DT-GEO: towards a digital twin for geophysical extremes

Arnau Folch(1), Ramon Carbonell(1), Antonio Costa(2), Beata OrleckaSikora(3), Piero Lanucara(4), Rosa M.Badia(5), Finn Lovholt(6), Jorge Macías(7), Sasha Brune(8), Alice Gabriel(9), Sara Barsotti(10), Jorn Behrens(11), Jorge Gomes(12), Jean Schmittbuhl(13), Carmela Freda(14), Joana Kocot(15), Domenico Giardini(16), Michael Afanasiev(17), Helen Glaves(18)

(1) Geociencias Barcelona (GEO3BCN-CSIC), Spain
(2) Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy
(3) Institute Geophysics - Polish Academy of Science, Poland
(4) CINECA Consorzio Interuniversitario, Italy
(5) Barcelona Supercomputing Center (BSC-CNS), Spain
(6) Stiftelsen Norges Geotekniske Institutt (NGI), Norway
(7)Universidad de Málaga (UMA), Spain
(8)German Research Centre for Geosciences (GFZ), Germany
(9) Ludwing-Maximilians Universitaet (LMU), Germany
(10) Icelandic Meteorological Office (IMO), Iceland
(11) Universität Hamburg, Germany
(12) Laboratorio Fisica Experimental de Partículas (LIP), Portugal
(13) Centre National de la Recherche Scientifique (CNRS), France
(14) European Plate Observing System (EPOS), Italy
(15) Akademia Gorniczo-Hutnicza (CYFRONET), Poland
(16) Federal Institute of Technology (ETH), Switzerland
(17) Mondaic AG, Switzerland
(18) U.K. Research and Innovation (UKRI), U.K.

DT-GEO

Project funded by Horizon Europe under the grant agreement No 101058129.

Contents

A Digital Twin for GEOphysical extremes

How it started?

June 2021

HORIZON-INFRA-2021-TECH-01-01	Interdisciplinary **digital twins** for modelling and simulating complex phenomena at the **service** of **research infrastructure** communities
Expected outcomes	• Availability of **pre-operational** prototypes of interdisciplinary digital twins • Integration and collaboration across different scientific domains and research infrastructures • Exploit data available through the Common European Data Spaces and the European Open Science Cloud (EOSC).

The GEO.8 – European Alliance for Earth Sciences

A consortium of 8 European Earth Science Institutions (founded in 2012) aiming at the use of joint infrastructures, the bundling of interests, and the promotion of joint project concepts

Geo.8 was the steering DT-GEO proposal group

September 2021

Proposal submitted

HORIZON-INFRA-2021-TECH-01-01

4 Digital Twins projects funded

Today...

1

Biodiversity Digital Twin for Advanced Modelling, Simulation and Prediction Capabilities (BioDT)

Digital Twin providing advanced modelling, simulation and prediction capabilities across relevant research infrastructures, the BioDT project will be able to more accurately model interaction between species and their environment.

2

A Digital Twin for GEOphysical extremes (DT-GEO)

Deploy 12 Digital Twin Components (DTCs) embedding flagship simulation codes, AI layers, large volumes of (real-time) data streams, data assimilation methodologies, and overarching workflows for deployment and execution in centralised HPC and virtual cloud computing RIs. Lead by CSIC.

3

An interdisciplinary Digital Twin Engine for science (interTwin)

Prototype of an interdisciplinary Digital Twin Engine (DTE), an open source platform that provides generic and tailored software components for modelling and simulation to integrate application-specific Digital Twins (DTs). Use cases for high-energy physics, radio astronomy, astrophysics, climate research, and environmental monitoring. Lead by EGI, the Consortium shares 4 partners with DT-GEO (CSIC, CNRS, LIP, UPV)

DestinE

4

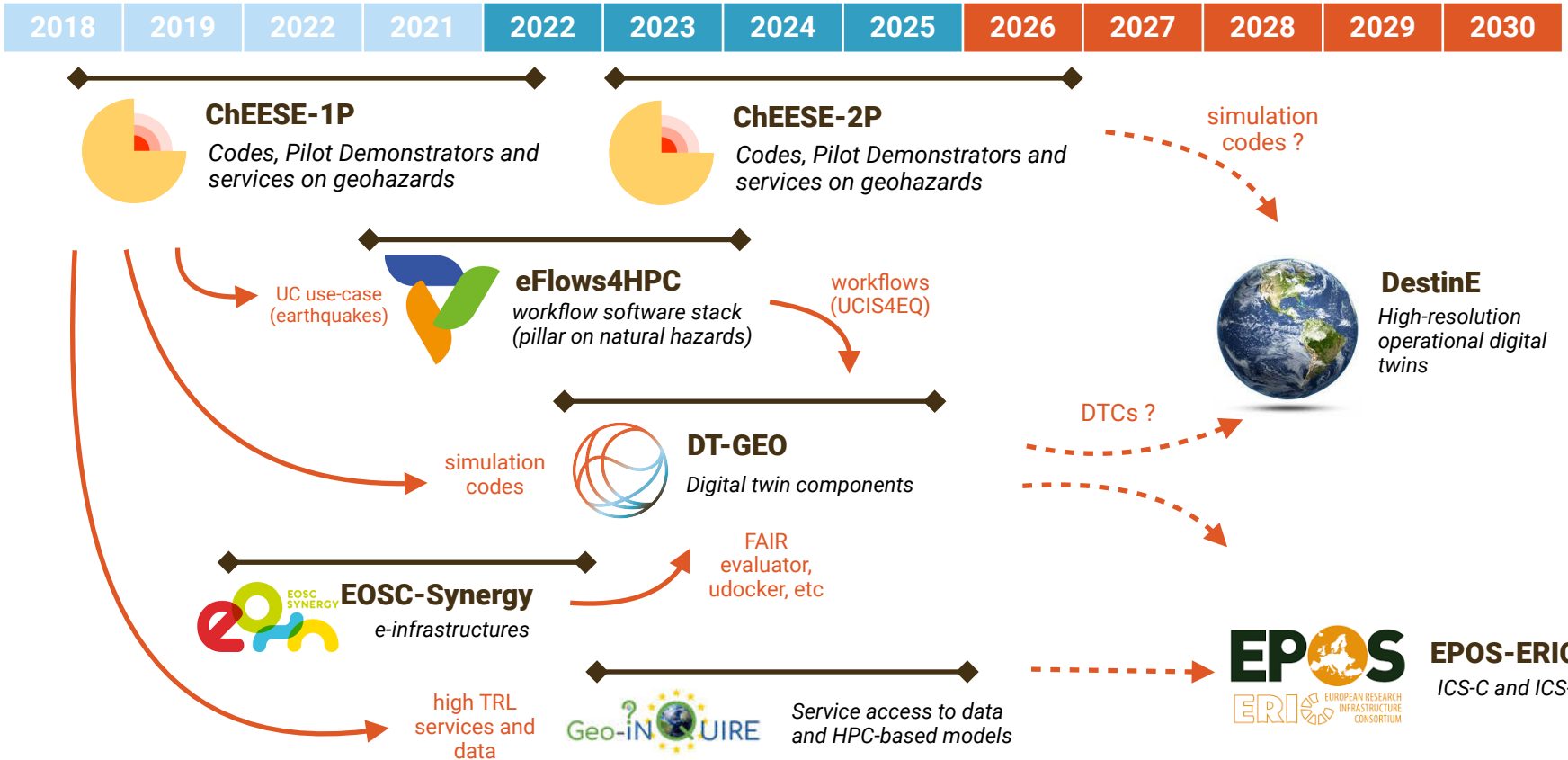
eBRAIN-Health - Actionable Multilevel Health Data (eBRAIN-Health)

Deliver a distributed research platform for modelling and simulating complex neurobiological phenomena of human brain function and dysfunction in a data protection compliant environment.

