POLYMODE NEWS

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In this issue:

MESOSCALE MONITORING IN THE EASTERN NORTH ATLANTIC (NORTH EAST ATLANTIC DYNAMICS STUDIES)

by John Gould

A subgroup of SCOR Working Group 34 (internal dynamics of the ocean) has been established to "consider the possibility of designing a suitable eastern North Atlantic experiment". This group, consisting of Joseph Gonella (Laboratoire d'Océanographie Physique, Paris), Gerold Siedler (Institut für Meereskunde [I.F.M.], Kiel), and John Gould (Institute of Oceanographic Sciences [I.O.S.], Wormley), met in late March, 1976 to consider how we might use the resources of European oceanographers to observe mesoscale activity in the eastern basin of the North Atlantic. We were joined by Harry Hill of the Fisheries Laboratory, Lowestoft, who had expressed interest in the project.

The outcome of the meeting was a plan for the maintenance of six mooring sites east of the Mid-Atlantic Ridge. The locations of these sites are shown in Figure 1.

Sites 1 and 2 will be the primary responsibility of the I.F.M.; Sites 3 and 4 will be maintained by I.O.S.; Sites 5 and 6 are the joint responsibility of I.O.S. and Lowestoft; and Site 7* will be maintained by National Center for the Exploitation of the Ocean (CNEXO). The mooring positions and water depths are given in the Table 1:

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THE ENTRAINMENT OF GULF STREAM WATER BY A CYCLONIC RING

by Phil Richardson

Nelson Hogg and John Dunlap showed an interesting XBT, GEK, and ship's drift section from Beaufort, North Carolina to Bermuda across the Gulf Stream and through two rings (POLYMODE News No. 7). They commented that "the strong northerly flow to west of the (westernmost) ring is a puzzling feature of each curve." I would like to offer an interpretation of some of this data.

Frequently, satellite infrared (IR) photographs show that when rings move close to the Gulf Stream, they entrain the warmer Gulf Stream core water and advect it cyclonically. Occasionally, this water is carried nearly all the way around the ring (see the IR photo of April 28, 1974 in MODE Hot Line News No. 83). During the time of the R/V Eastward cruise described by Hogg and Dunlap (14-15 October, 1975), this phenomenon was observed by satellite. My interpretation of the IR data from this period is shown in Figures 2 and 3 . The warm Gulf Stream water is clearly visible in Hogg and Dunlap's Figure 2a (reproduced here with my added notations as Figure 3) over the Gulf Stream and over the left side of the western ring.

Associated with the edge of the warm-core water is a 100 m rise of the seasonal thermo-

(continued page 4, lower half)

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*[Editor's Note: All references to Site 7 were added in press by the editor.]

MESOSCALE MONITORING IN THE EASTERN NORTH ATLANTIC (continued)

Site	Position	General Area	Depth
1	33°N, 22°W	Center Madeira Abyssal Plain	5200 m
2	38°N, 17°W	East of Azores Fracture Zone	5400 m
3	42°N, 14°W	Iberian Abyssal Plain	5200 m
4	41°N, 25°W	Flank of the Mid-Atlantic Ridge	3400 m
5	46°N, 17°W	In Abyssal Hills Diffusion-Exp. site	4500 m
6	52½°N, 17¾°W	I.O.S. mooring 117	4100 m
7	42°N, 10°W	Galicia Trough	3000 m

Table 1 (Gould)

The factors governing the choice of sites were that the pattern of moorings should cover a large area of the eastern North Atlantic and that the moorings should be far from large topographic features, such as islands and continental slopes. Additional specific considerations were:

Site 1--at the center of a large (Madeira) abyssal plain.

Site 2--fills the gap between moorings north and south of the Azores Fracture Zone.

Site 3--an abyssal plain site near the location of the I.O.S. 1975 topographic experiment and from which three months of current records are available.

Site 4--on the flank of the Mid-Atlantic Ridge; data at this location may give an indication of any anomalous conditions due to the presence of this large topographic feature.

Site 5--chosen by Lowestoft for their diffucion studies in the deep ocean.

Site 6--not far removed from the northern extremity of the basin. Current records of almost four months duration were collected at this position by I.O.S. in 1972.

Site 7--a mooring will be set for at least a year by the French CNEXO in early 1977.

All of the moorings will have subsurface buoyancy and current meters at 600, 1500, 3000 m depth, and at 500 m above the sea bed. All the sites will be maintained for a minimum of one year, and hopefully for two years or more. The first deployments will be late in 1976 or late in 1977.

The rather small total effort involved has consciously been widely spread to produce an "incoherent" array. From this we hope to gain information on the large-scale spatial variability of energy levels, time scales, and vertical current structure. Information on mesoscale spatial variability will not be forthcoming from the initial array experiment. Although such information is important, the present level of equipment availability makes the deployment of additional "coherent" clusters impossible. Should this situation alter, however, coherent arrays will be set in conjunction with the large-scale array.

In the meantime, as much information as possible on the smaller scales will be collected from CTD or XBT surveys and from a study of existing hydrographic data.

The POLYMODE* News is produced at the Woods Hole Oceanographic Institution. It is edited by Ferris Webster and Leigh Stoecker.

If you have material of interest for this newsletter, please get in touch with either of the above at the Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, Telephone (617) 548-1400.

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*POLYMODE is derived from the names of the U.S.S.R. POLYGON experiments and the Mid-Ocean Dynamics Experiment (MODE).

MESOSCALE EDDY STRUCTURE IN THE POLYGON AREA

by Luch Fomin and Abram Yampolsky

Koshlyakov (MODE Hot Line News No. 12) studied the structure of an anticyclonic eddy observed during the POLYGON experiment in the tropical Atlantic in 1970. He estimated eddy parameters and the evolution with time of the eddy, considering mainly the spatial distribution of the currents measured over the mooring array. Here, in order to study the local kinematics of a mesoscale eddy field in the POLYGON area, we start with the temporal variability of currents at every point of the array. We then estimate the spatial variation of the parameters describing the temporal variability. This method seems to be fruitful because time series are more informative than the spatial distribution of vectors.

We consider here only results from the 300 m level where data are the most extensive. Short-period fluctuations, including inertial motions, were eliminated by a low-pass filter. It was convenient for our calculations to use a co-ordinate system with horizontal axes x and y directed northwest and southwest, respectively: x = y = 0 at the array center, t = 0 at the middle of the measurement period (9 June, 1970).

The hodograph of velocity shown in Figure 4 exhibits two time scales of variability: loops of the hodograph with clockwise rotation have a period of between two and three months; the motion of the loops counterclockwise has a scale of about one year. The time-scale estimates were refined by computations, and it was found that the dominant periods were 75, 80, 300, and 400 days.

