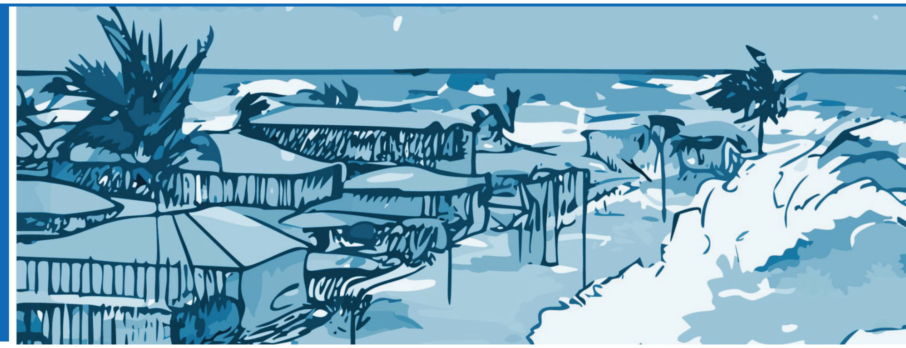
Tsunami Evacuation Mapping Workshop



Montpellier, France

30 June – 4 July 2025

Dr. Matthieu Péroche
Pr. Frédéric Leone
Louis Monnier
Emilie Lagahé
Monique Gherardi

CoastWAVE 2.0 Project

IOC-UNESCO (EU DG ECHO)

How to cite :

Péroche, M., Leone, F., Monnier, L., Lagahé, E., & Gherardi, M. (2025). Tsunami Evacuation Mapping Workshop. CoastWave 2.0 Project, IOC-UNESCO / EU DG ECHO, Montpellier, France.

Contact : matthieu.peroche@univ-montp3.fr

unesco
Intergovernmental Oceanographic Commission

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

CoastWAVE NEAMTWS

LAGAM
LABORATOIRE DE GEOGRAPHIE ET D'AMENAGEMENT DE MONTPELLIER

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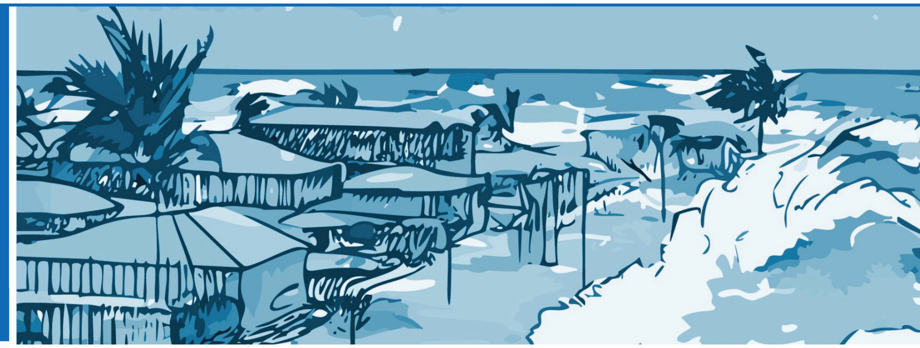
Contents

Thank you to all the workshop participants for this week of knowledge sharing, for your involvement and your good mood despite this heatwave !

Tsunami Evacuation Mapping Workshop

30 June – 4 July 2025



CoastWAVE 2.0 Project

IOC-UNESCO (EU DG ECHO)

Dr. Matthieu Péroche
Louis Monnier

Lesson #1

Tsunami evacuation zone mapping

Contact : matthieu.peroche@univ-montp3.fr

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Lesson's overview

Use of a DEM to map a "standardized" inland tsunami evacuation zone.

1. Theory

- Cannes area
- Presentation of the selected approach for evacuation area definition in France
- Pro and cons

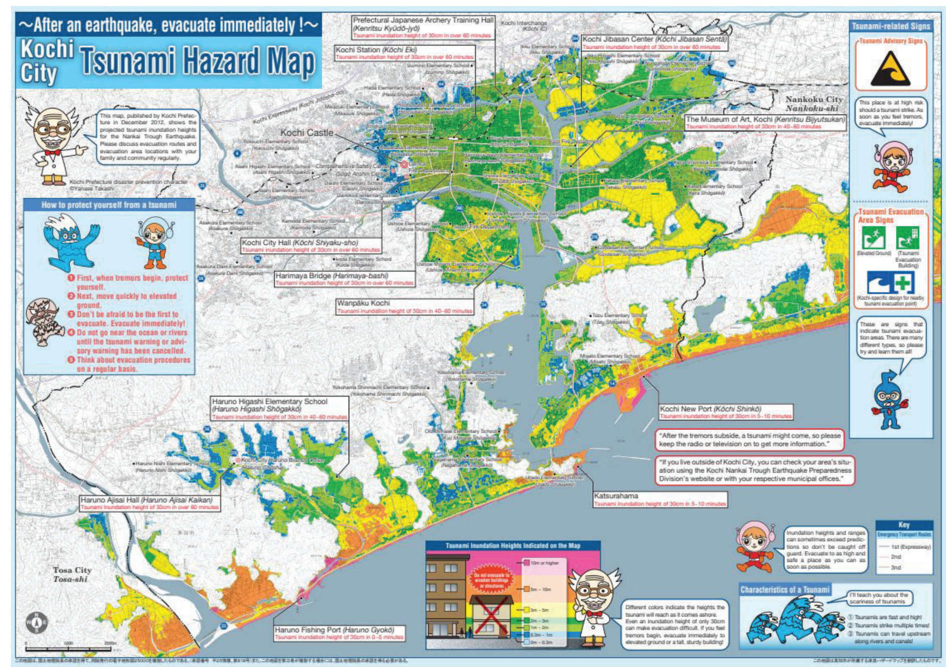
2. Practice

- Extract the altitude range set from numerical modelisation using DEM and GIS
- Corrections needed for a coherent evacuation zone
- Derivate safe zone

Tsunami evacuation zone mapping

Mapping Tsunami Evacuation Zones: 4 Key Methods

- Different methods exist to map tsunami danger zones
- The choice depends on data availability, local knowledge, and technical capacity
- Methods range from advanced simulations to basic elevation-based approaches
- Each method offers trade-offs in precision, effort, and accessibility



Mapping Tsunami Evacuation Zones - 1. Envelope from Multiple Simulations (deterministic or probabilistic)

Definition

This method combines the results of several validated tsunami simulations to produce a single envelope representing the maximum potential inundation.

Applications

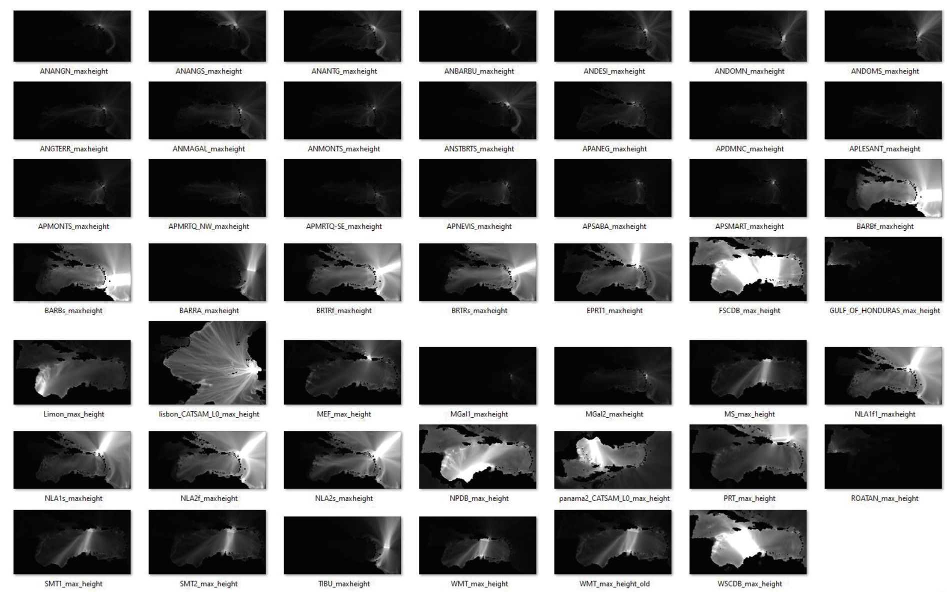
- High-exposure coastal zones
- Critical infrastructure (ports, airports, energy sites)

Strengths

- Conservative and robust
- Detailed outputs for maximums : wave arrival time, water depth, flow speed
- Integrates uncertainty from different scenarios
- Ideal for long-term planning and zoning

Limitations

- Requires multiple simulations
- High technical and financial cost
- Not always feasible for small territories



Mapping Tsunami Evacuation Zones - 2 : Hydrodynamic Modelling (Single Scenario)

Definition

Numerical simulation of tsunami generation, propagation, and inundation for **one predefined scenario** (often the worst-case plausible event).

Applications

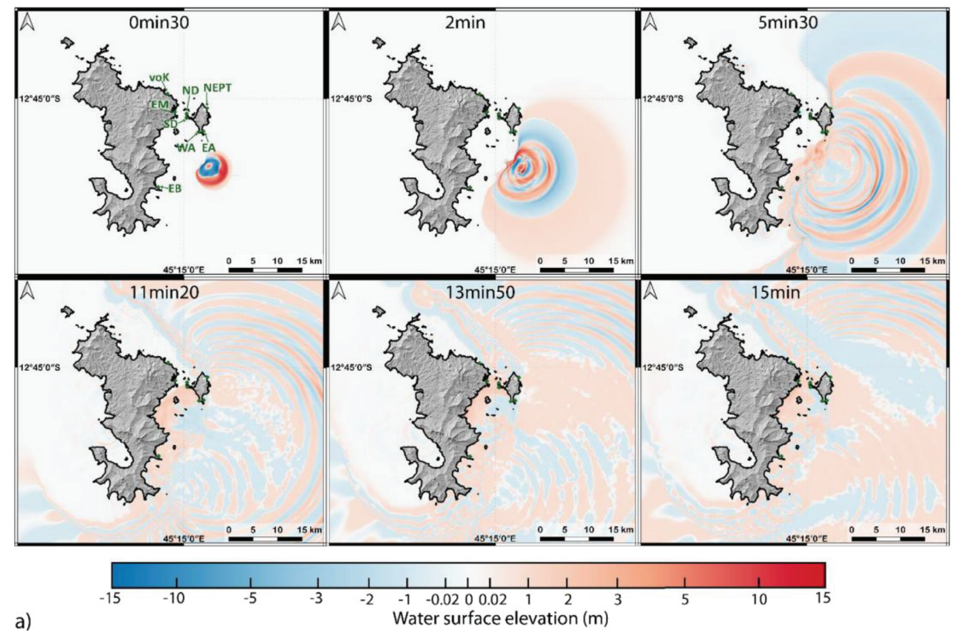
- High-exposure coastal zones
- Critical infrastructure (ports, airports, energy sites)

Strengths

- Physically accurate and scenario-specific
- Detailed outputs: wave arrival time, water depth, flow spe
- Helps visualize and communicate local risk
- Ideal for long-term planning and zoning

Limitations

- Requires multiple simulations
- Only reflects one event configuration
- May miss other potential threat sources



Pablo Poulain et al, 2022

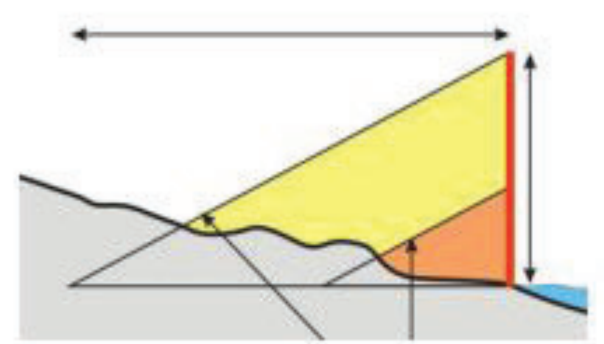
Mapping Tsunami Evacuation Zones - 3 : Topographic Projection from Simulated Coastal Heights

Definition

Inundation zones are derived by **projecting simulated maximum wave heights onto land**, using a Digital Elevation Model (DEM). No inland flood modelling is performed.

Applications

- Territories with access to tsunami simulations but limited modelling capacity
- Easier to generalize over **large coastal areas**
- Suitable for regional-scale evacuation planning



Strengths

- Uses outputs from actual tsunami scenarios
- Faster and less costly than full inundation models
- Requires fewer computational resources

Limitations

- Still needs accurate input data (DEM, coastal wave heights)
- Doesn't account for local hydrodynamics (flow, obstacles, direction)
- May overestimate or underestimate extent in flat or complex terrain

Mapping Tsunami Evacuation Zones - 4 : Simple Elevation-Based Method ("Bathtub")

Definition

Tsunami danger zones are mapped using a fixed elevation threshold (e.g. 10–15 m), without relying on simulation outputs. It is also recommended to set a maximum inland penetration distance, to avoid unrealistic inland extents in flat terrain.

