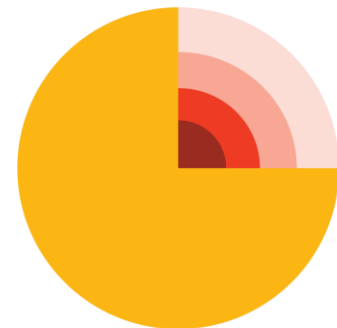


Sorbonne Université and its role in ChEESE 2

Laetitia Le Pourhiet
Sorbonne Université



ChEESE



Presentation Outline

01

Sorbonne University

Beneficiary

02

pTatin3D

A flagship code

03

Pilot Demonstrator

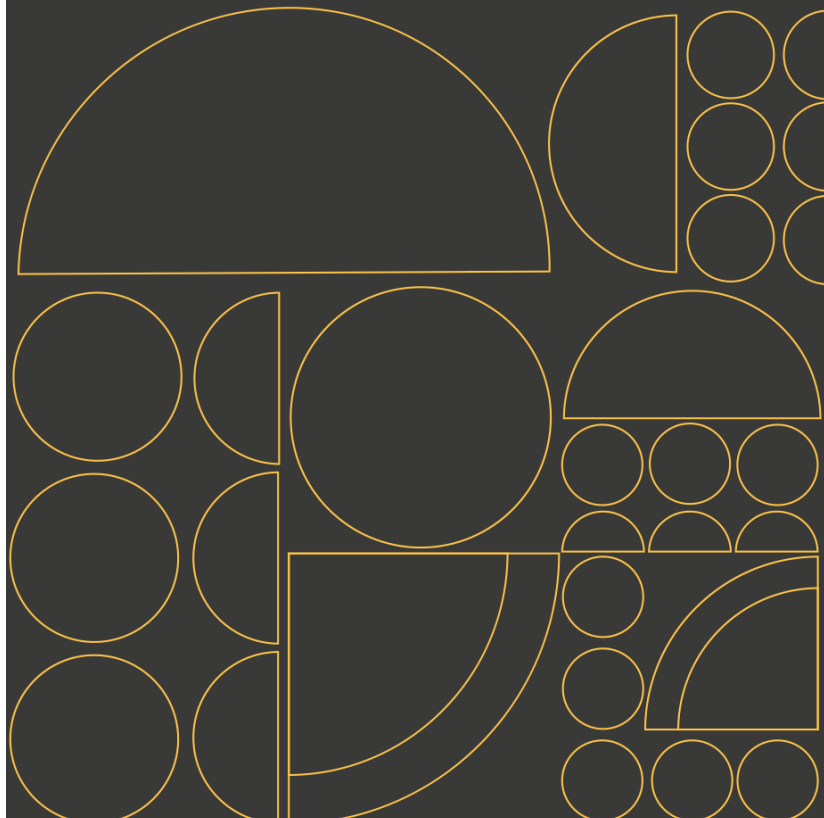
04

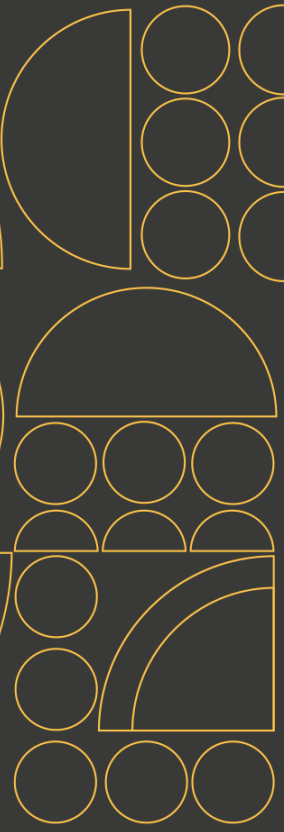
Other actions in ChEESE2



01

Sorbonne University





Combining Humanities, Sciences and Medicine

In Education:

- **52,000 students**, of which **10,200 are international**
- **53 bachelor's degrees** of which **19 are bi-disciplinary**
- **33 master's degrees** with more than **39 international specializations**

