GreenSurge 2.0: A Scalable and Efficient Additive model for Storm Surge Modeling

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Motivation

Picture credit : alliance/dpa, Isaac, New Orleans

Picture credit: Samoa Meteorological Service

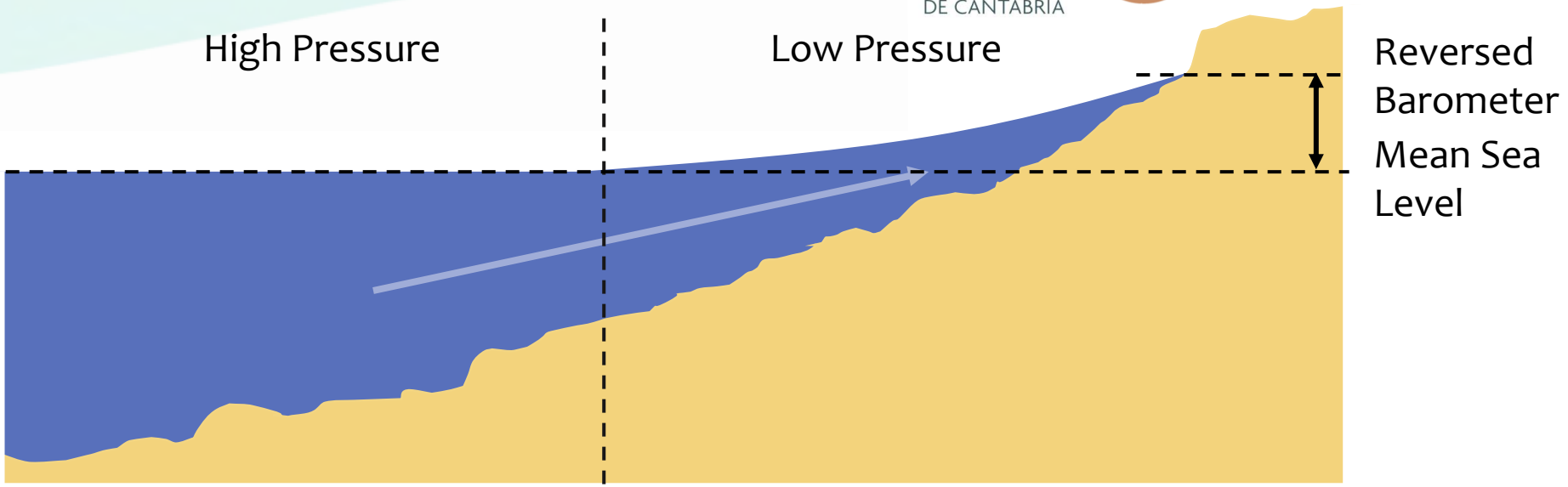
Need to improve Early Warning Systems
(Winter et al., 2020)

~~Computational Cost~~

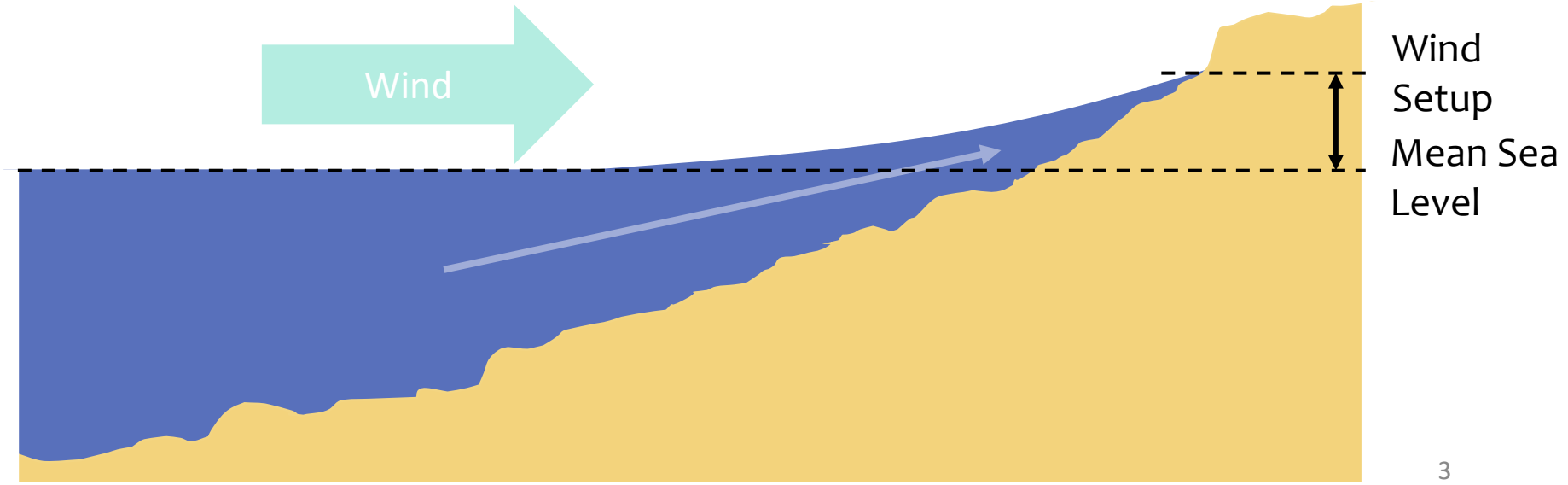
Hybrid Downscaling

Storm Surge

Pressure component



Wind Setup



GreenSurge 1.0

Green-based Hybrid modelling of Storm **Surge**

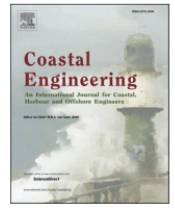
Atmospheric fields → GreenSurge → **Sea Level**

- Green's function database: level response to unit wind-sources from any direction over predefined bins
- Wind field from Holland formulation

