



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic

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Axiom Data Science LLC
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- Project Champion: Jon Berkson, Ph.D., USCG, CG-WWM
- Project Advocates: USCG (HQ, Pacific Area, District 17, RDC);
NOAA (OCS, AK Region, IOOS);
Steering Comm. member organizations
Arctic Waterways Safety Committee, Crowley Marine

Product Tanker Briefly Aground Off Alaska



File image courtesy Champion Tankers
By MarEx 2016-06-24 19:57:32

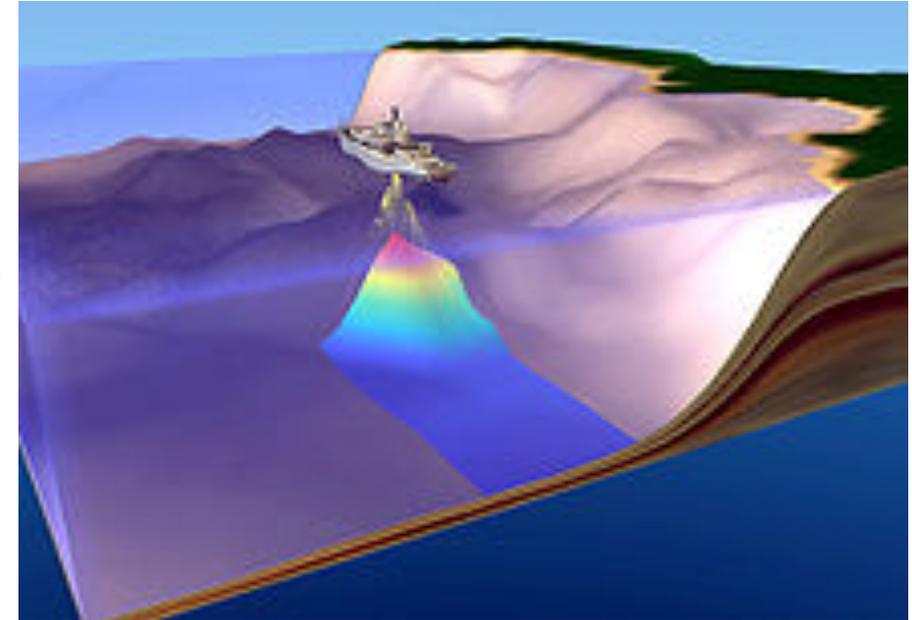
On Friday, the Coast Guard reported that the Norway-flagged chemical tanker *Champion Ebony* went aground near Nunivak Island, Alaska on the morning of June 24.

Coast Guard Sector Anchorage received a report from the National Response Center at 0924 hours that the *Ebony* ran aground carrying approximately 14 million gallons of various fuel products.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Description and Baseline

- Much of the Arctic region remains uncharted or has outdated bathymetry, sometimes dating back centuries.
- Despite major advances in hydrographic technology, conducting modern bathymetry surveys is challenging and expensive, especially in the Arctic.
 - The Beaufort and Chukchi seas are hundreds of miles from the nearest deep-water ports, and are ice-free for only short periods during summer, on the order of weeks.
 - An emergency in this region could be catastrophic.
 - Incident prevention by having more accurate charts is a priority.
- This project is using historical Automated Information System (AIS) tracking information from the Arctic to help prioritize where modern hydrographic surveys should be made.
 - The data will also be used to create products that inform decision-making about vessel traffic and safety.





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Description and Baseline

- The primary goal of this project is to develop summaries of AIS data that can be used directly in the NOAA OCS Hydrographic Health Model.
 - The model is used to prioritize areas for new or improved hydrographic surveys.
- The research effort will develop the capability to reduce execution time for computation, handling and analyzing exceptionally large collections of AIS data.
- Additional AIS data-derived data products will be developed and made publically available through a value-added, intuitive and user-driven web-based tool.
- **Baseline:** This proposal builds on previous NOAA OCS investments, including the Integrated Ocean Observing System (IOOS)-funded special project, NOAA OCS: AIS Big Data Project.
 - This new ADAC supported project will modify the proof-of-concept workflow from an NOAA OCS pilot effort to scale-up to the larger U.S. Arctic EEZ area and will deliver the AIS data in an application-ready format for prioritizing bathymetric surveys using the NOAA-OCS Hydrographic Health Model.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Motivation

Major seafloor features that could pose hazards to navigation are unaccounted for and several recent groundings off the coast of Western Alaska have been attributed to crews relying on inaccurate navigational charts. Existing bathymetric maps, if they exist, are decades or even centuries old and lack necessary detail.

Outdated Maps Could Have Caused The Champion Ebony To Run Aground

By Adrian Wagner • Jun 28, 2016



The Champion Ebony ran aground on a shoal 10 miles from shore on Friday. But that shoal was not on the map the crew was using, says a maritime executive familiar with the grounding.

