SCEC workshop: Earthquake Source Inversion

Introduction

- Scope of the workshop
- Review of an initial blindtest

Martin Mai

Morgan Page

Danijel Schorlemmer

Logistics & Overview

Overview Talks

8:00 – 8:10	Martin Mai	Introduction: Scope of the workshop & review of an initial blind-test
8:10 – 8:25	Morgan Page	Strategies for uncertainty assessment in source inversions
8:25 – 8:40	Yuji Yagi	Importance of covariance components for finite-source inversions
8:40 – 8:55	Kazuki Koketsu	Current status of source inversion methods in Japan
8:55 – 9:10	Raul Madariaga	Inverting for dynamic source parameters
9:10 – 9:25	Ruth Harris	Experience from the Dynamic Code Validation Project
9:25 – 9:40	Danijel Schorlemmer	An existing testing center: CSEP
9:40 – 10:00		Coffee break

Discussion Session: Planning an Earthquake Source Inversion Validation Exercise

10:00 – 10:40	DISCUSSION 1: Science issues / General questions
10:40 – 11:20	DISCUSSION 2: General set-up of the exercise
11:20 – 12:00	DISCUSSION 3: Logistics, Resources, Management

Logistics & Overview

- Do we want to carry out such an exercise ?
- If yes …
  - what are the most burning issues scientifically?
  - how do we tackle the different aspects/problems in earthquake source inversion?
  - how do we organize ourselves?
- If yes …
  - who does what, when, and how?
  - need of a group of people who take the lead and oversee the whole process
- If not …
  - spend the rest of the day at the pool with a drink

Logistics & Overview

10:00 – 12:00 OPEN DISCUSSION – PLANNING THE SOURCE-INVERSION VALIDATION EXERCISE

10:00 – 10:40 Science issues / General questions

- source inversion: an under-determined problem
- how to best quantify waveform fits ?
- how to optimally weight different data sets used in the inversion ?
- effects of source-receiver constellation ?
- effects of different stabilizing/smoothing constraints?

10:40 – 11:20 General set-up of the exercise

- Greens functions: pre-computed or velocity-density models specified ?
- Greens functions: Simple media or realistic structures ?
- source geometry: how much information should be provided ?
- what "data" (synthetics) are desired/needed? Statics, strong-motion, teleseismics?
- "clean" synthetics or noise-contaminated ?
- how to compare inversion results; what are relevant statistical measures ?
- a fully prospective inversion ?

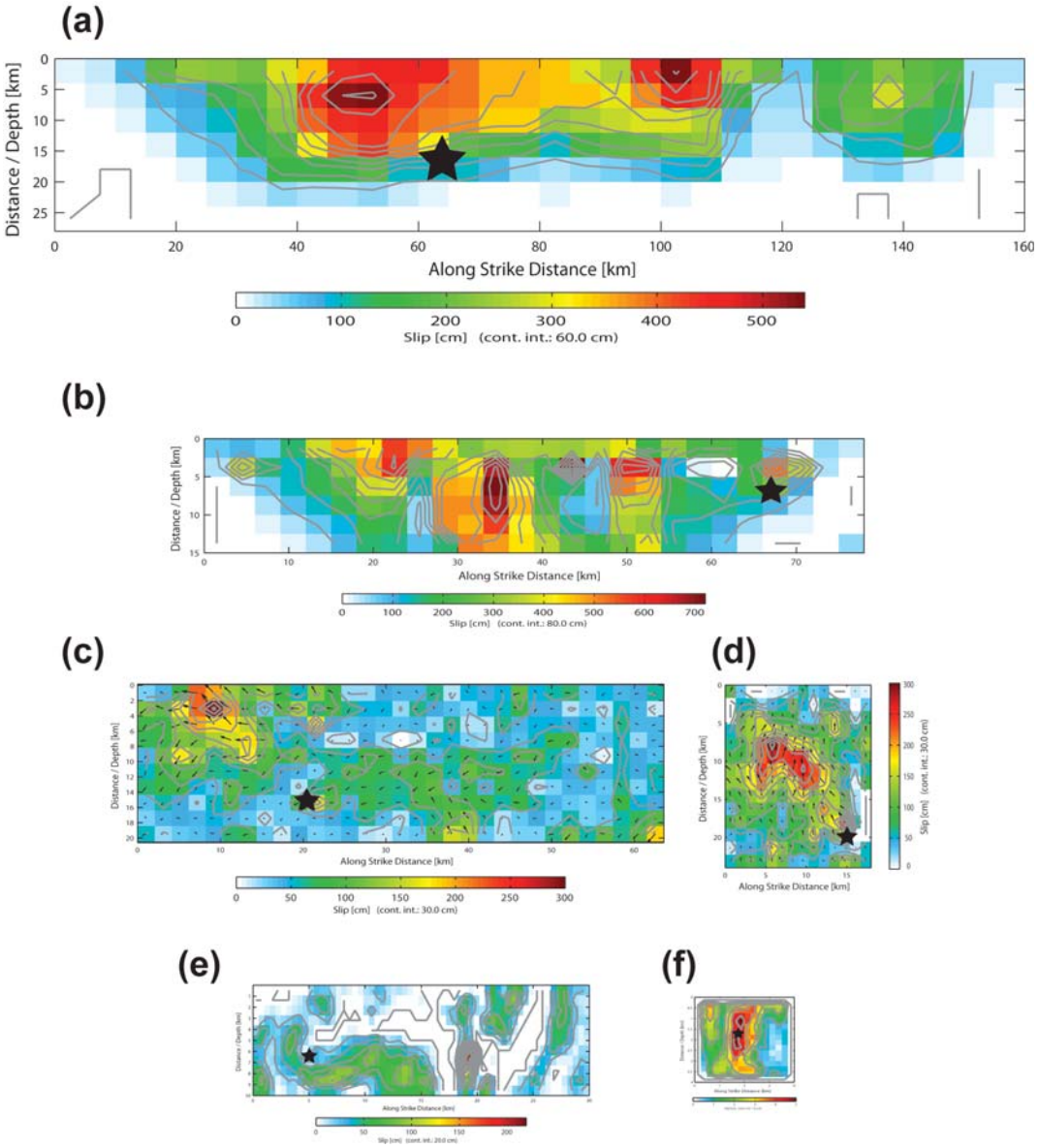
11:20 – 12:00 Logistics, Resource, Management

