Cruise Report
C-263
SEA Semester: Oceans & Climate

Scientific Data Collected Aboard
SSV *Corwith Cramer*

Las Palmas, Canary Islands, Spain – Portsmouth, Dominica – Christiansted, St. Croix, USVI
14 November 2015 – 23 December 2015

Sea Education Association
Woods Hole, Massachusetts

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<u>SEA Semester: Oceans and Climate Program Participants</u>
SSV *Corwith Cramer*, Cruise C-263

Faculty (Shore)

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Deb Goodwin	Oceanography
Erin Bryant	Ocean Policy

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Students

Peter Barron	Carleton College
Jamie Dalgleish	Mount Allison University
Jennifer Dong	Grinnell College
Kennedy Holland	Claremont McKenna College
Colette Kelly	Barnard College of Columbia University
Jennifer Kenyon	Louisiana State University
Eben Kopp	Bowdoin College
Jeffrey Morgan	Boston University
Siya Qiu	Boston University
Anna Simpson	University of New Hampshire
Holly Westbrook	University of Connecticut, Avery Point
Emma Wightman	Roger Williams University

Introduction

This cruise report provides a summary of scientific activities aboard the SSV *Corwith Cramer* during cruise C-263 (14 November – 23 December 2015). The over 3400 nm, six-week cruise served as the scientific data collection portion of the *Sea Semester: Oceans & Climate* program with Sea Education Association (SEA). Extensive oceanographic sampling was conducted for both student research projects (Table 1) and the ongoing SEA research program. Students examined physical, chemical, biological, and environmental oceanographic characteristics in accordance with their written proposals and presented their results in a final poster session and papers (available upon request from SEA).

The brief summary of data contained in this report is not intended to represent final data interpretation and should not be excerpted or cited without written permission from SEA.

Amy NS Siuda, PhD
Chief Scientists, C-263

Table 1. Student research projects, C-263.

Title	Student Investigators
Thermal content and transport in Tropical Atlantic and their effect on hurricane intensification.	Peter Barron and Anna Simpson
Analyzing climate effects on the water masses of the tropical North Atlantic.	Jamie Dalgleish and Holly Westbrook
The influence of ocean acidification on pteropod and foraminifera density in the North Atlantic.	Jennifer Dong
The spatial distribution and covariance of CO_2 flux, carbonate concentrations, and nutrients in the northern Tropical Atlantic.	Kennedy Holland, Colette Kelly, Jennifer Kenyon
Phytoplankton community structure: A longitudinal survey on temperature and nutrient ratios in the southern North Atlantic Ocean.	Eben Kopp and Jeffrey Morgan
Phytoplankton response to climate change across the subtropical North Atlantic Ocean.	Siya Qiu and Emma Wightman

Data Description

This section provides a record of data collected aboard the SSV *Corwith Cramer* cruise C-263 (US State Department Cruise: F2015-044) from Las Palmas, Canary Islands, Spain to Christiansted, USVI, USA (Figure 1).

