Response to the reviewers' comments on "Species-resolved inventory of forest biogenic volatile organic emissions across China with MEGAN v3.2"

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We sincerely thank editor and five reviewers for dedicating your time to read our manuscript and present important comments. We carefully studied these comments and revised the manuscript accordingly. Replies to these comments are listed point by point below. To make it easy to track our revisions, all modified texts are marked in red in the revised manuscript.

1. **We strengthened the evaluation against observed BVOC fluxes.** We added seasonal statistics and time-series comparisons of species-resolved and PFT-based simulations at four forest sites and moved the evaluation table into the main text. These analyses better demonstrate the benefits of species-level refinement and identify remaining discrepancies across compounds, sites, and seasons.

2. **We added a PFT-based SOA simulation for direct comparison.** Both configurations are now evaluated against 32 observational records from 30 sites, grouped into urban, rural, and background environments. The revised Figure 7 and Table 3 document improvements in correlation and overall error while acknowledging persistent underestimation. We also discuss specific potential causes, including precursor emissions, anthropogenic-biogenic interactions, aqueous-phase chemistry, and gas-particle partitioning.

3. **We improved the traceability and reproducibility of the emission inventory.** We clarified emission-factor selection, specific leaf area conversion, and the species-genus-family substitution hierarchy. The Appendix now provides representative assignment examples, sesquiterpene emission factors, and supporting references. The model code and individual emission inventories for all 234 tree species have also been archived on Zenodo.

4. **We clarified the scenario design and its limitations.** We explained the distinct purposes of the multi-year inventories, single-year species-attribution calculations, and paired SOA simulations. We also documented the delineation of the common 78 Mha afforestation area, clarified the MEGAN canopy formulation and emission units, and expanded the discussion of mixed-stand allocation, specific leaf area uncertainty, and the fixed meteorological baseline.

5. **We strengthened the interpretation of emission patterns and their management implications.** We added evergreen-deciduous comparisons and linked regional emission patterns to species-specific emission capacity and climatic controls. We now prominently highlight the contrast between isoprene-dominated increments under BIO and monoterpene-dominated increments under SUIT. The concluding discussion emphasizes region-specific afforestation planning that jointly considers carbon sequestration, ecological suitability, and air quality.

Editor (Remarks to the Author):

although you provide the reference to a zenodo archive for the MEGAN code, I do not find a code availability section. Please add this before or after the data availability section in you article.

[Response] Thank you for pointing out this omission. We have added a separate "Code availability" section after the "Data availability" section (Lines 961-963). This section provides the Zenodo reference for the species-resolved MEGAN v3.2 model code used in this study, together with a link to the official MEGAN website for installation guidance and supporting documentation.

Lines 961-963:

"The species-resolved MEGAN v3.2 model code used in this study is publicly available at https://doi.org/10.5281/zenodo.21212755 (Liu et al., 2026). Installation guidance and supporting documentation are available from the official MEGAN website (https://bai.ess.uci.edu/megan)."

Reviewer #1 (Remarks to the Author):

[General Comments] This study presents an impressive dataset applicable for BVOC emissions modeling in China, providing estimates of tree species distribution maps, emission factor database along with improvements in LAI and land cover classification over China. The Appendix provides the EF's for isoprene and monoterpenes, while the associated Zenodo archive provides estimates of total BVOC emissions at grid box level. Some evaluation is provided by intercomparing emission isoprene emission fluxes at available measurement sites, as well as SOA concentrations. The isoprene emission totals are put into perspective by comparing them with literature values.

[Response] We appreciate the time and effort that you have dedicated to providing valuable feedback on our manuscript. Your constructive comments have helped us substantially improve the manuscript quality. Following your suggestions, additional experiments and substantial revisions have been made. Please find our detailed responses below.

While this manuscript is very valuable, and provides important input to the discussion of impact of different vegetation on the BVOC emissions in different scenarios, and to the science community by providing a compilation of EF's, still some aspects can be improved.

The evaluation section should be strengthened by giving more emphasis to the isoprene flux evaluation, which is the primary means of evaluation of the improvement obtained here. Presentation of the evaluation results in the Table should be promoted to the primary text rather than the Appendix.

[Response] We thank the reviewer for this constructive suggestion. We have strengthened Section 3.1, placing particular emphasis on isoprene fluxes as a direct test of the species-level emission update. To support this evaluation, the relevant statistics have been moved from the Appendix into Table 2 in the main text, which reports seasonal observed and simulated mean fluxes for each site. We have additionally included Figs. 3-6, showing time series of observed fluxes together with simulations from both Exist-SPE and Exist-PFT at the four monitoring sites.

The expanded analysis (Lines 411-460) shows that Exist-SPE consistently reduced isoprene MB and RMSE across seasons at DZ and QYZ, and improved monoterpene estimates at LA and CBM. However, these improvements were not uniform across all compounds and sites, and discrepancies in episodic high-flux events remained.

Lines 411-460:

"Site-specific analysis further showed how species-level emission factors affected the agreement between simulated and observed BVOC fluxes across seasons (Table 2). The DZ station (Fig. 3), dominated by *Hevea brasiliensis*, was classified as tropical broadleaf forest in the PFT scheme, with emission factors of 8.59 nmol m^{-2} s^{-1} for isoprene and 0.70 nmol m^{-2} s^{-1} for monoterpenes. These values deviated from the measured values (isoprene: 0.09 nmol m^{-2} s^{-1}; monoterpenes: 2.22 nmol m^{-2} s^{-1}), leading to an overestimation of isoprene and underestimation of monoterpenes emission, with mean biases of +1.87 and -1.65 mg m^{-2} h^{-1}. For isoprene (Fig. 3), observed fluxes showed a clear seasonal contrast, with higher means in spring and summer (1.04 and 1.15 mg m^{-2} h^{-1}, Table 2) than in autumn and winter (0.34 and 0.45 mg m^{-2} h^{-1}). Both the PFT-based and Exist-SPE configurations captured this broad seasonal pattern, but Exist-SPE consistently brought simulated magnitudes closer to observations across seasons. In summer, the simulated mean decreased from 3.55 to 2.15 mg m^{-2} h^{-1} and RMSE decreased from 2.89 to 1.55 mg m^{-2} h^{-1}; in winter, the mean decreased from 1.19 to 0.72 mg m^{-2} h^{-1} and RMSE decreased from 0.91 to 0.47 mg m^{-2} h^{-1}. This consistent improvement across seasons supports the use of a species-specific isoprene emission capacity for this rubber plantation. Monoterpene observations at DZ exhibited a different seasonal pattern (Fig. 3): the mean was lowest in summer (1.33 mg m^{-2} h^{-1}), whereas appreciable emissions persisted in autumn and winter (2.84 and 2.18 mg m^{-2} h^{-1}, Table 2). Exist-SPE alleviated the PFT-based underestimation in spring, autumn, and winter, although it did not reproduce the observed summer minimum. Thus, the species-level update improved the representation of the relatively low-isoprene, higher-monoterpene emission profile of this plantation, but did not fully capture its monoterpene seasonality.

At QYZ station, dominated by *Pinus massoniana*, observed isoprene and monoterpene fluxes both peaked in summer, but their responses to species-level parameterization differed (Fig. 4). For isoprene, observed mean fluxes increased from

0.084 mg m^{-2} h^{-1} in spring to 0.263 mg m^{-2} h^{-1} in summer before declining to 0.051 mg m^{-2} h^{-1} in autumn. By replacing the default PFT isoprene emission factor (8.30 nmol m^{-2} s^{-1}) with the species-specific value (0.39 nmol m^{-2} s^{-1}), more than an order of magnitude lower, Exist-SPE reduced MB by 65-71% and RMSE by 65-68% across all three seasons. The largest absolute improvement occurred in summer, when the simulated mean isoprene emission decreased from 2.45 to 0.90 mg m^{-2} h^{-1} and RMSE from 2.39 to 0.77 mg m^{-2} h^{-1}. For monoterpenes, both configurations reproduced the higher mean emissions in summer than others but underestimated episodic high fluxes (Fig. 4), with differences in RMSE between schemes ranging from 0.01 to 0.03 mg m^{-2} h^{-1} (Table 2). Thus, the evaluation at QYZ demonstrates a consistent reduction in isoprene bias and RMSE across the sampled seasons, whereas monoterpene performance remained broadly comparable between the two configurations.

At LA station, dominated by *Phyllostachys edulis*, the species-level update increased the isoprene emission factor from 11.50 to 23.65 nmol m^{-2} s^{-1} and decreased the monoterpene factor from 0.60 to 0.08 nmol m^{-2} s^{-1}, producing contrasting adjustments in simulated emissions (Fig. 5). Observed isoprene and monoterpene fluxes both declined from summer to winter, with seasonal means decreasing from 1.91 to 0.005 mg m^{-2} h^{-1} and from 0.03 to 0.006 mg m^{-2} h^{-1}, respectively. Both configurations reproduced this seasonal decline. For isoprene (Fig. 5), Exist-SPE more closely reproduced the amplitudes of some summer emission peaks, including the observed peak near 10 mg m^{-2} h^{-1} in July. For monoterpenes, Exist-SPE reduced the magnitude of MB and RMSE. In summer, the simulated mean decreased from 0.53 to 0.21 mg m^{-2} h^{-1} towards the observed 0.03 mg m^{-2} h^{-1}, while RMSE decreased from 0.53 to 0.20 mg m^{-2} h^{-1} (Table 2). The winter mean of 0.005 mg m^{-2} h^{-1} closely matched the observed 0.006 mg m^{-2} h^{-1}. Thus, the LA evaluation indicates improved representation of selected summer isoprene peak magnitudes and a consistent reduction in monoterpene errors across seasons (Fig. 5).

At the CBM station, dominated by a mixture of *Betula platyphylla*, *Populus davidiana*, and *Quercus mongolica*, isoprene exhibited a pronounced seasonal contrast, with mean flux declining by 83% from summer to autumn, whereas monoterpenes showed both lower flux magnitudes and a more modest seasonal decline of 44% (Fig. 6). Both configurations captured the direction of this seasonal transition. Summer isoprene was characterized by mean overestimation alongside underestimation of

several major emission peaks. Although Exist-SPE reduced the error at some peaks, it simultaneously increased the overall seasonal positive bias (Fig. 6), raising RMSE from 1.08 to 1.30 mg m^{-2} h^{-1} (Table 2). This result indicates that increasing emission capacity did not resolve the mismatch between mean fluxes and episodic maxima. For monoterpenes, the two simulated time series largely overlapped (Fig. 6); Exist-SPE reduced mean overestimation and lowered summer RMSE from 0.25 to 0.23 mg m^{-2} h^{-1} (Table 2), while both configurations underestimated several observed peaks."

Table 2. Comparison of simulated and observed BVOCs at four stations (mg m^{-2} h^{-1}).

Sites	Compounds	OBS	Exist-SPE			Exist-PFT		
			AVE	MB	RMSE	AVE	MB	RMSE
DZ-spring	ISOP	1.04	2.40	1.36	1.85	3.97	2.93	3.23
	MONO	3.70	1.86	-1.83	3.13	1.14	-2.55	3.61
DZ-summer	ISOP	1.15	2.15	1.00	1.55	3.55	2.40	2.89
	MONO	1.33	1.75	0.43	1.18	1.08	-0.25	1.06
DZ-autumn	ISOP	0.34	1.04	0.70	0.92	1.71	1.38	1.63
	MONO	2.84	1.16	-1.68	3.54	0.72	-2.12	3.71
DZ-winter	ISOP	0.45	0.72	0.28	0.47	1.19	0.75	0.91
	MONO	2.18	0.80	-1.38	3.63	0.50	-1.68	3.78
LA-summer	ISOP	1.91	5.36	3.45	4.17	3.87	1.96	2.81
	MONO	0.03	0.21	0.18	0.20	0.53	0.50	0.53
LA-	ISOP	0.13	1.11	0.97	1.24	0.80	0.67	0.86
autumn	MONO	0.02	0.06	0.05	0.06	0.16	0.14	0.17
LA- winter	ISOP	0.005	0.061	0.056	0.067	0.044	0.039	0.047
	MONO	0.006	0.005	-0.001	0.011	0.012	0.006	0.013
CBM-	ISOP	1.10	1.87	0.77	1.30	1.36	0.26	1.08
summer	MONO	0.18	0.27	0.10	0.23	0.30	0.12	0.25
CBM-	ISOP	0.19	0.69	0.50	0.65	0.50	0.31	0.45
autumn	MONO	0.10	0.12	0.02	0.07	0.13	0.03	0.07
QYZ-	ISOP	0.08	0.63	0.54	0.59	1.71	1.63	1.75

spring	MONO	0.36	0.38	0.02	0.32	0.47	0.11	0.34
QYZ-	ISOP	0.26	0.90	0.64	0.77	2.45	2.19	2.39
summer	MONO	0.70	0.54	-0.16	0.66	0.67	-0.03	0.65
QYZ-	ISOP	0.05	0.55	0.50	0.57	1.50	1.44	1.63
autumn	MONO	0.36	0.39	0.03	0.40	0.48	0.12	0.43

MB denotes mean bias, RMSE denotes root mean square error, Exist-SPE represents the species-level approach, and Exist-PFT represents the traditional plant functional type approach.

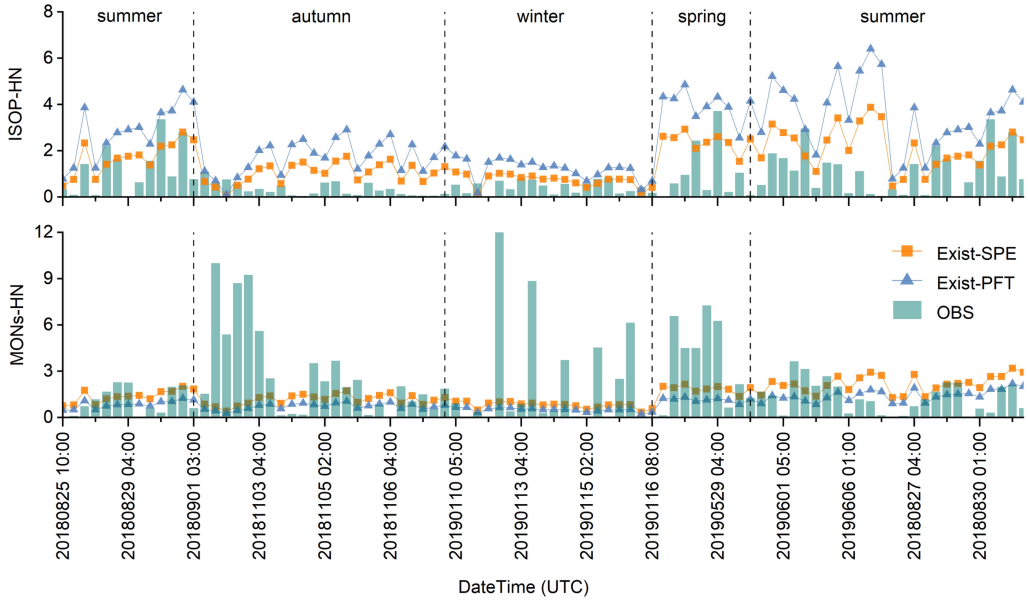

Figure 3 | Observed versus simulated isoprene and monoterpene emissions at Danzhou. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

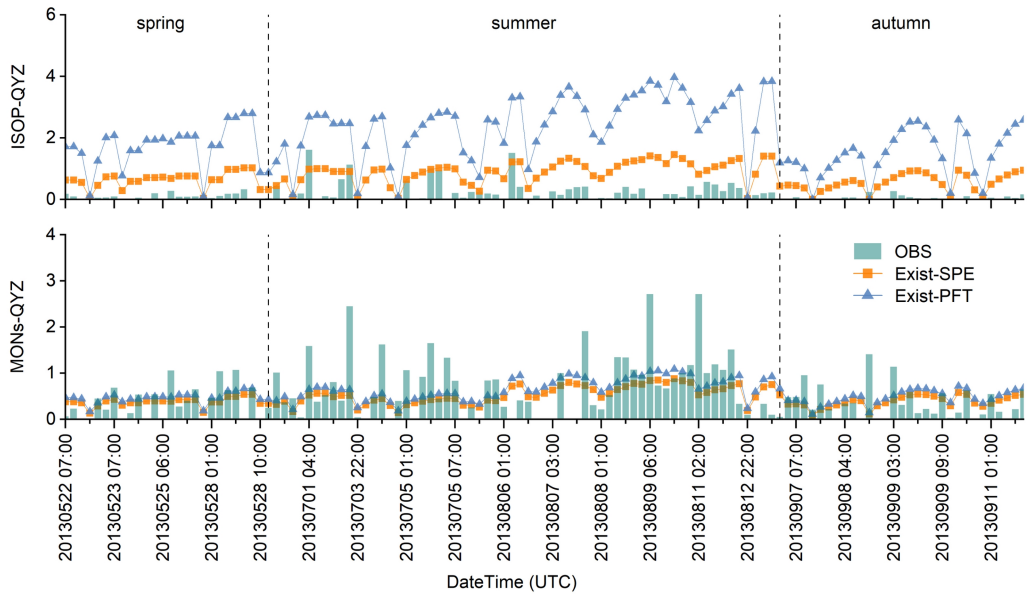

Figure 4 | Observed versus simulated isoprene and monoterpene emissions at Qianyanzhou. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

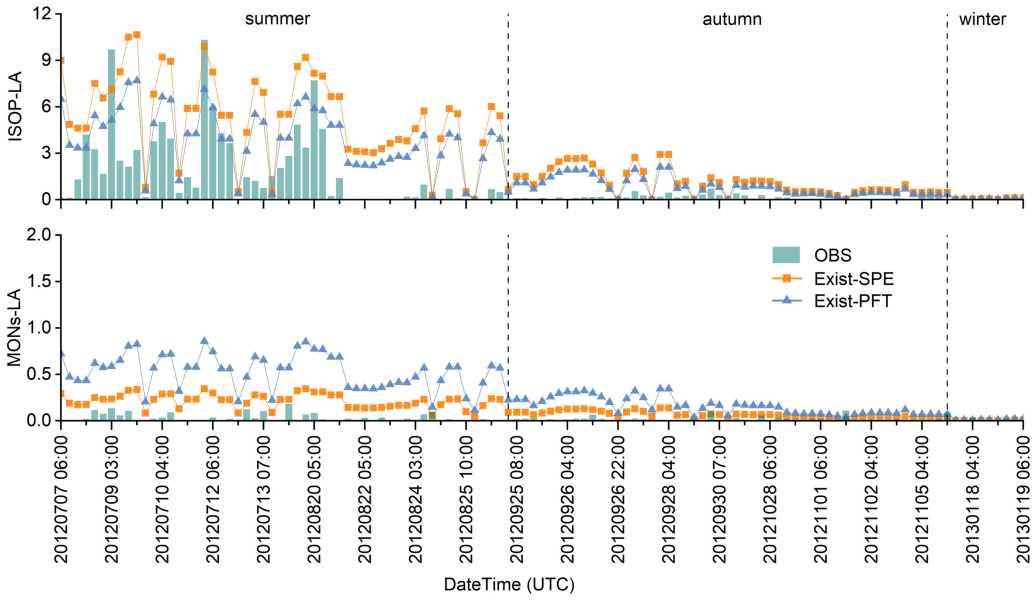

Figure 5 | Observed versus simulated isoprene and monoterpene emissions at Linan. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

