

Supplementary Materials: Characteristics of Trace Metal Elements in Ambient Sub-Micron Particulate Matter in a Coastal Megacity of Northern China Influenced by Shipping Emissions from 2018 to 2022

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Figure S1. Domestic Vessel Emission Control Areas Regulated by the MOT

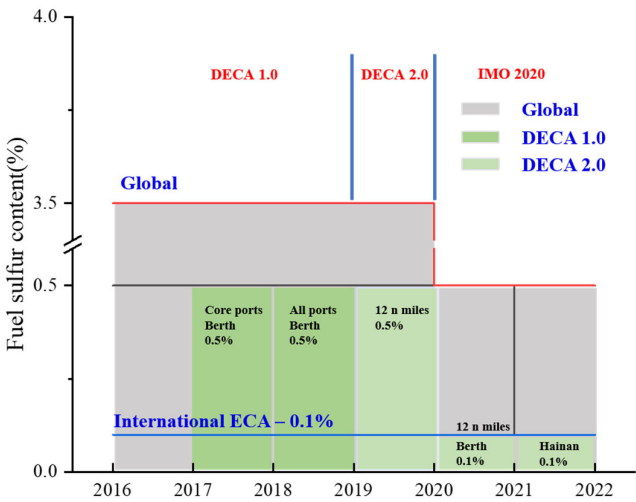
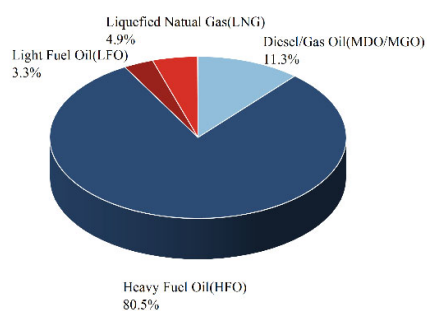
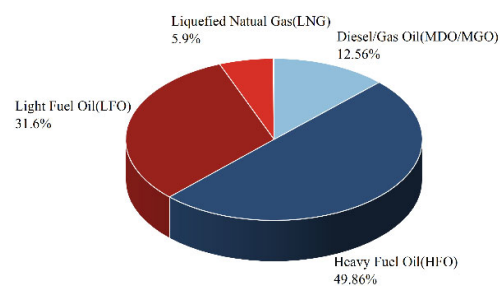


Figure S2. Evolution of sulfur content requirements for fuels in DECAs in China.

(a) 2019



(b) 2020



(c) 2021

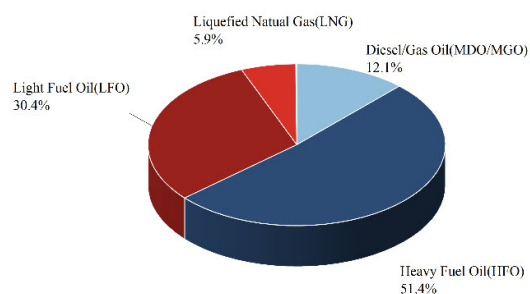


Figure S3. The aggregated annual amount of each type of fuel oil consumed by all ships of 5,000 GT and above from 2019 to 2021. Data from “Report of fuel oil consumption data submitted to the IMO Ship Fuel Oil Consumption Database in Global Integrated Shipping Information System,” <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MEPC-79th-session.aspx>

