Atlantic Behavioral Response Study (BRS): 2018 Annual Progress Report

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Cuvier's beaked whale (*Ziphius cavirostris*) off Cape Hatteras. Photographed by Danielle Waples, taken under National Marine Fisheries Service Scientific Research Permit No. 19903 issued to Andy Read/Duke University.

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Acronyms and Abbreviations

BRS	Behavioral Response Study
CEE	controlled exposure experiment
DAF	Douglas ARGOS filtered
dB re 1 µPa	decibel(s) referenced to 1 micro Pascal
GEE	generalized estimating equation
km	kilohertz
m	meter(s)
MFAS	mid-frequency active sonar
min	minute(s)
NPS	Naval Postgraduate School
ONR	Office of Naval Research
photo-ID	photo-identification
RL	received level
RHIB	rigid-hulled inflatable boat
RMS	root mean square
SD	standard deviation
sec	second(s)
SNR	signal-to-noise ratio
SEA	Southall Environmental Associates
SOCAL	Southern California
SPOT	Smart Position and Temperature
U.S.	United States

Executive Summary

The Atlantic Behavioral Response Study (BRS) project was conceived, designed, and initiated through a collaboration of researchers involved in several of these previous and ongoing studies under the U.S. Navy's Marine Species Monitoring Program , including baseline monitoring of key species such as Cuvier's beaked whales (*Ziphius cavirostris*) and short-finned pilot whales (*Globicephala macrorhynchus*) off the coast of Cape Hatteras, North Carolina. The current project was designed to transition and advance approaches from previous BRS work supported by the Navy's Living Marine Resources program to examine behavioral responses of priority marine mammal species to military sonar off the Atlantic coast for the first time. The Atlantic-BRS project was designed through collaborative planning to develop a prioritized experimental design resulting involving the controlled exposure of multiple individuals to mid-frequency active sonar (MFAS) over using a variety of strategically-deployed tag sensors. The approach employs both short-term, high-resolution acoustic tags and longer-term, coarser resolution satellite-linked location and behavior tags to study responses at different temporal and spatial scales.

Some 2018 field operations were limited by weather, mechanical issues and operational schedules with Navy ships, and limited availability of the simulated MFAS source due to maintenance needs that precluded controlled exposure experiments (CEEs) on multiple occasions. We also experienced substantial failures with DTAGs, losing two tags with data from simulated MFAS CEEs. However, building on the first field season of this project (see: Southall et. al 2018), the 2018 field season was generally quite successful. More satellite tags were deployed on both species, with an unprecedented number of simultaneously tagged beaked whales, some of which were tagged within the same social groups. We also conducted four times as many CEEs (doubling the number of operational Navy ship CEEs) with a comparable increase in exposed-animal events in 2018. Existing analytical approaches are now being applied to these data, with novel integration on different time/space scales. In addition, a new paradigm of spatial analysis has been developed to address errors associated with position estimates from the satellite tags and consequent implications for modeling received noise during CEEs. This approach has improved since 2017, and new approaches are being applied in order to develop a systematic, empirical method of determining which whales should be included in the full received level (RL) and response analyses.

We have completed individual-based analyses of the 2017 beaked whale data in terms of horizontal avoidance and changes in diving behavior. Changes were measured during either the operational or simulated MFAS source in a few individuals. Analyses within individuals of the 2017 pilot whales and all 2018 data are ongoing. Complete analyses across individuals will require additional data from subsequent field efforts. However, given the scenario that occurred in summer 2018 with many simultaneously tagged beaked whales during a period when a Navy ship is available, major progress may be made quickly. From analyses conducted on the 2017 and 2018 data so far, all exposed individuals continued to utilize the study area following CEEs (i.e., there was no obvious large-scale avoidance or abandonment of habitat). We are continuing to analyze potential responses using several methods to investigate subtler potential responses, to the extent possible given the resolution of available data. A number of methodological and analytical lessons learned from 2018 are also described here as they relate to the experimental plans for the 2019 field effort.

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1. Overview

1.1 Overall project design and objectives

The Atlantic Behavioral Response Study (Atlantic-BRS) was developed following extensive planning discussions with researchers and U.S. Navy personnel as well as the transition of research and monitoring methods from the Southern California Behavioral Response Study (SOCAL-BRS) funded primarily by the U.S. Navy's Living Marine Resources (LMR) program, as well as the Office of Naval Research (ONR). For the past two years, a research collaboration of scientists from Duke University, Southall Environmental Associates (SEA), Cascadia Research, and the University of St. Andrews has conducted strategic tag deployments and controlled exposure experiments (CEEs) on beaked and pilot whales off the coast of Cape Hatteras, North Carolina. This collaboration has had unprecedented success in tagging high-priority beaked whales and has conducted CEEs with both operational mid-frequency active sonar (MFAS) systems from Navy surface vessels (e.g. SQS-53C-equipped combat vessels) as well as experimental simulations of these systems. This report describes the objectives, field methods and results, and analyses conducted to date. Most focus here is on field accomplishments from the 2018 field season, although the response analyses conducted largely consider data collected in 2017 (Southall et al 2018) as detailed analyses of the 2018 field data are still ongoing.

Most previous studies have either used short-term, high-resolution tag sensors to measure fine-scale behavior in response to calibrated metrics of experimental noise exposure from acoustic tags or coarser-scale, longer-term measurements of movement and diving during incidental exposures during sonar training operations. This study is unique in bringing both approaches together, building on previous experience with both tag types on these species in this location. Specifically, the overall design involves expanding the temporal and spatial scales of previous BRS efforts by combining short-term, high-resolution acoustic archival tags (DTAGs) and satellite-linked, time-depth recording tags (SLTRDs) simultaneously deployed on multiple individuals of focal species in the same CEEs.

The overall research objective is to provide direct, quantitative measurements of marine mammal behavior before, during, and after known exposures to MFAS signals in order to better describe behavioral response probability in relation to key exposure variables (received sound level, proximity, animal behavioral state). These measurements will have direct implications for and contributions to more informed assessments of the probability and magnitude of potential behavioral responses of these species. They will be directly applicable to the Navy in meeting their mandated requirements to understand the impacts of their MFAS training operations on protected species and to the regulatory agencies in evaluating potential responses within regulatory contexts.

Several key categories of potential behavioral responses are being evaluated, including potential avoidance of sound sources that influence habitat usage, changes in foraging behavior, and changes in social behavior. While the overall experimental approach using CEEs and comparing exposure among conditions before, during, and after noise exposure is common, several methodological parameters (e.g., tag types and configuration settings, nominal target exposure levels) differ slightly among species given known variability in their life history, baseline behavior, and susceptibility to noise exposure. As in previous studies, explicit monitoring and mitigation protocols have been established in conducting and evaluating CEEs in order to meet experimental objectives while ensuring that studies are conducted according to both permit authorizations and ethical standards. Further, these monitoring and experimental objectives, field work dates, and outcomes of these studies thus far have been communicated transparently to interested stakeholders.

1.2 Experimental Design

As discussed extensively in advance planning, there was considerable value identified in maintaining consistency with other BRS projects in the initial experimental design of this project. Given this, and the success in deploying many tags and successfully conducting both real ship MFAS and simulated MFAS CEEs in 2017, few changes were made in the overall design prior to the 2018 field effort. Differences were largely in field configurations, timing of effort, tag settings, etc., rather than changes in experimental design. Such consistency is seen as critical to allow comparisons to be drawn among studies and support the meta-analyses needed to derive dose-response probabilistic functions. The resulting overall design involves multiple different kinds of monitoring methodologies and platforms, with lessons learned from a variety of different research and monitoring programs funded by the Navy. These included quantitative measurements of individual behavior using tags of several types attached to animals, small-boat-based individual and group focal follow observations, targeted collection of individual tissue biopsy samples and photo-identification (photo-ID), and remote passive acoustic monitoring from archival recorders deployed in the general area.

Given the coordination required with Navy combat vessels equipped with SQS-53C sonar systems for BRS efforts off the coast of Cape Hatteras, the overall experimental design was based on the methods employed in the SOCAL (Southern California) BRS using CEEs with both simulated MFAS and operational vessel-based 53C systems (Southall et al. 2012; 2016). This design includes a period during which baseline behavioral data are collected prior to the CEE - a minimum of 60 minutes for animals with DTAGs, and a 24-hour minimum for animals equipped with satellite tags; most baseline data periods were in practice much longer for this tag type. Pre-exposure baseline behavioral data collection primarily involved data from tag sensors, supplemented by focal follows of tagged animals by observers in small boats where possible using methods consistent with those employed in SOCAL.

Sonar transmissions during CEEs occurred in the same manner as in SOCAL-BRS (as in Southall et al. 2012). Simulated MFAS sources were deployed to a 20-meter (m) depth from a drifting (not under power) vessel and operated for a total of 30 minutes (min) at output source levels from 160 to a maximum of 212 decibels (root mean square) referenced to 1 microPascal (dB [RMS] re 1 μPa). Vessels were positioned at ranges from subjects that met experimental objectives (described below). Full scale sources included transmission of full power (235 dB [RMS] re 1 μPa) signals of a constant nominal 53-C waveform type (single ping sequence using two sequential CP/CW waveforms 0.5-second (sec) duration each with 0.1 sec separation for total ping series 1.1 sec duration). Signals were transmitted with a 25 sec repetition rate, using surface duct sector search mode, and 3° downward vertical steering. Transmissions occurred for a total duration of 60 min with the transmitting ship transiting in a direct course at a net (over ground) speed of 8 knots. Based on the position of a focal animal, the starting position and course for the transmitting vessel was determined using custom *in situ* propagation modeling tools using the Navy-consistent models and unclassified databases in software developed and provided by the Naval Postgraduate School (NPS). The course of the vessel was designed to result in an escalation in RL at the presumed location of focal individuals based on their movement, to the extent it is known. This was designed to be generally but not directly toward individuals. Given the large number of tagged individuals exposed during CEEs, individuals had varied MFAS exposure conditions during CEEs in terms of exposure range and received level. Target received levels for the focal animals were increased slightly in 2018 based on the limited responses observed from initial analyses of the 2017 data (which are consistent with more detailed analyses conducted subsequently) ranged from 120 to 160 dB RMS, depending upon species and the aggregate location of focal individuals (120 to 135 dB for beaked whales, 135 to 160 dB for pilot whales). The experimental design allows for positioning of MFAS sources to result in target received levels at focal individuals. However, this resulted in a variety of received levels for other individuals incidentally exposed at positions and ranges that were not explicitly controlled but were known (with error) from positions derived from satellite tags.

Following exposure cessation, monitoring of experimental subjects was maintained. Satellite tags were programmed to continue collecting data consistently for days or weeks following CEEs. Focal animals (particularly for DTAG individuals) were monitored for a further 60 min, employing the same focal animal sampling protocol. At the end of this sampling period post CEEs, attempts to obtain biopsy samples were made for focal individuals as well as potentially other animals in the group. Biopsy samples will be used to determine the sex and reproductive status of the whales and to potentially measure the level stress hormones in exposed whales.

To maximize the chances of successful coordination with Navy ships engaged in training exercises in areas that are several tens to approximately 100 killometers (km) from the study site, the experimental design called for a single CEE within each week. This schedule also addressed the potential for habituation or sensitization of animals within the relatively small area and the relatively infrequent sonar transmissions here, compared other studies which have occurred in training ranges where sonar is used more routinely. The clear priority was to conduct CEEs using operational SQS-53C MFAS sonar systems from actual Navy vessels. The simulated MFAS sonar source is more comparable to operational systems such as helicopter dipping sonars (AN/AQS-13) and is thus more appropriate for comparison with those kinds of systems in terms of response. It was thus clearly identified as secondary priority and was reserved for instances where tagged animals are available, weather conditions support CEEs, but Navy ships were unavailable.

1.3 Overall Analytical Approach

Behavioral response analyses focus on how animals, in this case beaked and pilot whales, change their behavior from baseline conditions during periods of MFAS exposure in known contexts during CEEs. The analytical methods being used directly transition and apply successful methods developed in other BRS studies (with these and related species), with specific questions and methods derived for differences in the nature of available data (tag type) and species in questions. Analyses of behavior and behavioral response for the Atlantic-BRS are designed to consider questions of (a) potential avoidance behavior; (b) potential changes in behavioral state; and (c) potential changes in social behavior. Short- and longer-term consequences of disturbance are initially being evaluated separately using established analytical methods for short- and medium-term tags. However, this study offers a unique opportunity to explore how these methods may complement one another and how high-resolution, short-term response data may inform methods used for longer-term monitoring. The specific data streams collected from different research platforms are given in **Table 1**, with their use in specific ongoing analyses relating to those questions addressed in **Tables 2 and 3** for pilot and beaked whales specifically. We developed these tables based on the overall data processing and analytical objectives in 2017. They are retained in this report as they still have relevance in the overall analytical approach. However, a recently developed set of data processing and analytical modules are also are given subsequently.

Analyses of short-term changes in movement, foraging and social interactions primarily involve analyses of DTAG data, supplemented with focal follow observations where possible, using different methods based on species type. Additional analyses of DTAG data are being conducted to construct informative priors to determine states and inform state-switching analysis of the longer-term satellite-linked tag records within a Bayesian framework. State-switching analysis in beaked whales is more straightforward than in pilot whales, because pilot whales possess a greater suite of behavioral states, making analysis more computationally intense and requiring a hierarchical approach. Analyses of longer-term movement patterns from the satellite tags provide information on the probability of longer-term avoidance (e.g., habitat abandonment) following exposure using metrics such as linearity of movement and residence time. Measures of social cohesion are being conducted in a more limited set of tag deployments where multiple individuals were tagged within a group.

Response variables, such as changes in heading or vocal behavior, are being evaluated with several regression models, including generalized linear (or additive) mixed-effects models and generalized estimating equations (GEEs). Exposure contextual variables include received noise exposure level, range to source, time since exposure, animal behavioral state, and relative movement. Change-point analyses and metrics of response intensities are being considered using individual-based analyses with methods including GEEs, Mahalanobis distance, or more univariate statistical analyses of individual behaviors. State switching models, are being used to examine the probability of changes in behavioral state following exposure (*e.g.*, from foraging to other states).

Different response questions and methods are applied based on tag type and associated data for both tagged pilot and beaked whales (**Tables 2 and 3**, respectively).

Table 1. Data streams collected as part of the Atlantic-BRS experiment and their intended products (see Table 2 for response analysis categories)

Data Stream	Task(s)	Product(s)	Where Used?
DTAGs *In-field processing*	Tag set-up, test files, cal files	Data Archive Summary Sheets	Metadata; Reporting
	Tag deployment/summary sheet with tag lat/long on/off, determine tag duration	Data Archive Summary Sheets	Metadata; Reporting
	Download tag; backup and archive tag data	Raw .dtg files	Raw data
	Create prh file; line up to acoustics	Processed .prh files	Processed data
	Photos of all DTAG animals archived and referenced for future deployments	Photo archives	Photo ID; field recognition, **SI response**
	Quick look acoustic audit – vocalizations	Audit files	Quick look analysis
DTAGs *Post-field processing and analysis*	CEE RL analysis (different metrics) and flow noise file generation	Processed RL and noise files	RLs covariate in **all analyses**; flow noise for speed calculations
	Uncorrected and corrected Pseudotracks	Raw ptrack; corrected ptrack	**HA response**
	Tag deployment quick look reports with dive profiles, pseudotrack, RLs	Data Archive Summary Sheets	Metadata; Reporting
	Full acoustic audit – vocalizations	Audit files	**FB response** **SI response**
	Call counts pre, during and post CEE	Audit files	**SI response**
	Click durations for focal individuals	Audit files	**FB response**
	Acoustic transitions between pre-defined foraging phases	Audit files	**FB response**
	Accelerometry data: depth, pitch, heading, MSA, turning angle pre, during and post CEE, during dives and during phases of dives	Processed prh data (by-dive)	**HA response** **FB response**
	Metrics for dive by dive analysis including: dive depth, dive duration, surface duration, number of buzzes, ascent and descent rates and durations	Processed dive data (by-dive)	**HA response** **FB response**
SAT TAGS *In field processing*	Summary sheets for each tag with all settings and deployment conditions	Data Archive Summary Sheets	Metadata; Reporting
	Archive photos of each sat tagged animal.	Photo archives	Photo ID; field recognition, **SI response**

Data Stream	Task(s)	Product(s)	Where Used?
	Quick look summaries/plots of locations ahead of CEE days to coordinate planning and positioning of Navy ships	Data Archive Summary Sheets	Quick-look analysis Metadata; Reporting
SAT TAGS *Post processing and analysis*	Smoothed X-Y track	Tracks and ARC-GIS plots	Metadata; Reporting **HA response**
	Movement reaction based on source-whale range (avoidance)	Analysis	**HA response**
	Horizontal speed calculations and analysis	Analysis	**HA response**
	Metrics for dive by dive analysis, max depth, duration.	By-individual summary files	Metadata; Reporting; FB analysis
	Time series analysis within and across individuals, state switching	Analysis	**HA response**
	Modelled RL and Acoustic range (source to whale)	Modelled RL and calculated positions	RLs covariate in **all analyses**
Overall Synthesis and Metadata *In field*	Daily across-project log during CEE-possible days, including coordination with ships	Daily Log	Metadata; Reporting
	Synthesis of known or estimated animal positions and planning for CEE locations/coordination	Pre-CEE summary	Metadata; Reporting
	Archive and back-up model runs and parameters used to estimate RLs	Data Archive Summary Sheets	Metadata; Reporting
	Ship tracks and transmission schedule (source log if scaled source)	Data Archive Summary Sheets	Metadata; Reporting
Overall Synthesis and Metadata *Post-processing*	Metadata summary of all CEEs with animal locations and ship tracks	Tracks and ARC-GIS plots	Metadata; Reporting
	Summary of modelled vs. actual RLs for DTAGS; model results for sat tags	RL Summary	Metadata; Reporting; **Response analyses**
FOCAL FOLLOW *In field*	Download data, scribe any spoken tracks, archive field vis obs and vessel track logs	Daily log files	Metadata; Reporting;
	Quick look reports and QA/QC; provide for integration with DTAG data for corrected pseudotracks	Quick look reports	Quick look analysis; Metadata; Reporting;

Data Stream	Task(s)	Product(s)	Where Used?
FOCAL FOLLOW *Post processing and analysis*	GPS data, location/habitat use	GIS maps; data analysis	Metadata; Reporting;
	Bin FF data into time samples	Data analysis	**SI response**
	Movement reaction based on source-whale range	Data analysis	**HA response**
	Metrics for analysis in binned samples: Social behaviour category, group size, distance to nearest other group, defined behaviour categories (spyhop, logging etc…), cohesion	Data analysis	**SI response**
	Covariates for analysis, integrate from other data sources	Data analysis	**SI response**
BIOPSY SAMPLES *In field*	Labelling and storage	Field data	Post Processing
BIOPSY SAMPLES *Post processing and analysis*	Sex id	Data summary	Potential use in **all response analyses**
	Hormones	Data summary	Separate analyses
	Stress, levels pre, and post	Data summary	Separate analyses
PHOTO ID *In field processing*	Compiling, naming, archiving photos	Archived data	Field recognition **SI response**
PHOTO ID *Post processing and analysis*	Grading and matching to existing catalogue	Catalog	Subsequent field recognition
	Group size estimate from photos	Data summary	**SI response**
	Group composition from photos	Data summary	**SI response**
	Individual sighting information	Catalog	Subsequent field recognition

Table 2. Response Questions and Analytical Methods: Pilot Whale Response Analyses

Behavioral Response Questions	Data Collection Method	Specific Metrics	Analytical Methods
Horizontal Avoidance (**HA**)	**DTAGs**	* *Velocity* (vert, horizontal) * *Heading differential* * *Heading variance*	1. **General Estimating Equations** (GEEs); exposure as predictor variable and these response metrics. 2. **Mahalanobis Distance** with these as input variables
	Focal Follows	* Location (range/bearing) to derive *source-animal range*	
	SAT TAGs	* X-Y positions to derive: *source-animal range spatial movements*	1. **Behavioral change-point analysis** of spatial movement 2. **Attraction/repulsion analytics** 3. **Spatial point-process methods**
Changes in Foraging Behavior (FB)	**DTAGs**	* *Depth* * *Buzzes* * *MSA*	1. **State-switching models** 2. **GEEs**; exposure as predictor variable and these response metrics
	SAT TAGs	* *Depth* * *Duration* * *Shape*	1. **GEEs**; exposure as predictor variable and these response metrics 2. **State-switching models**
Changes in Social Interactions (SI)	**DTAGs**	* *Call rates*	1. **General Linear Models** (GLM) 2. **GEEs**; exposure as predictor variable and these response metrics
	Focal Follows	* *Lat/lon position* * *Focal animal speed* * *Group size* * *Group spread* * *Surface synchrony* * *Heading synchrony* * *Behavioral state/activity*	
	SAT TAGs	* *Inter-animal distance*; only for animals tagged in same group	1. **Group Dynamic Movement Models** (Langrock et al., Hanks et al.)

Table 3. Response Questions and Analytical Methods: Beaked Whale Response Analyses

Behavioral Response Questions	Data Collection Method	Specific Metrics	Analytical Methods
Horizontal Avoidance (**HA**)	**DTAGs**	* *Velocity* (vert, horizontal) * *Heading differential* * *Heading variance*	1. **General Estimating Equations** (GEEs); exposure as predictor variable and these response metrics. 2. **Mahalanobis Distance** with these as input variables
	Focal Follows	* Location (range/bearing) to derive *source-animal range*	
	SAT TAGs	* X-Y positions to derive: *source-animal range* *spatial movements*	1. **Behavioral change-point analysis** of spatial movement 2. **Attraction/repulsion analytics** 3. **Spatial point-process methods**
Changes in Foraging Behavior (FB)	**DTAGs**	* *Depth* * *Clicks* * *MSA*	1. **State-switching models** 2. **GEEs**; exposure as predictor variable and these response metrics
	SAT TAGs	* *Depth* * *Duration* * *Shape*	1. **GEEs**; exposure as predictor variable and these response metrics 2. **State-switching models**
Changes in Social Interactions (SI)	**Focal Follows**	* *Lat/lon positions* * *Group size* * *Diving synchrony*	1. **General Linear Models** (GLM) 2. **GEEs**; exposure as predictor variable and these response metrics
	SAT TAGs	* *Inter-animal distance*; animals tagged in group	1. **Group Dynamic Movement Models**

Building on these data processing and analysis descriptions, we subsequently developed a series of data processing and analysis modules as flow chart diagrams to better illustrate the complex and inter-related processes being utilized in the Atlantic-BRS project. These include an overall flowchart of the data processing and analysis procedures (called 'modules') (**Figure 1**), as well as a field data processing module (**Figure 2**), sat tag data processing module (**Figure 3**), DTAG data processing module (**Figure 4**), and a diving behavioral response module (**Figure 5**).

Figure 1. Overall flowchart of Atlantic-BRS data processing and analysis procedures

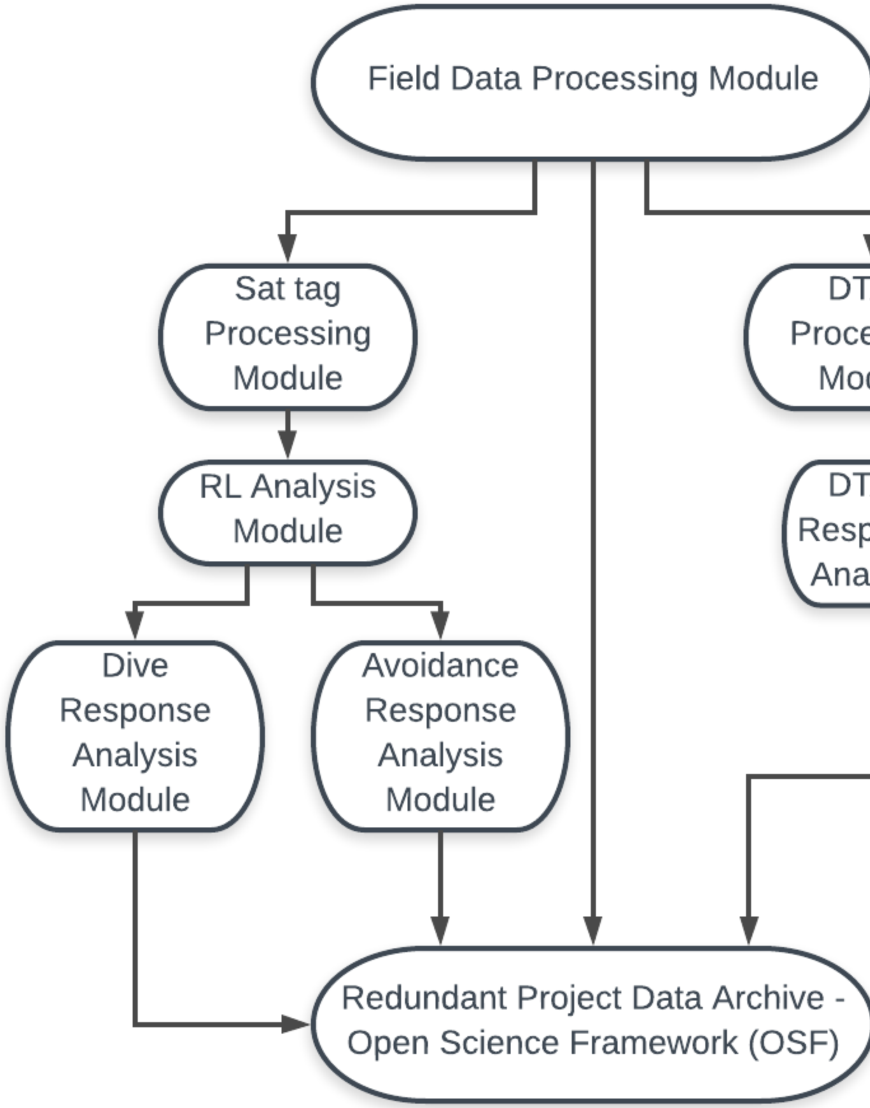


Figure 2. Atlantic-BRS field data processing module

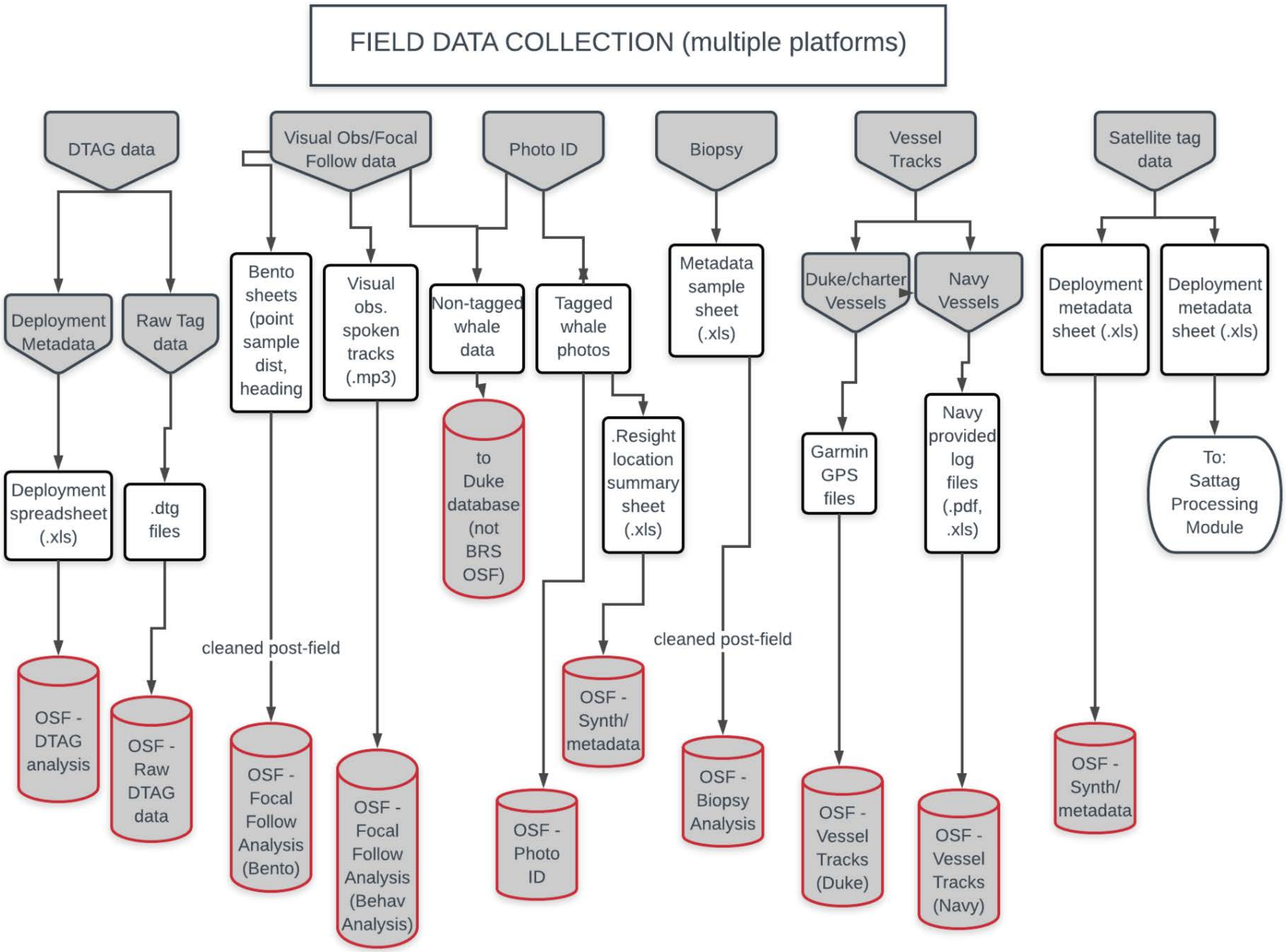


Figure 3. Atlantic-BRS sat tag data processing module

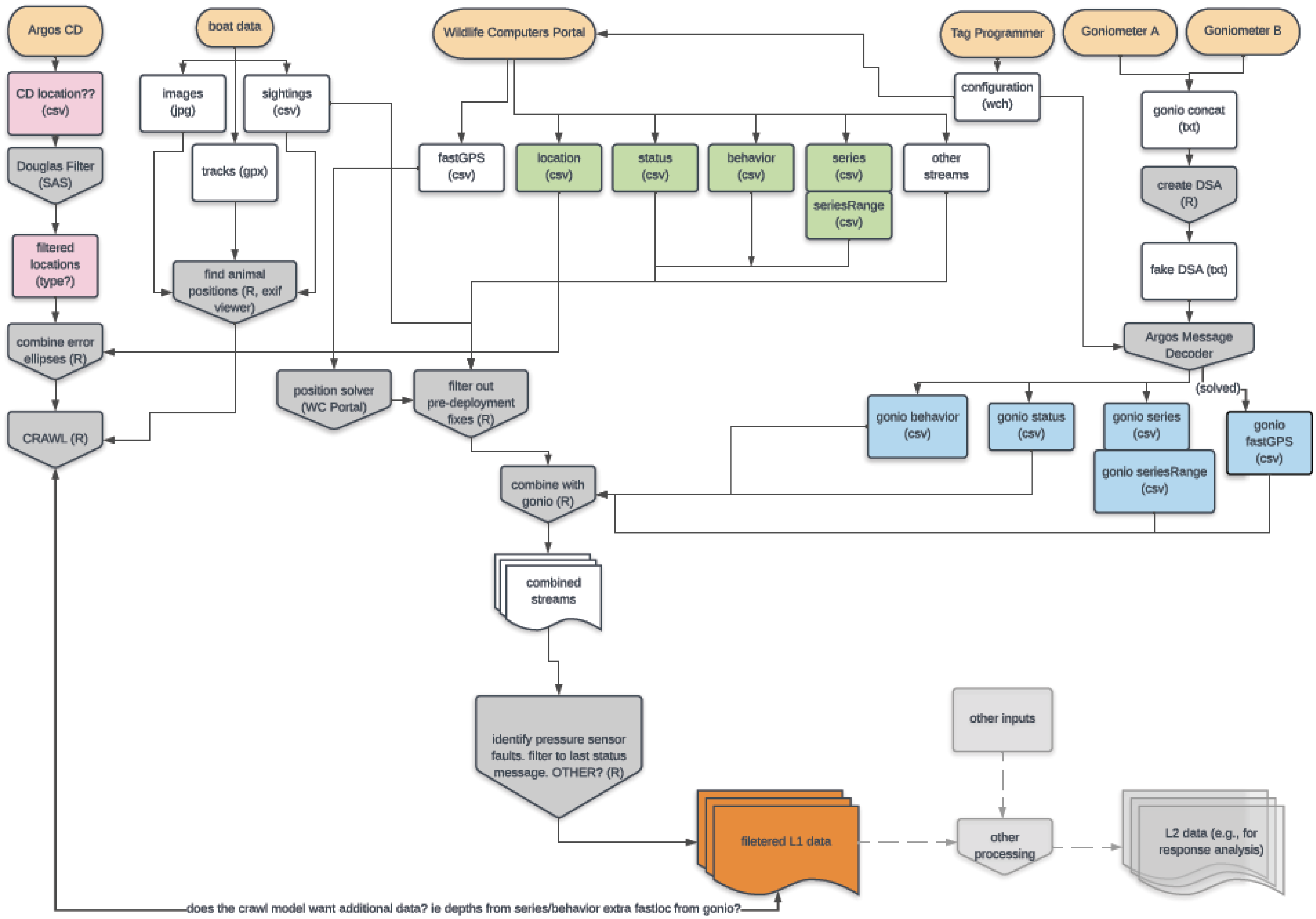


Figure 4. Atlantic-BRS DTAG data processing module

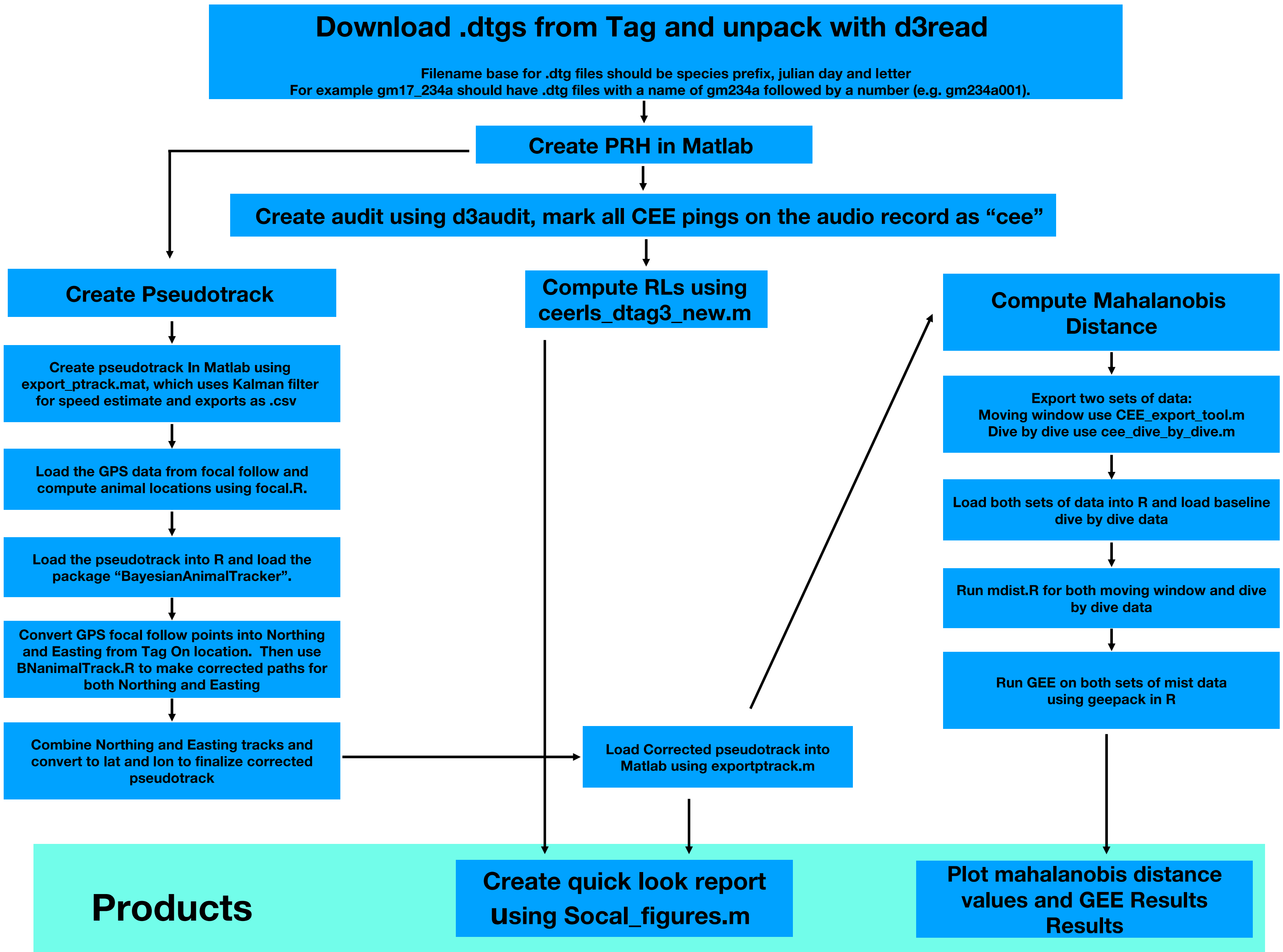
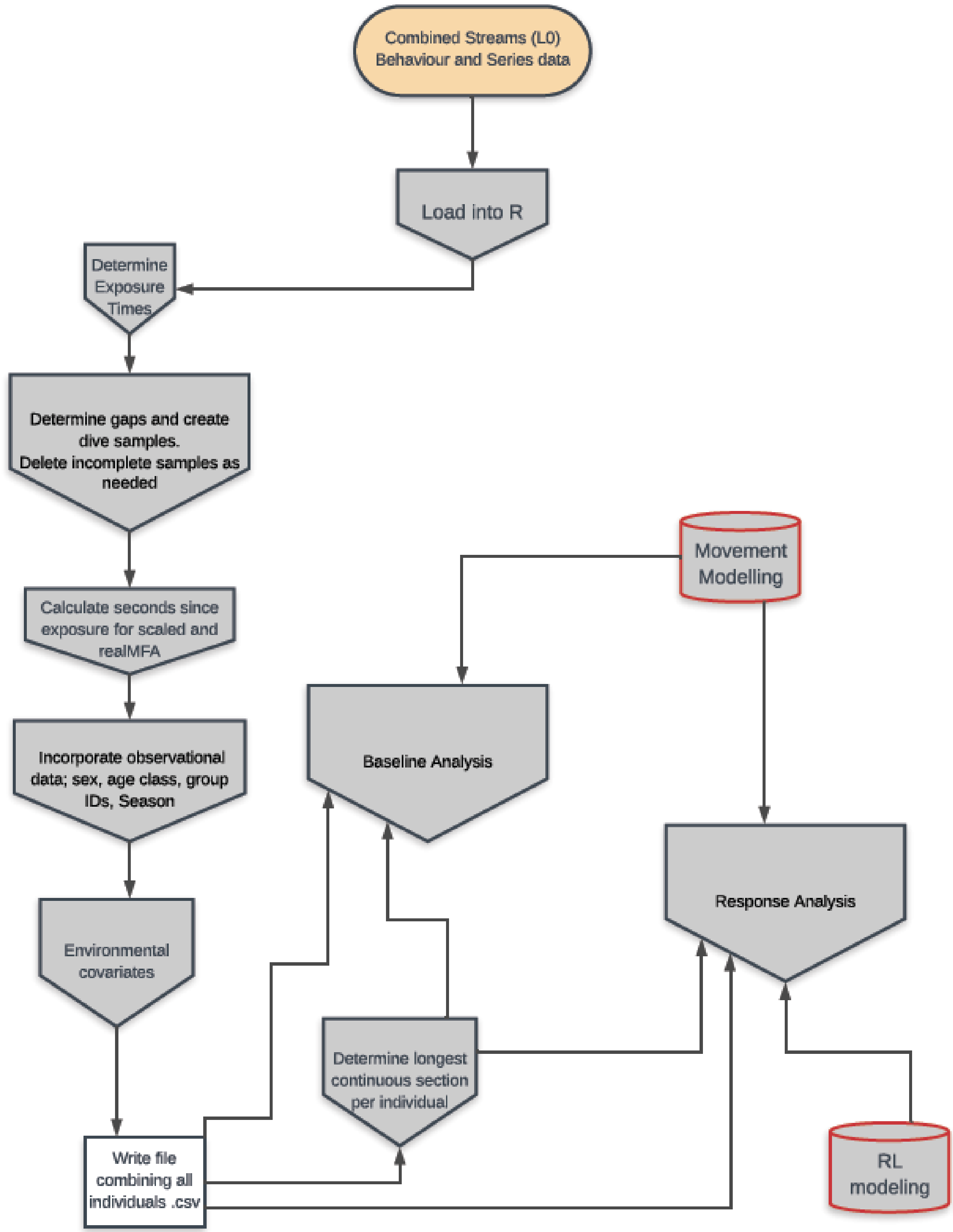


Figure 5. Atlantic-BRS diving behavioral response module



1.4 Field Logistics and Configuration

The 2018 Atlantic-BRS field effort consisted of a spring (May-June) and summer (August) field campaign. The second period was shifted from September based on lessons learned from the 2017 field effort. This proved beneficial because several major tropical storms and hurricanes occurred at the study site in September 2018.

Each field period had an initial phase focusing on advance deployment of satellite tags followed by a more intensive, larger team effort during periods when Navy ships were potentially available during which deployment of either satellite tags or DTAGs were attempted and CEEs were conducted. Satellite tags were deployed from the R/V *Barber* during several weeks prior to the onset of CEE efforts during both phases, as well as several tagging efforts between CEEs. The field team for this portion of the project included four individuals from Duke, Cascadia, and (for the summer effort) HDR, who collectively located animals, positioned the boat for tagging, deployed the tags, and collected photo-ID and other data from groups. The *R/V Barber* is an 8 m aluminum-hulled SAFE boat capable of handling heavy seas and transited offshore on a daily basis on days when sea conditions were suitable for locating and tagging animals.

During periods in which DTAG deployments and CEEs were attempted, a research crew of 10 individuals was involved and worked from three vessels: (1) the R/V *Barber* (with an identical crew of four); (2) a second (6 m) rigid-hulled inflatable boat (RHIB) (R/V *Exocetus*) with a crew of three (driver, tagger, and visual observer) that either ran out from Oregon Inlet or was based from an offshore vessel; and (3) a third offshore research platform (predominately the *F/V Kahuna* but in some instance the *F/V Hog Wild*, both based out of Manteo, North Carolina) that housed the simulated sound source, provided and additional tracking and visual observation platform, and supported three additional personnel (one chief scientist, one visual observer/radio tracker, and one DTAG field technician that served as an additional visual observer and conducted DTAG tracking/recovery).

In terms of tag sensors, two types were deployed, short-term, high resolution archival acoustic and movement tags (DTAGs) and depth-transmitting satellite tags. Five version 3 DTAGs from the University of Michigan were obtained through a lease agreement for each period of Navy ship availability and were returned for servicing between each of the two field periods. A total of 33 Low-Impact Minimally Percutaneous Electronic Transmitter (LIMPET) satellite-linked tags were available, with a target of deploying 15 in each of the two field periods. Priority was placed (given the interest in feeding and diving behavior) in the use of SPLASH10-A depth transmitting tags; almost all tags available were of this type with a small number of SPLASH-10F tags that reported fastloc GPS positions but lacked depth transmissions. The initial tagging priority was on Cuvier’s beaked whales as this species is of high Navy interest, but is more challenging to tag. Pilot whales were tagged with a secondary priority and nearer to the beginning of the first CEE period. Efforts were made to deploy multiple tags in social groups of either species, in order to evaluate potential changes in social associations as a response metric during CEEs. Substantial progress was made in this regard, as is discussed.

Considerable advance planning and coordination was conducted to ensure effective communication between the field team conducting tagging operations and planning CEEs with Navy field operations. This included extensive and sustained planning discussions between the

Atlantic-BRS team and Navy representatives, evaluating and applying lessons-learned in terms of field communications and coordination from previous research and operational experience. Communication protocols with redundancies and regular contact periods were developed with designated Navy representatives, with logistical, operational, and communication approaches leveraging protocols developed in the SOCAL-BRS project. The research team coordinated before, during, and after the field effort through designated representatives, including regular updates and communication, as well as quick look summaries following field operations.

Finally, the research team undertook several measures to openly and transparently communicate research plans and objectives externally. This included presentations of research objectives, experimental and monitoring protocols, and initial 2017 results at the U.S. Navy's marine species monitoring program technical review meeting held in San Diego in spring 2017, and a scientific presentation by chief scientist B. Southall at the Effects of Sound on Marine Mammals (ESOMM) conference in September 2017. Duke also provided direction regarding research plans and established lines of communication in the unlikely event of any marine mammal stranding occurring during operations with representatives from the Mid-Atlantic Marine Mammal Stranding Network. We provided summary information during and following research activities, as appropriate, through participating research organizations. Results will continue to be presented in open scientific and public meetings, as well as peer-review publications.

2. Field Effort

2.1 Summary of 2018 Field Effort: Accomplishments and Assessment

PHASE I (SPRING 2018)

Field dates:

- **1–14 May 2018**: Shore-based satellite tag deployment effort (two field days with suitable conditions for tagging) from *Barber.*
- **15–31 May**: Satellite tag and DTAG effort with multiple simulated MFAS CEEs with both focal species and tag types; Navy ships unavailable.
- **3–5 June**: Successful operational Navy ship 53C MFAS CEE conducted with *USS NITZE* involving 12 satellite-tagged whales of both species and multiple re-sights of tagged focal whales following CEE.
- **6–8 June**: Additional satellite tag data post-exposure and photo-ID re-sight collection and additional DTAG deployments with one control CEE
- **13–16 June**: Successful operational Navy ship 53C MFAS CEE conducted with *USS RAMAGE* involving 12 satellite tagged whales of both species and multiple re-sights of tagged focal whales following CEE. This was later vessel availability than planned and several tags were only reporting partial data during this period.

Accomplishments:

- Successful deployment of 12 of a possible 15 satellite tags (2 beaked whales; 10 pilot whales).
- Two successful CEEs with operational Navy vessels. The first was coordinated directly with a delegate for the BRS project on board, but the second CEE was coordinated with the vessel remotely via secure communications from shore.
- Seven DTAGs deployed on pilot whales. Three of these were focal whales in simulated MFAS CEEs or controls, however two of these were lost due to a combination of tag detachment and VHF transmitter failures. Substantial effort was expended to relocate tags, including aerial searches, but they were not recovered.
- First successful deployment of a DTAG on a simultaneously satellite-tagged whale; DTAG detached before CEE, but this was a major accomplishment we had been trying hard to achieve and bodes well for future efforts.
- Improved and expanded efforts to relocate sat-tagged animals in the field using goniometer detections. This significantly increases chances of subsequent tag deployments, improves animal pseudotracks by providing high confidence surface locations, and results in many photo-ID resights to evaluate group composition and social interactions.

- Progress in tag deployment strategies to reduce/eliminate gaps in satellite tag data and to improve temporal resolution on diving and behavioral data; several deployments of fastloc tags on pilot whales to improve positional accuracy.

Assessment of field approach:

- Weather was typical overall for May-June; several excellent periods, many workable days, some blown out days, and a number of marginal condition days where just relocations of previously tagged animals was possible.
- Animal sightings: Generally good; groups of both focal species in target areas but fewer beaked whale sightings in good tagging conditions than in summer effort.
- RHIB operations worked well and as expected. Multiple goniometers substantially improved field operations.
- DTAG issues were limiting and resulted in the loss of focal whale data for two CEEs. Considerable time and effort was also spent in diagnosing problems and chasing wayward tags.
- Problems with the simulated MFAS source were experienced with the first CEE and continued throughout this field effort, although two more CEEs were conducted.
- Navy ship availability was the best for any phase of the project to date. Both ships were available as scheduled and participated successfully and provided source transmission and XBT data after field effort as requested.

PHASE II (SUMMER 2018)

Field dates:

- **5–7 August 2018**: Shore-based satellite tag deployment effort from R/V *Barber* that was three of the most amazing days ever off Hatteras or anywhere for tagging beaked whales. There were 11 (!) Cuvier's beaked whales and five pilot whales tagged during this pre-CEE tagging period with strategically different series and behavioral log settings and several fastloc tags.
- **8–14 August**: Resights and photo ID of satellite tagged whales; Navy ships unavailable.
- **15 August**: Successful DTAG deployment, control sequence, and recovery; real ship and simulated MFAS source unavailable.
- **16–25 August**: Resights and photo-ID of satellite tagged whales.
- **26–29 August**: Satellite tag and DTAG deployments and successful simulated MFAS source CEE and follow up resights.

Accomplishments:

- Successful deployment of 19 of a possible 19 satellite tags (11 beaked whales; 8 pilot whales).
- Successful deployment and recovery of two DTAGs (both pilot whales).

- Successful completion of one simulated MFAS source CEE and one control CEE.
- Continued improvement and effort in relocating tagged whales for resights, photo-ID, and group composition.
- Major new insights into adaptive tuned tag programming settings to increase dive resolution during specified focal periods.
- Major new insights into social behavior of Cuvier's beaked whales, with implications for response analyses.

Assessment of field approach:

- Decisions to move summer effort earlier to avoid September were appropriate. Very good conditions occurred during several windows with workable weather at least for re-sight detections on most days in August. Major storms were experienced in the area in September.
- Continued high degree of success with locating and tagging beaked whales. Thanks to a high density of animals and skilled field teams, very high rates of tag deployments per field day continue to be achieved, including the most productive string of days ever for this species.
- The lack of either real ships or the simulated source due to repair delays during this unique period with so many tagged whales was very unfortunate. A large amount of baseline and social behavioral data was collected which will is being used in a number of ways to quantify baseline parameters and interpret subsequent responses to disturbance.

2.2 Tag deployments

Satellite tag deployments were conducted by researchers from Cascadia and HDR in coordination with the Atlantic-BRS. Details regarding the tag configurations, deployments, and baseline data collected from these tags is provided in Baird et al. 2019. A summary of the tag deployments completed during the periods within the overall Atlantic-BRS effort is provided here for individuals of both species. Overall, 31 satellite tags were deployed - 13 on Cuvier's beaked whales and 18 on pilot whales (**Tables 4, 5**).

Nine DTAGs were also deployed on pilot whales during the 2018 field effort (seven during phase I and two during phase II; see **Table 6**). Deployments included the first successful full deployment on a simultaneously satellite tagged animal (Gm18_157a was the same animal as GmTag205), although this was a brief (< 1h) deployment and did not involve a CEE. Another DTAG individual (Gm18_145a) was in the same group as a satellite tagged whale (Gm197) during a simulated MFAS CEE (18-02). Two DTAGs were lost due to tag release and/or VHF failures, both unfortunately containing data from complete simulated MFAS sequences (CEEs 18-02 and 18-03). Two DTAGs were successfully deployed and recovered following complete control CEEs (18-05 and 18-07). One DTAG was successfully deployed and recovered following a complete simulated MFAS CEE sequence (18-08). Quick look summaries of DTAG results during successful CEEs are provided within respective sub-sections of Section 2.3. Baseline diving behavior from DTAG deployments during non-CEE periods is given in Section 2.4.

Table 4. Satellite tag deployments during Atlantic-BRS field efforts for Cuvier's beaked whales in 2018

Species[1]/ Tag ID	Sex/age class	Deployment date	Sighting #	Deploy. latitude (°N)	Deploy. longitude (°W)	Depth at tagging location (m)	Other data streams	Tag duration (days)
ZcTag069	Adult Male	5/24/18	5	35.69	74.78	748	time series	38.90
ZcTag070	Adult Male	5/25/18	1	35.54	74.77	977	behavior	12.52
ZcTag071	Adult Male	8/5/18	9	35.73	74.78	1,031	none	34.33
ZcTag072	Adult Male	8/5/18	9	35.72	74.78	985	time series	42.91
ZcTag073	Adult Male	8/5/18	14	35.55	74.75	1,232	time series	43.63
ZcTag074*	Adult Male	8/6/18	4	34.47	74.77	N/A	N/A	0
ZcTag075	Adult Male	8/6/18	4	35.48	74.78	780	time series	41.38
ZcTag076	Adult Male	8/6/18	4	35.47	74.78	872	behavior	41.78
ZcTag077	Adult Male	8/6/18	6	35.51	74.75	1,181	FastGPS	23.72
ZcTag078	Adult Male	8/6/18	7	35.57	74.74	1,240	behavior	23.23
ZcTag079	Adult Female/Sub-adult Male	8/7/18	1	35.57	74.78	563	time series	43.32
ZcTag080	Adult Male	8/7/18	3	35.56	74.78	513	time series	43.81
ZcTag081	Sub-adult Unknown	8/7/18	3	35.59	74.75	1,124	time series	57.34

[1]Zc = *Ziphius cavirostris*, m=meter(s), *tag failed on impact, N/A = not applicable

Table 5. Satellite tag deployments during Atlantic-BRS field efforts for pilot whales in 2018

Species[1]/ Tag ID	Sex/age class	Deployment date	Sighting #	Deploy. latitude (°N)	Deploy. longitude (°W)	Depth at tagging location (m)	Other data streams	Tag duration (days)
GmTag197	Adult Male	5/11/18	2	35.69	74.78	695	behavior	27.03
GmTag198	Adult Male	5/22/18	1	35.73	74.79	814	FastGPS/behavior	19.53
GmTag199	Adult Female/Sub-adult Male	5/24/18	1	35.64	74.76	768	behavior	7.59
GmTag200	Adult Female/Sub-adult Male	5/24/18	6	35.76	74.80	754	FastGPS/behavior	11.30
GmTag201	Adult Female/Sub-adult Male	5/30/18	3	35.79	74.79	1,056	behavior	27.50
GmTag202	Adult Female/Sub-adult Male	5/30/18	6	35.62	74.79	1,235	behavior	25.63
GmTag203	Adult Female/Sub-adult Male	5/31/18	4	35.93	74.77	520	behavior	17.39
GmTag204	Adult Female/Sub-adult Male	5/31/18	4	35.93	74.78	455	behavior	30.17
GmTag205	Adult Male	5/31/18	5	35.92	74.78	604	FastGPS/behavior	27.28
GmTag206	Adult Female/Sub-adult Male	5/31/18	5	35.92	74.79	618	behavior	31.56
GmTag207	Adult Male	8/5/18	4	35.74	74.82	289	behavior	10.23
GmTag208	Adult Female/Sub-adult Male	8/5/18	5	35.75	74.82	339	FastGPS	10.54
GmTag209*	Adult Female/Sub-adult Male	8/6/18	2	35.49	74.73	N/A	N/A	0
GmTag210	Adult Male	8/6/18	3	35.48	74.75	1,173	behavior	20.50
GmTag211	Adult Female/Sub-adult Male	8/6/18	3	35.48	74.75	1,196	behavior	18.00
GmTag216	Adult Male	8/26/18	1	35.61	74.79	498	behavior	13.02
GmTag217	Adult Male	8/26/18	2	35.61	74.79	462	behavior	27.49
GmTag218	Adult Male	8/26/18	4	35.66	74.78	464	behavior	21.69

Gm = *Globicephala macrorhynchus*; m=meter(s); *Tag gone shortly after deployment, likely due to a conspecific interaction; FastGPS=Fastloc-GPS locations

Table 6. DTAG deployments during Atlantic-BRS field efforts for pilot whales in 2018

Tag ID	Deployment date	Deploy. latitude (°N)	Deploy. longitude (°W)	Baseline or CEE number	Tag duration (hours)	Recovered?
Gm18_145a*	5/25/18	35.69	74.75	CEE 18-02	n/a	No
Gm18_150a	5/30/18	35.83	74.83	Baseline	n/a	No
Gm18_150b	5/30/18	35.85	74.81	CEE 18-03	n/a	No
Gm18_157a**	6/6/18	35.57	74.75	Baseline	1.2	Yes
Gm18_157b	6/6/18	35.59	74.76	CEE 18-05	3.2	Yes
Gm18_159a	6/8/18	35.66	74.80	Baseline	0.8	Yes
Gm18_159b	6/8/18	35.63	74.79	Baseline	0.6	Yes
Gm18_227a	8/15/18	35.74	74.81	CEE 18-07	4.3	Yes
Gm18_239a	8/27/18	35.85	74.80	CEE 18-08	2.5	Yes

* In group with GmTag 197 during CEE 18-02

** Same individual as GmTag205

2.3 CEEs Conducted

During the Atlantic-BRS 2018 field effort, eight CEE sequences were conducted. The CEE identifier numbers, dates, CEE type, and “focal” individuals (note: many other individuals were also exposed) are given in **Table 7**.

Table 7. CEEs conducted during Atlantic-BRS field efforts

CEE ID	Date	CEE Type	Focal whales	CEE duration (min)	CEE source latitude (°N) at CEE start	CEE source longitude (°W) at CEE start
18-01	5/15/18	Simulated MFAS	Gm197	30	35.90	74.79
18-02	5/25/18	Simulated MFAS	Gm18_145a; Gm197	30	35.66	74.74
18-03	5/30/18	Simulated MFAS	Gm18_150b	30	35.88	74.81
18-04	6/3/18	Real MFA (*USS NITZE*)	Zc69; Zc70; Gm198; Gm201; Gm202	60	35.85	74.36
18-05	6/6/18	Silent Control	Gm18_157b	30	35.60	74.77
18-06	6/13/18	Real MFA (*USS RAMAGE*)	Zc69; Gm203; Gm204; Gm205	60	35.82	74.74
18-07	6/8/18	Silent Control	Gm18_227a	30	35.75	74.79
18-08	8/15/18	Simulated MFAS	Gm18_239a	30	35.84	74.79

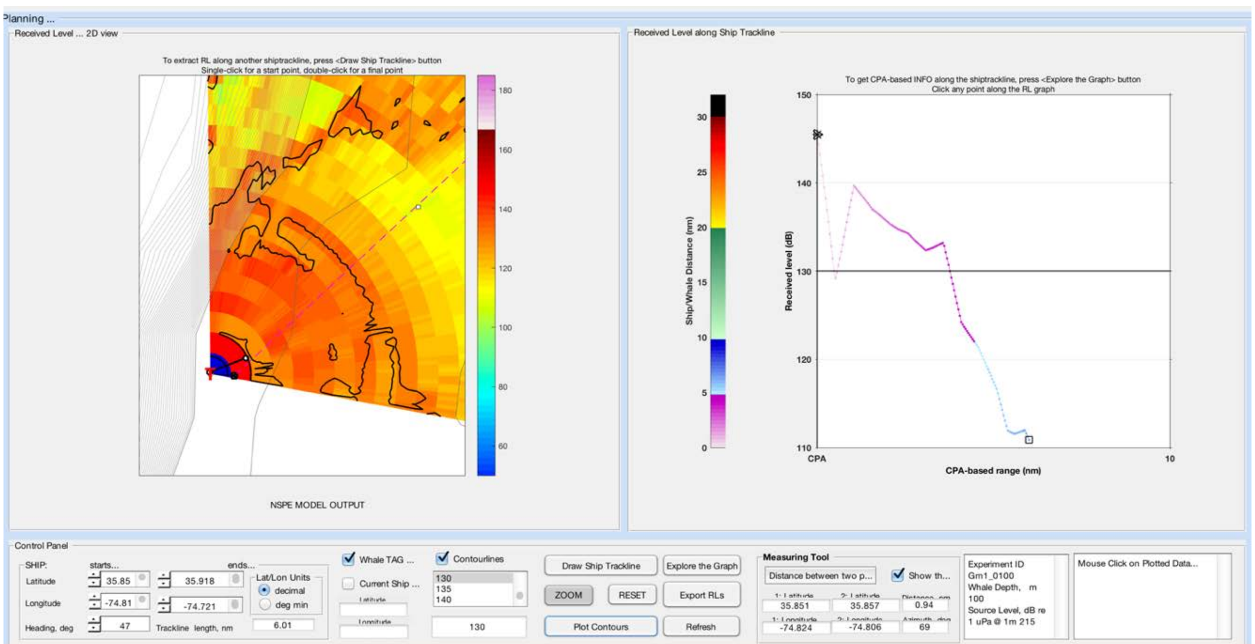
Subsequently, we provide a synthesis of each CEE conducted with standardized tables and figures for each including: (1) metadata summaries; (2) planning RL modeling (where applicable), (3) modeled positions from satellite tag locations for individuals exposed during each CEE using several methods; and (4) dive records for satellite tagged whales during CEEs; and (5) DTAG quicklook summaries for applicable CEEs (Sections 2.3.1 through 2.3.8). A brief description of each standardized figure type is provided within Section 2.3.1, which is applicable for all subsequent figures of the same type. Figures are provided for all individuals where tags reported sufficient data during CEE periods. In some instances, gaps in data reporting occurred or tags had ceased to report data of a particular type (e.g., dive data) but were still reporting other types (e.g., ARGOS positions) based on how tags were strategically set up based on expectations of CEE timing.

2.3.1 CEE #18-01: Simulated MFAS

Table 8. Metadata summary for Atlantic-BRS CEE# 18-01

CEE Conditions	Metadata Summary
CEE Identifier	**18-01**
Date	**5/15/18**
Type	**Simulated MFAS** from 15-element vertical line array projecting deployed to 20 m depth from *F/V Kahuna* (stationary)
Signal Parameters	Three-segment (1.2 s total duration) pings (3.5–4 kilohertz [kHz]); 212 dB re 1 µPa (RMS) sound pressure level; 25 s repetition rate
Start time (UTC)	14:20:45
Start lat/lon	35.89841; -74.79169
End time (UTC)	14:50:45
End lat/lon	35.90507; -74.78449
Beaked whales monitored with tags during CEE	None
Pilot whales monitored with tags during CEE	**Gm197 (focal)**

Figure 6. RL model prediction at 100 m depth for focal whale Gm197 for Atlantic-BRS CEE# 18-01



NOTE: These RL model prediction plots were generated using the Naval Postgraduate School (NPS) sound propagation tool used in the field to estimate received levels for animals at known/estimated tag location (T) with a MFAS source positioned at a strategic location (small white circle in left plots). Right panels show modeled RLs at different positions along tracks. For simulated MFAS CEEs (as here) where the source is not moving under power (drifting), this is indicated as the closest point of approach for the model estimate. Model runs are shown for different focal animals (where appropriate) and different animal depths in the water column, based on species and location differences.

Figure 7. RL model prediction at 500 m depth for focal whale Gm197 for Atlantic-BRS CEE# 18-01

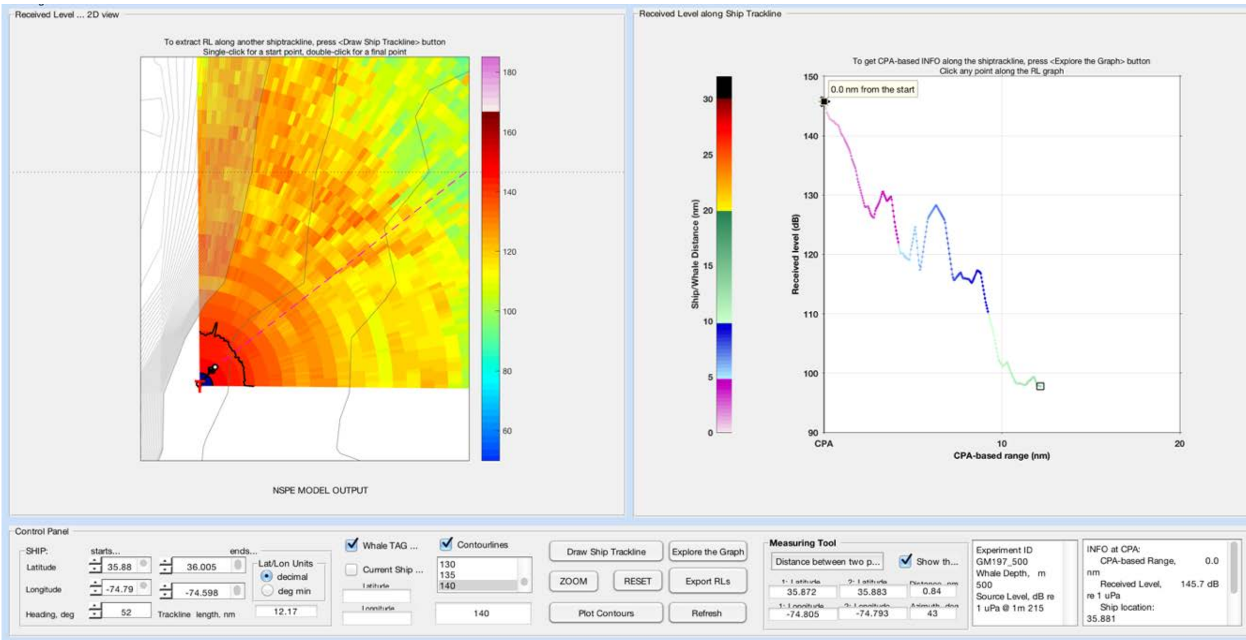
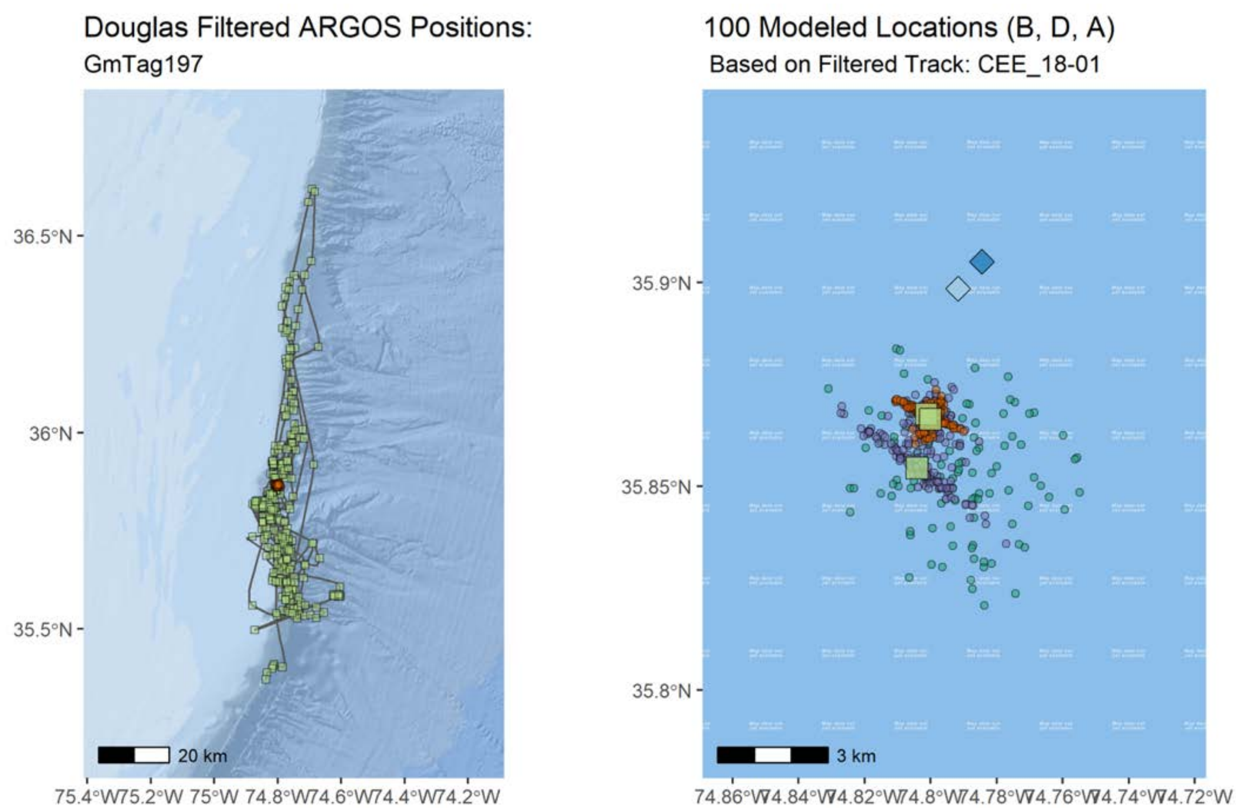
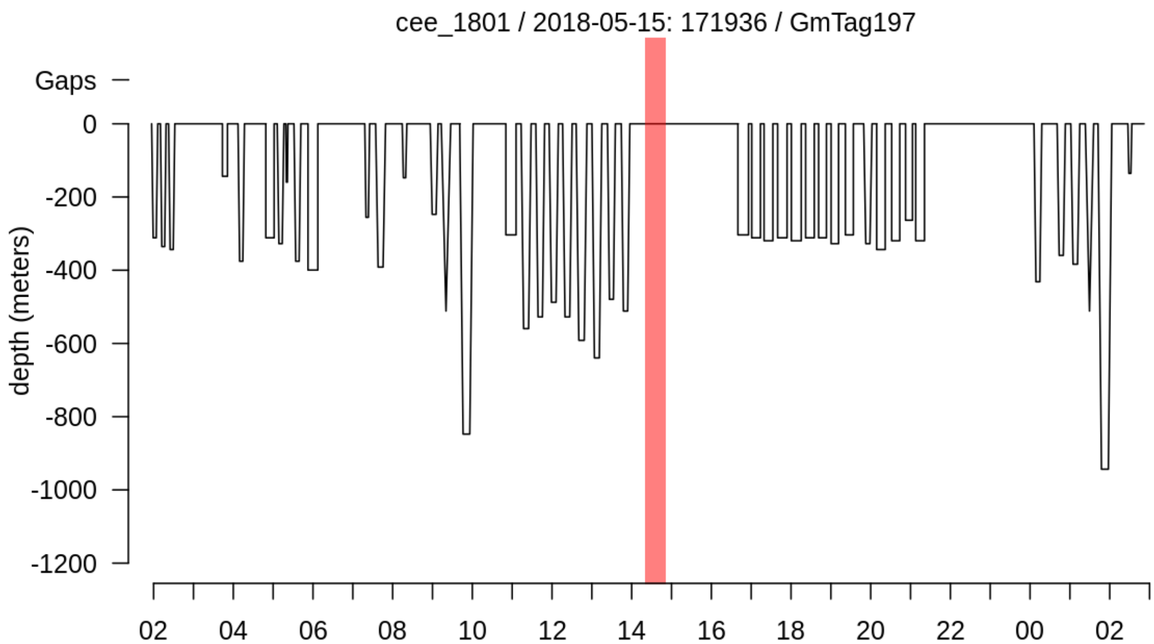


Figure 8. Estimated surface positions for focal whale Gm197 before, during, and after Atlantic-BRS CEE# 18-01



NOTE: These plots have two panels for each individual specific to each CEE. Left panels show modeled animal locations from both Douglas ARGOS filtered (DAF) tracks with the location along the entire track (in green squares) during the respective CEE indicated with track imputations during the CEE indicated along this track shown as orange dots. Right panels show modeled locations from 100 imputed tracks based upon the simple DAF track corrected with surface locations to better account for spatial error in the underlying data. Locations of the MFAS sound source are shown as diamonds, with pale blue representing locations at the start of CEEs and darker blue indicating ending locations. The 100 positions for each imputed track are shown one hour before CEEs (green dots), at the start of CEEs (orange dots), and one hour after CEEs (purple dots); yellow squares indicate the single DAF track location during each respective phase.

