Geophysical Research Abstracts, Vol. 8, 05770, 2006
SRef-ID: 1607-7962/gra/EGU06-A-05770

Application of a new wavelet-based method to the detection and characterization of the normal modes of the Earth

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Many time series in geophysics contain transient excitations with attenuation by diffusion that are difficult to detect and characterize when their intensity is low compared to noise. This is a typical question in the characterization of the seismic normal modes of the Earth and the possible detection of the translational motion of the inner core, the so-called Slichter triplet. This detection remains a non trivial problem since the most appropriate instruments for recording its effect at the Earth's surface, the superconducting gravimeters, have a noise level (a few nGal where 1 nGal = 10^{-12}g with g the surface gravity) slightly above the expected amplitude of modeled Slichter triplets (less than 1 nGal). To detect and characterize such low intensity damped transient waves, we introduce a new wavelet family and use a continuous wavelet-based analysis. Indeed, Morlet or Gabor type signal decompositions now widely used by geophysicists do not perform well in the analysis of low amplitude damped free oscillations. To improve the detection of causal damped transient waves, we introduce a continuous wavelet-based method using correlations with causal damped sinusoids that serve as the wavelet basis. Tests on synthetic data demonstrate the high frequency and temporal resolution reached and the ability of the proposed method to characterize damped free oscillations (frequency, time of excitation and damping rate). The application on time-varying gravity data recorded by superconducting gravimeters after the 2004 M_w = 9.3 Sumatra-Andaman earthquake clearly demonstrates the ability of this wavelet family to characterize the frequency and damping of the seismic normal modes of the Earth.