11TH EGU GALILEO CONFERENCE

Solid Earth and Geohazards in the Exascale Era

ChEESE

# HPC (European) projects in the Solid Earth ecosystem

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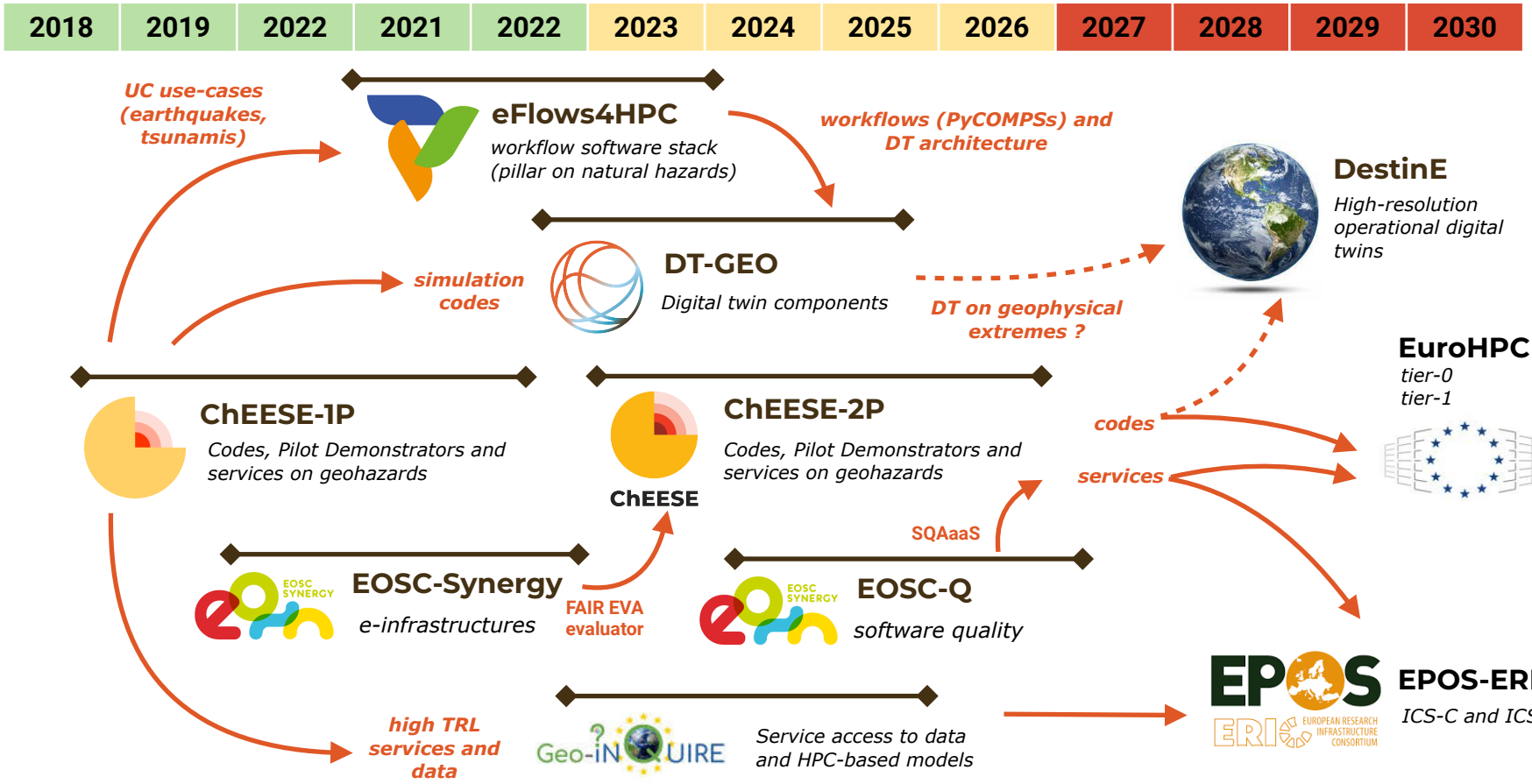
# Recent and current European initiatives related to HPC and SE

