Acquisition Directorate

Research & Development Center

Ice Condition (ICECON) Model

Agenda

- **Background**
- **Project Objectives**
- **U.S. National Ice Center (USNIC) Scoring and Classification**
- **ICECON Method**
- **ICECON Product**
- **Mobile Application (App)**
- **Summary and Conclusion**

Background

- **Fall 2015 D9 "Ice Condition Scale" issue paper:**
  - Develop effective scale AND Forecast ICECON out to 72 hours.
- **Discussions continued through January 2016 with interested parties (e.g., CG-WWM-3, D9, D17, USNIC, RDC, and ADAC).**
- **Arctic Domain Awareness Center (ADAC) is a Center of Excellence located at the University of Alaska Anchorage.**
- **ADAC is part of the U.S. Department Homeland Security, Science & Technology Office of University Programs.**
- **In partnership with U.S. and Canadian ice experts, ADAC's role in this effort is collaboration with RDC and D9 to develop an effective ICECON methodology, classification, and forecast system.**

Project Objectives

- **Develop the Ice Condition Index (ICECON levels 1 to 5) to describe ice conditions severity for the Great Lakes, similar to the Saffir-Simpson scale (hurricanes) and the Beaufort scale (high winds);**
- **ICECON able to provide 72-hour forecast of ice conditions;**
- **ICECON as a decision support tool for the management of winter maritime transit in the Great Lakes.**

USNIC ICECON Scoring and Classification

- **Initial ICECON scoring table presented by USNIC:**

Table1: Scoring scheme defined by the NIC algorithm

Ice concen. *tenths*	Point score	Thickness *inches*	Point score	Air temp. *°F*	Point score	Wind conditions	Point score	Ice Type	Point score	**Total score**	**ICECON index**
< 1	0	0	0	≥32	0	0-20 kts off-ice	0	Fast ice	5	**0**	**0**
1-3	5	1 – 2	2	25 – 31	2	> 20 kts off-ice	2	Rafted ice	10	**1 - 15**	**1**
4-6	10	2 – 5	10	10 – 24	5	0-20 kts on-ice	5	Brash ice	10	**16-30**	**2**
7-9	20	6 – 11	15	<10	10	> 20 kts on-ice	10	Hummocked / ridged ice	25	**31-50**	**3**
10	25	12 - 27	20							**51-75**	**4**
		≥28	25							**>75**	**5**

- **Initial ICECON:**
  - Based on inputs such as ice/wind charts and field observation of ice.
  - Not compatible with ice forecast models (e.g., ice models do not generally provide ice type information).

USNIC ICECON Scoring & Classification

- **ICECON classifications presented by USNIC:**

ICECON Scores	ICECON Index	Impact to vessels
0-15	1	Minimum ice concentrations and thickness. Does not present hindrance to commercial navigation.
16 -30	2	Light ice conditions present. Still open water areas. May be some hindrance to less ice-capable ships.
31 -50	3	Light-to-moderate ice conditions present. Less ice-capable ships may need icebreaker assistance for transit and/or be at risk for damage.
51 -75	4	Moderate-to-heavy Ice conditions present. All commercial ships may require icebreaker assistance for transit.
>75	5	Heavy-to-extreme ice conditions. All transits require icebreaker escort.

ICECON Method

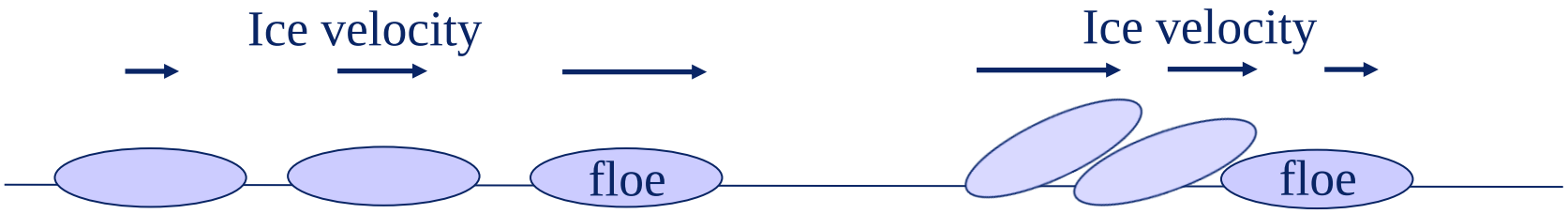
- **ICECON developed at ADAC is based on USNIC ICECON, but uses ice forecast models as inputs.**
- **ICECON is formed from several ice-related environmental parameters:**
  - Ice concentration (C_{ice}); Ice thickness (H_{ice}); Near-ice air temperature (T_{air});
  - Ice divergence (Div_{ice}); Dynamic ice pressure (P_{ice}).
- **Linear optimization algorithm for coefficient weights:**

$$\text{ICECON Score} = a_1 * C_{ice} + a_2 * H_{ice} + a_3 * T_{air} + a_4 * Div_{ice} + a_5 * P_{ice}$$

  - Monte Carlo optimization scheme to determine the appropriate weights or coefficients (a_i) for each parameter;
  - Quantifies an appropriate range of values for each coefficient and searches for the optimal combinations by comparing them with ship-based ICECON observation data.

