ARCTIC DOMAIN AWARENESS CENTER
A DEPARTMENT OF HOMELAND SECURITY CENTER OF EXCELLENCE

ADAC Year 7 Annual Meeting

...Via Conference Call, 2-3 June 2021

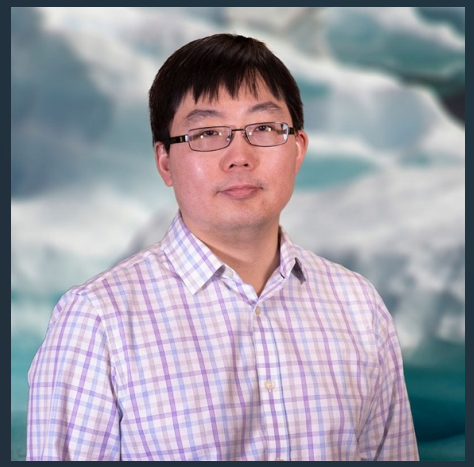
ADAC Project Briefing

Arctic Ice Condition Index

A presentation by

Jifeng Peng, University of Alaska Anchorage
Shawn Butler, University of Alaska Anchorage
JinIun Zhang, University of Washington
Kelsey Frazier, University of Alaska Anchorage

ADAC Project: Arctic Ice Conditions Index (ARCTICE)




Project team

- Dr. Jifeng Peng, University of Alaska Anchorage
- Dr. Shawn Butler, University of Alaska Anchorage
- Dr. Jinlun Zhang, University of Washington
- Kelsey Frazier, University of Alaska Anchorage

ADAC Project: Arctic Ice Conditions Index (ARCTICE)

Project Champions

- CDR Christopher Tuckey, CG-WWM

Project Support

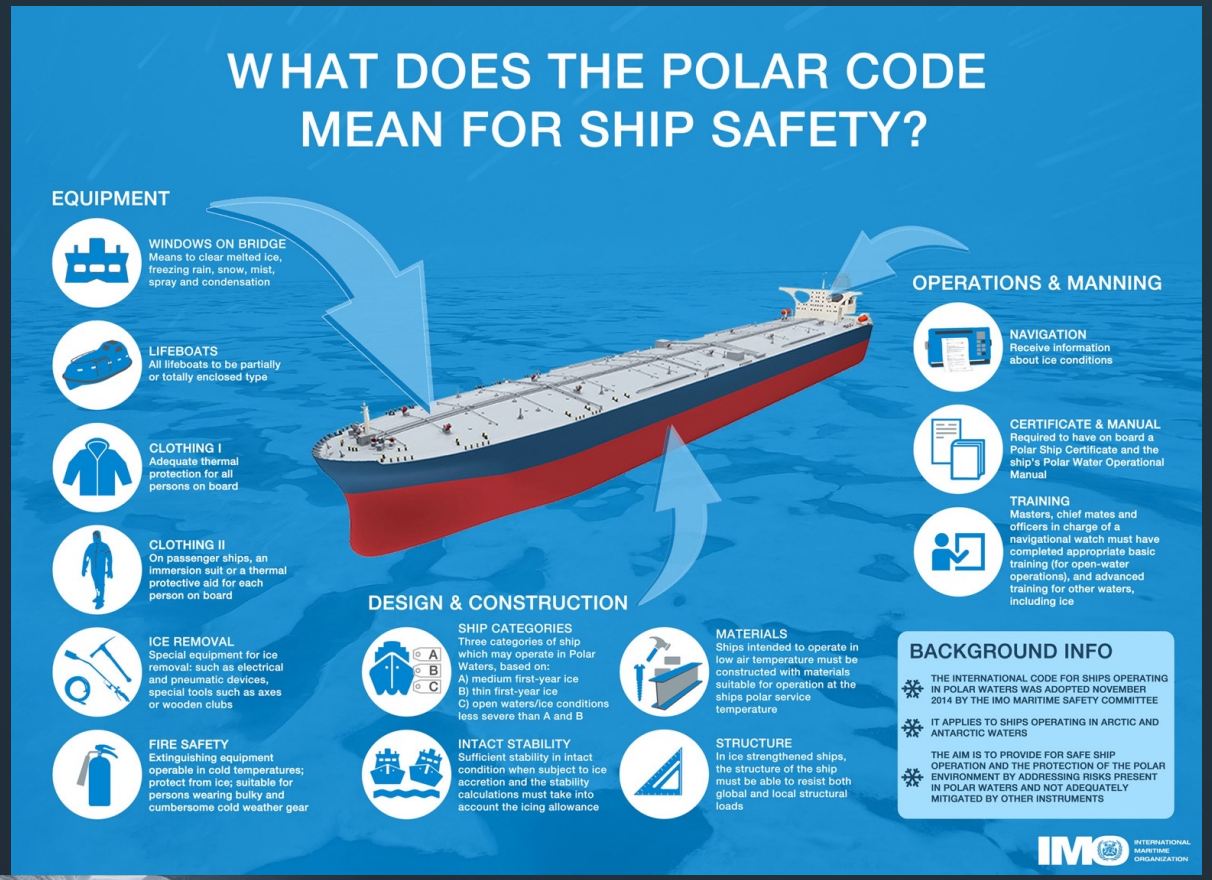
- Karin Messenger, CG RDC
- Sam Cheung, CG, RDC

Project Collaborators

- Jonathan Edwards-Opperman, NIC
- Capt. (Ret) Phillip Thorne, CG D17
- Axiom Data Science

Arctic Ice Conditions Index (ARCTICE)

Description and Baseline

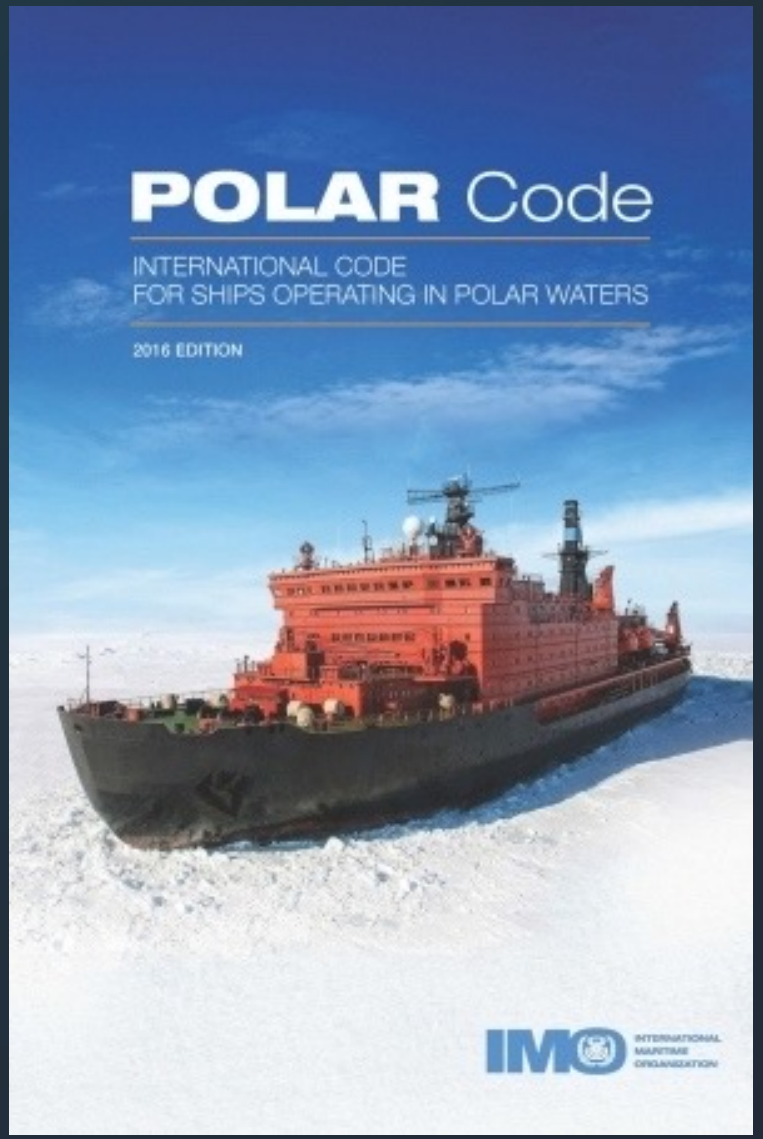


- Leveraging team and research skills which developed Great Lakes ICECON, project ARCTICE will develop a high-resolution ice condition index for U.S. Arctic Maritime Exclusive Economic Zone (EEZ), including Bering, Chukchi and Beaufort Sea regions
- *ARCTICE* produces an easy-to-understand numeral to communicate ice conditions that are relevant to the capabilities of an individual vessel. This index will be available for current and future ice conditions, providing forecasts up to 1 month in advance
- *ARCTICE* supports vessel captains and officers in route planning and determining associated risk for traveling through a region of Arctic water