Beyond our expectations, two wave pairs with constant amplitudes can approximate the variations in the velocity components at all points of the array from early May to mid-August (Figure 5). At the beginning and end of the measurement period, the approximation deteriorates, which could testify to a more complicated long-term wave structure. The calculations have also shown that wave phases vary from one point to another monotonically proportional to the distance between them.

We can approximate the time-space structure of POLYGON currents by four simple, plane waves:

$$u = u_0(x,y) + \sum_{j=1}^{2} a_j \cos(2\pi y/L_j - 2\pi t/T_j + \theta_j) ,$$

$$v = v_0(x,y) + \sum_{j=1}^{2} a_j \cos(2\pi x/L_j - 2\pi t/T_j + \theta_j) .$$

Calculated wave parameters are tabulated in Table 2.

The additive constant velocity (u_0, v_0) was not high at the 300 m level, $|v_0| \leq 5$ cm/sec. If one assumes that the wave parameters estimated above are also valid in the vicinity of the array, a mesoscale velocity field can be constructed beyond the array square.

Two fast waves form a densly-packed field of eddy disturbances (Figure 6a). The eddy pattern moves in the direction of 280° at 8.9 km/day. Within the period of 1 May to 15 August, three eddies of this kind have passed, while within one-half year up to five eddies could pass.

The slow eddy field is shown in Figure 6b. This kind of eddy disturbance moves in the direction of 265° at 2.4 km/day. Within the time of the observations, hardly more than one eddy has passed through the array.

Figure 7 shows the evolution of the sum of two densely-packed eddy fields. They illustrate the horizontal structure and time evolution of mesoscale currents in the POLYGON area. The current field is rather complicated and varies periodically in time and space.

(continued page 4)

MESOSCALE EDDY STRUCTURE IN THE POLYGON AREA (continued)

One can conclude that the anticyclonic POLYGON eddy described by Koshlyakov was 300 km southwest of the center of the array at the beginning of May. After 20 days, the eddy was in the array and moving westward at 6 km/day. The eddy current velocity within circular streamlines initially rose and then began decreasing. The orientation of eddy axes did not vary with time. By 10 July, the eddy reached the state in which it was at the beginning of May. By 20 July, the eddy quickly spread to the northwest.

The evolution of the anticyclonic eddy from 1 May to 20 May is shown in Figure 8. One mesoscale eddy disappears and another forms as the eddies shown there (1 May and 15-20 May) have been formed by different pairs of fast and slow eddy disturbances. Thus, the anticyclonic eddy was formed between 5 May and 10 May, east of the array center. It moved to the west about 500 km during three months. It disappeared at the end of July.

The small dimensions of the array and the short duration of the measurements enabled us to estimate local parameters of component waves only. The streamline pattern obtained here cannot be expanded in space and time far from a point x = y = t = 0. A more detailed impression of the eddy field may be obtained during a more extensive future experiment we hope to conduct. The results should be useful for planning POLYMODE.

Velocity Component	a (cm/sec)	L (km)	T (days)	θ (rad.)	Movement Speed (km/day)	Movement Direction	Wave Type
u	10	440	80	-2.75	5.0	225	Fast
v	5	550	75	0.73	7.3	315	
u	7	750	400	-2.19	1.9	225	Slow
v	5	450	300	0.00	1.5	315	

Table 2 (Fomin and Yampolsky)

THE ENTRAINMENT OF GULF STREAM WATER BY A CYCLONIC RING (continued)

cline. By assuming geostrophy, we expect to find strong shear (vertical shear in the horizontal current) and a strong surface current located where the isotherms change depth. The density difference between the warm water in the core and cooler water offshore gives rise to a counter current of the Gulf Stream, as seen in the velocity section in Figure 3. The counter current would have been swifter if the warm core had been somewhat to the right, such that its right edge was not located over the steeply sloping isotherms of the main thermocline in the Stream.

The point is that the warm core advected by the ring is equivalent to the warm core advected by the Gulf Stream; the warm core gives rise to the ring's counter current located at 72°W. The shear associated with the right edge of the core adds to the ring shear, giving the large, southward, 200-cm/sec jet located near 71°W.

The return trip of the R/V Eastward just missed the edge of the ring, but it did clip the edge of the warm core advected by the ring. The result is the appearance of an anticyclonic near-surface eddy.

CTD AND HYDROGRAPHIC INTERCOMPARISON ABOARD AKADEMIK KURCHATOV

by Bob Millard

A CTD and hydrographic intercomparison was conducted in July, 1975 to test the feasibility of using the W.H.O.I./Brown CTD profiler and other hydrographic equipment aboard Soviet ships, and to compare the U. S. and U.S.S.R. CTD and hydrographic measurement techniques and accuracies. The intercomparison was made during the twenty-first expedition of the R/V *Akademik Kurchatov* by participants from the Shirshov Institute of Oceanology in Moscow, the Marine Hydrophysical Institute of the Ukranian S.S.R., and the Woods Hole Oceanographic Institution (see photo). Professor Vladimir Kort was the Chief Scientist for the expedition, and Dr. Anatoly Paramonov was the coordinator of the intercomparison. The Woods Hole members of the expedition found warm hospitality and good friendships among the *Kurchatov*'s scientific party and crew.

We sailed from Reykjavik, Iceland on 28 July, 1975 to the POLYGON mooring locations in the vicinity of 65°N and 0°W. After the recovery and launching of moorings and a hydrographic survey of the area, we began the CTD and hydrographic intercomparison. Standard Nansen bottle stations were made using paired U. S./U.S.S.R. thermometers and Nansen bottles. A comparison was also made between U. S. and U.S.S.R. salinometers and standard waters.

There were two types of CTD's to be compared (see photo): the ISTOK, designed and built at the Marine Hydrophysical Institute, and the AIST, designed and built at the Institute of Oceanology. The two Soviet CTD's look identical, and both use the same copper

(continued page 6)

Participants and instruments in the CTD and hydrographic intercomparison on the *Akademik Kurchatov* are, from left to right, Tarasiemko, Karasov, Maslov, Staroselskaya, Bugnov, Pademov, Volochkov, Goncharov, Ivanov, Nowak, Millard, Brillenko, Kort, Captain Rebains, Stalcup, Kharbonova, Zaburdaev, Morosov, Chernekova, Ivanchik, Borzenkov, Paramanov. The instruments are the AIST, the W.H.O.I./ Brown CTD (shown with Rosette sampler), and the ISTOK.

