CRUISE REPORT

R/V ENDEAVOR, Cruise EN651

27 February 2020 – 17 March 2020
Bridgetown, Barbados to Praia, Cape Verde

Chief Scientist
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Principle Investigators, NSF Grant OCE-1433150
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Shipboard Science Party
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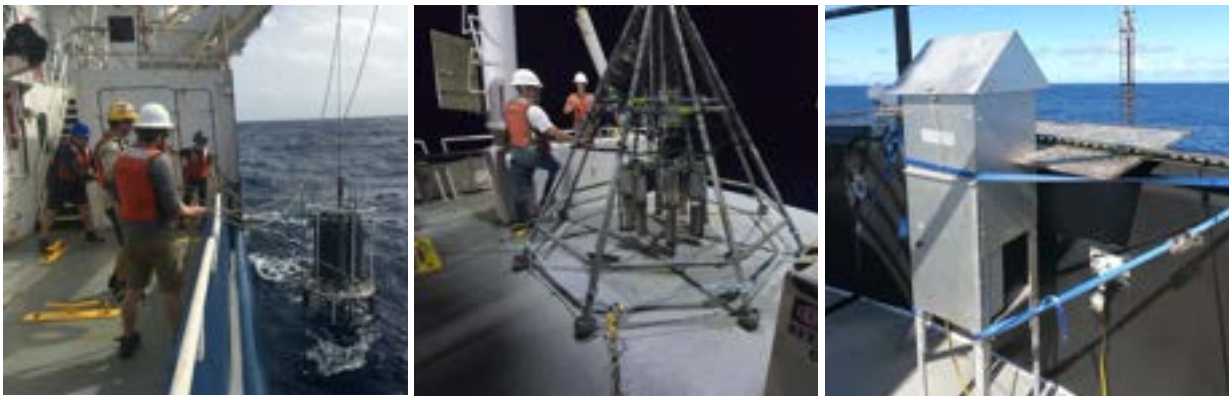
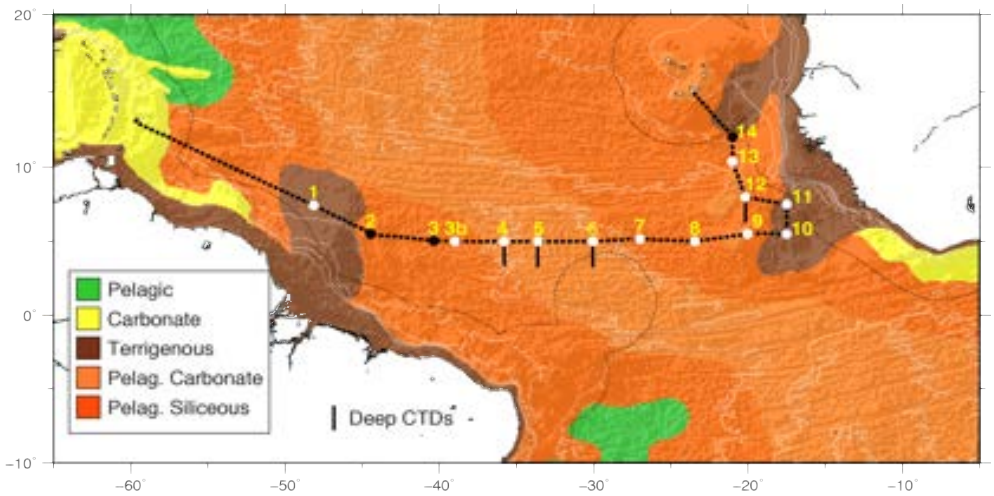


Images of CTD rosette casts (left) and multi-corer operations (center) and hi-vol samplers (right) aboard the *R/V Endeavor*. Photos by Sam Katz, GSO/URI graduate student.



Ship's track of the *R/V Endeavor* with coring and sampling stations occupied during EN651.

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Executive Summary

During Cruise EN651 we occupied 15 different stations along a west-to-east transect of the equatorial Atlantic centered on about 5˚N and successfully collected sediment samples from 12 multicore deployments, water samples/water column measurements from 16 CTD rosette casts, and near-continuous air and surface water sampling. Our sites included a variety of sediment deposition environments including the Amazon Submarine Fan, a series of sites across the Mid-Atlantic Ridge, and sites on the Sierra Leone Rise and adjacent Sierra Leone Basin.

We successfully achieved our primary and most important goals of collecting sediment, water samples, and air samples along a west-to-east transect in the tropical Atlantic centered on about 5˚N. In addition, we also were able to collect similar samples along a roughly south-to-north transect along the eastern edge of the Atlantic along the 20˚ W meridian within about 500 km from the African coast. Planned coring locations were spaced equidistant across the west-to-east transect; however, actual stations were identified with brief sub-bottom surveys to ensure sediment sampled was characteristic of the region and/or primarily pelagic in origin (e.g., on flat-lying sediments away from potential mass wasting vents or turbidite flow). CTD and water-sampling casts were conducted at all but one station (e.g., 3b) and varied between casts to depths of 1000 m and full-ocean depth (e.g., ~ 4000 m). Air and surface water sampling for particulate matter were collected only while the ship was underway and when the apparent wind was within 45˚ of the ship's bow.

I. Introduction

This research cruise was the result of a successful proposal to the US National Science Foundation, Division of Ocean Sciences (Proposal Number OCE-1924191). The lead Principle Investigators (Lohmann and Pockalny) requested support to collect sediments, water particles, and air particles to characterize the concentrations and sources of black carbon across tropical Atlantic air and sediment.