ICECON Method: Ice Divergence

- **USNIC's ICECON uses wind condition 'on-ice' and 'off-ice' to describe the impact of wind on ice motion.**
- **ADAC ICECON directly utilizes ice velocity from ice models that are influenced by both wind and water currents.**
- **Ice divergence is calculated from ice velocity and describes the relative motion of ice.**
  - **It affects the formation of ice leads and ridges.**



Ice divergence > 0
Ice tends to breakup
Leads

Ice divergence < 0
Ice tends to aggregate
Ridges

ICECON Method: Ice Pressure

- **USNIC's ICECON uses ice types that are not available in ice forecast models and therefore cannot be used.**
- **Discussion with D9 ice breaker fleet COs indicated that ice pressure is a very important ice parameter.**
- **Static ice pressure only accounts for the weight of the ice sheet whereas dynamic ice pressure also accounts for additional pressure due to ice motion.**
- **Dynamic ice pressure is desired as it is more relevant to ice ridges.**

ICECON Method: WCPS Model

- **In June 2019, USNIC suggested evaluating the Water Cycle Prediction System (WCPS) from Environment and Climate Change Canada (ECCC) as the ICECON data source.**
- **WCPS is free to use through an agreement between USNIC and ECCC.**
- **The ADAC team evaluated WCPS and considered it an appropriate ice model as ICECON input:**
  - WCPS is an operational model with 72-hour forecast at 2 km spatial resolution;
  - Data includes all parameters required for ICECON calculation, including dynamic ice pressure.

ICECON Method: WCPS-based ICECON

- **Revised the ICECON algorithm using the WCPS data with the 2019-20 ship-based ice observation data from D9.**
- **WCPS only has data from Jan 2020 forward so the ship-based ice data from the previous ice season were not usable for calibration.**
- **Ship-based ice observation data from D9:**
  - Some had incomplete info such as coordinates, time-stamps;
  - Because of the light ice season, many additional entries were located in locks and narrows straits where there is no data from WCPS (WCPS only provides data for the lakes, not for the connecting waterways);
  - A total of 103 complete data entries were available.

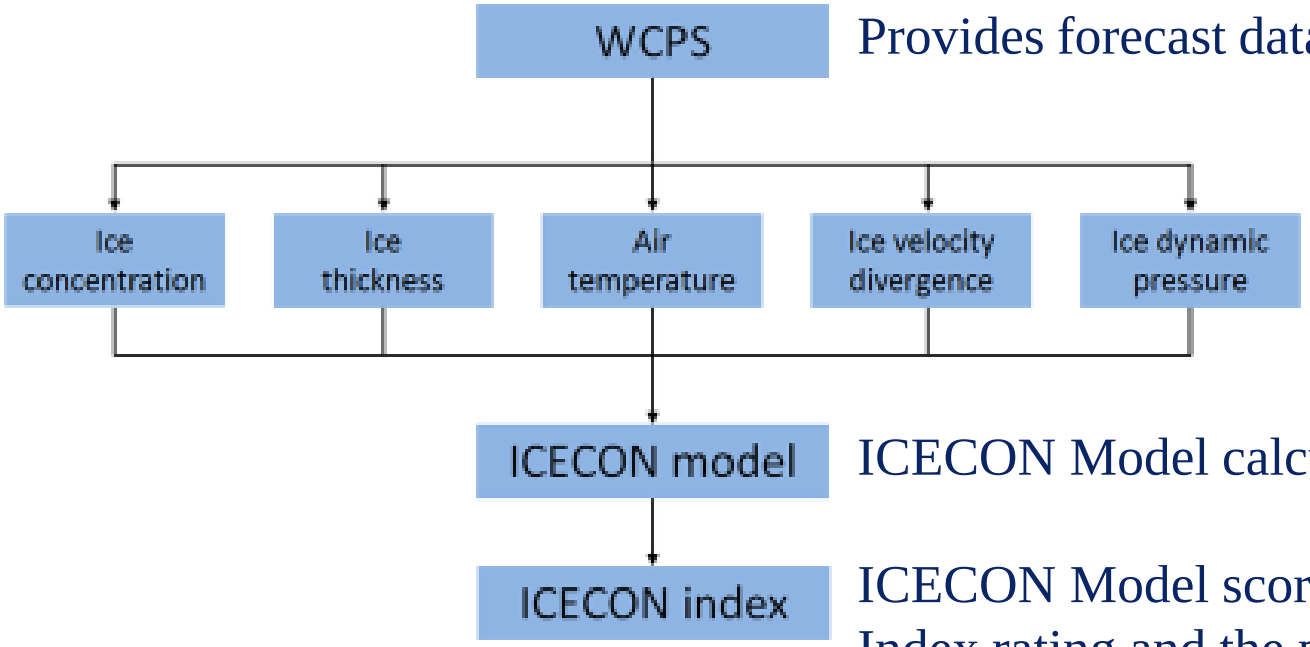
ICECON Method: WCPS-based ICECON Algorithm Evaluation

- **Compared the ICECON algorithm output with the 2019-20 ship-based ice observation data from D9.**
- **The overall predictive accuracy (a.k.a. "concurrent rate" - where ICECON algorithm level matched D9 data) is 70% - a significant improvement from a 50% concurrent rate using USNIC's initial scoring table.**
- **The concurrent rates were also calculated for each ICECON level (no ICECON 5 data because of the light ice season).**

ICECON	Concurrent Rate (the same ICECON level from the algorithm and from D9 data)
1	67%
2	65%
3	70%
4	72%
5	No data

