



High Performance Simulations based on new processor architecture for seismology and geophysics

ANR-JST ICT French – Japanese Workshop

Fabrice Dupros and **Hideo Aochi**

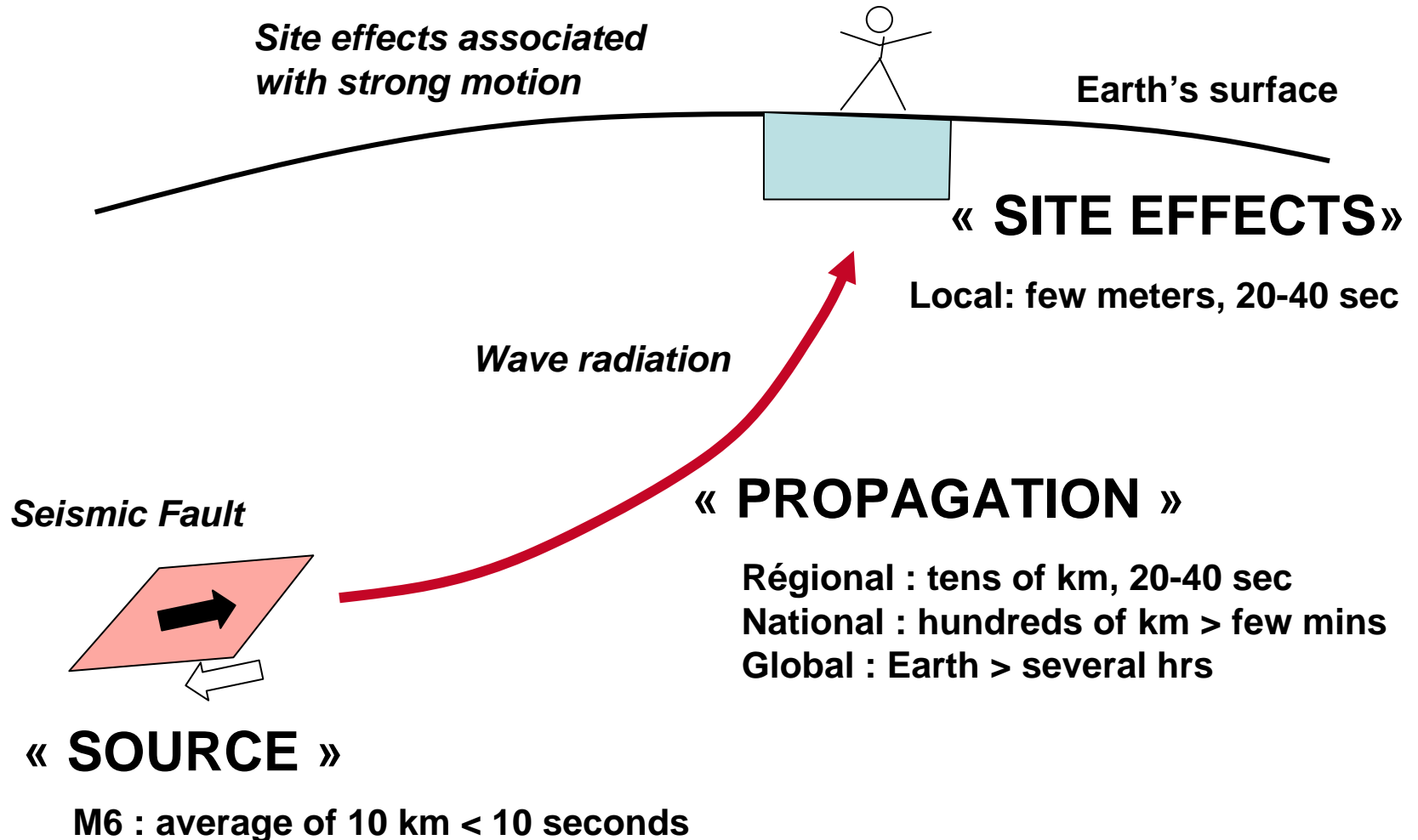
BRGM at a glance

France's leading public institution in Earth Science applications for the management of resources and surface and subsurface risks.

- > Understanding geological processes.
- > Providing necessary tools for surface, subsurface and resource management, for risk and pollution prevention.

- > Over 600 researchers located in Orleans, France.

Different scales for the observation of seismic phenomena



➔ Requirements from the physics

- ✓ Refinement of mesh to consider strong motion simulation.
- ✓ Increase the complexity of the model (geology, physics, coupling..)

Use of HPC for realistic three-dimensional simulation

➔ Trends in parallel architectures

- ✓ Increase of the number of cores
- ✓ Memory hierarchy

➔ Impact for applications in geophysics ?

➔ Which programming model to maximize performance ?



NUMASIS Project



2006-2009 ANR program

« High Performance Computing »