Contents lists available at ScienceDirect

Coastal Engineering

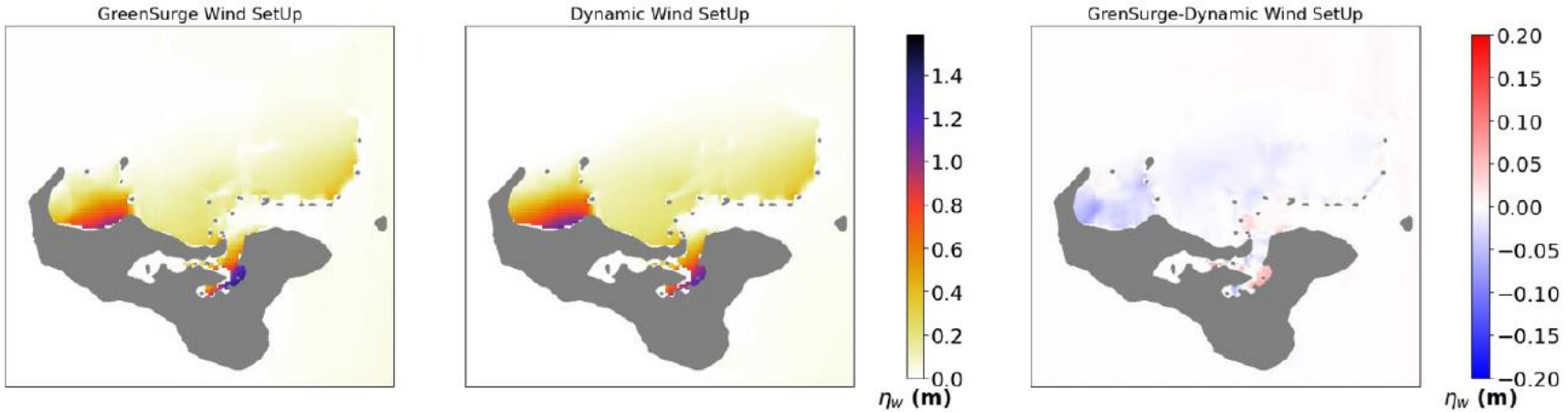
journal homepage: www.elsevier.com/locate/coastaleng



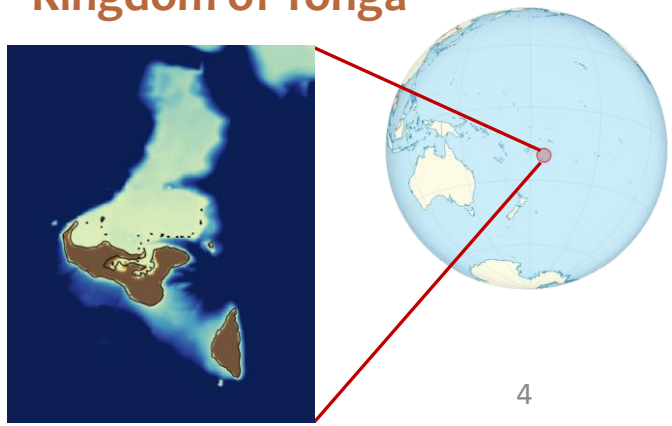
GreenSurge: An efficient additive model for predicting storm surge induced by tropical cyclones

Beatriz Pérez-Díaz *, Laura Cagigal, Sonia Castanedo, Valvanuz Fernandez-Quiruelas, Fernando J. Méndez

Tropical Cyclone Harold 2020



Study site: Kingdom of Tonga

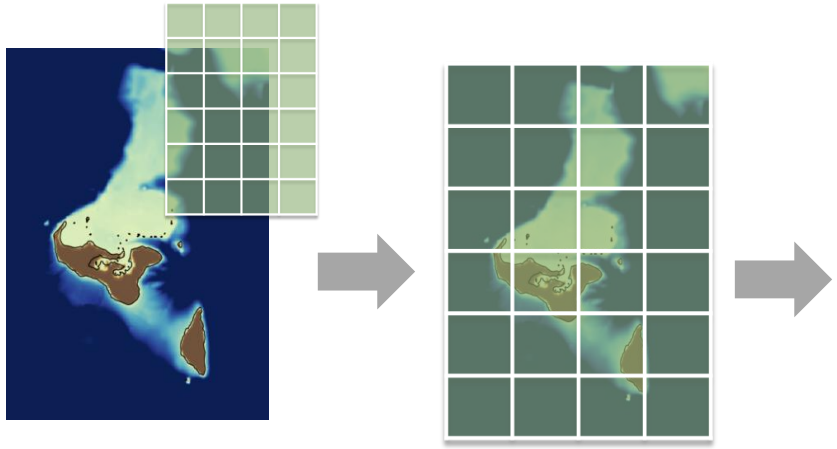


GreenSurge Methodology
Pre-run case Library Construction

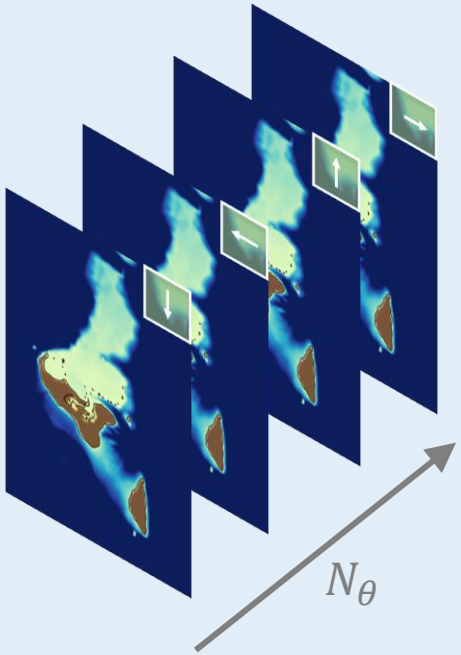
Inputs

- Computation domain
- Boundary conditions
- Forcing Tiles size and shape (N_C)
- Unitary wind magnitude (W)
- Direction discretization ($N_\theta = 360° / \Delta\theta$)
- Computation parameters
- Evolution time (T)
- Forcing sampling (dt)

