Hindcasting Wave Conditions on the North American Great Lakes

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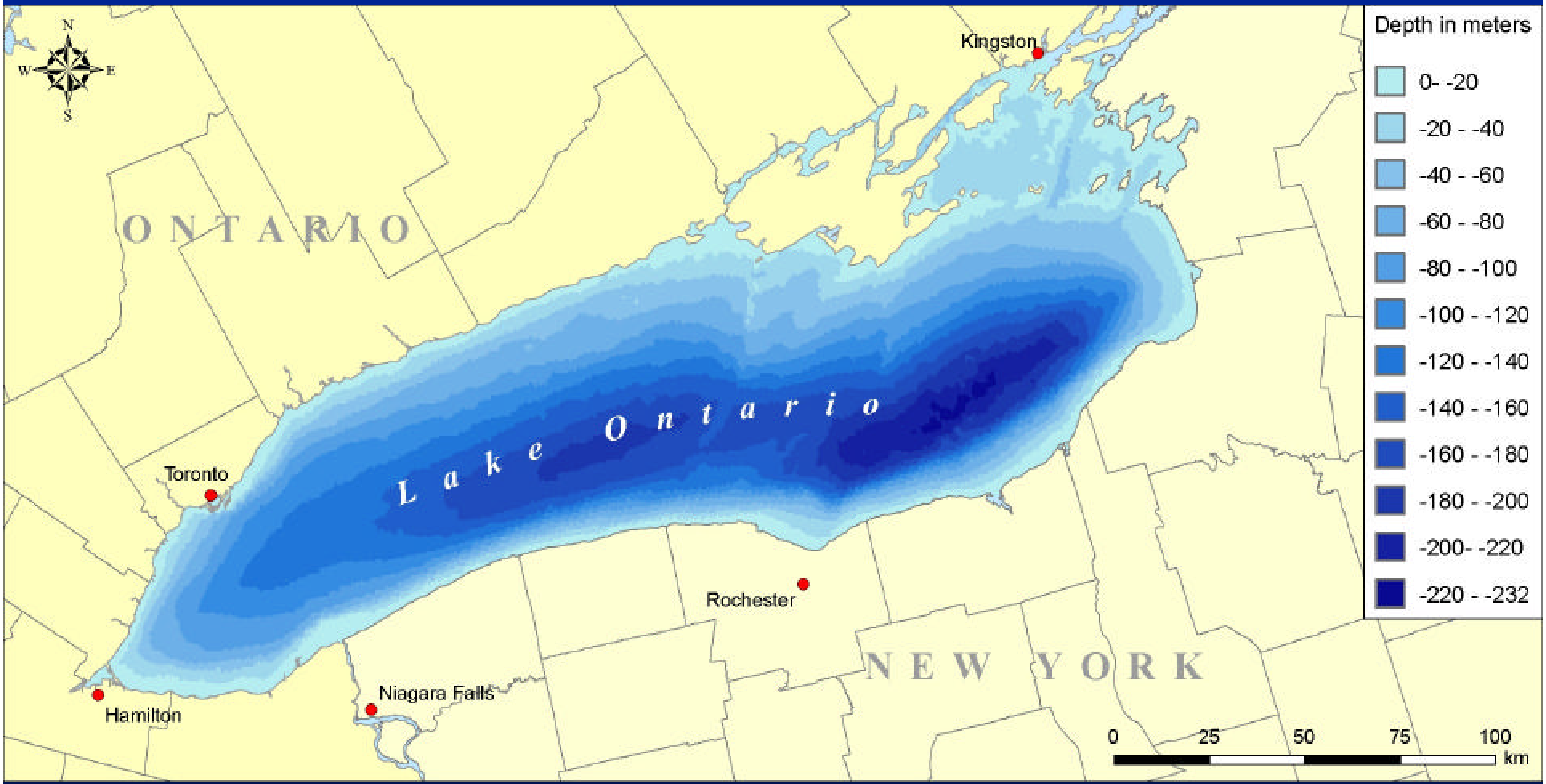
Baird


CANADA
UNITED STATES
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
N
S
W
E
0
75
150
225
300
km

Lake Ontario

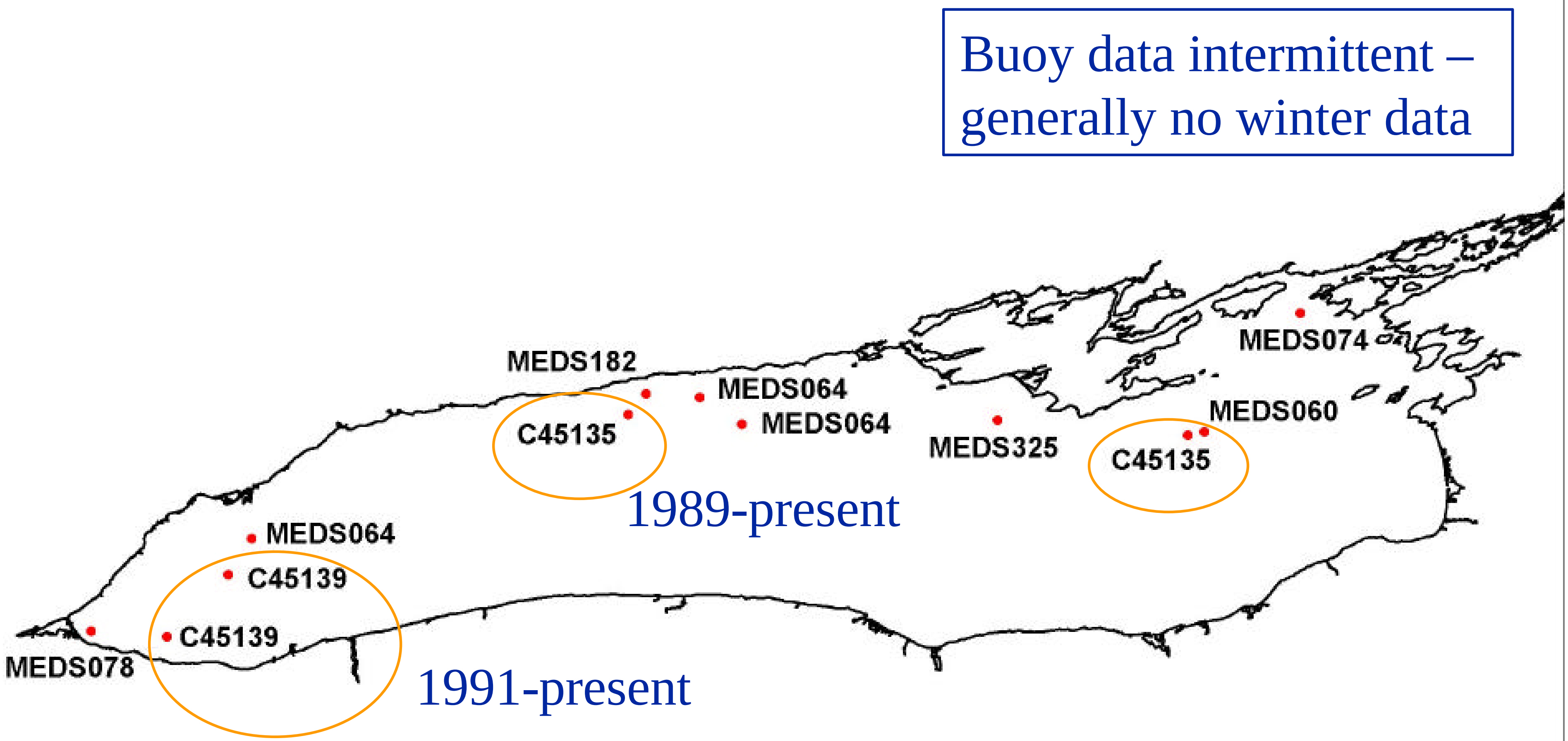
- 310 km long
- 85 km wide
- Avg depth of 86 m
- Max depth 244 m