These samples will be used to test a primary hypothesis that sedimentary black carbon across the tropical Atlantic originates from biomass burning and is mainly delivered via atmospheric deposition. Anticipated observations and predictive consequences in support of this hypothesis include

1) sedimentary black carbon in the tropical Atlantic is ^{14}C-modern
2) atmospheric black carbon particles in the marine boundary layer of the tropical Atlantic are ^{14}C - enriched and originate from biomass burning
3) overall black carbon concentrations will decrease with increasing distance from Africa and contain relatively more soot black carbon.

The cruise achieved the primary goal of collecting sediment cores, water samples, and air samples along a west-to-east transect in the tropical Atlantic centered on about 5˚N (Fig. 1, Table I). In addition, we also were able to collect similar samples along a roughly south-to-north transect along the eastern edge of the Atlantic along the 20˚ W meridian within about 500 km from the African coast.

We collected multi-cores from 12 stations with recovery of at the sediment-water interface extending to depths of 30 to 80 cm. A total of 16 CTD rosette casts at all but one coring station (e.g., station 3b) were deployed to depths of 1000 m and/or full-ocean depth (e.g., ~4000 m). A total of 12 water samples were taken at each CTD cast at varying depths depending on water column properties. Near-surface water samples were taken and filtered while the ship was underway. Air samples with high volume air samplers were obtained while the ship was underway and apparent wind direction conditions were appropriate (e.g., within 45˚ of the bow).

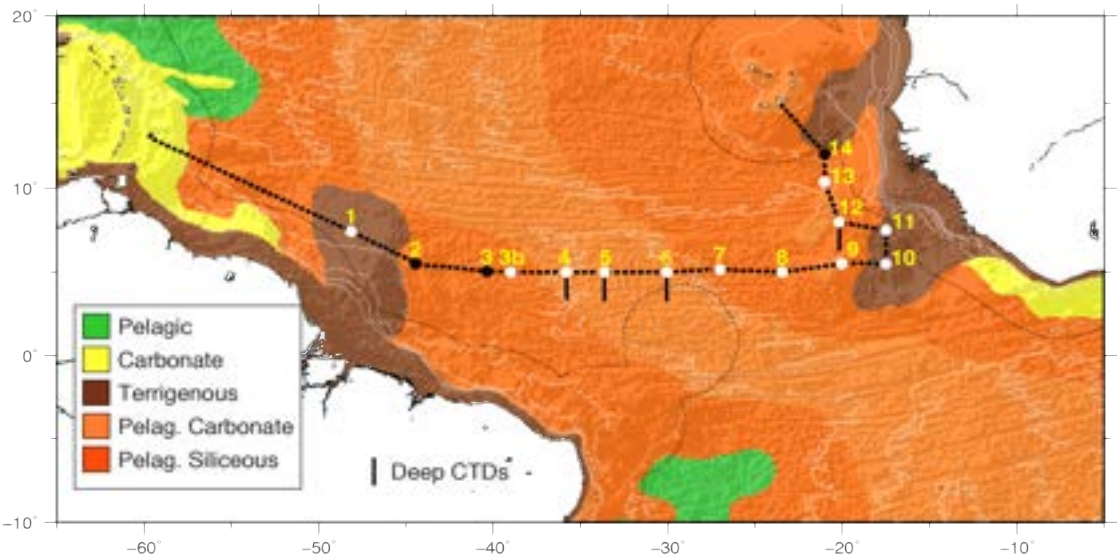

Figure 1. Location map of coring stations overlain on sediment type (Dutkiewicz et al., 2015). White dots indicate successful sediment coring sites and black dots indicate unsuccessful coring sites. Vertical black line indicates sites of deep CTD. Ship's track is shown as thick dotted line, EEZs are shown as thin dotted lines, and 1000-m bathymetry contours are shown as white lines.

Table I. General information for each station occupied by EN651. Events in gray indicate no sediments recovered in the core. Events with a * indicate sediment samples obtained from scrapings on corer. Events with a ^ indicate aborted deployments.

Station	Longitude	Latitude	Depth	Start Station (UTC)	End Station (UTC)	Events			
	(+E/-W)	(+N/-S)	(m)	(mm/dd/yy hh:mm)	(mm/dd/yy hh:mm)				
EN651-01	-48˚ 08.7'	07˚ 25.0'	4250	03/01/20 13:19	03/02/20 00:15	CTD01	MC01	MC02	
EN651-02	-44˚ 27.0'	05˚ 29.0'	3310	03/03/20 02:29	03/03/20 15:28	CTD01	MC01*	MC02	BC01
EN651-03	-40˚ 21.8'	05˚ 02.4'	4645	03/04/20 17:48	03/05/20 04:52	CTD01	MC01	MC02	
EN651-03b	-38˚ 58.8'	04˚ 59.8'	4660	03/05/20 13:07	03/05/20 17:38	MC01			
EN651-04	-35˚ 47.2'	05˚ 59.9'	3990	03/06/20 13:27	03/06/20 20:28	CTD01(deep)	MC01		
EN651-05	-33˚ 36.6'	05˚ 00.2'	3730	03/07/20 11:35	03/07/20 21:29	CTD01(deep)	MC01^	MC02^	MC03
EN651-06	-30˚ 03.4'	04˚ 59.8'	3605	03/08/20 19:46	03/09/20 02:01	CTD01(deep)	MC01		
EN651-07	-27˚ 00.0'	05˚ 09.9'	4275	03/09/20 19:46	03/10/20 01:09	CTD01	MC01		
EN651-08	-23˚ 26.5'	05˚ 00.0'	4320	03/10/20 22:24	03/11/20 04:16	CTD01	MC01		
EN651-09	-20˚ 00.0'	05˚ 30.1'	2840	03/11/20 22:24	03/12/20 04:24	CTD01	MC01		
EN651-10	-17˚ 30.0'	05˚ 30.0'	4965	03/12/20 18:17	03/13/20 00:17	CTD01	MC01		
EN651-11	-17˚ 30.0'	07˚ 30.0'	4820	03/13/20 11:51	03/13/20 17:50	CTD01	MC01		
EN651-12	-20˚ 10.8'	07˚ 59.2'	4180	03/14/20 10:30	03/14/20 19:27	CTD01(deep)	MC01	CTD02	
EN651-13	-21˚ 00.0'	10˚ 22.5'	5130	03/15/20 09:20	03/15/20 17:50	CTD01	MC01	CTD02	
EN651-14	-21˚ 00.0'	12˚ 00.0'	4890	03/16/20 04:00	03/16/20 21:58	MC01	CTD01		

