The MSC Beaufort Wind and Wave Reanalysis

Val Swail
Environment Canada

Vincent Cardone, Brian Callahan,
Mike Ferguson, Dan Gummer and
Andrew Cox
Oceanweather Inc.
Cos Cob, CT, USA

Introduction: History of Studies leading up to the MSC-B

- Murray and Maes (1986) extreme wave climate review of 100-year wave 4-16 m
- 1990-92: PERD hindcast of 30 severe storms for Canadian Beaufort using 2-G wave model over period 1957-88; 100-year waves varied from 2m near shore to 6m offshore; also included sensitivity to alternative probabilistic ice cover
- 1993: PERD update to include 29 storms in Canadian Beaufort as possible erosion producing storms
- 1993-2005: dormant period in Beaufort Sea interest
- 2005-07: interest in continuous hindcast of 20+ years – *this study*

Introduction: Purpose of MSC-B

- Apply the same methodology used in the MSC50 NA hindcast to the Canadian Beaufort Sea to produce a high-quality climatology
- "Continuous" multi-decadal hindcast for both operating and extreme metocean statistics
- Increase resolution of Beaufort basin model
- Increase temporal resolution of archive
- Increase accuracy to reduce uncertainty on any climate or design data statistics
- Wind and wave databases and Beaufort Sea Atlas online

Challenges

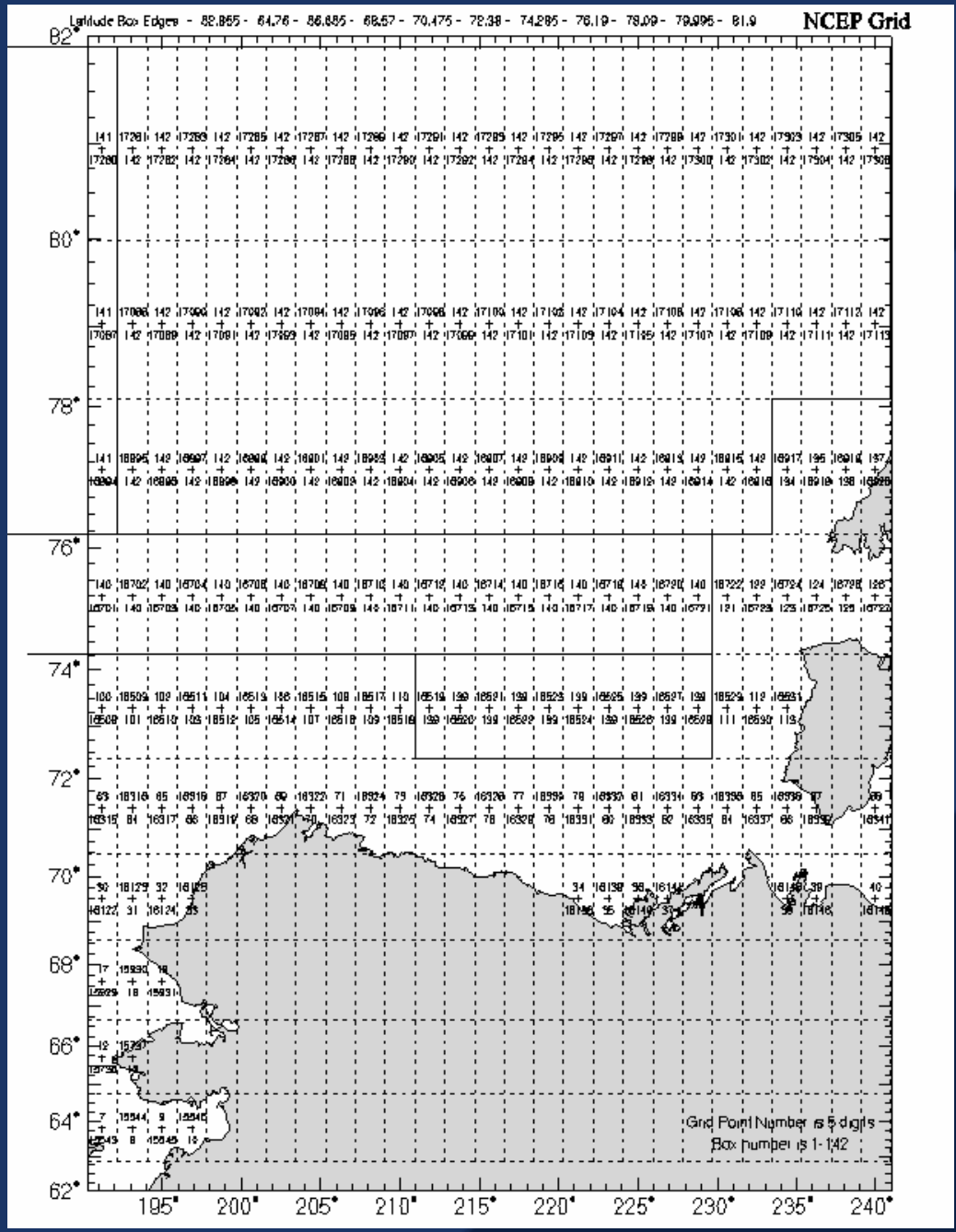
- Scarcity of in situ meteorological data
- Almost total absence of transient ship and moored weather buoy reports
- Highly variable and complex nature of sea ice cover
- Reanalysis wind fields considerably less accurate in Arctic
- Limited satellite products available even in recent years due to latitude of study area