Human brain

A Digital Twin for GEOphysical extremes

DT-GEO ecosystem: background and destination



A Digital Twin for GEOphysical extremes

Towards Destination Earth?

Destination Earth

Phase 1 (Sep 2022-May 2024)			Phase 2?		Phase 3?			
2022	2023	2024	2025	2026	2027	2028	2029	2030

CATS	Climate Adaption digital TwinS (lead by CSC)
DEODE	Destination Earth On-Demand Extremes (lead by Meto France)

Extend to new applications
Integrate components

ECMWF	Digital Twins, fusion of real-time observations and high-resolution predictive modelling
ESA	Core Service Platform, a user-friendly entry point for DestinE users
EUMETSAT	Data lake; access to the data needed for the Digital Twins and the Core Service Platform operations

Addition of other DTs and (dowstream) services

HPC (and cloud?)

HORIZON-INFRA-2021-TECH-01-01	**DT-GEO**:	Geophysical extremes (lead by CSIC)
	BioDT:	Biodiversity (lead CSC)
	InterTwin:	Interdisciplinary engine (lead by EGI)
H2020-EU.3.2. - SOCIETAL CHALLENGES	**ILIAD**:	Ocean (leal by NETCOMPANY)

A Digital Twin for GEOphysical extremes

Project Information

Type of Action	Horizon-RIA
Call	HORIZON-INFRA-2021-TECH-01 (Next generation of scientific instrumentation, tools and methods)
Topic	HORIZON-INFRA-2021-TECH-01-01 (Interdisciplinary digital twins for modelling and simulating complex phenomena at the service of research infrastructure communities)
Grant Agreement No	101058129
Start Date	1 Sep 2022
End Date	31 Aug 2025
Budget (EU part)	11,138,287€
Budget (total)	15,110,537€ (includes co-funding from Switzerland and U.K.)
Person Months (PMs)	1712 in total (1399 from EU funds)
Partners	26

A Digital Twin for GEOphysical extremes

Consortium Composition

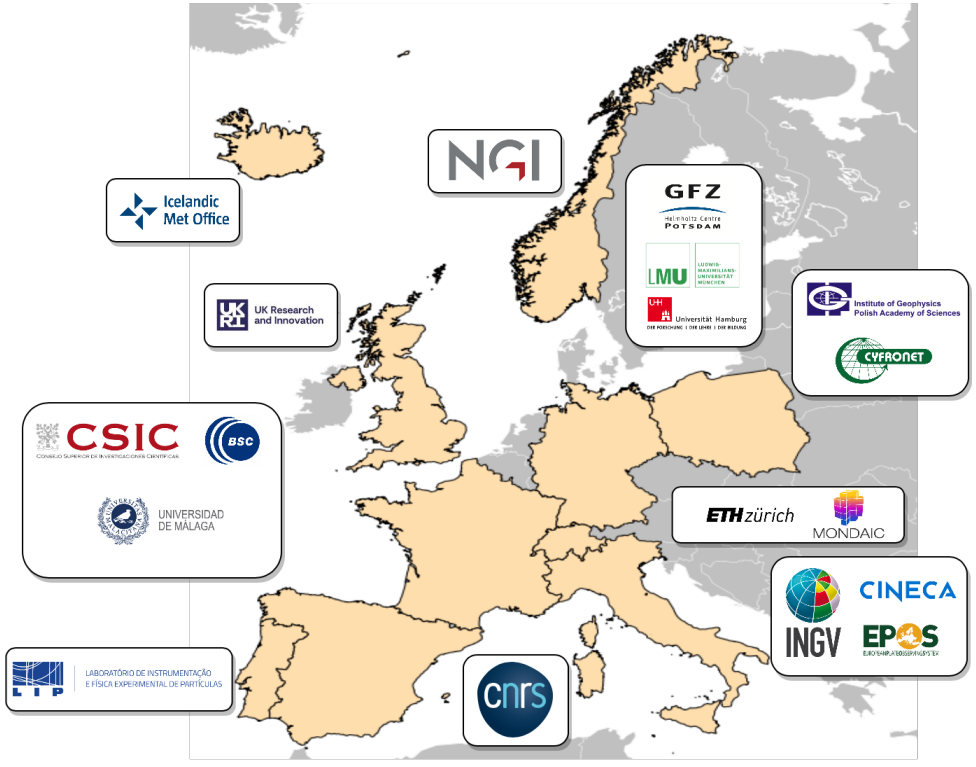
26 **Participating Organisations**
From 10 different countries

15 **Beneficiary Partners**
CSIC, INGV, IGF, CIN, BSC, NGI, UMA, GFZ, LMU, IMO, UHAM, LIP, CNRS, EPOS, ACK

8 **Affiliated Entities**
UPV (affiliated to CSIC)
UNISTRA, UGA, IRD, OCA, UCA, IPGP, UP (all affiliated to CNRS)

3 **Associated Partners**
2 from Switzerland (ETH and MON)
1 from U.K. (UKRI)

Country count	BEN	TOTAL
	1	8
	3	3
	1	1
	3	3
	1	1
	2	2
	1	1
	3	4
	0	2
	0	1
	15	26



A Digital Twin for GEOphysical extremes

kick-off (Barcelona)

On 19-20 September 2022, the Digital Twin for GEOphysical Extremes (DT-GEO) – kicked off in Barcelona, bringing together more than 100 collaborators and scientific researchers both in person and online

A Digital Twin for GEOphysical extremes

4 General (high-level) Objectives

01 Deploy a pre-operational prototype of **Digital Twin** (DT) on geophysical extremes for its future integration in the Destination Earth initiative.

02 Implement 12 self-contained **Digital Twin Components** (DTCs) addressing specific hazardous phenomena from volcanoes, tsunamis, earthquakes, and anthropogenically-induced extremes to conduct precise **data-informed** early warning systems, forecasts, and hazard assessments across multiple time scales.

03 Provide a flexible framework for EOSC-enabling and FAIR-validation of project assets and outcomes and its integration in the European Plate Observing System (**EPOS**) and HPC (**EuroHPC/FENIX**) and (virtual) cloud computing Research Infrastructures (RIs).

04 Verify DTCs in operational environments at 13 **Site Demonstrators** (SDs) of particular relevance located in Europe and beyond.

