Challenges in computational seismology

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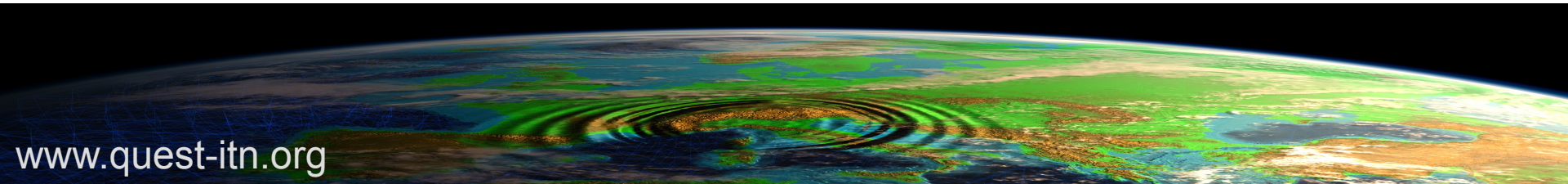
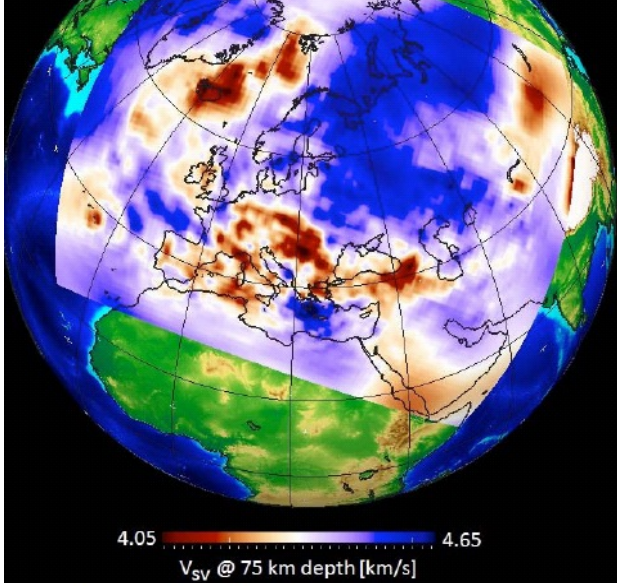
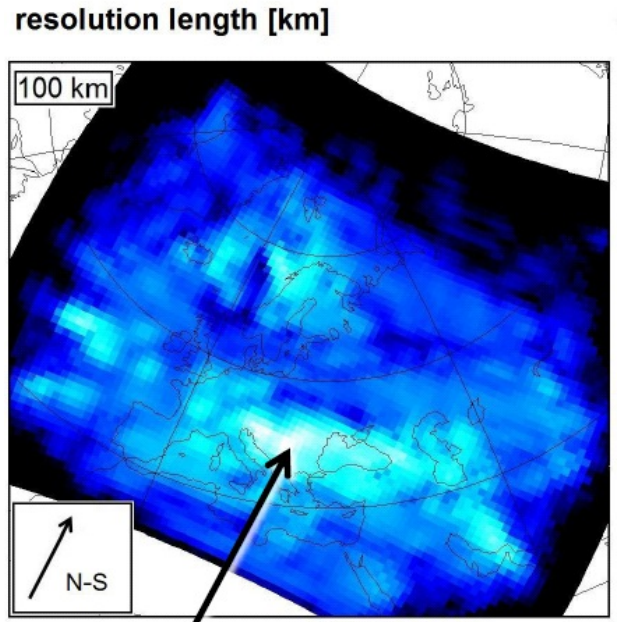
Contributors: M. Bernauer, A. Fichtner, P. Käufl, L. Krischer, A. Molina, C. Pelties, A. Schiemenz, M. Simon, S. Wenk



Inverse modeling

- So you have a new model based on FWI!
- What do the blobs mean?
- Can you give numbers as to how relevant one blob is w.r.t. to another? Why is it better than the ray-based model (if at all)?
- What if a geodynamicist turns the blob into a story (and publishes in *Science*)?
- How much nonlinear search do we need?

