USING SHIP TRACKING DATA FOR DECISION MAKING

Carol Janzen and Molly McCammon,
Alaska Ocean Observing System

Rob Bochenek, Axiom Data Science

Ed Page and Bill Benning, Marine Exchange of Alaska

Stephen R. Braund Associates

Automated Information System (AIS)
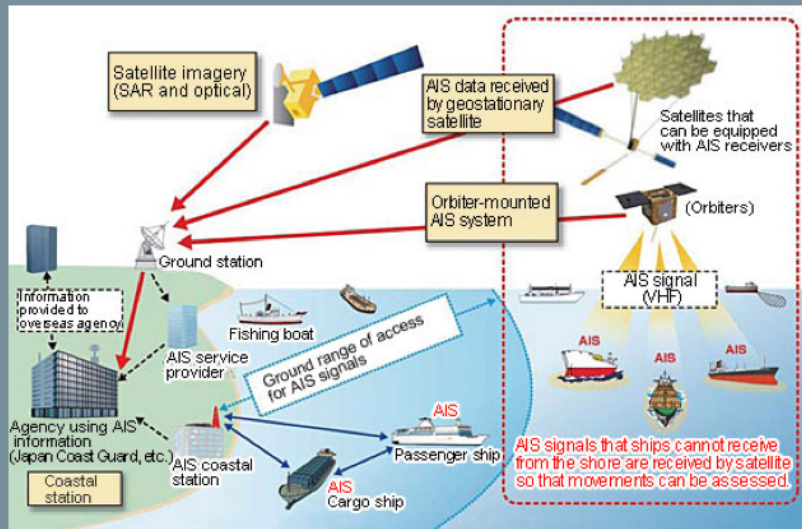
Diagram of AIS data being transmitted to land-based and satellite receivers. (Photo credit: Japan Aerospace Exploration Agency)

AIS is a system of shipboard transmitters and land-based and satellite-based receivers that allow vessel locations to be broadcast and recorded

AIS operates in the VHF frequency
Capability of transmitting information in real time
Provides major benefits in collision avoidance, vessel tracking, fleet planning and management.

For questions:
- Limited range for terrestrial receivers: this means we may not have data for ships transiting far offshore.
- We do not know the location and range of all land-based receivers, if there are no data in a specific location, we cannot distinguish between "there was never a ship here" and "there was a ship here but it's not within range of a receiver".
- Duplicate messages due to overlap in range of terrestrial receivers: this is fairly easy to deal with, and is one of the first steps we take in cleaning up the data.
- Incorrect measurements sent by the ship: AIS data is self-reported, so it is possible to have incorrect measurements for location, speed over ground, etc. Therefore, the analyst must be skeptical and independently verify measurements whenever

possible. For example, when building voyages we calculate speed between pings and discard data points where the ship is moving impossibly fast.

- Incorrect ship identification: this includes using a duplicate MMSI or reporting the incorrect vessel category. To help combat this misinformation, we use data from the Authoritative Vessel Identification Service (AVIS) provided by the US Coast Guard.

The Automatic Identification System (AIS)

- On-board tracking system, transmitting over VHF
    - AIS equipment integrates with vessel navigation systems, such as GPS
    - Other AIS-equipped ships can see traffic in the area
    - Land-based (and satellite) receiver networks can collect data for an entire region

- Increasing interest in analyzing historic datasets
    - Prioritizing hydrographic surveys
    - Predicting probability and impact of oil spills
    - Quantifying interaction of shipping with marine wildlife & potential subsistence harvests
   - Homeland Security

Ship to ship
Ship to shore
Ship to satellite

https://sat-trak.com/
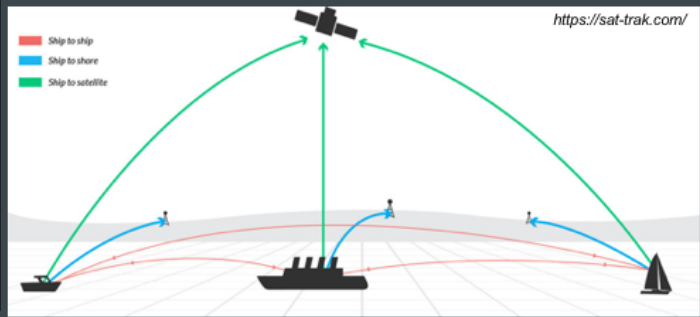
**Traditionally used for real-time maritime applications**

