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C. S. S. Hudson, Jan. - Apr. 1967 Current Measurements on Hydrographic Stations

Notes on Method, and Station List

by

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Current Measurements on Hydrographic Stations

Sometimes, when hydrographic stations are being made, an unexpected wire angle may suggest that there are strong relative currents within the vertical column being sampled. Usually, though, nothing more is learnt about the currents beyond just suspecting their presence, and a ship hove-to on station is not a particularly steady platform from which to hang current meters.

However, the region of the Denmark Straits overflow seemed a favourable one in which to see what could be done about measuring currents on station, without interfering with the usual water-sampling procedure. Strong relative currents could be expected within a few hundred metres of the surface, which might be measurable in spite of the erratic movement of the ship on station. These notes are concerned with the current meters used and the "Hudson's" behaviour on station, relevant to using current meters. ~~A station list and an account of the current measurements themselves will appear separately.~~

Method

Two current meters were used simultaneously, to measure the difference in current between the end of the hydrographic wire and some shallow depth. A Kelvin-Hughes direct-reading current meter (DRCM), at a nominal depth of 15m, was read continuously and the average reading written down at 1 min. intervals. This gave the flow of water past the ship, not too much influenced by the shape of the hull (some evidence about this will be given later). A telemetering current meter developed by the Chr. Michelsen Institute, Bergen (BCM) was attached to the end of the hydrographic wire, together with the usual pinger, lead weight or whatever gear was in use. The BCM signals (a coded sequence of long and short pulses indicating rotor count, magnetic heading and temperature at 50-sec. intervals) were transmitted acoustically at 13·5 kc/s and received on an echo-sounding transducer hung over the ship's side, which was connected to a Sanborn recorder via a tuned amplifier. Usable records were obtained with the BCM down to 1785m, but that was close to the limit of the acoustic system. Most of the stations were in depths less than 1000m and except for one case when bad wire angles were experienced there was no difficulty with acoustic reception, using the over-the-side transducer. The hull-mounted echo sounding transducer, suffered too much from blanking by aeration to be usable for this purpose except in fairly calm conditions.

The usual practice was to put down the cast of water bottles and then take a current meter reading during the 7 - 10 mins. wait at the maximum depth, while the thermometers were equilibrating and the messengers travelling. Further measurements (usually 5 mins. each) were made at selected depths on the way up. This added very little to the overall time required to make a section, since water bottles were being removed and samples could be drawn during the 5-min. waits on the way up, and with closely-spaced stations the rate of working was limited by the time taken to clear the bottles and read the thermometers before starting the next station. The BCM records were decoded and mean values determined for the flow of water past the meter, at each depth where a measurement was made. At stations CM 18 - 27 the BCM was used below the bathysonde.

If the ship moved steadily through the water when on station, the current at any depth, relative to the surface, could be found by subtracting the steady DRCM reading from the BCM reading. The ship's movement on station is however quite variable; typically the vector mean over a period of an hour may be $\frac{1}{2}$ knot, but successive 5-minute means may differ from each other by as much as $\frac{1}{2}$kt, and the 1-minute readings fluctuate even more. These near-surface fluctuations of the ship's movement must penetrate down to the BCM at the end of the wire, with some delay and smoothing. A rough idea of the time constant involved can be got from considering a simple case, with the ship initially stopped and then suddenly moving with uniform velocity. The wire will change from vertical to a towing curve extending over some horizontal distance, and the time-constant required will be at least the time taken to steam that distance at the imposed uniform velocity. Using rough estimates of drag and weight of equipment used, and typically 800m of wire out, a time constant of about 7 mins. is suggested for $\frac{1}{2}$ knot speed change. However, these speed changes are not made arbitrarily but are applied deliberately in manoeuvring to keep the wire vertical at the surface. A fluctuation would not be allowed to persist more than a minute or two if it began to cause a wire angle of 10° or more, so that a simple towing situation does not arise. Without any real justification, but with the idea of making some allowance for the delayed and smoothed response of the end of the wire to the surface fluctuations of velocity, deep currents relative to the surface have been calculated by comparing the BCM reading with the mean DRCM reading over the same 5 mins. and the preceding 5 min. interval. Half the difference between these two 5-min. mean DRCM readings has been taken as a minimum estimate of the uncertainty of the relative current. Longer observations (7 - 10 mins.) were made at depths exceeding 1000m at some stations, and for these the DRCM readings were averaged over correspondingly longer periods.

To get true currents from the measurements relative to the surface, an estimate has to be made of the surface current. The mean DRCM reading for the whole station (typically 45 mins. duration) gave the mean flow of water past the ship at 15m depth. Loran observations were made every 15 mins., when conditions were suitable, to determine the ship's movement over the ground. Adding these two vectors gave the current at 15m depth. When the Loran was good, there was no difficulty in resetting to the nearest 1 μsec equivalent to ± ·02 ml. on 1L5 and ± ·04 ml. on 1L4 in the Denmark Strait area. The uncertainty in the ship's movement over the ground, in a 45-min. run, was therefore at least ± 0·4 kt, and might be much worse in poor Loran conditions. Farther south along the Greenland slope (CM 24 - 27) Loran coverage was better and its contribution to uncertainty of the surface current estimate might be as low as ± 0·15 kt. The mean DRCM reading had typically an uncertainty of about ± 0·2 kt, and the overall uncertainty of the surface current estimate combining Loran and DRCM observations should be in the range ± 0·3 to ± 0·5 knot. This is slightly more than the average uncertainty in measuring the relative currents, arising from the variable movement of the ship through the water, though the latter varies considerably with wind speed, and direction of current shear in relation to the wind as described below.

Behaviour of the "Hudson" on station

All these current measuring stations were worked with the ship hove to, with the wind on the starboard quarter. The transverse component of wind causes leeway to port which keeps the wire away from the ship's side. Fore and aft movement is a balance between the longitudinal component of wind and the thrust of the propellers going astern. Figs. 1-5 show the movement of the ship through the water on each station, in relation to wind and mean ship's head. It may come as a bit of a surprise to see that most of the ship's movement on station is leeway, and that this can often be as much as 1 knot. In Fig. 6 the leeway is plotted against transverse component of wind. The points are very scattered, but assuming that the leeway is proportional to wind speed (and ignoring effects of rudder and bow thruster on transverse speed) it looks as if the "Hudson" makes leeway on station at 1/23rd of the transverse wind speed. This will of course depend on the draught, being more when the ship is light. For comparison, the "Discovery" makes leeway on station at 1/15th of the transverse wind speed (having about the same amount of superstructure but less draught).

When strong relative currents are present, the wire tends to lead in the direction of the deep relative current and the ship has to be manoeuvred to reduce this tendency, i.e. the ship has to be made to drift in the direction of the deep relative current. The ease or difficulty with which this can be done depends on the direction of the current in relation to the wind. If the deep relative current runs directly against the wind, the ship can increase speed astern and steering becomes more stable. If the deep relative current runs out to port, the ship can be given more leeway by putting the wind nearer the starbd beam. The difficult situations arise when the deep relative current runs downwind or to starboard. In the first case, the ship has to reduce revs astern in order to drift downwind and is liable to fall away from the wind direction. In the second case, in order to make leeway to starboard to keep up with the wire, the wind may have to be put on the port quarter, and then brought back again as the wire is recovered. It may be expected therefore that the variability of the ship's movement through the water on station will depend not only on the wind speed and sea state, but on whether the relative currents are in a favourable or unfavourable direction.

As an index of variability of ship's movement, and of the reliability of relative current measurements, the r.m.s. difference between successive 5 - minute means of the DRCM readings has been calculated for each station. These are shown plotted vs. wind speed and wave height in Fig. 7. At stations unaffected by strong relative currents, the variability is roughly proportional to wind speed and not much dependent on estimated wave height. At wind speeds up to 30 knots, the mean of a pair of 5 - minute averages of the DRCM may be expected to have an uncertainty of ± 0·3 kt or less, except in unfavourable circumstances. Note that, to have a significant effect on the wire angle, it is the combination of speed and thickness of the deep relative current that is important (total drag on the wire). The fast currents near the bottom at stations CM 3, 4, 5 etc. did not cause bad wire angles at the surface.

