Larnaca, Cyprus, site-specific inundation maps fro
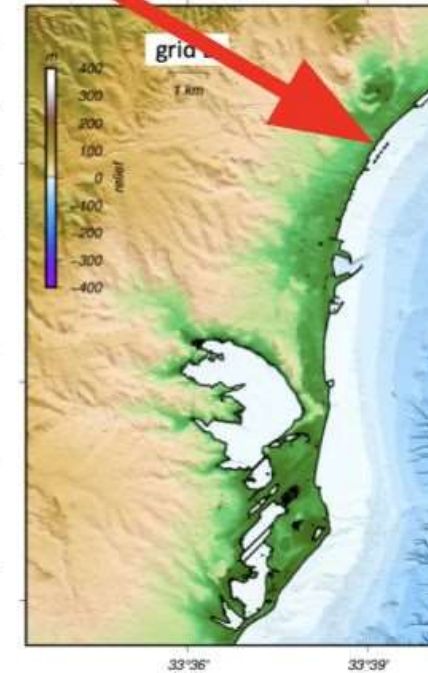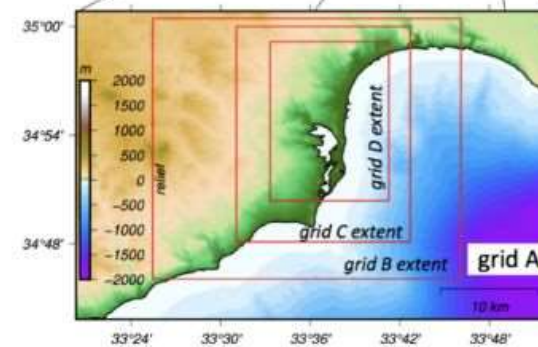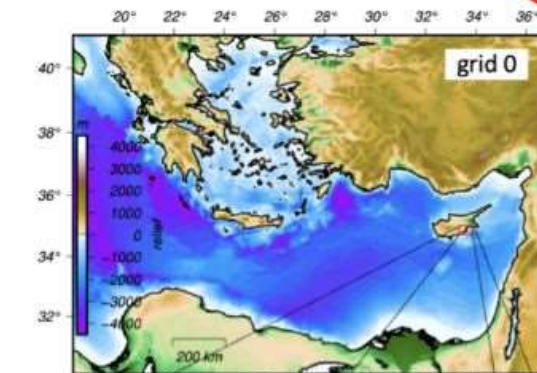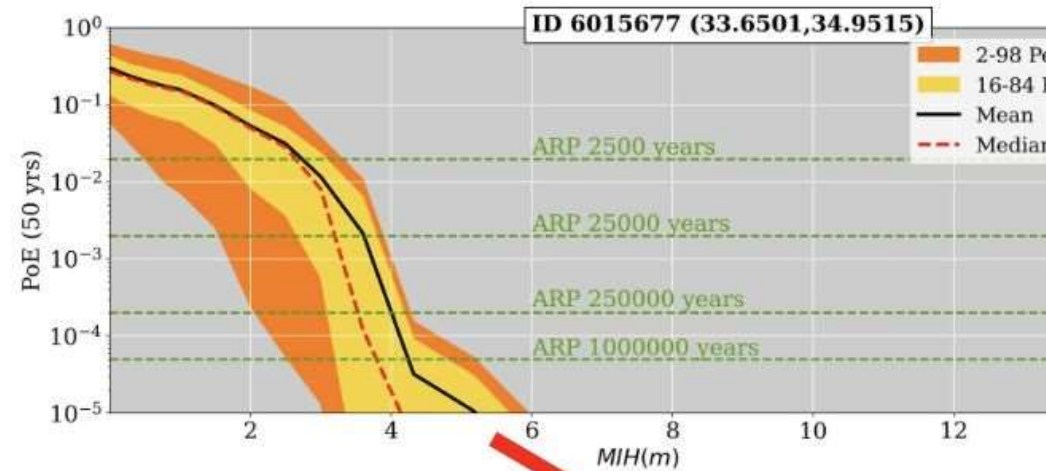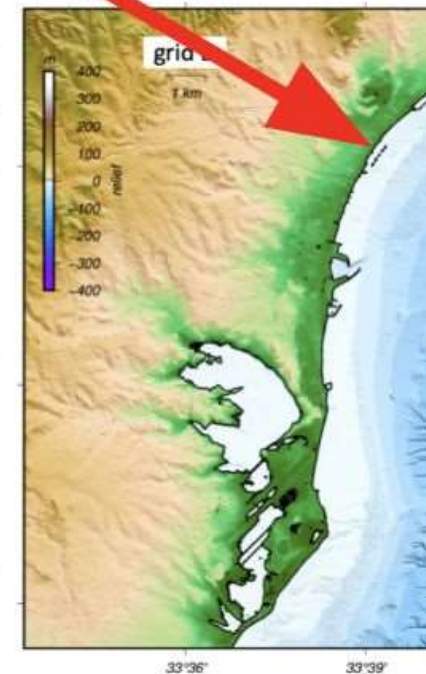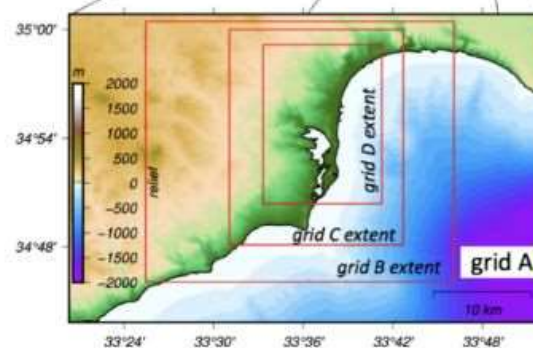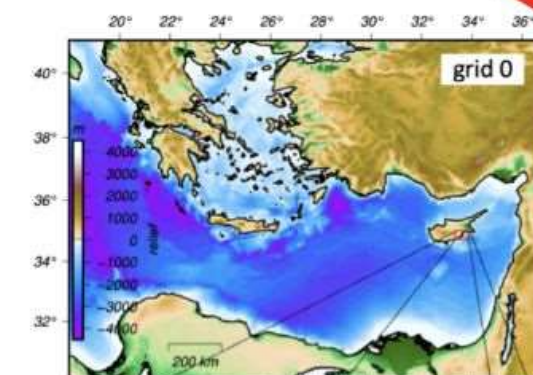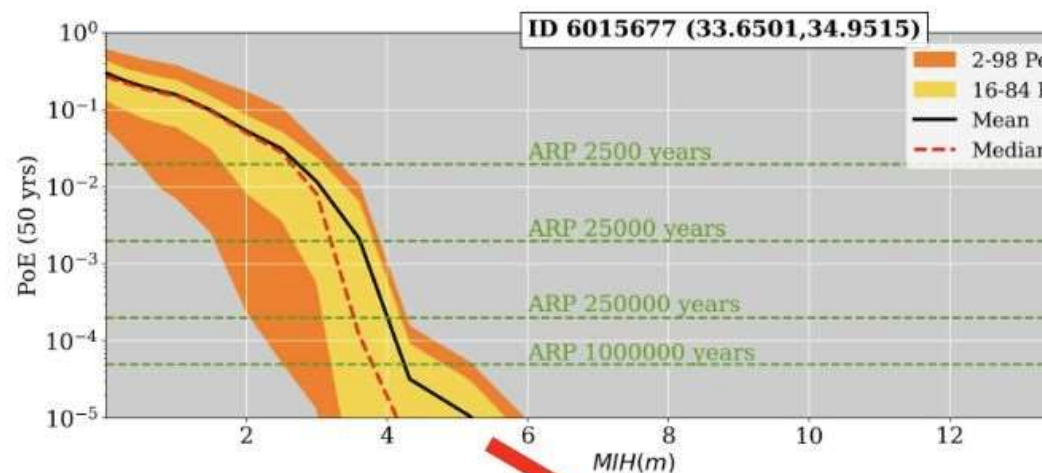
Hazard Mapping

HAZARD CURVES, MAPS

- **Model for the Exceedance rate/probability for a given time interval of different values for the hazard intensity, typically the flow depth, or the height with respect to the sea level**
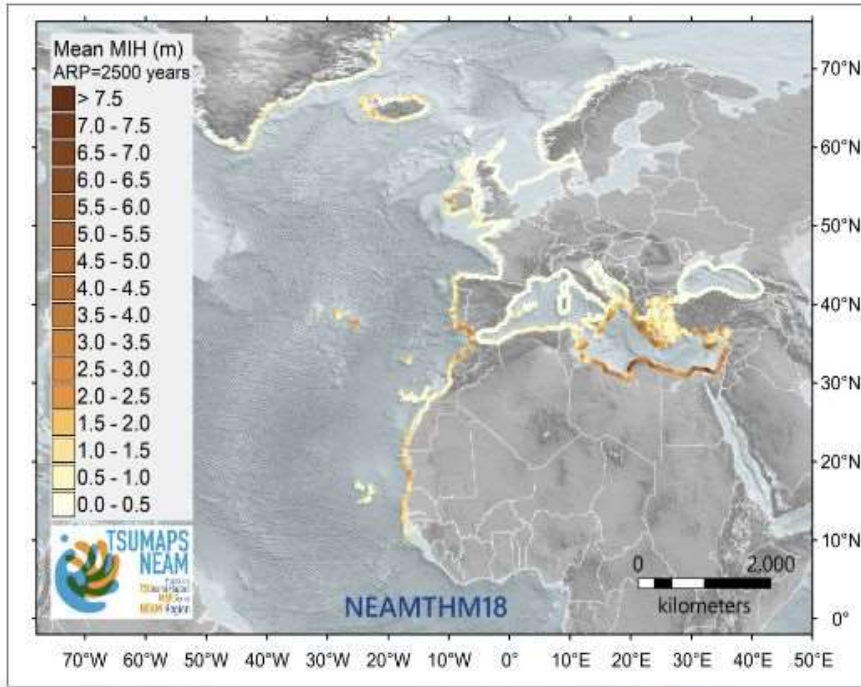- **Uncertainty of these estimates**

Hazard Mapping

1. Bathymetry data points with 10 m spacing from 0 to 50 m depth.
2. Bathymetry data points with 50 m spacing from 50 to 250 m depth.
3. High-resolution Digital Elevation Model (DEM) with 1 m spacing based on LiDAR collected in 2014.
4. Shoreline corresponding to the Mean Sea Level from data collected in 2014.
5. Orthophotos along the coastline collected in 2014; the receipt of the complete set of orthophotos covering the entirety of the study area is still pending.
6. Coverage area of the Municipality of Larnaca.
7. Census layer corresponding to year 2011, containing information on population and buildings.
8. Beach access points.
9. Reference buildings layer with a limited number of significant buildings, like public buildings, city hall, churches etc.
10. An additional layer on buildings in the Municipality of Larnaca.
11. Road network covering the study area, with partial information, such as road name and number of lanes, where available.

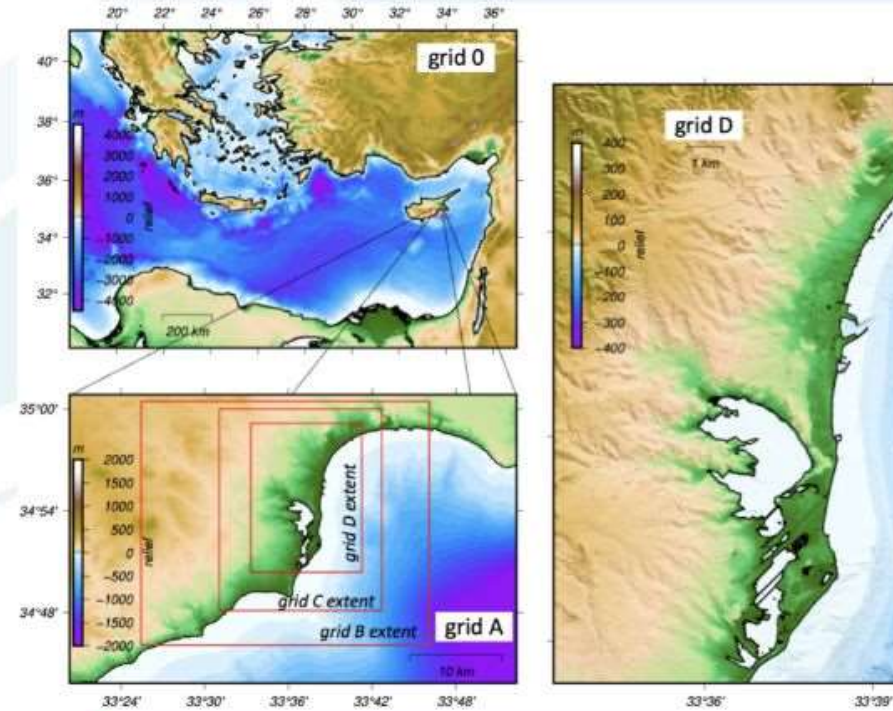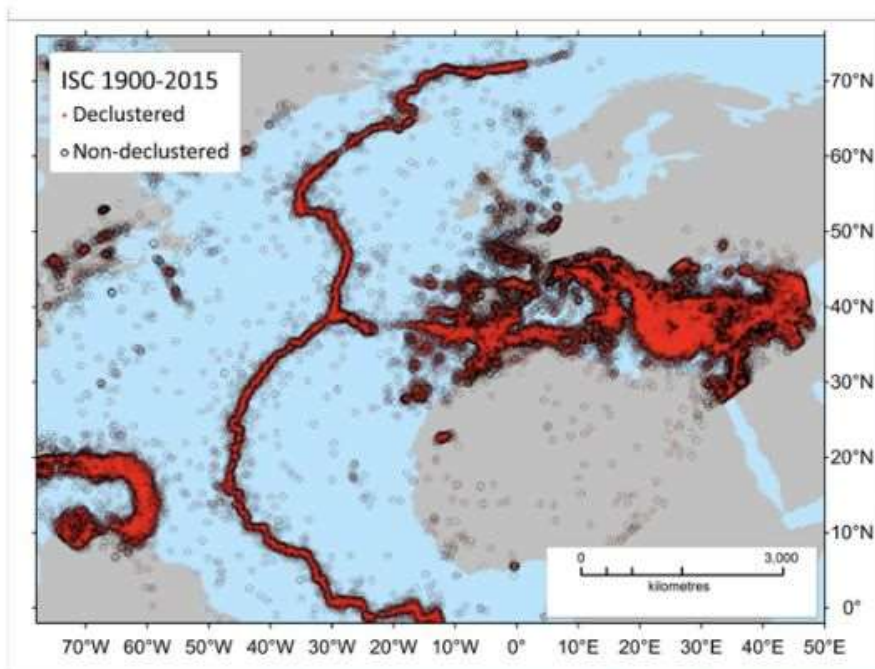| Name	Lon. extent (deg)	Lat. extent (deg)	Grid size	Cell size (m)	Data source
grid 0	18.0026/36.9996	30.0034/40.9989	5425x3813	320	SRTM15+
grid A	33.3387/33.8728	34.7303/35.0144	306x198	160	DLS/EMODnet
grid B	33.4241/33.7682	34.7674/35.0075	394x334	80	DLS/EMODnet
grid C	33.5175/33.7116	34.8017/34.9998	888x1100	20	DLS/EMODnet
grid D	33.5552/33.6878	34.8397/34.9861	2424x3248	5	DLS/EMODnet

