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Geoscientific Model Development Discussions

Interactive comment on "Grid-Stretching Capability for the GEOS-Chem 13.0.0 Atmospheric Chemistry Model" *by* Liam Bindle et al.

Anonymous Referee #1

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General Comments

The manuscript describes the introduction of stretched-grids for GEOS-Chem in its high-performance implementation GCHP. It demonstrates its abilities in high-resolution modeling by performing two refined simulations, one for the contiguous US using broad refinement, and one for California with a strong refinement of about 10 km. Comparison with TROPOMI tropospheric NO2 retrievals reveals reasonable spatial agreement of the simulated columns, while computational expenses can be cut down significantly in comparison with a global high-resolution run.

Overall, I read the manuscript with curiosity. Grid-stretching, when implemented in global chemistry models benefiting from a HPC environment, has the potential to overcome the barriers which practically limit the models' resolution due to missing computa-

tional resources and model parallelism. Nested simulations are the classical approach, but are hampered by the necessity to define and transfer adequate initial and boundary conditions or coupling parameters between the model domains. Grid-stretching is seamless and easy to use, once the capabilities have been set up properly. The authors' work builds up on a series of recent developments for GEOS-Chem and its components, including grid-independent chemical transport, introduction of stretched-grids for the FV3 dynamical core, improved parallelism and coupling of model components, and the use of grid-independent emission inventories. Here, for the first time all these developments have been combined to allow for high-resolution refinement of chemistry simulations, technically feasible for localized resolutions down to 10 km. Although more validation of the model setup will be needed, e.g. by comparison with in situ measurements, by using equally high resolution meteorological data, or by evaluating transport and diffusion of longer-lived species, I recommend to publish the paper without such extensions but after responding to some minor corrections which are outlined below.

Specific Comments

Introduction

Please give some more overview on other grid refinement techniques, like adaptive mesh refinement (e.g, Slingo et al., 2009; Garcia-Menendez and Odman, 2011) and parent-child coupling (Zängl et al., 2015).

Lines 17-19: Please add production and destruction by chemical reaction.

Lines 19-20: In addition to missing computational resources, models typically also lack sufficient model parallelism, making high resolution simulations inefficient or even unfeasible.

Lines 26-29: Add a few more references which reflect pioneer or developments apart from GEOS-Chem, e.g. Miyakoda and Rosati (1977), Zhang et al. (1986), Krol et al. (2005).

Development of Stretched-Grids in GEOS-Chem

For better orientation to users not familiar with GEOS-Chem: Please add an overview of used cubed-sphere sizes together with an estimate of model resolution in km. This can be given as a table or as a formula if apllicable.

Line 60: Refences should be given already in the introduction.

Lines 64-65: Add references to Rienecker et al. (2008), Todling and El Akkraoui (2018).

Lines 81-82: Re-formulate this sentence. A rotation in latitude (longitude) direction must result in a new target latitude (longitude).

Lines 115-116: Re-formulate this sentence: "A constraint for S, such that the refined domain diameter is greater than wtf . . ."

Line 126: While the constraints given in this section are clear to me, I cannot follow the choice of C104 here. How is this number derived?

Lines 128-131: All emissions presented here are for the US only. What about emissions outside this region? They may play a role for transported species.

Lines 130-131: Add reference to van der Werf et al. (2017).

Lines 145-149: This rather short section raises expectations, that either you will explain next the prototype simulation or the benchmarking code, but you don't follow this path further. Either this section needs to be extended by some more details or even more shortened.

Lines 154-156: If I understood correctly, you chose a stretch factor of 2.4 to achieve a similar resolution of C96-global and C96e-NA over the US. The target point is chosen so that the grid boxes have minimal overlap over the US. Please state this more clearly.

Lines 162-166: Have all simulations been performed using exactly the same time step, vertical resolution, meteorological and chemical input data?

Stretched-Grid Case-Studies

Lines 171-173: I would not call this an assimilation of meteorological data into GEOS-Chem, as the text suggests, it's rather a kind of nudging.

Lines 198-201: For readers not familiar with US geography: Please specify location and type of source for emissions at "Four Corners" and "near Denver". I argue these emissions are from large power plants. Both locations could also be marked in Fig. 6.

Lines 210-211: Can you give a reference?

Lines 211-214: It should be noted here that a resolution of 9-10 km is at the lower edge of what can be simulated using traditional model physics parameterizations.

Lines 216-217: It would indeed be interesting to compare your simulations with a run using meteorological input with higher horizontal, vertical, and temporal resolution.

Line 224: Is any spinup used for this simulation?

Lines 225-228: Please mark less well known cities in Figure 8.

Conclusions

Lines 241-242: Which grid methods exactly can be used by GEOS-Chem?

Appendix A

Line 261: Is it possible to give a formula for deriving the average resolution?

Figures

Figure 1: You could add for illustration, that the number of grid faces is always 6.

Figure 3: "C94-global" can be omitted in the lower panel.

Figure 4: Chemical species are given in mixing ratios, not as concentrations. Please specify mole mole-1 or kg kg-1.

Figure 6: Please mark locations of Denver and Four Corners. What can be said about the point source in western Wyoming, which is only visible in the high resolution simulations?

Figure 8: Please mark locations of Sacramento, Fresno, and Bakersfield. Why are emissions in the San Francisco Bay area largely underestimated in C90-global?

Technical Corrections

Lines 277-278: Exchange “B5” by “B4” (two times).

References:

Garcia-Menendez, F. and Odman, M. T.: Adaptive grid use in airquality modeling, Atmosphere, 2, 484–509, 2011.

Krol, M., Houweling, S., Bregman, B., van den Broek, M., Segers, A., van Velthoven, P., Peters, W., Dentener, F., and Bergamaschi, P.: The two-way nested global chemistry-transport zoom model TM5: algorithm and applications, Atmos. Chem. Phys., 5, 417–432, https://doi.org/10.5194/acp-5-417-2005, 2005.

Miyakoda, K., and Rosati, A.: One-way nested grid models: The interface conditions and the numerical accuracy, Mon. Weather Rev., 105, 1092-1107, 1977.

Rienecker, M. M., and Coauthors, 2008. The GEOS-5 data assimilation systemâĂŤDocumentation of versions 5.0.1, 5.1.0, and 5.2.0. NASA/TM-2008-104606, Vol. 27, 118 pp., https://gmao.gsfc.nasa.gov/pubs/docs/GEOS5_104606-Vol27.pdf.

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van der Werf, G. R., Randerson, J. T., Giglio, L., van Leeuwen, T. T., Chen, Y., Rogers, B. M., Mu, M., van Marle, M. J. E., Morton, D. C., Collatz, G. J., Yokelson, R. J., and Kasibhatla, P. S.: Global fire emissions estimates during 1997–2016, Earth Syst. Sci.

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Zängl, G., Reinert, D., Rípodas, P., and Baldauf, M.: The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core, Q. J. Roy. Meteor. Soc., 141, 563–579, doi:10.1002/qj.2378,2015.

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