

REFERENCES

- Alexopoulos, E., 2010: Introduction to multivariate regression analysis.
- Apostolopoulos, I. D., G. Fouskas, and S. N. Pandis, 2023: Field Calibration of a Low-Cost Air Quality Monitoring Device in an Urban Background Site Using Machine Learning Models. *Atmosphere*, **14**, 368, <https://doi.org/10.3390/atmos14020368>.
- Baron, R., and J. Saffell, 2017: Amperometric Gas Sensors as a Low Cost Emerging Technology Platform for Air Quality Monitoring Applications: A Review. *ACS Sens.*, **2**, 1553–1566, <https://doi.org/10.1021/acssensors.7b00620>.
- Baruah, A., O. Zivan, A. Bigi, and G. Ghermandi, 2023: Evaluation of low-cost gas sensors to quantify intra-urban variability of atmospheric pollutants. *Environ. Sci. Atmospheres*, **3**, 830–841, <https://doi.org/10.1039/D2EA00165A>.
- Bigi, A., M. Mueller, S. K. Grange, G. Ghermandi, and C. Hueglin, 2018: Performance of NO, NO₂; low cost sensors and three calibration approaches within a real world application. *Atmospheric Meas. Tech.*, **11**, 3717–3735, <https://doi.org/10.5194/amt-11-3717-2018>.
- Bisignano, A., F. Carotenuto, A. Zaldei, and L. Giovannini, 2022: Field calibration of a low-cost sensors network to assess traffic-related air pollution along the Brenner highway. *Atmos. Environ.*, **275**, 119008, <https://doi.org/10.1016/j.atmosenv.2022.119008>.
- Bousiotis, D., G. Allison, D. C. S. Beddows, R. M. Harrison, and F. D. Pope, 2023: Towards comprehensive air quality management using low-cost sensors for pollution source apportionment. *Npj Clim. Atmospheric Sci.*, **6**, 122, <https://doi.org/10.1038/s41612-023-00424-0>.
- Breiman, L., 2001: Random Forests. *Mach. Learn.*, **45**, 5–32, <https://doi.org/10.1023/A:1010933404324>.
- Brotzge, J. A., and Coauthors, 2020: A Technical Overview of the New York State Mesonet Standard Network. *J. Atmospheric Ocean. Technol.*, **37**, 1827–1845, <https://doi.org/10.1175/JTECH-D-19-0220.1>.
- Castell, N., F. R. Dauge, P. Schneider, M. Vogt, U. Lerner, B. Fishbain, D. Broday, and A. Bartonova, 2017: Can commercial low-cost sensor platforms contribute to air quality monitoring and exposure estimates? *Environ. Int.*, **99**, 293–302, <https://doi.org/10.1016/j.envint.2016.12.007>.
- Cavaliere, A., and Coauthors, 2018: Development of Low-Cost Air Quality Stations for Next Generation Monitoring Networks: Calibration and Validation of PM_{2.5} and PM₁₀ Sensors. *Sensors*, **18**, 2843, <https://doi.org/10.3390/s18092843>.
- Chen, Y., D. Q. Rich, M. Masiol, and P. K. Hopke, 2023: Changes in ambient air pollutants in New York State from 2005 to 2019: Effects of policy implementations and economic and technological changes. *Atmos. Environ.*, **311**, 119996, <https://doi.org/10.1016/j.atmosenv.2023.119996>.
- Civerolo, K. L., O. V. Rattigan, H. D. Felton, and J. J. Schwab, 2017: Changes in Gas-Phase Air Pollutants across New York State, USA. *Aerosol Air Qual. Res.*, **17**, 147–166, <https://doi.org/10.4209/aaqr.2016.04.0141>.
- Clements, A., R. Duvall, D. Greene, and T. Dye, 2022: Enhanced Air Sensor Guidebook (2022).
- Clements, A. L., W. G. Griswold, A. Rs, J. E. Johnston, M. M. Herting, J. Thorson, A.

- Collier-Oxandale, and M. Hannigan, 2017: Low-Cost Air Quality Monitoring Tools: From Research to Practice (A Workshop Summary). *Sensors*, **17**, 2478, <https://doi.org/10.3390/s17112478>.
