

We appreciate the generally favorable nature of the peer reviews and the opportunity to enhance the paper by responding to specific comments. Comments are shown in italics, with responses provided below.

Response to SC1: 'Executive Editor Comment':

To comply with GMD guidelines, we added the version number to the title:

"Enhanced representation of soil NO emissions in the Community Multi-scale Air Quality (CMAQ) model version 5.0.2"

Response to RC1: Anonymous Referee #1:

Lines 68-69: Suggest rewording this sentence for clarification. It seems to suggest that deposition is a larger source of N in agricultural soils than fertilizer, which does not seem to be supported by the referenced papers.

We agree that the sentence was unclear, and have simplified the paragraph to the following for clarity:

Both wet and dry deposition act as sources of nitrogen to soils (Yienger and Levy, 1995; Hudman et al., 2012). N is deposited in both oxidized (e.g., nitrate) and reduced (e.g., ammonium) forms, with ammonium representing a growing share of N deposition in the U.S. as anthropogenic NO_x emissions are controlled (Li et al., 2016).

Li, Y., Schichtel, B.A., Walker, J.T., Schwede, D.B., Chen, X., Lehmann, C.M., Puchalski, M.A., Gay, D.A. and Collett, J.L.: Increasing importance of deposition of reduced nitrogen in the United States. Proceedings of the National Academy of Sciences, p.201525736, 2016.

The last two paragraphs of the introduction talk about your approach without specifically mentioning that you will be applying your updates to the CMAQ model (ie: you don't say you are running CMAQ). You should add that. Also, the text does not say whether you are running your simulation with bi-di (Figure 3 would suggest you are.) Can you clarify in the text?

We clarify that the update is being applied to CMAQ (line 111) and that the bi-directional capability of CMAQ (which currently affects ammonia only) was applied (line 315-316).

Methodology: Lines 156-157: Awkward use of the word “significant”. Are you trying to say that dry spring fertilizer application happens a lot?

We rephrased this to “is common practice”.

Lines 164-165: make units consistent.

The units for mass have been made consistent.

Lines 174-175: Personally curious, is there an existing or theoretical pathway through which this information could be used to reduce fertilizer demand and actual application? Would it be significant?

Yes, N deposition in theory reduces the need for fertilizer and it is accounted for implicitly in EPIC’s simulated farming practices.

Lines 285-287: Do you say anywhere what the baseline year is for EPIC? (ie: land use, and management practices must be based on some start point? Or updated annually?)

We clarify in Section 2.1.3 that 2011 is the baseline year and that EPIC updates land use and farm management practices annually based on the USDA Agricultural Resource Management Survey (ARMS) (Lines 174-177).

Results and Discussion: Lines 356-357: this is in stark contrast to your introduction and suggested purpose for evaluating improved representation of key factors (ie: that NO emissions from soil are 1.5 to 4.5 times too low in the traditional YL representation). You discuss some reasons why (lines 436-438). Why would these factors not apply to other areas that are not over-estimated?

In their global comparison of BDSNP-based soil NO emissions with an OMI satellite-based inversion, Vinken et al. (2014) found the central US to be one of the few areas where the BDSNP inventory over-estimated the satellite-based results (see Figures 6-7). This contrasted with other regions (Sahel, Australia and Eastern Europe) where Vinken found the BDSNP soil NO inventory to underestimate OMI-based results. The reasons for these regional differences are still not well understood. (Lines 369-371)

Lines 384-396: was met model performance for rain evaluated for this region in July? Ie: did you test this hypothesis? Since this also could help explain the over-estimation in the mid-west, it seems like this would be important to test.

The figure below (included in supplementary material as Figure S6) evaluates modeled meteorological performance for precipitation compared to National Atmospheric Deposition Program (NADP) precipitation values for July 2011 on a monthly mean basis. Given the large site-to-site variability in WRF performance for precipitation, we remove the claim that a wet bias caused an over-estimation of soil NO.