CTD = hydrocast with CTD and 12-bottle Niskin bottle rosette
MC = multi-corer deployments with Ocean Instruments MC-800
BC = box corer

Background

Black carbon (BC) is a highly graphitized incomplete combustion byproduct that could be a sink for fixed carbon, especially when deposited to pelagic sediments (Kuhlbusch 1998). In the atmosphere, BC is a key driver of global climate change; it is second only to CO_2 in its contribution to global warming (Bond et al. 2013; Bond and Sun 2005; Gustafsson and Ramanathan 2016; Ramanathan and Carmichael 2008). There is a general assumption that rivers deliver most or all BC to the ocean (Coppola et al. 2018; Elmquist et al. 2008; Kuhlbusch 1998; Masiello and Druffel 2001; Mitra et al. 2014, 2002; Suman et al. 1997). Yet the effects and fluxes of BC are not well constrained in general circulation models. For example, few BC flux measurements are available in remote ocean sediments due to the expense and difficulty of obtaining samples. The proposed work is thus relevant and timely for our understanding of the carbon cycle, a key component of our ability to forecast climate and its change. Our proposed work is important because the formation of BC during incomplete combustion results in a fraction of carbon not being available for the biological pump and deep ocean respiration. Once deposited to the ocean, BC is buried in sediments, and can account for significant fractions of the organic matter preserved in sediments. Hence, our results would contribute towards accounting some of the 'missing' terrestrial OC in sediments, as all BC is landmass derived (Hedges et al. 1997).

Education and Outreach

Cruise EN 651 provided an educational component to three graduate students (Sam Katz, URI; Ben Geyman, Harvard University; and Nuria Penalva, Autonomous University of Barcelona, Catalonia-Spain) one MATE-at-Sea intern (Lydia Sgouros, Case Western, OH). A fourth (Spanish) graduate student was supposed to be trained on the transit back from Cape Verde, but due to concerns about CoVID-19, she was not allowed to board the ship prior to our departure back to Narragansett (RI). The cruise provided an opportunity for all members of the science team to be trained in cross-disciplinary oceanography through the collaboration with complementary science activities and foci.

1. During the return transit, Lohmann was interviewed by a journalist working for AGU's *EOS* magazine about the impact of COVID-19 on seagoing research (https://eos.org/articles/during-a-pandemic-is-oceangoing-research-safe?utm_source=eos&utm_medium=email&utm_campaign=EosBuzz041020).

2. Several local TV stations also picked up on our COVID-delayed return to the US and covered the story: At sea when pandemic struck, Endeavor makes it home
   WJAR-TV, April 29, 2020
   WPRI-TV, April 29, 2020
   WPRI-TV, April 30, 2020

Societal Relevance

Results from the research above are highly relevant to our understanding of the carbon cycle. If soot BC is indeed an important fraction of deep sea sediment, even less marine-produced organic carbon is sequestered in sediments. Currently, the prevailing view is that black carbon is mostly delivered via fluvial discharges to the ocean. Yet our previous results from tropical Atlantic Ocean sediment show very young BC in the sediment, possibly from aeolian deposition, challenging the view of current BC sources to and cycling in the oceans. We will test the extent to which BC is ^{14}C modern across the Atlantic Ocean by concurrently sampling BC in atmosphere, water column and sediment. Our previous results also imply that C_4 biomass burning is an important BC source in tropical Atlantic Ocean sediment. The origin of BC in atmosphere, water column and sediment will be assessed by ^{13}C and ^{14}C isotope ratio analysis, and the sources corroborated with organic tracers. To address concerns that a given BC method is not adequate, we will be relying on two complementary BC methods, and thereby strengthen confidence in BC concentrations and fluxes. The proposed research will help close the gap between known BC emissions and sinks.

Data Management

The underway data, CTD casts, and cores from this cruise will be delivered to national data archives and core repositories shortly after the completion of the cruise. Access to these data will be made available immediately to other researchers. Derived onboard measurements from sediment, water, and air samples will remain the property of the respective research groups until publication. Individual research groups will be responsible for uploading the published or unpublished data to the appropriate repository (e.g., SedDB, BCO-DMO, NGDC).

All relevant raw underway geophysical data (e.g., navigation, bathymetry, seismics, and ADCP) data will be immediately uploaded and openly accessible through the R2R program. No moratorium is anticipated for these raw data.

All meteorological surface measurements (e.g., wind, pressure, temperature, salinity and fluorometry) and water column measurements (e.g., CTD salinity, temperature, fluorometry) will be provided to NOAA or other appropriate repositories for immediate access and use through the NSF-supported R2R program (www.rvdata.us).

