COASTAL FLOODING RISK POST PROCESSING, GUIDANCE TO ASSIST PREDICTIONS SERVICES

Emergency Management Strategy
(Predicting and Alerting for Coastal Flooding)

Devon Telford

2nd International Workshop on waves, Storm Surges and Coastal Hazards

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Coastal Flooding Risk

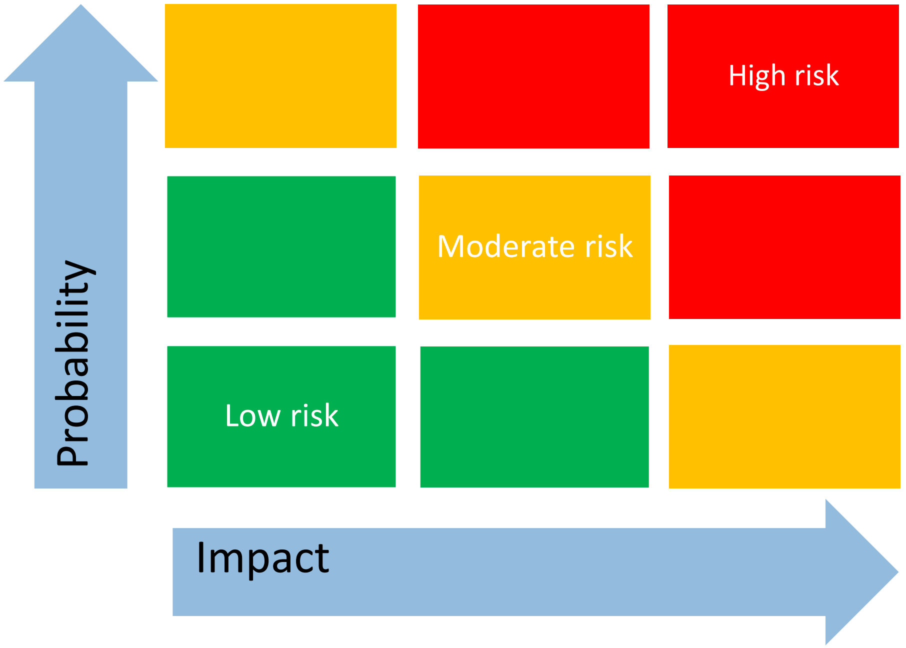
Coastal Flooding Risk:

Probability of the hazard:

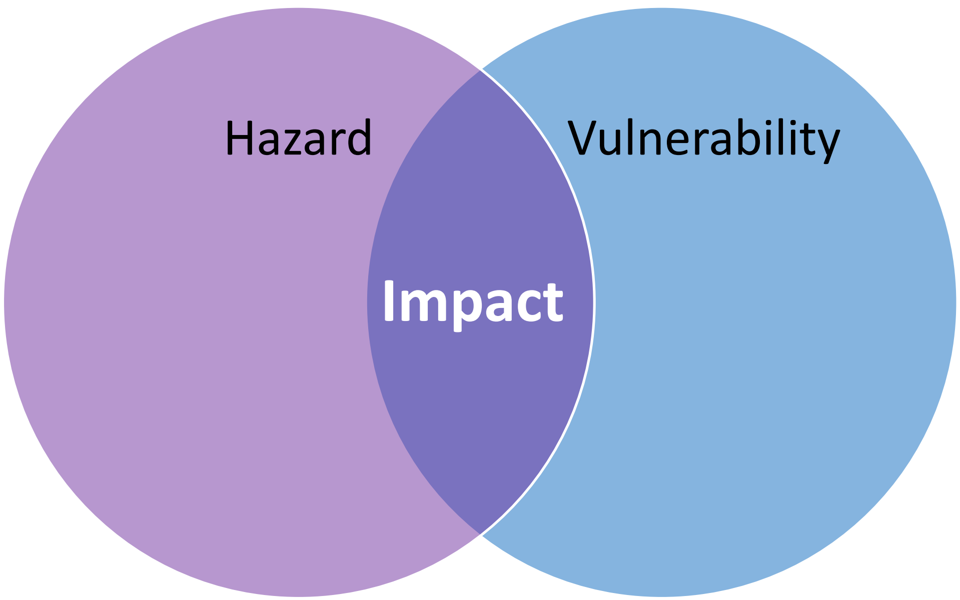
Some volume/level of water incident along the coast.

Impact of the hazard:

How vulnerable the object is that is affected by the volume/level of water.



Coastal Flooding Impact



Coastal Flooding Impact:

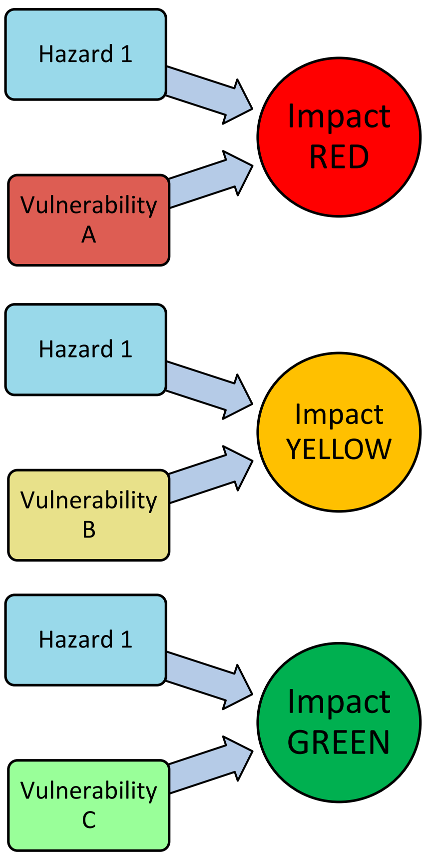
Hazard:

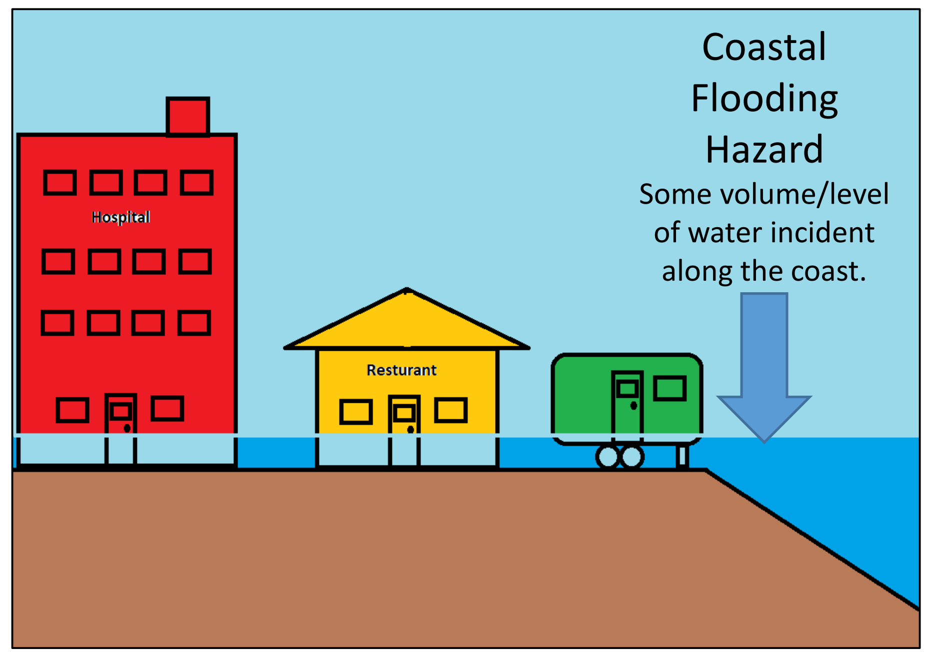
Some volume/level of water incident along the coast.

Vulnerability:

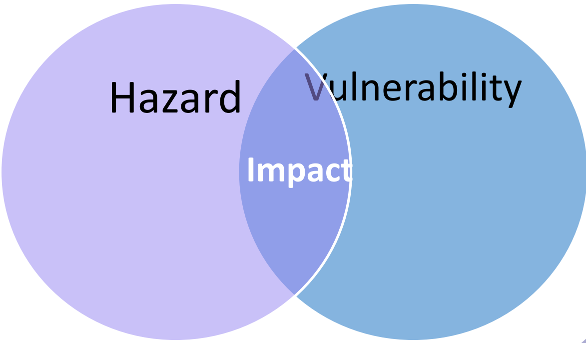
Dependent on what that volume/level of water comes in contact with.

Coastal Flooding Impact



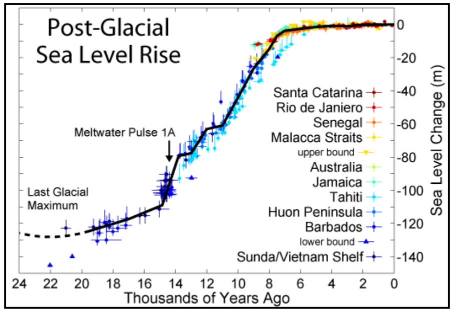


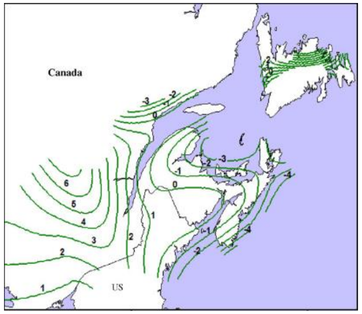
Coastal Flooding Hazard

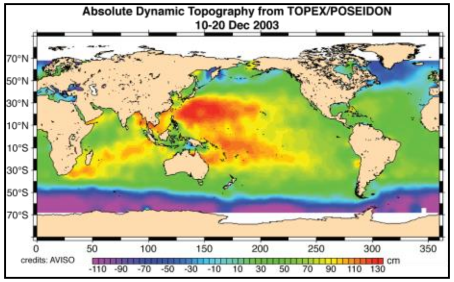


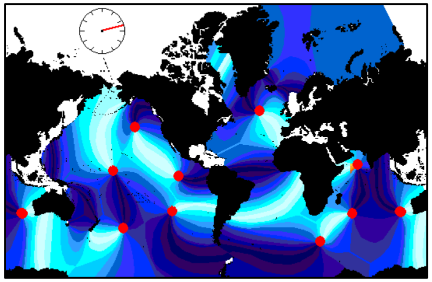
Coastal Flooding Hazard
Some volume/level of water incident along the coast..