Arctic Ice Conditions Index (ARCTICE)

Description and Baseline

- Historically many Arctic nations use their own methods for communicating ice conditions. Following the addition of the “POLARIS amendment” to the International Maritime Organization (IMO) Polar Code, communication tools on ice conditions started to migrate to a uniform methodology.
- The POLARIS amendment to the IMO Polar Code is based on vetted ice condition processes from the Canadian AIRSS system, the Russian Ice Certificate concept, and additional inputs from other coastal administrators.
- While the IMO has no existing or planned international enforcement privileges, the IMO Polar Code is seen as a “best practices” guide, many nations require that vessels comply with the Polar Code.



Arctic Ice Conditions Index (ARCTICE)

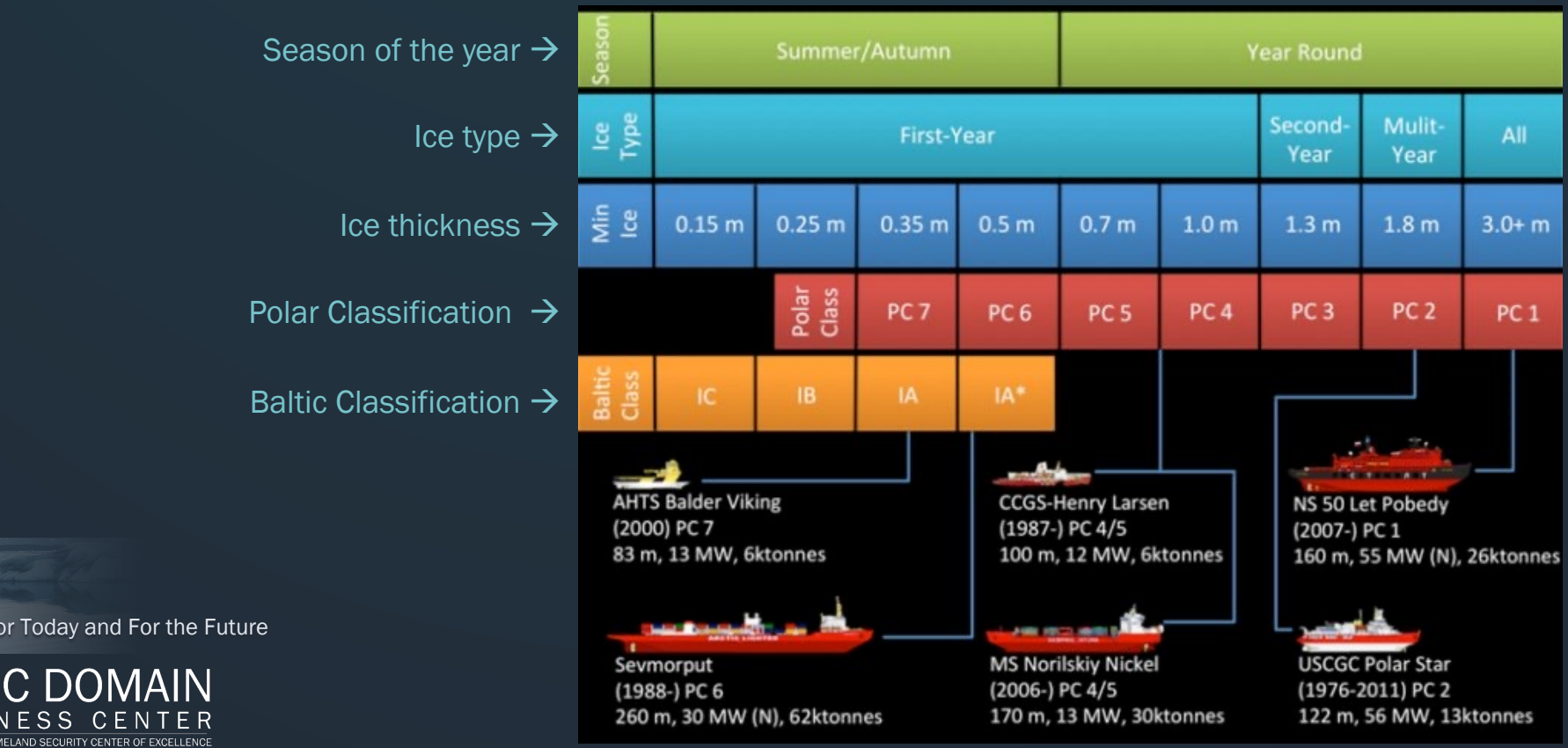
Relevance to DHS and USCG

- Exponential increases in ship traffic through US Arctic EEZ
- Foreign industry is transporting LNG through Chukchi and Bering Sea year round, attracting interest from other companies and nations
- Arctic mariners experience long distances between ports of call, communication shortfalls, increasingly unpredictable weather patters, and limited USCG SAR availability
- Vessels historically have travelled through the ice without knowledge of potential risks from the sea ice, sometimes getting stuck and needing assistance

Arctic Ice Conditions Index (ARCTICE)

Prior Work Completed

1. *Provide and confirm the ARCTICE vessel classification index.* The Polar Code uses the International Association of Classification Society (IACS) Polar Class Unified Requirements and the Finnish-Swedish Ice Class Rules (Baltic Ice Class). The project team has identified the correlation between the Polar Class/Baltic Ice Class and the ABS Ice Class.



Arctic Ice Conditions Index (ARCTICE)

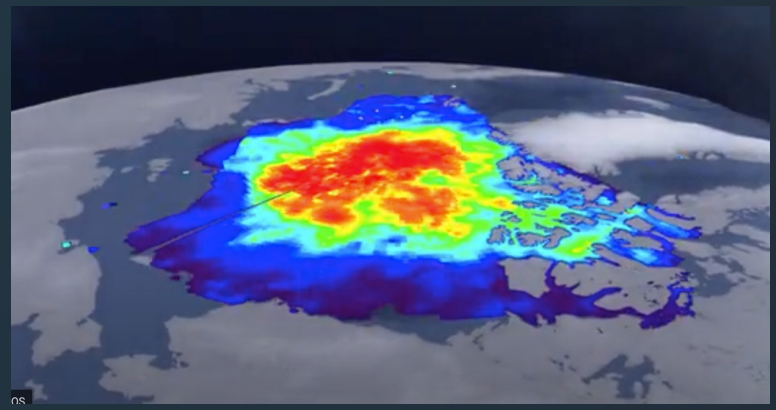
Prior Work Completed

2. *Investigate other national models (in particular, Canadian programs).* The project team has investigated the Arctic Ice Regime Shipping System (AIRSS) as a regulatory standard for ice condition used by the Canadian authority. It is the basis of the POLARIS in the Polar Code and very similar to POLARIS.
3. *Determine suitable environmental factors.* Following Polar Code POLARIS, the project team used ice types and their area fractions (or partial concentrations) as the environmental parameters.