- overall strategy and rough time-frame
- formats for submission of models/synthetics ?
- authorization of data streams ?
- needed computational/infrastructure resources ?
- proposal for future funding for these efforts ?

See page 5/6 in the SCEC proceedings volume

Earthquake Rupture Models

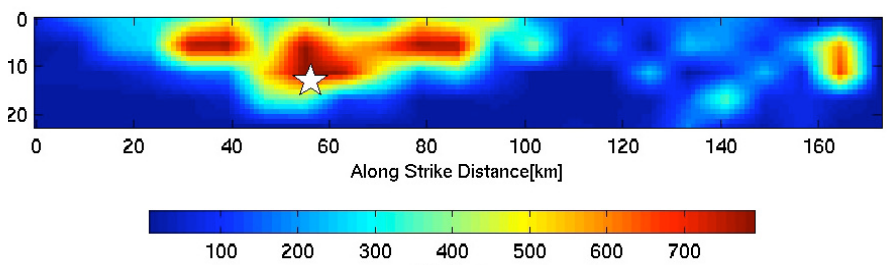
- Finite-source inversion are done almost routinely today, using a variety of inversion / modeling approaches, different data sets and processing steps
- We use the slip models to infer rupture dynamics, to devise source-characterization methods for ground-motion simulations, to perform Coulomb stress modeling, to ….
- But: how “good”, i.e. reliable and robust, are these rupture models ?

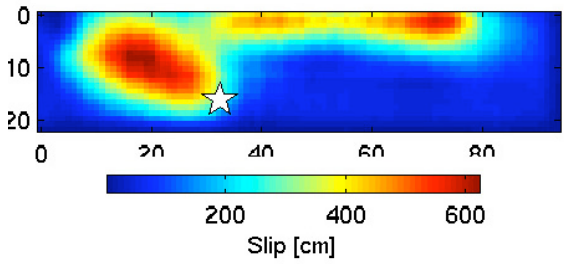


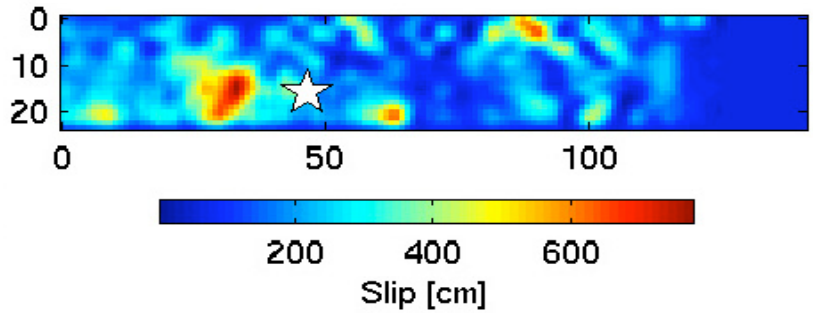
An example: Intra-event variability

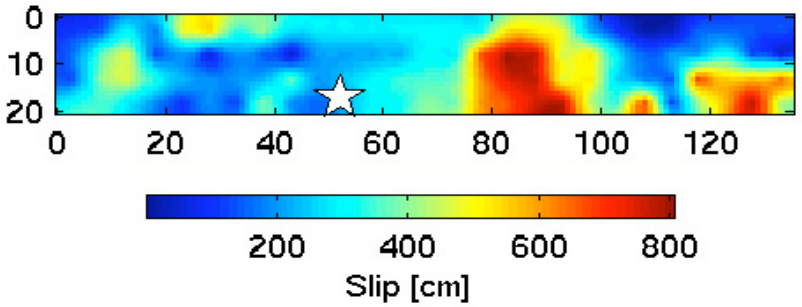
- In cases where multiple slip-inversion solutions exist for a single earthquake we often find striking differences in the slip maps!
- What drives the large differences between these slip models?