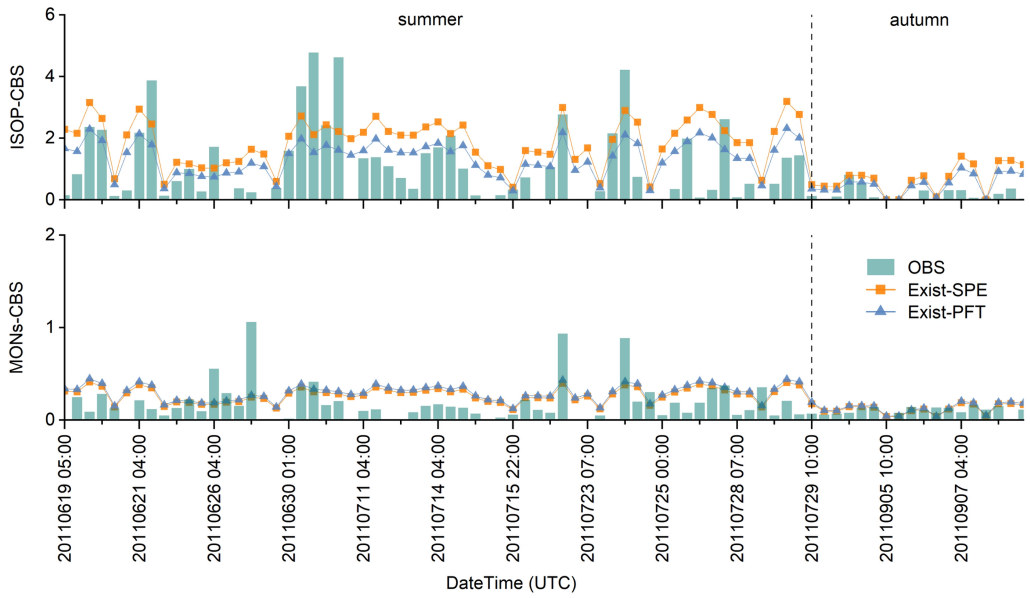

Figure 6 | Observed versus simulated isoprene and monoterpene emissions at Changbai. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

Contrary, the evaluation against SOA observations should either be strengthened as well, either by presenting, analyzing and intercomparing the results from different emission scenarios, and better understanding and interpretation of the observations and modeling errors, or alternatively giving this less weight by moving the results to the appendix.

[Response] We thank the reviewer for this suggestion. We have strengthened Section 3.2 and revised Fig. 7 by comparing the Exist-SPE and Exist-PFT simulations, examining model performance at urban, rural, and background sites, and expanding the literature-supported discussion of potential bias sources. The revised manuscript clarifies both the improvements achieved through species-level refinement and the remaining uncertainties (Line 493-558).

Line 493-558:

"To further evaluate the species-resolved BVOC emissions inventory (Exist-SPE), we integrated it into the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem; configuration detailed in Table S3) to simulate SOA over China in 2018. Simulated concentrations were evaluated against 32 ground-based observation records from 30 monitoring stations across China (Fig. 2), yielding a

positive correlation between simulations and observations (r = 0.55). The mean simulated concentration was 3.47 μg m^{-3}, compared with the observed mean of 4.72 μg m^{-3}, corresponding to a mean bias (MB) of -1.26 μg m^{-3} and a normalized mean bias of -26.64% (Fig. 7a). Beyond this overall underestimation, discrepancies across individual records were characterized by a root mean square error (RMSE) of 3.16 μg m^{-3} and a mean absolute error (MAE) of 2.39 μg m^{-3}. Model performance varied across sites over an observed concentration range of 0.81-15.40 μg m^{-3} (Fig. 7a). The relatively low concentrations at LZ and QMLM were reproduced, while simulated magnitudes closely matched observations at BJ, BN, SY, and JX. Nevertheless, concentrations were underestimated in 23 of the 32 records, with larger absolute deficits at several high-concentration sites (Fig. 7a). These included CD (simulated: 2.49 μg m^{-3} versus observed: 9.40 μg m^{-3}; difference: -6.91 μg m^{-3}), XT (3.01 versus 8.80; -5.79 μg m^{-3}), and PY (4.38 versus 12.50; -8.12 μg m^{-3}), highlighting the remaining difficulty in reproducing elevated SOA concentrations at these sites. Compared with Exist-PFT, Exist-SPE increased the correlation with observations from 0.52 to 0.55 while reducing MAE by 7.88% and RMSE by 2.61%, with MB remaining largely unchanged (-1.20 versus -1.26 μg m^{-3}, Fig. 7a). These results indicate that species-level refinement improved overall agreement across individual records, although systematic underestimation persisted.

To evaluate how model performance varied across sampling environments, the monitoring stations were classified into three categories: urban (13 stations), rural (6 stations), and background sites (11 stations, Fig. 7a), representing locations within or near cities, non-urban rural environments, and representative regional background conditions, respectively. The response to species-level refinement differed among the three groups. At urban and background sites, Exist-SPE yielded consistent improvements in agreement with observations, with correlation coefficients increasing from 0.40 to 0.53 and from 0.54 to 0.63, respectively, accompanied by corresponding reductions in error: urban MAE decreased from 3.16 to 2.55 μg m^{-3}, while background RMSE declined from 2.12 to 2.04 μg m^{-3}. At rural sites, the simulated mean approached the observed mean despite an increase in absolute error, suggesting a more complex response to the refined inventory.

The clearest improvement occurred at urban sites, where the correlation coefficient increased from 0.40 to 0.53 and MAE decreased from 3.16 to 2.55 μg m^{-3}. Exist-SPE reduced overestimation at HF, lowering the simulated concentration from 9.00 to 6.15

μg m^{-3} toward the observed 5.44 μg m^{-3}, while alleviating underestimation at XZ, where the simulation increased from 6.62 to 7.56 μg m^{-3} against the observed 9.60 μg m^{-3}. Similar improvements were observed at KM and TY through reduced overestimation, and through reduced underestimation at HL (Fig. 7a). These corrections demonstrate that refining forest BVOC emissions improved SOA concentrations at receptors beyond forest environments. Despite persistent underestimation at XT, PY, and ZY, RMSE nevertheless decreased from 3.89 to 3.61 μg m^{-3}, and the overall reduction in MAE and RMSE points to improved agreement across individual records despite the continued systematic underestimation.

At rural sites, Exist-SPE increased the simulated mean SOA concentration from 3.82 to 4.12 μg m^{-3} toward the observed 5.23 μg m^{-3}, however, the response across individual stations was heterogeneous. Underestimation was reduced at TYU, whereas it intensified at KP, and overestimation increased at QYZ, resulting in an overall increase in RMSE from 3.45 to 3.83 μg m^{-3}. This divergence indicates that the apparent reduction in group-level bias did not correspond to a consistent improvement across the six rural records.

Background sites encompass a range of environments, including lakeside locations, high plateaus, and high-altitude mountain settings, as well as forest-surrounded sites such as XL and SH. At these stations, Exist-SPE increased the correlation coefficient from 0.54 to 0.63 and reduced RMSE from 2.12 to 2.04 μg m^{-3}, reflecting improved agreement with the observed concentration pattern. However, simulated concentrations at most sites showed limited variation between configurations, and an overall underestimation of approximately 45-46% persisted. This limited response suggests that refining forest emission factors alone exerts a weaker influence on SOA concentrations at these receptors, where regional transport and non-forest emission sources likely play a more substantial role. Taken together, these results support species-level refinement as a meaningful improvement to the forest BVOC inventory, evidenced by reduced absolute errors at urban sites and enhanced correlations at both urban and background sites. However, the lack of uniform improvement across all site types underscores the need for further attention to non-forest precursor emissions and to the broader processes governing SOA formation and transport.

The systematic SOA underestimation likely reflects limitations in both precursor emissions and chemical processing. BVOC sources in this inventory are restricted to forests, excluding precursor contributions from croplands, shrublands, and grasslands,

whose contribution to the SOA deficit remains unquantified. Within forests themselves, insufficient measurements for certain native tree species may bias the assigned emission factors, though neither the direction nor the magnitude of this bias can currently be established. Chemical uncertainties provide additional plausible explanations. Including both anthropogenic and biogenic precursors does not ensure that their coupled effects on SOA formation are fully represented: anthropogenic pollution can modify biogenic oxidation pathways and promote aerosol formation through sulfate-mediated uptake of isoprene oxidation products (Surratt et al., 2010; Hu et al., 2017). Incomplete treatment of these processes could therefore contribute to underestimation in polluted air masses. Likewise, simplified aqueous-phase pathways could suppress SOA production under conditions favorable for reactive uptake. Li et al. (2019) demonstrated that incorporating dicarbonyl uptake substantially reduced the SOA deficit in a regional simulation over China. Finally, uncertainties in product volatility can alter gas-particle partitioning and SOA evolution during atmospheric aging (Cappa and Wilson, 2012). Incomplete emission coverage and chemical processing limitations shared by both configurations point to a common source of systematic bias that species-level refinement alone cannot resolve."

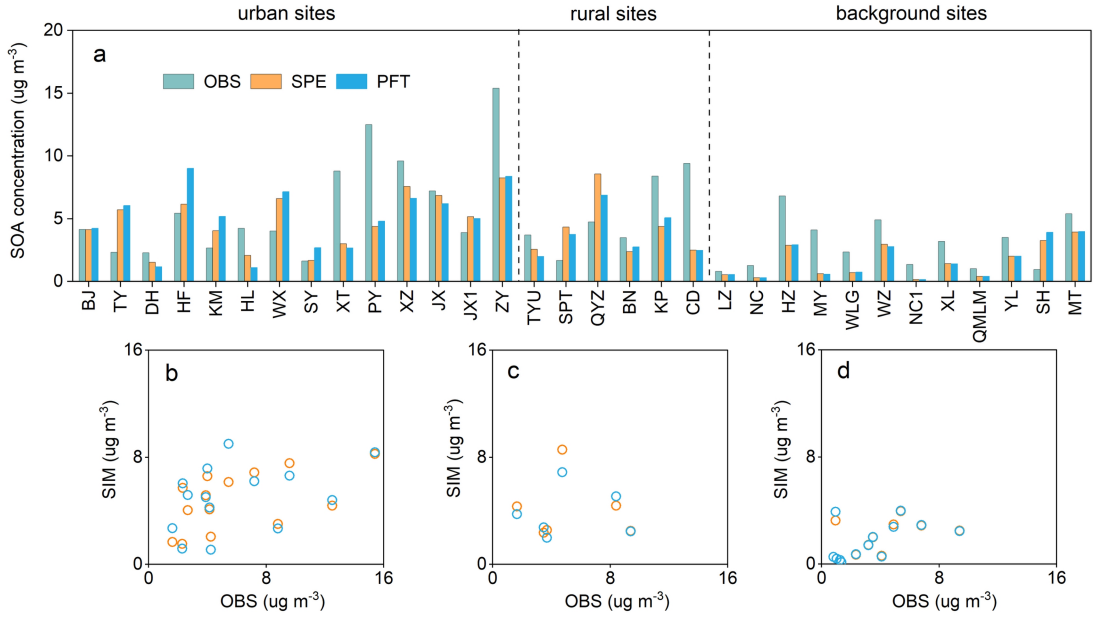

Figure 7 | Comparison of observed and simulated surface SOA concentrations across China. a, SOA concentrations at observation sites grouped into urban, rural, and background categories. Green bars indicate observations compiled from previous studies, while yellow and blue bars show concentrations simulated using Exist-SPE and Exist-PFT, respectively. **b-d**, Observed versus simulated SOA concentrations at urban (b), rural (c), and background (d) sites. Yellow and blue circles represent Exist-SPE and Exist-PFT simulations, respectively. Observational data were compiled from Ding et al. (2014), Zhang et al. (2024), Zheng et al. (2017), Zhu et al. (2016), Zhang et al. (2018b), Xu et al. (2018), Zhang et al. (2019), Qin et al. (2017), Hu et al. (2016), Hu et al. (2013), Huang

et al. (2011), Huang et al. (2013), Du et al. (2015), Li et al. (2020a), Wang et al. (2016b), and Zhang et al. (2018a).

Table 3. Evaluation of SOA simulated by Exist-SPE and Exist-PFT inventories against observations at 30 sites (μg m-3).

	Sites	scenario	OBS	SIM	MB	MAE	RMSE	r
All sites	30	Exist-SPE	4.72	3.47	-1.26	2.39	3.16	0.55
		Exist-PFT	4.72	3.53	-1.20	2.60	3.25	0.52
Urban	13	Exist-SPE	6.01	4.79	-1.22	2.55	3.61	0.53
		Exist-PFT	6.01	5.02	-0.99	3.16	3.89	0.40
Rural	6	Exist-SPE	5.23	4.12	-1.11	3.28	3.83	-0.10
		Exist-PFT	5.23	3.82	-1.41	2.82	3.45	0.06
Background	11	Exist-SPE	2.97	1.59	-1.38	1.76	2.04	0.63
		Exist-PFT	2.97	1.64	-1.33	1.83	2.12	0.54

Note: OBS and SIM denote mean observed and simulated concentrations, respectively; MB, MAE, and RMSE denote mean bias, mean absolute error, and root mean square error, respectively; r denotes the Pearson correlation coefficient. All metrics except r are expressed in μg m^{-3}.

1. Surratt, J. D., Chan, A. W. H., Eddingsaas, N. C., Chan, M. N., Loza, C. L., Kwan, A. J., Hersey, S. P., Flagan, R. C., Wennberg, P. O., and Seinfeld, J. H.: Reactive intermediates revealed in secondary organic aerosol formation from isoprene, Proc. Natl. Acad. Sci. USA, 107, 6640 – 6645, https://doi.org/10.1073/pnas.0911114107, 2010.
2. Hu, J., Wang, P., Ying, Q., Zhang, H., Chen, J., Ge, X., Li, X., Jiang, J., Wang, S., Zhang, J., Zhao, Y., and Zhang, Y.: Modeling biogenic and anthropogenic secondary organic aerosol in China, Atmos. Chem. Phys., 17, 77–92, https://doi.org/10.5194/acp-17-77-2017, 2017.
3. Li, J., Zhang, M., Tang, G., Sun, Y., Wu, F., and Xu, Y.: Assessment of dicarbonyl contributions to secondary organic aerosols over China using RAMS-CMAQ, Atmos. Chem. Phys., 19, 6481–6495, https://doi.org/10.5194/acp-19-6481-2019, 2019.
4. Cappa, C. D. and Wilson, K. R.: Multi-generation gas-phase oxidation, equilibrium partitioning, and the formation and evolution of secondary organic aerosol, Atmos. Chem. Phys., 12, 9505–9528, https://doi.org/10.5194/acp-12-9505-2012, 2012.

Also, while the authors present EF's for isoprene and monoterpenes, they ignore the presentation of EF's for other types (sesquiterpenes, and other BVOC's), while they still report on their overall magnitude. Also sesquiterpenes are considered important for SOA formation. Therefore it is not traceable how they obtain the EF's for these values; please provide more details on this aspect here.

[Response] We thank the reviewer for highlighting this issue. Most available emission factor measurements concern isoprene and monoterpenes, whereas measurements for

sesquiterpenes are limited. We therefore primarily used PFT-based emission factors for sesquiterpenes and updated the values for 12 tree species with available measurements. Table S4 now includes sesquiterpene emission factors and the source references for isoprene, monoterpene, and sesquiterpene emission factors.

Table S4. BVOC emission factors for individual tree species (nmol m^{-2} s^{-1})

Dominant species	ISOP	MONO	SESQ	reference
Pinus massoniana	3.92E-01	7.14E-01	9.00E-02	1, 2, 3, 4, 5, 6, 7, 8, 9
Cunninghamia lanceolata	6.71E-03	3.28E-01	9.00E-02	1, 2, 10, 11, 12
Larix gmelinii	4.47E-02	3.44E-01	9.00E-02	4, 8, 12, 13, 14, 15, 16
Larix gmelinii Rupr.	4.47E-02	3.44E-01	9.00E-02	4, 8, 12, 13, 14, 15, 16
……	……	……	……	……

More generally, it would help in the judgement if the authors provide traceability as to how all the numbers (EF's) are derived, either by providing a reference (citation) of one of the 144 peer-reviewed studies, or by an alternative datasource.

[Response] We thank the reviewer for this suggestion. We have added the source references for the emission factors in Table S4 to clarify their provenance and improve traceability.

Likewise, one of the main outcomes of this study is a gridded dataset of forest tree species distribution. Yet this dataset appears not available through Zenodo. Also the actual MEGAN code, used to ingest this dataset, and convert this to emissions, is not shared in the Zenodo archive. I understand this is a requirement of GMD, following also the Executive Editor comment.

[Response] We thank the reviewer for this comment. We would like to clarify that the

underlying forest distribution dataset is a 1:1,000,000 forest type vector map produced by the China Forest Vegetation Survey project of the Chinese Academy of Forestry, based on surveys conducted during 2013-2017. This map was an existing input dataset, rather than a new mapping product developed in this study, and is available at https://doi.org/10.12041/geodata.43370179401687.ver1.db. We have archived the MEGAN code used to ingest the distribution data and calculate emissions on Zenodo, together with species-specific BVOC emission inventories for all 234 tree species, and update the Code and Data Availability statement accordingly.

Line 989-991:

"The 1:1,000,000 forest type vector map was obtained from the China Forest Vegetation Survey project of the Chinese Academy of Forestry, based on surveys conducted during 2013-2017, and is available at http://www.doi.org/10.12041/geodata.43370179401687.ver1.db (Chen et al., 2020)."

Detailed comments:

Line 388: Table S4 is briefly introduced and discussed. But this table is put together rather superficially, while it contains key information regarding the fidelity of the model and its improvements. Therefore I recommend to put more emphasis on this evaluation aspects. For instance, the table caption appears incomplete, not properly describing what is in the Table. (Missing units). It would additionally help to get information on the absolute average emissions from the observation, to judge if the mean bias / RMSE numbers are significant.

