The response of the spectrum of the earth's surface tremor in the area of shale oil production

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One can expect that changes in the noise characteristics of a dynamic system characterizes the degree of its stability, the approach or removal of the system state from the bifurcation point. One of these characteristics is the slope of the noise spectrum of the system in double logarithmic coordinates [Rodkin et al., 2007; Lyubushin and Yakovlev, 2014; Lyubushin, 2019]. With regard to seismic noise recorded by low-frequency seismic sensors or GPS stations, changes in a few of noise characteristics were considered in [Filatov, Lyubushin, 2019; Lyubushin, 2019]. These changes were interpreted as precursor signs of a strong earthquake.

A certain difficulty in interpreting the results of such calculations is that the acting factor is unknown. Such factor, however, can be considered to be known in the case of shale hydrocarbons production. In these cases, the induced seismicity is also known in sufficient details, this seismicity also characterizes the stability of the system and the danger of a stronger earthquake.

The paper presents the results of the analysis of the GPS noise field of deformations in an area of intensive shale oil production (Oklahoma, USA) together with data on injection regimes. The seismic regime of this area was analyzed in [Vorobieva et al., 2020], where the relationship between seismicity and the injection regime was shown.

We have shown a strong spatial scale-dependent correlation between the intensity of downloads and the correlation coefficient between the spectral slope of the GPS tremor and the volumes of downloads. An interesting and non-obvious result is the fact of negative correlations. Thus, an increase in the volume of downloads leads to a decrease in the slope of the power spectrum of the GPS tremor, which is interpreted as a decrease in the contribution of low frequencies. Note that the use of noise analysis to assess the current seismic hazard has, in comparison with the method based on seismicity monitoring, the advantage that noise analysis allows regularity and continuity of monitoring, which are inaccessible due to the relative rarity of seismic events.

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