Sediment cores will be stored at the NSF-funded Rock and Core Repository at GSO-URI and access to samples will follow established protocols. Solid material, in the form of cores will be curated and retained after the expedition and made available to other investigators that wish to use them for other means.

Cruise related materials including the cruise report, figure archives, and relevant data will be temporarily hosted on a password-protected server at GSO-URI for access by the cruise participants and the proposal's PIs.

Shipboard Scientific Party

The shipboard scientific party (names and affiliations in *Appendix A*) consisted of several groups of individuals grouped according to their expertise and research interest.

Chief Scientist:	Lohmann
Site Selection:	Pockalny
Sediment Samples:	Lohmann, Katz, Geyman, Rosell-Mele, Penalva Arias
CTD Casts:	Geyman, Rosell-Mele, Penalva Arias
Water Column Samples:	Geyman, Rosell-Mele, Penalva Arias
Surface Water Samples:	Katz, Lohmann
Air Samples:	Lohmann, Katz, Rosell-Mele, Penalva Arias

II. Operations

Overview

Our proposed cruise plans requested 20 days at sea and assumed start and end ports of Bridgetown, Barbados and Dakar, Senegal, respectively. These plans included 5.5 days of transit to/from our operational area, 8.5 days of transit between coring sites, and 6 days on station at 10 coring sites along a west-to-east transect centered on 5˚N. Our planned on-station order of events included a 3-hour site survey, a CTD rosette cast to 1000 m, and two multi-corer deployments for an average on-station time of 0.6 days. We assumed 30 m/min wireline speeds for both the CTD casts and multi-corer deployments.

Our actual cruise aboard the *R/V Endeavor* began in Bridgetown, Barbados on February 27th, 2020, but the end port was changed to Praia, Cape Verde for security purposes and the cruise ended on March 17th, 2020. We departed Barbados 3 days later than anticipated due to issues with a ship's generator; however, our cruise was extended to provide us with the requested 20 days at sea.

Our actual order of events generally followed our proposed plan, but the actual time allocations differed (Fig. 2). Our site survey time and CTD casts required less time than planned, even though 4 casts were extended to ~4000 m depth and there were multiple casts at 2 sites.
Our coring time was significantly reduced after Station 3b once the multi-corer was fine-tuned and only one deployment was required to obtain the required sediment samples.
The much-improved efficiency of on-station operations allowed us to occupy 4 additional sites and begin a roughly south-to-north transect located about 500 km offshore of Africa between Sierra Leone Rise and Cape Verde Plateau. A detailed timeline of cruise operations is provided in Figure 3.

We should also note that the cruise occurred during the COVID-19 pandemic in early 2020 and required rerouting of the *R/V Endeavor* back to its home port in Narragansett, RI after the cruise. We had originally planned to continue air and water sampling as the ship transited to Port Everglades FL for its next cruise, but those plans have been modified. Most of the science participants were allowed to remain on the vessel for the transit back due to cancelled flights; however, our two colleagues from U.A. Barcelona disembarked in Cape Verde and transited back to Barcelona on a later flight.

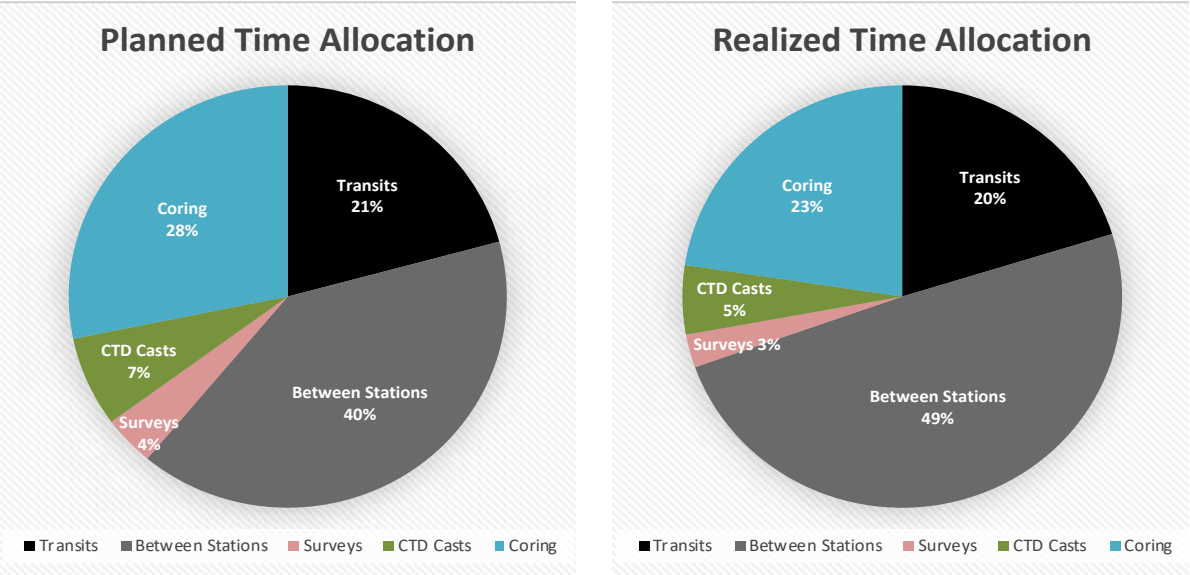

Figure 2. Pie charts comparing planned (left) and actual (right) time allocation during the cruise.

