



RDM for SeisSol using the Geo-INQUIRE SDL

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Readiness of HPC Extreme-scaling Applications (3rd Edition)

ISC HPC 2026 Workshop

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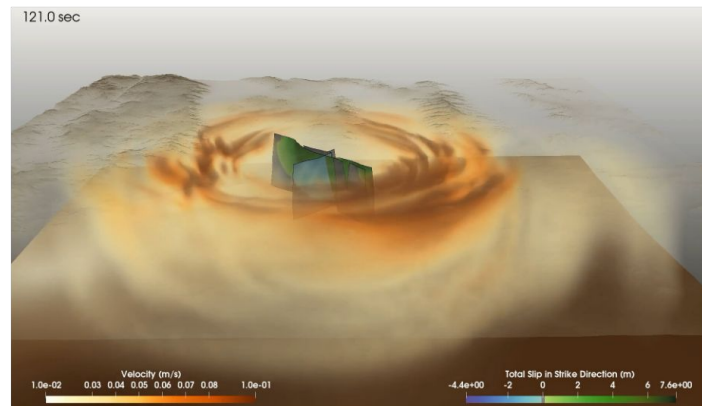


SeisSol in a Nutshell

- **open-source** community code for **physic-based 3D dynamic rupture simulations of Earthquakes**
- uses **Discontinuous Galerkin discretization** and **local time-stepping on unstructured adaptive tetrahedral meshes**.
- Scalable performance at Petascale has been demonstrated **up to several thousands of nodes**
- Joint development by **LMU (Alice Gabriel, “Computational Seismology”)** and **TUM (Michael Bader, “Hardware-aware algorithms and software for HPC”)**

References:

Breuer et al., ISC14, Heinecke et al., SC14,
Breuer et al., IEEE16, Heinecke et al., SC16, Rettenberger et al., EASC16
Uphoff & Bader, HPCS'16, Uphoff et al., SC17
Wolf et al., ICCS'20, Uphoff & Bader, TOMS'20
Dorozhinskii & Bader, HPC Asia'21, Gabriel et. al., SC25



Propagation of seismic waves (2019 Ridgecrest earthquakes). Visualization of 15 TB of 3D volumetric data on unstructured tetrahedral meshes on Frontera. Taufiqurrahman et al., Nature, 2023
Abrams et al., SC23, Visualization showcase

SeisSol on Github: <https://github.com/SeisSol/SeisSol/doi.org/10.5281/zenodo.4672483>

SeisSol Documentation: <https://seissol.readthedocs.io/>

SeisSol Training: <https://github.com/SeisSol/Training>
+video introductions online

Based on Slides from Alice-Agnes Gabriel



From “hero runs” to everyday examples

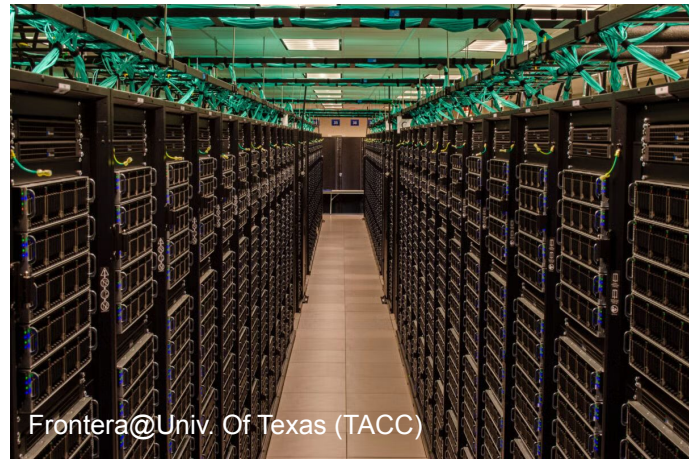
5 Hz Turkey simulation (larger area)

- required 9h on full (~8200 nodes) of Frontera,
- and a large mesh with 685 millions cell,
- + polynomial order 5 basis functions

Everyday Examples: Typical model size:

- meshes of ~10M elements,
- 200m spatial sampling of fault geometry,
- 200m finest sampling of topography,
- seismic wavefield up to 2 Hz in fault vicinity
- Comp. costs ~10,000 CPUh

Increases in compute power now allow for **many calibration runs**,
”**catalog generation**” and even **uncertainty analysis** with
UM-Bridge > Increasingly data-rich



Based on Slides from Alice-Agnes Gabriel



Take-home messages

- **SeisSol is a “joint (ad)venture” of seismologists (LMU) and “hardware/numerics guys” (TUM)**
- **While SeisSol can be used for hero runs, more computing time is spent in “everyday” scenarios**
- **Increases in machine size and capability now enable bigger parameter studies leading to an significant increase in data**

- **This calls for unified workflows to store and access SeisSol data (input files, meshes, job scripts, outputs and data products)**
- **The Alto-Tiberina Earthquake Catalog (a DT-Geo “digital twin component” with a rapid response workflow) used the Geo-INQUIRE Simulation Data Lake (SDL)**



Usual approach takes weeks

★ **EQ occurs**

Collect Geological information (faults, geometry)

generate mesh (spatial grid)

Initial input parameters (stress, friction)

Run & Compare with observables (Waveform fit)

Adapt/Refine Input parameters

> first high-resolution SeisSol results take weeks

Iterate until best fit, increase resolution

Solution: Pre-computed catalog for rapid response

★ **EQ occurs**

Do everything above a priori

Select plausible input parameters

Pre-compute & store EQ catalog

Download observables (Waveforms)

Select closest entry from the catalog

> results within minutes

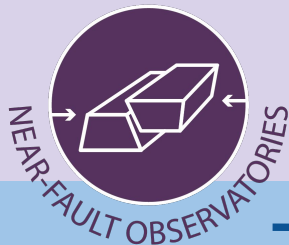


DT-Geo Demonstrator: Alto-Tiberina Catalog

Observation data & physics

- Fault geometry
- Stress orientation
- Frictional properties
- Medium properties

Multi-data constraints from
Near-Fault Observatory
TABOO



Access data available
within min to hours
after the event

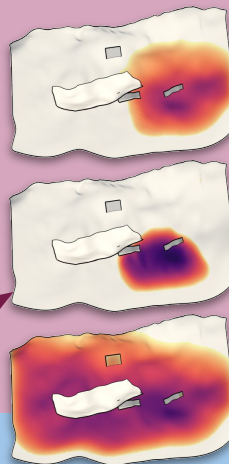
Moderate to
large event
occurrence

SeisSol

3D dynamic rupture &
seismic wave
propagation

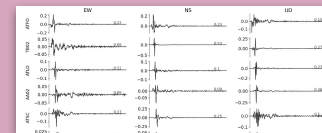
Varying
nucleation location
and values of
unconstrained parameters

Catalog of **physic-based
rupture scenarios...**

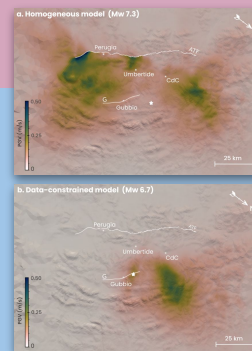


Simulation Workflow

... with associated
synthetic data
(ground motion, static
displacement, etc)...