Increasing interest in using these rich datasets to provide insight into a wide array of oceanographic problems
- **prioritizing hydrographic surveys**
- **predicting the probability and impact of oil spills**
- **quantifying the amount of vessel interactions with marine wildlife**
- **Changing vessel route patterns with changing ice conditions (Arctic)**

AIS installations in Alaska are Operated in a Network by the Marine Exchange of Alaska
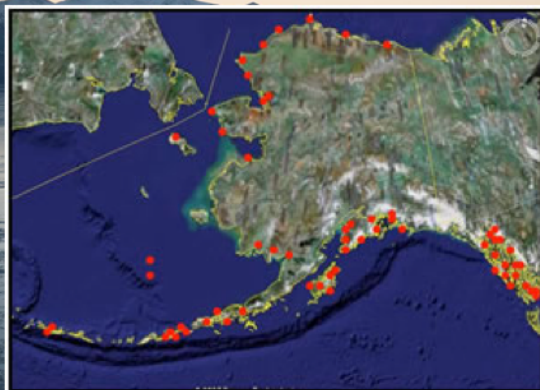
100+ AIS receiving stations in Alaska
48 operating in Arctic Region
Operated by MXAK - Marine Exchange Alaska
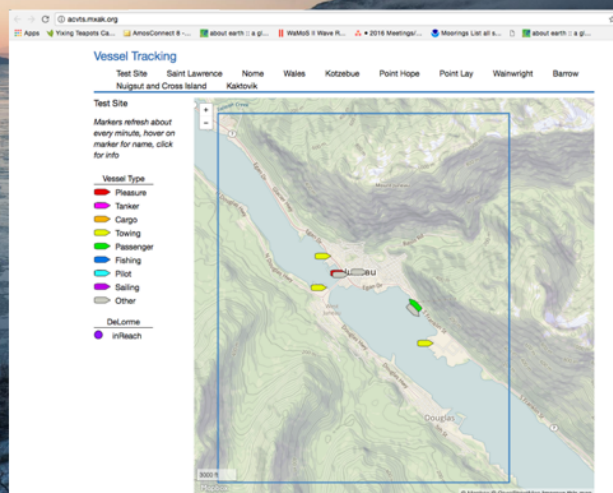
Alaska is this nation's Maritime State! Over 10,000 commercial vessels sail the 33,000 miles of Alaska coastline and thousands of miles of rivers. The opening of Arctic waters to maritime traffic are presenting new challenges with respect to maritime safety and environmental protection.

The Marine Exchange of Alaska is a non-profit organization that maintains the only terrestrial AIS network in Alaska
Their biggest customers - USCG and Commercial shipping ops

MXAK offers free AIS access to Arctic communities: http://acvts.mxak.org/.