Goal: Seismic simulation on NUMA and multicore architectures

Partners: INRIA (5 teams) – BULL – BRGM – CEA – TOTAL

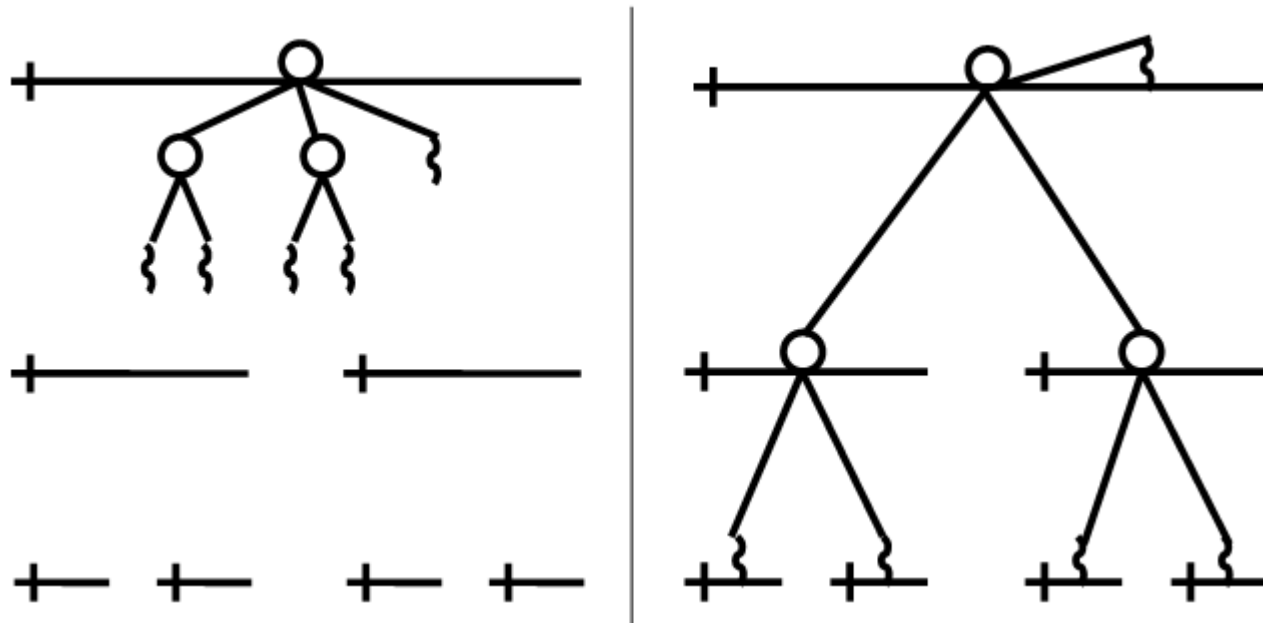
Leader: J-F Méhaut (INRIA/LIG)

- ✓ Thread scheduling and Memory affinity
- ✓ Numa and multicore aware algorithm and numerical libraries
- ✓ Large scale numerical simulation



NUMASIS Project

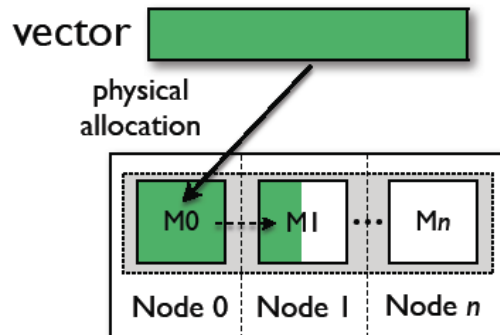
Thread scheduling and OpenMP Runtime (INRIA Runtime)



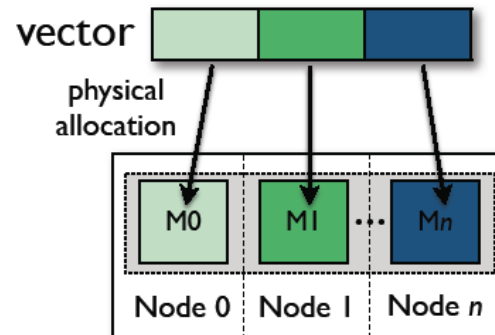
NUMASIS Project

Memory Affinity Interface (INRIA MESCAL)

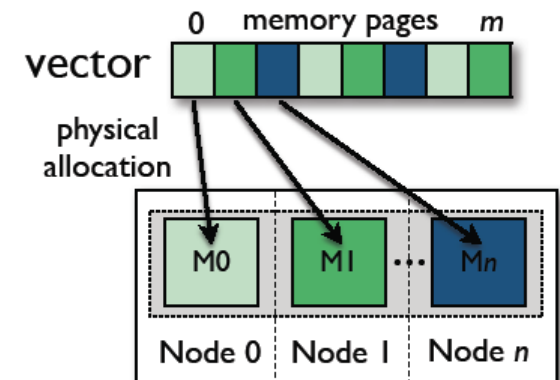
bind_all policy



bind_block policy

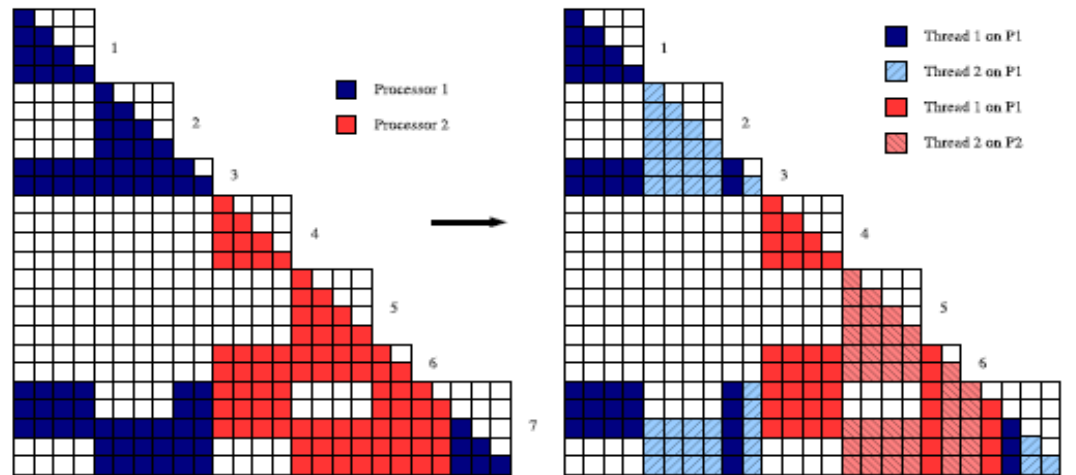


cyclic policy

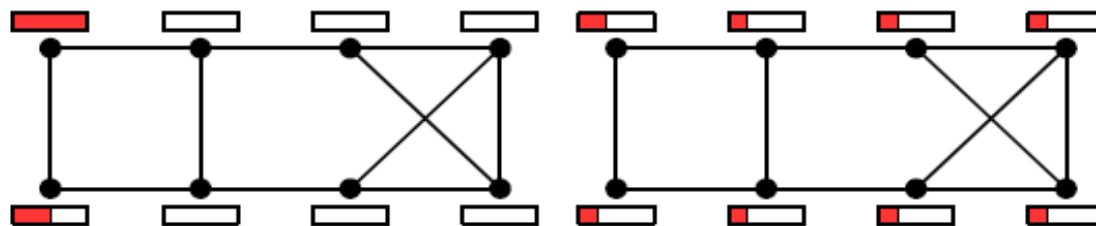


NUMASIS Project

NUMA-Aware numerical solver (INRIA Scalaplix)



