New prognostic technology for analysis of low–frequency seismic noise variations (on the example of the Russian Far East)

© 2021 G.N. Kopylova[1], A.A. Lyubushin[2], L.N. Taranova[1]

[1]KD GS RAS, Petropavlovsk Kamchatsky, Russia; [2]IPE RAS, Moscow, Russia

Received December 24, 2020

Abstract A new technology for predicting strong earthquakes with a magnitude range of Mw about 7 and more is considered, based on the use of continuous recordings of seismic noise on a network of 21 broadband stations of the GS RAS in the region of the Kamchatka Peninsula, the Commander Islands and the Paramushir Island. The article is described a forecasting algorithm created by A.A. Lyubushin, IPE RAS, and the state of its implementation in the Kamchatka Division GS RAS for the purpose of an advance (months - first years) assessment of the strong earthquakes preparation sites. The data processing algorithm includes the calculation of four noise statistics time series for each station and the construction of their spatial distribution maps for different time intervals. We used four noise statistics, including the minimal entropy of the orthogonal wavelet coefficients squares and three characteristics of the multifractal spectrum of singularity – the generalized Hurst exponent, the carrier width, and the spectral wavelet exponent. Based on previous research, characteristic features of the four seismic noise statistics behavior at preparation stages of the local earthquakes 2013-2016 with Mw=6.6-8.3 were revealed, corresponding to similar changes before the two earthquakes with Mw=8.3 and 9.0 in Japan. It was found that an increase in the danger of a strong earthquake is accompanied by an increase in minimal entropy and a decrease in the carrier width and other parameters of the singularity spectrum. Since 2020, the processing of current data from the network of broadband stations of the GS RAS in the Far East region has been carried out in accordance with the seismic forecasting algorithm for drawing up quarterly forecast conclusions, which are sent to the Russian Expert Council on Earthquake Forecasting, Seismic Hazard and Risk Assessment (REC) and to Kamchatka Branch of REC.

Keywords seismic noise, seismic forecasting algorithm, earthquake forecast, Kamchatka Peninsula.

For citation Kopylova, G.N., Lyubushin, A.A., & Taranova, L.N. (2021). [New prognostic technology for analysis of low-frequency seismic noise variations (on the example of the Russian Far East)]. *Rossiiskii seismologicheskii zhurnal* [Russian Journal of Seismology], *3*(1), 75-91. (In Russ.). DOI: https://doi.org/10.35540/2686-7907.2021.1.05

References

Akopian, S.T., Bondur, V.G., & Rogozhin, E.A. (2017). Technology for monitoring and forecasting strong earthquakes in Russia with the use of the seismic entropy method. I*zvestiya Physics of the Solid Earth*, *53*, 32-51. doi:10.1134/S1069351317010025

Argus, D.F., & Gordon, R.G. (1991). No-net-rotation model of current plate velocities incorporating plate motion model NUVEL-1. *Geophysical Research Letters*, *18*, 2039-2042. doi:10.1029/91 GL01532

Chebrov, D.V., Kugaenko, Iu.A., Abubakirov, I.R., Lander, A.V., Pavlov, V.M., Saltykov, V.A., & Titkov, N.N. (2017). [Near Islands Aleutian Earthquake of July 17, 2017 with Mw=7.8 at the border of the Commander seismic gap]. V*estnik KRAUNTS. Seriya: Nauki o Zemle* [Bulletin KRAUNZ. Series: Earth Sciences], 3(35), 22-25. (In Russ.). Retrieved from *http://www.kscnet.ru/journal/kraesc/article/viewFile/140/pdf*

Chebrov, D.V., Kugaenko, Iu.A., Lander, A.V., Abubakirov, I.R., Voropaev, P.V., Gusev, A.A., Droznin, D.V., Droznina, S.Ia., Ivanova, E.I., Kravchenko, N.M., Matveenko, E.A., Mitiushkina, S.V., Ototiuk, D.A., Pavlov, V.M., Raevskaia, A.A., Saltykov, V.A., Seniukov, S.L., Skorkina, A.A., & Serafimova, Iu.K. (2017). [South Ozernovsk earthquake of March 29, 2017 with Mw=6.6, K_S=15.0, I=6 (Kamchatka)]. *Vestnik KRAUNTS. Seriya: Nauki o Zemle* [Bulletin KRAUNZ. Series: Earth Sciences], *3*(35), 7-21. (In Russ.). Retrieved from *http://www.kscnet.ru/journal/kraesc/article/viewFile/139/pd*f