Wind forcing partition



For each forcing tile



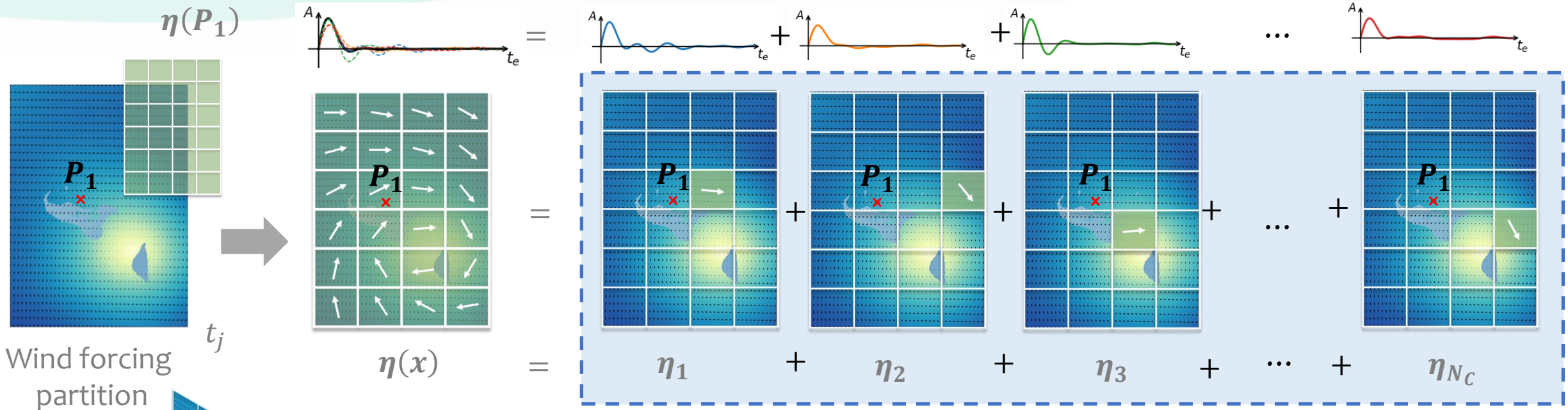
Delft3D

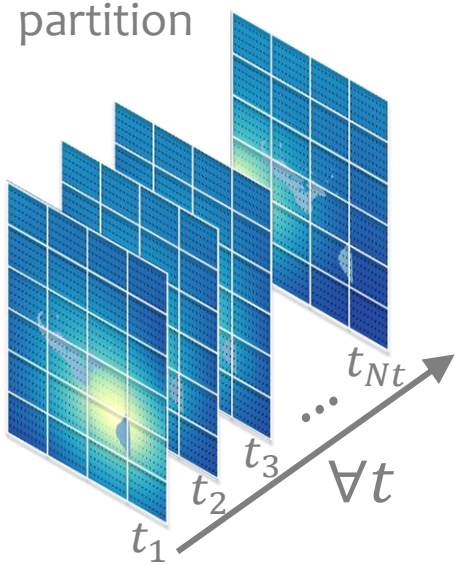
For each forcing tile and each direction

Output

GreenSurge library
Evolution of the wind generated surge during T
(size N_C* N_θ cases)

GreenSurge Methodology Reconstruction





Linear Summation

$$\eta(x,t) = \sum_{i=1}^{Nc} \sum_{j=1}^{Nt} \alpha \eta_{ij}$$

re-scaling

$$\alpha = f(W, C_D)$$

GreenSurge 2.0

- **Automation and Generalization** of the GreenSurge hybrid model
  - Mesh Generation tool
  - Numerical model, from Delft 3D to Delft 3D Flexible Mesh
  - Support for different atmospheric forcings
  - Application to different regions

- Study sites
  - Kingdom of Tonga
  - Northern Sea
  - South Oahu (Hawaii)

Mesh generation tool

UNIVERSIDAD DE CANTABRIA

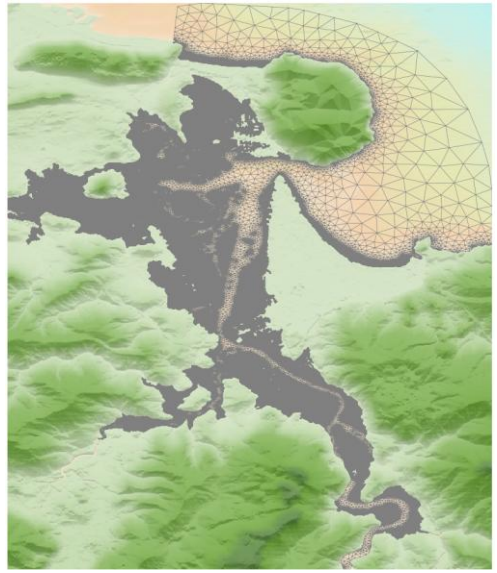
GeOcean

OCSMesh

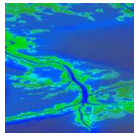
BlueMath

Key Objectives

- Computationally efficient
- Compatible with different models
- Open-source
- Scalable: from global ocean to local estuary applications

