# MOBILIZING RESEARCH FOR ENHANCING CLIMATE RESILIENCE:

## MODELLING WETLAND RESPONSE THROUGH THE COASTAL WETLAND RESPONSE MODEL (CWRM)

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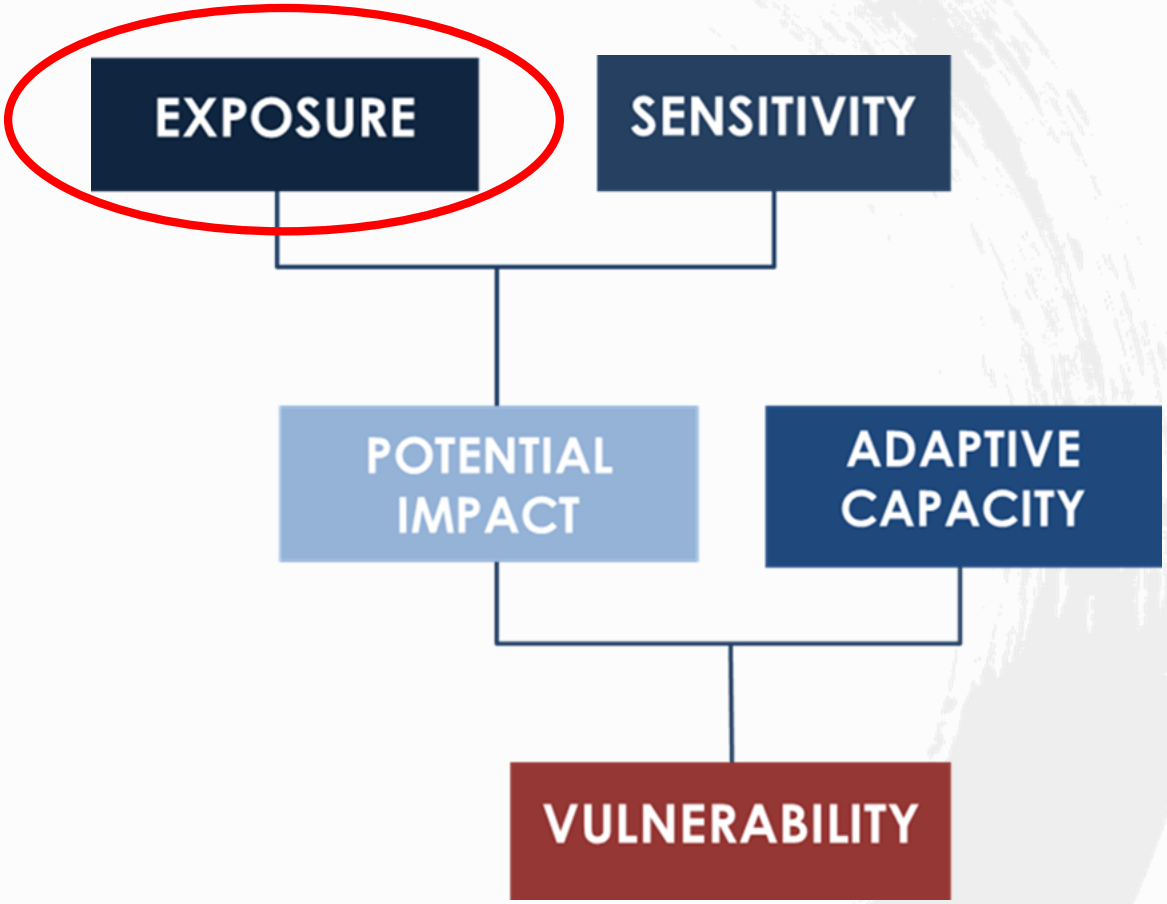
Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

CWRM is modelling Great Lake coastal wetland **exposure** and response to water level variations under different climate scenarios



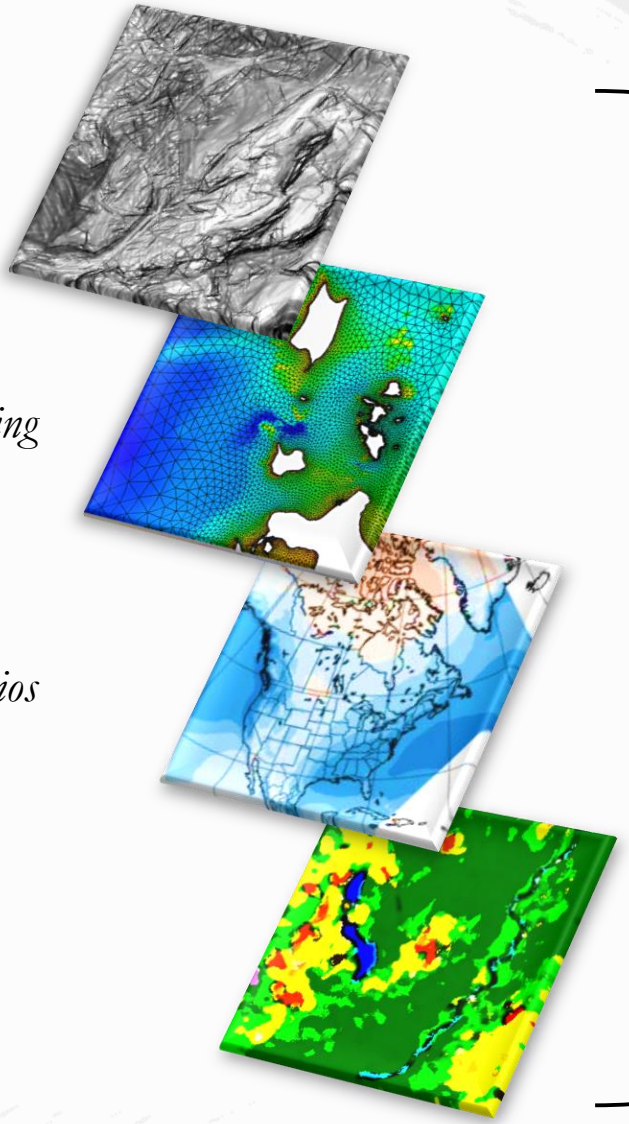
CWRM is an **integrated 2D habitat modelling** platform relying on a collection of georeferenced layers used to evaluate the **effect of long-term hydroclimatic time series on plant habitats.**