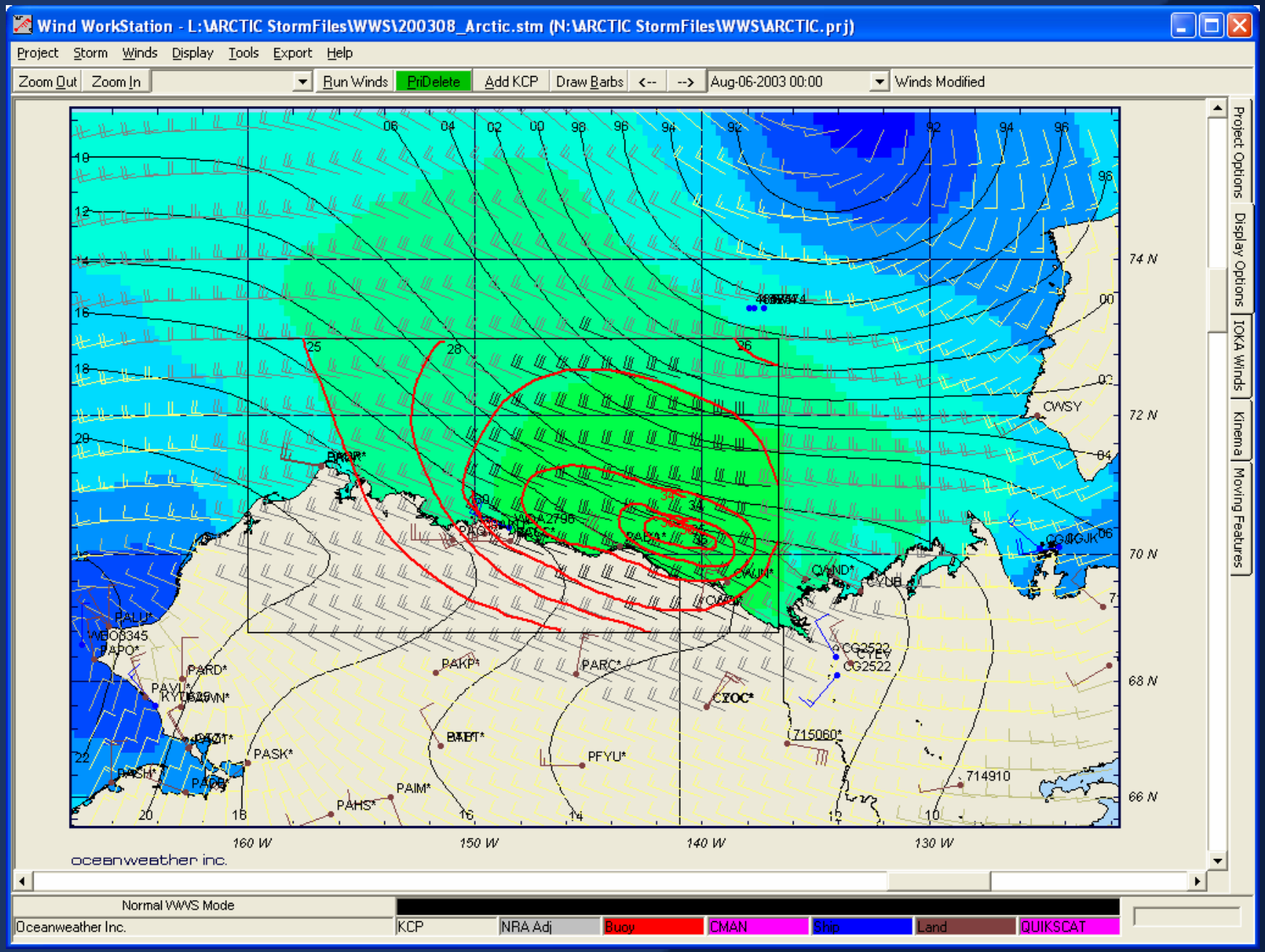
Wind Field Methodology

- OWI Interactive Objective Kinematic Analysis still the basis for hindcast wind fields
  - QuikSCAT to correct systematic errors in NRA winds
  - adjust coastal wind measurements to effective over-water exposure using station-dependent overwater/overland transformation ratios
  - Import marine and adjusted coastal winds into WWS with adjusted winds from transient ships
  - Apply IOKA to storm periods

QuikSCAT/NRA Wind Correlations

- SCAT and NRA data matched for all NRA grid boxes in the Beaufort Sea - fewer than 500 comparisons per box
- NRA 6-hourly winds linearly interpolated to nearest hour of satellite observation
- Direction stratifications are 90 degree segments based on NRA direction starting with 45-135, and all directions
- Standard difference statistics and Q-Q distributions computed
- If Q-Q linear then a simple correction algorithm is applied for speed; direction adjusted by mean difference
- Result: NRA winds biased low, especially for south and east winds, so were increased

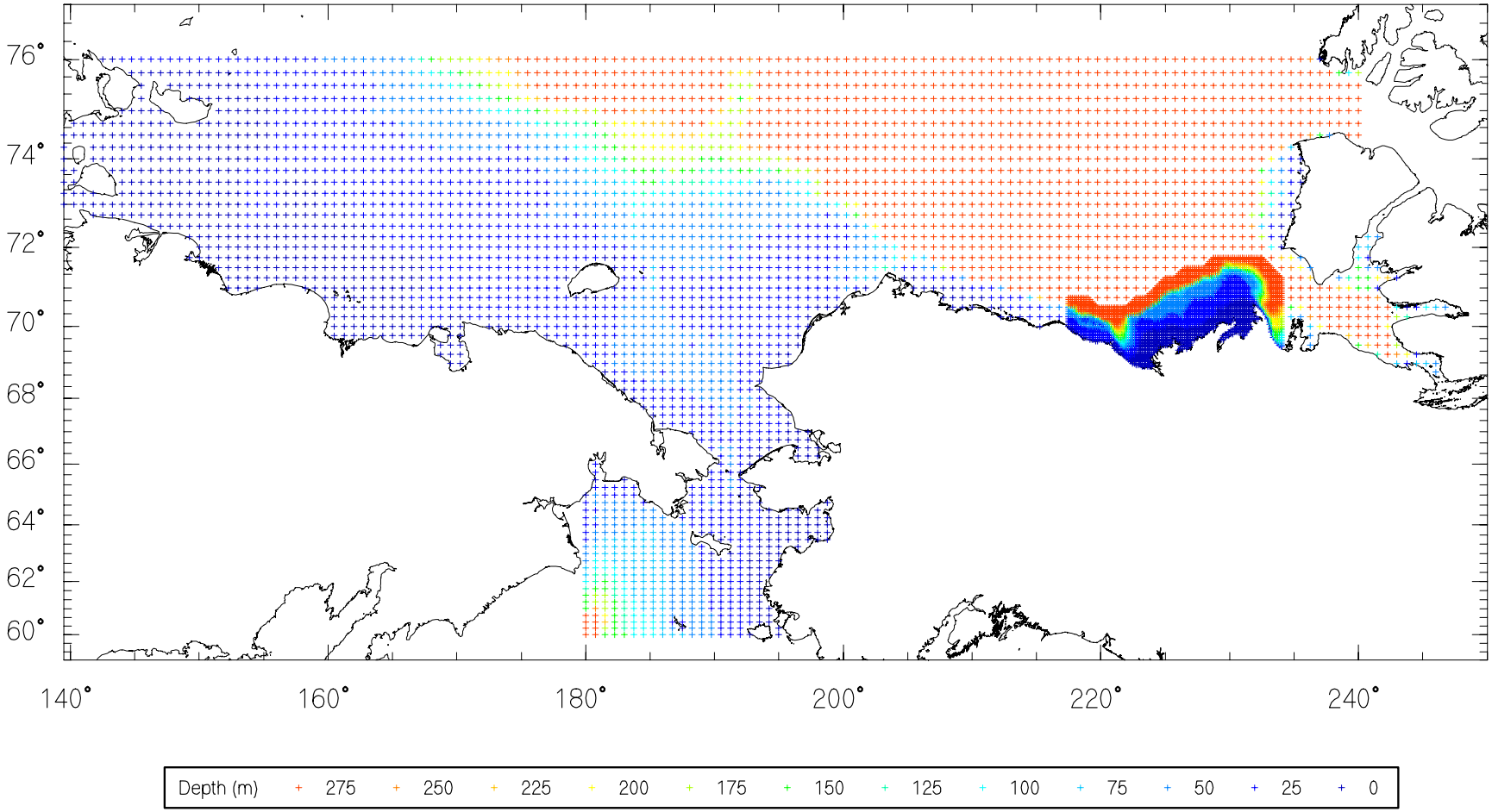

Latitude Box Edges - 82.865 - 84.76 - 86.655 - 88.57 - 70.475 - 72.38 - 74.285 - 76.19 - 78.09 - 79.995 - 81.9
NCEP Grid
82°
80°
78°
76°
74°
72°
70°
68°
66°
64°
62°
195°
200°
205°
210°
215°
220°
225°
230°
235°
240°
Grid Point Number is 5 digits
Box number is 1-142