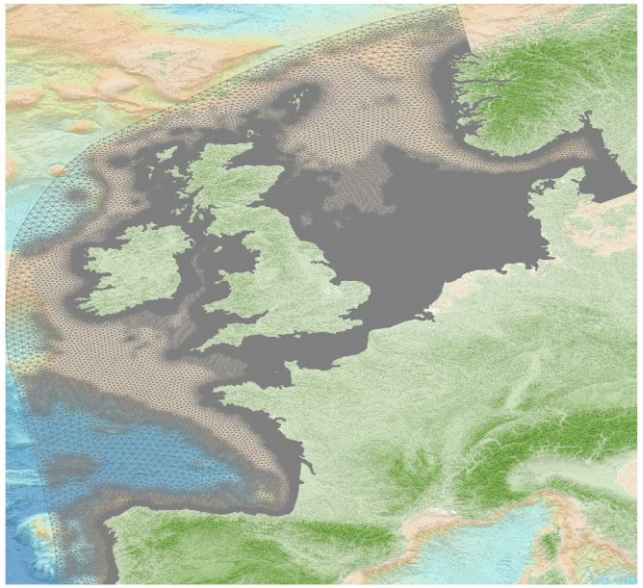


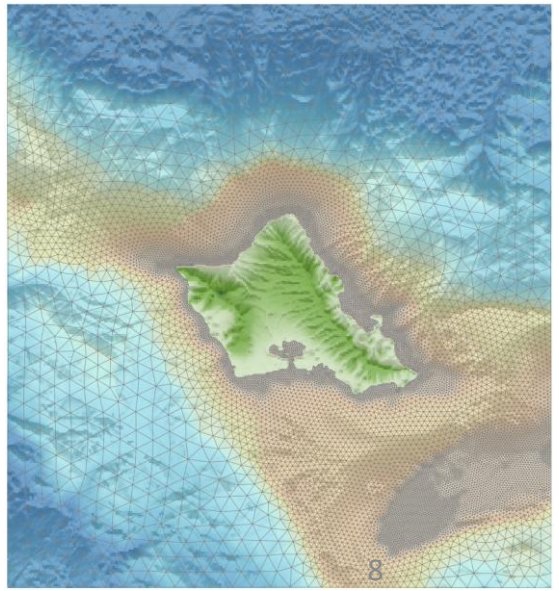
SWAN
Simulating WAves Nearshore



Delft3D FM

SCHISM

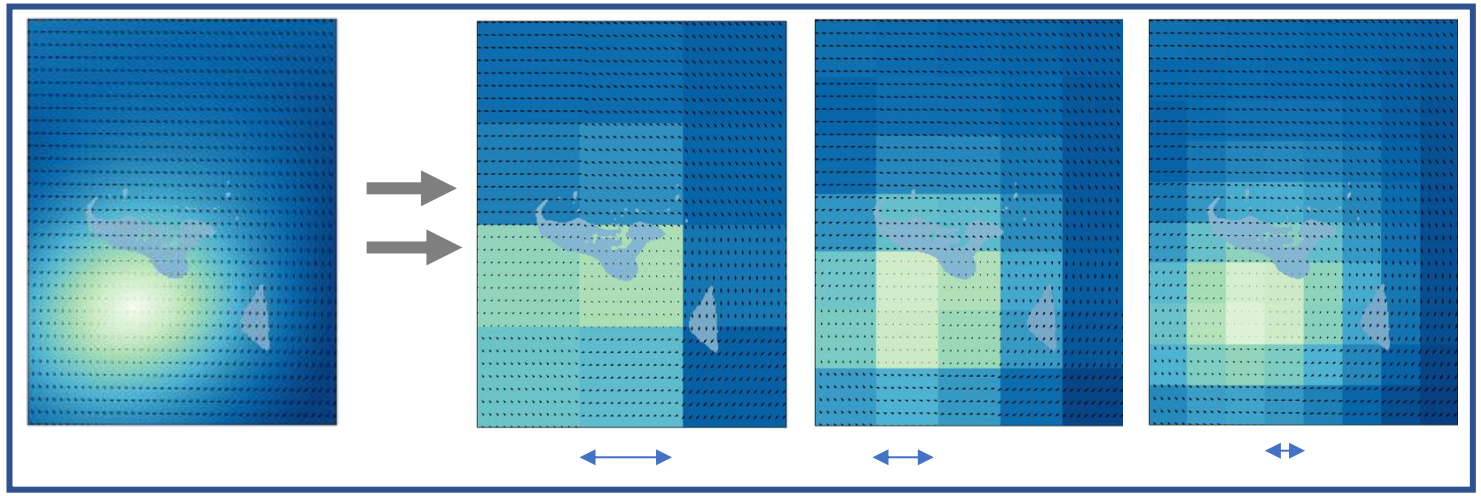




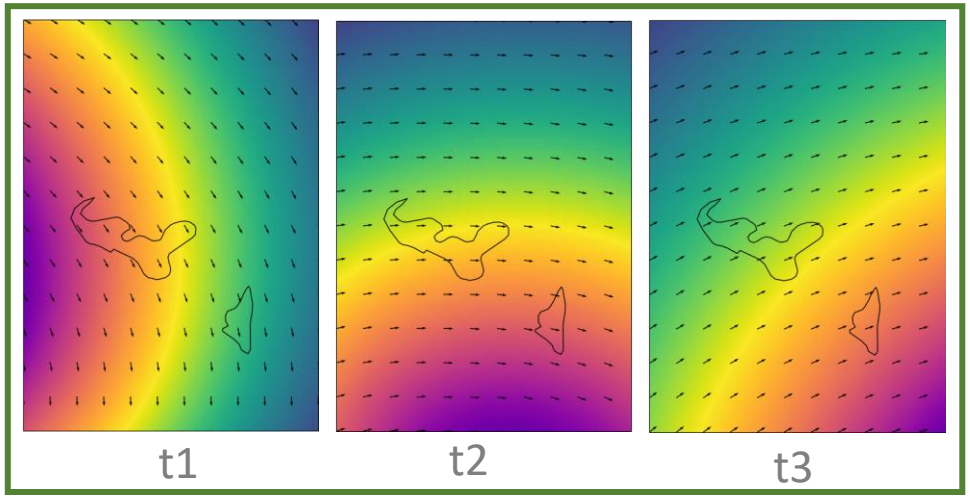
GreenSurge Methodology
Input parameters

GreenSurge parameters :

- Forcing Tiles size
- Unitary wind magnitude
- Direction discretization
- Evolution time
- Forcing sampling



Forcing Tiles size and shape (N_C)



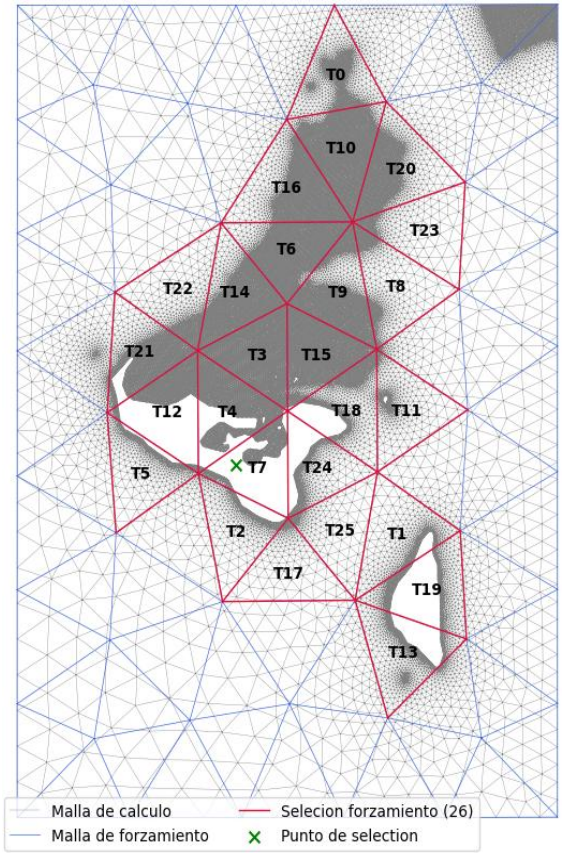
Forcing sampling (dt)