Shell icebreaker Fennica struck uncharted reef, Coast Guard says

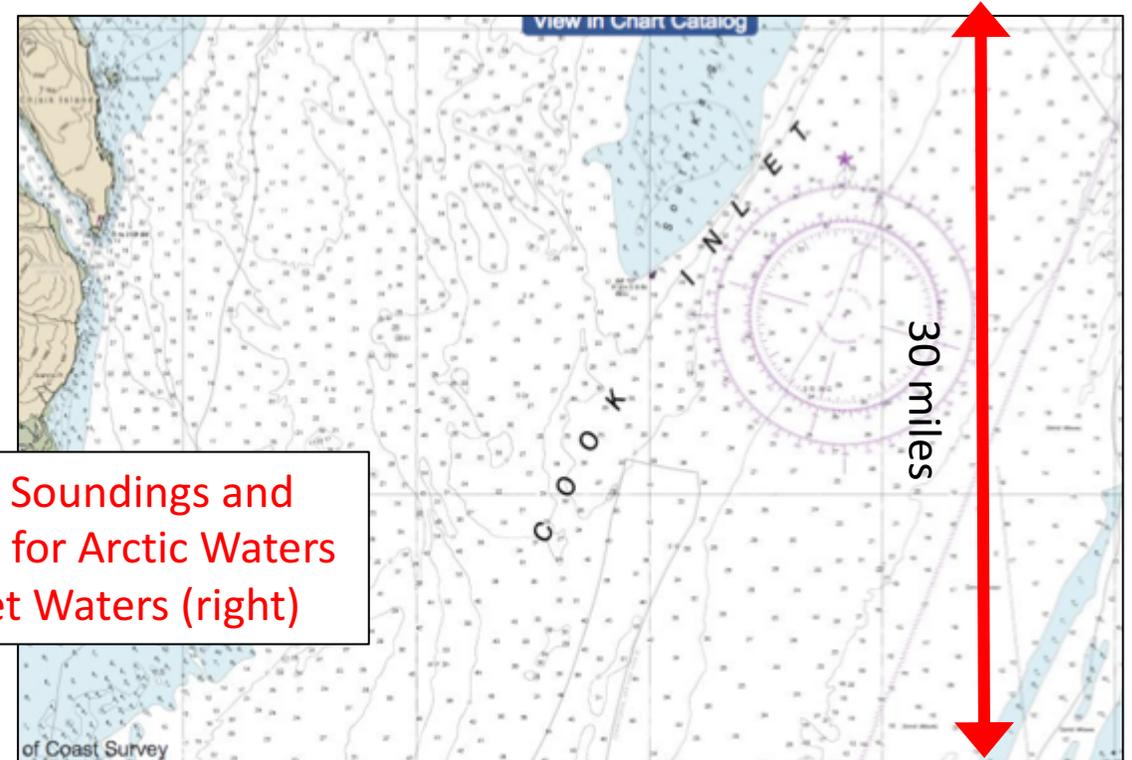
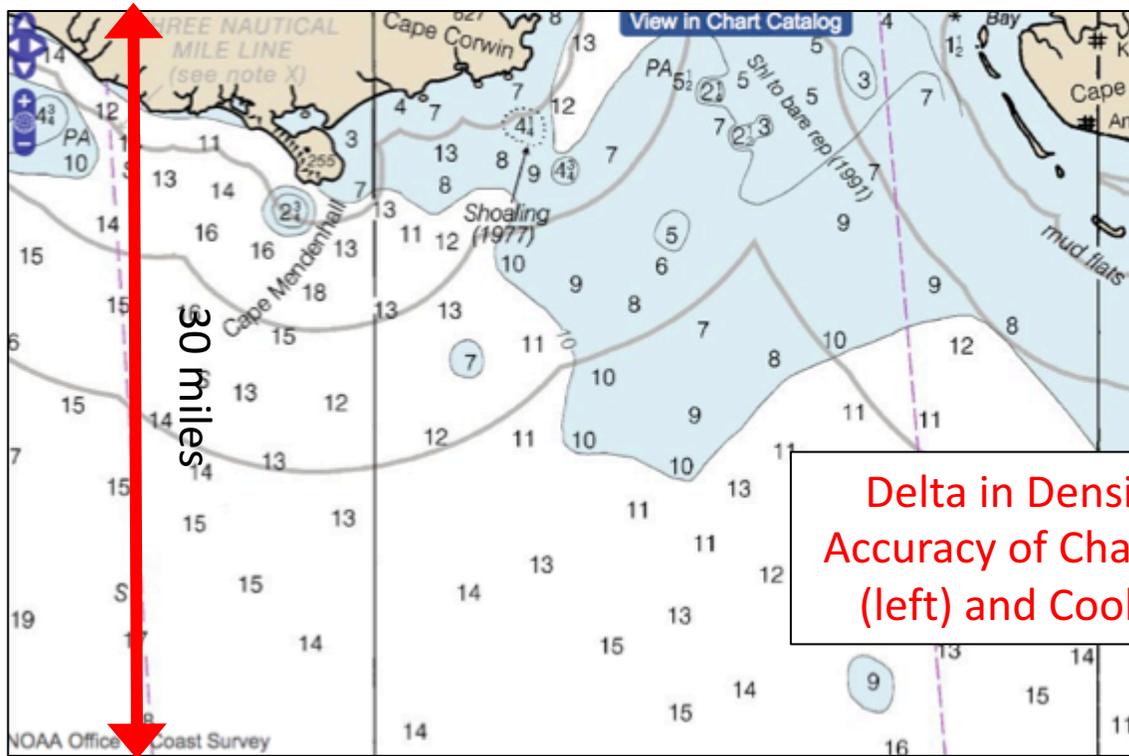


Nov 30, 2016 01:58 PM
by Casey Conley

At the time, navigation charts showed the shallowest point along *Fennica's* trackline was 31.5 feet. However, data used to create those charts was nearly 80 years old.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Motivation



Delta in Density of Soundings and Accuracy of Charting for Arctic Waters (left) and Cook Inlet Waters (right)





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Relevance to DHS and USCG

- The project responds to the Arctic Domain Awareness Center (ADAC) Arctic Ions workshop highlighted need to improve awareness and understanding of nearshore bathymetry across the Arctic, in particular the North American Arctic.
- The project addresses the need and supply of critical data related to vessel tracking and bathymetry for incorporation into the ADAC Arctic Information Fusion Center.
- The final data portal and tools will aid the U.S. DHS, the USCG and NOAA goals to promote safe transit and maritime operations in a changing environment by providing useable, customizable summaries of extremely large volume AIS vessel traffic data.
- The end products will provide useful tools to identify shipping patterns in regions with inadequate depth information, and will better inform the prioritization of areas in the U.S. Exclusive Economic Zone (EEZ) for modern bathymetric surveying.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Research Method

- The proposed research method utilizes a minimum of 5 years of vetted, quality reviewed and parsed historical MXAK AIS information as input into the NOAA OCS Hydrographic Health Model.
- Work entails processing and analyzing a very large dataset for which traditional database management tools are inadequate.
- The Project Team is developing the capability to significantly reduce execution time for handling and analyzing extremely large collections of AIS vessel tracking data.
 - Optimizing a high capacity, parallel compute workflow to solve current data volume processing challenges;
 - Streamlining workflow to delivers valuable summaries of vessel density patterns;
 - Reducing extensive quantities of data across multiple vessel types, environments, and locations.
- Data analysis products will be produced hundreds of times faster than with a traditional database, and will provide users the ability to run ad-hoc queries and apply decision-making for intermediate results.