A Digital Twin for GEOphysical extremes

Research Infrastructures and Communities

EuroHPC JU

Develop, deploy, extend and maintain a world-leading federated, secure and hyper-connected supercomputing and data infrastructure ecosystem

EPOS-ERIC

14 countries gathering hundreds of individual research infrastructures in Solid Earth science providing integrated data, data products, and facilities for researchers

FENIX RI

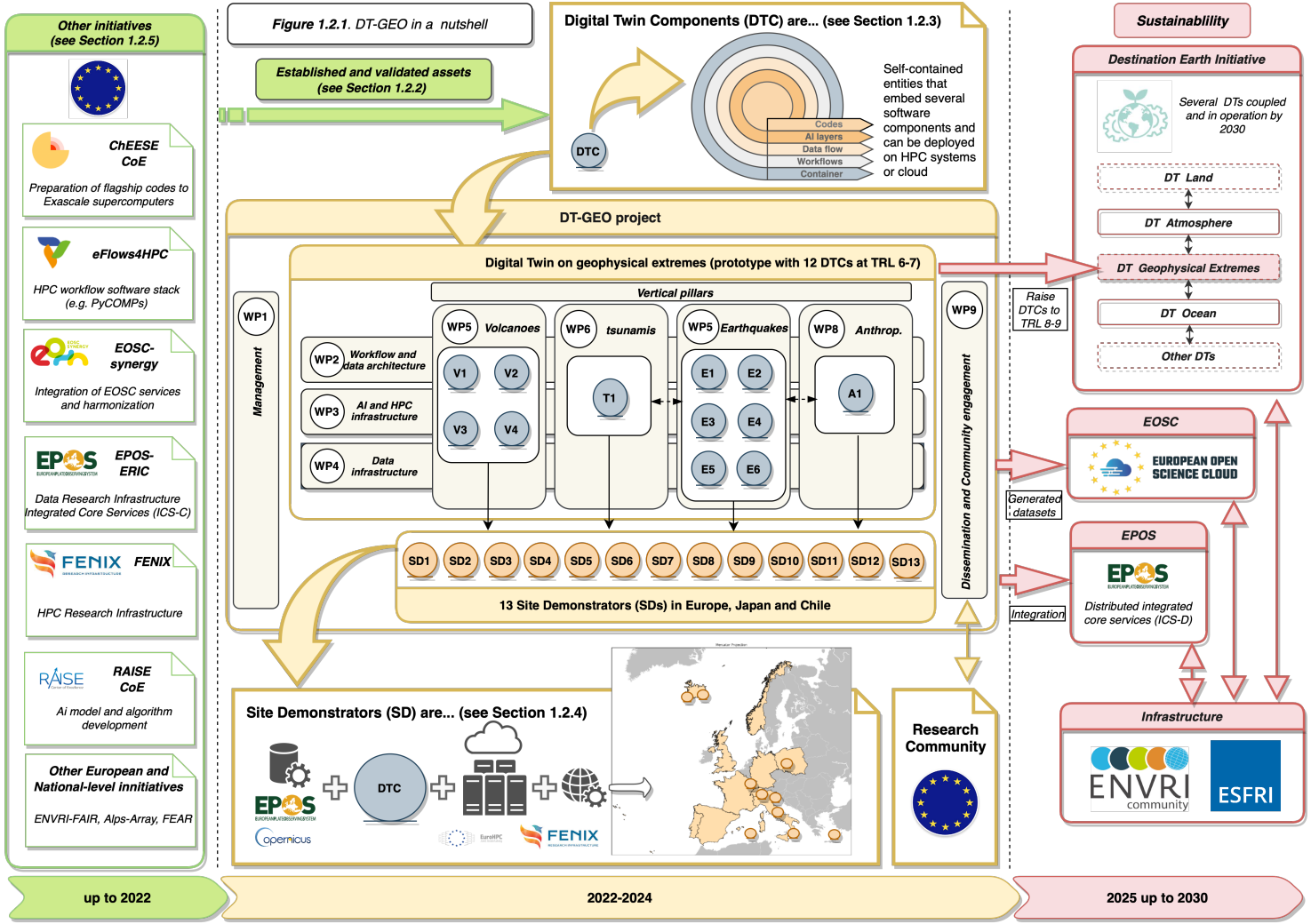
e-infrastructure gathering 6 supercomputing centers and providing federated access to scalable compute resources and data infrastructure

EOSC

Federated and open multi-disciplinary environment for seamless access, FAIR management, and reliable reuse of digital objects along the research life cycle

A Digital Twin for GEOphysical extremes

The project in a nutshell



A Digital Twin for GEOphysical extremes

Software stack

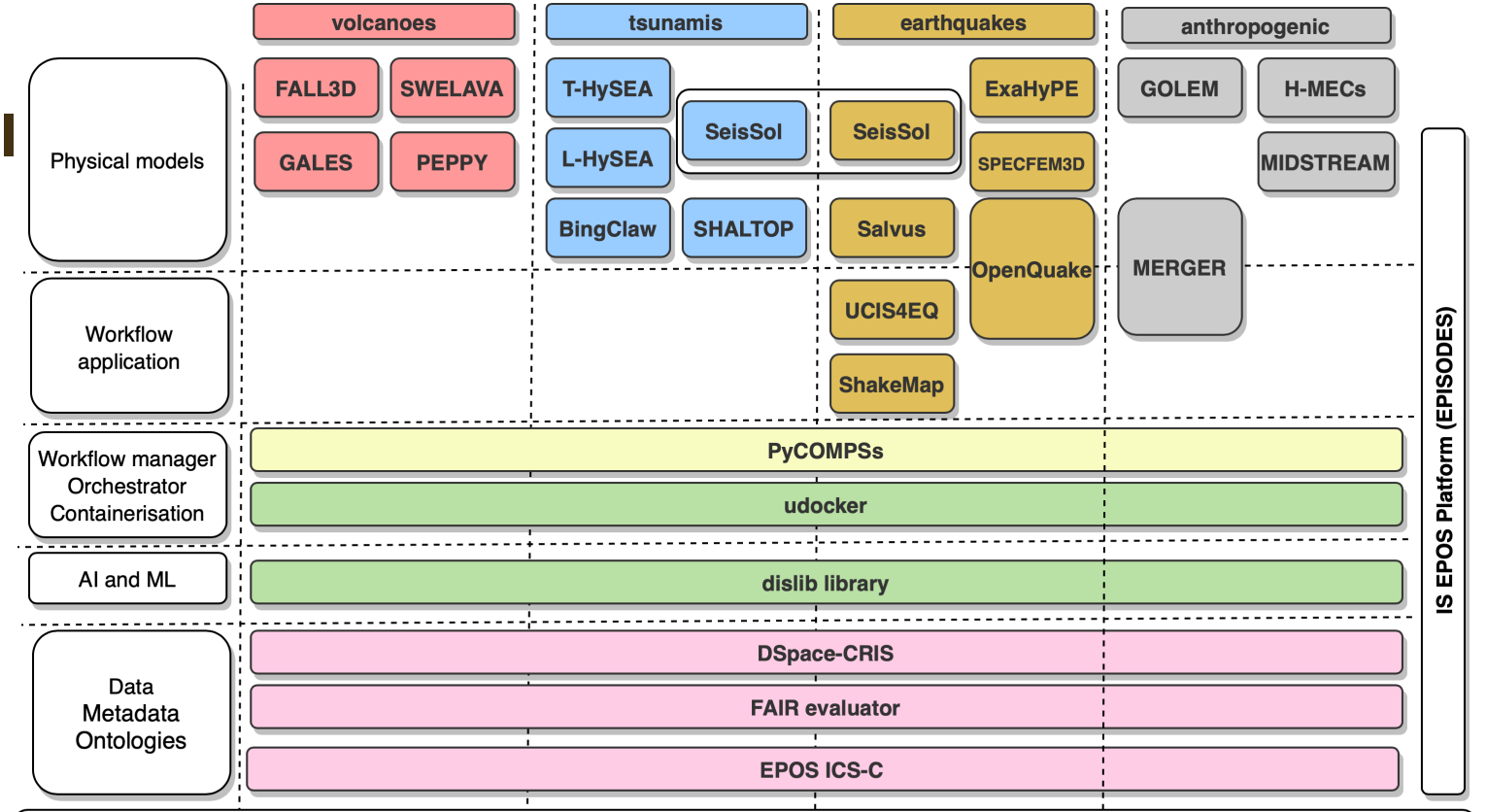


Figure 1.2.2. DT-GEO baseline software stack ordered by categories (white boxes). The following colour code is used for the WPs (see Sec. 3.1.1)

WP2 WP3 WP4 WP5 WP6 WP7 WP8

A Digital Twin for GEOphysical extremes

3 transversal pillars

Pillar 1: Workflows and data architecture

What?

