

*Inria*



université  
de BORDEAUX

# Cardamom

**Certified Adaptive discRete moDEls for robust simulATIons of  
coMplex fLOws with Moving fronts**

# Cardamom

## 2015 (EPC in 2016)

H. Beaugendre, B. INP  
M. Colin, B. INP  
PM Congedo, Inria  
C. Dobrzinsky, B.INP  
M. Kazolea, Inria  
L. Mieussens, B. INP  
M. Ricchiuto, Inria



## 21/04/2021

N.Barral, B. INP (fall 2019)  
H. Beaugendre, B. INP  
M. Colin, B. INP  
E. Gaburro, Inria (December 2020)  
M. Kazolea, Inria  
M. Parisot, Inria (End 2019)  
M. Ricchiuto, inria

8 PhDs  
3 postdoc  
3 engineers

R. Abgrall, Int.Chair  
A. Frohely, MMG

Anne-Laure Gautier  
(mais aussi S. Blondel Duthil, N. Jahier)

# Cardamom

## Projets:

3 région, 3 ANR (1 coord.m 2 en cours), 1FUI, 3 Eu. (1 coord., 2 en cours), 1 Eu IF (MSCA Superman)  
2 Cordis, 2 ADT, 3 EA

## Partners and Collaborations:

BRGM: UHAINA, Intercarnot, 2 ANR in phase 2

CEA: 2 PhDs (1 via LRC with IMB) -> num.meth. tsunamis + simulation of turbulent supersonic flows

ONERA: 1 PhD -> improved immersed methods for turbulent flows

EDF: numerical schemes in TELEMAC

PMEs: BGS IT&E, EXOES, Seaturns, etc

Academia: Duke U., Polytech. Montreal, RISE, U. Trento, Politecnico Milano, U. Roma la Sapienza, etc etc

## Production and visibility:

Codes: MMG/ParMMG, Aerosol/UHAINA, + X (with X large) research codes of variable (small) size

Publications: >50, JCP, SIAM SISC, Computers&Fluids, JFM, Coast.Eng., Oc.Mod, WaterWaves, etc etc

E. Boards: Computers & Fluids, J.Comput.Phys., Water Waves, Applications and Applied Math.

Organisation: B'WAVES series, EMRSIM series, MS at major conf. (SIAM, ECCOMAS, WCCM, etc.)

