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Interactive comment on "Capturing interactions between nitrogen and hydrological cycles under historical climate and land use: Susquehanna watershed analysis with the GFDL Land Model LM3-TAN" *by* M. Lee et al.

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<Q. Zhang>

Dear Reviewer,

We deeply appreciate the time and effort you spent on reviewing our manuscript. We trust that all of your comments are addressed in the following point-by-point reply to your comments, and which greatly helped to improve our manuscript.

Reviewer's Comments 1:

Table 3: For the 9 short-term SRBC sites, it seems that only limited periods of data (around 1 year or less) were used in the model evaluation, given that the modeling period ends in 2005. Therefore, the author may consider specifying how many (or which) months of data at these new sites were used.

Response 1:

In this research, we only used "annual" N loads to evaluate the model. Fig. 5 shows annual N loads at the Marietta station for the period 1987-2005. Fig. 6 shows 17 year (1989-2005) average N loads for the 6 long-term stations and annual N loads for the year 2005 for the 15 monitoring stations including the 9 short-term stations.

Reviewer's Comments 2:

Table 4: It is not very clear how the non-point and point source loads for each subbasins were obtained. If this is from literature or SRBC, a citation would help readers better understand the source.

Response 2:

We cited all of the used non-point and point N sources for the entire basin in the section 5, page 5684, lines 1-21.

Reviewer's Comments 3:

Figure 3: This is a comprehensive map. Nicely done. However, what is missing from this map is the Conowingo site (managed by USGS) at the basin outlet. It is surprising (and also a waste of resource) that the Conowingo site was not used in the model, which has even longer N data for multiple sub-species than any of the long-term SRBC sites (1979). To clarify, Marietta is actually the most downstream "SRBC" site. It may be misleading if not including "SRBC" (in line 5 of Section 7.1). To me, it would be very interesting to see how much the results would be affected by including this outlet site in the model. If the authors are concerned with the reservoir system located between Marietta and Conowingo sites and want to exclude potential influences by the reservoir

system on their model, then such kind of considerations should be at least briefly discussed in the text. In fact, N load has not been affected much by the reservoir system, at least not to the extent that phosphorous and sediment have. These issues have been recently examined by Hirsch (2012) [http://pubs.usgs.gov/sir/2012/5185/] and Zhang et al. (2013) [http://www.sciencedirect.com/science/article/pii/S0048969713001757].

Response 3:

Agreed, we will modify “the last downstream station Marietta” to “the last downstream SRBC station Marietta” in page 5686, line 5 and page 5670, lines 17-18.

We will modify Table 3 to include the Conowingo site description.

We will modify Figure 3 to include the Conowingo site on the map.

We will modify Figure 5 to include simulated and reported nitrate-N loads at Conowingo.

We will modify “15 monitoring stations” to “16 monitoring stations” in page 5670, line 14; page 5674, line 2; and page 5686, line 4.

We will modify page 5683, lines 7-13 to read:

Chemical constituents of the basin’s water were monitored by the USGS and Susquehanna River Basin Commission (SRBC). One USGS and six SRBC long-term nutrient monitoring sites monitored since 1985 and 9 newly introduced SRBC sites monitored since either 2004 or 2005 to present (Table 3; Fig. 3; McGonigal, 2011; USGS, 2014) were chosen for model evaluation. The 16 sites vary in sub-basin area and land use. Among the USGS and SRBC sites, the Conowingo and Marietta sites on the main channel of the Susquehanna River have the largest sub-basin areas respectively (70,189 and 67,314 km2).

We will modify “(ESTIMATOR; SRBC)” to “(ESTIMATOR; SRBC, 2006; USGS, 2014)” in page 5683, line 22.

This is a valid comment and we plan to modify page 5683, lines 7-13 to read:

The model also produced reasonable temporal patterns of annual dissolved-N (r = 0.7), nitrate-N (r = 0.6), ammonium-N (r = 0.7), and dissolved organic-N (r = 0.6) loads (Fig. 5; Table 5). At Conowingo, 20 year average simulated nitrate-N load agreed well with the corresponding reported value (-3.7%), but the model, which doesn’t have lakes or reservoirs, fails to capture inter-annual variations of the loads (r = 0.2), which are affected by the reservoir system between the Marietta and Conowingo monitoring sites (Fig. 5).

Because Marietta is very close to Conowingo and its sub-basin covers 95 percent of the entire Susquehanna watershed, calibrating the model based on the reported data at Marietta does not make a significant difference. Still, we agree that Conowingo is a better site for model calibration since it is the last downstream station. We will use the data from the Conowingo site when we calibrate our next version of the model capable of simulating N in lakes and reservoirs.

Reviewer’s Comments 4:

Figure 4: The figure caption is a little confusing for (c) and (d) – do they only differ by unit? Why "fertilizer, manure, and legume applications" are grouped? In addition, unit is missing for CSO (b).

Response 4:

We will add the unit (kg km-2 yr-1) for the CSO in Fig. 4.

