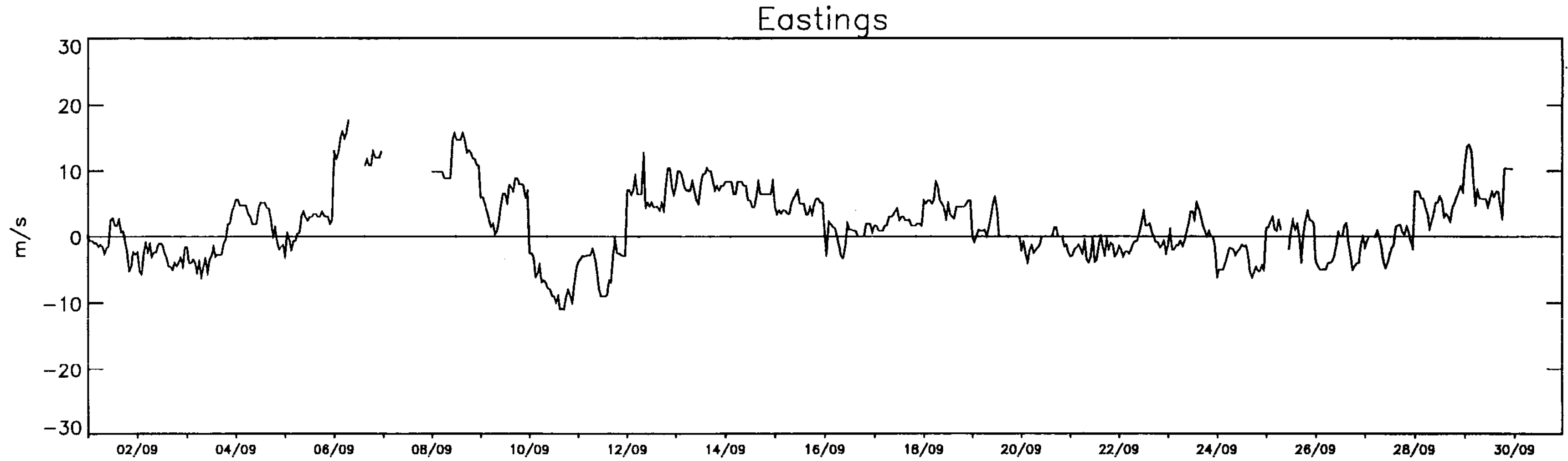
Northings
m/s
30
20
10
0
-10
-20
-30
02/08
04/08
06/08
08/08
10/08
12/08
14/08
16/08
18/08
20/08
22/08
24/08
26/08
28/08
30/08



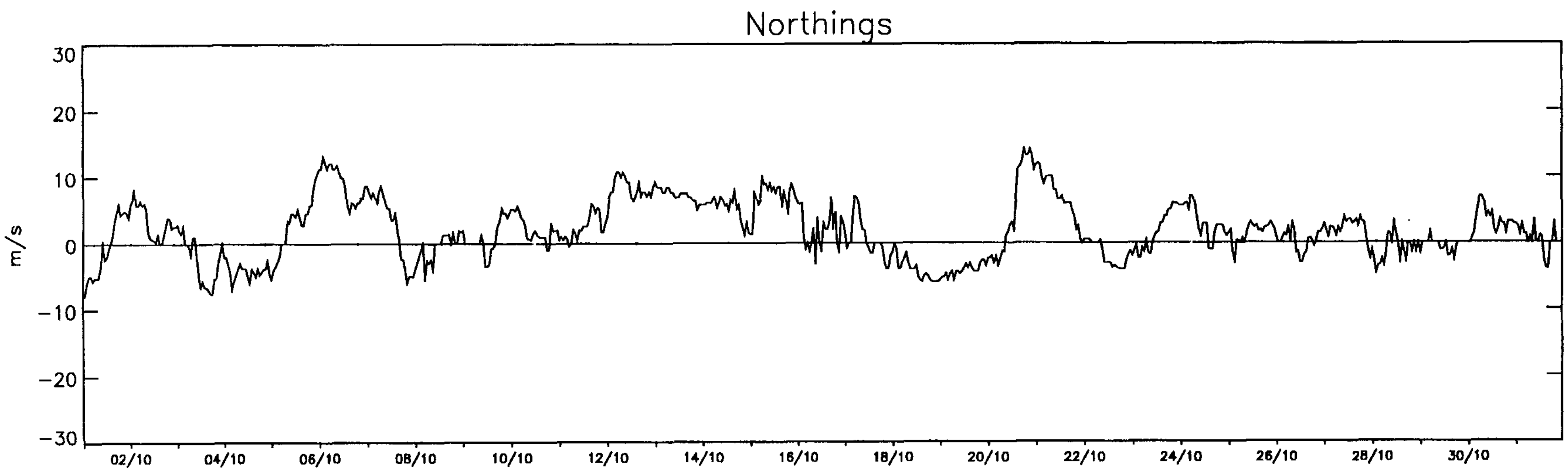
Eastings
m/s
30
20
10
0
-10
-20
-30
02/08
04/08
06/08
08/08
10/08
12/08
14/08
16/08
18/08
20/08
22/08
24/08
26/08
28/08
30/08