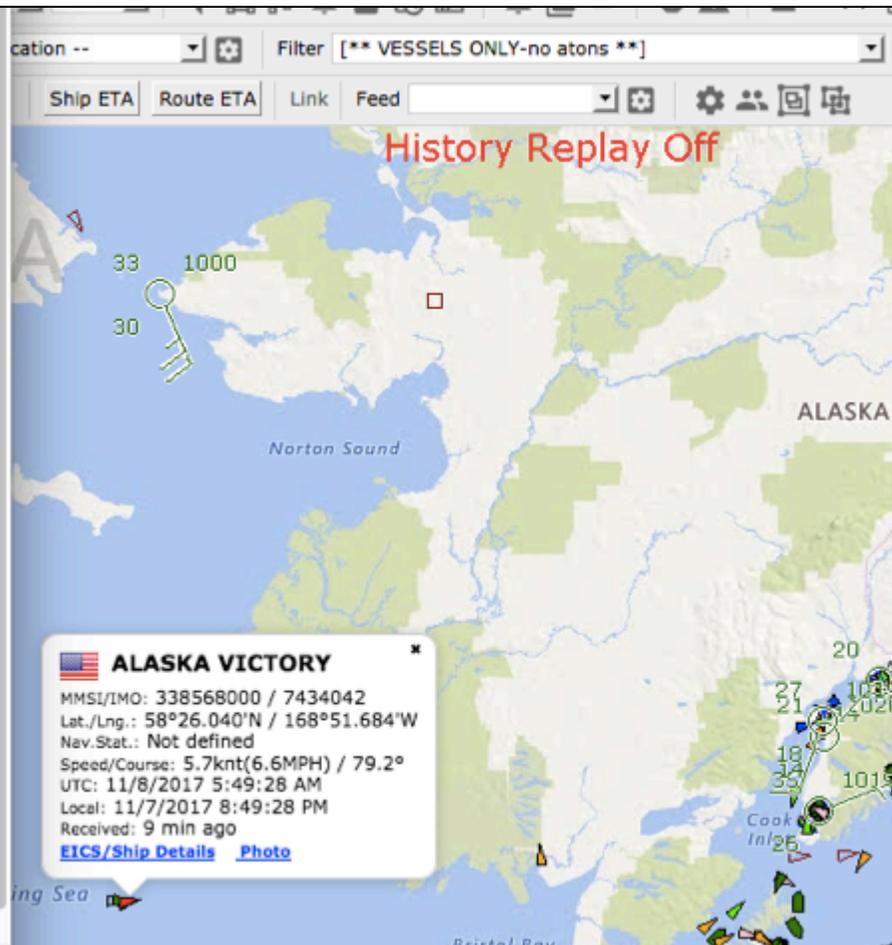
Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Prior Work

- NOAA has prioritized survey efforts in several isolated areas of Alaska, using the only historical AIS data available from the Marine Exchange of Alaska's (MXAK) terrestrial based vessel tracking network.
 - MXAK Network is comprised of over 100 AIS receivers, 48 of which are in the Arctic (2016).
 - Area of coverage in the last 5 years has increased 30%.
 - Earlier prioritization efforts were conducted for spatially limited regions, where data resources were both spatially and temporally tractable.
 - This projects up-scales the spatial as well as temporal capabilities for this kind of work.
- This project builds on previous NOAA OCS investments and leverages a current project funded by the National Science Foundation Gulf Research Program: *Synthesizing ship tracking data, oil spill model results, and subsistence use information into a unique, interactive tool to aid research and planning in coastal communities bordering the Alaska Beaufort Sea.*
 - Benefits of developing the pilot cloud-based cluster workflow are its portability and scalability to larger datasets on larger compute clusters and its adaptability to summarization and analysis of other high-volume datasets.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Current Efforts - Issues With Raw Data

Name	ALASKA VICTORY
MMSI	338568000
IMO	7434042
Call Sign	WBC9661
Type/Cargo	
Length x Beam	0m x 0m
Draught	
Nav. Status	Not defined
Last Seen UTC	11/8/2017 5:49 AM
Last Seen Loc	11/7/2017 8:49 PM
Latitude	58°26.040'N
Longitude	168°51.684'W
Nearest MM	
Speed	5.7knt(6.6MPH)
Course	79.2°
Heading	
Rate of Turn	
Destination	
ETA	
Last AIS UTC	11/7/2017 1:04 AM
Last LRIT UTC	11/8/2017 5:49 AM
Last AIS Lat	58°25.430'N
Last AIS Long	169°39.885'W
Last LRIT Lat	58°26.040'N
Last LRIT Long	168°51.684'W
Pos. Accuracy	Low (>10m)
Pos. Fix. Dev.	Undefined
IP	0.0.207.14:110c

Incomplete Data

Name	ALASKA VICTORY
MMSI	338568000
IMO	7434042
Call Sign	WBC9661
Type/Cargo	?
Length x Beam	0m x 0m ?
Draught	?
Nav. Status	Not defined ?
Last Seen UTC	11/8/2017 5:49 AM
Last Seen Loc	11/7/2017 8:49 PM
Latitude	58°26.040'N
Longitude	168°51.684'W
Nearest MM	
Speed	5.7knt(6.6MPH)
Course	79.2°





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Current Efforts – Vetting Data

Sample of Raw AIS data versus Corrected Data

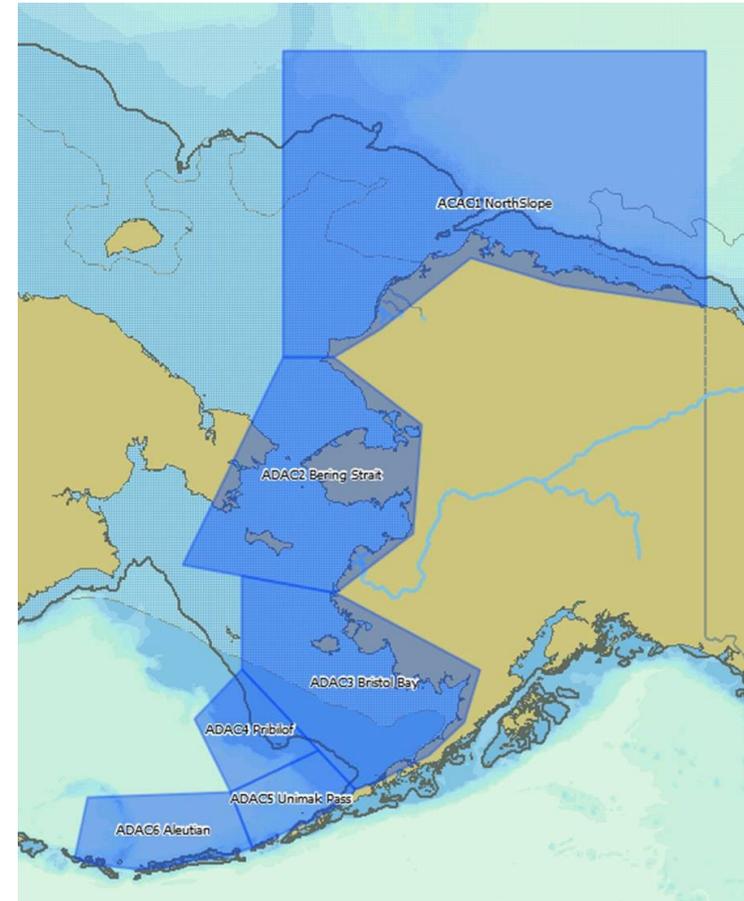
MMSI	Name	Raw Ship Type	Corrected Ship Type
367141000	AIVIQ	Towing	Offshore Supply Vsl
367562110	ALULAQ	N/A	Tug
367562110	ALULAQ	Undefined	Tug
367494000	AQUILA	Reserved	Offshore Supply Vsl
367494000	AQUILA	Dredging	Offshore Supply Vsl
441619000	ARAON	Other	Research
303396000	ARCTIC_BEAR	N/A	Tug
367108560	BRISTOLEXPLORER	N/A	Offshore Supply Vsl
303902000	CG HEALY	Dredging	Military
303902000	CGC HEALY	Military	
369960000	FAIRWEATHER	Other	Research
230245000	FENNICA	Other	Offshore Supply Vsl
367438220	GRETA	Other	Cargo Vessel
366840000	HARVEY CHAMPION	Cargo	Offshore Supply Vsl
368584000	HARVEY SPIRIT	Other	Offshore Supply Vsl
367507790	HARVEY SUPPORTER	Cargo	Offshore Supply Vsl
366927570	ISLAND SPIRIT	N/A	Tug





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Current Efforts – Scope

- 2013, 2014, and 2015 data are vetted for Utqiagvik (formerly known as Barrow) to the eastern Beaufort Sea (North Slope Region).
 - Final data for the Beaufort Sea 2013-Nov 2017 (end of shipping season) will be completed November 15, 2017.
- Beaufort to Bering Strait will be next
 - ETC 1 December 2017
- Bering Sea (biggest chunk of data)
 - ETC 1 February 2018
- Raw data test runs have been completed.