- POLARIS quantifies the ice condition by a "Risk Index Outcome" method (RIO)

$$\mathrm{RIO} = \sum_{i} (C_i \times RV_i)$$

- C_i is the partial concentration of an ice type within the ice regime, and RV_i is the corresponding risk index value for a given ice type and a ship Ice Class



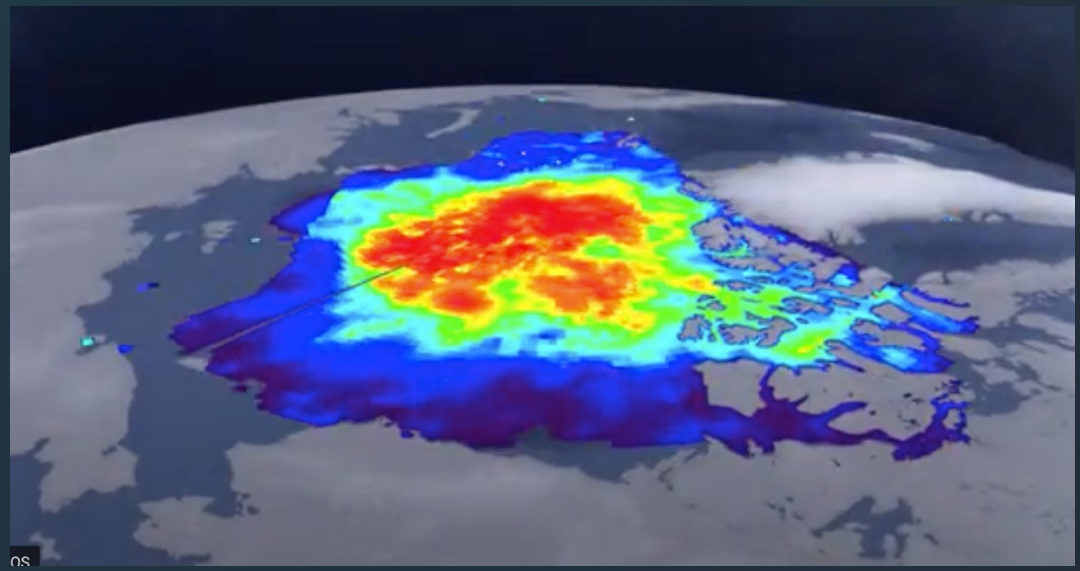
HIOMAS

https://arcticdomainawarenesscenter.org/P08_HIOMAS

Arctic Ice Conditions Index (ARCTICE)

Prior Work Completed

- Environmental inputs come from ADAC's High Resolution Ice-Ocean Modeling and Assimilation System (HIOMAS)
- Selected High-resolution Ice-Ocean Modeling and Assimilation System (HIOMAS) model :
  - ice and ocean current forecast data on high-resolution (1 km) grid for US Arctic EEZ
  - forecast of ice condition up to 1 month
  - spatial distribution of ice motion and thickness
  - the area fraction of thick-ridged or multi-year ice



HIOMAS: https://arcticdomainawarenesscenter.org/P08_HIOMAS

- Updating HIOMAS model:

  In the original HIOMAS, there are 8 ice categories for partial sea ice concentration provided as output;

  The ARCTICE algorithm received these categories, then linear interpolation was employed to calculate the 12 partial sea ice concentrations the Polaris RIO requires;

  To increase the accuracy of ARCTICE, an updated HIOMAS model was established in which the partial sea ice concentration output increased from 8 categories to 24.

Arctic Ice Conditions Index (ARCTICE)

Prior Work Completed

$$\mathrm{RIO} = \sum_{i} (C_i \times RV_i)$$

- C_i is the partial concentration of an ice type within the ice regime, and RV_i is the corresponding risk index value for a given ice type and a ship Ice Class

Increasing Ice Thickness (Severity) →

Decreasing Ice Class ↓

Winter Risk Values (RVs)													
Polar Ship Category	Ice Class	Ice Free –	New Ice 0-10 cm	Grey Ice 10-15 cm	Grey White Ice 15-30 cm	Thin First-year Ice 1st Stage 30-50 cm	Thin First-year Ice 2nd Stage 50-70 cm	Medium First-year Ice 1st Stage 70-95 cm	Medium First-year Ice 2nd Stage 95-120 cm	Thick First-year Ice 120-200 cm	Second-year Ice 120-200 cm	Light Multi-year Ice 250-300 cm	Heavy Multi-year Ice 300+ cm
A	PC 1	3	3	3	3	2	2	2	2	2	2	1	1
	PC 2	3	3	3	3	2	2	2	2	2	1	1	0
	PC 3	3	3	3	3	2	2	2	2	2	1	0	-1
	PC 4	3	3	3	3	2	2	2	2	1	0	-1	-2
	PC 5	3	3	3	3	2	2	1	1	0	-1	-2	-2
B	PC 6	3	2	2	2	2	1	1	0	-1	-2	-3	-3
	PC 7	3	2	2	2	1	1	1	-1	-2	-3	-3	-3
C	IA Super	3	2	2	2	2	1	0	-1	-2	-3	-4	-4
	1A	3	2	2	2	1	0	-1	-2	-3	-4	-4	-4
	1B	3	2	2	1	0	-1	-2	-3	-3	-4	-5	-5
	1C	3	2	1	0	-1	-2	-2	-3	-4	-4	-5	-6
	No Ice Class	3	1	0	-1	-2	-3	-3	-3	-4	-5	-6	-6

Arctic Ice Conditions Index (ARCTICE)

Prior Work Completed

ARCTICE decision thresholds:

- As the RIO value decreases (gets more negative) the risk of significant vessel/ice interactions increases

RIO	Ice Classes PC1-PC7	Ice Class below PC7 or not assigned
RIO ≥ 0	Normal sailing	Normal sailing
-10 ≤ RIO < 0	Elevated sailing risk, proceed sailing with caution	Sailing subject to special consideration (i.e., sailing not recommended)
RIO < -10	Sailing subject to special consideration (i.e., sailing not recommended)	Sailing subject to special consideration (i.e., sailing not recommended)

Arctic Ice Conditions Index (ARCTICE)

Prior Work Completed

4. *Create, then optimize a forecast numeric Arctic ice condition index for Arctic waters.* A computer code has been developed to generate the POLARIS index for various Polar Class vessels.
5. *Investigate suitable access.* Ensuring ease of access to ARCTICE for the Arctic mariner is a particular challenge for this project. Output from the ARCTICE system needs to consider that operators will utilize satellite data for access and bandwidth will be limited. The team discussed with USCG D17 for the most suitable approach to publish the Ice Condition Index for easy access for mariners.

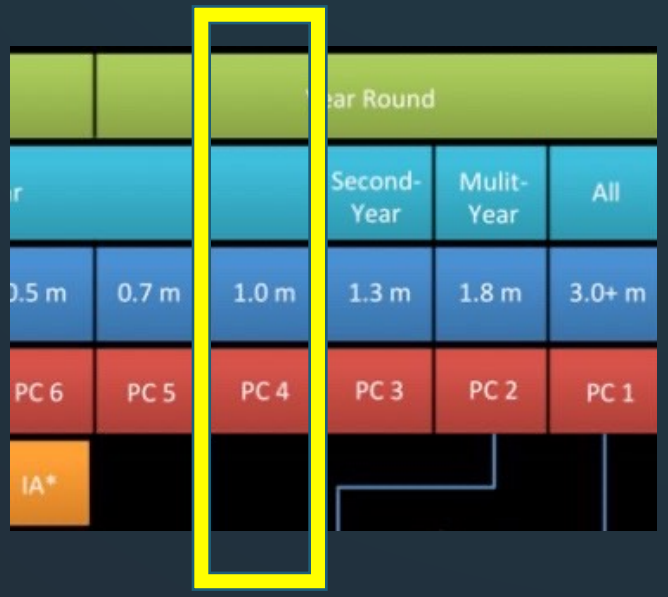
Arctic Ice Conditions Index (ARCTICE)

