GeoPF:
Simulation of full waveforms for 3-D Earth structures

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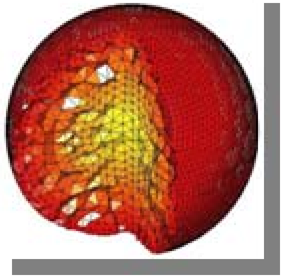
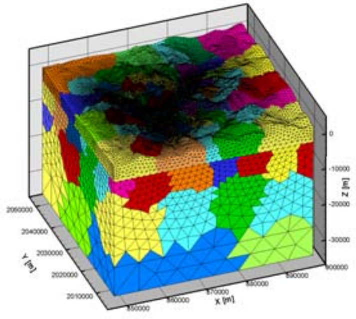
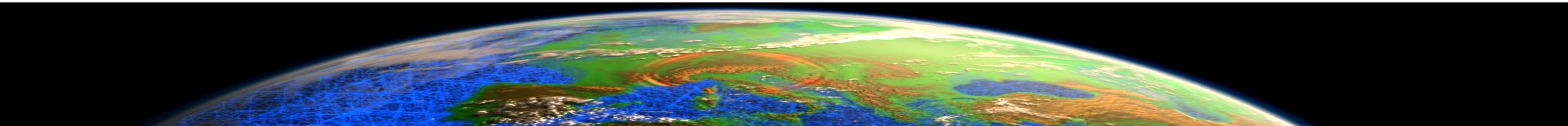


I 3-D wave propagation through complex Earth models on all scales

- Unstructured grids – discontinuous Galerkin
- Global waves – reservoir problems – dynamic rupture

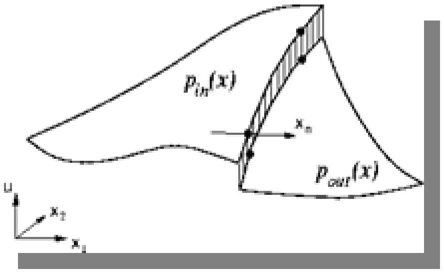


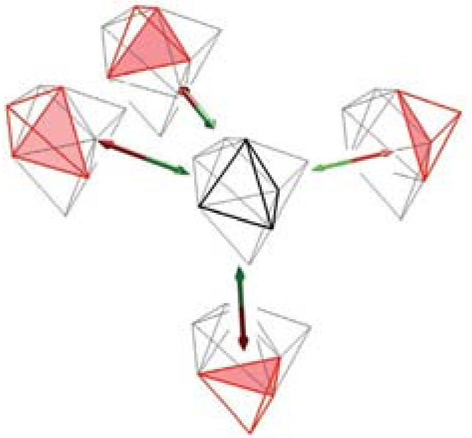
II GeoPF – the final year



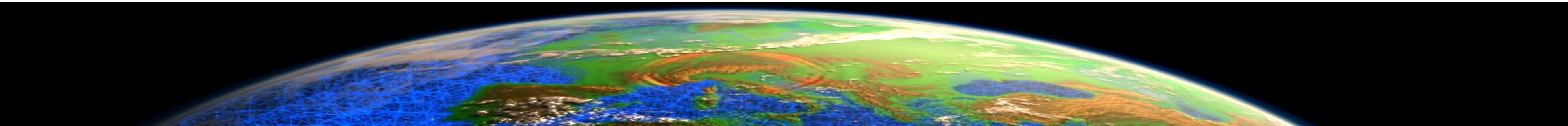
Arbirtrarily high-orDER - Discontinuous Galerkin

- Combination of a **discontinuous Galerkin method** with ADER time integration
- Piecewise polynomial approximation combined with fluxes across elements (**finite volumes**)
- **Time integration as accurate as spatial approximation**, applicable also to strongly irregular meshes (not so usually for FD, FE, SE)
- The scheme is entirely local, no large matrix inversion -> **efficient parallelization**
- **Drawback**: Algorithms on tetrahedral grids **slower** than spectral element schemes on hexahedra



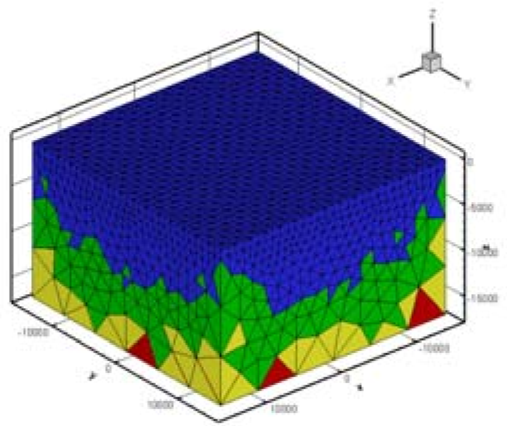


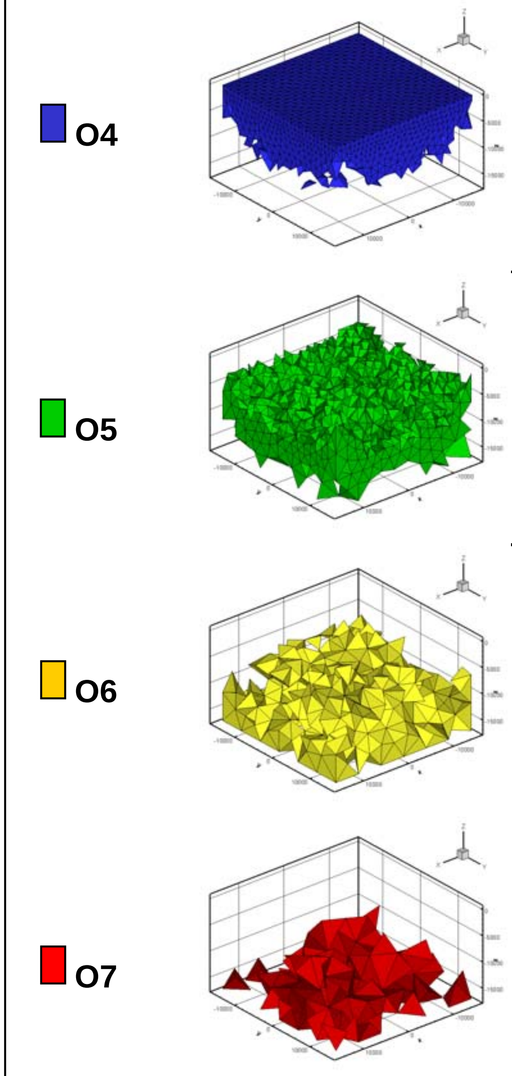
Several articles in Geophys. J. Int., Geophysics, a.o. by Käser, Dumbser, de la Puente, and co-workers