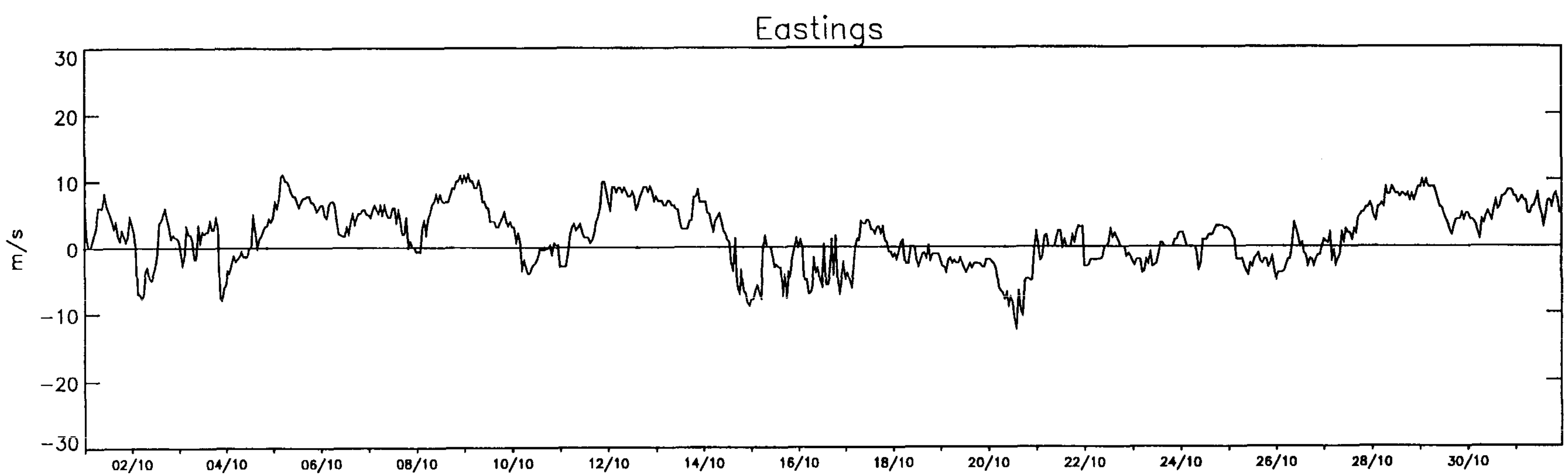
September 1993



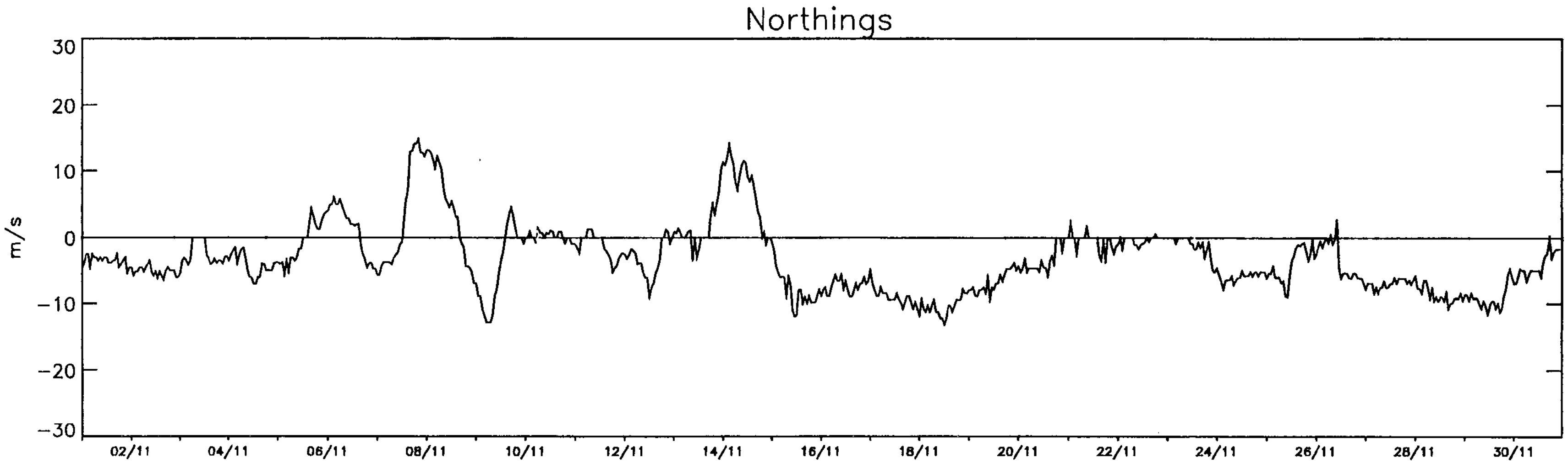


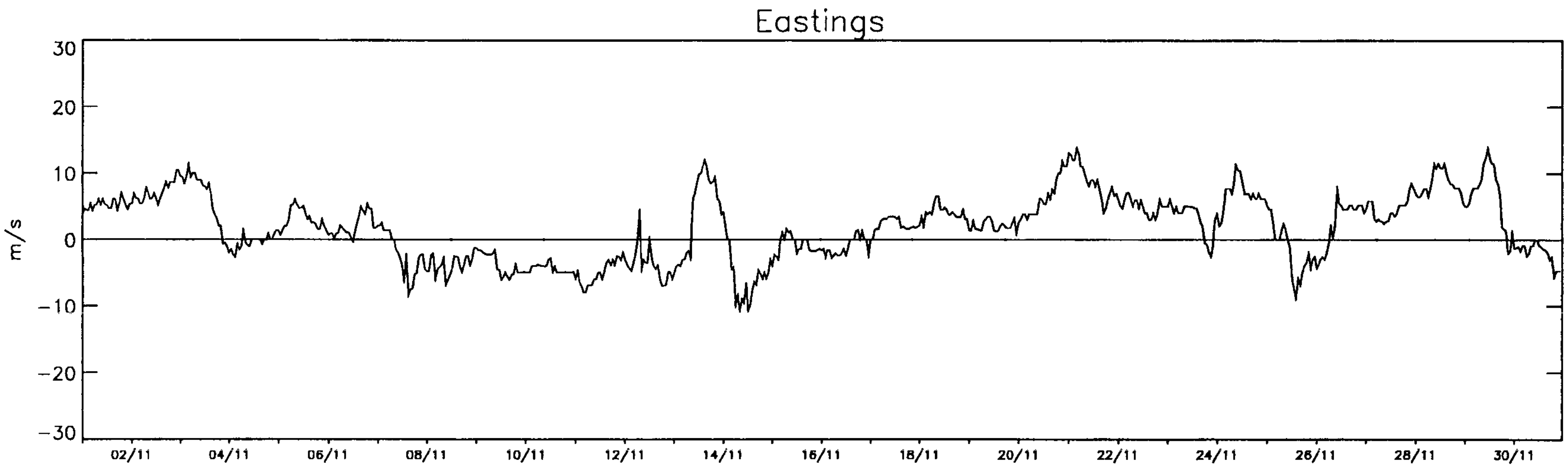
October 1993



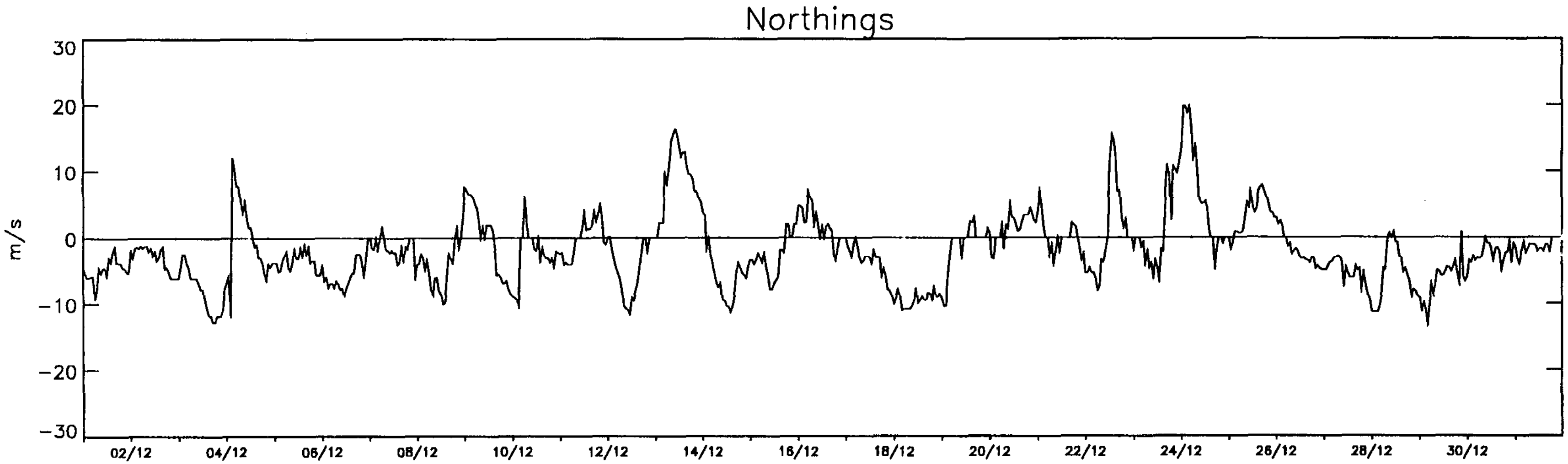