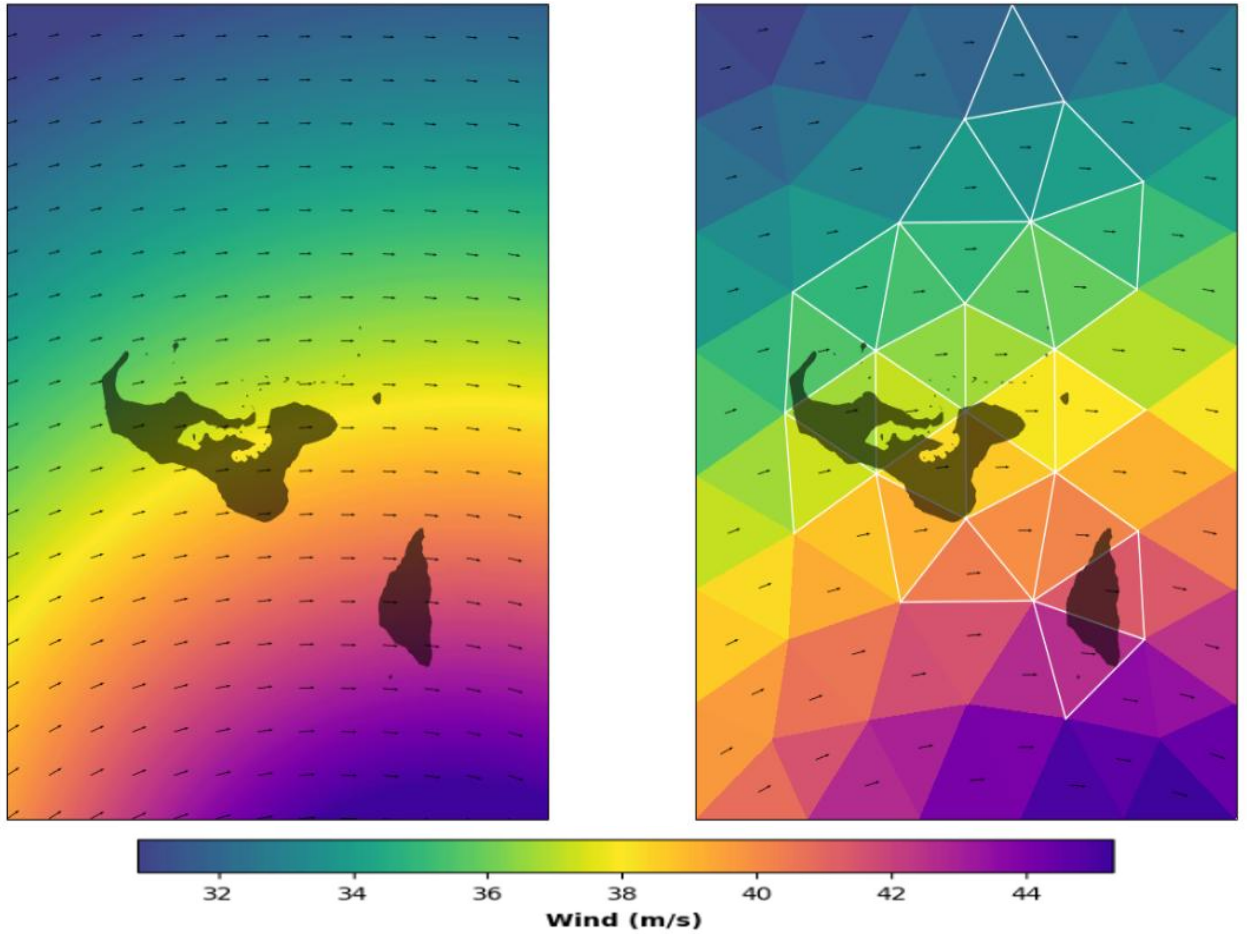
GreenSurge 2.0 Tonga

Delft3D → Delft3D FM

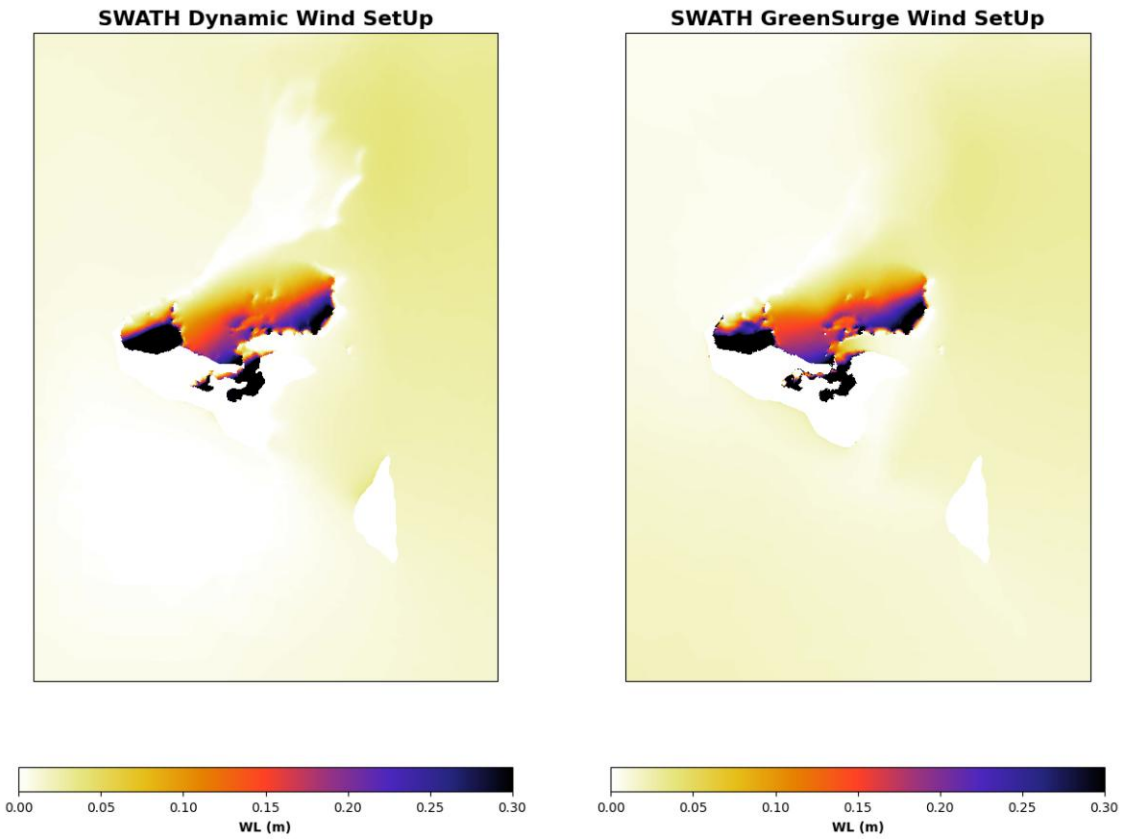
	Computational Grid	Forcing Grid
Step 1	Regular	Regular
Step 2	Irregular	Regular
Step 3	Irregular	Irregular

