The problem with density

We are developing new methods for seismic tomography that better constrain density variations in the Earth. While density variations drive convection in the Earth and serve to discriminate between thermal and compositional heterogeneities, classical seismological observables and gravity provide only weak constraints (figures 1, 2), with strong trade-offs (figure 3). Instead of simply scaling density to velocity, we attempt to address this issue using full waveform inversion schemes based on numerical wave propagation with adjoint techniques, including any information that can help constrain 3D density structure (diagram 1).

1. Density inversion how-to

Soft constraints:* gravity and mineral physics info are included as input data

Hard constraints:* make sure the updated model has the correct mass / moment of inertia

Input: real seismograms from unknown Earth density model

Calculate synthetics in some test model

Compare data and synthetics from test model using a misfit functional

Calculate a model update based on this misfit

Calculate synthetics in the updated model

Repeat until OK

Diagram 1: The schematics of seismic inversion. Extra information, meant to better constrain 3D density variation, can be incorporated in different ways – as soft constraints (i.e. minimising an augmented misfit functional that includes all the data) or as hard constraints (i.e. adjustment of the model after updating it so that it definitely fits those constraints).

2. Current state of affairs

We have developed a 2D wave propagation code for efficient calculation and assessment of synthetic inversions. With this code we calculate pure travel time sensitivity kernels (figure 2) and waveform sensitivity kernels (figure 3). An illustration of P-SV wave propagation is shown in figure 4. We are currently incorporating gravitational constraints into our inversions, as depicted in diagram 1.

* videos of these calculations can be watched online: [www.geo.uu.nl/~blom](http://www.geo.uu.nl/~blom) or use the QR-code.