Regional

NEAMTHM18
Basili et al., 2021

IMPOSSIBLE!
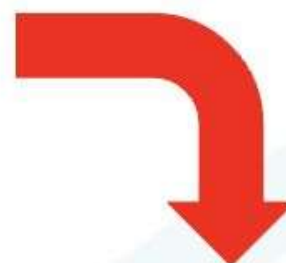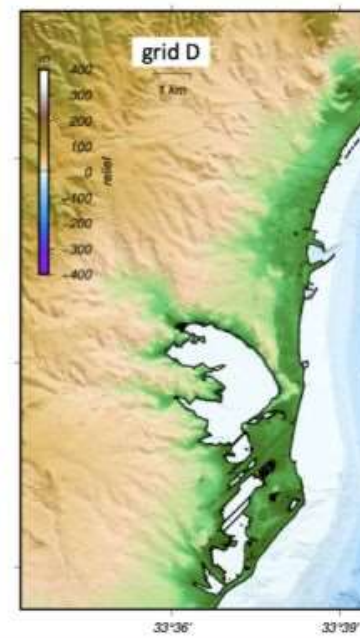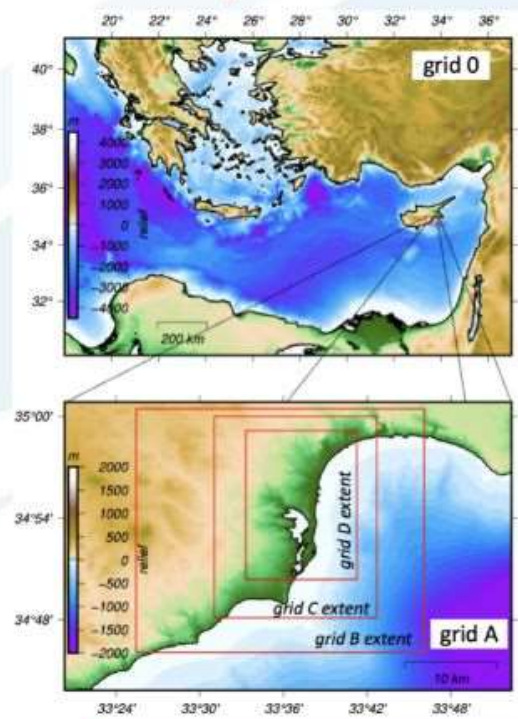Too many high-resolu
simulations

Local, High Resolution

ISTITUTO NAZIONALE DI GEOFISICA E VU

CENTRO
ALLERTA
TSUNAMI

ISC 1900-2015
· Declustered
∘ Non-declustered

Regional

NEAMTHM18
Basili et al., 2021

IMPOSSIBLE!
Too many high-resolu
simulations

grid 0

grid D

grid C extent
grid B extent
grid D extent
grid A

Local, High Resolution

ISTITUTO NAZIONALE DI GEOFISICA E VU

Consider only significant sources for Larnaca: Disaggregation from NEAMTHM18
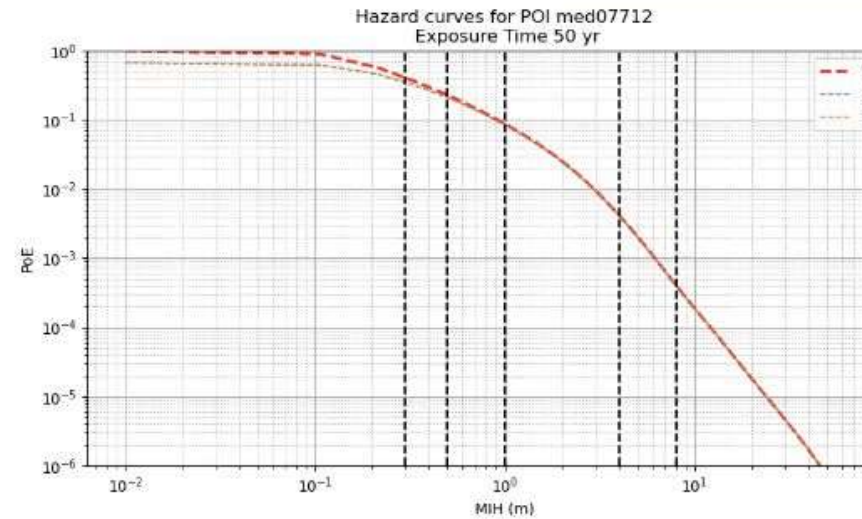
TOTAL: 23164 Simulations

ISTITUTO NAZIONALE DI GEOFISICA E VU
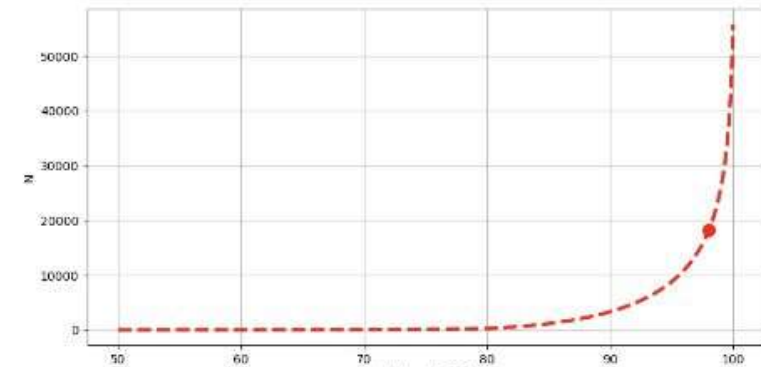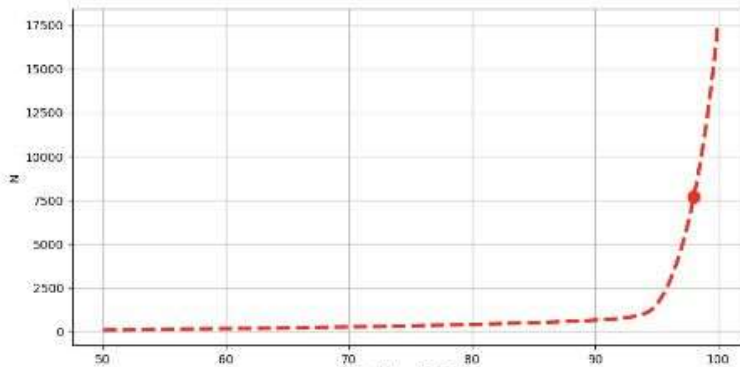
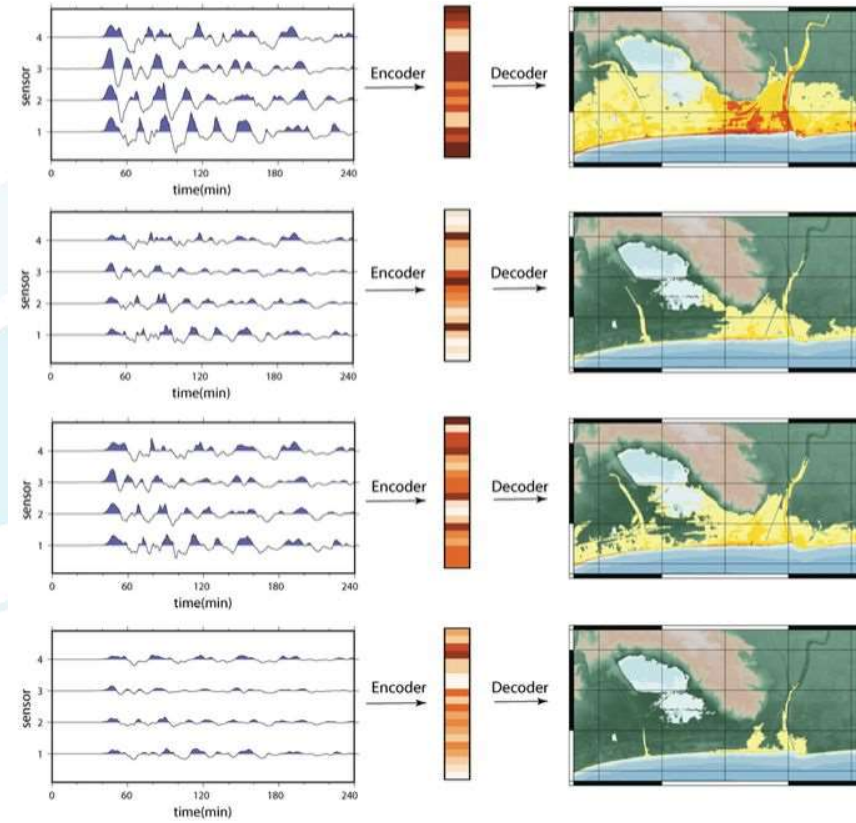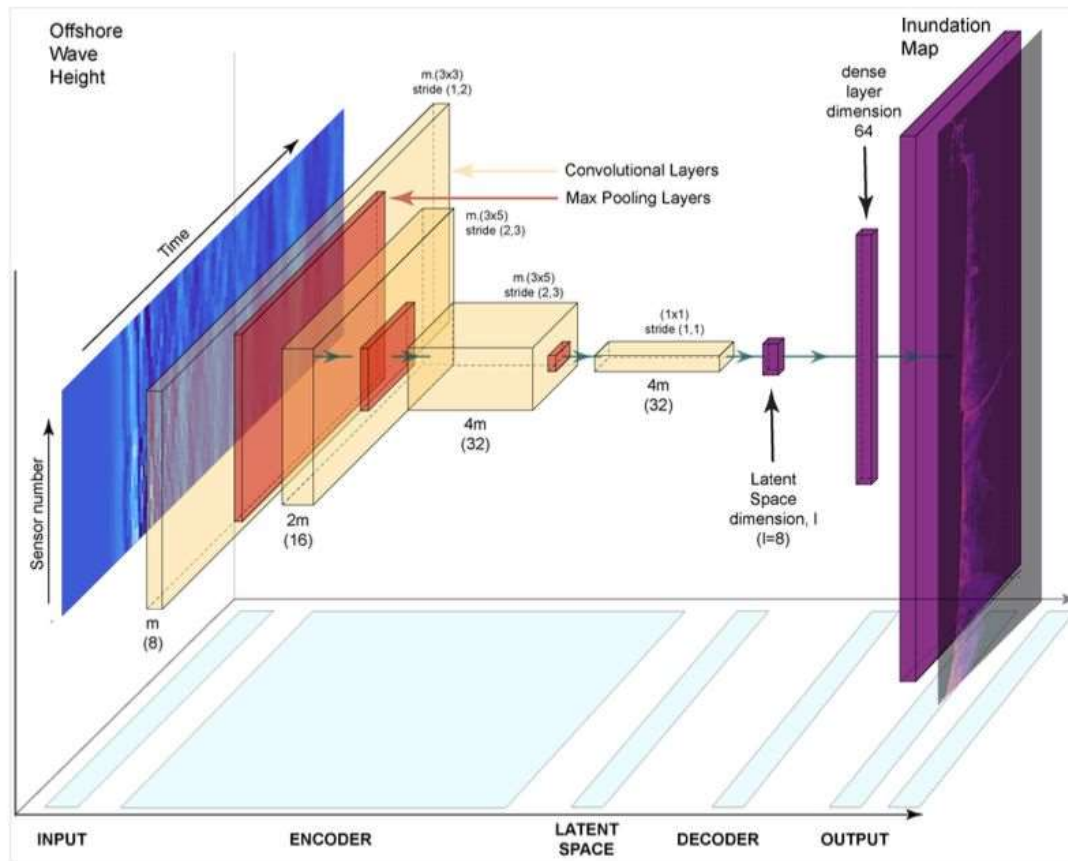# Other approaches

