Implications of Ice Cover on Storm Surge Dynamics in the Beaufort Sea

Mike Salisbury, P.E.
Atkins North America, Inc.
Michael.Salisbury@atkinsglobal.com

Andrew Cox
Oceanweather, Inc.
andrewc@oceanweather.com

Val Swail
Environment Canada
Val.Swail@ec.gc.ca

ATKINS

Background and Motivation

- Planned coastal resource development projects
- MSC Beaufort Project
  - Previously completed wind and wave climatology studies
  - 30+ year continuous hindcast simulation
- Complex storm surge/ice cover dynamics

Brief Description of Methodology

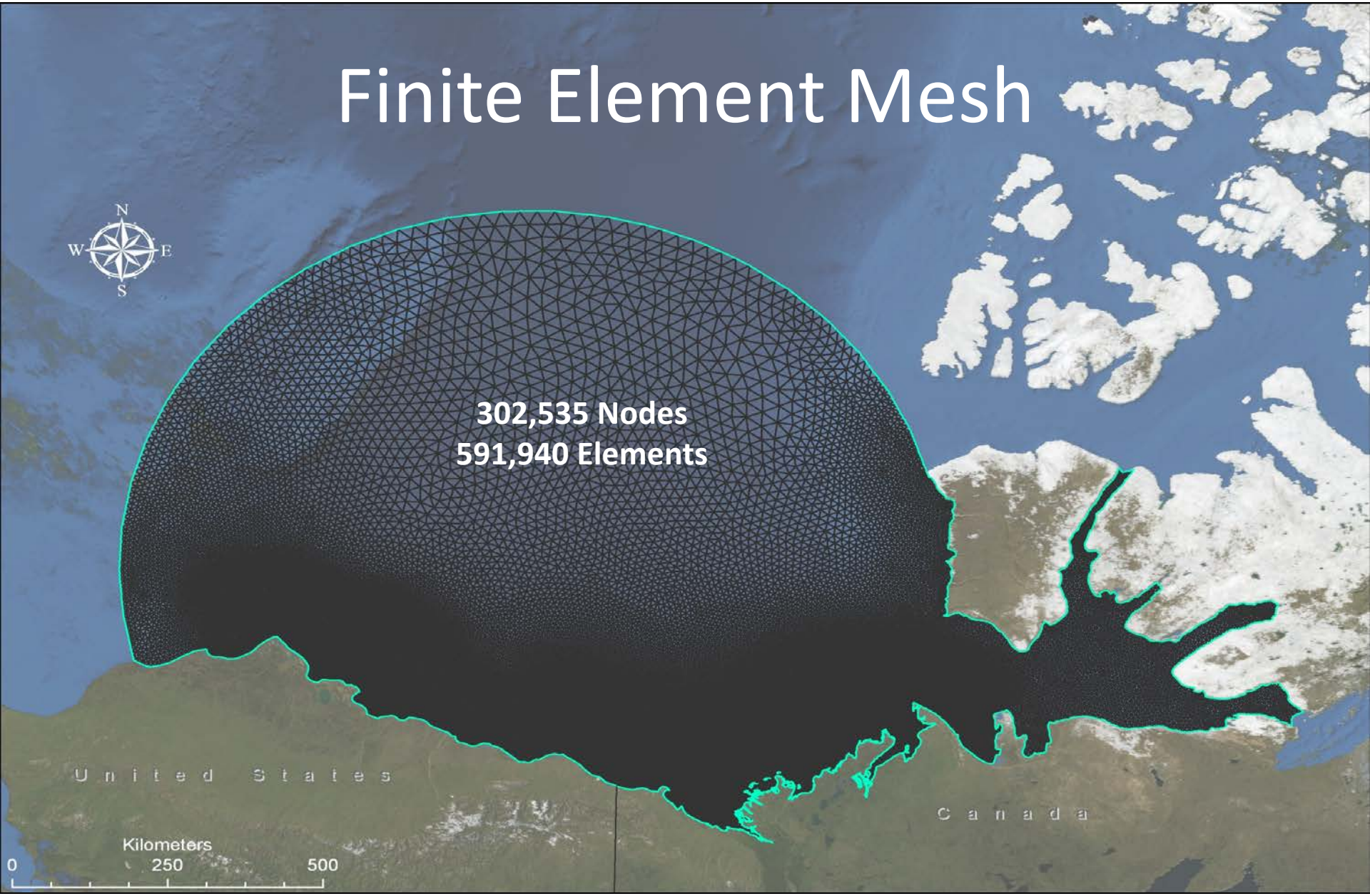
- Develop ADCIRC finite element mesh
- Astronomic tide resynthesis
- Validate storm surge during open water conditions
- Ice cover data and ICE CUBE method
- Fast ice and wind stress adjustment

Summary of Conclusions

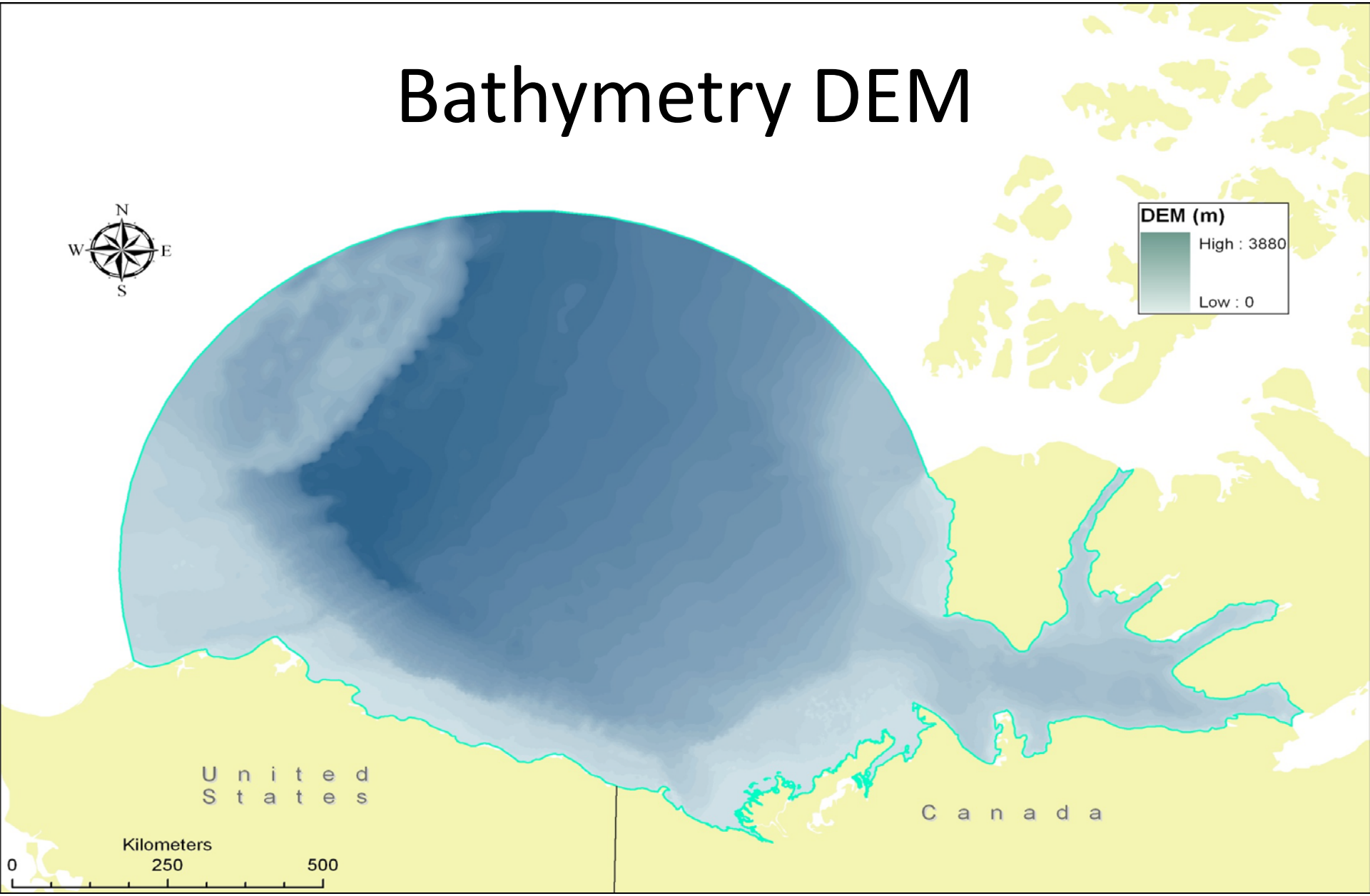
- Model performs well during open-water conditions
- Ice cover impacts surge levels – sometimes significantly
- ICE CUBE method provides a flexible method for incorporating ice cover data under certain conditions
- Shore-fast ice also important in shallower waters


Study Area
N
W
E
S
Arctic Ocean
Northwestern Passages
Banks Island
Victoria Island
Barrow, Alaska
Beaufort Sea
United States
Canada
Kilometers
0
250
500