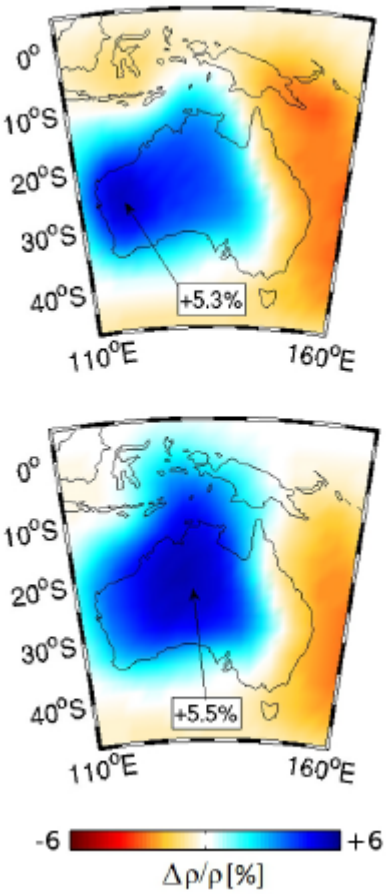


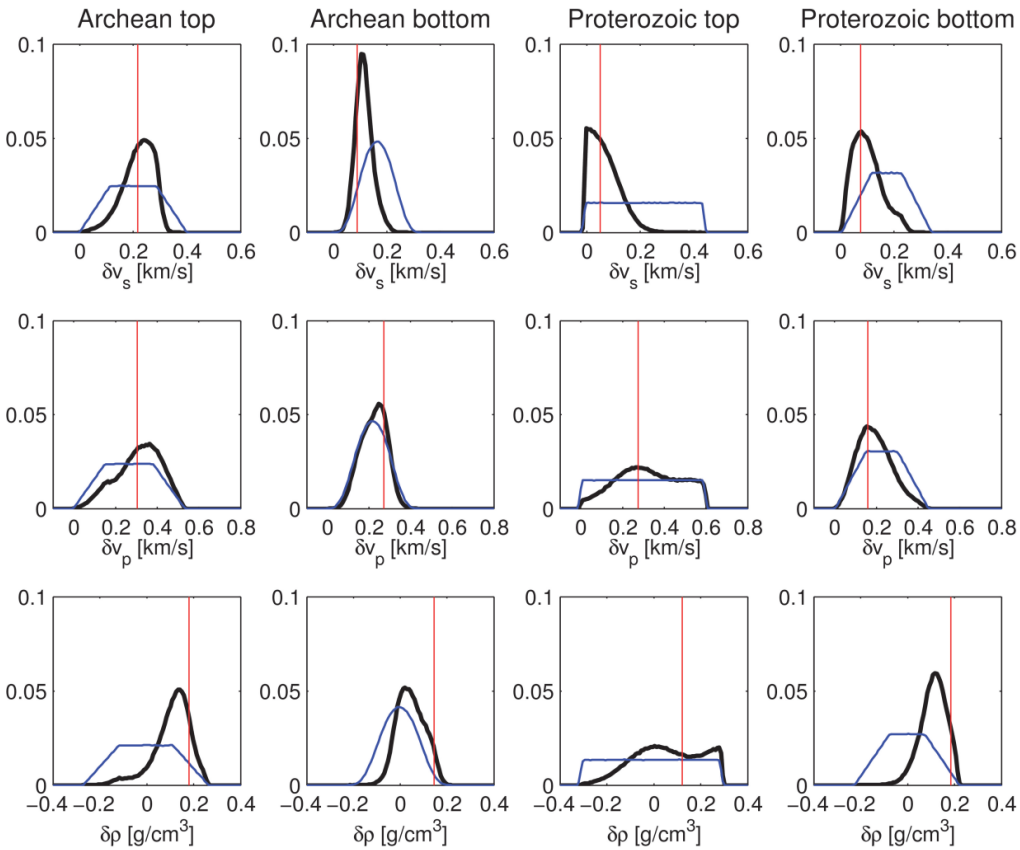


Fishing in the dark – Hypothesis testing

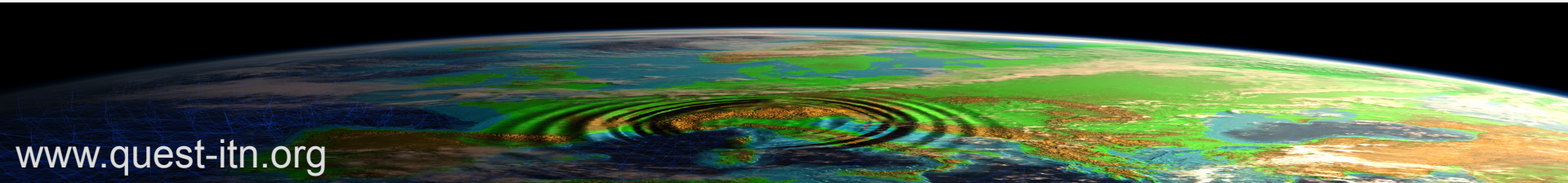
… low d-o-f models …

Monte Carlo with 3-D simulations!



