Radiative transfer theory pdf

General radiative transfer theory. Acoustic radiative transfer theory. Basis of radiative transfer theory. Microwave radiative transfer theory. Theory of atmospheric radiative transfer. A differential theory of radiative transfer. Radiative transfer theory equation. Radiative transfer theory remote sensing.

We propose a new technique to obtain spectra of origin and seismic moments of regional earthquakes from seismic tail envelopes. Compared to existing methods, our approach is based on a physical model of the scattering process that produces the seismic queue. This allows direct estimate of the parameters of origin, without the need to correct the proportional coefficients with reference events. We see an appreciable advantage because the method is independent of output from other techniques, such as reference events provided by the moment increments. The main component of our method is a joint inversion of seismic records for the parameters of origin and site, as well as for the average parameters that take isotropic and instropy sources, acoustic dispersion in half space. The method is tested with recordings of 11 earthquakes (4 Â ¢ â € œthe Â¤ 6) from the German regional seismic network at epicentral distances less than 1000 km. We reverse the tracks in eight frequency bands between 0.2 and 24 Hz and show that our seismic moment estimates are in good agreement with the values obtained in independent studies using the waveform reversal techniques. In fact, our estimates of the seismic moment are better than the approximations obtained from local magnitudes using specifically derived empirical relations for the study region. The parameters that describe the dispersion means are the average free path that we found about 690 km on average and the intrinsic quality factor for which we get IQ = 500 under 3 Hz. The tail, the theory of radiative transfer, dispersion, The seismic moment since it was recognized for some time that the amplitudes of the regional queue are proportional to the excitement of the source, the attempts to extract information on the seismic source from the queue have a long history. Aki & Chouet (1975) were the first to study the spectra of origin with the waves of the queue. Due to the available tools obtained of origin over 3 Hz. It is necessary a correction for the attenuation that involves an empirical quality factor that describes the intrinsic and dispersed attenuation. Measurements are made relative to one another and must be adjusted to reference events. Mayeda & Walter (1996) used 2-D multiple dispersion to approximate tail envelopes and measure queue amplitudes. Additional corrections of the empirical distance were introduced above 0.2 Hz. Mayeda & Walter (1996) proposed that the influence of the dispersion of the wave of the body, which is not described by their 2-D dispersion model, required this empirical change. They transformed the amplitudes of the queue resolved in frequency to point-rate spectra using the reference events. Mayeda (2003) has extended this empirical approach and ended up with 12 free parameters that describe the tail envelopes. Mayeda (2003) tested the method and applied to the Dead Sea split. Morasca (2005) used it to analyze the moment of energy moment in the Western Alps. Mayeda's approach (2003) and Morasca (2005) is completely empirical and has no connection with the physics of the dissemination process. Dewsberry & Crosson (1995) used the single patterned model in a detailed analysis of seismic spectra of 78 US Nut earthquakes. They also provided queue q estimates and site amplification. All these studies share the fact that they need reference events with known source spectra to correct the proportional coefficients to obtain absolute values for source spectra. On the contrary, the approach presented here is independent of external information because the physical dispersion model provides a direct relationship between the amplitude of the queue and the source excitement without any coefficient of This direct relationship was previously used by Nakahara (1998). On the basis of theoretical developments of Sato (1997), presented an approach to study the process of origin of large earthquakes in detail. Nakahara (1998) used a model of more isotropic acoustic dispersion to reverse the spatial distribution of non-Isotropian Isotropians Energy radiation on the fault. In this method, the average parameters are taken from studies that belong to another branch of the tail surveys. The aforementioned studies focus on the properties of the propagation medium rather than on the source and aim to separate the effects of intrinsic and disseminated attenuation to characterize the small-heterogeneity and the dissipation of energy. For example, there are several studies (Fehler 1992; Mayeda 1992; white 2002) applying multiple analysis of the Windows Time window (MLTWA) developed by Hoshiba (1991). MLTWA is based on multiple isotropic acoustic dispersion and use energy reports integrated into three consecutive time windows to separate intrinsic and dispersed attenuation. An improvement in the geometric approach is due to Margerin (1998), which shapes the propagation of energy in a layer above a half space. Lacombe (2003) Use a similar model consisting of a layer of dispersion that overlap a transparent medium space to characterize the attenuation properties of the LG waves. All these studies apply the normalization of the