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

A presentation by

Carol Janzen, AOOS
Jessica Austin and Rob Bochenek, Axiom Data Science
Ed Page, Marine Exchange of Alaska
AIS PAC: AIS for Prioritizing Arctic Charting

Project Principal Investigator(s)
- Carol Janzen, Ph.D., Project Lead, Alaska Ocean Observing System
- Rob Bochenek, Jessica Austin, Axiom Data Science
- CAPT. Ed Page (USCG, Ret.), Marine Exchange of Alaska

Lead Institution: Seward Association for the Advancement of Marine Science on behalf of the Alaska Ocean Observing System

Supporting Team: Marine Exchange of Alaska
Axiom Data Science LLC

Student Participation: Lonnie Young, ADAC Fellow

Project Champion: Jon Berkson, Ph.D., USCG, CG-WWM

Project Advocates: USCG (HQ, Pacific Area, District 17, RDC);
NOAA (OCS, AK Region, IOOS); BOEM
AIS PAC: Description and Baseline

Conducting modern bathymetry surveys challenging and expensive, especially in the Arctic

- To focus survey efforts, NOAA’s Office of Coast Surveys currently uses the Hydrographic Health Model to help prioritize where to conduct surveys
  - One inputs is AIS vessel tracking data
  - AIS data format required is a traffic “heatmap”
    - cumulative vessel traffic in an area over a given period of time

Problem: Datasets are immense

- Typically 10s of billions of raw messages per year
- Processing these big data limited by standard infrastructure and computing power
- AIS data is currently being processed in small temporal or spatial subsets
AIS PAC modified and improved a prototype workflow in order to scale it to larger datasets
- By use of larger compute clusters

AIS PAC focused on a 5-year record for the entire U.S. Arctic EEZ
- Bering Sea north of the Aleutians to the Eastern Beaufort
AIS PAC: Methods:
The Data – Marine Exchange of Alaska

- The MXAK maintains the only terrestrial AIS network in Alaska
  - Over 100 AIS receivers statewide
  - 48 in the Arctic

- MXAK also maintains an Arctic-specific vessel catalog, which has been quality-checked for valid vessel categories

AIS PAC Dataset
- 2013 - 2017
- 1.4 billion raw messages
- 131 GB uncompressed data
AIS PAC: Methods – Raw AIS Messages

- **MXAK AIS Messages** are collected by land-based receivers
  - MXAK aggregates messages, and provides them as a database
  - Each message includes: timestamp, ship MMSI, latitude, longitude, speed over ground, etc.

- **Vessel Catalogs (AVIS)**
  - Maps MMSI to vessel attributes
  - Ship type, max draft, length, etc

- **Possible data issues**
  - Duplicate data due to range overlap
  - Self-reported data errors

Other issues like transmission range limitations, need to be understood while analyzing data.
AIS PAC: Vetting Raw AIS Data

- Raw AIS Data transmitted by thousands of vessels were inaccurate or incomplete
- Compared information transmitted by vessels to international data bases and identified errors or missing information
- Ensured the data used in the study was accurate

<table>
<thead>
<tr>
<th>MMSI</th>
<th>NAME</th>
<th>LENGTH (m)</th>
<th>BEAM (m)</th>
<th>DRAFT (m)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>338117119</td>
<td>HELENKA B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Cargo Ship</td>
</tr>
<tr>
<td>338117119</td>
<td>HELENKA B</td>
<td>46.6</td>
<td>10.2</td>
<td>3.3</td>
<td>Cargo ship</td>
</tr>
<tr>
<td>355557000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Undefined</td>
</tr>
<tr>
<td>355557000</td>
<td>SUZAKU</td>
<td>189</td>
<td>32</td>
<td>11</td>
<td>Cargo Vessel</td>
</tr>
<tr>
<td>367141000</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>367141000</td>
<td>AIVIQ</td>
<td>109</td>
<td>24</td>
<td>8</td>
<td>OSV</td>
</tr>
<tr>
<td>367122000</td>
<td>R/V OCEAN STARR</td>
<td>56</td>
<td>12</td>
<td>4</td>
<td>WIG</td>
</tr>
<tr>
<td>367122000</td>
<td>R/V OCEAN STARR</td>
<td>56</td>
<td>12</td>
<td>4</td>
<td>Research Vsl</td>
</tr>
</tbody>
</table>
AIS PAC: Methods – What is a compute cluster?

