DT-GEO

A Digital Twin for GEOphysical extremes

Jumeau numérique = modèle numérique qui reconstitue fidèlement un objet, un processus ou un système.

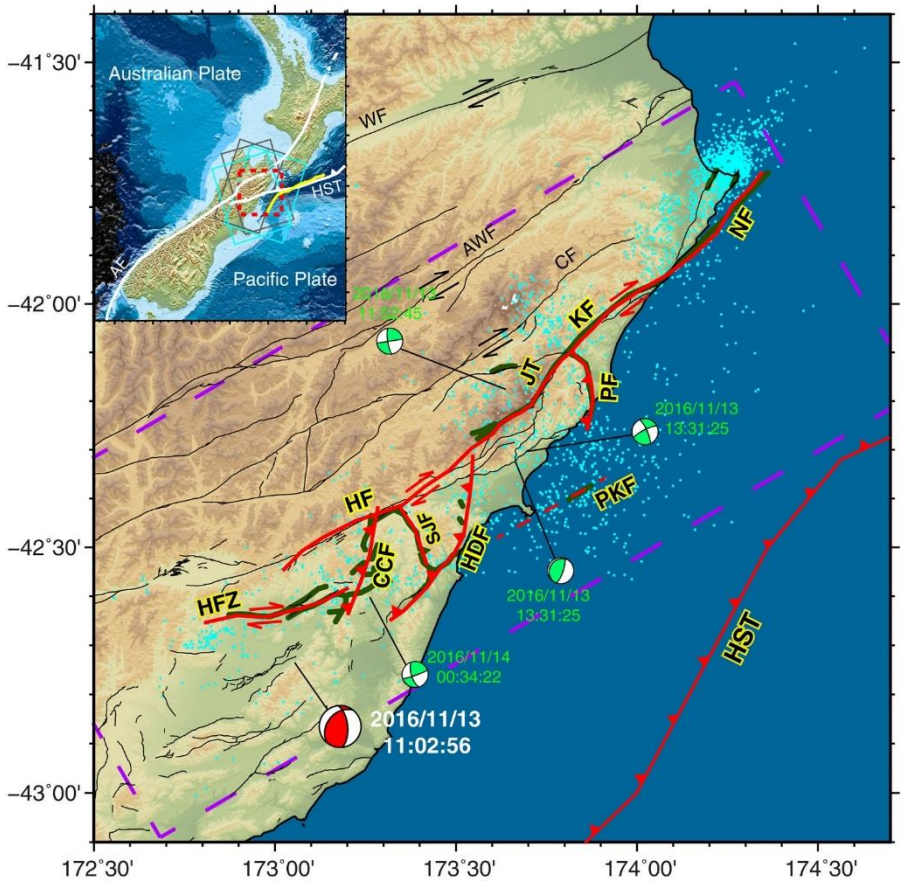
Présenté par Jean-Paul AMPUERO (Geoazur, IRD – UniCA)
aux rencontres EPOS-FR, Saint-Jean-Cap-Ferrat, 08/11/23

This project has received funding from the European Union's Horizon research and innovation programme under the grant agreement No 101058129