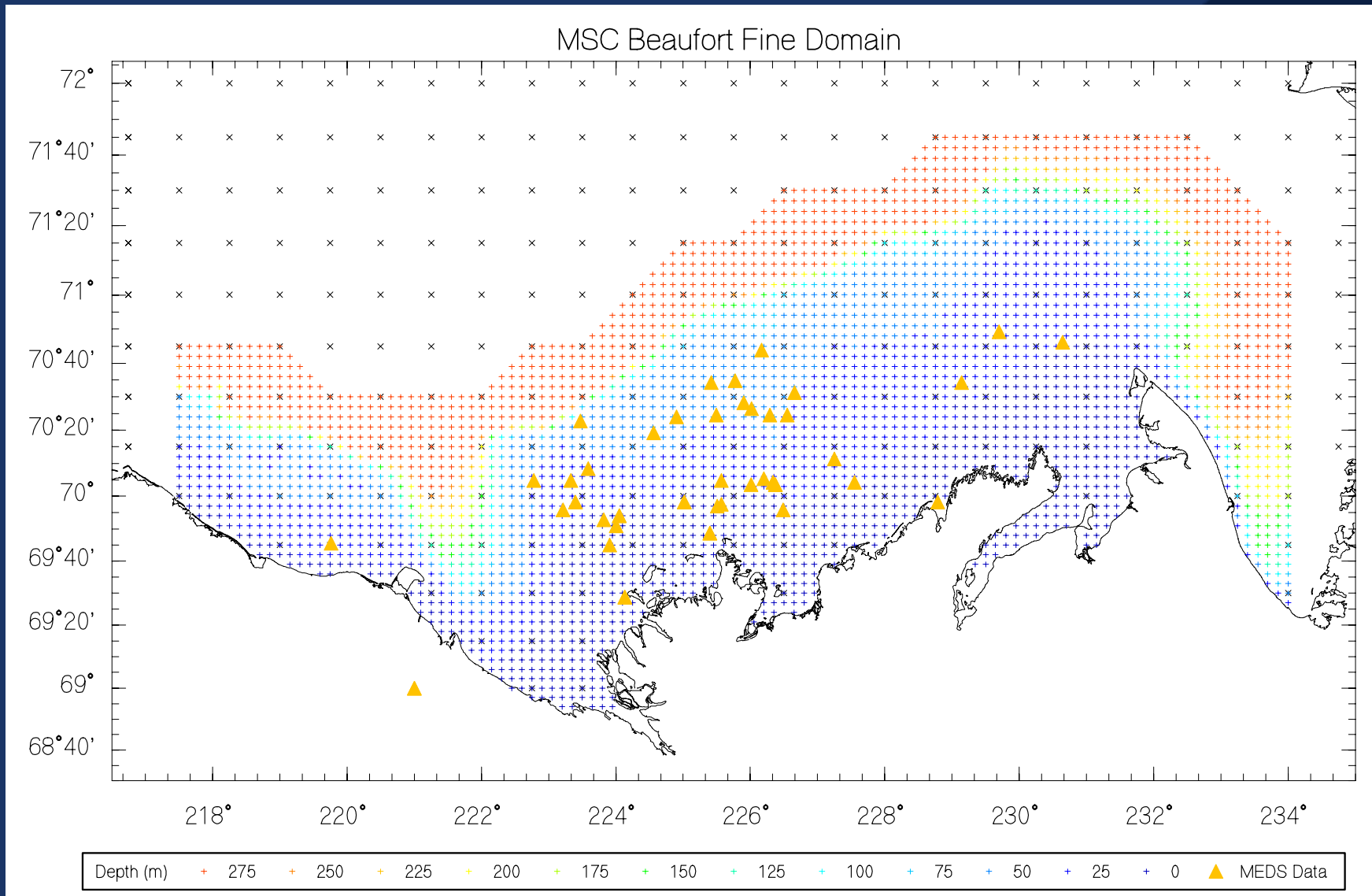


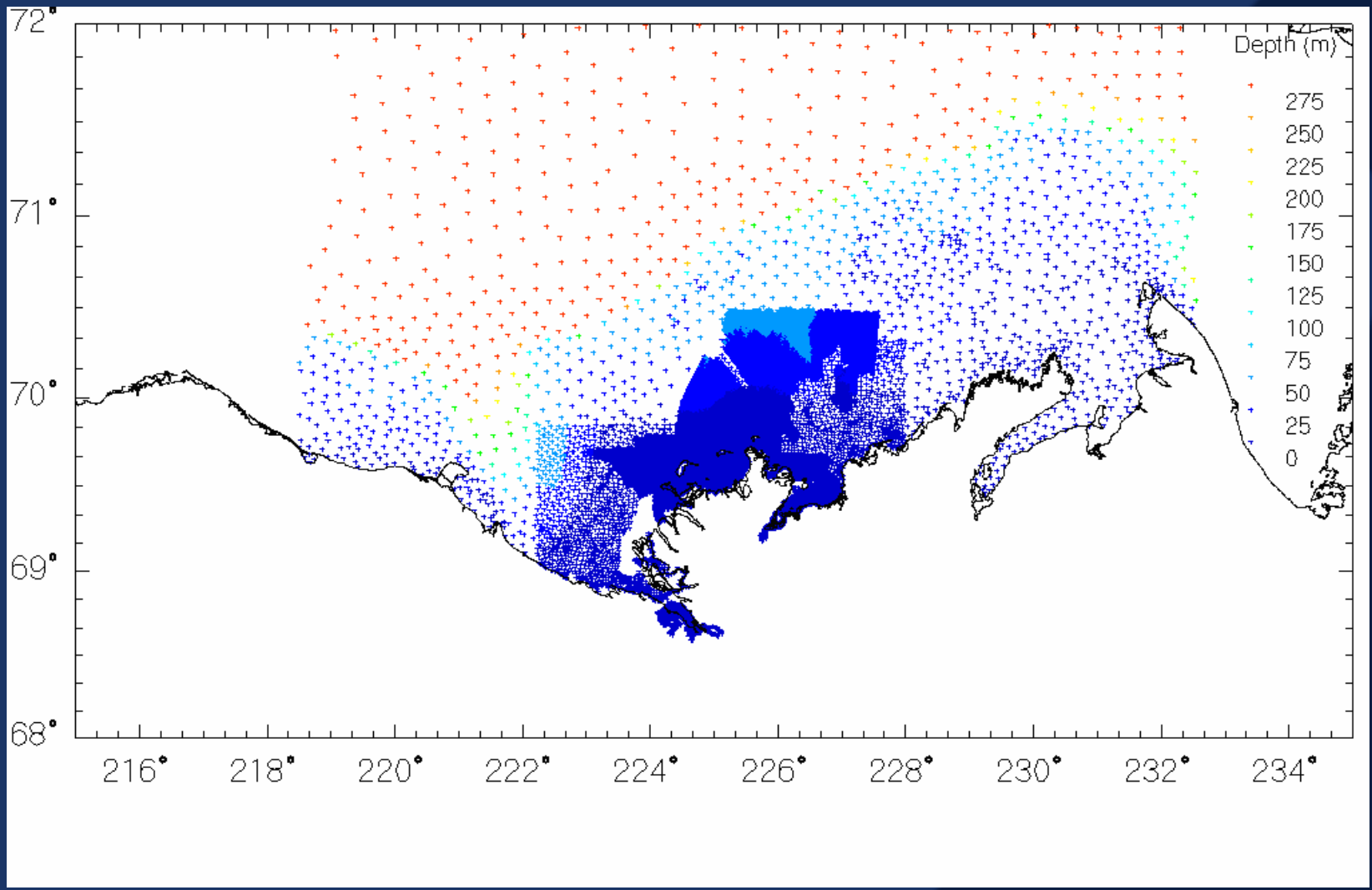
Wave Modelling Methodology

- OWI 3-G shallow water model
  - 28 km coarse grid; nested 5 km fine mesh
  - 3442 active grid points
  - Boundary spectra from OWI GROW hindcast
- Bathymetry
  - GEBCO 2003 1 minute data
  - CHS data for fine mesh area
  - Little smoothing required

MSC Beaufort Coarse and Fine Domain




MSC Beaufort Fine Domain
72°
71°40'
71°20'
71°
70°40'
70°20'
70°
69°40'
69°20'
69°
68°40'
218°
220°
222°
224°
226°
228°
230°
232°
234°
Depth (m)
275
250
225
200
175
150
125
100
75
50
25
0
MEDS Data



