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RIASSUNTI ESTESI DELLE COMUNICAZIONI

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OCEANOGRAFIA E DI
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THE USE OF CONTINUOUS WAVELET TRANSFORM FOR GROUND ROLL ATTENUATION

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Introduction. In seismic reflection land data, Ground-Roll (GR) constitutes an high amplitude and low frequency noise that obliterates the reflected events decreasing the quality of the seimograms and, as a consequence, of the final stack section. Many processing methods are adopted to reduce the GR noise but the dispersive nature of the surface waves makes it difficult to design an optimal window for classical 1D filtering approaches based on short time Fourier Transform or for 2D approaches based on singular value decomposition. Also, 2D methods such as the *f-k* filtering can generate artifacts or can give poor results if the surface waves are aliased or if the traces are not regularly spaced. An additional difficulty is that the characteristics of the surface waves change depending on the near surface properties so that their features can vary drastically along the seismic line. This, requires to adapt the parameters of the processing operators according to the changing characteristics of the GR. Actual and more sophisticated methods consist in the estimation of the surface waves followed by adaptive subtraction but they are computationally expensive and time consuming.

Source and/or receiver array design still remains the less invasive approach to reduce the surface waves noise and, for near surface survey, Tognarelli and Stucchi (2016) proposed an acquisition scheme that permits to perform different array simulations in the processing lab. Arrays are not able to remove the GR, they are effective to partially reduce the GR and at improving the signal window.

In the last years, the continuous wavelet transform (CWT) (Daubechies, 1990,1992) has been used in a wide range of geophysical and geological disciplines such as seismic, oceanography, and climatology (Torrence and Compo, 1998; Lau and Weng,1995; Deighan and Watts, 1997; Sinha *et al.*, 2005; Farge, 1992; Sadowsky, 1996), but also in other contexts like image processing, music and medicine fields (Mallat, 2009). In general, the CWT analysis can be applied successfully to all time or spatial series that represent a non-stationary process, with the aim of investigating the spectral components and how they change over time and/or space.

In this work, the CWT is used to analyse the shot gathers from a near surface seismic land survey and an intuitive filtering procedure, applied in the wavelet domain and aimed at attenuating the GR, is presented. The improvement of the data quality is shown and discussed for the shot gathers and finally for the stack section.

Method. The CWT is defined as the convolution between a sampled time series $x_{n'}$ and a scaled and translated version of a mother wavelet ψ:

$$W_n(a) = \sum_{n'=0}^{N-1} x_n \psi^* \left[\frac{(n'-n)\, \delta t}{a} \right] \qquad (1)$$

where N is the number of samples in the time series, δt is the sample rate, a is the scale (or dilatation) and $n\delta t$ is the translation b. The mother wavelet ψ is translated of b and scaled of a during the CWT process and acts on the input series $x_{n'}$ as a band-pass filter whose central frequency changes as the scale parameter a changes. In this work, the complex Morlet is chosen as mother wavelet, b is set equal to the sample rate and a is defined by the exponential

$$a_j = a_0\, 2^{j\delta_j} \qquad (2)$$

where a_o is the smaller scale that can be correctly resolved, $j=0,1,\ldots,J$ is the scale index and δ_j determines the sampling in the scale. For a Morlet wavelet, the relationship between Fourier period $1/f$ and the scale a can be directly computed. The CWT is a 1D operator whose computation yields, for each trace, a time-frequency diagram called wavelet spectrum. The wavelet spectrum allows to analyse the frequency content over time of a trace and, if necessary, to remove the