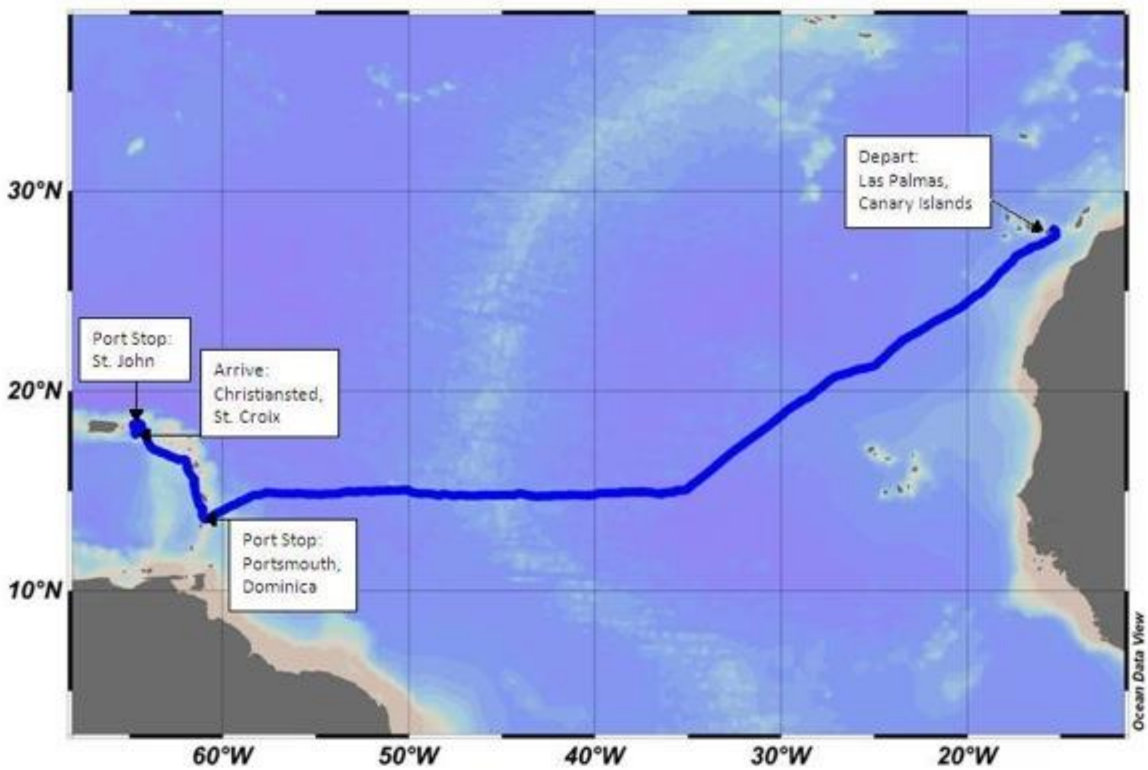

Figure 1. Hourly positions along the C-263 cruise track.

During the 5-week voyage, we sampled at 56 discrete oceanographic stations (Table 2) and five discrete surface water sampling stations (Table 3). Additionally, we continuously sampled water depth and sub-bottom profiles (CHIRP system), upper ocean currents (ADCP, Figure 2), and sea surface temperature, salinity, CDOM fluorescence, in-vivo chlorophyll fluorescence, and transmittance (seawater flow-through system, Figure 3 – temperature, salinity). Discrete CTD measurements of vertical temperature and salinity profiles were also collected from the top 500 m (Figure 4). Additional instrumentation on the CTDs allowed for profiling fluorescence. Detailed summaries of net tow data are included in Table 4. Lengthy CTD, CHIRP, ADCP and flow-through data are not fully presented here. All unpublished data can be made available by arrangement with the SEA data archivist (contact information, p. 2).

Table 2. Oceanographic sampling stations. X indicates use of sampling equipment. (NT = Neuston Tow, MN = Meter Net, PN = Phytoplankton Net, DN = Dip Net, CTD = CTD, HC = hydrocast (subsurface water sampling with Niskin Bottles).

Station	Date	Time	Latitude (N)	Longitude (W)	General Locale	NT	MN	PN	DN	CTD/HC
C263-001	16-Nov-15	0956	27°24.5'	15°57.7'	Canary Current	X				X
C263-002	16-Nov-15	2355	27°10.1'	16°38.3'	Canary Current	X	X			X
C263-003	17-Nov-15	1004	26°44.3'	17°25.5'	Canary Current	X		X		X
C263-004	18-Nov-15	0046	25°52.9'	18°18.9'	Canary Current	X				X
C263-005	18-Nov-15	1105	25°05.2'	19°06.9'	Canary Current	X		X		X
C263-006	19-Nov-15	0056	24°22.0'	20°7.9'	Canary Current	X	X			X
C263-007	19-Nov-15	0957	23°52.8'	20°58.1'	Canary Current			X		X
C263-008	21-Nov-15	1010	21°26.6'	24°47.5'	Transition Zone			X		
C263-009	22-Nov-15	0924	20°42.8'	27°6.7'	Transition Zone			X		
C263-010	22-Nov-15	2351	19°51.8'	28°18.8'	Transition Zone	X				X
C263-011	23-Nov-15	1006	19°29.3'	28°59.3'	Transition Zone	X		X		X
C263-012	23-Nov-15	2348	18°57.5'	29°47.7'	Transition Zone	X	X			X
C263-013	24-Nov-15	1031	18°33.4'	30°17.9'	Transition Zone	X		X		X
C263-014	24-Nov-15	2355	17°55.1'	31°12.8'	Eastern Tropical N. Atlantic	X				X
C263-015	25-Nov-15	0959	17°25.3'	31°56.5'	Eastern Tropical N. Atlantic	X		X		X
C263-016	25-Nov-15	2355	16°53.3'	32°44.2'	Eastern Tropical N. Atlantic	X				X
C263-017	26-Nov-15	1003	16°20.0'	33°20.1'	Eastern Tropical N. Atlantic	X		X	X	X
C263-018	26-Nov-15	2306	15°41.0'	34°16.4'	Eastern Tropical N. Atlantic	X				X
C263-019	27-Nov-15	1002	15°16.1'	34°52.7'	Eastern Tropical N. Atlantic	X		X		X
C263-020	27-Nov-15	2349	15°01.1'	35°40.4'	Eastern Tropical N. Atlantic	X				X
C263-021	28-Nov-15	1006	14°54.4'	36°23.8'	Eastern Tropical N. Atlantic	X		X		X
C263-022	29-Nov-15	0008	14°58.2'	37°35.1'	Eastern Tropical N. Atlantic	X				
C263-023	29-Nov-15	1059	14°57.0'	38°36.2'	Eastern Tropical N. Atlantic	X		X		X
C263-024	29-Nov-15	2350	14°54.7'	39°33.7'	Eastern Tropical N. Atlantic	X				X
C263-025	30-Nov-15	0955	14°48.9'	40°14.4'	Eastern Tropical N. Atlantic	X		X	X	X
C263-026	30-Nov-15	2349	14°49.9'	41°22.8'	Eastern Tropical N. Atlantic	X				X
C263-027	1-Dec-15	0952	14°46.9'	42°18.2'	Eastern Tropical N. Atlantic	X		X		X
C263-028	1-Dec-15	2352	14°47.4'	43°28.2'	Eastern Tropical N. Atlantic	X				X

