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UNCERTAINTY ON SEISMIC SOURCES AND BATHYMETRY FOR TSUNAMI MODELLING

26th IUGG General Assembly

David **Imbert** | Ekaterina **Antoshchenkova***
Audrey **Gailler** | Hélène **Hébert**

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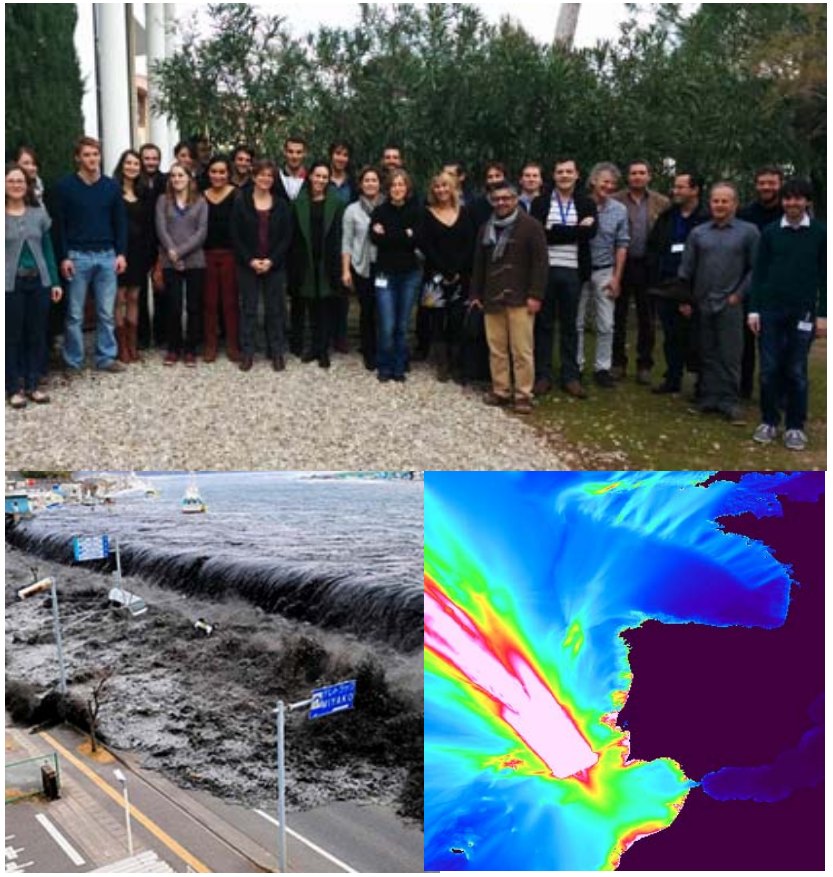
*IRSN

TANDEM PROJECT

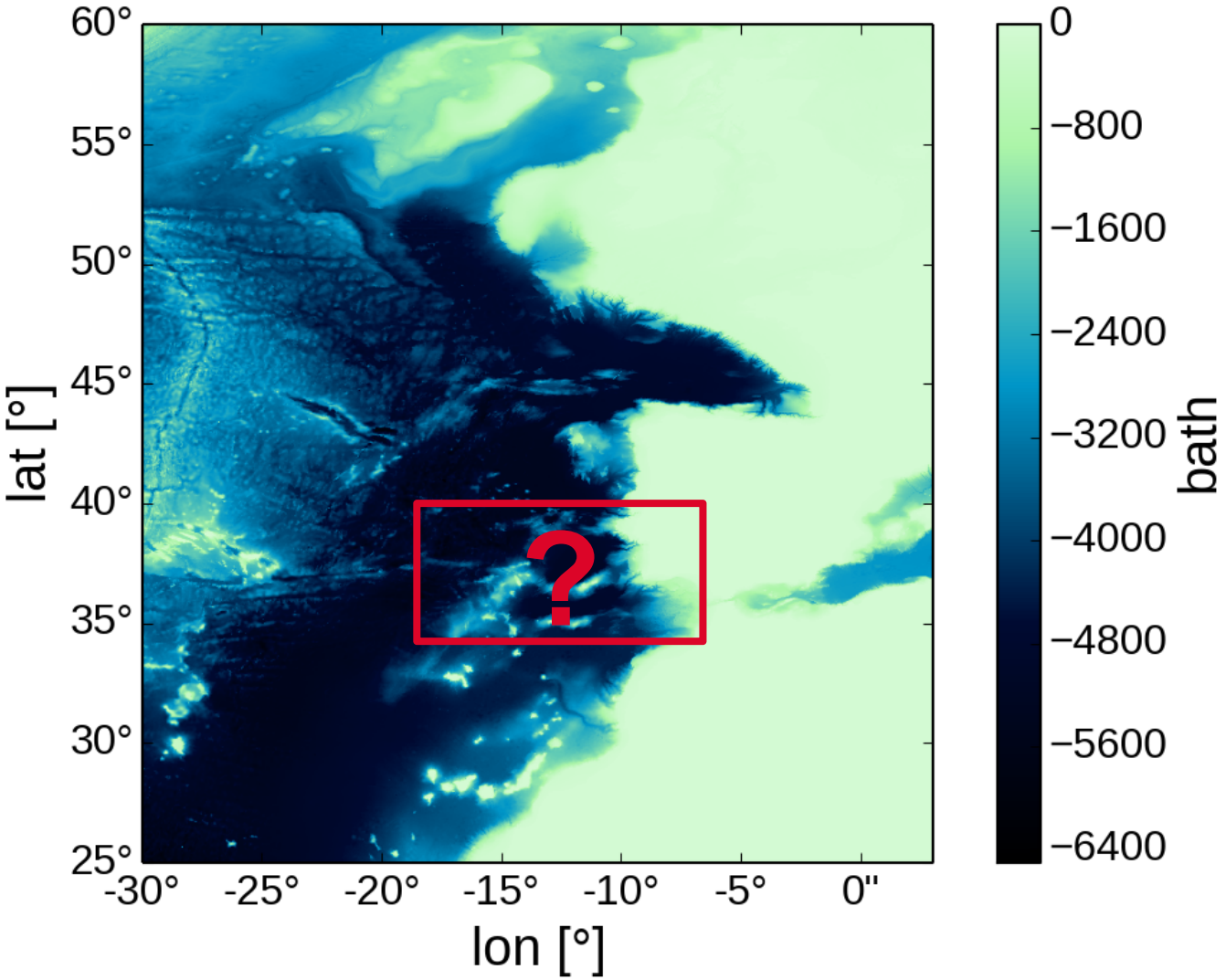
- TANDEM : *T*sunamis in the *A*tlantic and the English cha*n*nel – *d*efinition of the *e*ffects through numerical *m*odeling
  - WP2 : influence of parameters and uncertainties



PURPOSE

- How do seismic source and bathymetry contribute to maximum water height?

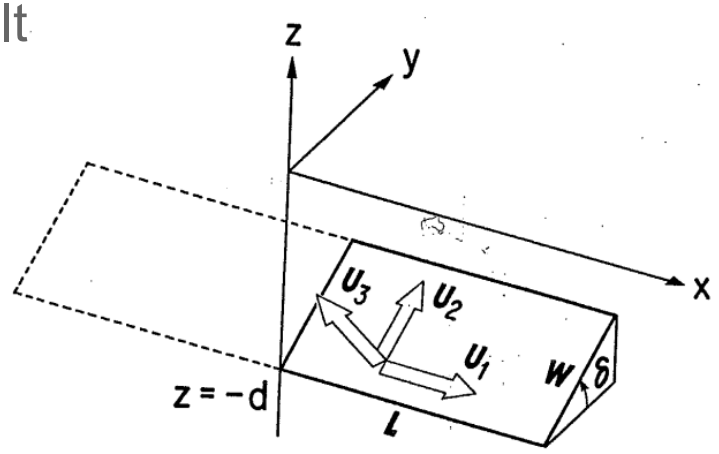
LISBON TSUNAMI (1755)



OKADA'S MODEL (1985)

Surface deformation due to shear and tensile faults in a half-space

- Function of geological parameters:
  - longitude of the centroid of the fault
  - latitude of the centroid of the fault
  - depth of the centroid of the fault
  - slip amplitude
  - strike
  - dip
  - rake
  - half length of the fault plane
  - width of the fault plane
  - shear modulus



Okada (1985)

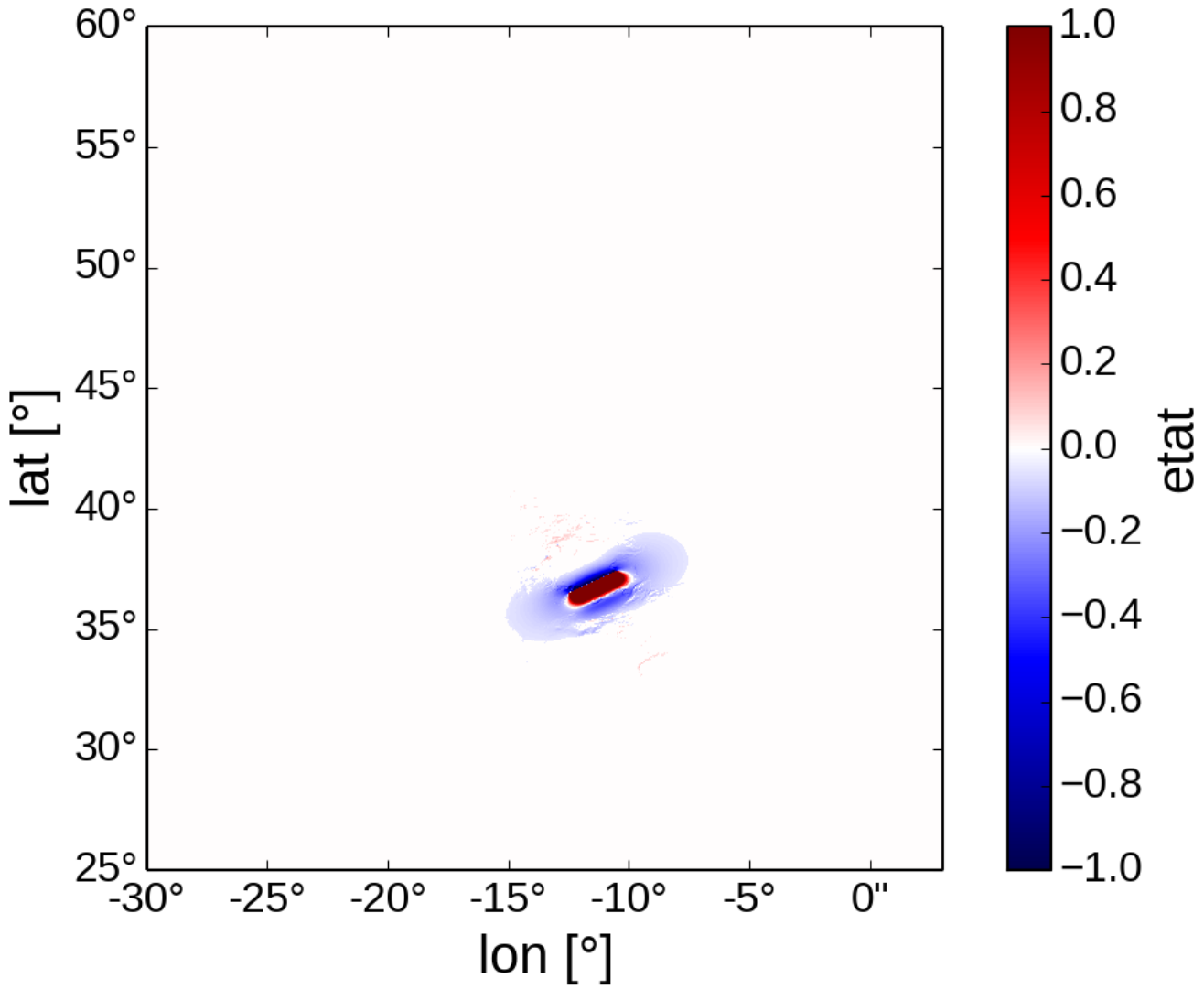
FDTD FOR SHALLOW WATER EQ.

