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Improved CVM upper mantle: A necessary step towards absolute crustal stress estimates in southern California

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Summary

We are improving the imaging of upper mantle beneath southern California to better understand its density structure and bring new constraints on lithosphere kinematics. Mantle tomography resolves high velocity (cool and dense) lithosphere beneath the Transverse Ranges, and low S-wave velocity (warm, buoyant and partly molten) beneath the Salton Trough. This defines a convective system that drives southern California crust into the Transverse Range, as discussed by Bird and Rosenstock (1984), Humphreys and Hager (1990), Fay and Humphreys (2006) and Fay et al. (2008).

New information on tomographic techniques and crustal structure (SCEC CVM) now permit improved upper mantle imaging, which in turn provide the information needed for an improved understanding of southern California lithosphere kinematics and dynamics, with particular relevance towards improving our understanding of southern California absolute crustal stress.

We proposed to improve southern California upper mantle imaging by:
1. using improved tomography (include more data, use finite frequency methods and 3-D ray tracing);
2. using better near surface corrections (from SCEC's crustal model CVM);
3. incorporating anisotropy corrections to the teleseismic data.

At present, we have incorporated the above-mentioned tomographic improvements. The resulting images (see Figure 1 and Figure 2) are similar to prior images, but altered (improved) in several ways. In particular, our current models have:

1. greater amplitudes of upper mantle seismic structures (RMS increase of 10-15% compared to other recent models);
2. reduced the thickness of high-velocity structures by 10-15% (owing to 3-D ray tracing); and
3. generally modified the structure (owing to the use of an improved crustal model) by small but noticeable amounts, especially below ~200 km.

Technical improvements in tomography

Following we summarize some of the technical aspects of our improved tomography.

- The southern California velocity model developed by SCEC, Caltech, and USGS groups (CVM-S4) is used to calculate crustal travel times in our model box. We applied these corrections (and elevation corrections) to a total of 1497 stations.

- Our body-wave tomography uses an approximation of the finite-frequency kernel described in Dahlen et al. (2000), similar to Schmandt and Humphreys (2010). We use 108,061 delay times for P modeling (with 1.0, 0.5, 0.3, and 0.1 Hz central frequencies) and 30,262 delay times for S modeling (0.4, 0.1, and 0.05 Hz). Model parameterization includes 10,672 nodes distributed on a rectangular grid variable in depth.

- We keep all the rays in our model, regardless of the back azimuthal distribution, by applying a ray-weighting algorithm. Each ray was weighted in inverse proportion to the local ray density in the back azimuth - ray parameter space, with improved results in minimizing the inherent streaking.

- Each phase of modeling included two steps: first we inverted our data and produced a tomography model, and then we use a 3-D ray-tracing algorithm to generate a new set of ray paths through the first iteration result. We used this last set of ray paths to invert for our final model. We find no need for the use of additional ray-tracing iterations.

- We have incorporated (but not yet used) an ability to prescribe an arbitrary anisotropy field in a node-wise fashion. Our intent is to (a) correct for the portion of azimuthal anisotropy (oriented horizontal fast axis) resolved by SKS arrivals, and (b) test for the influence of radial anisotropy (vertical fast axis) in major high-velocity structures. The latter would significantly elevate V_P/V_S in high-velocity structures.

References

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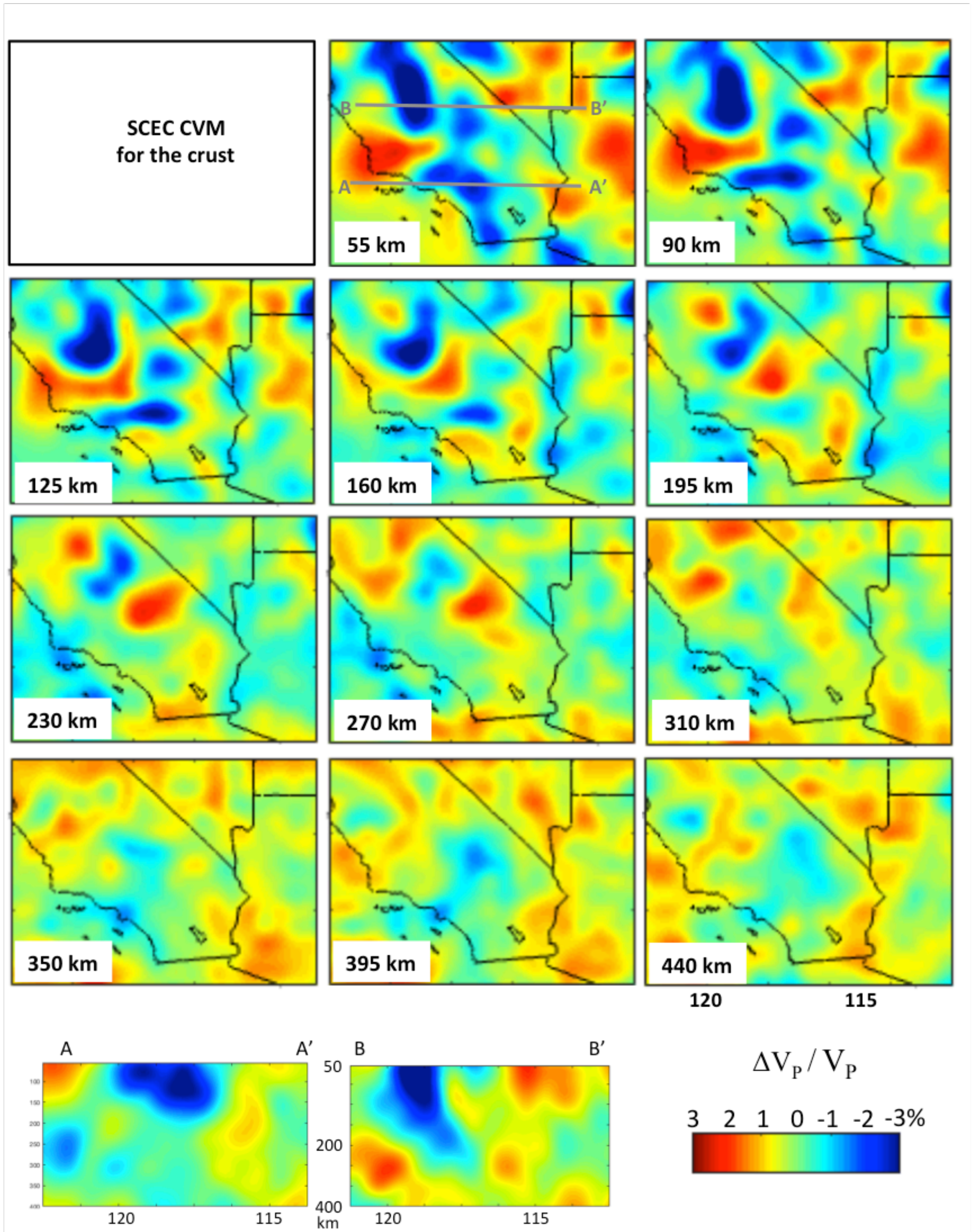