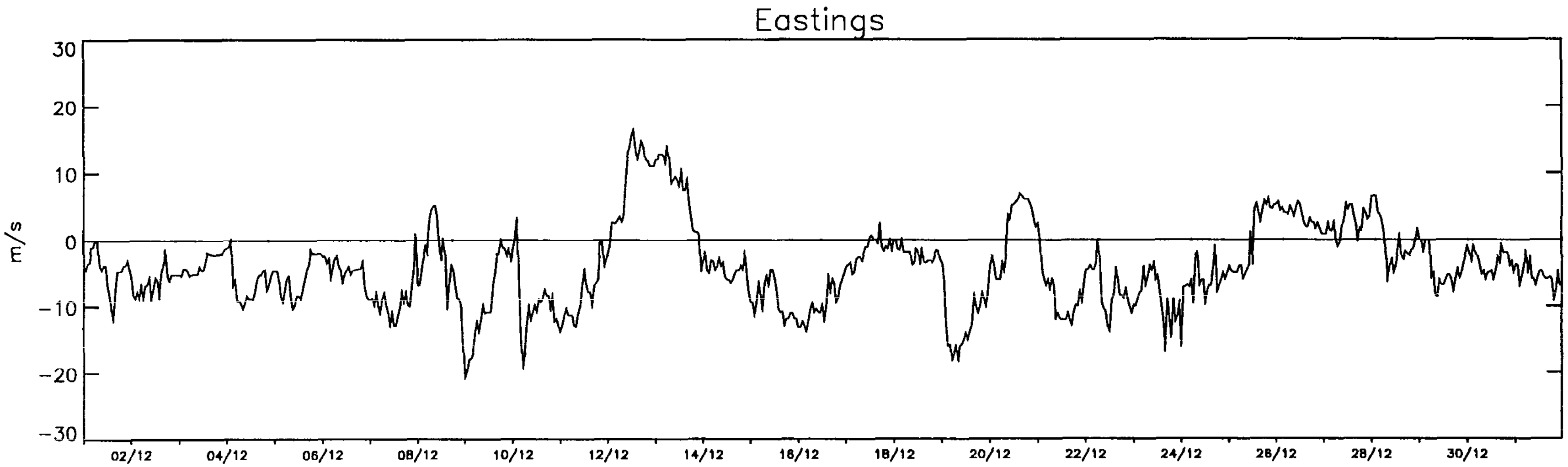
November 1993



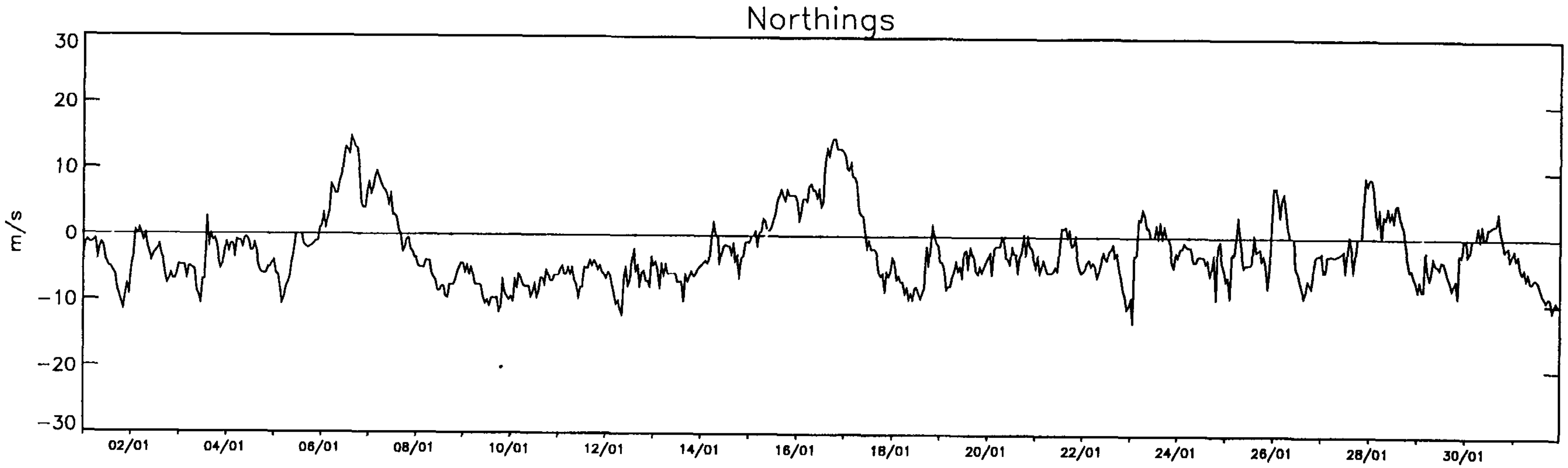


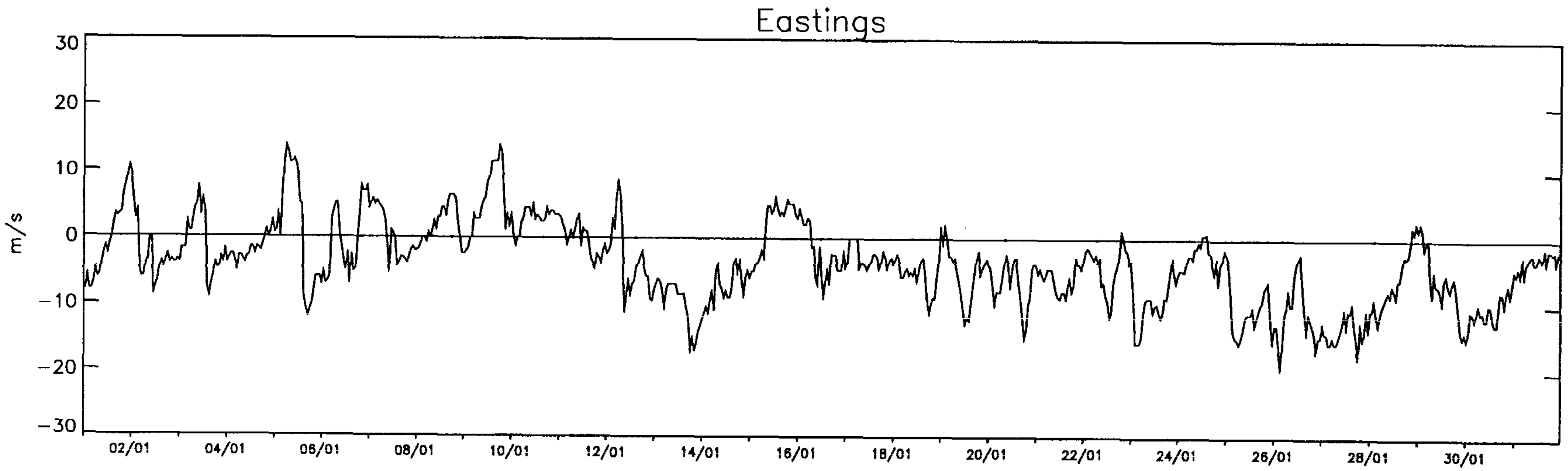
December 1993



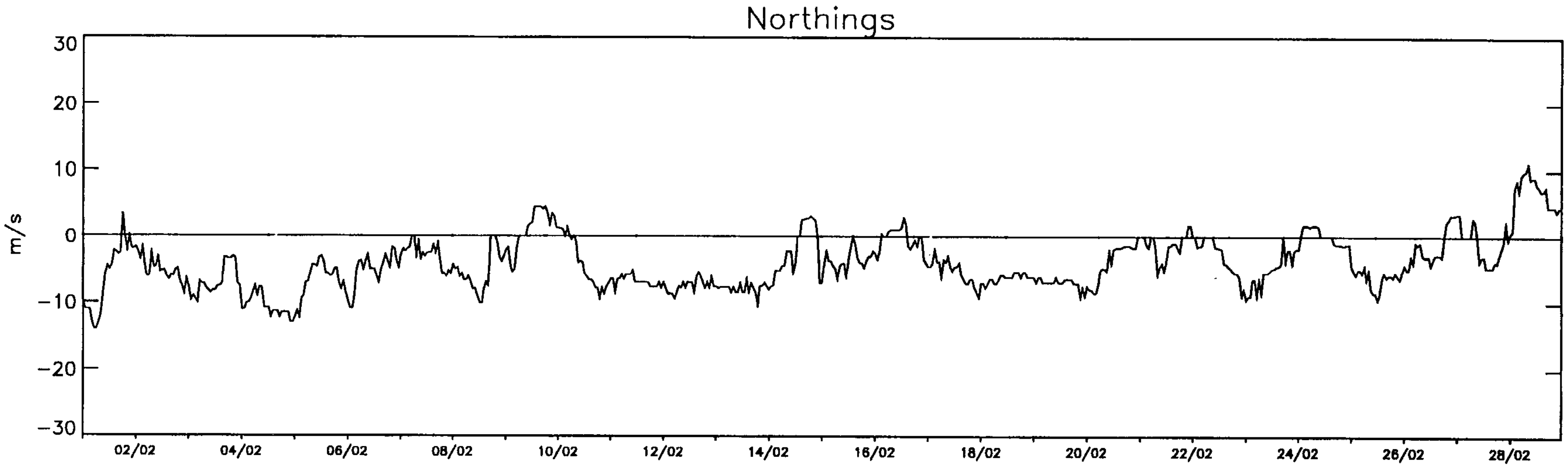