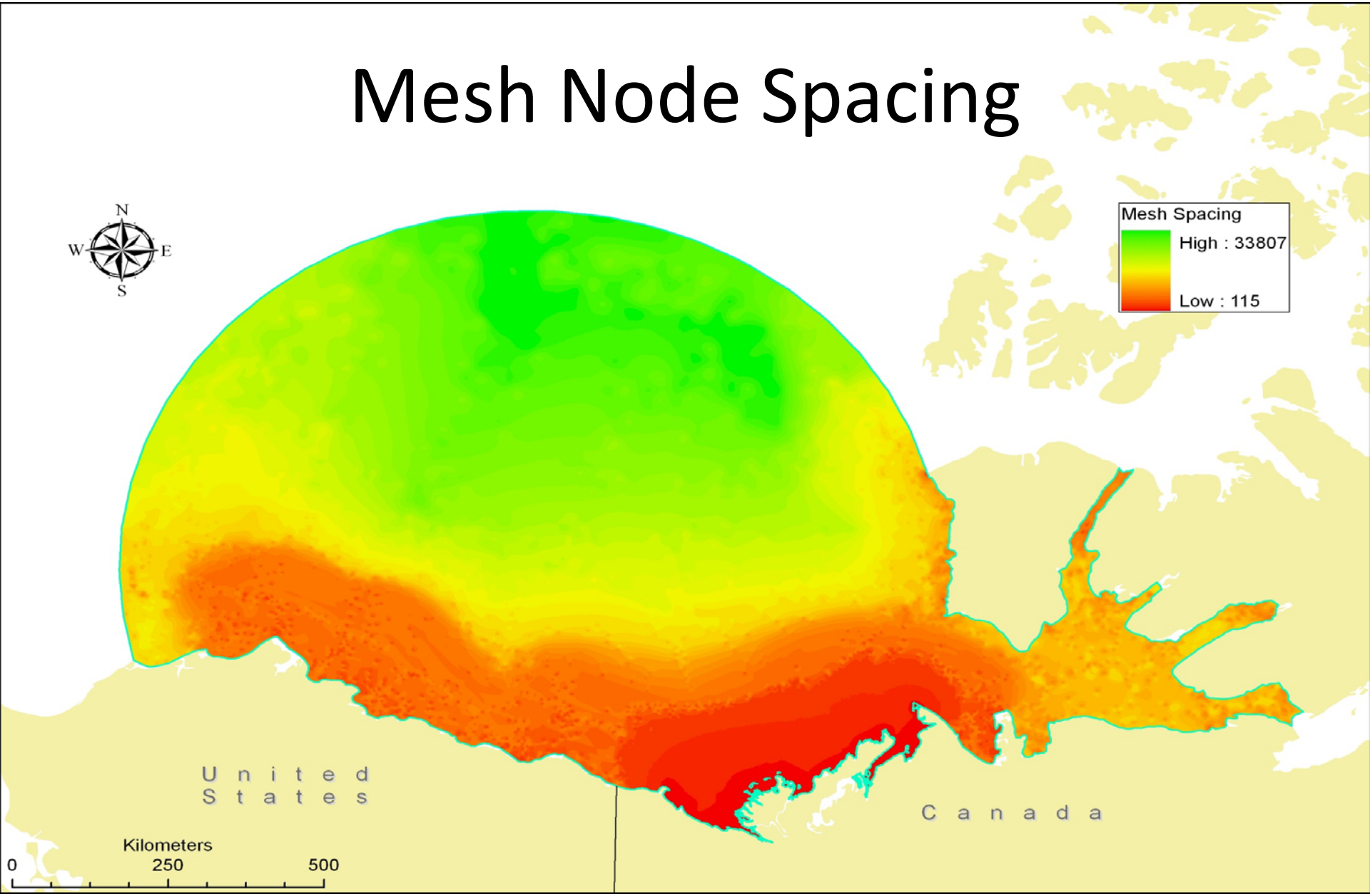
Finite Element Mesh



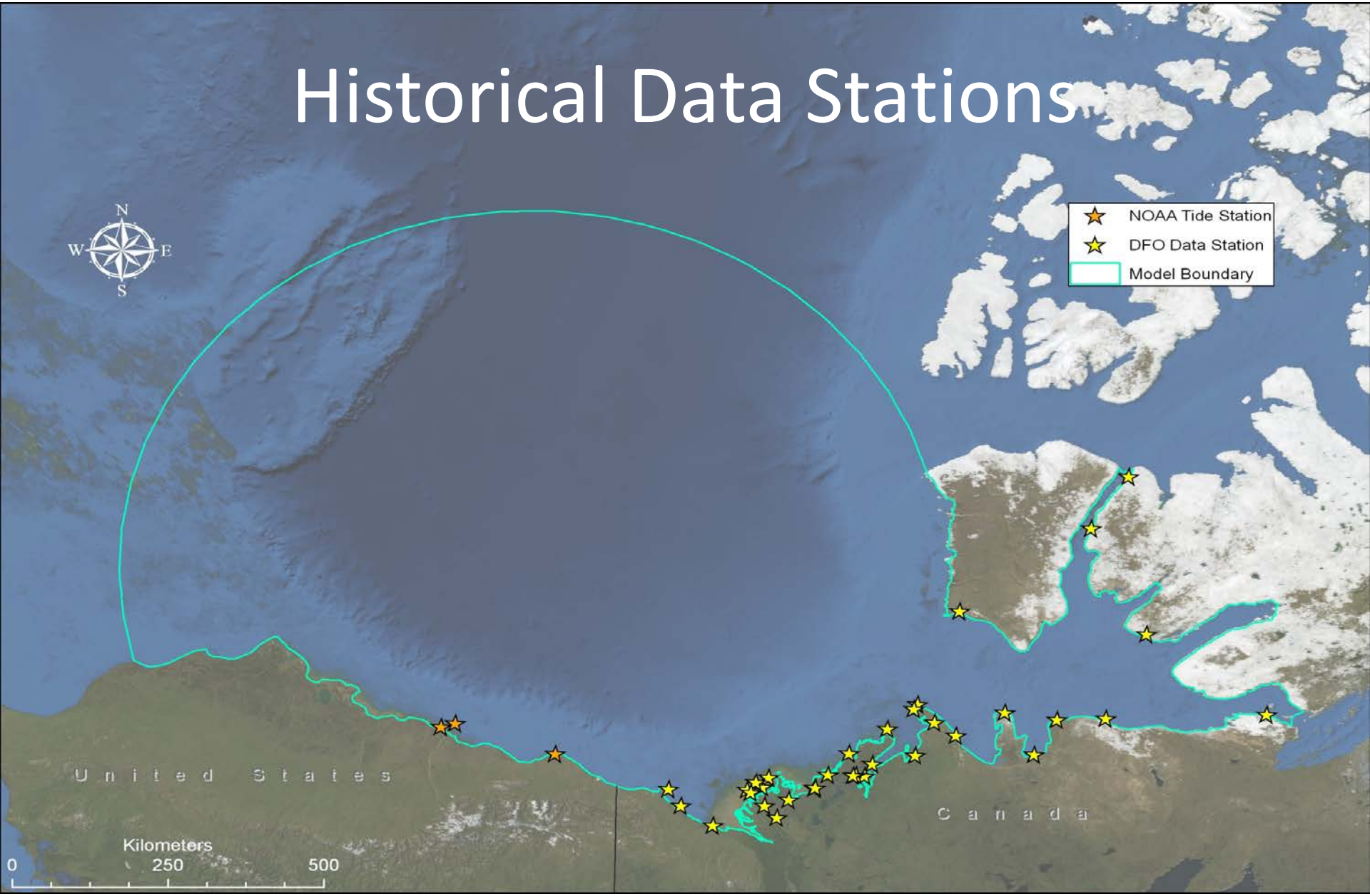
Bathymetry DEM



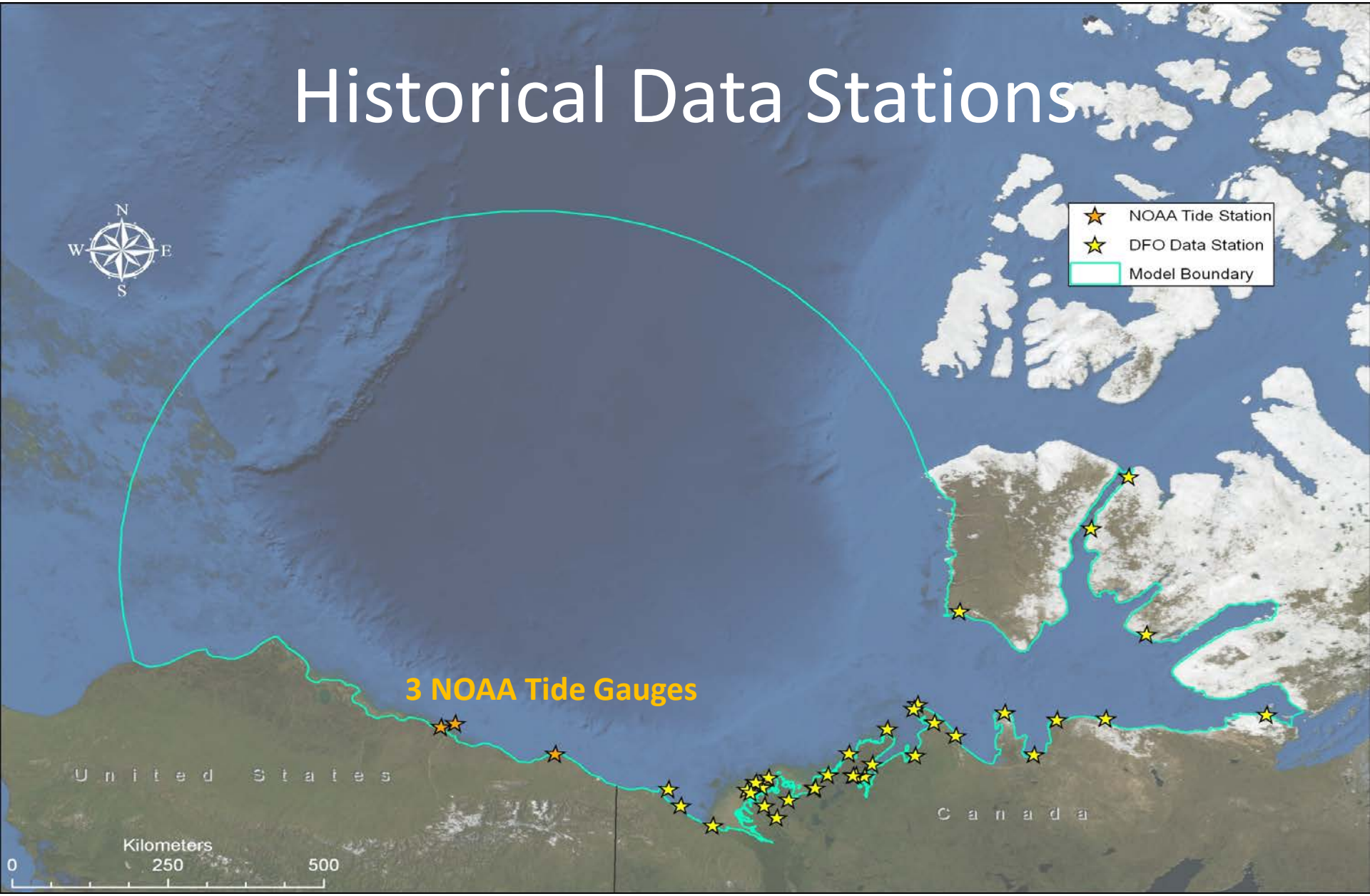
Mesh Node Spacing



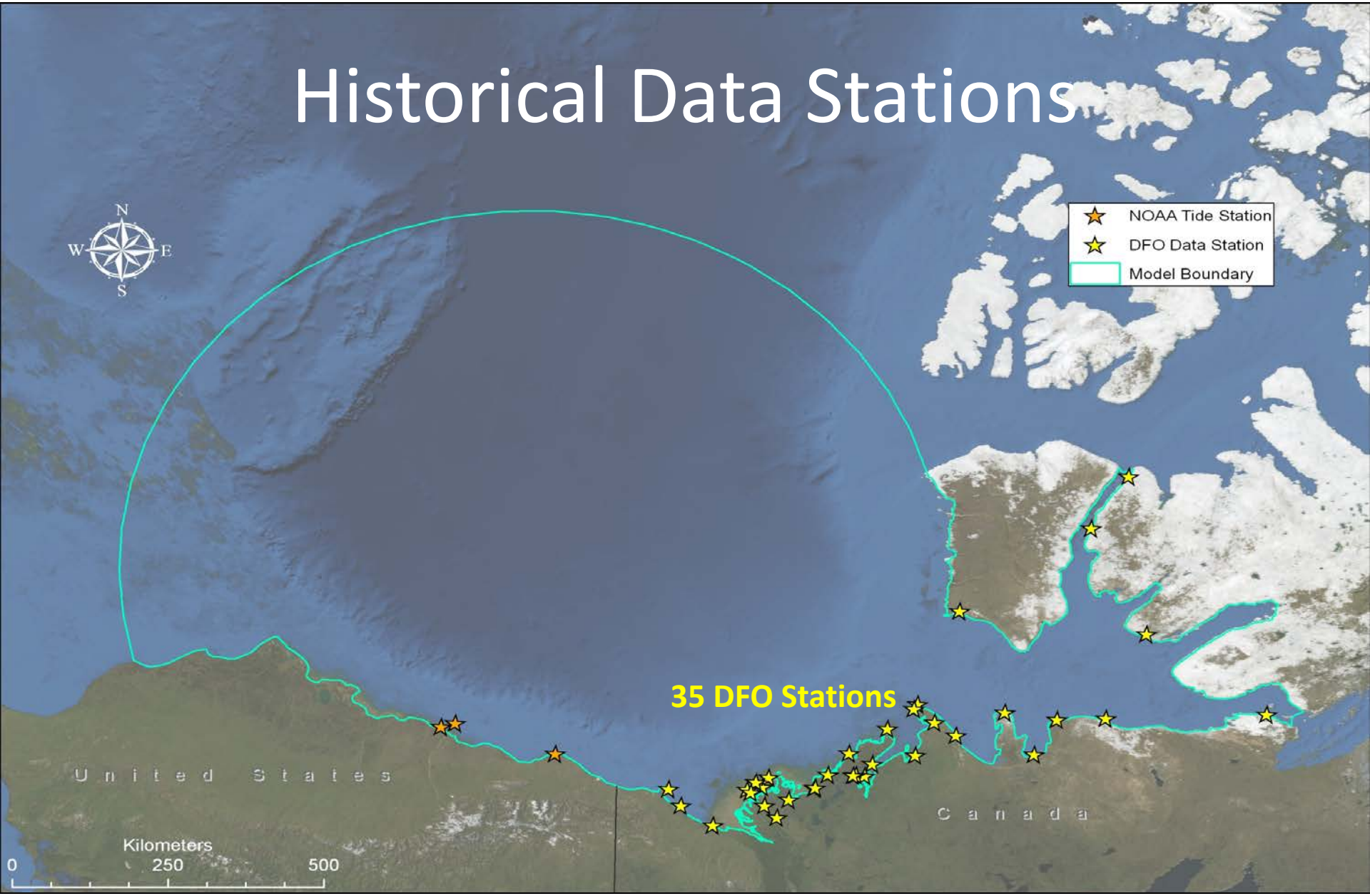
Historical Data Stations



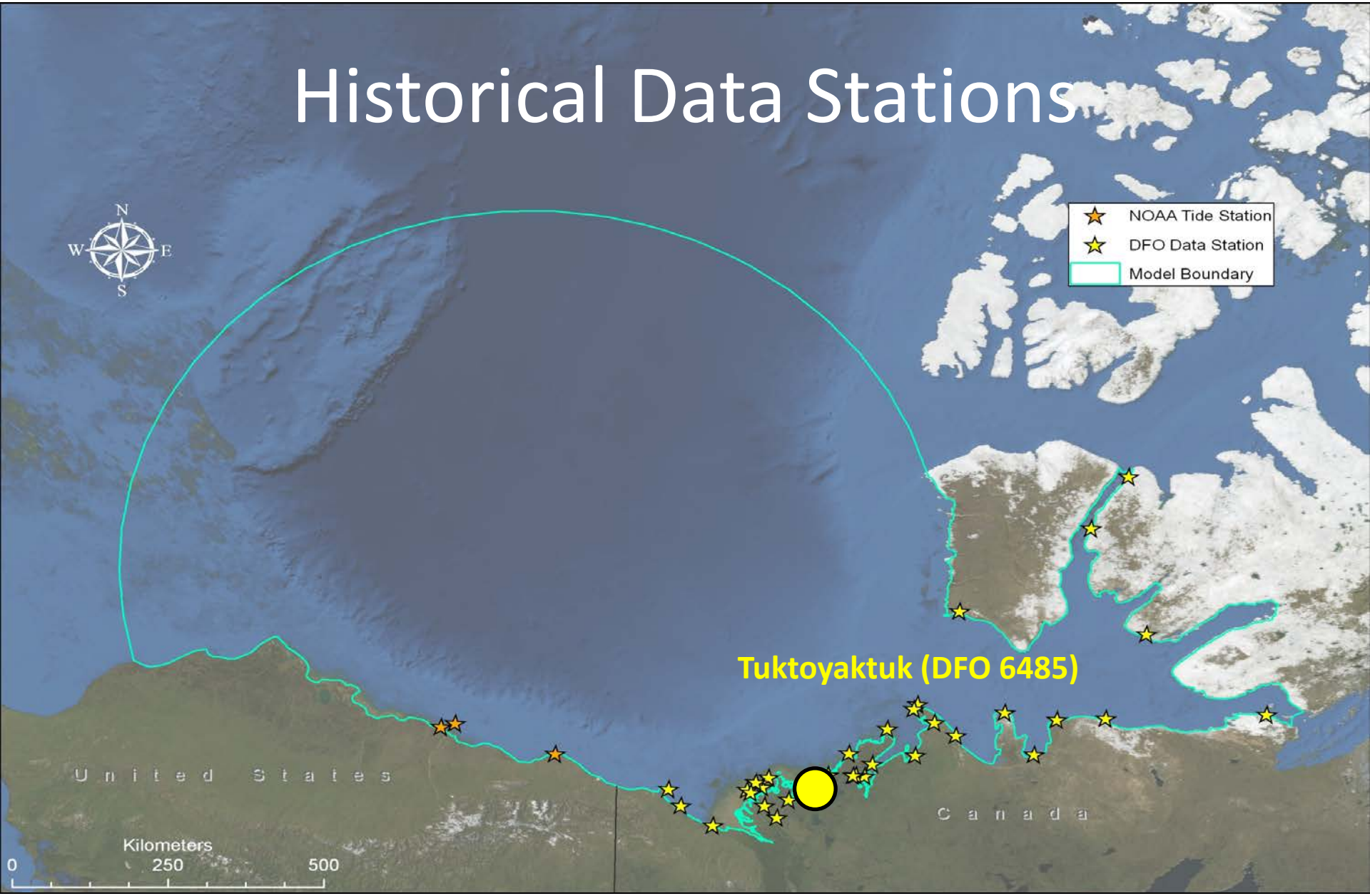
Historical Data Stations



Historical Data Stations



Historical Data Stations



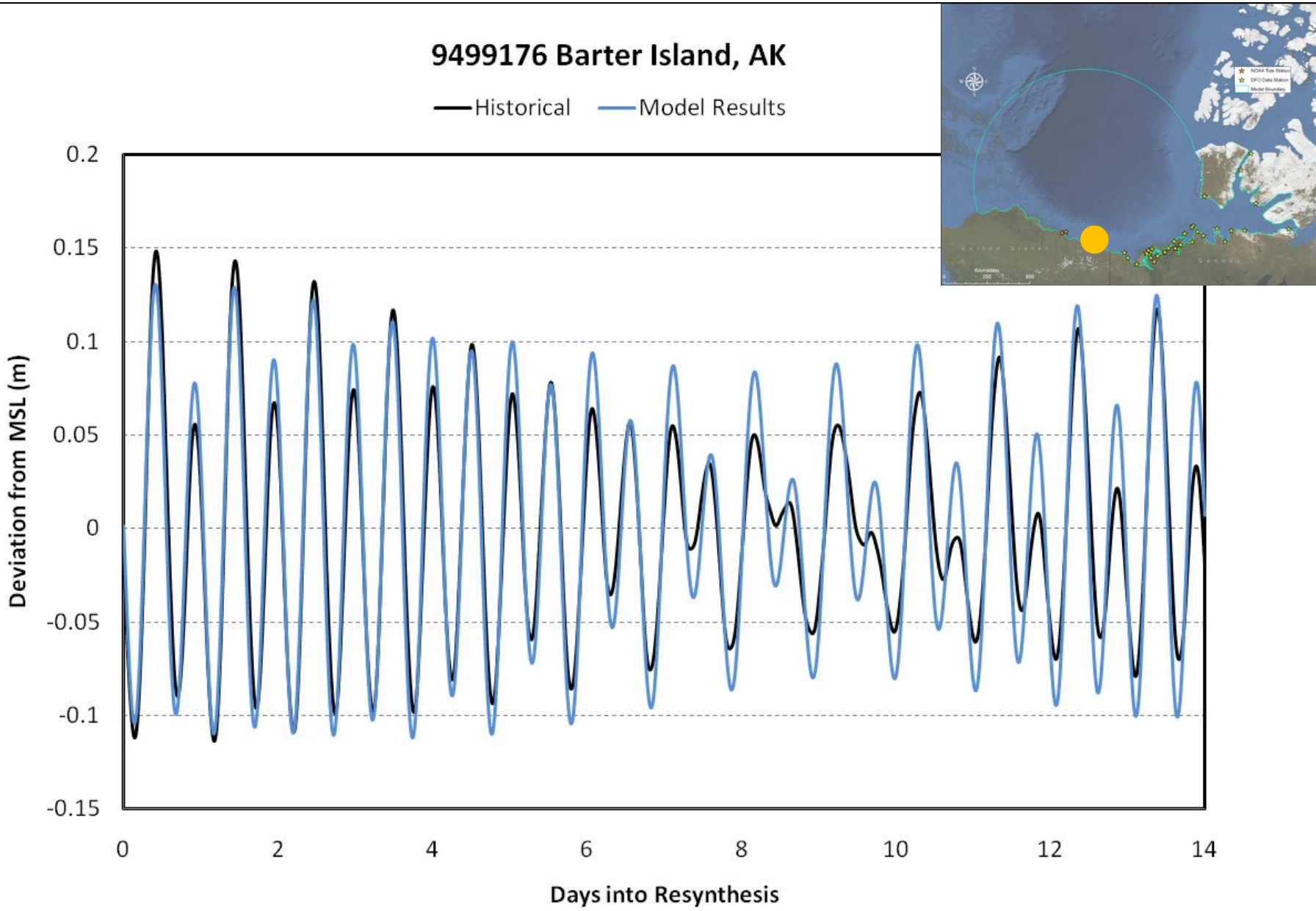
ADCIRC Model

Advanced Circulation, Two-Dimensional Depth-Integrated (ADCIRC-2DDI) model