Traditional data storage and processing techniques are insufficient to deal with “Big AIS data”

We use a compute cluster built on top of an open-source engine for large scale processing.

HPC clusters are the modern version of a super-computer
AIS PAC: Methods – NOAA’s Hydrographic Health Model

- The Hydrographic Health Model uses input metrics like:
  - When was this area last surveyed?
  - What is the seafloor complexity rating?
  - What is the typical vessel traffic in this area?

- AIS data is one input, but an important one for this model
- Focus is on ships that are moving and in U.S. waters
- Data need to be split out by ship type, metric, and region
  - Tanker, Cargo, Passenger, Other, and All ships
  - Total Vessel Count and Unique Vessel Count
- 500 m resolution
- Albers Equal Area projections minimize distortions
AIS PAC: Methods – The Workflow

AIS data are not processed in a single step; instead, the analysis takes place over several stages in a pipeline, or what we call a workflow.

ADVANTAGES OF THIS APPROACH:
• The entire process does not have to be re-run to redo the analysis at a single stage.
• It can provide the result of individual stages as their own data product.
• We can quickly fix bugs, tweak our algorithm, or filter the data in specific ways to generate custom data products.

• SEE http://ais.axds.co/ for more details on methods and approach
## AIS PAC: Methods – Time to process

<table>
<thead>
<tr>
<th>MXAK Arctic Dataset, 5 Years 2013-2017</th>
<th>Time to Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,394,801,013 messages (131 GB)</td>
<td>Input</td>
</tr>
<tr>
<td>146,759,770 pings (10.5% of raw messages)</td>
<td>1 hour</td>
</tr>
<tr>
<td>753,339 voyages (~ length 57 pings)</td>
<td>1.3 hours</td>
</tr>
<tr>
<td>50 heatmap files</td>
<td>1.5 hours</td>
</tr>
<tr>
<td><strong>Overall Computation Time</strong></td>
<td><strong>3.8 hours</strong></td>
</tr>
<tr>
<td></td>
<td>~45 mins/year</td>
</tr>
</tbody>
</table>

- **Raw AIS Messages**
- **Vessel Pings**
- **Daily Voyages**
- **Vessel Traffic**
- **Heatmaps**

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ADAC: Research for the Arctic Operator... For Today and For the Future
### AIS PAC: Methods – How Does This Scale Up?

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>74,212,891,806 messages (7.5 TB)</td>
<td>Input</td>
</tr>
<tr>
<td>2,017,535,550 pings (2.72% of raw messages)</td>
<td>40.7 hours</td>
</tr>
<tr>
<td>12,297,024 voyages (~ length 51 pings)</td>
<td>3.2 hour</td>
</tr>
<tr>
<td>30 heatmap files</td>
<td>1.5 hours</td>
</tr>
<tr>
<td><strong>Overall Computation Time</strong></td>
<td><strong>45.4 hours</strong></td>
</tr>
</tbody>
</table>
**AIS PAC: Current Year Metrics**

**MEMORANDUM FOR:** Dr. Carol Jamzen (AOOS)  
AIS for Prioritizing Arctic Charting Project Team Lead

**FROM:** Patrick Keown  
Geospatial Data Manager, NOAA Office of Coast Survey

**SUBJECT:** Effectiveness of AIS for Prioritizing Arctic Charting Data Products

28 March 2019

Following delivery of data products to NOAA’s Office of Coast Survey by Axiom Data Science (Axiom) and the Alaska Ocean Observing System (AOOS) as part of the Arctic Domain Awareness Center (ADAC) project, *AIS for Prioritizing Arctic Charting* Coast Survey has effectively integrated these AIS data into the “Hydro-Health” prioritization model.