*Elevation (DEM)*

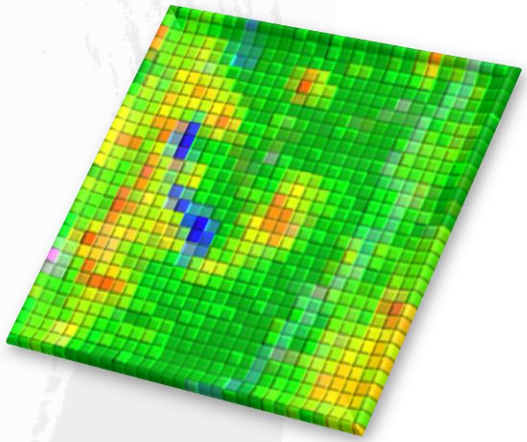
*Physical modelling*

*Climatic scenarios*

*Vegetation*

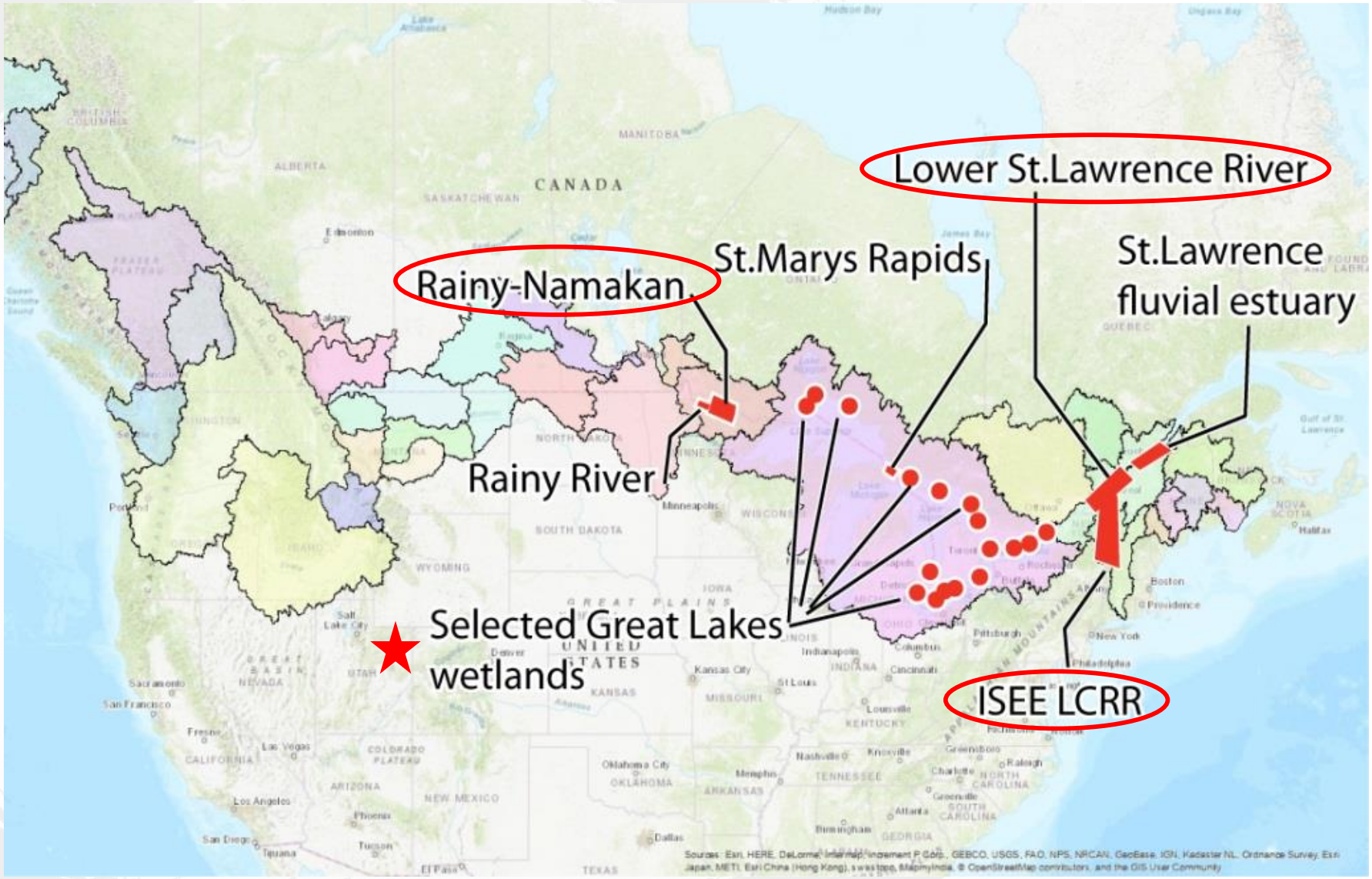


*Covering 1 388 km² at 10m resolution*
*Which represents 138 300 000 point-grid*

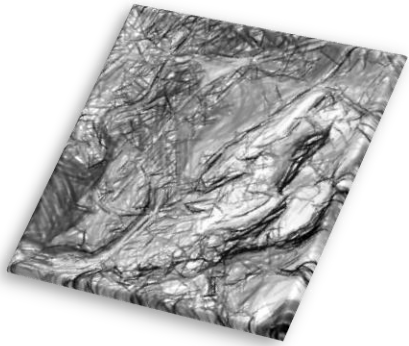


*MSC-Québec has developed similar systems in 6 other watersheds in Canada:*

Three of those integrated systems included a wetland model

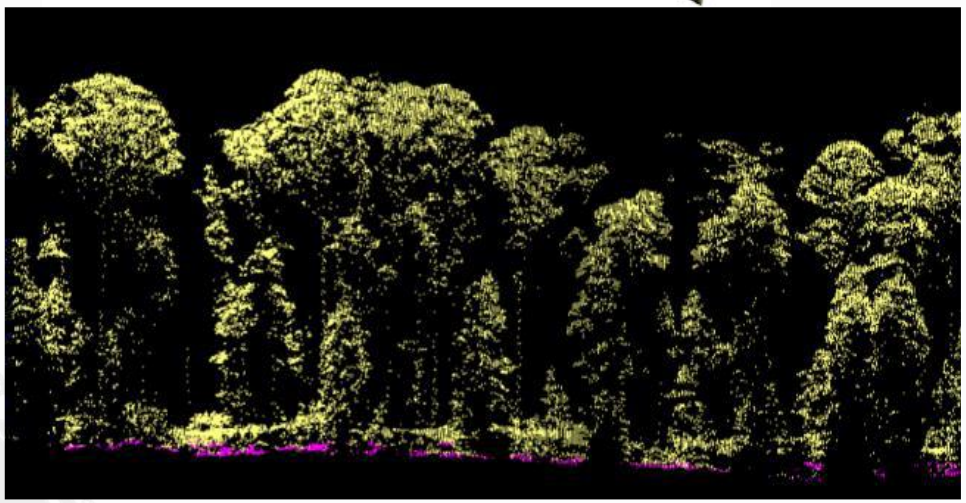


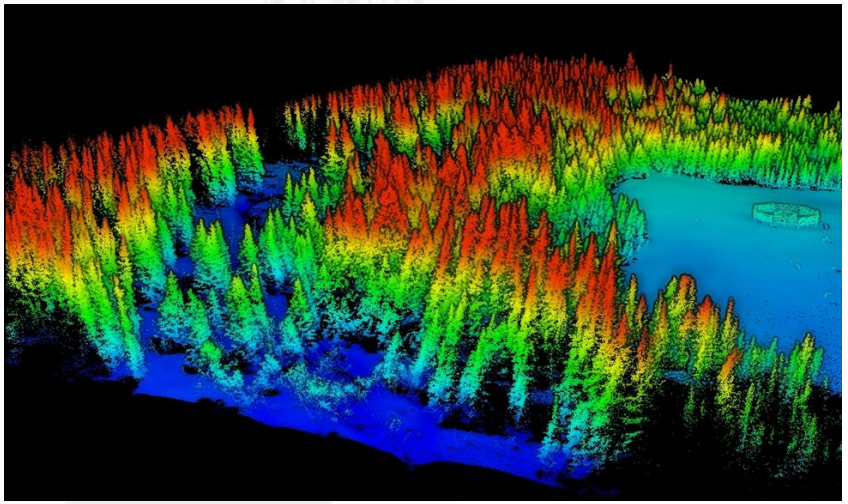
# *The first « layer » of the CWRM is the Digital Elevation Model*



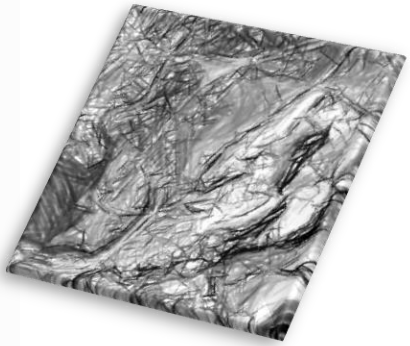
Digital Terrain Model (bare earth) generated from Lidar point clouds

*Lidar-derived DEMs in dense areas such as coastal wetlands, creates positive bias in elevation and resulting in significant vertical errors*

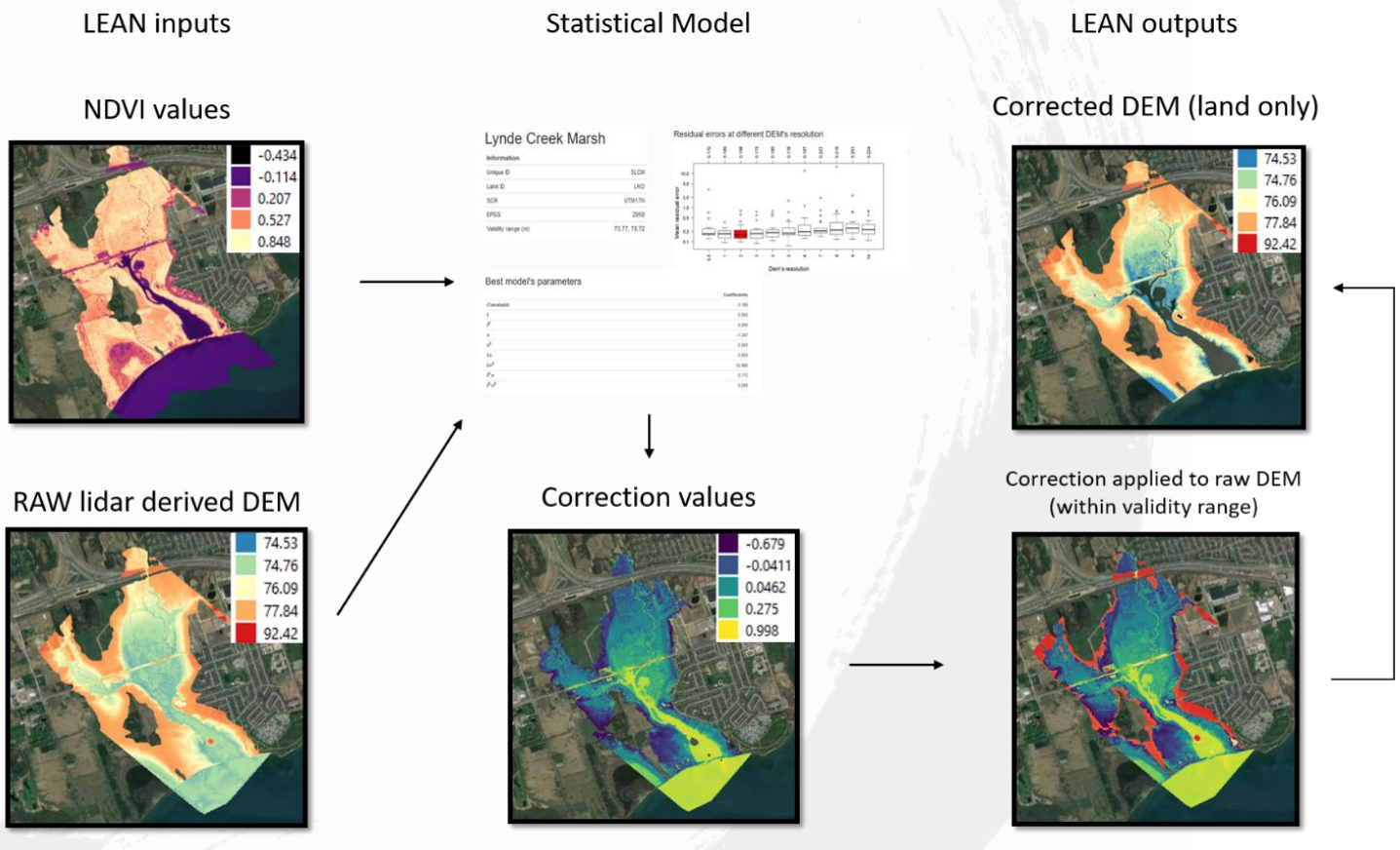




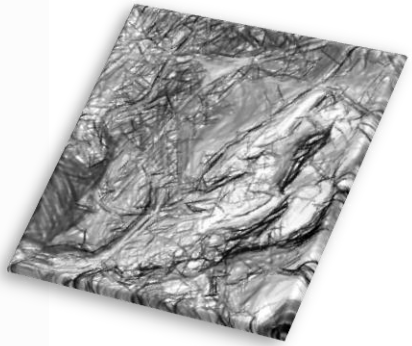
# *Improve accuracy of topographic data*



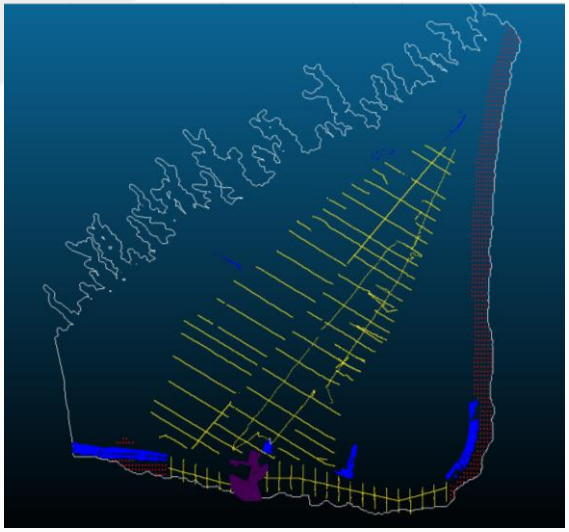
- *DEM's accuracy is critical to wetland plant succession models.*
- *Necessity to apply an error correction method to the LIDAR datasets*
- *Application of statistical correction model based on multispectral imagery and ground truth points (LEAN method , Buffington et al., 2016)*
- *RMSE of 24 cm on average (reduction of ~50%)*



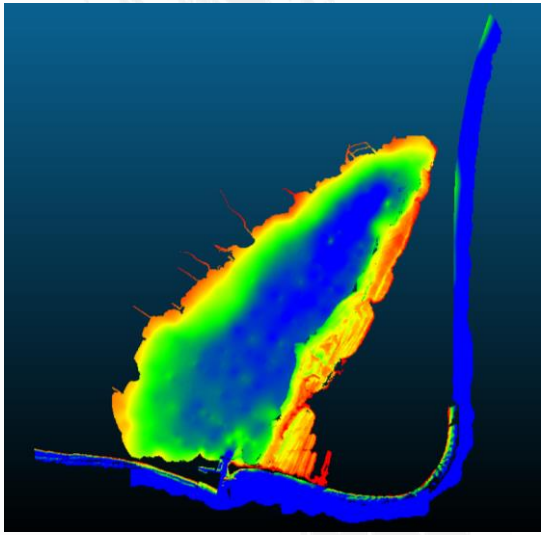
# *Mulptiple bathymetry datasets to flawless DEMs*