From offshore to onshore probabilistic tsunami hazard assessment via efficient Monte-Carlo sar
Davies et al., 2022 (GJI)
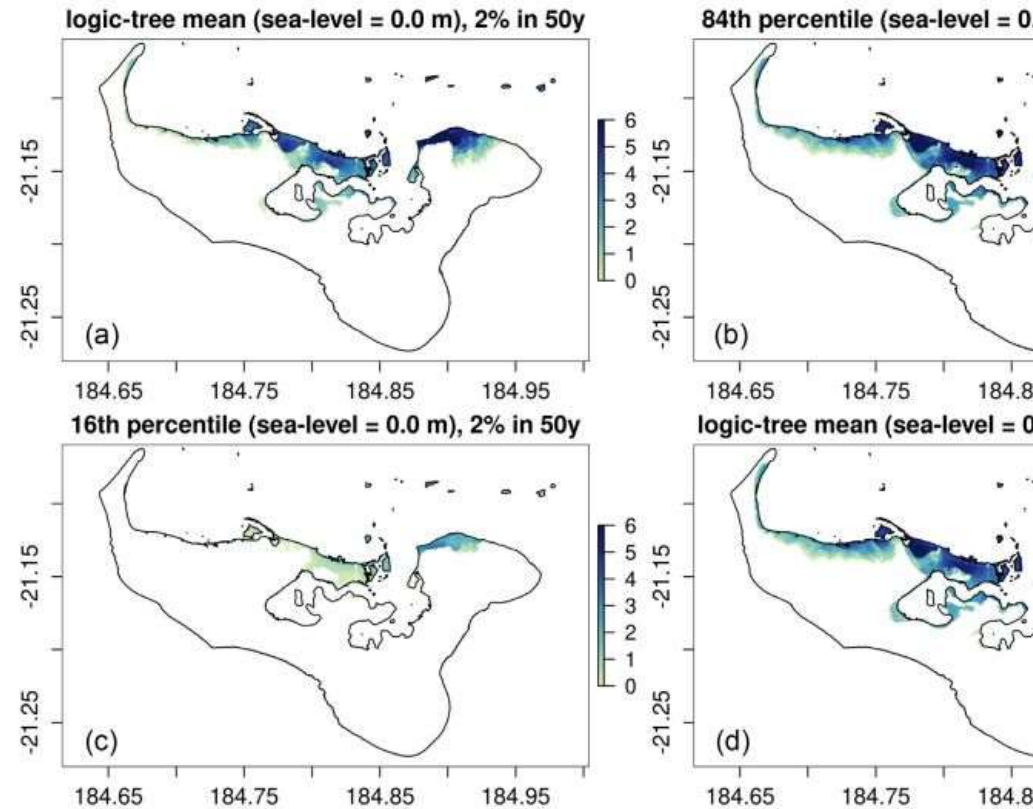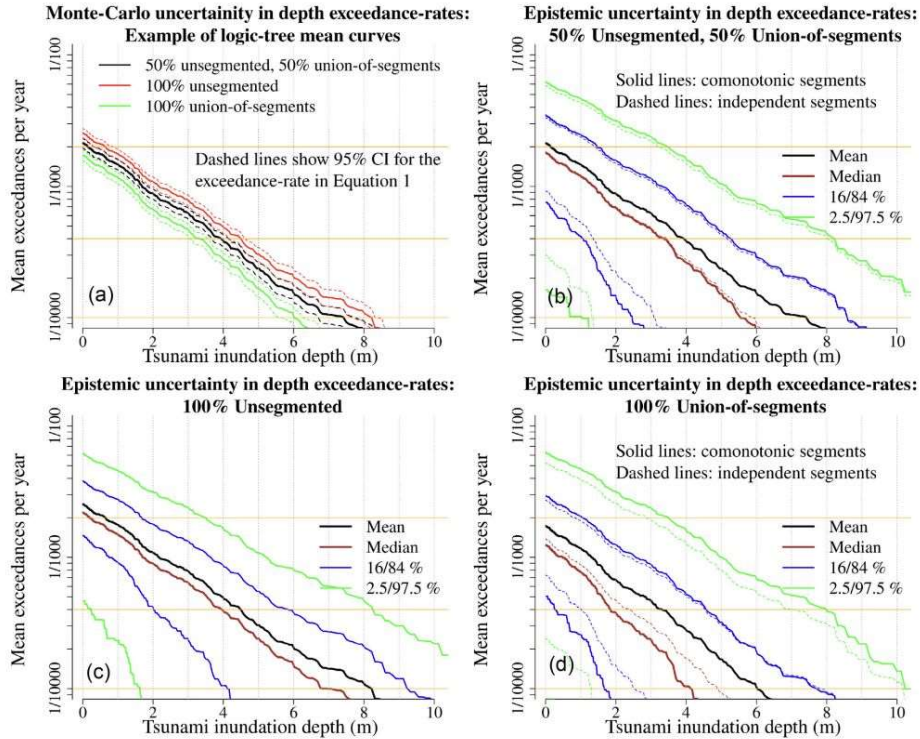
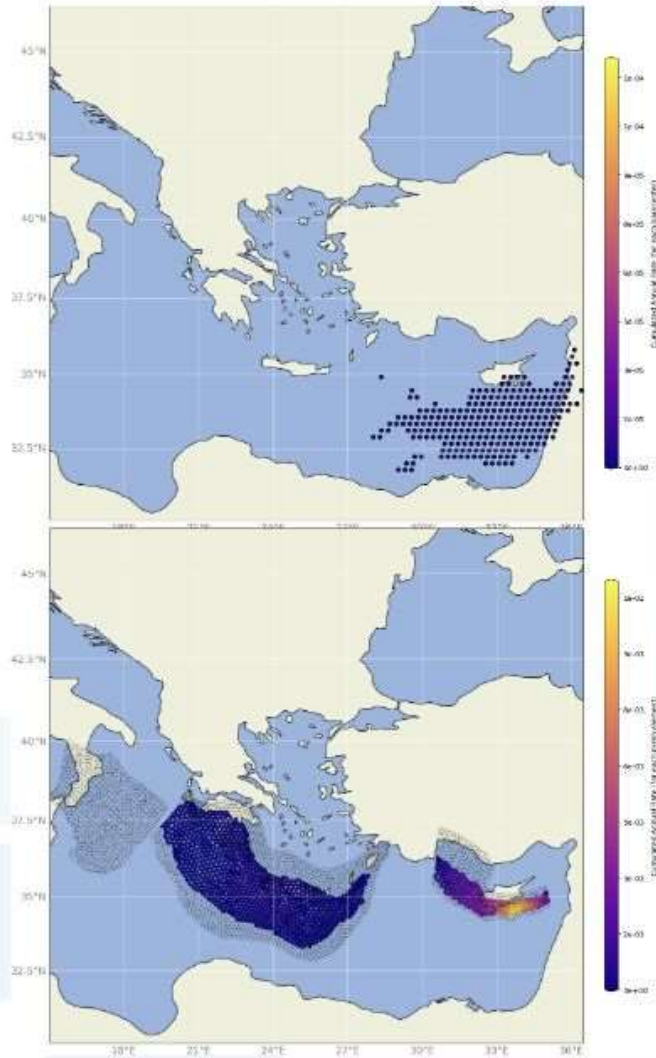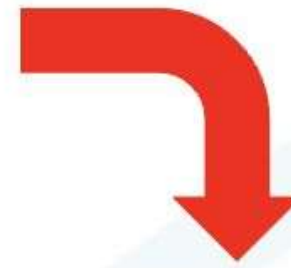Machine Learning Emulation of High Resolution Inundation Maps. Storrøsten et al., 2024 (GJI, a

POSSIBLE!
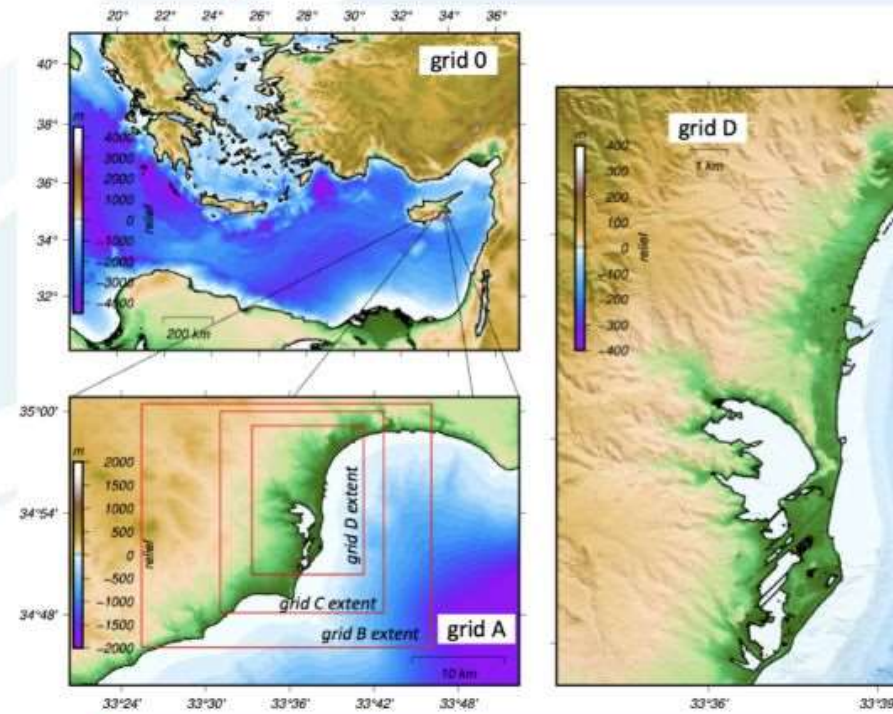Many high-resolution
simulations

Selection from the Regional model

Local, High-Resolution
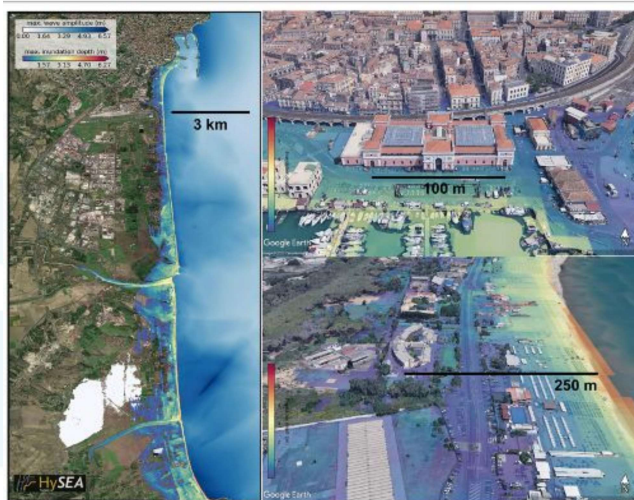
CENTRO ALLERTA TSUNAMI

ISTITUTO NAZIONALE DI GEOFISICA E VU

Numerical Tsunami Simulations

Tsunami Simulation Code

Tsunami-HySEA GPU-Based Code,
EDANYA Group, University of Malaga

Computational Facility

Mercalli Cluster @INGV


```
            **** M E R C A L L I ****

* 14 CPU nodes, quad-16-core Intel(R) Xeon(R) Gold 5218 processors
  clocked @ 2.30GHz and 512GB RAM

*  6 GPU nodes, dual-20-core Intel(R) Xeon(R) Gold 6248 processors
   clocked @ 2.50GHz and 384GB RAM, 8x nVidia A100 units

* Total: 1136 CPU cores, 9472 GB RAM (~8GB/core), 48 nVidia A100 units

                    ~~~~~~~~~~~~~~~

* CentOS 7.7 Core Operating System, PBS Pro 2021.1 batch scheduler

* A local scratch partition (without backup) is available in
  /data/users/<your_username>, or $data

* Type 'module avail' to get a list of available software modules
```

~100k GPU-h
(~2,5 months

for

- **~8 M cells**
  resolution
  grid)
- **~25k simu**
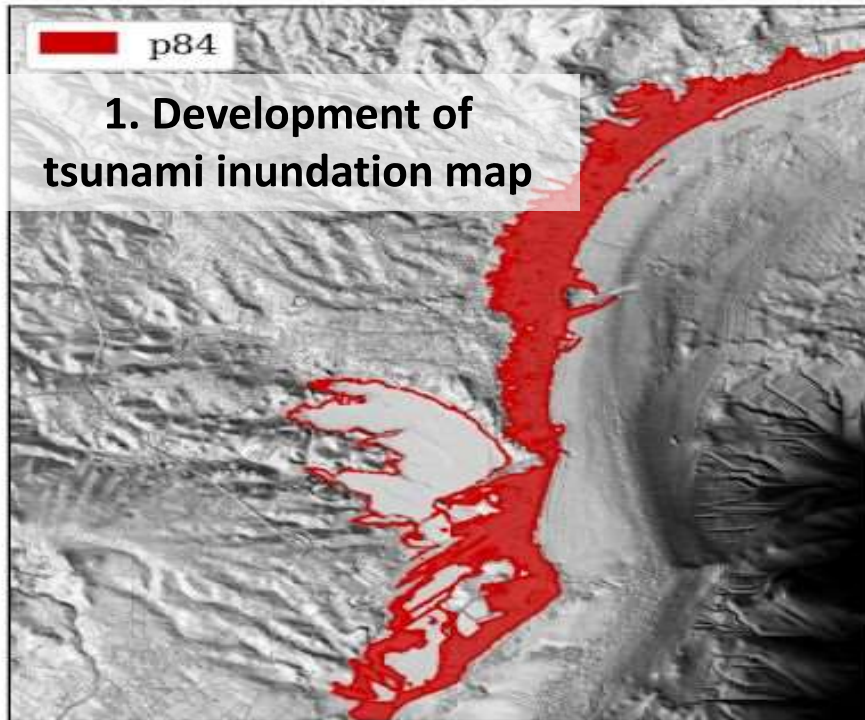 accuracy f
  disaggrega

HySEA

UNIVERSIDAD DE MÁLAGA

CENTRO
ALLERTA
TSUNAMI

ISTITUTO NAZIONALE DI GEOFISICA E VU

The Larnaca project

Tsunami modelling, inundation and evacuation mapping in Larnaca area within the frame
CoastWAVE project

1. Development of tsunami inundation map

2. tsuna

from hazard to inundation mapping

HAZARD CURVES, MAPS

THRESHOLDS

For coastal planning
(evacuation maps)
- **2500 yr ARP**
- **84th percentile**

i.e.

~ 2% in 50 yr

- Model for the Exceedance rate/probability for a given time interval of different values for the hazard intensity, typically the flow depth, or the height with respect to the sea level
- Uncertainty of these estimates

- Validation of the hazard maps
- Selection of the design rate/probability/return period
- Selection of the design model uncertainty level
- Safety factors

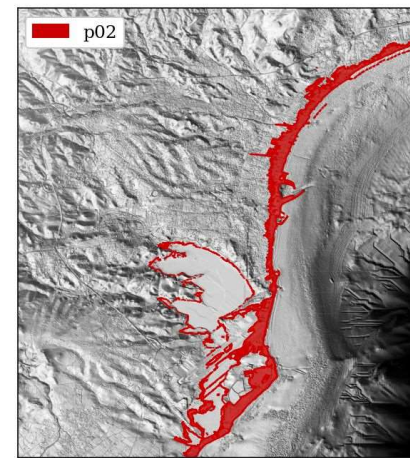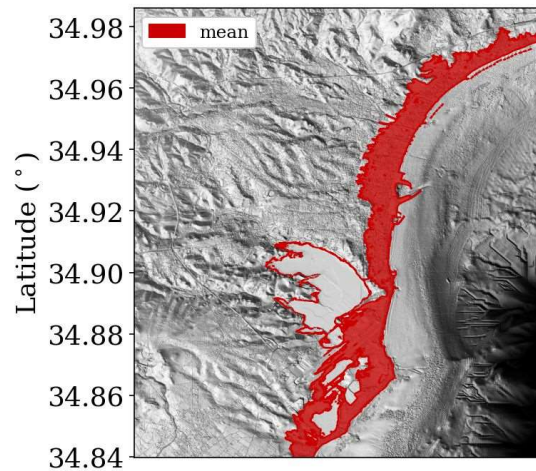Here the desired level of risk reduction is implicitly chosen

