

# Exploring the Wind and Wave Climate in the Great Lakes

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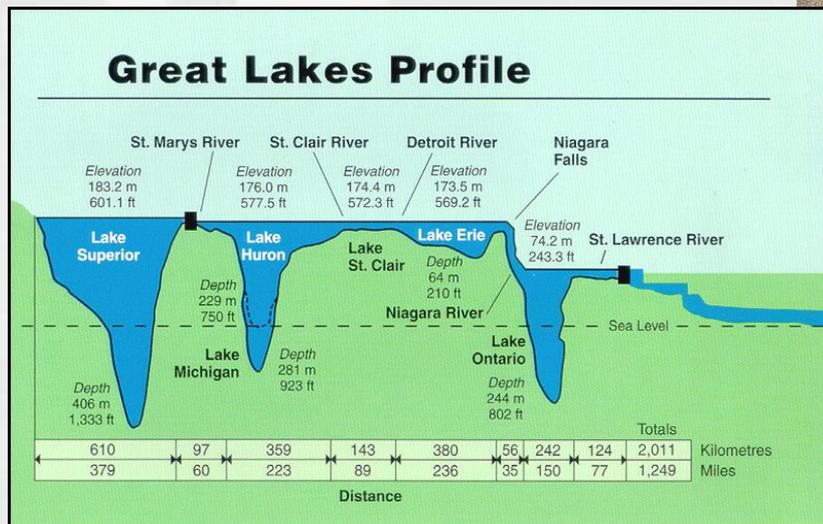


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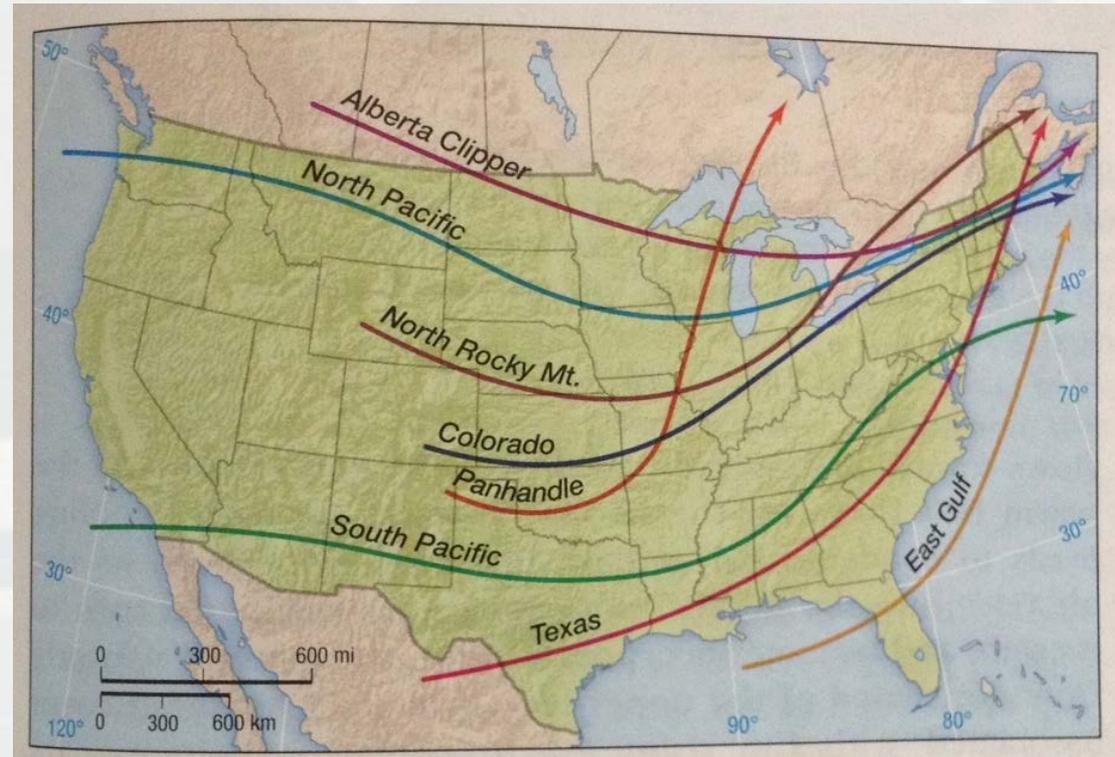
# Setting / Motivation

- North America US: Great Lakes
  - ▶ Five major lakes
  - ▶ Bounded by coastline
  - ▶ Moderate fetch-lengths
  - ▶ Range in water depths
  - ▶ Cyclo-genesis
  - ▶ Icing in winter months



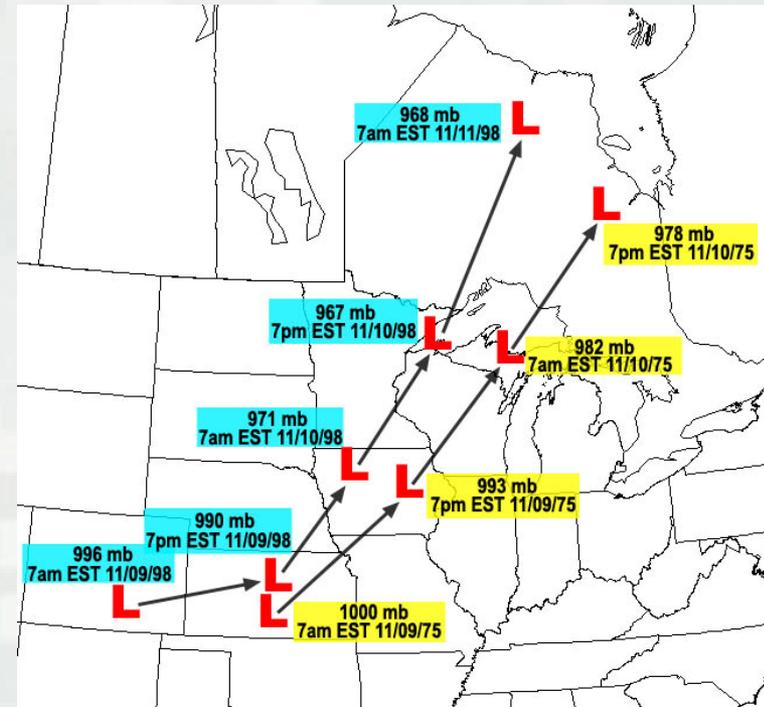
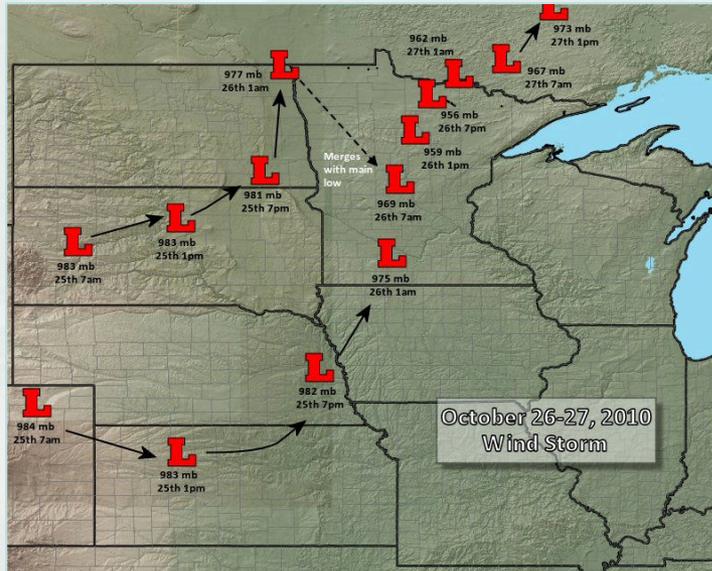
# Setting: Meteorology

- Meteorology
  - ▶ Dominated by cyclo genesis
    - Rapid wind shifts
    - Short duration
    - Winds 20-25 m/s
  - ▶ Intensity: storm path
  - ▶ Orographic effects
    - Spatial coherency
    - Steering by topography
  - ▶ Thermal winds



