U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway Miami FL 33149
TEL: 305-361-4328
FAX: 305-361-4392
EMAIL: ryan.smith@noaa.gov

May 20, 2009

CRUISE REPORT

STATE DEPARTMENT CRUISE ID:
DOS-2008-128

NOAA CRUISE ID:
NF-09-03

SHIP NAME:
NOAA Ship Nancy Foster

OPERATING AGENCY:
National Oceanic and Atmospheric Administration (NOAA)

PROJECT TITLE:
Coral Reef Ecosystem Research

CRUISE DATES:
April 7, 2009 through April 20, 2009

CHIEF SCIENTIST:
Ryan H. Smith
NOAA/AOML/PhOD
4301 Rickenbacker Causeway
Miami, FL 33149 USA
305-361-4328 (tel)
305-361-4392 (fax)

CLEARANCE COUNTRIES:
United Kingdom, for Anguilla and British Virgin Islands
Guadeloupe/France, for Saint Martin and Saint Barthelemy
Netherlands Antilles, for Saba, Sint Eustatius, and Sint Maarten
Saint Kitts and Nevis

PORT OF EMBARKATION:
San Juan, Puerto Rico (USA)

PORT OF DISEMBARKATION:
San Juan, Puerto Rico (USA)

CRUISE REPORT

CORAL REEF ECOSYSTEM RESEARCH

NOAA Ship Nancy Foster
NF-09-03
April 7-20, 2009

1. Cruise Summary

Introduction and Objectives

The United States Virgin Islands' (USVI) Grammanik Bank, located to the south of St. Thomas, is the site of a multi-species spawning aggregation for economically important fish including yellowfin grouper, Nassau grouper, tiger grouper, and dog snapper. Fishing pressure at this suspected source of larval recruits prompted the US Caribbean Fishery Management Council (CFMC) in 2004 to close the bank yearly from February to April. A series of banks south of the USVI (St. Thomas and St. John) and the British Virgin Islands (BVI) provide similar habitats and spawning aggregation sites. Prior to the inception of this study, the biological and physical processes which drive production on these banks, the circulation connecting these banks, and the flows across these banks had not been quantified. As the 2004 management decisions were made in the absence of these data, regional Marine Protected Area (MPA) designations and temporary closures are presently based on professional judgment rather than quantifiable, defensible scientific information. In addition, meeting new annual catch limit (ACL) requirements of the Magnuson-Stevens reauthorization has become a priority of the CFMC. However, data limitations preclude comprehensive stock assessments for most fisheries in the region.

To address these data gaps, National Oceanic and Atmospheric Administration (NOAA) scientists from the Southeast Fisheries Science Center (SEFSC) and the Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami, Florida, working with scientists from the University of the Virgin Islands (UVI) and Department of Planning and Natural Resources (DPNR) in St. Thomas, are presently conducting a multi-year, interdisciplinary research project utilizing the *NOAA Ship Nancy Foster* to conduct biological and physical oceanographic surveys of the Virgin Islands (VI) bank ecosystems and surrounding regional waters. The long-term sustainability of fisheries in the VI and surrounding regions will depend on a comprehensive understanding of regional spawning aggregations, larval transport, and overall larval recruitment in the study area.

This endeavor, titled the Coral Reef Ecosystem Research (CRER) program, is directed at answering one over-arching question:

How are the unprotected VI banks, MPAs such as the Hind Bank Marine Conservation District, seasonally closed areas such as Grammanik Bank, inshore areas and adjacent islands ecologically linked via regional reef fish larval dispersal, transport, and life-history patterns?

Data collected from this program will not only provide information on a data-poor region, but have the potential to address two specific needs identified through a comprehensive review process recently completed by SEFSC and CFMC. First, should fish stocks be delineated from individual island groups (e.g. Puerto Rico, St. Thomas/St. John, and St. Croix), from the US Caribbean, or from the broader Caribbean region? This interdisciplinary effort will provide information on the interconnectivity of fish populations and assist in this stock delineation. Secondly, *indices of abundance* have been identified as a critical component of the length-based assessment methods currently employed in the US Caribbean. However, regional indices are lacking, or in some cases nonexistent. CRER will serve to improve existing and generate new indices of abundance for the study area.

Methods

In an effort to develop more specific hypotheses, project scientists have been collecting data since 2007 during annual field surveys of the region. The 2007 and 2008 research cruises sampled water properties, currents, and dispersal and transport of settlement-stage larvae in the VI and neighboring regions. Data collection efforts continued in 2009 during the project's third research cruise, the details of which are outlined in this report.

The third Coral Reef Ecosystem Research cruise (NF-09-03) was conducted aboard the *NOAA Ship Nancy Foster* April 7-20, 2009. The ship embarked from San Juan, Puerto Rico on April 7th, and following the completed survey returned to San Juan on April 20th. The cruise was broken into two legs, with a mid-cruise port stop at Road Town, Tortola, BVI on April 14th. In-port activities at Road Town included an 'at-sea' open house and survey demonstration for BVI Conservation and Fisheries Department (CFD) officers, a dockside open house and tour for CFD personnel, and a presentation and discussion of project data and preliminary results with CFD scientists at their headquarters in Road Town.

Similarly to previous project cruises, NF-09-03 was designed to gather data necessary for the assessment of regional spatial variations in the supply of settlement-stage fishes, linkages between regional spawning aggregation sites, and the effectiveness of existing CFMC management decisions. To this end, the April 2009 survey was extended to include the eastern and northern coastal regions of St. Croix. This additional spatial coverage will help to determine whether MPAs and conservation areas south of St.

Thomas should be managed together with sensitive coastal sites around St. Croix, or if each island's marine ecosystem can effectively be managed as a separate entity.

The survey, whose track and station locations are shown in Figure 1, included bongo, and 1-meter MOCNESS trawl tows, as well as CTD casts profiling, temperature, salinity, dissolved oxygen, chlorophyll, and water velocity. Continuous surface measurements of temperature, salinity, chlorophyll, and water velocity were also collected via the ship's flow-through system and hull-mounted acoustic Doppler current profiler (ADCP). Ten satellite-tracked, Lagrangian surface drifters were deployed across the survey domain to augment Eulerian current velocity measurements. Additionally, satellite ocean color images were downloaded, processed, and utilized during the cruise to determine the specific locations of oceanic features such as current fronts, recirculations, and gyres, and to direct adaptive sampling of these features as the survey progressed.

2. Scientific Personnel

NF-09-03 Participants:

Ryan Smith	USA	NOAA/AOML/PhOD	Chief Scientist
Elizabeth Johns	USA	NOAA/AOML/PhOD	Scientist
Nelson Melo	USA	NOAA/AOML/PhOD	Scientist
Grant Rawson	USA	NOAA/AOML/PhOD	Scientist
John Lamkin	USA	NOAA/NMFS/SEFSC	Scientist
Trika Gerard	USA	NOAA/NMFS/SEFSC	Scientist
Estrella Malca	USA	NOAA/NMFS/SEFSC	Scientist
Alex Ender	Switzerland	NOAA/NMFS/SEFSC	Student
Barbara Muhling	Australia	NOAA/NMFS/SEFSC	Scientist
Aki Shiroza	Japan	NOAA/NMFS/SEFSC	Scientist
Francisco Fuenmayor	USA	NOAA Corps. (SEFSC)	Scientist
Kevin Brown	USA	UVI, St. Thomas	Scientist
Ariane Frappier	USA	UVI, St. Thomas	Student

3. Discrete Sampling

Bongo Tows

Bongo tows were conducted throughout the course of the survey at station locations listed in Table 1 and plotted in Figure 1. Catches were collected from 97 tows using a 0.9 m bongo net with a mesh size of 0.505 mm. Each horizontal subsurface tow was performed for approximately 10 minutes. Volumes filtered were calculated using a mechanical flow meter attached to the mouth of the bongo net.

