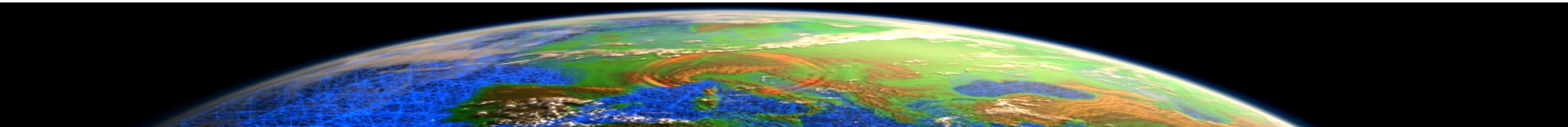
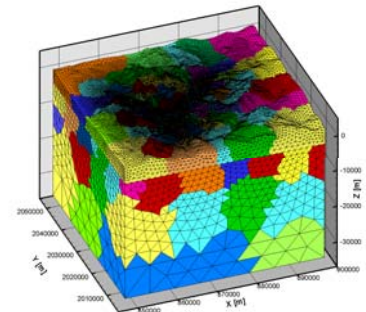
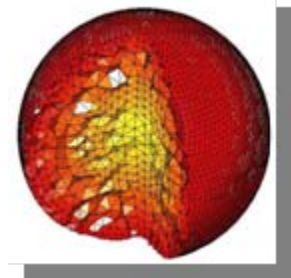




# GeoPF: Simulation of full waveforms for 3-D Earth structures

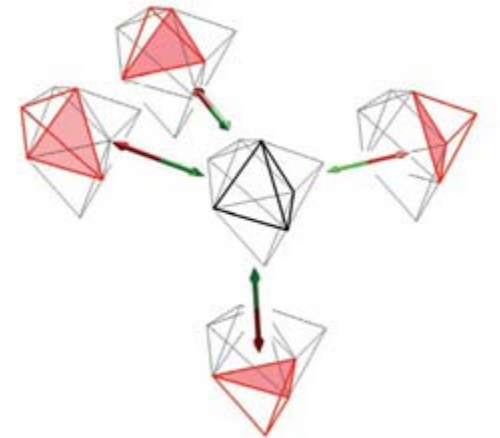
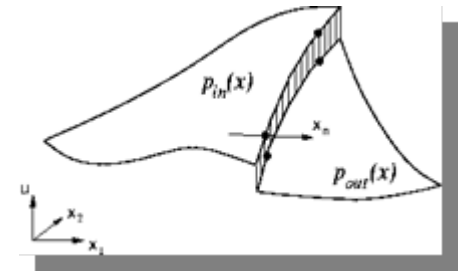
Heiner Igel, Martin Käser, **Stefan Wenk**, Andreas Fichtner, Verena Hermann,  
Seismology Section, Earth Sciences, LMU Munich

- 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**

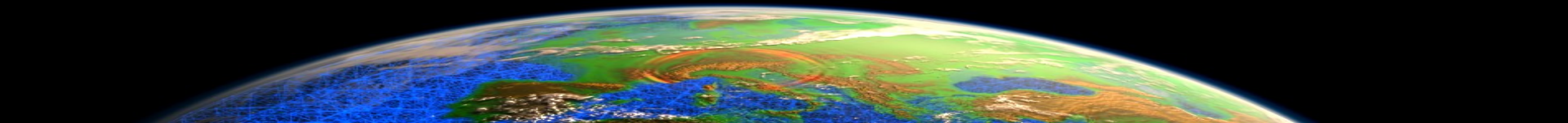


# Arbitrarily high-order DER - Discontinuous Galerkin

- 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

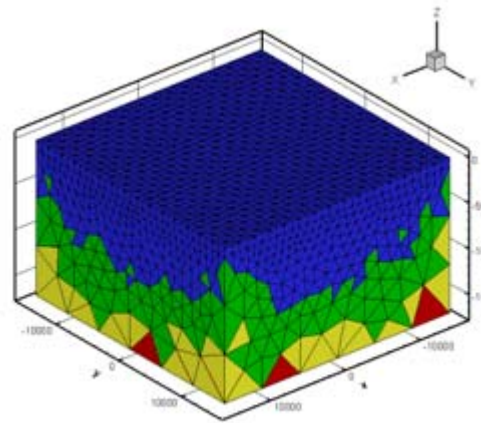


Several articles in Geophys. J. Int., Geophysics, a.o. by Käser, Dumbser, de la Puente, and co-workers

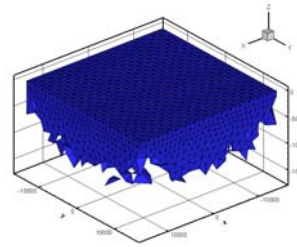


# P-adaptivity

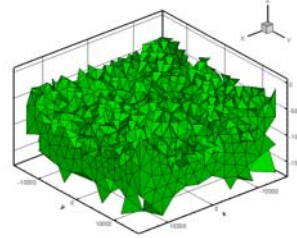
- Use high precision (i.e., high-order polynomials) only where necessary
- High precision where cells are large (high velocities)
- Low precision where cells are small (because of structural heterogeneities)