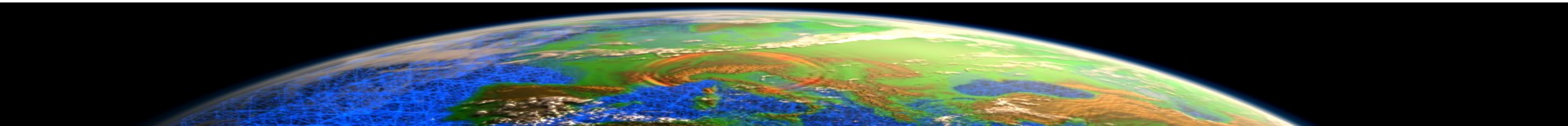
P-adaptivity

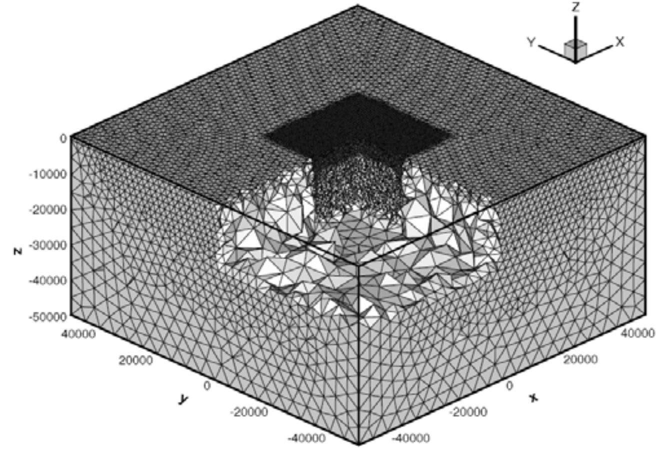
- Use high precision (i.e., high-order polynomials) only where necessary
- High precision where cells are large (high velocities)
- Low precision where cells are small (because of structural heterogeneities)





