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2014 Europe Honorary Lecturer

Full waveform inversion of seismic data: Investigating the Earth for high-resolution velocities and more…

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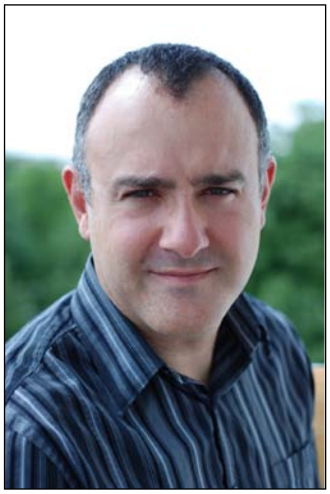

The principles of full waveform inversion (FWI) have been established for about 30 years. This approach aims at finding an Earth model that explains the seismic data. This is achieved by estimating the physical properties of the subsurface (Vp, Vs, density, attenuation, anisotropic parameters, etc.) within an inverse problem that aims at minimizing the difference between seismic data acquired in the field and predicted data modeled in a computer. The ultimate goal of FWI is therefore very ambitious as this multiparameter inversion is a highly nonlinear and ill-posed problem. In addition, it requires accurate and efficient modeling of the wave equation which makes it challenging to apply to real, industrial-scale, 3D problems.

In recent years, rapid improvement of supercomputers and breakthroughs in numerical computations of various forms of the wave equation allowed the academic community and the seismic industry to apply this technique in 3D.

Initial applications of 3D FWI made the assumption of acoustic-wave propagation, thus ignoring viscoelastic effects and mainly focusing on the recovery of a single parameter: acoustic velocity (Vp).

While the recovery of this unique Earth model parameter seems to fall short of the stated ambition of FWI, it is at the heart of prestack depth imaging commonly used by the seismic industry. In order to obtain an image in depth, a velocity model must be estimated prior to performing prestack depth migration (PSDM) which produces the final image for geologic interpretation.

The process of velocity model building is a critical stage of this workflow and is conventionally performed using ray-based reflection-tomography techniques. Velocity models derived by such methods are typically low-resolution and are used only for PSDM.

In this presentation, I will first review the basic theory of FWI. I will then define, by means of illustrative synthetic examples, the key parameters that play a role in the success of FWI (data and model requirements). This will lead to the understanding of why FWI has enjoyed its most success in the recovery of shallow velocity anomalies.

I will continue by showing real data examples that demonstrate the potential of FWI to generate high-resolution velocity models which may improve the images produced by PSDM. Because of the highly detailed nature of the velocity field produced from FWI, it also contains valuable information that can be used directly for geologic interpretation. I shall finally discuss ongoing research and the evolution of FWI across the academic and industrial communities.

This lecture is intended for a large audience and no background knowledge about FWI is needed.

Biography

Laurent Sirgue joined Total, France in 2009 as a geophysicist. He has been conducting research on the topic of full waveform inversion (FWI) for nearly 15 years.

Laurent received a BSc in physics from Versailles University in 1995 and an MSc in geophysics from the University of Strasbourg in 1997. He joined CGG in 1998 as a research geophysicist. In 1999, CGG sponsored Laurent's 16-month National Service, which took him to Queen's University, Kingston, Canada, where he worked with Gerhard Pratt on FWI.

In 2003, Laurent received his PhD from the University of Paris-sud XI. His dissertation research also focused on FWI. CGG sponsored Laurent's doctoral research in collaboration with Professor Pratt. As a postdoctoral researcher at Total (Pau, France), Laurent conducted research on reservoir characterization. In 2004, he joined the depth-imaging group at BP America where his work focused mainly on FWI.

Laurent has received a number of awards for his research including Honorable Mention for Best Paper in Geophysics in 2004 and the 2010 Bonarelli Award for best oral presentation at the EAGE Annual Conference.

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