A suite of models for the 1999 Izmit (M 7.5) earthquake



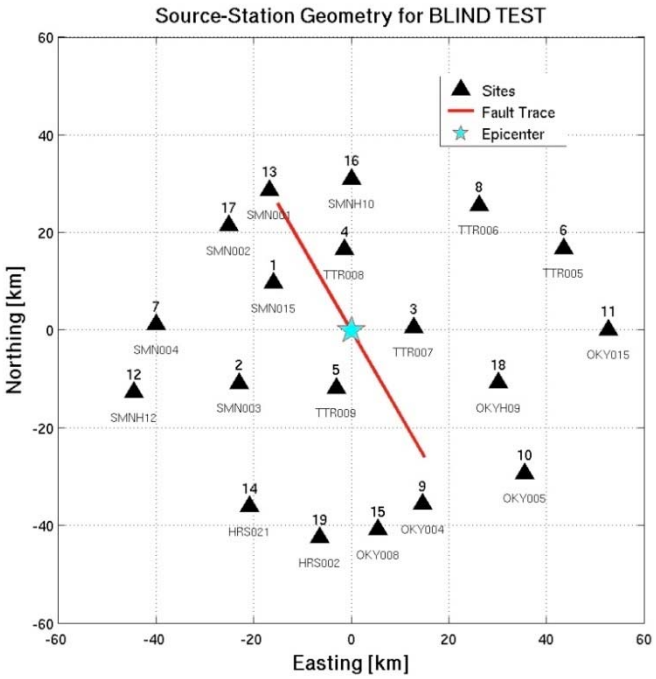


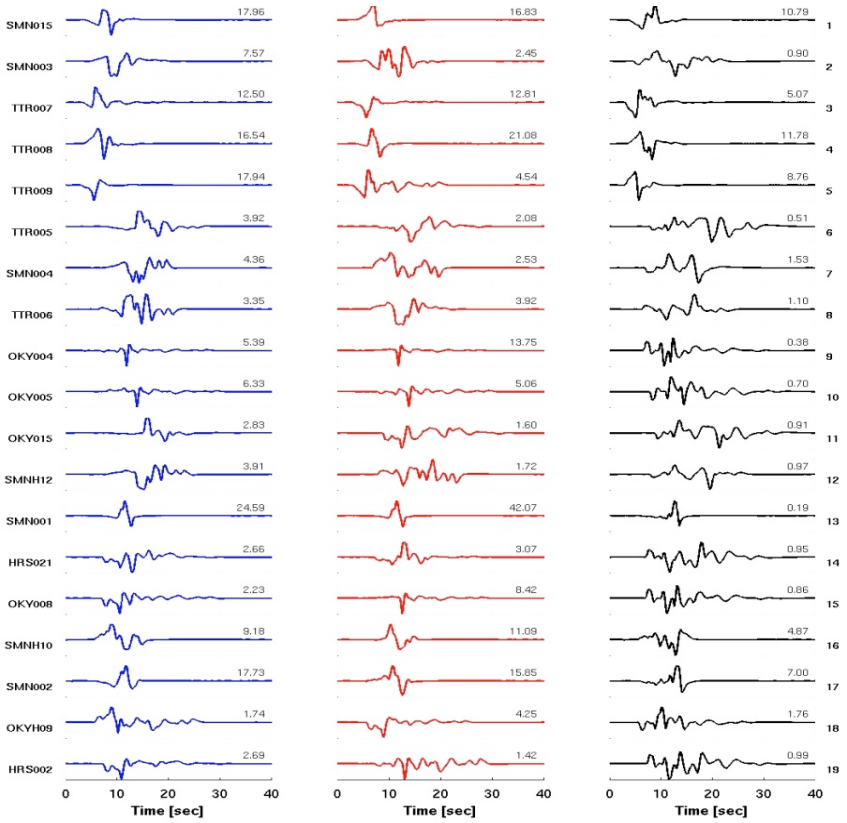




SPICE: Blind Test on Source Inversion

- Source geometry and station distribution similar to the 2000 Tottori earthquake
- Synthetic seismograms for 19 near-fault sites (COMPSYN, f_{max} ~ 3 Hz)
- Known: seismic moment: 1.43 10^{19} Nm, geometry (strike, dip, rake: 150°, 90°, 180°), hypocentral location and depth (Z= 12.5 km), velocity-density structure
- Unknown: slip on fault plane, rupture velocity & rise time (both constant)