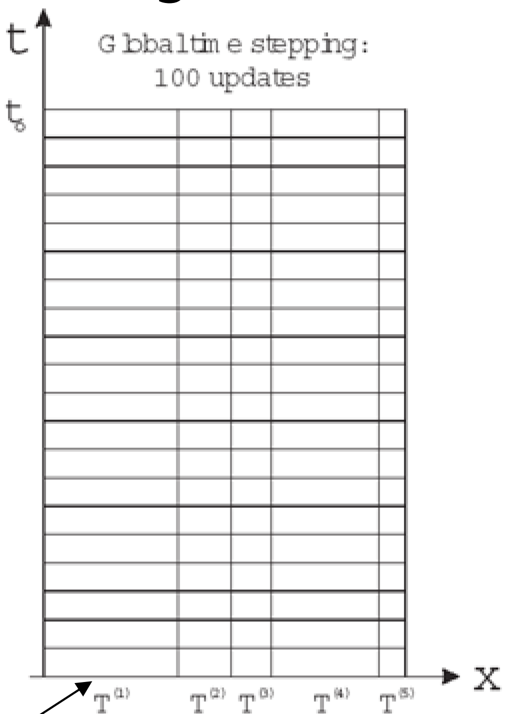
Dumbser, Käser and Toro, GJI, 2007



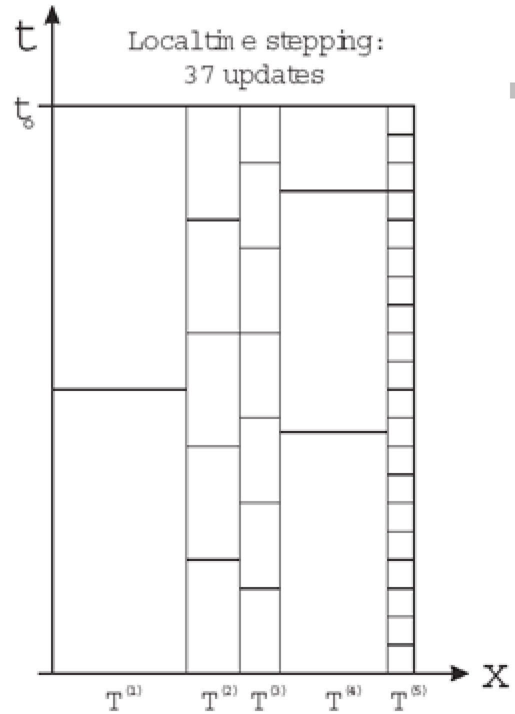


Local time-stepping

global



local



Time

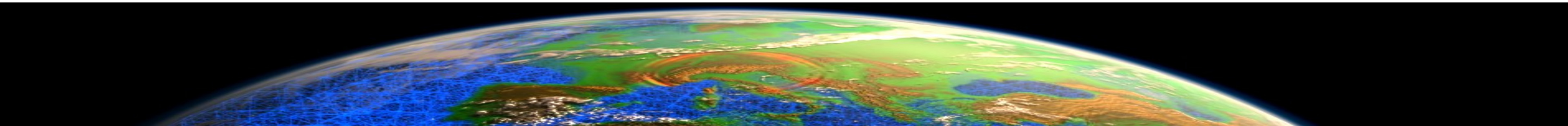
Space

Space

Element

Local time-stepping is possible without loosing the accuracy of the scheme

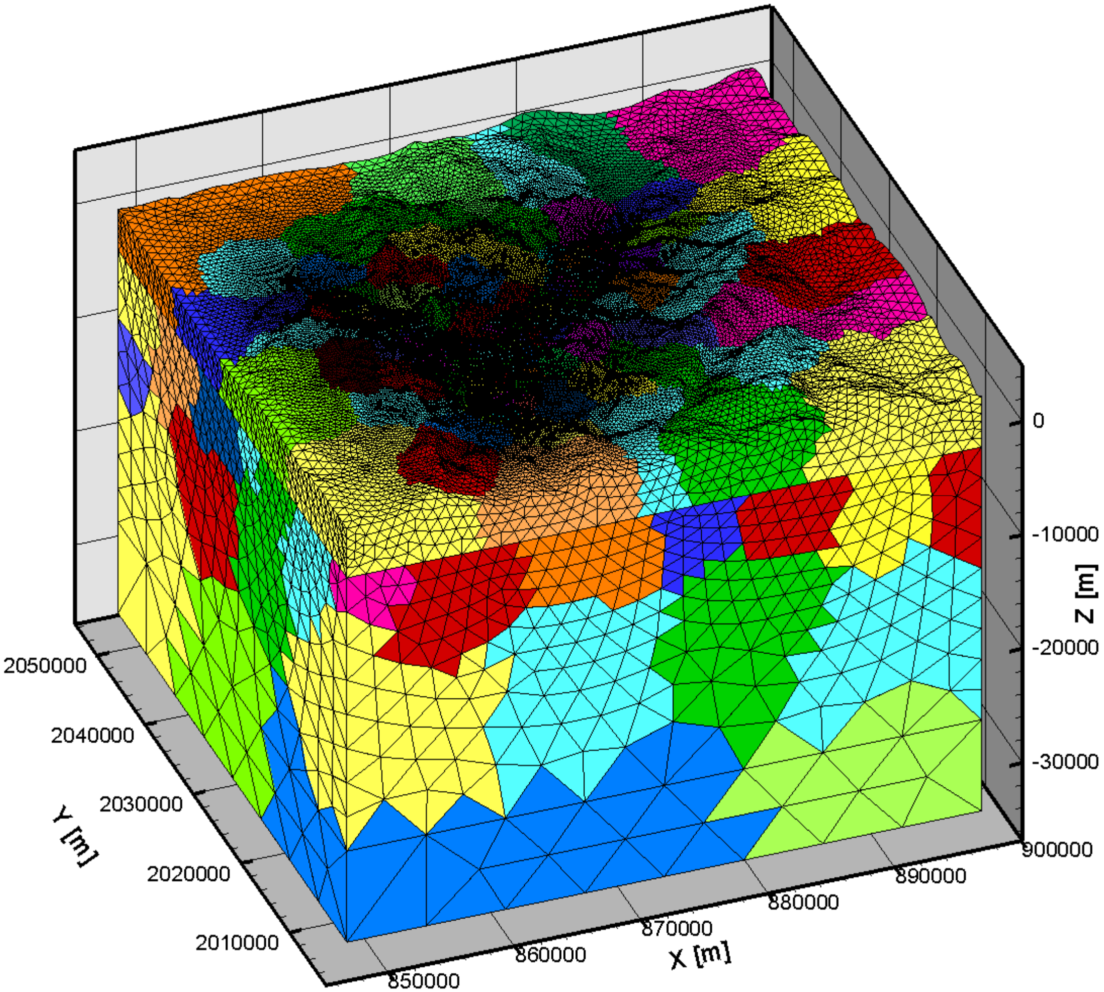
Dumbser, Käser and Toro, GJI, 2007

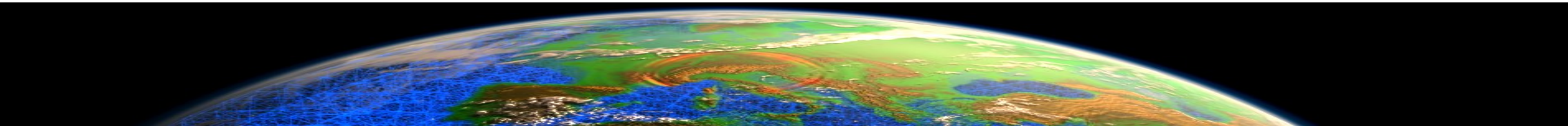


Mesh Partitioning and Parallel Computing

the problem of load blancing

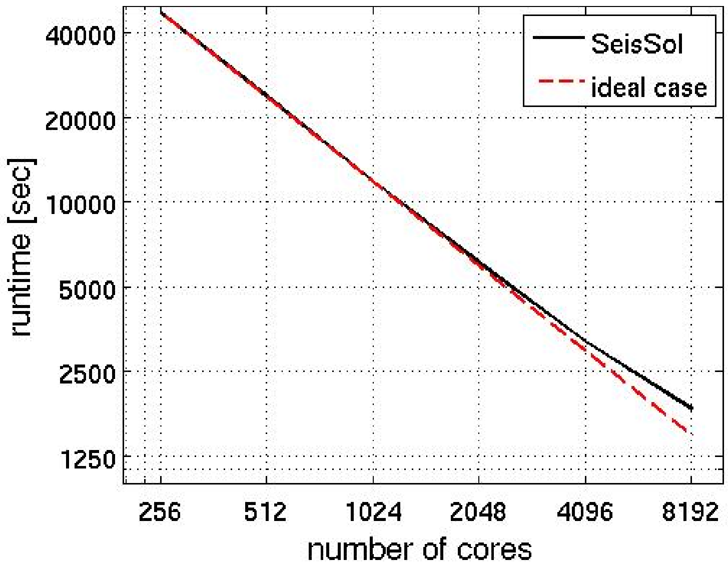
Same color means same processor

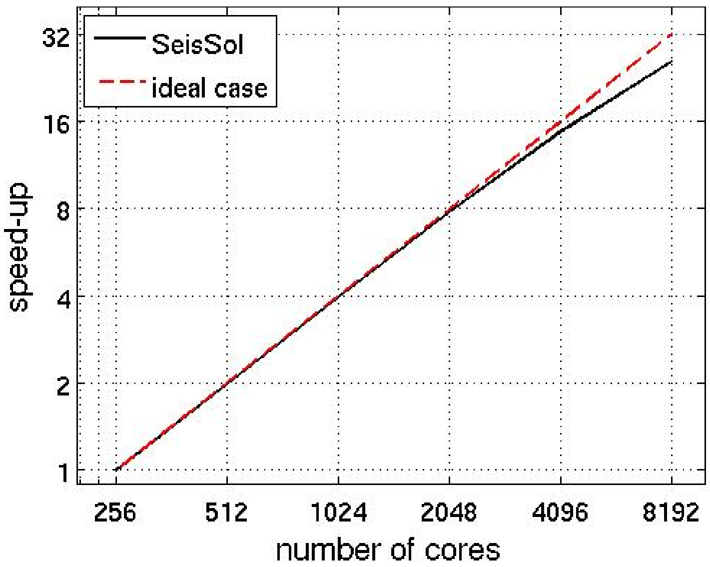


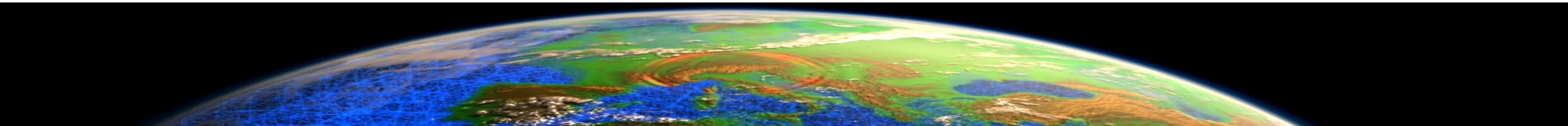


Strong Scaling

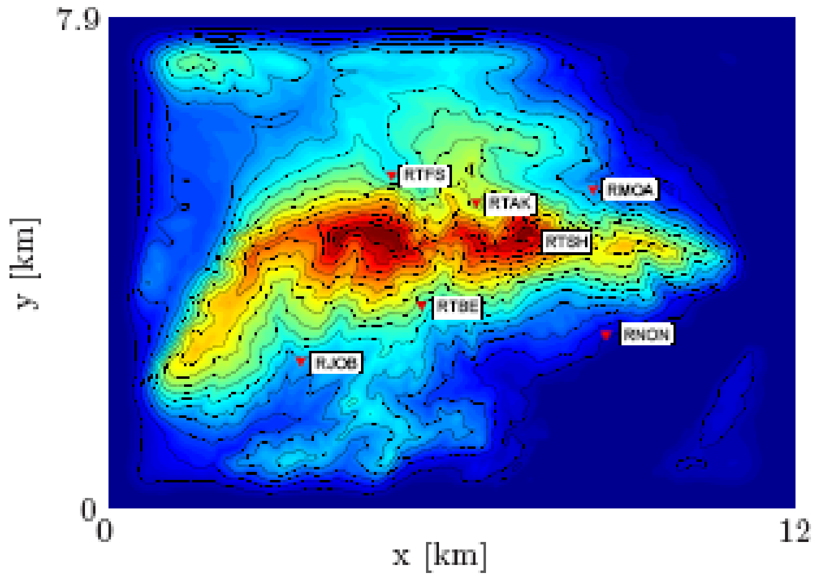
Approximation order	1	2	3	4	5	6	7	8
m (DOF per element)	1	4	10	20	35	56	84	120
Me (memory per element [bytes])	2664	2880	3312	4032	5112	6624	8640	11232
Elements per core M_c = 0.5GB	200,000	180,000	160,000	130,000	100,000	80,000	60,000	45,000