$$\begin{cases} \partial_t U + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + g_z\frac{\partial H}{\partial x} = C_F\ V \\ \partial_t V + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + g_z\frac{\partial H}{\partial y} = C_F\ U \\ \partial_t H + \frac{\partial((D+H)U)}{\partial x} + \frac{\partial((D+H)V)}{\partial y} = 0 \end{cases}$$

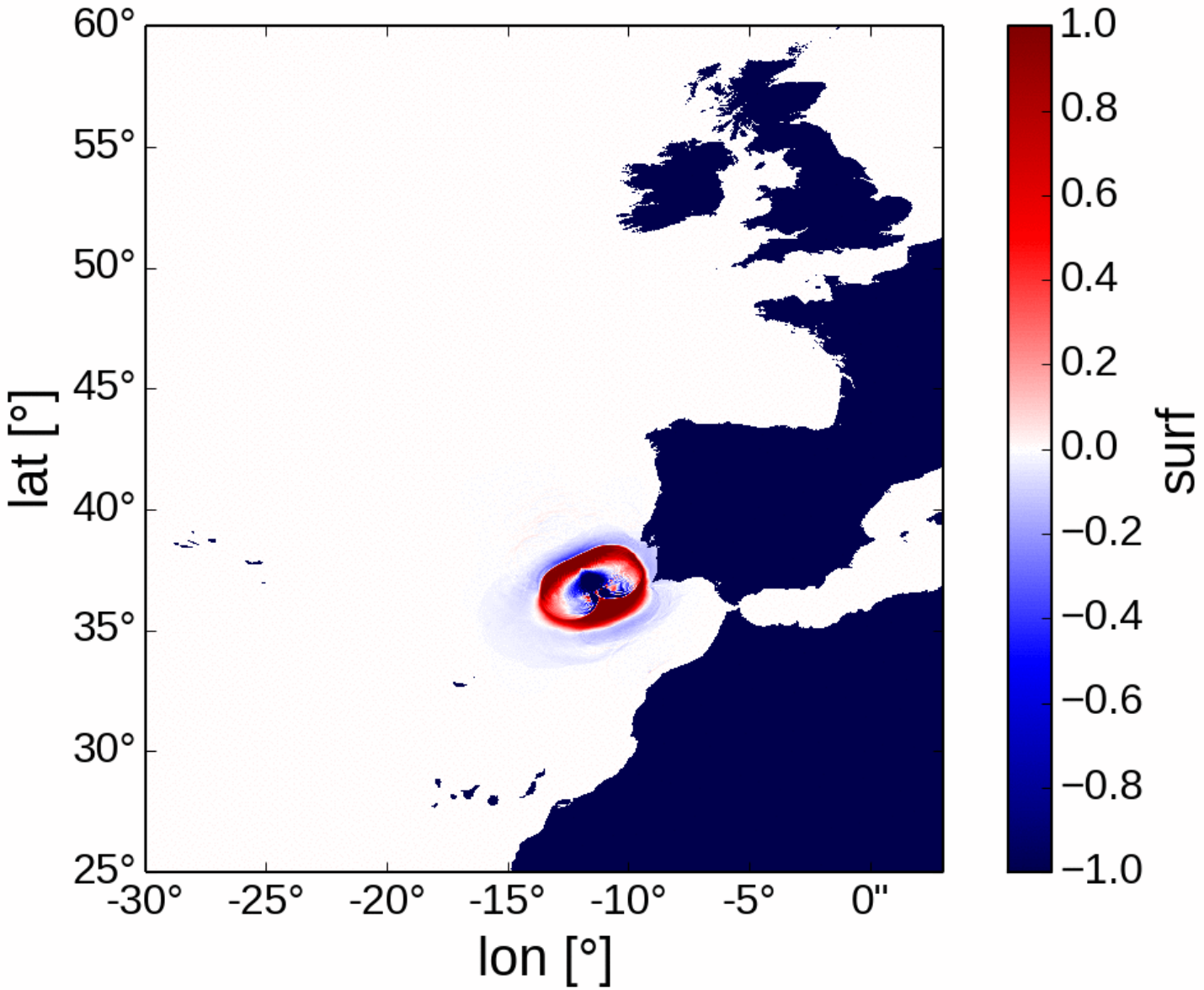
U,V : velocity field
H : water height above mean water level
D : depth of water at resting
C_F : Coriolis parameter
g_z : gravity

- Function of bathymetry D
- $O(\Delta x^2)$ upwind scheme from Mader (1988)
- $O(\Delta t^2)$ Crank-Nicholson scheme from Heinrich (1996)

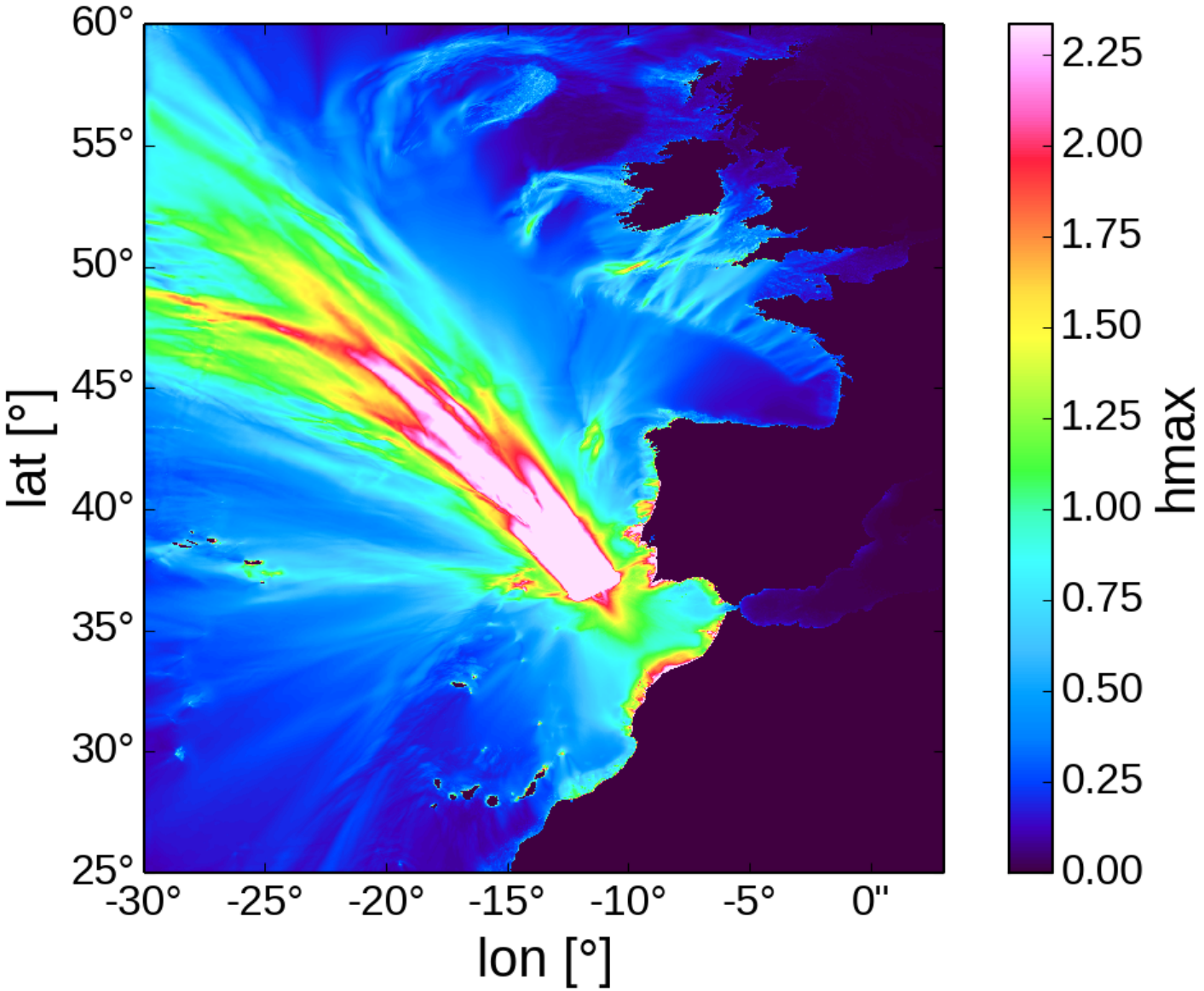
EX: JOHNSTON'S SOURCE (1996)