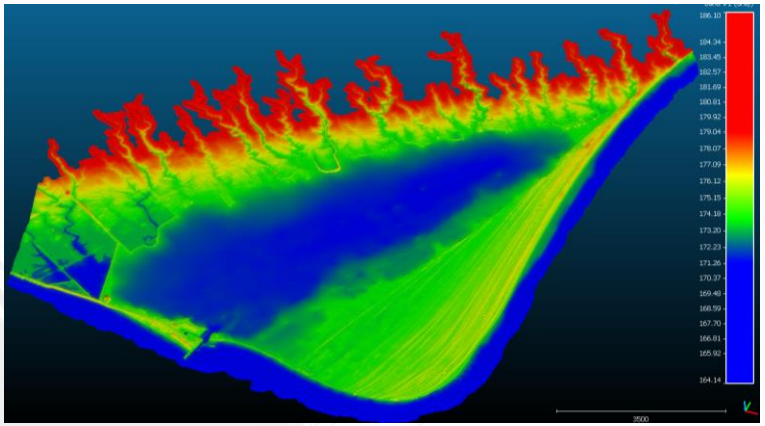
*Integration of multiple bathymetry datasets*



*Interpolation on regular grid (Kriging)*

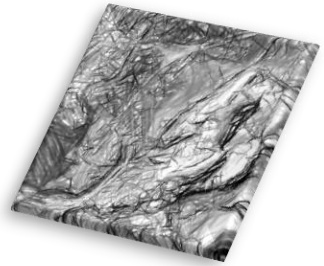


*Integration with topographic datasets and creation of final DEM*

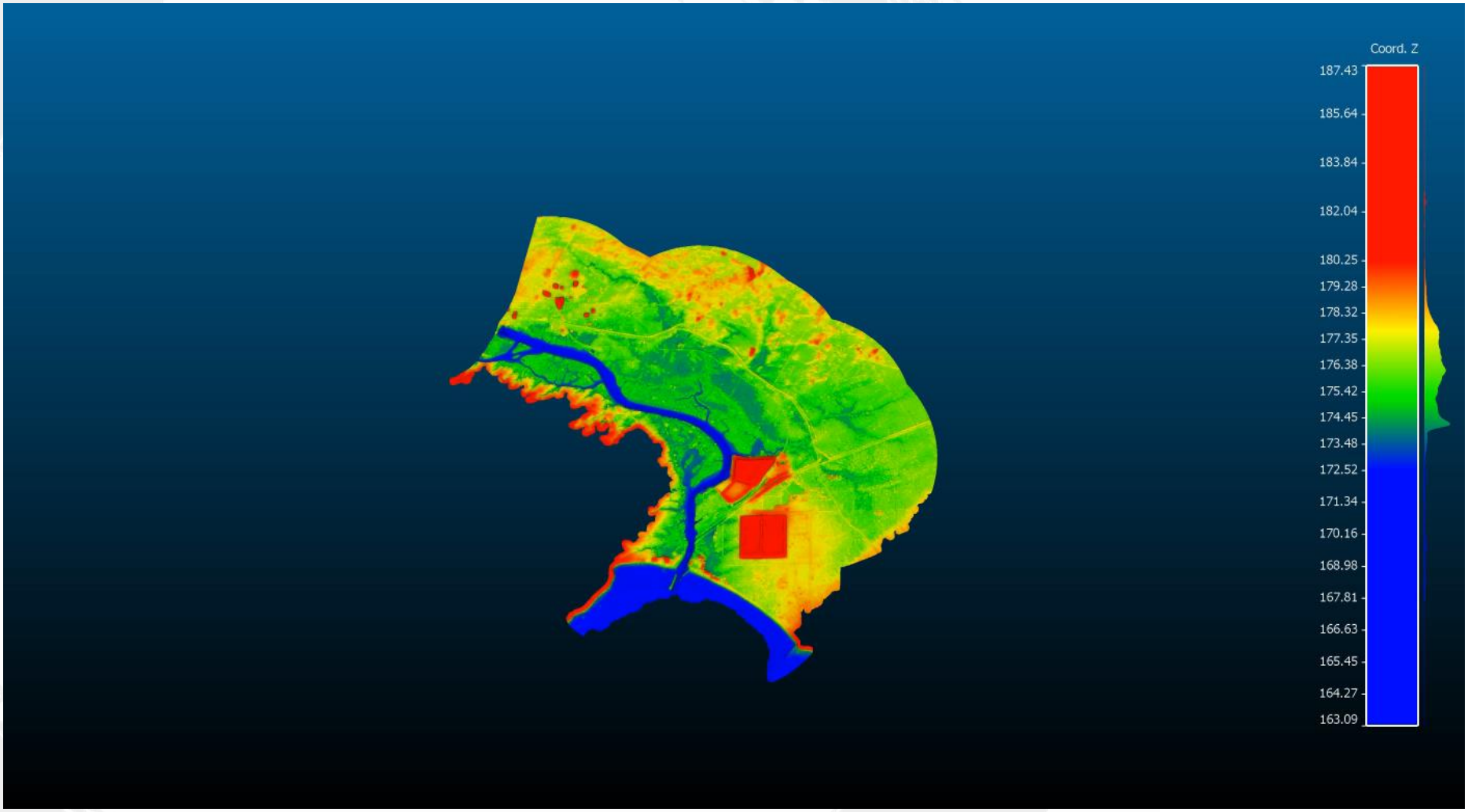


*RMSE of 26.6cm when compared to 9135 groud-truth points*

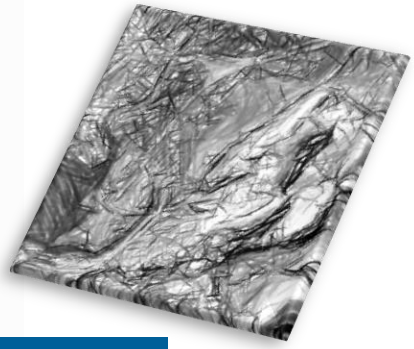
# *DEM created for the 26 study sites*

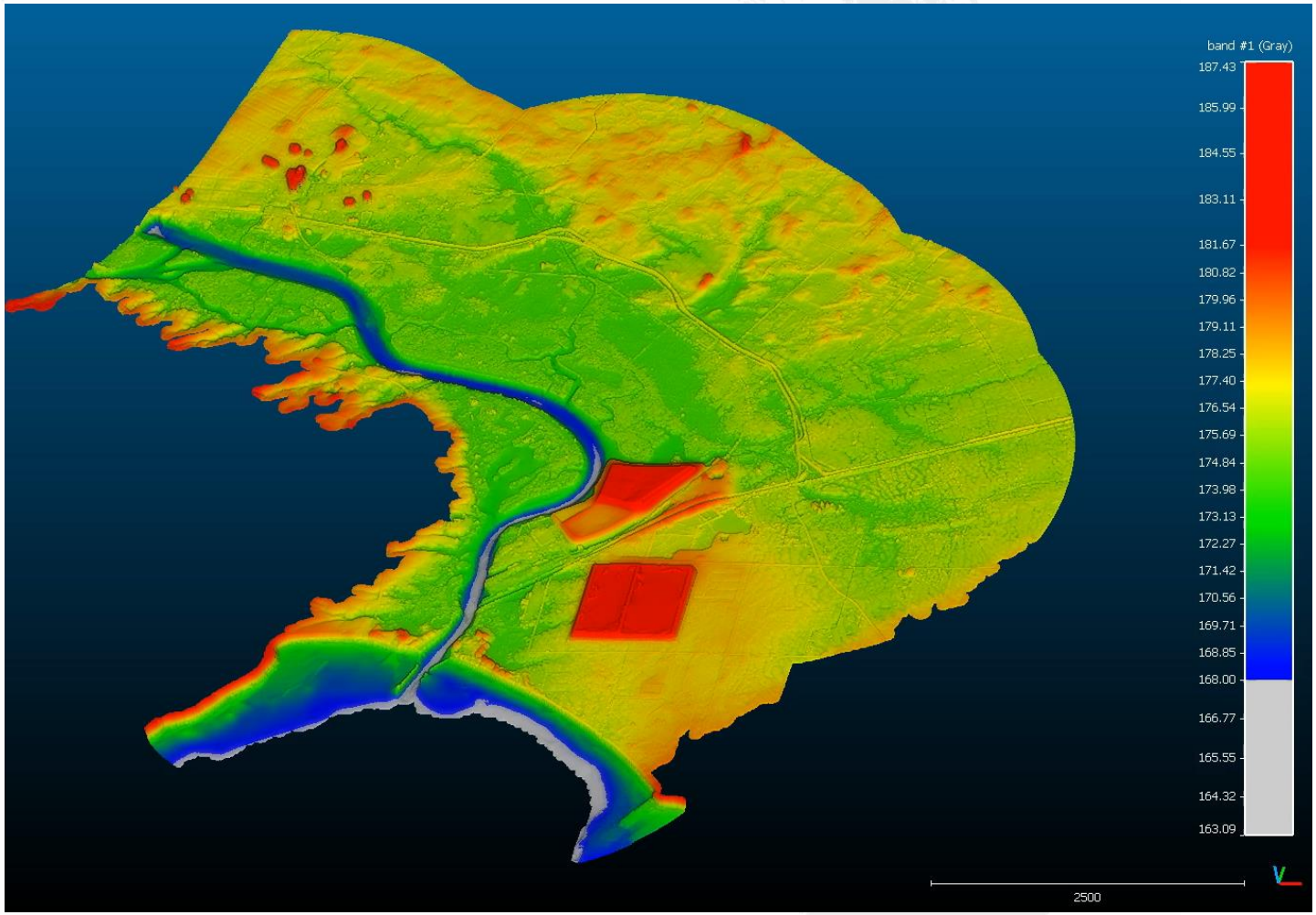


Example for Grand River Mouth:
Accurate elevation values at 2 m resolution

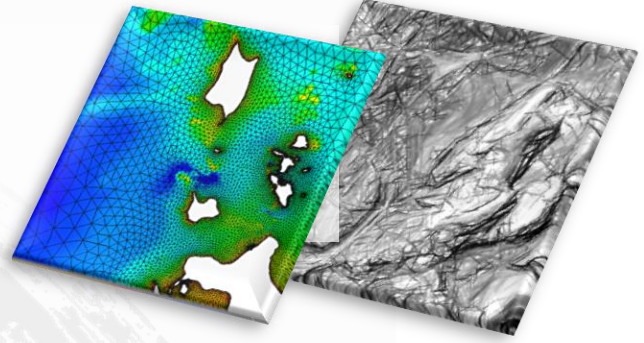


*With DEM, it is possible to show how water level variations may affect wetlands*