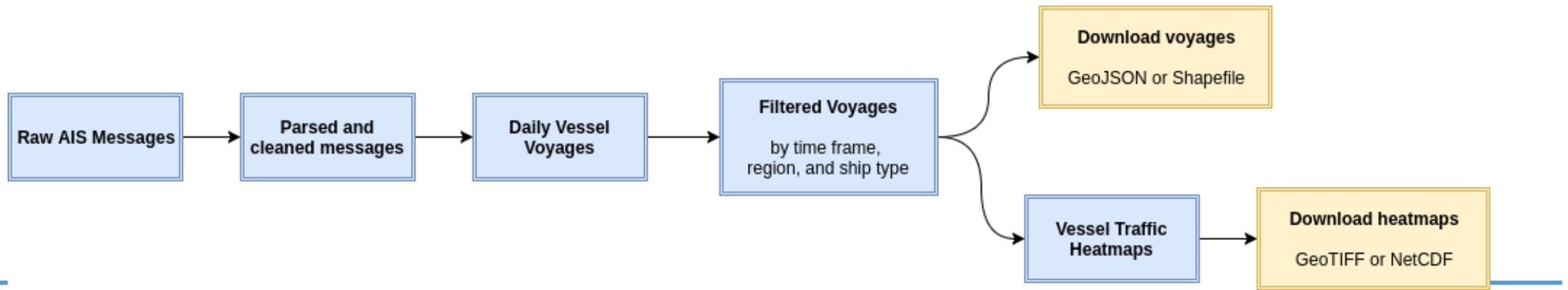


Region defined by ADAC as Arctic in blue.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Current Efforts – Data Workflow

- The workflow built for the NOAA OCS: AIS Big Data Project has been revamped to improve efficiency, performance and reusability on this project.
 - We've tested this new workflow on three years of raw, unvetted data (2016-2016 Terrestrial AIS data, and 2016 Satellite AIS data) with good results.
- Actively working on Phase 1 MXAK vetted and configured data spanning Barrow eastward to eastern Beaufort Sea to the Canadian border.
- With the current workflow, we will be running through the following pipeline for each dataset:



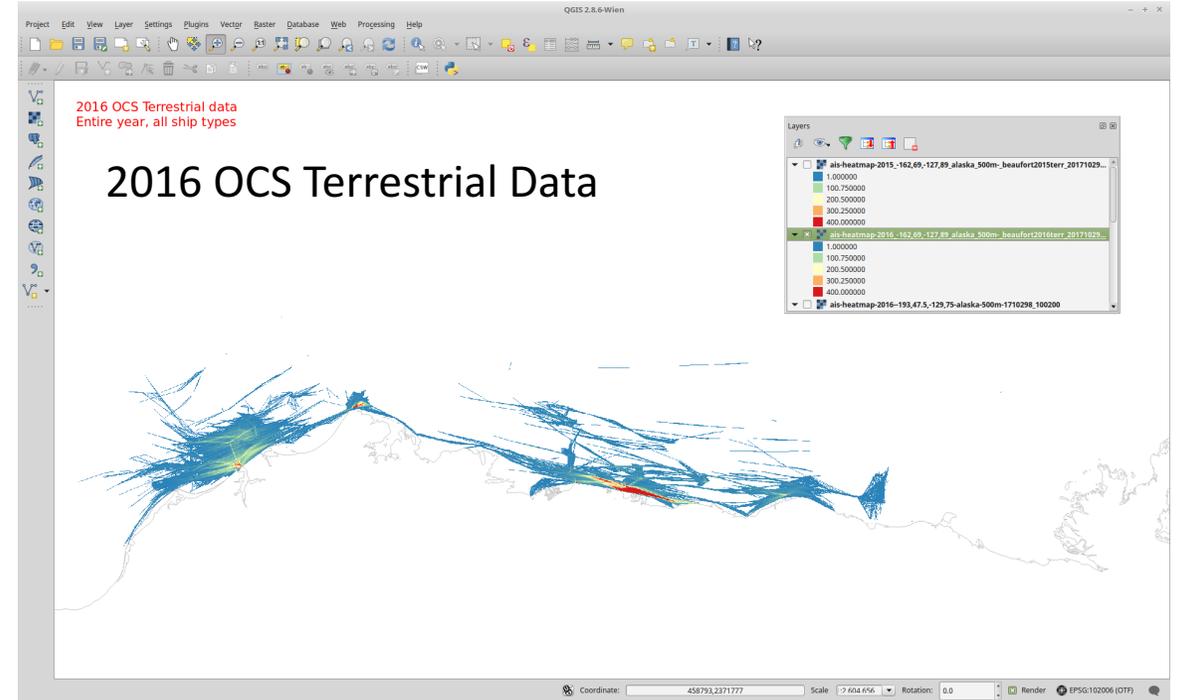
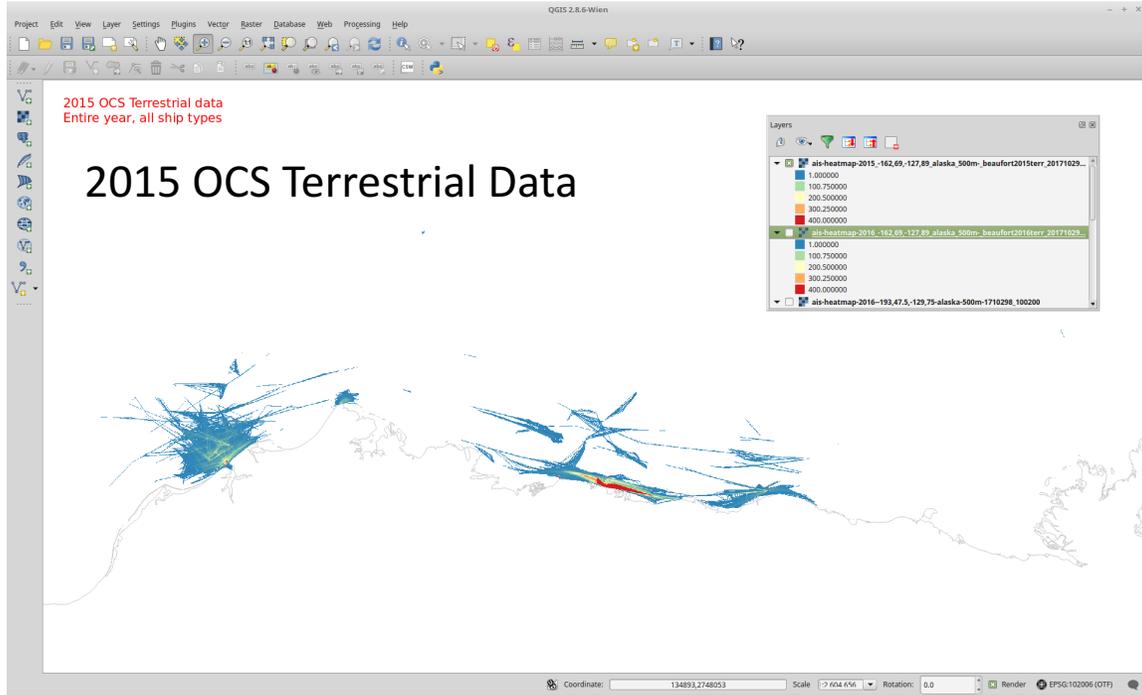


Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Projected Efforts - Illustration

- For illustration, consider 2015 Terrestrial data from NOAA OCS Big Data project
 - Raw AIS Messages --> Parsed and Cleaned messages took **40 hours to process 74 billion messages.**
 - Parsed and Cleaned Messages --> Daily Vessel Voyages took 90 minutes.
 - Voyages --> Vessel Traffic Heat Maps took **1.5 hours for the continental US (all ship types), and 10 minutes for the Alaskan arctic (all ship types).**
- This approach requires running the first two stages (raw messages --> vessel voyages) once per dataset.
- Custom “heat maps” are then created and filtered by time, region, ship type, etc., in a matter of minutes to hours.
 - Development and testing cycle is very fast, so feedback can be quickly incorporated from users of these data, making it easy to tweak analysis or fix bugs without much delay.
 - Create a wide variety of products up-front with little effort.
 - Quickly create new custom products as our users request them.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Projected Efforts – Visualizations



Sample screenshots from the Beaufort provide trial data visualizations.

Shown here using raw, un-vetted USCG data from 2015 and 2016, Northslope



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Research Schedule and Milestones

	First year of Project Research		Progress	Why Not Reached
	QTR 1	QTR 2		
Project initiation	X		Complete contractual agreements, conduct monthly PI Team Meetings, complete ADAC video interviews (Janzen and Bochenek), Partner's Roundtable (09/07/17), ADAC all hands on calls, Project Lead tele-conference meeting with Project Champion and project summary report from partners RoundTable forwarded (10/2017).	NA
Convene initial and routine stakeholder meetings available via teleconference and webinar services	X		Establish Project Steering Committee: (Core committee shown) <ul style="list-style-type: none"> • Project Champion – Dr. Jon Berkson • NOAA Navigation Manager, Alaska Region – Bart Buesseler • Arctic Waterways Council & Crowley Fuels, Marine Eng. Director – Greg Pavellas • ADAC, Director - Dr. Randy "Church" Kee • NOAA OCS, Geospatial Data Program Manager – Patrick Keown • Kickoff conference call – mid-December 2017 (TBD after annual meeting) • Project scoping and prototype products conference call – TBD January 2018. 	NA
Prepare and quality review AIS data	X	X	Data are being vetted in 3 phases (1 - Barrow to Canadian Beaufort; 2- Barrow to Bering Strait; 3: Bering Strait to southern boundary TBD). Beaufort and Bering Strate data have been vetted and corrected ed through 2016. 2017 data and remaining Bering Sea data south of Bering Strait are in process.	NA
Transfer AIS data and optimize high-computer cluster workflow		X	The high-performance computing cluster is in place with a functional workflow. The system is being tested using raw non-vetted AIS data from other sources to optimize processing. Transfer of AIS data will be underway in Q2-3 in order to incorporate full suite of 2017 data.	NA





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Current Year Metrics

Current Year Metrics Year 1	Progress	Why Not Reached
Complete AIS data quality review and processing	Raw AIS data in process of being configured for transfer to Axiom high compute cluster. Listings of incorrect vessel AIS information and corrected data have been developed for vessels operating in the Beaufort Sea for 2013, 2014 and 2015 and provided to Axiom for incorporation into the final product workflow.	NA
Complete configured AIS data transfer	Underway: Evaluation and configuration of vetted data is occurring in three regional phases: Phase 1 – Barrow to Eastern Beaufort Sea; Phase 2 – Bering Strait to Barrow; Phase 3 – North of Aleutians to Bering Strait.	NA
Complete optimization of the high-computer cluster workflow for high quantity data handling	Complete: The high-performance computing cluster is in place, with a functional workflow trial underway. Continued improvements to increase the efficiency of the prior NOAA OCS project workflow are being made. Improvements will initially be incremental.	NA
Initiate development of vessel density maps generated from the transferred AIS data	Started development of prototype vessel density maps generated using 2 years Terrestrial and 1 year Satellite Arctic basin AIS raw (non-vetted) data. Prototype products will help guide discussions with Steering Committee on product needs, scope, and attributes going forward. Prototype data are not vetted and still retain errors, so are only being used to help with workflow modifications and product prototype development that will be used for final vetted MXAK data ingestion and processing.	NA
Document and curate AIS metadata throughout the project (in preparation for data archival);	All processes and workflow modifications are being tracked and documented.	
Develop technical documentation of data ingestion and prioritization processes utilized on the project to facilitate re-use and workflow scaling for other big-data analysis projects.	On target: Members of the project team are currently authoring a technical whitepaper on data ingestion processes, and will use this as a start to the development of specific technical documentation for this project.	