MOCNESS Tows

A Multiple Opening/Closing Net and Environmental Sampling System (MOCNESS) was deployed at offshore and 'shelf-break' sampling stations (Table 1, Figure 1). 57 MOCNESS tows were conducted to a depth of 100 meters. During each tow, at the device's maximum depth, MOCNESS operators tripped a down-cast net, and then incrementally tripped nets during the up-cast every 25 meters (for a total of 5 nets/catches). Approximately 300 m^3 of water were filtered by each net. All nets were constructed with a 0.333 meter mesh and designed with a 1 m^2 projected area (mouth opening).

CTD Casts

At each station location, hydrographic measurements were recorded with a pumped Sea-Bird 911*plus* CTD system. In total, 105 CTD casts were conducted over the course of the survey. On 18 of these casts, a 300 kHz RD Instruments (RDI) broadband lowered acoustic Doppler current profiler (LADCP) was employed to measure water velocity. The CTD was configured with a Paroscientific *Digiquartz* pressure sensor and dual temperature, conductivity, and oxygen sensors. A Wetlabs *ECO-AFL* chlorophyll-a fluorometer was also attached to the CTD. All temperature (model SBE 3*plus*), conductivity (model SBE 4), and oxygen sensors (model SBE 43) were calibrated by the manufacturer prior to the research cruise. Raw fluorometer voltages were correlated to chlorophyll-a concentration following the cruise. The CTD was connected to a 24-position Sea-Bird Carousel water sampler. 10-liter Niskin bottles were attached to the sampler.

The instrument package was typically lowered from the surface to 10-20 meters above the sea floor. During the cast, continuous measurements of salinity, temperature, dissolved oxygen, and chlorophyll were obtained from the 9*plus* (the 9*plus* is the underwater unit/component of the CTD 911*plus* system). Niskin bottles were fired at predetermined depths providing water samples for use in conductivity, oxygen, and fluorometer sensor calibration. CTD cast locations are listed in Table 1 and plotted in Figure 1.

4. Continuous Sampling

Flow-Through System

The *NOAA Ship Nancy Foster* is equipped with a continuous flow-through seawater system, designed to measure water properties of the sea surface. During NF-09-03, the system was equipped with a Sea-Bird SBE21 thermosalinograph, a Turner 10 fluorometer (leg I only), and a Seapoint fluorometer (leg II only). The thermosalinograph, or *TSG*, measured sea surface temperature and salinity. The fluorometers measured surface chlorophyll-a concentration. These data were logged by the ship's Scientific Computer System (SCS) at 10-second intervals and paired with shipboard GPS position data.

Hull-Mounted ADCP

Continuous measurements of upper-ocean current velocity were collected throughout the survey via the shipboard acoustic Doppler current profiler (SADCP). The *Foster* is equipped with an RDI 150 kHz Ocean Surveyor SADCP. The instrument range varied from 150 to 200 m depth during the cruise depending on SADCP resolution (bin size). SADCP bin size was set to 4 m for the entire survey except for the section conducted across Anegada Passage where, in an effort to achieve maximum penetration with the instrument, the bin size was set to 8 m. Current velocity vectors produced from the SADCP data collected are plotted in Figures 2a-2d. SADCP data collected across Anegada Passage were combined with LADCP data collected at 8 Anegada CTD stations to produce a velocity section for the passage and to calculate total Atlantic inflow (volume transport) through Anegada Passage (Figure 3).

5. Lagrangian Surface Drifters

Based on in situ data collected and satellite ocean color images downloaded during the course of the survey, 10 Standard Velocity Profiler (SVP), satellite-tracked, Lagrangian surface drifters were deployed at targeted features present in the study area. Deployment locations are listed in Table 2. Drifter trajectories (through May 14, 2009) are plotted in Figure 4.

6. Preliminary Results

As the April 2009 survey progressed, flow-through and CTD data revealed areas of low surface salinity and very high surface chlorophyll across parts of the study area. Confirmed by satellite ocean color imagery, this large area of "green water" could be traced back to its South American sources: the Orinoco and Amazon Rivers. In situ observations of this remote riverine outflow revealed a surface layer approximately 20 meters thick, relatively high in temperature, low in salinity, and rich in plankton and other biological content.

Features of this plume can be seen in Figure 5. This single-pass image, showing surface chlorophyll-a concentration, was recorded on April 14, 2009 by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's *Aqua* satellite. From April 15-20 (leg II), the plume continued to elongate northward. Once outside the Caribbean (via Anegada Passage), this riverine signal was advected towards the northwest with the wind-driven circulation of the North Atlantic subtropical gyre. Additionally, the cyclonic Atlantic inflow eddy, west of the plume and northeast of St. Croix in Figure 5, continued to grow in size and extend farther to the south. This can be seen in the SADCP surface velocity data (Figure 2a) and in the surface drifter trajectories (Figure 4).

Though observed in the general area during most years, Orinoco and Amazon riverine signals typically appear farther west, south of Puerto Rico, advected by Atlantic inflow through the Caribbean Island passages. However, the plume observed this April extended farther to the northeast, surrounding the US and British Virgin Islands. Eye witness reports from fishermen and charter dive boats, as well as islands residents, described this green water event as something that they had never seen in the area before. Previously these river plumes have been primarily studied using remote sensing techniques. Fortunately, the NF-09-03 survey was able to capture this unusual, transient event with a full suite of oceanographic and biological sampling methods. The additional in situ data gathered during this cruise will aid in understanding the extent of this event and its effect on the region.

Drifter trajectories show the highly variable nature of the surface flow in the study area (Figure 4). Additionally, they exemplify the potential connectivity between regional ecosystems. A majority of the buoys deployed in the Virgin Islands Basin (VIB) and Anegada Passage drifted through *Virgin Passage*, separating Culebra and St. Thomas. En route, these drifters passed across important spawning grounds on the banks south of St. Thomas, St. John, and the BVI. Comparisons of the regional variation in biota along these trajectories will be made once bongo and MOCNESS catches have been sorted and identified.

The volume transport section across Anegada Passage yielded a net *outflow* of 0.93 Sv from the Caribbean Sea into the Atlantic Ocean (1 Sv $\equiv 10^6 m^3 s^{-1}$). However, transport associated with the North Atlantic western boundary circulation (upper 800 meters) totaled a 1.02 Sv *inflow* from the Atlantic. The transport sections shown in Figures 3a and 3b are characterized by inflow of surface and thermocline waters, and outflow of intermediate waters. Though the mean surface flow was into the Caribbean, outflow at the riverine plume location shown in Figure 5 is evident in Figure 3b. Our drifter deployed in the Leeward Islands followed this same pathway on its exit through the passage (Figure 4). Additionally, inflow of North Atlantic Deep Water (NADW) is evident across the deepest extent of the Anegada Passage sill. As one of only two deep Caribbean passages (the other being Windward Passage between Cuba and Hispaniola), this deep inflow at Anegada plays an important role in the ventilation of the abyssal Caribbean.

7. Release of Project Data

In accordance with the provisions specified in the cruise instructions and application for foreign clearances, the complete data set assembled during the NF-09-03 research cruise will be provided to all clearance countries. Identification and analysis of biological samples and shipboard data analysis commenced immediately following the conclusion of the cruise and should be completed by mid 2010. All processed data (biological and oceanographic) collected during the cruise will be delivered to the U.S. Department of State within 18 months of the completion of the cruise (by October 20, 2010).