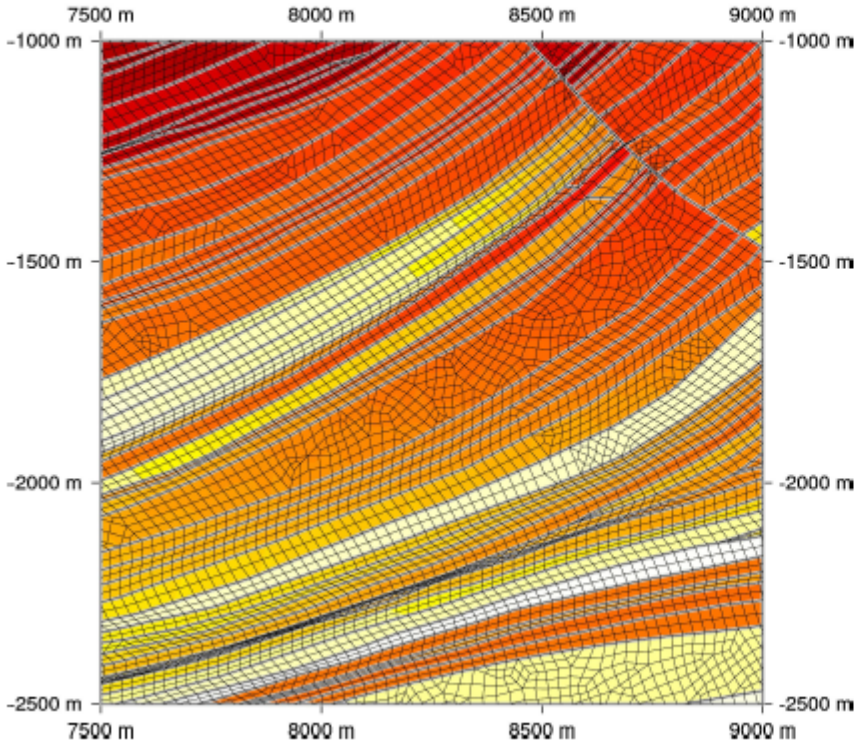


Käufl, Fichtner, Igel, GJI, 2013

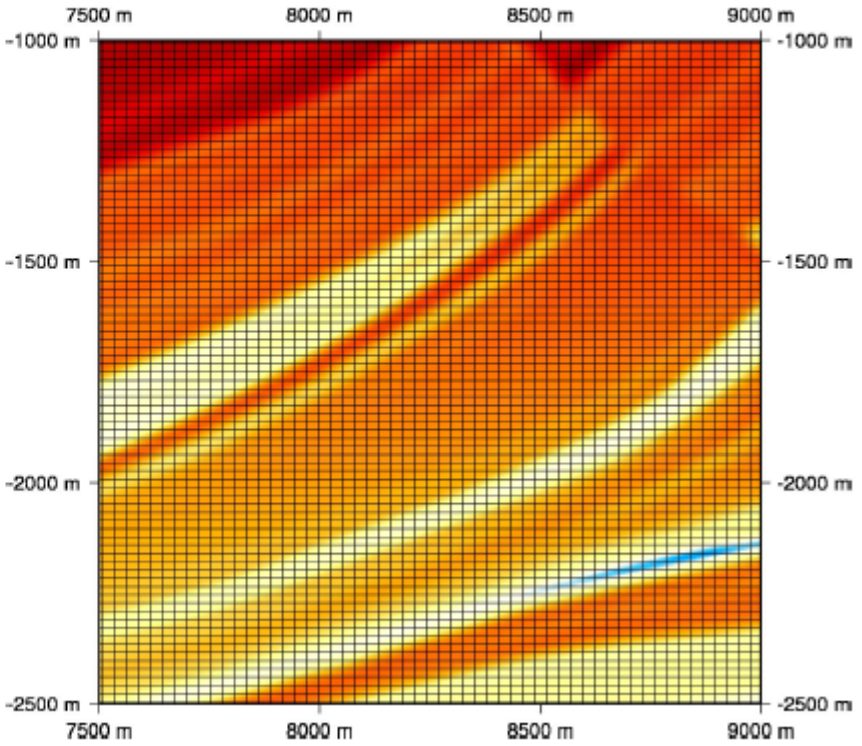


Inverse modeling – Homogenization

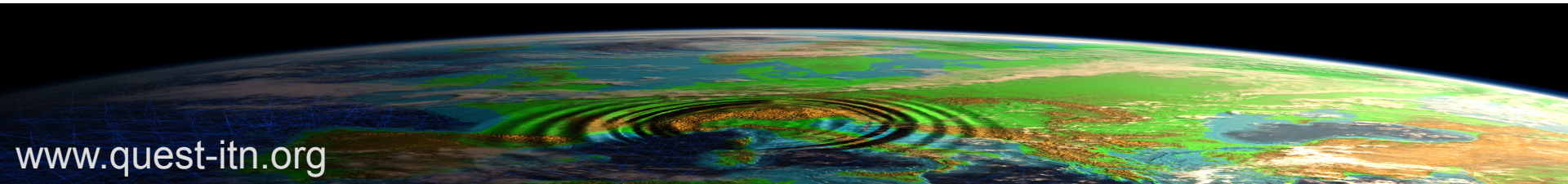
Mesh for the original model



Mesh for the homogenized model

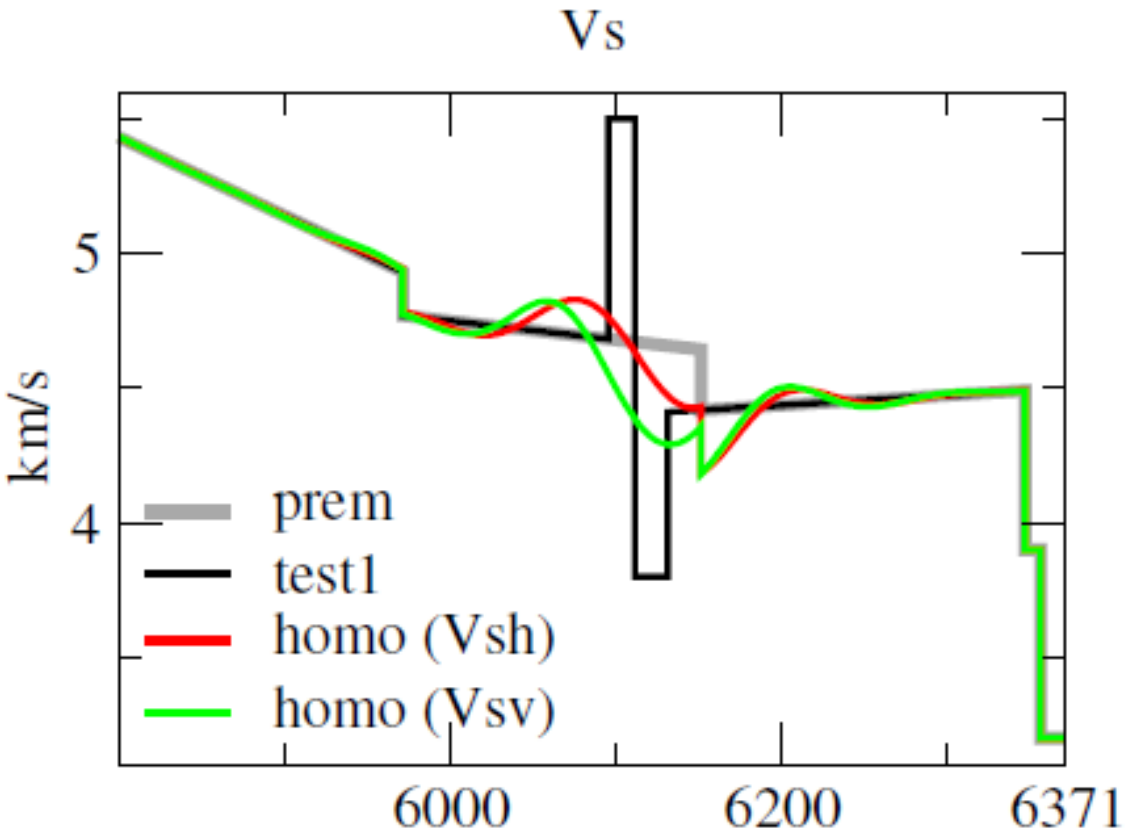


Courtesy: Yann Capdeville



Inverse modeling – Homogenization

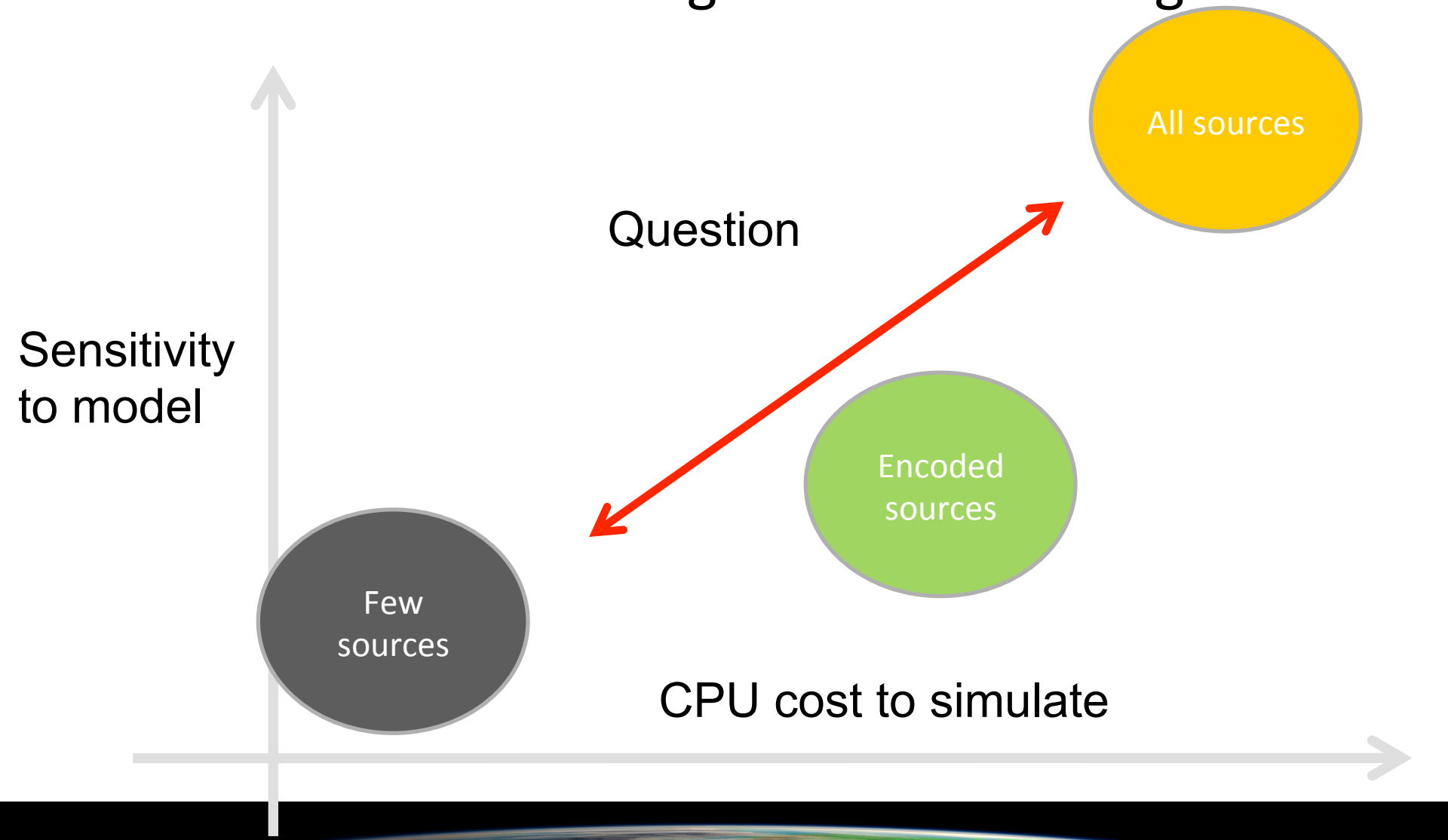
... picture this!