AOOS is partnering with the Marine Exchange to add weather stations to some of the AIS stations to provide more localized weather.
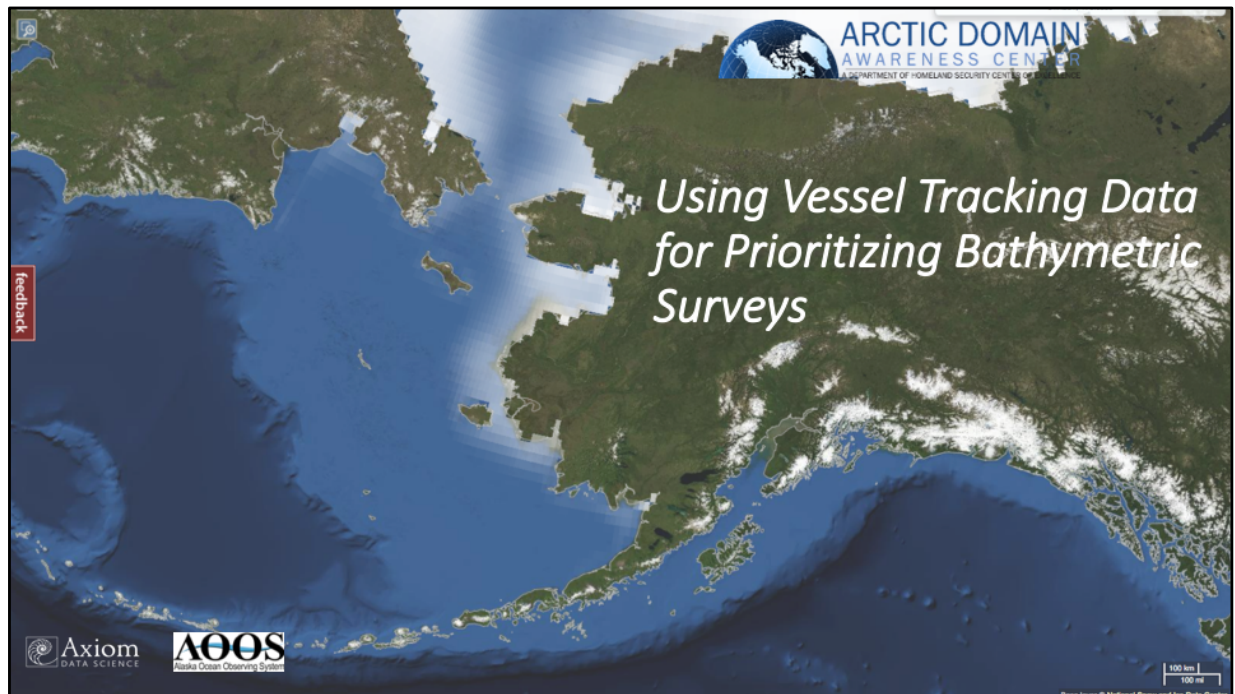
Other sources of AIS data include:
USCG Terrestrial sources
NOAA OCS (Office of Coast Survey)
Marine Cadastre Terrestrial – NOAA Office of Coastal Management
Occasional private installations.

Using Vessel Tracking Data for Prioritizing Bathymetric Surveys

AOOS has two projects with Axiom and the MXAK, to develop tools to process these large data streams for Alaska (and nationwide areas for IOOS).

The reason for wanting to be able to break out these data is to help develop products that can be used for decision support.

I am going to briefly introduce the two projects here.

This first project is Funded by the Arctic Domain Awareness Center over at UAA

This is a Dept. of Homeland Security (DHS) Center of Excellence, and the main customers include DHS and the USCG.
- Other benefactors will be NOAA , Resource managers at BOEM, USFWS, NOAA
- Coastal communities interested with shipping trends and patterns in their region

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.

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ADAC: Research for the Arctic Operator...For Today and For the Future

Axiom DATA SCIENCE

AOOS Alaska Ocean Observing System

There have been several motivating factors in the last 5 years alone that illustrate the need for improved bathymetric information in the US Arctic, which for this project, encompasses the area from the southern Bering Sea all the way to the eastern Beaufort Sea.

Two such examples include the incidents with the Champion Ebony, a Norwegian oil tanker which grazed the ocean bottom near Nunivak Island in the Bering Sea, and the Shell Oil Company ice breaker ship Fennica, which struck an uncharted reef shortly after leaving Dutch Harbor.

The Champion Ebony ran aground on a shoal 10 miles from shore. That shoal was not on the map the crew was using. At present, huge takers are relying on maps that could be over a 100 years old, dating from before the development of modern ocean mapping techniques.

The Fennica struck an uncharted rock roughly 22.5 feet below the surface. *Fennica*'s draft was 26.25 feet at the time of the accident. With tidal conditions, the ship was about 9 inches too deep to clear the rock. 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.