Objectives:

- To develop a minimum 40-year hourly wave climate for all of Lake Ontario
- Target period: 1961-2000
- Data used as basis for subsequent numerical modellng of sediment transport and erosion studies
- Study time frame short (2 ½ months) – objective modeling techniques required

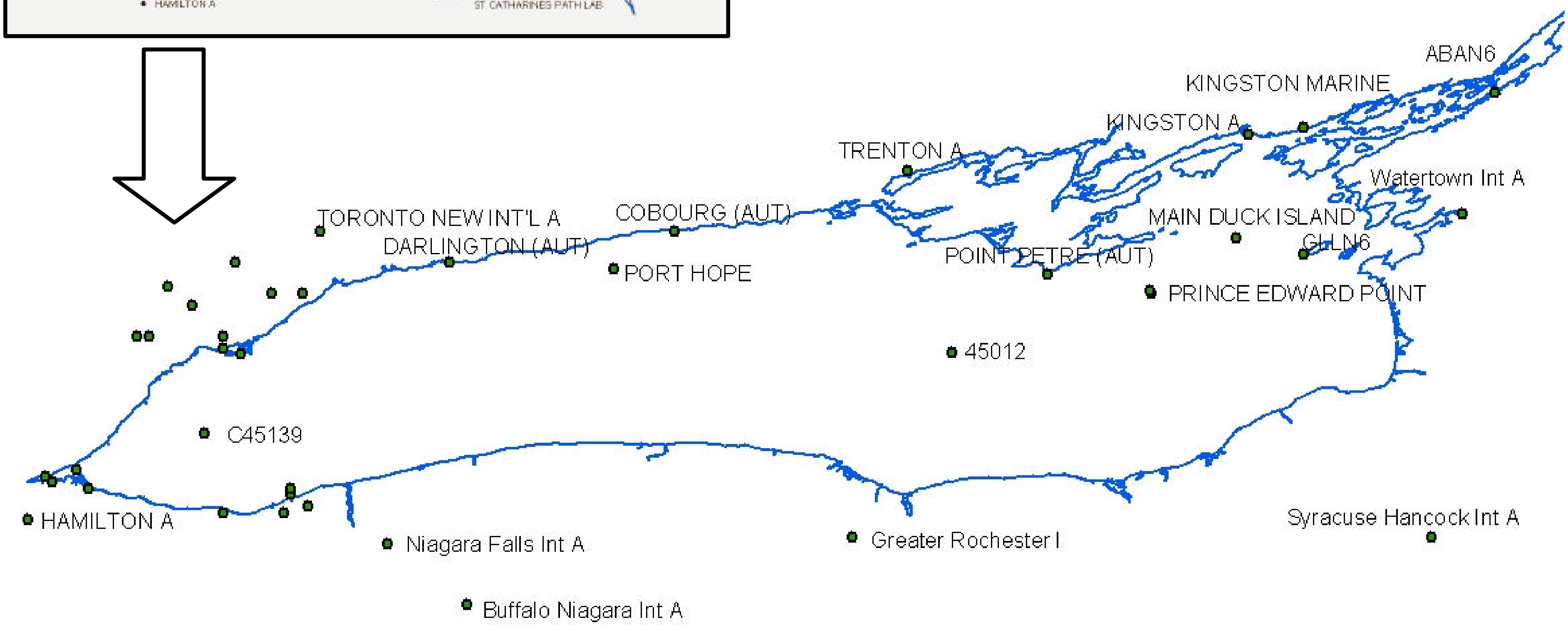
Wave Data Availability



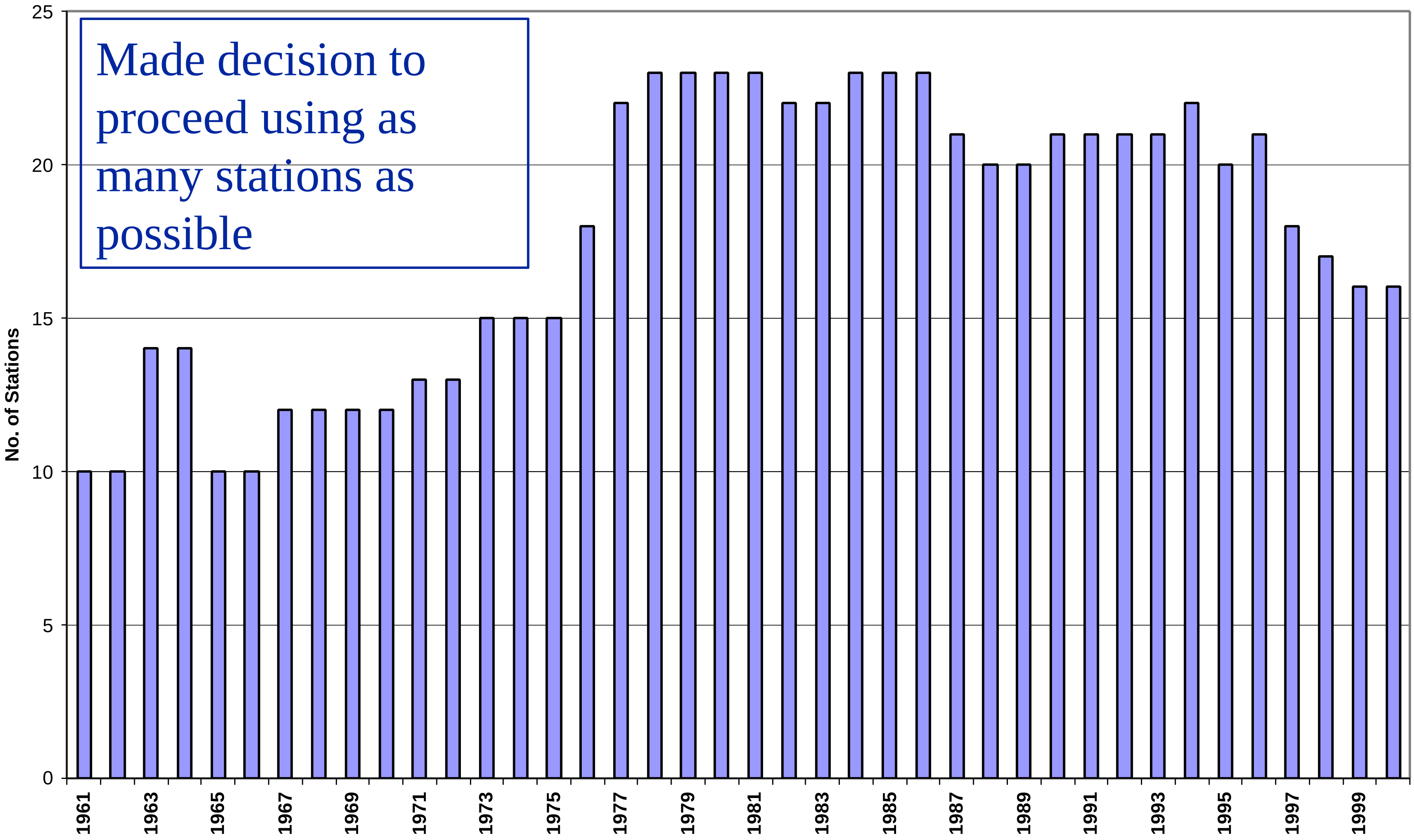
Wind Field Development

- Atmospheric model data of insufficient resolution or duration