Applications

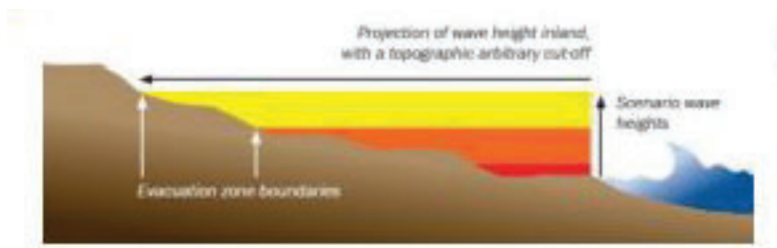
- Territories with no access to tsunami modelling
- Useful for early-stage planning and awareness
- Can be applied using basic topographic data (DEM)

Strengths

- Requires no simulation
- Easy to implement and to communicate to the public
- A good starting point for evacuation planning

Limitations

- May overestimate inland extent
- No information on wave dynamics or timing
- Assumptions must be validated by risk management authorities



A Common Approach for French Territories

An Operational Choice

- Evacuation planning in France began with the **Simple Elevation-Based Method (10 m threshold)**
- Selected due to the **lack of usable simulation data** and the need for **consistency across territories**
- Informed by **international practices**, **historical runup values**, and **partial modelling outputs**

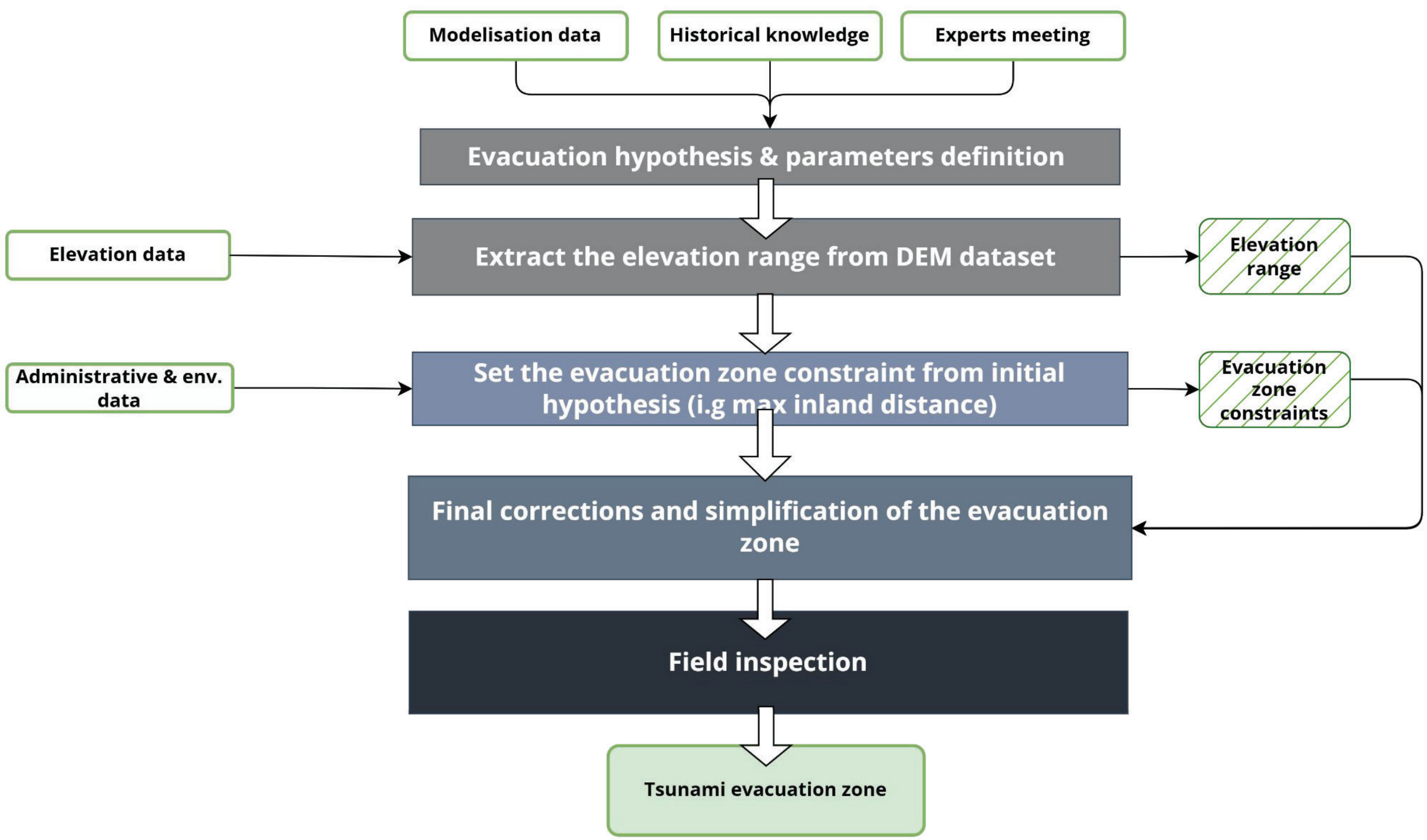
Progressive National Deployment

- Method first used in the **French Antilles (2013–2014)**
- Then **adapted and applied in the Mediterranean (2019)** under the **TASOMA project**
- Finally **adopted in Mayotte (2020)** as a starting point for tsunami preparedness

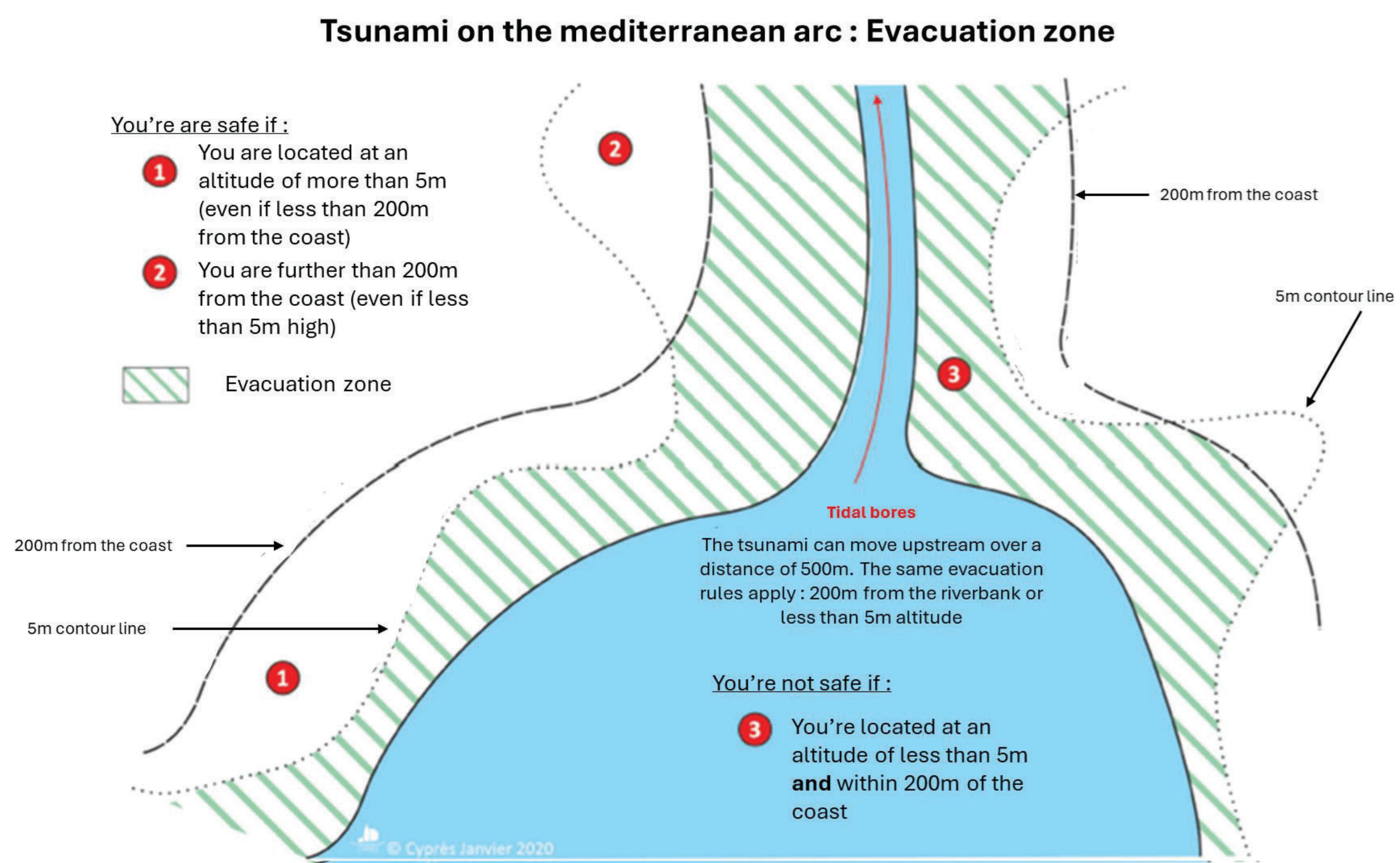
A simple, shared method has enabled nationwide progress in tsunami evacuation planning, despite data gaps and regional diversity.

Tsunami evacuation zone mapping

Overview of the theoretical stages

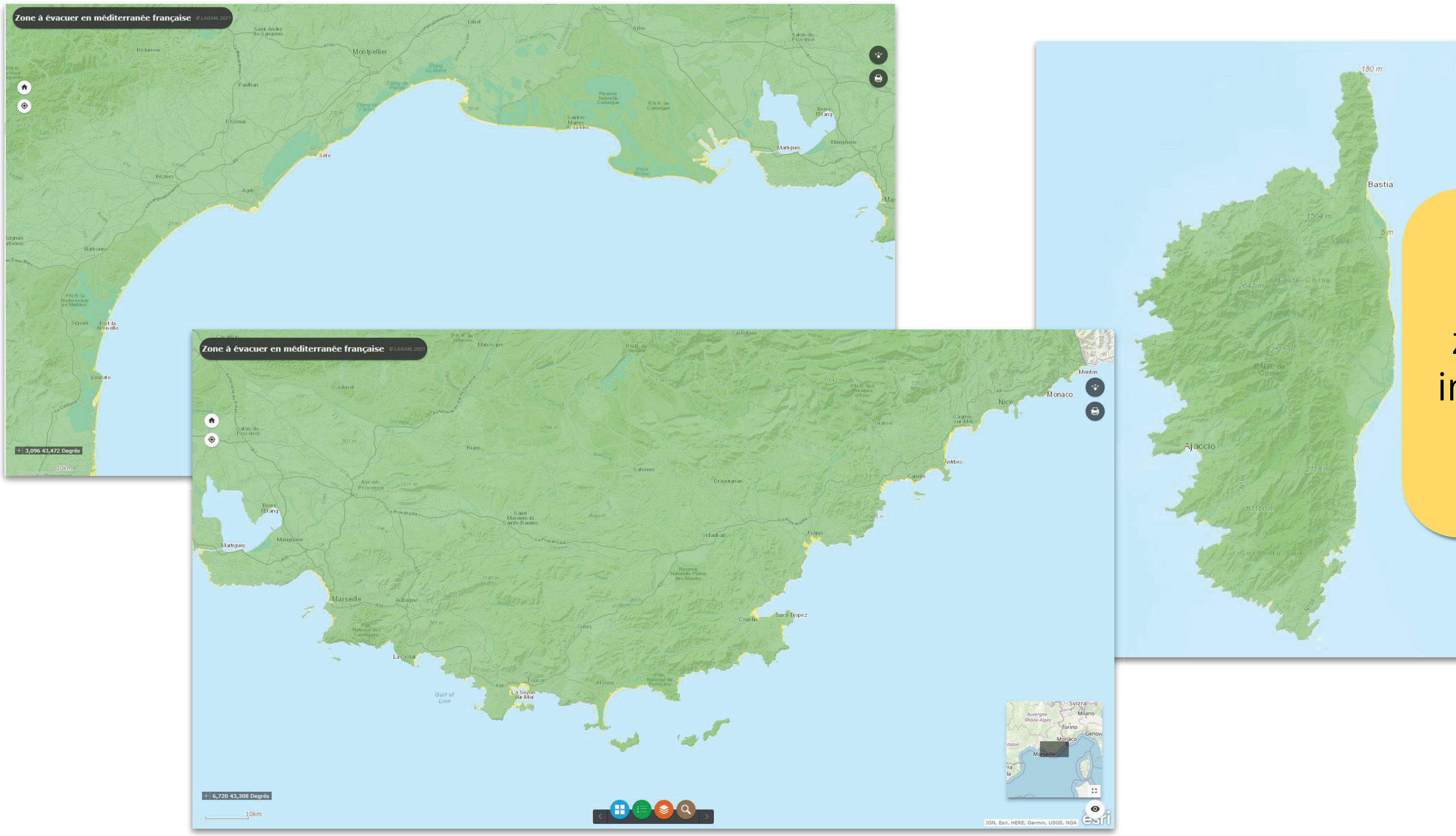


Selected tsunami evacuation zone definition for the french mediterranean coast



Tsunami evacuation zone mapping

Selected tsunami evacuation zone definition for the french mediterranean coast



Using this method, we were able to map the evacuation zone for the entire coastline in around a month during the

TASOMA Project

https://arcg.is/1vfGSz

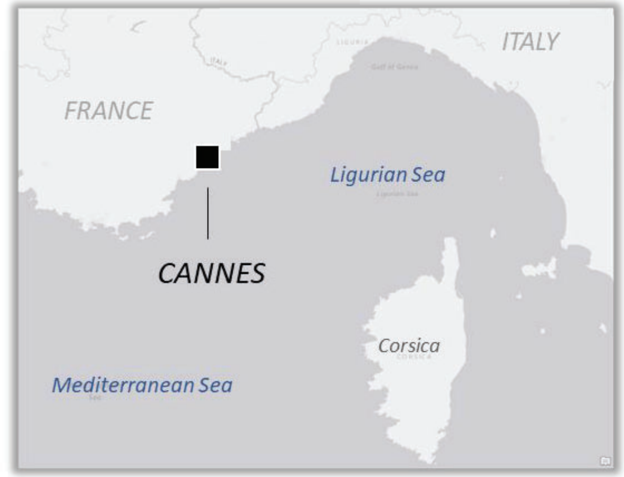
Université Montpellier Paul Valéry - LAGAM

Dr. Matthieu Péroche (matthieu.peroche@univ-montp3.fr) - Louis Monnier

Tsunami evacuation zone mapping

Cannes area presentation

- ✓ Population of 74,686 *(INSEE, 2019)*
- ✓ 3 million visitors per year
- ✓ 320 cruise passengers in 2017
- ✓ Nearly 130 hotels and 500 restaurants
- ✓ Accommodation capacity of 17,000 people