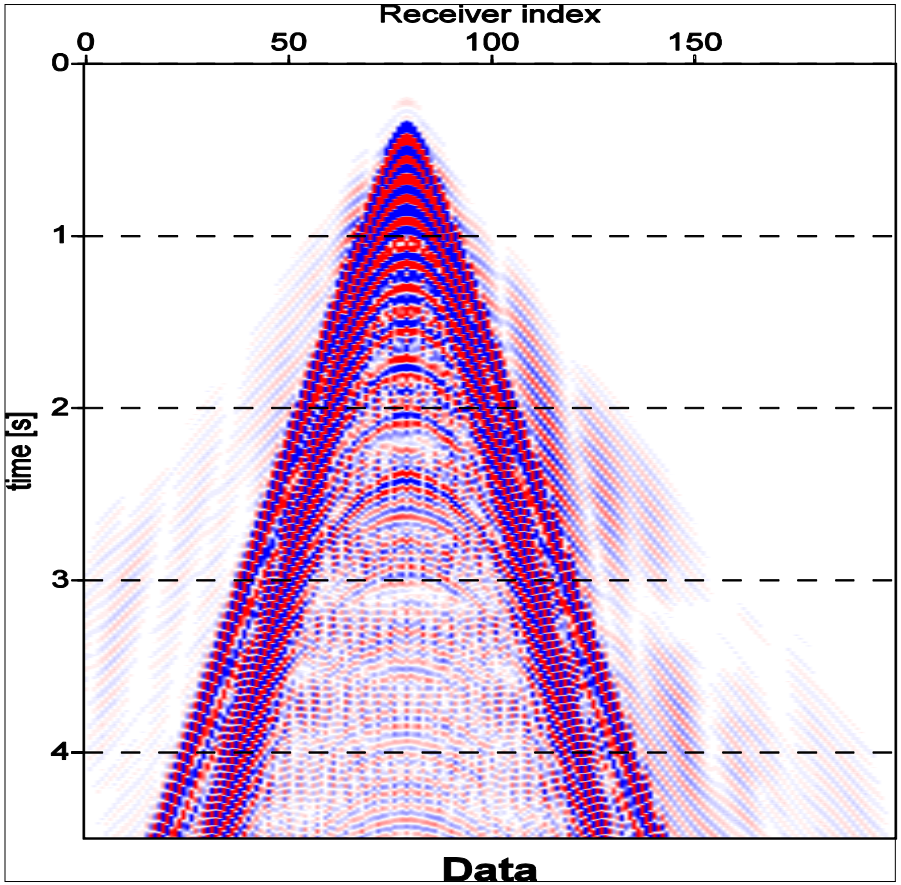
Seismograms for **test1** and **homo** are indistinguishable!


