Estimation of Wave Heights during Extreme Events in Lake St. Clair

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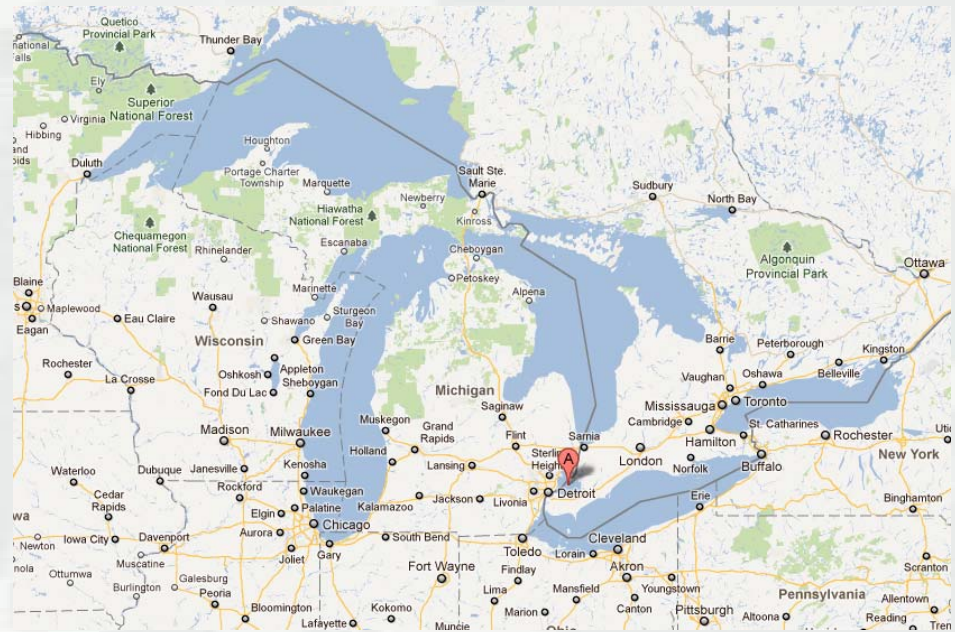**Engineer Research and Development Center Coastal and Hydraulics Laboratory**

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Motivation

- Understanding wave response of Lake St. Clair during storm events
  - ▶ 430 sq miles
  - ▶ Max depth of ~ 6 meters
- Commercial / residential properties
  - ▶ Detroit on southwest banks

Methodology

- **3GWAM Cycle 4.5.1C**
  - ► 18-sec grid
  - ► Shallow water mechanisms
  - ► CFSR Wind Field
  - ► 12 day storm simulations
- **Evaluation**
  - ► Canadian buoy 45147
  - ► Bulk parameters H_s, T_p, T_m, Ws, θ_{dir}
  - ► Field Experiment (GLERL / Canada)
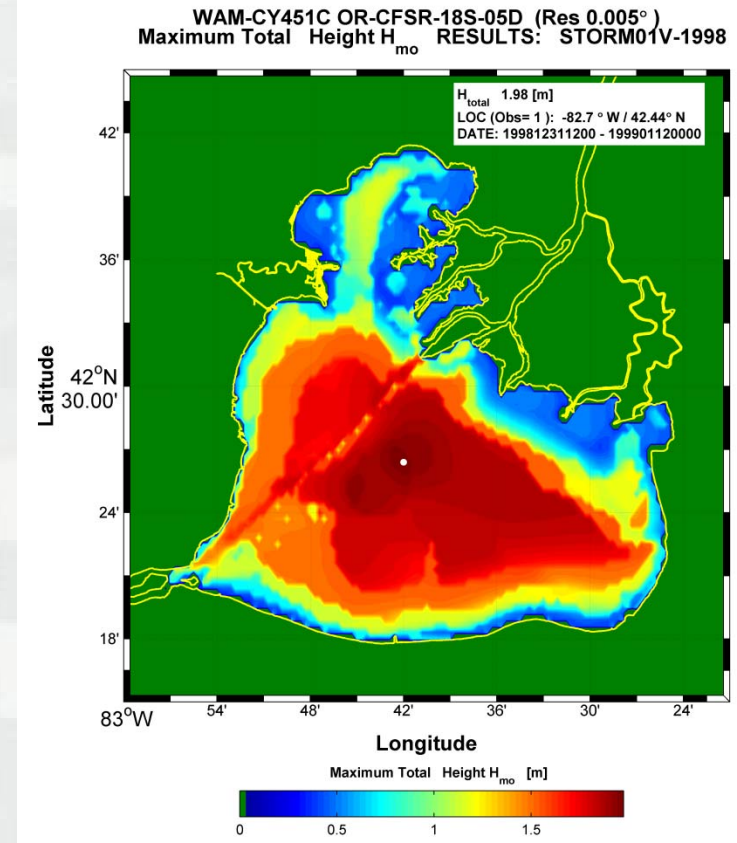
Summary of Conclusions

