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PROFILES IN SCIENCE



Professor Michael Tinkham

Professor Michael Tinkham, who is Gordon McKay Professor of Applied Physics and Professor of Physics and Chairman of the Physics Department at Harvard, has been an ONR Contractor for many years. Most recently he was a member of the 1976 Navy Study on Superconductivity Electronics. Before going to Harvard in 1966 Professor Tinkham was at the University of California, Berkeley, where he became a well known pioneer in the far-infrared spectroscopy of solids, making the first spectroscopic observation of antiferromagnetic resonance, temperature-dependent soft-modes in ferroelectrics, and other phenomena.

At Harvard he has continued to work on superconductivity in the areas of fluctuation effects, quantum interference devices, Josephson effect at far infrared frequencies, non-equilibrium superconductivity, and far-infrared spectroscopy of solids.

Among his many contributions to the scientific literature are two popular text books, "Group Theory and Quantum Mechanics" (1964) and "Introduction to Superconductivity" (1975). He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences.

Naval Uses for an Algal Toxicity Test

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Introduction

In today's concern for the environment the Navy must be prepared to justify its actions in situations where precedents do not exist. For example, dredging a channel to make it deep enough for safe ship passage has been standard practice but now there must be assurances that dredging and the disposal of spoils will not harm the environment. Coating a ship's hull with antifouling paints has long been recognized as a Navy need, but the use of certain new coatings raises questions about possible damaging effects on the biota, and some harbors now prohibit the docking of ships painted with the new class of compounds known as organotins. The list of Navy problems concerning toxicity assessments is long and growing each year. Therefore, it is increasingly important to be able to judge "This is too toxic" or "That should not pose an environmental problem" in various situations.

Final judgments on questions of toxicity often must be made with "chronic" tests in which animals, such as fish or mussels, are exposed to pollutant concentrations only slightly higher than ambient. Such tests are lengthy and expensive, and therefore are ill-suited to situations in which only rough estimates are required. For many purposes, "acute" tests with higher pollutant concentrations are more satisfactory because they are faster and a greater number of assays can be run at one time. Acute tests can utilize either plants or animals as toxicity indicators. We have chosen to use microscopic plants (algae, the "grass" of the sea) because of their reliability and our previous experience with them. Those who have the difficulty in growing an attractive lawn may question the use of any biological test, particularly one based on plants, but one of the great problems involved (that of duplicating the culture conditions) is considerably simpler with liquid cultures than with those based on soils. For example, a previous Naval Research Laboratory (NRL) study demonstrated that an algal culture supplied constantly with nutrients will produce oxygen at an hourly rate which varies less than

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0.7% over a period of three days (1), and it is believed that this performance could have continued for long periods.

Besides their reproducibility, algae have two additional virtues for use in toxicity tests; they grow quickly, proceeding through several generations in a few days, and they have very little mass which can be an advantage in measurements of pollutant uptake. If the amount of pollutant absorbed by a test organism is an appreciable fraction of that added, the value of the experiment is diminished. Algal cultures of the type used in these studies contain less than 10 milligrams per liter, therefore, a great absorption of pollutant can take place without reducing the pollutant concentration completely.

The illuminated aquarium, with 500 ml flasks containing test cultures used in these studies, is shown in Figure 1.

Measuring the Growth of Algae

There are many possible approaches to measurements of the growth taking place in an algal culture. The two methods used most often are a count of the cells and a determination of the chlorophyll content. The former can be done either with a microscope or with an electronic

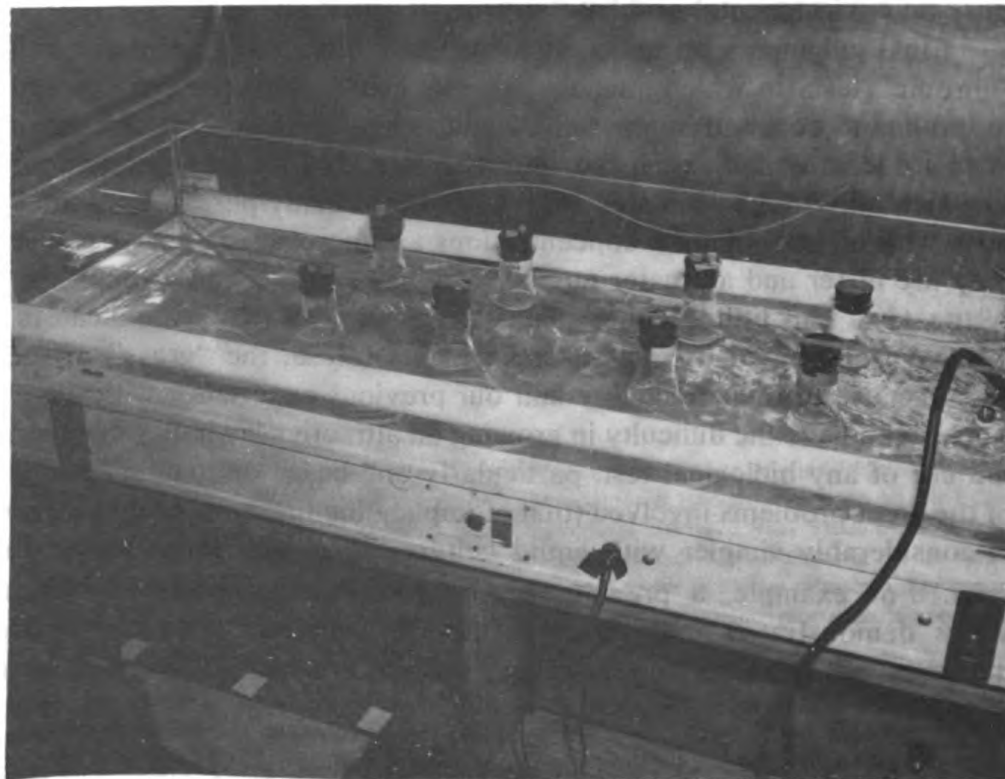


Figure 1 — Lighted aquarium, with test flasks and stirrers, used in algal toxicity test.

particle counter, while the latter generally involves filtering the cells, grinding them in a chlorophyll-extracting solvent, and then measuring the spectral absorbance or fluorescence. Each method has its pitfalls: cell counting can be misleading in situations where a pollutant prevents cell division but does not stop growth, and chlorophyll determinations performed in the customary way are time consuming. We have found that satisfactory estimates of chlorophyll content can be made with a new technique (2) which avoids the tedium of the extraction process. It consists simply of determining the fluorescence of the algal culture in the presence of the herbicide DCMU (dichlorophenyl dimethyl urea). Twenty microliters of a DCMU solution are added to 2 ml of the culture in a small vial which is then placed in a fluorometer, and, with the push of a button, the fluorescence is measured. Fluorescence measurements for determinations of chlorophyll content are not new (3), but their interpretation can be confused by the effects of physical or chemical stresses imposed on the algal cells. The addition of DCMU blocks the photosynthetic apparatus of the cells, and in this condition their fluorescence is a direct measure of their chlorophyll content.

Applications of Algal Toxicity Test

Fuel Biocides

The Navy is beset with problems caused by growths of bacteria, fungi, and yeasts in fuel systems. These organisms degrade tank linings, clog filters, and generate debris in the tanks of certain ships. One approach to this microbial contamination problem is to add a biocide to the fuel or to the water phase, thereby preventing the growths of the organisms. A difficulty associated with this approach is that when the fuel tanks are refilled, the biocide-treated water must be discharged and this might have a detrimental effect on marine life. Thus if several compounds have sufficient toxicity, but one is quickly degraded by sunlight, then that one would be the logical choice. Obviously it would be helpful to know which biocide loses its toxicity most quickly in sunlight but to determine this with the organisms contaminating the fuel would be extremely time consuming. By substituting algae for the organisms in question, it is possible to make a more convenient estimate of the rate of solar degradation of the biocides.

For this study, stock solutions of the biocides were prepared and divided into equal portions; one was kept in darkness while the other was exposed to light. The light exposures included 96- and 192-hours before a 100 watt bulb, and 14 days out of doors. Each experiment consisted of determining the effects of three concentrations of three biocides, dark- and light-exposed, on the growth of the alga *Phaeodactylum tricornutum* and the results shown in Table I indicate the

Table 1. Results of toxicity tests with biocides exposed to light for various times

Toxicant	Concentration ppm	Exposure of Stock Solutions	Decrease in Growth Resulting from Toxicants			
			Fresh Stock Solution	Stock solutions exposed to:		
				Incandescent light 96 hrs	192 hrs	Sunlight 14 days
2-(tertiary butylamine)- thiopyridine- N-oxide	0.005	Light	-	45	31	9
		Dark	28	51	54	55
	0.015	Light	-	94	60	11
		Dark	76	95	83	89
	0.050	Light	-	99	93	7
		Dark	99	99	99	99
methylene bisthiocyanate	0.5	Light	-	0	1	4
		Dark	17	0	4	1
	1.5	Light	-	13	6	5
		Dark	22	16	9	9
	5.0	Light	-	59	48	24
		Dark	69	57	59	60
hexahydro-1,3,5- tris-(2-hydroxy- ethyl) -s-triazine	1.0	Light	-	6	4	9
		Dark	4	3	4	9
	3.0	Light	-	50	48	50
		Dark	36	55	48	50
	10.0	Light	-	93	88	90
		Dark	91	94	92	94

following: a) the solutions kept in the dark retained their toxicity although there appeared to be a gradual decrease in effectiveness in the case of the methylene bithiocyanate, b) the thiopyridine and the bithiocyanate compounds lost considerable toxicity upon exposure to light and, c) the triazine compound lost none of its toxicity in the light. After a subsequent exposure to 2 days of sunlight in quartz vessels, the thiopyridine and bithiocyanate compounds showed no toxicity even at the highest concentrations tested (0.5 and 5.0 ppm respectively).

