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DETAILED OBSERVATIONS OF THE

KUROSHIO AND ITS EDDIES - OCTOBER 1976

by

Barry P. Blumenthal Robert E. Cheney

NAVOCEANO Technical Note 3700-76-78

U.S. NAVAL OCEANOGRAPHIC OFFICE WASHINGTON, D.C. 20373

January 1978

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ABSTRACT

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Two Kuroshio eddies -- one cyclonic and one anticyclonic -- were located east of Japan during October 1976 and were the subject of a detailed ship survey. A segment of the Kuroshio between the two eddies was also studied. The data consist of 212 XBT's and 29 deep STD stations. These observations represent some of the most thorough measurements of Kuroshio eddies presently available and the first detailed description of a cyclonic eddy.

The cyclonic Kuroshio eddy had an overall diameter of 250 km and was estimated to be 4 months old. Temperature at the eddy center was 7°C colder than outside at a depth of 400 m. The anticyclonic eddy was 120 km in diameter and was 7°C warmer than surrounding water at 400 m. It was at least 8 months old and was beginning to coalesce with the Kuroshio. Comparison of these two eddies with several Gulf Stream eddies shows them to be similar features in many respects.

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I. INTRODUCTION

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As part of its study of oceanic fronts, the Naval Oceanographic Office conducted a joint ship/aircraft survey of the Kuroshio and Oyashio frontal system east of Japan during October 1976. The Kuroshio and Oyashio fronts were tracked from the coast eastward to about 155°E. Analysis of the aircraft data, reported by Cheney (1977), revealed a complicated frontal zone with numerous eddies present. This report deals with the data collected aboard USNS SILAS BENT (T-AGS 26) in selected features of the region during 18-31 October.

II. DATA

During the initial aircraft survey (9-22 October 1976), positions of a cyclonic Kuroshio eddy, the Kuroshio, and an anticyclonic Kuroshio eddy were relayed to SILAS BENT. Two-hundred twelve SXBTs (shipboard expendable bathythermographs) and 29 STD (salinity-temperature-depth) profiles were subsequently obtained during a detailed survey of each of these three features.

Raw data from a Plessey model 9040 STD sensor were sampled every 0.5 s and recorded on magnetic tape. Data were than averaged and values obtained at 1 m intervals. Corrections were applied by comparing values from Niskin bottle samples and reversing thermometers to those obtained by the instrument. The accuracy of the STD system was within 0.02°C in temperature and about 0.01°/.. in salinity. The depth accuracy was within 2 m. Navigation was by satellite and positions were accurate to within 0.2 km.

III. DISCUSSION

For each of the three features investigated by the BENT, four vertical sections (vertical exaggeration 200:1) are presented: 1) temperature; 2) salinity; 3) sound speed and 4) geostrophic current velocity. Sound speed is derived from Wilson's (1960) equation, and geostrophic velocity is referenced to the maximum depth of the STD cast in each feature. Selected STD data used in geostrophic current calculations and other derived parameters are listed in the Appendices.

A. Kuroshio Cyclonic Eddy

A Kuroshio cyclonic (cold) eddy, centered at 33°N, 143°E, was surveyed from SILAS BENT during 18-24 October, 1976. These observations are particularly significant in that few cold eddy studies have ever been made and the little information that does exist (Masuzawa, 1957) is not recent. Temperature at 400 m in the cold eddy is shown in figure 1, along with SXBT and STD location. The overall diameter of the eddy is approximately 250 km*. Temperature at 400 m is 7°C colder at the eddy center than outside and the net horizontal gradient is 0.06°C km⁻¹.

Figure 2 is a zonal temperature section through the eddy along 33°N (center at station 6). The main thermocline at the center of the eddy is 300 m shallower than in the subtropical water surrounding it. A remarkable feature that is readily apparent is the fact that the cold core extends to 3000 m, although at this depth temperatures in the eddy are only 0.05°C colder than outside.

The age of this eddy may be estimated by assuming a decay rate similar to those measured for Gulf Stream eddies. Assuming reasonable initial conditions for the depth of the thermocline at the eddy core ($15^{\circ}C$ at 75 m) and a linear sinking rate of 0.5 m day⁻¹ (Parker, 1971; Cheney and Richardson, 1976) the estimated age of this eddy is four months.

^{*}The intersection of the 15°C isotherm with a depth of 500 m has been used as a standard to define the diameters of Gulf Stream cyclonic eddies. A equivalent definition for Kuroshio cyclonic eddies is 9°C at 500 m depth; this yields a diameter of 170 km for the Kuroshio eddy discussed here.

Figure 3 shows the existence of an intermediate salinity minimum, representative of North Pacific Intermediate Water (NPIW). The axis of the minimum is shallower at the eddy center (500 m compared 750 m outside) and creates an interesting situation: above the minimum the eddy represents a negative salinity anomaly along horizontal surfaces while the opposite is true at depths greater than the minimum.