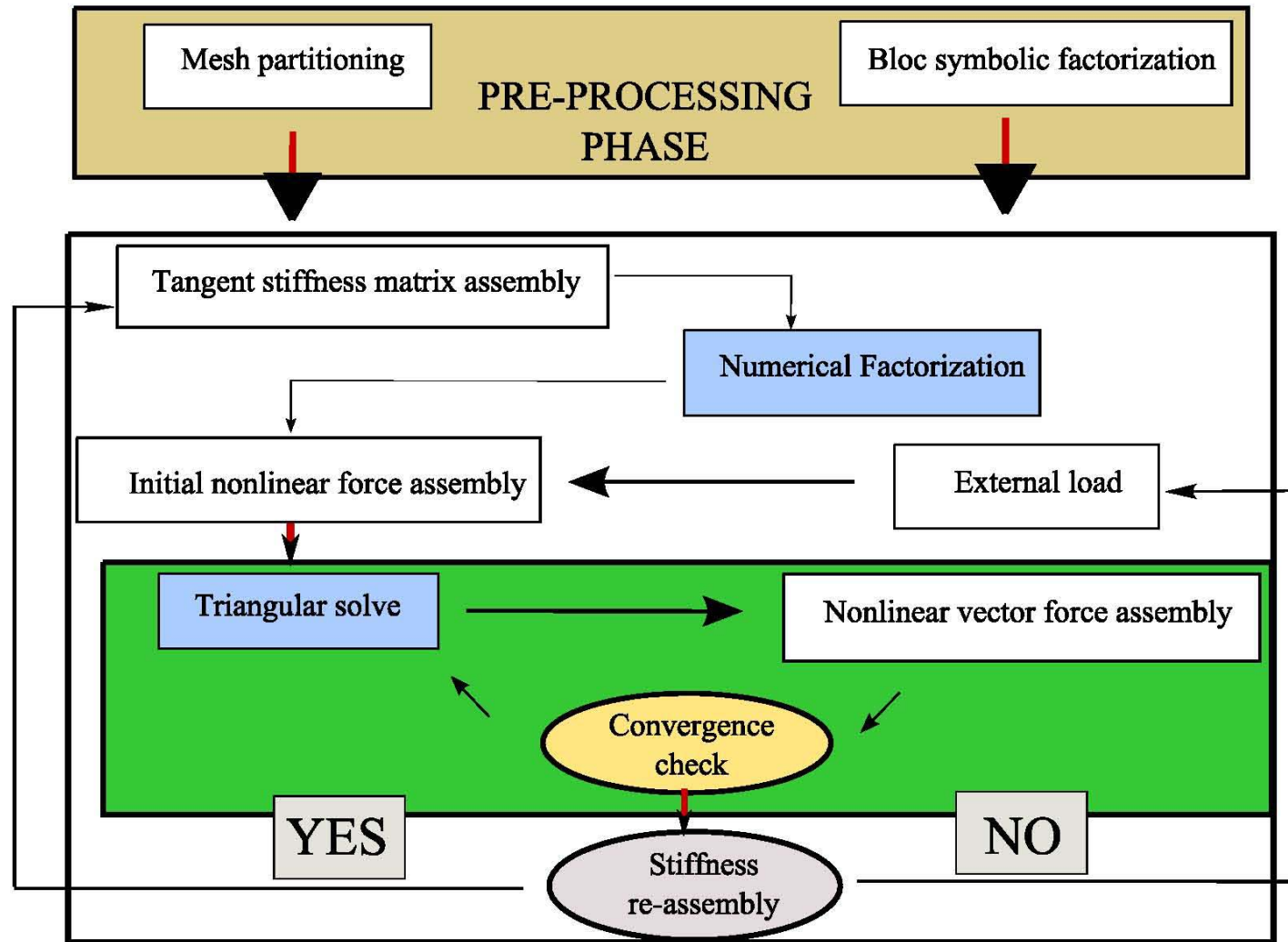
(a) Localization of new NUMA-aware allocation in the matrix