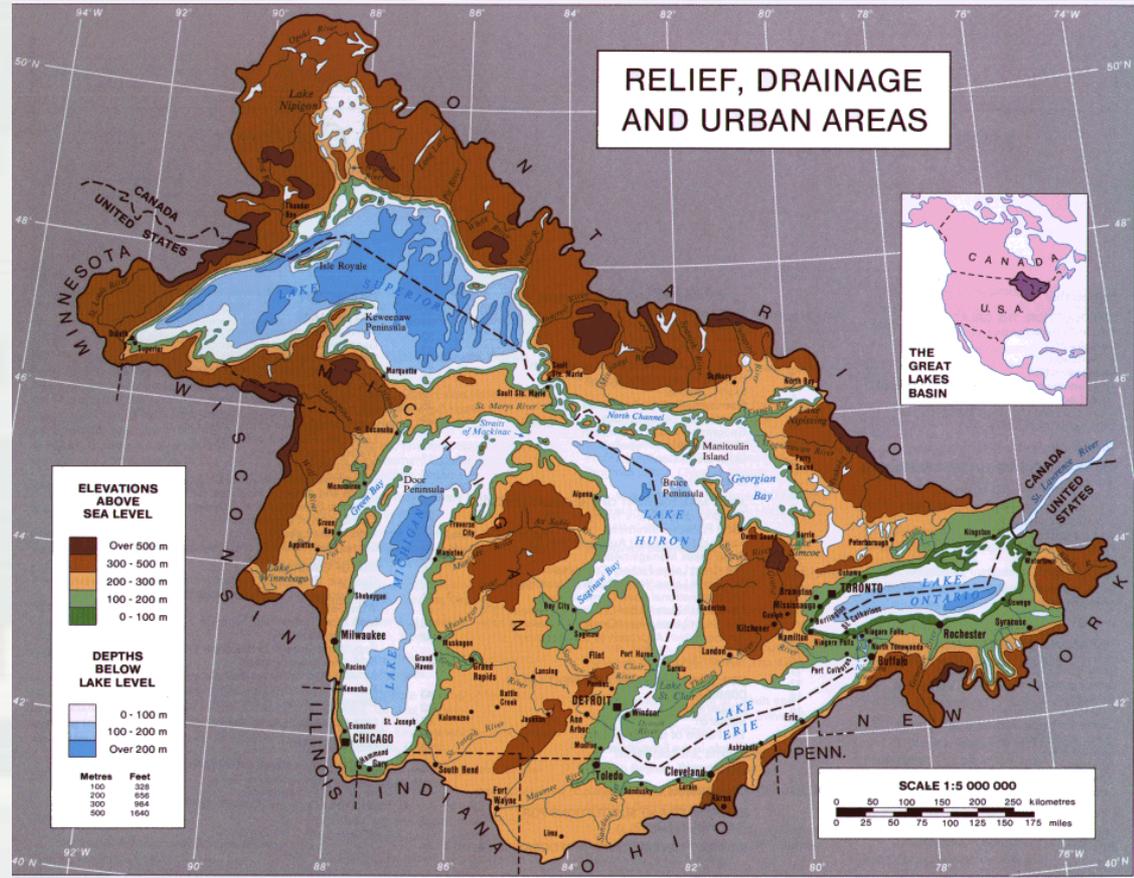
# Meteorology: Storms

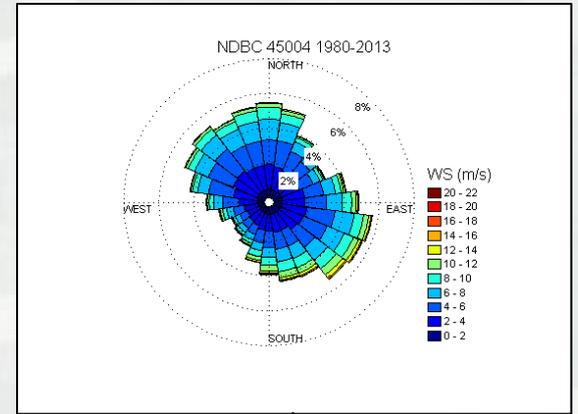
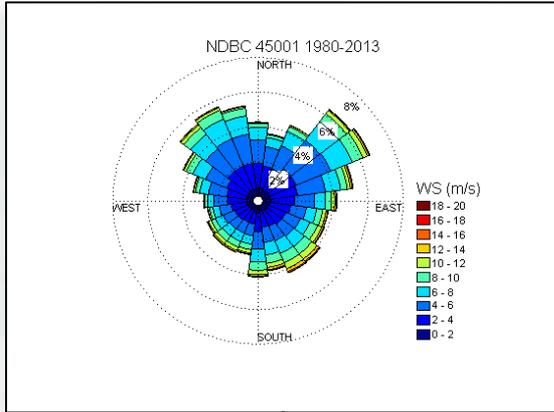
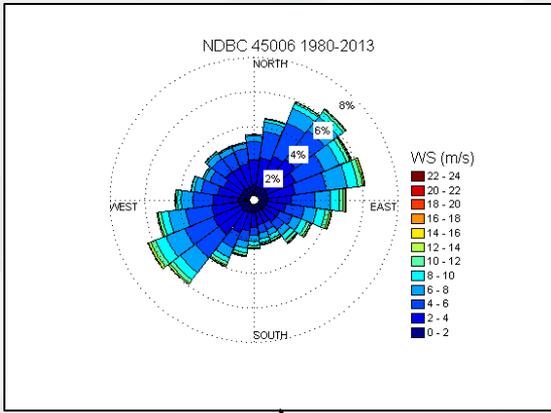
- Major Events
  - Edmund Fitzgerald (11/1975)
  - Hurricane Huron (09/1996)
  - Clone-Edmund Fitzgerald (11/1998)
  - Chiclone** (10/2010)
  - Decaying Tropical Storms
  - Storm of 1913



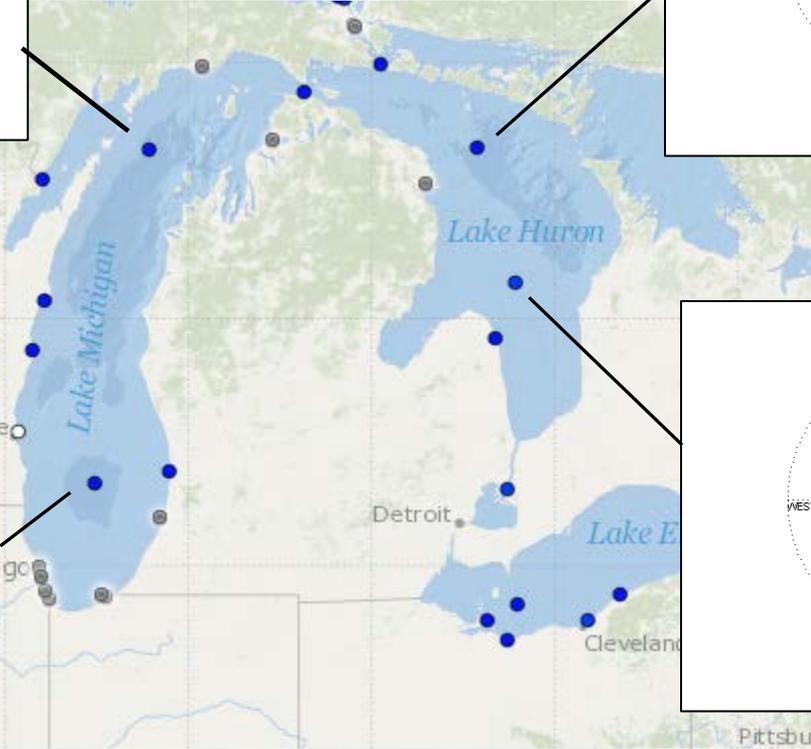
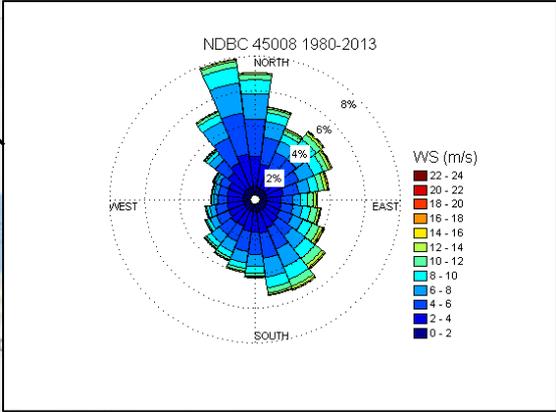
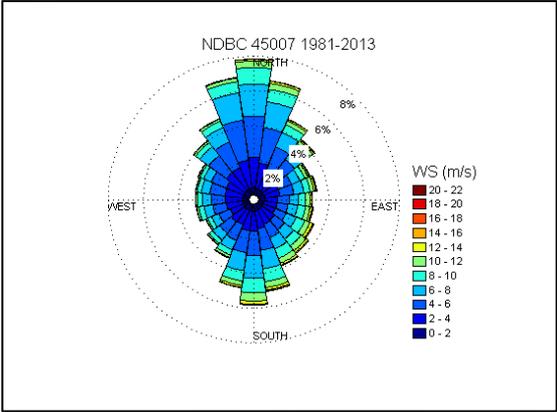
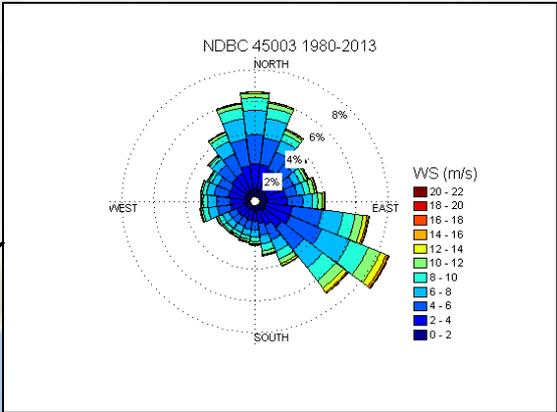
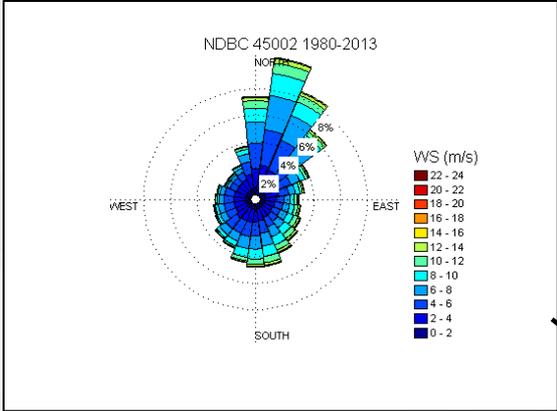
# Meteorology: Orography

