An Empirically Based Wind Driven Wave Nowcasting System: Case Study of Salto Caxias Reservoir in Brazil

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Motivation

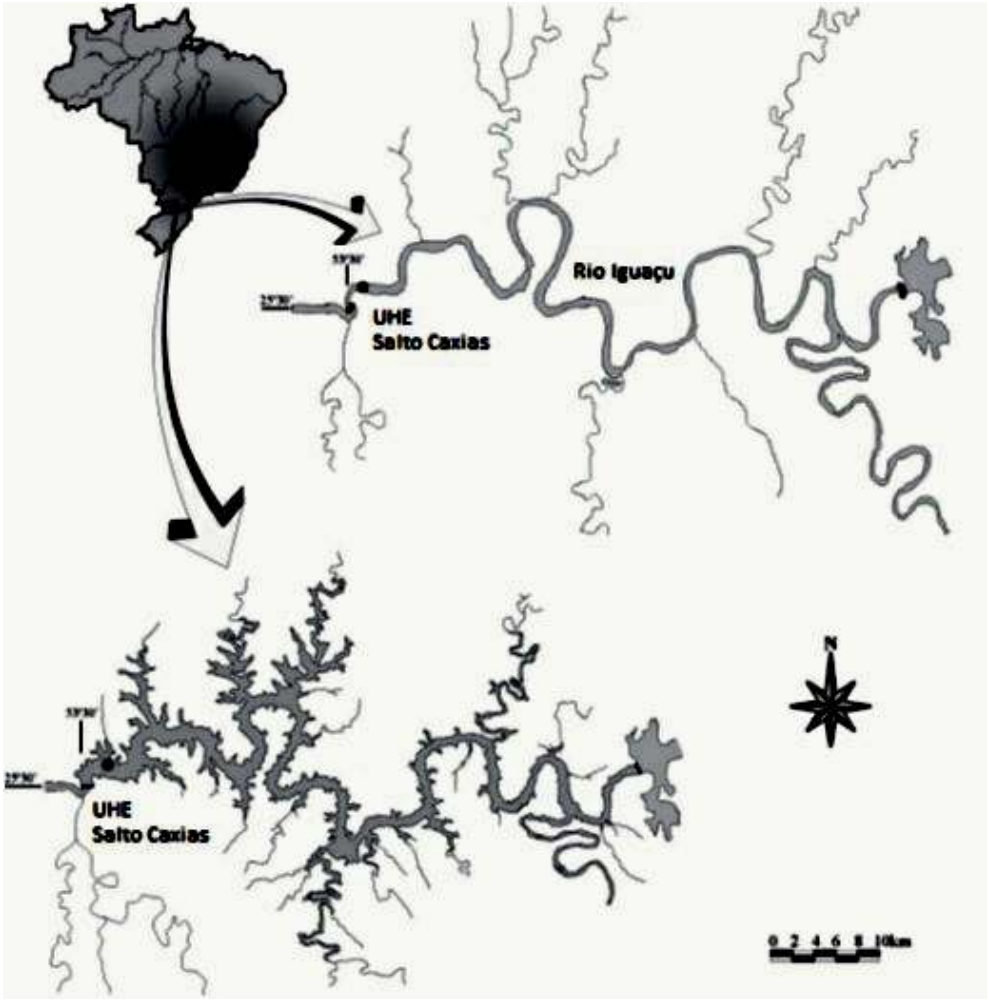
- Lack of automated global access systems designed to simulate and forecast the wave fields produced by the wind action in interior waters
- Main difficulties: high investments for acquisition and maintenance of field equipments and complexity in the development of numerical models capable of processing large amounts of data and mapping the results to automated platforms

Objectives

- To estimate the wave heights of Salto Caxias reservoir for severe wind scenarios by employing ONDACAD - a fully portable and automated computational model to simulate the wave fields in lakes and reservoirs

Area of Study

- Salto Caxias reservoir: southwest region of the State of Paraná in Brazil
- The fifth and most downstream on the cascade of the Iguaçu River
- Highly dentritic and meandering (area of 141 km^2 and main axis of 96 km)