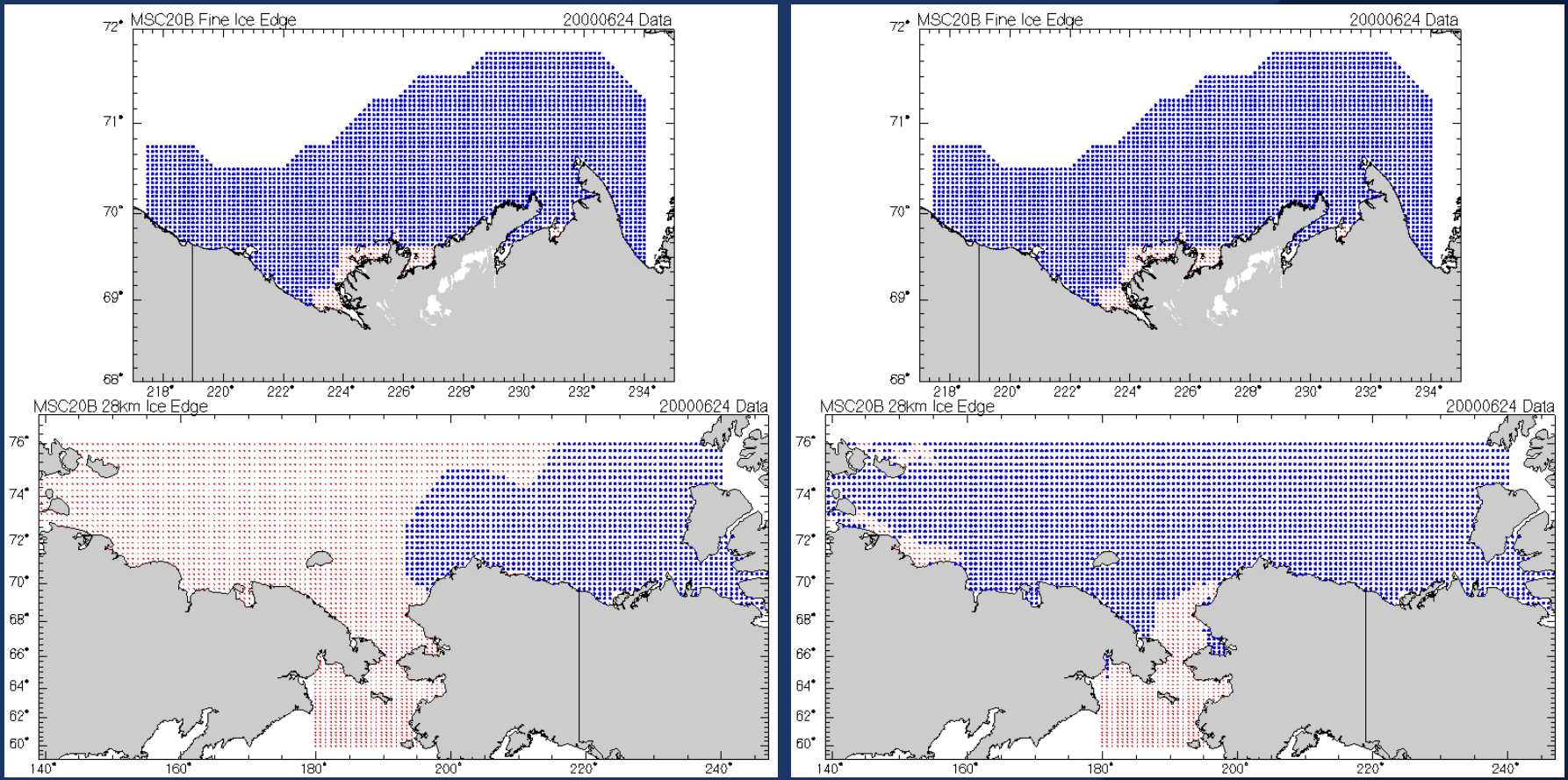
Depth measurements provided by CHS for use in the Beaufort wave model

Ice Edge

- In the wave model grid point locations with > 50% ice concentration are considered as land, with no wave generation or propagation
- Ice edge updated on weekly basis
- In Canadian waters CIS high resolution ice data set used
- Other areas GFSC/DMSP ice data used, with blending since CIS data did not cover the entire 28 km model domain

Ice concentration data sources

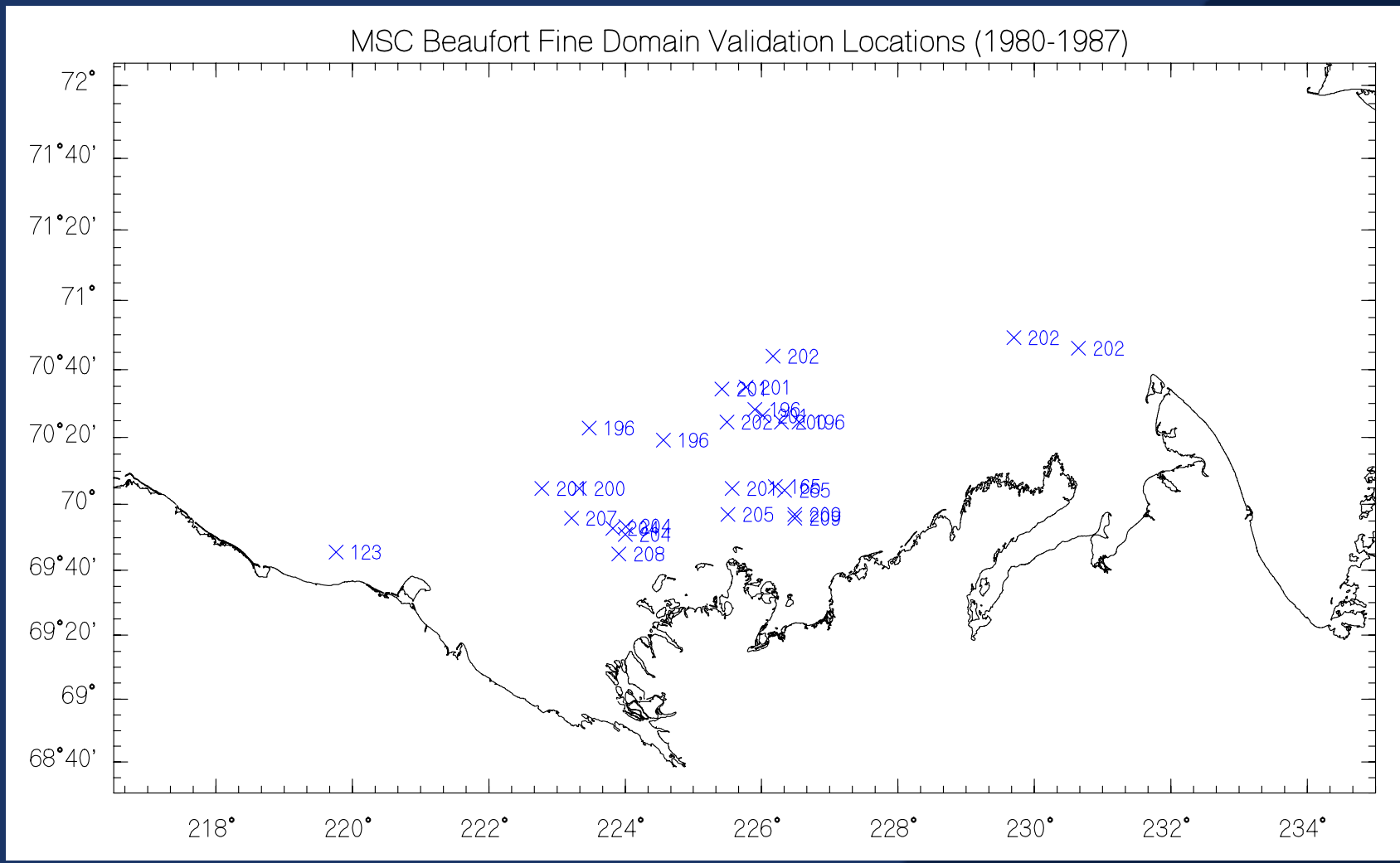
Source	Frequency	Coverage	Date Range
GFSC	Daily	Full	Nov1978-Dec 2000
DMSP	Daily	Full	Jan 2001-Present
CIS NetCDF	Weekly	Canadian Waters	Jan 1971-Present