Albert Tarantola, 1949-2009

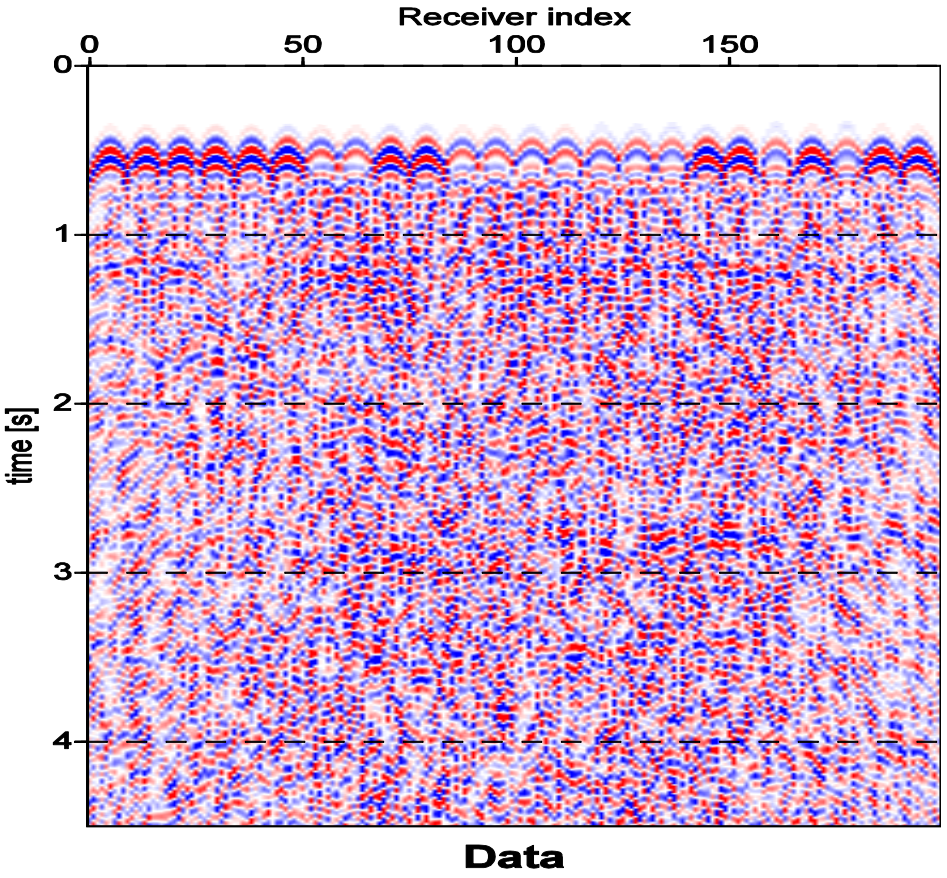
Inverse modeling – Source stacking



Single shot

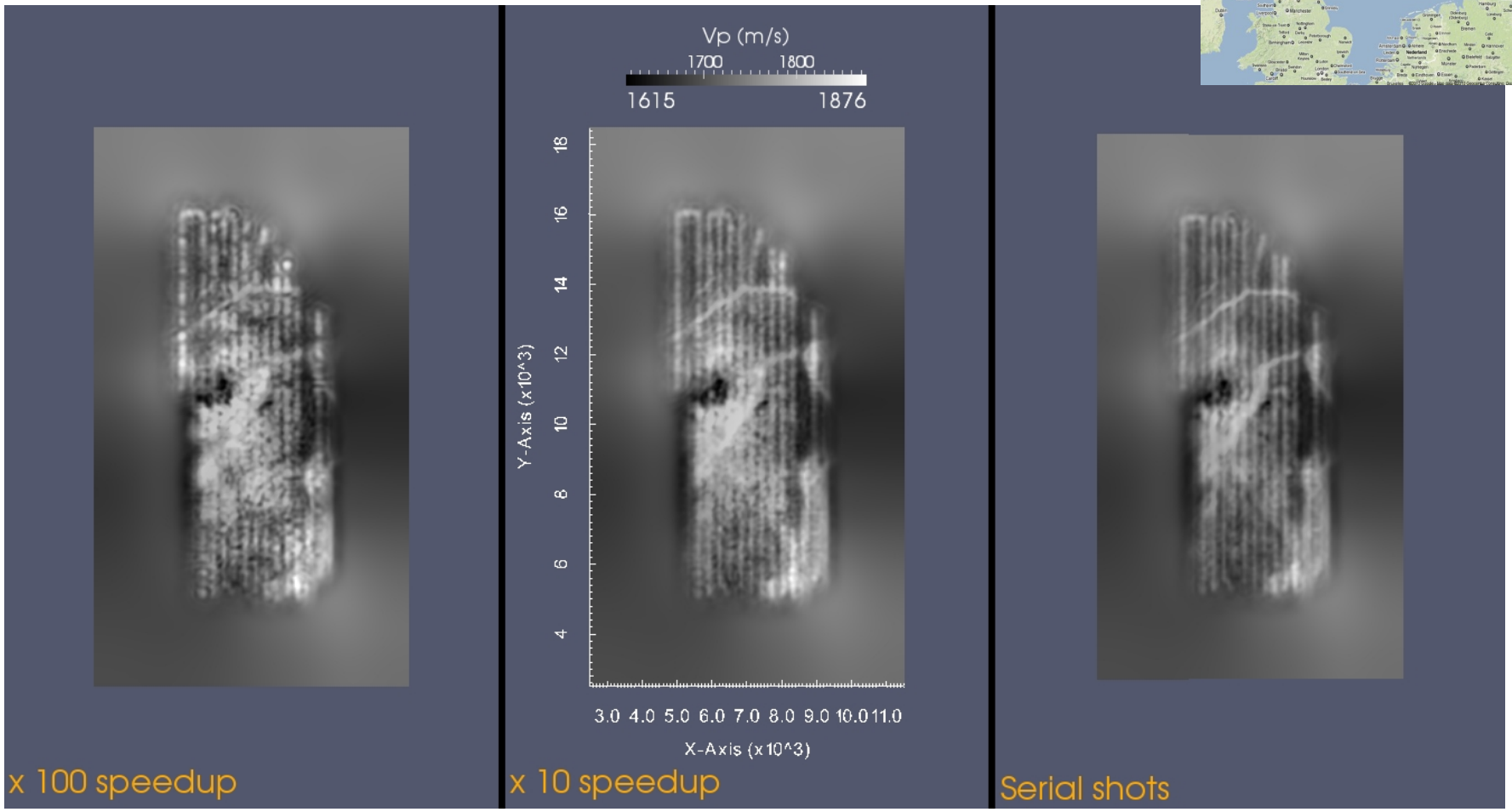


Encoded shots



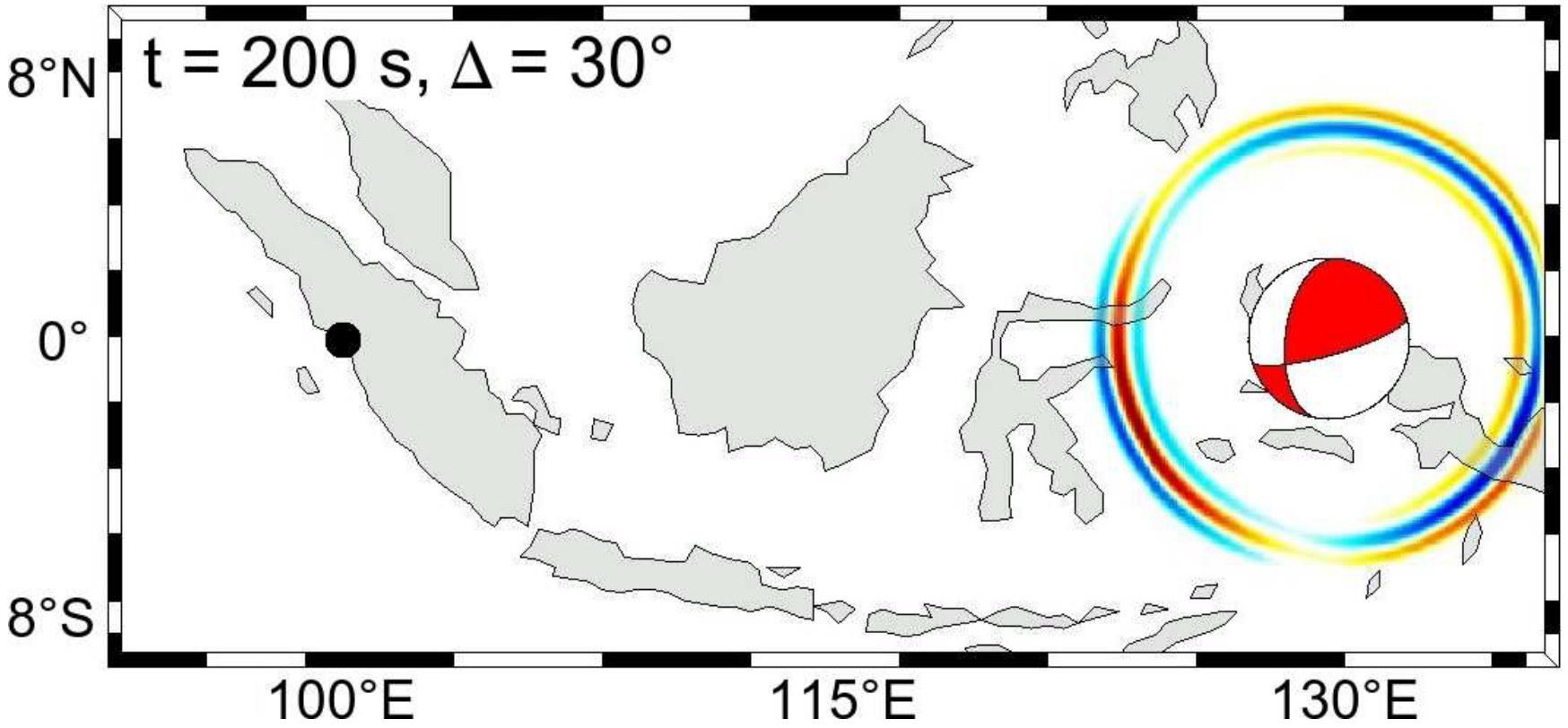
Real data: Valhall

3000 receivers, 50000 sources

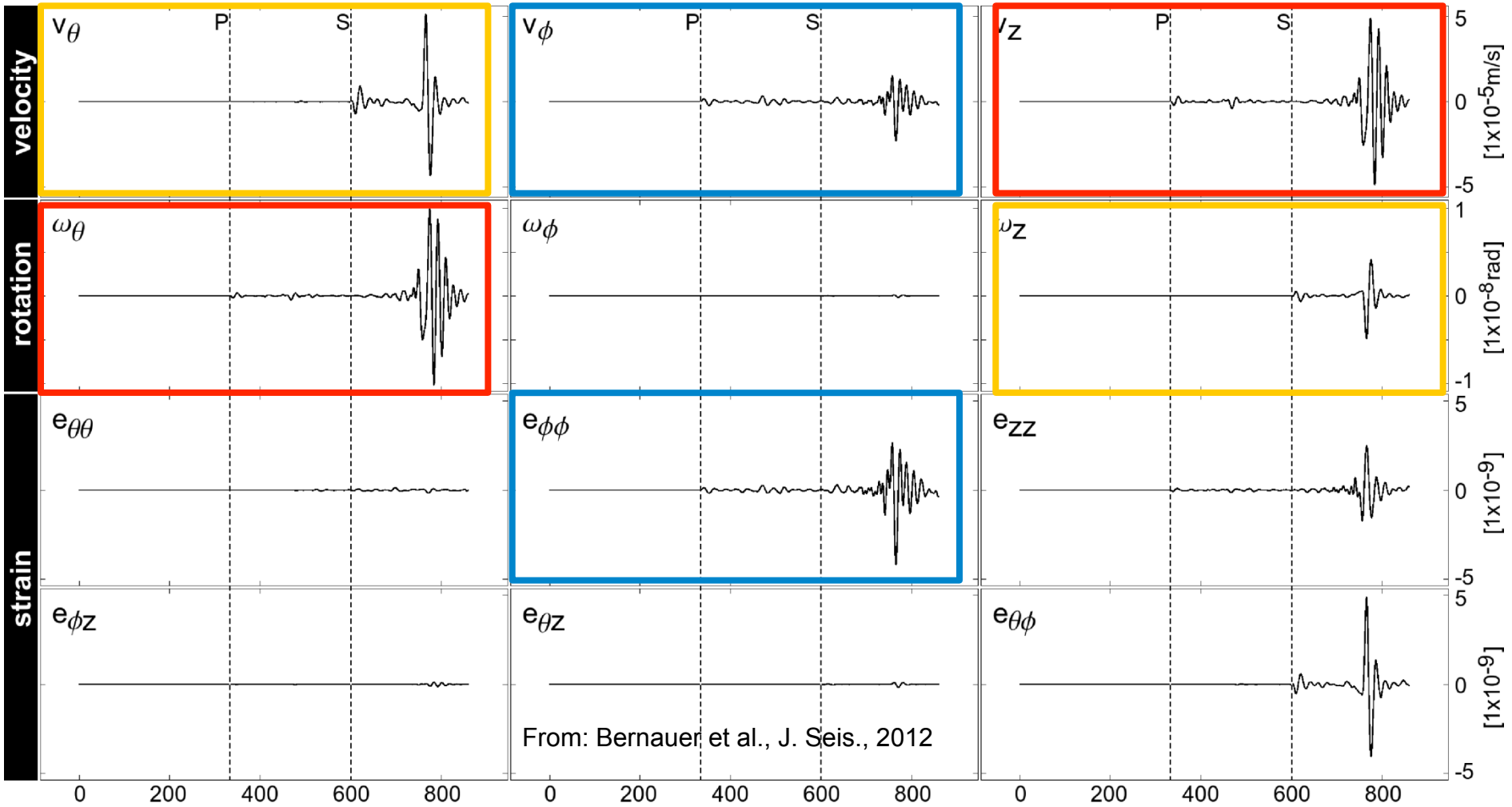


Schiemenz and Igel, GJI, in print.

Theory: Going beyond 3C



Going beyond 3C



From: Bernauer et al., J. Seis., 2012

From: Bernauer et al., J. Seis., 2012

Going beyond 3C