We designed the model to apply agricultural N sources (fertilizer, manure, and legume applications) into crop land use. Section 2.1 (page 5675, lines 1-7), section 5 (page 5685 lines 3-7), and Fig. 1 may help to understand the model structure. We have four different land uses in a grid cell. Fig. 4c shows the agricultural N application rate to each grid cell, while Fig. 4d shows the agricultural N application rate to each crop land use in each grid cell.

Reviewer’s Comments 5:

Figure 5: The word "observed data" is not strictly correct, since the SRBC loads were calculated based on the ESTIMATOR model. I suggest alternative wording such as "estimated load based on monitoring data", if a definition of "observed" is not given in the caption.

Response 5:

“observed” will be changed to “reported”.

Reviewer’s Comments 6:

Figure 6: It might be more clear if two contrasting colors are used, instead of light and dark colors.

Response 6:

We prefer the figure as is since it is clear if it is printed in black and white. We assume that many readers will print the document in B&E.

Reviewer’s Comments 7:

Figure 7: It is inconsistent with other figures that here the unit is in logarithm scale. If this is because the values are rather large, why not use units such as "10ˆ6kg/year"?

Response 7:

For Fig. 7, we used a logarithmic scale because the results cover a large range of values. This way helps the small stream N loads to be mapped in different colors. In fact, using actual values instead of the logarithms results in figures very similar to Fig. 10 where most of values range from 0-2.5% and are described in only one color, purple. Hence, we prefer to keep the logarithmic scale for this figure.

Interactive comment on Biogeosciences Discuss., 11, 5669, 2014.

Table 3. Susquehanna River Basin Geographic Statistics for the USGS and SRBC nutrient monitoring sites (McGonigal, 2011; USGS, 2014).

Site Location	Waterbody	Sub basin Area, km^2	2000 Land Use Percentages					
			Water/ Wetland	Urban	Agricultural		Forest	Other
					Cropland	Pasture		
7 Long-term Sites								
Towanda, 1989~	Susquehanna	20,194	2	5	17	5	71	0
Danville, 1985~	Susquehanna	29,060	2	6	16	5	70	1
Lewisburg, 1985~	W B Susque	17,734	1	5	8	2	84	0
Newport, 1985~	Juniata	8,687	1	6	14	4	74	1
Marietta, 1987~	Susquehanna	67,314	2	7	14	5	72	0
Conestoga, 1985~	Conestoga	1,217	1	24	12	36	26	1
Conowingo, 1985~	Susquehanna	70,189	2	9	7	19	63	0
9 Newly Introduced Sites								
Conklin, 2005~	Susquehanna	5,778	3	3	18	4	71	1
Smithboro, 2004~	Susquehanna	11,989	3	5	17	5	70	0
Campbell, 2005~	Cohocton	1,217	3	4	13	6	74	0
Chemung, 2004~	Chemung	6,488	2	5	15	5	73	0
Wilkes-Barre, 2004~	Susquehanna	25,785	2	6	16	5	71	0
Karthaus, 2004~	W B Susque	3,785	1	6	11	1	80	1
Castanea, 2004~	Bald Eagle	1,087	1	8	11	3	76	1
Saxton, 2004~	Raystown B Juni	1,957	<0.5	6	18	5	71	0
Manchester, 2004~	W Conewago	1,320	2	13	12	36	36	1

Fig. 1. Table 3

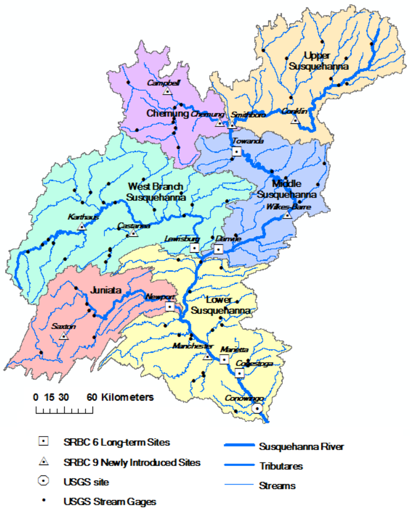

Figure 3. Map of the Susquehanna watershed, showing 6 major sub-basins, main stem of the Susquehanna River, major tributaries (Chemung, West Branch Susquehanna, and Juniata River), streams, and the location of USGS stream gauges and USGS and SRBC nutrient monitoring sites.

Fig. 2. Figure 3

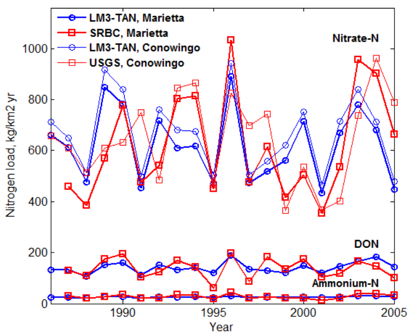

Figure 5. 20 years (1986-2005) of the simulated stream N loads (normalized by sub-basin areas) at Marietta and Conowingo and the corresponding reported data from SRBC and USGS.

Fig. 3. Figure 5