Champion Ebony story:
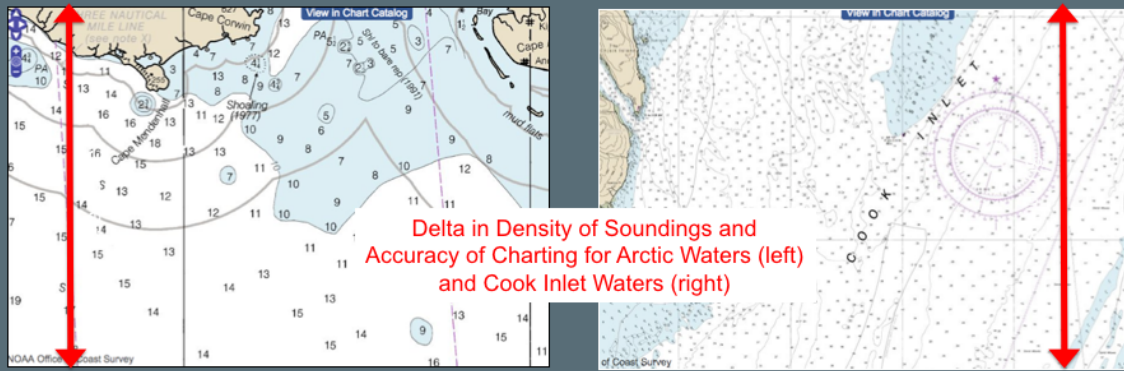http://kyuk.org/post/outdated-maps-could-have-caused-champion-ebony-run-aground

Fennica Story:
http://www.professionalmariner.com/December-January-2017/Shell-icebreaker-Fennica-struck-uncharted-reef-Coast-Guard-says/

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)

To illustrate, These two map sections that are shown at the same scale further illustrate the low resolution bathymetry currently available in much of the Arctic (left panel) as compared to other regions in Alaska, such as Cook Inlet in Prince William Sound in southeast Alaska (shown in the right panel).

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
- Despite major advances in hydrographic technology, conducting modern bathymetry surveys is challenging and expensive, especially in the Arctic.
- This project is using 5 years of 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.
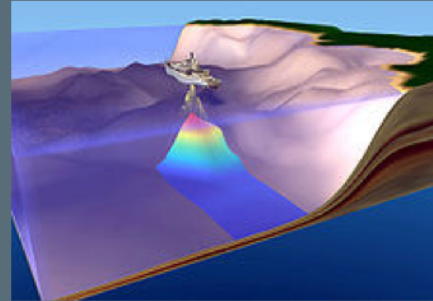
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This project is designed to address issues with outdated and uncharted bathymetric information in the Arctic.

One of the ways NOAA prioritizes where to conduct new surveys is to run a model that uses ship tracking information as an input, but they need a way to get the data into a manageable format.

Bathymetric survey operations are expensive, and given the Arctic is in need of large scale surveying to bring the region into a safer operational realm for shipping, NOAA, who oversees survey operations needs to know what areas should be surveyed first.

To help prioritize where new survey efforts should occur to remedy replete information on soundings in the Arctic, we are using 5 years of Automated Information System - AIS ship tracking data - to identify historical as well and emerging shipping patterns in the region.

These data are processed to a format that NOAA can use in their models to prioritize areas that have a need for updated bathymetric charts.

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

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Furthermore, not only are the data files are big, they have errors, so the first step is to edit and clear up any missing information or misinformation.

Here, we show the problem close up with an example of the Ship Type category. Of course, the AIS information contains much more categories than this.

The Alulaq shown in gray here, lacks ship type, and had to be corrected. Twice.
The Aquila shows conflicting ship type, neither were correct!

The CG Healy, shown twice here has one correct record (white) and an incorrect record (dredging, highlighted in Yellow).

The activity might have been what was programmed into the vessel classification by mistake, so these errors have to be resolved first.
Only one of these records was correct!

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How do we handle these large data sets? - Cluster Computing
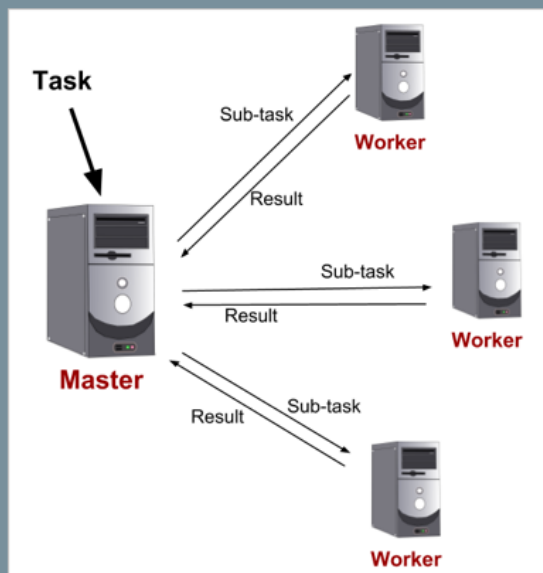
Problem: Due to immense size of these datasets—typically 10s of billions of raw messages per year—and limitations on infrastructure and computing power, AIS data must currently be processed in small temporal or spatial subsets.