Each experiment with the algal toxicity test required only 2 days incubation whereas weeks or months would have been necessary to obtain results with anaerobic bacteria. A more complete discussion of the results is obtained in Reference 4.

Wood Preservatives

The resistance of tropical woods to attack by termites and marine borers has been studied at NRL for some time. With the cooperation of the Western Regional Laboratory of the U.S. Department of Agriculture, some of the active components of these woods have been identified and later synthesized; their effectiveness in protecting normally-susceptible woods from attack is now being determined in field tests. Whether these compounds should replace creosote, the traditional but imperfect treatment, depends in part on their toxicity to marine life. The algal toxicity test is being used to examine this question and those compounds which are highly toxic to the algae will have a lower priority in the field studies than those with little or no algicidal activity. The toxicity of each compound toward marine borers and teredos also is being investigated in cooperative studies with Harvard University and the Southern Regional Laboratory of USDA.

Sediment Studies

A major use of the algal toxicity test has concerned the study of sediments. Much discussion has been generated around the disposal of dredge spoils and a natural question is, "How toxic are sediments?" Through the cooperation of the Naval Civil Engineering Laboratory and the personnel at the Trident site at Bangor, Washington, we obtained 16 sediment and soil samples, each of which had been analyzed for 24 elements by the X-ray fluorescence technique. Thus, it was possible to make comparisons between the elemental composition of the samples and their effect on algae. The algae were cultured in the extracts of the sediments and then analyzed for lead, copper, and zinc. There was generally no correlation between the concentration of these metals in the sediments and their uptake by algae (5); this was to be expected because heavy metals are tightly bound by sediments containing humic materials or even certain inorganic colloids.

This study demonstrated several factors to be considered in future research:

1) The commercially available synthetic seawater (Instant Ocean) which was used in this study varied considerably in its trace metal content from one batch to another. Therefore, comparisons of metal concentrations among algal cells grown in different batches of Instant Ocean were not possible.

2) Hourly measurements of pH changes, intended to provide rate measurements of CO₂ uptake, were often compromised by the effects of certain sediment extractives on the pH electrodes.

3) Sediments located within several hundred feet of each other in a harbor may vary greatly in their toxicity to algae.

4) Sediments from a freshwater lake pure enough to support abundant fish populations may be toxic if discharged into a salt water environment.

In response to the problem raised by the variability of Instant Ocean, we have adopted as standard practice the use of a synthetic seawater based on the formula devised by Lyman and Fleming (6). This is made in 600 liter quantities from distilled water and chemically pure reagents; because the formula as devised provides less dissolved CO₂ than desired we have added slightly higher amounts of NaHCO₃. At this writing, algal cells cultured at different times in this seawater have not been analyzed for heavy metals but the hope is that they will be considerably more uniform in this regard than those cultured in Instant Ocean.

As part of the sediment toxicity study, we are now collecting sediments from diverse oceanic and coastal sites to determine the background levels of toxicity. Preliminary indications are that aqueous extracts of sediments generally cause a slight delay in the start of algal growths but eventually increase the yield because of the nutrients liberated from the sediments. Among the sediments which have promoted growth are a fine grained black sludge from the dock at Tokyo Bay and a greenish mud from a depth of 1340 meters in the Cariaco Trench off Venezuela.

One of the prominent concerns about sediments is that they contain heavy metals in concentrations often much higher than those found in the water. This might be particularly important to bottom dwelling animals which ingest particulates, but less so to the algae which are subject only to the influences of dissolved elements. It is well known that sediments are scavengers for heavy metals and therefore, by removing metals from the water, influence the growth of algae. Recent research in this laboratory has emphasized another role that sediments may play in mediating the effects of heavy metals, that is in releasing organic components which form complexes with heavy metals and reduce

their toxicity. A laboratory experiment was performed in which the filtered seawater extract of an innocuous sediment was shown to protect an algal culture against the toxic effects of several metals; copper and zinc were added at concentrations normally inhibiting the algal growth by 50%, but in the presence of the sediment extract (though it formed only a small percentage of the total volume) neither metal had any toxicity! Presumably the humic acid components of the sediment were responsible for the complexation of the metals which reduced their toxicity. In any case, it is obvious from this study (and others) that the concentration of a metal in the water is not the only determinant in its activity regarding the biota, and strictly chemical tests are of limited value in the prediction of effects of dredge spoils disposal.

Assessment of the Algal Toxicity Test

Among the factors contributing to the reliability of the algal toxicity test are the washing of the cells, to remove all residual nutrients and thereby insure that each batch of cells has the same potential for growth, and the constant stirring which keeps the cells in the light at all times. Table 2 contains a summary of the average growth rates of the controls and the average inhibitions obtained with a standard toxicant dose of 0.0033 parts per million mercury for the most recent tests. The numbers indicate a constant performance on the part of the algal cultures, and it might be well to stress just how precise the conditions must be in order to duplicate effects obtained with such small concentrations of pollutants. A concentration of one part per million can be described as one drop in 16 gallons, and one part per billion as one drop in 500 barrels. It is noteworthy that 3.3 parts per billion of mercury (3.3 micrograms/kilogram) not only affects the growth of algae, but that its activity is repeatable from one test to another.

In designing a toxicity test with microorganisms there can be a trade-off between a fairly rapid test involving only a few days of growth, starting with a relatively heavy inoculum, and a longer test in which fewer cells serve as the inoculum. The effect of a toxicant is related inversely to the number of cells present. Therefore, if the goal is to provide a highly sensitive test, the approach would be to use an extremely dilute inoculum. For our purposes the most useful approach has been to use a rapid test involving an inoculum which is more concentrated than the phytoplankton density prevailing in most marine waters. In Table 3 is a listing of several metals of ecological interest with the corresponding concentrations required to decrease the growth rate of *Phaeodactylum* by 50%. Note that copper, while it is considered highly toxic, is two orders of magnitude less toxic than mercury. Also, it is worth mentioning that cadmium showed no inhibition of algal growth

Table 2. Data on growth of controls, and inhibition by 0.0033 ppm mercury, for toxicity tests

	Packed cell volume of inoculum	Growth rate constant for controls	Inhibition by mercury
Average	2.75	.074	34.7%
Standard deviation	.19	.003	5.4

when added at 50 ppm, although analyses made of the cells cultured for 2 days in its presence absorbed more than 90% of the cadmium added. The concentrations shown in Table 3 are higher than those normally found when sediments are stirred with seawater. Therefore, if a sediment elutriate is inhibitory to algal growth in this test it might be that some organic component is responsible for the toxicity; another possibility is the additive effects of several metal ion species.

Complexations of heavy metals by naturally occurring organic compounds can have a profound effect on the growth of organisms. Blue-green algae detect a major difference between a few micrograms of copper per liter, added artificially, and a similar increase in indigenous copper which occurs during wind mixing (7). The copepod, *Euchaeta japonica*, in its earliest stages of development can survive in water containing relatively high copper concentrations so long as sediment extracts are present (8). Both of these are examples in which a metal is rendered less toxic by the presence of an organic complexing agent, but it is also possible that an inorganic element can counteract the effect of a toxic metal. This was suggested in a report describing the role of selenium in the detoxification of methylmercury by marine mammals (9). To determine whether the same antagonism might be displayed with another class of marine organisms (algae), and at the same time demonstrate the relevance of the algal toxicity test, we studied the joint effects of selenium and mercury on the growth of *Phaeodactylum tricornutum*. Table 4 contains a summary of the findings, and indeed when selenium was present at a molar concentration ten times that of the mercury, it completely reversed the toxic action of the mercury.

The major point to be made in this discussion is that the concentration of a metal in solution is not a valid measure of its toxicity unless all competing complexations or synergistic effects can be ruled out. In the examples cited above it is evident that the behavior of the algae can parallel that of more complex organisms insofar as heavy metals are concerned. Also there is justification for the use of a living organism as an indicator of the relative toxicities of pollutants rather than chemical

Table 3. Concentrations of metals required to reduce algal growth rate by 50%

<u>Metal</u>	<u>PPM</u>
Hg	0.004
Cu	0.41
Zn	6.8
Pb	> 15.0
Cd	>> 50.0

Table 4. Effects of mercury and selenium, singly and combined, on growth of algae

<u>Element</u>	<u>Concentration</u>	<u>Growth effect</u>
Hg	2×10^{-8} M	-48%
Se	2×10^{-9} M	+3%
"	2×10^{-8} M	+3%
"	2×10^{-7} M	+6%
Hg, plus	2×10^{-8} M	
Se	2×10^{-9} M	-57%
"	2×10^{-8} M	-45%
"	2×10^{-7} M	+3%

analyses of the pollutants. Each test, whether chemical or biological, provides information having certain limitations. The algal toxicity test described here is useful in ranking the relative toxicities of pollutants, and it is reproducible; it can be made considerably more sensitive, if necessary, by reducing the concentration of the inoculum. Adsorption phenomena would then become increasingly important and a decrease in the concentration of pollutant, commensurate with that of the inoculum, would result in less inhibition than expected.