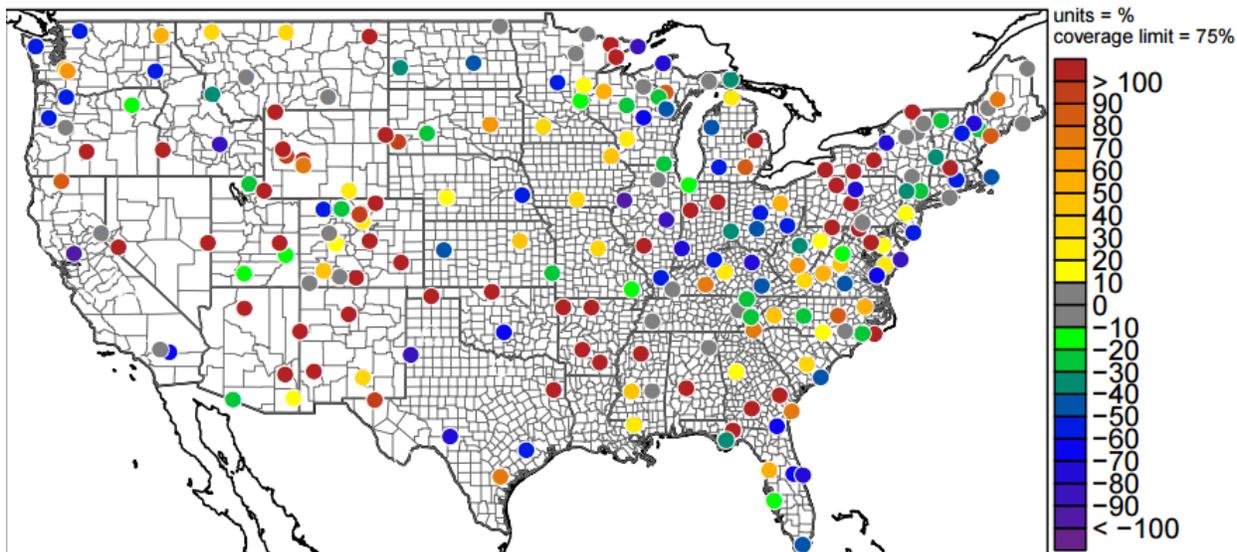


Fig. Normalized mean bias (%) of WRF model relative to NADP observed monthly mean precipitation for July 2011

Response to RC1: Reviewer 2:

Comment 1. In Section 1 Introduction and Section 2 Methodology, the authors spend a lot of effort to describe the YL, BDSNP (Potter with old biome) and BDSNP (EPIC with new biome) schemes. To help readers better understand the differences between the three schemes, I would suggest the authors adding a table to summarize them.

We adopt the reviewer's suggestion by adding Table A3.

Comment 2. Tables 2 & 3. For modeled daily average PM2.5 and MDA8 Ozone concentrations, the differences between the three schemes are very small. I would suggest the authors conducting a t-test to examine if the differences in the modeling results over the studying domain are statistically significant or not.

We performed ANOVA (Analysis of variance) and t-test for MDA8 Ozone and daily average PM2.5 modeled concentrations as suggested by the reviewer. For MDA8 ozone, the differences between YL and BDSNP are significant (F ratio> F critical; $p < 0.05$), but the differences between the two BDSNP runs were not significant ($p > 0.05$). (Lines 376-378)

For MDA8 Ozone: $F \text{ ratio} > F_{\text{critical}}$ and $P\text{-value} \ll 0.05$ from ANOVA analysis so the difference between 3 schemes are statistically significant.

Anova: Single Factor
(for MDA8 Ozone)

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
YL	458	25237	55.10262	120.9107
BDSNP (Potter with old Biome)	458	26336	57.50218	136.8501
BDSNP (EPIC with new Biome)	458	26520	57.90393	140.6297

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	2101.707	2	1050.854	7.913244	0.000383	3.002288
Within Groups	182064.4	1371	132.7968			
Total	184166.2	1373				

	One-tailed t-test P-value	2-tailed t-test P-value
YL vs BDSNP(Potter with old biome)	0.000714399	0.001428798
YL vs BDSNP (EPIC with new biome)	0.000111204	0.000222407
BDSNP (Potter with old biome) vs BDSNP (EPIC with new biome)	0.302939969	0.605879938

For PM2.5 (daily mean), $F\text{-ratio} < F_{\text{critical}}$ and $p\text{-value} > 0.05$ in comparisons among the three cases, so the differences are not that statistically significant.

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
YL	81	478.456	5.906864	7.94423
BDSNP (Potter with old Biome)	81	489.285	6.040556	8.556796
BDSNP (EPIC with new Biome)	81	492.356	6.078469	8.771841

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1.316495	2	0.658247	0.078137	0.924861	3.033439
Within Groups	2021.829	240	8.424289			
Total	2023.146	242				

	One-tailed t-test P-value	2-tailed t-test P-value
YL vs BDSNP(Potter with old biome)	0.383729	0.767459
YL vs BDSNP (EPIC with new biome)	0.353058	0.706116
BDSNP (Potter with old biome) vs BDSNP (EPIC with new biome)	0.467386	0.934773

Comment 3. Pages 30-31. The quality of Figures 4 & 5 needs to be improved. The figures are stretched horizontally or vertically.

Revised manuscript provides figures with better quality without distortion.

Comment 4. For Figure 10, the unit formats of x- and y- axis should be consistent. Currently, "PM2.5; $\mu\text{g m}^{-3}$ " is used for x-axis, but "PM2.5 ($\mu\text{g m}^{-3}$)" is used for the y-axis.

In the revised version, parentheses are used for both unit formats (x- and y- axis).