Similar approaches:
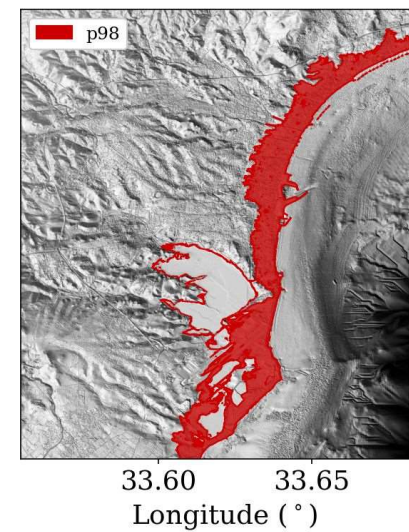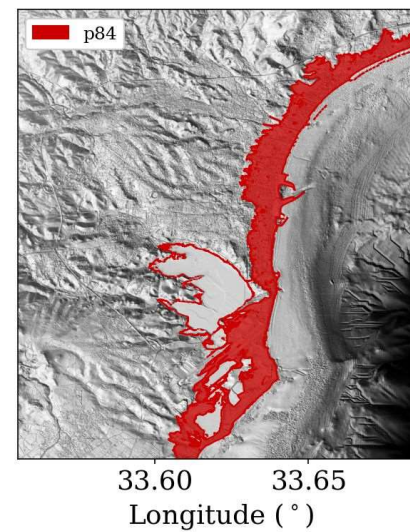- New Zealand inundation mappin
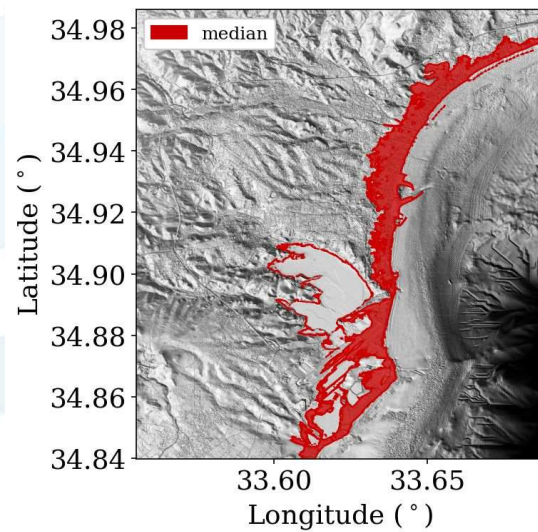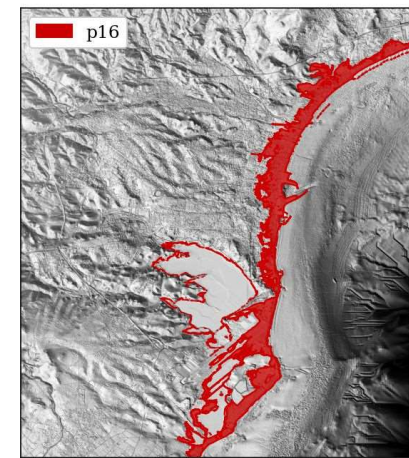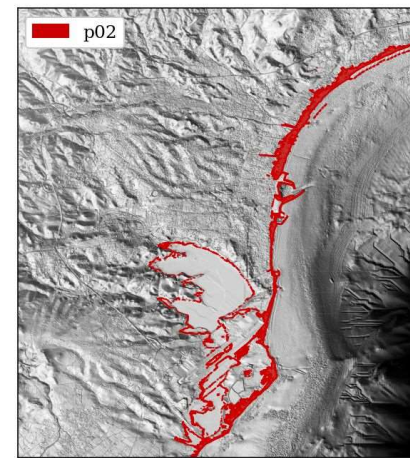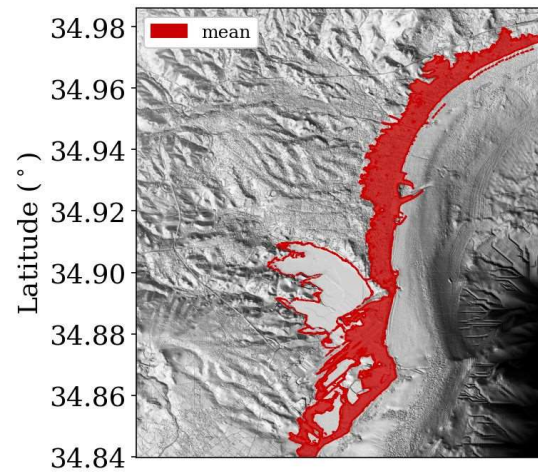- US ASCE7-16 Building Codes

CENTRO
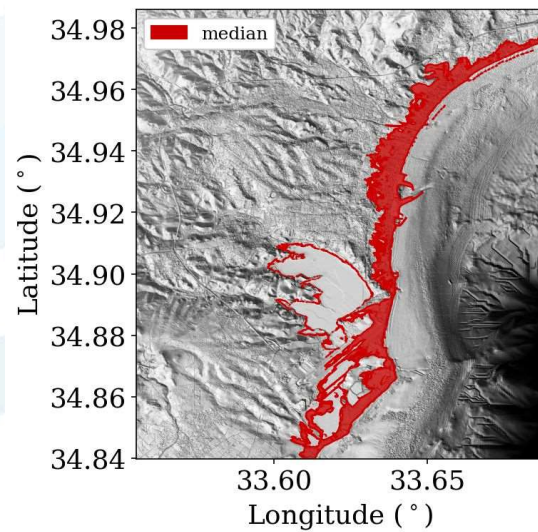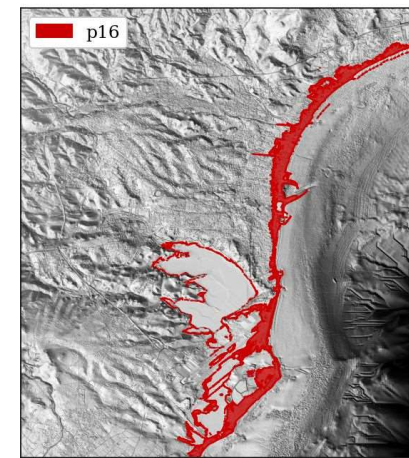ALLERTA
TSUNAMI

ISTITUTO NAZIONALE DI GEOFISICA E VU
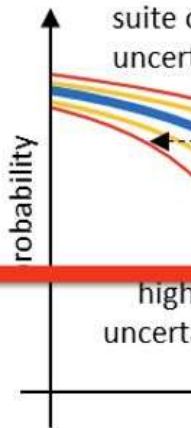
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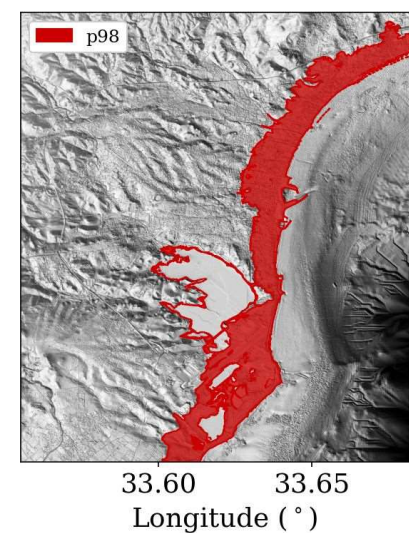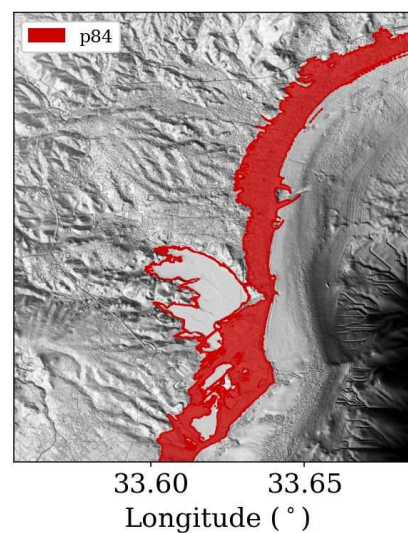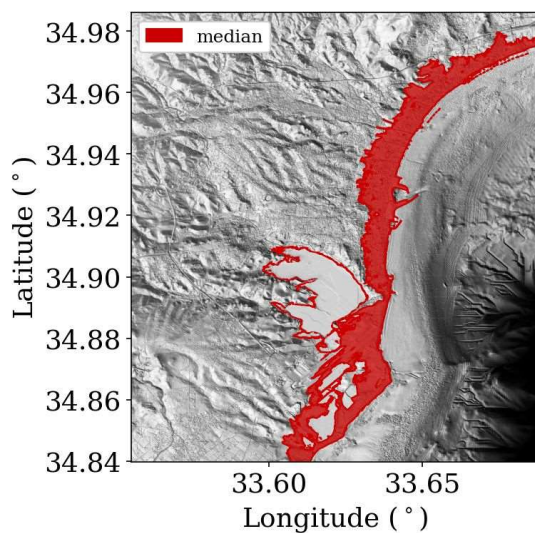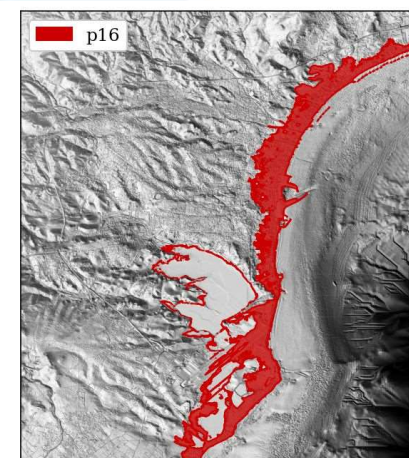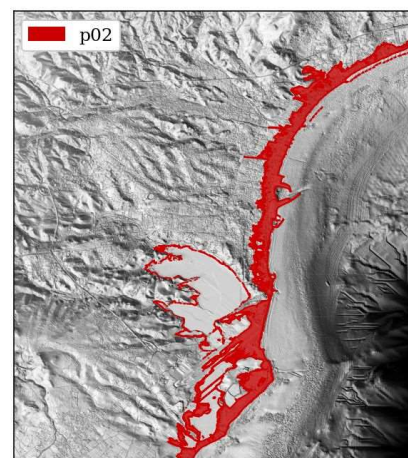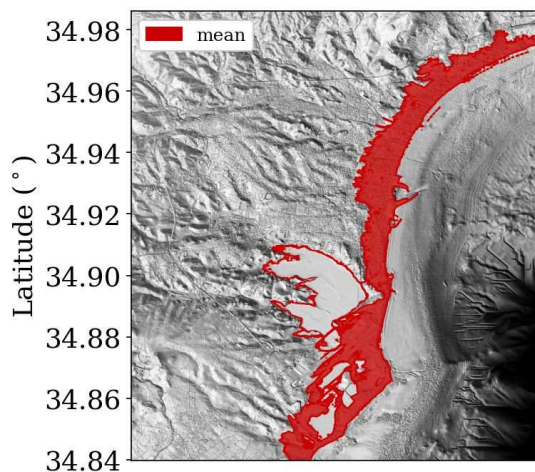
Inundation extent: 250kyr ARP
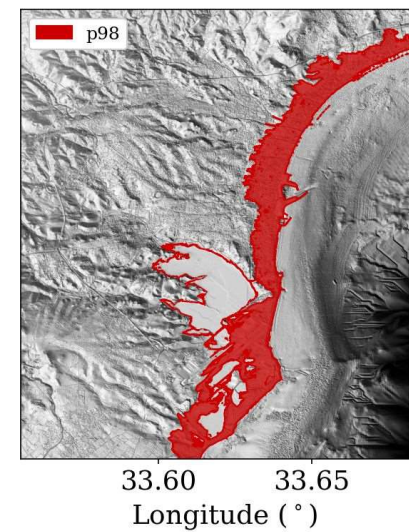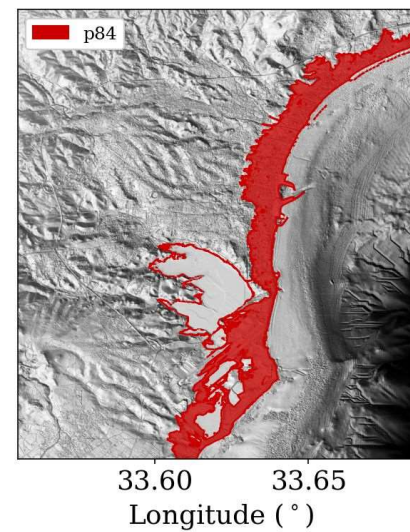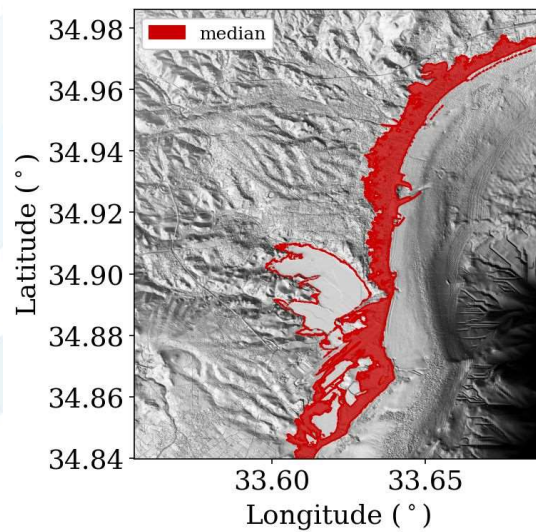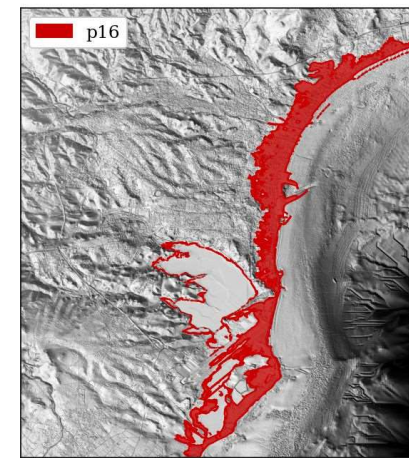
Inundation extent: 25kyr ARP