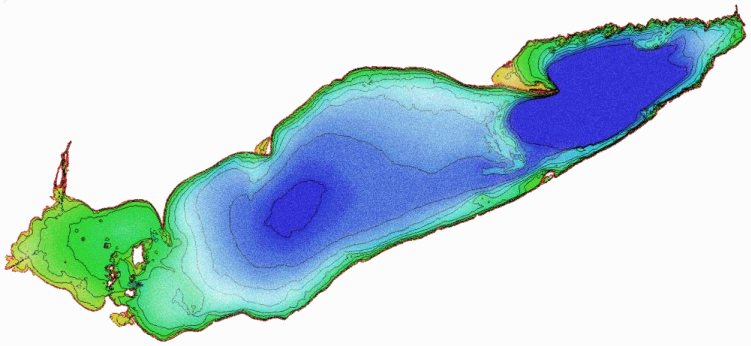




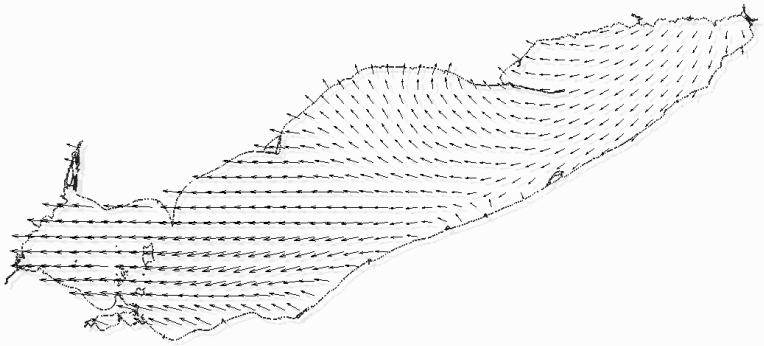
*The second « layer » of the CWRM is the physical models which include the 2D hydrodynamic model (H2D2)*



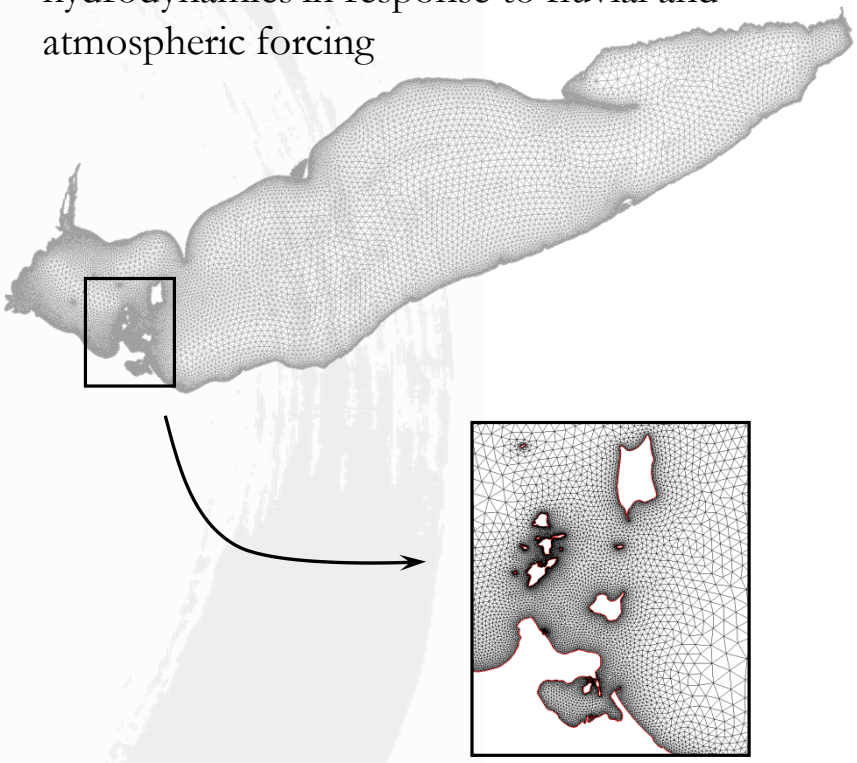
Flow in/out, tributaries, evaporation/precipitation



Winds



Spatial and temporal description of the hydrodynamics in response to fluvial and atmospheric forcing



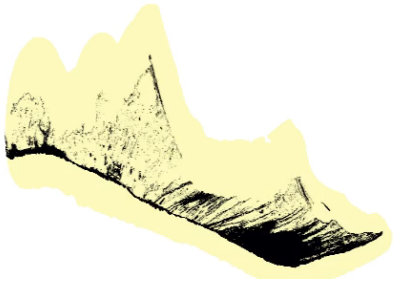
*FOR EVERY HOUR OF EACH GROWING SEASON OF THE TIME SERIES*

*From H2D2, several physical variables can be calculated for every point of the CWRM for every time step*

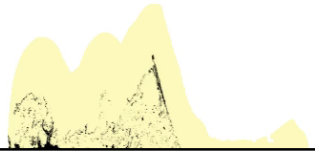
Physical variables at Long Point Wetland during 2009 growing season

Physical variables at time 2009-04-01 00:00:00

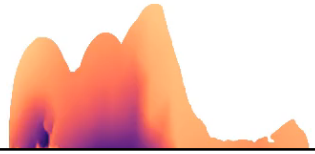
*Emerged pts*



*Emerged pts w/o physics*



*Physics WL Δ*

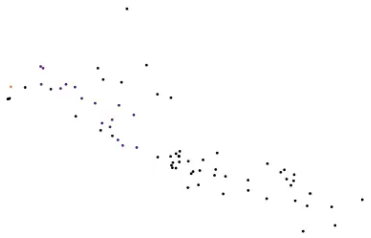


Generates 9 Variables at 1 688 292 points for every 5136 hour of the growing season

X 68 years

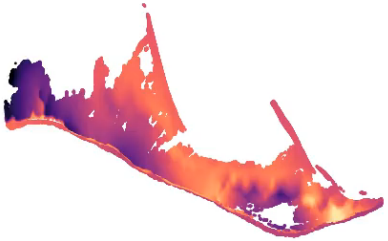
X 26 sites

*Window's length*



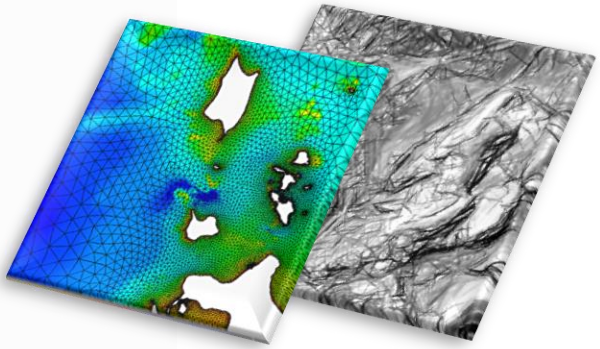
*Cycle's max length*

*Scale average power*

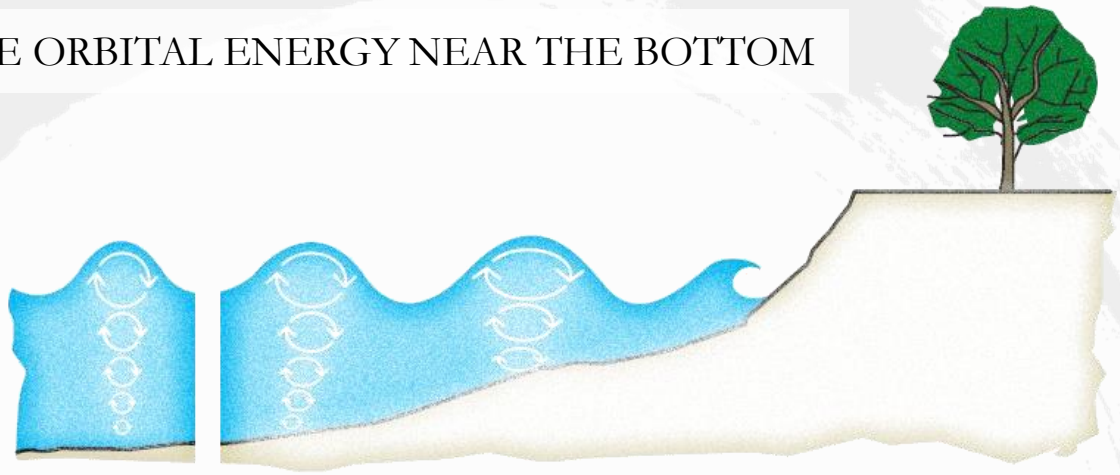


*Not affected by physics*

*Another physical model of the CWRM is the wave model (Wave Watch 3 / SWAN)*



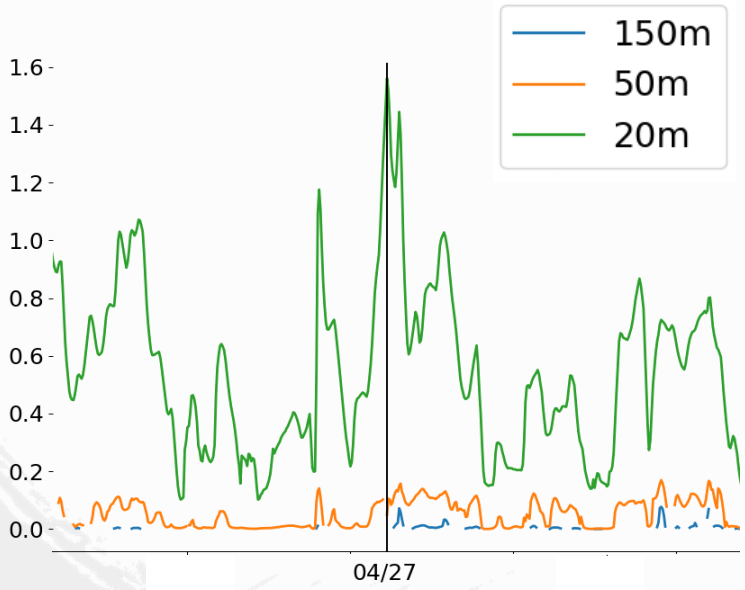
WAVE ORBITAL ENERGY NEAR THE BOTTOM

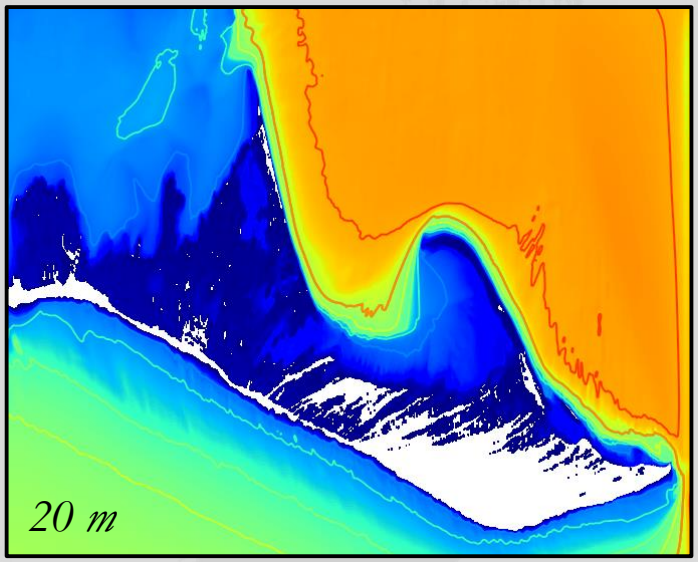


*Also…*

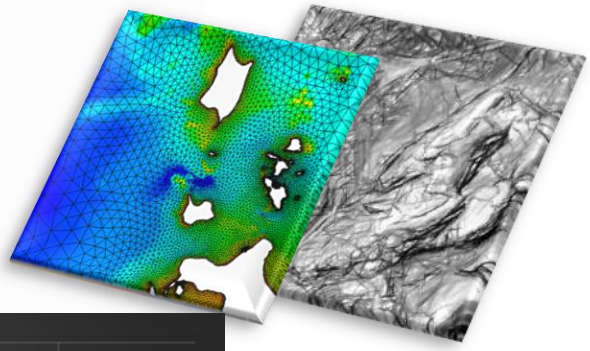
- *Direction*
- *Mean wavelength*
- *Mean period*