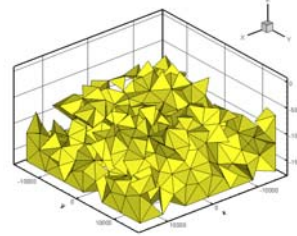
■ O4



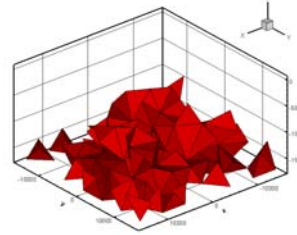
■ O5



■ O6



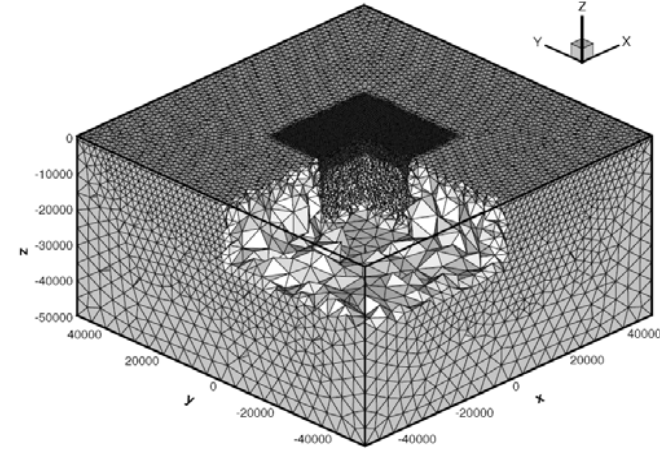
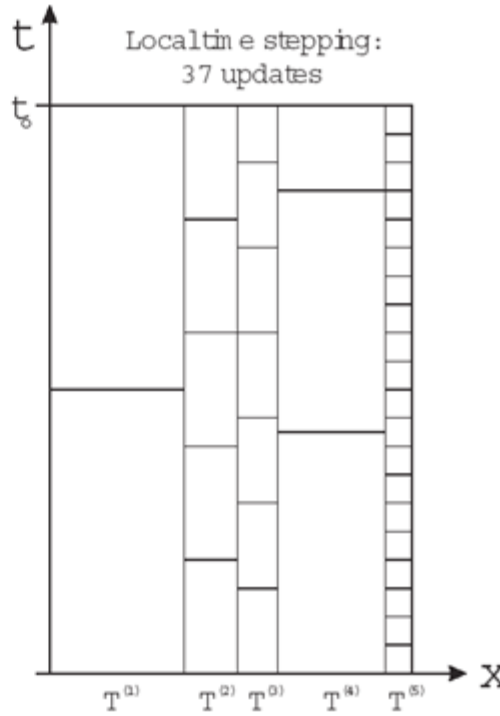
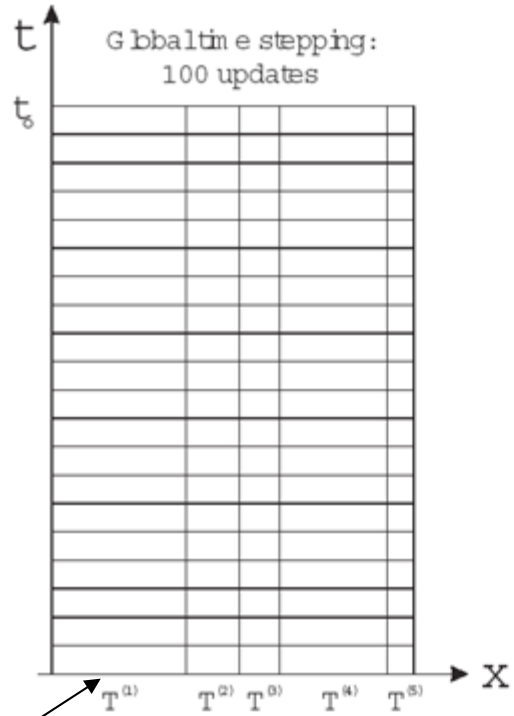
■ O7



# Local time-stepping

*global*

*local*



*Time*

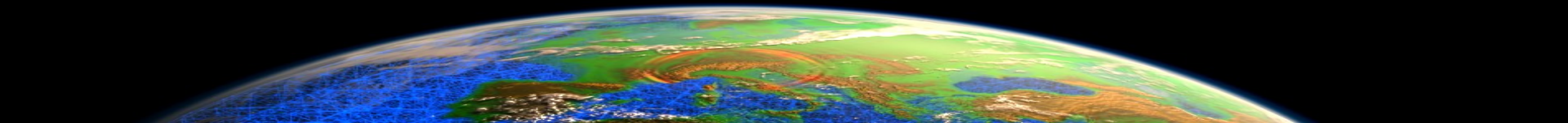
*Element*

*Space*

*Space*

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

Dumbser, Käser and Toro, *GJI*, 2007

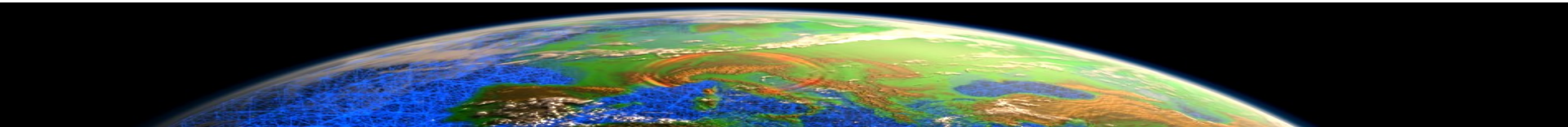
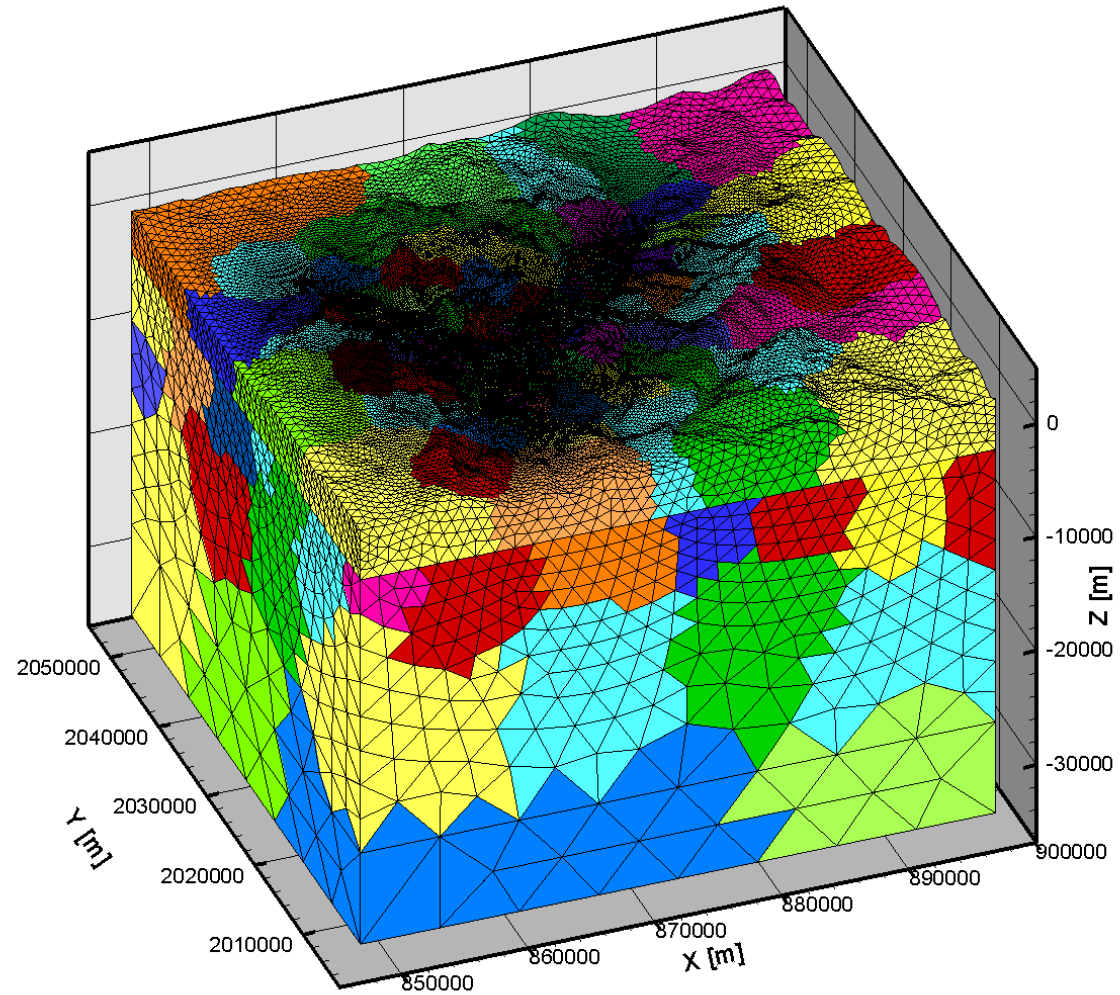