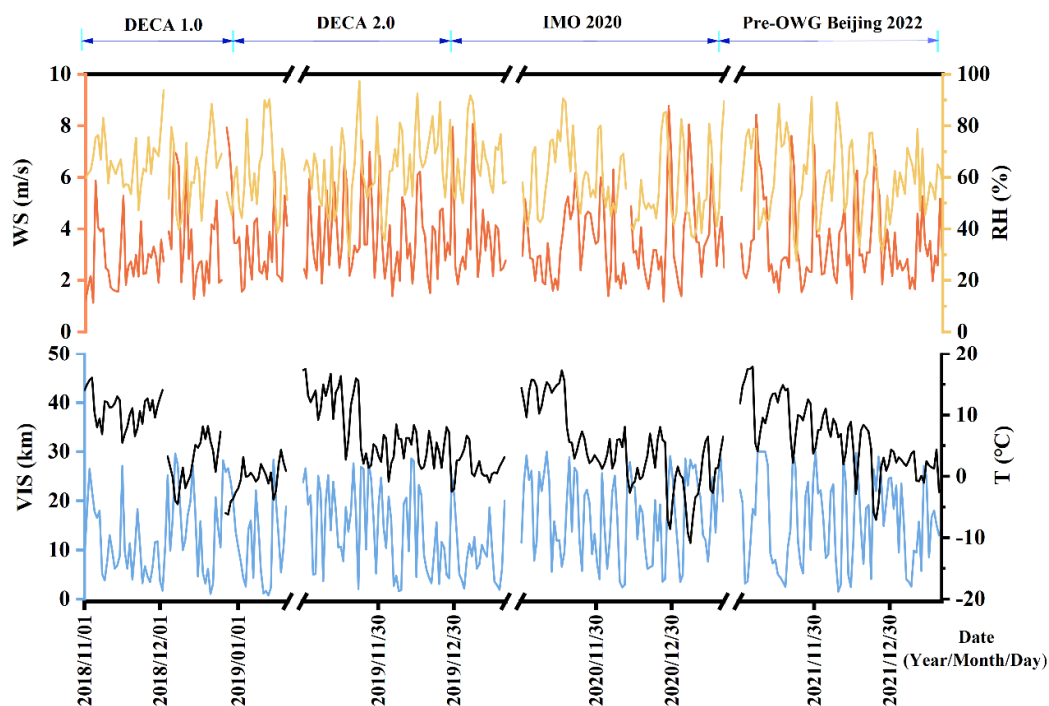


Figure S4 Time series of Wind speed, Relative humidity, temperature, and visibility during observation.

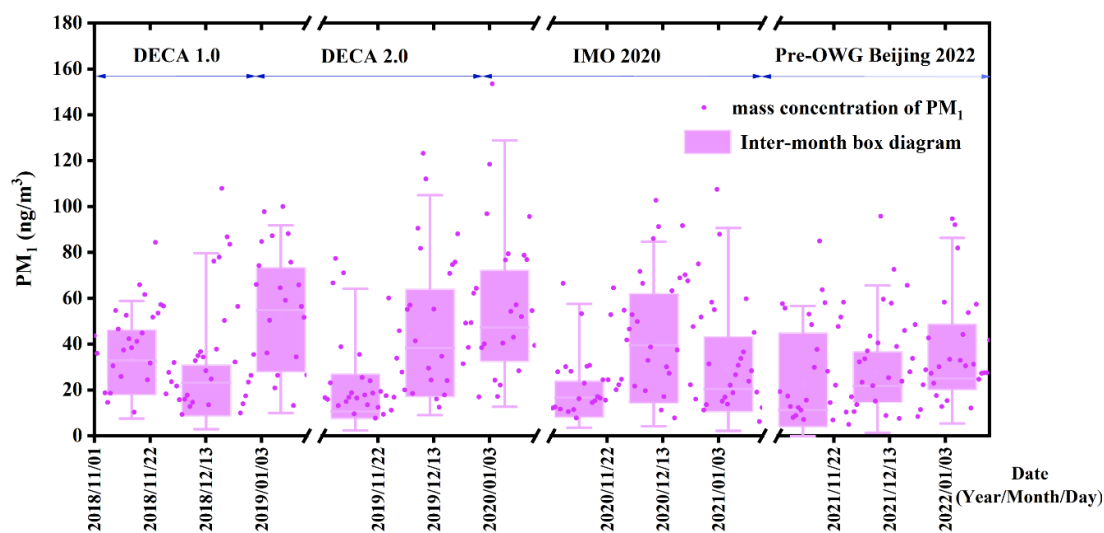


Figure S5 Time series of PM₁ concentrations during observation.

