Operational Storm Surge Forecasting for the Greak Lakes:
Real-Time Data & Decision Support Systems to Facilitate Early
Warnings for Shoreline Communities

By Patrick Delaney, DHI

Acknowledgements:
Gord Gallant, Ministry of Natural Resources and Forestry
Jacob Sorensen and Jorgen Mariegaard, DHI
Background

- Ontario Ministry of Natural Resources and Forestry (MNRF) operates a Surface Water Monitoring Centre in Peterborough, ON
- The centre observes water levels on lakes, rivers and streams in Ontario for the purpose of:
  - assessing the severity of drought
  - predicting where/when there is a risk of flooding
  - limiting the impact of flooding and drought by enabling government and other agencies to put emergency response plans into operation
  - identifying sensitive and risk prone areas for flooding and drought throughout the province
Forecasting System Objectives

• Great Lakes Storm Surge Operational System (GLSSOS) was developed for the purpose of providing a flood early warning system for Canadian communities located along the shorelines of the Great Lakes
  – Lake Superior, Lake Huron, Lake St. Clair, Lake Erie and Lake Ontario
• DHI was hired to develop and calibrate hydrodynamic and wave models for each of the 5 lakes and then develop a system for continually running the models in forecasting mode and generating reports
  – MIKE 21 was used for the modelling while MIKE OPERATIONS components were used for the forecasting system
Presentation Outline

• About Storm Surge
• System Components
• System Configuration
• Reporting
• Conclusions
About Storm Surge
Storm Surge – What is it?

Sustained high winds from one direction can push the water level up at one end of the lake and make the level drop by a corresponding amount at the opposite end.

Elevated water levels are further exacerbated by wind generated waves.
GLSSOS Configuration
GLSSOS Components

• Existing WISKI database where the near real-time water level and wave height data for the lakes are stored
• Meteorological forcings from Environment Canada
• A calibrated hydrodynamic model and a wave model for each lake
• An operational system that facilitates the automation of data retrieval, model execution, and result publication on a regular schedule
• A web-based management console to control and monitor the operational system performance
GLSSOS Components

- Water Level and Wave Height Measurements
  - Availability of near real-time data was critical for the success of the project as it facilitate a more accurate forecast

<table>
<thead>
<tr>
<th>Lake</th>
<th>Water Level Stations</th>
<th>Wave Height Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Superior</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Lake Huron</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Lake St. Clair</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Lake Erie</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Lake Ontario</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>
GLSSOS Components

• Meteorological Data
  – Environment Canada provided access to twice daily forecasts of wind, barometric pressure, and Albedo
GLSSOS Components

• Hydrodynamic and Wave Models
  – MIKE 21 Flexible Mesh software used to develop and calibrate the models for each lake (approx. 0.25 - 1 km² elements along shoreline)
  • Bathymetry
  • Bed resistance
  • Wind Forcing
  • Ice Coverage
  • Initial Conditions

Calibration Events
  - June 1 - June 30, 2002
  - June 1 - July 2, 2004
  - Nov 15 – Dec 15, 2006
  - Feb 1 – Feb 28, 2007
GLSSOS Components

• Hydrodynamic and Wave Models
  - MIKE 21 Flexible Mesh software used to develop and calibrate the models for each lake
GLSSOS Components

- Hydrodynamic Models
  - Data Assimilation is applied in hindcast and forecast period
    - The model is run for the hindcast period (12 hours) to ensure that all available observations are assimilated
    - The model is then run for the forecast period (48 hours) the data assimilation is applied via initial conditions for wind correction, water level and currents
GLSSOS Components

• Hydrodynamic Models
  − Data Assimilation techniques applied to improve accuracy of forecasts
    • a process whereby an algorithm is used to interpret the deviation of the model hindcast to observations and create a consistent estimate of wind correction, water level and currents throughout each lake
    • This estimate of model parameters and wind speed is subsequently used to initiate the forecast and more accurately reflect the observed conditions and improve predictions
GLSSOS Components

• Hydrodynamic Models
  – Data Assimilation is applied in hindcast and forecast period
GLSSOS Configuration
MIKE OPERATIONS On-line forecasting and operational control

Operational Overview
Notifications & Alarms
Emergency Response
System Optimisation
System Control

Data Integration
One window to all data
Notifications & Alarms
On-line Control (Data driven)
Data reporting

Objective Decision Making
Stakeholder involvement
Robust Decisions
Wise investments
GLSSOS Configuration

- Automation is handled using Windows Scripting Host
- Management of all system data is handled by a central MySQL database
  - Model definitions
  - Model progress
  - Published results
GLSSOS Configuration

- System management is handled by Dashboard Manager
  - MIKE OPERATIONS component for Decision Support System development
  - Main View provides a high level overview of the system and results
GLSSOS Configuration

- System management is handled by Dashboard Manager
  - MIKE OPERATIONS component for Decision Support System development
  - Model view is used to monitor the progress/success of each individual model
  - User intervention is available
GLSSOS Reporting
GLSSOS Reporting

- Results published to OMNR&F website
  - 48 hour forecast for water level, wave height, mean wave direction, and peak wave height
    - Lake Superior: Schrieber, Thunder Bay and Gros Cap
    - Lake Huron: Sarnia, Tobermory, Parry Sound
    - Lake St. Clair: Bell River, Mitchell Bay
    - Lake Erie: Port Colbourne, Long Point, Port Stanley, Hillman Marsh
    - Lake Ontario: Kingston, Coburg, Burlington
GLSSOS Reporting
GLSSOS Reporting

Great Lakes Storm Surge Model

Displaying animations from the anim/Ontario2DSW/waveperiod folder. Times shown are GMT.
GLSSOS Reporting

• Last significant wind event was Christmas Day, 2014
• GLSSOS provided an accurate 48 hour forecast and a very accurate 36 hour forecast
• Local authorities were alerted with sufficient time to notify residents and businesses in the affected communities
Conclusions

• GLSSOS has been in operation since 2007 and has proven to be a robust operational forecasting system
• It delivers accurate and reliable 48 hour forecasts of water levels and wave heights for the Great Lakes communities in Ontario
• The level of accuracy demonstrated by the historical performance of the forecasts has developed a strong sense of confidence in the system and has proven to be a valuable tool for facilitating emergency response preparations in potentially affected communities
Q&A:
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Recorded demonstration if time permits