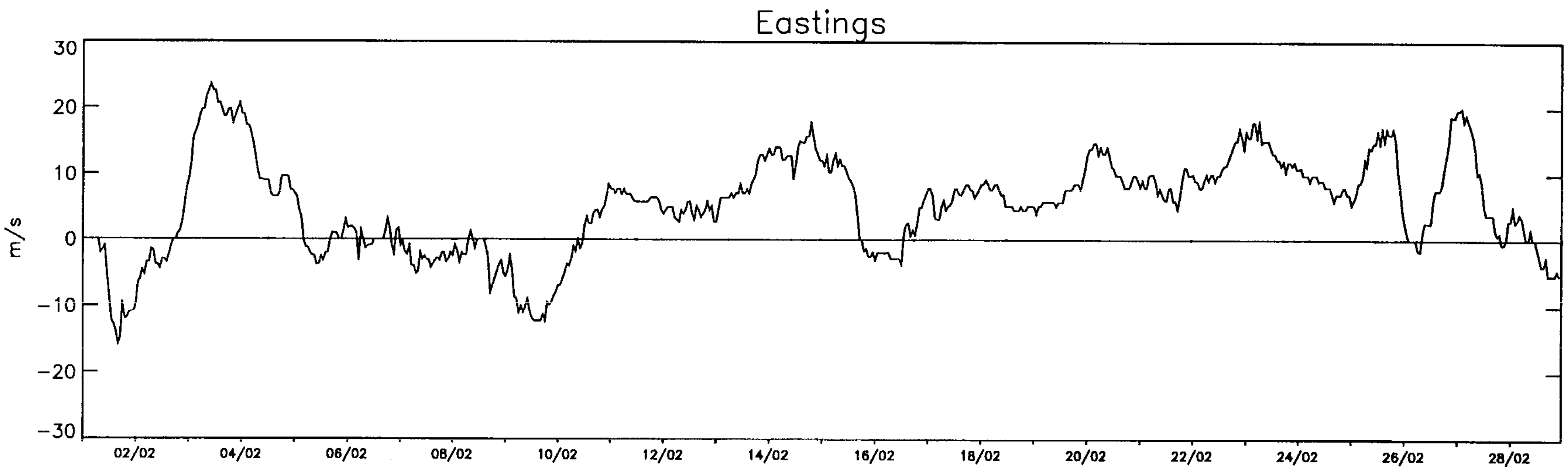
January 1994



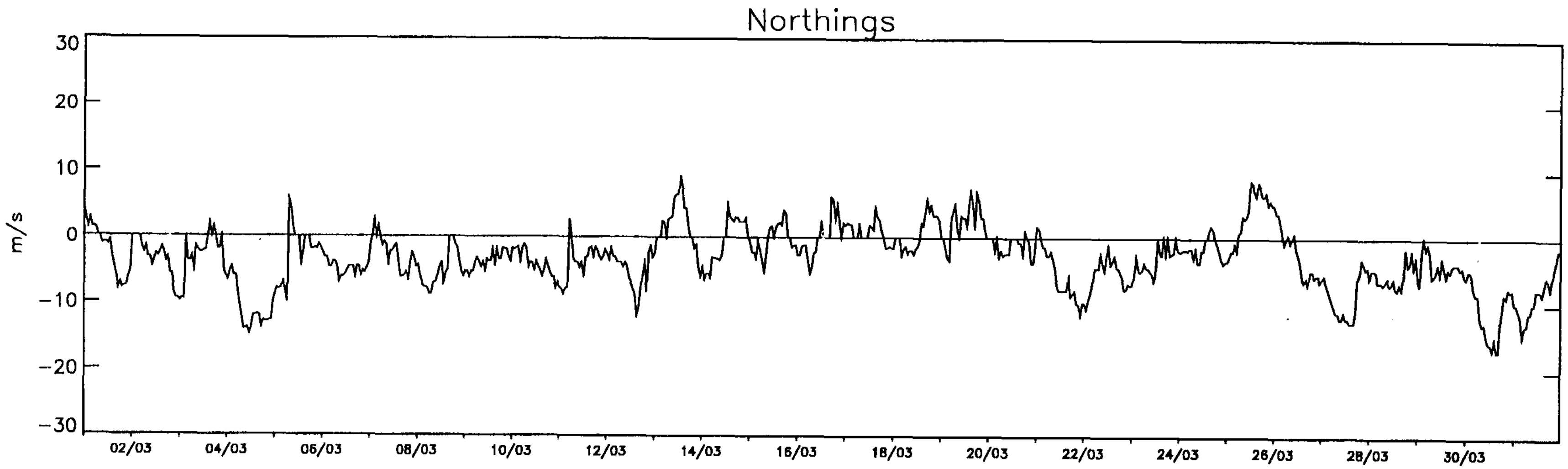


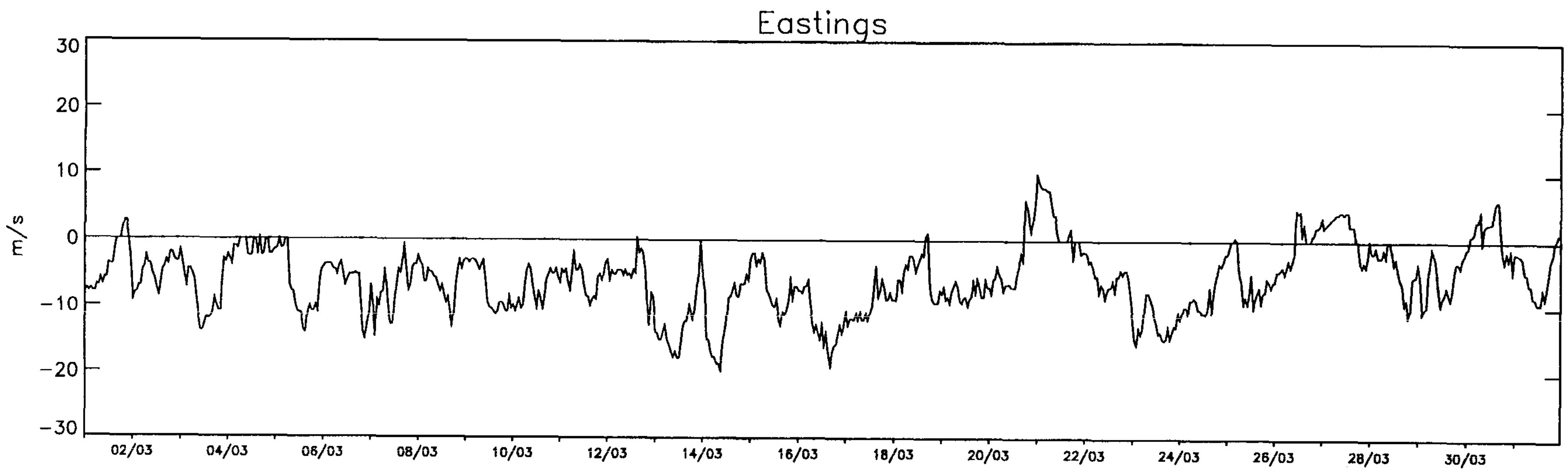
February 1994



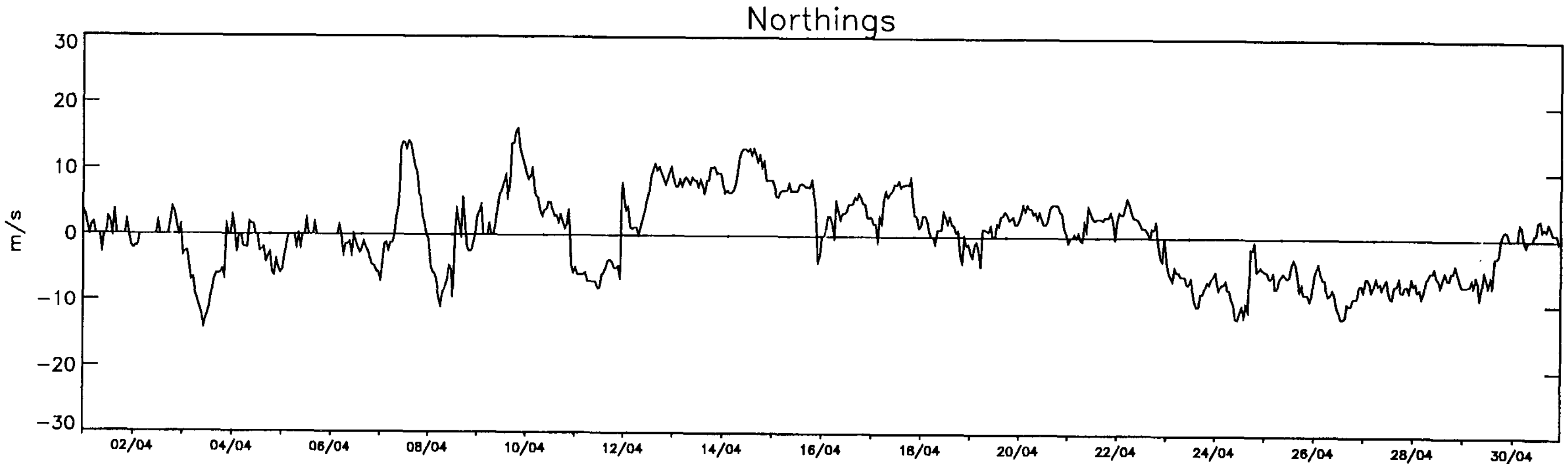