EPOS-FR FRANCE
EUROPEANPLATEOBSERVINGSYSTEM

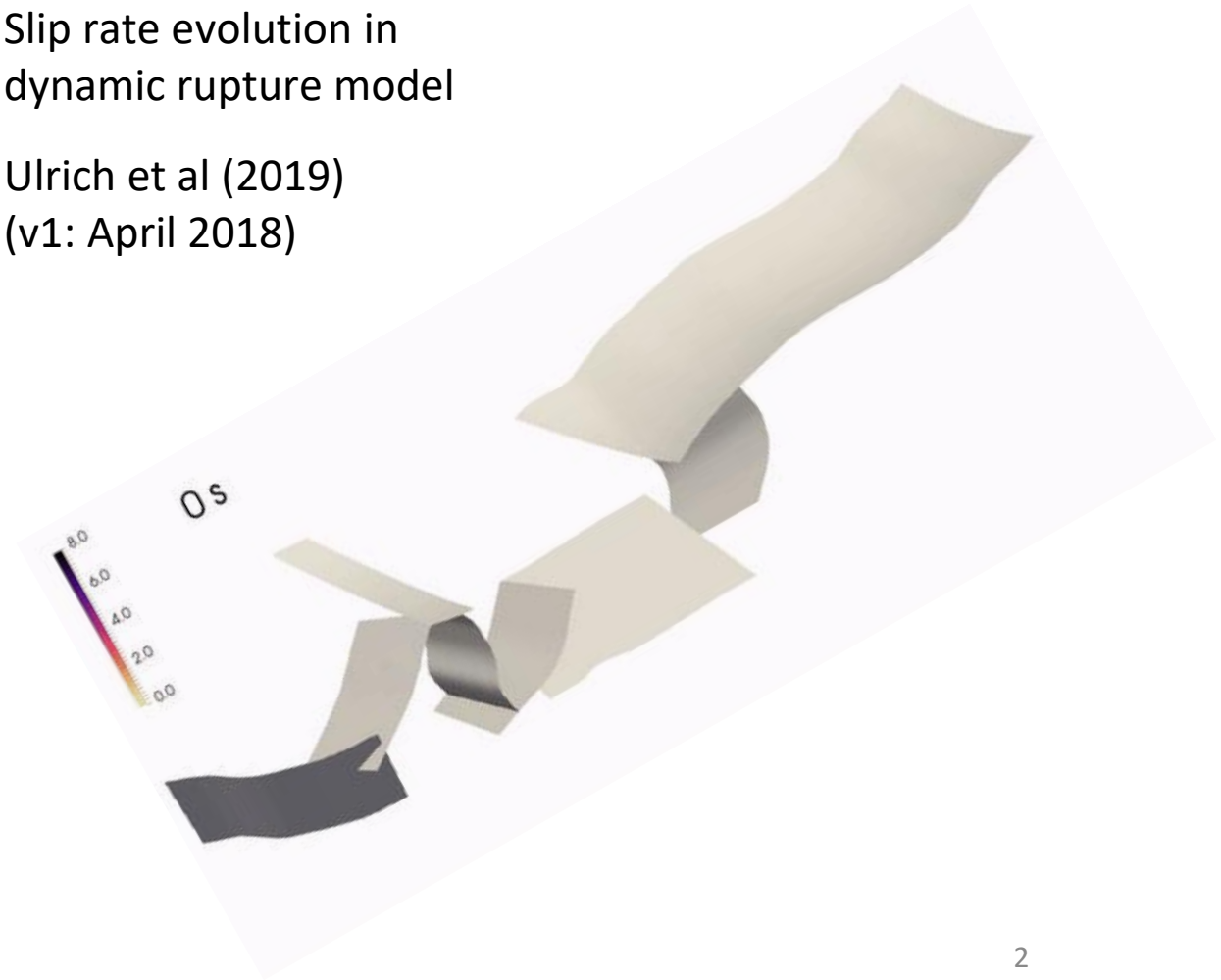
Complexity of earthquake rupture
2016 Mw 7.8 Kaikoura, New Zealand earthquake

Rupture cascade on a fault network
(14 Nov 2016)



Slip rate evolution in
dynamic rupture model

Ulrich et al (2019)
(v1: April 2018)



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/virtual cloud computing (**EuroHPC**) 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

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

HORIZON-INFRA-2021-TECH-01-01

4 Digital Twins projects funded

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.

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. 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

Consortium Composition

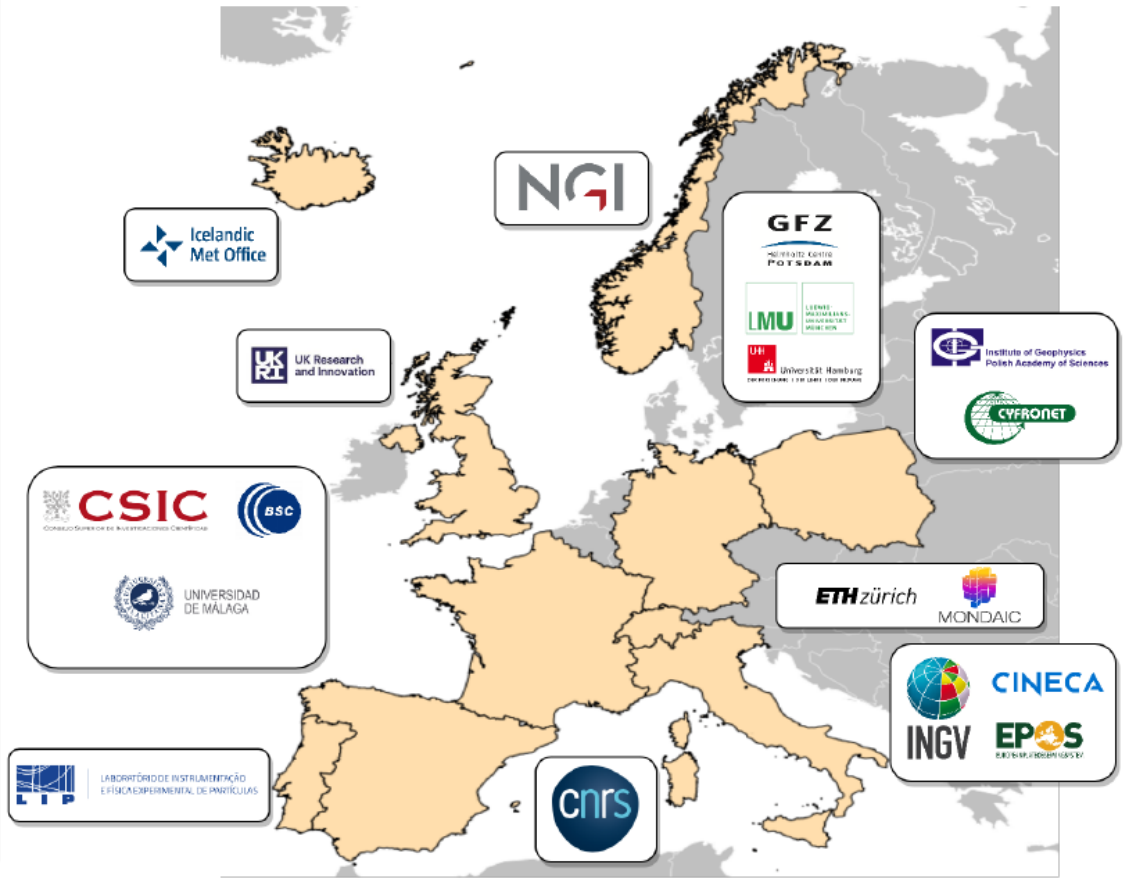
26 **Participating Organisations**
From 10 different countries