The idea of an r.m.s. variability may be a useful guide to the kind of uncertainty to be expected in using current meters, but of course the variations are not random, sometimes conditions may be quite steady except for one or two large manoeuvres which completely dominate the r.m.s. variability. On such a station one could improve the current meter results by waiting for things to settle down, after a large manoeuvre. In the present series of observations, though, the readings were taken at the time available without waiting, since one of the aims was to make these measurements with as little interruption as possible to the normal water-sampling routine. Examples of steady and fluctuating conditions are shown in Figs. 8 and 9, where the components of each DRCM and BCM reading are plotted against time for stations CM 14 and 21. Although some short-period fluctuations can be seen in the BCM readings, as may be expected they do not correlate visibly with the DRCM fluctuations except when the BCM was at its shallowest depths. In station CM 21, evidently most of the variability was contributed by two large fluctuations, where the ship fell off the wind and had to go astern more vigorously to get back into it again.

Note on the BCM and DRCM

Part of the short period variability of the BCM readings comes from the coarseness of digitizing the rotor count. The BCM was intended as an anchored current meter, with one cycle being read at intervals of $\frac{1}{2}$ hr or so. With the normal gearbox provided between rotor and continuous potentiometer (40,000 : 1 reduction) a speed past the rotor of 1 cm/sec changes the rotor signal by approximately 1 bit per half hour. With the meter cycling continuously, as we were using it, this is much too insensitive and the gearbox ratio was changed to 8,000 : 1. Even this was fairly coarse - approx. 7 cm/sec for 1 bit change per cycle - but the gearbox ratio could not be reduced conveniently any further and might have begun to impose appreciable load on the rotor. Thus the speeds that can be inferred from the change in rotor count between successive cycles are quantized in 7 cm/sec jumps. The 5 - minute mean takes in 6 cycles, though, so that the mean should not be too coarse on this account, but some of the minute-by-minute scatter is caused by it.

The BCM is not the ideal meter for use on a wire over the side. The acoustic link is useful when the meter has to be used with water bottles, but with the STD some means of bringing the current meter signal up the conducting cable would be more satisfactory. The coding system is not easy to interpret directly into current and the temperature information is redundant when the STD is in use. The recording meter developed by Frassetto could be adapted to provide a shipboard record of current speed and direction, via the STD cable, that could be read much more rapidly.

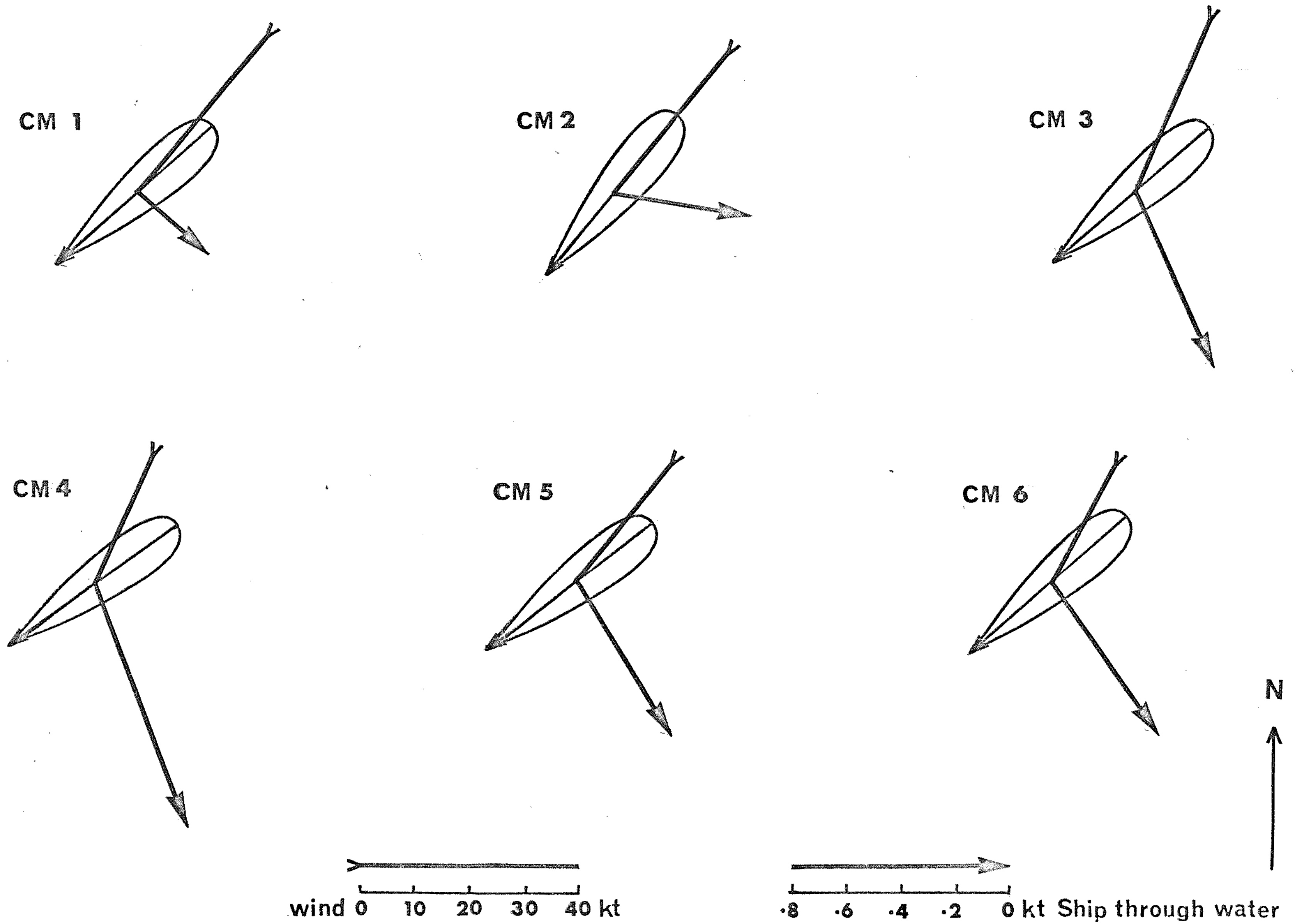
A self-recording meter of some kind would be more suitable than the DRCM, for use as the shallow meter. One advantage of the DRCM for this application is its fluxgate compass, which is less affected by proximity of the ship's hull than a free compass needle would be.

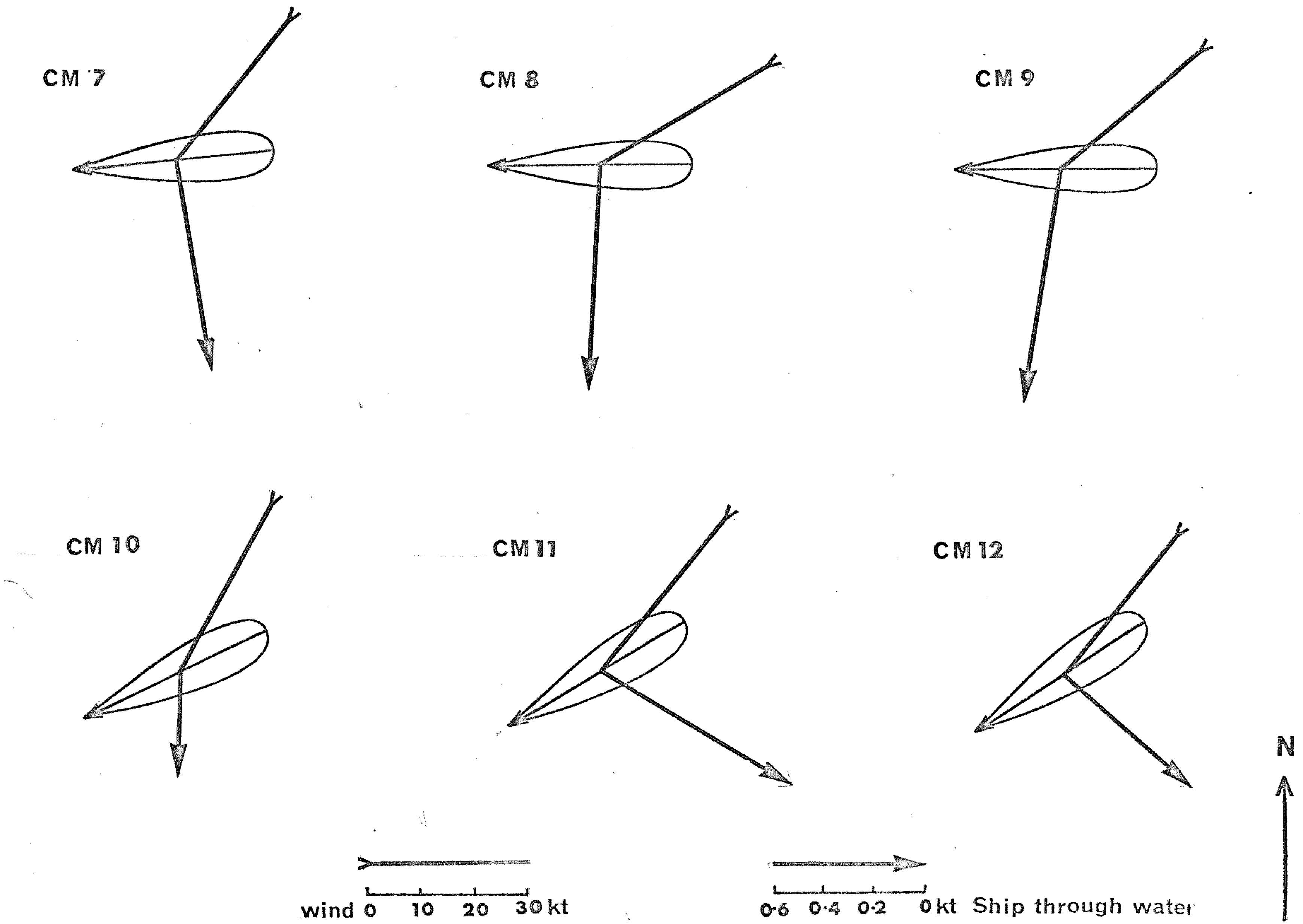
On the question of how deep the shallow meter should be, to avoid trouble due to the flow being distorted by the presence of the hull, we have found that 10m seems a satisfactory depth for the "Discovery", i.e. about twice the draught. On that basis, 15m was used on board "Hudson".