ICECON Method: Process Chart

ICECON flow chart



Provides forecast data

Model inputs from WCPS

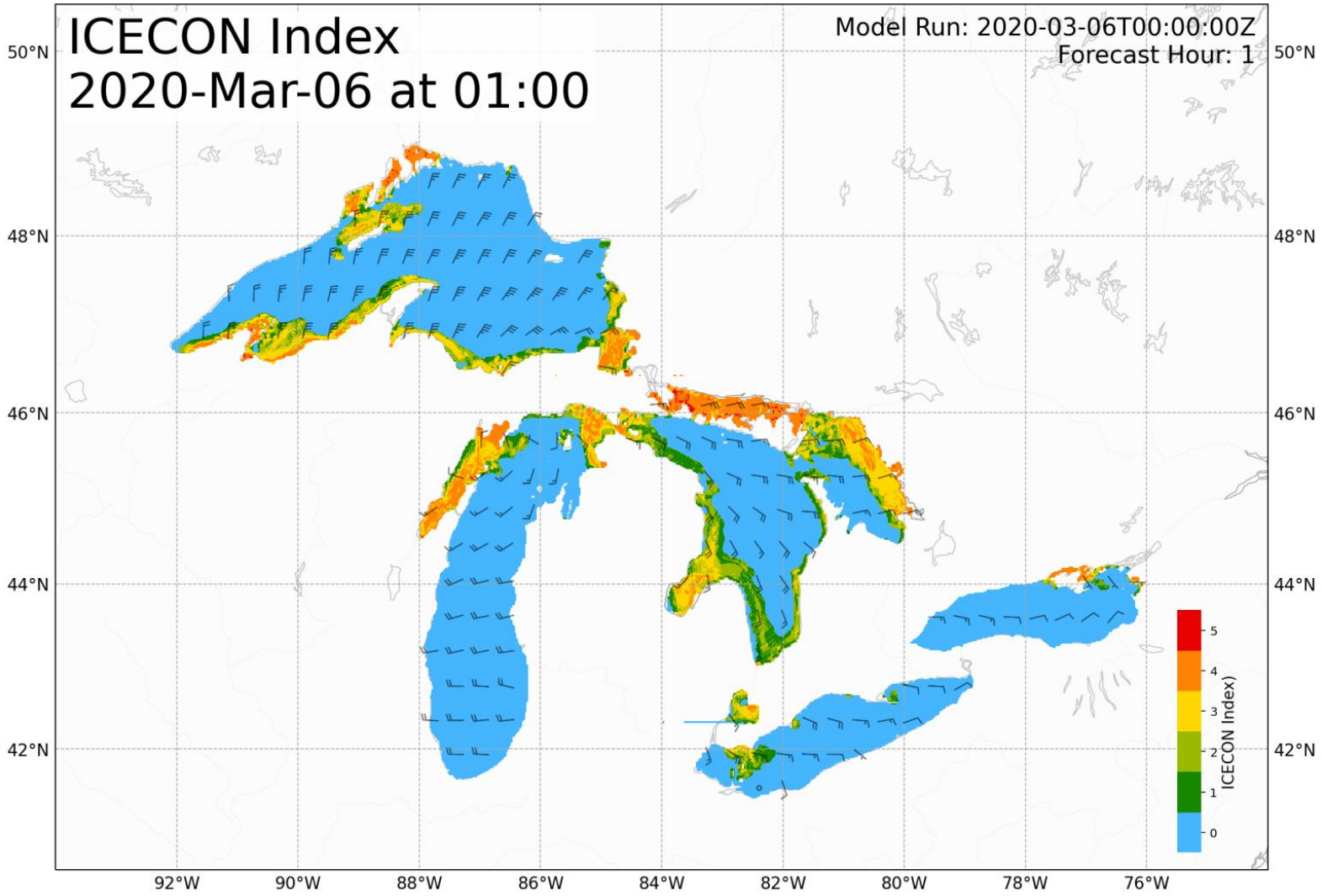
ICECON Model calculates scores

ICECON Model scores are translated to the Index rating and the product is generated