Inundation extent: 10kyr ARP
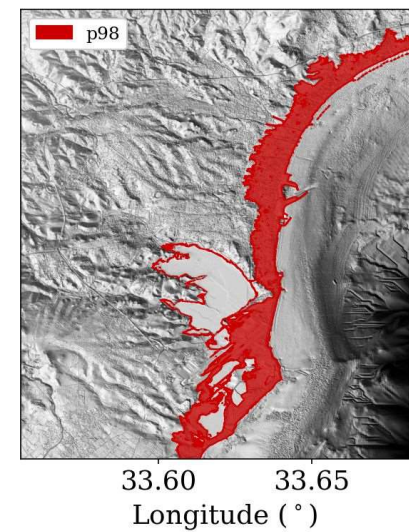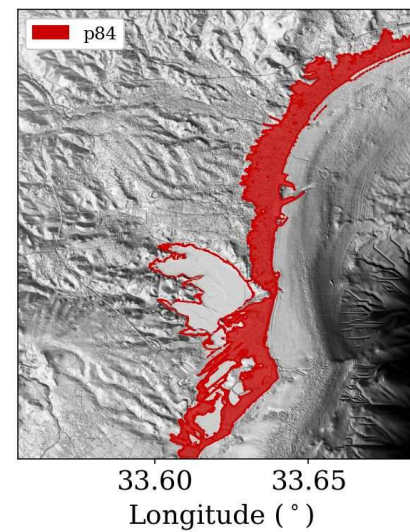
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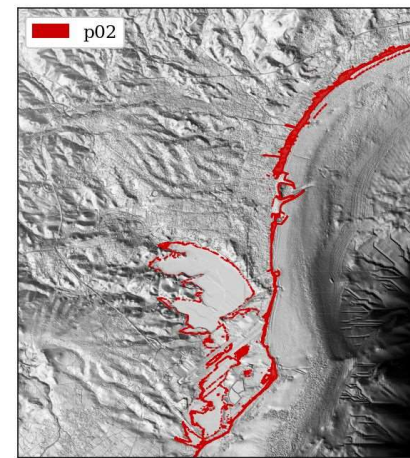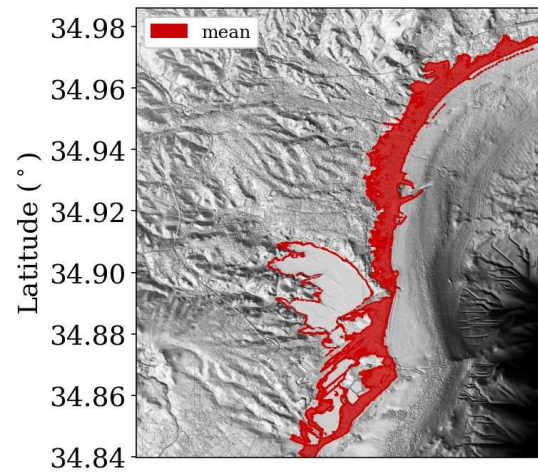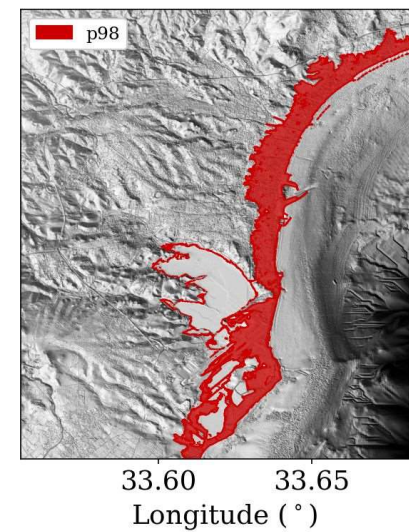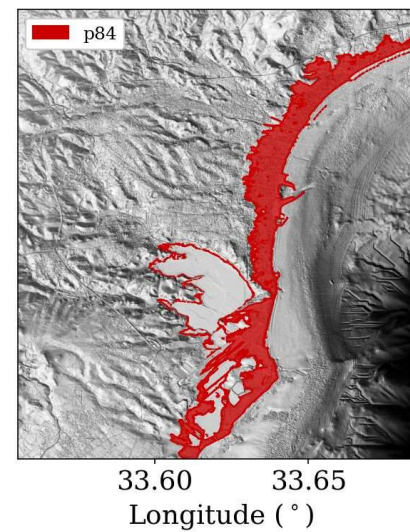
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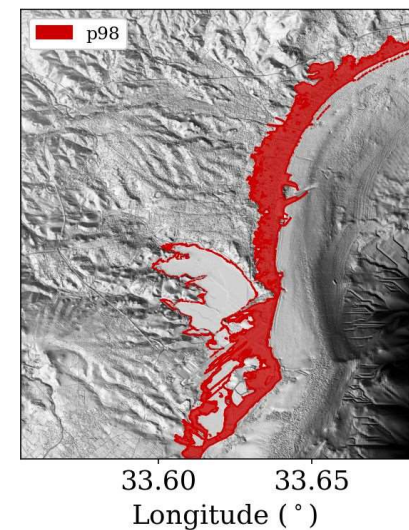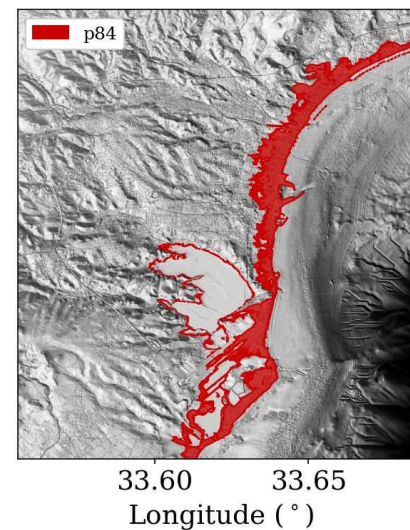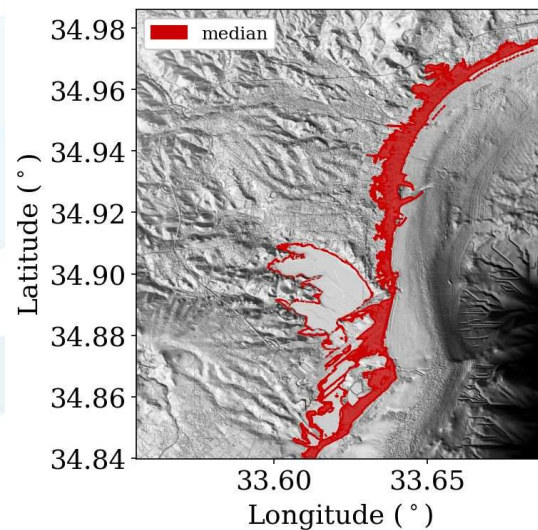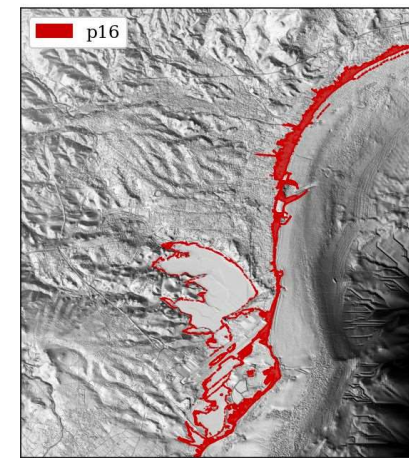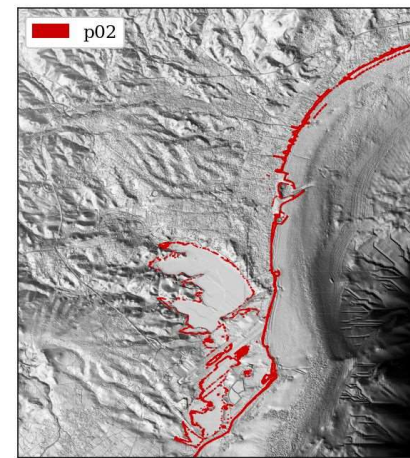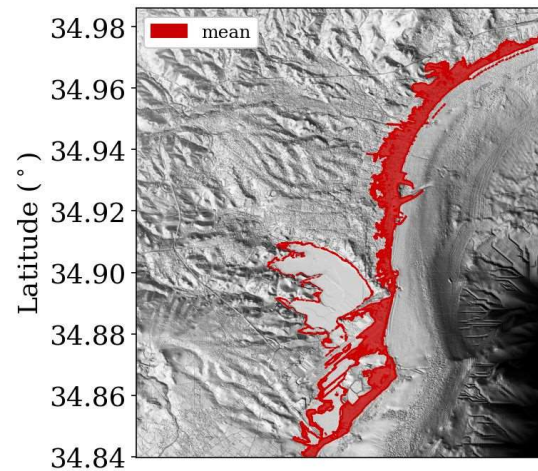
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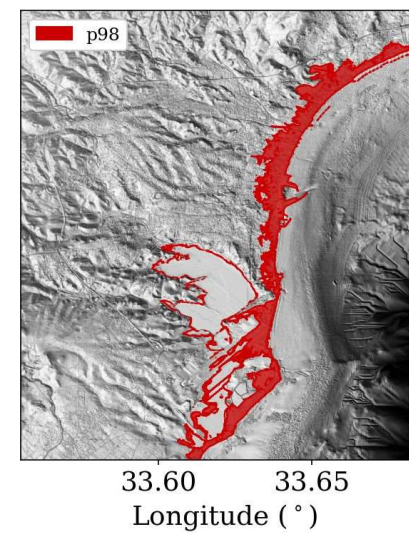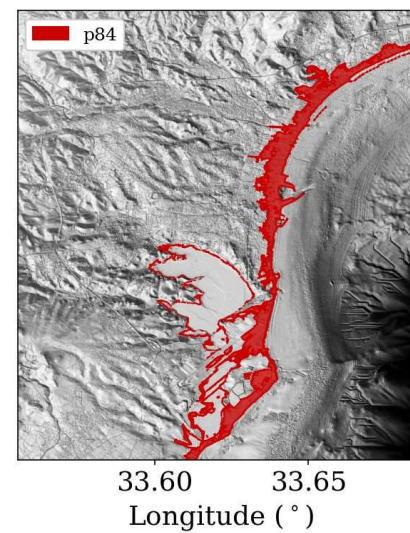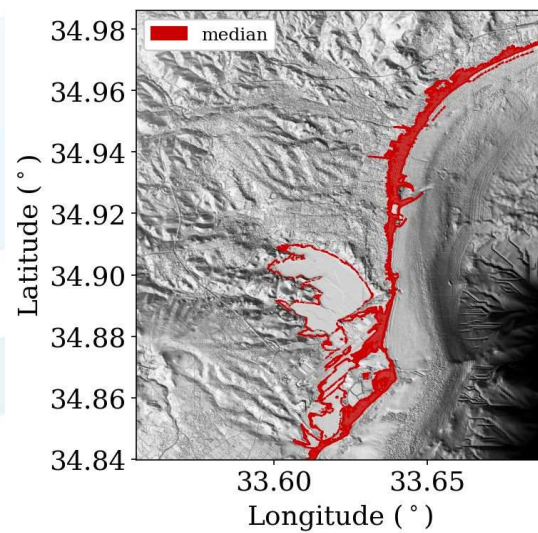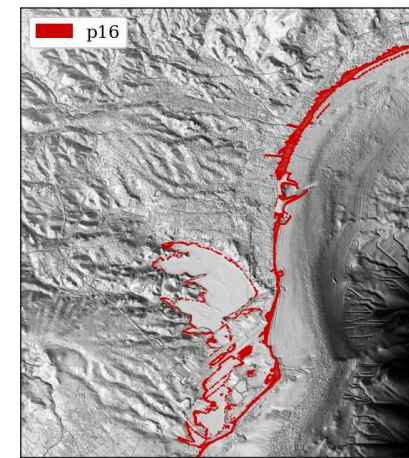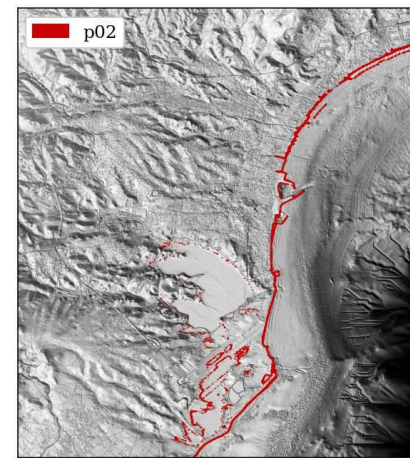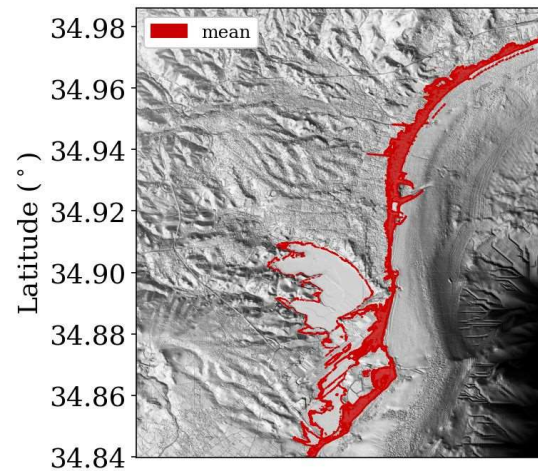
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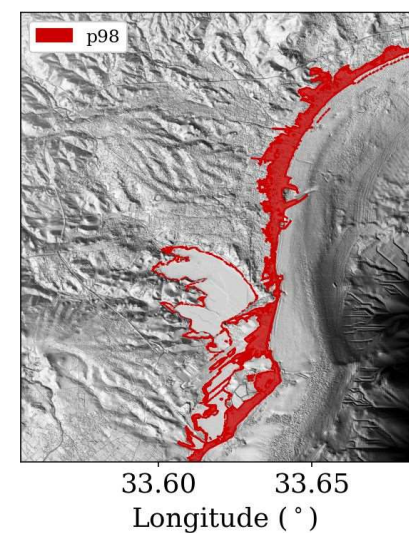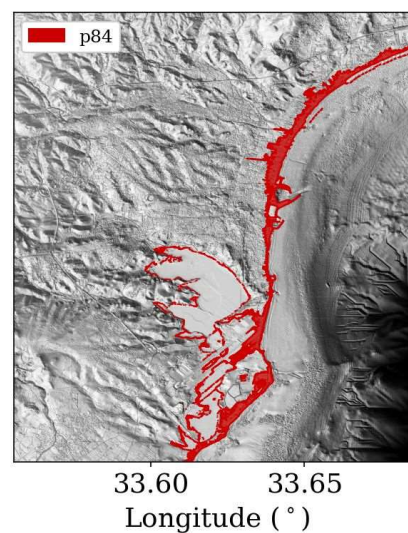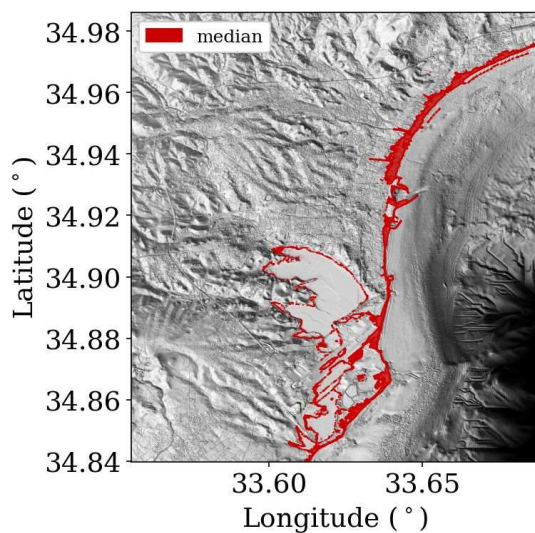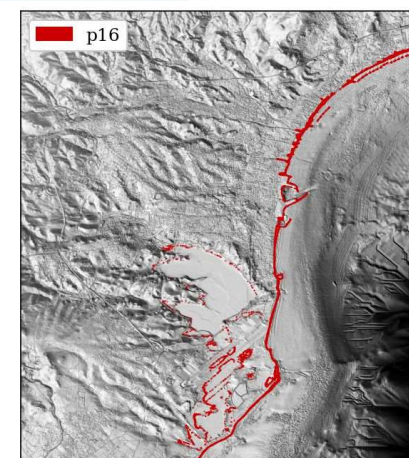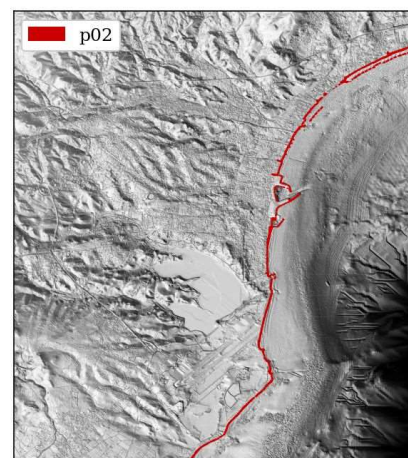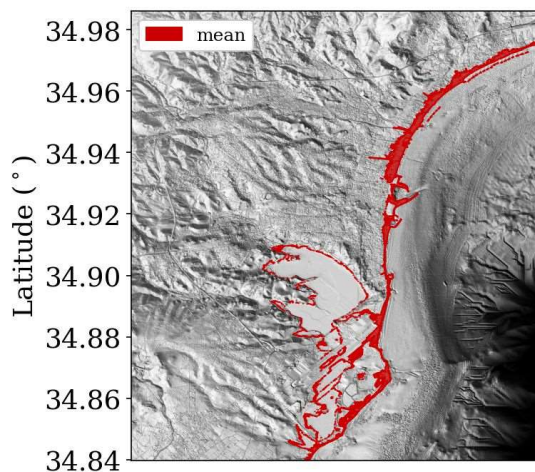
Flow Depth: 1Myr ARP