Table 2 continued.

Station	Date	Time	Latitude (N)	Longitude (W)	General Locale	NT	MN	PN	DN	CTD/HC
C263-029	2-Dec-15	0950	14°50.2'	44°16.9'	Eastern Tropical N. Atlantic	X		X	X	X
C263-030	2-Dec-15	2352	14°48.2'	45°21.0'	Western Tropical N. Atlantic	X				X
C263-031	3-Dec-15	0951	14°59.9'	46°10.3'	Western Tropical N. Atlantic	X		X		X
C263-032	3-Dec-15	2355	14°48.6'	47°21.7'	Western Tropical N. Atlantic	X				X
C263-033	4-Dec-15	1009	14°48.9'	48°15.9'	Western Tropical N. Atlantic	X		X		X
C263-034	4-Dec-15	2358	14°53.2'	49°19.9'	Western Tropical N. Atlantic	X				X
C263-035	5-Dec-15	0904	15°04.4'	50°04.6'	Western Tropical N. Atlantic	X		X		X
C263-036	5-Dec-15	2355	15°02.8'	51°09.0'	Western Tropical N. Atlantic	X				X
C263-037	6-Dec-15	0948	15°01.3'	51°49.7'	Western Tropical N. Atlantic	X		X		X
C263-038	6-Dec-15	2306	14°59.6'	52°42.3'	Western Tropical N. Atlantic	X				X
C263-039	7-Dec-15	0939	14°54.8'	53°04.3'	Western Tropical N. Atlantic	X		X	X	X
C263-040	7-Dec-15	2353	14°51.6'	54°33.1'	Western Tropical N. Atlantic	X				X
C263-041	8-Dec-15	0954	14°51.6'	55°18.4'	Western Tropical N. Atlantic	X		X		X
C263-042	8-Dec-15	2356	14°53.8'	56°01.9'	Western Tropical N. Atlantic	X				X
C263-043	9-Dec-15	0938	14°53.2'	56°39.0'	Western Tropical N. Atlantic	X		X		X
C263-044	9-Dec-15	2349	14°55.9'	57°40.3'	Western Tropical N. Atlantic	X				X
C263-045	11-Dec-15	0015	14°17.6'	59°26.7'	Western Tropical N. Atlantic	X				
C263-046	11-Dec-15	1214	13°57.2'	60°10.9'	Western Tropical N. Atlantic	X				X
C263-047	11-Dec-15	1919	13°53.6'	60°18.6'	Western Tropical N. Atlantic			X		
C263-048	12-Dec-15	0012	13°36.6'	60°52.8'	Eastern Caribbean	X				
C263-049	12-Dec-15	1142	13°53.3'	61°06.7'	Eastern Caribbean	X				
C263-050	12-Dec-15	2345	14°11.7'	61°08.0'	Eastern Caribbean	X				
C263-051	13-Dec-15	1145	15°15.5'	61°31.4'	Eastern Caribbean	X				
C263-052	19-Dec-15	0013	16°34.9'	62°20.4'	Eastern Caribbean	X				
C263-053	19-Dec-15	1156	16°54.3'	63°10.9'	Eastern Caribbean	X				
C263-054	19-Dec-15	2358	17°26.4'	64°00.9'	Eastern Caribbean	X				
C263-055	20-Dec-15	1155	18°08.9'	64°19.3'	Eastern Caribbean	X				
C263-056	20-Dec-15	2317	18°17.1'	64°25.3'	Eastern Caribbean	X				

Table 3. Surface station data (SS-XXX). Blank = no data.