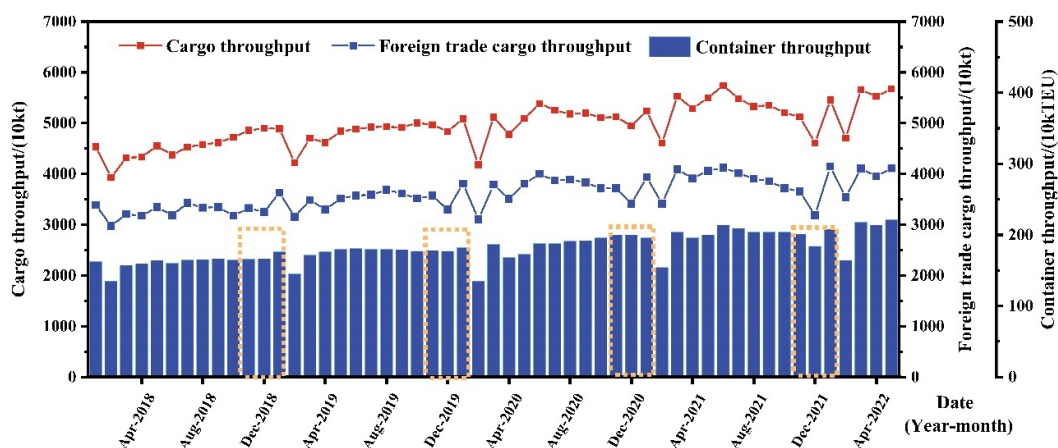


Figure S6. Monthly cargo throughput, foreign trade cargo throughput, and container throughput of Port in Qingdao.

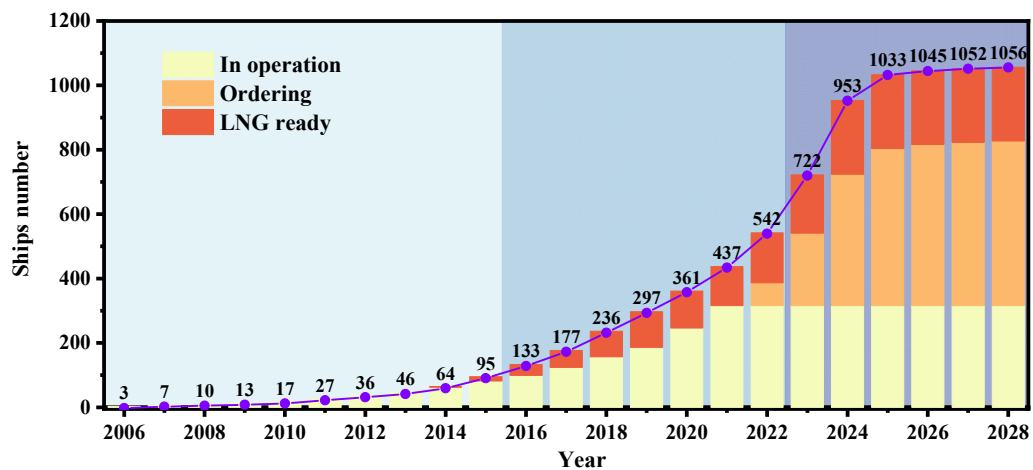


Figure S7 Yearly development of LNG-fueled fleet.