Wind layer from the application of the dynamic Holland Model





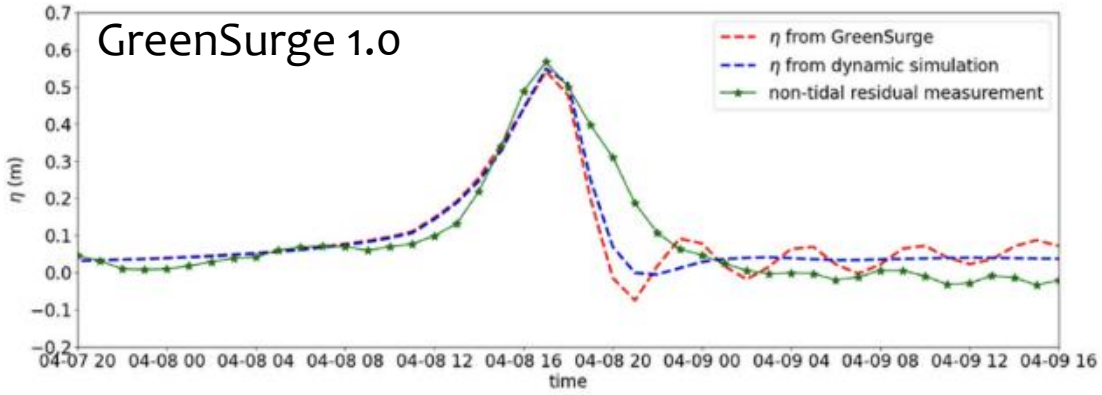
GreenSurge 2.0 Tonga

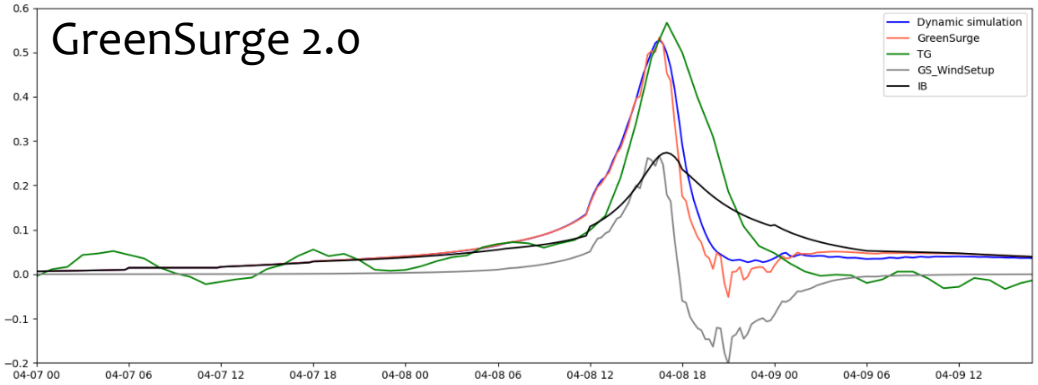


Tropical Cyclone Harold 2020

Optimization of the Inputs

- Forcing sampling (T) 1 h to 15 minutes
- Evolution time (dt) 25 hours to 24 hours
- Linear wind-speed drag parameterization
- Cases of the pre-run library number from 1920 to 576

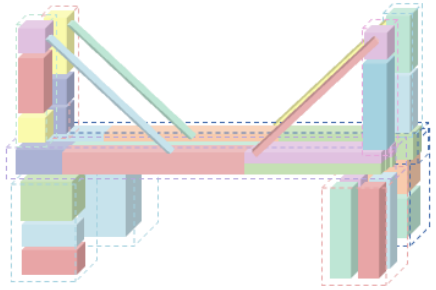




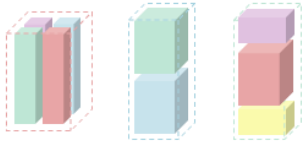
BlueMath

BlueMath

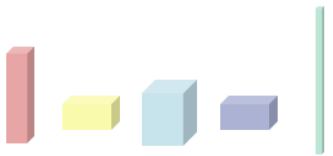
Climate Services



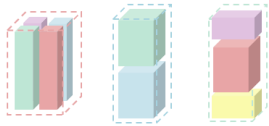
Methods



Toolkit



Methods



Statistical Downscaling

SD	**WT Emulator** (Camus et al., 2014)	**DWT** (datamining)	**Montecarlo** (datamining)	
SD	**TESLA** (Anderson et al., 2019)	**DWT** (datamining)	**ALR** (datamining)	**Montecarlo** (datamining)

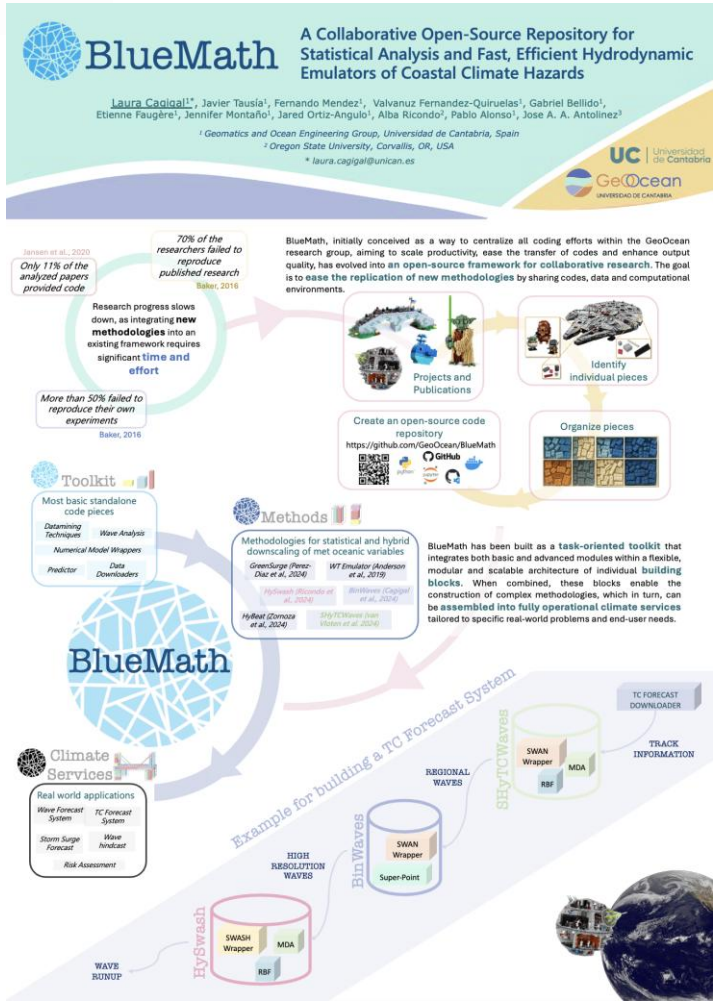
Hybrid Downscaling

HD	**BinWaves** (Cagigal et al., 2024)	**SWAN** (wrapper)				
HD	**GreenSurge** (Pérez-Díaz et al., 2024)	**Delft3D** (wrapper)				
HD	**SHyTCWaves** (van Vloten et al., 2023)	**MDA** (datamining)	**SWAN** (wrapper)			
HD	**HyBeat** (Zornoza et al., 2024)	**LHS** (datamining)	**MDA** (datamining)	**XBeach** (wrapper)	**2D PCA** (datamining)	**RBF** (datamining)
HD	**HySwash** (Ricondo et al., 2024)	**LHS** (datamining)	**MDA** (datamining)	**SWASH** (wrapper)	**1D PCA** (datamining)	**RBF** (datamining)