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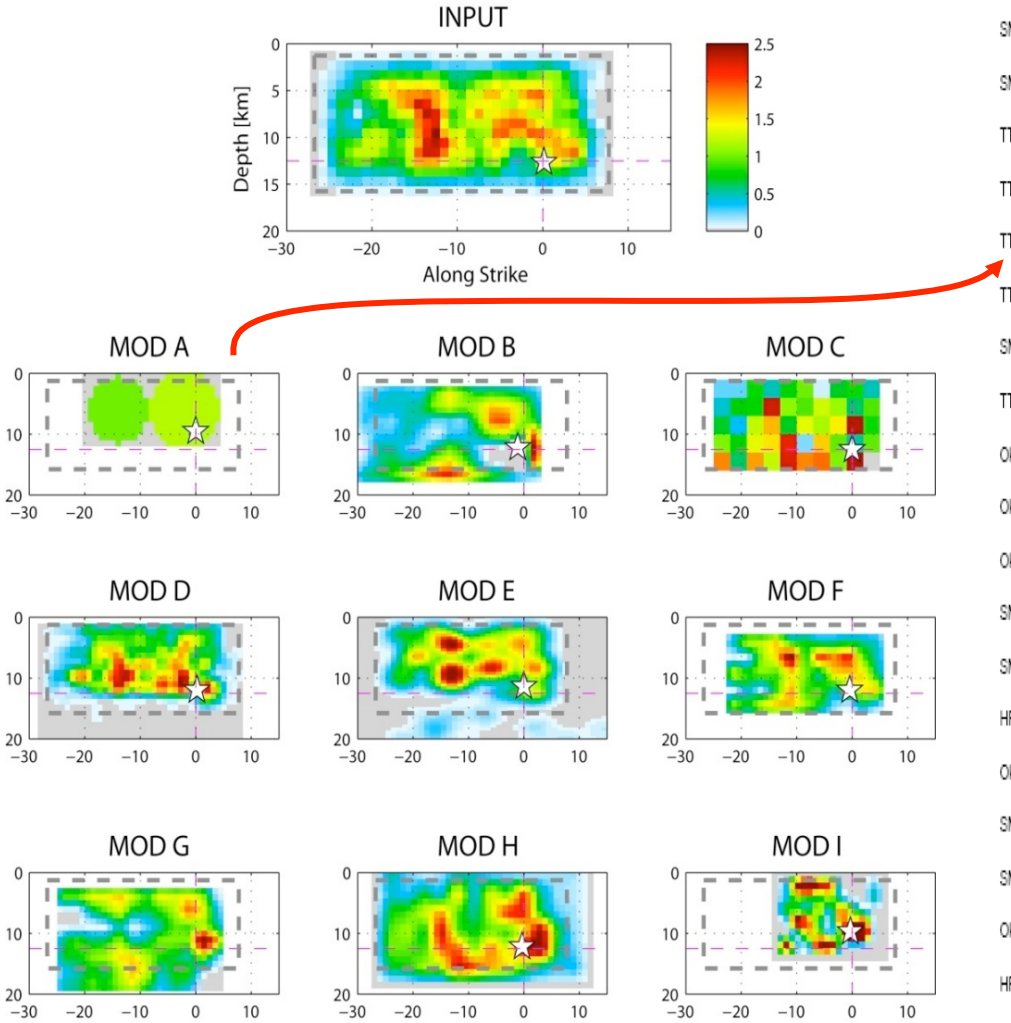
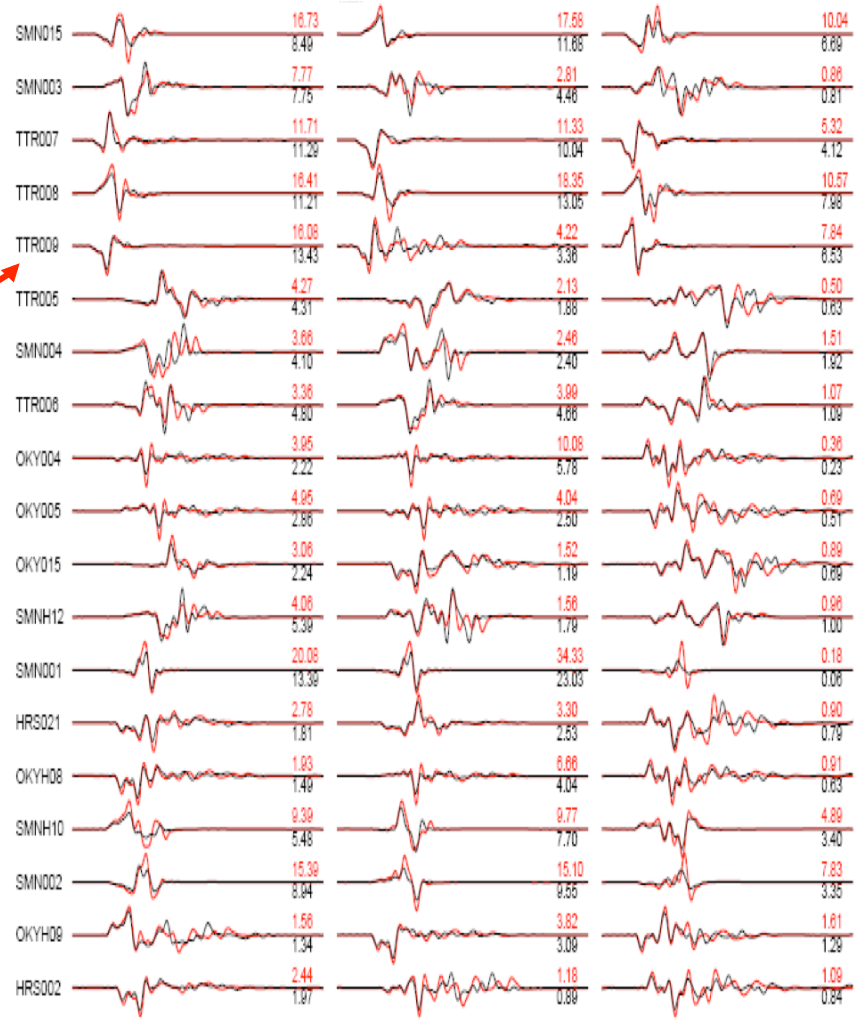
SPICE: Blind Test on Source Inversion

