

Advancing operational global aerosol forecasting with machine learning

Lei Li, Ke Gui^a, Xutao Zhang^a, Huizheng Che^a, Yu Zheng^a, Oleg Dubovik^b, Jun Wang^c, Xiaoye Zhang^a

^a*Chinese Academy of Meteorological Sciences, Beijing, China*

^b*Université de Lille, CNRS, UMR 8518–Laboratoire d'Optique Atmosphérique, Lille, France*

^c*Department of Chemical and Biochemical Engineering, The University of Iowa, Iowa City, IA, USA*

**Presenting author (Lei Li, lilei@cma.gov.cn)*

Aerosol forecasting is important for air-quality management, health risk assessment and climate change mitigation. However, it is more complex than weather forecasting, owing to the interactions between aerosol physicochemical processes and atmospheric dynamics, resulting in high uncertainty and computational costs. Here we develop a machine-learning-driven Global Aerosol-Meteorology Forecasting System (AI-GAMFS), which provides reliable 5-day, 3-hourly forecasts of aerosol optical components and surface concentrations. AI-GAMFS combines a vision transformer and U-Net in a backbone network, robustly capturing the complex aerosol-meteorology interactions via global attention and spatiotemporal encoding. Trained on 42 years of aerosol reanalysis data and initialized with Global Earth Observing System Forward Processing (GEOS-FP) analyses, AI-GAMFS delivers operational 5-day forecasts in 1 minute. Evaluation with independent ground-based observations suggests improved performance compared with the Copernicus Atmosphere Monitoring Service and regional dust models in forecasting aerosol optical depth and dust components. Compared with GEOS-FP10, it has a lower root-mean-square error for global aerosol optical depth, with comparable dust forecasting skill and improved surface aerosol component forecasts over the USA and China. Our results provide a step forward in leveraging machine learning to refine aerosol forecasting and may help warn against aerosol pollution events such as dust storms and wildfires.

References

- [1] Ke Gui, Xutao Zhang, Huizheng Che, Lei Li, Yu Zheng, Linchang An, Yucong Miao, Hujia Zhao, Oleg Dubovik, Brent Holben, Jun Wang, Pawan Gupta, Elena S. Lind, Carlos Toledano, Hong Wang, Zhili Wang, Yaqiang Wang, Xiaomeng Huang, Kan Dai, Xiangao Xia, Xiaofeng Xu & Xiaoye Zhang, 2026: Advancing operational global aerosol forecasting with machine learning. *Naure*, 651,658-665.

Preferred mode of presentation: Oral