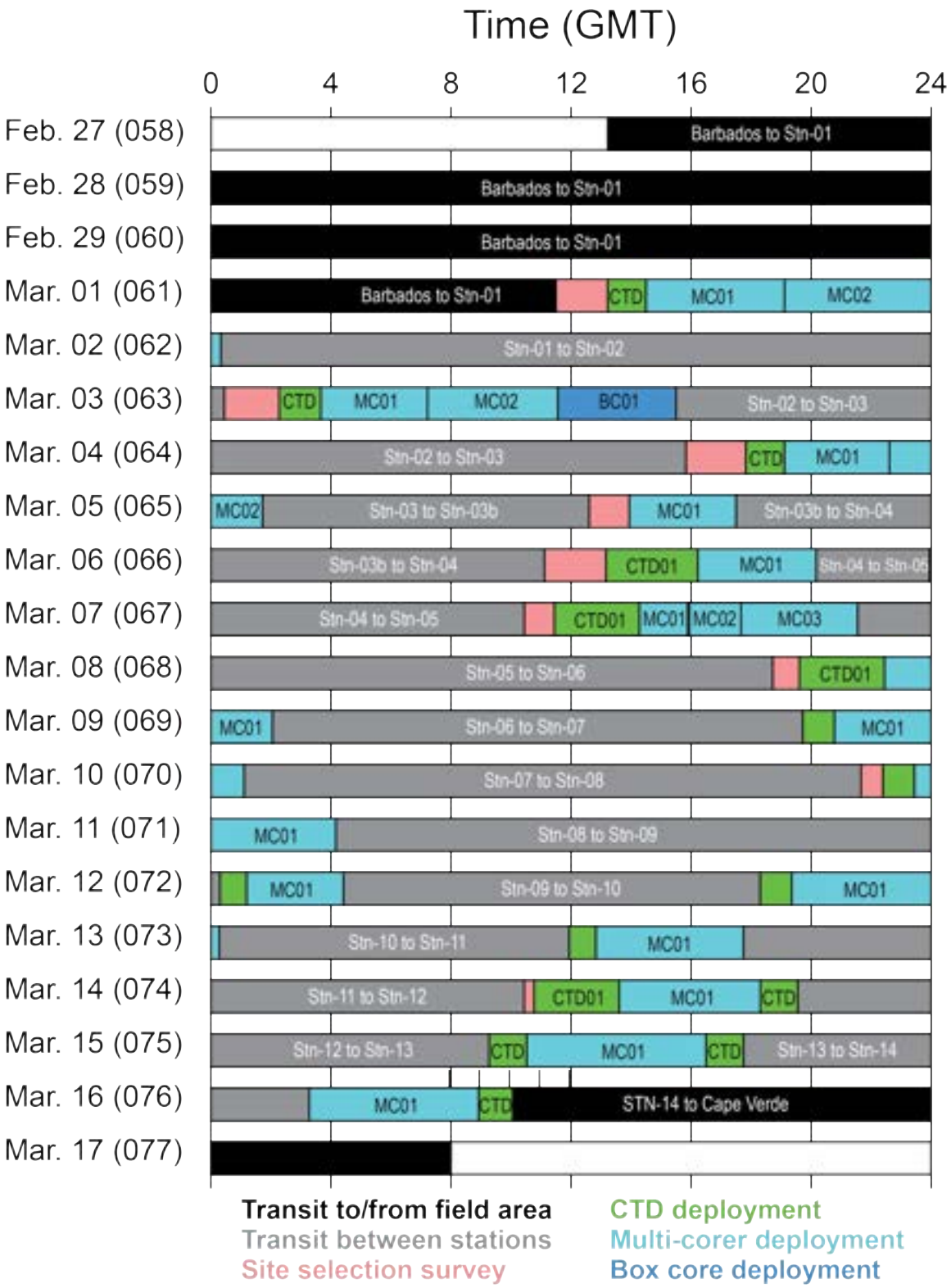

Figure 3. Daily timeline of operations during cruise EN651. Color code is the same as the pie charts in Fig. 2.

Coring Site Selection *(Pockalny)*

Objectives. Our principal geophysical objectives were to locate coring sites and to characterize the tectonic/depositional setting.

Protocol. These objectives were achieved primarily with Knudsen 320B and 3260 sub-bottom echosounders; however, previously collected multibeam bathymetry and backscatter data also were used to target coring sites.

The sub-bottom data were collected at ship speeds of 7 to 10 knots for about 30 minutes prior to arriving at a target site and then another 30 minutes after leaving the station. The data were recorded in .kea, .keb, and SEGY formats and transferred to a Dell PC to view the data. The .keb files were converted to compressed .keb formats with Knudsen's Conversion Utility application and then viewed with the SounderSuite PostSurvey v.4.07 application. Contrast values were adjusted to optimize seismic section images and then saved as bitmap formats.

Previously collected multibeam data were obtained from the NOAA multibeam archive (https://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html) and then processed with shell scripts using MB-Systems and Generic Mapping Tools. In regions where multibeam data were not available, we used the GMRT mapping tool (https://www.gmrt.org/GMRTMapTool/) to extract gridded bathymetry data. The trackline locations of the seismic sections were obtained from the shipboard SCS data files in the 60sec format.

Preliminary Results. Sub-bottom seismic data and previous multibeam data and satellite-derived topography were combined to generate regional views of the sediment profiles and coring areas (see Appendix B, Site Summaries).

Post-cruise Activities. Post-cruise activities will include generating site maps of geophysical and environmental data as needed in support of related project activities.