[Response] We thank the reviewer for this suggestion. We have redesigned the table and moved it to the main text as Table 2, adding mean observed emissions (OBS) and units (mg m^{-2} h^{-1}) to facilitate interpretation of the bias and RMSE. We have also added seasonal analyses and time-series comparisons of observed and simulated BVOCs emissions at each site to better illustrate the improvements (Fig. 3-6). The "Validation with BVOC observations" section has been strengthened accordingly (Lines 467-491).

Table 2. Comparison of simulated and observed BVOCs at four stations (mg m^{-2} h^{-1}).

Sites	Compounds	OBS	Exist-SPE			Exist-PFT		
			AVE	MB	RMSE	AVE	MB	RMSE

DZ-spring	ISOP	1.04	2.40	1.36	1.85	3.97	2.93	3.23
	MONO	3.70	1.86	-1.83	3.13	1.14	-2.55	3.61
DZ-summer	ISOP	1.15	2.15	1.00	1.55	3.55	2.40	2.89
	MONO	1.33	1.75	0.43	1.18	1.08	-0.25	1.06
DZ-autumn	ISOP	0.34	1.04	0.70	0.92	1.71	1.38	1.63
	MONO	2.84	1.16	-1.68	3.54	0.72	-2.12	3.71
DZ-winter	ISOP	0.45	0.72	0.28	0.47	1.19	0.75	0.91
	MONO	2.18	0.80	-1.38	3.63	0.50	-1.68	3.78
LA-summer	ISOP	1.91	5.36	3.45	4.17	3.87	1.96	2.81
	MONO	0.03	0.21	0.18	0.20	0.53	0.50	0.53
LA-	ISOP	0.13	1.11	0.97	1.24	0.80	0.67	0.86
autumn	MONO	0.02	0.06	0.05	0.06	0.16	0.14	0.17
LA- winter	ISOP	0.005	0.061	0.056	0.067	0.044	0.039	0.047
	MONO	0.006	0.005	-0.001	0.011	0.012	0.006	0.013
CBM-	ISOP	1.10	1.87	0.77	1.30	1.36	0.26	1.08
summer	MONO	0.18	0.27	0.10	0.23	0.30	0.12	0.25
CBM-	ISOP	0.19	0.69	0.50	0.65	0.50	0.31	0.45
autumn	MONO	0.10	0.12	0.02	0.07	0.13	0.03	0.07
QYZ-	ISOP	0.08	0.63	0.54	0.59	1.71	1.63	1.75
spring	MONO	0.36	0.38	0.02	0.32	0.47	0.11	0.34
QYZ-	ISOP	0.26	0.90	0.64	0.77	2.45	2.19	2.39
summer	MONO	0.70	0.54	-0.16	0.66	0.67	-0.03	0.65
QYZ-	ISOP	0.05	0.55	0.50	0.57	1.50	1.44	1.63
autumn	MONO	0.36	0.39	0.03	0.40	0.48	0.12	0.43

MB denotes mean bias, RMSE denotes root mean square error, Exist-SPE represents the species-level approach, and Exist-PFT represents the traditional plant functional type approach.

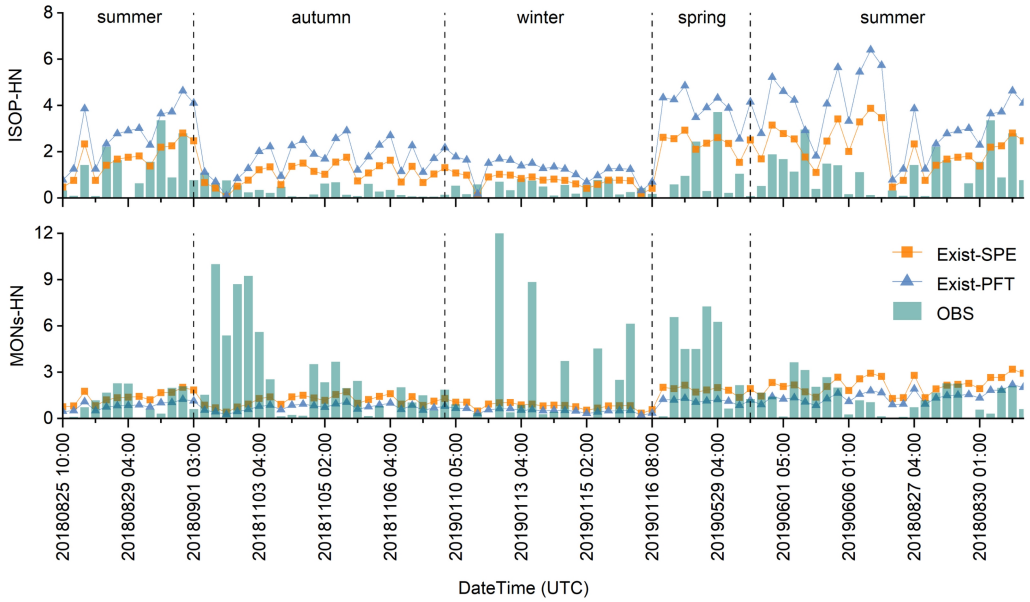

Figure 3 | Observed versus simulated isoprene and monoterpene emissions at Danzhou. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

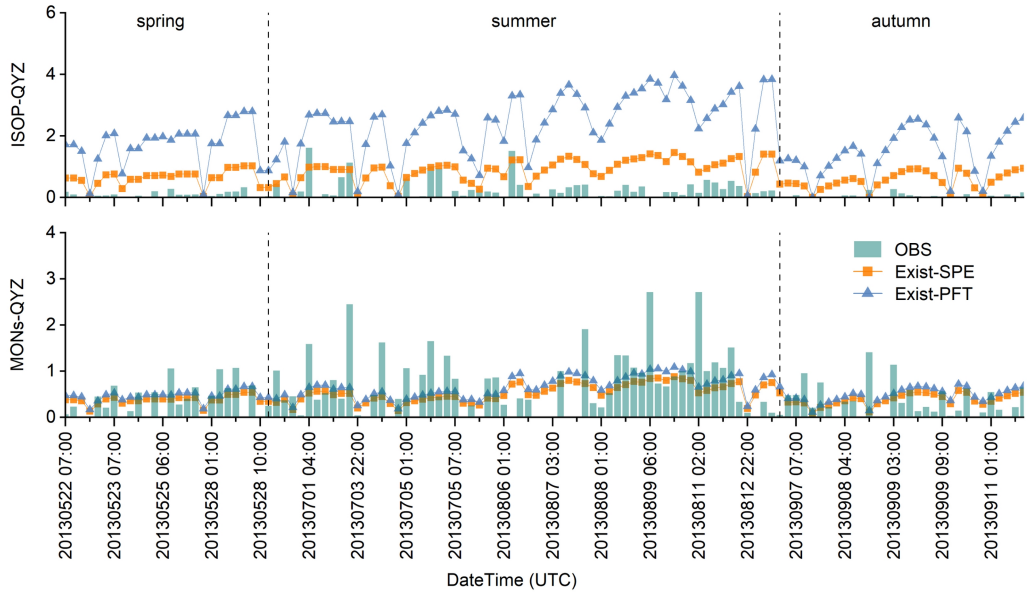

Figure 4 | Observed versus simulated isoprene and monoterpene emissions at Qianyanzhou. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

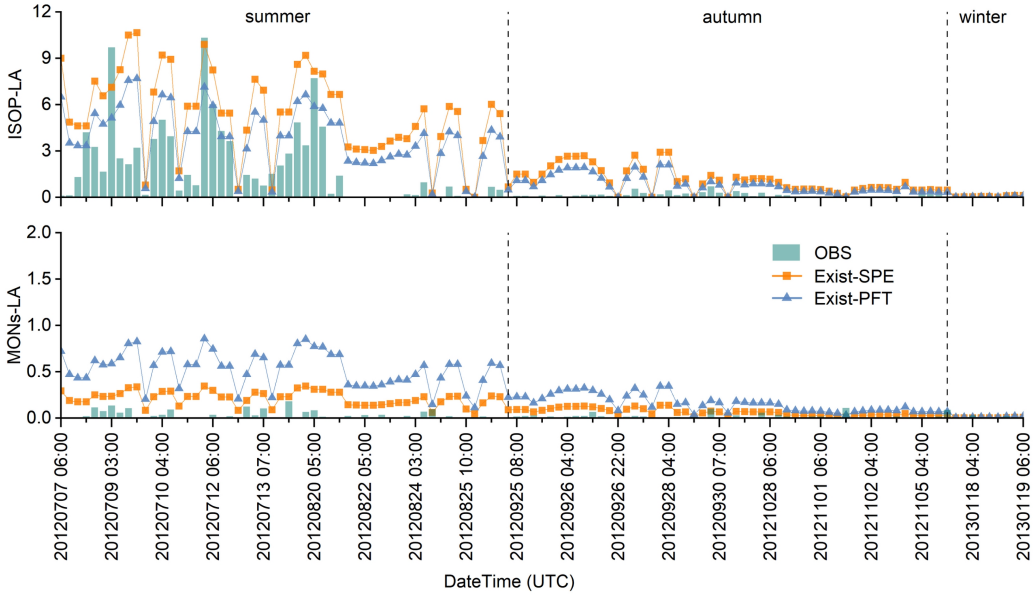

Figure 5 | Observed versus simulated isoprene and monoterpene emissions at Linan. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

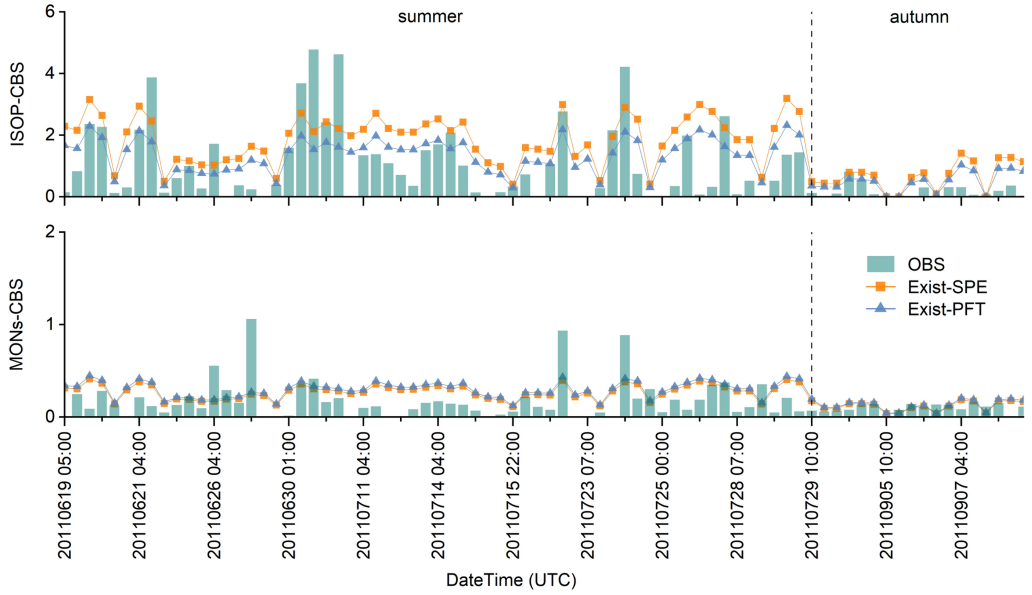

Figure 6 | Observed versus simulated isoprene and monoterpene emissions at Changbai. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

On linke 386 the description of the performance at LA is incomplete and should be checked more carefully. The improvement in performance is only seen for

monoterpenes and not for isoprene. Then this table may be promoted to the main text rather than given in the appendix.

[Response] We thank the reviewer for this correction. We have revised the LA discussion to clarify that Exist-SPE consistently reduces monoterpene errors across seasons and more closely reproduces the magnitudes of selected summer isoprene peaks. We have also moved the evaluation table to the main text as Table 2. The revised manuscript is provided below:

Lines 440-450:

"At LA station, dominated by *Phyllostachys edulis*, the species-level update increased the isoprene emission factor from 11.50 to 23.65 nmol m^{-2} s^{-1} and decreased the monoterpene factor from 0.60 to 0.08 nmol m^{-2} s^{-1}, producing contrasting adjustments in simulated emissions (Fig. 5). Observed isoprene and monoterpene fluxes both declined from summer to winter, with seasonal means decreasing from 1.91 to 0.005 mg m^{-2} h^{-1} and from 0.03 to 0.006 mg m^{-2} h^{-1}, respectively. Both configurations reproduced this seasonal decline. For isoprene (Fig. 5), Exist-SPE more closely reproduced the amplitudes of some summer emission peaks than Exist-PFT, including the observed peak near 10 mg m^{-2} h^{-1} in July. For monoterpenes, Exist-SPE reduced the magnitude of MB and RMSE. In summer, the simulated mean decreased from 0.53 to 0.21 mg m^{-2} h^{-1} towards the observed 0.03 mg m^{-2} h^{-1}, while RMSE decreased from 0.53 to 0.20 mg m^{-2} h^{-1} (Table 2). The winter mean of 0.005 mg m^{-2} h^{-1} closely matched the observed 0.006 mg m^{-2} h^{-1}. Thus, the LA evaluation indicates improved representation of selected summer isoprene peak magnitudes and a consistent reduction in monoterpene errors across seasons (Fig. 5)."

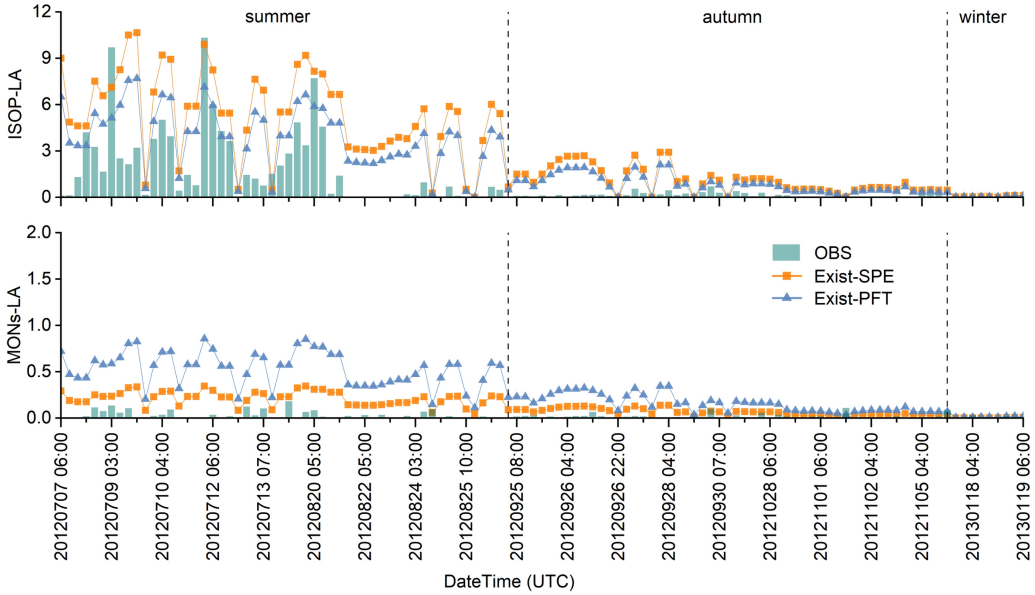

Figure 5 | Observed versus simulated isoprene and monoterpene emissions at Linan. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

Likewise, Sec. 3.2 provides an assessment of SOA, which is a derivative of the alternating BVOC trace gas emissions, associated to many uncertainties. Currently it only reports on the quality of simulation Exist-SPE, but it would be logical to also discuss the other experiments, as done for the BVOC emissions. A closer assessment of these evaluations would be welcome, e.g. selecting only observations and time periods that are known to be affected by SOA from BVOC would be advised. Otherwise, this evaluation is not really informative, and could/should be left to the appendix instead.

[Response] We thank the reviewer for this suggestion. We have added the Exist-PFT sensitivity experiment and compared SOA concentrations simulated with Exist-SPE and Exist-PFT against observations. We have also strengthened Section 3.2 by examining differences between the two configurations across site categories and discussing the remaining model–observation discrepancies and associated uncertainties. The revised text can be found in section "3.2 Evaluation with SOA observations" (Lines 493-558).

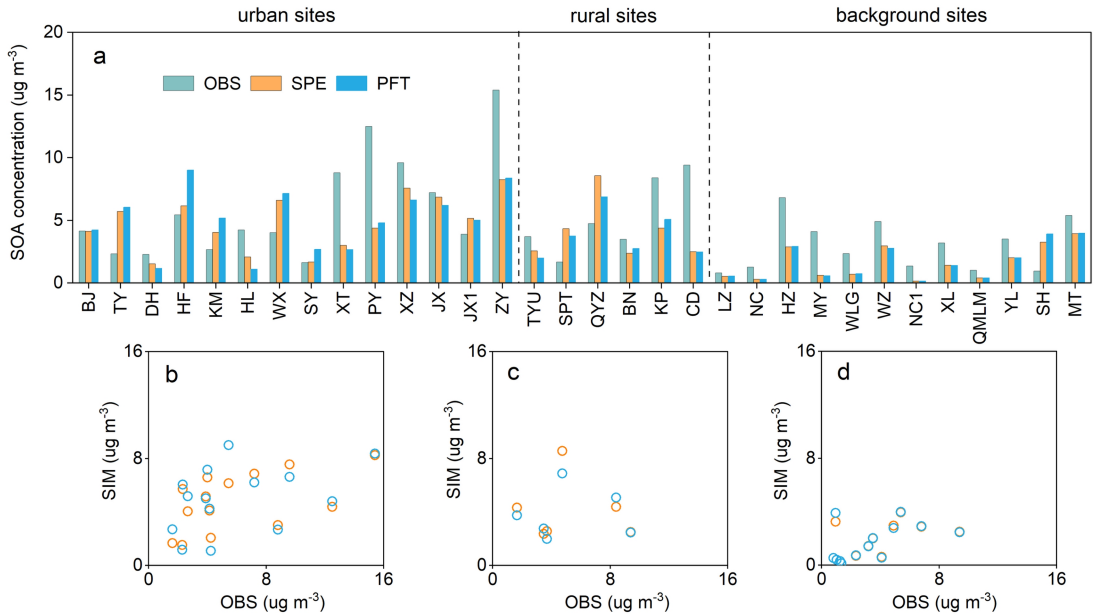

Figure 7 | Comparison of observed and simulated surface SOA concentrations across China. a, SOA concentrations at observation sites grouped into urban, rural, and background categories. Green bars indicate observations compiled from previous studies, while yellow and blue bars show concentrations simulated using Exist-SPE and Exist-PFT, respectively. **b-d**, Observed versus simulated SOA concentrations at urban (b), rural (c), and background (d) sites. Yellow and blue circles represent Exist-SPE and Exist-PFT simulations, respectively. Observational data were compiled from Ding et al. (2014), Zhang et al. (2024), Zheng et al. (2017), Zhu et al. (2016), Zhang et al. (2018b), Xu et al. (2018), Zhang et al. (2019), Qin et al. (2017), Hu et al. (2016), Hu et al. (2013), Huang et al. (2011), Huang et al. (2013), Du et al. (2015), Li et al. (2020a), Wang et al. (2016b), and Zhang et al. (2018a).