SIGNIFICATIVE WAVE HEIGHT

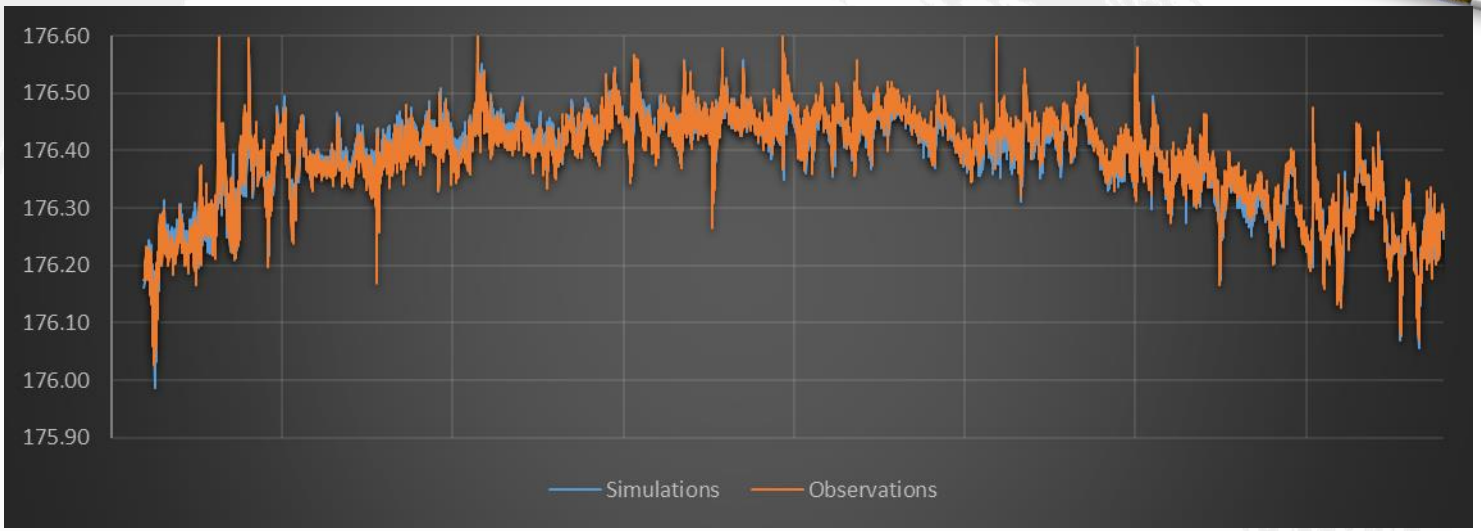


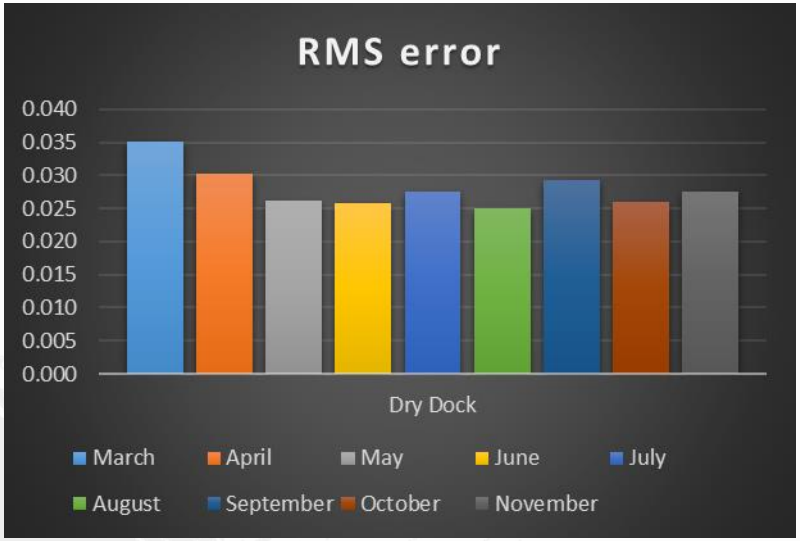



# *Physical Modelling: (Observation, simulation , calibration)*



*Simulated and observed water levels near Detroit River Marsh during 2016 growing seasons*

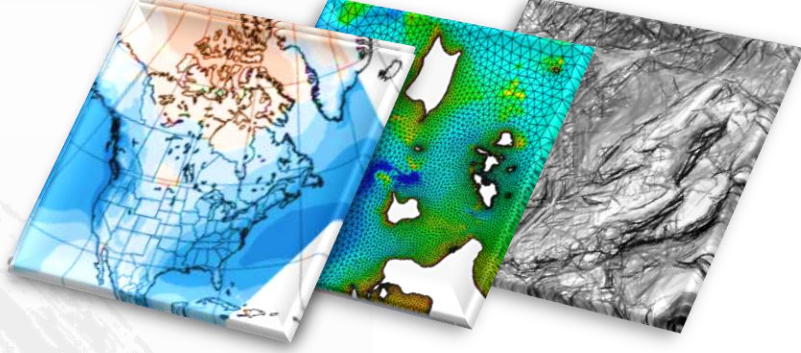



*Model output at every hour during the growing season*

*Water levels mean error of 3-4cm*

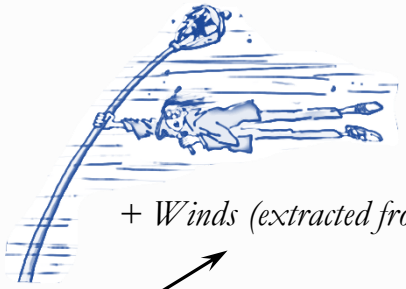
# *Physical Modelling: Climatic projections*



*Recent past / future physical conditions ?*

*FRANK'S RESULTS*
*(flow at main rivers, mean water level)*

*Climatic Scenarios*
*1980-2100*
*(RCP 4,5 / 8,5)*



*+ Winds (extracted from scenarios)*

Global warming (Emission Scenarios)

**Initial conditions**


**1980**

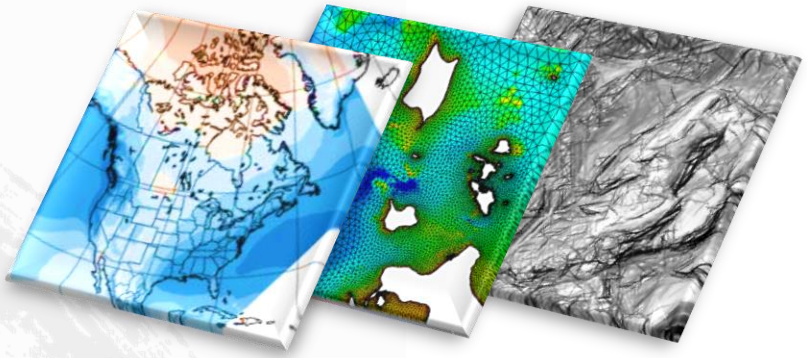
**Current conditions**

**2010**

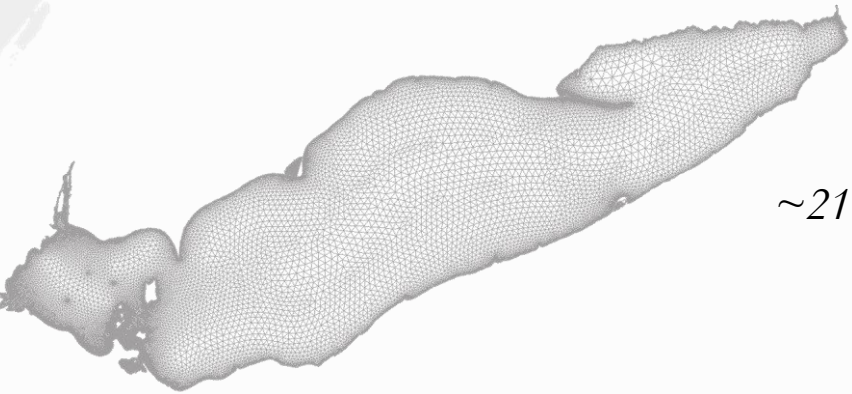
**Future climate**

**2070-2100**

# *Physical Modelling : A Great Lake of data…*



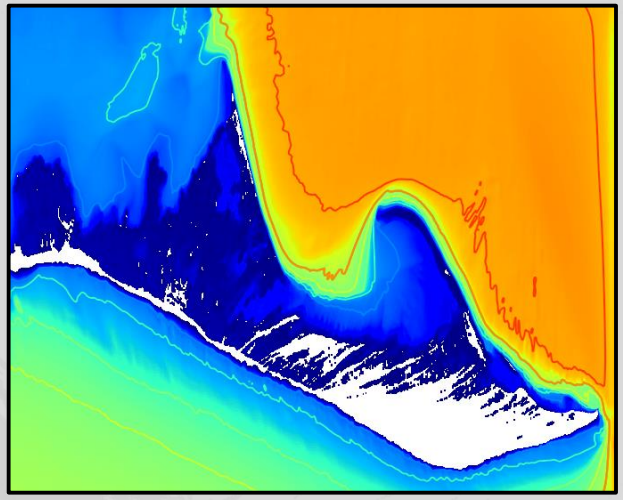
*Only for Lake Erie…*



*~21 days of computing*

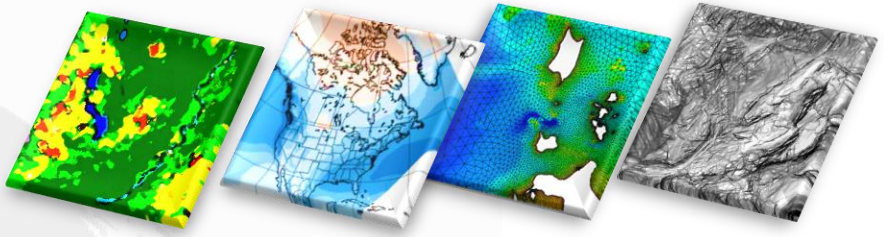
*Using up to 1/3 of the most powerfull computer in Canada! ~800 laptops!*

