29 3-D Seismic Velocity Structure of the Hawaii Hotspot from Joint Inversion of Body Wave and Surface Wave Data

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29.1 Introduction:

The Hawaii hotspot and the associated chain of islands have been long regarded as the case example of a deep-rooted mantle plume. However the efforts to detect a thermal plume seismically have been inconclusive. While the tomography model of *Wolfe et al.* (2009, 2011) suggests a lower mantle plume southeast of Hawaii, *Cao et al.* (2011) use scattering off the underside of the 660 km discontinuity to argue that the source of the hotspot is a broad region to the southwest. They image a broad down-warping of the 660 discontinuity that they interpret as being due to a hot region of the uppermost lower-mantle approximately 2000km wide. They suggest that the Hawaii volcanism is fed by small-scale convection in the upper mantle around the periphery of this broad lower-mantle feature.

Previous body wave tomography models may not be able to resolve between a continuous plume-like structure and separate anomalies at different depths resulting from small-scale mantle convection. In this study we combine the complementary sensitivities of body and surface-waves in order to improve resolution of mantle structure beneath Hawaii. The main limitation of body-wave tomography alone is the lack of resolution at shallow lithospheric depth where ray paths do not cross each other. By adding surface-wave constraints to the inversion as well, the resolution of the crustal and upper mantle structure is improved.

29.2 Data Processing:

We used data from the deployment of temporary broadband ocean-bottom seismometers (OBSs) of the Hawaiian Plume-Lithosphere Undersea Melt Experiment (PLUME), which was designed to determine mantle seismic velocity structure beneath the Hawaiian hotspot.

In a first step we oriented the PLUME OBS horizontal components using teleseismic P-wave particle motions. Generally we obtained stable and reliable orientations over a range of earthquake back-azimuths. Due to the high noise of the OBS data in some frequency bands we began by filtering in the period band of 0.04-1Hz. We measured ∼1100 P-wave relative arrival times on the vertical component and ∼750 S-wave relative arrival times (include direct S and SKS phases) on the SV component using multi-channel cross correlation. We use a total of ∼70 events which are distributed in as wide a range of back azimuth directions as possible. We also use surface wave constraints and apply the two-plane wave tomography method to invert for the phase velocity structure. This tomography method, which also considers the finite frequency effects, inverts the phase data and amplitude information simultaneously for the phase velocity at each point across the region in addition to incoming wavefield parameters. We use surface waves from 71 events with magnitude greater than 5.8 to generate phase velocity maps from 25 sec to 100 sec. These maps clearly show the low velocities beneath the islands surrounded by relatively high phase velocity.

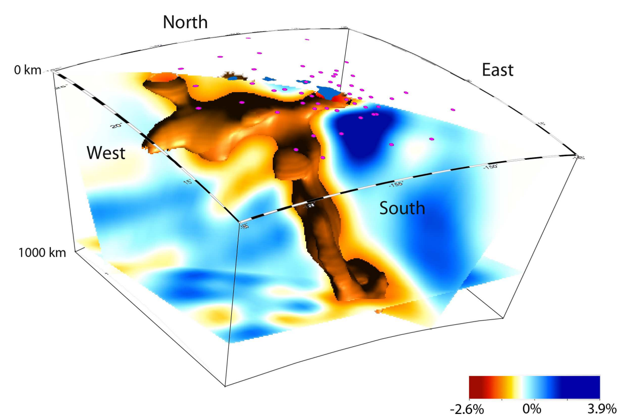

Figure 2.57: 3D view of our preliminary S-velocity model for the mantle beneath Hawaii. The location of the islands (blue) and the PLUME array (pink) are shown on the surface of the model volume.