Sound speeds in the eddy (figure 4) are low within the core and high in the surrounding water at the same depth, with a net difference of 25 m s⁻¹. Axial depth of the deep sound channel (DSC) shows an abrupt change from 900 m in the subtropical water to 500 m in the eddy core. Although sonic layer depth (SLD) shows no appreciable change across the eddy in this case, the uplifted thermocline at the eddy center represents a barrier to vertical motions and creates the potential for large SLD differences to occur. Periods of intense vertical mixing, such as during winter storms, would establish deep mixed layers outside the cold eddy while layers would remain shallow near the center.

A geostrophic velocity section for the cold eddy is shown in figure 5. The shaded portion represents southward flow (towards the reader). In order to account for centripetal accelerations, a correction was applied according to the gradient wind relationship (gradient currents are less than geostrophic currents in a cyclonic eddy). Maximum surface current velocity in the eddy is 80 cm s⁻¹ (1.5 kt) and the tangential volume transport is $50 \times 10^6 \text{ m}^3 \text{ s}^{-1}$.

Both the available potential energy (APE) and kinetic energy (KE) were determined for this eddy. The APE is the energy which would become available if the density stratification became everywhere barotropic, and the KE is the energy of the eddy's mean tangential motion. The potential energy anomaly, χ , is defined as: $\chi = \frac{1}{g} \int_{0}^{P} P\delta dP \quad (erg \ cm^{-2}) \quad (Fofonoff, 1962)$

where g = acceleration of gravity (cm s⁻²)

P = pressure (dB)

 δ = specific volume anomaly (cm³g⁻¹)

This quanty was computed for each STD profile. Difference between the potential energy anomaly at any point inside the eddy and the reference value (station 10) is the APE per unit area, and the total APE of the eddy was obtained by summing these differences over the area of the eddy.

Total KE was determined from computed gradient current velocities by a summation over the eddy's area, where KE per unit area is defined as:

$$KE = 1/2 \int_{0}^{P} \rho v^2 dP (erg cm^{-2})$$

 $\rho = \text{density} (\text{g cm}^{-3})$

 $v = current velocity (cm s^{-1})$

Since most eddies are not circular, but slightly elliptical, both the APE and KE summations were performed by considering the eddy boundary to be composed of two semicircles of different radii and integrating over the area in each half of the dddy.

Total APE and KE of the cold Kuroshio eddy are 1.3×10^{24} ergs and 3.3×10^{22} ergs, respectively. This yields a ratio of APE/KE = 40. Wright (1972) has estimated the APE/KE ratio of the ocean to be between 10 and 50. Studies of four different cyclonic Gulf Stream eddies have shown this ratio to range from 15 to 46 (Khedouri and Gemmill, 1974; Cheney and Khedouri, 1975; Cheney and Richardson, 1976). The fact that a Kuroshio cyclonic eddy has an APE/KE ratio similar to that of Gulf Stream eddies is not surprising since both are formed by western boundary currents with similar scales,

transports, and speeds.

Cheney and Richardson (1976) followed a cyclonic Gulf Stream eddy for 14 months and determined that its APE decay rate was approximately 10²¹ ergs per day. If we apply this decay rate to the Kuroshio eddy we arrive at a total predicted lifetime of 3.9 years. It is possible that energy is lost more rapidly during the later stages of decay and therefore this estimate may be high. However, Gulf Stream eddies have been observed to last as long as two years.

Figure 6 is a composite T-S diagram for the ten STD stations in the Kuroshio cold eddy. Three stations near the center of the eddy (5, 6, and 7) provide evidence of the less saline core of the confluence zone water thus confirming that the eddy was formed from a Kuroshio meander. The other stations maintain a tight T-S relationship except in the region of the salinity minimum. The central STD stations (5 and 6) display the most pronounced salinity minima.

B. Kuroshio

An STD section was obtained across the Kuroshio at $147^{\circ}00$ 'E (figure 7). The cross-current temperature difference at 400 m is 10° C and the horizontal gradient is 0.1° C km⁻¹. The temperature section in figure 8 shows the front extending to 2500 m with a horizontal temperature difference of 0.1° C at this depth. The center of the main thermocline (10° C) slopes down from 150 m at the northern portion of the section to 600 m south of the Kuroshio with a maximum slope of 7.5 m km⁻¹. The nearly isothermal layer ($16^{\circ}-18^{\circ}$ C) between the upper and main thermoclines is Subtropical Mode Water (Masuzawa, 1969). The T-S characteristics of this water (T= 17° C, S= $34.8^{\circ}/_{\circ \circ}$) make it a counterpart of the 18° Water in the Sargasso Sea (Worthington, 1959).

