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Interactive comment on "Power Spectra of Random Heterogeneities of the Solid Earth" *by* Haruo Sato

Margerin (Referee)

ludovic.margerin@irap.omp.eu

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The manuscript "Power Spectra of Random Heterogeneities of the Solid Earth" summarizes in an accessible and comprehensive way more than 30 years of measurements and observations of Earth heterogeneity on a very broad range of scales (from 10ˆ-8 to 10ˆ4 kms). While the focus is put on seismic methods, other approaches (well-logging, direct observations from rock samples) are also presented. Furthermore, the author provides interesting research directions for future seismological developments, in particular he introduces the distorted wave Born approximation for the modeling of energy transport in the high-frequency regime ka » 1, where k is the central wavenumber of the wave and a the correlation distance. In the future, it would be interesting to see how this method may be extended to polarized elastic waves. The paper is well illustrated and very pleasant to read. It will be a very useful reference for seismologists interested in the stochastic description of Earth Heterogeneity as well as other geoscientists eager to understand how seismologists map small-scale heterogeneities.

General question:

Figure 8 is a central result of the compilation made by the author, where he demonstrates a universal feature of the power spectrum of elastic fluctuations in the Earth: namely that this spectrum is very well described by the von-Karman model with an exponent close to 0, suggesting that the different envelopes of the Earth are rich in small-scales. This Figure is also a source of interrogation. If the power-law is universal then does it contain information on the dynamic processes that are at the origin of the heterogeneity? Indeed, one would expect that different tectonic processes occurring in different envelopes of the Earth leave different imprints in the power spectrum of heterogeneities at small-scale. And to some extent, this is what seismological observations -recalled by the author- also suggest. For example, the observation of guided waves indicate the presence of small-scale heterogeneities with anisotropic scale-lengths in subducting slabs. In Japan, Pulse broadening is wildly different between fore-arc and back-arc regions. Yet Figure 8 seems to imply that the same power spectrum can match completely different geological environments at different scales. Therefore, I wonder whether the important information is really contained in the exponent of the power spectrum or if it should be used in conjunction with other measurements like frequency dependent attenuation, vp/vs ratio, etc... or if the model should be complexified (introduction of anisotropic scale lengths)?

Technical questions:

(1) The author rightfully points out that the use of the Born approximation (BA) is problematic at high-frequency. Indeed BA predicts an increase of attenuation without limit as ka tends to infinity. The author also suggests that the limit of applicability of BA is the same as the limit of applicability of the Bourret approximation from mean-field theory.

Yet, the catastrophic increase of attenuation predicted by BA does NOT occur in the Bourret approximation. Bourret approximation does in fact predict the same geometrical limit as the phase screen approximation, although in a much less transparent way since it involves the solution of an implicit equation for the wavenumber of the mean field. It is only when the solution of this implicit equation is simplified by employing the BA that the Bourret approximation fails. But conceptually, I think that the limit of validity of the 2 approximations should be distinguished.

(2) The author explains that the Phase Screen Approximation cannot model the coda. It is not clear to me how the sentence should be interpreted. Certainly the method cannot model wide-angle scattering. At the same time, if the random walker takes a large number of steps, it may eventually come back to its starting point, thereby generating a coda. In optics, this situation is very common. For instance, light diffusion in tissues is in a regime of very strong forward scattering, where the transport mean free path (the length scale of the diffusion process) is much larger than the mean free path (the length of a single step of the random walker). Could the author elaborate a bit on this point?

(3) In the text, the author refers to various estimates of the power spectrum of heterogeneities based on different sampling of the random process. Some estimates are based on 1-D sampling, others on 2-D sampling. It would be interesting to briefly recall how one extrapolates from either a 1-D or 2-D power spectrum to a 3-D one. What are the necessary assumptions (isotropy?) and what is the relation between the measured 1-D or 2-D power law and its 3-D extrapolation?

(4) Would it be possible to explain in simple terms why the classical BA and the phase-screen approximation disagree for $ka < 0.2$ in the example shown in Figure 5? More generally is there a simple criterion which could be employed to know whether one should employ the BA or its distorted-wave version?

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