... and associated **shake maps**



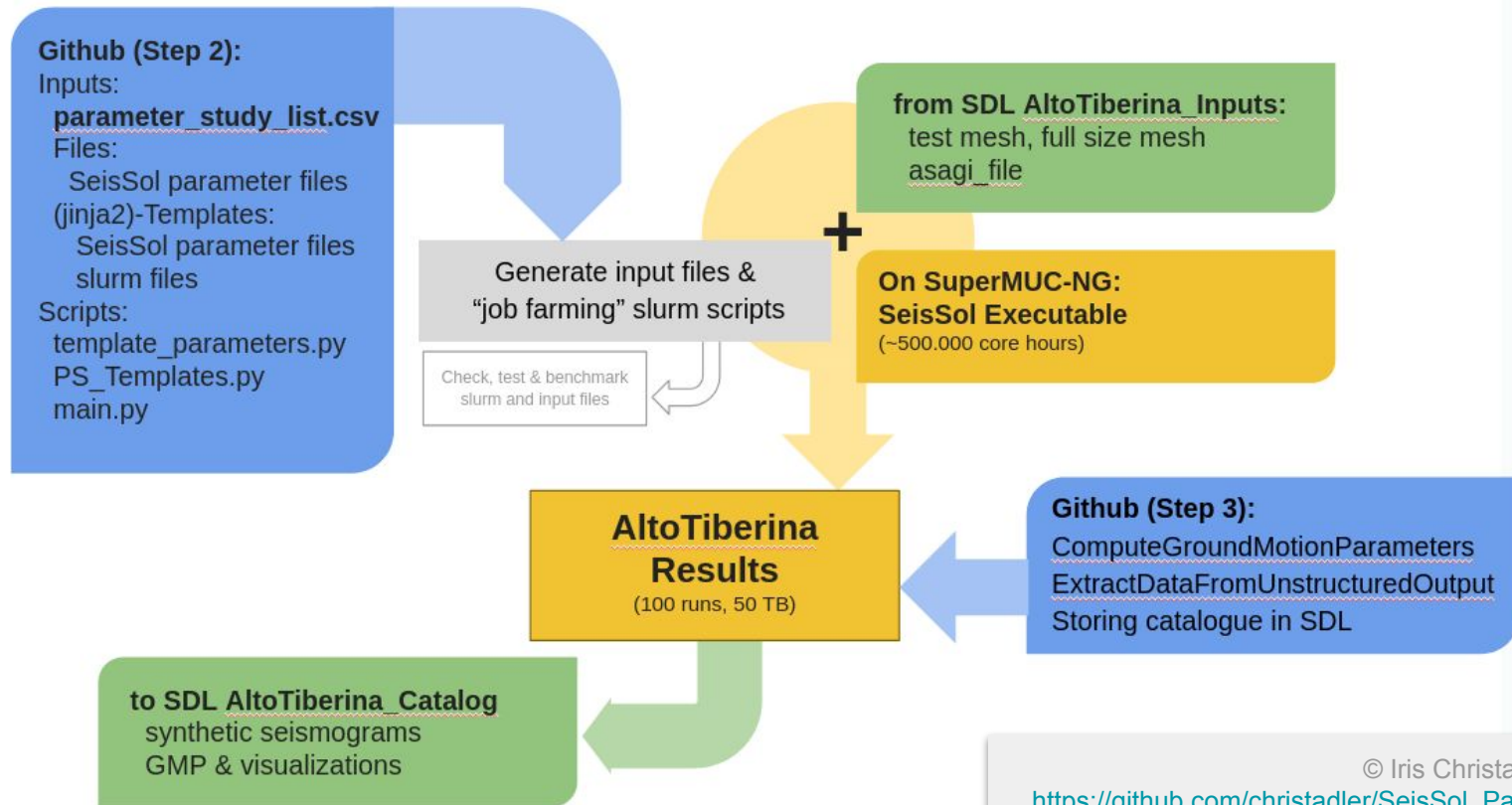
Search the catalog & output
the **best fitting scenario(s)**
(by comparing observations
and synthetics)

FAIR Data for follow-on research

© Mathilde Marchandon (LMU)



Alto-Tiberina Catalog: Catalog-Creation Workflow



© Iris Christadler (LMU),
https://github.com/christadler/SeisSol_ParamStudies

Alto-Tiberina Catalog: Rapid-Response Workflow

README.md (setup once)

1. create venv with `requirements.yaml`
2. test venv with `cronjob.sh`
3. add crontab entry from `cronjob.txt`

Cronjob `detect_event.py` (runs every hour)

`detect_event.py` via `obsproxy.clients.fdsn` from
<https://www.seismicportal.eu>

if no_earthquake_happened : exit; else:

`download_waveforms.py` from
TABOO Near Fault Observatory

`search_catalog.py` for best fit with
data from `AltoTiberina_catalog`

outputs: closest simulation from catalog

workflow schema

Github (Step 4):

