**Biogeosciences
Discussions**

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Interactive comment on "Linking agricultural crop management and air quality models for regional to national-scale nitrogen assessments" *by* E. J. Cooter et al.

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RESPONSE TO REVIEWER #1 COMMENTS:

Comment: L15P6096: I am not sure I fully understand what "temporally progressive spatial patterns" really are. Is there maybe a simpler way of describing what you mean. Are you talking about distributions that vary in space and time? I believe this expression also appears somewhere in the main text foe which I commend the authors.

Response: "An state-level evaluation of EPIC-simulated crop management activities associated with fertilizer application at planting compared with similar USDA state-level event estimates shows temporally progressive spatial patterns that agree well with one

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another. " has been modified to read "Initial fertilizer application often occurs when crops are planted. State-level time series of simulated cumulative planted area compare well with similar USDA estimates." I was unable to locate the other referenced phrase, but text on L5p6016 has been modified for clarity and to agree with this language.

Comment: L3P6098: reference Sutton et al. appears again with different year but not in the list of references. reference missing or wrong year given?

Response: This has been corrected.

Comment: L9P6101: the concept of "accumulated heat units" is introduced but no further detail is given. I think it would be helpful for the readers unfamiliar with the subject if a brief explanation would be added; one sentence would be enough.

Response: Heat Units are now defined and an equation has been added.

Comment: L16P6103: the "use of a weather simulator" in EPIC is mentioned but not further discussed. Again, one or two additional sentences of explanation would help the reader.

Response: The weather simulator is now more fully described and references provided for various components.

Comment: L9P6105: I think it would help a balanced presentation if Figure 4 would include maybe one less favourable example of comparison for other crops/locations since it is mentioned in the text.

Response: A third set of graphics has been added to Figure 4 illustrating a case in which further management adjustments are needed to meet our plant/harvest date activity targets. Discussion of these panels has been added.

Comment: L22P6107: can you clarify what you mean by a "one atmosphere system". I am not sure I am familiar with this term.

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Response: Traditionally, air quality models have addressed individual pollutant issues, such as urban ozone, regional acid deposition, particles, nitrogen, and toxics problems, separately. However, many of the air pollutants are subjected to the same meteorology and oxidation processes. CMAQ takes a comprehensive multi-scale and multi-pollutant approach. "One atmosphere" is used to describe this more holistic approach. The text has been modified to reflect this clarification.

Comment: L19P6110: I am not a big fan of references in the Abstract and Conclusions but if it is absolutely necessary...

Response: No change was made.

Comment: L4P6112: it is stated that "expert knowledge" is used in addition to USDA data and fertilizer sales. Can you clarify what you mean by this; are we talking about empirical data; an educated guess or some other data source.

Response: The term "expert knowledge" has been changed to "recommendations of knowledgeable agricultural experts.."

Comment: P6124: For the final publication I'd like to see the quality of the plots in Figure 4 B, C and D to be more on par with Figure 4 A.

Response: I assume you are referring to Figure 5 since that is the only figure with panels A-D. Upon review, we could not see any noticeable difference in graphics quality across the panels.

Comment: P6126: the caption specifies that both the black line and the black triangle represent median biases from the observations. Isn't one of them meant to be the mean bias? Or do I misunderstand the Figure entirely?

Response: The black triangles on the plot were mislabeled as the median bias and should have been the mean bias and in the caption. This has been corrected.

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RESPONSE TO REVIWER #2 COMMENTS:

Comment: Given the title of this manuscript, would it be appropriate to include a reference in the Background and Introduction section to the 2011 EPA Scientific Advisory Board report on reactive nitrogen in the United States (see http://yosemite.epa.gov/sab/sabproduct.nsf/0/67057225CC780623852578F10059533D/F ile/EP A− SAB − 11 − 013 − unsigned.pdf)?

Response: The reference has been added.

