

Response to referee comments on “Technical note: 12-km resolution capability for the global GEOS-Chem model of atmospheric composition”

Response to Anonymous Referee #2:

The manuscript “Technical note: 12-km resolution capability for the global GEOS-Chem model of atmospheric composition” by Xiaolin Wang et al. presents the new option to apply a 12 km nest in GEOS-Chem simulations using the global wind archive from NASA GEOS_FP meteorological data assimilation system at 12 km resolution. 12 km nested simulations are evaluated against simulations at 25 km resolution and observations.

This 12 km resolution nested capability of GEOS-Chem is a great advance and very helpful for the atmospheric chemistry and composition modelling community. I think the manuscript would better fit the scope of GMD than ACP. I would suggest transferring it and the review to GMD. Independent of the journal, some points should be addressed before publication.

We thank the reviewer for the positive assessment and the helpful suggestions. Below we provide a point-by-point response to the reviewer’s comments and have revised the manuscript accordingly. Our replies are shown in blue and *revised text is shown in italic blue*. Line numbers refer to the revised manuscript with marked revisions. We believe ACP remains an appropriate venue for this work, as the focus is on the scientific implications and broad applications of the model 12-km capability rather than on major model development.

Major comments

The manuscript is lacking of conclusions. This is kind of surprising because the first chapters of the manuscript are well structured. A small summary is provided at the end of chapter 5, but only the last sentence of the summary is related to chapter 5 itself. I would suggest to move this summary into a proper conclusion chapter, which also should include an outlook.

Thank you for this suggestion. We have revised the previous summary into a conclusion section and added an outlook at the end.

[Section 6, lines 319–323]: *“Overall, this 12-km capability further extends the application of GEOS-Chem in regional atmospheric chemistry and in the use of high-resolution satellite observations to quantify emissions of air pollutants and greenhouse gases at fine spatial scales. Higher model resolution improves the representation of finer concentration gradients and inverse model sensitivity through improved transport and chemistry.”*

Related to the missing conclusions: The manuscript describes the model development well, but lacks in highlighting the scientific impact of these developments.

This has been addressed in our response to the previous comment.

Minor comments

In general:

Please check for a uniform presentation, i.e. “ $0.125^\circ \times 0.15625^\circ$ ” (line 16) and “ $0.125^\circ \times 0.15625^\circ$ ” (line 35) or “ $\approx 12 \times 12 \text{ km}^2$ ” (line 35), “” and “ $\approx 25\text{-km}$ ” (line 73).

Thank you for pointing this out. We have revised the manuscript for consistency.

[Abstract, lines 16–21]: “...from March 2021 onward by accessing a new hourly cubed-sphere C720 (approximately $12 \text{ km} \times 12 \text{ km}$ resolution)... We evaluate this 12-km configuration of GEOS-Chem by comparison with the standard 25-km ($0.25^\circ \times 0.3125^\circ$ resolution)... ”

[Section1, lines 41–43]: “Here we introduce the capability to conduct offline GEOS-Chem simulations at $0.125^\circ \times 0.15625^\circ$ ($\approx 12 \text{ km} \times 12 \text{ km}$) resolution...”

[Section1, lines 83–84]: “The one-way nested GC-Classic capability at GEOS-FP $0.25^\circ \times 0.3125^\circ$ (referred to as 25-km) resolution...”

The date of latest access is missing for most of the links.

Thank you. We have checked the manuscript and added the latest access dates throughout.

Line 32-33: For my understanding, does that mean that the chemistry and meteorology are not coupled, i.e. the chemistry has no feedback on the meteorology?

Yes, we have clarified this in lines 36–41:

“The standard offline configuration of GEOS-Chem is driven by archived Goddard Earth Observing System (GEOS) meteorological data from the NASA Global Modeling and Assimilation Office (GMAO), with no feedback of chemistry on meteorology. GEOS-Chem can also operate online in dynamical coupling with Earth system models (Fritz et al., 2022; Hu et al., 2018; Lu et al., 2020) or the WRF regional model (Lin et al., 2020).”

Line 38: It might be good to include already here, why the simulations are possible from March 2021 and not from an earlier date.

We have revised the sentence to clarify that the simulations begin in March 2021 because the GEOS-FP C720 advection archive is only available from that date onward.

[Lines 41–44]: “Here we introduce the capability to conduct offline GEOS-Chem simulations at $0.125^\circ \times 0.15625^\circ$ ($\approx 12 \text{ km} \times 12 \text{ km}$) resolution by exploiting a new GEOS advection data archive (grid-scale winds) available from March 2021 onward.”

Line 38: What does onward mean? Until when are the NASA GEOS-FP data available?

Thank you for this question. This has been clarified in our response to the previous comment.

Line 99 and 100: Is ‘online’ meant by “on the fly”?

Yes, we have revised the text to clarify this. Lines 119–121 now read:

“Other non-advection meteorological inputs including convective mass fluxes and vertical mixing depths are from the standard GEOS-FP archive at $0.25^\circ \times 0.3125^\circ$ resolution and are dynamically regridded to $0.125^\circ \times 0.15625^\circ$ at runtime.”

Line 115: ‘7 times’ instead of “7×”.

Corrected.

Line 116: See remark to line 115.

Corrected.

Line 225 and following: It would be helpful to include one or two sentences about the basics of analytical inversion of satellite data for readers, who are not familiar with this topic.

Thank you for the helpful suggestion. We have added a brief description of the IMI inversion framework in lines 264–270:

“It uses Bayesian inference to minimize the mismatch between the TROPOMI methane column observations and the corresponding concentrations simulated by GEOS-Chem, regularized by prior information on emissions. GEOS-Chem is applied to construct the Jacobian matrix describing the sensitivity of TROPOMI observations to emissions as simulated by the model transport. This is then used together with the TROPOMI observations, prior emission estimates, and prior and observational error statistics to derive optimized (posterior) emissions.”

Figure 2:

Out of curiosity: Can you explain, what causes the stratospheric negative delta ^{222}Rn difference between 20°N and 30°N in June?

Thank you for this question. We have added a brief discussion in the revised manuscript:

[Lines 183–187]: *“The lower ^{222}Rn concentrations in the tropical stratosphere in June, combined with the lower ^7Be concentrations below the tropopause, may reflect greater restriction of transport across the tropopause at higher resolution (Stanevich et al., 2020) but would require further investigation because the absolute changes are very small.”*

Do you know, what causes the enhanced ^7Be at 12 km resolution compared to 25 km resolution in the troposphere between 20°N and 30°N in June?

Thank you for this question. We have added a brief explanation in the revised manuscript:

[Lines 216–217]: *“The ⁷Be lifetime against deposition is 3% higher at 25-km resolution, explaining the slightly higher overall tropospheric concentrations.”*

It would be great to see for reference how vertical winds for the two different resolutions look like.

Thank you for raising this point. Vertical winds are not directly used in GEOS-Chem, and vertical advection is derived from horizontal mass flux convergence. For this reason, we use the TransportTracers simulation as a benchmark for model vertical transport. We have clarified this in the revised manuscript:

[Lines 165–167]: *“These tracers are particularly useful for evaluating model vertical transport, whereas grid-scale vertical winds are calculated from horizontal mass flux convergence and is not directly available in the model.”*