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



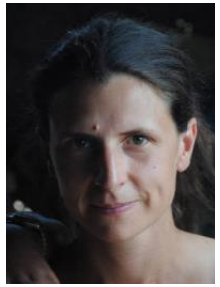
CNRS @ DT-GEO :

Paris (IPGP)
Grenoble (ISTERRE)
Nice (GEOAZUR)
Strasbourg (ITES/ICUBE)

IPGP

ISTerre

Institut **Terre & Environnement** de **Strasbourg** | ITES | UMR 7063 de l'**Université** de Strasbourg



GeoAzur
TERRE - OCÉAN - ESPACE

A Digital Twin for GEOphysical extremes

9 Work-packages (WPs)

WP	WP Title	Lead Partner
1	Project Management	CSIC
2	Workflows and data architecture	BSC
3	Computational infrastructure and AI	CIN
4	EOSC-enabled data management plan and exploitation	CSIC-UKRI
5	Volcanoes	INGV
6	Tsunamis	NGI
7	Earthquakes	ETH
8	Anthropogenic geophysical extremes	IGF-CNRS
9	Dissemination, outreach, and Community engagement	CSIC

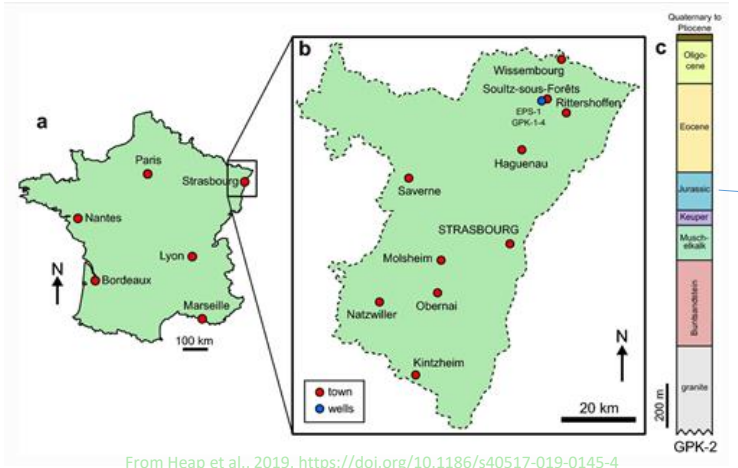
WP8: Anthropogenic Geophysical Extreme Forecasting

Objectives

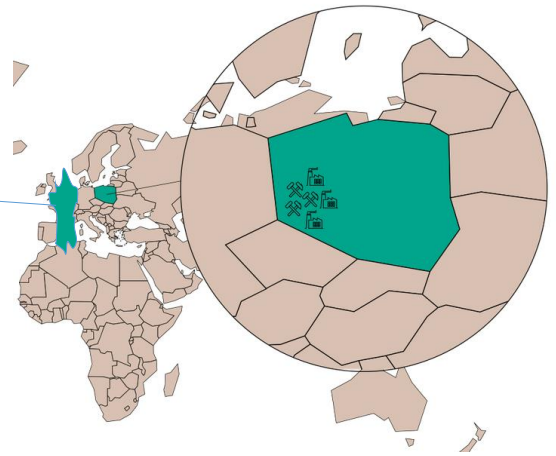
To develop and implement 1 Digital Twin Component (DTC) for with 4 outcomes:

- **forecasting of long-range responses of geo-reservoirs**
- **forecasting of late responses of geo-reservoirs**
- **modelling of the largest magnitude**
- **map of estimated induced seismic hazard**

To test the DTC-A through demonstrators at two relevant European sites: Strasbourg geothermal site in France and the KGHM copper ore mine in Poland.