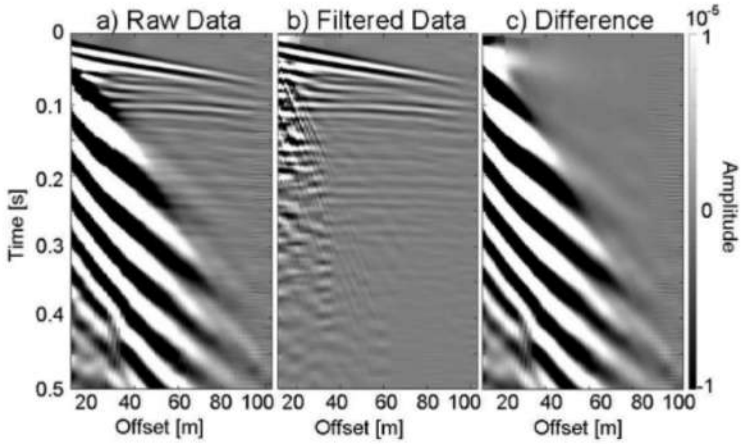

Fig. 1 - a) Raw gather. b) Same gather after filtering in the wavelet domain. c) Difference between a) and b).

frequency components pertinent to the noise. It is also possible, from the wavelet spectrum, to reconstruct the trace by means of the inverse continuous wavelet transform (ICWT) (Farge, 1992; Sadowsky, 1996). If the wavelet spectrum is modified, i.e. some frequency components are zeroed, the reconstruction yields a trace characterized by the lack of the removed frequency components. This, corresponds to filter the data in the wavelet domain.

Results. The presented real data are from a near surface reflection survey acquired at Luni, in Tuscany (Italy). 185 shot gathers were acquired using a 10 kg sledgehammer and a 48-channel single geophone spread as the energy source and the recording device. The sampling interval was 0.5 ms and the record length 1s. The spacing between the receivers is 2 m and 1m is the spacing adopted for the sources. More about the acquisition can be found in Tognarelli and Stucchi (2016). In Fig. 1a is illustrated an example of raw gather which is clearly contaminated by GR. Fig. 2 shows the