| Project | | Funding | GA No | Period | Budget | #Partners | Only for Solid Earth? |
|---|---|---|---|---|---|---|---|
| **ChEESE-1P** |  | H2020 | 823844 | 2018-2022 | 7.6 M€ | 13 | Y |
| **EOSC-Synergy** |   | H2020 | 857647 | 2019-2022 | 5.6 M€ | 19 | N |
| **eFlows4HPC** |  | EuroHPC | 955558 | 2021-2023 | 7.6 M€ | 16 | N |
| **DT-GEO** |  | HE | 101058129 | 2022-2025 | 15.1 M€ | 18 | Y |
| **Geo-INQUIRE** |   | HE | 101058518 | 2022-2026 | 13.9 M€ | 52 | Y |
| **ChEESE-2P** |   | EuroHPC | 101093038 | 2023-2026 | 7.7 M€ | 17 | Y |

# An ecosystem of interrelated projects with long-term (2027-2030) ambitions



# The ChEESE Center of Excellence: underpinning concept

ChEESE

**Covers 3 approaches to exascale**

01

## Capability computing

Solve problems that traditionally have been parameterized because are unaffordable with current hardware

02

## Capacity computing

Solve ensembles of single problems affordable with current petascale-range machines but that can aggregate into an exascale workflow (e.g. data inversion, model data assimilation, uncertainty quantification, etc)

03

## Urgent computing

Solve capability/capacity problems under strict time constrains in terms of time-to-solution (emergency situations)

**ChEESE sustains on 3 pillars: codes, pilots and services**

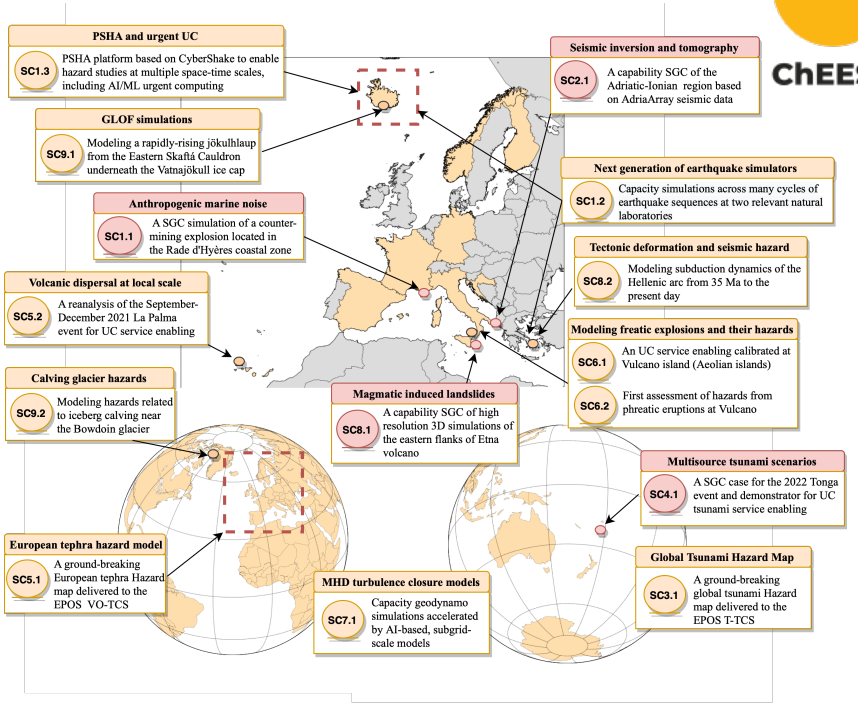
# ChEESE Pillar 1: Flagship codes

| Area | No | Code | Accelerated | Mini-app |
|---|---|---|---|---|
| Computational Seismology | 1 | SeisSol | CUDA | yes |
| | 2 | SPECFEM3D | CUDA, HIP | yes |
| | 3 | ExaHyPE | on-going | no |
| | 4 | Tandem | on-going | yes |
| MHD | 5 | xSHELLS | CUDA | yes |
| Tsunami modelling | 6 | HySEA | CUDA | yes |
| Volcanology | 7 | FALL3D | OpenACC | yes |
| | 8 | OpenPDAC | on-going | no |
| Geodynamics | 9 | LaMEM | on-going | no |
| | 10 | pTatin3D | CUDA | yes |
| Glacier modelling | 11 | Elmer/ICE | on-going | no |

