ChEESE

www.cheese-coe-eu

Center of Excellence for Exascale in Solid Earth

Related Projects II:

ChEESE

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University of Málaga

AGITHAR

Accelerating Global science in Tsunami Hazard and Risk Analysis

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

European Commission

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 823844

What is ChEESE?

Centre of Excellence for Exascale in Solid Earth

Project information

ChEESE

Grant agreement ID: 823844

Status
Ongoing project

Start date
1 November 2018

End date
31 October 2021

Funded under:
H2020-EU.1.4.1.3.

Overall budget:
€ 7 683 241,25

EU contribution
€ 7 683 241,25

Coordinated by:
BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION
Spain

Objectives

ChEESE

01 Establish a ***new Center of Excellence (CoE) in the domain of Solid Earth (SE)*** targeting the preparation of 10 Community flagship European codes for the upcoming pre-Exascale (2020) and Exascale (2022) supercomputers.

02 Address **15 scientific, technical, and socio-economic Exascale Computational Challenges (ECC)** in the domain of Solid Earth.

03 Develop ***12 Pilot Demonstrators and enable services oriented to society*** on critical aspects of geohazards like hazard assessment, urgent computing, and early warning forecast.

04 ***Integrate*** around ***HPC and HDA*** (High-end Data Analysis) transversal European institutions in charge of operational ***geophysical monitoring networks, Tier-0 supercomputing centers, academia, hardware developers, and third-parties from SMEs*** (Small and Medium size Enterprises), ***Industry and public governance bodies*** (civil protection).

Introduction Video

ChEESE Consortium

ChEESE

- 13 partners from 4 EU Members States (Spain, Italy, Germany, France) and 3 Associated Countries (Norway., Switzerland, Iceland)
- 3 Tier-0 supercomputing centers (BSC, CINECA, HLRS)
- 3 institutions in charge of Geophysical monitoring networks in 3 European countries

ChEESE

Project Leader

ARNAU FOLCH
Environmental Simulation Group Manager at Barcelona Supercomputing Center

Coordinator

BSC
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Industry and Users Board

ChEESE

GEO GROUP ON EARTH OBSERVATIONS

GSNL

EPOS EUROPEAN PLATE OBSERVING SYSTEM

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

REPSOL

GW4 Isambard

GOBIERNO DE ESPAÑA
MINISTERIO DE FOMENTO
INSTITUTO GEOGRÁFICO NACIONAL

Schlumberger

IASPEI
International Association of Seismology and Physics of the Earth's Interior

RÍKISLÖGREGLUSTJÓRINN
ALMANNAVARNADEILD

IAVCEI
International Association of Volcanology and Chemistry of the Earth's Interior

MITIGA SOLUTIONS

10 Flagship Codes

</> FLAGSHIP CODES

Code name	Area	Application
ExaHyPE	Computational Seismology	Earthquake simulations in highly heterogeneous media
Salvus	Computational Seismology	Wave propagation through complex unstructured domains, seismic tomography, medical ultrasound tomography
SeisSol	Computational Seismology	Earthquake simulations in various settings including induced earthquakes
SPECFEM3D	Computational Seismology	Earthquake simulations in various settings, imaging of complex geological objects
PARODY_PDAF	Magnetohydrodynamics	Geodynamo simulations and ensemble assimilation experiments
XSHELLS	Magnetohydrodynamics	Geodynamo simulations, liquid metal planetary core simulations
ASHEE	Physical Volcanology	Volcanic plume and PDC simulator
FALL3D	Physical Volcanology	Forecast of volcanic ash clouds, volcanic ash fallout and volcanic ash resuspension, tephra dispersal and fallout hazard assessment
T-HySEA	Tsunamis	Faster-than-real-time (FTRT) simulations for Tsunami Early Warning Systems (TEWS), Probabilistic Tsunami Hazard Assessment (PTHA), tsunami inundation maps
L-HySEA	Tsunamis	Subaerial and submarine granular landslides, landslide generated tsunamis