CTD AND HYDROGRAPHIC INTERCOMPARISON ABOARD AKADEMIK KURCHATOV (continued)

thermometer, inductive conductivity sensor, and vibration pressure sensor, but they do differ in detail. For instance, the ISTOK pressure circuit has a second pressure-protected vibration for temperature compensation.

Two methods of CTD intercomparison were used: Simultaneous lowerings to 500 m were made from bow and stern winches separated by 80 m and sequences of deep stations to 2000 m. The AIST and ISTOK CTD's had a depth limitation of 2000 m. The longest series of deep stations (Kurchatov station 1778, Table I) was a series of nine lowerings over 12 hours in the sequence AIST, ISTOK, and W.H.O.I./Brown CTD. The joint yo-yo stations and other deep comparisons are summarized in Table 3.

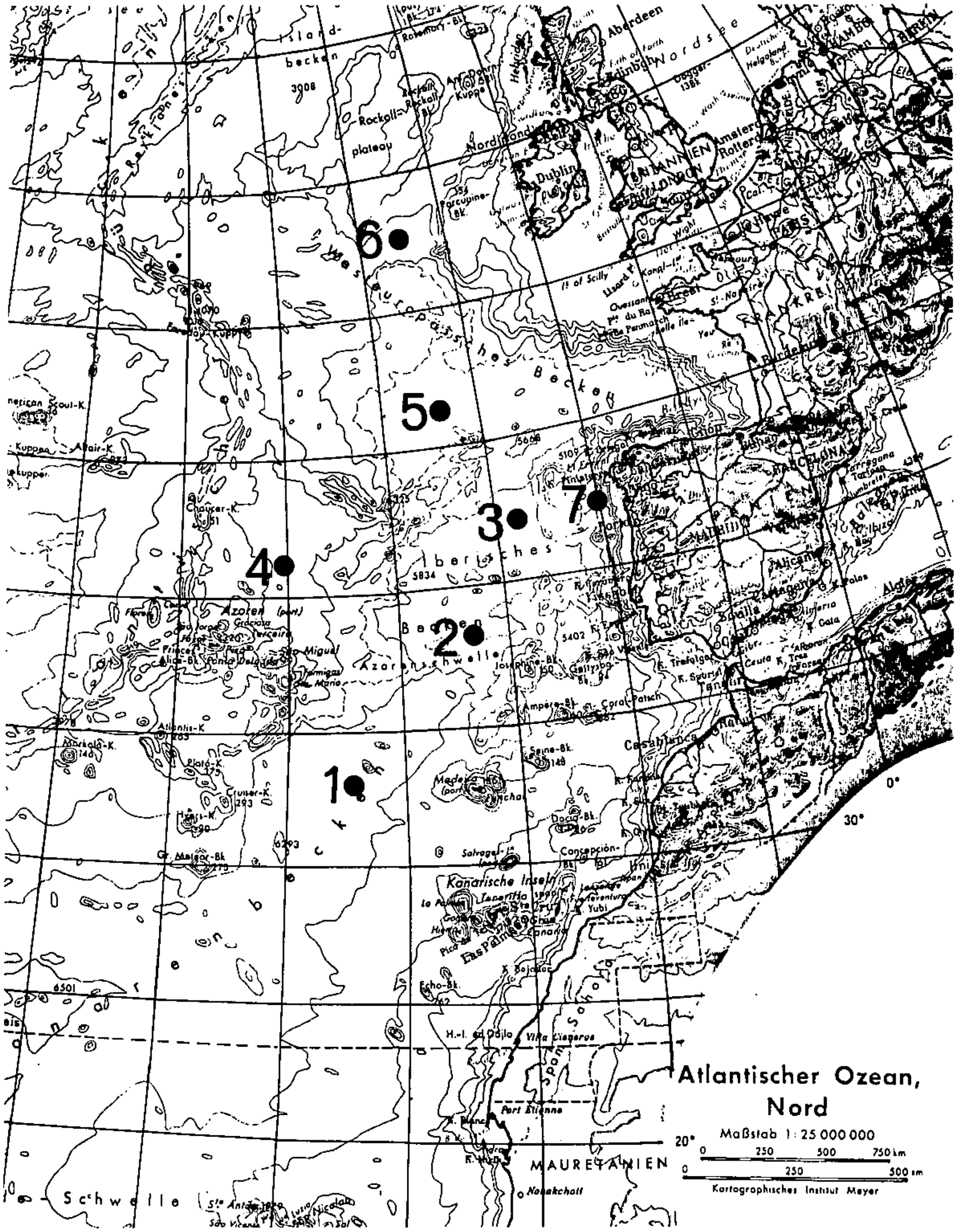
Classical hydrography was collected in order to check CTD calibrations, particularly salinity. The W.H.O.I./Brown CTD stations were taken with four-to-six Rosette water bottles on the way up. The Soviets used a single Nansen bottle above the AIST and alongside the ISTOK. The ISTOK had a 16-bottle Rosette sampler which was lowered to its depth limit of 500 m on the final day of the intercomparison.

Tentative comparisons between Soviet and U. S. CTD's are given in the Preliminary Intercomparison Report, written by Paramonov with contributions from other members of the intercomparison. A sample joint profile, taken from the report, is shown in Figure 9 . Listings of processed pressure, temperature, and salinity data for stations indicated in Table I were exchanged in February, 1976.

WHOI Station	Kurchatov Station	Date	Time (Z)	Location	Pressure	Comments
1	--	2 Aug	1230	65°04.5'N, 0°03.1'W	1513	Test CTD
2	--	2 Aug	2034	65°07.5'N, 0°01.6'E	2037	Test Rosette & CTD
3	1777	3 Aug	1125	65°22.2'N, 0°34.2'E	1260	Test CTD & Rosette
4-9	1777	3 Aug	1645	65°27.8'N, 0°48.6'E	500	Joint lowerings
10*	1778	4 Aug	1130	65°10.6'N, 0°00.4'W	1883	AIST, ISTOK
11*	1778	4 Aug	1545	65°13.9'N, 0°0.9'N	1889	2nd deep comparison
12*	1778	4 Aug	1952	65°18.2'N, 0°03.4'W	1756	3rd deep comparison
13	1779	5 Aug	0925	65°21.0'N, 0°10.0'W	398	75-200 dbar joint yo-yo with ISTOK
14*	1780	5 Aug	1745	65°54.9'N, 0°46.6'W	500	srf-150 dbar joint yo-yo with ISTOK
15		7 Aug	1330	65°09.7'N, 0°0.7'E	2023	Deep Station
16*		7 Aug	1450	65°09.7'N 0°0.7'E	348	Joint AIST comparison 150-350,
17	1783	7 Aug	1955	65°04.0'N, 0°0.3'E	1999	Compare deep AIST
18		17 Aug	0856	65°03.0'N, 0°03.5'W	497	Joint ISTOK
19*		17 Aug	1345	65°03.0'N, 0°03.5'W	2031	Deep comparison
WHOI hydro		17 Aug	1120	65°03.0'N, 0°03.5'W	2000	Bottles every 200 m