CTD and Niskin Rosette Casts *(Benjamin Geyman, Harvard U., Paulson School of Engineering and Applied Sciences)*

Objectives. Harvard's participation in the EN651 cruise provided an opportunity for graduate training in oceanographic measurement of trace metals and associated clean sampling and handling procedures. Research goals included characterizing: (i) the vertical distribution of mercury and methylmercury species in the epi- and mesopelagic water column, and (ii) examining accumulation of mercury in deep-sea sediments. Seawater mercury distributions have not been extensively studied in the Equatorial Atlantic Ocean, and data collected during EN651 will be used to support evaluation of global ocean mercury transport models.

Protocol.

CTD Configuration

Config file: EN651_0444a.xmlcon
SBE 911plus/917plus CTD
WET Labs ECO-AFL/FL – fluorometer
WET Labs C-Star – transmissometer
SBE 43 – O_2
Biospherical/Licor - PAR/Irradiance
SBE Carousel
Ocean Test Equipment – Niskin bottles (10-L)

Seawater was collected from stations 1 – 10 at between the surface and 4,000 m depth using Niskin bottles deployed on a CTD rosette. Seawater collected for Hg analysis was transferred within 1 hour of recovery into 1 L, acid-cleaned glass bottles following "clean hands-dirty hands" techniques outlined in EPA Method 1669 (1996). An additional 1 L sample was collected into plastic bottles at each depth for filtration and analysis of chlorophyll *a* (chl *a*). Mercury samples were transferred to a clean workspace outfitted with a HEPA filtered air-source and filtered onto 0.2 µm Nucleopore polycarbonate filters. Filters were dried in the hood, transferred to acid-cleaned petri dishes, and preserved at -20° C until analysis. Filtrate was poured off into 250/125 mL acid-cleaned glass bottles for analysis of total mercury, methylmercury, and dissolved organic carbon (DOC)/nutrients. Mercury samples were acidified with 0.5%$_{v/v}$ hydrochloric acid (HCl) and refrigerated at 4° C, and DOC/nutrient samples were frozen. A separate aliquot of 500 – 1000 mL was filtered onto a 25 mm glass fiber filter for chl *a* analysis, and the filter was stored frozen in a petri dish, wrapped in aluminum foil. Samples for exploratory analysis of PFAS in seawater were also collected from the upper 250 m of the water column, transferred to HDPE bottles and stored at 4° C.

Sediment cores were collected using an MC-800 multi-corer, and a single core was sectioned and preserved at each site for Hg analysis. Prior to sectioning, S. Katz identified distinct horizons and recorded the position and Munsell color (Munsell Color Company, Inc., 2009). The top 20 cm of each Hg core was sectioned at intervals of 0.5 – 2 cm, with highest sampling density concentrated near the top of the core. This scheme is designed to maximize sampling resolution within the last 1000 years while leaving sufficient material for Hg stable isotopic analysis. Age models will be constructed for each core using radiocarbon dating of total organic carbon (to be performed by S. Katz), and this will be the basis for calculation of Hg accumulation rates (Hg_{AR}). Sectioning was performed using an aluminum sheet and plastic spoon, and samples have been stored in plastic containers and stored at -80° C until analysis.

Post-cruise Activities. Seawater samples and particulate filters will be measured for total mercury, methylmercury, PFAS, DOC/nutrients, chlorophyll *a,* and total suspended solids (TSS) at the *Biogeochemistry for Global Contaminants Lab* in Cambridge, MA. These data will be interpreted alongside oceanographic parameters recorded by the CTD and detailed in *Appendix D: CTD / Rosette Operations.* Prior to analysis, sediment samples will be freeze-dried and homogenized. Concentration and thermal fractionation measurements will be performed by combustion using a direct mercury analyzer (Milestone DMA-80). Isotopic composition will be determined by MC-ICP-MS (Thermo Neptune) following isolation of Hg from sediment by combustion- or digestion-based matrix separation techniques.

Table II. Anticipated Measurements

Medium	Measurement	n
Seawater	Total mercury (Hg)	60
	Methylmercury (MeHg)	60
	PFAS	30
	Dissolved organic carbon (DOC)	60
	Chlorophyll *a* (Chl *a*)	60
	Total suspended solids (TSS)	60
Sediment	Total mercury (Hg)	180
	Mercury thermo-desorption (MTD)	30-180
	Mercury stable isotopes	30-180

See Appendix E for details of the CTD and Niskin water sample operations by the cruise participants from the Autonomous University of Barcelona.

Surface Water Sampling *(Katz, Lohmann)*

Objectives. The goal of surface water particle sampling was to collect recently deposited particulate black carbon across the equatorial Atlantic for source analysis.

Protocol. During transits to and between sites, water from the shipboard centrifugal pump was filtered through quartz fiber filters (142 mm diameter). Quartz fiber filters had been baked at 450 ˚C and stored in combusted aluminum foil before being placed in the filter housing for a maximum of 12 hrs. Flow rate was measured at the start and end of each sample period and total flow was recorded with a flow meter. Samples were wrapped in combusted aluminum foil before being stored at -20 ˚C.