15 Exascale Computational Challenges (ECC)

In Computational Seismology

- Full-waveform inversion (FWI)
- High-resolution subsurface imaging
- Near real-time seismic scenarios
- Physics-based Probabilistic Seismic Hazard Analysis (PSHA)

In Magnetohydrodynamics (MHD)

- The dynamo model
- Earth's magnetic field evolution

In Physical Volcanology

- Volcanic plumes and Pyroclastic Density Currents (PDCs)
- High-resolution volcanic ash dispersal
- Subsurface thermo-fluid dynamics of magmas
- Probabilistic Volcanic Hazard Analysis (PVHA)

In Tsunami Modelling

- Faster Than Real Time (FTRT) tsunami computations
- Near real-time tsunami source inversion
- Probabilistic Tsunami Forecast (PTF) for early warning and rapid post-event assessment
- Probabilistic Tsunami Hazard Analysis (PTHA)

In Observational Seismology

- Automated array-based statistical detection and restoration of seismic slow-earthquakes

12 Pilot Demonstrators (PD)

PILOTS

Pilot Demonstrator name	Flagship Code	Initial TRL	Target TRL
Urgent seismic simulations	ExaHyPE, Salvus, SPECFEM3D	3	5-6
Faster than real-time tsunami simulations	T-HySEA, L-HySEA	2	6-7
High-resolution volcanic plume simulation	ASHEE, FALL3D	1	4
Physics-based tsunami-earthquake interaction	SeisSol, ExaHyPE	2	4
Physics-based probabilistic seismic hazard assessment (PSHA)	SeisSol, ExaHyPE, AWP-ODC(*)	4	6-7
Probabilistic volcanic hazard assessment (PVHA)	FALL3D	3	6-7
Probabilistic tsunami hazard assessment (PTHA)	T-HySEA L-HySEA	3	5-7
Probabilistic Tsunami Forecast (PTF) for early warning and rapid post event assessment	T-HySEA	3	6-8
Seismic tomography	SPECFEM3D, Salvus	4	6
Array-based statistical source detection and restoration and Machine learning from earthquake/ volcano monitoring	BackTrackBB (**)	2	4
Geomagnetic forecasts	PARODY_PDAF, XSHELLS	2	4
High-resolution volcanic ash dispersal forecast	FALL3D	3	6-7

Workplan

The objectives of the Project will be achieved through activities organized in six workpackages:

WP1 Management

This workpackage deals with the administrative and financial management of the project, including the monitoring and assessment of the quality of the project outcomes.

WP2 HPC Software Engineering

This workpackage will develop the so-called building blocks for the project, identify and solve the bottlenecks that partly or completely affect the performances of the 10 Flagship codes towards pre-Exascale and Exascale and task on co-design, understood as a set of tools and techniques for software and Exascale hardware prototype testing.

WP3 HPC Modelling Workflows and Tools

The aim of this workpackage is to address challenges encountered by applications in attaining Exascale levels which go beyond the immediate scalability issues, maintain load balances in simulations which adapt dynamically and demonstrate the suitability and performance of selected codes on the largest scales, by running real scientific workloads on the latest available large scale systems including the expected Exascale systems.

Workplan

The objectives of the Project will be achieved through activities organized in six workpackages:

WP4 Exascale Pilot Demonstrators

The objectives of this workpackage are to provide geophysical simulations with a potential usefulness for management of geological resources, civil protection or insurance, among others. Reduce the gap between HPC algorithms capabilities and end-users needs (response time, throughput, etc.), provide an easy access to HPC codes for SE Applications and build PD as an end-to-end solution that can be easily compared to the state of the art in the fields of hazard assessment, civil protection or fundamental R&D.

WP5 Service Validation and Enabling

The aim of this workpackage is to coordinate the effort to make the Pilot Demonstrators available as Pilot Services to a broader user community by improving their TRL above 5 and involve the geophysical community (in coordination and synergy with other pan-European initiatives) and the non-scientific stakeholders (industrial partners, observatories, civil protection authorities, in particular those involved in the project), in the proper definition of the Validation process in the context of geophysical applications, especially focusing on hazard and risk assessment goals. It also aims to validate and implement some of the Pilot Services (those achieving TRL 7-8), by integrating the workflows in the HPC ecosystem and evaluate the resources to enable their operational deployment.

