**Response to Reviewer #2**

Dear Editor and Reviewer:

We greatly appreciate your consideration and the reviewer's insightful and constructive comments on the manuscript "**HONO Formation Mechanisms and Impacts on Ambient Oxidants in Coastal Regions of Fujian, China**" (egusphere-2025-2630). We have carefully revised the manuscript to address all the comments described below. Reviewer comments are shown in black. Our responses are shown in blue. The revised texts are shown in red.

This paper conducted a one-month HONO observation at a suburban site in coastal Fujian, combined with an improved WRF-Chem simulation, to systematically investigate the mechanism of high noontime HONO and the impact of shipping emissions on regional oxidizing capacity. The overall idea is complete, with close integration of observation and simulation, and the results are of great significance for a deep understanding of the HONO source mechanism in coastal areas and for quantifying the contribution of shipping emissions to regional atmospheric oxidizing capacity. However, this study still has many shortcomings in model settings, discussion depth and expression, and the authors need to carefully revise the paper to ensure the reliability and rationality of the results. The specific comments are as follows:

**Response:** We thank you for the comments. Based on your helpful and insightful comments, we have revised our manuscript, and the point-by-point responses to the specific comments were given subsequently. We sincerely hope these revisions could address your concerns.

1. Section 2.1 states that the observation site is about 25 km from the Taiwan Strait. However, during the daytime, HONO quickly dissipates due to photolysis, with a typical lifetime of only a few tens of minutes. The researchers also reported low wind speeds during the observation period (average WS = 2.1 $ms^{-1}$). A simple transport calculation gives: the transport time from the ocean to the observation site is 3.3 hours ($t = 25000/2.1/3600$), which is one order of magnitude longer than the daytime HONO lifetime. Under this condition, any HONO directly emitted over the Strait is expected to decay significantly before reaching the receptor site. Therefore, the paper may overestimate the contribution of daytime shipping emissions to observed HONO concentrations and atmospheric oxidizing capacity.

**Response:** We thank the reviewer for this insightful comment. We agree with your point that the simple calculation correctly shows that due to short photochemical lifetime of 10-20 minutes, HONO cannot undergo direct long-range transport from the Taiwan Strait to the local observation site. We would like to clarify that our central argument is not the transport of HONO itself, but rather that of its more stable precursors, mainly nitrogen oxides ($NO_x$). Our model simulates the process wherein $NO_x$ emitted from shipping activities is transported to the coastal areas. Upon arrival, this precursor-rich airmass undergoes rapid chemical conversion to HONO (light-enhanced heterogeneous reactions and photo-oxidation reactions), contributing to the observed high production rates during the daytime. Therefore, the contribution from shipping emissions is mainly realized through the transport of precursors followed by local formation, a mechanism consistent with the short lifetime of HONO. To clarify this point, we have revised the manuscript as follows.

***Revisions in Section 3.3.2:***

*It is worth noting that the contribution from shipping emissions to coastal HONO formation is mainly driven by the transport of precursors including $NO_x$ and $NO_3^-$. That is, shipping emissions affect daytime HONO formation via precursor transport followed by local chemical production despite HONO's short atmospheric lifetime.*

2. L89-L90: $NO_2$ was measured using 17i, also using chemiluminescence, which will overestimate $NO_2$ concentration and should be corrected. In addition, the concentration units of the same species in the manuscript should be unified. Was the concentration of NO, an important precursor of HONO, measured? Why is it not shown?

   **Response:** Thank you for pointing this out. We acknowledge the point that standard chemiluminescence analyzers with molybdenum converters (such as the Thermo 17i) can have a positive artifact from other reactive nitrogen species, potentially leading to an overestimation of the true $NO_2$ concentration (Dunlea et al., 2007). No specific correction was applied to the data in our study, and we have added a cautionary note regarding this uncertainty to the Methods section. We have performed a careful check of the entire manuscript and unified the concentration units for all species to ensure consistency. Regarding NO, this species was measured during the field campaign; however, the amount of valid data was insufficient for a robust analysis, and therefore it is not presented in this study.

   ***Revisions in Section 2.1:***

*For mode 17i, we acknowledge that the chemiluminescence instrument with a molybdenum converter used for $NO_2$ measurements may be subject to positive artifacts from other reactive nitrogen species, which represents a potential source of uncertainty in the $NO_2$ data used for model evaluation (Dunlea et al., 2007).*

3. L134-136: In most studies the $NO_2$ uptake coefficient on the ground is smaller than that on the aerosol surface. The authors should provide sufficient reasons for this choice. In addition, the light-enhanced $NO_2$ uptake coefficient is generally on the order of $10^{-5}$, and in some studies $1\times10^{-3}$ has only been used as the upper limit of $NO_2$ heterogeneous reactions. This value will seriously overestimate the contribution of $NO_2$ heterogeneous reactions, and it is recommended that the authors reconsider the value. In addition, selecting 1.45% as the emission factor is also significantly higher than the commonly used 0.8%. The authors should calculate the corresponding emission factor based on field observations to increase the rationality of the value.