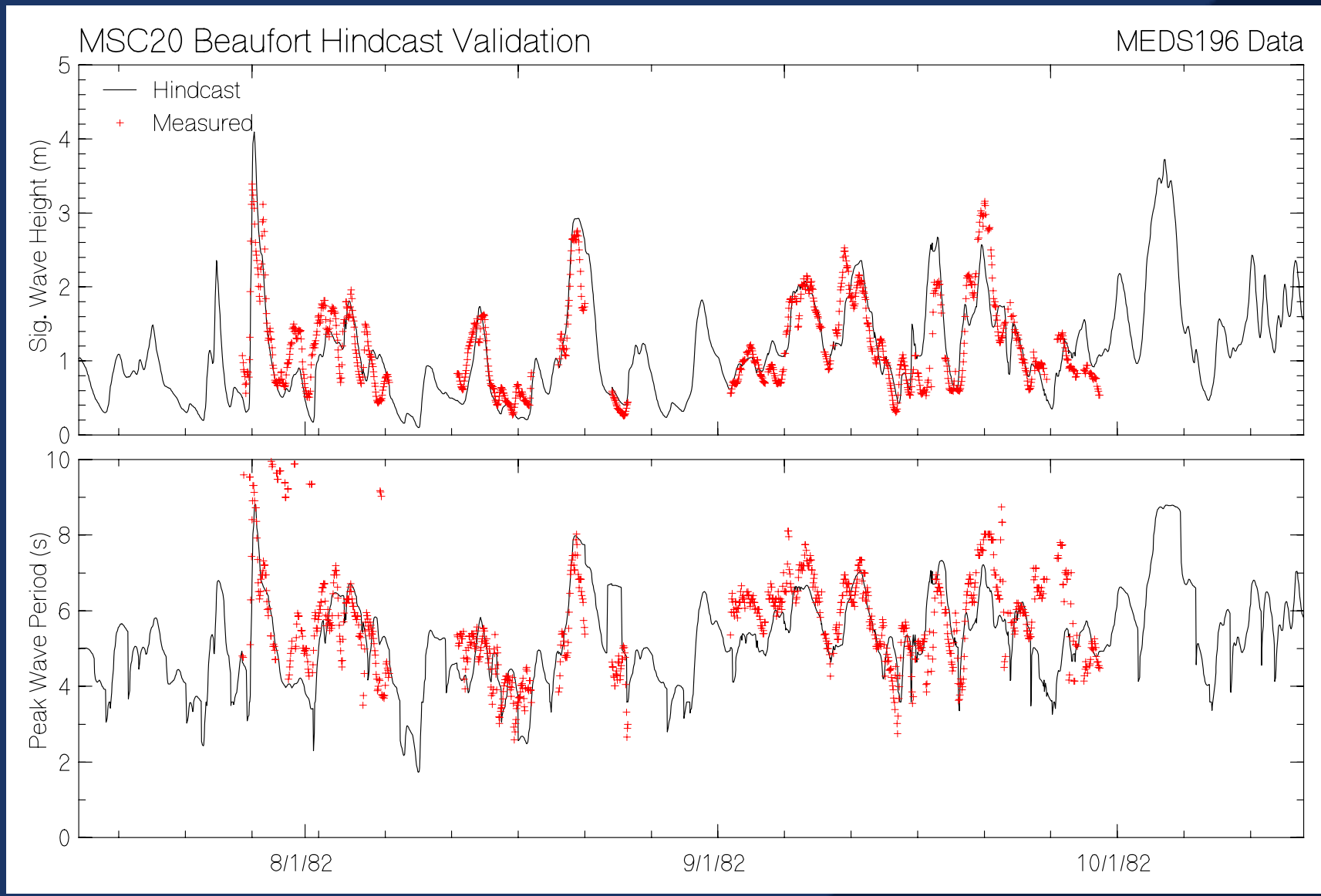


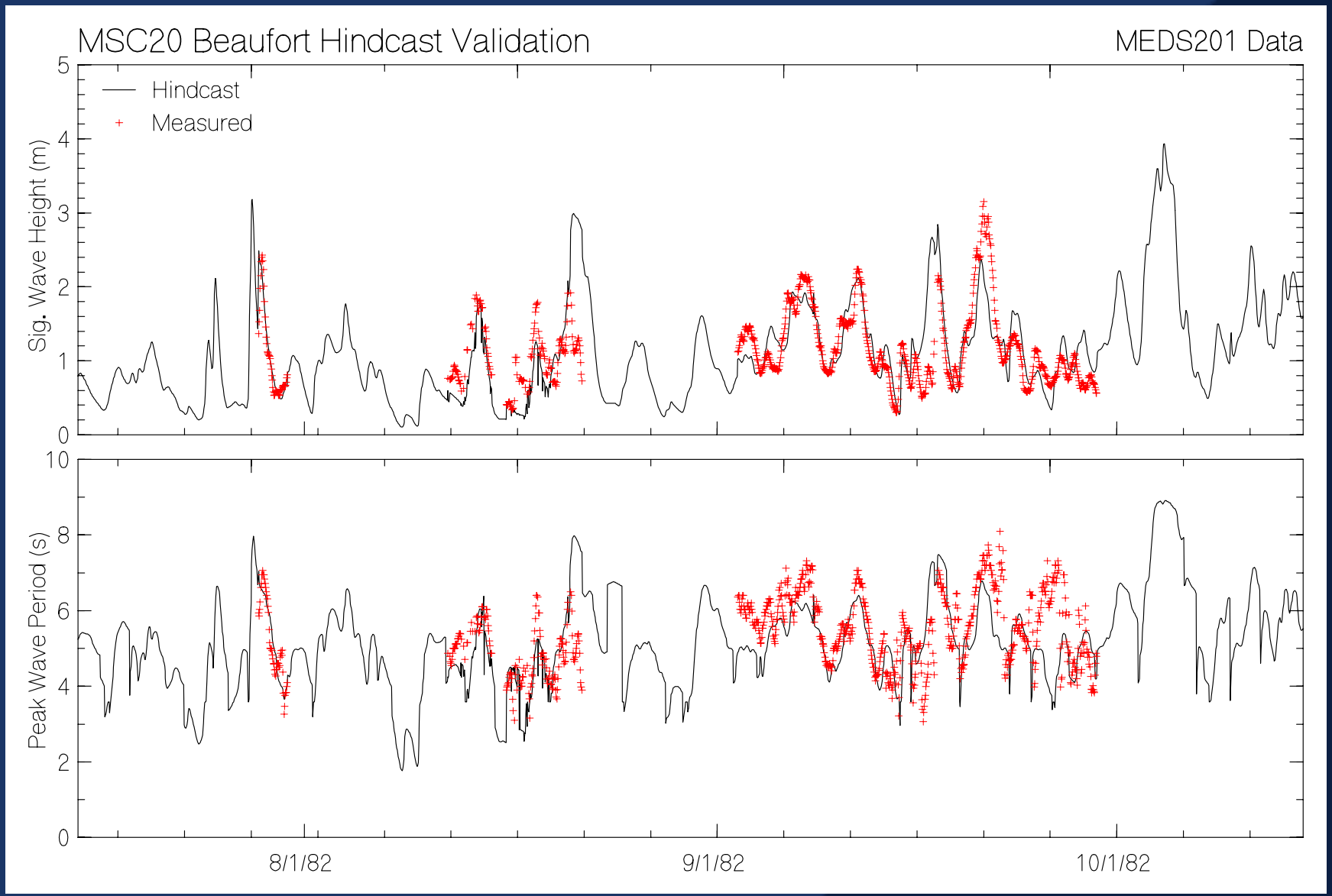
Comparison of weekly ice edge (blue represents greater than 50% concentration) valid June-24-2000 from the Canadian Ice Service (left) and final blended ice edge (right) from multiple ice data sources on the MSC Beaufort coarse and fine model domain

