# NEW TSUNAMI HAZARD ASSESSMENT OF CHAÑARAL, CHILE, AFTER THE COASTAL MORPHOLOGY CHANGES DUE TO THE 2015 RIVER FLOOD


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*The mission of the Research Center for Integrated* ***Disaster Risk*** *Management,* ***CIGIDEN****, is to develop, integrate, and transfer* ***scientific*** *knowledge and form advanced human capital that contributes to reduce the social* ***consequences*** *of extreme* ***natural events****.*

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CIGIDEN brings together researchers from diverse areas including: **social sciences**, **geosciences**, **engineering**, **architecture** and **design**.

Our team consists of:

**8** principal investigators.

**45** researchers.

**9** postdoctoral researchers.

**Support** staff.

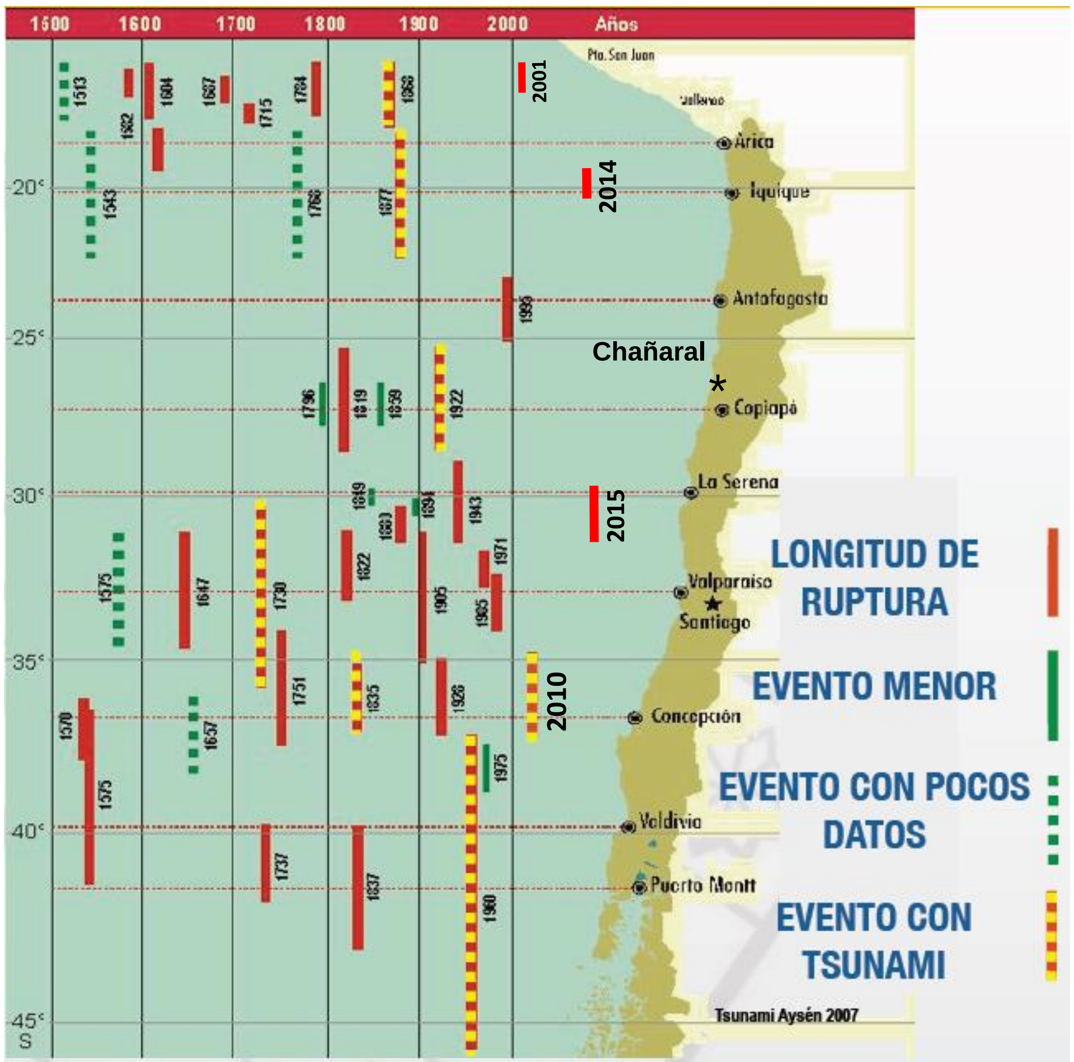
And numerous **students** pursuing **undergraduate** and **graduate** programs.