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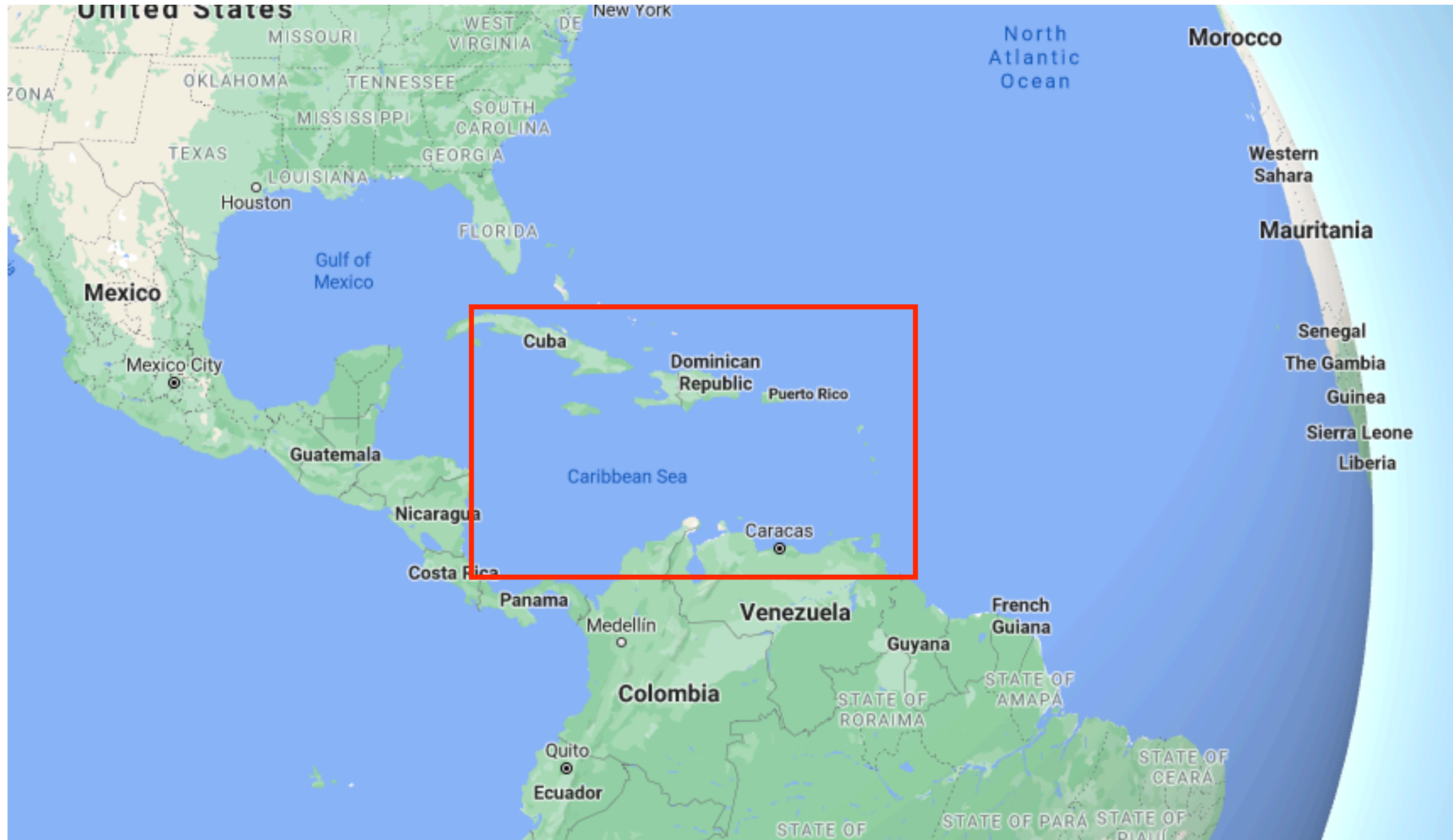
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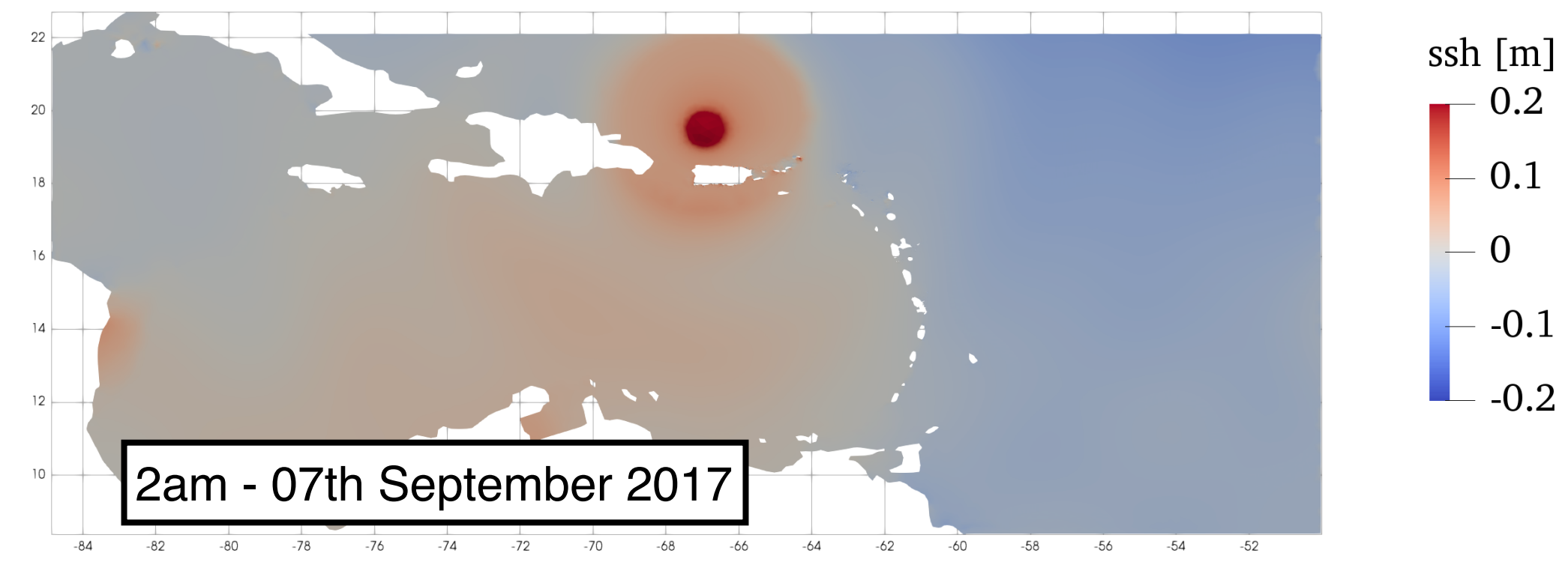
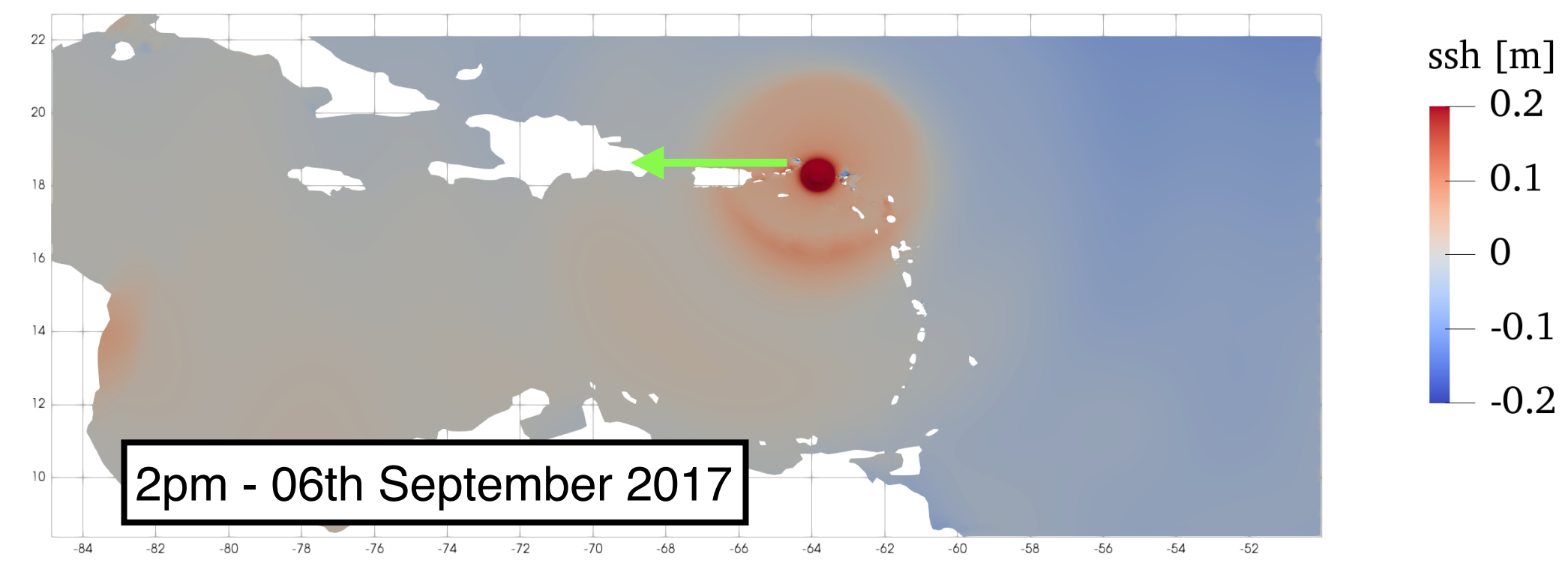
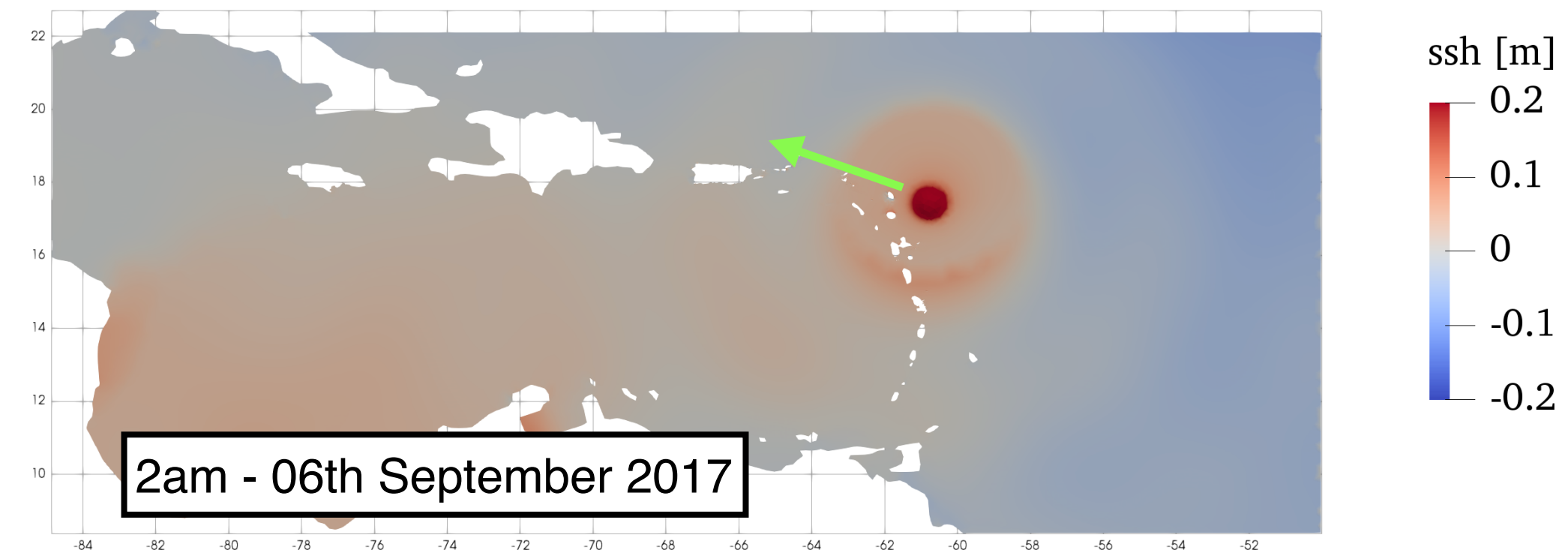
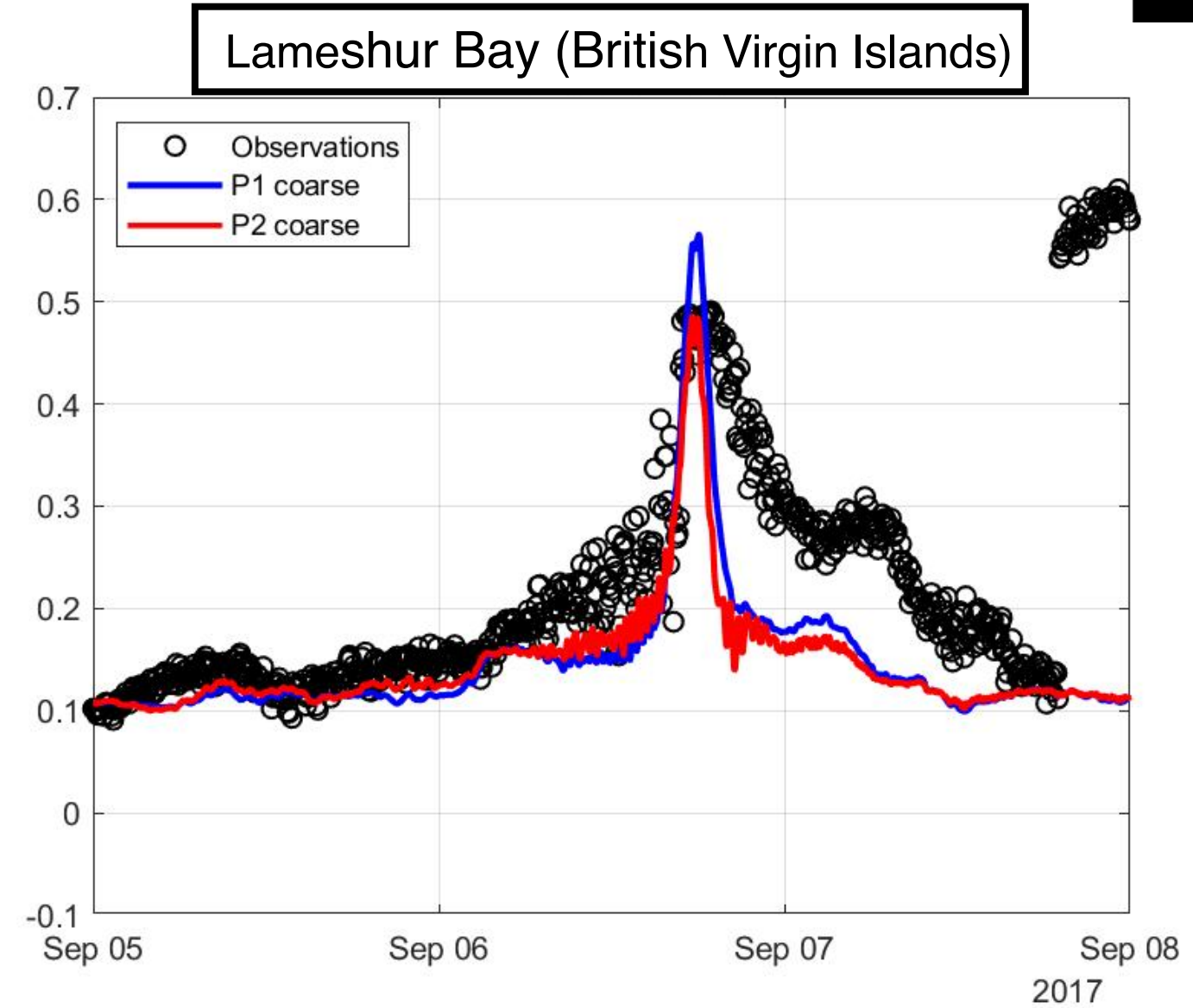
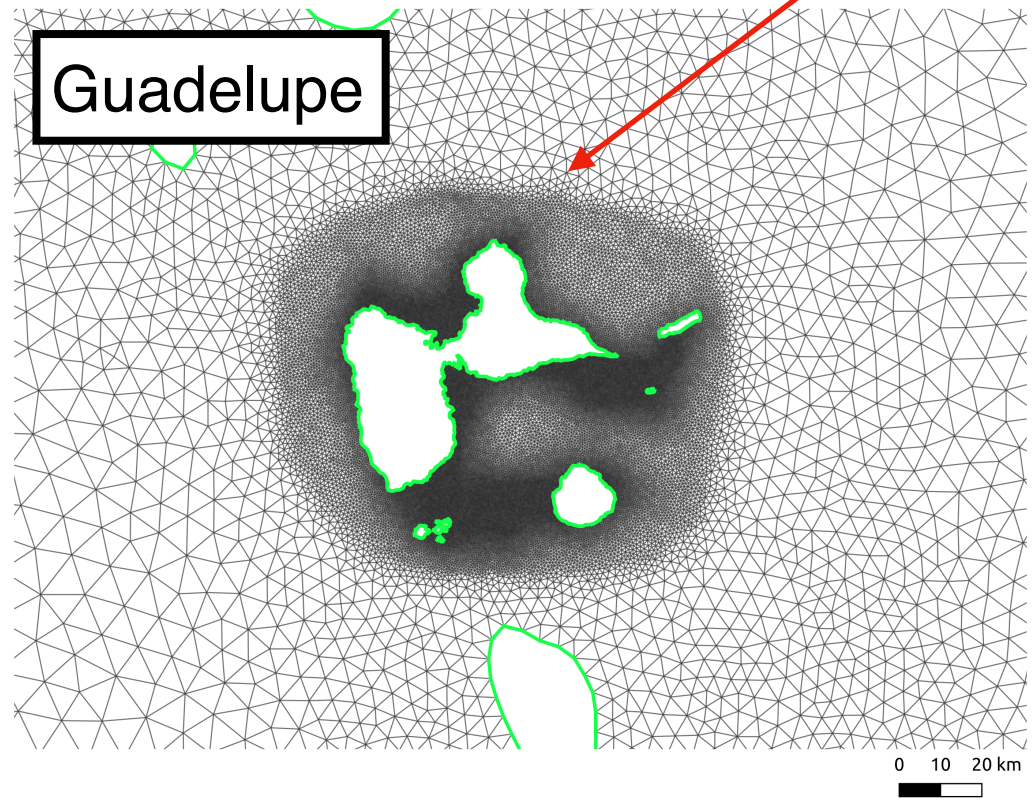
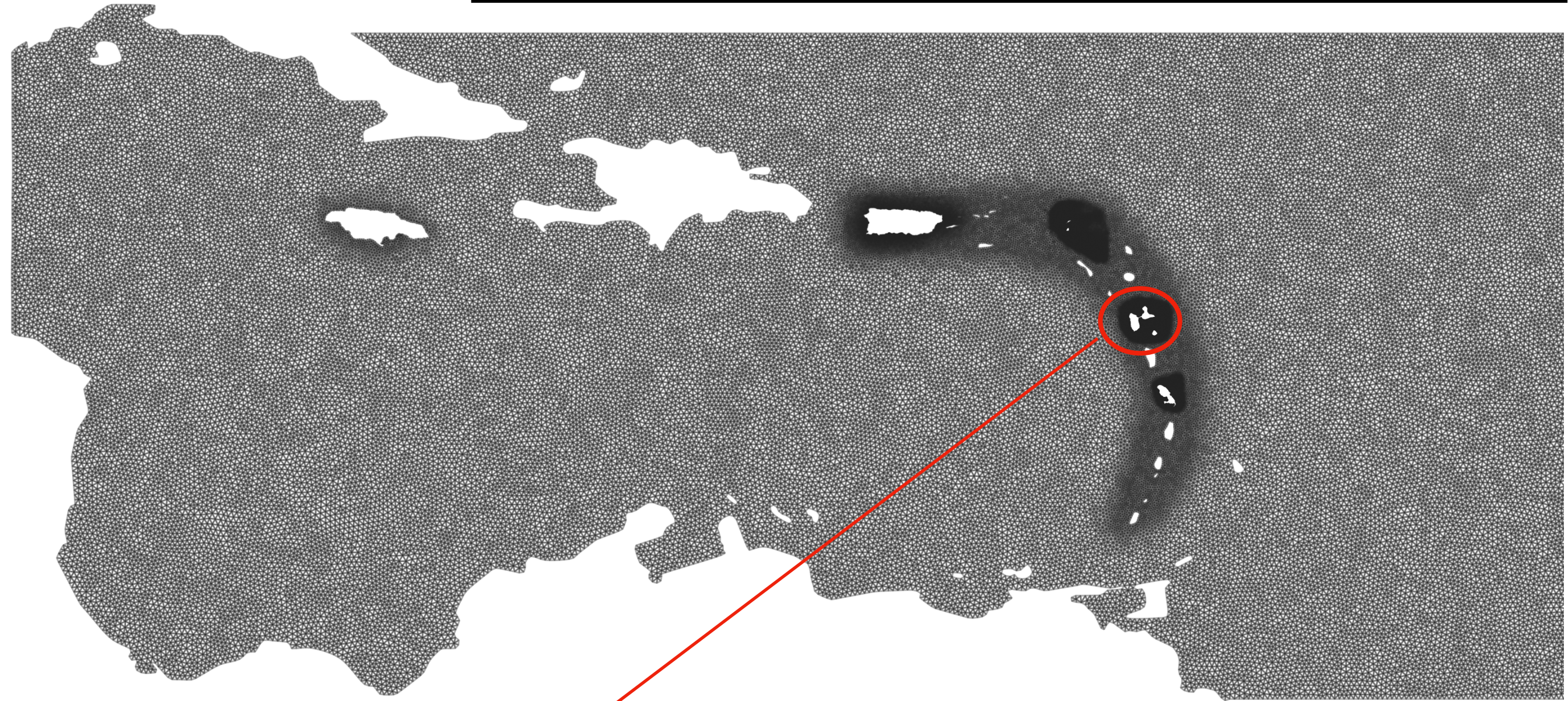
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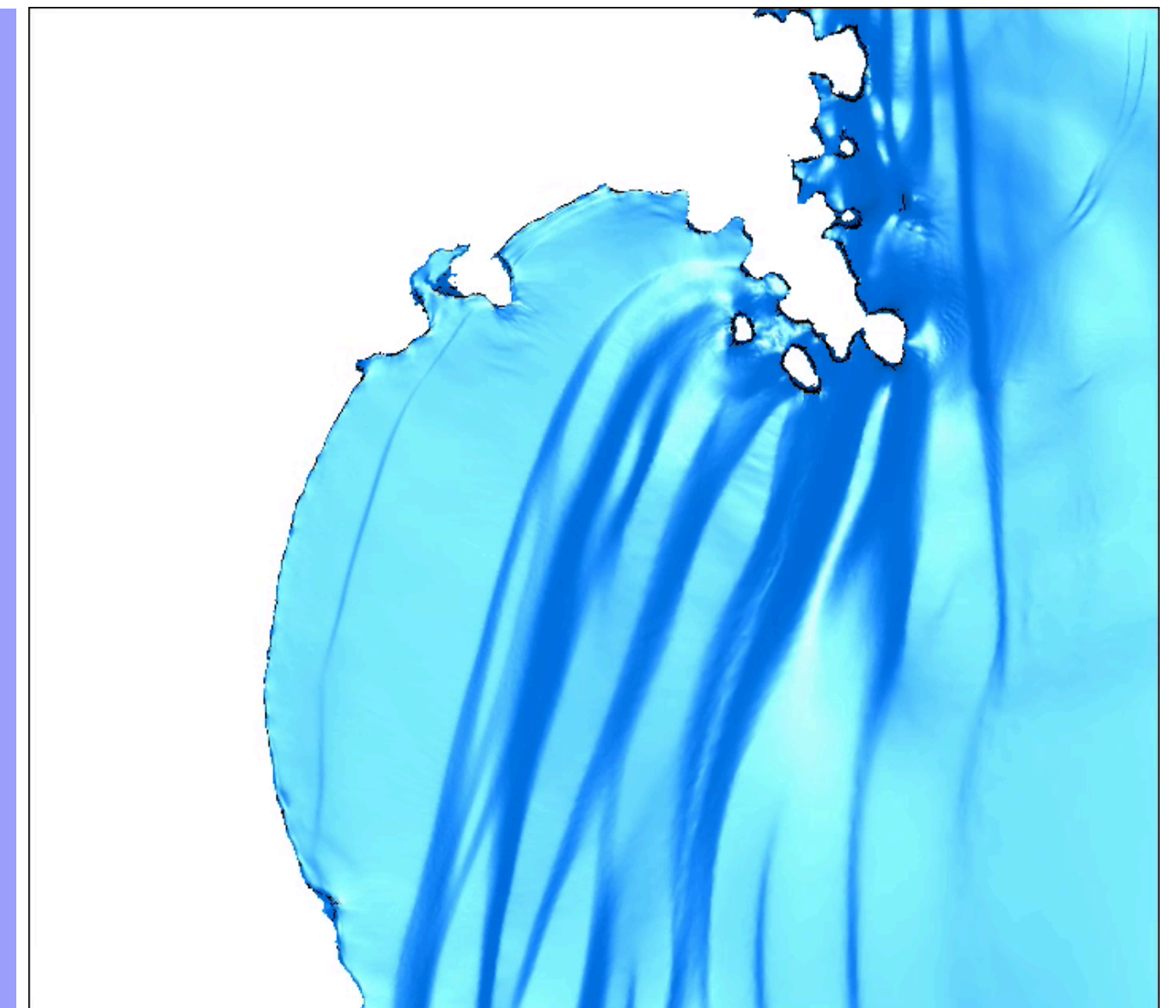
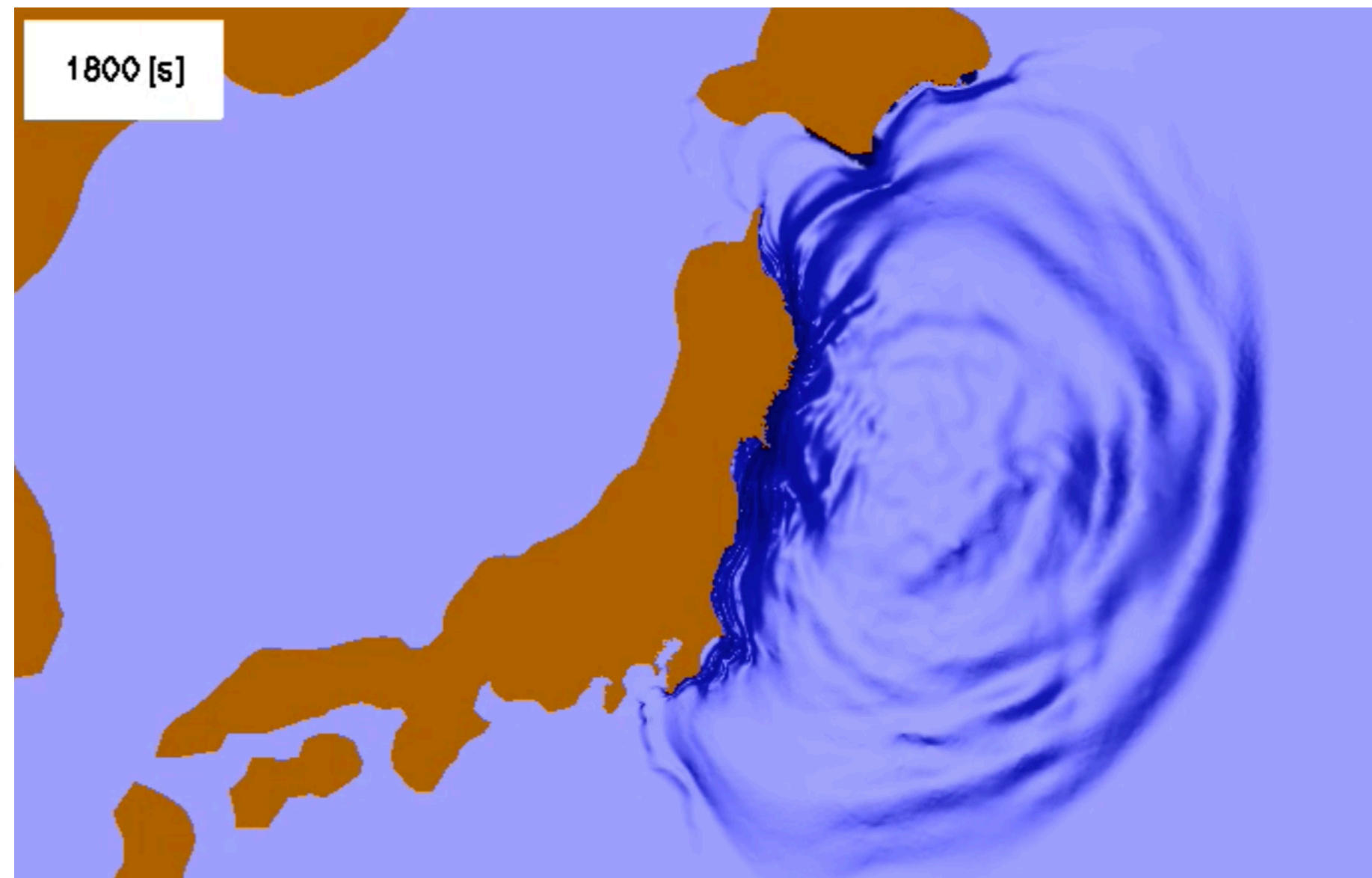
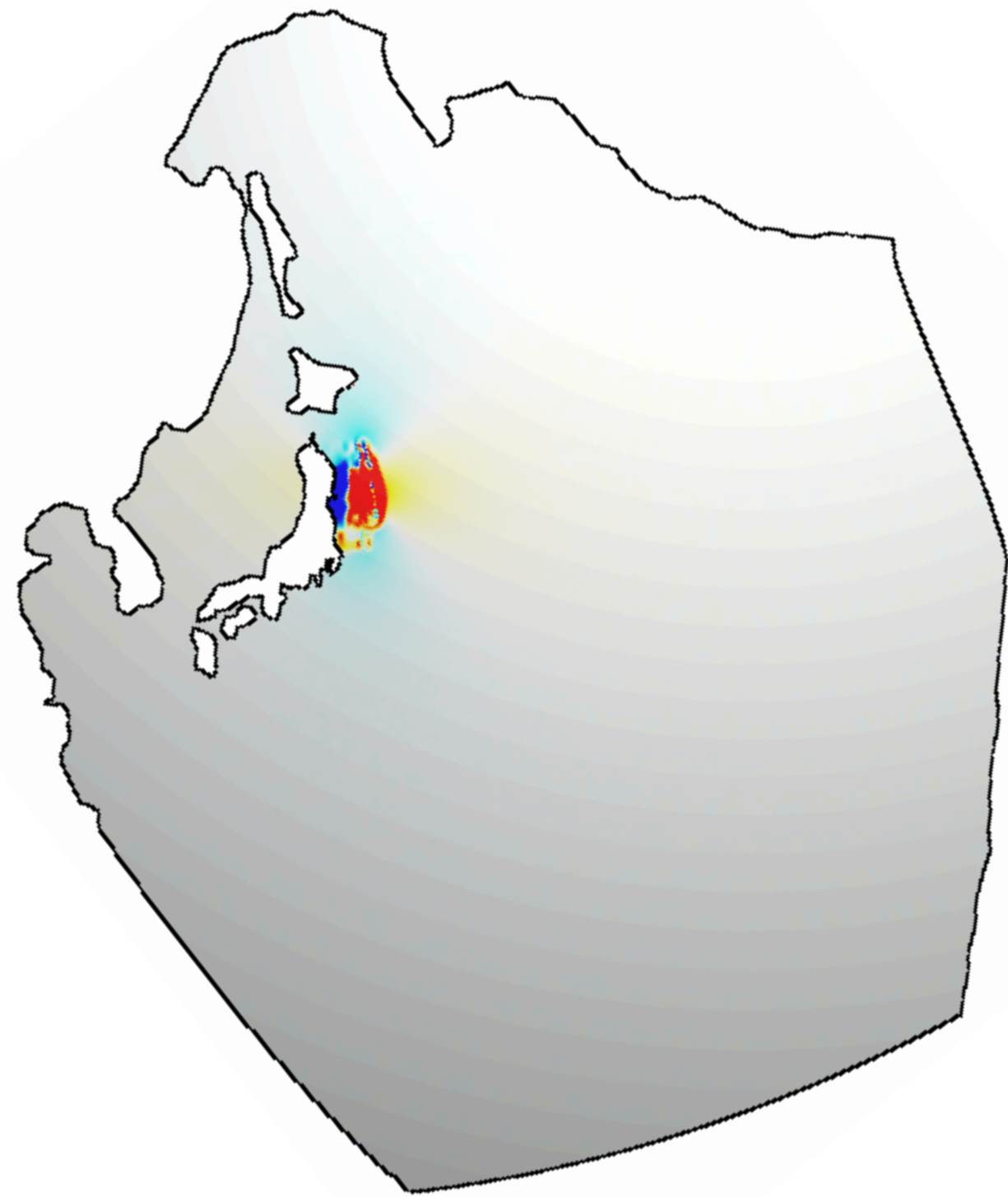
# Hurricane Irma (Caribbean Islands, September 2017)