- Concas, F., J. Mineraud, E. Lagerspetz, S. Varjonen, X. Liu, K. Puolamäki, P. Nurmi, and S. Tarkoma, 2021: Low-Cost Outdoor Air Quality Monitoring and Sensor Calibration: A Survey and Critical Analysis. *ACM Trans. Sens. Netw.*, **17**, 1–44, <https://doi.org/10.1145/3446005>.
- Cross, E. S., L. R. Williams, D. K. Lewis, G. R. Magoon, T. B. Onasch, M. L. Kaminsky, D. R. Worsnop, and J. T. Jayne, 2017: Use of electrochemical sensors for measurement of air pollution: correcting interference response and validating measurements. *Atmospheric Meas. Tech.*, **10**, 3575–3588, <https://doi.org/10.5194/amt-10-3575-2017>.
- Dallo, F., and Coauthors, 2021: Calibration and assessment of electrochemical low-cost sensors in remote alpine harsh environments. *Atmospheric Meas. Tech.*, **14**, 6005–6021, <https://doi.org/10.5194/amt-14-6005-2021>.
- D’Elia, G., M. Ferro, P. Sommella, S. De Vito, S. Ferlito, P. D’Auria, and G. D. Francia, 2022: Influence of Concept Drift on Metrological Performance of Low-Cost NO₂ Sensors. *IEEE Trans. Instrum. Meas.*, **71**, 1–11, <https://doi.org/10.1109/TIM.2022.3188028>.
- deSouza, P., and Coauthors, 2022: *Calibrating Networks of Low-Cost Air Quality Sensors*. Aerosols/In Situ Measurement/Data Processing and Information Retrieval.
- EPA, 2025: *8-Hour Ozone (2015) Nonattainment Area Area/State/County Report*. United States Environmental Protection Agency, <https://www.epa.gov/green-book/green-book-8-hour-ozone-2015-area-information>.
- Ferrer-Cid, P., J. M. Barcelo-Ordinas, and J. Garcia-Vidal, 2022: Raw data collected from NO₂, O₃ and NO air pollution electrochemical low-cost sensors. *Data Brief*, **45**, 108586, <https://doi.org/10.1016/j.dib.2022.108586>.
- Giordano, M. R., C. Malings, S. N. Pandis, A. A. Presto, V. F. McNeill, D. M. Westervelt, M. Beekmann, and R. Subramanian, 2021: From low-cost sensors to high-quality data: A summary of challenges and best practices for effectively calibrating low-cost particulate matter mass sensors. *J. Aerosol Sci.*, **158**, 105833, <https://doi.org/10.1016/j.jaerosci.2021.105833>.
- Gonzalez, A., A. Boies, J. Swason, and D. Kittelson, 2019: *Field Calibration of Low-Cost Air Pollution Sensors*. Gases/In Situ Measurement/Instruments and Platforms.
- Han, P., H. Mei, D. Liu, N. Zeng, X. Tang, Y. Wang, and Y. Pan, 2021: Calibrations of Low-Cost Air Pollution Monitoring Sensors for CO, NO₂, O₃, and SO₂. *Sensors*, **21**, 256, <https://doi.org/10.3390/s21010256>.
- Hodoli, C. G., and Coauthors, 2025: Urban Air Quality Management at Low Cost Using Micro Air Sensors: A Case Study from Accra, Ghana. *ACS EST Air*, **2**, 201–214, <https://doi.org/10.1021/acsestair.4c00172>.
- Holder, A. L., A. K. Mebust, L. A. Maghran, M. R. McGown, K. E. Stewart, D. M. Vallano, R. A. Elleman, and K. R. Baker, 2020: Field Evaluation of Low-Cost Particulate Matter Sensors for Measuring Wildfire Smoke. *Sensors*, **20**, 4796, <https://doi.org/10.3390/s20174796>.
- Ionascu, M.-E., N. Castell, O. Boncalo, P. Schneider, M. Darie, and M. Marcu, 2021: Calibration of CO, NO₂, and O₃ Using Airify: A Low-Cost Sensor Cluster for Air Quality Monitoring. *Sensors*, **21**, 7977, <https://doi.org/10.3390/s21237977>.