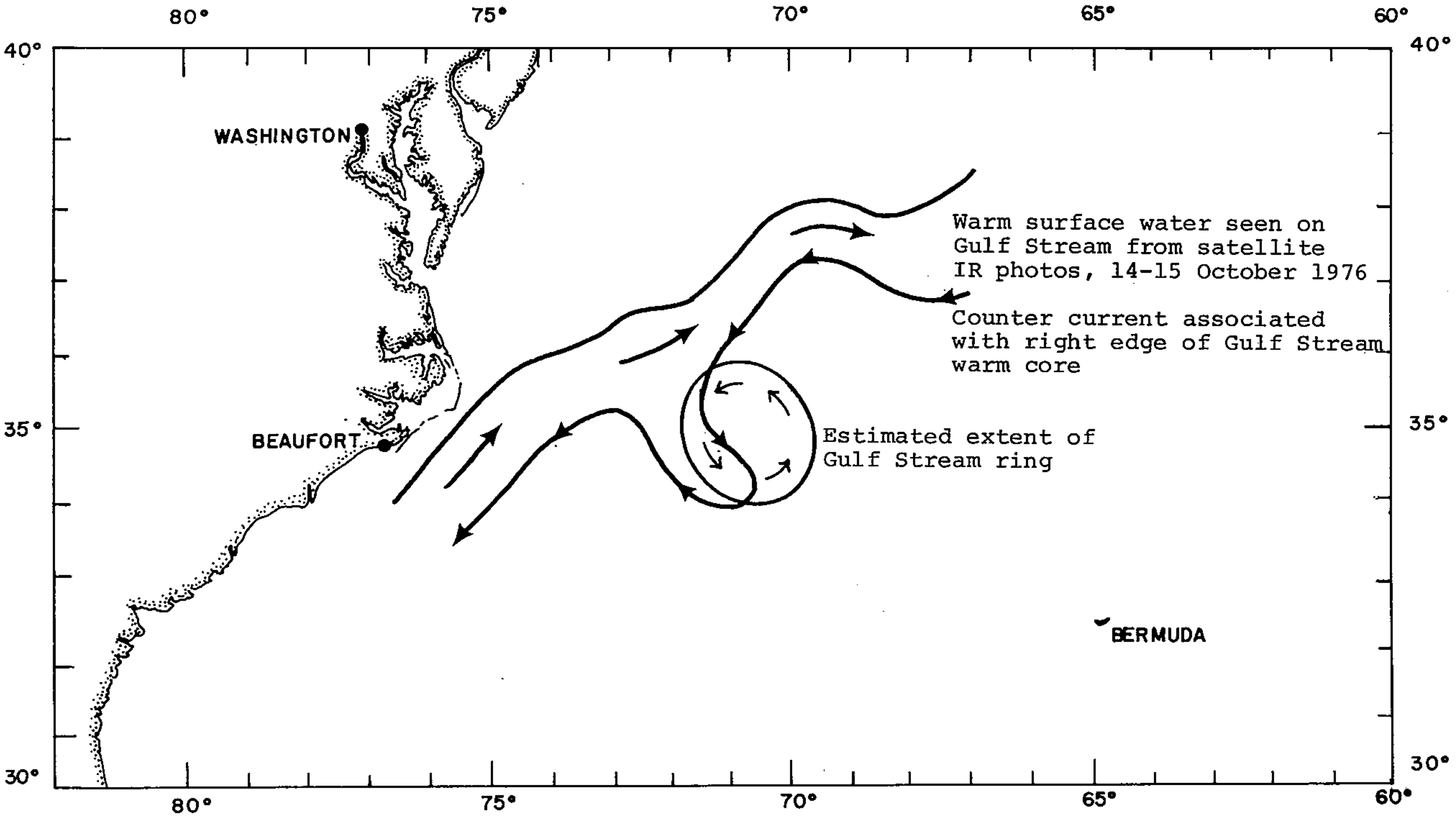
*Exchanged data

Summary of WHOI/Brown CTD stations
Table 3 (Millard)



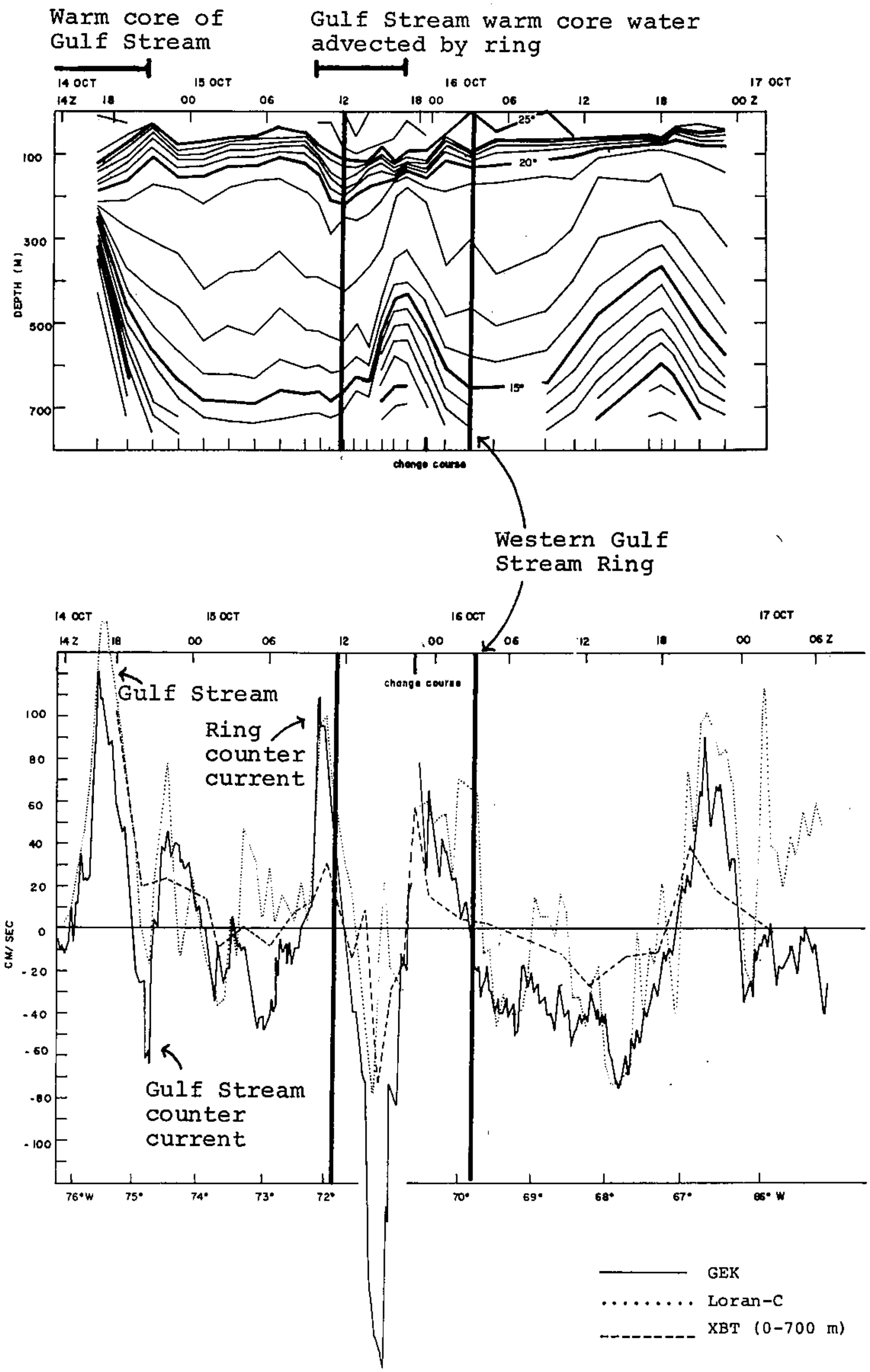
Locations of the North East Atlantic Dynamics Studies (NEADS) site moorings.