From Heap et al., 2019, https://doi.org/10.1186/s40517-019-0145-4

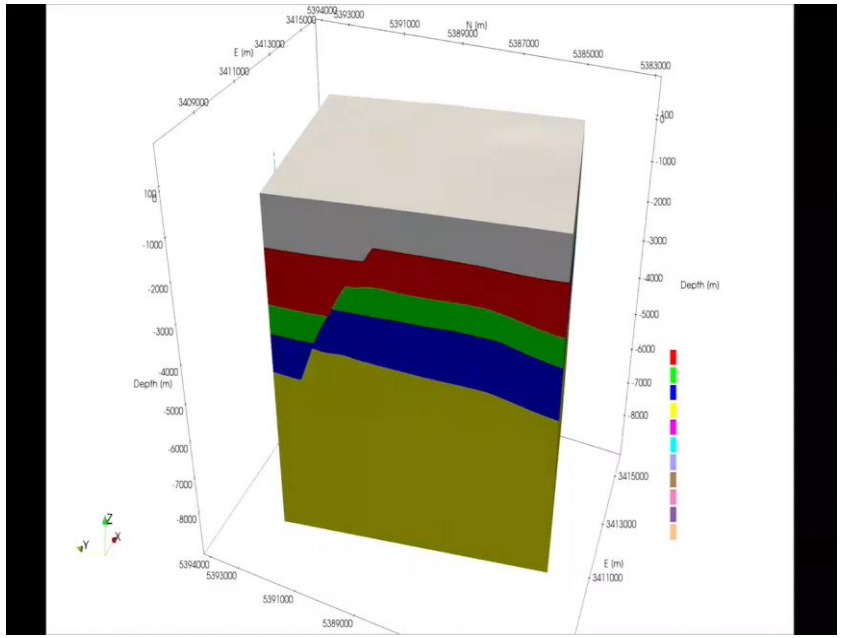


https://raportcsr2019.kghm.com/Grupa-KGHM-i-otoczenie#nasze-aktywa

WP8: Anthropogenic Geophysical Extreme Forecasting

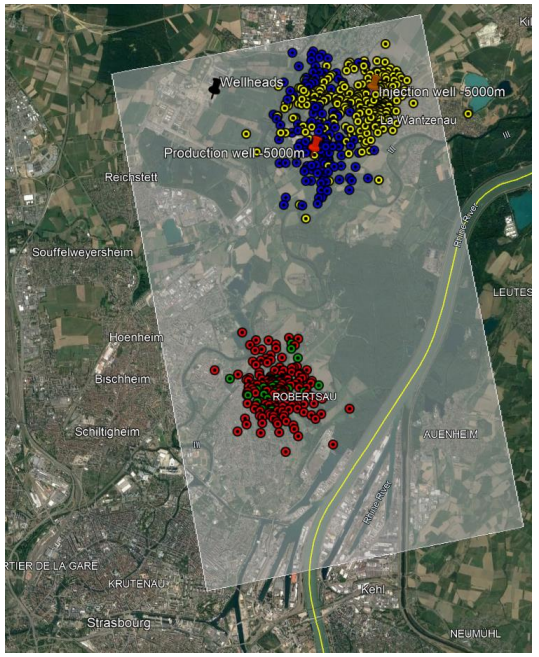
T8.6. Testing and validation

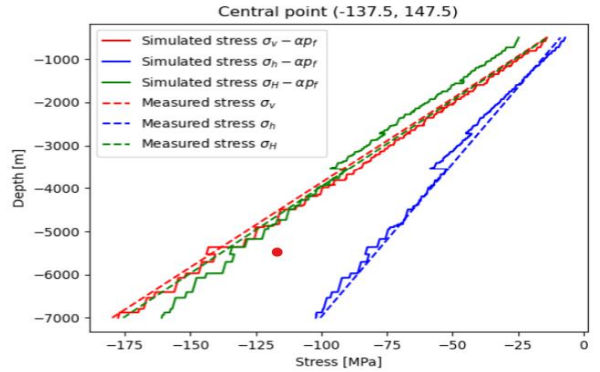
Demonstrator site testing: Strasbourg test-bed -> CNRS Strasbourg/GFZ