AIS data provided by this ADAC project increased Coast Survey’s ability to understand arctic vessel traffic for the purposes of establishing hydrographic survey priorities as well as defining charting requirements. These data have been integrated into the Hydro-Health model and will aid future surveying and charting efforts.

Coast Survey greatly appreciates the assistance of ADAC, AOOS, and Axiom to create products that inform decision-making about vessel traffic and safety in the rapidly changing Arctic environment.

**METRICS:**

1. Deliver processed, quality controlled, and formatted data to NOAA OCS office for use in the Hydrographic Health model.
   - Success: 100% data processed and transferred to NOAA
2. Document and curate AIS metadata.
   - Success: 100% curated AIS metadata, AIS Data Portal
3. 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.
   - Success is 100% documentation;
   - Cliffnotes at AIS Vessel Traffic Data Products Webpage
   - Full description on methods available in a paper currently in review for publication.
AIS PAC: Key Accomplishments – AIS Vessel Traffic Data Products Webpage (https://ais.axds.co/)

AIS Vessel Traffic Data

The Automatic Identification System (AIS) is a system of on-board broadcast and recorded. AIS operates in the VHF frequency band and is used to provide dynamic vessel traffic data. The data is transmitted using an Automatic Identification System (AIS) transponder and can be used by Hydrographic organizations to look at trends in traffic flow.

Step 4. Vessel Traffic Heatmaps

To generate a heatmap, we divide the given region into a grid, then count the number of voyage crossings through each grid cell. Cell size is configurable, but by default is 500 meters. The exact projection will vary based on region, but an equal-area projection is always used. Once generated, this heatmap grid can be exported as GeoTIFF or NetCDF.

Heatmaps are generated by overlaying a grid and then counting the voyage crossings in each grid cell.

Heatmap Metrics

- **Heatmap Generation**: The heatmap is generated by dividing the region into a grid and counting the number of voyage crossings in each grid cell.
- **Heatmap Export**: The heatmap grid can be exported as GeoTIFF or NetCDF files.
- **Heatmap Analysis**: The heatmap can be used to analyze trends in vessel traffic flow.
AIS PAC: Progress on Metrics

Second principle goal of the project
• Derive additional AIS data products that can be made publicly available through a value-added, intuitive and user-driven web-based tool/data portal.

METRICS:
1. Gather PI, stakeholder and Steering Committee feedback on data products and increase use-competency of the developing tool.
   • Success: Delivery of a stakeholder driven webpage/data portal options.
2. Public access to the curated AIS data and the user-tool, made possible through the AOOS data system and AIS PAC webpage/data portal.
   • Success: AIS PAC webpage/data portal published
3. Present vessel traffic data products to 50 or more decision-makers and make these products available in a web-based platform for public access.
   • Spring 2018 - AIS PAC Steering Committee meeting (Mar’18); AGU Ocean Sciences Conference (Feb’18); IPCOMM meeting (Apr’18).
   • Nov 9 ‘18 Workshop (7 + project team)
   • Nov 15 ‘2018 Workshop (10 + project team)
AIS PAC: Key Accomplishments – Project Webpage

Background

The U.S. Arctic is experiencing significant changes vastly recognized by both Alaska coastal communities and regulatory agencies across the region. Including the U.S. Coast Guard, September 2019 experienced the third lowest sea ice volume on record for the month of September (2012 is the lowest), and the spring of 2019 experienced the lowest sea ice extent off Western Alaska despite a more than 100% point of record breaking. Sea ice coverage has decreased to the point that existing northern shipping lanes around the world are open for longer periods of time and are projected to experience a continued increase in marine vessel traffic (Arctic Council, 2019). In recognizing a large area of historically ice covered Arctic waters has rapidly evolved into a new maritime frontier, it is important the scales where deep draft vessels are starting to see are expanded to modern day standards. A maritime casualty in the Arctic, which extends from the southern Bering Sea all the way into international waters of the Arctic Ocean, has few infrastructure support resources, creates for greater risk of loss of life and environmental harm to marine casualties in most other maritime regions, where there are more resources available, less harsh weather conditions and more resilient and less pristine environments.

