The impact of seismicity on high angular resolution astronomy: the case of the Canarian Observatories

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The work

Seismicity induces ground vertical and horizontal displacements that could affect the image quality obtained by telescopes in a similar fashion than atmospheric turbulence. In this work, we study the effect of local seismicity relative to atmospheric turbulence upon the image quality of astronomical observations at El Teide observatory and Roque de los Muchachos observatory, both in the Canary Islands, Spain. Three different aspects of seismicity are studied, namely regional volcanism and seismicity (that is compared with other astronomical sites), seismic noise and possible resonances between seismic noise and the structure of telescopes.

Seismicity

- The Canary Islands are located in a low seismic area. Largest recorded earthquake had a magnitude 5.2 (Richter scale)
- Seismicity is mainly concentrated between the islands of Tenerife and Gran Canaria (Figure 1)
- The island of La Palma, hosting the Roque de los Muchachos Observatory, has very low seismic activity.
- **Ground peak horizontal acceleration with a 10% of probability of being exceeded in 50 year corresponds to 0.06g for the eastern part of Tenerife (including the observatory) and 0.05g elsewhere. These values are significantly lower than those expected at Paranal, 0.34g, and Mauna Kea, 0.4g (GSHAP).**

Volcanism

- El Teide observatory has a very low probability of being affected by lava flows, since it is protected by topography from lava flows originated in the Teide-Pico Viejo volcanic complex. Volcanism closer to the Observatory is older than 30.000 years. Only two small eruptions at the beginning of the XVIII century that did not affect the area of the observatory (see Figure 2).
- Ash ejecting eruptions have been unusual in the most recent history of Tenerife (last 10.000 years). Hazard analysis based on the last ash-ejecting eruption (Montaña Blanca, 2000 years ago) showed that El Teide observatory is located in a low probability area of being affected by ashfall (see Figure 2).
- Probabilities that the Roque de los Muchachos observatory could be affected by ashfall and/or lava flows are negligible, since volcanic activity ceased more than 1 Ma ago and present day activity is located in the south of the island of La Palma (see Figure 3).

Seismic Noise

- Seismic noise measurements were carried on three locations at both observatories (see Figures 4 and 5). Noise level is high in a frequency windows around 1 Hz, likely of anthropogenic origin (see Figures 6 and 9).
- The soil's main resonance frequency was found at 0.6 Hz for El Teide Observatory (see Figure 7). This value is significantly different to the lower resonance mode of large telescopes (between 1 and 2 Hz). Hence we do not expect significant contributions of soil amplifications to the vibrations of the telescopes. The presence of resonance peaks at Roque de los Muchachos observatory is less clear and significant differences are found among the three monitored sites (Figure 10). Further measurements must be carried out.
- Vibration analyses were carried out at the 1.5m Carlos Sánchez telescope (El Teide Observatory) and 2.5mNOT, 4.2mWHT and 10.4mGTC telescopes (Roque de los Muchachos) using the spectral response of speckle patterns obtained with the CCD camera FASTCAM (see Figures 8 and 11).
- The combined effect of atmospheric turbulence and telescope vibrations are significantly larger than the seismic noise measured in both observatories.

Regional seismicity and volcanism

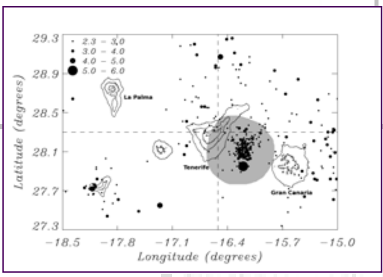

Figure 1. Seismicity in the Western Canaries for the period 1985-2008. Light grey area corresponds to the region where the ground peak horizontal acceleration with a 10% of probability of being exceeded in 50 year is 0.06g; elsewhere the 10% of probability of being exceeded in 50 year is 0.05g. Vertical and horizontal dashed lines cross at the location of El Teide observatory.

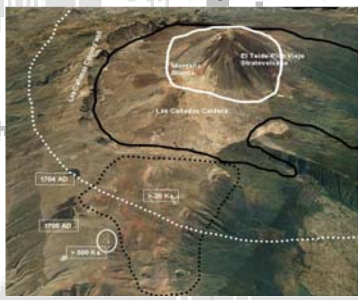

Figure 2. Aerial view of central Tenerife taken from Google-Earth. The El Teide observatory lies within the white ellipse. The area enclosed by the black solid line corresponds to the region that has been affected by lava flows from El Teide-Pico Viejo Edifice. The area enclosed by the black dotted lines was affected by basaltic lava flows from the NE dorsal ridge. White solid and dotted lines encloses the area where there is 50% and 10%, respectively, probability that at least 10 centimetres of volcanic ash could fall after an eruption like the last one that occurred in central Tenerife. White squares show the estimated age of volcanic eruptive activity.

