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Discussions

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# *Interactive comment on* "Revised treatment of wet scavenging processes dramatically improves GEOS-Chem 12.0.0 simulations of nitric acid, nitrate, and ammonium over the United States" *by* Gan Luo et al.

**Anonymous Referee #2**

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This paper presented a revised wet scavenging parameterization that considers the spatiotemporal variability of cloud liquid water content and an empirical washout (below-cloud scavenging) rate in the GEOS-Chem global chemical transport model. The authors showed that the updated parameterization significantly improves simulated annual mean (and seasonal) mass concentrations of nitric acid, nitrate, and ammonium as compared with surface observations over the U.S. This is an important contribution to the improvement of GEOS-Chem. Minor revision is recommended before publication on GMD.

Major comments:

The impact of updated wet scavenging on model simulations was only assessed at the surface level and for nitric acid, nitrate, and ammonium over the U.S. It's not shown how the updated treatment of scavenging affects the global aerosol simulations, especially the vertical profiles and other aerosol species (e.g., sulfate). Consider discussing this in the Summary and Discussions section. Lead-210 aerosol tracer has been used to test wet deposition in GEOS-Chem (e.g., Liu et al., 2001), and this updated scavenging parameterization will need to be tested with (at least) lead-210 before it is incorporated into the standard version of the model.

Page 5, equation 4: 1). "CW is grid-box mean cloud water content". What's the corresponding variable name in MERRA-2? Does it include both cloud liquid (QL) and ice (QI), or QL only? 2). It's not clear why the rain water term "Pr*DeltaT" is needed. There is no prognostic precipitation (no raining condensate) in MERRA-2 or GEOS-5. Prognostic cloud liquid and ice are autoconverted to estimate precipitation. Are "CW" values for pre-conversion or post-conversion? More explanation as well as references are needed.

Page 7, lines 20-23: The first-order rainout parameterization is not used for convective precipitation scavenging in GEOS-Chem driven by MERRA-2. Instead, scavenging in convective updrafts are coupled with convective transport (e.g., see section 2.3.1 of Liu et al., 2001).

Minor comments:

Title: Suggest adding "surface" to the title since this study examined the impact of revised scavenging on surface aerosol concentrations only.

Page 1, line 21: typo "mentoring" ("monitoring")

Page 3, lines 6-7: are there references for this statement?

Page 3, line 14: change "in-site observations" to "surface observations"

Page 3: A brief description of the GEOS-Chem model is needed here before discussing the wet scavenging scheme.

Page 3, section 2: See this webpage http://acmg.seas.harvard.edu/geos/geos_chem_narrative.html for "Narrative description (and how to cite GEOS-Chem)", which provides guidance on citing relevant model components. "The wet deposition scheme in GEOS-Chem is described by Liu et al. [2001] for water-soluble aerosols and by Amos et al. [2012] for gases. Scavenging of aerosol by snow and cold/mixed precipitation is described by Wang et al. [2011, 2014]." Suggest citing Jacob et al. (2000) along with one of these publications, where appropriate, since it is an unpublished document. The first-order rainout parameterization (equations 1 and 2) is based on Giorgi and Chameides (1986), which also needs to be referenced.

Specify the units for variables in all equations in the text.

Page 4, line 3: condensed water content includes liquid and ice phases. Do you revise warm cloud scavenging only here? Does "Pr" (rate of new precipitation formation) include snow? How about ice cloud scavenging?

Page 4, lines 23-25: Croft et al. (2016) previously used GEOS-5 cloud liquid and ice water content to replace the fixed value in their GEOS-Chem-TOMAS simulations. Consider citing that work here. (Croft, B., Martin, R. V., Leaitch, W. R., Tunved, P., Breider, T. J., D'Andrea, S. D., and Pierce, J. R.: Processes controlling the annual cycle of Arctic aerosol number and size distributions, Atmos. Chem. Phys., 16, 3665-3682, https://doi.org/10.5194/acp-16-3665-2016, 2016.)

Page 8, line 4: these references are not for rainout and washout parameterizations, but for the standard GEOS-Chem model (or other model components).

Page 9, line 13: CCW or ICCW?

Page 9, line 17: concentrations OF; line 20: showS

Fig. 2 caption: indicate the year and number of sites over the U.S., and note the small

differences between blue and green dashed lines.

Fig.3 caption: annual mean surface

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Discussion paper