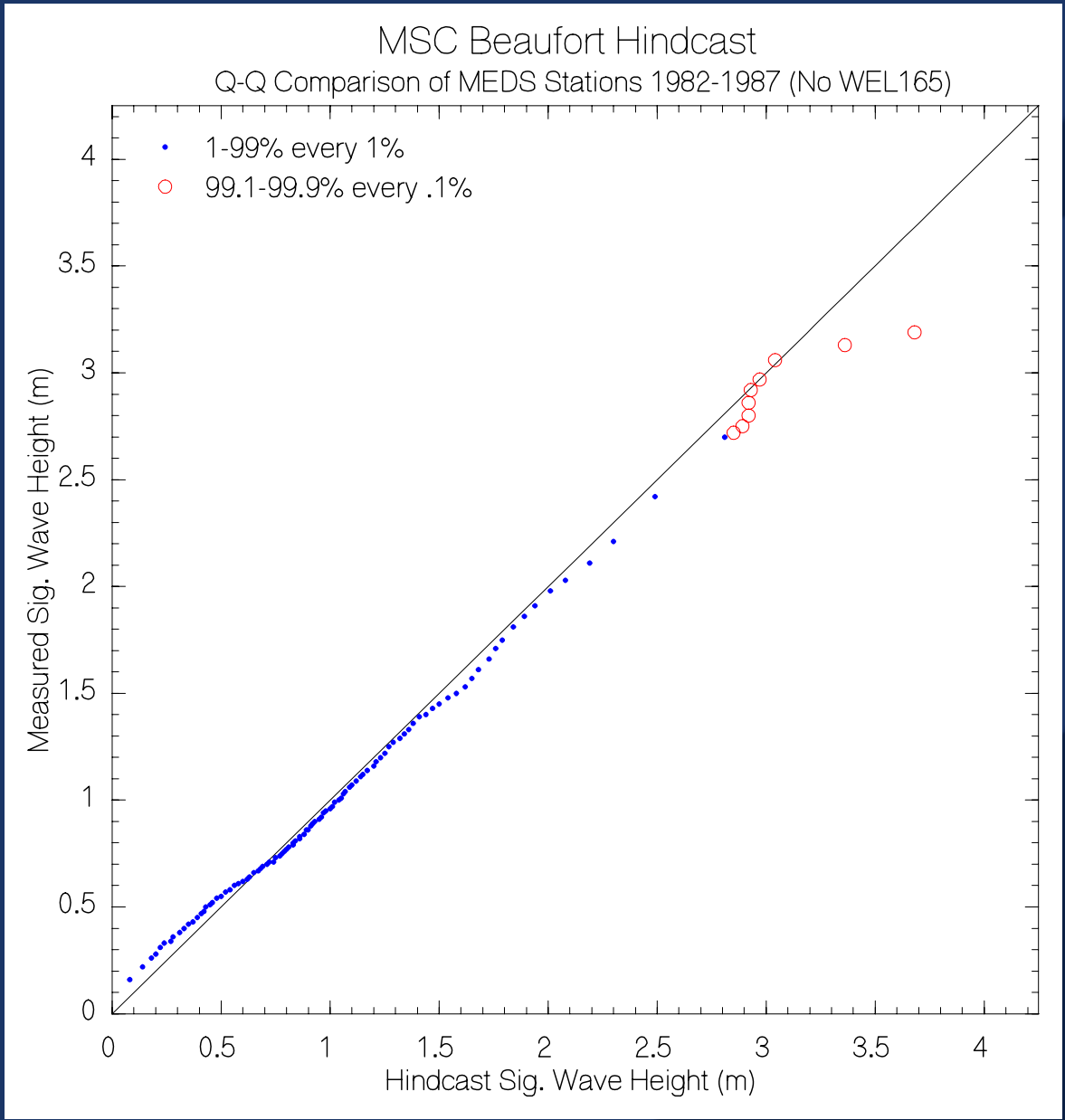
Validation

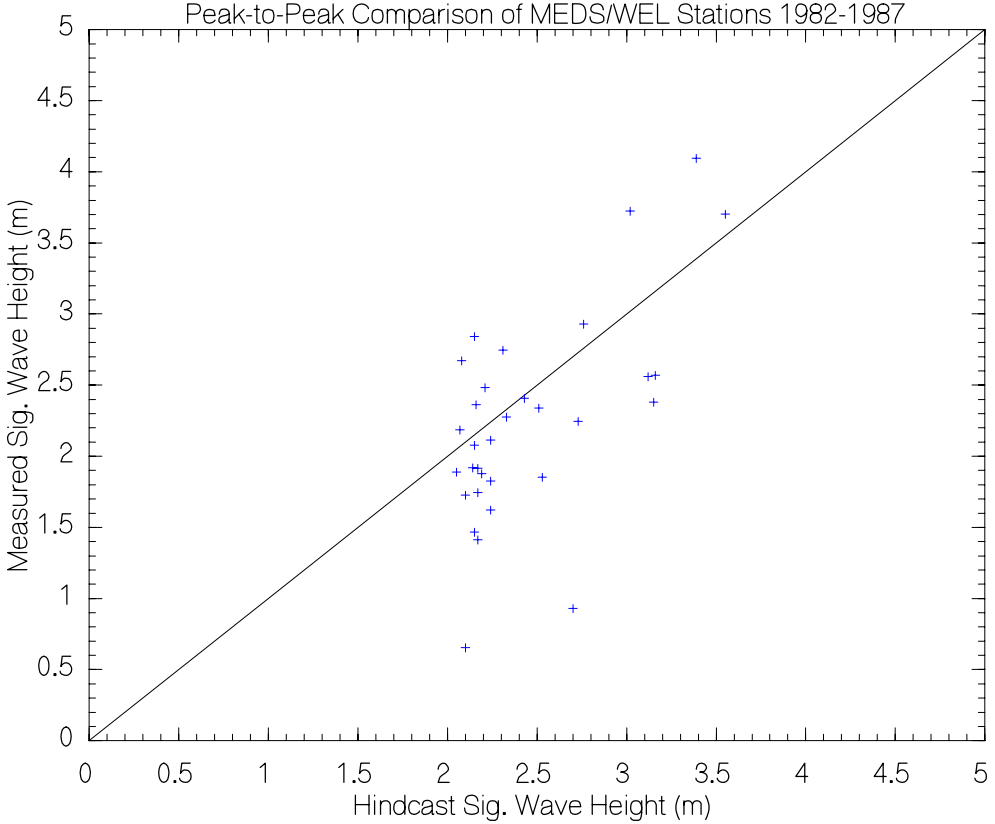
- MEDS - 12 buoys, 26 deployments in ice-free period over 1981-86
- Additional months hindcast in this period using same methodology since no in situ data in study period
- Water depths 11 to 71 m
- SI 42%, larger than MSC50 due to larger uncertainty in wind fields and low mean measurement (0.99 m)
- Q-Q plots show good agreement > 99th
- Peak-to-peak showed hindcast low bias of 22 cm and SI 23%


MSC Beaufort Fine Domain Validation Locations (1980-1987)
72°
71°40'
71°20'
71°
70°40'
70°20'
70°
69°40'
69°20'
69°
68°40'
218°
220°
222°
224°
226°
228°
230°
232°
234°
123
196
200
201
202
204
205
207
208


MSC20 Beaufort Hindcast Validation
MEDS196 Data
Hindcast
Measured
Sig. Wave Height (m)
Peak Wave Period (s)
0
1
2
3
4
5
0
2
4
6
8
10
8/1/82
9/1/82
10/1/82


MSC20 Beaufort Hindcast Validation
MEDS201 Data
Hindcast
Measured
Sig. Wave Height (m)
Peak Wave Period (s)
0
1
2
3
4
5
0
2
4
6
8
10
8/1/82
9/1/82
10/1/82


MSC Beaufort Hindcast
Q-Q Comparison of MEDS Stations 1982-1987 (No WEL165)
1-99% every 1%
99.1-99.9% every .1%
Measured Sig. Wave Height (m)
Hindcast Sig. Wave Height (m)
0
0.5
1
1.5
2
2.5
3
3.5
4