In Research:

- **3,300 academic researchers**
- **3,100 partner researchers**
- **115 research structures**
- **3,740 doctoral students**

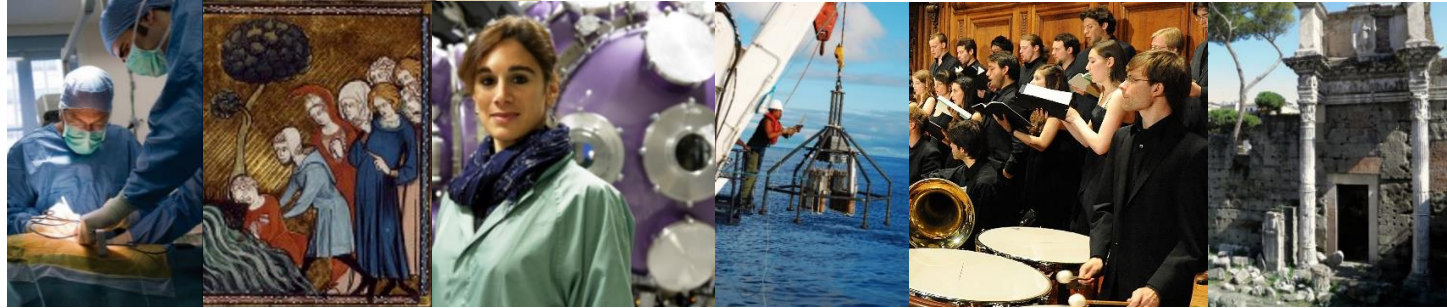


World-Class Science and Engineering

- **1,520** academic researchers
- **18,500** students
- **87** laboratories
- **Polytech-Sorbonne** engineering school
- **4 oceanic observatories** on three coasts and in Paris
- **2 institutes:** Astrophysics of Paris and Henri Poincaré
- **2 science of the universe** observatories
- **Both basic and applied research:**
 - Mathematics, Computer Sciences and Engineering
 - Energy, Matter and the Universe
 - Living Earth, Oceans & the Environment
 - Life Sciences



Research Deep in the Domains and Across Disciplines



In **partnership** with national research organizations:



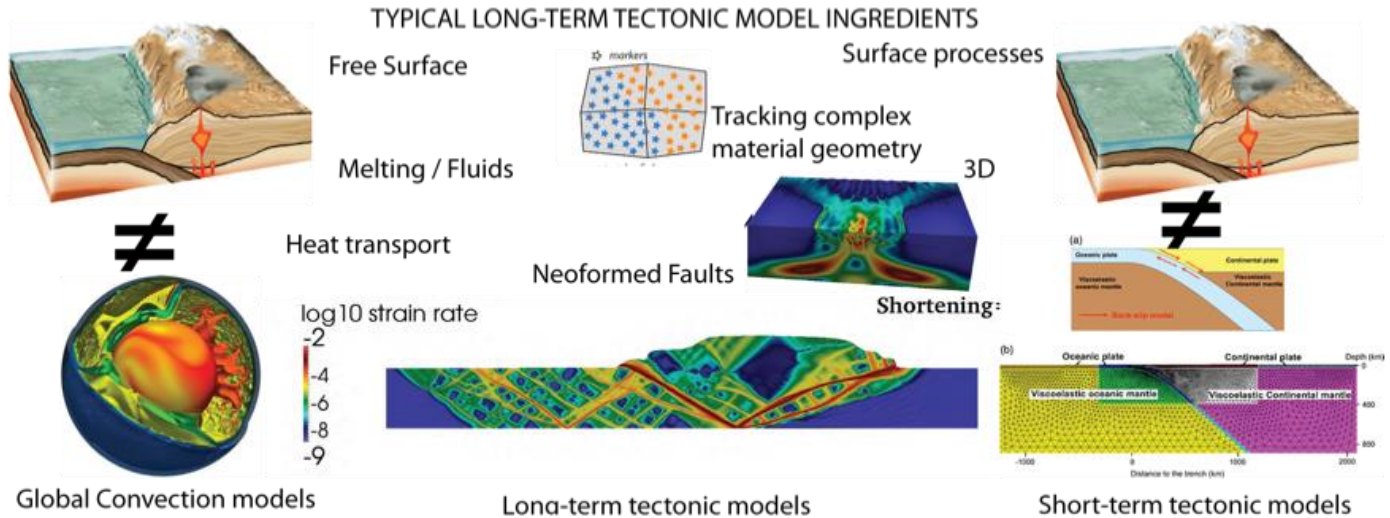
02

pTatin3D

an example of problem driven new development
in PETSc Library



We need special codes because
we deal with problem that are in between solid mechanics and fluid mechanics



pTatin3D philosophy

- Science objectives drive implementation choices
- Discretization quality is not comprised due to issues related to computational cost (memory, time)
- Users want performance versatility
 - fast solution on a supercomputer
 - high-resolution on a small workstation/cluster
- Solvers must be configurable at run-time
 - “simple” problems can use cheap methods
 - “hard” problems can exploit robust (expensive?) methods if and when required



Governing equations

- **Conservation of momentum and mass**

$$\begin{aligned}\nabla \cdot (\eta(\nabla u + \nabla u^T)) - \nabla p &= f && \text{in } \Omega \\ \nabla \cdot u &= 0\end{aligned}$$

$$u = \bar{u} \text{ on } \Gamma_D$$

$$\sigma \cdot n = \bar{t} \text{ on } \Gamma_N$$

- **Conservation of energy**

$$\rho C_p \frac{DT}{Dt} = \nabla \cdot (k \nabla T) + Q$$

- **Coefficient evolution**

$$\frac{d\psi}{dt} + u \cdot \nabla \psi = 0 \quad \longrightarrow \quad \frac{D\eta}{Dt} = 0, \quad \frac{Df_i}{Dt} = 0$$

Solving incompressible Stokes
with large variation in coefficients
requires a lot of MG levels



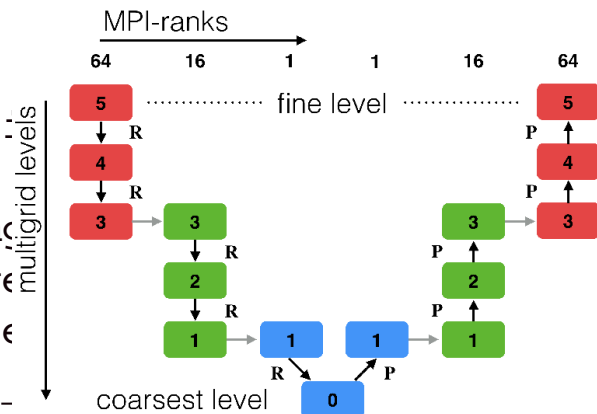
PC_TELESCOPE API

```

-pc_type mg
-pc_mg_levels 2
-pc_mg_galerkin
-mg_coarse_pc_type telescope
-mg_coarse_pc_telescope_reduction_factor 2

-mg_coarse_telescope_pc_type mg
-mg_coarse_telescope_pc_mg_levels 2
-mg_coarse_telescope_pc_mg_galerkin
-mg_coarse_telescope_mg_coarse_pc_type telescope
-mg_coarse_telescope_mg_coarse_pc_telescope_reduction_factor 2

-mg_coarse_telescope_mg_coarse_telescope_pc_type mg
-mg_coarse_telescope_mg_coarse_telescope_pc_mg_levels 2
-mg_coarse_telescope_mg_coarse_telescope_pc_mg_galerkin
    
```