Chebrov, D.V., Kugaenko, Y.A., Lander, A.V. et al. (2019). Near Islands Aleutian Earthquake with Mw=7.8 on July 17, 2017: I. Extended rupture along the

Commander block of the Aleutian Island Arc from observations in Kamchatka. *Izvestiya Physics of the Solid Eart*h, *55*, 576-599. doi:10.1134/S1069351319040037

Chebrov, V.N. (2015). [100 years of instrumental seismological observations in Kamchatka]. In *Problemy kompleksnogo geofizicheskogo monitoringa Dal'nego Vostoka Rossii. Problemy kompleksnogo geofizicheskogo monitoringa Dal'nego Vostoka Rossii. Trudy Piatoi nauchno-tekhnicheskoi konferentsii. Otv. red. V.N. Chebrov* [Problems of complex geophysical monitoring of the Russian Far East. Proceedings of the Fifth Scientific and Technical Conference. Ed. V.N. Chebrov] (pp. 6-13). Obninsk, Russia: GS RAS Publ. (In Russ.). Retrieved from *http://emsd.ru/static/library/2015_conf/book.pdf*

Chebrov, V.N., Kugaenko, Iu.A., Vikulina, S.V., Krvchenko, N.M., Matveenko, E.A., Mitiushkina, S.V., Raevskaia, A.A., Saltykov, V.A., Chebrov, D.V., & Lander, A.V. (2013). [The deep sea of Okhotsk earthquake of May 24, 2013 with a magnitude of Mw=8.3 is the strongest seismic event off the coast of Kamchatka during the period of detailed seismological observations]. *Vestnik KRAUNTS. Seriya: Nauki o Zeml*e [Bulletin KRAUNZ. Series: Earth Sciences], *1*(21), 17-24. (In Russ.). Retrieved from *http://www.kscnet.ru/journal/kraesc/article/viewFile/343/pdf*

Chebrova, A.Yu., Chemarev, A.S., Matveenko, E.A., & Chebrov, D.V. (2020). Seismological data information system in Kamchatka branch of GS RAS: organization principles, main elements and key functions. *Geophysical Researc*h, *21*(3), 66-91. doi:10.21455/gr2020.3-5

DeMets, C.R., Gordon, R.G, Argus, D.F., & Stein, S. (1990). Current plate motions. *Geophysical Journal International*, *101*, 425-478.

Gordeev, E.I., Pinegina, T.K., Lander, A.V. et al. (2015). Beringia: Seismic hazard and fundamental problems of geotectonics. *Izvestiya Physics of the Solid Eart*h, *51*, 512-521. doi:10.1134/S1069351315030039

Ivanov, V.Yu., & Kasimova, V.A. (2009). [Creation of the layout of gis - project "Petropavlovsk geodynamical polygon" for an information supply with system for complex geophysical observations]. *Vestnik KRAUNTS. Seriya*: *Nauki o Zem*le [Bulletin KRAUNZ. Series: Earth Sciences], *1*(13), 208-213. (In Russ.). Retrieved from *http://www.kscnet.ru/journal/kraesc/article/viewFile/534/pdf*

Kasimova, V.A., Kopylova, G.N., & Lyubushin, A.A. (2018). Variations in the parameters of background seismic noise during the preparation stages of strong earthquakes in the Kamchatka region. I*zvestiya Physics of the Solid Earth*, *54*, 269-283. doi:10.1134/S1069351318020076

Kopylova, G.N., Ivanov, V.Yu., & Kasimova, V.A. (2009). The implementation of information system elements for interpreting integrated geophysical observations in Kamchatka. *Russian Journal Earth Sciences*, *11*, ES1006. doi:10.2205/2009ES000329

Kozhurin, A.I. (2007). Active faulting in the Kamchatsky peninsula, Kamchatka-Aleutian junction. In *Eichelberger J.*, *Gordeev E.*, *Kasahara M. et al.* (*eds*) *Volcanism and Subduction: The Kamchatka Region. Geophysical Monograph Series*, *V. 172*, (pp. 263-282). American Geophysical Union Publ.