- Orographic effects
  - ▶ Smaller scale of
    - Mistrals
    - Gulf of Tehuantepec
    - Aleutian Islands



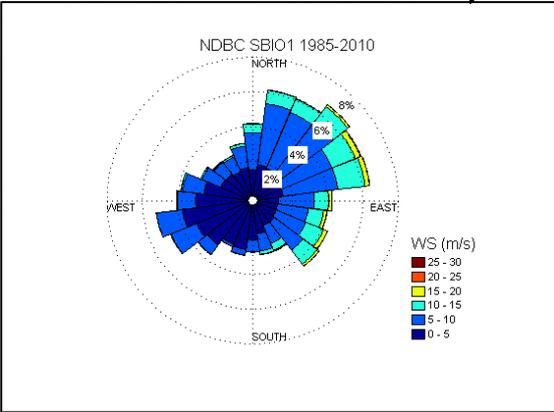
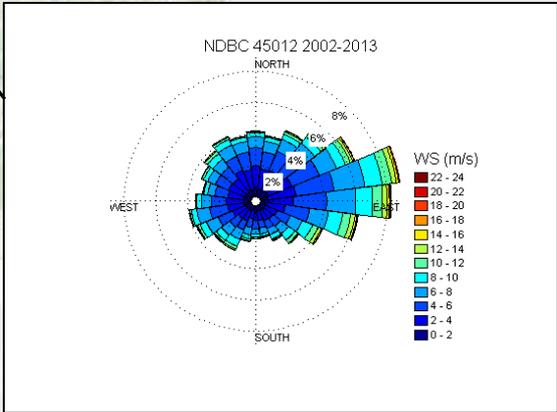
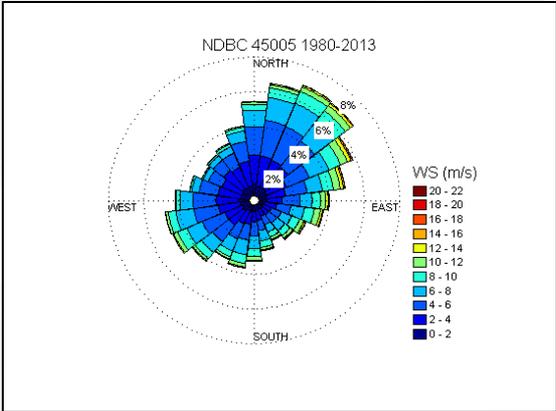


Lake Superior



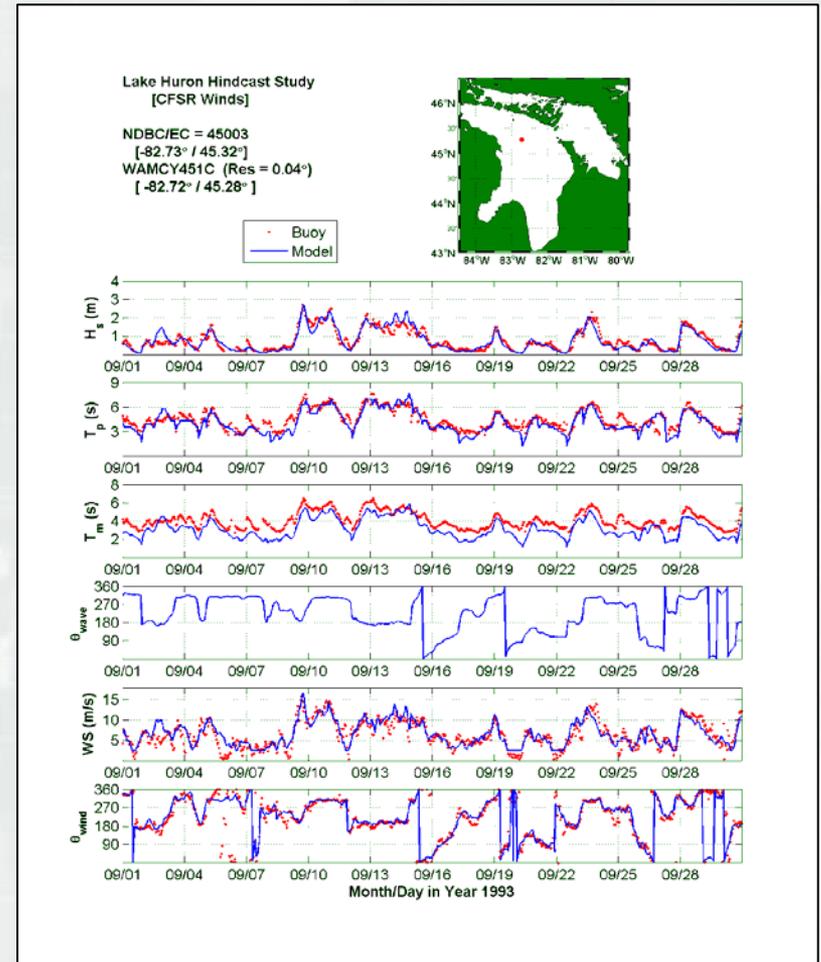
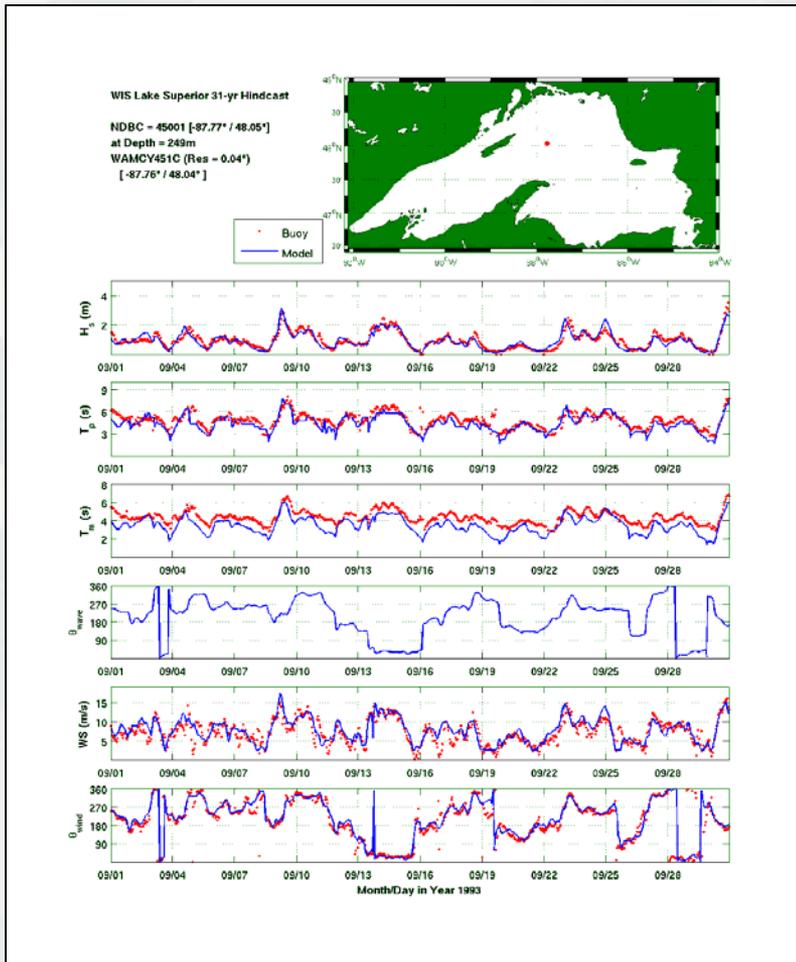
Lake Michigan / Lake Huron