queue (AKI 1980) to correct the undesirable effects of the source and site amplifications. The normalization of the tail, however, fails for small events with a shortest queue, since the queue can be dominated by random seismic noise before the requirement of homogeneous distribution of energy in space is satisfied. In the present study, we exceed this disadvantage by including the source excitation and the amplification of the site directly in the inversion process. We present an approach to estimate the spectrum of origin jointly reversing the seismic record for the average parameters and the effects of the site. The merit of this integrated approach is that (i) is independent of external information as the spectrum of origin of the reference events because we use a physical model of the dispersion process for which we obtain the parameters in reversing. This model provides a direct relationship between the amplitude of the queue and source excitement. (Ii) It is applicable for smaller events because the source excitement and site amplification factors are estimated in reversal, therefore no normalization of the queue is required. The card is organized as follows. We describe the modeling of Sismogram envelopes in section 2 and introduce data selection and the study area in section 3. We describe the reversing scheme in section 4 and shows the reversing results in section 5. 2 modeling envelopes of the Envelope are modeled using radiative theory transfer. The dispersion of waves in 3-D space is regulated by radiative transfer or from the equation of Boltzmann (Margerin 1998). Here we limit ourselves to the histropic dispersion of the waves s in a half space with an isotropic source. In full-space the effective function of energy density Green G (T, R) is given by the following integral equation 1 (Sato & Fehler 1998, p. 175). 2 is the Green function for the energy of consistent waves. Here V0 and G0 denote the average speed of waves s and the total dispersion coefficient, respectively. R = | R | The distance of the source receiver and H is the Step Heaviside function. The exact solution of the EQ. (1) involves a processing of 2-D Fourier (Zeng 1991; Sato & Fehler 1998, p. 177). To accelerate the inversion we use an analytical approximation to the solution of 1 obtained from PaaStchens (1997) interpolating between the explicit solutions of the Boltzmann equation in 2-D and 4-d. The PAACHENS (1997) Law 3 solution where. Recently this interpolation has been used by Abubakirov (2005) in an MLTWA. It is a good approximation of the EQ solution. (1) Given by Zeng (1991). The deviation from the exact solution is less than 5% in Hargest deviations occur in the queue of the live wave. The accuracy of the approximation for the direct wave and its tail is reasonable in our context because we will only use an average value in a short window following the direct wave. This window is widely dominated by the unpaught wave energy that is correctly correctly in EQ. (3). The condition of the border for radiative transfer into a means of space is zero flow of vertical energy on the surface. Assuming the total reflection, we explain this condition by introducing a source of the mirror over the surface for which the function of energy density is G (T, R +), with R + be the distance between the receiver and the mirror source. On the surface the flow up of the actual source is equal to the flow down of the mirror source, so satisfying the contour condition. The function of energy density is the function of the medium space is therefore GH (T, X) = G (T, R) + G (T, R +). In the following we assume that the receiver is on the surface where R = R +. In this case GH (T, X) = 2G (T, R) (cf.wegler 2004). With this treatment we consider only the conditions of the contour for the transfer of energy. Specific effects deriving from the conditions of the contour of the waves equation such as the conversions of the mode, surface waves and the reflection coefficients dependent on the corner are not accounted for. The energy density for an arbitrary source can be obtained with the convolution with the source function. In our analysis we assume a function of origin of the WÃž '' (R) Ãž'a (t) module where w is the energy of the spectral source in J / Hz. The intrinsic absorption can be accounted for with a further factor Employee from time is ¢ 'BT with the intrinsic absorption parameter b. Finally we get 45 for the emod energy density (T, R) of our model to half-room at Time T and distance R from the source of energy W. Ri is the site's response to station I. 3 The regional data and data of Setting for this study were recorded by the German regional seismic network (GRSN), the Gräfenberg Array (GRF) and the Reference Station of the Array Geress. The stations are equipped with STS-2 or STS-1 (GRF stations) broadband sesmometers and traces are sampled at 80 Hz. Refer to Korn (2002) for a detailed discussion by the GRSN. For this job we use data of 25 different stations (fig. 1). Open in New TabDownload SlideMap of Germany and neighboring countries. Gray triangles: broadband stations of the German regional seismic network, the Gräfenberg matrix and the Geress GEC2 station (the station codes are added); Black stars: the earthquakes used in this study (occurrence dates are added). To the sources we use local and regional events from Germany and adjacent areas in the period from the installation of the GRSN in 1991 to 2004 December. We