Figure 9. Available dive data for focal whale Gm197 before, during, and after Atlantic-BRS CEE# 18-01



NOTE: These plots illustrate dive data for days during which CEEs occurred. Time (in GMT, which is +4 hours from EDT during CEE periods) is indicated on the x-axis, with depth indicated on the y-axis). CEE periods are indicated as red bars. It should be noted that differential temporal resolution in available dive data across these figures are evident for tags with different time series settings. It should also be noted that based on these settings, some tags ceased reporting dive data during some CEEs but were still reporting ARGOS position estimates.

2.3.2 CEE #18-02: Simulated MFAS

Table 9. Metadata summary for Atlantic-BRS CEE# 18-02

CEE Conditions	Metadata Summary
CEE Identifier	18-02
Date	5/25/18
Type	Simulated MFAS from 15-element vertical line array deployed to 20 m depth from *F/V Kahuna* (stationary)
Signal Parameters	Three-segment (1.2 s total duration) pings (3.5–4 kHz); 212 dB re 1 µPa (RMS) sound pressure level; 25s repetition rate
Start time (UTC)	16:33:00
Start lat/lon	35.66087; -74.73924
End time (UTC)	17:03:00
End lat/lon	35.66393; -74.73707
Beaked whales monitored with tags during CEE	Incidental: Zc69, Zc70
Pilot whales monitored with tags during CEE	Focal: Gm18_145a (DTAG not recovered) and Gm197 (in group with Gm18_145a) Incidental: Gm198, Gm199, Gm200

Figure 10. RL model prediction at 10 m depth for focal whales Gm18_145a and Gm197 (within same social group) for Atlantic-BRS CEE# 18-02

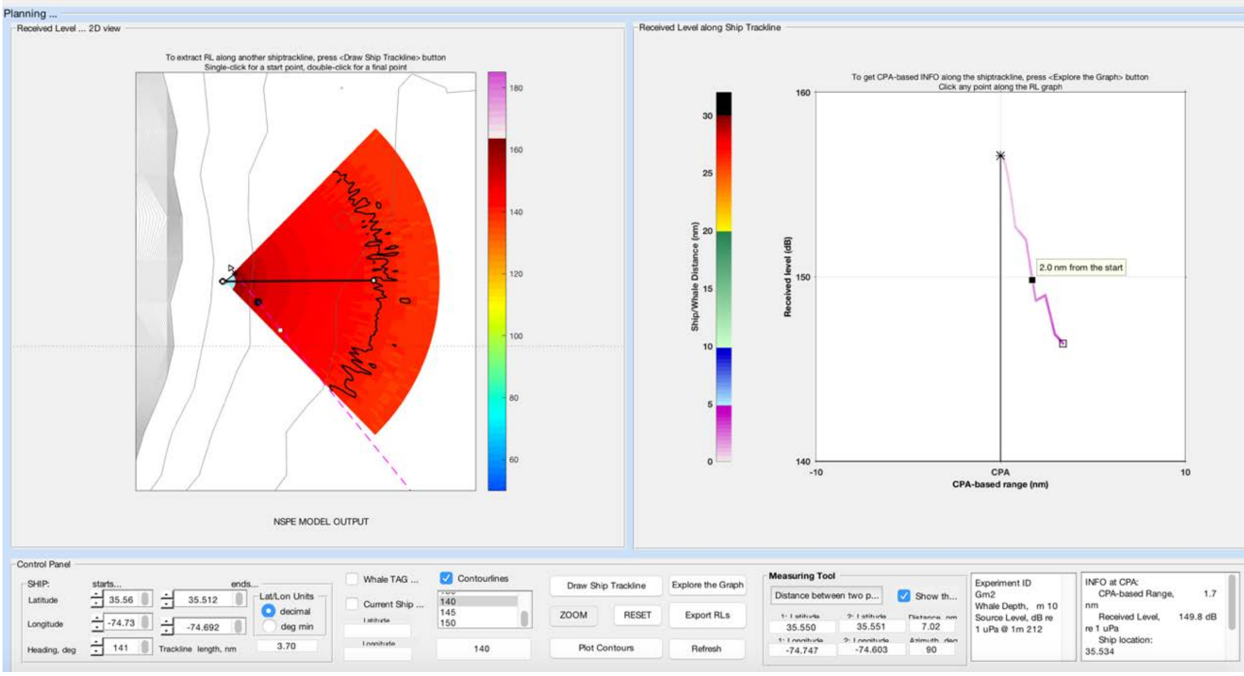


Figure 11. RL model prediction at 500 m depth for focal whales Gm18_145a and Gm197 (within same social group) for Atlantic-BRS CEE# 18-02

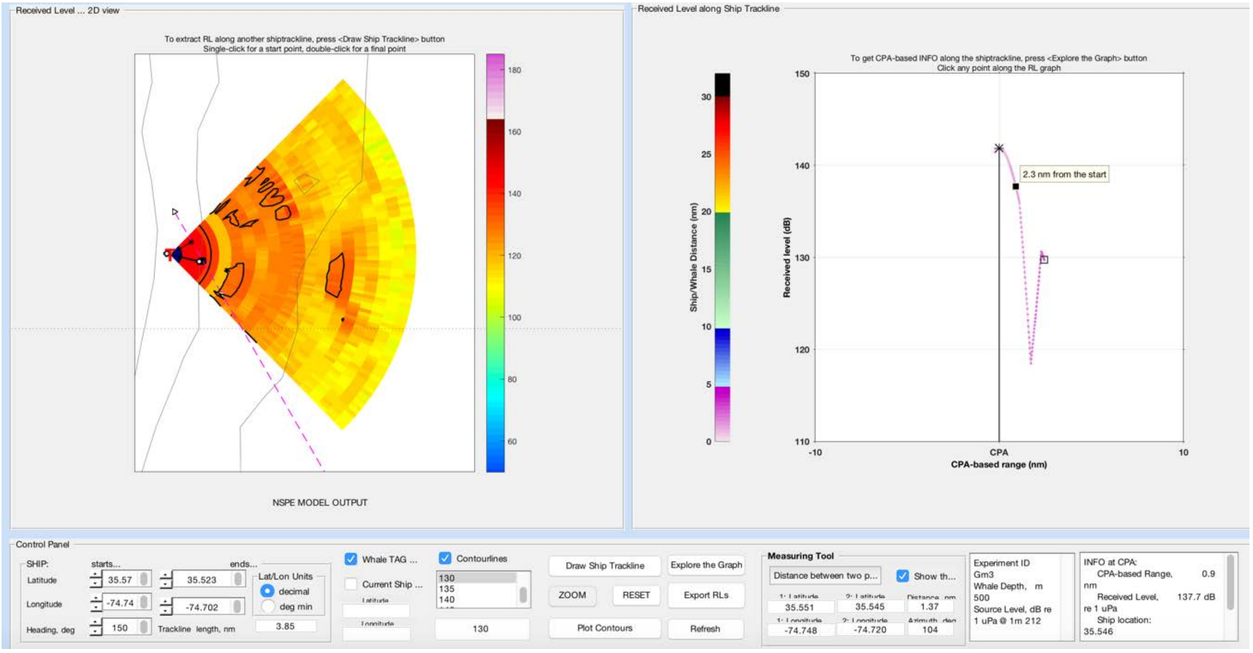


Figure 12. Estimated surface positions for whale Zc69 before, during, and after Atlantic-BRS CEE# 18-02

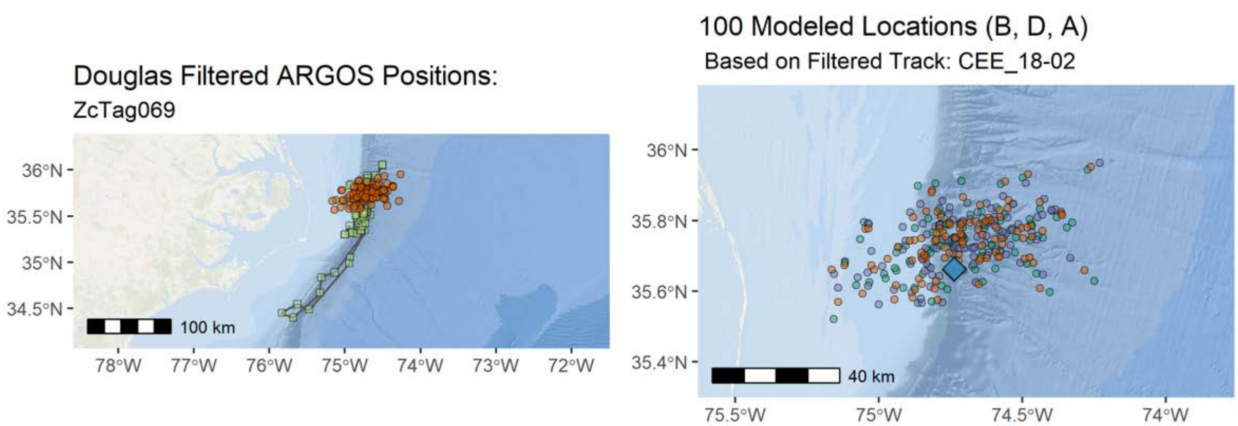


Figure 13. Available dive data for whale Zc69 before, during, and after Atlantic-BRS CEE# 18-02

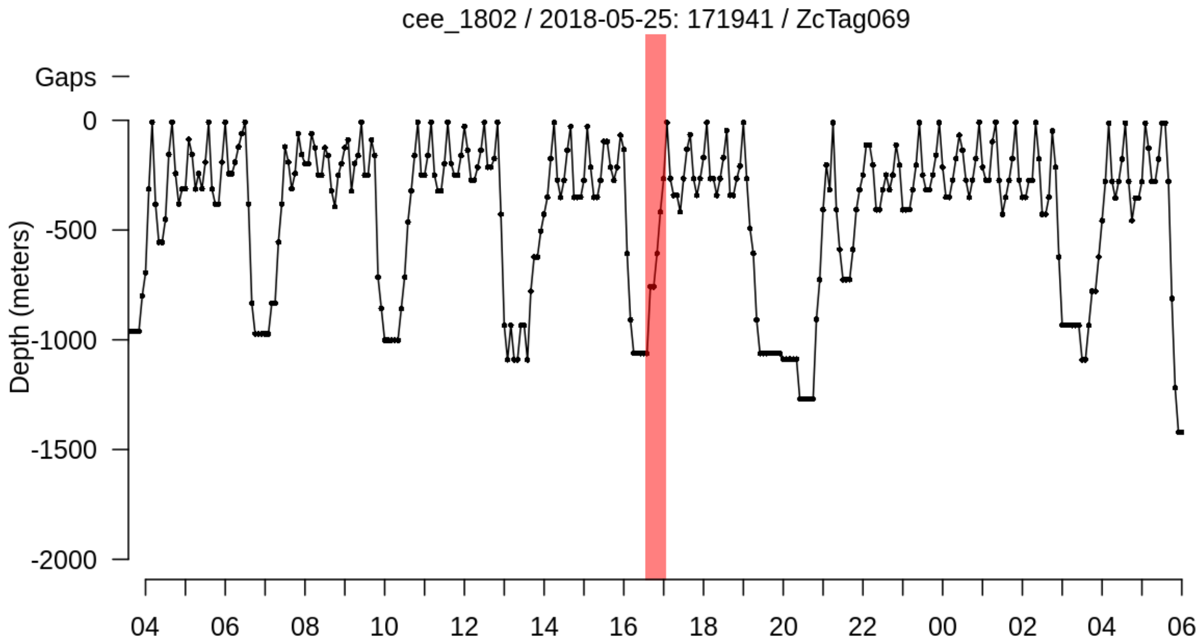


Figure 14. Estimated surface positions for whale Zc70 before, during, and after Atlantic-BRS CEE# 18-02

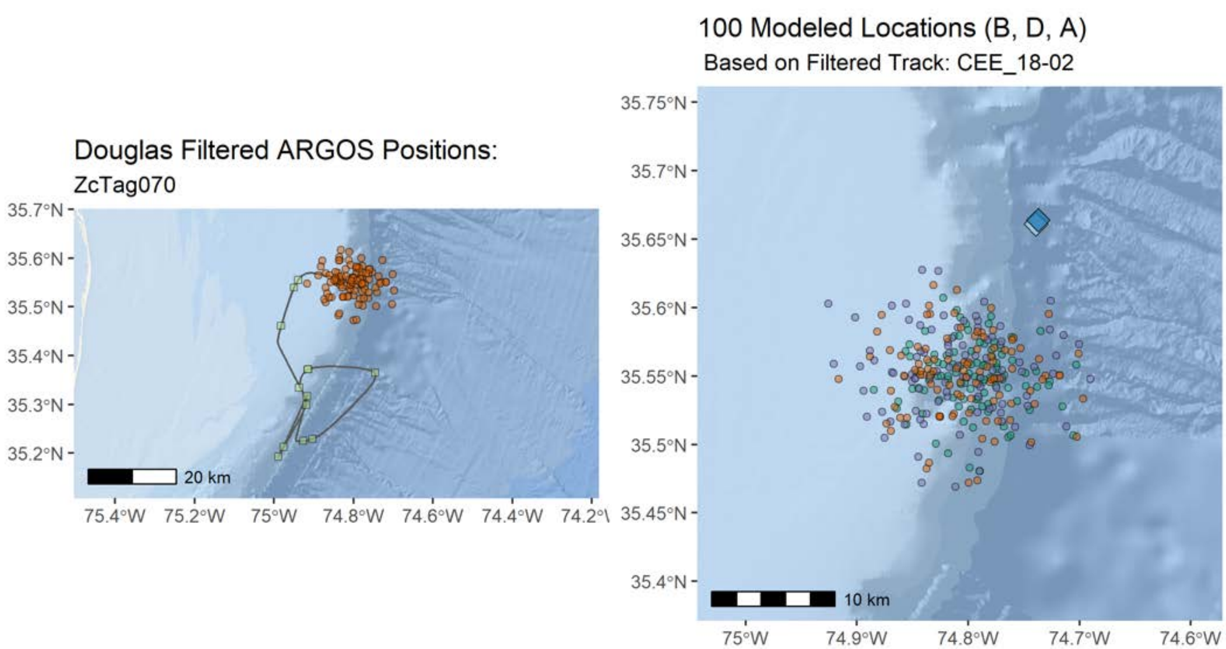


Figure 15. Available dive data for whale Zc70 before, during, and after Atlantic-BRS CEE# 18-02

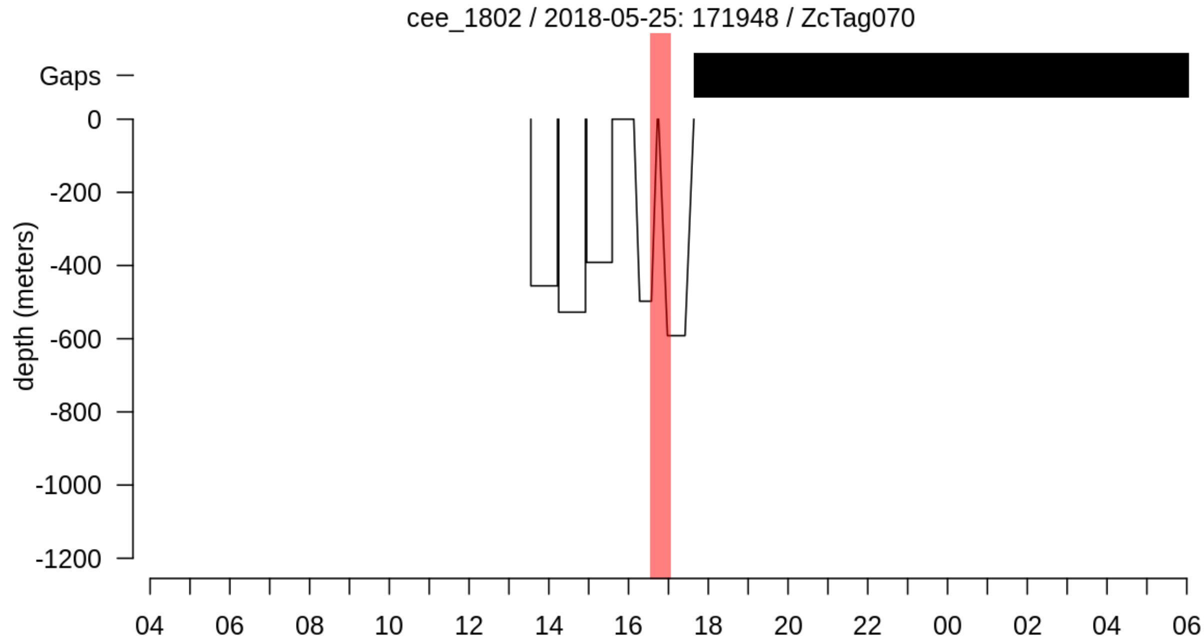


Figure 16. Estimated surface positions for focal whale Gm197 before, during, and after Atlantic-BRS CEE# 18-02

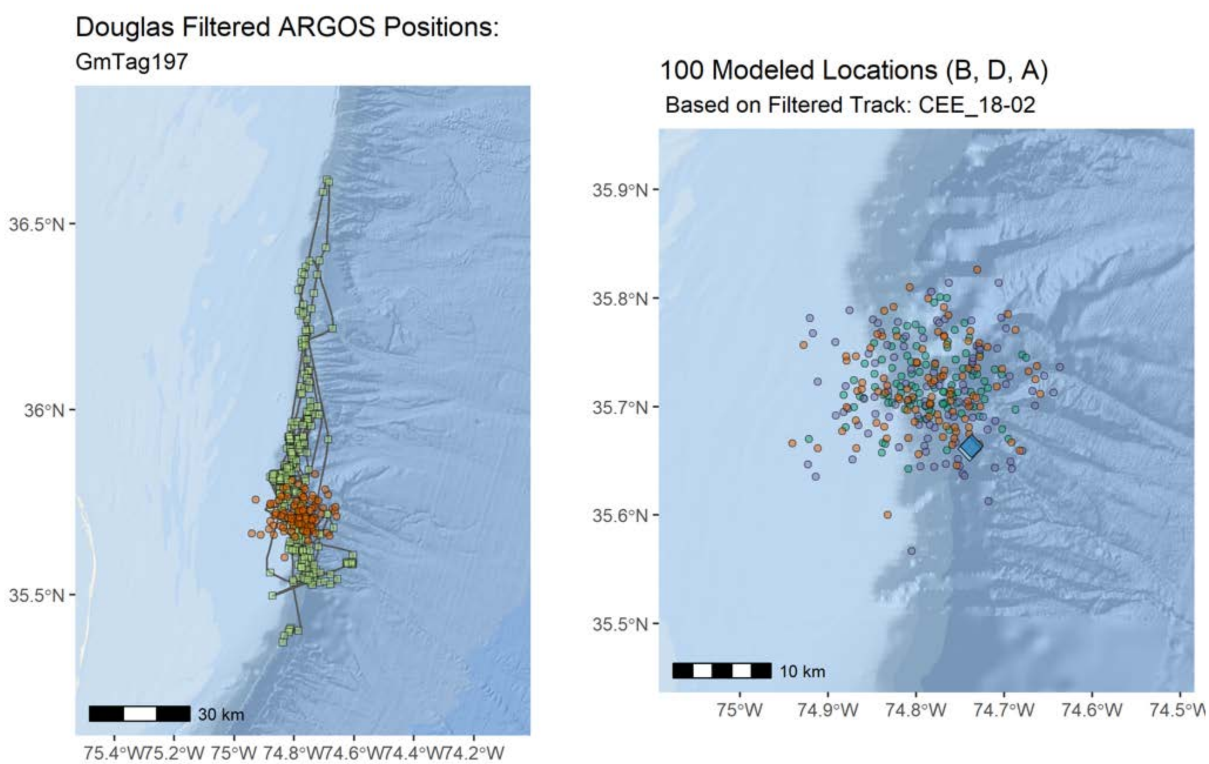


Figure 17. Available dive data for whale Gm197 before, during, and after Atlantic-BRS CEE# 18-02

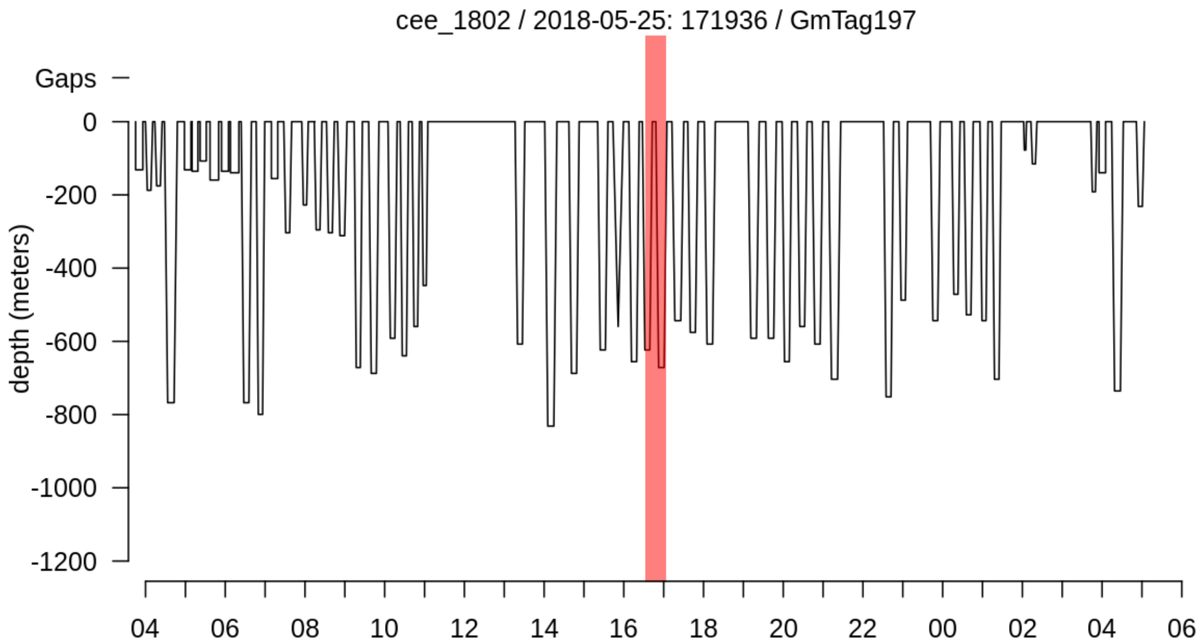


Figure 18. Estimated surface positions for whale Gm198 before, during, and after Atlantic-BRS CEE# 18-02

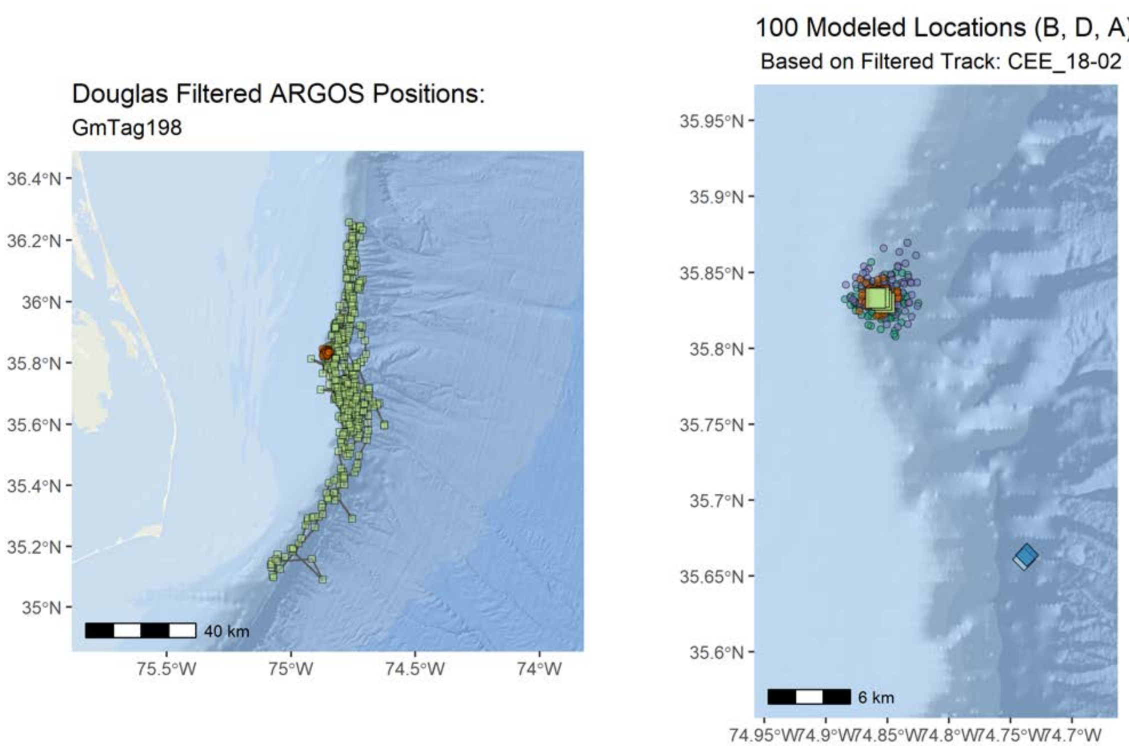


Figure 19. Available dive data for whale Gm198 before, during, and after Atlantic-BRS CEE# 18-02

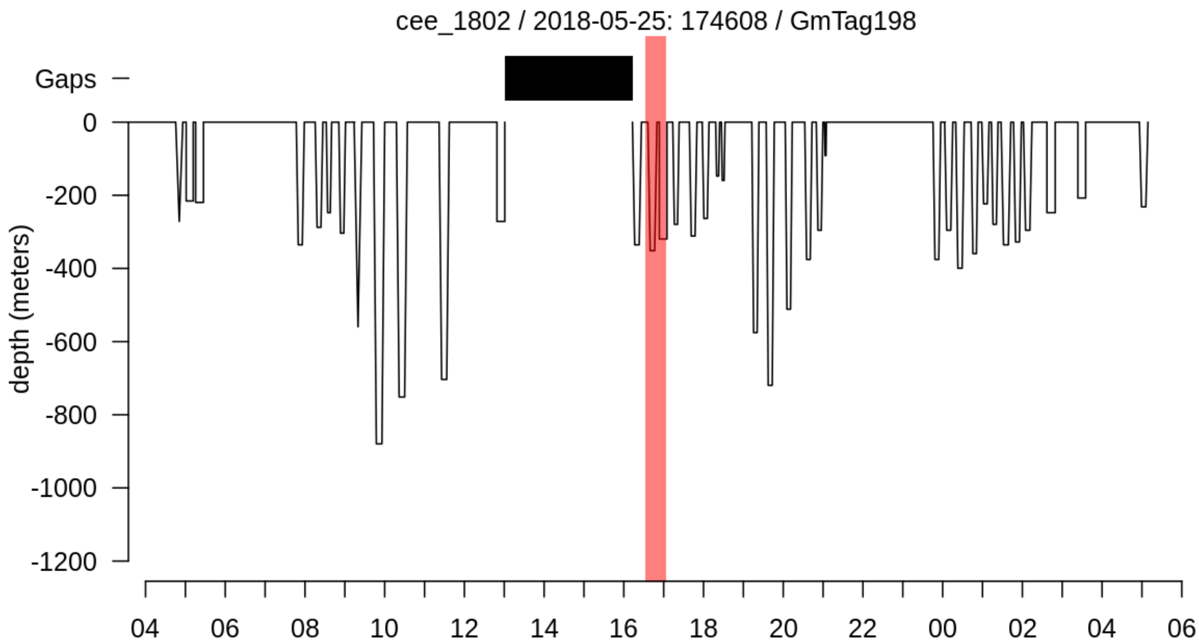


Figure 20. Estimated surface positions for whale Gm199 before, during, and after Atlantic-BRS CEE# 18-02

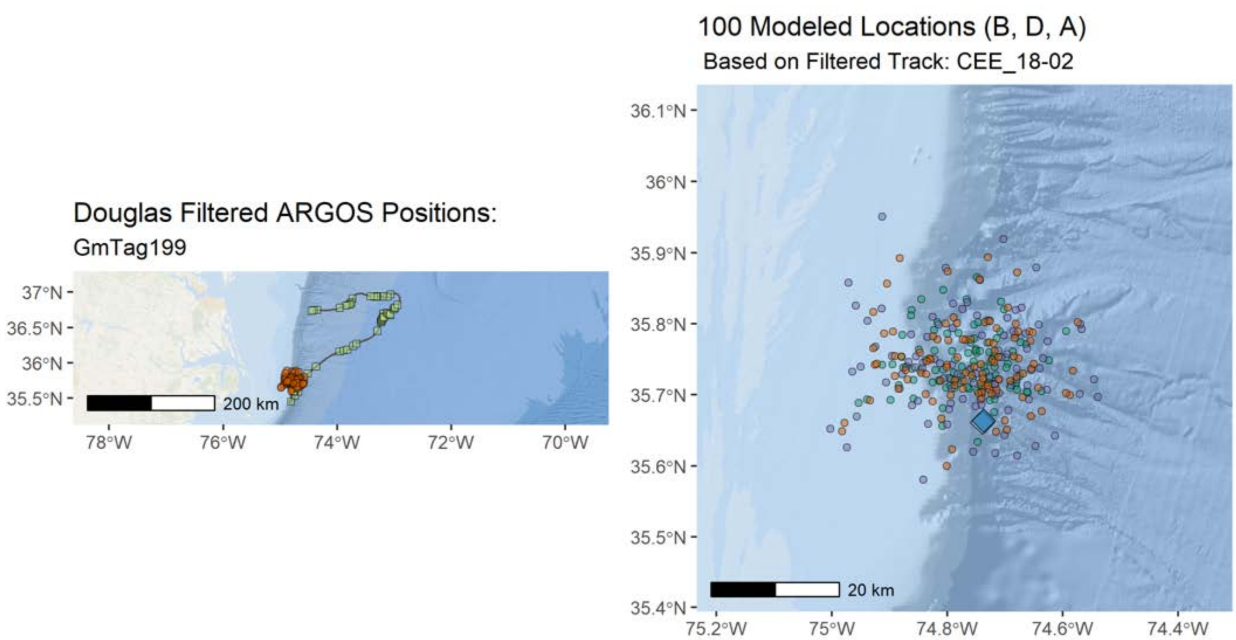


Figure 21. Available dive data for whale Gm199 before, during, and after Atlantic-BRS CEE# 18-02

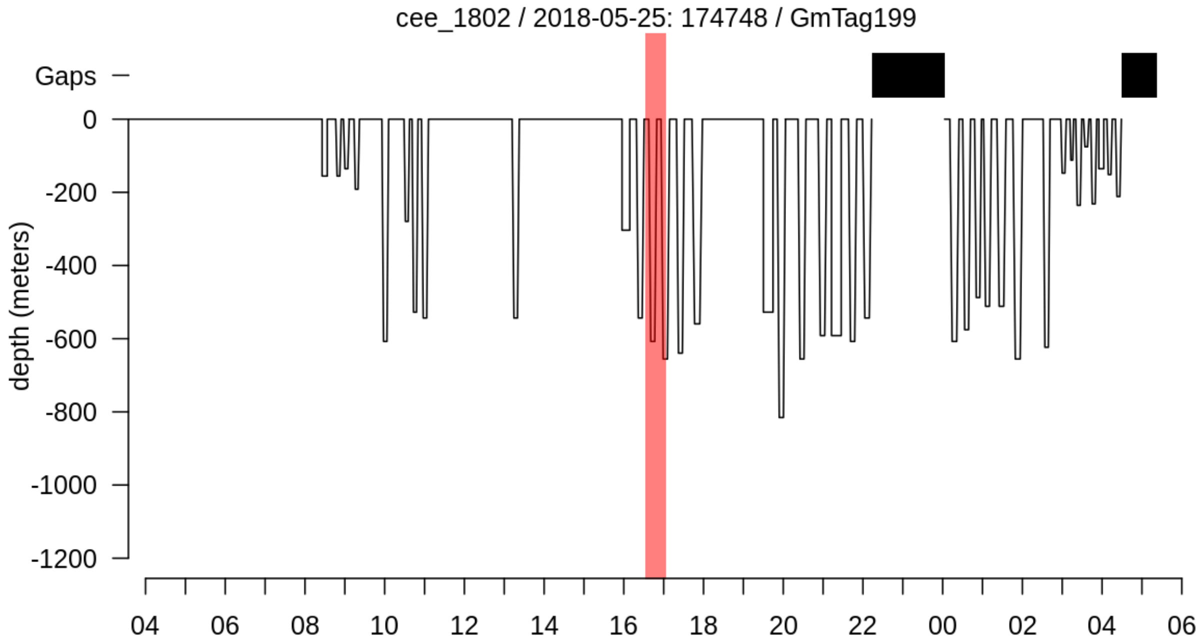
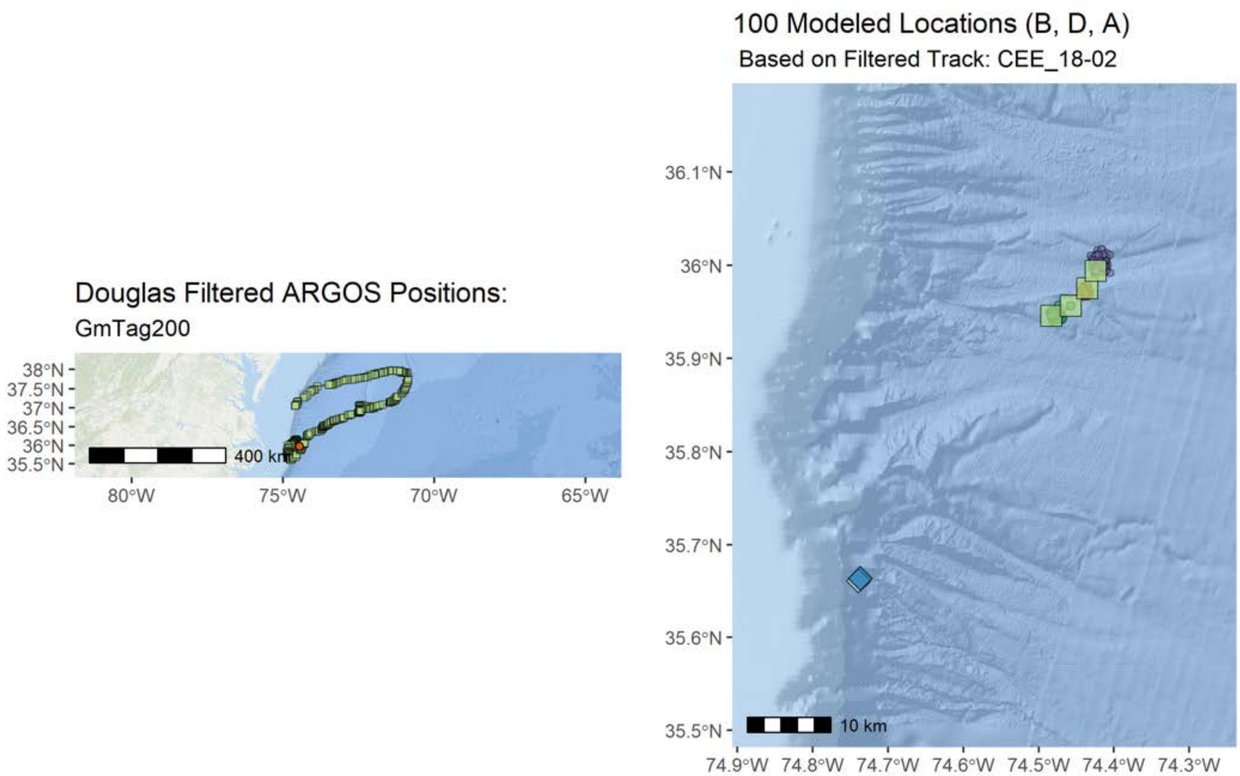
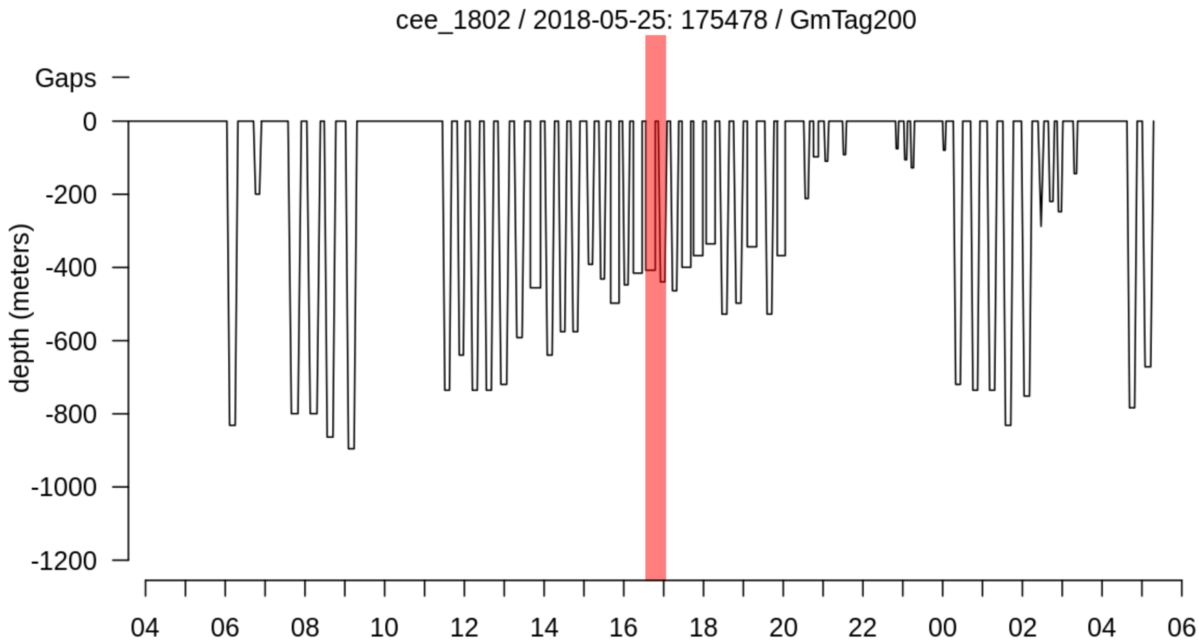


Figure 22. Estimated surface positions for whale Gm200 before, during, and after Atlantic-BRS CEE# 18-02



1 **Figure 23. Available dive data for whale Gm200 before, during, and after Atlantic-BRS CEE# 18-02**

2 

3 2.3.3 CEE 18-03: Simulated MFAS

4 **Table 10. Metadata summary for Atlantic-BRS CEE# 18-03**

CEE Conditions	Metadata Summary
CEE Identifier	18-03
Date	5/30/18
Type	Simulated MFAS from 15-element vertical line array projecting deployed to 20 m depth from *F/V Kahuna* (stationary)
Signal Parameters	Three-segment 1.2 s total duration pings (3.5–4 kHz); 212 dB re 1 µPa (RMS) sound pressure level; 25 s repetition rate
Start time (UTC)	17:49:00
Start lat/lon	35.87765; -74.81288
End time (UTC)	18:19:00
End lat/lon	35.88489; -74.82071
Beaked whales monitored with tags during CEE	Incidental: Zc69, Zc70
Pilot whales monitored with tags during CEE	Focal: Gm18_150a (DTAG not recovered) Incidental: Gm197, Gm198, Gm199, Gm200, Gm201, Gm202 (deployed just before CEE; insufficient baseline)

Figure 24. RL model prediction at 10 m depth for focal whale Gm18_150a for Atlantic-BRS CEE# 18-03

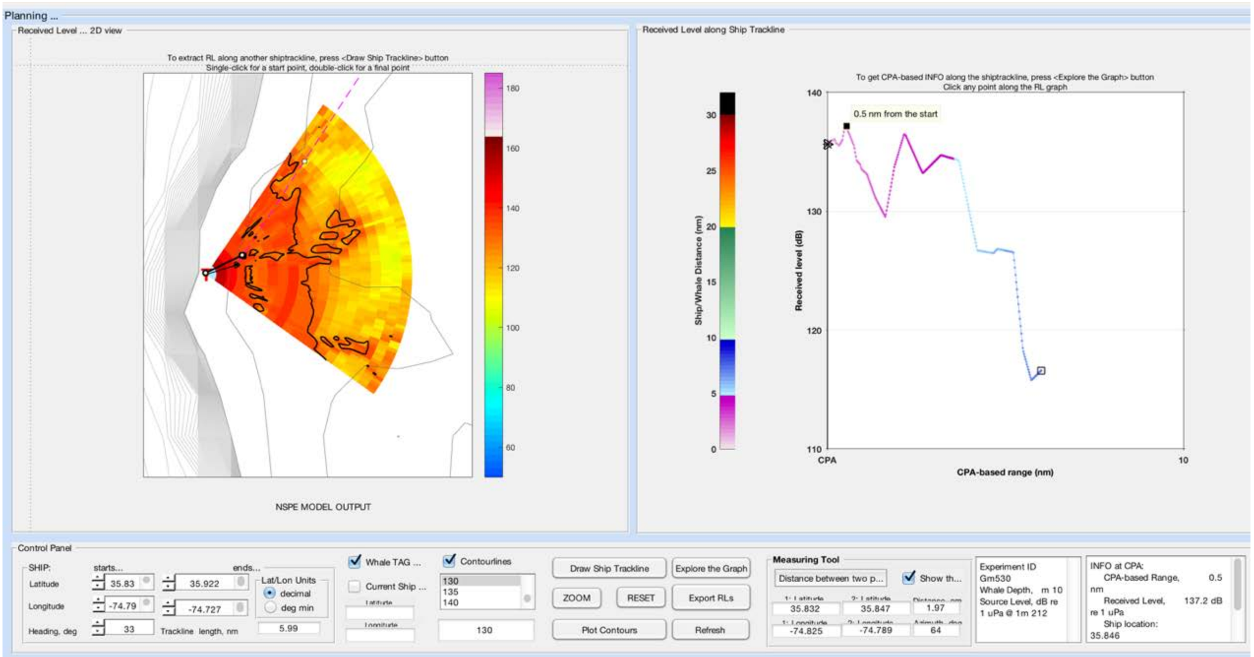


Figure 25. RL model prediction at 500 m depth for focal whale Gm18_150a for Atlantic-BRS CEE# 18-03

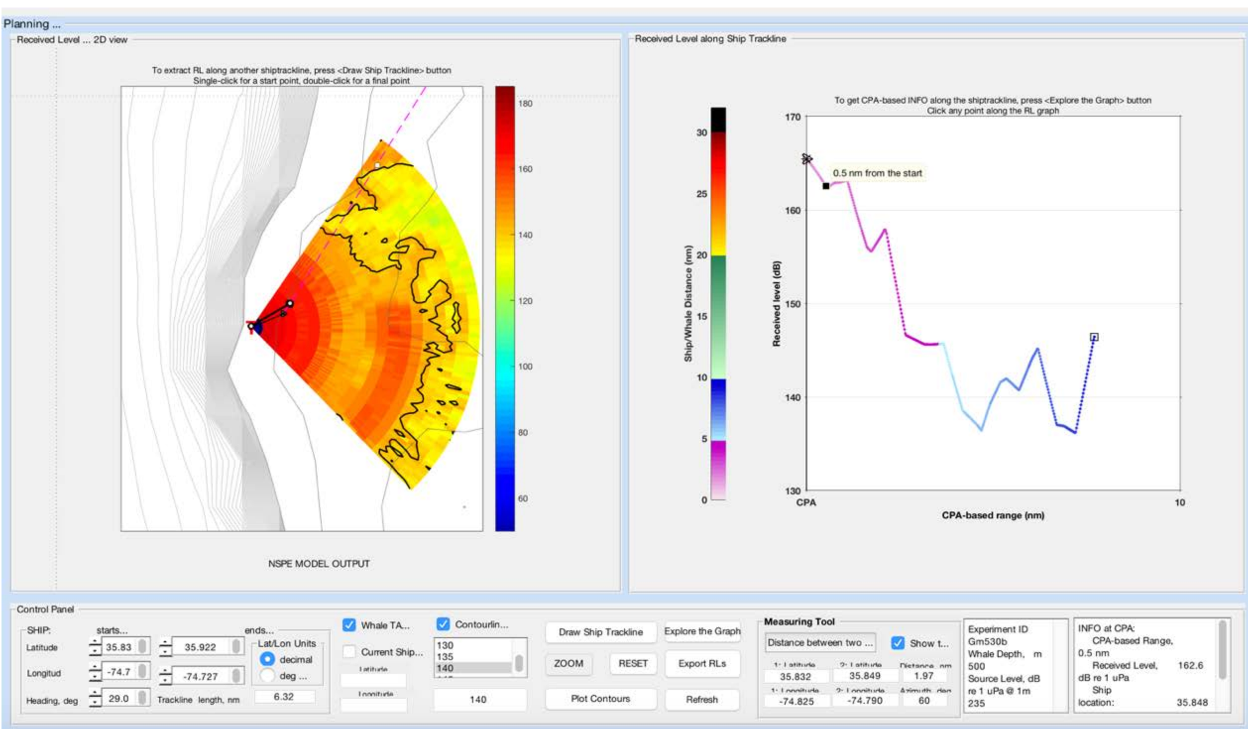


Figure 26. Estimated surface positions for whale Zc69 before, during, and after Atlantic-BRS CEE# 18-03

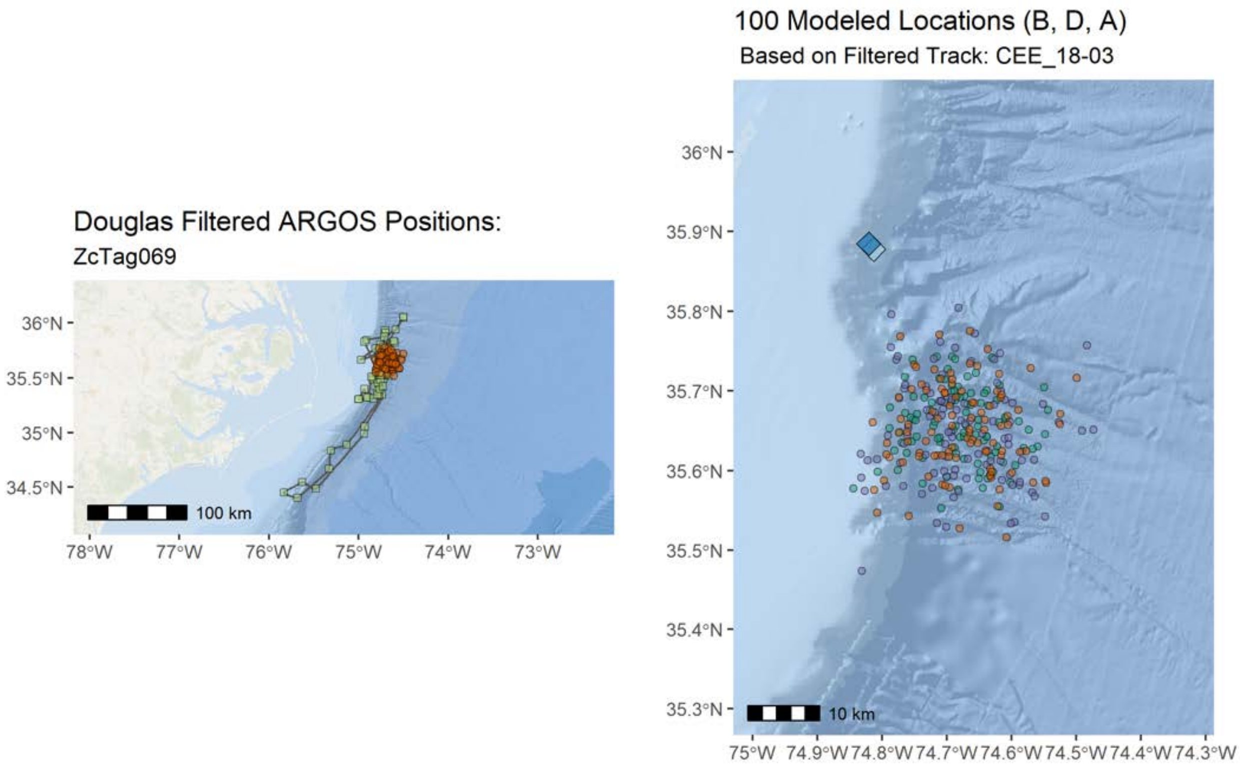


Figure 27. Available dive data for whale Zc69 before, during, and after Atlantic-BRS CEE# 18-03

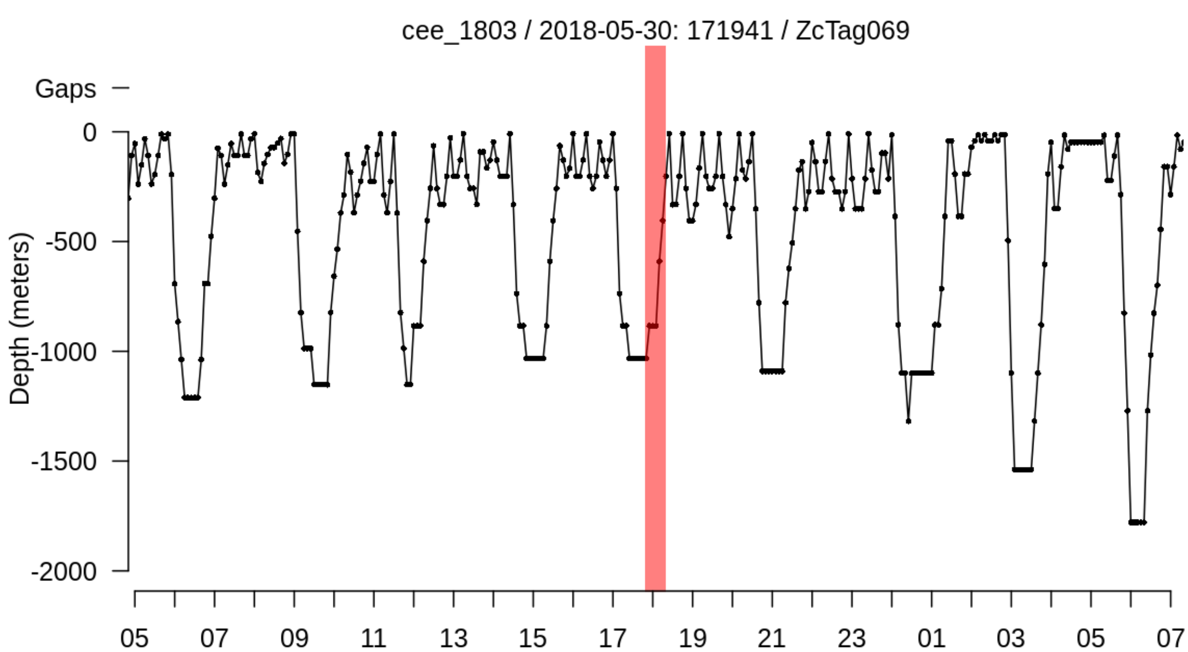


Figure 28. Estimated surface positions for whale Zc70 before, during, and after Atlantic-BRS CEE# 18-03

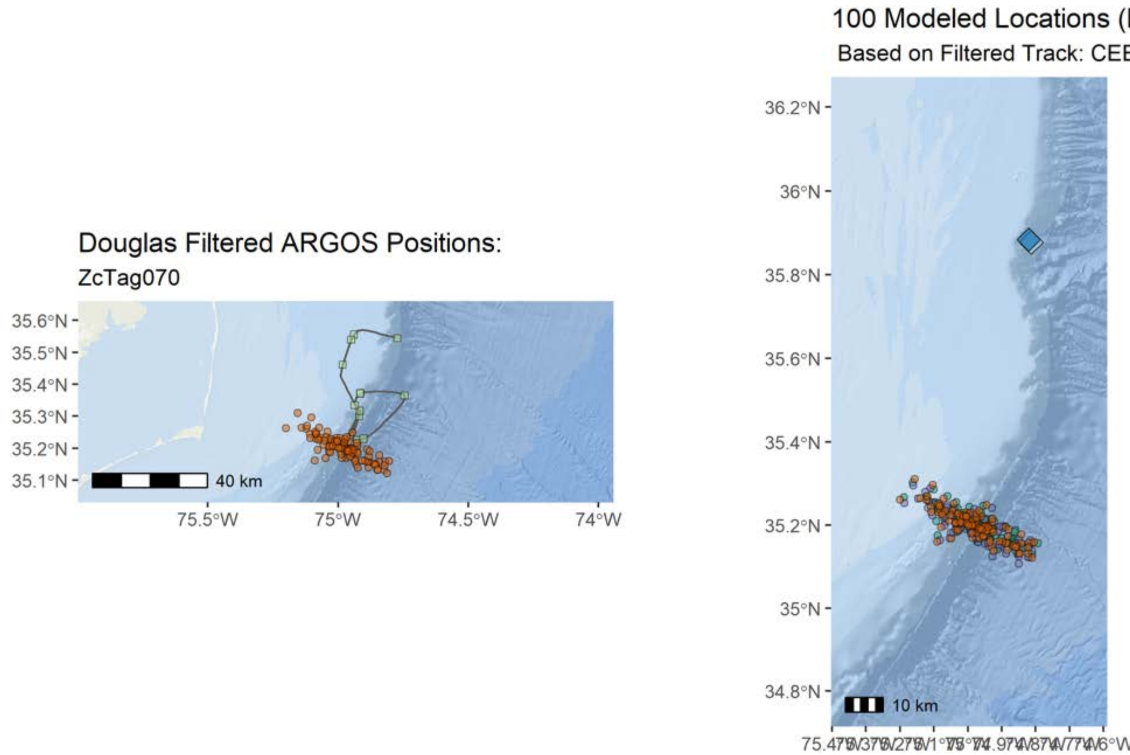


Figure 29. Available dive data for whale Zc70 before, during, and after Atlantic-BRS CEE# 18-03

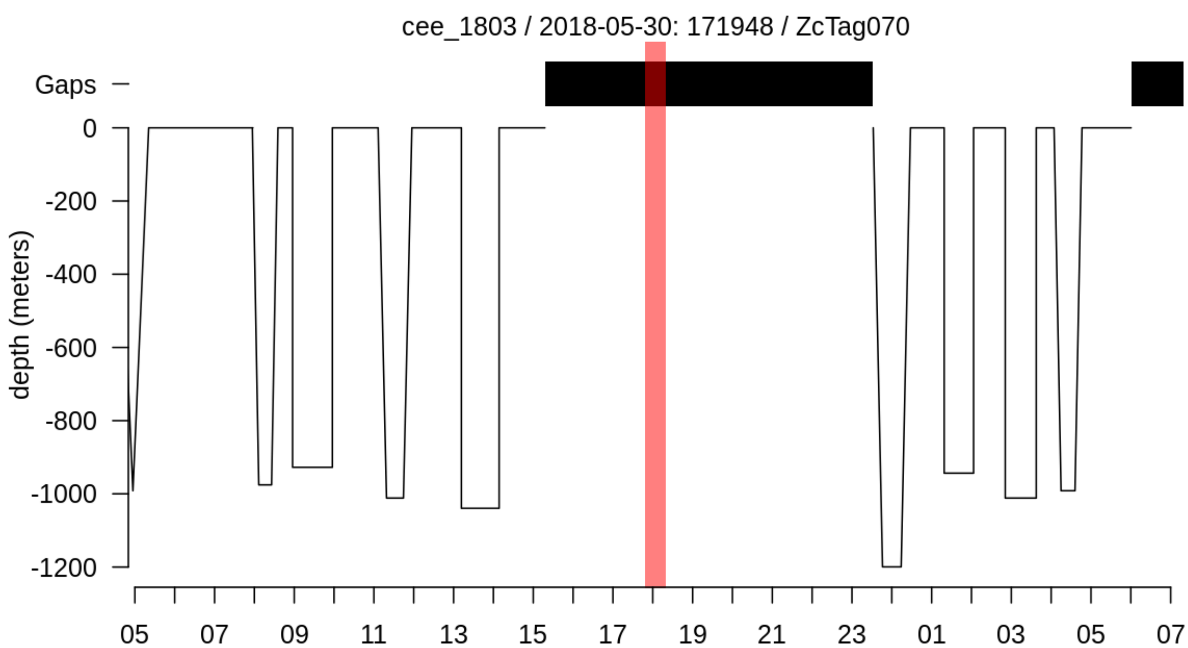


Figure 30. Estimated surface positions for whale Gm197 before, during, and after Atlantic-BRS CEE# 18-03

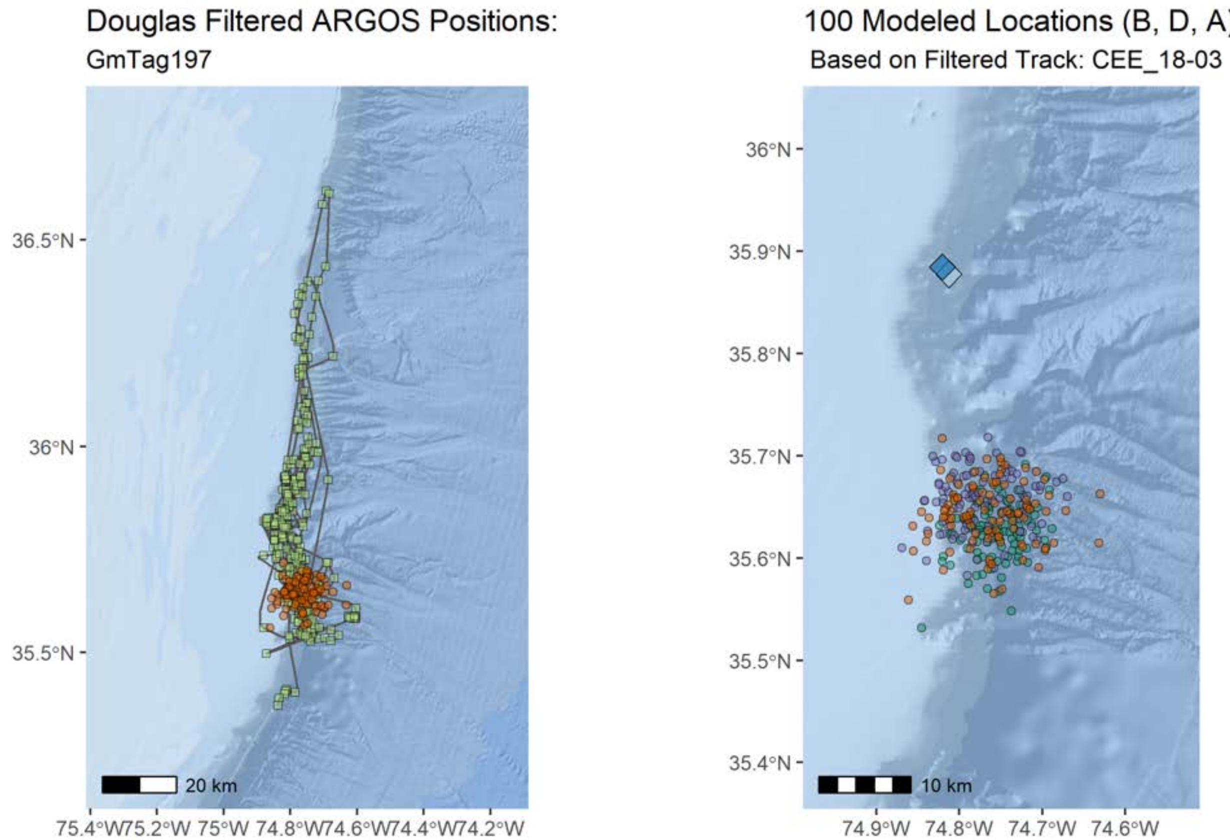


Figure 31. Available dive data for focal whale Gm197 before, during, and after Atlantic-BRS CEE# 18-03

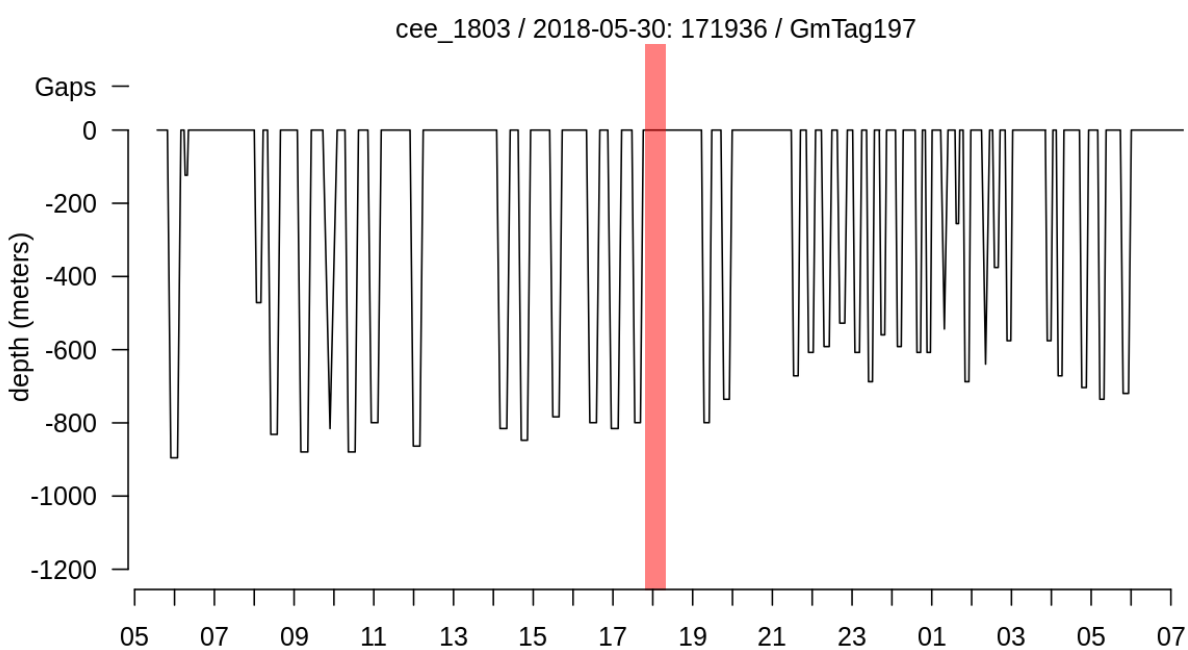


Figure 32. Estimated surface positions for whale Gm198 before, during, and after Atlantic-BRS CEE# 18-03

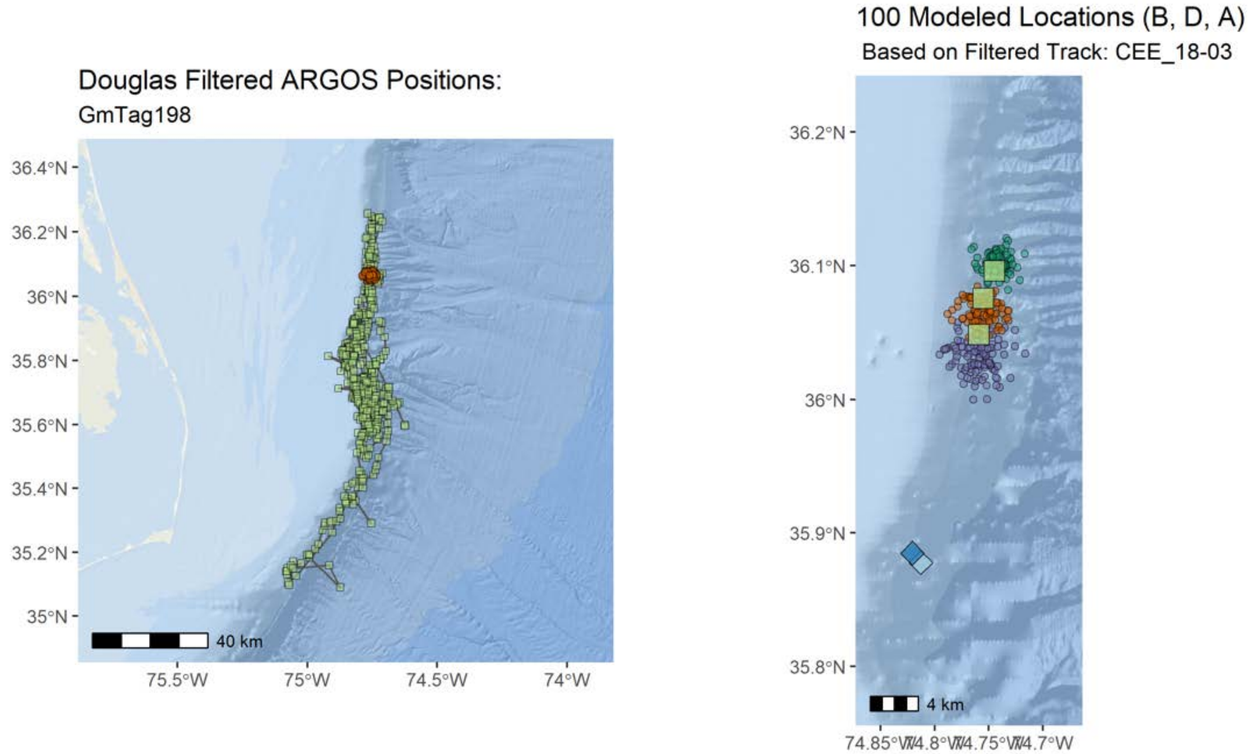


Figure 33. Available dive data for whale Gm198 before, during, and after Atlantic-BRS CEE# 18-03

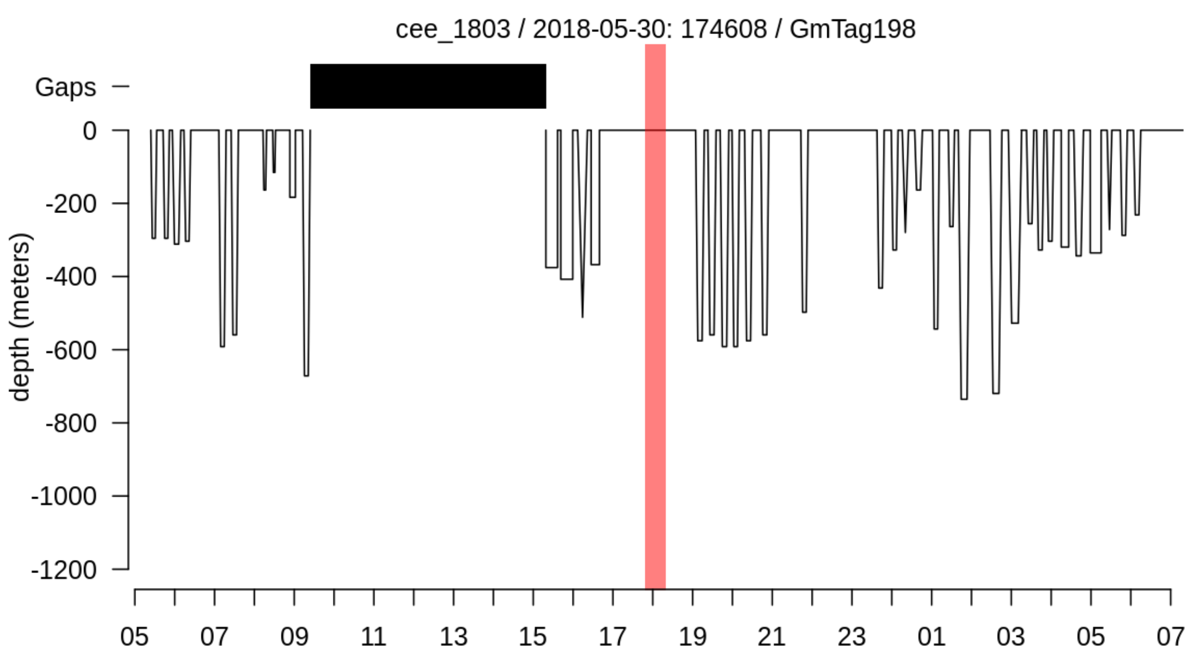


Figure 34. Estimated surface positions for whale Gm199 before, during, and after Atlantic-BRS CEE# 18-03