# Mesh Partitioning and Parallel Computing

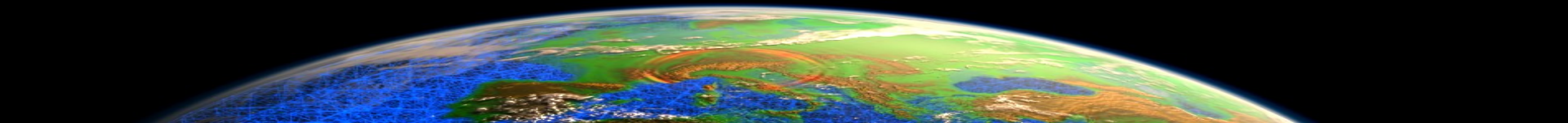
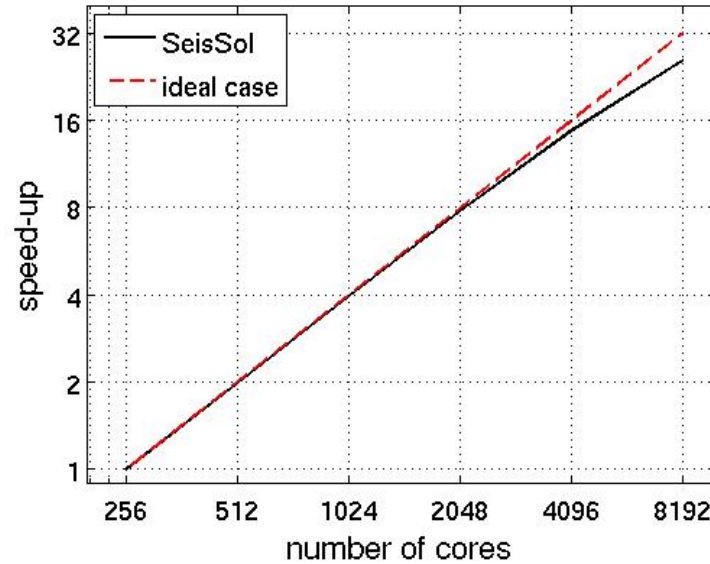
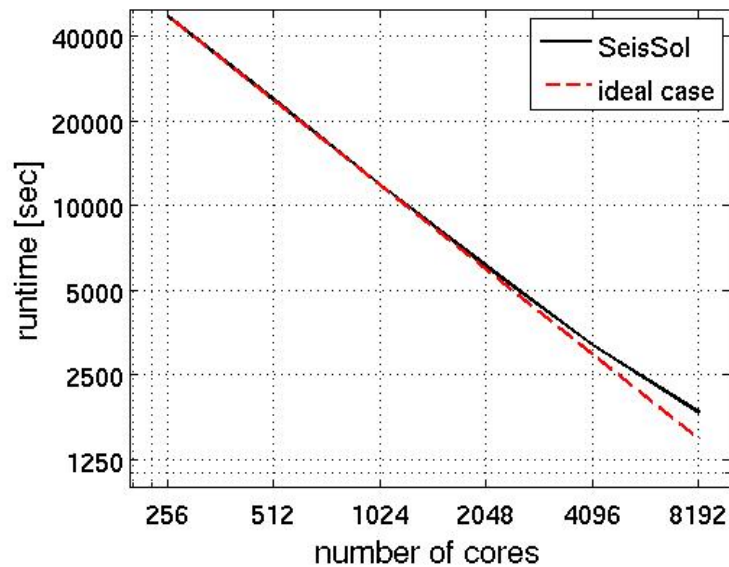
the problem of **load blancing**

Same color  
means same  
processor

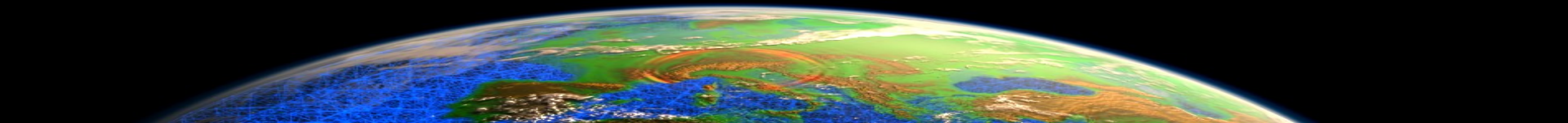
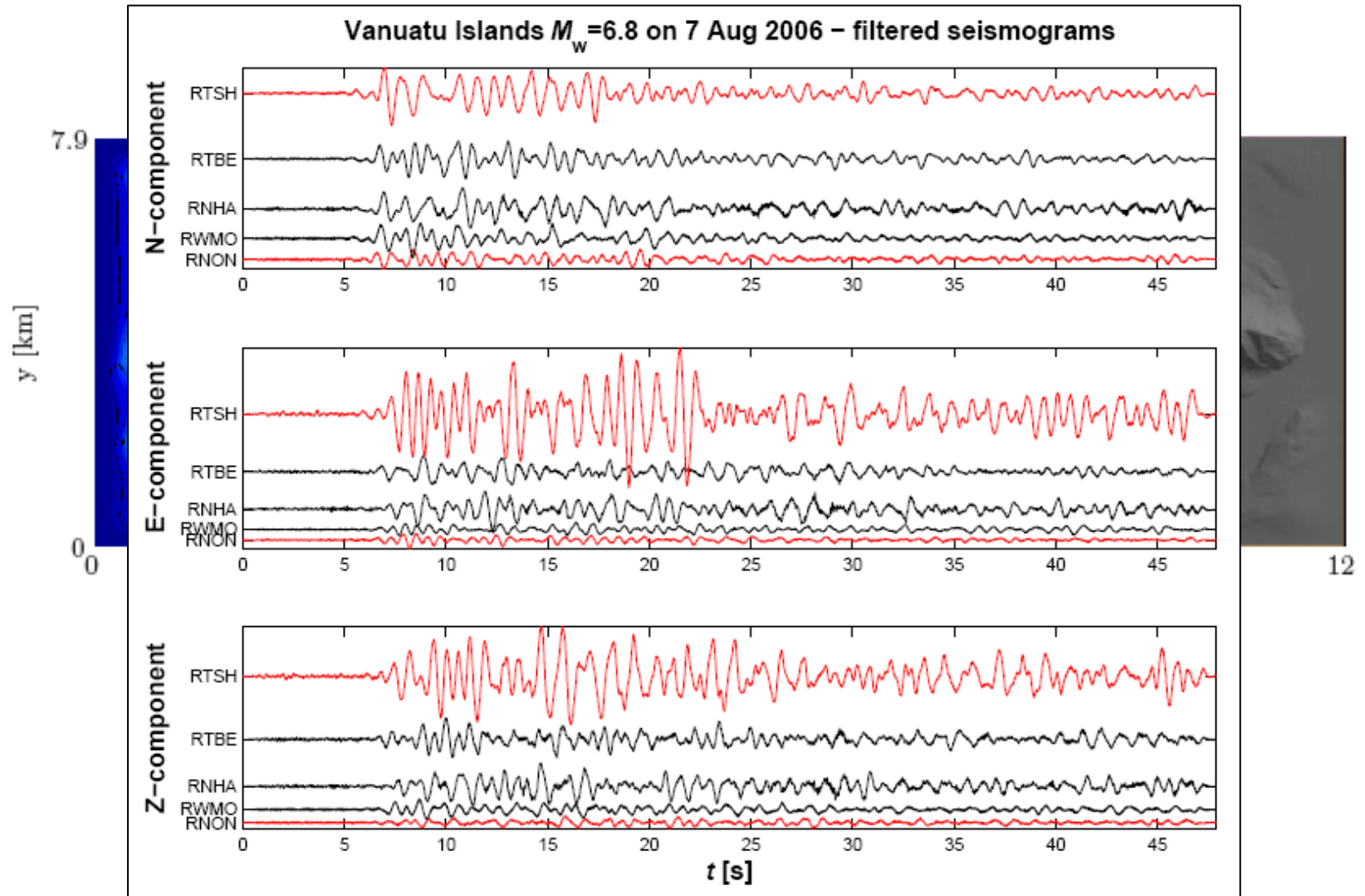