Flowdepth [m]; ARP: 1000000 years
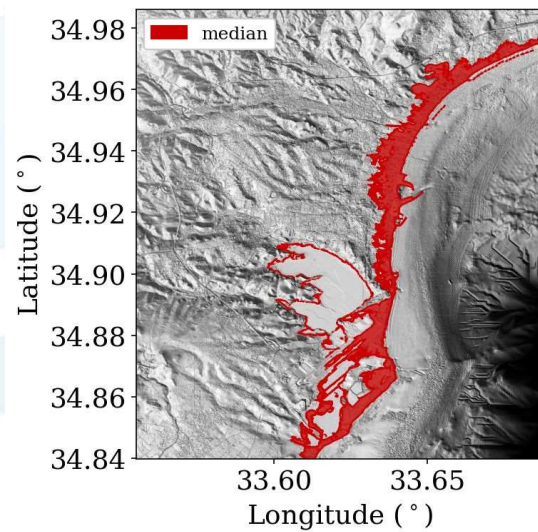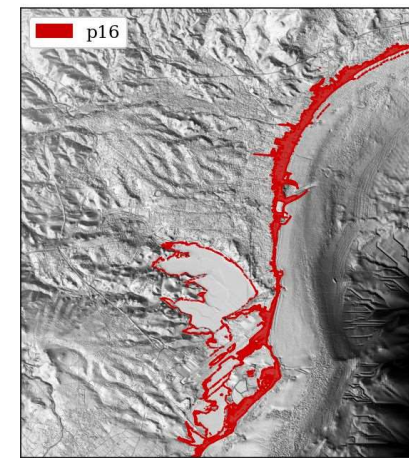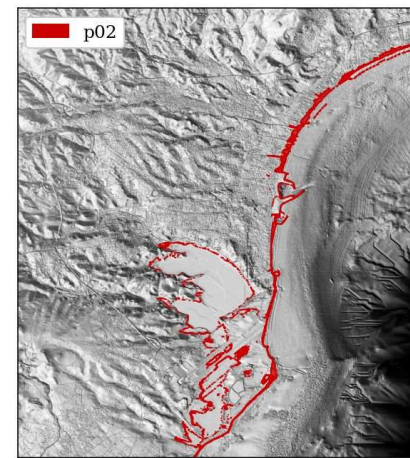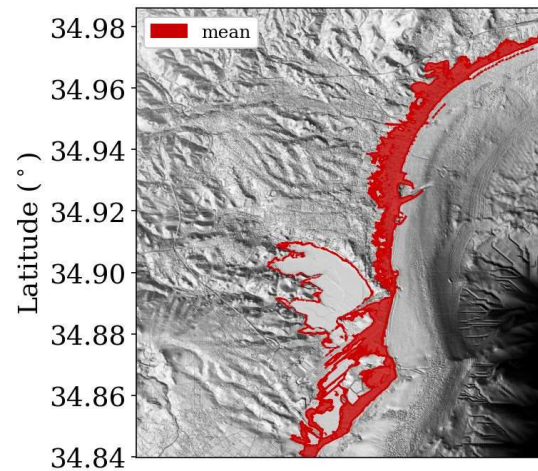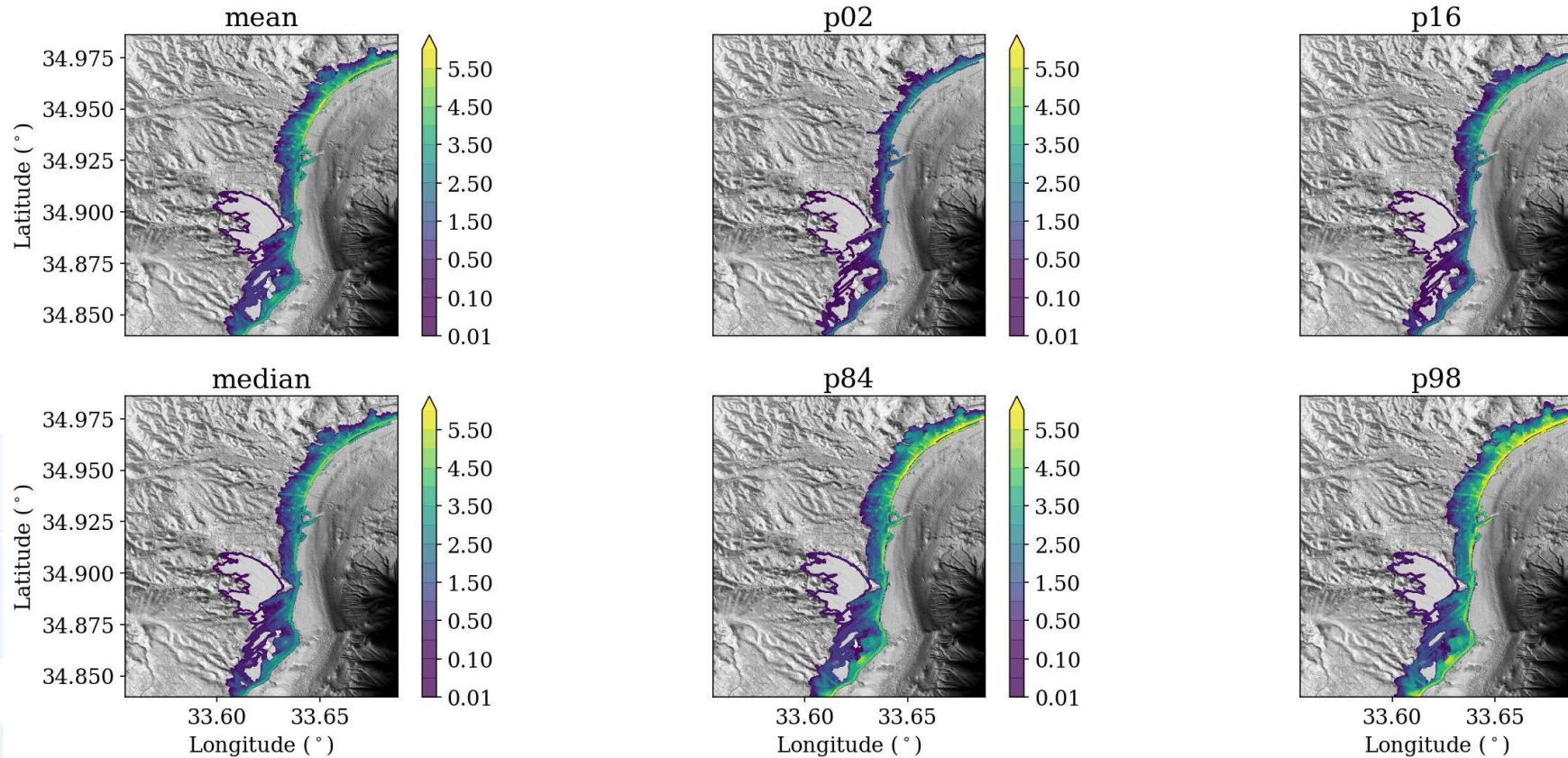
Flow Depth: 250kyr ARP

Flowdepth [m]; ARP: 250000 years
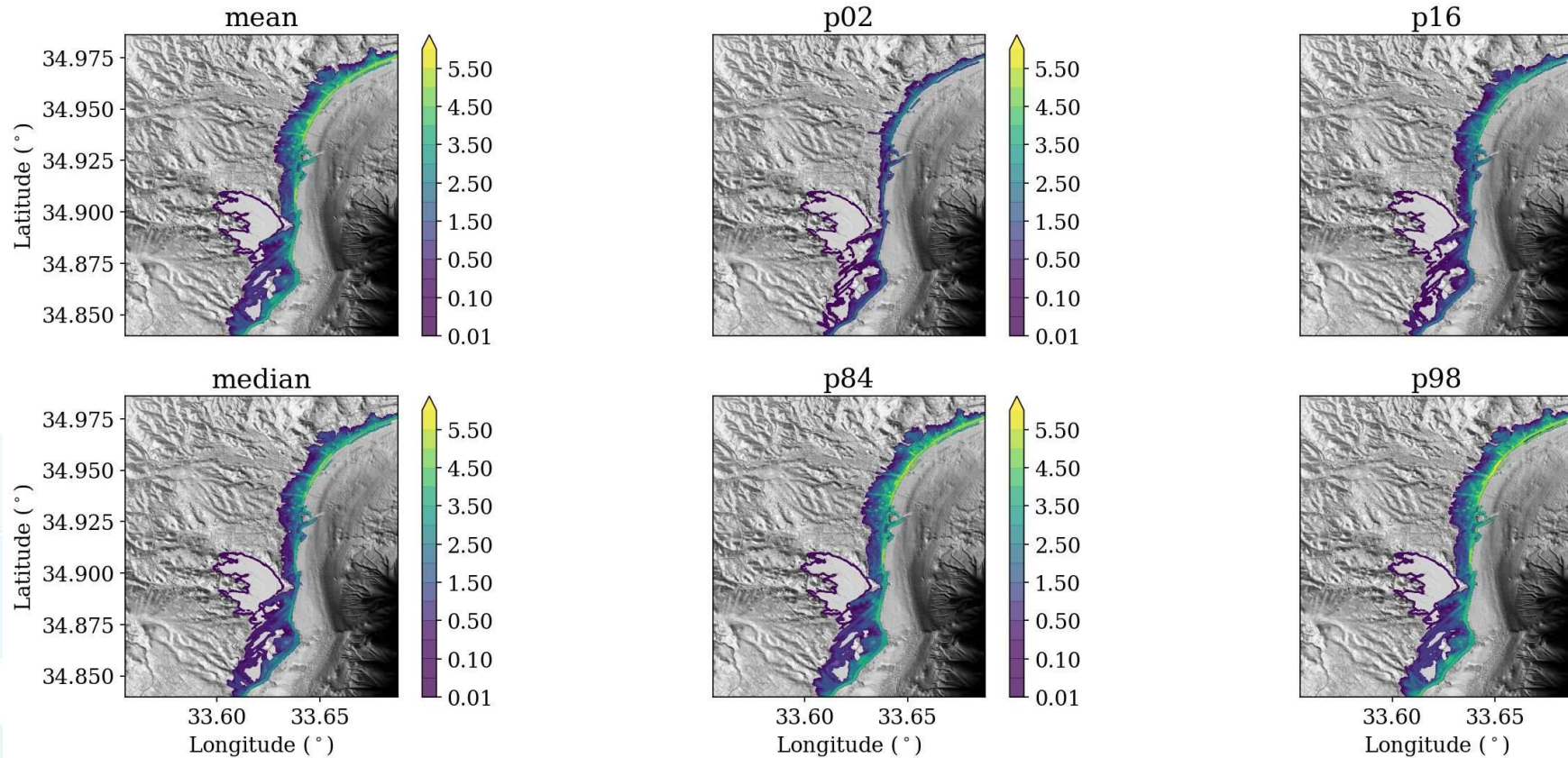
Flow Depth: 25kyr ARP

Flowdepth [m]; ARP: 25000 years
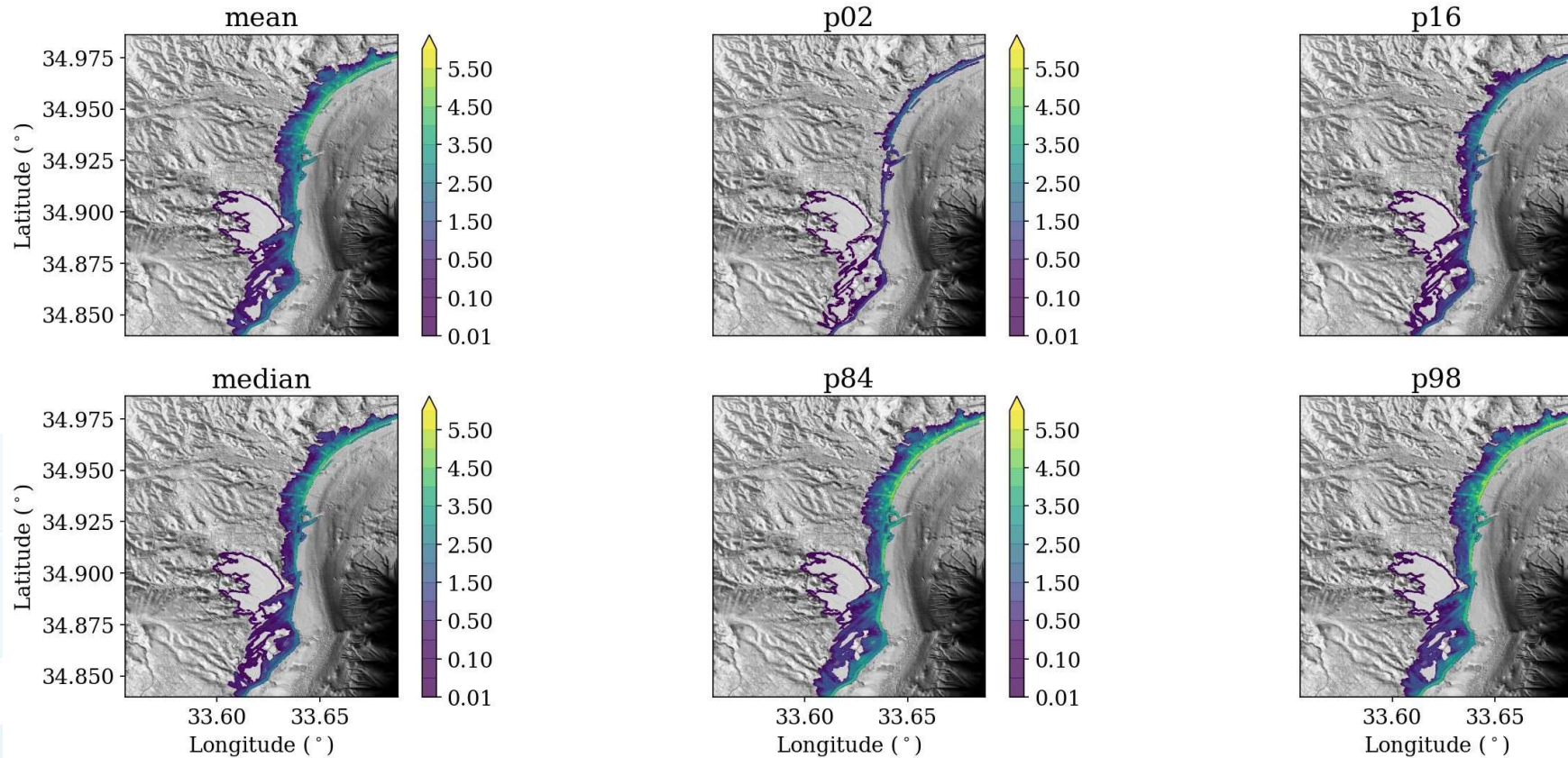
Flow Depth: 10kyr ARP