WP6 Dissemination, Training and Outreach

This workpackage will take care of all dissemination and training activities. It is concerned with the dissemination of the knowledge and results of the project.

Results related to Tsunamis

Exascale Pilot Demonstrators (PDs) are “small-scale” proofs of concept aimed at testing codes on Exascale hardware prototypes.

PD2 Faster tan Real-Time Tsunami Simulations
Increase the size of the problems by increasing spatial resolution and/ or producing longer simulations while still computing FTRT for TEWS including inundation for a particular target coastal zone.

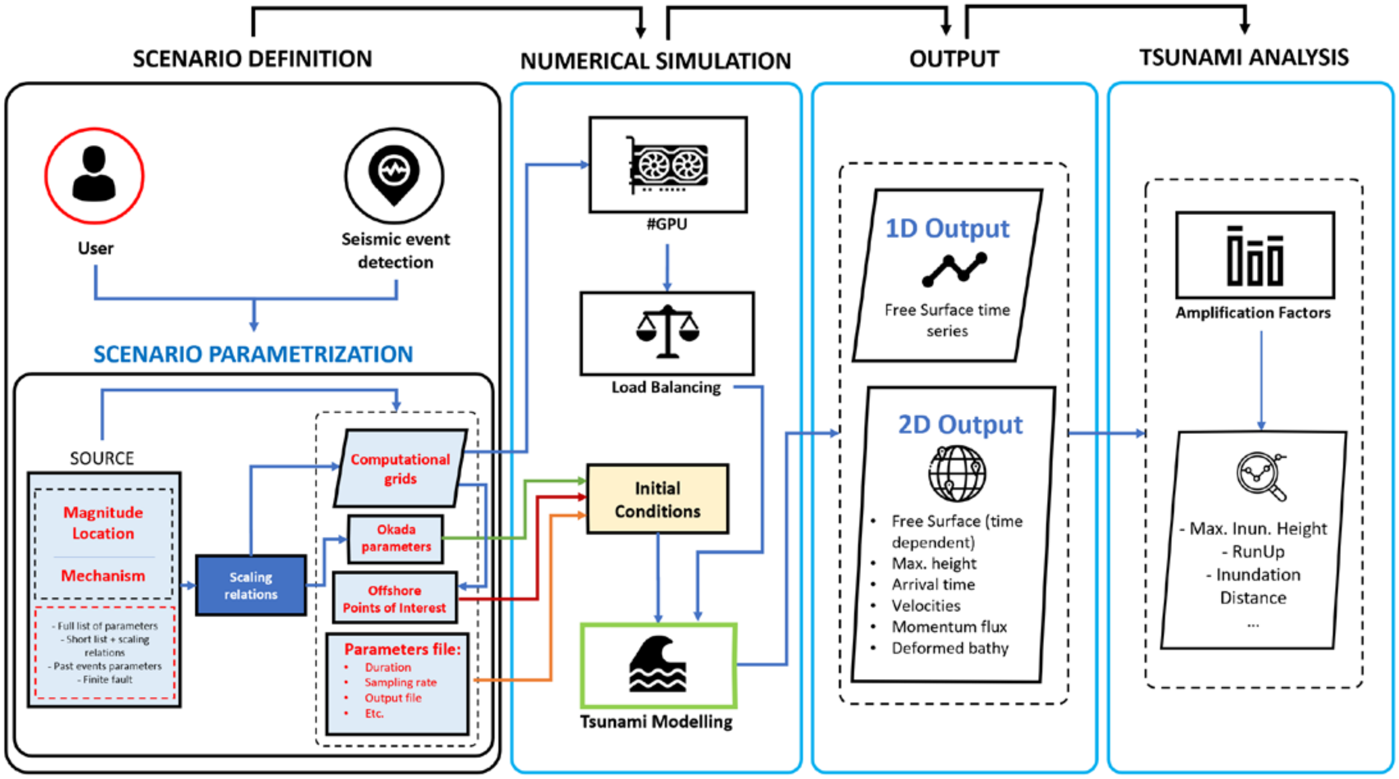
PD7 Probabilistic Tsunami Hazard Assessment (PTHA)
Enable fast computation of tsunami-genesis covering a high amount of uncertain input parameters for uncertainty quantification of tsunami-genesis and impact, which is not possible with present models and HPC capabilities.