- 9 groups; the slip models from 5 groups are “visually” similar to the input model
- variability in inferred rise time and rupture velocity (both constant) up to 20%
- waveform fits in all cases implied visually a “very good fit” ….

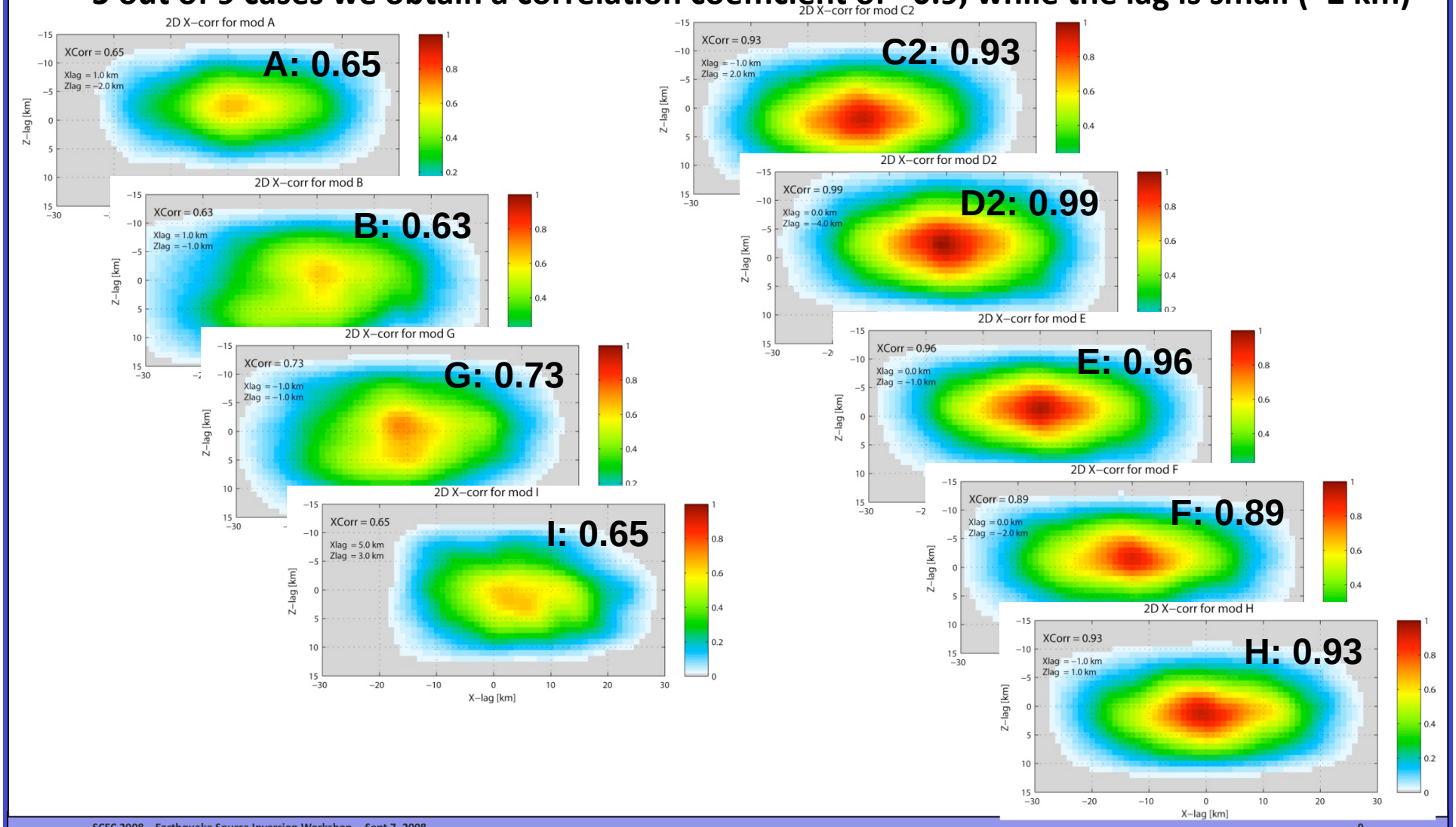




SPICE: Blind Test on Source Inversion

Quantitative comparison: 2D cross-correlation input - solution

- 4 out of 9 inversion results show a CC-coef like a random, but correlated model!
- 5 out of 9 cases we obtain a correlation coefficient of ~0.9, while the lag is small (~2 km)



Summary / Conclusion

- **The first solutions for the blind test were unexpected**

  - Despite the "simplicity" of the input model, inversions could not resolve slip very well; uncertainties in rupture velocity and rise time up to 20%
  - Despite differences among all inversion solutions, predicted waveforms are remarkably similar (f < 1 Hz), resulting in low misfit values (generally L_2-norm)
  - 4 out of 9 inversion results are, statistically speaking, NOT better than a random model with somehow correlated slip!

  - We should continue & expand these efforts, to understand better the earthquake source inversion problem
  - Workshop to form a core-group and to involve more people, in particular those with well-established techniques

  - http://www.seismo.ethz.ch/staff/martin/BlindTest.html
  - http://www.spice-rtn.org/library/valid