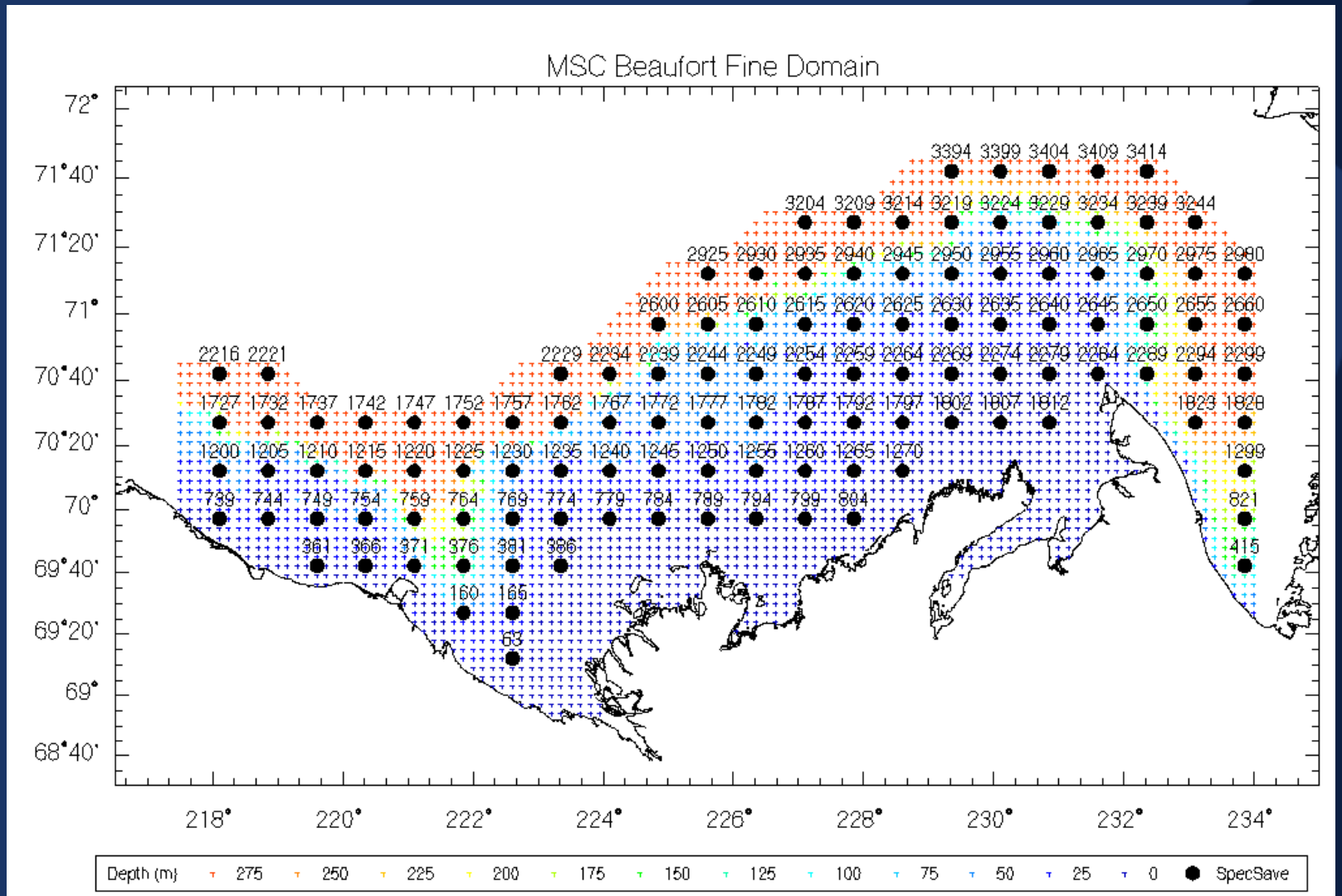


Hindcast Period : 01-JAN-1982 00:00:00 to 01-JAN-1988 00:00:00

	Station	Grid Point	Number of Pts	Mean Meas	Mean Hind	Diff (H-M)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Sig Wave Ht (m)	MEDS196	0	9	2.61	2.54	-0.07	0.50	0.49	0.19	0.44	0.67
Wave Period (s)	MEDS196	0	9	7.33	7.06	-0.27	0.58	0.51	0.07	0.44	0.76
Sig Wave Ht (m)	MEDS201	0	7	2.35	2.21	-0.14	0.43	0.41	0.17	0.14	0.26
Wave Period (s)	MEDS201	0	7	6.90	6.53	-0.36	0.60	0.48	0.07	0.14	0.22
Sig Wave Ht (m)	MEDS204	0	4	2.34	1.79	-0.55	0.56	0.11	0.05	0.00	0.95
Wave Period (s)	MEDS204	0	4	6.87	5.92	-0.95	1.02	0.39	0.06	0.00	0.84
Sig Wave Ht (m)	MEDS265	0	5	2.47	2.41	-0.05	0.45	0.44	0.18	0.60	0.85
Wave Period (s)	MEDS265	0	5	7.09	6.94	-0.16	0.64	0.62	0.09	0.40	0.82
Sig Wave Ht (m)	Combined	0	32	2.45	2.24	-0.22	0.60	0.56	0.23	0.31	0.63
Wave Period (s)	Combined	0	32	7.66	6.61	-1.05	4.11	3.98	0.52	0.31	-0.29

Hindcast Products

- Hourly archive 1985-2005 at all grid points in fine mesh (to be extended to Canadian domain)
- Wave spectra at selected fine mesh points
- Beaufort sea wave atlas on DVD (to be online)
  - Mean, sd, %ile, exceedance, anomaly
  - Individual and collective months, years
  - Extremal analysis at each grid point



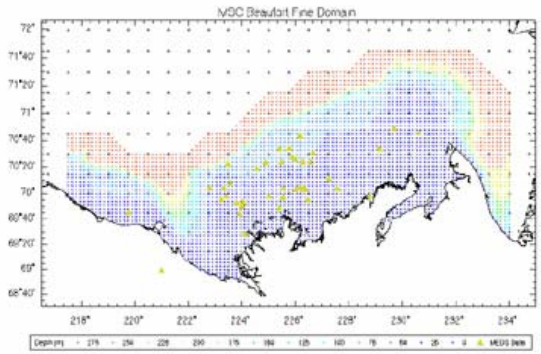
Beaufort wind and wave archive (colored by depth) and wave spectra (black) locations

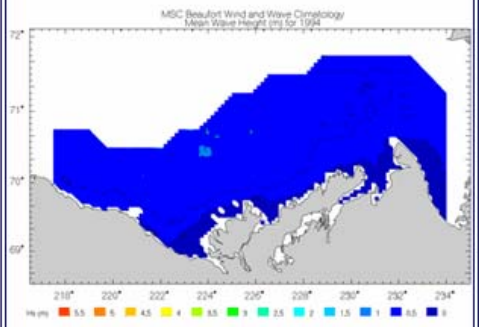
MSC

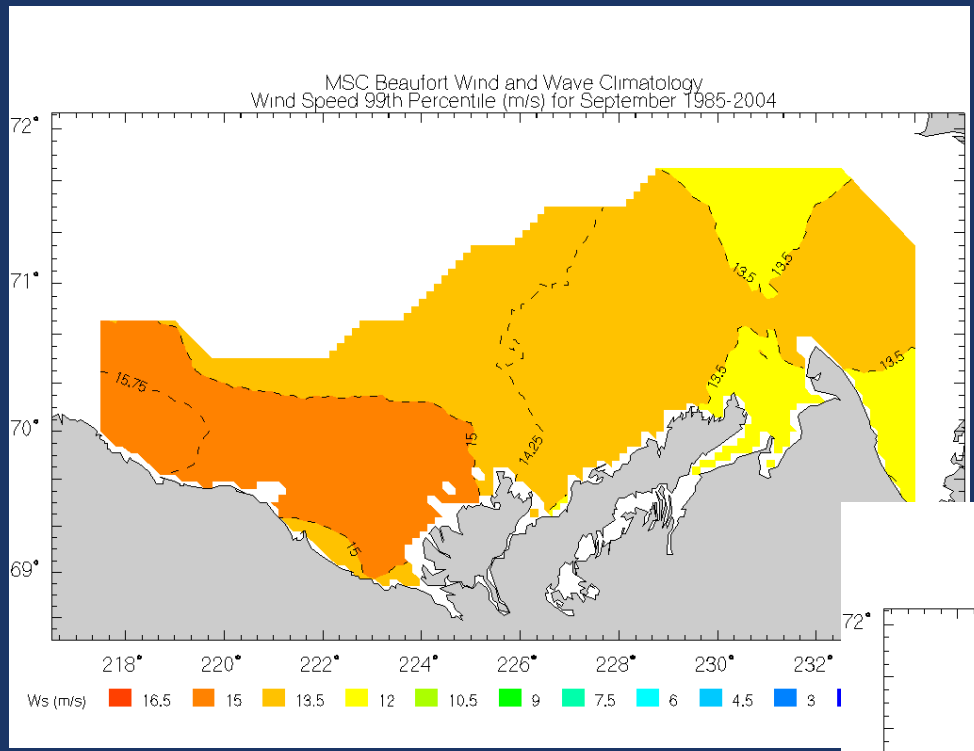
Beaufort Wind and Wave Climatology

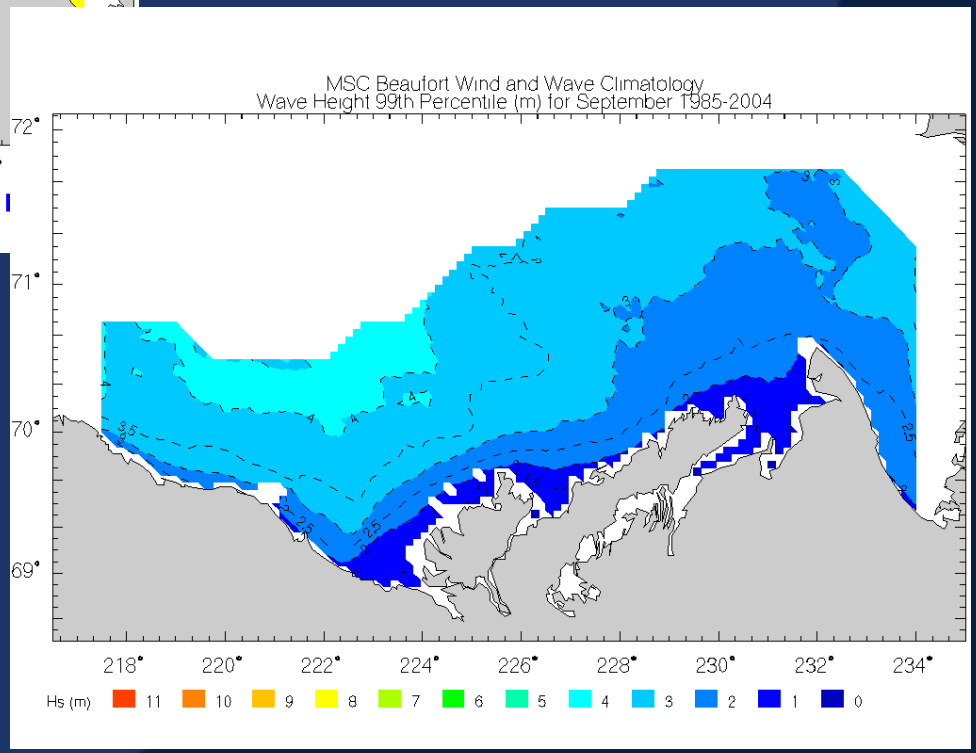
A 21-year continuous wind and wave hindcast