Water height variations over time

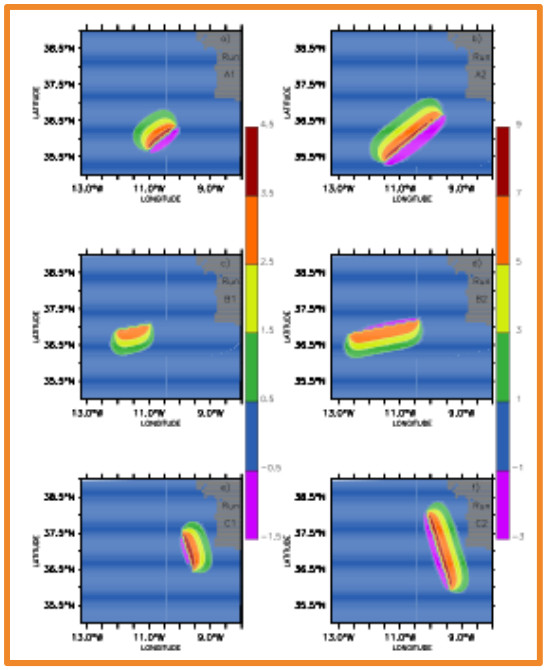


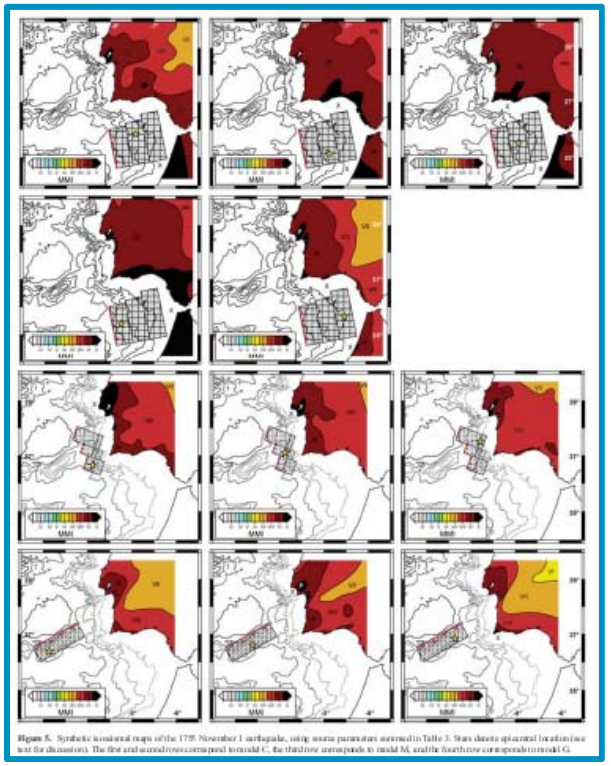
Maximum water height variations (*hmax*)



WIDE RANGE SOURCES

- Johnston (1996)
- Baptista et al. (1998)
- Zitellini et al. (1999)
- Gutscher et al. (2006)
- Grandin et al. (2007)
- Horsburgh et al. (2008)
- and others !





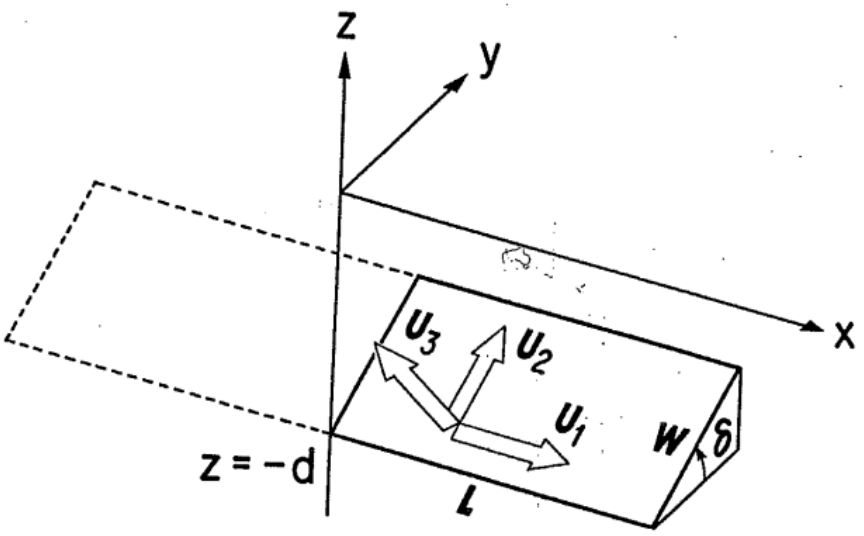
- Natural variability of known faults
- Variability due to unknown faults

RANGES OF PARAMETERS

- **11** input parameters:
  - long [-18;-7] °
  - lat [34;40] °
  - depth [2;80] km
  - slip [2;25] m
  - strike [0;359.9] °
  - dip [1;89] °
  - rake [-179.9;179.9] °
  - hL [50;100] km
  - width [15;95] km
  - mu [30;70] GPa

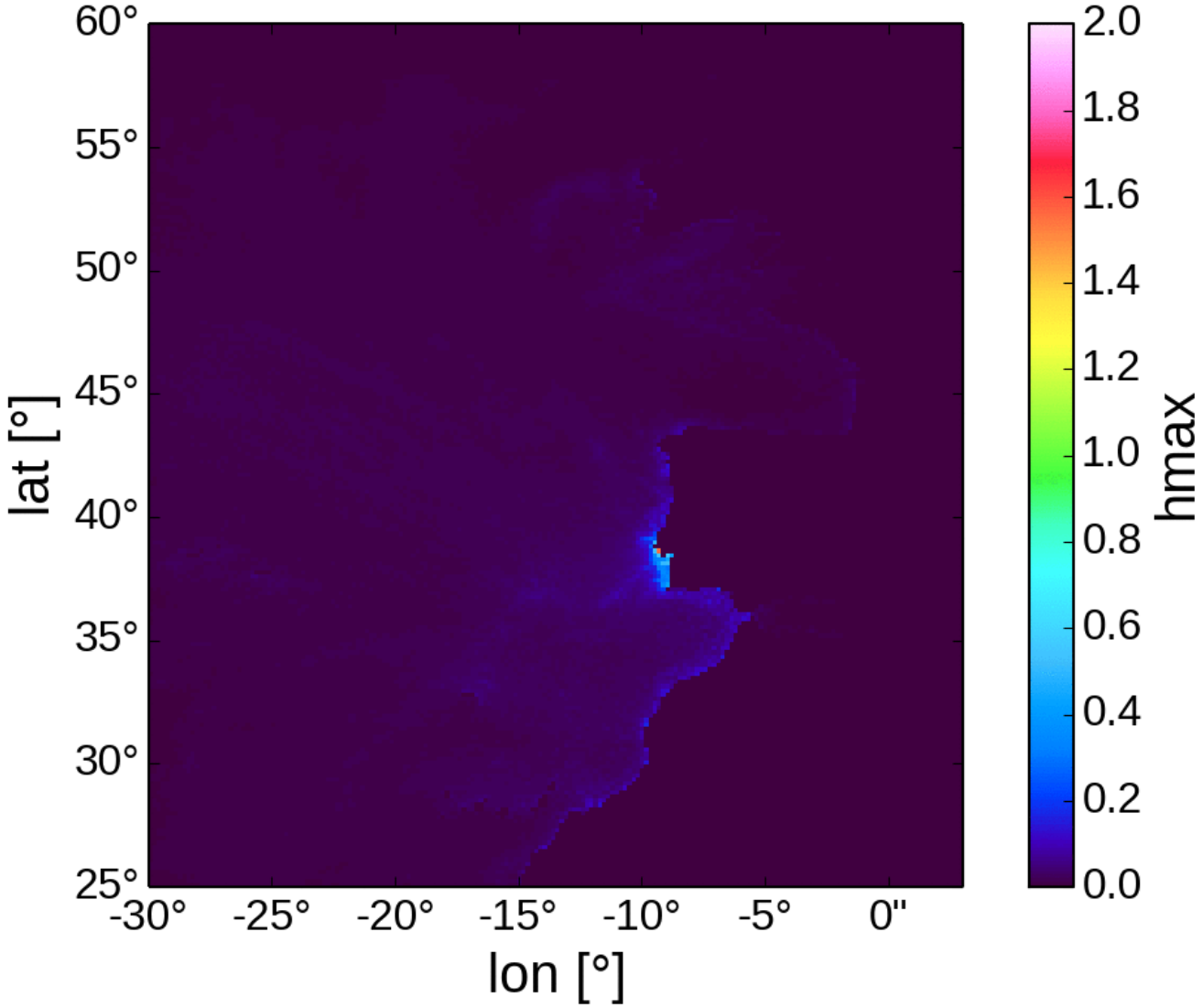
  - dx [1;14] min

→ uniform distributions



Okada (1985)