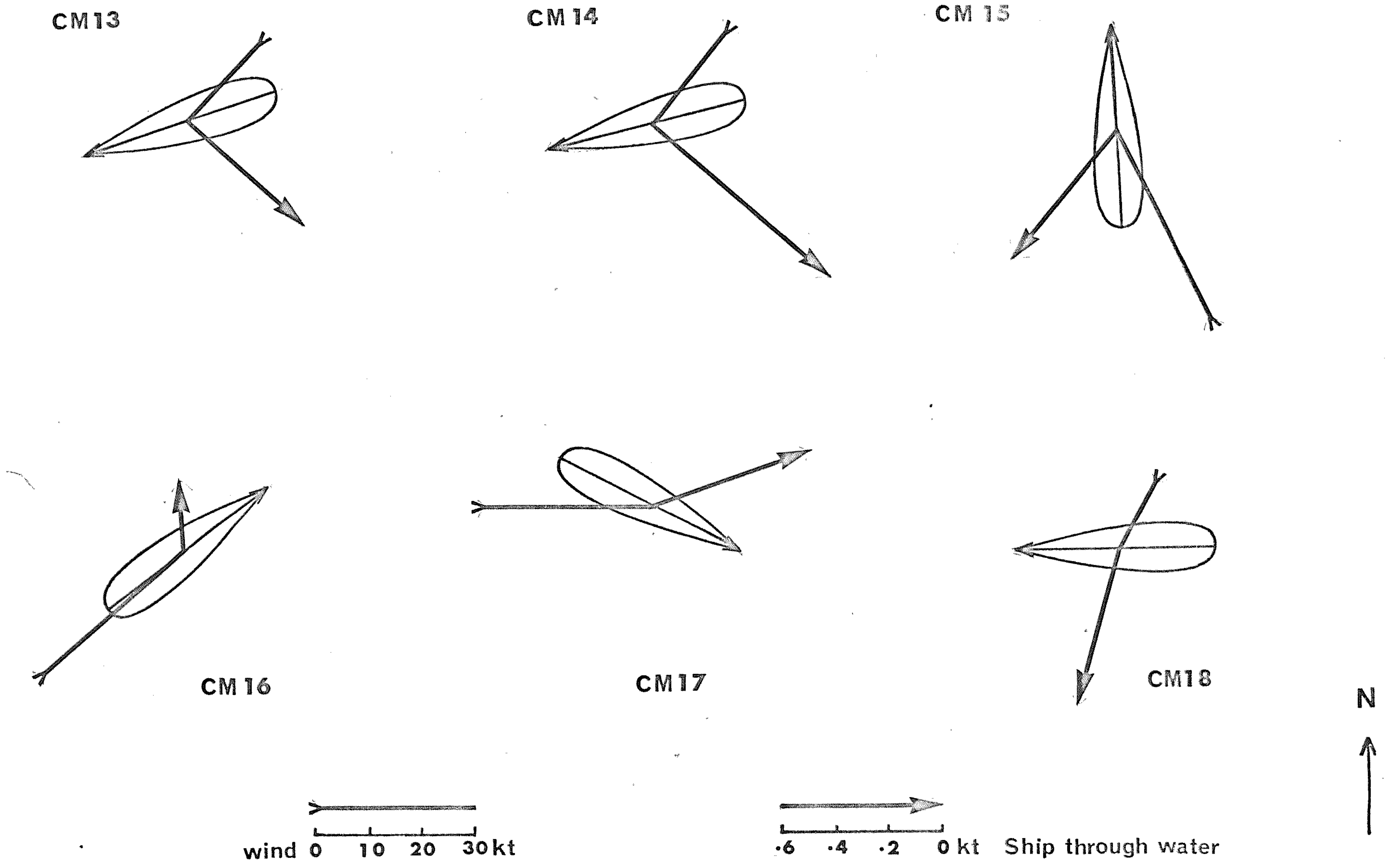
At those stations where there was a thick isopycnal layer at the surface, relatively small differences of current were observed when both BCM and DRCM were within the layer. This in itself suggests that the shallow meter was not being badly affected by the ship, and that the calibrations of the two meters were in reasonable agreement. Looking more closely at these differences of current within the uniform top layer, though, some are appreciably bigger than their estimated uncertainties. They appear to be in the sense that would be expected from the frictional effect of the wind. Observations of relative current in an isopycnal (within ·01 in σ_t) layer were made at 15 stations. Two of these had variable wind and 6 of the remainder had an uncertainty on the relative current of at least half the magnitude of the current. The remaining 7 observations are shown in Fig. 10. The current at 15m depth is plotted relative to that at the point deeper in the layer (depth marked at the origin). In all 7 cases the relative current (surface relative to deep) is to the right of the wind. The mean angle of deflexion is 64° (± 26°) The ratio of relative cureent to wind speed (brought to same units) is ·012 (± ·005).