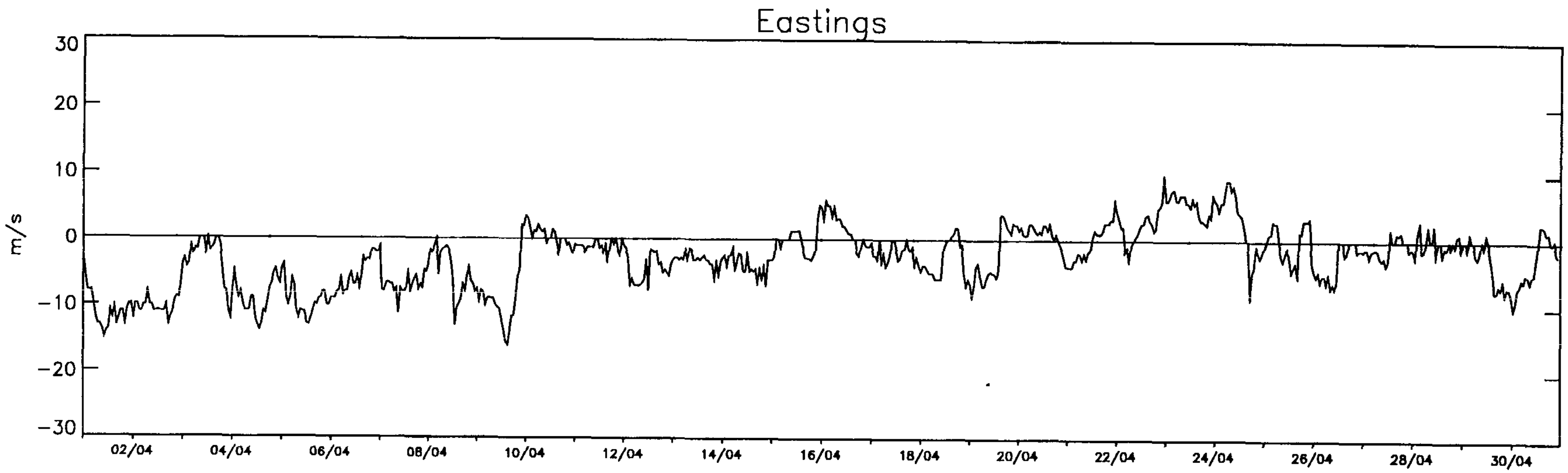
March 1994


Northings
m/s
30
20
10
0
-10
-20
-30
02/03
04/03
06/03
08/03
10/03
12/03
14/03
16/03
18/03
20/03
22/03
24/03
26/03
28/03
30/03