*Irma*

# Hurricane Irma (Caribbean Islands, September 2017)





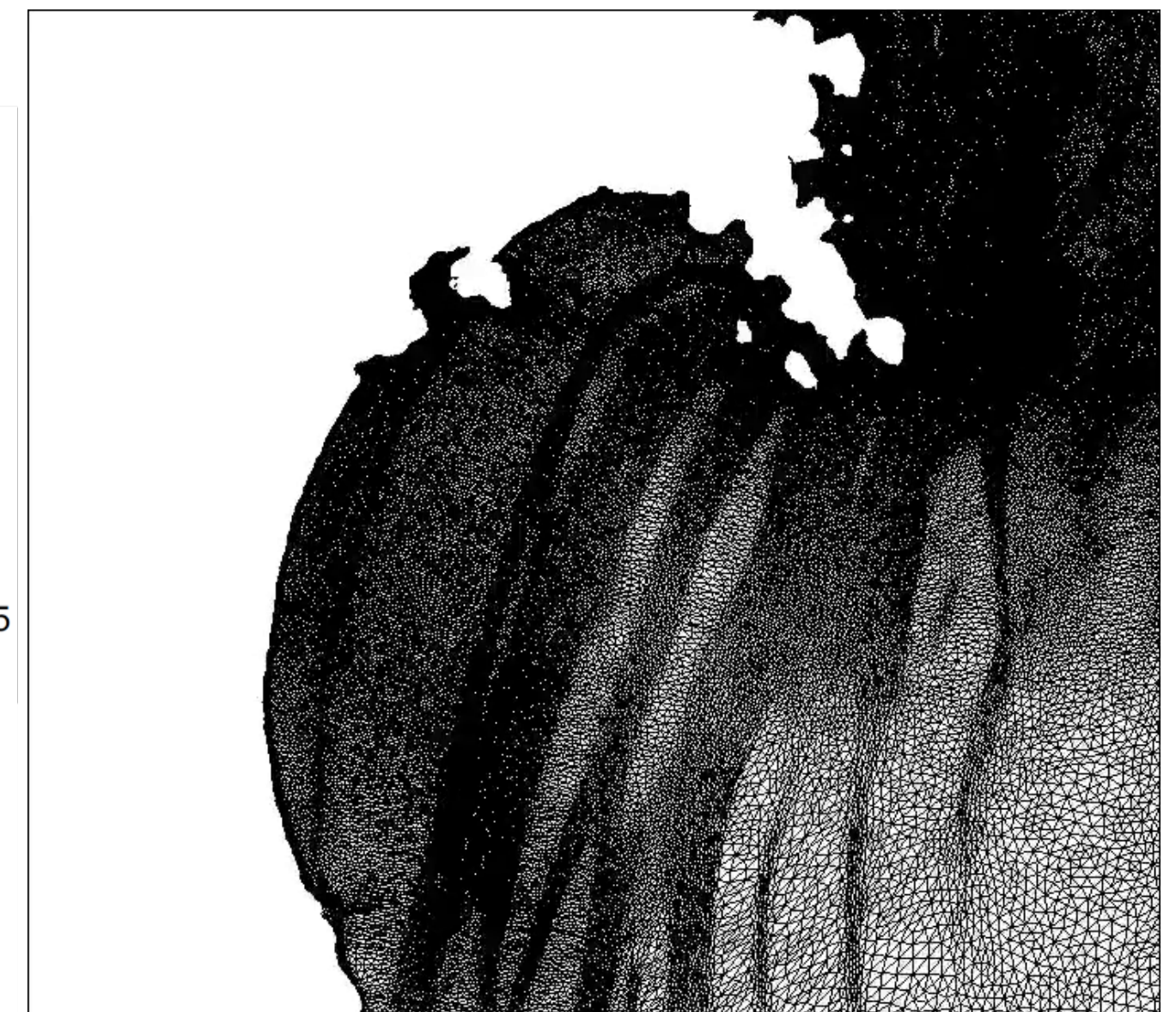
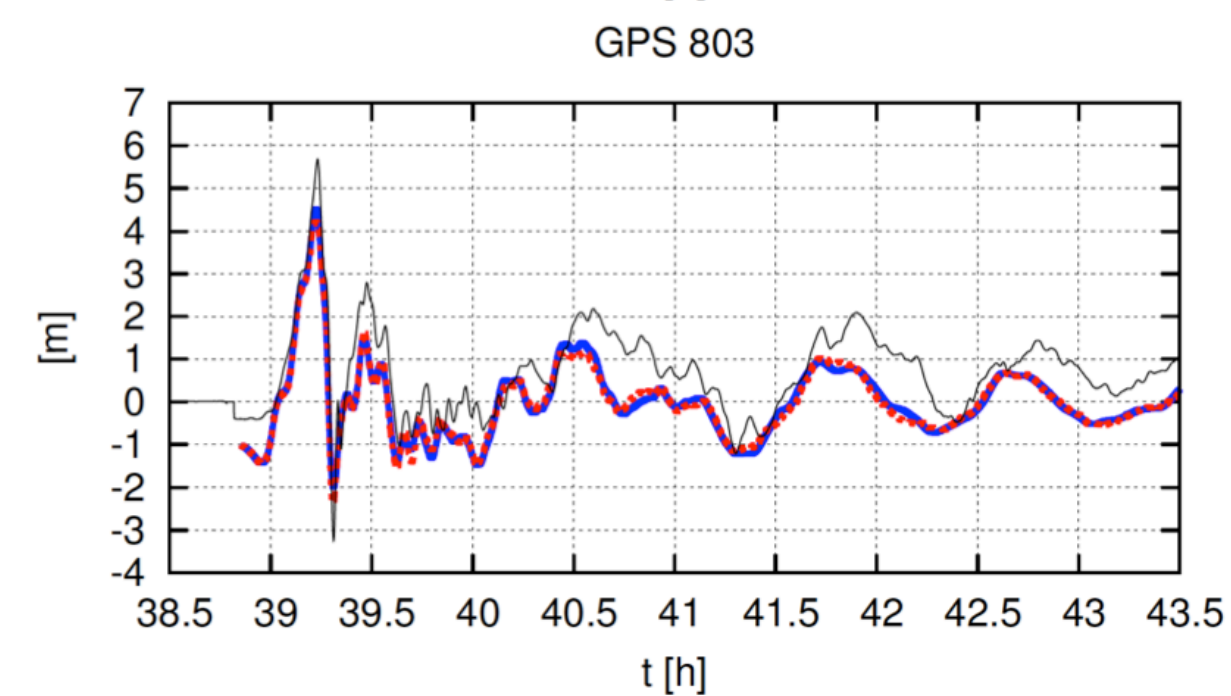
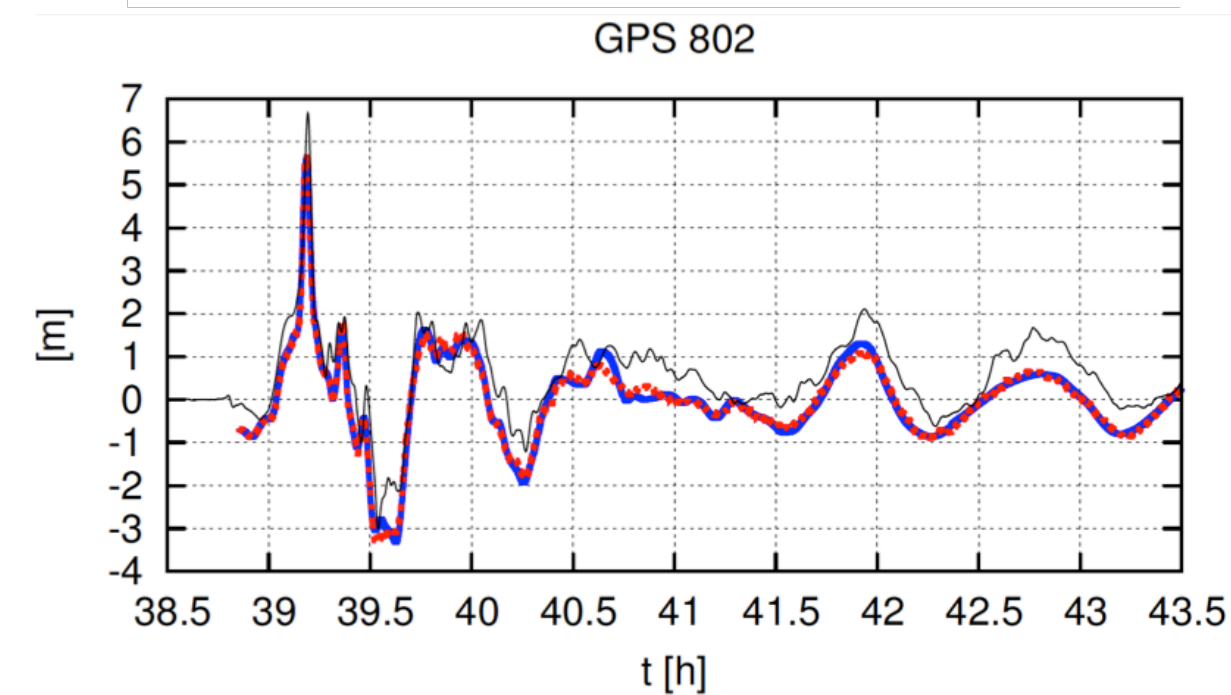
**Curvilinear coordinates**