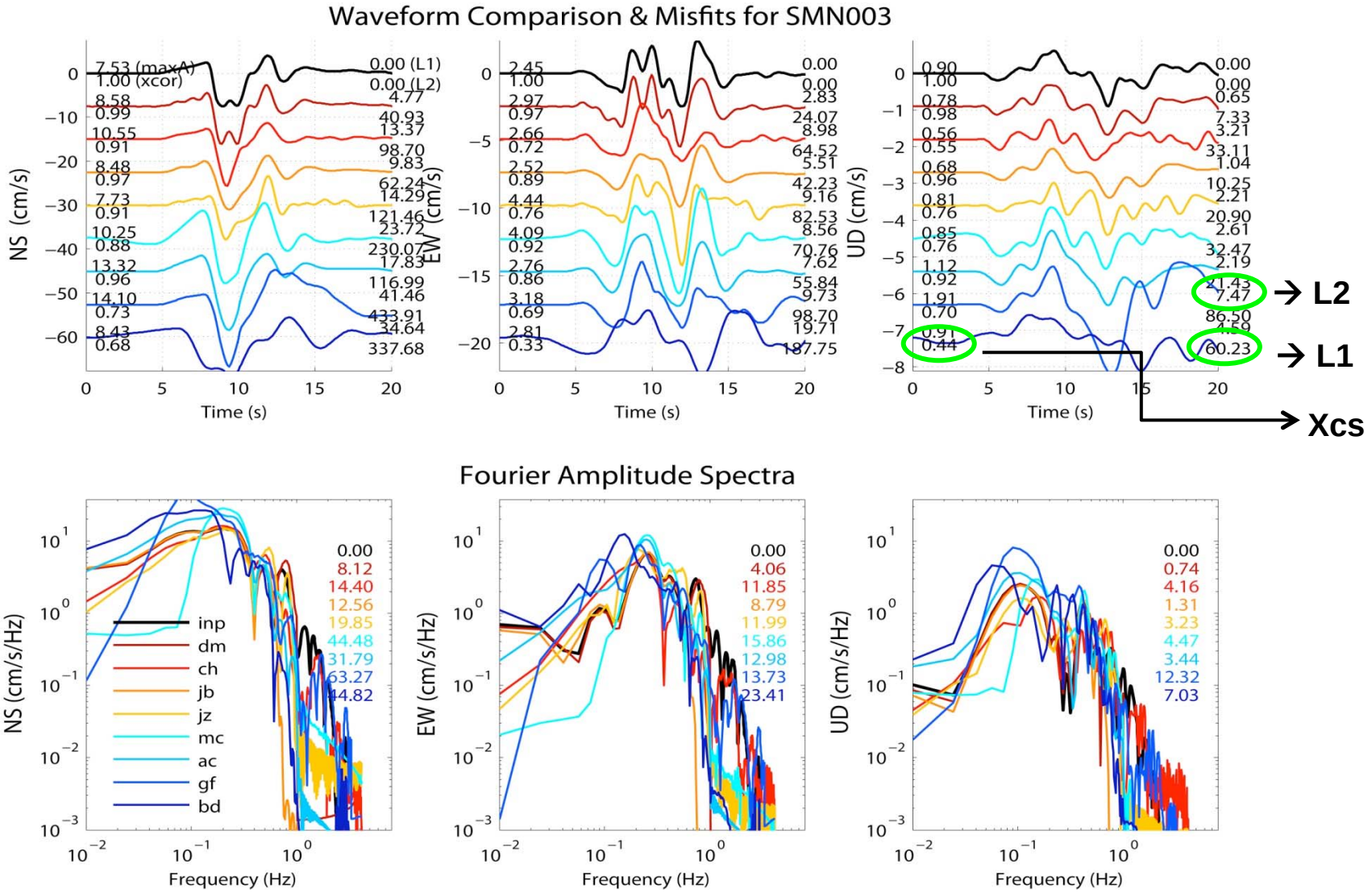
Blind Test on Source Inversion

Additional slides

Blind Test on Source Inversion

Results 3: waveform fits

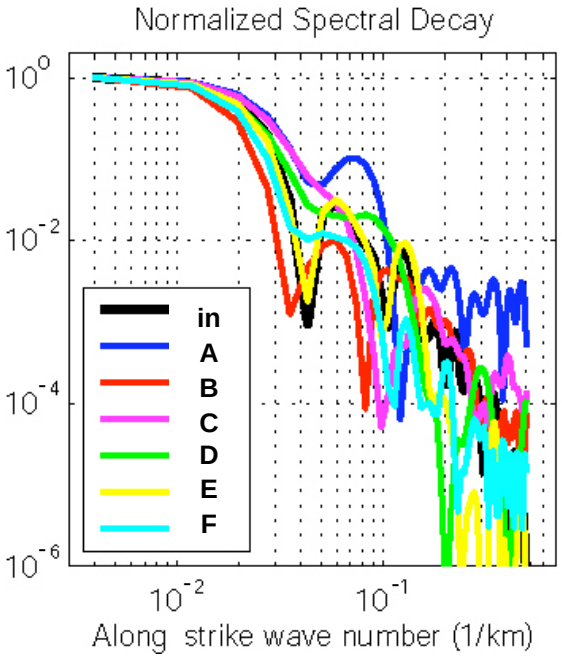
- **Investigating the waveform fits at a representative station:**