Figure 1 (Gould)



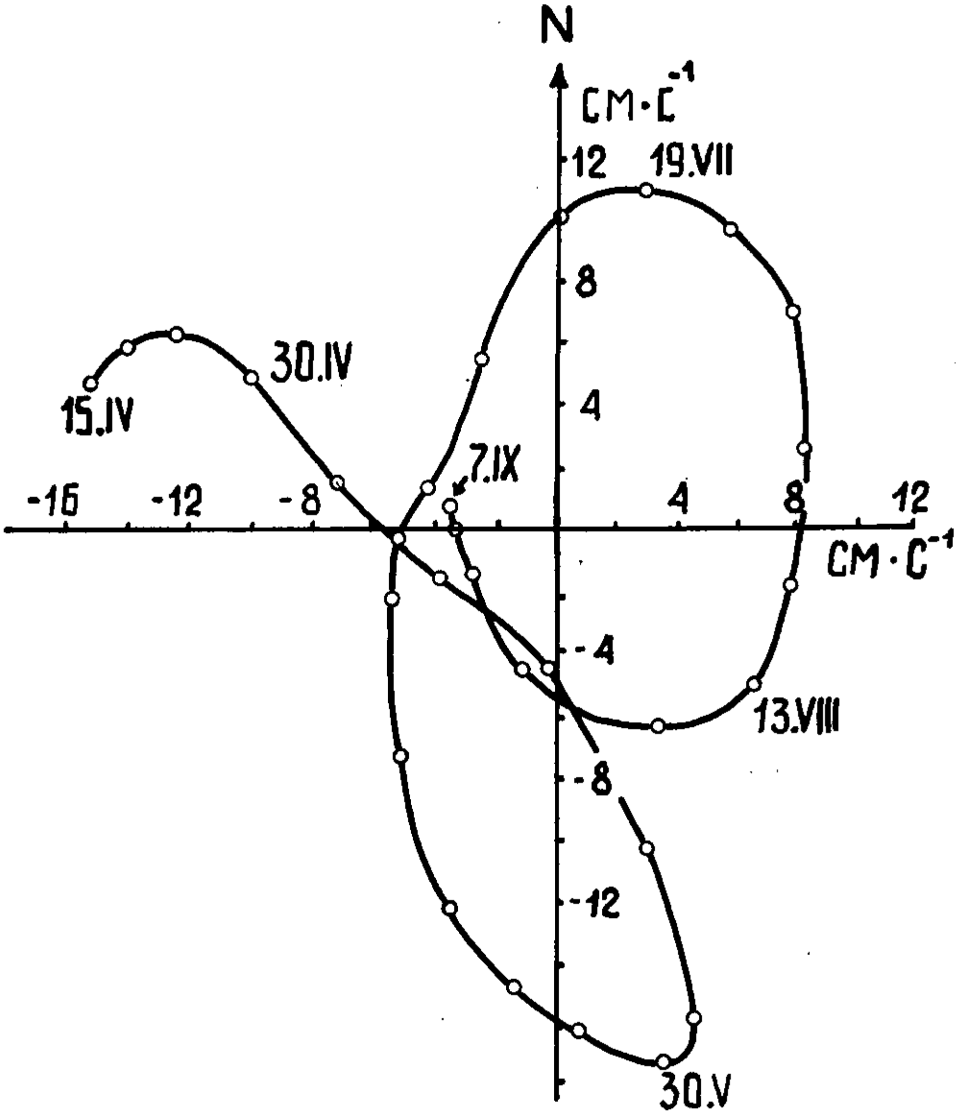
An interpretation of the satellite infrared data from 14-15 October 1975

Figure 2 (Richardson)