MAXIMUM WATER HEIGHT VARIABILITY

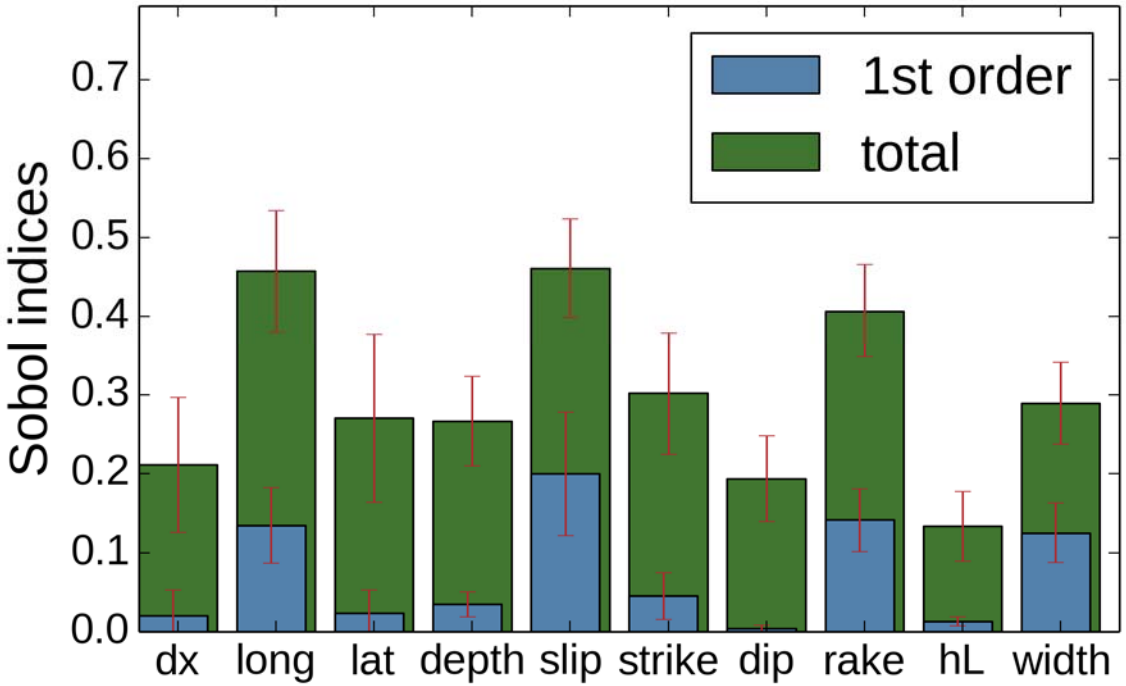


SENSITIVITY ANALYSIS

- Quantitative sensitivity analysis by variance decomposition
- FAST method (*Fourier Amplitude Sensitivity Test*, Cukier et al. 1973)
  - 5,500 runs
  - ~ 2 days of computation
- Compute Sobol indicies:
  - S: 1st order Sobol indicies → individual contribution
  - T: total order Sobol indices → total contribution

GLOBAL SENSITIVITY

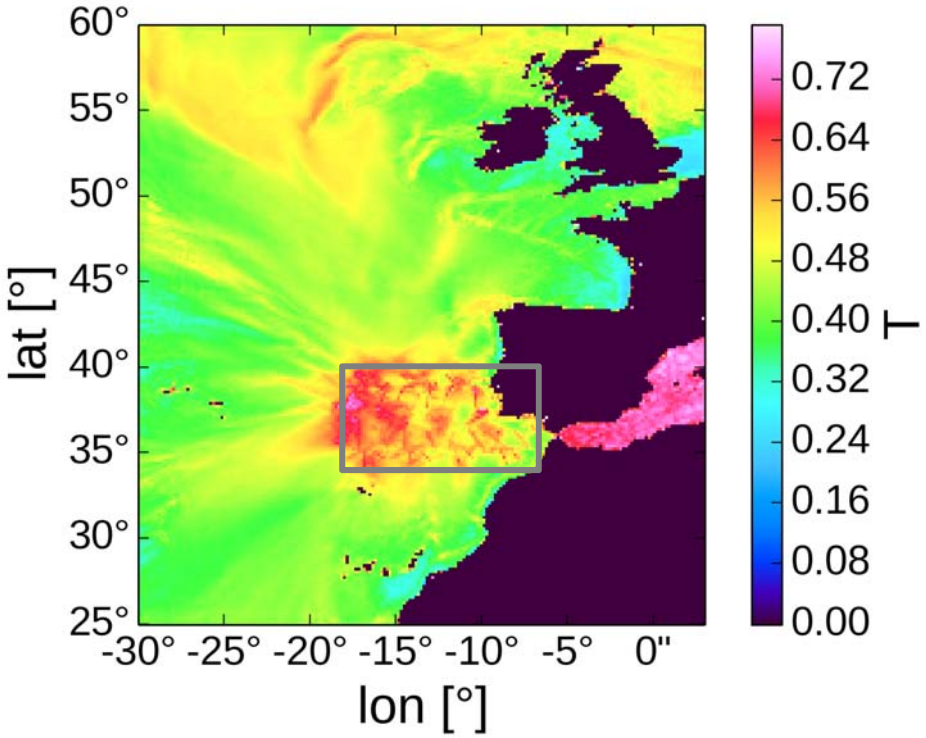
Mean Sobol indicies



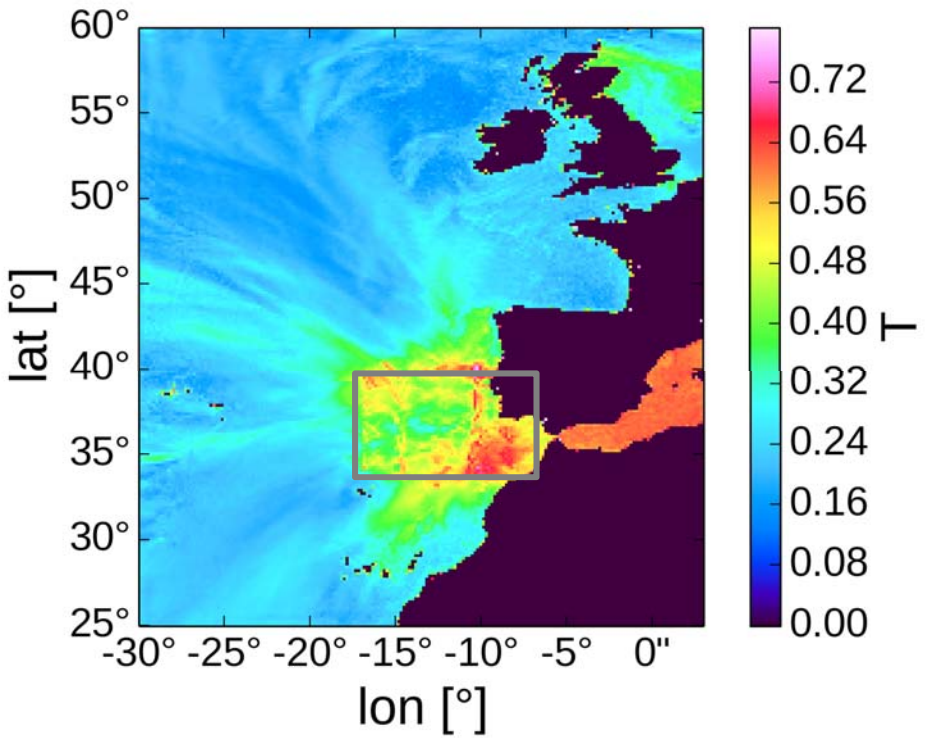
- No negligible parameters
- Strong interactions between parameters
- Many variations depending on location

SENSITIVITY TO LOCATION

longitude (*lon*)

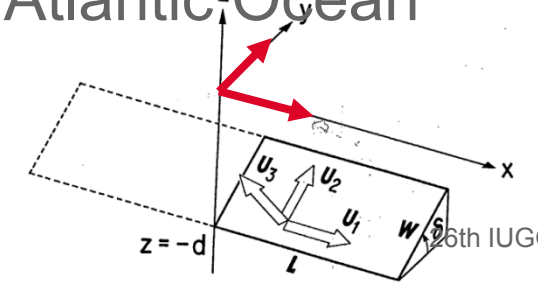


latitude (*lat*)



