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Stochastic analysis of global surface-wave phase-anomaly data

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We invert global seismic data to determine directly the power spectrum, rather than the three-dimensional (3D) structure of the Earth. Inverting the spectrum is computationally much cheaper then inverting the structure itself: as a consequence, this approach should in principle constrain the statistics of planetary structure up to harmonic degrees higher than those of currently available 3D models. We employ an algorithm first devised in the early 1990s by Gudmundsson and co-workers in order to identify the power spectrum of the Earth (rather than three-dimensional structure) via a linearized least-squares inversion. The underlying concept is the following: seismic rays starting at close sources and arriving at close receivers are collected, and the variance of the associated delay times calculated; this exercise is repeated for a range of values of the maximum distance (bin size) between close sources and between close receivers; the dependence of calculated variance on the inter-source and inter-receiver distance can then be linked to the power spectrum of the planet. For the time being, we limit ourselves to the relatively small, two-dimensional problem of determining global phase velocity maps of surface waves at a given mode from observations of teleseismic surface-wave phase delays. A series of synthetic tests is performed in order to evaluate the resolution limits of the algorithm, exploring the dependence of resolution on the number of available data, on the complexity of the assumed "input" Earth model, and on the simplifying assumption of ray theory. Synthetic data are alternatively built in a ray-theory framework, or numerically via the membrane-wave approach. We find that linearized stochastic analysis of global traveltime data, the way it is implemented here, has severe resolution limits: (i) if the input model coincides with the superposition of two single spherical harmonic functions of relatively close harmonic degrees, the two peaks in the spectrum cannot be distinguished in the output model; (ii) the main peaks of a more realistic input model are likewise smeared. In order to understand if these resolution problems can be related to the assumptions of the algorithm, a completely non-linear approach will be used, so that the numerous mathematical approximations required by the original algorithm will become unnecessary.