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Powerful Submillimeter Radiation Generator

Naval Research Laboratory (NRL) scientists have developed a new theoretical model for producing intense submillimeter radiation. The scientists have experimentally realized this concept, producing megawatts of electromagnetic radiation at wavelengths equal to fractions of a millimeter — the most powerful submillimeter radiation ever produced by man.

The development is expected to have a strong impact on the Navy's continuing efforts to improve its radar and communications systems through the development of submillimeter radar and other hardware from information gained in the research.

As an additional application it is expected that this energy source might eventually be used as a method to heat deuterium to thermonuclear temperatures required in the long-sought goal of the controlled fusion program.

This new approach to the high energy source is based on reflection of incident microwave radiation from a beam of highly energetic electrons which travel near the speed of light (186,000 miles per second).

The incident microwave radiation is at a relatively low frequency, while the reflected radiation is shifted to a much higher submillimeter frequency. This frequency shift phenomenon is known as the Doppler effect and is similar to that which takes place when the whistle of an approaching train rises in pitch.

The reflection process is one in which the low frequency microwave signal produces oscillations in the electron beam in addition to the high frequency submillimeter radiation. The process can be reinforced by careful tuning of an applied magnetic field to produce a resonance effect.

A theoretical analysis indicated that the reflection can involve a substantial flow of power from the electron beam into submillimeter radiation, and that the power in the submillimeter radiation can be much larger than the power in the low frequency incident radiation.

Tracking the Kuroshio by Nimbus 6

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Texas A and M University

During February, 1977, we had the opportunity of participating with scientists of the Japan Hydrographic Department and the Ocean Research Institute of the University of Tokyo in a pilot study of the Kuroshio. This is a preliminary report of our efforts. This expedition was funded by the Office of Naval Research and the National Science Foundation.

As one of the major Western Boundary Currents (WBC), the Kuroshio has long been an object of intense study. In many respects, the Kuroshio is quite similar to the Gulf Stream, another well-studied WBC. There is, however, one major difference. The Gulf Stream has only one preferred path as it flows along the eastern seaboard of the U.S., but in the region south of the main island of Honshu, the Kuroshio follows one of two possible paths. One path follows quite closely the coastline of Honshu. In the other, a large meander develops south of Honshu. This meander is believed to extend as far south as 30°N or about 300 km from the other path. Examples of these two paths are shown in Figure 1 which were taken from bulletins that are distributed regularly by the Japan Hydrographic Department.

When the Kuroshio is in its meander mode, a cold water mass develops between the meander and the coastline. South of the meander, a warm core eddy is believed to exist. This meander circulates some of the Kuroshio water with the subtropical counter current system (Rikiishi and Yoshida, 1974) and perhaps the Kuroshio itself south of Kyushu.

Because the strong currents of the Kuroshio have such a significant effect on the shipping industry, and the intrusion of the cold water mass greatly affects the fishing industry and weather over the northern part of Honshu, Japan expends a considerable effort in monitoring the Kuroshio. This includes almost continuous ship surveys by such diverse agencies as Japan Fisheries Agency, Japan Meteorological Agency, and the Hydrographic Department. These ship surveys include closely

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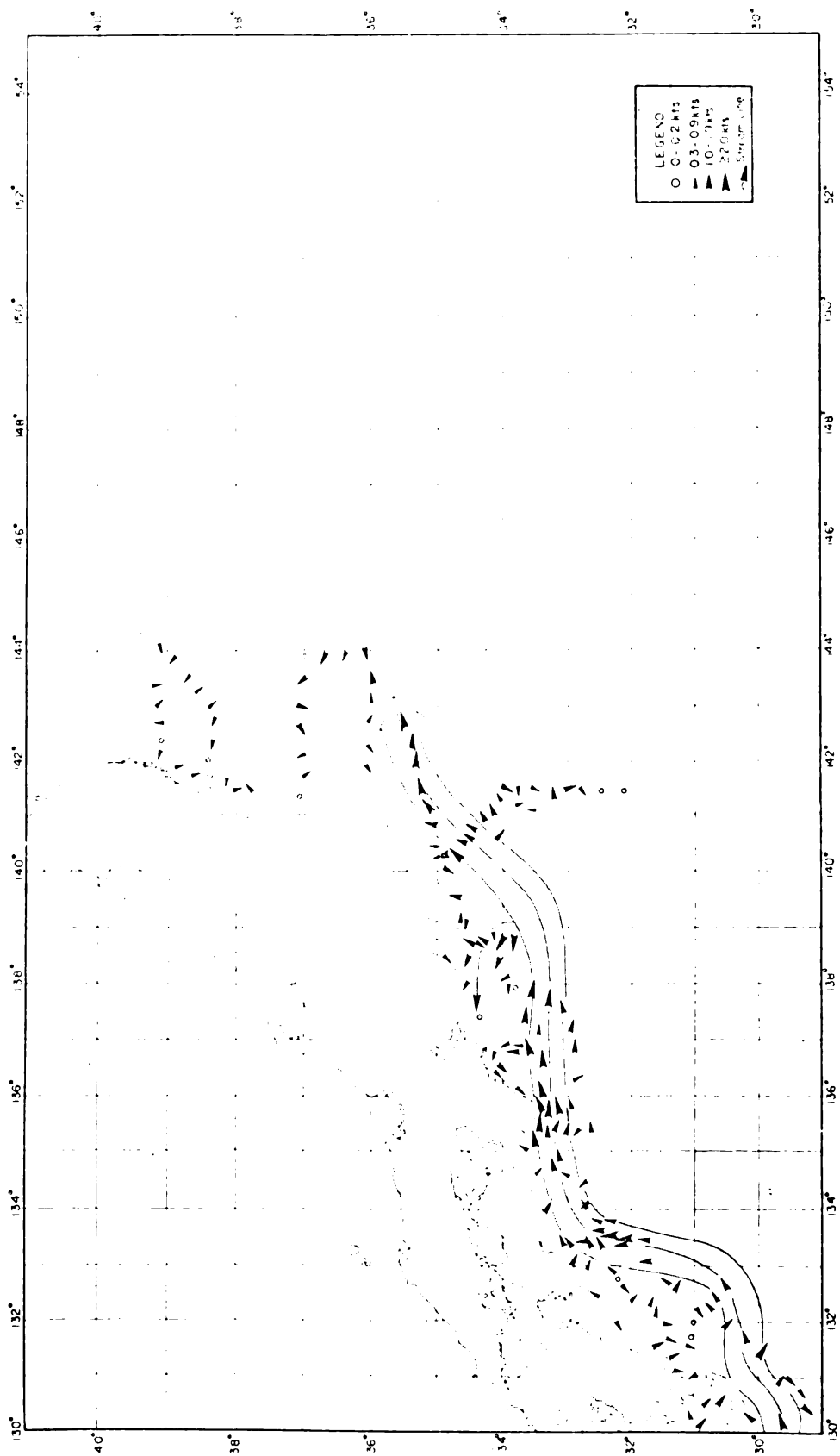


Figure 1a — Two possible paths of the Kuroshio as shown from Japan Hydrographic Department bulletin: 1 June — 17 June, 1975