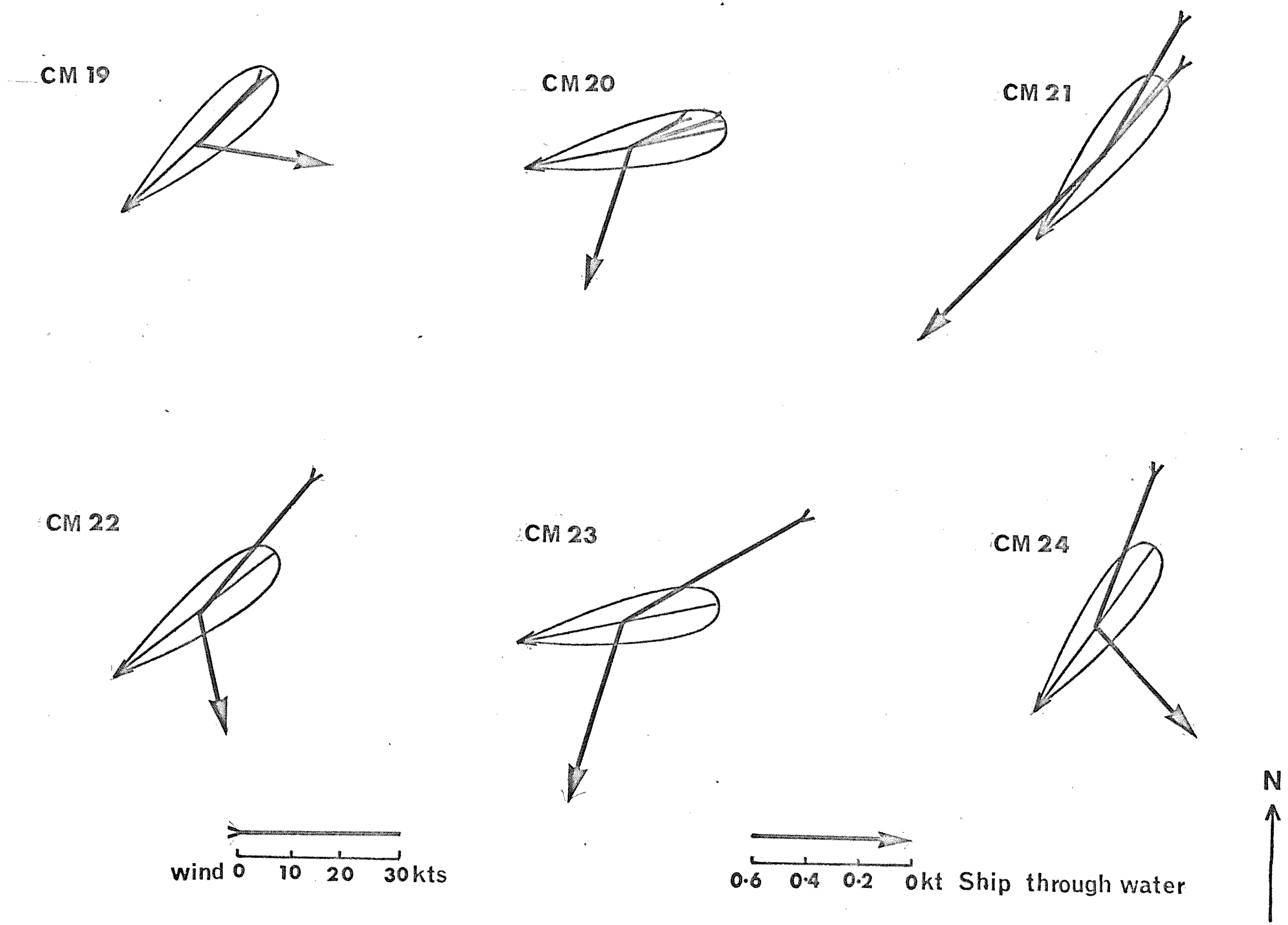
For an Ekman spiral (see Defant, Vol.I. p.418), $V_o = \frac{\cdot 012}{\sqrt{\sin \phi}} w$

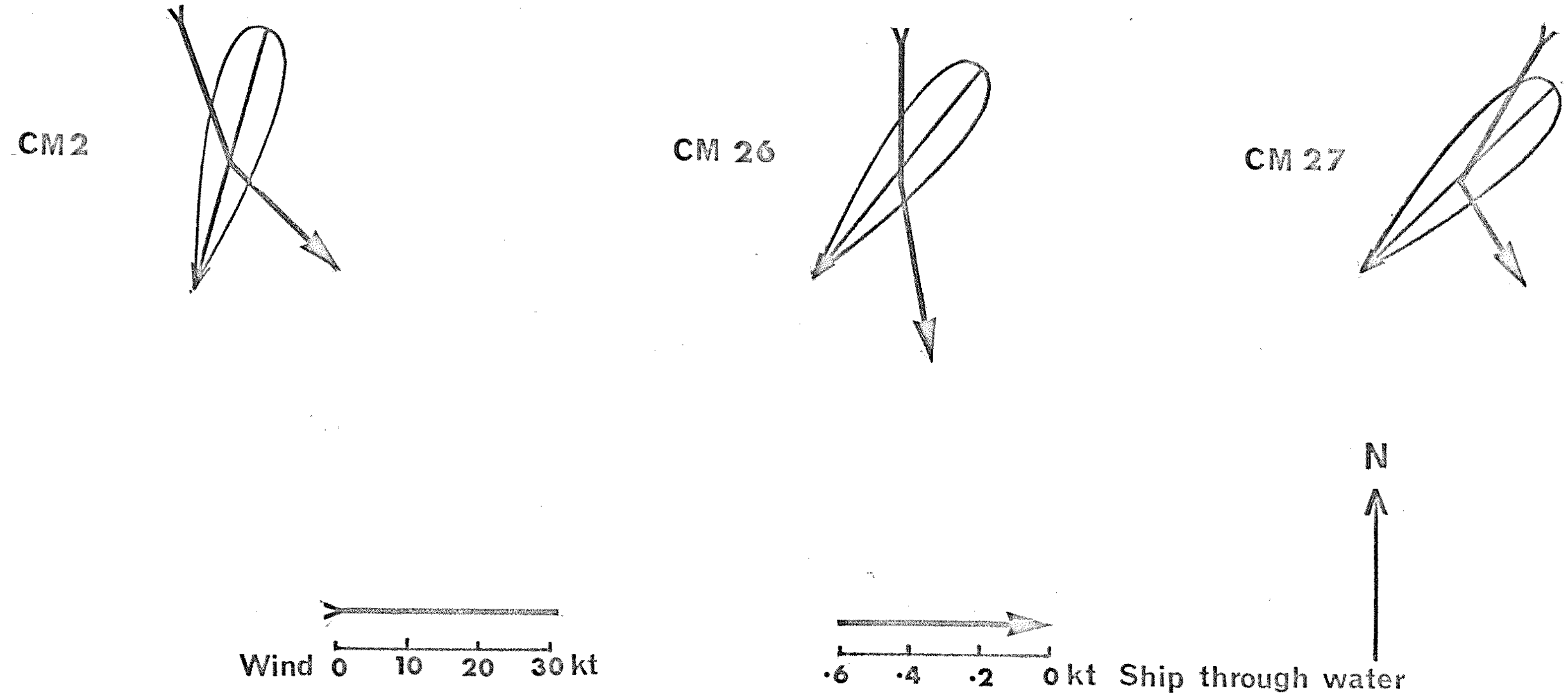
V_o = surface current, w = wind speed, ϕ = latitude. In our case ϕ mean = 65° and V_o = ·0127w, so that our observed mean ratio agrees very well. Why should it? The depth of homogeneous layer required for the Ekman spiral is $D = \frac{7.61 w}{\sqrt{\sin\phi}}$ (D in m. if w in m/sec) i.e. D ≈ 70m and our layers are easily deep enough in most cases. And 15m, though not the surface, is shallow compared to 70m, and the Ekman current would not be expected to have decreased much and should have rotated a bit clockwise, as observed. Since the average magnitude of these relative currents is 18 cm/sec, and their mean value appears to agree with the expected current to within about 40%, it seems unlikely that any systematic difference between BCM and DRCM will exceed 8 cm/sec, whether it arises from differences of meter calibration, or wave action on the DRCM, or distortion of the shallow flow due to the ship's presence.

