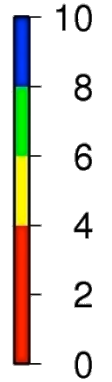
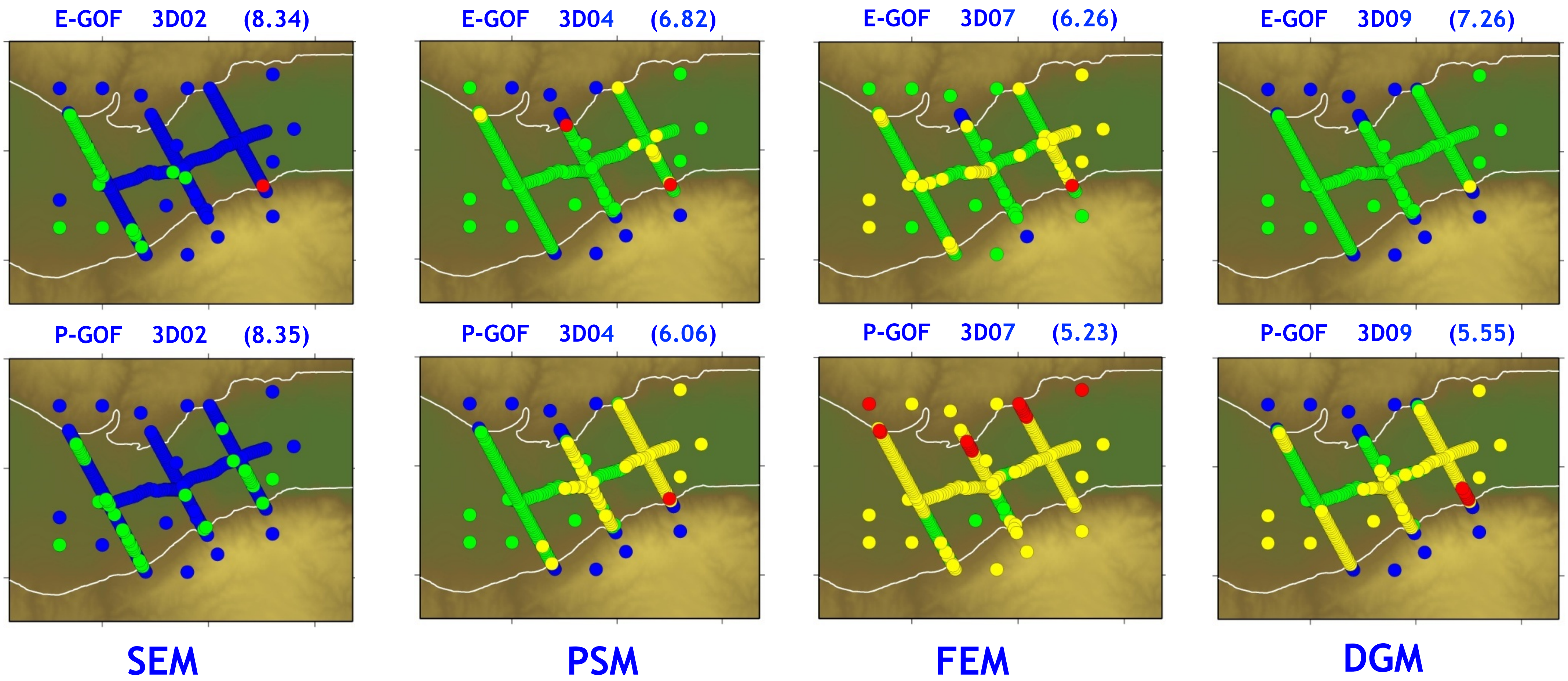
Case Bb (elastic, 1D vertical gradient)

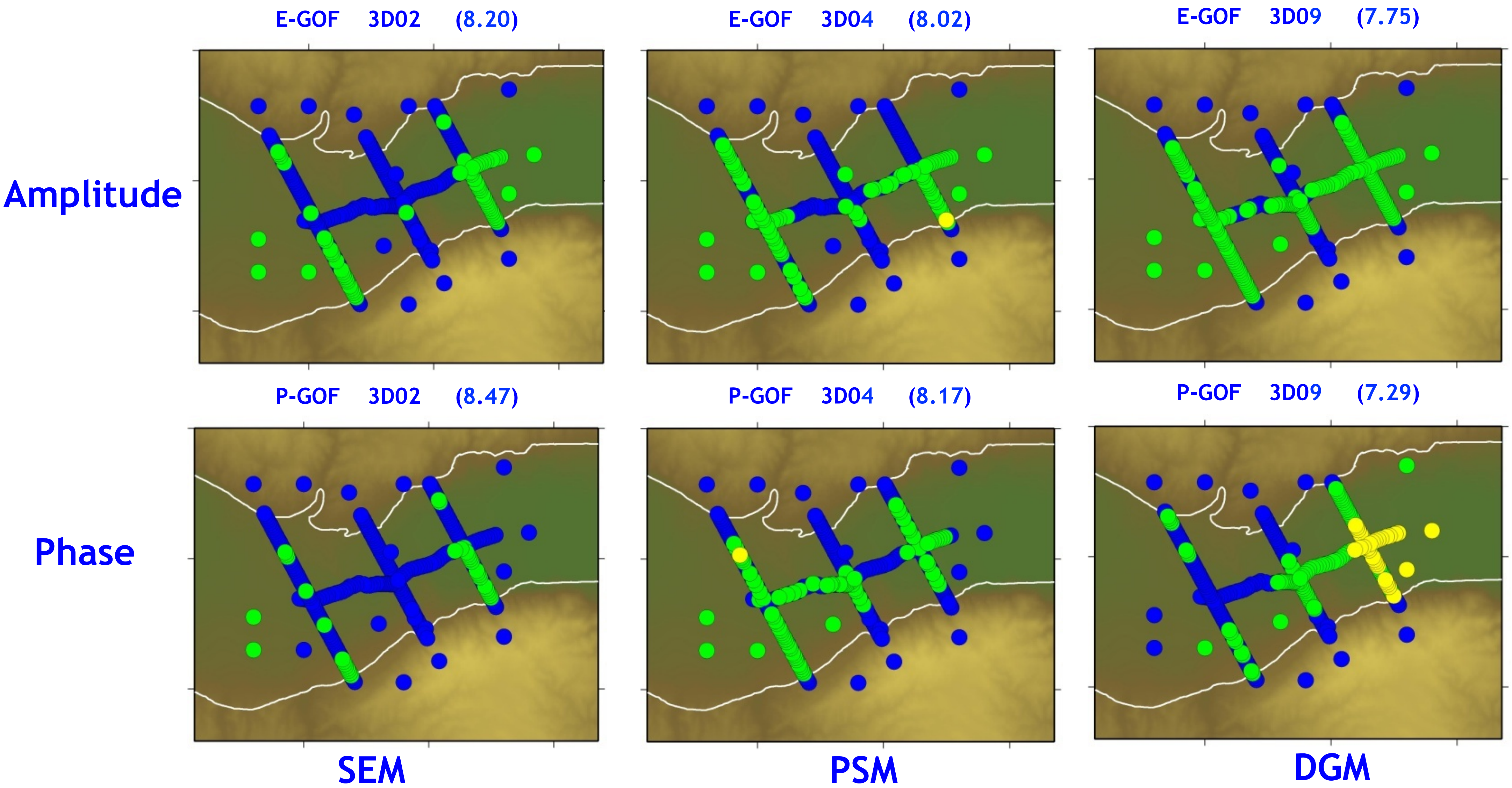


Time-frequency envelope (E-GOF) and phase (P-GOF) goodness-of-fits
reference: 3D01