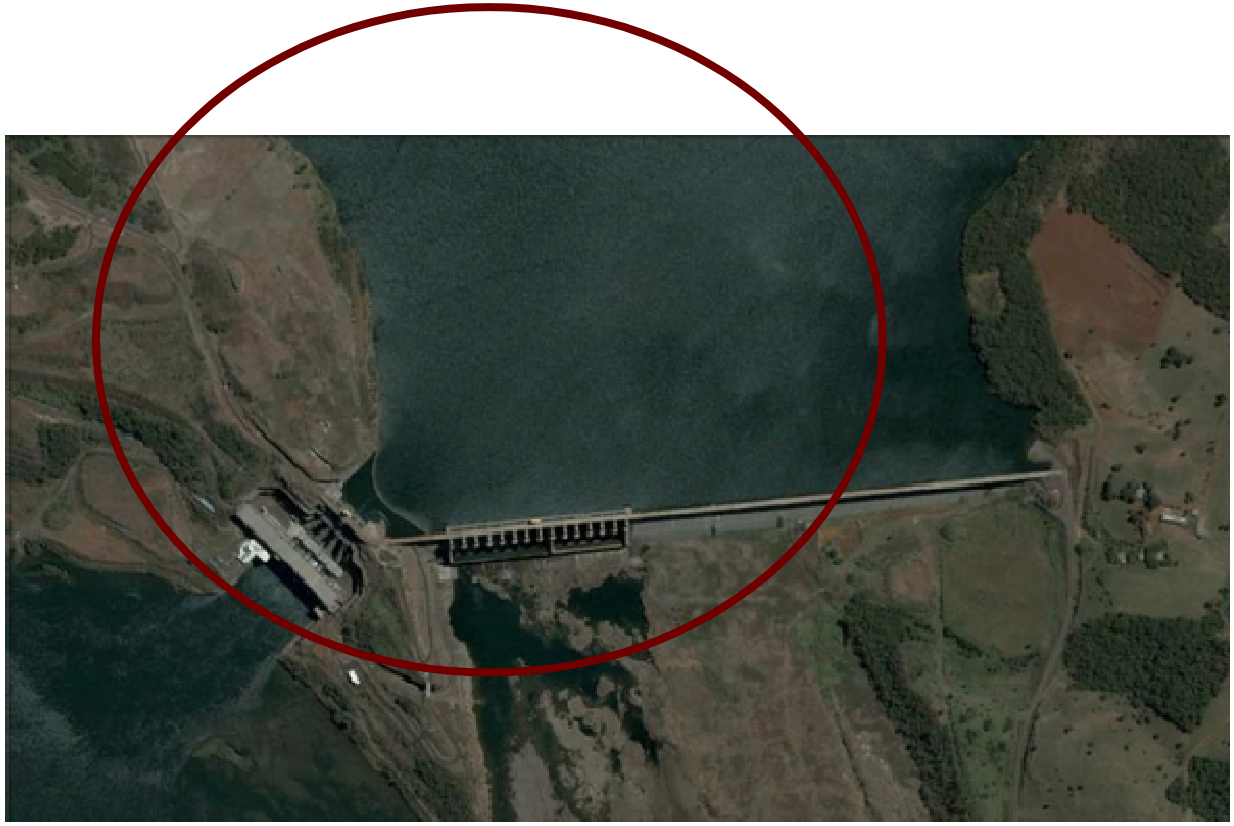


Salto Caxias Dam

Photos by Victor Carvalho

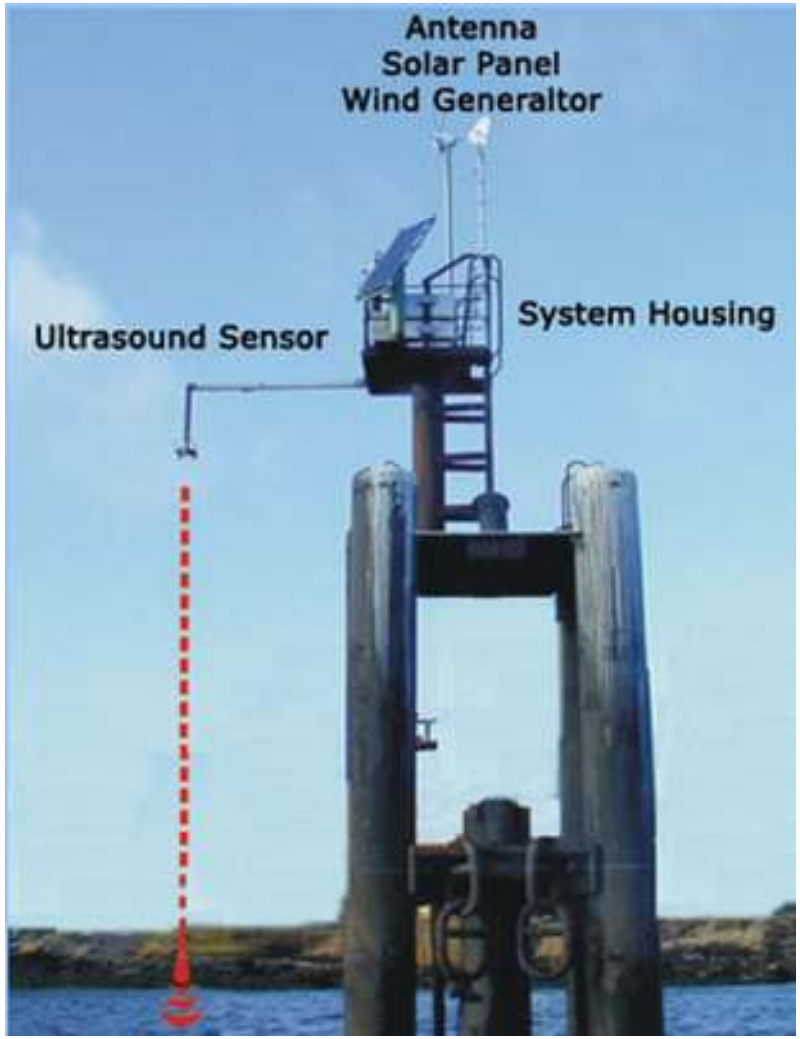
Wave Monitoring System

- A wave monitoring system will be installed in the near field of the Dam and integrated to the model in the future



Wave Monitoring System

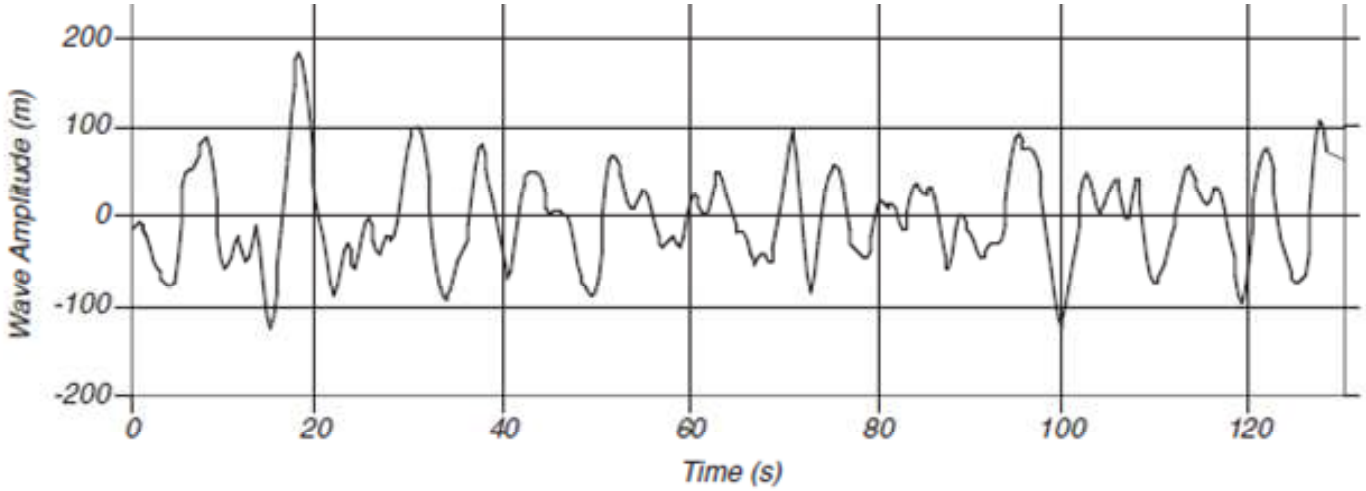
- LOG_aLevel by General Acoustics e.K.
- Remote sensing, stand alone, water level gauge on the basis of ultrasonic sensors
- Free of calibration or maintenance needs
- Narrow sound beam with angle of 3 degrees and measurements in a frequency of 5 Hz