*Generating ~1000 Tb of data*



*~3 months of computing*

# Wetland succession model



## Several steps are needed to create a wetland successional model

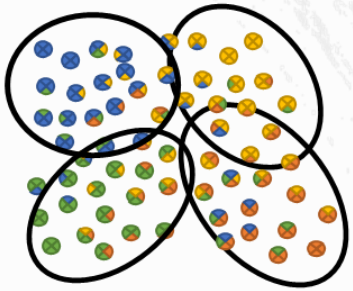
### 1. Field vegetation surveys

~700 species identified

**Calibration**: 2018
- 23 sites
- 2937 quadrats

**Validation**: 2019
- 26 sites
- 3651 quadrats

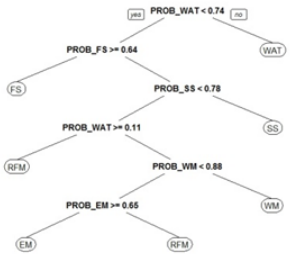
### 2. Clustering analysis



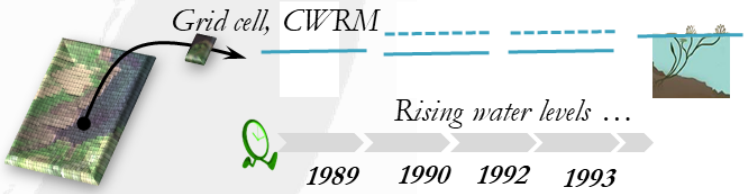

### 3. Interpolation of physical variables at observations points from CWRM

- Bottom slope
- Bottom curvature
- Mean water depth during growing season
- Mean number of wet-dry cycles during growing season
- Mean percent of weeks flooded during growing season
- Mean orbital wave energy at bottom during growing season
- Total orbital wave energy during growing season

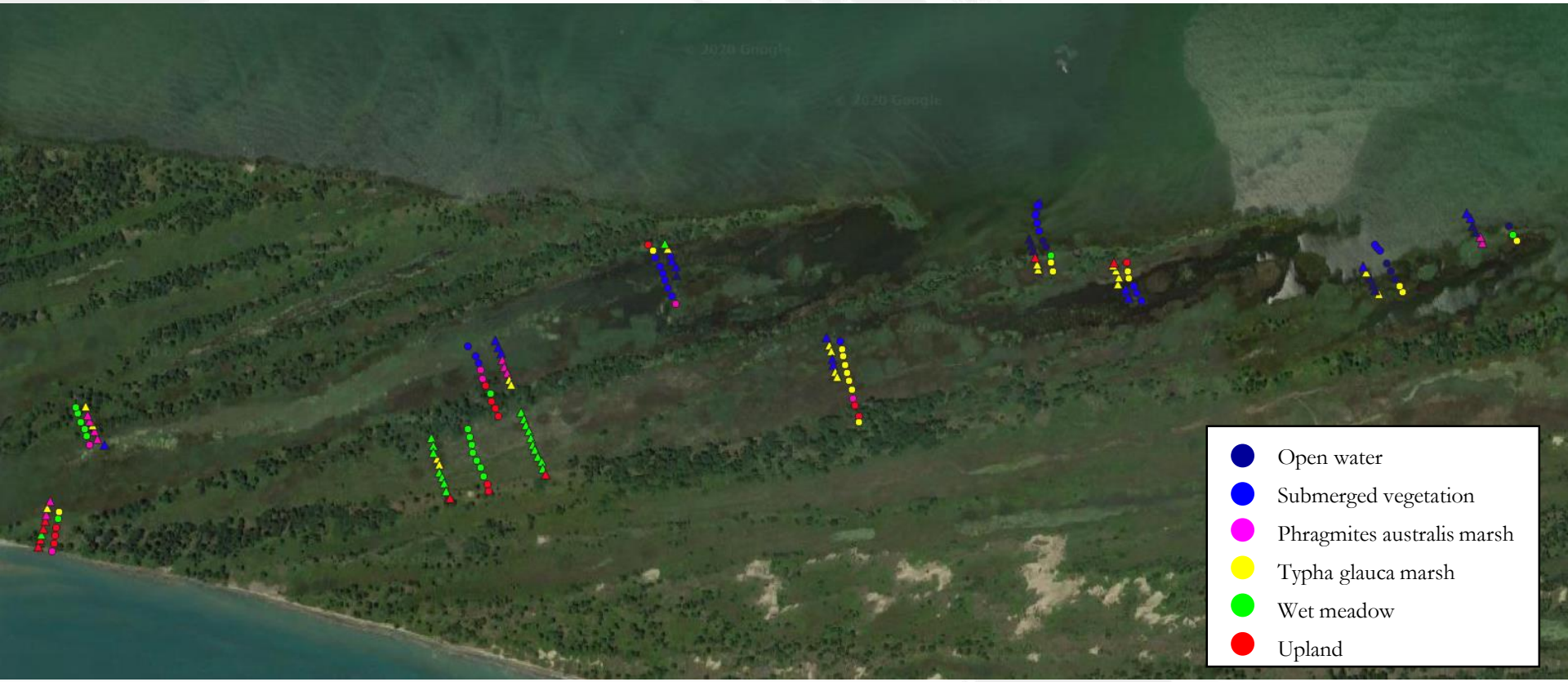
### 4. Binomial logistic regression and deep learning + AIC selection + Classification tree




### 5. Succession algorithm



# *Preliminary cluster analysis of Long Point indicates 6 wetland types*




○ *2018 quadrats* △ *2019 quadrats*

*Vegetation type that are possible to model for now are:*

**Groups that will be modelled**

- *Open water (limit condition)*
- *Submerged vegetation*
- *Emergent marsh*
- *Meadow marsh*
- *Swamps*
- *Phragmites*
- *Hybrid cattail*
- *Upland (limit condition)*

**Other possibilities***

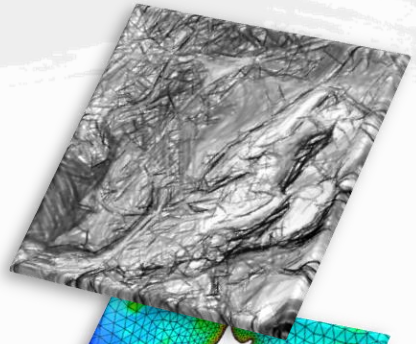
- *Non persistent emergent marsh*
- *Wild Rice*
- *Hydrocharis morsus-ranae*
- *Myriophyllum spicatum*

** Depends on the number of observations. We will know better at the end of the clustering analysis*

*** For now, clustering analysis have been done for Lake Erie, Lake Ontario and Detroit River Marsh*

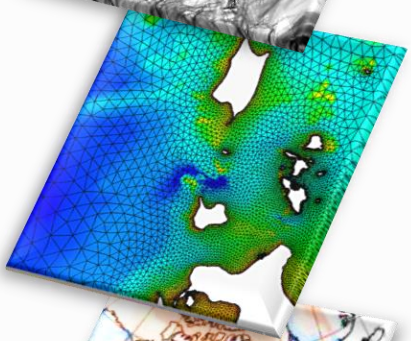
# *A work in progress…*

*Elevation (DEM)*



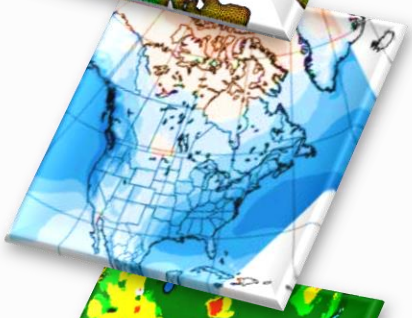
→ *26 sites completed*

*Physical modelling*



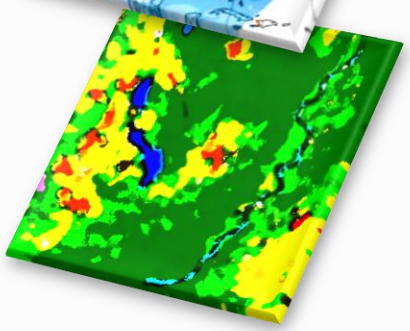
→ *LKE and LSC completed for 1980 to 2018*
*LKO, LKH, LKS underway*
*2070 to 2100 still has to be done for all sites*

*Climatic scenarios*



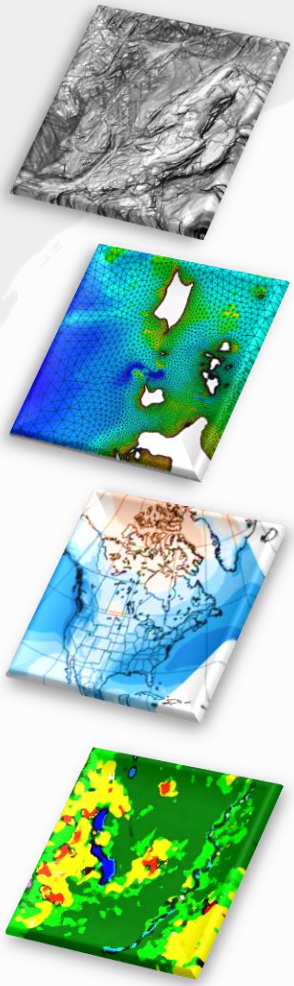
→ *Work underway by MSC Ontario*

*Vegetation*

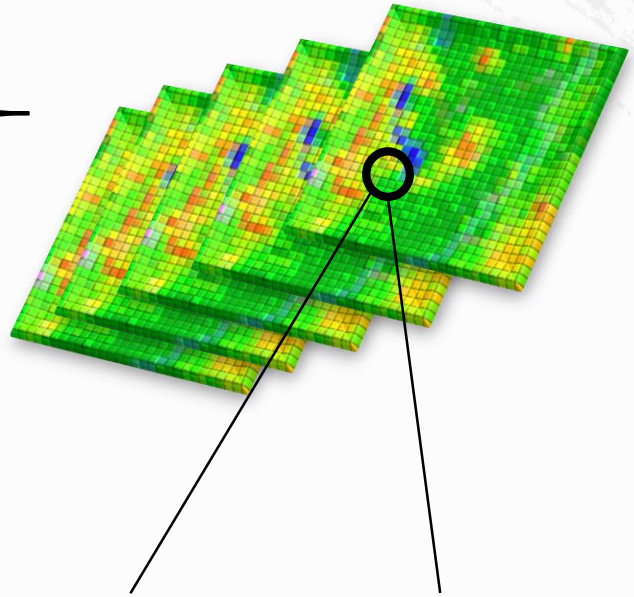


→ *Clustering analysis done for 14 sites*
*Succession algorithm still to be developed*