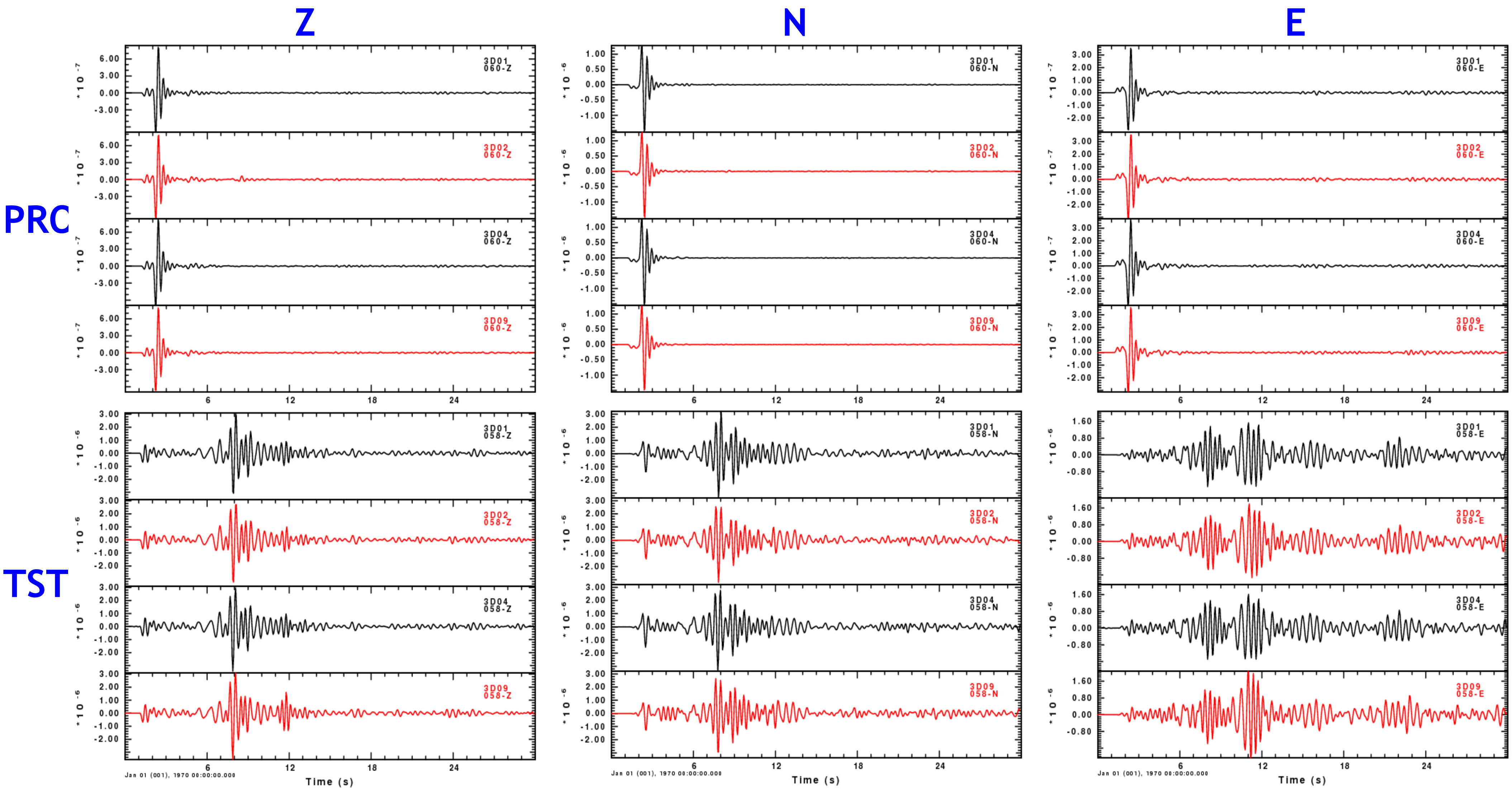
Better than 3HL : discretization of material discontinuities

3D Verification 4 (Be) : piecewise linear gradient, NO damping



Even better: Lower impedance contrast on edges

Be (piecewise linear gradient, NO damping)



Conclusions - 3D Verification

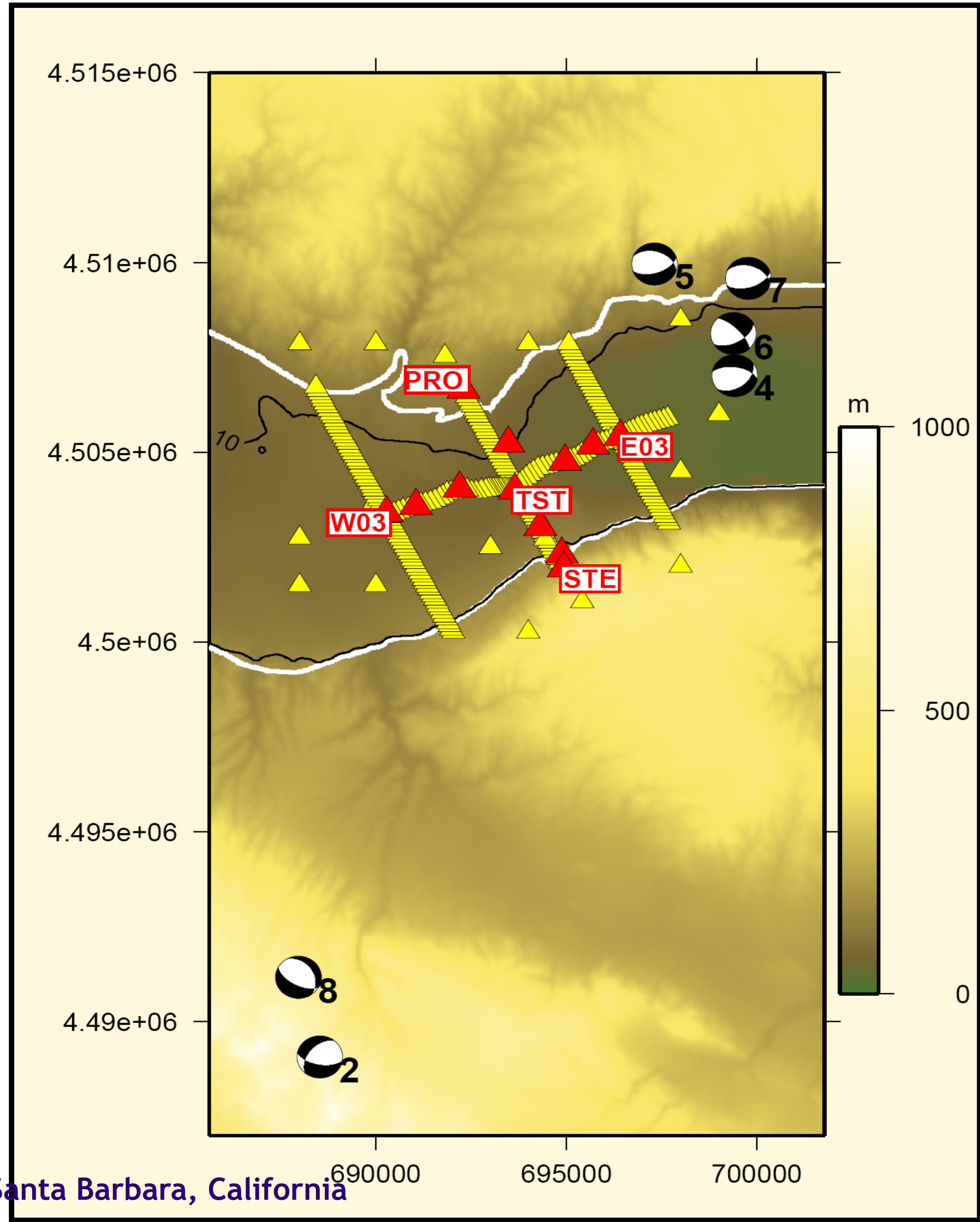
- numerical simulation of ground motion is not yet a ”press-button” procedure,
- Good match up to 4 Hz obtained between various simulation techniques indicates a very encouraging level of maturity.
  - teams and codes who already compared their results are more likely to provide satisfactory results at the first iteration
  - Most of other teams demonstrated capability to iterate and improve their prediction in the course of the project
- Emphasis on the importance of
  - the actual implementation of damping
  - the details of the discretization process for interfaces with large impedance contrast (or gradient discontinuities)
  - proper accounting of large Poisson's ratios
  - non-reflecting boundary and free-surface condition

Validation : modelled earthquakes

A selection of 6 local earthquakes

- ("within the computation box")
- (required careful data check : signs, gains, focal mechanisms, etc.)

Event #	Mag	Depth	Strike	Dip	Rake
2	2.8	6.9 km	100°	60°	-50°
4	4.4	5 km	53°	43°	-127°
5	3.1	6 km	72°	55°	-113°
6	3.9	6 km	61°	55°	-115°
7	3.4	5 km	72°	55°	-113°
8	3.8	10 km	329°	34°	-64°