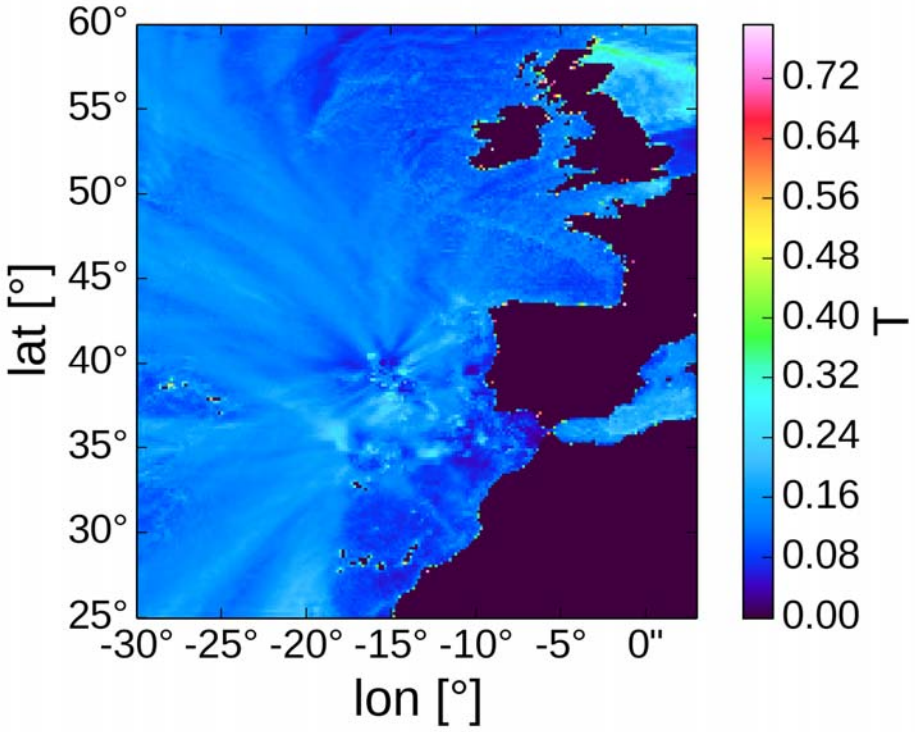
++ North Atlantic Ocean

++ Portugal

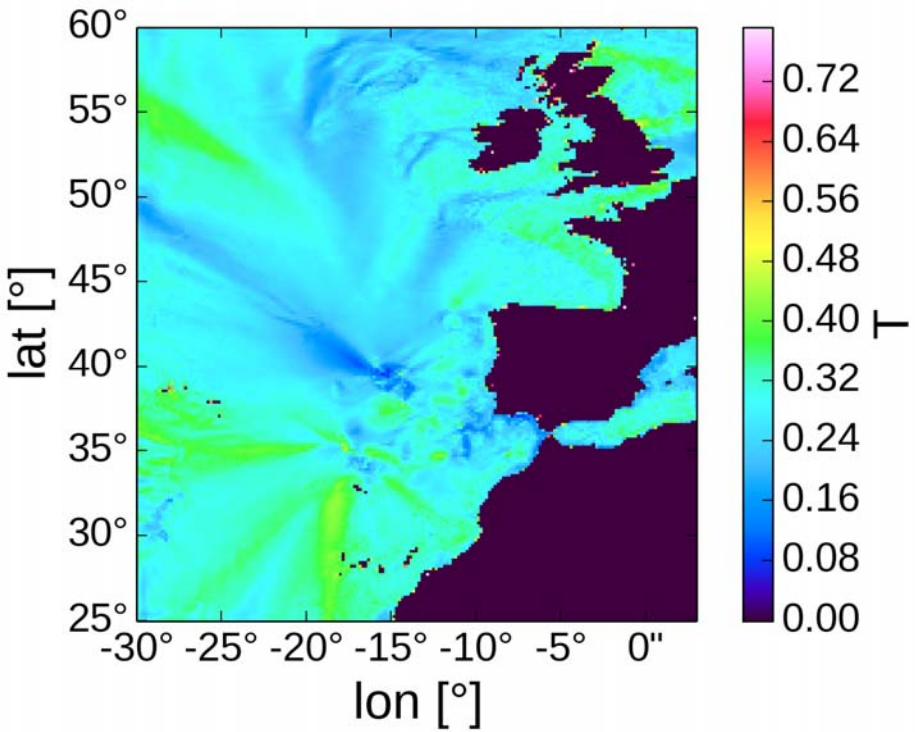


SENSITIVITY TO DIMENSIONS

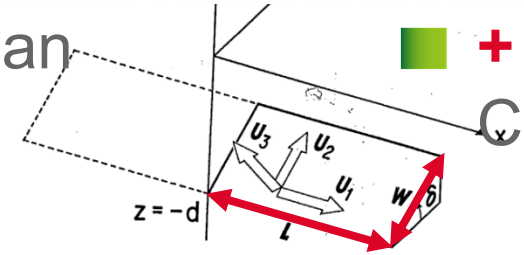
length



width

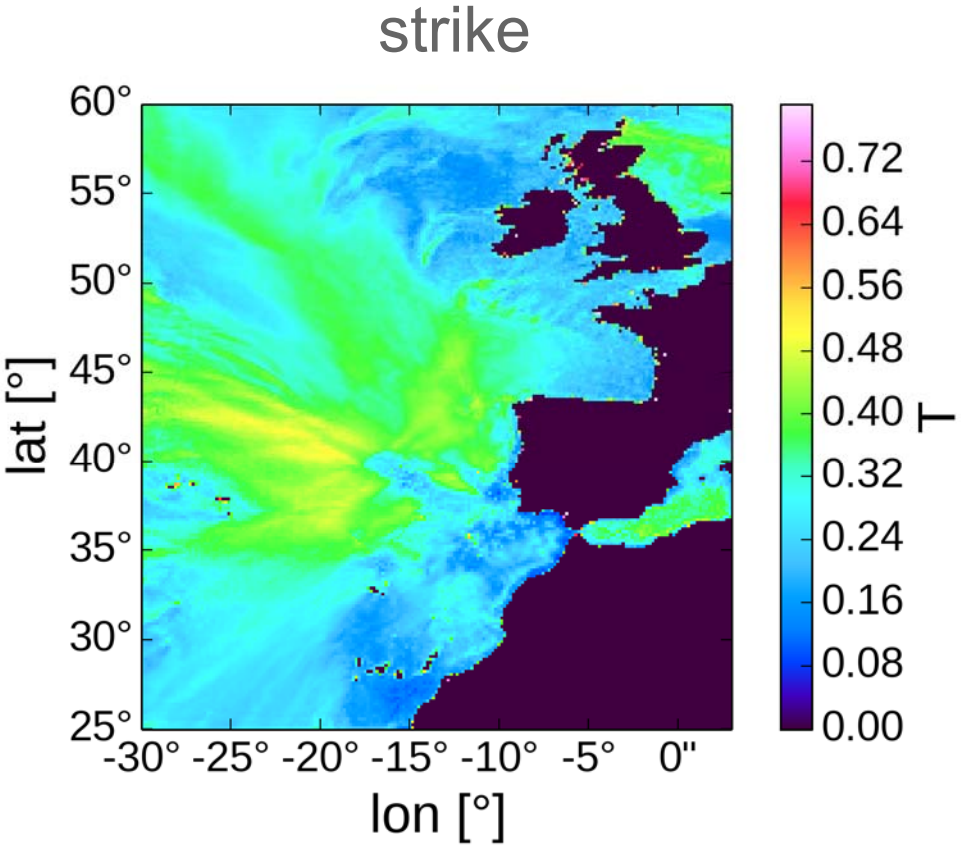


– – Atlantic Ocean

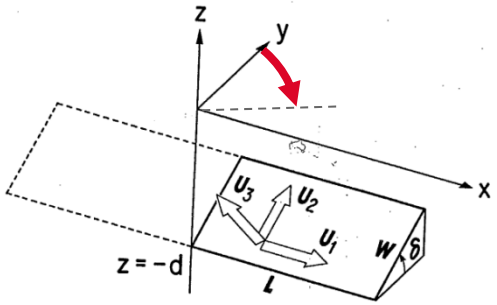


\+ Azores, France, English Channel, British Islands

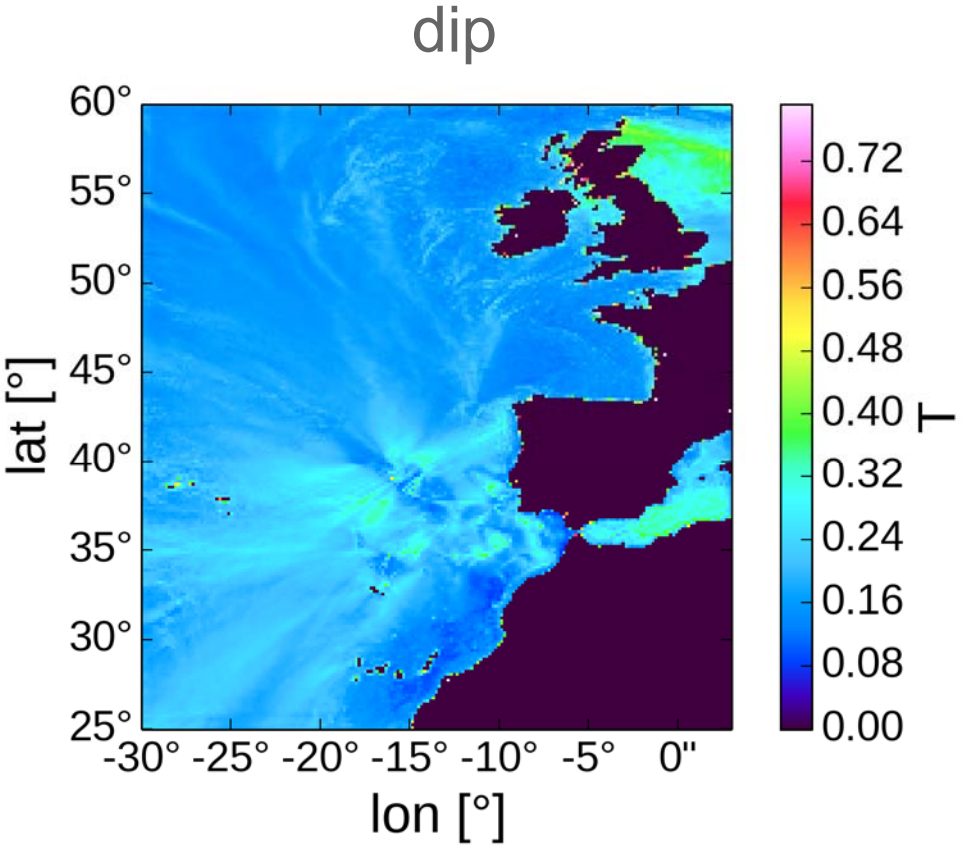
SENSITIVITY TO STRIKE



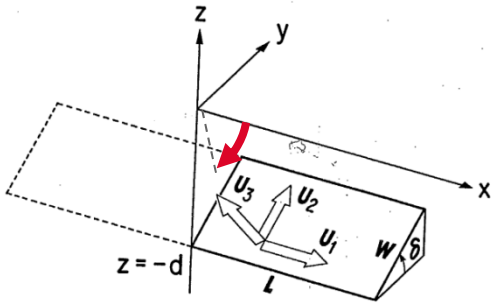
- ++ Atlantic Ocean
- ++ North Portugal



SENSITIVITY TO DIP

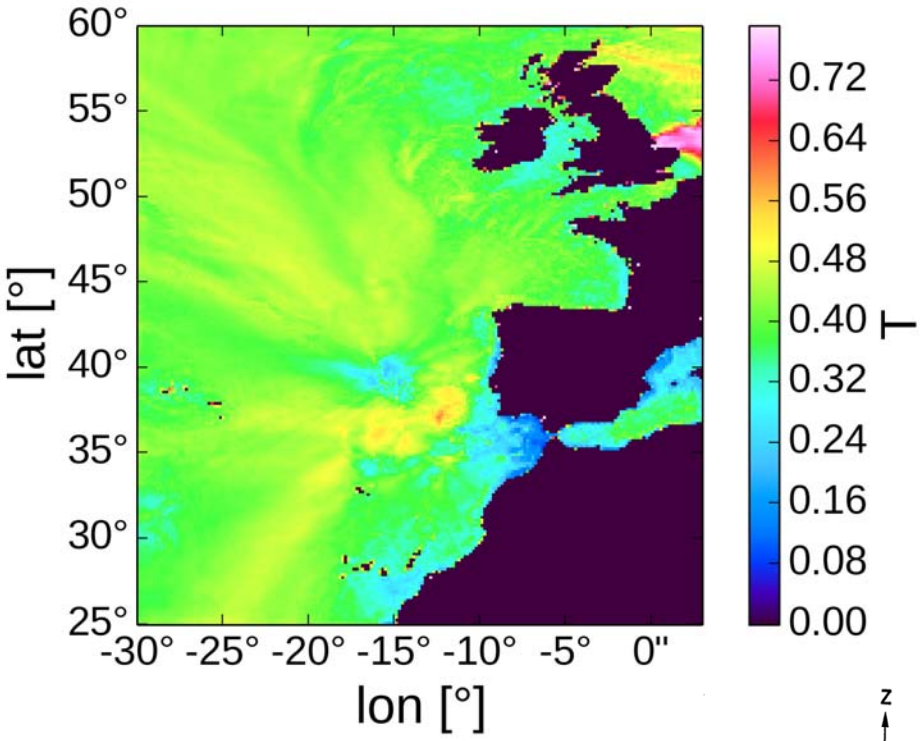