Rotation

$$\frac{|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)|}{|curl\,\boldsymbol{u}(\boldsymbol{x}^r)|} = \beta$$

Definition: apparent S wave speed

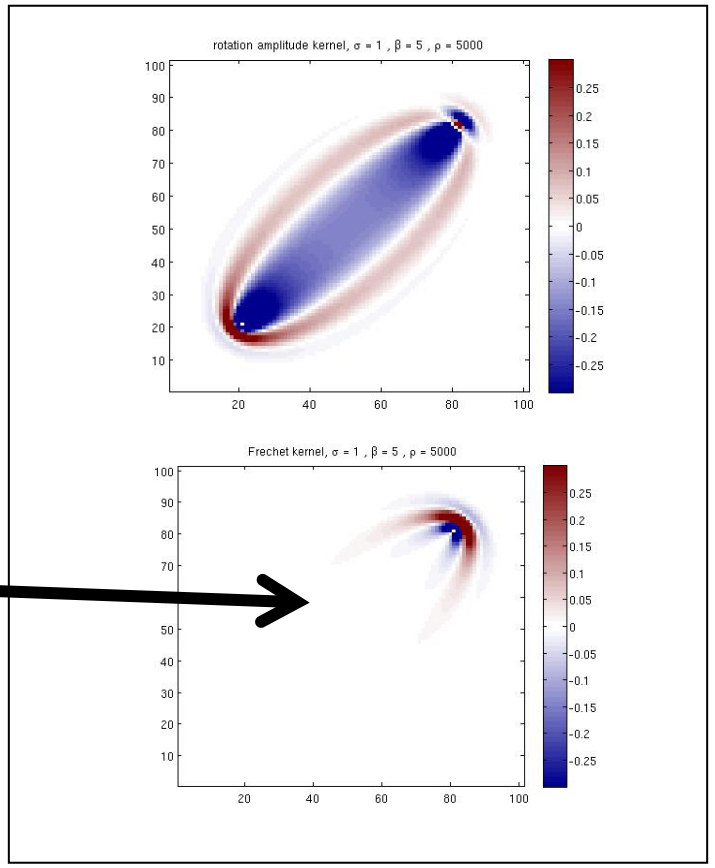
$$\beta_a(\boldsymbol{x}^r) \overset{\text{def}}{=} \frac{\|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)\|_2}{\|curl\,\boldsymbol{u}(\boldsymbol{x}^r)\|_2}$$

Strain

$$\frac{|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)|}{|div\,\boldsymbol{u}(\boldsymbol{x}^r)|} = \alpha$$