Figure 1. **P-wave** velocity perturbations beneath southern California. Upper 440 km of model shown. Bottom: E-W cross sections through Transverse Range (A-A') and Isabella (B-B') anomalies

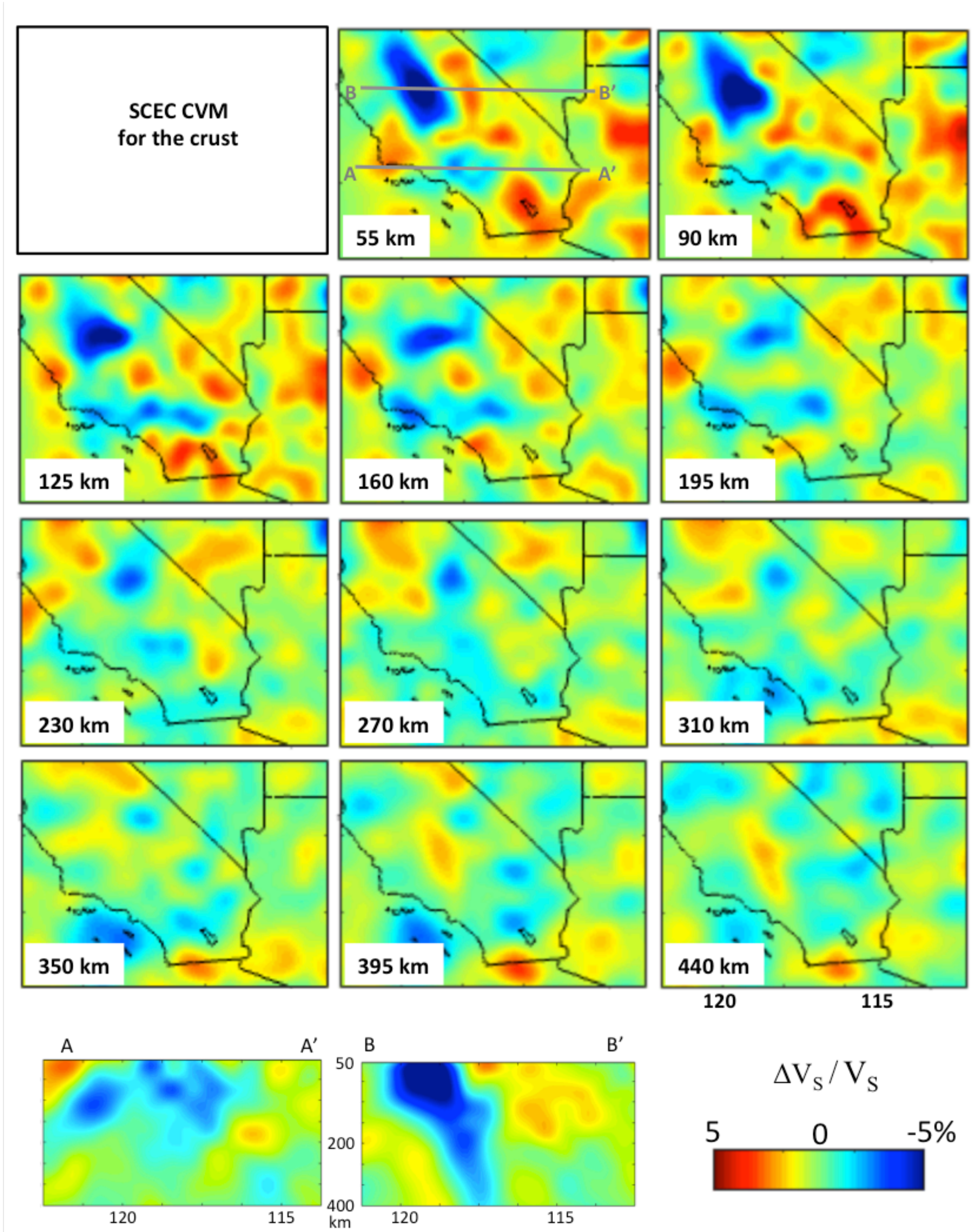

Figure 2. **S-wave** velocity perturbations beneath southern California. Upper 440 km of model shown. Bottom: E-W cross sections through Transverse Range (A-A') and Isabella (B-B') anomalies