Comment: As may be the case for many potential readers of this paper I do not have a lot of familiarity with the EPIC model. Section 2 of the manuscript gives a very good overview of this model and how it was set up and used in this study, but there are still some additional details that I would like to know: If EPIC is a field-scale model (p. 6099, l. 17), how does it handle multiple fields and grids, i.e., arrays of fields?

Response: The heading for section 3 will be changed to "Continental-scale EPIC application and evaluation" and a new section 3.1 headed "Continental-scale application of EPIC" will be added containing the following text:

This application assumes that each 12km model cell contains multiple EPIC monoculture "fields", but the location of each field within a grid cell is spatially indeterminate. Previous regional air quality applications suggest that this level of indeterminacy is sufficient for modeling regional emission and atmospheric transport of agricultural chemicals (e.g., pesticides Cooter et al., 2002a and 2002b). As described in section 2.1.2, agricultural area in a grid cell is determined using the 30m 2001 NLCD data layer (classes 81 and 82), and the distribution of specific crops within these NLCD grid areas is determined using the USDA County crop statistics. Each 12km grid cell is assigned to a County polygon and is assumed to mirror that County's crop distribution. When a grid cell spans multiple County polygons, the NLCD-determined agricultural area is assigned proportionally to each County and the appropriate County crop distribution is applied to those grid areas. An EPIC field, then, is defined as the agricultural

area assigned to a specific crop within a 12km grid. There can be up to 42 fields (21 rainfed or irrigated crops, see Table 2) in a grid cell in this application. As noted in section 2.1.1 and 2.1.3, specific crop and soil combinations vary by 8-digit HUC, and crop-specific management varies on an agricultural production area basis. Once again grid cells crops (fields) are assigned to HUCs and production areas based on the proportion of area contained within HUC or production region polygon resulting in a suit of "typical" field-scale scenarios for each grid cell. EPIC is then run for each crop scenario in each grid cell ($\sim$246,000 scenarios, i.e., simulations) across the full U.S. model domain. These results are then area-weighted (weights based on NLCD and USDA County statistics) to an aggregate grid-cell estimate of fertilizer input, which can then be shared with the regional air quality model.

Cooter, E.J. and Hutzell, W.T., 2002. "A Regional Atmospheric Fate and Transport Model for Atrazine. 1. Development and Implementation," Environ. Sci. Technol. , 36(19): 4091-4098.

Cooter, E.J., Hutzell, W.T., Foreman W. ,and Majewski, M., 2002. "A Regional Atmospheric Fate and Transport Model for Atrazine. 2. Evaluation," Environ. Sci. Technol. , 36 (21): 4593-4599.

Comment: Section 2.1 mentions a target grid (p. 6100, l. 22), but to me this term merely suggests a design goal. The rest of Section 2 then mentions grid cells a few times and Figure 3 is discussed, but it is not until the unexplained 14,400 factor appears in Eq. 1 that there is strong evidence that EPIC was in fact run for a continental-scale 12 km by 12 km grid on some unmentioned map projection. The paper would be strengthened if a sentence could be added here to say that in fact EPIC was run for a continental 12 km by 12 km rectangular grid on such-and-such a map projection. Then some text should be added to Sections 2.1 to 2.3 to explain how the various agriculture-related input data sets were allocated to this 12 km by 12 km grid and, conversely, how the county-level inorganic N use values presented in Fig. 5a were obtained from this grid.

Response: See new discussion 3.1 above.

Comment: Section 2.1.2 mentions that the USGS NLCD, which contains 29 aggregate land use categories, was used but it does not mention exactly which of those 29 categories were used in this study. This information seems to be provided later on in Section 3.2, but it might be more appropriate to mention it earlier in the manuscript.

Response: This information has been added to section 2.1.2.

Comment: Section 2.1.3 mentions that there are 150,000 8-digit HUCs in the continental U.S. with an average areal extent of âĹij 2,000 km2, which implies a total area of âĹij 300 million km2, but my understanding is that the area of the continental U.S. is a bit over 9 million km2. Please check and correct as necessary.

