Chapter 6

Characterizing the Noise for Seismic Arrays: Case of Study for the Alice Springs ARray (ASAR)

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/54387

1. Introduction

A seismic array is defined as a suite of seismometers with similar characteristics. Seismic array were originally built to detect and identify nuclear explosions. Since their development all over the world, seismic arrays have contributed to study interior of volcanoes, continental crust and lithosphere, determination of core-mantle boundary and the structure of inner core. Seismic arrays have been used to perform many regional tomographic studies (e.g., Achauer and the KRISP Working Group, 1994; Ritter et al., 1998, 2001); they helped to resolve fine-scale structure well below the resolution level of global seismology in many different places in the Earth, from the crust using body waves (e.g., Rothert and Ritter, 2001) and surface waves (e.g., Pavlis and Mahdi, 1996; Cotte et al., 2000), the upper mantle (e.g., Rost and Weber, 2001), the lower mantle (e.g., Castle and Creager, 1999), the core-mantle boundary (e.g., Thomas et al., 1999; Rost and Revenaugh, 2001), and the inner core (e.g., Vidale et al., 2000; Vidale and Earle, 2000; Helffrich et al., 2002). A different branch of seismology that benefited from arrays is "forensic seismology" (Koper et al., 1999; 2001; Koper and Wallace 2003). Studied have been also carried out to track the rapture propagation of large and moderate earthquakes (Goldstein and Archuleta 1991a,b: Spudich and Cranswick 1984; Huang 2001; D'Amico et al. 2010; Sufri et al. 2012; Koper et al. 2012), studies related to the seismic noise have been also developed using seismic arrays (Koper and Fathei, 2007; Gerstoft et al. 2006; D'Amico et al. 2008; Schulte-Pelkum et al., 2004). For example Gerstoft et al. (2006) used beamforming of seismic noise recorded on California Seismic Network to identify body and surface waves generated by the Hurricane Katrina. Schulte-Pelkum et al., (2004) measured direction and amplitude of ocean-generated seismic noise in the western United States. Koper and Fatehi (2007) used 950, randomly chose, 4-sec long time windows from 1996 to 2004 at the CMAR array located in Thailand. In their work they found, around 1Hz, a large noise peak coming from southwest near 220 degrees and an apparent velocity of 3.5-4.0km/s. Their results are robust from year-to-year and are also consistent from season to season. Two lesser noise peaks show probably a seasonal dependence, being much stronger in the fall and winter than in the summer and spring. Neither peak is sensitive to the "hour-to-hour" analysis meaning they are uncorrelated to anthropical noise. Koper and De Foy (2008) showed that the seismic noise recorded at the CMAR array during 1995-2004 can be strongly correlated with the ocean wave's heights. They carried out this information by using data from TOPEX/POSEIDON satellite tracks and explained them by the local monsoon-driven climate. For all this different purpose a lot of different arrays techniques and methods have been developed (for reviews see: Rost and Thomas, 2002; Filson, 1975) and applied to a wide number of high-quality data set.

The main goal of this chapter is to highlight the main characteristics of noise for the Alice Springs ARray (Australia). Furthermore detecting the noise we would like, if it exists, try to found the large peak noise, the predominant direction and estimate the optimal phase velocity and eventual time dependence. This kind of study could play a key role in for the isolation of the seismic noise in designing new arrays or particular instruments such as the construction of gravitational wave detectors (Hoffmann et al.,2002 and reference in therein). Theoretically knowing the seismic noise features and source it will be possible to subtract its effect from the data.

2. Data set and processing

Alice Springs Array is located in Australia and it is made by 19 vertical component short period seismographs deployed with an effective aperture of about 10 km (Fig.1). We ignored elevation differences among the array elements and considered only 2D wavenumber vectors. This is a reasonable since the ASAR array is relatively flat.

Continuous data were available from 1994 to 2004 and it was possible to get them by using the "autodrm request" of the U.S. Army Space and missile Defense Command monitoring research program (www.rdss.info, last access in 2009). It supports different researches related to the nuclear explosions monitoring. Time series containing randomly noise recorded for each station in all the time period where recordings are available. In the present paper data from 1999 to 2001 are used. We extracted several minutes of continuous data once a week for the selected time period, making sure to vary the time of day and the day of the week (Fig. 2). We used the Generic Array Processing software (GAP; Koper 2005), a set of freely C programs for processing seismic array data. These programs operate on binary SAC files and output GMT (Wessel and Smith, 1991) scripts for visualizing the results; they were developed to work both with small aperture array and other type of array as well. In present paper we used in particular the program called "capon.c" that performs the signal processing following the maximum likelihood Capon (1969) method; the idea is to use a spectral density function that provides the information concerning the power as a function of frequency, this function also provides the vector velocities of the propagating waves. This kind of approach is also known in literature as frequency-wavenumber (f-k) analysis; it offers the opportunity to determine the back-azimuth and the slowness of coherent seismic waves with a high resolution. Furthermore, it has the possibility to detect and discriminate simultaneously several microseismic sources. Each trace was examined to eliminate those with spurious transients or glitches, null traces and those contain obvious earthquake energy. After this selection the original dataset was reduced about of the 5%; each time window is 5 minutes long. Figure 3 shows a schematic diagram of the method applied in this study. The analyses are performed at different frequency bands (around 0.4Hz, 0.6Hz, 0.8 Hz, 1.0Hz, 2.0Hz and 4.0Hz).

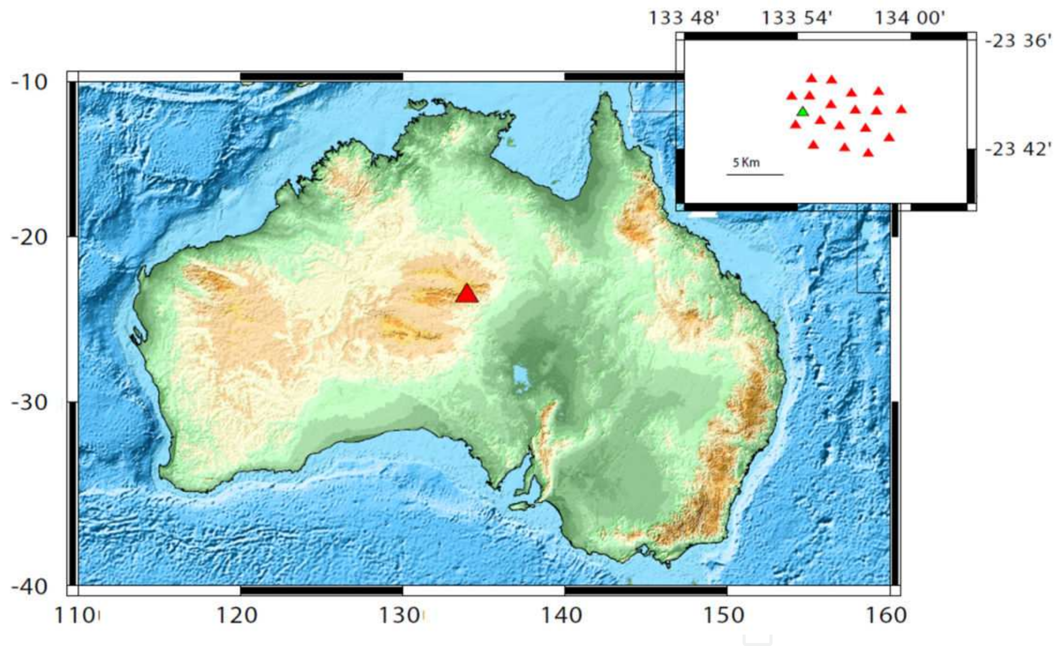

Figure 1. Alice Springs Array (ASAR) location and array geometry. The white triangle in the top panel represents the reference element, while the dark gray triangles are the other 18 elements of the array