**Response:** We thank the reviewer for the careful comment on these key heterogeneous uptake coefficients. Our choice of parameterization is in accordance with several previous modeling studies conducted in China (Zhang et al., 2021; Liu et al., 2019a; Zhang et al., 2024). To be specific, under dark conditions, we set the $NO_2$ uptake coefficients to $8\times10^{-6}$ for the ground surface and $4\times10^{-6}$ for aerosol surfaces. For daytime, these values were dynamically scaled with solar radiation, reaching their maximums only under the strongest sunlight conditions at $6\times10^{-5}$ for the ground surface and $1\times10^{-3}$ for aerosol surfaces. We acknowledge that the value of $1\times10^{-3}$ represents an upper limit for the light-enhanced $NO_2$ uptake on aerosol surfaces as reported in the literature. However, the critical factor in this coastal study area is the low ambient aerosol concentrations. This limited availability of aerosol surface area means that even with a high uptake coefficient, the overall contribution of this pathway to HONO formation is minimal. While $PM_{2.5}$ mass concentration was not measured during this campaign, our model simulates a regional average $PM_{2.5}$ concentration of approximately 11.9 μg $m^{-3}$, proposing a relative clean condition. Simultaneously, the WRF-Chem model reveals that the contribution from heterogeneous reactions on aerosol surfaces accounted for a negligible 2% of the total daytime HONO production (Figure 5). Therefore, we are confident that this parameter does not overestimate the HONO budget in the present study. We have rephrased the relevant texts in the revised manuscript to clarify the rationale behind these choices.

Regarding the HONO/$NO_x$ emission ratio, we used a value of 1.45% in this study, which is higher than the more widely adopted value of 0.8% (Kurtenbach et al., 2001). Our choice of 1.45% is based on the estimates of Hu et al. (2022), which derived this ratio from a long-term measurement campaign in Xiamen, a coastal city also located in the study region. We agree with the reviewer that deriving a constrained emission ratio directly from our own field observations would be the most robust approach. However, characterizing the direct emission ratio requires a long-term dataset (typically several months to a year) to collect sufficient fresh emission plumes (Liu et al., 2019b). As our measurement campaign was limited to a one-month period, we were unable to derive a statistically robust HONO/$NO_x$ ratio from our dataset. Thus, we consider the ratio proposed by Hu et al. from a nearby location to be an appropriate alternative.

***Revisions in Section 2.3:***

*The $NO_2$ heterogeneous uptake on ground and aerosol surfaces was parameterized as a light-dependent process, with uptake coefficients (γ) chosen in accordance with previous studies in China (Zhang et al., 2021; Liu et al., 2019a; Zhang et al., 2024). The base nighttime uptake coefficients of $NO_2$ were set to $8\times10^{-6}$ for the ground surface and $4\times10^{-6}$ for aerosol surfaces. During the daytime, these values were dynamically increased with solar radiation using a linear equation, reaching their maximums of $6\times10^{-5}$ and $1\times10^{-3}$, respectively (Liu et al., 2019).*

4. The IOA index increased from 0.62 (BASE) to 0.69 (REV), which is not very high. At the same time, in Fig. 3a and 3b, the fit of the REV simulation results with the observations is poor, and the simulated values are significantly higher than the observed values on many days. These simulation results are difficult to convince readers. Did the authors consider the effect of rainy days when calculating the model evaluation index? The authors did not clearly state this. In the diurnal variation diagram of Fig. 3b, why are the three curves shifted?

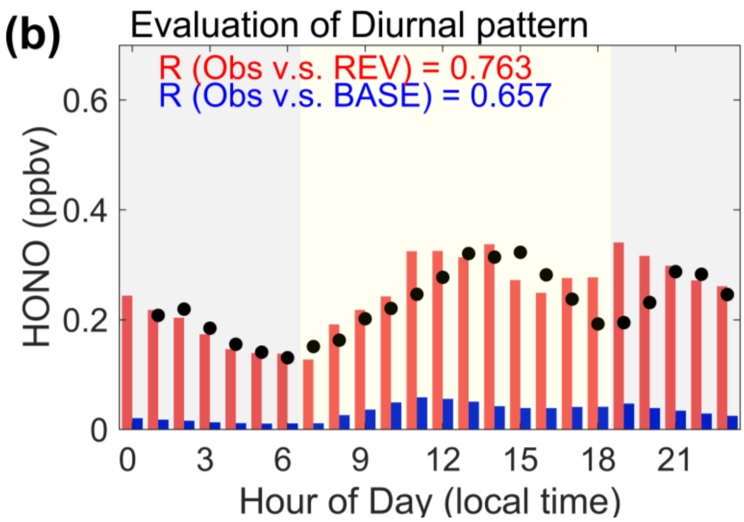
**Response:** We would like to thank the reviewer for the detailed feedback on our model evaluation. We indeed agree with you that the improvement of IOA index from 0.62 to 0.69 is modest. As shown in Figure 3b, the BASE simulation, which only includes the homogeneous reaction of NO+OH, is also able to produce a midday HONO peak. However, a key deficiency in the BASE case is that this peak occurs much earlier than observed. The revised HONO model could more accurately captures the timing of the observed peak concentration around 14:00. More importantly, the BASE case failed to reproduce the observed magnitude of HONO concentrations. This improvement in REV is better reflected by NMB and RMSE. Regarding the systematic overestimation from $19^{th}$ to $25^{th}$ of May, this period corresponds to continuous rainfall, during which model is likely affected by uncertainties from wet scavenging. Our current evaluation in Table 3 is based on the entire month to provide an assessment. To address your point, we have conducted an additional evaluation using a dataset filtered for non-rainy conditions only to better demonstrate the model's performance under typical dry conditions. Concerning the "shift" of the curves in Figure 3b, this presentation style was chosen to give a direct comparison between observations and simulations. To improve clarity for the reader, we have revised the figure's presentation as follows.