Response: There are several problems with this statement. It has been corrected to indicate there are 2119 8-digit HUCs in the continental US, with an average size of 3813 km2. Area for the coterminous US is 8080463 km2. This HUC characterization results in an area of 8079747.

Comment: Section 2.1.3 mentions that EPIC was run for a 25-year spin-up period, Section 2.1.4 describes the weather data needed as input by EPIC, and Section 4 talks about coupling EPIC output to CMAQ, but I was not able to find any discussion of the time step used by EPIC or the time resolution of EPIC inputs or outputs. Please add this information to the manuscript.

Response: This has been added in section 2.

Comment: Section 4 lists the EPIC outputs supplied to CMAQ as "fertilization rates, timing, method, and managed soil pH values". Up to this point in the manuscript, however, the only previous mention of soil pH was that it is one of the soil characteristics that must be input to EPIC (Sec. 2.1.3). Is soil pH also a time-dependent prognostic field that is predicted by EPIC and that was referred to by the general term "soil characteristics" on p. 6103, l. 5?

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Response: Yes, soil pH is a standard soil characteristic that is output by EPIC

Comment: I am not entirely clear on the way the contribution of manure to NH3 emissions was handled. In Eq. 1 it is subtracted from crop N demand, although the text does not explain why this was done. Presumably this was to allow an apples-to-apple comparison with the other estimates of commercial fertilizer application shown in Fig.5. But in Section 4 it is not indicated whether or not the EPIC fertilization rate estimates that are supplied to CMAQ do include manure application.

Response: In section 3.2, "inorganic" has been added to the description of the databases being compared to make it clear that the subtraction of manure in equation 1 is to facilitate apples-to-apples comparisons. Ammonia emissions when manure is produced and land application of manure associated with animal feeding operations are included in the NEI emission factor for animal facilities (a function of County level animal numbers) and is not included here to avoid double counting. The text has been checked throughout to emphasize the fertilizer application provided to CMAQ is inorganic NH3 only. A sentence has been added to section 4 that states, "The NEI estimates of animal feeding operation emissions are retained to characterize direct ammonia emissions from organic sources (manure)."

Comment: The discussion of Eq. 1 in Section 3.2 does not explain the purpose or give the units of the 14,400 factor.

Response: The conversion factor, 14400 has been defined as the number of ha contained within one 12 km rectangular model grid cell.

Comment: For the 5-year average annual inorganic N use values calculated by EPIC and plotted in Fig. 5a, how much interannual variability is there in this field given that the weather simulator described in Sec. 2.1.4 apparently generates (hourly? daily?) statistical fluctuations?

Response: The exploration of interannual variability is underway and the evaluations

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presented here will be repeated for year-specific weather. The weather simulator is internal to EPIC and simulates only daily weather conditions. This information is now included in an expanded description of the weather simulator.

Comment: In Section 4, with respect to the synchronization between EPIC outputs and CMAQ time steps, what is the frequency of EPIC outputs and what is the CMAQ time step that was used for the 2002 simulation?

Response: This has been clarified. EPIC fertilizer estimates are output on a daily basis and CMAQ operates using a dynamic time step that is dependent on the horizontal and vertical grid spacing and meteorology ($\sim$5 minutes for a 12 km grid spacing)

Comment: In Section 4, concerning the statement on p. 6108, l. 22 that "Ammonia evasion and NH+ nitrification losses were modeled for each CMAQ soil layer", how many CMAQ soil layers were there?

Response: The sentence has been revised to explicitly state the number and depth of the CMAQ soil layers.