# Lake Erie / Lake Ontario



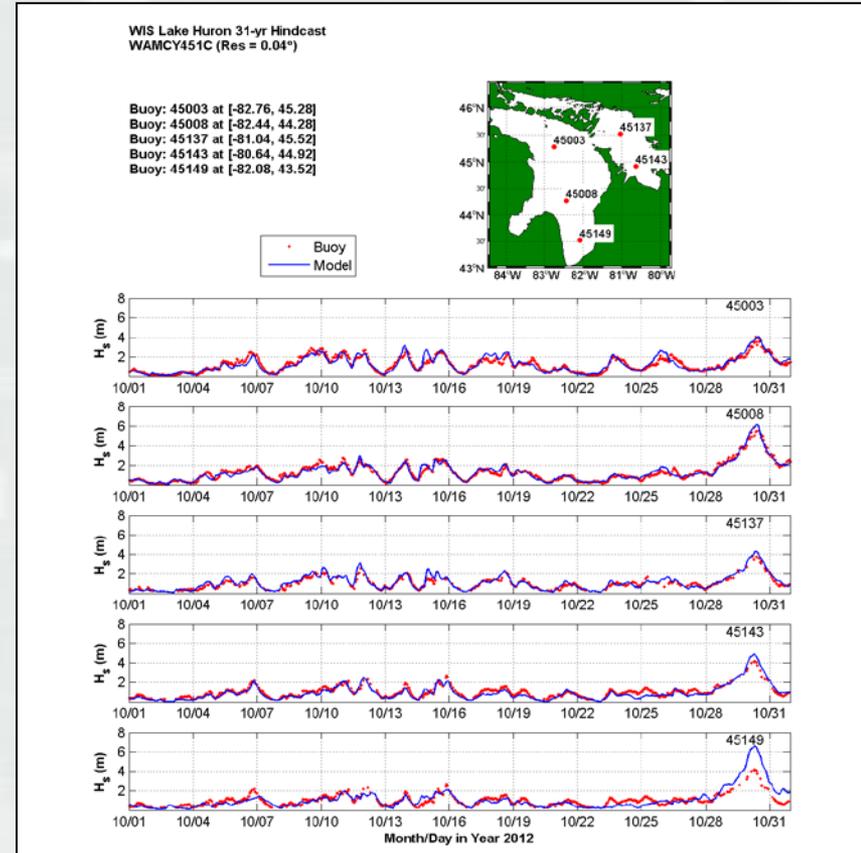
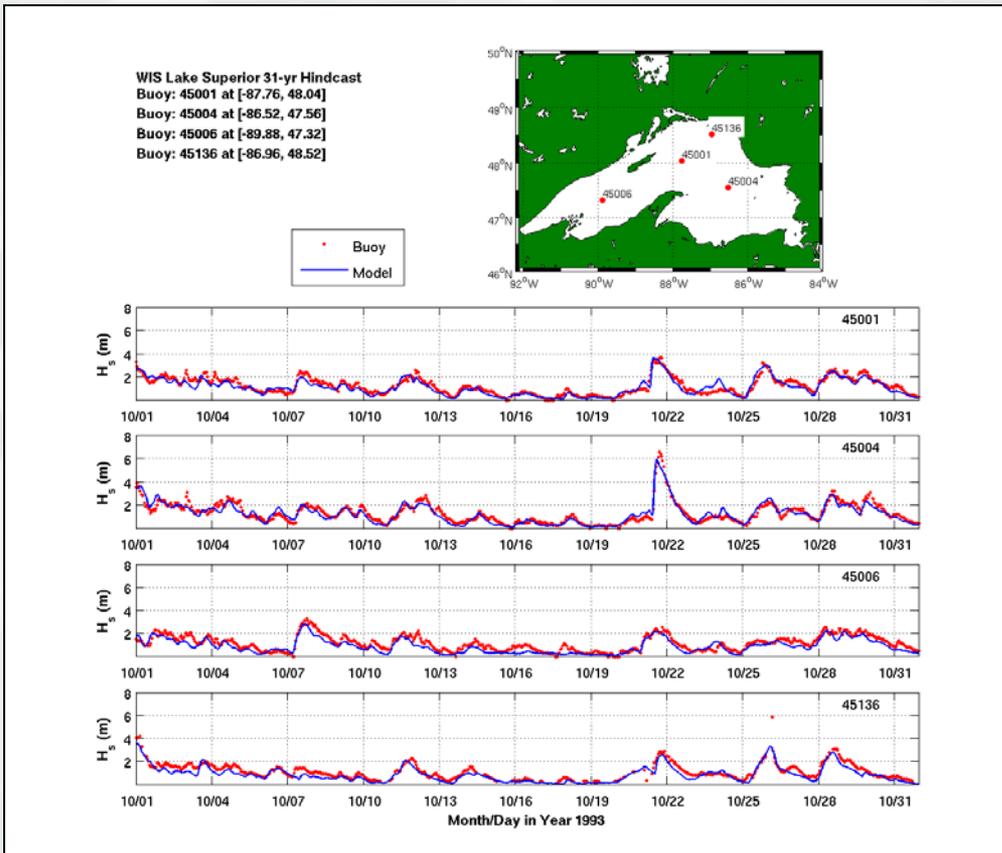
# Events: Frontal Passages

- Dominated by frontal passages



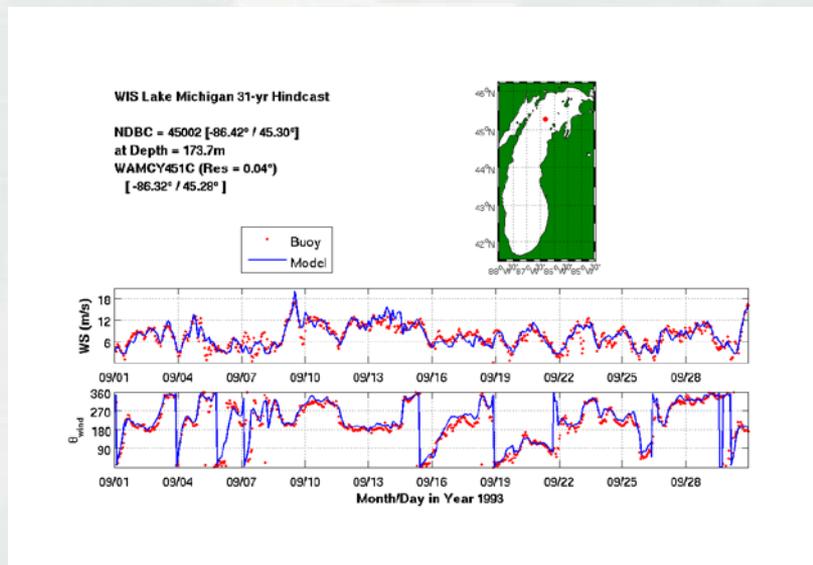
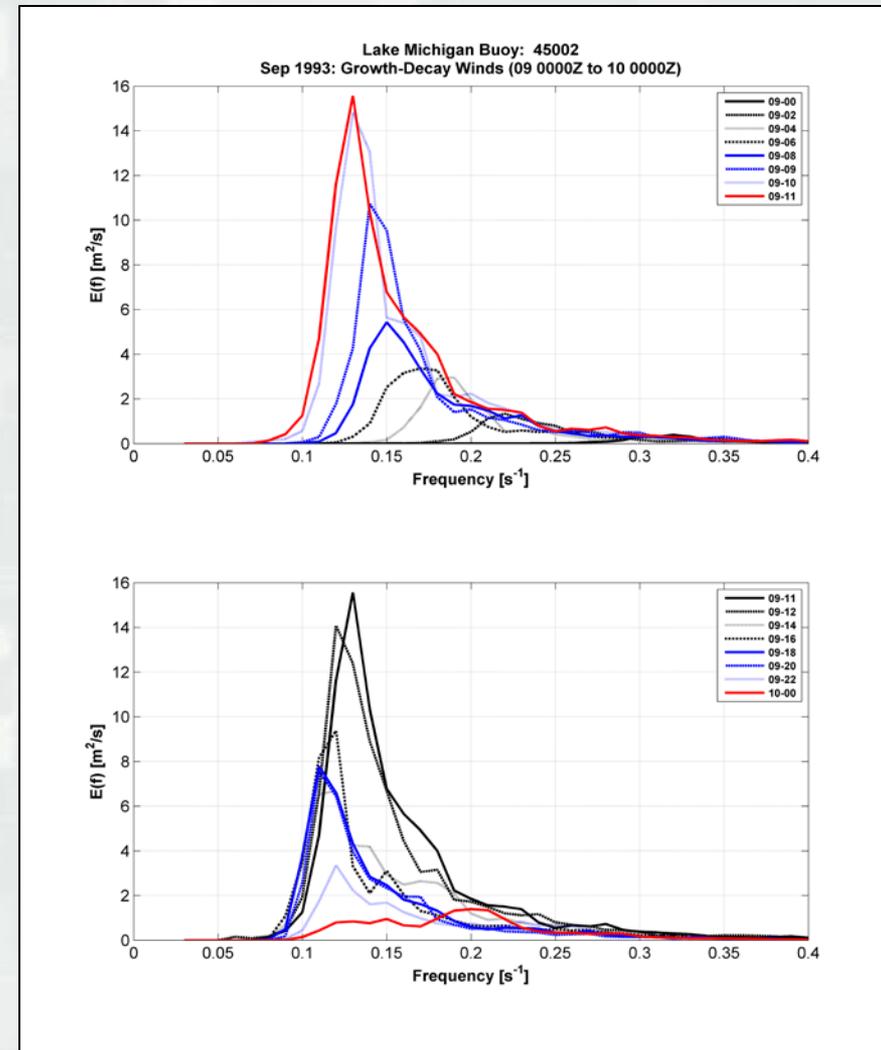
# Meteorology: Spatial Coherency

- Meteorology
  - ▶ Spatial Coherency / modulated by local effects
  - ▶ Waves react to primary synoptic-scale forcing