(b) Initial allocation

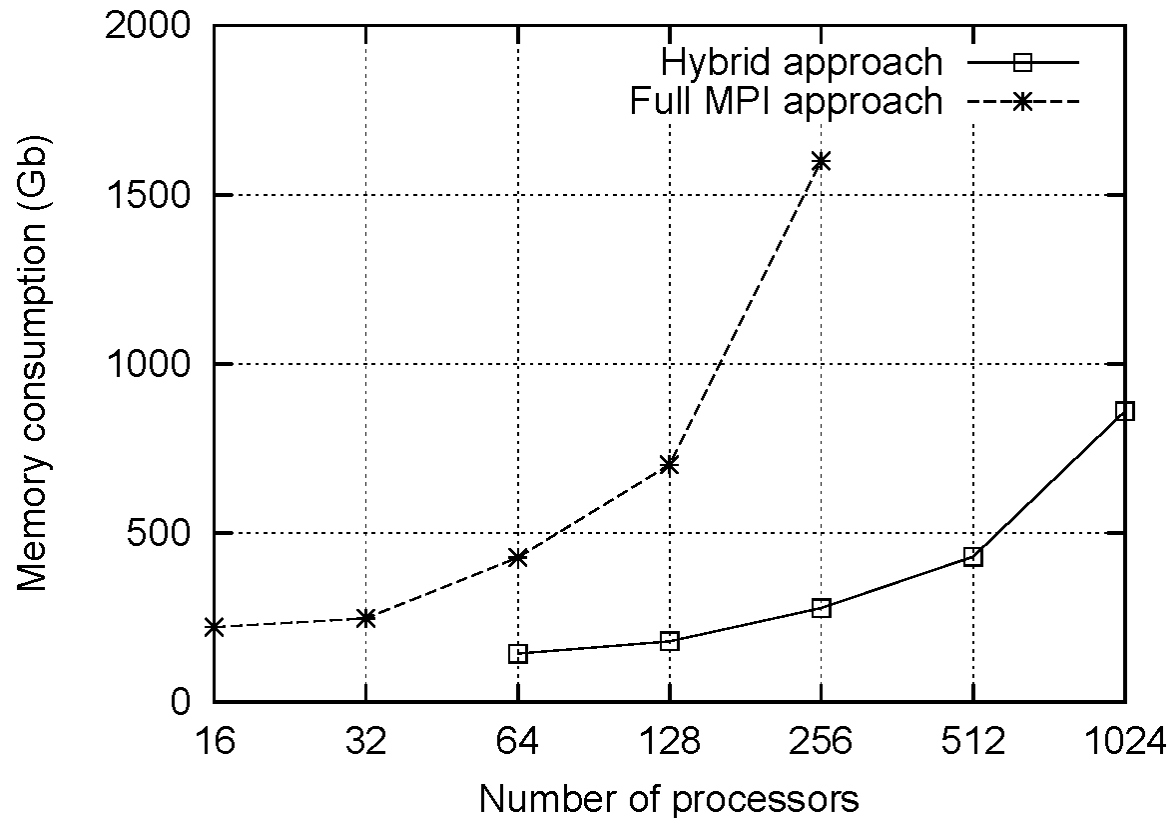
(c) New NUMA-aware allocation

Finite-elements numerical method



Sparse Direct numerical solver – Pastix (INRIA)

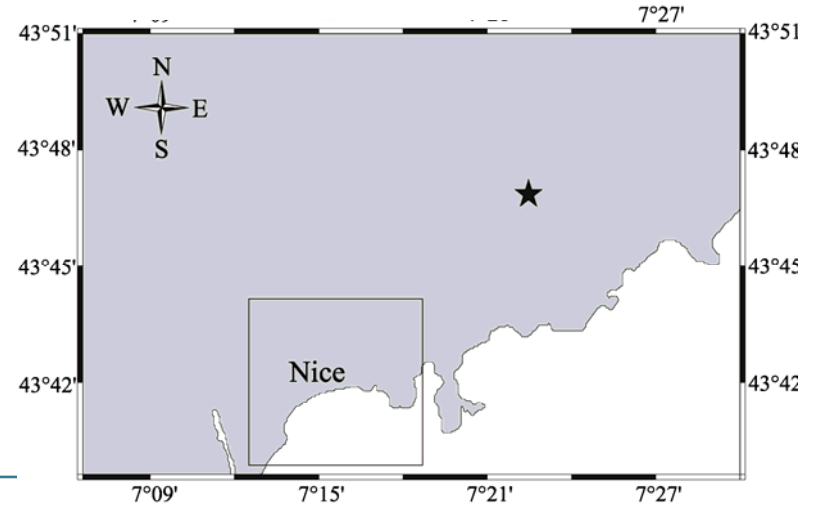
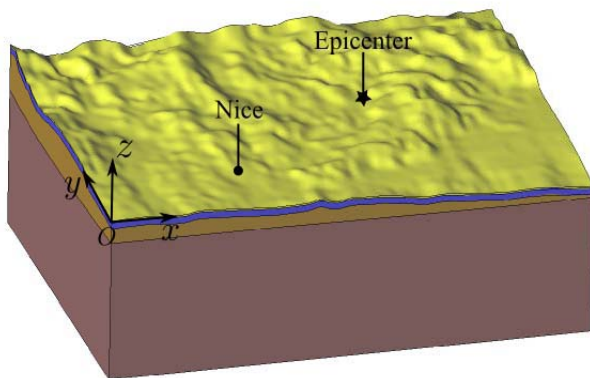
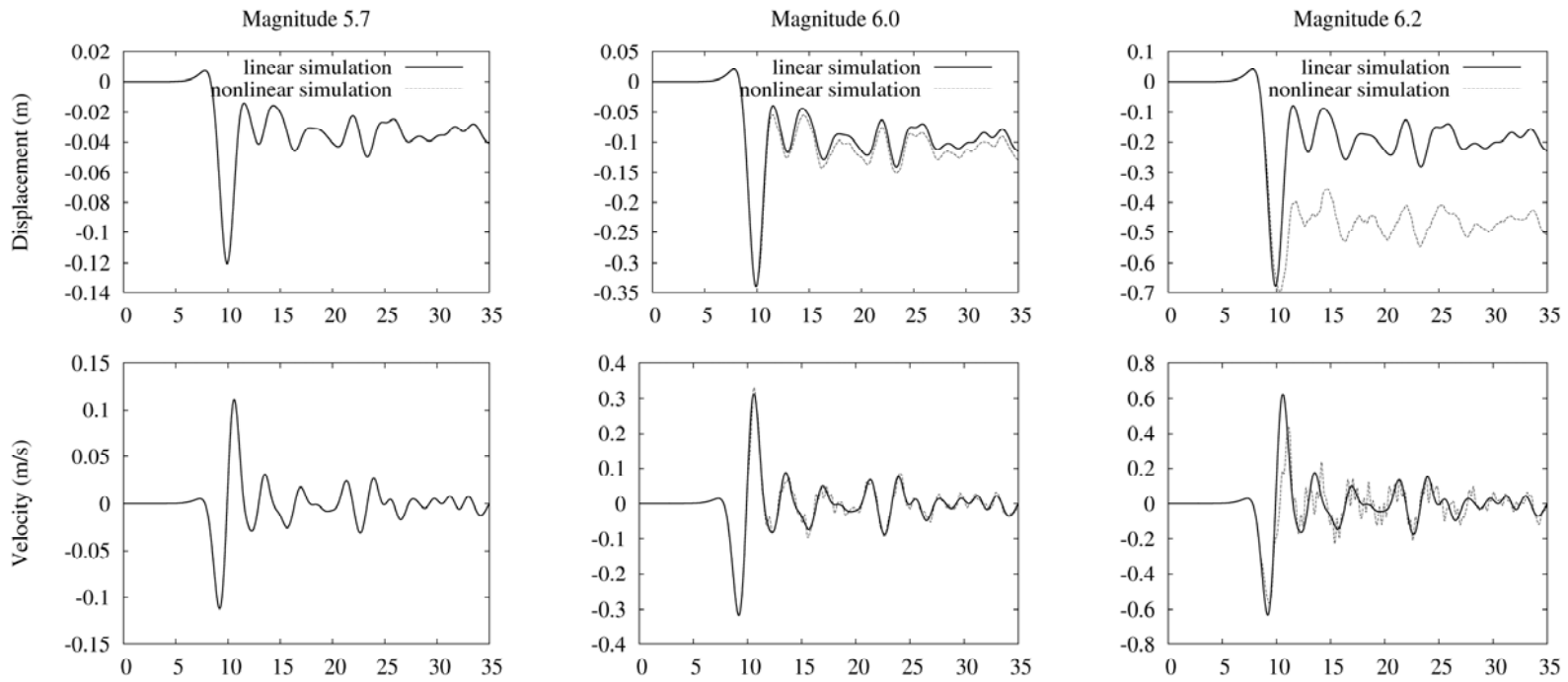
- Target material nonlinearity : Implicit numerical scheme
- Sparse Direct linear solver due to ill-conditioning (bottleneck)