The salinity section (figure 9) shows the salinity minimum layer which corresponds to NPIW. Comparison with the temperature section in figure 8 reveals that the axis of the minimum follows the bottom of the main thermocline (5°C). The core of the NPIW occurs at a depth of 300 m in the region between the Oyashio Front and the Kuroshio, with a minimum salinity of approximately $33.6^{\circ}/_{\circ \circ}$. South of the Kuroshio, the salinity minimum layer reaches a maximum depth of 800 m with a salinity value of $33.7^{\circ}/$

The sound speed section through the Kuroshio (figure 10) shows the depth of the DSC axis and the SLD. SLD changes from 50 to 90 m as the front is crossed from north to south. DSC exhibits a more dramatic ch from 400 m north of the Kuroshio to 1230 m in the subtropical water of the Central Region.

Geostrophic velocity calculations for the Kuroshio were performed assuming a "level of no motion" at 2500 db. Shaded portions in figure 11 represent westward flow. The maximum surface current speed is about 185 cm s⁻¹ (3.6 kt) which is equal to the average value measured by geomagnetic electrokinetograph (GEK) at 145°E (Kawai, 1969). A countercurrent is seen approximately 150 km to the south (right) of the Kuroshio axis having a maximum value of 11 cm s⁻¹ (0.2 kt). A very weak deep return flow between stations 13 and 14 is also evident. The net volume transport through this section is $64 \ge 10^6 \text{ m}^3 \text{ s}^{-1}$ towards the east, but only about 57 x $10^6 \text{ m}^3 \text{ s}^{-1}$ is due to the main body of the Kuroshio (between stations 16 and 12).

T-S diagrams for the ten STD stations taken in the Kuroshio are shown in figure 12. Station 17 was taken at the northern edge of the Kuroshio while the southern edge is represented by station 12. The salinity minimum

occurs at 310 m and 780 m for stations 17 and 12, respectively. In the upper portion of the diagram, the five southern stations (higher temperatures) are distinctly different from the five northern stations. All profiles converge to a tighter fit at about 10°C, the isotherm representative of the main thermocline. This is the western North Pacific Central Water. At the bottom of the diagram (T=1.8°C, S=34.6°/••) is western North Pacific Deep Water.

C. Kuroshio Anticyclonic Eddy

The initial survey on 16 October by the NAVOCEANO aircraft located an anticyclonic (warm) eddy at $37^{\circ}50$ 'N, $143^{\circ}20$ 'E (Cheney, 1977). During the time between the aircraft and ship surveys, the eddy center moved 52 km southeastward at an average speed of 4 km day⁻¹ to $37^{\circ}30$ 'N, $143^{\circ}45$ 'E. The ship XBT survey (figure 7) suggested that the eddy was attached to the northern edge of the Kuroshio. Subsequent satellite imagery on 2 November confirmed that the eddy was indeed coalescing with the Kuroshio. Although interaction with the Kuroshio may have had a slight effect on the eddy during the ship survey, the STD section obtained on 30 October is believed to be representative of the eddy's structure.

The average diameter of the eddy is 120 km (defined by the 6°C isotherm at 400 m). At 400 m, temperatures at the eddy center are 6° to 7°C greater than in the surrounding waters. Kitano (1975) discussed the size and movement of anticyclonic eddies off Japan based on 17 years of data and found that eddies had an average diameter of 130 km, a mean translational speed of less than 1 km day⁻¹, and lifetimes on the order of a year.

The zonal temperature section through the eddy along $37^{\circ}30$ 'N is shown in figure 13. The isothermal core of approximately 11°C was created during winter by vertical mixing; this indicates that the eddy is at least eight months old. The seasonal thermocline (12° - 18°C) forms a "cap" over the isothermal core. Temperatures at the eddy center are 6°C warmer than outside at 400 m and 0.3°C warmer at 1500 m.

In the anticyclonic eddy, the salinity minimum occurs at 700 m in the center and at 400 m outside (figure 14). Maximum horizontal salinity gradient occurs at 600 m; salinity at the eddy center is $0.5^{\circ}/..$ less than outside at this depth. The $34.5^{\circ}/..$ isopleth indicates that the eddy extends to at least 1500 m.

The sound speed section (figure 15) indicates little change in SLD across the eddy. Maximum sound speed occurs at the top of the main thermocline in the warm core of the eddy, with a maximum horizontal change of 25 m s⁻¹ at 400 m. The DSC axis is depressed from 400 m in the surrounding water to a depth of 700 m in the center.

Figure 16 is the current velocity section through the warm eddy. The shaded region represents southward flow (toward the reader). Corrections for centripetal accelerations have been applied to the computed geostrophic velocities. Maximum current is approximately 100 cm s⁻¹ (2.1 kt) while the volume transport is $42 \times 10^6 \text{ m}^3 \text{ s}^{-1}$.

Total APE and KE of the eddy are 3.7×10^{23} ergs and 3.6×10^{22} ergs, respectively (APE/KE = 10). Saunders (1971) calculated a value of 30 for the APE/KE ratio for an anticyclonic Gulf Stream eddy, although the accuracy of this figure is only \pm 50%. Khedouri and Gemmill (1974) found the ratio to be 18 for a larger Gulf Stream warm eddy.