# Classic Wind-Wave Growth/Decay

- Waves in the Great Lakes dominated by growth
  - Winds blow, waves increase
  - Wind shifts / decreases: wave energy decreases
  - The lakes “re-set” for the next storm event

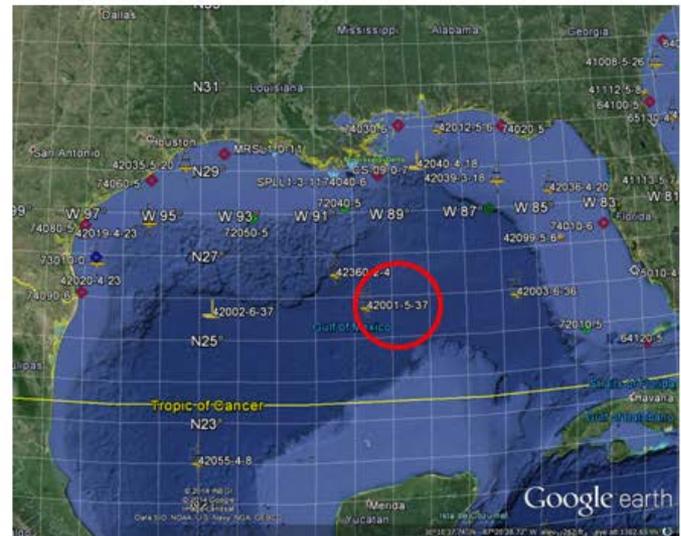
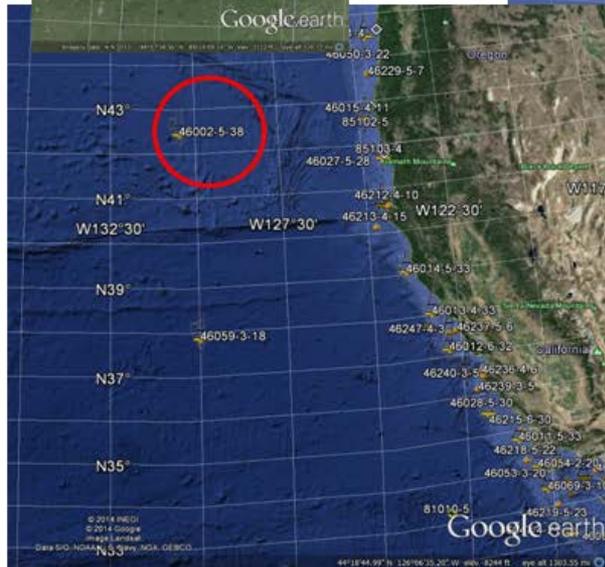
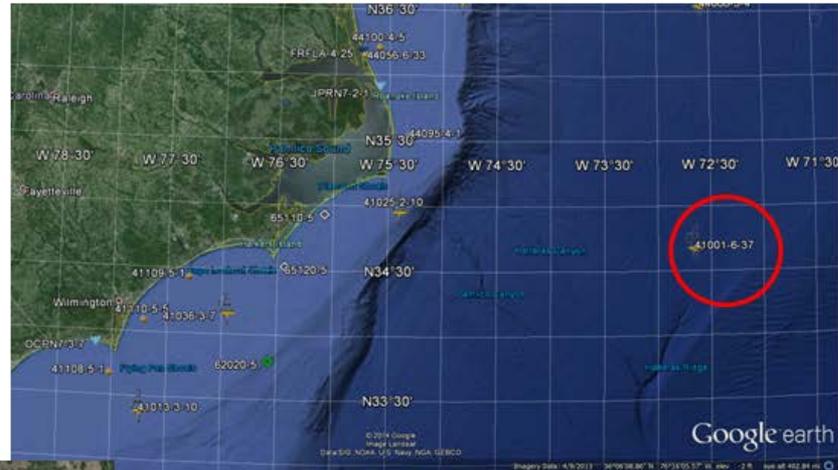


# Similarities/Differences

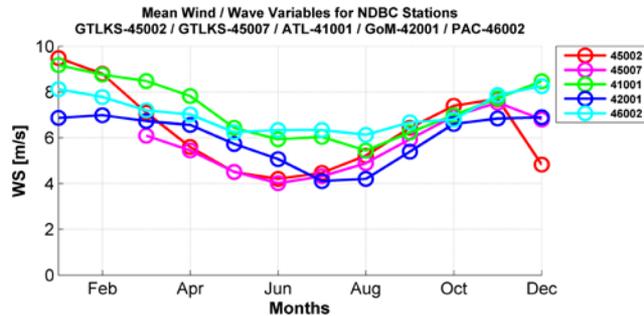
- If you get the winds right what about the waves?
  - ▶ Self-similarity principles in wind-wave growth
  - ▶ Great Lakes vs Atlantic / Gulf of Mexico / Pacific
- Five long-term measurement sites
  - ▶ NDBC buoy data (~30-yr duration)
  - ▶ Estimates of winds and waves

Station	Domain	Record Length		Location		Depth (m)	No. Obs	
		Start Date	End Date	Latitude	Longitude		WND	HGT
45002	Lake Michigan	1980-05	2012-12	45.344	-86.411	175.3	192108	205108
45007	Lake Michigan	1981-07	2012-12	42.674	-87.026	160.0	268746	267080
41001	Atlantic	1980-02	2012-12	34.561	-72.631	4462.3	164216	149749
42001	Gulf of Mexico	1980-01	2012-12	25.888	-89.658	3365.0	175053	147974
46002	Pacific	1980-01	2012-12	42.589	-130.474	3444.0	213392	217757

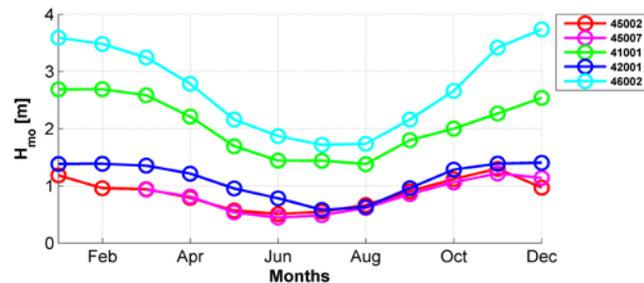
# Long-Term Point Source Measurement Sites