Flowdepth [m]; ARP: 10000 years
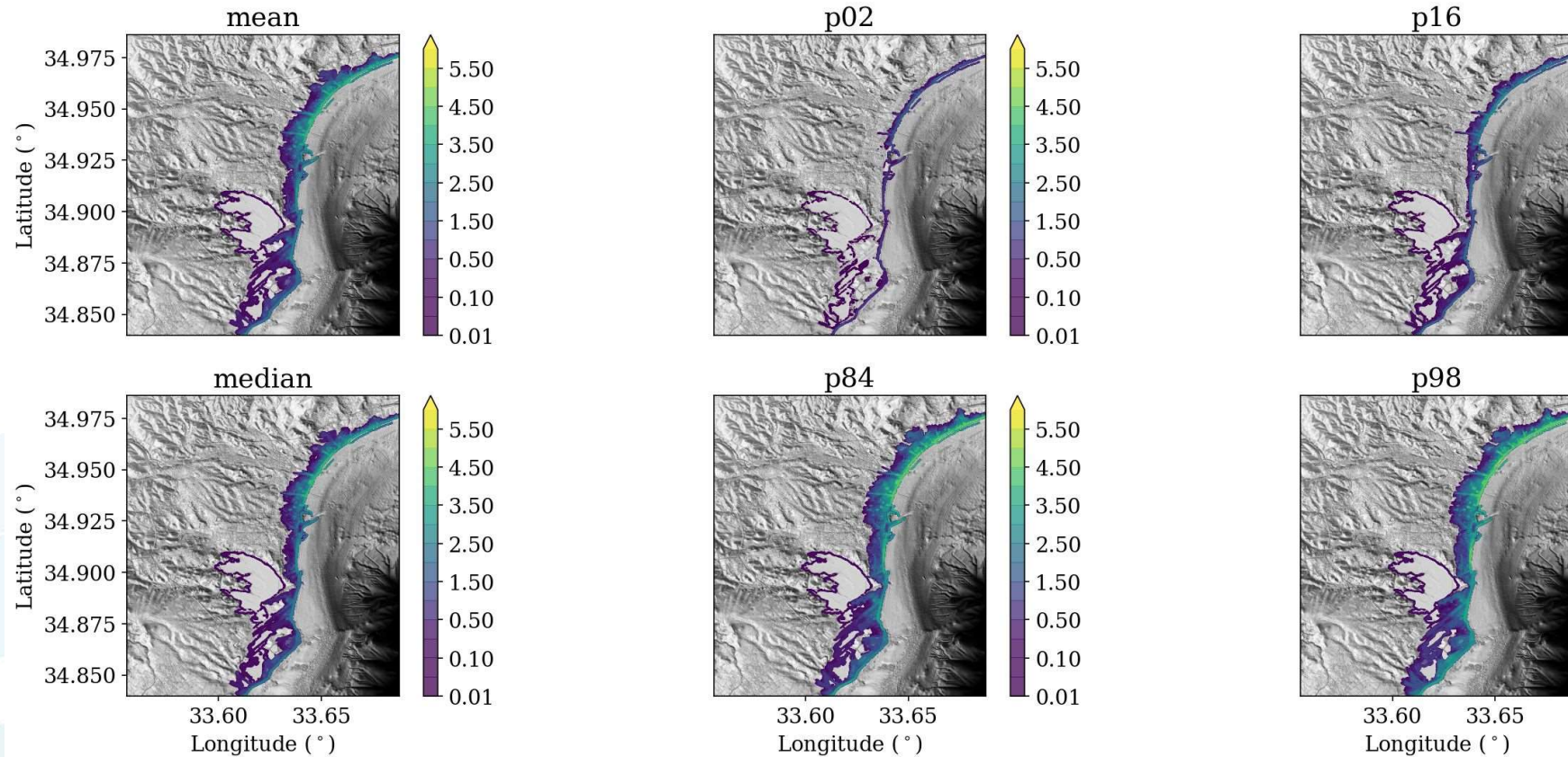
Flow Depth: 5000yr ARP

Flowdepth [m]; ARP: 5000 years
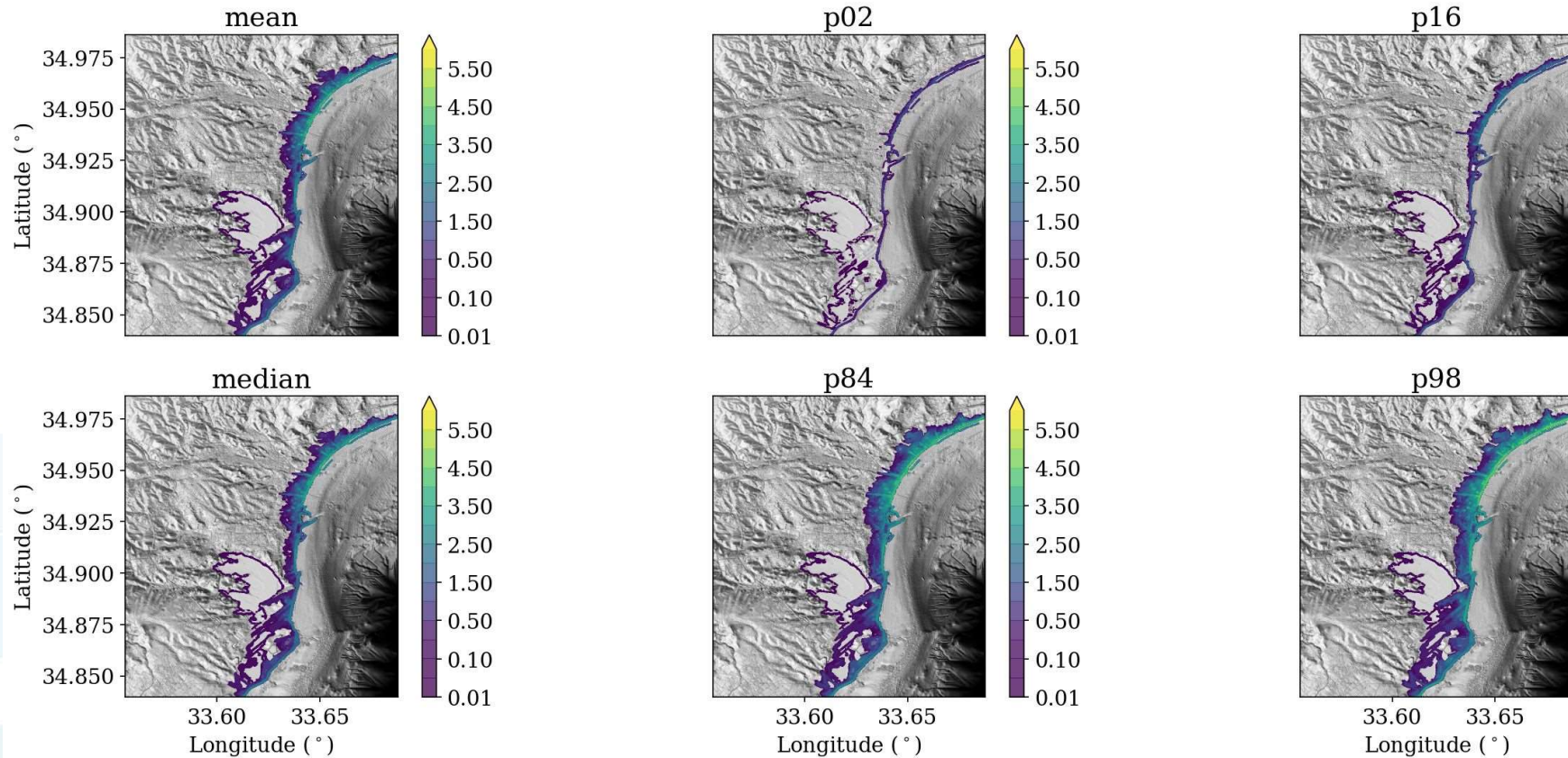
Flow Depth: 2500yr ARP

Flowdepth [m]; ARP: 2500 years
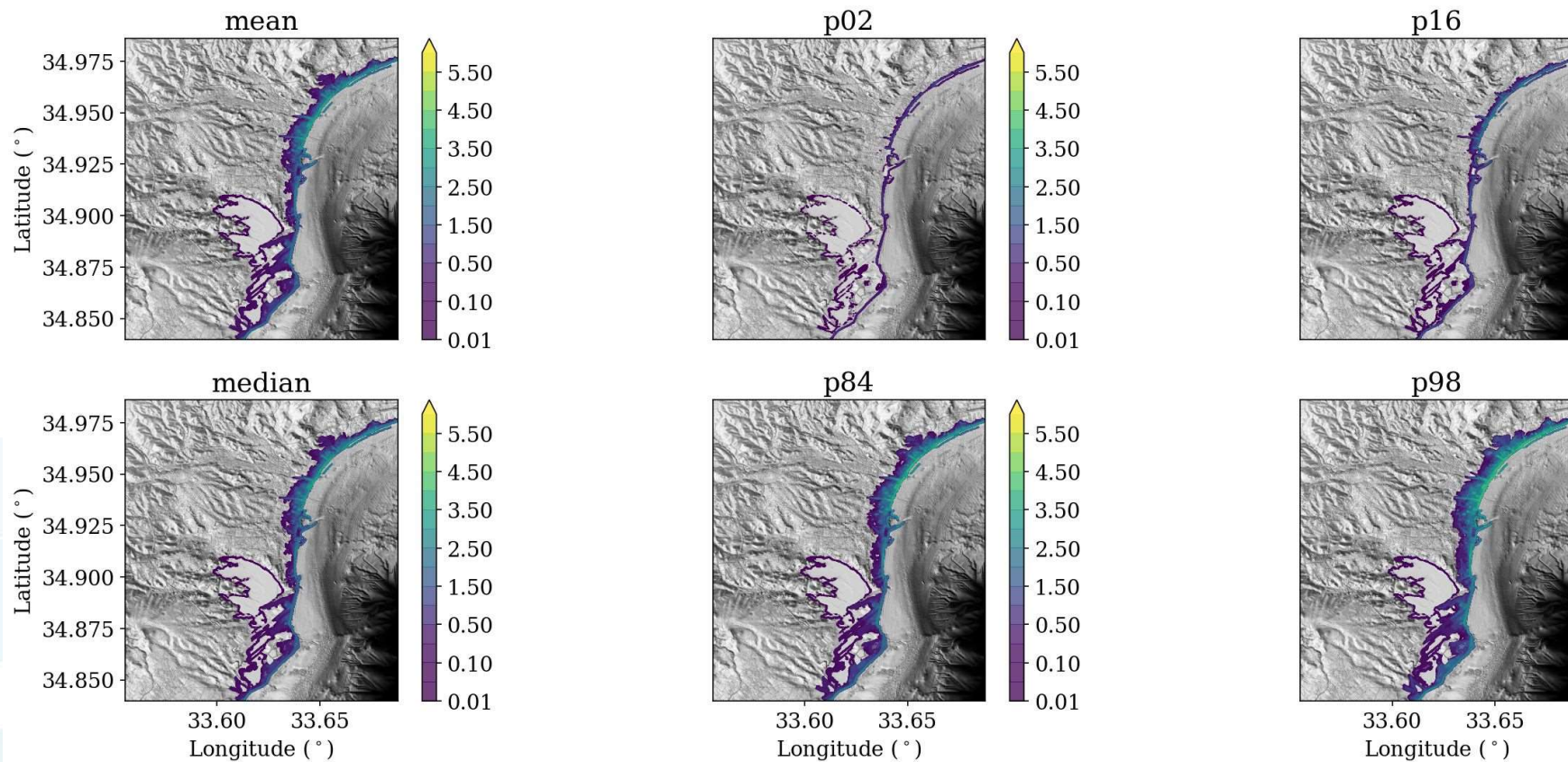
Flow Depth: 1000yr ARP

Flowdepth [m]; ARP: 1000 years
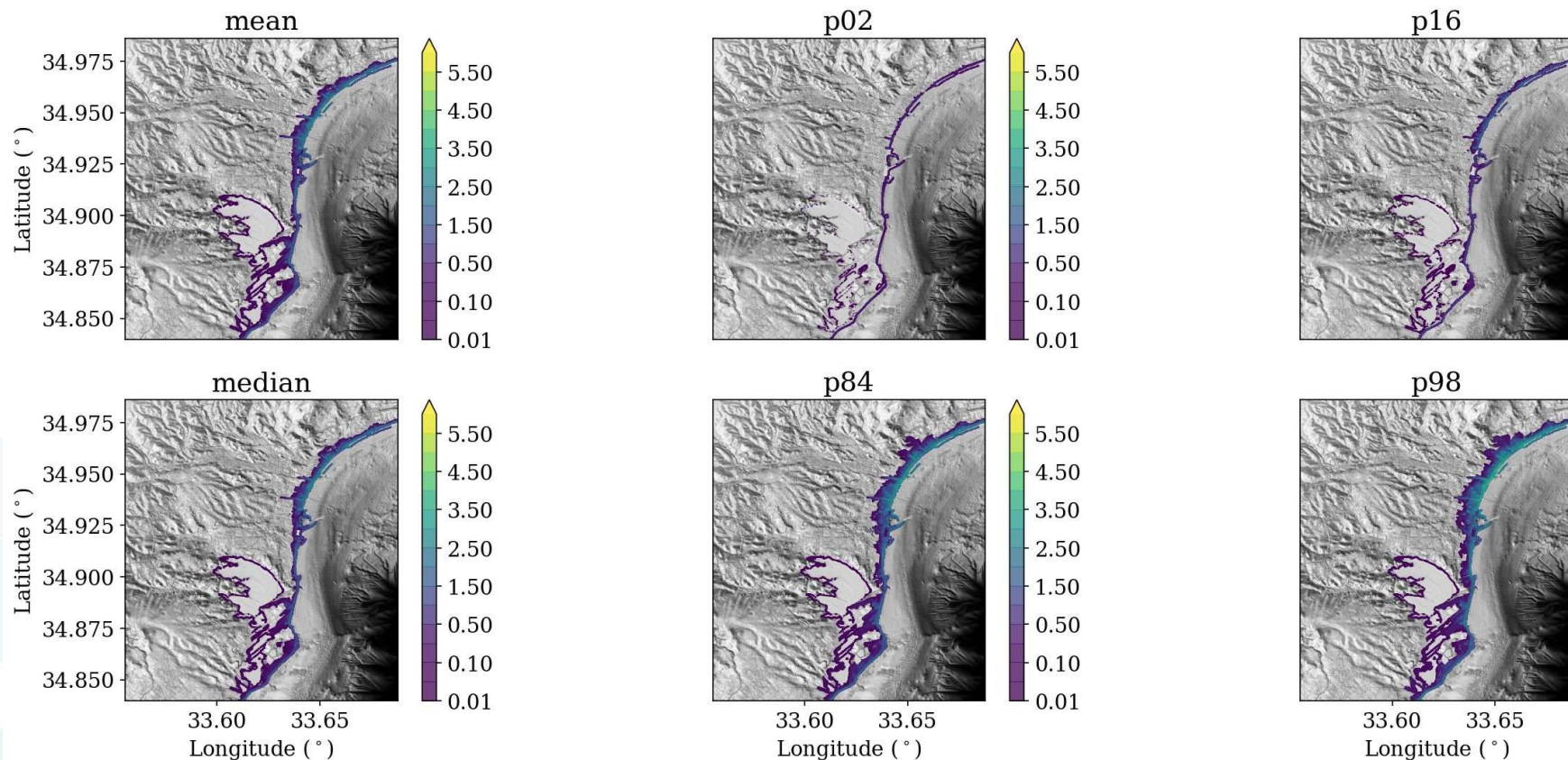
Flow Depth: 500yr ARP