**Need to model realistic effects  
(topography, soil elevation, meteo, etc)**

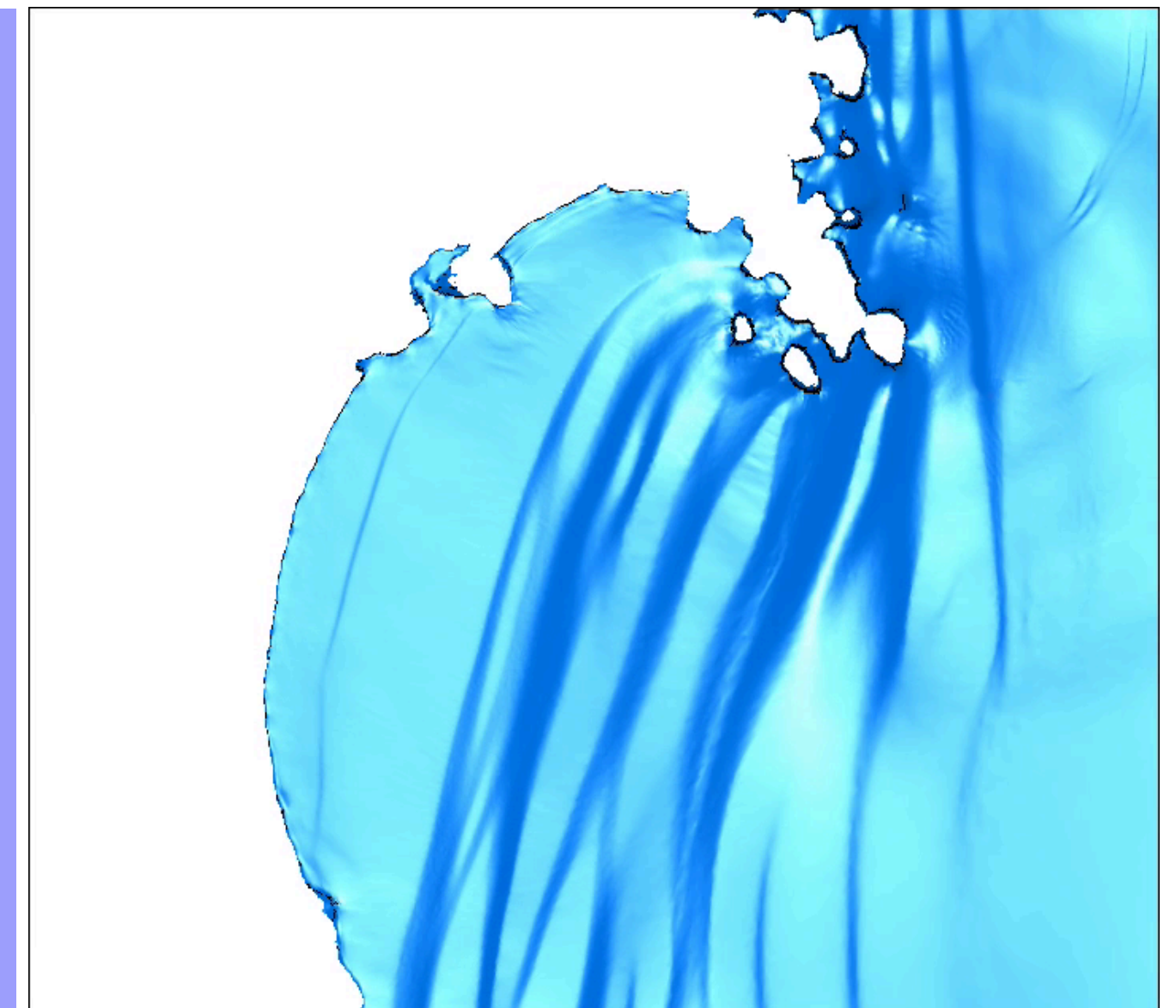
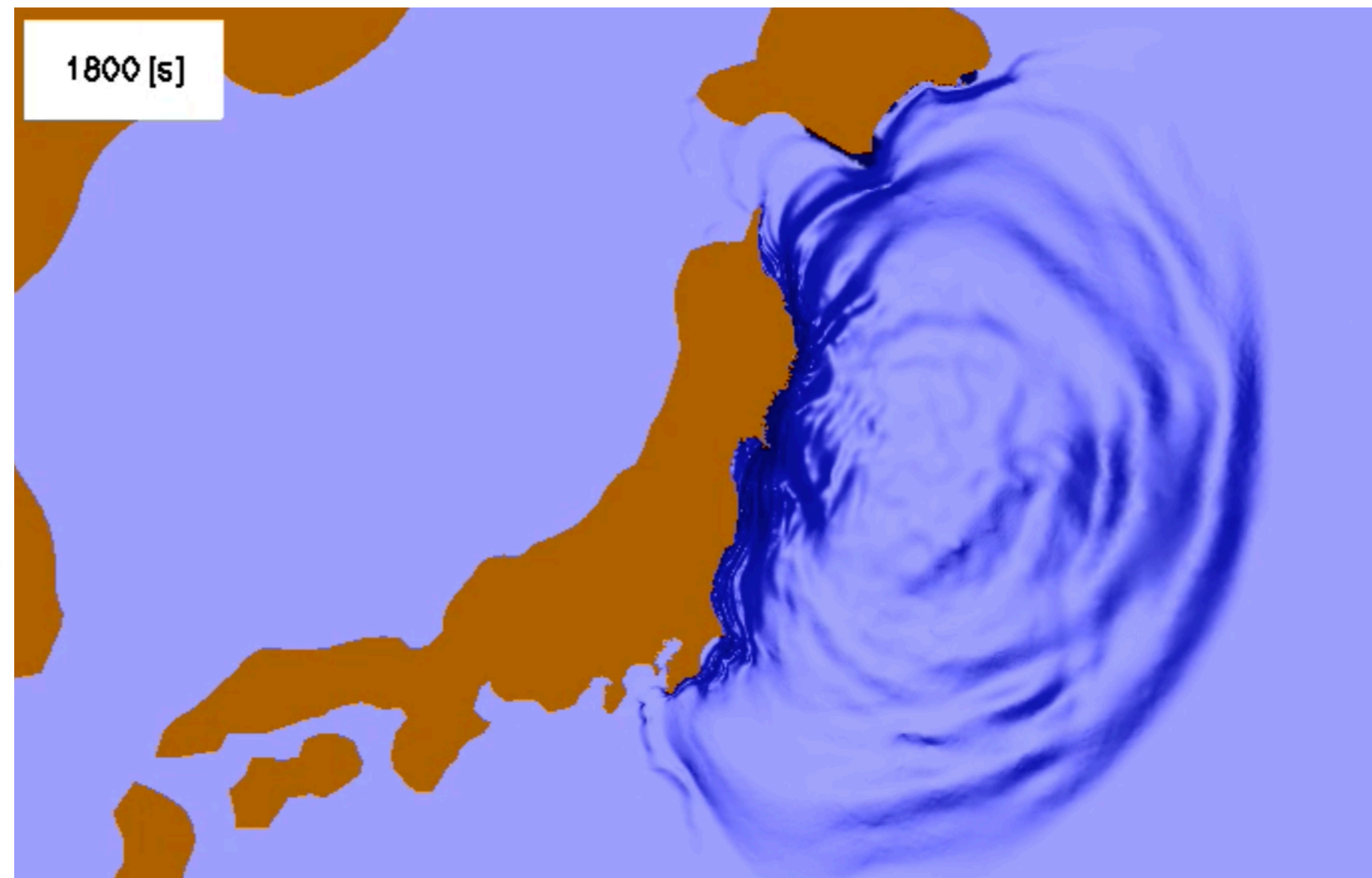
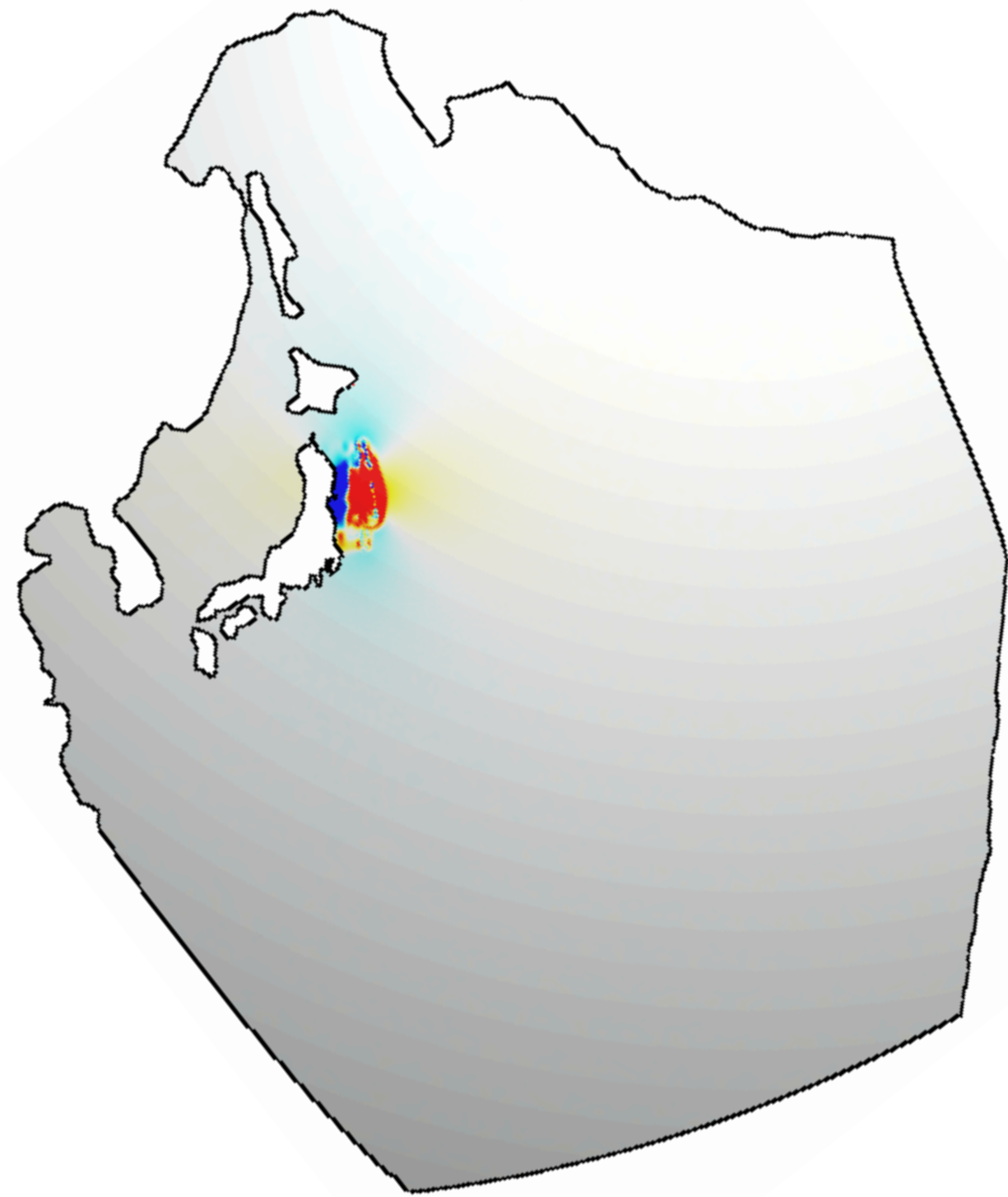
**Moving Fronts/multiscale**