Atlantic Ocean

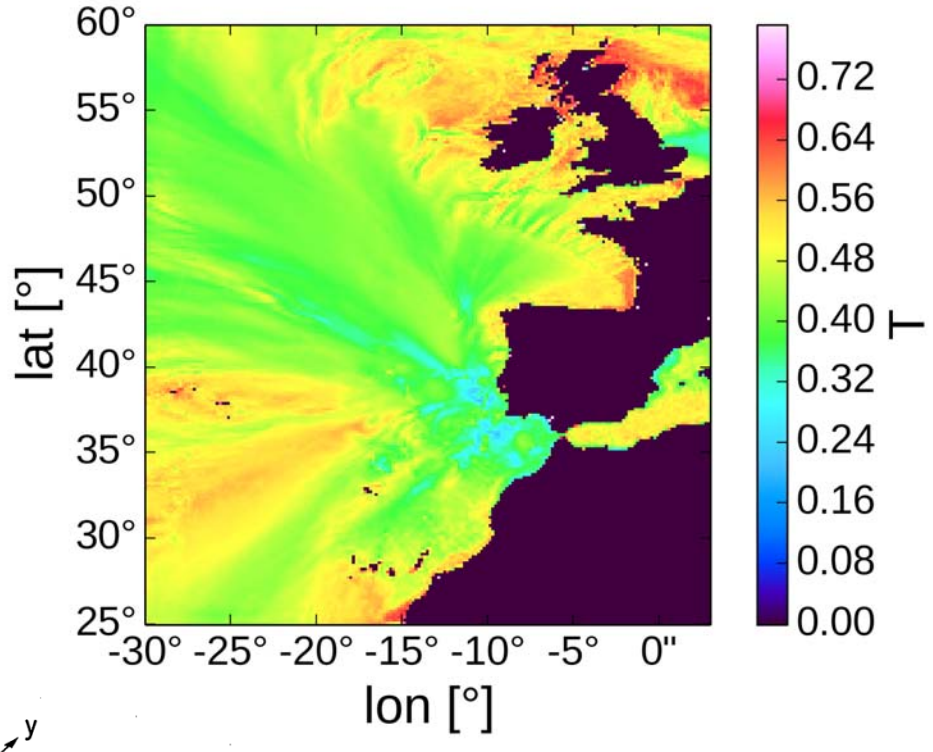


SENSITIVITY TO RAKE AND SLIP

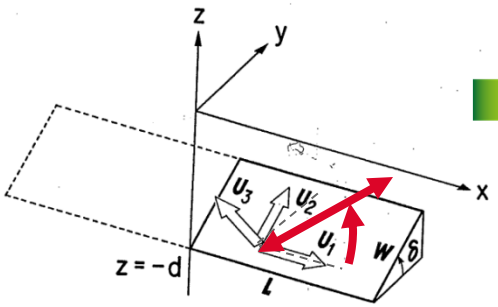
rake



slip

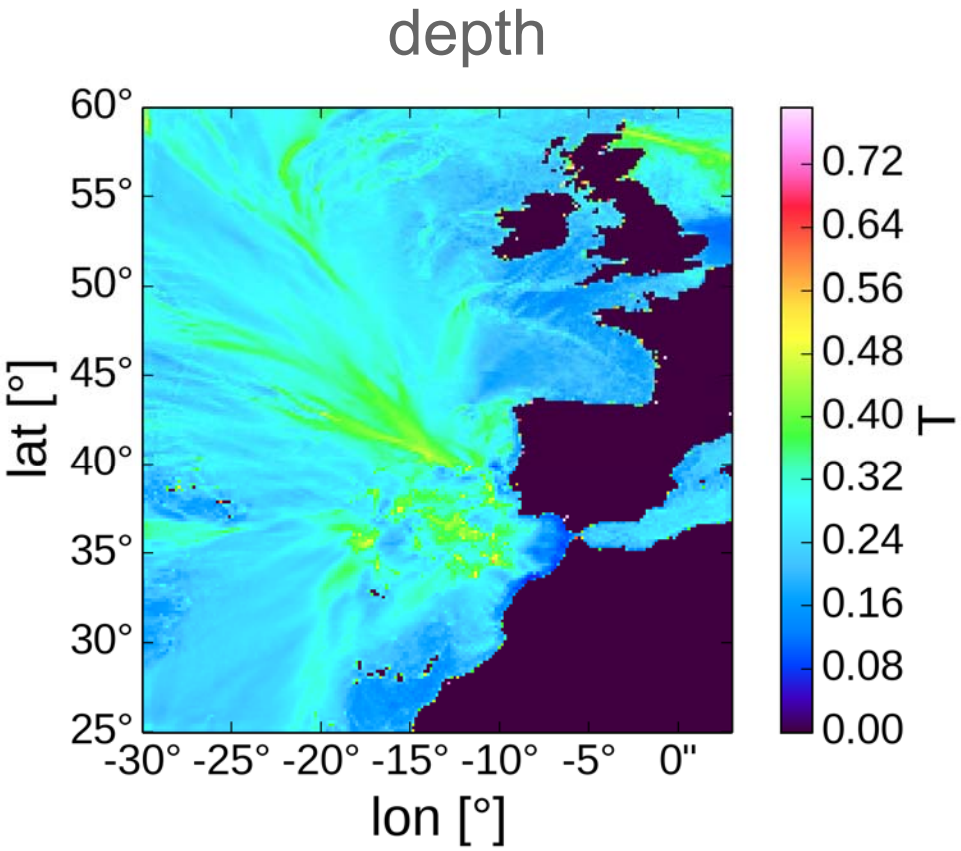


- **+** everywhere
- **−** Gulf of Cadiz

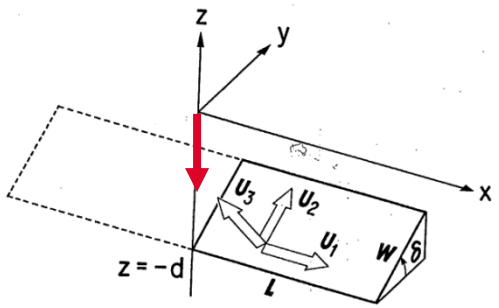


- **++** Bay of Biscay, British Islands, Azores, Canary Islands

SENSITIVITY TO DEPTH

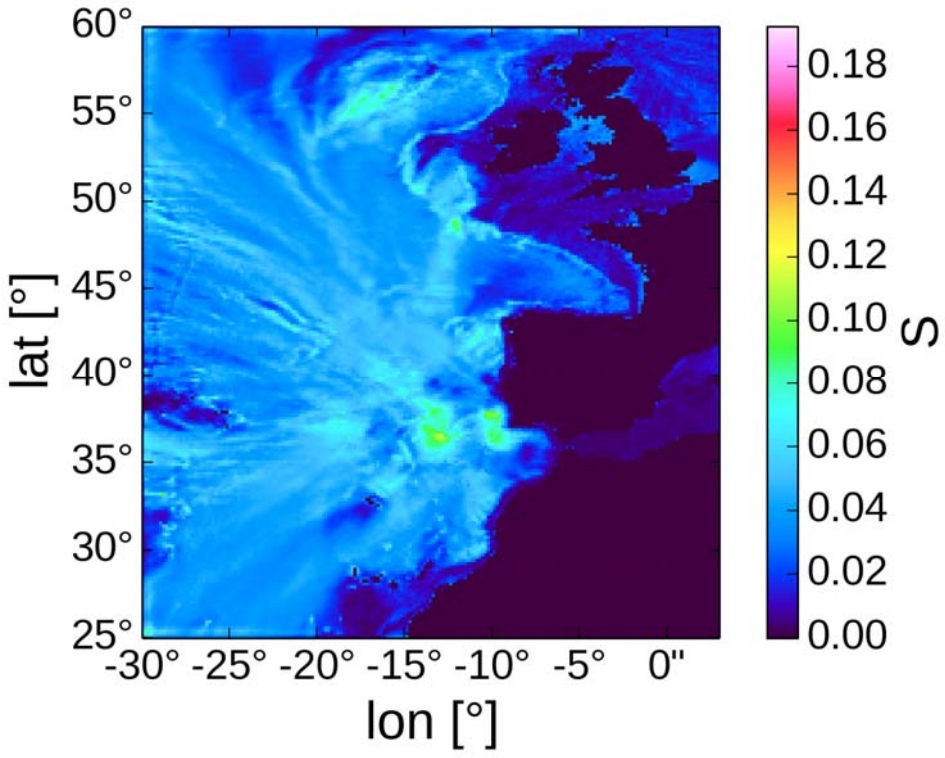


- + West Atlantic Ocean
- + West Portugal

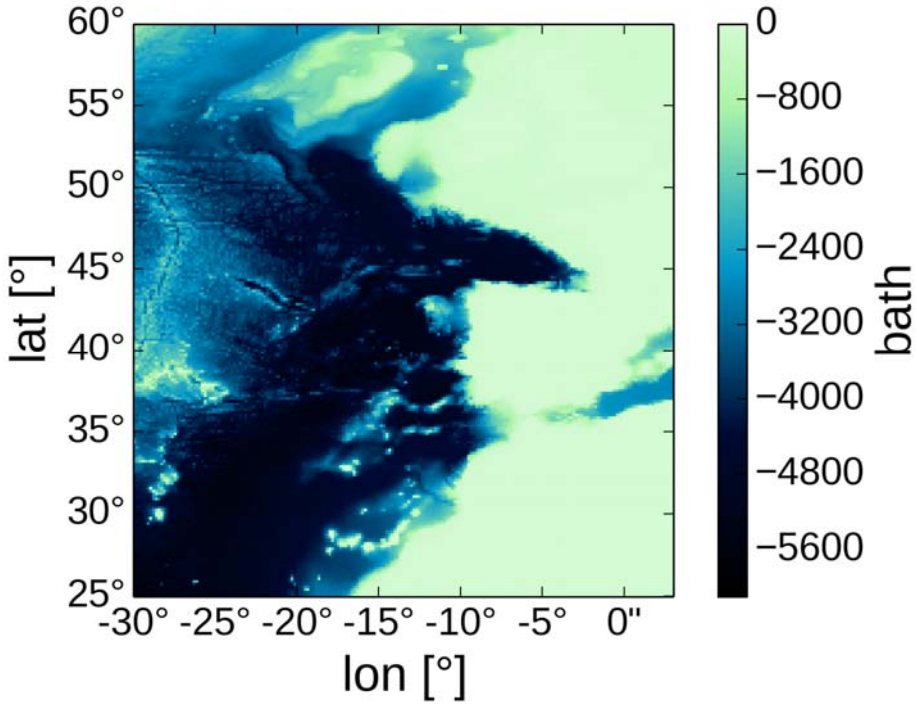


SENSITIVITY TO DEPTH

depth
(individual contribution)