- Developed directly from observed winds at (primarily) land-based stations

Meteorological Observing Stations (1961-2000)



Variation in Numbers of Meteorological Stations by Year

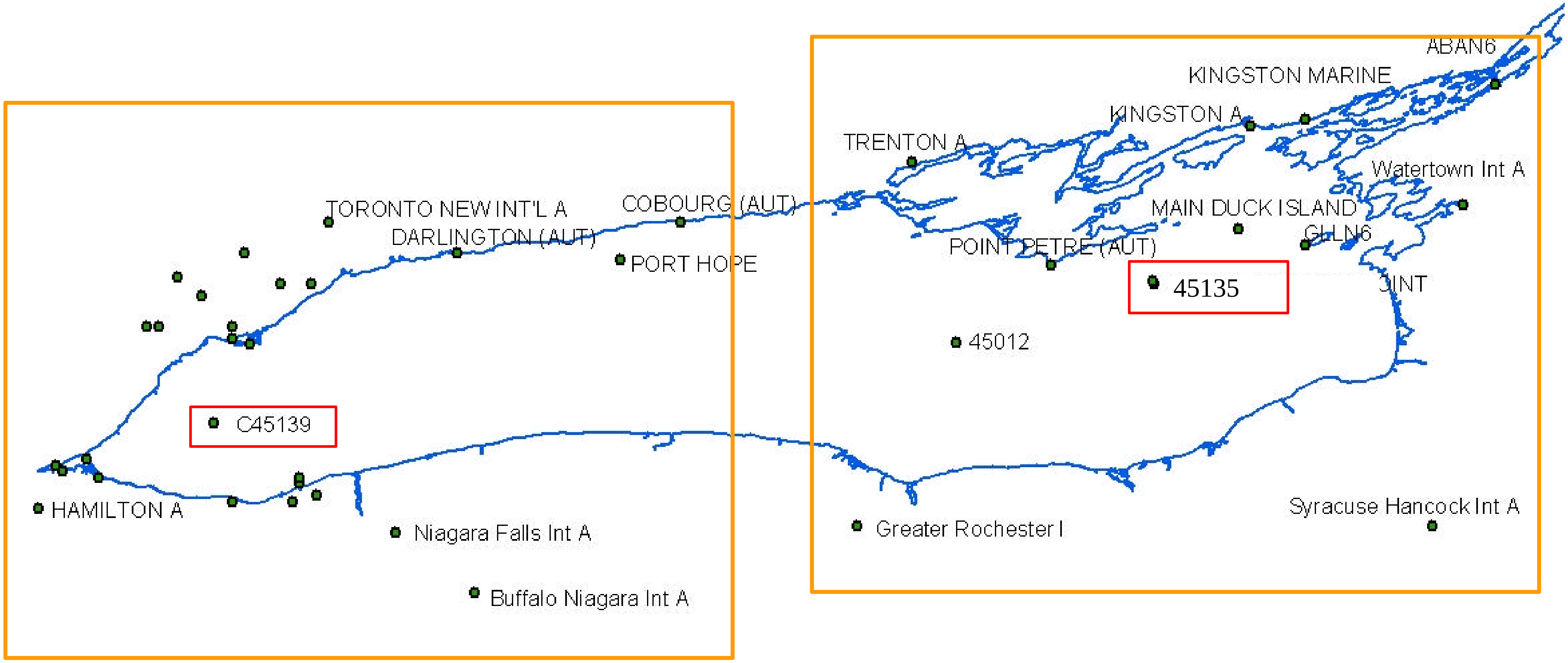


Initial Wind Data Adjustment

- Station selection procedures
- Quality control checks
- Adjustment to equivalent 10 m winds considering air-water temperature difference
- Initial adjustment to overwater wind speed and direction using Resio & Vincent (1976).

