Global $P$- and $S$-wave tomography from finite-frequency traveltime residual measurements

L. Schardong$^{1,2}$, S. Chevrot$^1$ and R.F Garcia$^{1,3}$

$^1$IRAP, Univ. of Toulouse
$^2$now at ERI, Univ. of Tokyo
$^3$now at ISAE, Univ. of Toulouse
Introduction

- **Problem:** poor resolution of small-scale structures (mostly in upper and lowermost mantle)

- **Solution:** using larger, higher-quality datasets and better imaging theories

- Building of a global database of HQ traveltime residuals including more seismic phases and frequency bands than previous works (*e.g.* Zaroli et al. [2010])

- Database constructed in such a way to adequate with finite-frequency theory (*Dahlen et al.* [2000]) and the computation of sensitivity kernels
Outline

- Measurements of finite-frequency (FF) traveltime residuals
- Method for the tomographic inversions
- Results for the inversion of FF datasets
- Results for the joint inversion of FF and ISC datasets
1. Measurements of traveltime residuals

Cross-correlation of waveforms

Traveltime residuals measured by cross-correlating observed waveforms with synthetics convolved by high-frequency source-time functions (Garcia, Schardong & Chevrot [2013])
Selection of high-quality data

Criterion based on fit quality of waveforms and coherency within the same event's residuals

<table>
<thead>
<tr>
<th>$f_0$ [Hz]</th>
<th>Quality</th>
<th>Coherency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0381</td>
<td>66%</td>
<td>98%</td>
</tr>
<tr>
<td>0.0725</td>
<td>58%</td>
<td>98%</td>
</tr>
<tr>
<td>0.2627</td>
<td>27%</td>
<td>98%</td>
</tr>
</tbody>
</table>

L. Schardong (ERI, Univ. of Tokyo)

Wednesday, December 11th 2013
Outline

• Measurements of finite-frequency (FF) traveltime residuals
• Method for the tomographic inversions
• Results for the inversion of FF datasets
• Results for the joint inversion of FF and ISC datasets
Input datasets

1) \(P\) traveltime residuals measured at 0.0725 Hz (\(P\text{-FF}\) dataset)
\(S\), \(ScS\) & \(SKS\) residuals measured at 0.0725 Hz (\(S\text{-FF}\))
2) \(P\text{-FF}\) combined with \(P\) & \(pP\) residuals from ISC (\(P\text{-FF+ISC}\))
\(S\text{-FF}\) combined with \(S\) residuals from ISC bulletins (\(S\text{-FF+ISC}\))
Inversion method

\[ \mathbf{G} \cdot \mathbf{m} = \mathbf{d} \]

- \( \mathbf{d} \): relative (event mean residual subtracted) traveltime residuals
- \( \mathbf{G} \): length of 1-D rays traced in ak135 (*Kennet et al.* [1995]), inside a global irregular grid designed from ray density
- \( \mathbf{m} \): inverted using iterative LSQR method (*Paige & Saunders* [1982])

---

**Wednesday, December 11th 2013**

L. Schardong (ERI, Univ. of Tokyo)
Outline

- Measurements of finite-frequency (FF) traveltime residuals
- Method for the tomographic inversions
- Results for the inversion of FF datasets
- Results for the joint inversion of FF and ISC datasets
Finite-frequency effects

The choice of data measured at 0.0725 Hz is the most reliable.
FF tomographic models

Models in good agreement with literature within well resolved areas.

3. Inversion of FF datasets

L. Schardong (ERI, Univ. of Tokyo)
Outline

- Measurements of finite-frequency (FF) traveltime residuals
- Method for the tomographic inversions
- Results for the inversion of FF datasets
- Results for the joint inversion of FF and ISC datasets
4. Inversion of FF+ISC datasets

**FF+ISC global tomographic models**

Low-quality in lithosphere and uppermost mantle, but images of subducting slabs very coherent with literature.

L. Schardong (ERI, Univ. of Tokyo)

Wednesday, December 11th 2013
Conclusions & Perspectives

- A global database of FF traveltime residuals for many seismic phases of interest and many frequency bands has been built.
- The quality of the database has been validated by preliminary global tomographic inversions.
- Future tomographic inversions will include the computation of FF sensitivity kernels (Fuji et al. [2012]) using multi-frequency traveltime residuals.
- FF theory will allow the use of complex seismic phases particularly sensitive to the lowermost mantle heterogeneities (Pdiff, PKP, …) and give a better resolution in this area.
- Crustal corrections will be included to improve the resolution in the lithosphere and upper mantle.

Regional results obtained by the same method will be presented on Friday, December 13th at 13:40 in the session “Comparative Structural Seismology of China and the US: Recent Advances and Future Directions I” – Poster S53A-2401 (Moscone South)
References

Dahlen, F. & A. Baig (2000), 150, GJI
Zaroli, C., E. Debayle & M. Sambridge (2010), 182, GJI
Friederich, W. & J. Dalkolmo (1995), 122, GJI
Engdahl, E., R. van der Hilst & R. Buland (1998), 88, BSSA
Bondár, I., S. Myers, E. Engdahl & E. Bergman (2004), 156, GJI
Buland, R. & C. Chapman (1983), 73, BSSA
Fukao, Y. & M. Obayashi (2013), 118, JGR
Fuji, N., S. Chevrot, L. Zhao, R. Geller & K. Kawai (2012), 190, GJI
Multi-frequency measurements

Measurements performed on waveforms band-pass filtered with central frequency ranging from 0.02 Hz to 0.4 Hz
Global S models: grid & resolution

(a) S–FF
(b) S–FF+ISC
(c) 410 km
(d) 1000 km
(e) 2000 km
(f) 2700 km

\( \log_{10}(N) \)

\( \delta v_s / v_s \) [%]
Cross-sections in the USA

P–FF at 0.0381 Hz

P–FF at 0.0725 Hz

P–FF at 0.2627 Hz

S–FF at 0.0381 Hz

S–FF at 0.0725 Hz

S–FF at 0.2627 Hz

Supplements

Wednesday, December 11th 2013
Cross-sections in South Africa

L. Schardong (ERI, Univ. of Tokyo)

Supplements

Wednesday, December 11th 2013

P–FF+ISC

S–FF+ISC

S31D-05 : 19/20
Cross-sections in the Pacific Ocean

Supplements

L. Schardong (ERI, Univ. of Tokyo)

Wednesday, December 11th 2013