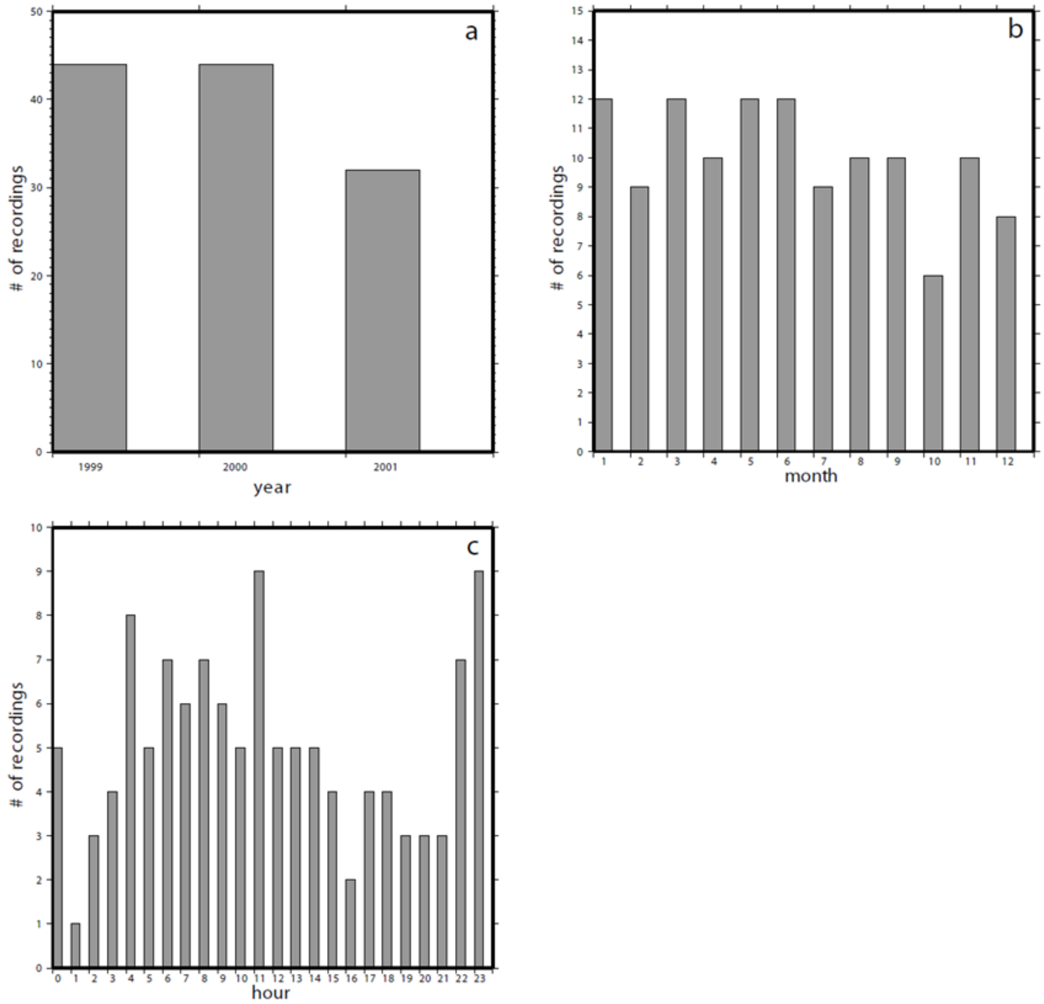

Figure 2. Characteristics of our data set of seismic noise recorded by ASAR. (a) number of recording as function of year, month (b) and hours (UTC) (c)

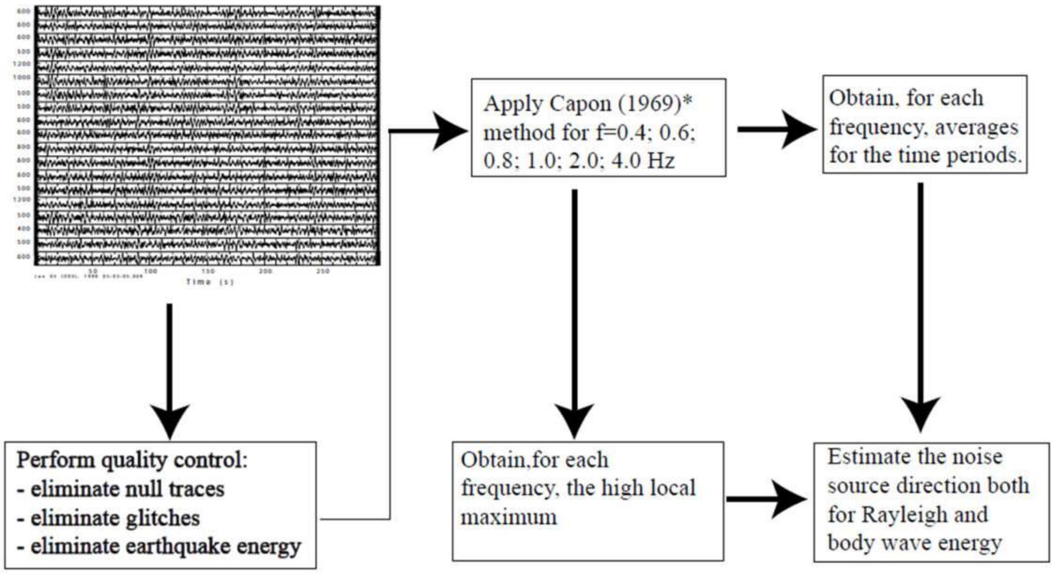

Figure 3. Example of used time windows and schematic representation of the procedure applied in the present study