- Jain, S., A. A. Presto, and N. Zimmerman, 2021: Spatial Modeling of Daily PM_{2.5}, NO₂, and

- CO Concentrations Measured by a Low-Cost Sensor Network: Comparison of Linear, Machine Learning, and Hybrid Land Use Models. *Environ. Sci. Technol.*, **55**, 8631–8641, <https://doi.org/10.1021/acs.est.1c02653>.
- Kang, Y., L. Aye, T. D. Ngo, and J. Zhou, 2022: Performance evaluation of low-cost air quality sensors: A review. *Sci. Total Environ.*, **818**, 151769, <https://doi.org/10.1016/j.scitotenv.2021.151769>.
- Karaoghlanian, N., B. Nouredine, N. Saliba, A. Shihadeh, and I. Lakkis, 2022: Low cost air quality sensors “PurpleAir” calibration and inter-calibration dataset in the context of Beirut, Lebanon. *Data Brief*, **41**, 108008, <https://doi.org/10.1016/j.dib.2022.108008>.
- Khreis, H., J. Johnson, K. Jack, B. Dadashova, and E. S. Park, 2022: Evaluating the Performance of Low-Cost Air Quality Monitors in Dallas, Texas. *Int. J. Environ. Res. Public Health*, **19**, 1647, <https://doi.org/10.3390/ijerph19031647>.
- Levy Zamora, M., C. Buehler, H. Lei, A. Datta, F. Xiong, D. R. Gentner, and K. Koehler, 2022: Evaluating the Performance of Using Low-Cost Sensors to Calibrate for Cross-Sensitivities in a Multipollutant Network. *ACS EST Eng.*, **2**, 780–793, <https://doi.org/10.1021/acsestengg.1c00367>.
- , ———, A. Datta, D. R. Gentner, and K. Koehler, 2023: Identifying optimal co-location calibration periods for low-cost sensors. *Atmospheric Meas. Tech.*, **16**, 169–179, <https://doi.org/10.5194/amt-16-169-2023>.
- Li, J., A. Haurlyiuk, C. Malings, S. R. Eilenberg, R. Subramanian, and A. A. Presto, 2021: Characterizing the Aging of Alphasense NO₂ Sensors in Long-Term Field Deployments. *ACS Sens.*, **6**, 2952–2959, <https://doi.org/10.1021/acssensors.1c00729>.
- Liaw, A., and M. Wiener, 2002: Classification and Regression by randomForest. *R News*, **2/3**, 18–22.
- Lu, J., A. Liu, F. Dong, F. Gu, J. Gama, and G. Zhang, 2018: Learning under Concept Drift: A Review. *IEEE Trans. Knowl. Data Eng.*, 1–1, <https://doi.org/10.1109/TKDE.2018.2876857>.
- Lundberg, S., and S. Lee, 2017: A Unified Approach to Interpreting Model Predictions. *31st Conf. Neural Inf. Process. Syst.*, <https://doi.org/10.48550/arXiv.1705.07874>.
- Malings, C., R. Tanzer, A. Haurlyiuk, S. P. N. Kumar, N. Zimmerman, L. B. Kara, A. A. Presto, and R. Subramanian, 2019: Development of a general calibration model and long-term performance evaluation of low-cost sensors for air pollutant gas monitoring. *Atmospheric Meas. Tech.*, **12**, 903–920, <https://doi.org/10.5194/amt-12-903-2019>.
- , ———, ———, P. K. Saha, A. L. Robinson, A. A. Presto, and R. Subramanian, 2020: Fine particle mass monitoring with low-cost sensors: Corrections and long-term performance evaluation. *Aerosol Sci. Technol.*, **54**, 160–174, <https://doi.org/10.1080/02786826.2019.1623863>.
- Matte, T. D., and Coauthors, 2013: Monitoring intraurban spatial patterns of multiple combustion air pollutants in New York City: Design and implementation. *J. Expo. Sci. Environ. Epidemiol.*, **23**, 223–231, <https://doi.org/10.1038/jes.2012.126>.
- Mead, M. I., and Coauthors, 2013: The use of electrochemical sensors for monitoring urban air quality in low-cost, high-density networks. *Atmos. Environ.*, **70**, 186–203, <https://doi.org/10.1016/j.atmosenv.2012.11.060>.