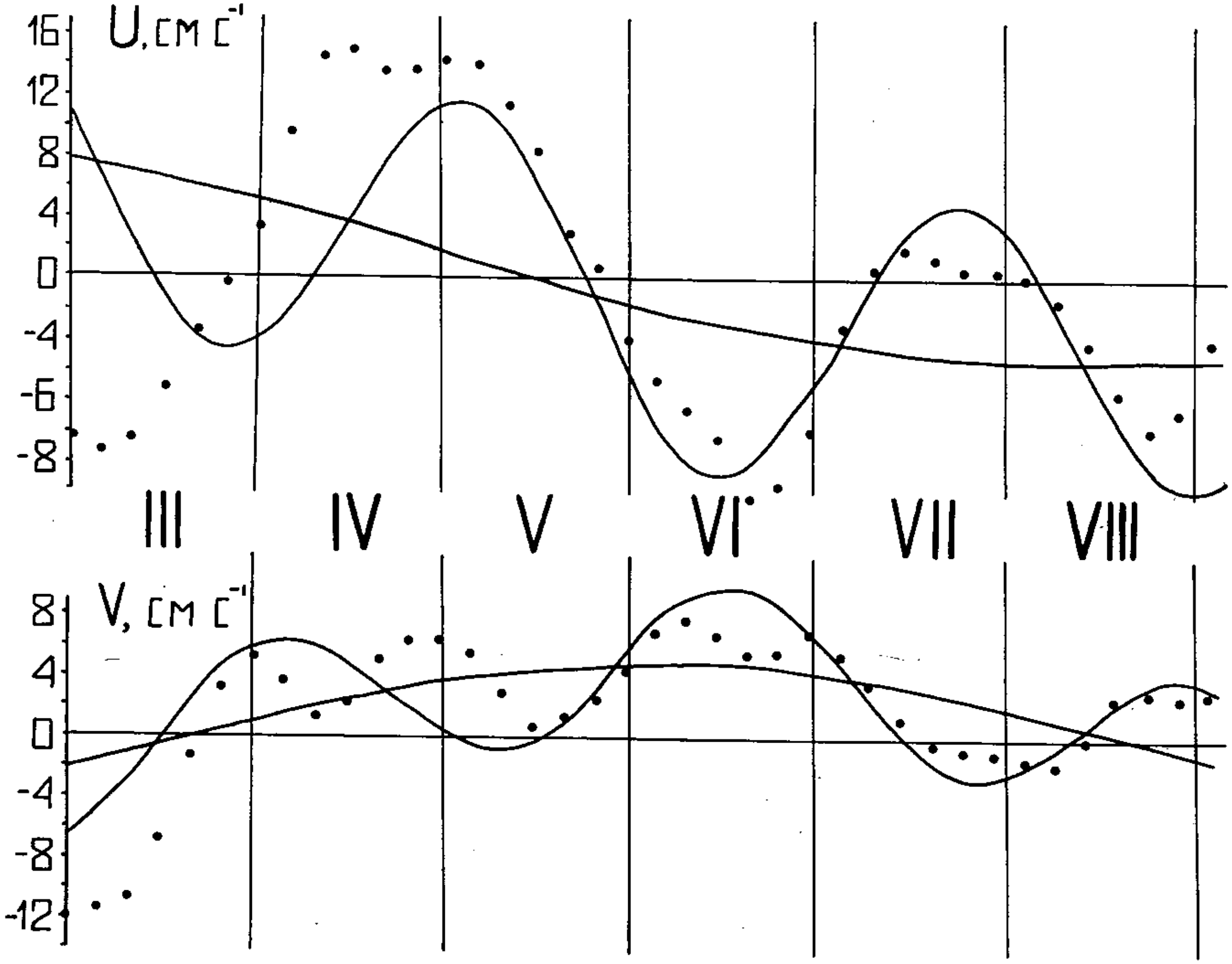
XBT isotherms (above) from Beaufort to Bermuda, 14-17 October 1975. The warm Gulf Stream ring water is visible over the Gulf Stream and over the left side of the western ring. Transverse velocities (below) from Beaufort to Bermuda, 14-17 October 1975, showing the counter current of the Gulf Stream.

Figure 3 (Richardson)



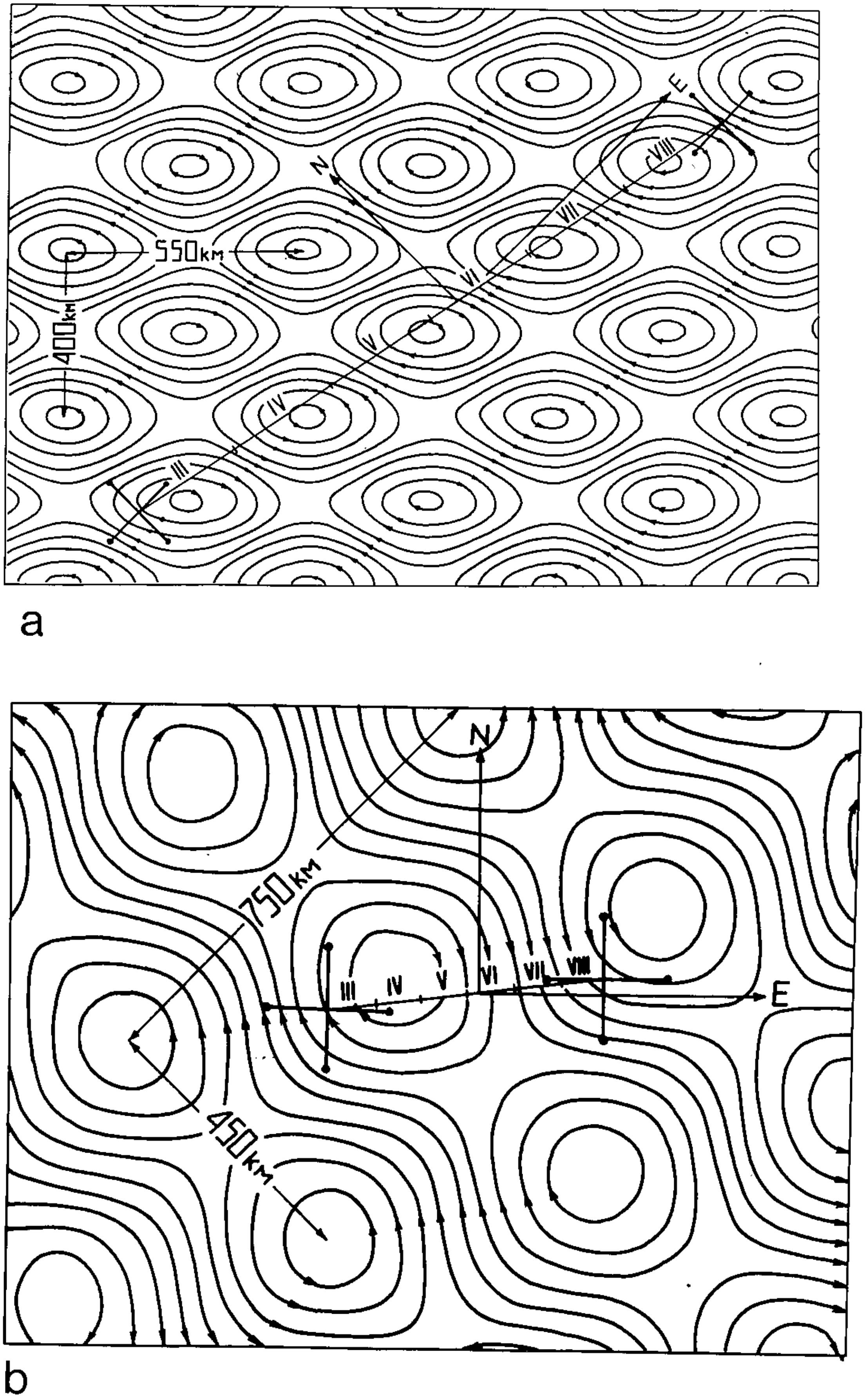
A typical hodograph of current velocity (from the most western point of the array, at 300 m). Points along the curve are at five-day intervals.