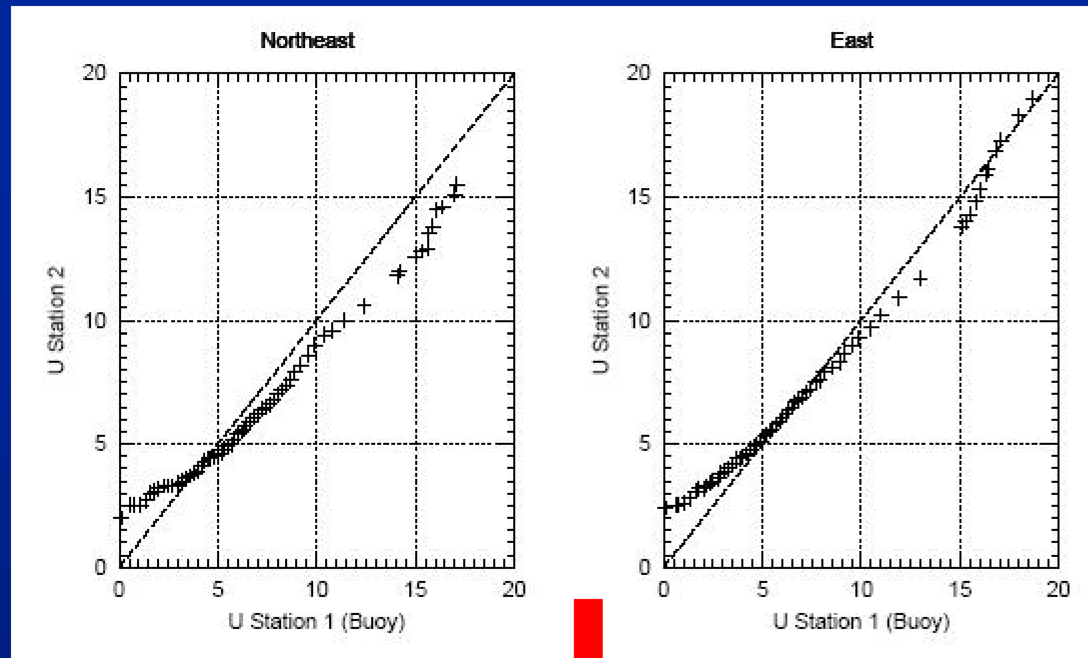
Final Wind Speed Adjustment

- Made land-based station observations statistically consistent with nearest buoy observations