Solution: Develop cluster computing infrastructure and applications to analyze the data across many machines in parallel

Previous workflow: single machine, small subset → days to weeks to process

New workflow: compute cluster, all US waters for one year → 48 hours

Once the data have been corrected, we can run ad-hoc queries to get vessel tracks or vessel traffic heatmaps for a specific region and time frame in a matter of minutes to hours.

How do we handle these large data sets?

- When doing analysis or transformations on large datasets, it's helpful to perform these calculations in parallel
- It's possible to parallelize your application across multiple cores (CPUs) on a single computer
- Another approach: join several computers over a network to form a "cluster"
  - The advantage here is that you can scale beyond the max number of cores
  - But you also add a huge amount of complexity
  - Over time, many frameworks have emerged to help manage this complexity. With the advent of these frameworks, along with the rise of cloud computing and containerization frameworks, these technologies have really come within our grasp -- hence the reason why "big data" is a buzzword.
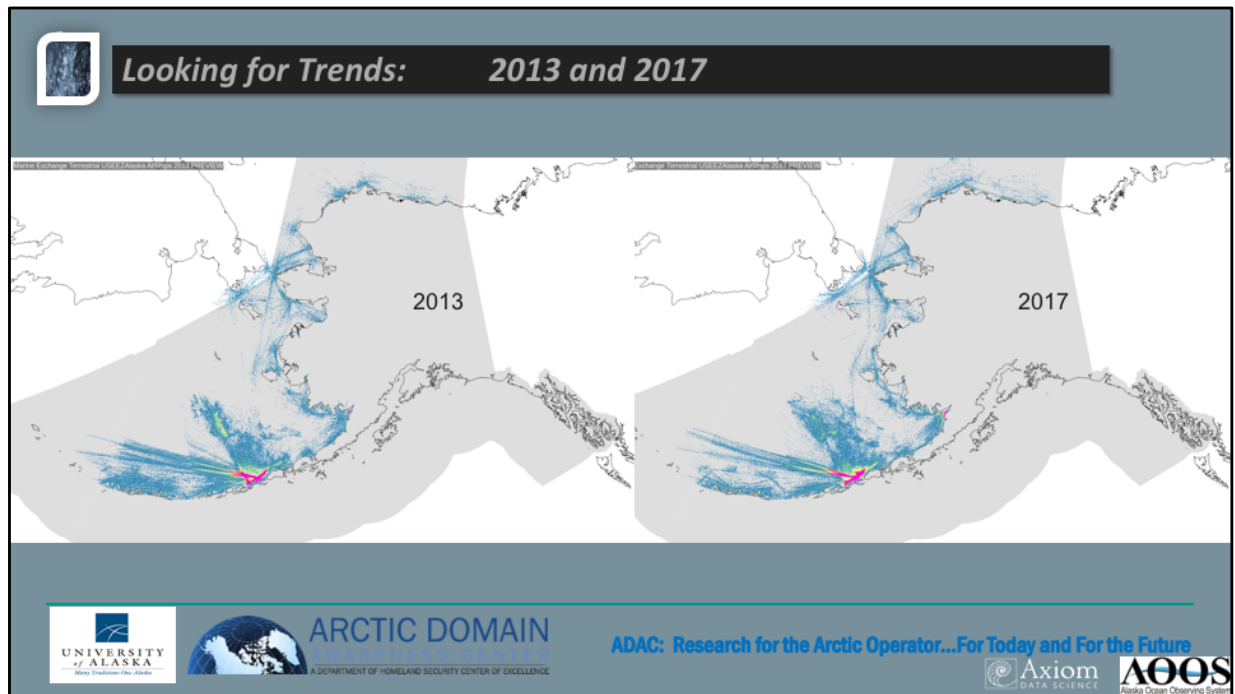
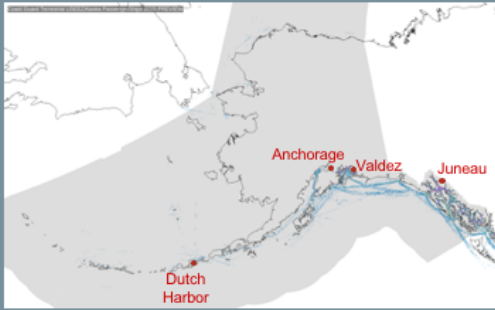**Once the records are broken down into manageable formats, the analytics can begin.**