Figure 4 (Fomin and Yampolsky)



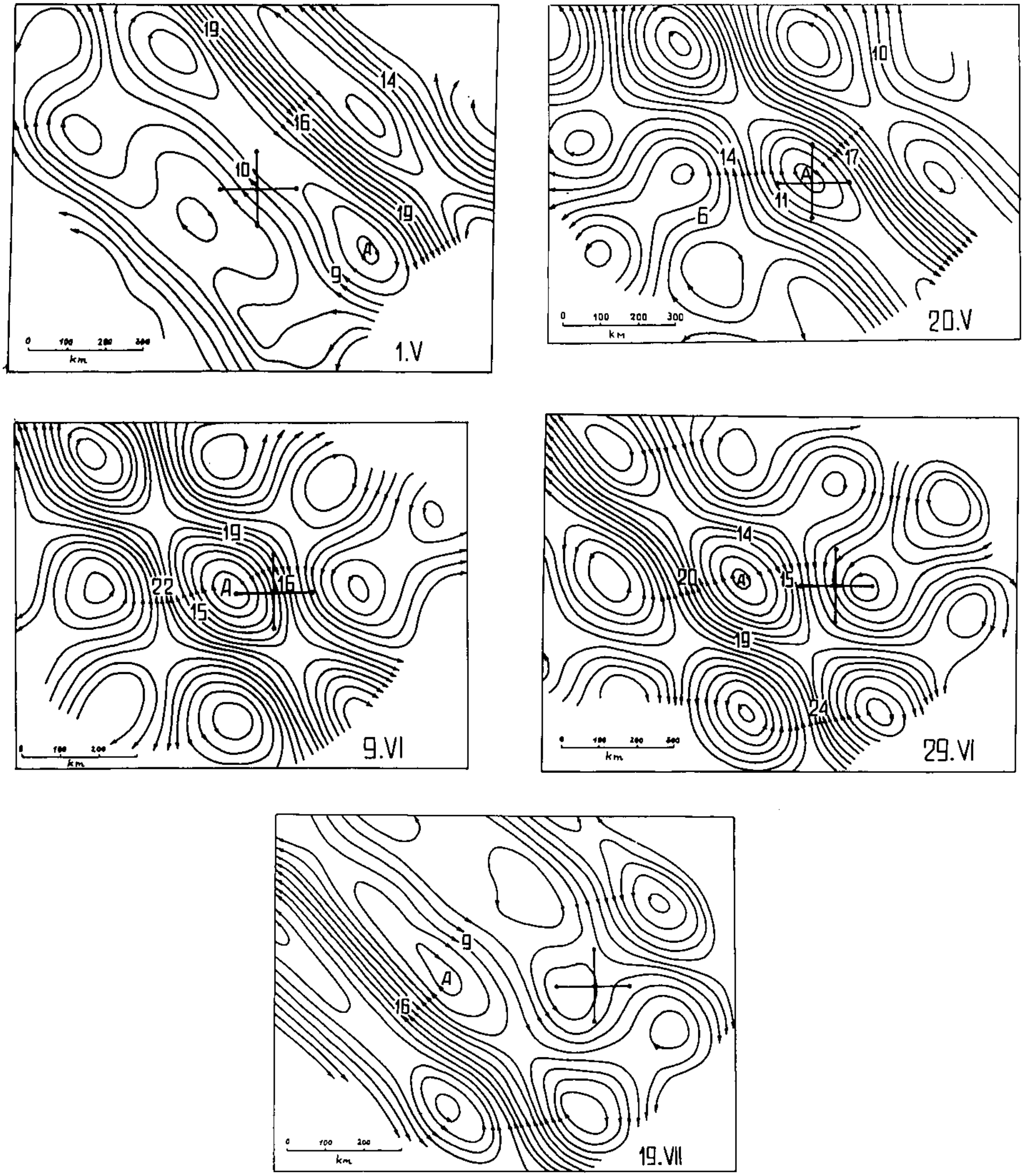
Observed velocity components (····) and two-wave approximation (———) for 300-m POLYGON currents. Here, $u_o = 2$ cm/sec; $v = 0$.

Figure 5 (Fomin and Yampolsky)



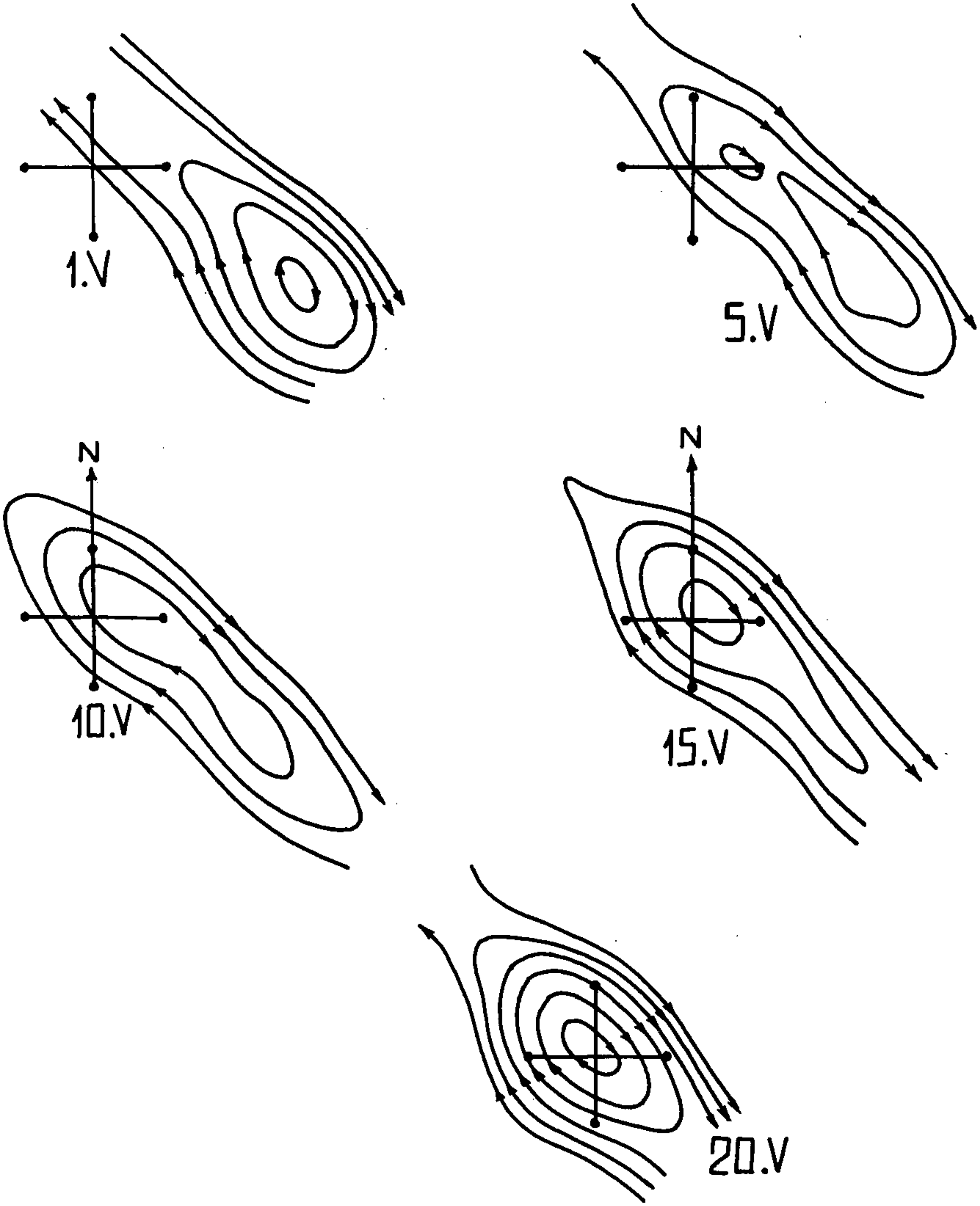
Streamlines formed by (a) two fast waves, and (b) a slow eddy field. Crosses indicate locations of the array in the streamfunction field on 1 May and 1 September.