Table 3. Evaluation of SOA simulated by Exist-SPE and Exist-PFT inventories against observations at 30 sites (μg m^{-3}).

	Sites	scenario	OBS	SIM	MB	MAE	RMSE	r
All sites	30	Exist-SPE	4.72	3.47	-1.26	2.39	3.16	0.55
		Exist-PFT	4.72	3.53	-1.20	2.60	3.25	0.52
Urban	13	Exist-SPE	6.01	4.79	-1.22	2.55	3.61	0.53
		Exist-PFT	6.01	5.02	-0.99	3.16	3.89	0.40
Rural	6	Exist-SPE	5.23	4.12	-1.11	3.28	3.83	-0.10
		Exist-PFT	5.23	3.82	-1.41	2.82	3.45	0.06
Background	11	Exist-SPE	2.97	1.59	-1.38	1.76	2.04	0.63
		Exist-PFT	2.97	1.64	-1.33	1.83	2.12	0.54

Note: OBS and SIM denote mean observed and simulated concentrations, respectively; MB, MAE, and RMSE denote mean bias, mean absolute error, and root mean square error, respectively; r denotes the Pearson correlation coefficient. All metrics except r are expressed in μg m^{-3}.

On line 427 the authors report on sesquiterpenes emissions, as well as other VOC species. It is actually unclear to me how these numbers are derived, given that no

species-specific information for other species than isoprene and monoterpenes is provided - do the authors use reference EFs from MEGANv3.2 for these?

[Response] We thank the reviewer for this comment. Because sesquiterpene emission factors are rarely reported in the available literature, we primarily used PFT-based values, as now clarified in the manuscript. We have also revised Table S4 to document the data sources for isoprene, monoterpene and sesquiterpene emission factors.

Table S4. BVOC emission factors for individual tree species (nmol m^{-2} s^{-1})

Dominant species	ISOP	MONO	SESQ	reference
Pinus massoniana	3.92E-01	7.14E-01	9.00E-02	1, 2, 3, 4, 5, 6, 7, 8, 9
Cunninghamia lanceolata	6.71E-03	3.28E-01	9.00E-02	1, 2, 10, 11, 12
Larix gmelinii	4.47E-02	3.44E-01	9.00E-02	4, 8, 12, 13, 14, 15, 16
Larix gmelinii Rupr.	4.47E-02	3.44E-01	9.00E-02	4, 8, 12, 13, 14, 15, 16
……	……	……	……	……

Finally, in all figures showing maps of China, please exclude the inset with the wider area over the seas south of China mainland: This does not contain any information that is relevant to this work on forest emissions - at least it is not visible due to the small size, and only distracts the reader.

[Response] We appreciate the reviewer's concern about figure clarity and agree that the inset adds little information on forest emissions. However, its inclusion follows the official requirements for national maps issued by China's Ministry of Natural Resources (*https://www.gov.cn/zhengce/zhengceku/2023-02/17/content_5741977.htm*). We hope the reviewer understand our decision to retain it.

technical comments

Line 36: "1000 Tg of reactive carbon" …, change to "1000 Tg of trace gases containing

reactive carbon" … ?

[Response] We thank the reviewer for this correction. We have revised the wording as suggested. The sentence now reads (Line 36):

"Biogenic volatile organic compounds (BVOCs) comprise ~90% of atmospheric non-methane organic vapors and contribute ~1000 Tg of trace gases containing reactive carbon to the troposphere annually (Goldstein et al., 2007; Guenther et al., 2012), with forests accounting for the dominant share (~90%) of global emissions."

Line 79: please spell out (explain) the units once. Especially I'm unfamiliar with the 'gdw' unit.

[Response] We thank the reviewer for this suggestion. We have clarified that "gdw" denotes grams of dry leaf weight. The revised text reads (Line 79):

"whereas *Acer truncatum* emits mainly monoterpenes (2.29 μg gdw^{-1} h^{-1}, expressed as micrograms per gram of dry leaf weight per hour)."

Line 330: "simulate SOA": change to: "simulate tropospheric chemistry and aerosol, including BVOCs and SOA" ?

[Response] We thank the reviewer for this suggestion. We have revised the sentence accordingly (Line 358):

"The fully coupled WRF-Chem configuration was then used to simulate tropospheric chemistry and aerosol, including BVOCs and SOA over 2018, with results compared against observations to evaluate the derived emission inventory."

Line 472: 'Exist-PEC' => 'Exist-SPE'

[Response] We thank the reviewer for identifying this typographical error. "Exist-PEC" has been corrected to "Exist-SPE" in the Fig. 8 caption (Line 618), which now reads:

"**Figure 8. Spatial patterns of BVOC emissions in China under species-resolved and PFT-based schemes.** Columns 1-3 show the annual mean emissions from the Exist-SPE, the Exist-PFT, and their difference, respectively. Rows 1-3 represent total

BVOCs, isoprene, and monoterpenes, respectively. All emission quantities are expressed on a compound-mass rather than carbon-mass basis."

Reviewer #2 (Remarks to the Author):

[General Comments] This manuscript develops a species-resolved inventory of forest biogenic volatile organic compound (BVOC) emissions in China and evaluates it against observations from four forest flux sites and 29 nationwide biogenic secondary organic aerosol (BSOA) monitoring sites. By combining species-level parameterization with multi-scale in situ evaluation, the study addresses an important limitation of conventional plant functional type (PFT)-based inventories.

The results reveal substantial differences in emission capacity among species within the same PFT, distinct species contributions to isoprene and monoterpene emissions, a pronounced south-to-north gradient, a summer maximum, and sustained wintertime emissions in tropical regions. The finding that a limited number of high-emitting species contribute disproportionately to the national BVOC budget highlights the importance of species composition, rather than forest area alone, in determining emission magnitude. The study also quantifies a 2.01 Tg bias associated with the conventional PFT-based approach and identifies its spatial patterns of overestimation and underestimation. Overall, the study is scientifically valuable and the main results are generally robust. However, the manuscript would benefit from more detailed model evaluation, additional quantitative comparisons, and deeper mechanistic interpretation. I therefore recommend minor revision.

[Response] We are grateful to the reviewer for the thoughtful and constructive comments. We have carefully addressed the concerns regarding the seasonal and spatial evaluation of model performance, the interpretation of model biases, and the mechanisms underlying emission patterns. The manuscript has been revised accordingly, and our point-by-point responses are provided below.

Special comments:

1. The evaluation at the four forest flux sites is based only on annual-mean mean bias (MB) and root-mean-square error (RMSE), without a seasonal breakdown. Given the strong sensitivity of BVOC emissions to temperature, solar radiation, and vegetation phenology, model biases may differ substantially between summer and winter. The

authors should therefore supplement Table S4 with seasonal MB and RMSE statistics, or provide an equivalent seasonal analysis, to identify more precisely when and where the model performs well or poorly.

[Response] We thank the reviewer for this suggestion. We have added seasonal average emissions, MB, and RMSE for both Exist-SPE and Exist-PFT at all four sites, covering the seasons with available observations. The revised table has been moved to the main text as Table 2. We have also added observed and simulated time series for BVOCs (Figs. 3-6) and expanded the site-specific seasonal analysis (3.1 Validation with BVOC observations, Lines 411-460).

"Site-specific analysis further showed how species-level emission factors affected the agreement between simulated and observed BVOC fluxes across seasons (Table 2). The DZ station (Fig. 3), dominated by *Hevea brasiliensis*, was classified as tropical broadleaf forest in the PFT scheme, with emission factors of 8.59 nmol m^{-2} s^{-1} for isoprene and 0.70 nmol m^{-2} s^{-1} for monoterpenes. These values deviated from the measured values (isoprene: 0.09 nmol m^{-2} s^{-1}; monoterpenes: 2.22 nmol m^{-2} s^{-1}), leading to an overestimation of isoprene and underestimation of monoterpenes emission, with mean biases of +1.87 and -1.65 mg m^{-2} h^{-1}. For isoprene (Fig. 3), observed fluxes showed a clear seasonal contrast, with higher means in spring and summer (1.04 and 1.15 mg m^{-2} h^{-1}, Table 2) than in autumn and winter (0.34 and 0.45 mg m^{-2} h^{-1}). Both the PFT-based and Exist-SPE configurations captured this broad seasonal pattern, but Exist-SPE consistently brought simulated magnitudes closer to observations across seasons. In summer, the simulated mean decreased from 3.55 to 2.15 mg m^{-2} h^{-1} and RMSE decreased from 2.89 to 1.55 mg m^{-2} h^{-1}; in winter, the mean decreased from 1.19 to 0.72 mg m^{-2} h^{-1} and RMSE decreased from 0.91 to 0.47 mg m^{-2} h^{-1}. This consistent improvement across seasons supports the use of a species-specific isoprene emission capacity for this rubber plantation. Monoterpene observations at DZ exhibited a different seasonal pattern (Fig. 3): the mean was lowest in summer (1.33 mg m^{-2} h^{-1}), whereas appreciable emissions persisted in autumn and winter (2.84 and 2.18 mg m^{-2} h^{-1}, Table 2). Exist-SPE alleviated the PFT-based underestimation in spring, autumn, and winter, although it did not reproduce the observed summer minimum. Thus, the species-level update improved the representation of the relatively low-isoprene, higher-monoterpene emission profile of this plantation, but did not fully capture its

monoterpene seasonality.

At QYZ station, dominated by *Pinus massoniana*, observed isoprene and monoterpene fluxes both peaked in summer, but their responses to species-level parameterization differed (Fig. 4). For isoprene, observed mean fluxes increased from 0.084 mg m^{-2} h^{-1} in spring to 0.263 mg m^{-2} h^{-1} in summer before declining to 0.051 mg m^{-2} h^{-1} in autumn. By replacing the default PFT isoprene emission factor (8.30 nmol m^{-2} s^{-1}) with the species-specific value (0.39 nmol m^{-2} s^{-1}), more than an order of magnitude lower, Exist-SPE reduced MB by 65-71% and RMSE by 65-68% across all three seasons. The largest absolute improvement occurred in summer, when the simulated mean decreased from 2.45 to 0.90 mg m^{-2} h^{-1} and RMSE from 2.39 to 0.77 mg m^{-2} h^{-1}. For monoterpenes, both configurations reproduced the higher mean emissions in summer than others but underestimated episodic high fluxes (Fig. 4), with scheme differences in RMSE ranging from 0.01 to 0.03 mg m^{-2} h^{-1} (Table 2). Thus, the evaluation at QYZ demonstrates a consistent reduction in isoprene bias and RMSE across the sampled seasons, whereas monoterpene performance remained broadly comparable between the two configurations.

At LA station, dominated by *Phyllostachys edulis*, the species-level update increased the isoprene emission factor from 11.50 to 23.65 nmol m^{-2} s^{-1} and decreased the monoterpene factor from 0.60 to 0.08 nmol m^{-2} s^{-1}, producing contrasting adjustments in simulated emissions (Fig. 5). Observed isoprene and monoterpene fluxes both declined from summer to winter, with seasonal means decreasing from 1.91 to 0.005 mg m^{-2} h^{-1} and from 0.03 to 0.006 mg m^{-2} h^{-1}, respectively. Both configurations reproduced this seasonal decline. For isoprene (Fig. 5), Exist-SPE more closely reproduced the amplitudes of some summer emission peaks, including the observed peak near 10 mg m^{-2} h^{-1} in July. For monoterpenes, Exist-SPE reduced the magnitude of MB and RMSE. In summer, the simulated mean decreased from 0.53 to 0.21 mg m^{-2} h^{-1} towards the observed 0.03 mg m^{-2} h^{-1}, while RMSE decreased from 0.53 to 0.20 mg m^{-2} h^{-1} (Table 2). The winter mean of 0.005 mg m^{-2} h^{-1} closely matched the observed 0.006 mg m^{-2} h^{-1}. Thus, the LA evaluation indicates improved representation of selected summer isoprene peak magnitudes and a consistent reduction in monoterpene errors across seasons (Fig. 5).

At the CBM station, dominated by a mixture of *Betula platyphylla*, *Populus davidiana*, and *Quercus mongolica*, isoprene exhibited a pronounced seasonal contrast,

with mean flux declining by 83% from summer to autumn, whereas monoterpenes showed both lower flux magnitudes and a more modest seasonal decline of 44% (Fig. 6). Both configurations captured the direction of this seasonal transition. Summer isoprene was characterized by mean overestimation alongside underestimation of several major emission peaks. Although Exist-SPE reduced the error at some peaks, it simultaneously increased the overall seasonal positive bias (Fig. 6), raising RMSE from 1.08 to 1.30 mg m^{-2} h^{-1} (Table 2). This result indicates that increasing emission capacity did not resolve the mismatch between mean fluxes and episodic maxima. For monoterpenes, the two simulated time series largely overlapped (Fig. 6); Exist-SPE reduced mean overestimation and lowered summer RMSE from 0.25 to 0.23 mg m^{-2} h^{-1} (Table 2), while both configurations underestimated several observed peaks."

Table 2. Comparison of simulated and observed BVOCs at four stations.

Sites	Compounds	OBS	Exist-SPE			Exist-PFT		
			AVE	MB	RMSE	AVE	MB	RMSE
DZ-spring	ISOP	1.04	2.40	1.36	1.85	3.97	2.93	3.23
	MONO	3.70	1.86	-1.83	3.13	1.14	-2.55	3.61
DZ-summer	ISOP	1.15	2.15	1.00	1.55	3.55	2.40	2.89
	MONO	1.33	1.75	0.43	1.18	1.08	-0.25	1.06
DZ-autumn	ISOP	0.34	1.04	0.70	0.92	1.71	1.38	1.63
	MONO	2.84	1.16	-1.68	3.54	0.72	-2.12	3.71
DZ-winter	ISOP	0.45	0.72	0.28	0.47	1.19	0.75	0.91
	MONO	2.18	0.80	-1.38	3.63	0.50	-1.68	3.78
LA-summer	ISOP	1.91	5.36	3.45	4.17	3.87	1.96	2.81
	MONO	0.03	0.21	0.18	0.20	0.53	0.50	0.53
LA-autumn	ISOP	0.13	1.11	0.97	1.24	0.80	0.67	0.86
	MONO	0.02	0.06	0.05	0.06	0.16	0.14	0.17
LA- winter	ISOP	0.005	0.061	0.056	0.067	0.044	0.039	0.047
	MONO	0.006	0.005	-0.001	0.011	0.012	0.006	0.013
CBM-summer	ISOP	1.10	1.87	0.77	1.30	1.36	0.26	1.08
	MONO	0.18	0.27	0.10	0.23	0.30	0.12	0.25

CBM-	ISOP	0.19	0.69	0.50	0.65	0.50	0.31	0.45
autumn	MONO	0.10	0.12	0.02	0.07	0.13	0.03	0.07
QYZ-	ISOP	0.08	0.63	0.54	0.59	1.71	1.63	1.75
spring	MONO	0.36	0.38	0.02	0.32	0.47	0.11	0.34
QYZ-	ISOP	0.26	0.90	0.64	0.77	2.45	2.19	2.39
summer	MONO	0.70	0.54	-0.16	0.66	0.67	-0.03	0.65
QYZ-	ISOP	0.05	0.55	0.50	0.57	1.50	1.44	1.63
autumn	MONO	0.36	0.39	0.03	0.40	0.48	0.12	0.43

MB denotes mean bias, RMSE denotes root mean square error, Exist-SPE represents the species-level approach, and Exist-PFT represents the traditional plant functional type approach.