3. Results and discussion

Figures 4 shows the number of recording as a function of the optimal ray parameter for the frequencies of 0.4, 0.6, 0.8, and 1.0 Hz. Figures 5, 6, 7, 8, 9, 11, and 12 show the time-averaged ambient noise field at ASAR array averaged per each year and the average for the three-year period and the three-year period respectively, binned according to month at the frequency of 0.4Hz, 0.6Hz, 0.8 Hz, 1.0Hz. Figure 13 reports the results obtained for 2.0 and 4.0Hz respectively and showing the average per each year and the average for the three-year period. Figure 14 plots the local maxima (from 0.4 to 1.0 Hz) computed using the Capon (1969) method; red dots represent all the local maxima while blue are the maxima having a relative power greater than 5db. We observed, for the frequencies of 0.4, 0.6, 0.8 and 1.0 Hz, the most prominent pick coming from the S-W direction with an optimal backazimuth around 190-200 degrees and an apparent velocity of about 3-4km/s indicative of higher mode Rayleigh waves. This energy is probably generated as waves from the interaction of oceanic waves with the coast in the Australian Bight. Because of the high attenuation of short period Rayleigh waves, it is really unlikely that the noise is generated further away from the ASAR array. It is also possible to highlight a possible correlation between noise peaks and the distance of the array to the coast line. In fact, according the plot in figure 14 for each different frequency it is possible to notice that the largest number of peak having a relative power greater than 5db is coming from the S-W direction; the second large number of peak is coming from the N-E direction and a very few are coming from the S-E part that is the largest distance from the coast. An other important noise peak shown in figure 14 occurs in the center of the plot, indicating that energy is coming almost with a vertical incidence on the array. There is not any peak for the high-frequencies (f=2.0; 4.0 Hz); that is probably due to the location of the array. Furthermore we can also point our attention on the amplitude as a function of time (fig. 15). It seems there are some seasonal patterns, in fact, the maximum peaks occur in the winter time while the minimum values are during the summer time (please remember that the array is located in the Southern Hemisphere).

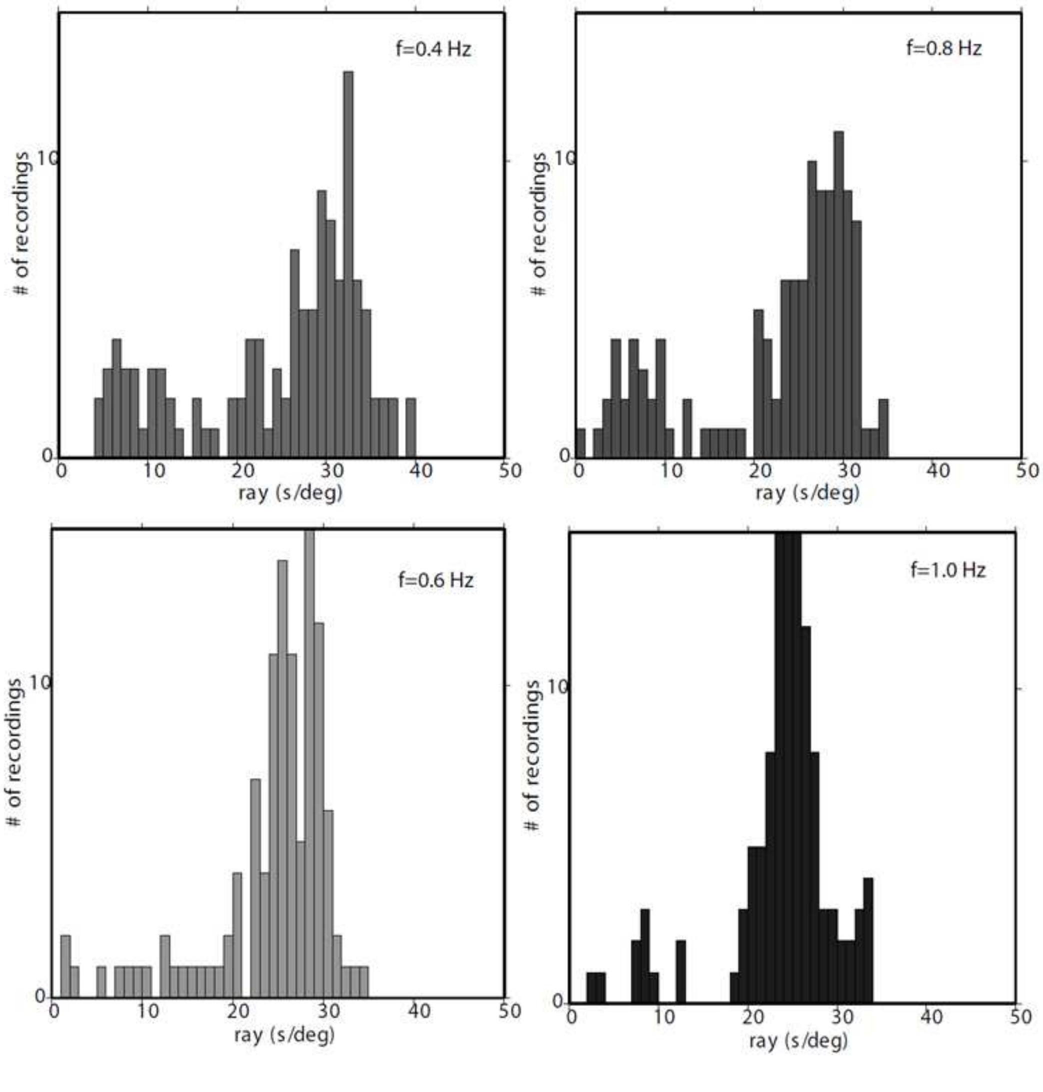

Figure 4. Number of recordings as a function of the optimal ray parameters for different frequency