PD8 Probabilistic Tsunami Forecast (PTF) for Early Warning and Rapid Post Event Assessment
Build of a big database of tsunami waveforms resulting from elementary sources covering a specific basin (e.g. Chile, Japan, or Mediterranean sea) to develop a fast probabilistic tsunami forecast at coastal locations through the combination of the pre-computed elementary sources (i.e. the tsunami impact PDF with different metrics).

UNIVERSITAS MALACITANA INGV NGI

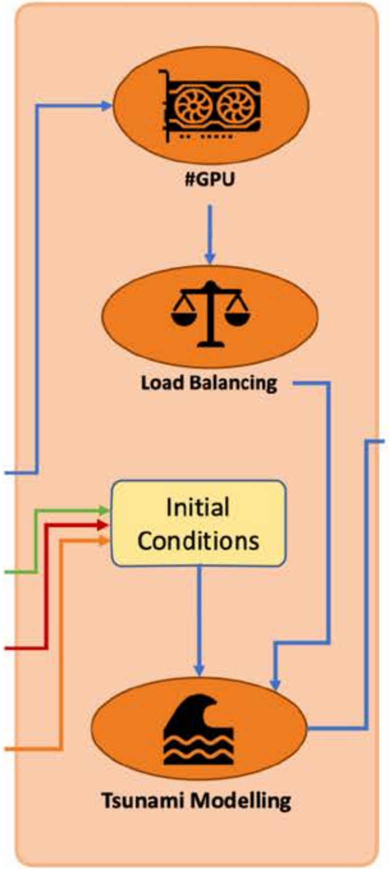
Results related to Tsunamis

PD2 FTRT WORKFLOW



Phase 2. Hazard assessment – computational component

NUMERICAL SIMULATION



The requirements

- Whole Mediterranean
- Spatial resolution: 30 arc sec
- Size of the problem: 10 M cells
  5,221 x 1,921 = 10.029.541
- Simulation time: 8 hours
- Time series – 15 s

The output

- Time series at 17,000 virtual buoys
- Maximal amplitude in the whole domain

Code improvements

2014

# GPUs	Computing Times	Speed-up
1	2141.11	1.00
2	1139.48	1.88
4	601.28	3.56
8	378.07	5.66
10	351.97	6.08

2017

# GPUs	Computing Times	Speed-up
1	1764.0	1.00
2	908.6	1.94
4	507.8	3.47
8	312.1	5.65
12	259	6.81

NVIDIA Titan Black
Atlantico cluster (EDANYA)
Kepler (2012)

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NVIDIA Titan Black
Atlantico cluster (EDANYA)
Kepler (2012)

NVIDIA Tesla P100
Atlantico cluster (EDANYA)
Pascal (2016)