BlueMath

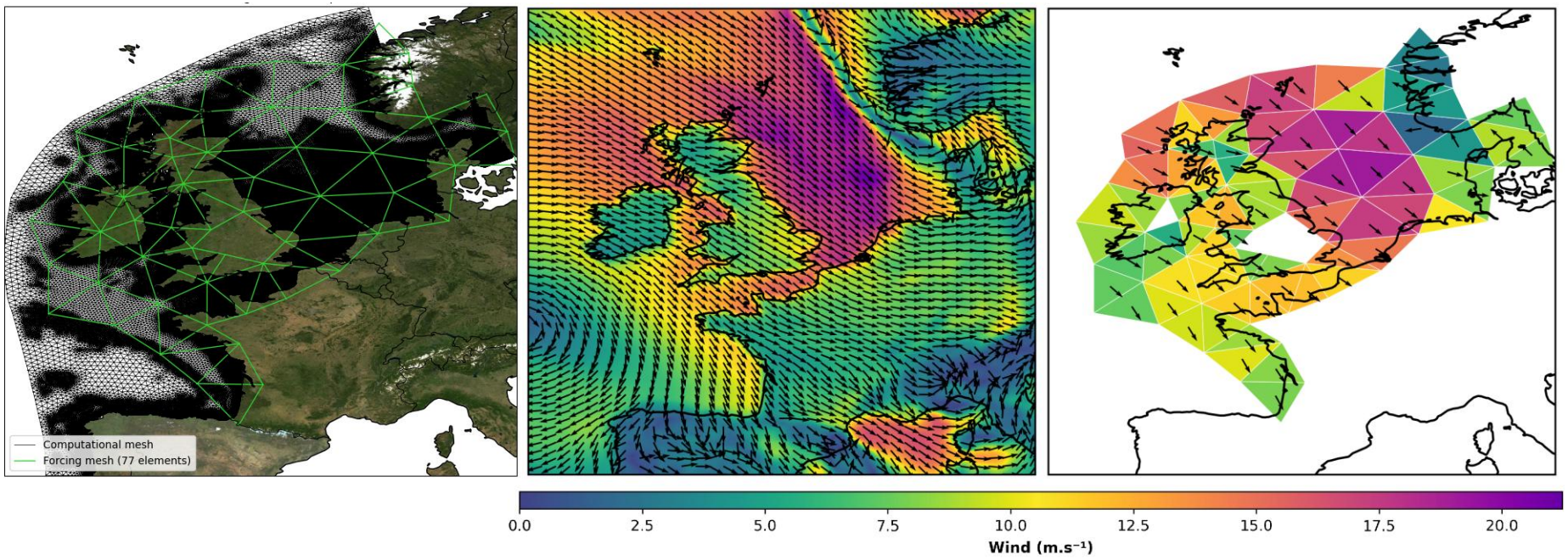
ROOM 2 Thursday between 15:05 and 15:10 :
BlueMath, A Collaborative Open-Source Repository for Statistical Analysis and Fast, Efficient Hydrodynamic Emulators of Coastal Climate Hazards

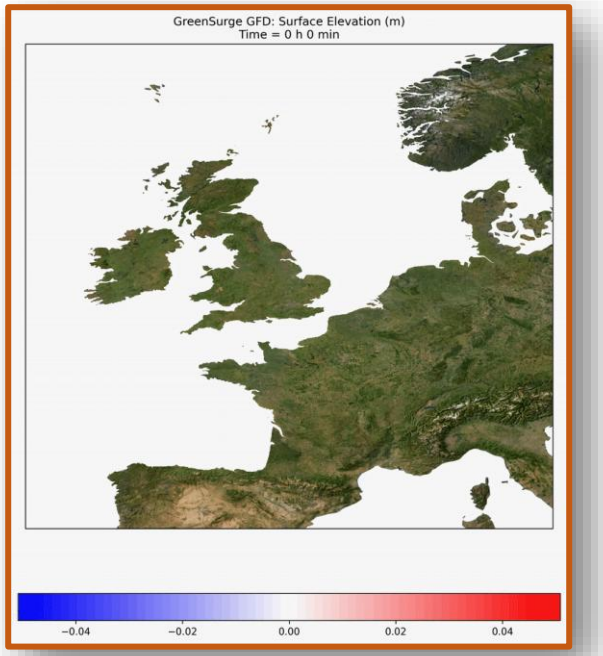
PRESENTER: Laura Cagigal



GreenSurge 2.0 North Sea setup

- Make a comparison with the GTSMv4.1 dataset (TU Delft)
  - Wind field from Era5 and Charnock parametrization
- Evaluate the accuracy and benefits of this methodology compared to the dynamical one

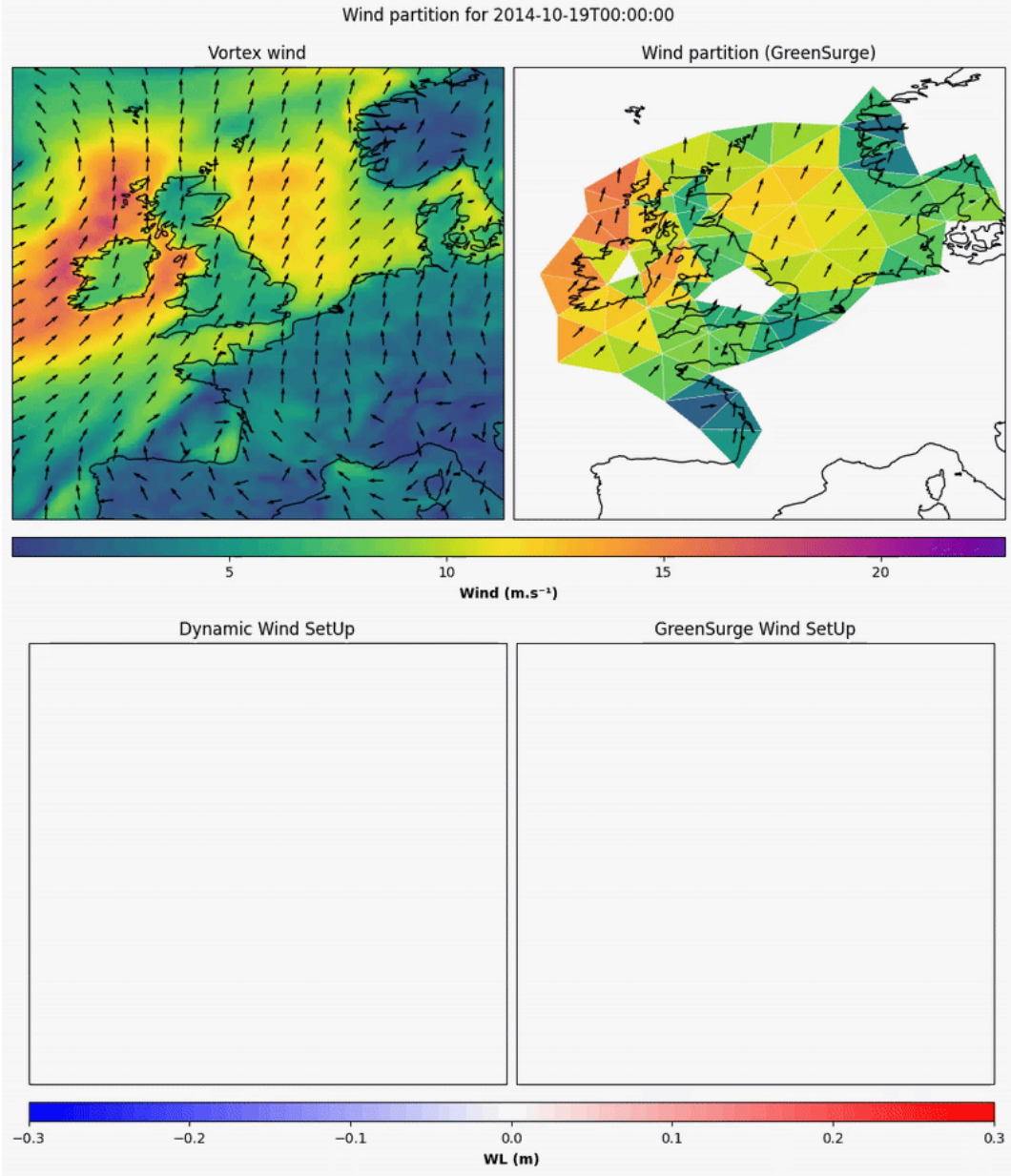




GreenSurge 2.0. North Sea

Inputs :