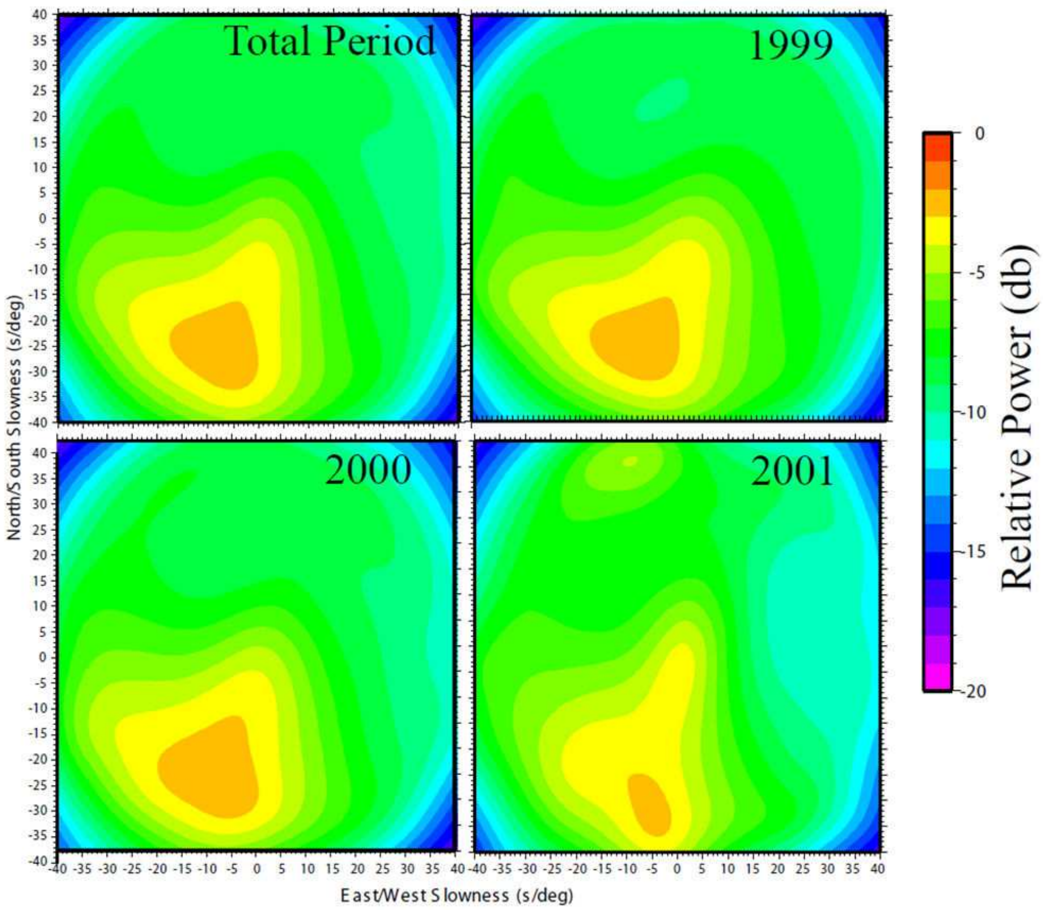

Figure 5. Average of the relative power per year at 0.4 Hz

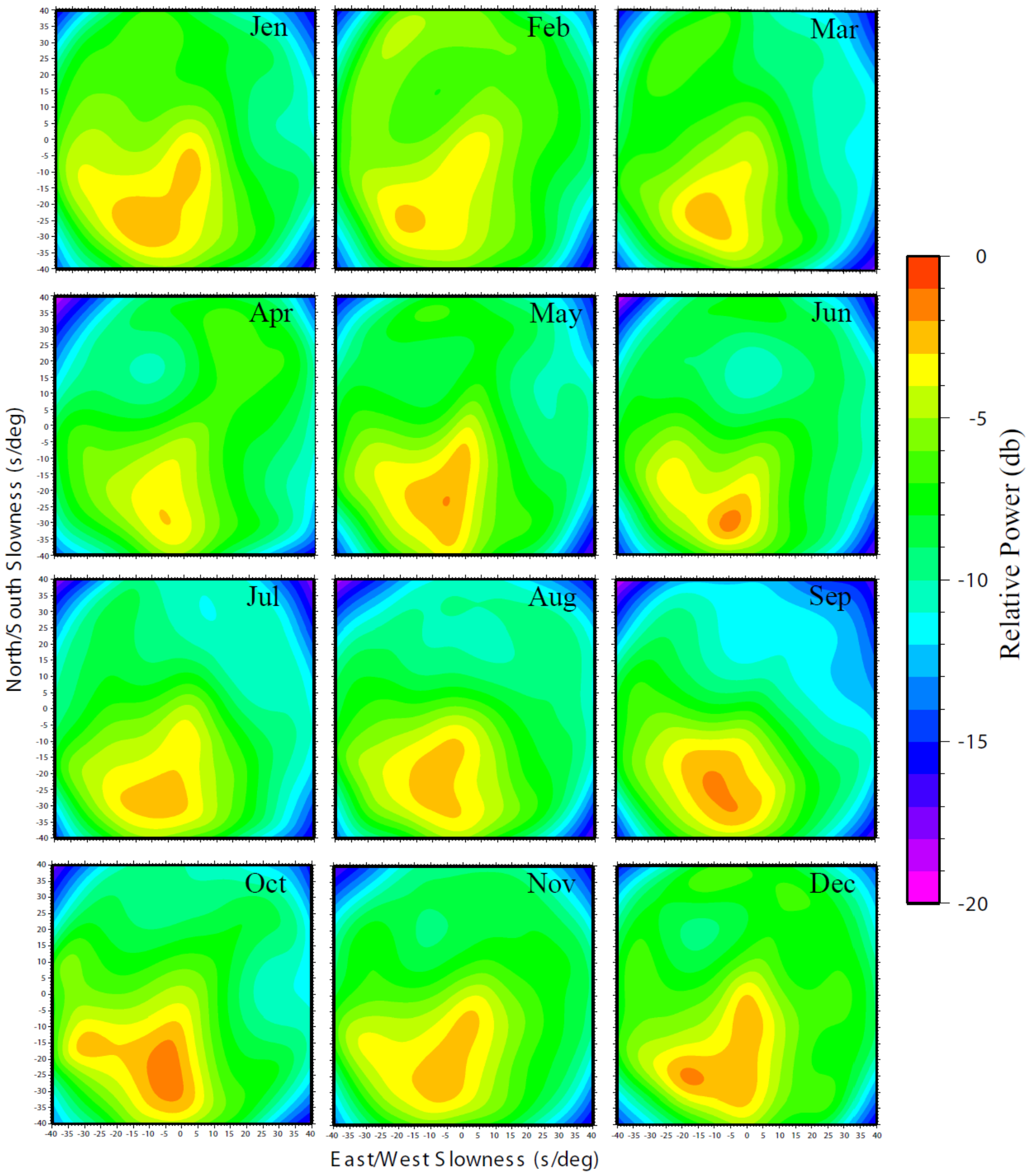

Figure 6. Average of the relative power per month at 0.4 Hz

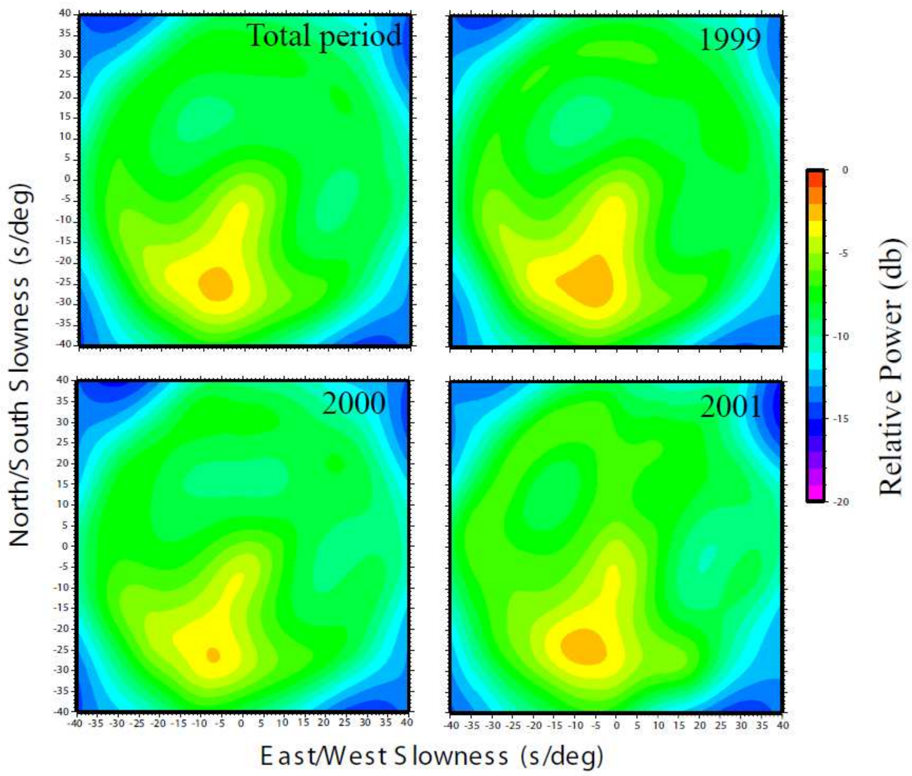