The Data

The Marine Exchange of Alaska (MEAK) currently operates 46 terrestrial AIS stations in the Arctic, receiving over 3 million messages per day.

Expected Data Products

The primary data product will be a consistently formatted synthesized end quality controlled AIS dataset, that can then be directly utilized by NOAA to help prioritize where modern bathymetric surveys need to occur for this rapidly changing region. The data product and affiliated web tools for visualizing the data will benefit other stakeholders interested in shipping trends in the Arctic.
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AIS PAC: Key Accomplishments – Project Data Portal
32 Data Sets Currently Available in the Catalog

AIS Vessel Traffic Data – Alaska-MXAK AK Terrest. – Monthly Totals
AIS Vessel Traffic Data – Alaska – MXAK AK Terrest. – Yearly Totals

Marine Habitats and Sensitive Biological areas
Example:
Pacific Walrus Coastal Haul-out DB 1852-2016

Community level socioeconomic and subsistence information
Example:
Oil spill risk to subsistence communities Kaktovik, Nuiqsut and Utqiagvik

Shipping and Transportation
Example:
Arctic Marine Shipping Assessment

Governmental boundaries
Examples:
Maritime Limits and Boundaries

Bathymetry information
Example:
International Bathymetric Chart of the Arctic

Weather
Old weather forecasts from 2012-2017

Ocean
Example:
NSIDC Sea Ice Concentration

ADAC Program Year 5 Annual Meeting 11-12 April 2019
AIS PAC: Key Accomplishments – Feedback Quotes

March 2018
Leland Snyder, NOAA Charting Office
“Having the ability to get data in a consistent format at various levels of preprocessing (Uniform Schema) and having a set of uniform tools to handle data will help a lot. “

LT. Bart Bueseller, NOAA Nav Manager Region 10 - AK
“...Alaskan Eskimo Whaling Commission ... I heard a comment regarding lack of knowledge of vessel traffic in the “back yards” of these native communities...if we create an outward facing way to show what kind of traffic is taking place in the Arctic, I think these communities would be very happy to see that.”

November 2018
CDR Jennifer Konon, USCG
“The ability to display and download AIS vessel traffic data, parsed by general categories (cargo, passenger, tanker, etc.) is very useful for planning the placement of resources such as cutters, aircraft, and people, etc. “
“It is helpful that the data itself is described in detail, with extensive documentation. This enables us to understand the characteristics of the data we are using.”
AIS PAC: Summary of Planned and Completed Research Outcomes

- Delivered quality controlled, 5-year record of AIS data for the U.S. Arctic in an application-ready format for prioritizing bathymetric surveys using the NOAA-OCS Hydrographic Health Model
  - Geotiffs are a knowledge product, utilized by NOAA for planning where to conduct surveys

- Completed AOOS hosted AIS PAC Project webpage and Data Portal

- Provided AIS data product demonstrations covering methods and data portal use to targeted customers, including the U.S. Coast Guard in Alaska and the AIS PAC project Steering Committee
AIS PAC: Other Key Accomplishments

• Developed capability to reduce execution time for handling and analyzing exceptionally large collections of AIS data - a large data analytics effort, which benefits future regional AIS data projects.

Going Forward:
• We are providing continued access to a dedicated AIS PAC data portal where future Arctic AIS data can be ingested, downloaded and/or evaluated using mapping tools on a the AOOS data system.
• Data are now available to inform decision-making about vessel traffic and safety for other stakeholders and the public.
AIS PAC: Example – Data catalog allows data layering with up to 32 different data products using 9 different map types

Yearly total vessel count – tankers for 2017, overplotted with Alaska OCS Wells and The Alaska maritime limits and boundaries.
AIS PAC: Examples - Data layering allows for quick view of data and analysis against other data of interest.

