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# Remote Sensing of Offshore Water Mass Features: Present and Potential Benefits to Virginia's Recreational Fishery for Marlin and Tuna

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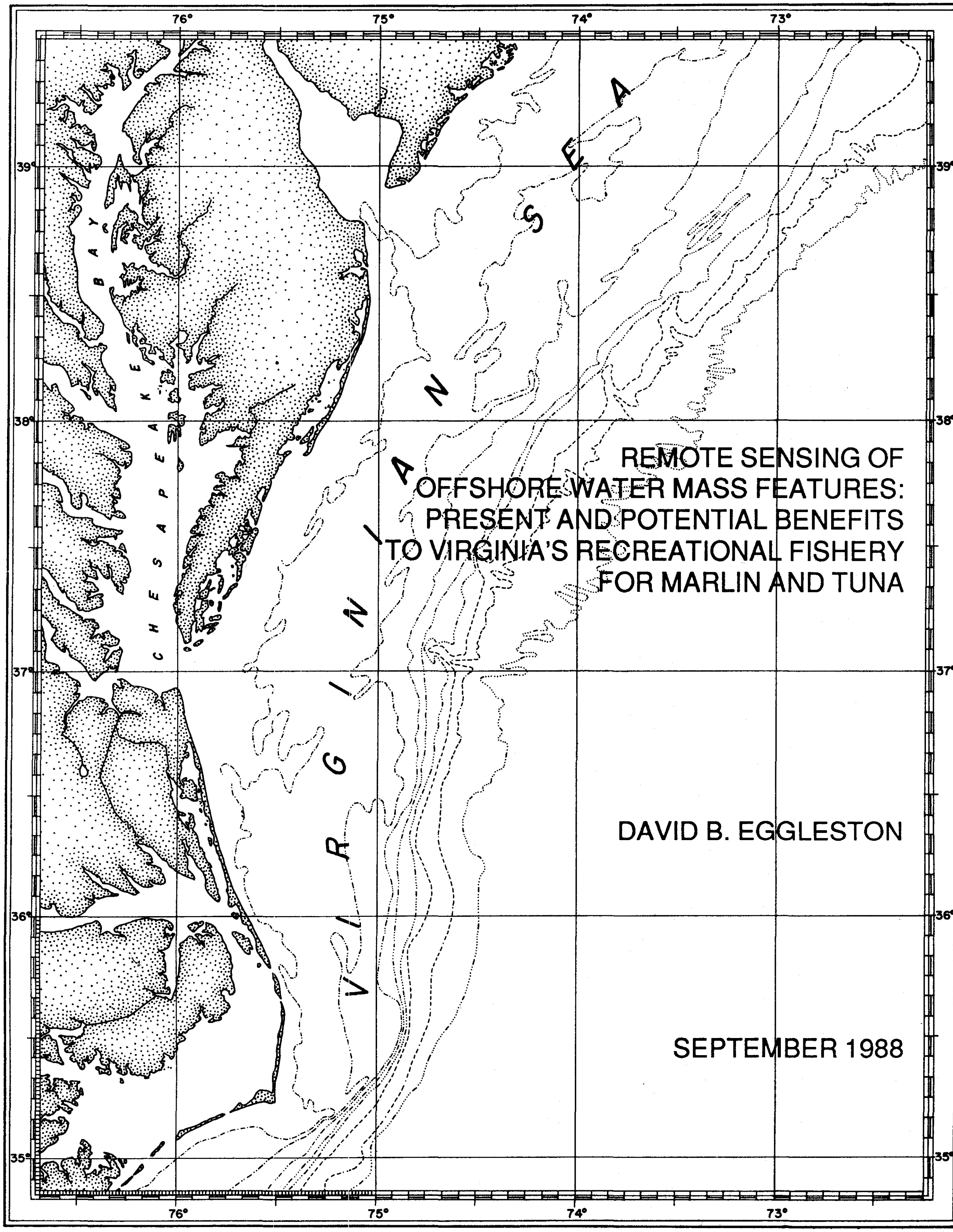


# REMOTE SENSING OF OFFSHORE WATER MASS FEATURES: PRESENT AND POTENTIAL BENEFITS TO VIRGINIA'S RECREATIONAL FISHERY FOR MARLIN AND TUNA

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# Remote Sensing of Offshore Water Mass Features: Present and Potential Benefits to Virginia's Recreational Fishery for Marlin and Tuna

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# INTRODUCTION

The distribution, abundance, and catchability of pelagic recreational fishes such as billfishes (Istiophoridae and Xiphidae) and tunas (Scombridae) are markedly influenced by known optimum temperatures and hydrographic frontal zones (Squire, 1962, 1974; Uda, 1973; Mather, et al. 1975; Laurs and Lynn, 1977; Magnuson, et al. 1980, 1981; Rockford, 1981; Shingu, 1981; Sund, et al. 1981; Laurs, et al. 1984). Environmental temperature directly influences fish metabolism which in turn affects life processes such as growth, development, and swimming speed (Laevastu and Hayes, 1983). Temperature effects on the movement, distribution, and nervous system response of fishes are summarized by Sullivan (1954). Sullivan (1954) stated that fish select a certain optimium temperature because of the effect of the same on their movement (activity, sensu Laevastu and Hayes, 1983), and concluded temperature change may act on a fish: 1) as a nervous stimulus, 2) as a modifier of metabolic processes and 3) as a modifier of bodily activity. Water temperature appears to play a vital role in white marlin (*Tetrapturus albidus*) distribution (Mather, et al. 1975). Early evidence indicated an average sea surface temperature (SST) of $24.8^{0}$ C to be the optimum for white marlin in the western North Atlantic (Squire, 1962). Squire (1974) found strong correlation between continuous $20.0\text{-}21.1^{0}$ C isotherms and increased catches of striped marlin (*Tretapturus audax*) in the Gulf of Mexico. When these distinct features degraded into discontinuous isotherms, productive striped marlin grounds diminished (Squire, 1974). For scombrids, Sund, et al. (1981) demonstrated the range of yellowfin tuna (Thunnus albacares) abundance in the Pacific Ocean to be directly limited by water temperatures of 20° C or less in both the horizontal and vertical planes. The Australian tuna fisheries use SST to locate southern bluefin tuna (Thunnus maccoyii) (Rockford, 1981). The majority of these fish are taken at water temperatures of 16.7-20.0 ° C (Rockford, 1981; Tranter, et al. 1983). Southern bluefin tuna in this temperature range are usually associated with sharp discontinuities in SST or hydrographic fronts.

Frontal zones are physical features of the epipelagic (surface to 200 m), which have been shown to play an important role in the recruitment of pelagic species (Norcross and Shaw, 1984). Fronts occur both at the boundary between counterposed currents, and at the boundaries along the circulation of currents (Knauss, 1978). These zones are usually very narrow with distinct gradients of temperature and sometimes salinity (Norcross and Shaw, 1984). The physical properties of these phenomena, such as varying densities, can cause either downwelling or upwelling, and promote vertical mixing (Norcross and Shaw, 1984). This mixing often results in increased primary and secondary production (Tranter, et al. 1983; Olson and Backus, 1985) which is generally attributed to intensified nutrient flux (Olson and Backus, 1985). Sufficient maintenance of the frontal zone may support increased herbivorous zooplankton populations (Dufour and Stretta, 1973; Tranter, et al. 1983; Svejkovsky and Lasker, 1985). Species that can detect the front or its anomalous biotic condition may then congregate at this interface in order to take advantage of increased prey availability (Svejkovky and Lasker, 1985; Olson and Backus, 1985).

Tuna tend to aggregate in regions of abrupt temperature gradients at the edges of frontal zones. Uda (1973) linked albacore (Thunnus alalunga) fishing grounds in the western Pacific to oceanic fronts in the region of the Kuroshio Current and Kuroshio extension waters. When these fronts are well developed, they may influence migration patterns and increase albacore catch rates in those areas (Laurs and Lynn, 1977). Tranter, et al. (1983) determined that schooling behavior of southern bluefin tuna at oceanic fronts in the southwestern Tasman Sea, was due to biological enrichment associated with these sharp SST fronts. Yellowfin tuna have been found concentrated along the Equatorial Countercurrent in the North Pacific ocean in frontal zones produced by eddies (Uda, 1973). These eddies tend to aggregate prey species that attract and serve as prey for tuna (Uda, 1973). In the western Atlantic, bluefin tuna (Thunnus thynnus) are found in cooler waters (15-21$^{o}$ C) on the edge of the Gulf Stream and yellowfin tuna are found in the warmer waters (20-28$^{o}$ C) of the Gulf Stream (Squire, 1962). Similar to tunas, billfish such as white marlin have been shown to aggregate near "rips" or "weed lines" that usually occur at the interfaces between different water masses (Mather, et al. 1975). The mechanisms underlying the association of large migratory fishes with oceanic frontal zones are discussed by Magnuson, et al. (1980).

The Virginia recreational fishery

Virginia's offshore recreational fishery is targeted primarily at bluefin tuna during June and July, and blue marlin (Makaira nigricans), white marlin, common dolphin (Coryphaena hippurus), and wahoo (Acanthocybium solanderi) from mid-July through October (Figley, 1983; Lucy and Bochenek, 1986). Billfishes are typically sought at the 100 fathom curve along the edge of the continental shelf, which ranges from 60-90 miles offshore (Schmidt, 1985). Besides these offshore pelagics, Virginia's charter and private boats also work closer to shore for Boston mackerel (Scomber scombrus) in March and April, and bluefish (Pomatomus saltatrix) and king mackerel (Scomberomorus cavalla) from mid-May through October (Schmidt, 1985).

Virginia's 1986 marlin-tuna fleet of both charter and private boats, as determined by the Lincoln-Peterson Index and the Frequency of Capture Method (Figley, 1984), was estimated to be 886 boats (Bochenek, dissertation in preparation). This value was estimated from the cooperative Virginia Institute of Marine Science (VIMS)/National Marine Fisheries Service (NMFS) pelagic recreational fishery study data base of 462 boats (Bochenek, dissertation in preparation). Of this total boat population, Rudee Inlet, at Virginia Beach was the home port for the majority of the fleet (278 boats), followed by Wachapreague Inlet, on Virginia's Eastern Shore (52 boats) and Lynnhaven Inlet, at Norfolk (16 boats) (Bochenek, dissertation in preparation).

From Rudee Inlet, popular billfish and tuna grounds are Norfolk Canyon, 70 miles east, and the "Cigar", a seamount 65 miles southeast (Schmidt, 1985; Lucy and Bochenek, 1986). The primary billfish and tuna grounds off the Virginia coast are illustrated in figure 1.

In 1978, Virginia's 110 charter boat fleet was estimated to have a total economic impact of $4.7 million (Marshall and Lucy, 1981). In 1983, the estimated fleet size for both private and charter boats was 455 (Figley, 1983). Virginia anglers fishing primarily for marlin and tuna spent over $7 million on boat maintenance and storage, tournament fees, bait, ice, and fuel in 1983 (Schmidt, 1985). The economic impact of tournaments is felt throughout these port communities as evidenced by the 1982 Virginia Beach Anglers Club Small Boat Marlin Tournament in which fishermen on 82 boats spent approximatly $33,000 on boat fuel, lodging, meals, and tournament fees (Lucy, 1983).

Purpose of study

During the 1985/86 Virginia fishing seasons, I served as a NMFS fishery reporting aide collecting catch and effort data on Virginia's offshore pelagic recreational fishery. Coordinated by the Marine Advisory Services at VIMS, this work resulted in direct contact (dockside and telephone interviews) with fishermen. During the course of this project I observed that several charter and private boat captains were unaware of oceanographic services available to them, nor the potential benefits of this type of information. Many of the fishermen interested in these services were unfamiliar with how to obtain them. In addition, no data were found that would indicate the past, present, or potential use of remote sensing information by the Virginia offshore recreational fishery (J. Lucy, VIMS, personal communication). Therefore the aim of the present study was: 1) to identify the various sources of environmental data products available to Virginia offshore recreational fishermen and 2) to determine the present and potential use of this information by the fishery.

# METHODS

In order to estimate the present and potential use of remote sensing information by the Virginia offshore recreational fishery, dockside and telephone interviews of both private and charter boat captains were obtained during the 1986 fishing season in which answers to the questionaire (Figure 2) were quantified. Through the cooperation of Mr. Jon Lucy of the Department of Marine Advisory Services at VIMS, telephone and dockside interviews for this study were made concurrent with interviews performed for the VIMS/NMFS assessment of catch trends in the marlin-tuna fishery. For a more detailed description of the study methodology see Figley (1984).

Information on the various sources of environmental data products available to Virginia offshore recreational fishermen were obtained by contacting federal, state, and private agencies, reveiwing published literature on these products, and by attending the Workshop on Sea Surface Temperature and Weather Programs, North Carolina Aquaria, Roanoke Island, NC, April 8-9, 1987.

# RESULTS

## Background: Gulf stream meanders and warm core rings

The major current of the western North Atlantic Ocean, the Gulf Stream, is the result of the shape of the coastline, bottom relief, prevailing winds, Coriolis parameter, and Eckman transport (Norcross and Shaw, 1984). These factors contribute to the formation of a subtropical anticyclonic circulation in which the Gulf Stream carries warm water north, travels along the western continental shelf, and merges with the North Atlantic Current (Norcross and Shaw, 1984). Surface layers of the Gulf Stream, which are relatively high in temperature and salinity but low in nutrients, form a dynamic front with the cooler, more nutrient-rich Virginia water mass on the continental shelf just north of Cape Hatteras (Magnuson, et al. 1981).

Gulf Stream rings (eddies) are generally formed downstream of Cape Hatteras where the stream meanders widely (Olson and Backus, 1985), possibly as a result of submarine topographic features (Richardson, 1980). These large meanders pinch off shoreward or seaward of the stream forming anticyclonic (warm-core) rings or cyclonic (cold-core) rings respectively (Lai and Richardson, 1977; Joyce and Wiebe, 1983). Although meanders and rings occur on both sides of the stream, it is only those on the left (shoreward) that sometimes move into the proximity of the fishing grounds of the continental shelf and slope (Chamberlin, 1977). Gulf Stream warm core rings (WCR) are injected into the northwest Atlantic Slope Water between the cold wall of the Gulf Stream and the continental shelf of northeastern United States (Saunders, 1971). WCR are typically 100 to 200 km in diameter and 700 to 1000 m deep at the time of formation, and consist of a rotating central core of Sargasso Sea water surrounded by a more rapidly rotating (up to 100 cm $s^{-1}$) annulus of Gulf Stream water (Nelson, et al. 1985). WCR typically move in a southwesterly direction at speeds of 3 to 5 km/day (Lai and Richardson, 1977). It is estimated that five WCR per year are formed in the western Atlantic (Lai and Richardson, 1977). The life span of WCR that cross west of the New England seamount chain and reach Cape Hatteras are usually about 6 months (Joyce and Wiebe, 1983).