`README.md`
`environment.yml`

`WF_Step4_cronjob.sh`
`WF_Step4_cronjob.txt`

`detect_event.py`
`download_waveforms.py`

Github (Step 5):

`search_catalog.py`

SDL:

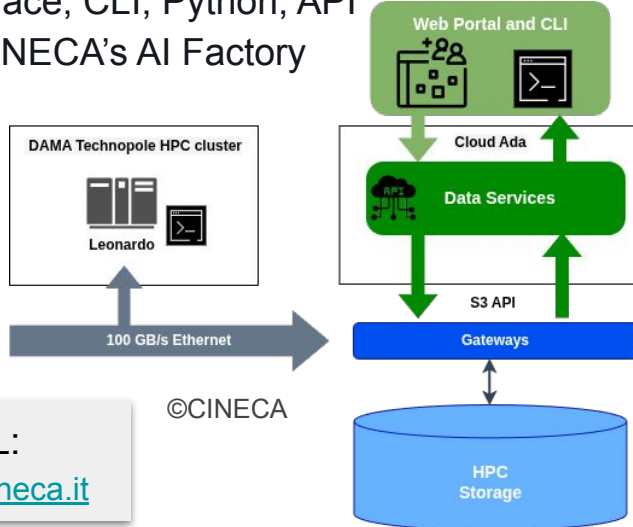
`AltoTiberina_catalog`

input data



Geo-INQUIRE Simulation Data Lake

- **Data portal for simulated data** (inputs, results & data products)
- **FAIR:** Findable*Accessible*Interoperable*Reusable
- **Easy & fast access:** Upload GB in minutes
- **Metadata & DOI,** long-term storage
- Webinterface, CLI, Python, API
- Part of CINECA's AI Factory



Access to SDL:

<https://sdl.hpc.cineca.it>

Simulation Data Lake | Catalog | User Guide | Sign in

← Experiments

AltoTiberina Catalog
Creator: Iris Christadler
Created on: 05/06/2025 10:27

exp41 + New Folder

Type to Filter files

Filename	Status	Elements
0005	✓	69
0000	✓	69
0009	✓	69
0002	✓	69
0008	✓	69
0006	✓	69
0004	✓	69

Access OGC Services

838 objects
Data volume: 3.33 GB

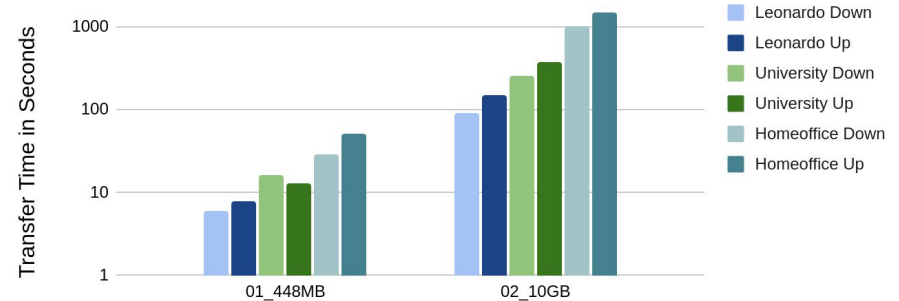
Versions
V1.0.0 Created: 05/05/2025

Experiment Details

Name: AltoTiberina Catalog
Description: AltoTiberinaCatalog for DT-Geo workflow
Authors: Iris Christadler, Mathilde Marchandon

