Figure S1. Comparative analysis of meteorological conditions between observations and model simulations over China during the dust event in April 2025, including daily mean temperature (T, unit: ℃), daily mean relative humidity (RH, unit: %), hourly total precipitation (Precipitation, unit: mm) and wind fields during 10-13 April 2025 BJT. Due to the lack of station-based precipitation observations, ERA5 reanalysis data are used for comparison in precipitation.
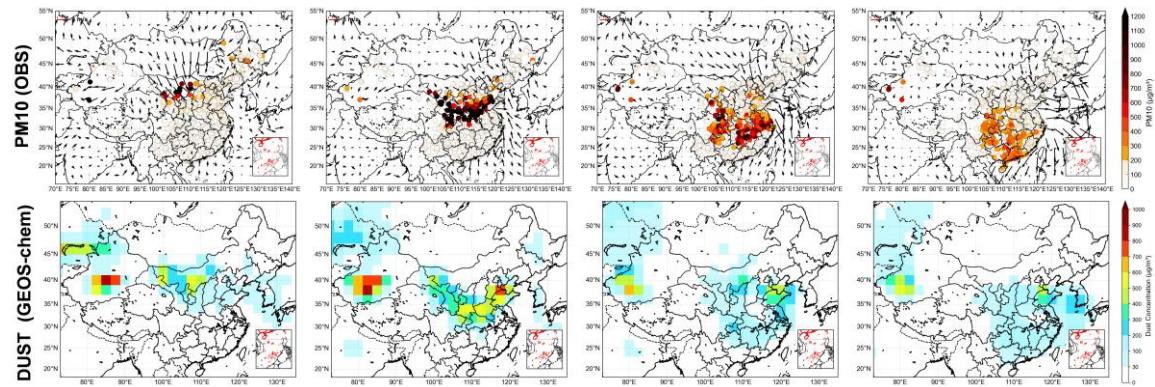
Figure S2. comparisons of simulated dust aerosol concentration (μg/m³) with observed PM₁₀ concentration (μg/m³) and AOD spatial distributions during 11-13 April 2025 BJT. The observational meteorological data are obtained from surface stations, while PM₁₀ concentration data are sourced from air quality monitoring stations.
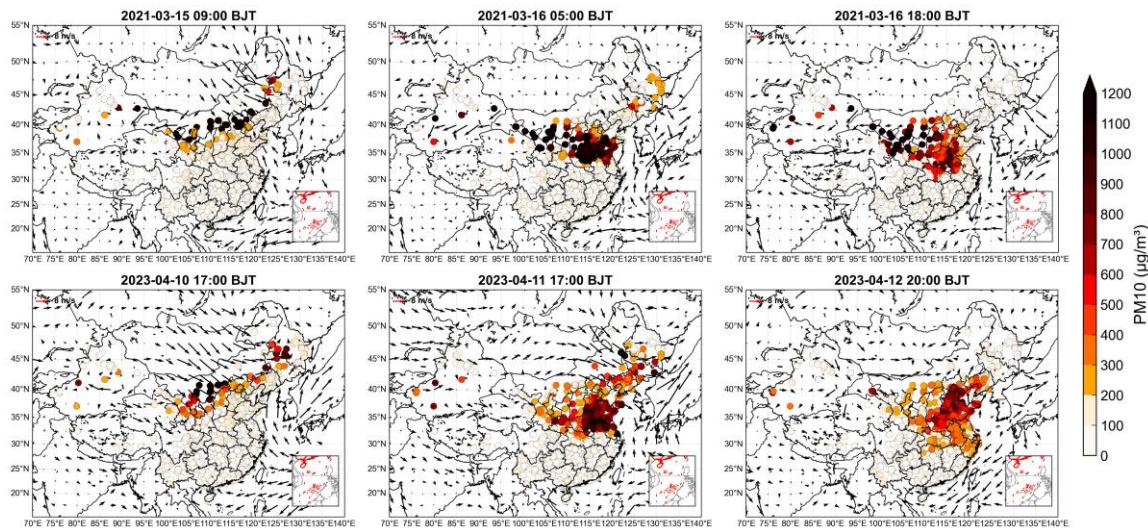
Figure S3. PM$_{10}$ concentration (μg/m³) variations during the severe dust storm event over China in March 2021 and during the severe dust storm event in April 2023.