- Long-wave, coastal and ocean circulation model
- Finite element based
- Simulates astronomic tides and storm surge

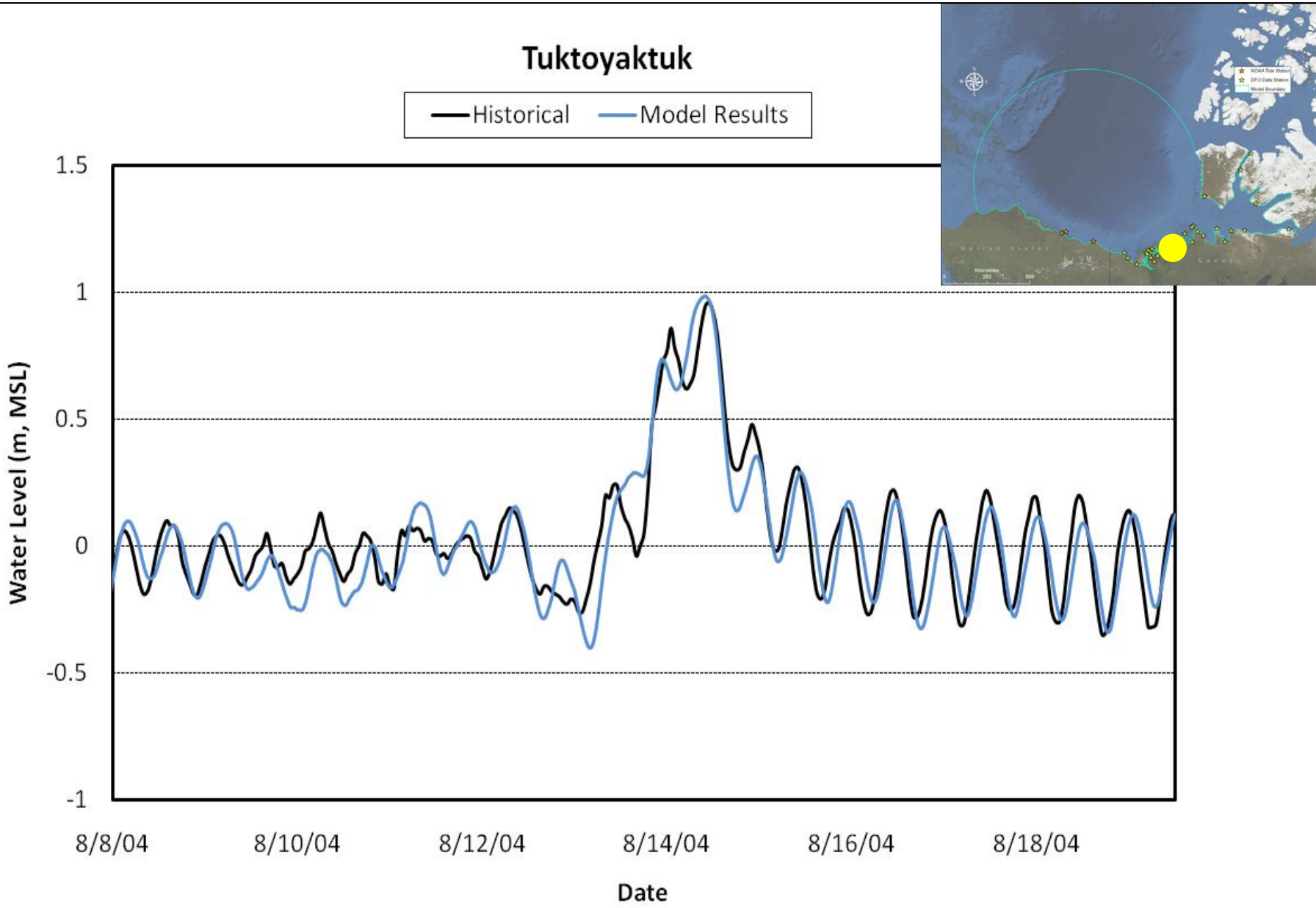
Astronomic Tide Comparison

- Open Ocean Boundary Conditions
  - AODTM5 tidal database
  - 8 constituents - K_1, K_2, M_2, N_2, O_1, Q_1, S_2, and P_1
- 90-day simulation, 8-sec time step
- Harmonic analysis performed over final 45-days
- Resynthesize model results and compare to historical data