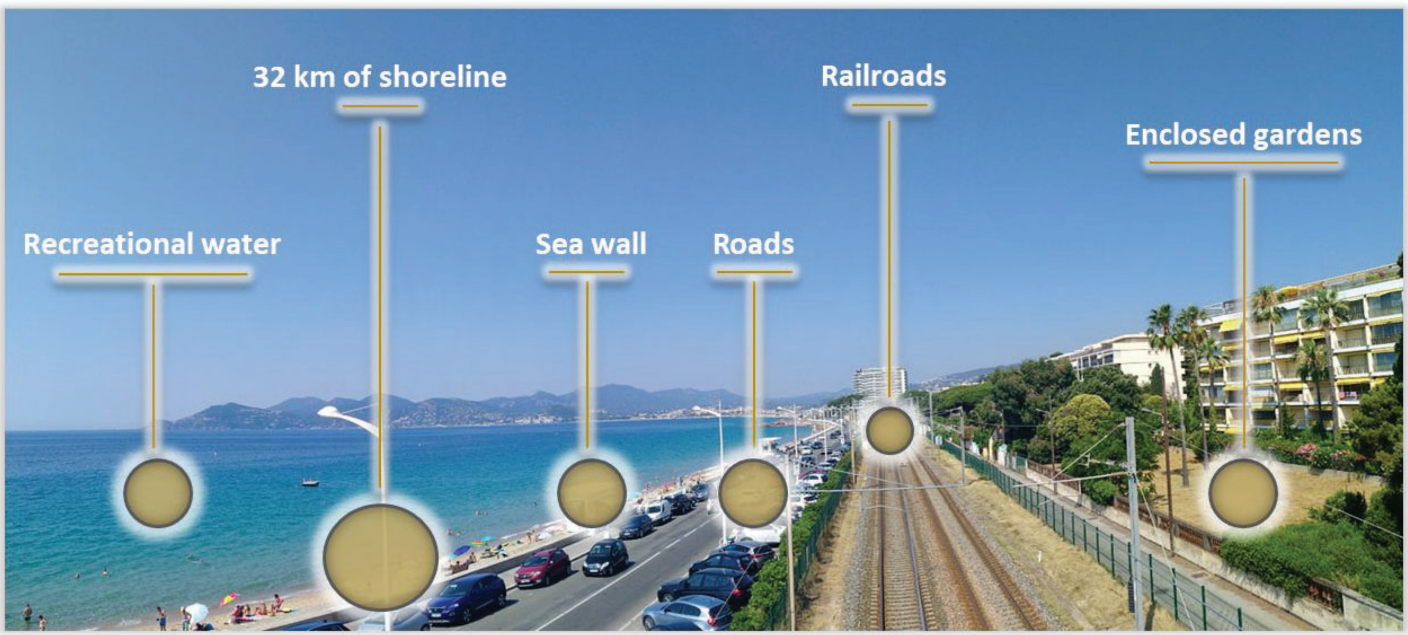


City of Cannes evacuation challenges in case of tsunami alert ...

Tsunami evacuation zone mapping

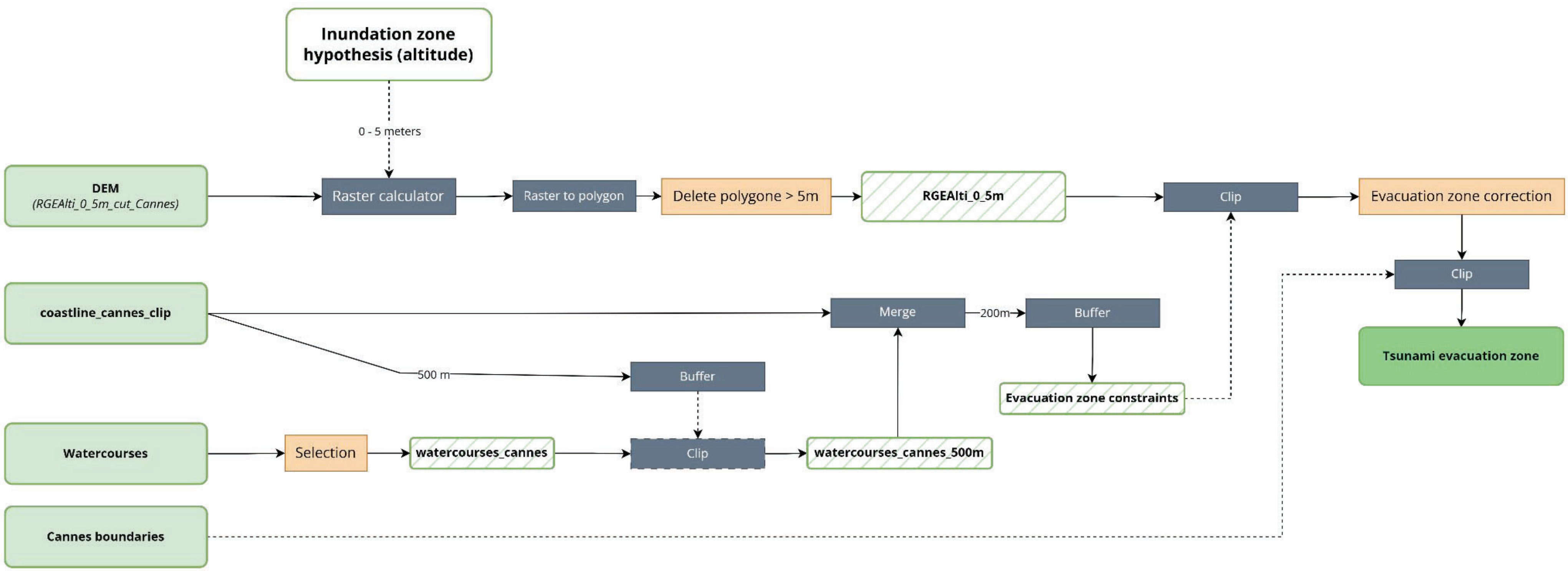
Cannes area presentation

1. For the past year, awareness-raising activities (public meeting, meeting in schools) have been carried out locally, in particular in collaboration with CENALT and DGSCGC.
2. Discussions within the national Tsunami working group have led to recommendations that have been validated at the national level.
3. A scientific partnership with the University Paul-Valéry Montpellier 3, has enabled the design of standardised evacuation plans and tsunami signage according to a method already deployed in the French West Indies (Caribbean sea)



"The taking into account of the Tsunami hazard in Cannes is part of a strong political will initiated since 2015 for a concerted management of natural risks and a better awareness of citizens".

GIS detailed overview



IGN

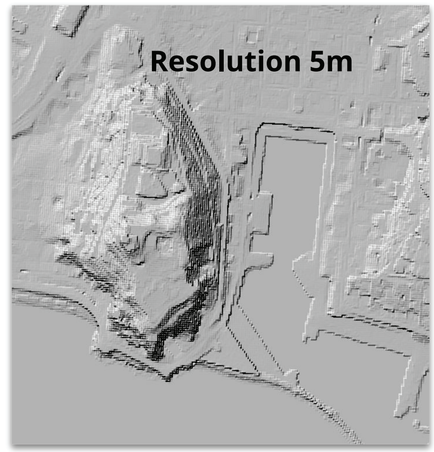
5m and 1m resolution DEM accessibility varies between countries.

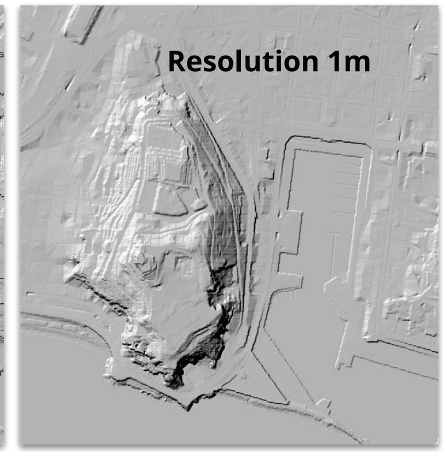
Pro

- Better accuracy for terrain with significant altitude variation
- High resolution evacuation zone

Cons

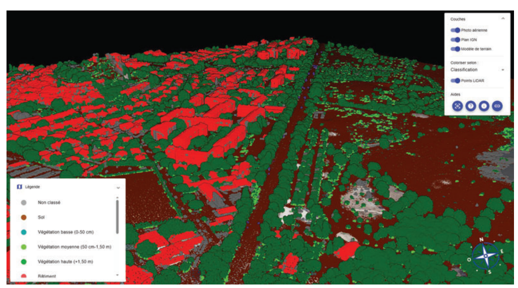
- Slow to process
- 1m res DEM cannot be used for a whole region on most computer.



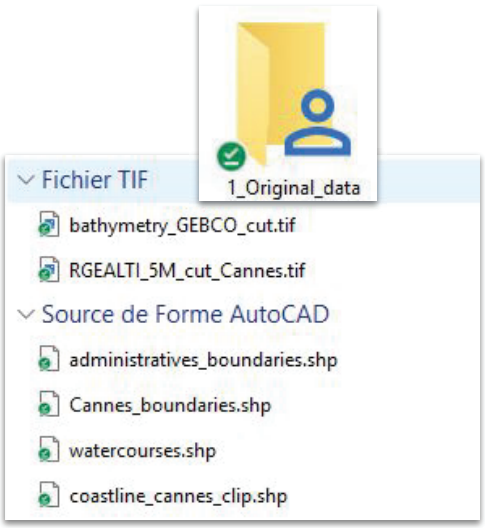


Programme national LiDAR HD :

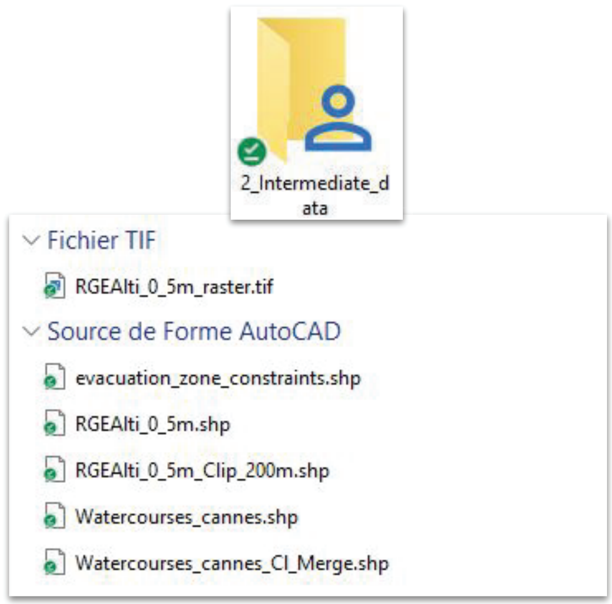
https://geoservices.ign.fr/lidarhd



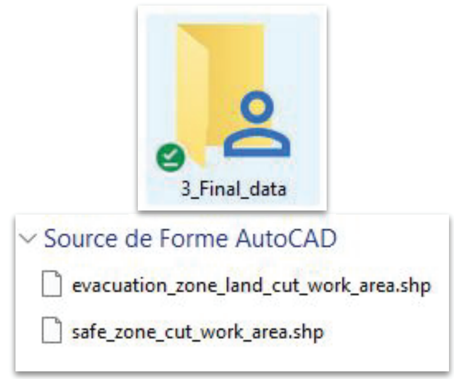
Lesson's data



Required layers for the lesson



Processed layers



Results

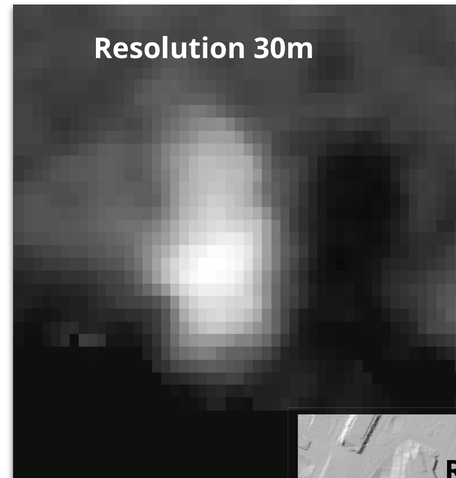
Tsunami evacuation zone mapping

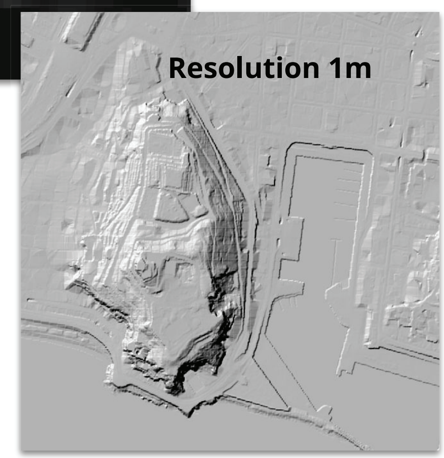
30m resolution DEM with a world coverage are largely available in open access.

