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Applying thermal constraints to improve seismic models of the continental and the oceanic lithosphere

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As with any inverse problem, seismic tomography suffers from limitations dictated by the distribution and quality of seismic data, as well as by trade-offs between diverse structures within the Earth. Regularizations are designed to control the over-interpretation of data, but do not guarantee the physical acceptability of the resulting models. These limitations are fundamental. To produce more realistic, physically acceptable earth models requires physical constraints to be applied during seismic tomography. We discuss two types of physical constraints derived from thermodynamics that can be usefully applied during inversions of seismic surface waves. The first is the assimilation of heat-flow information in the seismic inversion. The second physical constraint imposes theoretical limits on the shape of the temperature curve with depth by explicitly specifying the equations that model the thermal state and evolution of the upper mantle and considering only the solutions to these equations. The application of these thermal constraints in seismic inversion involves a straightforward modification of the Monte-Carlo inversion that is re-formulated in the model space of thermal parameters such as the apparent lithospheric age, the temperature in the uppermost mantle directly beneath Moho, the mantle temperature gradient (or mantle heat flux), and the potential temperature of the sublithospheric convecting mantle. We present examples of application of this new inversion method over broad oceanic and stable continental areas and discuss how these thermal constraints can be useful in designing a European reference Earth model.