# Contents



UCSC

# 1 Introduction

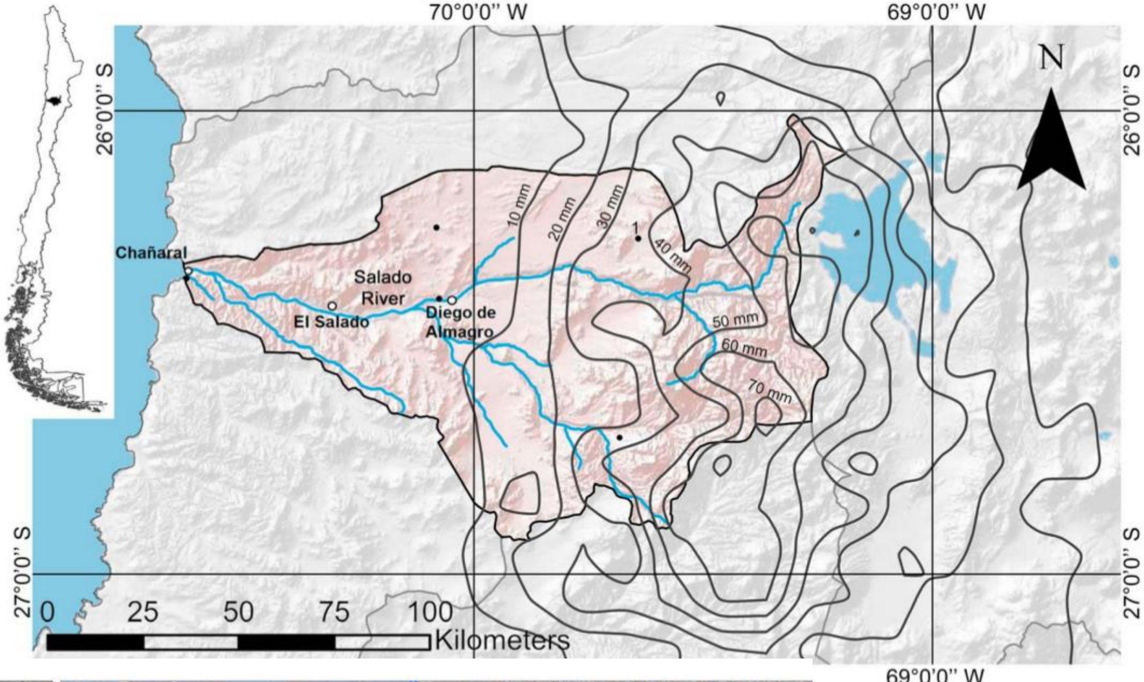


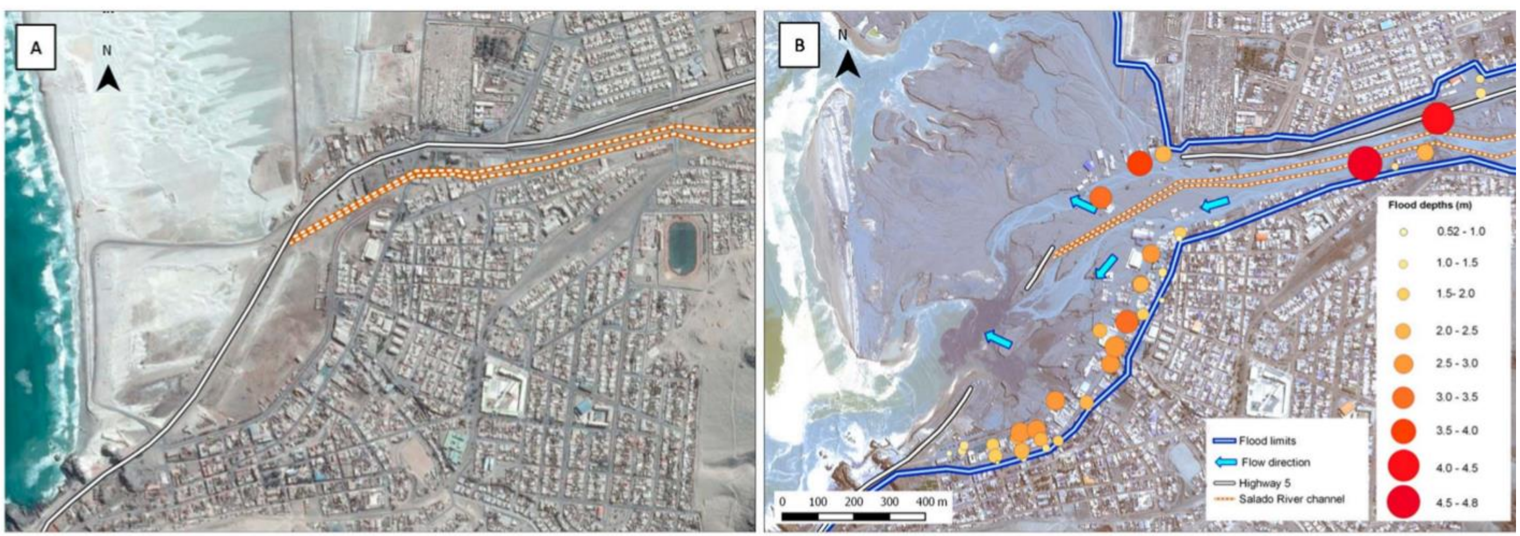

- The last tsunami which affected Chañaral occured in 1922 (Mw 8,3)


(SHOA, 2014)

# 1 Introduction

- Flood in 2015




(Wilcox et al 2016)

# 1 Introduction

- Flood in 2015


(Cubelos et al, in preparation)