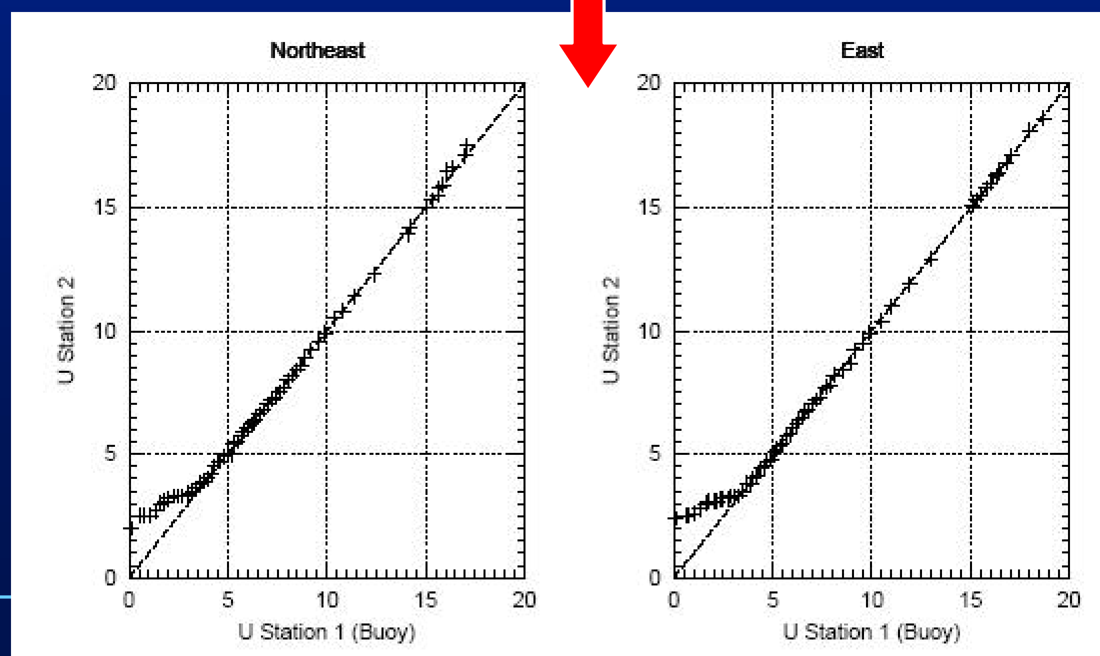


Example for Two Octants of One Observing Station

Before Adjustment



After Adjustment



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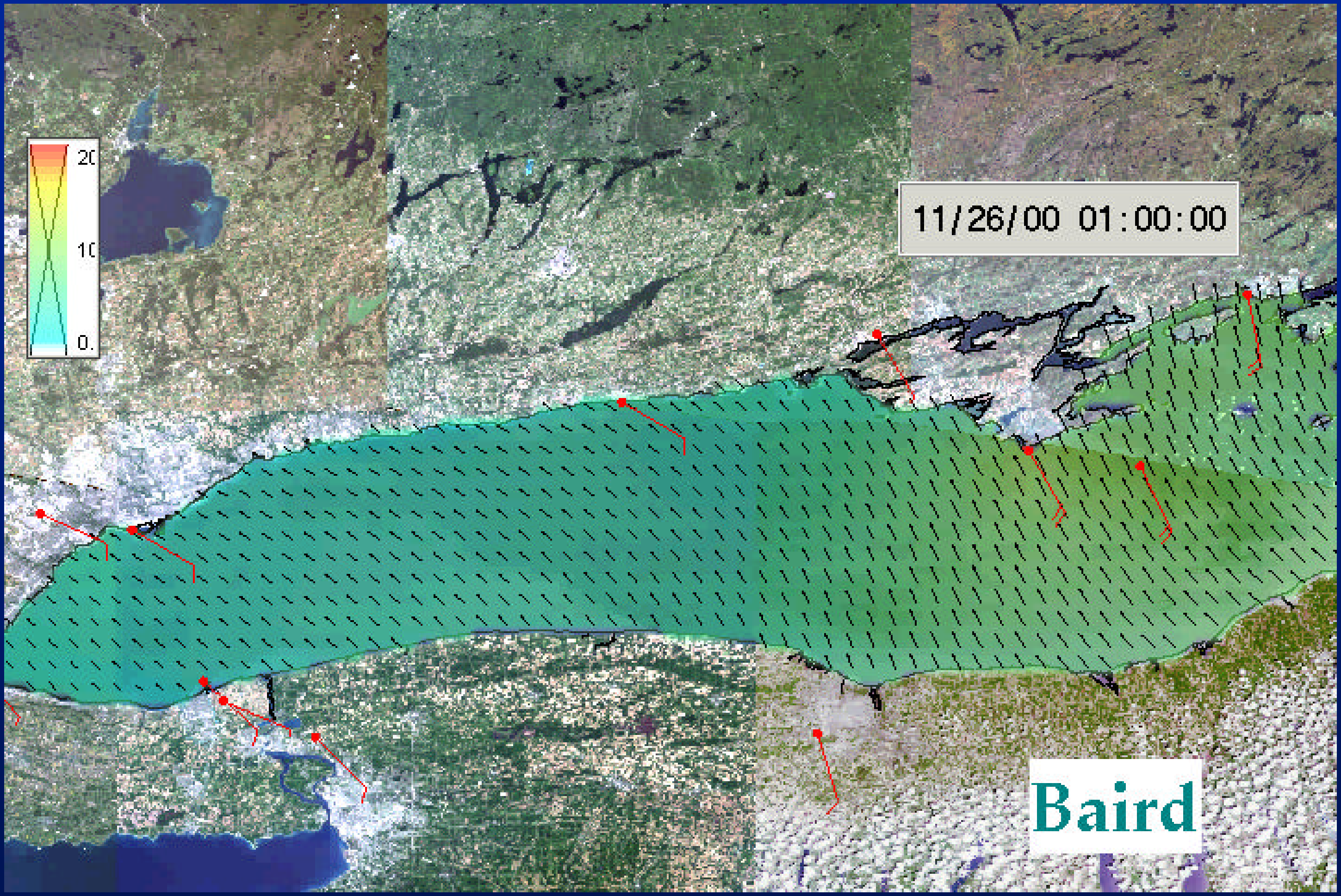
Wind Interpolation to the Model Grid

- Natural neighbour interpolation
  - *Sambridge, Braun and McQueen (1995)*
  - *Paper available on internet*
- Methodology based on concepts developed in computational geometry (Delaunay tessellation)
- Well tested at Great Lakes Environmental Research Laboratory