9499176 Barter Island, AK
Historical
Model Results
Deviation from MSL (m)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
2
4
6
8
10
12
14
Days into Resynthesis

Storm Surge: Open Water Conditions

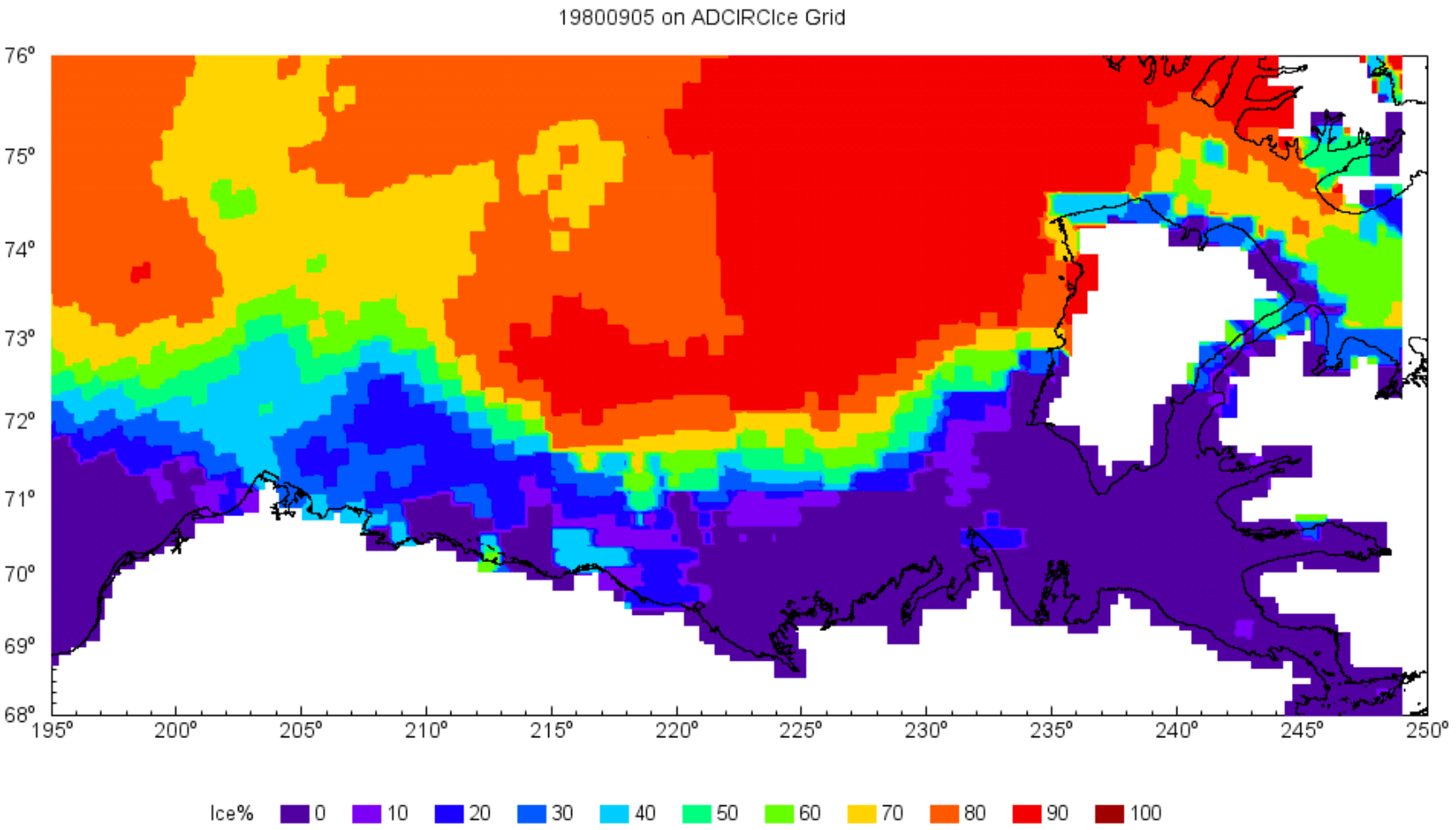
- August 6, 2004 – August 20, 2004
- Isolated surge event
- Open water conditions (relatively minimal ice cover)
- Wind/pressure field data input to the ADCIRC model
- Wind stress based on Garrett's formulation
  - ➢ No adjustments due to ice cover data