Maps can be generated as well to visualize where ship traffic patterns might be changing.

The maps can be queried to display vessel type, size, draft, and other categories.
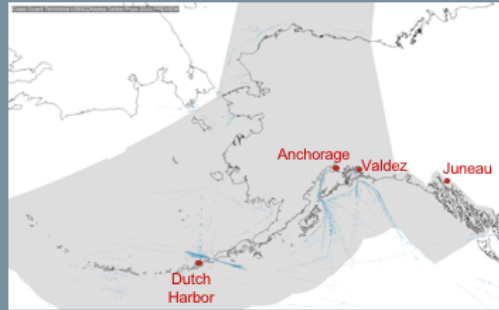
Example here shows all ship traffic using AIS in 2013 and 4 years later in 2017.

NOAA uses a model to help prioritize where they should perform updated bathymetric surveys.

One of the model inputs is AIS vessel data information, which can be used against existing bathymetric information to determine areas that need to be charted for the level and type of traffic occurring.

The data need to be checked for accuracy and then formatted in a way that the model can use.

Due to the size of these data, this has posed a problem in the past, and restricted use to very select regions.

NOAA solicited help from AXIOM a few years back to solve this problem and invested in the development of the tools being expanding on these projects.

Both of the projects happening today were spun off the original Big Data efforts to try to wrangle these data for applications like NOAA's Hydrographic Health Model.

Developing a Community Impacts Decision Support Tool for the Alaska Beaufort Sea

OBJECTIVES:

- Synthesize ship tracking data, oil spill model results, and subsistence use information
- Run oil spill trajectory models to identify likelihood of spill impacts in Beaufort
- Incorporate subsistence harvester and use-area intensity data into the model, and compare to the spill impact density maps

- Goal is to understand where a spill is most likely to occur based on the frequency of vessels, and how different subsistence activities and their relative timing could be impacted in the event of a spill.
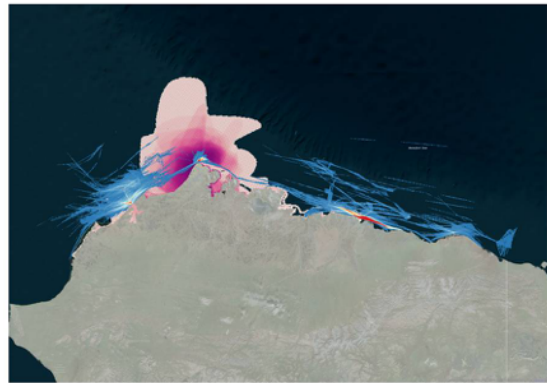
Figure 3. Example image of harvester intensity index for the community of Utqiaġvik (formerly Barrow) relative to marine traffic.

Another project funded by the National Academy of Sciences will allow us to use AIS data to develop an interactive tool to aid research and planning in coastal communities bordering the Alaska Beaufort Sea

SRB&A compiled and inventoried subsistence use area and harvest information from multiple studies dating as far back as the 1970s for the three study communities of Utqiaġvik (formerly Barrow), Nuiqsut, and Kaktovik.

The sources inventoried included
- **15 harvest studies and eight subsistence mapping studies for Utqiaġvik,**
- **17 harvest and eight subsistence mapping studies for Nuiqsut, and**
- **16 harvest and four subsistence mapping studies for Kaktovik.**

To determine which subsistence activities would most likely be impacted from a spill, subsistence activity data for each community will be analyzed against spill impact density maps in Year 2.

Thanks to Marine Exchange for Bringing AIS to Alaska!
(Mary Island Installation)

To learn more, please visit: http://ais.axds.co