WCR frenquently interact with the Gulf Stream, slope water, and shelf water, usually by entraining surface waters into the anticyclonic flow (Joyce and Stalcup, 1985). Recent satellite images of the ocean surface suggest that the interaction of WCR with the Gulf Stream typically begins with a collision between the ring and a growing meander (Joyce, et al. 1984). As a result of this collision, a narrow band (10-15 km) of Gulf Stream water starts flowing along the western side of the ring and after a number of days the band envelops most of the ring (Nof, 1986). These rings seldom, if ever, penetrate south of Cape Hatteras where the western edge of the Gulf Stream is within approximately 80 km of the shelf break (Nelson, et al. 1985).

Newly formed WCR contain many chemical and biological properties associated with their Gulf Stream and Sargasso Sea source waters (Nelson, et al. 1985). WCR undergo biological transformations that are both greater in magnitude and more rapid than those observed in cold-core rings; initially low in phytoplankton biomass and primary productivity, they frequently become local maxima in both properties (Joyce, et al. 1984; Nelson, et al. 1985). In 1977, NMFS initiated a program to monitor the effects of Gulf Stream meanders and WCR on the fishing grounds of the western mid-Atlantic (Chamberlin, 1977). The results of this program identified five kinds of environmental effects and their possible influences on fishing and fishery resources:

1) Warming of the upper continental slope and outer shelf by direct contact of a meander or ring. This may influence the timing of seasonal migrations of fish as well as the timing and location of their spawning.

2) Injection of warm, saline water into the colder less saline waters of the shelf by turbulent mixing at the inshore boundary of a meander or ring. This may influence the fishery resources similar to that of direct warming.
3) Entrainment of shelf water off the shelf. The most profound effects of entraiment on fishing grounds may be changes in circulation and in water mass properties resulting from the replacement of the waters lost from the shelf.
4) Upwelling along the continental slope, which may result in nutrient enrichment near the surface and increased primary productivity.
5) Strong currents on the outer shelf and upper slope may prolong submergence of lobster pot surface floats which may result in gear losses.

Background: Satellite remote sensing information

The National Oceanic and Atmospheric Administration's (NOAA) polar orbiting satellite infrared imagery is the primary data source for generating the Oceanographic Analysis (Figures 3 and 4) and Sea Surface Thermal Analysis (Figures 5 and 6). The satellite has an altitude of 833 ± 90 km and orbits the earth such that each geographic area of the earth is viewed twice daily. Geostationary Environmental Satellite (GOES) infrared imagery is the secondary data source for generating the Oceanographic Analysis. This satellite orbits 42,550 km above the Earth's equator, and orbits the Earth at the same speed that the Earth spins on its axis. Therefore, GOES appears fixed over the same point of the equator at all times. The advantage of GOES data is that the frenquency of coverage is every 30 minutes whereas NOAA's polar-orbiting frenquency of coverage is approximately every 12 hours.

The measurements are digitized aboard the satellite and transmitted to the Command and Acqusition Stations at Wallops Island, Virginia and Gilmore Creek, Alaska; then they are relayed to the National Environmental Satellite, Data, and Information Service (NESDIS) processing facility at Suitland, Maryland.

The Advanced Very High Resolution Radiometer (AVHRR) infrared sensors aboard the polar orbiting meteorological satellites are characterized by high sensitivity in narrow wave lengths, fine ground resolution, and an extensive data archive (Laurs, 1985). These thermal infrared sensors are positioned aboard the geostationary and polar orbiting satellites and measure thermal energy radiated back from the top two millimeters of the ocean surface through the earth's atmosphere, with a spatial resolution of 8 km and 1 km respectively (Maul, et al. 1984). Owing to radiative and convective heat transfer processes, the derived SST information is considered representative of conditions in the upper mixed layer of the ocean (Laurs, 1985; Roffer, 1986). When clouds, high humidity conditions, or smog cover an area, temperature information derived from infrared bands are either inaccurate or not reliable (Roffer, 1986; Dr. S. Baig, National Weather Service NWS, personal communication). In order to "correct" the satellite data for cloud cover, the NESDIS (NOAA) mathematically manipulates the raw satellite data using various algorithms derived from basic radiative transfer equations (Roffer, 1986; Dr. S. Baign, NWS, personal communication). The corrected temperature data are contoured by either one or five degree intervals to produce various sea surface isotherm charts. Ocean currents and frontal zone positions can be determined basically from the thermal contrasts that appear on the NOAA and GOES infrared imagery (Laurs, 1985).

The Coastal Zone Color Scanner (CZCS), on board the Nimbus-7 polar orbiting satellite, is the only sensor in orbit specifically designed to study living marine resources (Laurs, 1985). The CZCS is capable of measuring very subtle variations in water color which are primarily due to changes in phytoplankton concentrations (Laurs, 1985). Ocean color measurements from the CZCS are being used in fishery resource applications to determine the locations of oceanic fronts, effluents, and water masses, to determine circulation patterns, and to make quantitative measurments of chlorophyll and sestonic concentrations (Laurs, 1985; Dr. S. Baig, NWS, personal communication).

Environmental data products are produced and distributed by NOAA's NWS, the U. S. Navy, federally funded Sea Grant College Advisory Programs (Roffer, 1986), and recently, by private industry (personal observation). Examples of these information products include surface temperature charts, subsurface ocean temperature profiles, wind reports, wave heights, ocean frontal analysis, current boundary locations, current velocities, weather reports, weather forcasting, reported fish landings, and local fishing forcasts.

## Application of remote sensing information to fisheries

The use of satellite remote sensing to produce synoptic measurements of the ocean is becoming increasingly important in fisheries applications (Laurs, 1985). The distribution and availability of albacore tuna off the west coast of the United States have been found to be related to oceanic fronts seen in AVHRR infrared and CZCS imagery (Laurs, 1985). Maul, et al. (1984) monitored the catch per unit effort (CPUE) of the Japanese longline fishery for Atlantic bluefin tuna (ABT) in the Gulf of Mexico, as a function of oceanic thermal fronts associated with the Gulf Loop Current and found a higher CPUE (85%) for ABT when fishing operations were located near the Loop Current, where the subsurface isotherm behavior was indicative of upwelling. These oceanographic features were detected by geostationary and NOAA-6 satellites.

Satellite infrared measurements have also been used to trace the development and duration of the various bluefin tuna fisheries along the east coast of the United States (Roffer, et al. 1982). These fisheries follow the movement of seasonal warming of near-shore surface waters which are monitored by observing the northerly progression of the 19-20$^{\circ}$ C isotherms in satellite infrared imagery (Laurs, 1985). El-Sayed and Trees (1985) related CZCS data to the menhaden (Brevortia tyrannus) fishery and to in-situ chlorophyll determinations in the Gulf of Mexico. Similar procedures indicated that rockfish (Sebastes sp.) may be correlated with chlorophyll fronts in the Montery Bay area of central California (Hauschildt, et al. 1985).

Recreational and commercial fishermen report that the use of oceanographic information products reduces running time, which translates into reduced operating costs (Roffer, 1986). The American Swordfish Association reported that by using available oceanographic information, the east coast swordfish fishery saved approximately $2.25 million dollars in fuel costs from 1981 through 1983 (Roffer, 1986). The average fuel savings for each recreational fisherman who subscribed to the New Jersey Sea Grant Extension Fisheries Advisory Program was reportedly 300 gallons per summer (Roffer, 1986).

Sources of environmental data products

1) Federal agencies

The majority of environmental data products which are applicable to Virginia fishing operations are produced and distributed by the National Oceanic and Atmospheric Administration (NOAA), NWS, and the U. S. Navy. The NOAA Oceanographic and Sea Surface Thermal Analysis charts, commonly known as "weatherfax" information, are available by prepaid subscription or automatic telecopier transmission. One Northwest Atlantic Oceanographic Analysis, or North Panel Chart (Figure 3) is generated Mondays, Wednesdays, and Fridays. It covers the area from 30-45$^{o}$ N and from about 46-76$^{o}$ W. The other Northwest Atlantic and Gulf of Mexico Oceanographic Analysis, or South Panel Chart (Figure 4) is generated on Tuesdays and Thursdays. It covers the U. S. East Coast area from 25-35$^{o}$ N and the Gulf of Mexico. Both analysis charts are distributed via automatic telecopier and postal service.

The Oceanographic Analysis charts are available by mail at various subscription rates ranging from $65-$10 for 5 charts per week (3 North Panel and 2 South Panel) or 2 charts per week (1 North Panel and 1 South Panel), respectively. The time lag between chart postal delivery and telecopier transmission methods is from 7-10 days. Both charts are available quarterly, semi-annually, and annually by contacting Bill Poust at (301)

763-8111. Further information on the various subscription services may be obtained by writing to:

NOAA/NESDIS/NCDC
Satellite Data Services Division
Attn: Gulf Stream Subscriptions
Room 100, World Weather Building
5200 Auth Road
Washington, D. C. 20233

The North Panel Oceanographic Analysis is available on Xerox 410 automatic telecopiers at (301) 763-8333, 9:30-11:30 am on Mondays, Tuesdays, and Thursdays and 5-7 pm on Mondays, Wednesdays, and Fridays. All times are local Washington, D. C. times. The North Panel Chart is also available at (301) 899-1139 on Mondays, Tuesdays, and Thursdays from 1-4 pm and on Monday-Friday 4 pm-8:30 am (all night). Sea Surface Thermal Analysis Charts are avialable at (301) 899-1139 from 8:30-1:00 pm Monday-Friday. For further information regarding the generation, interpretation, or distribution of either chart type via telecopier transmission contact Ms. Jennifer Clark at (301) 763-8030 or write to:

Ms. Jennifer Clark
National Weather Service Forecast Office
World Weather Building, Room 302
Washington, D. C. 20233

Also available by telecopier, the Mid-Atlantic Marine Information Service (MIDAS), through the University of Maryland, provides information on the location of the west wall of the Gulf Stream, maximum Gulf Stream current velocities, verified and suspected warm core ring locations, inshore and offshore weather forecasts, and local notices to mariners. This menu driven service is free and may be accessed by calling (301) 454-8700.

Additional MIDAS systems may be accessed by the following phone numbers:

1. Norfolk, VA (804) 857-0312
2. Washington, D. C. (301) 899-322-0686
3. Wilmington, Delaware (302) 322-1164

Further information on the various MIDAS systems may be obtained by contacting:

Ms. Dorothy Kropp
Ocean Sevices Unit
National Weather Forecast Office
World Weather Building, Room 302
Washington, D. C. 20233
(301) 763-8239

On May 1, 1987, NMFS at Narragansett, Rhode Island, began producing weekly modified Oceanographic Analysis charts every Tuesday. This chart series covers the shelf water region from Cape Cod, Massachusetts to Cape May, New Jersey out to the 200 meter depth contour. One representative example of this service is shown by figure 7. Although the regions covered are not applicable to most Virginia fishermen, those fishermen participating in tournaments in the Baltimore and Washington Canyon areas might benefit from this free service. Further information on this may be obtained by contacting:

Mr. Reed Armstrong
National Marine Fisheries Services
Marine Climatology Investigation
South Ferry Road
Narrangansett, RI 02882-1199
(401) 782-3280

Oceanographic data products produced by the U. S. Navy are generally unavailable to the public. Only military personel associated with the Naval Eastern Oceanography Center, Naval Air Station, Norfolk, Virginia are capable of accessing this information. On numerous occasions, while working at Rudee Inlet, I was shown Navy SST and ocean frontal analysis charts which were approximately 1 day old. Those captains that were in possession of these charts felt that they had better resolution and were easier to apply than similar products produced by the NWS. Representative examples of these charts are shown by figures 8, 9, 10, and 11.

The National Weather Service Forecast Offices in Boston, Massachusetts and Washington, D. C. have established a radiofax service to provide fascimile weather charts as well as alphanumeric forecasts for all marine interests operating north of $35^{o}$ N latitude (Cape Hatteras) and west of $60^{o}$ W longitude (Sable Island), and north of $32^{o}$ N latitude (Savannah, GA) and west of $35^{o}$ W longitude respectively. Some of these charts provide forecast information for geographic areas greater than those indicated. Data prepared by the NWS office in Boston is relayed via phone link to the U. S. Coast Gaurd Communications Station located in Marshfield, Massachusetts, and broadcast daily at 1800z on 7530 kHz frequency. Data prepared by the NWS office in Washington, D. C. is relayed via phone link to the University of Delaware's College of Marine Studies transmitting site located in Lewes, Delaware, and broadcast daily from 0645z-0803z and 1845z-2003z on 4223 kHz frequency.

All that is needed to receive these data are a high frequency (HF) shipboard weather chart recorder and an inexpensive antenna. For those boats that already possess a suitable HF single side-band radio, recorders are available less the built-in radio. Further information on the NWS radiofacsimile services is available by writing to:

National Weather Service Forecast Office
Room 302
World Weather Building
Washington, D. C. 20233
or
National Weather Service Forecast Office
Logan International Airport
Boston, Massachusetts 021128
(617) 223-3110

The Gulf Stream Bulletin is a radio broadcast derived from the Oceanographic Analysis. It is a series of latitude/longitude points that, when connected, define the west wall of the Gulf Stream. Also described are Gulf Stream current velocities and verified warm and cold core ring locations. This information is broadcast over Coast Guard radio Portsmouth, Virginia at 1600z and 2200z on single side band frequencies 6506.4kHz, 8765.4kHz, and 13113.2kHz. Another radio broadcast similar to the Gulf Stream Wall Bulletin is included in the marine package on NOAA weather radio. The radio frequencies are 162.4 MHz in Baltimore, Maryland and 162.55MHz in Norfolk, Virginia.

2) State Sea Grant Programs

Presently two state Sea Grant Marine Advisory Services Programs offer surface water temperature charts on a subscription basis. These charts include both the NWS/NESDIS Oceanographic Analysis and the Sea Surface Thermal Analysis. The University of Delaware Sea Grant Marine Advisory Service (MAS) offers free of charge to all interested parties, copies of these NOAA charts which are shown by figures 12 and 13. These charts are available every Friday morning from the MAS office in Lewes, Delaware by telecopier transmission or mail service.

A similar service is provided by the University of North Carolina (UNC) Sea Grant College Program which receives and processes NOAA data on Wednesdays with the majority of charts received by fishermen on Fridays. At present UNC Sea Grant has 250 subscribers each paying $8 for 35 weeks of this service. A representative example of these charts is shown by figure 14. Various local nautical markers are plotted on these charts in order to aid in referencing oceanographic feature locations.