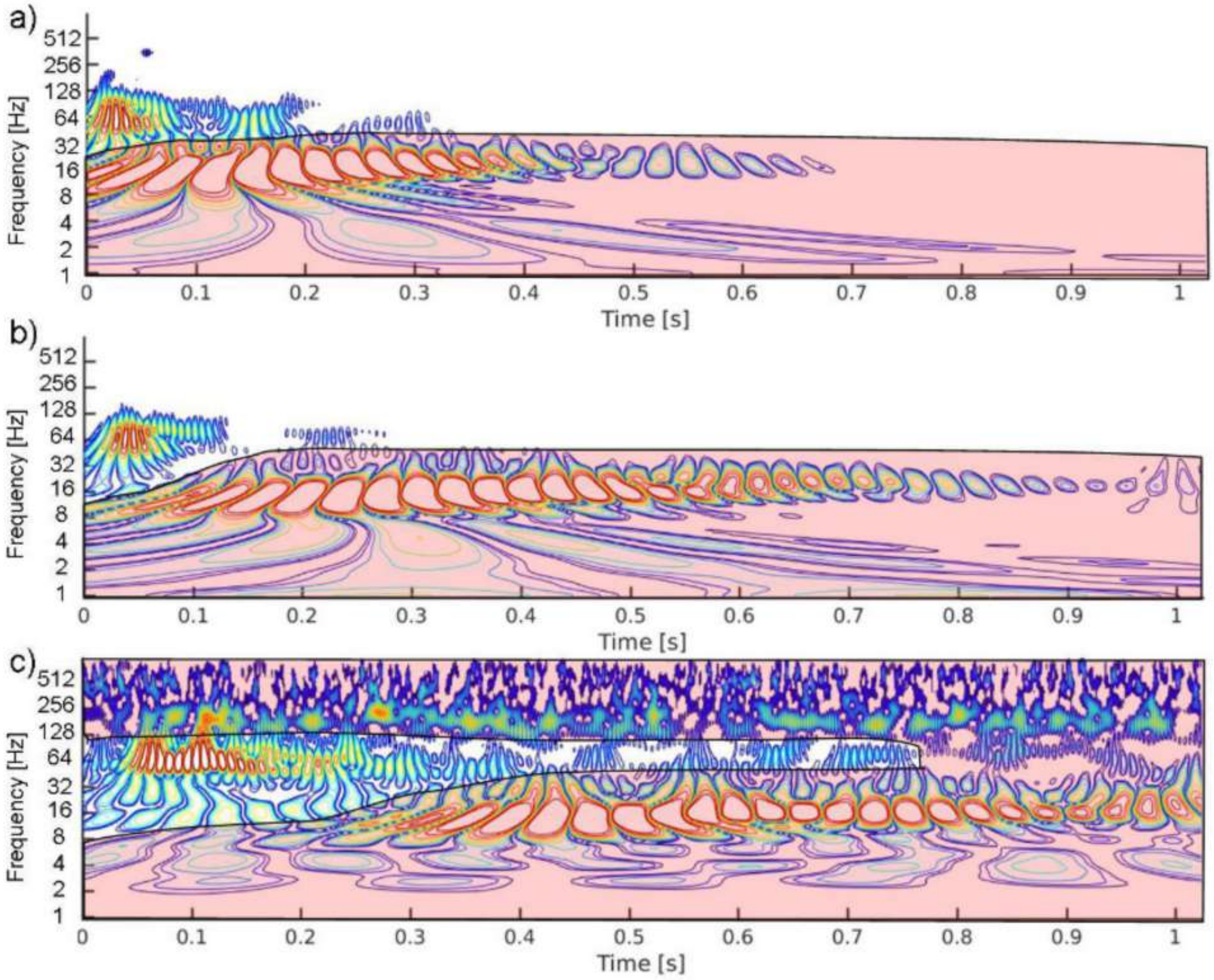

Fig. 2 - Wavelet spectra of three traces extracted from the raw gather illustrated in Fig. 1a and located at offset=20 m (a), 40 m (b) and 90 m (c). In red, are highlighted the mute masks applied for the showed spectra.

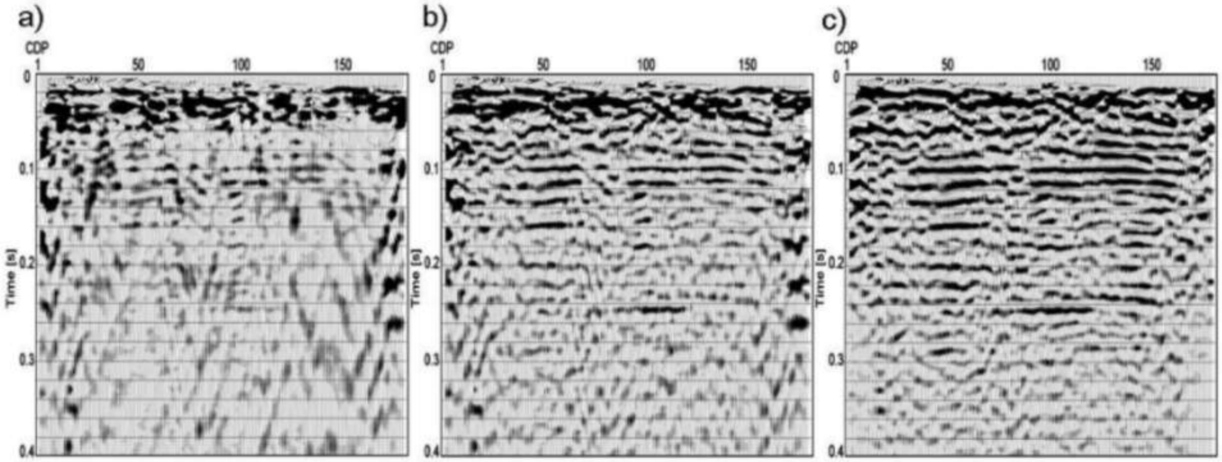

Fig. 3 - Comparison between the raw stack section (a)), the stack section obtained after a band-pass filter (b)) and the stack section obtained filtering the data in the wavelet domain(c)). The sections are represented using the same amplitude range.

wavelet spectra of three traces extracted from the gather of Fig. 1a and located at offset 20 m (Fig. 2a), 40 m (Fig. 2b) and 90 m (Fig. 2c) respectively. In red colour, the contour of Fig. 2 puts in evidence the time-frequency coordinates related to the stronger events observed in the time-offset domain (Fig. 1a).