**Large scales/long times (hours or days)**

Reference — ADAPT-ALE — Obs.Data







**Equations: right ones, in the right form**

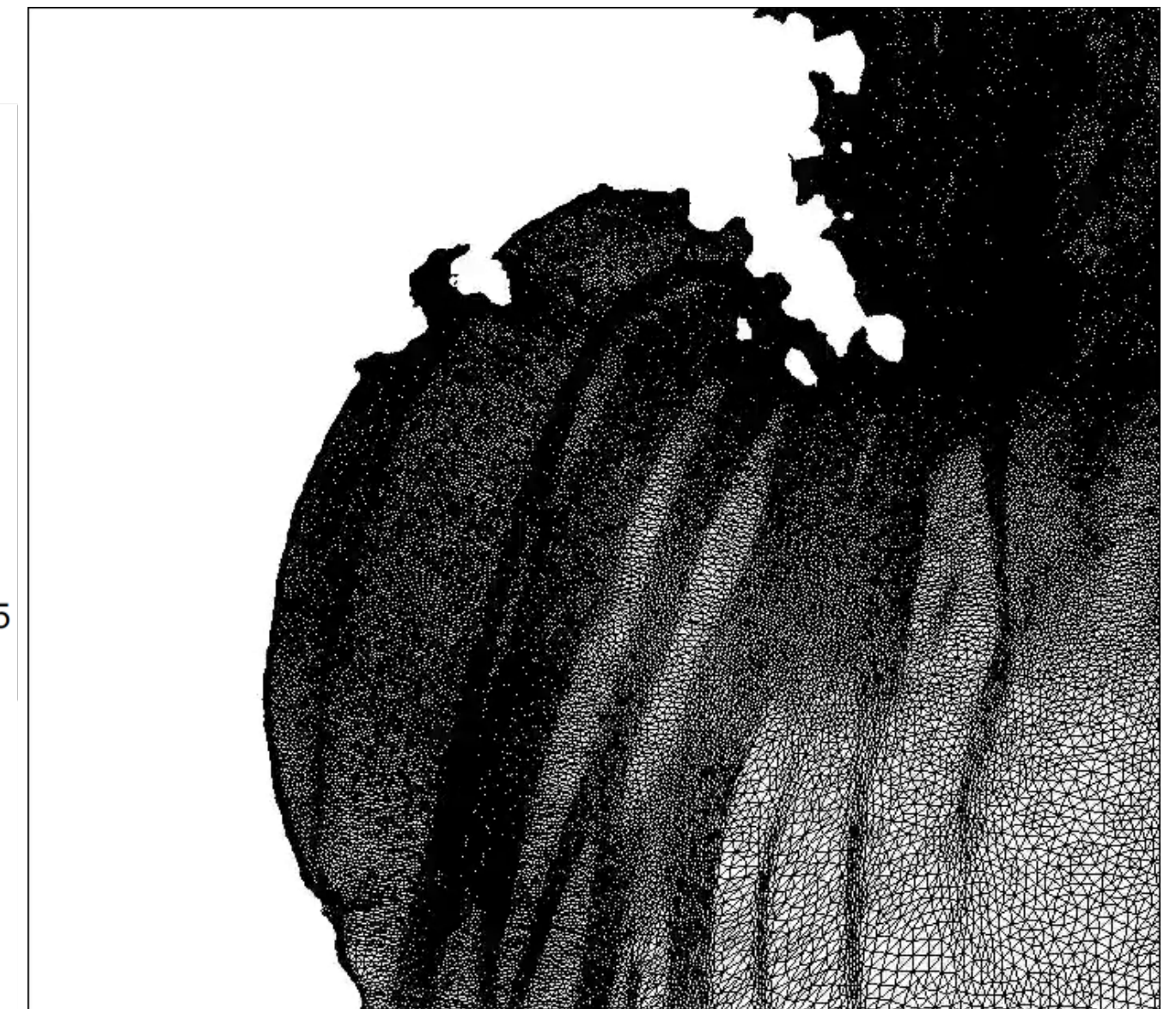
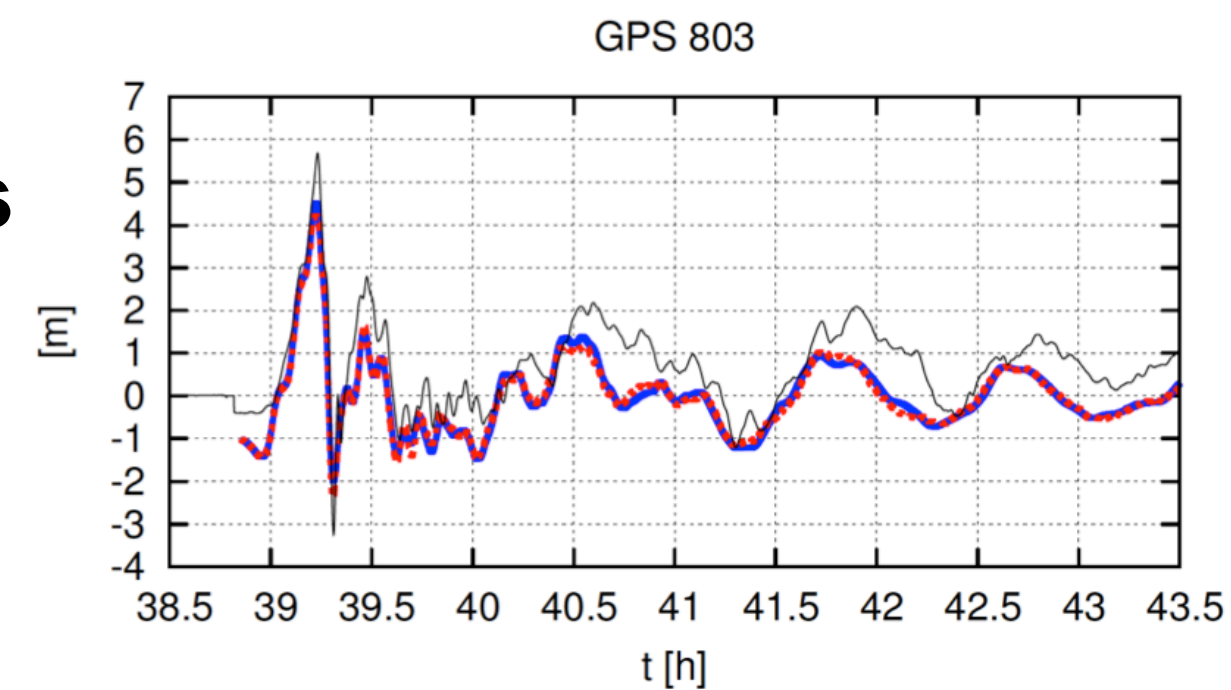
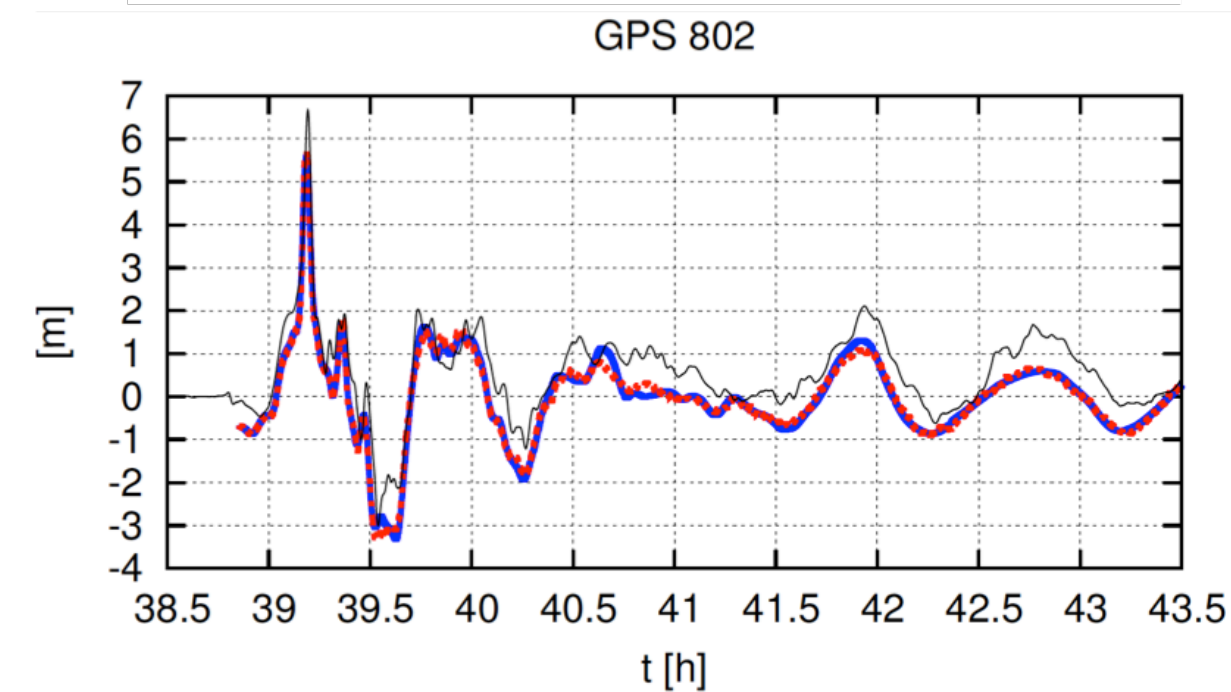
**Mesh: generating, adapting, moving**

**Numerical methods and constraints**

**Codes: 1D, 2D, 3D, ... research vs operations**

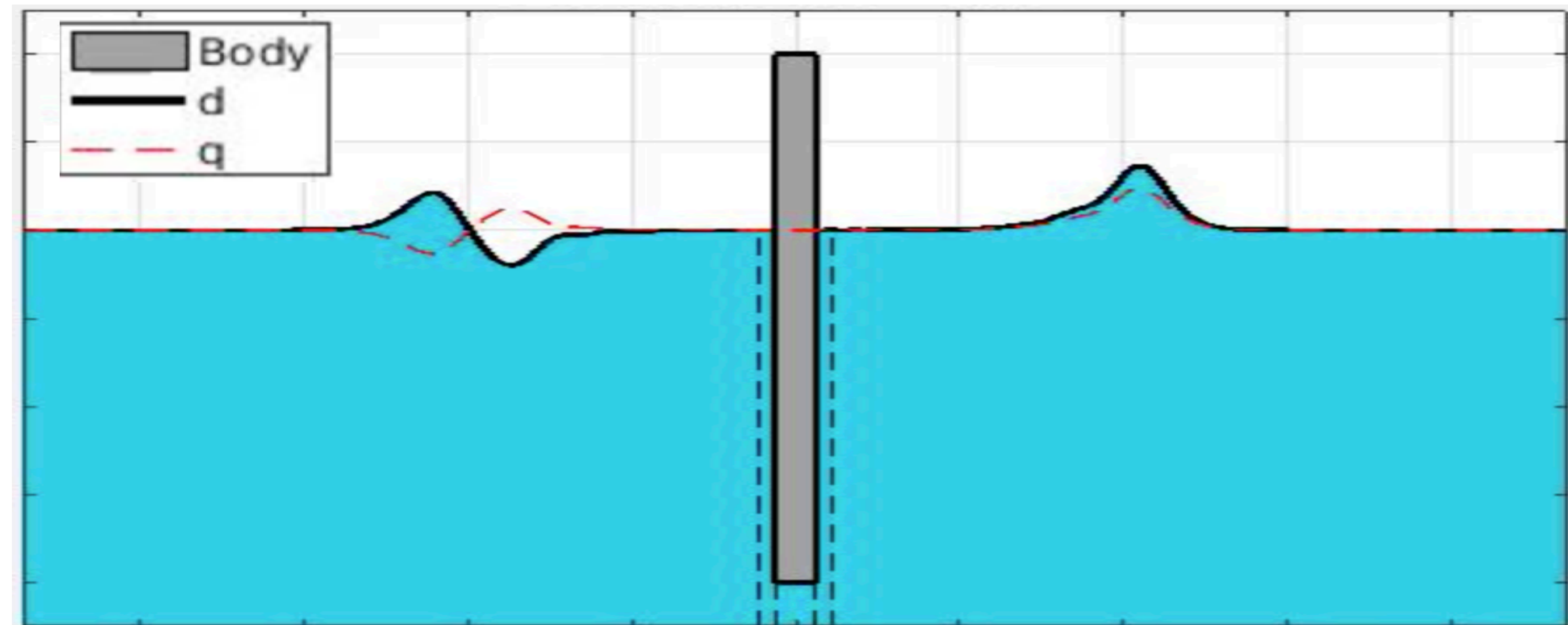
**Robustness: sensitivity wrt parameters**

Reference — ADAPT-ALE — Obs.Data



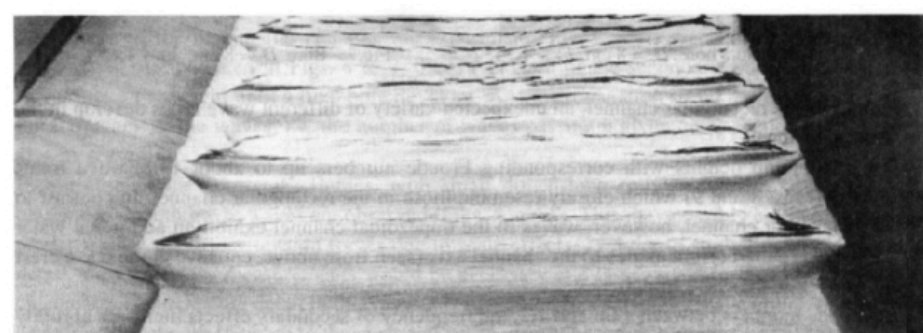
# Large scale models complex flows:

PDE modelling, numerical discretizations, applications

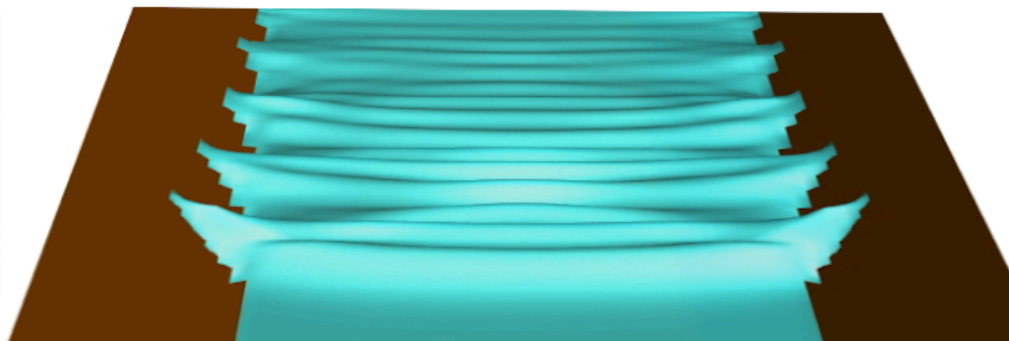
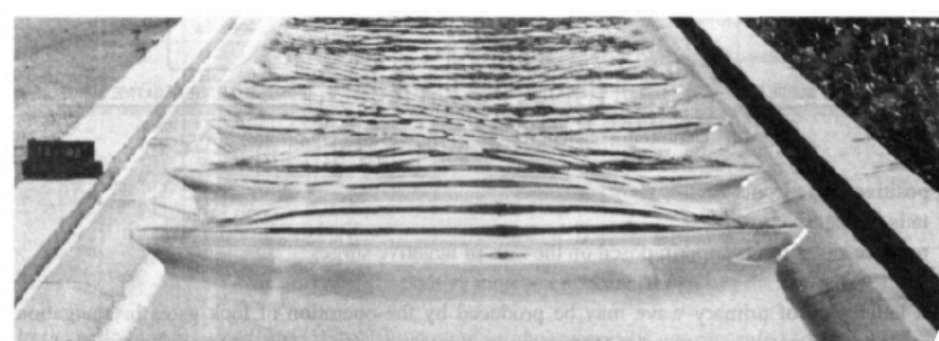