Eastings
m/s
30
20
10
0
-10
-20
-30
02/03
04/03
06/03
08/03
10/03
12/03
14/03
16/03
18/03
20/03
22/03
24/03
26/03
28/03
30/03

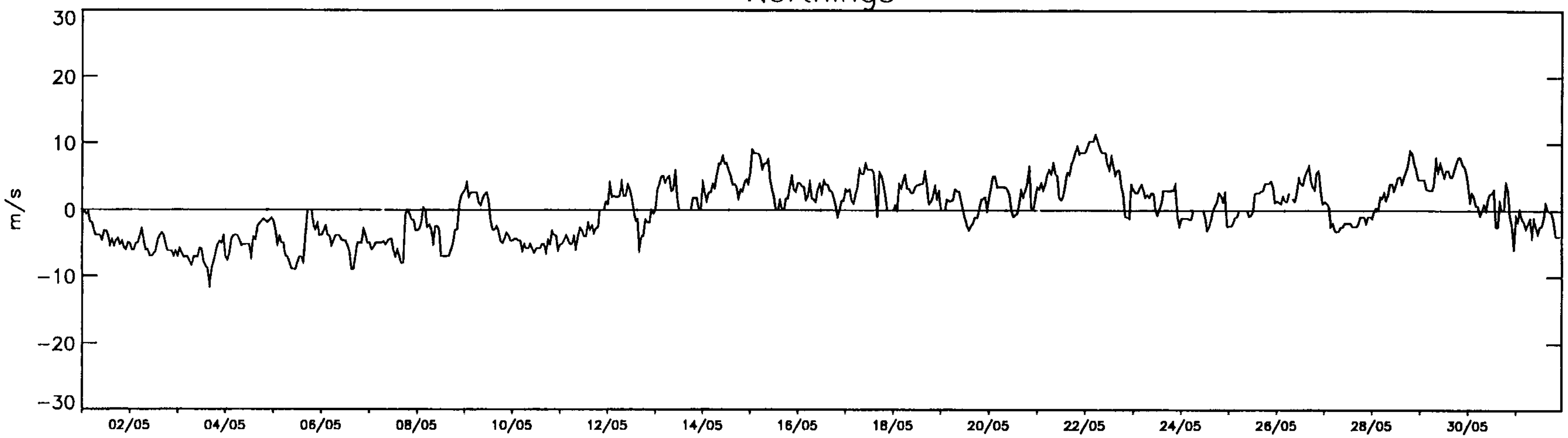
April 1994


Northings
30
20
10
0
−10
−20
−30
m/s
02/04
04/04
06/04
08/04
10/04
12/04
14/04
16/04
18/04
20/04
22/04
24/04
26/04
28/04
30/04

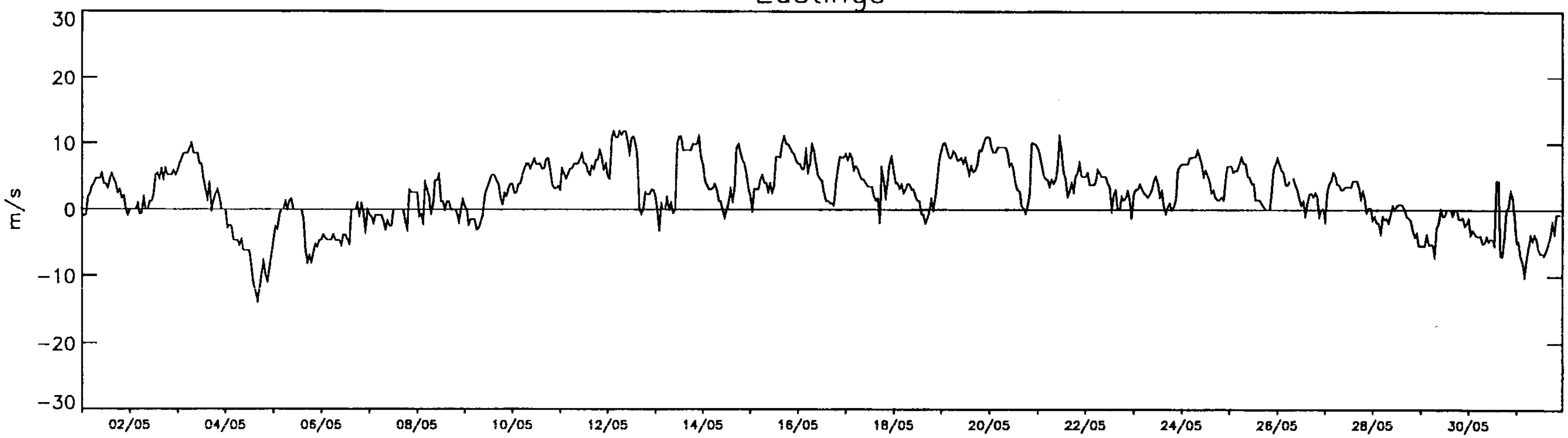

Eastings
30
20
10
0
−10
−20
−30
m/s
02/04
04/04
06/04
08/04
10/04
12/04
14/04
16/04
18/04
20/04
22/04
24/04
26/04
28/04
30/04