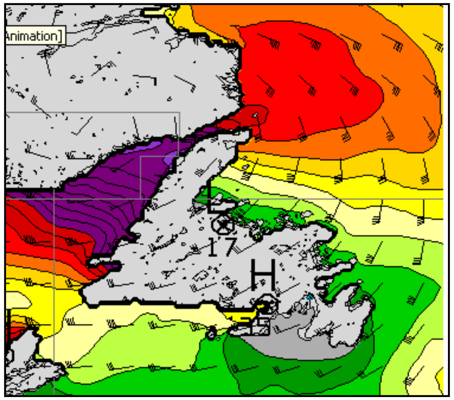
- Relative mean sea level
  - Post-glacial rebound:
  - Sea level rise:
- Steric Sea level Changes
- Tide
- Storm surge
- Wave set-up:.
- Wave runup
- Wave overtopping











Coastal Flooding Hazard

These 7 processes have different time scales and different amplitudes.

Coastal Flooding Hazard -> Water level along the coast

1. **Relative mean sea level**
   A. Post-glacial rebound: cm/year.
   B. Sea level rise: cm/year.
2. **Steric Sea level Changes:** cm/month, cm's amplitude, pseudo-annual return period.
3. **Tide:** cm-m/hour, meter's amplitude, 28 year return period.
4. **Storm surge:** cm/hr, cm-m's amplitude.
5. **Wave set-up:** cm-m/seconds-minutes, cm-m's amplitude.
6. **Wave runup:** cm-m/seconds-minutes, cm-m's amplitude.
7. **Wave overtopping:** 0-1 m^3/s per m.

Modelled at at Natural Resources Canada (NRCan).

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Processes are being accounted for at the Canadian Center for Meteorological and Environmental Predictions (CCMEP) as well as the Department of Fisheries and Oceans (DFO)

Coastal Flooding Hazard

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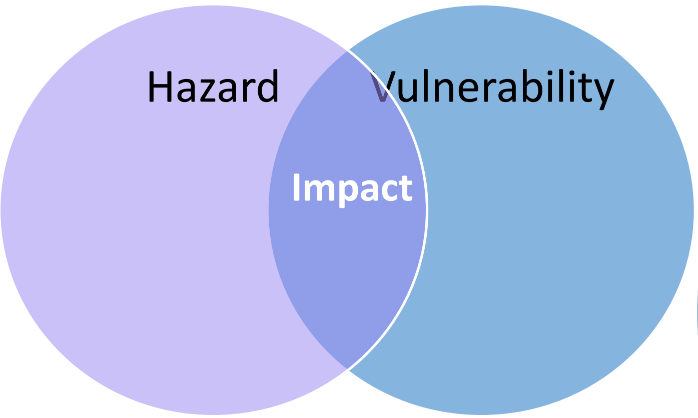
Requires resources (items 5–7)

Coastal Flooding Vulnerability



Coastal Flooding Vulnerability

Dependent on what a volume/level of water comes in contact with.

Infrastructure & Social Resilience:

- The capacity to cope during and after coastal flooding.
- The socio-economic value of what the volume of water interacts with.
  - e.g. Hospital or evacuation route vs. flood plain.

Susceptibility to Impact:

- The probable degree of damage or harm from coastal flooding.
  - e.g. A house of straw vs. a house of bricks.

Coastal Flooding Vulnerability

Coastal Flooding Vulnerability

Dependent on what a volume/level of water comes in contact with.

- Safety of Traffic
- Structural Safety
- Essential Infrastructure
- Highly Resilient
- More Resilient
- Less Resilient
- Water Compatible
- Coastal Erodibility

Require stakeholder Engagement.

- Provincial/Territorial Governments
- Municipal Governments
- Academia
- Other Federal Departments
  - Department of Fisheries and Oceans
  - Parks Canada
  - Natural Resources Canada
  - National Research Council

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Storm Surge and High Water Level Bulletins and Warnings

- **Part of the Public and Marine Programs**
- **The Storm Surge and High Water Level Warnings are both intended to inform the Public and Marine Communities of the possible occurrence of coastal flooding.**

Example of a Storm Surge Warning

WWCN11 CWHX 030825
STORM SURGE WARNING
FOR NOVA SCOTIA
ISSUED BY ENVIRONMENT CANADA
AT 4:25 A.M. AST WEDNESDAY 3 JANUARY 2018.

STORM SURGE WARNING FOR:
=NEW= HALIFAX METRO AND HALIFAX COUNTY WEST
=NEW= HALIFAX COUNTY - EAST OF PORTERS LAKE
=NEW= LUNENBURG COUNTY
=NEW= QUEENS COUNTY
=NEW= SHELBURNE COUNTY
=NEW= YARMOUTH COUNTY
=NEW= GUYSBOROUGH COUNTY.

==DISCUSSION==

HIGH STORM SURGE LEVELS AND LARGE WAVES ARE EXPECTED TO IMPACT THE COAST.

DURING HIGH TIDE THURSDAY EVENING, WATER LEVELS ALONG THE ATLANTIC COAST WILL BE ELEVATED ENOUGH TO CAUSE COASTAL FLOODING IN VULNERABLE AREAS. IN ADDITION VERY LARGE WAVES COMING IN TO THE COAST FROM THE SOUTH WILL CONTRIBUTE TO THE HIGH WATER AND WILL LIKELY CAUSE SOME DAMAGE TO COASTAL INFRASTRUCTURE.

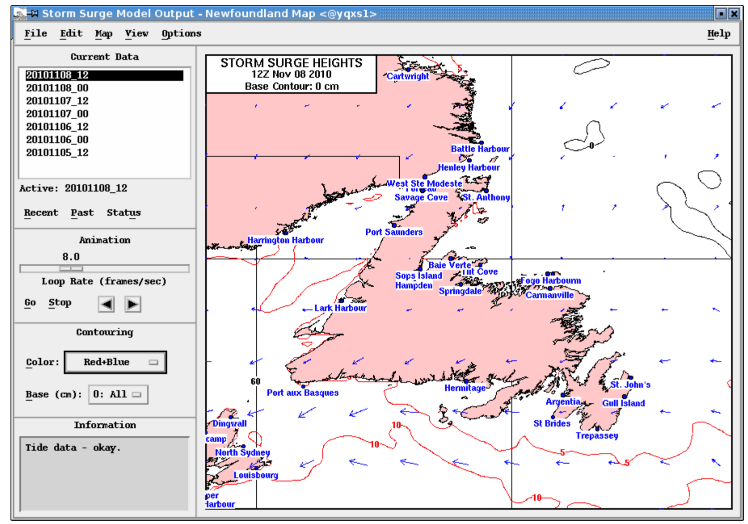
ENVIRONMENT CANADA CONTINUES TO CLOSELY MONITOR THE DEVELOPMENT OF THIS STORM AND WILL PROVIDE UPDATES AS THE STORM NEARS.

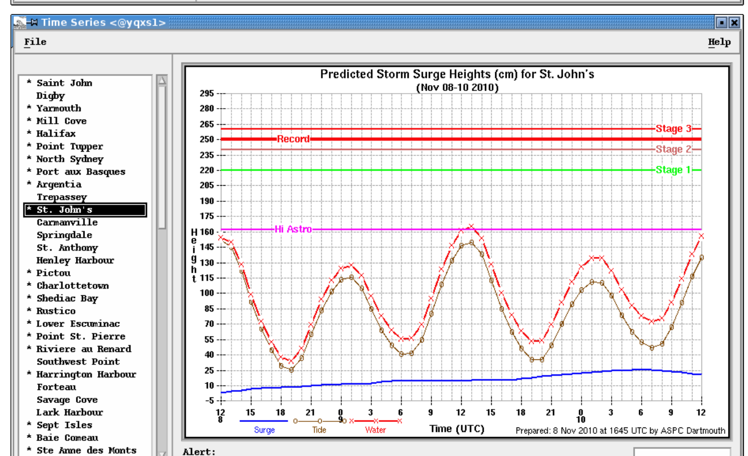
HIGH WAVES COMBINED WITH THE SURGE MAY CAUSE DAMAGE ALONG THE COAST. COASTAL FLOODING IS LIKELY. PEOPLE CLOSE TO THE SHORELINE SHOULD STAY ON THE LOOKOUT FOR WORSENING CONDITIONS. STORM SURGE WARNINGS ARE ISSUED WHEN WATER LEVELS POSE A THREAT TO COASTAL REGIONS.