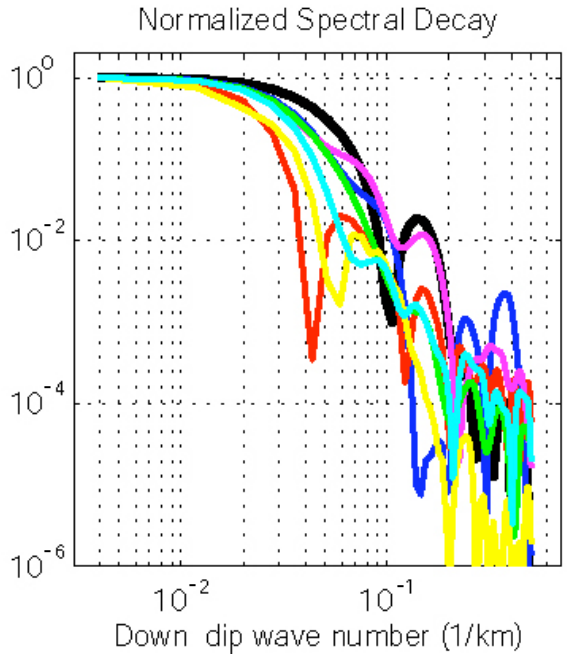


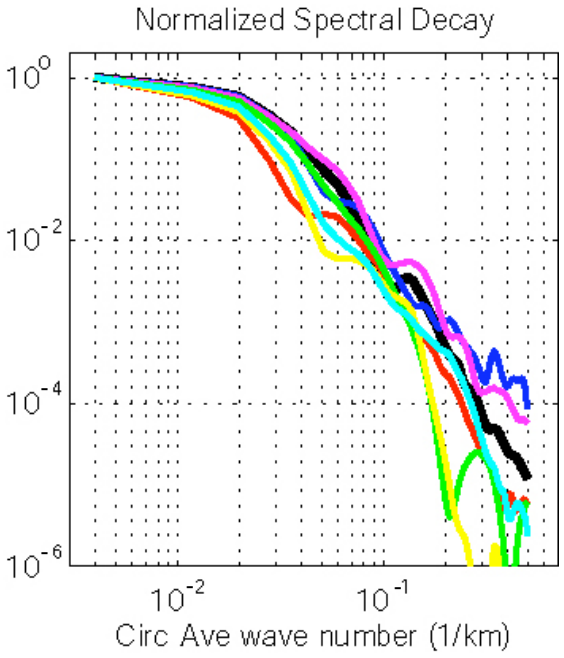
Blind Test on Source Inversion

Quantitative comparison of slip models, II

- Spectral characteristics of input and inverted models to asses the scale-lengths up to which they agree with each other
- Spectral decay roughly consistent for wave-length ~ 5-10 km
- At smaller scales (higher wavenumbers) the models deviate significantly



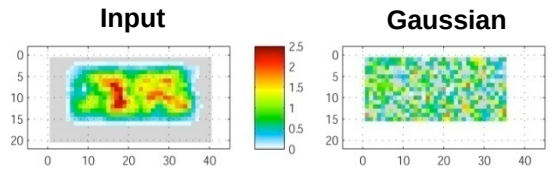


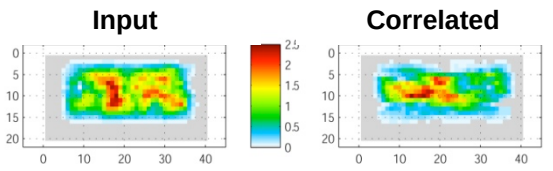


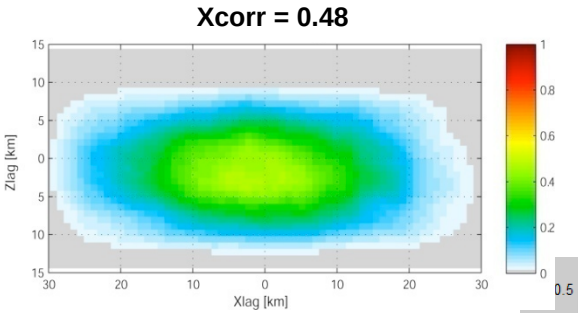