For nearly five years, the New Jersey Sea Grant Extension Service had been involved with compiling and distributing sea surface temperature charts and other oceanographic information to commercial and recreational fishermen from Massachusetts to Virginia. In 1985 this program was taken over by private industry in order to allow New Jersey Sea Grant to work on oter fishery related projects. The New Jersey Sea Grant Extension Service still works with oceanographers and fishermen on information feedback but is no longer operationally involved. Further information on the previously described State Sea Grant Programs services may be obtained by contacting the following:

Delaware Sea Grant Advisory Service
College of Marine Studies
700 Pilottown Rd.
Lewes, Delaware 19958
(302) 645-4250

UNC Sea Grant College Program
N. C. Marine Resources Center
Kure Beach, North Carolina 28449
(919) 548-8257

New Jersey Sea Grant Extension Service
Ocean County Extension Office
Agricultural Center, Whitesville Road
Toms River, New Jersey 08753
(201) 349-1152

3) Private industry

Private oceanographic products distributors appear to offer the most comprehensive, region-specific coverage for recreational fishermen. Roffer's Ocean Fishing Forecasting Service, Inc. develops a variety of charts from NWS, NESDIS, and National Aeronautics and Space Administration (NASA) generated data. The forecast charts are updated on an 18 hour per day (6 am-12:30 am), seven day schedule and are available to suscribers on this schedule. The graphics produced by Roffer's are created on an Apple Macintosh Plus personal computer system (Figures 15, 16, 17, and 18).

Roffer's strongly recomends using computerized electronic mail (e.g. Easy Link) or telecopiers to receive the charts. With these methods it is possible to receive an updated chart approximately one hour after a satellite transmits its ocean temperature data to NASA. Roffer's prices are based on the subscriber using electronic mail or telecopier services.

Fishermen who remain at sea for periods greater than two nights can use their single-side band radios to receive their charts with either on-board telecopiers, personal computers, or voice using a numbers only format (plotted lat./long. or loran coordinates). The numbers only format can be received via telex as well. For those subscribers who prefer to receive their charts by mail, various "surface" mail services (e.g. Federal Express, United Parcel Service) can be used at an additional cost to the subscriber.

There are several different subscriber plans covering specific regions from Maine to Venezuela and offering anywhere from 3 to 7 updates per week. Prices range from a minimum of $200/individual to $3000/marina or fishing club. A "super tournament special" is offered for $250. This is a special personalized one-day forecast using the 2-5 am and 7-9 am satellite passes which includes transmitting two "customized" charts to the dock at 5:30 am and 12:00 am via electronic mail, telecopier, or single-side band radio.

The names of subscribers are held in confidence. Individuals that become involved in the voluntary "catch information reporting program" may receive catch information from other subscribers. Coded identification tags on some charts allow Roffer's Services to identify those individuals not adhering to the sales contract which states that the subscriber will not copy, photocopy, reproduce, etc. any of the transmitted charts. Further information regarding this service may be obtained by contacting the following address:

Roffs
Roffer's Ocean Fishing Forecasting Service
8542 S. W. 102 St.
Miami, Florida 33156
(305) 274-5759

Offshore Services, Inc., out of New Jersey, monitors sea surface temperatures and the movements of Gulf Stream WCR and fingers between Block and Norfolk Canyons. Oceanographic Analysis and Sea Surface Temperature charts are distributed biweekly along with a publication entitled "The Edge" which "pinpoints" and "thoroughly explains" possible "hot" fishing areas, reports on Canyon fishing activities, and includes interviews from local charter boat captains. This service costs $95 (1987) and is provided from mid-June through mid-October. A representative example of an Ocean Services, Inc. SST chart is shown by figure 19. For further information on this product contact:

Mr. Len Belcaro
Offshore Services, Inc.
339 Herbertsville Road
Bricktown, New Jersey 08724
(201) 840-4900

Present and potential use of remote sensing information by the Virginia recreational fishery

A total of 159 individual telephone and dockside interviews, using the questionaire shown by figure 2, were completed during the 1986 Virginia fishing season. This sample size represented 34.4% of the current VIMS data base or 17.9% of the estimated 1986 fleet size. Of the total number sampled, 30.2% considered the location of Gulf Stream WCR and fingers when planning their offshore fishing trips. Slightly more than two-thirds (70.8%) of this group were made up of private boats. The oceanographic information services used by both recreational and charter boat captains consisted of the following sources listed in decreasing order of use: NOAA/NWS weatherfax (27.1%), the U. S. Navy (27.0%), friends with unidentifiable sources (27%), Delaware Sea Grant (8.4%), employees of NASA Wallops Island (4.2%), Gulf Stream Wall Bulletin (4.2%), Offshore Services, Inc. (4.2%), Roffer's Forecasting Services, Inc. (4.2%), and the University of Maryland's MIDAS service (2.1%).

The majority (94%) of boats that used the charts reported better fishing locations and increased catch rates. Travel time was reduced for 75% of the respondents with a mean fuel savings of 16.7%. For charter boats consuming 100-150 gallons of fuel per day at approximately $1.30/gallon, estimated fuel savings may range from $16.70-$33.40/day. Charter boats working an average of 104 days per season (Marshall and Lucy, 1981) might save an average of $1736.80-$3473.60/season. One-fourth (25%) received the charts on a timely enough basis to make proper operational decisions with 62.5% using informal U. S. Navy sources, followed by NOAA/NWS weatherfax (25%) and Offshore Services, Inc. (12.5%). Seventy-five percent of those interviewed were not sure if the charts arrived on a timely enough basis to make proper operational decisions. An overwhelming majority (98.0%) of those fishermen currently receiving charts were interested in receiving additional remote sensing information for free, while 75% were willing to pay a $20 annual subscription fee. Most of those fishermen unwilling to pay a fee for this service were receiving free information from the U. S. Navy.

Of the total number sampled, over two-thirds (69.8%) did not consider the location of Gulf Stream WCR or fingers when planning their offshore fishing trips. A large portion (82%) of this group were interested in receiving various oceanographic products, but were unfamiliar with the means to obtain them. One individual had been trying to receive charts for over four years. Of this group, 7.2% reported that their boats were incapable of venturing far enough offshore to use the currently available chart services. An even smaller portion (4.5%) of this group were not familiar with oceanographic features such as Gulf Stream WCR or remote sensing information services. Various other individuals did not consider using currently available information because "it (fishing) is all a matter of luck" or "I go where the fish were caught the day before". Of the total population that did not consider the location of Gulf Stream WCR and fingers when planning their offshore fishing trips, 94% were interested in receiving satellite information on a subscription basis for free, while 74% were willing to pay a $20/year subscription fee.

## DISCUSSION

### Limitations to the applicability of remote sensing information

In general, the major limitation to applying remote sensing information to various fisheries is that the present satellite sensors measure SST and ocean color only through a cloud free atmosphere. This has hampered the utilization and acceptance of satellite technology in fisheries research and fish harvesting applications because many important fisheries are located in areas which have dense cloud cover much of the time (Laurs, 1985). The mid-Atlantic Bight experiences 25% cloud cover during the summer versus 75% in winter (Dr. S. Baig, NWS, personal communication). Another drawback to satellite infrared temperature and ocean color measurements is their restriction to the uppermost "skin" of the ocean surface (Laurs, 1985). Many recreational and commercially important species live below the thermocline or on the bottom where temperatures may be quite different from the surface. Another shortcoming of infrared imagery is that its use to detect fronts in opean ocean areas may be limited to periods prior to the onset of seasonal warming (Dr. S. Baig, NWS, personal communication). Therefore, remote sensing information is probably most applicable to the Virginia offshore recreational fishery during cloud free spring, early summer, and fall fishing periods. The recent developments in the use of microwave radiometers that can measure SST with high resolution through the clouds, along with advanced infrared sensors, may circumvent these problems.

The primary limitations expressed by interviewed satellite chart users were; "lengthy" chart delivery times and lack of detailed information inside the 100 fathom curve. The former problem may be eliminated by accessing this information via telecopier. In rare instances, variations in chart quality that are due to telephone line interference in the telecopier are seen. Those users who cannot access a telecopier may have to resort to same day or next day "surface" mail services provided by the private sector.

The latter problem has several solutions which may be found at either the private, federal, or state levels. The simplest solution would involve receiving region-specific "customized" charts from the private sector. Custom features might include but are not limited to Loran-C overlay and/or a fishing locations overlay, similar to figure 5, showing pertinent submarine topographic features. Those users who are unwilling to pay the higher subscription fees associated with private companies must find solutions at the federal or state levels. The only potential solution at the federal level, would require individual Virginia fishermen to contact the various federal government agencies listed, and voice their requests. The two state Sea Grant Programs currently offering this service provide somewhat greater detail inside the 100 fathom curve for their specific regions. Unfortunately, the Virginia offshore recreational fishing grounds, shown by figure 1, are located at the extreme edges of coverage provided by these services and thus lack the desired detail inside the 100 fathom curve. One possible solution would be for individual Virginia fishermen to contact the various state agencies indicated, and voice their requests. Another solution at the state level, would be for the Virginia Sea Grant College Program to implement a similar service aimed specifically at the Virginia offshore recreational fishery. This solution would satisfy two needs: 1) it would hopefully provide fishermen with charts possessing greater detail inside the 100 fathom curve, and 2) it would fufill the needs of the Virginia recreational fishery represented by this survey, who were interested in receiving this type of information and applying it to their fishing. Although this is a positive solution, it contains within it a prerequisite which must be addressed. This prerequisite involves educating the Virginia offshore fishery with the various sources and means of obtaining applicable oceanographic products. A comprehensive, up-to-date information package aimed at Virginia recreational fishermen would generate further input into all levels of chart distribution. This would allow the Virginia Sea Grant College Program to benefit recreational fishermen without becoming intimately involved with compiling and distributing this type of information. Private, federal, and other state agencies could likely fufill the needs identified by this survey.

Application of oceanographic products to recreational fishing

The information analysed in this study revealed a strong desire by those sampled, to receive and apply remotely sensed information to their offshore fishing trips. Despite the limitations discussed, there is considerable evidence supporting the application of oceanographic products to various fisheries. The Oceanographic Analysis and Sea Surface Thermal Analysis Charts are useful only if the person reading them knows how to properly interpret them. The Oceanographic Analysis locates the Gulf Stream and associated meanders as well as WCR, while the Sea Surface Thermal Analysis provides detailed SST Analysis of the rings, shelf, slope, and Gulf Stream waters. Typically "temperature breaks" occur near the 100 fathom curve; however, this break tends to move inshore or offshore of this line depending upon prevailing winds and other oceanographic phenomena (Clark, et al. 1984). The charts may define the location of this break and describe the magnitude of the temperature change associated with it.

Owing to the circulation patterns exhibited by WCR, the outer edges have been shown to have increased biological enrichment relative to the surrounding waters (Tranter, et al. 1983). This circulation pattern may support an edge associated food chain (Olson and Backus, 1985). The southwesterly movement of WCR (Lai and Richardson, 1977) tends to congregate predator and prey in the northeast portion of the ring (Clark, et al. 1984). When WCR occur within the range of offshore sportfishing boats, fishermen should concentrate their efforts along the ring edges. Fishermen should be aware of recent storm activity which may alter the location of these features.

In summary, an information package directed towards identifying the availability of various sources of oceanographic products available to Virginia offshore recreational fishermen should satisfy the needs of the fishery sampled in this study. The use of these charts, combined with an awareness of the various factors affecting billfish and tuna distribution and abundance patterns (e.g. temperature, oceanic frontal zones, water clarity, submarine topographic features) should better help fishermen identify areas where fish are likely to be found, and possibly reduce the time and cost associated with getting to these areas.

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# LITERATURE CITED

Bochenek, E. Virginia's pelagic recreational fishery for tuna and billfishes: Biological, socioeconomic, and fishery components for the 1983-1985 seasons. Dissertation, School of Marine Science, College of William and Mary, Williamsburg, VA (in preparation).

Chamberlin, J. L. 1977. Monitoring effects of Gulf Stream meanders and warm core eddies on the Continental Shelf and Slope. Reprint from the International Commission For The Northwest Atlantic Fisheries Annual Meeting 1977. No. 2. pp. 145-153.

Clark, J., R. Lawrence, G. Flemlin. 1984. Ocean Analysis. The Fish Boat. May, 1984. 35 p.

Dufour, P. and J. M. Stretta. 1973. Fronts thermiques et thermohalins dans la region du Cap Lopez (golfe du Guinee) juin-juillet 1972: Phytoplancton, zooplancton, micronekton et peche thoniere. Doc. Sci. Cent. Rech. Oceanogr. Abidjan, 4: 99-142.

El-Sayed, S. and C. C. Trees. 1985. Some remote sensing activities in the Gulf of Mexico. In: R. Amidei (ed). Applications of Remote Sensing to Fisheries and Coastal Resources. California Sea Grant Workshop, San Diego, CA. November 30, 1983. Report No. T-CSGCP-012. pp. 27-32

Figley, W. 1983. Survey of recreational tuna and marlin fishing in the mid-Atlantic in 1983. New Jersey Dept. of Environmental Protection, Marine Fisheries Admin. 8 p.

Figley, W. 1984. Recreational fishery for large offshore pelagic fishes of the mid-Atlantic Coast. Final Report prepared for the National Marine Fisheries Project: NA-83-FA-D-00001. 66 p.

Hauschildt, K., J. Nolten, R. Wittenberg. 1985. Application of the coastal zone color scanner to a coastal fishery. In: R. Amidei (ed). Applications of Remote Sensing to Fisheries and Coastal Resources. California Sea Grant Workshop, San Diego, CA, November 30, 1983. Report No. T-CSGCP-012. pp. 23-26

Joyce, T. M., R. Backus, K. Baker, P. Blackwelder, O. Brown, T. Cowles, R. Evans, G.Fryxell, D. Mountain, D. Olson, R. Schlitz, R. Schmitt, P. Smith, R. Smith, P. Wiebe. 1984. Rapid evolution of a Gulf Stream warm-core ring. Nature, London. 308: 837-840.

Joyce, T. M. and M. E. Stalcup. 1985. Wintertime convection in a Gulf Stream warm-core ring. Jour. Phys. Oceanogr. 15: 1032-1042.

Joyce, T. and P. Wiebe. 1983. Warm-core rings of the Gulf Stream. Oceanus 26(2): 34-44.

Knauss, J. A. 1978. Introduction to physical oceanography. Prentice-Hall, Inc. Englewood Cliffs, N. J. 338 p.

Laevastu, T. and M. L. Hayes. 1983. Fisheries Oceanography and Ecology. Fishing News Books Ltd., Farnham, Surrey, England, 199 p.

Lai, D. and P. Richardson. 1977. Distribution and movement of Gulf Stream rings. J. Phys. Oceanogr. 7: 670-683.