Station	Date	Time	Latitude (N)	Longitude (W)	Temp. (deg. C)	Salinity (PSU)	Chl-a (ug/L)	PO4 (μM)	NOX (μM)	pH	Alk
SS-001	21-Nov-15	1205	21°21.6'	24°51.4'	25.1	36.674	0.038	0.000	0.204	7.943	1.96
SS-002	22-Nov-15	0000	20°58.8'	26°12.9'	25.6	36.734	0.058	0.034		7.992	2.26
SS-003	22-Nov-15	1154	20°38.2'	27°15.4'	25.6	36.948	0.090	0.017	0.183	7.953	2.23
SS-004	23-Nov-15	0104	19°49.3'	28°18.9'	25.7	37.072					2.21
SS-005	29-Nov-15	0012	14°58.1'	37°35.1'	26.7	36.532	0.018	0.000	0.065	7.927	
SS-006	3-Dec-15	1040	14°48.6'	46°11.1'	27.1	35.210	0.085	0.001	0.000	7.910	2.07

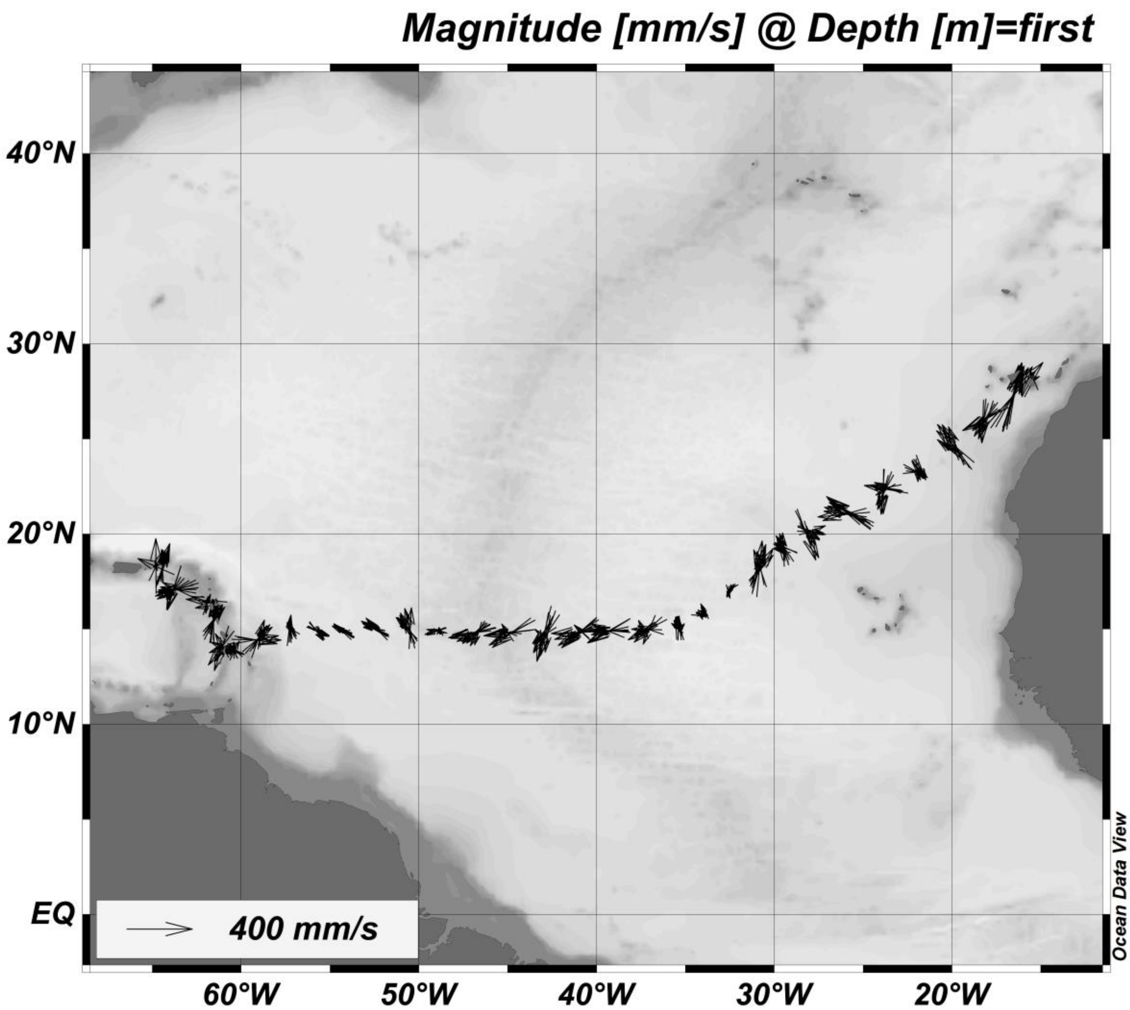

Figure 2. Surface current direction and velocity measured with the ADCP from 2000 to 0000 daily.