8. Acknowledgments

The support and assistance provided by the officers and crew of the *NOAA Ship Nancy Foster*, and the dedicated efforts of UVI participants Kevin Brown and Ariane Frappier are gratefully acknowledged.

Conversations with BVI Conservation and Fisheries Department scientific personnel, during our Road Town visit, regarding BVI coastal regions and spawning aggregation sites were a valuable asset to the study. CRER looks forward to future scientific collaboration with BVI CFD as the project continues over the coming years.

Table 1. NF-09-03 Discrete Sampling Stations

April 7-20, 2009

Completed Casts and Tows…		Latitude			Longitude			Decimal Deg	Decimal Deg
Name	Description	Deg	Min		Deg	Min		Latitude	Longitude
PR-01 (001)	ctd, moc, bongo	18	06.6	N	65	12.4	W	18.110	-65.207
PR-02 (002)	ctd, bongo	18	12.2	N	65	12.4	W	18.203	-65.207
VI-57 (003)	ctd, bongo	18	21.1	N	65	08.4	W	18.352	-65.140
VI-58 (004)	ctd, bongo	18	16.1	N	65	06.5	W	18.268	-65.108
VI-59 (005)	ctd, moc, bongo	18	09.9	N	65	06.5	W	18.165	-65.108
VI-60 (006)	ctd, moc, bongo	18	05.6	N	65	06.5	W	18.093	-65.108
VI-61 (007)	ctd, bongo	18	11.8	N	65	04.6	W	18.197	-65.077
VI-01 (008)	ctd, bongo	18	17.3	N	65	02.0	W	18.288	-65.033
VI-02 (009)	ctd, ladcp, moc, bongo	18	11.8	N	65	02.0	W	18.197	-65.033
VI-03 (010)	ctd, ladcp, moc, bongo	18	05.6	N	65	02.0	W	18.093	-65.033
VI-04 (011)	ctd, bongo	18	17.3	N	64	57.5	W	18.288	-64.958
VI-05 (012)	ctd, ladcp, moc, bongo	18	10.9	N	64	57.5	W	18.182	-64.958
VI-06 (013)	ctd, moc, bongo	18	05.6	N	64	57.5	W	18.093	-64.958
VI-07 (014)	ctd, bongo	18	10.2	N	64	54.3	W	18.170	-64.905
VI-08 (015)	ctd, bongo	18	15.9	N	64	53.8	W	18.265	-64.897
VI-09 (016)	ctd, bongo	18	16.2	N	64	51.5	W	18.270	-64.858
VI-10 (017)	ctd, moc, bongo	18	11.5	N	64	51.5	W	18.192	-64.858
VI-11 (018)	ctd, ladcp, moc, bongo	18	05.6	N	64	51.5	W	18.093	-64.858
VI-62 (019)	ctd, ladcp, moc, bongo	18	00.9	N	64	51.5	W	18.015	-64.858
VI-12 (020)	ctd, moc, bongo	18	10.9	N	64	47.6	W	18.182	-64.793
VI-13 (021)	ctd, bongo	18	16.6	N	64	47.6	W	18.277	-64.793
VI-53 (024)	ctd, bongo	18	24.4	N	65	00.1	W	18.407	-65.002
VI-52 (025)	ctd, bongo	18	30.3	N	65	04.5	W	18.505	-65.075
VI-56 (026)	ctd, bongo	18	27.5	N	65	09.9	W	18.458	-65.165
VI-55 (027)	ctd, moc, bongo	18	33.9	N	65	11.4	W	18.565	-65.190
VI-54 (028)	ctd, moc, bongo	18	41.5	N	65	13.3	W	18.692	-65.222
VI-50 (029)	ctd, moc, bongo	18	43.2	N	65	03.6	W	18.720	-65.060
VI-51 (030)	ctd, moc, bongo	18	36.1	N	65	02.3	W	18.602	-65.038
VI-48 (031)	ctd, bongo	18	30.4	N	64	54.4	W	18.507	-64.907
VI-49 (032)	ctd, moc, bongo	18	37.0	N	64	56.1	W	18.617	-64.935
VI-41 (033)	ctd, moc, bongo	18	45.2	N	64	55.7	W	18.753	-64.928
VI-42 (034)	ctd, moc, bongo	18	39.4	N	64	50.2	W	18.657	-64.837
VI-43 (035)	ctd, bongo	18	35.9	N	64	46.9	W	18.598	-64.782
VI-44 (036)	ctd, bongo	18	31.3	N	64	42.5	W	18.522	-64.708
VI-45 (037)	ctd, bongo	18	28.0	N	64	39.4	W	18.467	-64.657
VI-37 (038)	ctd, bongo	18	32.3	N	64	33.6	W	18.538	-64.560
VI-38 (039)	ctd, bongo	18	37.1	N	64	38.2	W	18.618	-64.637
VI-39 (040)	ctd, bongo	18	42.0	N	64	42.8	W	18.700	-64.713
VI-40 (041)	ctd, moc, bongo	18	46.3	N	64	46.9	W	18.772	-64.782
VI-34 (042)	ctd, moc, bongo	18	55.4	N	64	40.8	W	18.923	-64.680
VI-35 (043)	ctd, moc, bongo	18	50.4	N	64	40.8	W	18.840	-64.680
VI-36 (044)	ctd, bongo	18	41.3	N	64	32.2	W	18.688	-64.537
VI-63 (045)	ctd, bongo	18	36.6	N	64	27.8	W	18.610	-64.463
VI-33 (046)	ctd, moc, bongo	18	47.9	N	64	31.2	W	18.798	-64.520

Table 1. Nominal cast / tow station locations.