ONDACAD Model

- The ONDACAD is an empirically based wind driven model designed to simulate the wave heights in lakes and reservoirs
- The model assumes uniformly wind distribution and does not account for the influences of the surrounding banks and for the effects of (i) wave refractive or diffractive propagation, (ii) wave-wave and non-linear interactions, (iii) depth-induced wave breaking and (iv) bottom dissipation
- The wave heights are determined by empirical equations such as the SMB that requires only the wind and fetch as input parameters

ONDACAD Model



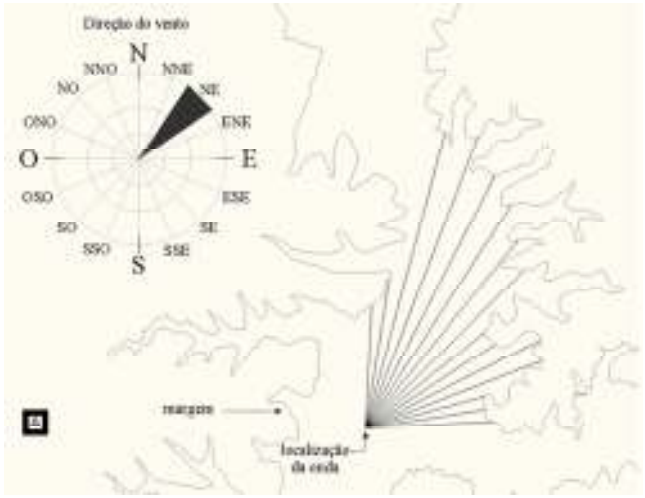
$$H_{1/3} = \frac{U_{10}^{\ 2}}{g} 0{,}283 \tanh\left[0{,}0125 \left(\frac{gF}{U_{10}^{\ 2}} \right)^{0{,}42} \right]$$

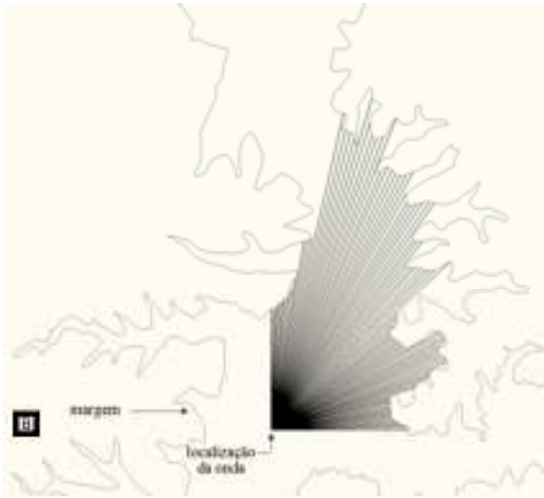
SMB parametric equation – Shore Protection Manual (1984)

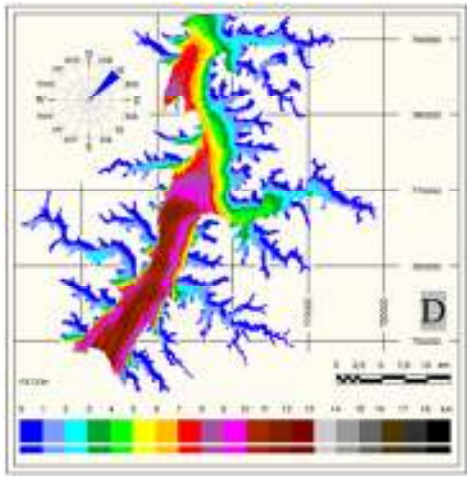
Effective Fetch

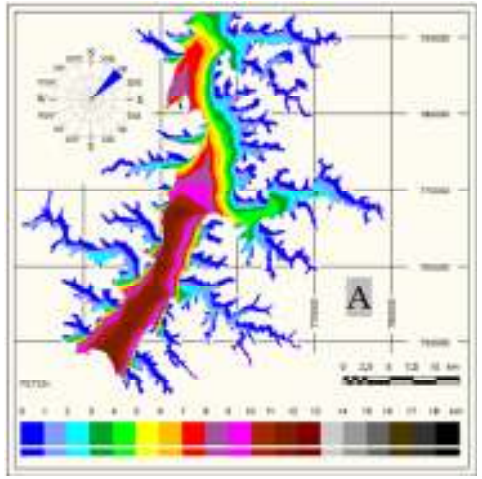
$$F = \sum_i x_i \cos\alpha_i \Big/ \sum_i \cos\alpha_i$$

$$F = \frac{\int_{-\alpha}^{\alpha} F\cos(\emptyset)\,d\emptyset}{\int_{-\alpha}^{\alpha} \cos(\emptyset)\,d\emptyset}$$









ONDACAD Model

- The main advantages of the model are:

1. The ability of processing large amounts of data and providing the results in form of maps to automated online platforms
2. The high performance in terms of computational time
3. The low cost of implementation and operation
4. The potential of obtaining satisfactory results for applications of wave nowcasting in lakes and reservoirs