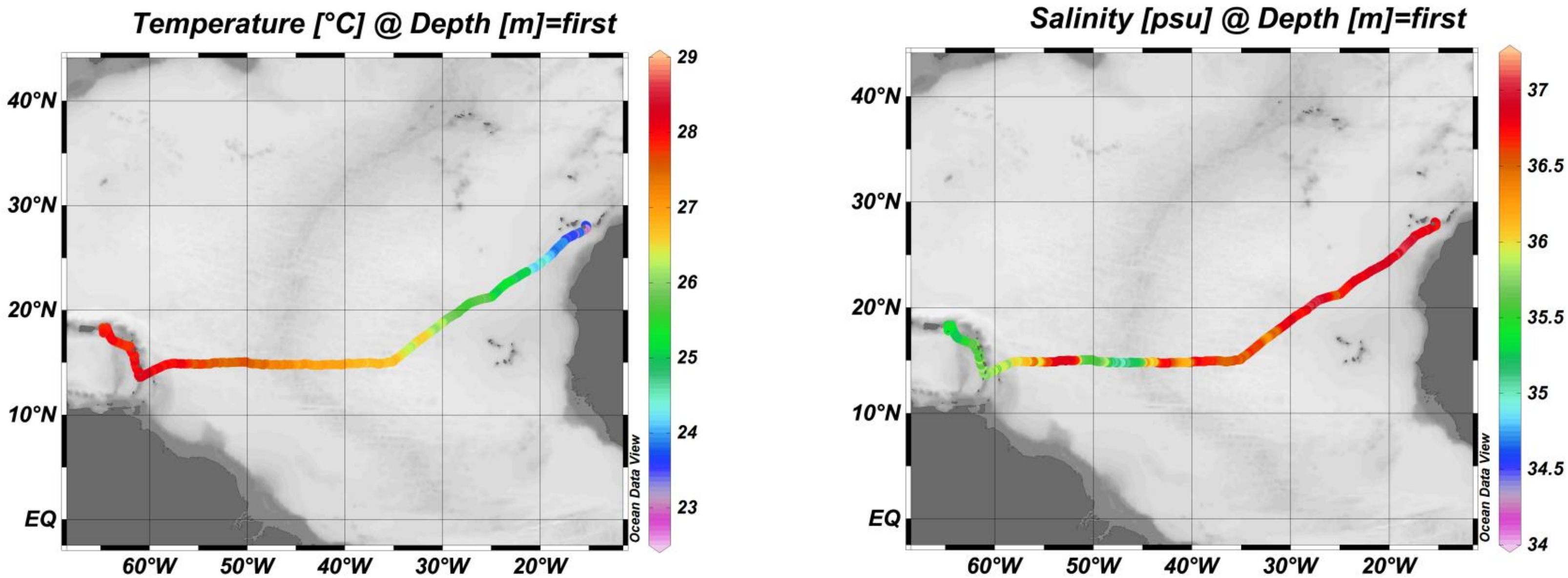

Figure 3. Surface temperature (left) and salinity (right) measurements from the continuous flow-through data logger.