**Energetic small scale effects  
in large scale flows** (ex. mascaret)

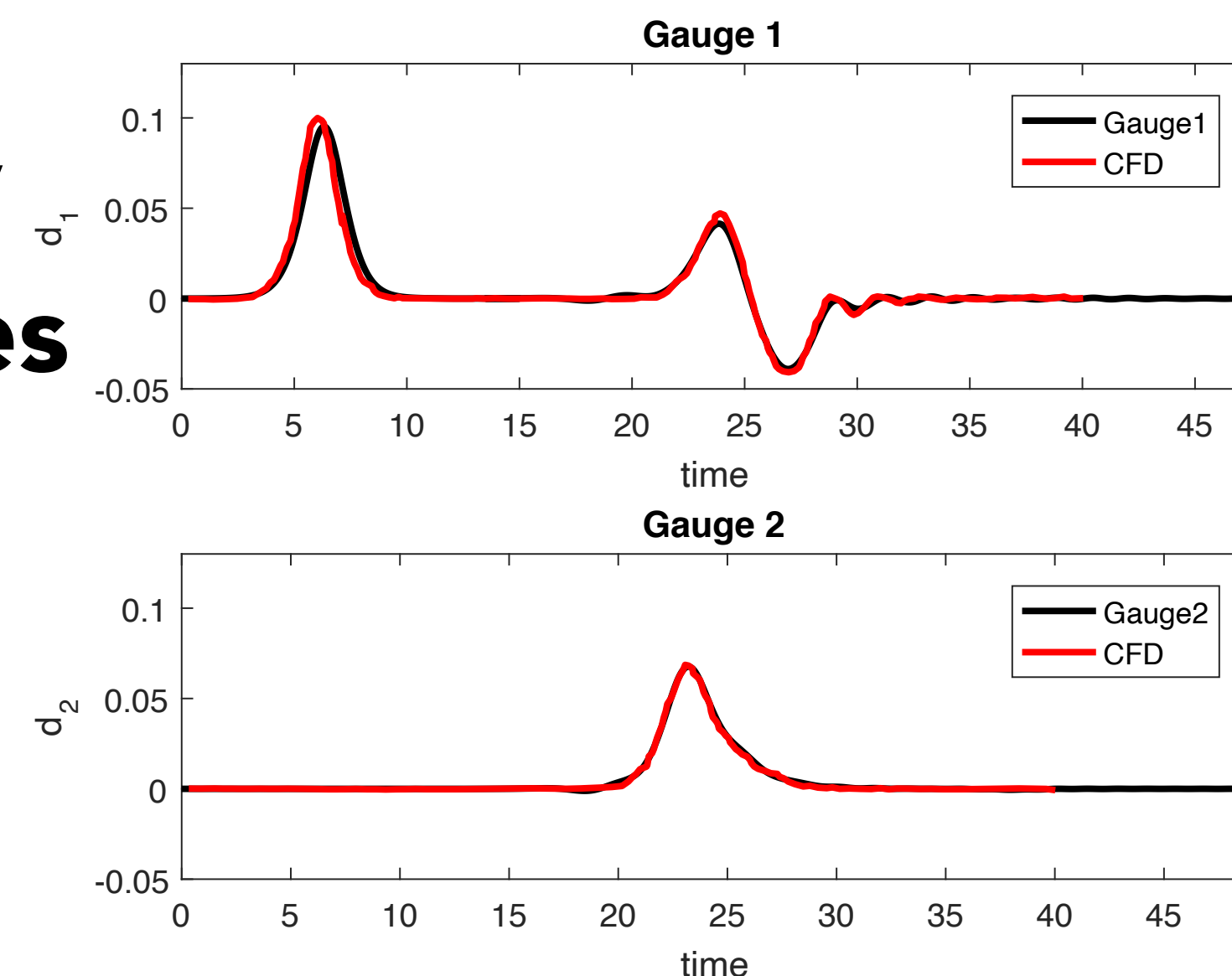
$Fr = 1.10$



$Fr = 1.17$

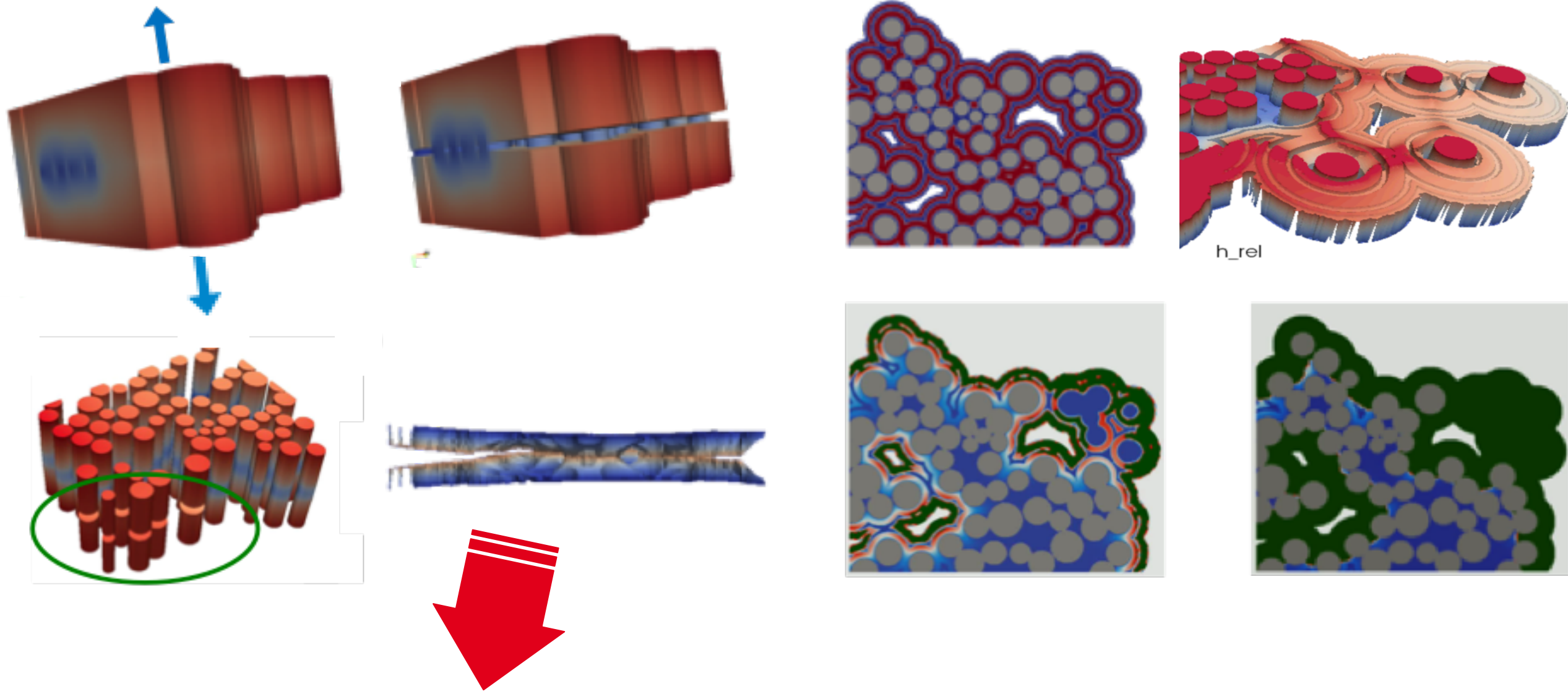


**Moored or freely  
floating structures**  
(pontoons, boats,  
waver energy  
converters, etc)

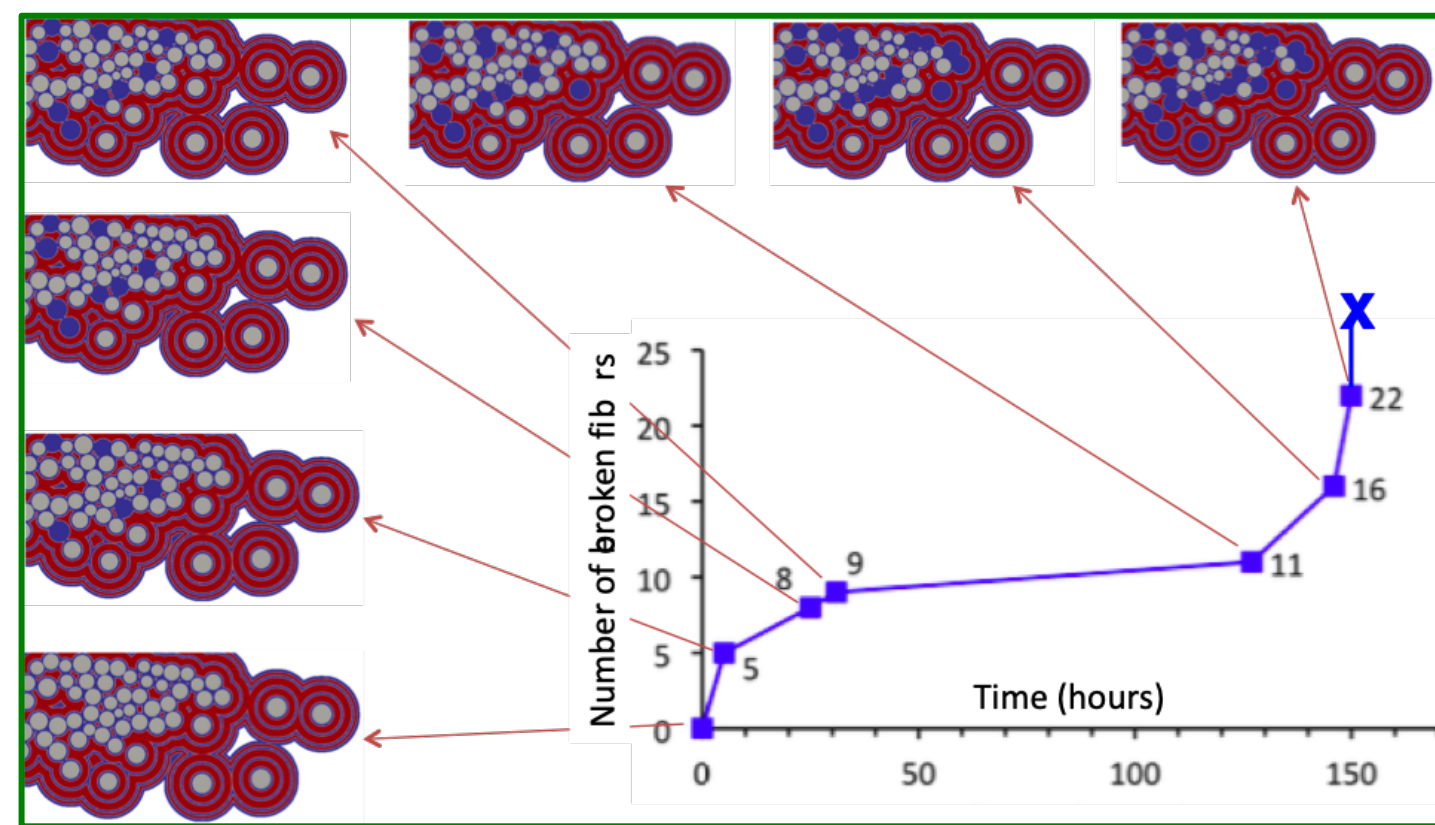
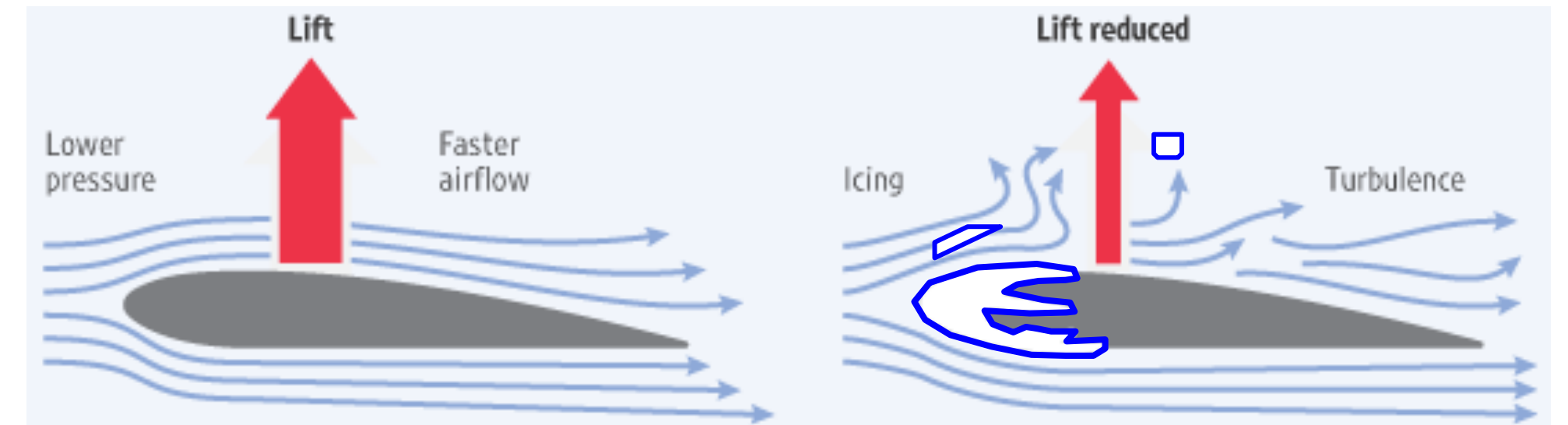


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PDE modelling, numerical discretizations, applications