The T-S diagrams for the warm Kuroshio eddy (figure 17) appear to be more diverse than those of either the Kuroshio or the cold eddy. This may be due in part to the inherent variability of the confluence zone water, which is being mixed into the warm eddy. An additional factor could be entrainment of Kuroshio water into the eddy during its coalescence. The depth of the salinity minimum for the center station (#27, 780 m), is much deeper than for the outside station (#17, 400 m), as is expected. The T-S curves converge to the Pacific Deep Water.

IV. SUMMARY AND CONCLUSIONS

These observations represent some of the most thorough measurements of Kuroshio eddies presently available. The cyclonic eddy data are particularly significant in that they provide the first detailed description of these features.

Selected physical properties of the two Kuroshio eddies are given in Tables 1 and 2. Similar properties for several Gulf Stream eddies are included. Comparison shows that the cyclonic Kuroshio eddy is remarkably similar to its Atlantic counterparts. No attempt is made here to adjust the values according to the different eddy ages, but the Kuroshio eddy's size, thermal structure, transport, and energy fall well within the range of values for cyclonic Gulf Stream eddies.

Table 2 indicates that the anticyclonic Kuroshio eddy has transport and energy significantly larger than the two Gulf Stream examples. This appears to be due to its larger overall size and depth (it is assumed that effects due to interaction with the Kuroshio are negligible). Gulf Stream eddies of comparable size have been observed (Cheney, 1976) but values of transport and energy are not available.

One fundamental difference in structure between Kuroshio and Gulf Stream eddies is the existence in the Pacific of the intermediate salinity minimum (salinity in the western North Atlantic decreases continuously with depth). Another basic difference is that the main thermocline in the Pacific subtropical gyre is 300 m shallower than in the Atlantic. Neverthe less, it is apparent that Kuroshio and Gulf Stream eddies are dynamically and acoustically similar features.

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		PHYSICAL PROPI	TABLE 1 ERTIES OF VARIO	US CYCLONIC EDDI	N N		
		Diameter (km)	Max Horizontal AT (*C)	Transport (10 ^{6m3} s-1)	APE (10 ²⁴ ergs)	KE (10 ²² ergs)	APE KE
	KUROSHIO EDDY						
	Blumenthal & Cheney (1978)	170 (9°/500 m) ^a	7	50 (ref 3000 m) ^b	1.3	3.3	40
	GULF STREAM EDDIES						
:	Khedouri & Gemmill (1974)	190 (15°/500 m)	10	59 (ref 2500 m)	3.0	8.5	35
11	Cheney & Khedouri (1975)	125 (15°/500 m)	10	40 (ref 3000 m)	1.0	4.7	21
	Cheney & Khedouri (1975)	150 (15°/500 m)	6	33 (ref 3000 m)	1.2	2.6	97
	Cheney & Richardson (1976)	160 (15°/500 m)	٢	60 (ref 3500 m)	6.0	5.6	17
	a = intersection of 9°C isc b = reference dpeth used fo	thermal surface t r transport, APE	with a depth of , and KE calcul	500 m ations			
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TABLE 2	OF VARIOUS AN
	PROPERTIES
	PHYSICAL

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	Dlameter (km)	Horizontal ΔT (°C)	Transport (10 ^{6m3} s-1)	APE (10 ²⁴ ergs)	(10 ^{22 ergs)}	APE KE
KUROSHIO EDDY						
Blumenthal & Cheney (1978)	125 (11°/200 m) ^a (6°/400 m)	٢	42 (ref 1500 m) ^b	0.4	3.6	10

GULF STREAM	EDDIE	
GULF S	TREAM	
	GULF S	

~30	18
0.3	0.6
.0.1 ^c	0.1
₽	22 (ref 1500 m)
7	7
90 (15°/,200 m)	85 (15°/200 m)
Saunders (1971)	Khedouri & Gemmill (1974)

a = 1 intersection of the 11° C isothermal surface with 200 m b = reference dpeth used for transport, APE, and KE calculations c = estimated from 200 m temperatures in the eddy

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Figure 2 - Temperature (°C) structure of the Kuroshio cold eddy. The main thermocline at the center of the eddy is uplifted 300 m from the surrounding water.



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Figure 8 - Temperature (°C) section across the Kuroshio, 24-26 October 1976. The nearly isothermal (16°-18°C) layer south of the Kuroshio is Subtropical Mode Water.

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Figure 9 - Salinity (°/...) structure across the Kuroshio. The axis of the salinity minimum is 500 m deeper south of the Kuroshio.



Figure 10 - Sound speed (m s⁻¹) structure of the Kuroshio. The DSC is 800 m shallower on the north side.



Shaded areas represent westward flow.



Figure 12 - T-S curves for Kuroshio STD stations. The northern edge is represented by station 17 and the southern edge by station 12.





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Shaded areas represent southward flow.



APPENDIX A

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STD DATA FROM KUROSHIO COLD EDDY

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(22-24 October 1976)

AND CALCULATED PARAMETERS

STATION NO.