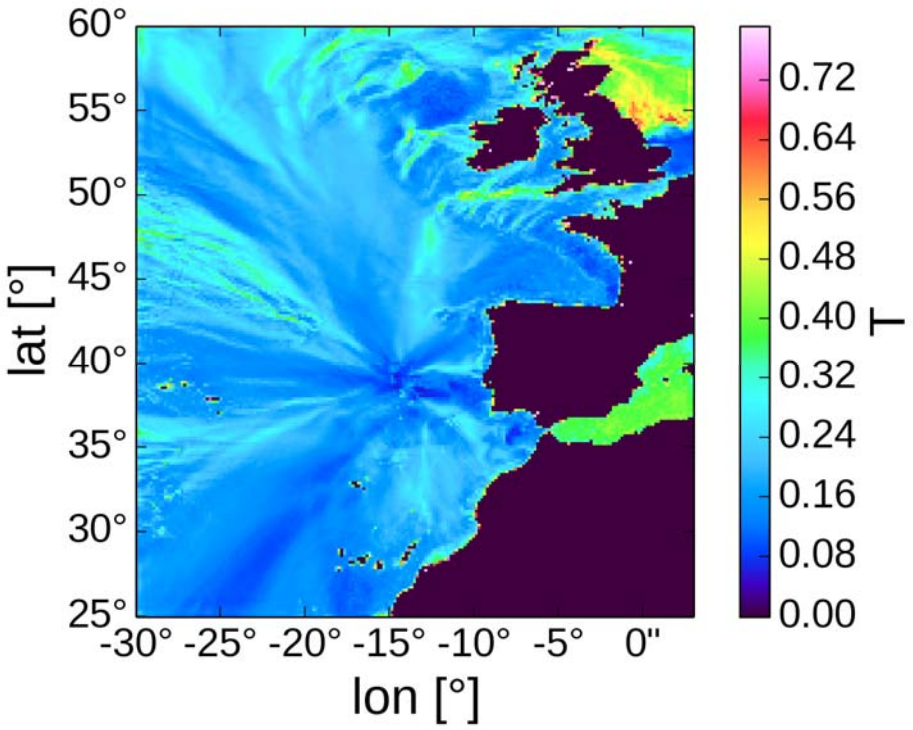
bathymetry D



S ~ f(D)

SENSITIVITY TO SPATIAL DISCRETIZATION

Δx

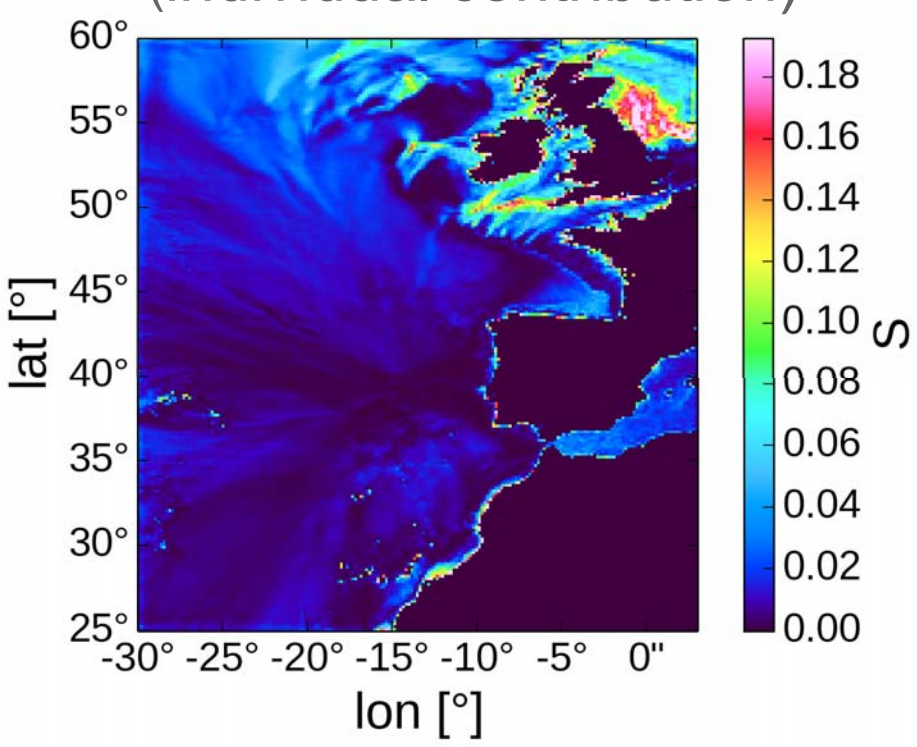


++ after Strait of Gibraltar

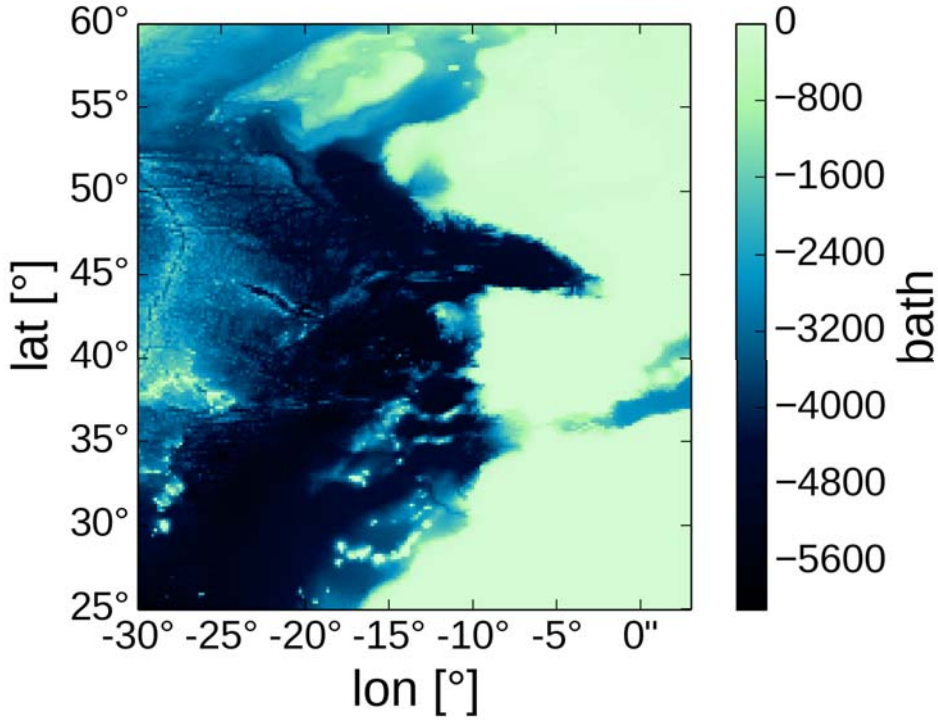
SENSITIVITY TO SPATIAL DISCRETIZATION

Δx

(individual contribution)



bathymetry D



- **++** all coast lines
- **+** shallow waters

CONCLUSIONS

- Maximum water heights are overall more sensitive to some parameters than others:
  - + longitude, rake and slip
  - − length of the fault, dip
- Sensitivity to parameters can change significantly depending on the studied area:
  - S-W France : width of the fault, slip
  - West Portugal : latitude
- Sensitivity to depth or spatial discretization are related to the bathymetry D

PROSPECTS

- Quantify uncertainties in terms of water heights
- Use finer grids near coasts and in shallow waters to investigate synthetic gages
- Test the sensitivity to the precision of bathymetry (z-axis)