# Strong Scaling

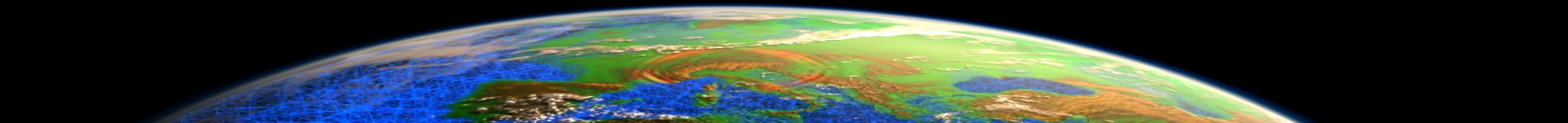
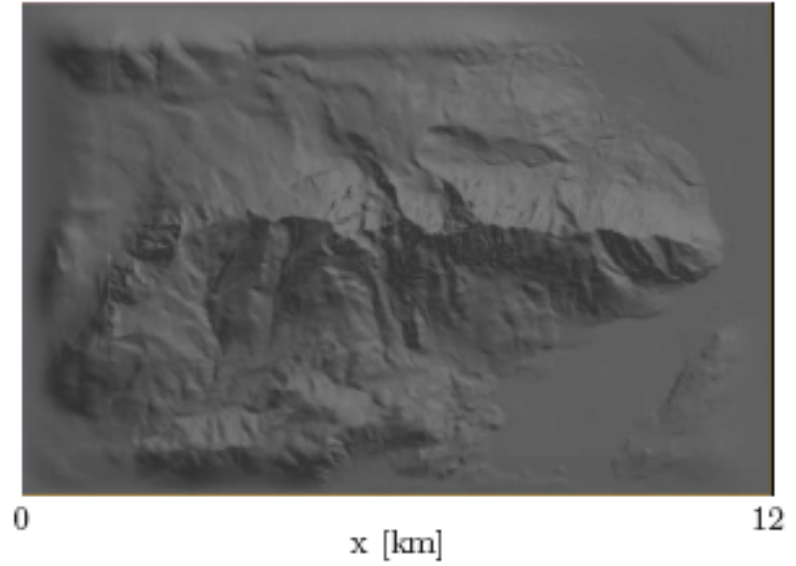
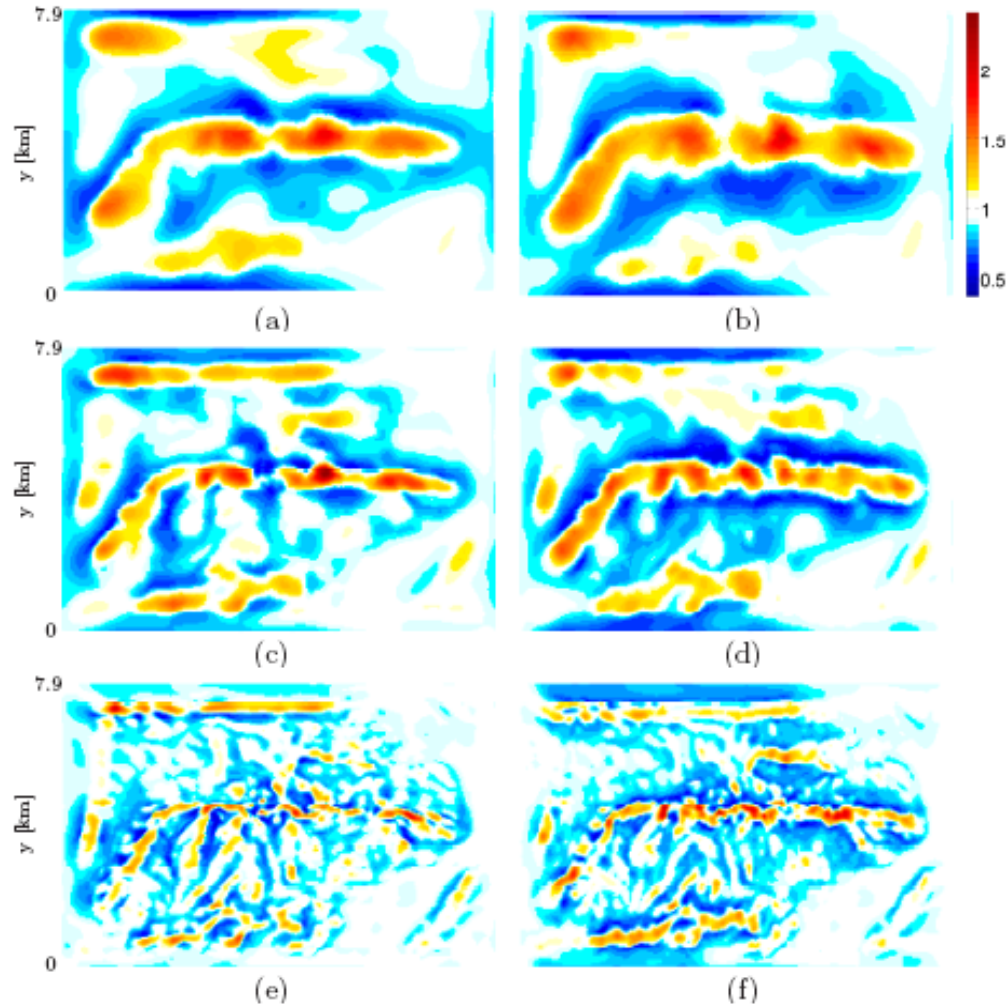
Approximation order	1	2	3	4	5	6	7	8
m (DOF per element)	1	4	10	20	35	56	84	120
Me (memory per element [bytes])	2664	2880	3312	4032	5112	6624	8640	11232
Elements per core $M_c = 0.5\text{GB}$	200,000	180,000	160,000	130,000	100,000	80,000	60,000	45,000