May 1994

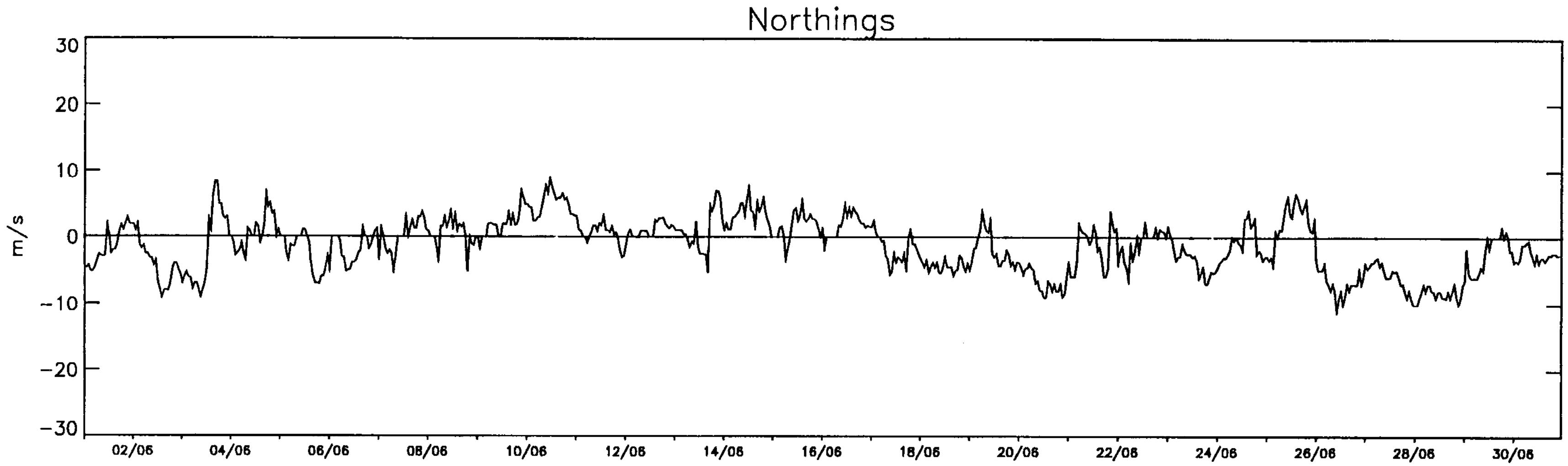
Northings

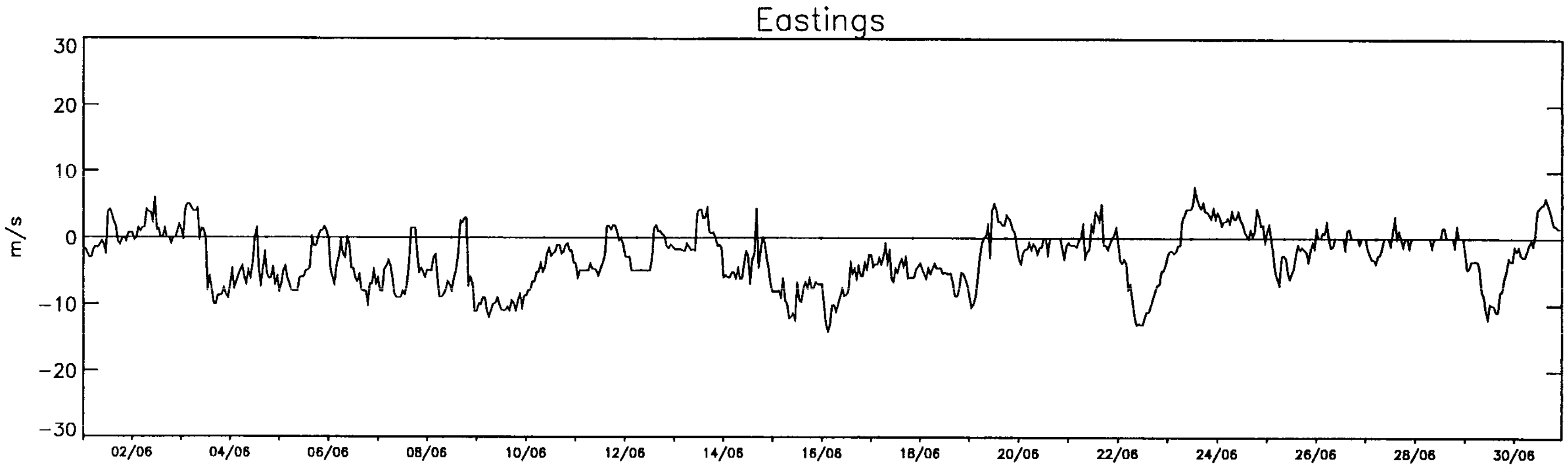


Eastings

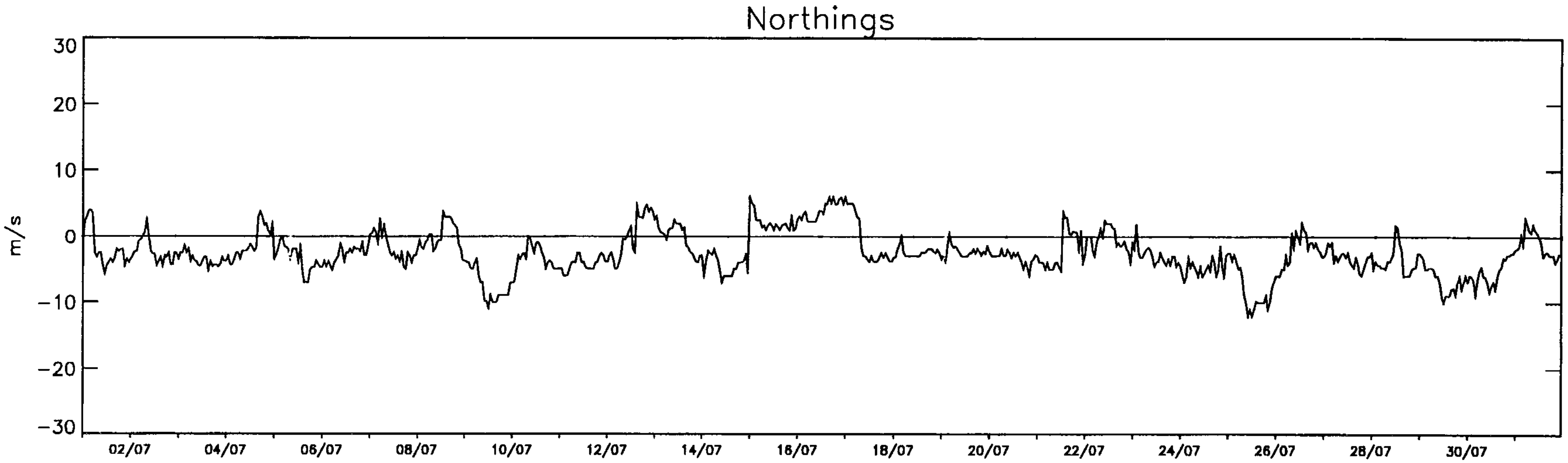


June 1994

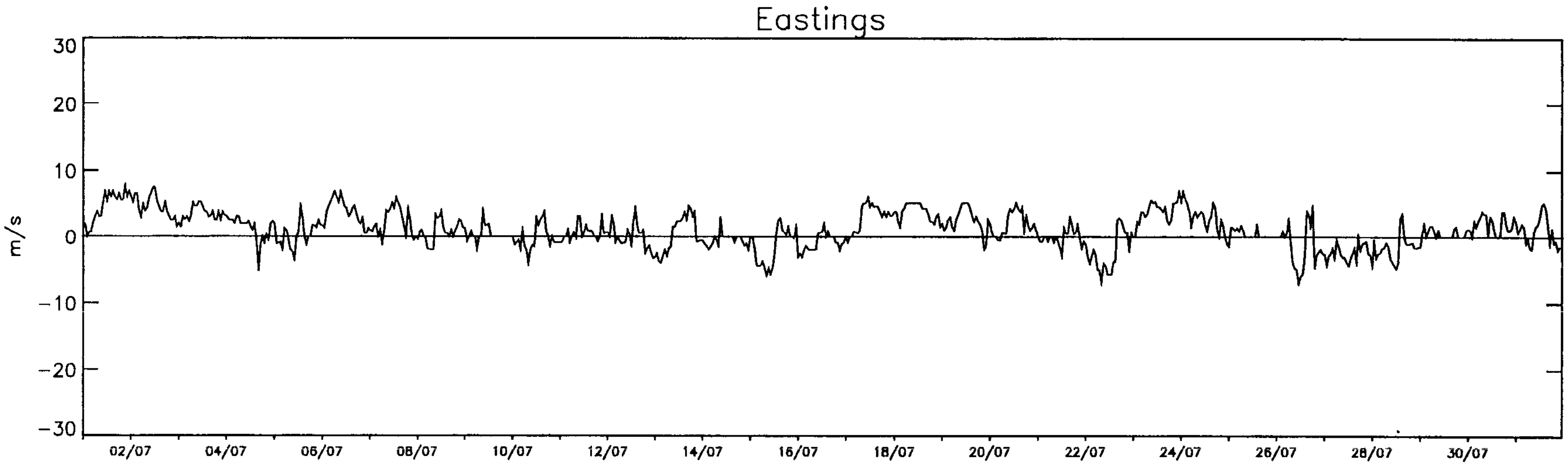

Northings
30
20
10
0
-10
-20
-30
m/s
02/06
04/06
06/06
08/06
10/06
12/06
14/06
16/06
18/06
20/06
22/06
24/06
26/06
28/06
30/06


Eastings
30
20
10
0
-10
-20
-30
m/s
02/06
04/06
06/06
08/06
10/06
12/06
14/06
16/06
18/06
20/06
22/06
24/06
26/06
28/06
30/06

July 1994

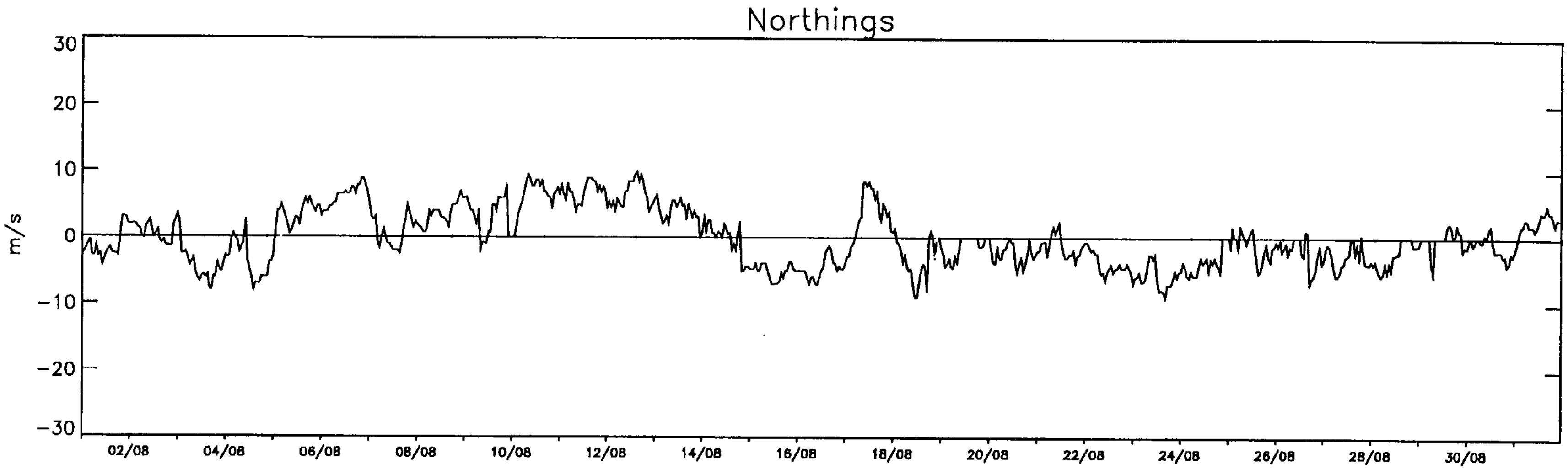


Northings
m/s
30
20
10
