Response to comments by referees

We thank the referee for the helpful comments and suggestions. Below are the detailed responses. The referee's comments are in *italic*; our responses are in red.

Reviewer #2

The effects of ship emissions on the formation of O_3 and $PM_{2.5}$ have a significant impact on the climate, air quality, and human health. However, limited attention has been paid to the production of ship-related radicals in evaluating the effects of ship emissions on secondary pollutants. This study used a revised regional chemical transport model (CBMZ was updated to CBMZ-ReNOM) to simulate the spatial distributions of HONO and $ClNO_2$ produced by ocean-going ships and their effects on the formation of O_3 and $PM_{2.5}$. Overall, this is a fundamental work with clear importance. It fulfils the necessary requirements to be published. I recommend it for publication after the authors consider several minor revisions to the manuscript.

1. The model simulations were performed from June 28 to July 31, 2018. It's the summertime for east Asia. Can you expect what's the change of main conclusions if you expand the simulation to all seasons? If it's hard to expect the results for different seasons, the title should be specified to summer.

Response: Thank you for your comment. We chose summer for this study because the relative impact of ship emission may be most distinctive in the western Pacific due to smallest influence of land emissions under large-scale winds from oceans. Moreover, high temperature and strong solar radiations during summer lead to the fast production of ozone and other secondary pollutants. However, it is difficult to expect the quantitative impact for other seasons. We have revised the title to indicate our work is for summer:

"Impact of International Shipping Emissions on Ozone and $PM_{2.5}$ in East Asia during Summer: The Important Role of HONO and $ClNO_2$".

2. The HONO emissions from land transportation sources were calculated using land-based NOx emissions and the HONO/NOx ratios (0.8% for gasoline and 2.3% for diesel). It should be noted that the estimation is quite rough. It would be useful to give a range of HONO and check the impacts.

Response: The emission ratio of 0.8% for gasoline and 2.3% for diesel are based on the previous experiments studies (Kurtenbach et al., 2001, Gutzwiller et al., 2002) and have been widely used in model studies(Zhang et al., 2016, Sun et al., 2020, Fu et al., 2019). These ratios are generally consistent with more recent measurements (Liu et al., 2019, Trinh et al., 2017). We believe these ratios are reasonable. We have cited the two papers (Kurtenbach et al., 2001, Gutzwiller et al., 2002) in the emissions section to explain the reasons for using these $HONO/NO_x$ ratios in this study.

3. The underpredicted O_3 on land is larger than on maritime regions. Are there any correlations between the two? If so, is the ReNOM scheme still important?

Response: the larger underpredicted O_3 in land area was related to the higher absolute value of O_3 in this area. Considering the different sources of ozone precursors in land and marine area, it is difficult to correlate the underpredicted ozone in these two regions. In our model results, the simulated ozone was improved by ReNOM scheme (with smaller bias) in both land and marine sites. We believe that the consideration of ReNOM scheme is important to improve the ozone simulation in these two areas.

4. Fig. 2. Both of the concentrations of HONO and $ClNO_2$ are very low on the ocean. How can you determine the contribution from ships is accurate, not noise from the model?

Response: Thank you for your comment. According to previous studies, the observed levels of HONO and $ClNO_2$ in remote oceans are low, 3-35 pptv and 89 pptv, respectively (Ye et al., 2016, Kasibhatla et al., 2018, Meusel et al., 2016). Our simulated results for these two species are consistent with the observed values. Moreover, the simulated HONO and $ClNO_2$ (especially HONO) over marine areas were consistent with the distribution of ship tracks. We also repeated the simulations for the same model runs and obtained the consistent results on HONO and $ClNO_2$. Therefore we believe that our simulated HONO and $ClNO_2$ in marine regions is mainly from ship emissions, not the noise from the model.

5. Fig.6d and 8d show a hot spot in inland area of south China. As the inland river ship emissions were not included in this study, how to explain the reason for the most significant changes happened in inland, which is isolated from shipping emissions? In another words, if other reasons would drive to such high increment, how to confirm the other increments are from ships not noise?

Response: Thank you for your comment. We also noticed some ship-induced hot spots in the inland areas. To check the accuracy of our model results, we had re-run the BASE and Default case with the same model setting. The hot spots in the inland areas of south China remained. The hot spots may be a result of inhomogeneous impact of ship emissions due to complicated dynamic and chemical processes that affect the fate and distribution of ship-emitted pollutants in the inland areas. In particular, the mountainous terrains in south China may have large influence on transport of ship emissions to the inland areas. We have added the below discussion in the revised version.

“In addition to the above coastal and oceanic areas, ship emissions also exert considerable impact on surface O3 in distant inland areas such as Sichuan basin, and interestingly there are some ‘hot spots’ of ozone increase/decrease in the inland areas due to ship emissions (Figure 6a-d) (as well as ROx (Figure 4a-d) and PM2.5 (Figure 8a-d)). These hot spots may be a result of inhomogeneous impact of ship emissions due to complicated dynamic and chemical processes that affect the fate and distribution of ship-emitted pollutants in the inland areas. In particular, the mountainous terrains in south China may have large influence on transport of ship emissions to the inland areas.”

6. Current titles for Fig. 6 and 8 are not appropriate.

Response: We changed the title for Fig. 6 to “24-hour daily averaged ozone variations (06:00-18:00 LST; Unit: ppbv) with (a) default chemistry (Def-Def_noship), (b) default and additional HONO chemistry (HONO-HONO_noship), (c) default and additional chlorine chemistry (Cl-Cl_noship), and (d) default and combined HONO and chlorine chemistry (BASE-BASE_noship). Arrows present simulated wind vectors from BASE case.”. The current title for Fig.8 changed to “Averaged $PM_{2.5}$ enhancements (Unit: $\mu g\ m^{-3}$) with (a) default chemistry (Def-Def_noship), (b) default and additional HONO chemistry (HONO-HONO_noship), (c) default and additional chlorine chemistry (Cl-Cl_noship), and (d) default and combined HONO and chlorine chemistry (BASE-BASE_noship). Arrows present simulated wind vectors from BASE case”

7. Section 3.2 and title for section 3.3 are missing.

Response: Thanks for pointing out this effort. It has been corrected.

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