Tuktoyaktuk
Historical
Model Results
1.5
1
0.5
0
-0.5
-1
Water Level (m, MSL)
8/8/04
8/10/04
8/12/04
8/14/04
8/16/04
8/18/04
Date

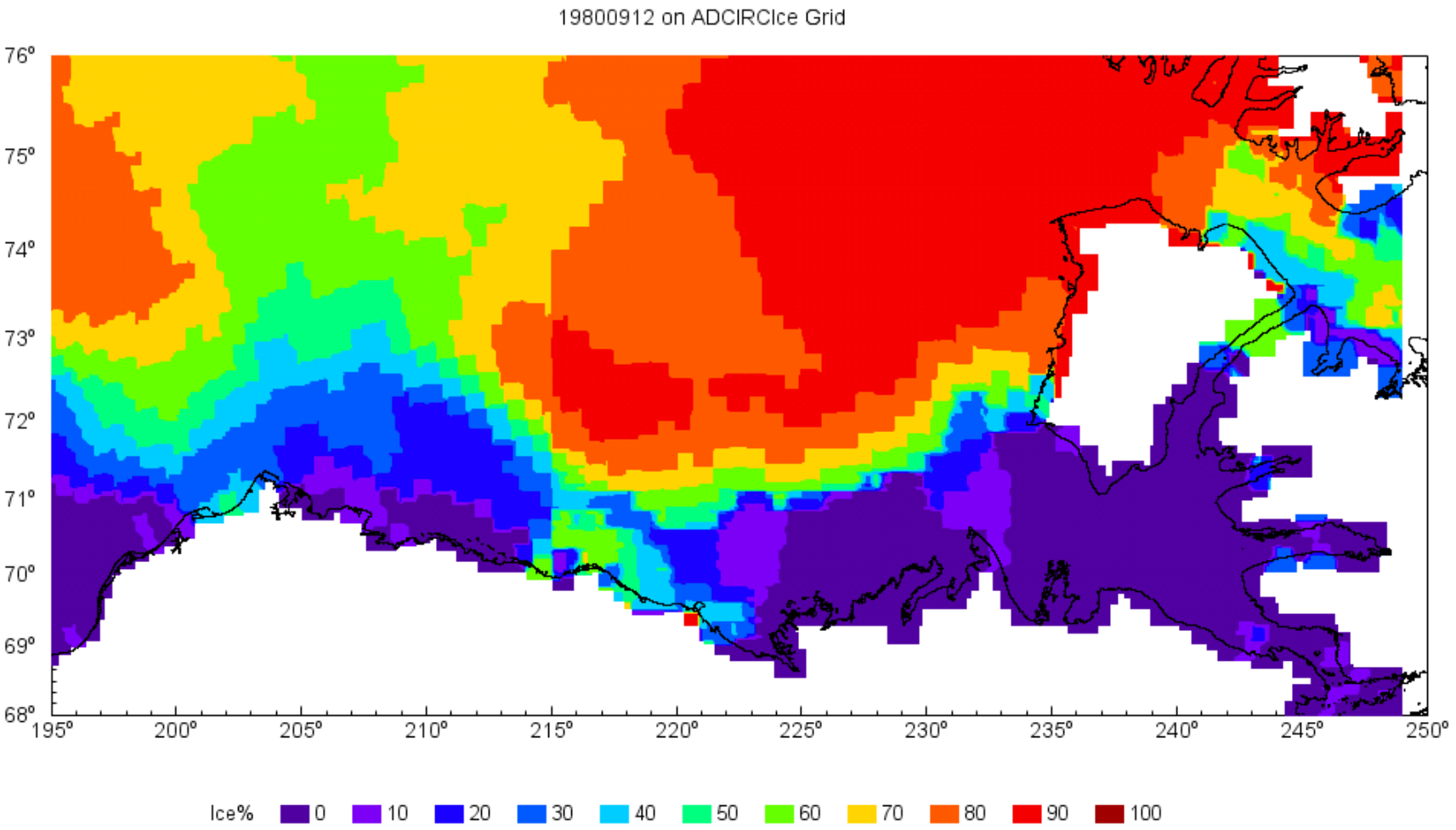
Storm Surge: Ice Cover Data

- Expansive ice cover throughout the Beaufort Sea during the Fall, Winter, and Spring seasons
- Data available in a 5-km grid
- Simulating 30+ years of data
  - Parameterization vs. calibration
  - Need a flexible, yet robust method
- Adjust wind drag coefficient based on ice cover

