Response to Referee's Comments #2

1. Fig 1, please unified the units, "nm" in figure 1 and "Nm" in the caption.

Response:

Thanks for the suggestion. The units were unified in Fig 1 and in its caption.

Revision in manuscript:

(1) Figure 1.

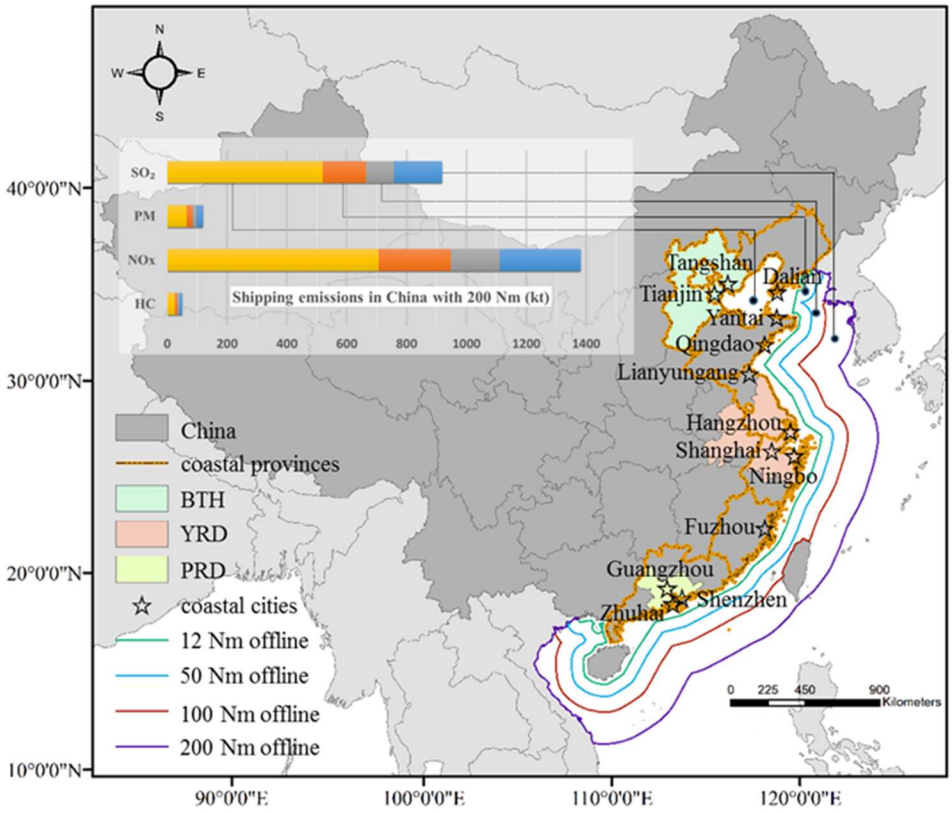


Fig 1: Study area and the contributions of different maritime areas for the total shipping emissions. The yellow, red, gray and blue columns represent the amount of shipping emissions in the areas within 12 Nm, 12-50 Nm, 50-100 Nm and 100-200 Nm off the Chinese coastline respectively.

2. Fig 2, why SO_2 was used in Fig 2 instead of $PM_{2.5}$?

Response:

Thanks for the question. We think that SO_2 is a better choice in this figure. The purpose of Fig 2 is to show the spatial distribution and seasonal variation of shipping emissions, and no matter which species is selected in this figure, the emission characteristics will be silimar because the same AIS data is used to calculate their emissions. Therefore, the importance of species is the only rule to select which one should be used in this figure. In our opinion, for the maritime sector, SO_2 emissions is more important than others in this study, including the primary PM, because of the following reseasons:

(1) The relative proportion of SO_2 emissions from ship is higher than other species when comparing to the emissions from land-based sources. The annual SO_2 and PM emissions from ships in China are 918.4 and 119.3 kt, which accounted for 20.2% and 4.3% of the inland emissions from all sectors in coastal provinces of the MEIC inventory (in manuscript Page 7, line 20-26).

(2) SO_2 emissions from ships influence the inland air qulity more significantly. For the most coastal regions and cities in China, secondary sulfate formed from the SO_2 emssions is the most important component in the ship-induced $PM_{2.5}$, and its regional averaged contribution to the total $PM_{2.5}$ increase is 31.9% (Fig 4.). While primary PM only accounted for 21.2% of the total ship-induced $PM_{2.5}$.