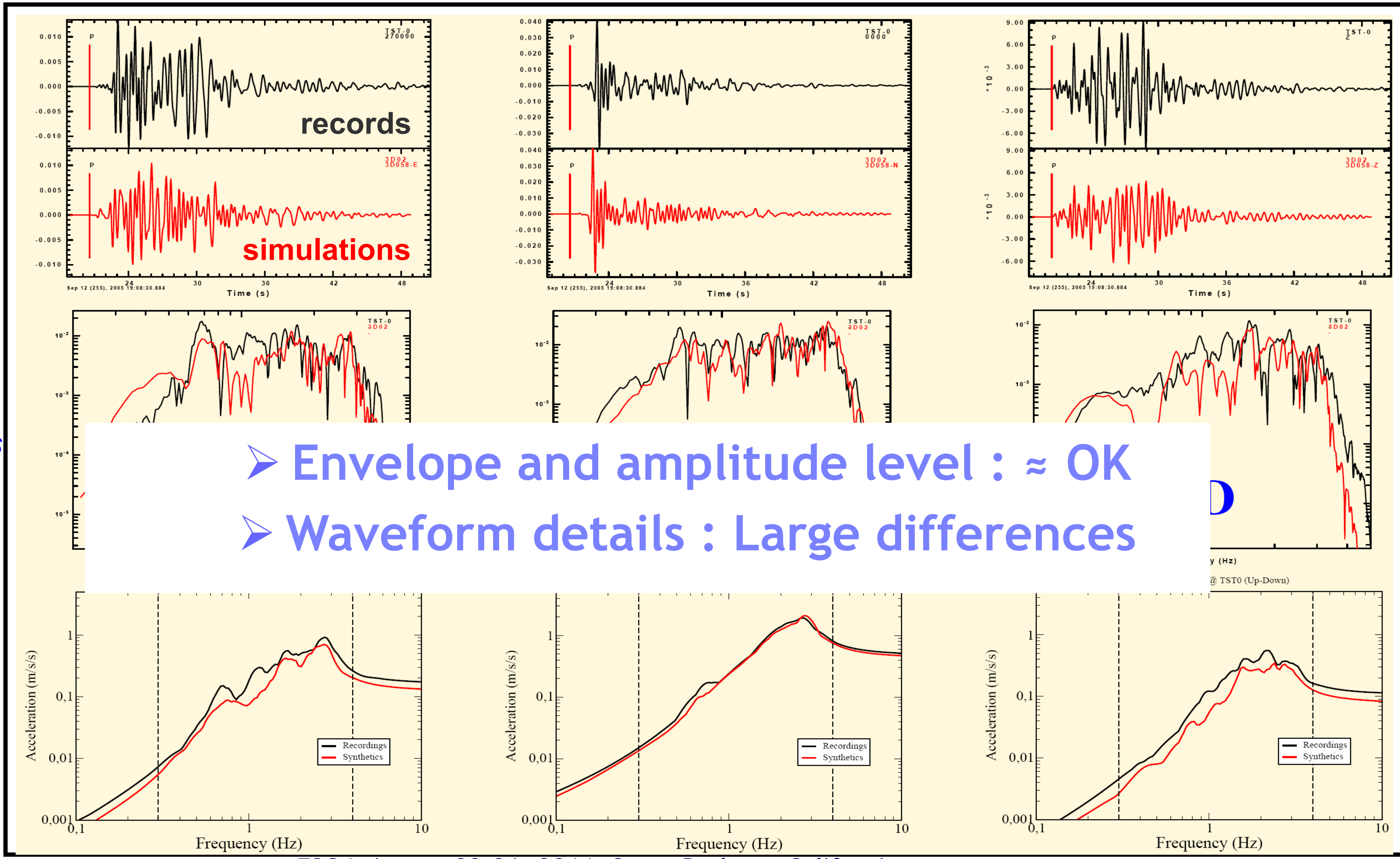
Validation : waveform and spectrum “visual” comparison

Station TST - event #4 (M = 4.4): example of a good agreement

Time histories

Fourier transforms

Response spectra



- Envelope and amplitude level : ≈ OK
- Waveform details : Large differences

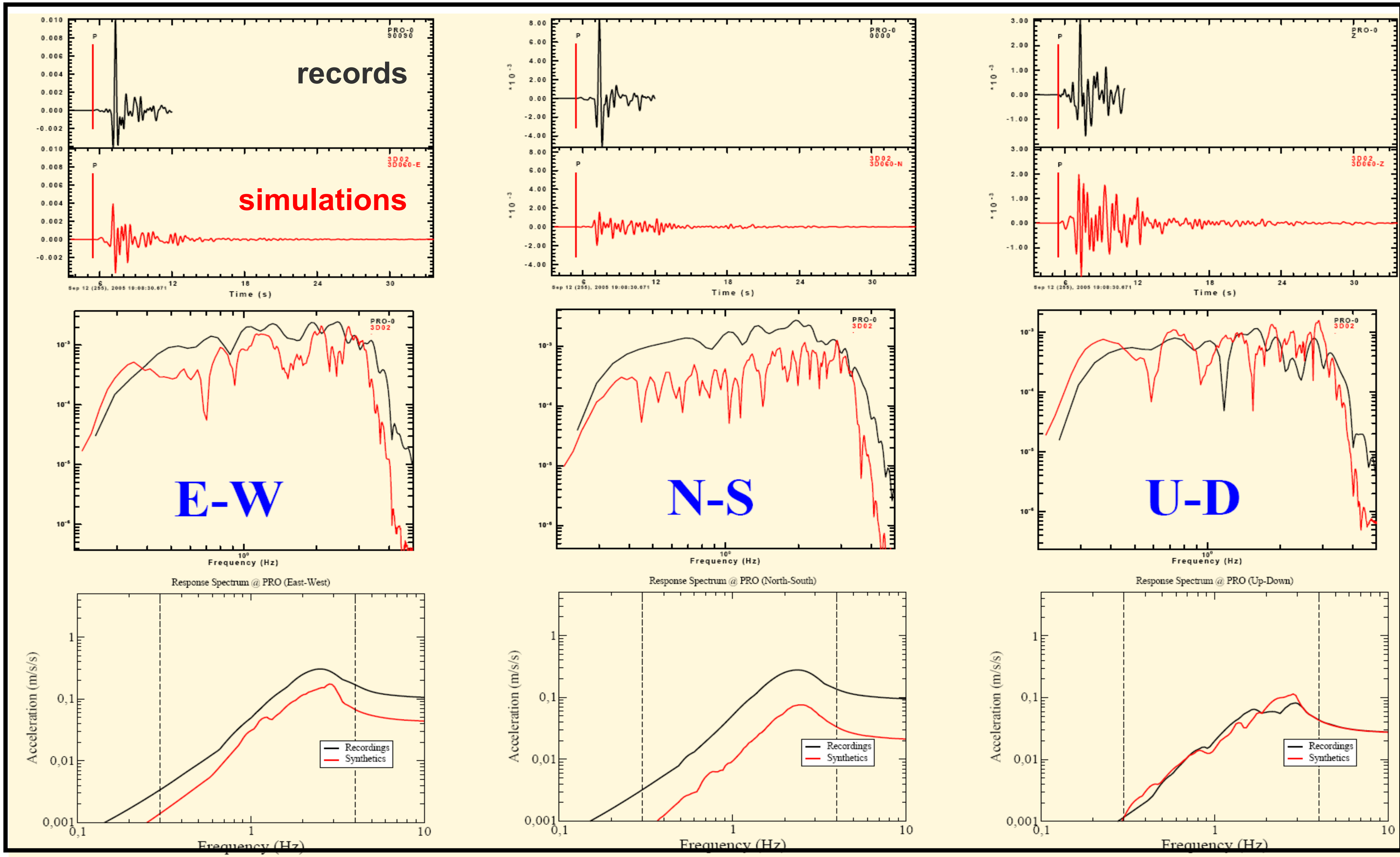
Validation : waveform and spectrum "visual" comparison

Station PRO - event #4 (M = 4.4): example of a perfectible agreement

Time histories

Fourier transforms

Response spectra

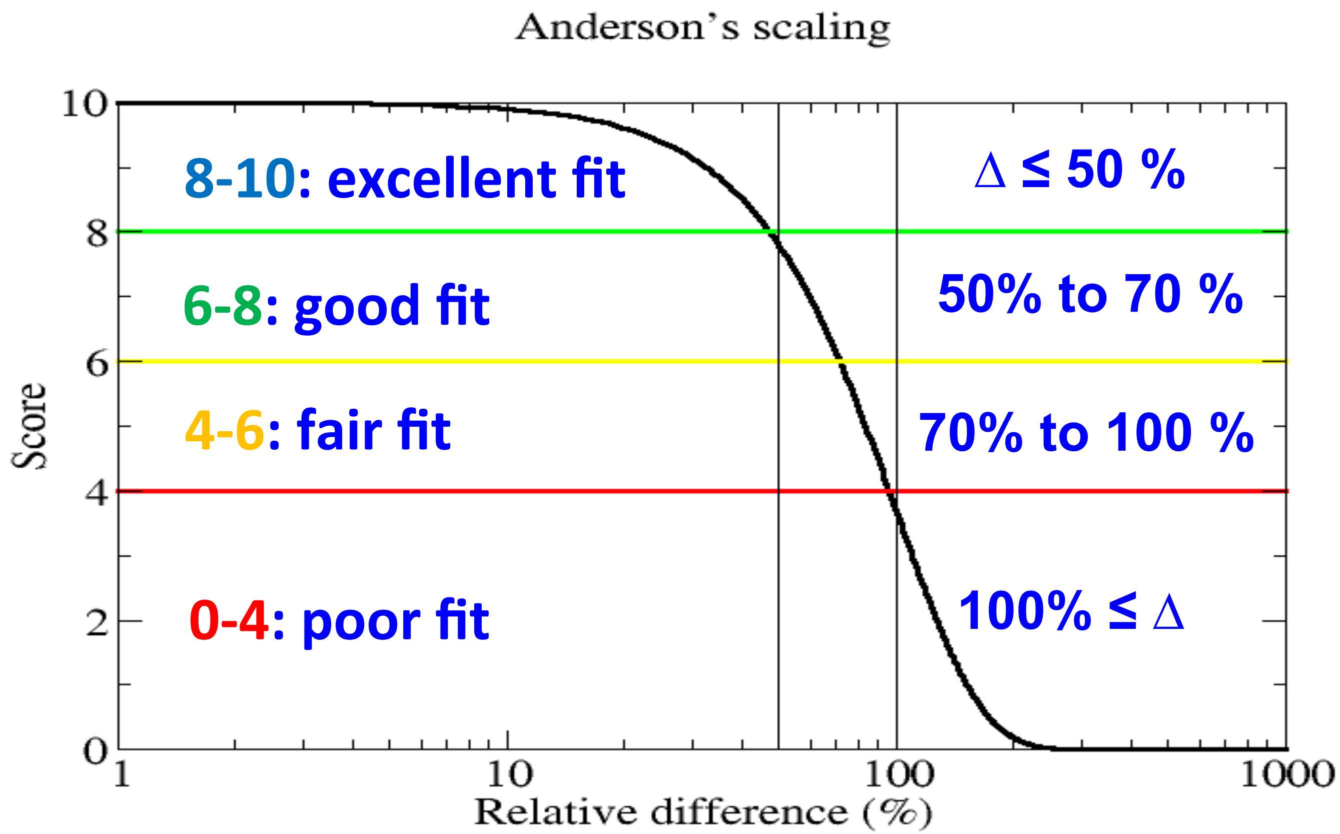


➔ *Large amplitude differences on horizontal components.*

New, less stringent, goodness-of-fit criteria

Anderson : Combination of 10 engineering parameters (average of 3 components):