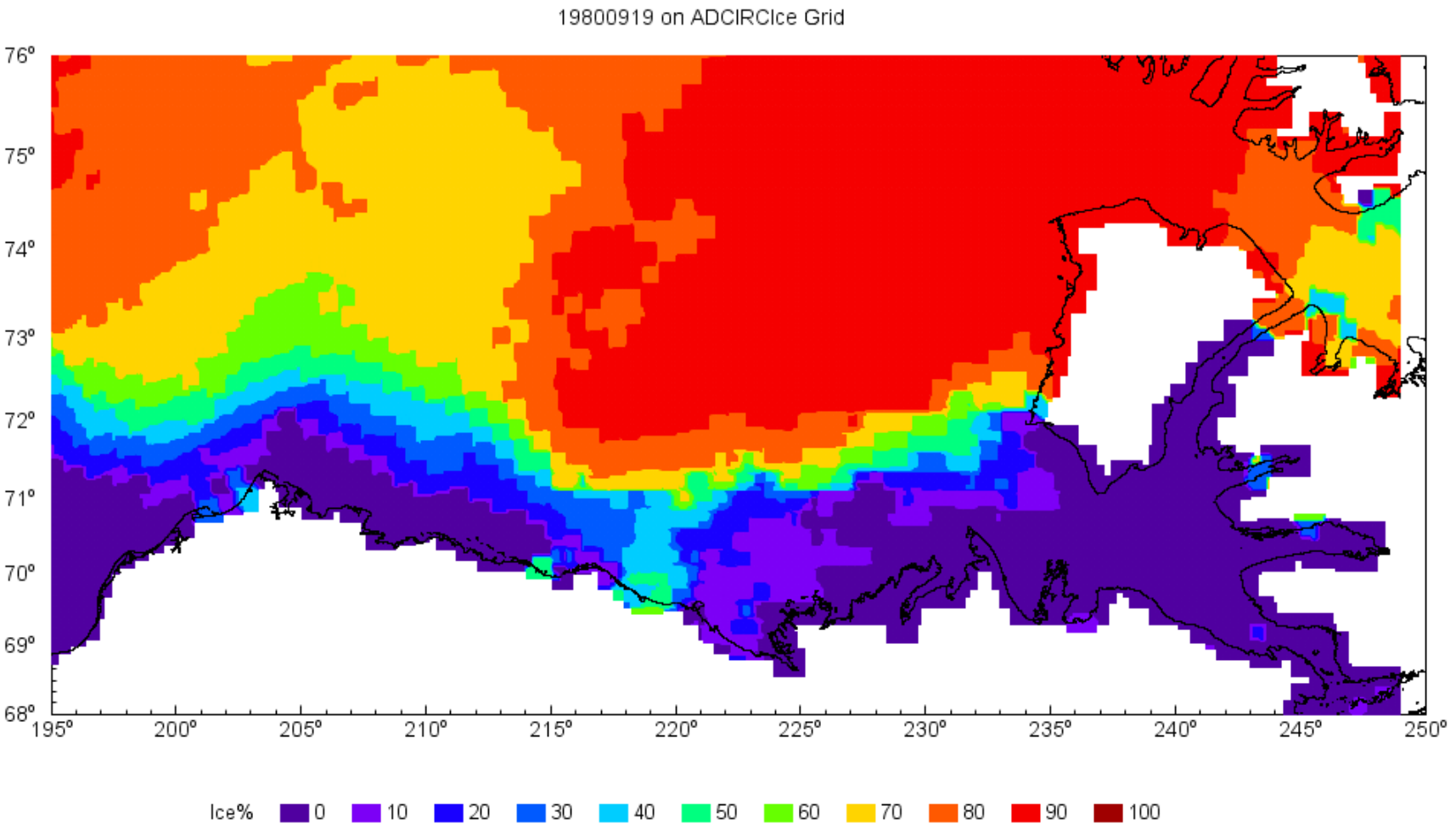
Ice Cover Data Example – 9/5/80



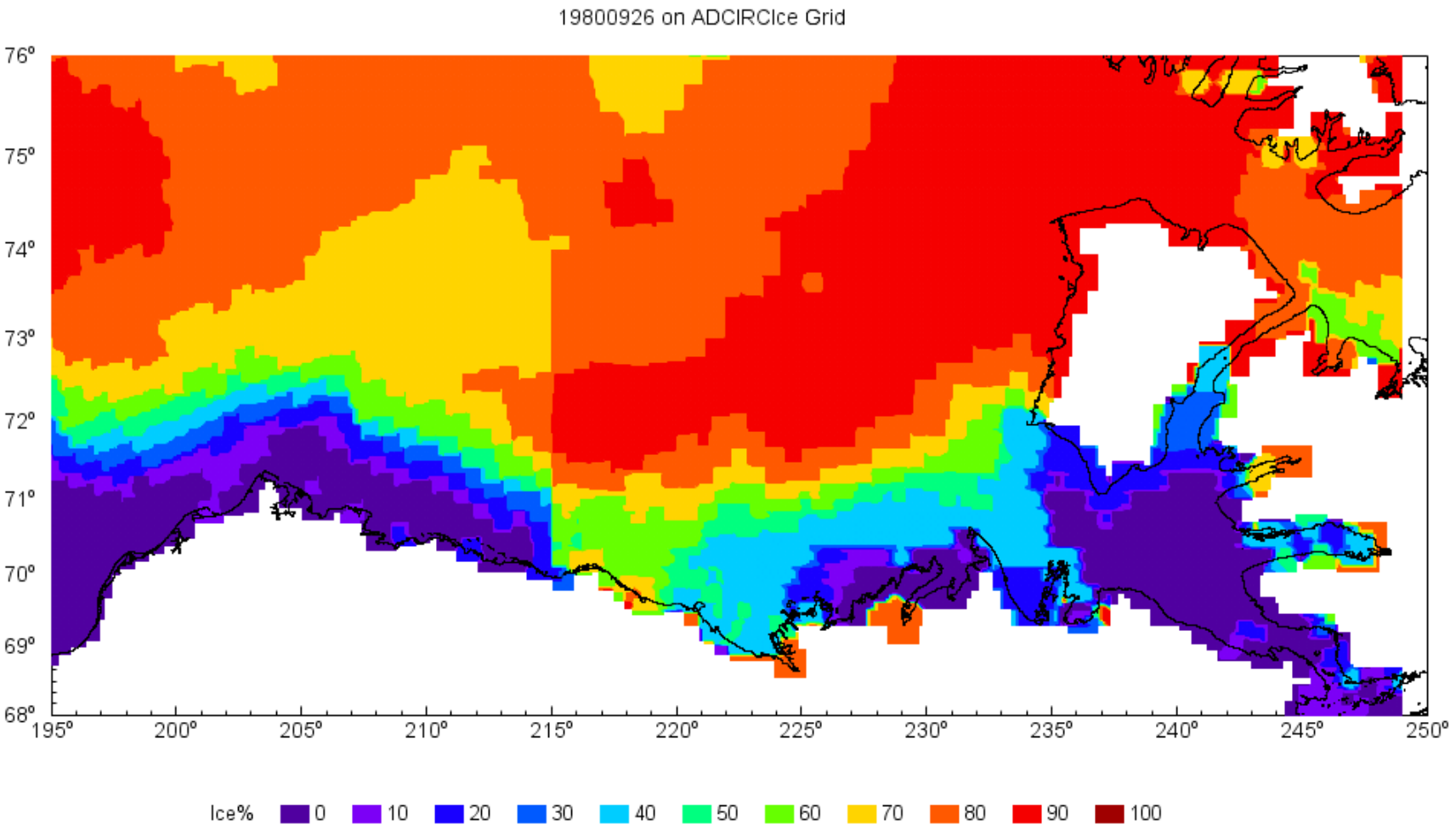
Ice Cover Data Example – 9/12/80



Ice Cover Data Example – 9/19/80



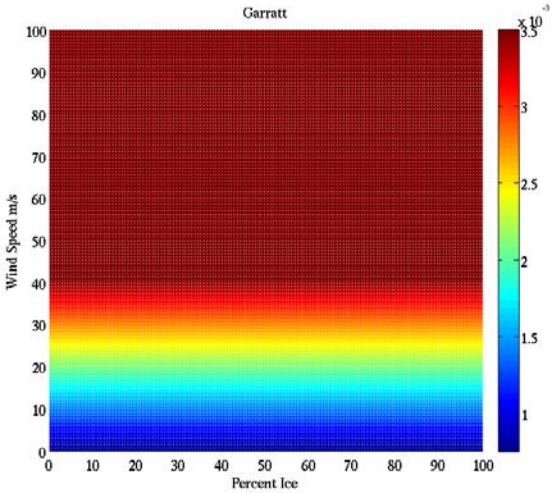
Ice Cover Data Example – 9/26/80



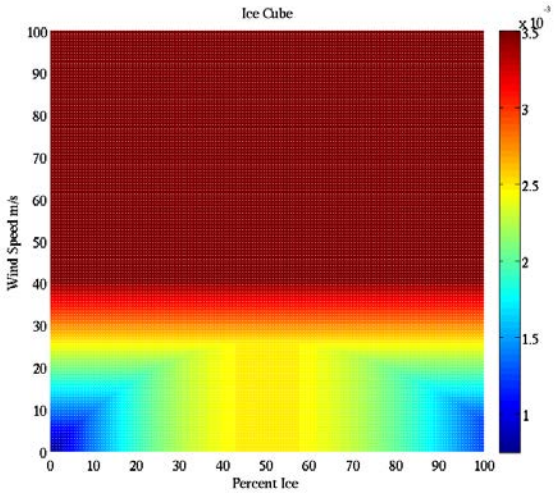
ICE CUBE Method

- Developed by the USACE Coastal & Hydraulics Laboratory
- Assumes ice floe contributes to water momentum
- Wind stress based on percent ice cover and wind speed