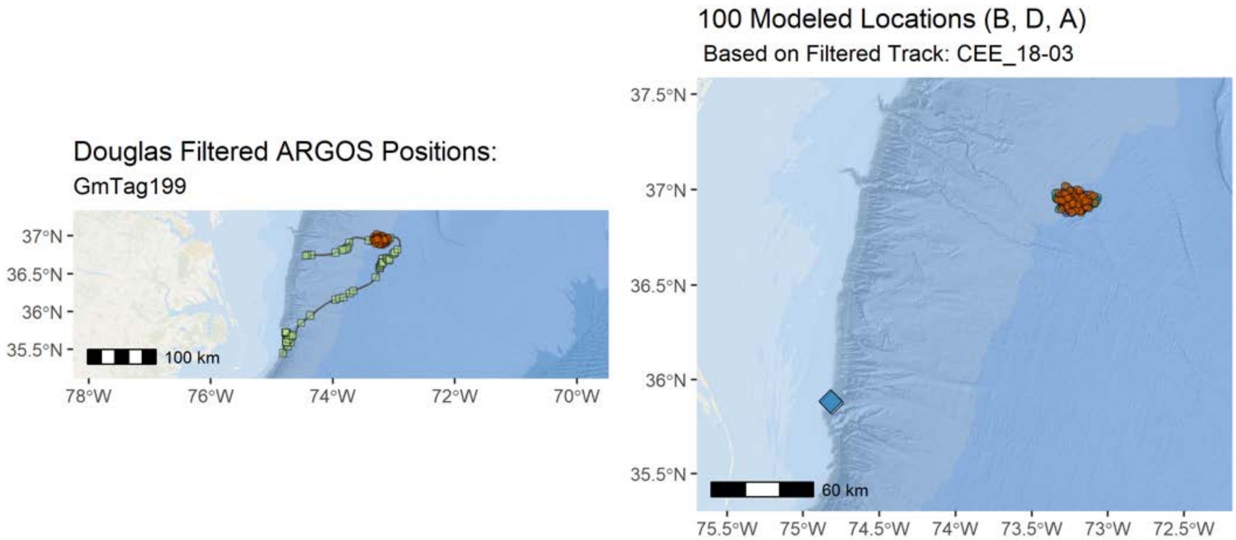


Figure 35. Available dive data for whale Gm199 before, during, and after Atlantic-BRS CEE# 18-03

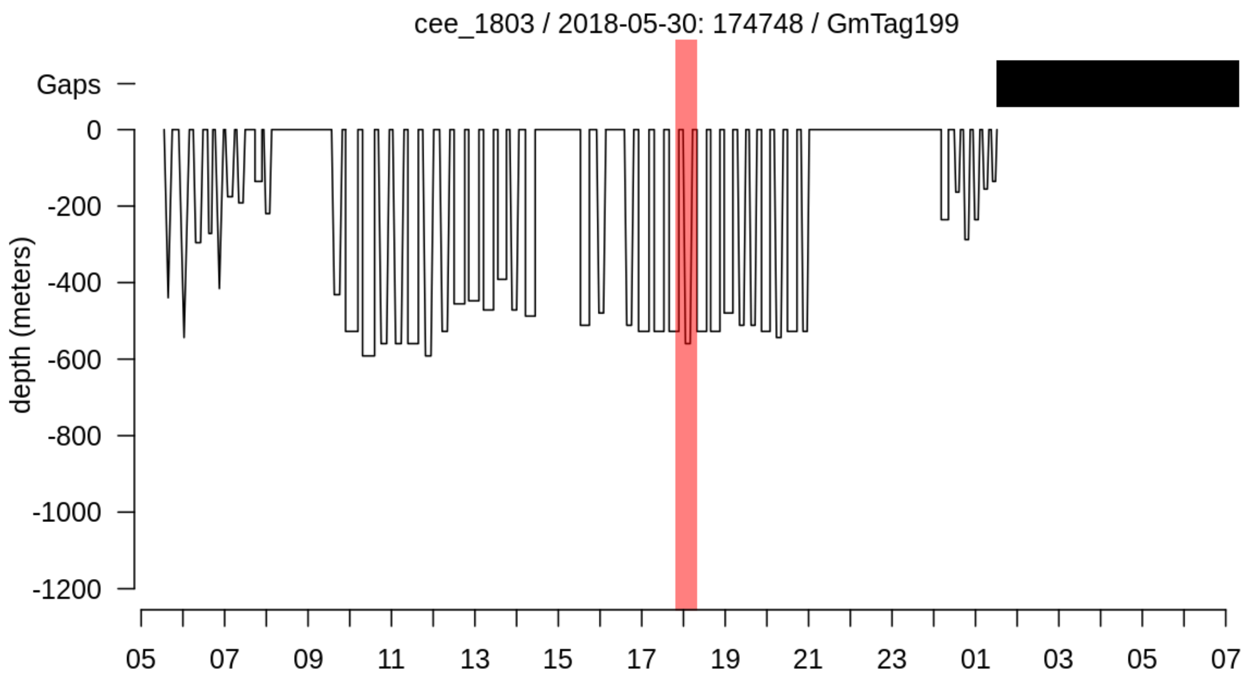


Figure 36. Estimated surface positions for whale Gm200 before, during, and after Atlantic-BRS CEE# 18-03

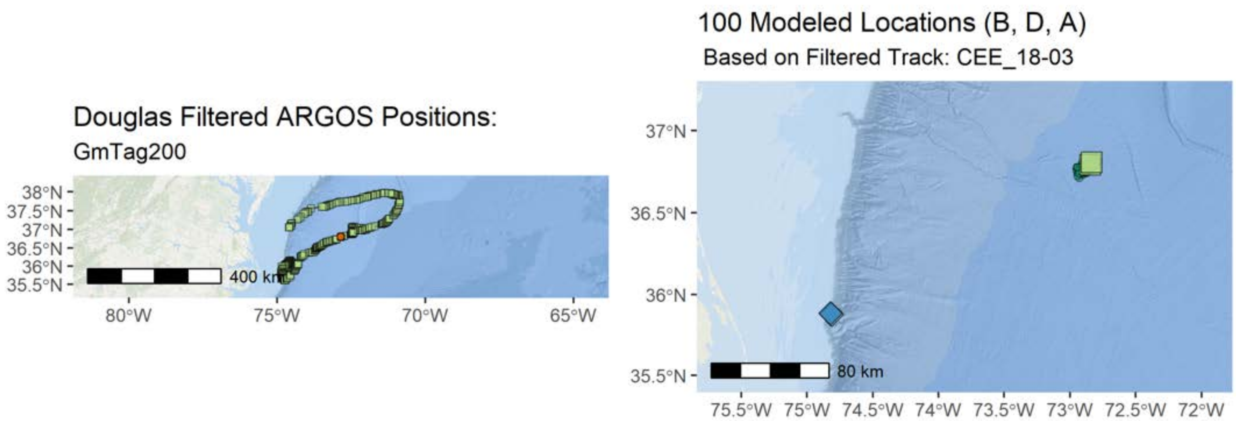


Figure 37. Available dive data for whale Gm200 before, during, and after Atlantic-BRS CEE# 18-03

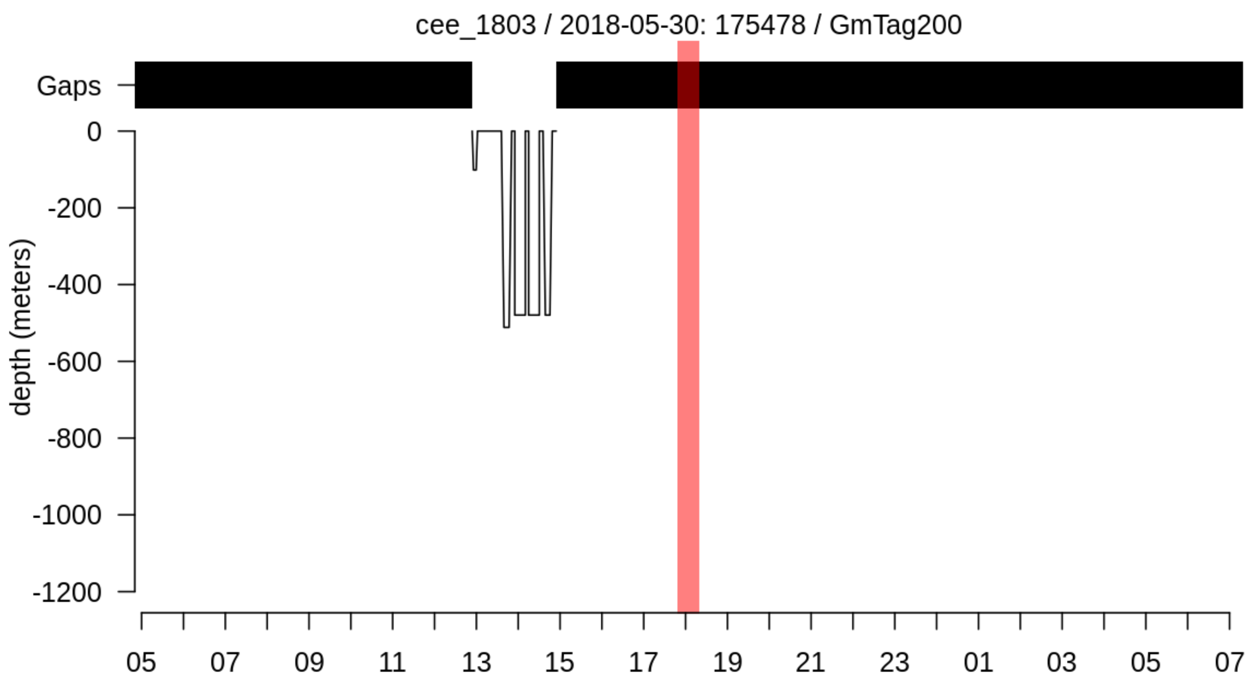


Figure 38. Estimated surface positions for whale Gm201 before, during, and after Atlantic-BRS CEE# 18-03

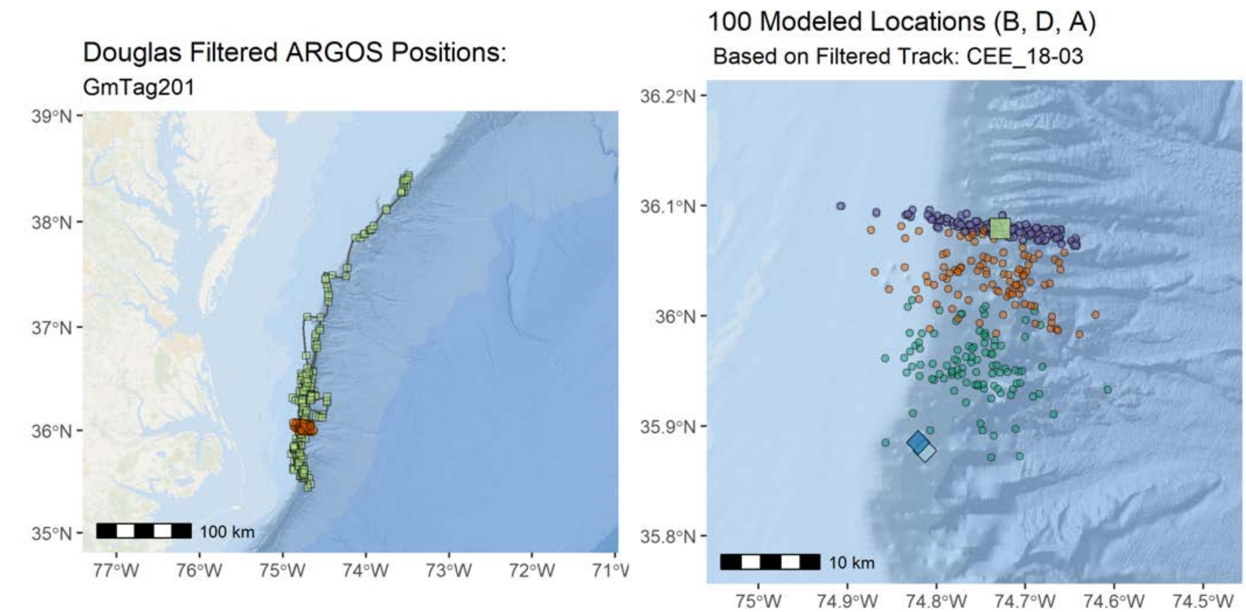
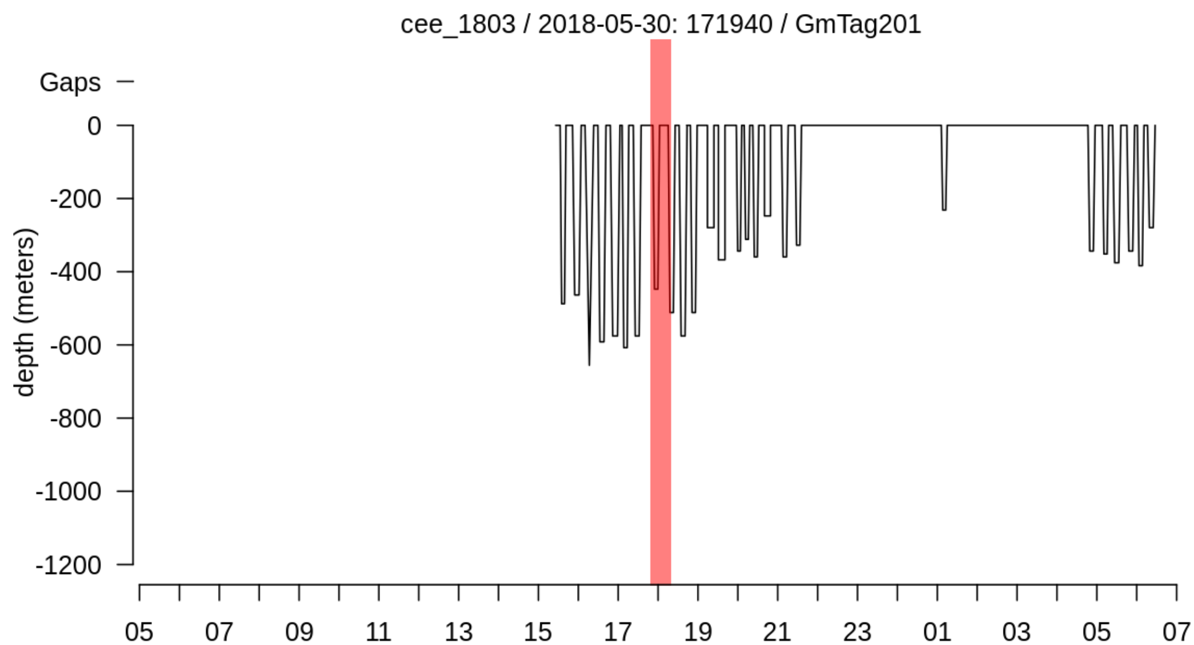


Figure 39. Available dive data for whale Gm201 before, during, and after Atlantic-BRS CEE# 18-03



2.3.4 CEE 18-04: Full-scale 53C (*USS NITZE*)

Table 11. Metadata summary for Atlantic-BRS CEE# 18-04

CEE Conditions	Metadata Summary
CEE Identifier	18-04
Date	6/3/18
Type	Operational MFAS - hull-mounted 53C on *USS NITZE* moving in a straight course at 8 kt over ground
Signal Parameters	Three-segment 1.2s total duration pings (3.5–4 kHz); 235 dB re 1 µPa (RMS) sound pressure source level; 25s repetition rate
Start time (UTC)	16:00:04
Start lat/lon	35.85405; -74.36027
End time (UTC)	17:00:04
End lat/lon	35.75417; -74.42361
Beaked whales monitored with tags during CEE	Focal: Zc69, Zc70
Pilot whales monitored with tags during CEE	Focal: Gm198 Incidental: Gm197, Gm198, Gm200, Gm201, Gm202, Gm203, Gm204, 205, 206

Figure 40. Map showing animal positions and initial and final requested positions of USS NITZE for Atlantic-BRS CEE# 18-04 on 3 June 2018

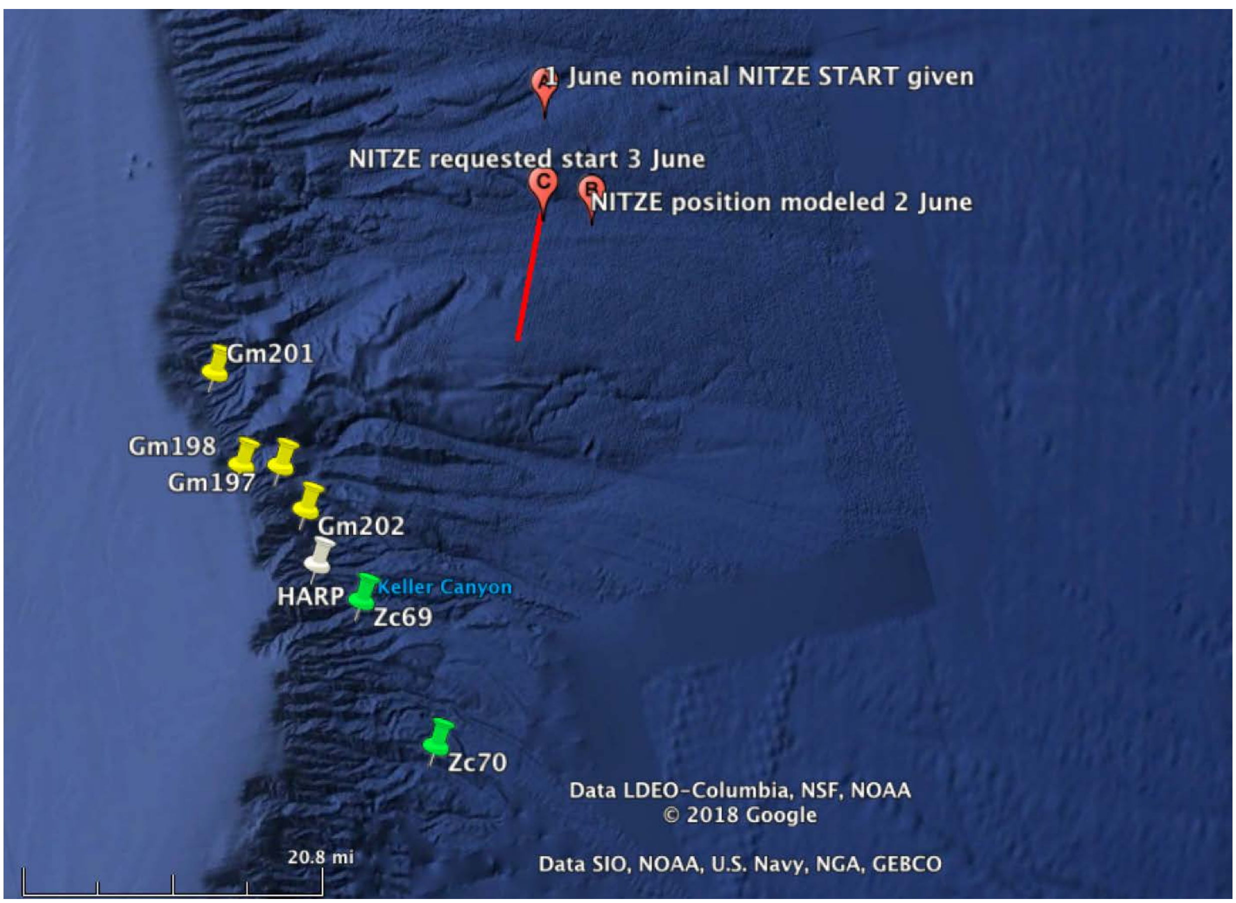


Figure 41. RL model prediction at 1,500 m depth for focal whale Zc69 for Atlantic-BRS CEE# 18-04 (END position of *USS NITZE*)

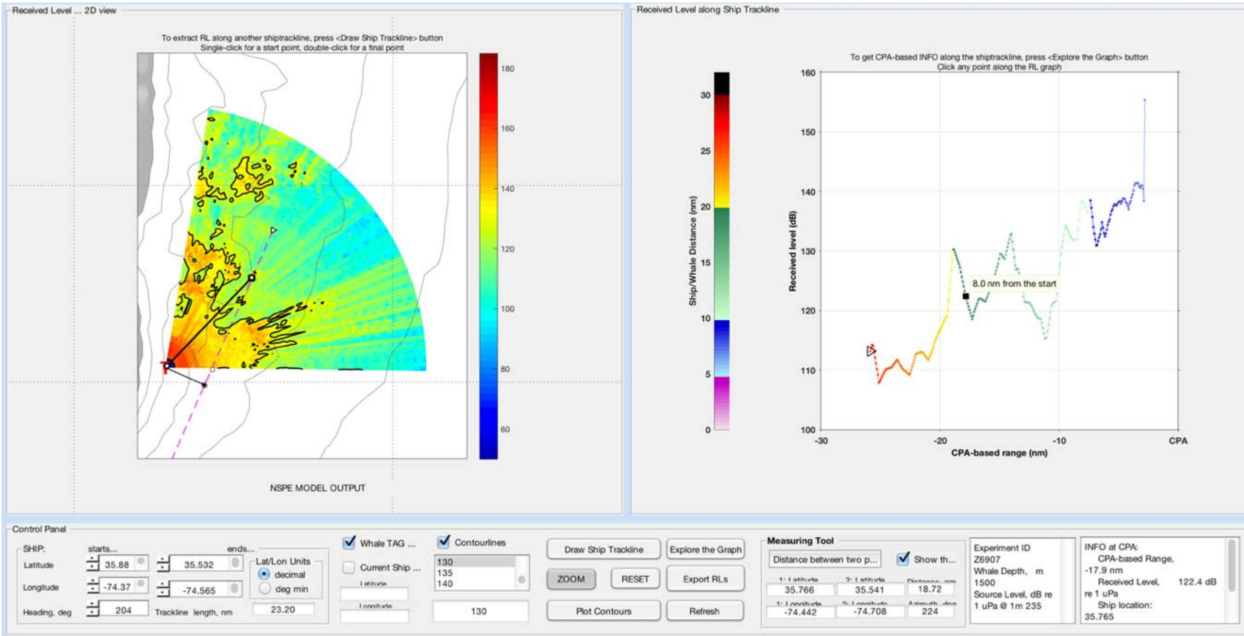


Figure 42. RL model prediction at 2,100 m depth for focal whale Zc70 for Atlantic-BRS CEE# 18-04 (END position of *USS NITZE*)

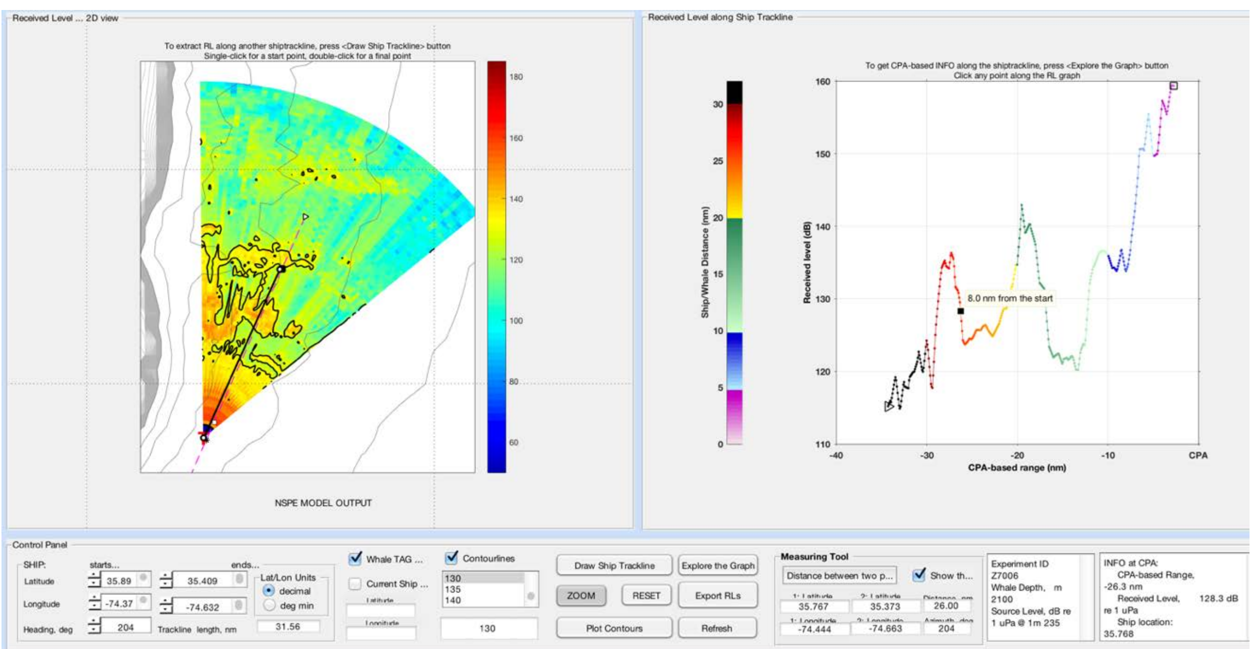


Figure 43. RL model prediction at 100 m depth for focal whale Gm198 for Atlantic-BRS CEE# 18-04 (END position of *USS NITZE*)

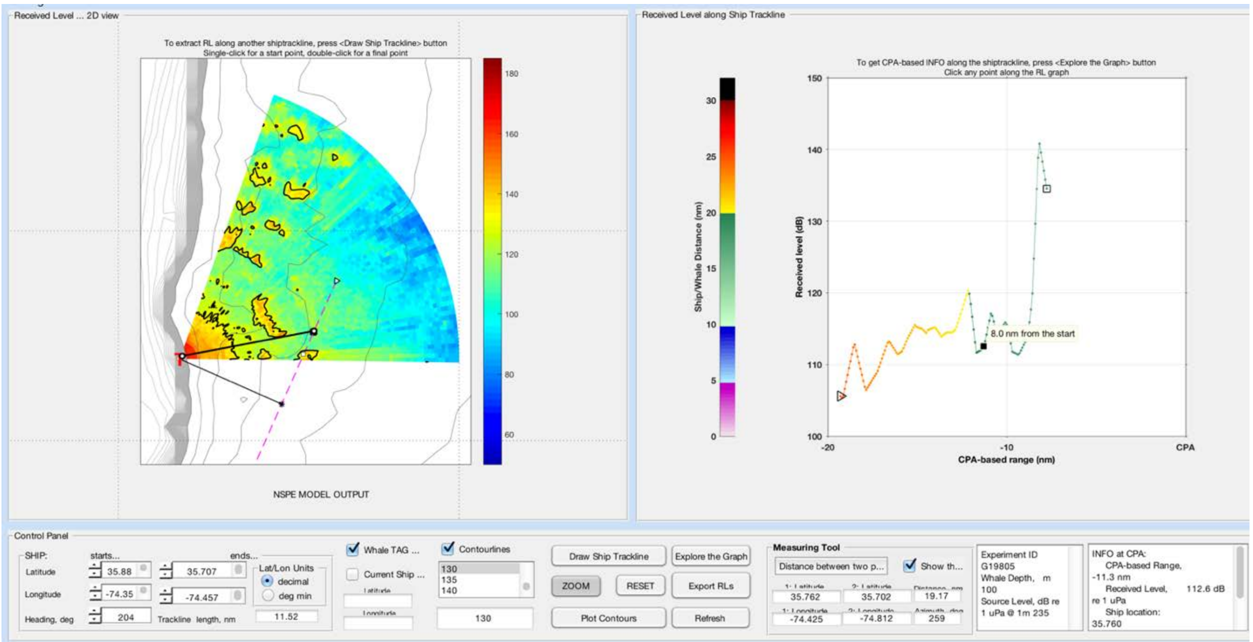


Figure 44. Estimated surface positions for focal whale Zc69 before, during, and after Atlantic-BRS CEE# 18-04

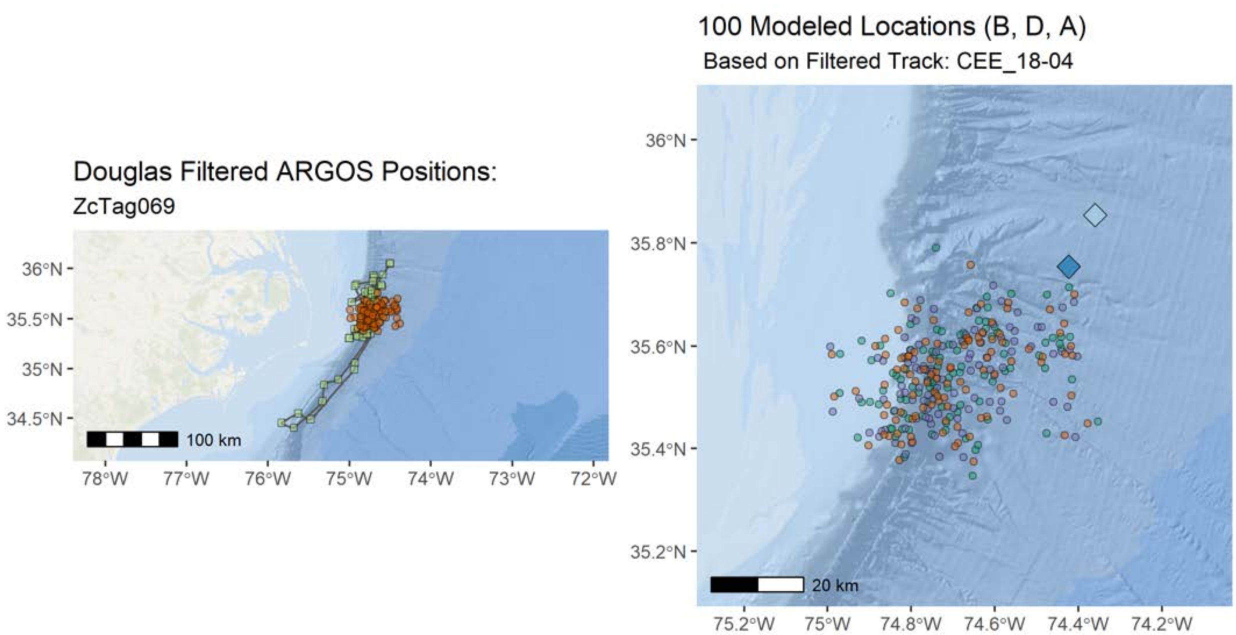


Figure 45. Available dive data for focal whale Zc69 before, during, and after Atlantic-BRS CEE# 18-04

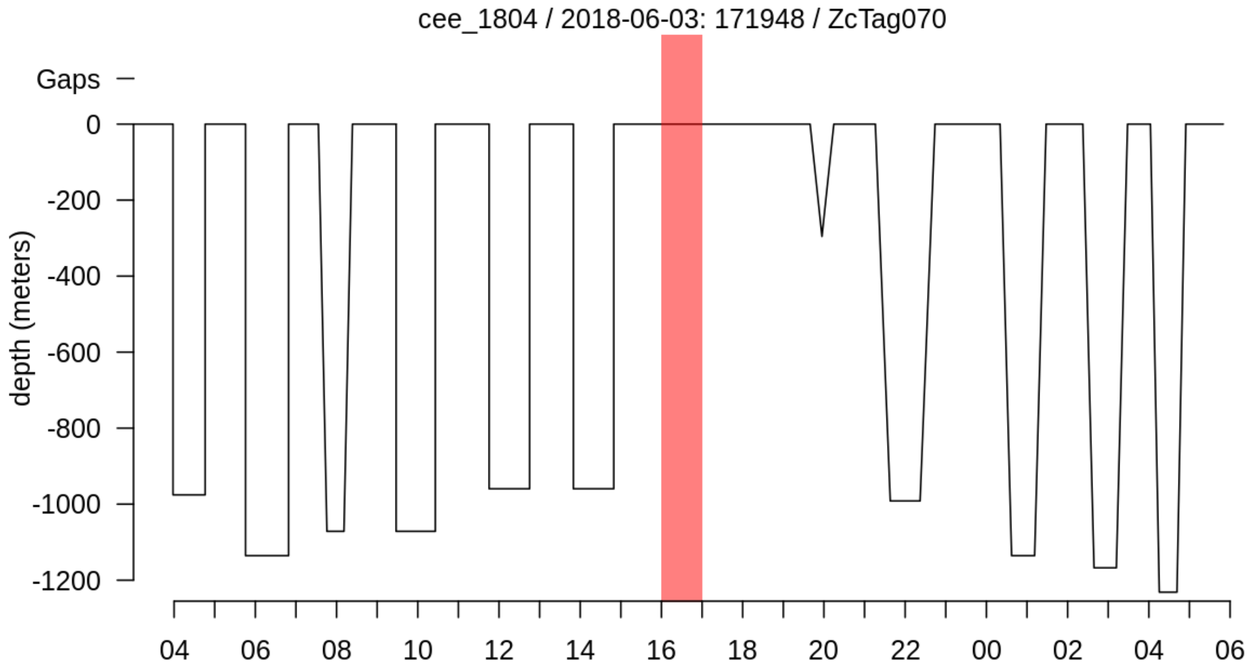


Figure 46. Estimated surface positions for focal whale Zc70 before, during, and after Atlantic-BRS CEE# 18-04

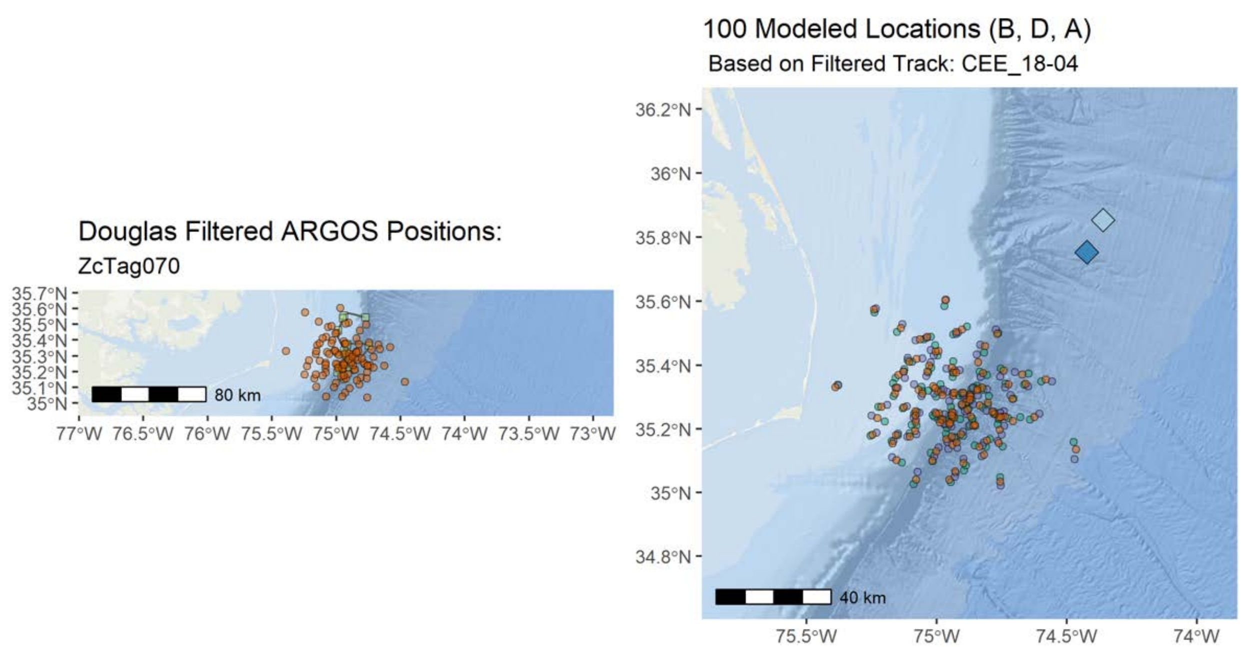


Figure 47. Available dive data for focal whale Zc70 before, during, and after Atlantic-BRS CEE# 18-04

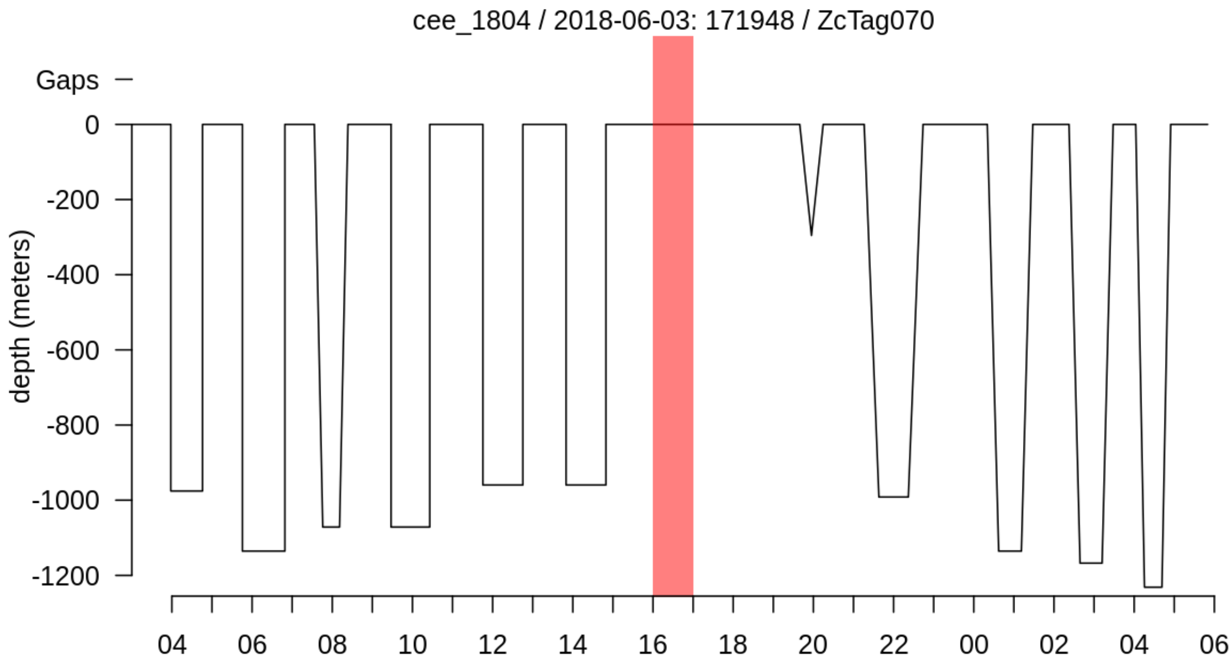


Figure 48. Estimated surface positions for whale Gm197 before, during, and after Atlantic-BRS CEE# 18-04

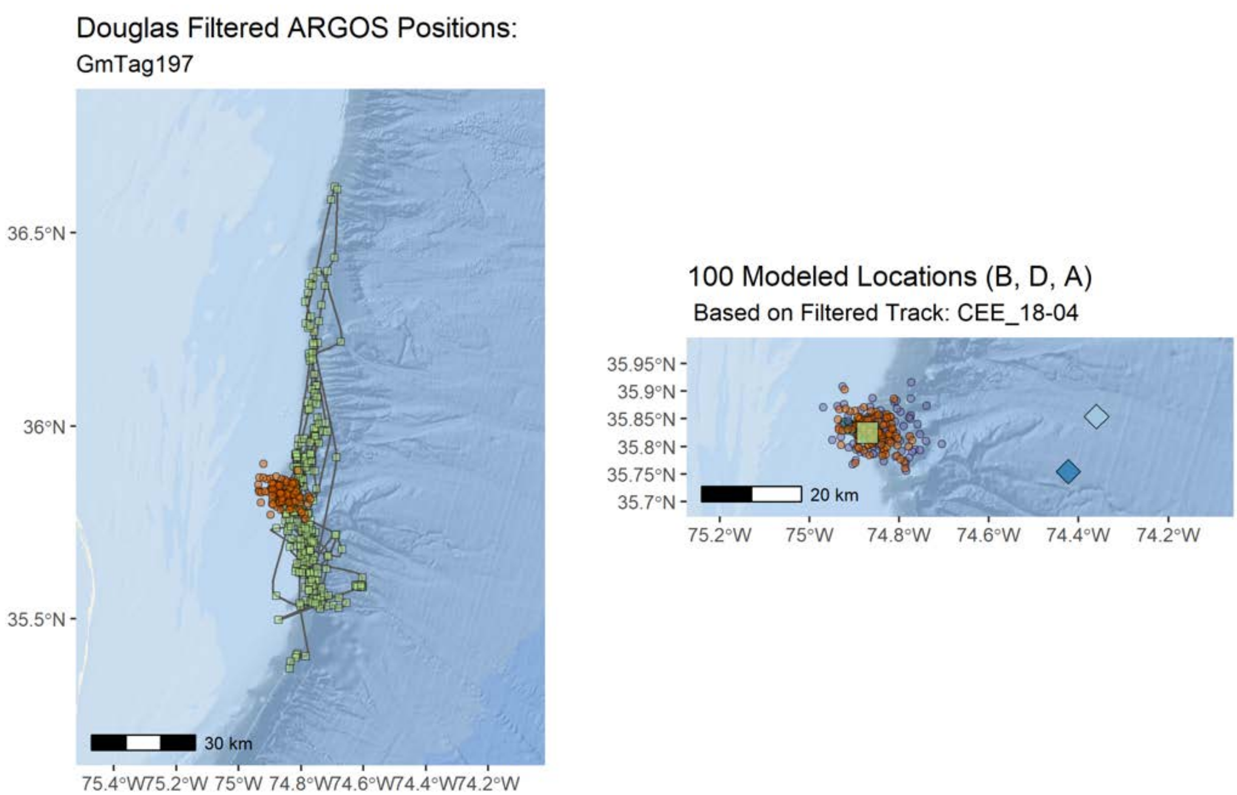


Figure 49. Available dive data for whale Gm197 before, during, and after Atlantic-BRS CEE# 18-04

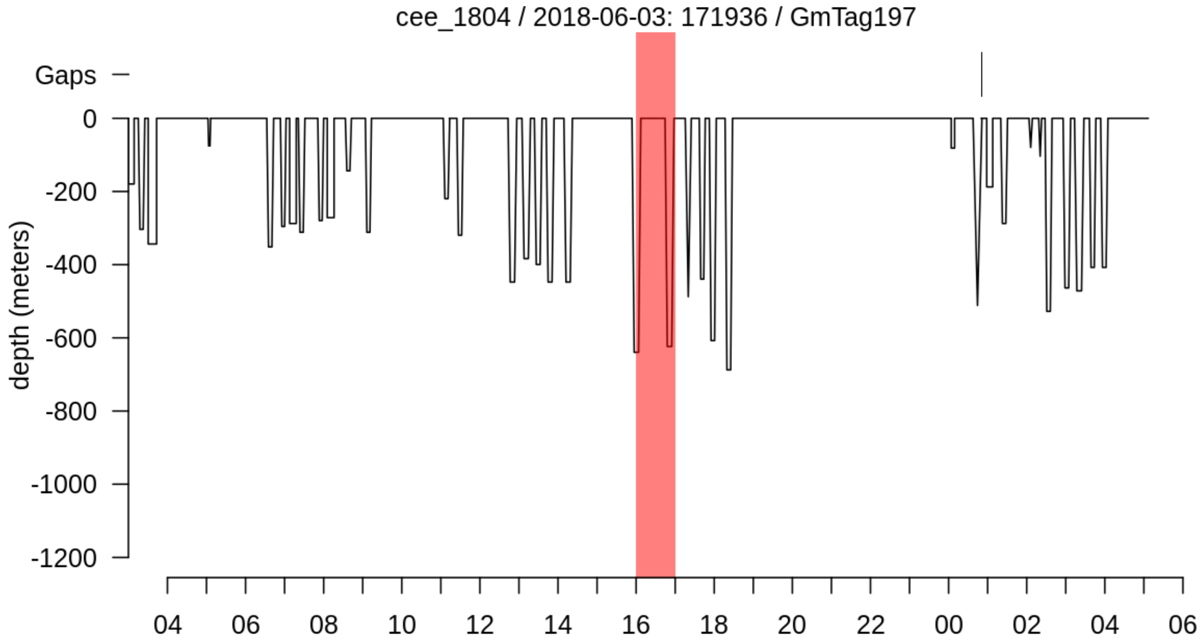


Figure 50. Estimated surface positions for focal whale Gm198 before, during, and after Atlantic-BRS CEE# 18-04

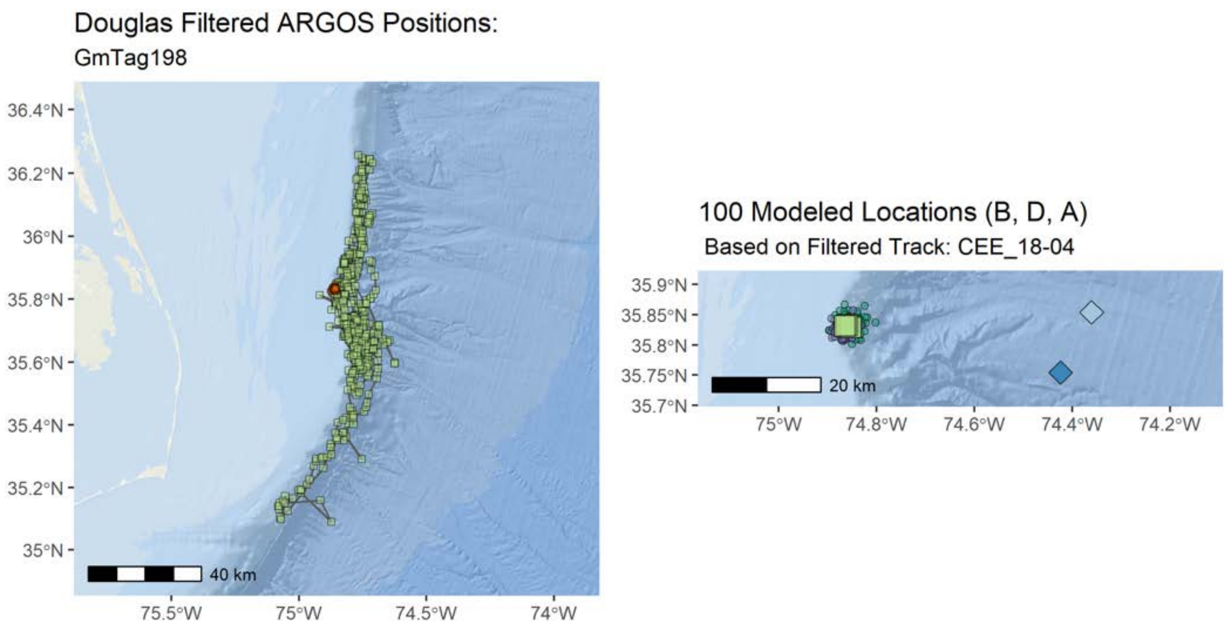


Figure 51. Available dive data for focal whale Gm198 before, during, and after Atlantic-BRS CEE# 18-04

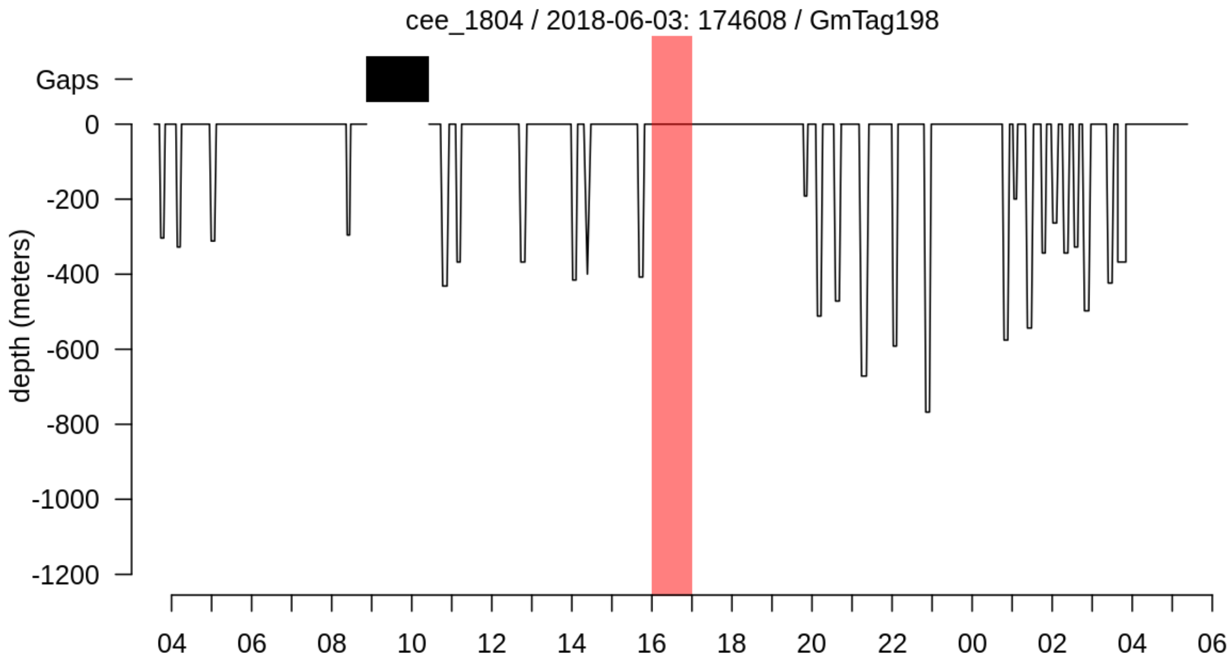


Figure 52. Estimated surface positions for whale Gm200 before, during, and after Atlantic-BRS CEE# 18-05

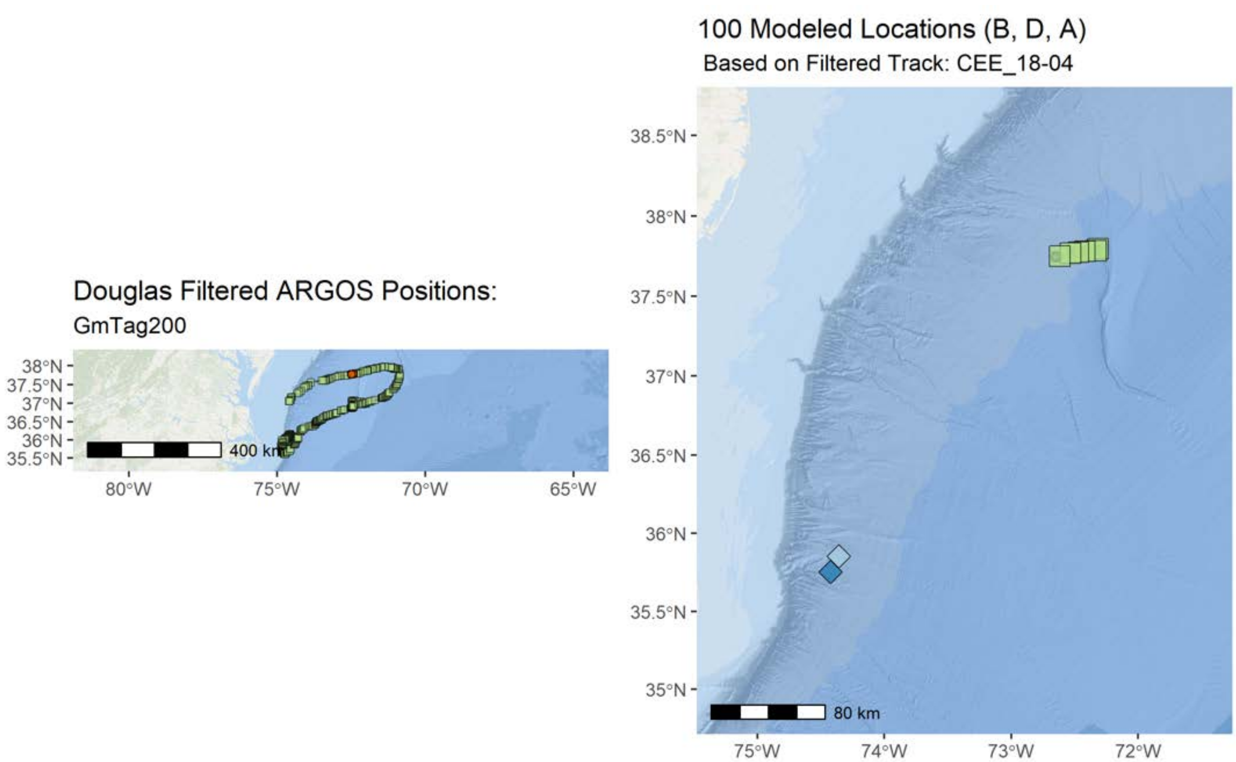


Figure 53. Available dive data for whale Gm200 before, during, and after Atlantic-BRS CEE# 18-04

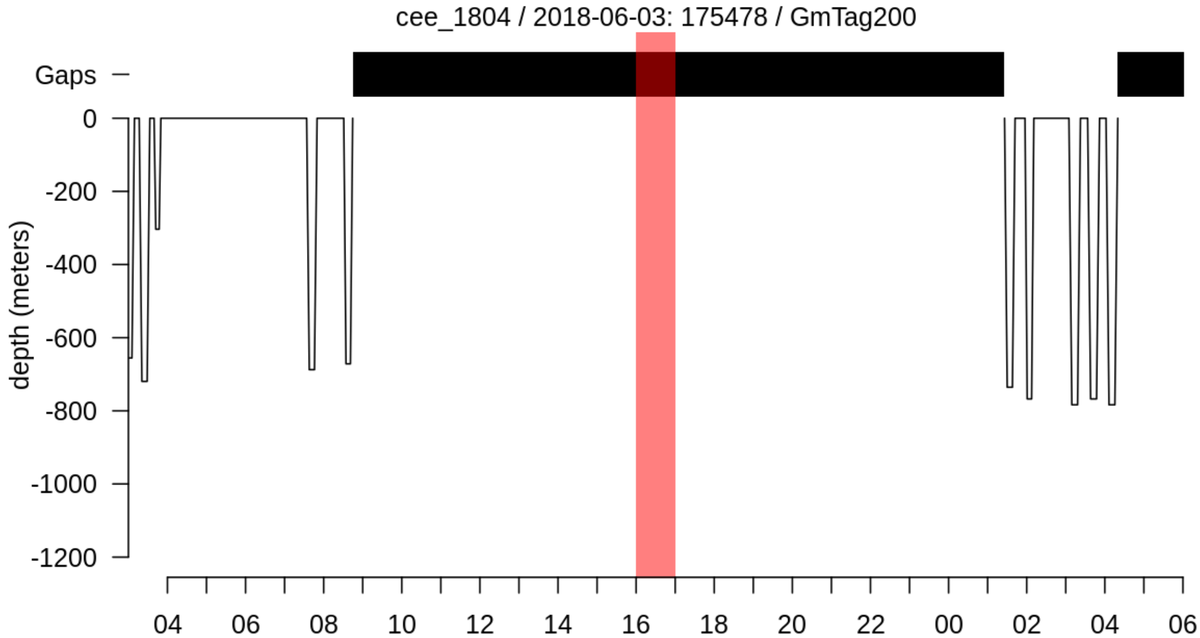


Figure 54. Estimated surface positions for whale Gm201 before, during, and after Atlantic-BRS CEE# 18-04

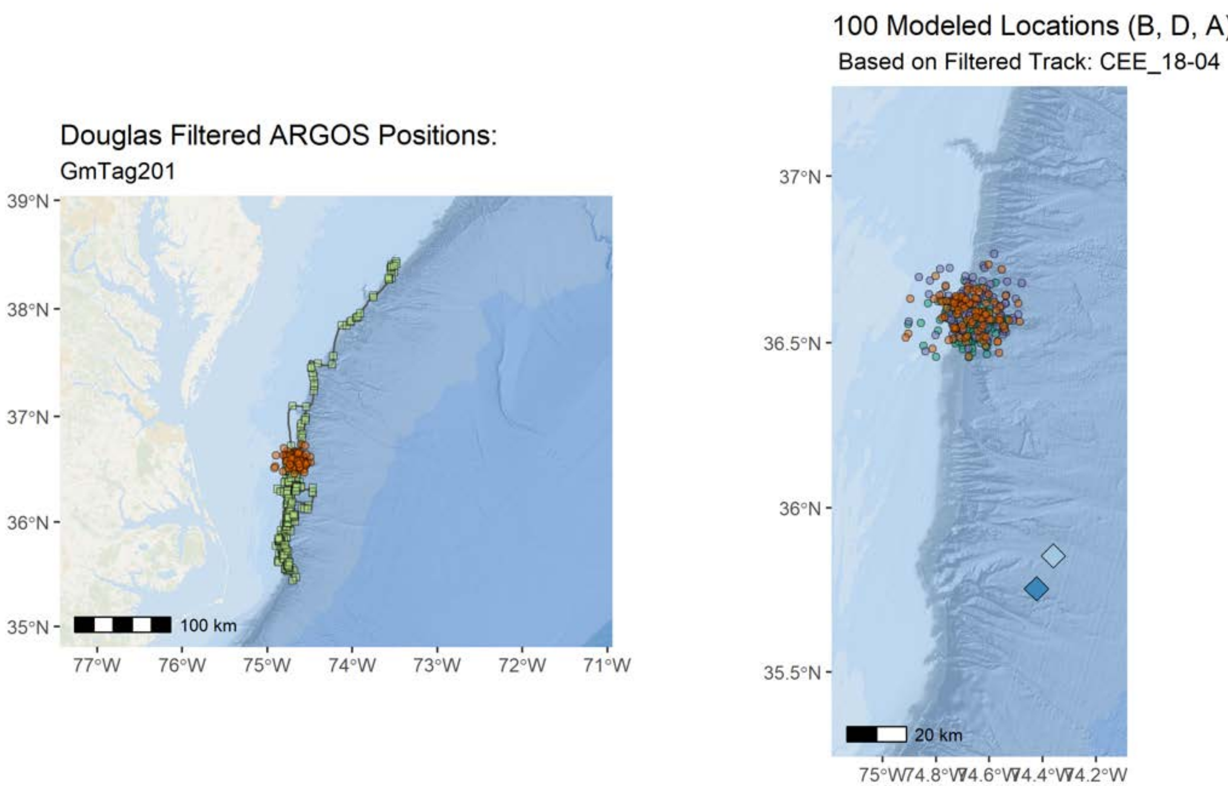


Figure 55. Available dive data for whale Gm201 before, during, and after Atlantic-BRS CEE# 18-04

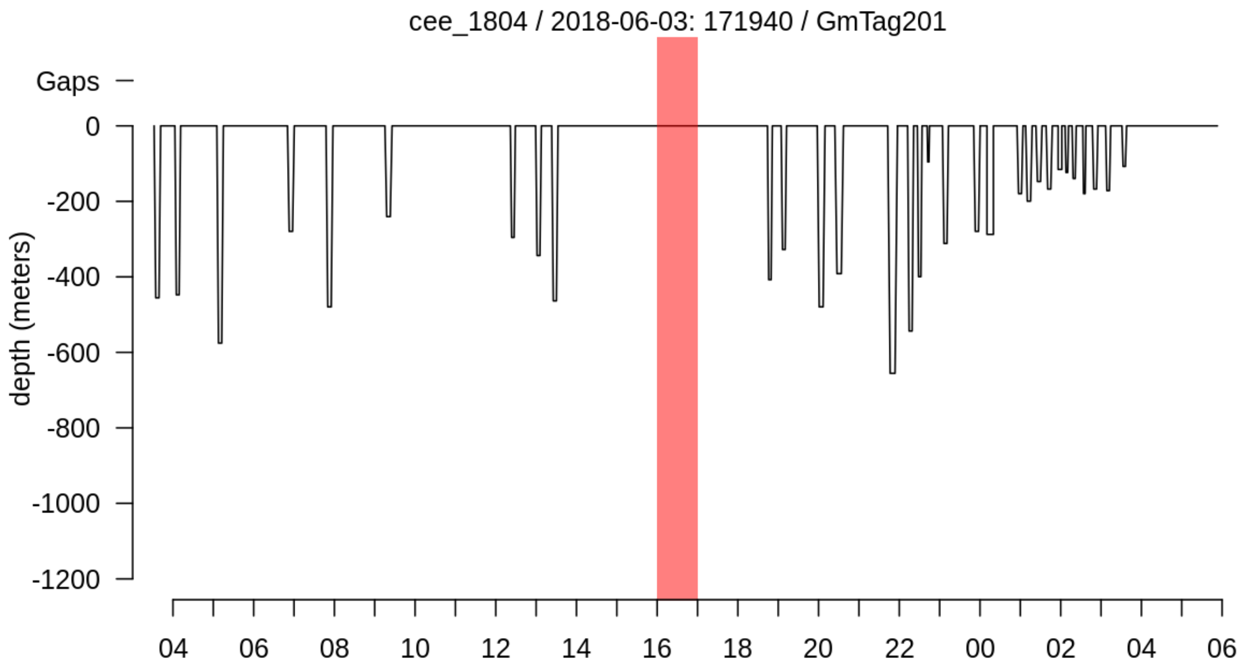


Figure 56. Estimated surface positions for whale Gm202 before, during, and after Atlantic-BRS CEE# 18-04

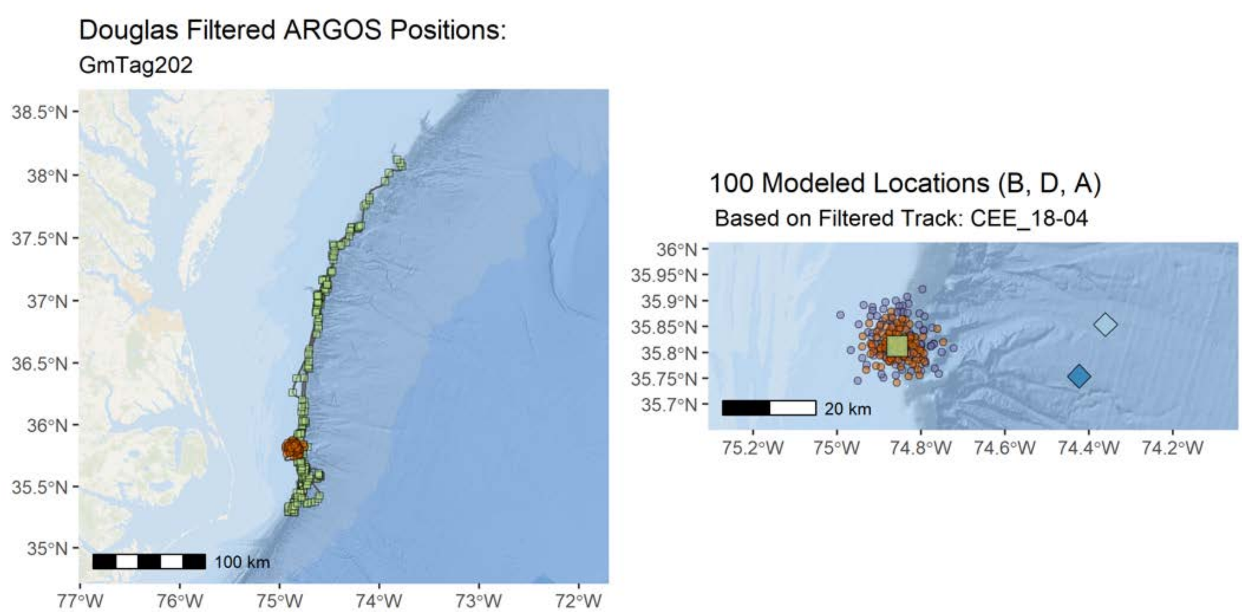


Figure 57. Available dive data for whale Gm202 before, during, and after Atlantic-BRS CEE# 18-04

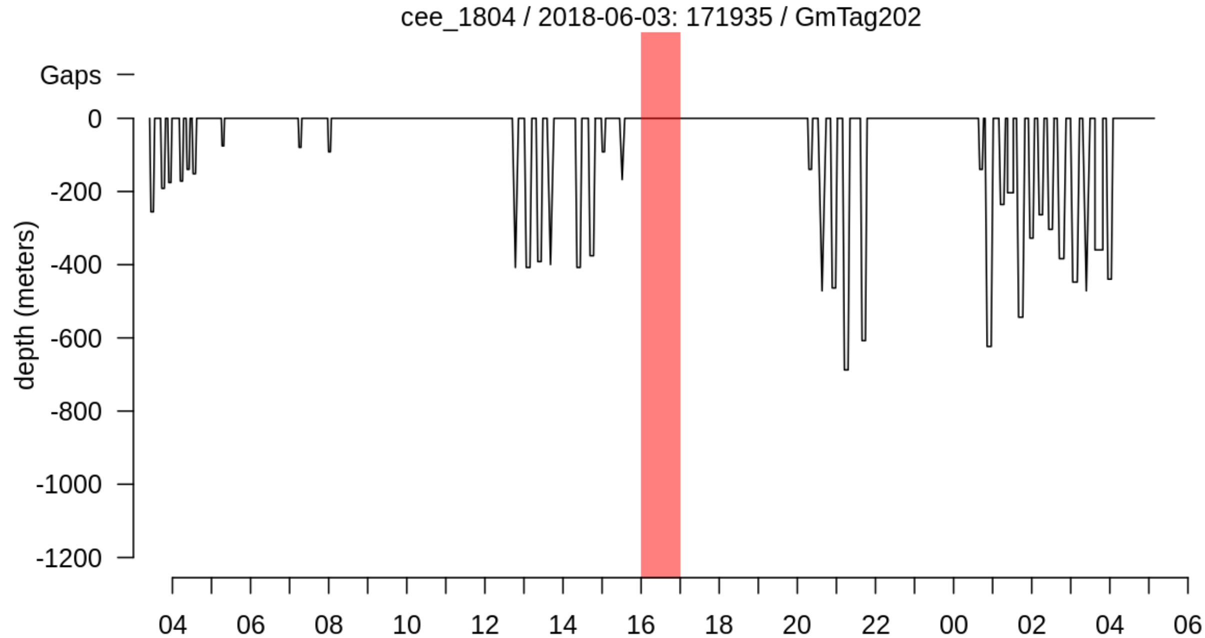


Figure 58. Estimated surface positions for whale Gm203 before, during, and after Atlantic-BRS CEE# 18-04

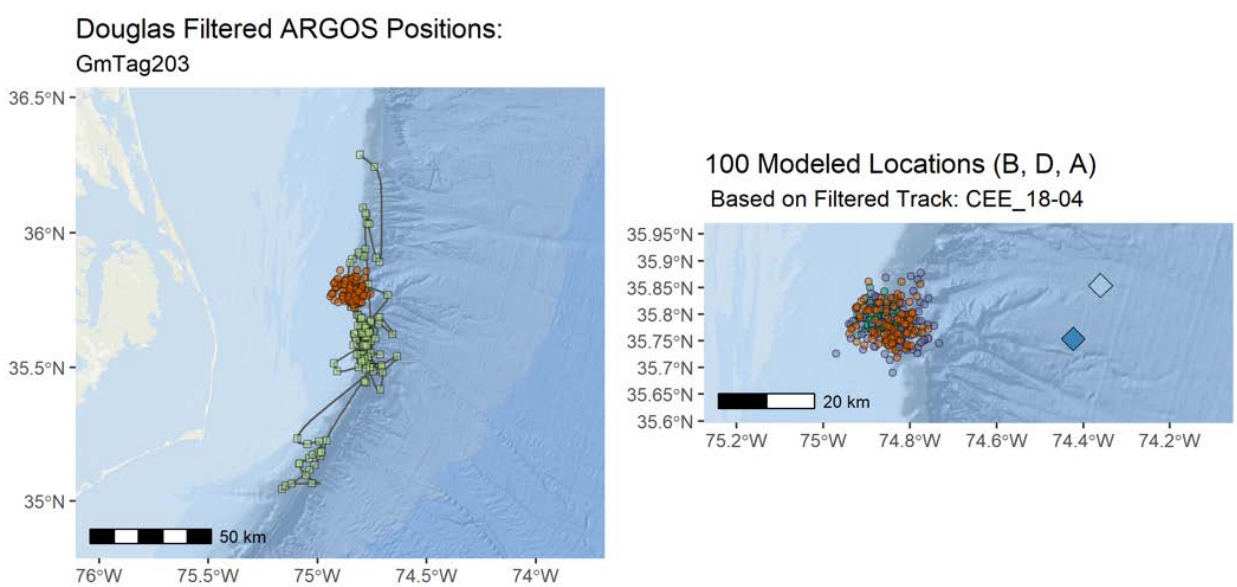


Figure 59. Available dive data for whale Gm203 before, during, and after Atlantic-BRS CEE# 18-04

