

DAFTAR PUSTAKA

- Anselin, L. and Rey, S.J., 2014. Modern spatial econometrics in practice: A guide to GeoDa, GeoDaSpace and PySAL. GeoDa Press.
- Badan Geologi Energi dan Sumber Daya Mineral, 2024. Laporan khusus kejadian gempa bumi merusak di Indonesia hingga September 2025 [Online]. Kementerian Energi dan Sumber Daya Mineral, Republik Indonesia. Available at: <https://geologi.esdm.go.id/media-center/laporan-khusus-kejadian-gempa-bumi-merusak-di-indonesia-hingga-september-2025> [Accessed: 3 December 2025].
- Bijlloos, G. and Meyers, J., 2021. A fast-converging kernel density estimator for dispersion in horizontally homogeneous meteorological conditions. *Atmosphere* 12, 1343. doi: 10.3390/atmos12101343.
- BMKG, 2023. Apakah gempabumi itu? [Online]. BMKG. Available at: <https://bbmkg3.bmkg.go.id/tentang-gempa>. [Accessed: 27 November 2025].
- BMKG, 2024. Katalog kejadian gempa bumi Indonesia [Online]. Badan Meteorologi, Klimatologi, dan Geofisika. Available at: <https://repogempa.bmkg.go.id/eventcatalog> [Accessed: 4 December 2024].
- Bolat, K., Tindemans, S.H. and Palensky, P., 2024. Stable training of probabilistic models using the leave-one-out maximum log-likelihood objective. arXiv preprint arXiv:2310.03556.
- Bolt, B.A. and Britannica Editors, 2025. Earthquake: Earthquake magnitude [Online]. Encyclopedia Britannica. Available at: <https://www.britannica.com/science/earthquake-geology/Earthquake-magnitude> [Accessed: 28 November 2025].
- Chen, M., Zhang, J., Ma, X. and Qian, L., 2025. Density change consistency clustering from density extreme. *Pattern Recognition*. 158, 110932. doi: 10.1016/j.patcog.2024.110932.
- Chen, S., 2015. Optimal *Bandwidth* selection for kernel density functionals estimation. *J. Probab. Stat.* 2015, 242683. doi: 10.1155/2015/242683.
- Dare, O.P. and Okiemute, E.S., 2020. Impact of different centroid means on the accuracy of orthometric height modelling by geometric geoid method. *Int. J. Sci. Rep.* 6(4), 124–130. doi: 10.18203/issn.2454-2156.IntJSciRep20201267.
- Darnah, Hayati, M.N., Wahyuningsih, S., Kamaruddin, I., Suyitno and Dani, A.T.R. et al., 2025. Locally kernel weighted maximum likelihood estimator for local linear multi-predictor Poisson regression. *MethodsX* 14, 103258. doi: 10.1016/j.mex.2025.103258.
- Davies, T.M. and Baddeley, A., 2017. Fast computation of spatially adaptive kernel estimates. *Stat. Comput.* pp. 1–20. doi: 10.1007/s11222-017-9772-4.
- Dong, L. and Luo, Q., 2022. Investigations and new insights on earthquake mechanics from fault slip experiments. *Earth-Sci. Rev.* 228, 104019. doi: 10.1016/j.earscirev.2022.104019.
- Dvořák, J. and Mrkvička, T., 2024. Nonparametric testing of the covariate significance for spatial point patterns under the presence of nuisance covariates. *J.*