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Planned Research Outcomes – Year 1

- **Application-ready, gridded files describing AIS vessel densities for use in the NOAA-OCS Hydrographic Health Model will be initiated and under development in the second half of Year 1 (to be completed by the second half of Year 2).**
 - **This step is important for the prioritization of areas for bathymetric surveying:**
 - **Gridded files provide the extracted AIS information needed for decision makers and stakeholders in the U.S. Arctic area;**
 - **They also provide patterns of historical as well as emerging vessel traffic patterns.**
 - **Results from this effort will format inputs to the Hydrographic Health Model whilst making those inputs readily accessible for other applications.**
- **The project team will begin planning application products and transition in the early stages of Year 1, immediately after defining summary data product specifications with the Steering Committee.**



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Planned Research Outcomes – Year 2

- By the end of the project in Year 2, final data products to be transferred:
 - NOAA-OCS for application in their Hydrographic Health Model.
 - Other applications identified through interactions with assigned USCG Project Champion(s), project Steering Committee and USCG Project Advocates.
 - Public project website/portal hosted by A00S.
- The investment in this foundational project will be leveraged to:
 - Improve efficiency in vetting, processing and analyzing AIS data that can be used for new research.
 - Improve access to the types of AIS data that is most useful to stakeholders, and make this information visually accessible to those who need it.
 - Expand capacity nationwide for AIS data handling for similar projects.
 - Help identify where the AIS system needs improvement, which could be used to guide USCG efforts at implementation processes and requirements.
- **Knowledge Product** - we (and others via documentation) will be able to apply the techniques pioneered in this project to other big data challenges with different types of data.



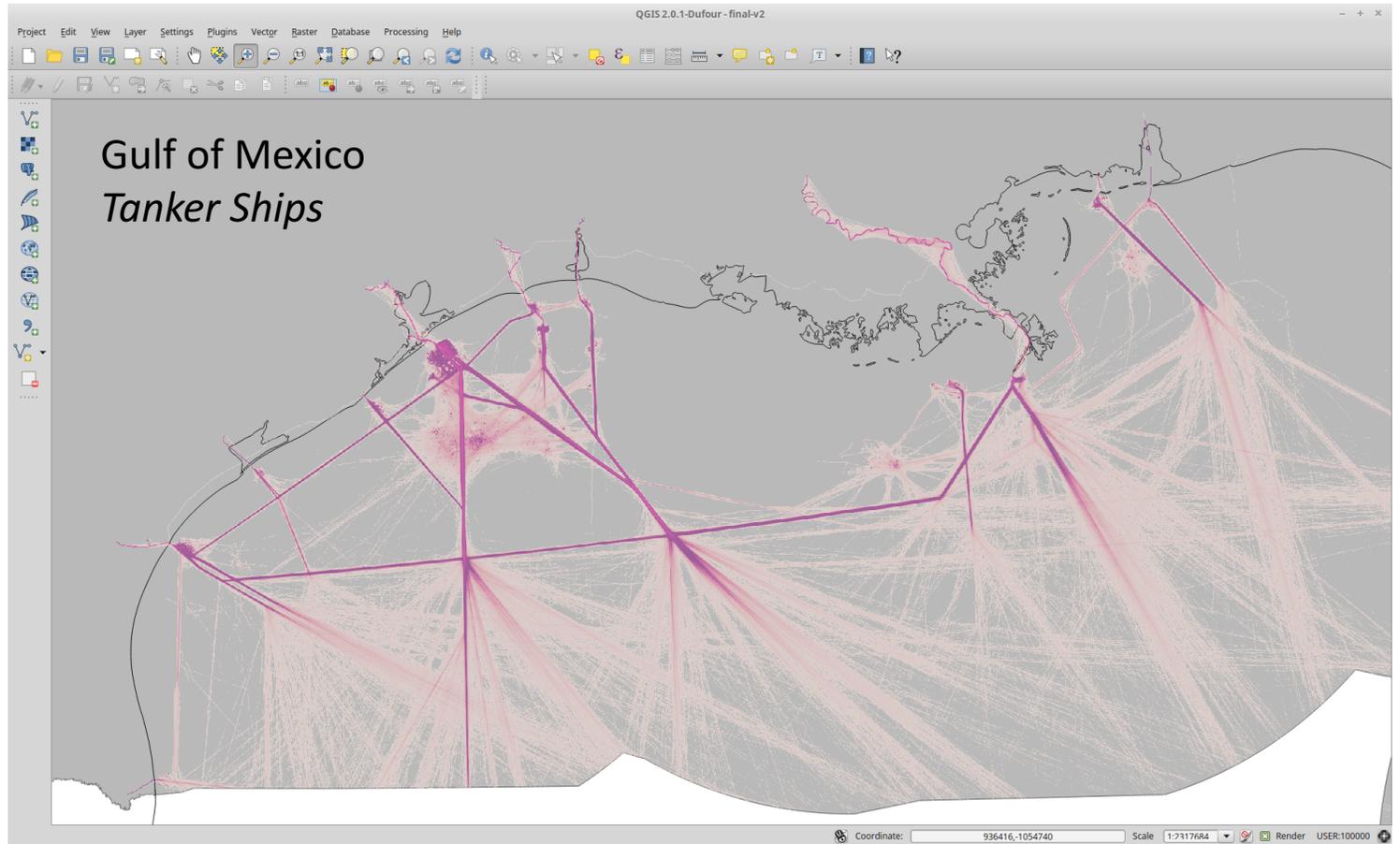
Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Developing Data Products

Example of a Product:

A “Heat Map” is a gridded image that shows visual and computational means used for identifying high concentrations of ship traffic. For the NOAA OCS project, we provided heat maps split up by vessel type.

In this example:

- Each cell is 500x500 m that represents the total count of vessels in that cell.
- The screenshot is with Tanker Ships in the Gulf Coast
- Next step, include bathymetric data





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Transition Plans and Pathways

- Regular communication with the Project Champion Dr. Jon Berkson will involve consultation on quarterly reviews and annual meetings, participation in quarterly steering committee meetings, and engagement in all product demos and trials.
- A communications and outreach plan for coordinating potential end users will be developed in Year 1 (Q2-3) with Steering Committee input.
 - For example: Identified stakeholders will participate in product prototype trial demonstrations/webinars, and will be asked to provide feedback on visuals, ease of use and other tool functionality.
- The project team is already participating in ADAC *“Customers and Partners” Roundtable meetings*, and will continue to inform and receive feedback on project progress and usefulness to USCG mariners and ADAC collaborators.
- In Year 2, final data products will be transferred in the form of geo-spatial gridded density files to NOAA-OCS for input into their Hydrographic Health Model and to other applications discovered through interactions with assigned USCG Project Champion(s), USCG Project Advocates and project Steering Committee.
- Final data products will be made publically available on the A00S Data System via the project website.
- Researchers expect to achieve TRL 7/8 for project-developed information products and software applications.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Ready for questions

Feedback...

- What are we missing?
- What can we improve?
- Who should we connect with to improve odds of research success?

QUIZ: How would this vessel be classified in AIS?



Soviet Ekranoplan / 1980s

Not quite a plane and not quite a ship.

Undetectable by radar and very, very quick.



