We would like to thank the reviewer for the constructive comments really helping to improve the paper. Below, we address each comment in full detail. Following the Reviewers' comments in black, please find our point-to-point responses in blue. Hereafter, all new added or modified sentences are marked in blue and italic in this response. The line numbers in the responses to comments are in accordance with the revised manuscript.

Q1： Many thanks for your efforts to improve the manuscript (and to Reviewers for the insightful discussion). The manuscript is now approaching the quality standard required by TC for publication. However, as a result of the second round of review, one more issue was identified which should be addressed prior to publication being possible: assessing the mechanism's regional impacts using independent observations (e.g., O3, PM2.5), where the simulated changes are sufficiently large to be meaningfully evaluated. The response to second round of review and manuscript corrections (if applicable) will be further assessed before a final decision is made.

Response: We thank the reviewer for the constructive suggestion. To assess the regional impacts of the revised mechanism with independent observations, we conducted a quantitative evaluation using the DLS station, an independent field site in Northeast China operated by the Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences. For both $PM_{2.5}$ and O_3, we compared the default (Y0) and revised (Y3) scenarios against the observed time series at the station (Figure S1).

The statistical indicators (Table S5) demonstrate a clear improvement in the revised scheme:

For $PM_{2.5}$: The mean bias (MB) improves from –10.56 to –1.39 μg/m^3, and the normalized mean bias (NMB) reduces from –22.33% to –2.93%, indicating that the systematic underestimation is virtually eliminated. The root mean square error (RMSE) drops from 37.09 to 24.54 μg/m^3, while the index of agreement (IOA) increases from 0.68 to 0.91, reflecting much better temporal coherence.

For O_3: The MB decreases from 19.42 to 13.91 μg/m^3 (NMB from 35.05% to 25.11%), and RMSE is reduced from 29.46 to 26.04 μg/m^3. The IOA improves from 0.72 to 0.77, suggesting that the revised scheme better captures the observed O_3 variability.

These quantitative metrics confirm that the revised mechanism yields significantly smaller biases and errors, and substantially higher agreement with the independent observations. The simulated changes induced by the mechanism are thus consistent with the observed magnitude and timing at this key regional site, supporting the credibility of our model-based conclusions on regional impacts.

Accordingly, we have revised and supplemented the manuscript in lines 311–317 as follows:

"*In addition, we further examine the effects of the revised model on secondary pollutants ($PM_{2.5}$ and O_3) at this site, which are also pronounced. For $PM_{2.5}$ the MB improves from –10.56 to –1.39 μg/m^3, and the IOA increases from 0.68 to 0.91; for O_3, the MB decreases from 19.42 to 13.91 μg/m^3, while the IOA improves from 0.72 to 0.77 (Table S5). These findings underscore that the updated parameterization not only refines $ClNO_2$ simulation but also yields significant improvements in simulating secondary aerosol and ozone formation.*"

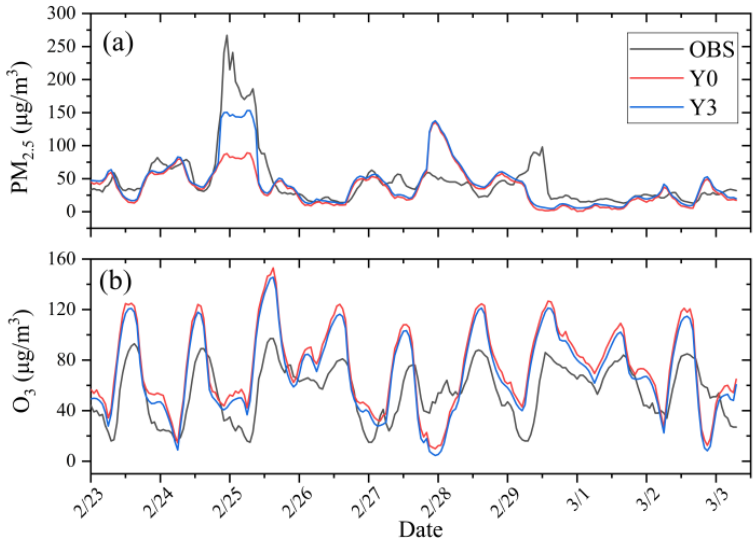

Figure S1 Comparison of simulated and observed values for YU20_A (Y0) and YU_A_G_Chl (Y3) the DLS station in Northeast China: (a) $PM_{2.5}$, (b) O_3.

Table S5 Statistical indicators for the simulation results of $PM_{2.5}$ and O_3 between Y0 and Y3 scenarios.

Species	Schemes	MB	NMB (%)	RMSE	IOA
$PM_{2.5}$	Y0 (default)	-10.56	-22.33	37.09	0.68
	Y3 (revised)	-1.39	-2.93	24.54	0.91
O_3	Y0 (default)	19.42	35.05	29.46	0.72
	Y3 (revised)	13.91	25.11	26.04	0.77