Figure 7. Average of the relative power per year at 0.6 Hz

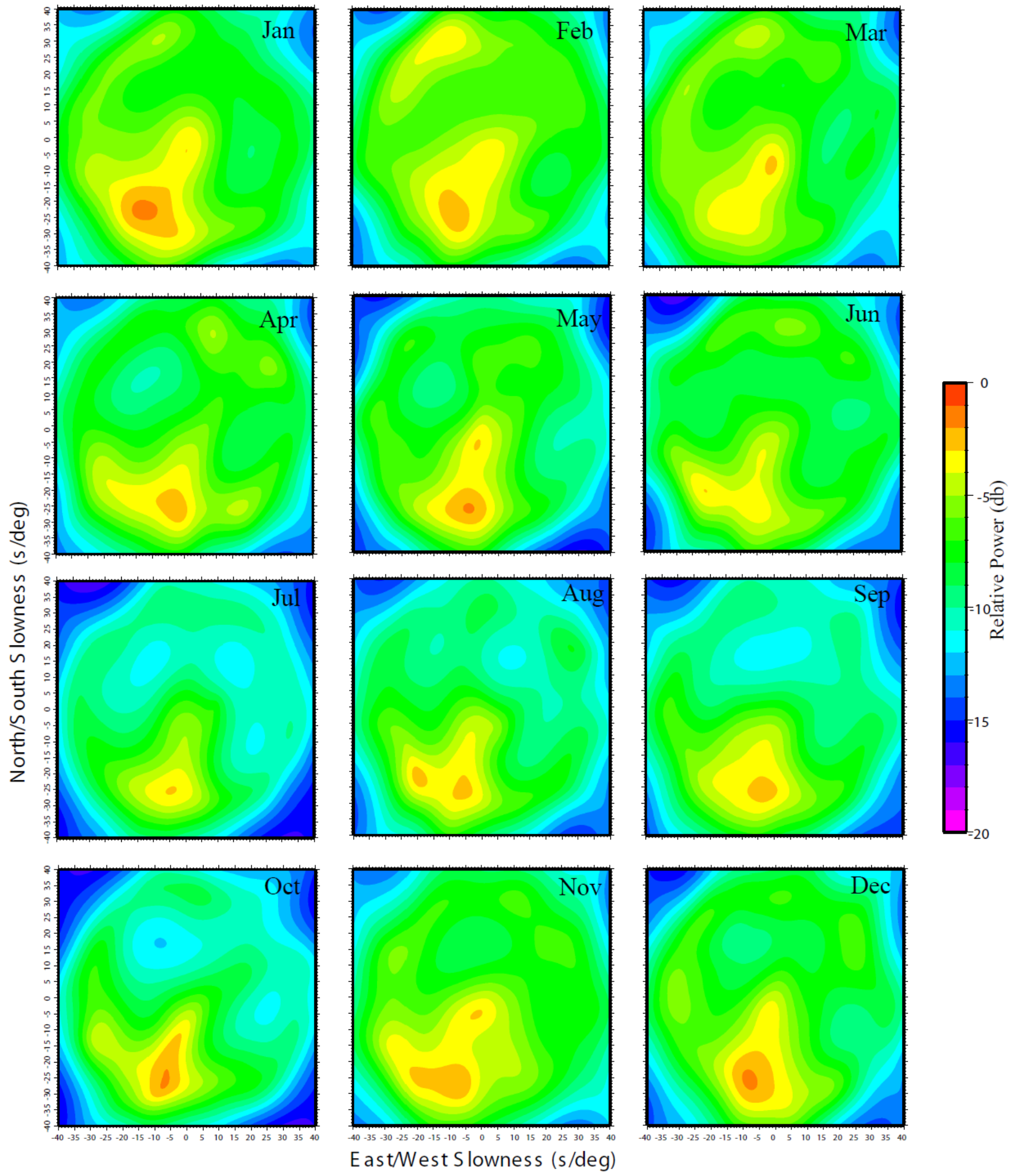

Figure 8. Average of the relative power per month at 0.6 Hz

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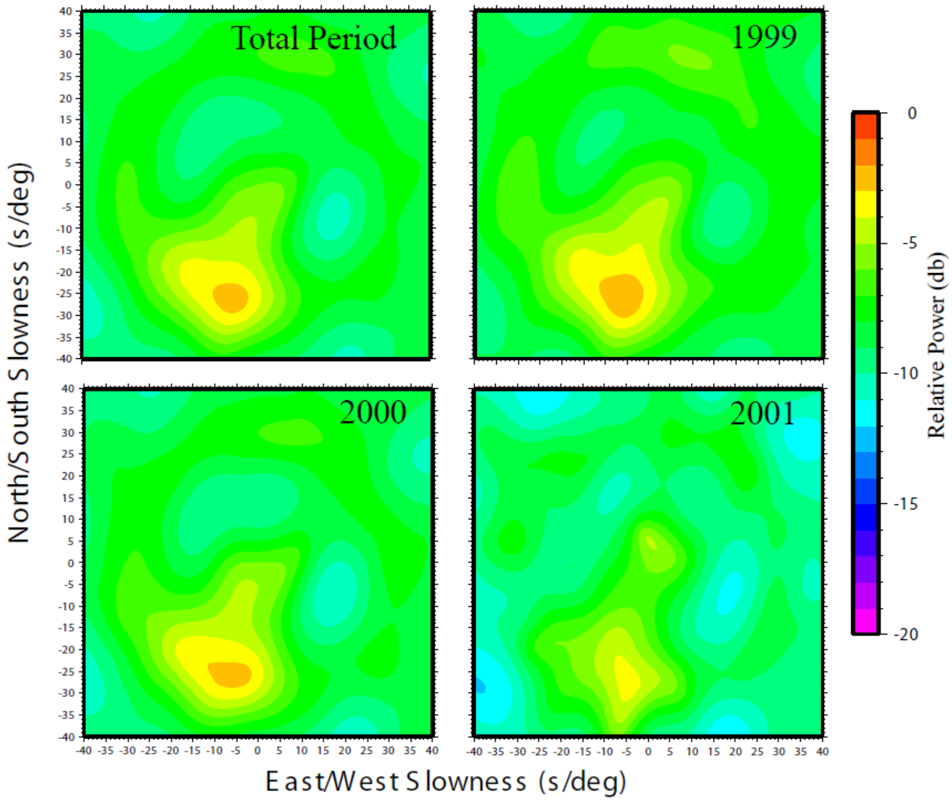