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DTN ANOM (H) 3.17992 . 39287 1.70013 91519. 91640. 2.55672 2.40077 2.10833 1.414AU 72106. + 2 4 9 4 4 • 1113 • 2.83758 . 99450 1.47743 .20107 15451. .98752 . 7/640 19764. 3.08756 2 . 99522 1.48904 0 + 2 H 5 H 5 +195C. 1.06737 2.90995 1.77343 2.69818 2 . 6 2 6 3 3 16636.5 1.22924 .79049 .28097 0 1 N • 00095 • 00170 06100. .00106 .00072 0ELTA. (CC/GM) •00461 .00392 .0000. .00236 90154 £1100. 00100 + 5000 + .00293 .0203 16100 00040 00004 .00462 00461 00309 00282 00275 00269 00248 00219 .00121 00092 00077 00059 00052 00048 0026 2898.20510 2820.40815 2752.35954 2558 . 05643 2509.50869 2412.44668 2363.93239 2315.42922 2218+45615 2169 • 98622 2121 • 52733 2 73.07946 .9684 1976.21674 9682.1927.80184 1227.00745 2878.75315 2839.85464 2800.96343 2776 . 66008 265501.2365 2606 . 6 1 5 3 8 2460 * 97211 2246.93715 9678 1831.00488 •9673 1734•25158 9464 1540.07542 9 - 97 925 2728+06182 2 24+64261 1017-54101 9660 1444.25227 0793 . 16611 2859.30301 2703.7469 0574.5465 STANUARU 3 .9721 9725 9724 9723 .9726 9720 9719 7179 7179 9706 .9702 .9700 •9695 1969. .9686 9669 9650 1496 .9711 .9704 .9688 1609 .9726 .9708 6999. **4350P** (47/22) .9697 .9622 2730.61855 2776.25549 2268.48260 2219.93398 нбібні 2901.38501 2841.44070 E7242.6585 2803.73687 2047.54192 2540.16478 2414.23718 2171.40103 2172.88347 74.38084 25.89245 1832.07225 1634.45496 1 10.49044 2648.84463 2511.50226 2442.86116 2345.63253 2317.04823 1977.0417A2 1928.95635 1445.02716 2842.29422 2842.76462 2779.35825 2754.98547 11965.2551 1227.6427 0576.84747 1641.71461 (H) DΥN 2 • .9753 .976. .9756 .9744 +679+ .9726 .9723 • 97 19 • 97 15 .9705 .9696 •9694 .9772 • 9 7 4 B .97JB 1126. .9691 .9676 .9646 6119. .9750 .9746 .9741 9730 .9708 .9702 .9699 .9771 .9686 9611 . 4667 .9656 .9437 9627 ASTP .9681 1 49/331 SIGMA 23.47 5 . 17 4 . 29 64.0 91.14 44.5 5.87 404 7.30 9 + 4 8 29.73 90.0 1.03 1.32 1.48 60°ű 5.58 7 . 72 9.78 12+27 11.1 11.00 1.41 2.97 23.36 10.5 40.4 4 . 74 4.5.6 8 . 1 2 16. U + 2 • 9 96.00 32 . 4 4 5 7 7 F 23.29 23.27 5.08 07. SIGNA-T 24.03 4.66 24.90 5.20 25.46 26+10 26.45 6.60 26.84 26.94 27.10 5 27.25 27.34 . 1 0 7.50 1.59 . 65 23.27 5.29 26,75 25.30 25.74 5.93 6 . 2 3 27.54 27 . 67 5.61 27.0 ~ 27.71 (0/00) SAL 51 4.56 14.47 4 - 7 4 4-24 34 . 76 4 • 7 4 1 - 67 4 • • 4 4.1.4 61.4 4 . 1 7 34 • 25 4.39 4 - 4 6 34.58 4 • 6 2 94 . 49 14.30 11.35 14.47 4.74 11.14 C 94.49 14.53 94.59 14.41 4 + 7 4 - 5 2 1.1 4 . 2 . 34.1 1 4 . 2 TENP. 22.95 10.8 7.60 4 . 4 9 1.50 3 . 20 2+95 .74 660 1.30 10.5 • 8 • .70 19.6 8 . 7 4 2.19 5 • 5 A 4.94 1.25 3 . 9 0 0. 4.37 4.75 3.54 2.34 1.17 9 • 5 9 5 . 4 4 23.97 23.94 6 . A 9 12.9 ē DEPTH" 80.0 +00+ 20. •0+ • 25. 50. .000 150. + 2 5 + • 00 5 550. 650. .001 7501 •00 850. •006 950. 200. 1000 1500 -1950. 2175 . ċ 75. •00 250. **600** 10001 1100 1400 1725 -2400 • [H] 1