Simulations

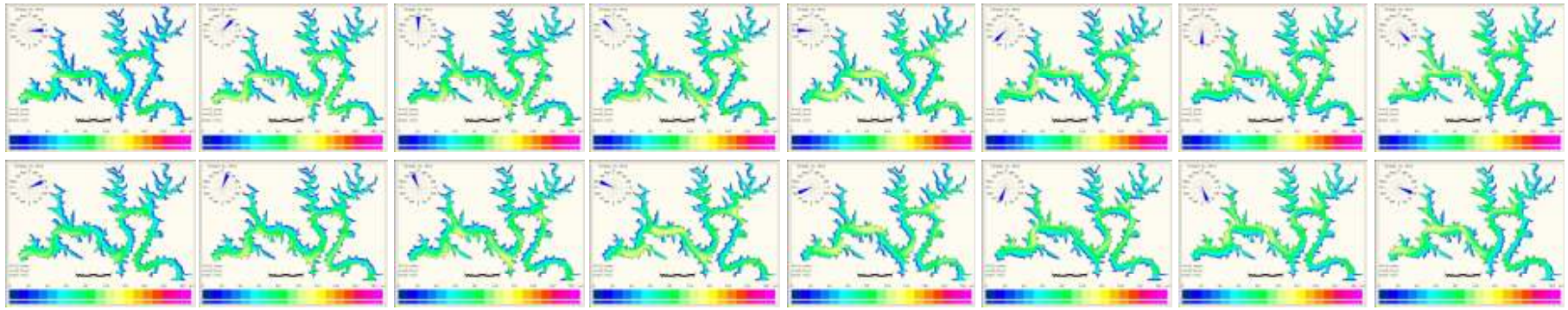
- 2-D computational mesh ≅ 15,000 cells
- Wind velocity and returning period

U_w (m/s)	25.7	29.3	38.2	50.9
RP (years)	10	20	50	100

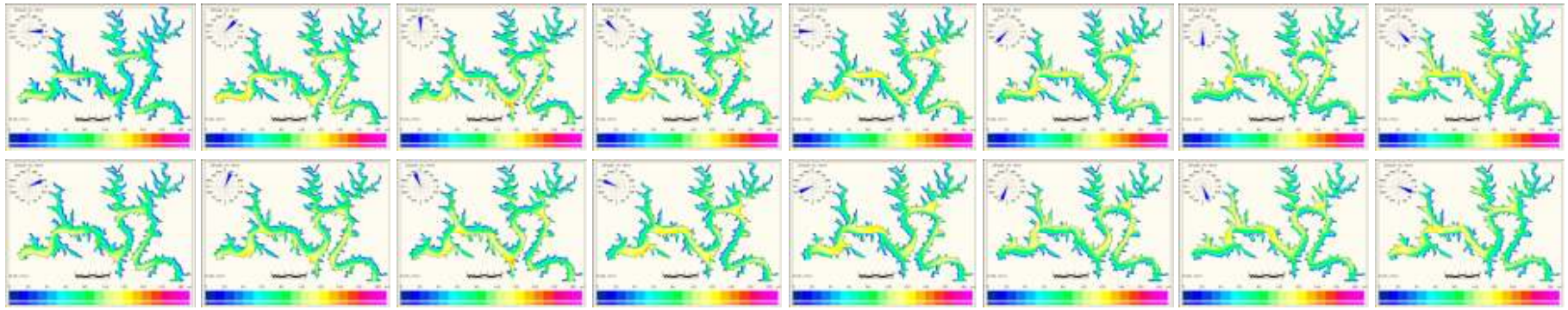
- 16 wind directions: generation of 64 maps
- Highest waves were generated by the fourth quadrant oriented winds