- Mijling, B., Q. Jiang, D. De Jonge, and S. Bocconi, 2018: Field calibration of electrochemical NO₂ sensors in a citizen science context. *Atmospheric Meas. Tech.*, **11**, 1297–1312, <https://doi.org/10.5194/amt-11-1297-2018>.

- Nowack, P., L. Konstantinovskiy, H. Gardiner, and J. Cant, 2021: Machine learning calibration of low-cost NO₂ and PM₁₀ sensors: non-linear algorithms and their impact on site transferability. *Atmospheric Meas. Tech.*, **14**, 5637–5655, <https://doi.org/10.5194/amt-14-5637-2021>.
- Nullis, C., 2024: Low-cost sensors can improve air quality monitoring and people's health. *World Meteorological Organization Media Releases*, June 13.
- NYSDEC, 2024: 2024 ANNUAL MONITORING NETWORK PLAN.
- Ouimette, J. R., W. C. Malm, B. A. Schichtel, P. J. Sheridan, E. Andrews, J. A. Ogren, and W. P. Arnott, 2022: Evaluating the PurpleAir monitor as an aerosol light scattering instrument. *Atmospheric Meas. Tech.*, **15**, 655–676, <https://doi.org/10.5194/amt-15-655-2022>.
- Papaconstantinou, R., and Coauthors, 2023: Field evaluation of low-cost electrochemical air quality gas sensors under extreme temperature and relative humidity conditions. *Atmospheric Meas. Tech.*, **16**, 3313–3329, <https://doi.org/10.5194/amt-16-3313-2023>.
- Pitiranggon, M., S. Johnson, J. Haney, H. Eisl, and K. Ito, 2021: Long-term trends in local and transported PM_{2.5} pollution in New York City. *Atmos. Environ.*, **248**, 118238, <https://doi.org/10.1016/j.atmosenv.2021.118238>.
- Rattigan, O. V., K. L. Civerolo, H. D. Felton, J. J. Schwab, and K. L. Demerjian, 2016: Long Term Trends in New York: PM 2.5 Mass and Particle Components. *Aerosol Air Qual. Res.*, **16**, 1191–1205, <https://doi.org/10.4209/aaqr.2015.05.0319>.
- Raysoni, A. U., S. D. Pinakana, E. Mendez, D. Wladyka, K. Sepielak, and O. Temby, 2023: A Review of Literature on the Usage of Low-Cost Sensors to Measure Particulate Matter. *Earth*, **4**, 168–186, <https://doi.org/10.3390/earth4010009>.
- Sahu, R., and Coauthors, 2021: Robust statistical calibration and characterization of portable low-cost air quality monitoring sensors to quantify real-time O₃ and NO₂ concentrations in diverse environments. *Atmospheric Meas. Tech.*, **14**, 37–52, <https://doi.org/10.5194/amt-14-37-2021>.
- Samad, A., D. R. Obando Nuñez, G. C. Solis Castillo, B. Laquai, and U. Vogt, 2020: Effect of Relative Humidity and Air Temperature on the Results Obtained from Low-Cost Gas Sensors for Ambient Air Quality Measurements. *Sensors*, **20**, 5175, <https://doi.org/10.3390/s20185175>.
- Sayahi, T., A. Butterfield, and K. E. Kelly, 2019: Long-term field evaluation of the Plantower PMS low-cost particulate matter sensors. *Environ. Pollut.*, **245**, 932–940, <https://doi.org/10.1016/j.envpol.2018.11.065>.
- Squizzato, S., 2018: PM_{2.5} and gaseous pollutants in New York State during 2005–2016: Spatial variability, temporal trends, and economic influences. *Atmos. Environ.*, **183**, 209–224, <https://doi.org/10.1016/j.atmosenv.2018.03.045>.
- Tryner, J., M. Phillips, C. Quinn, G. Neymark, A. Wilson, S. H. Jathar, E. Carter, and J. Volckens, 2021: Design and testing of a low-cost sensor and sampling platform for indoor air quality. *Build. Environ.*, **206**, 108398, <https://doi.org/10.1016/j.buildenv.2021.108398>.
- Vanderpool, R., 2024: EPA scientists develop and evaluate Federal Reference & Equivalent Methods for measuring key air pollutants.