- 3GWAM used to model extreme waves
  - ► Canadian buoy 45147 used for evaluation
    - Adjustments needed to account for "suspect" data
  - ► Forced with CFSR wind fields
    - Correct for marine exposure on winds
 - ► Evaluation shows good agreement between model and buoy results

Canadian Buoy 45147

- Canadian Buoy 45147
  - ► 1.7-m Watchkeeper buoy
  - ► AXYS sensor / analysis package
    - • 3.3-m anemometer elevation
    - • Other meteorological sensors
    - • No wave direction measurements
  - ► Located: 42.43 N / 82.68 W
  - ► Removed: ~ December
  - ► Re-deployed: ~ March/April

45147

Canadian Buoy 45147

Canadian Buoy 45147 Energy Density Spectrum

C45147 Signal to Noise Filter
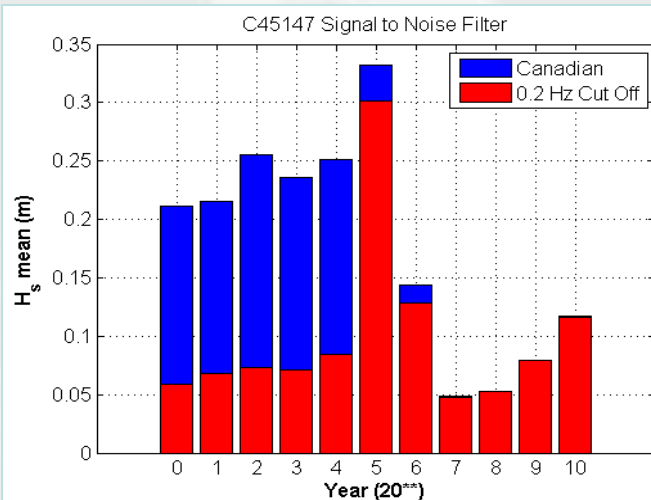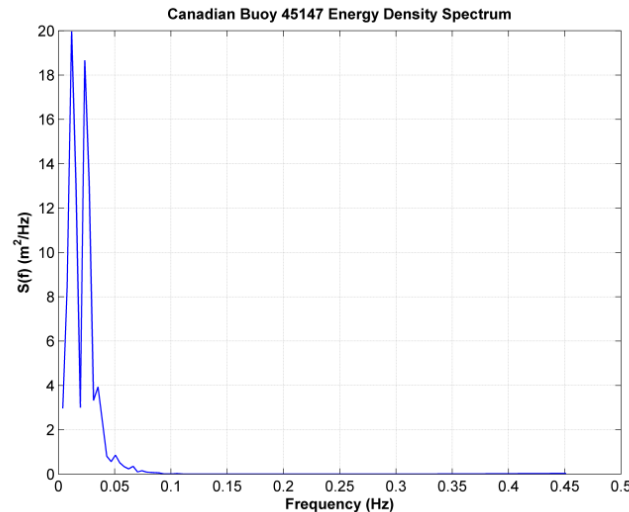
- ▶ Archive: 2000 – 2010
- ▶ Integral / spectral data
  - • Spectra
    - ▷ Frequency domain changes
    - ▷ 41 to 100 frequency bins
    - ▷ Records low frequency energy: NOISE
- ▶ Solution
  - • Truncate Spectra at 0.2 Hz
  - • Decreased Wave Heights prior to 2005
    - ▷ 2005 is considered "Bad Data"
- ▶ Environment Canada
  - • Verified our findings
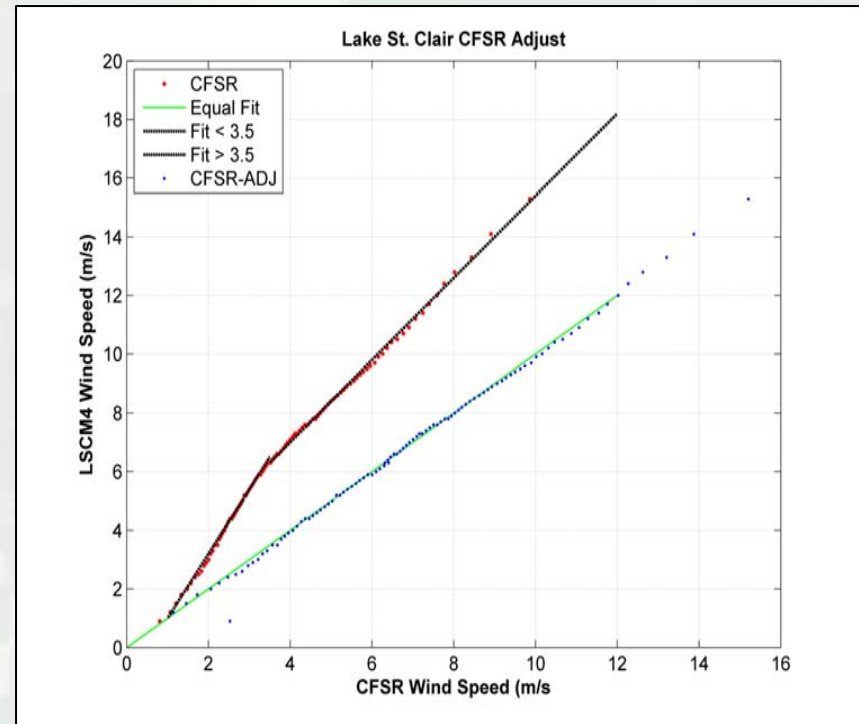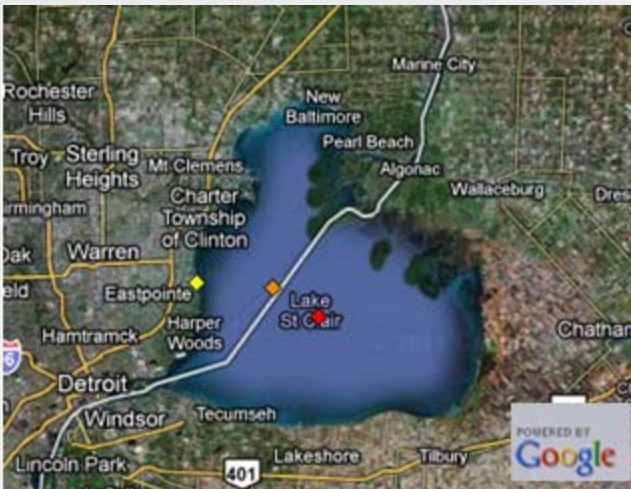 - • Correcting their archive