Observed sea ice concentration for June 24, 2013 and monthly total vessel count - other vessels June 2013.
AIS PAC: Examples – A variety of data to compare with AIS data, including ocean observational information that can be used for emergency response planning.

HF Radar surface currents for August 9, 2017 over-plotted with August 2017 monthly total passenger vessels in the region.
AIS PAC: Transition Plan – Project Leveraging

The investment in this foundational project will also be leveraged to:

- Improve efficiency in vetting, processing and analyzing AIS data that can be used for new research
- Improve access to types of AIS information most useful to stakeholders (vessel category queries)
- Make this information visually accessible to those who need it
- Expand capacity nationwide for AIS data handling for similar projects
  - We have applied techniques already to even larger AIS datasets
- Help identify where the AIS system needs improvement, which could be used to guide USCG efforts at implementation processes and requirements
AIS PAC: Transition Plan

Application-ready geotiffs describing AIS vessel densities delivered to NOAA for use in the NOAA-OCS Hydrographic Health Model

The Alaska Ocean Observing System (AOOS) being a regional association of the NOAA funded Integrated Ocean Observing System (IOOS) is the transition target for the raw and processed AIS data
- The AOOS data system can house and display data in the most efficient and robust manner at this time

Links available for other websites

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
AIS PAC: EXAMPLE: Integrated data products describing vessel traffic patterns, estimated oil spill impacts, and subsistence use data from the communities of Utqiagvik (formerly Barrow), Nuiqsut, and Kaktovik along the Beaufort Sea coast.
AIS PAC: Transition Plan – Future Activities?

“We would definitely use this tool if it continues to ingest recent AIS data (doesn’t stop at 2017).”

- Update Arctic AIS database annually to maintain momentum with this important project
  - Additional support will be required to make regular updates to the database
  - Recommend extending data to incorporate Satellite data, for offshore reach
- As new products, data classifications and queries are continuing to be developed inhouse or by user requests, with plan to make products available on the AIS PAC Data Portal
AIS PAC: Future Data Product Development

Monthly Voyage Count within ROI

- Other
- Tanker
- Passenger
- Cargo
AIS PAC: WEBLINKS

- AIS PAC webpage:  
  https://www.aoos.org/ais-4-bathy/

- Data portal:  
  https://pac.portal.aoos.org
  - Map data alongside other datasets and various mapping options
  - Download data as NetCDF
  - WMS, NCSS, OpenDAP access

- Vessel Traffic Vessel Products website:  
  http://ais.axds.co
  - Details on process and methods, preview other AIS datasets, other data sources available here for download
Ready for questions

Mary Island Marine Exchange of Alaska AIS Installation
AIS PAC: Description and Baseline

Project Goal

To aid the U.S. Coast Guard 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 that will better inform the prioritization of areas in the U.S. Arctic Exclusive Economic Zone (EEZ) for bathymetric surveying.
AIS PAC: Relevance

- Much of the Arctic remains uncharted or has low resolution bathymetry, and often, these data are outdated sometimes dating back centuries

- This impedes a NOAA and U.S. Coast Guard priority, which is Incident prevention in the Arctic

- The recent Arctic Domain Awareness Center (ADAC) Arctic IoNS workshop recommended improved awareness and understanding of nearshore bathymetry across the Arctic, in particular the North American Arctic, to improve maritime domain awareness and safety in the Arctic

- This project aims to make vessel tracking information from the Automated Information System (AIS) available for use by NOAA and the U.S. Coast Guard to help prioritize charting efforts and route planning for the Arctic

- The outcomes will provide the needed data products for these efforts, and will also provide tools to process large AIS datasets going forward
AIS PAC: Methods

Traditional data storage and processing techniques are insufficient to deal with “Big AIS data”