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic

- EXTRA SLIDES for Q&A



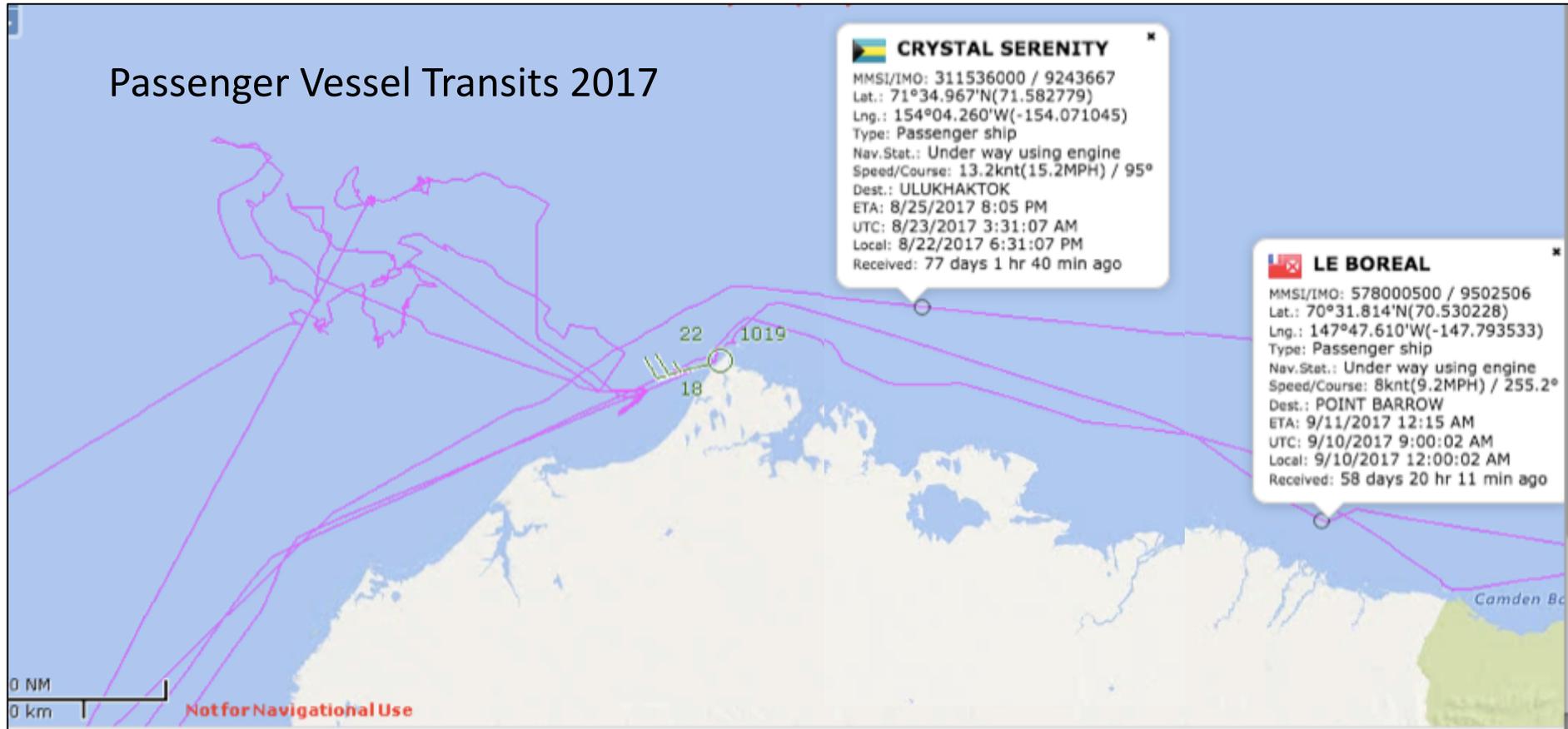


Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Description and Baseline – Other Uses of Data by ADAC

- **ADAC also plans to leverage these data in determining appropriate geographic areas to develop processed Satellite Derived Bathymetry (SDB), and expects derived project data accessibility to a new Arctic Information Fusion Capability (Program Year 4).**
- **SDB offers the following, though is largely still limited by depth accuracy:**
 - **Good coverage (within depth and image limitations); not as good as Multi-beam echo sounder (MBES), some objects may be missed, but better than single-beam echo sounders (SBES) and leadline.**
 - **Better object detection than leadline, but not as good as SBES used with side scan sonar or a MBES.**
 - **Good positional accuracy. Similar to MBES and SBES. Better than historic leadline.**
 - **Lesser depth accuracy than MBES, SBES and leadline.**



Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Example Marine Exchange AIS Data





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Issues With Raw AIS Data



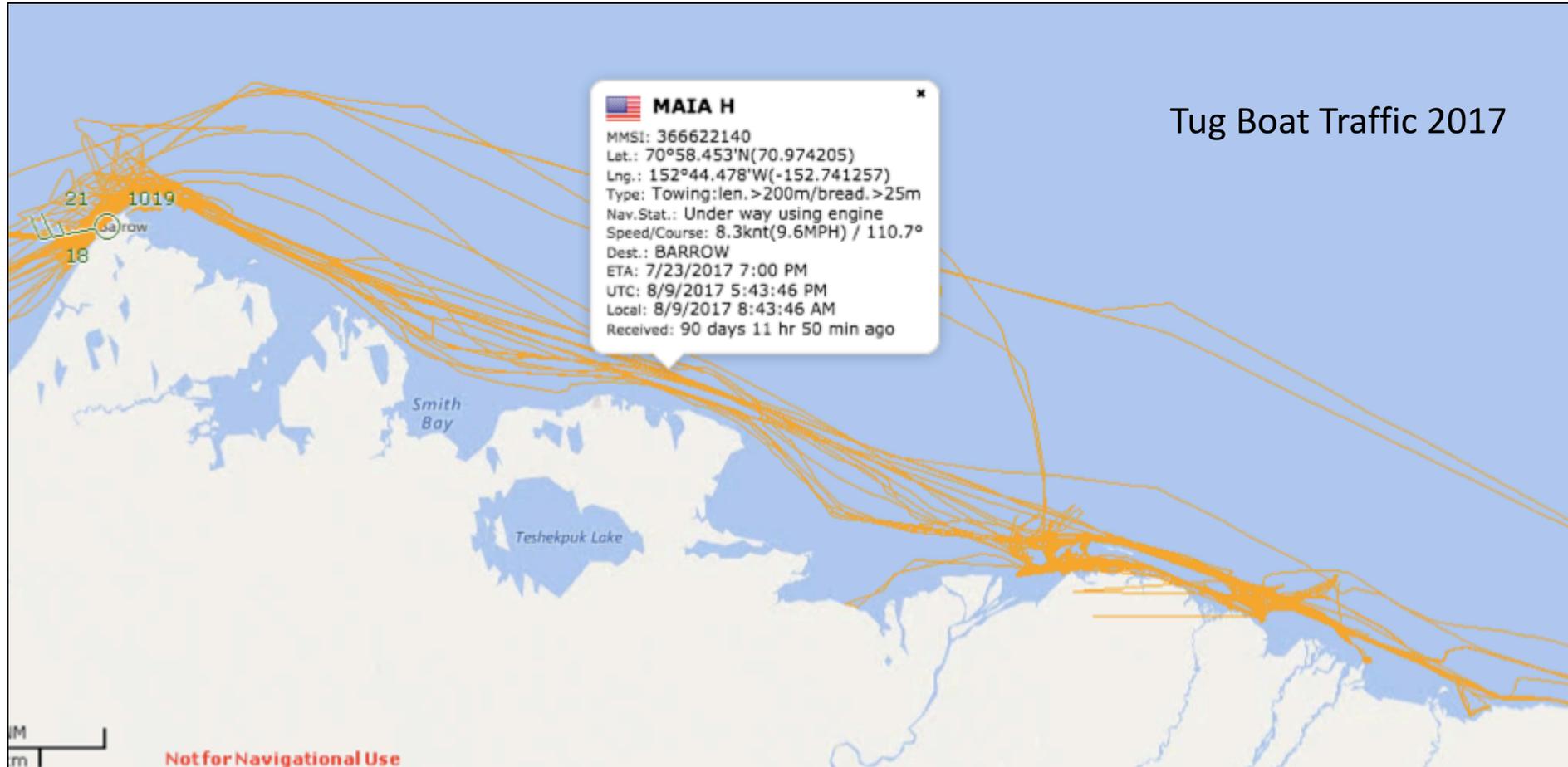
PROF.MULTANOVSKIY ✕
MMSI/IMO: 273432910 / 8010362
Lat.: 72°03.233'N(72.053894)
Lng.: 161°38.484'W(-161.641373)
Type: Passenger ship
Nav.Stat.: Under way using engine
Speed/Course: 2.9knt(3.3MPH) / 262.1°
Dest.: NOME USA
ETA: 7/2/2017 10:30 AM
UTC: 6/27/2017 2:34:12 PM
Local: 6/27/2017 5:34:12 AM
Received: 133 days 14 hr 37 min ago