Advantages of Natural Neighbour Interpolation

- The interpolation is “local”
- Original values at each data point are recovered exactly
- Derivatives are continuous
- Interpolated field is smooth
- Works extremely well for irregularly spaced data (density of observation points varies significantly)
- Readily adaptable to situations where number of reference points varies in time

Wind Field Assessment



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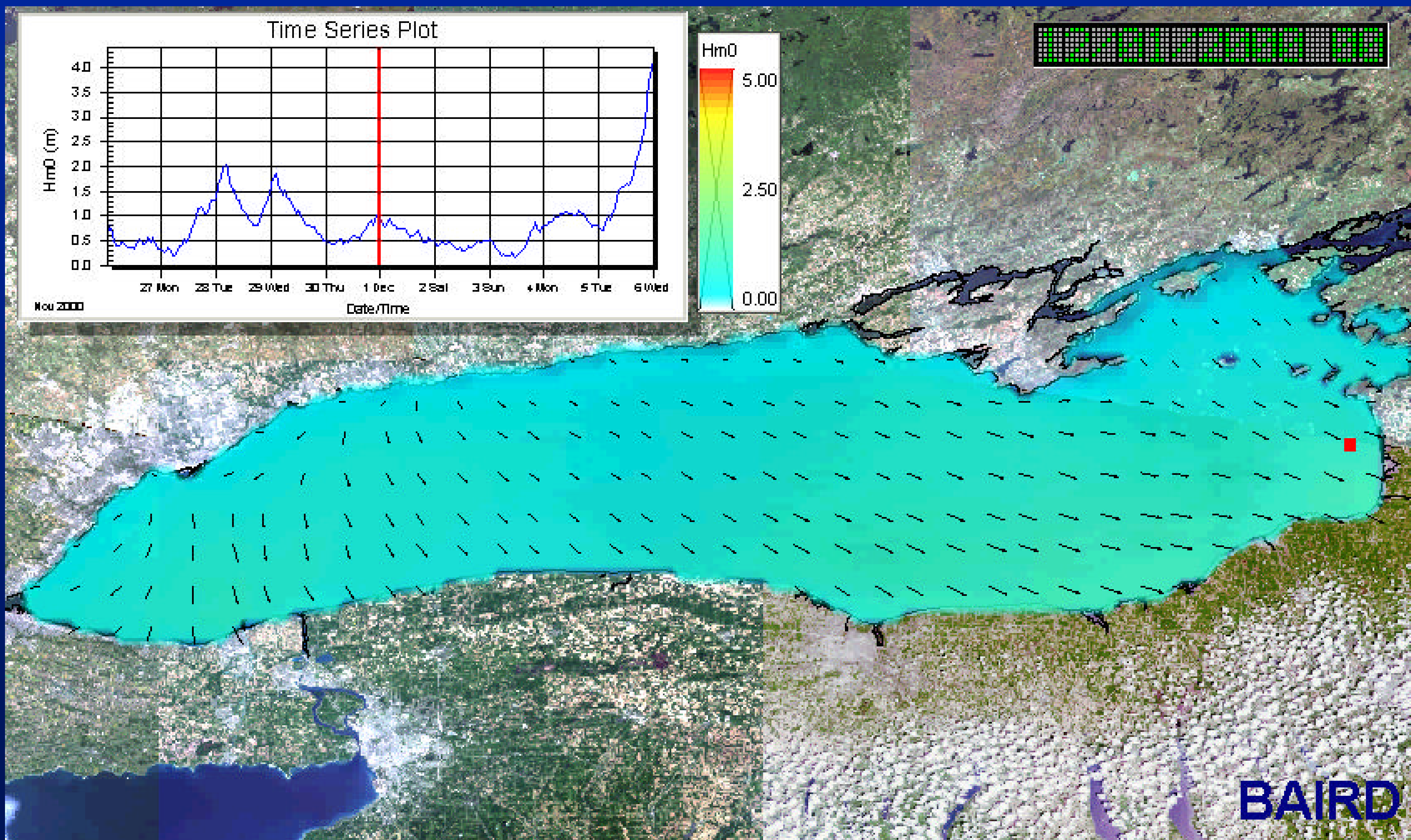
The Wave Model