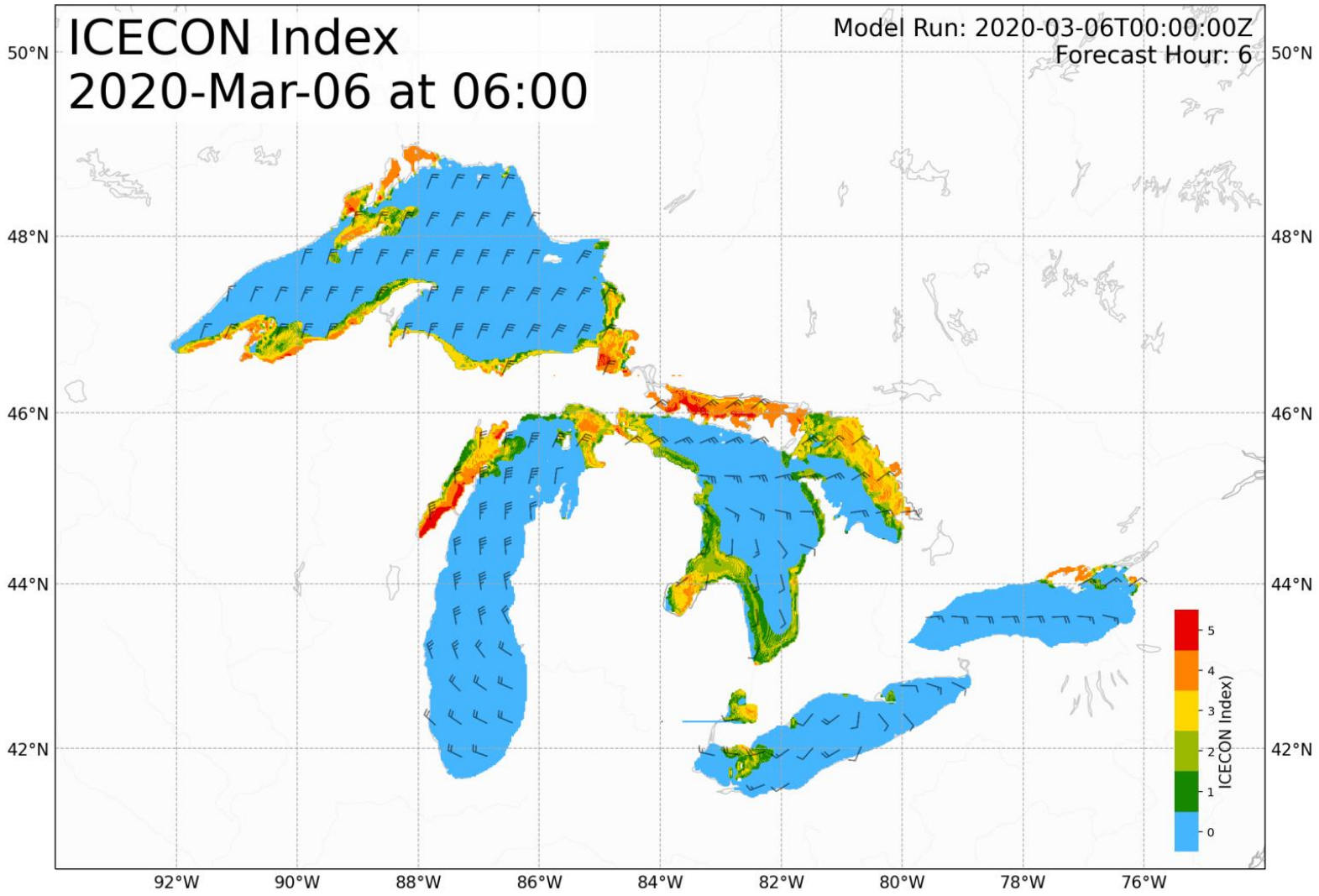
ICECON Product

- **ICECON model is hosted at Axiom Data Science.**
- **Provides a 72-hour forecast everyday with plots of ICECON at 1, 6, 12, 24, 48, and 72 hours.**
- **Products also include plots of ice concentration and ice thickness and all plots superimposed with wind barbs (requested by D9).**
- **Product plots:**
  - png formatted (smaller file size, easier to send via email).
  - geotiff formatted (larger file size, higher resolution).
- **USNIC agreed to publish the ICECON products to users.**