- C1: Arias duration - Max(t)
- C2: Energy duration - Max(t)
- C3: Arias intensity
- C4: Energy integral
- C5: Peak acceleration
- C6 : Peak velocity
- C7 : peak displacement
- C8 : Response spectra - Mean(f)
- C9 : Fourier spectra - Mean(f)
- C10 : Correlation coefficient

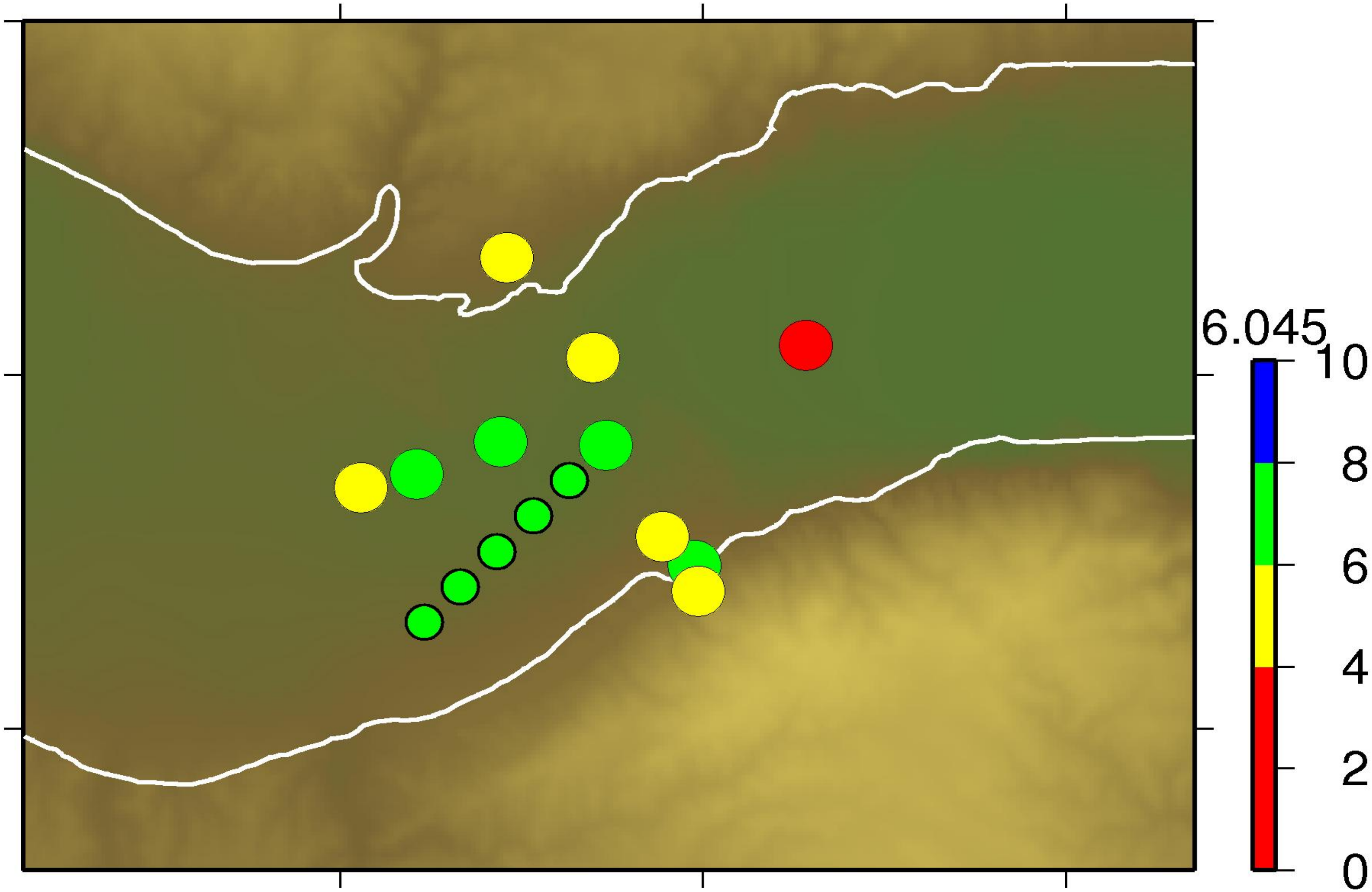


Each criterion is measured and scaled between 0 and 10:

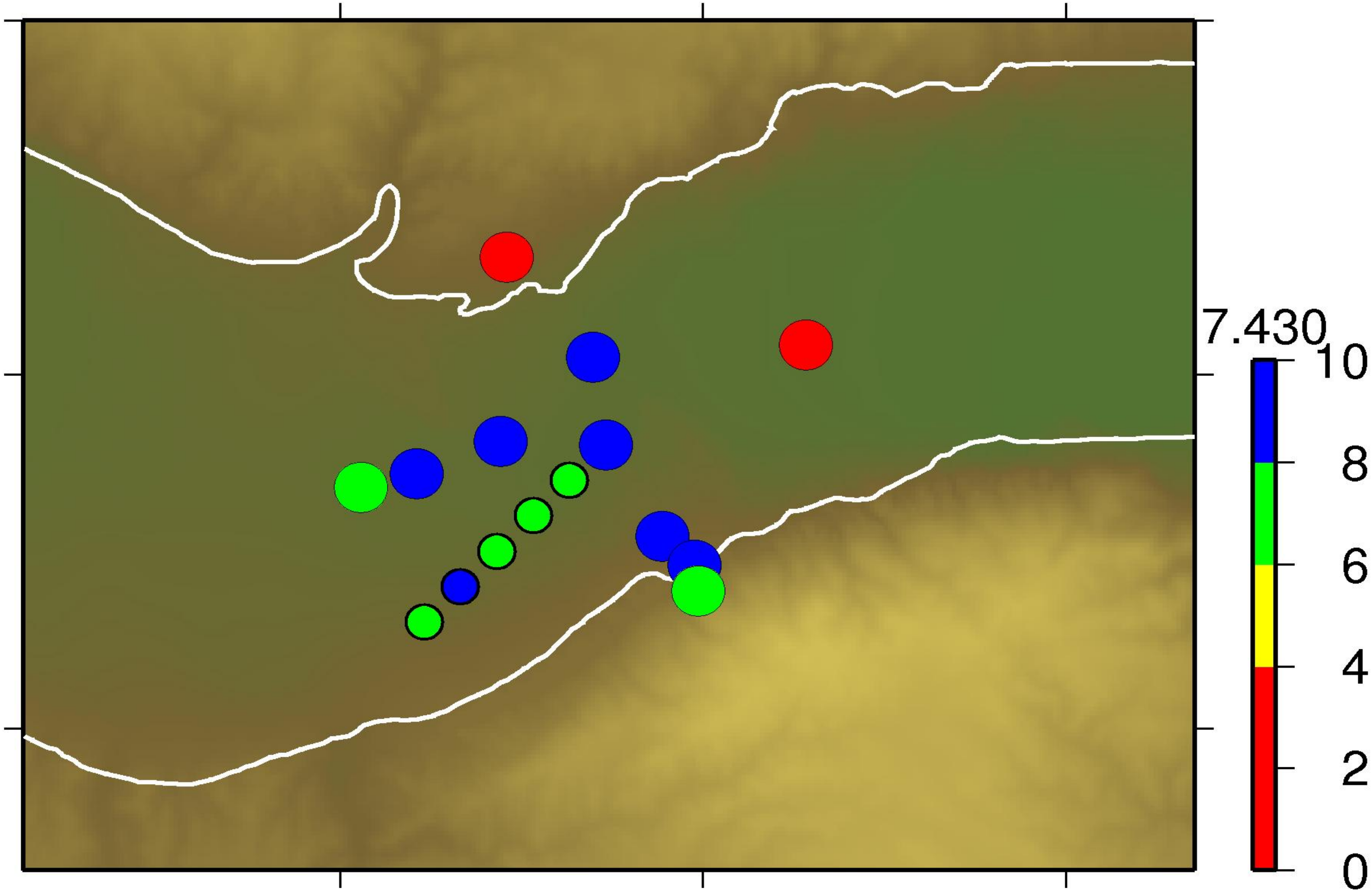
Gof=10 Exp(-diff²)