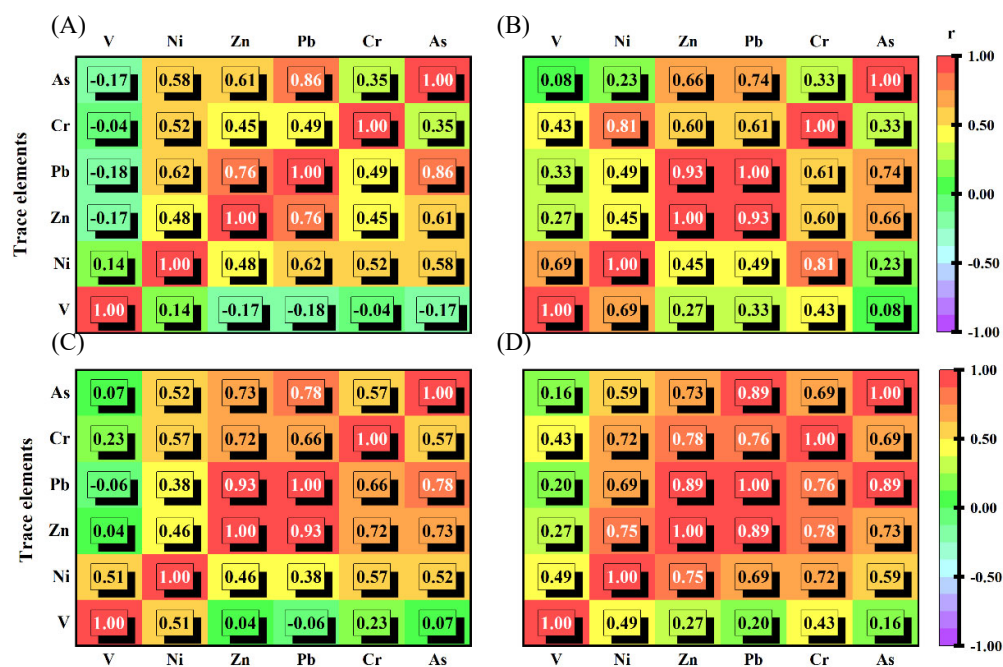


Figure S8 Correlation coefficients of trace elements during DECA 1.0(A), DECA 2.0(B), IMO 2020(C) and Pre-OWG Beijing 2022(D).

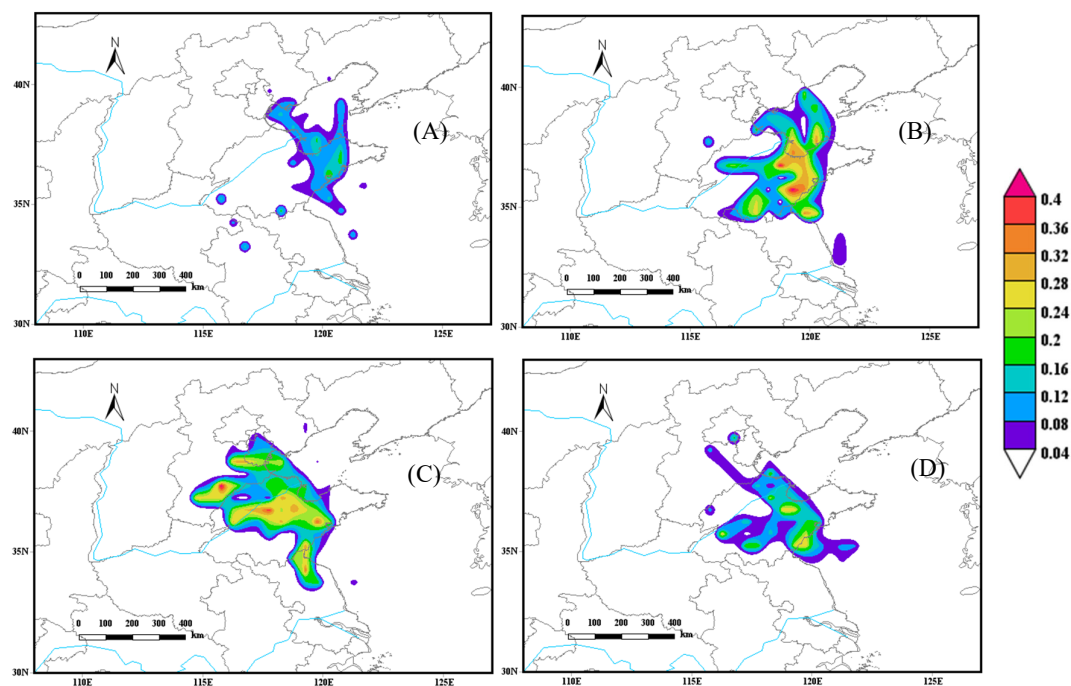


Figure S9 Potential emission areas of SO₂ in PM₁ in DECA 1.0(A), DECA 2.0(B), IMO 2020(C) and Pre-OWG Beijing 2022(D).

Table

Table S1 Ratio of secondary dissolution concentration of metal elements in PM₁ to blank sample concentration

Trace elements	V	Cr	Ni	Zn	As	Pb
Ratio	0.89	0.79	0.77	0.26	2.03	0.58