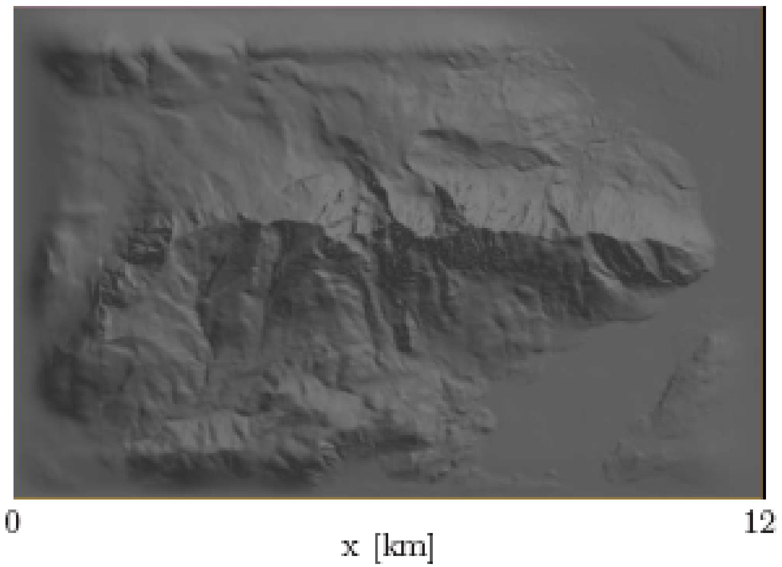


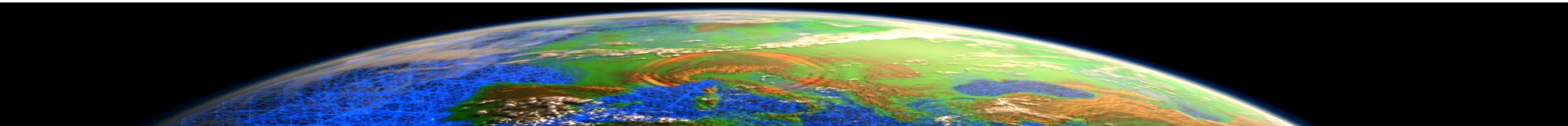




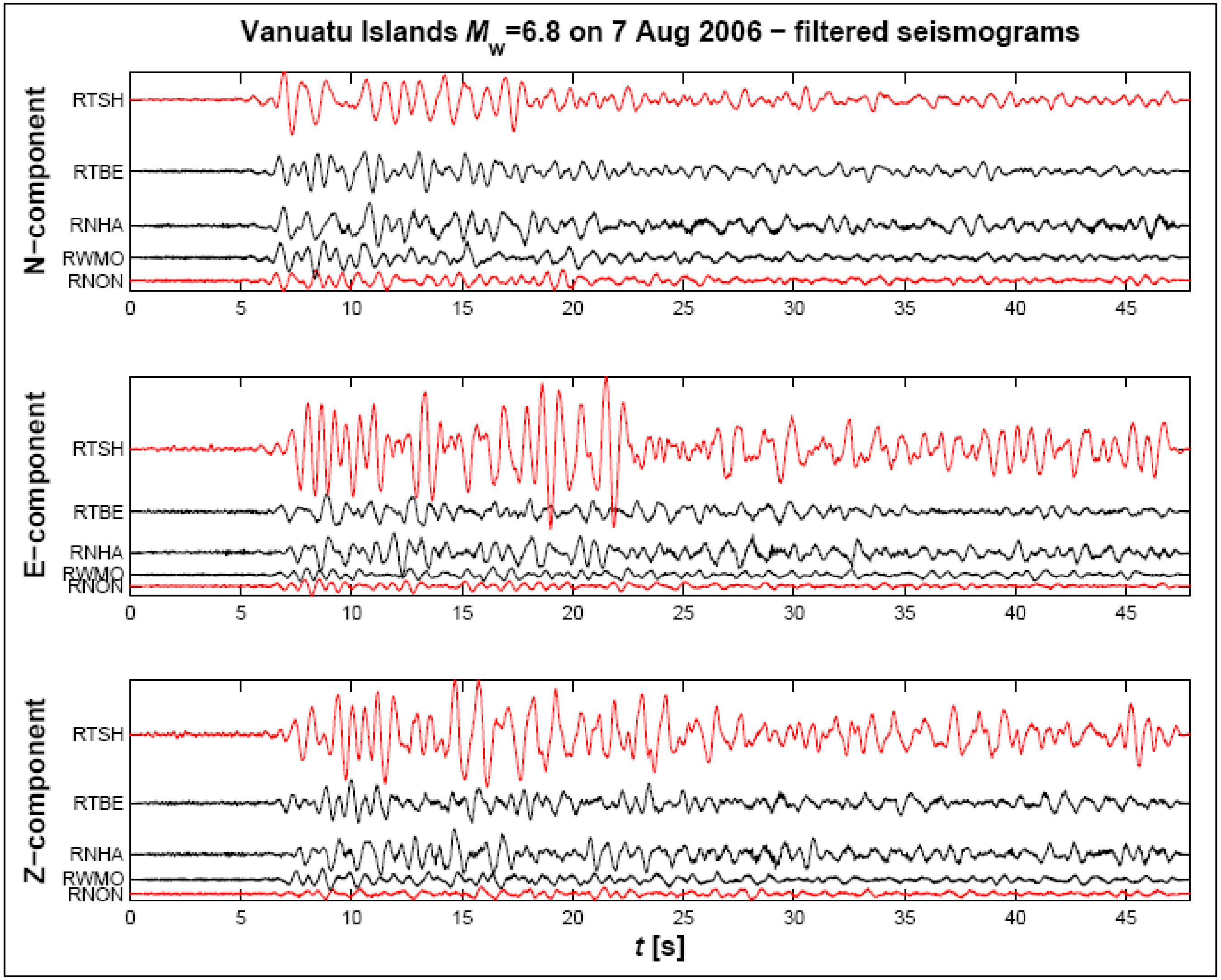
Topographic effects
Bad Reichenhall Area - Hochstaufen