***Revisions in Section 3.2:***

*As summarized in Table 3, while the improvement in the Index of Agreement (IOA, varies from 0 to 1) is modest (from 0.62 to 0.69), the revised model shows a fundamental improvement in capturing the magnitude of HONO concentrations. This is demonstrated by the dramatic enhancements in the Normalized Mean Bias (NMB, varies from -∞ to +∞), which improved from -86% to +8%, and the Root Mean Square Error (RMSE, varies from -∞ to +∞), which decreased by 21%. While the revised model reasonably reproduced the observed temporal variations in HONO concentrations during the study period, an underestimation existed on 16-18 May, suggesting a potential omission of HONO sources. The systematic overestimation during 21-25 May corresponds to a period of continuous rainfall. To provide an evaluation focused on the normal conditions, we also calculated the statistics for non-rainy periods only, where the model performance improved further (IOA = 0.70, NMB = -5%, RMSE = 0.21 ppbv).*

*Figure 3b illustrates that the REV case successfully captured the higher HONO concentrations observed around noon. The Pearson's correlation coefficient (R) between the measurements and simulations increased from 0.657 (BASE) to 0.763 (REV). The REV simulation accurately captured the timing of the observed diurnal peak around 14:00, which the BASE case simulates several hours too early.*

***Revisions in Figure 3b:***




5. Why do the authors not consider the removal pathway of HONO deposition, especially since nighttime HONO removal is mainly the deposition process.

   **Response:** Thank you for this insightful comment. This is an excellent point. We fully agree that dry deposition is an important sink for HONO, particularly during nighttime. In our source-oriented method (SOM) analysis, the focus was specifically on quantifying the contributions from various chemical production and loss pathways, which is why deposition was not explicitly tracked as a sink in the budget analyses (Grell et al., 2005). However, the dry deposition process for HONO and other species is indeed calculated online within the standard WRF-Chem framework and contributes to the overall simulated concentrations. We have rephrased the relevant texts in the revised manuscript to acknowledge the importance of deposition as a nighttime sink for HONO.

   ***Revisions in Section 2.3:***

   *We also quantified two HONO chemical sink pathways: photodissociation of HONO (HONO+hv) as well as OH-oxidation removal (HONO+OH). Additionally, it should be noted that dry deposition, an important sink for HONO especially at night, is calculated within the standard WRF-Chem deposition module but was not explicitly tracked in this chemical budget analysis since our focus here was on chemical pathways.*

6. The authors should provide $PM_{2.5}$ concentrations to support the conclusion that $NO_2$ heterogeneous reactions on the aerosol surface contribute little.

   **Response:** Thank you for this constructive suggestion. We do agree with you that $PM_{2.5}$ data would strengthen our conclusion. While $PM_{2.5}$ mass concentration was not measured during this campaign, our model simulates a regional average $PM_{2.5}$ concentration of approximately 11.9 μg $m^{-3}$, which is significantly lower than those typical concentrations in inland regions of China. We have added this simulated value and a brief discussion to the revised manuscript to support our point that the contribution from the heterogeneous uptake of $NO_2$ on aerosol surfaces is limited in clean coastal environment.

***Revisions in Section 3.3.1:***

*Similarly, the contribution from the heterogeneous $NO_2$ uptake on aerosol surfaces (1–2%) was lower than that reported for inland areas (3–20%), because of lower particle concentrations in coastal regions. The WRF-Chem model shows that the average $PM_{2.5}$ concentration over the coastal areas of Fujian was 11.9 μg $m^{-3}$ during the study period, which is categorized into the clean state and is much lower than the levels in typical inland regions.*

7. In the updated HONO sources, the parameter values should be explicitly provided or the calculation process shown. For example, how were the S/V of ground and aerosol surfaces calculated?

   **Response:** Thanks for your careful reminder. We have added the illustration of calculating the key parameter surface area density (*S/V*) for the ground surface and aerosol surfaces in the method section as you suggested.

   ***Revisions in Section 2.3:***

   *$S_a/V$ and $S_g/V$ are aerosol and ground surface area densities ($m^2$ $m^{-3}$), respectively. $S_a/V$ could be calculated through the MOSAIC aerosol module, which categorized different types of aerosols into four size bins ranging from 3.9 nm to 10 μm, i.e. 0.039-0.156 μm, 0.156-0.625 μm, 0.625-2.500 μm and 2.500-10.000 μm (Zaveri et al., 2008). $S_g/V$ was derived based on the underlying surface category. In vegetation grid cells, $S_g/V$ was estimated as the ratio of the two-fold of leaf area index (LAI, $m^2$ $m^{-2}$) to the model height of the first layer (Zhang et al., 2016). For urban areas, the ground surface area density $S_g/V$ was empirically set from 0.1 to 0.3 depending on the fraction of urban area using a linear formula (Zhang et al., 2024). It is noted that the model only accounts for heterogeneous uptake of $NO_2$ on ground surface in the first layer, while the reaction on aerosol surfaces occurs in all model layers.*

8. In Section 3.3.2 the authors explain "…meaning that shipping emissions contributed less to coastal NOx during the daytime." However, the daytime HONO production rate is relatively high. In theory, as an important precursor of HONO, if the impact of NOx from shipping emissions is low, even if there are light-enhanced reactions, the HONO production rate should be limited. Therefore, the high daytime HONO production rate cannot be explained by "light-dependent reaction pathways." At the same time, the explanation in Section 3.3.3 is also not valid.