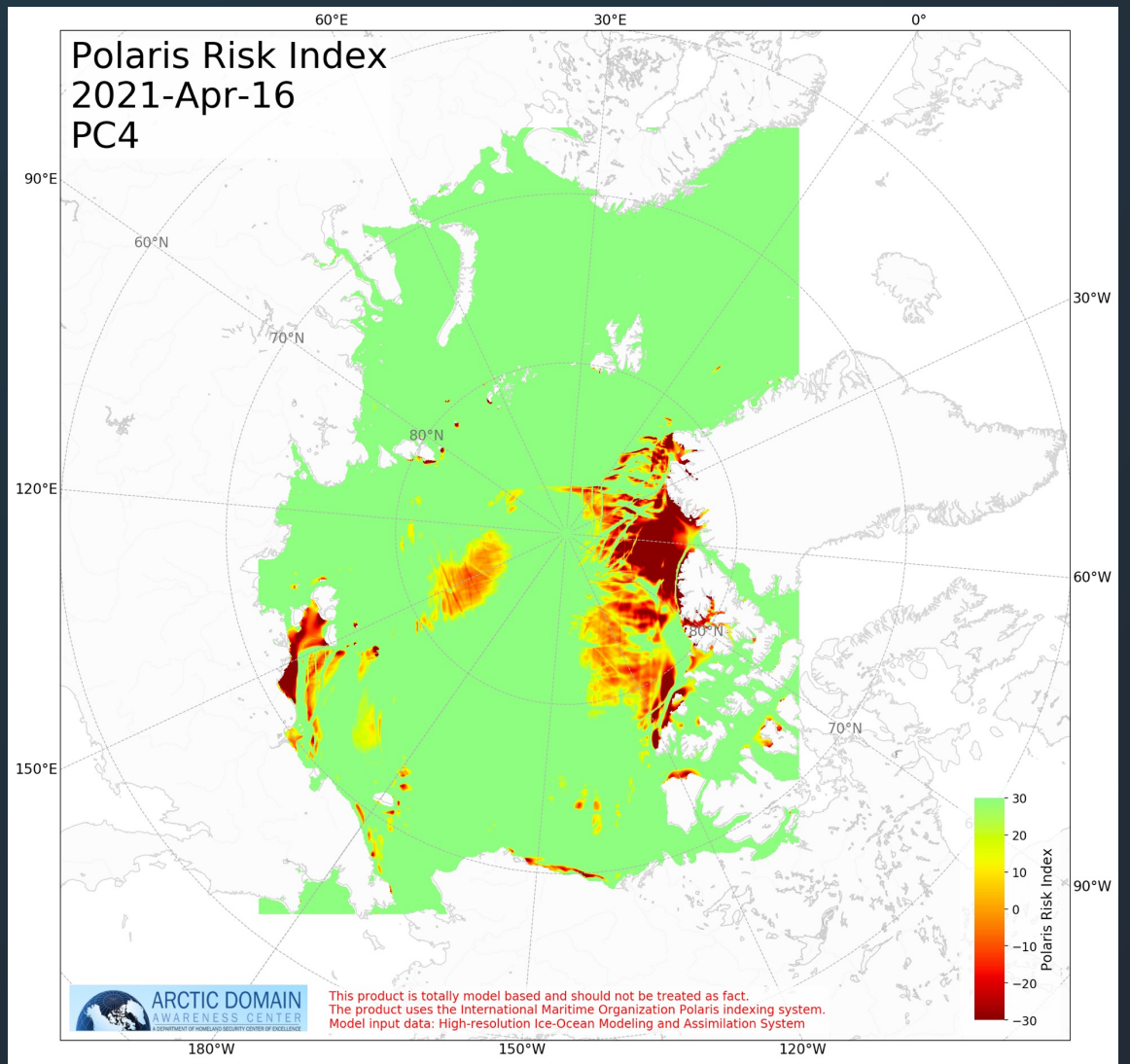
Research Tasks for Year 7

1. Finalize the integration of the index to a visualization tool as an aid to vessel mariner planning and underway activities. COMPLETED
2. Automate a forecast numeric Arctic ice condition index for Arctic waters. COMPLETED
3. Conduct ARCTICE validation. COMPLETED
4. Transition the ARCTICE to an operational destination. COMPLETED

Arctic Ice Conditions Index (ARCTICE)

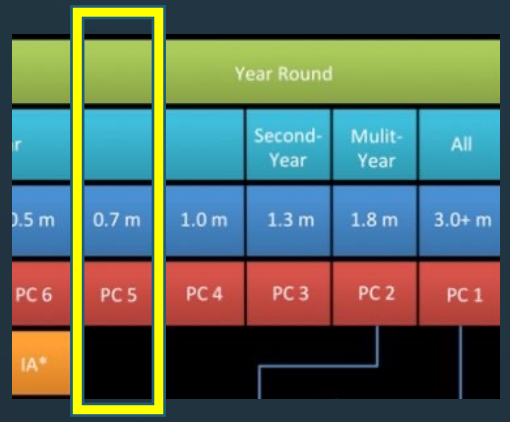
Task 1: Finalize the integration of the index to a visualization tool as an aid to vessel mariner planning and underway activities



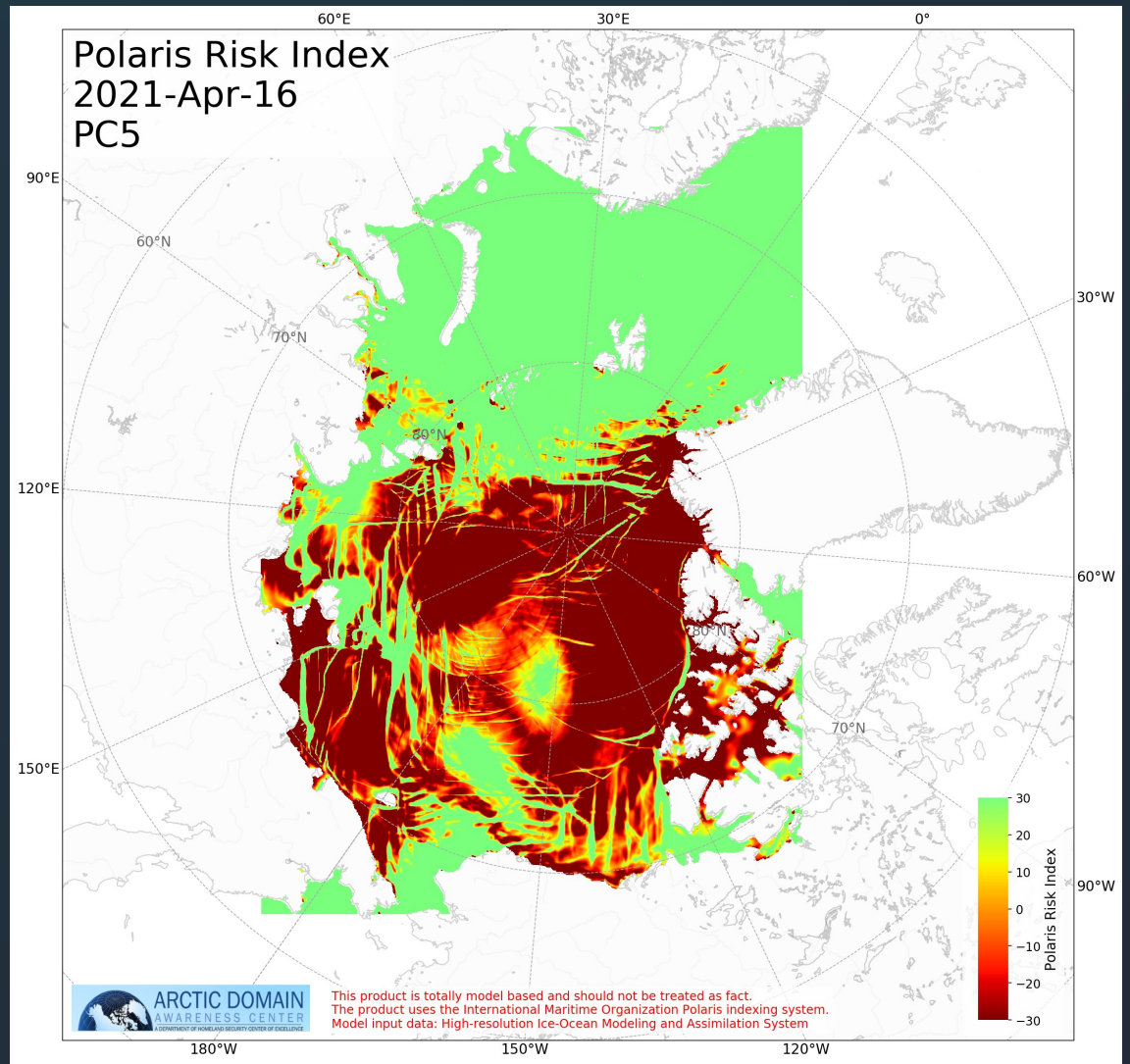


Arctic Ice Conditions Index (ARCTICE)

Task 1: Finalize the integration of the index to a visualization tool as an aid to vessel mariner planning and underway activities



The “claw marks” in the plot are caused by “leads” in the ice. As the ice moves, it separates and reveals the ocean’s surface. These open areas are leads. Ice regrows here but will be thinner and that’s what makes those claw marks.