# Topographic effects



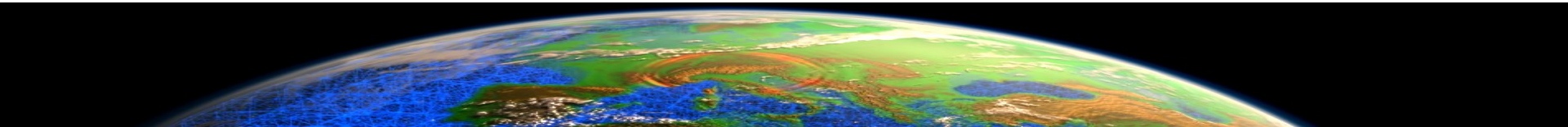
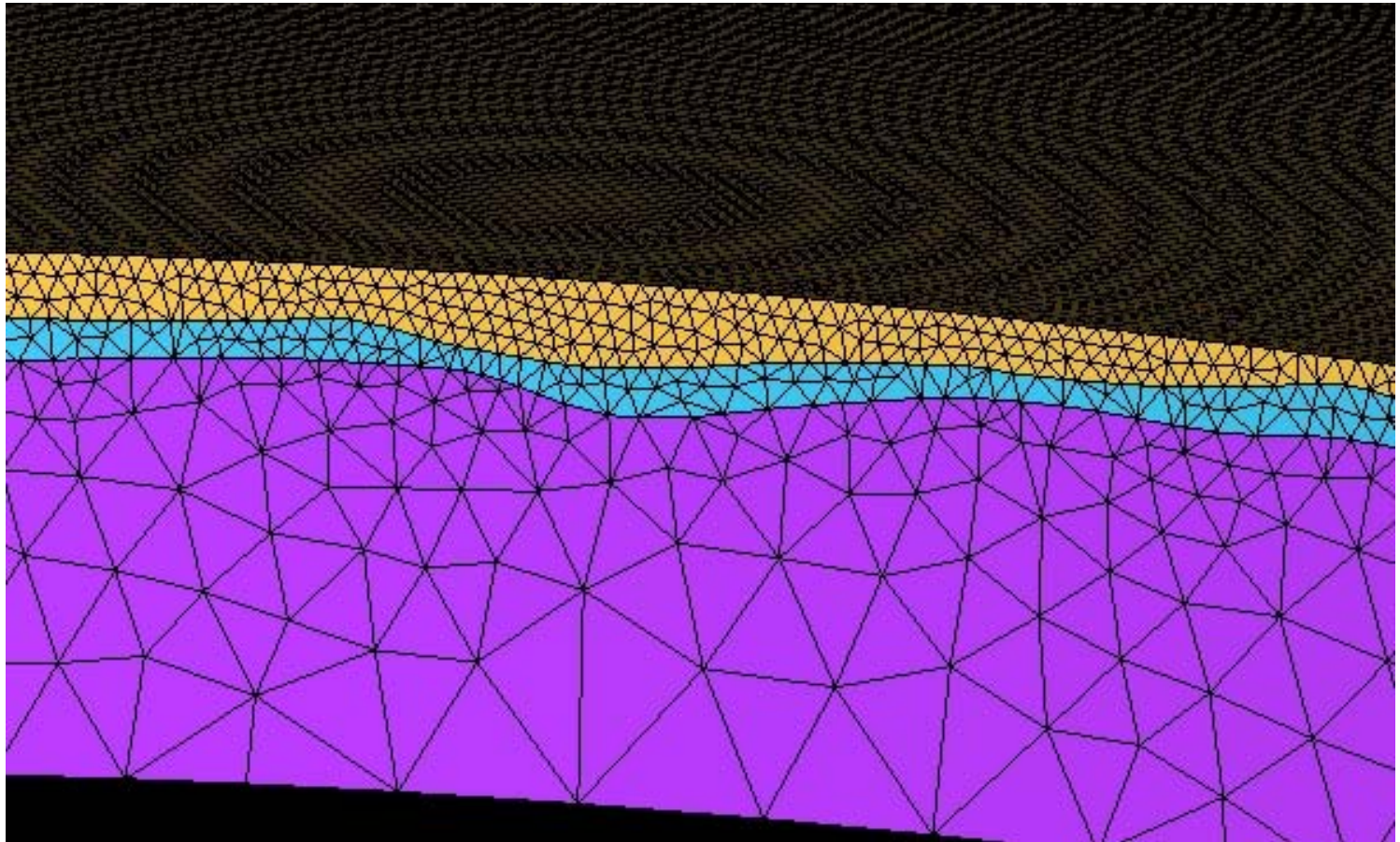
# Topographic Effects