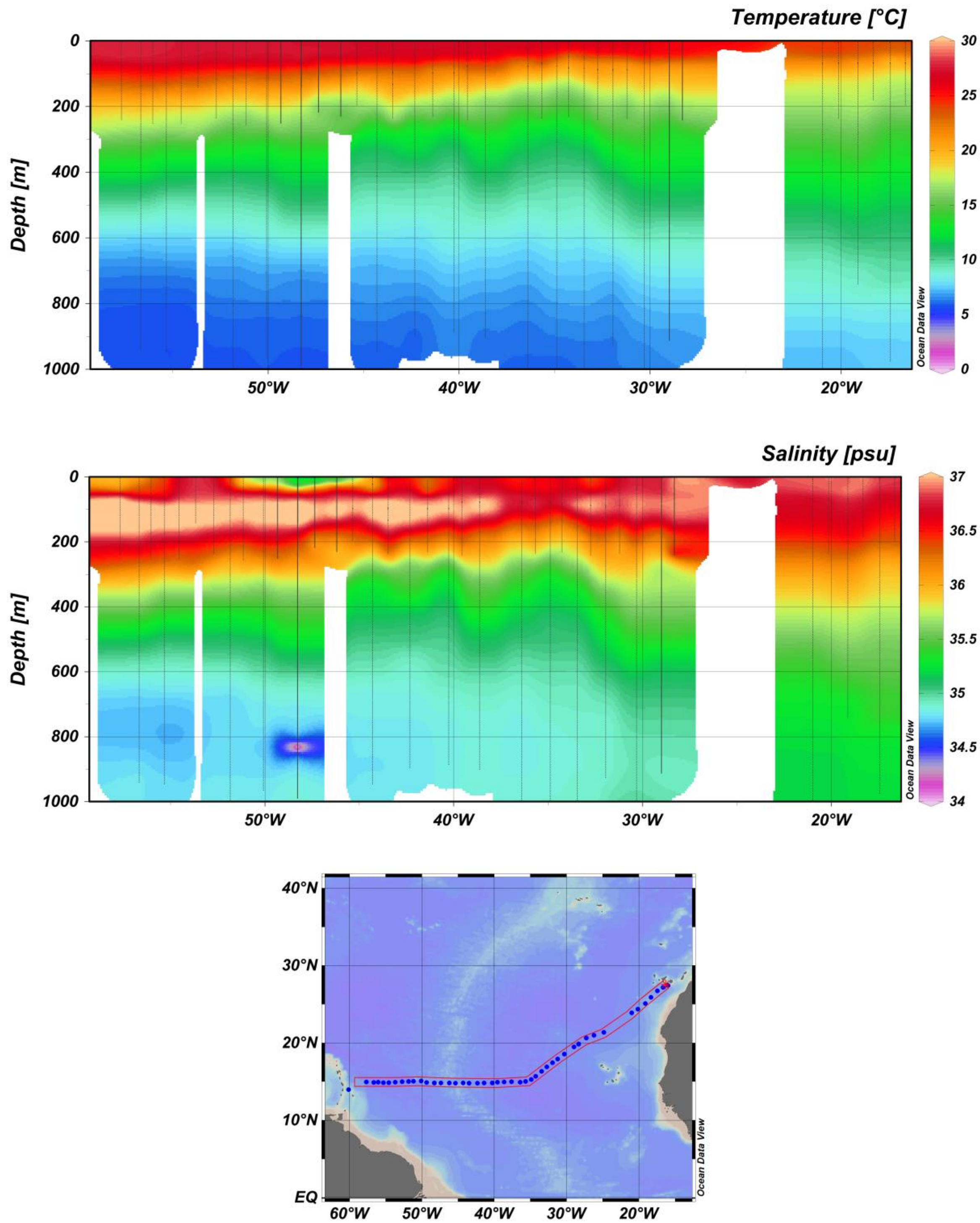

Figure 4. Temperature (top) and salinity (middle) sections derived from twice daily CTD casts along the cruise transect (bottom).

Table 4. Neuston net tow data. 333 μm mesh. Blank indicates no data collected.

Station	Tow Dist. (m)	Zoo. Density (mL/m^2)	Phyllo-soma (#)	Lepto-cephali (#)	Myctophid (#)	Halobates (#)	*Sargassum* (g)	Plastic pellets (#)	Plastic pieces (#)
C263-001-NT	2381.4	0.0017	0	0	0	74	0	0	0
C263-002-NT	1411.5	0.0138	0	0	0	4	0	1	2
C263-003-NT	1912.0	0.0050	0	0	0	5	0	0	4
C263-004-NT	2170.5	0.0048	0	0	0	9	0	0	2
C263-005-NT	2385.6	0.0019	0	0	0	19	0	0	1
C263-006-NT	1801.1	0.0250	0	0	0	1	0	0	1
C263-010-NT	2573.0	0.0045	0	0	1	50	0	0	1
C263-011-NT	2196.0	0.0009	0	0	0	7	0	0	3
C263-012-NT	1603.9	0.0081	0	0	0	3	0	0	0
C263-013-NT	2409.0	0.0012	0	0	0	15	0	0	1
C263-014-NT	1654.3	0.0051	0	0	3	39	0	0	0
C263-015-NT	2175.0	0.0023	0	0	0	2	0	0	12
C263-016-NT	2503.0	0.0044	0	0	1	19	35	0	1
C263-017-NT	2648.2	0.0034	0	0	0	0	160	0	0
C263-018-NT	2533.6	0.0053	0	0	5	65	18	0	1
C263-019-NT	1531.4	0.0014	0	0	0	5	42	0	3
C263-020-NT	2812.0	0.0025	0	0	2	41	4	0	0
C263-021-NT	2162.9	0.0018	0	0	0	11	0	0	6
C263-022-NT	1444.0	0.0055	0	0	1	0	0	0	0
C263-023-NT	1686.4	0.0018	0	0	0	2	0	0	0
C263-024-NT	1913.7	0.0034	0	0	1	12	101	0	0
C263-025-NT	2210.5	0.0031	0	0	0	0	580	0	0
C263-026-NT	2449.7	0.0049	0	0	5	3	1275	0	1
C263-027-NT	2040.5	0.0081	0	0	0	0	2920	0	0
C263-028-NT	1451.5	0.0059	0	0	2	3	4115	0	0
C263-029-NT	2678.0	0.0058	0	0	0	1	1500	0	0
C263-030-NT	1572.9	0.0076	0	0	3	2	1010	0	0

Table 4 continued.