# 1 Introduction

- Objective

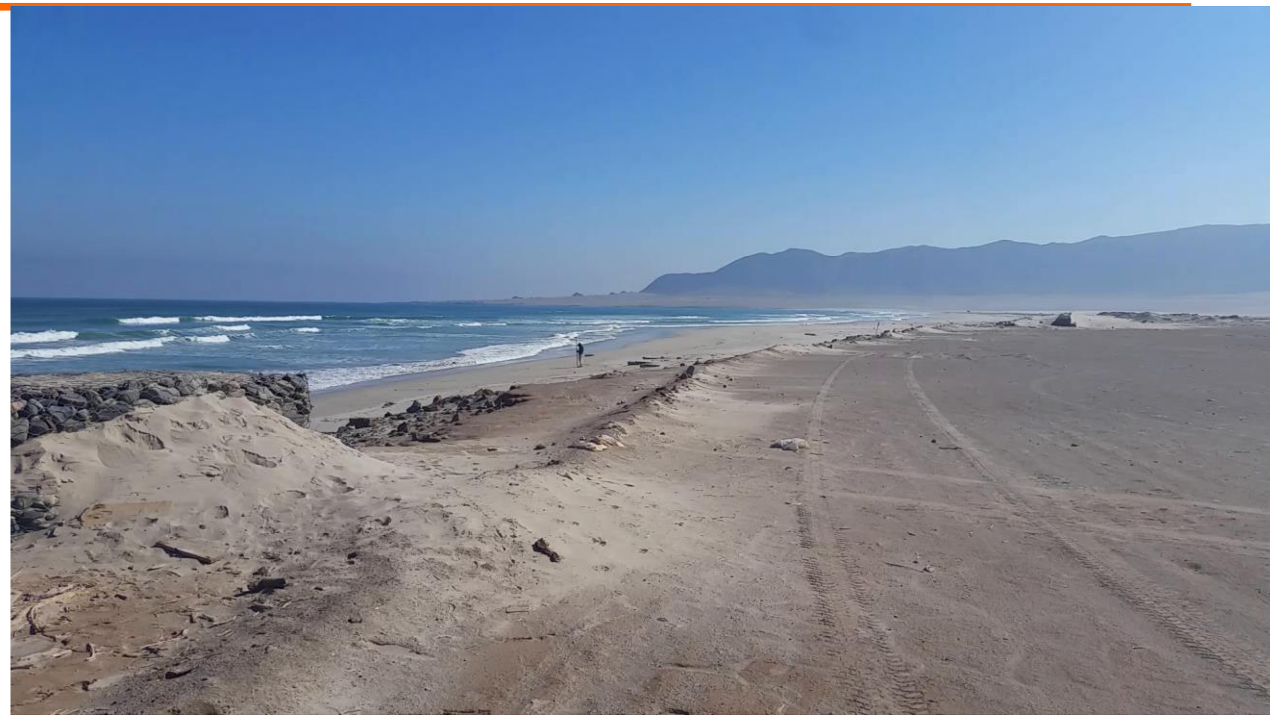
The present work assesses the tsunami hazard considering the new coastal morphology, given that coastal erosion would allow a tsunami to easily surge into the river and subsequently the town.

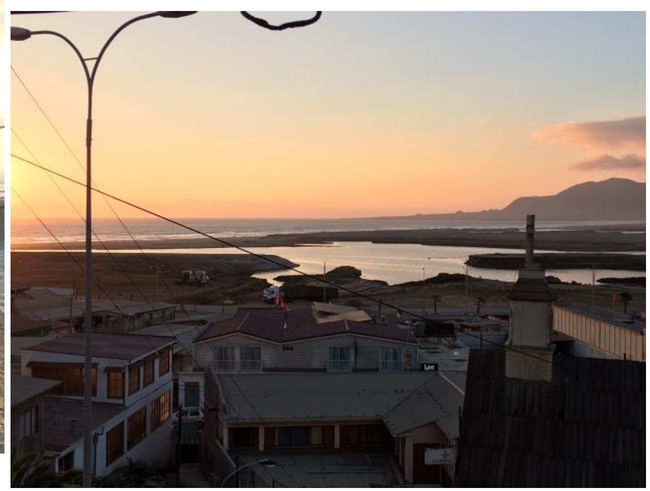
# 2 Field survey

-Collect existing LiDAR Topography

- Processing existing bathymetry

-Topography along the beach





# 3 Tsunami numerical simulations

- Numerical simulations with NEOWAVE model

$$\frac{\partial U}{\partial t}+\frac{U}{R\cos\phi}\frac{\partial U}{\partial\lambda}+\frac{V}{R}\frac{\partial U}{\partial\phi}-\left(2\Omega+\frac{U}{R\cos\phi}\right)V\sin\phi$$
$$=-\frac{g}{R\cos\phi}\frac{\partial\zeta}{\partial\lambda}-\frac{1}{2}\frac{1}{R\cos\phi}\frac{\partial q}{\partial\lambda}-\frac{1}{2}\frac{q}{DR\cos\phi}\frac{\partial(\zeta-h+\eta)}{\partial\lambda}-n^2\frac{g}{D^{1/3}}\frac{U\sqrt{U^2+V^2}}{D}$$

$$\frac{\partial V}{\partial t}+\frac{U}{R\cos\phi}\frac{\partial V}{\partial\lambda}+\frac{V}{R}\frac{\partial V}{\partial\phi}+\left(2\Omega+\frac{U}{R\cos\phi}\right)U\sin\phi$$
$$=-\frac{g}{R}\frac{\partial\zeta}{\partial\phi}-\frac{1}{2}\frac{1}{R}\frac{\partial q}{\partial\phi}-\frac{1}{2}\frac{q}{DR}\frac{\partial(\zeta-h+\eta)}{\partial\phi}-n^2\frac{g}{D^{1/3}}\frac{V\sqrt{U^2+V^2}}{D}$$