APACHE SPARK:
Open-source engine for large-scale data processing

GeoTrellis:
Distributed spatial processing

Alluxio:
Stores frequently used data in memory for quickly access

Gluster FS:
Distributed file storage

Master

16 computers
368 total cores
1500 GB available memory (RAM)

Data Analysis Applications

GIS-enabled Spark Cluster

Geo-spatial framework

In-memory virtual storage

AIS Vessel Tracking Dataset

GlusterFS

Distributed file system

ALLUXIO

Distributed spatial processing

ADAC: Research for the Arctic Operator... For Today and For the Future
AIS PAC: Methods – Hydrographic Health Model

- The Hydrographic Health Model establishes survey priorities across all U.S. waters
  - Managed by NOAA Office of Coast Survey (OCS)
  - Includes input metrics like: When was this area last surveyed? What is the seafloor complexity? What is the typical vessel traffic in this area? etc
- AIS data is one input, but an important one for this model
- Focus is on ships that are moving and that are in U.S. waters
- Data need to be split out by ship type, metric, and region
  - Tanker, Cargo, Passenger, Other, and All ships
  - Total Vessel Count and Unique Vessel Count
- 500 m resolution - Albers Equal Area
AIS PAC: Vessel Classifications - To simplify resulting data products, Vessel Service is grouped into four broad categories: Passenger, Tanker, Cargo, and Other

**Passenger**
- Passenger (Inspected and Uninspected)
- Passenger Barge (Inspected and Uninspected)

**Tanker**
- Public Tankship/Barge
- Tank Barge
- Tank Ship

**Cargo**
- Freight Barge
- Freight Ship
- Industrial Vessel
- Public Freight

**Other**
- Commercial Fishing Vessel
- Fish Processing Vessel
- Mobile Offshore Drilling Unit
- Offshore Supply Vessel
- Oil Recovery
- Public Vessel
- Recreational
- Research Vessel
- SAR Aircraft
- School Ship
- Towing Vessel
- NON-VESSEL
- Unclassified
### AIS PAC: Current Year Schedule and Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Status: Ahead, On Time, Behind</th>
<th>Y5-Q1 Sep 18</th>
<th>Y5-Q2 Dec 18</th>
<th>Progress</th>
<th>Why not Reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convene Steering Committee Meetings</td>
<td></td>
<td></td>
<td>X</td>
<td>Complete: Steering Committee and Project Champion updated regularly with quarterly reports. Invitations sent to SC, PC, and stakeholders for Nov 9’18 workshop/webinar in Anchorage, and Nov 15’18 Juneau workshop.</td>
<td>Scheduling the 2nd steering committee in summer not possible.</td>
</tr>
<tr>
<td>Prepare and quality review AIS data; fix unresolved issues:</td>
<td>X</td>
<td></td>
<td></td>
<td>Ahead: Completed Y1-Q3. All issues resolved</td>
<td>NA</td>
</tr>
<tr>
<td>Transfer AIS Data</td>
<td>X</td>
<td></td>
<td></td>
<td>Ahead: Completed Y1-Q3</td>
<td>NA</td>
</tr>
<tr>
<td>Implement Cluster parallelization of US Arctic EEZ AIS data</td>
<td>X</td>
<td>X</td>
<td></td>
<td>On Time: Data processing pipeline operationalized and applied to other large AIS data sets successfully.</td>
<td>NA</td>
</tr>
</tbody>
</table>

ADAC: Research for the Arctic Operator... For Today and For the Future
# AIS PAC: Current Year Schedule and Milestones (contin)