CFSR Wind Field

- NCEP Climate Forecast System Reanalysis: CFSR
  - ► 0.5-deg Resolution
  - ► 30-year data set
    - 1979 through 2009
  - ► Land/Sea mask
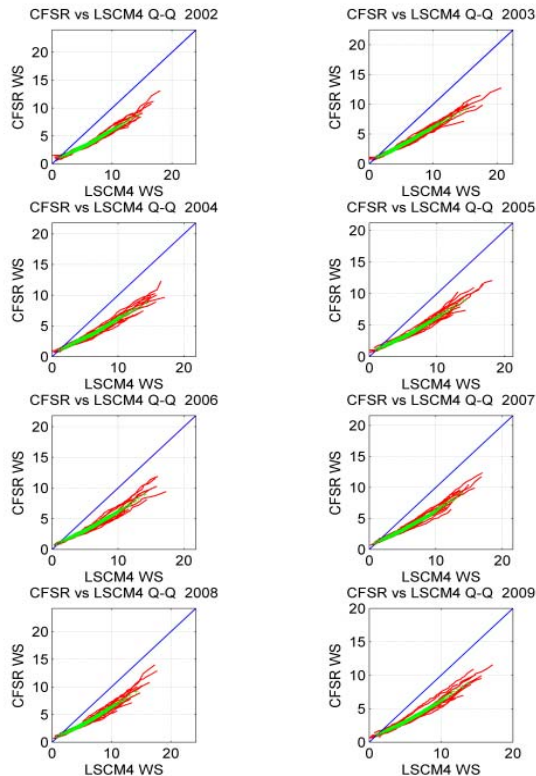   - Lake St. Clair in land mask
    - Wind speed adjustments
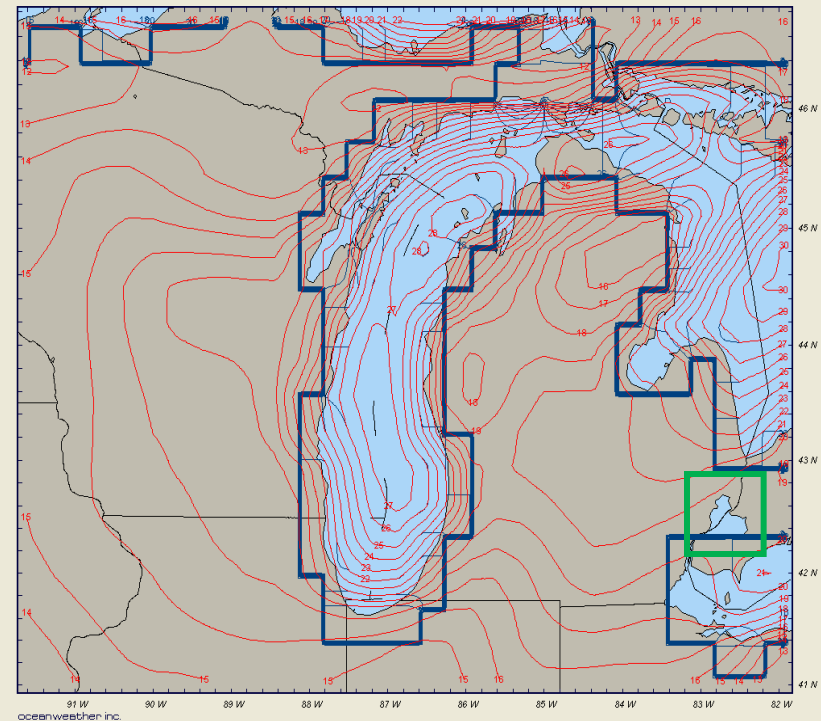
CFSR Wind Field

- C-MAN Station LSCM4

- Two linear relationships based on Q-Q

  ► $W_s < 3.5$:

    - $W_s = 2.2 \cdot W_s - 1.2$
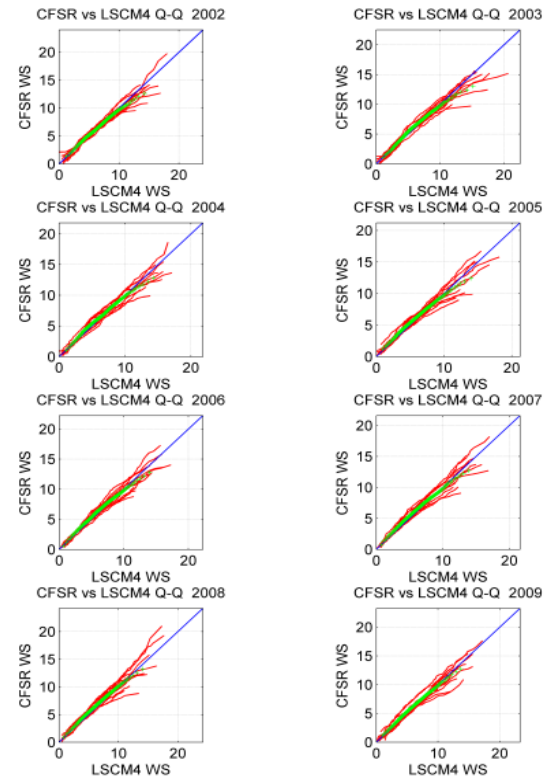
  ► $W_s > 3.5$

    - $W_s = 1.4 \cdot W_s + 1.4$

# CFSR Wind Field

Original CFSR

Adjusted CFSR

Wave Modeling

- Input to 3GWAM
  - ► Bathymetric Grid
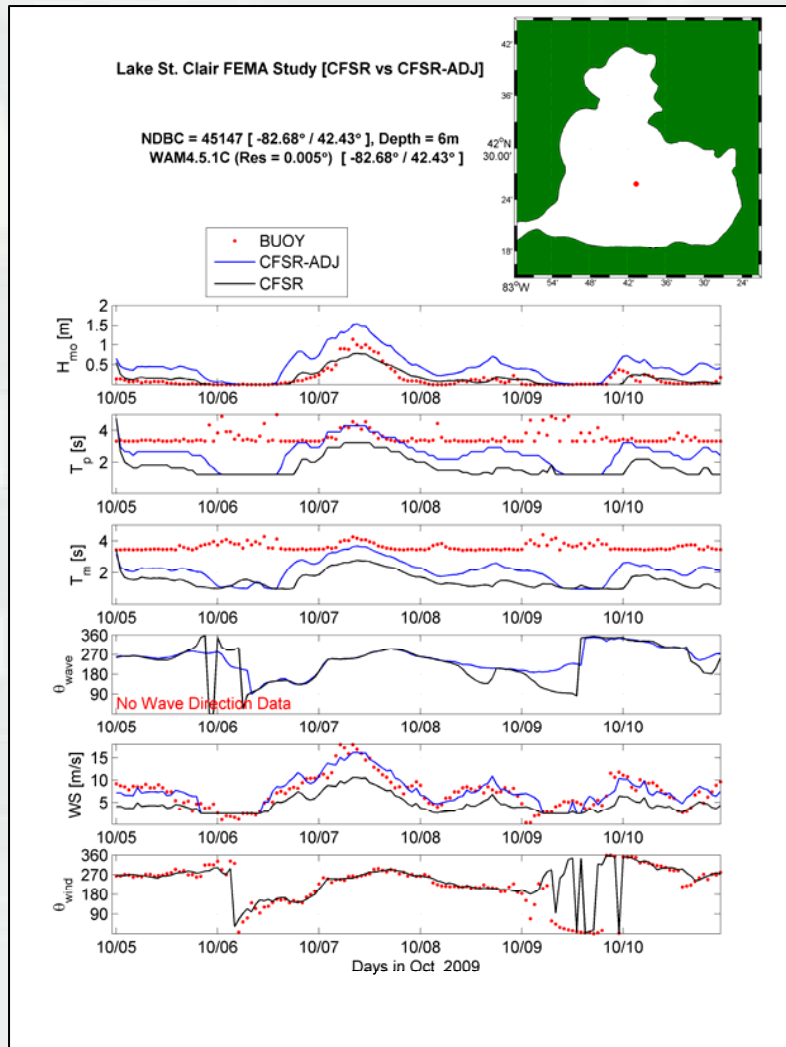   - • Derived from NOAA/GLERL
    - • ADCIRC Preliminary Mesh
      - ▷ Set shoreline
      - ▷ Consistent depths
    - • 3-arc second
      - ▷ Maximum resolution
      - ▷ Testing required
    - • OPEN COAST
  - ► Model Resolution
    - • Frequency / Direction
    - • Wave Climate Specific
    - • Numerical Stability
    - • Processes Dependent

