



Full-waveform inversion with wavefield gradients

Sneha Singh¹, Yann Capdeville¹, Heiner Igel², Navid Hedjazian³, and Thomas Bodin³

¹Laboratoire de Planétologie et Géodynamique, Nantes, France

²Department für Geo und Umweltwissenschaften, LMU München, Germany

³Laboratoire de Géologie de Lyon, France

Wavefield gradient instruments, such as rotational sensors and DAS systems, are becoming more and more accessible in seismology. Their usage for Full Waveform Inversion (FWI) is in sight. Nevertheless, local small-scale heterogeneities, like geological inhomogeneities, surface topographies, and cavities are known to affect wavefield gradients. This effect is in fact measurable with current instruments. For example, the agreement between data and synthetics computed in a tomographic model is often not as good for rotation as it is for displacement.

The theory of homogenization can help us understand why small-scale heterogeneities strongly affect wavefield gradients, but not the wavefield itself. It tells us that at any receiver measuring wavefield gradient, small-scale heterogeneities cause the wavefield gradient to couple with strain through a coupling tensor \mathbf{J} . Furthermore, this \mathbf{J} is 1) independent of source, 2) independent of time, but 3) only dependent on the receiver location. Consequently, we can invert for \mathbf{J} based on an effective model for which synthetics fit displacement data reasonably well. Once inverted, \mathbf{J} can be used to correct all other wavefield gradients at that receiver.

Here, we aim to understand the benefits and drawbacks of wavefield gradient sensors in a FWI context. We show that FWIs performed with rotations and strains are equivalent to that performed with displacements provided that 1) the number of data is sufficient, and 2) the receivers are placed far away from heterogeneities. In the case that receivers are placed near heterogeneities, we find that due to the effect of these heterogeneities, an incorrect model is recovered from inversion. In this case therefore, the coupling tensor \mathbf{J} needs to be taken into account for each receiver to get rid of the effect.