JADE CINES/GENCI platform

Impact of the programming model on the memory consumption

French Riviera strong motion simulations



Finite differences numerical method

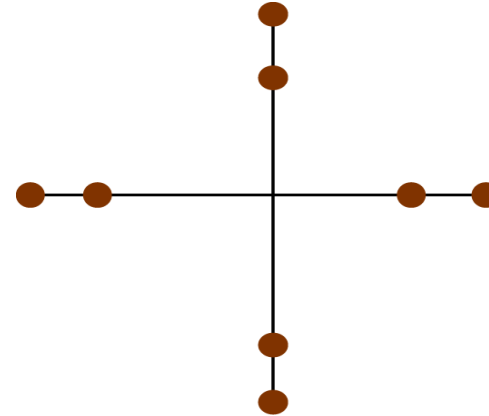
```
For i=1,Nx  
For j=1,Ny  
For k=1,Nz  
init()
```

Initialization

```
For i=1,Nx  
For j=1,Ny  
For k=1,Nz  
compute_velocity()
```

```
For i=1,Nx  
For j=1,Ny  
For k=1,Nz  
compute_stress()
```

Time step loop



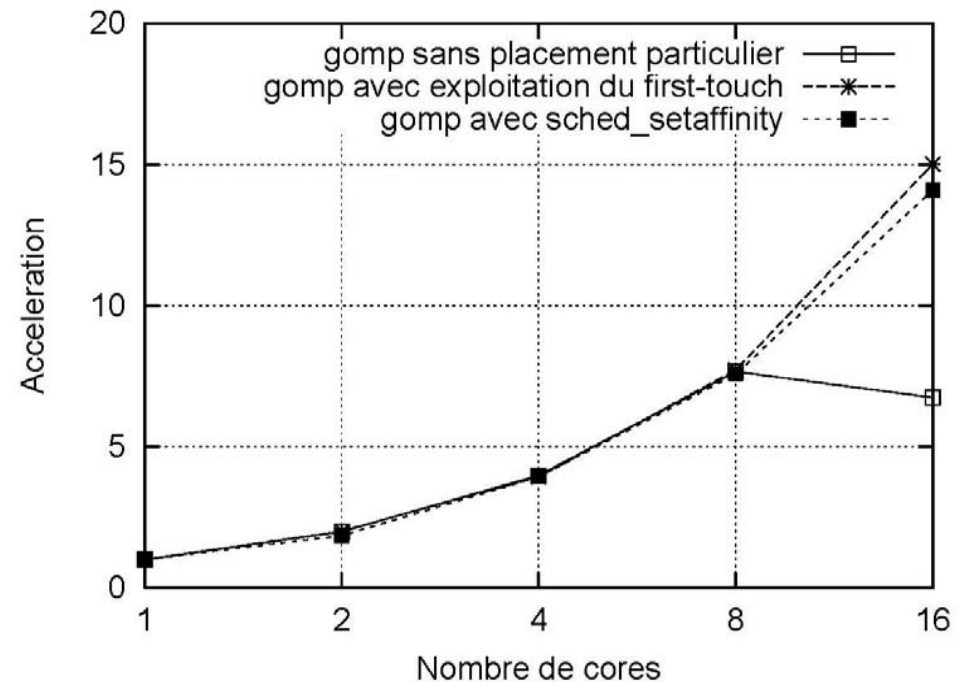
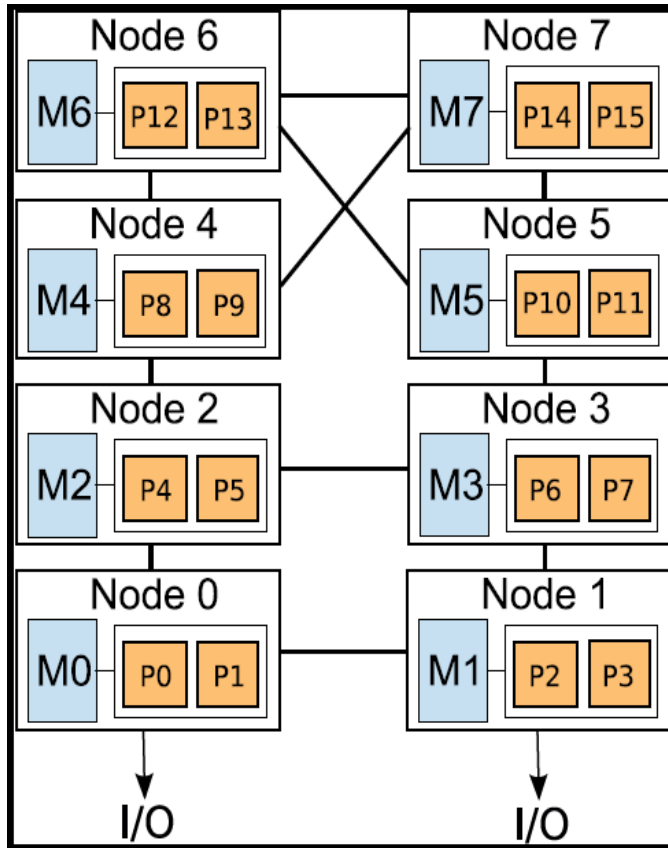
Free surface
condition