Laurs, R. M. 1985. Applications of satellite remote sensing to fisheries. In: R. Amidei (ed). Applications of Remote Sensing To Fisheries and Coastal Resources. California Sea Grant Workshop, San Diego, CA. November 30, 1983. Report No. T-CSGCP-012. pp. 9-18

Laurs, R. M. and R. J. Lynn. 1977. Seasonal migration of North Pacific albacore, Thunnus alalunga, into North American coastal waters: Distribution, relative abundance, and association with transition zone waters. Fish. Bull. 75: 795-822.

Laurs, R. M., P. C. Fielder, D. R. Montgomery. 1984. Albacore tuna catch distributions relative environmental features observed from satellites. Deep-Sea Res. 31(9): 1085-1099.

Lucy, J. 1983. Summary of the impact of the Eigth Annual Virginia Beach Anglers Club Small Boat Marlin Tournament. VIMS, Marine Resource Report No. 83-3, page 2.

Lucy, J. and E. Bochenek. 1986. Economic and catch assessments of Rudee Inlet's recreational fishery, Virginia Beach, Virginia. Paper presented at the 42nd Annual Northeast Fish and Wildlife Conference (Abstract). Hershey, PA, Abstract No. 47.

Magnuson, J. J., S. B. Brandt, D. J. Stewart. 1980. Habitat preferences and fisheries oceanography, in Fish Behavior and its Use in the Capture and Culture of Fishes, ICLARM Conf.Proceedings, 5, Int. Cent. Living Aquatic Resource Manag., Manila, 371-382.

Magnuson, J. J., C. L. Harrington, D. J. Stewart, G. N. Harbst. 1981. Responses of macrofauna to short-term dynamics of a Gulf Stream front on the continental shelf, in Coastal Upwelling, F. A. Richards, ed., Coastal and Estuarine Sciences, 1, American Geophysical Union, Washington, D. C., pp. 441-448.

Marshall, A. and J. Lucy. 1981. Virginia's charter and head boat fishery analysis of catch and socioeconomic impacts. Special Report in Applied Marine Science and Ocean Engineering No. 253. Virginia Sea Grant Program. Va. Inst. Mar. Sci. 90 p.

Mather, F. J. III, H. L. Clark, J. M. Mason, Jr. 1975. Synopsis of the biology of the white marlin, Tetrapturus albidus Poey, 1861. Proc. International billfish symposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 3. Species Synopsis. NOAA Tech. Rept. NMFS-SSRF-675. pp. 55-94.

Maul, G. A., F. Williams, M. Roffer, F. M. Sousa. 1984. Remotely sensed oceanographic patterns and variability in bluefin tuna catch in the Gulf of Mexico. Oceanol. Acta. 7(4): 469-479.

Nelson, D. M., H. W. Ducklow, G. L. Hitchcock, M. A. Brzezinski, T. J. Cowles, C. Garside, R. W. Gould, Jr., T. M. Joyce, C. Langdon, J. J. McCarthy, C. S Yentsch. 1985. Distribution and composition of biogenic particulate matter in a Gulf Stream warm-core ring. Deep-Sea Res. 32(11): 1347-1369.

Nof, D. 1986. The collision between Gulf Stream and warm-core rings. Deep-Sea Res. 33(3): 359-378.

Norcross, B. L. and R. F. Shaw. 1984. Oceanic and estuarine transport of fish eggs and larvae: A review. Trans. Am. Fish. Soc. 113: 153-165.

Olson, D. B. and R. H. Backus. 1985. The concentrating of organisms at fronts: A cold-water fish and a warm-core Gulf Stream ring. Jour. Mar. Res. 43: 113-137.

Richardson, P. L. 1980. Gulf Stream ring trajectories. Jour. Phys. Oceanogr. 10(1): 90-104.

Rockford, D. J. 1981. Anomalously warm sea surface temperatures in the western Tasman Sea. Thier causes and effects upon southern bluefin tuna catch 1966-1977. Rep. Div. Fish. Oceanogr. CSIRO. Cronulla. No. 114. Publ.: Commonwealth scientific and industrial research organization, Cronulla, Australia. 21 p.

Roffer, M. 1986. Hi-Tech fishing via satellite. In: R. Crawford (ed). 1986 World Record Game Fishes. Freshwater, Salterwater, and Fly Fishing. The Int'l Game Fish Assoc. Ft. Lauderdale, FL. 35-48.

Roffer, M., M. Carl, and F. Williams. 1982. Atlantic bluefin tuna-oceanography remote sensing. Proc. 32nd Annual Tuna Conf. IATTC, La Jolla, CA.

Saunders, P. M. 1971. Anticyclonic eddies formed from shoreward meanders of the Gulf Stream. Deep-Sea Res. 18: 1207-1219.

Schmidt, S. 1985. Virginia's recreational fishery: Catching fish is big business. Marine Resource Bulletin. Virginia Sea Grant College Program. Va. Inst. Mar. Sci., College of William and Mary. 17(3): 1-6.

Shingu, C. 1981. Ecology and stock of southern bluefin tuna. CSIRO, Di. Fish. Oceanogr. Rep. No. 131.

Squire, J. L., Jr. 1962. Marlin and swordfish in oceanic waters of the western North Atlantic. Copeia. (1): 216-219.

Squire,J. L., Jr. 1974. Catch distribution and related sea surface temperature for striped marlin (Tetrapturus audax) caught off San Diego, CA. Proc. Int'l. Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 2. NOAA NMFS-675 188-193.

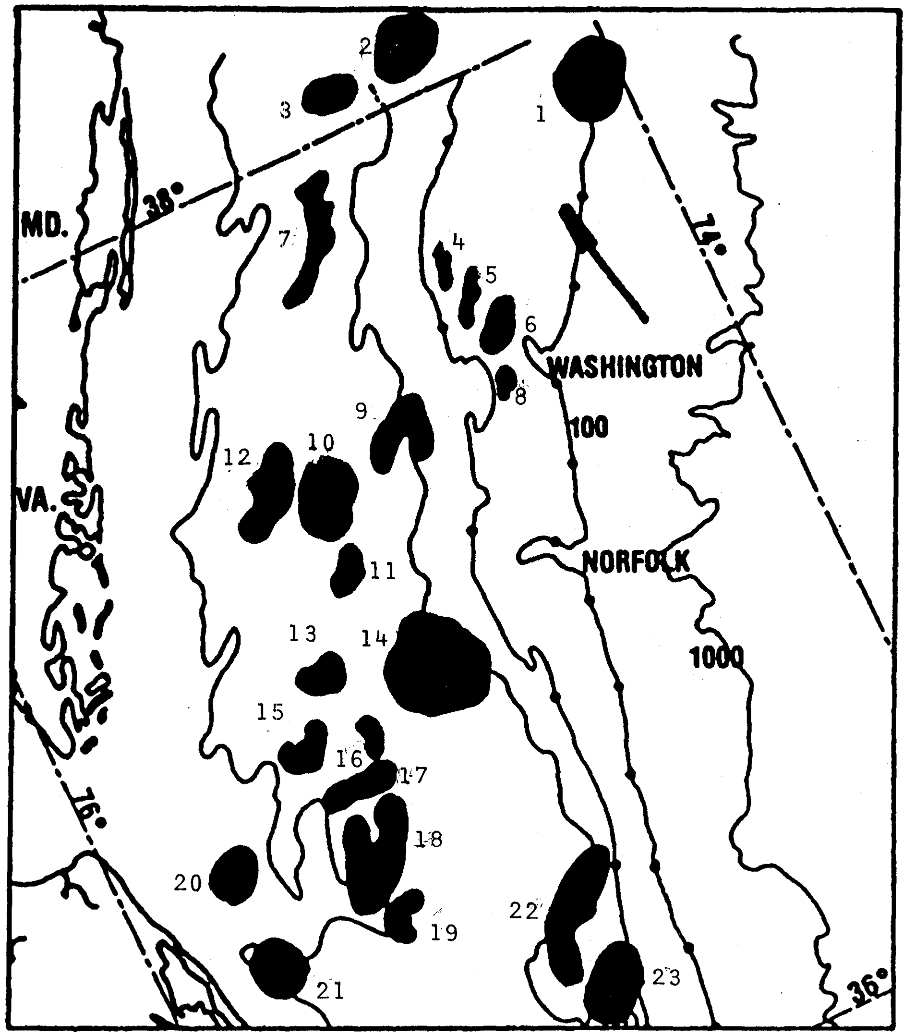
Sullivan, C. M. 1954. Temperature reception and responses in fish. Jour. Fish. Res. Bd. Canada, 11(2), 153-170.

Sund, P. N., M. Blackburn, F. Williams. 1981. Tunas and their environment in the Pacific Ocean: a review. Oceanogr. Mar. Biol. an Annual Review. 19: 443-512.

Svejovsky, J. and R. Lasker. 1985. Effects of thermal structure on albacore distribution. In: R. Amidei (ed). Applications of Remote Sensing to Fisheries and Coastal Resources. Califiornia Sea Grant Workshop, San Diego, CA. November 30, 1983. Report No. T-CSGCP-012. pp. 19-26

Tranter, D. J., G. S. Leech, D. Airey. 1983. Edge enrichment in an Ocean Eddy. Austr. Jour. Mar. Freshwater Res. 34: 665-680.

Uda, M. 1973. Pulsative fluctuation of oceanic fronts in association with the tuna fishing grounds and fisheries. Journal of the Faculty of Marine Science and Technology, Tokai University. 7: 245-265.




## Tuna and Billfish Grounds off the Virginia Coast

1. Poor Man's Canyon
2. The Fingers
3. Jackspot
4. First Lump
5. Second Lump
6. Rockpile
7. Lumps
8. 29 Fathom Lumps
9. 20 Fathom Fingers
10. 21 Mile Hill
11. Hambone (26 Mile Hill)
12. No Name
13. Triangle Wrecks
14. The Fingers
15. Fish Hook
16. Hot Dogs
17. SE Lumps
18. Horseshoe
19. Boomerang
20. V Buoy
21. 4A Buoy
22. Cigar
23. Honey Hole

Figure 1. Virginia Offshore Recreational Fishing Locations.

**SURVEY OF THE USE OF GULF STREAM WARM CORE RINGS AND FINGER LOCATIONS BY RECREATIONAL FISHERMEN IN VIRGINIA - 1986**

Interviewer_________ Date__________ Dockside______ Phone_______
Capt. Name__________________ Boat Length___ Private___ Charter___
Primary Inlet Used During The Fishing Season_________________

1. Do You Consider The Location Of Warm Core Rings Or Fingers When Planning Your Offshore Fishing Trip ?
A) Yes____ B) No____ C) Not Familiar With____
If Yes Go To Part A) If No Go To Part B)

---

A.)

1. Where Do You Get Your Information And Of What Form Is It In ?

---

2. Do You Feel That Better Fishing Spots Are Located By The Above Information ? Yes____ No____
3. Is Travel Time Reduced ? Yes____ No____ Not Sure____
4. Does The Information Provided Arrive In Time For You To Make Operational Decisions For Proposed Fishing Trips ?
Yes____ No____ Not Sure____
5. Would You Be Interested In Receiving Satellite Information On A Subscription Basis ? Yes____ No____
6. At A Nominal Cost (ie. $20.00/yr.) ? Yes____ No____

---

B.)

1. Why Is The Location Of Warm Core Rings And Fingers Not Considered When Planning Your Offshore Fishing Trip ?

---

2. Would You Be Interested In Receiving Satellite Information On A Subscription Basis ? Yes____ No____
3. At A Nominal Cost (ie. $20.00/yr.) ? Yes____ No____

---

Remarks And/Or Any Particular Experience With Warm Core Rings:

Address For Further Information:

_______________________
_______________________
_______________________

Figure 2. Survey form for estimating the present and potential use of remote sensing information by the Virginia offshore recreational fishery.

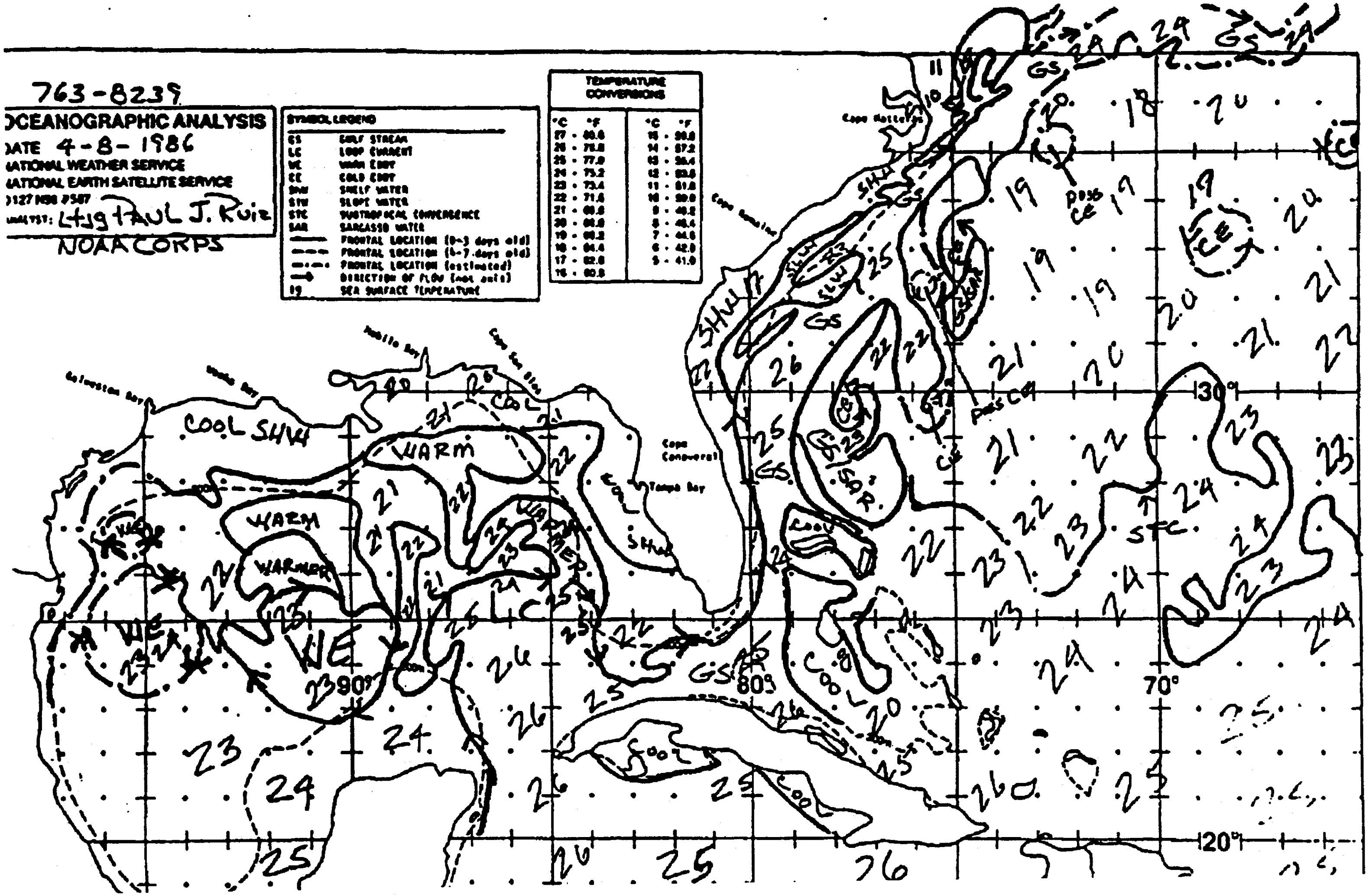



Figure 3. NOAA/NWS South Panel Oceanographic Analysis Chart.