- Design and develop the **architecture of DTC workflows** and data aspects
- Enable the deployment and **execution of workflows** in HPC systems, virtual cloud environments, and federated RI composed of both types of resources
- Make the architecture of the workflows more extendable, easy to deploy and maintainable through a modular approach

How?

- Workflow development (HPCWaaS)
  - TOSCA workflow for high-level topology + computational workflow as a simple python script (PyCOMPSs)
- Workflow deployment
  - Workflows' components deployed as HPC-ready containers
  - Workflows registered as services ready to use
- Workflow execution
  - End user starts execution of the workflow as a service. PyCOMPSs runtime orchestrates workflow execution in the HPC system

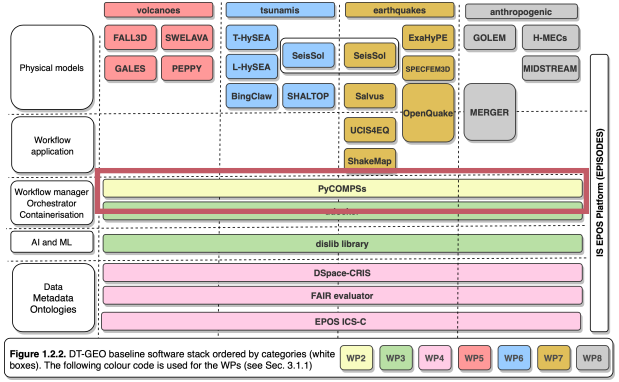


Figure 1.2.2. DT-GEO baseline software stack ordered by categories (white boxes). The following colour code is used for the WPs (see Sec. 3.1.1)

A Digital Twin for GEOphysical extremes

3 transversal pillars

Pillar2: Computational infrastructure and AI

What?

- Provide access to the DT-GEO HPC/cloud infrastructure including **support to containerisation and execution** on the EuroHPC Research Infrastructure (RI) of DTCs and SDs.
- Manage the **on-demand execution** of DT-GEO workflows including technical user-support and direct engagement with the 4 vertical pillars

How?

- FENIX quota credits via FENIX User Management System (FURMS)
- Resources will be extended to MARCONI 100 (M100) and GALILEO 100 (G100) for interactive and massively scalable GPU-enabled workflows
- Adapt the DT-GEO infrastructure to run on external Elastic Cloud Computing Clusters
- Use udocker and dislib
- Integration of DT-GEO software tools and FENIX middleware components (e.g. job submission, services configuration, workflow orchestration e.g. at client side, configuration of specific data management tools, etc.)

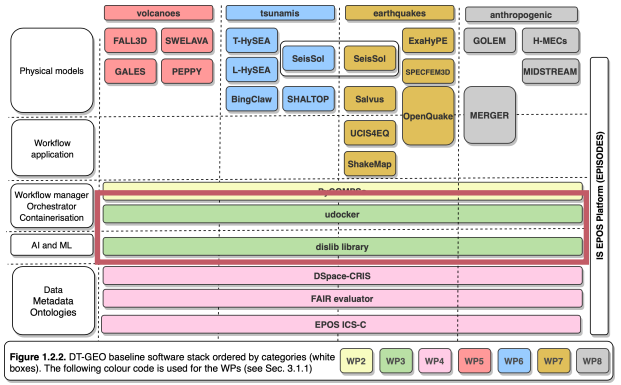


Figure 1.2.2. DT-GEO baseline software stack ordered by categories (white boxes). The following colour code is used for the WPs (see Sec. 3.1.1)

A Digital Twin for GEOphysical extremes

3 transversal pillars

Pillar3: EOSC-enabled data management plan and exploitation

What?

- Provide a flexible environment to check the quality of the generated asset repositories and integration of data/software quality management in EOSC through an **automatic FAIR validation**.
- Develop a holistic approach to **quality in services** and software from the point of view of deployment of DTCs.

How?

- Ensure quality of the digital assets extending the EOSC-synergy project results on SQAaaS using CI/CD pipelines
- FAIR validation (DSpace-CRIS data model and FAIR validator)

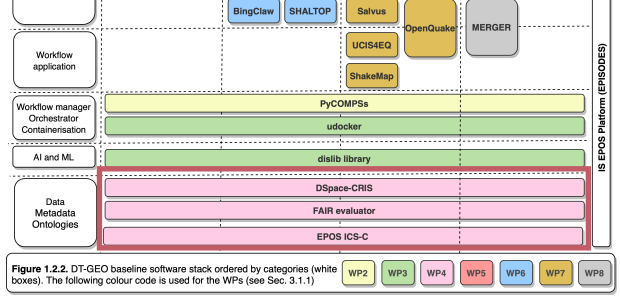


Figure 1.2.2. DT-GEO baseline software stack ordered by categories (white boxes). The following colour code is used for the WPs (see Sec. 3.1.1)

A Digital Twin for GEOphysical extremes

4 vertical pillars

Volcanoes	Tsunamis	Earthquakes	Anthropogenic geophysical extremes
• Develop and implement **4 DTCs** for volcano-related extremes	• Develop and implement **1 DTC** for data-informed Probabilistic Tsunami Forecasting (PTF)	• Develop and implement **6 DTCs** covering earthquake-related aspects over long and short time scales	• Develop and implement **1 DTC** for Anthropogenic Geophysical Extreme Forecasting (AGEF)
• Test the 4 DTC-V through **3 site demonstrators** at relevant European sites: Mt. Etna in Italy (SD1), and Grímsvötn and Fagradalsfjall in Iceland (SD2 and SD3 respectively).	• Test the DTC-T1 through **4 site demonstrators** at relevant sites: Mediterranean sea coast (SD4), Eastern Sicily (SD5), Chilean cost (SD6), and Eastern Honshu coast in Japan (SD7).	• Test the 6 DTC-E at **4 relevant sites**: Euro-Med (SD8), Central Apennines and Alto-Tiberina (SD9), Bedretto Lab (SD10) and the Alps (SD11).	• Test the DTC-A through **2 site demonstrators** at relevant European sites: Strasbourg geothermal site in France (SD12) and KGHM copper ore mine in Poland (SD13).