- Comput. Graph. Stat.* 33(4), 1434–1445. doi: 10.1080/10618600.2024.2357626.
- Evers, J., 2025. Plate tectonics and the Ring of Fire [Online]. National Geographic Society. Available at: <https://education.nationalgeographic.org/resource/plate-tectonics-ring-fire/> [Accessed: 31 December 2025].
- Fadli, A., Priyambodo, T.K., Putra, A.E. and Suryanto, W., 2025. Kernel density estimation for seismic hazard mapping in Indonesia: Influence of kernel function, *Bandwidth* size, and *grid* resolution. *Trends in Sciences* 22(8), 10064. doi: 10.48048/tis.2025.10064.
- Fan, L., Liang, S., Chen, H., Hu, Y., Zhang, X. and Liu, Z. et al., 2018. Spatio-temporal analysis of the geographical centroids for three major crops in China from 1949 to 2014. *J. Geogr. Sci.* 28, 1672–1684. doi: 10.1007/s11442-018-1539-0.
- Givens, G.H. and Hoeting, J.A., 2013. Computational Statistics. 2nd ed. Wiley, Hoboken, NJ.
- Govorov, M., Beconyťe, G. and Gienko, G., 2025. Exploration-based statistical learning for selecting kernel density estimates of spatial point patterns. *Trans. GIS* 29, e70051, 1–29. doi: 10.1111/tgis.70051.
- Govorov, M., Beconyťe, G. and Gienko, G., 2025. Exploration-based statistical learning for selecting kernel density estimates of spatial point patterns. *Trans. GIS* 29, e70051, 1–29. doi: 10.1111/tgis.70051.
- Gutenberg, B. and Richter, C.F., 1944. Frequency of earthquakes in California. *Bull. Seismol. Soc. Am.* 34(4), 185–188. doi: 10.1785/BSSA0340040185.
- Heidenreich, N.-B., Schindler, A. and Sperlich, S., 2013. *Bandwidth* selection for kernel density estimation: A review of fully automatic selectors. *AStA Adv. Stat. Anal.* 97, 403–433. doi: 10.1007/s10182-013-0216-y.
- Helmstetter, A. and Sornette, D., 2003. Foreshocks explained by cascades of triggered seismicity. *J. Geophys. Res.* 108(B10), 2457. doi: 10.1029/2003JB002409.
- Hlávka, Z., Hlubinka, D. and Hudecová, Š., 2023. Multivariate quantile-based permutation tests with application to functional data. Unpublished manuscript, Department of Statistics, Charles University, Prague, 21 pp.
- Jafari, A., Fox, G., Rundle, J.B., Donnellan, A. and Ludwig, L.G. et al., 2024. Time series foundation models and deep learning architectures for earthquake temporal and spatial nowcasting. *GeoHazards* 5, 1247–1274. doi: 10.3390/geohazards5040059.
- Klaichim, S., Sinsomboonthong, J. and Supapokorn, T., 2024. The shifted Chebyshev series-based plug-in for *Bandwidth* selection in kernel density estimation. *Commun. Stat. Appl. Methods* 31(3), 337–347. doi: 10.29220/CSAM.2024.31.3.337.
- Lee, J., and Wong, D. W. S. (2001). Statistical Analysis with Arcview GIS. John Wiley & Sons, Inc.

- Li, D., 2017. Kernel estimations for multivariate density functional with bootstrap. *Commun. Stat. Theory Methods* 46(9), 4631–4641. doi: 10.1080/03610926.2015.1012392.
- Li, K., Gao, X., Fu, S., Diao, X., Ye, P., Xue, B., Yu, J., & Huang, Z. (2022). Robust outlier detection based on the changing rate of directed density ratio. *Expert Systems With Applications*, 207, 117988. <https://doi.org/10.1016/j.eswa.2022.117988>
- Liu, F., Yu, Y., Song, P., Fan, Y. and Tong, X., 2020. Scalable KDE-based top-n local outlier detection over large-scale data streams. *Knowl.-Based Syst.* 204, 106186. doi: 10.1016/j.knosys.2020.106186.
- Liu, Q., Liu, W., Tang, J., Deng, M. and Liu, Y., 2019. Permutation-test-based clustering method for detection of dynamic patterns in spatio-temporal datasets. *Comput. Environ. Urban Syst.* 75, 204–216.
- Mailanda, R., Kusnandar, D., and Miftahul Huda, ainul. 2022. Analisis Autokorelasi Spasial Kasus Positif Covid-19 Menggunakan Indeks Moran dan LISA. *Buletin Ilmiah Math. Stat. Dan Terapannya (Bimaster)*, 11(3), 483–492.
- Mammen, E., Martínez-Miranda, M.D., Nielsen, J.P. and Sperlich, S., 2011. Do-validation for kernel density estimation. *J. Am. Stat. Assoc.* 106(494), 651–660. doi: 10.1198/jasa.2011.tm08687.
- McCaffrey, R., 2009. The tectonic framework of the Sumatran subduction zone. *Annu. Rev. Earth Planet. Sci.* 37, 345–366. doi: 10.1146/annurev.earth.031208.100212.
- Mufarida, B., 2024. BMKG: 7.358 Gempa Bumi Guncang Indonesia Sepanjang 2024 [Online]. iNews.id, Jakarta Pusat. Available at: <https://www.inews.id/news/nasional/bmkg-7358-gempa-bumi-guncang-indonesia-sepanjang-2024> [Accessed: 13 November 2025].
- Muttayy, F., Nugraha, A.D., Puspito, N.T., Sahara, D.P., Zulfakri, Z. and Rohadi, S. et al., 2023. Double-difference earthquake relocation using waveform cross-correlation in Central and East Java, Indonesia. *Geosci. Lett.* 10, 5. doi: 10.1186/s40562-022-00259-2.
- Nanda, C.A., Nugraha, A.L. and Firdaus, H.S., 2019. Analisis tingkat daerah rawan kriminalitas menggunakan metode *kernel density* di wilayah hukum Polrestaes Kota Semarang. *J. Geodesi*.
- NCEI, 2024. Informasi Gempa Bumi Bahaya NCEI [Online]. Available at: <https://www.ngdc.noaa.gov/hazel/view/hazards/earthquake/event-more-info/10737> [Accessed: 13 November 2025].
- Nurtas, M., Zhantaev, Z., Altaibek, A., Nurakynov, S., Mekebayev, N., Shiyapov, K. et al., 2024. Predicting the Likelihood of an Earthquake by Leveraging Volumetric Statistical Data Through Machine Learning Techniques. *Engineered Science* [Online]. Available from: https://www.espublisher.com/uploads/article_html/10.30919-es1031.htm [Accessed: 14 November 2025].