Water Depth Field for Lake St. Clair
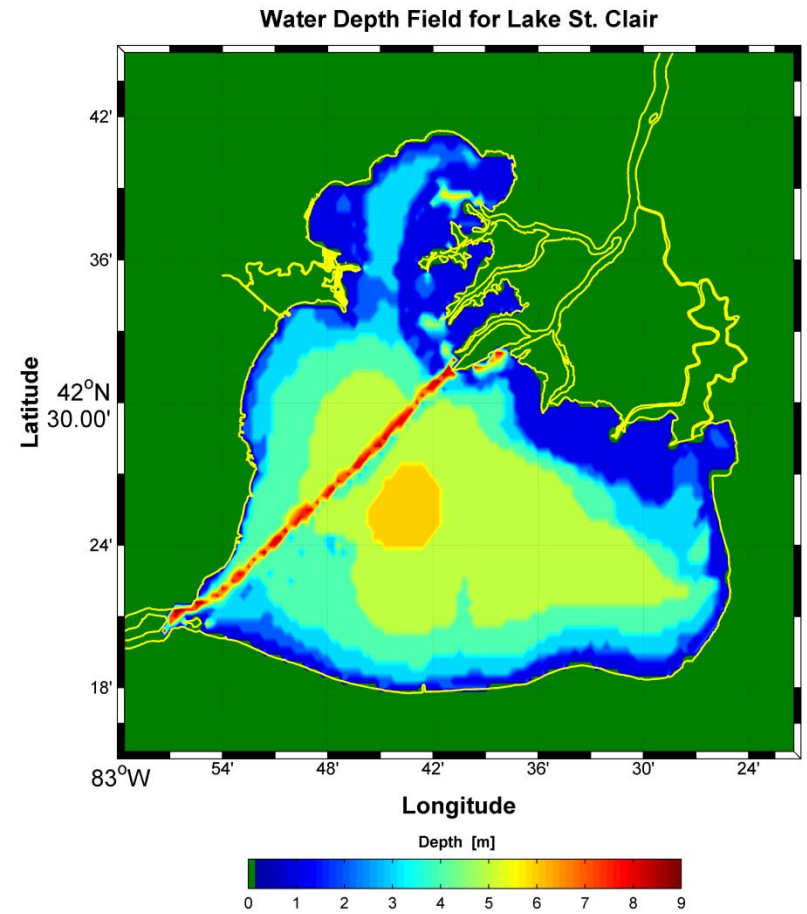
3GWAM Evaluation