- Shuttle Radar Topography Mission (SRTM) - https://dwtkns.com/srtm30m/
- Copernicus DEM - Global and European Digital Elevation Model https://dataspace.copernicus.eu/explore-data/data-collections/copernicus-contributing-missions/collections-description/COP-DEM

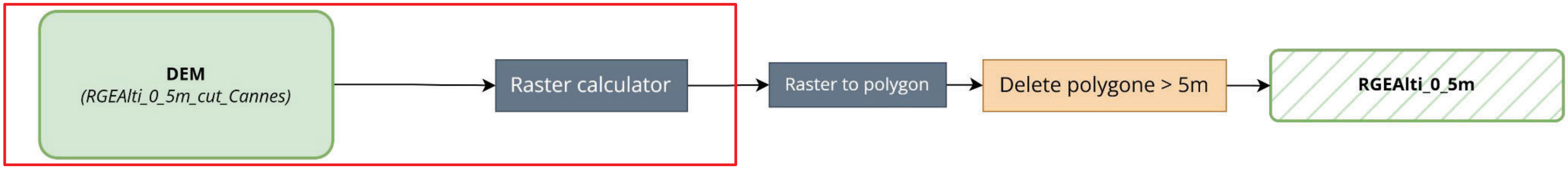
Pro
- Fast to process
- Suitable for large studie's area (country)
- World coverage

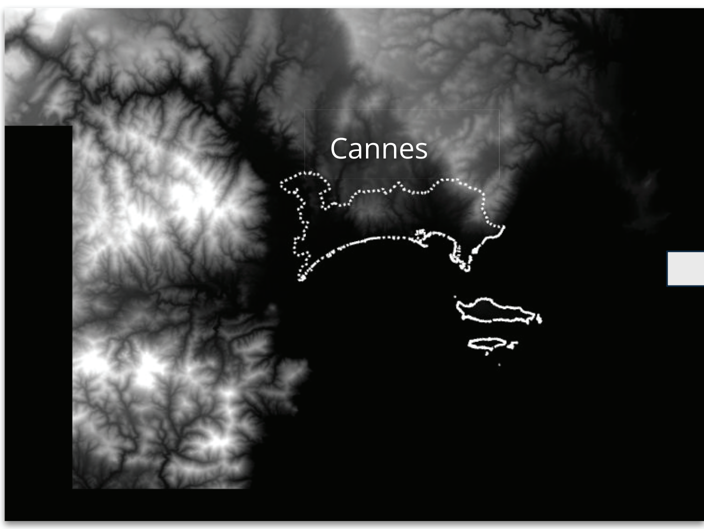
Cons
- Low evacuation zone precision
- Not suitable on terrain with significant altitude variation

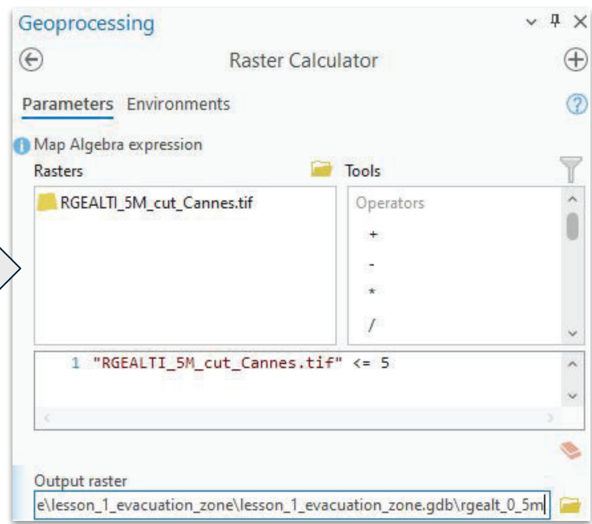


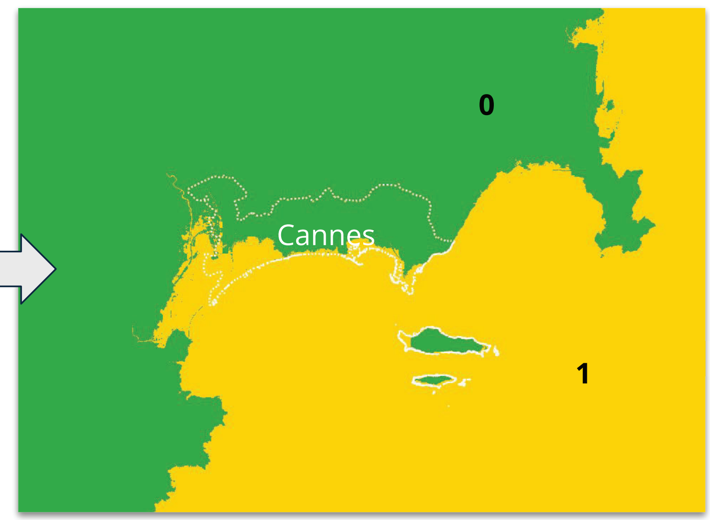


Tsunami evacuation zone mapping





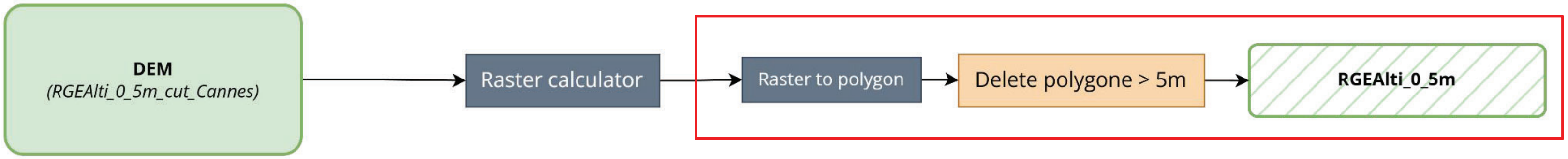


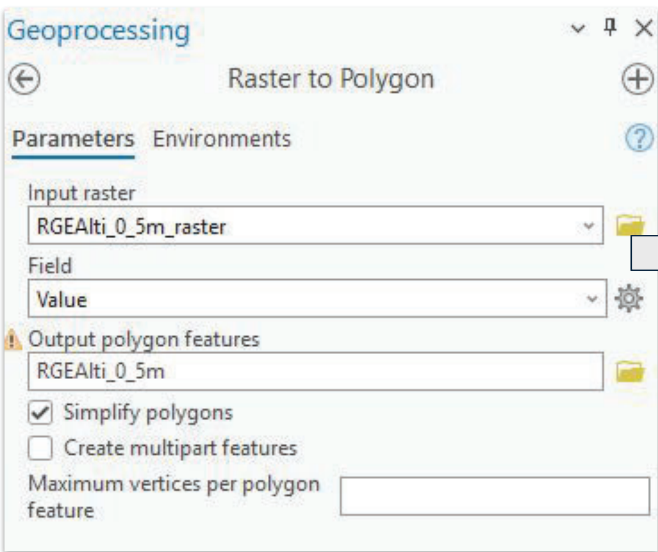


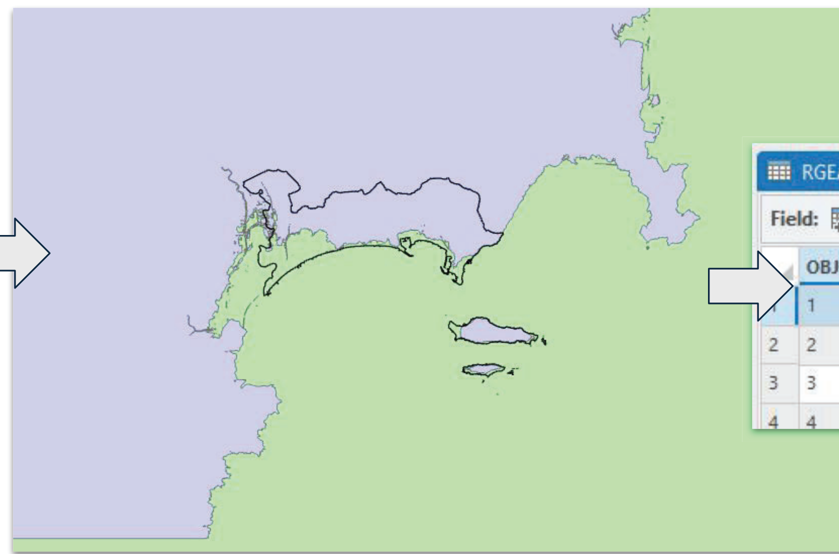
Each pixels in the image have a pixel elevation value

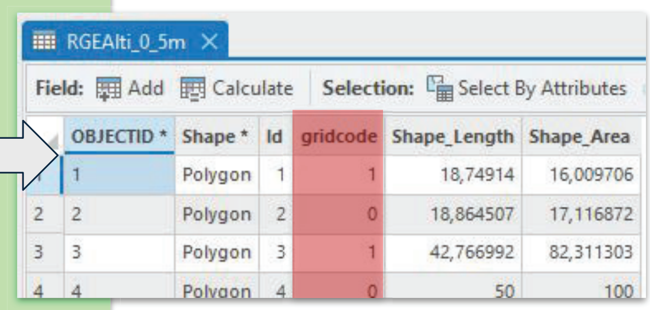
“LAYER_NAME” <= 5

Pixel’s value is now “**0**” or “**1**” depending if the pixel elevation value matched the condition or not.



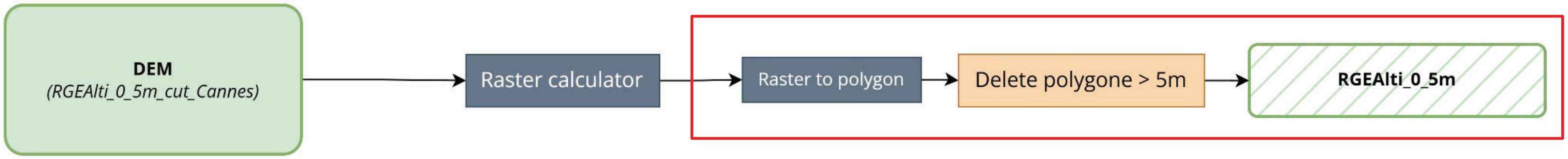


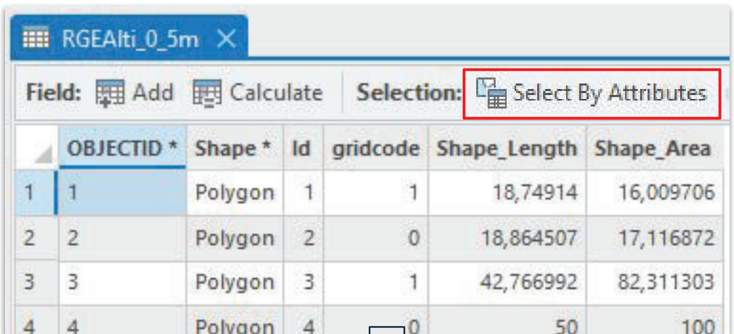


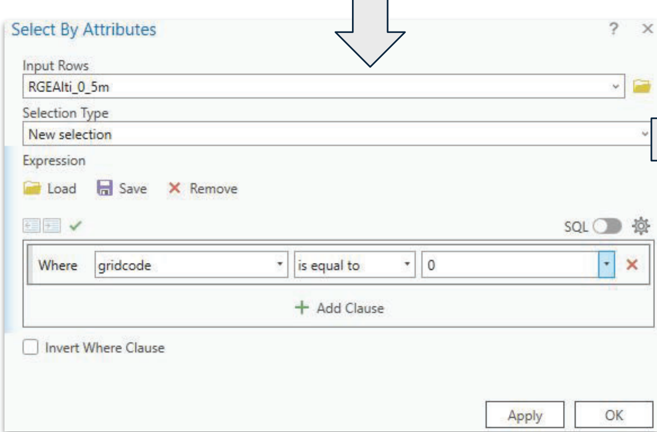


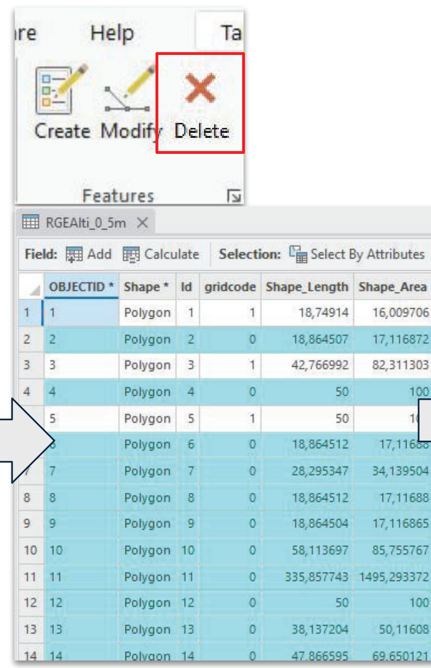
The previous raster’s pixel values are in the field **“gridcode”.**