- Oh, Y., Lyu, P., Ko, S., Min, J. and Song, J., 2024. Enhancing broiler weight estimation through Gaussian kernel density estimation modeling. *Agriculture* 14, 809. doi: 10.3390/agriculture14060809.
- Okohene, P.A. and Ozbek, M.E., 2025. Integrating environmental conditions into machine learning models for predicting bridge deterioration. *Appl. Sci.* 15, 12042. doi: 10.3390/app152210242.
- Park, P.J., Manjourides, J., Bonetti, M. and Pagano, M., 2009. A permutation test for determining significance of clusters with applications to spatial and gene expression data. *Computational Statistics and Data Analysis* 53, 4290–4300.
- Qin, T. and Huang, W.-M., 2024. On kernel-based variational autoencoder. *arXiv preprint arXiv:2405.12783*. Available at: <https://arxiv.org/abs/2405.12783> [Accessed on 18 November 2025].
- Qin, X., Cao, L., Rundensteiner, E.A. and Madden, S., 2019. Scalable kernel density estimation-based local outlier detection over large data streams. In: *Proceedings of the 22nd International Conference on Extending Database Technology (EDBT)*; 26–29 March 2019, Lisbon, Portugal. OpenProceedings, pp. 421–432. doi: 10.5441/002/edbt.2019.37.
- Rakhi, Gupta, B. and Lamba, S.S., 2024. An efficient local outlier detection approach using kernel density estimation. *Franklin Open* 8, 100162. doi: 10.1016/j.fraope.2024.100162.
- Ruangguru, 2021. Perhatikan gambar letak lempeng tektonik di Indonesia berikut berdasarkan gambar di atas [Online]. Ruangguru. Available at: https://roboguru.ruangguru.com/question/perhatikan-gambar-letak-lempeng-tektonik-di-indonesia-berikut-berdasarkan-gambar-di-atas_QU-2VA07R86 [Accessed: 31 December 2025].
- Sakdiyah, K. and Choiruddin, A., 2020. Model Inhomogeneous Log-Gaussian Cox Process (LGCP) untuk pemetaan risiko gempa bumi di Sumatra. *Jurnal Sains Seni ITS* 9(2).
- Schlosser, S., 2024. Scale and resolution [Online]. In: *Making Effective Maps: Cartographic Visualization for GIS*. Pressbooks, University of Colorado. Available at: <https://colorado.pressbooks.pub/makingmaps/chapter/chapter-7-scale-and-resolution/>. [Accessed 18 November 2025].
- Siloko, I.U., Nwankwo, W. and Siloko, E.A., 2020. A new family of kernels from the beta polynomial kernels with applications in density estimation. *Int. J. Adv. Intell. Inform.* 6(3), 235–245. doi: 10.26555/ijain.v6i3.456.
- Silverman, B.W., 1986. *Density Estimation for Statistics and Data Analysis*. Chapman and Hall, London.
- Simanungkalit, M.A., Hidayat, A., Nugroho, R.A. and Depari, A.S., 2024. Analisis *hotspot* (Getis Ord Gi*) pola spasial frekuensi kecelakaan lalu lintas di Kota Balikpapan. *Compact: Spatial Development Journal* 3(1), 1-10.
- Skinner, C.J. and Coulthard, T.J., 2023. Testing the sensitivity of the CAESAR-Lisflood landscape evolution model to *grid* cell size. *Earth Surf. Dynam.* 11, 695–711. doi: 10.5194/esurf-11-695-2023.