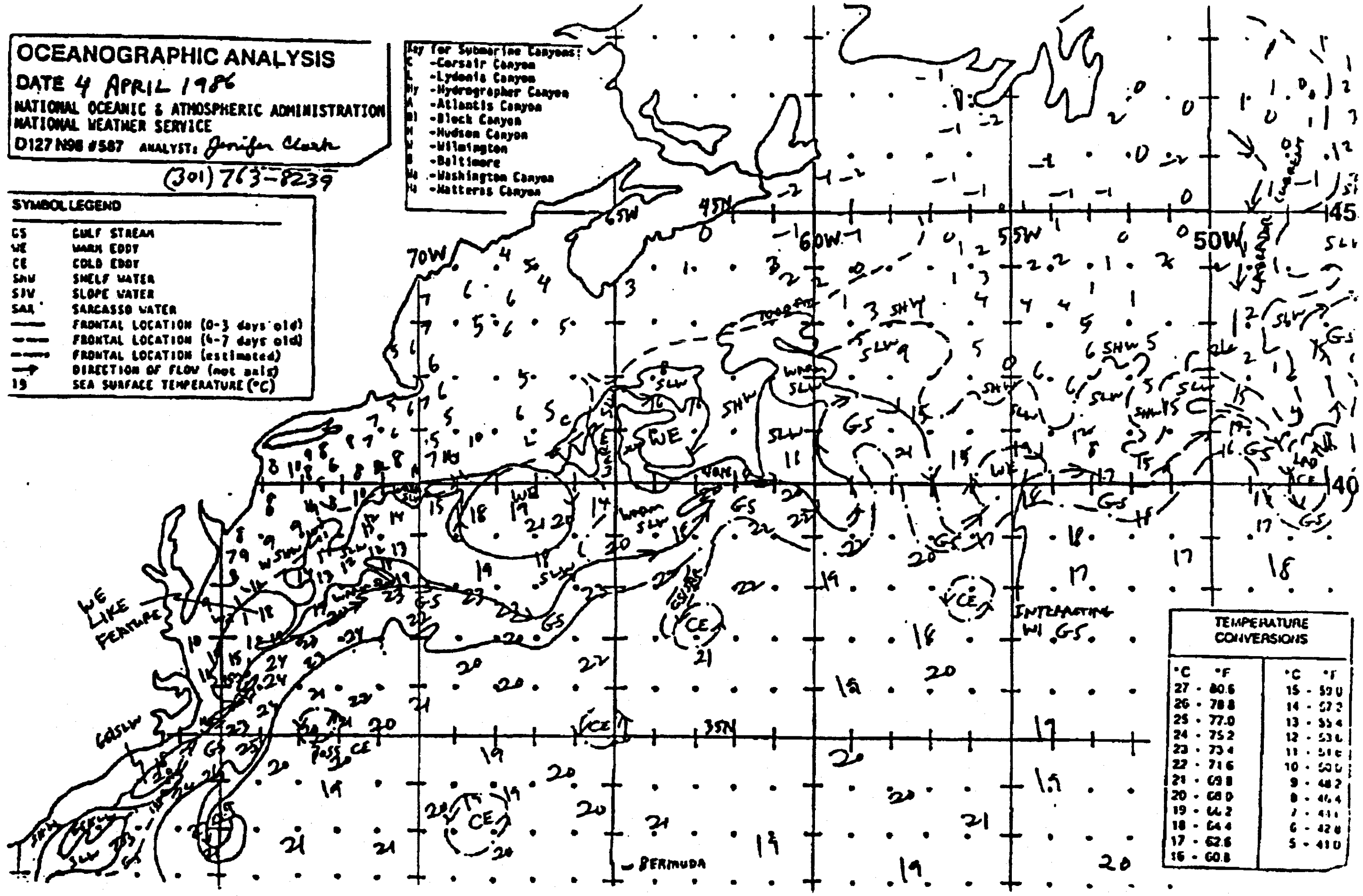



Figure 4. NOAA/NWS North Panel Oceanographic Analysis Chart.

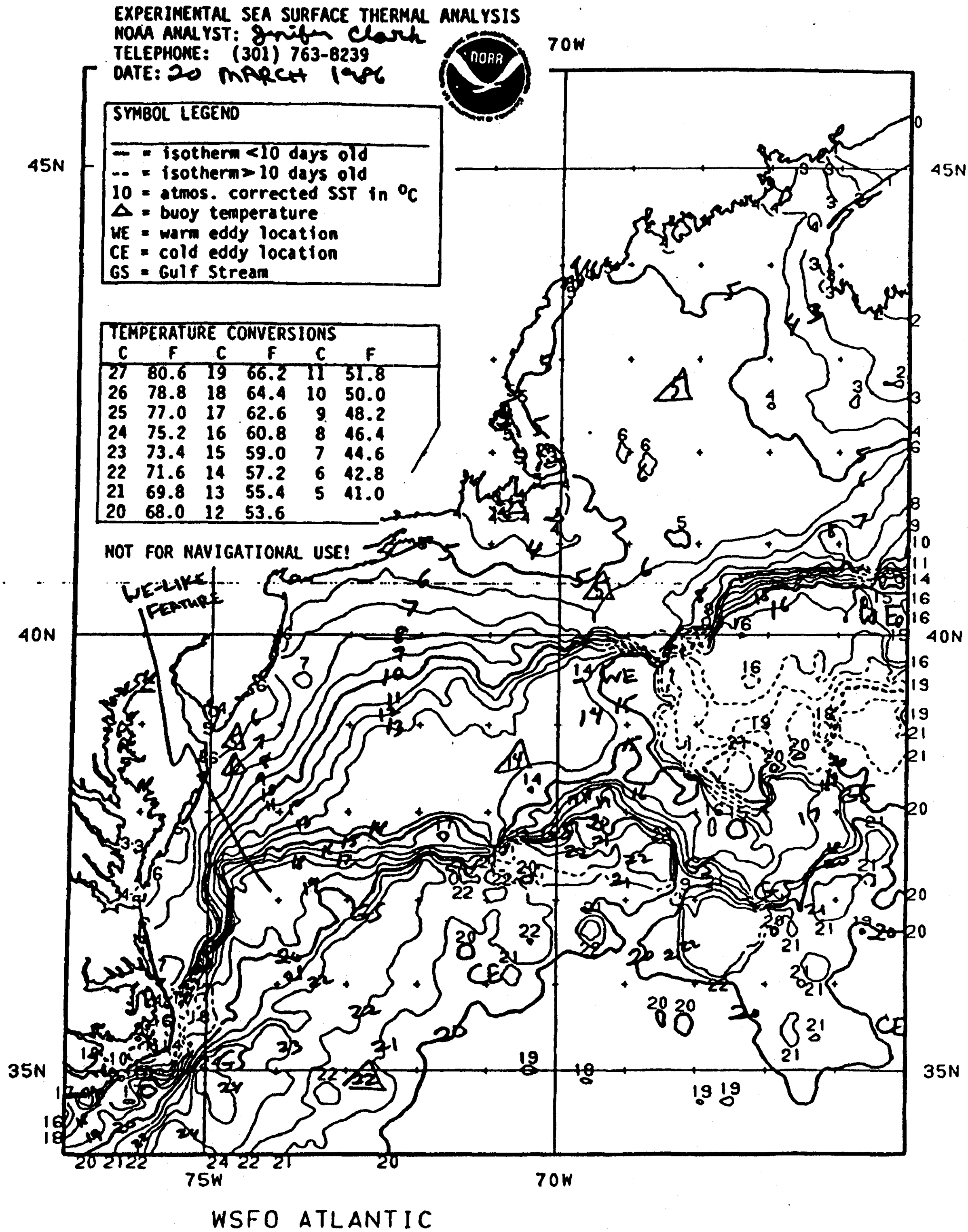



Figure 5. NOAA/NWS North Panel Sea Surface Thermal Analysis Chart.

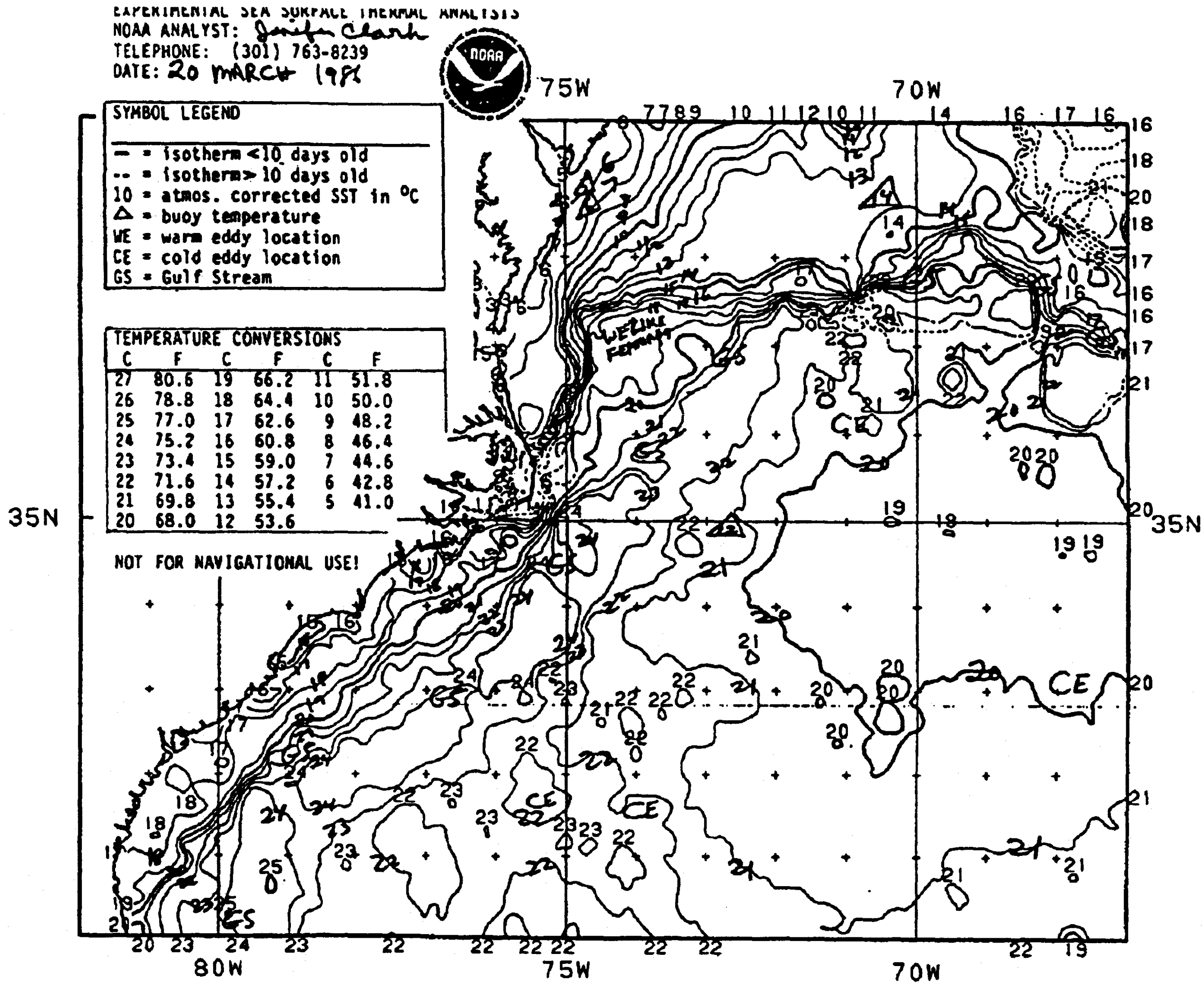



Figure 6. NOAA/NWS South Panel Sea Surface Thermal Analysis Chart.

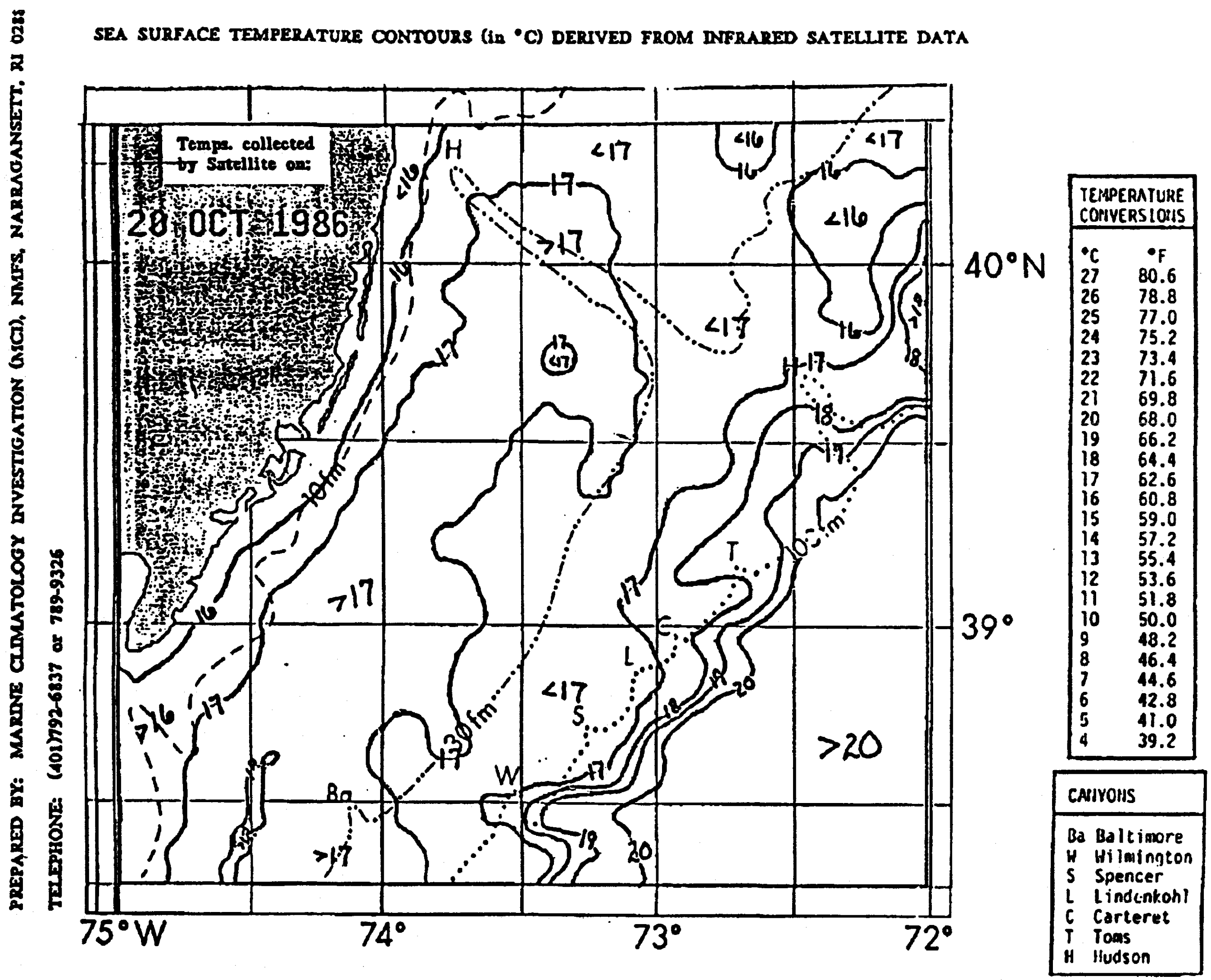



Figure 7. NMFS/Narragansett, Rhode Island Oceanographic Analysis Chart.