   **Response:** Thanks for your conducive comments and we acknowledge the need for a clearer explanation. While the relative contribution of shipping emissions to the total $NO_x$ concentration is lower during the daytime, the absolute concentration of $NO_x$ from both shipping and continental sources remains sufficient to fuel HONO production. The dramatic increase in the HONO production rate is driven by the enhanced efficiency of light-dependent pathways. Therefore, the high production rate is a consequence of sufficient precursor availability combined with high photochemical conversion efficiency. We have rephrased the relevant texts in the revised manuscript to for clarity.

   ***Revisions in Section 3.3.3:***

   *The captured high HONO concentrations over the study region between 11:00 and 14:00 were attributed to the increase in chemical production rates (see Figures 5a and 7a). There are two main factors. One is a sufficient supply of $NO_x$ precursors from both continental and shipping emission sources that, even while being at a diurnal minimum around noon, remains ample to fuel the subsequent reactions. The other is an enhanced reaction rate of light-dependent pathways under intense solar radiation.*

9. Sensitivity analysis was not sufficiently carried out. The authors should scale the various parameters used by a certain proportion and then analyze how this parameter change affects the contribution of HONO sources or the impact on $OH/O_3$ concentrations. The uncertainty analysis in Section 3.5 is not an explanation of the reasons for the parameter values, but should involve sensitivity experiments for the parameter values and discussion of their impact on HONO production rate, OH and $O_3$.

   **Response:** We thank the reviewer for this constructive suggestion. Among those parameters used in this study, the $HONO/NO_x$ ratio was based on long-term observations in Fujian and was representative (Hu et al., 2022). Similarly, our parameterizations for heterogeneous $NO_2$ uptake on the ground surface (varying between $10^{-6}$ to $10^{-5}$) and nitrate photolysis were set to robust and median-level values widely used in previous studies (Fu et al., 2019; Wang et al., 2025; Zhang et al., 2021). This leaves the uptake coefficient of $NO_2$ on aerosol surfaces ($\gamma_a$) as the parameter with the largest uncertainty in our scheme, for which we adopted an upper-limit value to represent the maximum light-enhanced process. Following your suggestion, we have conducted two additional sensitivity experiments to quantitatively assess the impact of this highly uncertain parameter. Specifically, we reduced the maximum daytime $\gamma_a$ by one and two orders of magnitude, respectively. To balance computational cost and storage, these new simulations were performed for the first seven days of our study period. Model results show that while lowering the $\gamma_a$ value does lead to a corresponding decrease in the HONO production rate from the heterogeneous uptake of $NO_2$ by aerosols, the impact on the overall HONO budget is negligible. The average daytime HONO concentration decreased by less than 2 pptv, a relative change of less than 1%. This finding provides quantitative support for our argument that due to the low aerosol abundance in this coastal region, the heterogeneous aerosol pathway contributes minimally to HONO formation, regardless of the precise $\gamma_a$ value. Consequently, the responses in $O_3$ and OH concentrations were also minimal. This confirms that our use of $1\times10^{-3}$ as an upper-limit for $\gamma_a$ is a reasonable choice and does not compromise the main conclusions of our study. We have incorporated this new analysis into the revised manuscript. We thank you again for this valuable suggestion.

**Table R1.** Influences of different $\gamma_a$ on daytime production rates, concentrations of HONO, and concentrations of ambient oxidants.

| Case | Maximum daytime $\gamma_a$ | Production rate from Hete_$NO_2$ on aerosols (ppbv $h^{-1}$) | HONO (ppbv) | $O_3$ (ppbv) | OH ($\times10^6$ molecules $cm^{-3}$) |
|---|---|---|---|---|---|
| REV | $1\times10^{-3}$ | 0.0156 | 0.223 | 40.3 | 6.1 |
| Sens1 | $1\times10^{-4}$ | 0.0016 | 0.221 | 40.4 | 6.1 |
| Sens2 | $1\times10^{-5}$ | 0.0002 | 0.221 | 40.4 | 6.1 |

***Revisions in Section 3.5:***

*Several uncertainties exist in the HONO simulations presented in this study, firstly related to the parameterization of key chemical pathways. These are mainly concentrated in the heterogeneous uptake coefficients and the nitrate aerosol photolysis rate. For the nitrate photolysis frequency, Zhang et al. (2022)*

*summarized that this value is approximately 1-3 orders of magnitude higher than the photolysis frequency of $HNO_3$. Our study adopted a median value of this range ($120J_{HNO3}$), which was inferred based on aircraft measurements in the North Atlantic marine boundary layer and has been widely used in previous studies (Fu et al., 2019; Ye et al., 2016; Zhang et al., 2021). For the heterogeneous uptake of $NO_2$ on solid surfaces, the dimensionless uptake coefficient typically ranges from $10^{-6}$ to $10^{-3}$. For the ground surface, we also applied a representative median value, with this coefficient varying from a nighttime baseline in the $10^{-6}$ range up to a maximum of $6\times10^{-5}$ under peak sunlight (Wang et al., 2025). For the aerosol surfaces, we set the maximum daytime value to $1\times10^{-3}$, an upper limit reported in the literature, which carries a potential uncertainty. To quantitatively assess the impact of this choice, we conducted an additional sensitivity analysis where the uptake coefficient $\gamma_a$ was reduced to $1\times10^{-4}$ and $1\times10^{-5}$, respectively. To minimize the computational burden, these simulations were performed for the first seven days of our study period. As shown in Table S4, model results show that while lowering the $\gamma_a$ value does lead to a corresponding decrease in the HONO production rate from the heterogeneous uptake of $NO_2$ by aerosols, the impact on the overall HONO budget is negligible. The average daytime HONO concentration decreased by less than 2 pptv, a relative change of less than 1%. This finding provides quantitative support for our argument that due to the low aerosol abundance in this coastal region, the heterogeneous aerosol pathway contributes minimally to HONO formation, regardless of the precise $\gamma_a$ value. Consequently, the responses in $O_3$ and OH concentrations were also minimal. This confirms that our use of $1\times10^{-3}$ as an upper-limit for $\gamma_a$ is a reasonable choice and does not compromise the main conclusions of our study.*