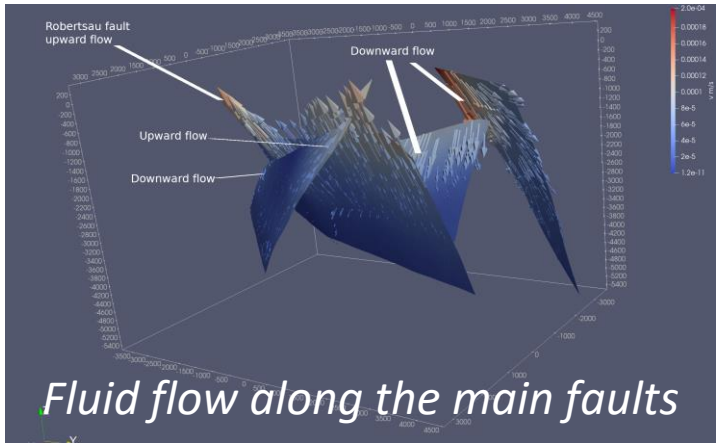
A first meshed model of the Strasbourg site (8x8x8 km³)

Induced seismicity at Strasbourg site





Check of in-situ stresses

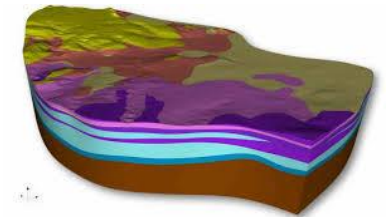


Fluid flow along the main faults

T8.2/T8.3. Forecasting of long-range and late responses of georeservoirs

Homogenization component

- **Wave propagation medium contains small-scale features that can hardly be represented at the discrete level.**
- **Homogenization allows to produce a smooth (easy-to-mesh), effective medium for a target resolution (minimum seismic wavelength).**