Absorbing
Conditions

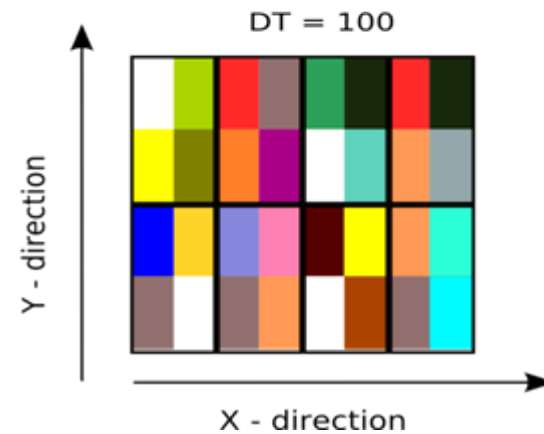
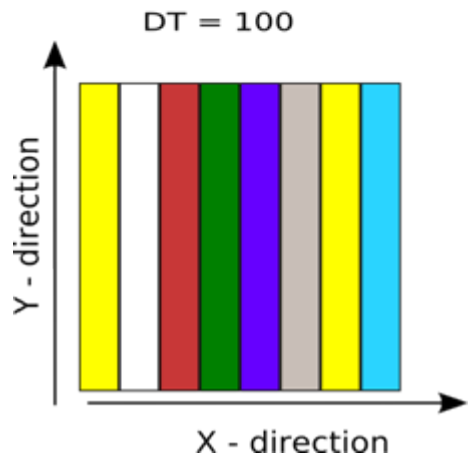
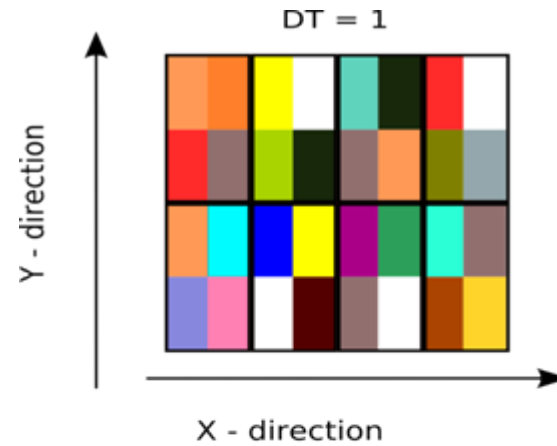
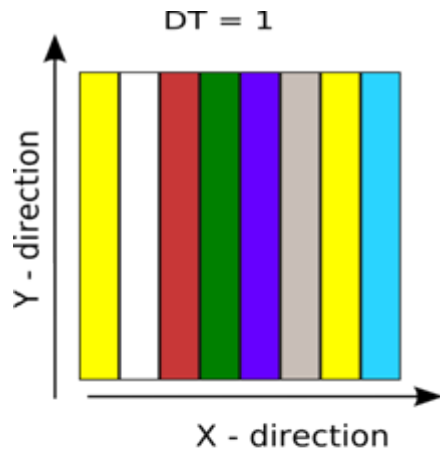
Physical
domain

Challenge: NUMA Penalty



Dupros.F, Pousa.C, Carissimi. A, Méhaut J.F : **Parallel simulations of seismic wave propagation on NUMA architectures.** *PARCO'09*

Memory access pattern



REGULAR

memory access pattern

IRREGULAR

memory access pattern

NUMA Penalty - Memory Affinity interface

OpenMP implementation of 3D seismic application

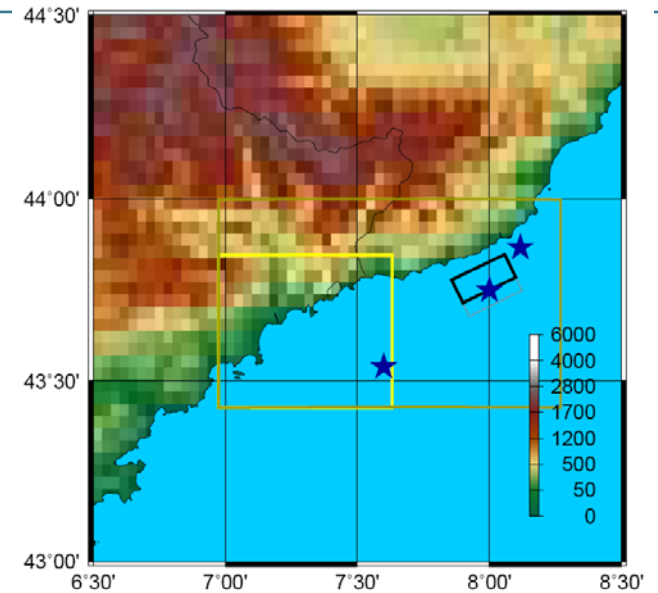
Problem size 2.6 Go	REGULAR memory access	IRREGULAR memory acces
First Touch	127.8	126.0
BIND memory policy	70.1	115.5
CYCLIC memory policy	63.0	67.2