29.3 Preliminary Results and Implications:

Figure 2.57 shows the S-velocity model derived from the body wave data. This shows the 3-D structure beneath the PLUME array to a depth of 1000km and reveals a several-hundred-kilometer-wide region of low velocities beneath Hawaii that dips to the southeast. The low velocities continue downward through the mantle transition zone and extend into the uppermost lower-mantle (although the resolution of lower mantle structure from this data set is limited). The independent P-wave images are generally consistent with S-wave structure. These images are consistent with the interpretation that the Hawaiian hotspot is the result of an upwelling high-temperature plume from the lower mantle. The broader upper-mantle low-velocity region immediately beneath the Hawaiian Islands likely reflects the horizontal spreading of the plume material beneath the lithosphere.

We also obtain a preliminary result from the joint body-wave and surface-wave inversion (Figure 2.58). The same shallow low velocity zone is imaged along the island chain and the deeper part is identical to the body-wave inversion image. The low velocity to the southwest of the island is also clear to a depth of 600km as mentioned above. If the observation here is true, it will provide a hot environment for the 660km discontinuity to the west of the Hawaii and may give a new perspective to the plume origin debate.

29.4 References

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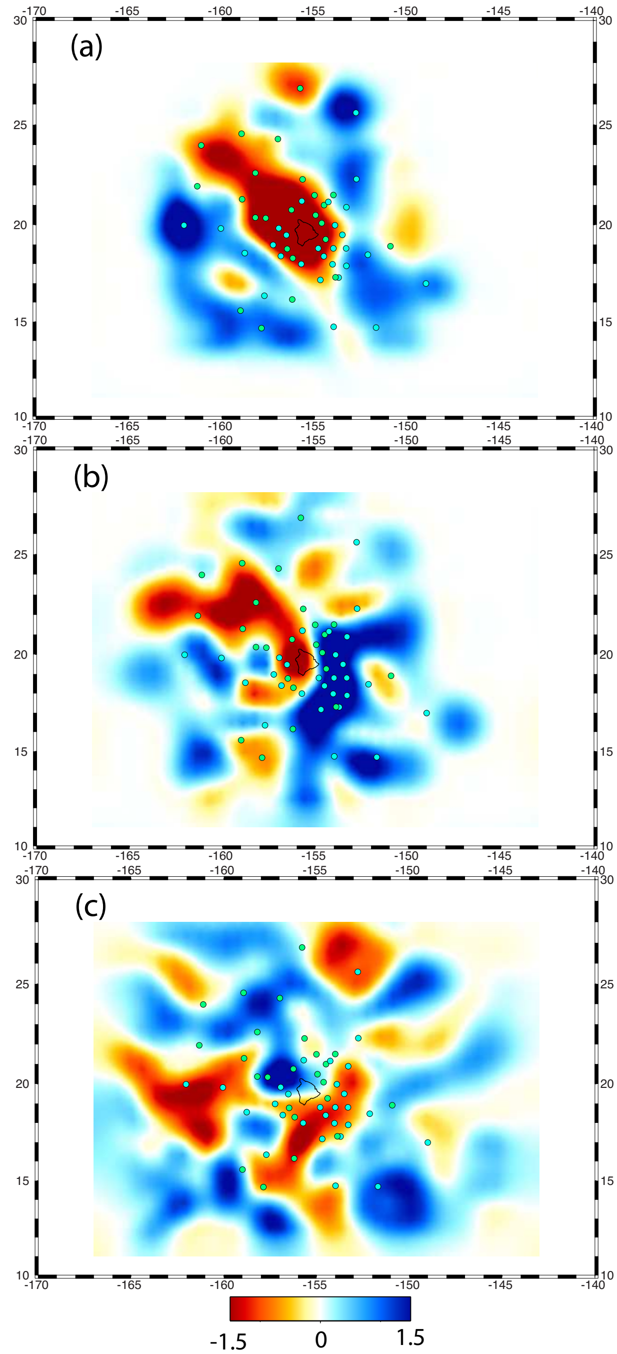

Figure 2.58: SV-velocity perturbation map around Hawaii at different depths using joint body- and surface-wave tomography. (a) 100 km (b) 300 km (c) 600 km depth