Flowdepth [m]; ARP: 500 years
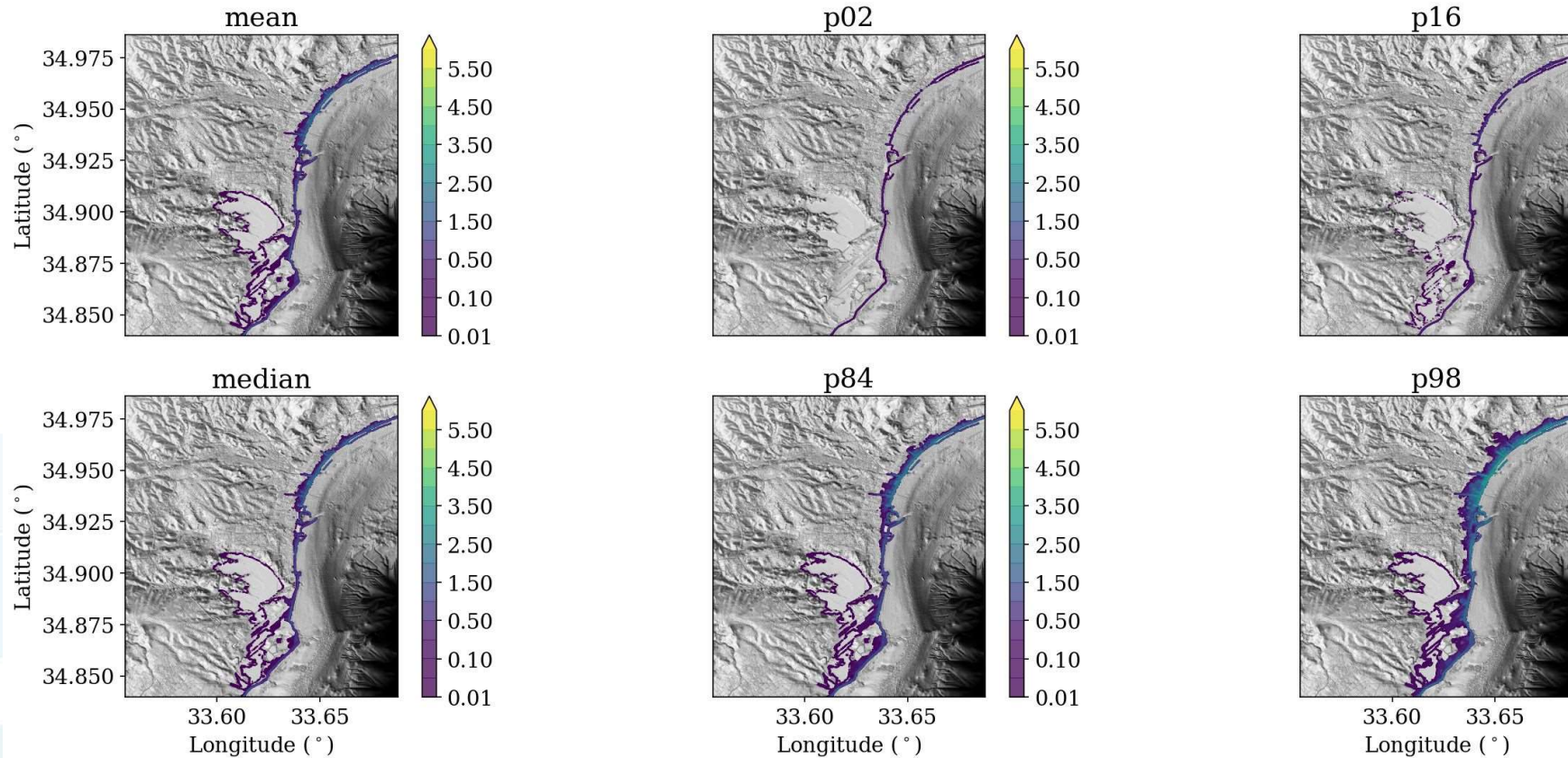
and finally Tsunami Inundation Mapping
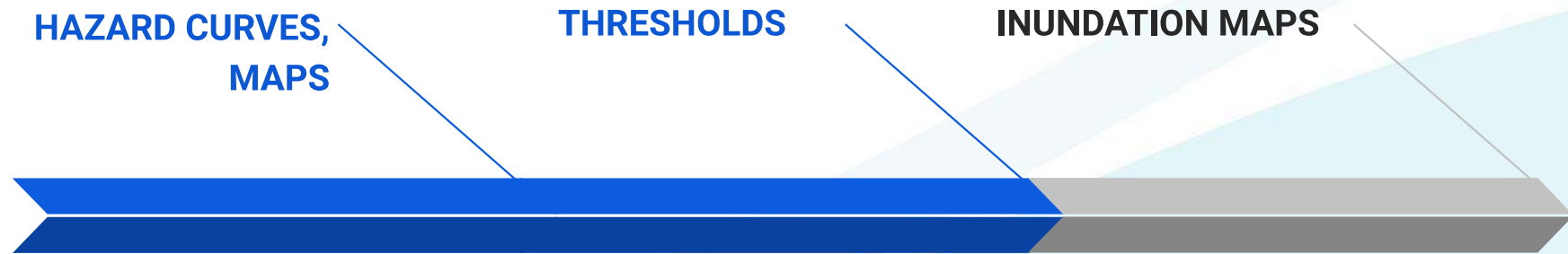
HAZARD CURVES, MAPS

THRESHOLDS

INUNDATION MAPS

- **Model for the Exceedance rate/probability for a given time interval of different values for the hazard intensity, typically the flow depth, or the height with respect to the sea level**
- **Uncertainty of these estimates**

- **Validation of the hazard maps**
- **Selection of the design rate/probability/return period**
- **Selection of the design model uncertainty level**
- **Safety factors**

Here the desired level of risk reduction is implicitly chosen

- **Selection of the design inundation as a result of the previous steps**
- **Validation and refinement of the maps**

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**Inundation as a function of the
and of the Average Return Peri**

Perc.	ARP	Annual probability (%)	50 years probability (%)	Area (km²)	Max Inun. depth (m)	Population Exposed	Crit. Bld. Exposed
P50	500	0.2	10	1.56	2.64	736	9
P50	1000	0.1	5	3.04	3.1	1976	16
P50	2500	0.04	2	4.93	3.8	4946	33
P50	5000	0.02	1	5.77	4.1	6202	34
P50	10000	0.01	0.5	6.22	4.3	7435	35
P84	500	0.2	10	2.57	3	1474	13
P84	1000	0.1	5	4.43	3.6	4198	30
P84	2500	0.04	2	5.82	4.2	6265	34
P84	5000	0.02	1	7.84	4.5	10597	51
P84	10000	0.01	0.5	8.56	4.9	11320	77
P98	500	0.2	10	4.45	3.7	4190	30
P98	1000	0.1	5	5.13	4.1	5360	33
P98	2500	0.04	2	7.49	4.4	9623	46
P98	5000	0.02	1	8.55	4.8	11303	77
P98	10000	0.01	0.5	9.29	5	11502	86

ARP exposed estimates curve

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- **2 cm** arrival times **insi...**
  designated inundation...
  - from inland simulat...
    series with ~**115m**...
    resolution
  - weighted by individ...
    scenarios rates (eve...
    normalized)

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and for Indian Ocean?

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Regional PTHA for Western Indian Ocean
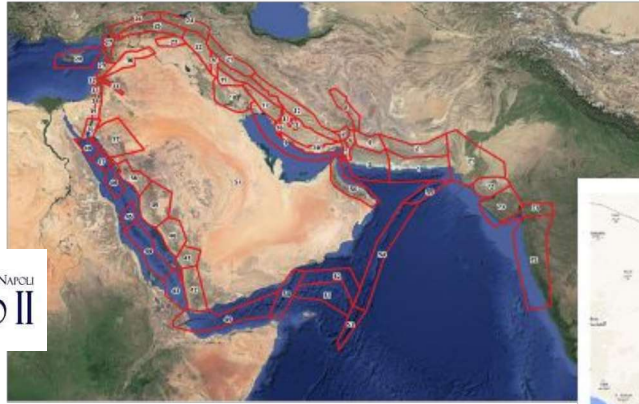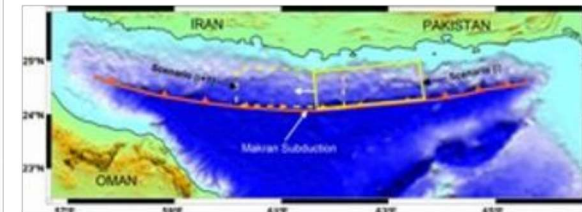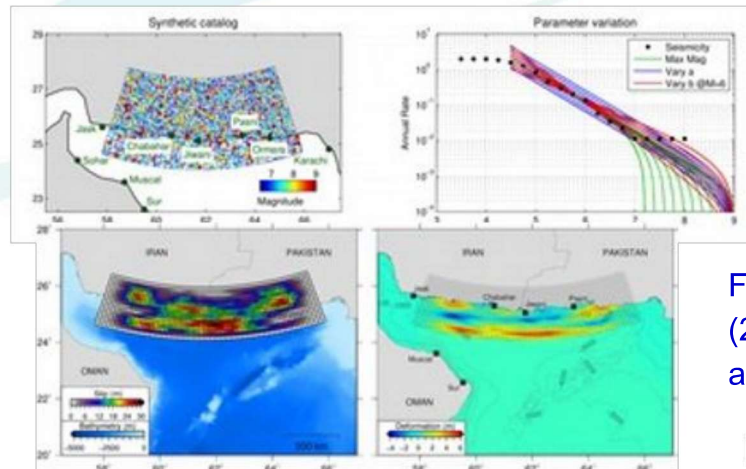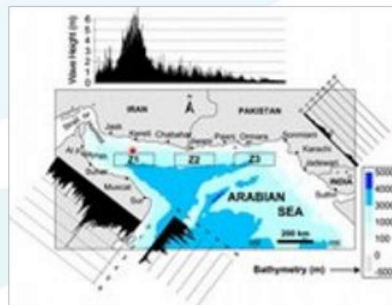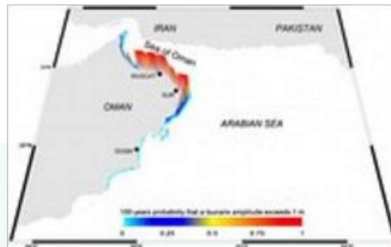
Figures from: Heidarzadeh & Kijko (2011), Nat (2016), NHESS; El-Hussain et al. (2016), Arab al. (2020), Nat Haz, Zafarani et al. (2022), Nat

- *Simulations of Tsunami from earthquakes and landslides with HySEA @ UMA, Mala*

- *Landslide Simulations with BingClaw @ NGI, Oslo, Norway*

- *Probabilistic Tsunami Hazard Analysis @ INGV, Rome, Italy (w/ the support of UMA*

- *Probabilistic Tsunami Hazard Analysis @ NGI, Oslo, Norway (w/ the support of UM*

- *High Performance Computing provided on Leonardo Supercomputer @ CINECA, B*

  (~4.5 M core-h per project)
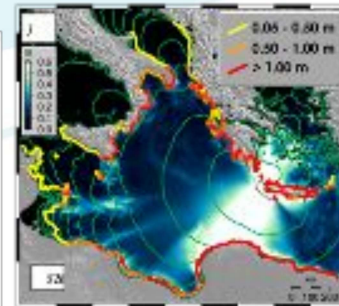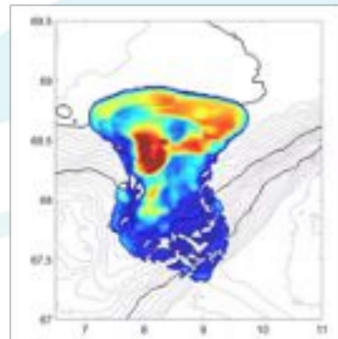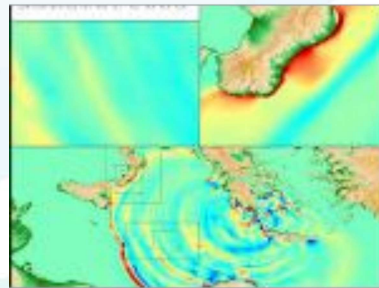
https://www.geo-inquire.eu/transnational-access/general-info

Access costs are covered by the project, which include the nece training at the specific installation for external users, equipmer consumables and the necessary support personnel. Some insta may provide travel and subsistence support to the selected use information will be available during the call.

Geo-INQUIRE prospective calendar of Transnational Access calls

Year 2 (October 2023 – September 2024)   Year 3 (October 2024 – September 2025)   Year 4 (

1st TA Call: Fall 2023   Access period...

Open   Review

Oct 2023 to   Jan 2024 to
Dec 2023   Mar 2024

2nd TA Call: Spring 2024   Access period...

Open   Review

Apr 2024 to   Jul 2024 to
Jun 2024   Sep 2024

3rd TA Call: Fall 2024   Access period...

Open   Review

Oct 2024 to   Jan 2025 to
Dec 2024   Mar 2025

4th TA Call: Spring 2025   A

Open   Review   All
                         fina
Apr 2025 to   Jul 2025 to
Jun 2025   Sep 2025

**CLOSED - EVALUATION
ONGOING**

**foreseen
02 May to 28 June 2024**

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Thank you

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