# Long-Term Point Source Measurement Sites

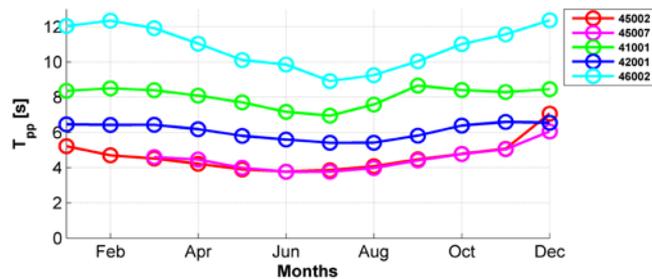


Seasonal oscillations in winds and waves



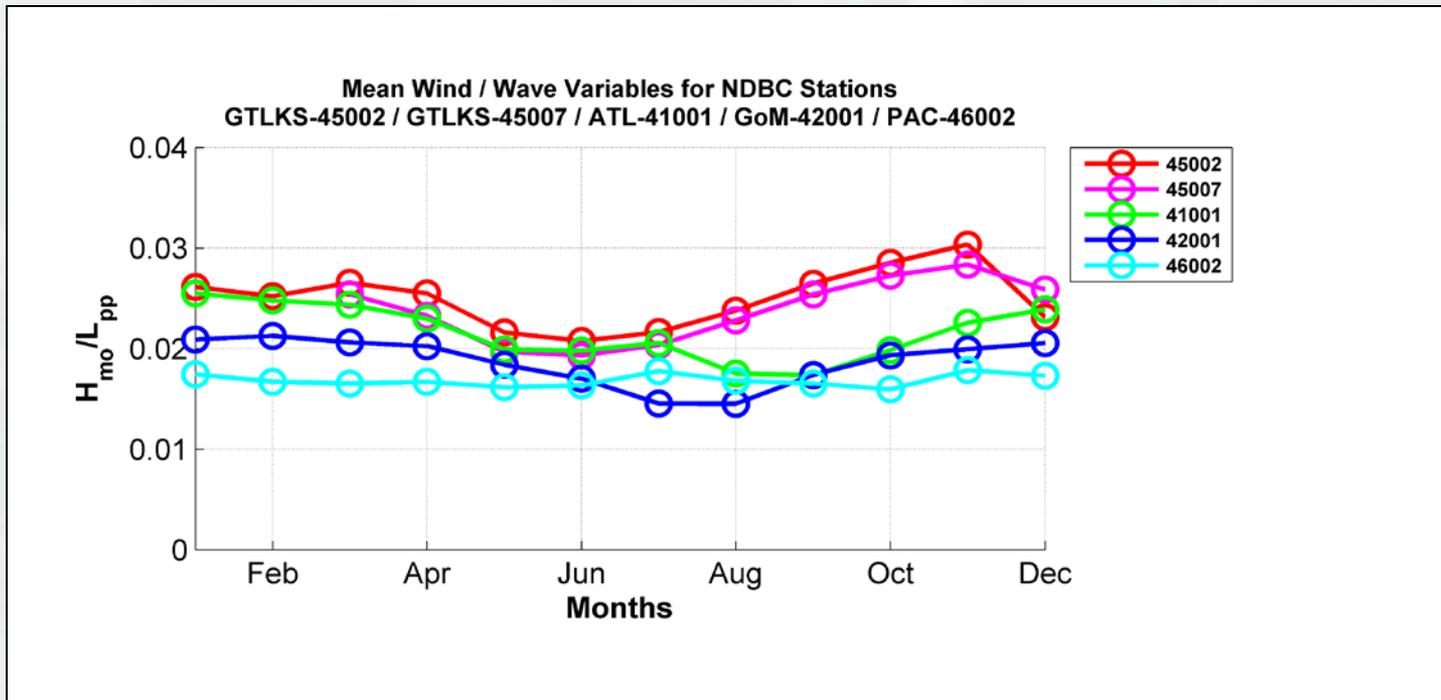
Mean wind speeds in Great Lakes similar

Mean significant wave heights lower in Great Lakes comparable to GoM



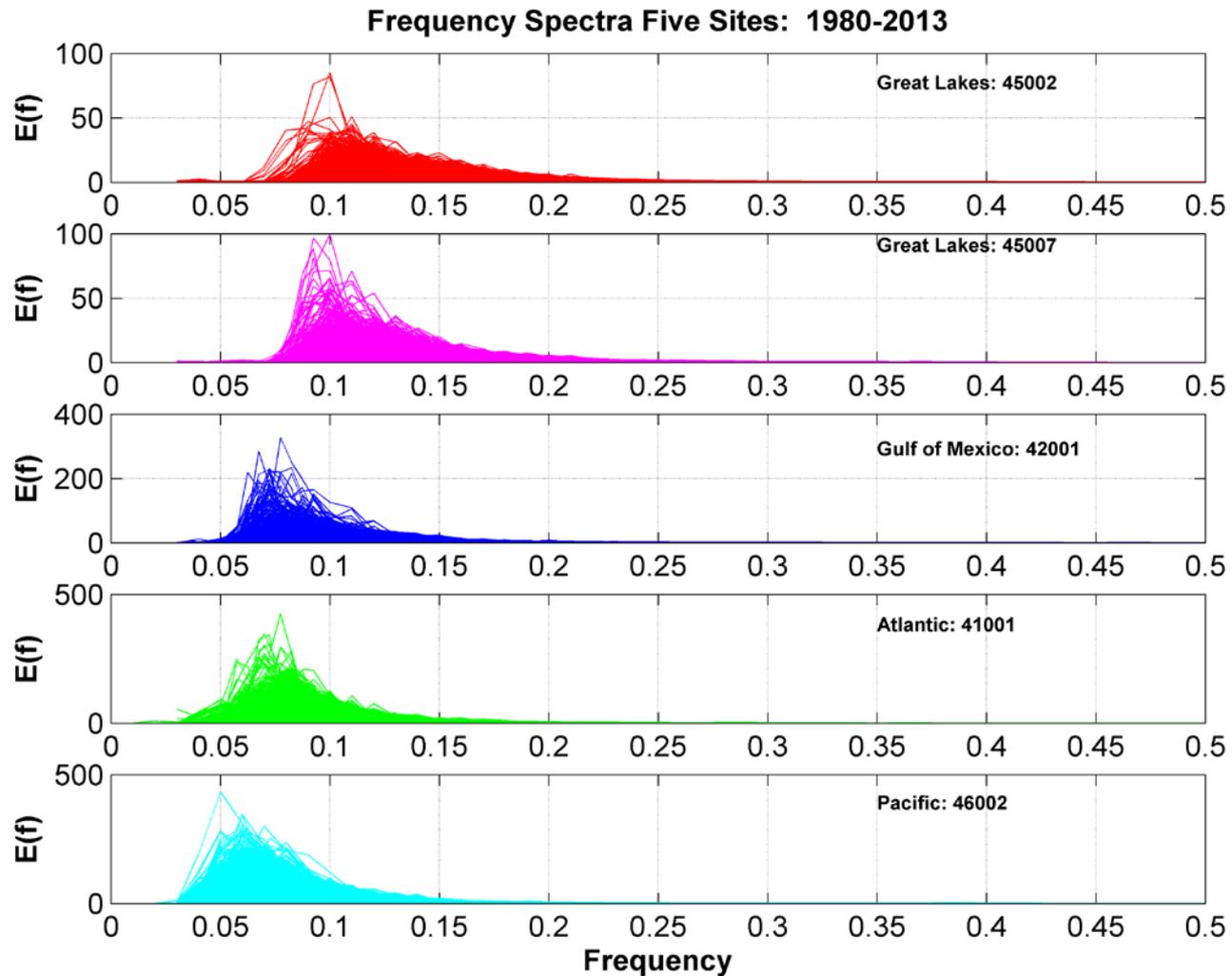
Mean wave periods lowest in Great Lakes

# Long-Term Point Source Measurement Sites



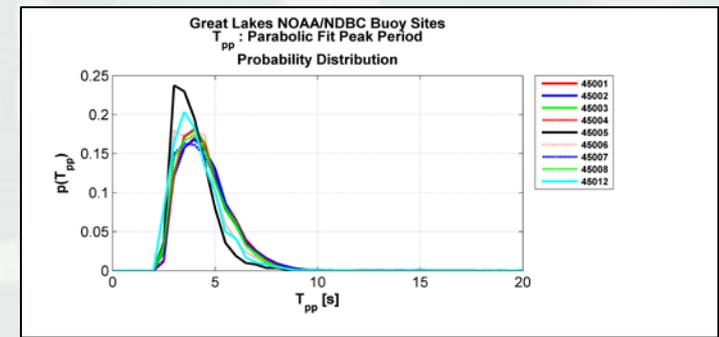
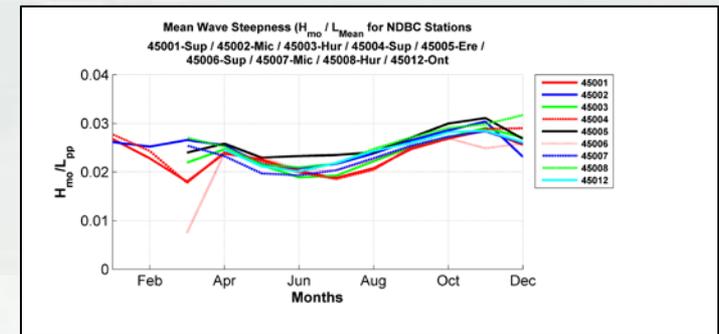
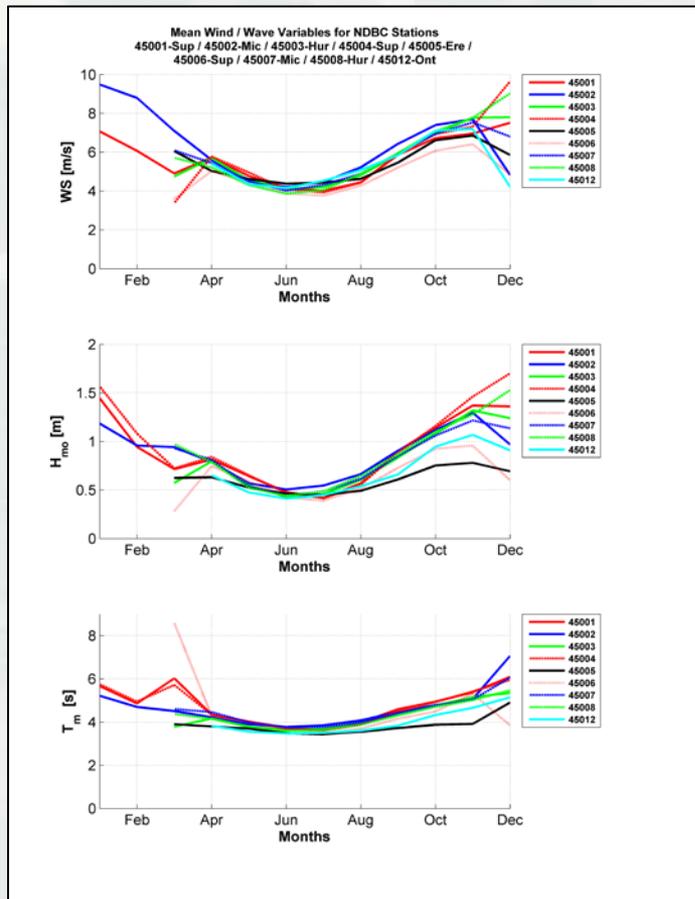
Wave steepness ( $f(H_{mo}/L_m)$ )  
50% higher in  
Great Lakes during storm season