a

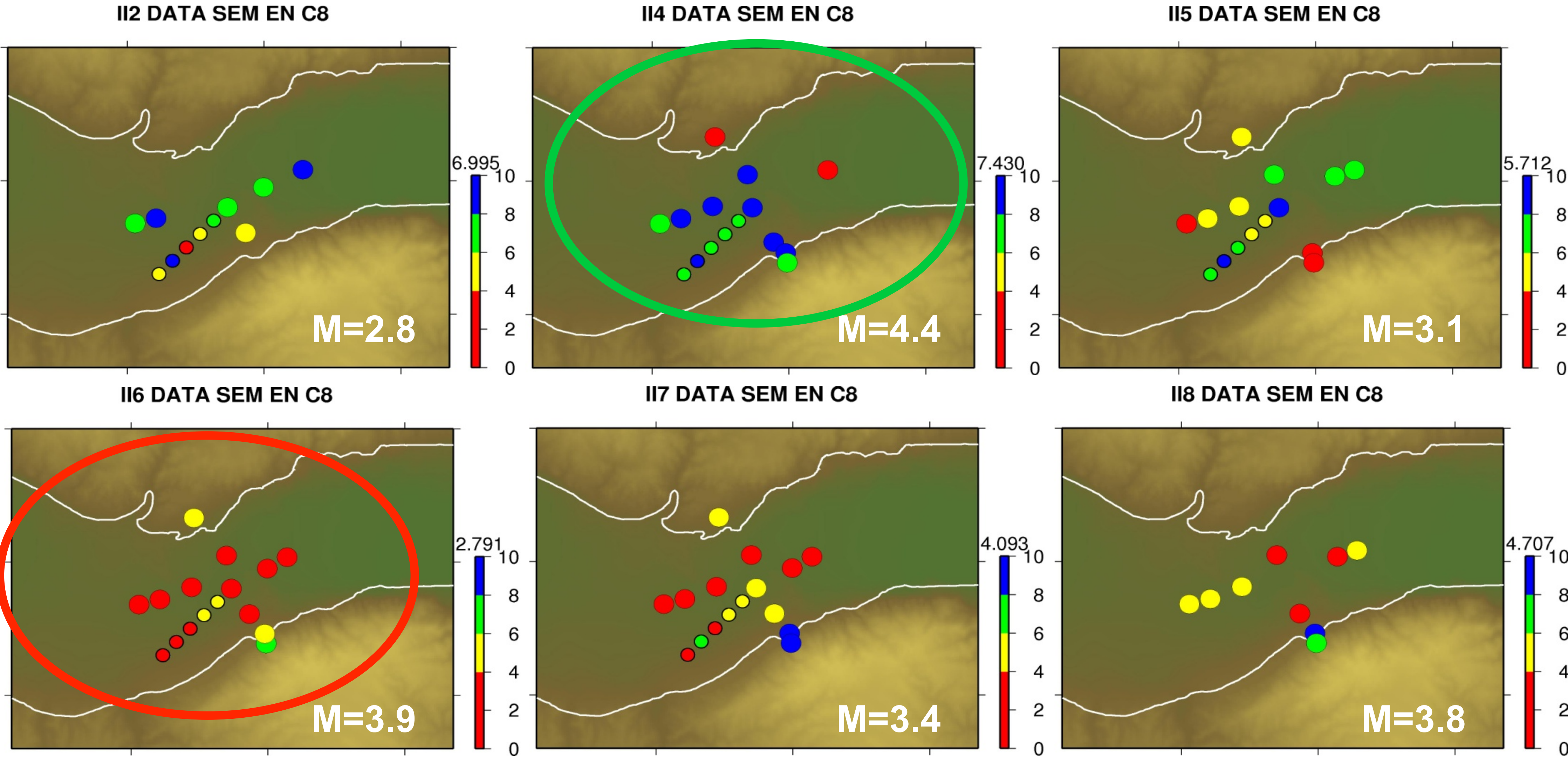
Event #4: Global "Goodness of fit" (all components)



Event #4: Response spectra (horizontal)



All events: Response spectra only (Hz components)



Best = larger magnitude (best location / characteristics)

Worst = ~~lower~~ second larger magnitude

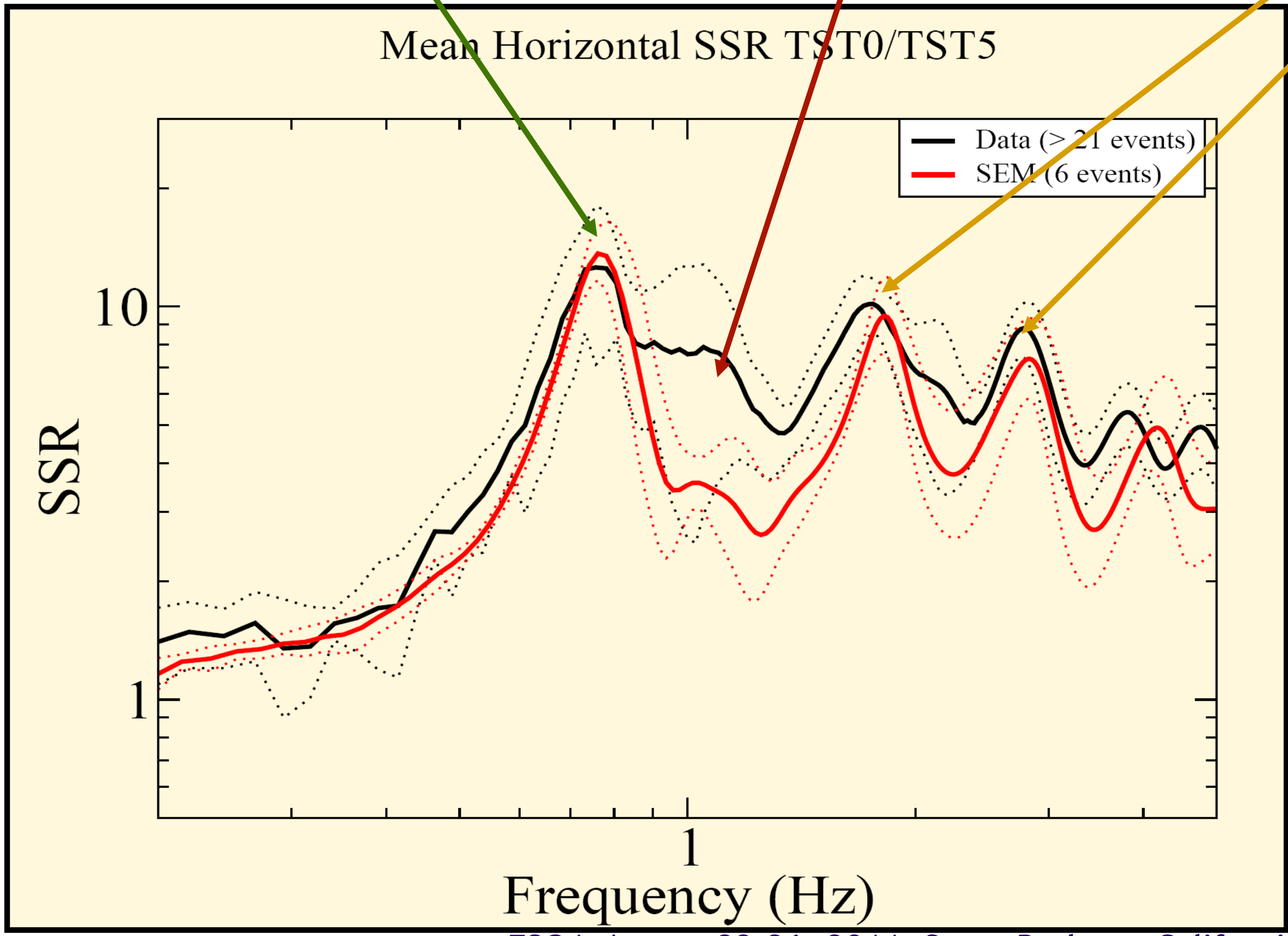
Mean amplification estimation at TST

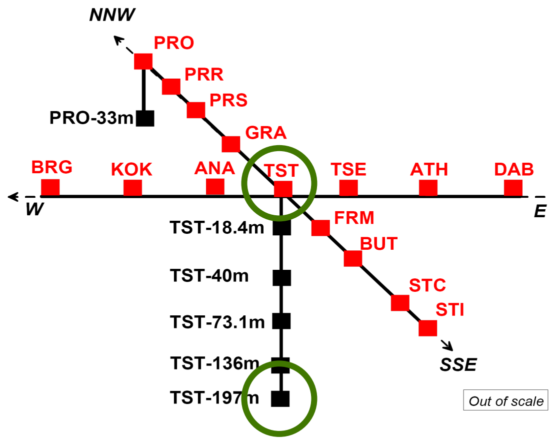
Synthesis : spectral ratio

Still needs to be understood…

Very good agreement

Rather good agreement





Validation : summary comments

Distance data / model larger than the smallest model/model distance

- (usefulness of verification phase !)
- Model
  - No evidence of "best / Better" Q model (Constant Q or Q(f))
  - No evidence of "bad geometry / velocity" in some specific part of the basin

TST amplification relatively well predicted (3D > 1D and 2D)

- (usefulness of borehole instrumentation)

Not bad, but could/should be improved : remaining work ahead !