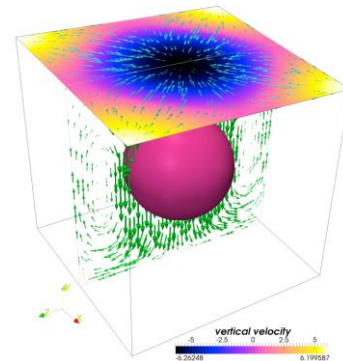


Linear Stokes Solver: Strong Scaling

- 96^3 Q2-P1 elements
- 3-level method
- Chebyshev(10)/Jacobi
- Coarse grid solvers:

$$R = 0.25$$

$$\Delta\eta = 10^4$$



H-Krylov	MPI-rank	12	4096 ranks
	Strategy		
H-Krylov	Smoother	4.8848e+02	1.1651e+02
	Solve	9.9545e+02	1.9926e+01
GAMG	Smoother	3.929e+01	4.8522e+00
	Solve	5.9950e+02	7.4663e+01
Repartition	Smoother	1.4882e+02	1.7607e+01
	Solve	6.4287e+02	8.0635e+01

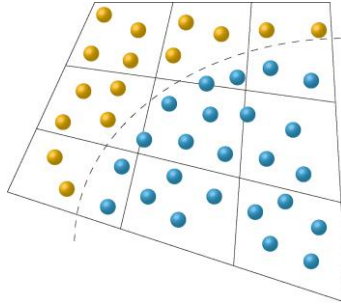
78% Strong scaling efficiency

45% Strong scaling efficiency

85% Strong scaling efficiency

Wall clock times (sec)

Discretisation uses MPM



Particle In Cell (PIC) *Harlow
& Welch, Phys. Fluids,
(1965)*

Material Point Method
(MPM) *Sulsky & Brackbill,
JCP, (1991)*

$$A(\mathbf{u}, \mathbf{v}) = \int_{\Omega} \sum_{i,j=1}^d 2\eta^{\lambda} D_{ij}(\mathbf{u}) D_{ij}(\mathbf{v}) dV,$$
$$F(\mathbf{v}) = \int_{\Omega} \mathbf{v} \cdot \mathbf{f}^{\lambda} dV + \int_{\Gamma_N} \mathbf{v} \cdot \bar{\mathbf{t}} dS.$$

- Reconstruct coefficients (**viscosity**, **density**) at quadrature points for the flow problem using material points

MPM is expensive in term of communication in 3D

DMSwarm API

```
/* Create a DMSwarm object */  
DMCreate( PETSC_COMM_WORLD , &swarm );  
DMSetType( swarm , DMSWARM );
```

Data Storage API

```
/* Fields requires a textual name, a dimension, and a data-type */  
DMSwarmRegisterPetscDatatypeField( swarm , "viscosity" , 1 , PETSC_REAL );  
DMSwarmRegisterPetscDatatypeField( swarm , "rock_type" , 1 , PETSC_INT );  
DMSwarmRegisterUserStructField( swarm , "packed_properties" , sizeof(struct MyCustomData) );  
DMSwarmFinalizeFieldRegister( swarm );
```

Data Manipulation API

```
DMSwarmSetLocalSizes( swarm , 100 , DMSWARM_BUFFER_DEFAULT );  
DMSwarmAddPoint( swarm ); /* Increase size by +1 */  
DMSwarmAddNPoints( swarm , points_to_add ); /* Increase size by +N */  
DMSwarmRemovePoint( swarm ); /* Decrease size by -1 */  
DMSwarmRemovePointAtIndex( swarm , pid_to_remove ); /* Delete specific point */
```

Data Access API

```
PetscReal *particle_viscosity;  
DMSwarmGetField( swarm , "viscosity" , &bs , &dtype , (void**)&particle_viscosity );  
DMSwarmRestoreField( swarm , "viscosity" , &bs , &dtype , (void**)&particle_viscosity );
```

Data Migration API

```
/*  
... user code to assign new owner neighbour ranks on each point ...  
*/  
DMSwarmMigrate( swarm , PETSC_TRUE ); /* TRUE implies sent points should be removed */
```