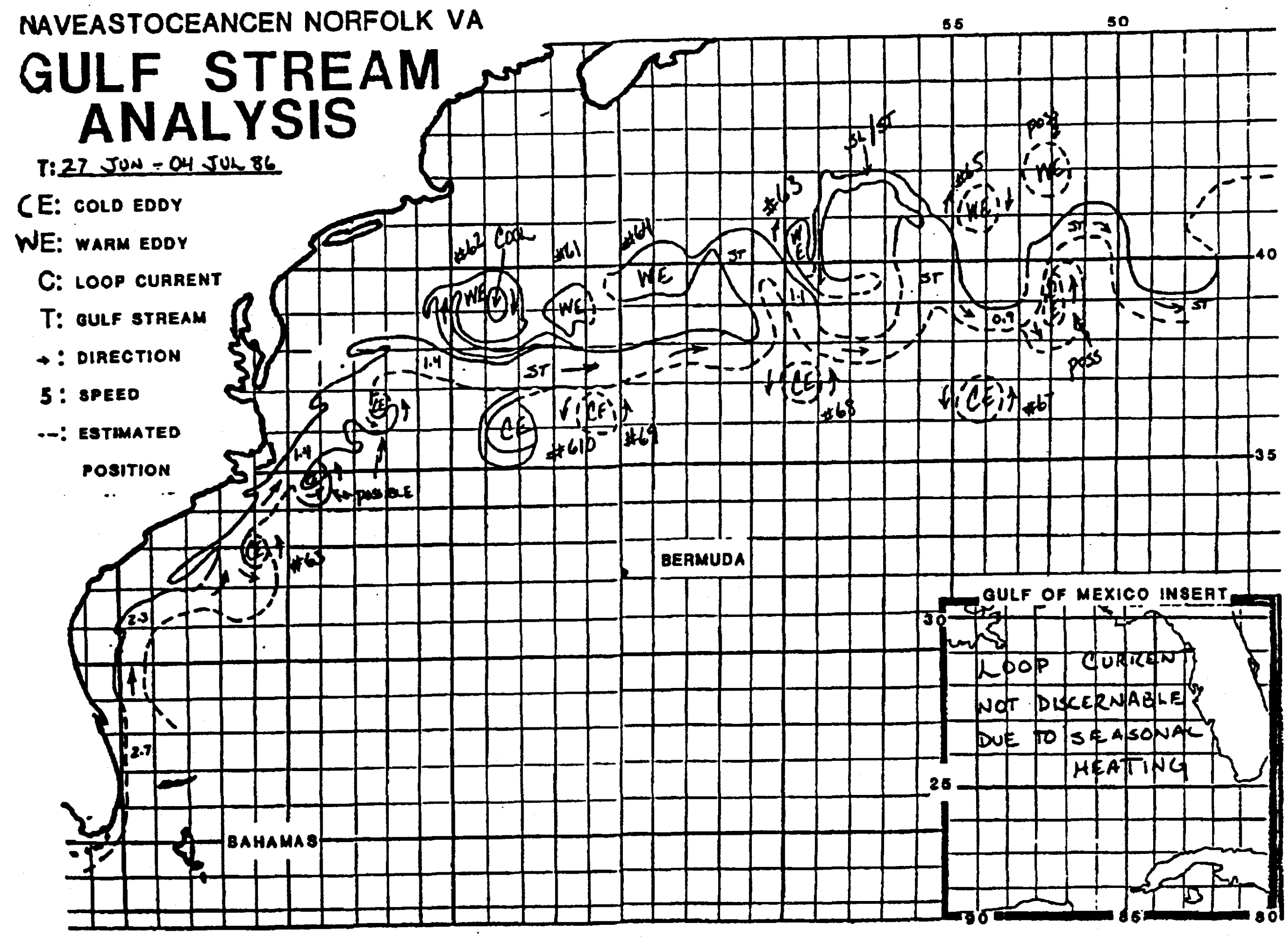



Figure 8. Naval Eastern Oceanography Center Gulf Stream Analysis Chart.

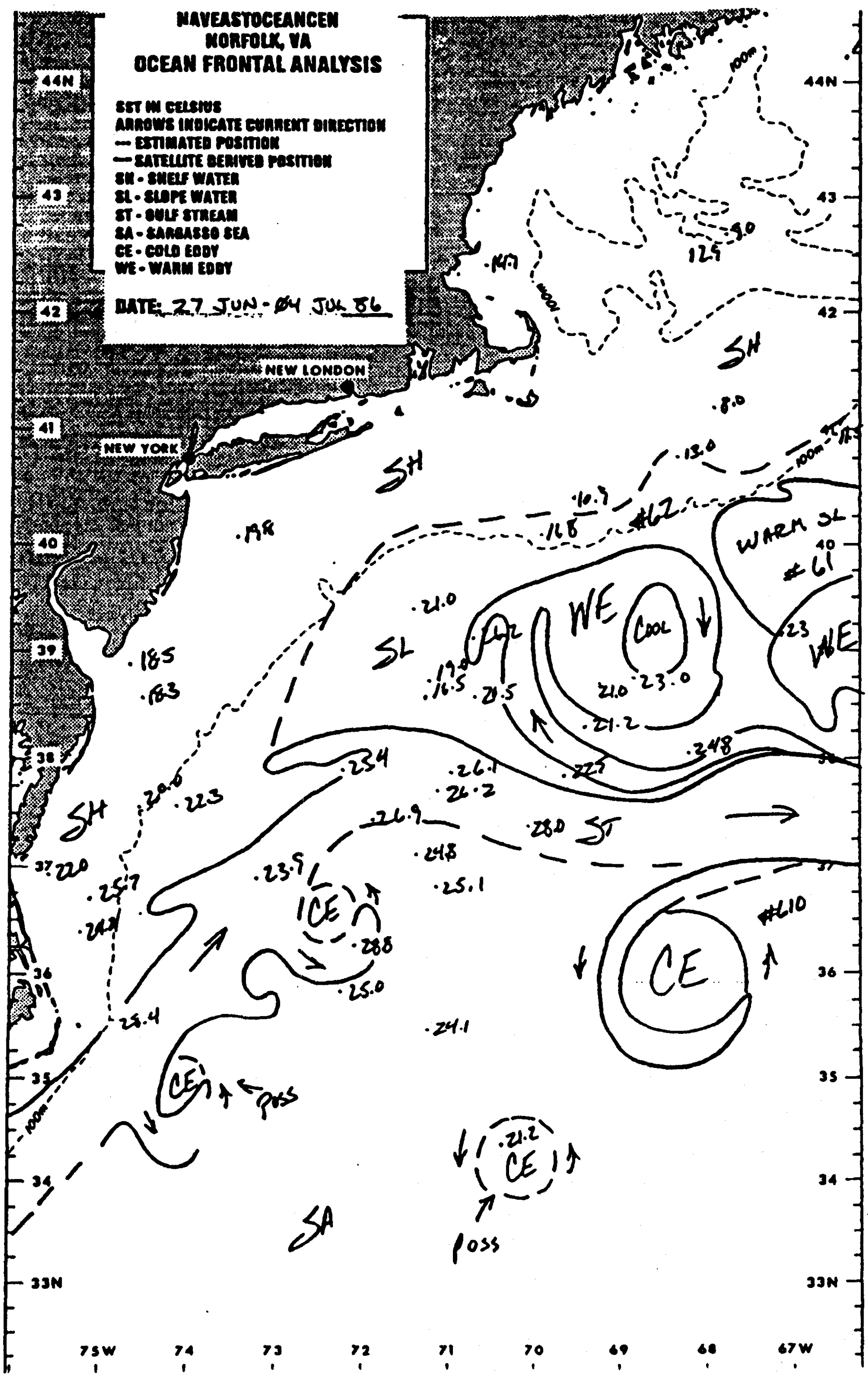



Figure 9. Naval Eastern Oceanography Center Ocean Frontal Analysis Center.

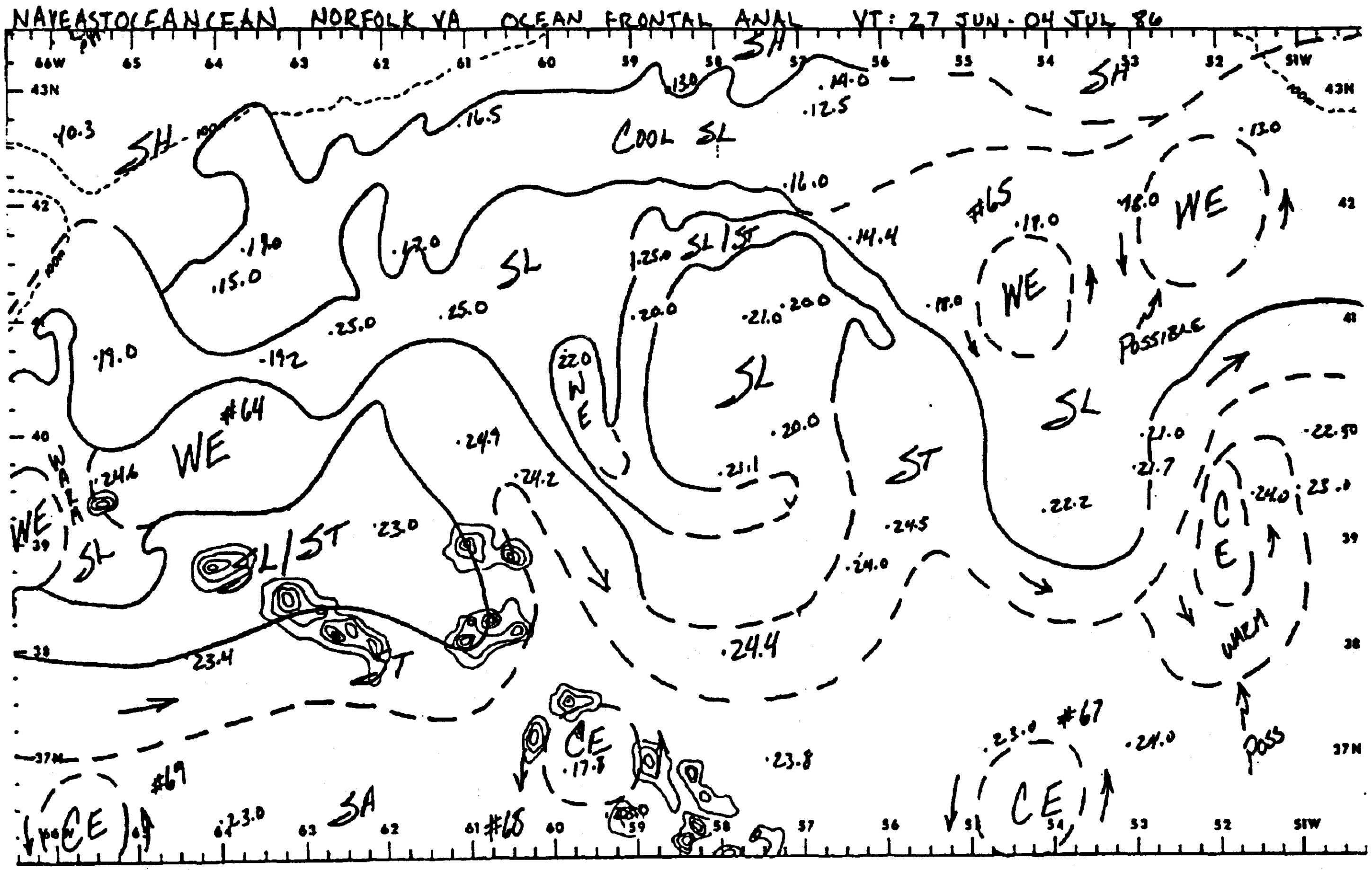



Figure 10. Naval Eastern Oceanography Center Ocean Frontal Analysis Chart.