choose events with local magnitudes estimated by the German central semological observatory (SZGRF) broader than or equal to 4. To reduce dispersion in the estimates of our parameters, we exclude events from the Alps due to differences in geological conditions. An event in 1994 on October 18th in the North Sea is excluded because we have observed suspicious differences in arrival times, perhaps due to localization errors or an unsuitable speed model. In the end we use 11 earthquakes (figure 1) and more than 100 broadband records with three components. Positions, magnitudes and depth as provided by the SZGRF are listed in Table 1. With the possible exception of the Roermond 1992 earthquake, where deep depths have been estimated even below 20 km (Korn 2002), the events occurred in the upper crust. The last three columns of Table 1 contain seismic moments estimated by the modeling of the waveform and the method presented here. They will be discussed later. Open in New TabDownload Sliderist of the earthquakes used in this study. The time of origin, the location, the depth and the local magnitudes are provided by the German Central Semification Observatory. The seismic moments estimated by the modeling of the waveforms are listed in column 6 with the respective references Column 7. The last column lists the seismic moments estimated in the present study. Data preparation provides filtering sesmograms in eight frequency bands centered at 0.1875, 0.375, 0.75, 1.5, 3.0, 6.0, 12.0 and 24.0 Hz with a narrow normalized Gaussian filter. Choose the filter in such a way that B (f) is frequency response, ensures that the spectral energy density is stored in the Process (Wegler 2006). Envelope sections are selected according to the following criteria: (i) s / n ratio of more than 4 (ii) without obvious disturbances, for example, replicas (manually controlled) (iii) hypocentral distance greater than 60 km. The hypocentral distance range is ¨ Limited at distances greater than 60 km because we use a simple semi-resistant speed model, with a speed of the average cut waves V0 = 3.5 km SA 1, which is appropriate for short distances.We getting the energy density observed EOBS (T, R), which is, seismogram envelopes, from the bandPassed speed sesmogram using 6 here 0 is the average density of the vehicle and indicates the transform of Hilbert. We use 0 = 2700 kg but 3 during this study. 4 Invursion In the inversion scheme is estimated values for the parameters G0, B, W and RI that minimize the MISFIT 7 function here N indicates the number of stations. Start yourself and correspond to the indexes of the first and last sample in the window Ã ¢ CodaÃ ¢ Time (Fig. 2) at the SIMO station. The ATOÃ ¢ Time window starts after Dual Traveltime of the S-Wave and ends when the S / N drops below 4. Simultaneously inverted all the tracks available for a certain event in a common frequency band for G0, B, W and RI . The inversion scheme is a combination of a 1-D grid search for G0 and a linear inversion for the remaining parameters. Fig. 2 illustrates the constraints of this process that operates in the following five phases. Opens in a new TabDownload SlideExample of an observed seismogram envelope (thin curve) on a logarithmic scale with the best adaptation of the model (bold black curve). Time windows used in the inversion are indicated at the bottom of the figure. Note that in the time window of the S-wave only the average values (black points) of envelope and models are equipped. (I) Take a value of G0 (a series of G0 is probable in a grid search) and calculate functions the energy density of Green G (T, RI) for all I stations, using the approximation in EQ. (3). (Ii) We equate EOBS (EQ. 6) and emod (EQ. 5) and terms REARRAYS AS 8 HERE HERE Denota LN Base and Logarithm. By inserting a linear curve to the left side of the EQ. (8) The appropriate values of B and (WRI) are obtained as a function of time. To reduce the effect of direct surface waves and anisotropic diffusion is inserted only in the graph in the time window Ã ¢ CODOÃ ¢ (Fig. 2) starting double the Traveltime S-wave. We also apply the constraint that the average values of the molded envelopes and detected at Ã ¢ Direct Time window S-WaveÃ ¢ (Fig. 2) are the same. Rated R from the source This time window contains samples with time lapse T in the range 3.5 km SA 1> R / T> 3.0 km SA 1. We apply this constraint to resolve the compromise between G0 and (WRI) which It exists in the next queue. (Iii) with the values of b and (wri) obtained in the two emod stage is explicitly calculated (eq. 5) at the estimate the mismat Ãžî¼ (eq. 7). (iv) Steps 02:59 are repeated for a range of G0 values. The final model for an event and a frequency band is that with the smallest value of Ãžî¼. (V) For the best model W and RI adaptation are explicitly calculated by simply taking W to be the logarithmic media of all values (WRI). In this way it is assumed that the average of the re-zero logarithms means that it is measured site amplifications with respect to the network average that is assumed to be one.The constraint that makes use of the Ã ¢ s-waveÃ ¢ direct comes temporal window from the Following problem. In a dispersion medium weakly the difference between the tail of two models with different W and G0 can be very small provided the WG0 product is the same for both models. The single dispersion approximation (Sato & Fehler 1998, p. 47) which is valid for small G0 provides that the emod