Table 1. NF-09-03 Discrete Sampling Stations

April 7-20, 2009

Completed Casts and Tows…		Latitude			Longitude			Decimal Deg	Decimal Deg
Name	Description	Deg	Min		Deg	Min		Latitude	Longitude
VI-32 (047)	ctd, moc, bongo	18	52.5	N	64	23.0	W	18.875	-64.383
VI-31 (048)	ctd, moc, bongo	18	47.5	N	64	23.0	W	18.792	-64.383
VI-30 (049)	ctd, moc, bongo	18	48.8	N	64	15.7	W	18.813	-64.262
VI-29 (050)	ctd, moc, bongo	18	43.2	N	64	13.2	W	18.720	-64.220
VI-28 (051)	ctd, moc, bongo	18	49.2	N	64	07.9	W	18.820	-64.132
VI-27 (052)	ctd, moc, bongo	18	36.0	N	64	07.9	W	18.600	-64.132
VI-64 (053)	ctd, ladcp, moc	18	25.8	N	64	11.5	W	18.430	-64.192
VI-26 (054)	ctd, moc, bongo	18	29.2	N	64	14.8	W	18.487	-64.247
VI-23 (055)	ctd, ladcp, moc	18	18.0	N	64	22.2	W	18.300	-64.370
VI-24 (056)	ctd, moc, bongo	18	22.0	N	64	25.5	W	18.367	-64.425
VI-21 (057)	ctd, ladcp, moc	18	14.0	N	64	29.3	W	18.233	-64.488
VI-22 (058)	ctd, bongo	18	18.4	N	64	32.6	W	18.307	-64.543
VI-20 (059)	ctd, bongo	18	17.0	N	64	36.0	W	18.283	-64.600
VI-17 (060)	ctd, ladcp, moc, bongo	18	10.4	N	64	36.2	W	18.173	-64.603
VI-65 (061)	ctd, bongo	18	07.1	N	64	34.2	W	18.118	-64.570
VI-25 (062)	ctd, bongo	18	24.3	N	64	31.1	W	18.405	-64.518
VI-19 (063)	ctd, bongo	18	17.9	N	64	40.9	W	18.298	-64.682
VI-14 (064)	ctd, bongo	18	17.5	N	64	43.7	W	18.292	-64.728
VI-15 (065)	ctd, moc, bongo	18	11.9	N	64	43.7	W	18.198	-64.728
VI-16 (066)	ctd, ladcp, moc, bongo	18	05.6	N	64	43.7	W	18.093	-64.728
VI-18 (067)	ctd, moc, bongo	18	14.6	N	64	38.8	W	18.243	-64.647
AN-1 (068)	ctd, ladcp, moc, bongo	18	25.0	N	64	20.2	W	18.417	-64.337
AN-2 (069)	ctd, ladcp	18	23.1	N	64	17.7	W	18.385	-64.295
AN-3 (070)	ctd, ladcp, moc, bongo	18	21.0	N	64	14.9	W	18.350	-64.248
AN-4 (071)	ctd, ladcp, moc, bongo	18	19.2	N	64	12.6	W	18.320	-64.210
AN-5 (072)	ctd, ladcp	18	17.9	N	64	10.9	W	18.298	-64.182
AN-6 (073)	ctd, ladcp, moc, bongo	18	17.0	N	63	56.7	W	18.283	-63.945
AN-7 (074)	ctd, ladcp, moc, bongo	18	15.3	N	63	36.8	W	18.255	-63.613
AN-8 (075)	ctd, ladcp	18	14.2	N	63	23.5	W	18.237	-63.392
LI-02 (076)	ctd, moc, bongo	18	06.5	N	63	20.8	W	18.108	-63.347
LI-07 (077)	ctd, moc, bongo	17	59.8	N	63	07.7	W	17.997	-63.128
LI-08 (078)	ctd, moc	17	52.7	N	63	17.9	W	17.878	-63.298
LI-09 (079)	ctd, moc, bongo	17	45.0	N	63	28.6	W	17.750	-63.477
LI-11 (080)	ctd, bongo	17	40.4	N	63	21.1	W	17.673	-63.352
LI-12 (081)	ctd, moc, bongo	17	38.8	N	63	12.6	W	17.647	-63.210
LI-16 (082)	ctd, moc, bongo	17	31.9	N	62	56.8	W	17.532	-62.947
LI-21 (083)	ctd, bongo	17	13.4	N	63	27.0	W	17.223	-63.450
LI-20 (084)	ctd, bongo	17	27.9	N	63	28.9	W	17.465	-63.482
LI-22 (085)	ctd, moc, bongo	17	30.9	N	63	43.9	W	17.515	-63.732
(086)	ctd, bongo	17	28.6	N	63	56.0	W	17.477	-63.933
(087)	ctd, bongo	17	26.2	N	64	09.2	W	17.437	-64.153
(088)	ctd, moc, bongo	17	24.0	N	64	21.0	W	17.400	-64.350
(089)	ctd, moc, bongo	17	54.9	N	64	17.1	W	17.915	-64.285
(090)	ctd, moc, bongo	18	01.3	N	64	26.0	W	18.022	-64.433

Table 1. Nominal cast / tow station locations.

Table 1. NF-09-03 Discrete Sampling Stations

April 7-20, 2009

Completed Casts and Tows…		Latitude			Longitude			Decimal Deg	Decimal Deg
Name	**Description**	**Deg**	**Min**		**Deg**	**Min**		**Latitude**	**Longitude**
CX-01 (091)	ctd, moc, bongo	17	49.7	N	64	25.4	W	17.828	-64.423
CX-02 (092)	ctd, moc, bongo	17	46.3	N	64	28.3	W	17.772	-64.472
(093)	ctd	17	48.6	N	64	29.5	W	17.810	-64.492
CX-03 (094)	ctd, moc, bongo	17	49.9	N	64	30.2	W	17.832	-64.503
CX-04 (095)	ctd, bongo	17	46.1	N	64	32.8	W	17.768	-64.547
CX-05 (096)	ctd, moc, bongo	17	48.5	N	64	34.1	W	17.808	-64.568
CX-06 (097)	ctd, moc, bongo	17	52.9	N	64	36.4	W	17.882	-64.607
CX-07 (098)	ctd, 2 bongos	17	49.5	N	64	38.7	W	17.825	-64.645
CX-08 (099)	ctd	17	47.2	N	64	39.7	W	17.787	-64.662
CX-09 (100)	ctd, bongo	17	46.7	N	64	43.8	W	17.778	-64.730
CX-10 (101)	ctd, bongo	17	47.7	N	64	45.5	W	17.795	-64.758
CX-11 (102)	ctd, bongo	17	52.7	N	64	45.5	W	17.878	-64.758
CX-12 (103)	ctd, bongo	17	46.5	N	64	51.5	W	17.775	-64.858
CX-13 (104)	ctd, bongo	17	51.5	N	64	51.5	W	17.858	-64.858
CX-14 (105)	ctd, bongo	17	56.2	N	64	51.5	W	17.937	-64.858

Table 1. Nominal cast / tow station locations.

Table 2. NF-09-03 Surface Drifter Deployments									*April 7-20, 2009*
Drifter Deployment Locations…		Latitude			Longitude			Decimal Deg	Decimal Deg
GDC#, WMO#	Time, Date (GMT)	Deg	Min		Deg	Min		Latitude	Longitude
79191, 41855	15:55, 10-APR-2009	18	01.7	N	64	51.3	W	18.028	-64.855
71846, 41907	08:00, 11-APR-2009	18	51.4	N	65	05.1	W	18.857	-65.085
71847, 41912	09:15, 12-APR-2009	18	55.4	N	64	40.8	W	18.923	-64.680
79292, 41915	09:15, 12-APR-2009	18	55.4	N	64	40.8	W	18.923	-64.680
79247, 41917	11:48, 13-APR-2009	18	26.7	N	64	10.4	W	18.445	-64.173
75198, 41918	23:32, 13-APR-2009	18	12.8	N	64	28.1	W	18.213	-64.468
79248, 41919	00:02, 17-APR-2009	18	16.2	N	63	47.1	W	18.270	-63.785
75229, 41932	14:37, 17-APR-2009	17	51.9	N	63	17.6	W	17.865	-63.293
79293, 41923	15:30, 18-APR-2009	17	24.1	N	64	20.7	W	17.402	-64.345
79282, 41920	19:42, 18-APR-2009	17	55.2	N	64	17.1	W	17.920	-64.285

Table 2. Surface drifter deployment locations.