THANK YOU FOR YOUR ATTENTION

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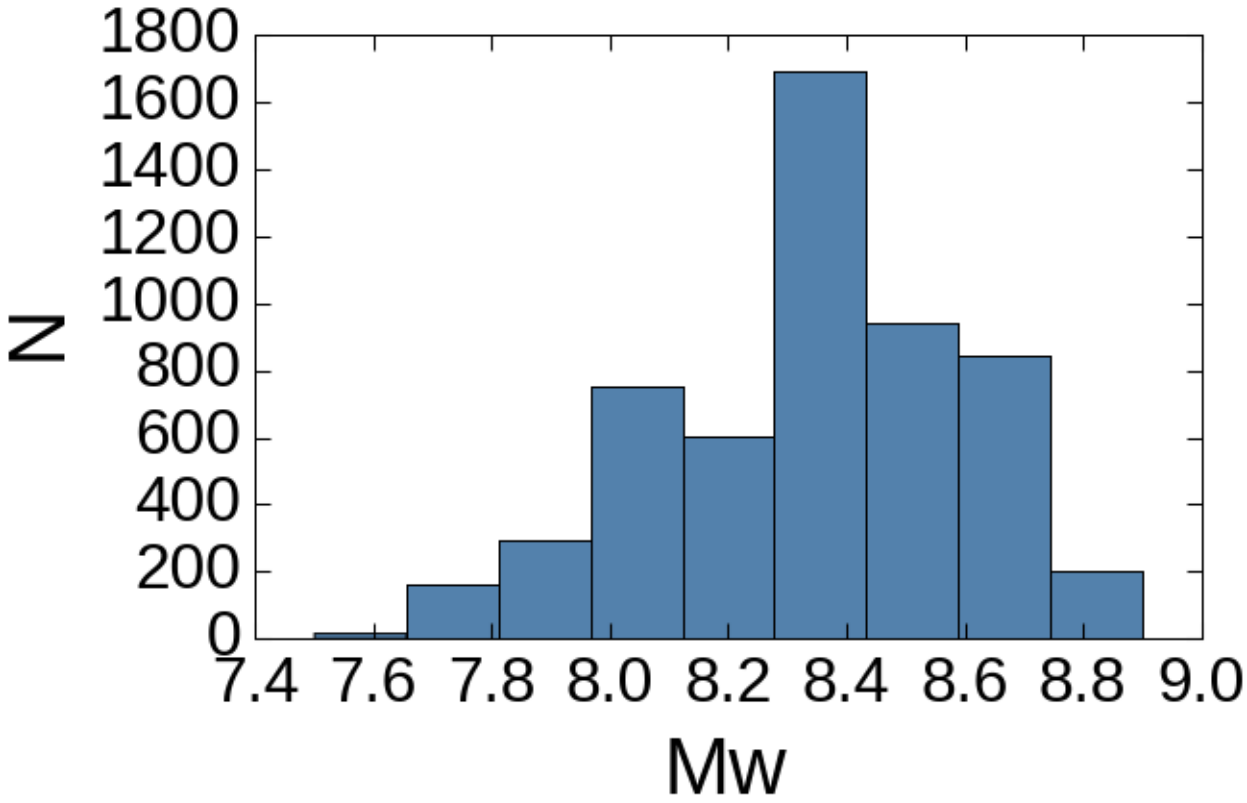
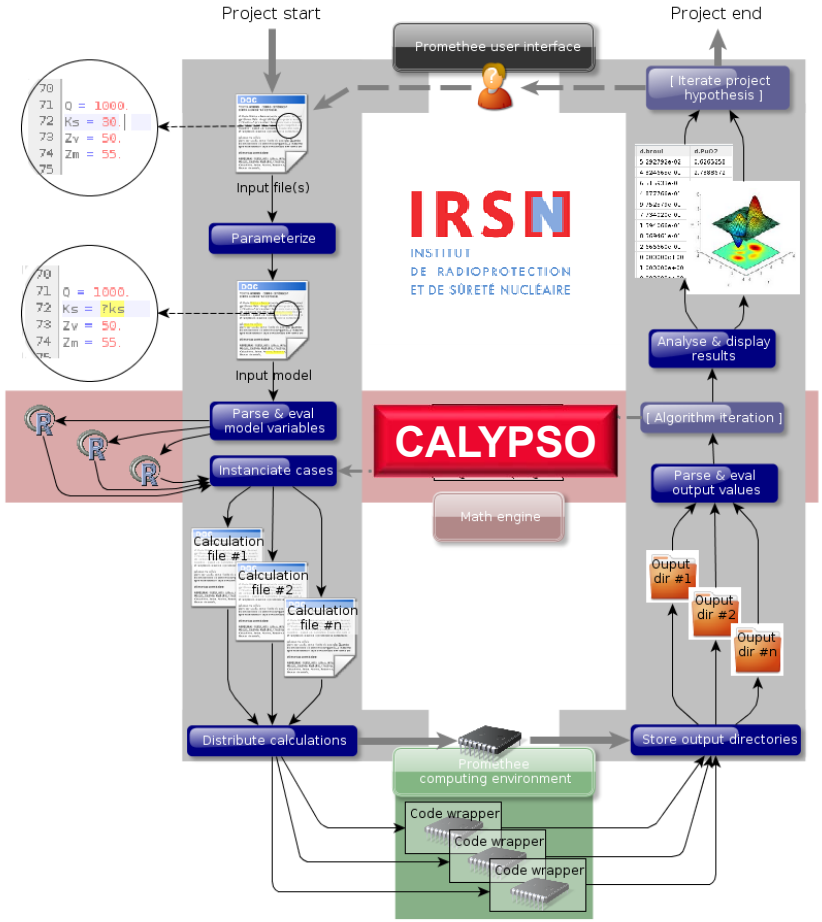
MAGNITUDE DISTRIBUTION

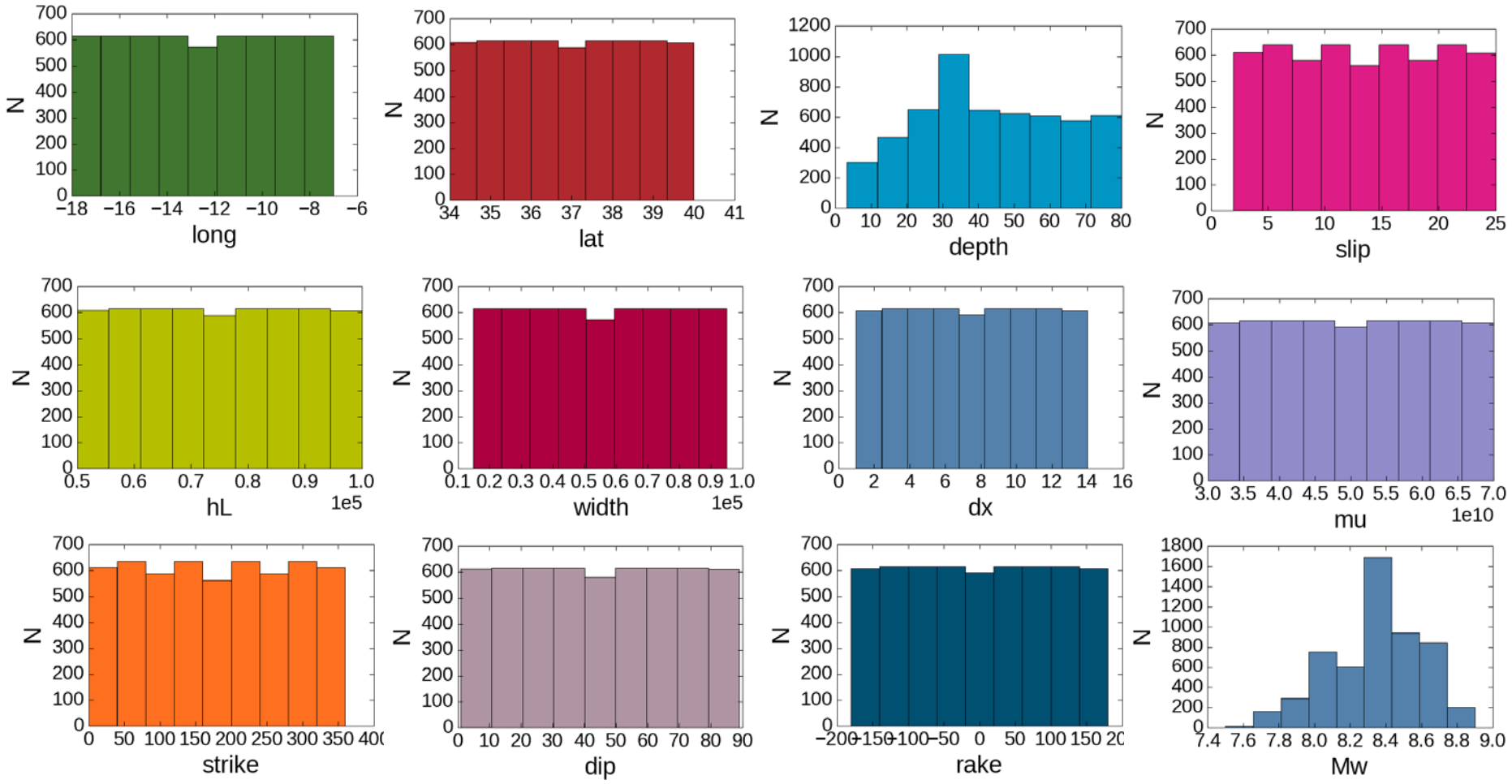


PROMETHEE

- Propagation d'incertitudes
  - modèle d'entrée : Calypso
  - paramètres d'entrée =>échantillons aléatoires
  - distribution des calculs sur les nœuds du cluster
  - analyse statistique des résultats via R

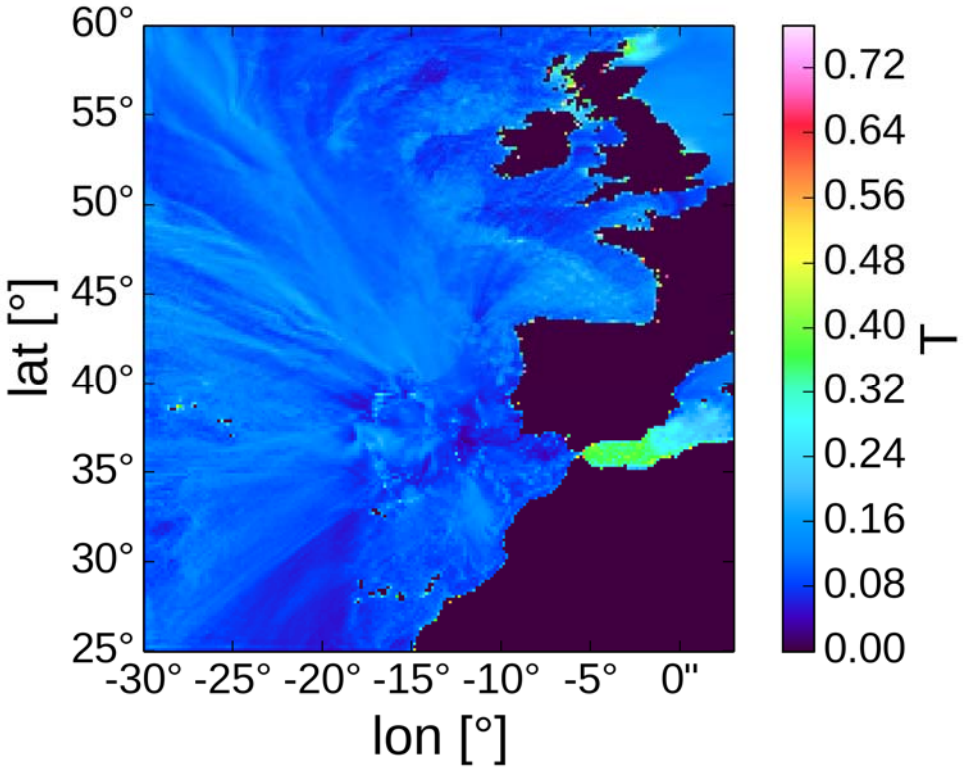


INPUT PARAMETERS DISTRIBUTION



SENSITIVITY TO TIME STEP

Time step



Atlantique ocean