Lander, A.V., Bukchin, B.G., Droznin, D.V., & Kiriushin, A.V. (1994). [Tektonicheskaia pozitsiia i ochagovye parametry Khailinskogo (Koriakskogo) zemletriaseniia 8 marta 1991 g.: sushchestvuet li plita Beringiia?]. *Vychislitel'naia seismologiia* [Computational Seismology], *26*, 103-122. (In Russ.).

Lyubushin, A.A. (2008). Microseismic noise in the low frequency range (Periods of 1—300 min): Properties and possible prognostic features. *Izvestiya Physics of the Solid Earth*, *44*, 275-290. doi:10.1134/s11486-008-4002-6

Lyubushin, A.A. (2009). Synchronization trends and rhythms of multifractal parameters of the field of low-frequency microseisms. *Izvestiya Physics of the Solid Earth*, *45*, 381-394. doi:10.1134/S1069351309050024

Lyubushin, A. (2010a). Multifractal parameters of low-frequency microseisms. In: *de Rubeis V., Czechowski Z., Teisseyre R.* (*eds.*) *Synchronization and Triggering: from Fracture to Earthquake Processes. Geoplanet: Earth and Planetary Sciences* (pp. 253-272). Berlin, Heidelberg: Springer Publ. doi:10.1007/978-3-642-12300-9_15

Lyubushin, A.A. (2010b). The statistics of the time segments of low-frequency microseisms: Trends and synchronization. *Izvestiya Physics of the Solid Earth*, *46*, 544-554. doi:10.1134/S1069351310060091

Lyubushin, A.A. (2011a). Cluster analysis of low-frequency microseismic noise. *Izvestiya Physics of the Solid Earth*, *47*, 488-495.

Lyubushin, A.A. (2011b). Seismic catastrophe in Japan on March 11, 2011: long-term prediction on the basis of low-frequency microseisms. *Izvestiya*, *Atmospheric and Oceanic Physics*, *46*(8), 904-921. doi:10.1134/S0001433811080056

Lyubushin, A.A. (2012a). Prediction of the Great Japanese Earthquake. *Nature*, *8*, 23-33.

Lyubushin, A. (2012b). Prognostic properties of low-frequency seismic noise. *Natural Science*, *4*, 659-666. doi:10.4236/ns.2012.428087

Lyubushin, A. (2013a). How soon would the next mega-earthquake occur in Japan? *Natural Science*, *5*, 1-7. doi:10.4236/ns.2013.58A1001

Lyubushin, A.A. (2013b). Mapping the properties of low-frequency microseisms for seismic hazard assessment. *Izvestiya Physics of the Solid Earth*, *49*, 9-18. doi:10.1134/S1069351313010084

Lyubushin, A.A. (2013c). Maps of linear synchronization for the properties of global low-frequency seismic noise. Geophysical Research, *1*, 11-20.

Lyubushin, A.A. (2014a). Analysis of coherence in global seismic noise for 1997–2012. *Izvestiya Physics of the Solid Earth*, *50*, 325-333. doi:10.1134/S1069351314030069

Lyubushin, A.A. (2014b). Dynamic estimate of seismic danger based on multifractal properties of low-frequency seismic noise. *Natural Hazards*, *70*, 471-483. doi:10.1007/s11069-013-0823-7

Lyubushin, A.A. (2015). Wavelet-based coherence measures of global seismic noise properties. *Journal of Seismology*, *19*, 329-340. doi:10.1007/s10950-014-9468-6

Lyubushin, A.A. (2016). Coherence between the fields of low-frequency seismic noise in Japan and California. *Izvestiya Physics of the Solid Earth*, *52*, 810-820. doi:10.1134/S1069351316050086