Figure 9. Average of the relative power per year at 0.8 Hz

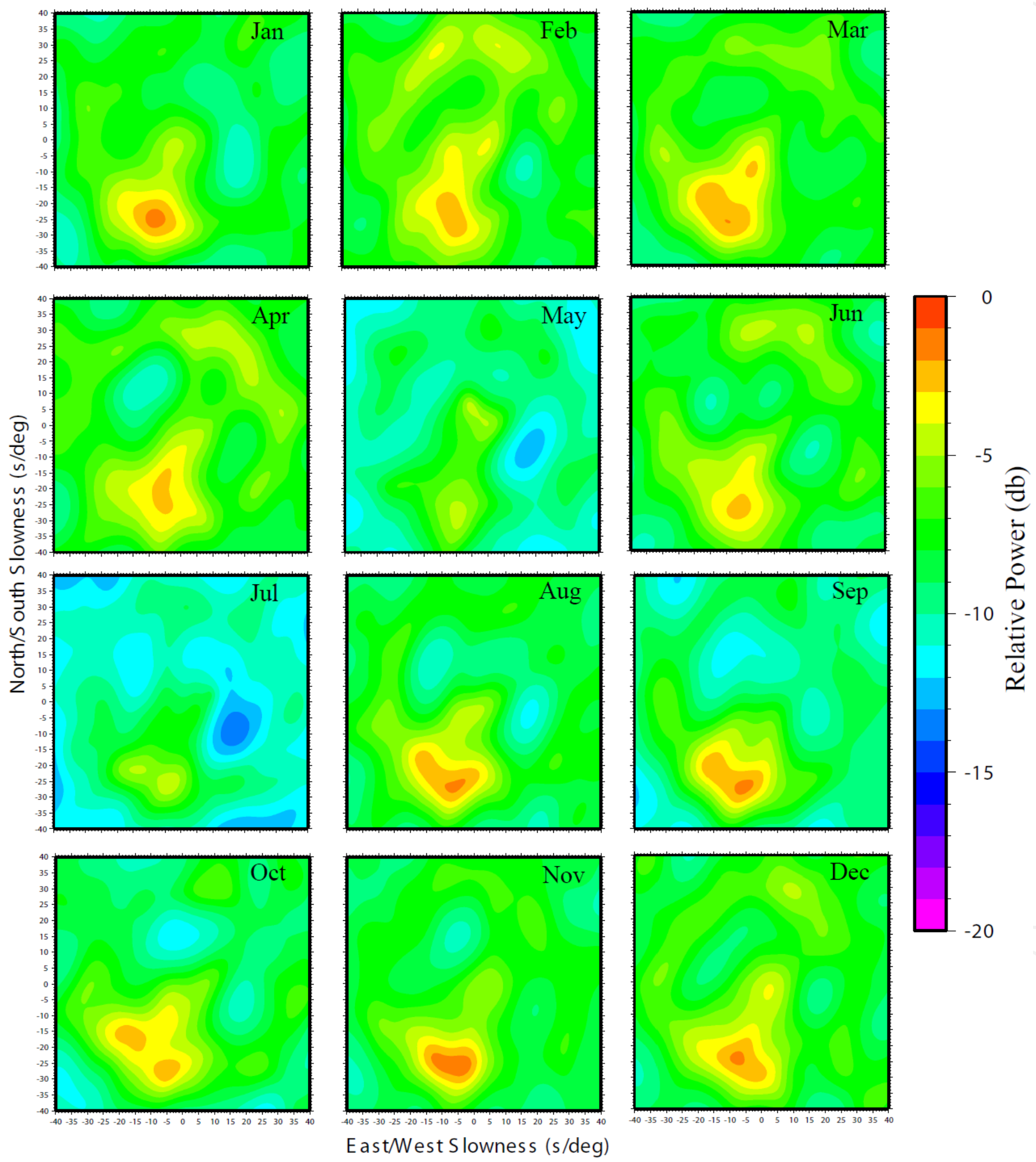

Figure 10. Average of the relative power per month at 0.8 Hz

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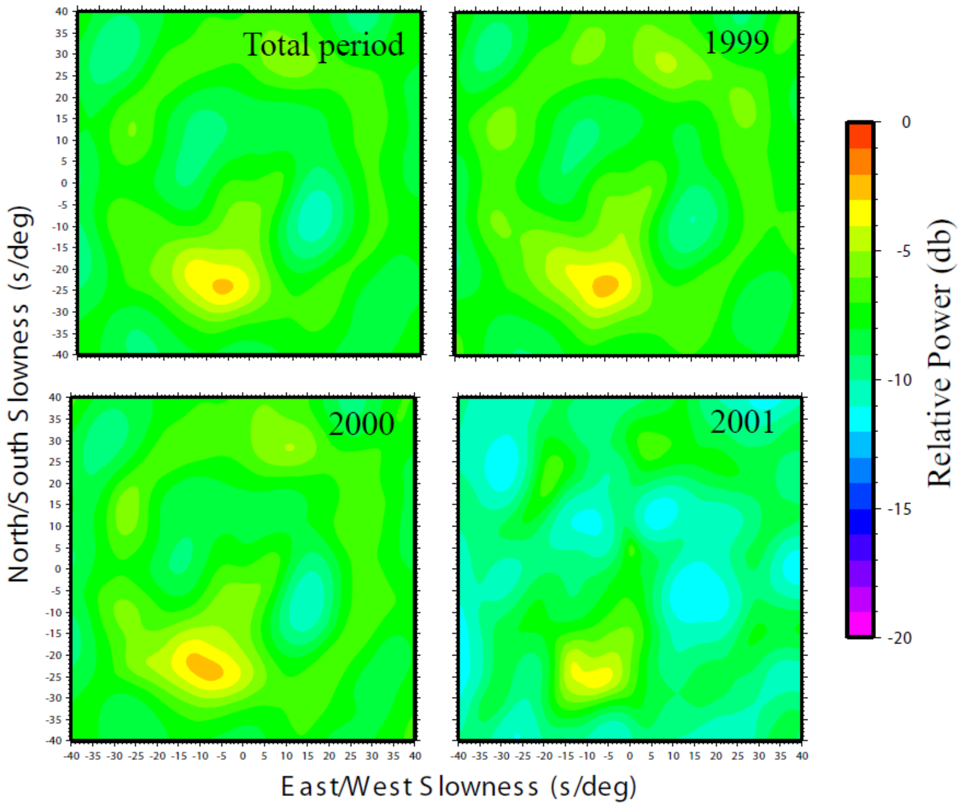