3. Page 8, Line 3, the reason for the season variations in the spatial distribution of shipping emissions need to be further discussed.

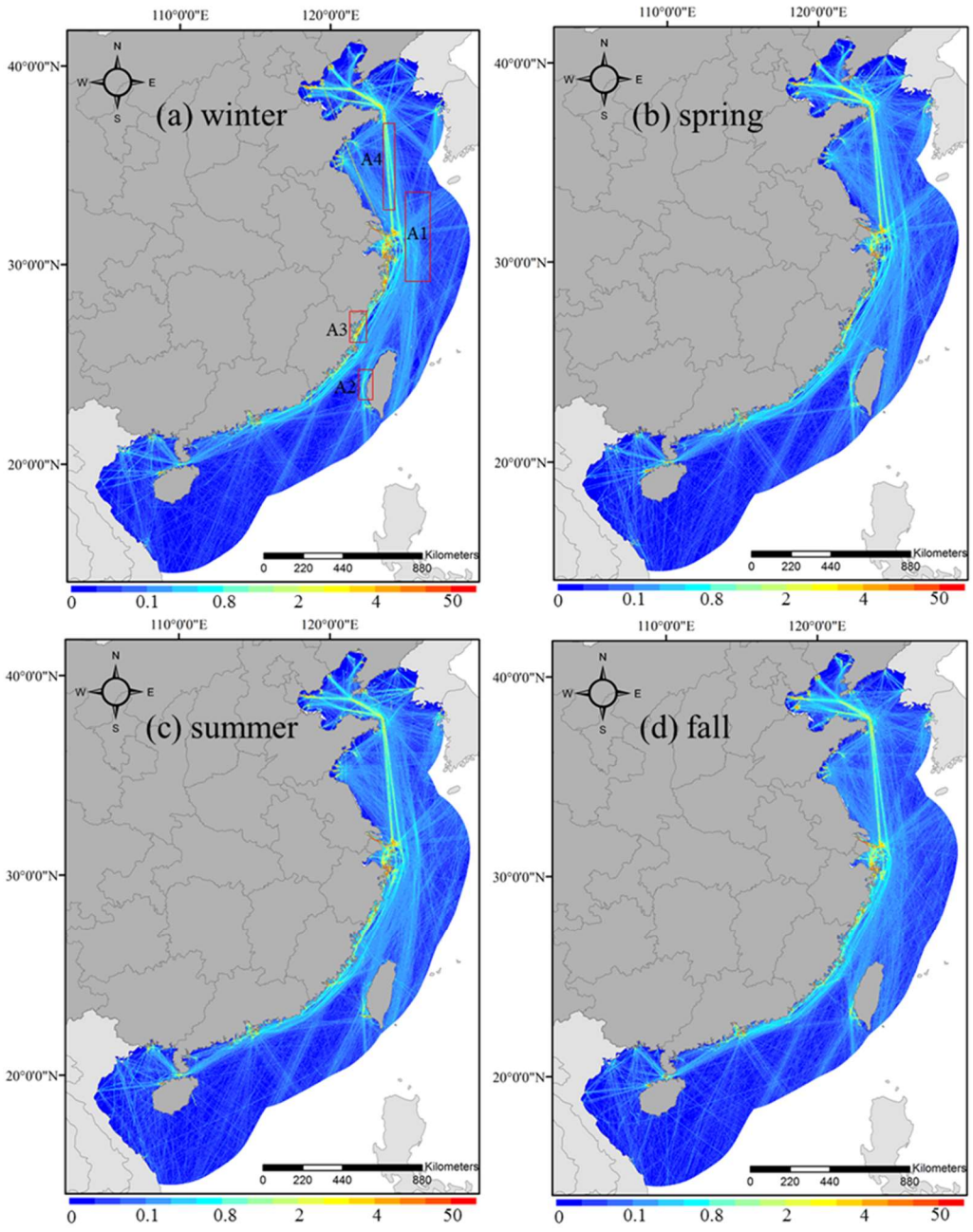
Response:

Thanks for the suggestion. To discuss the reason for the seasonal variation in the spatial distribution of shipping emissions, we identified the seasonal changes of emissions from different ship types, and find which type is mainly responsible for these emission changes. More details were added in the manuscript.