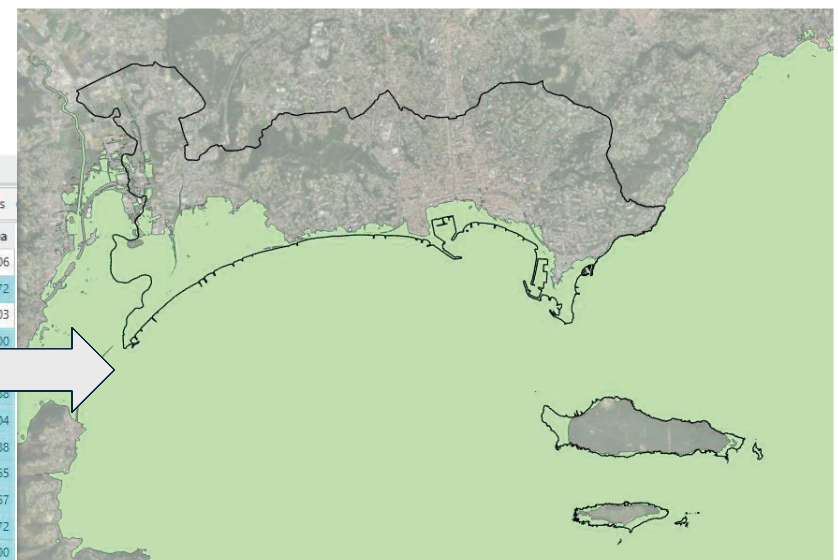
Tsunami evacuation zone mapping





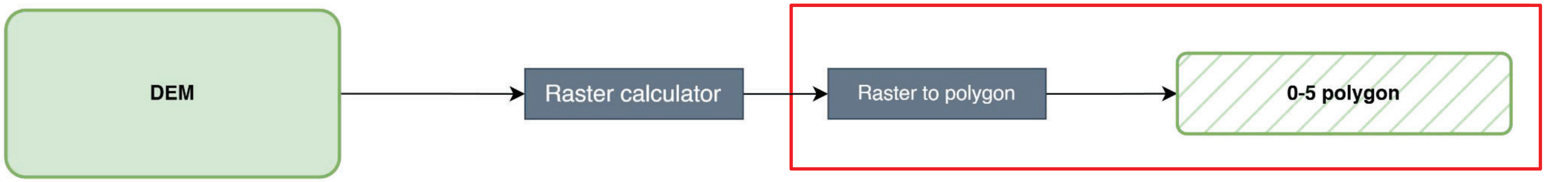






Dr. Matthieu Péroche (matthieu.peroche@univ-montp3.fr) - Louis Monnier

Tsunami evacuation zone mapping

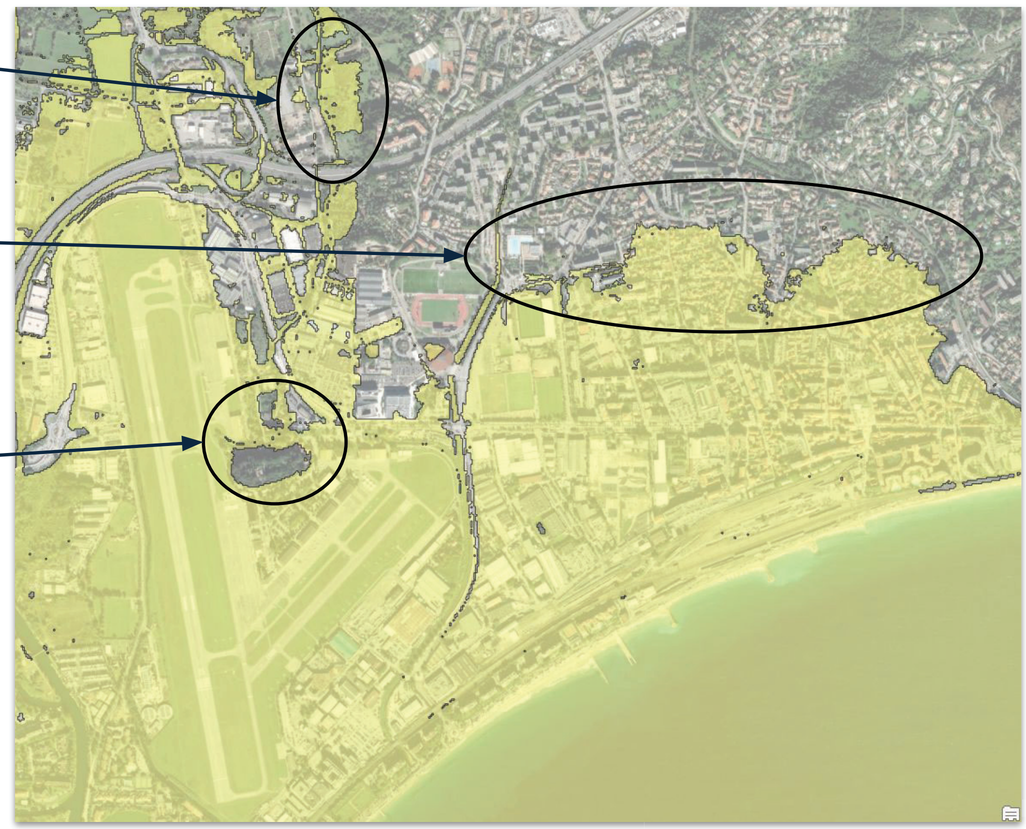


we obtain a polygon with a very precise level of detail that leads to several geometries to be generalized

Isolated polygon

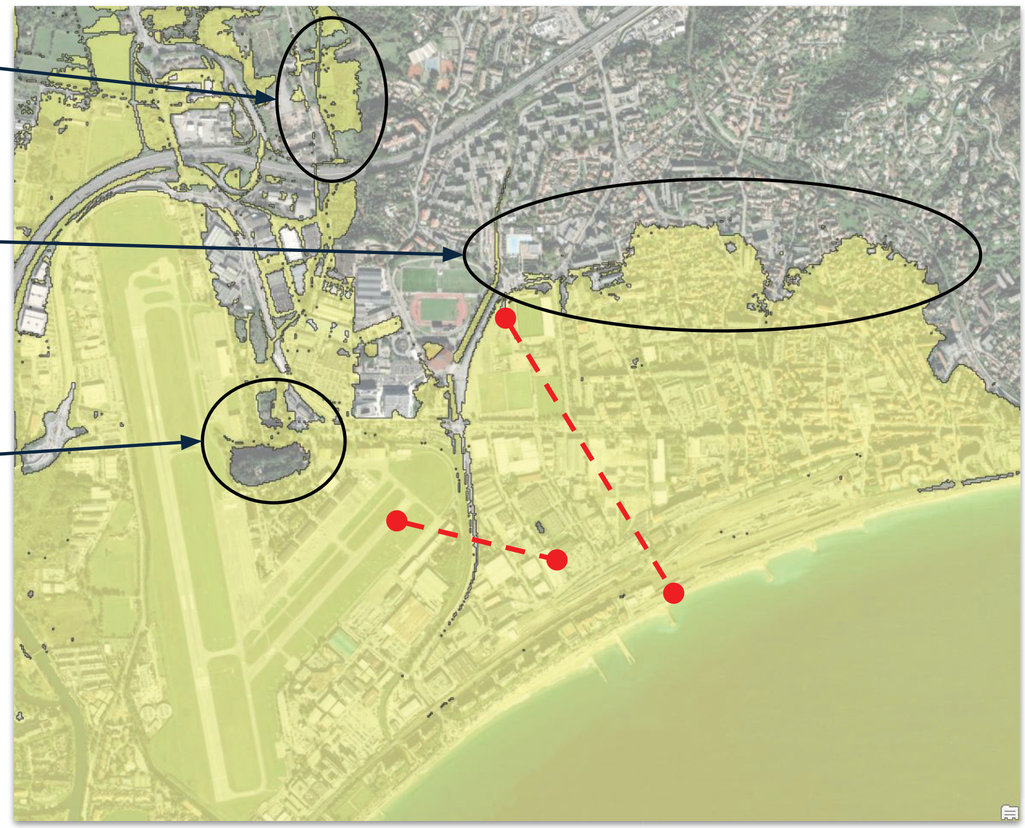
Polygon’s edges need simplification

local variations in altitude must be deleted



Tsunami evacuation zone mapping

DEM → Raster calculator → Raster to polygon → 0-5 polygon



Isolated polygon

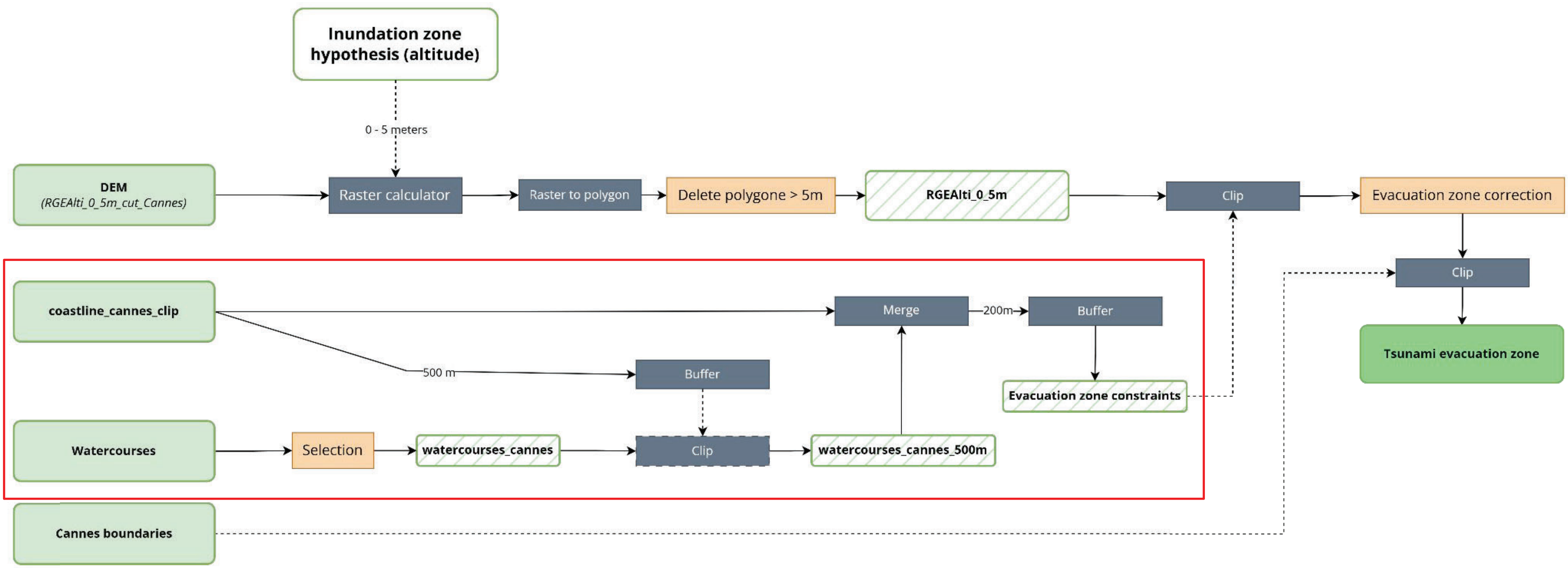
Polygon's edges need simplification

local variations in altitude must be deleted

we obtain a polygon with a very precise level of detail that leads to several geometries to be generalized

Before this step, **we need to take into account the initial assumptions regarding maximum distances inland and around watercourses**.

Tsunami evacuation zone mapping



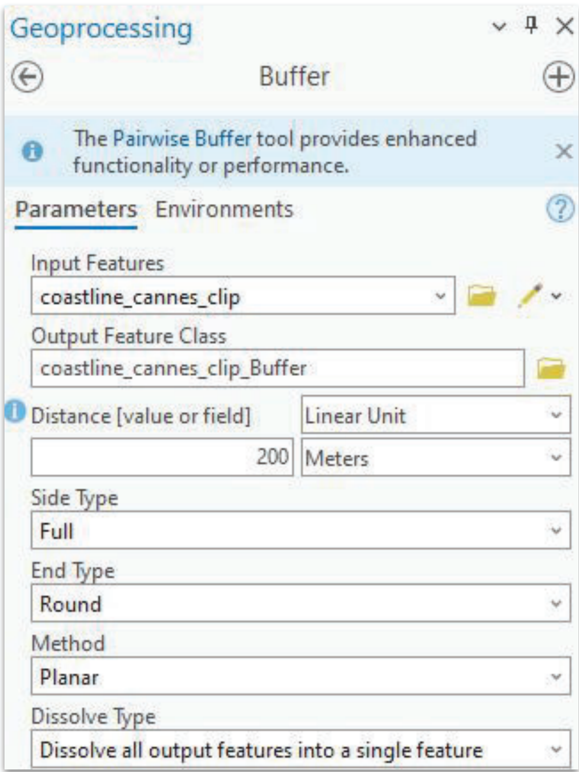
Tsunami evacuation zone mapping

Only open-air hydrographic network will be taken into account for the evacuation zone
⇒ During **field mission** or trough **aerial image interpretation**