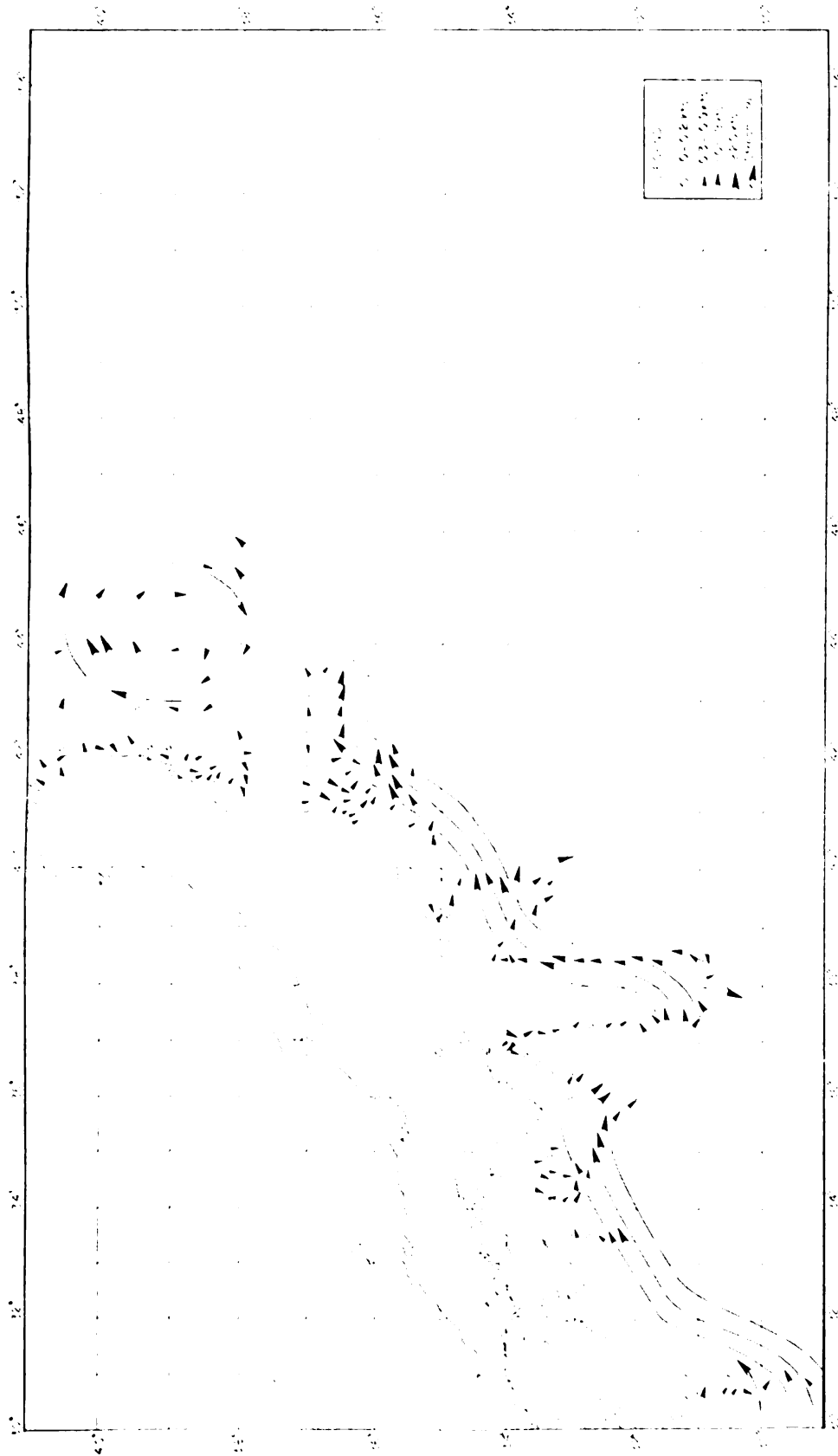


Figure 1b -- Two possible paths of the Kuroshio as shown from Japan Hydrographic Department bulletins from 1 December 1975

spaced expendable bathythermograph (XBT) stations, some hydrographic stations, and continuous underway geomagnetic electro kinetograph (GEK) measurements. The Hydrographic Department is responsible for assimilating all of the data from these diverse sources and producing a bulletin on the location and intensity of the Kuroshio. This bulletin comes out every other Saturday and includes observations made as late as the previous day. Figuring conservatively, over six-hundred days of ship time per year are allocated by the Japanese government for monitoring the Kuroshio. Despite this effort, the Japanese feel that there are significant scales of motion of the Kuroshio which are not detected by either the frequency or the scale of the surveys.

Because one of us had previously successfully tracked the Gulf Stream (Kirwan, *et al.*, 1976) by the Nimbus 6 satellite, the Japanese were anxious to test this technique with the Kuroshio. Thus, we were invited to participate in a cooperative pilot experiment in February, 1977.

We deployed four drifters, each drogued at 100 m by a 9.2 m personnel parachute, off the island of Kyushu. The deployments were made from the R/V TAKUYO which was made available by the Hydrographic Department of the Marine Safety Agency of Japan.

This pilot experiment had a number of goals. First, we wished to compare the results of the drifter tracks and velocities with that obtained by GEK and the hydrographic surveys. The second goal was to verify the existence of the cold and warm water eddies. The third objective was to study the variability of the currents in the extension region.

The drifters are tracked by the Random Access Measurement System (RAMS) onboard Nimbus 6. A brief summary of the way the system operates is as follows. The transmit terminal in the buoy transmits approximately 1 second every minute. The transmission contains a four-digit identifier and four eight-digit data words. Actually, the system has the capability of transmitting eight data words, four words in alternate transmissions. The data are recorded by the satellite during the fly-by (~ 20 min.). The buoy positions are determined by Doppler shifts of the transmissions occurring during the fly-by.

The satellite is in a sun-synchronous polar orbit which crosses the equator northward bound at local noon and southward at midnight. The orbital period is about 107 minutes. Each orbit crosses the equator 27° longitude further west than the previous orbit.

Discussion of Trajectories West of 140°E

The four drifters were deployed along a line normal to the axis of the Kuroshio just east of Honshu. The trajectories up to Julian day 110 are shown in figure 2. Drifter 106 was deployed just to the landward

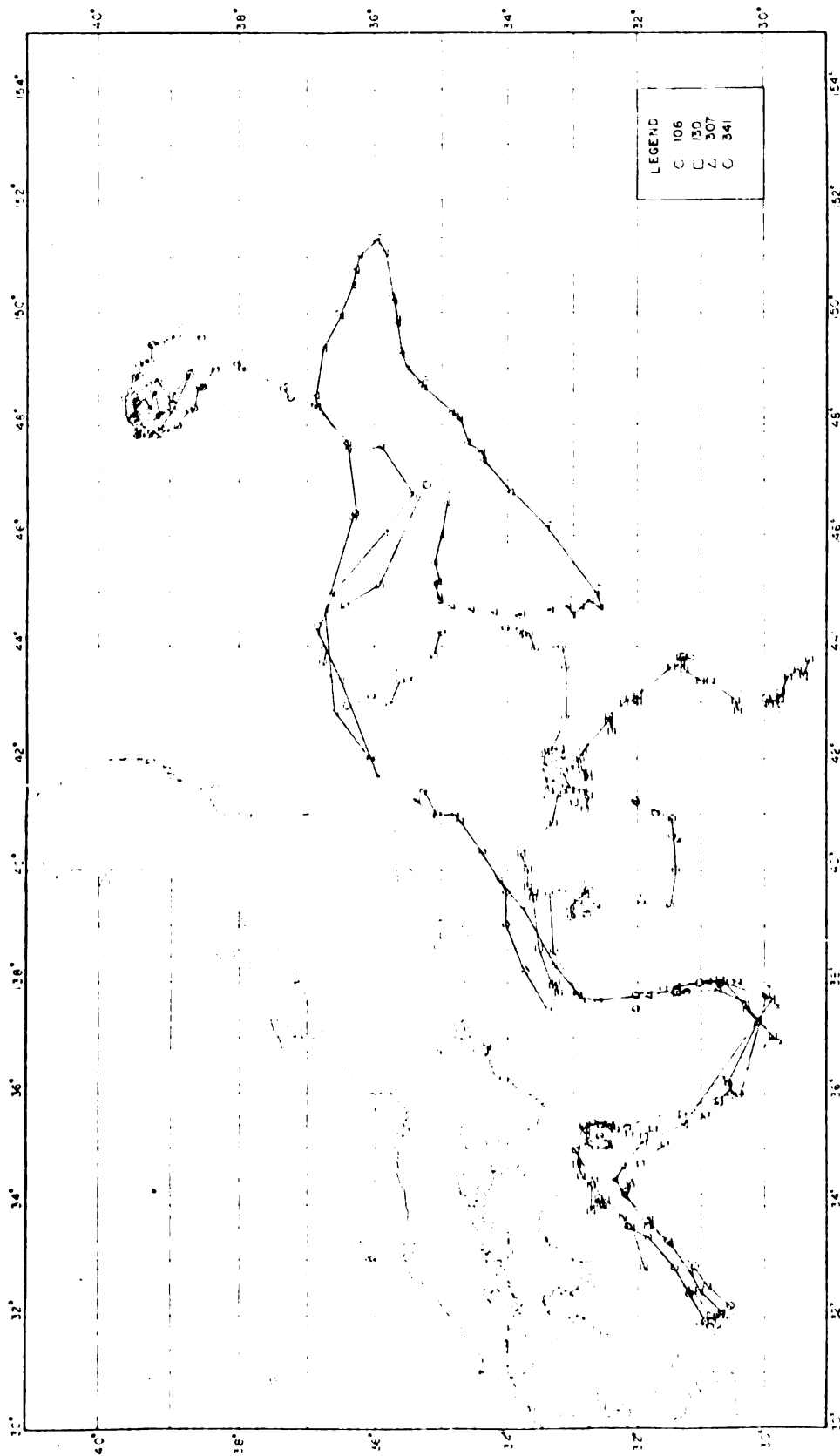


Figure 2 — Summary of drifter trajectories from time of deployment to Julian day 110 of 1977.

side of the high speed core of the Kuroshio as determined by GEK. Drifter 130 was deployed just to the seaward side of this core. Drifters 307 and 341 respectively were deployed out on the flank of the current. The deployment scheme was selected with the expectation that 106 would break off into the cold core eddy and that 341 would peel off into the warm core eddy.

Figure 2 shows that the drifters all moved at approximately the same velocity (2 – 2 1/2 knots) until Julian day 54. At that time, 341 took off to the southeast along the meander axis. However, as indicated in figure 2, it did not leave the Kuroshio as we had anticipated. At the other extreme was 106, which from day 56 to day 60 was entrained in a small anticyclonic eddy. It rejoined the main flow of the Kuroshio on day 62.

This is a puzzling result. The model of White and McCreary (1976) suggests that 106 should have undergone the greatest acceleration as the flow enters the meander and that 341 would exhibit the least acceleration. Instead, there appears to be an area of stagnation on the northern part of the Kuroshio as it starts the meander.

Examination of figure 2 shows that the trajectories of all four drifters, along the eastern flank of the meander, are quite close, even though there is as much as eleven days difference in the time of traverse. This supports the view of Japanese scientists that during days 47 – 59 the meander was in an extreme western position, and that it was beginning to move eastward. Thus, in eleven days the western part of the current could have moved 20 km to the east. Such east-west migrations of the meander are well documented in the Japanese oceanographic literature.