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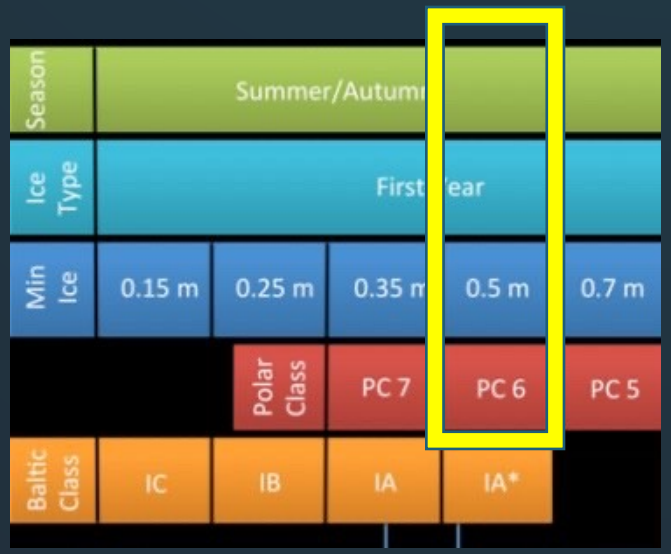
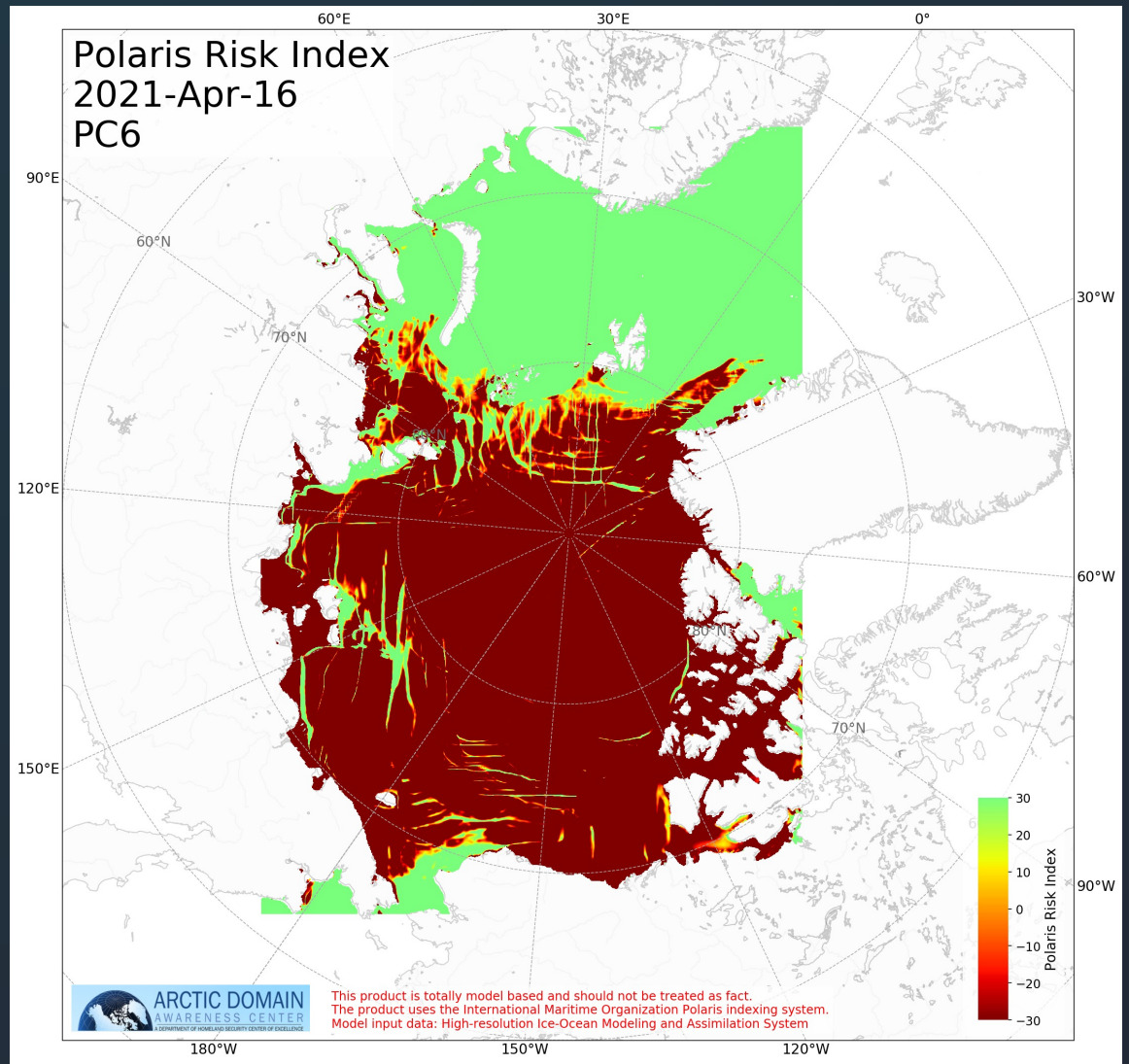
Arctic Ice Conditions Index (ARCTICE)

Task 1: Finalize the integration of the index to a visualization tool as an aid to vessel mariner planning and underway activities





Arctic Ice Conditions Index (ARCTICE)

Task 2: Automate a forecast numeric Arctic ice condition index for Arctic waters & Task 3: Conduct ARCTICE validation

- The ADAC team and project partner Axiom Data Science established a new python script for automatic calculation;
- Sanity check of the manual product;
- Parsed the HIOMAS data as input data for ARCTICE;
- Generated plots in .png and geotiff formats;
- ARCTICE (based on 24-category-ice HIOMAX) fully operational on Axiom server, completed in Q3.

Arctic Ice Conditions Index (ARCTICE)

Task 4: Transition the ARCTICE to an operational destination

- Product web server up: https://static-plotter-web.srv.axds.co/arctice/plots/

Index of /arctice/plots/

../	
1a/	23-Apr-2021 02:01
1b/	23-Apr-2021 02:01
1c/	23-Apr-2021 02:01
ia_super/	23-Apr-2021 02:01
no_class/	23-Apr-2021 02:01
pc1/	23-Apr-2021 02:01
pc2/	23-Apr-2021 02:01
pc3/	23-Apr-2021 02:01
pc4/	23-Apr-2021 02:01
pc5/	23-Apr-2021 02:01
pc6/	23-Apr-2021 02:01
pc7/	23-Apr-2021 02:01

Index of /arctice/plots/pc1/

../	
2020-11-11/	02-Dec-2020 23:55
2020-11-18/	08-Dec-2020 02:32
2020-11-25/	12-Dec-2020 02:32
2020-12-02/	17-Dec-2020 02:32
2020-12-09/	22-Dec-2020 02:32
2020-12-16/	29-Dec-2020 02:33
2021-01-01/	21-Jan-2021 02:33
2021-01-08/	06-Feb-2021 02:32
2021-01-15/	09-Feb-2021 02:32
2021-01-22/	11-Feb-2021 02:32
2021-01-29/	15-Feb-2021 02:32
2021-02-05/	19-Feb-2021 02:33
2021-02-12/	21-Feb-2021 02:33
2021-02-26/	29-Mar-2021 02:33
2021-03-05/	01-Apr-2021 02:33
2021-03-12/	04-Apr-2021 02:33
2021-03-19/	09-Apr-2021 02:33
2021-03-26/	12-Apr-2021 02:33
2021-04-02/	15-Apr-2021 02:33
2021-04-16/	23-Apr-2021 02:3

- Each class has a list of plots produced weekly. Historic plots available.