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	UTN ANOM	(Y)		2.459.42	2 . 4005	2.767.5	2071995	2.64343	2.57195	2.50323	2 - 43647	4 4 7 1 7 4 4 9 4 7 4 7 4 4	2.05688	1.94377	1.84034	1.74587	1.66076	1.5837.0	1.51363	1 . 4 4 9 05	1.38748	1.33040	1 • 27712	1+22757	1.18143	1.13781	1.05616	• 9 8 0 5 6 	0 4 4 7 4 4 0 	6779	• 7 / 7 9 6	. 63920	¥6112.	. 39484	19592.	.17582	16690.	• • • • •
	DELTA	(H)/J)		*****	• • • • • •	12200.	11000.	.00293	• 00280	• 00270	+00263		96400.	.00217	.00197	.00181	.00160	.00149	26100.	•00127	61100.	01100 •	coloo.	• 000 9 5	•0000•	• 00085	• 00078	• 00073	• 000 • 8	•000•	.0000	19000 •	• 00053	1 5000 1	• 00048	• 000 • 2	.00047	• 00047
	STANUAKU	(H) (H)	2898.202.8682	10606.9205	10720.764	2420+0545	2800.96343	2776.64000	2752.35954	2728.06102	2703.76691	2029(1029Z	2558.05643	2509.50869	2440197211	2412+44668	2363.93239	2315.42922	2266.93715	2218 45615	2149.98622	2121+52733	2 73.07946	2 24 . 64 261	1976.21674	1927+80184	1831.00488	1734•25158	163/ • 54181	24678.095[1444.25227	1227 • 00745	1 9.97925	0793 . 16611	0576.54651	0340.17890	0144.00180	000000
* -	A 35 G P	(49/22)	47/29 .97.26	. 97.25	+9124	.9723	.9722	.9721	.9720	.9719	126.	0 1 1 0		9708	9706	.9704	.9702	.9700	.9697	.9695	.9493	.9691	. 9680	. 9636	• 9 6 8 4	. 9682	.9678	.9673	9669	• 7 6 6 4	.9660	.9450	1 4 9 6 .	1596.	.9622	6196.	.9603	.9597
1259	DYN HEIGHT	(H)	7 0 + C • 1 4 2 / 2 4 7 - 2 4 7 1 4 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	24/42.2444	2442.72326	04491.6495	28413.68138	17606.9775	2754.93150	2730.56506	2706.20359	2057.4914/	C.C.C	97237,112723 97237,1136	2442.81246	2414.19256	2345.59315	2317.01292	2248.45078	2219.90520	09676.1715	2122.85773	2 74.35658	2 25.87017	1977.39416	1928.93965	1832.06104	1735.23215	1534.4516/	1541.71795	1445.03024	1227.64665	1 10.49064	0793.56096	0574.85011	0360.35472	0144.07177	000000
F	ASTP	(49/ 77)	. 770.		.9109	. 7758	.9754	.9750	.9748	1 19745	. 9744	1 L / L 4	12.79.	0579.	.9726	.9722	• 9718	.9714	.9710	.9708	.9705	.9702	.9649	.9646	696.	.9690	.9655	.9680	. 76/6	106.	.9666	.9457	.9646	.9636	.9627	•9617	.9608	.9602
	SIGHA		23.35	C	23.41	24.75	25.26	25.43	25 . R 9	24+12	24.31	24457		27.74	20.18	28.59	29.75	29.40	29.81	30.11	30.42	30.75	31.06	2v•ic	14.16	31.95	32.49	11.66	33.52	10.45] 4 . 5]	35.57	34.25	27.75	34.77	39.80	4 p. A l	4 7 F
78 HR . 76 17	1 GHA-T	•	23.35		22.25	24.40	24.82	25.08	25,22	25.34	26.42		# C • C 7	25.95	26.16	26.24	26.55	26.66	26.83	26.88	26.96	27.05	27.12	27 . 19	27.26	27.31	27.38	27.44	27.44	27.51	27,55	27.58	27 . 66	27.68	27 . 71	27.72	27.73	27.74
0A M0 22 11	SALS	(00/0)	34.49		24.47	14.71	34 - 70	34 • 7 4	34 • 75	34 + 7 4	12+24	2/0/0		34 • 5 1	34+45	46.40	14.19	11.40	34.10	11.45	11.40	94.14	34 • 1 9	21.12	34 • 26	16.95	34.37	14.40	31.1	94.50	34.49	34.52	34•58	34 • 60	34.62	24.42	14.64	19.50
L0N 141053M	TEMP	(2)	23.74	11.12	23.49	20.69	18.97	14.05	17.49	16.96	[4:4]		5/ 61	78061	12010	10.78	8.73	7.54	6 • 2 A	5•9ŋ	5 . 27	4+71	46.4	3.54	. 3.59	3152	3 • 23	2 + 9 9	2 . 7 A	2 • 6 2	2 . 4 4	2+34	2002	1 • 8 4	1 • 7 4	1 • 67	1 • • 1	1:54
LAT 320594	DEPTH	Ê.	0		•09	•00	.001	125.	150.	175.	200.		150	• 00 1	450.	500.	550.	• 0 0 9	650.	1001	. 750.	9009	850.	•006	950	10001	1100	1200.	1300	• • • • •	1500.	1725.	1950.	2175.	2400.	26250	2850.	+000f