2 NVIDIA Tesla P100 – 257 sec!!!

NVIDIA Tesla V100
BSC CTE-POWER
Volta, 2018

1 NVIDIA Tesla V100 – 284 sec!!!

More recent computing times

2019 – Before Audit

# GPUs	Computing Times	Speed-up
1	284.14	1.00
4	97.20	2.92
8	66.54	4.27
16	50.09	5.67
32	38.24	7.43

2019 – After Audit

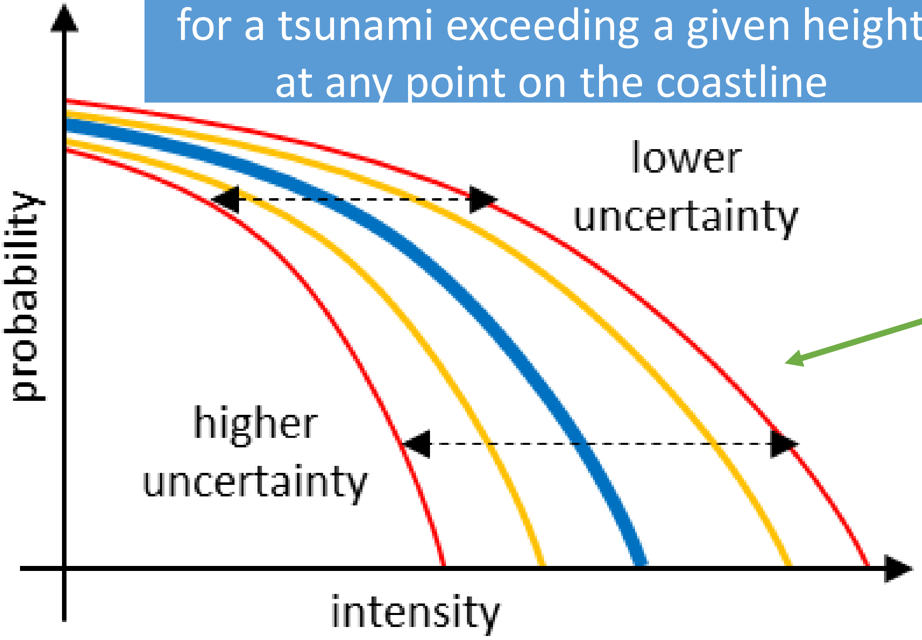
# GPUs	Computing Times	Speed-up
1	286.51	1.00
4	83.35	3.44
8	48.62	5.89
16	31.49	9.10
32	23.24	12.33

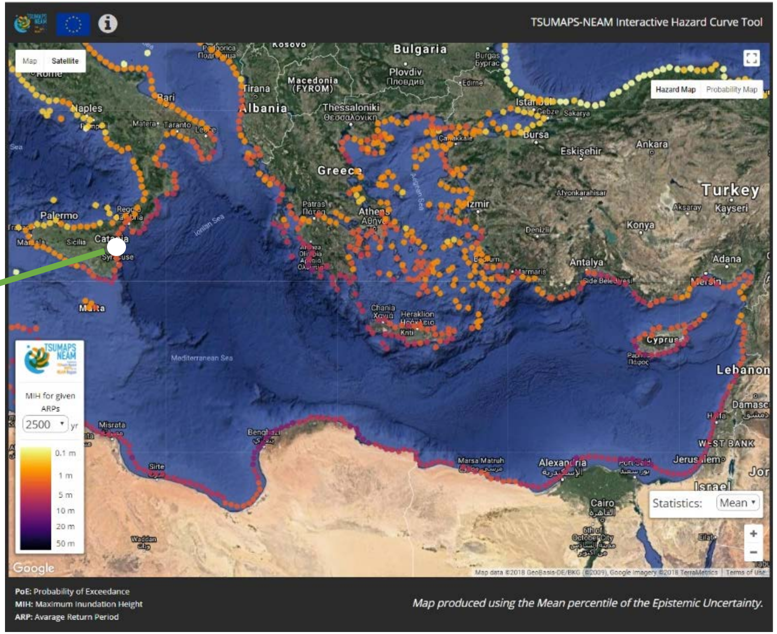
NVIDIA Tesla V100
BSC CTE-POWER
Volta, 2018

What is the Probabilistic Tsunami Hazard Assessment telling us

PD7

PTHA gives: Probability and uncertainty for a tsunami exceeding a given height at any point on the coastline





Probabilistic Tsunami Hazard Assessment (PTHA)

Main steps in earthquake-PTHA:

Discretise sources

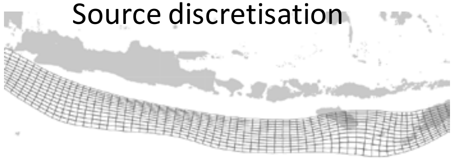
Perform regionalisation and define annual source probabilities

