updated 18 June 2021

Cruise Report for GEOTRACES GApr13-Leg 3 (BAIT-III, AE 1921, BATS 362)

R/V *Atlantic Explorer*, Bermuda Atlantic Time-series Study Region, 16-22 August 2019

Overview of BAIT Project (GEOTRACES Process Study GApr13):

Jointly funded by the US National Science Foundation and the UK Natural Environment Research Council, the Bermuda Atlantic Iron Time-series (BAIT) project aims to combine field data from the Bermuda Atlantic Time-series Study (BATS) region with an established, state-of-the-art ocean biogeochemical model in order to constrain the pools, fluxes and physicochemical transformations that control the oceanic distribution of dissolved iron (DFe), thereby advancing our ability to model the ocean iron cycle and project its sensitivity to future change. Specifically, seasonally resolved data on the vertical (upper 2,000 m) and lateral (tens of km) distributions of particulate, dissolved, colloidal, soluble and ligand-bound iron species will be obtained from the chemical analysis of water column samples collected during five cruises, spanning a full annual cycles, shared with the monthly BATS program cruises. These data, along with ancillary data from then BATS program, will be used to test and inform numerical modeling experiments, and thus derive an improved understanding of the mechanisms that control the distribution and dynamics of DFe in the oceanic water column.

BAIT-III Cruise Synopsis:

GEOTRACES cruise GApr13-Leg 3 (BAIT-III) was piggybacked on BATS cruise 362, with an extra two sea days added to the BATS program cruise to accommodate the BAIT program activities and another ancillary project (PIs Curry, Grundle and Lomas). Participants on GApr13-Leg 3 were were Peter Sedwick (Old Dominion University, BAIT PI), Rod Johnson (Bermuda Institute of Ocean Sciences, Chief Scientist, BATS PI, BAIT co-PI), Shannon Burns (University of South Florida, graduate student), Salvatore Caprara (University of South Florida, postdoctoral fellow), Gabby Kim (Colby College, undergraduate student), Dan Ohnemus (Skidaway Institute of Oceanography, BAIT co-PI), and Bettina Sohst (Old Dominion University, research specialist).

Weather was favorable, with sunny weather and nearly calm wind conditions, except during the final day at sea when winds increased to ~10-20 kts. The BAIT project sampling followed a similar sampling strategy to that used on BAIT-I and BAIT-II, with the addition of near-surface seawater samples collected for dissolved and particulate phases using Niskin-X samplers that were deployed by hand from a small boat. Sampling was generally successful, despite damage to the trace metal carousel frame during the first depoyment at the BATS station (due to a snagged tag line), after which temporary repairs were undertaken at sea. The crew and marine technicians aboard R/V *Atlantic Explorer*, and the BATS program team, provided invaluable assistance.

During the cruise period, the Mercator Ocean model forecasts suggested that the BATS area was located near the southern extent of the boundary between an anticyclone centered west-northwest of Bermuda, and a narrow cyclonic feature centered to the northeast of Bermuda, with predominantly north-to-south flows diverging near the BATS station (Fig. 1). However, this Mercator analysis was not borne out by shipboard ADCP and hydrographic observations, as well

as sediment-trap drift during the cruise, which indicated the presence of a small, sub-mesoscale anticyclonic circulation feature located approximately between the BATS station and BATS Spatial Stations #1 and #2.