0
-10
-20
-30
02/07
04/07
06/07
08/07
10/07
12/07
14/07
16/07
18/07
20/07
22/07
24/07
26/07
28/07
30/07

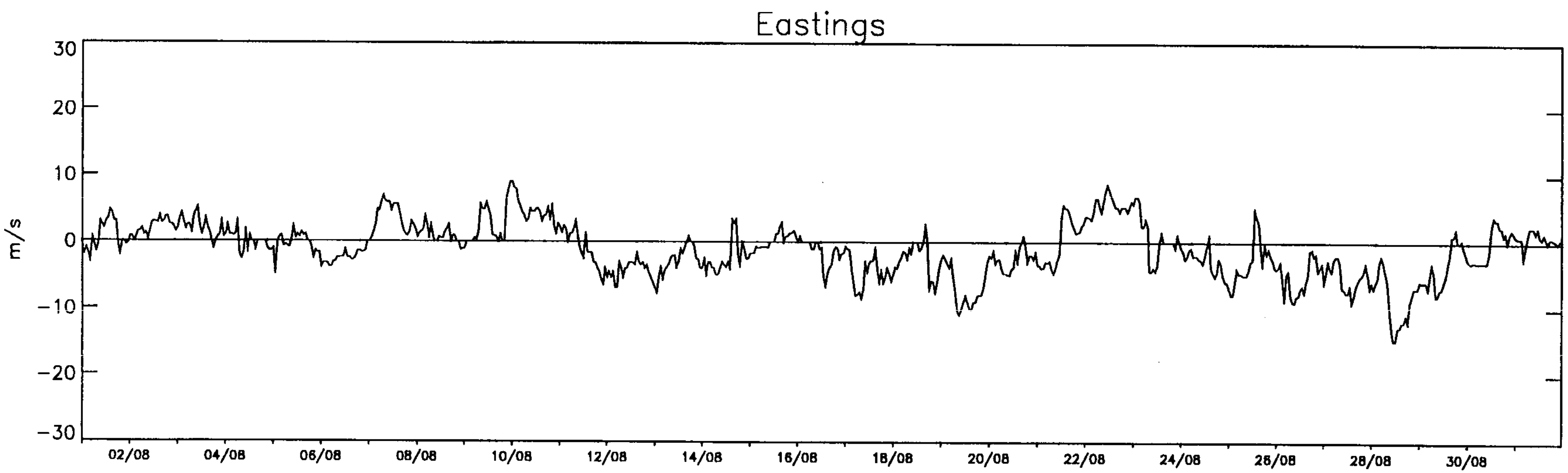


Eastings
m/s
30
20
10
0
-10
-20
-30
02/07
04/07
06/07
08/07
10/07
12/07
14/07
16/07
18/07
20/07
22/07
24/07
26/07
28/07
30/07

August 1994



Northings
m/s
30
20
10
0
−10
−20
−30
02/08
04/08
06/08
08/08
10/08
12/08
14/08
16/08
18/08
20/08
22/08
24/08
26/08
28/08
30/08



Eastings
m/s
30
20
10
0
−10
−20
−30
02/08
04/08
06/08
08/08
10/08
12/08
14/08
16/08
18/08
20/08
22/08
24/08
26/08
28/08
30/08