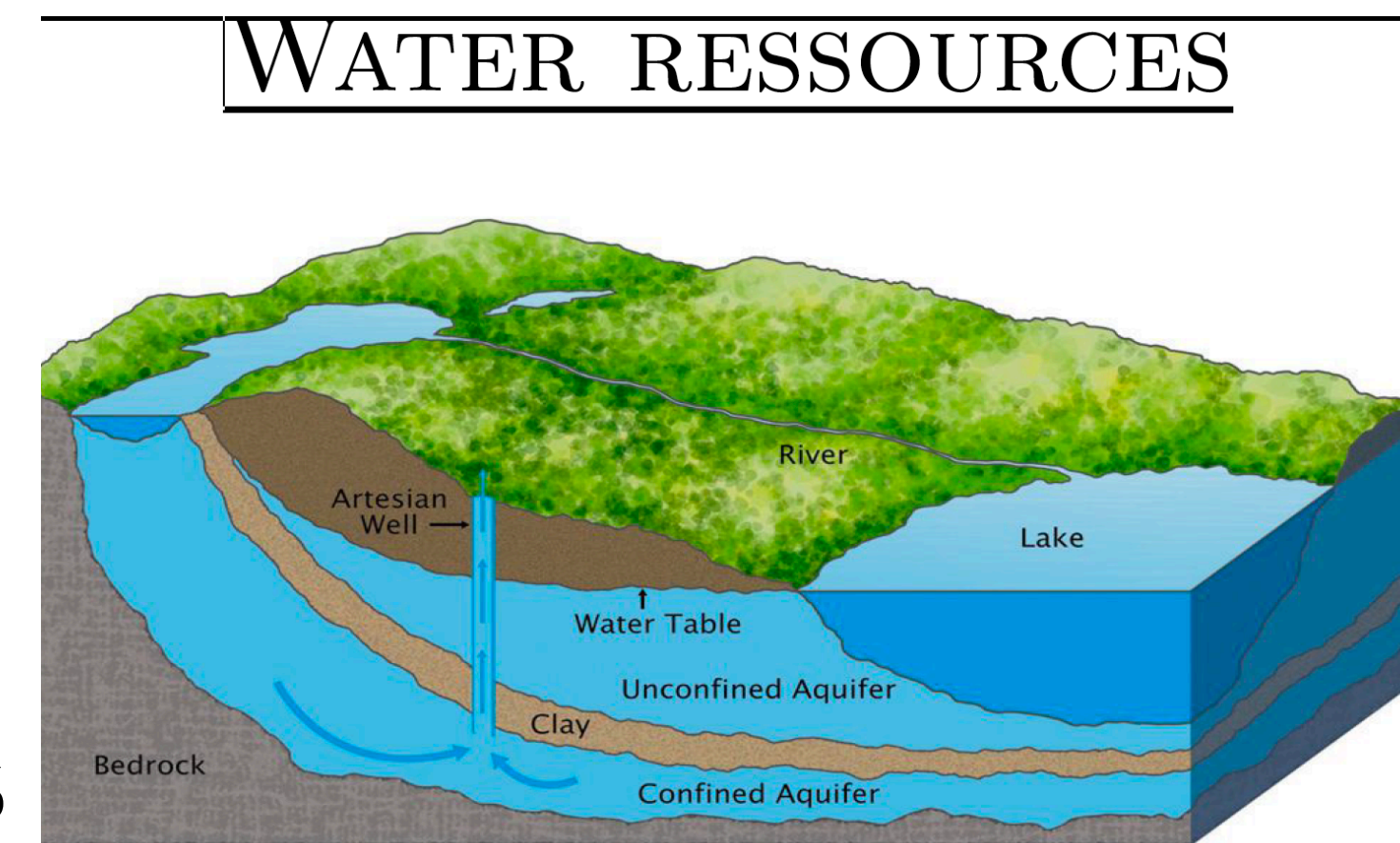


## Modelling wing icing



## Lifetime modelling for self healing composites

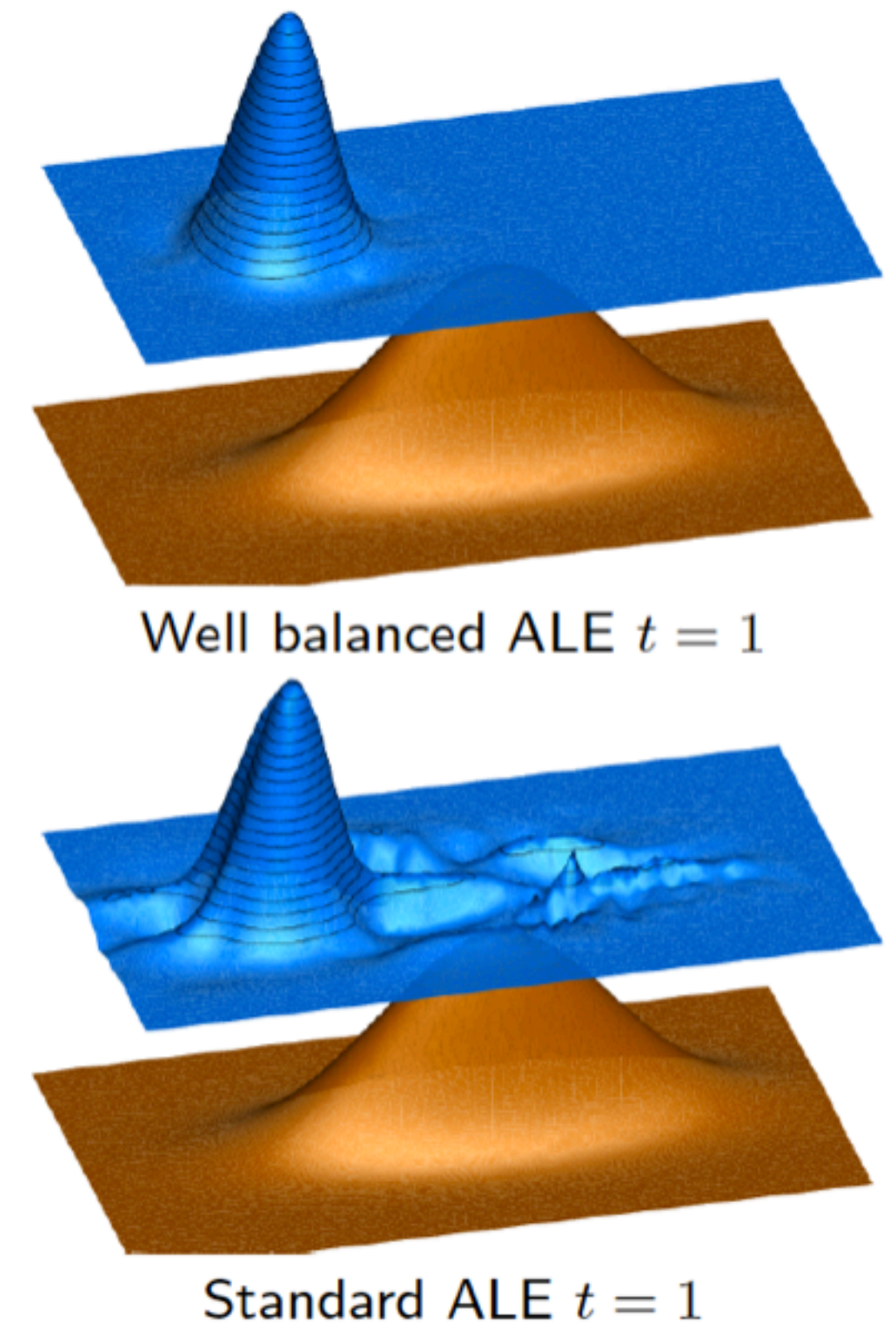
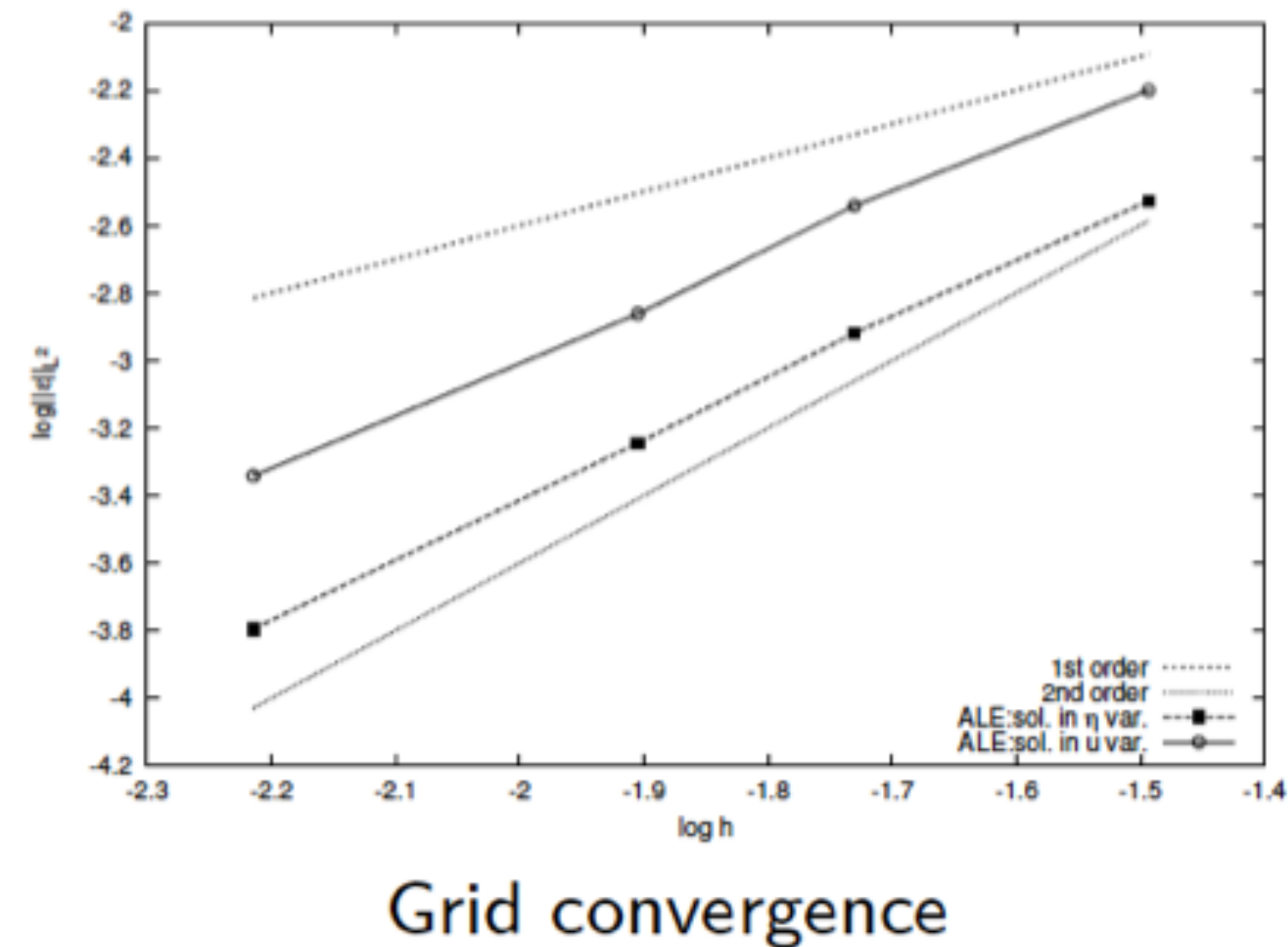
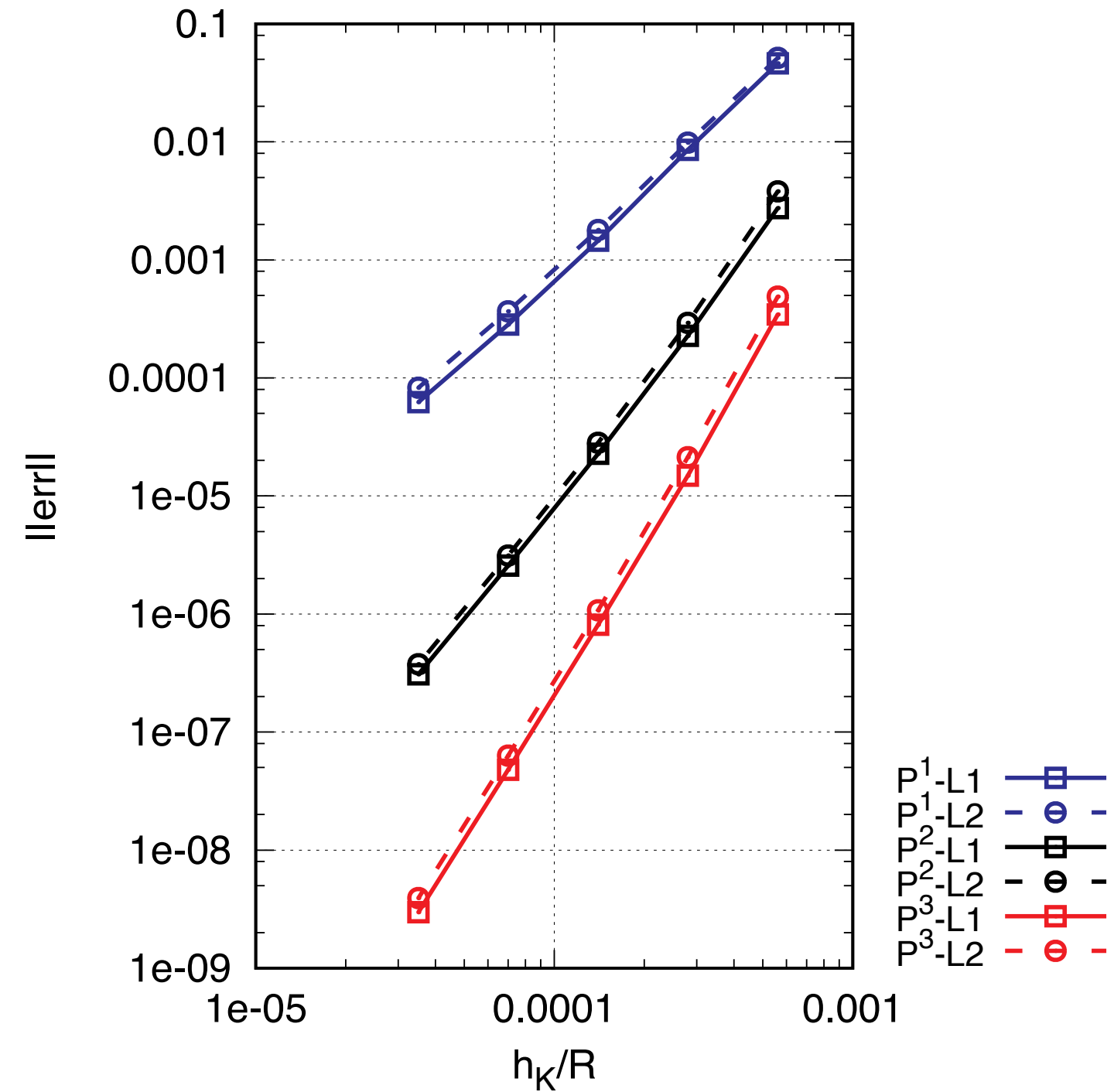
## Free surface and underground water flows

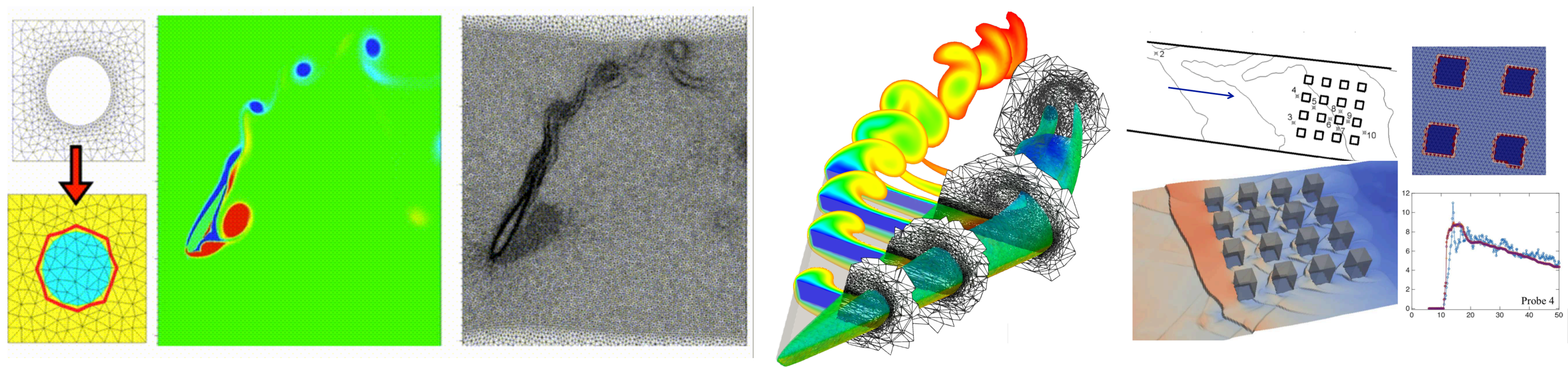


# High order numerical methods with additional constraints :

well balanced, moving meshes, additional conservation relations, etc

$$a F(u_1) + b G(u_2) + c = 0 \implies (u_1, u_2) \quad \text{with} \quad u_1 + u_2 = d$$





## Boundary/interfaces conditions: rule the complexity of the flow

Physical regime (in/out)