# Long-Term Point Source Measurement Sites

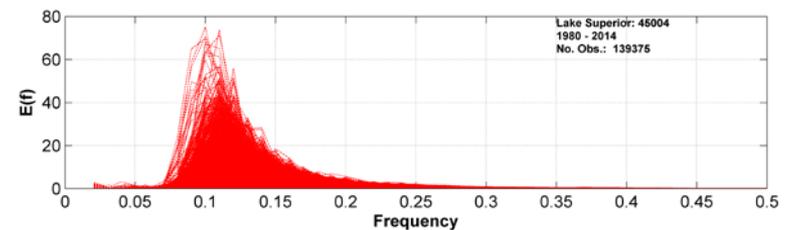
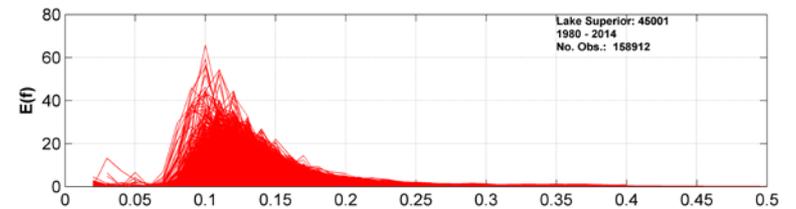
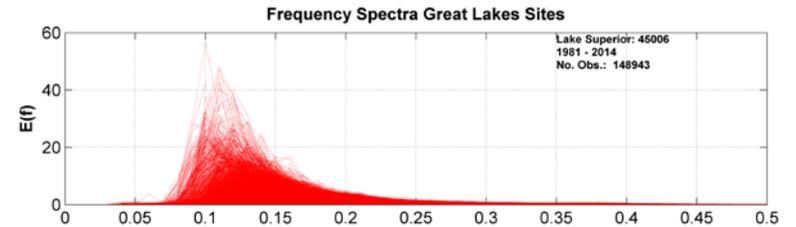
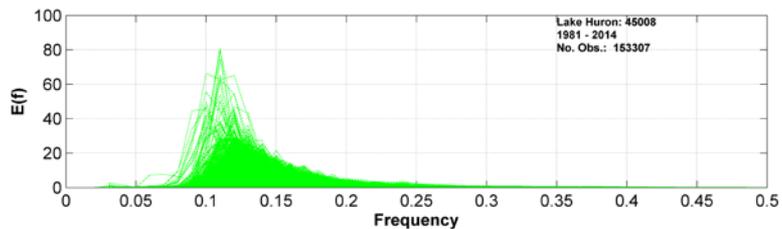
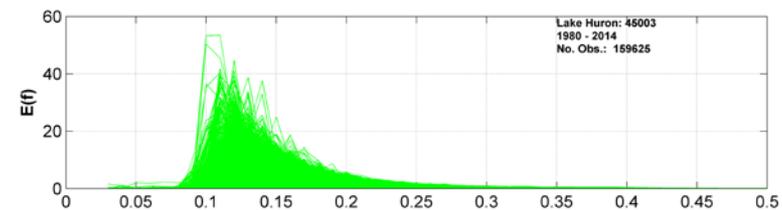
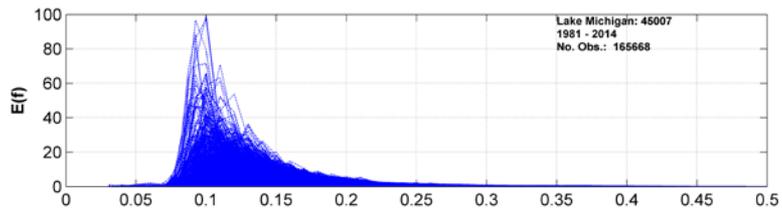
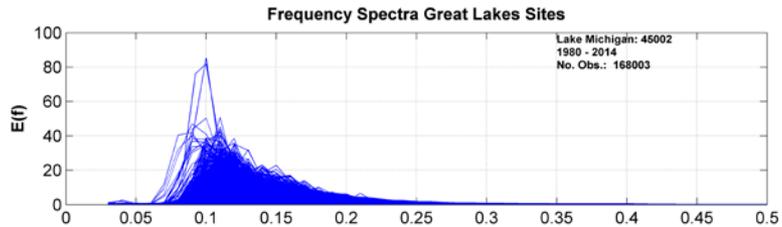


# Long-Term Point Source Measurement Sites

- Trends similar for all Great Lakes
  - ▶ Winds / Waves / Steepness and Spectra
  - ▶ Lake Erie is the OUTLIER (different from others!)

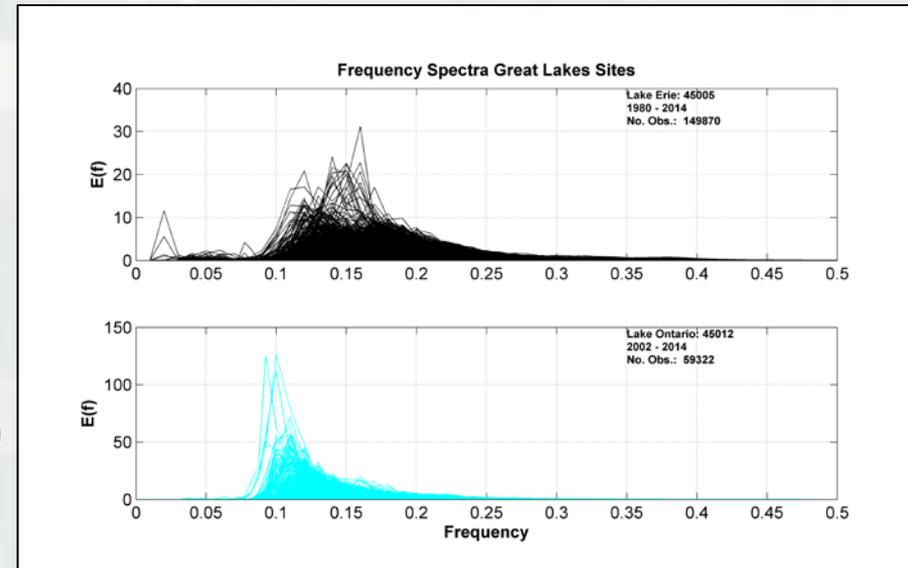
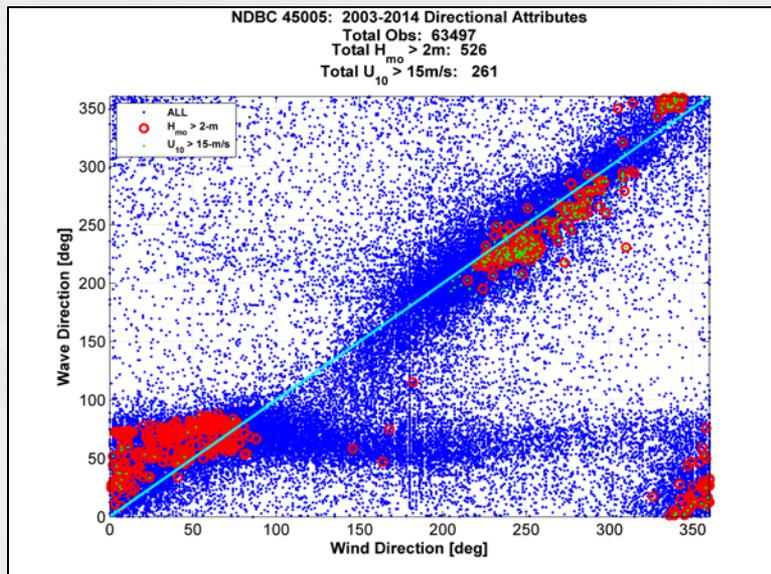