NF-09-03 Completed Cruise Track and Station Locations (April 7, 2009 - April 20, 2009)

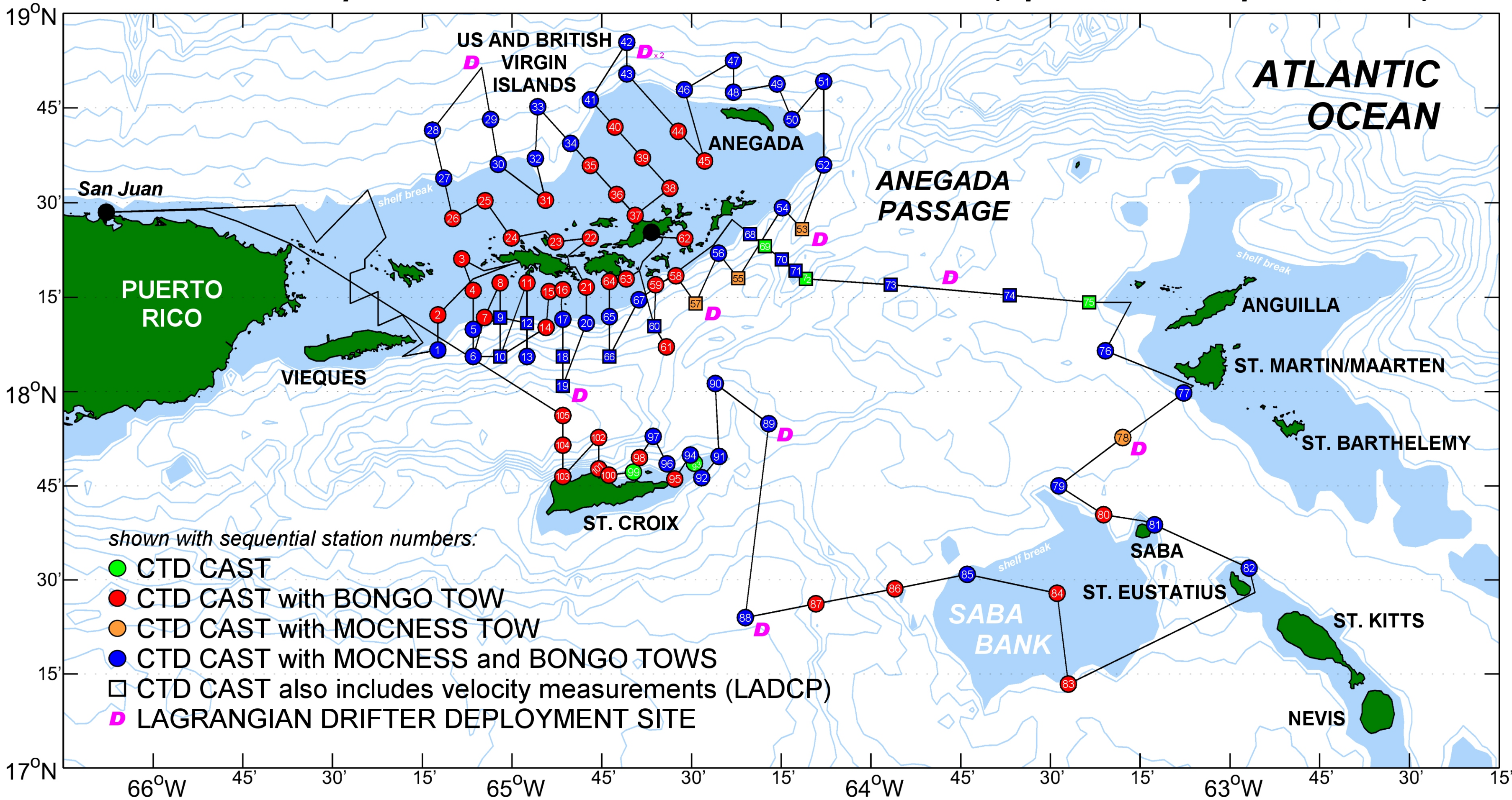
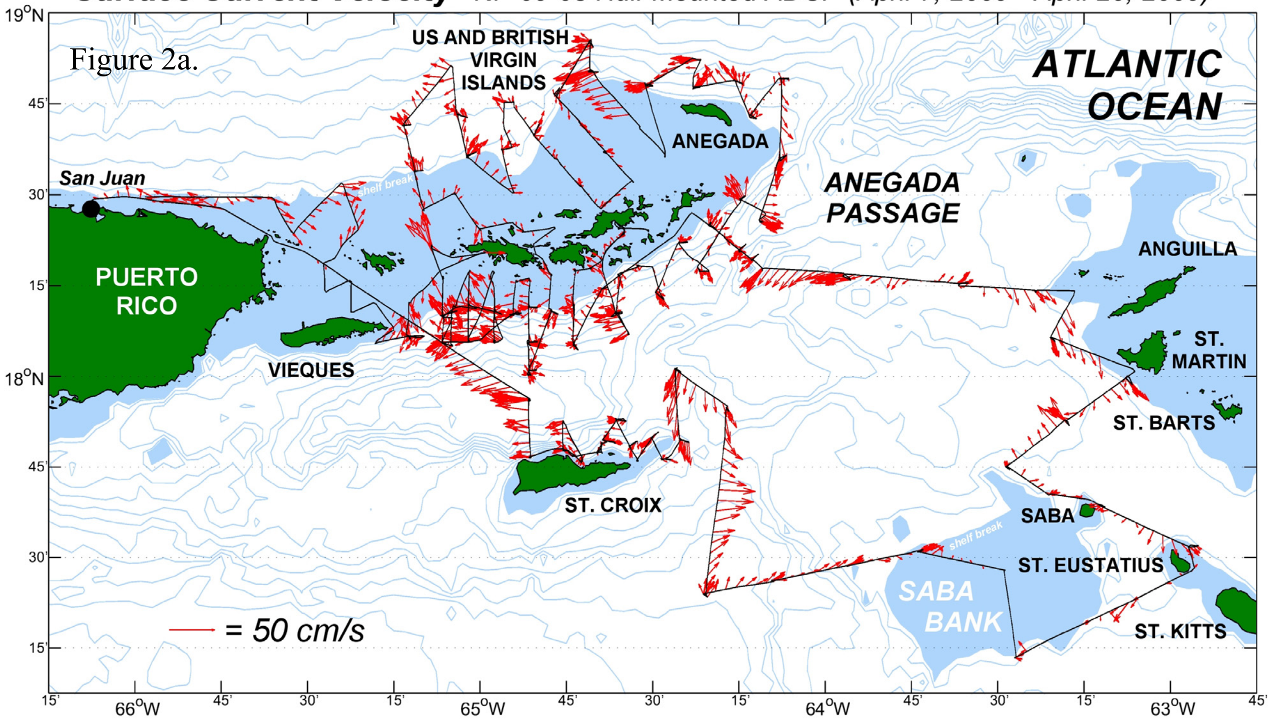
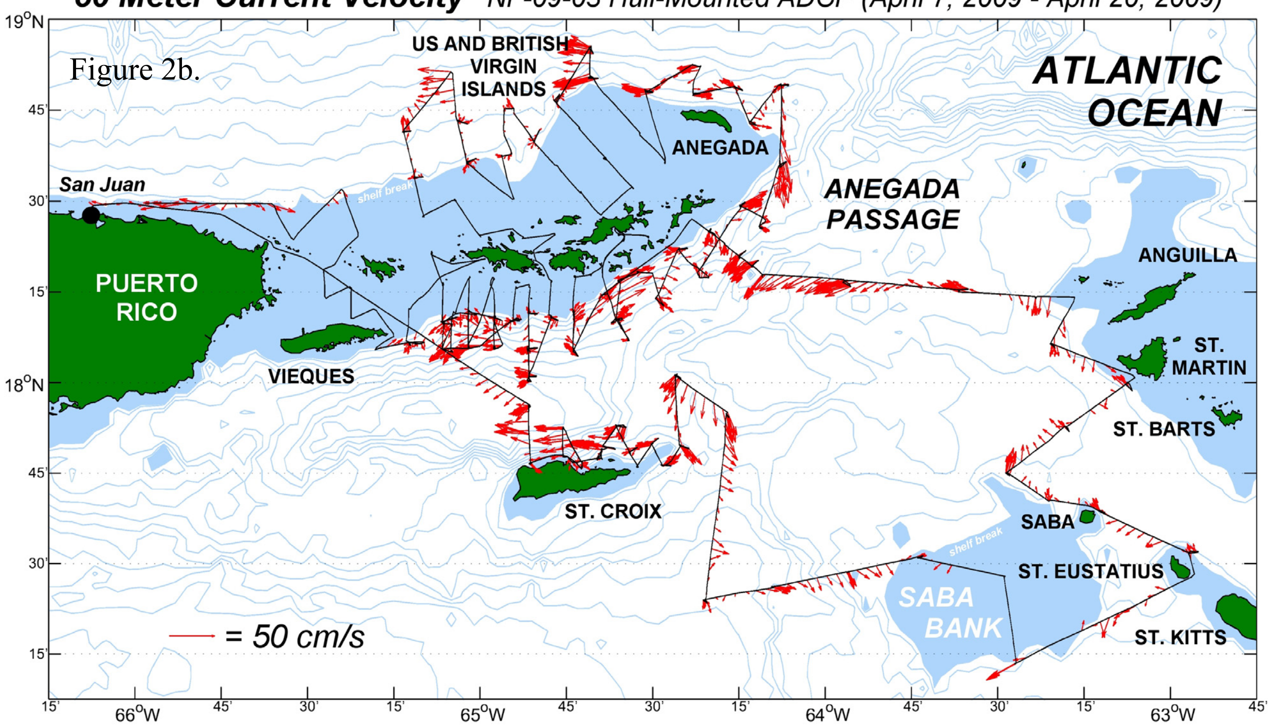