Station	Tow Dist. (m)	Zoo. Density (mL/m^2)	Phyllo-soma (#)	Lepto-cephali (#)	Myctophid (#)	Halobates (#)	*Sargassum* (g)	Plastic pellets (#)	Plastic pieces (#)
C263-031-NT	2138.0	0.0218	0	0	0	0	313	0	1
C263-032-NT	2876.0	0.0049	0	0	15	4	650	0	0
C263-033-NT	2244.1	0.0060	0	0	0	0	775	0	0
C263-034-NT	1481.3	0.0084	0	0	6	2	1995	0	0
C263-035-NT	2383.8	0.0026	0	0	0	4	2025	0	0
C263-036-NT	1607.3	0.0037	0	0	12	24	25	0	0
C263-037-NT	2278.9	0.0010	0	0	0	6	30	0	1
C263-038-NT	1913.6	0.0052	0	0	8	18	39	0	0
C263-039-NT	2397.4	0.0018	0	0	0	0	1786	0	0
C263-040-NT	1837.4	0.0131	0	0	12	2	2583	0	0
C263-041-NT	1911.9	0.0047	0	0	0	0	981	0	1
C263-042-NT	1739.8	0.0060	0	0	31	15	20256	0	9
C263-043-NT	2089.6	0.0046	0	0	0	0	3800	0	0
C263-044-NT	1159.3	0.0065	0	0	3	14	89	0	0
C263-045-NT	1449.1	0.0090	0	0	3	7	489	0	0
C263-046-NT	1576.1	0.0014	0	0	0	0	22	0	0
C263-048-NT	1300.3	0.0104	0	1	1	0	0	0	0
C263-049-NT	1127.6	0.0067	0	0	0	0	348	0	0
C263-050-NT	2233.3	0.0014	0	1	4	0	134	0	0
C263-051-NT	2497.5	0.0010	0	0	0	4	1	0	0
C263-052-NT	2337.7	0.0036	0	0	4	0	124	0	0
C263-053-NT	2192.8	0.0018	0	0	0	1	362	0	0
C263-054-NT	1406.3	0.0071	0	0	4	1	160	0	0
C263-055-NT	1596.7	0.0091	0	0	0	0	250	0	0
C263-056-NT	1574.4	0.0046	0	0	7	1	400	2	1

ABSTRACTS -

Thermal content and transport in Tropical Atlantic and their effect on hurricane intensification.

Peter Barron and Anna Simpson

The equatorial North Atlantic Ocean plays a key role in driving global water circulation and heat transport. Oceanic heat content plays a role in local cyclogenesis and intensification, and the North Equatorial Current region of the Atlantic Ocean is a hotbed for hurricane activity. An observational study of heat content and transport in the surface 500 m was conducted from Gran Canaria to the Caribbean Islands. Heat was primarily found to be transported southward in the Canary Current and westward in the North Equatorial Current as expected. Unexpected regions of heat transport occurred in a few areas such as a strong northeast current from 200m to 500m in the Canary Current region, likely due to eddies or a countercurrent. In addition, surface cells of north and south transport in the North Equatorial Current region could result from localized wind stress. The mixed layer depth was compared to historic seasonal thermoclines from the time period 2000-2011, and was found to be relatively consistent with expected trends. The presence of a layer of water of at least 26.5°C to a depth of 50m, a criterion is necessary for cyclogenesis, existed in December. The meeting of this threshold after the end of the hurricane season suggests that other contributing factors are more significant to the formation of hurricanes. A more detailed, comprehensive study must be conducted within these currents and less well defined transitional areas to better understand the way in which heat will be transported in the Tropical North Atlantic.

Analyzing climate effects on the water masses of the tropical North Atlantic.