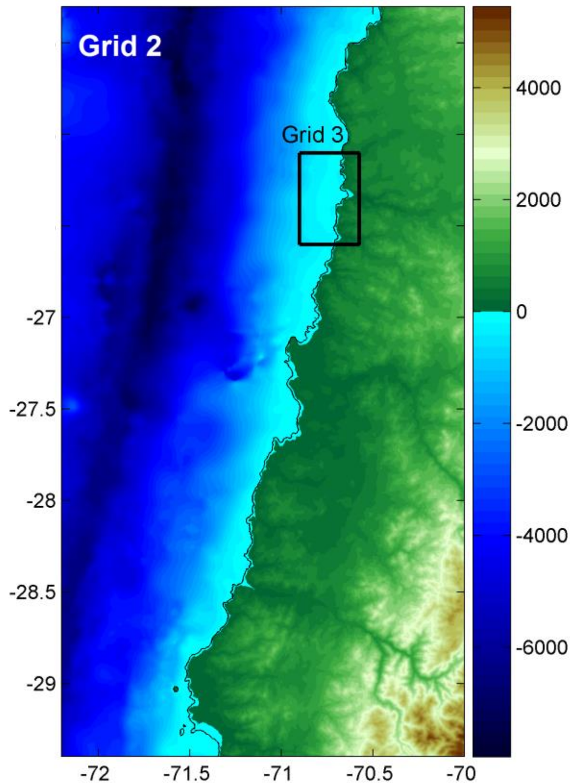
$$\frac{\partial W}{\partial t}=\frac{q}{D}$$

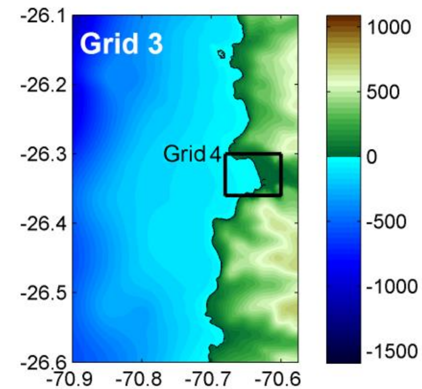
$$\frac{\partial(\zeta-\eta)}{\partial t}+\frac{1}{R\cos\phi}\frac{\partial(UD)}{\partial\lambda}+\frac{1}{R\cos\phi}\frac{\partial(V\cos\phi D)}{\partial\phi}=0$$

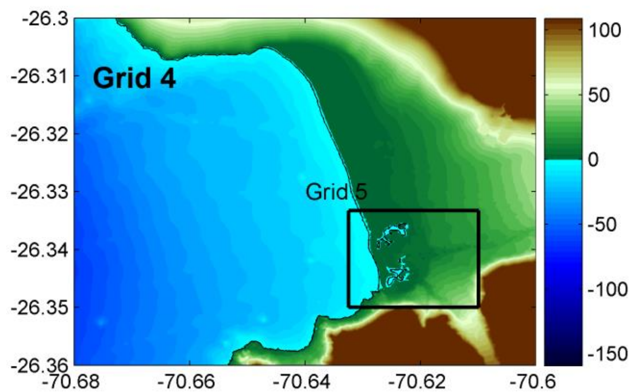
(Yamazaki et al 2011)