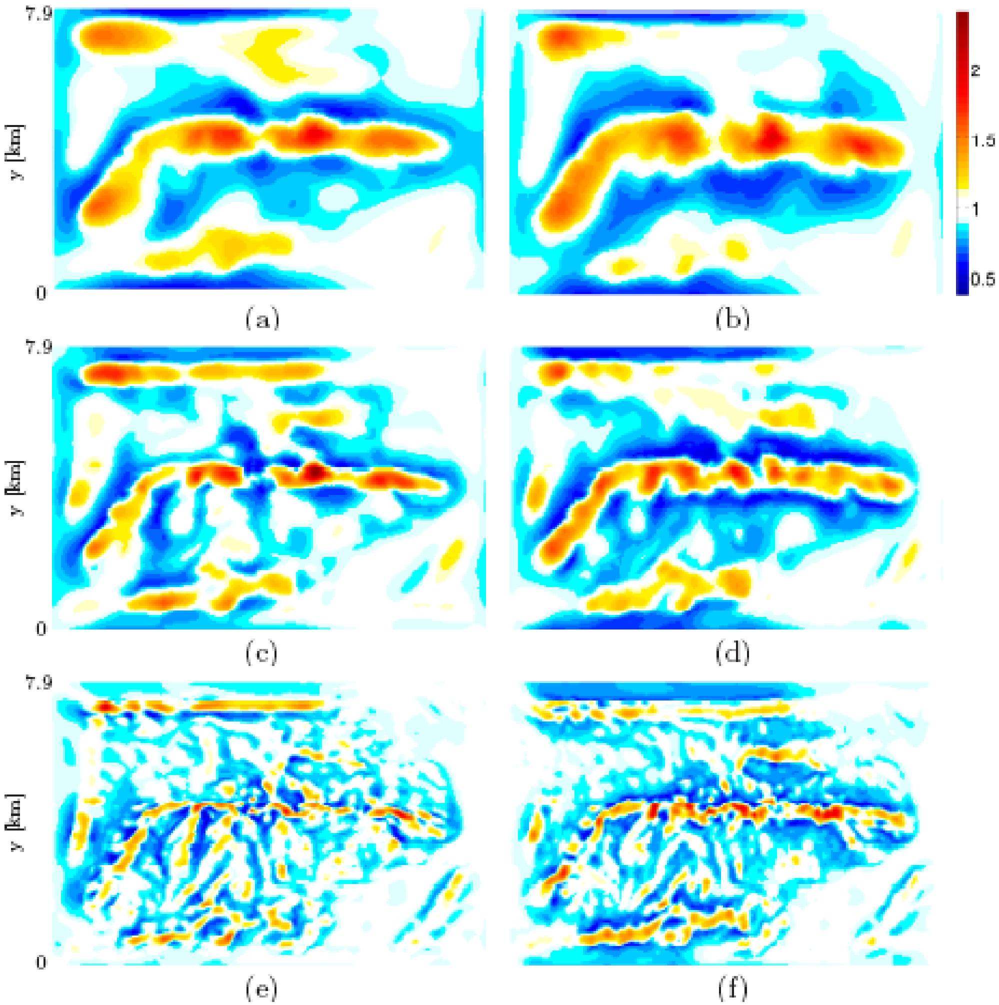


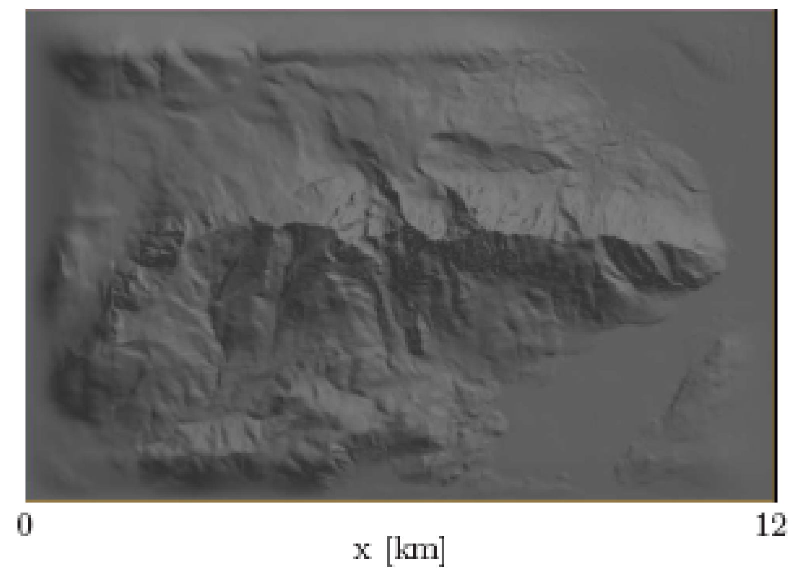


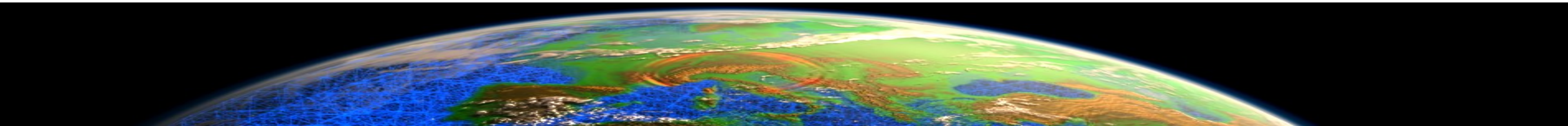
Observations



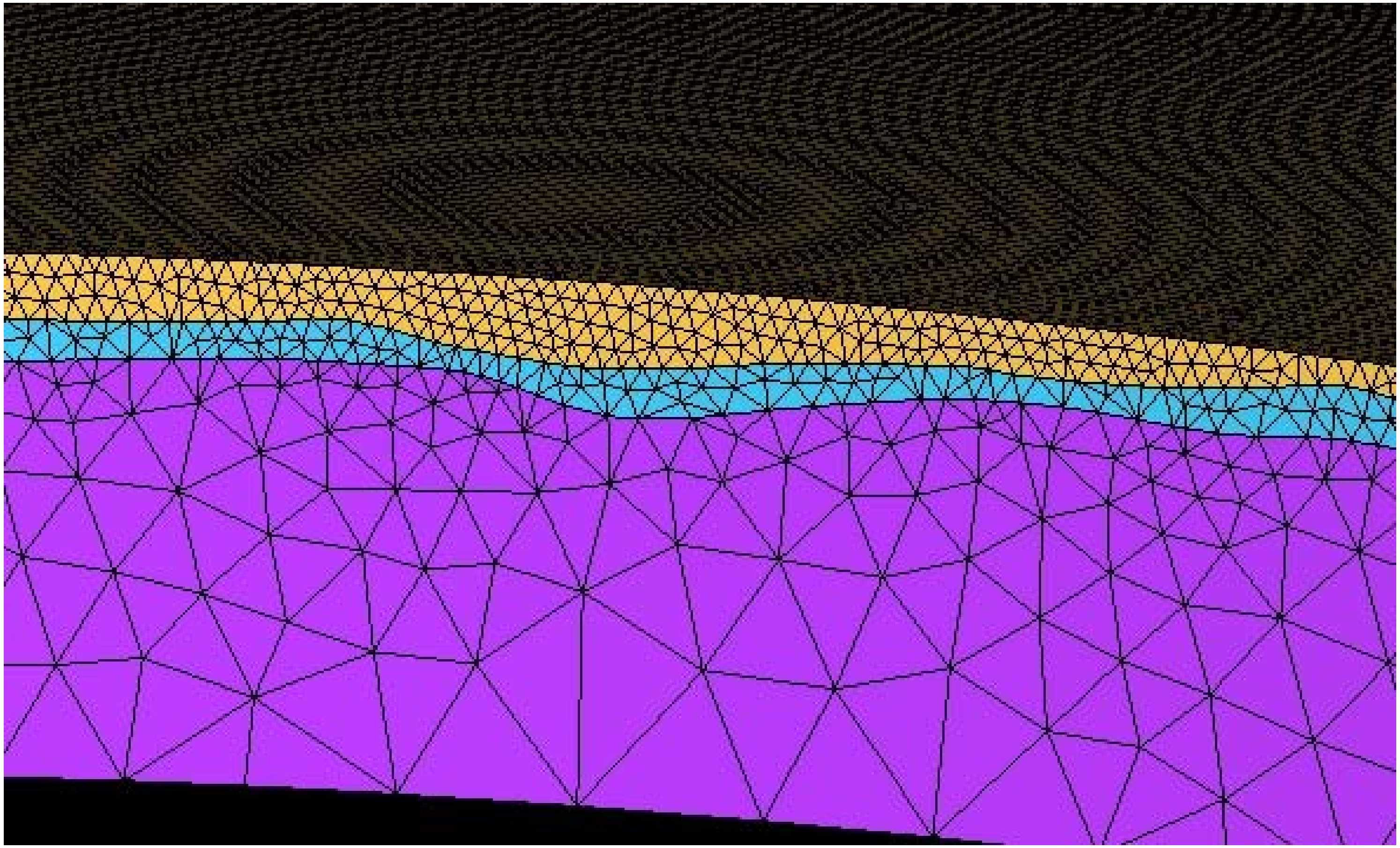
Topographic Effects

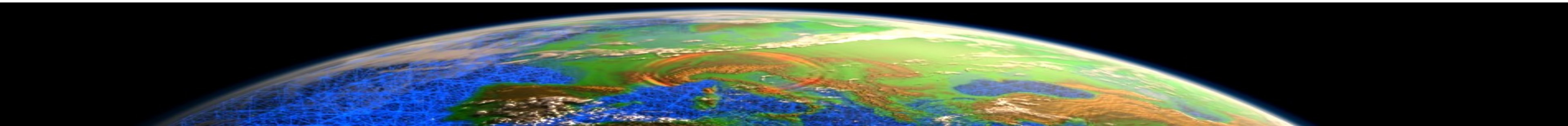






Regional and Global Wave Propagation
crust, crust, crust!





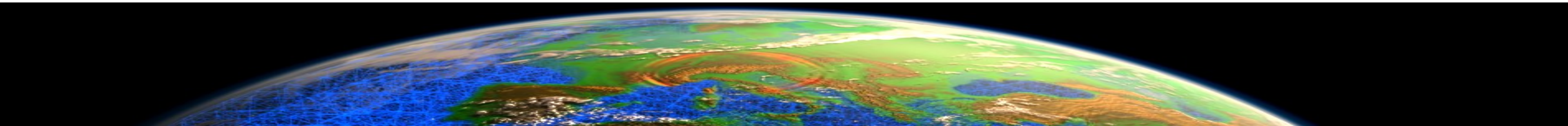
Earthquake scenarios for Europe

Sanna Pyysalo