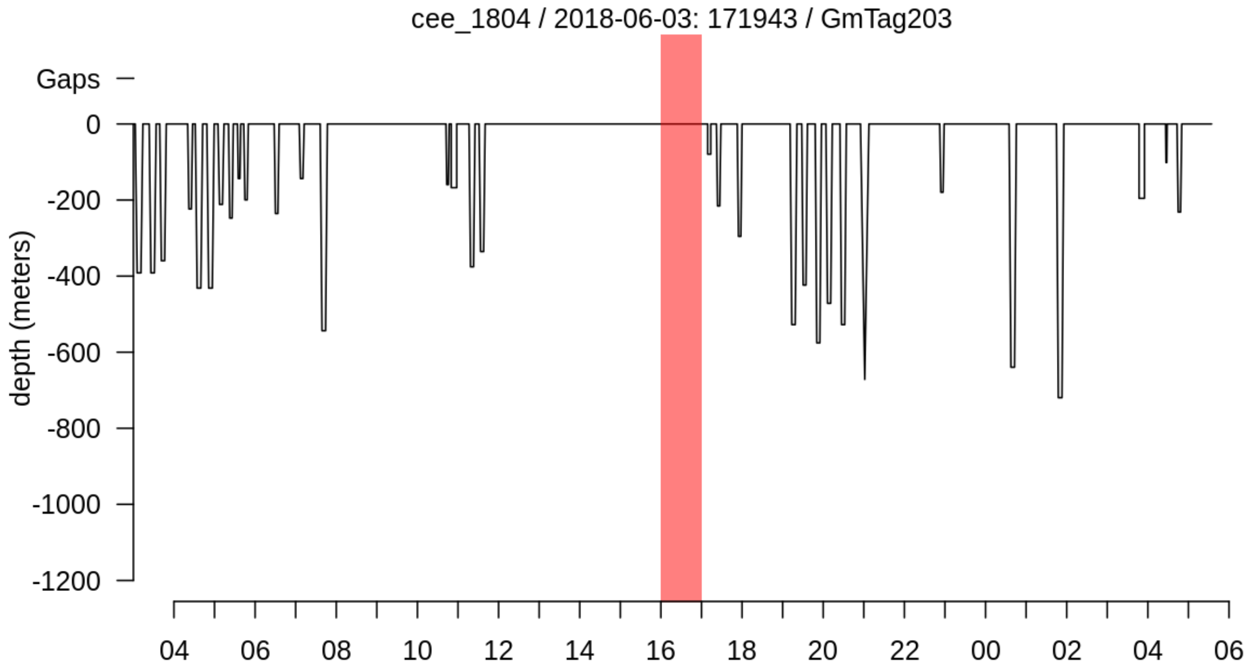


Figure 60. Estimated surface positions for whale Gm204 before, during, and after Atlantic-BRS CEE# 18-04

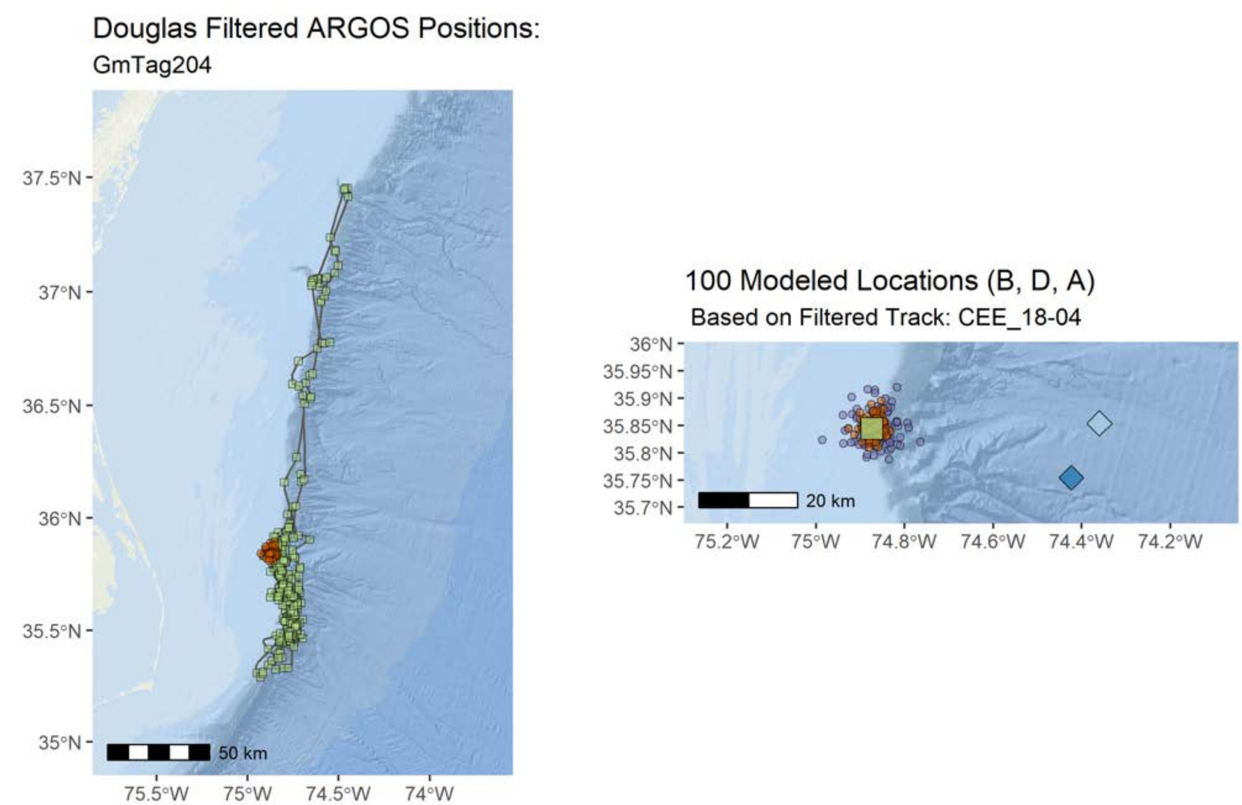


Figure 61. Available dive data for whale Gm204 before, during, and after Atlantic-BRS CEE# 18-04

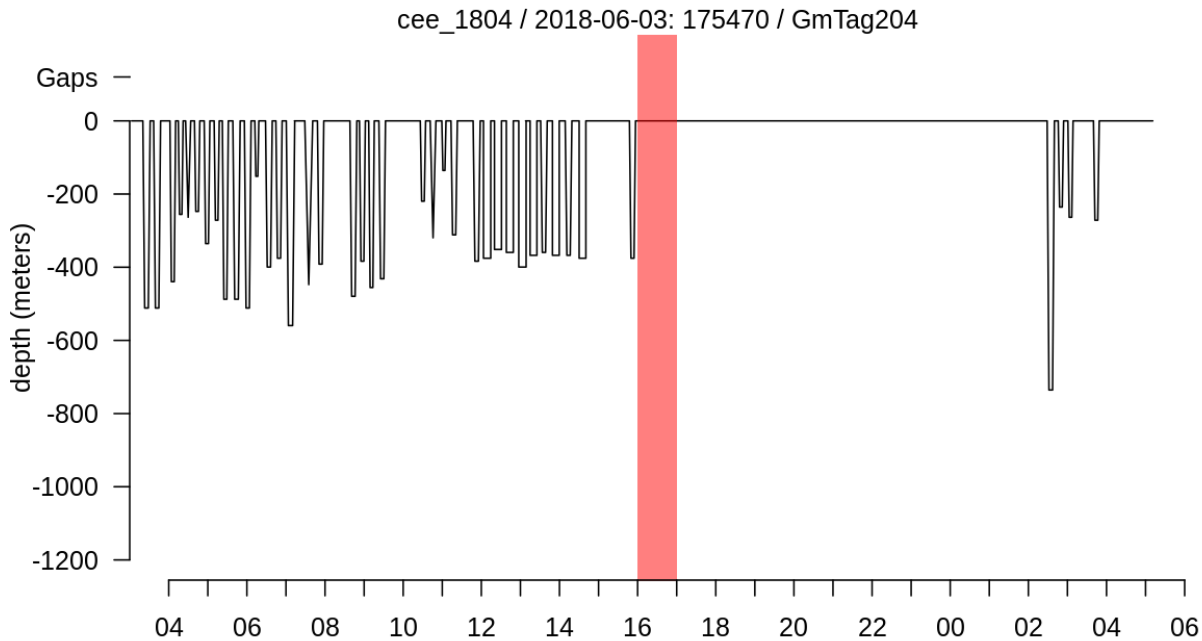


Figure 62. Estimated surface positions for whale Gm205 before, during, and after Atlantic-BRS CEE# 18-04

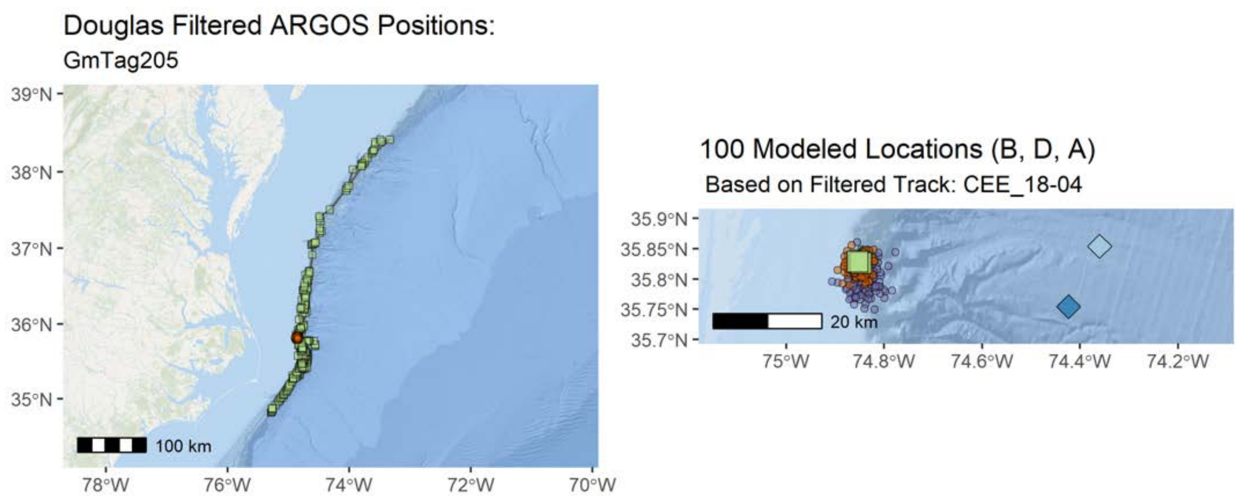


Figure 63. Available dive data for whale Gm205 before, during, and after Atlantic-BRS CEE# 18-04

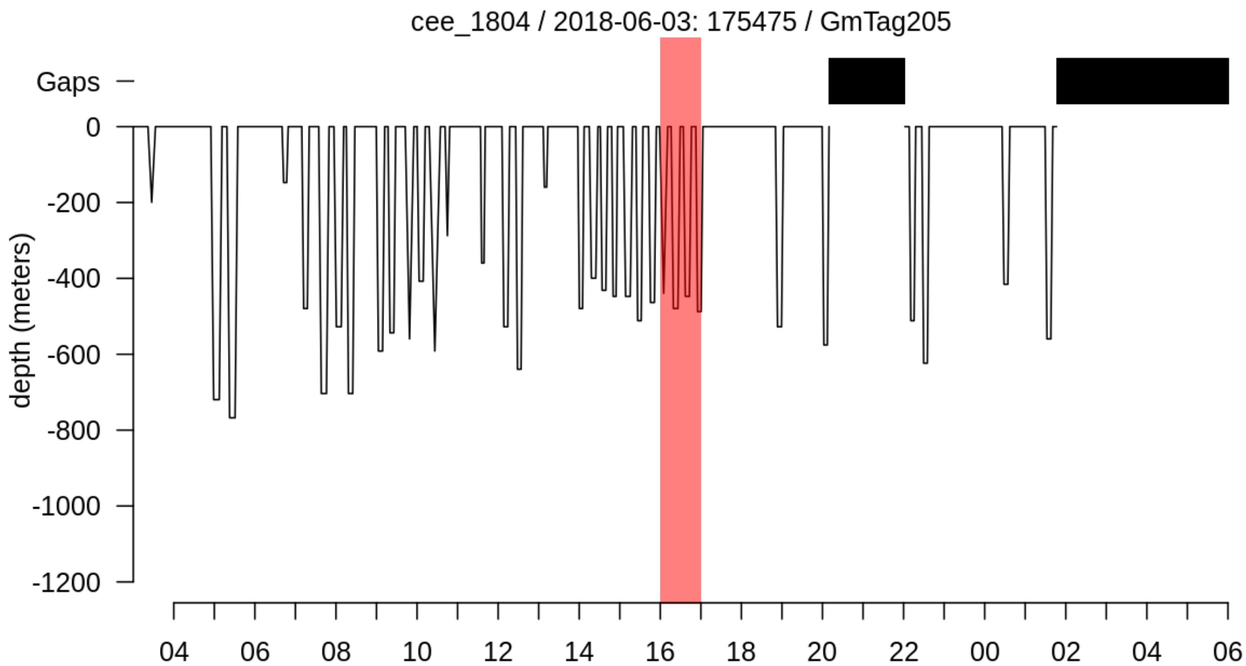


Figure 64. Estimated surface positions for whale Gm206 before, during, and after Atlantic-BRS CEE# 18-04

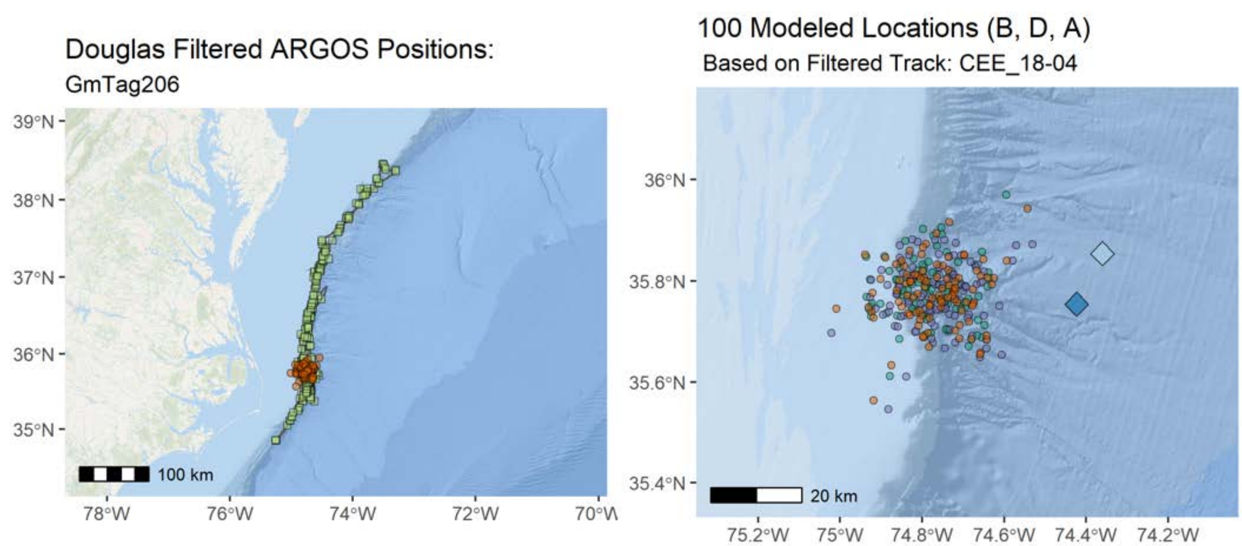
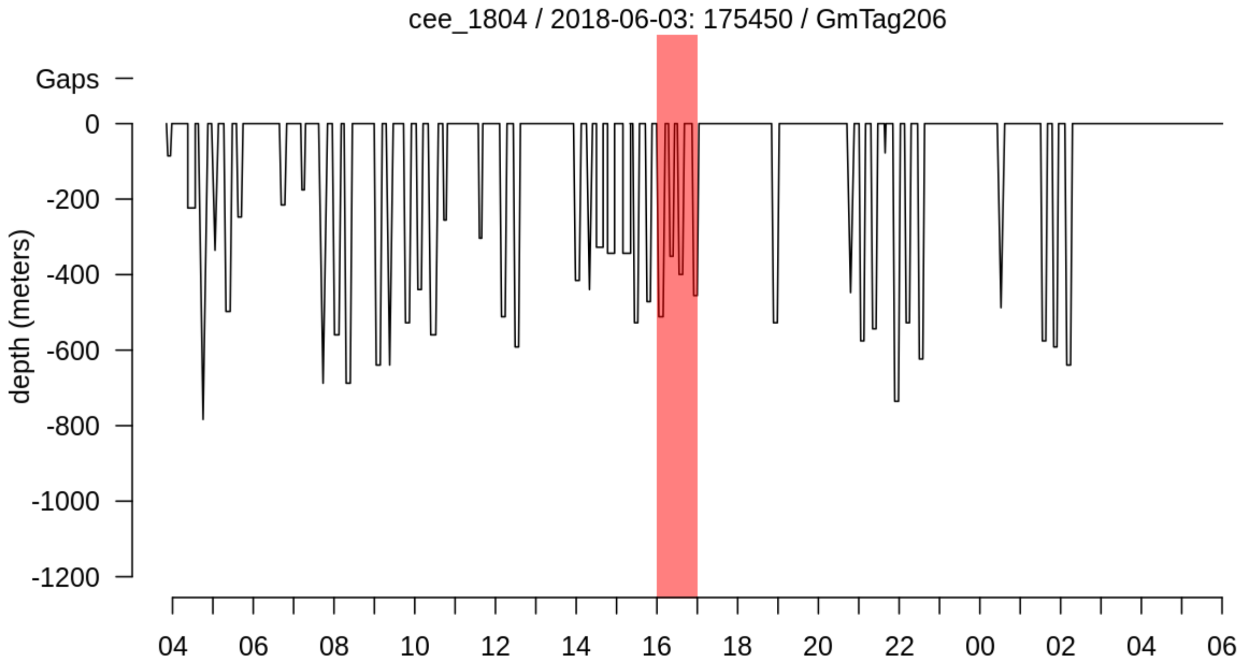


Figure 65. Available dive data for whale Gm206 before, during, and after Atlantic-BRS CEE# 18-04



2.3.5 CEE 18-05: Silent Control

Table 12. Metadata summary for Atlantic-BRS CEE# 18-05

CEE Conditions	Metadata Summary
CEE Identifier	18-05
Date	6/6/18
Type	Silent control 15-element vertical line array deployed to 20 m depth from *F/V Kahuna* (stationary), but not activated
Signal Parameters	None; ambient noise conditions with vessel operating as if source was activated
Start time (UTC)	18:48:00
Start lat/lon	35.599188; -74.768605
End time (UTC)	19:18:00
End lat/lon	35.6040533; -74.7615616
Beaked whales monitored with tags during CEE	Focal: None Incidental: Zc69, Zc70
Pilot whales monitored with tags during CEE	Focal: Gm18_157b Incidental: Gm197, Gm198, Gm201, Gm202, Gm203, Gm204, Gm205, Gm206

Figure 66. Uncorrected pseudotrack based on surface positions and tag data for focal whale Gm18_157a (DTAG) before, during, and after Atlantic-BRS CEE# 18-05

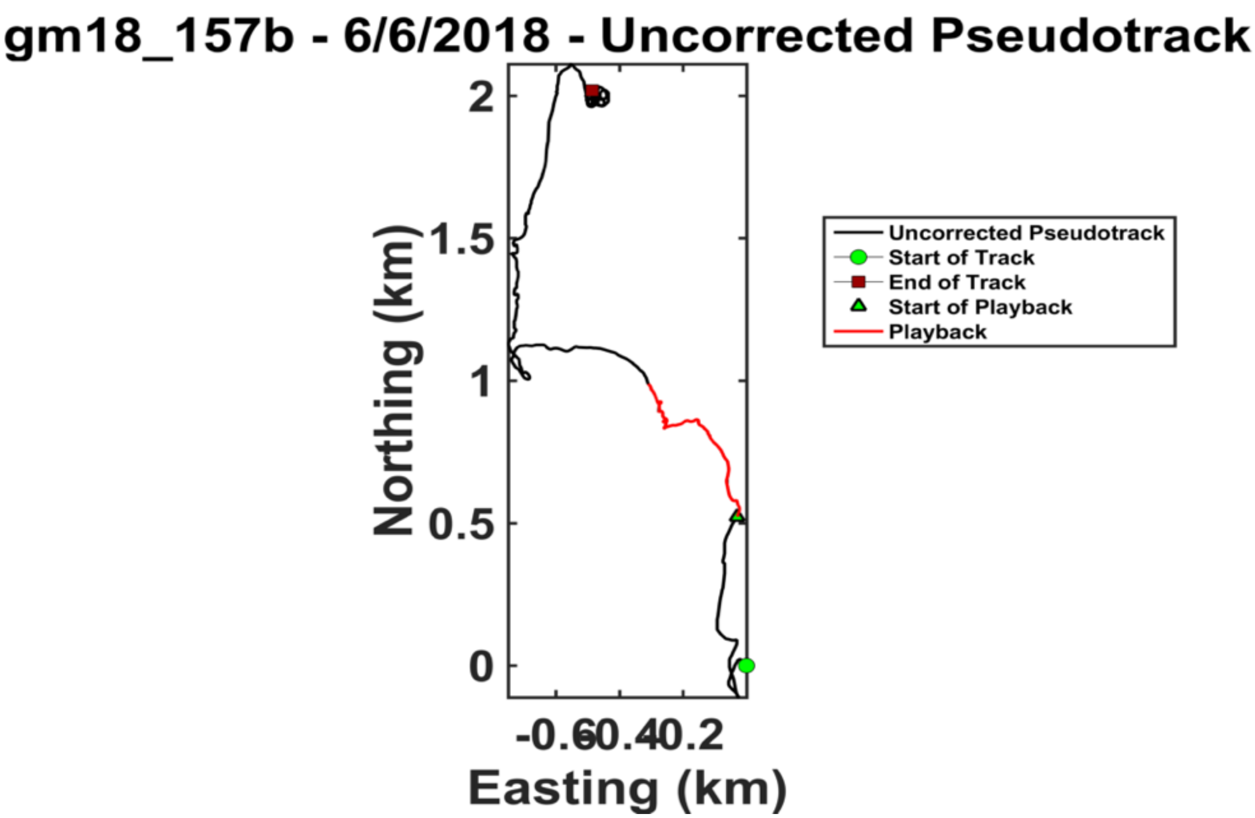


Figure 67. Available dive data for focal whale Gm18_157a (DTAG) before, during, and after Atlantic-BRS CEE# 18-05

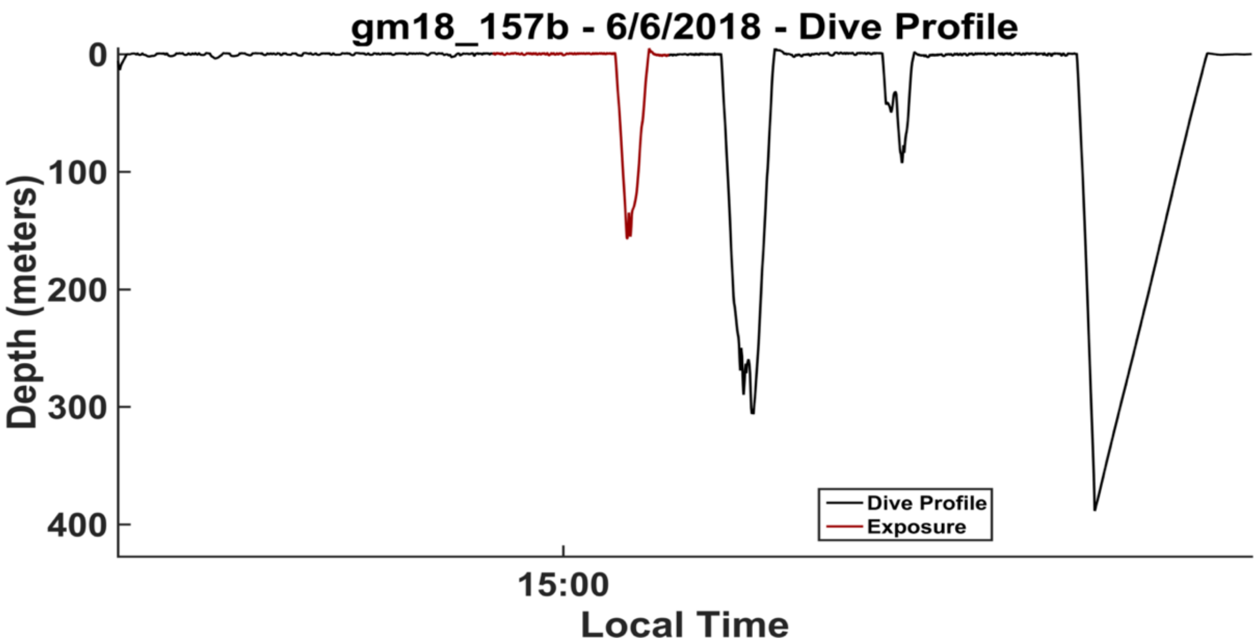


Figure 68. Estimated surface positions for whale Zc69 before, during, and after Atlantic-BRS CEE# 18-05

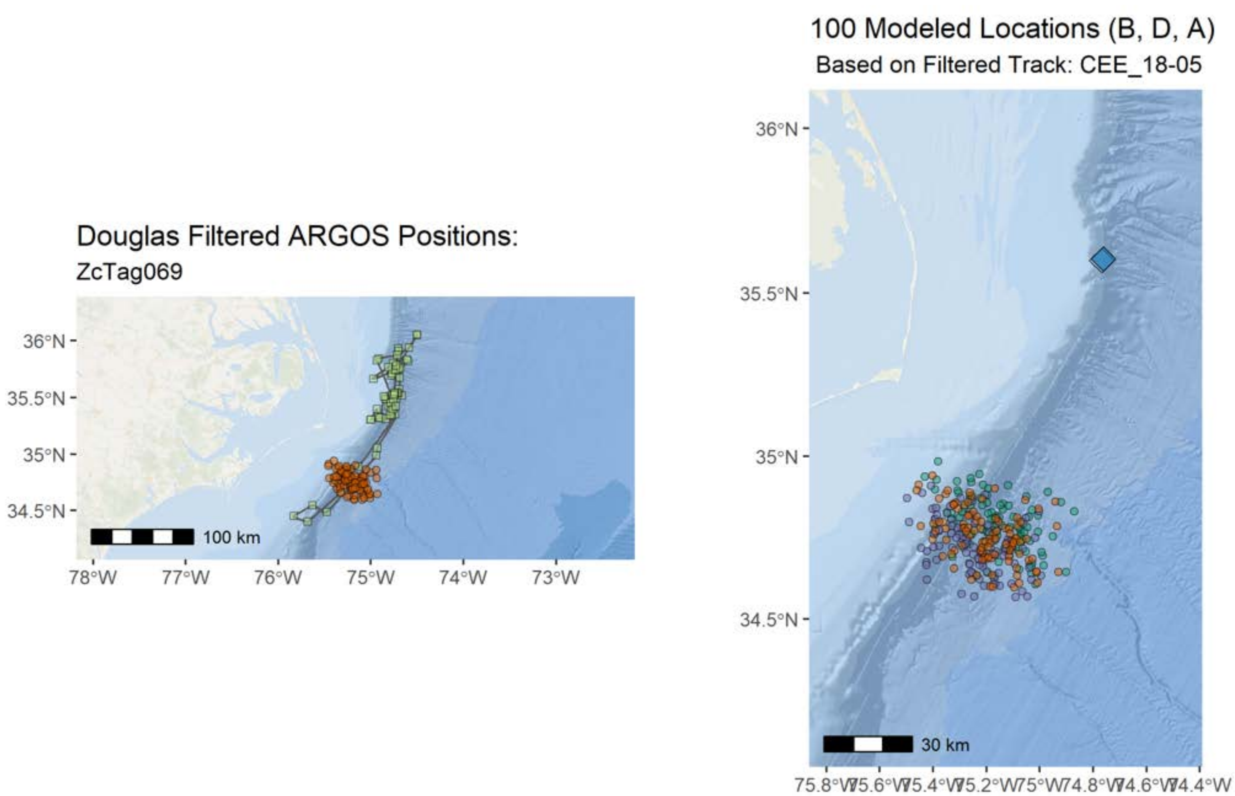


Figure 69. Available dive data for focal whale Zc69 before, during, and after Atlantic-BRS CEE# 18-05

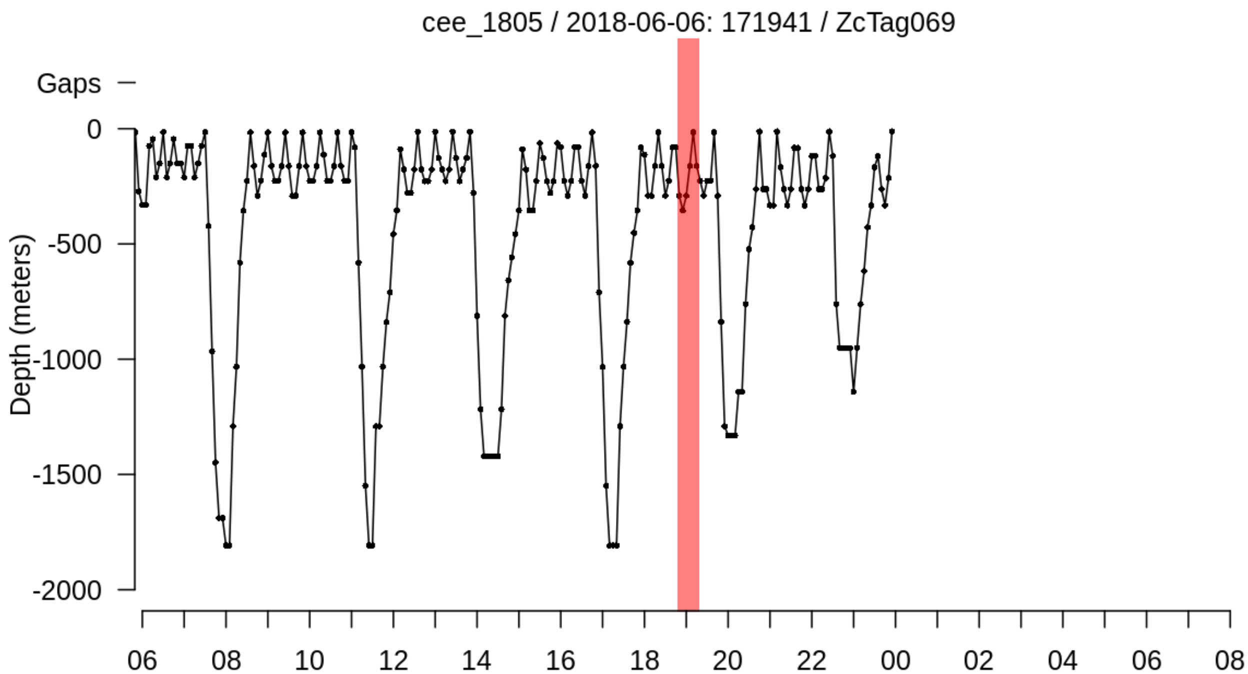


Figure 70. Estimated surface positions for whale Zc70 before, during, and after Atlantic-BRS CEE# 18-05

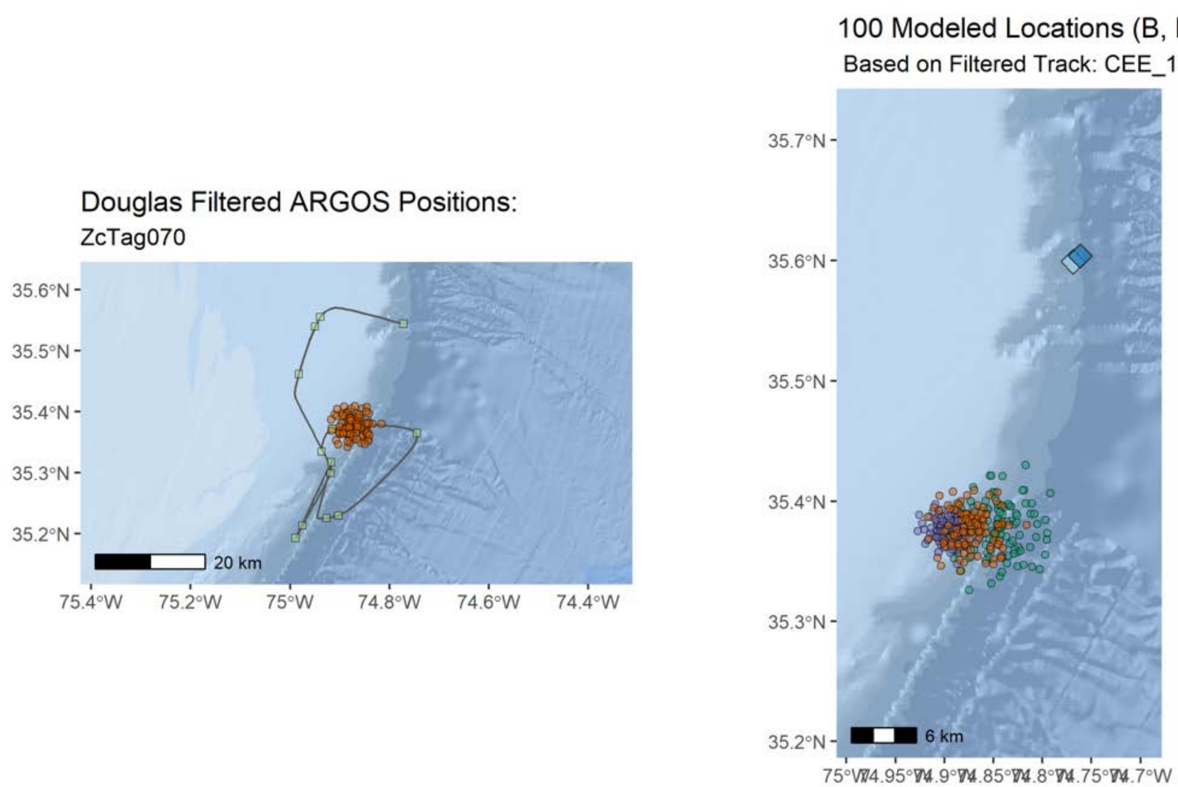


Figure 71. Estimated surface positions for whale Gm197 before, during, and after Atlantic-BRS CEE# 18-05

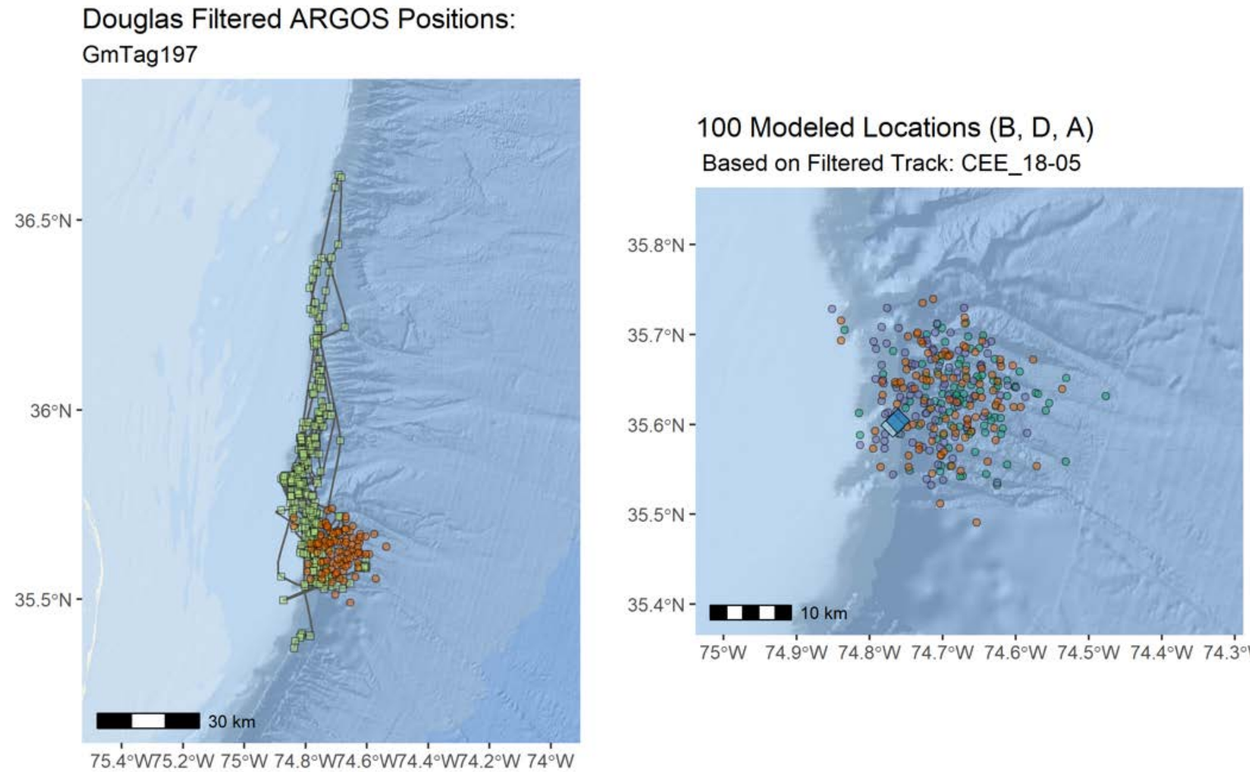


Figure 72. Available dive data for whale Gm197 before, during, and after Atlantic-BRS CEE# 18-05

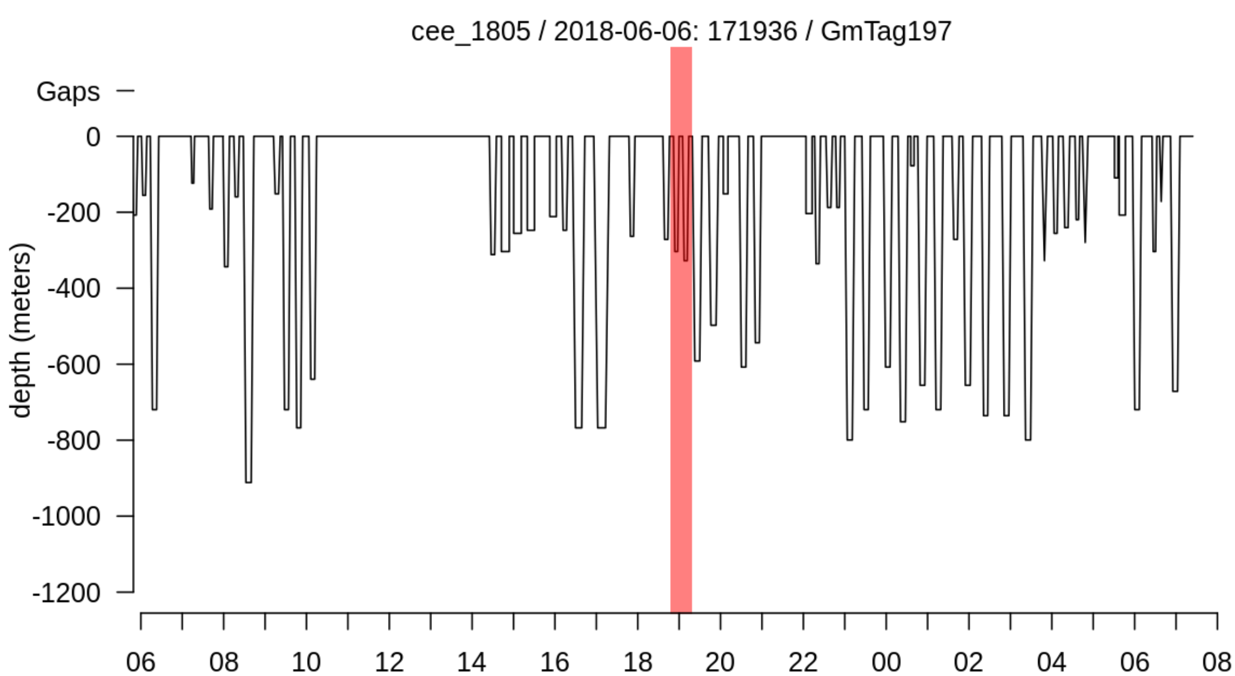


Figure 73. Estimated surface positions for focal whale Gm198 before, during, and after Atlantic-BRS CEE# 18-05

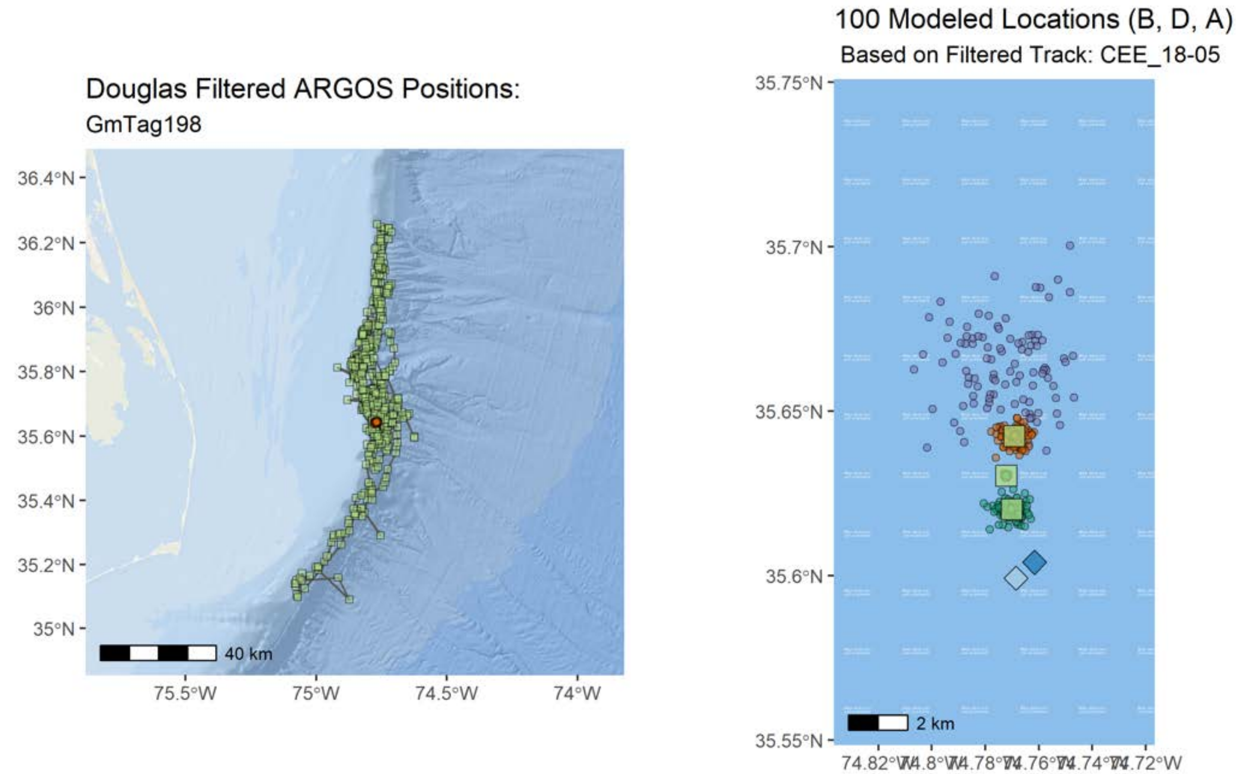


Figure 74. Available dive data for focal whale Gm198 before, during, and after Atlantic-BRS CEE# 18-05

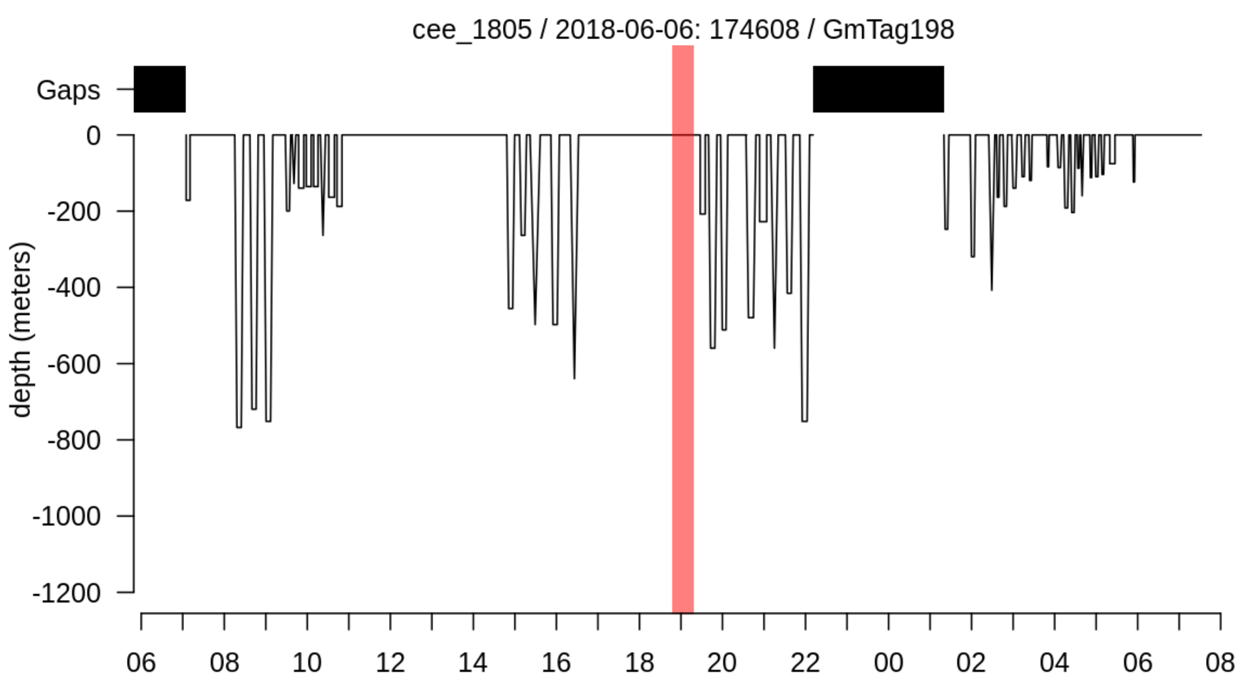


Figure 75. Estimated surface positions for whale Gm201 before, during, and after Atlantic-BRS CEE# 18-05

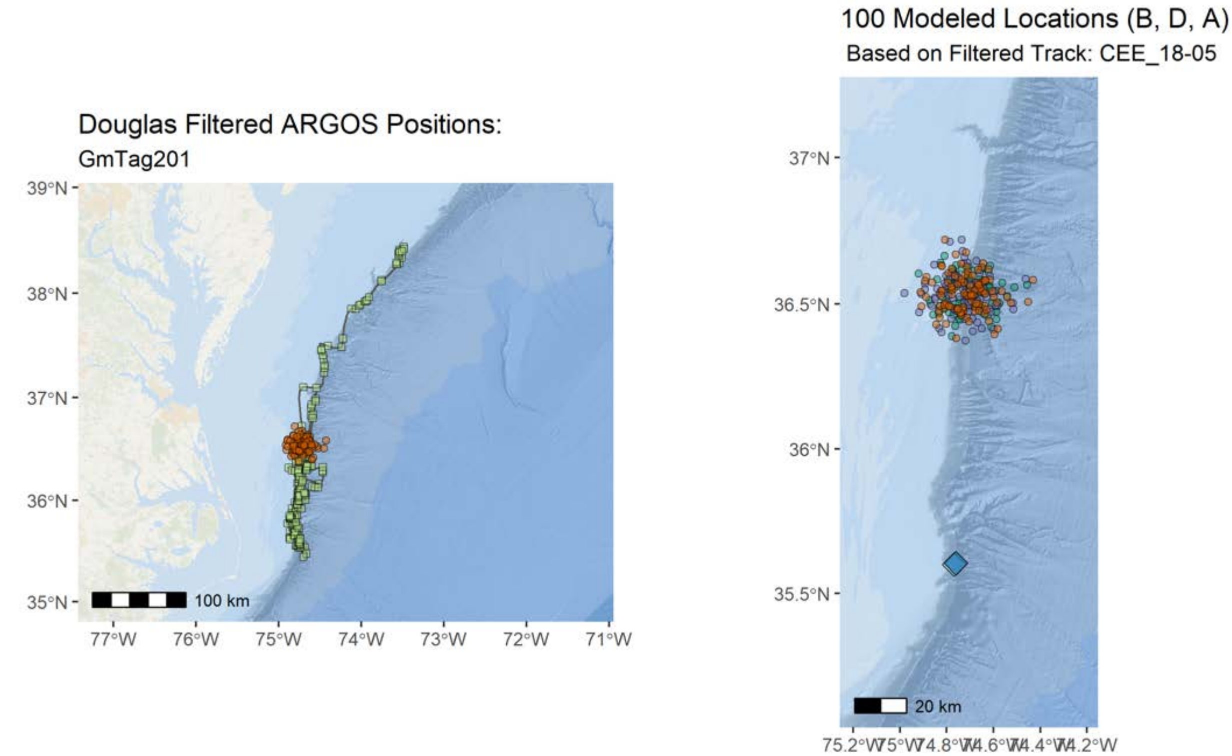


Figure 76. Available dive data for whale Gm201 before, during, and after Atlantic-BRS CEE# 18-05

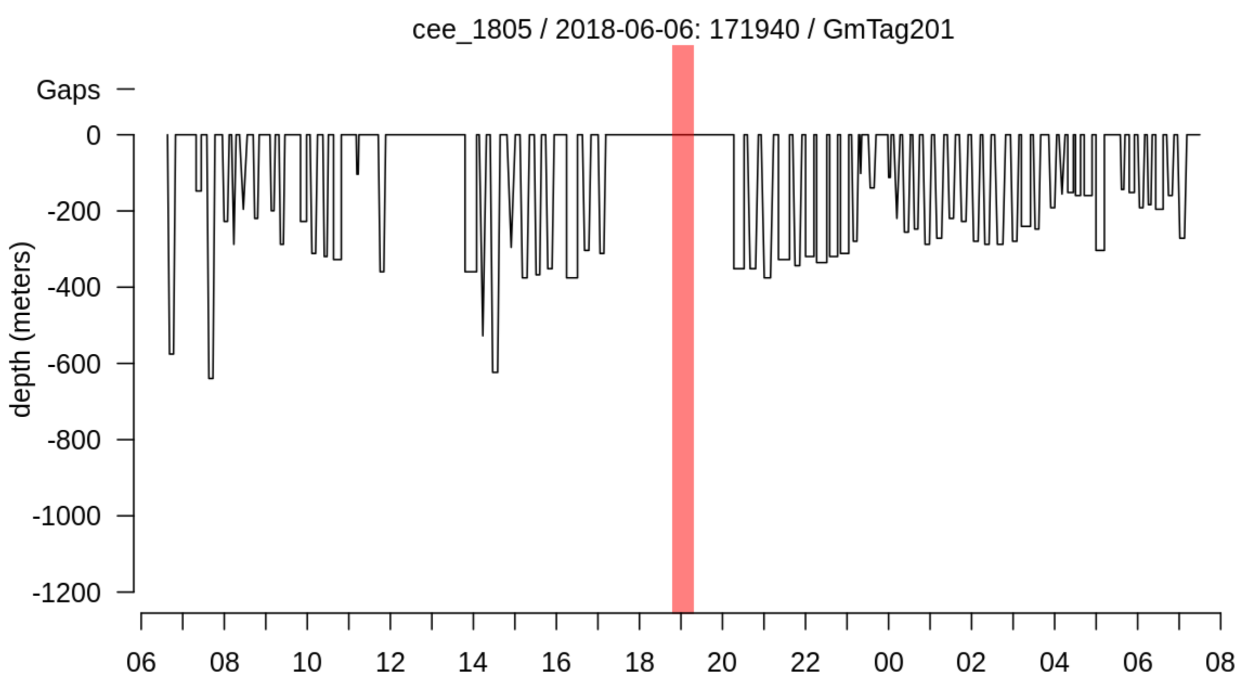


Figure 77. Estimated surface positions for whale Gm202 before, during, and after Atlantic-BRS CEE# 18-05

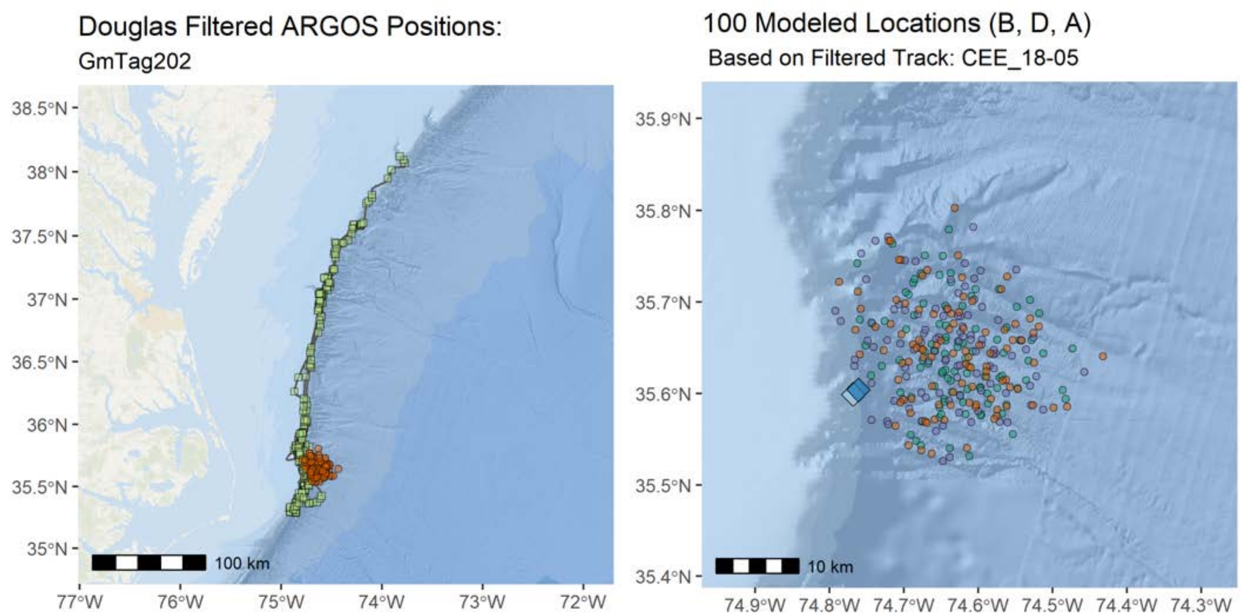


Figure 78. Available dive data for whale Gm202 before, during, and after Atlantic-BRS CEE# 18-05

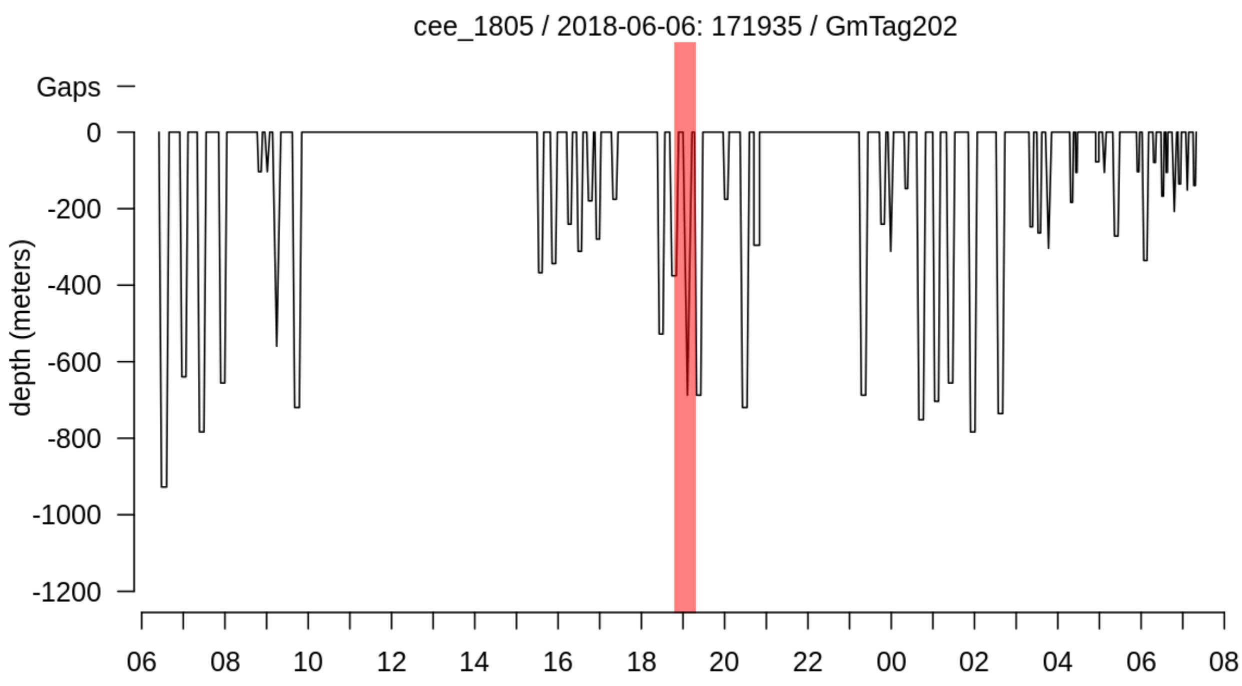


Figure 79. Estimated surface positions for whale Gm203 before, during, and after Atlantic-BRS CEE# 18-05

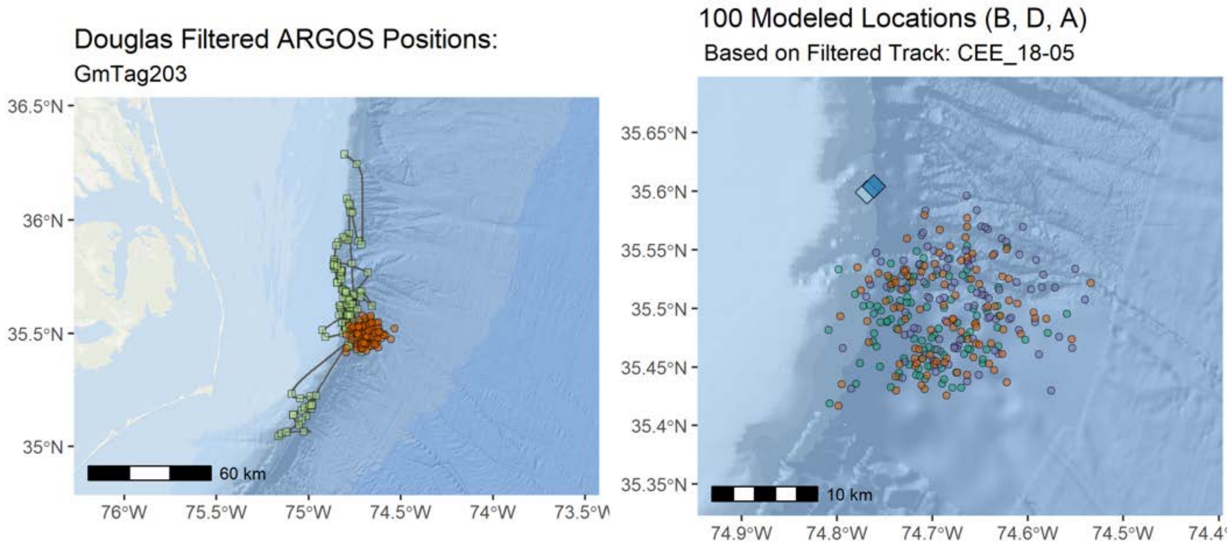


Figure 79. Available dive data for whale Gm203 before, during, and after Atlantic-BRS CEE# 18-05

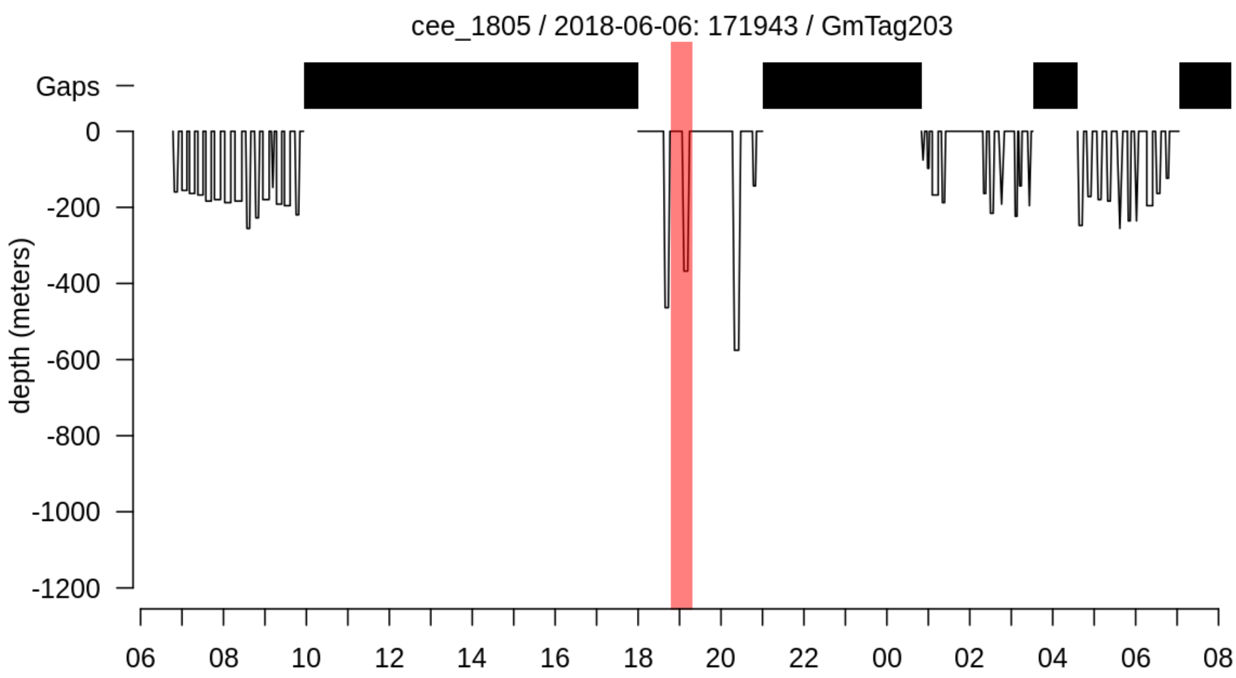


Figure 80. Estimated surface positions for whale Gm204 before, during, and after Atlantic-BRS CEE# 18-05

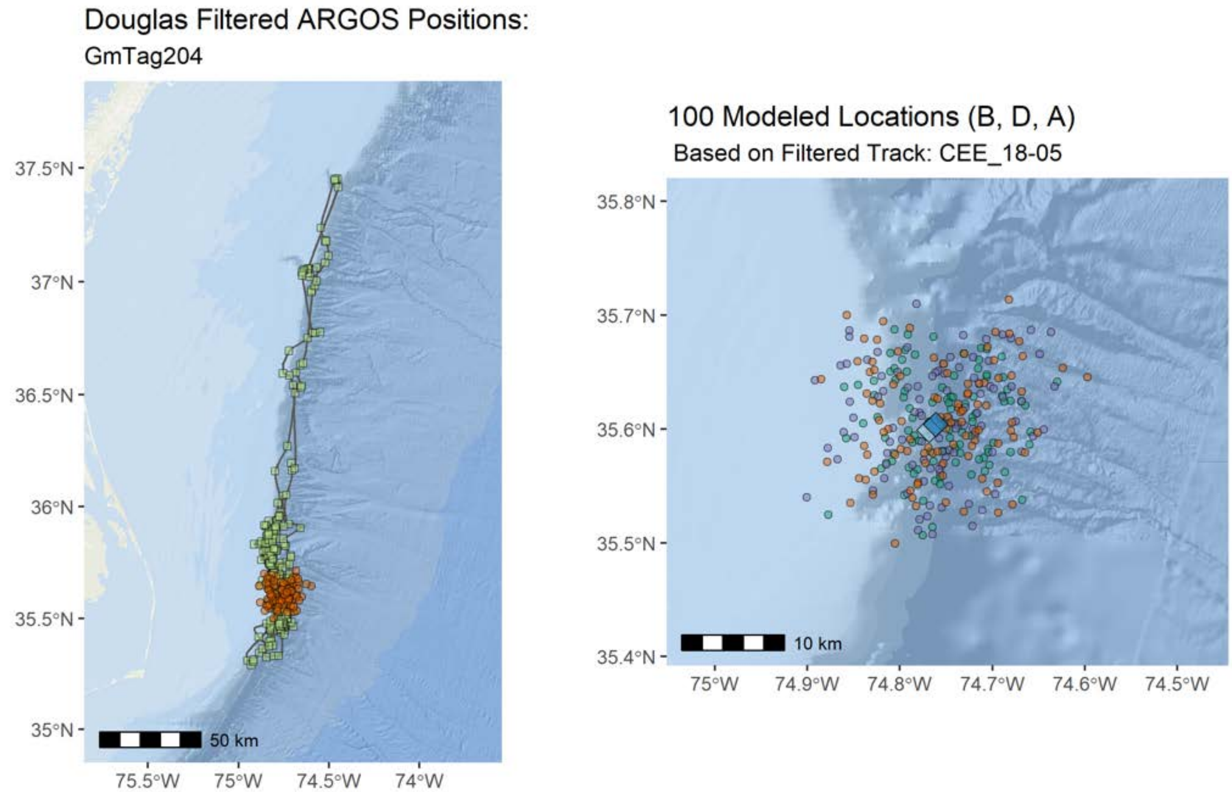


Figure 81. Available dive data for whale Gm204 before, during, and after Atlantic-BRS CEE# 18-05

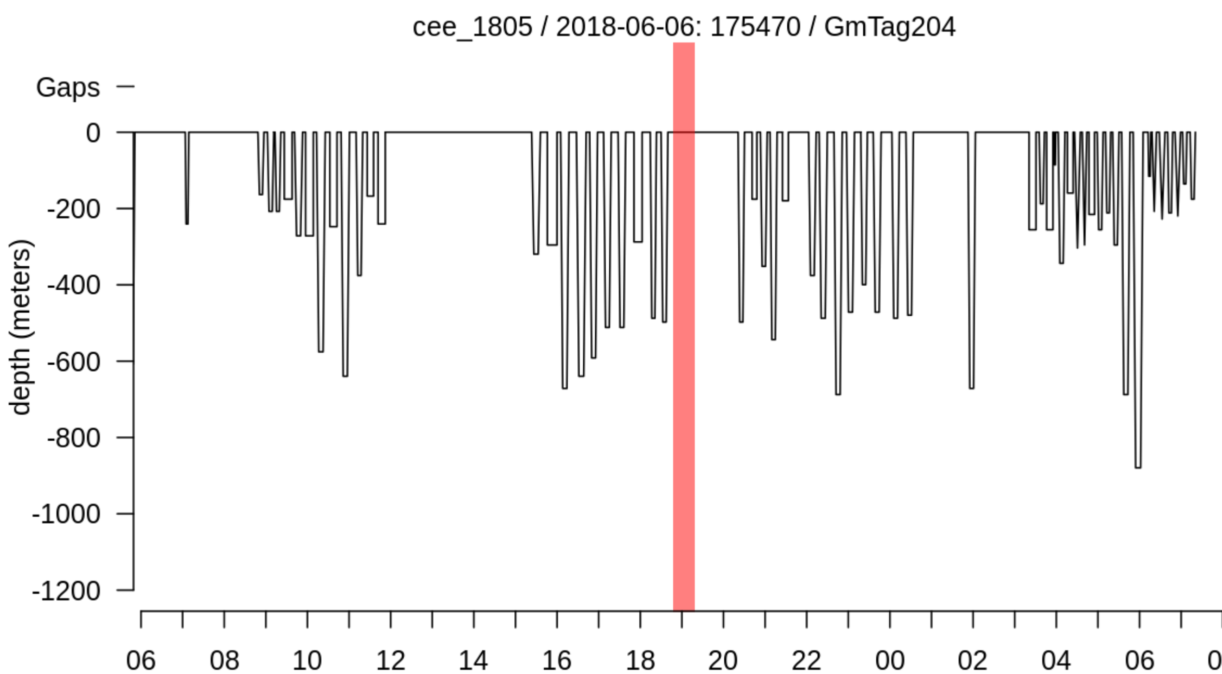


Figure 82. Estimated surface positions for whale Gm205 before, during, and after Atlantic-BRS CEE# 18-05