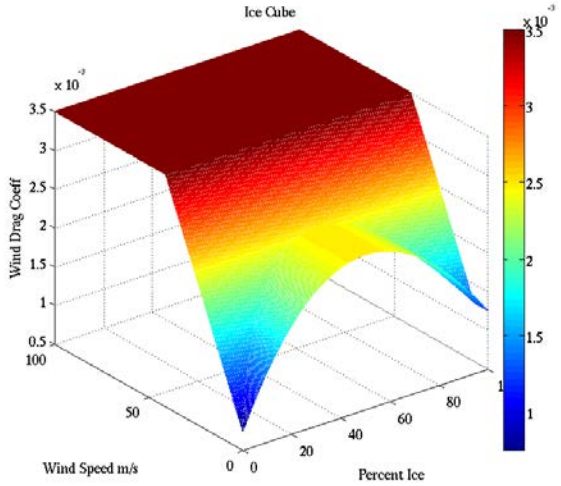
Garratt



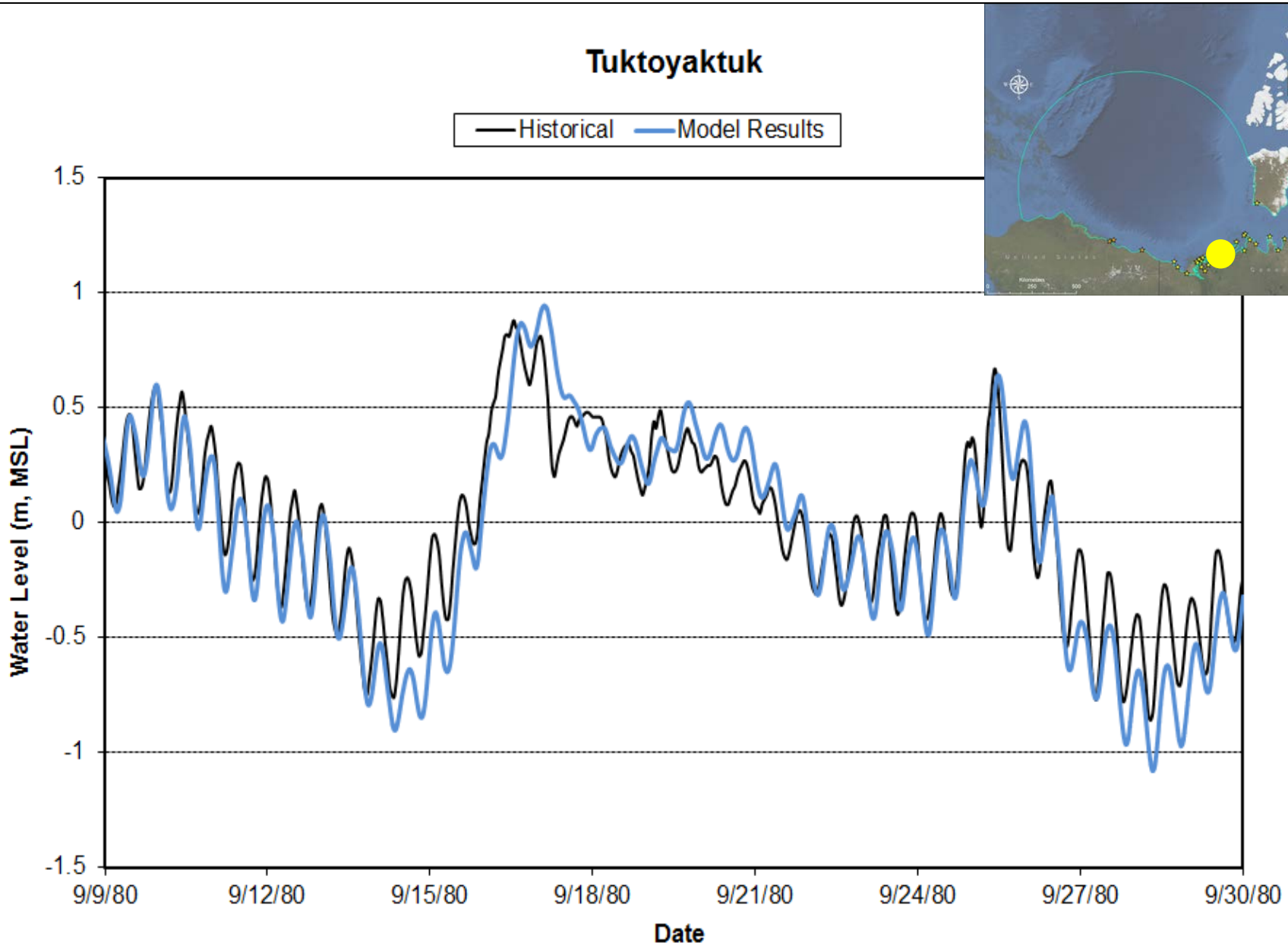
Garratt + ICE CUBE



Garratt + ICE CUBE



Source: Chris Massey and Ray Chapman, USACE


Tuktoyaktuk
Historical
Model Results
Water Level (m, MSL)
1.5
1
0.5
0
-0.5
-1
-1.5
9/9/80
9/12/80
9/15/80
9/18/80
9/21/80
9/24/80
9/27/80
9/30/80
Date

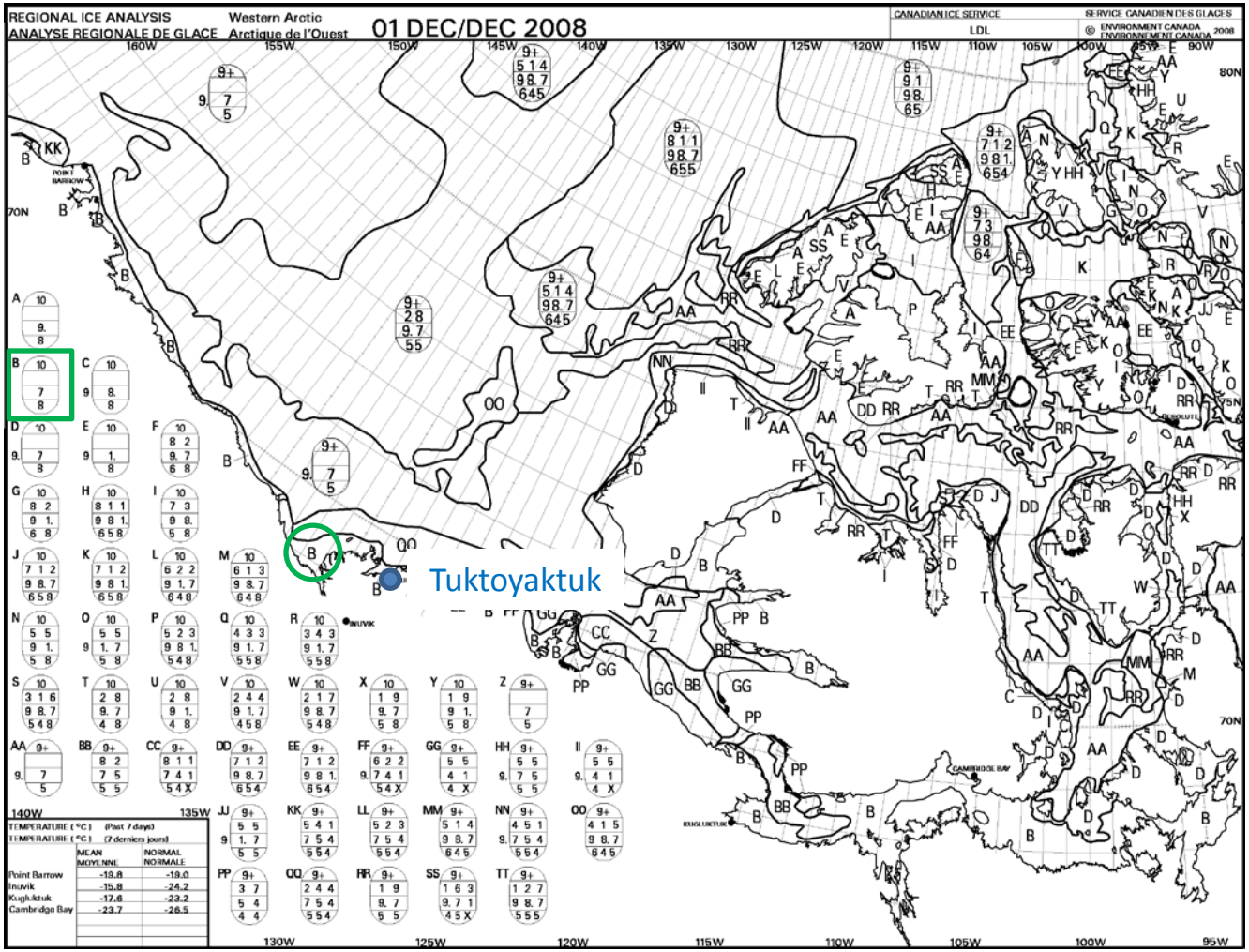
Fast Ice

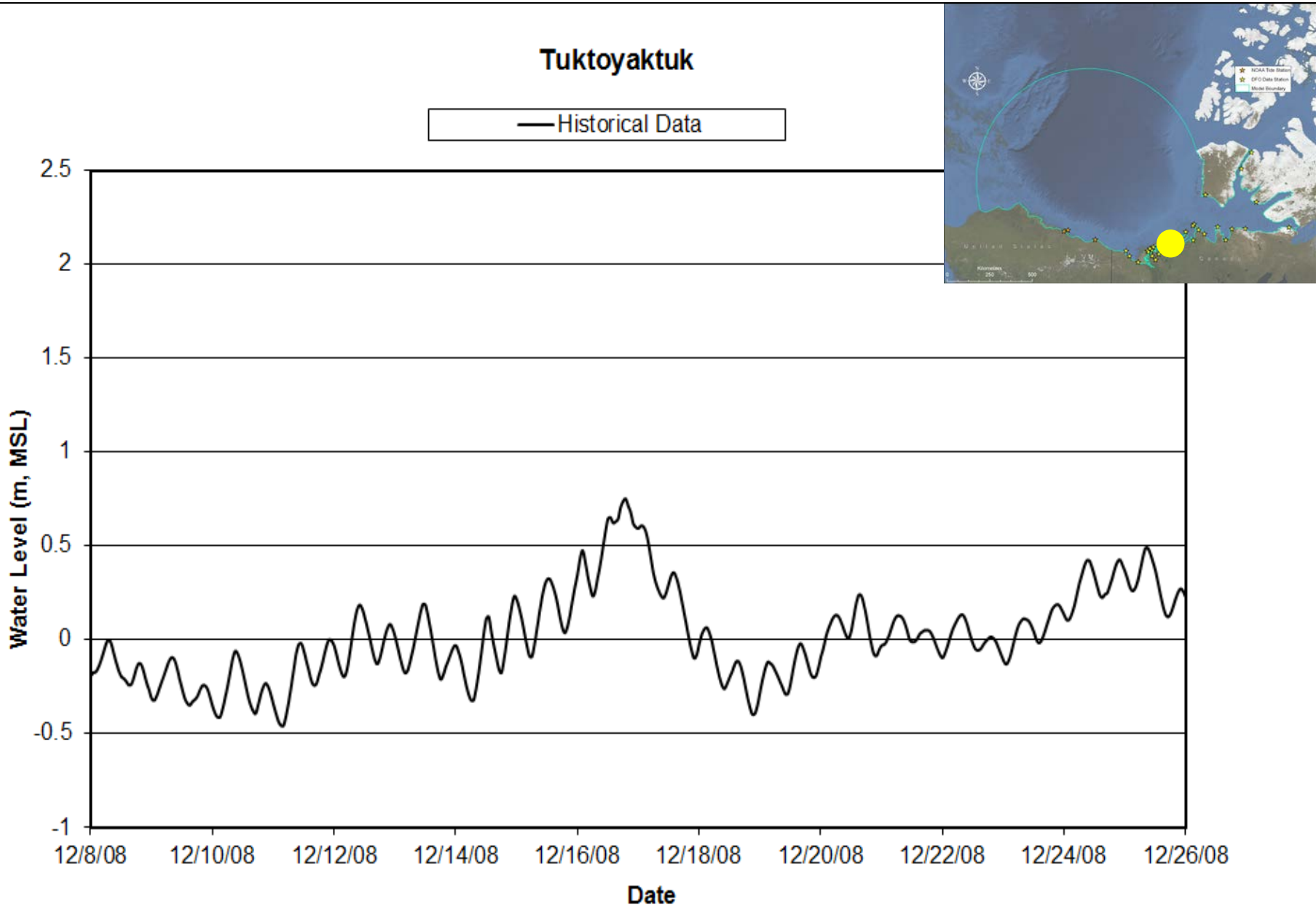
- Expansive, semi-rigid layer of ice (think Ice Road Truckers)
- Anchored to the shore or bottom
- Typically occurs in shallower waters
- Relatively minimal lateral movement due to winds or currents