- Global gof(Anderson) at most 6 (i.e. 70% difference…);
  - Hz response spectra predicted with at least 50% error
- priority : source and model characterization
  - uncertainties in source parameters
  - capabilities of geophysical surveys
    - underground structure at short wavelength
    - still a few very badly known parameters (e.g., material damping)

next challenges

Main conclusions to be remembered

- Neither 3D,L nor (2D) NL numerical simulations are yet "press-button"
  - Too fast applications may yield very wrong results (and large untrust from end-users)
  - Still room for improvements

- BUT very similar results are possible even with completely different numerical schemes (3D, L)
  - (probably indicative of the "exact" solution)
  - Never use only one method, prefer at least two
  - Use quantitative assessments of the mismatch between predictions

- Conditions for careful use
  - well-validated techniques & codes
  - Well trained users
  - Careful model implementation
  - External review
  - Check with data !

Work to be pursued

Further work planned within "E2VP2"

- More distant events (outside the box)
- Until which frequency are the deterministic modelling approaches relevant ?
- Which geotechnical parameters are the more important (geometry of interfaces, velocity, attenuation) ?

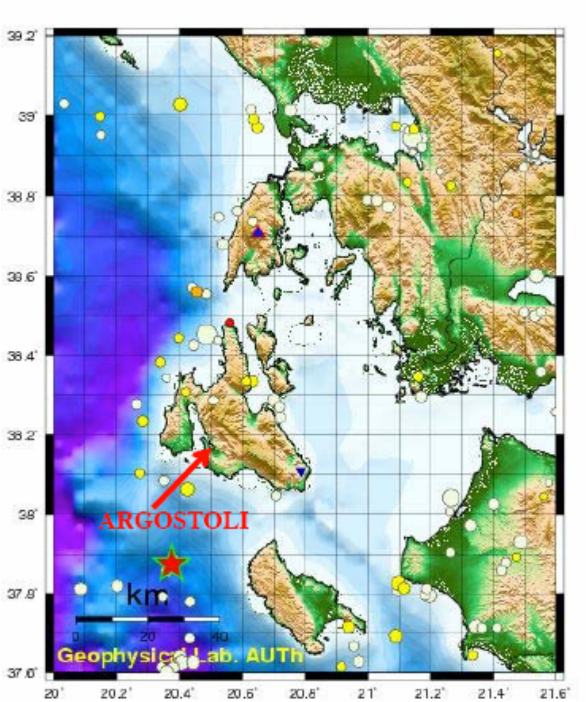
Cashima2 / Sigma

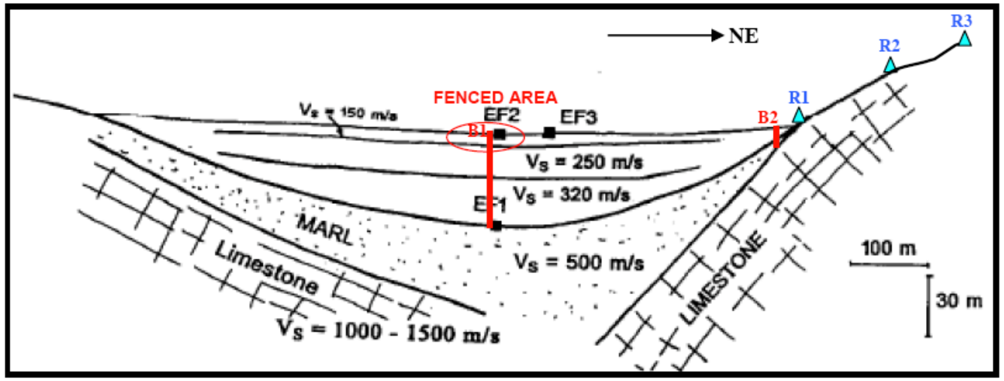
- Site survey techniques : Invasive / non-invasive for Vs(z)
- NL issue

NERA

- Basin effects + spatial variability & ground strains
- a new site : Argostoli / Western Greece

A new test-site in Europe : Argostoli





E2VP related poster

- Chaljub, E., P. Moczo, J. Kristek, P.-Y. Bard & F. Hollender: Relevance of ground motion numerical simulations : what have we learned since the ESG2006 benchmark ?

Ackowledgments

- We thank the participants of the project for contributing to this paper with their results: E. Priolo, P. Klin, T. Iwata, A. Iwaki, S. Aoi, F. Le Piver, C. Mariotti, J. Bielak, R. Taborda, H. Karaoglu, V. Etienne and J. Virieux.

- Slovak Research and Development Agency (contract N° APVV-0435-07, project OPTIMODE) and the Bilateral French-Slovak project SK-FR-0028-09.

- Funding by the European Union through the Initial Training Network QUEST (grant agreement 238007), a Marie Curie Action within the 'People' Programme.

THANK YOU


« Kick-off », Cadarache (may 2008)

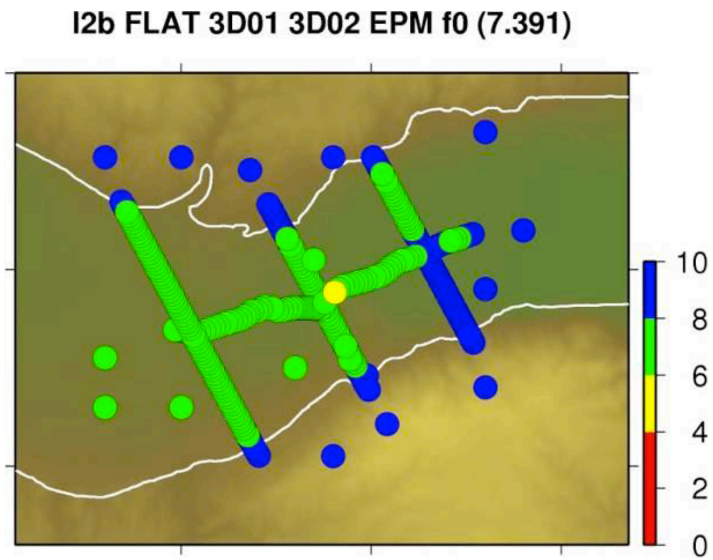

Workshop 3, Cadarache (oct. 2009)


Workshop 1, Grenoble (nov. 2008)

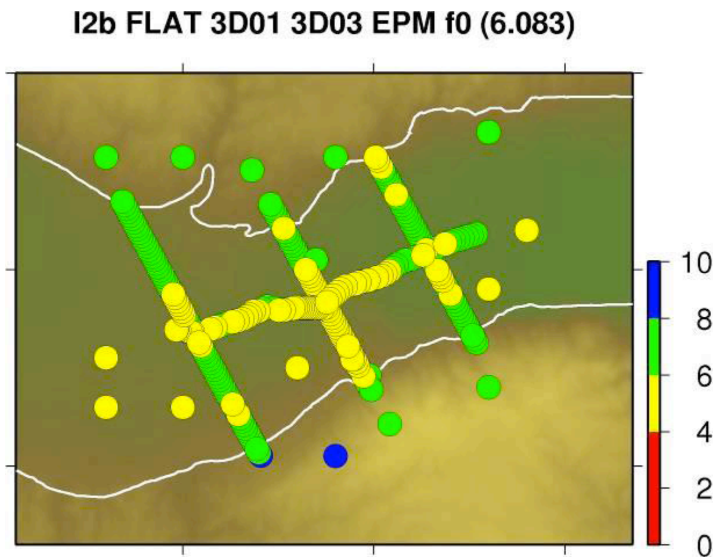

Workshop 2, Cadarache (may 2009)

Bd case : Overall Goodness of fit (BB, 3C)