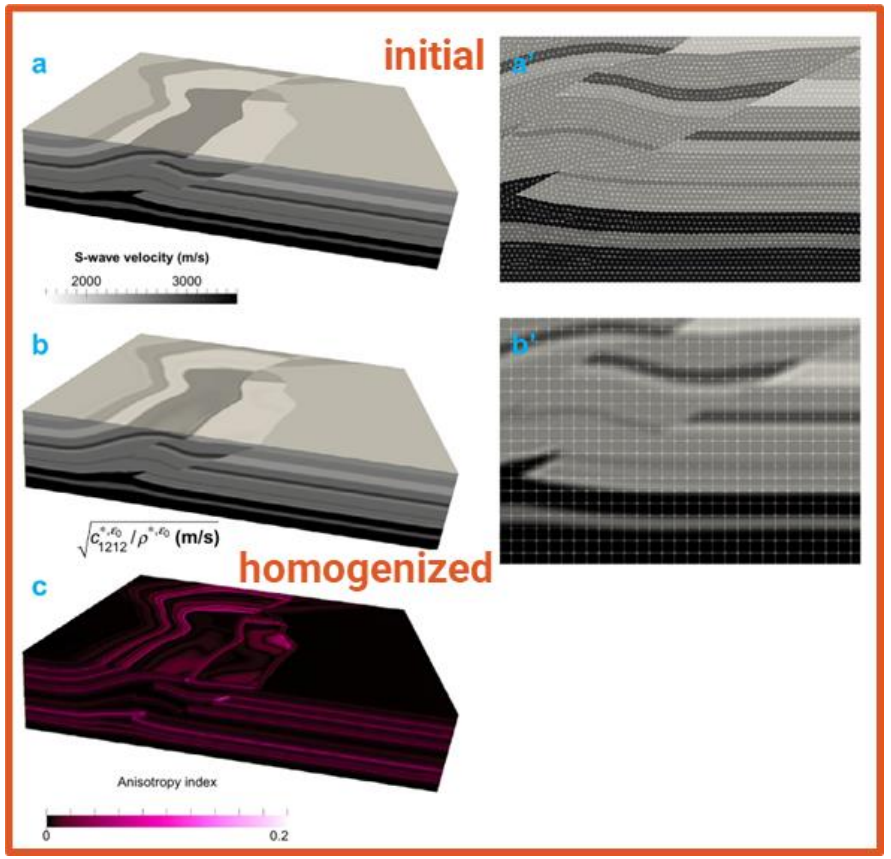


Geology

Geotechnics
Geophysics

Homog. Component

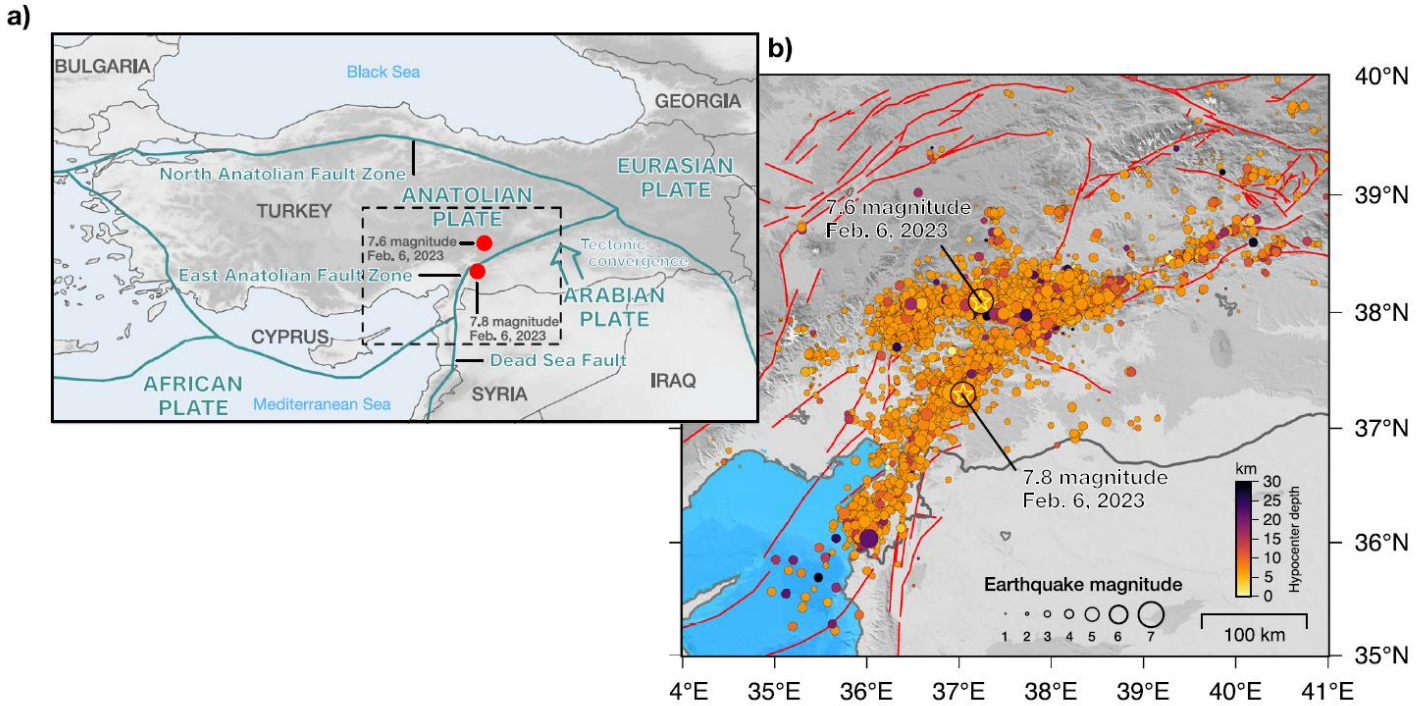
Mesh & Solve



communications earth & environment
COMMENT
https://doi.org/10.1038/s43247-023-00747-z OPEN

Earthquake doublet in Turkey and Syria

Luca Dal Zilio[1]✉ & Jean-Paul Ampuero[2]



WP7 Earthquakes

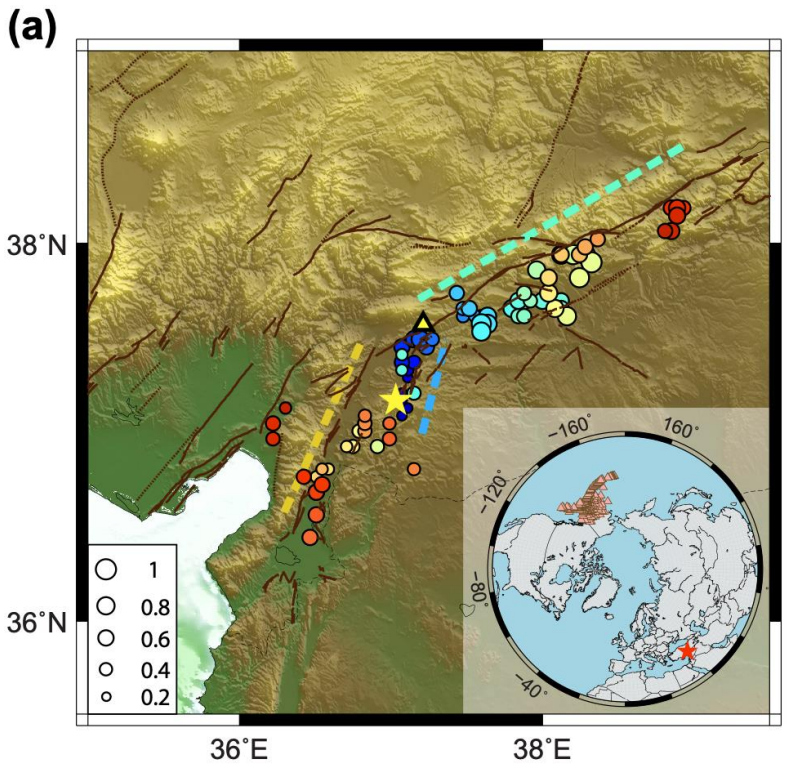
The February 6 2023 earthquake sequence in Turkey occurred as we were preparing our automated workflows for DT-GEO.