10. L373-L374: After adding HONO sources in the model, the daytime maximum OH concentration increased to $12.1\times10^6$ molecules cm$^{-3}$, significantly higher than OH concentrations observed in southern China in May, which further challenges the rationality of the parameter values in the updated HONO parameterization scheme. It also shows that the enhancement effect of HONO on $O_3$ in this study is significantly higher than previously reported ranges, which should also be considered in terms of the rationality of the parameters used.

    **Response:** We thank the reviewer for this critical point. We acknowledge that the lack of direct OH radical measurements at our site in Fujian prevents a direct validation of the simulated concentrations. Following your suggestion, we have reviewed previous observational studies of OH radicals in China to provide context for our modeling results. A comparison conducted by Ma et al. (2022) summarized five systematic OH radical measurement campaigns across major polluted regions in China, including the North China Plain, the Yangtze River Delta, and the Pearl River Delta. As shown in Figure R1, their results show that the observed noon-time OH concentrations range from $4\times10^6$ molecules $cm^{-3}$ to $13\times10^6$ molecules $cm^{-3}$. Our simulated daily maximum OH concentration ($12.1\times10^6$ molecules $cm^{-3}$) falls near the upper end of this observed range. While this comparison suggests our simulated value is not outside the range of concentrations measured in other photochemically active environments in China, we agree that further validation against local, in-situ measurements is essential to assess the reasonableness of the updated HONO parameterization scheme. We have revised the manuscript to include this important discussion.

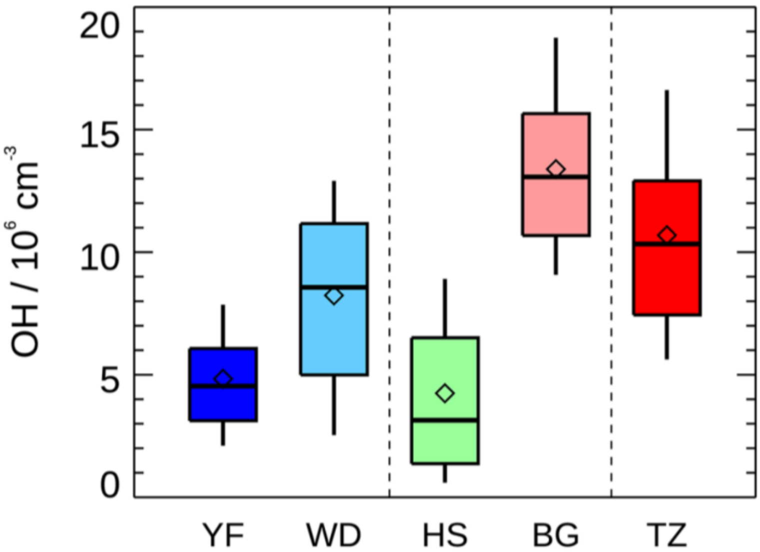



**Figure R1.** Summary of OH radical concentrations (noontime, 11:00–13:00) measured in five summer field campaigns in China. Yufa (YF) and Wangdu (WD) campaigns in the North China Plain, Heshan (HS) and Backgarden (BG) campaigns in the Pearl River Delta, and Taizhou (TZ) campaign in Yangtze River Delta. The box–whisker plot shows the 90th, 75th, 50th, 25th, and 10th percentile values of noon OH radical concentrations in each campaign. The diamond shows the mean values of noon OH radical concentrations. This figure was directly obtained from Ma et al. (2022).

Regarding the $O_3$ enhancement, while the relative increase (44%) is high, we emphasize that the absolute increase (~9.9 ppbv) is consistent with many previous studies (Table 4). The high relative increase is attributed to the fact that the BASE case severely underestimated $O_3$ concentrations, leading to a very low baseline. The REV case corrects this bias and makes $O_3$ levels much closer to observations, highlighting the critical role of HONO chemistry in this coastal environment. To make this point clearer, we have added a discussion in the revised manuscript.

***Revisions in Section 3.4.1:***

*Concurrently, the daily maximum OH concentration rose from 7.5×$10^6$ molecules $cm^{-3}$ (BASE) to 12.1×$10^6$ molecules $cm^{-3}$ (REV). Measurements of OH radicals were not available in this study for a direct model validation. However, a comprehensive study presenting OH measurements from five field campaigns in China reported that observed noon-time peak OH concentrations range from 4×$10^6$ molecules $cm^{-3}$ to 13×$10^6$ molecules $cm^{-3}$ across the NCP, YRD, and PRD regions (Ma et al., 2022). The daily maximum OH concentration simulated in our study falls near the upper end of this observed range. While this suggests our simulated value is within the scope of previously measured concentrations in other photochemically active regions of China, we acknowledge that future validation with local measurements is crucial to fully confirm the reasonableness of the updated HONO chemistry.*

***Revisions in Section 3.4.2:***

*While the relative enhancement of 44% appears high, it is largely a consequence of correcting the significant underestimation of $O_3$ in the BASE simulation. The absolute increase is in line with the values reported by many previous modeling studies, emphasizing the importance of including complete HONO sources as possible in 3D models to accurately simulate coastal $O_3$.*

11. The authors quantified the increments of HONO, NOx, and $NO_3^-$ from shipping emissions, but there is a lack of spatial comparison analysis with actual shipping routes/port areas. It is recommended to add route or port distribution maps in the SI, and group the analysis by wind direction, to explore the modulation effect of nearshore $O_3$ return/reaction on HONO and NOx.