Results

- RP=10 yrs - Highest waves ≅ 120 cm

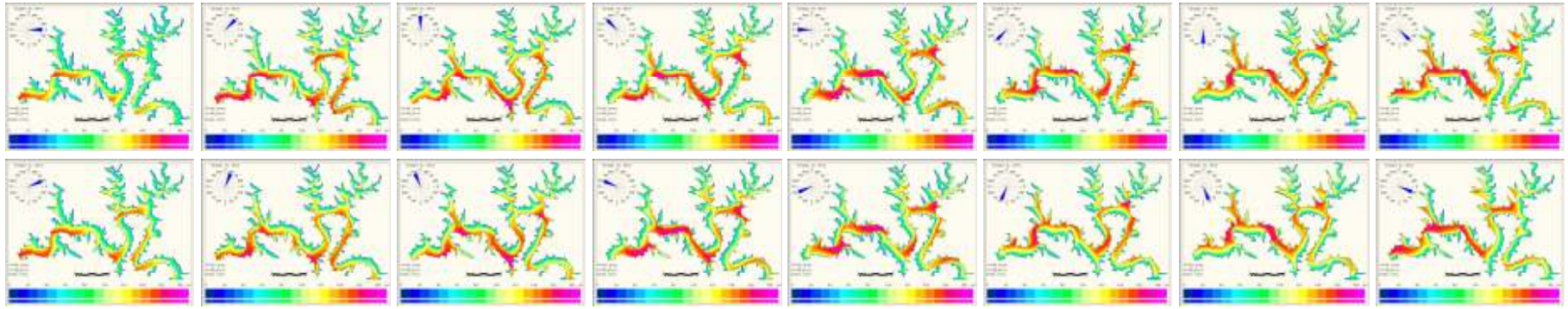


- RP=20 yrs - Highest waves ≅ 140 cm

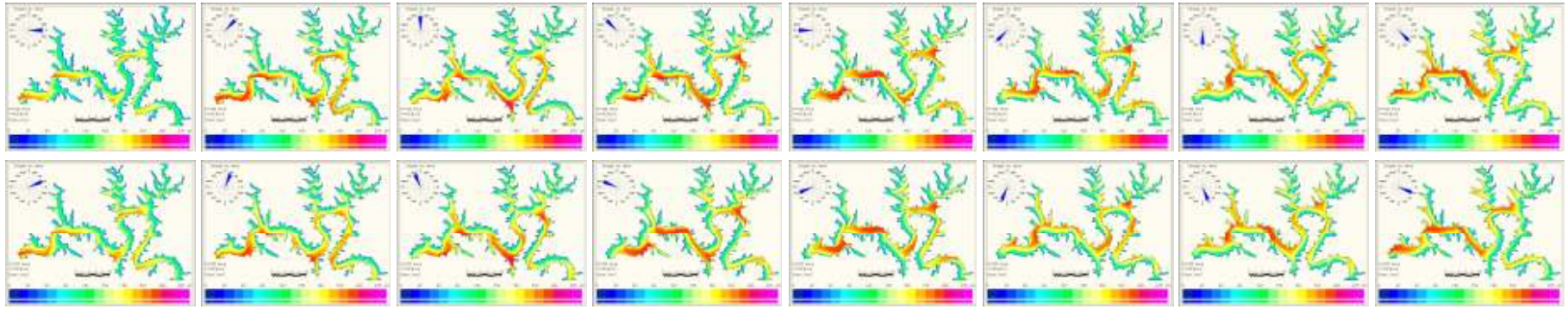


Results