Figure 3 compares the four trajectories with the Japanese analysis of the current location and the temperature field at 100 m for days 47 – 59. The dashed lines in these figures are areas in which there is a paucity of hydrographic or GEK data. The agreement with the current chart generally is quite good with only minor discrepancies where there is a lack of data. Note that on the western leg of the meander, two days are missing in the track of 307, thus the straight line between date points is not a good representation of the actual track. Finally, there is no evidence in the hydrographic or current charts of the anticyclonic eddy detected by 106, but it is of such small scale that it might not have been detected by the survey.

Data from days 60 through 74 are compared in figure 4. Up to the time the drifters reach the Izu Ridge, which runs southward along 140°W, the 100 m temperature field, the current chart, and trajectories are in excellent agreement. It was encouraging to note that 307 went straight through the Izu Ridge right in the core of the current. The track of 130 as it peels off from the main flow east of the ridge is also indicated in the current chart. Drifter 341, after it reaches the ridge,

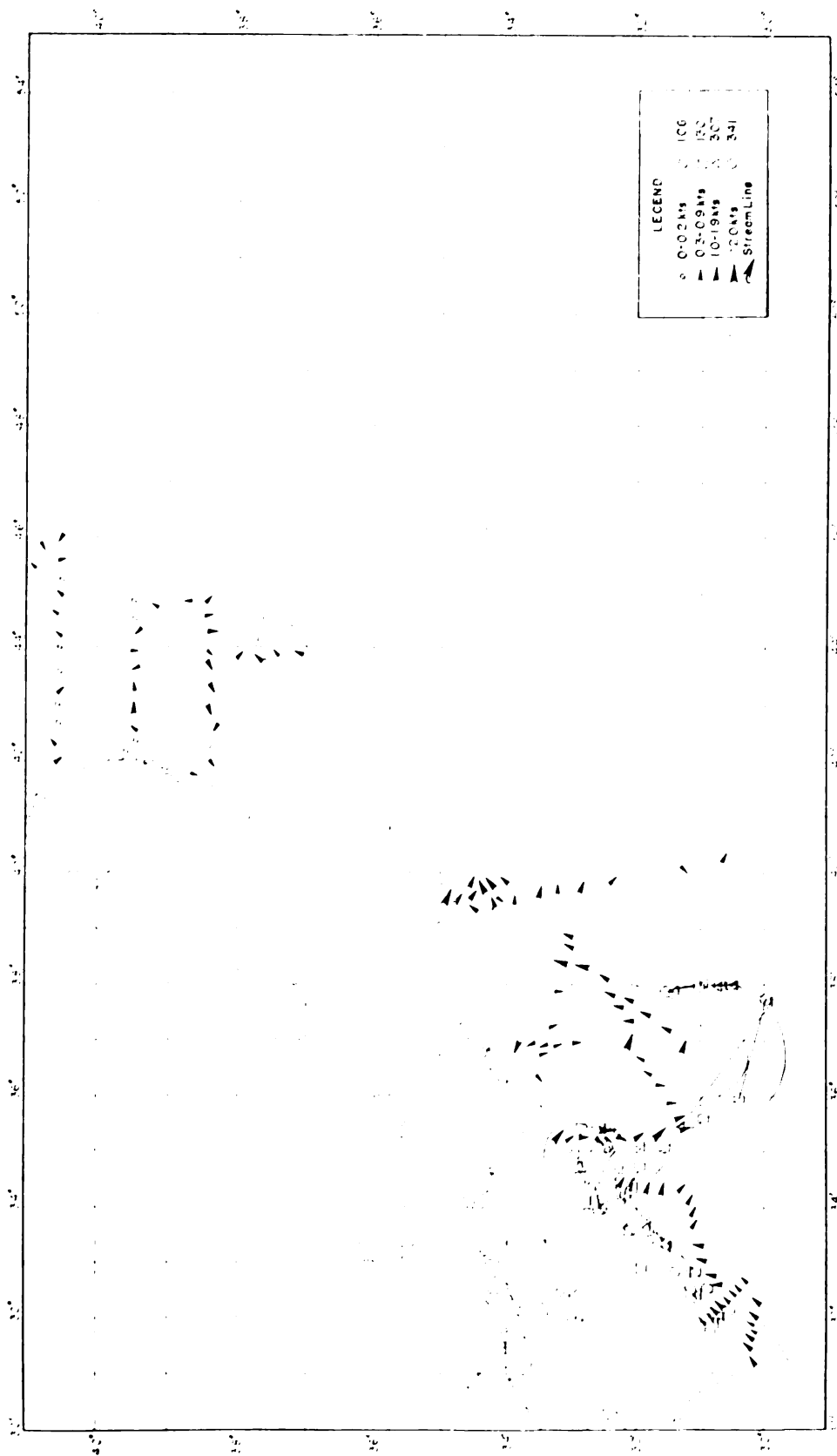


Figure 3a - Comparison of drifter tracks with current

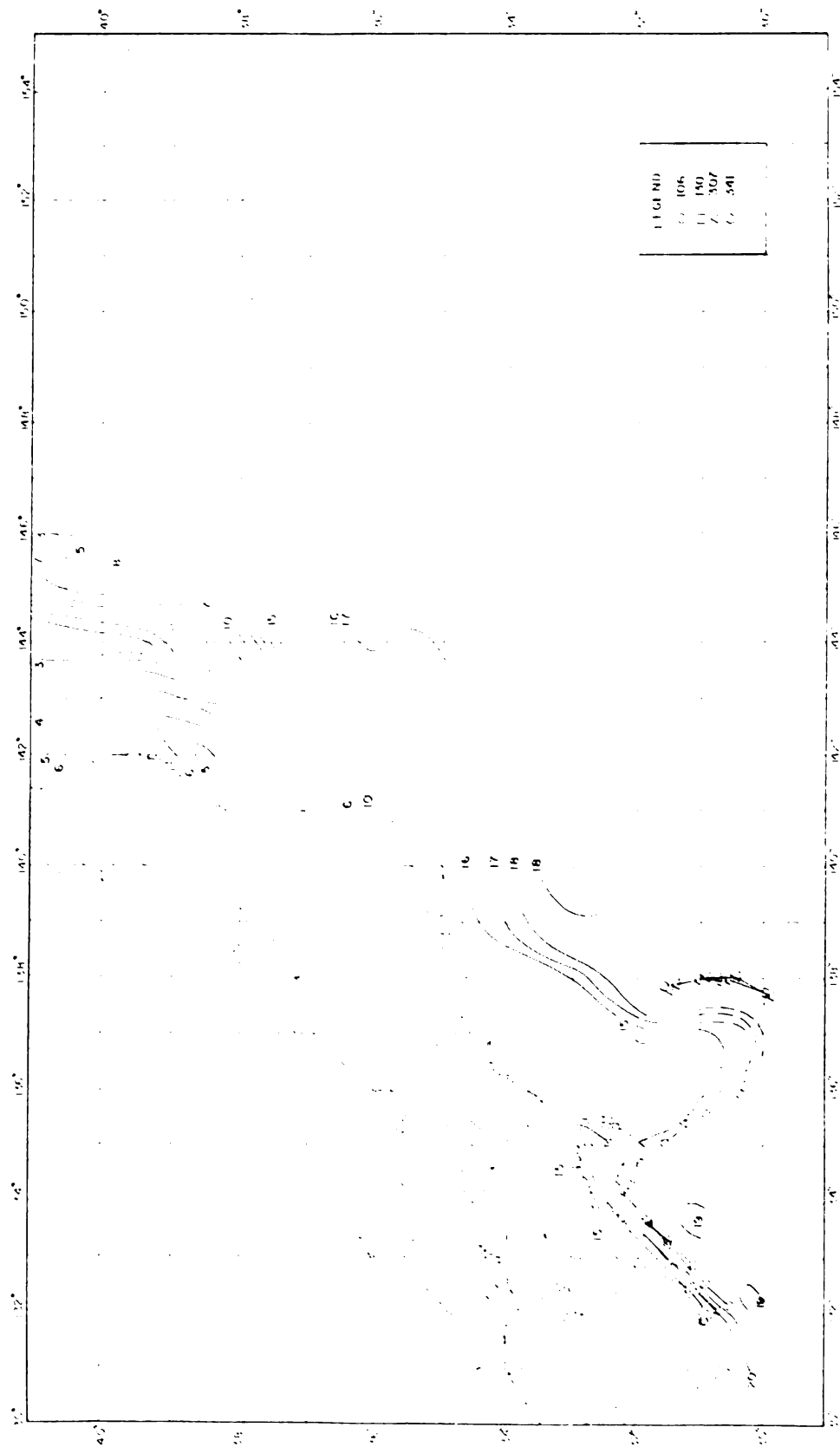


Figure 3b — Comparison of drifter tracks with temperature for days 60-74 as provided in Hydrographic Department bulletin.