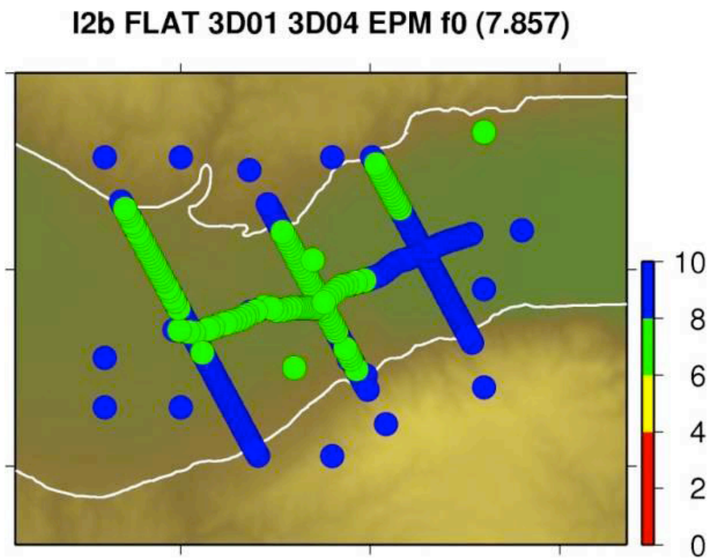
FDM / SEM



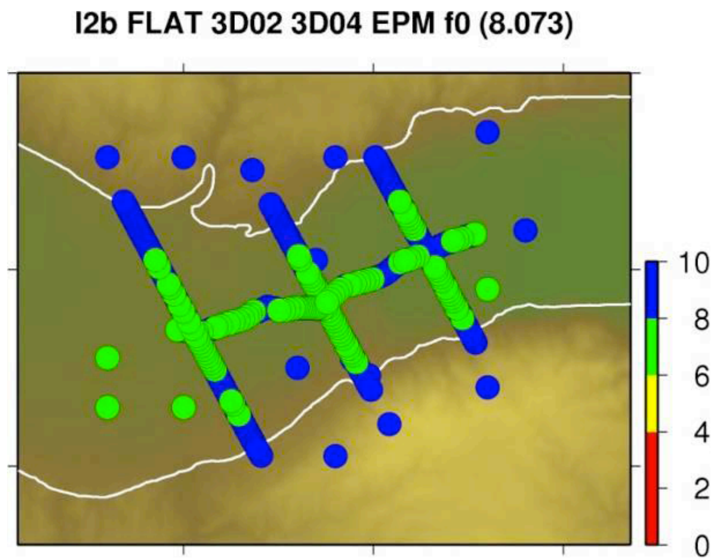
FDM / FDM



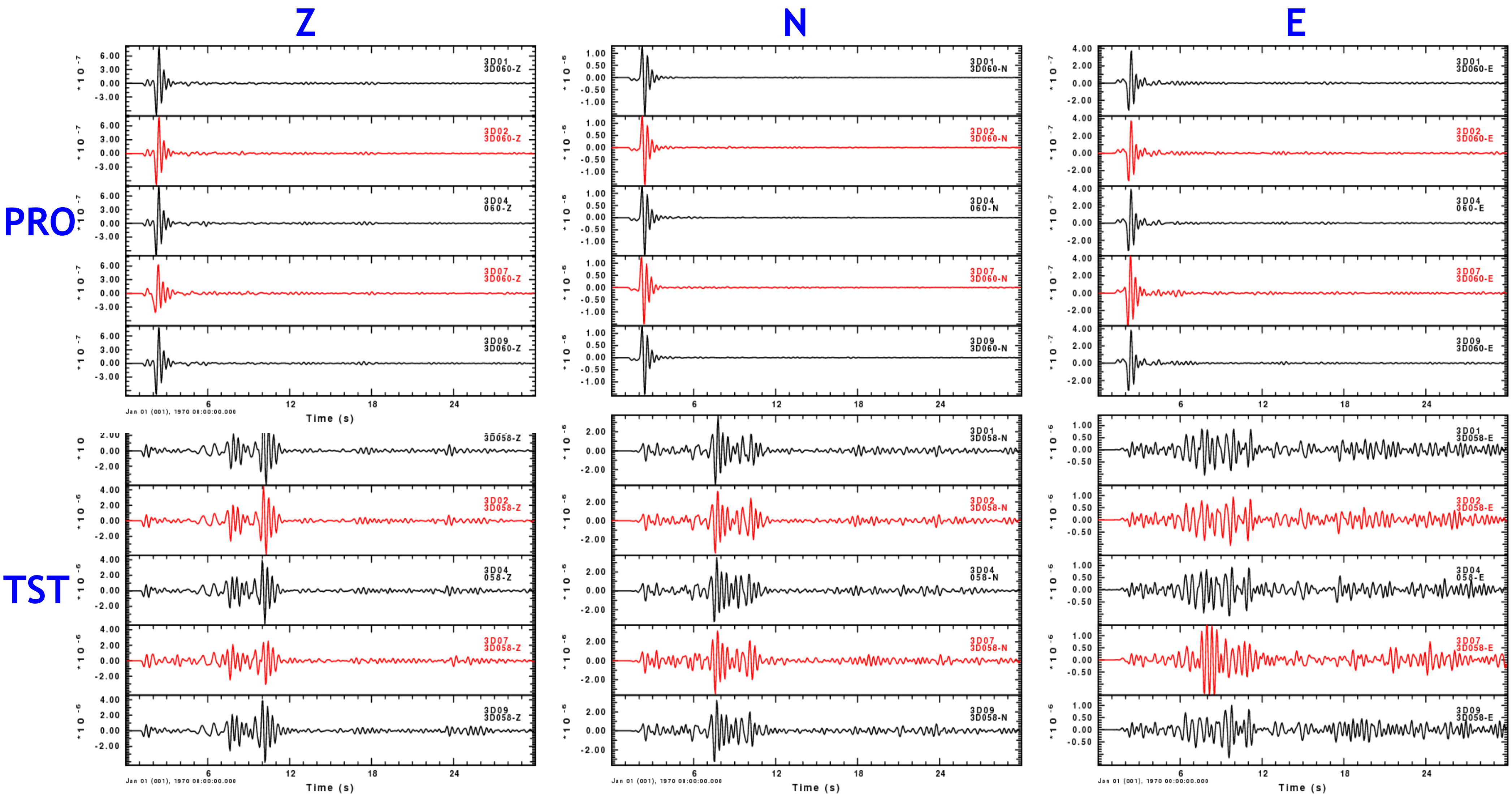
FDM / PSM



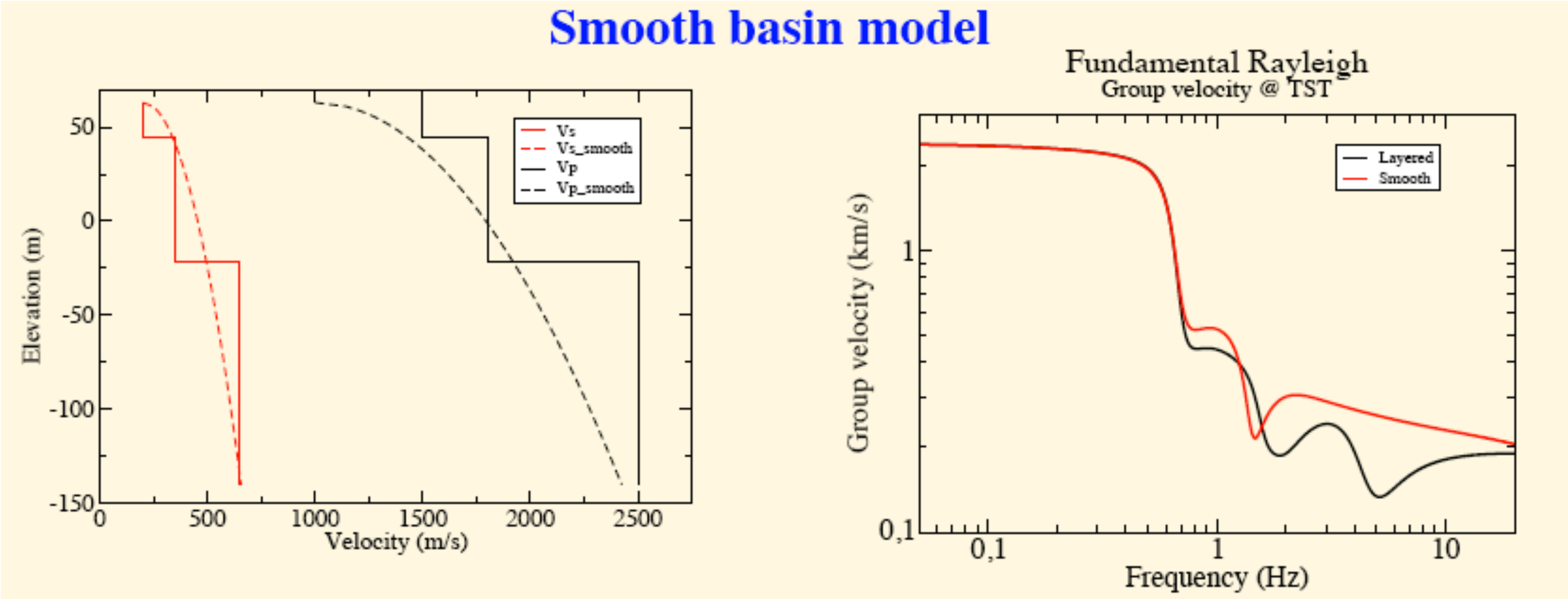
SEM / PSM



Verification, smooth gradient, no damping (5 teams: FD, SE, PS, FE, DG)