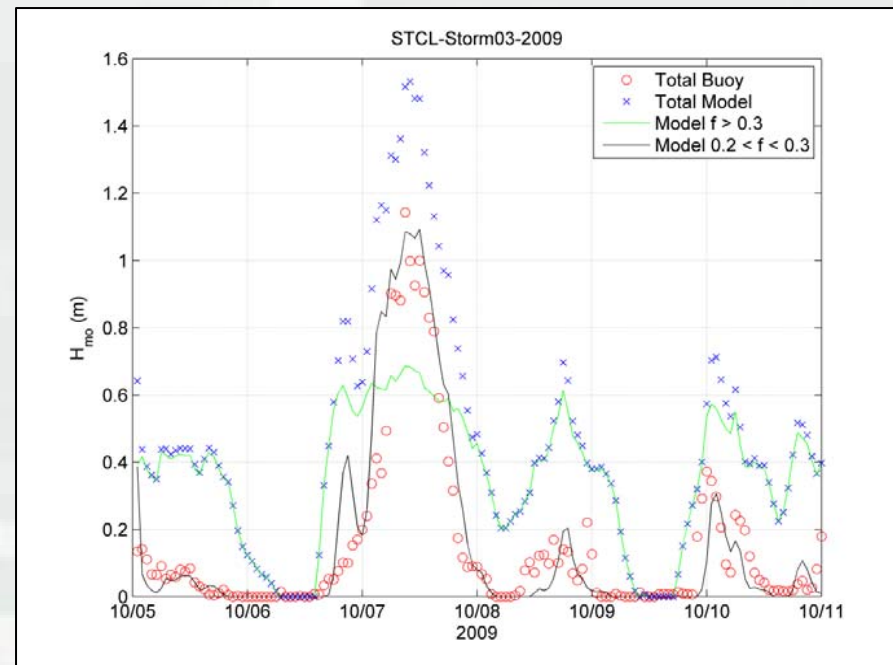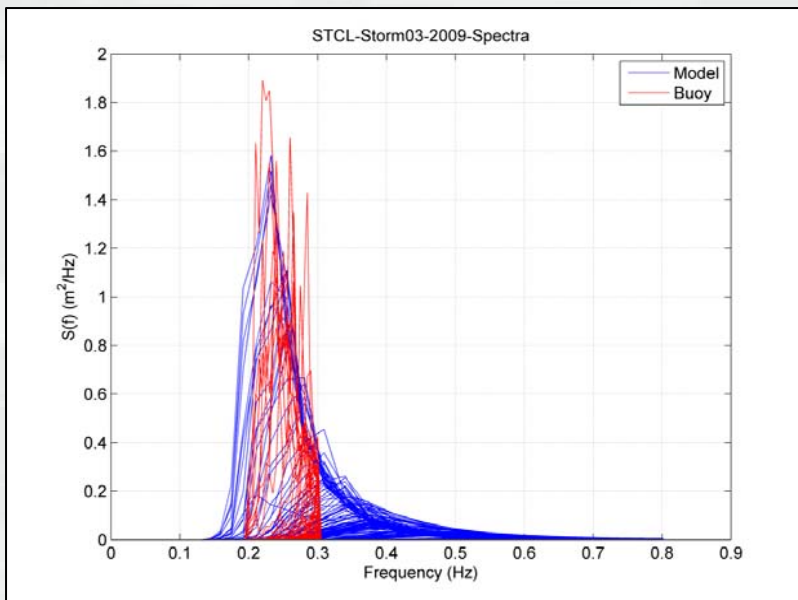
- Nov. 2009 Storm
  - ► Top ranked wave event
  - ► Simple Growth
    - $W_S \sim 15\text{-m/s}$
    - $\theta_{wind} \sim 270°$

- WAM Simulation
  - ► Wind Forcing
    - CFSR vs. CFSR-ADJ
    - No ice

Measurement Evaluation

- 45147
  - ► Energy between frequency bands 0.2-0.3 Hz
- 3GWAM
  - ► Adjusted frequency range fits data

Conclusions

- Wave Measurements
  - ► Canadian buoy 45147
  - ► Filtered to remove low frequency noise
- CFSR wind field
  - ► Adjusted to minimize land-mask effects
    - Approximate marine exposure
    - Two linear fits used with inflection point at 3.5-m/s
- 3GWAM
  - ► Evaluation results show good agreement
  - ► Best fit requires similar frequency range to buoy

QUESTIONS