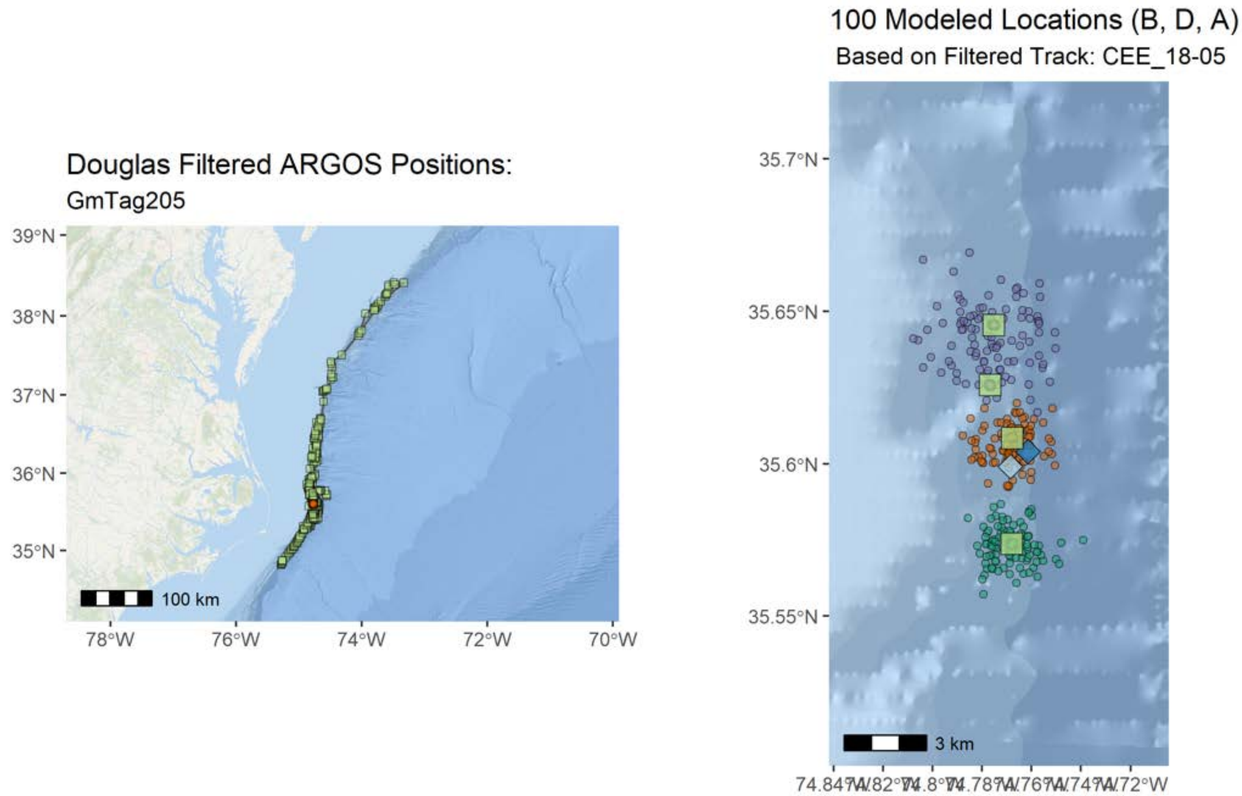


Figure 83. Available dive data for whale Gm205 before, during, and after Atlantic-BRS CEE# 18-05

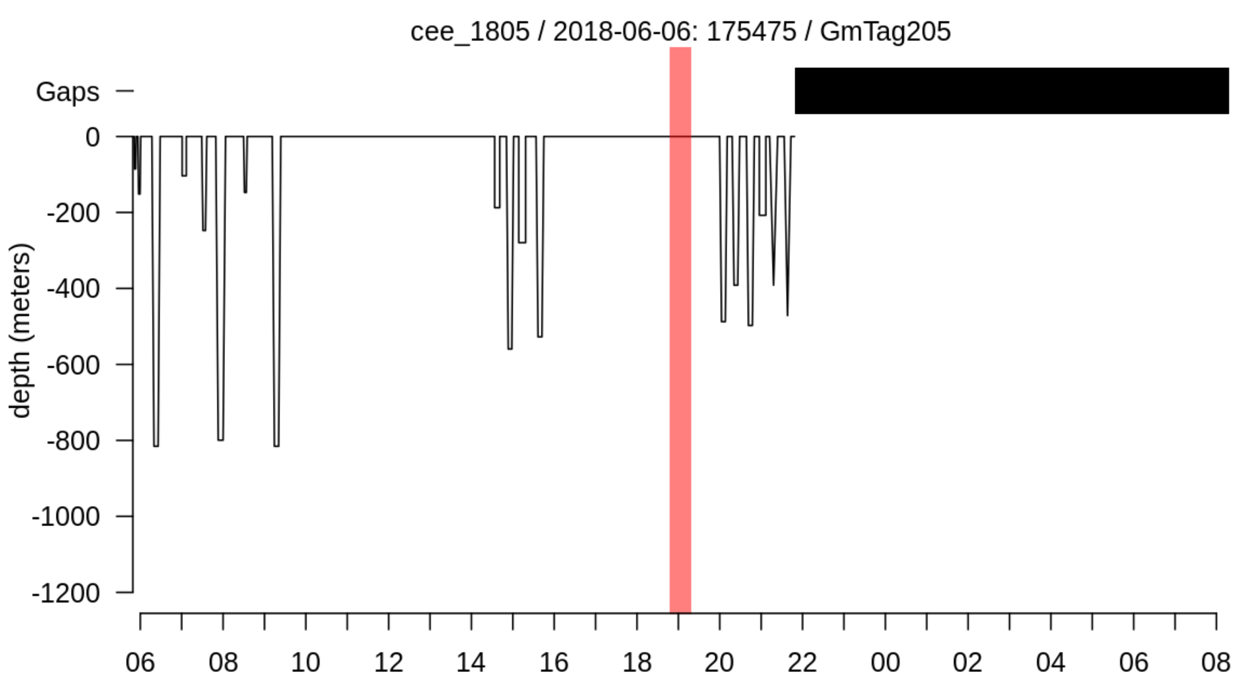


Figure 84. Estimated surface positions for whale Gm206 before, during, and after Atlantic-BRS CEE# 18-05

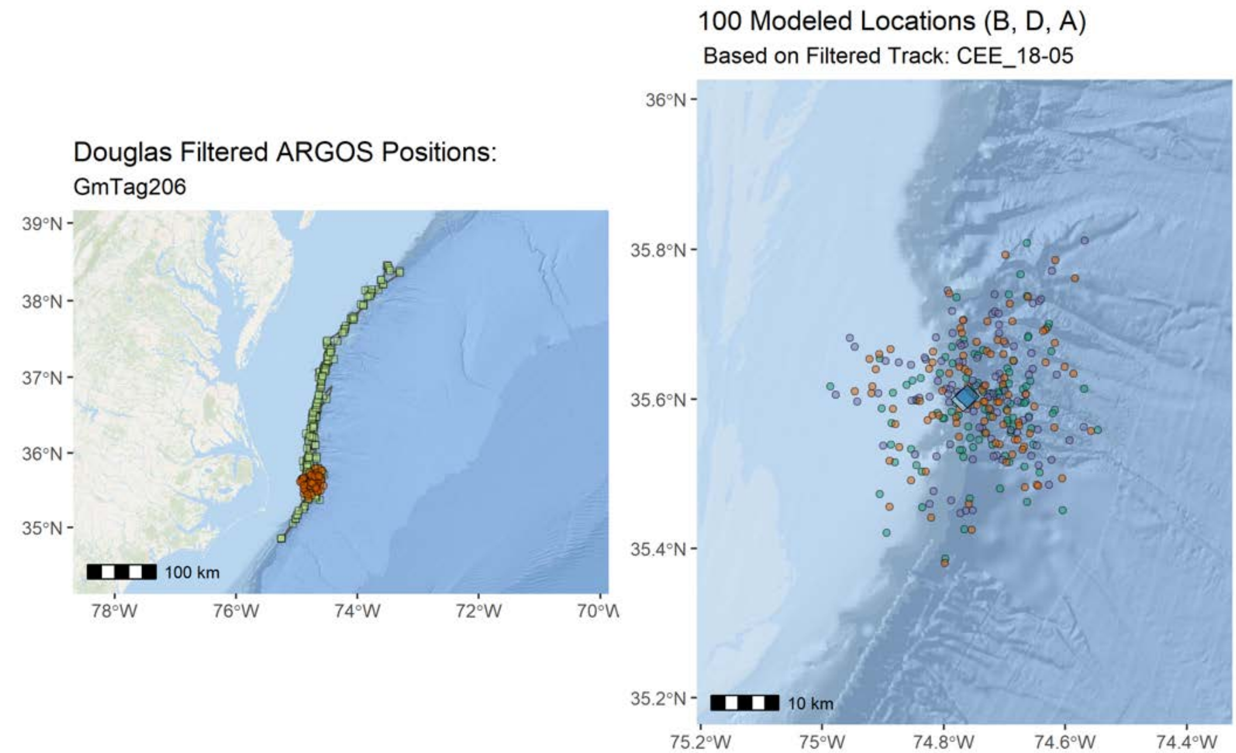
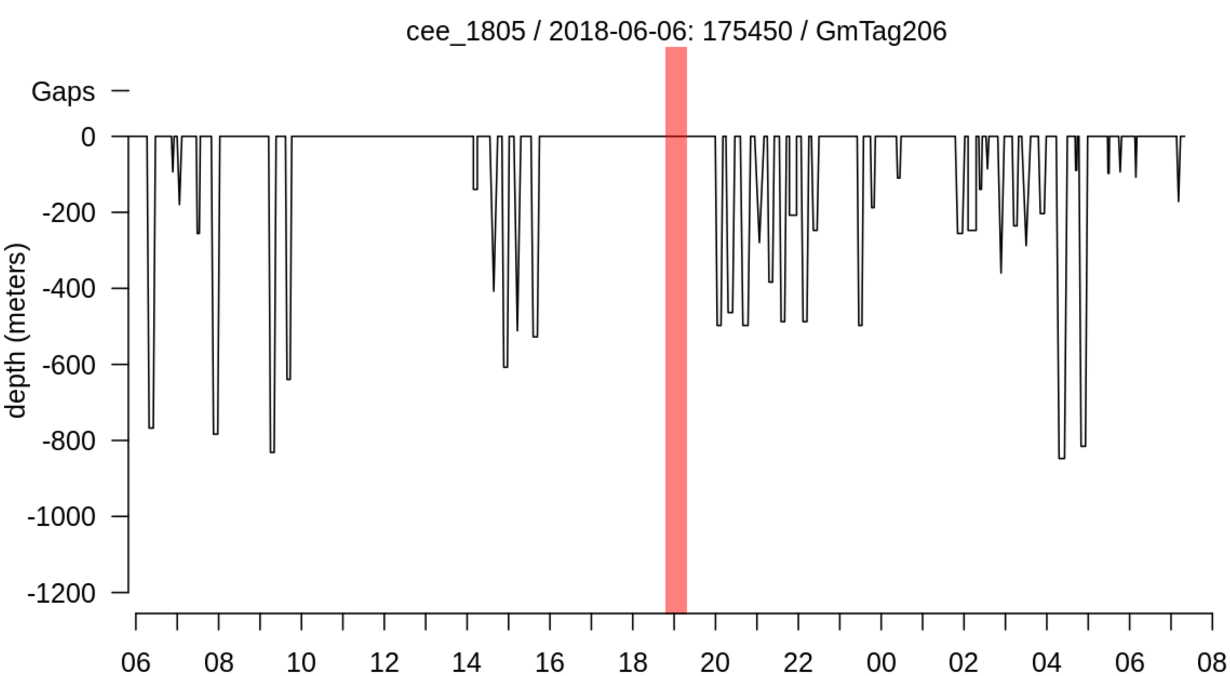


Figure 85. Available dive data for whale Gm206 before, during, and after Atlantic-BRS CEE# 18-05



2.3.6 CEE 18-06: Full-scale 53C (*USS RAMAGE*)

Table 13. Metadata summary for Atlantic-BRS CEE# 18-06

CEE Conditions	Metadata Summary
CEE Identifier	18-06
Date	6/13/18
Type	Operational MFAS - hull-mounted 53C on USS RAMAGE moving in a straight course at 8 kt over ground
Signal Parameters	Three-segment 1.2s total duration pings (3.5–4 kHz); 235 dB re 1 µPa (RMS) sound pressure source level; 25s repetition rate
Start time (UTC)	14:06:00
Start lat/lon	35.818; -74.737
End time (UTC)	15:06:00
End lat/lon	35.6915; -74.736
Beaked whales monitored with tags during CEE	Focal: Zc69 (followed; sat tag was position only at this point)
Pilot whales monitored with tags during CEE	Focal: Gm203 Incidental: Gm201, Gm202, Gm204, Gm205, Gm206

Figure 86. Map showing animal positions and initial and final requested positions of *USS RAMAGE* for Atlantic-BRS CEE# 18-06 on 13 June 2018

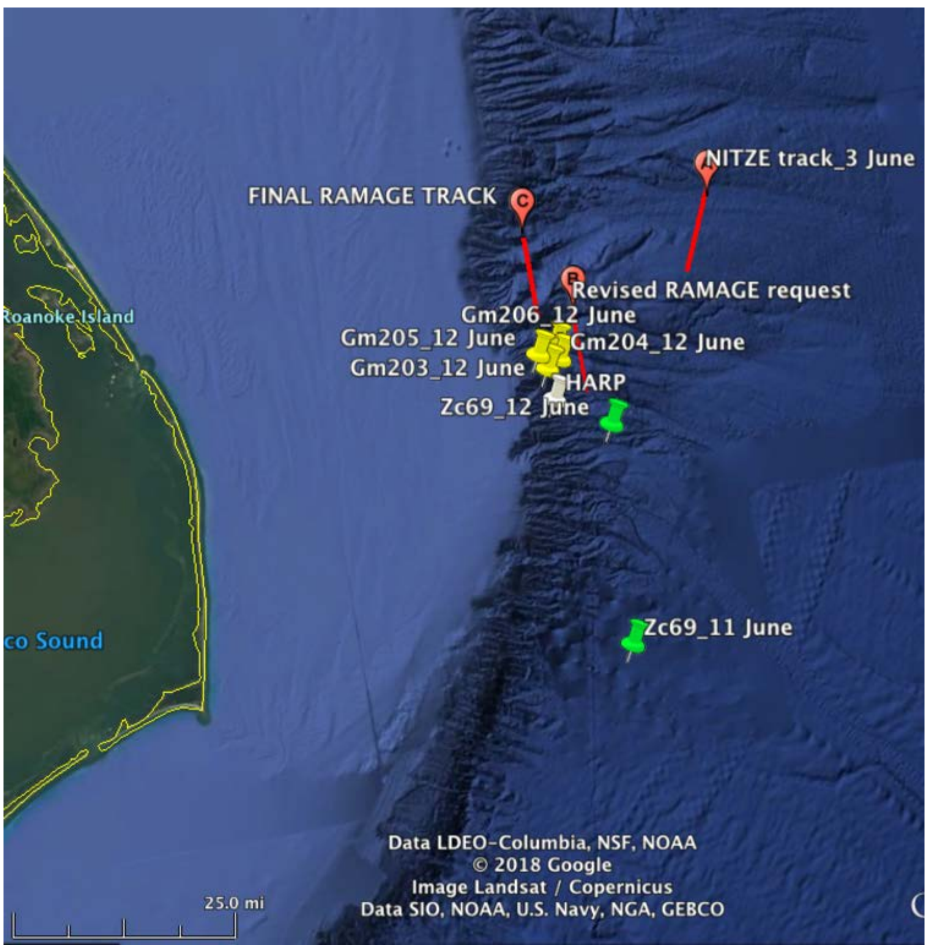


Figure 87. RL model prediction at 10 m depth for focal whale Zc69 for Atlantic-BRS CEE# 18-06 (END position of *USS RAMAGE*)

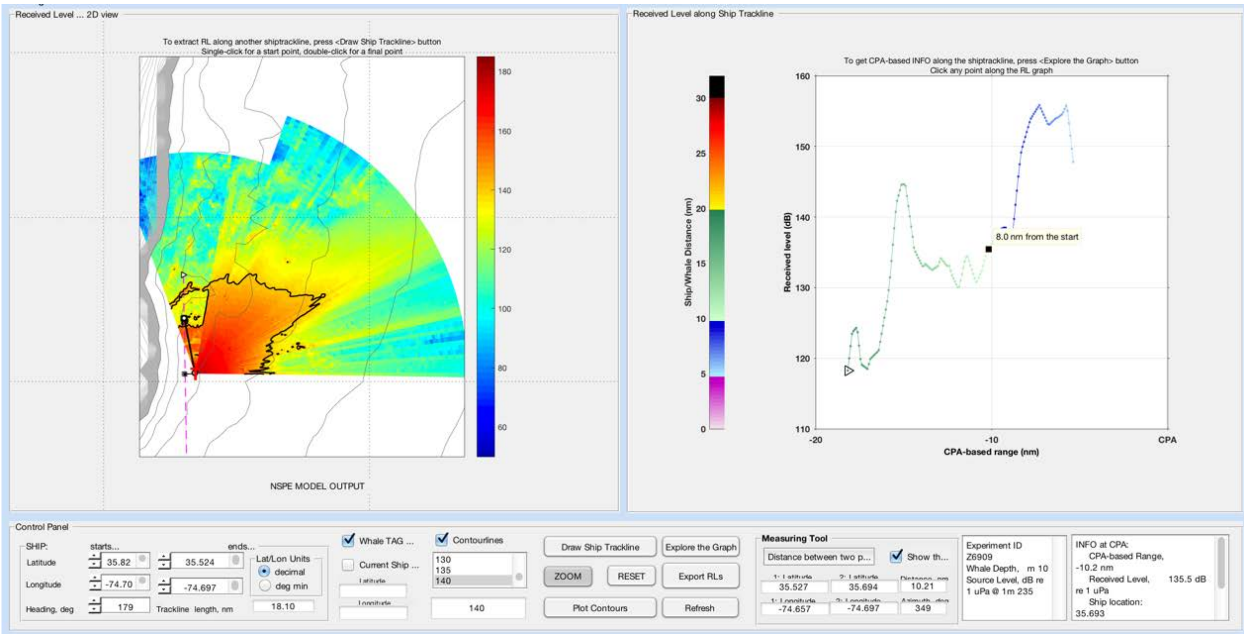


Figure 88. RL model prediction at 2,200 m depth for focal whale Zc69 for Atlantic-BRS CEE# 18-06 (END position of *USS RAMAGE*)

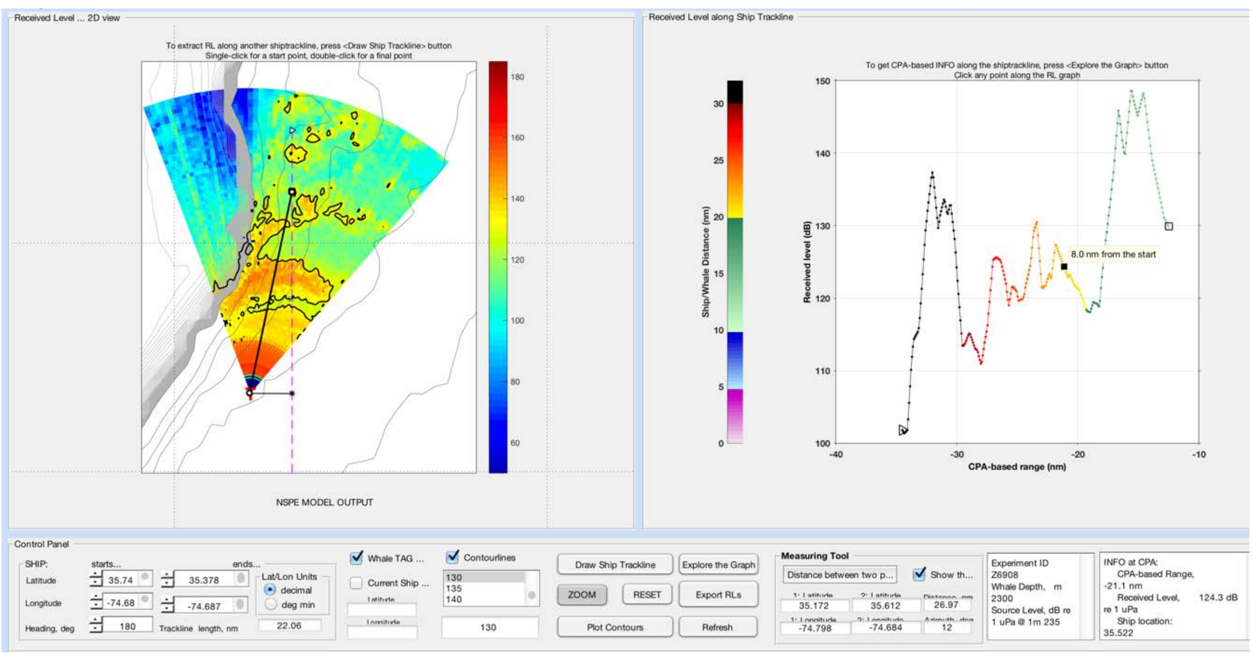


Figure 89. RL model prediction at 10 m depth for focal whale Gm203 for Atlantic-BRS CEE# 18-06 (END position of *USS RAMAGE*)

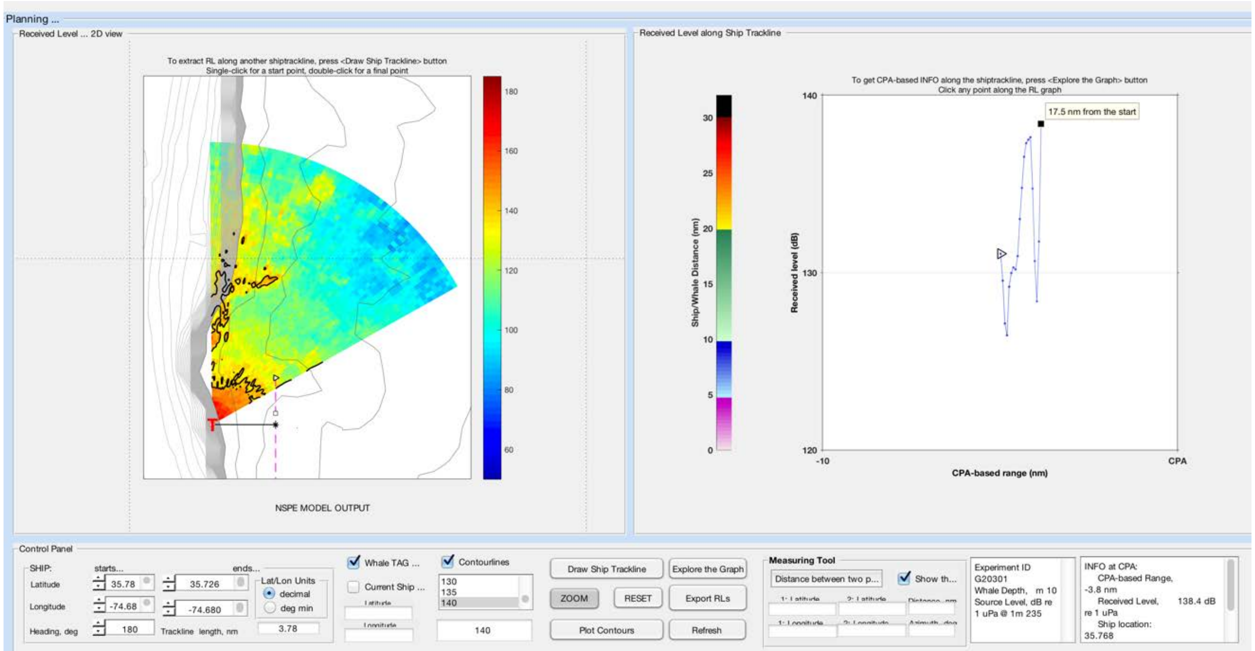


Figure 90. RL model prediction at 300 m depth for focal whale Gm203 for Atlantic-BRS CEE# 18-06 (END position of *USS RAMAGE*)

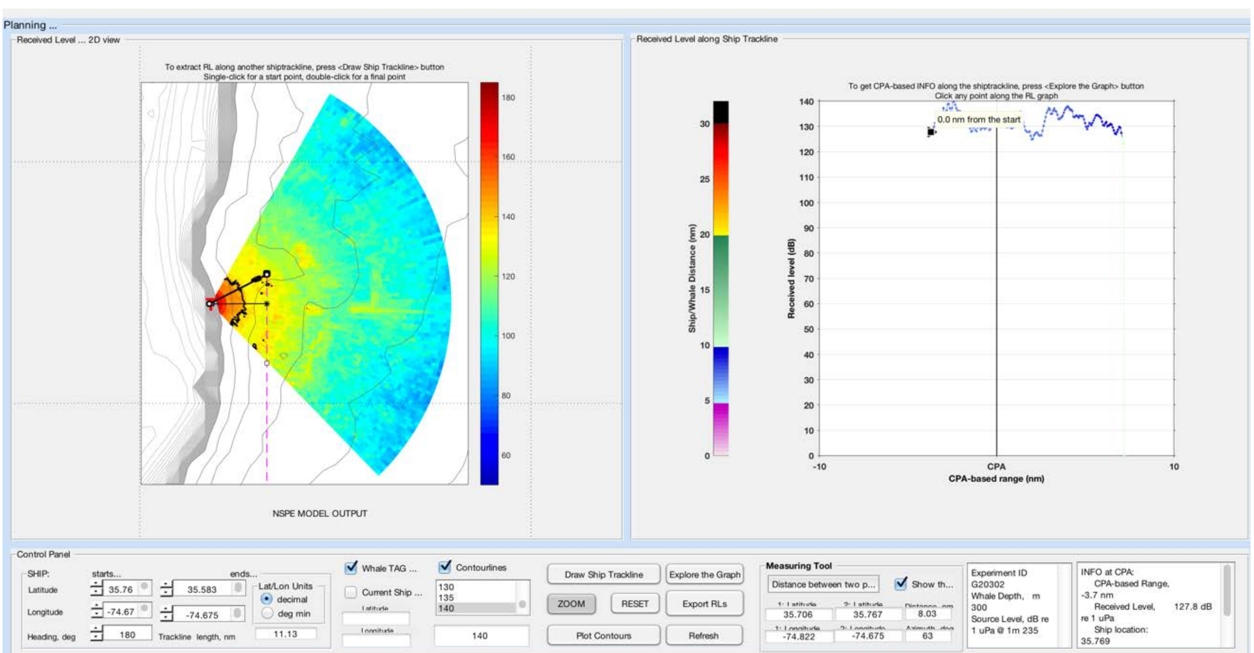


Figure 91. Estimated surface positions for focal whale Zc69 before, during, and after Atlantic-BRS CEE# 18-06

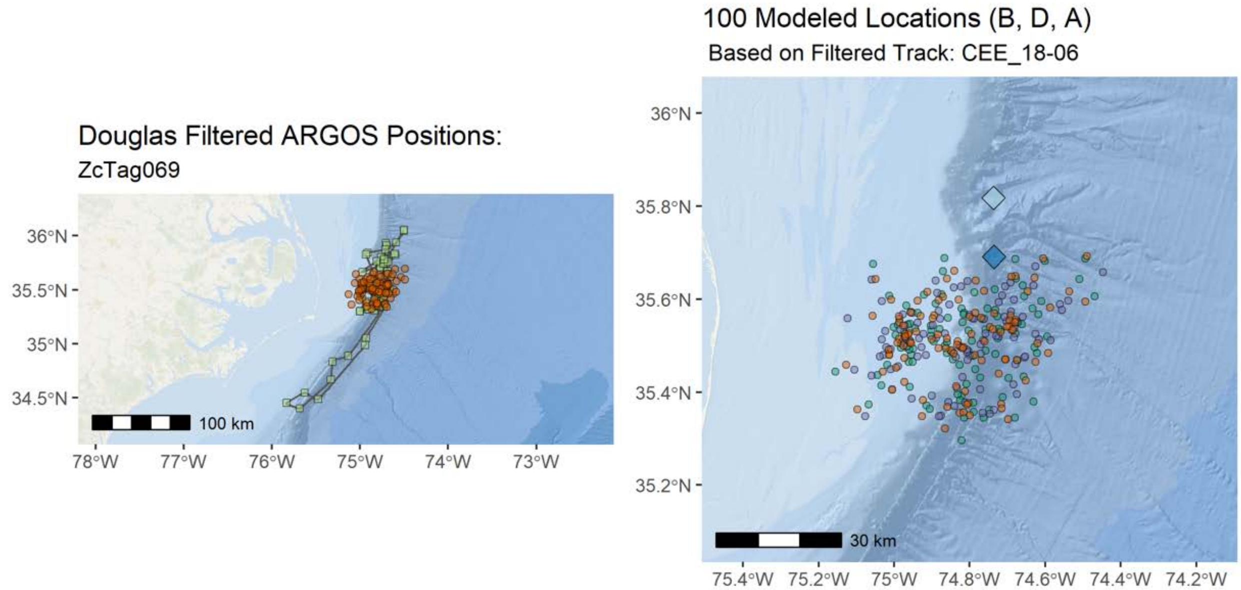


Figure 92. Estimated surface positions for focal whale Gm201 before, during, and after Atlantic-BRS CEE# 18-06

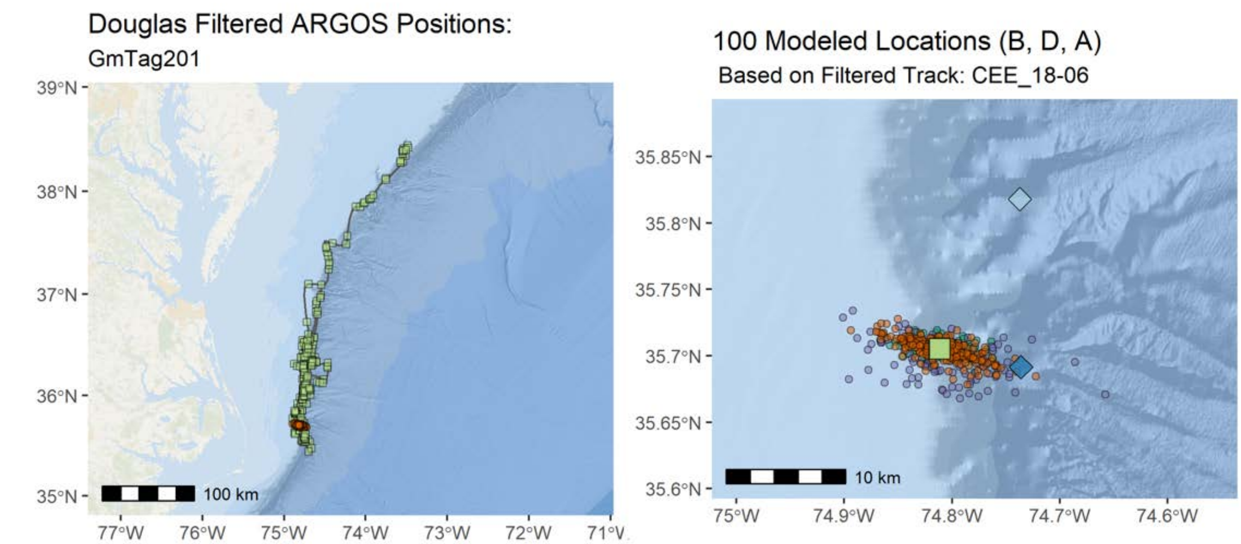


Figure 93. Available dive data for focal whale Gm201 before, during, and after Atlantic-BRS CEE# 18-06

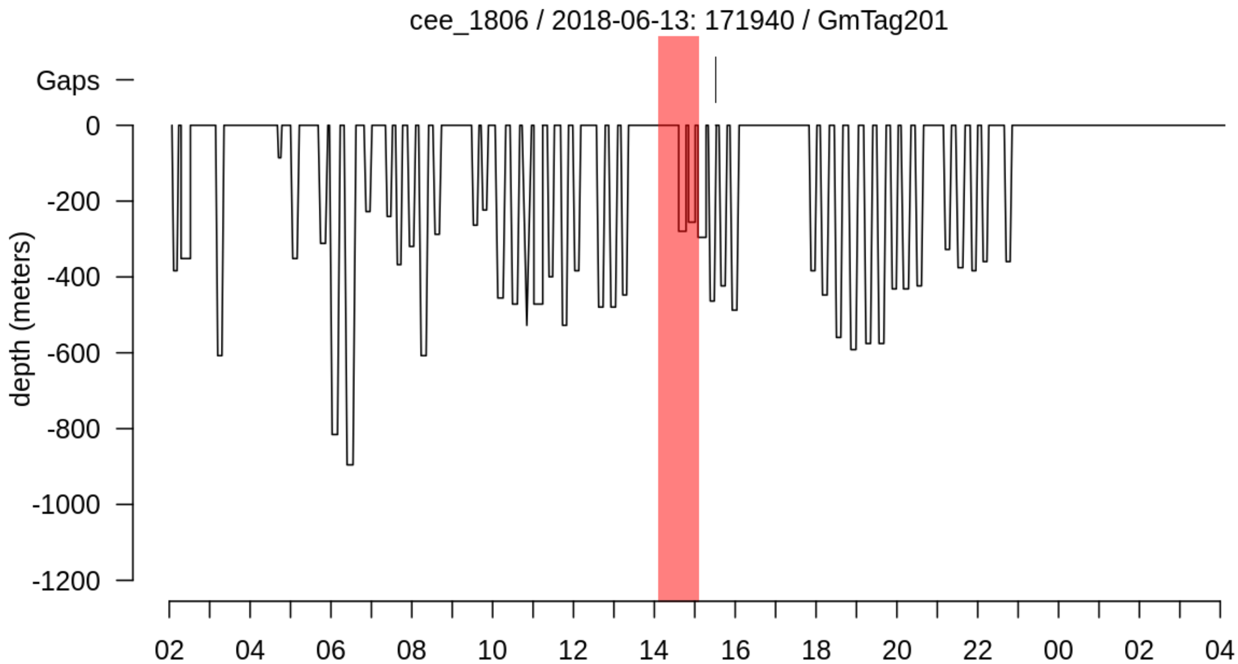


Figure 94. Estimated surface positions for focal whale Gm202 before, during, and after Atlantic-BRS CEE# 18-06

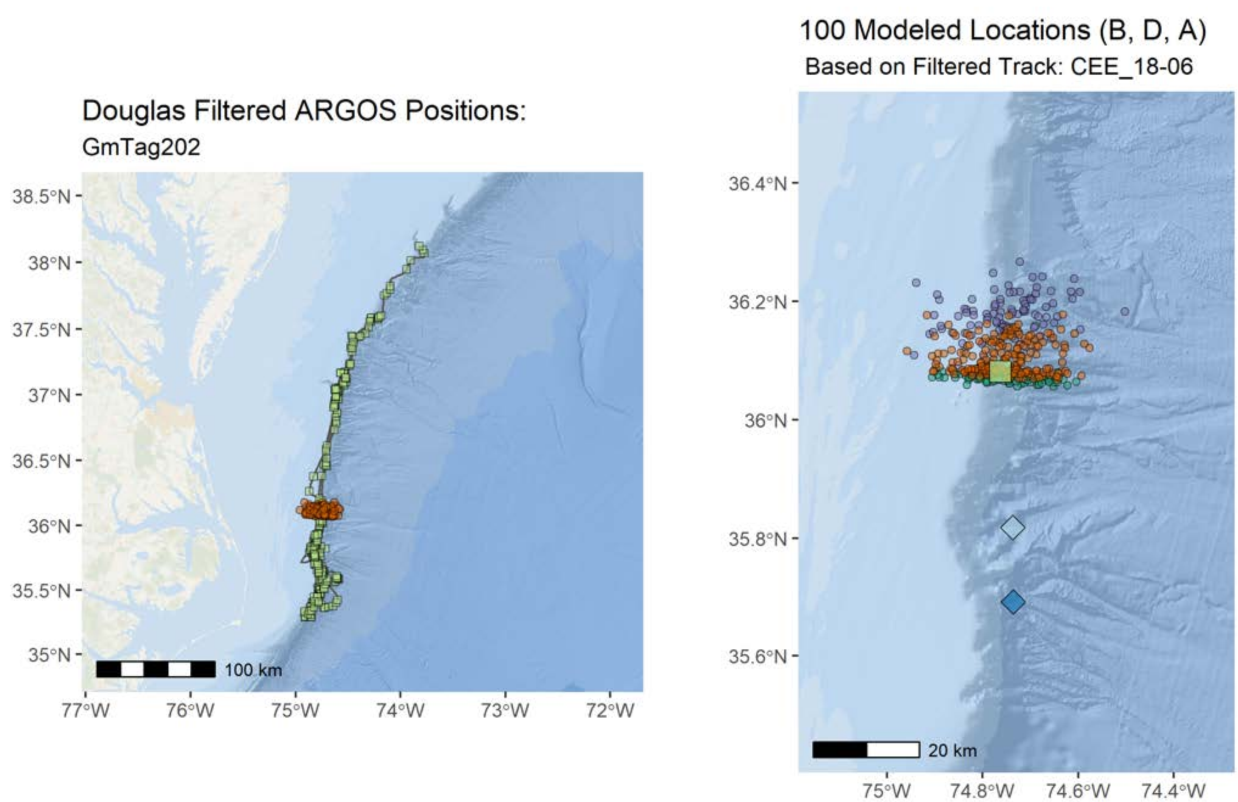


Figure 95. Available dive data for whale Gm202 before, during, and after Atlantic-BRS CEE# 18-06

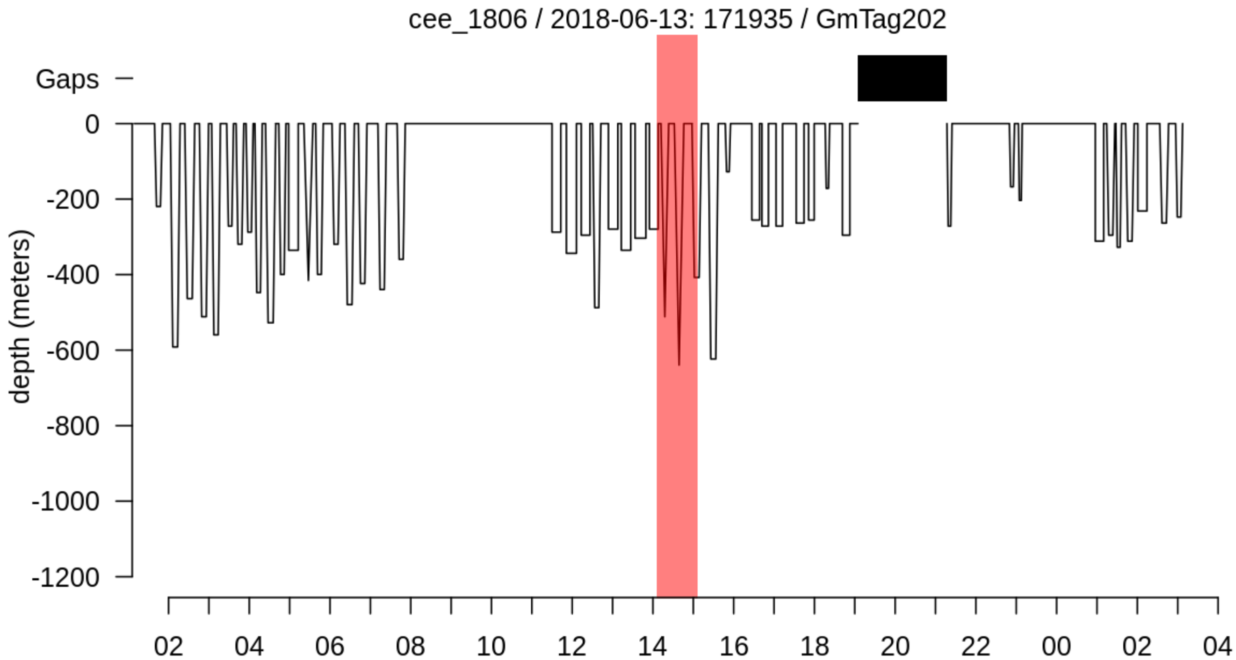


Figure 96. Estimated surface positions for focal whale Gm203 before, during, and after Atlantic-BRS CEE# 18-06

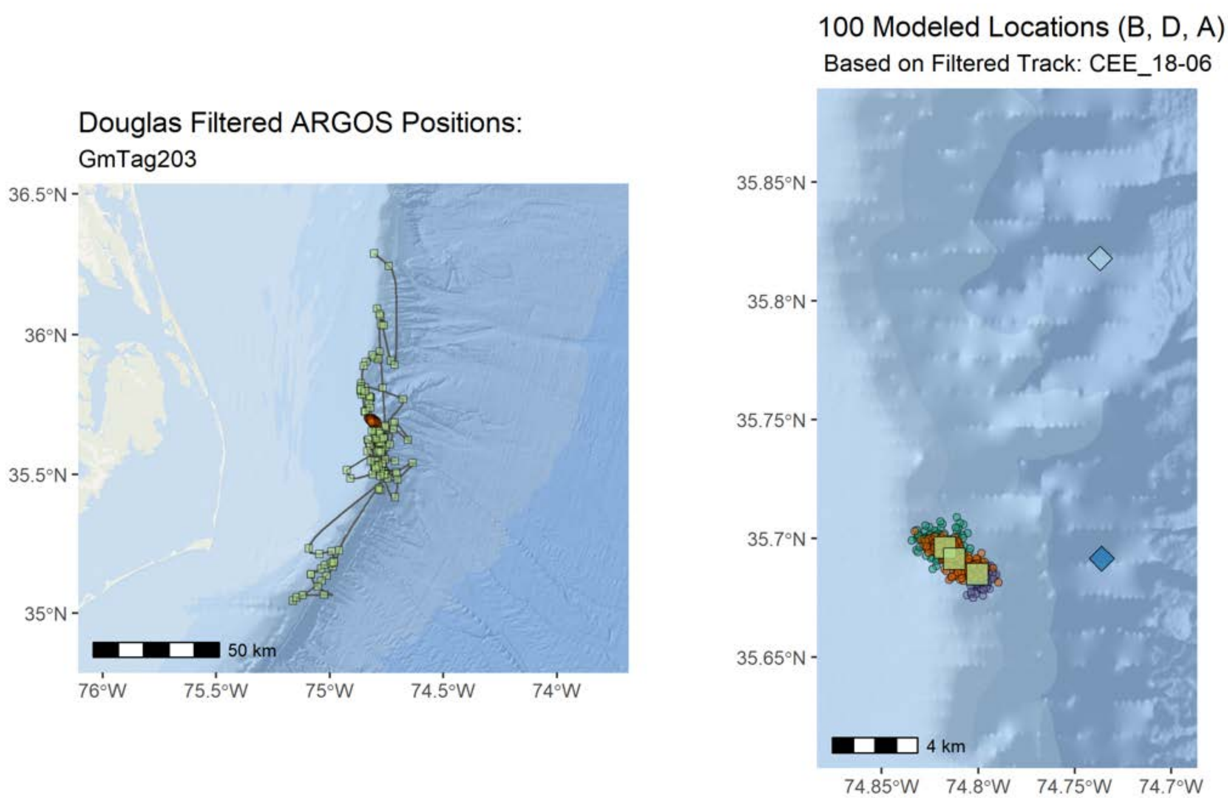


Figure 97. Available dive data for whale Gm203 before, during, and after Atlantic-BRS CEE# 18-06

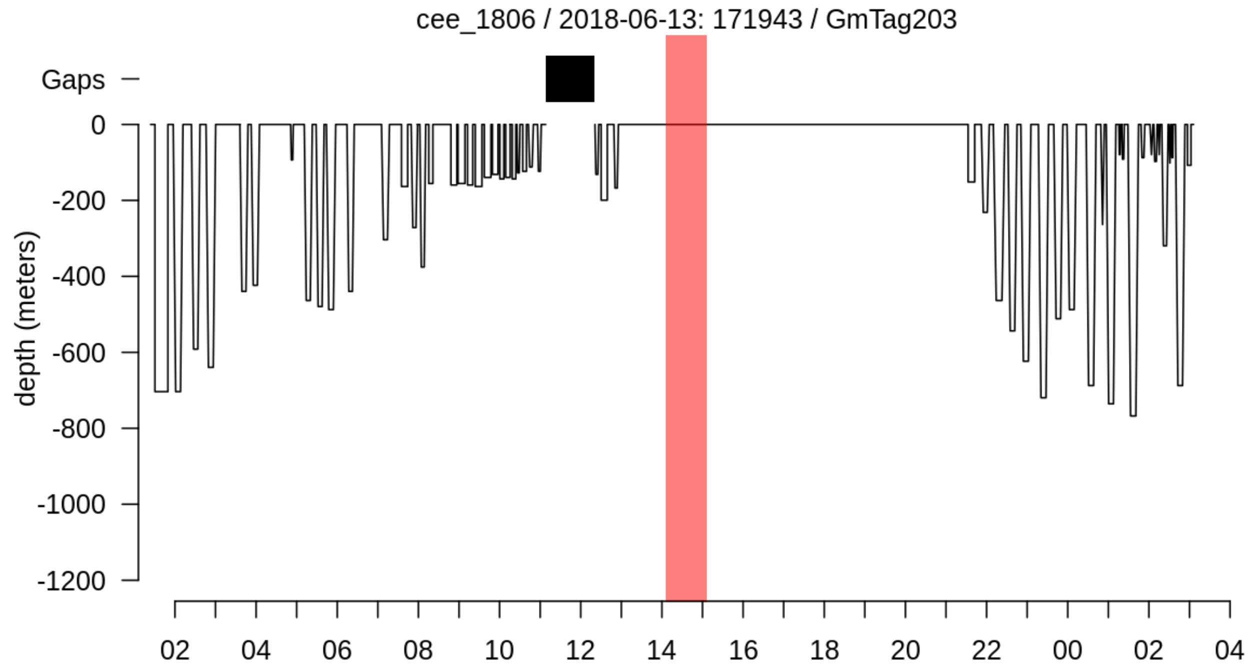


Figure 98. Estimated surface positions for focal whale Gm204 before, during, and after Atlantic-BRS CEE# 18-06

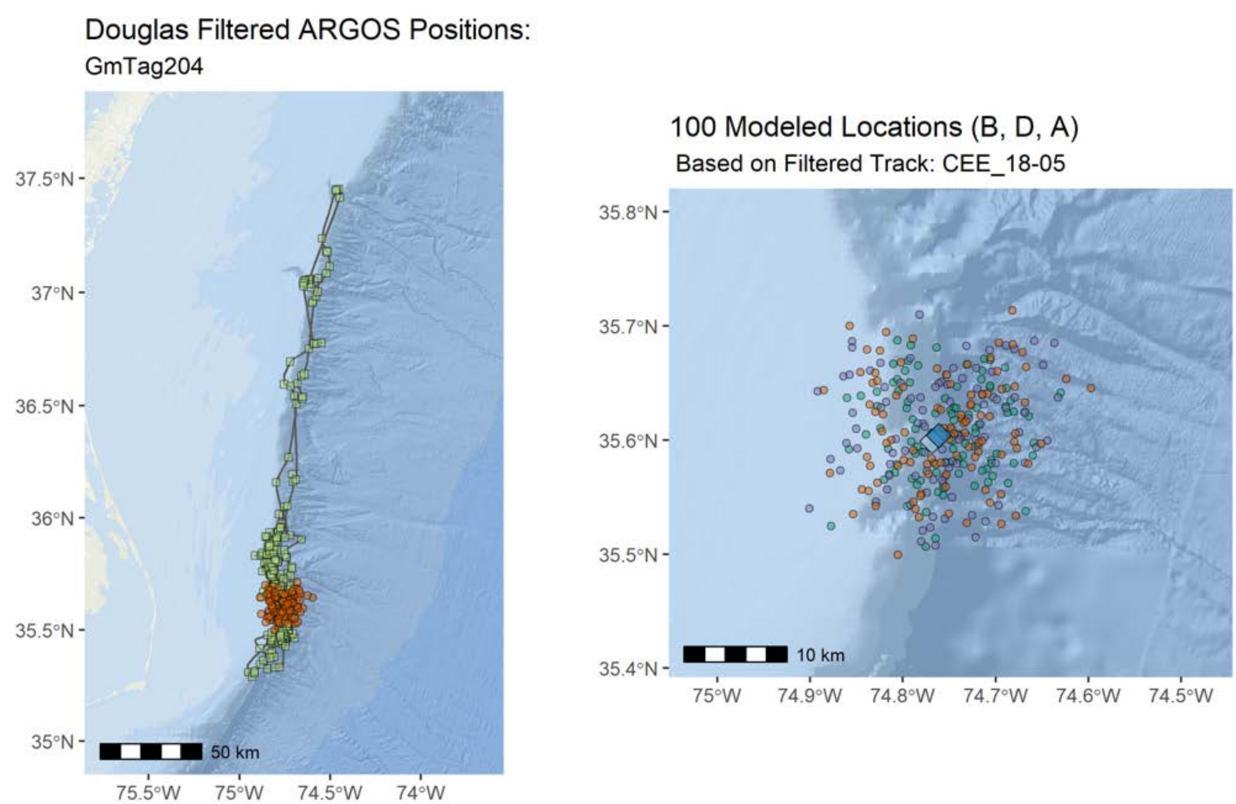


Figure 99. Available dive data for whale Gm204 before, during, and after Atlantic-BRS CEE# 18-06

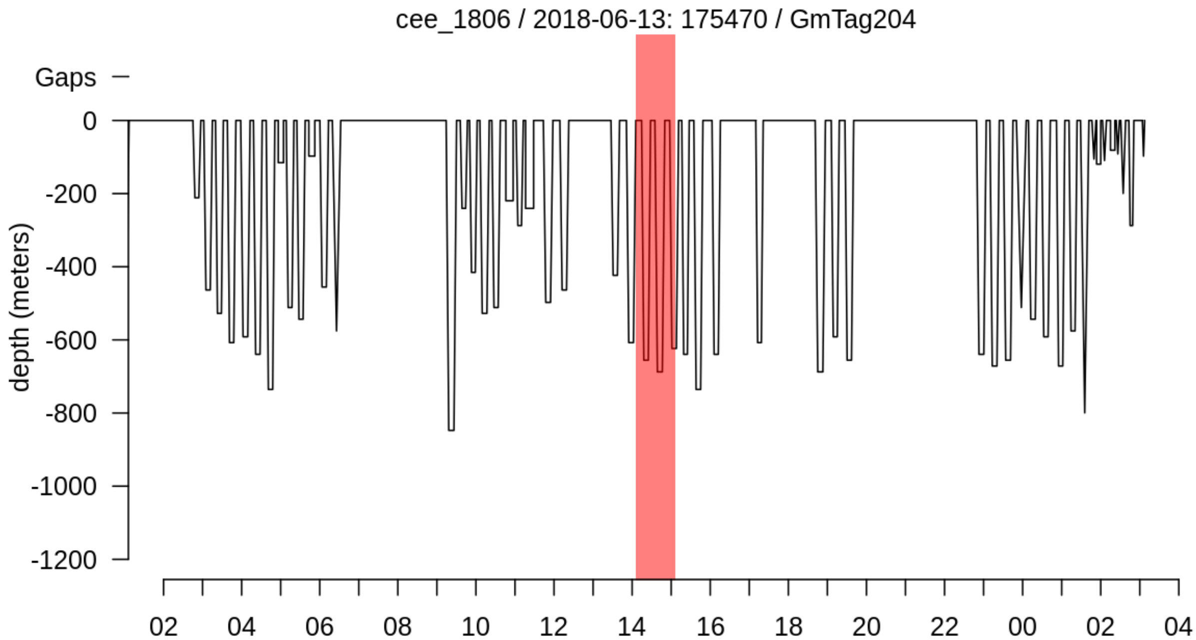


Figure 100. Estimated surface positions for focal whale Gm205 before, during, and after Atlantic-BRS CEE# 18-06

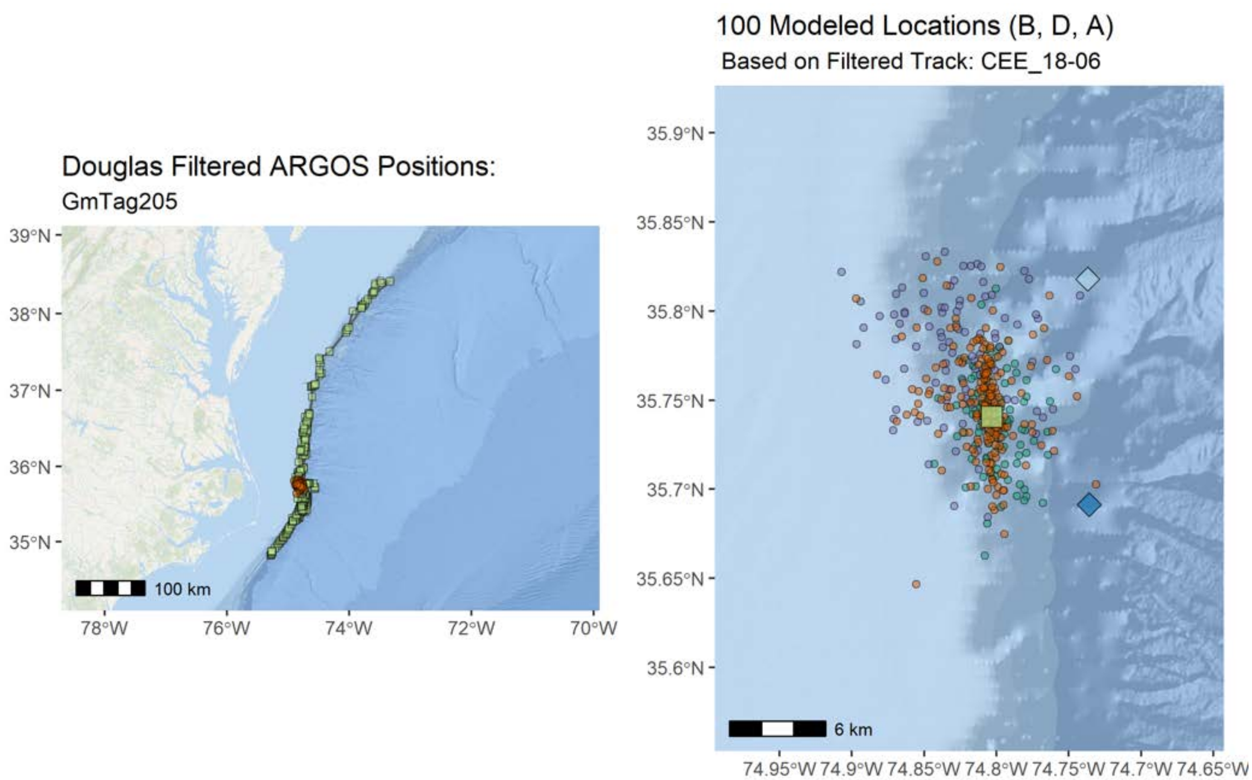


Figure 101. Available dive data for whale Gm205 before, during, and after Atlantic-BRS CEE# 18-06

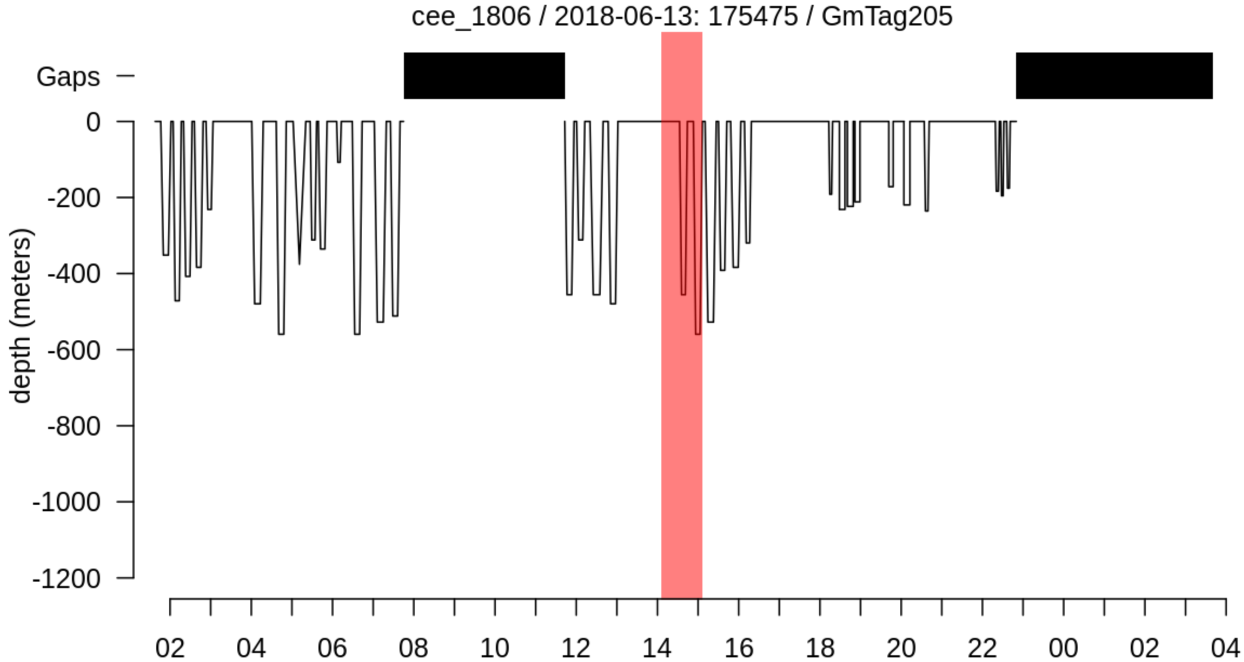


Figure 102. Estimated surface positions for focal whale Gm206 before, during, and after Atlantic-BRS CEE# 18-06

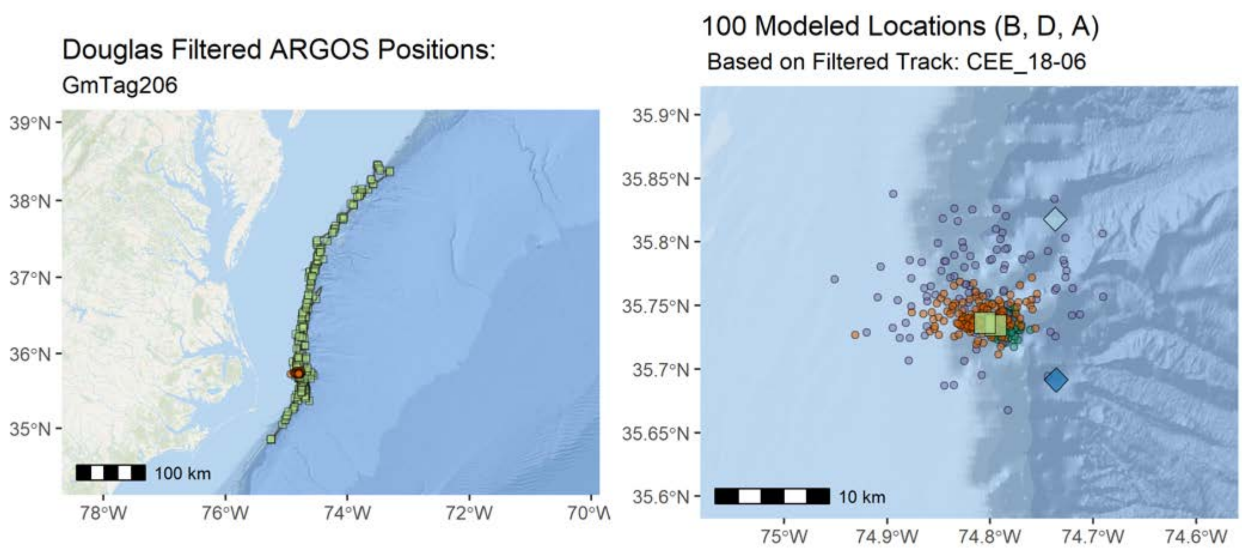
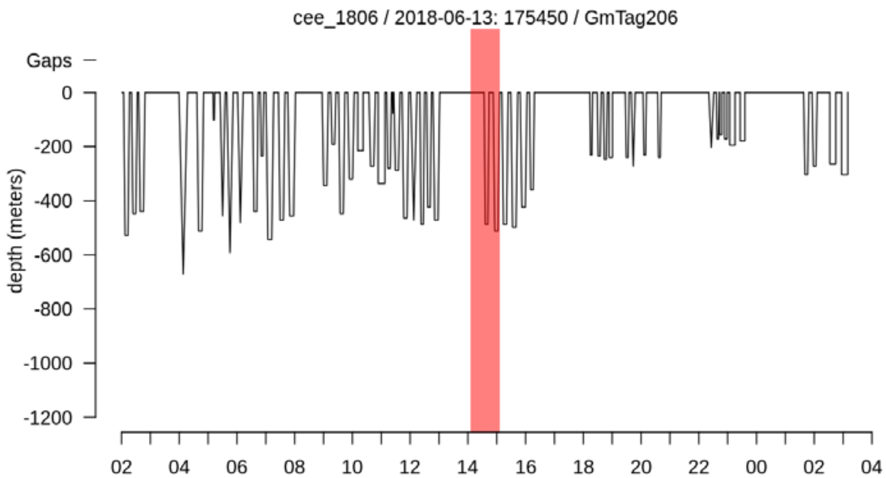


Figure 103. Available dive data for whale Gm206 before, during, and after Atlantic-BRS CEE# 18-06



2.3.7 CEE #18-07: Silent Control

Table 14. Metadata summary for Atlantic-BRS CEE# 18-07

CEE Conditions	Metadata Summary
CEE Identifier	**18-07**
Date	**8/15/18**
Type	**Silent control** 15-element vertical line array deployed to 20 m depth from *F/V Kahuna* (stationary), but not activated
Signal Parameters	None; ambient noise conditions with vessel operating as if source was activated
Start time (UTC)	16:00:00
Start lat/lon	35.750985; -74.795325
End time (UTC)	16:30:00
End lat/lon	35.759158; -74.796618
Beaked whales monitored with tags during CEE	Focal: None Incidental: Zc72, Zc73, Zc76, Zc77, Zc78, Zc79, Zc80, Zc81
Pilot whales monitored with tags during CEE	Focal: **Gm18_227a** Incidental: Gm207, Gm210, Gm211

Figure 104. Uncorrected pseudotrack based on surface positions and tag data for focal whale Gm18_227a (DTAG) before, during, and after Atlantic-BRS CEE# 18-07

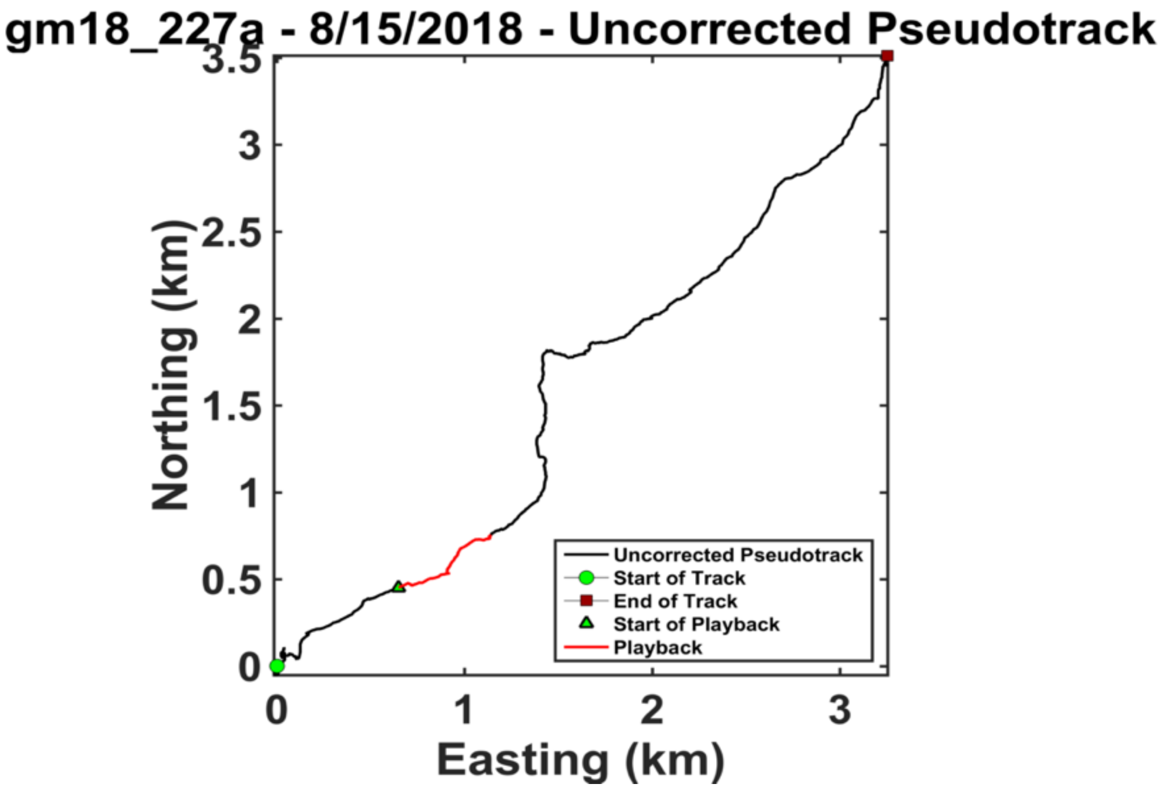


Figure 105. Available dive data for focal whale Gm18_227a (DTAG) before, during, and after Atlantic-BRS CEE# 18-07

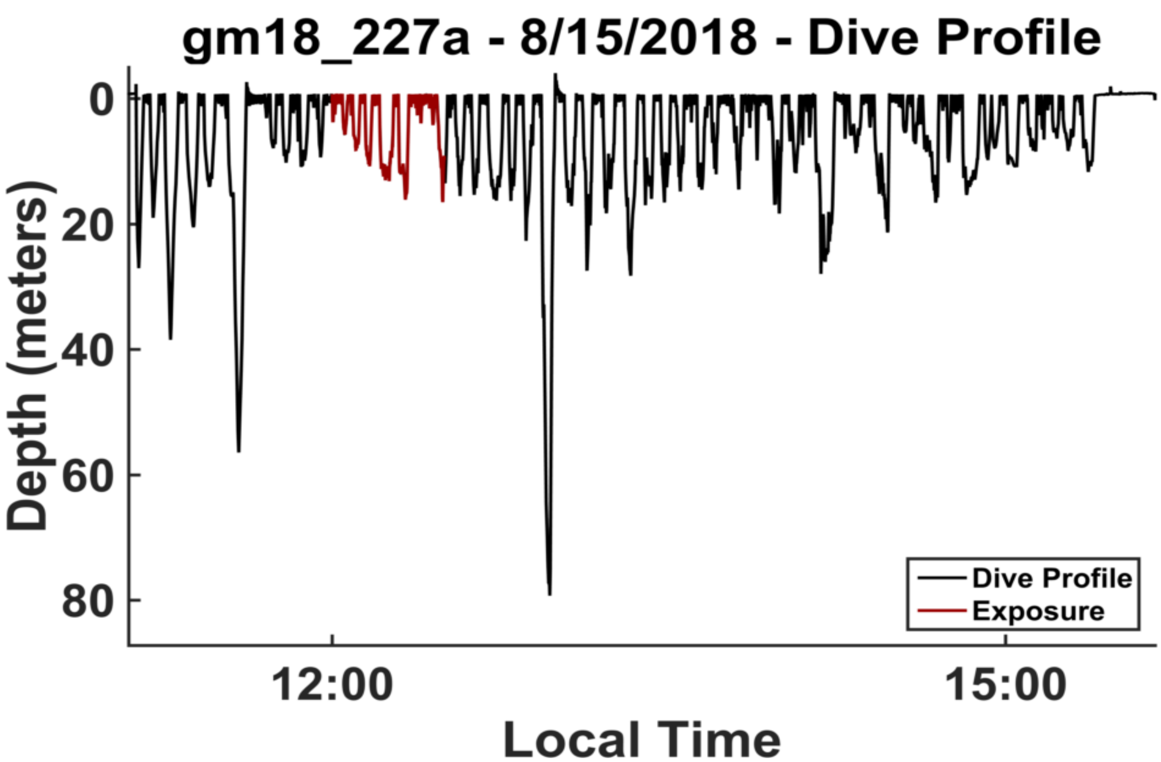


Figure 106. Estimated surface positions for whale Zc72 before, during, and after Atlantic-BRS CEE# 18-07

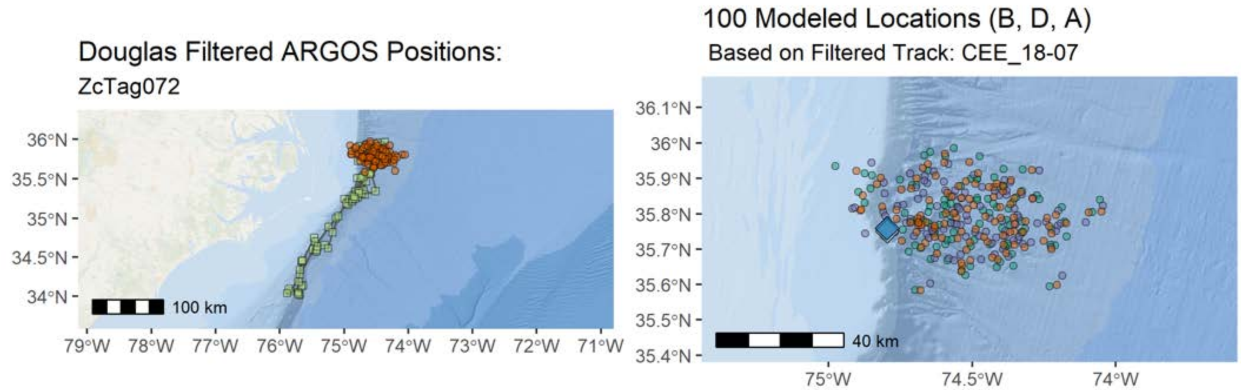


Figure 106. Available dive data for whale Zc72 before, during, and after Atlantic-BRS CEE# 18-07