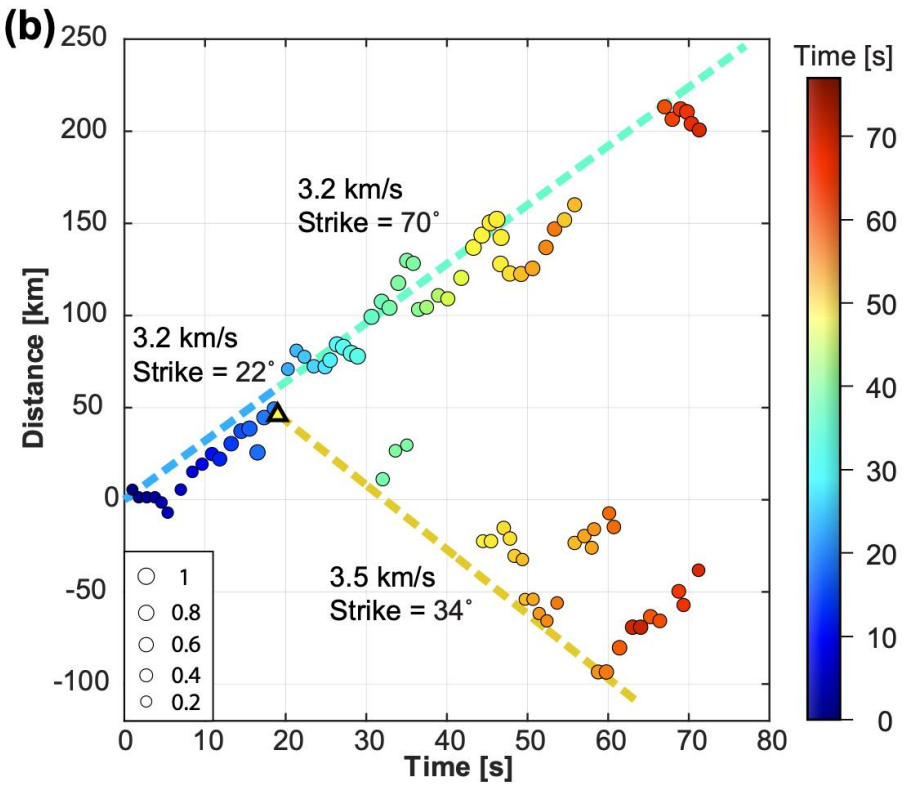
A very important earthquake:
large and complex rupture,
very well recorded by near-fault sensors.

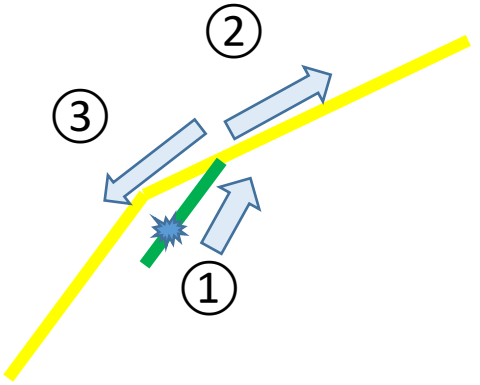
Great study case for DT-GEO,
stimulation for our teams.

On Day 1, **DT-GEO postdoc Yuqing Xie** ran a **teleseismic back-projection** of the mainshock.

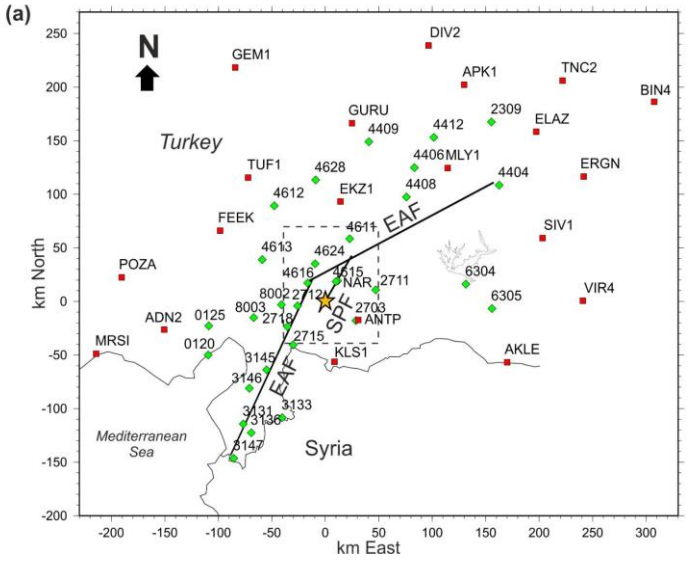
Her results provided an initial image of the rupture process which we then used to motivate dynamic rupture modeling