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		•0•	23.99	34.24	23.09	23:15	. 9772	2842.36763	+272.	2839.85468	• 00481	2.51294	1532.
			21	34+37	23.93	24.28	.9763	2822.83290	.9723	2820.40815	10400 • ·	2 . 4 2 4 7 3	15260
	ļ	100.	19.01	34+49	24.65	25.09	.9755	2803.31475	.9722	2800.9634J		2.35130	15201
		125.	17.24	34 . 52	25.10	25 + 4 6	.9750	2778.93339	.9721	2776.66008	.00291	2.27329	15151
		150.	16.28	34.56	25.37	24.03	.9746	2754.56322	.9720	2752.35954	• 00266	2.203.6	15134
		175.	10.51	34 . 56	25.65	24.43	.9743	2710.20223	• 1 2 4 •	2728.04182	.00240	2,14039	1509.
		200.	98.51	34.52	25.86	24+75	£272,	2705.84976	.9717	2703 . 7 4 4 9 1	.00221	2.0 ⁸ 2A2	1506
		250.	12.01	34+39	26.13	27 . 26	.9735	2657.16448	.9715	2655.18553	.00195	1.97893	1500.
		100 E	10.25	34 • 27	26.36	27 . 72	.9730	26n8.50210	. 97 13	2606.61538	+00124	1.88670	14954
		350.	9.23	34•24	26.51	28:10	.9727	2559.85962	. 9711	2558.05643	09100.	1,80316	14924
		1001	8.04	54.13	26.61	28.43	.9724	2511.23407	.9708	2509.50869	12100.	1.72536	1480.
		450.	6 • 8 A	34.10	26.75	29.81	.9720	2462.62545	.9706	2460.97211	100.	1.65332	1484.
	ĺ	500.	5.03	19.66	26.83	29.15	. 9717	2414.03369	.9704	2412.44668	.00128	1.58699	1477.
		550.	40.4	33.66	26.89	29.45	+126.	2345.45701	.9702	2363.93239	• 00121	1.52460	14744
		•009	C 6 • #	34.12	27.01	29.79	1126.	2316.89548	.9700	2315.42922	-00112	1.46624	1479.
		\$ 50•	11 - 1	34.17	27.08	30.05	• 9708	2248.34903	.9697	2266.93715	00100.	1.41187	14794
		100.	101	34•15	27 . 1 4	30.39	.9705	2219.81679	• 9 6 9 5	2218.45615	•0000•	1.36042	14764
		150.	1.91	34•20	27.18	30.46	.9702	2171.29797	6999.	2169 • 98622	• 000 9 6	1.31174	1477.
•	i	800	1000	34 • 26	27.23	10.94	.9700	2122.79212	1696.	2121.52733	.00092	1.26478	1478.
		050	1.75	34 • 29	27.27	26.16	.9697	2 74.29427	.9680	2 73.07946	•00088	1.21979	14784
		•006	3 • 6 4	16.46	27.30	0*•16	.9695	2 25.01093	.9686	2 24 • 6 4 2 6 1	•0000•	16971.1	1479.
		950.	33.0	34.35	27,35	31.76	.9692	86126.7791	• 9 6 8 4	1976.21674	18000+	1.13463	1479.
		1000	****	34•35	27.36	32.00	• 9 6 9 0	1928.89621	.9682	1927.80184	• 00080	1.09436	1479.
		11000	30.05	0+++0	27.42	32.54	.9685	1832.02223	.9678	1831.00488	• 000 •	1.01735	1480.
		12001	2.79	*****	27.48	90.66	.9680	1735.19770	.9673	1734.25158	• 0009 • 9	1946.	14804
		1300 •	2 . 6 4	34+4.7	2752	33.56	.9675	1638.42099	.9669	1637.54181	•00045	• 8 7 9 1 8	1481
	i	1400	2 . 49	34 • 48	27.54	34.24	.9471	1541.69028	.9664	1540.87542	.00043	•814A5	1982.
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		1725.	2,15	34+56	27.63	35.42	• 9 6 5 6	1277.63042	.9450	1227.00745	+00025	+ 62297	1487.
		1950.	1.95	34•59	27 . 67	34.49	.9546	1 10.48227	1 4 9 6 • 1	1 9.97925	1 5000 .	. 50302	1490
		2175.	1 - 7 9	14.46	27.70	37.75	.9636	0793.55415	1596.	0793.16611	••000•	.39004	1493.
		2400 •	1.70	34 • 62	27.71	39.78	.9627	0576.84767	.9622	0574.54651	.00048	128117	1996
~	-	2625.	1 • 6 4	24.43	27.72	J9.A O	.9417	0160.15110	.9413	0340.17890	• 000 • 2	.17440	1500
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ċ	24.94	09.40	23.07	21.07	.4774	12952.1045	.9726	01507 . 0602	.00480	21192.6	1534.20
20.	24.84	14.46	23.10	23.19	[1/6.	2081.90439	.4726	2878.75315	• 00478	62441.	1534.44
•0•	24.89	14.46	23.10	23.27	6114.	2842.34250	.9725	2859.30301	• 0 0 4 7 9	12920.6	1534.79
•0•	21.53	34.59	24.06	24.32	.9763	2842.82737	.9724	2039.45468	.00389	2.97271	1526.73