HTTP://WEATHER.GC.CA
END/ASPC

Storm Surge and High Water Level Bulletins and Warnings

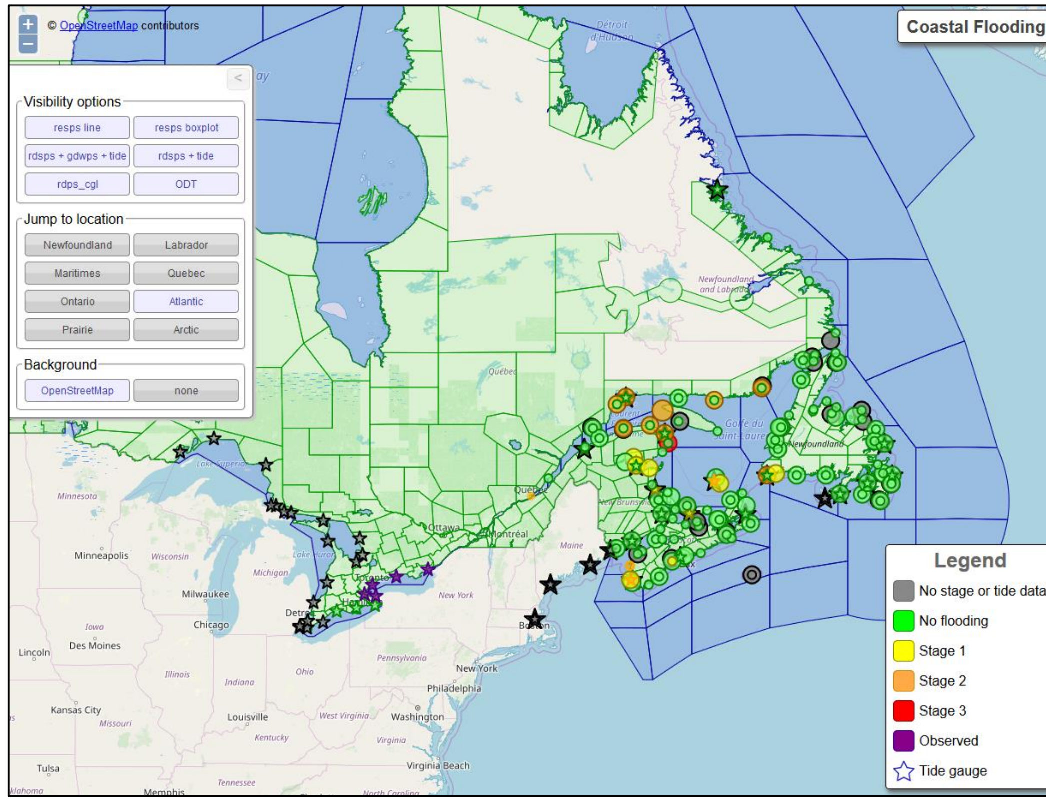
- **History of the program**
  - 1978: As a result of the Groundhog Day storm of 1976
    - Atmospheric Environment Service (AES) in the Atlantic Region accepted the responsibility for alerting the public whenever coastal sea levels appeared likely to be significantly higher than normal.
  - 2001: Barotropic ocean model system and Storm Surge Prediction and Water Level Alert Project
    - Bobanovic,1997, and Bobanovic and Thompson, 2004.
    - The devastating storm of January 21, 2000 was a benchmark storm for the Maritimes where water levels that were reached were unprecedented in the known water level history of those areas affected.





Storm Surge and High Water Level Bulletins and Warnings

- Storm Tide
- Storm Tide with Waves
- Lake Levels with Storm Surge



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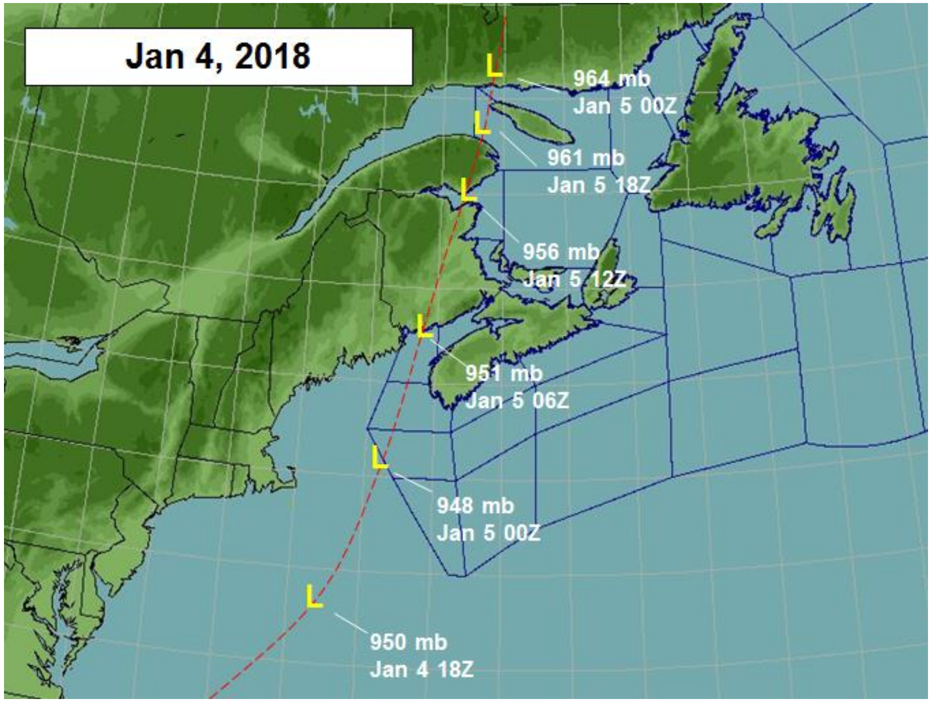
Event Date: 4-5 January 2018

- A low pressure system that developed off the coast of Florida the morning of January 4th, rapidly deepened as it tracked north to reach a central pressure of 950mb while it was still south of Cape Cod.
- The low tracked into the Bay of Fundy after midnight and then through New Brunswick the morning of January 5th, and reached the north shore of Quebec that evening.
- Winds were highest along the Atlantic Coast of Nova Scotia with gusts 100 to 120 km/h observed.
- Storm surge, high waves and large tides caused flooding along many parts of the coast from Digby County to Guysborough County. Yarmouth recorded a high water level of 5.40 m and Halifax recorded a high water level of 2.74 m.



Event Date: 4-5 January 2018

Top: During the storm surge event January 4, 2018.
Bottom: Under non storm surge conditions.

Photo from @NS_TIR (twitter)

Photo from Google Maps

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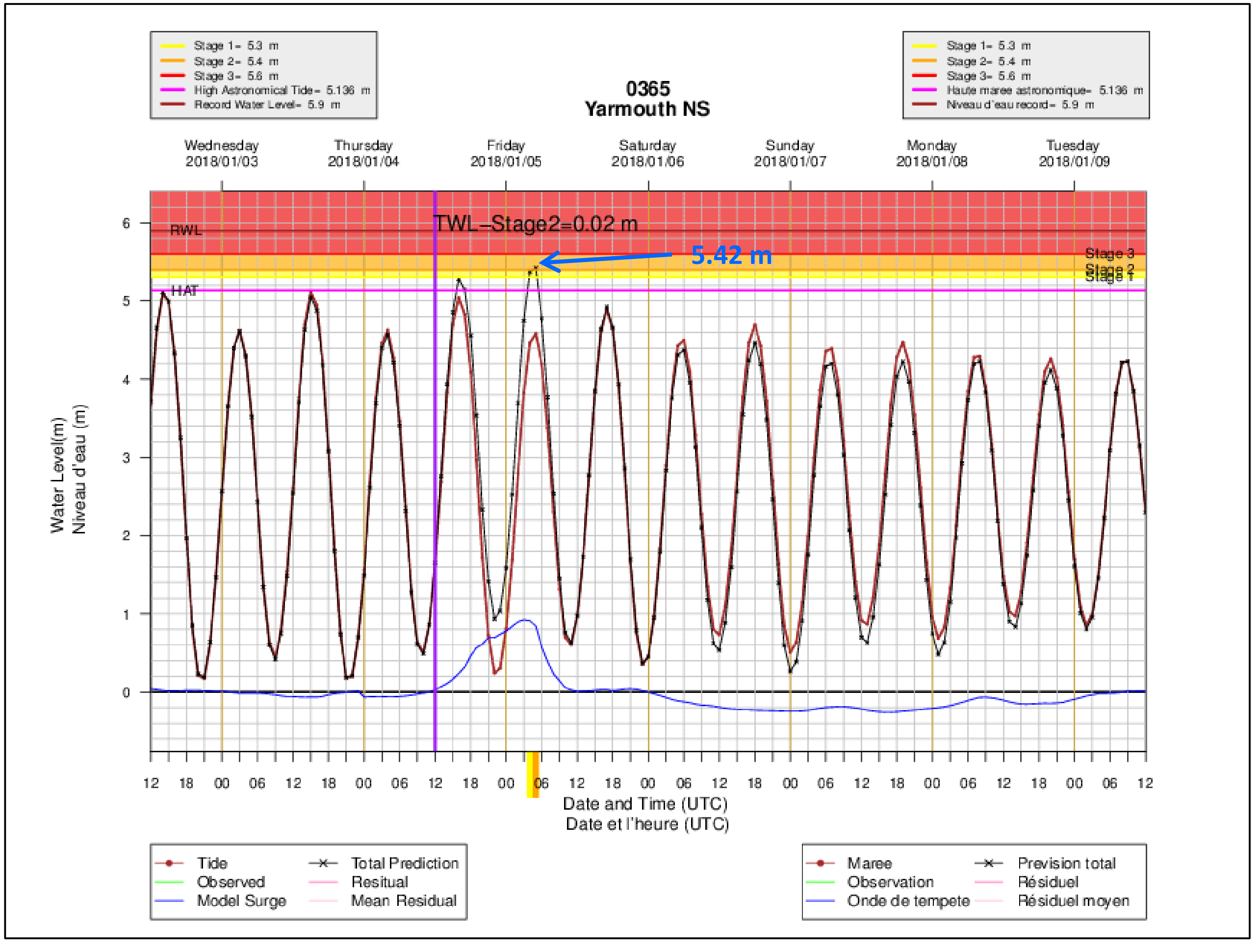
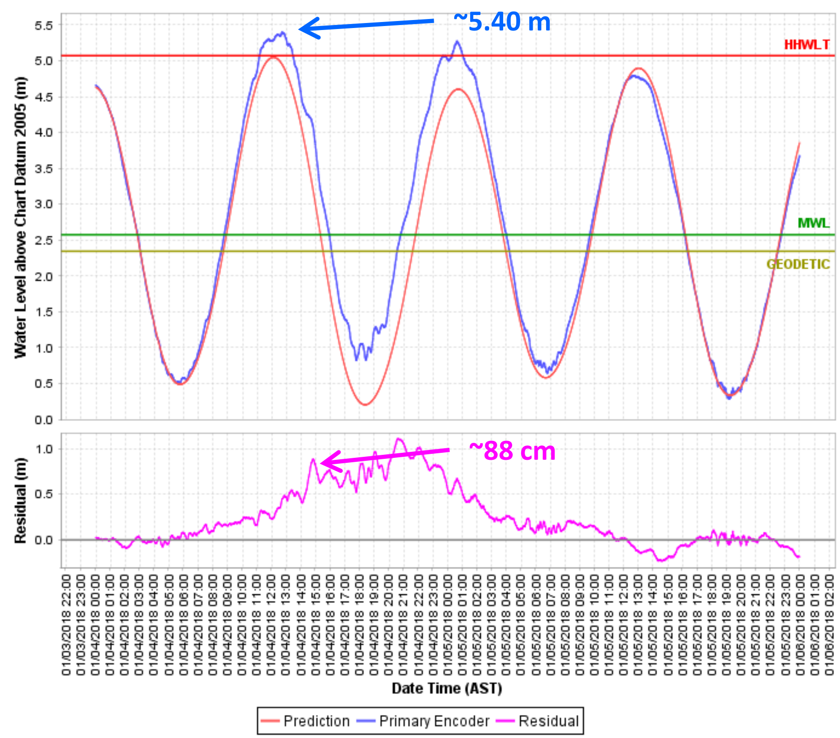