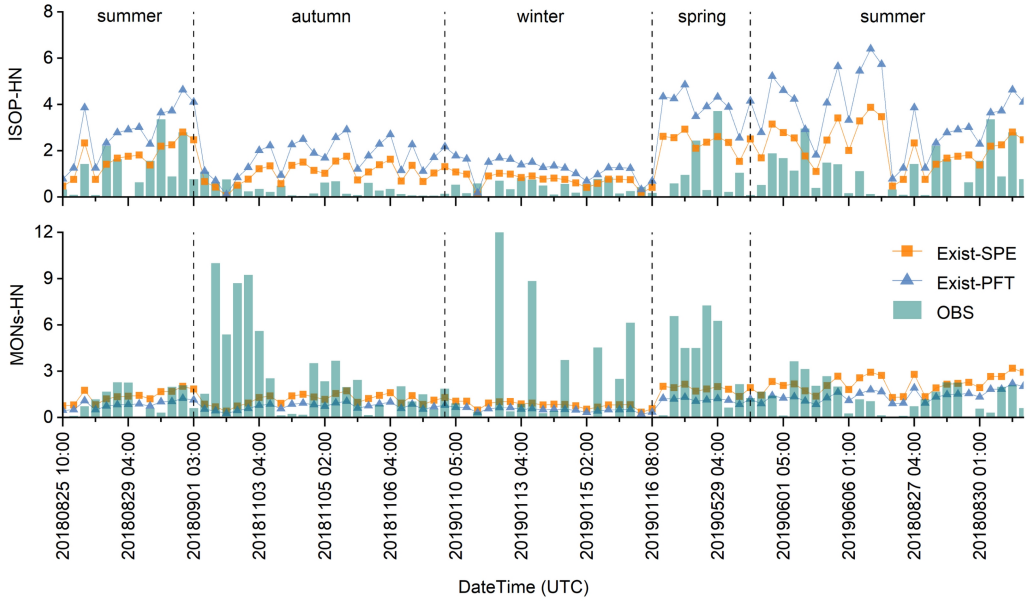

Figure 3 | Observed versus simulated isoprene and monoterpene emissions at Danzhou. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

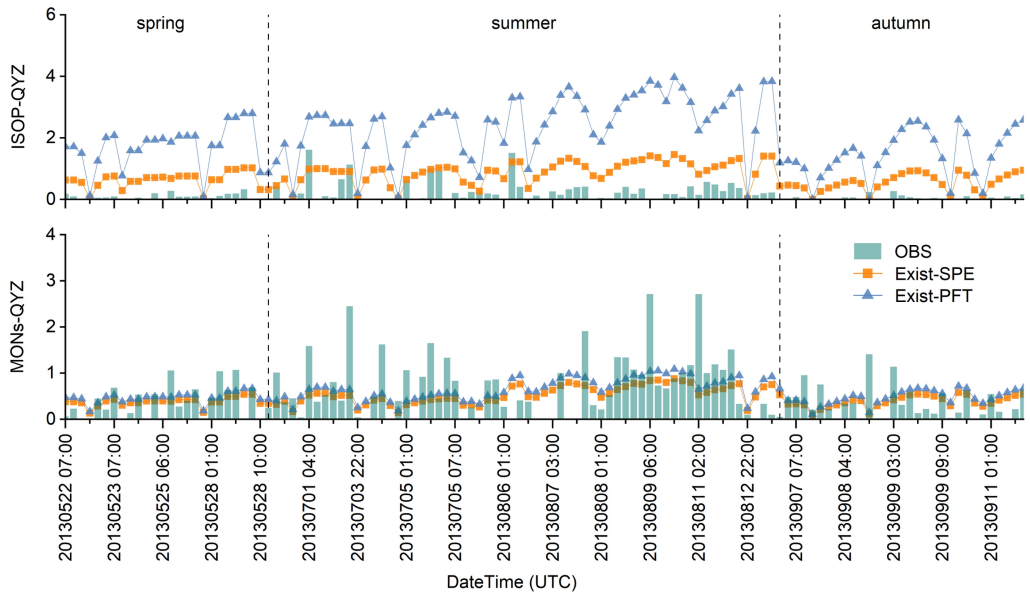

Figure 4 | Observed versus simulated isoprene and monoterpene emissions at Qianyanzhou. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

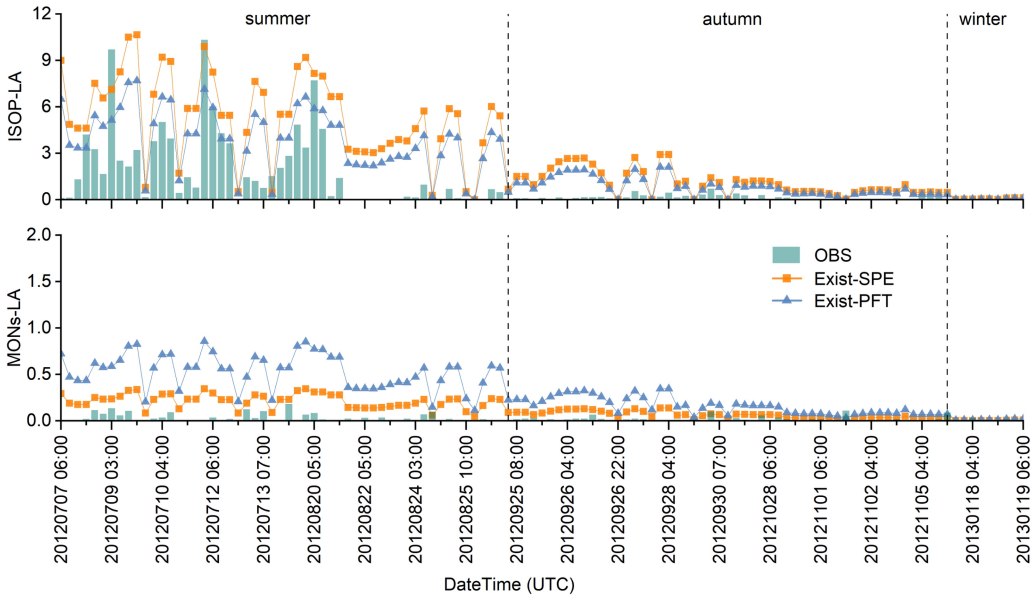

Figure 5 | Observed versus simulated isoprene and monoterpene emissions at Linan. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

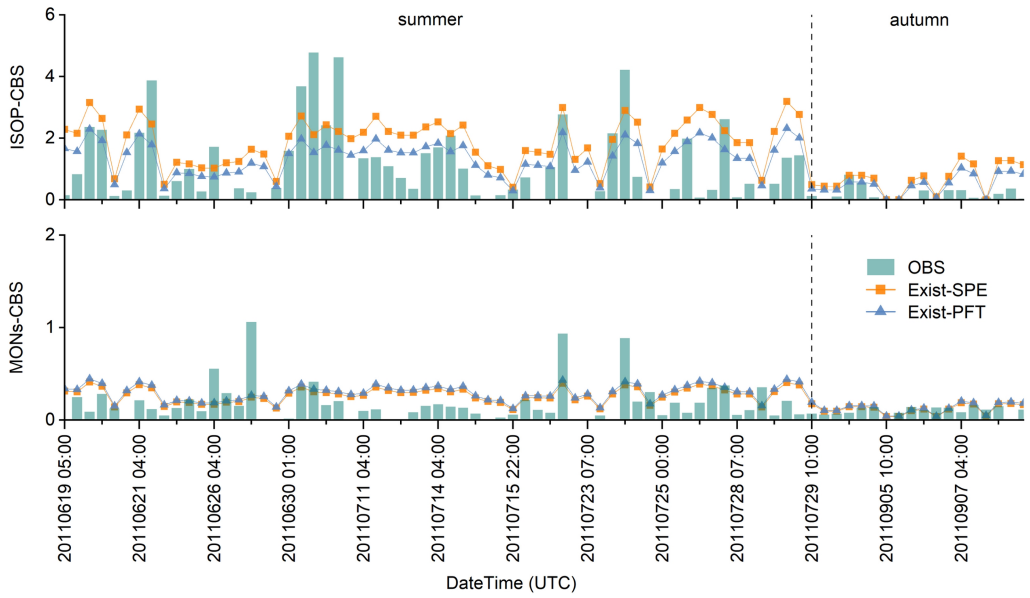

Figure 6 | Observed versus simulated isoprene and monoterpene emissions at Changbai. a, Comparison of observed and simulated isoprene emissions. **b,** Comparison of observed and simulated monoterpene emissions. Green bars represent observations (OBS), while the yellow and blue lines represent simulations using species-level emission factors (SPE) for existing forests in China and the plant functional type (PFT)-based approach, respectively.

2. The WRF-Chem simulations systematically underestimate BSOA concentrations, but the Discussion attributes this discrepancy only broadly to uncertainties in aerosol processes. This explanation is too general to be diagnostically useful. The authors should discuss the most plausible specific sources of bias and, where possible, their relative importance. Potential contributors include incomplete representation of SOA formation arising from anthropogenic-biogenic VOC interactions, underestimate demission factors for under-sampled native tree species, missing or simplified aqueous-phase SOA pathways, and uncertainties in gas-particle partitioning and chemical aging. A more specific discussion would improve confidence in the model evaluation.

[Response] We thank the reviewer for this suggestion. We have expanded the discussion in Lines 544-558 to address specific potential bias sources, including omitted non-forest BVOC emissions, uncertain emission factors for insufficiently sampled native tree species, anthropogenic-biogenic chemical interactions, aqueous-phase SOA formation, and gas-particle partitioning and chemical aging. The revised discussion includes supporting literature and distinguishes plausible explanations from established causes. We also acknowledge that the relative contributions of these factors cannot be quantified from the present simulations. The added text is provided below:

Lines 544-558:

"The systematic SOA underestimation likely reflects limitations in both precursor emissions and chemical processing. BVOC sources in this inventory are restricted to forests, excluding precursor contributions from croplands, shrublands, and grasslands, whose contribution to the SOA deficit remains unquantified. Within forests themselves, insufficient measurements for certain native tree species may bias the assigned emission factors, though neither the direction nor the magnitude of this bias can currently be established. Chemical uncertainties provide additional plausible explanations. Including both anthropogenic and biogenic precursors does not ensure that their coupled effects on SOA formation are fully represented: anthropogenic pollution can modify biogenic oxidation pathways and promote aerosol formation through sulfate-mediated uptake of isoprene oxidation products (Surratt et al., 2010; Hu et al., 2017). Incomplete treatment of these processes could therefore contribute to underestimation in polluted air masses. Likewise, simplified aqueous-phase pathways could suppress SOA production under conditions favorable for reactive uptake. Li et al. (2019) demonstrated that incorporating dicarbonyl uptake substantially reduced the SOA deficit in a regional simulation over China. Finally, uncertainties in product volatility can alter gas-particle partitioning and SOA evolution during atmospheric aging (Cappa and Wilson, 2012). Incomplete emission coverage and chemical processing limitations shared by both configurations point to a common source of systematic bias that species-level refinement alone cannot resolve."

3. The evaluation against the 29 nationwide BSOA sites reports only a single overall correlation coefficient (r=0.78). Because BVOC availability and anthropogenic pollution backgrounds vary markedly among southern forest regions, northern agricultural areas, and urban environments, the authors should stratify the evaluation by region or site type. Reporting regional correlation coefficients together with bias and error metrics would more clearly reveal the spatial strengths and limitations of the model.

[Response] We thank the reviewer for this suggestion. We have stratified the updated evaluation of 30 sites into urban (13 sites), rural (6 sites), and background (11 sites) categories and compared Exist-SPE and Exist-PFT within each group.

Relative to Exist-PFT, Exist-SPE increases the correlation from 0.40 to 0.53 at urban sites and from 0.54 to 0.63 at background sites. Urban MAE decreases from 3.16 to 2.55 μg m^{-3}, while background RMSE decreases from 2.12 to 2.04 μg m^{-3}. At rural sites, the simulated mean approaches the observed mean, but MAE and RMSE increase, indicating that improvements are not uniform across site categories. The comparisons and statistical metrics are presented in Fig. 7 and Table 3, with detailed analysis in Section 3.2 "Evaluation with SOA observations" (Lines 560-571).

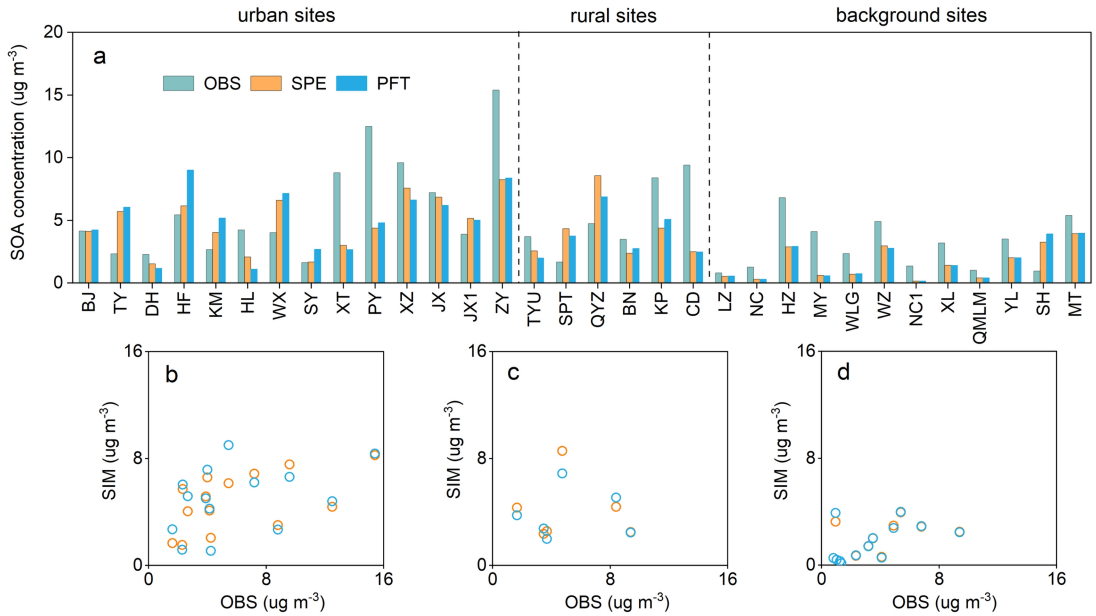

Figure 7 | Comparison of observed and simulated surface SOA concentrations across China. a, SOA concentrations at observation sites grouped into urban, rural, and background categories. Green bars indicate observations compiled from previous studies, while yellow and blue bars show concentrations simulated using Exist-SPE and Exist-PFT, respectively. **b-d**, Observed versus simulated SOA concentrations at urban (b), rural (c), and background (d) sites. Yellow and blue circles represent Exist-SPE and Exist-PFT simulations, respectively. Observational data were compiled from Ding et al. (2014), Zhang et al. (2024), Zheng et al. (2017), Zhu et al. (2016), Zhang et al. (2018b), Xu et al. (2018), Zhang et al. (2019), Qin et al. (2017), Hu et al. (2016), Hu et al. (2013), Huang et al. (2011), Huang et al. (2013), Du et al. (2015), Li et al. (2020a), Wang et al. (2016b), and Zhang et al. (2018a).

Table 3. Evaluation of SOA simulated by Exist-SPE and Exist-PFT inventories against observations at 30 sites (μg m^{-3}).

	Sites	scenario	OBS	SIM	MB	MAE	RMSE	r
All sites	30	Exist-SPE	4.72	3.47	-1.26	2.39	3.16	0.55
		Exist-PFT	4.72	3.53	-1.20	2.60	3.25	0.52
Urban	13	Exist-SPE	6.01	4.79	-1.22	2.55	3.61	0.53
		Exist-PFT	6.01	5.02	-0.99	3.16	3.89	0.40
Rural	6	Exist-SPE	5.23	4.12	-1.11	3.28	3.83	-0.10

	Sites	scenario	OBS	SIM	MB	MAE	RMSE	r
		Exist-PFT	5.23	3.82	-1.41	2.82	3.45	0.06
Background	11	Exist-SPE	2.97	1.59	-1.38	1.76	2.04	0.63
		Exist-PFT	2.97	1.64	-1.33	1.83	2.12	0.54

Note: OBS and SIM denote mean observed and simulated concentrations, respectively; MB, MAE, and RMSE denote mean bias, mean absolute error, and root mean square error, respectively; r denotes the Pearson correlation coefficient. All metrics except r are expressed in μg m^{-3}.

4. Section 4.1 describes the south-to-north decrease in emissions but provides limited explanation for the particularly low values in western China. The authors should add a concise mechanistic interpretation. For example, low temperatures over the Tibetan Plateau suppress vegetation activity and BVOC production, whereas the arid and semi-arid regions of northwestern China have sparse forest cover and therefore limited biogenic emission capacity. This addition would provide a more complete explanation of the national spatial pattern.

[Response] We thank the reviewer for this suggestion. We have added a mechanistic explanation for the low emissions in western China (Lines 636-641).

"Emissions are also low in the western China, though the underlying constraints differ between subregions. Over the Tibetan Plateau, persistently low temperatures restrict temperature-dependent BVOC synthesis and release (Guenther et al., 2012), while in the arid and semi-arid zones of northwestern China, sparse forest cover reduces the availability of emitting biomass. Together, these distinct climatic and vegetation constraints converge to produce a consistently low-emission regime across western China, in agreement with previous estimates (Cao et al., 2022)."

5. Section 4.3 attributes the finding that summer contributes 49.9% of annual emissions primarily to temperature and light. The interpretation would be more complete if the authors also distinguished the seasonal responses of deciduous and evergreen species. Deciduous species contribute little during winter because of leaf senescence and abscission, whereas evergreen species in southern China can sustain emissions throughout the year. Contrasting these phenological groups would provide a clearer mechanistic explanation for the national seasonal cycle.

[Response] We thank the reviewer for this suggestion. We have added Fig. 14 and

expanded Section 4.3 to compare the seasonal emissions of evergreen and deciduous species. The revised discussion explains how their contrasting leaf phenology, together with temperature and light, contributes to the national seasonal cycle (Line 781-791).

“This latitudinal contrast is echoed at the functional-group level when species are stratified by leaf habit (Fig. 14). In summer, emissions from evergreen and deciduous species are comparable, reaching 2.68 and 2.44 Tg, respectively. In winter, emissions decline to 0.41 Tg for evergreen species and 0.23 Tg for deciduous species, corresponding to reductions of 84.7% and 90.6% (Fig. 14). Consequently, the evergreen contribution to total forest BVOC emissions increases from 52.3% in summer to 64.1% in winter. The steeper decline among deciduous species is consistent with seasonal leaf senescence and abscission, which reduce emitting leaf area in addition to the effects of lower temperature and light availability. Evergreen species retain foliage through winter, allowing continued emissions where climatic conditions remain favorable, particularly in southern China; nevertheless, their substantial winter decline indicates that foliage retention alone does not sustain summer-level emission rates. Together, these contrasting responses suggest that vegetation phenology, in conjunction with temperature and light availability, contributes to the pronounced seasonal cycle observed at the national scale.”

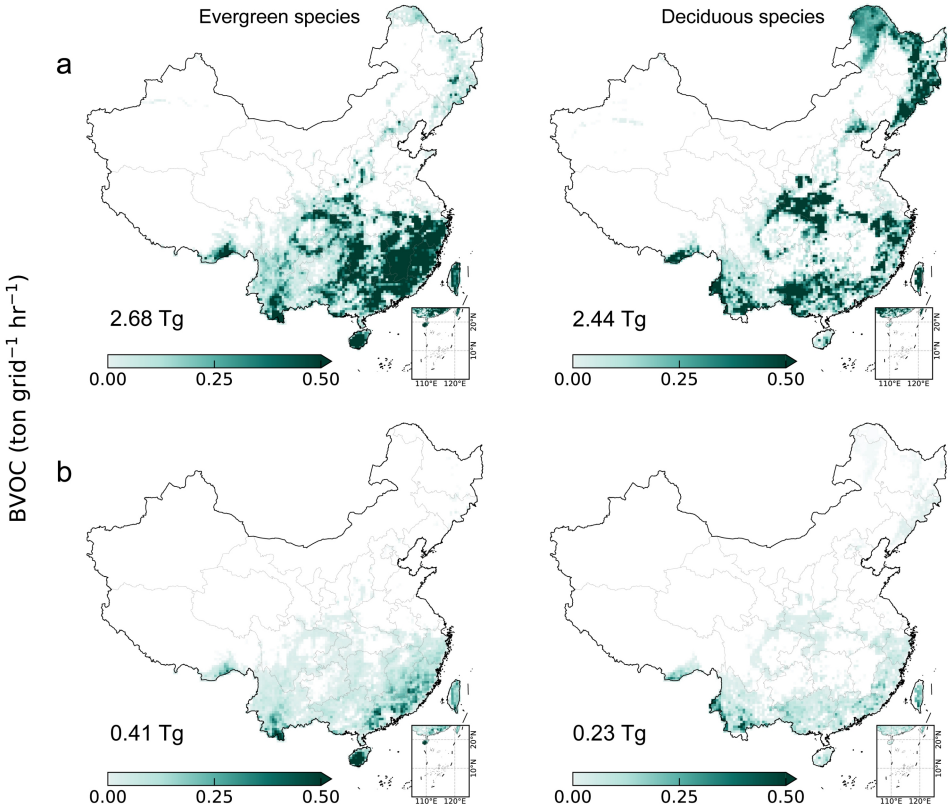

Figure 14 | Spatial distribution of BVOC emissions from evergreen and deciduous forests in China during summer and winter. Green shading indicates gridded BVOC emission rates (ton grid^{-1} hr^{-1}) for (a) summer (JJA) and (b) winter (DJF), illustrating the contrasting seasonal emission patterns between evergreen and deciduous forest types across China.