Non cased drainage

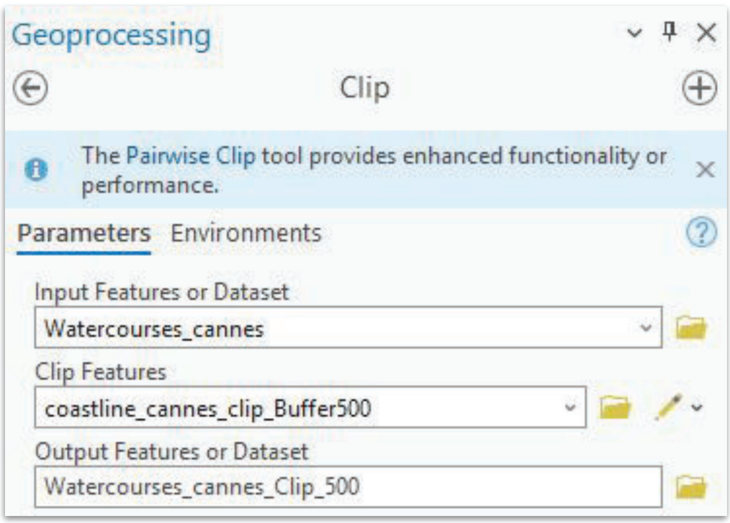
Cased drainage

Generate **500 meters buffer** on clipped coastline

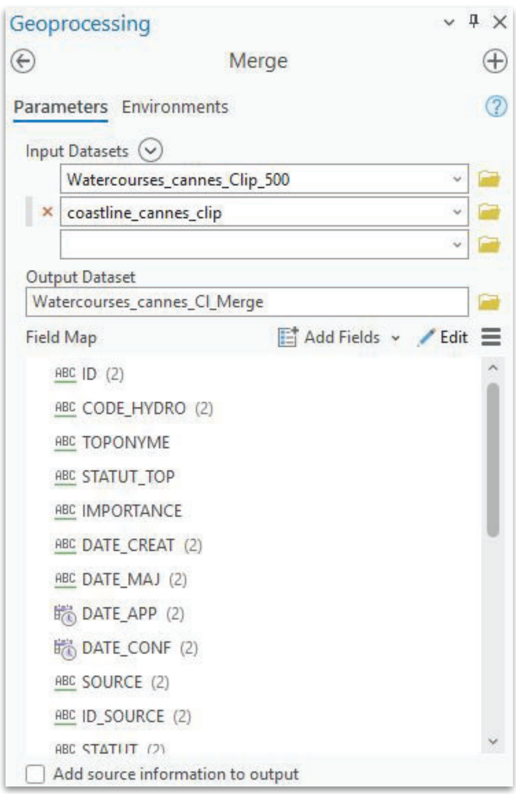


Tsunami evacuation zone mapping

Clip watercourse with previous buffer

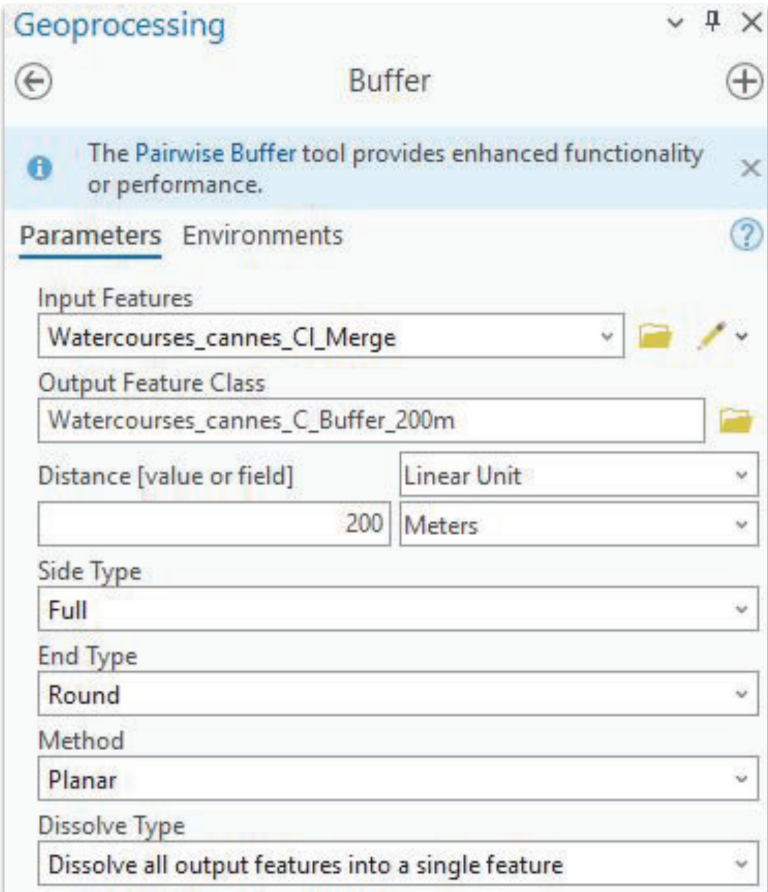


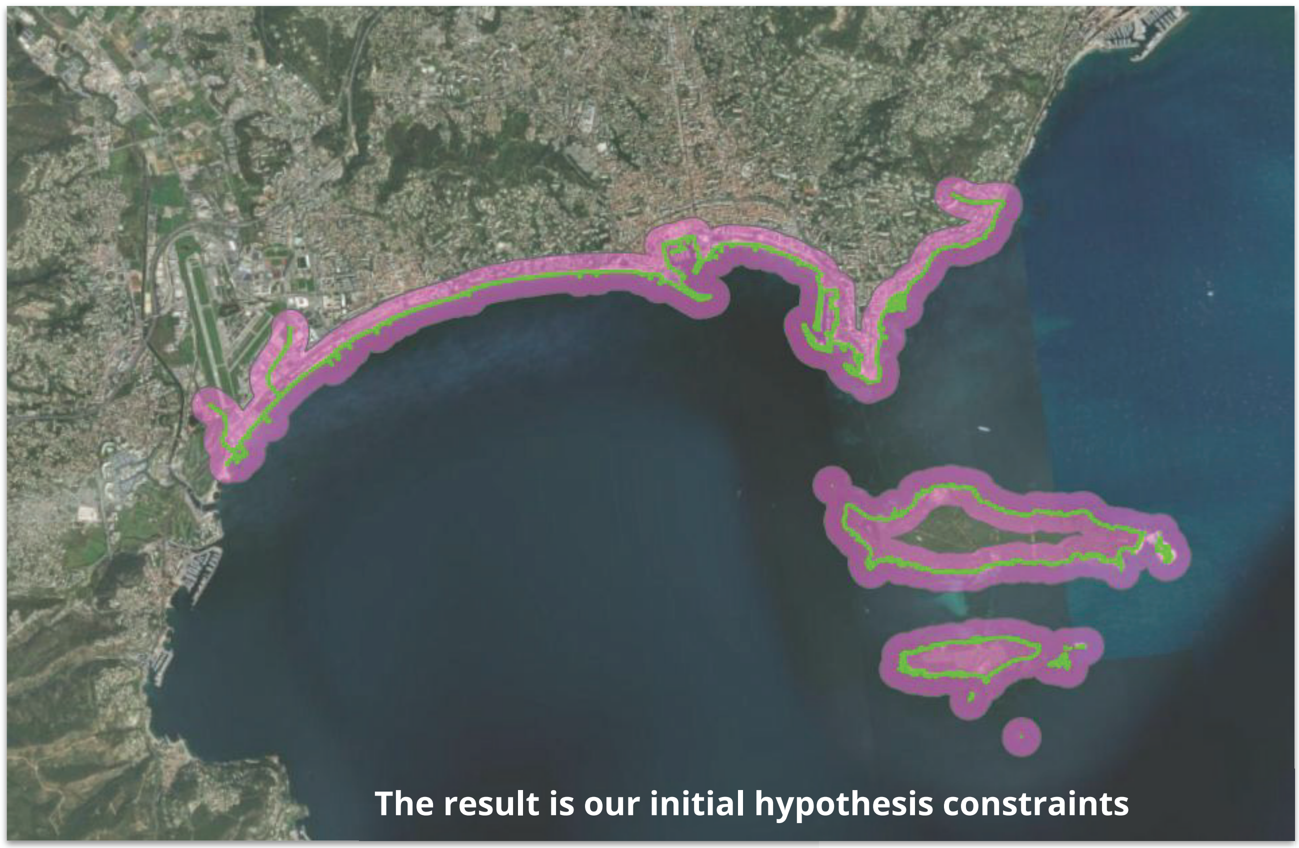
Merge both watercourse & coastline



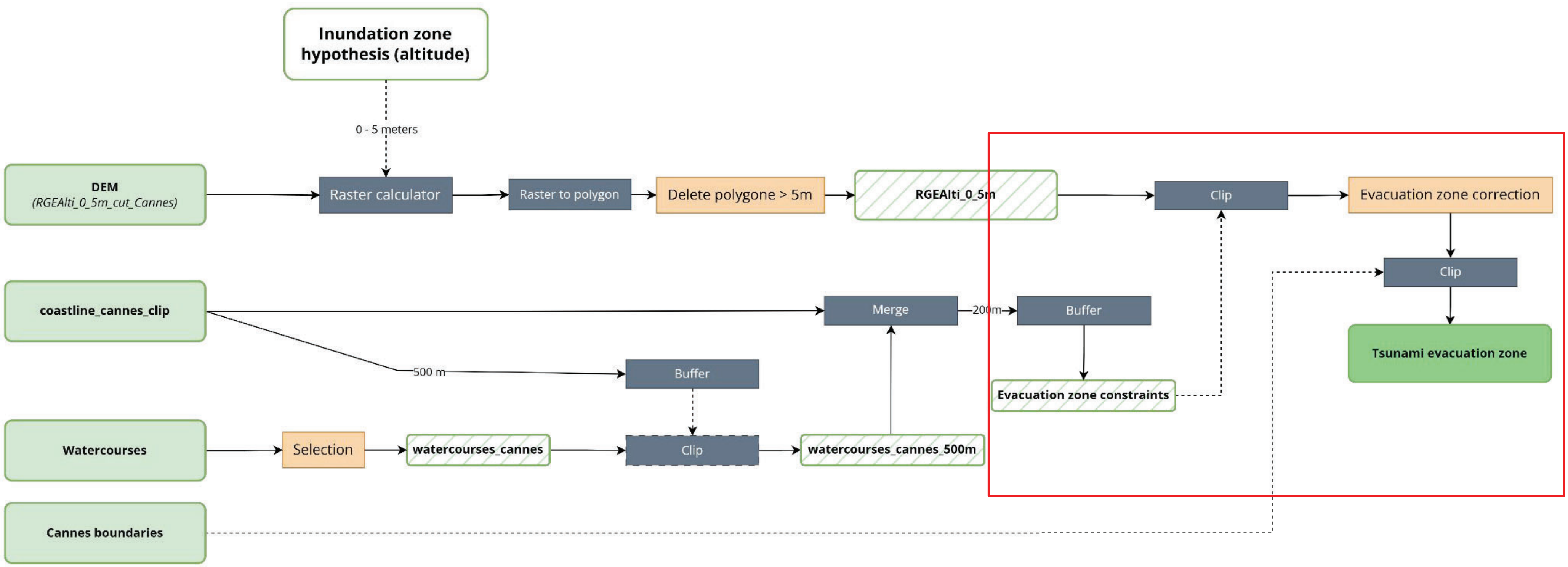
Tsunami evacuation zone mapping

Generate **200 meters buffers** with the merged layer and export the result as “**evacuation_zone_constraints**”

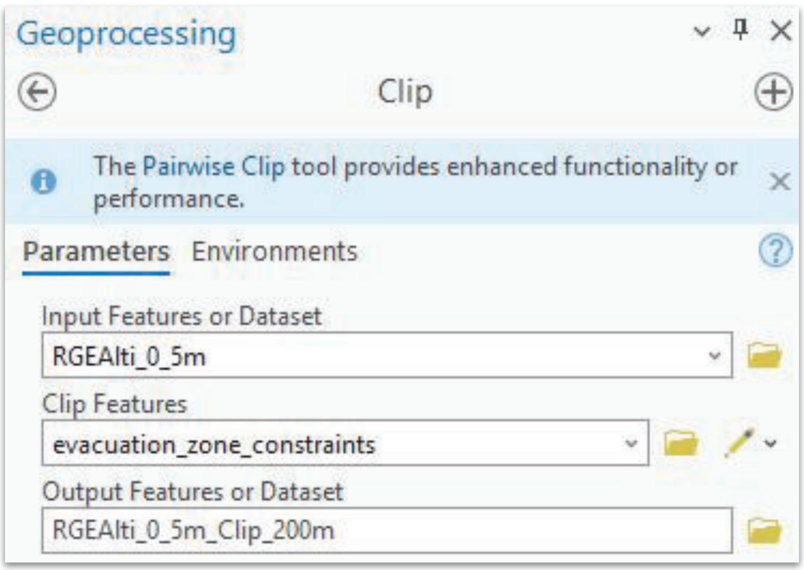




Tsunami evacuation zone mapping



Clip the **RGEAlti_0_5m** on the **evacuation_zone_constraints** layer.

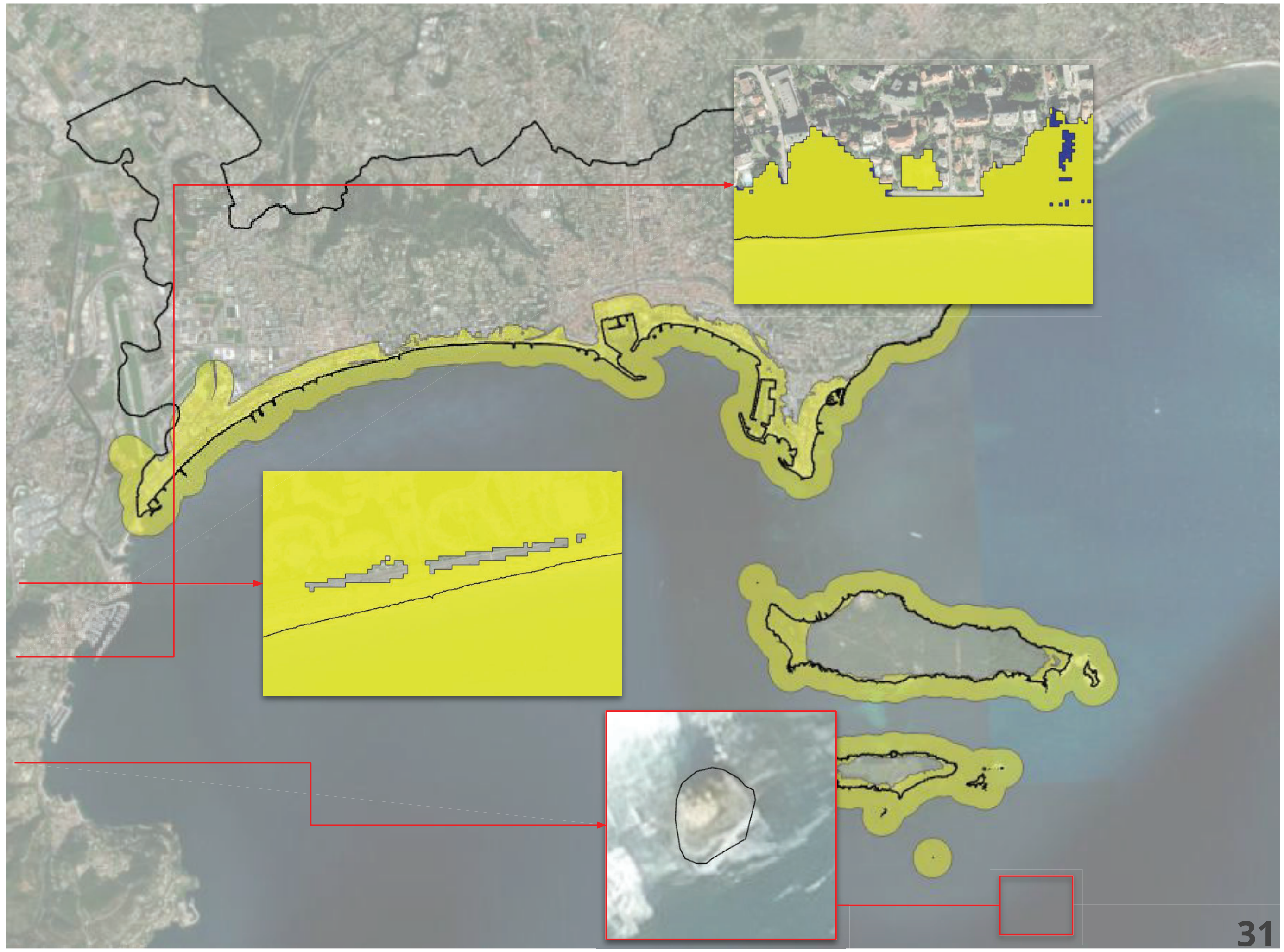


Tsunami evacuation zone mapping

Clipping the RGEAlti_0_5m with the constraints polygon provide us a **raw version** of the evacuation zone which will be used to create the final tsunami evacuation zone.

