Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., referee comment RC2
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Comment on gmd-2022-76

Anonymous Referee #2

Referee comment on "Downscaling atmospheric chemistry simulations with physically consistent deep learning" by Andrew Geiss et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-76-RC2, 2022

General Comments

This manuscript describes the effort to use deep convolutional neural networks (CNNs) to downscale atmospheric chemistry simulations, focusing on NO_2, SO_2, CO, O_3, and $PM_{2.5}$. The authors develop and evaluate the performance of SISR-CNNs and VSR-CNNs, demonstrating that these new methods outperform nearest neighbor, bilinear, and bicubic interpolations, as well as "Clim." Especially, the authors develop methods that can strictly enforce physical conservation laws within CNNs, perform large and asymmetric resolution changes (8 x 10) between common model grid resolutions, account for non-uniform grid cell areas, super resolve log-normally distributed datasets, and leverage additional inputs such as high-resolution climatologies and model state variables. This work is significant not only for the community of atmospheric chemists but also for climate modelers. This manuscript is well written, and it should be published after the authors address my comments listed below.

Specific Comments

(1) Perhaps I misunderstood, but I do not fully grasp how the conservation enforcement layer works. According to equations (3) and (4), the output from this layer appears to be P (mixing ratio in a single low resolution grid cell)? How does this layer interface with the output layer ("0.25° x 0.25° Resolution Output")? Any variable transformations occurring here? For gradient descent to update the parameters, I am under the impression that "weights" and "biases" are needed, but I cannot locate such parameters in this conservation enforcement layer. It would be helpful for readers to have more information.

(2) I would like to bring to the authors' attention some related prior work that develops a CNN kernel for unstructured grids for spherical signals, which may enhance the model's performance. I believe a short discussion would be beneficial.

https://openreview.net/forum?id=Bkl-43C9FQ

(3) If I'm correct, SISR-CNNs and VSR-CNNs can only process "one pollutant" at a time? Or they can process "multiple pollutants" (such as RGB channels in an image) simultaneously?

(4) Line 110: There are multiple ways to degrade or prepare low resolution data, making the term "degraded" unclear. Readers may believe, for instance, that the authors conducted simulations with two resolutions separately (using a nested mesh for example). Consequently, I believe that "2-D averaging" should be made explicit here.

(5) Line 171-174: Any citations to support the argument made in factor (1)? Glorot and Bengio (2010) spoke about normalized Initialization for deep feedforward neural networks, but not for convolutional neural networks.

(6) Additional information about the runtime would be beneficial for users. For instance, the number of GPUs used and the training time for SISR-CNNs and VSR-CNNs.

Technical Corrections

Line 190: What is "a-priori"? Is this a typo?