Event Date: 4-5 January 2018

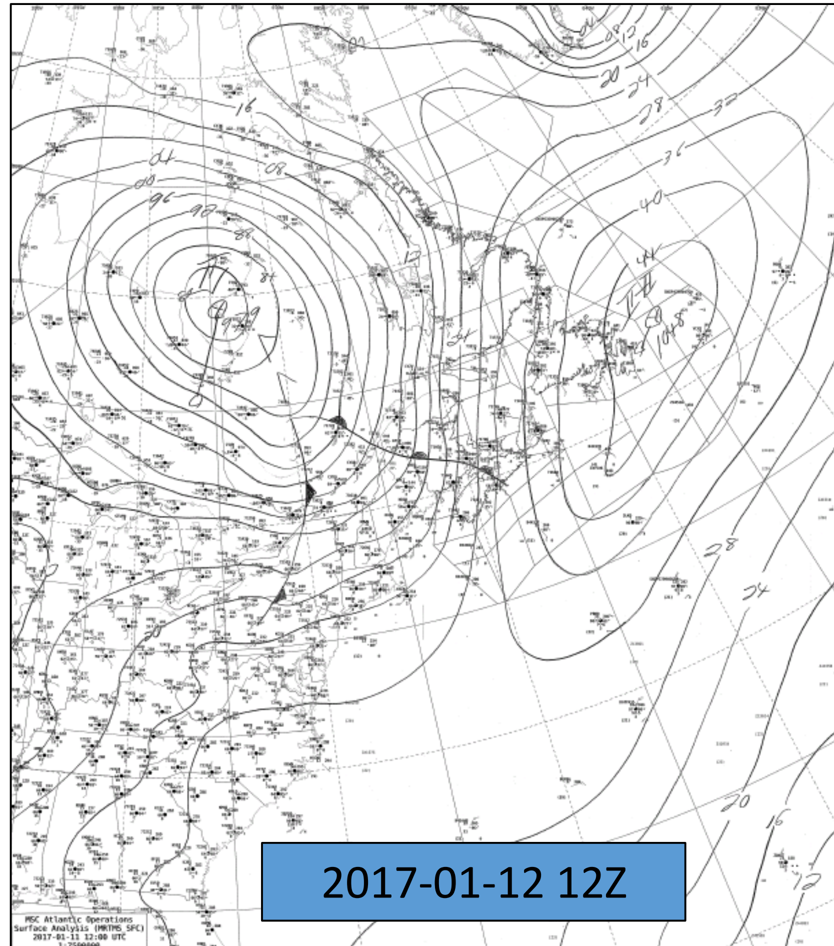
- **From the Yarmouth tide gauge, a residual of 88 cm was observed near noon on January 4th , resulting in a peak total water level of 5.40 m at high tide**
  - 5.4 m corresponds to flood stage 2

- **The predicted stage 2 storm tide of 5.42 m verifies well against the tide gauge observations.**



Event Date: 11 January 2017

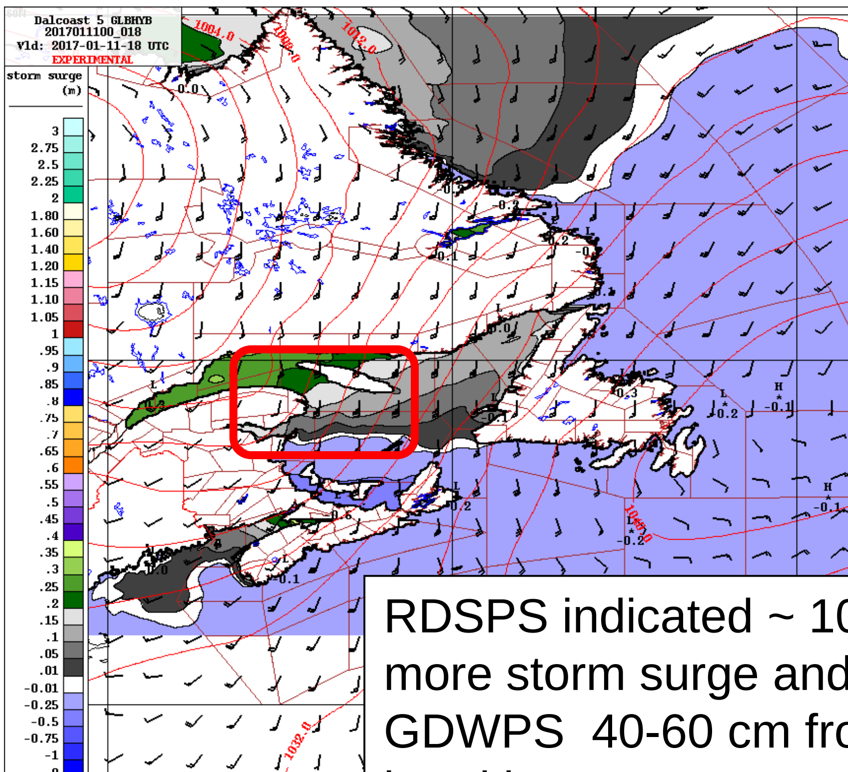
- **In the early hours on Jan 11 2017, a deep low pressure system (982 mb) moved north across the Great Lakes to lie over the Hudson later that evening.**
- **Gale to storm force winds were recorded across most of the Maritimes and eastern Quebec.**
- **High waves and large tides caused flooding along parts of the Gaspésie Peninsula and the Fundy shore of New Brunswick.**