We used 5 nested grids with a highest grid resolution of ~10 m

Timesteps from 2s to 0.0625s



# 3 Tsunami numerical simulations

## Propagation: numerical formulation

- The model calculates U and V at the cell interface

- ζ, q, W at the center of the cell

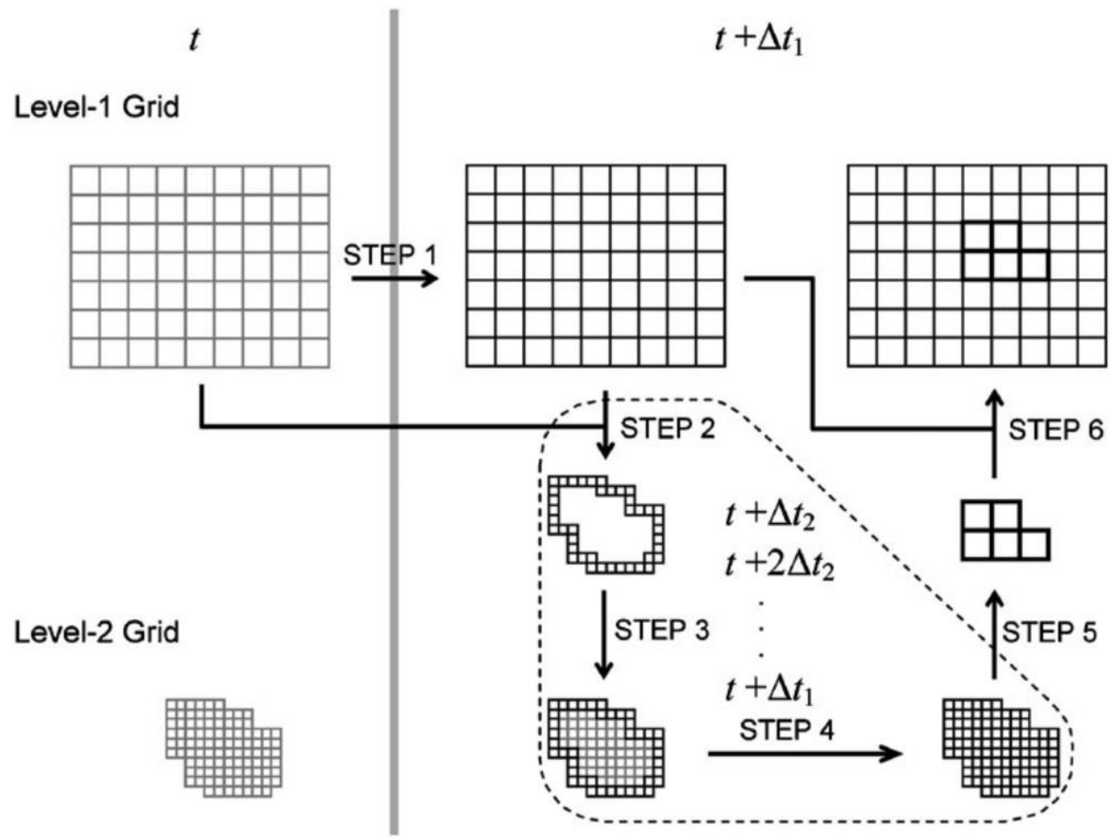
If non-hydrostatic term is omitted, an explicit formulation is used for a hydrostatic solution

The numerical scheme of non-hydrostatic solution is implicit

The vertical velocity on the seafloor is evaluated from the boundary condition

The model uses a two-way grid nesting. Each grid uses different timestep.

The model is run in Linux with Intel-fortran compiler




(Yamazaki et al 2011)