- Tenreiro, C., 2020. *Bandwidth* selection for kernel density estimation: A Hermite series-based direct plug-in approach. *J. Stat. Comput. Simul.* 90(18), 3433–3453. doi: 10.1080/00949655.2020.1804571.
- UNDRR, 2018. UNISDR calls for greater attention to disaster risk in the Pacific's Ring of Fire [Online]. United Nations Office for Disaster Risk Reduction. Available at: <https://www.undrr.org/news/unisdr-calls-greater-attention-disaster-risk-pacifics-ring-fire> [Accessed: 31 December 2025].
- Uzuazor, S.I. and Amaju, O.S., 2023. A comparative study of higher order kernel estimation and kernel density derivative estimation of the Gaussian kernel estimator with data application. *Pak. J. Stat. Oper. Res.* 19(2), 299–311. doi: 10.18187/pjsor.v19i2.4233.
- Wagner, H.H. and Dray, S., 2015. Generating spatially constrained null models for irregularly spaced data using Moran spectral randomization methods. *Methods Ecol. Evol.* 6(10), 1169–1178. doi: 10.1111/2041-210X.12407.
- Wardana, W., Munibah, K., and Baliwati, Y. F. 2023. Pola Sebaran Spasial Stunting di Kabupaten Lampung Selatan dengan Pendekatan Autokorelasi Spasial. *Journal of Regional and Rural Development Planning*, 7(1), 68–78.
- Wasser, L.A., 2021. The relationship between raster resolution, spatial extent & number of pixels [Online]. NEON Science, National Ecological Observatory Network. Available at: <https://www.neonscience.org/resources/learning-hub/tutorials/raster-res-extent-pixels-r>. [Accessed 18 November 2025].
- Węglarczyk, S., 2018. Kernel density estimation and its application. In: *Proceedings of the XLVIII Seminar of Applied Mathematics*. ITM Web of Conferences 23, 00037. doi: 10.1051/itmconf/20182300037.
- Yoon, S., Park, F.C., Yun, G., Kim, I. and Noh, Y., 2023. Variational weighting for kernel density ratios. In: *Proceedings of the 37th Conference on Neural Information Processing Systems (NeurIPS 2023)*.
- Zhang, G., 2022. Detecting and visualizing observation hot-spots in massive volunteer-contributed geographic data across spatial scales using GPU-accelerated kernel density estimation. *ISPRS Int. J. Geo-Inf.* 11, 55, 1–15. doi: 10.3390/ijgi11010055.
- Zhou, B., Ma, X., Luo, Y. and Yang, D., 2019. Wind power prediction based on LSTM networks and nonparametric kernel density estimation. *IEEE Access* 7, 165279–165292.

LAMPIRAN

Lampiran 1. Data Penelitian

No.	Waktu	Bujur (x)	Lintang (y)	Magnitudo
1	2021-01-01 00:22:54	117.80922	-8.21	3.48
2	2021-01-01 00:33:29	118.48936	-9.01	4.27
3	2021-01-01 00:33:29	118.48936	-9.01	4.28
4	2021-01-01 02:33:53	120.53139	-1.85	3.97
5	2021-01-01 02:33:53	120.53139	-1.85	3.92
6	2021-01-01 03:19:52	114.0378	-6.04	5.58
7	2021-01-01 03:21:15	120.74245	-9.9	3.05
8	2021-01-01 03:25:07	120.6063	-9.72	2.49
9	2021-01-01 03:27:03	96.51611	4.32	2.75
10	2021-01-01 03:31:03	101.02269	-5.39	4.83
11	2021-01-01 03:44:06	131.80984	-3.1	3.59
12	2021-01-01 04:05:15	124.45344	-0.22	4.68
13	2021-01-01 05:03:10	119.05688	-9.14	3.29
14	2021-01-01 05:51:06	119.83083	-9.69	2.87
15	2021-01-01 05:52:29	130.52267	-2.76	3.27
16	2021-01-01 08:44:49	120.66437	-9.78	2.99
17	2021-01-01 08:55:55	111.07145	-4.31	5.32
18	2021-01-01 08:57:43	119.03639	-8.9	2.77
19	2021-01-01 11:13:23	128.66589	-7.58	4.21
20	2021-01-01 11:32:18	127.28616	2.25	3.77
21	2021-01-01 20:35:22	119.44214	-9.25	2.55
22	2021-01-01 23:24:25	126.61842	0.3	3.06
23	2021-01-02 00:02:02	126.11481	-4.48	4.32
24	2021-01-02 00:02:02	126.11481	-4.48	4.11
25	2021-01-02 00:23:07	128.26082	1.9	2.84
26	2021-01-02 00:23:34	103.51709	-6.02	3
27	2021-01-02 00:24:09	116.23518	-8.45	1.97
28	2021-01-02 00:32:14	128.29002	-3.53	2.25
29	2021-01-02 01:07:12	114.85698	-8.39	2.32
30	2021-01-02 03:43:06	121.75929	-0.35	3.15
31	2021-01-02 04:24:54	134.25865	-2.21	3.53
32.	2021-01-02 05:18:58	121.92201	0.53	3.96
33	2021-01-02 06:33:23	138.31104	-4.31	4.78
34	2021-01-02 07:48:28	139.19608	-3.16	3.46
35	2021-01-02 08:03:52	125.16638	-7.18	4.07
⋮	⋮	⋮	⋮	⋮
39.324	2024-12-31 23:58:59	97.31882	1,66	2.95