- RP=50 yrs - Highest waves ≅ 185 cm



- RP=100 yrs - Highest waves ≅ 255 cm



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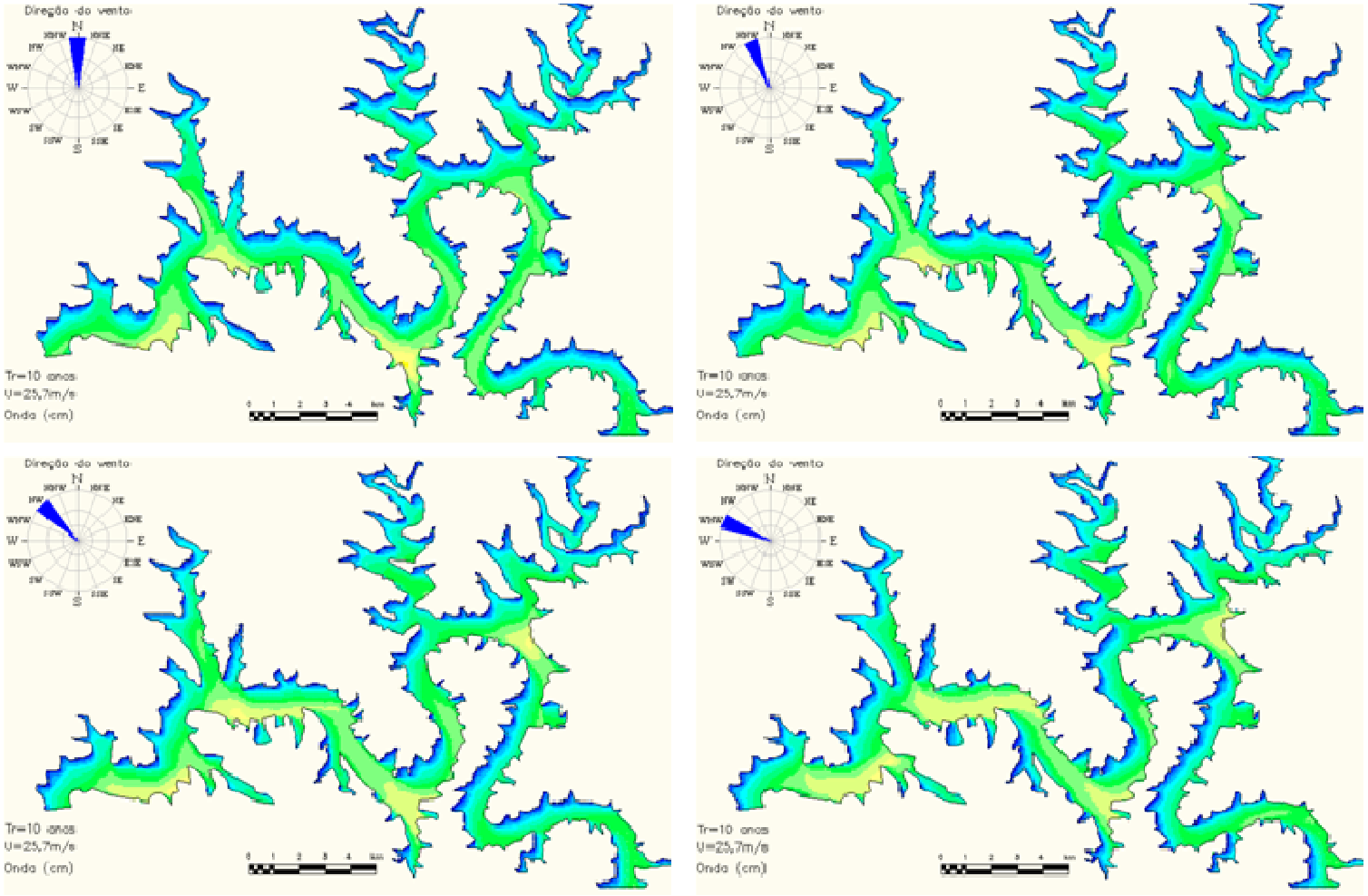
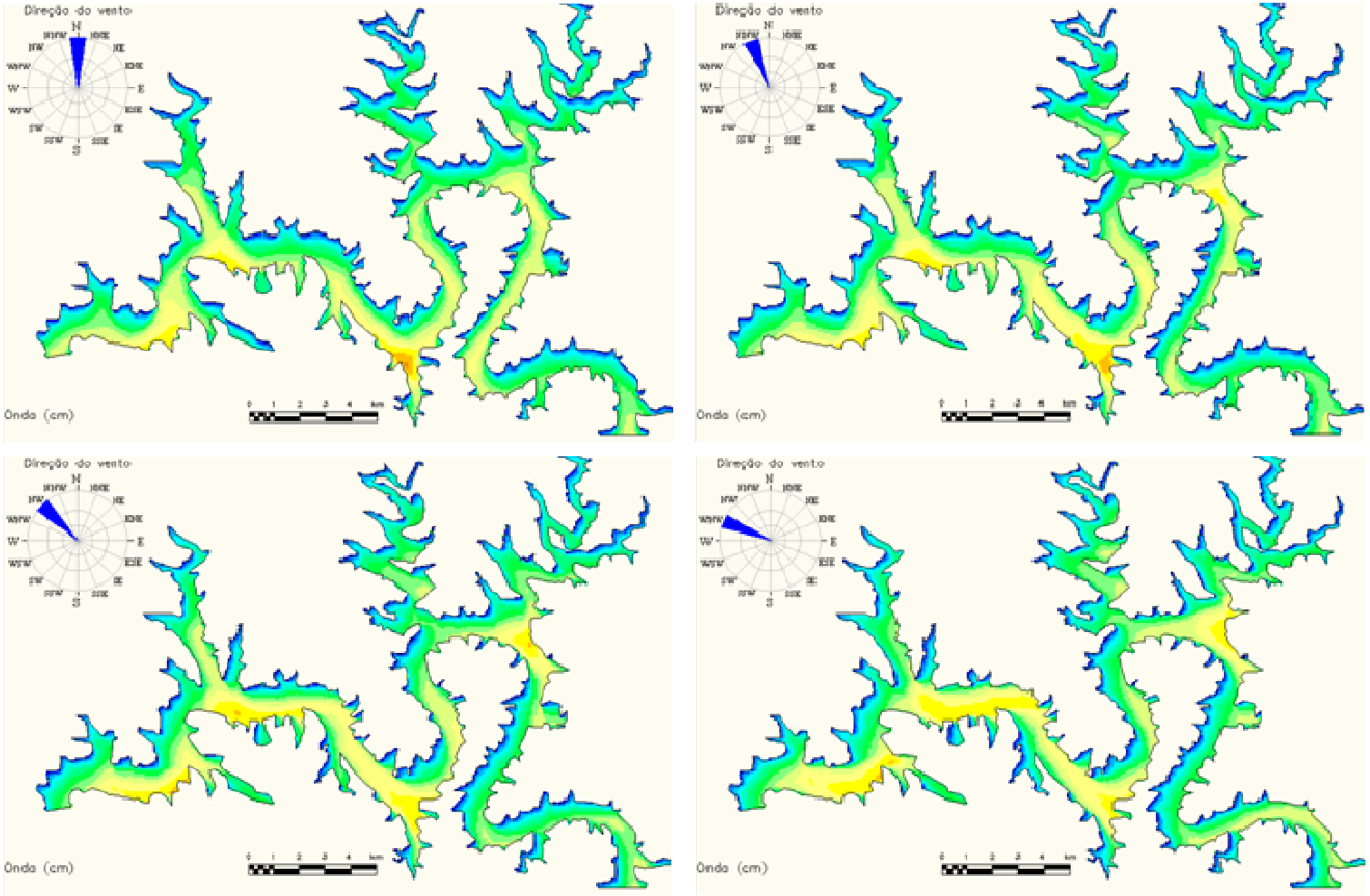