Figure 1. Discrete sampling locations occupied during NF-09-03, operations conducted, and completed cruise track.

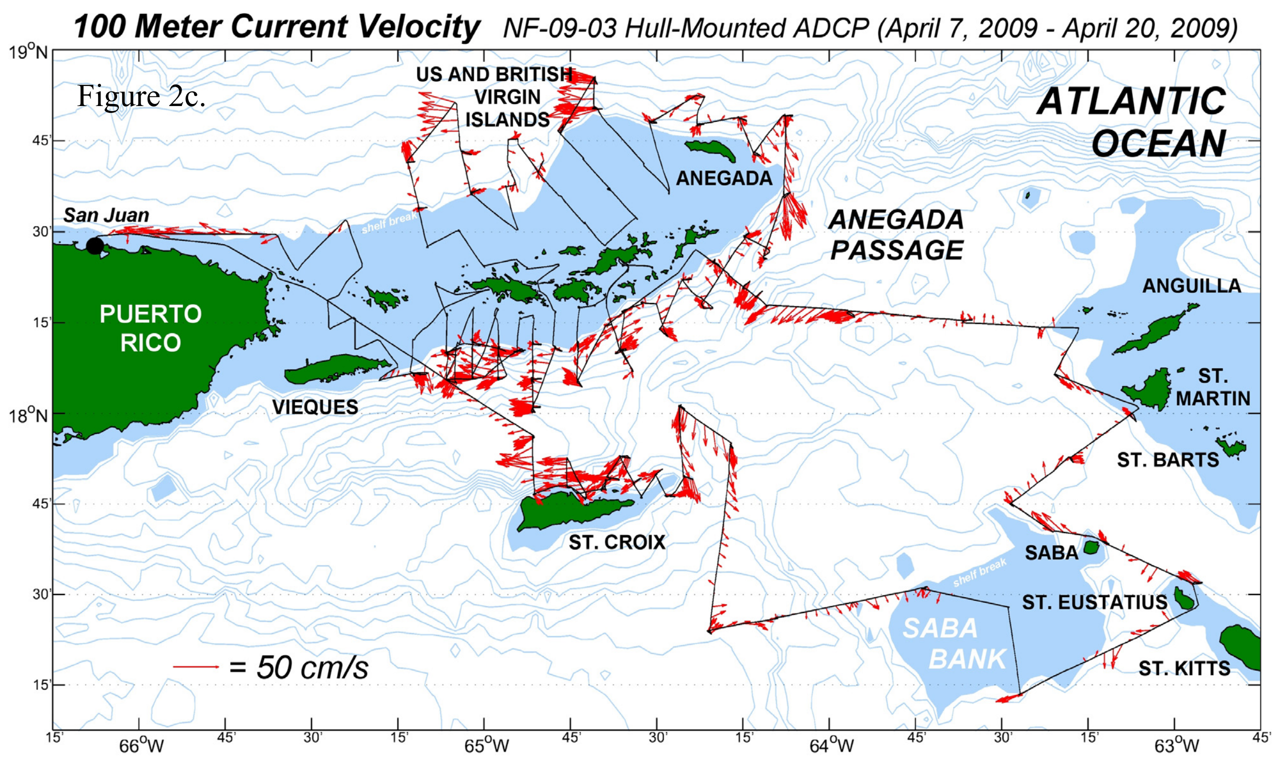
Surface Current Velocity *NF-09-03 Hull-Mounted ADCP (April 7, 2009 - April 20, 2009)*

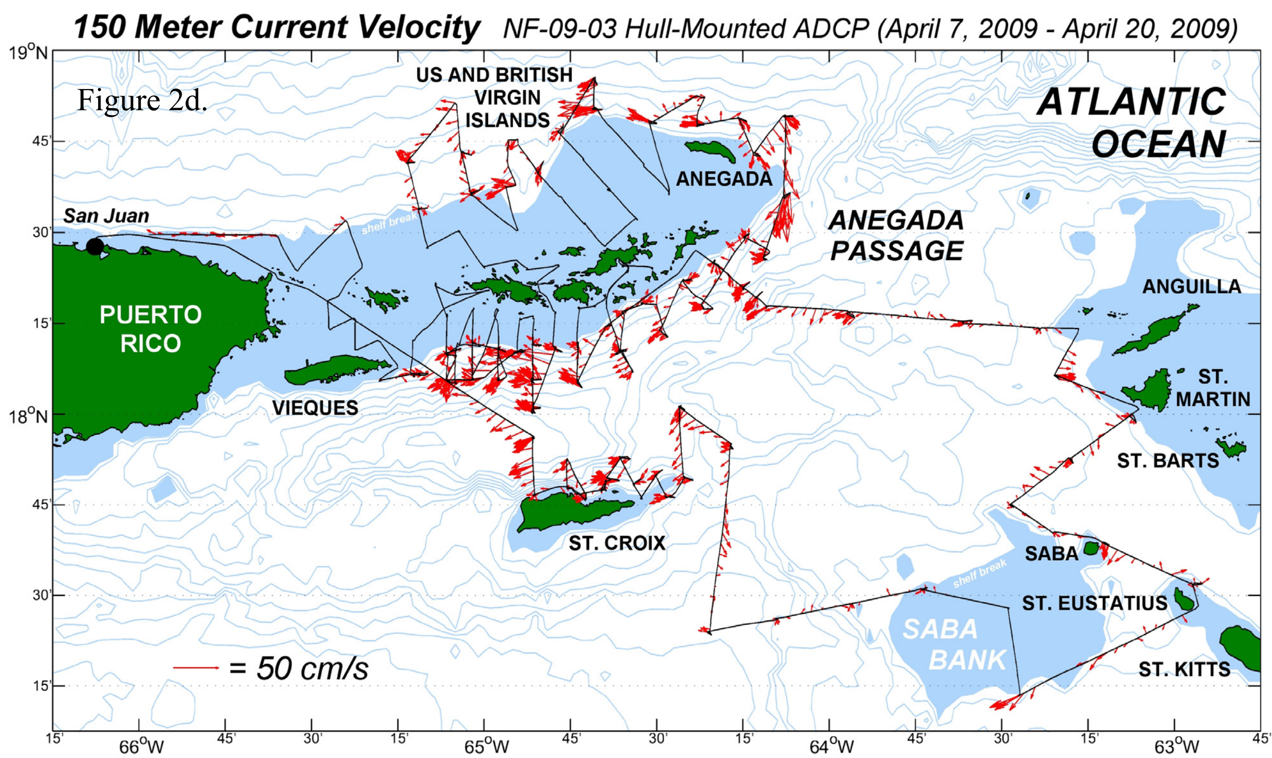


50 Meter Current Velocity *NF-09-03 Hull-Mounted ADCP (April 7, 2009 - April 20, 2009)*



Figures 2a and 2b. SADCP surface and 50 m current velocity vectors.