| Code preparation activities | |
|---|---|
| Model Physics | New model physics, couplings and forcing terms |
| Code preparation | Code audit(s) and related POP metrics |
| | GPU porting and fine tuning |
| | Single heterogeneous node performance |
| | Multi-node performance |
| | Algorithmic improvements |
| | Resilience and fault tolerance |
| | IO performance |
| co-desing | Co-design with mini-apps (EuPEX, EuPILOT) |

# ChEESE Pillar 2: Pilot Demonstrators (PDs)

| No | PD name | Area | Initial TRL | Target TRL |
|---|---|---|---|---|
| 1 | Extreme-scale modeling of seismic hazards | CS | 5 | 7 |
| 2 | Joint seismic inversion and tomography | | 4 | 6 |
| 3 | Global tsunami hazard and uncertainty quantification | T | 6 | 8-9 |
| 4 | Complex multi-source tsunami modeling | | 3 | 5 |
| 5 | Ensemble-based volcanic dispersal at multiple scales | V | 5 | 7-8 |
| 6 | Multiphase 3D volcanic explosion modeling | | 4 | 7 |
| 7 | The Earth's dynamo model | MHD | 3 | 5 |
| 8 | Geodynamics to geohazards | GD | 3 | 5 |
| 9 | Glacial outburst floods | GL | 2 | 4 |




PDs materialise in 15 Simulation Cases (SCs) to produce:

- Open datasets
- Urgent computing service enabling
- TCS-TSU and TCS-VO in EPOS

# ChEESE Pillar 3: Services

ChEESE

**01**

**Urgent Computing (UC) service enabling at EuroHPC systems (emergency access mode)**

*Collaboration with IUB members (exercises) and EuroHPC Infrastructure Advisory Group (INFRAG) for UC service certification, deployment, and access*

| | | |
|---|---|---|
| **PD1** | SC1.3 | Physics-based PSHA and urgent UQ |
| **PD4** | SC4.1 | Multi-source high-resolution tsunamigenic scenarios |
| **PD5** | SC5.2 | Volcanic dispersal at multiple scales |
| **PD6** | SC6.1 | Multiphase flow simulation of phreatic eruptions |

**02**

**Services integrated in EPOS Tematic Core Services (TCS)**

*TCS-TSU and TCS-VO*

| | | |
|---|---|---|
| **PD3** | SC3.1 | Global Tsunami Hazard Map |
| **PD5** | SC5.1 | The European tephra hazard map |

**03**

**CI/CD in EuroHPC systems**

*Collaboration with CASTIEL-2*

EOSC SYNERGY → ChEESE

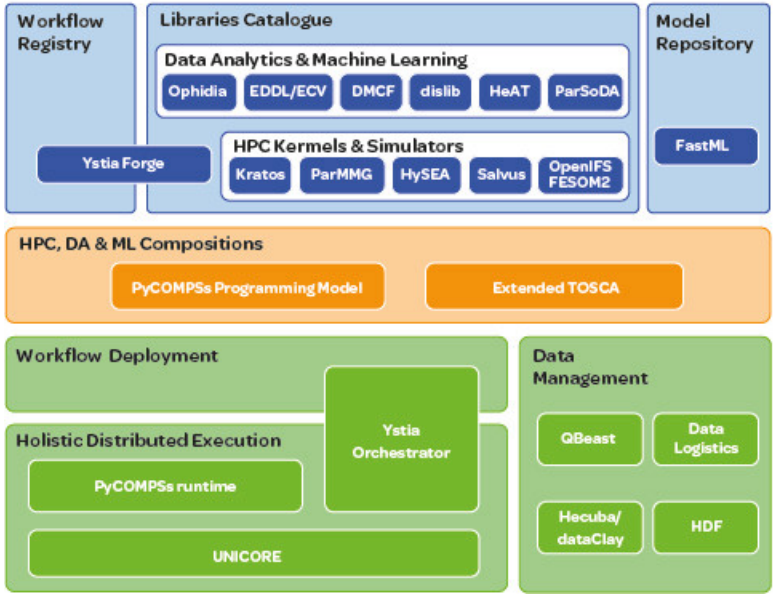
- Software Quality Assurance as a Service (SQAaaS)