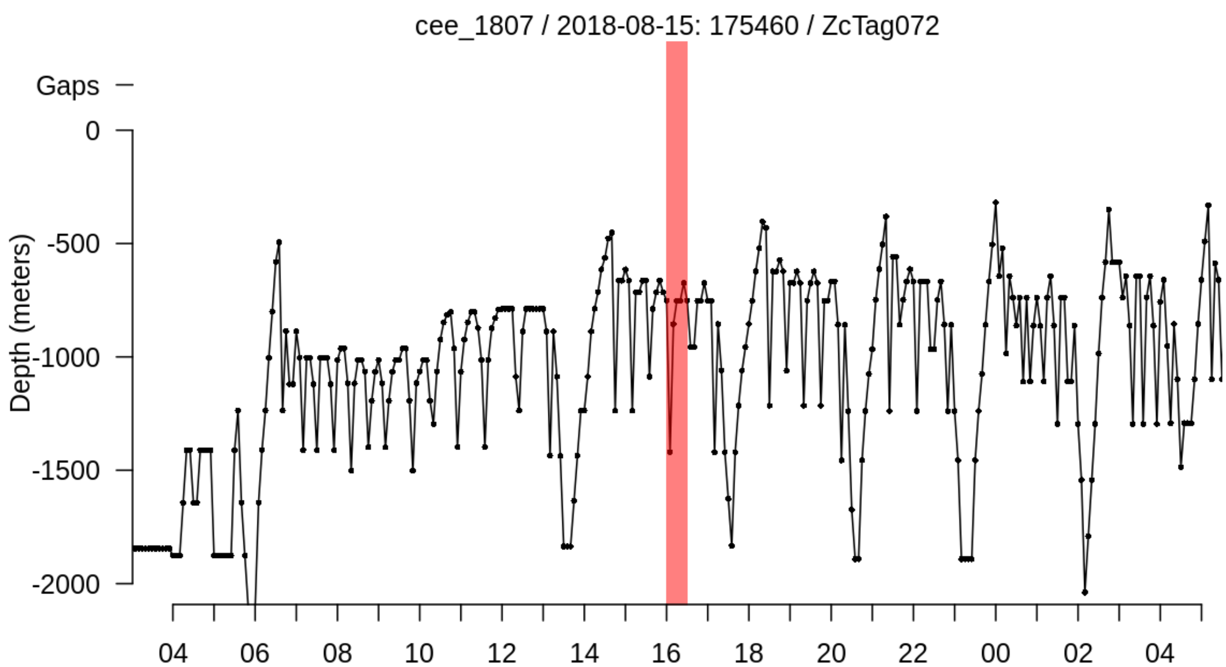


Figure 107. Estimated surface positions for whale Zc73 before, during, and after Atlantic-BRS CEE# 18-07

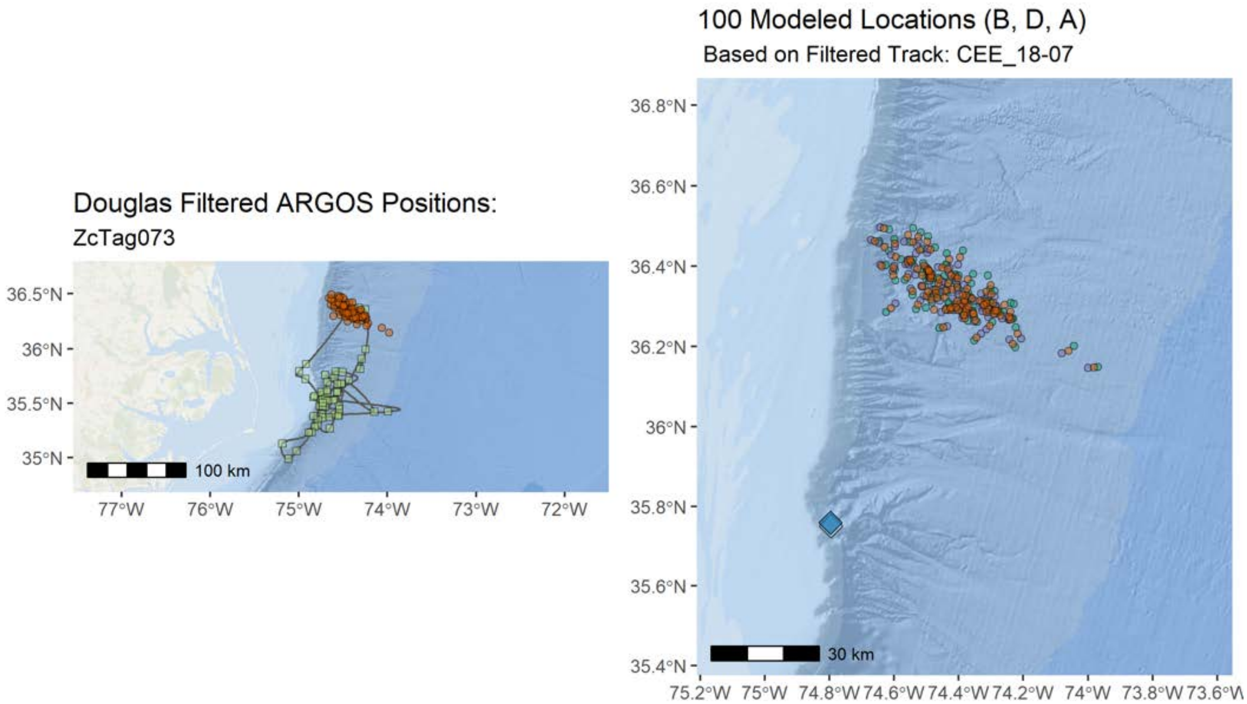


Figure 108. Available dive data for whale Zc73 before, during, and after Atlantic-BRS CEE# 18-07

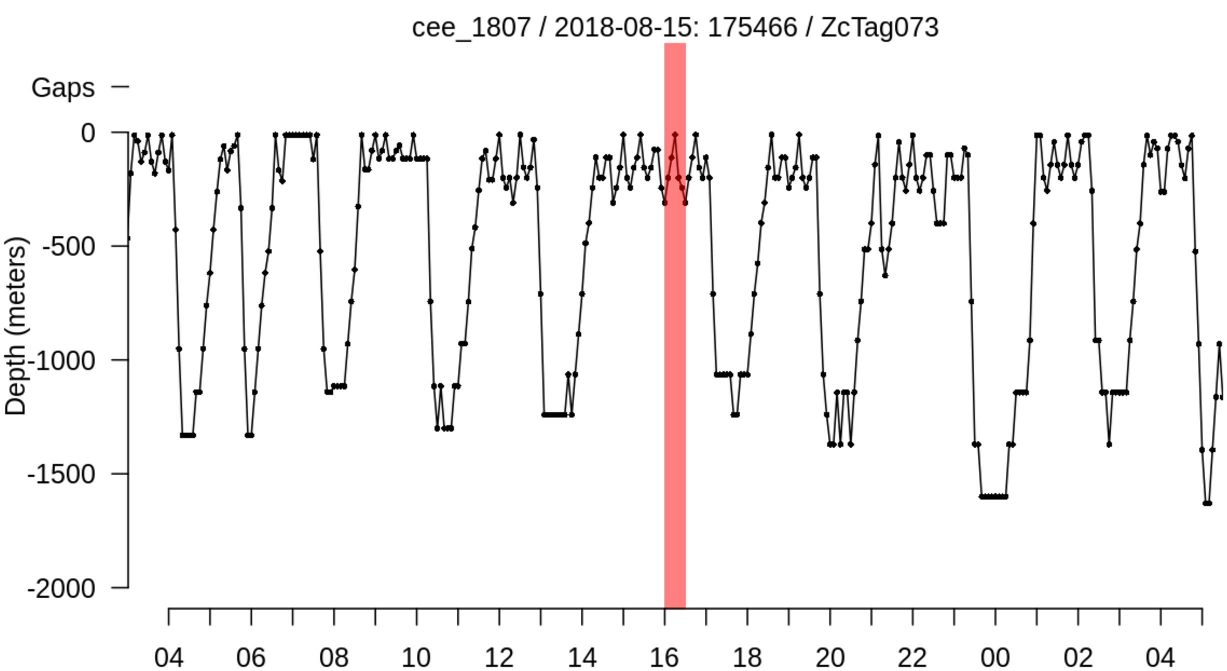


Figure 109. Estimated surface positions for whale Zc75 before, during, and after Atlantic-BRS CEE# 18-07

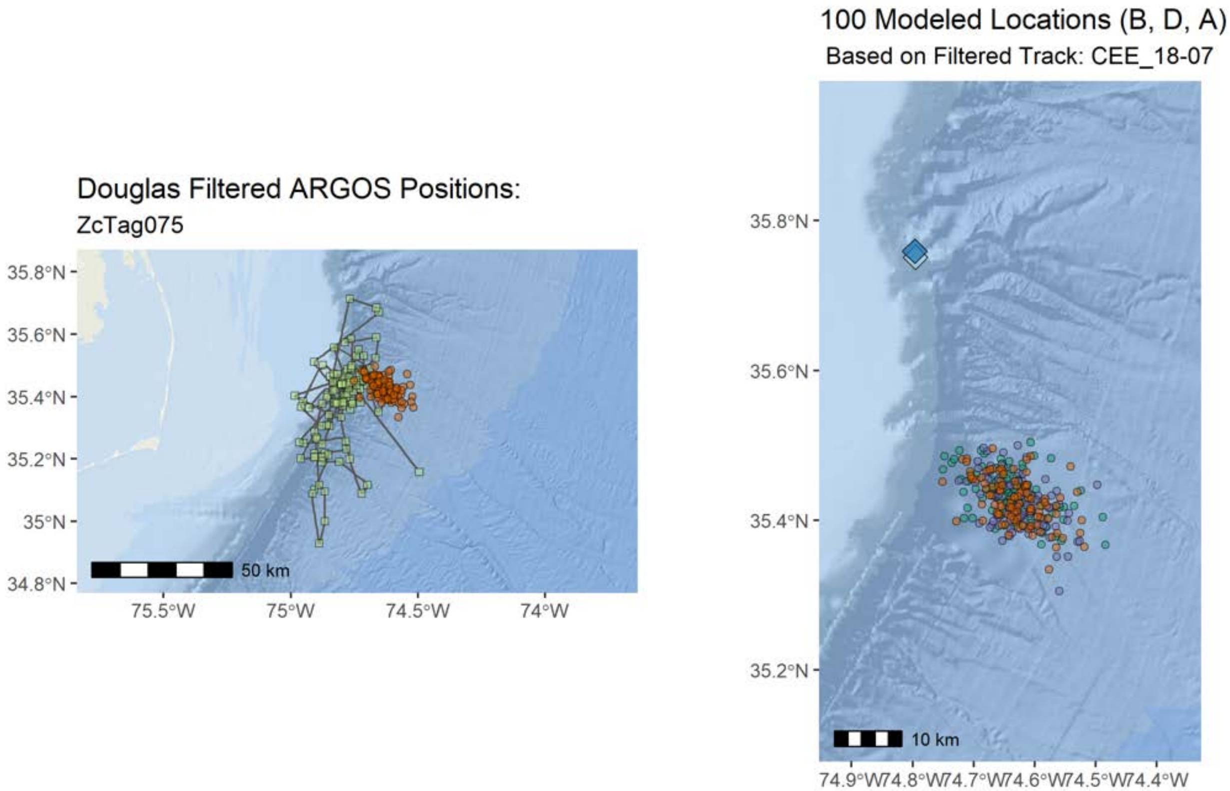


Figure 110. Available dive data for whale Zc75 before, during, and after Atlantic-BRS CEE# 18-07

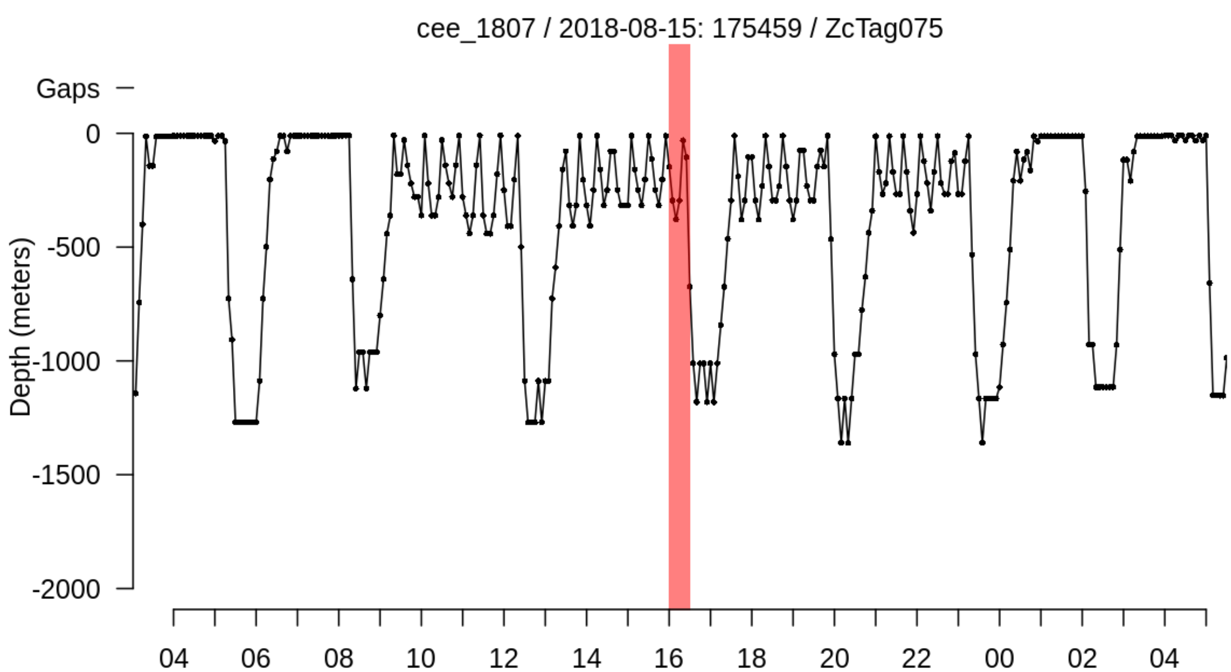


Figure 111. Estimated surface positions for whale Zc76 before, during, and after Atlantic-BRS CEE# 18-07

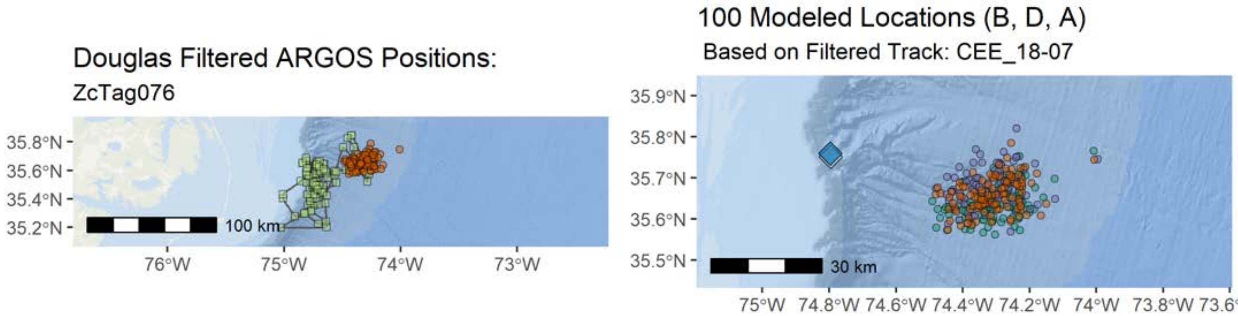


Figure 112. Available dive data for whale Zc76 before, during, and after Atlantic-BRS CEE# 18-07

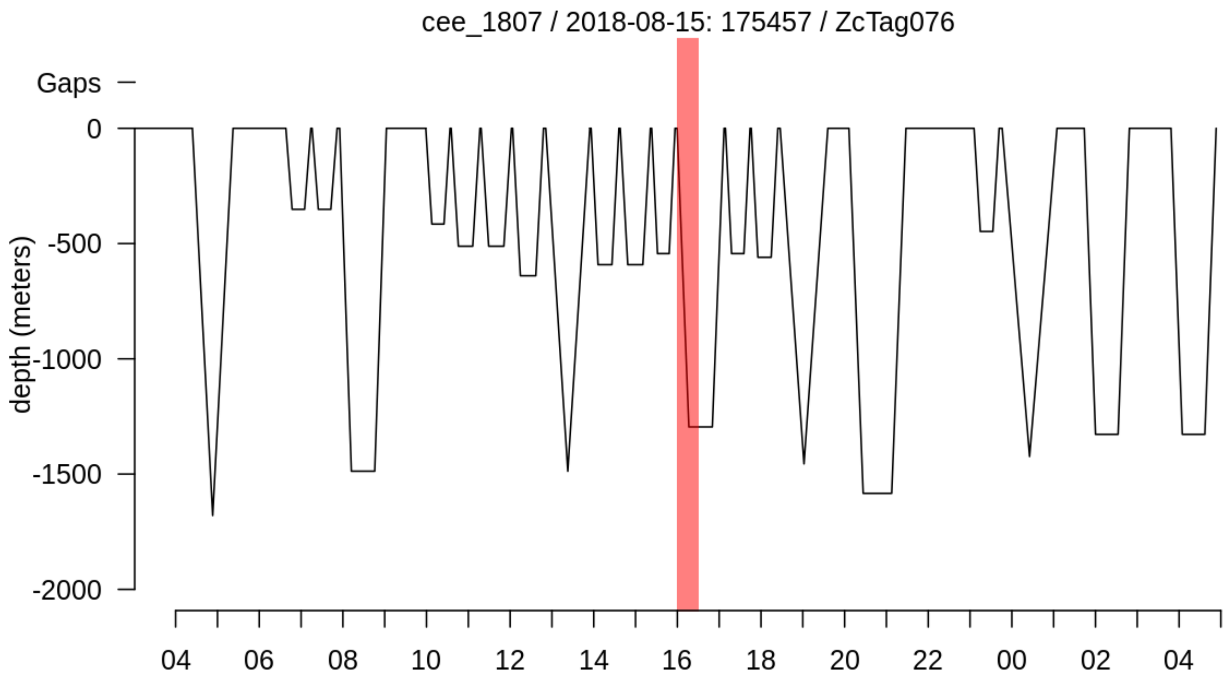


Figure 113. Estimated surface positions for whale Zc77 before, during, and after Atlantic-BRS CEE# 18-07

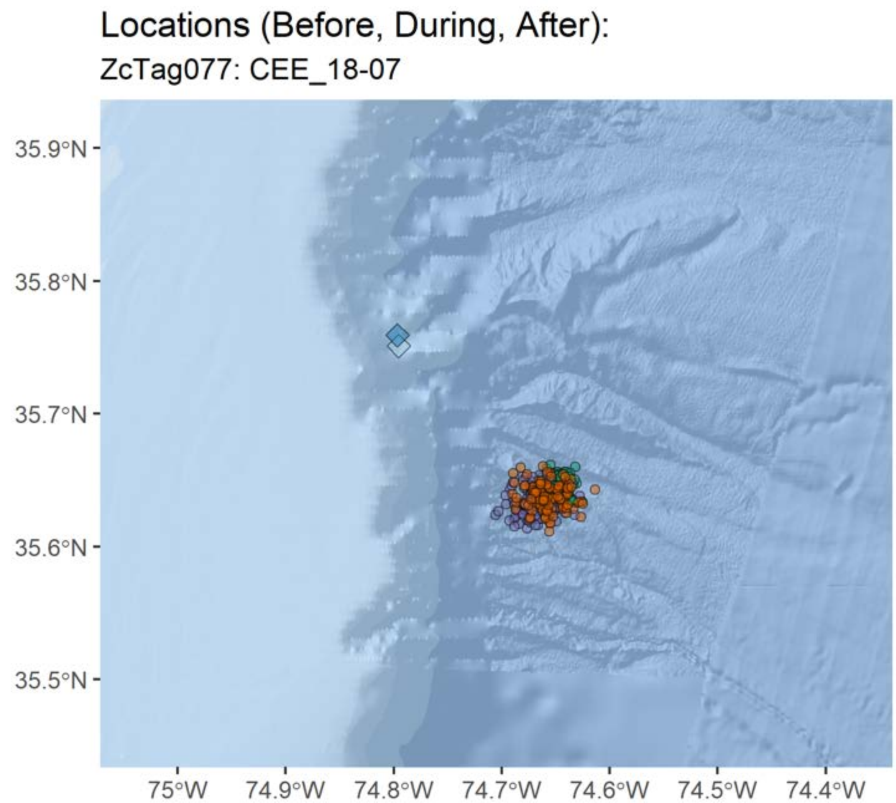


Figure 114. Estimated surface positions for whale Zc78 before, during, and after Atlantic-BRS CEE# 18-07

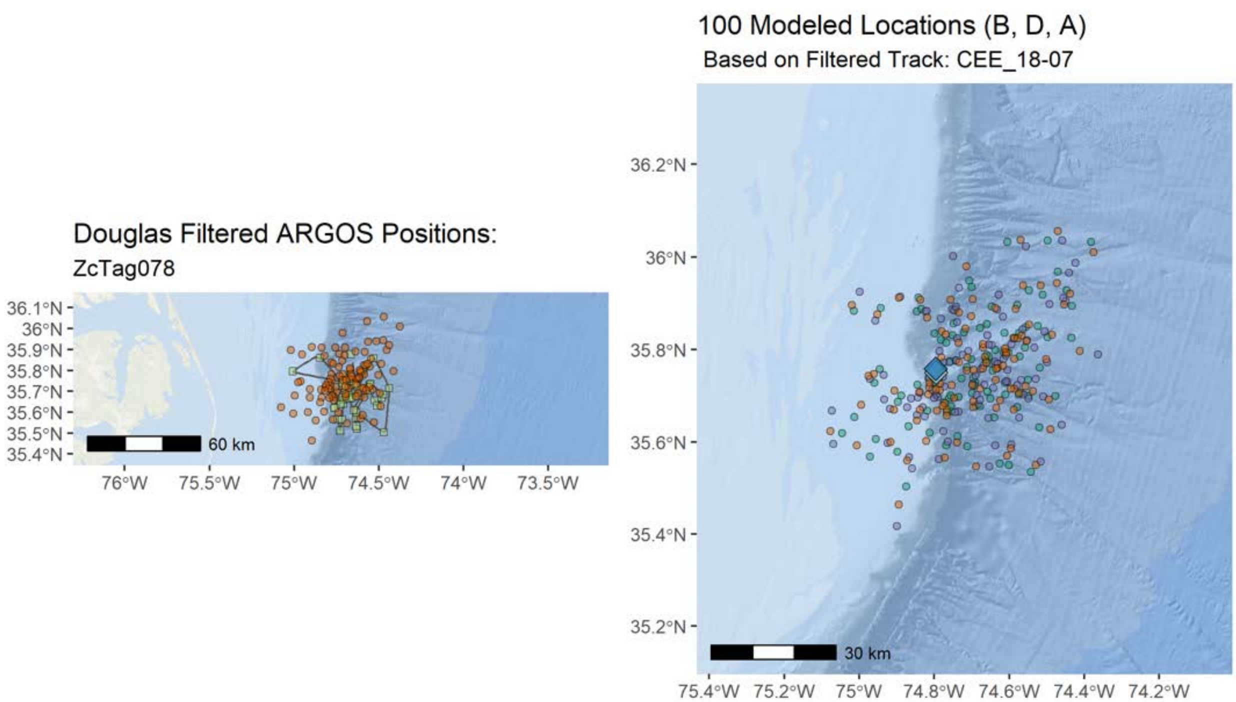


Figure 115. Available dive data for whale Zc78 before, during, and after Atlantic-BRS CEE# 18-07

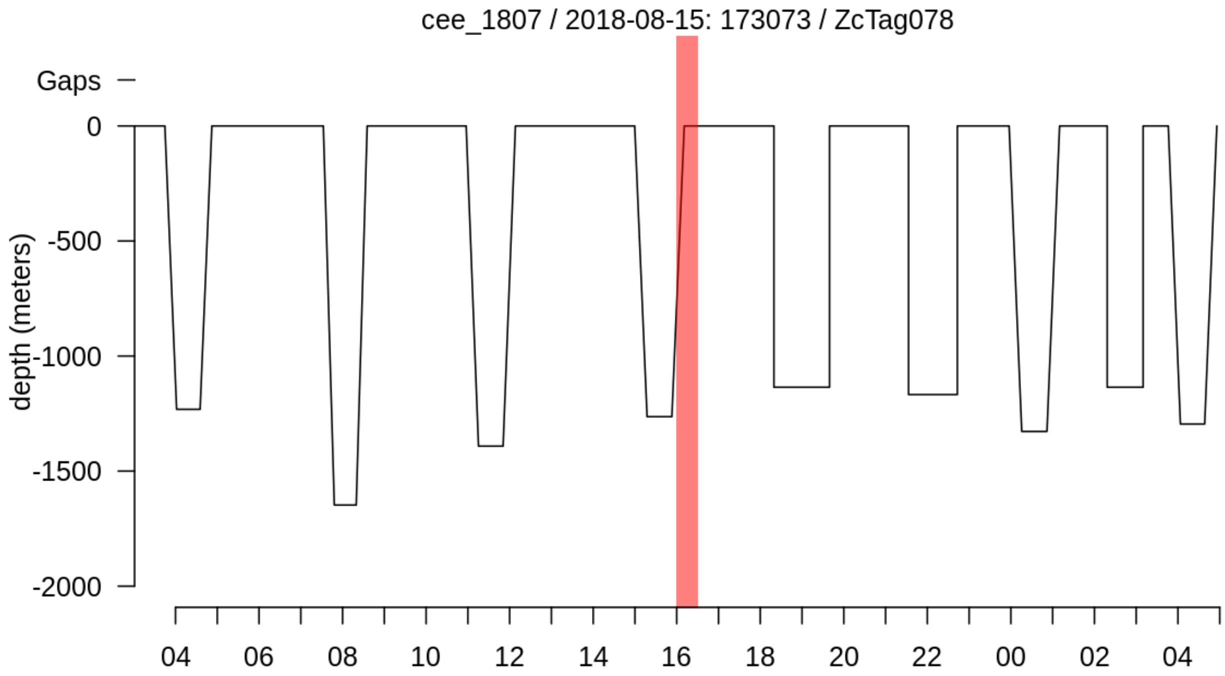


Figure 116. Estimated surface positions for whale Zc79 before, during, and after Atlantic-BRS CEE# 18-07

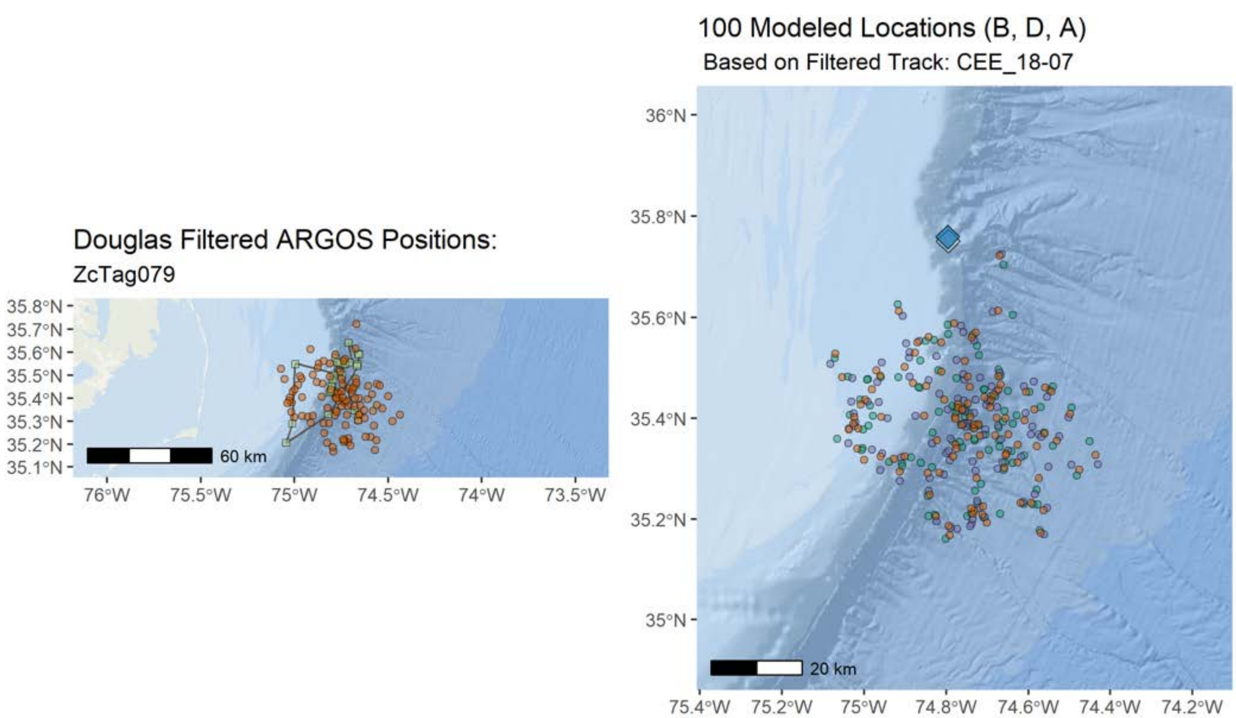


Figure 117. Available dive data for whale Zc79 before, during, and after Atlantic-BRS CEE# 18-07

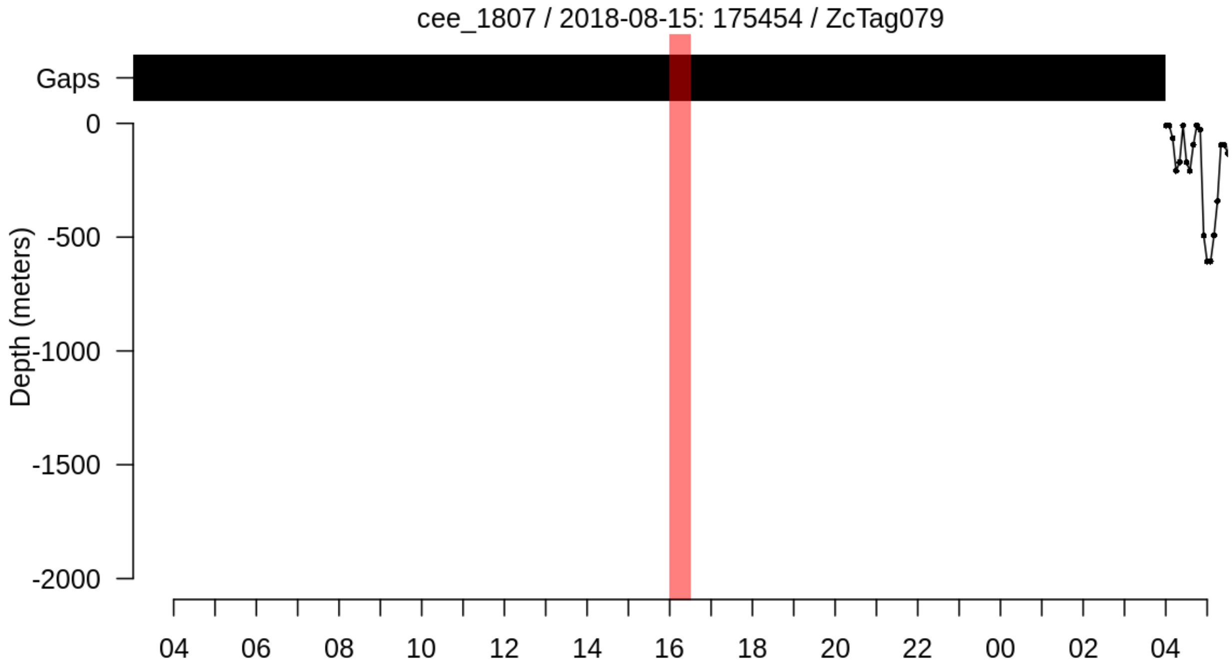


Figure 118. Estimated surface positions for whale Zc80 before, during, and after Atlantic-BRS CEE# 18-07

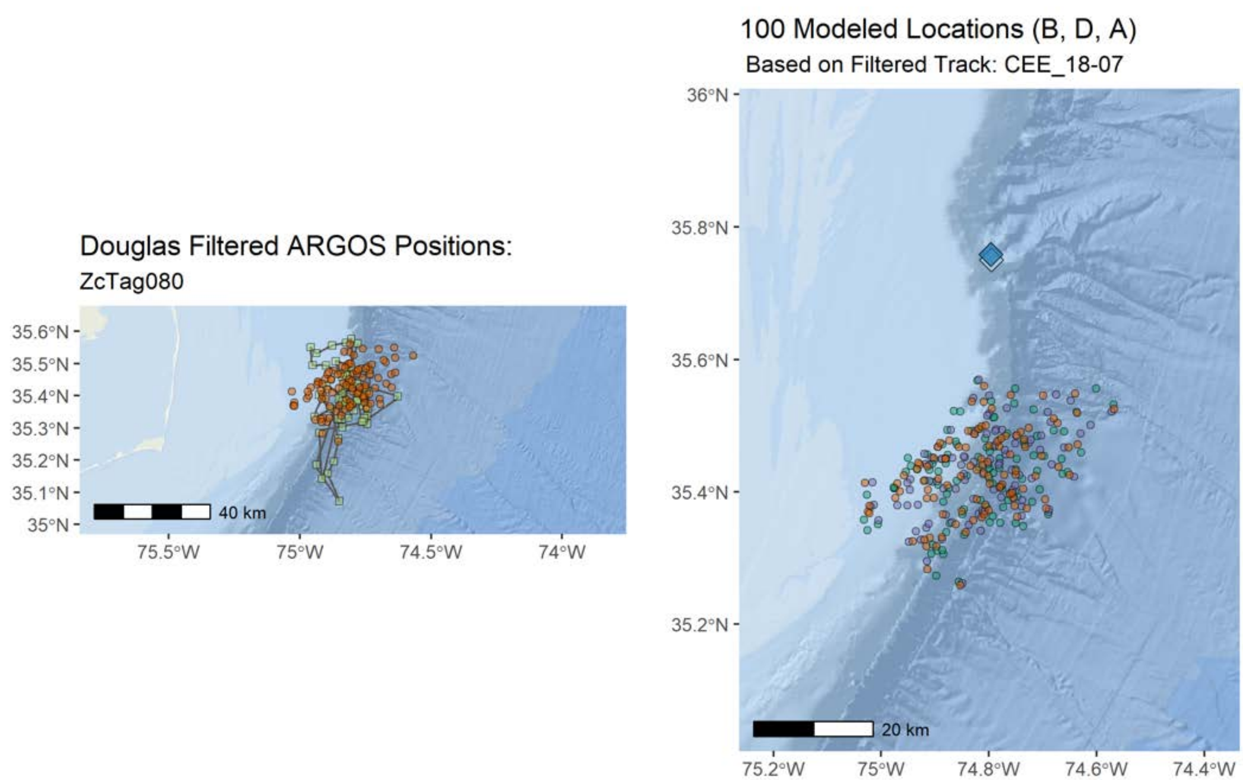


Figure 119. Available dive data for whale Zc80 before, during, and after Atlantic-BRS CEE# 18-07

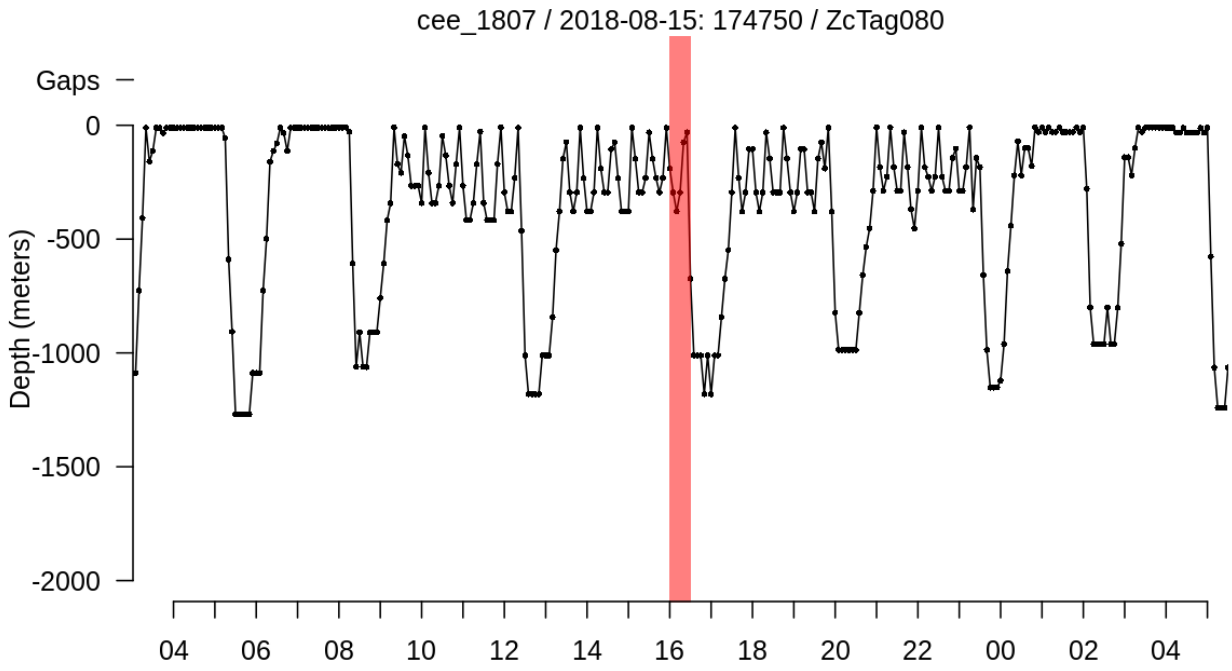


Figure 120. Estimated surface positions for whale Zc81 before, during, and after Atlantic-BRS CEE# 18-07

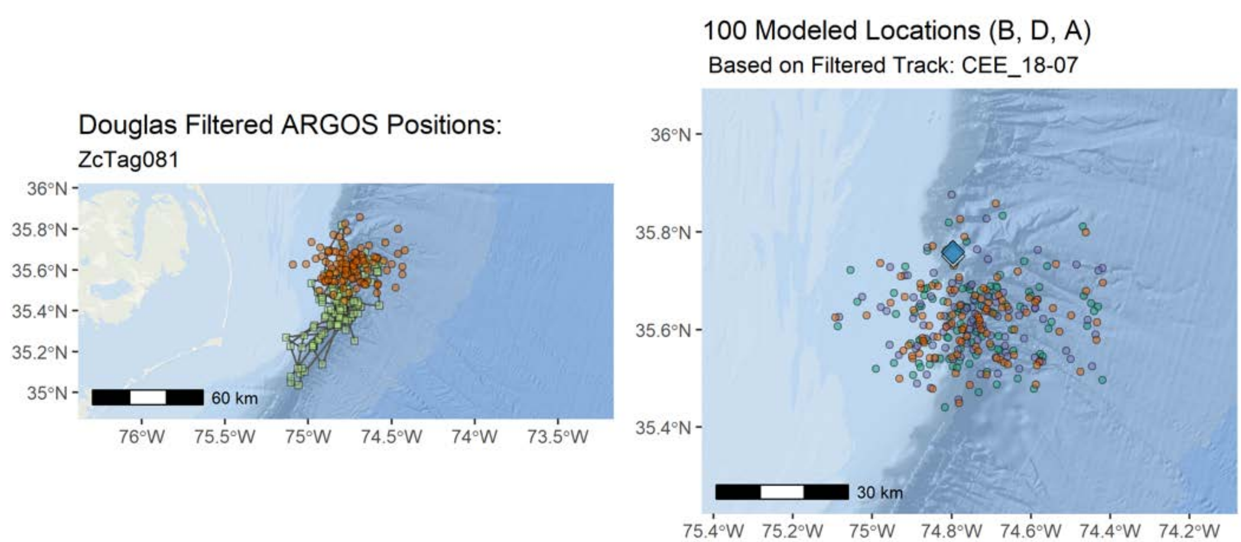


Figure 121. Available dive data for whale Zc81 before, during, and after Atlantic-BRS CEE# 18-07

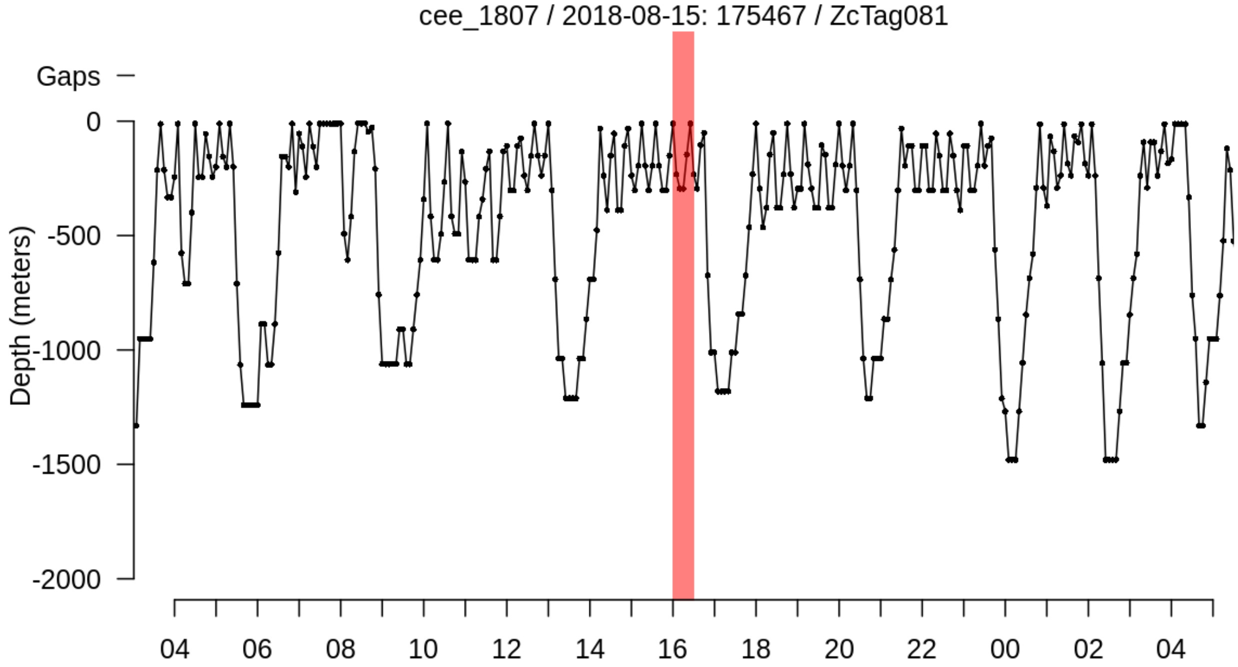


Figure 122. Estimated surface positions for whale Gm207 before, during, and after Atlantic-BRS CEE# 18-07

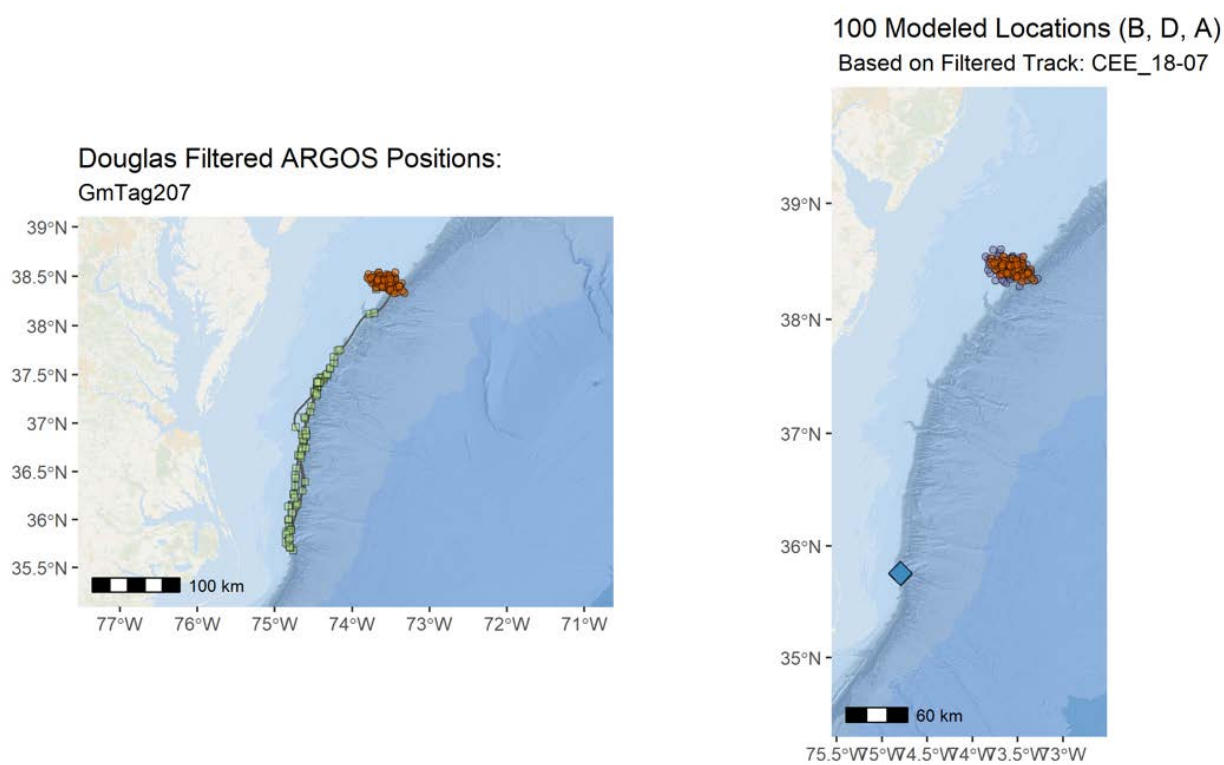


Figure 123. Available dive data for whale Gm207 before, during, and after Atlantic-BRS CEE# 18-07

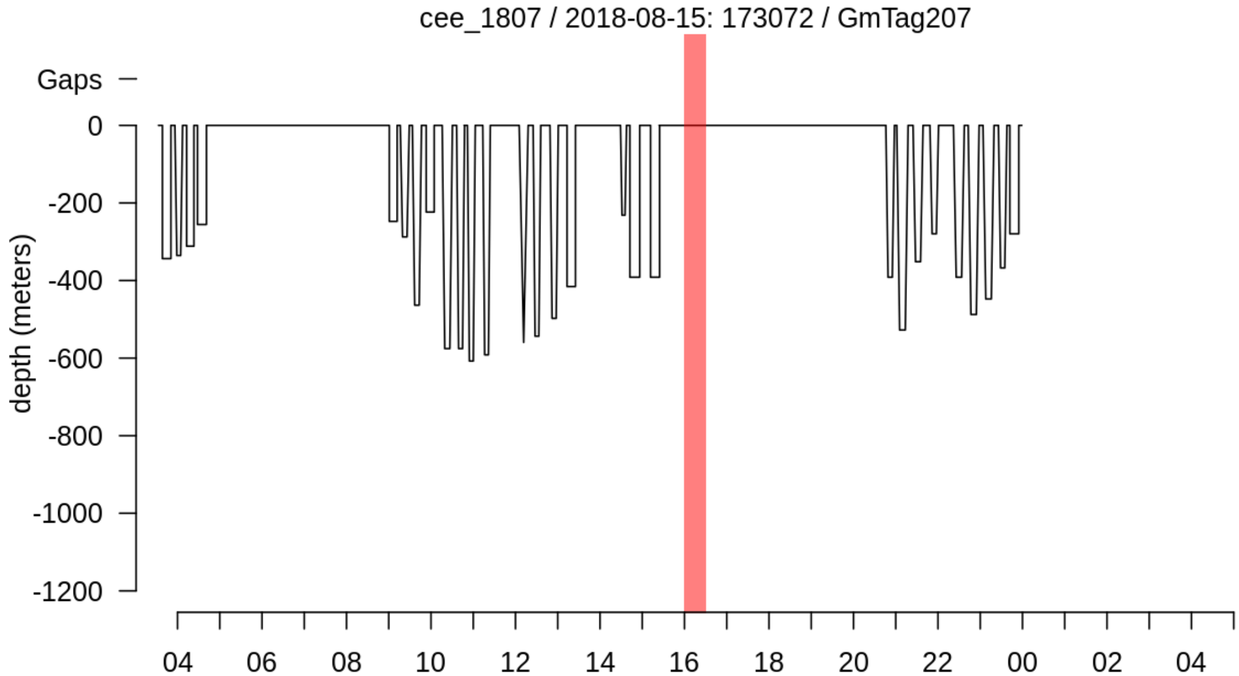


Figure 124. Estimated surface positions for whale Gm208 before, during, and after Atlantic-BRS CEE# 18-07

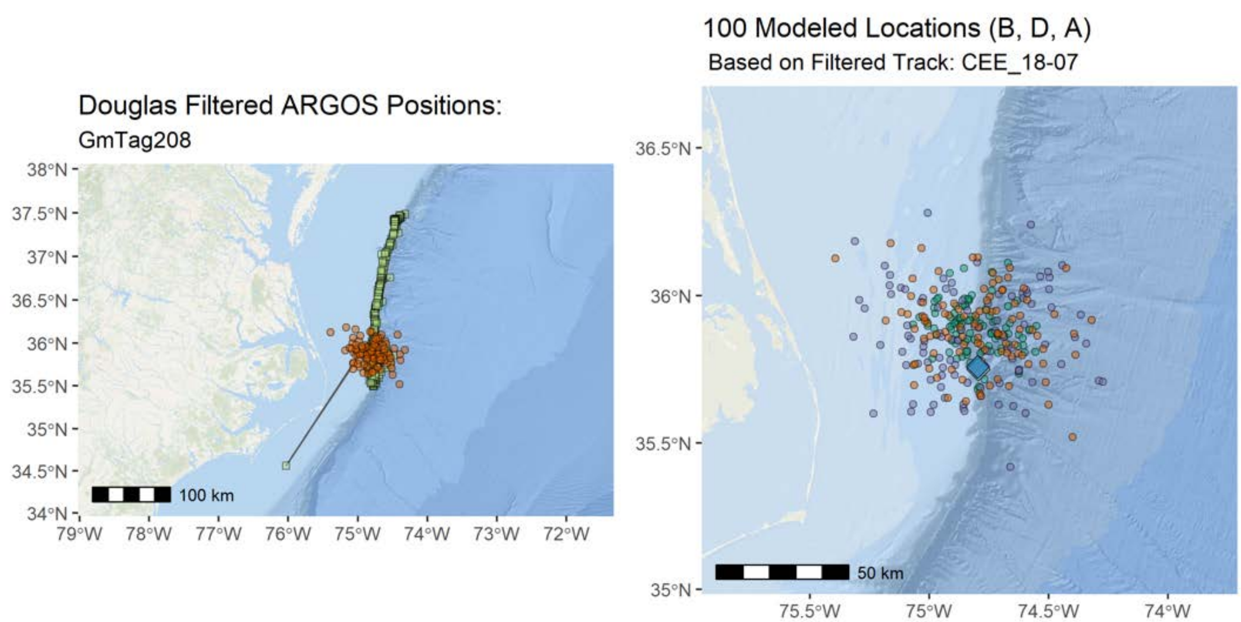


Figure 125. Estimated surface positions for whale Gm210 before, during, and after Atlantic-BRS CEE# 18-07

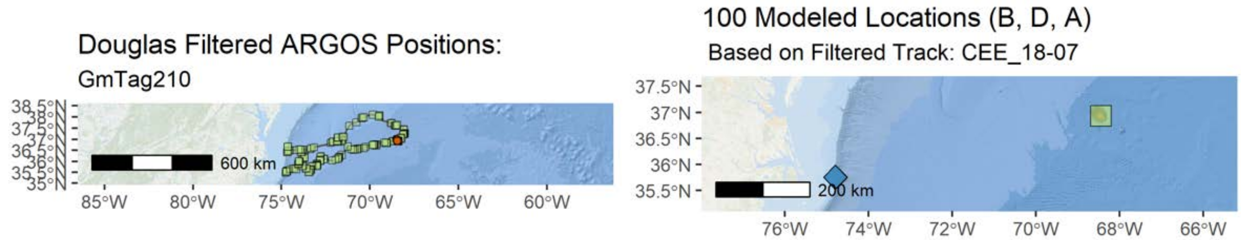


Figure 126. Available dive data for whale Gm210 before, during, and after Atlantic-BRS CEE# 18-07

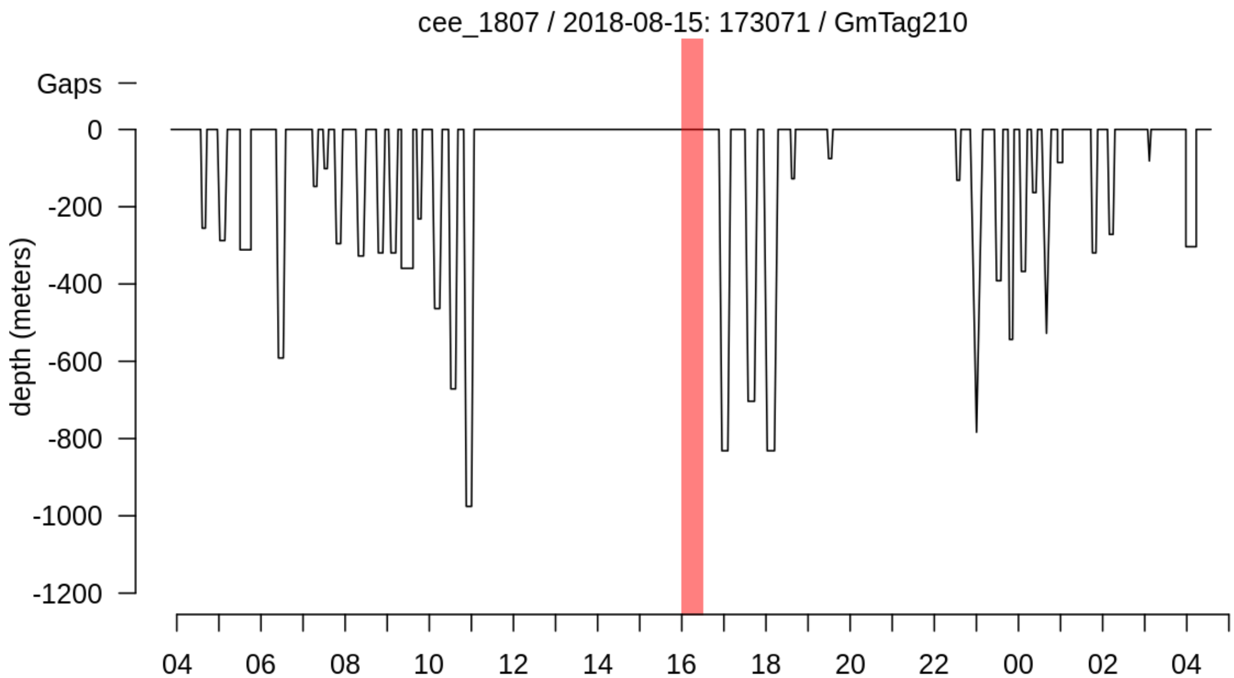


Figure 127. Estimated surface positions for focal whale Gm211 before, during, and after Atlantic-BRS CEE# 18-07

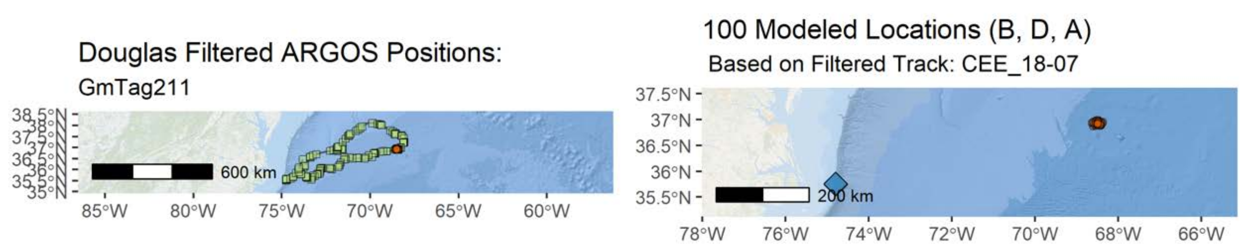
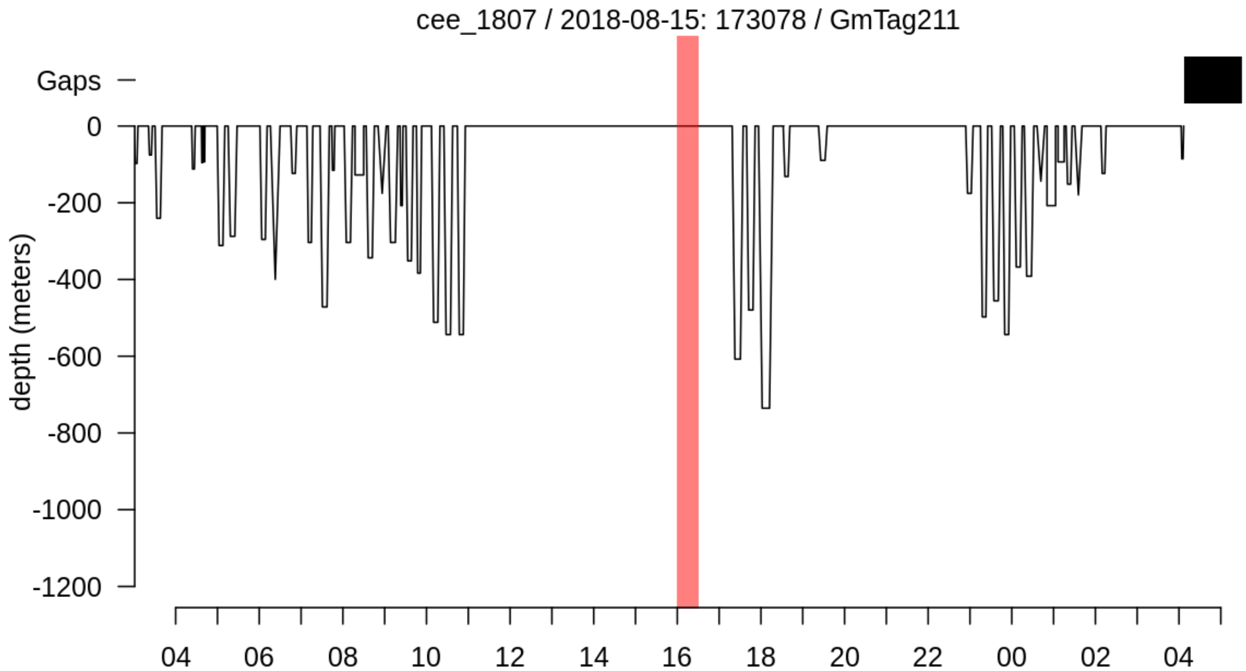


Figure 128. Available dive data for whale Gm211 before, during, and after Atlantic-BRS CEE# 18-07



2.3.8 CEE #18-08 – Simulated MFAS

Table 15. Metadata summary for Atlantic-BRS CEE# 18-08

CEE Conditions	Metadata Summary
CEE Identifier	**18-08**
Date	**8/27/18**
Type	**Simulated MFAS** from 15-element vertical line array deployed to 20 m depth from *F/V Kahuna* (stationary)
Signal Parameters	Three-segment (1.2 s total duration) pings (3.5–4 kHz); 212 dB re 1 µPa (RMS) sound pressure level; 25s repetition rate
Start time (UTC)	18:56:00
Start lat/lon	35.848087; -74.786848
End time (UTC)	19:26:00
End lat/lon	35.854292; -74.778645
Beaked whales monitored with tags during CEE	Incidental: Zc72, Zc73, Zc75, Zc76, Zc78, Zc79, Zc80
Pilot whales monitored with tags during CEE	Focal: **Gm18_239a** Incidental: Gm216, Gm217, Gm218

Figure 129. RL model prediction at 10 m depth for focal whale Gm18_239a for Atlantic-BRS CEE# 18-08

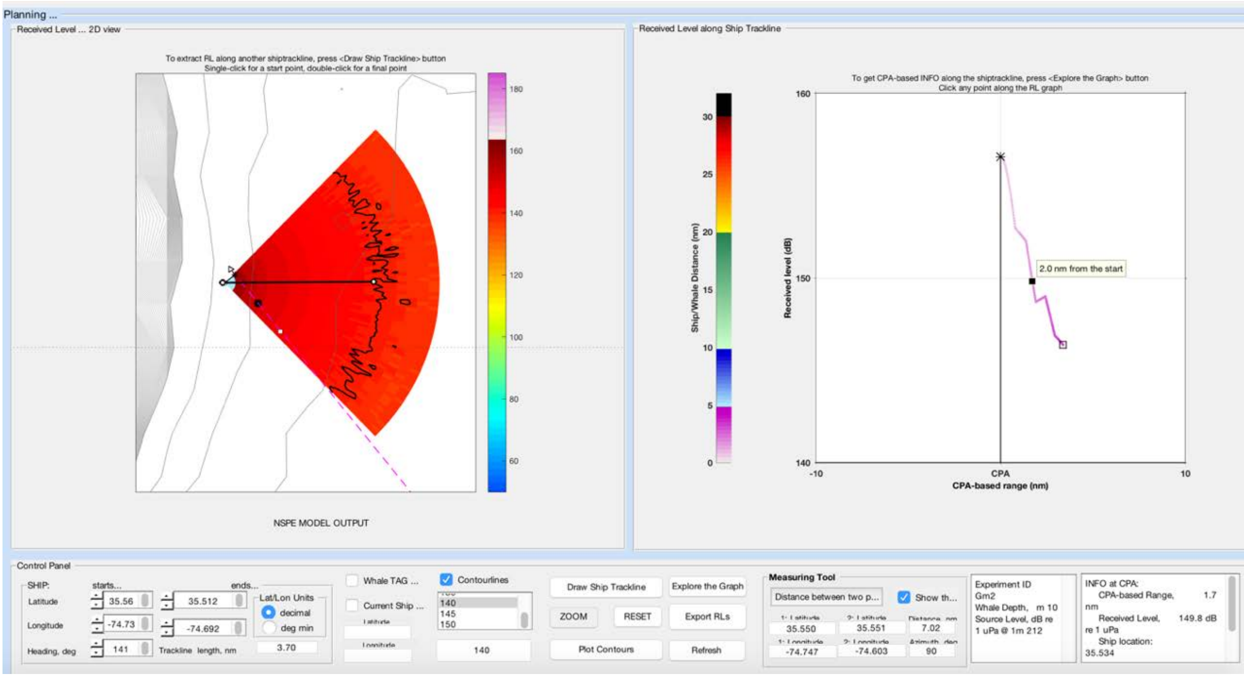


Figure 130. RL model prediction at 500 m depth for focal whales Gm18_239a for Atlantic-BRS CEE# 18-08

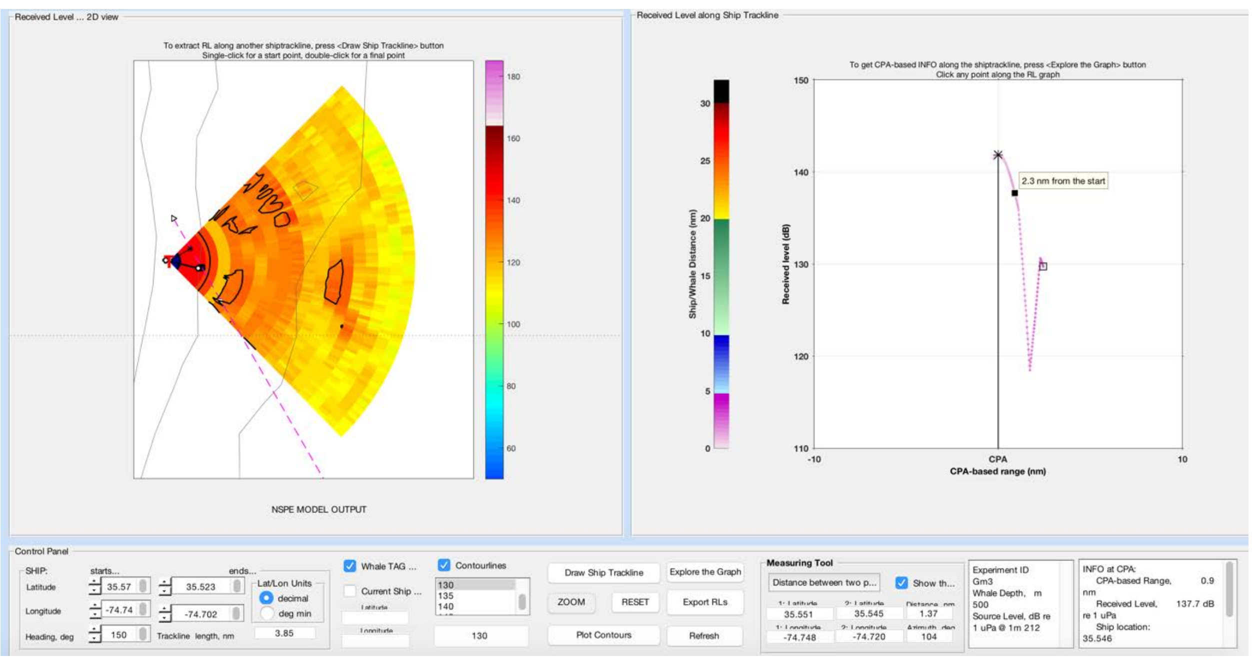


Figure 131. Uncorrected pseudotrack based on surface positions and tag data for focal whale Gm18_239a (DTAG) before, during, and after Atlantic-BRS CEE# 18-08

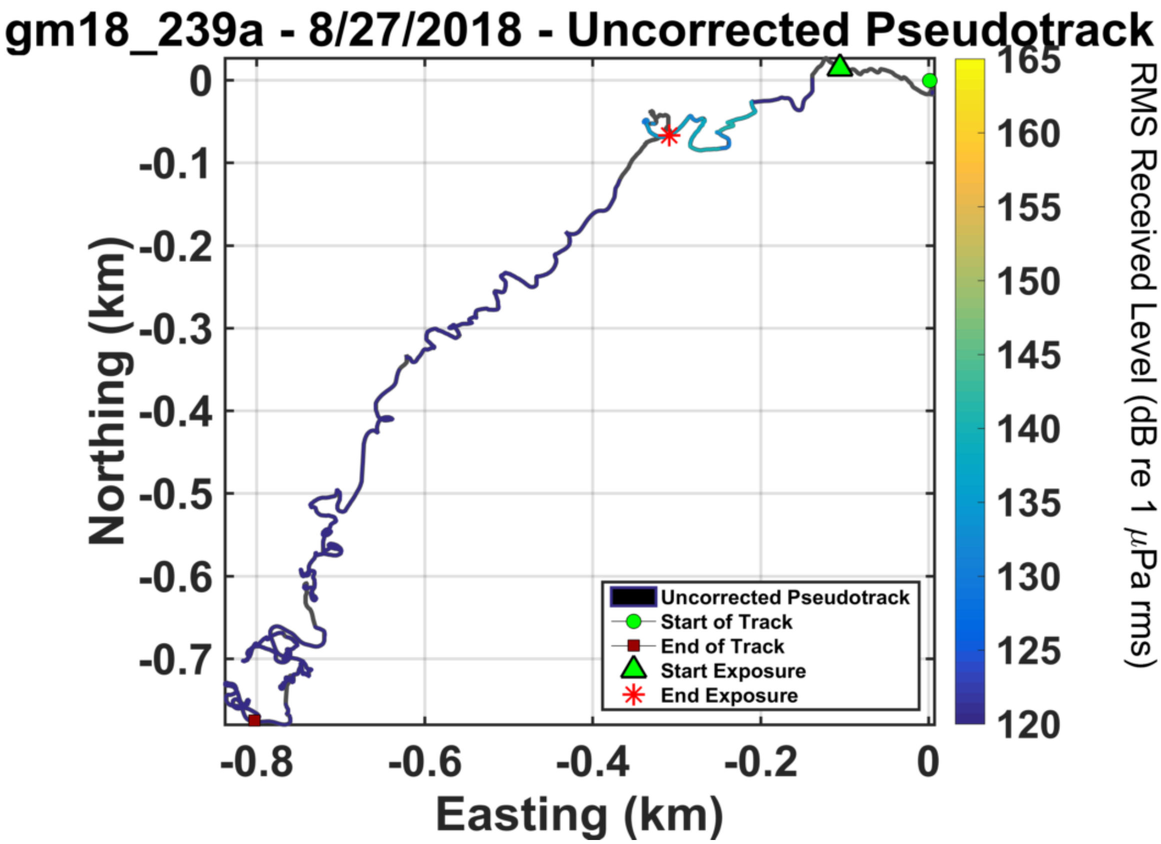


Figure 132. Available dive data (with RLs) for focal whale Gm18_239a (DTAG) before, during, and after Atlantic-BRS CEE# 18-08