    **Response:** Thanks for this constructive comment. This is an excellent suggestion to improve our analysis. In the revised manuscript, we have added a map of the major shipping routes and ports (please refer to Figure R2), which was obtained from the team at Tsinghua University who developed the shipping emission inventory model (Wang et al., 2021).

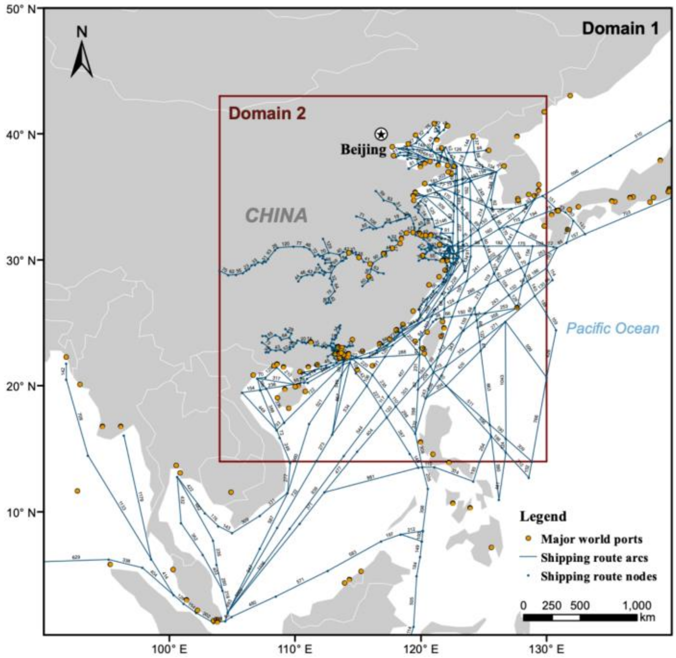



**Figure R2.** The spatial distribution of shipping route network and major ports around China. The figures next to the shipping route arcs are the geodesic distances calculated from the ArcGIS tool. This map was directly obtained from Wang et al. (2021).

Regarding the nearshore $O_3$ return, we consider that this process is primarily driven by local sea-land breeze (SLB) circulation. Following the criteria from Liu et al. (2025), we performed an analysis to identify SLB events during our study period. Specifically, an effective SLB cycle requires distinct land (01:00-08:00) and sea (13:00-20:00) breeze phases, with region-specific directional criteria (sea breezes from 50°-220°; land breezes from 240°-40° for coastal Fujian), minimum duration requirements (≥ 4 hours), and exclusion of strong synoptic winds (>10 m $s^{-1}$). As illustrated in Figure R3a, our analysis reveals that a classic SLB event occurred on only one day during the entire one-month study period (May 30$^{th}$). A further analysis of the large-scale atmospheric circulation (Figure R3b) confirms that for most of the period, the coastal region of Fujian was dominated by a persistent northeasterly synoptic flow. This synoptic pattern suppressed the formation of local, thermally-driven circulations, thus limiting their overall role in transport. This analysis directly addresses the reviewer's suggestion to group the analysis by wind direction. It demonstrates that the dominant transport regime during our study was a consistent synoptic flow, not a recurring local SLB circulation. Our WRF-Chem model simulates these atmospheric transport processes, meaning the net effect of both the dominant synoptic winds and any intermittent local circulations is inherently accounted for in our monthly average results. Therefore, our monthly scale assessment is representative of the prevailing conditions, and a separate, detailed analysis focusing only on the single anomalous SLB day would not be representative of the entire period. To make these points clearer, we have incorporated this analysis into the revised manuscript. We would like to express our gratitude again for this insightful suggestion.