Figures 2c and 2d. SADCP 100 m and 150 m current velocity vectors.

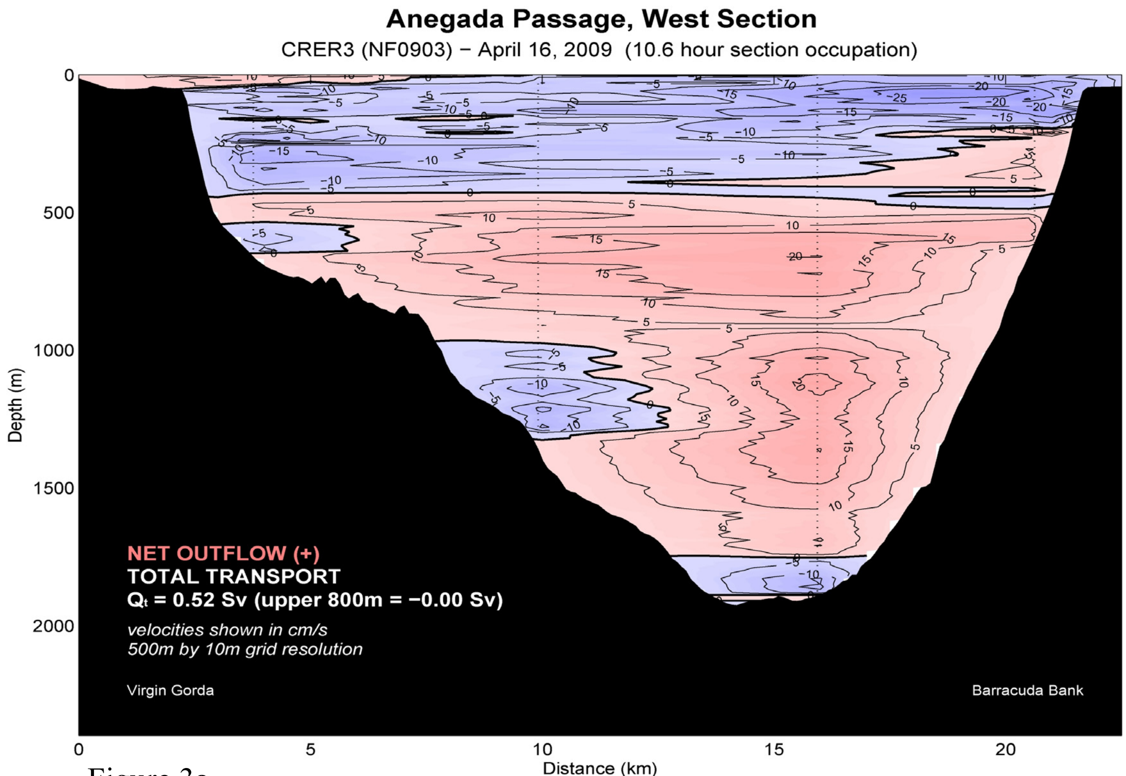


Figure 3a.

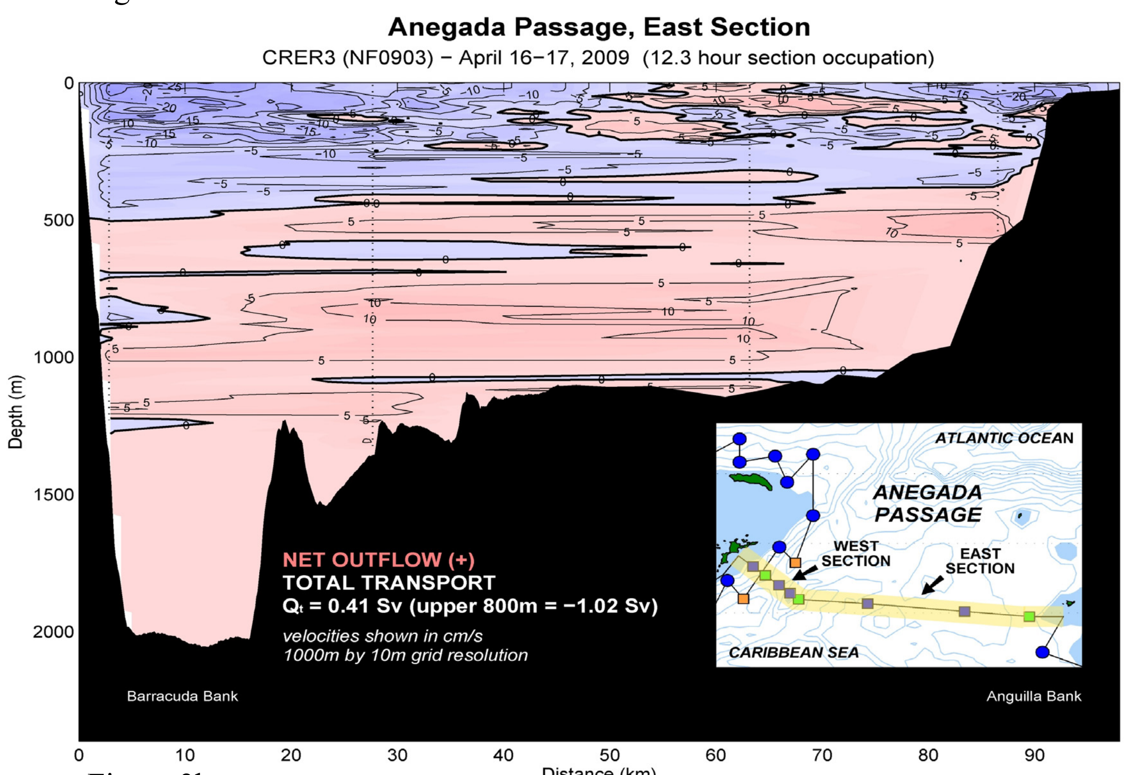


Figure 3b.

Figures 3a and 3b. NF-09-03 Anegada Passage velocity section calculated from LADCP and SADCP data. Total volume transport = 0.93 Sv outflow (from the Caribbean Sea into the Atlantic Ocean).
Upper 800 m transport = 1.02 Sv inflow. 1 Sv ≡ $10^6 m^3 s^{-1}$.