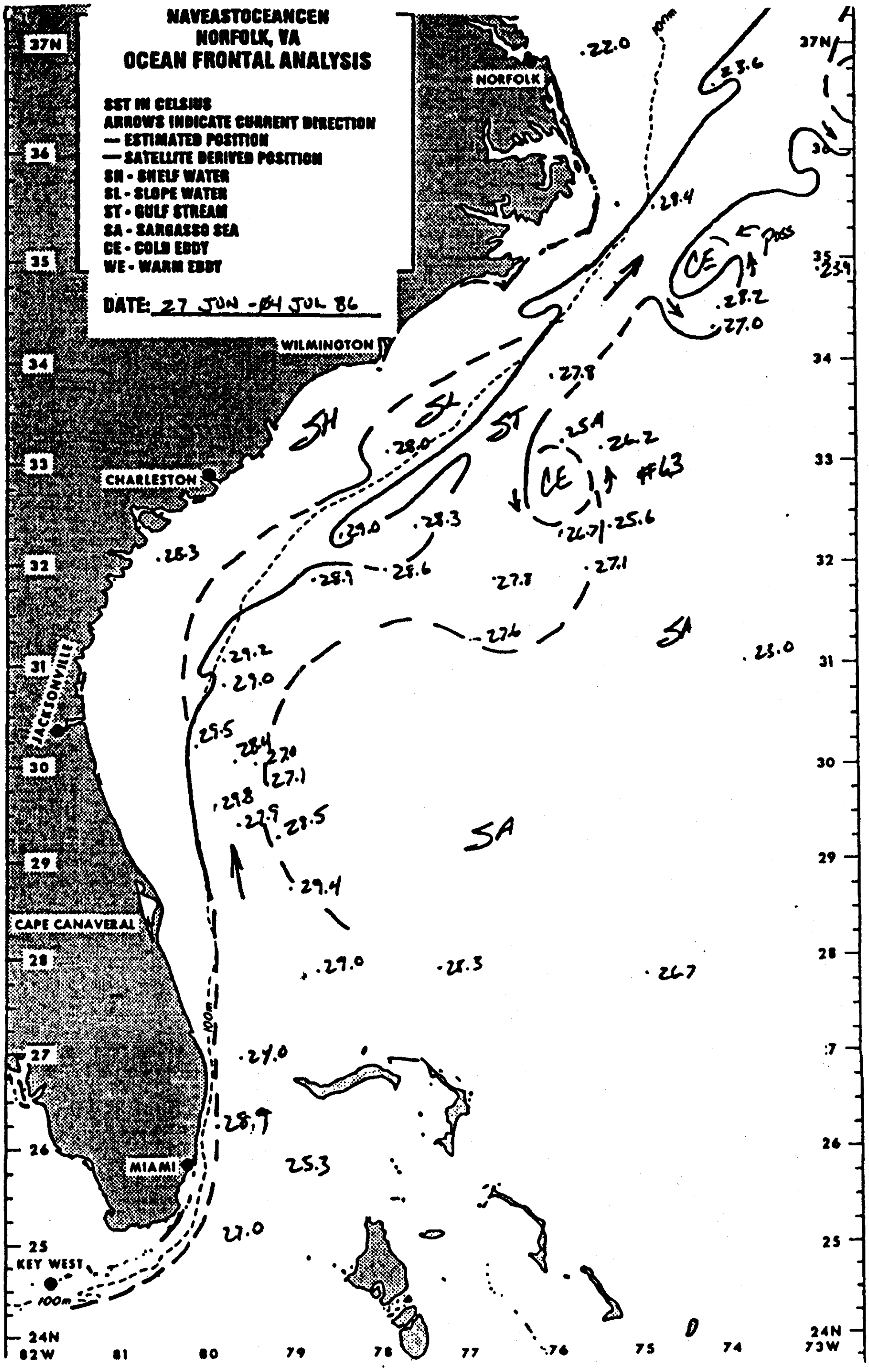



Figure 11. Naval Eastern Oceanography Center Ocean Frontal Analysis Chart.

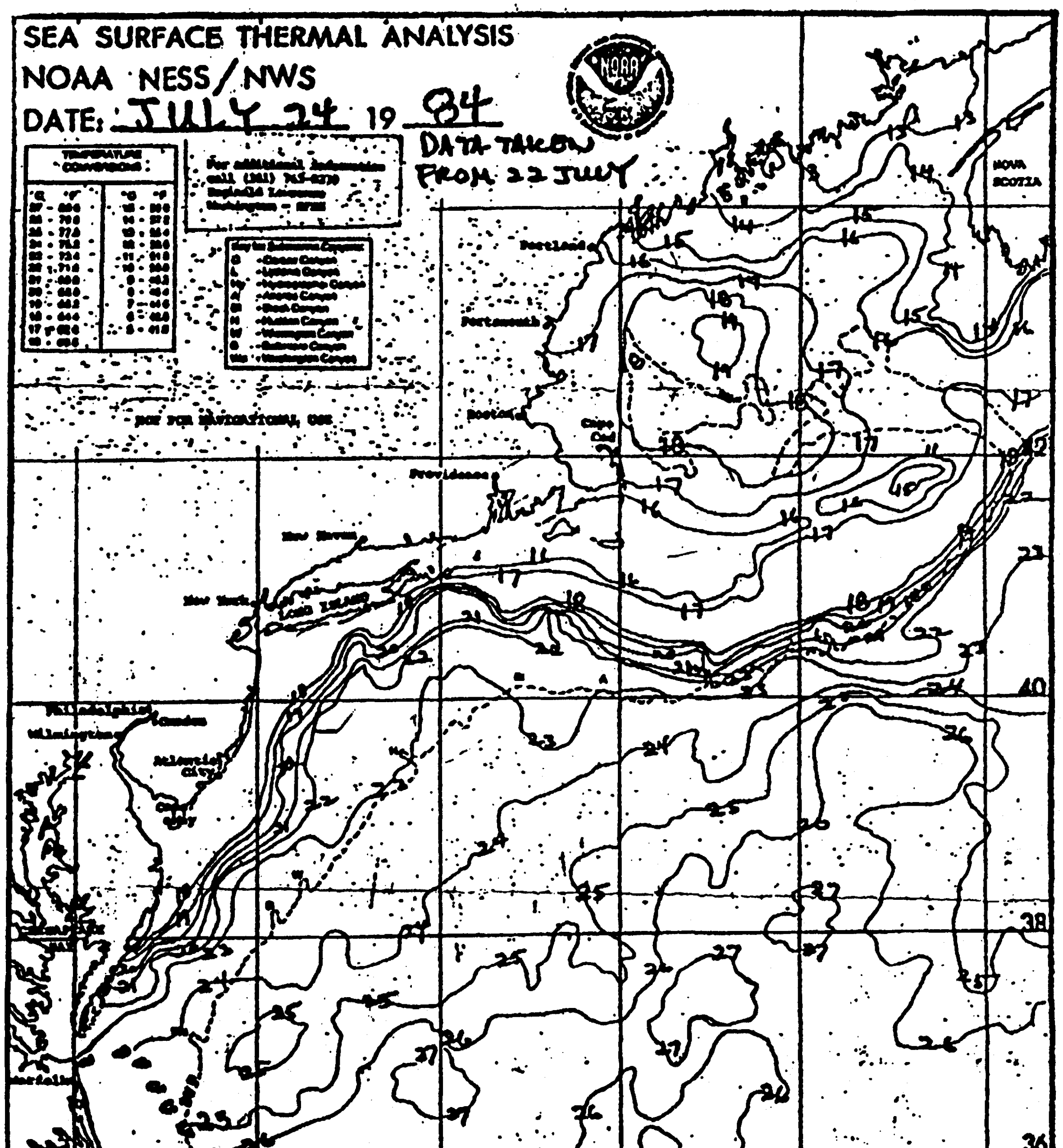



Figure 12. University of Delaware Sea Grant (MAS) Sea Surface Thermal Analysis Chart.

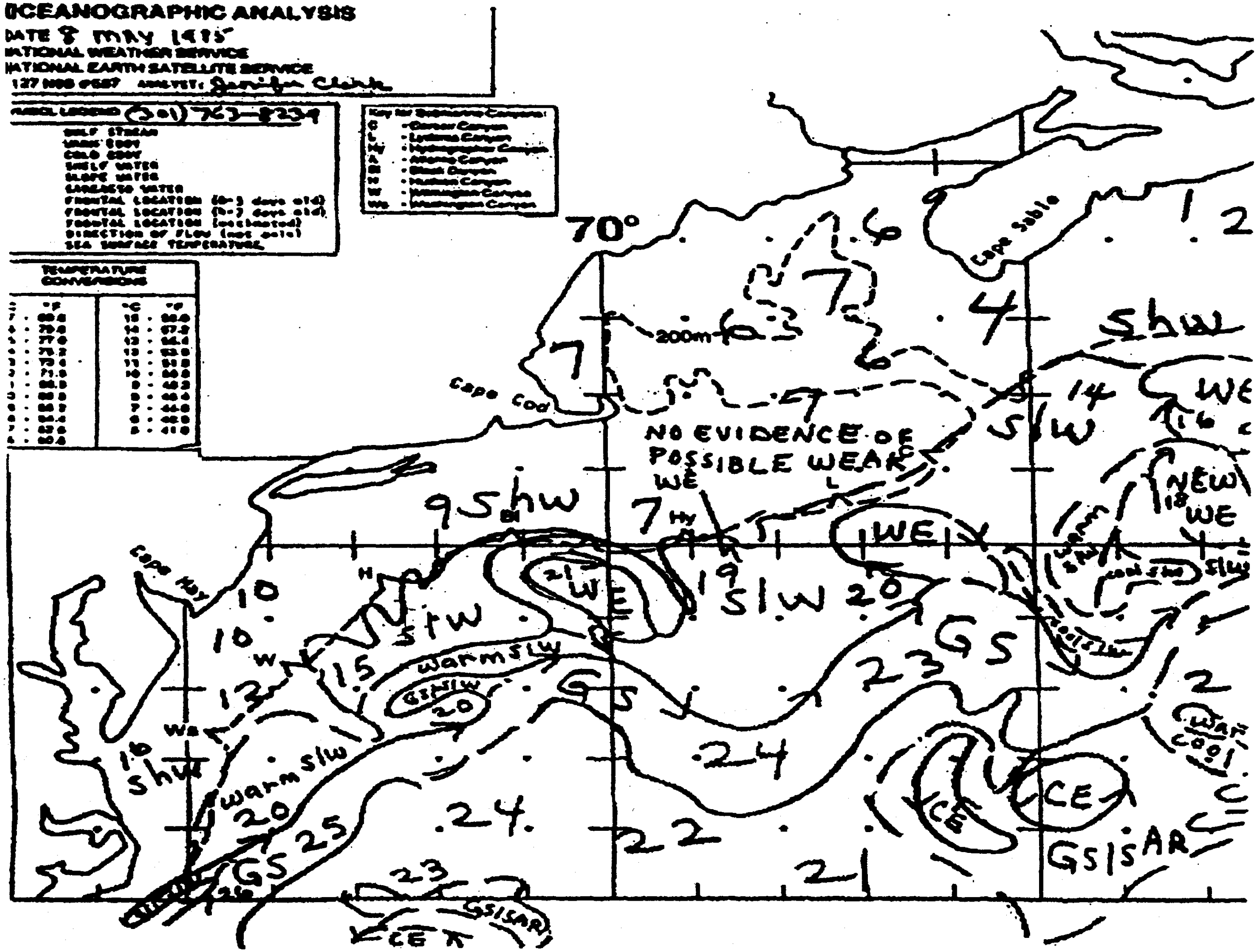
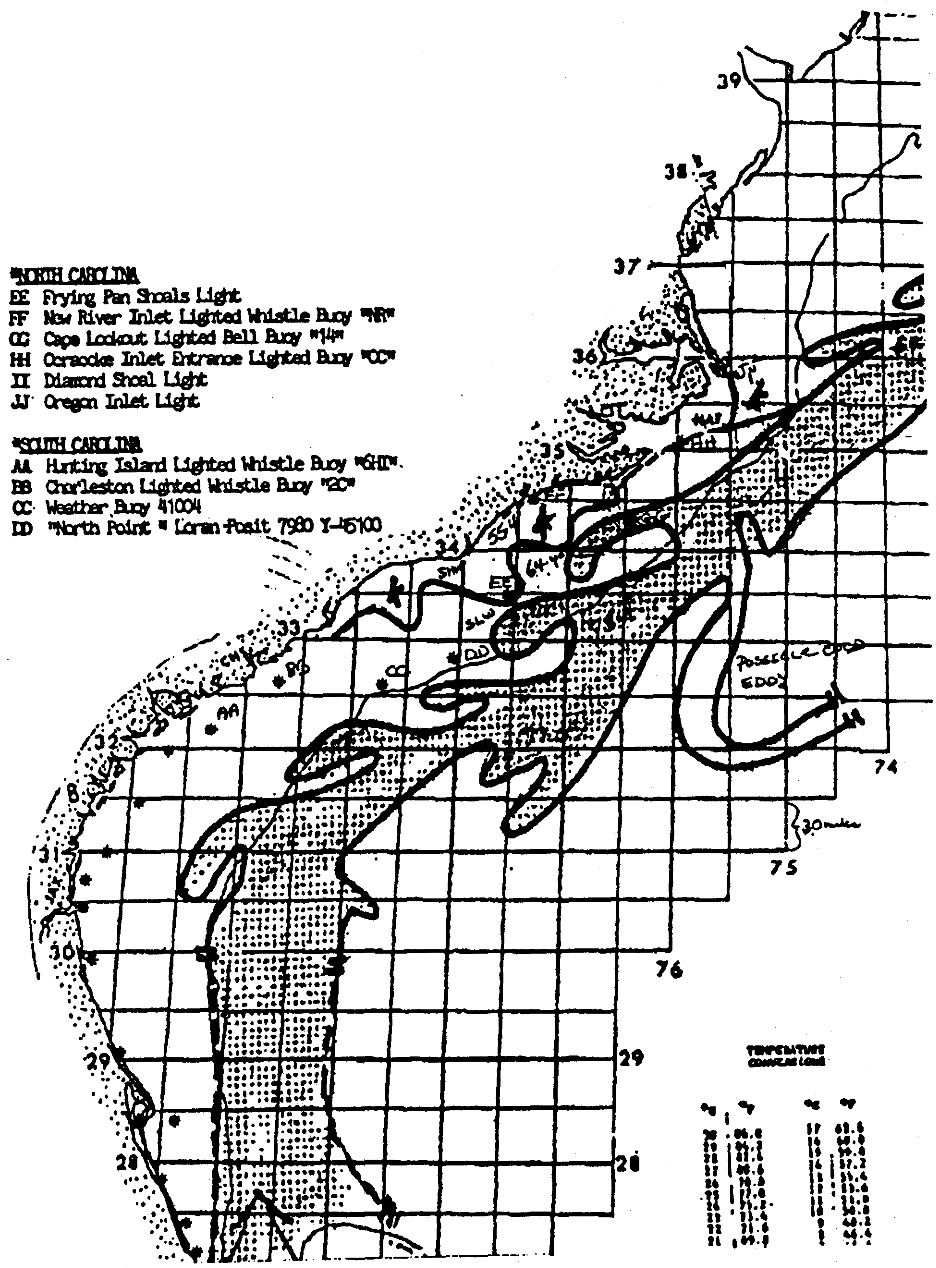



Figure 13. University of Delaware Sea Grant (MAS) Oceanographic Analysis Chart.

COURTESY OF NORTH CAROLINA SEA GRANT

Analysis Date 09 Mar 88
Next Analysis 16 Mar 88




SHW = Shelf Water
SLW = Slope Water

Figure 14. University of North Carolina Sea Grant Gulfstream Analysis Chart.