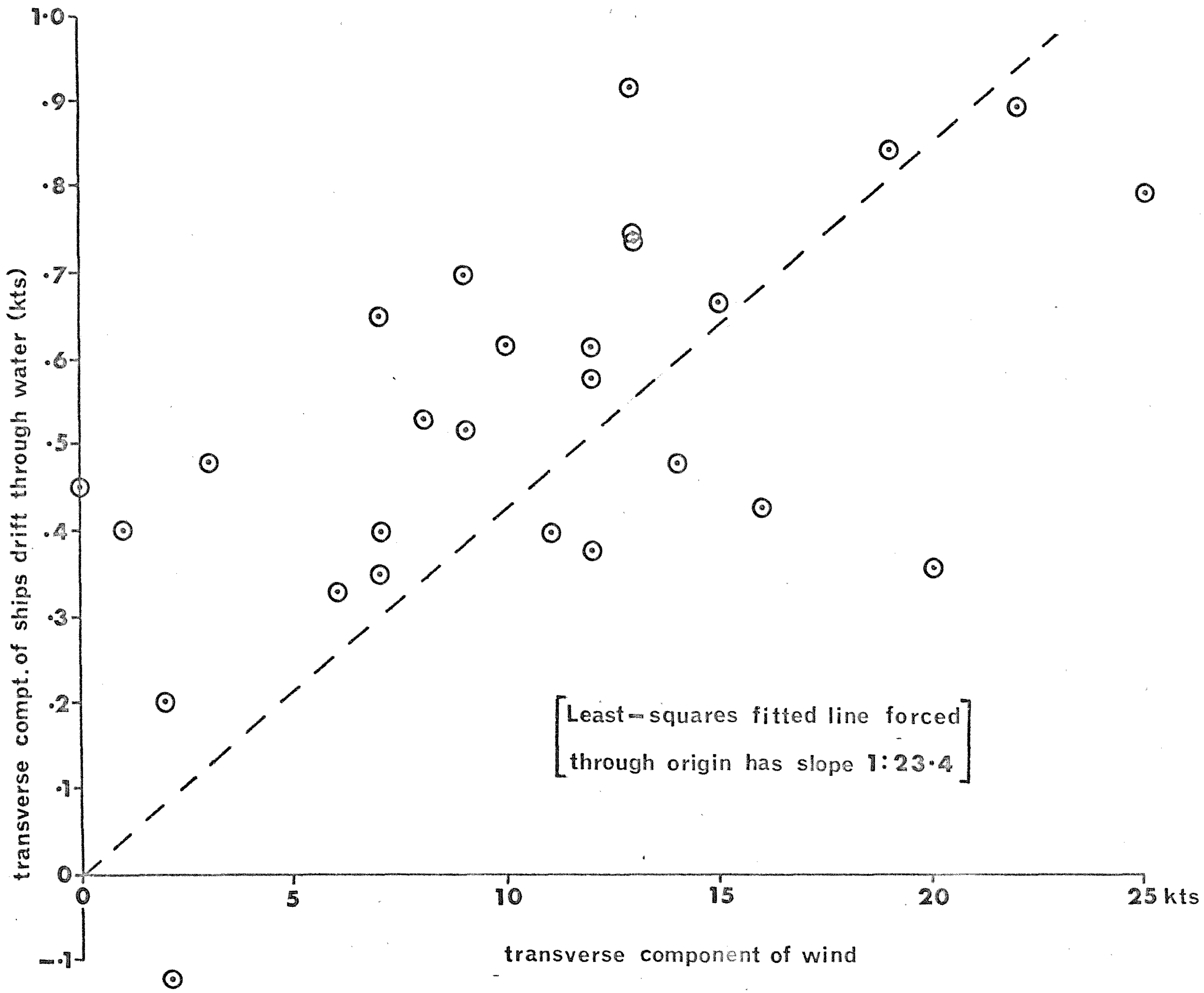

CM 1
CM 2
CM 3
CM 4
CM 5
CM 6
N
wind 0 10 20 30 40 kt
·8 ·6 ·4 ·2 0 kt Ship through water


CM 7
CM 8
CM 9
CM 10
CM 11
CM 12
wind 0 10 20 30 kt
0·6 0·4 0·2 0 kt Ship through water
N

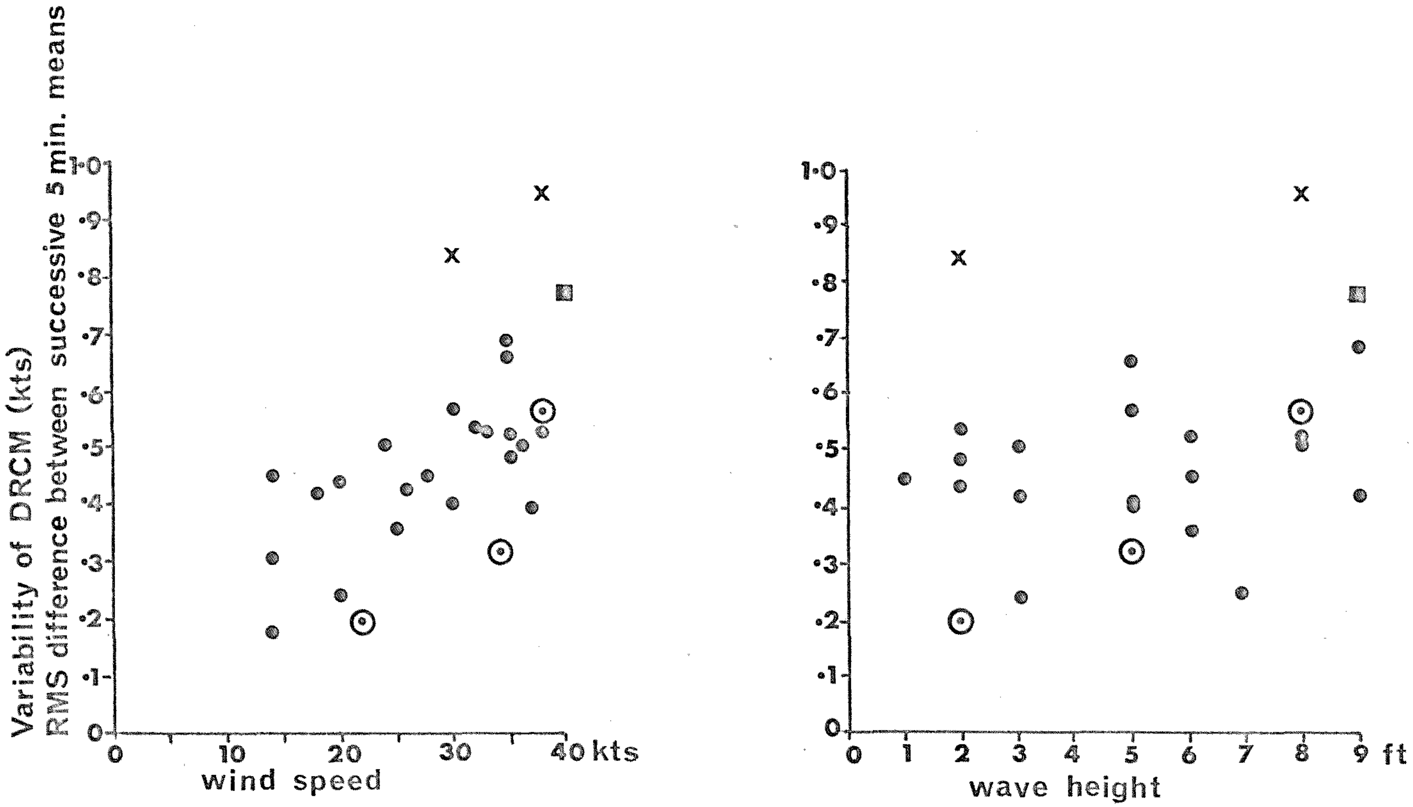

CM13
CM14
CM 15
CM 16
CM17
CM18
N
wind 0 10 20 30kt
·6 ·4 ·2 0kt Ship through water


CM 19
CM 20
CM 21
CM 22
CM 23
CM 24
wind 0 10 20 30 kts
0·6 0·4 0·2 0 kt Ship through water
N


CM2
CM 26
CM 27
N
Wind 0 10 20 30 kt
·6 ·4 ·2 0 kt Ship through water



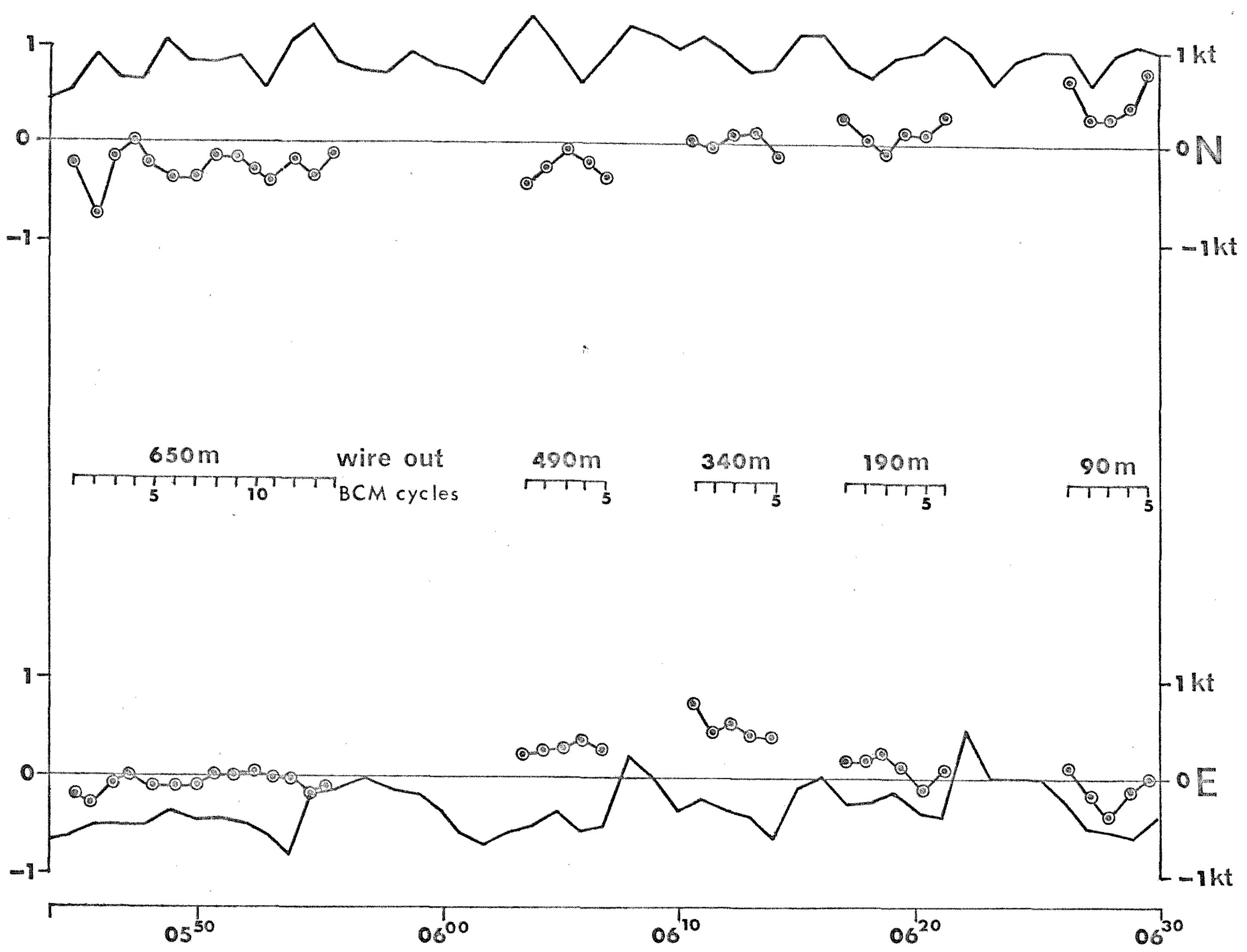
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
−·1
transverse compt. of ships drift through water (kts)
0
5
10
15
20
25 kts
transverse component of wind
[Least−squares fitted line forced through origin has slope 1:23·4]