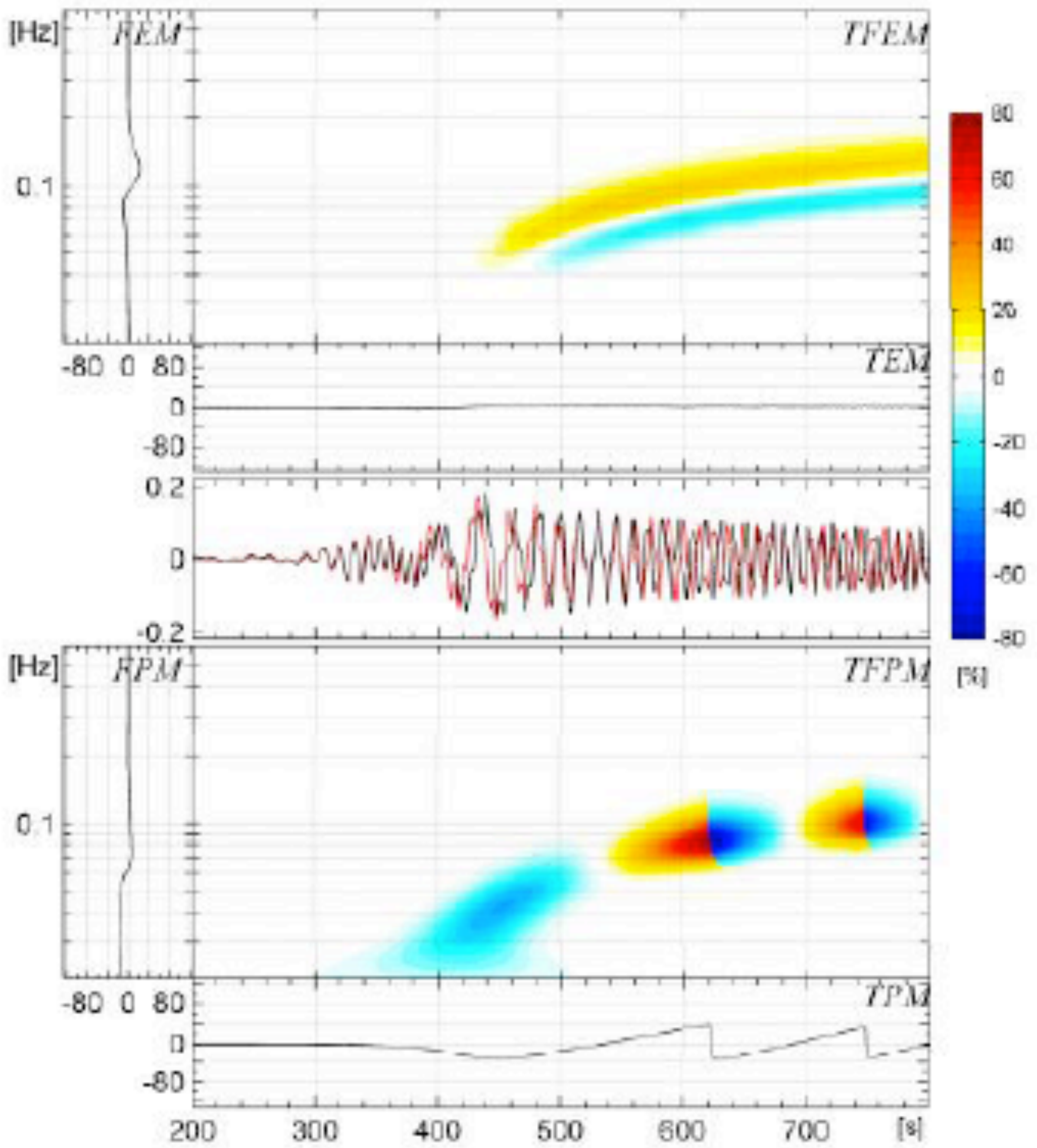


Alternative smooth gradient model (Bb)



Quantitative measure of misfit using Time Frequency Misfit criteria (Kristekova et al., 2009)

Wavelet analysis

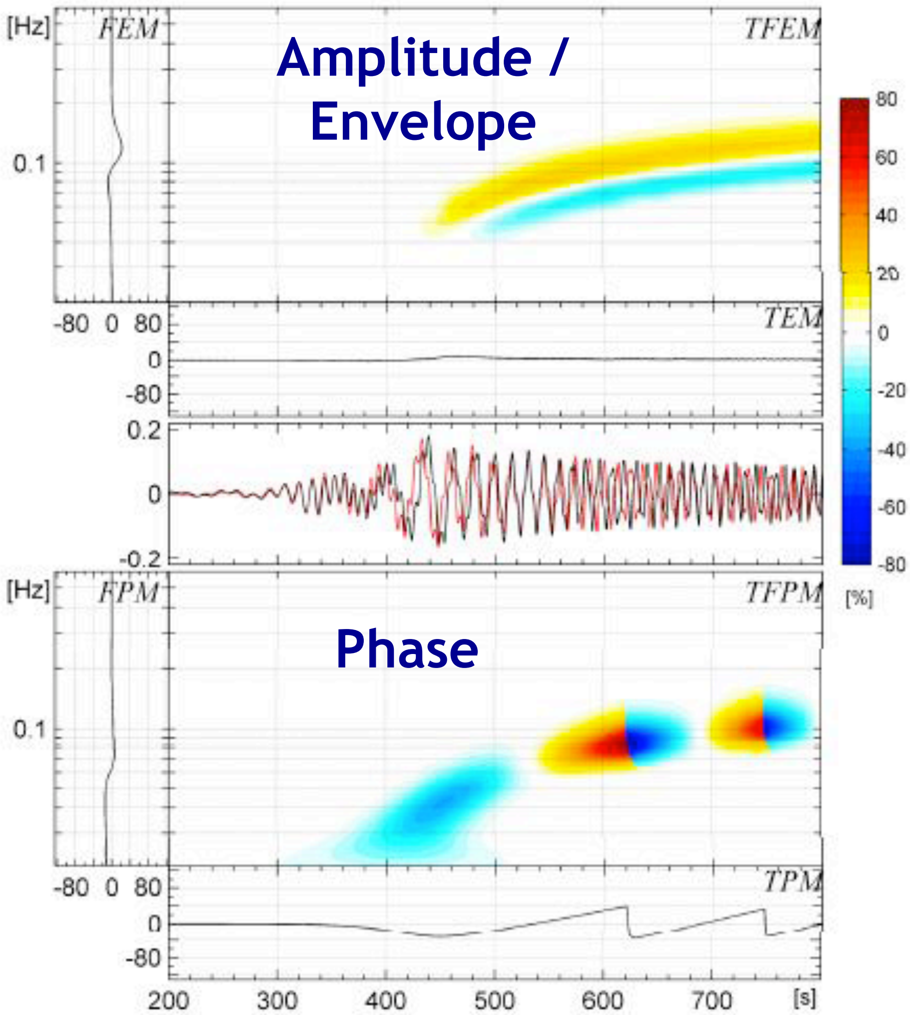


Amplitude / Envelope

Phase

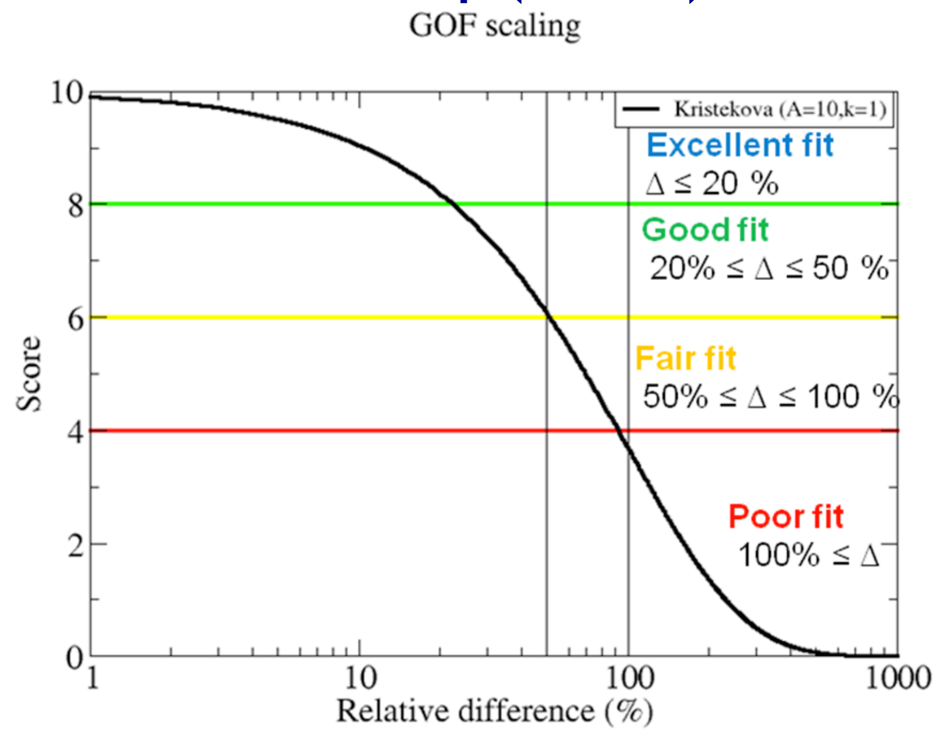
Quantitative measure of fit using time-frequency misfit criteria (Kristekova et al., 2009)

Wavelet analysis



Goodness of fit

10. exp (-misfit)



Validation – summary comments 2

Limited to local, weak to moderate magnitude events with significant high frequency contents

- Satisfactory match of ”overall” characteristics (amplitude, envelope, duration)
  - to be balanced by
- Large differences in the details of waveforms
- Distance data / model larger than the smallest model/model distance

Limitations to increase in maximum frequency are mainly related to

- uncertainties in source parameters
- capabilities of geophysical surveys
  - underground structure at short wavelength
  - still a few very badly known parameters (e.g., material damping)

next challenges