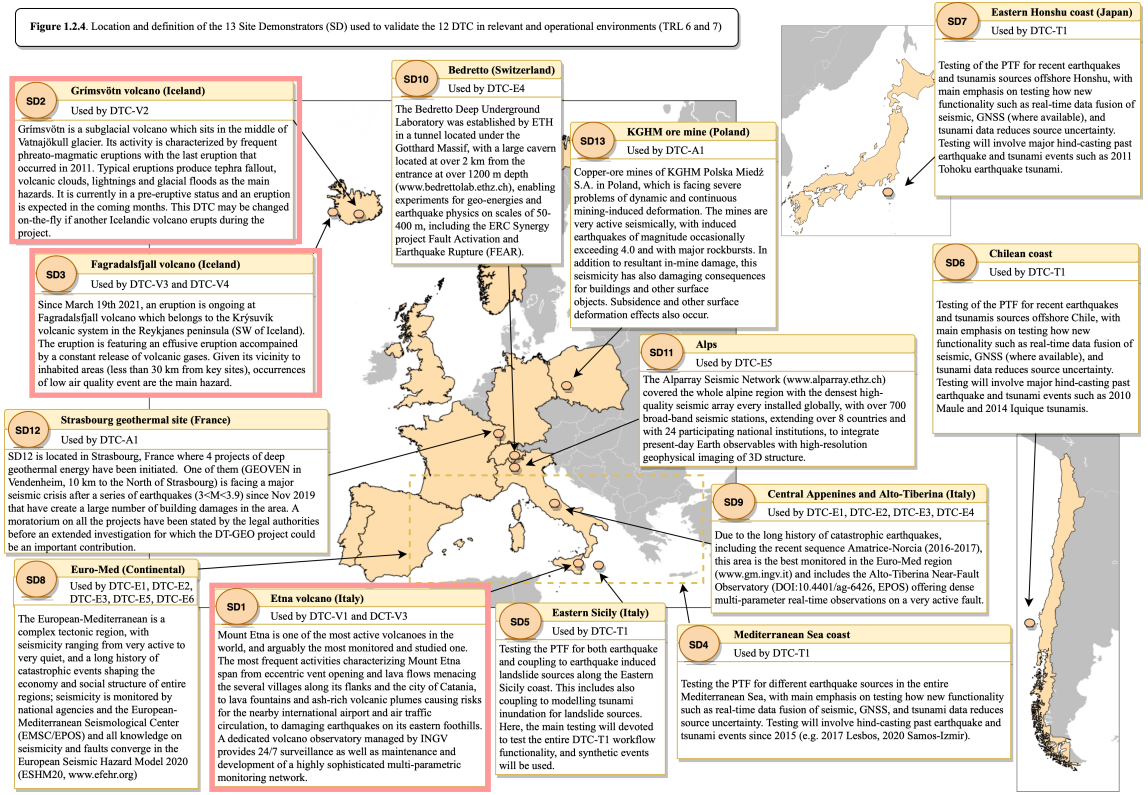
A Digital Twin for GEOphysical extremes

12 Digital Twin Components (DTCs)

DTC	Code	Hazard	Name	Target TRL (KPI)	Site Demonstrator (SD)
1	DTC-V1	Volcano (WP5)	Volcanic unrest dynamics	6	SD1
2	DTC-V2		Volcanic ash clouds and deposition	7	SD2
3	DTC-V3		Lava flows	6	SD1, SD3
4	DTC-V4		Volcanic gas dispersal and deposition	7	SD3
5	DTC-T1	Tsunami (WP6)	Probabilistic Tsunami Forecasting (PTF)	7	SD4, SD5, SD6, SD7
6	DTC-E1	Earthquake (WP7)	Probabilistic Seismic Hazard and Risk Assessment	7	SD8
7	DTC-E2		Earthquake short-term forecasting	7	SD8, SD9
8	DTC-E3		Tomography and Ground Motion Models (GMM)	7	SD8, SD9
9	DTC-E4		Fault rupture forecasting	7	SD9, SD10
10	DTC-E5		Tomography and shaking simulation	6	SD8, SD11
11	DTC-E6		Rapid event and shaking characterization	7	SD8
12	DTC-A1	Anthropogenic (WP8)	Anthropogenic geophysical extreme forecasting (AGEF)	6	SD12, SD13

A Digital Twin for GEOphysical extremes

DTC-V and related Site Demonstrators (SDs)



DTC-V1	**Volcanic unrest dynamics**	INGV

Merge multi-parametric data from ground-based and remote observation systems (on-site monitoring networks and satellites) with global modelling of magma and rock dynamics with GALES and with AI approach

DTC-V2	**Volcanic ash clouds**	CSIC

Merge real-time geostationary satellite observations with the FALL3D model using the on-line data assimilation PDAF system to generate deterministic and ensemble-based probabilistic forecast products

DTC-V3	**Lava flows**	INGV

Merge real-time multi-parametric data from ground-based and remote observation systems with deterministic modelling of lava flow propagation and inundation areas including Bayesian modelling of vent opening

DTC-V4	**Volcanic gas dispersal**	IMO

Train an AI algorithm with air-quality data, along with the meteorological fields. This element will feed a forecasting dispersal model to improve our capability to develop an EWS

A Digital Twin for GEOphysical extremes

DTC-T and related Site Demonstrators (SDs)

Figure 1.2.4. Location and definition of the 13 Site Demonstrators (SD) used to validate the 12 DTC in relevant and operational environments (TRL 6 and 7)

SD2 Grímsvötn volcano (Iceland)
Used by DTC-V2

Grímsvötn is a subglacial volcano which sits in the middle of Vatnajökull glacier. Its activity is characterized by frequent phreato-magmatic eruptions with the last eruption that occurred in 2011. Typical eruptions produce tephra fallout, volcanic clouds, lightnings and glacial floods as the main hazards. It is currently in a pre-eruptive status and an eruption is expected in the coming months. This DTC may be changed on-the-fly if another Icelandic volcano erupts during the project.

SD3 Fagradalsfjall volcano (Iceland)
Used by DTC-V3 and DTC-V4

Since March 19th 2021, an eruption is ongoing at Fagradalsfjall volcano which belongs to the Krýsuvík volcanic system in the Reykjanes peninsula (SW of Iceland). The eruption is featuring an effusive eruption accompanied by a constant release of volcanic gases. Given its vicinity to inhabited areas (less than 30 km from key sites), occurrences of low air quality event are the main hazard.

SD12 Strasbourg geothermal site (France)
Used by DTC-A1

SD12 is located in Strasbourg, France where 4 projects of deep geothermal energy have been initiated. One of them (GEOVEN in Vendenheim, 10 km to the North of Strasbourg) is facing a major seismic crisis after a series of earthquakes (3<M<3.9) since Nov 2019 that have create a large number of building damages in the area. A moratorium on all the projects have been stated by the legal authorities before an extended investigation for which the DT-GEO project could be an important contribution.

SD8 Euro-Med (Continental)
Used by DTC-E1, DTC-E2, DTC-E3, DTC-E5, DTC-E6

The European-Mediterranean is a complex tectonic region, with seismicity ranging from very active to very quiet, and a long history of catastrophic events shaping the economy and social structure of entire regions; seismicity is monitored by national agencies and the European-Mediterranean Seismological Center (EMSC/EPOS) and all knowledge on seismicity and faults converge in the European Seismic Hazard Model 2020 (ESHM20, www.efehr.org)

SD1 Etna volcano (Italy)
Used by DTC-V1 and DCT-V3

Mount Etna is one of the most active volcanoes in the world, and arguably the most monitored and studied one. The most frequent activities characterizing Mount Etna span from eccentric vent opening and lava flows menacing the several villages along its flanks and the city of Catania, to lava fountains and ash-rich volcanic plumes causing risks for the nearby international airport and air traffic circulation, to damaging earthquakes on its eastern foothills. A dedicated volcano observatory managed by INGV provides 24/7 surveillance as well as maintenance and development of a highly sophisticated multi-parametric monitoring network.

SD10 Bedretto (Switzerland)
Used by DTC-E4

The Bedretto Deep Underground Laboratory was established by ETH in a tunnel located under the Gotthard Massif, with a large cavern located at over 2 km from the entrance at over 1200 m depth (www.bedrettolab.ethz.ch), enabling experiments for geo-energies and earthquake physics on scales of 50-400 m, including the ERC Synergy project Fault Activation and Earthquake Rupture (FEAR).