- Polar classes 1-7, Baltic classes ia super, 1a, 1b, 1c, and vessels with 'no class' for ice

Index of /arctice/plots/pc1/2021-04-16/

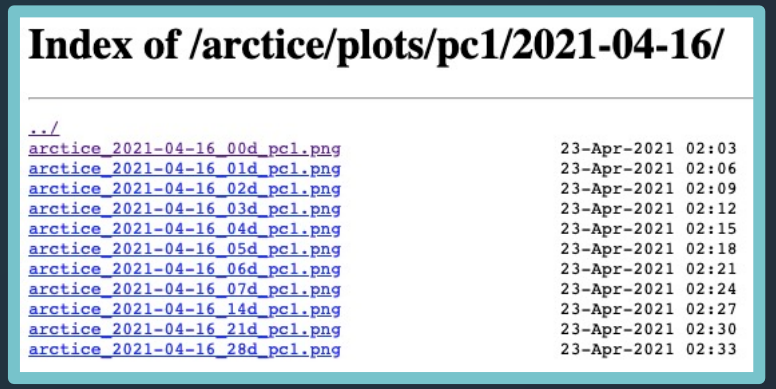
../	
arctice_2021-04-16_00d_pc1.png	23-Apr-2021 02:03
arctice_2021-04-16_01d_pc1.png	23-Apr-2021 02:06
arctice_2021-04-16_02d_pc1.png	23-Apr-2021 02:09
arctice_2021-04-16_03d_pc1.png	23-Apr-2021 02:12
arctice_2021-04-16_04d_pc1.png	23-Apr-2021 02:15
arctice_2021-04-16_05d_pc1.png	23-Apr-2021 02:18
arctice_2021-04-16_06d_pc1.png	23-Apr-2021 02:21
arctice_2021-04-16_07d_pc1.png	23-Apr-2021 02:24
arctice_2021-04-16_14d_pc1.png	23-Apr-2021 02:27
arctice_2021-04-16_21d_pc1.png	23-Apr-2021 02:30
arctice_2021-04-16_28d_pc1.png	23-Apr-2021 02:33

- Now cast (current day, each day for the present week, then 14, 21, and 28 days in advance

Arctic Ice Conditions Index (ARCTICE)

Task 4: Transition the ARCTICE to an operational destination

- Further potential improvement
  - Currently each ARCTICE plot is individually listed;
  - To make it easier to navigate, upgrade to combine the individual plots into a single file;
  - Exploring other improvements such as front-facing website with thumbnails or geotifs for ArcGIS (year 8 task).



Index of /arctice/plots/pc1/2021-04-16/

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arctice_2021-04-16_21d_pc1.png	23-Apr-2021 02:30
arctice_2021-04-16_28d_pc1.png	23-Apr-2021 02:33

Arctic Ice Conditions Index (ARCTICE)

Additional Work

- Outreach: presentations include ASIP 2020, Arctic C-ICE, Qilak LNG, and NSF NNA Arctic Shipping project.
- Potential ARCTICE case study using observed conditions from USCGC Healey (Summer 2022).
- Considering user experience for ARCTICE display and modes of interaction
- Journal article for ARCTICE underway. Team plans to have the article ready for center review at the end of May, out for peer review in June 2021.

Arctic Ice Conditions Index (ARCTICE)

Case Study: Russian LNG

- January 2021, Russian LNG tankers traversed the Northeast Passage, from Sabetta LNG terminal on Yamal Peninsula to China
- No icebreaker escort – 10 days to cover 2474 n. miles (~9.5 knots)

Arctic Ice Conditions Index (ARCTICE)

Case Study: Russian LNG

Russian Maritime Register of Shipping Arctic Ice Classes

Ice class	Typical speed, knots	Ice concentration and type	Winter – spring	Summer – fall	Methods of surmounting ice ridges
			Ice thickness, m		
Arc 9	12	Very close floating and compact multi-year ice	3.5	4.0	Surmount of ice ridges and episodic ramming of compact ice fields
Arc 8	10	Close floating second year ice	2.1	3.0	Regular ramming
Arc 7		Close floating first-year ice	1.4	1.7	Episodic ramming
Arc 6	6-8	Open floating first-year ice	1.1	1.3	Continuous motion
Arc 5		Open floating first-year ice	0.8	1.0	
Arc 4		Open floating first-year ice	0.6	0.8	

Photo credit: https://www.ship-technology.com/projects/christophe-de-margerie-class-icebreaking-lng-carriers

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Arctic Ice Conditions Index (ARCTICE)

Case Study: Russian LNG

- News outlets state the 'Christophe de Margerie' left port January 5 and passed through the Bering Strait on January 16, 2021 having traveled in "thick" sea ice during that time
- ARCTICE ran Jan 1, predicting ice conditions up to 28 days in advance