Corrections are needed at this point :

1. Removing off-lands parts
2. Removing holes due to local elevation change
3. Removing parts not connected with the sea
4. Smoothing the polygon's edges
5. Removing small inhabited islet

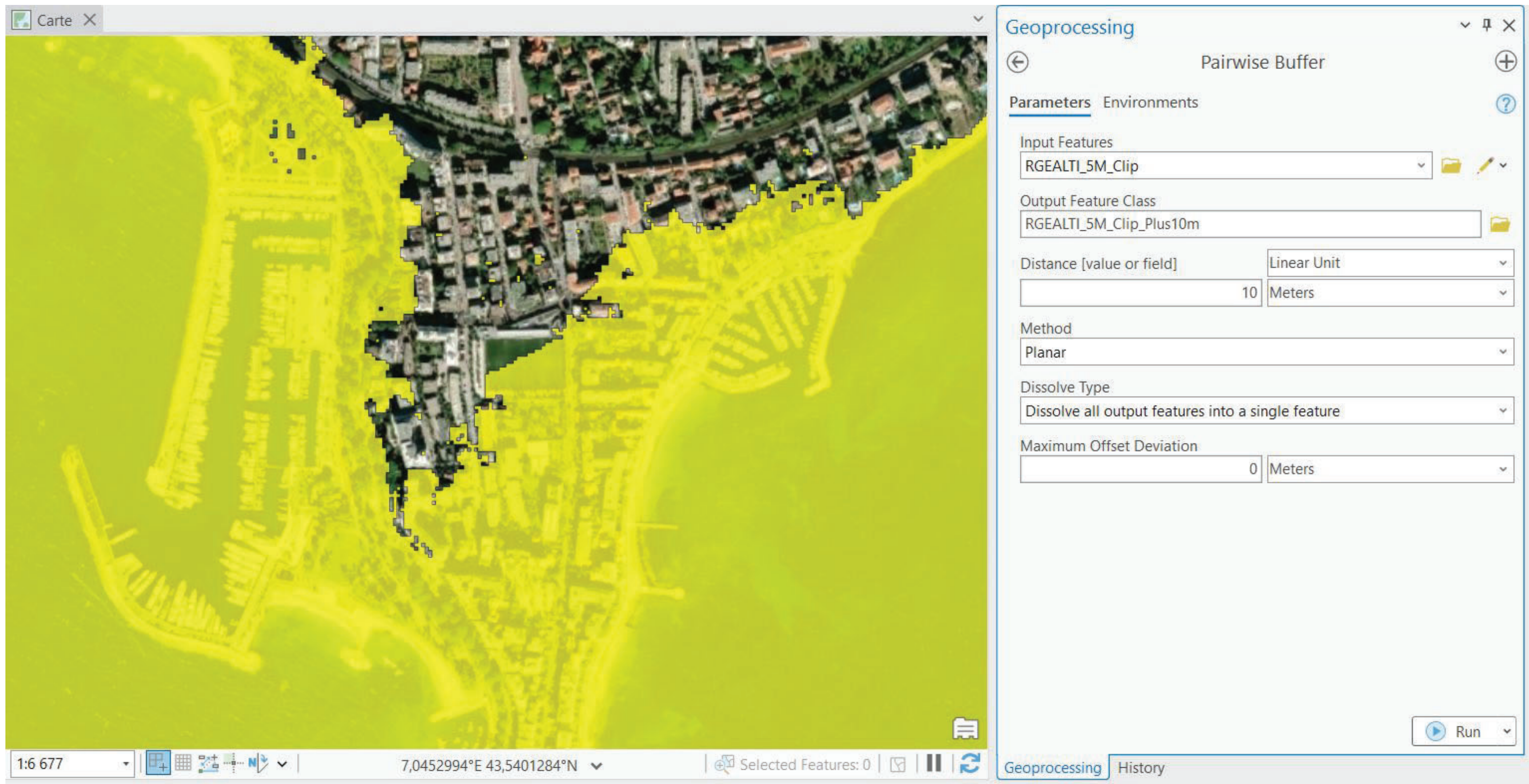


Dr. Matthieu Péroche (matthieu.peroche@univ-montp3.fr) - Louis Monnier

Tsunami evacuation zone mapping

Erosion & Dilation on Vector Data

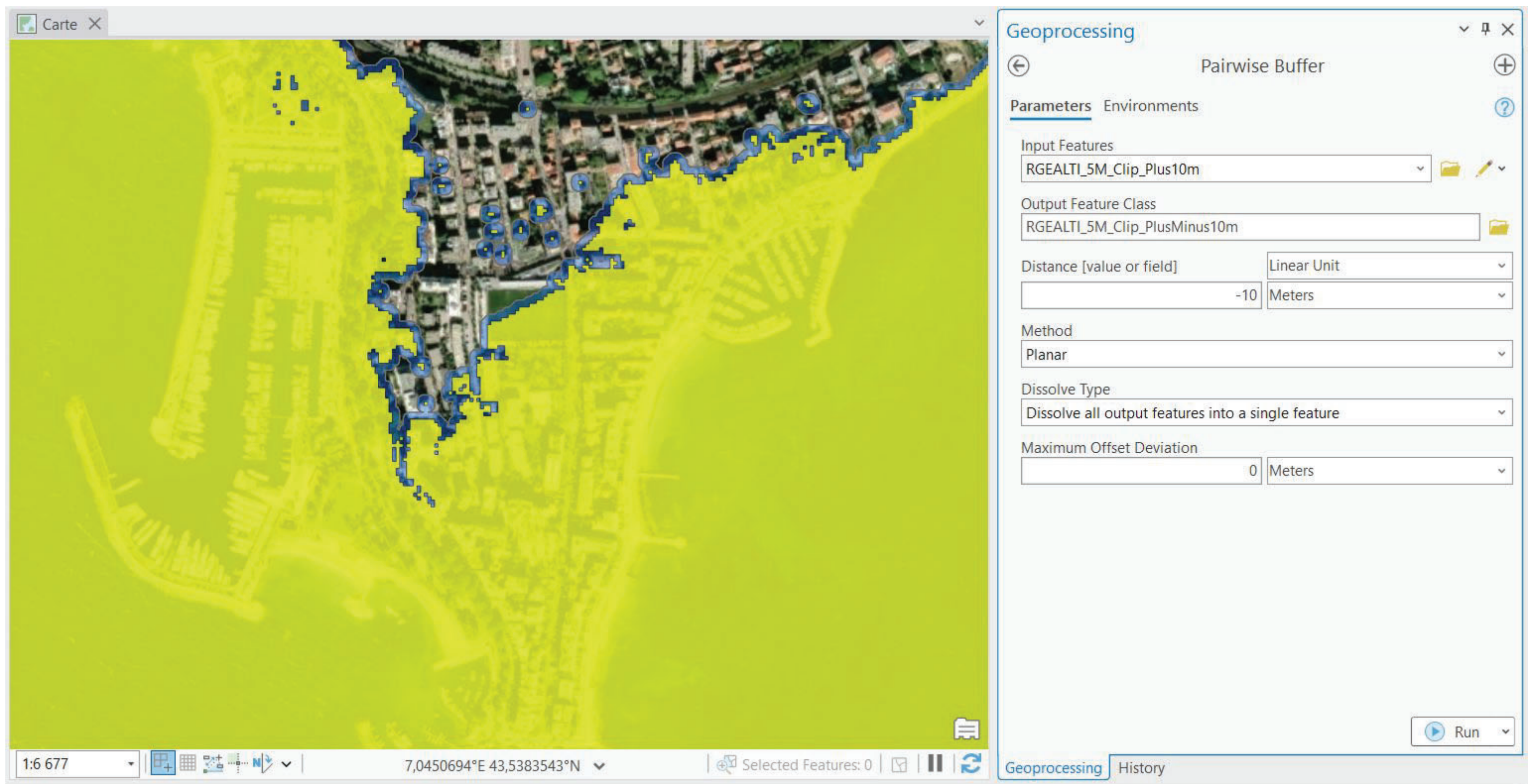
Buffer the "evacuation_zone" layer by **10 meters** to smooth and connect isolated depressions.



Tsunami evacuation zone mapping

Erosion & Dilation on Vector Data

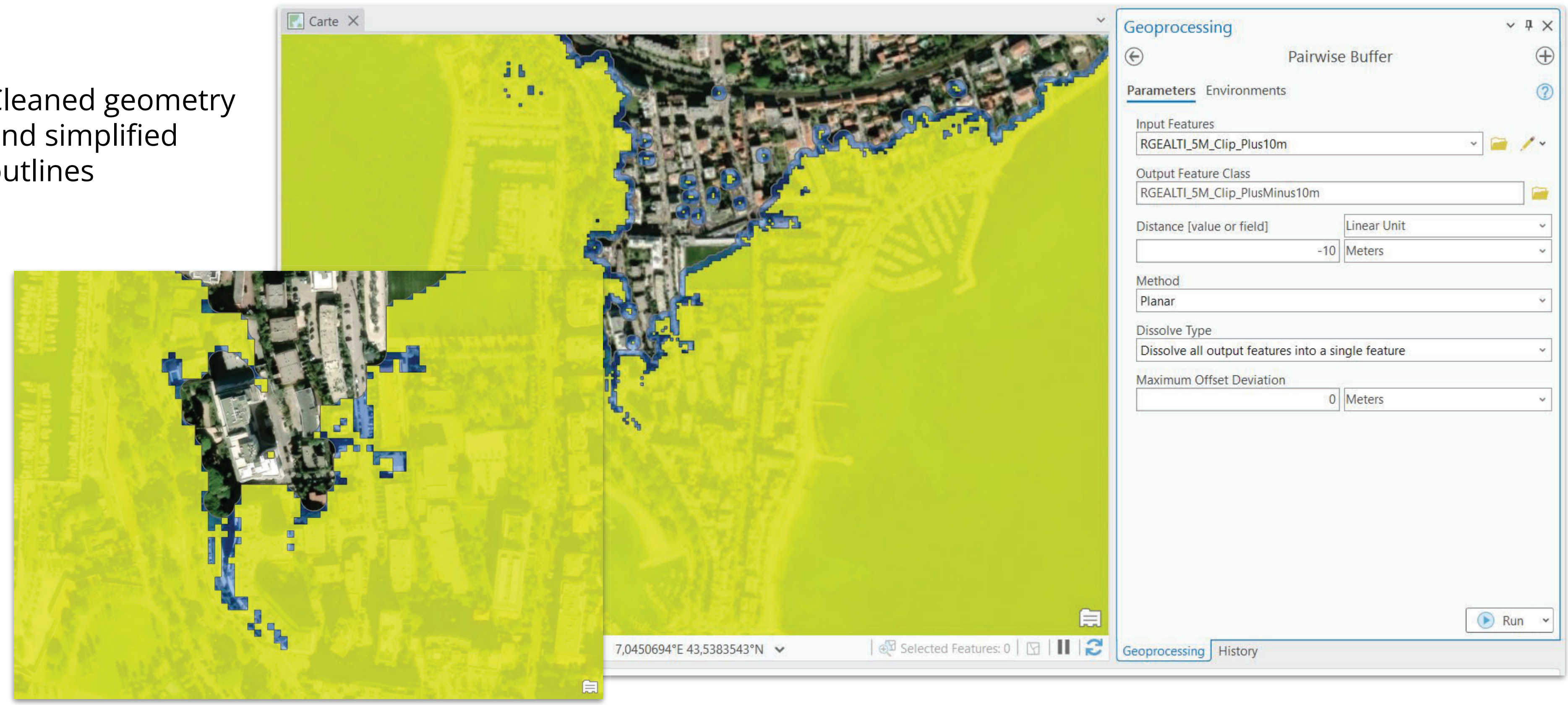
Buffer the "evacuation_zone" layer by **-10 meters** to simplify the geometry and eliminate narrow connections.