Table III: Surface water sampling information

ID	Start Date/Time	End Date/Time	Sample Type	Initial Flow Rate (L/min)	End Flow Rate (L/min)	Total Flow (L)
EN651-1W-QFF	2/27/20 15:40	2/27/20 15:40	FB	NA	NA	NA
EN651-2W-QFF	2/27/20 15:44	2/27/20 21:00	FS	0.74	0.5	220.6
EN651-3W-QFF	2/27/20 21:09	2/28/20 2:07	FS	0.66	0.5	192.9
EN651-4W-QFF	2/28/20 2:23	2/28/20 10:18	FS	0.7	0.35	297.2
EN651-5W-QFF	2/28/20 10:24	2/28/20 15:16	FS	0.7	0.58	211
EN651-6W-QFF	2/28/20 15:34	2/28/20 20:54	FS	0.68	0.88	255.3
EN651-7W-QFF	2/28/20 21:07	2/29/20 1:42	FS	0.7	0.72	242.3
EN651-8W-QFF	2/29/20 2:03	2/29/20 10:07	FS	1.2	0.66	405.5
EN651-9W-QFF	2/29/20 10:16	2/29/20 13:50	FS	0.6	0.82	198.9
EN651-10W-QFF	2/29/20 14:03	2/29/20 19:39	FS	1.4	0.66	382.3
EN651-11W-QFF	2/29/20 19:50	3/1/20 0:47	FS	1.02	0.84	287.1
EN651-12W-QFF	3/1/20 0:57	3/1/20 9:42	FS	1.28	0.66	473.2
EN651-13W-QFF	3/1/20 9:48	3/1/20 12:42	FS	1.26	0.94	182.2
EN651-14W-QFF	3/2/20 0:41	3/2/20 10:17	FS	0.9	0.6	503.7
EN651-15W-QFF	3/2/20 10:23	3/2/20 12:29	FS	1.24	1.1	153.4
EN651-16W-QFF	3/2/20 12:37	3/2/20 12:37	FB	NA	NA	NA
EN651-17W-QFF	3/2/20 12:52	3/2/20 19:45	FS	1.38	1.04	503.2
EN651-18W-QFF	3/2/20 19:52	3/3/20 2:16	FS	1.4	0.94	475.5
EN651-19W-QFF	3/3/20 16:10	3/4/20 0:18	FS	1.38	0.44	508.7
EN651-20W-QFF	3/4/20 0:24	3/4/20 10:44	FS	0.7	0.6	457.2
EN651-21W-QFF	3/4/20 10:54	3/4/20 17:07	FS	1.36	1.02	449.3
EN651-22W-QFF	3/5/20 5:23	3/5/20 12:54	FS	1.22	1.08	430.4
EN651-23W-QFF	3/5/20 18:02	3/5/20 23:48	FS	1.38	1.04	430.4
EN651-24W-QFF	3/5/20 23:53	3/6/20 11:30	FS	0.52	0.98	426.3
EN651-25W-QFF	3/6/20 21:23	3/7/20 0:20	FS	1.2	0.94	188.9
EN651-26W-QFF	3/7/20 0:24	3/7/20 8:46	FS	1.36	0.68	503.6
EN651-27W-QFF	3/7/20 8:52	3/7/20 11:09	FS	1.2	0.9	323.3
EN651-28W-QFF	3/7/20 19:15	3/7/20 19:15	FB	NA	NA	NA
EN651-29W-QFF	3/7/20 21:49	3/8/20 9:20	FS	1.4	0.5	588.8

EN651-30W-QFF	3/8/20 9:36	3/8/20 19:15	FS	1.34	0.72	572.2
EN651-31W-QFF	3/9/20 2:36	3/9/20 10:33	FS	1.3	0.64	343.9
EN651-32W-QFF	3/9/20 10:38	3/9/20 19:53	FS	0.74	0.8	408.6
EN651-33W-QFF	3/10/20 1:41	3/10/20 9:30	FS	1.04	0.8	430.6
EN651-34W-QFF	3/10/20 9:36	3/10/20 12:43	FS	1.42	0.86	211
EN651-35W-QFF	3/10/20 12:50	3/10/20 12:50	FB	NA	NA	NA
EN651-36W-QFF	3/10/20 12:59	3/10/20 19:28	FS	0.82	0.5	297.8
EN651-37W-QFF	3/10/20 19:32	3/10/20 22:30	FS	1.4	1.4	189
EN651-38W-QFF	3/11/20 4:38	3/12/20 0:08	FS	1.4	0.3	747.4
EN651-39W-QFF	3/12/20 4:47	3/12/20 16:19	FS	1.08	0.6	634.7
EN651-40W-QFF	3/13/20 0:47	3/13/20 11:48	FS	0.7	0.8	502.4
EN651-41W-QFF	3/13/20 18:22	3/14/20 10:16	FS	1.6	0.5	809.5
EN651-42W-QFF	3/14/20 10:31	3/13/20 10:31	FB	NA	NA	NA
EN651-43W-QFF	3/14/20 19:48	3/15/20 9:57	FS	1.5	1.04	611.2
EN651-44W-QFF	3/16/20 10:16	3/16/20 20:05	FS	1.4	0.6	566.2
EN651-45W-QFF	3/16/20 20:18	3/17/20 8:30	FS	1	0.72	546.8

FS = Field Sample; FB = Field Blank

Post-cruise Activities. Black carbon will be oxidized using the CTO-375 method for establishing concentrations and deriving the origin though $\delta^{13}C$ and $\Delta^{14}C$ (Winiger et al. 2015; Zencak et al. 2007). Black carbon concentrations will also be tested using the thermo-optical Sunset method (Birch and Cary 1996), which is a routine measurement technique for aerosols, but has not been tried for aqueous particles. The origin of black carbon will also be assessed from the ratios of polycyclic aromatic hydrocarbons (PAHs) (Yunker et al. 2002) and levoglucosan concentrations, a tracer of softwood combustion (Simoneit et al. 1999; Simoneit and Elias 2000).

Sediment Sampling *(Lohmann, Katz, Geyman, Rosell-Mele, Penalva Arias)*

Objectives. The objectives of collection and sectioning of sediment cores is to determine age and origin of black carbon in equatorial Atlantic sediments.

Protocol. MC-800 tubes were labeled (EN651-"Site number"-MC"coring attempt number""letter of core",ex: EN651-01-MC01a) and photograph before sectioning. All cores and core sections were stored at -20 ˚C.