Jamie Dalgleish and Holly Westbrook

This study was performed first to observe water masses in the Tropical North Atlantic Ocean. Second, this study aimed to compare data from this cruise track to that from World Ocean Circulation Experiment (WOCE) A05, which was used for a comparison over time. These data were used to identify changes in the temperature and salinity of water masses. In addition, we located changes in dissolved oxygen concentrations and depth ranges of oxygen minimum zones (OMZs) within specific water masses. Temperature, salinity, density, and oxygen profiles were collected using a CTD from the SSV Corwith Cramer. The Tropical North Atlantic was crossed from Gran Canaria to Dominica. Western and Eastern Atlantic Subarctic Intermediate Water masses were found to have the greatest changes in temperature-salinity relationships over time. These water masses had much lower salinity in 2015 than they did in 1992. In addition, they also experienced the largest decrease in dissolved oxygen concentration within their local OMZs, as well as the greatest increase in OMZ depth range. The temperatures of other water masses either remained unchanged over time, or were lower than those of the historic data, but not by a significant difference.

The influence of ocean acidification on pteropod and foraminifera density in the North Atlantic.

Jennifer Dong

Known as two of the most abundant calcifying organisms, pteropods and foraminifera have been studied as indicator organisms regarding the influence of pH in ocean waters. As carbon dioxide uptake by water increases, as does the acidity. The purpose of this study is to determine whether population density of pteropods and foraminifera reflect change in pH levels in the North Atlantic Ocean. Collected data indicates that there is statistical significance that does not support the hypothesis. As pH decreases, density of pteropods increases while there is no significance seen in foraminifera.

The spatial distribution and covariance of CO_2 flux, carbonate concentrations, and nutrients in the northern Tropical Atlantic.

Kennedy Holland, Colette Kelly, Jennifer Kenyon

Increasing atmospheric carbon dioxide is changing the chemistry of the oceans. The oceans can act as sources or sinks for carbon dioxide, as indicated by CO_2 flux. In seawater, carbon dioxide lowers carbonate saturation and shifts nutrient ratios. Source regions with higher seawater pCO_2 tend to have lower carbonate saturation, or Ω values. Higher total carbon can also shift nitrate concentrations in seawater, which are known to correlate with carbon concentrations via the Redfield Ratio. CO_2 flux decreases from east to west in the tropical North Atlantic due to decreasing seawater pCO_2 and decreasing wind speed. Ω values have an inverse relationship with CO_2 flux in the tropical North Atlantic, and are driven primarily by increasing SST. The Canary Current region and Eastern Tropical North Atlantic region share a positive correlation between total carbon concentration and nitrate values.

Phytoplankton community structure: A longitudinal survey on temperature and nutrient ratios in the southern North Atlantic Ocean.

Eben Kopp and Jeffrey Morgan

Water samples were collected at the surface and deep chlorophyll maximum along a longitudinal transect of the southern North Atlantic Ocean to study the relationship of phytoplankton community structure (via size-fractionated chlorophyll-*a* analysis) with temperature and the ratio of nitrogen to phosphorus (measured via nitrite+nitrate:phosphate). The size fractions measured were 8.0, 1.2, and 0.45 μm. No significant relationship was seen between community structure and temperature, or between community structure and N:P. These results did not correlate with past studies of the same relationships. In most cases, there is a significant relationship between community structure and temperature. We suggest that some outlying factor like physical and chemical forcing or grazing may have influenced our observed trends. However, there was an observed trend of smaller phytoplankton (higher concentrations of chlorophyll-*a* on smaller filter sizes) with increasing distance from land in the surface waters which was expected. Alterations in phytoplankton community size structure can result in bottom up control of large scale ecosystems, impacting both biological and chemical processes in the marine environment.

Phytoplankton response to climate change across the subtropical North Atlantic Ocean.

Siya Qiu and Emma Wightman

Phytoplankton require nutrients and sunlight to thrive. Typically, these factors combine in the surface ocean, where the sunlight penetrates the surface and nutrients are present in the mixed layer. However, the composition of the water column changes as sea surface temperature (SST) fluctuates. The mixed layer depth (MLD) increases with cooler waters, and becomes shallower in warmer waters. These relationships, between SST, MLD, Chl-a concentration, and phytoplankton cell size were analyzed across the Northern Equatorial North Atlantic, aboard the SSV Corwith Cramer. Water samples were collected with Niskin bottles every morning from 5 m for Chl-a analysis. Temperature profiles were collected with a CTD, for analyzing SST and MLD. Data from 2003-2014 was combined with cruise track data and used to analyze these trends further, and create a more thorough data set. An inverse relationship was discovered between SST and MLD; when SST increased, MLD decreased. Direct relationships were discovered between MLD and Chl-a concentration as well as MLD and phytoplankton cell size, indicating that a shallower MLD leads to a lower Chl-a concentration and smaller phytoplankton biomass. Studying these trends provides a starting point for understanding how climate change effects the oceanic community, starting with its smallest members.