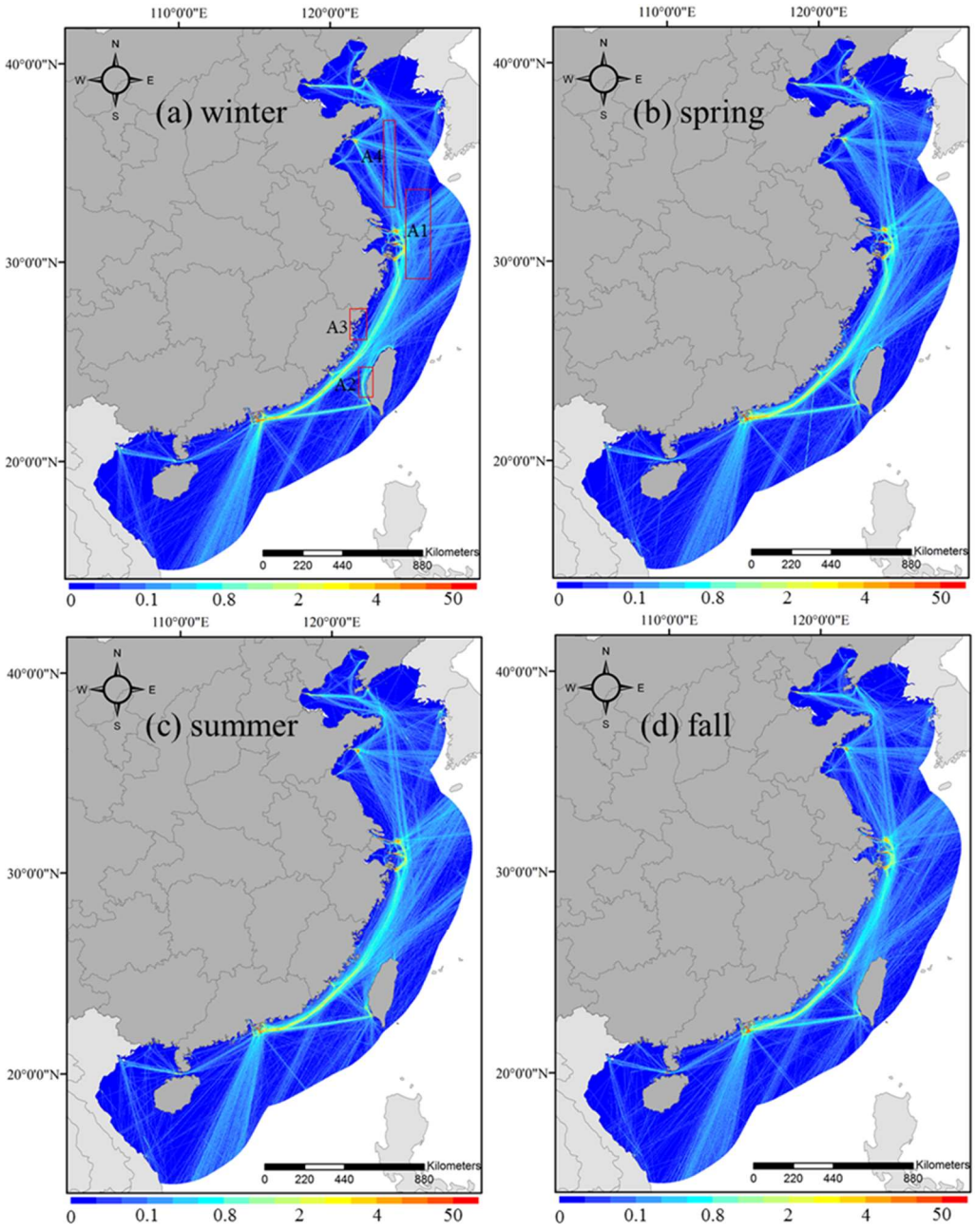
Revision in manuscript:

(1) *Page 8, Line 19-25: "These seasonal changes were closely related to the activity variations of different ship types (Fig. S4-6). In spring and summer, mainly due to the increase of long-distance cargo ships, significant emissions occurred in water traffic lanes far from the YRD region (A1). The decrease of cargo ship activities in Fuzhou port during summer and fall also resulted in the obviously reduced shipping emissions in A2. The emissions in A3 were lower in summer and fall because of the decreased activities of all ship types, including cargo ships, containers and tankers."*