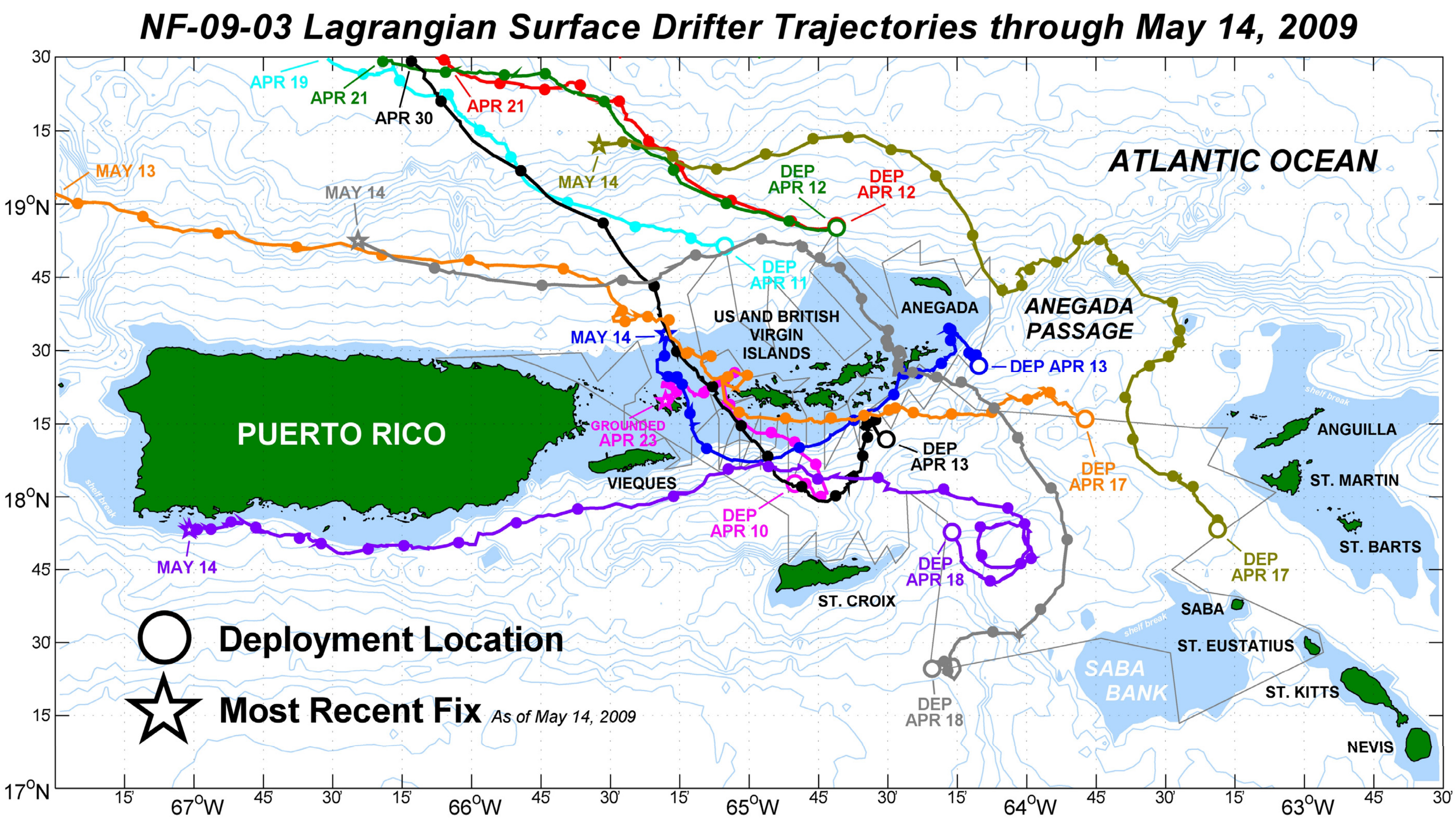


Figure 4. Lagrangian surface drifter deployment locations and trajectories through May 14, 2009. Solid dots along trajectory indicate 24-hour intervals.

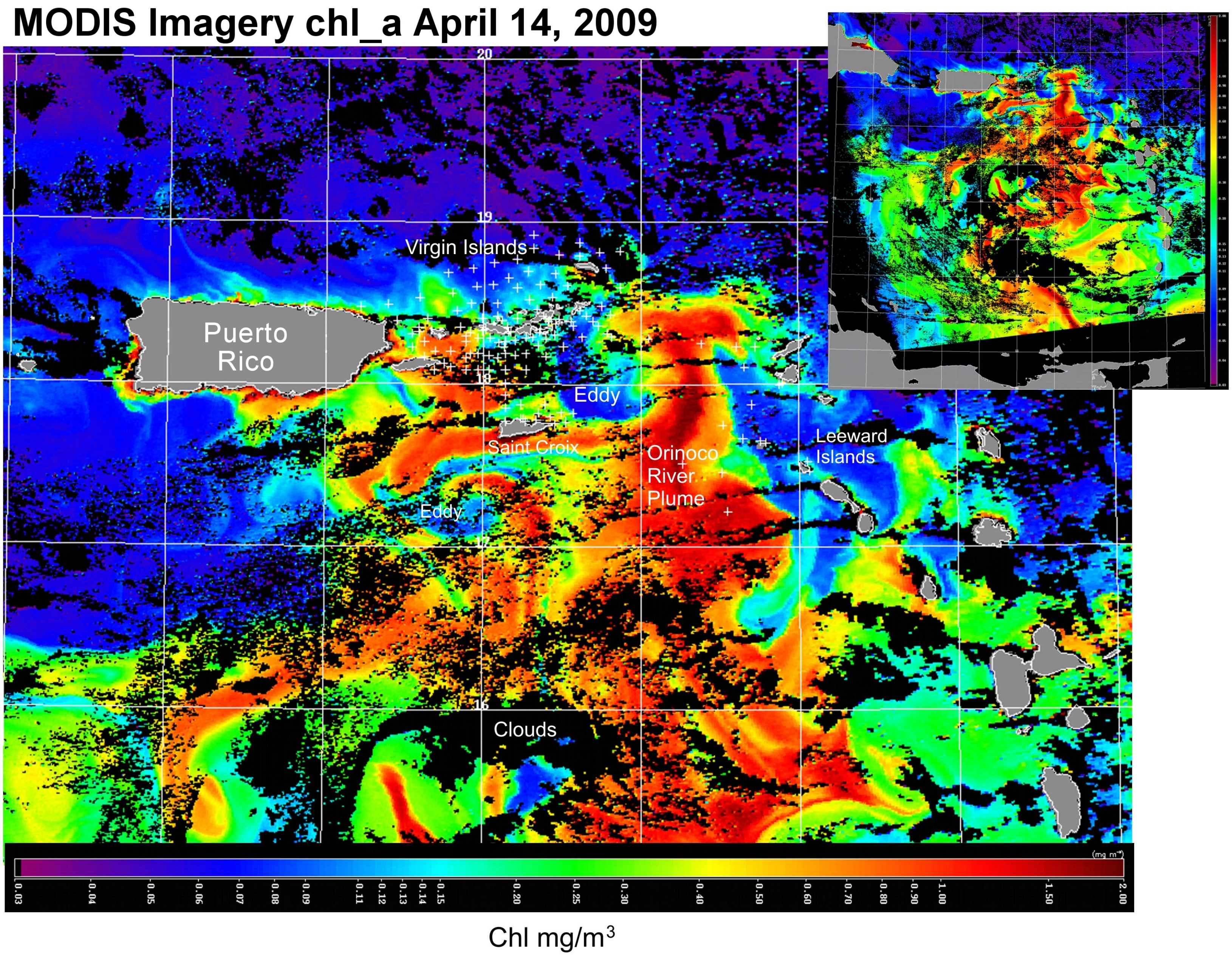


Figure 5. April 14, 2009 MODIS ocean color satellite imagery covering the northeastern Caribbean Sea. Surface waters with the highest chlorophyll concentrations are shown in dark red (the lowest, in dark blue/violet).