- Vardoulakis, S., E. Solazzo, and J. Lumbreras, 2011: Intra-urban and street scale variability of BTEX, NO₂ and O₃ in Birmingham, UK: Implications for exposure assessment. *Atmos. Environ.*, **45**, 5069–5078, <https://doi.org/10.1016/j.atmosenv.2011.06.038>.
- Vikram, S., and Coauthors, 2019: *Evaluating and Improving the Reliability of Gas-Phase Sensor System Calibrations Across New Locations for Ambient Measurements and*

- Personal Exposure Monitoring. Gases/In Situ Measurement/Data Processing and Information Retrieval*,.
- Wadlow, T., 2025: How are the latest air pollution models closing coverage gaps to save lives? *Meteorological Technology International*, February 7.
- Wang, A., and Coauthors, 2023: Leveraging machine learning algorithms to advance low-cost air sensor calibration in stationary and mobile settings. *Atmos. Environ.*, **301**, 119692, <https://doi.org/10.1016/j.atmosenv.2023.119692>.
- Wang, C., Q. Wu, M. Weimer, and E. Zhu, 2021: FLAML: A Fast and Lightweight AutoML Library. *Fourth Conf. Mach. Learn. Syst.*, <https://doi.org/10.48550/arXiv.1911.04706>.
- Wang, Z., and Coauthors, 2024: Severe Global Environmental Issues Caused by Canada's Record-Breaking Wildfires in 2023. *Adv. Atmospheric Sci.*, **41**, 565–571, <https://doi.org/10.1007/s00376-023-3241-0>.
- Williamson, A., 2022: New York city micronet : comprehensive site metadata and classifications and characteristics of the urban heat island. University at Albany, State University of New York, .
- Winter, A. R., Y. Zhu, N. G. Asimow, M. Y. Patel, and R. C. Cohen, 2025: A Scalable Calibration Method for Enhanced Accuracy in Dense Air Quality Monitoring Networks. *Environ. Sci. Technol.*, [acs.est.4c08855](https://doi.org/10.1021/acs.est.4c08855), <https://doi.org/10.1021/acs.est.4c08855>.
- Zauli-Sajani, S., S. Marchesi, C. Pironi, C. Barbieri, V. Poluzzi, and A. Colacci, 2021: Assessment of air quality sensor system performance after relocation. *Atmospheric Pollut. Res.*, **12**, 282–291, <https://doi.org/10.1016/j.apr.2020.11.010>.
- Zhang, H., and Q. Ying, 2011: Contributions of local and regional sources of NO_x to ozone concentrations in Southeast Texas. *Atmos. Environ.*, **45**, 2877–2887, <https://doi.org/10.1016/j.atmosenv.2011.02.047>.
- Zhang, J., M. Ninneman, E. Joseph, M. J. Schwab, B. Shrestha, and J. J. Schwab, 2020: Mobile laboratory measurements of high surface ozone levels and spatial heterogeneity during LISTOS 2018: Evidence for sea-breeze influence. *J. Geophys. Res. Atmospheres*, <https://doi.org/10.1029/2019JD031961>.
- Zimmerman, N., A. A. Presto, S. P. N. Kumar, J. Gu, A. Haurlyuk, E. S. Robinson, A. L. Robinson, and R. Subramanian, 2018: A machine learning calibration model using random forests to improve sensor performance for lower-cost air quality monitoring. *Atmospheric Meas. Tech.*, **11**, 291–313, <https://doi.org/10.5194/amt-11-291-2018>.
- Zuidema, C., N. Afshar-Mohajer, M. Tatum, G. Thomas, T. Peters, and K. Koehler, 2019: Efficacy of Paired Electrochemical Sensors for Measuring Ozone Concentrations. *J. Occup. Environ. Hyg.*, **16**, 179–190, <https://doi.org/10.1080/15459624.2018.1540872>.
- , and Coauthors, 2021: Deployment, Calibration, and Cross-Validation of Low-Cost Electrochemical Sensors for Carbon Monoxide, Nitrogen Oxides, and Ozone for an Epidemiological Study. *Sensors*, **21**, 4214, <https://doi.org/10.3390/s21124214>.