The water on top of the core was syphoned off and a thin piece of stainless-steel sheet was slid under the foot of the tube. The foot was bent up and the stainless-steel sheet was used to transfer the core to the core extruder. Cores were sectioned at 1 cm intervals down to 10 cm, then 2 cm intervals down to 20 cm, using the piece of stainless-steel and a cake spatula to cut them. The remainder of the core was wrapped in combusted aluminum foil and placed in a zip-lock bag for storage. Sections of cores were stored in amber glass jars placed in a freezer. One core was transferred with the extruder to a PVC tube and capped for archival storage. If 5 or more cores were recovered 0.5 cm sections would be taken down to 10 cm and the remainder of the core wrapped in foil and zip-lock bag before being frozen. Due to limited supply of jars the 0.5 cm core sections were wrapped in combusted aluminum foil and placed in a ziplock bag before being stored with other samples.

Post-cruise Activities. Black carbon will be oxidized using the CTO-375 method for establishing concentrations and deriving the origin though $\delta^{13}C$ and $\Delta^{14}C$ (Winiger et al. 2015; Zencak et al. 2007). The sources of black carbon will also be derived from the ratio of polycyclic aromatic hydrocarbons (PAHs) (Yunker et al. 2002) and levoglucosan concentrations (Simoneit et al. 1999; Simoneit and Elias 2000).

Air Sampling *(Lohmann, Katz)*

Objectives. The goal of atmospheric particle sampling was to collect particulate black carbon across the equatorial Atlantic for source analysis.

Protocol. During transits to and between sites hi-vol samplers were run on the roof of the pilothouse when the apparent wind was less than 45˚ off the bow. Plywood was placed over the railing to increase airflow to the hi-vol sampler (Figure 4). Quartz fiber filters baked at 450˚C and stored in combusted aluminum foil were installed in the hi-vol and run for a maximum of 24 hours when wind permitted. Flow rate was measured using at the start and end of each sample period. Sample were folded and wrapped in combusted aluminum foil before being stored at -20˚C.

Figure 4: Photo of hi-vol sampler with plywood used to improve airflow to sampler

Table IV. Hi-vol sampling information

ID	Start Date/Time	End Date/Time	Type	Average flow (m^3/sec)	Total Flow Volume (m^3)
EN651_01A_QFF	2/27/20 14:15	2/27/20 14:15	FB	NA	NA
EN651_02A_QFF	2/27/20 13:35	2/28/20 14:20	FS	0.0172	1449.01
EN651_03A_QFF	2/28/20 14:35	2/29/20 13:16	FS	0.0172	1408.40
EN651_04A_QFF	2/29/20 13:22	3/01/20 11:51	FS	0.0172	1394.70
EN651_05A_QFF	3/02/20 00:23	3/03/20 00:53	FS	0.0183	1618.64
EN651_06A_QFF	3/03/20 16:01	3/04/20 16:37	FS	0.0213	1905.61
EN651_07A_QFF	3/04/20 18:40	3/04/20 23:54	FS	0.0204	393.97
EN651_08A_QFF	3/05/20 00:25	3/05/20 00:25	FB	NA	NA
EN651_09A_QFF	3/05/20 00:41	3/05/20 04:56	FB	NA	NA

EN651_10A_QFF	3/05/20 05:07	3/05/20 12:37	FS	0.0227	613.93
EN651_11A_QFF	3/05/20 17:51	3/06/20 11:14	FS	0.0209	1309.99
EN651_12A_QFF	3/06/20 20:38	3/07/20 10:26	FS	0.0209	1040.55
EN651_13A_QFF	3/07/20 10:33	3/07/20 10:33	FB	NA	NA
EN651_14A_QFF	3/07/20 10:58	3/07/20 10:58	FB	NA	NA
EN651_15A_QFF	3/07/20 21:34	3/08/20 19:01	FS	0.0227	1760.45
EN651_16A_QFF	3/09/20 02:20	3/09/20 19:42	FS	0.0232	1453.81
EN651_17A_QFF	3/10/20 01:22	3/10/20 20:20	FS	0.0232	1754.38
EN651_18A_QFF	3/11/20 04:35	3/11/20 23:56	FS	0.0234	1644.97
EN651_19A_QFF	3/12/20 04:35	3/12/20 18:09	FS	0.0236	1152.30
EN651_20A_QFF	3/13/20 00:31	3/13/20 11:37	FS	0.0233	933.78
EN651_21A_QFF	3/13/20 18:08	3/14/20 09:55	FS	0.0233	1324.49
EN651_22A_QFF	3/14/20 10:09	3/14/20 10:09	FB	NA	NA
EN651_23A_QFF	3/14/20 19:38	3/15/20 09:46	FS	0.0237	1207.68
EN651_24A_QFF	3/16/20 10:16	3/17/20 08:17	FS	0.0237	1876.31

FS = Field Sample; FB = Field Blank

Post-cruise Activities. Black carbon will be oxidized using the CTO-375 method for establishing concentrations and deriving the origin though $\delta^{13}C$ and $\Delta^{14}C$ (Winiger et al. 2015; Zencak et al. 2007). Black carbon concentrations will also be measured using the thermo-optical Sunset method (Birch and Cary 1996), which is a routine measurement technique for aerosols. The origin of black carbon will also be assessed from the ratios of polycyclic aromatic hydrocarbons (PAHs) (Yunker et al. 2002) and levoglucosan concentrations, a tracer of softwood combustion (Simoneit et al. 1999; Simoneit and Elias 2000).

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