Seismic hazards and ground motion amplitudes will be better estimated in the future thanks to the EuQuake project. Its research results were achieved using supercomputing resources offered by DEISA. The project started in June 2008 and ended in August 2009.

II
Outlook: the final year

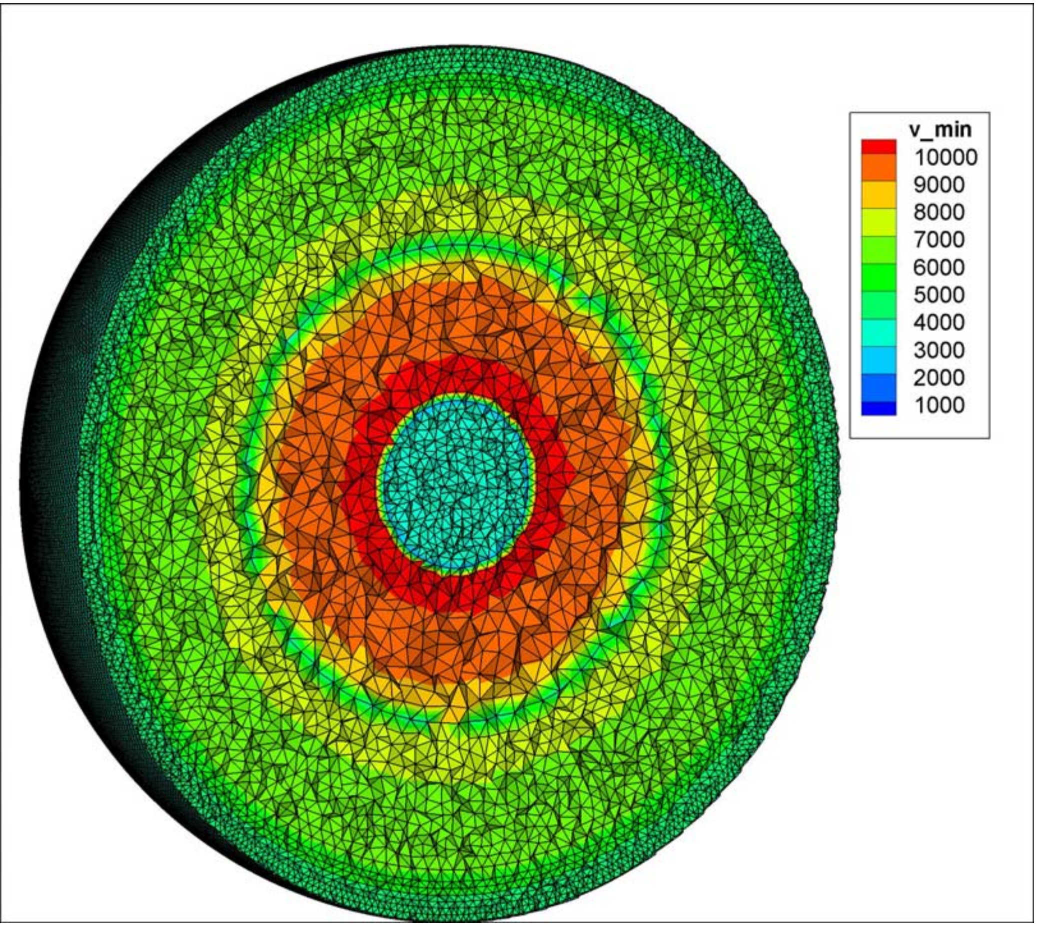
global wave propagation – nodal basis functions – benchmarking – applications