# eFlows4HPC: enabling workflows for HPC, HPDA and ML

- Delivery of workflows software stack and added value services tailored to 3 user's communities: industrial digital twins, climate, and UC for natural hazards
- HPC Workflow as a Service (HPCWaaS) platform to facilitate the reusability of the complex workflows in federated HPC infrastructure
- Links with other projects:

| | |
|---|---|
|  | The eFlows UC pillar leverages workflows and codes from ChEESE-1P (modeling of earthquakes and tsunamis shortly after an event is recorded) |
|  | The eFlows4HPC architecture and software stack has been inherited by DT-GEO (with some variations) |

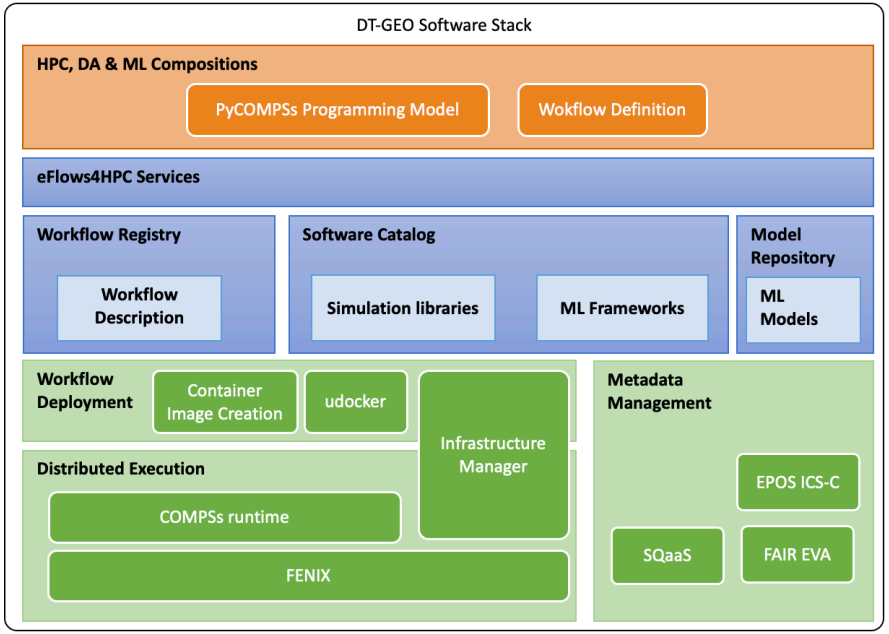
*eflows4HPC software stack*



# DT-GEO: a digital twin for geophysical extremes

- Deploy a pre-operational prototype of Digital Twin (DT) on geophysical extremes for its future integration in the Destination Earth (DestinE) mission-like innitiative
- Implement 12 self-contained Digital Twin Components (workflows) addressing hazardous phenomena from volcanoes (4 DTCs), tsunamis (1 DTC), earthquakes (6 DTCs), and anthropogenic seismicity (1 DTC)
- Links with other projects:

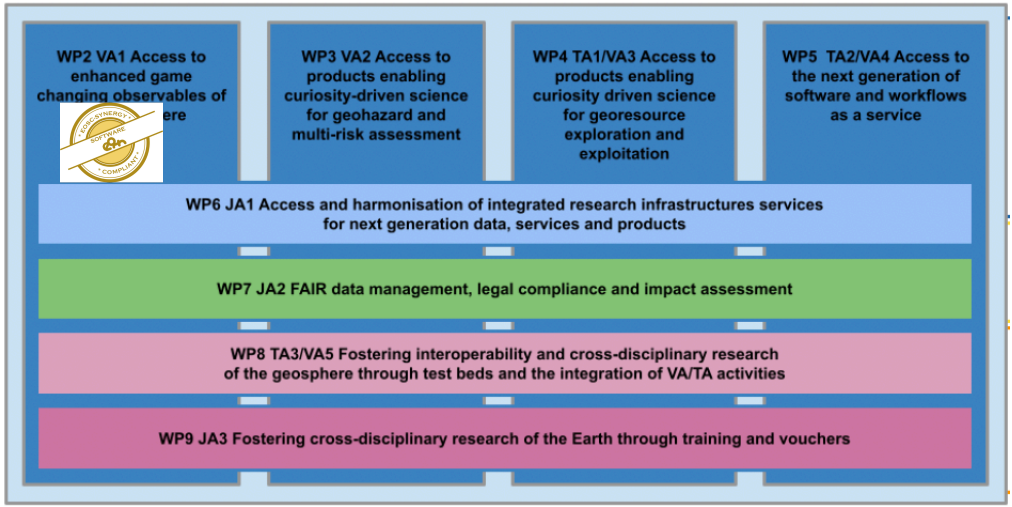
| | |
|---|---|
| → | Most simulation codes (physical models) inherited from ChEESE |
| → | The eFlows4HPC architecture and most software stack is inherited by DT-GEO |
| → | FAIR data evaluator based on EPOS metadata scheme (ICS-C) |
| → | Integration in DestinE (next project, INFRA-2024 call); early attempts for UC cases |



# Geo-INQUIRE: giving access to exisitng products

- A portfolio of 150 Virtual Access (VA) and on-site Transnational Access (TA) to geosphere data, products, and services offered to the scientific community
- Provision of innovative data-management, simulation, training, and visualisation techniques at the interface with HPC facilities
- Includes VA and TA for a set of SaaS and WaaS derived from ChEESE-1P (the so-called ChEESE-CoE RI)

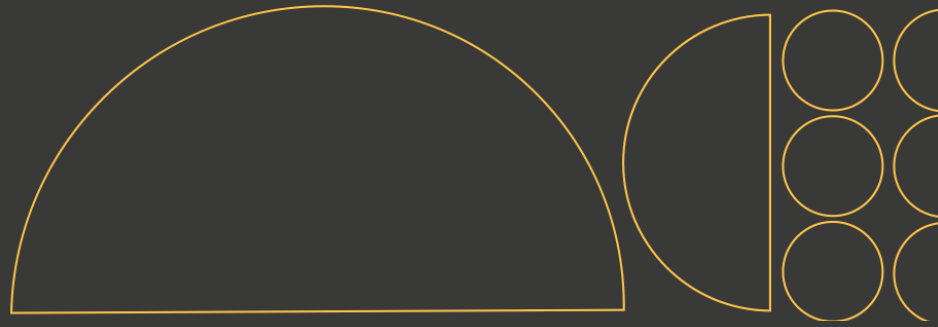
| | |
|---|---|
|  | • SaaS: 4 HPC codes inherited (SeisSol, ExaHyPE, HySEA, FALL3D)<br>• WaaS: for probabilistic hazard analysis (earthquakes, tsunamis, volcanoes) |
|  | • Deployment and interoperability of datasets/ products of the RIs EPOS-ERIC |



# Summary and Conclusions

- Europe has a rich ecosystem of synergistic projects adressing HPC and Solid Earth
- Funding during the period 2018-2026 exceeds 50M€ (will likely grow)
- Tackling of codes, workflows, HPDA, AI and services; emphasis on interoperability and data/ software FAIRness
- DestinE, EPOS and EuroHPC are the main community targets for outreach and operations

# Thank you!



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