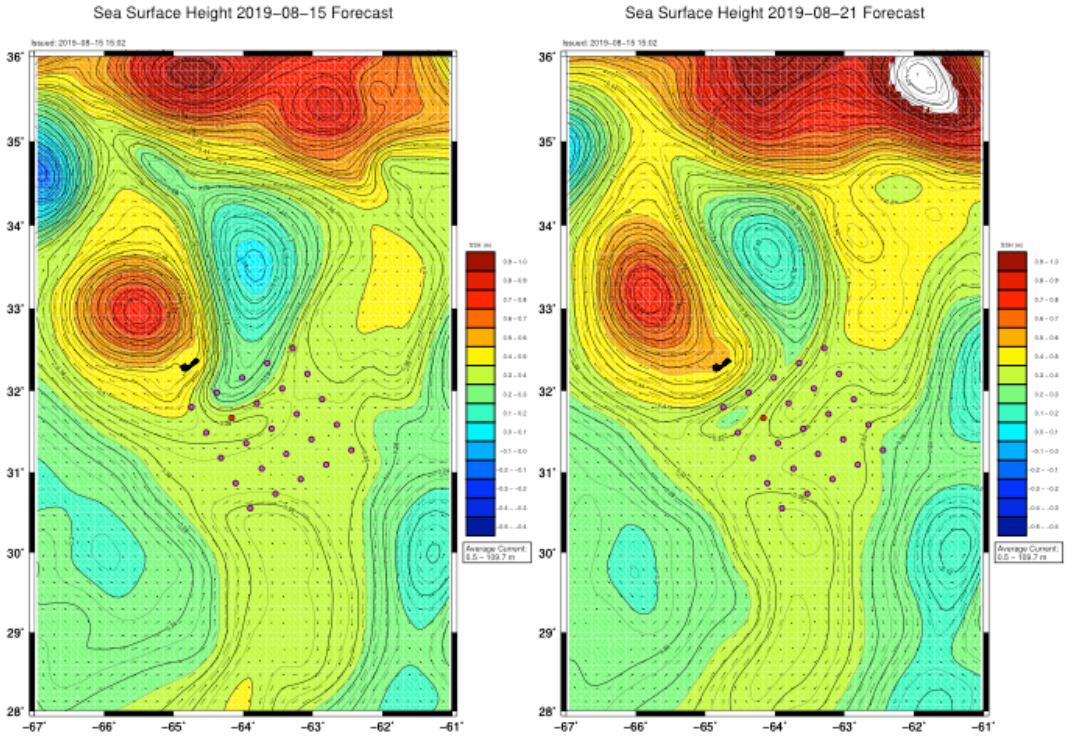

Figure 1. *Mercator Ocean model sea surface height forecasts for BATS region, 15 August (left) and 21 August (right) 2019.*

After a test/bottle soak cast of the trace-metal CTD (TMCTD) rosette at Hydrostation S, the BAIT water column sampling (TMCTD casts and McLane pump deployments) was undertaken at BATS and BATS Spatial Stations #1 and #2 to provide information on mesoscale lateral gradients. Following the BAIT-I and BAIT-II sampling strategy, nominal TMCTD sampling depths were selected between 20 m and 1700 m (limited by available line on winch and wire angle), and included the subsurface chlorophyll maximum (SCM), the dissolved oxygen minimum, and density surfaces of 26.1, 26.3 and 26.6 sigma, as estimated from immediately preceding BATS CTD casts. As noted above, the TMCTD water-column samples were augmented by near-surface samples collected from a small boat upwind of the research vessel in a hand-held Niskin-X sampler. Nominal McLane pump deployment depths included those used by Mak Saito's ongoing sampling program (30 m, SCM, 150 m, 200 m), and other depths of interest where possible.

Surface mixed layers were generally in the 10-30 m thickness range (defined as the depth at which temperature changes by 0.2°C relative to a 10 m reference depth, after de Boyer Montegut et al. 2004), which was somewhat surprising given the very warm, calm conditions during the cruise, with surface water temperatures near 29°C. The depth of the SCM typically varied between ~75-110 m, and was sometimes a broad feature with more than one maximum.

Reference:

de Boyer Montégut, C., Madec, G., Fischer, A.S., Lazar, A. and Iudicone, D., 2004. Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology. *Journal of Geophysical Research: Oceans*, 109(C12).

Summary of BAIT-III Sampling Operations:
(all sampling depths are nominal)

1). Test/bottle soak TMCTD cast, TM-000
Recovered 22:31 GMT, 16 Aug 2019, near 32°10.385'N, 64°28.962'W (Hydrostation S)
Deployed to ~1700 m depth, bottles closed sequentially at 160-140 m depth; no samples taken

2). Near-surface Niskin-X collection using small boat collected at ~21:17 GMT, 17 Aug 2019, near 31°39.964'N, 64°10.373'W (near BATS, corresponds to surface sample for cast TM-001)
Subsamples taken for dissolved Fe, soluble Fe, dissolved Co, dissolved Al, dissolved Fe isotopes, dissolved Fe ligands, soluble Fe ligands, cellular metals, and dissolved macronutrients

3). TMCTD cast for particles, TMP-001
Aborted TMCTD deployment because tag line snagged and damaged carousel; enacted temporary repair with stainless steel hose clamps and ratchet straps, then re-deployed and recovered 04:43 GMT, 18 Aug 2019, at 31°38.173'N, 64°12.777'W (near BATS)
Samples collected at 20, 30, 50, 75, 100, 180, 200, 390, 600, 865, 1000, 1700 m depth
All bottles filtered through 0.4 μm membranes for particles