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Y5-Q1 Sep 18</th>
<th>Y5-Q2 Dec 18</th>
<th>Progress</th>
<th>Why not Reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate vessel density outputs/products to Steering Committee (SC)</td>
<td>X</td>
<td>X</td>
<td>On Time: Project updates &amp; Quarterly Reports shared with PC; link to Project webpage/data portal sent to PC and SC for feedback Oct 3’18</td>
<td>NA</td>
</tr>
<tr>
<td>Develop interactive web-based tool</td>
<td>X</td>
<td></td>
<td>Ahead: AIS products page public Mar ’18; Project webpage/data portal developed Jul-Aug ‘18; shared with ADAC (Church) Sep ‘18. Provided two workshops Nov 9 &amp; 15, ‘18; Public launch TBC Dec ‘18</td>
<td>NA</td>
</tr>
<tr>
<td>Deliver final data products to NOAA OCS</td>
<td>X</td>
<td></td>
<td>Ahead: Transfer of 5-year vetted/ formatted AIS records to NOAA OCS complete Y1-Q4</td>
<td>NA</td>
</tr>
</tbody>
</table>
## AIS PAC: Current Year Schedule and Milestones (contin)

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Y5-Q1 Sep 18</th>
<th>Y5-Q2 Dec 18</th>
<th>Progress</th>
<th>Why not Reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide data available to public on AOOS and ADAC websites</td>
<td>X</td>
<td></td>
<td>Ahead: Data products available on AOOS Data Portal; Oct 3’18 project webpage/data portal in review, To Be Completed by Dec’18</td>
<td>NA</td>
</tr>
<tr>
<td>Host Workshops/webinars to train and share tool functionality – Anchorage and Juneau</td>
<td>X</td>
<td></td>
<td>On Time: Convened two 1/3 day workshops in Anchorage (with webinar) Nov 9, and Juneau, Nov 15,’18. Total participants: 17 no including Project Team, Mostly from USCG, NOAA.</td>
<td>NA</td>
</tr>
</tbody>
</table>
AIS PAC: Key Accomplishments – Project Steering Committee and Stakeholder Feedback Meeting
March 2018

AIS PAC Steering Committee:
- Dr. Jon Berkson (U.S. Coast Guard (USCG) Head Quarters; ADAC Project Champion)
- Lt. Bart Buesseler (NOAA Alaska Region, Navigation Manager)
- Patrick Keown (Geospatial Data Manager Coast Survey Development Lab (CSDL), Office of Coast Survey (OCS), NOAA)
- Paul Webb (USCG, CIV, District 17 – Juneau, AK)
- Dr. Guillermo Auad (Senior Advisor and Ocean Coordinator, Bureau of Ocean Energy Management)
- Randy “Church” Kee (Major General, U.S. Air Force (Retired), Executive Director ADAC)

Additional Stakeholder Participants:
- Lt. Matt Forney, OMAO/DOD/Interagency Liaison, OCS, NOAA
- Leland Sneider, NOAA Geographer
- Frank Parker, USCG Office of Nav. Systems
- John Hauman, NGA (National Geospatial-Intelligence Agency)
- Christina Fandel, Office of Coast Survey (OCS), NOAA
AIS PAC: Methods

Raw AIS Messages -> Vessel Pings -> Daily Vessel Voyages -> Segment Vessel Voyages -> Vessel Traffic Heatmaps

Raw Messages are parsed and cleaned up

Vessel Pings -> Voyages: At least two pings long, broken up if the points are too sparse, broken up if the ship stopped in one place for a long time, then started again (ferries for example)

Voyages get filtered (ship classification, region, time frame, other metrics)

Divide region into a grid, then count crossings -> Heatmaps
AIS PAC: Methods - Raw Messages to Vessel Pings

- Marine Exchange provided a fully quality controlled data record for this project.
- We further parse and clean the messages
  - Discard invalid messages
  - Discard any messages that are not Class A Position Reports
  - Remove duplicate messages
- Result is called a Vessel Ping

**MXAK Arctic Data**
- Input: 1,394,801,013 raw messages 131GB uncomp
- Output: 146,759,770 pings (10.5% of raw messages)
- Total time: 59 Minutes (~ 11.8 min/year or 2 secs/day)

**2015 Terrestrial US**
- Regions: Continental US, Alaska, Hawaii
- Input: 74,212,891,806 raw messages 7.5TB uncomp
- Output: 2,017,535,550 pings (2.72% of raw messages)
- Total time: 40.7 hrs (~6.7 min/day)
AIS PAC: Methods – Vessel Pings to Vessel Voyages