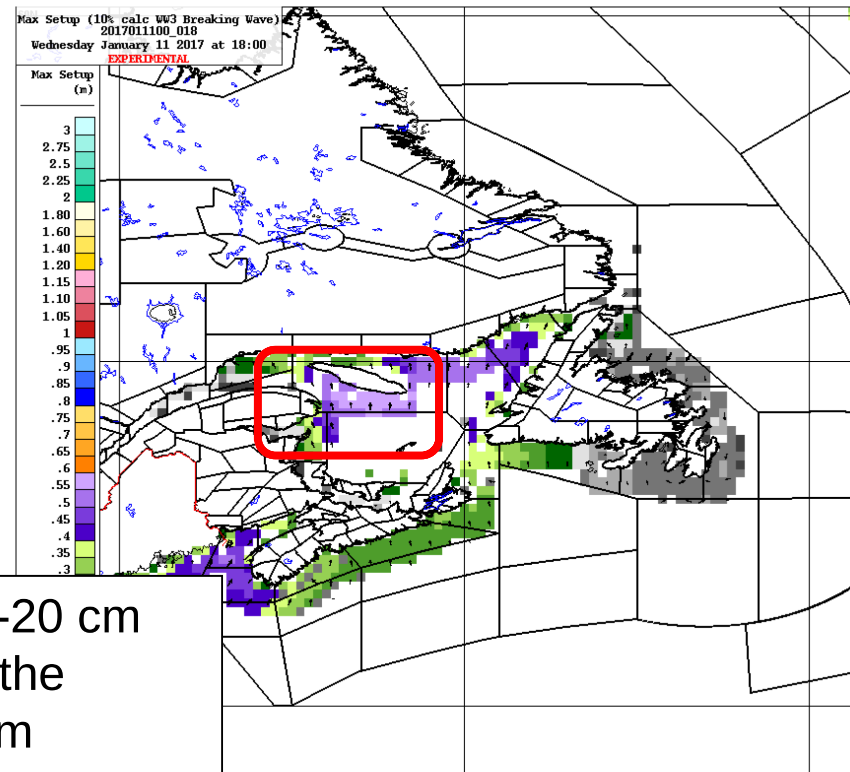
Event Date: 11 January 2017

Model Guidance: 2017-01-11 00Z t+18

RDSPS



GDWPS
10% breaking wave height

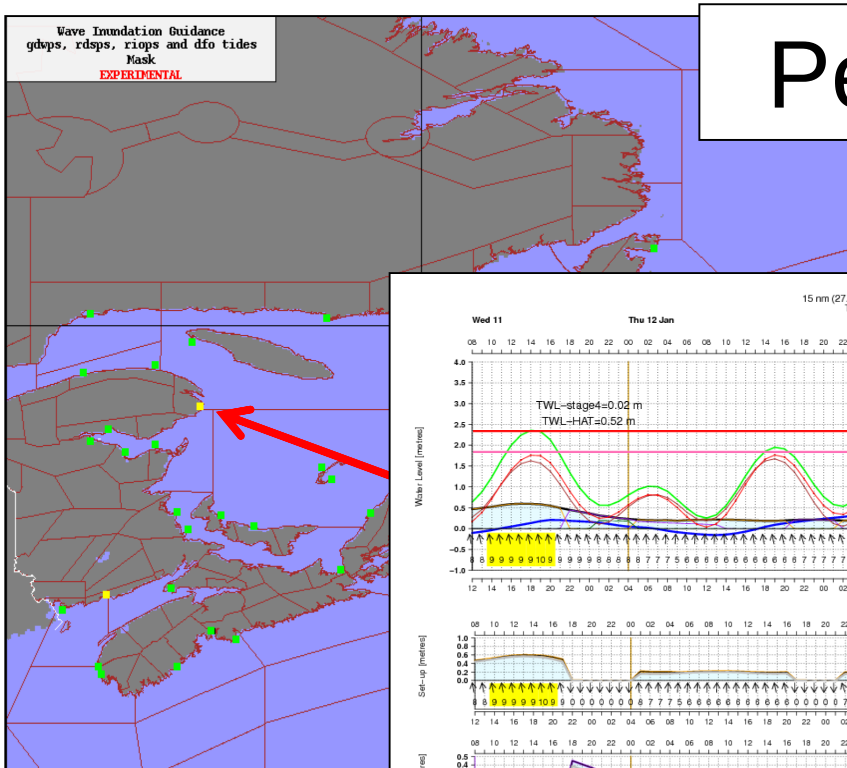


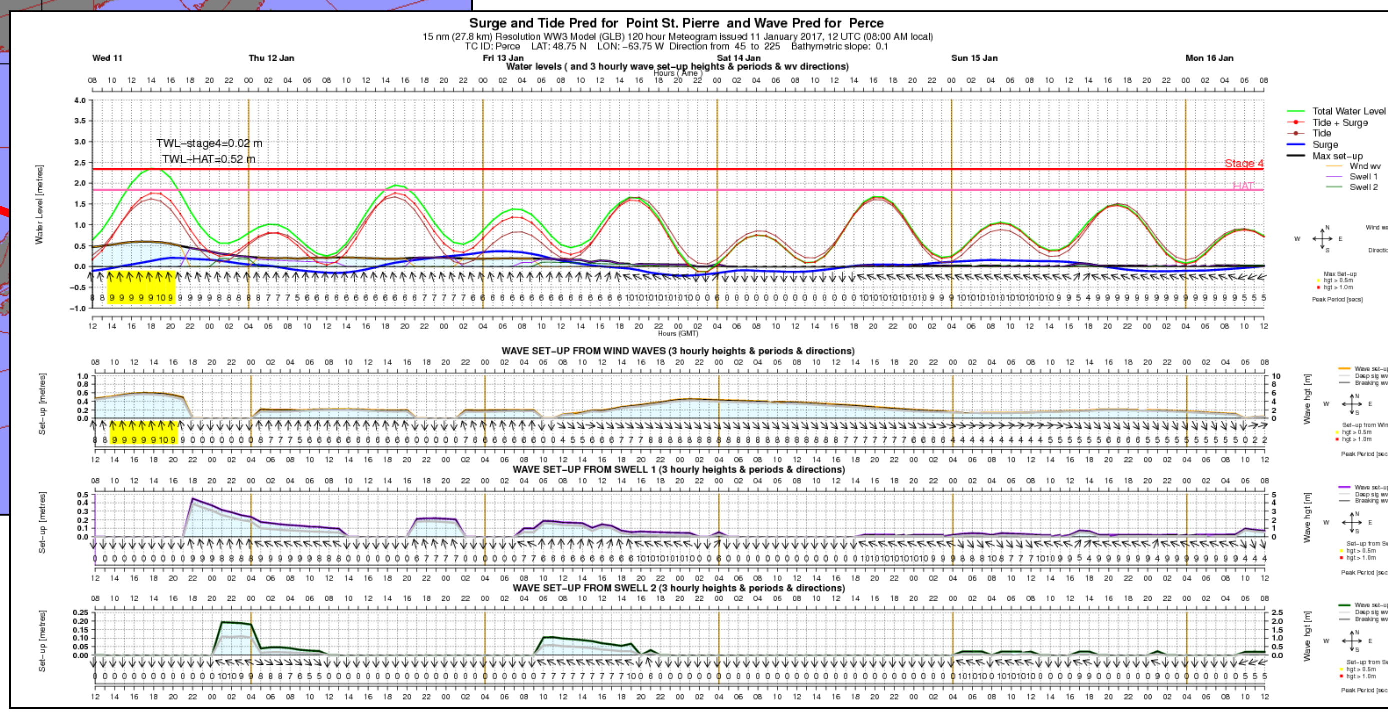
RDSPS indicated ~ 10-20 cm more storm surge and the GDWPS 40-60 cm from breaking waves.

Event Date: 11 January 2017

Model Guidance: 2017-01-11 00Z

Percé





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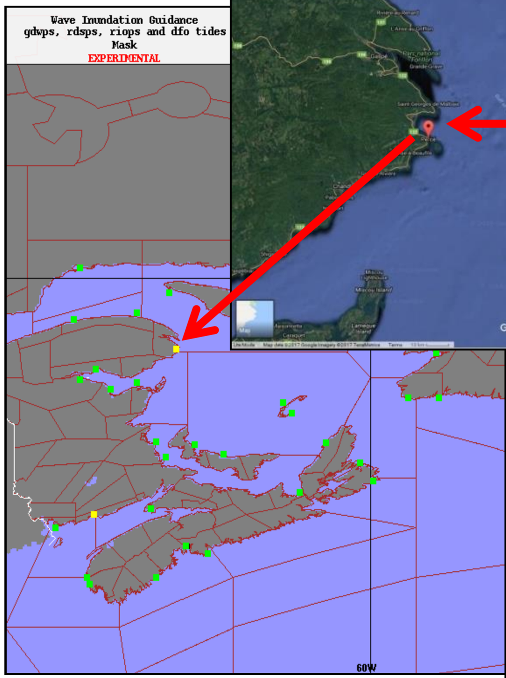
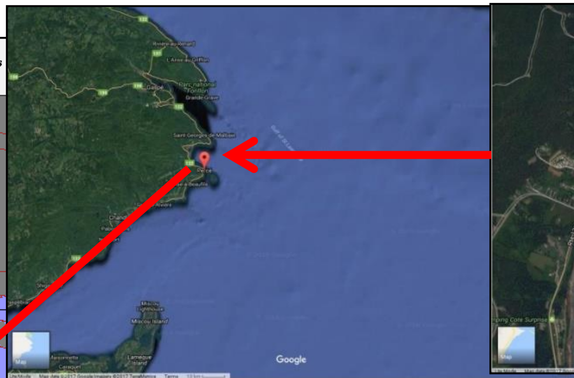
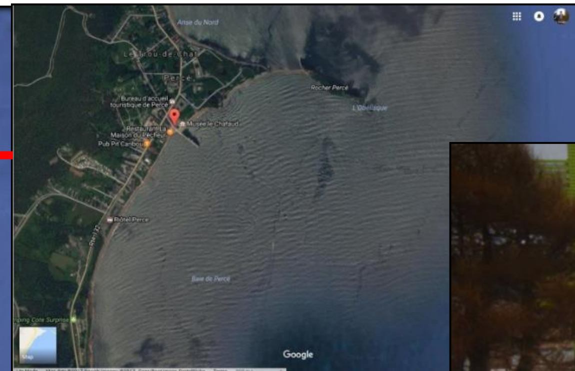
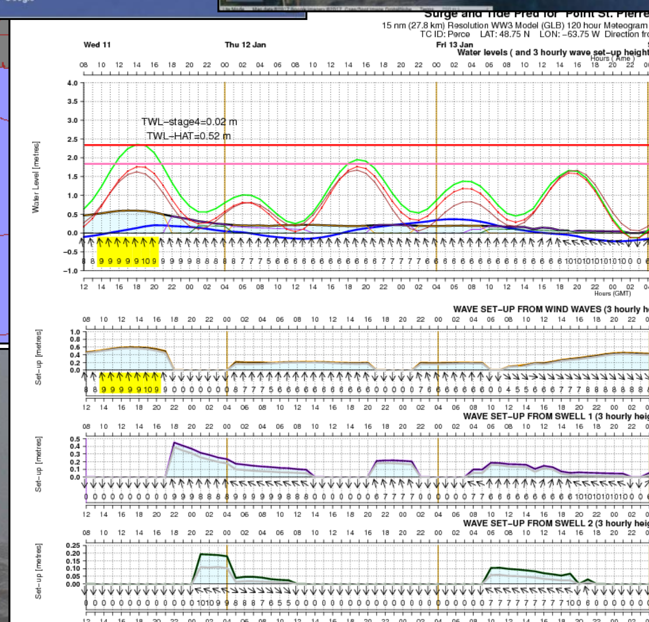
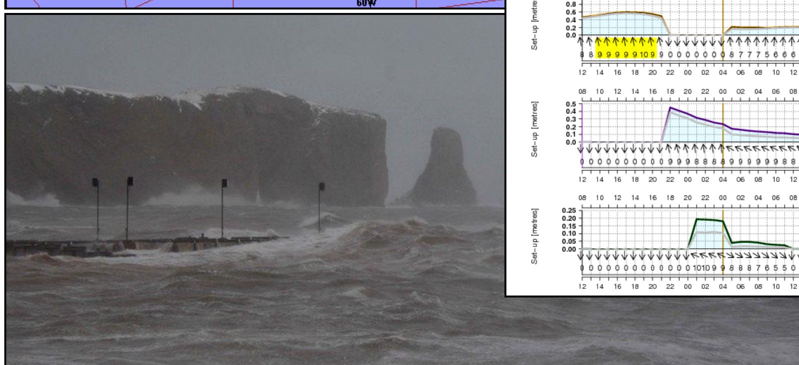
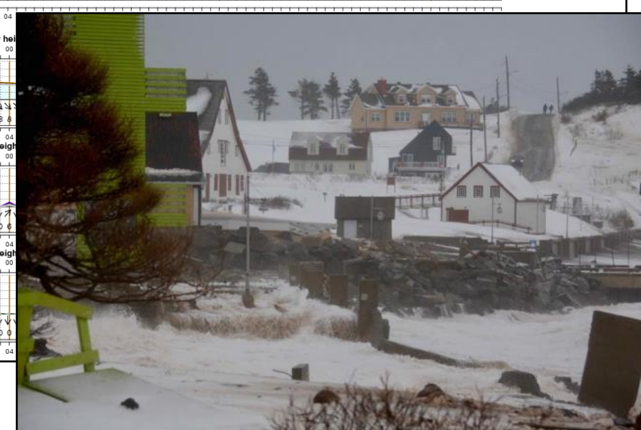