# 3 Tsunami numerical simulations

Tsunami source

The 1922-like tsunami

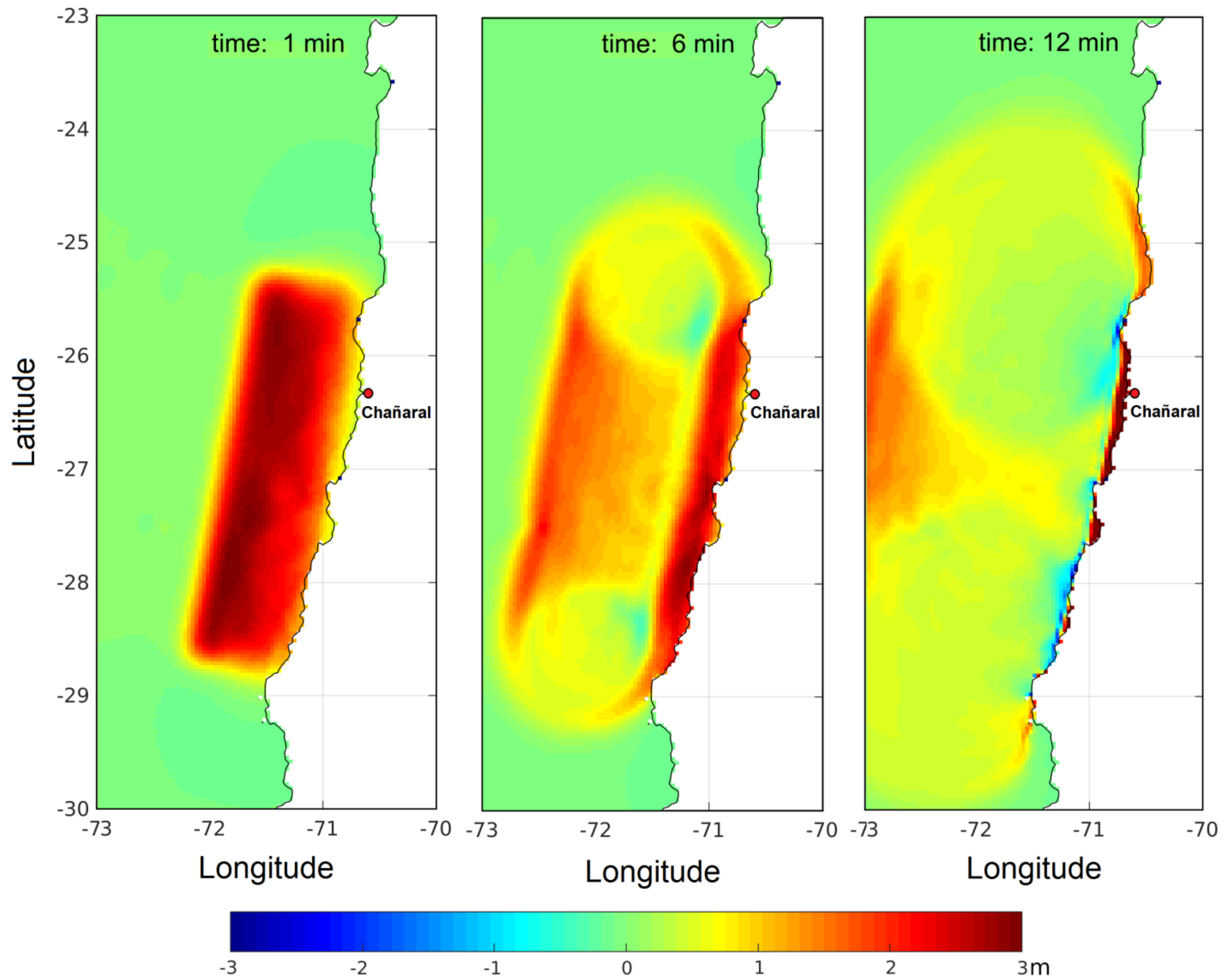
L=380km

W=130km

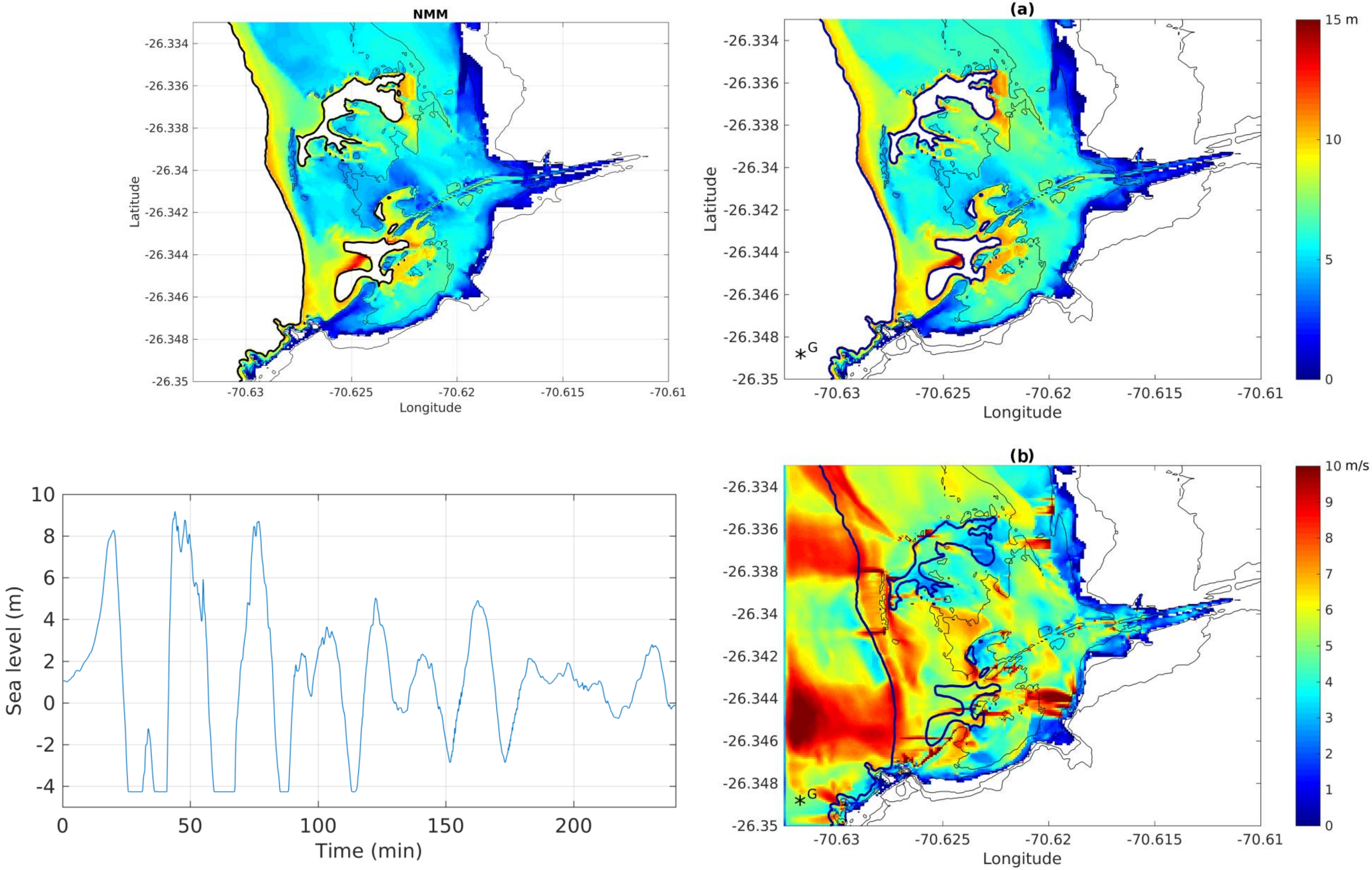
D=8m

Mw 8.65

the same used by SHOA,2014)



# 4 Results


NMM
(a)
(b)
Latitude
Longitude
-26.334
-26.336
-26.338
-26.34
-26.342
-26.344
-26.346
-26.348
-26.35
-70.63
-70.625
-70.62
-70.615
-70.61
G
15 m
10
5
0
10 m/s
9
8
7
6
5
4
3
2
1
0
Sea level (m)
Time (min)
0
50
100
150
200
10
8
6
4
2
-2
-4

# 4 Results

Max. Inundation

# 5 Future challenge

Probabilistic approach

# 5 Future challenge

Why do we need to use a probabilistic approach?