Misleading AIS data:
Vessel not “passenger
ship” – research vessel



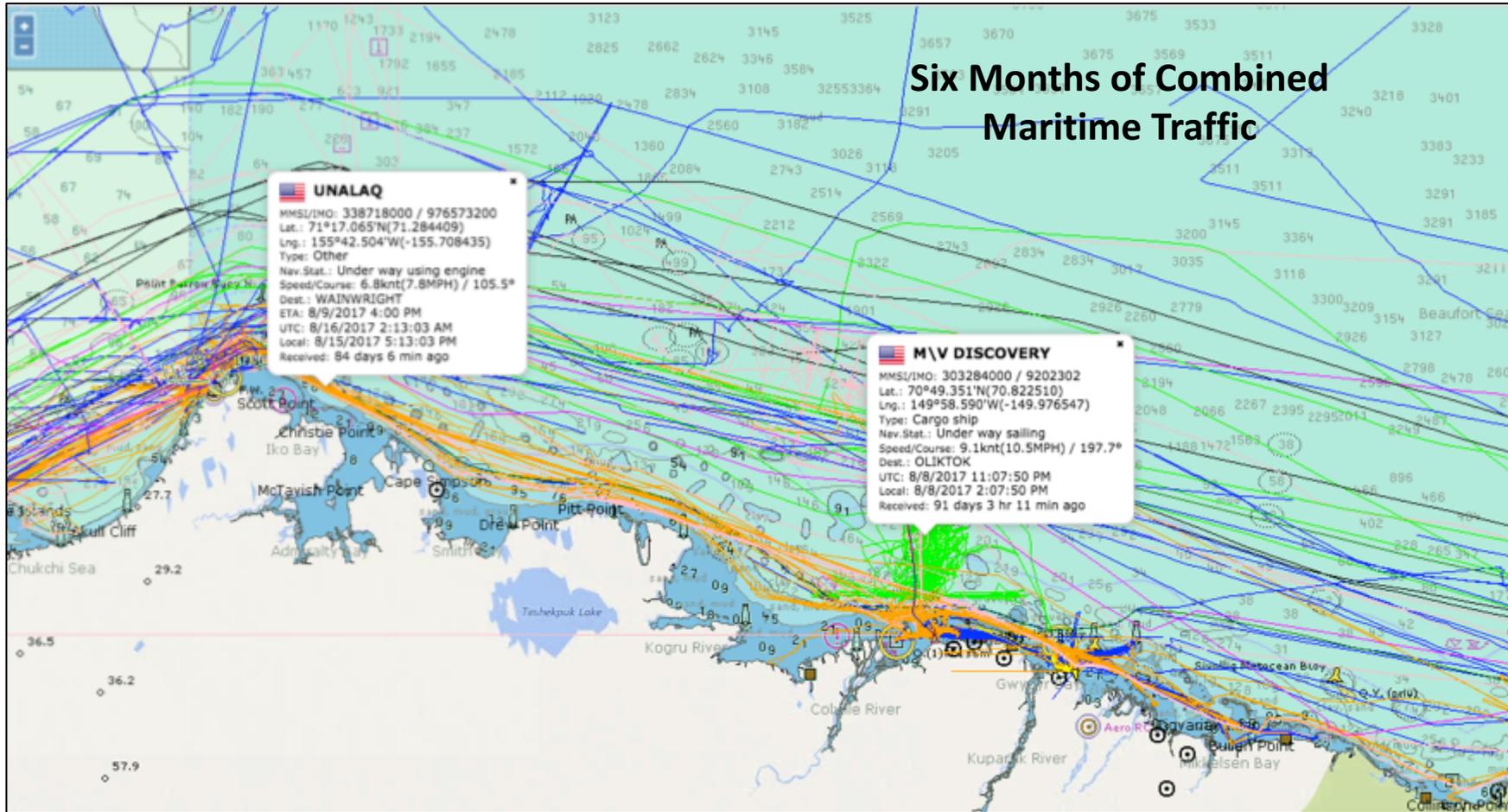


Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Example Raw AIS Data by Vessel Type





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Example Marine Exchange AIS Data



Icon	Ship Type
	Cargo
	Fishing
	Towing
	Passenger
	Pilot
	Tanker
	Military
	Pleasure Craft
	Tug
	Other
	HSC
	Anti Pollution
	Towing
	Towing 200/25
	Search/Resc
	Law enforc





Using Vessel Tracking Data to Prioritize Bathymetric Surveying in a Rapidly Changing Arctic: Current Efforts Using Ancillary Data

- **Raw, unvetted AIS data between 2009 and 2016 from other sources (NOAA satellite AIS data and USCG data store 2015-2016) are being used to test workflow.**
 - **Developed basic automated processing protocols and completed initial quality checks of 2015 and 2016 data.**
 - **Initial QC includes removing duplicate records, incomplete records, and junk records (indecipherable), but does not reconcile errors in other information.**
- **NOTE: These data are ancillary to the MXAK data, and are not vetted for use in the NOAA OCS Hydrographic Health Model.**