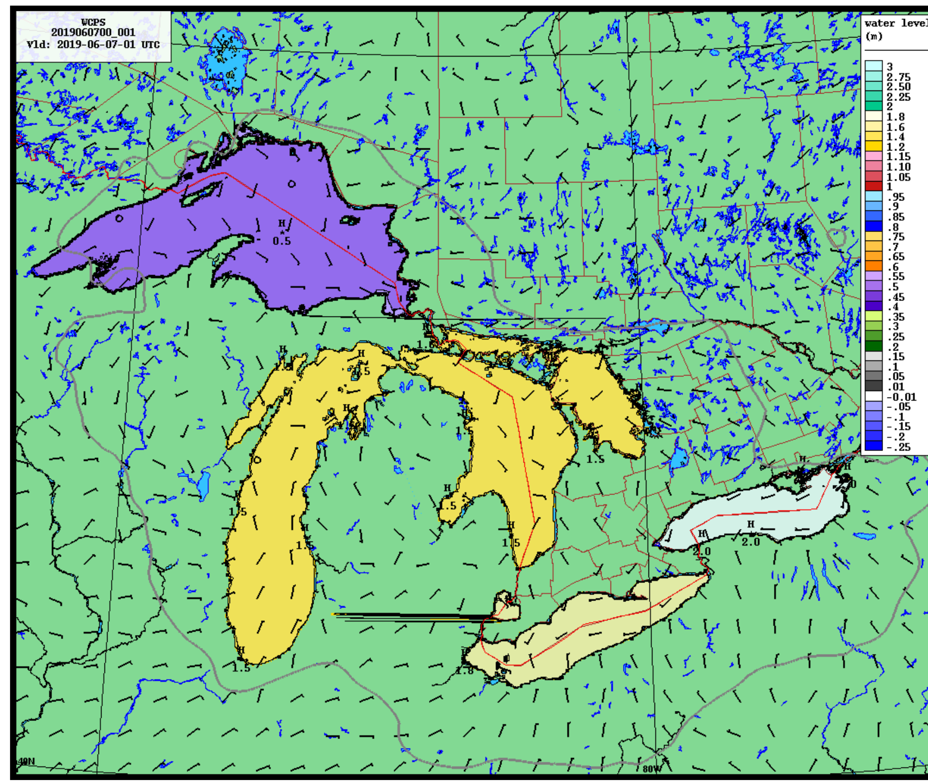


Storm Surge and Lake Levels

WCPS RDPS_CGL debiased with Lake Level Observations

- **In the spring of 2017, an experimental water cycle prediction system was used to accurately predict high water levels along the shores of the Great Lakes.**

- **This system provides advance warning on the magnitude of expected increases during periods of historically high water levels, used to inform Ontario's provincial authorities of the foreseeable risk and to help The Great Lakes—St. Lawrence Regulation Office in managing water levels on Lake Ontario.**



Storm Surge and Lake Levels

WCPS RDPS_CGL debiased with Lake Level Observations

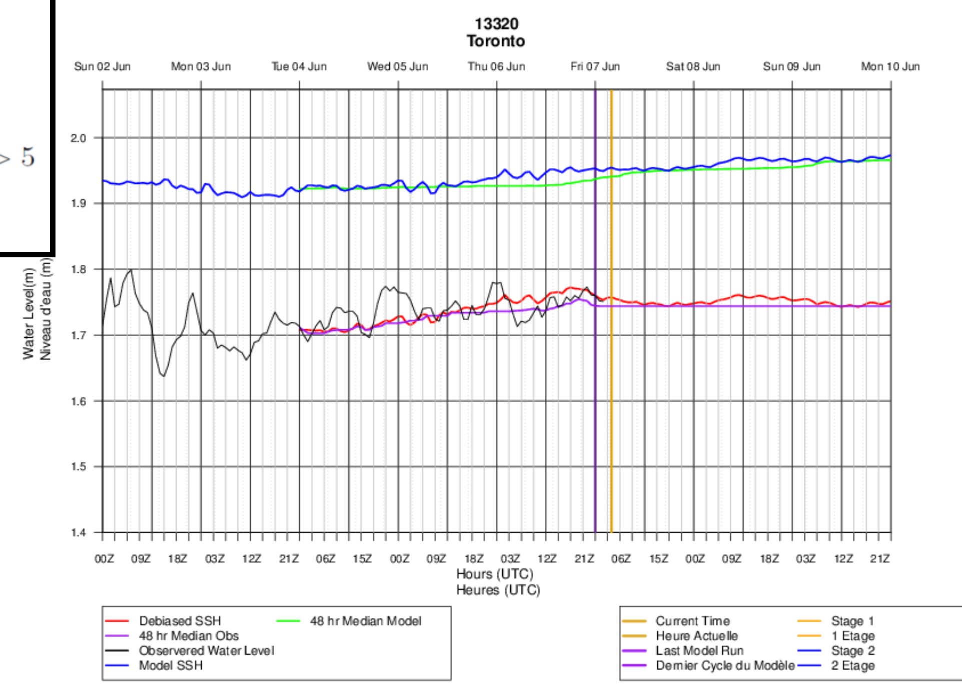
Bias removal technique

Why? To account for systematic errors in tributary flow prediction

For each forecast, a **corrected RL** is calculated, based on the **median** of the forecast of the **2 previous days** (using the first 24h only of each forecast).

$$\mathrm{WL}_c^i(t) = \mathrm{SSH}^i(t) + \mathrm{RL_c}^i,\ \forall i$$

$$\mathrm{RL_c}^i = \mathrm{median}(\mathrm{WL}_{\mathrm{obs}}^{i-5,\dots,i-1}) - \mathrm{median}(\mathrm{SSH}^{i-5,\dots,i-1(0-24\,\mathrm{h})}),\ \mathrm{for}\ i > 5$$



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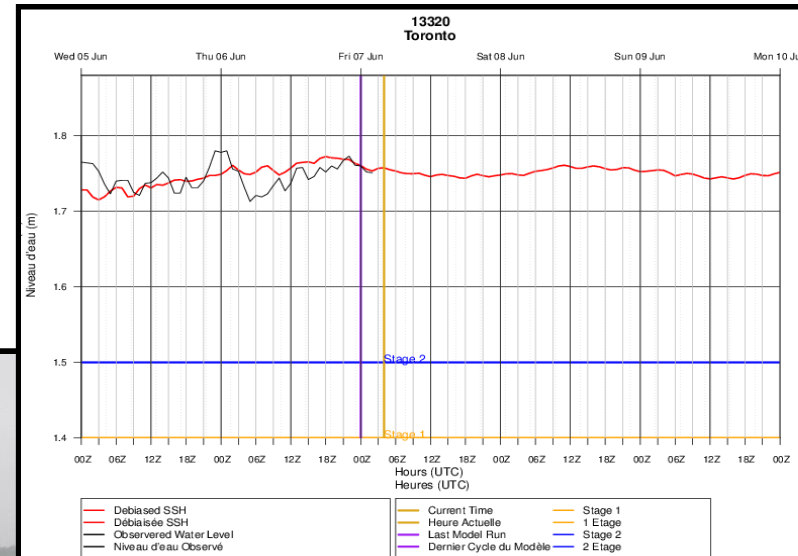


Predicting and Alerting for Coastal Flooding

ECCC is beginning to work on a "Predicting and Alerting for Coastal Flooding" program.

This program is being initialized with the 2019 "Emergency Management Strategy" Treasure Board Submission.

This is further building on the 2018 "Adapting Canada's Weather and Water Services to Climate Change" Treasure Board Submission

Stakeholder Engagement

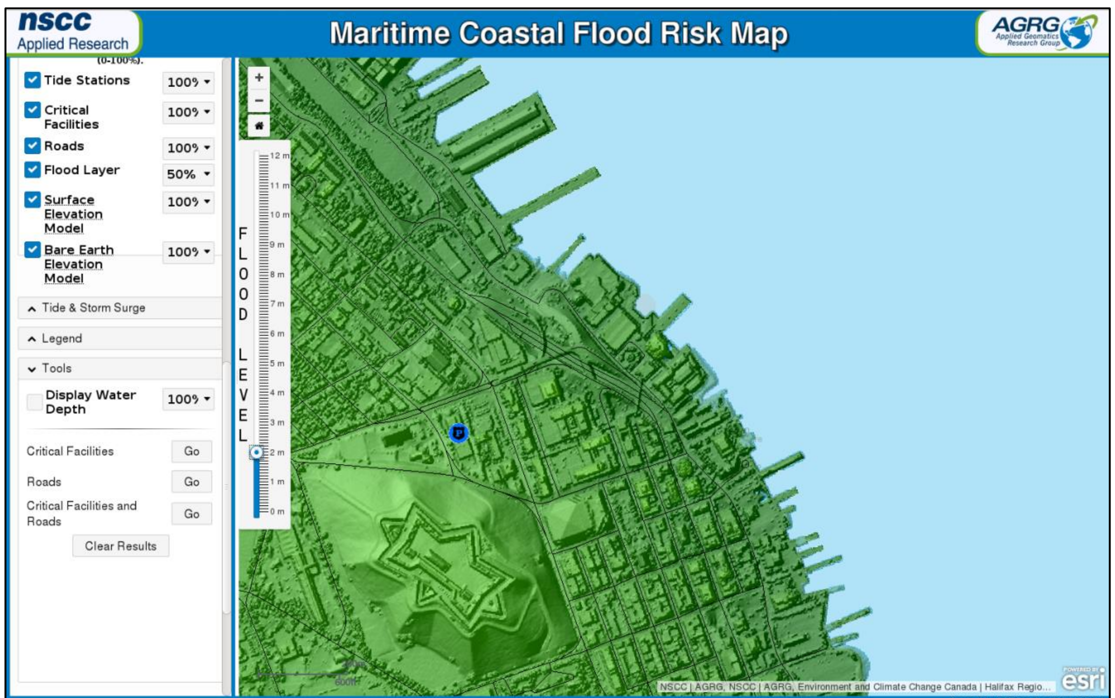
- Prediction Services need to work with the Provinces/Territories/Municipalities/Indigenous groups to identify:
  - How they are currently serving their stakeholders?
  - How they disseminate their flooding information?
  - How they are receiving information pertaining to coastal flooding?
  - How they are using the information they receive?