80.	10.02	34.67	24.53	24.48	. 4757	2823.30753	.9723	2820+40815	••00•	2.49940	1523.08
1001	18.91	34.66	24.80	25 . 24	.9754	28n3.79649	.9722	2800.96343	• 1 0 0 0 •	2.83307	1520.33
125.	18.02	14.74	25.09	25.44	.9750	2779.41673	12791	2776.64008	.00293	2.75646	1518.28
150.	12.51	34 • 7 4	25.21	25.87	.9748	2755.04440	.9720	2752+35954	.00282	2.60487	1517.26
175.	17.07	34.72	25.30	24+07	9746	2730.67726	.9719	2728.06142	• 00274	2.61544	1516.28
-002	16.89	24.73	25.37	24.26	.9744	2706.31474	.9717	27n3.76641	.00267	2.54782	1515.89
250.	4 + 4 H	34.72	25.45	24.56	1 + 2 6 .	2647.60108	.9715	2655 • 18551	.00262	2.41555	1515.61
•005	15 • 8 n	34 • 67	25,56	24 . 89	.4738	2608.90237	6179.	2606.61534	• 00253	2 + 2 8 7 0 0	1514+40
350.	15.01	10.46	25.69	27.24	.9735	2540.21995	.9711	2558+05643	.00241	2.16352	1512.67
•00+	13.84	34.52	25.86	27 . 45	.9731	2511.55553	.9708	2509+50869	• 00225	2,04685	1509.67
450.	12.92	34 • 4 7	26.02	24.03	.9727	2442.90975	.9706	2440+97211	• 00 2 1 1	1.937,5	1507.31
2000	11.52	36.46	26.19	24 . 4 4	.9723	2414.28275	.9704	2412.44660	• 0 0 1 9 5	1.83607	1503.17
550.	9 . 9 >	34.22	26.38	2A . A 6	. 97 19	2345.67548	.9702	2343.93239	• 00177	1.74309	1198.11
• 00 •	8 • S n	34.16	26.56	29.29	.9715	2317.08823	• • 7 00	2315+42922	•00159	1.45902	1493.58
4 2 Q +	7.63	34 • 15	26.68	29.45	.9712	2248.51952	.9697	2266.93715		1.58237	1491.06
100.	0 Y • 9	34.12	26.79	30.00	• 9709	2219-96751	.9695	2218 . 45615	16100.	1.51136	1488.18
. 150.	5 . 1 7	20.40	26.91	10.17	.9705	2171.43252	.9692	2169.98622	• 00 24	1.44630	1482.77
8 00•	4 • • •	11.03	26.97	30.47	.9702	16619.5415	.9641	2121.52733	00118	1.38598	1481.49
850.	4 • 7 5	34.16	27.06	30.99	6 A 9 A 4	2 74.40859	. 9688	2 73.07946	• 0 0 1 0 0 •	1.32913	1482.87
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			2/117		0040	F1762.65/1	7/0/0	1/37.25150		810011	112071
	2.70		27.49	31.08	.967.	1541.736ÅB	.9444	1540-87542	- 000	- 1 2 C	
1500.	2+58	74.42	27.52	34.48	.9667	PE440.3441	.9660	1444.25227	.00046	. 79407	1485.01
1725.	2.27	1.53	27.60	35.69	.9656	1227.66157	.9650	1227.00745	• 0000 •	. 65412	1487.55
1950.	2.04	34.56	27.64	34.46	.9446	1 10.50540	1696.	1 9.97925	• 00055	.52615	1490.50
21750	1.90	99.45	27 . 66	17.76	.9637	0793.57123	1696.	0793-14611	• 00052	.40522	1493.67
2400.	1.77	34 • 60	27.69	34.75	.9627	0576.85623	.9622	0576.56651	• 00050	.28973	1496.98
26250	1.44	34 • 62	27.71	39.79	.9417	0360.35782	.9413	0360.17890	8 6 0 0 0 • 8	.17892	1500.49
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		24.54	14.64	23.22	22.22	5179.	2901.4774C	.9726	2848.20510	.00467	3.27252	1533.43
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APPENDIX B

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STD DATA FROM THE KUROSHIO (24-26 October 1976)

AND CALCULATED PARAMETERS

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			S VEL Miteri	521.14	541.47	241.51	29.212	503.60	496.70	468.62	469.34 461.34	479.11	475.40	476.50	475.58	474+96	476.64	476.52	477.17	4//.54	4/8.72	479.82	442.28	483.60	446.57 469.80	61.294	496.56 498.15
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APPENDIX C

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STD DATA FROM KUROSHIO WARM EDDY

(29-30 October 1976)

AND CALCULATED PARAMETERS

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