Figure 3. Aerial view of central La Palma taken from Google-Earth. The Roque de los Muchachos observatory lies within the white ellipse. The area enclosed by the black dotted lines was affected by basaltic lava flows from the Cumbre Vieja Volcano. White squares show the estimated age of volcanic eruptive activity.

Local site effects

Figure 4. Aerial view of El Teide Observatory taken from Google-Earth. Black circles labeled as S1, S2 and S3 correspond to the locations where seismic noise measurements were carried out.

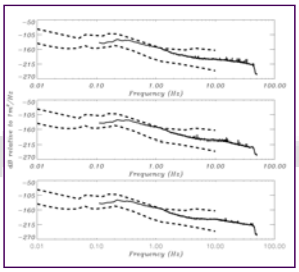

Figure 6. Power spectra of the displacement vertical component of the seismic signal measured at S1 (lower panel), S2 (central panel) and S3 (upper panel) at El Teide Observatory. Dashed lines correspond to the world-wide Peterson´s high and low seismic noise levels.

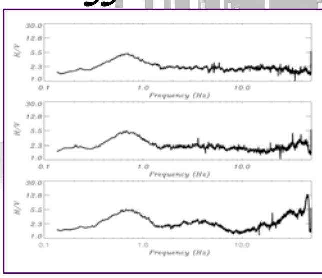

Figure 7. Resonance peak analysis through the Nakamura's H/V ratio of the seismic signal measured at S1 (lower panel), S2 (central panel) and S3 (upper panel) at El Teide Observatory.

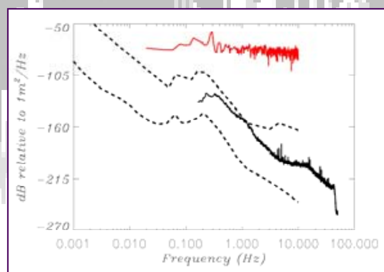

Figure 8. Power spectra of the seismic vertical component displacement measured at S2 at El Teide Observatory (black line). Dashed lines correspond to the Peterson´s high and low seismic noise model. Red solid line corresponds to the power spectra of the variation in time of the most intense peak of the speckle patterns for a target star measured at the 1.5m Carlos Sánchez telescope.

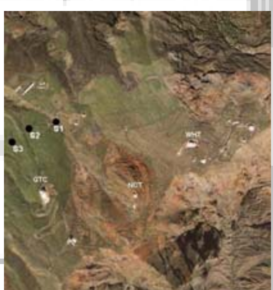

Figure 5. Aerial view of Roque de los Muchachos Observatory taken from Google-Earth. Black circles labeled as S1, S2 and S3 correspond to the locations where seismic noise measurements were carried out.

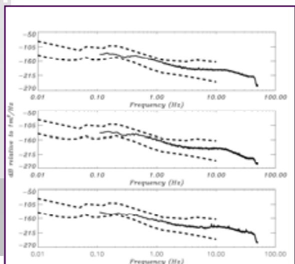

Figure 9. As in Figure 6, but for Roque de los Muchachos Observatory.

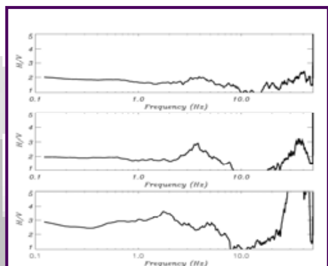

Figure 10. As in Figure 7, but for Roque de los Muchachos Observatory.

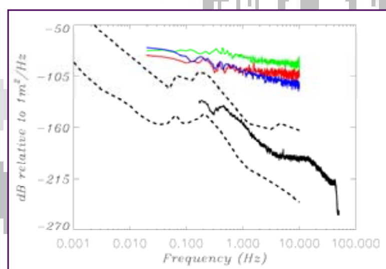

Figure 11. As in Figure 8, but black line corresponds to S2 at Roque de los Muchachos Observatory. Red, blue and green lines correspond to the power spectra of the variation in time of the most intense peak of the speckle patterns for a target star measured at the 4.2mWHT, 10.4mGTC and 2.5mNOT telescopes, respectively.