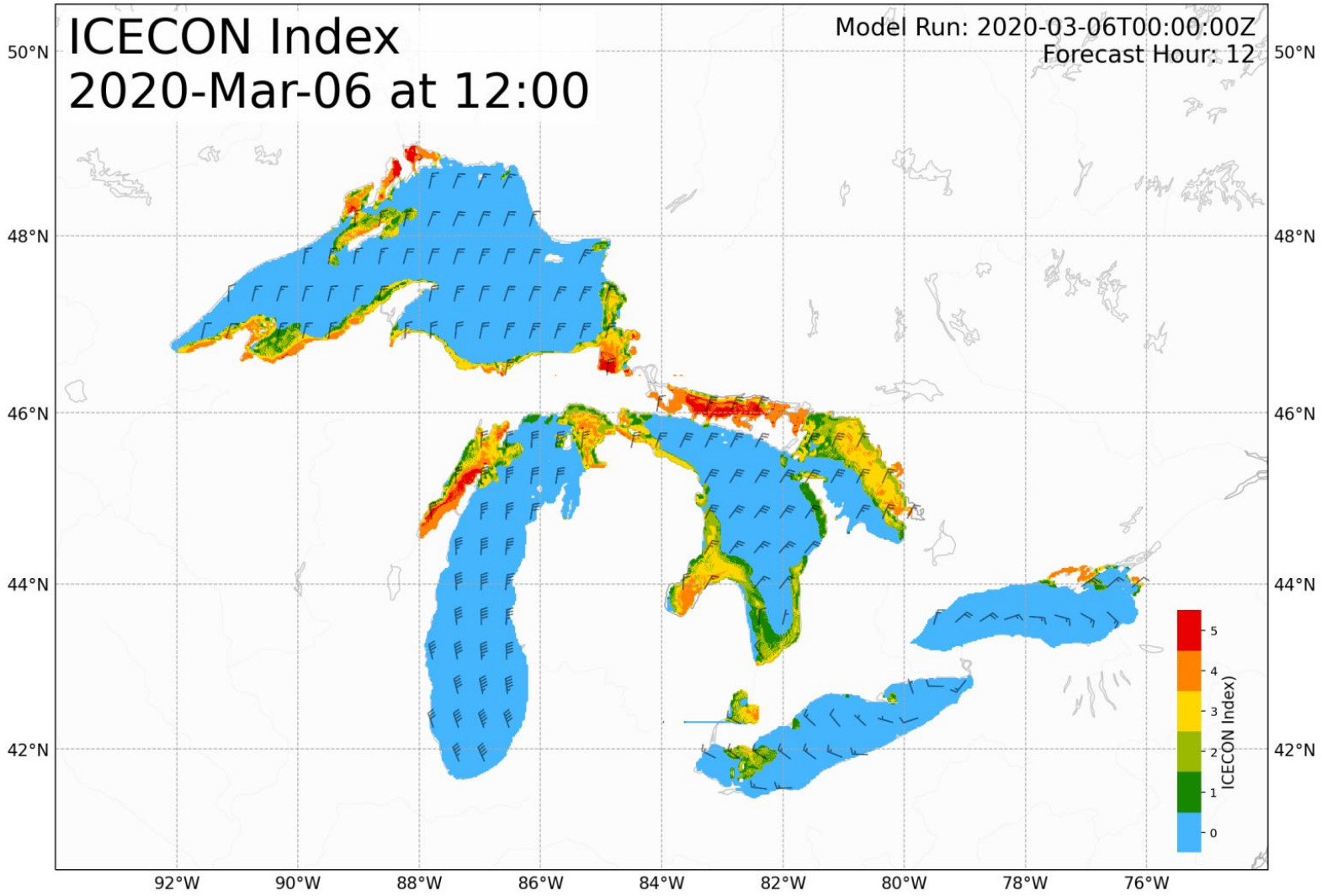
ICECON Product: Plot at 0100 Hour



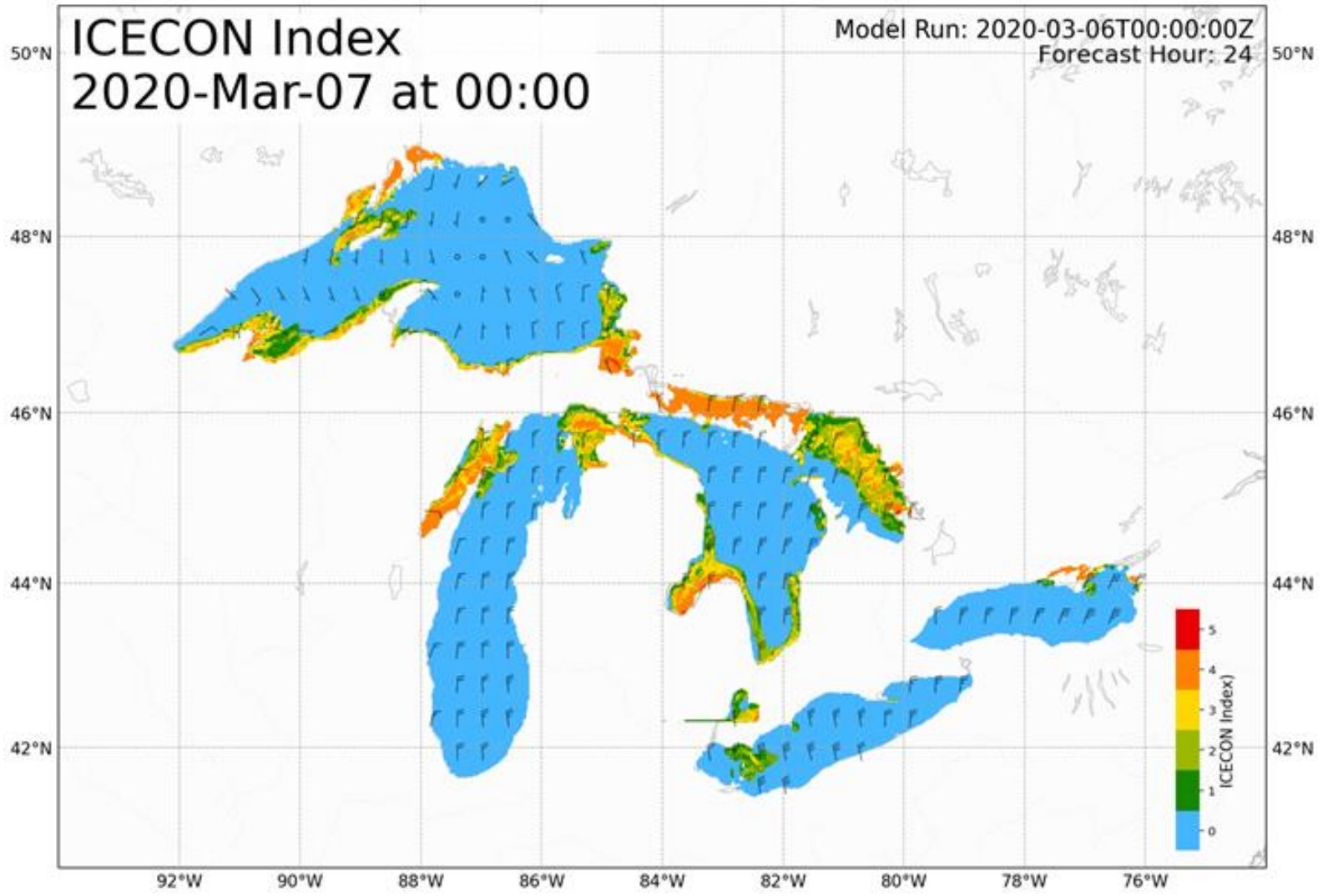
ICECON Product: Plot at 0600 Hour



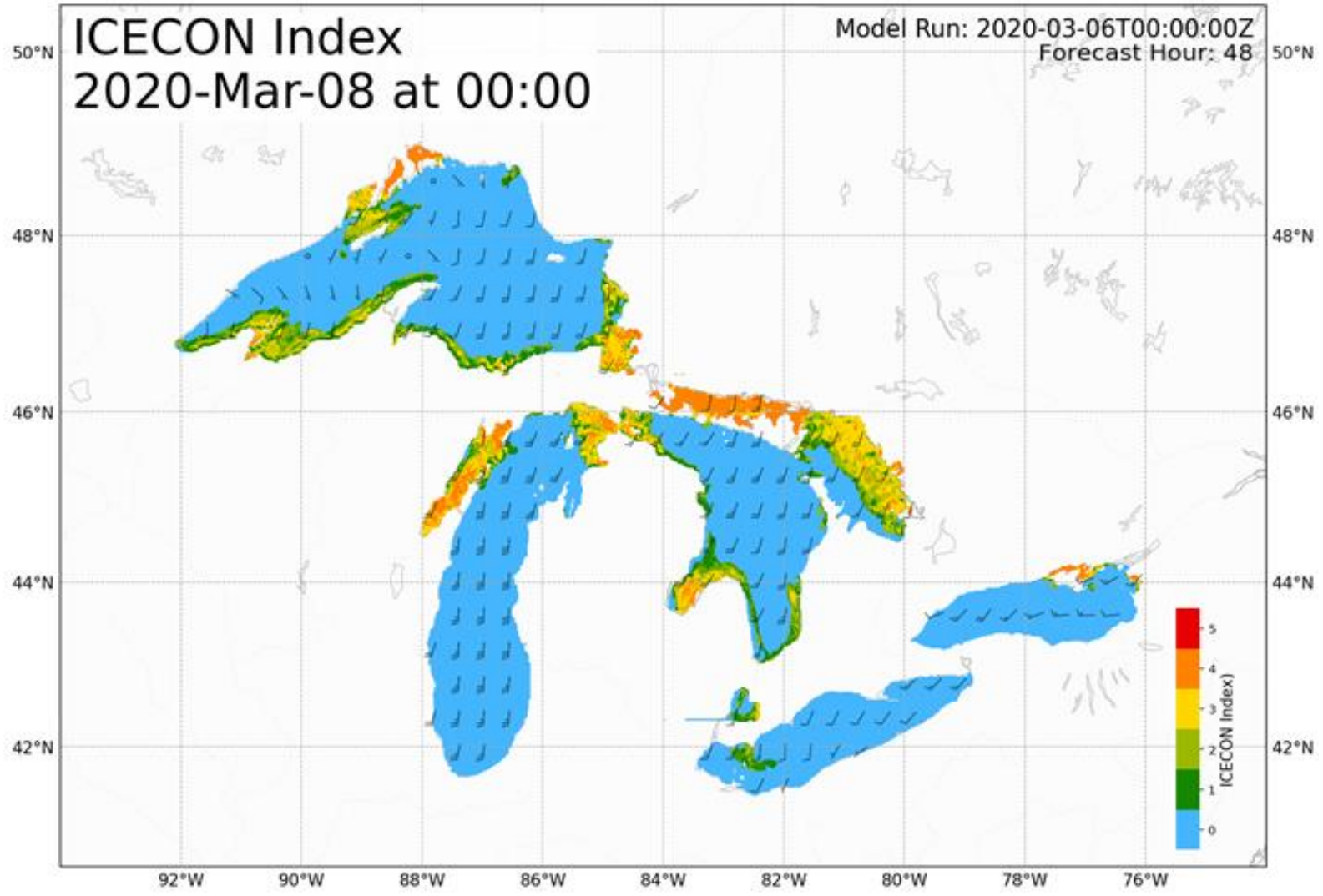
ICECON Product: Plot at 1200 Hour



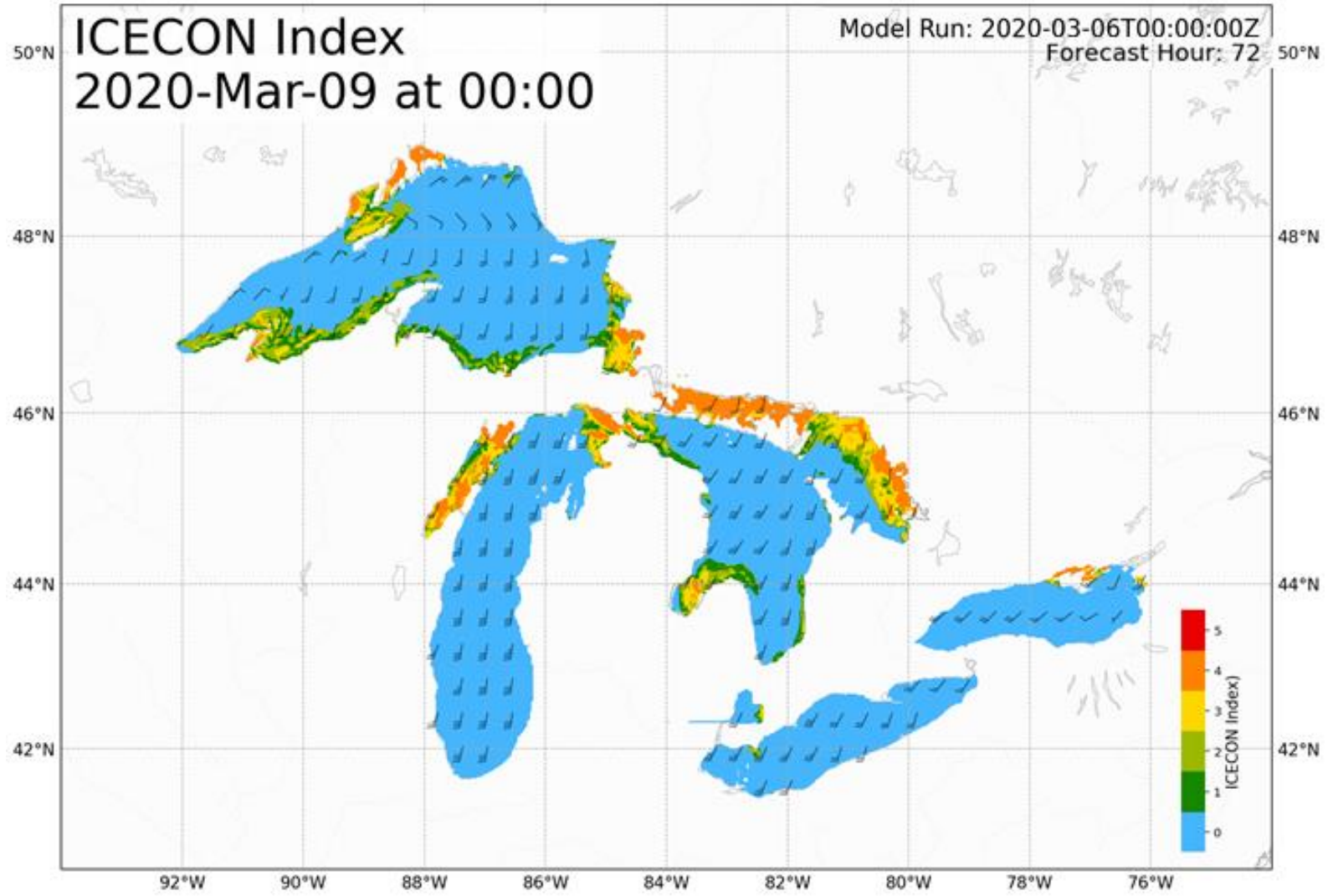