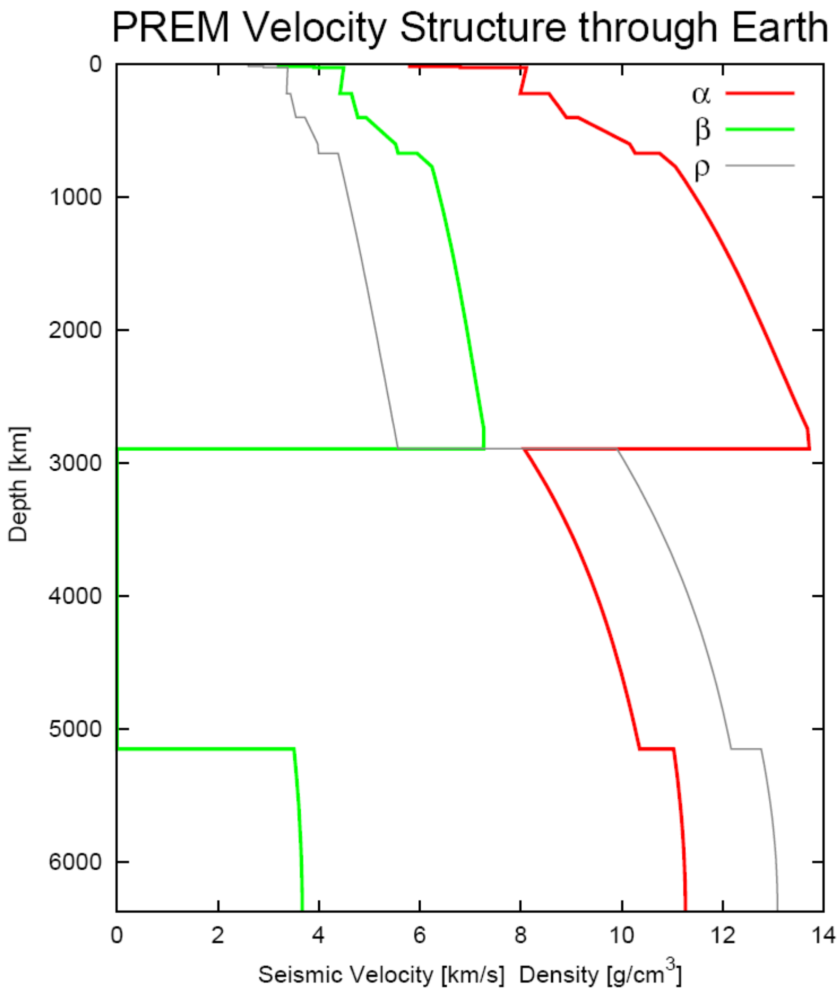


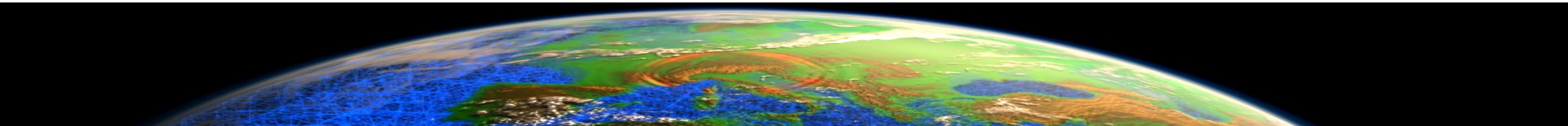
Global wave propagation

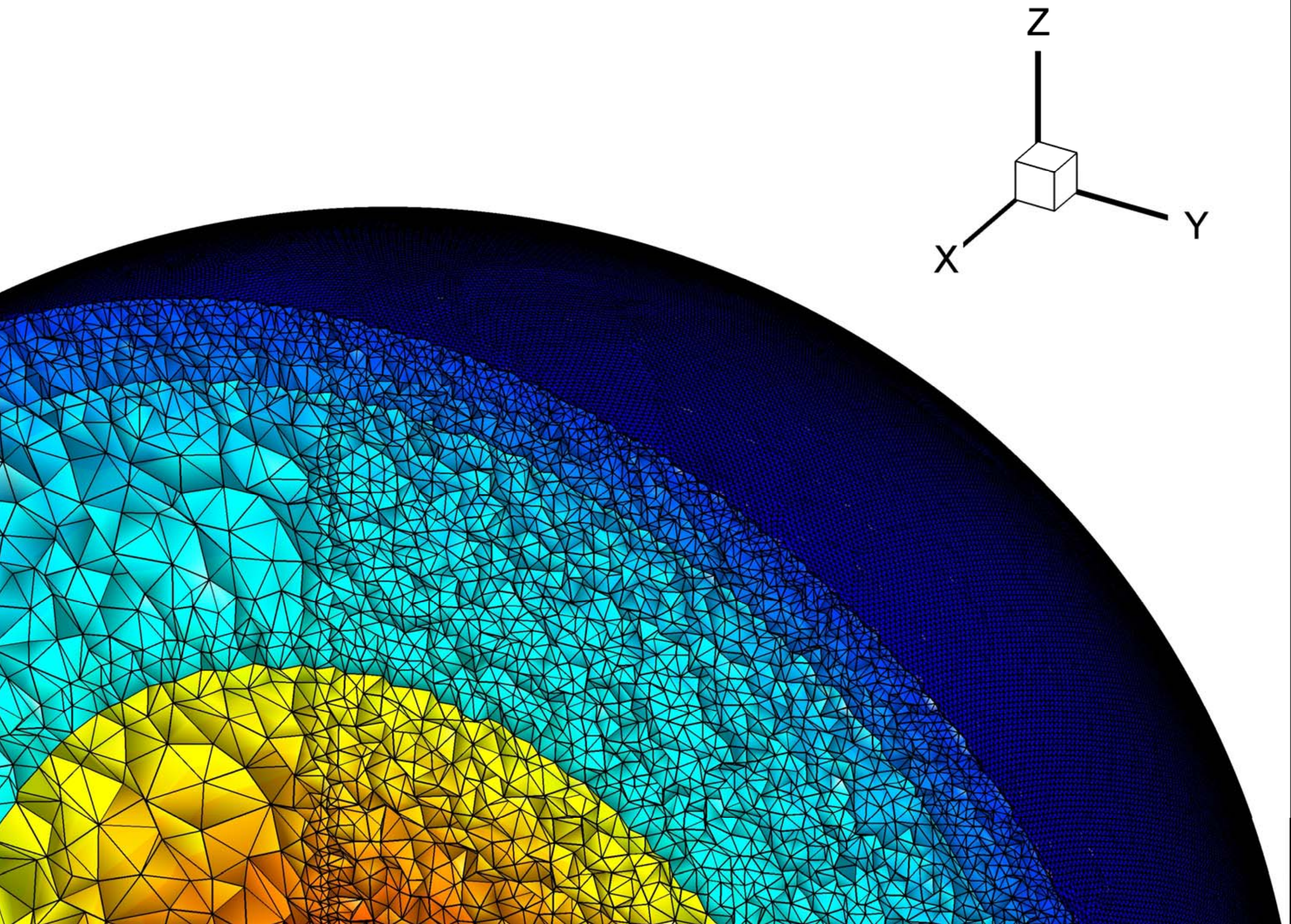
… keeping the number of points per wavelength constant …