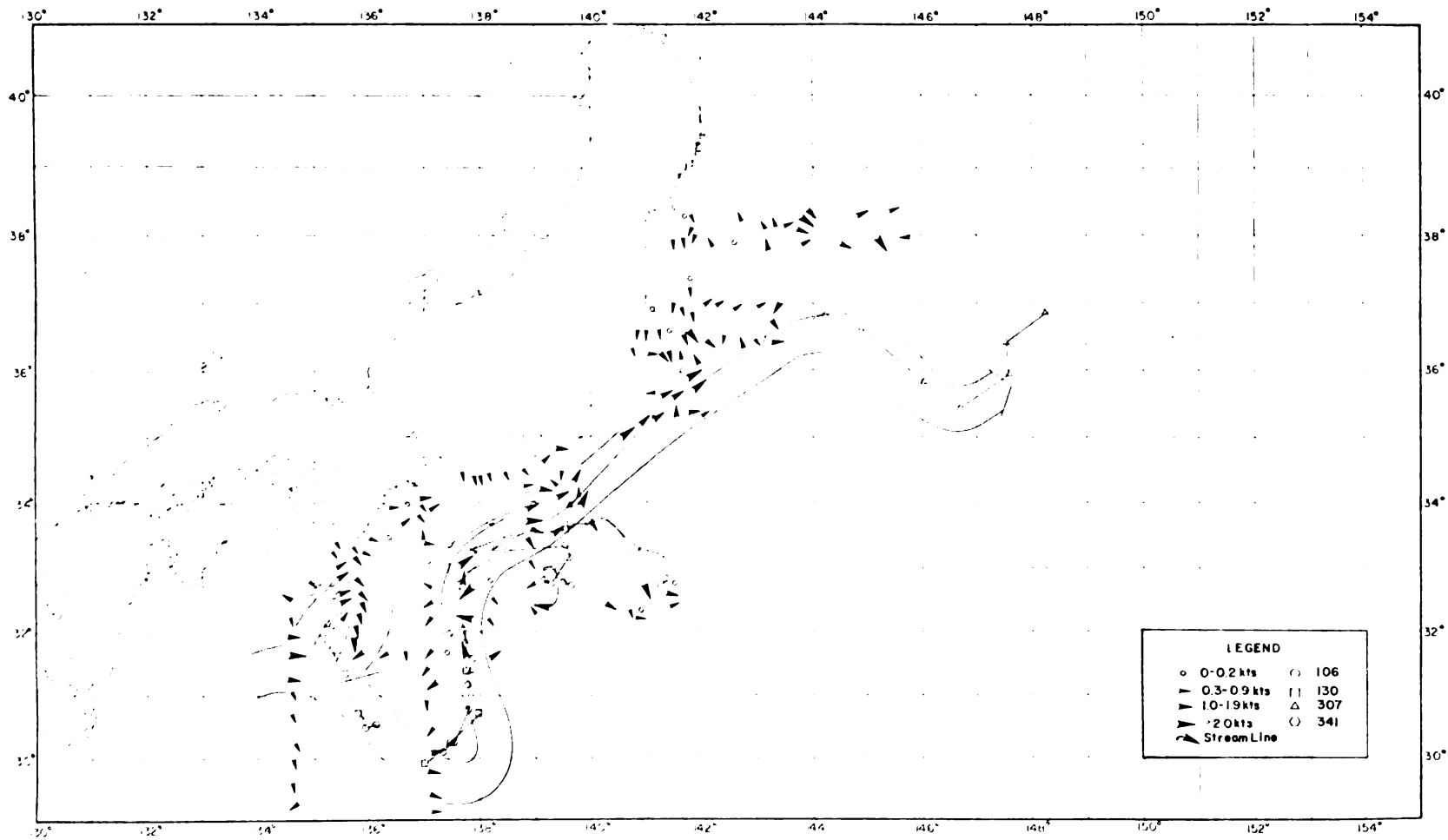


Figure 4a - Comparison of drifter tracks with current

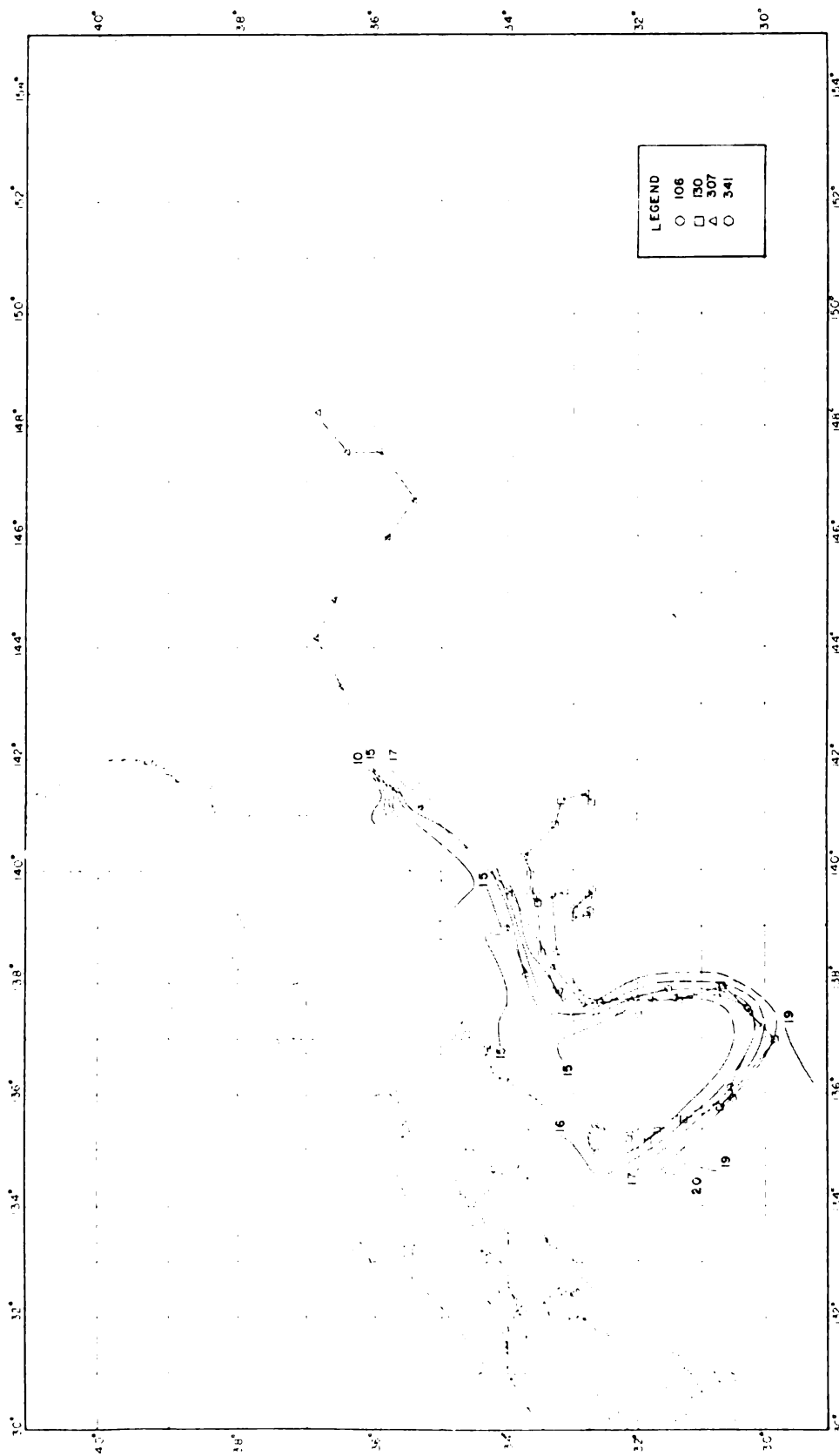


Figure 4b — Comparison of drifter tracks with current temperature for days 60-74 as provided in Hydrographic Department bulletin.

enters an anticyclonic eddy which is not inconsistent with the surface flow field as determined by GEK.

For days 75 – 90, only 106 and 341 remain in the survey area. The latter is seen in figure 5 to be following the main current axis east of the Izu Ridge. Drifter 341 drifted slowly southward (about .1 kt.) until it reached $30^{\circ} 30'$. At this point it turned eastward and then northward. This track is quite consistent with the GEK survey.

Discussion of Trajectories in Kuroshio Extension

It is well known that the flow east of the Izu Ridge is quite complex. Data from numerous hydrographic surveys indicate a very complicated structure of the dynamic topography with rapid large-scale changes. Ocean fronts and large eddies are conspicuous features here.

The trajectories in this region (see figure 2) attest to this. Drifters 307 and 130 came through the Izu Ridge at the same point but separated in time by about five days. Their initial tracks upon departing the ridge are nearly identical to latitude 148° . At this point, however, 130 broke off in a large warm core eddy north of the Kuroshio. Drifter 307, on the other hand, follows a wave-like pattern to approximately 151° longitude, at which time it did an about-face and started flowing to the southwest. On day 95 it turned abruptly northward and then on day 105 eastward.

Drifters 106 and 341 have been moving slowly just to the south of the mean axis of the Kuroshio. They arrived in this area by completely different routes; 341 having performed an end run around the ridge, while 106 came shooting through the gap at $33^{\circ} 30'$. Since day 109, however, 341 has been following closely the trajectory of 307, except that it looped much further to the north.

A more detailed interpretation of these tracks cannot be made without concurrent hydrographic or infrared satellite data. The hydrographic data is being obtained through the North Pacific Experiment (NORPAX) TRANSPAC XBT program. It will be several months, however, before it is available to make such a comparison. It should also be noted that data from the drifters is still being received from Nimbus 6.

Summary

To summarize, the agreement between the trajectories and the surveys is excellent. Main features of the Kuroshio such as path and velocity are duplicated in both the drifter and survey data sets. The trajectories, however, failed to detect either the warm or cold core eddies associated with the meander. Also, it was quite remarkable to find that 130 pinched off into a warm core ring.