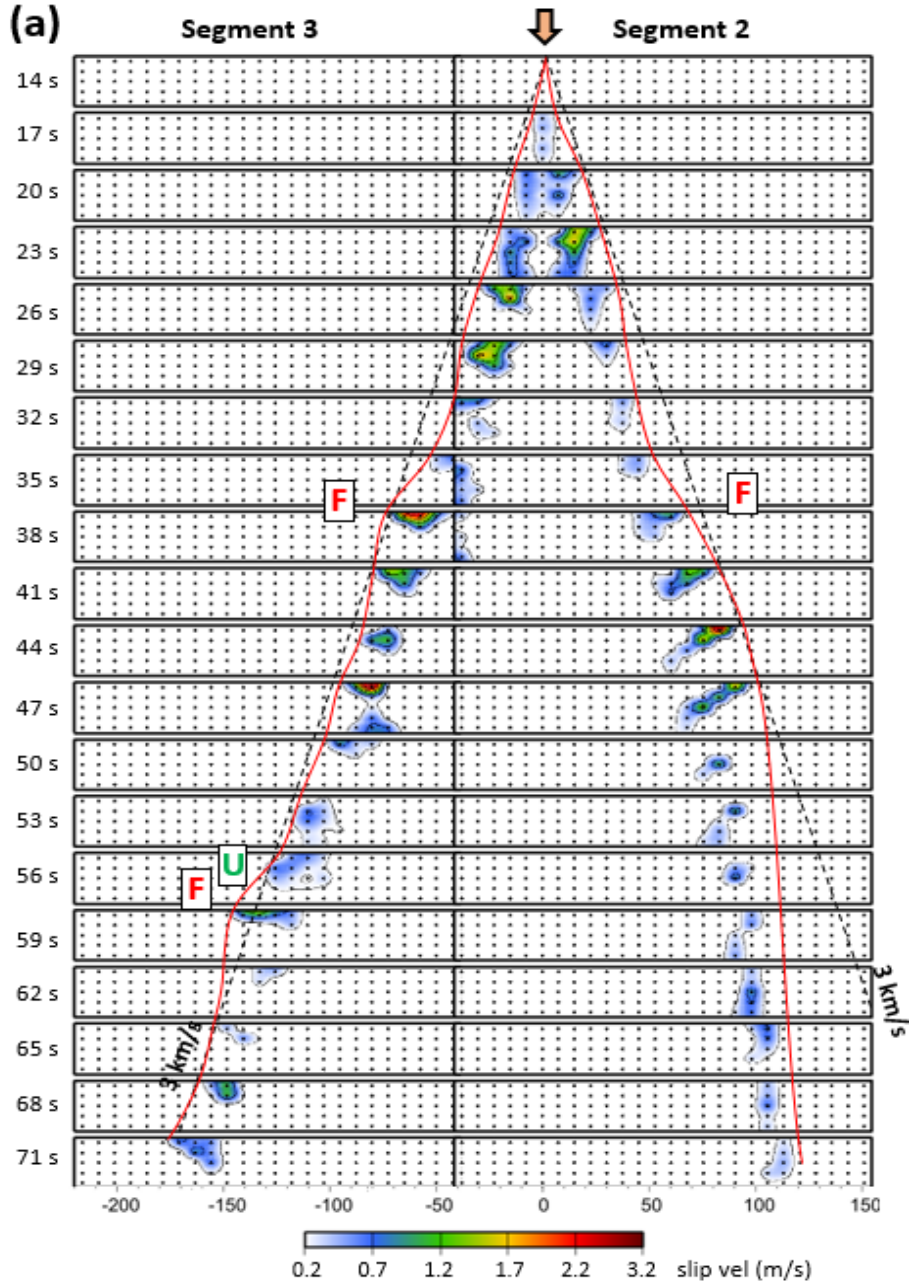






Amazingly dense set of near-fault strong-motion recordings (AFAD).





Within the month that followed, Bertrand Delouis ran finite source inversions of strong motion and GNSS data, with a code that will be integrated in DT-GEO workflows.

We obtained one of the finest views of a large earthquake ever!

Delouis et al (BSSA 2023, submitted on 17/04/23)

DT-GEO

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Présenté par Jean-Paul AMPUERO (Geoazur, IRD – UniCA)
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