Tsunami evacuation zone mapping

Erosion & Dilation on Vector Data

Cleaned geometry and simplified outlines



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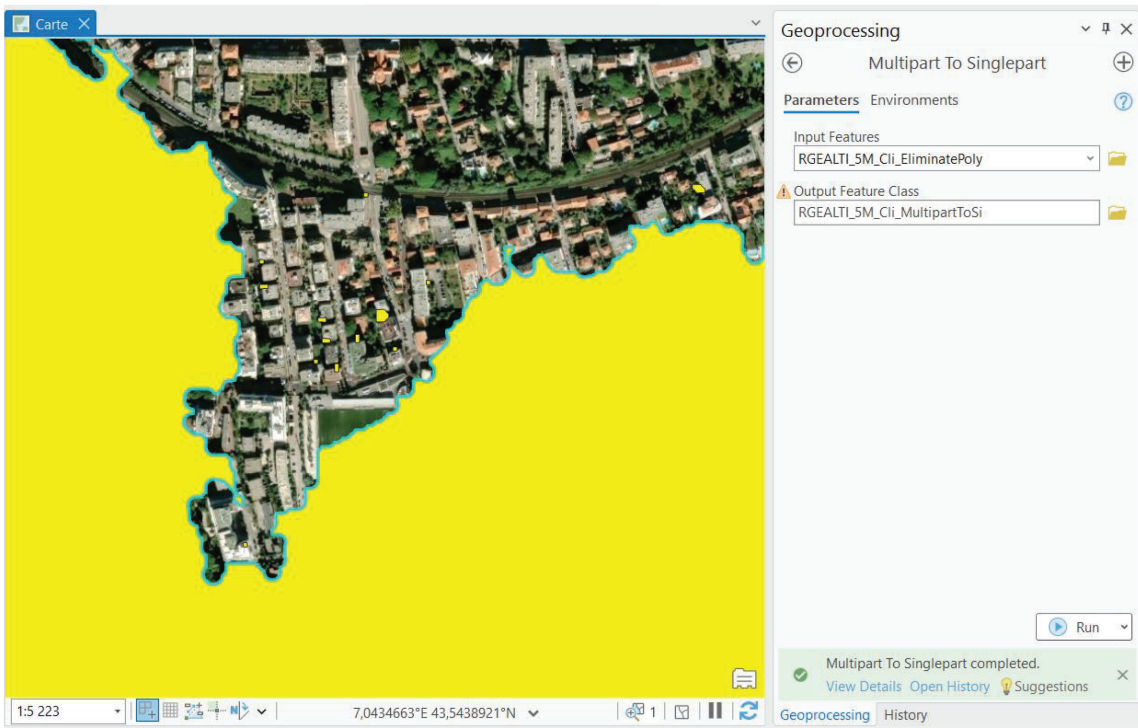
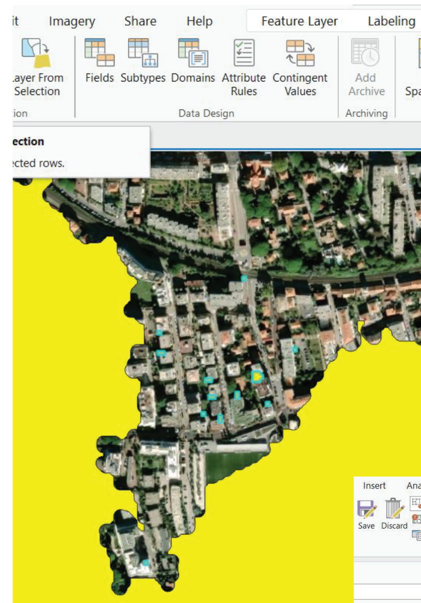
The **Eliminate Polygon Part** geoprocessing tool allows holes larger than the ***minimum hole size*** parameter
→ The result of the algorithm can vary significantly depending on the input parameters.

Tsunami evacuation zone mapping

The **Eliminate Polygon Part** geoprocessing tool allows holes larger than the ***minimum hole size*** parameter
→ The result of the algorithm can vary significantly depending on the input parameters.

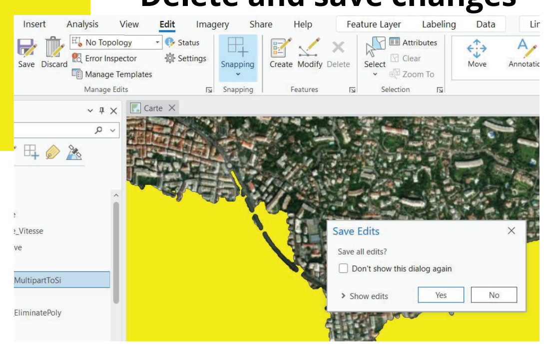
Select





Inverse selection

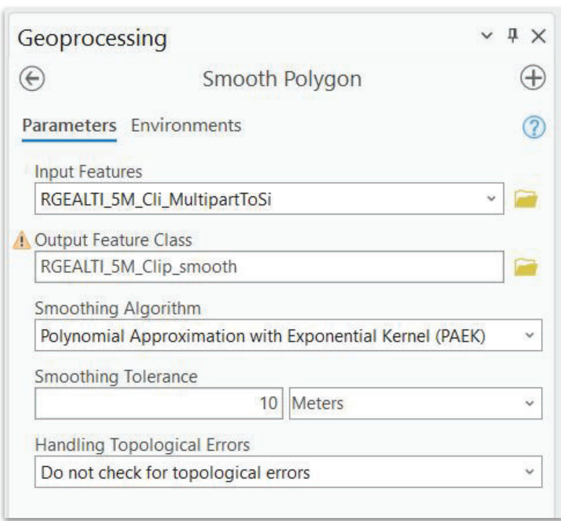
Delete and save changes

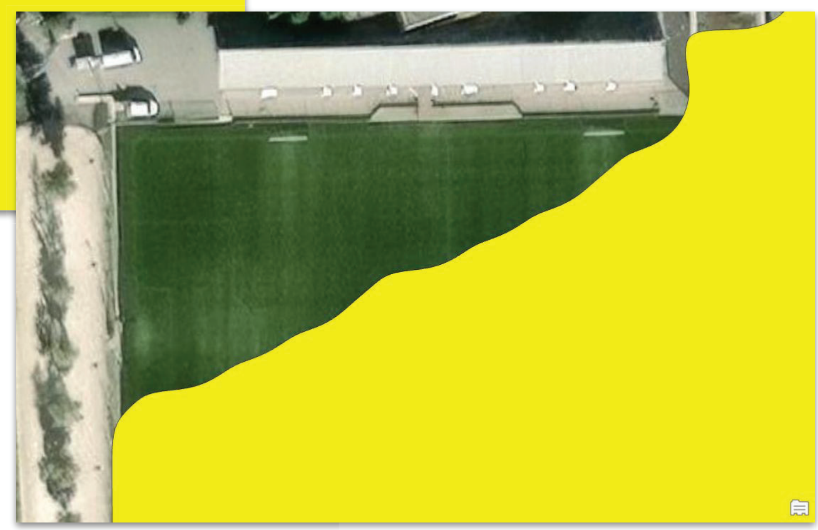


Dr. Matthieu Péroche (matthieu.peroche@univ-montp3.fr) - Louis Monnier

Polygon Smoothing for Clearer Boundaries

Smooth the evacuation_zone layer to reduce angular shapes and improve boundary readability.



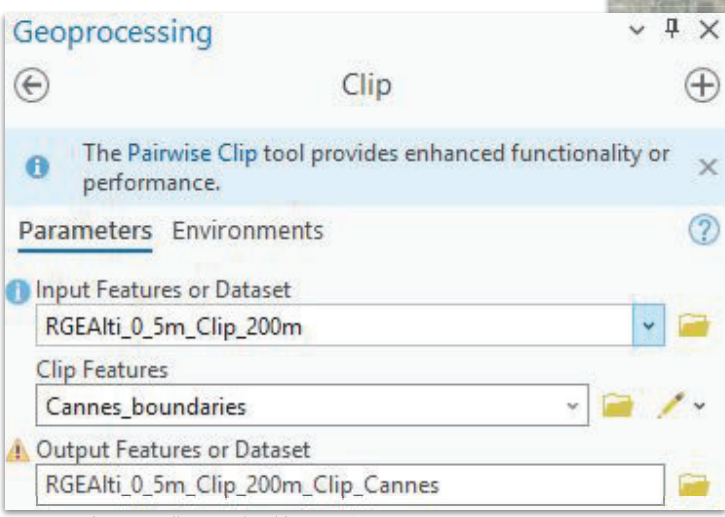


Tsunami evacuation zone mapping

Removing off-land parts by clipping the layer with Cannes boundaries polygon.

→ Clipping the layer with coastline is also possible if the communitie's boundaries aren't accurate along the coast.

If so, generate a polygon using a high resolution coastline and the edges of your work area



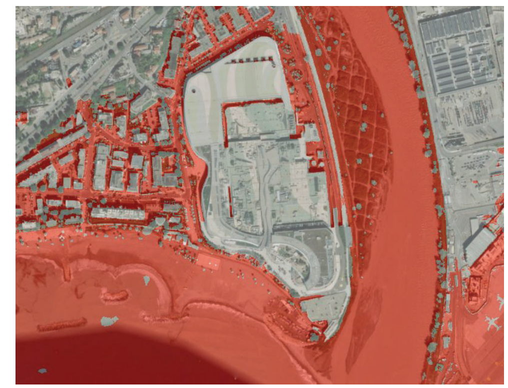
Tsunami evacuation zone mapping

Make sure that the result of the clipping operations is conform to our initial hypothesis (0-5m high & 200m inland or 500m inland near watercourses that are connected to the sea)

Tsunami evacuation zone mapping

Field verification is mandatory in order to detect errors or the need for local adaptations that cannot be assessed through imagery analysis.

Lidar's 0-5m range extraction (in red)



E.g : Cap 3000, Nice's metropole's largest mall

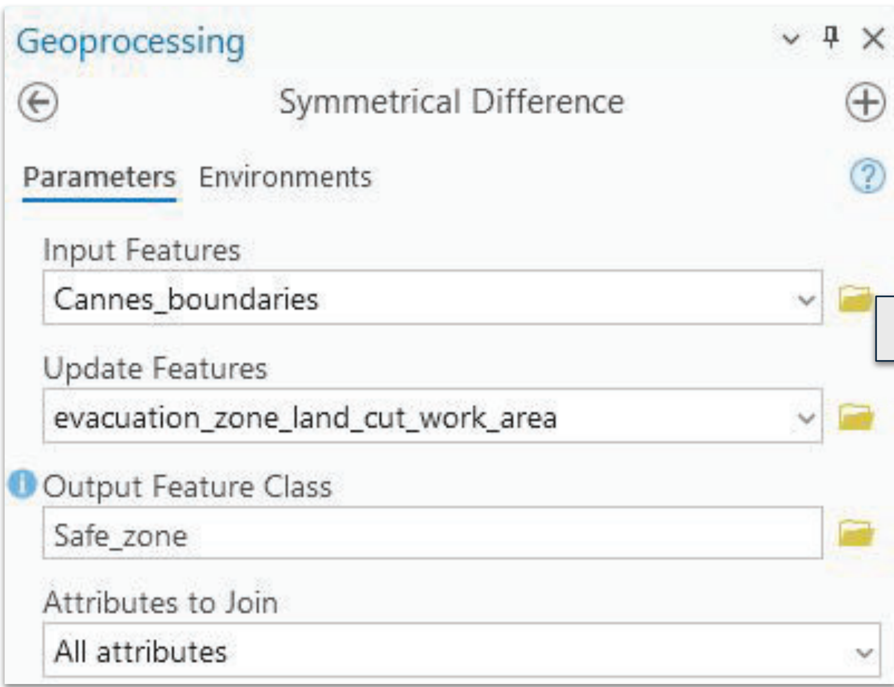
Due to the large numbers of visitors, the authorities decided to make an exception to the standard evacuation instructions for this shopping center : people already in the mall will have to stay inside.

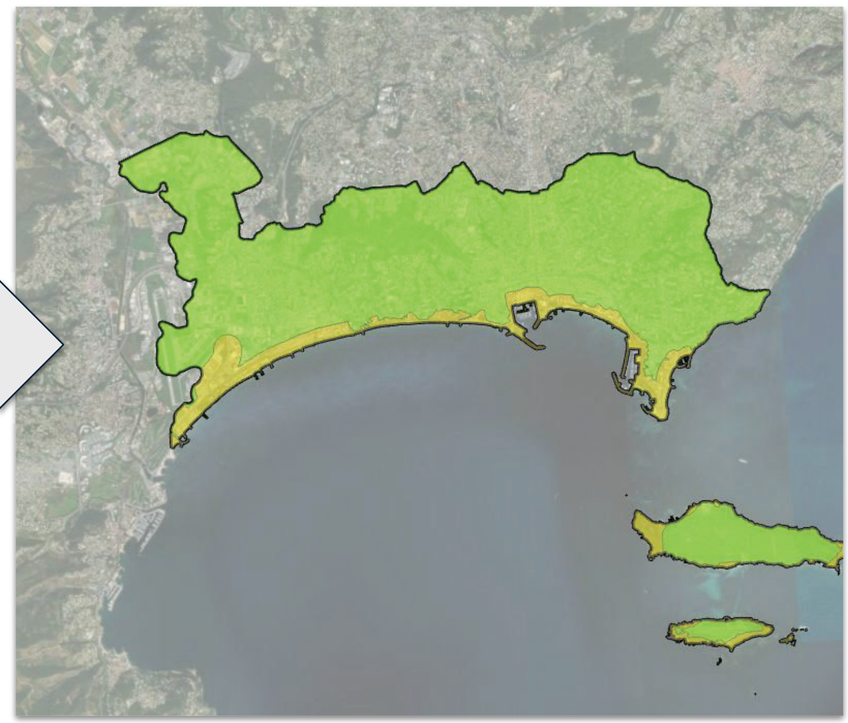
Field visit allowed to take into account the recently constructed seafront terrace that wasn't available on satellite imagery at the beginning of the project.

The evacuation zone along the mall was modified based on the field verification and up-to-date Lidar data

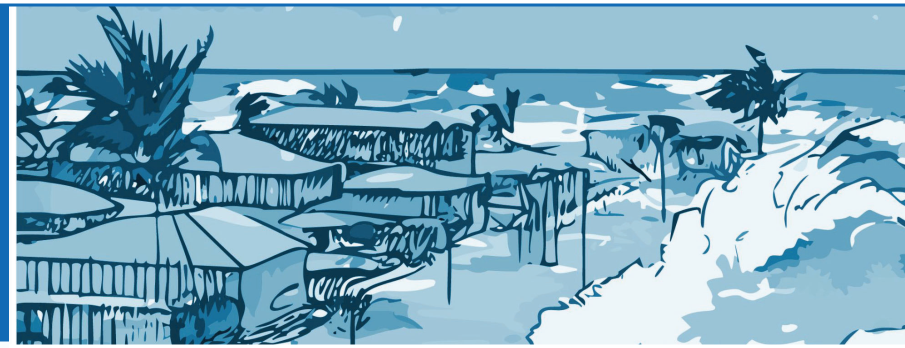
Generate the tsunami safe zone !

Use the **Symmetrical difference** tool between the evacuation zone and Cannes boundaries to generate the safe zone





Tsunami Evacuation Mapping Workshop



Dr. Matthieu Péroche
Louis Monnier

CoastWAVE 2.0 Project

IOC-UNESCO (EU DG ECHO)

30 June – 4 July 2025

Contact : matthieu.peroche@univ-montp3.fr

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Intergovernmental Oceanographic Commission

Funded by European Union Humanitarian Aid

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

CoastWAVE NEAMTWS

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