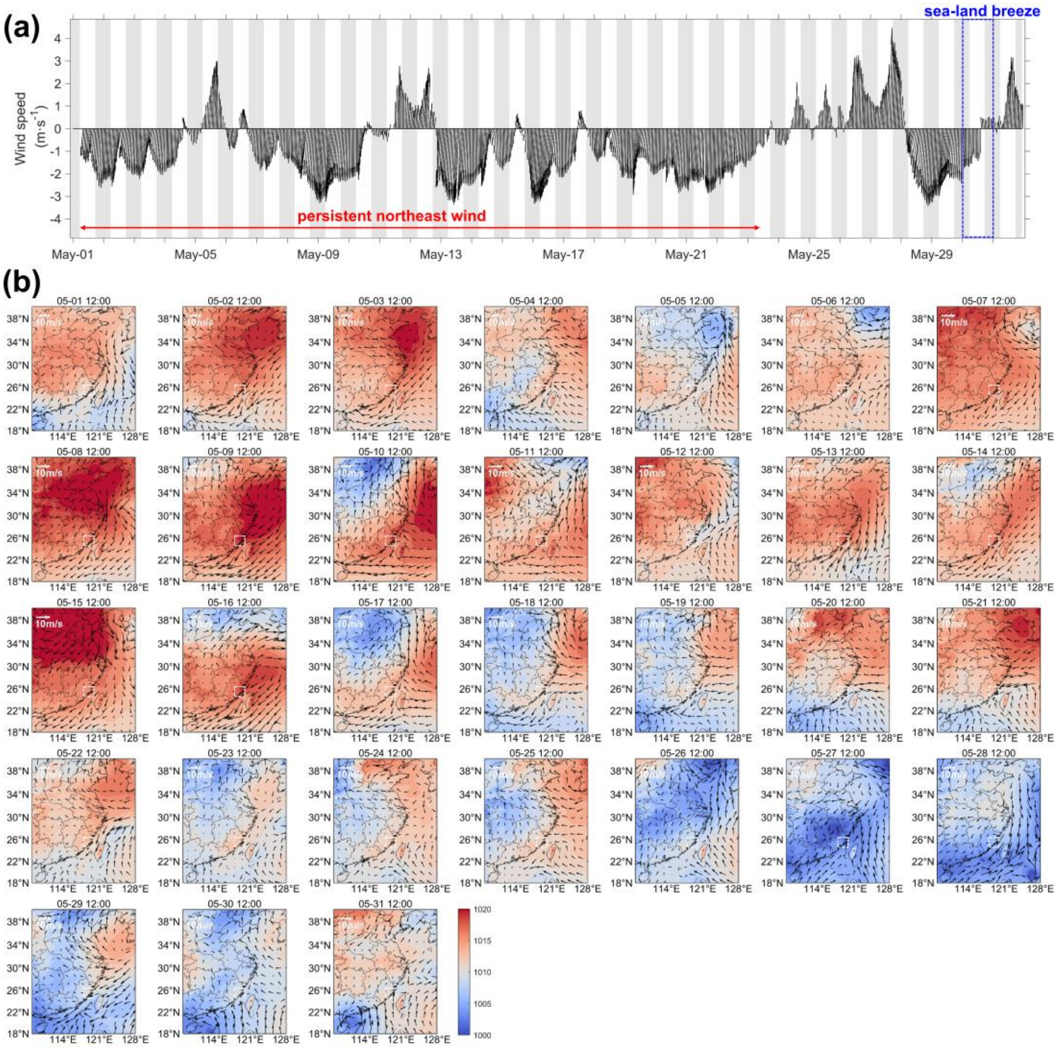



**Figure R3.** Wind fields during the study period. Panel (a) shows the temporal variations of wind vectors at the site DZSK. The shaded areas represent the nighttime (19:00 to 6:00). Panel (b) illustrates the spatial pattern of the sea level pressure (hPa) and the surface wind field at 12:00 on each day in May 2024.

***Revisions in Section 3.3.2:***

*The impact of the shipping emissions is based on the atmospheric transport of air pollutants from the upstream region. Specifically, the regional transport is driven by both background circulation and local circulations such as sea-land breeze (SLB). Following the criteria of SLB given by Liu et al. (2025), we identified SLB events over the study region based on the local wind field data exhibited in Figure*

*2. The further analysis of wind fields demonstrates that the study area is less affected by the SLB. The impact of shipping emissions on HONO formation was mainly attributed to the transport effect of regional persistent northeasterly wind.*

12. Some minor errors: L45 "organic volatile organic compounds (VOCs)" is incorrect; L107 misstates, not Fig. 2b; where is Fig. 3c; L349-L350 and L363-L365 both mention the average daily OH radical production rate, but the values are completely different. The authors should carefully check and distinguish them.

    **Response:** We sincerely thank the reviewer for the careful reading and pointing out these errors. We have made the following corrections: (1) "organic volatile organic compounds" has been corrected to "volatile organic compounds"; (2) the reference to Fig. 2b has been corrected to Fig. 1b; (3) the reference to Fig. 3c is a typo and has been corrected to Fig. 3b; (4) Regarding the two different OH production rates, we have clarified the text to explicitly state that the value of 2.61 ppbv $h^{-1}$ represents the total OH production rate, which includes the dominant secondary conversion from $HO_2$+NO , while the value of 1.52 ppbv $h^{-1}$ represents the average rate from primary sources only during the daytime.

    ***Revisions in Section 3.4.1:***

    *Generally, the average daytime production rate of OH from primary sources in the coastal regions of Fujian was estimated to be 1.52 ppbv $h^{-1}$.*

**References**

Dunlea, E. J., Herndon, S. C., Nelson, D. D., Volkamer, R. M., Martini, F. S., Sheehy, P. M., Zahniser, M. S., Shorter, J. H., Wormhoudt, J. C., Lamb, B. K., Allwine, E. J., Gaffney, J. S., Marley, N. A., Grutter, M., Marquez, C., Blanco, S., Cardenas, B., Retama, A., Villegas, C. R. R., Kolb, C. E., Molina, L. T., and Molina, M. J.: Evaluation of nitrogen dioxide chemiluminescence monitors in a polluted urban environment, Atmos Chem Phys, 2007.

Fu, X., Wang, T., Zhang, L., Li, Q., Wang, Z., Xia, M., Yun, H., Wang, W., Yu, C., Yue, D., Zhou, Y., Zheng, J., and Han, R.: The significant contribution of HONO to secondary pollutants during a severe winter pollution event in southern China, Atmospheric Chem. Phys., 19, 1–14, https://doi.org/10.5194/acp-19-1-2019, 2019.

Grell, G. A., Peckham, S. E., Schmitz, R., McKeen, S. A., Frost, G., Skamarock, W. C., and Eder, B.: Fully coupled "online" chemistry within the WRF model, Atmos. Environ., 39, 6957–6975, https://doi.org/10.1016/j.atmosenv.2005.04.027, 2005.