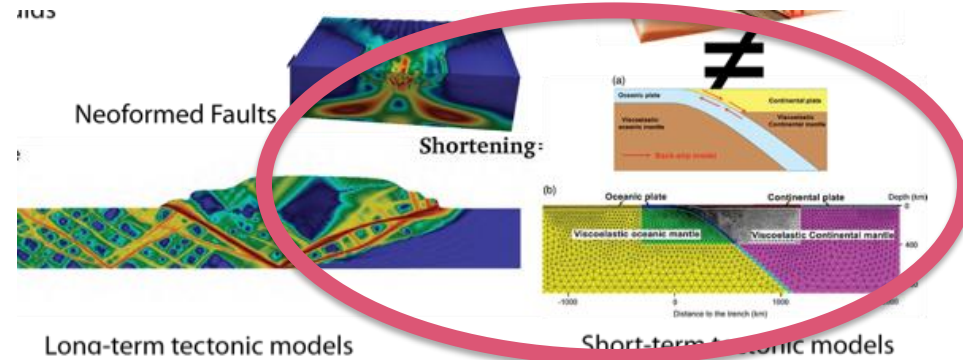
03

PD / SC's



Exascale capability simulation cases and Scientific Grand Challenges

One way linking of rupture propagation code to long-term geodynamic modeling



T5.1.10.

Add support for Navier-slip type boundary conditions for spherical cap regional model domains using a symmetric Nitsche formulation.

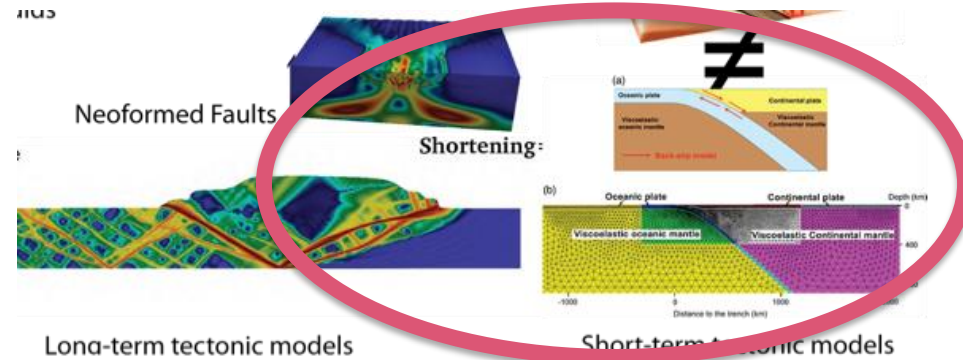
Accurate projection of material properties (stress and density) into a field defined on a mesh.

Integration of pTatin3D output data formats with ASAGI to enable efficient import of 3D volume data into SeisSol.



Exascale capability simulation cases and Scientific Grand Challenges

One way linking of rupture propagation code to long-term geodynamic modeling



SC8.2

3D evolution of tectonic deformation and rheology as driver of seismic hazard in the Hellenic arc

Simulate the evolution of the tectonic structure of the upper plate of the Hellenic subduction zone in response to subduction dynamics from 35 Ma to the present day with a 1 km spatial resolution.



04

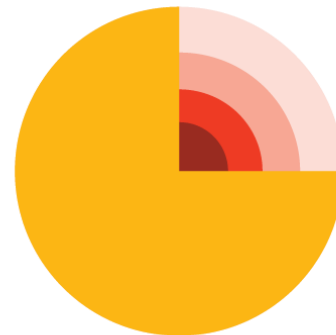
Other actions



SU participation to work Packages and specific tasks :

Work Package	Person Months/ Tasks
WP1: Project Management	1pm
WP2: Exascale technical challenges in flagship codes	7 pm T2.1, T2.3
WP3: Co-design with European HPC vendors and technologies	3 pm T3.1,T3.3
WP4: Simulation ecosystem	
WP5: Farming Pilot Demonstrators	7pm T5.1.4, T5.1.10
WP6: SCs and service enabling using EuroHPC infrastructures	4pm T6.1, T6.2
WP7: Dissemination, outreach and capacity building	1pm

Thank you



ChEESE-2P



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