- **Vessel Voyages** describe the probable path of a ship
- **Voyages are:**
  - At least two *pings* long
  - Broken up if the points are too sparse
  - Broken up if the ship stopped in one place for a long time, then started again
    - This accounts for ferries or tugboats for example)

**MXAK Arctic Dataset**
- Input: 146,759,770 pings
- **Output:** 753,339 voyages
  - Avg length: 57 pings
  - Total time: 77 mins (~15 mins/year)

**2015 Terrestrial US EEZ**
- Input: 2,017,535,550 pings
- **Output:** 12,297,024 voyages
  - Avg length: 51 pings
    - (~31% of pings used)
  - Total time: 3.2 hrs (~31 sec/day)
AIS PAC: Methods – Vessel Pings to Vessel Voyages

Algorithm for generating vessel voyages

Diagram:
- Current ping
- Is it the ship's first ping?
  - YES: Keep (new voyage)
  - NO: Calculate speed
    - sog_given = sog listed in the NMEA message (or 0 if sog is null in the message)
    - sog_calc = distance_since_last_ping / time_since_last_ping
    - Is sog_calc > 18 m/s?
      - NO: Is sog_given > 0.3 m/s?
        - NO: Has it been more than 60km since the last ping?
          - YES: Keep (new voyage)
          - NO: Has it been less than 100m AND more than 10min since the ship last moved?
            - YES: Keep (new voyage)
            - NO: In other words, has the ship paused? If it has, we want to start a new voyage (brrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr
AIS PAC: Methods – Segment or Filtered Vessel Voyages

- Join to Vessel Catalog by ship identifier (MMSI)
- Segment data by
  - Region
  - Ship Type
  - Metrics (Vessel count type)
  - Time Frame (monthly, yearly)
- Ship Type Classifications
  - Tanker, Cargo, Passenger, Other
  - This categorization comes from NOAA OCS Hydrographic Health Model
  - This is configurable: we can generate heatmaps for other categories!

**MXAK Arctic Dataset**
- 50 total files
- 5 Ship types: Tanker, Cargo, Passenger, Other, All ships
- 2 Metrics: Total vessel count, Unique Vessel Count

**2015 Terrestrial US EEZ**
- 30 total files
- 5 Ship Types: Tanker, Cargo, Passenger, Other, All ships
- 2 Metrics: Total Vessel Count and Unique Vessel Count
AIS PAC: Methods – Vessel Traffic Heatmaps

- Divide region into a grid, then count crossings
- Heatmap format is configurable
  - GeoTIFF or NetCDF
  - Arbitrary grid size; default is 500 meters
  - Choice of Albers Equal Area projection
- Possible metrics
  - Total traffic volume
    - Total number of intersections between daily vessel voyages and heatmap grid cell.
  - Unique vessel count
    - Number of unique vessel intersections with each grid cell
    - If vessel passes a cell more than once/day, only counted once
AIS PAC: Examples – A variety of data to compare with AIS data, including local community subsistence use information can be utilized for risk assessments on resources.

Relative subsistence harvest intensity map for Bowhead whales, for September with monthly total vessel count – other vessels September 2017.
AIS PAC: Methods – Vessel Traffic Heatmaps

**MXAK Arctic Dataset**
- Input: 753,339 voyages
- Output: 50 heatmap files
- Total time: 92 minutes
  (Includes filtering and creating heatmaps)

**2015 Terrestrial US EEZ**
- Input: 12,297,024 voyages
- Output: 30 heatmap files
- Total time: 90 minutes
  (Includes filtering and creating heatmaps)

**OVERALL COMPUTATION TIME:**
- **MXAK Arctic Dataset:** 3.8 hrs
  (avg of 45 mins per year)
- **2015 Terrestrial US EEZ:** 45.4 hrs

**UPSHOT:** Once we get to the point where we're filtering voyages and creating heatmaps, we can create those results in a matter of minutes to hours.