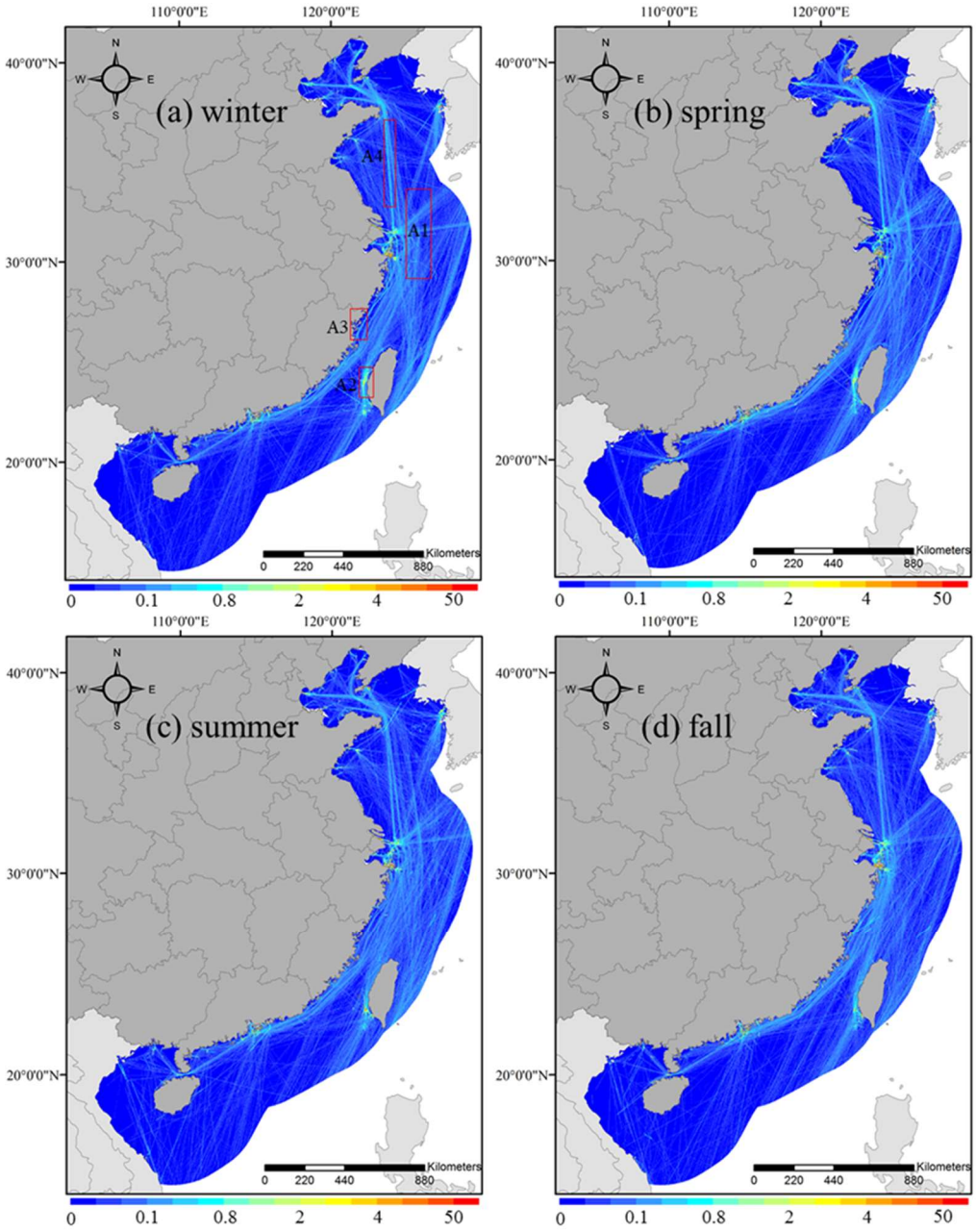
(2) *Fig. S4. Spatial distributions of SO_2 emissions from cargo ships at a resolution of 3 km×3 km (unit, ton/grid) in (a) winter; (b) spring; (c) summer; and (d) fall.*



(3) *Fig. S5. Spatial distributions of SO_2 emissions from containers at a resolution of 3 km×3 km (unit, ton/grid) in (a) winter; (b) spring; (c) summer; and (d) fall.*



(4) *Fig. S6. Spatial distributions of SO_2 emissions from tankers at a resolution of 3 km×3 km (unit, ton/grid) in (a) winter; (b) spring; (c) summer; and (d) fall.*



4. In my opinion, fishing ships also contributed a lot according to recent study, but most of them had no AIS data. What kind of ships were considered in this study? Are fishing ships included here?