6. The finding that Hevea brasiliensis becomes the third-largest national BVOC source in winter is potentially novel but is discussed only briefly. The authors should elaborate on the physiological and climatic mechanisms underlying this pattern. Persistently high temperatures in tropical southern China can sustain metabolic activity throughout winter, while the evergreen habit of Hevea brasiliensis avoids the winter leaf loss characteristic of deciduous species. These factors help explain why low-latitude southern China remains a persistent high-emission region during winter.

[Response] We thank the reviewer for this suggestion. We have expanded the discussion of regional climate conditions and species-specific characteristics that may explain the relatively large winter contribution of *Hevea brasiliensis* (Lines 769-770 and 771-775).

Lines 769-770:

"The low-latitude distribution of *Hevea brasiliensis* in tropical southern China

experiences persistently high temperatures and solar radiation that sustain enzymatic and photosynthetic activity throughout winter, allowing temperature-dependent BVOC synthesis to continue whereas emissions from high-latitude species decline."

Lines 771-775:

"As an evergreen species, *Hevea brasiliensis* retains an active canopy throughout the year, in contrast to deciduous species, which shed their foliage during the dormant season. Given the close coupling between leaf biomass and BVOC output, this sustained foliar activity enables emissions to persist at levels unattainable by deciduous competitors in winter. These climatic and phenological factors together account for the disproportionate importance of low-latitude southern China as a winter BVOC source, despite the overall decline in national emissions."

Reviewer #3 (Remarks to the Author):

[General Comments] This study extends MEGAN v3.2 beyond conventional PFT-based representations by developing a species-resolved BVOC emission inventory for 234 dominant tree species covering over 90% of China's forest area. By integrating forest inventory data, MODIS products, and emission measurements from 144 studies, the authors establish a localized MEGAN framework and a compound-specific emission factor database for isoprene, monoterpenes, and sesquiterpenes. The study further evaluates two afforestation scenarios and demonstrates that species selection can substantially alter both the magnitude and chemical composition of BVOC emissions. These results provide improved biogenic emission inputs for ozone and BSOA modeling and useful guidance for coordinating afforestation with air-quality management.

The overall framework and experimental design are sound. However, several methodological details, including parameter definitions, dataset suitability, and figure annotations, require clarification and standardization. I therefore recommend acceptance after minor revision.

Specific Comment:

1. In Equation (1), the canopy production and consumption correction parameter (ρ) is introduced only with a nominal definition, without any calculation rules or supporting literature; since this parameter is central to BVOC canopy loss correction, the omission of its specification undermines model reproducibility, and the authors should provide the calculation formula for ρ (or its parameterization scheme) and cite the original reference(s) that define this term, or explicitly state that the parameter is adopted directly from MEGAN v3.2 without modification and provide the appropriate citation.

[Response] We thank the reviewer for this suggestion. We have clarified the physical meaning of ρ, added the original reference, and explicitly stated that the default treatment of canopy production and loss in MEGAN v3.2 was retained without modification (Line 136-138).

Guenther et al. (2006) parameterized the canopy escape fraction for isoprene as:

$$\rho = 1 - \frac{\mathrm{D}}{\lambda * \mu * \tau + D}$$

where D is canopy depth (m), μ is friction velocity (m s^{-1}), τ is the above-canopy isoprene lifetime (s), and λ is an empirical coefficient. This formulation constitutes the original basis for the parameterization of within-canopy isoprene loss and is cited here for that purpose, rather than to indicate that the scheme was newly implemented in the present simulations. The model's default canopy treatment was retained without modification.

Line 136-138:

"The dimensionless factor ρ accounts for the loss and transformation of emitted compounds within the canopy before they reach the above-canopy atmosphere (Guenther et al., 2006). In this study, the default treatment of canopy production and loss in MEGAN v3.2 was retained without modification."

Guenther, A., Karl, T., Harley, P., Wiedinmyer, C., Palmer, P. I., and Geron, C.: Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature), Atmos. Chem. Phys., 6, 3181–3210, https://doi.org/10.5194/acp-6-3181-2006, 2006.

2. In Equation (3), the canopy environment coefficient is specified only to the extent that γ = 1 under standard conditions, with no fixed numerical value or justification for the chosen setting; as this coefficient serves as the baseline for all environmental activity factors, its value must be reported to ensure reproducibility, and the authors should clearly state the fixed numerical value adopted in this study, indicate the source from which it is derived (e.g., MEGAN default or literature), and briefly justify its appropriateness for the Chinese forest context.

[Response] We thank the reviewer for requesting this clarification. In earlier MEGAN formulations, the canopy environment coefficient normalizes emission activity to unity under standard conditions, with its value depending on the canopy model (Guenther et al., 2006, 2012). However, Silva et al. (2020) explain that the transition from canopy-scale to leaf-level emission factors in the full MEGAN3 implementation removes the need for this separate normalization factor.

This distinction is consistent with the MEGAN v3.2 source code used in our study, which integrates light and temperature responses across five canopy layers and

combines them with LAI and other activity factors without applying a separate canopy environment coefficient. We retained the default implementation without regional adjustment. Differences among Chinese forests are represented through canopy characteristics, species-specific emission factors, LAI, and meteorological inputs. We revised Eq. (3) and the accompanying description to reflect this implementation (Line 146-149).

"No separate canopy environment coefficient is applied in the MEGAN v3.2 implementation used here. This is consistent with the transition to leaf-level emission factors in the full MEGAN3 framework, which removes the need for the separate canopy normalization used with canopy-scale emission factors (Silva et al., 2020)."

Silva, S. J., Heald, C. L., and Guenther, A. B.: Development of a reduced-complexity plant canopy physics surrogate model for use in chemical transport models: a case study with GEOS-Chem v12.3.0, Geosci. Model Dev., 13, 2569–2585, https://doi.org/10.5194/gmd-13-2569-2020, 2020.

3. In Section 2.2.1, the authors describe the operational procedure of equally splitting mixed-stand polygon areas among co-dominant species but do not explicitly acknowledge that this simplification introduces estimation bias; since China's forest inventory does not provide species-level stocking fractions for mixed stands, equal-proportion splitting is a pragmatic compromise, yet without prior disclosure of this limitation, readers may interpret the results as absolute rather than as the best available estimates, so the authors should explicitly state in Section 2.2.1 that the equal-proportion assumption is adopted due to the lack of species-level area ratios and briefly note that this approach may introduce allocation bias, while also adding a dedicated statement in the Discussion (Section 6) addressing this uncertainty and its potential implications for the emission estimates, consistent with the existing discussion of tree age and stress-response uncertainties.

[Response] We thank the reviewer for this suggestion. We have clarified in Section 2.2.1 that equal partitioning was adopted because species-level area fractions were unavailable and explicitly acknowledged the potential allocation bias (Lines 187-189). We have also expanded Section 6 to explain how this uncertainty may affect species-specific area estimates and propagate into estimates of total BVOC emissions and their chemical composition (Lines 907-909).

Line 187-189:

"This equal-proportion assumption was applied across all mixed stands because species-level area ratios were not available at the grid scale. Although total forest area is conserved, equal partitioning may introduce species-level allocation bias where actual species proportions differ from the assumed fractions."

Line 907-909:

"Third, mixed-stand areas were divided equally among co-dominant species because species-level area fractions were unavailable. Deviations from the actual proportions may bias species-specific area estimates and, where emission factors differ among species, affect both total BVOC emissions and their chemical composition."

4. In Section 2.2.2, the specific leaf area (SLA) data used to convert emission rates into emission factors are drawn from the European FloraVeg.EU database, but the authors do not justify the suitability of this database for Chinese tree species; given that leaf morphology and phenology differ substantially between European and native Chinese species, the use of substitute SLA data may introduce systematic errors on the order of 5-10%, so the authors should add a justification statement clarifying that where domestic SLA measurements for Chinese species are unavailable (which applies to the majority of the 234 species), SLA values from congeneric species in East Asia were prioritized, and when no East Asian congeneric data existed, values from European congeners were adopted, while also acknowledging that this substitution may introduce a systematic bias of approximately 5-10% in the derived emission factors and considering adding a sentence in the Discussion to acknowledge this source of uncertainty.

[Response] We thank the reviewer for this suggestion. We have clarified in Section 2.2.2 that published SLA measurements for the target species in East Asia were prioritized, with missing values supplemented by European records for the same species from FloraVeg.EU (Lines 199-204). We have also acknowledged in Section 6 that regional variation in SLA may bias the derived emission factors and subsequent BVOC emission estimates (Lines 910-912). As the magnitude and direction of this bias have not been quantified, we describe this uncertainty without assigning a numerical range.

Line 199-204:

"SLA values were preferentially compiled from published measurements for the target species in East Asia, with missing values supplemented by conspecific records from FloraVeg.EU database (www.floraveg.eu/; Chytrý et al., 2024), an online repository documenting biological traits, ecological indicator values, and distributional information for plant species. This approach preserves species-level correspondence, although geographic variation in SLA within species may introduce uncertainty into the conversion of mass-based emission rates to leaf-area-based emission factors."

Line 910-912:

"Fourth, European SLA data were used where measurements in East Asia were unavailable. Regional variation in SLA may introduce bias into the derived emission factors and subsequent BVOC emission estimates, and its magnitude and direction remain unquantified."

5. In Section 2.2.2, the "species measurement → congeneric mean → family mean" three-tier substitution rule for species lacking observational emission data is described only in text; given that this substitution hierarchy is a core procedure for constructing the emission factor database for 234 species, the purely textual description reduces readability and reproducibility for other researchers who may wish to adopt or adapt the database, and the authors should add a concise supplementary table (e.g., Table S1 or in Appendix A) that visually summarizes the priority hierarchy of the three-tier substitution rule, with example cases illustrating how values were assigned for representative species, which will greatly improve the transparency and reusability of the database.

[Response] We thank the reviewer for this suggestion. We have added Table S1 in Appendix to summarize the three-tier assignment hierarchy at the species, genus, and family levels. The table provides representative examples, including the target and source species, BVOC compound, assigned emission factor, and supporting references, to improve the transparency and reproducibility of the database construction.

Table S1. Priority hierarchy for assigning species-specific BVOC emission factors (ug g^{-1} h^{-1}).

Item	Species level	Genus level	Family level
Data availability	Species-specific data available	Genus-level data used (no species data)	Family-level data used (no species or genus data)

Target species	*Quercus aliena*	*Albizia kalkora*	*Bambusoideae*
Source species	*Quercus aliena*	*Albizia julibrissin*	*Bamboo*
BVOC compound	Isoprene	Isoprene	Isoprene
Emission factor	74.23	2	12
References	Yang et al., 2021	Guenther et al., 2024b	Guenther et al., 2024b

6. In Section 2.2.2, the procedure used to combine emission rates (K values) from multiple literature sources is not sufficiently clear. The manuscript does not indicate whether canopy- scale flux measurements from Chinese forest ecosystems were prioritized over leaf-level chamber measurements, or whether domestic studies were given preference over international sources. Because canopy-scale observations are generally more representative of local environmental conditions, the authors should explicitly define the data-selection hierarchy. Measurements from Chinese forest ecosystems should be given the highest priority, followed by leaf-level measurements for Chinese tree species, and then by international studies and the default MEGAN database. When multiple values are available at the same priority level, the arithmetic mean should be used unless an alternative choice is clearly justified. Clarifying these rules would improve methodological transparency and facilitate independent replication.

[Response] We thank the reviewer for this comment. We have clarified the data-selection hierarchy in Section 2.2.2 (Lines 212-215): measurements for the target species in China were prioritized, followed by international measurements for the same species and default MEGAN emission factors. We have also specified that multiple measurements were combined using their arithmetic mean or represented by the observed value closest to that mean.

Lines 212-215:

"When multiple sources were available, measurements for the target species in China were prioritized, followed by international measurements for the same species and default MEGAN emission factors. When emission rates for certain species vary across multiple sources, we prioritized the arithmetic mean of available measurements or the observed value closest to that mean."

7. In Section 2.3.1, the 78 Mha potential afforestation area is presented with its total area only, but the authors do not specify the underlying data source(s) nor the screening criteria (e.g., slope constraints, ecological redlines, pre-existing native vegetation, land-use competition) used to define this potential area; since this boundary directly determines the emission increment magnitude under the A&R scenarios, the lack of transparency reduces the credibility of the scenario analyses, and the authors should fully document the delineation criteria and data sources used to define the 78 Mha potential afforestation area, explicitly referencing the original methodology from Xu et al. (2023) and including, at minimum, the base datasets used, the exclusion criteria applied (e.g., slope > 25°, existing cropland, urban areas, ecological conservation zones), and any additional filters relevant to the Chinese afforestation policy context, which will fully anchor the scenario design in the peer-reviewed literature and enable proper interpretation of the emission increment estimates.

[Response] We thank the reviewer for this suggestion. We have expanded Section 2.3.1 (Lines 260-269) to document the data sources and delineation criteria underlying the 78 Mha potential forestation area, following Xu et al. (2023). The revised text explains the agreement required among three potential forest predictions and the subsequent exclusion of existing forests, cropland, and urban areas using inventory and satellite datasets. It also clarifies that BIO and SUIT share this spatial extent but differ in tree-species allocation.

Lines 260-269:

"Both A&R scenarios adopted the 78 Mha potential forestation area delineated by Xu et al. (2023) at 1-km resolution. Potential forest extent was determined by combining three approaches: random-forest predictions based on tree-cover observations and environmental variables from WorldClim v2.1, SoilGrids250m, and GMTED2010; the World Resources Institute potential forest map; and ORCHIDEE simulations driven by the China Meteorological Forcing Dataset. Only locations identified as potential forest by all three approaches were retained, thereby excluding areas with lower agreement among the predictions. Existing forests, cropland, and urban areas were subsequently excluded using the 2013-2017 China Forest Vegetation Survey and six satellite-derived datasets: Hansen Global Forest Change, CNLUC, MODIS MCD12Q1, GLC-FCS3, GlobeLand30, and ESA-CC. The resulting 78 Mha defines the common spatial extent of the BIO and SUIT scenarios, which differ in tree-species allocation. Detailed

delineation procedures and dataset specifications are provided in Xu et al. (2023)."

8. In Section 2.3.1, the BIO (biomass-maximization) scenario is described in terms of its species selection logic (carbon storage optimization), but its ecological limitations are not mentioned; without an explicit caveat that this scenario is optimized solely for carbon storage at the expense of biodiversity conservation, soil erosion control, and other ecosystem services, policy-oriented readers may misinterpret the BIO scenario as the preferred afforestation pathway, and the authors should add a brief sentence immediately following the BIO scenario description, such as: "It should be noted that the BIO scenario is optimized solely for aboveground carbon accumulation and does not account for other ecosystem services, including biodiversity conservation, soil erosion control, or water provision," which will provide balanced context and prevent misinterpretation of the scenario as universally optimal.

[Response] We thank the reviewer for this suggestion. We have clarified the ecological limitations of the BIO scenario in Section 2.3.1 (Lines 275-279).

Lines 275-279:
"However, species selection in the BIO scenario is optimized for biomass carbon storage, without explicitly incorporating biodiversity conservation, soil erosion control, or water provision into the optimization objectives (Xu et al., 2023). The scenario therefore does not represent a universally preferred afforestation strategy, and its implementation requires consideration of local ecological conditions and management priorities."

9. The WRF meteorological simulations are performed for the period 2018–2022, yet the BSOA evaluation uses only 2018–2020, and the truncation of the final two years is not explained; the temporal mismatch between simulation and evaluation raises questions about the experimental design logic and may confuse readers, so the authors should add a brief explanation to Section 2.4 (or Section 3.2, as appropriate) clarifying that ground-based BSOA observations were unavailable for 2021–2022 for the 29 monitoring stations used in this study, and therefore the evaluation period was necessarily limited to 2018–2020, which simply clarifies that the evaluation reflects the period for which sufficient observational constraints were available, rather than a deliberate data omission.

[Response] We thank the reviewer for highlighting the ambiguity in the simulation periods. The five-year BVOC simulations for 2018-2022 were intended to reduce the influence of individual-year meteorological variability on the emission inventory (Lines 336-338). The original SOA evaluation used the three-year mean for 2018-2020 to reduce dependence on a single meteorological year while limiting the computational cost of fully coupled WRF-Chem simulations. The chemistry simulations therefore covered a shorter period than the meteorology-only simulations used to construct the five-year BVOC inventory.

In the revised evaluation, we use 2018 simulations for both Exist-SPE and the newly added Exist-PFT experiment to compare the emission schemes under identical meteorological conditions. The observations comprise 32 records from 30 sites, with sampling periods spanning 2011-2022. Simulating each historical sampling period for both schemes would require substantial computational resources; we therefore compare observations with 2018 simulations averaged over the corresponding calendar dates. We have clarified this design and acknowledged that differences between simulation and observation years introduce uncertainty into the evaluation (Lines 359-364).

Lines 336-338:
"Exist-SPE simulated species-resolved forest BVOC emissions for 2018-2022. The resulting five-year mean inventory was used to reduce the influence of interannual meteorological variability and to drive WRF-Chem simulations of SOA for inventory evaluation."

Lines 359-364:
"The Exist-SPE and Exist-PFT simulations used identical meteorological forcing and model configurations to ensure a consistent comparison of the emission schemes. Evaluation used 32 observational records from 30 sites, with sampling periods spanning 2011-2022. Simulated SOA concentrations were averaged over the corresponding calendar dates in 2018. This approach aligns the seasonal sampling windows, although meteorological differences between simulation and observation years introduce uncertainty into the comparison."

10. Exist-SPE uses a 5-year mean (2018–2022), whereas Exist-IND, BIO-IND, and SUIT-IND use only a single year (2019), and the authors do not explain the rationale

for this difference in temporal averaging across scenarios, which may puzzle readers; the authors should add a clear explanatory footnote or parenthetical note below Table 1 (Simulation Scenarios), specifying that Exist-SPE uses the 5-year mean to align with the multi-year observational datasets used for model evaluation (BVOC and BSOA), reducing the influence of interannual meteorological variability on validation metrics, while the IND scenarios use a single year (2019) with fixed meteorology specifically to isolate the effects of species composition and forest cover changes from climate variability, thereby enabling a clean attribution of emission differences to vegetation characteristics alone, which will eliminate any ambiguity regarding the scenario logic.