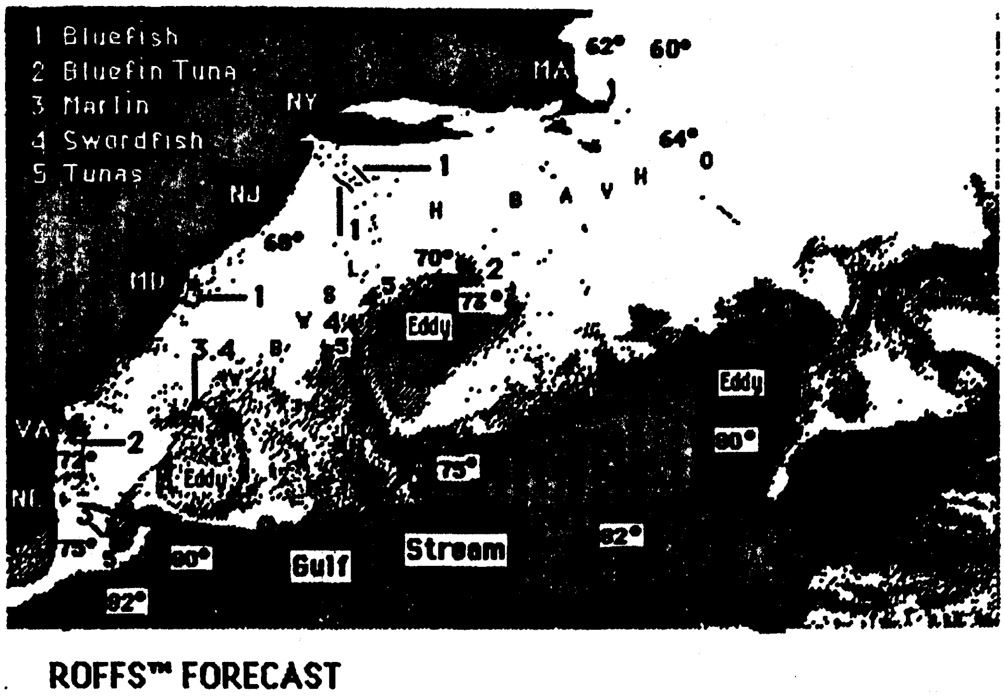



Figure 15. Roffer's Ocean Fishing Forecasting Service Chart.

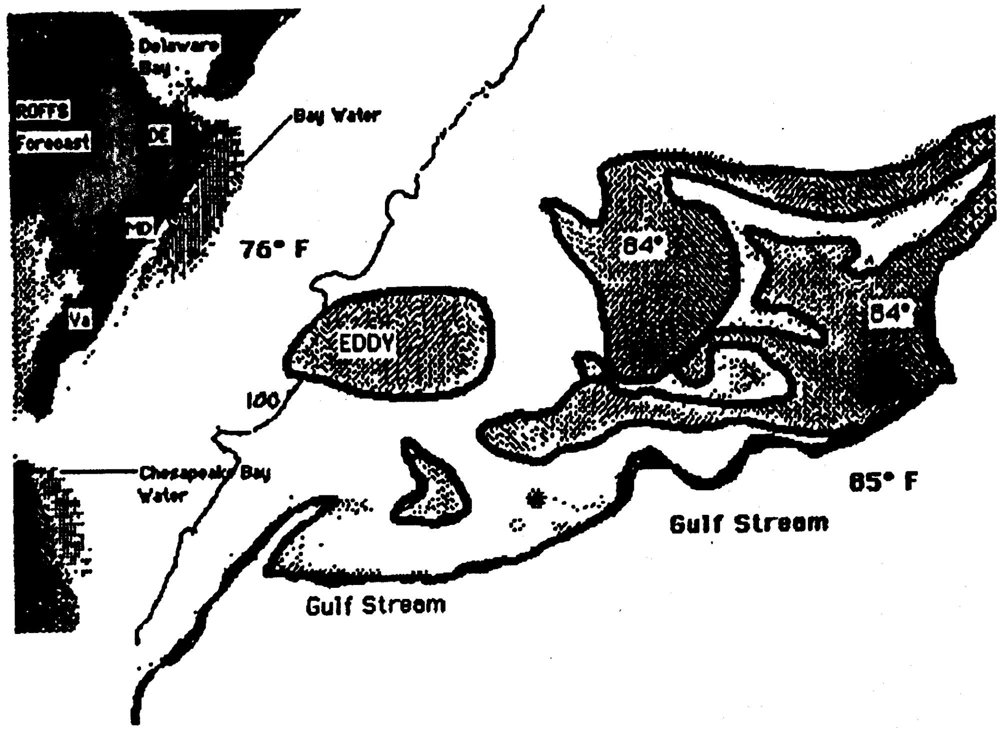



Figure 16. Roffer's Ocean Fishing Forecasting Service Chart.

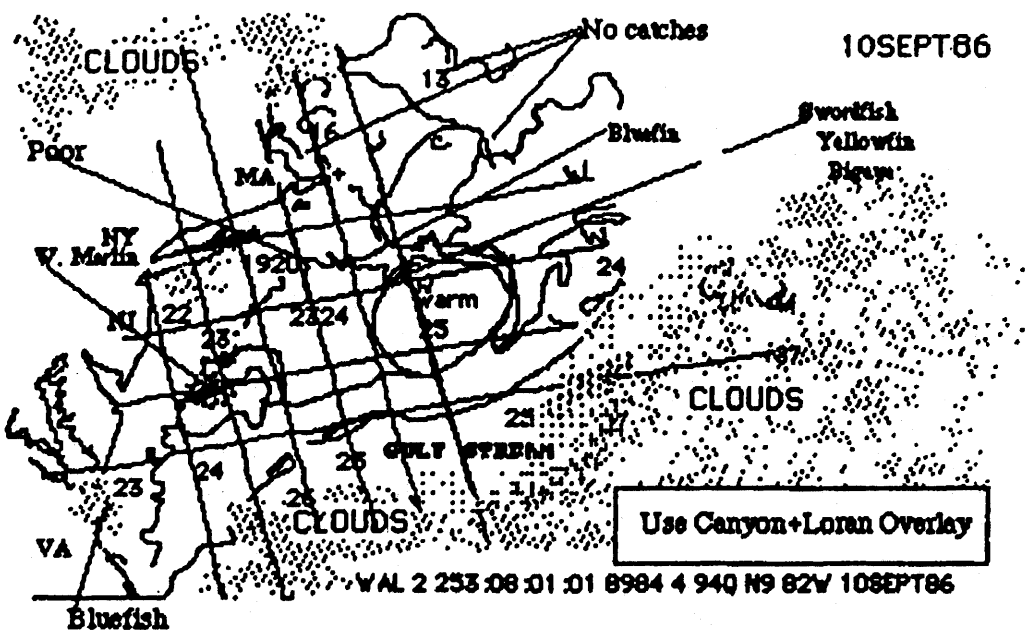



Figure 17. Roffer's Ocean Fishing Forecasting Sevice Chart.

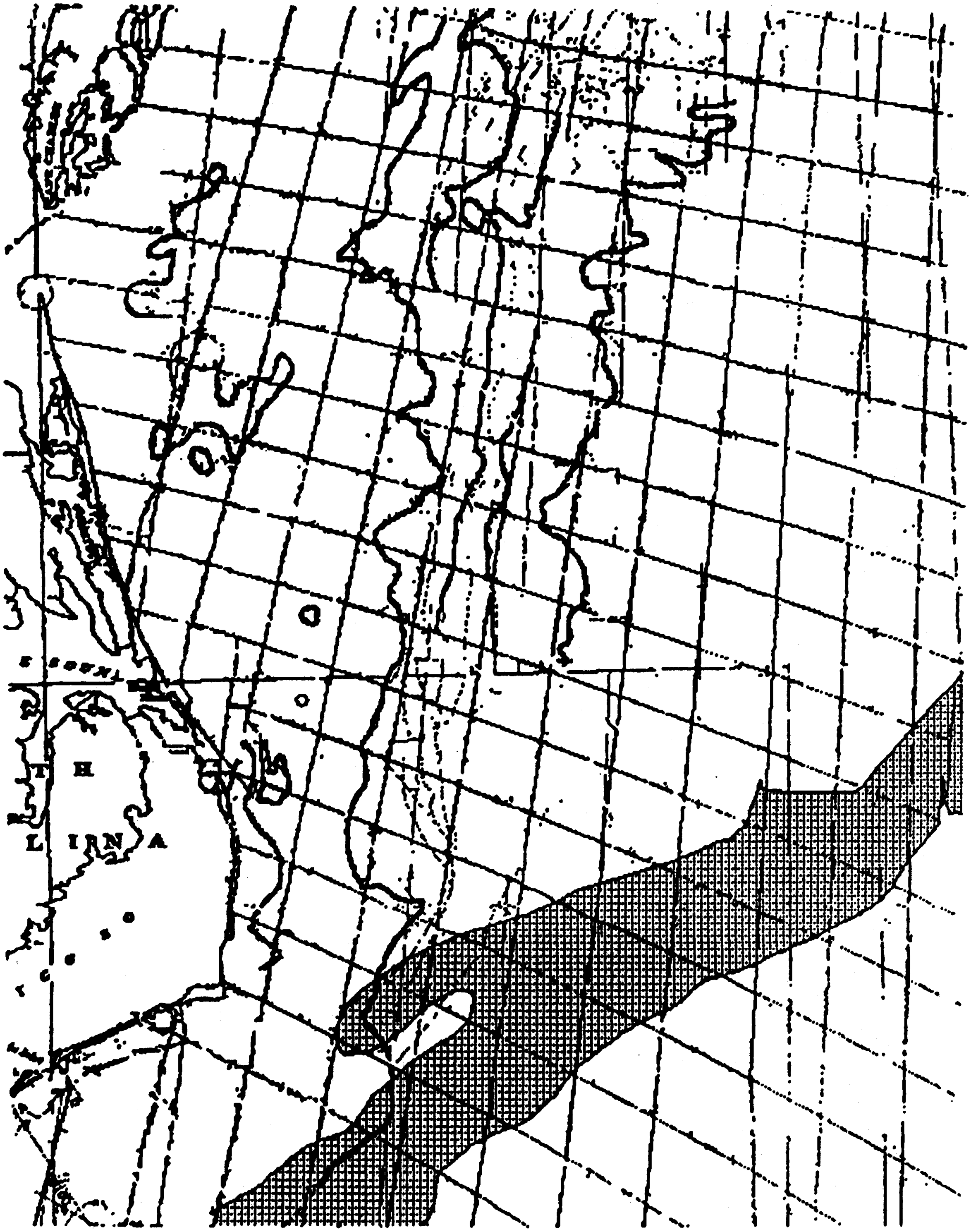
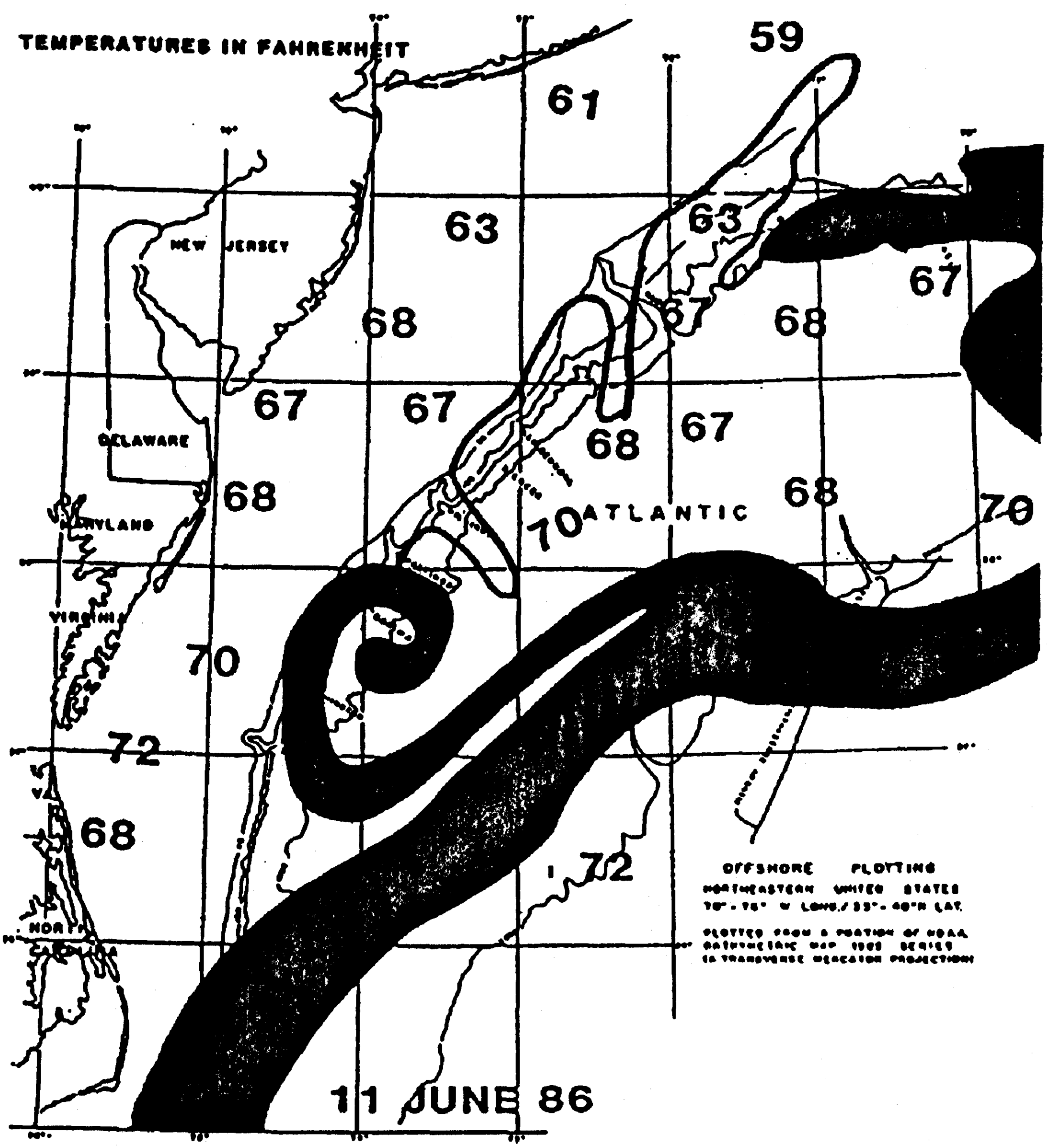


Figure 18. Roffer's Ocean Fishing Forecasting Service Chart.




# SURFACE TEMPERATURE CHARTS

This surface temperature chart was prepared by OFFSHORE SERVICES for use by canyon fishermen from Block to Norfolk Canyon. Accompanied by a full narrative, these charts can pinpoint areas of greater billfish and tuna activity through movements of warm eddies and fingers of the Gulf Stream.

Figure 19. Offshore Services Inc. Sea Surface Thermal Analysis Chart.