Index of /arctice/plots/pc3/2021-01-01/

../	
arctice_2021-01-01_00d_pc3.png	21-Jan-2021 02:03
arctice_2021-01-01_01d_pc3.png	21-Jan-2021 02:06
arctice_2021-01-01_02d_pc3.png	21-Jan-2021 02:09
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arctice_2021-01-01_21d_pc3.png	21-Jan-2021 02:30
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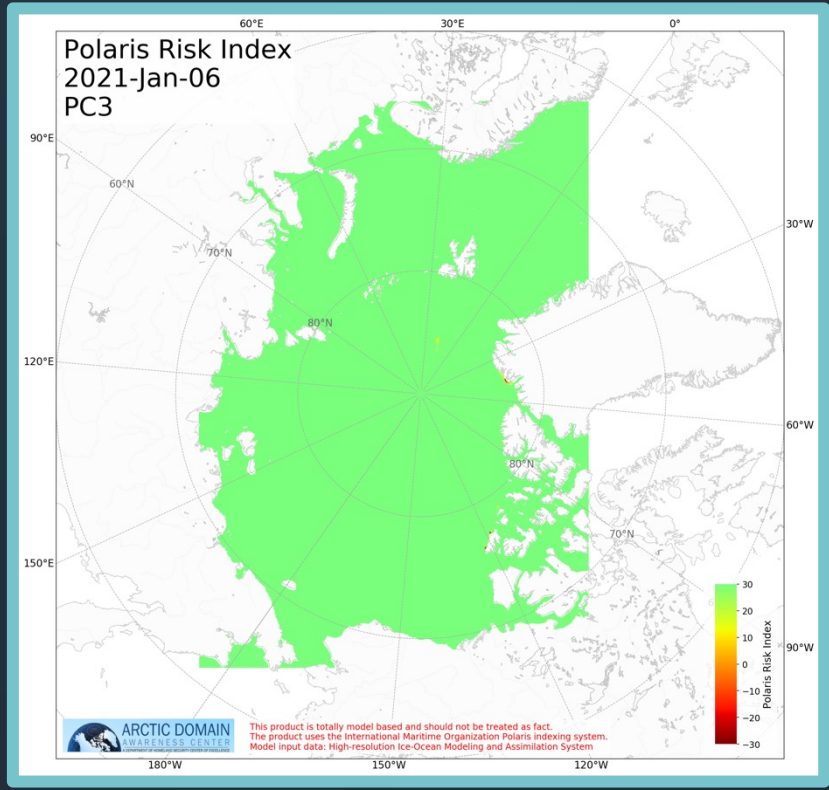
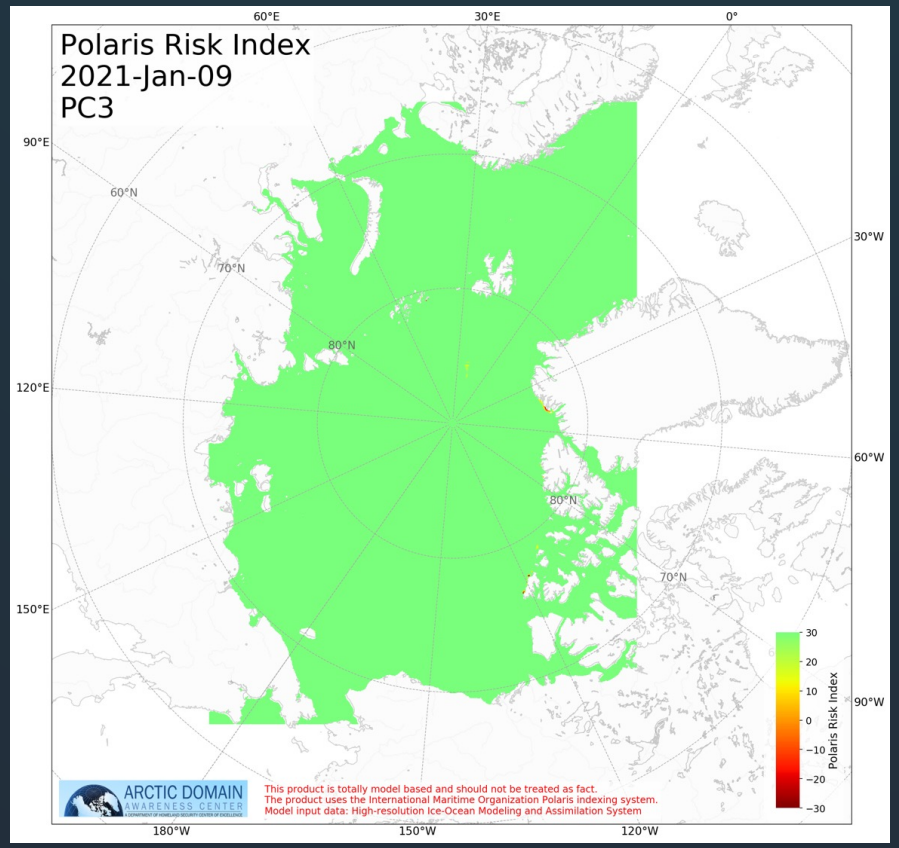
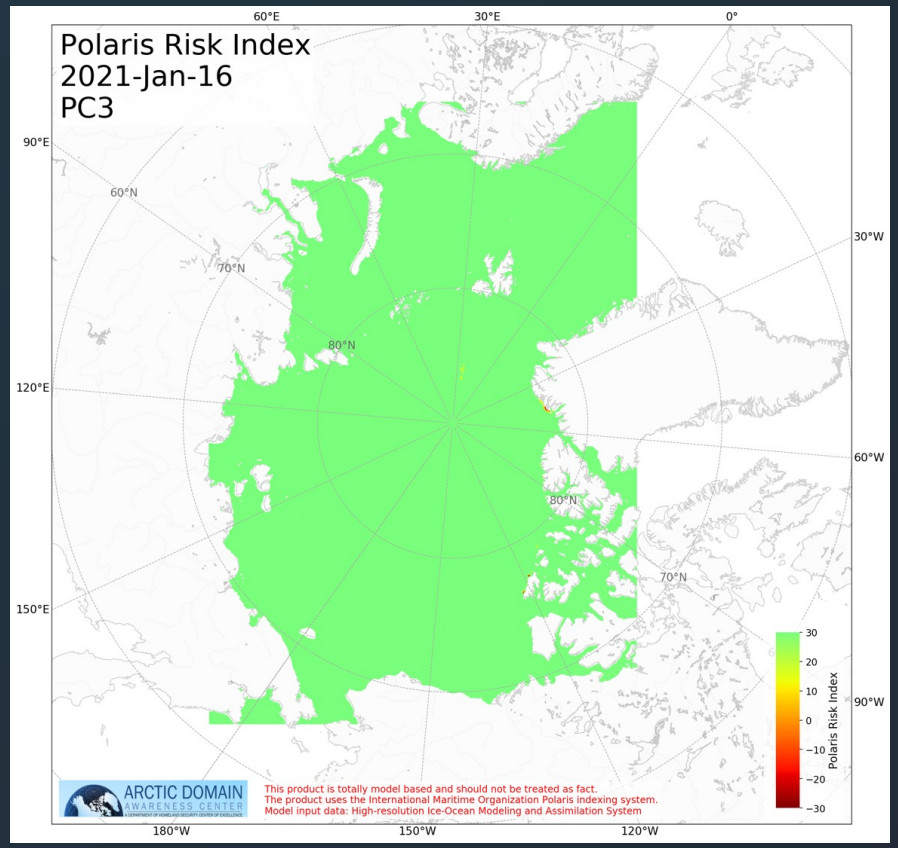


Arctic Ice Conditions Index (ARCTICE)