Comment: In Section 4 the comparison of CMAQ PM2.5-NO3 predictions with CSN and IM- PROVE PM2.5-NO3 measurements shown in Figure 7 might be bewildering to some readers. No explanation is given in the text as to why a PM2.5-NO3 comparison was performed as opposed to a PM2.5-NH4 comparison or why particle nitrate is a good proxy for particle ammonium. And can the authors comment on how similar the resultswere for the comparison of CMAQ predictions with CSN PM2.5-NO3 vs. PM2.5-NH4? Note that the similarity in evaluation results between the CSN urban measurements (Fig. 7b) and IMPROVE rural measurements (Fig. 7c) supports the statement that particle ammonium is a regional pollutant.

Response: The NO3- aerosol was used to evaluate these simulations because the largest changes in the emissions were in the early spring and late fall when the NO3- aerosol is sensitive to changes in ambient NH3, and due to the lack of IMPROVE NH4+

and ambient NH3 observations. CSN PM2.5-NH4 observations were not included in this evaluation due to uncertainty that the heterogeneity in urban emissions may add to the evaluation.

Comment: One conclusion listed in Section 5 is that the EPIC predicted planting date "should fall within 10 days of observed dates" (p. 6110, l. 7). I am not sure that conclusion was discussed or supported in Sec. 3.1 or elsewhere in the manuscript.

Response: This statement has been modified to "A preliminary evaluation of 5-yr average results suggests good agreement between simulated and observed timing of fertilizer applications at planting and . . .."

TECHNICAL AND TYPOGRAPHICAL CORRECTIONS

p. 6096, l. 12: Should soil processes also be mentioned? AGREE p. 6096, l. 20: Would "atmospheric particle nitrate concentrations" be more accurate? AGREE p. 6099, l. 2: "effect" rather than "affect". CORRECTED

p. 6099, l. 22: Perhaps "... the construction of terraces and the installation of tile ...". AGREE p. 6101, l. 24: "US Corn Belt"? CORRECTED p. 6106, l. 16-17: Which of the USEPA and USGS estimates is the larger one?

RESPONSE: The USEPA estimate is larger since it includes non-commercial agriculture purchases (see ms).

p. 6107, l. 25: If CMAQ is a "modeling system" (l. 19), then do you really want to say that the CMAQ CTM is also a "modeling system"? AGREE

p. 6107, l. 26-27: Concerning emissions being parameterized as emission factors, would it be more accurate to say "the product of emission factors and activity rates"? AGREE

p. 6108, l. 6: "coarse aerosols" CORRECTED

p. 6110, l. 23: "generation of I/O API formatted"? CORRECTED

p. 6112, l. 4: "allocate"? CORRECTED

p. 6117: I noticed two missing references: CORRECTED

p. 6118, l. 4: Reference in Table 1 caption to Fig. 1 should be to Fig. 2. And what is the "organizing principle" for the order of the production regions as given?

Response: The table is now organized geographically, east to west and north to south.

p. 6118, Table 1: The "PA" column does not sum to 100. Is the value for manure missing? CORRECTED

p. 6121: Would "USDA Farm Production Regions" be a better caption (cf. Sec. 2.1.1). AGREE

p. 6123, Fig. 4: Better x-axis caption might be "Week Ending Julian Day". AGREE

p. 6124, Fig. 5: Perhaps "(A) 5-yr average annual plant ... of inorganic N use (kg/county),"? CORRECTED

p. 6126, Fig. 7: The acronyms "CONUS" and "CAFO" are not defined in the manuscript; are NH3 emissions from on-road mobile sources as reported in the 2005 NEI also considered? Also, "CSN", not "STN"? And perhaps "Monthly model ambient NO3 biases for 2002 at urban ..."

Response: The acronyms were defined and the referee's suggested wording was used.

p. 6126, Fig. 7: Doesn't the black line in the box-and-whiskers plots represent the mean bias?

Response: The black line is the 50th percentile in these box plots which is the median bias. However, the black triangles on the pot were mislabeled as the median bias and should have been the mean bias and in the caption.

p. 6126, Fig. 7: Can the y-axis labels and the embedded keys in the three panels be made any larger?

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Response: The font in the y-axis labels and legend was increased.

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