Figure 11. Average of the relative power per year at 1 Hz

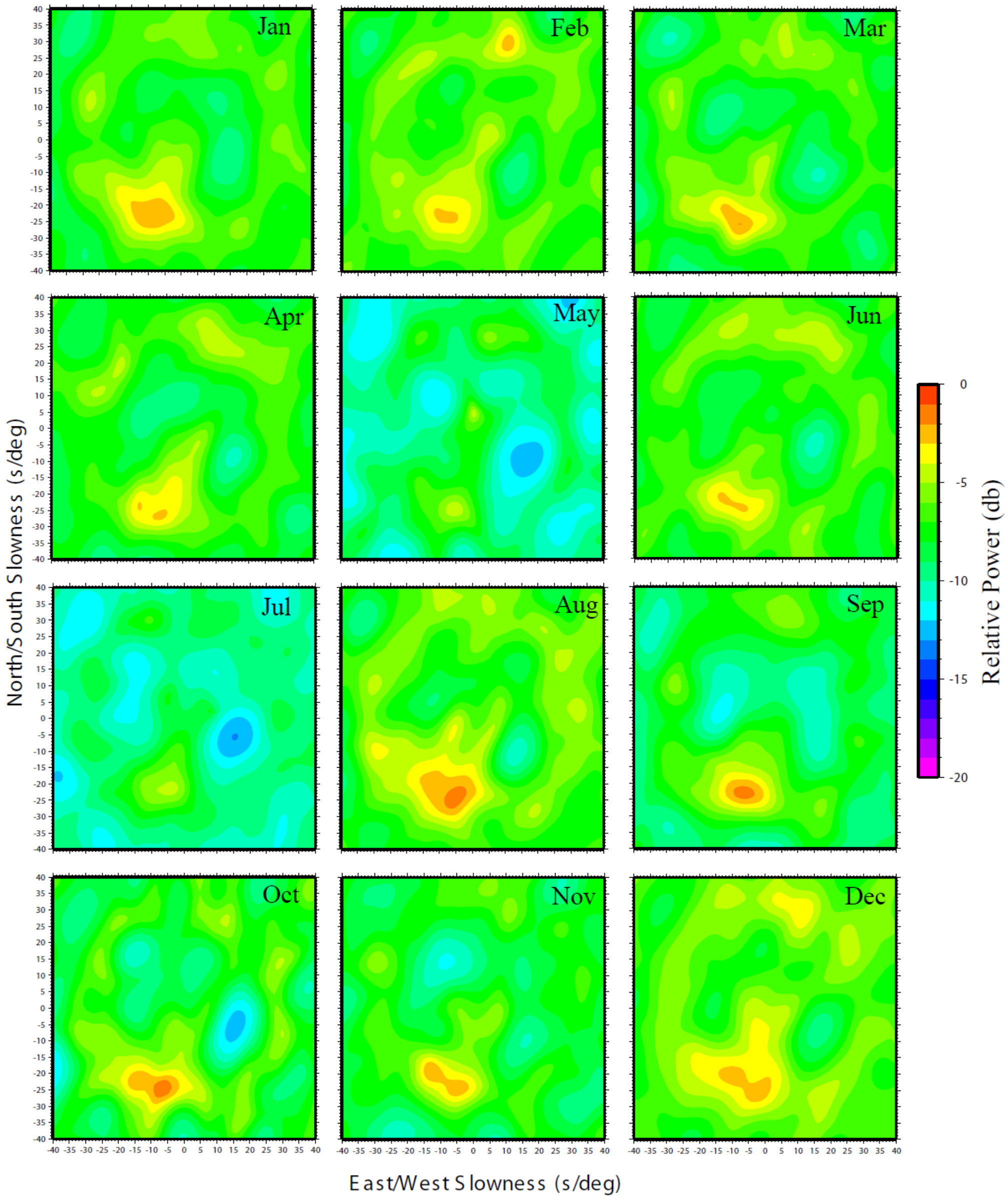

Figure 12. Average of the relative power per month at 1 Hz

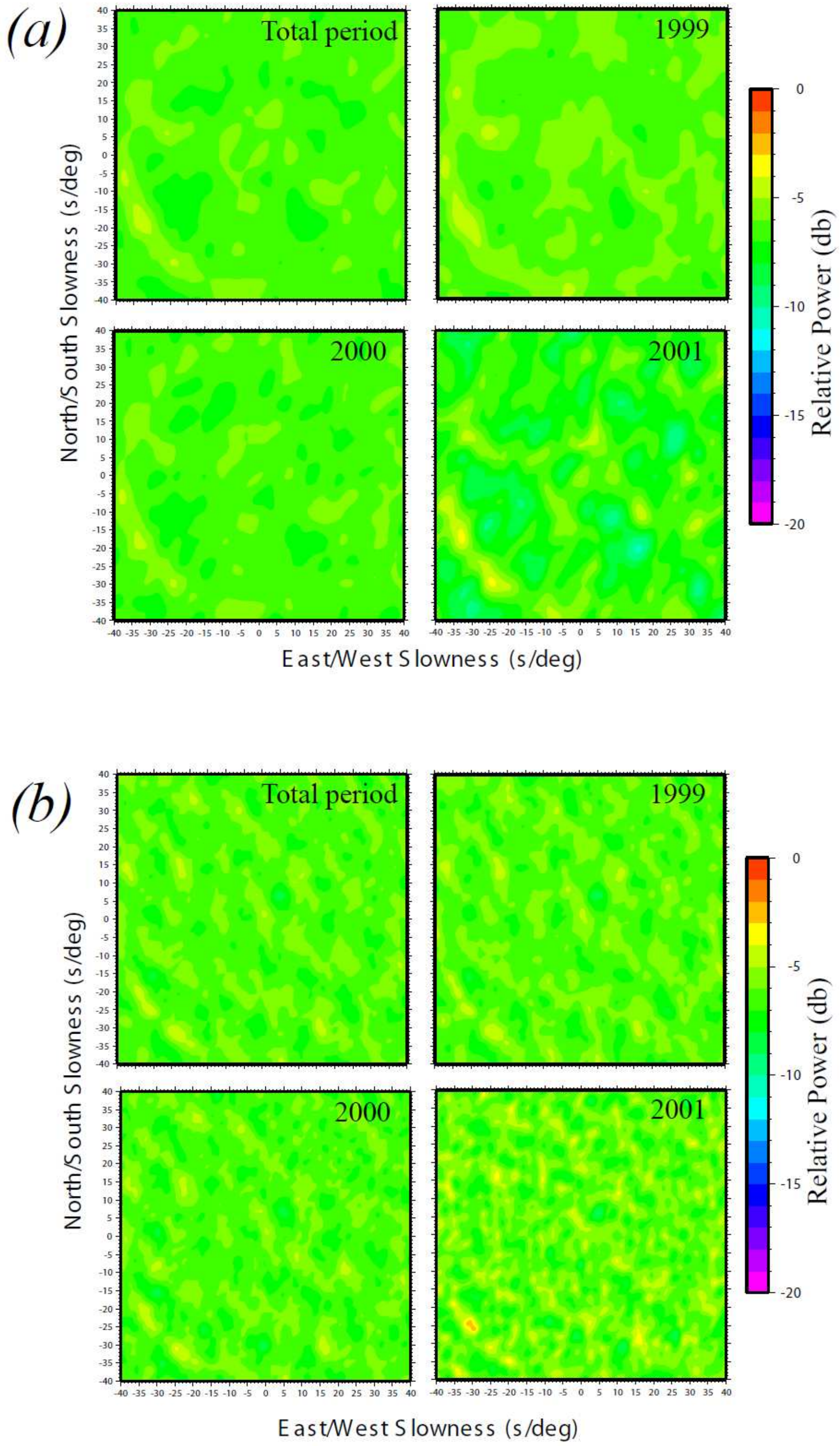

Figure 13. Average of the relative power per year at 2 Hz (a) and 4 Hz (b)