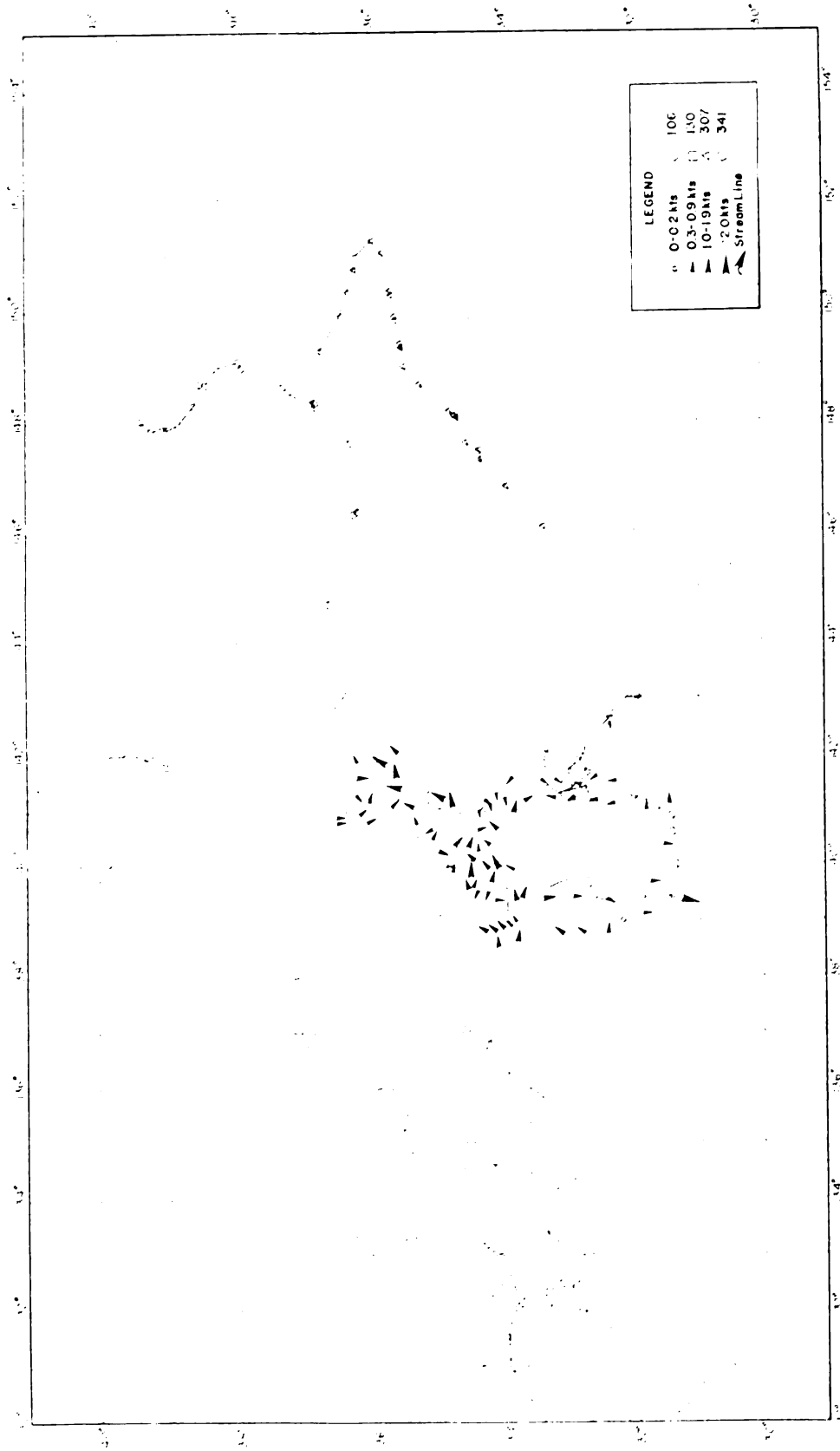


Figure 5a — Comparison of drifter tracks with current

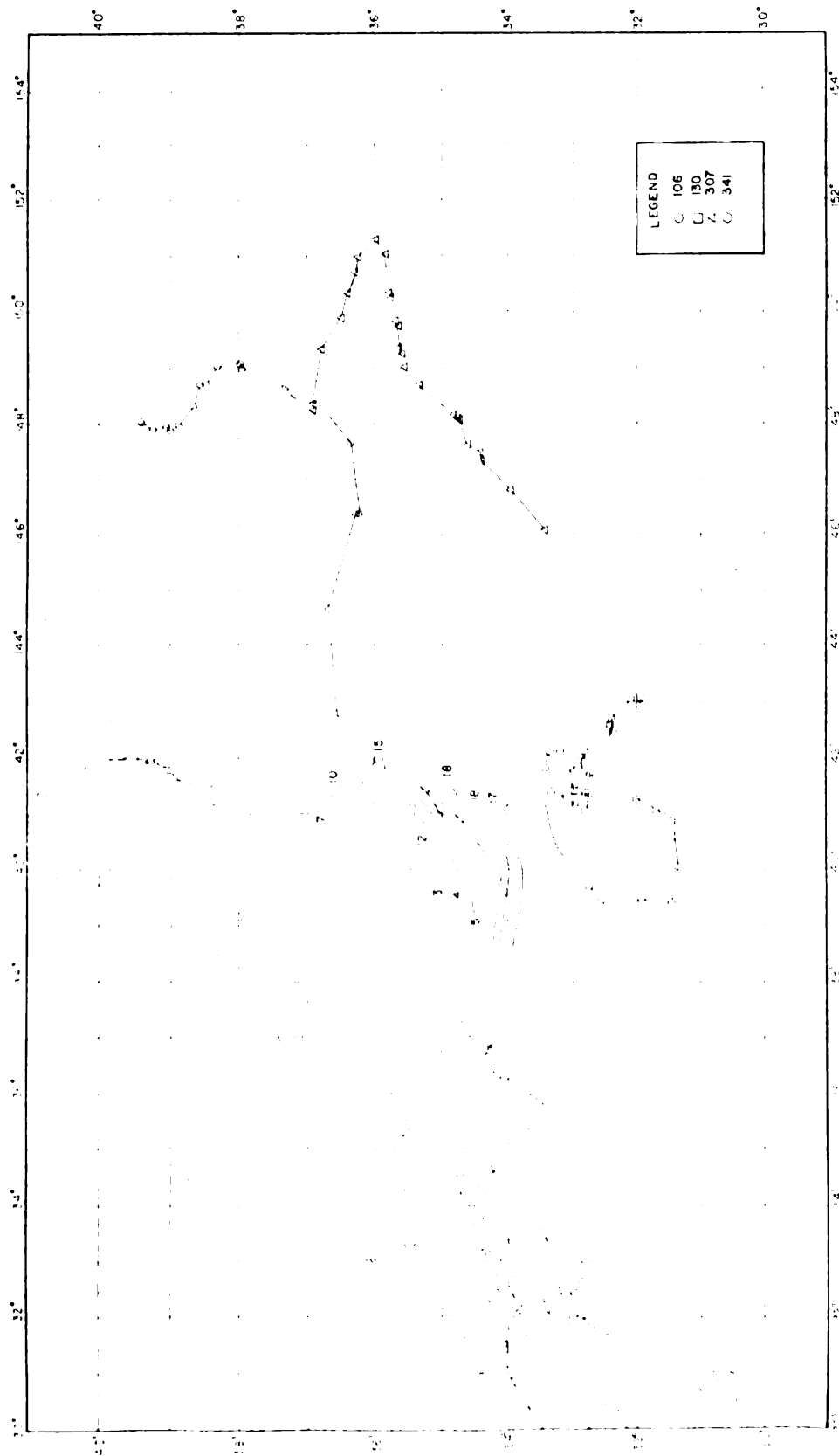


Figure 50 — Comparison of dotted tracks with current temperature for days 75-90 as provided in Hydrographic Department bulletin.

From the Navy's standpoint, one of the most significant results is the demonstration of a (nearly) real time data return capability provided by Nimbus 6. The RAMS on this satellite has the capability of returning not only position but environmental data as well. The transmit terminal electronics are very reliable and draw very low power so that long-term, remote, and inexpensive sensing capability is possible now for operational use by the fleet.

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Short Wavelength Laser Radiation

Optical scientists at the Naval Research Laboratory (NRL) report they have been able to generate coherent laser radiation at a wavelength of 53.22 nanometers...the shortest wavelength ever reported. This is a major step in the development of x-ray laser systems.

The researchers say X-ray laser systems when developed would open up a world of ways to process and test new materials for use in electronics, and provide a new technique for producing super miniaturized electronic micro-circuitry.

X-ray laser would give scientists a new tool for the microscopic study of crystals and giant molecules; and aid in the development of weapons effects simulation.

Research Notes

Towards an Automatic Programming System

A prototype of a totally automatic computer programming system is under development at MIT. Unlike automatic programming efforts at other research centers, the MIT objective includes creating computer capabilities for going beyond an awareness of fundamental programming methodologies to incorporate deep machine knowledge or expertise about particular applications domains, e.g., inventory control, electronics repair, medical care, etc. At the center of the MIT concept is the conviction that automatic programming requires a thorough machine understanding of the domains for which the computer programs are ultimately to be produced. Inherent to this concept is the notion that an automated system can assimilate new knowledge, and can learn from experience.

While a primitive version of the described capability is at a demonstration stage of development, operational versions of such systems are estimated to be about five years off. MIT researchers are currently working in a decision/data base environment of inventory control and warehousing. Attention, however, is being directed at problems of extending or generalizing the system to other domains. Office of Naval Research and Advanced Research Projects Agency funds support this effort.