Minimum occurring wave speed

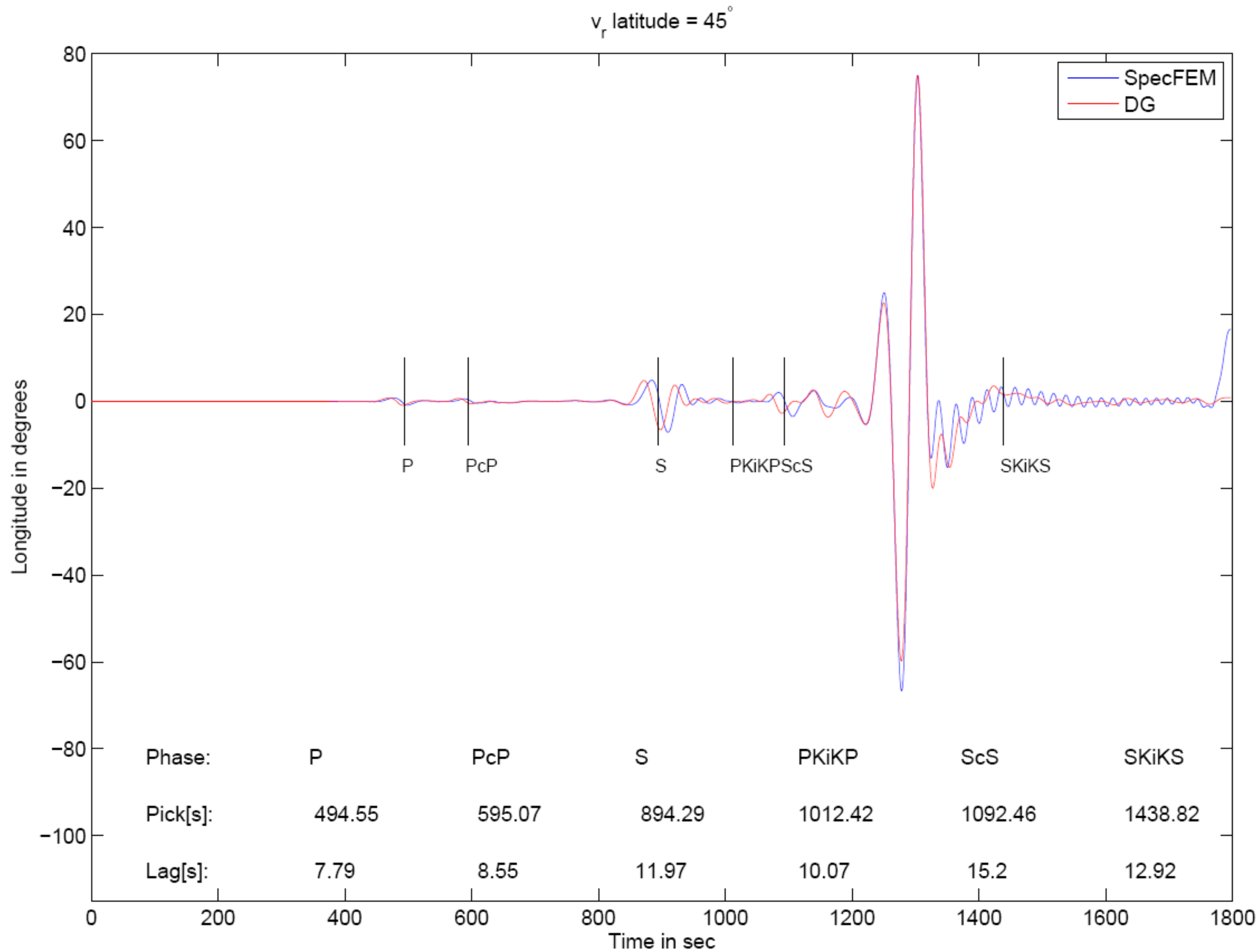


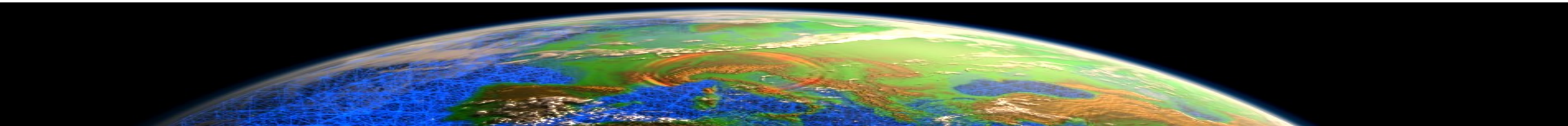





Z
X
Y

Benchmarking





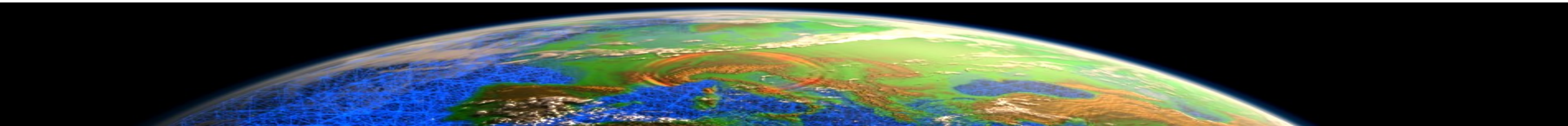
Specific tasks

- Grid generation: how can we efficiently generate grids with topography and internal interfaces (GOCAD)

- Adaption of a new algorithm DG approach with nodal basis functions (that means parameters can easily vary inside elements)

- Combination of hexahedral and tetrahedral grids (tets for complex surface, cubed sphere inside –> specfem)

- Applications to complex mantle models (e.g. geodynamic models of Peter Bunge: seismic signature of mantle convection models)



Integration with other projects

- Cooperation with Toulouse (Prof Komatitsch) on the use of GPUs
- QUEST: EU-wide „Initial Training Network“
- TOAST: BMBF funded project on tomography
- MAC: Optimization
- DEISA-DECI – GLOBUS
- parSeis (pending)

- **openTomo.org** – a portal for computational seismology