**Design purposes**

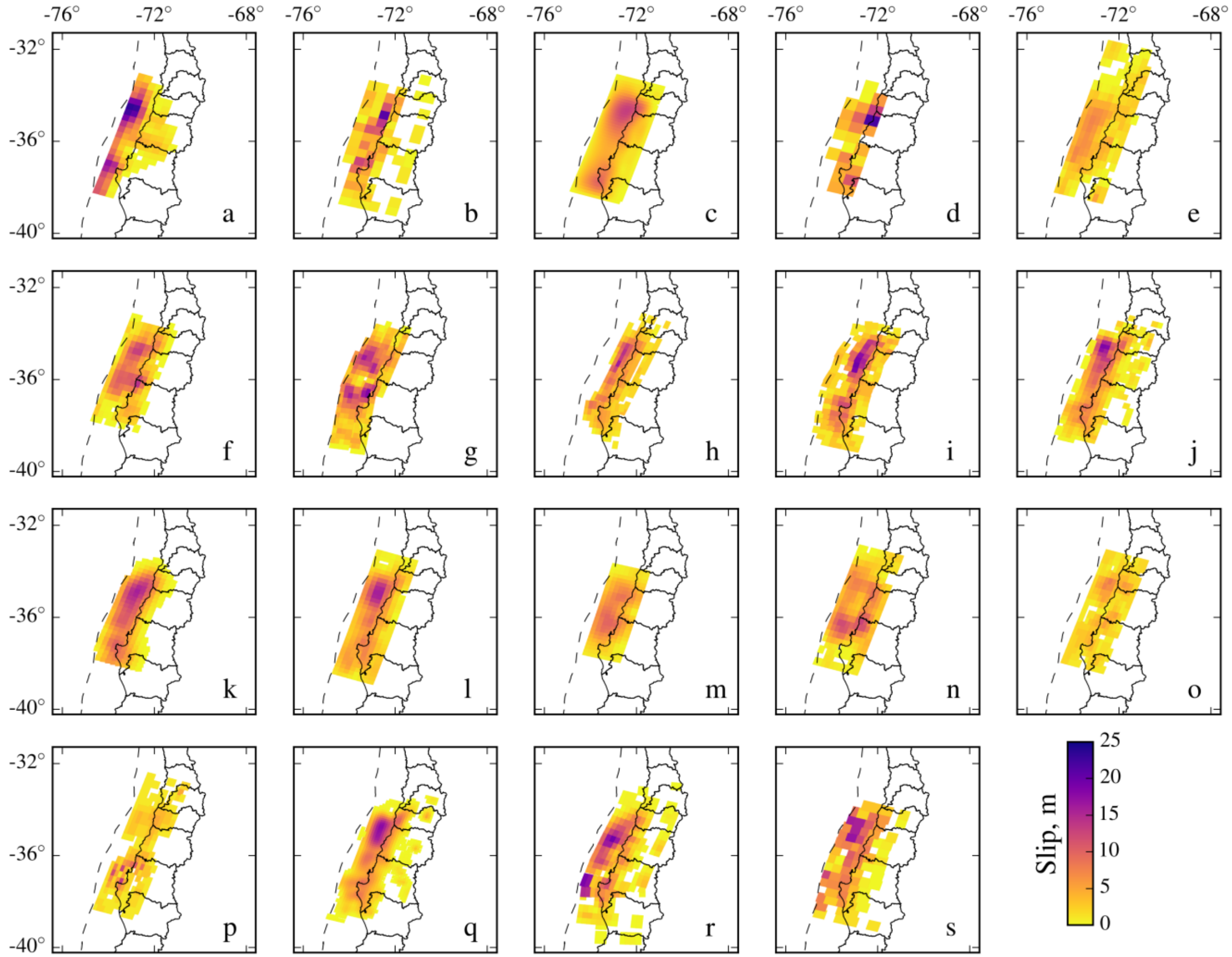
↓

statistical analysis

↓

Database
(real or synthetic)

We could not use only one deterministic tsunami scenario!

