Rayleigh wave ellipticity measurements in the Iberian Peninsula and Morocco

Clara Gómez-García[1], Antonio Villaseñor[1]
[1]Institute of Earth Sciences "Jaume Almera" (CSIC)
cgomez@ictja.csic.es, antonio@ictja.csic.es

Abstract- *We combine Rayleigh wave ellipticity, or H/V (horizontal to vertical) amplitude ratios, measurements obtained using teleseismic earthquake recordings and ambient noise cross correlations to provide improved constraints on the crustal models across the Iberian Peninsula and Morocco. To obtain the H/V ratios, we use more than 250 shallow (h<40 km) teleseismic events with magnitudes Mw>6.0 recorded at more than 450 seismic stations. We also use all the multicomponent ambient noise cross correlations computed for each station pair for the time period 2010 to 2012. Periods between 20 and 100 seconds are investigated. We observe a good agreement between the uppermost geological features of the crust and the obtained Rayleigh H/V ratios, with low values in major mountain ranges and high ratios in sedimentary basins. Combination of Rayleigh H/V ratio measurements from both earthquakes and ambient noise data with phase velocities and other types of seismic data will help to better constrain the Earth's structure at different crustal levels.*

I. INTRODUCTION

Rayleigh waves are distinguished among other things by an elliptic trajectory of particle motion in the vertical-radial plane. Rayleigh wave ellipticity, defined as the ratio of horizontal to vertical spectral amplitudes (H/V ratio from now on for simplicity), has substantial shallow earth sensitivity since it depends on the local crustal structure.

Traditionally, ambient noise combined with the H/V spectral ratio have usually been used in microzonation studies, to characterize site response, predict ground motion or invert for S velocity (e.g., Ref. [4] and [9]). However, the interpretation of the H/V ratios in these studies depends on the noise composition. Measurements from ambient noise predominantly consist on fundamental mode Rayleigh waves for low frequency microseisms (<1 Hz) but for higher frequency microtremors (>1 Hz) there is no consensus. The microtremor H/V ratio has no clear physical origin because it depends on the contents of noise signals and the relative amplitudes among different wave types (see Ref. [2] and [3] for a review).

Studies of Rayleigh H/V ratios from earthquake signals for long periods (>20 sec) are less common (e.g., Ref. [5], [6] and [10]) because it has been reported considerable variability in the observations due to the influence of small scale heterogeneity [5]. In spite of the large scatter observed in Rayleigh H/V ratios for long periods, Reference [10] described stable estimates after collecting statistics for numerous earthquakes.

Recently, a new approach has been provided to study the crustal structure using Rayleigh wave ellipticity for earthquake signals or ambient noise cross correlations [6][7][8][11]. As Rayleigh wave ellipticity provides independent information from phase velocity data, a joint inversion will improve the inversions based only on phase velocity. In this work, we perform a Rayleigh wave H/V ratio study using teleseismic earthquake recordings and multicomponent ambient noise cross correlations with the aim of obtaining improved constraints on the uppermost crustal structure in the Iberian Peninsula and Morocco.

II. DATA ANALYSIS

We compute Rayleigh H/V ratios for more than 250 teleseismic events between 2010 and 2012 by more than 450 stations from several seismic networks deployed across the Iberian Peninsula and Morocco.

Focusing on the study of teleseismic signals, we use shallow earthquakes ($h \leq 40$ km) to minimize overtone contamination and large enough (magnitudes $M_w > 6.0$) to ensure the excitation of low-noise, long period, mantle waves [5]. To compute the H/V ratios at each station location we first rotate the three component recordings, for each earthquake and station, from East-West, North-South and vertical to transverse, radial and vertical components. Then, we remove the instrument response and apply a band-pass filter in the frequency band 0.02 to 20 Hz. Differences in the sampling rates for different instruments are taken into account for the analysis. As we have a large collection of records, we compute the H/V ratios using a frequency-time analysis (FTAN, [1]) applied in an automated way.

III. RESULTS AND CONCLUSIONS

Rayleigh H/V ratios are related to the elastic properties of materials and velocity gradients in the upper crust. Zones such as sedimentary basins are associated to high H/V ratios whereas low H/V measurements are related to major mountain ranges. In Fig. 1 we show the Rayleigh H/V ratios estimated for more than 450 sites in the Iberian Peninsula and Morocco for 30 seconds of period. We observe high H/V ratios in sedimentary basins (Cenozoic and Foreland basins) as Guadalquivir and Ebro Basins and low H/V ratios in Pyrenees, Iberian Massif and High Atlas. Although the standard deviation for each average H/V ratio is, in general, very small, we would need to consider a larger collection of teleseismic signals to make the results statistically significant [10].

The combination of Rayleigh H/V ratio measurements using both earthquakes and ambient noise data with phase velocity and other types of seismic data will provide us with a more realistic interpretation of the upper crust structure across the

Iberian Peninsula and Morocco and a better understanding of the relationship between geologic features at different crustal levels. Moreover, the inclusion of short-period Rayleigh wave H/V ratio measurements based on noise cross correlations in the H/V ratios obtained from earthquakes enables to resolve the structure in the uppermost 1 km since they are more sensitive to near-surface structure.

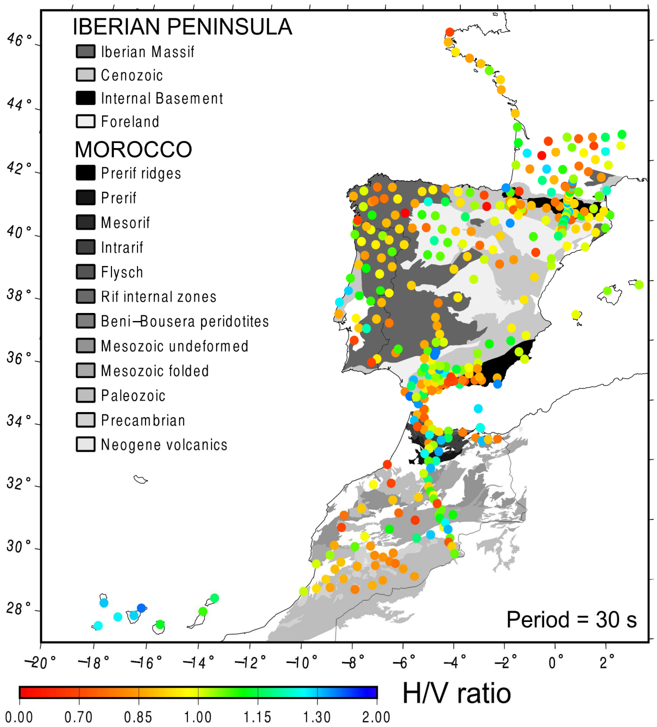

Fig. 1. 30 s Rayleigh wave H/V ratio across the Iberian Peninsula and Morocco.

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