The MIT interest (for any particular applications areas) is not to create radically new algorithms or systems, but to facilitate the implementation of relatively standard systems quickly, cheaply, and accurately. The design approach takes advantage of the repetitive nature (similarities) across systems built for particular domains; it draws from its file or memory of resident, previously optimized formulation appropriate to the user's requirements, and requests additional or specialized input from the user only when a requirement for "unique" information manifests itself in the course of developing a particular system's application. Provisions have been built in for English language interaction between machines and people when such specialized input is being sought.

To make this automated programming system work, MIT researchers have created two major modules. Module I, essentially of an Artificial Intelligence nature consists of: (1) a resident library of models or decision algorithms appropriate to an application's domain area, (2) a touch screen menu customizer or questionnaire which permits the user to "educate" the computer system on his requirements or ties to the resident library, (3) a natural language interactive capability to treat specialized/unique user specified needs, and (4) a model builder which produces decision algorithms from user descriptions of inputs (data) and outputs (report formats). Module II consists of: (1) a system optimizer whose function it is to integrate over all of the selected library pieces and new inputs relevant to a user specified application system, and (2) a Processor which automatically produces machine code (computer programs).

Excimer Laser Research may Help Solve Nuclear Waste Problem

Laser scientists at the Naval Research Laboratory report that the development and use of rare gas-halide excimer lasers may lead to substantial improvements over methods currently used for the reprocessing and separation of nuclear wastes.

Dr. Terence Donohue has successfully separated lanthanide mixtures photochemically through the use of the ultraviolet outputs of argon fluoride and krypton fluoride lasers. This work, is of particular importance since 20% of the wastes from nuclear reactors are lanthanides (also known as rare earths). The chemically related actinides, including plutonium and curium, constitute another 20% of reactor wastes. The reprocessing of these wastes is one of the nuclear industry's biggest problems, and photochemical separation may significantly enhance or complement presently employed separation technology.

Dr. Donohue says that he has observed separation factors exceeding 30 in this totally new method of separating mixtures of the lanthanides. This process is based upon the fact that three of the rare earths (europium, samarium, and ytterbium) can be photochemically reduced when irradiated in the charge-transfer bands. In particular, the wavelength of this band for europium ions in water is at 1900 Å, and is accessible to the highly efficient ArF excimer laser.

An aqueous solution of these ions is used since most of the possible compounds are water soluble and there are none of the vapor pressure limitations one generally finds in gas phase work. In addition, reagent densities can be made large, and a great variety of chemical reactions are possible in the liquid state.

The rare earths are a group of 14 chemically and physically similar metals and are found in over 100 different minerals. The term "rare" is a misnomer, since these elements are more abundant than mercury, cadmium or arsenic. However, their chemical similarity makes separation difficult and thus expensive.

A classic economic situation has developed where demand for the lanthanides has increased as improved separation methods have allowed wider availability and lower costs. This new separation process may allow even further reductions in their cost.

Presently, the most valuable rare earth from an industrial standpoint is europium. This element is in high demand for use as the red phosphor in color television, even though it costs over \$1000 a kilogram. Dr. Donohue hopes that his techniques can reduce the cost of this valuable material.

The chemical similarity between individual elements within the lanthanide group parallels that found in isotopes of a given element. However, the differences in their absorption spectra are much more pronounced than the spectral differences between isotopes of a given element.

These differences are retained in the liquid phase in the case of the lanthanides and allow lasers to excite only one particular component of a mixture of the elements. A similar situation exists in the actinide group and lanthanide photoseparation technology should be applicable to these elements, as well.

The advent of efficient lasers in the ultraviolet has provided photochemists with an extremely versatile tool which will allow them to undertake a variety

of new experiments not possible until now. This work is being cosponsored by the Energy Research and Development Administration (ERDA), Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR).

Project HIRISE Extends Communication Range

Recently the Office of Naval Research, in cooperation with Naval Air Development Center Warminster (NADC) completed a series of test flights of a balloon system (HIRISE) designed to carry an expendable radio transceiver which effectively extends the UHF radio horizon as the balloon ascends to higher and higher altitudes. NADC has responsibility for the development of the transceiver with ONR accepting responsibility for the development of the balloon platform, its packaging and deployment. In addition ONR through its contractor, Raven Industries of Sioux Falls, South Dakota, sponsored test flights of the system from Sioux Falls and Rapid City, S.D.

No problems were experienced with the balloon platform, however the new, wide band (10 MHz) communications sub-system experienced internal temperature fluctuations which prevented the transmitting station from locking on to reference frequencies. This problem, however, was encountered only on the initial flight. During subsequent flights the wide band and narrow band sub-systems performed as desired. NADC and ONR representatives present at the tests were quite pleased with the results.

The Navy problem addressed by this joint ONR/NADC development concerns the loss of radio contact with tactical units as they proceed beyond the UHF radio horizon (line-of-sight). Placing a relay station at the high altitude extends the UHF radio horizon manyfold. Past and present fleet practice has been to station an aircraft at altitude to act as a relay station. This is expensive and required a dedicated aircraft which could be more gainfully employed doing other missions. HIRISE, as envisioned, will be a self-inflating, self-launching balloon system capable of carrying the communications relay equipment to an altitude of 70,000 feet (minimum wind field altitude). This of course greatly exceeds the ceiling altitude of aircraft normally assigned to relay missions, and greatly extends the radio horizon beyond present capabilities. Placing the platform at minimum and field altitudes assures the tactical commander of several hours extended range communications with his tactical units.

Ultrasonic Transducer Power Output Measurements

Martin Greenspan, National Bureau of Standards presented a paper with Frank Breckenridge, and Carl Tschiegg as co-authors at the recent meeting of the Acoustical Society of America in San Diego, in which he described a new instrument for the measurement of the total sound-power output of an ultrasonic transducer. The work was partially supported by ONR.

The instrument measures the total power (actually presented at the radiation conductance, which is the power per volt²) radiated into water over a broad frequency range typically encompassing several resonances of the transducer; the results are presented as a graph of radiation conductance, G_R vs frequency. The results are absolute, in the sense that at any frequency covered by the test the value of G_R scaled from the graph multiplied by the square of the voltage on the terminals of the transducer gives the total power, radiated into water, within an accuracy of a few percent.

There are some important applications. The transducers used in nondestructive evaluation are subject to hard wear and abuse, so that they develop such defects as partial depolarization, partial or total detachment of the backload or of the wear-plate, and cracks. There is reason to believe that the G_R vs f curve is sensitive to incipient failures of these kinds and that, therefore, the integrity of transducers can be easily monitored. In fact, new transducers are not always what one might hope. Among new transducers, serious disparities have been found between two which are nominally identical, as well as one having a pronounced subharmonic resonance, one of which the fundamental resonance is 40 percent higher than the design (or advertised) value, and one which has hardly any output at all.

The transducers used in ultrasonic therapy suffer from similar problems. These are usually narrow-band devices operating at a single, fixed frequency. Any such transducer can be calibrated quickly and easily — the frequencies fall well within the frequency range of the equipment.

Earth-Based Ions in Van Allen Radiation Belts

The unexpected discovery of large quantities of energetic oxygen ions from the earth's atmosphere in the Van Allen radiation belts has been revealed by a group of Lockheed scientists at the Spring Meeting of the American Geophysical Union.

The new findings contrast with previous generally accepted beliefs that the Van Allen belts-doughnut-shaped regions of high radiation which surround the earth, are composed mostly of hydrogen ions and electrons from the sun.

In their recent experimental work with satellite-borne measuring instruments, Drs. R. G. Johnson, R. D. Sharp, and E. G. Shelley of Lockheed's Palo Alto Laboratories found that many ions in the Van Allen belts are of earth origin. They consist of oxygen, helium, and hydrogen ions from the earth's high-altitude electrified atmosphere (ionosphere) which are injected into the radiation belts by an electric potential associated with aurora borealis (Northern lights).

The discovery will lead to a better understanding of the mechanisms by which these charged particles flow from the earth's ionosphere into its radiation belts. This in turn could shed new light on the varying influence of the ionosphere on radio communication and particularly its effect on such communication in the polar regions.

Measurements of the "earth-based" ions in the radiation belts were made with a new type of space instrument developed for the Office of Naval Research by scientists at the Lockheed laboratories in California. Called a mass spectrometer, the instrument will differentiate between the heavy "earth" ions and the light ions from the sun.

Little is known of the electric potential which appears to be injecting these earth-based ions into the Van Allen belts.

The new discovery of earth-based ions in the Van Allen belts and the analysis of particle movement and behavior will provide further insight into the interrelationship of the earth's electrified atmosphere and its radiation belts. This understanding will also enable man to make better use of the space environment and of the orbiting satellites and laboratories which are serving his needs on earth.

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Naval Uses for an Algal

Toxicity TestPATRICK J. HANNAN 1
CONSTANCE PATOUILLET

The algal toxicity test described here is useful in ranking the relative toxicities of pollutants, and it is reproducible.

Tracking the Kuroshio by Nimbus 6A. C. VASTANO 11
A. D. KIRWAN

From the Navy's standpoint, one of the most significant results is the demonstration of a nearly real time data return capability by Nimbus 6.

Research Notes 25

Cover Caption

Artists concept of Nimbus 6 Satellite as it looks on station. (See page 11).

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