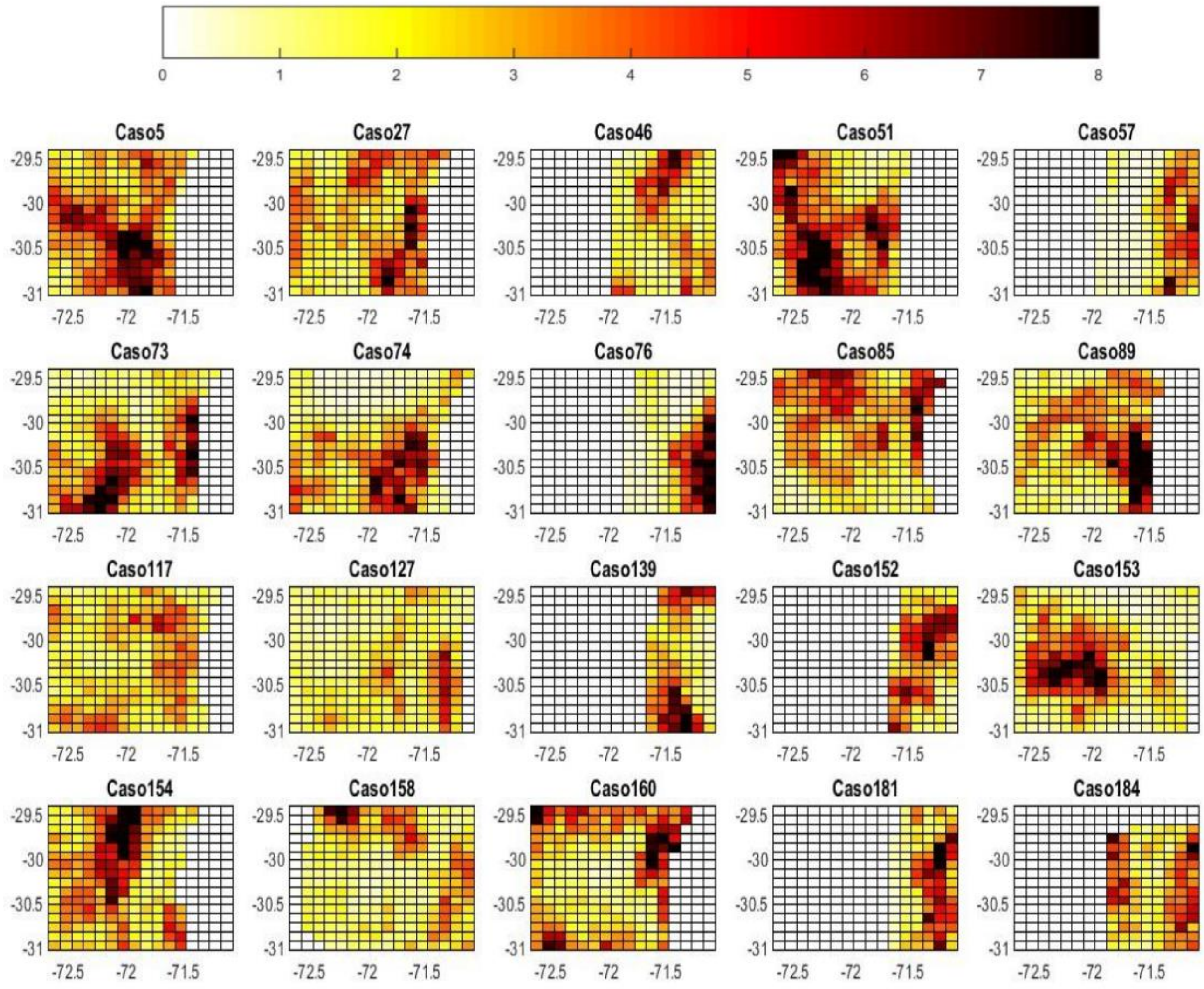



(Cienfuegos et al 2018)

# 5 Future challenge

Example of a Mw 8.2 event

Stochastic slip using the KL method



# 5 Probabilistic approach

How to run ~1000 scenarios?

**A**uthomatic **T**sunami **S**imulation **U**sing **N**eowave (ATSUN)

(matlab, phyton, tkinter, eaasygui, Linux, fortran)

**Numerical setup**

- Girds size
- time steps
- simulation time

- G-R law (N° of events)

**Tsunami scenarios**

- epicenter location
- event size (L, W)
-stochastic slip

(subfaults with cero slip are eliminated)

Folder with all tsunami scenarios, ex:
1_M88_256.txt

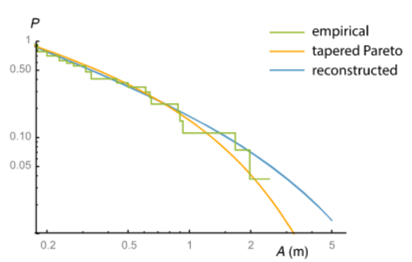
**Tsunami simulations**

- read input file
- read number of subfaults
- compile files
- run simulation
- save output files (z, u, v)

**Output analysis**
- read z, u and v for each scenario

Montecarlo

**synthetic database**




(Grezio et al 2017)

# 6 Conclusions

- The numerical simulations showed that maximum runup can reach up to 15 m and significant part of the coastal community can be flooded by the tsunami.

- It was also observed that the first tsunami wave can arrive within 15 min, and tsunami resonance can play an important role in tsunami wave amplification.

- The simulations indicate that three large waves could strike the town, with the second one being the largest.

- Finally, future mitigation measures for both tsunami and river flood should consider a multi-hazard risk assessment, due to the fact that both hazards behave in a completely different way →Probabilistic approach

# acknowledgements

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