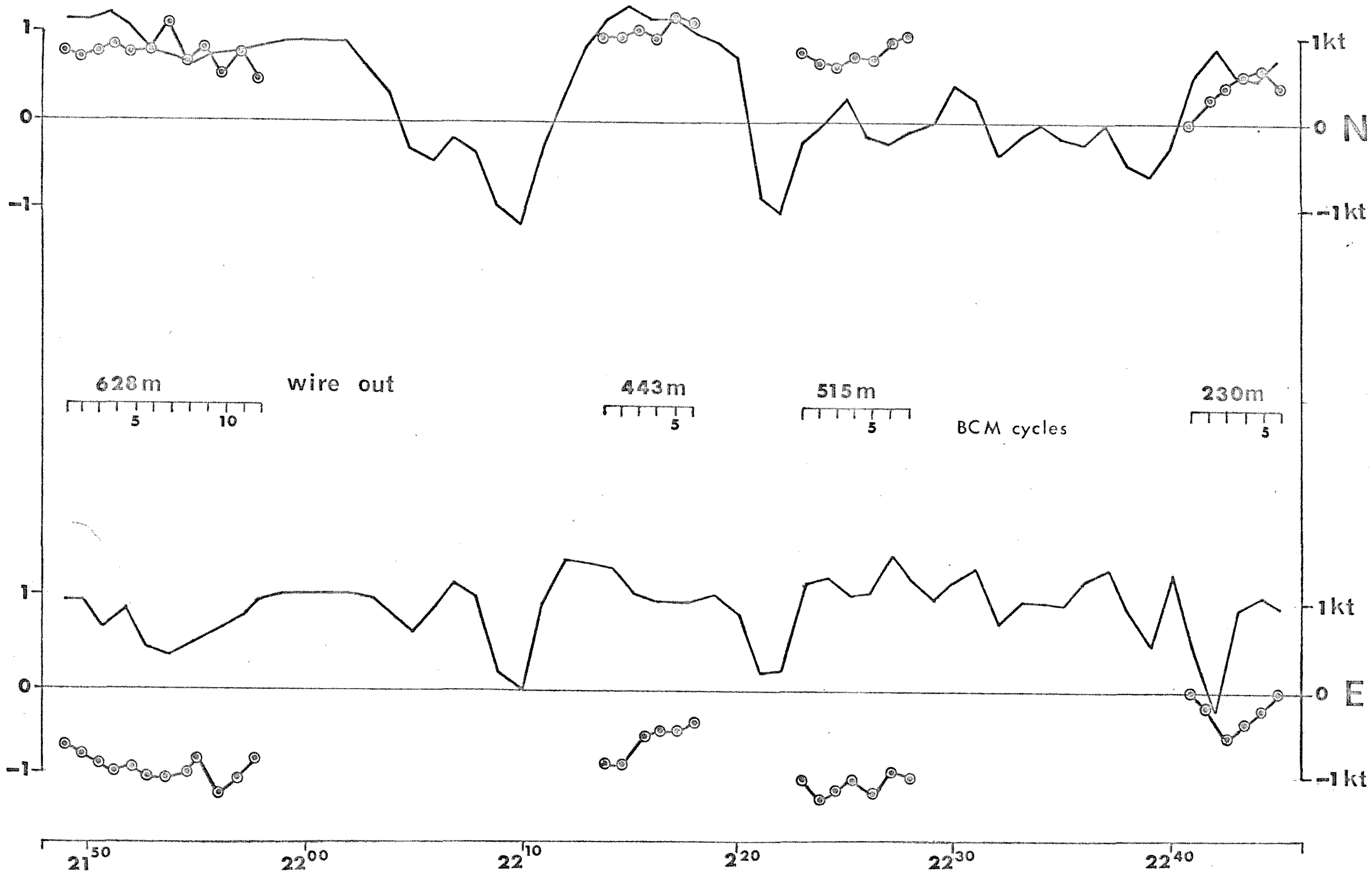
⊙ favourable relative current (CM 8, 12, 14)

x unfavourable relative current (CM 21, 23)

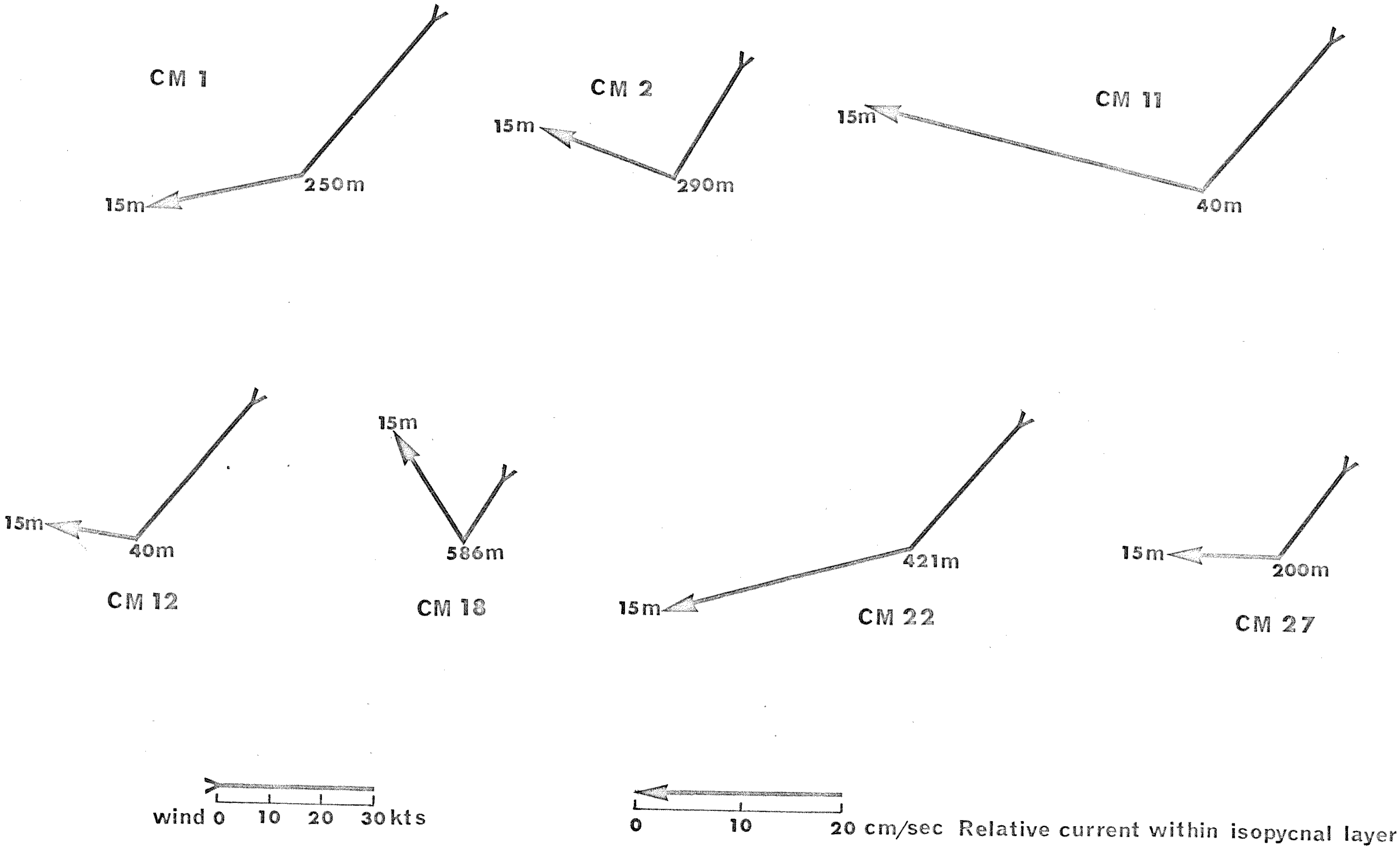
▪ large change of wind during station (CM 15)