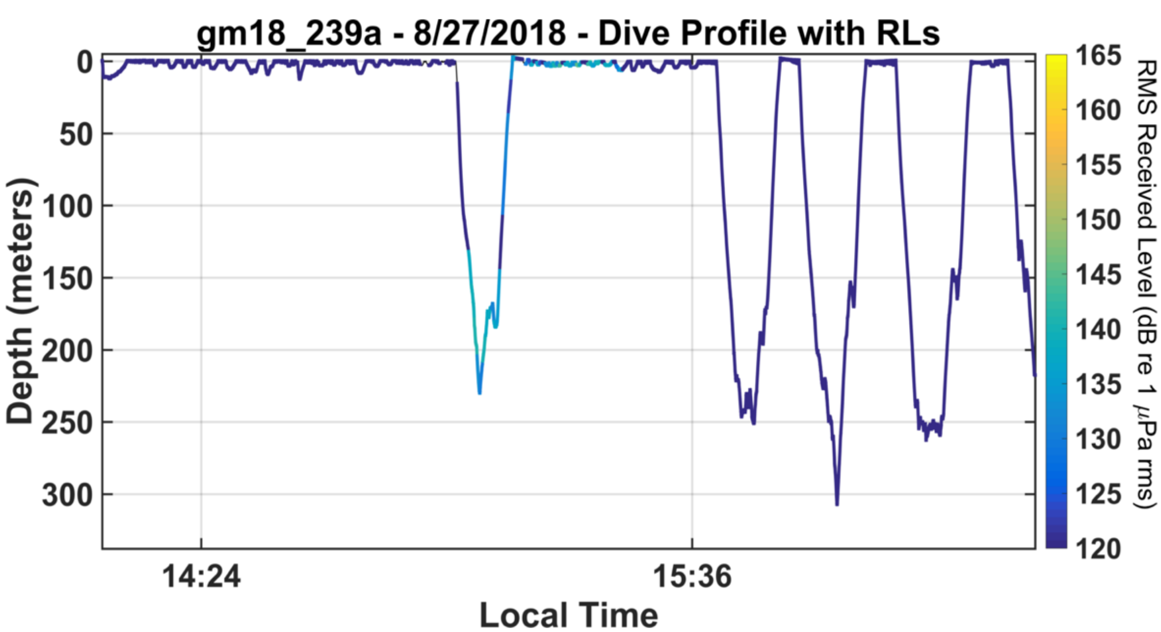


Figure 133. Dive profile with RLs (RMS) for focal whale Gm18_239a (DTAG) before, during, and after Atlantic-BRS CEE# 18-08

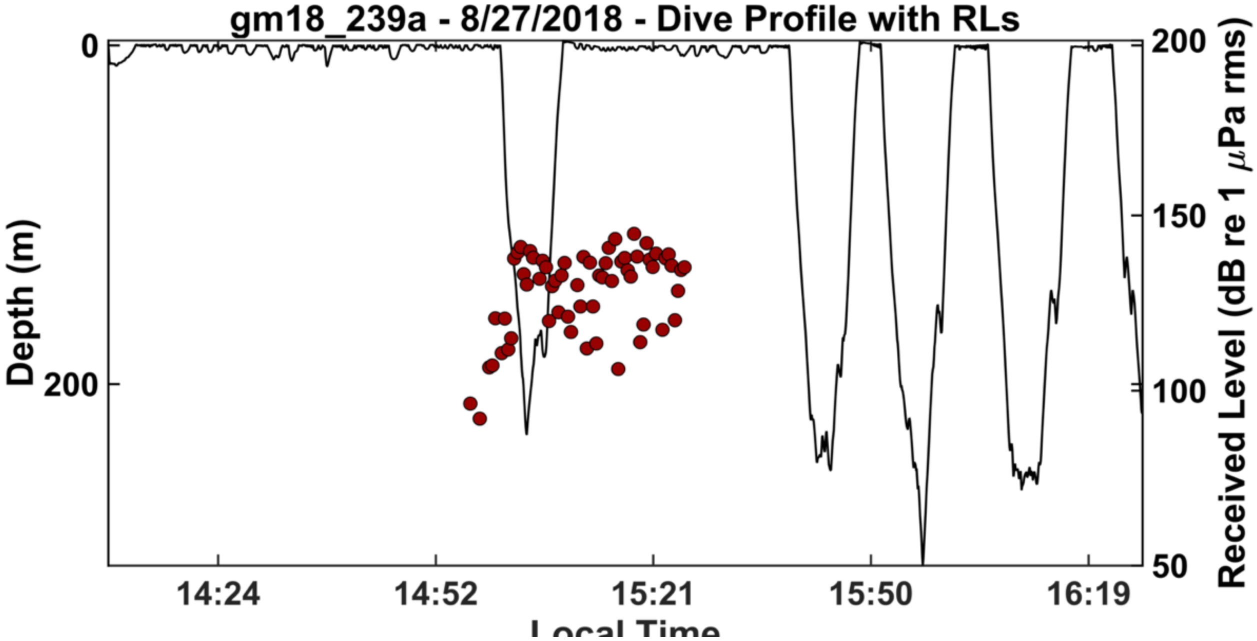


Figure 134. RLs (RMS) as a function of depth for focal whale Gm18_239a (DTAG) during Atlantic-BRS CEE# 18-08

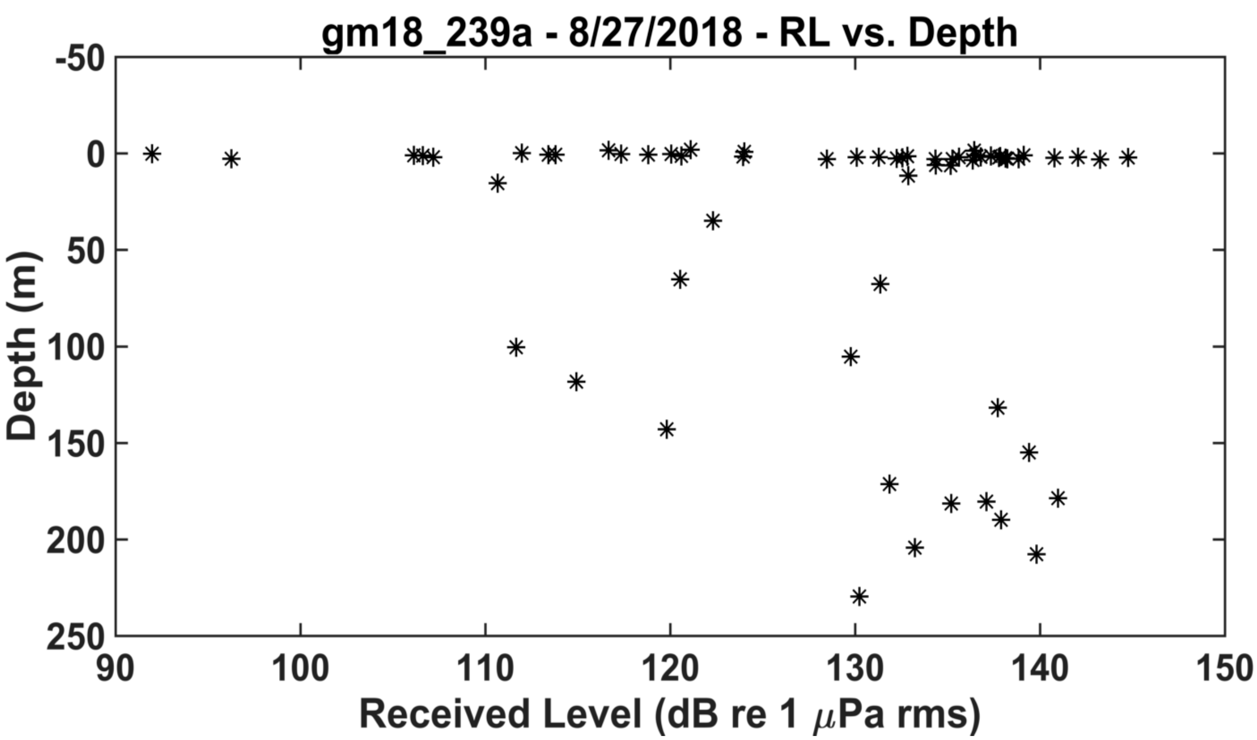


Figure 135. RLs (RMS) relative to RMS noise level for focal whale Gm18_239a (DTAG) during Atlantic-BRS CEE# 18-08

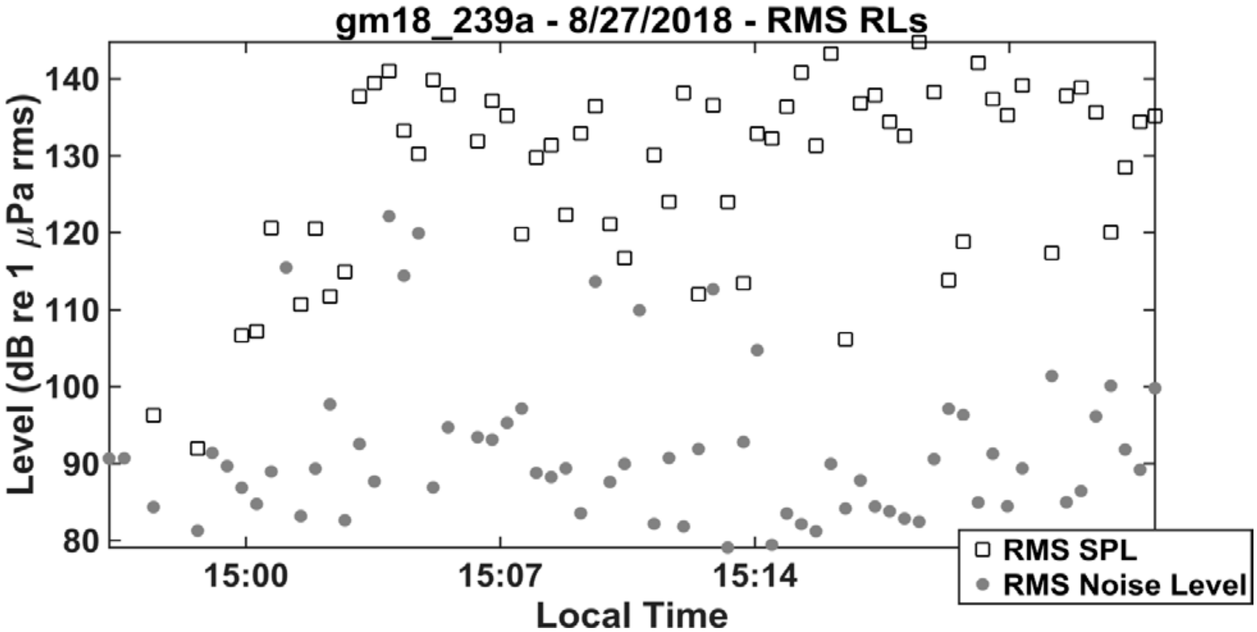


Figure 136. RLs (Peak SPL) relative to peak noise level for focal whale Gm18_239a (DTAG) during Atlantic-BRS CEE# 18-08

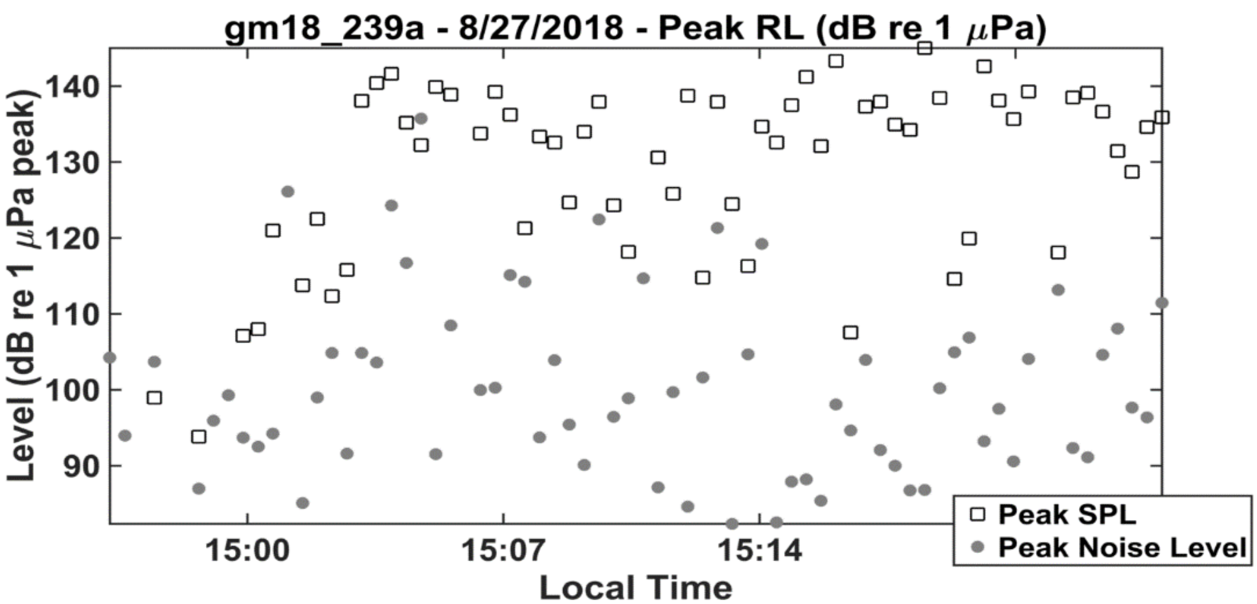


Figure 137. RLs (per pulse and continuous SEL) for focal whale Gm18_239a (DTAG) during Atlantic-BRS CEE# 18-08

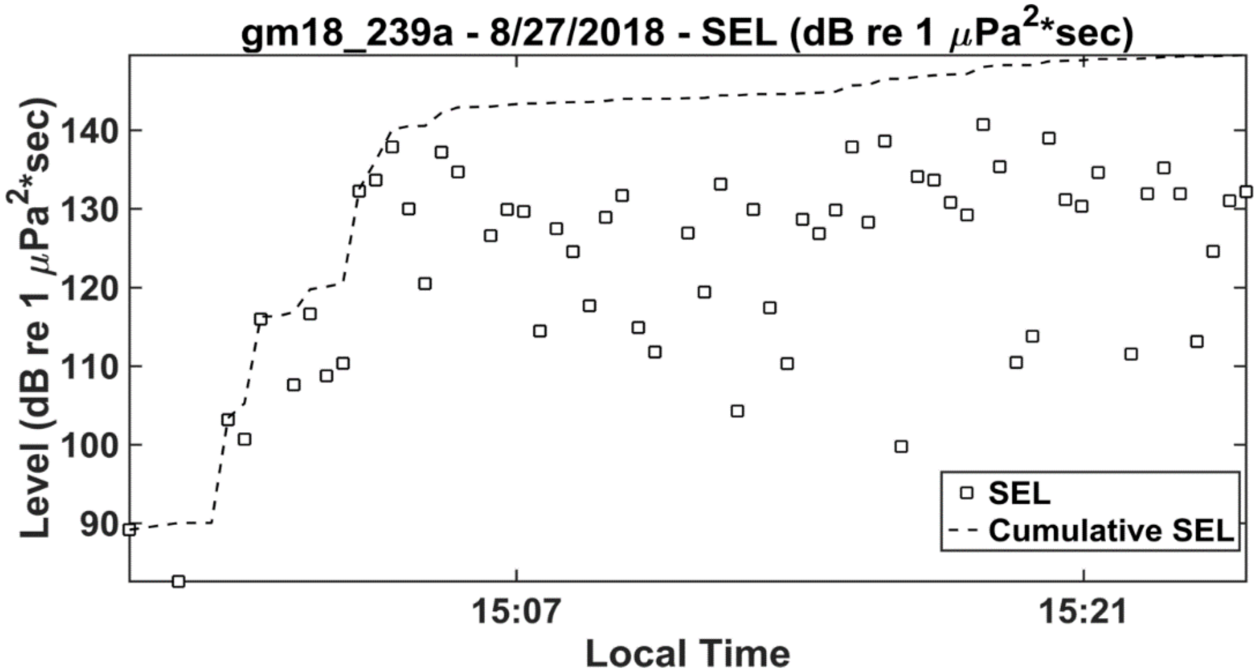


Figure 138. RLs (in signal-to-noise ratio (SNR)) for focal whale Gm18_239a (DTAG) during Atlantic-BRS CEE# 18-08

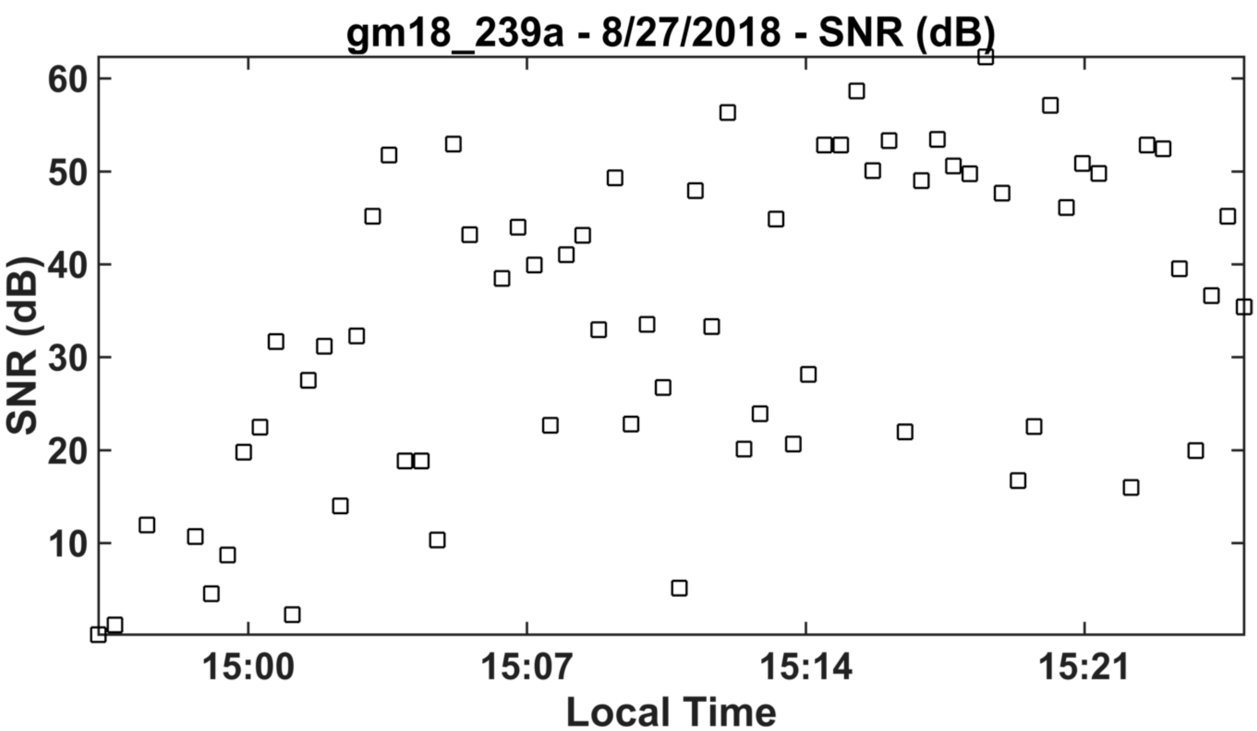


Table 16. Received Levels (RMS, Peak, SNR) for focal whale Gm18_239a (DTAG) during Atlantic-BRS CEE# 18-08

Time	Depth (m)	SPL_RMS	SPL_Peak	SNR
'27.08.2018 18:56:07.921'	2.149304939	NaN	NaN	0.148303
'27.08.2018 18:56:33.601'	1.760616106	NaN	NaN	1.189104
'27.08.2018 18:57:22.961'	2.782756277	96.2714025	98.92557	11.9461
'27.08.2018 18:58:37.841'	0.185547931	91.972696	93.8107	10.68487
'27.08.2018 18:59:03.041'	1.545117581	NaN	NaN	4.53952
'27.08.2018 18:59:27.921'	0.76888234	NaN	NaN	8.698066
'27.08.2018 18:59:53.041'	1.199979938	106.620098	107.0878	19.76428
'27.08.2018 19:00:18.081'	1.989847046	107.179747	107.9671	22.46278
'27.08.2018 19:00:43.041'	1.322550482	120.605447	120.9689	31.66722
'27.08.2018 19:01:08.161'	0.330541792	NaN	NaN	2.27747
'27.08.2018 19:01:33.041'	15.43595374	110.672144	113.7527	27.50435
'27.08.2018 19:01:58.081'	65.3494067	120.532824	122.497	31.18788
'27.08.2018 19:02:22.961'	100.4899653	111.676745	112.3113	13.98316
'27.08.2018 19:02:48.161'	118.3635925	114.923224	115.7881	32.28701
'27.08.2018 19:03:13.041'	131.8222867	137.717188	138.0397	45.17774
'27.08.2018 19:03:38.161'	155.0093086	139.418252	140.394	51.75942
'27.08.2018 19:04:03.121'	178.6919377	140.980424	141.6071	18.8464
'27.08.2018 19:04:28.161'	204.2690605	133.23851	135.1808	18.84681
'27.08.2018 19:04:53.121'	229.6114109	130.230504	132.2153	10.31003
'27.08.2018 19:05:17.921'	207.7380016	139.806998	139.87	52.9282
'27.08.2018 19:05:43.121'	189.924867	137.88849	138.8648	43.17628
'27.08.2018 19:06:33.121'	171.3628219	131.856825	133.7556	38.45427
'27.08.2018 19:06:58.161'	180.4872809	137.097762	139.2257	44.00208
'27.08.2018 19:07:23.281'	181.404894	135.193707	136.2055	39.91553
'27.08.2018 19:07:48.161'	142.9456553	119.814013	121.2777	22.66971
'27.08.2018 19:08:13.281'	105.3574593	129.76274	133.3435	41.01251
'27.08.2018 19:08:38.241'	67.71865159	131.367957	132.5465	43.11842
'27.08.2018 19:09:03.201'	34.95711144	122.311291	124.6647	32.94113
'27.08.2018 19:09:28.321'	11.56370073	132.871787	133.9653	49.31136
'27.08.2018 19:09:53.201'	-1.373056414	136.438317	137.9013	22.80631
'27.08.2018 19:10:18.081'	-1.907490777	121.100857	124.2885	33.51842
'27.08.2018 19:10:43.121'	-1.570414212	116.673045	118.147	26.74846
'27.08.2018 19:11:08.241'	-1.195542883	NaN	NaN	5.138121
'27.08.2018 19:11:33.281'	2.018097873	130.084344	130.6048	47.9339
'27.08.2018 19:11:58.561'	-0.825754233	124.010095	125.8214	33.29395
'27.08.2018 19:12:23.121'	2.437519837	138.140533	138.7164	56.33968

Figure 139. Estimated surface positions for whale Zc72 before, during, and after Atlantic-BRS CEE# 18-08

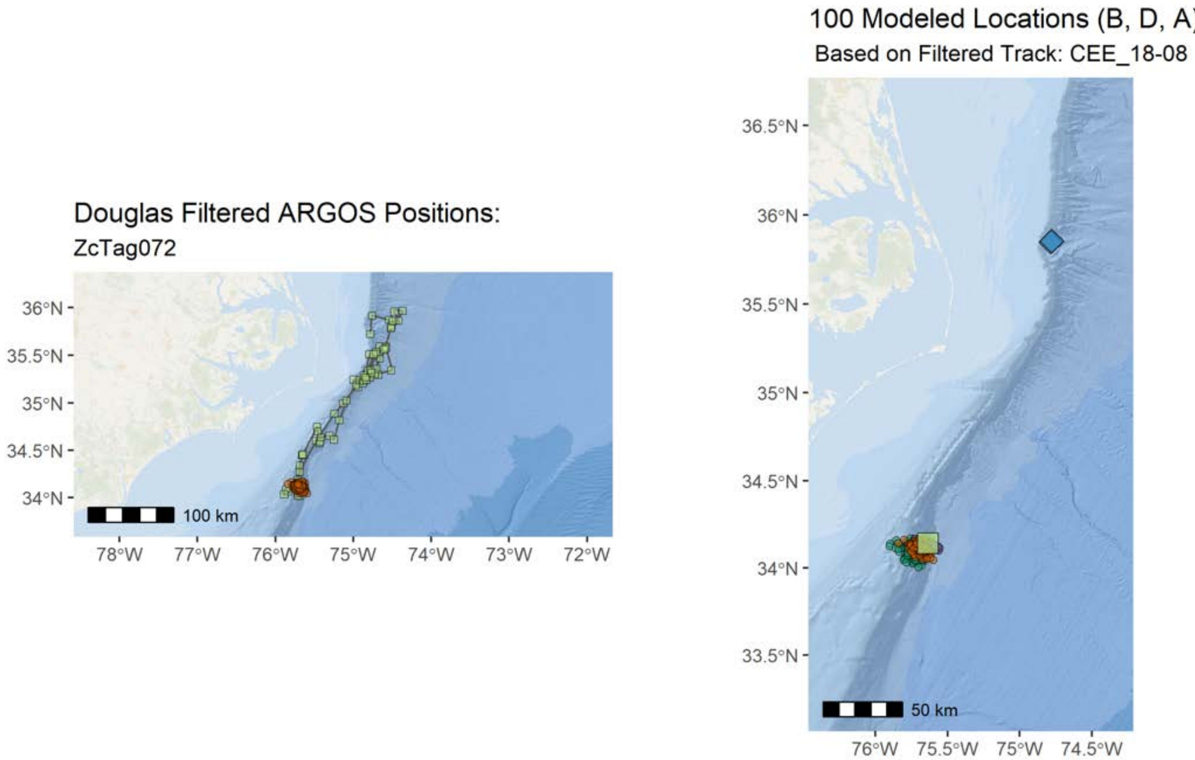


Figure 140. Estimated surface positions for whale Zc73 before, during, and after Atlantic-BRS CEE# 18-08

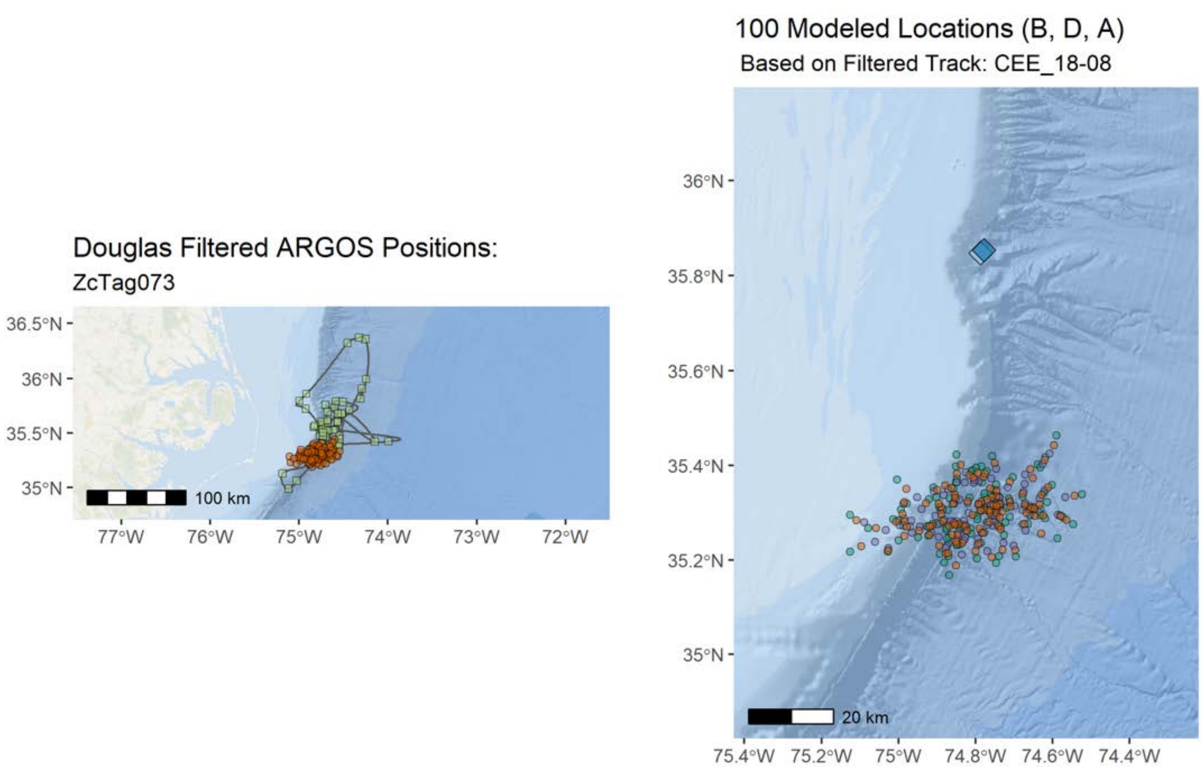


Figure 141. Available dive data for whale Zc73 before, during, and after Atlantic-BRS CEE# 18-08

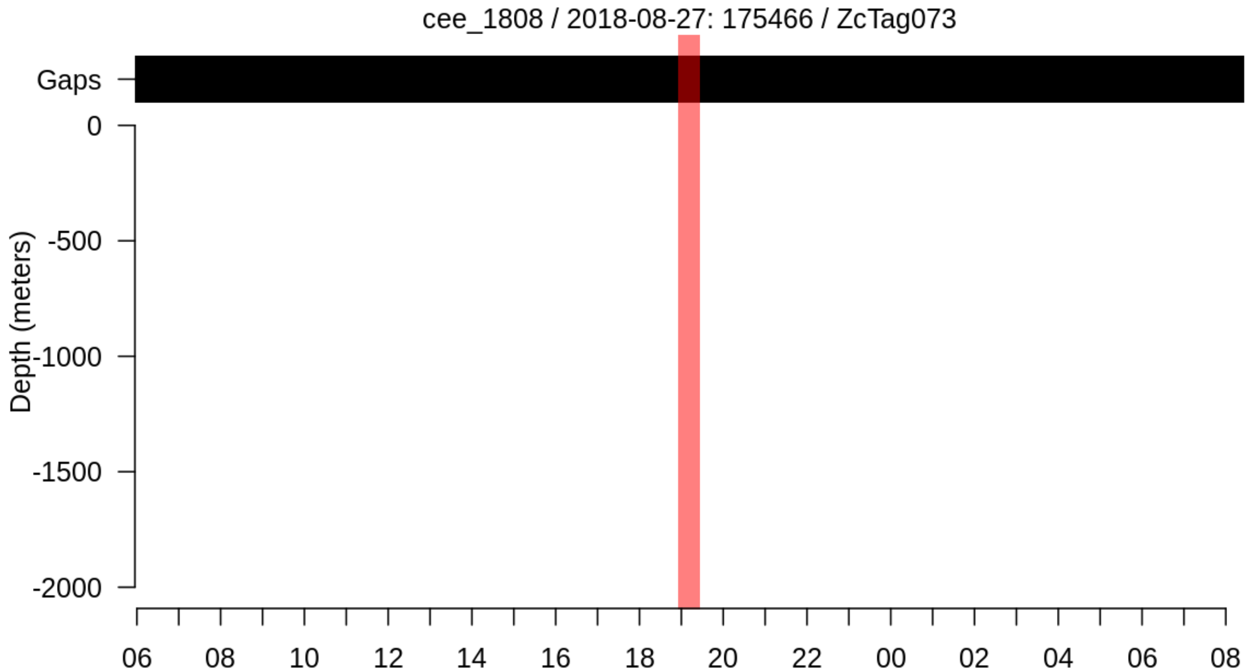


Figure 142. Estimated surface positions for whale Zc75 before, during, and after Atlantic-BRS CEE# 18-08

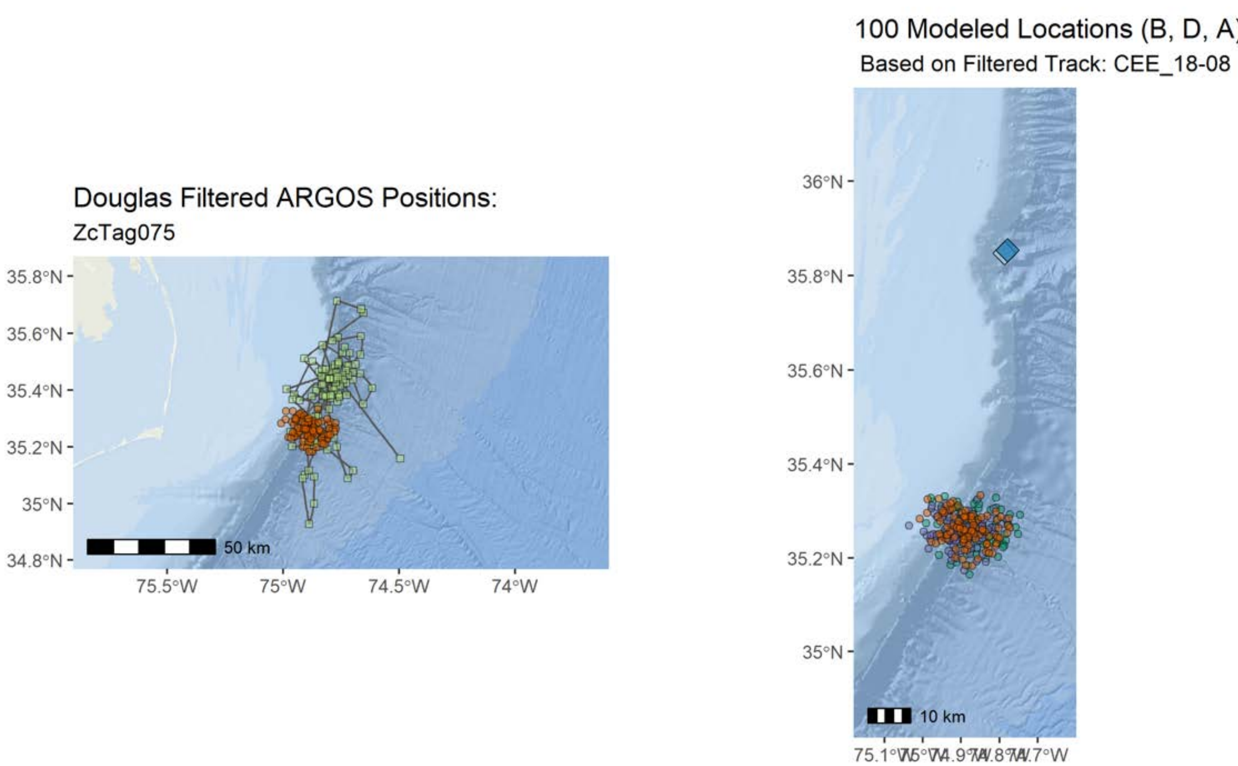


Figure 143. Available dive data for whale Zc76 before, during, and after Atlantic-BRS CEE# 18-08

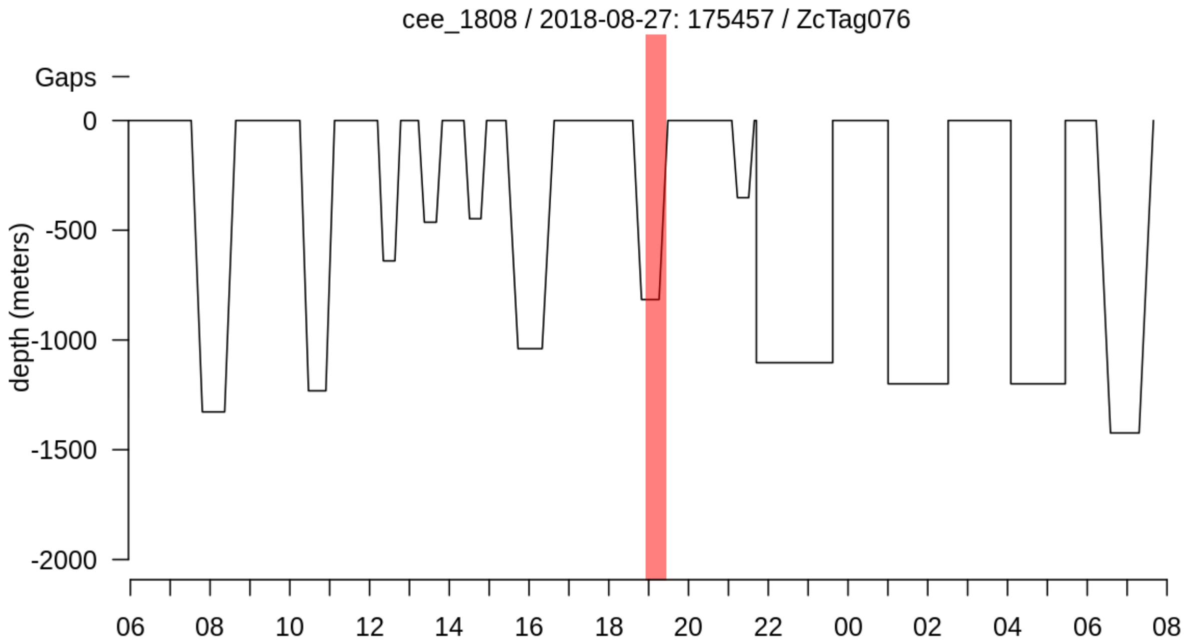


Figure 144. Estimated surface positions for whale Zc78 before, during, and after Atlantic-BRS CEE# 18-08

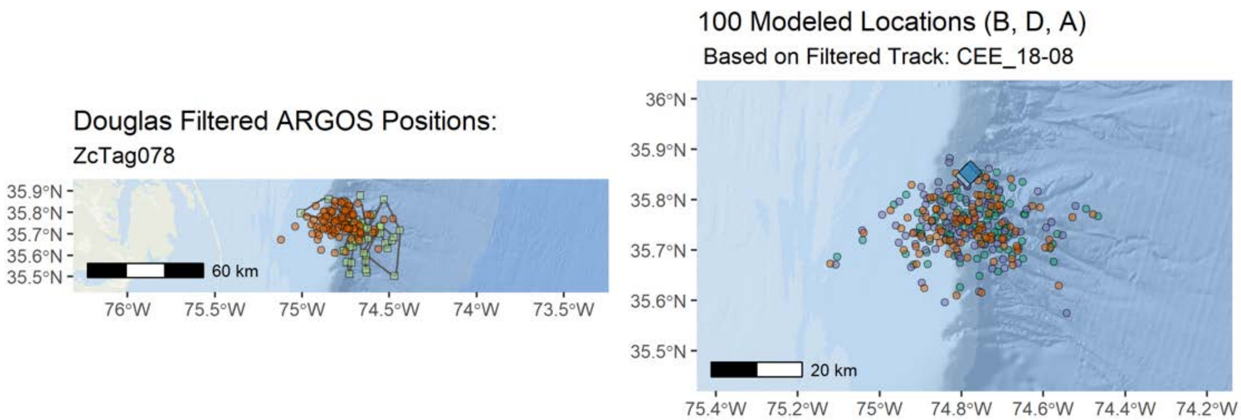


Figure 145. Available dive data for whale Zc78 before, during, and after Atlantic-BRS CEE# 18-08

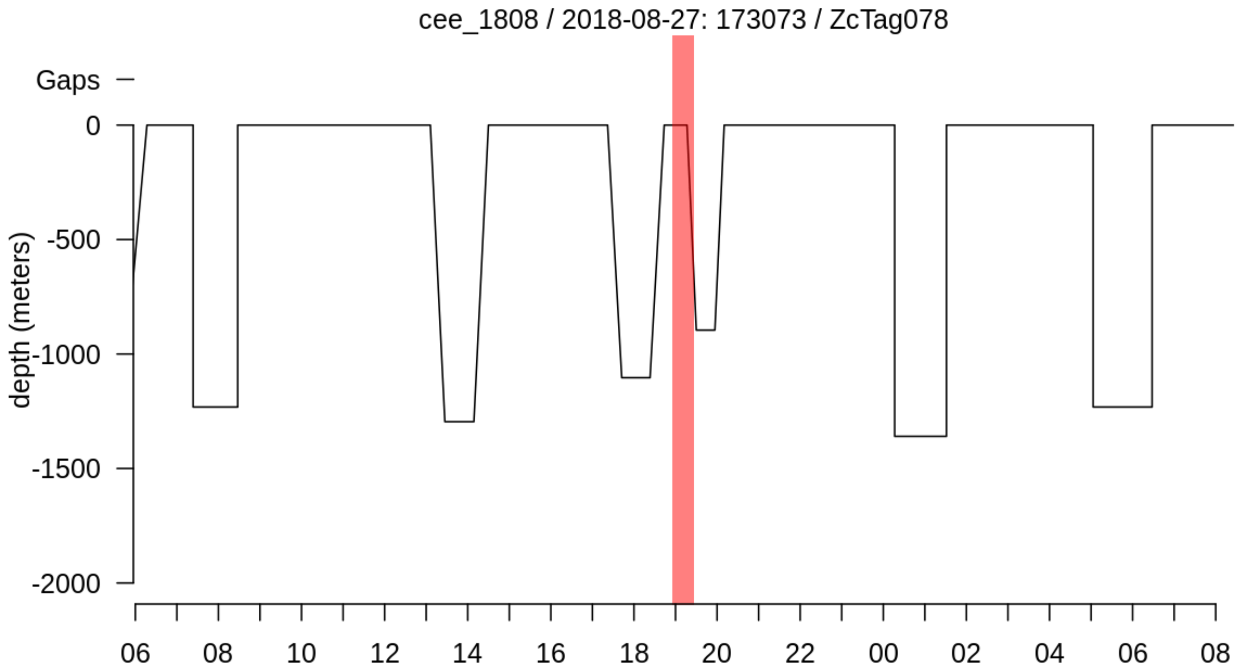


Figure 146. Estimated surface positions for whale Zc79 before, during, and after Atlantic-BRS CEE# 18-08

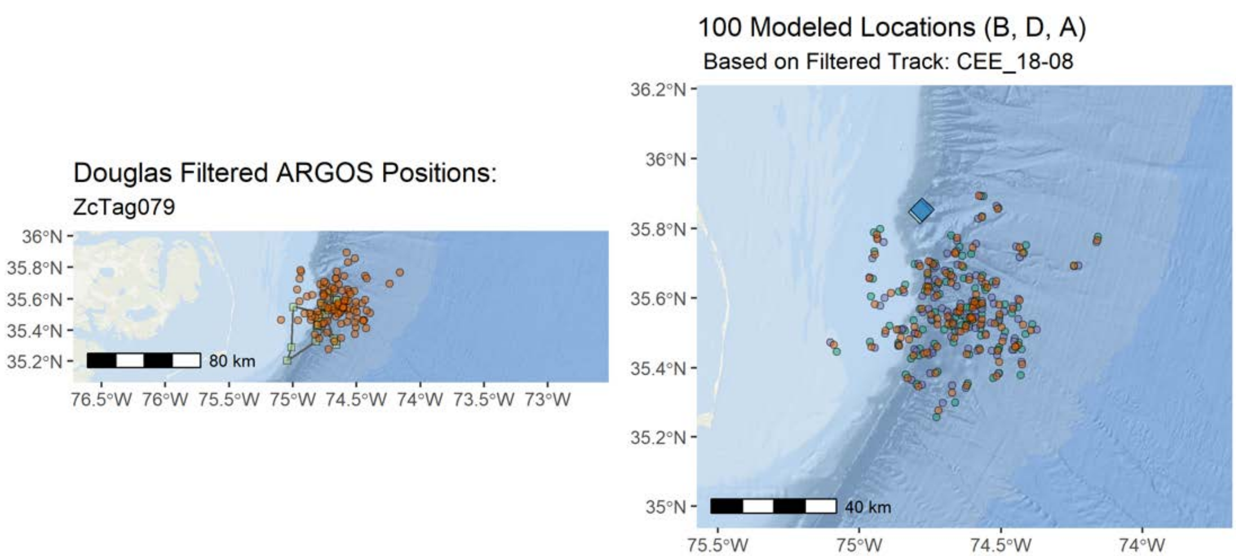


Figure 147. Available dive data for whale Zc79 before, during, and after Atlantic-BRS CEE# 18-08

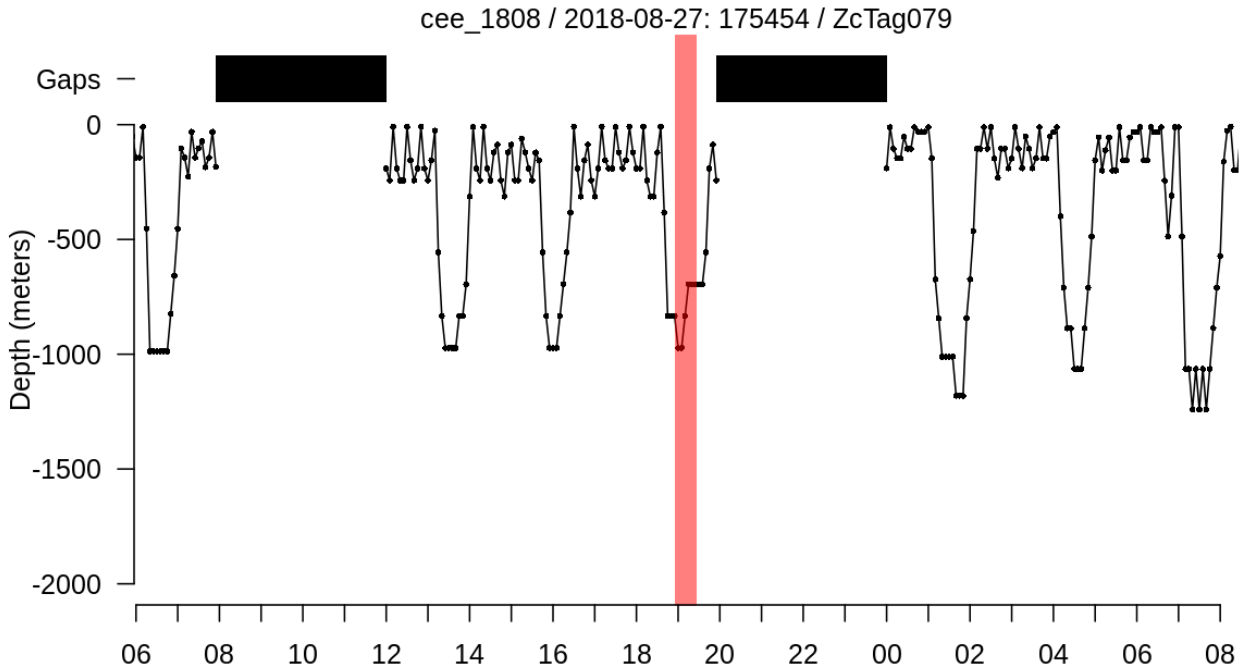


Figure 148. Estimated surface positions for whale Zc80 before, during, and after Atlantic-BRS CEE# 18-08

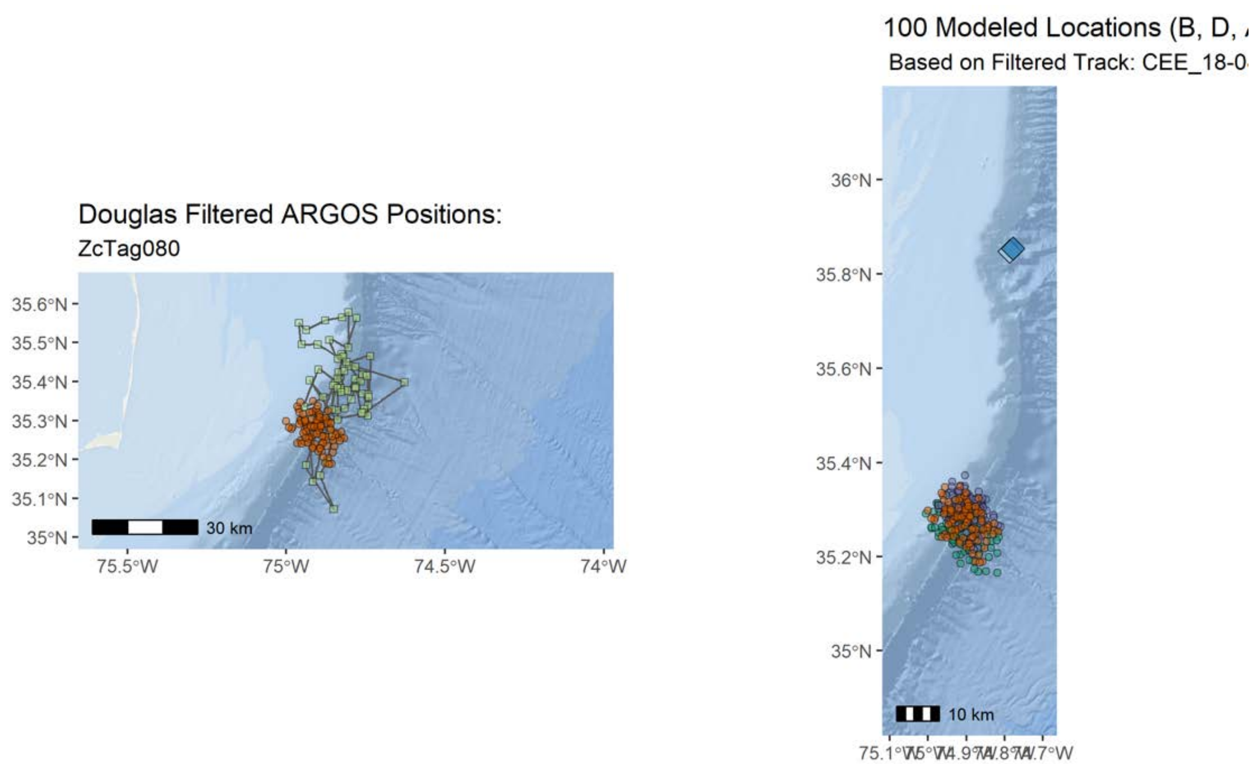


Figure 149. Estimated surface positions for whale Gm216 before, during, and after Atlantic-BRS CEE# 18-08

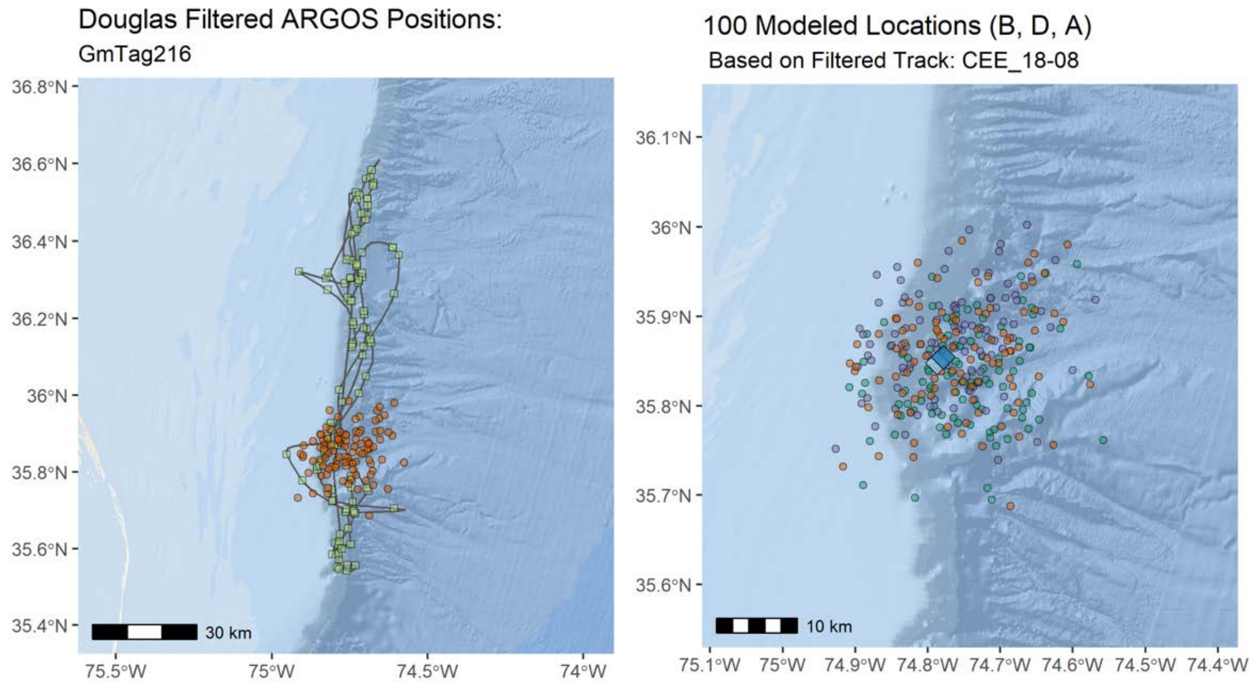


Figure 150. Available dive data for whale Gm216 before, during, and after Atlantic-BRS CEE# 18-08

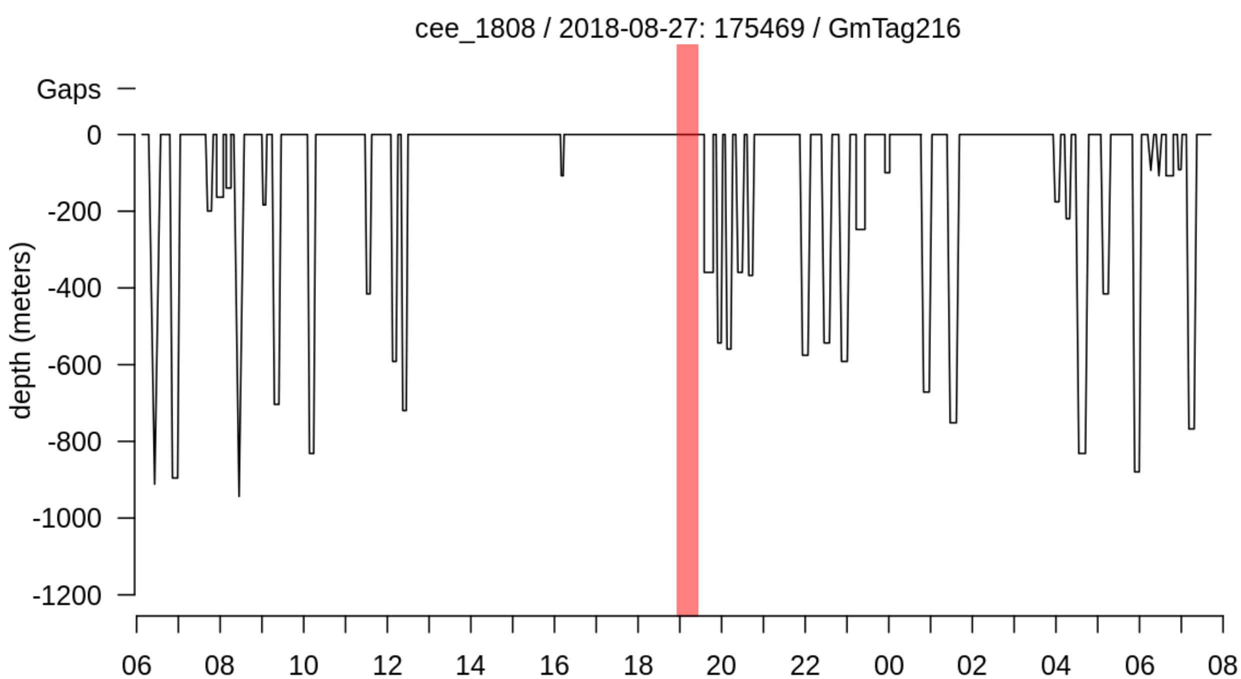


Figure 151. Estimated surface positions for focal whale Gm217 before, during, and after Atlantic-BRS CEE# 18-08

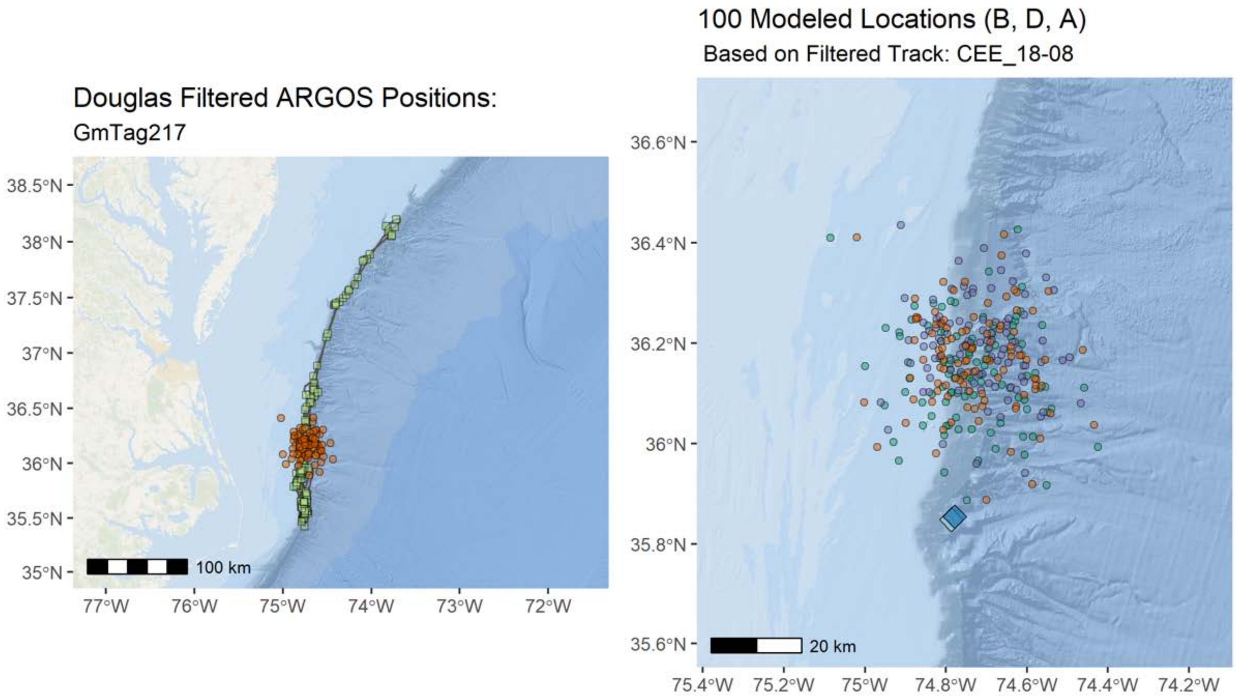


Figure 152. Available dive data for whale Gm217 before, during, and after Atlantic-BRS CEE# 18-08

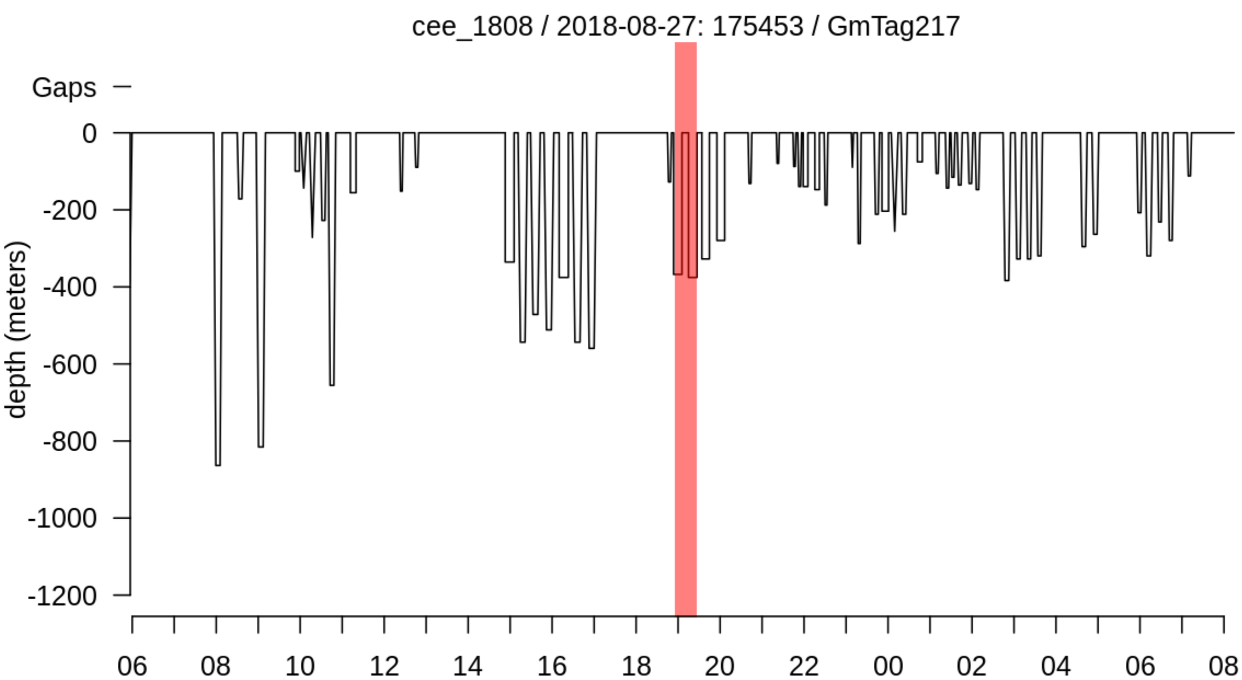


Figure 153. Estimated surface positions for focal whale Gm218 before, during, and after Atlantic-BRS CEE# 18-08

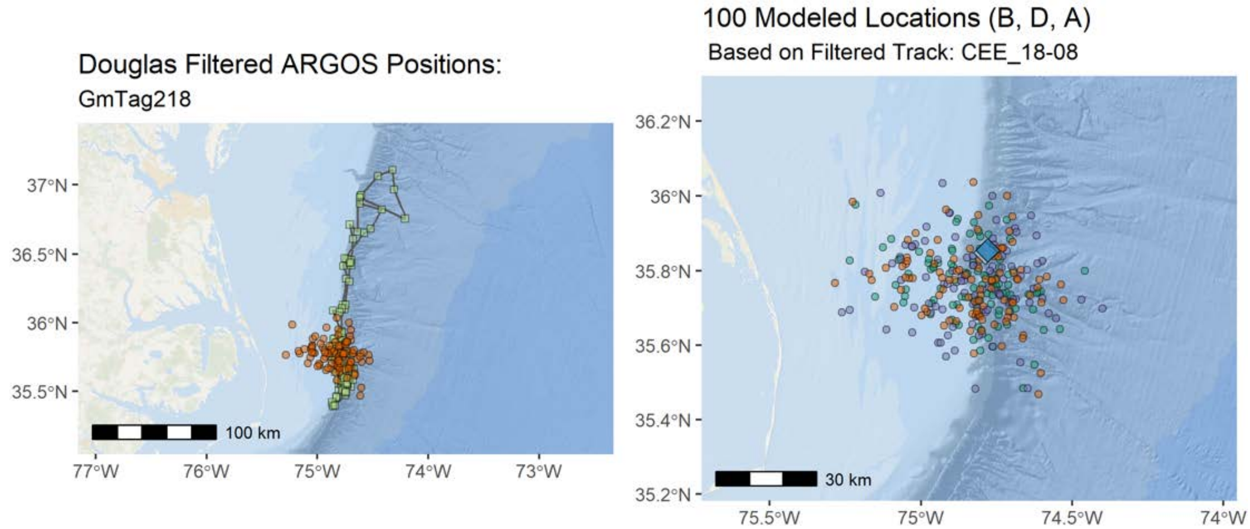
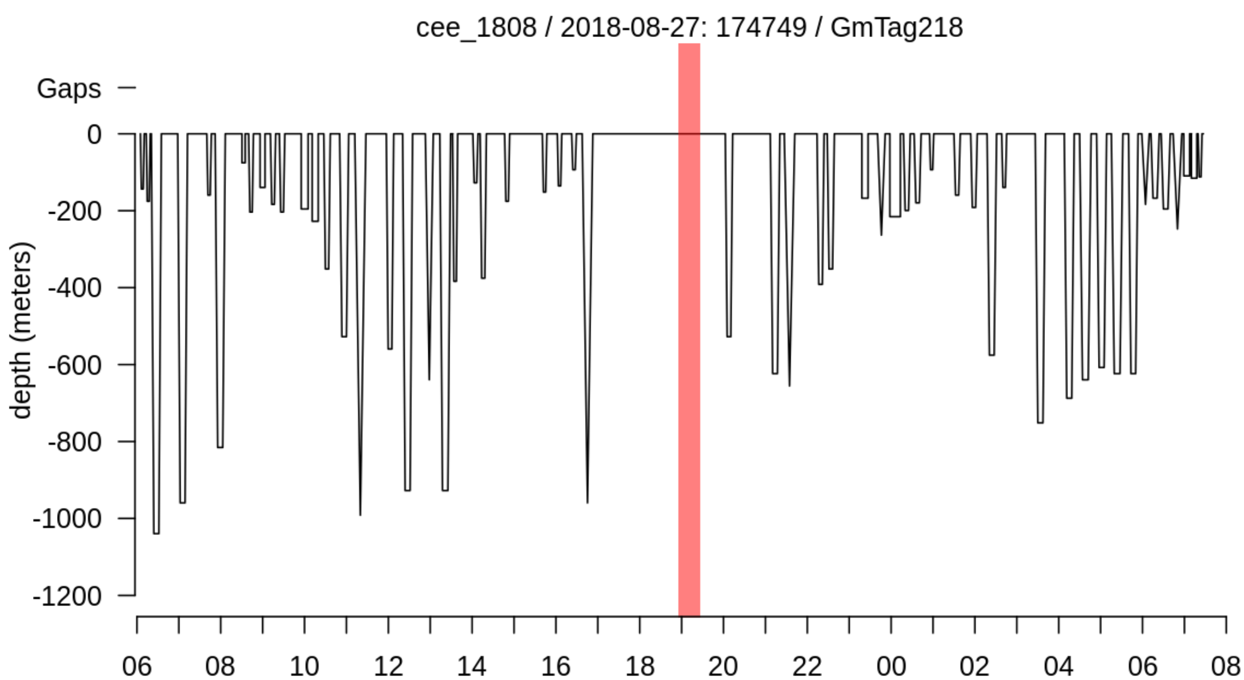


Figure 154. Available dive data for whale Gm218 before, during, and after Atlantic-BRS CEE# 18-08



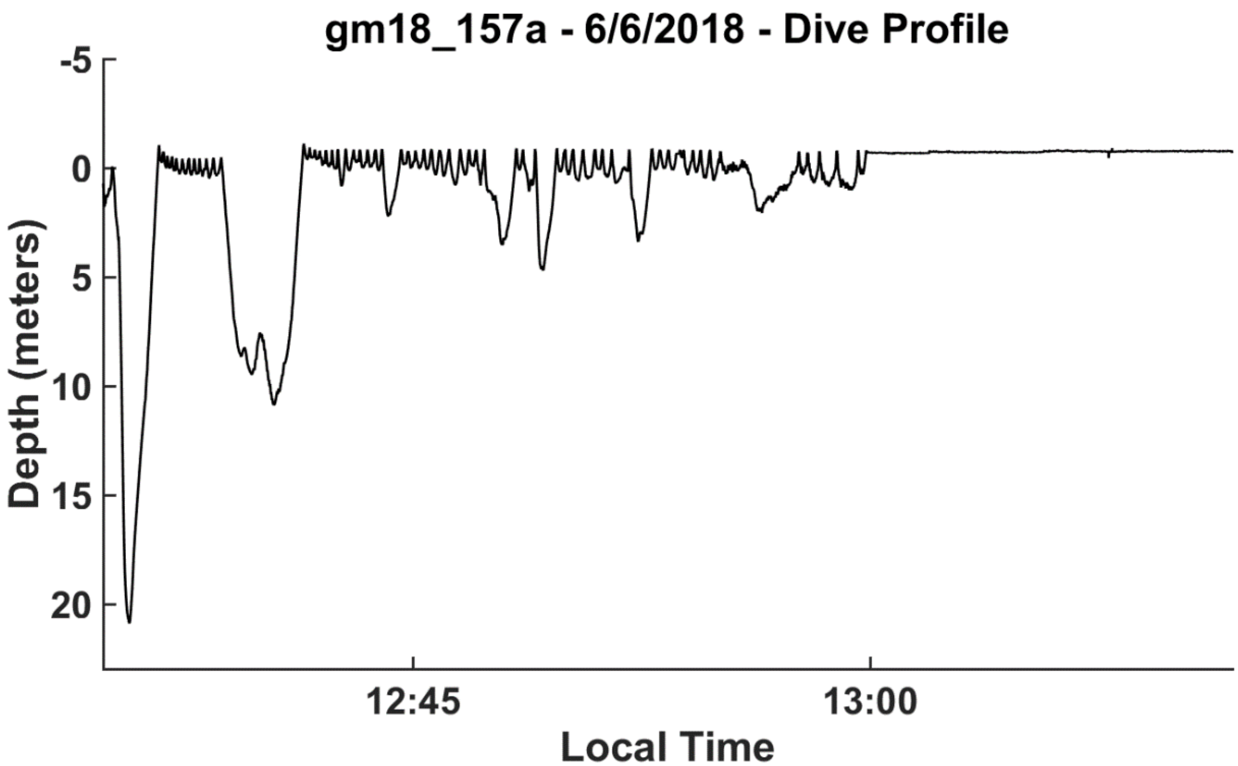
2.4 Baseline DTAG Deployments – No CEEs

2.4.1 Gm18_157a

Date:	6 June, 2018
Species:	*Short-finned pilot whale*
Dtag#:	d3-312
Tag Recording Start Time:	16:34:48 UTC
Tag On Animal:	16:35:00 UTC
Tag-on Location:	35.566240, -74.753882
Tag Recovered:	
CEE information:	No CEE

NOTE: Same individual that was simultaneously satellite tagged (Gm205)

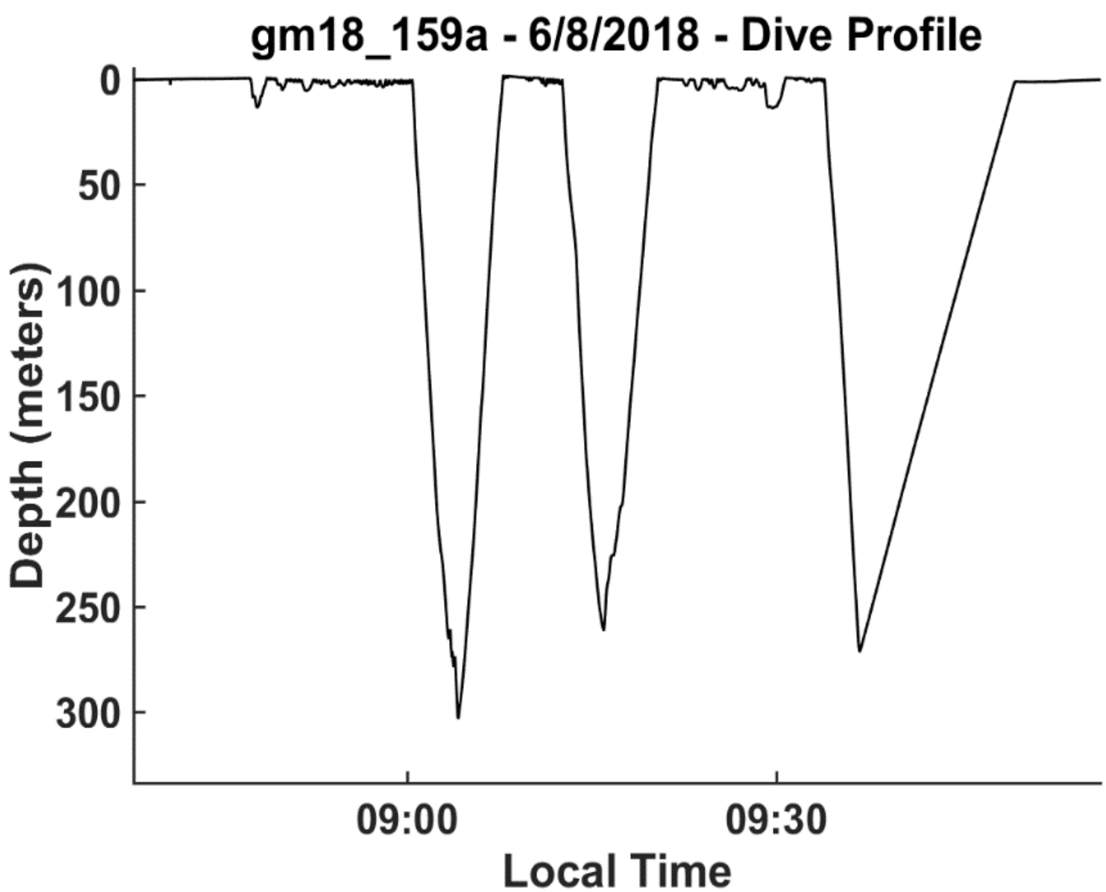
Figure 155. Baseline DTAG deployment on whale Gm18_157a



2.4.2 Gm18_159a

Date: 8 June, 2018
Species: Short-finned pilot whale
Dtag#: d3-312
Tag Recording Start Time: 12:37:48 UTC
Tag On Animal: 2:47:15 UTC
Tag-on Location: 35.660620, -74.796795

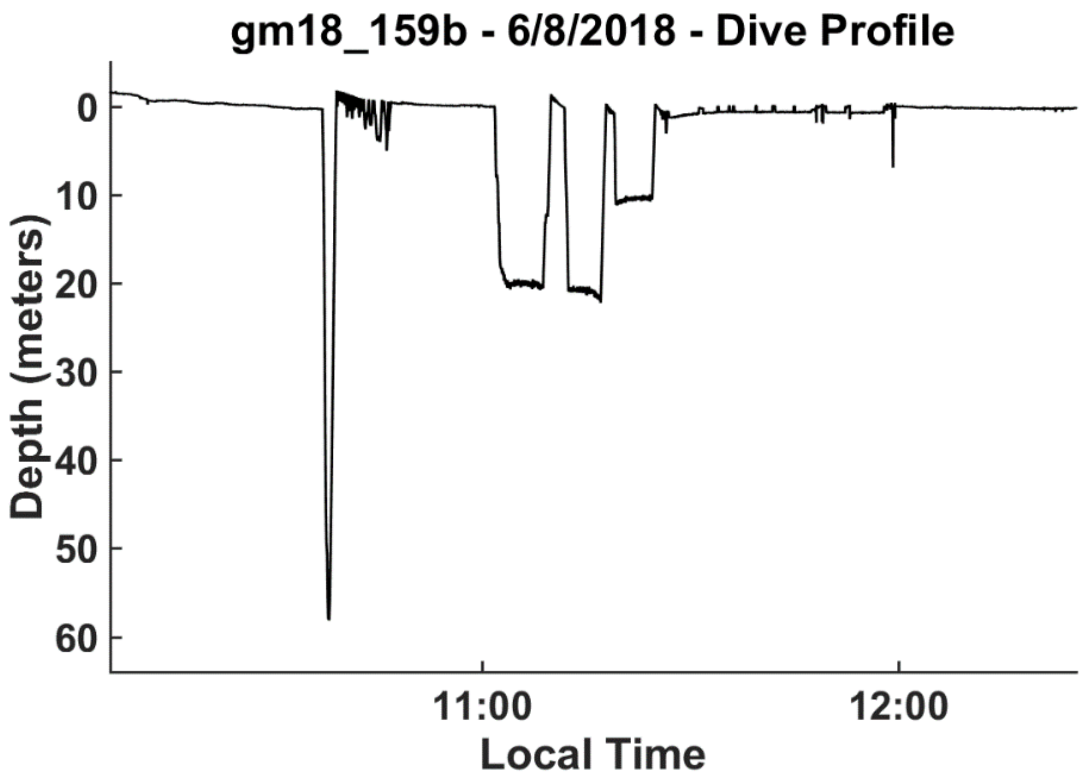
Figure 156. Baseline DTAG deployment on whale Gm18_159a



2.4.3 Gm18_159b

Date:	8 June, 2018
Species:	Short-finned pilot whale
Dtag#:	d3-312
Tag Recording Start Time:	14:06:23 UTC
Tag On Animal:	17:37:57 UTC
Tag-on Location:	35.59341167, -74.757215

Figure 157. Baseline DTAG deployment on whale Gm18_159b



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3. CEE Exposure-Response Analyses: Status and Preliminary Results

3.1 Baseline Animal Movement and Diving Data

As shown in **Tables 4 and 5**, the 31 satellite tags deployed on (13) beaked whales and (18) pilot whales recorded individual movement and diving data for many hundreds of total days. This is in addition to 26 tags (14 beaked whales; 12 pilot whales) deployed in 2017, making these two years of effort off Cape Hatteras, in addition to the baseline satellite tag deployments conducted ahead of the Atlantic-BRS project, among the largest set of baseline data on these species available in the world. The collective dataset includes tens of thousands of hours of data both prior to and following either of the CEEs conducted. The analysis of potential response as a function of exposure is ongoing and will include additional CEEs (see below). But even if responses were to last several days, many tags recorded for weeks after CEEs. Additional high-resolution kinematic and acoustic data were also obtained from the six DTAGs deployed and recovered (see **Table 6**), with the first successfully recovered DTAG from a simultaneously satellite tagged whale. These data augment previously collected baseline data in serving as the foundation against which potential fine-scale behavioral responses are analyzed.