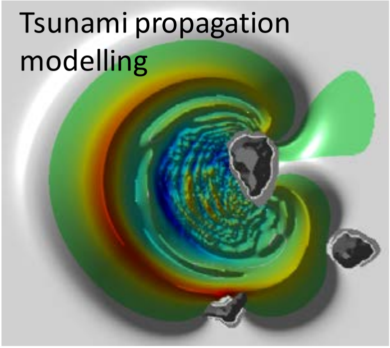
Create synthetic earthquake scenarios

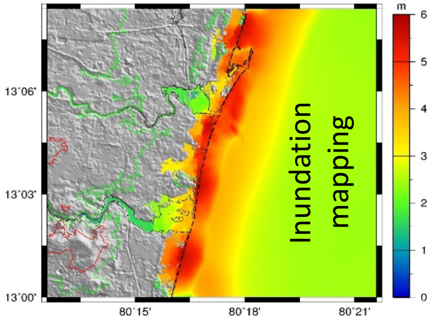
Define points or area of interest

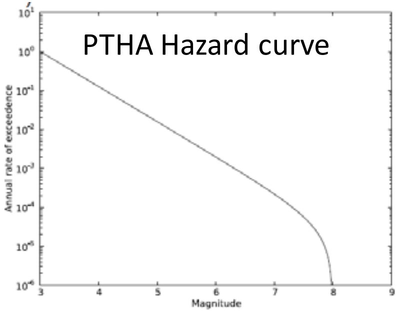
Simulate the wave propagation and inundation for each source on HPC resource

For each scenario at each point, associate tsunami heights with event probability









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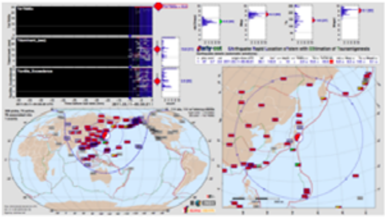
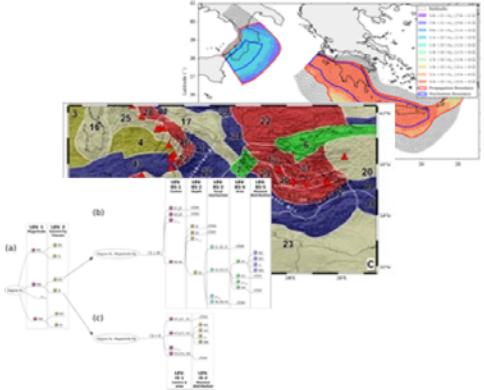
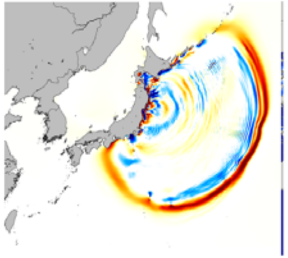
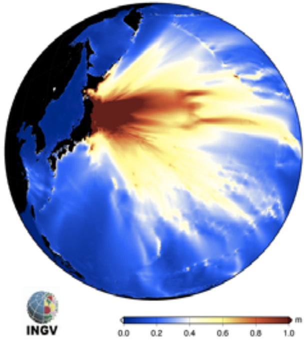
PD7

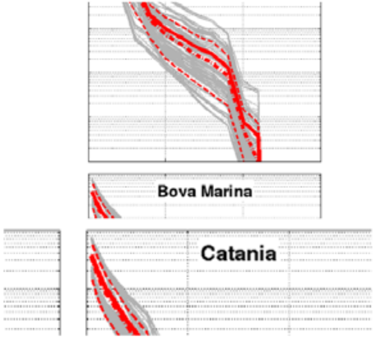
PD8

Main steps in PTF

- **Real-time seismic parameters** (location,magnitude) with their uncertainty
- **Seismic parameters** not available in real time (focal mechanism), **from past seismicity and tectonic knowledge** (**LONG-TERM PROBABILITIES**, from PD7)
- **Tsunami numerical simulations** (from PD2)
- **Ensemble uncertainty modeling**, by perturbing initial conditions of numerical simulations and combining probabilities





Selva et al., GJI, 2016

ChEESE Impact

1

New codes and software for the next wave of exascale computers

2

A more competitive Europe in terms of science and industry

3

Better models to prevent damage and losses from geohazards

AGITHAR

More info in

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www.linkedin.com/ company/ cheese-coe

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