CM 14 components of DRCM —— and BCM ⊙—⊙ (magnetic)



CM 21 components of DRCM —— and BCM ⊙——⊙ (magnetic)


CM 1
15m
250m
CM 2
15m
290m
CM 11
15m
40m
15m
40m
CM 12
15m
586m
CM 18
15m
421m
CM 22
15m
200m
CM 27
wind 0 10 20 30 kts
0 10 20 cm/sec Relative current within isopycnal layer

CM Station Data

CM No.	Wire out (m)	Depth (m)	Press. (dbar)	Deep current (1) (relative to 15m depth)		Scatter (1)	Components of deep current relative to 16m. (034°T)	(304°T)		"True" current (2)		Components of true current (034°T)	(304°T)	T°C
1									(15m)	15cm/sec,	310°T	+ 2cm/sec	+ 18cm/sec	
	250	246	248	16cm/sec	076°T	± 5cm/sec	+ 11cm/sec	-11cm/sec		15,	005°	+ 13	+ 7	6.88
	350	343	347	43,	162°	±14	- 26	-34		29,	181°	- 24	- 16	6.86
	450	442	446	22,	105°	± 9	+ 8	-21		10,	050°	+ 10	- 3	6.67
	550	540	545	10,	058°	± 7	+ 9	- 4		18,	340°	+ 11	+ 14	6.52
	650	638	644	5,	231°	± 7	- 5	+ 2		20,	295°	- 3	+ 20	6.48
2									(15m)	35,	284°	- 12	+ 33	
	250	250	252	8,	040°	±16	+ 9	- 1		32,	298°	- 3	+ 32	6.74
	500	500	504	15,	183°	±15	- 12	- 9		35,	259°	- 24	+ 24	6.62
	750	749	756	20,	083°	±18	+ 14	-15		18,	310°	+ 2	+ 18	5.68
3									(15m)	58,	293°	- 10	+ 57	
	400	392	395	23,	004°	±16	+ 19	+11		69,	311°	+ 9	+ 68	6.68
	700	683	690	55,	219°	± 3	- 48	+12		90,	263°	- 58	+ 69	4.35
	750	730	737	84,	203°	±12	- 84	-15		103,	238°	- 94	+ 42	0.75-1.05
4									(15m)	118,	323°	+ 38	+112	
	565	565	570	16,	208°		- 16	- 1		113,	315°	+ 22	+111	4.3 -4.9°
	615	605	610	55,	229°	±16	- 53	+13		127,	297°	- 15	+125	3.35-4.15°
	640	624	630	88,	217°	± 4	- 87	+ 4		126,	281°	- 49	+116	2.95-3.3°
	659	644	650	111,	214°	±11	-111	0		133,	271°	- 73	+112	2.3 -2.7°
	675	661	667	88,	201°	± 8	- 87	-21		104,	276°	- 49	+ 91	1.4 -1.7°
5									(15m)	134,	275°	- 65	+116	
	300	296	298	24,	127°	± 5	- 1	-23		114,	269°	- 66	+ 93	4.5°
	450	443	447	27,	114°	±15	+ 4	-26		109,	270°	- 61	+ 90	3.6° -4.0°
	500	492	497	53,	195°	±17	- 49	-18		152,	255°	-114	+ 98	2.6° -3.0°
	530	521	526	51,	199°	±11	- 49	-14		154,	256°	-114	+102	1.6° -1.9°
	564	555	560	68,	182°	±10	- 57	-34		147,	248°	-122	+ 82	1.50°
	575	566	571	61,	152°	±12	- 30	-52		114,	248°	- 95	+ .64	1.45°

Notes

(1) "Deep current relative to 15m depth" is the mean reading of the Bergen meter at that depth, minus the mean DRCM reading averaged over the same time interval and the preceding 5 mins. "Scatter" is half the difference between the mean DRCM reading in the same time interval and the mean in the preceding 5 mins.

(2) "True" current = ship's velocity over ground (Loran) + mean DRCM reading for whole station + Deep current relative to 15m depth.

CM No.	Wire out (m)	Depth (m)	Press. (dbar.)	Deep current (relative to 15m depth)		Scatter	Components of deep current relative to 15m		Components of deep current relative to 15m			"True" current		Components of true current		T°C
														(034°T)	(304°T)	
6							(034°T)	(304°T)	(034°T)	(304°T)	(15m)	147cm/sec,	285°T	- 48cm/sec	+138 cm/sec	
	290	290	293	14cm/sec,	110°T	± 4cm/sec	+ 2cm/sec	- 12cm/sec	+ 2cm/sec	- 12cm/sec		134,	284°	- 46	+126	5.0° - 5.15°
	340	340	343	10,	115°	± 9	+ 1	- 10	+ 1	- 10		137,	284°	- 47	+128	4.9° - 5.3°
	390	390	394	7,	183°	± 4	- 7	- 4	- 7	- 4		146,	282°	- 55	+134	2.5° - 2.8°
	430	430	434	27,	185°	± 4	- 24	- 14	- 24	- 14		144,	274°	- 72	+124	1.2° - 1.6°
	450	450	454	48,	188°	± 12	- 44	- 20	- 44	- 20		149,	266°	- 92	+118	1.1° - 1.35°
	475	476	480	56,	150°	± 14	- 26	- 50	- 26	- 50		116,	264°	- 74	+ 88	0.95° - 1.1°
	485	486	490	56,	165°	± 10	- 38	- 44	- 38	- 44		128,	262°	- 86	+ 94	0.95° - 1.1°
7							(037°)	(307°)	(037°)	(307°)	(15m)	78,	012°			
	242	236	238	10,	062°	± 10	+ 9	- 4	+ 9	- 4						6.25° - 6.3°
	492	481	485	16,	127°	± 18	0	- 16	0	- 16						5.45° - 5.7°
	517	505	510	84,	228°	± 26	- 82	+ 15	- 82	+ 15						- .5 - +2.35°
	542	529	534	78,	258°	± 28	- 59	+ 51	- 59	+ 51						- .5°
	562	549	554	74,	230°	± 16	- 72	+ 16	- 72	+ 16						± .5°
	575	562	567	60,	222°	± 2	- 59	+ 5	- 59	+ 5						- .5°- -.2°
8							(037°)	(307°)	(037°)	(307°)	(15m)	44,	002°			
	192	192	194	14,	129°	± 14	0	- 14	0	- 14		38,	020°			5.9°
	292	292	295	20,	157°	± 4	- 10	- 17	- 10	- 17		27,	020°			2.6° - 3.15°
	342	342	345	56,	217°	± 4	- 56	0	- 56	0		32,	268°			0° - 0.25°
	392	392	396	57,	214°	± 6	- 57	- 3	- 57	- 3		30,	263°			0.9°
	442	442	446	46,	215°	± 8	- 46	- 2	- 46	- 2		25,	283°			0.5° - 0.65°
	492	494	498	59,	227°	± 10	- 58	+ 10	- 58	+ 10		42,	275°			0.1° - 0.25°
	542	544	549	40,	222°	± 20	- 40	+ 3	- 40	+ 3		29,	300°			-.15° - -.2°
	602	603	609	55,	194°	± 16	- 51	-.22	- 51	-.22		15,	232°			-.15° - -.3°
9												Deep rel. to 15m. compts. (2)				
							(037°)	(307°)	(037°)	(307°)		(029°)	(299°)			
	100	99	100	13,	119°	± 8	+ 2	- 13	+ 2	- 13		0	- 13			6.2°
	200	198	200	13,	333°	± 7	+ 6	+ 12	+ 6	+ 12		+ 7	+ 11			+ 3.3°
	250	248	250	43,	230°	± 10	- 42	+ 10	- 42	+ 10		-40	+ 15			+ 0.2°
	300	297	300	36,	222°	± 10	- 36	+ 3	- 36	+ 3		-35	+ 8			+ 0.91°
	350	347	350	34,	234°	± 8	- 32	+ 10	- 32	+ 10		-30	+ 14			+ 0.74°
	400	396	400	48,	236°	± 12	- 45	+ 15	- 45	+ 15		-43	+ 21			+ 0.55°
	450	446	450	39,	227°	± 20	- 38	+ 7	- 38	+ 7		-37	+ 12			+ 0.33°
	500	495	500	49,	221°	± 30	- 49	+ 3	- 49	+ 3		-48	+ 10			- 0.02°
	560	554	559	32,	207°	± 15	- 31	- 6	- 31	- 6		-32	- 1			- 0.1°