ICECON Product: Plot at 2400 Hour



ICECON Product: Plot at 4800 Hour



ICECON Product: Plot at 7200 Hour



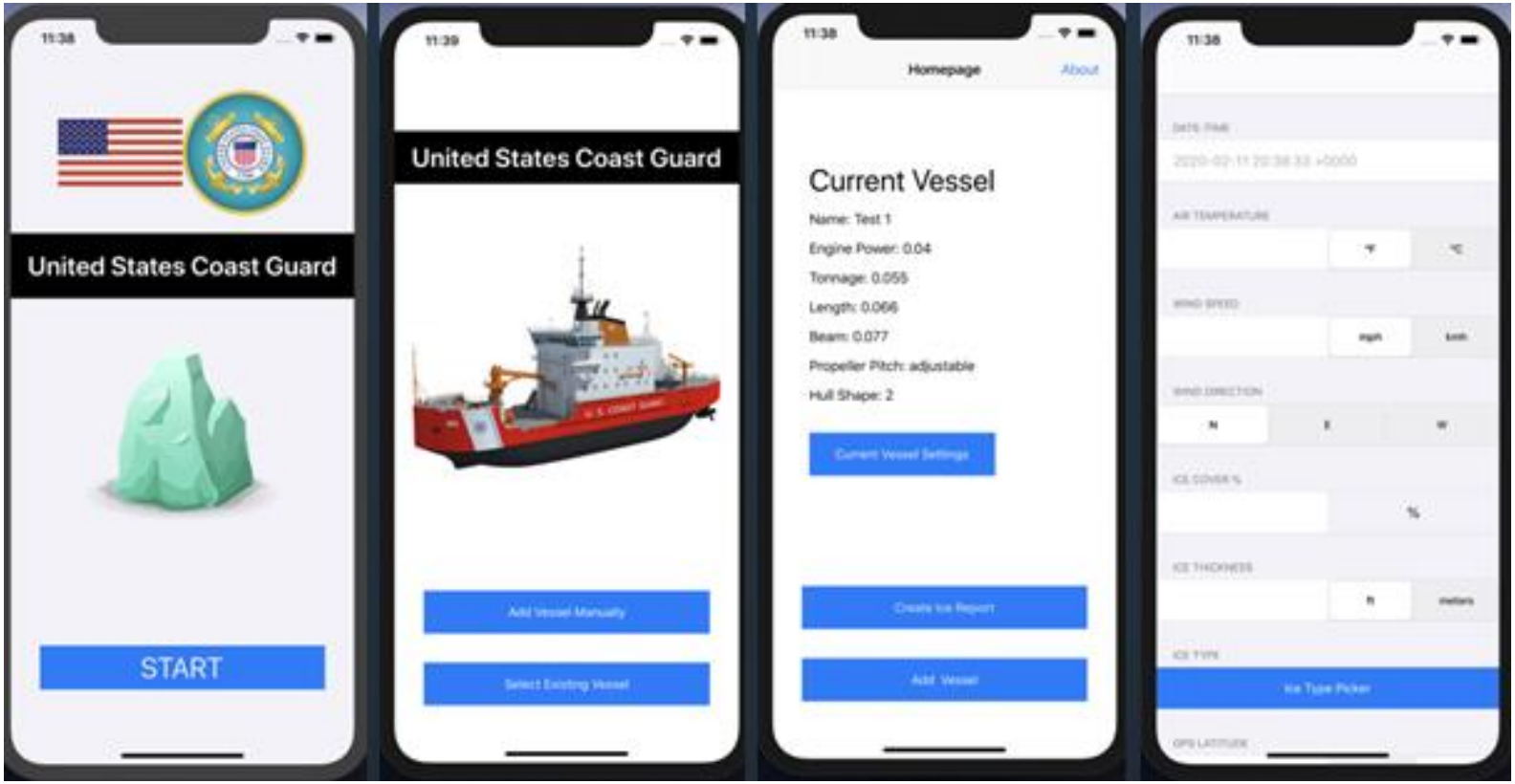
Mobile App for Data Collection

- **Currently, D9 is using a beta-version of the App and the results and feedback have been positive.**
- **Mariners can efficiently employ the App and make data entries based on observation.**
- **ADAC is currently updating both the iOS and Android Apps:**
  - iOS App is working through licensing restrictions.
  - Android App is projected to be available in the Google App Store in Fall 2020…search for:

    "Ice Condition Observation Reporting Tool"

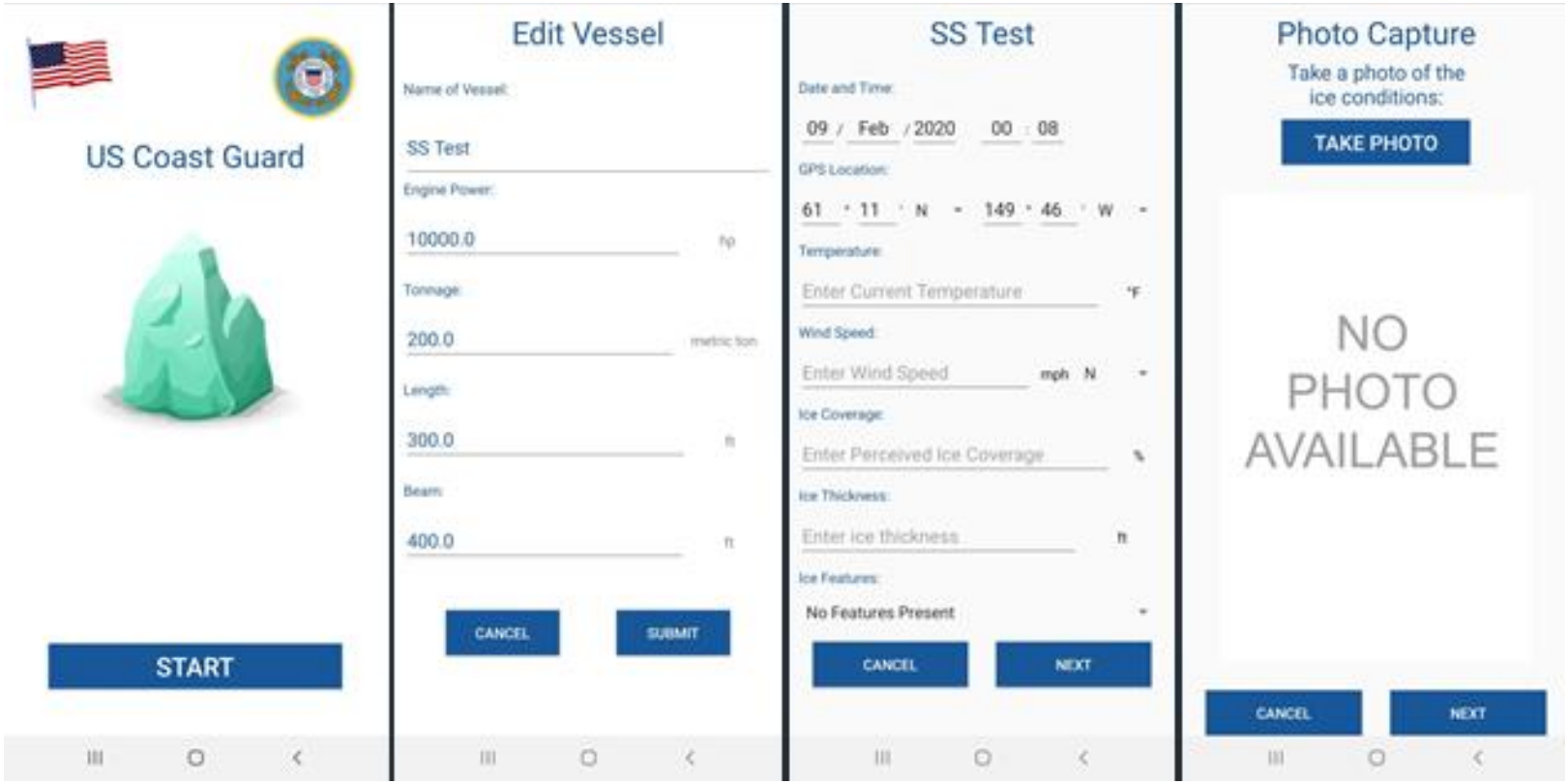
Mobile App – iOS

- **Interface on the iOS App for facilitating the collection of additional ship-based ICECON observations.**



Mobile App – Android

- **Interface on the Android App for facilitating the collection of additional ship-based ICECON observations.**



Summary and Conclusion

- **Promising results:**
  - WCPS based model provides 72-hour forecast at 2 km spatial resolution.
  - Data includes all parameters required for ICECON calculation.
  - The overall concurrent rate is 70% - a significant improvement from a 50% concurrent rate using USNIC's initial scoring table.
  - Model will benefit from additional data & analysis by ADAC.
  - Model could benefit from exploration of other algorithmic approaches.
- **Model should move forward:**
  - Transition ICECON Model to USNIC:
    - ✓ USNIC already part of current team.
    - ✓ Supports use of science and information gained from Great Lakes ICECON research in ADAC's follow-on Arctic Ice Condition (ARCTICE) research effort in D17.
    - ✓ More time to assess ICECON Model's accuracy.
  - Consider acquisition and sustainment options for model and mobile apps.

Questions?