SD13 KGHM ore mine (Poland)
Used by DTC-A1

Copper-ore mines of KGHM Polska Miedź S.A. in Poland, which is facing severe problems of dynamic and continuous mining-induced deformation. The mines are very active seismically, with induced earthquakes of magnitude occasionally exceeding 4.0 and with major rockbursts. In addition to resultant in-mine damage, this seismicity has also damaging consequences for buildings and other surface objects. Subsidence and other surface deformation effects also occur.

SD11 Alps
Used by DTC-E5

The Alparray Seismic Network (www.alparray.ethz.ch) covered the whole alpine region with the densest high-quality seismic array every installed globally, with over 700 broad-band seismic stations, extending over 8 countries and with 24 participating national institutions, to integrate present-day Earth observables with high-resolution geophysical imaging of 3D structure.

SD9 Central Appenines and Alto-Tiberina (Italy)
Used by DTC-E1, DTC-E2, DTC-E3, DTC-E4

Due to the long history of catastrophic earthquakes, including the recent sequence Amatrice-Norcia (2016-2017), this area is the best monitored in the Euro-Med region (www.gm.ingv.it) and includes the Alto-Tiberina Near-Fault Observatory (DOI:10.4401/ag-6426, EPOS) offering dense multi-parameter real-time observations on a very active fault.

SD5 Eastern Sicily (Italy)
Used by DTC-T1

Testing the PTF for both earthquake and coupling to earthquake induced landslide sources along the Eastern Sicily coast. This includes also coupling to modelling tsunami inundation for landslide sources. Here, the main testing will devoted to test the entire DTC-T1 workflow functionality, and synthetic events will be used.

SD4 Mediterranean Sea coast
Used by DTC-T1

Testing the PTF for different earthquake sources in the entire Mediterranean Sea, with main emphasis on testing how new functionality such as real-time data fusion of seismic, GNSS, and tsunami data reduces source uncertainty. Testing will involve hind-casting past earthquake and tsunami events since 2015 (e.g. 2017 Lesbos, 2020 Samos-Izmir).

SD7 Eastern Honshu coast (Japan)
Used by DTC-T1

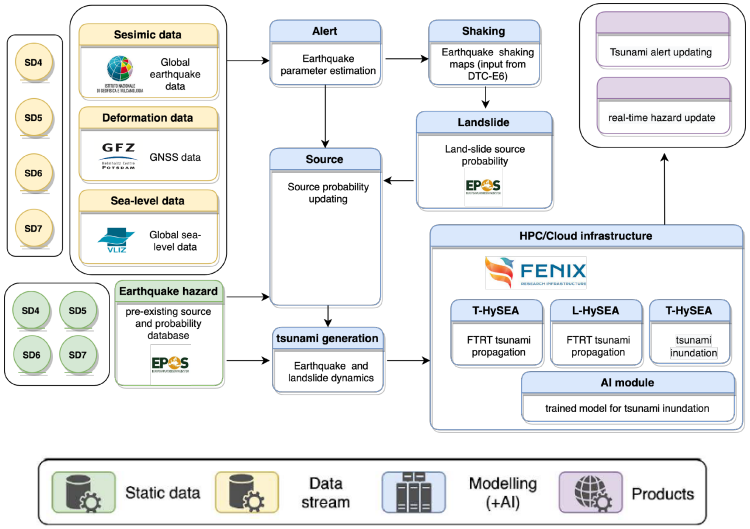
Testing of the PTF for recent earthquakes and tsunamis sources offshore Honshu, with main emphasis on testing how new functionality such as real-time data fusion of seismic, GNSS (where available), and tsunami data reduces source uncertainty. Testing will involve major hind-casting past earthquake and tsunami events such as 2011 Tohoku earthquake tsunami.

SD6 Chilean coast
Used by DTC-T1

Testing of the PTF for recent earthquakes and tsunamis sources offshore Chile, with main emphasis on testing how new functionality such as real-time data fusion of seismic, GNSS (where available), and tsunami data reduces source uncertainty. Testing will involve major hind-casting past earthquake and tsunami events such as 2010 Maule and 2014 Iquique tsunamis.

DTC-T1	**Probabilistic Tsunami Forecasting (PTF)**	NGI-INGV

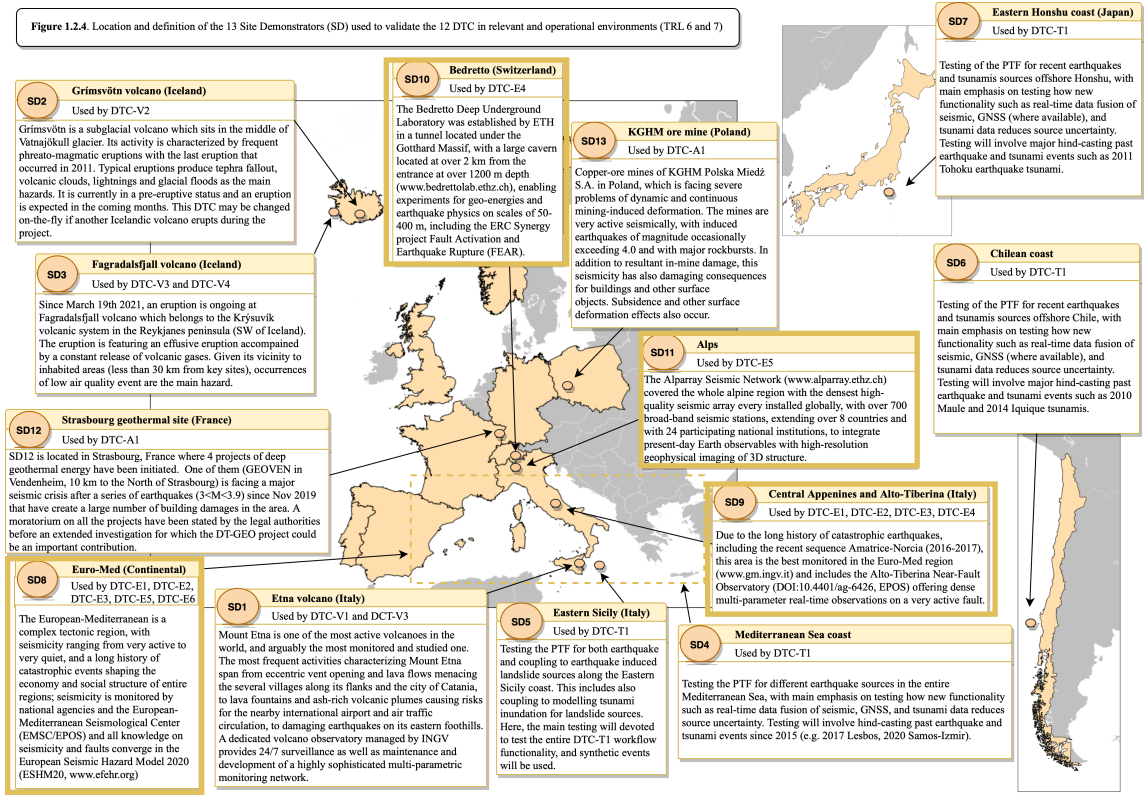
Integrate physics-based tsunami models with related processes through sophisticated models for earthquakes, cascading events such as landslides induced by ground shaking, all interoperable. Data and model fusion



A Digital Twin for GEOphysical extremes

DTC-E and related Site Demonstrators (SDs)

Figure 1.2.4. Location and definition of the 13 Site Demonstrators (SD) used to validate the 12 DTC in relevant and operational environments (TRL 6 and 7)