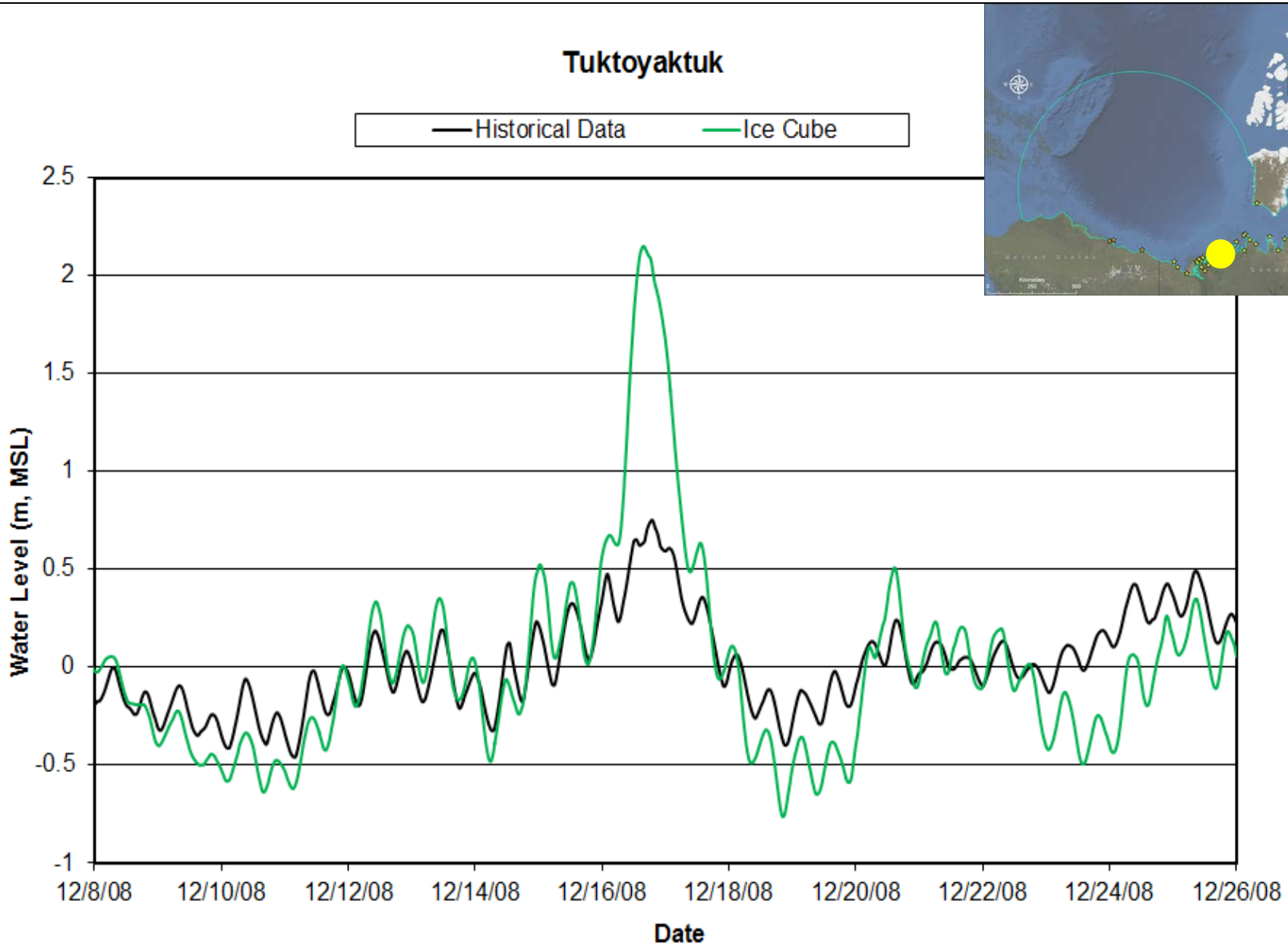
Ice Floe

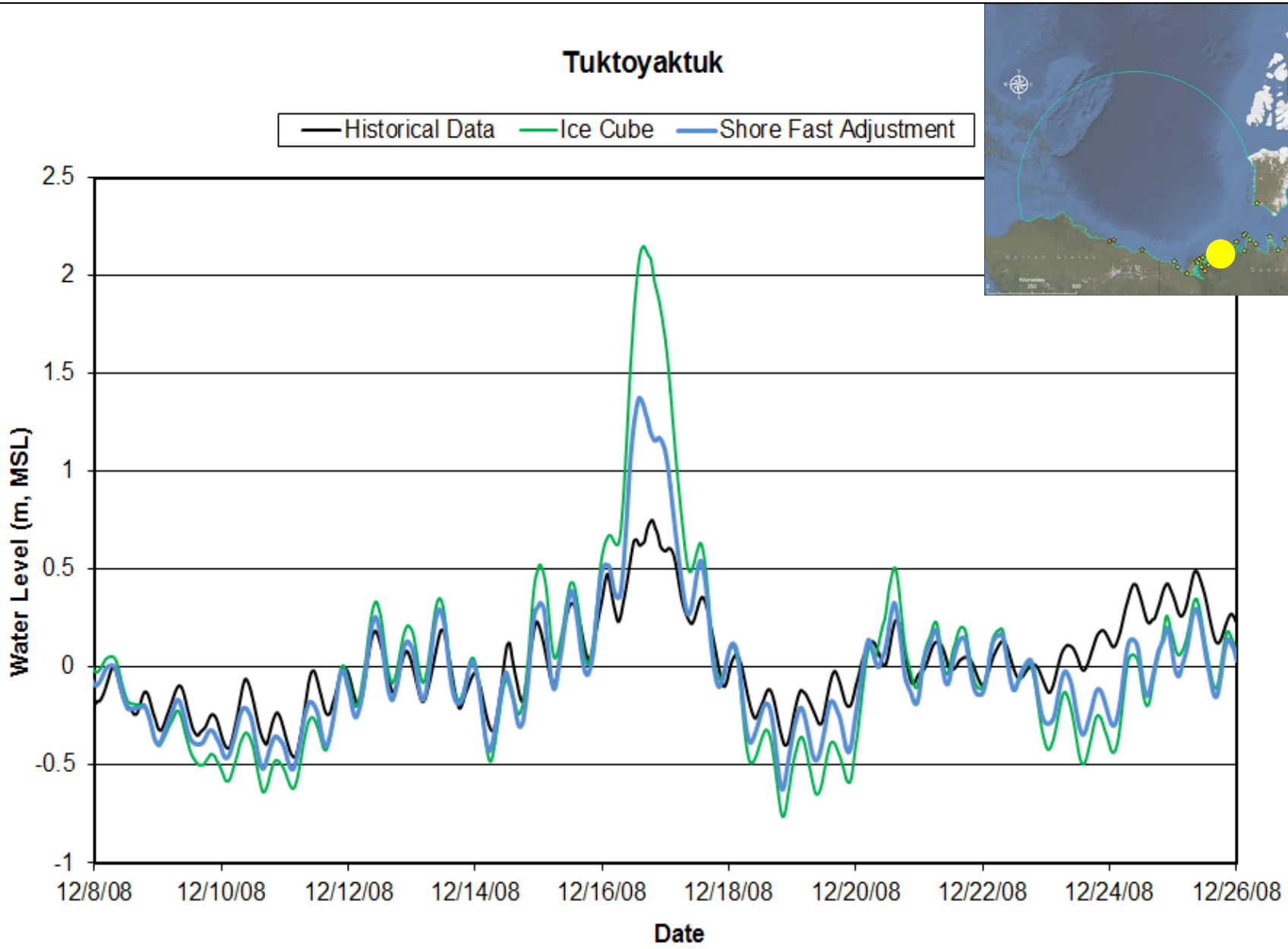
Fast Ice

Fast Ice


REGIONAL ICE ANALYSIS
ANALYSE REGIONALE DE GLACE
Western Arctic
Arctique de l'Ouest
01 DEC/DEC 2008
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
ENVIRONMENT CANADA
ENVIRONNEMENT CANADA
Tuktoyaktuk
TEMPERATURE (°C) (Past 7 days)
TEMPERATURE (°C) (7 derniers jours)
MEAN MOYENNE
NORMAL NORMALE
Point Barrow -19.8 -19.0
Inuvik -15.8 -24.2
Kugluktuk -17.6 -23.2
Cambridge Bay -23.7 -26.5


Tuktoyaktuk
Historical Data
Water Level (m, MSL)
2.5
2
1.5
1
0.5
0
-0.5
-1
12/8/08
12/10/08
12/12/08
12/14/08
12/16/08
12/18/08
12/20/08
12/22/08
12/24/08
12/26/08
Date


Tuktoyaktuk
Historical Data
Ice Cube
Water Level (m, MSL)
2.5
2
1.5
1
0.5
0
-0.5
-1
12/8/08
12/10/08
12/12/08
12/14/08
12/16/08
12/18/08
12/20/08
12/22/08
12/24/08
12/26/08
Date


Tuktoyaktuk
Historical Data
Ice Cube
Shore Fast Adjustment
Water Level (m, MSL)
2.5
2
1.5
1
0.5
0
-0.5
-1
12/8/08
12/10/08
12/12/08
12/14/08
12/16/08
12/18/08
12/20/08
12/22/08
12/24/08
12/26/08
Date

Conclusions and Future Work

- Model performs well during open-water conditions
- ICE CUBE method provides a flexible method for incorporating ice cover data under certain conditions
- Shore-fast ice also important in shallower waters
- Continue fast ice sensitivity analysis
- Perform full hindcast simulation with ICE CUBE and fast-ice adjustments incorporated

Acknowledgement

The authors wish to thank the Canadian federal **Program of Energy Research and Development** for providing funding support throughout the course of this project.