- They also hold a majority of the digital elevation maps (DEM’s).

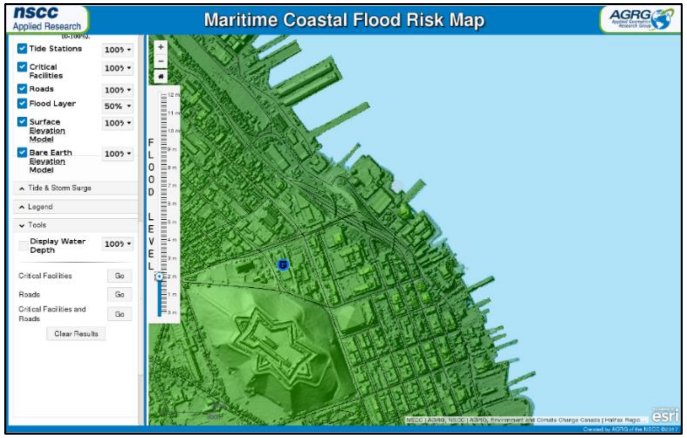
- These DEM’s are necessary to identify the coastal flooding vulnerabilities.

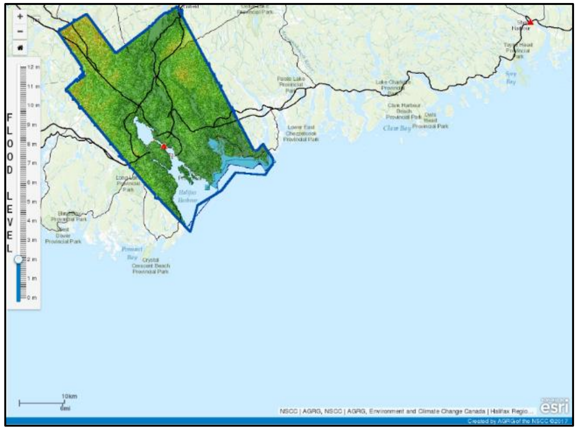
Stakeholder Engagement

- When DEM's are attained:
  - A common vertical datum needs to be determined, or at least a means of translating from one datum to another.
  - The coastal flooding vulnerabilities are identified and binned.



The Challenge of Scale and Resolution

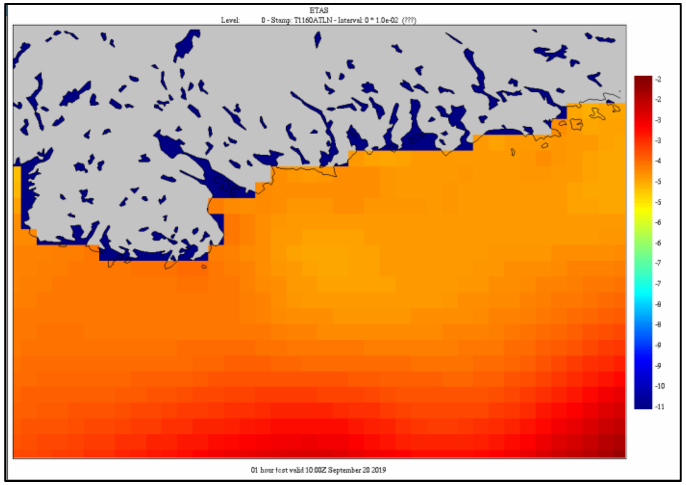




- **Lidar has ~30 cm between data points.**

- **The rdsps has about ~3.7 km between data points.**

- **4 degrees of magnitude apart, 10^4.**



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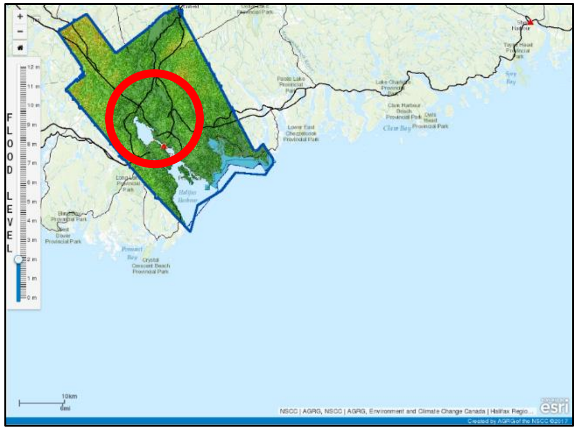
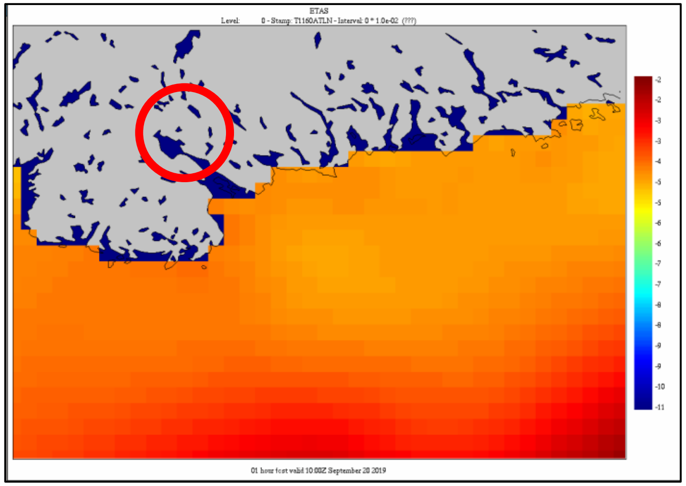
The Challenge of Scale and Resolution

- **The vulnerabilities and hazards often do not intersect.**

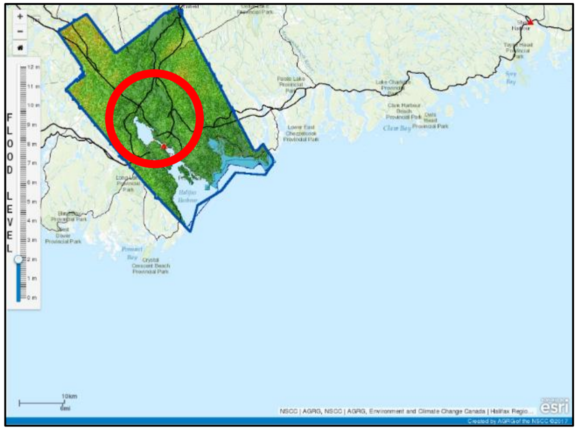


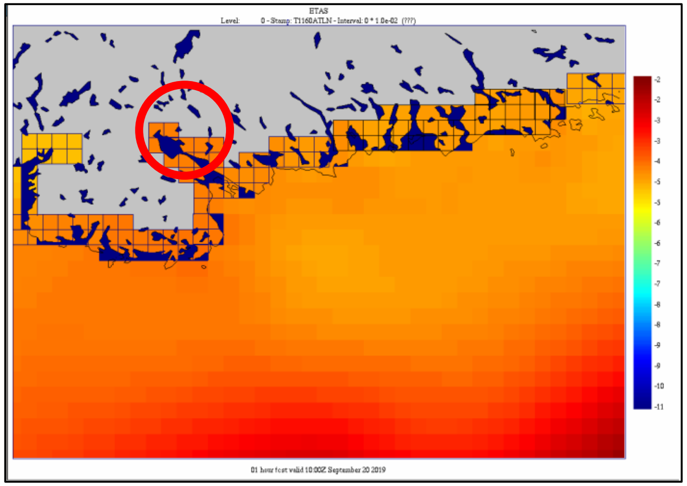


The Challenge of Scale and Resolution

- **The vulnerabilities and hazards often do not intersect.**

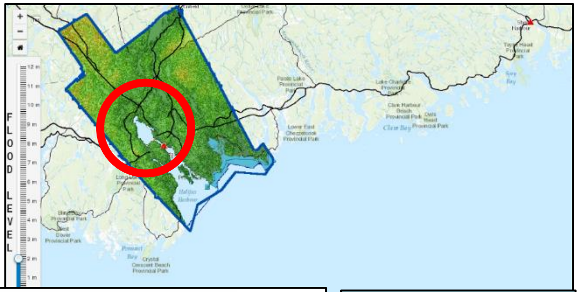
- **Or can we extrapolate the hazard to the vulnerability?**