energy density is proportional WG0. In this interval it is intrinsically W and separate G0. However, even for moderate scattering not adequately shaped in the single range of diffusion can be Unable to separate W and G0 cause noisy data and other simplifications in the model if only information from the queue is used. In contrast the density of ballistic energy is proportional. Here a compromise is observed between G0 and B which corresponds to the fact that intrinsic and dispersion attenuation cannot only be separated uncatched energy. However, the energy and W overall attenuation can be separated due to the different time dependence.in to the inversion we are envelopes in the window Ã ¢ CodaÃ ¢ Tempo indicated in fig. 2. However, limit the possible models of these that predict Correctly the ballistic energy in the window via S-Wave ¢ time (fig. 2). We want to emphasize that in a dispersion means it is weak on the one hand it is not possible to estimate in a reliable way moda WA tail only without a priori knowledge of G0. On the other hand it is possible to estimate W exclusively from the ballistic wave because in order to apply theory of radiative transfer that provides energy source w owl G0 and B separate. We note that the information from the undressed wave is implicitly evaluated also MLTWA for G0 and B separate from the first time interval of the MLTWA generally contains ballistic energy. 5 Results As simultaneously inverted all available registrations are implicitly assumed that there are no lateral variations in the G0 and B structural parameters. Our results represent media entire values on possible regional variations. An example of adaptation we get with our model is given in fig. 3. The detected envelopes are traced as thin lines while bold lines represent model envelopes. Average energy density values in the Time window S-WaveÃ ¢ Direct Ã ¢ are indicated as gray and black points for envelopes observed and modeled, respectively. The model typically adapts envelopes in the time window Ã ¢ CODOÃ ¢. Deviations in the window via S-WaveÃ ¢ are probably due to the source directional. It will open in a new TabDownload SlideComparison between the envelopes (subtle curves) of the 2003/02/22 earthquake with the model (bold black curve) in the band of 1.5 Hz on a logarithmic scale. Time windows used in the inversion are indicated with gray bars at the bottom of the plots. Note that in the S-Wave race time window only the average envelope and model values are mounted. These levels are indicated as gray and black points for the envelope and the model, respectively.in the following sections, first present the results of the attenuation parameters as they are fundamental for the source parameters esteem that we present below. It will also be briefly remembered the estimates of site amplifications. 5.1 Attenuation Parameters Scattering force can be expressed in terms of G0 Total diffusion coefficient which is the inverse of the free medium or in terms of dispersion parameter attenuation SCQ ¢ 1. The ratio between the two is 9 where F indicates frequency. Fig. 4 Show G0 depending on the frequency. The small gray points in fig. 4 indicate the measures of the individual earthquakes. The dispersion of these values is due to the uncertainties of the measurements but the regional differences added to the dispersion force will increase the variations of the G0 values. Blackheads with error bars indicate the logarithmic averages of the individual measurements together with their 95 percent confidence limits. individual measurements vary from 10a 7 mA 1 and 10a 5 mA 1. logarithmic averages range from 9 10 bis 7 mA 1 and 3 10 bis 6 mA 1. There is no significant frequency dependence of G0 and logarithmically mediated on all measurements Regardless, frequency is obtained a value of 1.45 10a 6 mA 1 corresponding to a free medium journey 690 kilometers. We compare our estimates with Abubakirov & Gusev (1990), Fehler (1992), Mayeda (1992) and Lacombe Which studied tail waves in Kamchatka, Japan, Hawaii / Long Valley / California Central and France, respectively. respectively. 2 summarizes the results of the different studies in the frequency bands centered at 3.0 Hz. Refer to White (2002) for the graphic representation of most of these results. The value obtained in the present study is low in this comparison, but the difference can be attributed to geological distinctions since the central European intraplate region is probably less heterogeneous than the volcanic areas listed in Table 2. Compared to the results of France obtained from Lacombe (2003) The difference could be partially due to a set-up of the different model. Open in new TabDownload Slidesulsults for the total dispersion coefficient of the waves S. Gray Points: dispersion coefficients measured by the reversal of individual events; Blackheads with error bars: logarithmic media of individual measurements with 95% security limits. The intrinsic attenuation parameter IQÂ'11 is related to the absorption parameter B as 10fig. 5 Displays the results of the individual measurements with small gray and logarithmic medium points in the individual frequency bands together with 95% of confidence limits as blackheads with error bars. Average with individual measurements in separate frequency bands we obtain iqÂ,19 values between 2.6 Ãƒ-10 'and 2.2 Ãƒ-10. For frequencies below 3 Hz IQÂ'1 is approximately constant at 2 Ãƒ-103. Above about 3 Hz we observe a decline in the power law like iqÃ ¢ '1 fÃ ¢' 1. Our values are between the range of results of different regions listed in Table 2 and very close to the results of France Laccombe (2003). However, there may be some prejudices because we reverse the regional records with a model to half a space. We probably probably probably "because the loss of energy through the Moho in a weakly dispersed cloak is mapped in attenuation (Margerin 1998; Wegler 2004). Open in a new tabdownload slidesulsultsulsults for the intrinsic absorption attenuation parameter. Gray points: attenuation parameter measured by the reversal of individual events; Blackheads with error bars: logarithmic media of individual measurements with 95% security limits. 