Case Study: Russian LNG

- Route planning may include pulling the predicted ice conditions



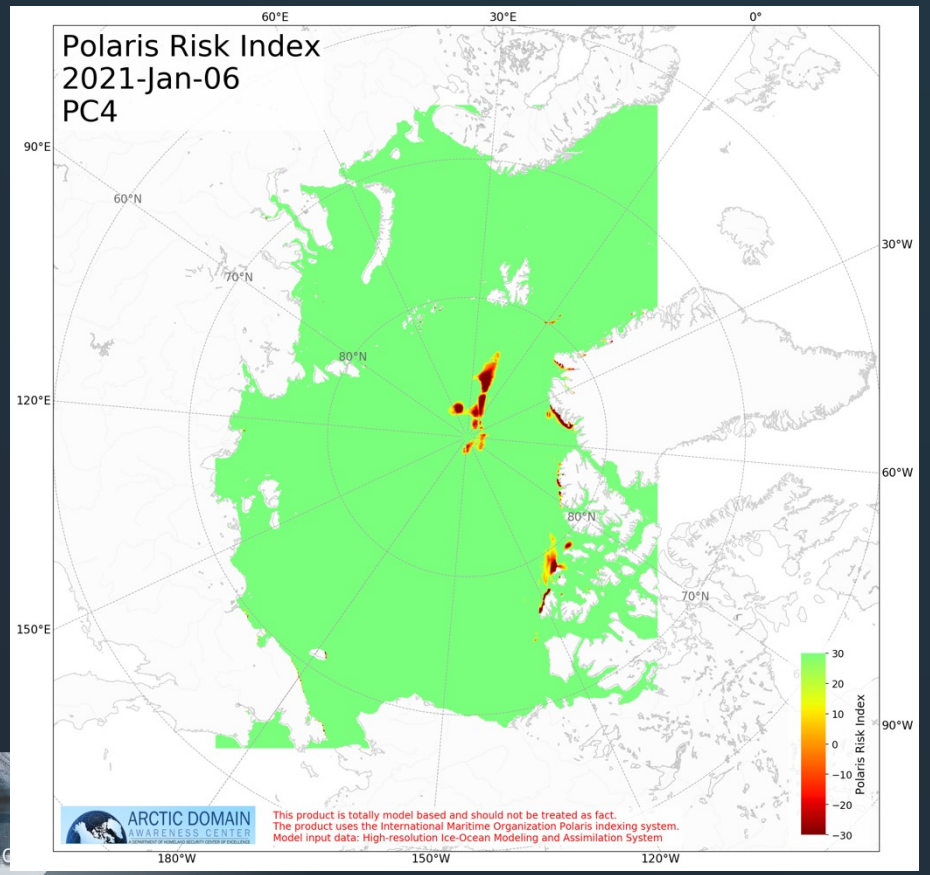


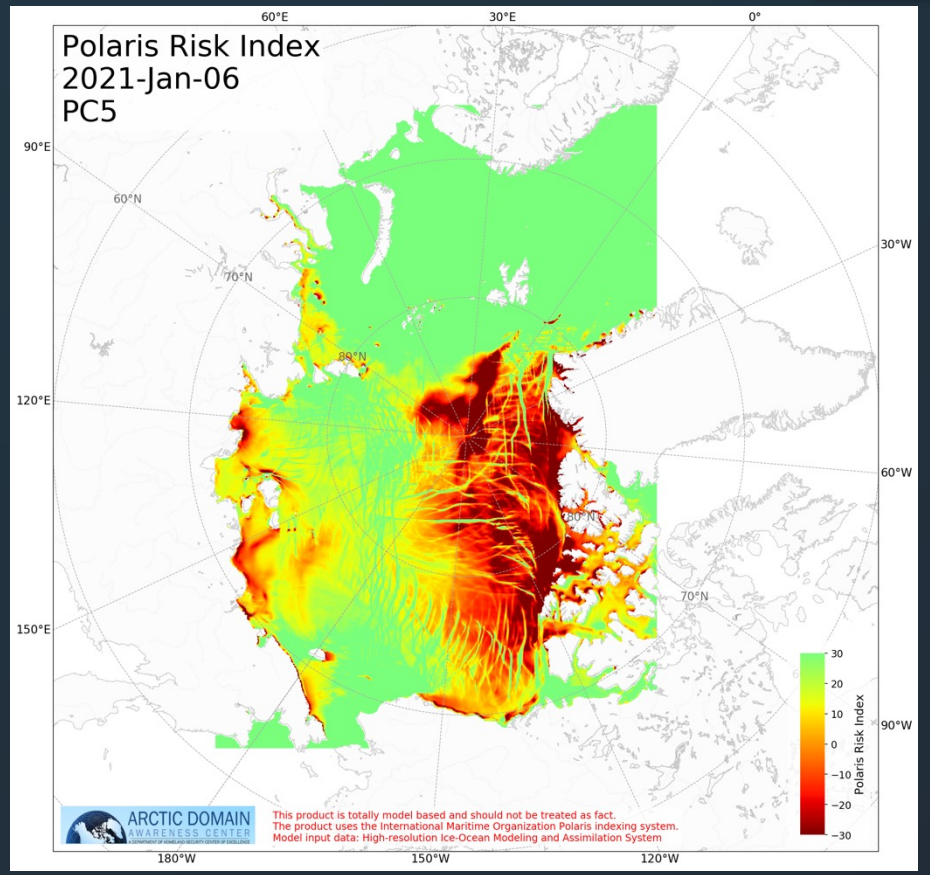
Arctic Ice Conditions Index (ARCTICE)

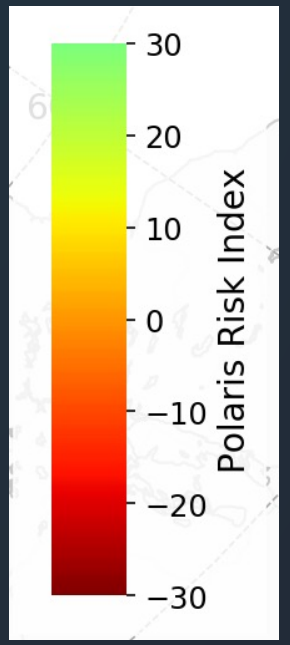
Case Study: Russian LNG

- Different vessel types encounter more challenging conditions

Season	Summer/Autumn				Year Round				
Ice Type	First-Year						Second-Year	Mulit-Year	All
Min Ice	0.15 m	0.25 m	0.35 m	0.5 m	0.7 m	1.0 m	1.3 m	1.8 m	3.0+ m
Polar Class		PC 7	PC 6		PC 5	PC 4	PC 3	PC 2	PC 1







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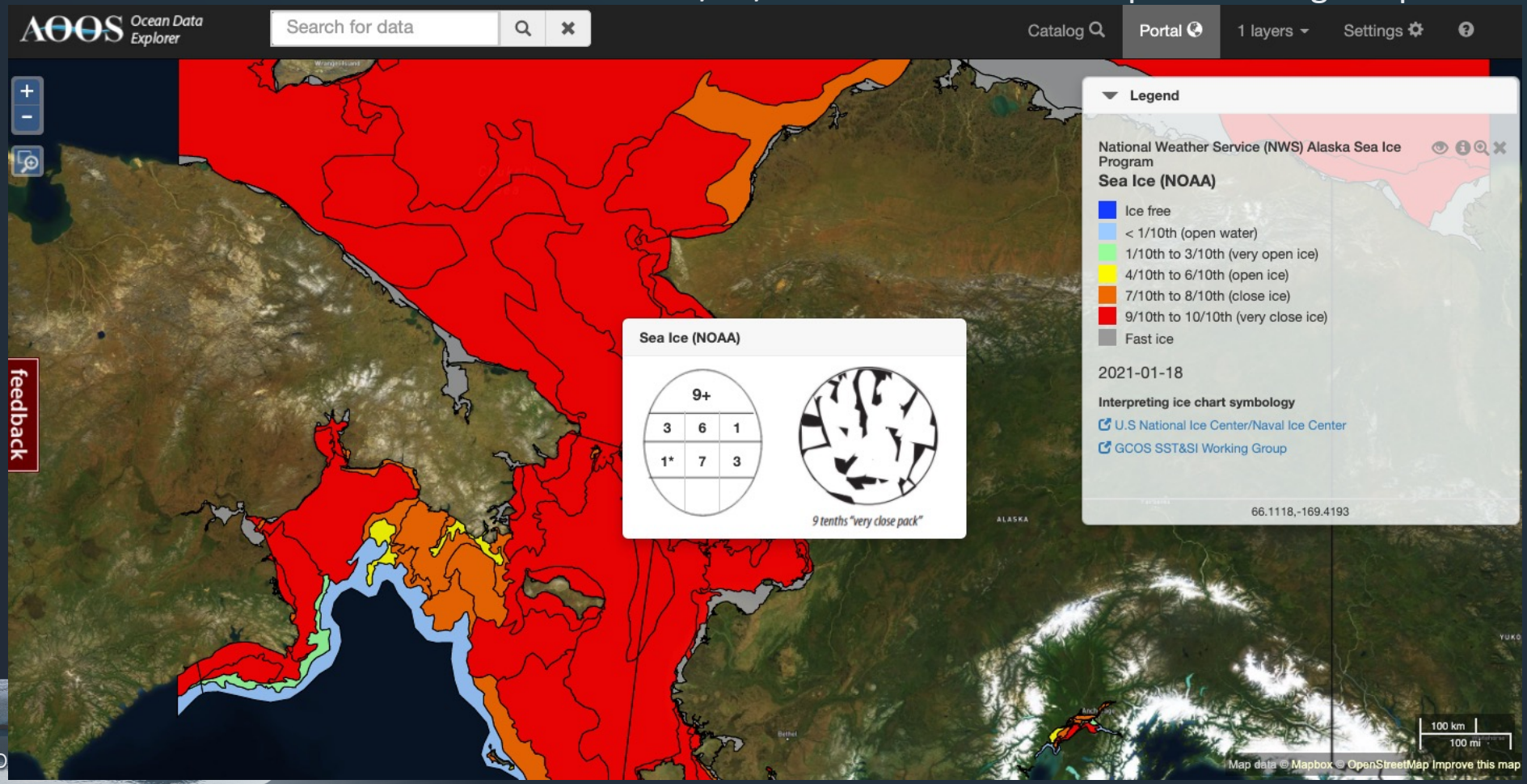
Arctic Ice Conditions Index (ARCTICE)

Case Study: Russian LNG

- What did the sea ice look like on 1/16/2021 when the Christophe de Margerie passed through the Bering Strait?



#	Sea Ice Thickness
1*	70-120 cm
7	30-70 cm
3	10-15 cm

Takeaway: Ice was below the 1.4 m Arc7 class max thickness and PC3 1.3 m max thickness requirements

Great Lakes Ice condition index (ICECON)

Update

- Product delivered to D9 and USNIC from December 2020 to April 2021;
- Per USNIC's evaluation 'overall, ICECON seems to be doing well';
- Occasionally the ICECON model overestimates the ice condition, but per analysis by USNIC, 'it has been pretty easy to trace the errors back to WCPS (the input data).'
- There have been some occasions where the WCPS model over-estimated freeze up or did not melt out enough ice as winds pushed the ice offshore toward warmer water. Since the WCPS model had an error, that error just translated over to ICECON.

Great Lakes Ice condition index (ICECON)

Update

- Android app delivery to D9 delayed into the ice season due to D9's transition to iOS devices and the additional requests for data encryption;
- Additional work with USCG WWM and D9 to revise the app to add 2-way communications between the ICECON model and ship observations (year 8 task).

Ready for Questions

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