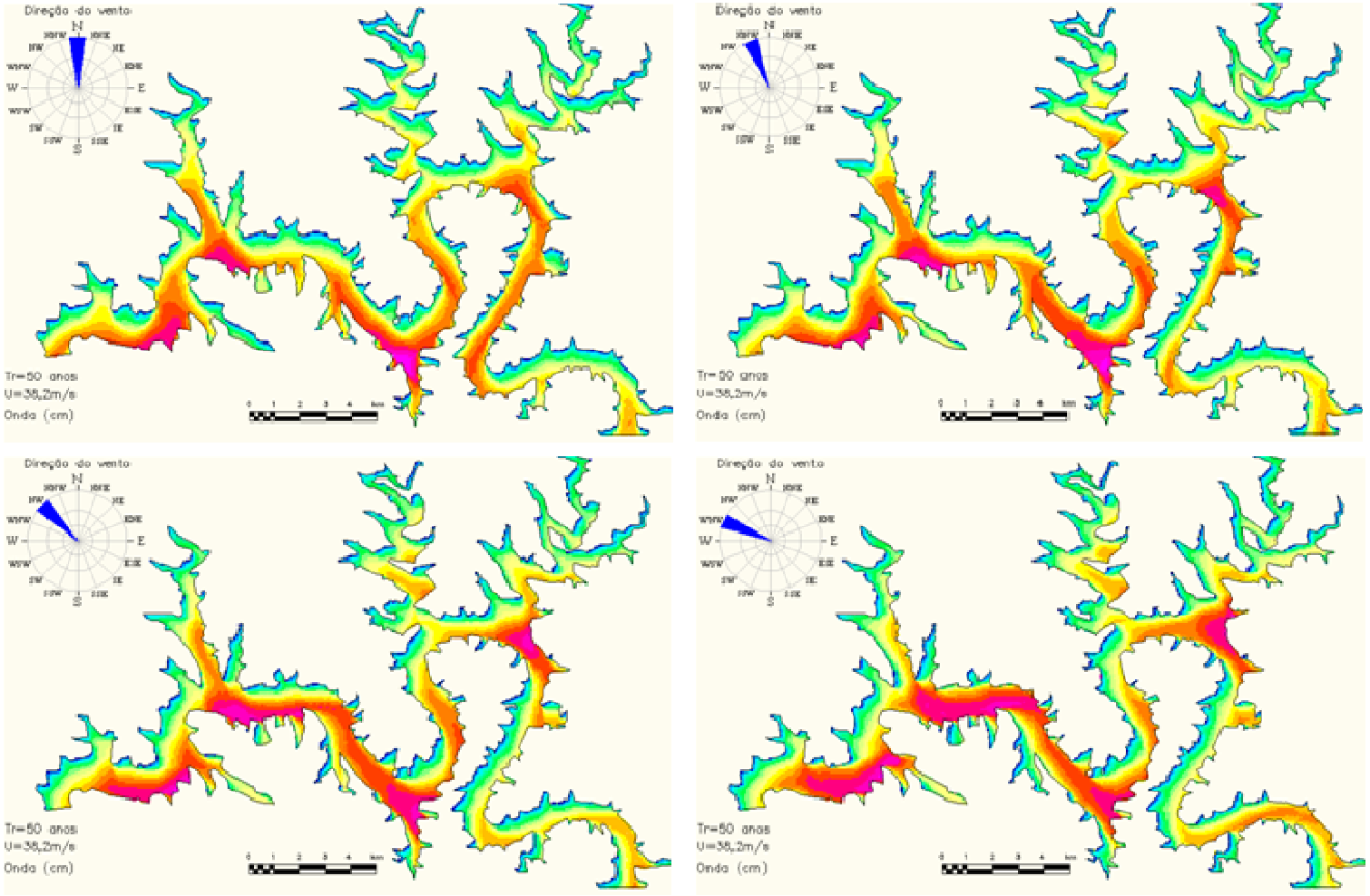
- U=25.7 m/s - Highest waves ≅ 120 cm

Results



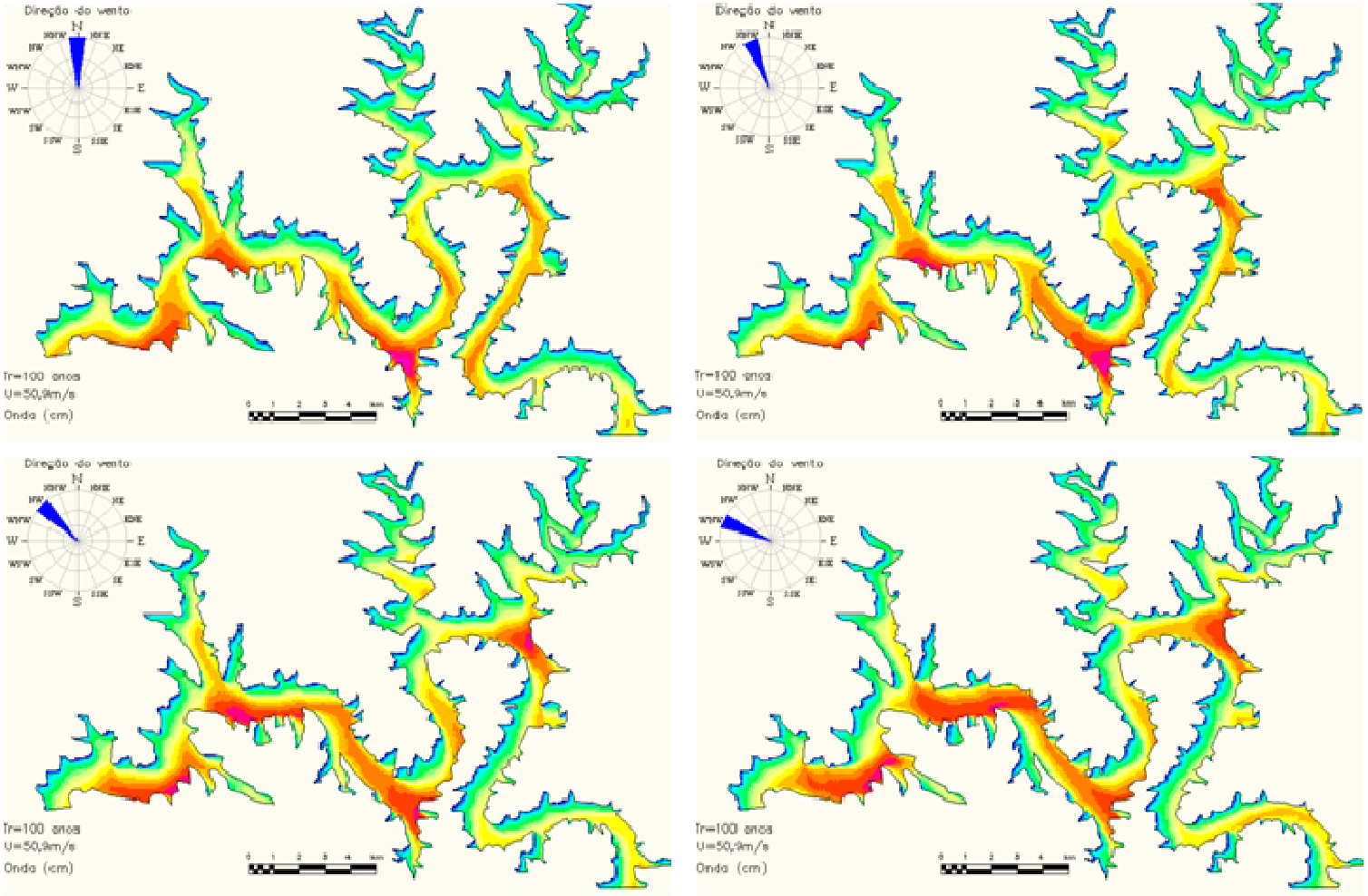
- U=29.3 m/s - Highest waves ≅ 140 cm

Results



- U=38.2 m/s - Highest waves ≅ 185 cm

Results



- U=50.9 m/s - Highest waves ≅ 255 cm

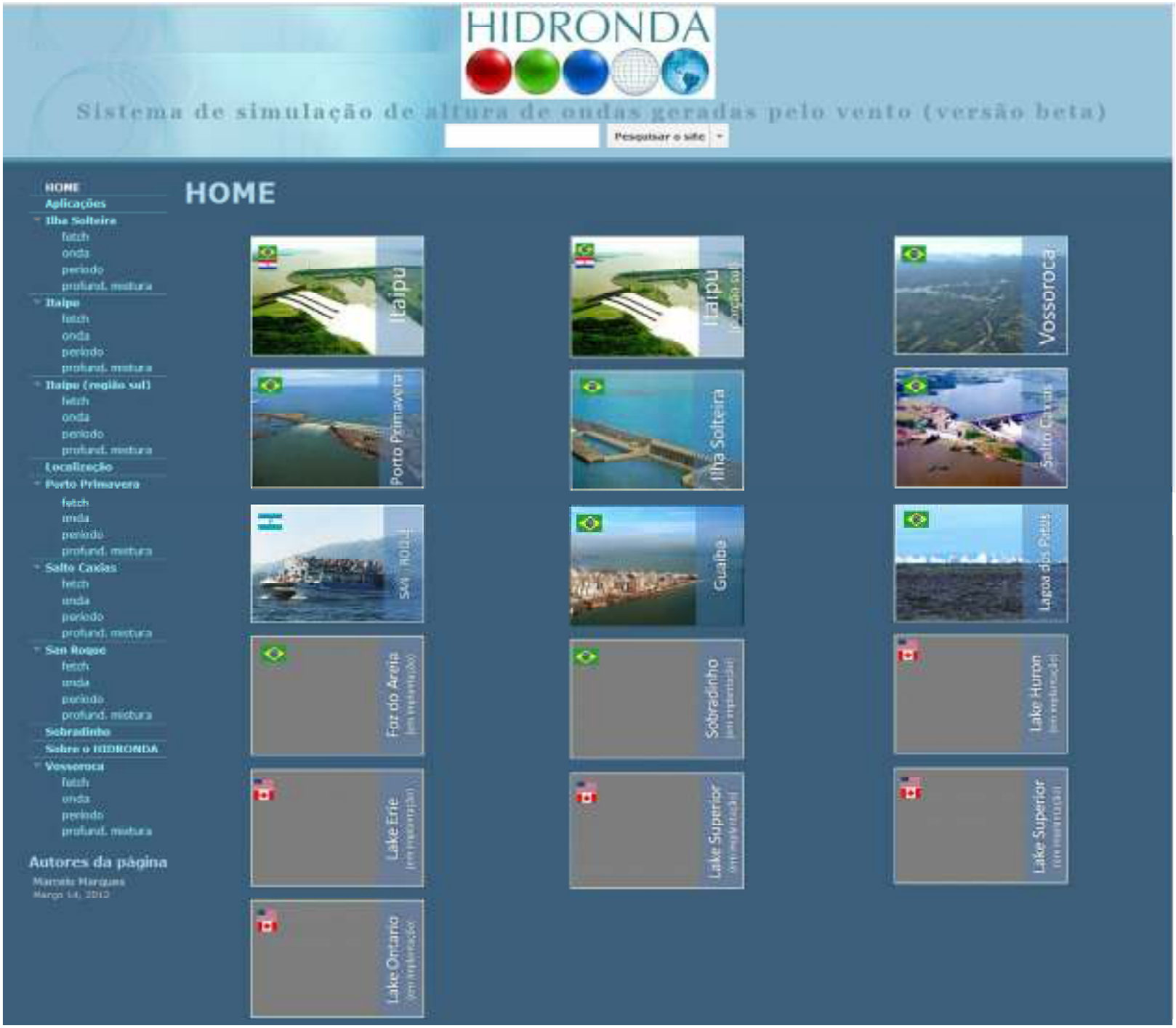
Final Remarks

- The next steps of the system development are: to integrate the wave monitoring system to the ONDACAD model, and to validate the results against monitored and modeled SWAN data (already in course)

Some Applications

- Studies of reservoir banks erosion considering the wave induced sediment transport, nowcast of waves for hydro transportation and operation of Lock and Dams, security for dams design, etc.