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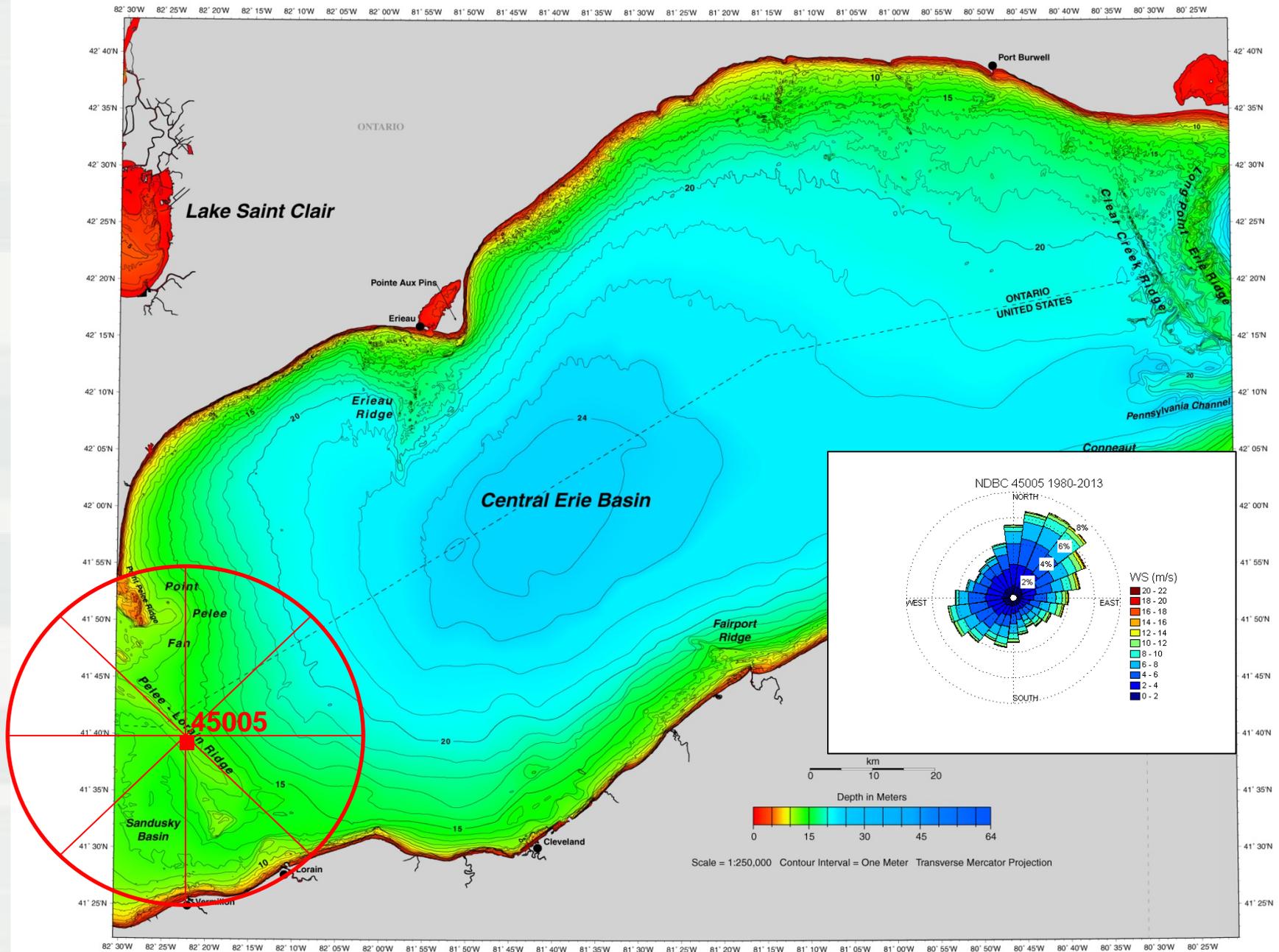


# Long-Term Point Source Measurement Sites

- Lake Erie site sits on ridge
  - ▶ Two basins: Central/Western
  - ▶ Dominant wind direction(s)
    - NE / SW
  - ▶ Buoy site sees both populations
  - ▶ Growth/Decay cycles are similar to other lakes (higher frequency)



Waves do not necessarily follow the direction of the wind



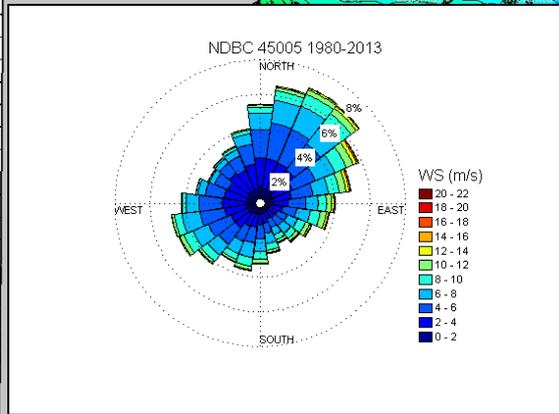
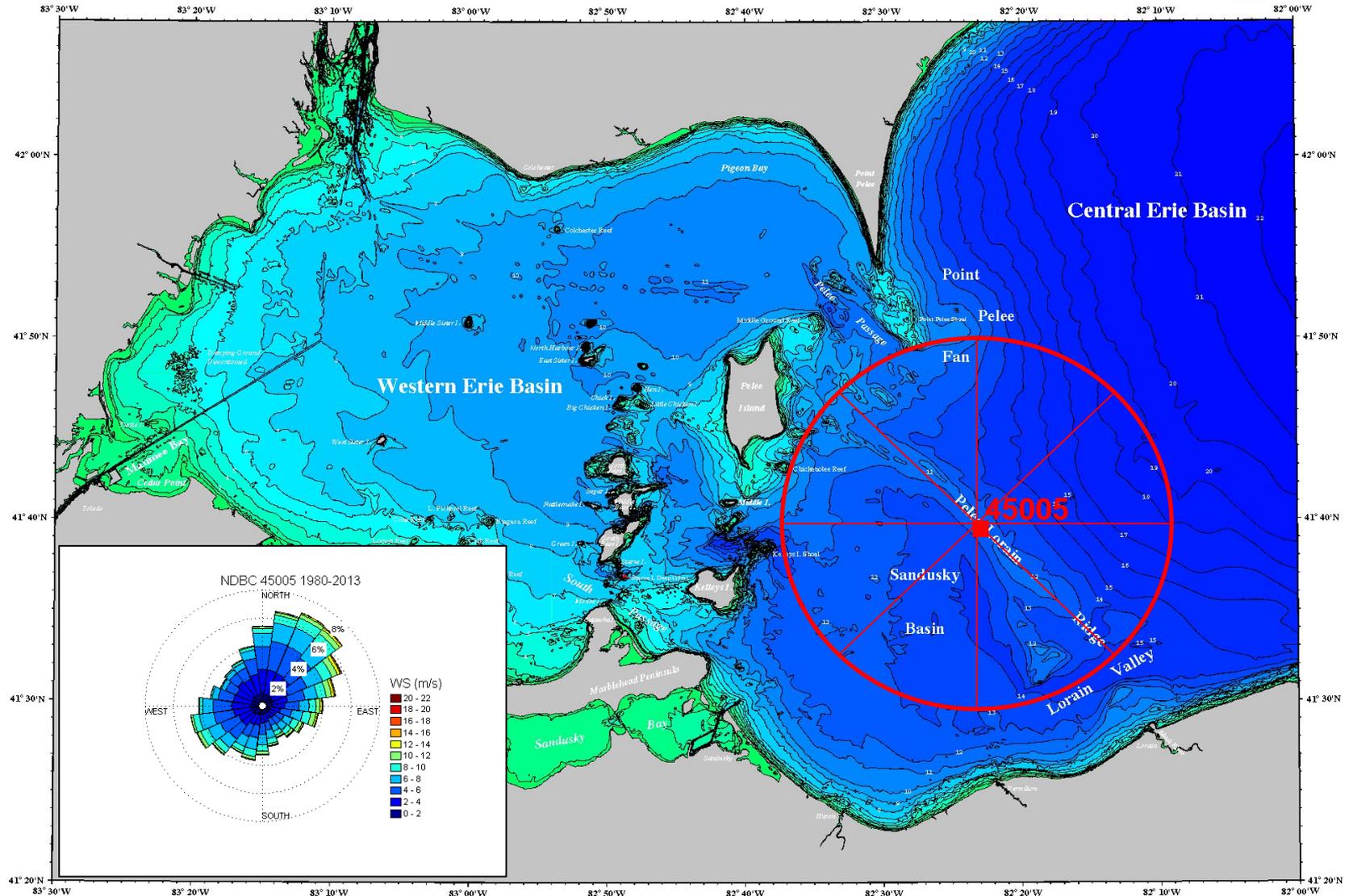


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NATIONAL GEOPHYSICAL DATA CENTER

# BATHYMETRY OF WESTERN LAKE ERIE

Plate 1

DEPARTMENT OF FISHERIES AND OCEANS  
CANADIAN HYDROGRAPHIC SERVICE



Bathymetry Compiled by:

Lisa A. Taylor National Oceanic and Atmospheric Administration,  
National Geophysical Data Center  
John S. Warren Department of Fisheries and Oceans,  
Canadian Hydrographic Service

# Observations

- Great Lakes Meteorology
  - ▶ Persistent / Consistent storm events
  - ▶ Orographic effects: local topographic features
  - ▶ Thermal winds: modulation of winds along coastline
    - Stability effects (unstable during stormy seasons)
  - ▶ Similar to other larger-water bodies
    - Excluding tropical events
  - ▶ Dramatically changes characteristics in the winter (ICE Effects)
- Wave Climate
  - ▶ Dominated by wind-sea generation
  - ▶ Self-similarity principles
  - ▶ Frequency range moves to higher values
  - ▶ Steepness larger for the Great Lakes
  - ▶ Basins re-set after each event (DEVOID OF SWELL ENERGY)

# Issues to Resolve

- **Meteorology**
  - ▶ Marine / Land Interface
  - ▶ Role of land/sea breezes
    - How far seaward?
    - Magnitude of the winds?
- **Ice Impact**
  - ▶ Boundary layer: roughness of ice
  - ▶ Growth / Decay of the wave field in building ice conditions
  - ▶ Are ice effects in the Great Lakes similar to the Arctic?
    - Excluding permanent ice pack
    - Ice rafting during spring thaw (erosion / coastal damage)



# Issues to Resolve

- Wave Climate
  - ▶ Quantifying the coastal wave climate
  - ▶ Need for more point-source measurements
  - ▶ Need for measurements in ice conditions
    - Bottom mounted
    - Ice resultant buoys / Expendable buoys
    - Others?



# QUESTIONS



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