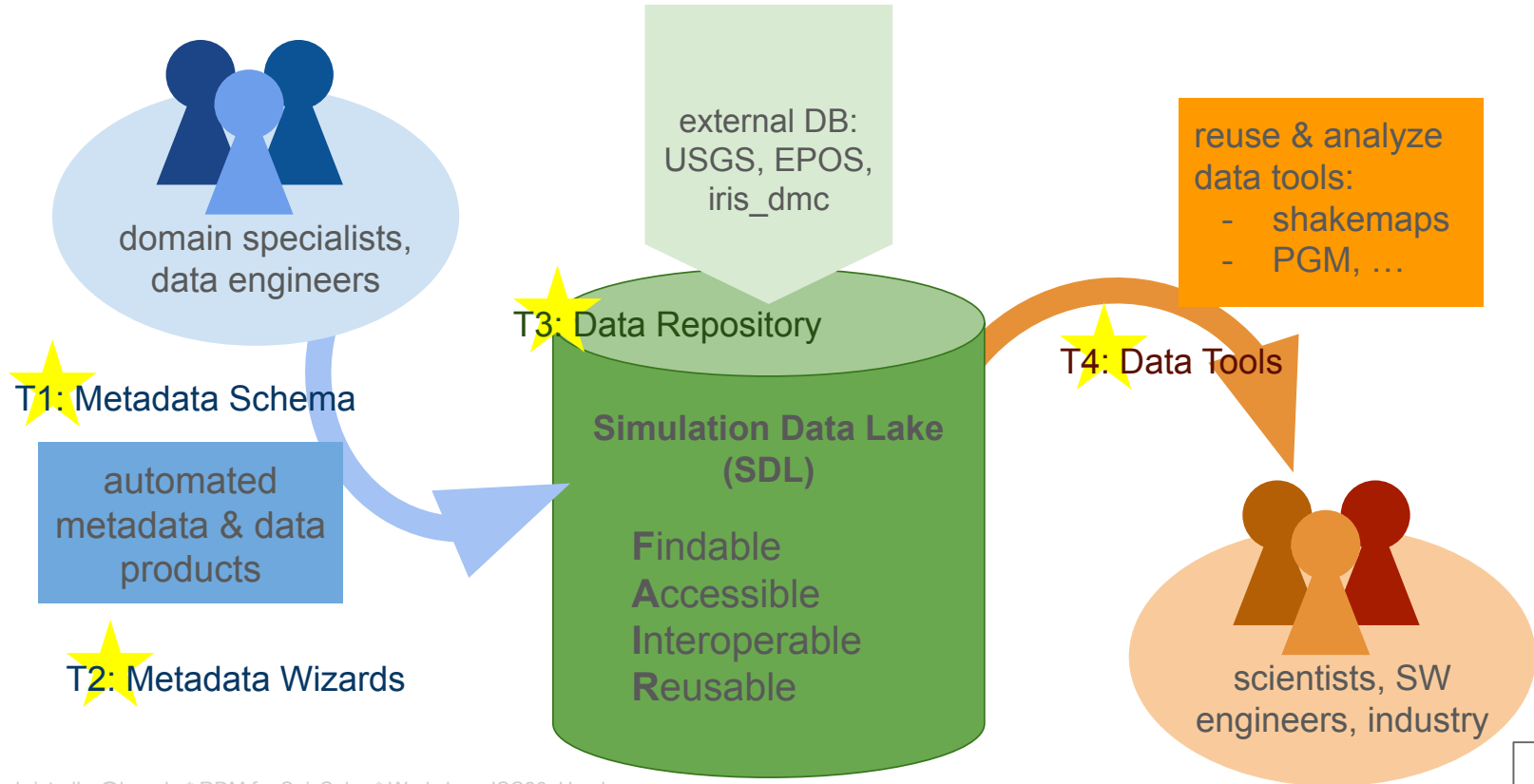
SDL Benchmark

blue: Leonardo@CINECA, green: heisenbug@LMU, turquoise: Laptop@Home



Testfiles (2MB: receiver file, 448MB: fault output, 10GB: S...

NFDI4Earth LUC Proposal



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Leading to an significant increase in data

- This calls for unified workflows to store and access SeisSol data
(input files, meshes, job scripts, outputs and data products)
- The Alto-Tiberina Earthquake Catalog (a DT-Geo “digital twin component” with a rapid response workflow) used the Geo-INQUIRE Simulation Data Lake (SDL)

- We are planning to provide an improved metadata schema and metadata “wizards”
to regularly store SeisSol outputs in a data lake





Thank you for your attention!



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