Analysing the wavelet spectra of Fig. 2, it is possible to localize both in frequency and in time the GR allowing to design a mute mask aimed at removing it. The mute masks applied for the spectra presented in Fig. 2 are highlighted in light red. Since the effects of the GR on the seismogram are offset dependent, different masks are required to adapt the characteristics of the GR. In this specific case, the offsets of the data are gathered into ten groups and a mask for each group is defined. The masks are drawn directly on the spectra by a user defined picking. Note that the spectrum in Fig. 2c exhibits the contamination of GR and of an high frequency noise that is included in the mute mask. In Fig. 1b is shown the same gather of Fig. 1a after the filtering in the wavelet domain and Fig. 1c illustrates the difference between them. As can be noted, the filtering produces a significant suppression of the surface waves. The improvement of the data quality can be also appreciated on the stack section (Fig. 3c) where the reflected events appear more energetic and continuous and where a general S/N enhancement can be observed. Fig. 3 show the raw stack section (Fig. 3a), the stack section with a traditional band-pass filter (15-25-130-150 Hz) applied, and the stack section obtained after filtering the data in the wavelet domain (Fig.3c).

Conclusions. In this work is presented the application of the continuous wavelet transform aimed at attenuating the Ground Roll on seismic data. The results shown demonstrate that filtering in the wavelet domain produces an improved data quality if compared with traditional band-pass filtering. In addition, the wavelet spectrum provides a time-frequency representation of the data where the components related to the GR can be easily detected allowing to design a mute mask in a simple way. With respect to many traditional methods, the showed procedure is not time consuming, is not computationally expensive and it doesn't generate artefacts. The continuous wavelet transform constitutes a powerful tool for analysing seismic data and its use can have many applications in the field of the seismic reflection.

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STUDY OF THE SEISMICALLY CHAOTIC UNITS NORTH OF THE GORRINGE BANK (SW IBERIAN MARGIN, ATLANTIC OCEAN): IMPLICATIONS FOR COASTAL TSUNAMI HAZARD

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Introduction. The Gulf of Cadiz, located at the African-Eurasian plate boundary, is a natural laboratory to study a broad spectrum of geological processes. Moderate to high magnitude earthquakes are frequent in this region. Moreover, the irregular seafloor morphology, characterized by huge seamounts, abyssal plains, steep slopes and submarine canyons, is a preconditioning factor for large submarine avalanches. Both earthquakes and landslides are potential triggering mechanisms for devastating tsunamis along the SW Iberian and NW African coasts. Historically, these areas have suffered major earthquakes and tsunamis, such as the famous 1755 M_W 8.7 Lisbon earthquake, one of the largest earthquake ever recorded in western Europe (Baptista *et al.*, 1998). The source of the 1755 earthquake is still matter of debate. In the SW Iberian margin, the plate boundary is diffuse, and deformation occurs along a 200 km wide band, in a transpressive regime (Zitellini *et al.*, 2009). The relative plate movement is accommodated by the recently discovered SWIM dextral strike – slip faults, and by a series of NE – SW trending thrusts that are often related to submarine anticlines and seamounts, such as the Gorringe Bank thrust (Fig. 1).

The Gorringe Bank is a thrust – related anticline that elevates over 5000 m above the surrounding abyssal plains. The *North Gorringe Chaotic Bodies* are seismically chaotic units whose analysis is presented in this work; they were identified at the feet of the Gorringe Bank's northern flank. Both accretionary prisms and landslides deposits are usually characterized by a seismically chaotic acoustic image caused by internal tectonic deformation in the first case, and by strong lithological and granulometrical heterogeneity, in the second case. The fact that the Gorringe Bank lies on the top of a regional thrust that has accommodated from 20 to 50 km of plate convergence between Africa and Eurasia since Early Cenozoic (Sartori *et al.*, 1994; Jimenez-Munt *et al.*, 2010) makes this area a favourable geological environment both for the