Response:

Thanks for the question. Ten ship types were considered in this study, including fishing boats, described in Table S1. However, we only considered a part of fishing boats that have AIS data, so their emissions were probably underestimated. Therefore, the introduction of ship types and their emissions were added in the manuscript.

Revision in manuscript:

(1) Page 5, Line 21-23: "The ocean-going vessels considered in this study were classified by 10 classification schemes, and lumped into four main types by cargo types, including cargo ship, container, tanker and others, as described in Table S1."

(2) Table S1. Ship types

Ship type		*Description (Liu et al., 2016)*
Cargo ship	*Auto Carrier*	*Self-propelled dry-cargo vessels that carry containerized automobiles.*
	Bulk Carrier	*Self-propelled dry-cargo ship that carries loose cargo.*
	General Cargo	*Self-propelled cargo vessel that carries a variety of dry cargo.*
	Reefer	*Self-propelled dry-cargo vessels that often carry perishable items.*
Container	*Container Ship*	*Self-propelled dry-cargo vessel that carries containerized cargo.*
Tanker	*Tanker*	*Self-propelled liquid-cargo vessels including chemical tankers, oil tankers, liquefied gas tanker, etc.*
Others	*Cruise Ship*	*Self-propelled cruise ships.*
	Miscellaneous	*Category for those vessels that do not fit into one of the other categories or are unidentified, including harbor service vessels, fishing boats.*
	Oceangoing Tugs/Tows	*Self-propelled tugboats and towboats that tow/push cargo or barges in the open ocean.*
	RORO	*Self-propelled vessel that handles cargo that is rolled on and off the ship, including ferries.*

(3) Page 7, Line 26-Page 8, Line 3: "The cargo ships were the most important contributor to the total shipping emissions, accounting for 43.7%, 43.4%, 41.9% and 40.5% of SO_2, PM, NOx and HC emissions. The container and tanker also contributed 24.7-28.4% and 17.5-19.7% of the total shipping emissions. However, emissions from fishing boats were probably underestimated in this study (approximately 1.0% of the totals) since most of them had no AIS data, which could affect the air quality significantly (Zhang et al., 2018)."

5. Page 13, line 22, delete one "in".

Response:

Thanks for the suggestion. One "in" was deleted in this line.

Revision in manuscript:

(1) Page 14, Line 10: "patterns in the north and south"

6. The subtitle of 3.1, 3.2 and 3.3 need to be reconsidered, please give more distinct expression

Response:

Thanks for the suggestion. The subtitles of 3.1, 3.2 and 3.3 were all reconsidered and revised in the manuscript.

Revision in manuscript:

(2) Page 7, Line 19: "3.1 Shipping emission inventory with high resolution"

(3) Page 8, Line 28: "3.2 Annual $PM_{2.5}$ impact from shipping emissions"

(4) Page 10, Line 25: "3.3 Seasonal $PM_{2.5}$ impact from shipping emissions"

Reference

Liu, H., Fu, M., Jin, X., Shang, Y., Shindell, D., Faluvegi, G., Shindell, C., and He, K.: Health and climate impacts of ocean-going vessels in East Asia, Nature Climate Change, 6, 1037-1041, 10.1038/nclimate3083, 2016.

Zhang, F., Chen, Y., Chen, Q., Feng, Y., Shang, Y., Yang, X., Gao, H., Tian, C., Li, J., Zhang, G., Matthias, V., and Xie, Z.: Real-World Emission Factors of Gaseous and Particulate Pollutants from Marine Fishing Boats and Their Total Emissions in China, Environ Sci Technol, 52, 4910-4919, 10.1021/acs.est.7b04002, 2018.

Liu, H., Fu, M., Jin, X., Shang, Y., Shindell, D., Faluvegi, G., Shindell, C., and He, K.: Health and climate impacts of ocean-going vessels in East Asia, Nature Climate Change, 6, 1037-1041, 10.1038/nclimate3083, 2016.

Zhang, F., Chen, Y., Chen, Q., Feng, Y., Shang, Y., Yang, X., Gao, H., Tian, C., Li, J., Zhang, G., Matthias, V., and Xie, Z.: Real-World Emission Factors of Gaseous and Particulate Pollutants from Marine Fishing Boats and Their Total Emissions in China, Environ Sci Technol, 52, 4910-4919, 10.1021/acs.est.7b04002, 2018.