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Bayesian Inversion for Ultra Low Velocity Zone parameters in the Earth's Lowermost Mantle: Multiple-Layered Structure Confirmed Beneath the East of the Philippines

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Ultra low velocity zones (ULVZs) are structures sitting on the top of the core mantle boundary with a strong reduction in P- and S-wave velocity and increased density. ULVZs have been extensively studied using 1-D and 2-D modelling of seismic waves reflected from and transmitted through the core mantle boundary. However, their physical origin and associated dynamics are currently debated. In addition, the forward problem (waveform modelling) is highly non-linear and non-unique with strong correlations between ULVZ parameters. We develop a rigorous Bayesian inversion to address these challenges. Sampling of the posterior probability density (the solution to a Bayesian inverse problem) is based on parallel interacting Markov chains (parallel tempering), which allows efficient sampling of difficult parameter spaces including multiple modes and strong parameter correlations. Uncertainties of ULVZ parameters are naturally addressed by the posterior distribution. In addition, noise on the data (residual errors) is addressed by a hierarchical Bayesian model which estimates the standard deviation from the data. Results are examined in terms of marginal densities of the ULVZ posterior, including profile-marginal and joint-marginal densities.

After demonstrating the feasibility of the method with synthetic examples, we apply the hierarchical Bayesian inversion to the waveforms of core reflected phases (ScP) from earthquakes originating in the Indonesian region and recorded on Hi-Net array stations in Japan. These waves sample the CMB beneath the east of the Philippines. The Bayesian information criterion (BIC) is applied to select the optimal parametrization (i.e. the number of layers) from competing ULVZ models. The BIC confirms the existence of a two-layer ULVZ in the lowermost mantle beneath the east of the Philippines. The upper ULVZ layer shows a sharp decrease in P- and S-wave velocity of up to $\sim$11% and $\sim$29%, and an increase in density of up to $\sim$28%. This layer could be interpreted as the partial melt of an iron enriched mantle component. The lower layer shows a sharp decrease in S-wave velocity of up to $\sim$30% with an insignificant change in P-wave velocity and density. This layer may represent basaltic material with a higher melt component and could be a result of an interaction between the melt and volatile gas from the core.