Hu, B., Duan, J., Hong, Y., Xu, L., Li, M., Bian, Y., Qin, M., Fang, W., Xie, P., and Chen, J.: Exploration of the atmospheric chemistry of nitrous acid in a coastal city of southeastern China: results from measurements across four seasons, Atmospheric Chem. Phys., 22, 371–393, https://doi.org/10.5194/acp-22-371-2022, 2022.

Kurtenbach, R., Becker, K. H., Gomes, J. A. G., Kleffmann, J., Lörzer, J. C., Spittler, M., Wiesen, P., Ackermann, R., Geyer, A., and Platt, U.: Investigations of emissions and heterogeneous formation of HONO in a road traffic tunnel, Atmos. Environ., 35, 3385–3394, https://doi.org/10.1016/S1352-2310(01)00138-8, 2001.

Liu, C., Wang, H., Li, L., Chen, X., Lu, X., and Fan, S.: Impacts of sea-land breeze on the coastal ozone in the Pearl River Delta, China, J. Environ. Sci., https://doi.org/10.1016/j.jes.2025.08.037, 2025.

Liu, Y., Lu, K., Li, X., Dong, H., Tan, Z., Wang, H., Zou, Q., Wu, Y., Zeng, L., Hu, M., Min, K.-E., Kecorius, S., Wiedensohler, A., and Zhang, Y.: A Comprehensive Model Test of the HONO Sources Constrained to Field Measurements at Rural North China Plain, Environ. Sci. Technol., 53, 3517–3525, https://doi.org/10.1021/acs.est.8b06367, 2019a.

Liu, Y., Nie, W., Xu, Z., Wang, T., Wang, R., Li, Y., Wang, L., Chi, X., and Ding, A.: Semi-quantitative understanding of source contribution to nitrous acid (HONO) based on 1 year of continuous observation at the SORPES station in eastern China, Atmospheric Chem. Phys., 19, 13289–13308, https://doi.org/10.5194/acp-19-13289-2019, 2019b.

Ma, X., Tan, Z., Lu, K., Yang, X., Chen, X., Wang, H., Chen, S., Fang, X., Li, S., Li, X., Liu, J., Liu, Y., Lou, S., Qiu, W., Wang, H., Zeng, L., and Zhang, Y.: OH and $HO_2$ radical chemistry at a suburban site during the EXPLORE-YRD campaign in 2018, Atmospheric Chem. Phys., 22, 7005–7028, https://doi.org/10.5194/acp-22-7005-2022, 2022.

Wang, L., Chai, J., Gaubert, B., and Huang, Y.: A review of measurements and model simulations of atmospheric nitrous acid, Atmos. Environ., 347, 121094, https://doi.org/10.1016/j.atmosenv.2025.121094, 2025.

Wang, X., Yi, W., Lv, Z., Deng, F., Zheng, S., Xu, H., Zhao, J., Liu, H., and He, K.: Ship emissions around China under gradually promoted control policies from 2016 to 2019, Atmospheric Chem. Phys., 21, 13835–13853, https://doi.org/10.5194/acp-21-13835-2021, 2021.

Ye, C., Zhou, X., Pu, D., Stutz, J., Festa, J., Spolaor, M., Tsai, C., Cantrell, C., Mauldin, R. L., Campos, T., Weinheimer, A., Hornbrook, R. S., Apel, E. C., Guenther, A., Kaser, L., Yuan, B., Karl, T., Haggerty, J., Hall, S., Ullmann, K., Smith, J. N., Ortega, J., and Knote, C.: Rapid cycling of reactive nitrogen in the marine boundary layer, Nature, 532, 489–491, https://doi.org/10.1038/nature17195, 2016.

Zaveri, R. A., Easter, R. C., Fast, J. D., and Peters, L. K.: Model for Simulating Aerosol Interactions and Chemistry (MOSAIC), J. Geophys. Res., 113, D13204, https://doi.org/10.1029/2007JD008782, 2008.

Zhang, H., Ren, C., Zhou, X., Tang, K., Liu, Y., Liu, T., Wang, J., Chi, X., Li, M., Li, N., Huang, X., and Ding, A.: Improving HONO Simulations and Evaluating Its Impacts on Secondary Pollution in the Yangtze River Delta Region, China, J. Geophys. Res. Atmospheres, 129, e2024JD041052, https://doi.org/10.1029/2024JD041052, 2024.

Zhang, J., Lian, C., Wang, W., Ge, M., Guo, Y., Ran, H., Zhang, Y., Zheng, F., Fan, X., Yan, C., Daellenbach, K. R., Liu, Y., Kulmala, M., and An, J.: Amplified role of potential HONO sources in O3 formation in North China Plain during autumn haze aggravating processes, Atmospheric Chem. Phys., 22, 3275–3302, https://doi.org/10.5194/acp-22-3275-2022, 2022.

Zhang, L., Wang, T., Zhang, Q., Zheng, J., Xu, Z., and Lv, M.: Potential sources of nitrous acid (HONO) and their impacts on ozone: A WRF-Chem study in a polluted subtropical region, J. Geophys. Res. Atmospheres, 121, 3645–3662, https://doi.org/10.1002/2015JD024468, 2016.

Zhang, S., Sarwar, G., Xing, J., Chu, B., Xue, C., Sarav, A., Ding, D., Zheng, H., Mu, Y., Duan, F., Ma, T., and He, H.: Improving the representation of HONO chemistry in CMAQ and examining its impact on haze over China, Atmospheric Chem. Phys., 21, 15809–15826, https://doi.org/10.5194/acp-21-15809-2021, 2021.