Blind Test on Source Inversion

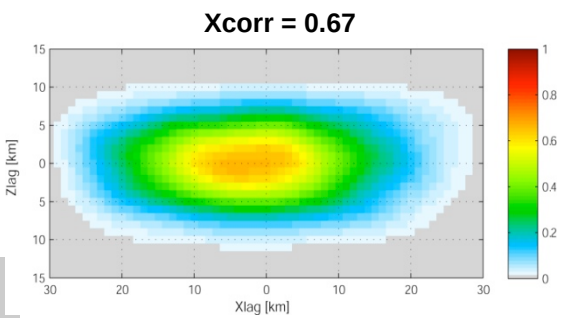
Quantitative comparison of slip models, I

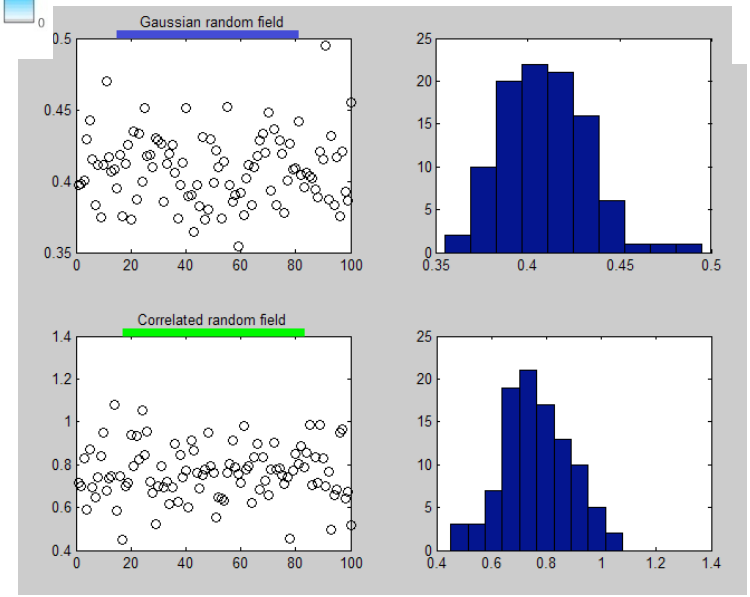
- We examine the 2D-cross-correlation between the input and the inverted models
- To calibrate the results, we first test a purely random field and a random, but correlated











Correlation coefficients for 100 realizations of random slip distributions, compared against the input model for the inversion

Gaussian: mean ~ 0.46
Correlated: mean ~ 0.72