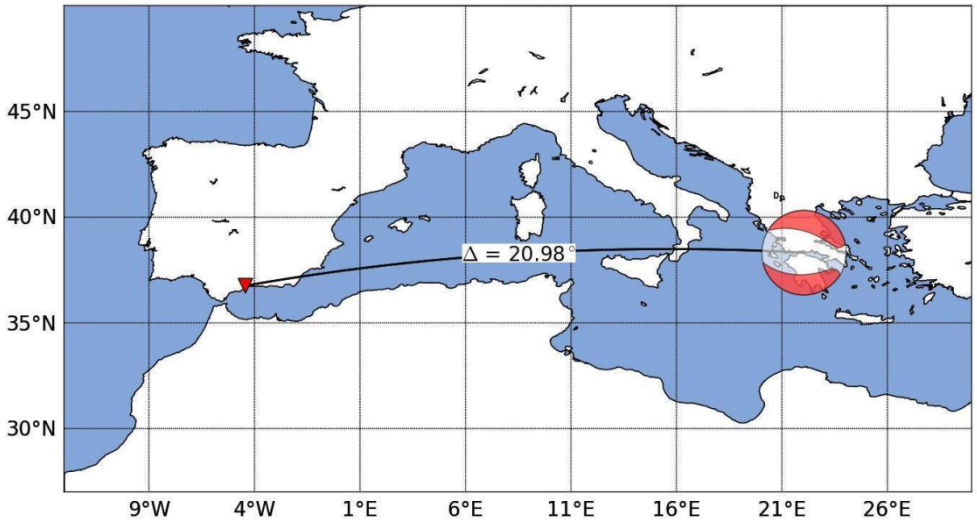
Definition: apparent P wave speed

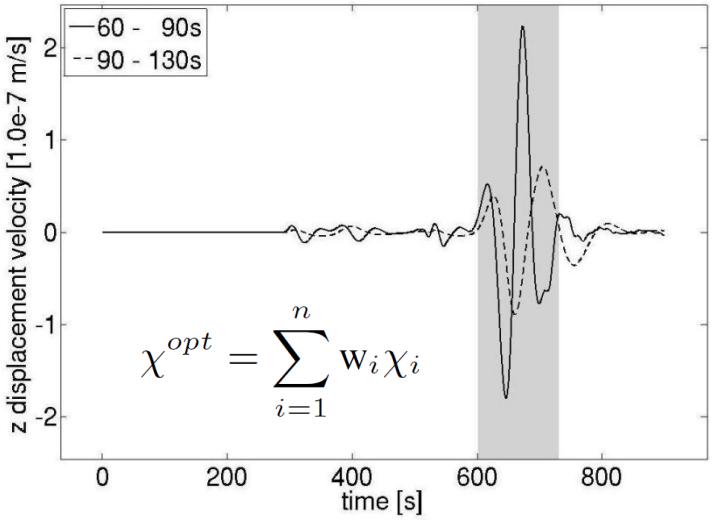
$$\alpha_a(\boldsymbol{x}^r) \overset{\text{def}}{=} \frac{\|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)\|_2}{\|div\,\boldsymbol{u}(\boldsymbol{x}^r)\|_2}$$



… cool localized kernels …
… phase velocities from **point measurements**

Sensitivity optimization





If you have **i** observables (e.g., translations, strains, rotations) and **j** model parameters (e.g., lam, mu, density) which linear combination of observables i maximizes the sensitivity of model parameter j (e.g., density)?

$$\nabla_{\mathbf{m}} \chi^{opt} \, \delta \, ln(\mathbf{m}) = \int_G \sum_{i,j} w_i K_{ij}(\mathbf{x}) \, \delta \, ln \left(m_j(\mathbf{x}) \right) d^3\mathbf{x}$$

-> principle component analysis
-> this formulation reproduces the *apparent velocities* previously introduced

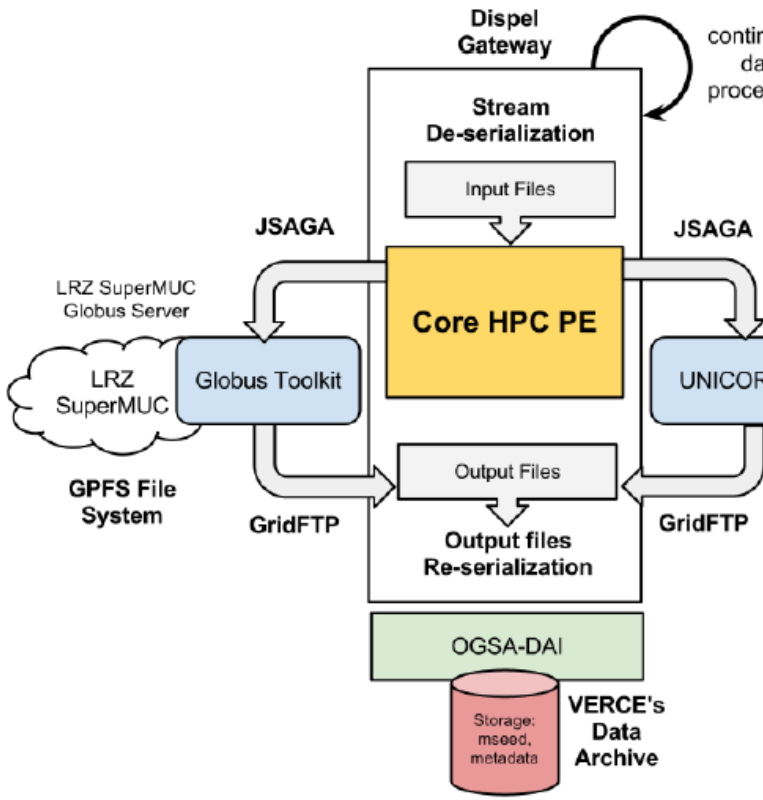
Bernauer, Fichtner, Igel, in preparation