Figure 6 (Fomin and Yampolsky)



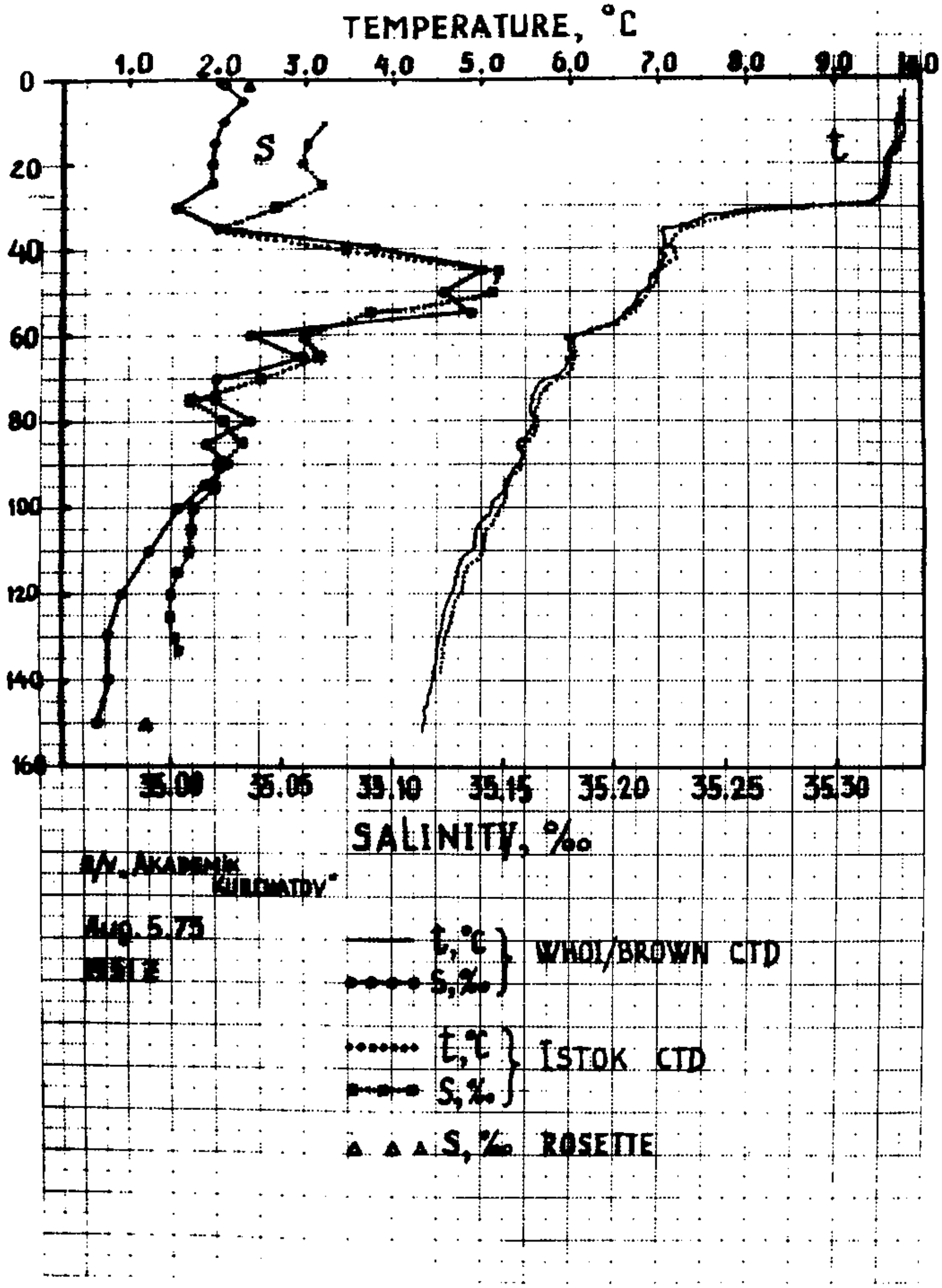
Streamlines of mesoscale eddy disturbances formed by four plane waves. The POLYGON anticyclonic eddy is marked "A". Current velocities (cm/sec) are shown at some points. Streamlines are shown for 1 May, 20 May, 9 June, 29 June, and 19 July.

Figure 7 (Fomin and Yampolsky)



The evolution of an eddy from 1 May to 20 May.
Note that one eddy disappears as another forms
due to pairs of fast and slow eddy disturbances.

Figure 8 (Fomin and Yampolsky)



Temperature and salinity comparison from simultaneous lowerings of the W.H.O.I./Brown CTD and the Marine Hydrophysical Institute ISTOK CTD. The instruments were separated by 80 m. (From the Preliminary Intercomparison Report, Paramonov, et al. Figure drawn by Zaburdaev.)

Figure 9 (Millard)

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