[Response] We thank the reviewer for highlighting the need to clarify the temporal design. Exist-SPE and Exist-PFT covers 2018-2022 to derive a multi-year mean emission inventory that reduces the influence of individual-year meteorological variability and provides a more representative estimate of forest BVOC emissions. For example, annual isoprene emissions ranged from 3.29 to 3.88 Tg, with the minimum approximately 15% below the maximum.

Exist-IND, BIO-IND, and SUIT-IND were designed to quantify individual species contributions and identify the principal BVOC-emitting taxa. They require 234, 161, and 199 separate simulations, respectively, totaling 594 full-year simulations. Each simulation produces 365 daily files, yielding 216,810 files for a single meteorological year. Given this computational demand, the species-level calculations were restricted to 2019. Using the same meteorological year across the three scenarios also enables comparison of species contributions and vegetation-driven emission differences under consistent meteorological conditions. These results therefore describe species contributions under 2019 conditions rather than their multi-year averages. We have added an explanatory note below Table 1 to clarify these distinct purposes and the rationale for the different simulation periods (Lines 382-388).

Lines 382-388:

"Note: Exist-SPE and Exist-PFT uses the 2018-2022 mean to reduce the influence of interannual meteorological variability and obtain a more representative BVOC inventory. The IND scenarios use fixed 2019 meteorology to quantify individual species contributions and identify dominant BVOC-emitting taxa. Restricting these calculations to one year limits the computational cost of generating separate inventories

for 234, 161, and 199 tree categories in Exist-IND, BIO-IND, and SUIT-IND, respectively, while enabling consistent comparisons of vegetation-driven emission differences. All mass-based BVOC emissions reported in this study are expressed as compound mass rather than carbon mass."

Technical Comment:

1. In Figure 1, abbreviations such as EF, LAI, and A&R appear for the first time without their full expanded forms, and the authors should expand all abbreviations in the figure caption at first appearance (EF = emission factor; LAI = leaf area index; A&R = afforestation and reforestation; etc.), or alternatively, add the expansions directly within the figure elements, which will improve the figure's self-contained readability.

[Response] We thank the reviewer for this suggestion. We have revised the Figure 1 caption to define A&R (afforestation and reforestation), EF (emission factor), and LAI (leaf area index) at first occurrence, improving the figure's self-contained readability (Lines 245-250).

Lines 245-250:
"Figure 1. Schematic overview of enhanced local inputs for estimating BVOC emissions in China from existing forests and afforestation & reforestation (A&R) scenarios using the MEGAN model. Red boxes highlight the four key local input enhancements: (1) Species map: refined tree species distribution maps capturing China's vegetation diversity, Sect. 2.2.1; (2) emission factors (EF) dataset: a species-specific emission factor database accounting for inter-specific variability in emission potentials, Sect. 2.2.2; (3) leaf area index (LAI): an enhanced leaf area index dataset representing canopy structure, Sect. 2.2.3; and (4) Landcover type: revised land cover data, Sect. 2.2.4."

2. The manuscript uses the terms "species-explicit" and "species-resolved" interchangeably, with the former appearing in the title and the latter used throughout most of the main text. This inconsistency affects the clarity and coherence of the manuscript. The terminology should be standardized throughout. Since "species-resolved" is more widely used in atmospheric modeling and already appears more frequently in the manuscript, I recommend adopting it consistently, including in the title,

for example: “Species-resolved modelling of forest biogenic volatile organic emissions across China.”

[Response] We thank the reviewer for this suggestion. We have standardized the terminology to “species-resolved” throughout the manuscript, including the title, and replaced “species-explicit” at Lines 1, 16, and 26.

3. In Table S4, numerous tree species are assigned zero values for isoprene and/or monoterpene emission factors, and readers may incorrectly interpret these zero values as indicating that these species emit absolutely no BVOCs, whereas in reality, a value of zero reflects that emissions are below the instrumental detection limit under standard measurement conditions, but trace emissions may still occur under field conditions; the authors should add a uniform explanatory note beneath Table S4, with wording to the effect that emission factor values of zero indicate that emissions were below the instrumental detection limit in available measurements and should not be interpreted as zero emission under all conditions, as trace-level emissions may occur in the field depending on environmental conditions, which will prevent misinterpretation of the emission factor database.

[Response] We thank the reviewer for this suggestion. We have added a note beneath Table S4 in Appendix clarifying that zero emission factors indicate emissions below instrumental detection limits in the available measurements, rather than an absence of emissions under all conditions (Supplementary Material Lines 50-53). We have also adopted scientific notation to preserve small non-zero values.

Supplementary Material Lines 50-53:
“Note: Zero emission factors indicate emissions below instrumental detection limits in the available measurements and should not be interpreted as an absence of emissions under all conditions. Trace emissions may occur under field conditions depending on environmental factors.”

4. Lines 179–182 repeat the aggregation procedure. This passage should be consolidated and rewritten more clearly.

[Response] We thank the reviewer for identifying this repetition. We have consolidated the two sentences into a single statement clarifying how species-specific areas were

aggregated across polygons (Lines 190-191).

Lines 190-191:

"Following disaggregation, the areas assigned to each species were summed across polygons to obtain the total forest area attributed to each of the 234 tree species."

5. Line 272: avoid "While but".

[Response] We thank the reviewer for identifying this grammatical error. We have revised the passage for clarity (Lines 298-299).

Lines 298-299:

"The A&R scenarios distinguish 15 forest types, each represented by a dominant species or species group. These categories remain too broad for species-resolved BVOC emission estimation in MEGAN."

Reviewer #4 (Remarks to the Author):

Biogenic volatile organic compounds (BVOCs) exert substantial impacts on climate change and air quality, as they act as critical precursors to tropospheric ozone and secondary organic aerosols (SOAs). To provide more comprehensive estimates of BVOC emissions, this study develops a species-resolved emission inventory built upon the MEGAN v3.2 modeling framework, combining with species-specific emission factors and high-resolution forest distribution datasets for China. Based on these methodological improvements, the manuscript further addresses China's 2060 carbon neutrality goal and associated large-scale afforestation initiatives by comparing two prevailing afforestation pathways: biomass maximization (BIO) and ecological suitability (SUIT). This manuscript presents the first systematic evaluation of how tree species selection modulates BVOC emission magnitudes and chemical composition, giving the work both fundamental atmospheric science value and direct policy relevance for forestry planning. The scientific contribution lies in establishing the complete research chain from "afforestation species planning → BVOC emissions → ozone/SOA" and breaking the single-dimension evaluation of carbon-centric afforestation by introducing an integrated greening assessment framework that balances carbon sequestration potential against air quality implications. Overall, the study's design and logical narrative are largely complete, yet several deficiencies remain: cursory mechanistic interpretations of scenario results, insufficient uncertainty analysis, non-standard figure annotations, and disorganized reference formatting. I recommend the manuscript be accepted with minor revisions.

1. The introduction only broadly describes China's rich tree species diversity but fails to highlight the core statistic that "234 dominant species cover 90% of the national forest area" upfront. Since this statistic is the foundational justification for constructing a large-scale species-resolved inventory, placing it early in the introduction would immediately establish the study's necessity and prevent readers from questioning why exactly 234 species were selected for simulation.

[Response] We thank the reviewer for this suggestion. We have strengthened the Introduction to emphasize that the 234 dominant tree species account for more than 90% of China's forest area. The revised text explicitly links this extensive coverage to

the rationale for selecting these species and reiterates their representativeness when introducing the study objectives (Lines 90-93, 102-104).

Lines 90-93:
"However, 234 dominant species account for more than 90% of national forest area, indicating that a species-resolved inventory constructed around these dominant taxa can represent the overwhelming majority of China's forest BVOC emissions while remaining tractable to develop and evaluate."

Lines 102-103:
"Here, we developed a species-resolved BVOC emission inventory for 234 dominant tree species that collectively represent more than 90% of China's forest area (Liu et al., 2026)."

2. The research objectives outlined in Lines 97–103 are overly general and fail to clearly articulate the three core innovations of this work. The authors should explicitly enumerate these advances to clearly distinguish their research from prior plant functional type (PFT)-based BVOC modeling studies:

(1) a localized species-resolved emission factor database covering 234 native species;

(2) a disaggregation algorithm for allocating mixed-stand areas to individual species;

(3) a compound-specific BVOC assessment under two carbon-neutrality-oriented afforestation scenarios.

[Response] We thank the reviewer for this suggestion. We have revised the final paragraph of the Introduction to explicitly identify three advances: a localized emission factor database for 234 dominant tree species, a spatial disaggregation procedure for allocating mixed-stand areas among species, and a compound-specific assessment of BVOC emissions under the BIO and SUIT afforestation scenarios. The revised text clarifies how these advances extend conventional PFT-based modeling and support the study objectives (Lines 102-112).

Lines 102-112:
"Here, we developed a species-resolved BVOC emission inventory for 234 dominant

tree species that collectively represent more than 90% of China's forest area (Liu et al., 2026). Our inventory rests on advances in three interconnected areas. To capture interspecific differences in BVOC emission capacity and composition, we first compiled a localized, species-specific emission factor database. We then developed a spatial disaggregation procedure that allocates mixed-stand areas among their constituent species, which allows forest cover to be mapped at the species level and ties each species' emission factors to its actual spatial distribution. Building on this foundation, we further quantified how compound-specific emissions respond to two afforestation and reforestation scenarios that share the same planting area but differ in how species are selected: one maximizing biomass (BIO) and the other prioritizing environmental suitability (SUIT) (Xu et al., 2023a). This framework identifies the dominant species contributing to current forest BVOC emissions and quantifies how species selection in support of carbon neutrality influences emission magnitude, spatial distribution, and chemical composition."

3. The key compositional contrast, isoprene dominance in BIO versus monoterpene dominance in SUIT, is described in scattered paragraphs without a standalone summary statement; given that this is the most critical finding for policy audiences, the authors should extract and highlight this conclusion in a prominent standalone sentence to ensure that non-modeling practitioners (e.g., forestry and environmental agency staff) can grasp the core result at a glance.

[Response] We thank the reviewer for this suggestion. We have highlighted the compositional contrast in the Abstract (Line 29) and added a standalone summary at the beginning of the A&R results section (Lines 813-818). These statements explicitly identify isoprene dominance in the BIO emission increment and monoterpene dominance in SUIT, making the implications of tree-species selection more accessible to readers.

Line 29:

"Notably, the dominant component of additional BVOC emissions shifts from isoprene under biomass maximization (BIO) to monoterpenes under environmental suitability (SUIT)."

Lines 813-818:

"Tree-species selection shapes the chemical composition of afforestation-induced BVOC emissions. Across an identical planting footprint of 78 Mha, contrasting forestation priorities fundamentally diverge the national chemical budget: biomass maximization (BIO) induces an isoprene-dominated emission surge, whereas environmental suitability (SUIT) triggers a monoterpene-dominated shift. This divergence demonstrates that tree species selection acts as an atmospheric lever, inherently dictating whether future afforestation promotes isoprene- or monoterpene-dominated photochemical regimes."

4. Under the BIO scenario, the emission increment hotspots for Quercus aquifolioides are concentrated across Southwest China. The current explanation only references the species' distribution without integrating emission factor properties and regional climatic controls. To fully interpret this spatial hotspot pattern, the authors should combine the high isoprene emission factor of this species (listed in Table S4) with the region's characteristic warm summers and strong solar radiation to deliver a complete mechanistic explanation.

[Response] We thank the reviewer for this suggestion. We have expanded the explanation in Lines 840-845 to link the southwestern hotspot to the extensive planting of *Quercus aquifolioides*, its high isoprene emission capacity, and the enhancement of modeled emissions by summer warmth and strong irradiance.

Lines 840-845:
"The southwestern hotspot reflects the spatial coincidence of extensive *Quercus aquifolioides* plantations (8.43 Mha) with meteorological conditions favorable for BVOC release. Its high, isoprene-dominated emission profile is further amplified by the region's summer warmth and high irradiance, which elevate the temperature- and light-dependent activity factors in MEGAN and translate its intrinsic capacity into elevated realized fluxes across the planted area. Planting extent thus determines where this source is located, while species-specific emission capacity and local meteorology jointly determine its intensity."

5. Under the SUIT scenario, Pinus yunnanensis occupies the largest planted area yet yields lower annual emissions than Pinus massoniana. The manuscript only briefly attributes this discrepancy to low temperatures at high altitudes. This is a typical case

of species-environment coupling and deserves a more rigorous explanation. The authors should compare the two pine species' monoterpene emission factors from Table S4, and explicitly quantify how low temperatures at high altitudes suppress metabolic activity, thereby co-driving the emission gap through both intrinsic emission capacity and environmental constraints.

[Response] We thank the reviewer for this suggestion. We have expanded the comparison in Lines 865-873 to quantify the 37.0% lower monoterpene emission factor of *Pinus yunnanensis* relative to *Pinus massoniana*. We also explain, with supporting references, how cooler conditions may limit monoterpene synthesis and volatilization, linking intrinsic emission capacity with environmental constraints. The temperature contribution was not isolated quantitatively in our simulations; the added discussion therefore provides a mechanistic interpretation of the emission difference.

Lines 865-873:

"In contrast, *Pinus yunnanensis* occupies a larger planted area than *Pinus massoniana* (8.91 versus 7.32 Mha) yet yields lower total BVOC emissions (0.56 versus 0.76 Tg yr^{-1}), reflecting the combined influence of species-specific and climatic constraints. Its monoterpene emission factor is 37.0% lower than that of *Pinus massoniana* (0.45 versus 0.71 nmol m^{-2} s^{-1}; Table S4), indicating a reduced intrinsic emission capacity. This is compounded by its concentration in cooler, high-elevation habitats, where lower ambient temperatures attenuate monoterpene synthase activity and reduce precursor vapor pressure, thereby suppressing both de novo biosynthesis and volatilization (Fischbach et al., 2000; Komenda and Koppmann, 2002). Together, these physiological and climatic constraints outweigh the effect of its larger planted area, resulting in a net emission deficit relative to *Pinus massoniana*."

Komenda, M. and Koppmann, R.: Monoterpene emissions from Scots pine (*Pinus sylvestris*): Field studies of emission rate variabilities, J. Geophys. Res.-Atmos., 107, 4161, https://doi.org/10.1029/2001JD000691, 2002.

Fischbach, R. J., Zimmer, I., Steinbrecher, R., Pfichner, A., and Schnitzler, J.-P.: Monoterpene synthase activities in leaves of *Picea abies* (L.) Karst. and *Quercus ilex* L., Phytochemistry, 54, 257–265, https://doi.org/10.1016/S0031-9422(00)00119-9, 2000.

6. Both scenarios adopt 2019 meteorology as a static baseline, with no discussion of biases introduced by excluding future climate warming effects. Rising temperatures will substantially enhance BVOC emissions across all tree species, meaning the current projected emission increments constitute conservative lower-bound estimates. The authors must explicitly acknowledge this limitation in the discussion section and note that ignoring warming-induced emission amplification imposes a negative bias on their emission projections.

[Response] We thank the reviewer for this suggestion. We have added a discussion of the fixed meteorological baseline and the potential amplification of BVOC emissions by future warming (Lines 928-932).

Lines 928-932:

"It should be noted that these scenario contrasts were evaluated under fixed meteorological condition for 2019. Because future warming would further enhance temperature-dependent BVOC emissions, the present estimates likely represent a conservative lower bound on the emission increments associated with A&R, particularly where temperature stimulation is sustained over the coming decades."

7. The policy implication section lacks sufficient depth and only provides a generic recommendation that BVOC emissions should be considered during afforestation planning. Given the study's strong applied value, the authors should provide more actionable, region-specific management advice. For example: moderately reducing the proportion of high-monoterpene species like Pinus massonianaand Hevea brasiliensis in southern afforestation projects, while concurrently evaluating ozone formation risks when deploying high-isoprene oak species for carbon sequestration in southwestern China.

[Response] We thank the reviewer for this suggestion. We have expanded the policy discussion (Lines 936-946) to address species-specific atmospheric risks and emphasize regional afforestation planning that jointly considers carbon sequestration, air quality, and local climatic conditions. The revised text is provided below.

Lines 936-946:

"More broadly, because afforestation simultaneously functions as a carbon sink and a

driver of BVOC-mediated changes in ozone, particulate air quality, and local climate through altered surface energy and water fluxes, its net environmental benefit cannot be assessed on climate-mitigation grounds alone. Specifically, under BIO, the isoprene-dominated surge is driven disproportionately by *Quercus aquifolioides*, raising surface ozone concerns when deployed in NO_X-rich environments. Conversely, under SUIT, *Pinus massoniana* accounts for the largest share of the monoterpene-dominated increment, enhancing SOA formation across warm, high-irradiance regions and potentially altering regional aerosol loading and radiative balance. Realizing the full impact of large-scale forestation therefore requires an integrated evaluation framework that jointly weighs carbon-sequestration potential against region-specific atmospheric consequences. The species-resolved inventory developed here provides a quantitative basis for such region-specific optimization, supporting the integration of biogenic emission considerations into future afforestation policy design."

Reviewer #5 (Remarks to the Author):

The manuscript describes estimation of biogenic VOC emissions in China using the MEGANv3.2 model. The important achievement of presented work is a compilation of species-specific emission factors with high-resolution forest composition data for China. In combination with updated MODIS LAI and refined MODIS land cover data the authors prepared a detailed regional input data that were used to calculate Chinese BVOC emission inventory for the period of 2018-2022. The authors performed a very thorough analysis of the newly obtained emission dataset by comparison with emissions calculated with less precise land cover inputs (PFT level), evaluating also contribution from individual tree species, to show the added value of the detailed tree land cover description and species-specific emission factors. The species-resolved as well as the PFT based BVOC emissions were compared to measured emission rates at four forest sites. Additionally, the species-resolved BVOCs were used in the WRF-chem model and the resulting SOA concentrations were evaluated with measurements. The manuscript also discussed potential future changes in BVOC emissions if the afforestation and reforestation (A&R) scenarios are applied for China. The two presented scenarios vary in tree species to be planted either to maximize the biomass or to satisfy the highest environmental suitability. Indeed, it is interesting to add yet another parameter, i.e. BVOC emission change (and eventually its impact on the atmospheric chemistry), on top of other environmental implications when creating A&R strategies. I acknowledge the effort to simulate future LAI with series of models trained on current time data and dependent on identified parameters that will carry the future land cover change.