- WAVAD 2nd Generation wave model
- Undertook sensitivity tests to assess f, $\Delta\ \theta$, Δs resolution
- Final Selected parameters:
  - *Grid Resolution: 3km*
  - *22 frequencies (2.5 to 15 s)*
  - *24 directional bins*
  - *6 minute time step*
- Daily ice field variation represented in hindcast from polygonal ice dataset

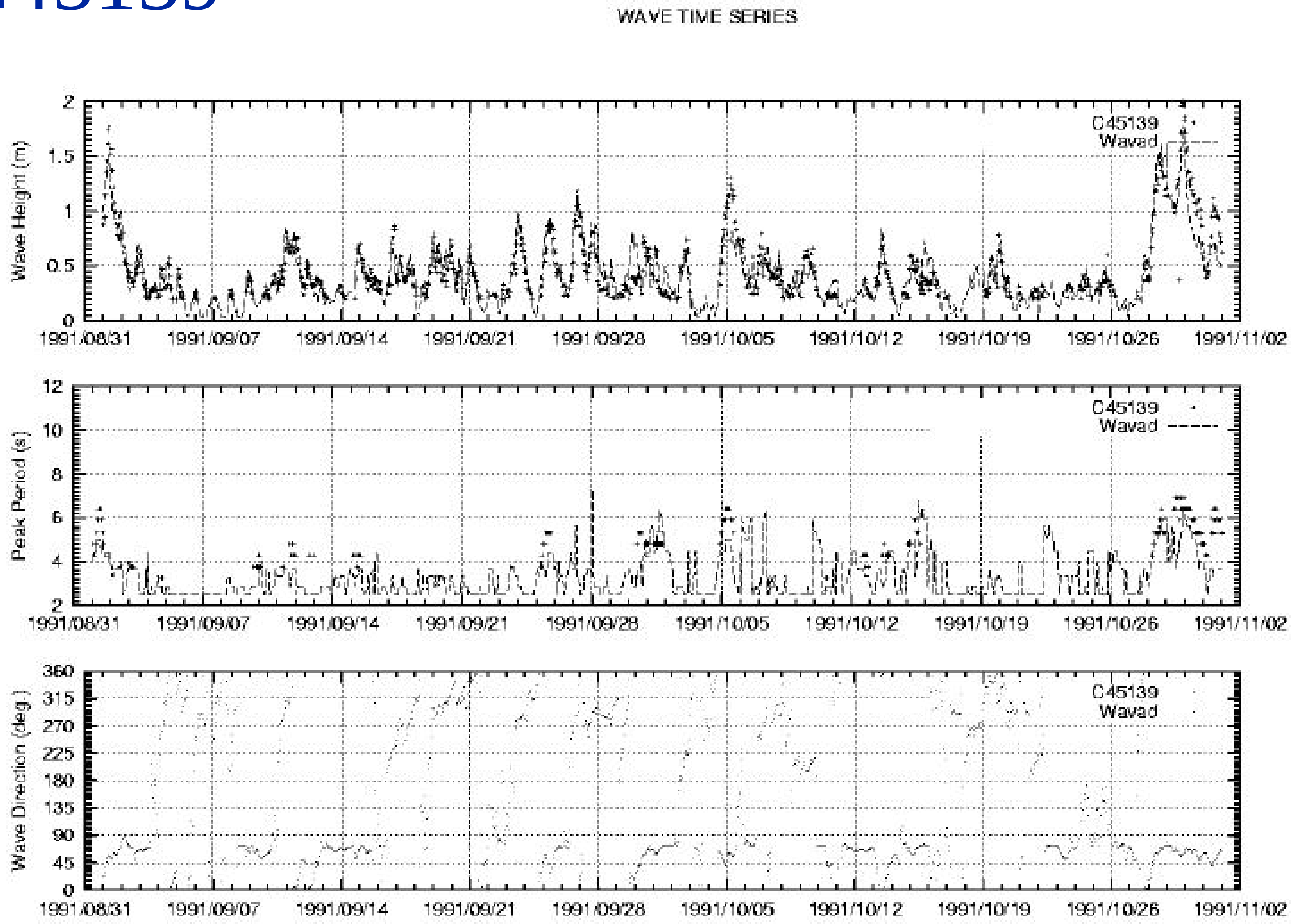
Hindcast Results



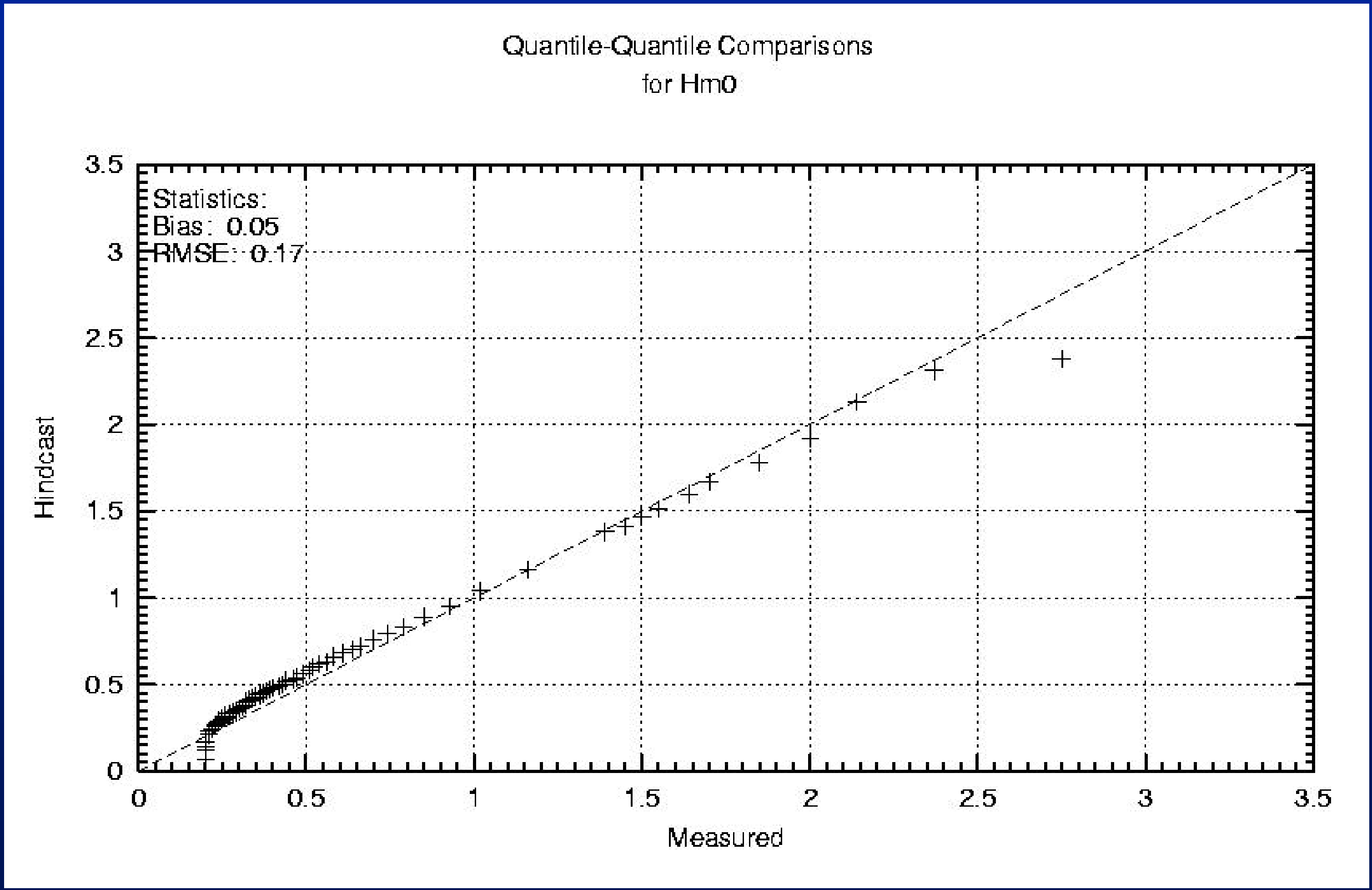
Model Validation

- Statistical measures, quantile-quantile plots and time series comparisons
- Primary comparisons against C45135 and C45139
- Inter-annual variability