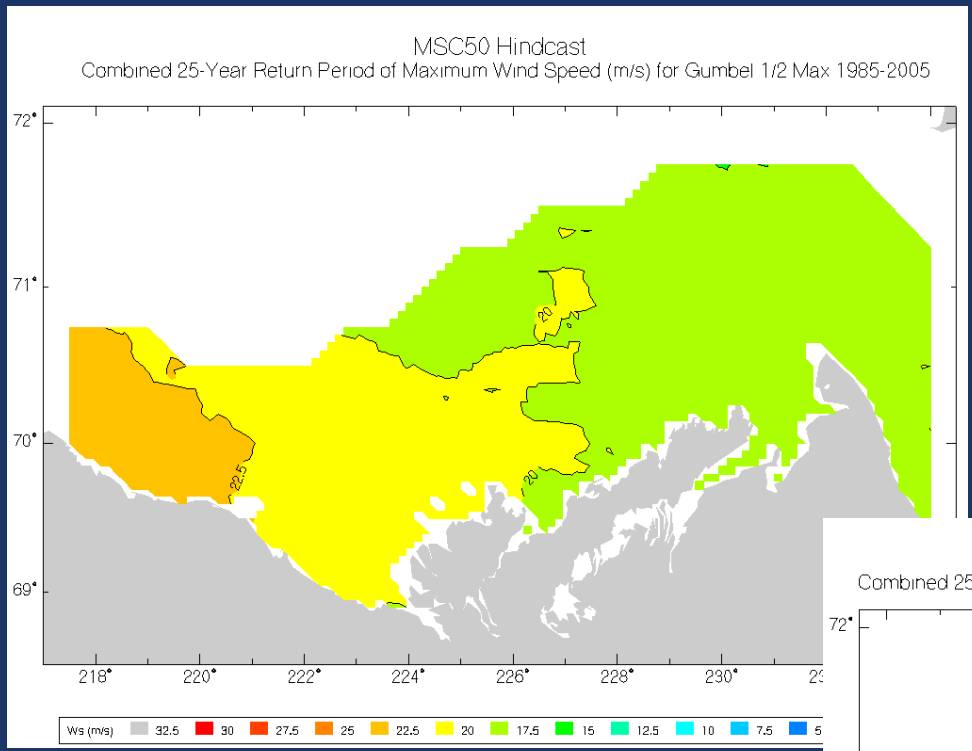
covering the period 1985-2005.

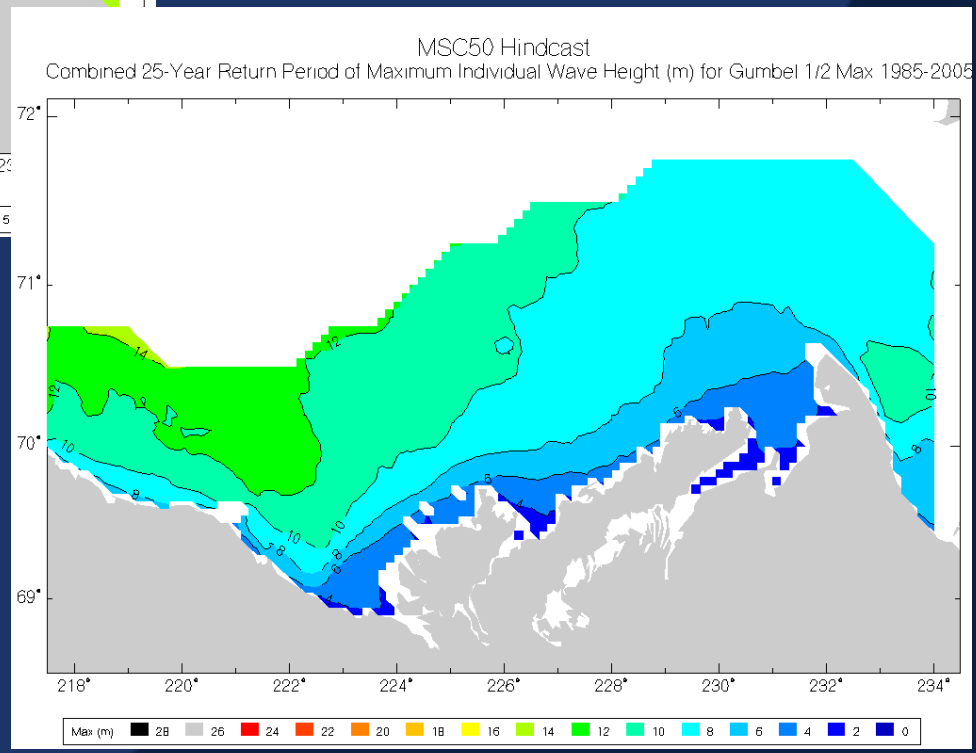


Ice Plots Weekly/Monthly ice data provided by the Canadian Ice Service	Validation Comparison with MEDS buoys	Wave Atlas Graphics and data analysis based on the wind and wave climatology
Wind and Wave Fields Synoptic sort (1-month, all points per file, gzipped) 17 Archived Wind and Wave Fields Description		Wave Spectra Archive 117 Archive Locations - gzipped by point Gif Image/CSV File of Archive Locations Spectra Description
Wind and Wave Timeseries Time sort (1 file per grid point, gzipped) 17 Archived Wind and Wave Fields Description	OSMOSIS Requires OSMOSIS be installed on your PC	Extremes Gumbel and Weibull extremes computed by point


MSC Beaufort Wind and Wave Climatology
Wind Speed 99th Percentile (m/s) for September 1985-2004
72°
71°
70°
69°
218°
220°
222°
224°
226°
228°
230°
232°
Ws (m/s)
16.5
15
13.5
12
10.5
9
7.5
6
4.5
3


MSC Beaufort Wind and Wave Climatology
Wave Height 99th Percentile (m) for September 1985-2004
72°
71°
70°
69°
218°
220°
222°
224°
226°
228°
230°
232°
234°
Hs (m)
11
10
9
8
7
6
5
4
3
2
1
0


MSC50 Hindcast
Combined 25-Year Return Period of Maximum Wind Speed (m/s) for Gumbel 1/2 Max 1985-2005
72°
71°
70°
69°
218°
220°
222°
224°
226°
228°
230°
Ws (m/s)
32.5
30
27.5
25
22.5
20
17.5
15
12.5
10
7.5


MSC50 Hindcast
Combined 25-Year Return Period of Maximum Individual Wave Height (m) for Gumbel 1/2 Max 1985-2005
72°
71°
70°
69°
218°
220°
222°
224°
226°
228°
230°
232°
234°
Max (m)
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

Summary And Future Work

- MSC-B provides a new high resolution wind and wave hindcast at higher temporal and spatial resolution than previous efforts: 21-year “continuous” hindcast with good agreement with measurements

- Extend hindcast to 40 years (1971-2010)
- Extend validation using earlier in situ data and recent altimeter data
- Investigate combined wind, wave, storm surge modelling for Canadian Beaufort
- Concerns involve wind field, bathymetry and land surface elevation data, sufficient high-quality validation data for wave and water levels
- Investigate use of SAR wind products for small scale variability close to coast
- Investigate similar efforts from USACE in US Beaufort


THE BEAUFORT SEA AFTER CLIMATE CHANGE?
THE END