The authors made a great and important effort to compile data of detailed tree species distribution in China together with their assignment with species-specific emission factors. Despite some inevitable assumptions and simplifications, this represents a valuable input dataset for BVOC emission modelling in Chinese region. The newly input data were successfully used in the MEGANv3.2 model and the resulting emissions were thoroughly evaluated and discussed. The manuscript is written comprehensively, with clear structure and very good English. It falls well within the scope of GMD. I recommend the manuscript for publication after addressing the following questions.

Questions to be clarified:

Can the authors please make clear what is the unit of the emissions? Is it Tg of BVOC species or Tg(C)? This is especially important when presenting the BVOC total (e.g. abstract, Table 2, Fig. 4, Conclusion), or the percentage fraction of individual BVOC to total BVOC (e.g. in Sect. 3.3, 4.1, 4.2), given the different molecular weights of different BVOCs. It would be clearer and without doubt or confusion, to state the emissions in Tg(C) and then calculate the percentage contribution of individual BVOC species to the emission total.

[Response] We thank the reviewer for raising this important point regarding unit clarity, and we apologize for not stating this explicitly in the original manuscript. To clarify, all emissions reported throughout this manuscript are expressed in Tg of compound mass (i.e., the mass of the BVOC species itself), not Tg of carbon (Tg C). This is consistent with the native output units of MEGAN, which calculates emission fluxes directly as compound mass rather than carbon mass.

We considered converting the reported totals to Tg C, as suggested by the reviewer, as this would indeed eliminate any ambiguity when comparing species with substantially different molecular weights and carbon contents. However, MEGAN estimates emissions for more than 200 individual BVOC compounds, each with distinct molecular formulae and carbon fractions. A rigorous Tg-to-TgC conversion would therefore require compiling the carbon mass fraction for every one of these compounds individually.

To address the reviewer's concern, we revised the manuscript to explicitly state, at first mention in the abstract, methods, and relevant results sections, that all emissions are reported in Tg of compound mass rather than Tg C. We also add a clarifying note in the relevant table and figure captions to ensure this unit convention is unambiguous.

Lines 19-20:
"Total forest BVOC emissions were estimated at 10.26 Tg of compound mass in 2019"

Lines 387-388:
"All mass-based BVOC emissions reported in this study are expressed as compound mass rather than carbon mass."

Lines 573-574:

"Our species-resolved scheme (Exist-SPE) estimated annual BVOC emissions at 30.28 Tg of compound mass in China"

Lines 616:

"Note Emission estimates from this study are expressed in Tg of compound mass, not Tg C."

Line 625:

"The national annual BVOC emissions in 2019 are estimated at 10.26 Tg on a compound-mass basis"

The soil moisture parameterization of Pegoraro et al. (2004) implemented in MEGANv2.1, and I believe in MEGANv3.2 as well, was shown not to represent the drought stress on plants leading to isoprene reduction accurately (e.g. Opacka et al. (2022) and references therein). Can the authors please confirm that the soil moisture parameterization they used in MEGANv3.2 (gamma_SM) is based on Pegoraro et al. (i.e. depending on soil moisture and wilting point value) and if so, can they estimate how much the soil moisture parameterization impacts their final isoprene emissions?

[Response] We thank the reviewer for highlighting this issue. We confirm that the soil-moisture correction implemented in the MEGAN v3.2 code used here depends on volumetric soil moisture and soil-type-dependent wilting points. However, this correction was disabled in our original simulations.

To quantify the effect of this setting, we performed an additional species-resolved simulation for 2019 with the soil-moisture correction enabled, keeping all other inputs unchanged. Annual forest isoprene emissions decreased from 3.57 to 2.68 Tg, a reduction of 24.9%. Total BVOC emissions decreased from 10.27 to 7.76 Tg (Fig. R1), with larger absolute reductions across southern China and parts of central China. The broad spatial distribution of emissions was retained.

To address limitations of soil-moisture-based drought parameterizations, Wang et al. (2022) developed alternative schemes that represent drought-induced changes in leaf temperature and physiological activity. These schemes improved agreement with observations at the evaluation site and reduced global annual isoprene emissions by

approximately 11% in 2012 relative to simulations without drought effects. However, they are not implemented in the MEGAN v3.2 code used here, and assessing their impact on our inventory would require further model development. Our sensitivity experiment therefore evaluates the effect of enabling the existing soil-moisture correction. We have clarified this distinction and incorporated the results and associated limitations into the revised manuscript (Line 912-916).

Line 912-916

"Fifth, the baseline simulations did not include explicit soil-moisture suppression and may therefore overestimate emissions during drought episodes. Representing this process remains challenging because conventional corrections depend on uncertain soil-moisture inputs and wilting-point thresholds (Opacka et al., 2022). Further evaluation of drought formulations incorporating leaf-temperature and physiological responses (Wang et al., 2022) could improve emission estimates under water-limited conditions."

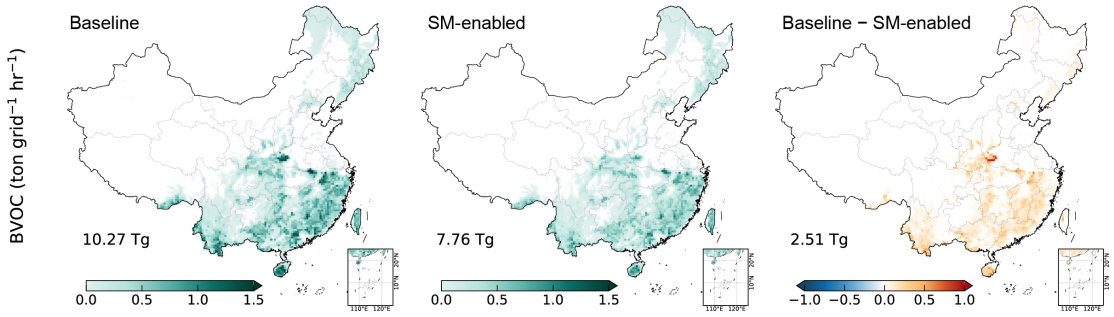

Figure R1 | Sensitivity of forest BVOC emissions to soil-moisture correction in 2019. Annual mean emission rates are shown for (**a**) the baseline simulation (γ_{SM} = 1), (**b**) the simulation with soil-moisture correction enabled, and (**c**) their difference (a - b). All other model inputs were identical. Positive differences indicate emission reductions following activation of the correction. Values within each panel denote annual emission totals or their difference, expressed in Tg of compound mass.

The performance of the WRF-Chem model with Exist-SPE to simulate BSOA is discussed (Sect. 3.2). Did the authors look at how would the model performance compare with measurements when using the Exist-PFT emissions with regard to BSOA?

[Response] We thank the reviewer for this suggestion. We have added an Exist-PFT experiment and compared its simulated BSOA concentrations with observations alongside Exist-SPE. Section 3.2 now evaluates both configurations across urban, rural,

and background sites, with correlation, bias, and error metrics presented in Fig. 7 and Table 3. The revised discussion identifies where species-level refinement improves performance and where discrepancies remain (Lines 493-558).

Lines 493-558:

"To further evaluate the species-resolved BVOC emissions inventory (Exist-SPE), we integrated it into the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem; configuration detailed in Table S3) to simulate SOA over China in 2018. Simulated concentrations were evaluated against 32 ground-based observation records from 30 monitoring stations across China (Fig. 2), yielding a positive correlation between simulations and observations ($r = 0.55$). The mean simulated concentration was 3.47 μg m^{-3}, compared with the observed mean of 4.72 μg m^{-3}, corresponding to a mean bias (MB) of -1.26 μg m^{-3} and a normalized mean bias of -26.64% (Fig. 7a). Beyond this overall underestimation, discrepancies across individual records were characterized by a root mean square error (RMSE) of 3.16 μg m^{-3} and a mean absolute error (MAE) of 2.39 μg m^{-3}. Model performance varied across sites over an observed concentration range of 0.81-15.40 μg m^{-3} (Fig. 7a). The relatively low concentrations at LZ and QMLM were reproduced, while simulated magnitudes closely matched observations at BJ, BN, SY, and JX. Nevertheless, concentrations were underestimated in 23 of the 32 records, with larger absolute deficits at several high-concentration sites (Fig. 7a). These included CD (simulated: 2.49 μg m^{-3} versus observed: 9.40 μg m^{-3}; difference: -6.91 μg m^{-3}), XT (3.01 versus 8.80; -5.79 μg m^{-3}), and PY (4.38 versus 12.50; -8.12 μg m^{-3}), highlighting the remaining difficulty in reproducing elevated SOA concentrations at these sites. Compared with Exist-PFT, Exist-SPE increased the correlation with observations from 0.52 to 0.55 while reducing MAE by 7.88% and RMSE by 2.61%, with MB remaining largely unchanged (-1.20 versus -1.26 μg m^{-3}, Fig. 7a). These results indicate that species-level refinement improved overall agreement across individual records, although systematic underestimation persisted.

To evaluate how model performance varied across sampling environments, the monitoring stations were classified into three categories: urban (13 stations), rural (6 stations), and background sites (11 stations, Fig. 7a), representing locations within or near cities, non-urban rural environments, and representative regional background conditions, respectively. The response to species-level refinement differed among the

three groups. At urban and background sites, Exist-SPE yielded consistent improvements in agreement with observations, with correlation coefficients increasing from 0.40 to 0.53 and from 0.54 to 0.63, respectively, accompanied by corresponding reductions in error: urban MAE decreased from 3.16 to 2.55 μg m^{-3}, while background RMSE declined from 2.12 to 2.04 μg m^{-3}. At rural sites, the simulated mean approached the observed mean despite an increase in absolute error, suggesting a more complex response to the refined inventory.

The clearest improvement occurred at urban sites, where the correlation coefficient increased from 0.40 to 0.53 and MAE decreased from 3.16 to 2.55 μg m^{-3}. Exist-SPE reduced overestimation at HF, lowering the simulated concentration from 9.00 to 6.15 μg m^{-3} toward the observed 5.44 μg m^{-3}, while alleviating underestimation at XZ, where the simulation increased from 6.62 to 7.56 μg m^{-3} against the observed 9.60 μg m^{-3}. Similar improvements were observed at KM and TY through reduced overestimation, and through reduced underestimation at HL (Fig. 7a). These corrections demonstrate that refining forest BVOC emissions improved SOA concentrations at receptors beyond forest environments. Despite persistent underestimation at XT, PY, and ZY, RMSE nevertheless decreased from 3.89 to 3.61 μg m^{-3}, and the overall reduction in MAE and RMSE points to improved agreement across individual records despite the continued systematic underestimation.

At rural sites, Exist-SPE increased the simulated mean from 3.82 to 4.12 μg m^{-3} toward the observed 5.23 μg m^{-3}, however, the response across individual stations was heterogeneous. Underestimation was reduced at TYU, whereas it intensified at KP, and overestimation increased at QYZ, resulting in an overall increase in RMSE from 3.45 to 3.83 μg m^{-3}. This divergence indicates that the apparent reduction in group-level bias did not correspond to a consistent improvement across the six rural records.

Background sites encompass a range of environments, including lakeside locations, high plateaus, and high-altitude mountain settings, as well as forest-surrounded sites such as XL and SH. At these stations, Exist-SPE increased the correlation coefficient from 0.54 to 0.63 and reduced RMSE from 2.12 to 2.04 μg m^{-3}, reflecting improved agreement with the observed concentration pattern. However, simulated concentrations at most sites showed limited variation between configurations, and an overall underestimation of approximately 45-46% persisted. This limited response suggests that refining forest emission factors alone exerts a weaker influence on SOA concentrations at these receptors, where regional transport and non-forest emission

sources likely play a more substantial role. Taken together, these results support species-level refinement as a meaningful improvement to the forest BVOC inventory, evidenced by reduced absolute errors at urban sites and enhanced correlations at both urban and background sites. However, the lack of uniform improvement across all site types underscores the need for further attention to non-forest precursor emissions and to the broader processes governing SOA formation and transport.

The systematic SOA underestimation likely reflects limitations in both precursor emissions and chemical processing. BVOC sources in this inventory are restricted to forests, excluding precursor contributions from croplands, shrublands, and grasslands, whose contribution to the SOA deficit remains unquantified. Within forests themselves, insufficient measurements for certain native tree species may bias the assigned emission factors, though neither the direction nor the magnitude of this bias can currently be established. Chemical uncertainties provide additional plausible explanations. Including both anthropogenic and biogenic precursors does not ensure that their coupled effects on SOA formation are fully represented: anthropogenic pollution can modify biogenic oxidation pathways and promote aerosol formation through sulfate-mediated uptake of isoprene oxidation products (Surratt et al., 2010; Hu et al., 2017). Incomplete treatment of these processes could therefore contribute to underestimation in polluted air masses. Likewise, simplified aqueous-phase pathways could suppress SOA production under conditions favorable for reactive uptake. Li et al. (2019) demonstrated that incorporating dicarbonyl uptake substantially reduced the SOA deficit in a regional simulation over China. Finally, uncertainties in product volatility can alter gas-particle partitioning and SOA evolution during atmospheric aging (Cappa and Wilson, 2012). Incomplete emission coverage and chemical processing limitations shared by both configurations point to a common source of systematic bias that species-level refinement alone cannot resolve."

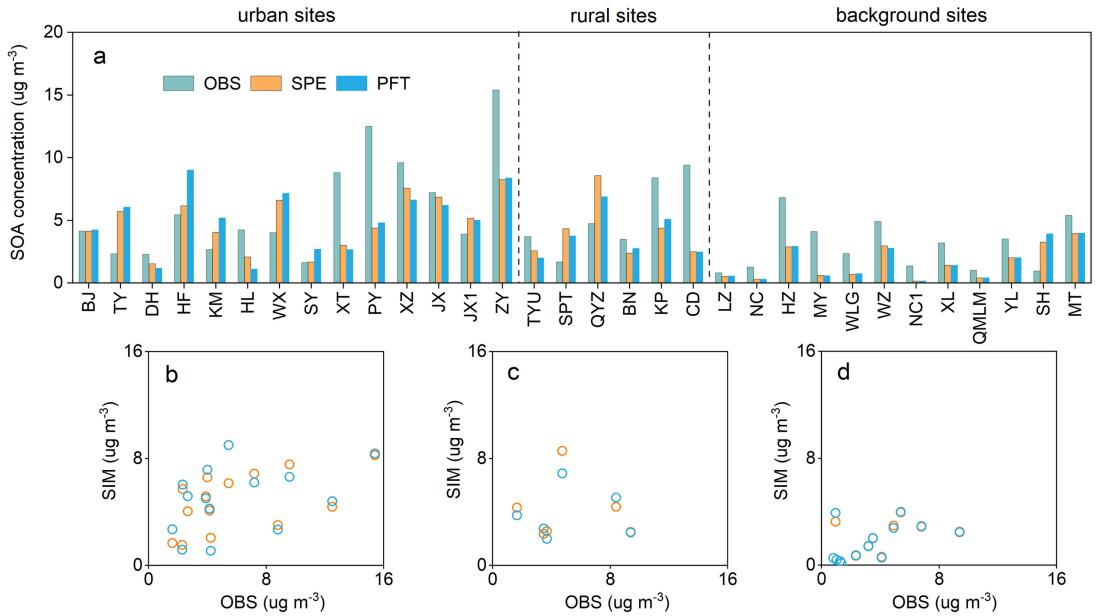

Figure 7 | Comparison of observed and simulated surface SOA concentrations across China. a, SOA concentrations at observation sites grouped into urban, rural, and background categories. Green bars indicate observations compiled from previous studies, while yellow and blue bars show concentrations simulated using Exist-SPE and Exist-PFT, respectively. **b-d**, Observed versus simulated SOA concentrations at urban (b), rural (c), and background (d) sites. Yellow and blue circles represent Exist-SPE and Exist-PFT simulations, respectively. Observational data were compiled from Ding et al. (2014), Zhang et al. (2024), Zheng et al. (2017), Zhu et al. (2016), Zhang et al. (2018b), Xu et al. (2018), Zhang et al. (2019), Qin et al. (2017), Hu et al. (2016), Hu et al. (2013), Huang et al. (2011), Huang et al. (2013), Du et al. (2015), Li et al. (2020a), Wang et al. (2016b), and Zhang et al. (2018a).

Table 3. Evaluation of SOA simulated by Exist-SPE and Exist-PFT inventories against observations at 30 sites (μg m^{-3}).

	Sites	scenario	OBS	SIM	MB	MAE	RMSE	r
All sites	30	Exist-SPE	4.72	3.47	-1.26	2.39	3.16	0.55
		Exist-PFT	4.72	3.53	-1.20	2.60	3.25	0.52
Urban	13	Exist-SPE	6.01	4.79	-1.22	2.55	3.61	0.53
		Exist-PFT	6.01	5.02	-0.99	3.16	3.89	0.40
Rural	6	Exist-SPE	5.23	4.12	-1.11	3.28	3.83	-0.10
		Exist-PFT	5.23	3.82	-1.41	2.82	3.45	0.06
Background	11	Exist-SPE	2.97	1.59	-1.38	1.76	2.04	0.63
		Exist-PFT	2.97	1.64	-1.33	1.83	2.12	0.54

Note: OBS and SIM denote mean observed and simulated concentrations, respectively; MB, MAE, and RMSE denote mean bias, mean absolute error, and root mean square error, respectively; r denotes the Pearson correlation coefficient. All metrics except r are expressed in μg m^{-3}.

Note: It would be interesting to see the impact of the BVOC emission increase under the future A&R scenarios (BIO and SUIT) on atmospheric chemistry. I understand this

was out of the scope of the current paper. Please see this as a suggestion that could be taken up in the follow-up study.

[Response] We thank the reviewer for this valuable suggestion. We are currently examining the atmospheric chemistry responses to BVOC emission changes under the BIO and SUIT scenarios in a follow-up study, using the species-resolved emissions from this work to drive paired WRF-Chem simulations for July across 2005-2024. Preliminary results indicate that A&R increases national BVOC emissions by 45% and raises the BSOA burden by 31%. Through aerosol radiative effects, this enhanced loading alters regional circulation and cloud cover, producing a south-north temperature dipole that amplifies the existing gradient by about 10% (0.33 ± 0.05 °C). The response depends on species composition: strategies prioritizing conifers yield a stronger dipole, amplifying the gradient by 0.40 ± 0.09 °C. These findings point to an underappreciated aerosol-climate pathway through which afforestation-induced BVOC emissions can influence atmospheric dynamics, and they underscore the need to consider species selection and BVOC-mediated feedbacks in future A&R design. The full analysis will be presented in the follow-up study.