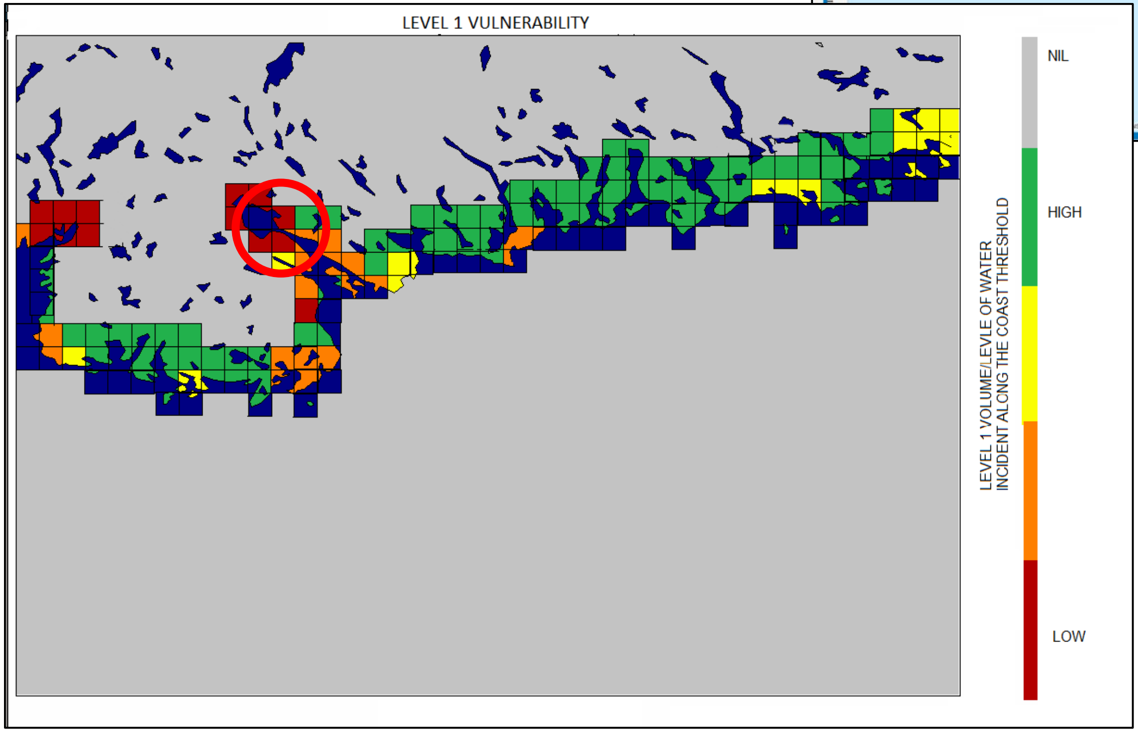


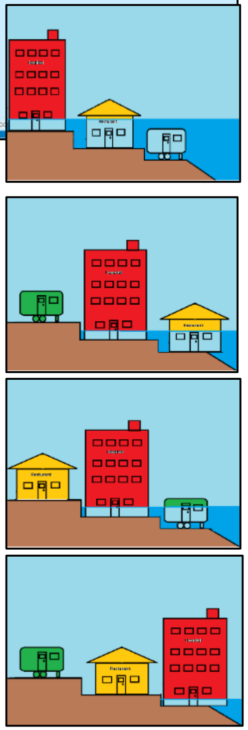
The Challenge of Scale and Resolution

- **Can we create a grid of hazard thresholds for a particular vulnerability level?**



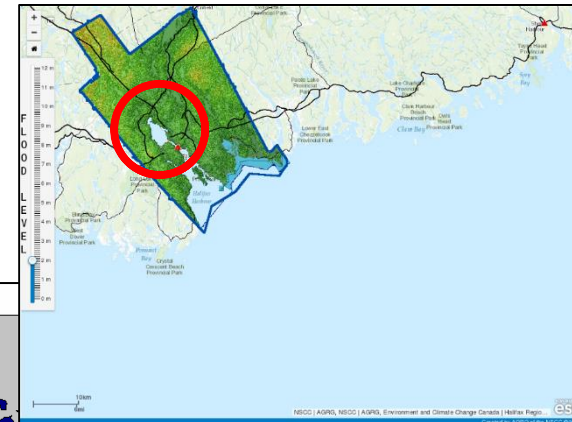
- **We can see what level of hazard would create impacts at locations for a given vulnerability.**

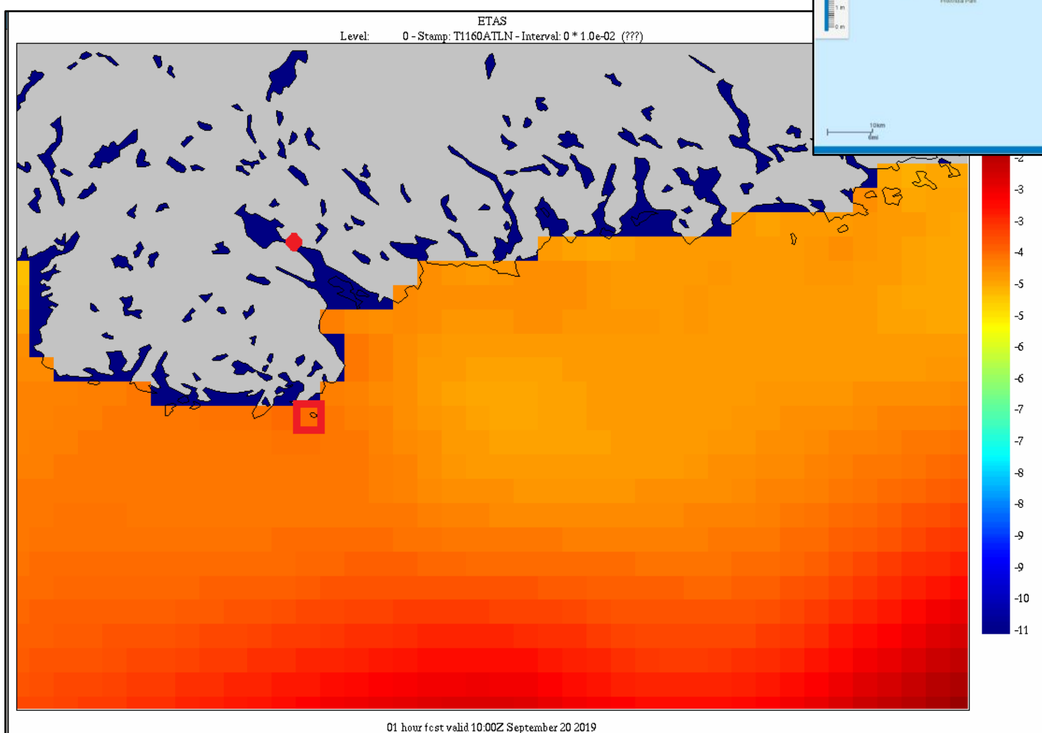




The Challenge of Scale and Resolution

- **Or can we relocate the vulnerability to the hazard?**





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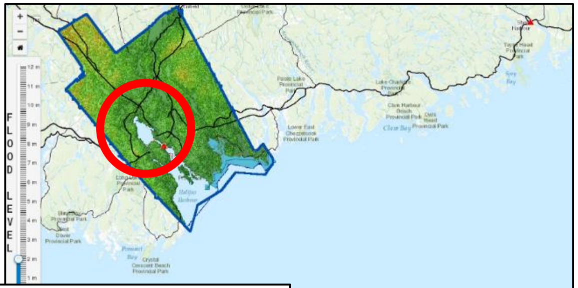
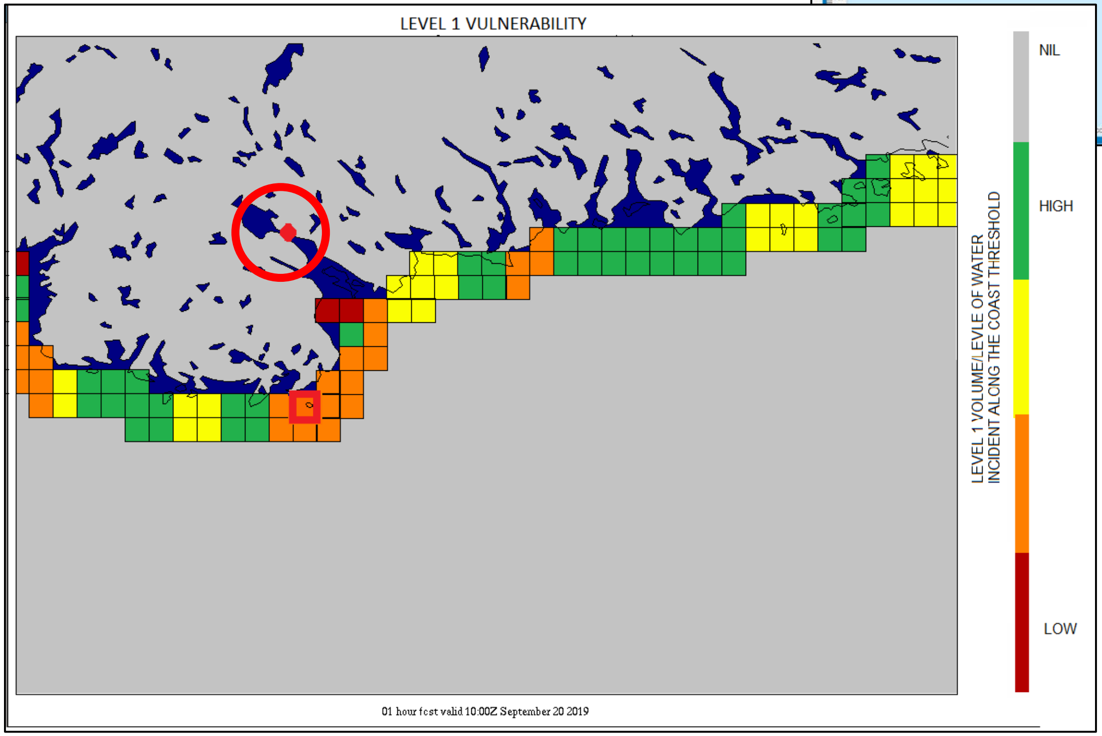
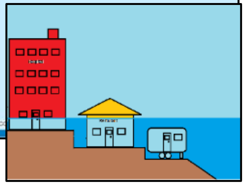
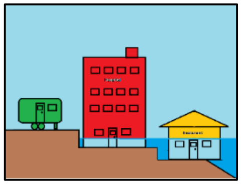
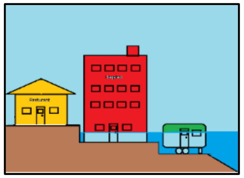


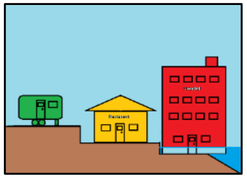
- **We can see what level of hazard would create impacts at locations which are the most vulnerable.**











NEXT STEPS

2019-2020

- Identify Project Board and Working Group members.
- Complete Project Charter.
- Establishment of federal partnership group (PS, NRCAN, ECCC, and DFO) and begin mandate and role and responsibility discussion.
- Develop a survey to understand the need of provincial/ territorial/ municipal/ indigenous clients.