# *CWRM in a nutshell….*



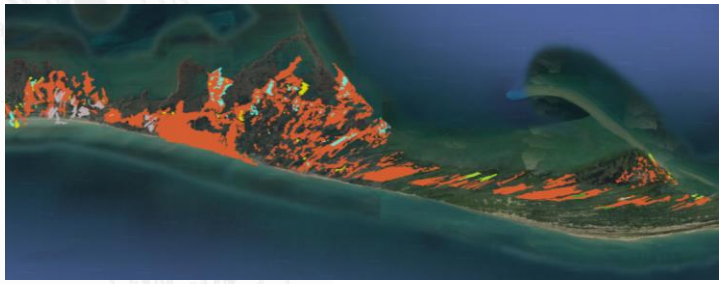
*26 sites*
*138 300 000 point-grid*



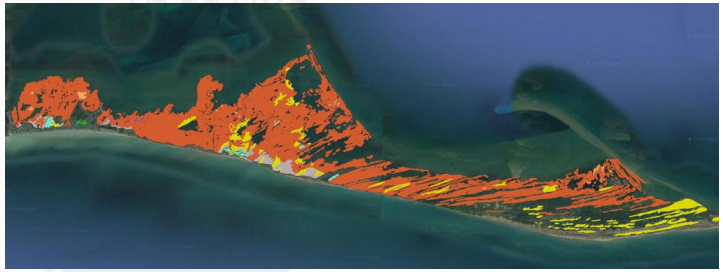
X

*Results for 68 growing seasons*
*(1980-2018 and 2070-2100)*

*Long Point in 1980*



*Long Point in 2018*



*Long Point in 2100*


## *Wetland class*

*Submerged vegetation*
*Emergent marsh*
*Meadow marsh*
*Swamps*
*Phragmites*
*Etc…*

# MERCI!

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Antoine Maranda M.ATDR, GIS expert
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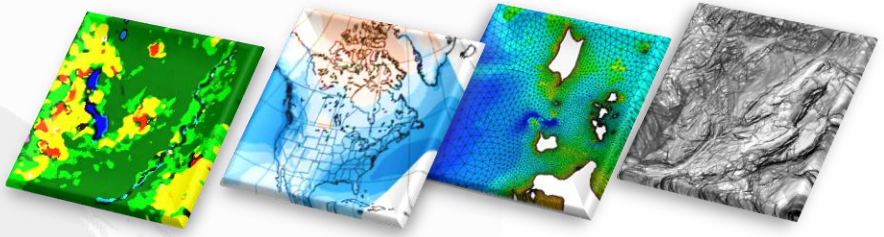
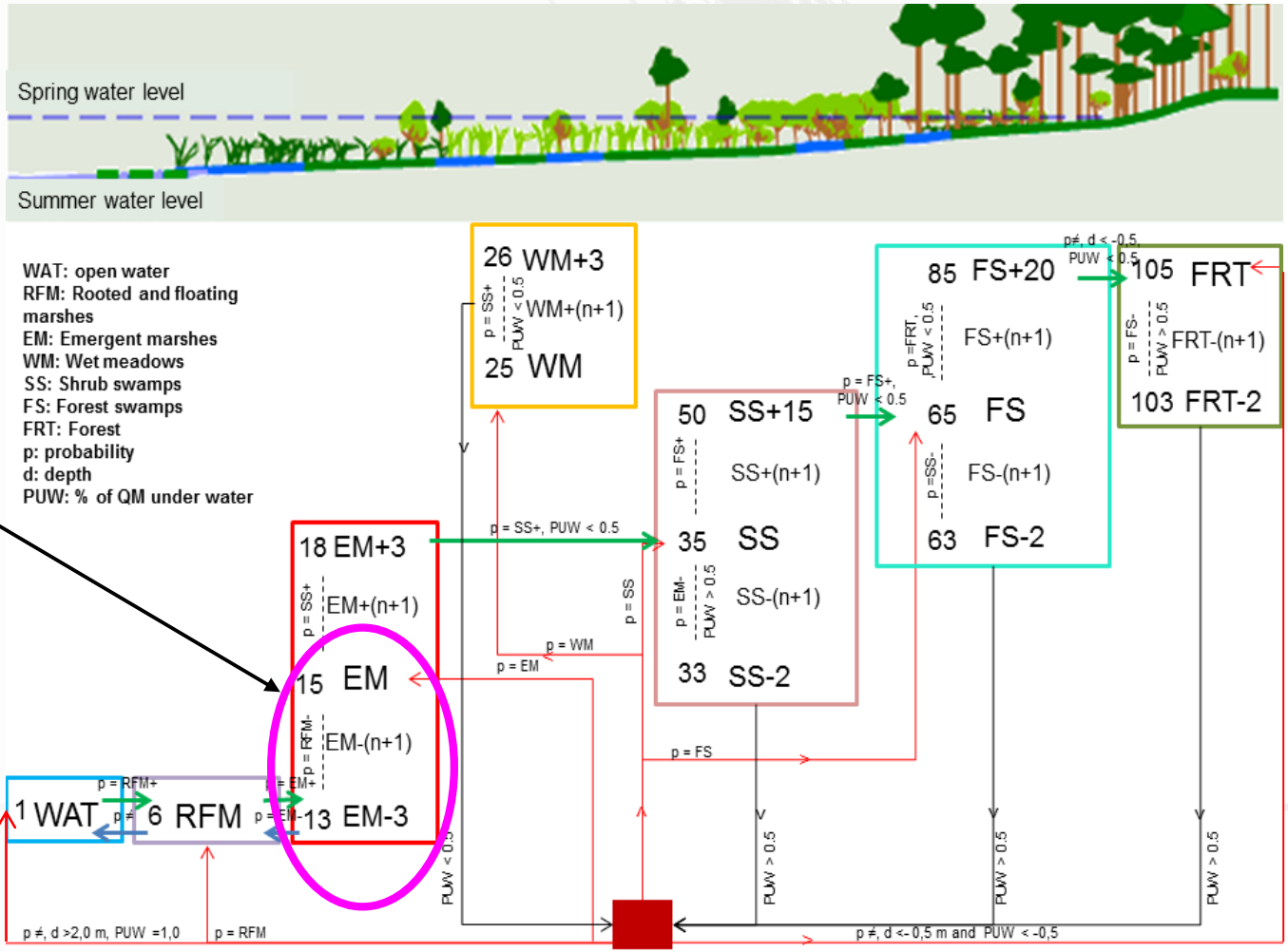
Information Sharing Meeting, Toronto, March 12th, 2020

# *Wetland succession model*

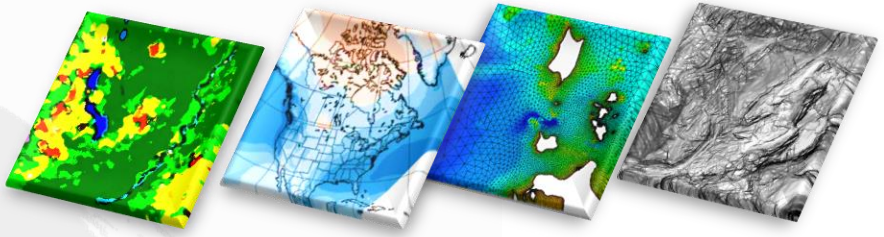


*A succession algorithm states at which rate a wetland type changes to another one after a water level variation*

*For example, an emergent marshe (EM) will need 3 years of high water levels to move from rooted to floated marshes*