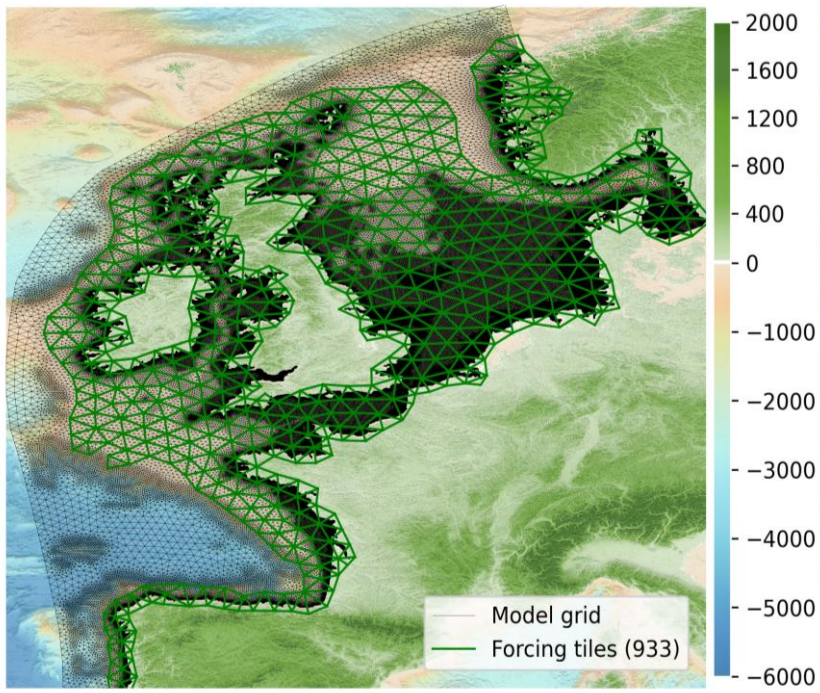
- Wind field from Era5 + Charnock wind-drag parametrization
- Evolution time (T) 48 hours
- Forcing time (dt) 1 hour (from Era5 time step)
- Unitary wind magnitude (W) 40 m/s
- Direction discretization (Δθ) 15°

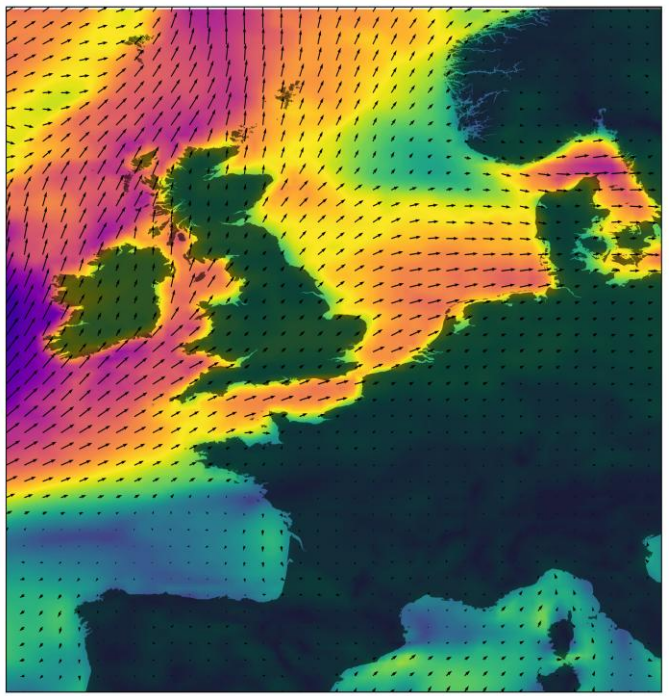


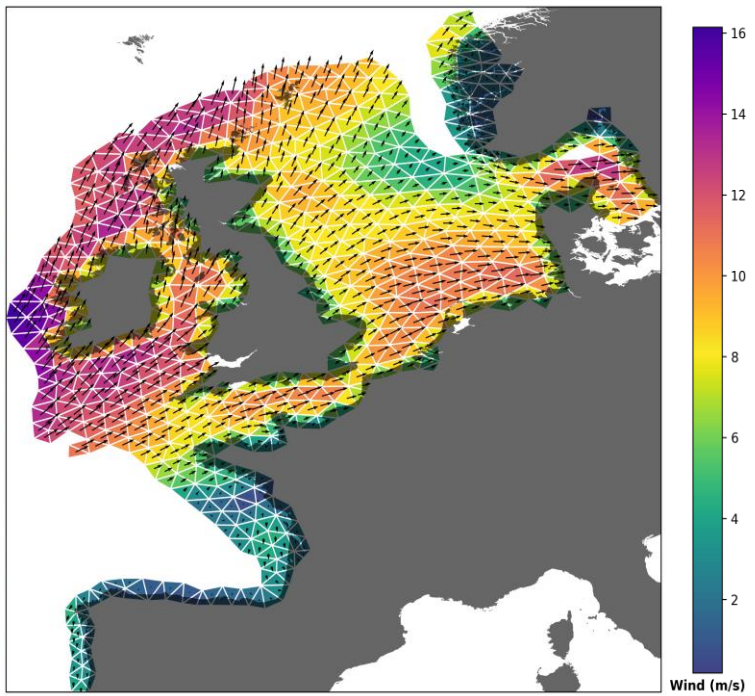
GreenSurge 2.0 North Sea full setup

Ongoing tasks
- Data Management
- Pressure effect modeling

Wind field from Era5







Acknowledgements

EasyFlood Emulating Automatically SYstems of coastal FLOODing. Funded by the spanish Ministry of Science and Innovation. Call 2022 - «Knowledge Generation Projects».

HyBay: An efficient hybrid tool to assess the effect of adaptation measures to climate change in estuaries and bays. Funded by the spanish Ministry of Science and Innovation. Call 2022 - «Knowledge Generation Projects».

MyFlood multi-scale hybrid shortterm predictions and climate change projections system for compound flooding. Funded by European Union Next GenerationEU/PRTR

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