# 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.

DEISA DIGEST

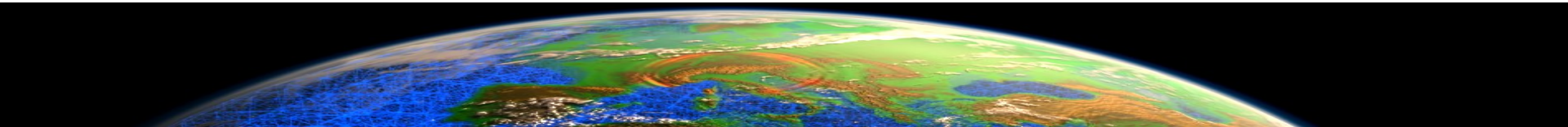
Extreme computing in Europe



## II

### Outlook: the final year

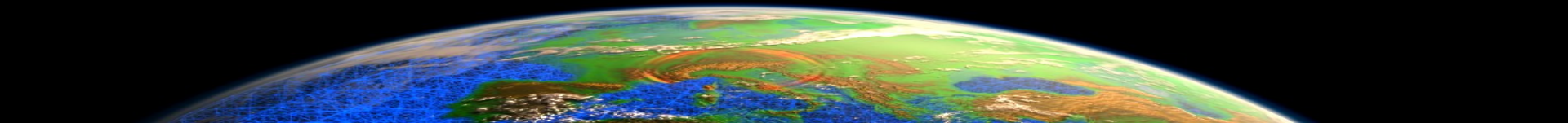
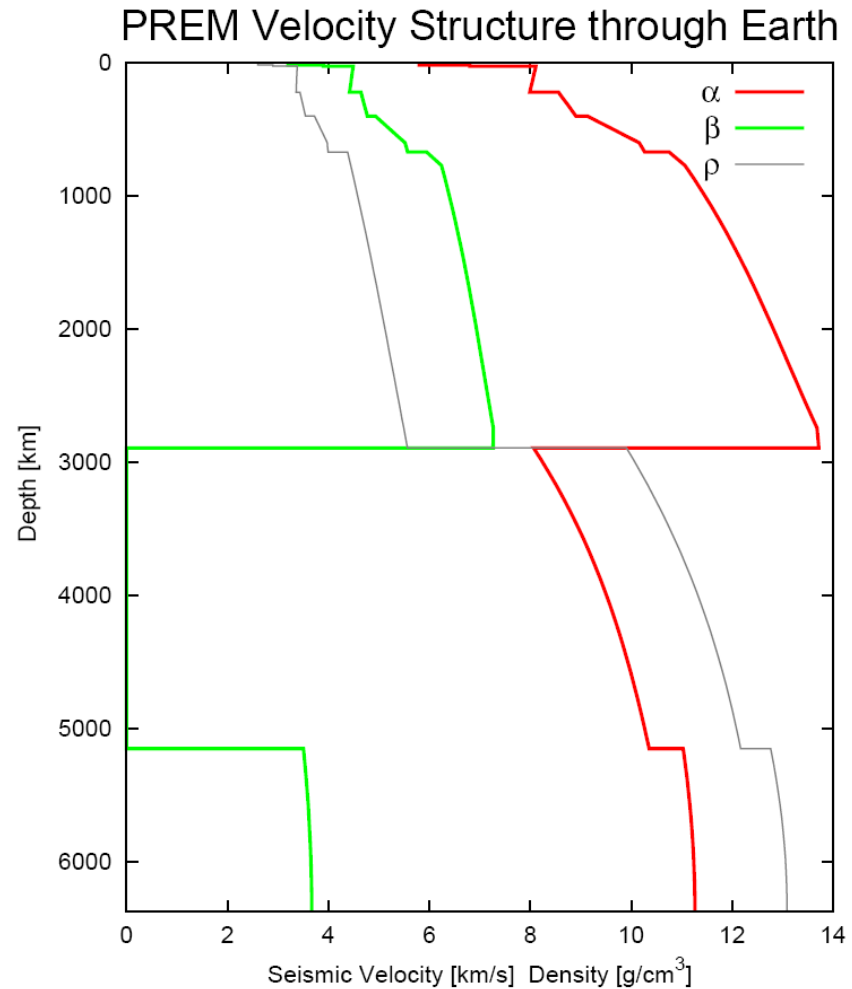
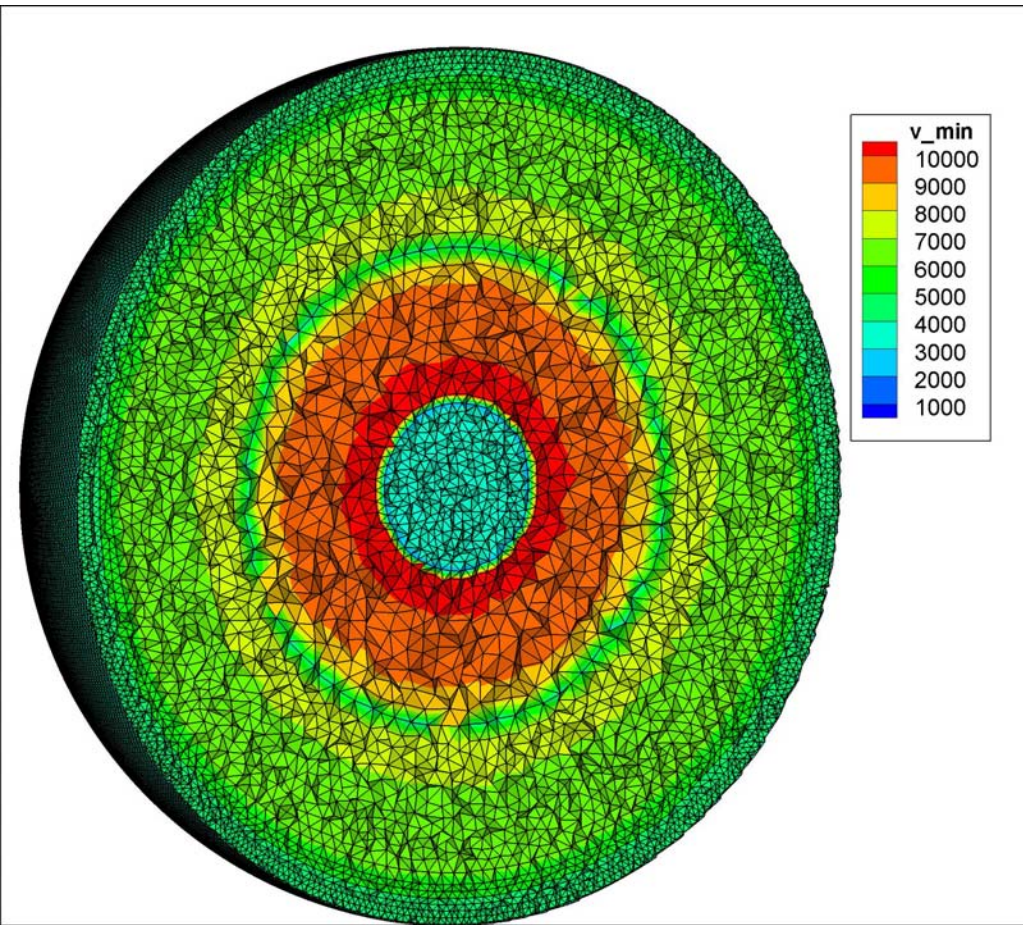
*global wave propagation – nodal  
basis functions – benchmarking –  
applications – new  
initiatives/projects*