CM No.	Wire out (m)	Depth (m)	Press. (dbar)	Deep currents (relative to 15m depth)		Scatter	Components of deep current relative to 15m.				T°C
10							(029°)	(299°)	(026°)	(296°)	
	40	40	40	18cm/sec,	007°T	(a)	+ 16cm/sec	+ 7cm/sec	+ 17cm/sec	+ 6cm/sec	5.9°
	90	89	90	20,	243°	± 10	- 18	+ 8	- 18	+ 9	1.85°
	140	138	139	23,	285°	± 5	- 6	+ 22	- 5	+ 22	+0.35°
	190	187	189	26,	301°	± 20	+ 1	+ 26	+ 2	+ 26	+0.6°
	240	236	238	21,	280°	± 10	- 7	+ 20	- 6	+ 20	+1.07°
	290	285	288	27,	290°	± 3	- 4	+ 27	- 3	+ 27	+0.94°
	340	334	337	26,	270°	± 20	- 13	+ 23	- 11	+ 23	+0.8°
	390	384	387	14,	286°	± 10	- 3	+ 14	- 2	+ 14	+0.6°
	470	463	467	22,	274°	± 3	- 10	+ 20	- 8	+ 20	+0.32°
	500	492	497	20,	265°	± 15	- 11	+ 16	- 10	+ 17	+0.28°
							(026°)	(296°)	(022°)	(292°)	
11	40	40	40	34,	103°	(a)	+ 8	- 33	+ 5	- 34	≤ -0.6°
	90	90	91	50,	076°	± 23	+ 32	- 39	+ 29	- 40	-0.15°
	140	140	141	43,	098°	± 7	+ 14	- 41	+ 11	- 42	0.3° -1.0°
	190	190	192	31,	125°	± 4	- 5	- 30	- 7	- 30	+0.75°
	240	240	242	44,	112°	± 6	+ 3	- 44	0	- 44	+0.25°
	340	340	343	30,	092°	± 2	+ 12	- 28	+ 10	- 28	+0.9°
	440	440	444	36,	081°	± 12	+ 21	- 30	+ 18	- 31	+0.6°
	490	490	495	30,	076°	± 6	+ 20	- 24	+ 18	-.23	+0.4°
12							(022°)	(292°)			
	40	40	40	9,	098°	(2)	+ 2	- 9			≤ -0.6°
	140	139	140	15,	071°	± 8	+ 10	- 11			≤ -0.6°
	240	239	241	32,	101°	± 3	+ 7	- 31			≤ -0.6°
	340	338	341	34,	091°	± 9	+ 12	- 32			+0.7°
	430	427	431	46,	079°	± 10	+ 25	- 39			+0.55°
13							(039°)	(309°)			
	142	143	144	18,	111°	± 5	+ 5	- 17			-0.6°
	292	292	295	41,	057°	± 8	+ 38	- 13			+0.25°
	442	441	445	35,	055°	± 3	+ 34	- 9			+1.0°
	582	580	585	32,	062°	± 8	+ 29	- 12			+0.7°

Notes (a) Bergen meter at 40m depth was compared only with same 5-min run on DRCM, not preceding 5 mins.

CM No.	Wire out (m)	Depth (m)	Press. (dbar)	Deep currents (relative to 15m depth)		Scatter	Components of deep current relative to 15m		"True" current			Components of true current	T°C
14							(039°)	(309°)					
	92	94	95	22cm/sec	123°T	± 5	+ 2cm/sec	- 22cm/sec					⩽ - 0.6°
	192	194	196	43,	125°	± 2	+ 3	- 43					0.0°
	342	344	347	63,	110°	± 2	+ 21	- 59					1.05°
	492	494	499	59,	117°	± 4	+ 12	- 58					+ 0.8°
	662	665	671	58,	127°	± 5	+ 2	- 58					+ 0.4°
15									(15m)	49cm/sec,	293°T		
	192	189	191	32,	152°	± 9				32,	253°		7.2°
	492	474	478	30,	137°	± 33				25,	262°		6.8°
	792	759	766	37,	100°	± 19				16,	324°		5.6°
	1102	1053	1063	34,	140°	± 22				24,	253°		4.9°
	1442	1362	1374	56,	139°	± 22				25,	200°		1.8°
16									(15m)	18,	340°		
	192	192	194	28,	296°	± 28				43,	313°		7.1°
	592	589	594	21,	343°	± 18				39,	342°		6.4°
	992	986	995	31,	221°	± 6				27,	256°		5.0°
	1287	1278	1290	44,	115°	± 28				34,	093°		4.5°
	1342	1345	1357	31,	151°	± 20				13,	140°		3.4°
	1457	1460	1473	39,	136°	± 12				24,	119°		2.35°
17									(15m)	68,	298°		
	1192	1180	1191	56,	122°	± 10				13,	280°		4.5°
	1492	1476	1489	57,	137°	± 18				23,	245°		4.1°
	1717	1698	1714	53,	159°					45,	247°		1.7°
18	586			13,	148°	± 6							6.45°
	683			33,	249°	± 3							5.1°
	737			25,	254°	± 3							4.2°
	801			100,	239°	± 9							+ 0.4°
19	419			30,	122°	± 2							6.3°
	559			14,	034°	± 1							5.9°
	703			20,	059°	± 7							5.7°

CM No.	Wire out (m)	Depth (m)	Press. (dbar)	Deep currents (relative to 15m depth)	Scatter	Components of deep current relative to 15m	"True" current	Components of true current	T°C
20									
	203			19cm/sec 146°T	± 12cm/sec				6.4°
	637			23, 353°	± 15				6.1°
	698			28, 268°	± 17				5.65°
21									
	233			61cm/sec 255°T	± 16				4.2°
	446			85, 262°	± 35				+0.3° - 0.9°
	518			111, 249°	± 33				+ 1.1°
	631			88, 231°	± 10				+ 0.8°
22									
	421			25, 076°	± 3				6.4°
	543			12, 284°	± 8				4.6°
	678			73, 270°	± 16				2.8° - 3.4°
	804			64, 252°	± 11				+ 0.7°
23									
	362-276			57, 323°	± 11				2.6° - 3.2°
	556			71, 313°	± 27				1.3°
	642			38, 276°	± 28				+ 0.8°
24							(15m) 34cm/sec 275°T		
	400			5, 027°	± 16		33, 283°		5.65°
	1088			41, 078°	± 12		12, 025°		4.0°
	1473			29, 077°	± 15		11, 330°		3.1°
	1740			20, 224°	± 15		50, 256°		1.6°
25							(15m) 45cm/sec 242°T		
	600			12, 285°	± 7		54, 250°		4.5°
	916			4, 197°	± 16		48, 238°		4.0°
	1135			5, 074°	± 9		41, 240°		3.3°
26							(15m) 48cm/sec 140°T		
	150			16cm/sec 324°T	± 10cm/sec		32, 138°		5.1°
	689			21, 258°	± 9		43, 166°		3.75°
	1200			26, 284°	± 14		31, 170°		2.95°
	1734			25, 000°	± 4		33, 111°		2.45°
27							(15m) 24, 240°		
	200			11, 091°			15, 218°		5.1°
	409			13, 035°	± 11		13, 264°		4.8°
	1019			2, 350°	± 6		23, 243°		3.8°
	1631			20, 287°	± 8		40, 261°		2.7°
	1785			22, 274°	± 4		44, 256°		1.95°