While the bulk of the analytical effort for the current project remains on the complex and extensive analyses of exposure, received level modeling, and behavioral response (see below), there are two current papers on baseline behavioral data in Cuvier's beaked whales that represent major contributions to the science and management of this key species. These publications are being led by the Duke team with participation from others in the overall Atlantic-BRS team and utilize data collected both before and during the Atlantic-BRS project: Diving behavior of Cuvier's beaked whales off Cape Hatteras, NC (Shearer et al., 2019), and a manuscript recently submitted to the Proceedings of the Royal Society (B) entitled "Extreme Synchrony in Diving Behavior of Cuvier's Beaked Whales off Cape Hatteras, North Carolina."

3.2 Progress on RL modeling for animal exposure events

Extensive analyses and development by SEA, Duke, and NPS colleagues regarding the use of propagation models from known MFAS source locations to quantitatively predict which animals would have received exposures during CEEs at audible levels. The objective of this approach is to use a systematic and site-specific means of evaluating exposure in order to determine which tagged animals should be included within the more complex RL exposure and all response analyses. This is an important decision because it will result in some animals at presumably great distances being excluded from subsequent analysis. We are trying to strike a balance between including animals at intermediate to longer ranges (tens to approximately 100 kilometers) that may have been exposed while not expending effort to run extensive modeling effort for animals that could not hear the source and who's inclusion could introduce type-I error. Based on extensive discussions and modeling has been conducted to come to some agreement upon the approach that will be applied.

Based on known locations of the USS NITZE (3 June 18) and USS RAMAGE (13 June 18), NPS modeled the radiated noise field in 360-deg radials at 10m depth bins. The plots below show these noise fields at a discrete depth (0-10m) for each (NITZE top; RAMAGE below) in terms of modeled RL (left) as well as in the 1/3rd-oct ambient noise level that would have to exist at each location in order to mask detection of the signal. These are essentially two ways of showing the same result, but the right plots demonstrate the RLs in relation to ambient noise and provide a means of predicting audibility based on some things we know or presume about cetacean hearing.

Figure 158. Modeled 360-deg sound fields from *USS NITZE* at end location of 3 June 18 CEE. The left panel shows modeled RLs (in dB re: 1μPa), while the right panel shows ambient noise levels within the 3.5 kHz 1/3-oct band that would be required to mask detection of the signal.

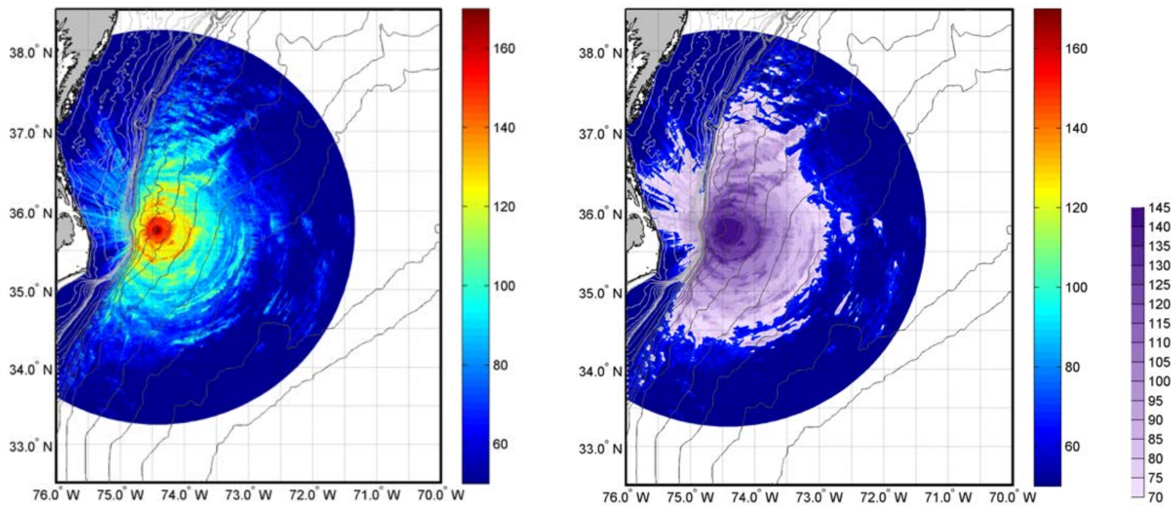
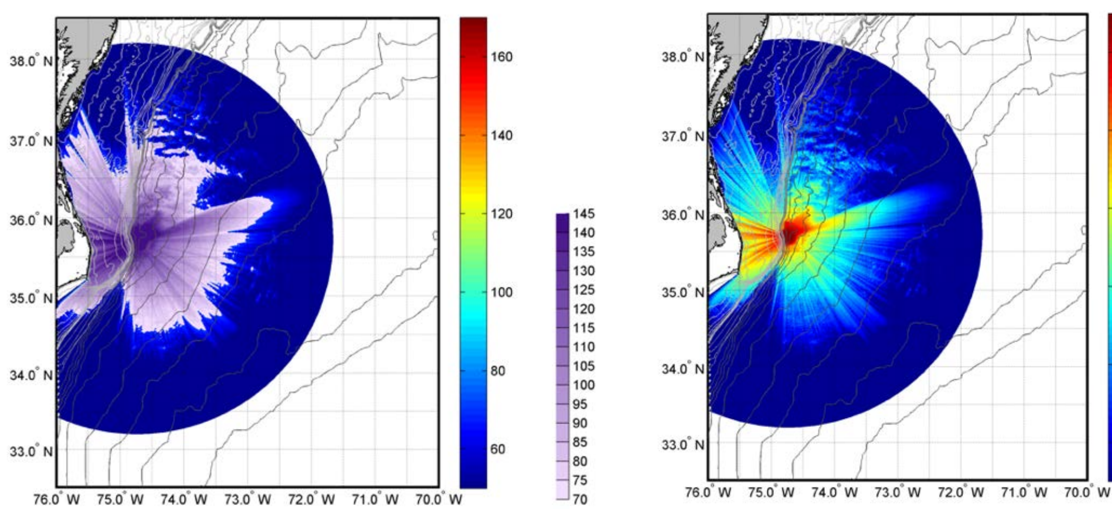


Figure 159. Modeled 360-deg sound fields from *USS RAMAGE* at end location of 13 June 18 CEE. The left panel shows modeled RLs (in dB re: 1μPa), while the right panel shows ambient noise levels within the 3.5 kHz 1/3-oct band that would be required to mask detection of the signal.



Following discussion of the model results, we developed a basic approach (with some underlying assumptions) in applying this in practice. This process is currently being conducted separately for each CEE, including controls assuming source level and location and assuming that the source was active – this will determine which individuals will be included in terms of analysis of the control responses. The process has the following steps:

(i) Calculate these noise footprints for each depth bin (10m resolution) at defined time intervals within CEEs (start, middle, end) based on known location of source at these times

(ii) Convolve RL footprints across all depths to give a maximum RL along any radial across all depths (note: this could be interpreted as overly conservative for pilot whales) – this provides an effective "footprint" of the exposure (at start, middle, end of CEE);

(iii) Determine the predicted 1/3rd-oct ambient noise level for 3.5 kHz center frequency band at that time (based on wind speed using predictive models – NPS is leading this and has been doing some empirical evaluation);

(iv) Define the region of the noise footprint where the 1/3-oct (RMS) MFAS level exceeds the 1/3rd-oct ambient noise level (SNR>0);

(v) For each individual, take 100 imputed track points at these defined times from movement modeling and overlay them onto noise footprint where SNR>0.

(vi) For individuals where more than 5 of these 100 locations fall within this defined footprint, the more complex and time consuming individual-based RL modeling and subsequent response analysis will be conducted. Whales with five or fewer points within this footprint will not be evaluated further for this exposure.

3.3 CEE response analyses

3.3.1 Behavioral analyses – baseline and diving response behavior

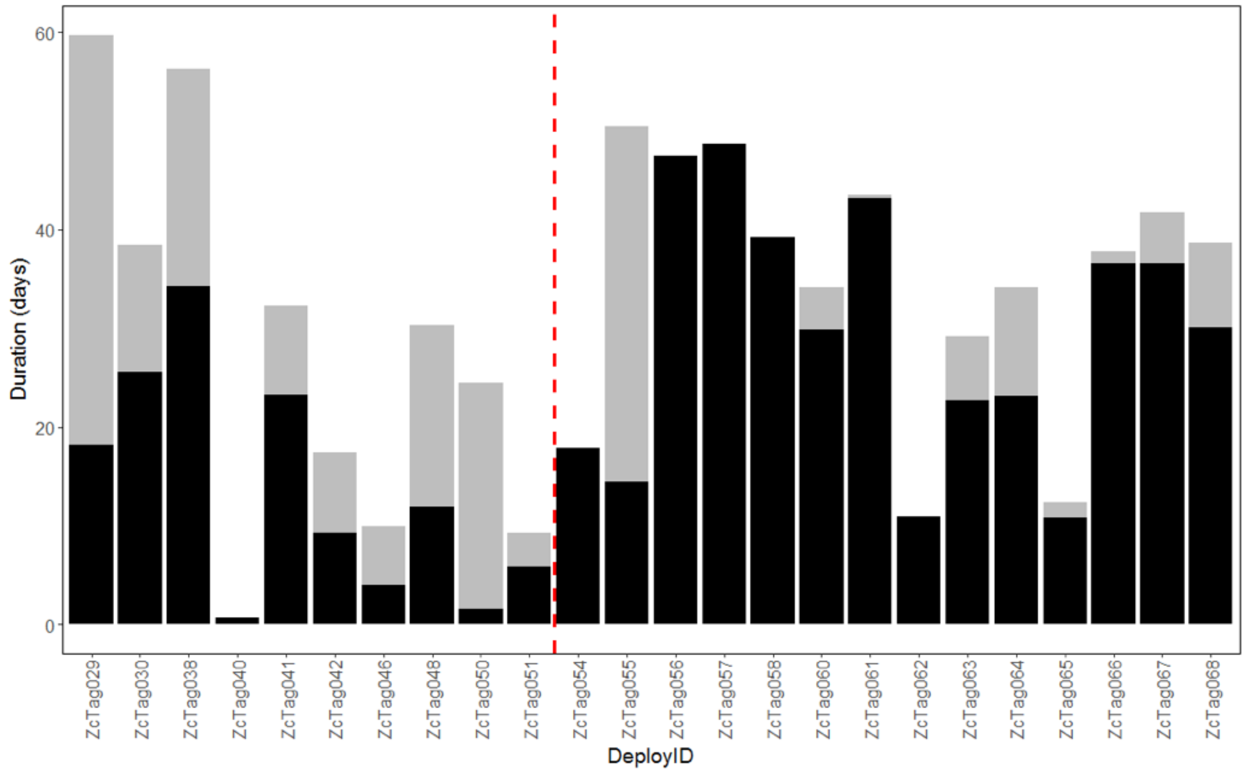
Changes in diving behavior are considered an important effect in behavioral response studies of deep-diving beaked whales due to the possibility of reduced foraging success as a consequence of exposure. During the Atlantic-BRS, one aim was to collect complete time series data consisting of entire bouts of foraging behavior. For beaked whales one deep, long-duration dive is considered a sampling unit of foraging. If these time series contain temporal gaps that span periods greater than the duration of the behavioral state in question, in this case an individual dive, accurate analysis of any response and subsequent biological interpretation of behavioral state transitions will be problematic. Similarly, accurate analysis of patterns in baseline data are needed for extended time series to account for assessment of effect. Our initial objective was to collect behavioral data from Cuvier's beaked whales to provide a continuous time series dataset of presumed foraging behavior over a period of weeks. To do this, we conducted an analysis using a Multiple Criteria Decision Making framework and data from satellite tag deployments that took place prior to the BRS effort in 2014–2016 (see Shearer et al., 2019 for details). We used the results from this analysis to determine the setting protocol for tags used during the Atlantic-BRS (Quick et al. in review). This setting protocol consisted of employing a highly constrained sampling regime, targeting dives of greater than 33 minutes in duration. Results from this approach yielded richer data on longer duration dives from all fourteen tags deployed in 2017.

Transmission duration for diving data for the 2017 BRS tags ranged from 10.9 to 50.4 days with a median of 34.7 days (**Table 17**). The number of gaps in the diving record ranged from zero to 17, with an average gap duration across all tags of 5.3 days, +/- 9.5 days (**Table 17**). This was a significant reduction in gaps compared to the pre BRS tags that had a mean gap duration across all tags of 14.4 days, +/- 12.3 days. The percentage of the total tag duration consisting of gaps ranged from zero to 71.3 percent with an average of 13.5 percent, +/- 19.7 percent (**Table 17**). This again was a significant reduction in gaps compared to the pre BRS tags that had a mean of 46.7 percent, +/- 25.7 percent. Five tags contained complete continuous diving records with no gaps at all and ranged from 10.9 to 48.7 days (**Table 17**). As well as successfully reducing gaps in the data we also succeeded in significantly increasing the amount of data on deep dives. The number of deep dives per tag ranged from 88 to 524 with a mean of 291.6, +/- 123.3 for the 2017 BRS tags compared to 142, +/- 112.1 for 2014-2016. The longest duration of continuous foraging data was 9.8 days (mean 2.2 days +/- 2.8 days) for the 2014–2016 tags with the number of foraging dives available for analysis ranging from 2 to 98, median 13.5. In 2017 the longest duration of continuous foraging data available for time-series analysis was 48.7 days (mean 19.4 days +/- 16.3 days), with the number of foraging dives available for analysis ranging from 41 to 524, median 118 (**Table 17, Figure 160**).

Table 17. Summary of satellite tag deployments from 2017

Deploy ID	First message date (time)	Last message date (time)	Transmission duration (days)	Number of gaps	Duration of gaps (days)	Percentage of total tag duration as gaps	Total foraging dives	Longest duration time-series in days (No. foraging dives)
ZcTag054	10-May-17 (16:17:00)	28-May-17 (14:23:00)	17.9	0	0	0	193	17.9 (193)
ZcTag055	10-May-17 (16:37:00)	30-Jun-17 (03:15:26)	50.4	16	35.9	71.3	161	6.3 (64)
ZcTag056	10-May-17 (18:59:00)	27-Jun-17 (07:35:10)	47.5	0	0	0	524	47.5 (524)
ZcTag057	16-May-17 (17:50:00)	04-Jul-17 (11:37:18)	48.7	0	0	0	303	48.7 (303)
ZcTag058	16-May-17 (19:48:00)	25-Jun-17 (01:42:36)	39.2	0	0	0	352	39.2 (352)
ZcTag060	17-Aug-17 (17:20:00)	20-Sep-17 (20:37:44)	34.1	7	4.2	12.3	278	9.7 (81)
ZcTag061	17-Aug-17 (18:08:00)	30-Sep-17 (05:01:16)	43.5	1	0.3	0.8	450	37.6 (386)
ZcTag062	17-Aug-17 (21:31:00)	28-Aug-17 (06:12:20)	10.9	0	0	0	88	10.9 (88)
ZcTag063	20-Aug-17 (16:54:00)	18-Sep-17 (21:39:44)	29.2	9	6.5	22.2	227	5 (41)
ZcTag064	20-Aug-17 (17:42:00)	23-Sep-17 (21:28:52)	34.2	17	11.1	32.6	238	9.4 (97)
ZcTag065	22-Aug-17 (17:09:00)	4-Sep-17 (03:09:48)	12.4	5	1.6	13	154	5.9 (82)
ZcTag066	04-Sep-17 (14:50:00)	12-Oct-17 (09:13:00)	37.8	3	1.2	3.1	393	16.9 (172)
ZcTag067	04-Sep-17 (14:53:00)	16-Oct-17 (08:39:48)	41.7	8	5.1	12.2	379	10.4 (122)
ZcTag068	04-Sep-17 (16:16:00)	13-Oct-17 (09:02:56)	38.7	17	8.6	22.1	343	6 (113)

Figure 160. Duration of gaps (grey bars) and data (black bars) expressed as the number of days for the total duration of each tag. Tags to the left of the red dashed line are baseline tags from 2014-2016. Tags to the right of the dashed line are 2017 tags with the updated settings.



Tag Errors

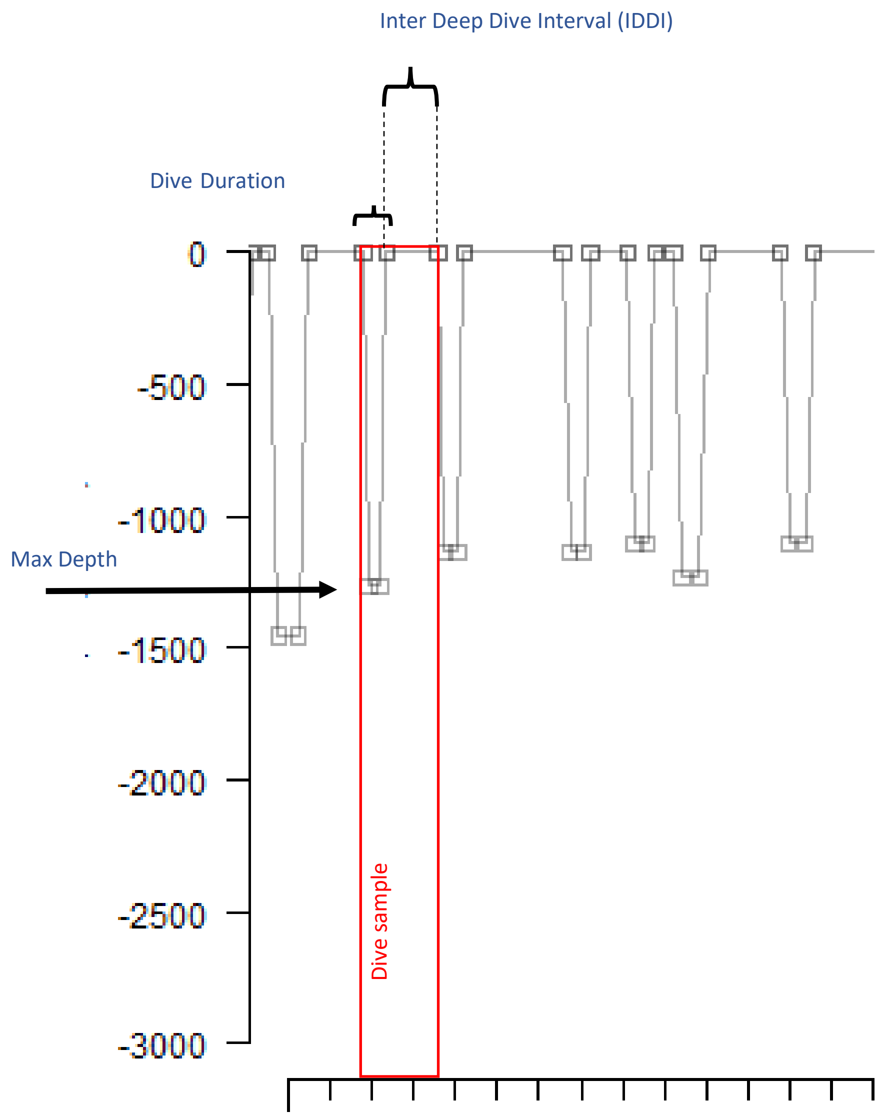
Tag records were systematically checked for errors that indicated failure or drift in any of the tag sensors. This included reviewing all tag status messages to assess information about battery voltage, the conductivity sensor, and the pressure sensor's depth offset at the surface, as well as identifying any biologically implausible records or messages with time overlaps. In total three tags had pressure sensor failures (**Table 18**) and data records were truncated to the last good depth sensor reading. This resulted in considerable loss of data for these three tags (**Table 18**). For the other eleven tags, data records were truncated back to the last good status message, which resulted in negligible data losses.

Table 18. Percentage of dives available for analysis after data truncation

DeployID	Cut off at dive	Percentage of dives available for analysis	Truncation Reason
ZcTag054	191	99	Last good status message
ZcTag055	144	89.4	Last good status message
ZcTag056	524	100	Last good status message
ZcTag057	136	44.9	Pressure sensor failure
ZcTag058	337	95.7	Last good status message
ZcTag060	254	91.4	Last good status message
ZcTag061	448	99.6	Last good status message
ZcTag062	87	98.9	Last good status message
ZcTag063	215	94.7	Last good status message
ZcTag064	201	84.5	Last good status message
ZcTag065	154	100	Last good status message
ZcTag066	244	62.1	Pressure sensor failure
ZcTag067	3	0.8	Pressure sensor failure
ZcTag068	330	96.2	Last good status message

Pressure sensor failures affect the depth data on the tags, but as dive starts and ends were determined by the conductivity sensor (i.e., if the tag was wet or dry), dive durations and surface interval data could be used for temporal sections of the tag where depth data can't. For the response analysis, it was decided that using the most truncated data was most appropriate as the data sample for all response analysis was a dive sample (**Figure 161**). However, for baseline analysis different data sets were considered for each of the three variables of maximum depth, dive duration and surface interval.

Figure 161. Dive sample used for response analysis. Each dive sample includes a dive with a maximum depth and duration and the following inter-deep dive interval.



Response Analysis

We conducted an individual-based analysis using Mahalanobis distance (DeRuiter et al. 2013), comparing an individual's dive samples post-exposure with its own average baseline dive samples. We did not include an individual analysis of ZcTag065 and ZcTag067 because of insufficient data. For ZcTag065, this was because of the simulated MFAS exposure (#17-01) taking place during dive number two, leaving insufficient data for the baseline category. For ZcTag067, this was because of tag failure issues leaving only three dives in total for analysis. The individual approach allows us to assess whether specific exposure and post-exposure dives are unusual over given time periods. The first step involved scaling and normalizing the three data streams: depth, duration and surface interval. We then carried out a k-means cluster analysis on all the baseline and pre-exposure dives, to determine if there was any evidence of the data containing different types of dives. We used silhouette analysis that showed there was little evidence for two clusters, so we proceeded without defining different clusters for the dives. This essentially means we treat all dives as belonging to the same dive type, which is not an unreasonable assumption considering the rigid sampling regimes we used of only recording dives over 33 min. We identified the exposure dive cycle using time stamps and labelled the exposure dive as during. Therefore, there are three exposure levels – baseline, during and post exposure. To ensure reasonable estimates of the variance-covariance matrix we included all of the data (including tags Zc065 and Zc067) from the August-September 2017 tags minus the 24-hour period post the scaled exposure and the 24-hour period post the real ship exposure. The same variance-covariance matrix was used for all analyses—i.e., each individual comparison with its own baseline.

We ran individual analysis for both CEEs in 2017 (#17-01: simulated MFAS; 17-02: operational MFAS from *USS MACFAUL*). We then fitted a GLM (or GEE if evidence of autocorrelation) to the distance values with exposure status (baseline, during/post), dive shape, bathymetry, distance to canyons, distance to shelf and time since exposure as explanatory variables. As each individual only had one or two dives during the exposure event, during couldn't be treated as a separate category in the exposure status variable when analyzing each individual separately. This may be done in further analysis where we combine all MDist values across individuals and analyze all individuals together. Combining all the data may allow us to detect more subtle responses because more data should provide more power. However, the MDist values will first need to be standardized. For the simulated MFAS exposure, baseline dives were defined as all dives before the exposure event for an individual. We then compared all baseline dives, the exposure dive and 24 hours of post-exposure dives with the average baseline dive for that individual. Three out of five whales exposed to simulated MFAS during CEE #2017-01 showed a significant difference in the Mahalanobis distances across the during and 24 hours post exposure compared to before exposure (**Figure 162, Table 19**).

Figure 162. Mahalanobis distance plots for the beaked whale exposures during CEE# 2017-01 (simulated MFAS). Black lines show dive samples prior to exposure. Blue lines show dive samples during the exposure and for the following 24 hours.

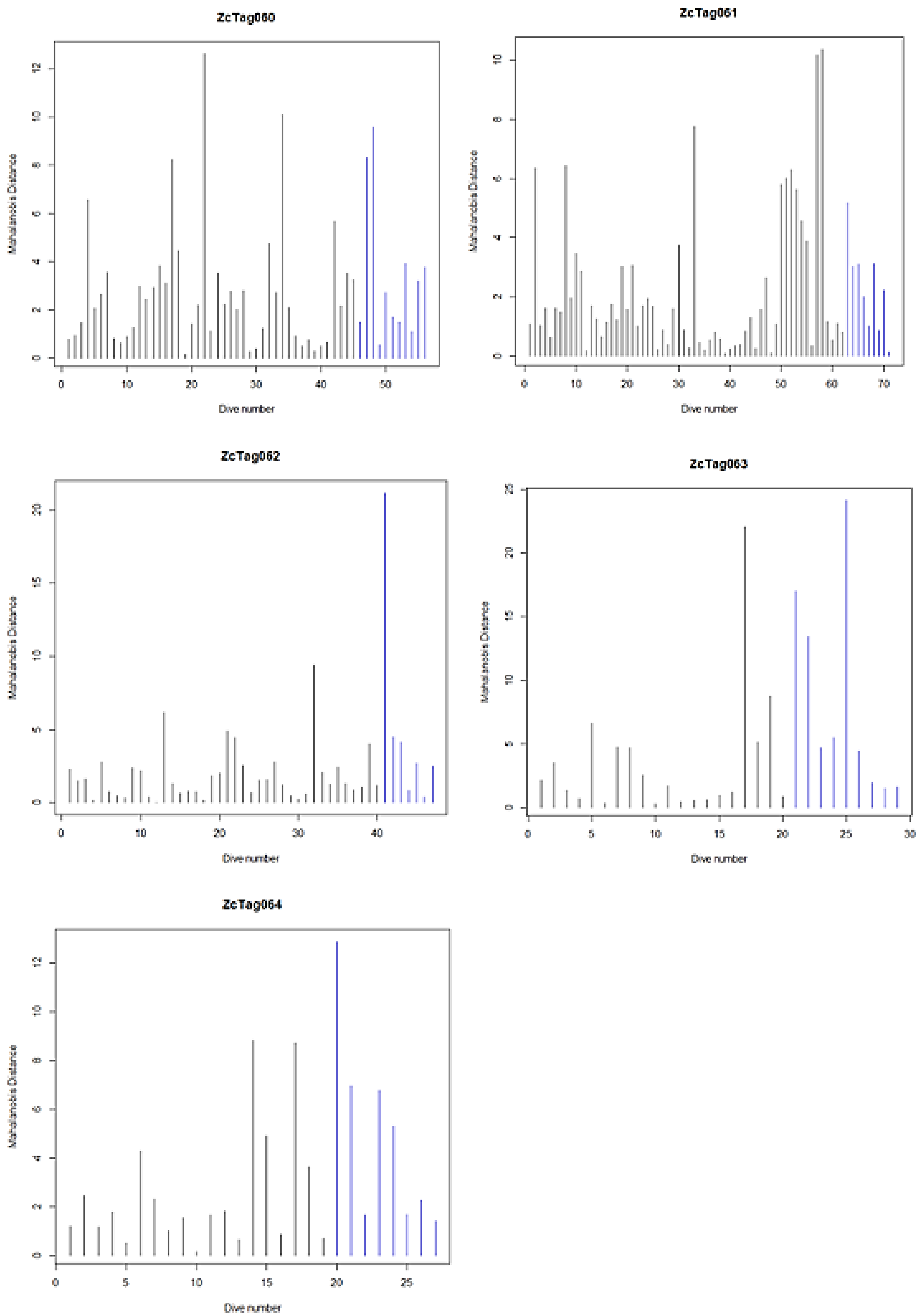
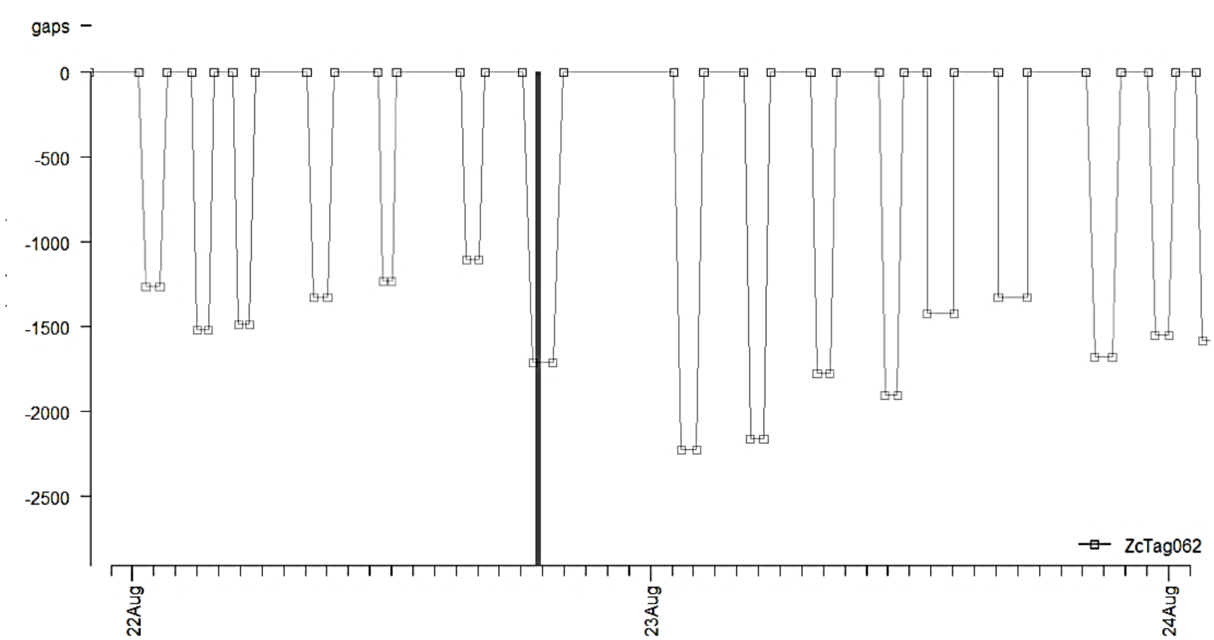


Table 19. Results from regression analysis fitted to Mahalanobis distances for CEE# 2017-01 (simulated MFAS).

Tag	Significant variables	Notes
Zc_060	None	
Zc_061	Dive shape	U-shaped dives had lower MDist values than other dive shapes
Zc_062	Exposure status Time since exposure	MDist was higher during/after exposure compared with before exposure MDist values decreased as time since exposure increased
Zc_063	Exposure status Time since exposure Bathymetry Distance to shelf	MDist was higher during/after compared with before exposure While time since exposure contributed significantly to model fit, the relationship between MDist and time was not significant. Negative relationship with bathymetry Negative relationship with distance to shelf.
Zc_064	Exposure status Distance to canyons Time since exposure	MDist was higher during/after compared with before exposure Positive relationship with distance to canyons. While time since exposure contributed significantly to model fit, the relationship between MDist and time was marginally non significant.

Animals ZcTag062, ZcTag063 and ZcTag064 all showed increases in Mahalanobis distance after the exposure event. For ZcTag 062, the MDist spike occurred on dive 41 which contained the exposure event (**Figure 163**). This dive was unusually long and was followed by an unusually long inter-deep dive interval.

Figure 163. Zoomed in section to dive profile of ZcTag062. Grey vertical line indicates exposure during CEE #17-01 (simulated MFAS).



For the 2017 operational MFAS CEE (#17-02; *USS MACFAUL*), exposure baseline dives were defined as all dives before the exposure event for an individual, excluding all instances of simulated MFAS exposure in CEE #17-01. For individuals that had been previously exposed to the simulated MFAS source, data from a 24-hour period, starting with the exposure were removed from the baseline behavioral analysis. We then compared all baseline dives, the exposure dive and 24 hours of post-exposure dives with the average baseline dive for that individual. One of the six whales exposed to the *USS MACFAUL* showed a significant difference in the Mahalanobis distances within the exposure and 24-hour post exposure periods compared to before exposure as well as a significant difference in time since exposure (**Table 20**, **Figure 164**). Three of the six whales did not show a difference with exposure status but did show significance in Mahalanobis distance with time since exposure. For whales ZcTag064 and ZcTag066, there are not any dives particularly unusual right after the exposure event compared with baseline (**Figure 164**). For whale ZcTag068, there is some indication that dive 81 was unusual because it was followed by a longer than normal inter deep dive interval, (**Figure 164**) and then Mahalanobis distance decreased again as time since exposure increased (**Figure 164**). There appears to be no significant difference with exposure status due to the high distance values in the baseline.

Table 20. Results from Regression analysis fitted to Mahalanobis distances for the 2017 operational MFAS CEE (#17-02).

Tag	Significant variables	Notes
Zc_060	Shape	U-shaped and V-shaped dives had lower MDist values than square dives
Zc_061	Exposure status Time since exposure	MDist was higher during/after exposure compared with before exposure MDist values decreased as time since exposure increased
Zc_063	Bathymetry Distance to shelf	Negative relationship with bathymetry Negative relationship with distance to shelf (perhaps more “unusual dives” in one habitat compared to another?)
Zc_064	Time since exposure Distance to shelf	MDist values decreased as time since exposure increased. Positive relationship with distance to shelf
Zc_066	Time since exposure	MDist values decreased as time since exposure increased.
Zc_068	Time since exposure	MDist values decreased as time since exposure increased

Figure 164. Mahalanobis distance analysis for six beaked whales during 2017 operational MFAS CEE (#17-02). Black lines show dive samples prior to exposure. Red lines show dive samples during the exposure and for the following 24 hours.

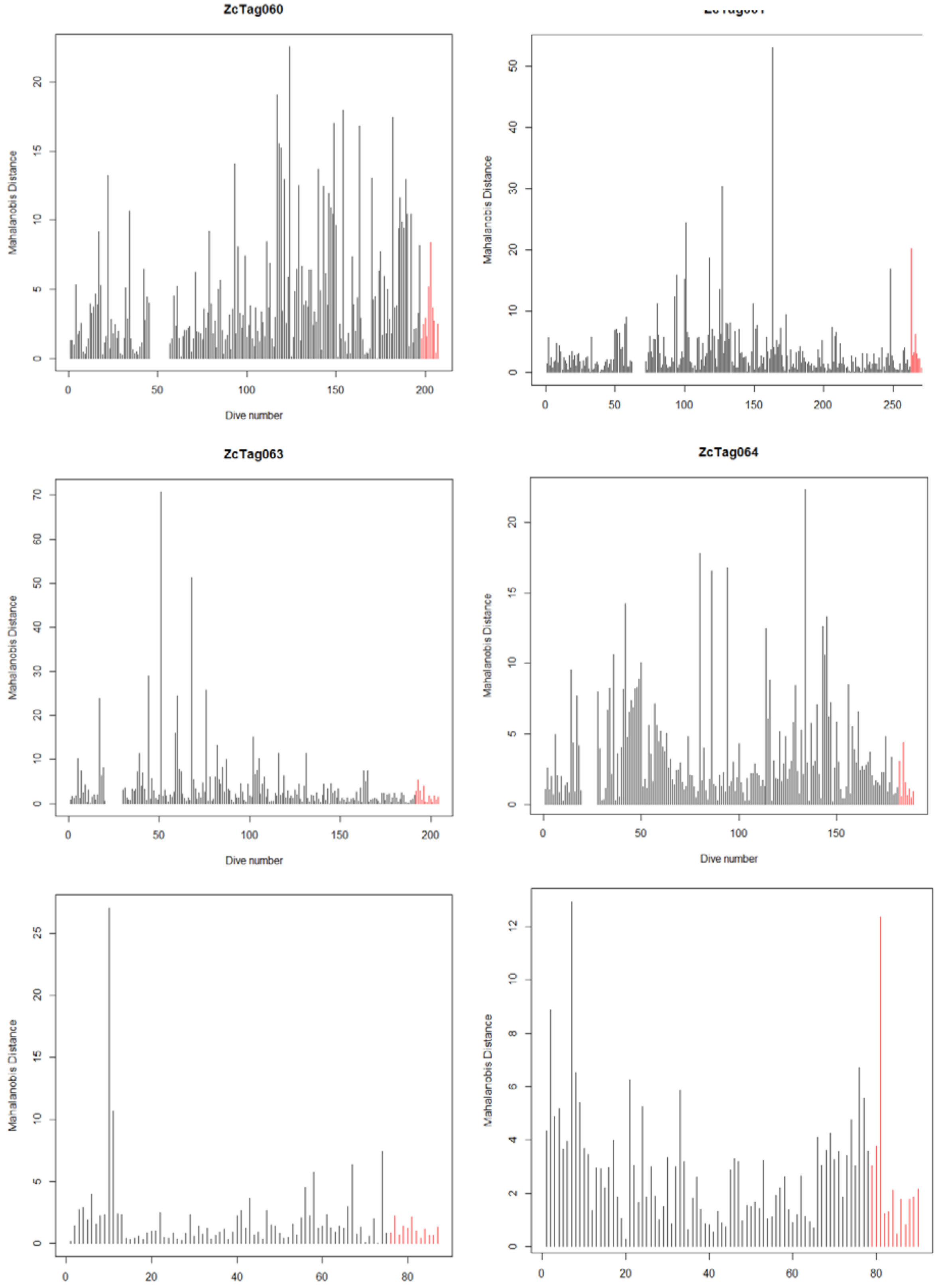
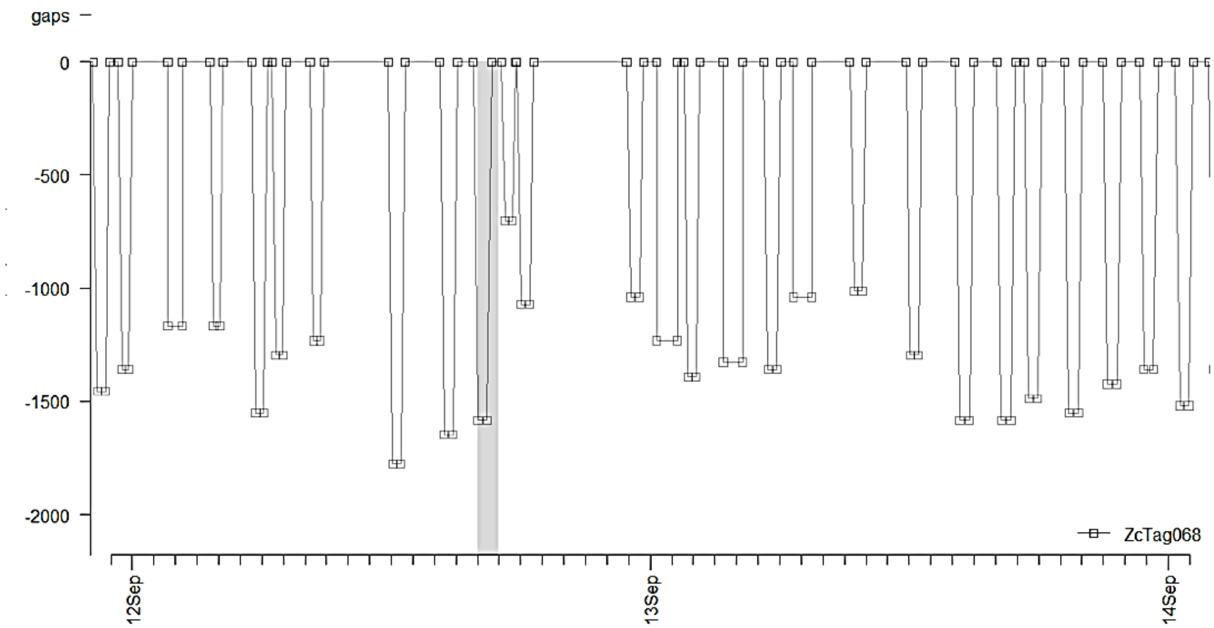


Figure 165. Zoomed in section to dive profile of ZcTag068. Grey vertical line indicates exposure during 2017 operational MFAS CEE (#17-02).



Baseline Analysis

It was clear from the exposure analysis that considerable variation existed in the baseline data (**Figure 166, 167**). This included some clear cyclical behavioral patterns showing up within and between animals in the absence of sonar exposure that complicated the assessment of behavioral response.

Parameter data from all baseline data from all tags (exposed and non-exposed) were considered as non-normal response variables and modelled within generalized linear models, with DeployID as the predictor. The parameter data were continuous, positive and skewed, so a gamma family and inverse link were used. The generalized linear models showed individual tag identifier to be a significant factor between some tags for all three of the parameters of interest. This shows that individual variation is an important factor to consider during analysis.

Figure 166. Boxplots of dive depth (top panel), dive duration (middle panel) and inter-deep dive interval (bottom panel) for baseline Ziphius deployments from 2016–2017 deployments

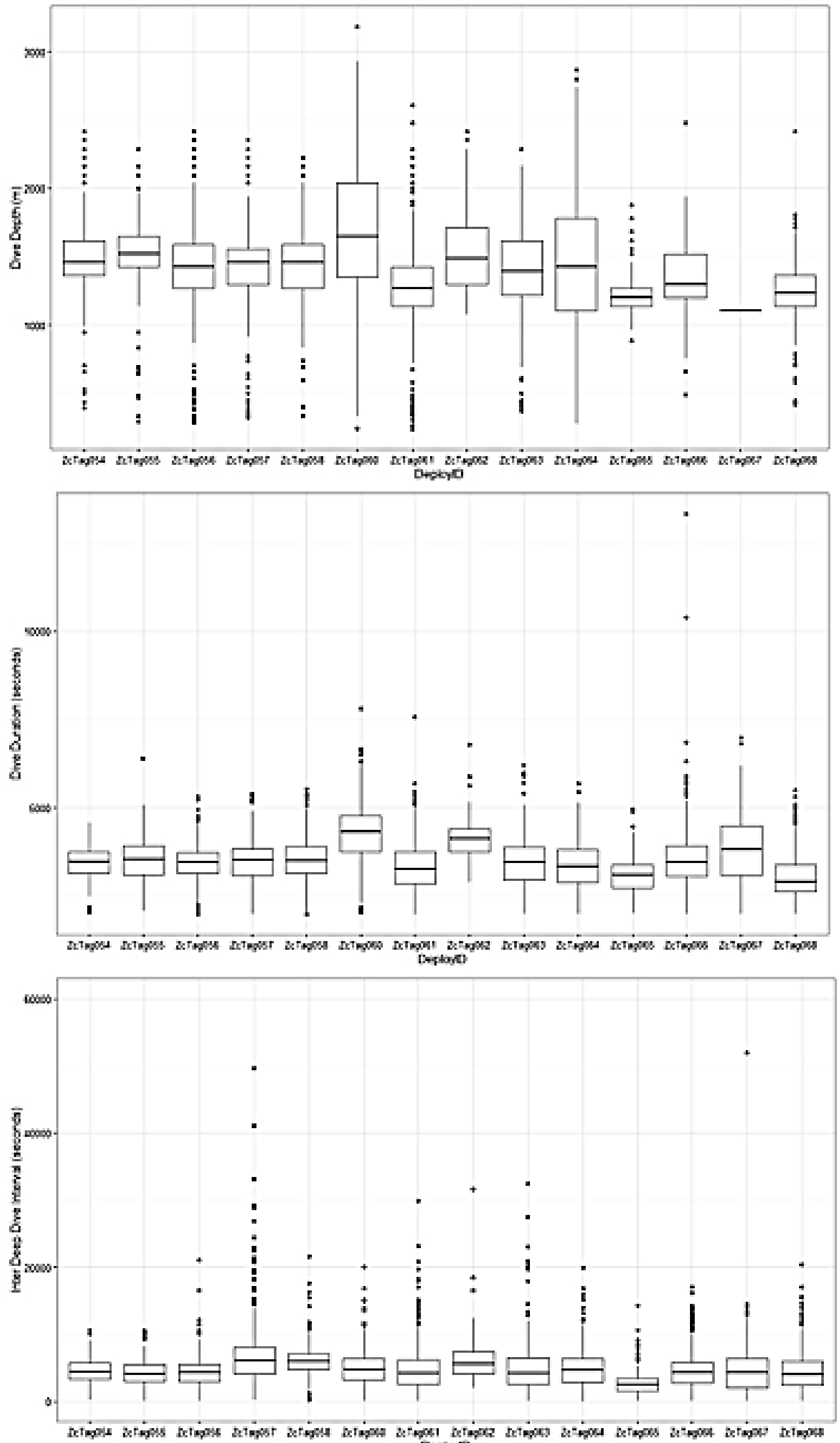
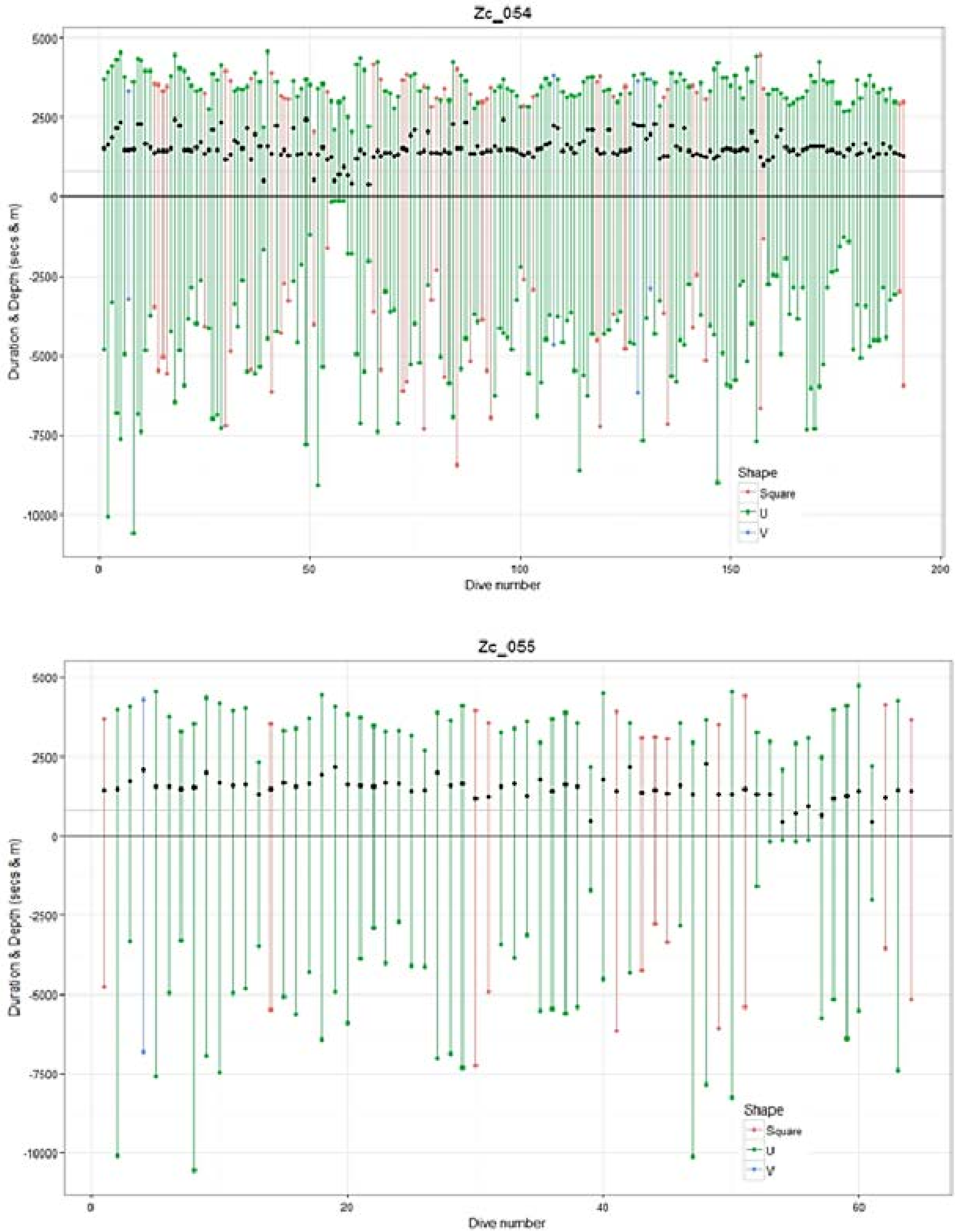


Figure 167. Plots of continuous dive samples for two baseline tags, showing cyclic nature of variables. Each line shows dive duration above the x-axis with following inter deep dive interval below the x-axis. Black dots show dive depth. Lines colored by shape.

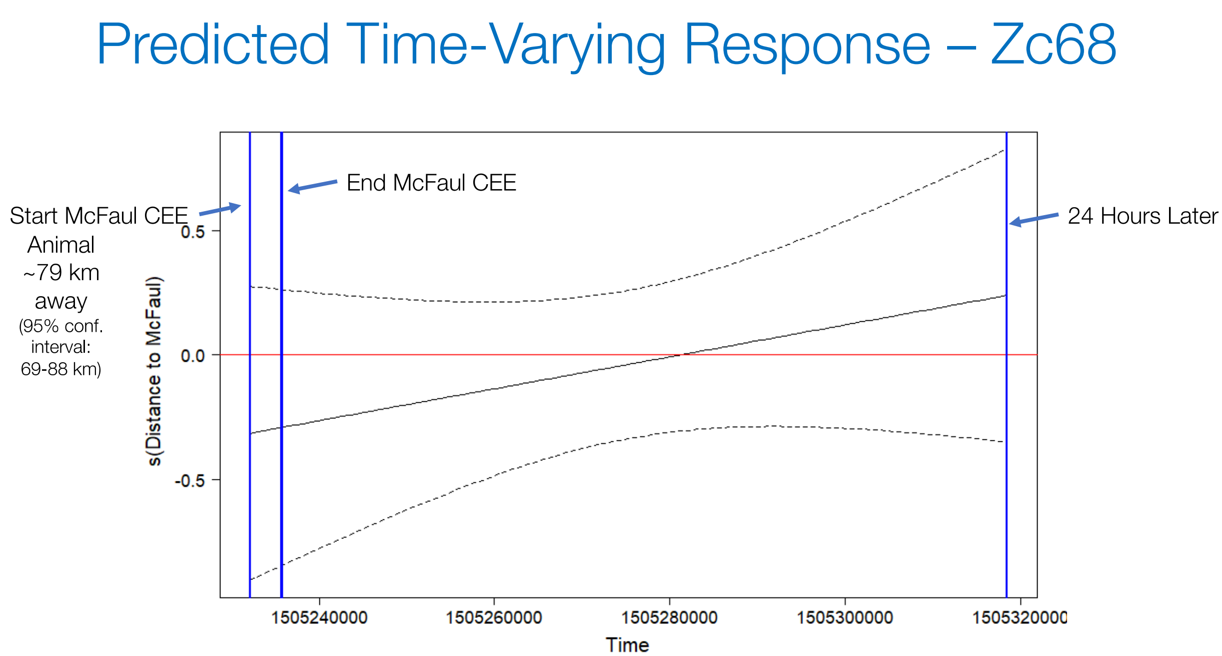


3.3.2 Avoidance analysis

At our recent analysis meeting (November in Durham, North Carolina), we reviewed the overall approach to the use of DF ARGOS locations, error ellipses, and track imputations using these data to characterize locations and incorporate positional error. This approach has been incorporated into a paper R. Schick (Duke) is leading on movement modeling and associated RL modeling that will soon be submitted to Aquatic Mammals in the special ESOMM issue. We agreed that this was a major step forward and a more robust way of characterizing positional error within the context of RL estimates. This analysis demonstrating the variance relative to the measured RLs from DTAGs within the simulated MFAS (CEE# 17-01) is particularly useful in establishing this method for subsequent analyses. The overall process of the movement modeling or the RL assessments for the 2018 data set have not been altered from the approach used in 2017 and presented to the Navy at the 2018 fleet monitoring meeting in San Diego. However, a major part of the discussion was how to use these processes to decide which individuals would ultimately be evaluated (see below).

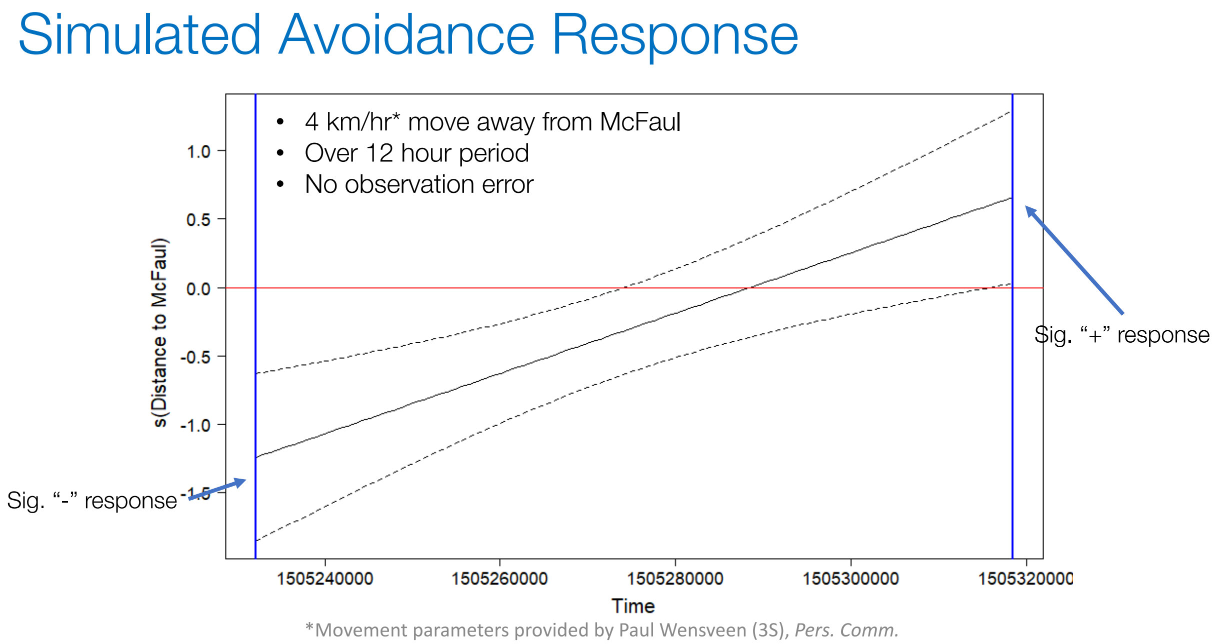
The Hanks et al. (2015) model for horizontal avoidance analysis method was applied to the 2017 beaked whales for the real MFAS (MACFAUL) CEEs and were also presented at the 2018 fleet monitoring meeting. An example of these avoidance responses is given below where the time-varying response based on the animals previous utilization of space over time is calculated. In this example (for Zc68 which was the focal whale in CEE# 17-02), the animals range to the vessel was no different from the MACFAUL that would have been expected based on how it had been utilizing the spatial environment prior to the CEE.

Figure 168. Example of predicted time-varying response analysis of potential avoidance response for Zc68 during CEE# 17-02.



Similar results were obtained with all of the other beaked whales except one (Zc66) at a relatively distant range from the CEE. This method was also evaluated based on a simulation of movement using the 3S team data of responses of bottlenose whales in Jan Mayan. This was done as an assessment of the sensitivity of this method for an instance where a clear avoidance was believed to occur; a response was clearly detected in this simulation.

Figure 169. Example of predicted time-varying response analysis of potential avoidance response for a simulated whale during CEE# 17-02.



While few avoidance responses were detected from 2017, this method is being used with the same calculations/method for all 2018 CEEs.

3.3.3 Social behavior analyses

While progress in this area has been limited thus far given the data collected, we recognize this as one of the three aspects of behavior we intend on analyzing and we discussed this in depth at our recent analysis meeting discussing what we might do and more importantly what additional data we may need to be able to do so.

The DTAG and associated focal follow data provide insight in terms of changes in group heading/spacing and/or group call rate on fine scales. This is likely more applicable to pilot whales than beaked whales. However, at present this is limited to just two simulated MFAS CEEs (none of three real ships had DTAGs). There is promise for some more insight on ongoing work on social behavior and synchrony in beaked whales with the satellite tags, especially with the series data settings. The recent paper submitted by Cioffi et al using data from deployments during the Atlantic-BRS and our growing experience in tagging and tracking multiple individuals within a group and documenting social interactions by resighting tagged animals multiple times provides a very important foundation for evaluating potential social responses in subsequent CEEs. Additional data are also needed for this as well, with a strong priority for tagging multiple individuals within groups using higher-resolution tag settings for more CEEs.

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4. Overall Assessment and Recommendations for 2019 Effort

4.1 General Assessment of Atlantic-BRS 2018 Accomplishments

- We were extremely successful in deploying satellite tags (31 of 33 available). This was especially true for Cuvier's beaked whales in which 13 satellite-linked tags of multiple types and a variety of settings were deployed, including 11 within a three-day period offering an unprecedented opportunity for CEEs with many beaked whales within the same social groups in the same area.

- Advance deployments of satellite tags and strategic tagging periods within CEE efforts provided multiple CEE opportunities for both species.

- We had reasonable success deploying DTAGs on pilot whales (nine deployments, five of which involved in CEEs), but because of tag malfunctions, two tags with simulated MFAS CEE data on them were lost and never recovered. No DTAGs were deployed on beaked whales in 2018.

- Opportunities to coordinate with Navy ships during spring alone exceeded all of 2017 (two of four possible weeks), but ships were unavailable during the summer period when most beaked whales were tagged simultaneously.

- A total of eight CEEs were conducted during the 2018 field season, a substantial improvement over the two conducted in the first field effort in 2017. This included two real Navy MFAS CEEs (vice one in 2017), four simulated MFAS CEEs (vice one in 2017), and two silent control sequences (vice none in 2017).

- Over the entire field period, a total of 85 unique CEE events with tagged whales being monitored occurred in 2018 (vice 21 in 2017) for nine individual beaked whales and 12 pilot whales. This resulted in an extremely large dataset with data processing taking many months and the need to prioritize data analysis to the most strategically important and relevant data.

- We continued to improve methods of receiving and utilizing signals from satellite tags using the ARGOS goniometer. This system allowed us to track and relocate tagged individuals many times to obtain photos, biopsy samples, and locate other individuals for tagging attempts. While it was a short deployment, we accomplished a major objective of deploying a DTAG on an individual pilot whales that was simultaneously being monitored with a satellite tag.

- Satellite tag settings we employed continued to prove very effective in reducing gaps in behavioral data. Further, we increasingly employed programming strategies that provided greatly enhanced resolution in dive data during specified periods. There are trade-offs in these decisions, however, including the fact that these approaches result in a limited period in which dive data are received. This was strategically determined based on Navy ship availability, which was effective in several conditions and not so in others.

- The limited number of surface positions and the large errors associated with these estimates generated by ARGOS, complicates our analysis of horizontal avoidance during CEEs and modeling of RLs. The latter is especially complex off the coast of Cape Hatteras, where even modest positional errors relative to the shelf break can have major consequences for modeled RLs.

- We have conducted an extensive analysis effort to address our research questions, including a robust geospatial modeling approach to evaluate horizontal movements and to model RLs. These are currently being applied to the 2018 data and described within an upcoming publication that has been accepted and is currently in final revision.

- Our analyses of horizontal avoidance, disruption of foraging behavior, and modification of social interactions are ongoing. As expected for pilot whales, but somewhat surprisingly for beaked whales, there is a high degree of inter-individual variability in baseline behavior that we've continued to see with the 2018 data.

- Within-individual change-point methods and time-space movement modeling approaches have been used to evaluate individual responses for 2017 beaked whales. No or very limited responses were documented for either of the 2017 CEEs.

- Similar to results from 2017, none of the four simulated MFAS CEEs, nor the two real ship 53C CEEs, resulted in large-scale avoidance of the study area by either focal species. All individuals monitored continued to use these areas and display typical movement and diving behavior in the days and weeks following CEEs.

4.2 Recommendations for 2019

- We recommend that the research approach we employed in 2017 and 2018 be continued to increase sample sizes for CEEs for both species. Of greatest priority is to obtain additional operational Navy vessel CEEs in conditions like those during the summer 2018 period where many animals are tagged simultaneously in a small area.

- Cape Hatteras offers an excellent study site, with the potential to locate, tag, and track individuals of several species, including Cuvier's beaked whales, with an incredible 24 whales tagged in two years. Given that this species is of high priority to the Navy and the site offers a unique condition of being occasionally exposed to MFAS but not being in the heart of a training range like other areas in the Bahamas, California, and Hawaii (and thus subject to criticisms of the generalizability of the data by testing habituated animals), the study site should be maintained.

- Given our successes in 2017 and 2018, we should maintain beaked whales as a high priority species for tagging and CEEs, as conditions allow.

- As many weeks of Navy ship coordination should be scheduled as possible, given the expected attrition due to scheduling and maintenance issues.

- The basic vessel configuration, with shore-based RHIBs and a sound source/tracking platform should be maintained. A single charter vessel should be selected to reduce the need to stage and restage tracking equipment.

- The combination of satellite tags and DTAG deployments should be maintained, with additional effort to simultaneously deploy DTAGs within groups with satellite tagged individuals.
- We should consider additional small increases (approximately 5 dB) in target RL range for CEEs, guided by results from ongoing analyses.
- Extensive planning and coordination discussions among the team and in coordination with the Navy will continue to be required, given the complexity and magnitude of logistical planning, field effort, and many simultaneous ongoing analyses.

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