Moving Fronts/bodies

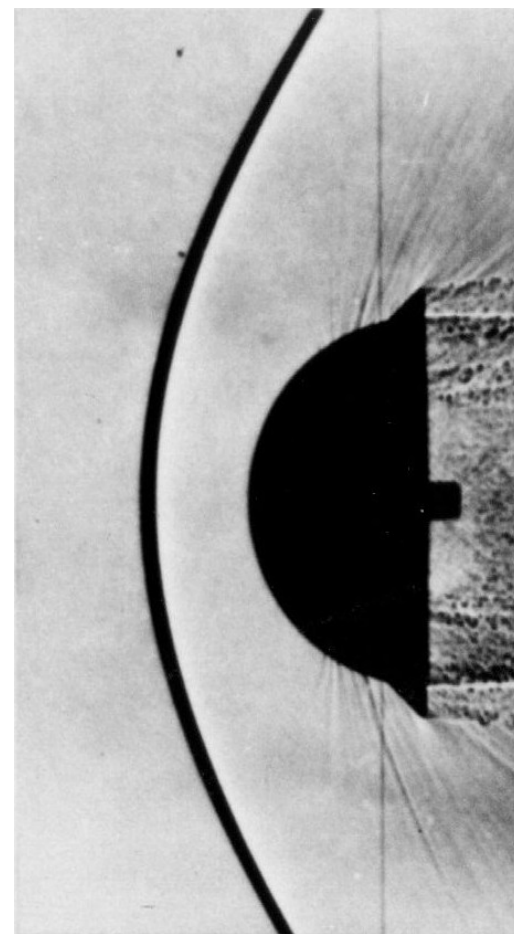
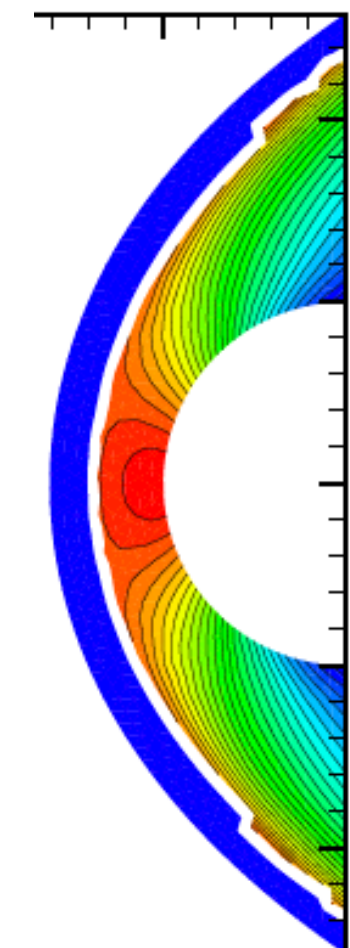
Domains with changing physics (shocks, phase change, etc)

Small scale effects (walls, turbulence)

Physical/numerical accuracy



→  
M = 20

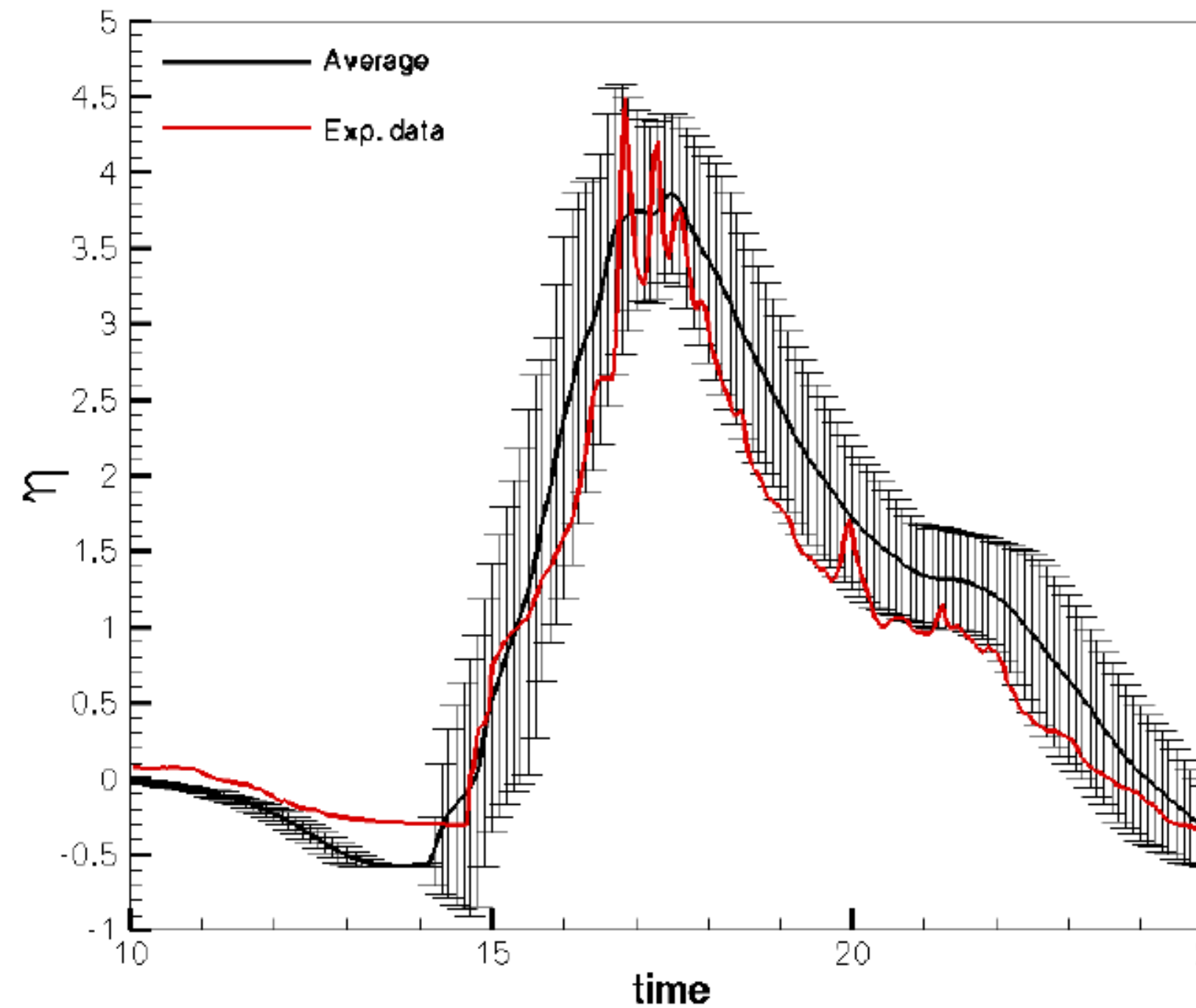
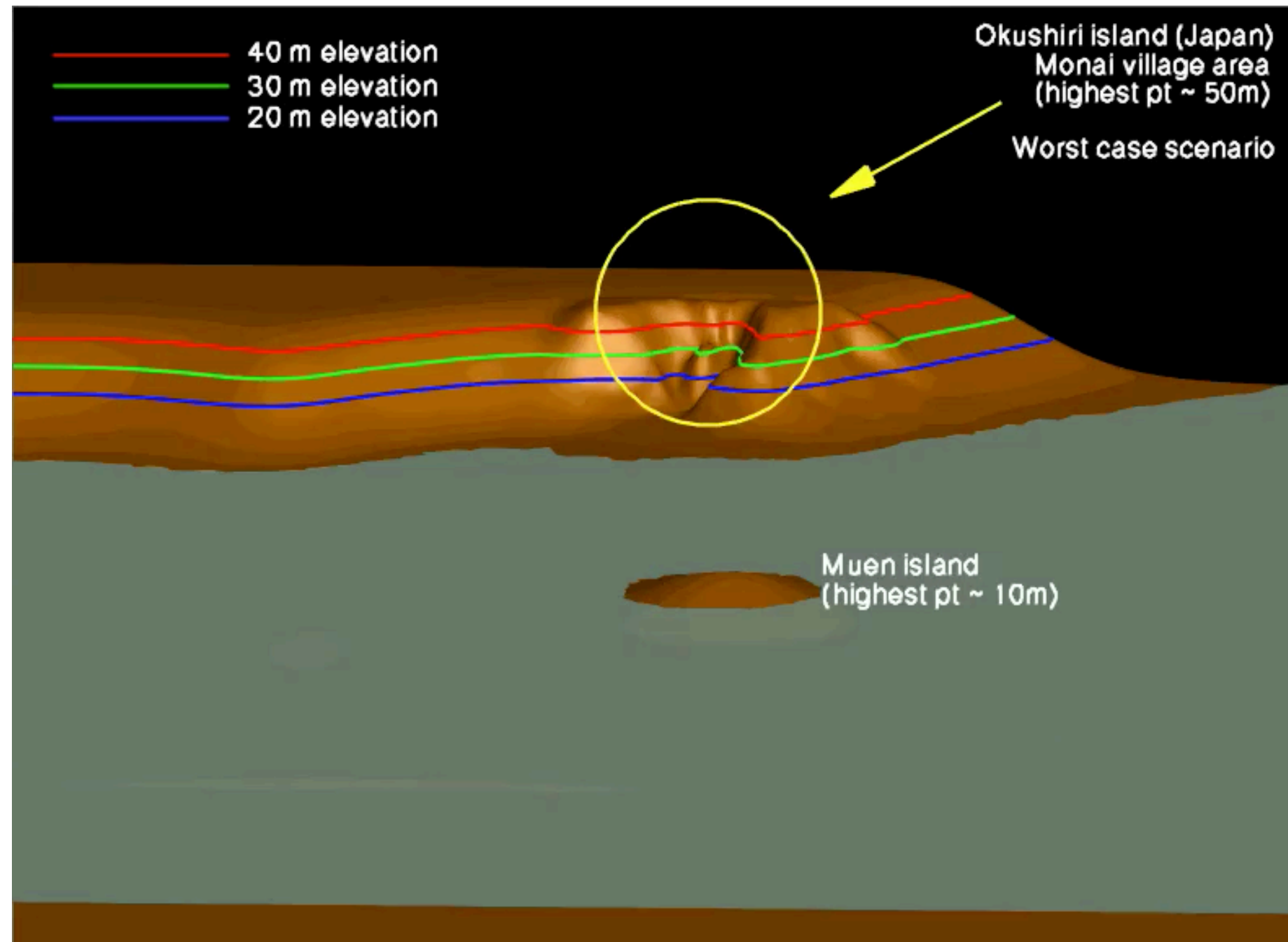


# Accounting for uncertainties

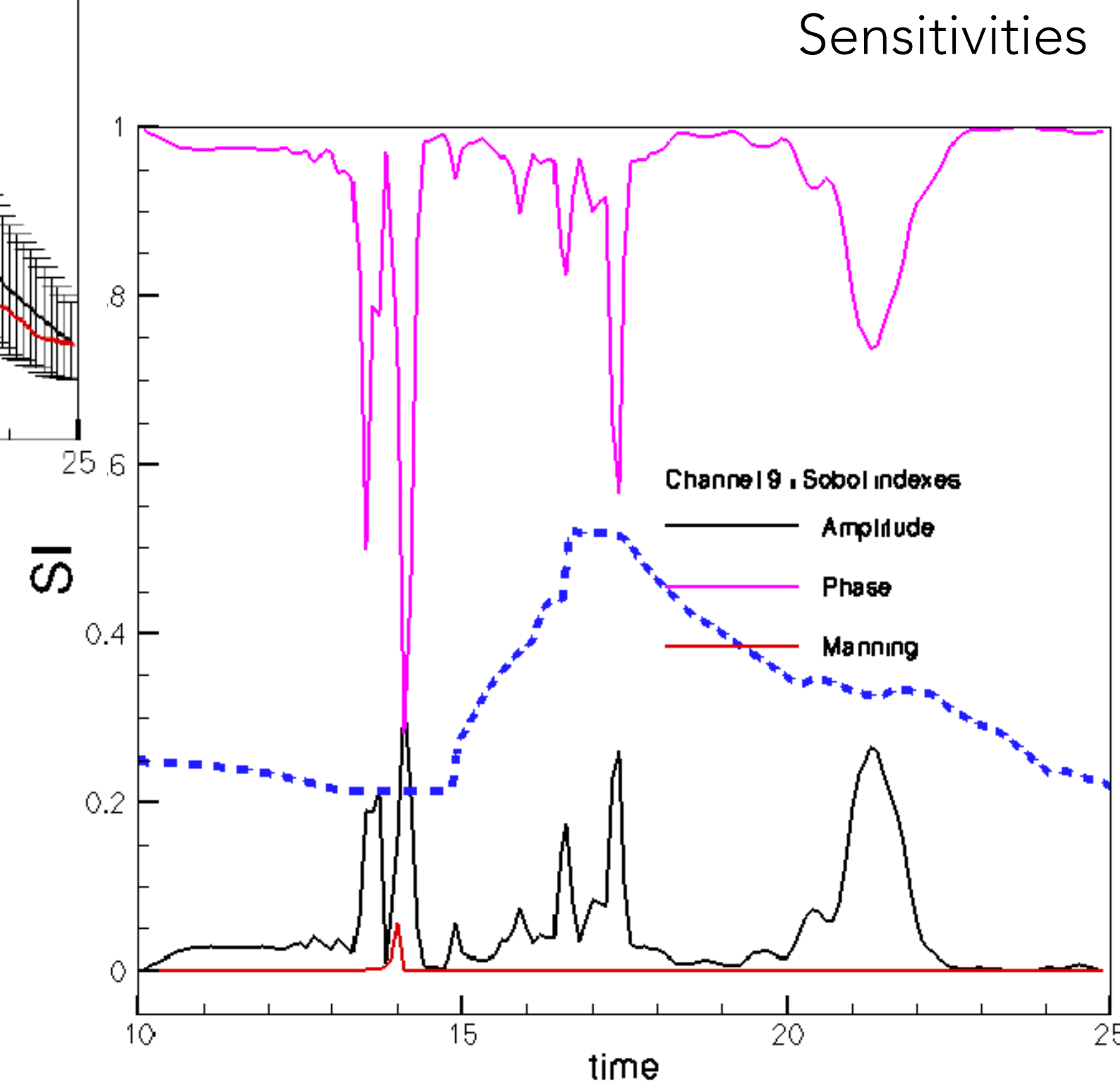
Model constants (fluid properties, PDE approximations, etc)

Problem data (geometry, boundary conditions, initial conditions, etc)

Scheme parameters, etc



Water elevation in offshore probe



Sensitivities

Monai valley: lab exp. reproducing 1994 disaster off coast Okushiri island

**Uncertainties on: Wave Amplitude and Phase, bottom friction**

# **Certified Adaptive discRete moDels for robust simulAtions of coMplex fLOws with Moving fronts**

**Waves and related pbs:** M. Parisot dispersive waves and floaters

**Numerical schemes for complex PDEs:** E. Gaburro's work and MSCA project Superman

**Embedded boundaries and interfaces:** IBM and turbulent aerodynamics by H. Beaugendre

**Mesh adaptation and co:** From error to meshes in OS codes with N. Barral

**External parameters and uncertainties:** E. Solai's racing electric cars

**Aerosol and UHAINA:** Developer's point of view from M. Lorini + C. Poette

**Lookout on possible evolutions:** some MOR for small scales and in embedded moving domains