DTC-E1	**Probabilistic Seismic Hazard and Risk Assessment**	ETH

Assimilate on-going seismicity and update the activity rates used for the seismogenic sources and distributed seismicity components of the ESHM20 of Europe. Hybrid GMM from DTC-E3 will be used to compute hybrid physics-based PSHA. PSRA will be computed from the two hazard branches using the OpenQuake vulnerability inventories

DTC-E2	**Earthquake short-term forecasting**	ETH

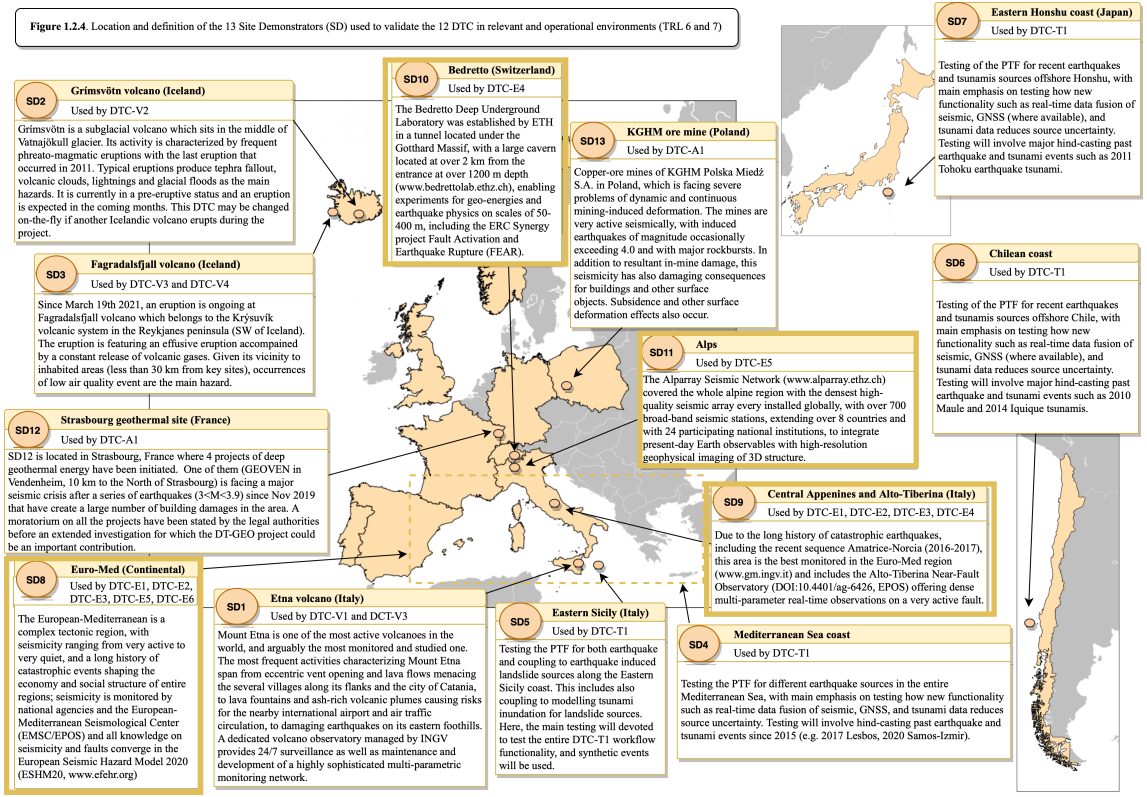
Computes short-term probabilities of occurrence for events of different magnitudes, foreshocks and aftershocks, and the corresponding event scenarios

DTC-E3	**Tomography and Ground Motion Models (GMM)**	GFZ

Assimilate continuous seismic waveforms to regress conditions to improve high-frequency, site-specific GMMs. Hybrid GMMs are derived combining data-fitted GMM and the shake-maps libraries developed in DTC-E5, accounting for different frequencies and resolution and enabling the computation of physics-based hazard and the continuous update of PSHA following an earthquake.

A Digital Twin for GEOphysical extremes

DTC-E and related Site Demonstrators (SDs)



DTC-E4	**Fault rupture forecasting**	LMU

DTC-E4 implements physics-based modelling of individual faults, the determination of probable, dynamically viable rupture scenarios and on-demand shake-maps (from DTC-E5) to estimate envelopes of expected shaking scenarios in a fault system approach.

DTC-E5	**Tomography and shaking simulation**	ETH

Inverts iteratively for the 3D structural model and generates shake-maps for the most relevant seismic sources; as new quakes are recorded, the source characteristics are inverted for and the corresponding shake-maps computed and added to the shake-maps library, allowing for on-demand rapid simulations.

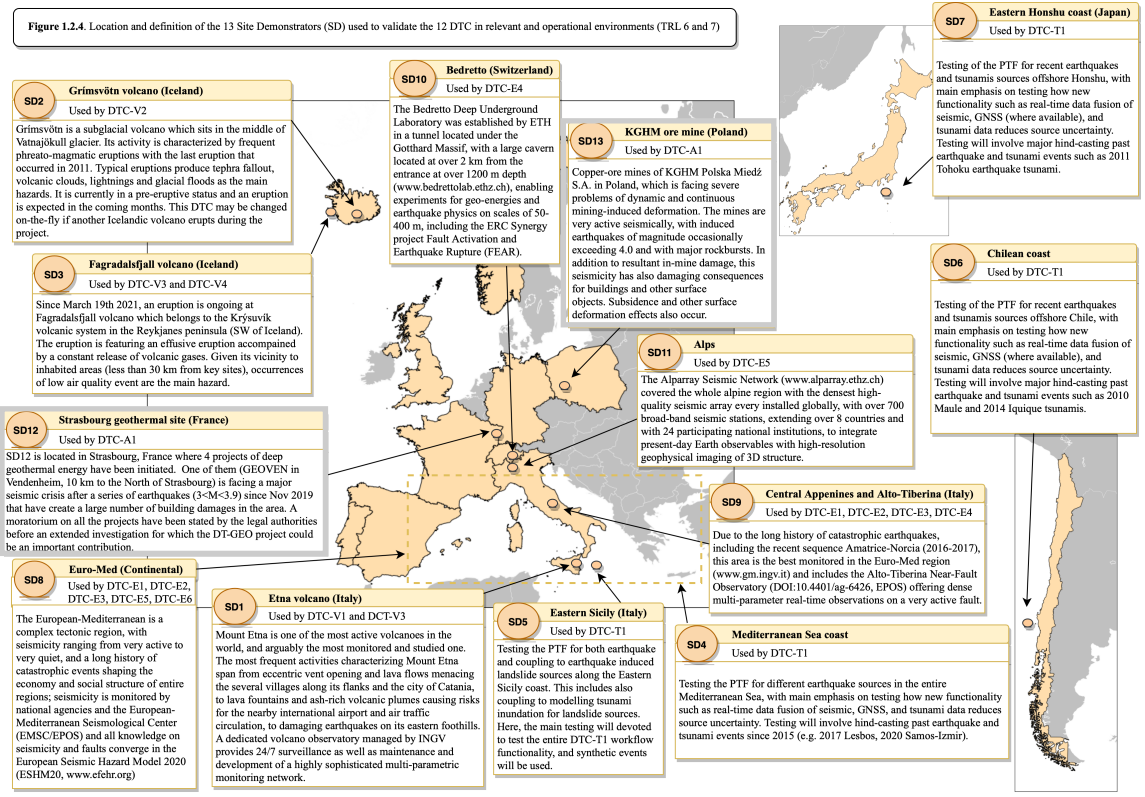
DTC-E6	**Rapid event and shaking characterisation**	ETH

Activated after a significant event alert and while the event is unfolding and the ground-shaking is propagating, with the purpose of providing very rapid warnings. The properties of the event are computed within second-to-minutes from the start of the event and rapid shake maps are computed.