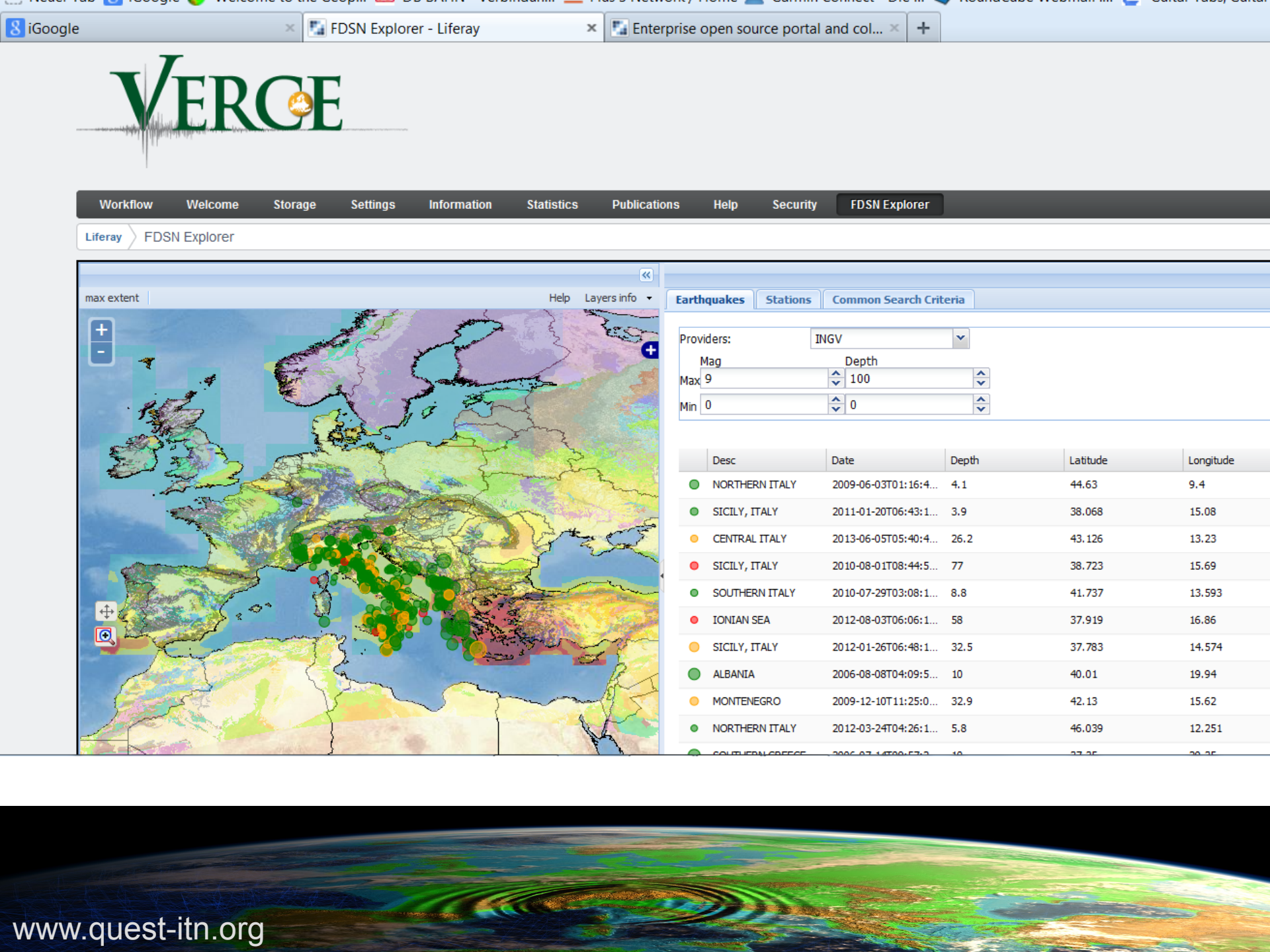
IT issues

- Are your results fully reproducible (in a few years time)?
- Do you remember what processing you did to your data?
- Do you remember which version of your code was used?
- Do your data formats comply with HPC infrastructure?
- Did you store metadata?

-> provenance, reproducibility

-> work flow frameworks

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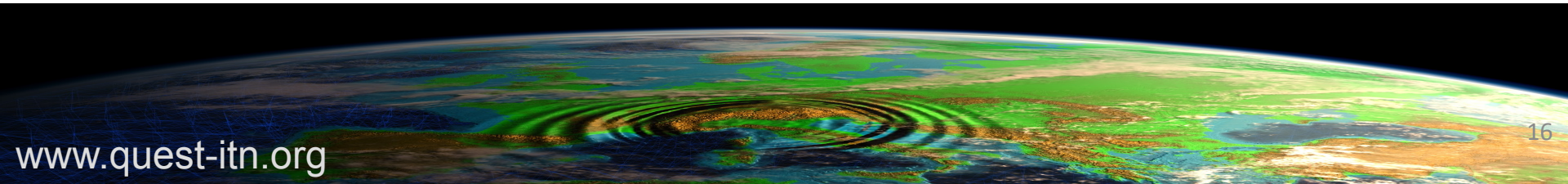
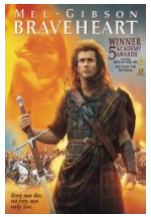
www.quest-itn.org

Conclusions

- The nature of our big challenges since the last CIG-SPICE-QUEST Meeting has changed
- To be efficient in our FWI adventure we need to embrace IT expertise more than ever
- Doing this (in a community effort) will speed up time-to-research for you (or your student)
- Quantifying uncertainty is very difficult, but one of the biggest long-term challenges



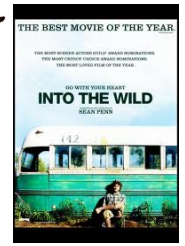
Nominees for **Best-Meeting-Organizer** are



Carl Tape – **Braveheart** (… taking on this workshop …)

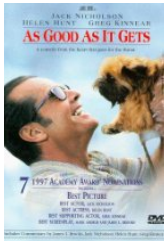
Carl Tape – **Basic Instinct** (… knowing we would love it …)

Carl Tape – **The Graduate** (… suggesting all the tutorials …)



Carl Tape – **Into the wild** (… sending us to Denali not to return …)

Carl Tape – **There will be blood** (… the soccer match …)

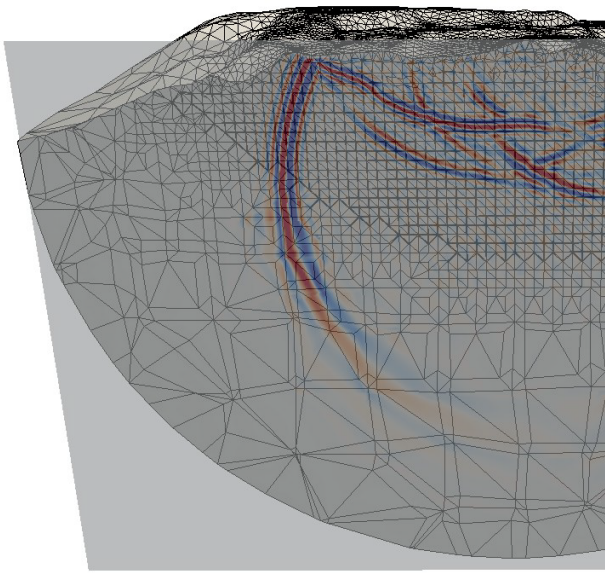


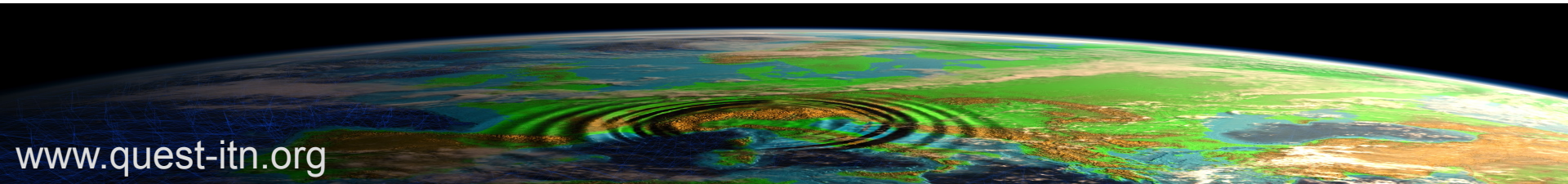
Carl Tape – **As good as it gets** (… our verdict on this workshop …)

And the **Golden Grizzly** goes to

Wave propagation solvers

- Happy with FD, FV, SE, FE, DG?
- Covering all physics we need?
- Will the specific code you use survive?
- Version controlled and benchmarked?
- Does your code scale well?
- Ready to embrace new architectures?
- How long does it take to mesh?
- Do you mesh each interface? Should we adopt homogenized models and regular grids?





Waveform inversion use case

(yes, I hate these kind of graphics, too!)