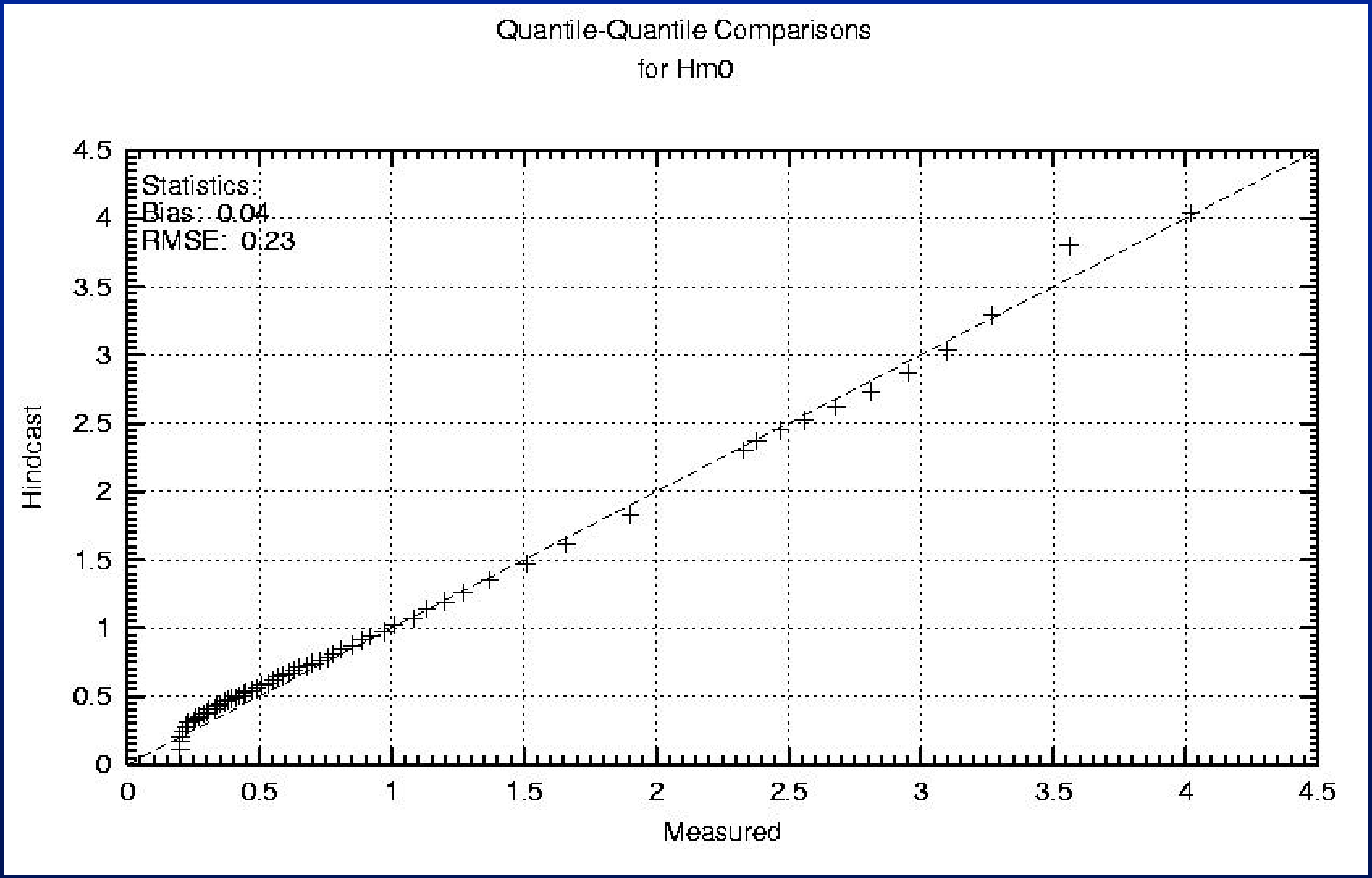
C45139


WAVE TIME SERIES
Wave Height (m)
C45139
Wavad
Peak Period (s)
Wave Direction (deg.)
1991/08/31
1991/09/07
1991/09/14
1991/09/21
1991/09/28
1991/10/05
1991/10/12
1991/10/19
1991/10/26
1991/11/02

Buoy C45139 (West End of Lake)



Buoy C45135 (East End of Lake)



Measures of Hindcast Skill

Buoy	Date	Hm0 (m)			Tp (s)		
		Bias	*RMSE*	*Correlation*	*Bias*	*RMSE*	*Correlation*
C45139	1991-93	0.05	0.17	0.86	-0.58	1.03	0.65
C45135	1989-90	0.03	0.22	0.92	-0.65	0.95	0.8
C45135	1991-96	0.04	0.23	0.9	-0.26	0.78	0.81

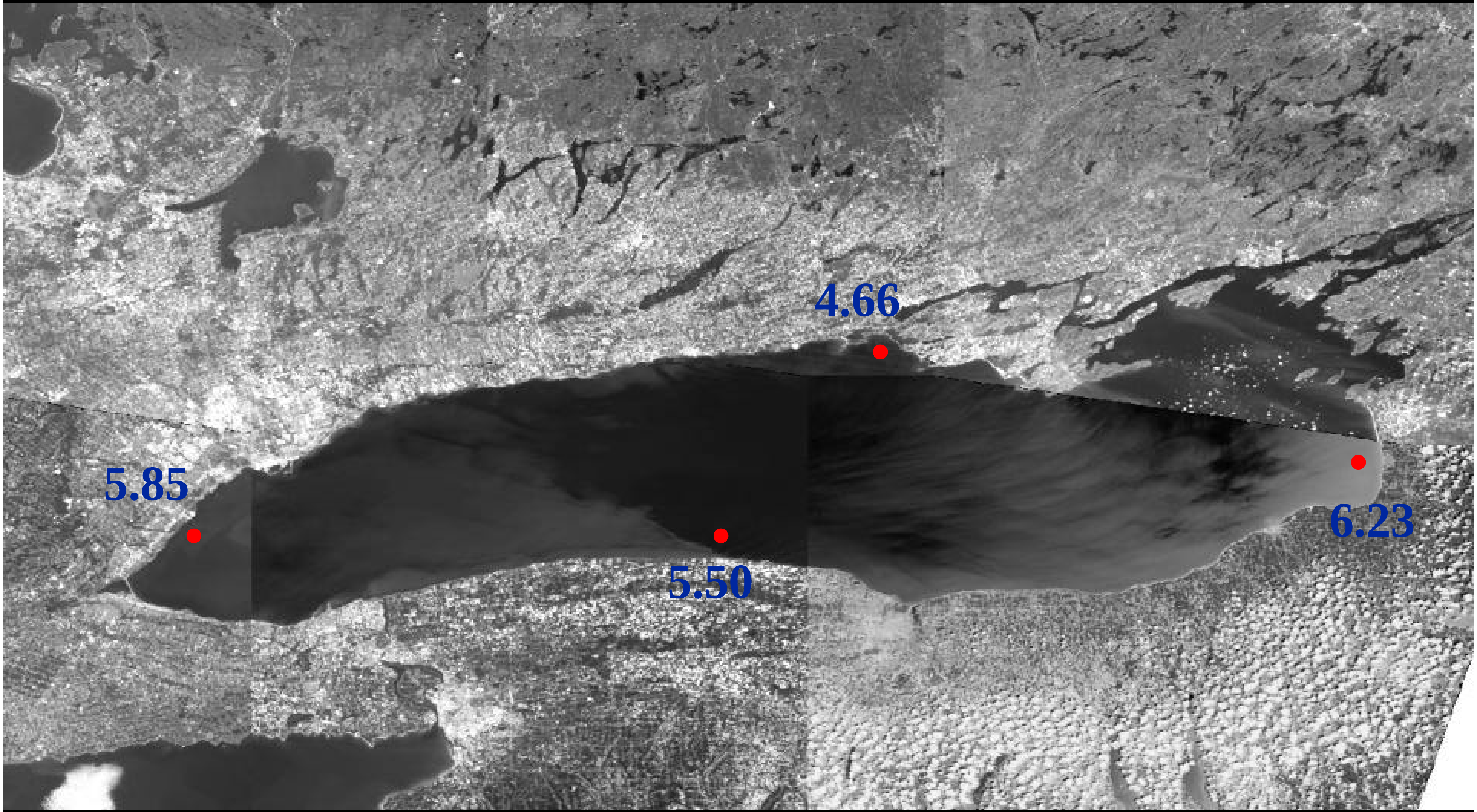
Comparison of Skill: With and Without Buoys

Buoy	C45135			C45139		
	Bias	*RMSE*	*Correlation*	*Bias*	*RMSE*	*Correlation*
With Buoys	0.04	0.23	0.9	0.06	0.17	0.87
Without Buoys	0.02	0.27	0.85	0.08	0.19	0.86

Production Simulations

- 40 year hindcast (1961-2000)
- Required 4 days of computer time
- Data archived at 307 locations around the lake.

Maximum Hm0 (m)



Conclusions

- A reliable 40-year wave climate has been developed for Lake Ontario, forming one of the primary driving forces for the subsequent shoreline studies
- The methodologies developed are "objective", and did not require subjective tuning

Future Investigations/Improvements

- Investigation of climate change scenarios
- Improved representation of wind directional changes from land to water
- Better estimation of waves with low wave height
- More extensive comparisons (including recent directional buoy data)