Lyubushin, A.A. (2017). Long-range coherence between seismic noise properties in Japan and California before and after Tohoku mega-earthquake. *Acta Geodaetica et Geophysica*, *52*, 467-478. doi:10.1007/s40328-016-0181-5

Lyubushin, A.A. (2018a). Cyclic properties of seismic noise and the problem of predictability of the strongest earthquakes in the Japanese islands. *Izvestiya, Atmospheric and Oceanic Physics*, *54*, 1460-1469. doi:10.1134/S0001433818100067

Lyubushin, A. (2018b). Synchronization of geophysical field fluctuations. In *Chelidze T.*, *Telesca L.*, *Vallianatos F.* (*eds*) *Complexity of Seismic Time Series: Measurement and Applications*, *Chapter 6*, (pp. 161-197). Amsterdam, Oxford, Cambridge: Elsevier Publ. doi:10.1016/B978-0-12-813138-1.00006-7

Lyubushin, A. (2019). Field of coherence of GPS-measured earth tremors. *GPS Solutions*, *23*, 120. doi:10.1007/s10291-019-0909-0

Lyubushin, A. (2020a). Trends of Global seismic noise properties in connection to irregularity of Earth's rotation. *Pure and Applied Geophysics*, 177, 621-636. doi:10.1007/s00024-019-02331-z

Lyubushin, A. (2020b). Connection of seismic noise properties in Japan and California with irregularity of Earth's rotation. *Pure and Applied Geophysics*, *177*, 4677-4689. doi:10.1007/s00024-020-02526-9

Lyubushin, A.A. (2020c). Seismic noise wavelet-based entropy in Southern California. *Journal of Seismology*. doi:10.1007/s10950-020-09950-3

Lyubushin, A. (2020d). Global seismic noise entropy. *Frontiers in Earth Science*, *8*, 611-663. doi:10.3389/feart.2020.611663

Lyubushin, A.A., Kopylova, G.N., Kasimova, V.A., & Taranova, L.N. (2015). [The properties of fields of low frequency noise from the network of broadband seismic stations in Kamchatka]. *Vestnik KRAUNTS. Seriya: Nauki o Zemle* [Bulletin KRAUNZ. Series: Earth Sciences], *2*(26), 20-36. (In Russ.). Retrieved from *http://www.kscnet.ru/kraesc/2015/2015_26/art3.pdf*

Mogi, K. (1985). *Earthquake prediction*. Tokyo, Japan: Academic press, 355 p.

Fedotov, S.A. (2005). *Dolgosrochnyy seysmicheskiy prognoz dlya Kurilo-Kamchatskoy dugi* [Long-term seismic forecast for Kurilo-Kamchatka arcs]. Moscow, Russia: Nauka Publ., 303 p. (In Russ.).

Firstov, P.P., Kopylova, G.N., Solomatin, A.V., & Serafimova, Yu.K. (2016). [Strong earthquake forecast near the Kamchatka peninsula]. *Vestnik KRAUNTS. Seriya: Nauki o Zemle* [Bulletin KRAUNZ. Series: Earth Sciences]. *4*(32), 106–114. (In Russ.). Retrieved from *http://www.kscnet.ru/journal/kraesc/article/viewFile/106/pdf*

Zonenshain, L.P., & Savostin, L.A. (1979). *Vvedenie v geodinamiku* [Introduction to Geodynamics]. Moscow, Russia: Nedra Publ., 311 p. (In Russ.).

Information about authors

Kopylova Galina Nikolaevna, Dr., Associate Professor, Chief Researcher of the Kamchatka Division of the Geophysical Survey of the Russian Academy of Sciences (KD GS RAS), Petropavlovsk-Kamchatsky, Russia. E-mail: gala@emsd.ru

Lyubushin Aleksey Aleksandrovich, Dr., Professor, Chief Researcher of the Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences (IPE RAS), Moscow, Russia. E-mail: lyubushin@yandex.ru

Taranova Larisa Nikolaevna, Research Engineer of the KD GS RAS, Petropavlovsk-Kamchatsky, Russia. E-mail: lara7@emsd.ru