A Digital Twin for GEOphysical extremes

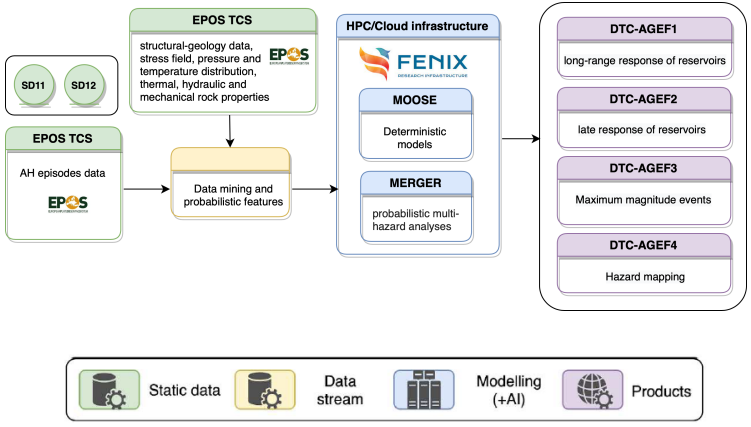
DTC-A and related Site Demonstrators (SDs)

Figure 1.2.4. Location and definition of the 13 Site Demonstrators (SD) used to validate the 12 DTC in relevant and operational environments (TRL 6 and 7)



DTC-A1	**Anthropogenic geophysical extreme forecasting**	CNRS-IGV

1) how far an anthropogenic extreme can be triggered from an industrial site? 2) how long and delayed could be the reservoir deformation? 3) what is the maximum arrestable magnitude of the earthquakes in the georeservoirs?



A Digital Twin for GEOphysical extremes

Keywords (take home message)

Digital Twin Components

Geophysical extremes
Site Demonstrators
DestinE

Research Infrastructures

EuroHPC (+virtual cloud)
FENIX
EPOS
ESFRI and ENVRI

Data-driven workflows

Interoperability
Containers
Microservices
FAIR validation

Operations and scenarios

Data-driven update
Forecasts
Urgent Computing

Upcoming deliverables (next 12 months)

Number	WP	Task	Name	Lead	Type	Level	Month	Date
D1	1	D1.1	Project Management and Quality Guidelines	CSIC	R	PU	M2	Oct 2022
D2	9	D9.1	Project Website	CSIC	DEC	PU	M2	Oct 2022
D3	9	D9.2	Communication and Dissemination Plan	CSIC	R	PU	M3	Nov 2022
D4	2	D2.1	Requirements, metrics and architecture design	BSC	R	PU	M6	Feb 2023
D5	3	D3.1	DT-GEO FENIX extended infrastructure	CIN	R	PU	M6	Feb 2023
D6	4	D4.1	Data Management Plan Requirement analysis for the architecture of the assets	UKRI	DEM	PU	M6	Feb 2023
D7	7	D7.1	Early definition of requirements and specifications DTC-E	ETH	R	PU	M6	Feb 2023
D8	8	D8.1	DT-AGEF Requirements and specifications	GFZ	R	PU	M6	Feb 2023
D9	9	D9.3	First project video	CSIC	DEC	PU	M6	Feb 2023
D10	6	D6.1	Interface definition towards other DT omponents and data	GFZ	R	PU	M8	Apr 2023

A Digital Twin for GEOphysical extremes

Milestones

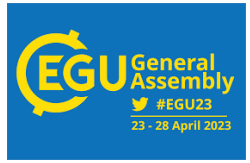
Number	Name	Lead Beneficiary	Deliverable related for verification	Month
M1	**DT-GEO workflow requirements and architecture**	**BSC CNS**	**D2.1**	**M6**
M2	**Characterization of HPC and cloud resources**	**CINECA**	**D3.1**	**M6**
M3	**DT-GEO software stack version 1**	**CSIC**	**D2.2**	**M12**
M4	Revision of DT-GEO workflow requirements and architecture	BSE CNS	D3.2	M20
M5	DTC's beta version	EPOS-ERIC	DTC Beta version	M24
M6	DTC's ginal version	INGV	Final DTC source code (available repository)	M32
M7	DTC's validated at the SDs	INGV	Final DTC source code available, Workshop with EAB	M36
M8	Sustainability of the DT	EPOS-ERIC	Effective liaison with Destination Earth	M36

Symposia: DTs and Destination Earth

Enabling Earth System Monitoring

A digital twin (DT) of an object is a digital replica that provides a way of visualizing, manipulating, and understanding its physical response to external forcings by dynamically fusing data and models. DTs of the Earth system aim to mimic its different components (atmosphere, ocean, land, lithosphere) with the aim of providing analyses, forecasts and quantified responses to “what if” scenarios for natural and anthropogenic hazards from their genesis to propagation and impact. These symposium target to bring together the research community within the key players involved: data providers, researchers, IT developers and HPC and data acquisition infrastructures. .

1. **Data Providers**
2. **Researchers**
3. **IT Developers**
4. **Data acquisition Infrastructures**



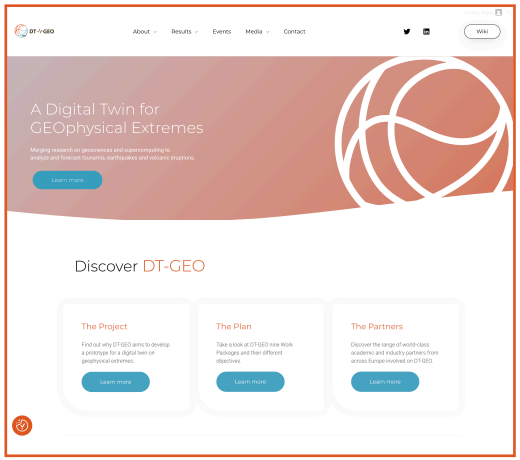
A Digital Twin for GEOphysical extremes

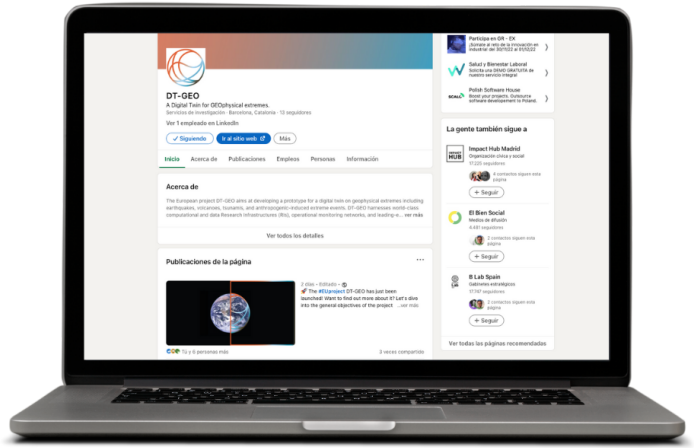
Dissemination

https://dtgeo.eu

@dtgeo_eu

linkedin.com/company/dt-geo/





THANK YOU

afolch@geo3bcn.csic.es

@dtgeo_eu

linkedin.com/company/dt-geo/

Project funded by Horizon Europe under the grant agreement No 101058129.