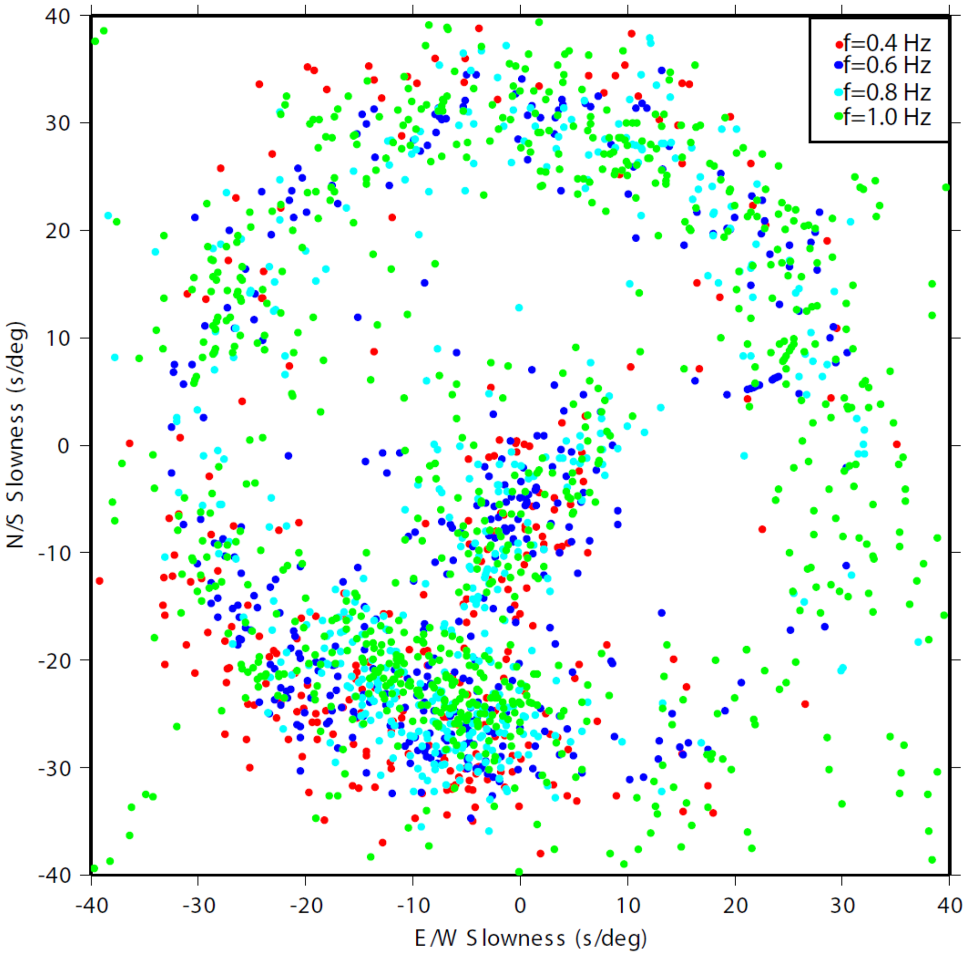

Figure 14. Local maxima computed using the Capon (1969) method having a relative power greater than 5db for different frequencies It is possible to notice a relationship between the maxima in the S-W and N-E direction; they seem be quite spread in the N-W and S-E directions; perhaps due to the distance between the array and the coast lines.

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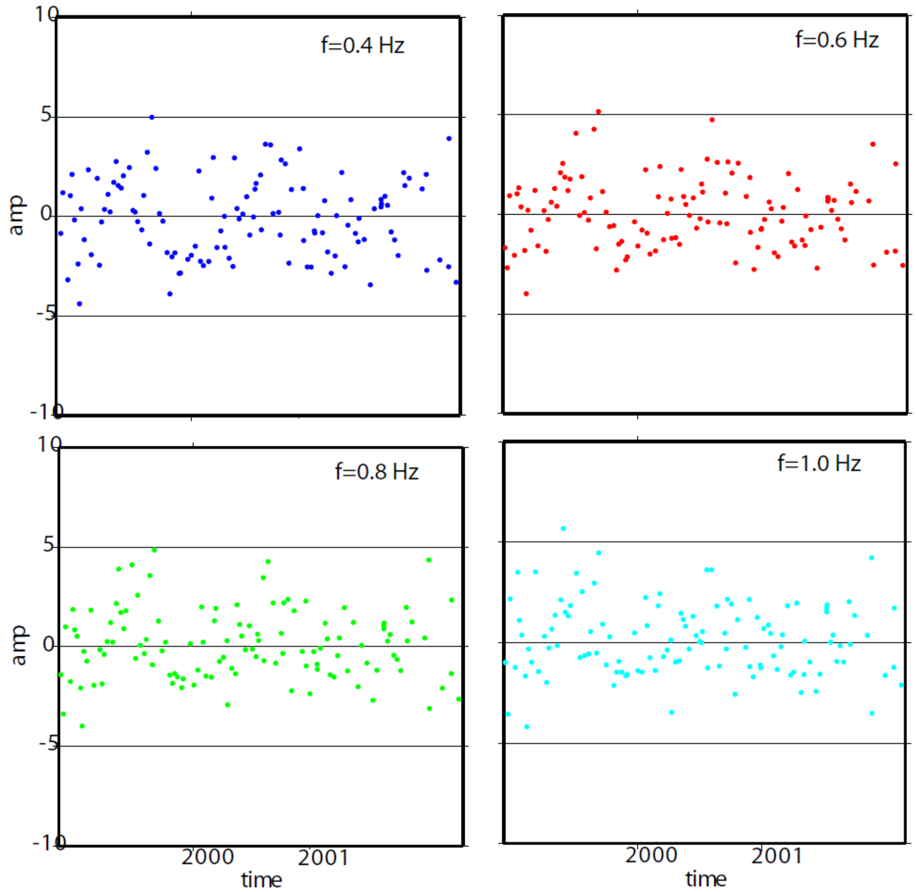

Figure 15. Maximum amplitude versus time

4. Concluding remarks

Seismic array have contributed to develop different studies to investigate the interior of the Earth. In this paper we used some array techniques in order to highlight the characteristic of noise for a relative small aperture array (about 10 km): the ASAR array located in central Australia. We used waveforms from 1999 to 2001 choosing the data in order to cover each year, month day and part of it. We used the Capon (1969) method and we performed the analysis at different frequencies (0.4, 0.6, 0.8, 1.0, 2.0 and 4.0 Hz). For each frequency the optimal ray parameter, the optimal phase velocity and the optimal backazimuth were calculated. Results show that there is a consistent peak for the optimal backazimuth around 190-200 degrees for the frequency ranged from 0.4 to 1.0 Hz; the maximum peak disappears for the 2.0 and 4.0Hz analysis. The predominant peak in the S-W direction could be interpreted as ocean waves interacting with the coast in the Australian Bight. The absence of peaks for the analysis above the 2.0 Hz confirm that there is no evidence of anthropical noise, that is probably due to the location of the array. We found a maximum peak around 3-4Km/s for the phase velocity indicative of higher-mode Rayleigh waves. Some dispersion is evident in the phase velocity peaks, and the large noise peak to the southwest is consistent from season to season, suggesting that there are some seasonal patterns as well. In some of the f-k spectra it is possible to notice a double peak, in which there appears to be a body-wave component to the noise.

The author thanks Dr. Keith Koper (University of Utah, USA) for providing the Generic Array Processing software. Data where obtained using the "autodrm request" of the U.S. Army Space and missile Defense Command monitoring research program (www.rdss.info, last access in 2009). The author is also very thankful to Ms. Silvia Vlase for her support.

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