- A beta version of HIDRONDA (the online automated ONDACAD applied for some lakes and reservoirs) is available in:

  https://sites.google.com/site/hidronda


HIDRONDA
Sistema de simulação de altura de ondas geradas pelo vento (versão beta)
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Sobre o HIDRONDA
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Salto Caxias
Guaíba
Lagoa dos Patos
Foz do Areia
Sobradinho
Lake Huron
Lake Erie
Lake Superior
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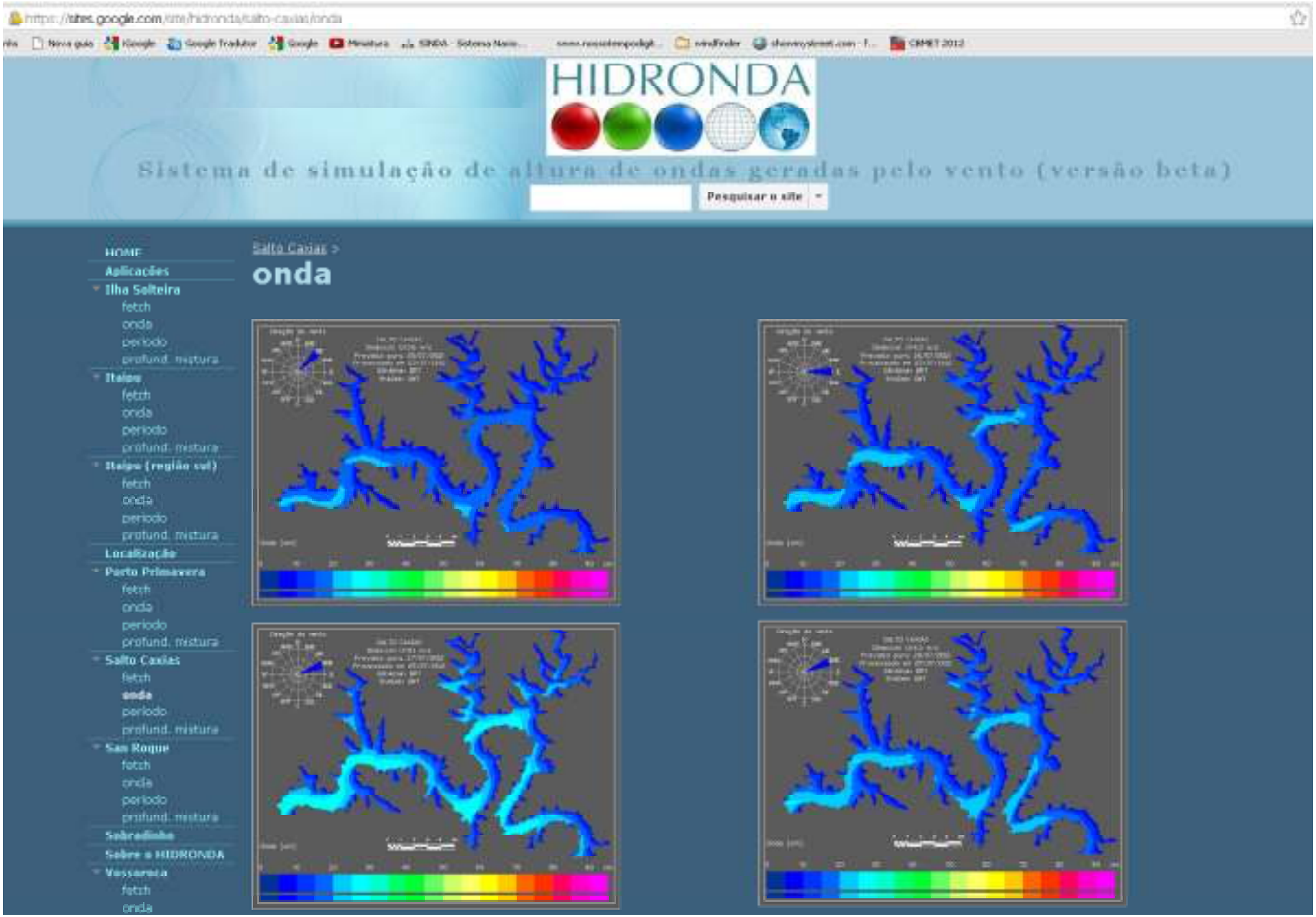
Lake Ontario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