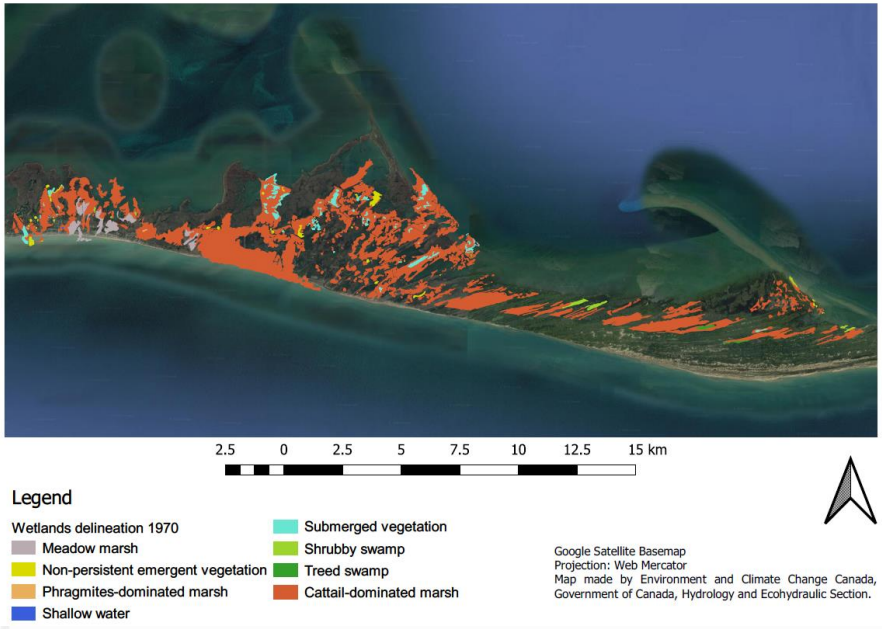


# *Wetland succession model*

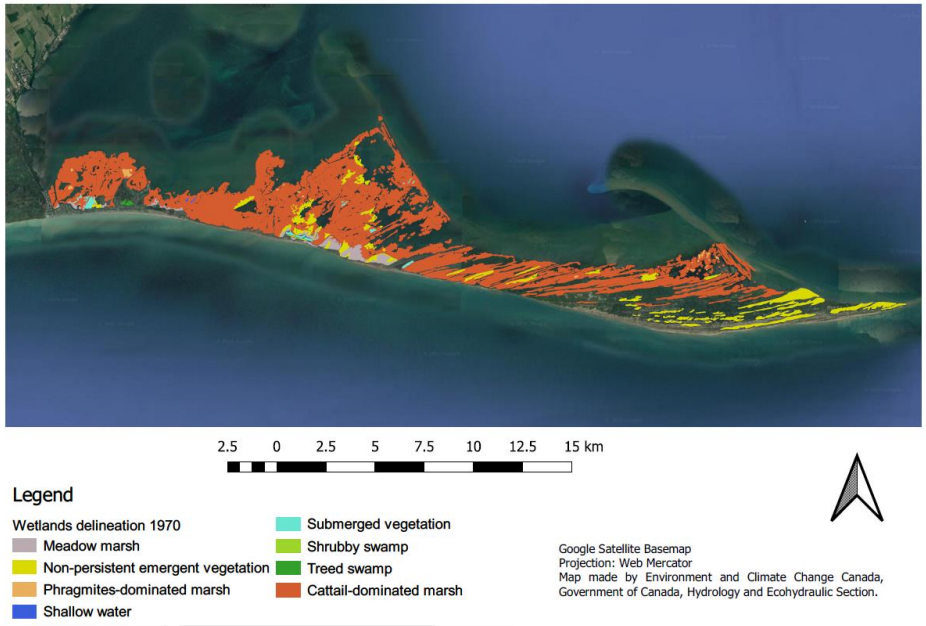


*Historical images are used to validate the succession algorithm*

**Wetlands delineation from aerial images acquired in 1970 at Long Point, Erie lake.**

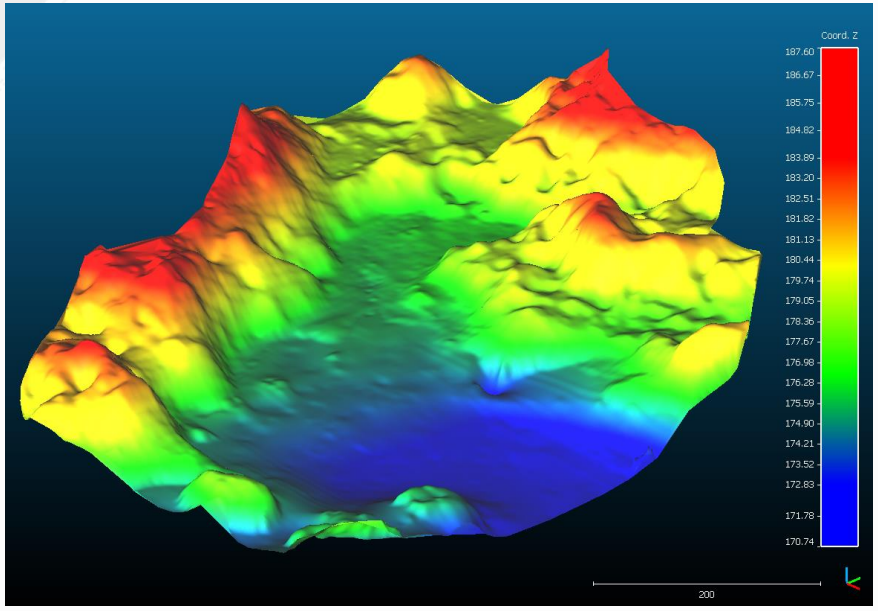



**Wetlands delineation from aerial images acquired in 2018 at Long Point, Erie lake.**

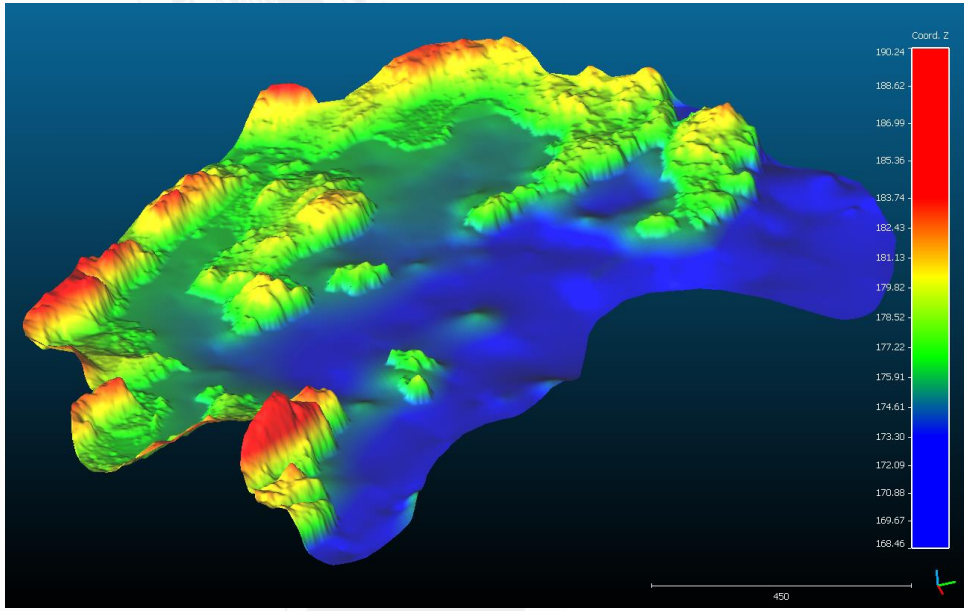


| Site\Technique | MBG | GCP | PGF | KGF | ONT | LMT |
|---|---|---|---|---|---|---|
| 1HID | 0.374 | 0.398 | 0.277 | 0.586 | 0.391 | 0.257 |
| 2ACM | 0.353 | 0.544 | 0.261 | 0.543 | nan | 0.294 |
| 3SBM | 0.501 | 0.638 | 0.454 | 0.628 | 0.587 | 0.189 |
| 4WMH | 0.456 | 0.593 | 0.385 | 0.52 | 0.53 | 0.255 |
| 5LCM | 0.27 | 0.351 | 0.205 | 0.343 | nan | 0.174 |
| 6JSM | 0.43 | 0.454 | 0.359 | 0.451 | nan | 0.425 |
| 7GRM | 1.017 | 1.222 | 0.719 | 1.171 | 0.409 | 0.34 |
| 8SPP | 0.394 | 0.56 | 0.357 | 0.477 | 0.427 | 0.204 |
| 9LPW | 0.717 | 0.812 | 0.712 | 0.76 | 0.776 | 0.294 |
| 10RBY | 0.496 | 0.637 | 0.465 | 0.553 | 0.558 | 0.306 |
| 11FCK | 0.258 | 0.351 | 0.259 | 0.303 | 0.314 | 0.189 |
| 12DRM | 0.384 | 0.488 | 0.35 | 0.441 | 0.449 | 0.247 |
| 13LSC | 0.603 | 0.737 | 0.558 | 0.67 | 0.672 | 0.295 |
| 15BDD | 0.415 | 0.47 | 0.396 | 0.465 | nan | 0.212 |
| 16HBW | 0.399 | 0.474 | 0.382 | 0.433 | nan | 0.252 |
| 17CSW | 0.224 | 0.29 | 0.21 | 0.287 | nan | 0.137 |
| 18HBW | 0.446 | 0.529 | 0.443 | 0.505 | nan | 0.19 |
| 19TBY | 0.294 | 0.356 | 0.268 | 0.345 | nan | 0.156 |
| 21KRW | 0.297 | 0.327 | 0.418 | 0.354 | nan | 0.248 |
| 22WHW | 0.532 | 0.601 | 0.5 | 0.552 | nan | 0.248 |
| 23ACK | 0.369 | 0.438 | 0.305 | 0.403 | nan | 0.235 |
| 24HCE | 0.288 | 0.342 | 0.296 | 0.304 | nan | 0.227 |
| 25MMH | 0.351 | 0.458 | 0.309 | 0.407 | nan | 0.352 |
| Average | 0.433 | 0.524 | 0.392 | 0.498 | 0.511 | 0.249 |
| Min | 0.224 | 0.290 | 0.205 | 0.287 | 0.314 | 0.137 |
| Max | 1.017 | 1.222 | 0.719 | 1.171 | 0.776 | 0.425 |

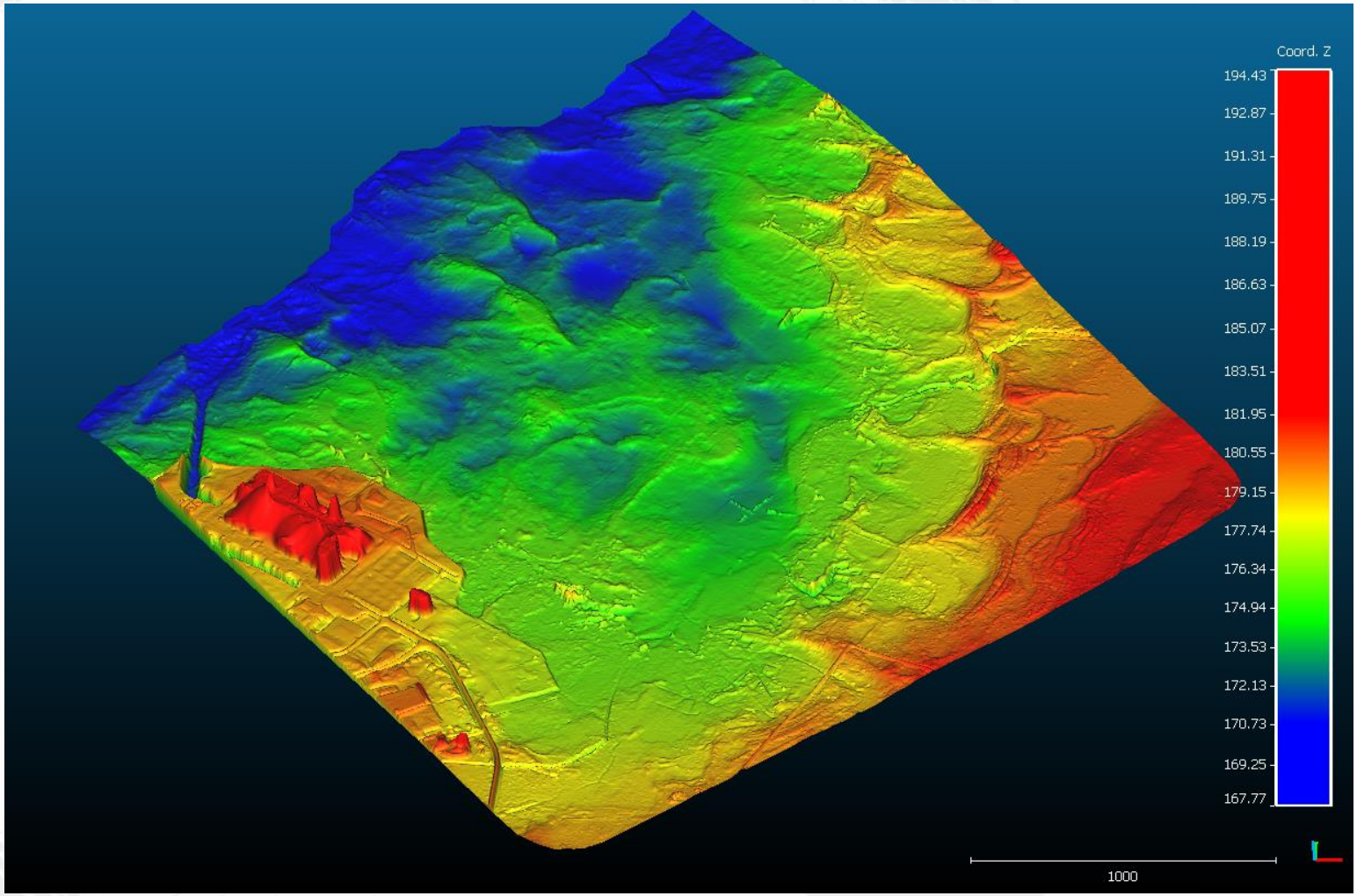
Coffin Rock




Francis Point



Baie du Dore


Coord. Z
194.43
192.87
191.31
189.75
188.19
186.63
185.07
183.51
181.95
180.55
179.15
177.74
176.34
174.94
173.53
172.13
170.73
169.25
167.77
1000

# Treasure Bay