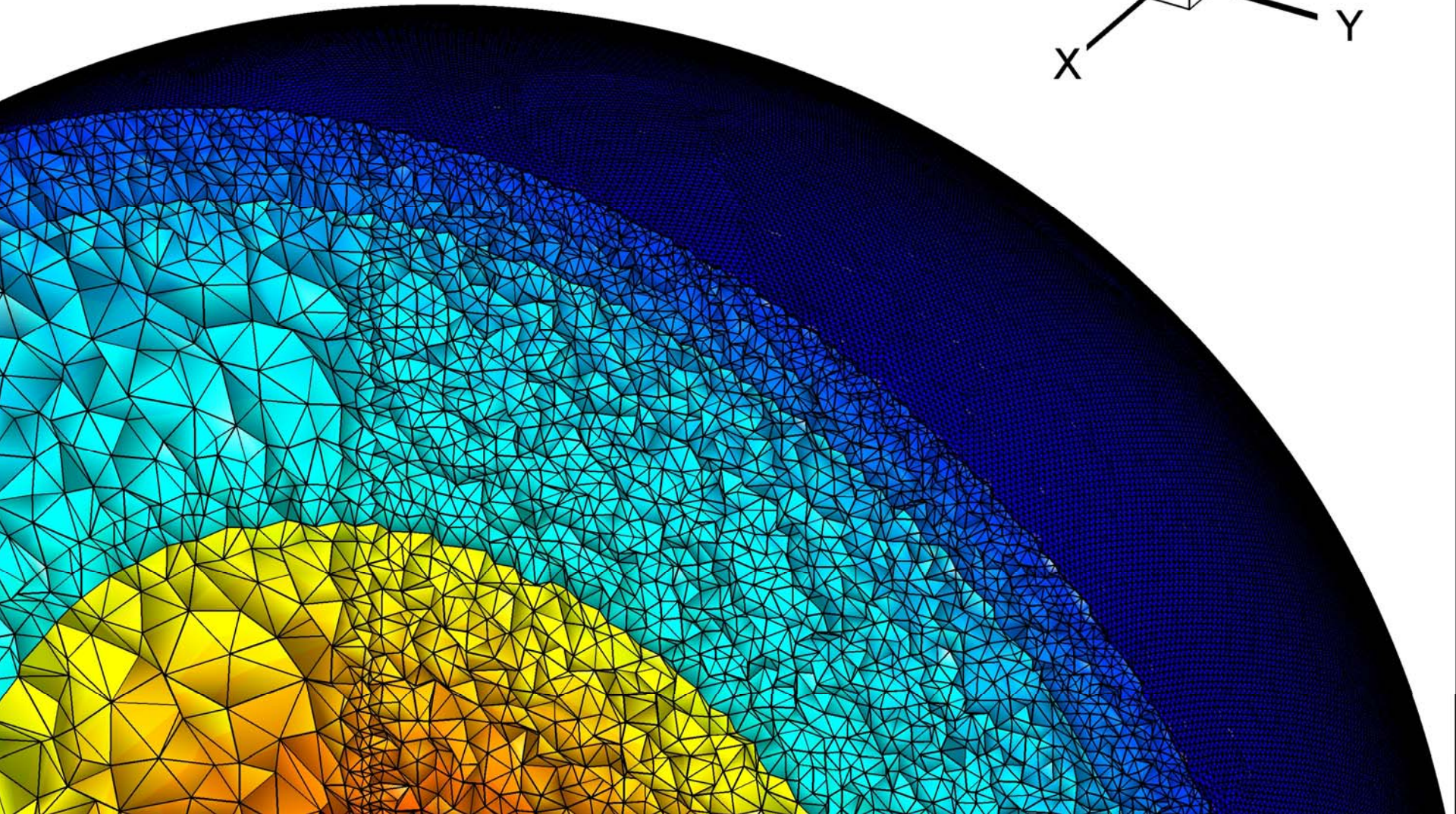
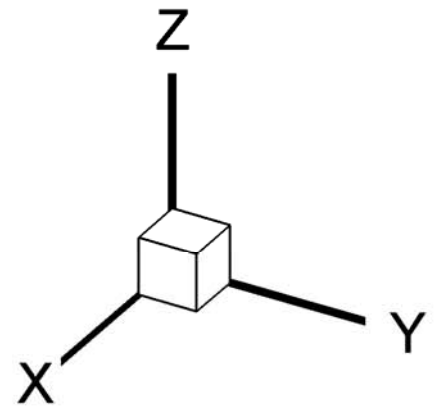


# Global wave propagation

... keeping the number of points per wavelength constant ...

Minimum occurring wave speed

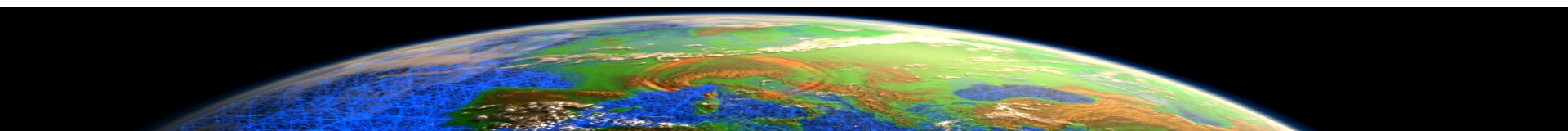
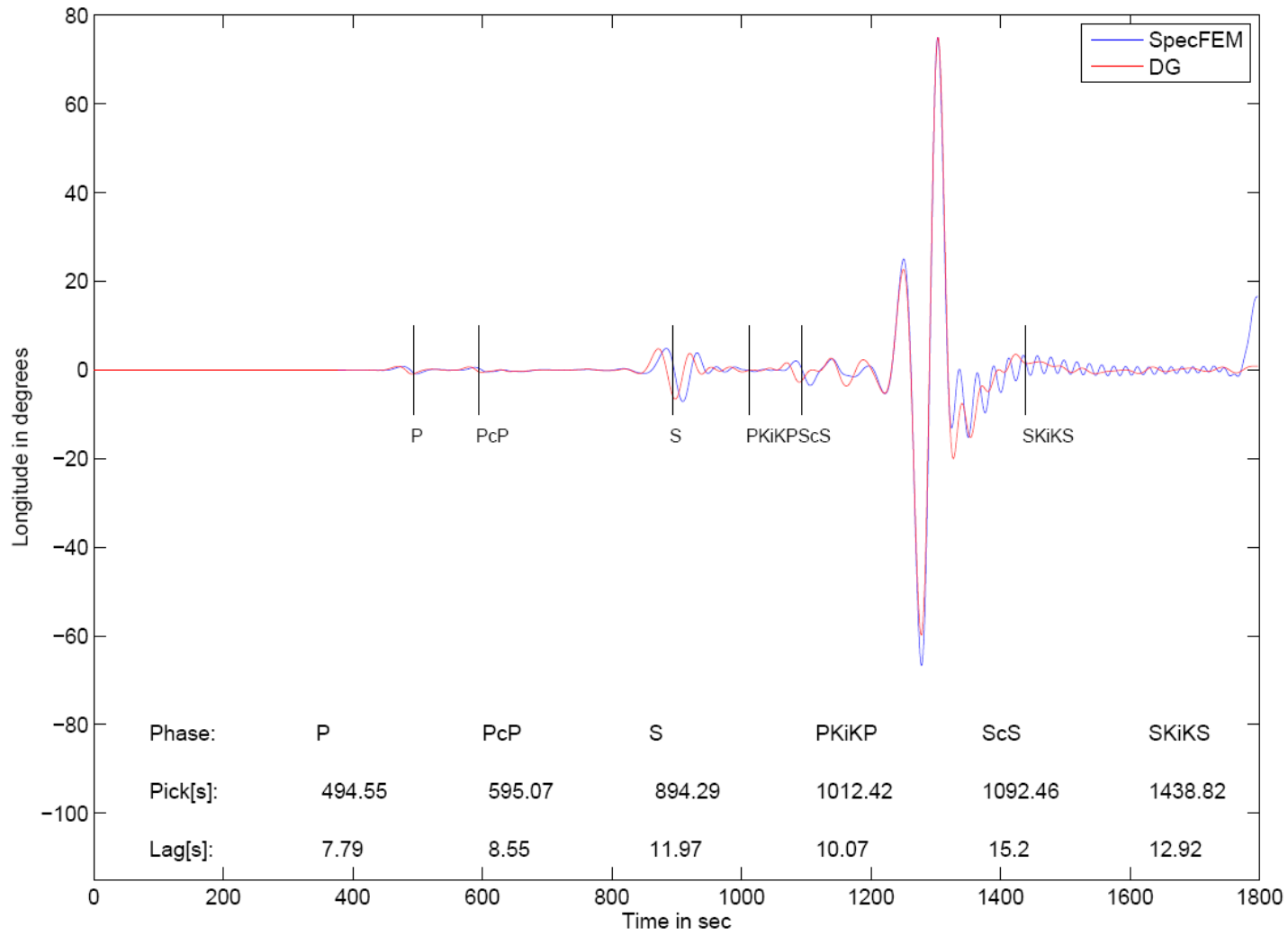