Problem size 18 Go	REGULAR memory access	IRREGULAR memory access
First Touch	92.3	90.1
BIND memory policy	83.1	184.8
CYCLIC memory policy	90.6	86.8

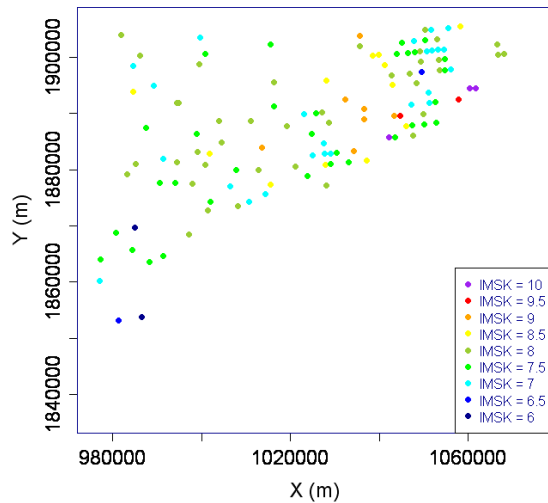
- Choice of the memory policy - knowledge of the underlying architecture
- Impact of the memory access

Ligure, SE France, en 1887 (M6.3?)

➤ **Reproduction of a historical earthquake and its scenario**

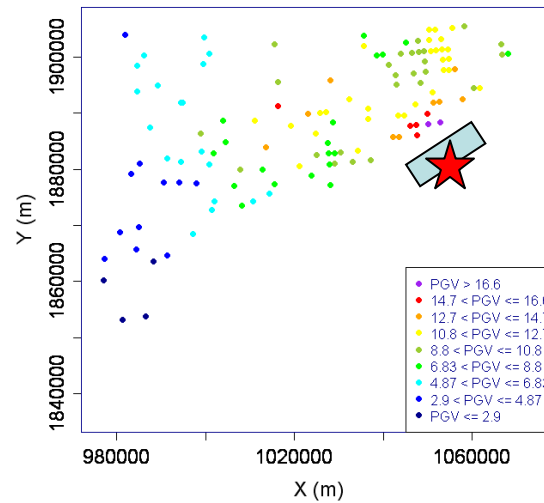


Intensity (MSK64)



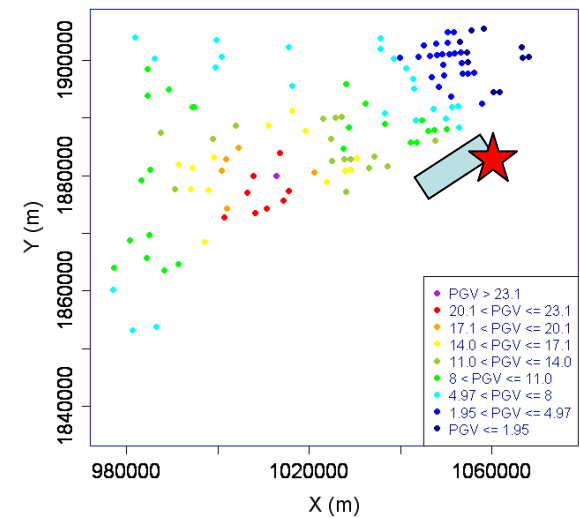
Observation

PGV (cm/s)



Simulation 1 (bi)

PGV (cm/s)

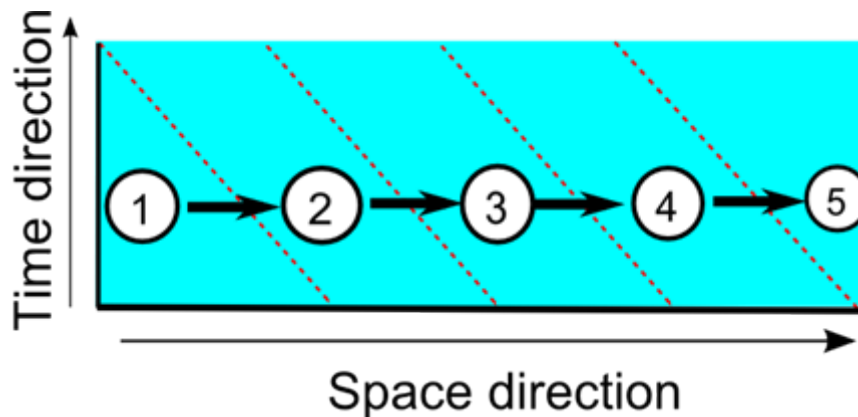


Simulation 2 (uni)