5.2 Source energy Because our approach is on a part based on a physical energy propagation model and, on the other hand, does not require a normalization of the queue, our Reversion W parameter can be interpreted directly. By measuring the source energy at various frequencies we get the Source energy spectrum w (Ã¯ â € °) of the radiate s waves. Assuming that the movement of the particles is caused by a double torque and is observed in the farthest field you can get a relationship between W (Ã¯ â € °) and the seismic moment by integrating the density of the energy flow on a sphere containing the source. Sato & Fehler (1998, p. 152) State 11 where V0, Ã¯ 0 em (Ã¯ â €) denotes the average S-Wave speed, the average density and processing of Fourier of the moment of the moment's function, respectively . From EQ. (11) The source spectrum is obtained Ã¯ â € ° | M (Ã¯ â €) |. In fig. 6 the source movement spectra of the events listed in Table 1 are shown. The error bars correspond to the resolution of our inversion process and not to the dispersion of individual measurements as in Figures 4 and 5. The maladed Ã®î¼ in EQ. 7 It is the variance of the logarithmic difference between the samples of the observed and modeled energy density. We use the test F to decide if two models are significantly different based on the relationship between their variances Ã®î¼. The error bars mark the range of values for displacement spectra that can be obtained for the models that cannot be distinguished from the best model based on the F test (Buttkus 2000, page 231) with a significance level of 5%. Open in New TabDDownload SlideDuckoolce Logarithmic Spectra Trap Source Source Earthquakes used in this study. The numbers within the graphs indicate event dates in Yyyy_mm_DD format. Points with continuous curve: Spectra esteemed source in this study. The error bars correspond to 95% of the trust limits of the reversing resolution (see the text for the explanation). The Part shown in black is an average to get MCODA0. Thick horizontal line: Seismic moment MWM0 estimated independently using waveform modeling techniques (Braunmiller 2002). Thin dashed curve: Omega-square spectra calculated independently of local magnitudes using empirical relationships. Low limit frequency corresponds MML0.most of the curves show the expected characteristics of a movement spectrum. A flat region can be observed towards the low frequency limit, while the decays shift over a frequency angle. There is a different behavior for the October 2004 event that has occurred in northern Germany which is tectically silent. Né the low-frequency plateau né the corner frequency can be observed. Consider this as proof of a complex source process.The low frequency plateau can be compared with a seismic moment MWM0 obtained regardless of waveform reversals. For most events we use the Solutions of the Swiss Regional Tensor Catalog which is available online at. Refer to Braunmiller (2002) for examples and a description of the method. The MWM0 estimates for the three events before 2000 can be found in Braunmiller (1994) and Braunmiller (2002). No seismic time is available for the event in 1995. The estimates of the inversion waveform of M0 are traced as thick lines in fig. 6. Obviously the low frequency values of our spectrum displacement correspond to the moments of the inversion waveform well. Assuming that the angular frequencies of the events used here exceed 1.5 Hz Take the logarithmic media of spectra displacement in the four lower frequency bands as the estimated estimate of the seismic moment denoted MCODA0. In fig. 7 the values of the seismic moment obtained in this study (McODA0) are traced against the values of the waveform modeling (MWM0). On average there is a difference of 36% between the waveform and the results of the queue. Open in New TabDownload SlideStail Plot of seismic moments obtained from seismic queue (MCODA0) In this study and moments estimated by local magnitudes (MML0) against the estimates of the seismic moments from the long modeling of the waveform of the period (MWM0). The straight line indicates the positions of the perfect agreement of the different estimates. Another reference that is interesting to compare with displacement spectra is the scale of the local magnitude. Recently Ramer & Hinzen (2004) studied earthquakes in the Northern Rhine area (around the bug station in fig. 1) and established the report 12 between the local ML magnitude and the seismic moment MML0 in NM. The ML SuperScript indicates that the seismic moment MML0 is estimated by local magnitudes. Figure 7 also shows the comparison of MML0 with the results of the Waveform Modeling (MWM0). On average the difference between the derivative moments â €