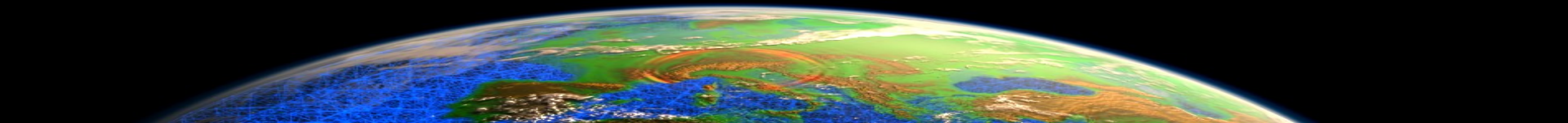
# Benchmarking

$v_r$  latitude =  $45^\circ$



# Spezielle Aufgaben

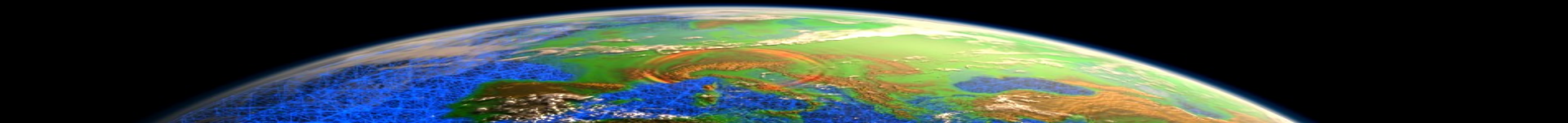
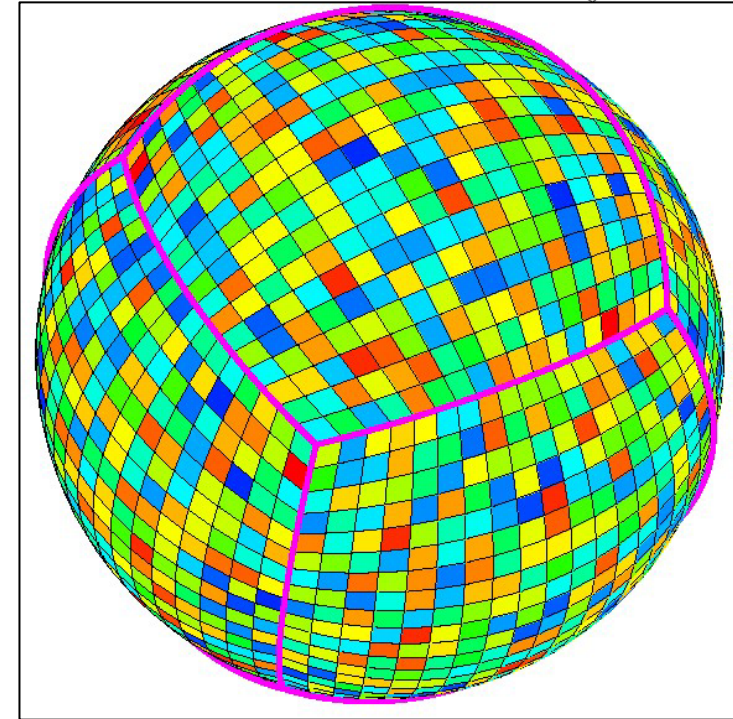
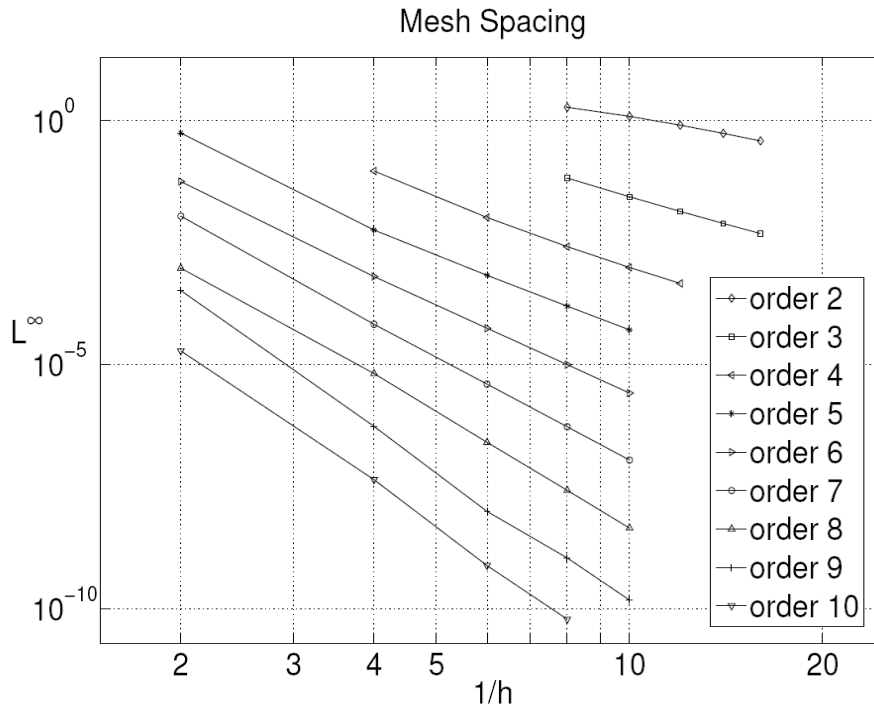
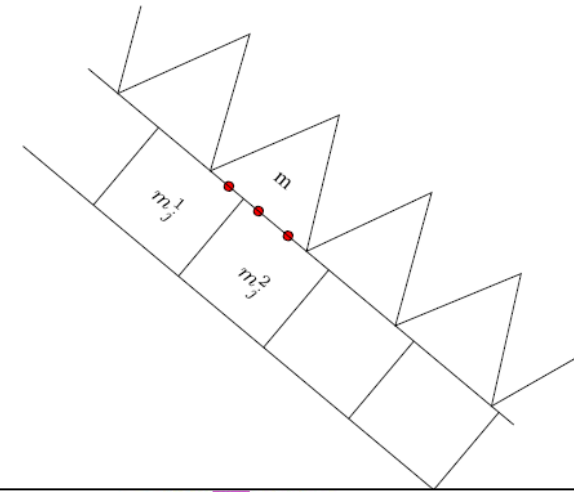
- Grid generation: how can we efficiently generate grids with topography and internal interfaces (GOCAD)
- Adaption of a new algorithm DG approach with nodal basis functions (that means parameters can easily vary inside elements)
- Combination of hexahedral and tetrahedral grids (tets for complex surface, cubed sphere inside → specfem)
- Applications to complex mantle models (e.g. geodynamic models of Peter Bunge: seismic signature of mantle convection models)





# Hex/Tet grids

Hybride Gitter aus Hexaeder- und Tetraederelementen müssen nicht-konform verknüpft werden, um Pyramiden-elemente zu vermeiden.







# Integration with other projects

- 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