Ongoing work

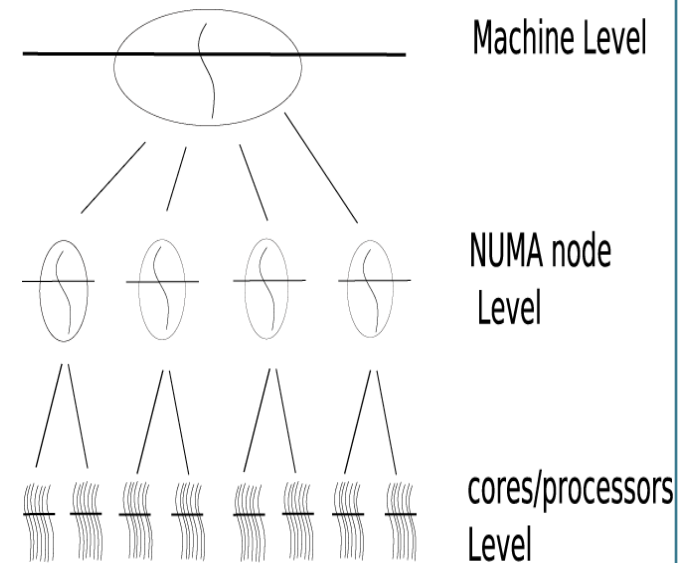
⇒ Timespace decomposition

- ✓ Time skewing /cache oblivious



⇒ Nested OpenMP parallelism

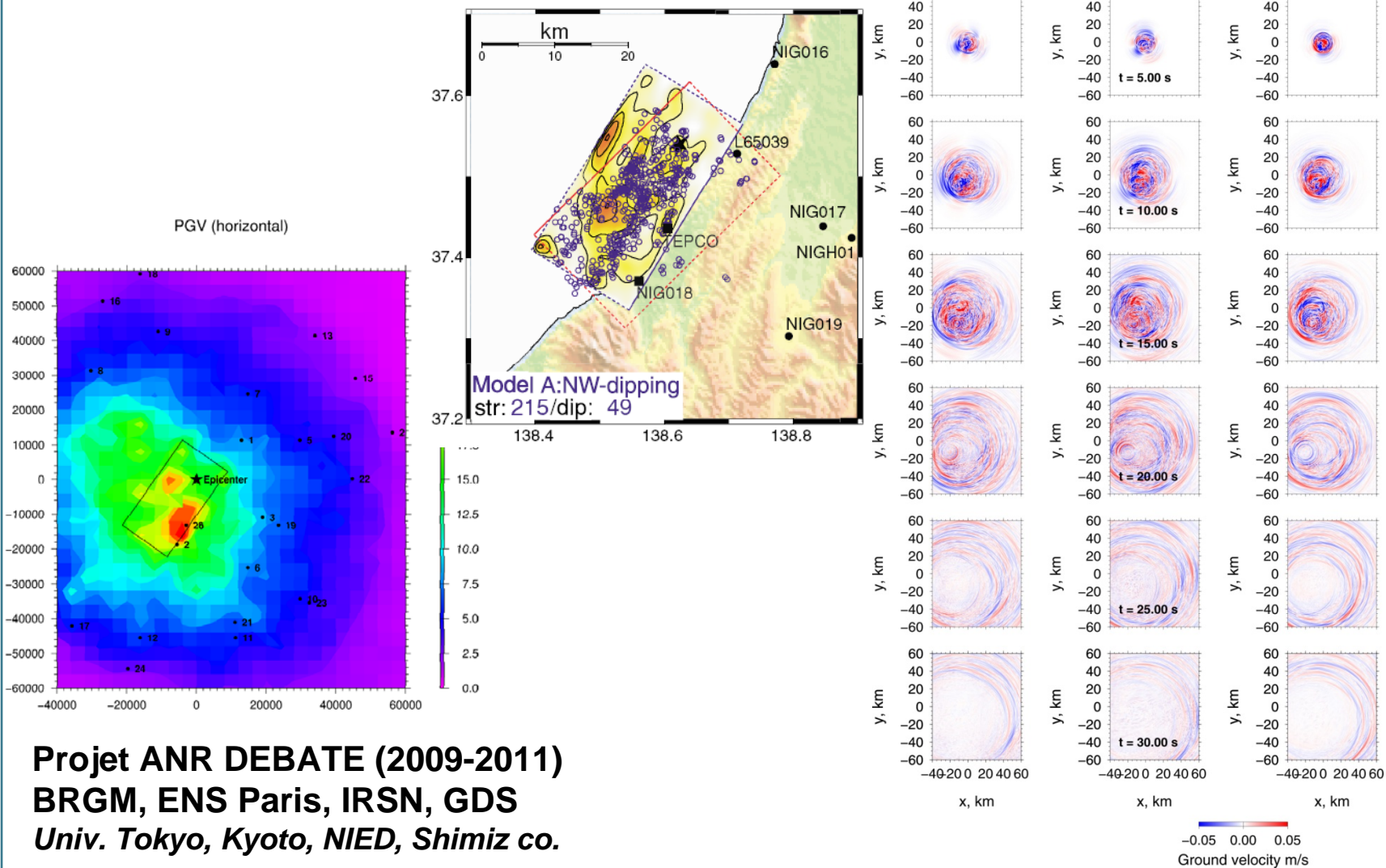
- ✓ Forestgomp framework (INRIA Runtime)



⇒ Very large scale simulations

- ✓ Validation of these proposition on emerging systems.
- ✓ Hybrid parallel linear solver for finite-elements method (Collaboration with INRIA)

New case study with Japanese colleagues Niigata-Chuetsu-Oki, Japon, en 2007



Projet ANR DEBATE (2009-2011)
BRGM, ENS Paris, IRSN, GDS
Univ. Tokyo, Kyoto, NIED, Shimiz co.

French-Japanese collaboration in numerical geophysics and seismology.

- Strong background of numerical scheme development in France.**
- Application and data-assimilation experiences in Japan.**
- Capitalize and extend the results of the NUMASIS project .**

⇒ French-Japanese workshop on earthquake source

- 5-9 October 2009, Paris-Orleans, France**
- Organized by BRGM, Univ Tokyo, AIST, IPGP, ENS Paris**



Thanks for your attention