4). TMCTD cast for dissolved species, TM-001
Recovered 09:48 GMT, 18 Aug 2019, at 31°37.882'N, 64°11.388'W (near BATS)
Samples collected at 20, 30, 50, 75, 100, 180, 200, 390, 600, 865, 1000, 1700 m depth
Subsamples taken for dissolved Fe, soluble Fe, dissolved Co, dissolved Al, dissolved Fe isotopes, dissolved Fe ligands, soluble Fe ligands (75, 200 m), cellular metals (20, 75 m), and dissolved macronutrients

5). Shallow McLane pump cast for particles, MCL-001
Recovered 15:30 GMT, 18 Aug 2019, at 31°36.310'N, 64°12.439'W (near BATS)
Pumps deployed at nominal depths of 30, 80, 150, 200 m

6). TMCTD cast for particles, TMP-002
Recovered 08:44 GMT, 20 Aug 2019, at 31°50.507'N, 64°44.067'W (near Spatial Station #1)
Samples collected at 20, 30, 75, 110, 150, 200, 260, 429, 620, 840, 1000, 1700 m depth
All bottles filtered through 0.4 μm membranes for particles

7). TMCTD cast for dissolved species, TM-002
Recovered 12:46 GMT, 20 Aug 2019, at 31°49.947'N, 64°44.600'W (near Spatial Station #1)
Samples collected at 20, 30, 75, 110, 150, 200, 260, 429, 620, 840, 1000, 1700 m depth
Subsamples taken for dissolved Fe, soluble Fe, dissolved Al, dissolved Fe isotopes, dissolved Fe ligands, cellular metals (20, 110 m), and dissolved macronutrients

8). Near-surface Niskin-X collection (2 samplers) using small boat collected at ~13:15 GMT, 20 Aug 2019, near 31°49.476'N, 64°43.838'W (near Spatial Station #1, corresponds to surface sample for cast TM-002); Subsamples taken for particle filtration and cellular metals (from one sampler), dissolved Fe, soluble Fe, dissolved Al, dissolved Fe isotopes, dissolved Fe ligands, dissolved Pb, and dissolved macronutrients (from other sampler)

9). Shallow McLane pump cast for particles, MCL-002
Recovered 17:30 GMT, 20 Aug 2019, at 31°50.595'N, 64°44.150'W (near Spatial Station #1)
Pumps deployed at nominal depths of 30, 110, 150, 260 m

10). Deep McLane pump cast for particles, MCL-003
Recovered 07:30 GMT, 21 Aug 2019, at 31°38.258'N, 64°11.343'W (near BATS)
Pumps deployed at nominal depths of 390, 600, 865, 1000 m

11). TMCTD cast for particles, TMP-003
Recovered 02:54 GMT, 22 Aug 2019, at 31°57.389'N, 64°21.662'W (near Spatial Station #2)
Samples collected at 20, 30, 50, 75, 105, 150, 208, 389, 598, 850, 1000, 1700 m depth
All bottles filtered through 0.4 μm membranes for particles

12). TMCTD cast for dissolved species, TM-003
Recovered 06:43 GMT, 22 Aug 2019, at 31°58.615'N, 64°22.788'W (near Spatial Station #2)
Samples collected at 20, 30, 50, 75, 105, 150, 208, 389, 598, 850, 1000, 1700 m depth
Subsamples taken for dissolved Fe, soluble Fe, dissolved Al, dissolved Fe isotopes, dissolved Fe ligands, cellular metals (20, 105 m), and dissolved macronutrients

13). Shallow McLane pump cast for particles, MCL-004
Recovered 10:44 GMT, 22 Aug 2019, at 31°57.498'N, 64°19.061'W (near Spatial Station #2)
Pumps deployed at nominal depths of 30, 105, 150, 208 m

14). Near-surface Niskin-X collection (2 samplers) using small boat collected at ~11:52 GMT, 22 Aug 2019, near 31°58.678'N, 64°22.834'W (near Spatial Station #2, corresponds to surface sample for cast TM-003); Subsamples taken for particle filtration and cellular metals (from one sampler), dissolved Fe, soluble Fe, dissolved Al, dissolved Fe isotopes, dissolved Fe ligands, and dissolved macronutrients (from other sampler)