Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-733-AC2, 2018


Hydrology and Earth System Sciences
Discussions

# *Interactive comment on* "A Bayesian Approach to Infer Nitrogen Loading Rates from Crop and Landuse Types Surrounding Private Wells in the Central Valley, California" *by* Katherine M. Ransom et al.

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Received and published: 20 February 2018

We appreciate the comments from referee #2. Below is a point by point discussion:

Point 1) We understand the point of view of the referee and agree we employed an existing statistical framework (Bayesian methods). Perhaps the use of the term "statistical framework" to describe our methods is not appropriate here and "innovative use of existing Bayesian methodology" and "the novel approach" or something similar would be more accurate. We would be willing to clarify the related statements in a revision.



Point 2) We think this is an excellent observation for the referee to point out and agree that the approach could be masking temporal dynamics of nitrate concentrations in groundwater. For example, of the initial set of wells in the dataset (before random location sampling) about 30% were sampled multiple times. Of those wells with multiple samples, the median range of observed nitrate values was 3.40 mg/L NO3-N (direction independent). Therefore, for this particular dataset, there are likely some significant temporal patters that could be investigated. In this paper, however, we focused on long-term average N loading from crop groups. For that, we maximized the number of samples available for the Bayesian analysis and did not split wells into temporal groups. The temporal aspects of nitrate loading are beyond the scope of this paper and may be best addressed as a separate study. The results of our study therefore represent the median rate of each landuse or crop groups between 2000-2015. We will add a sentence or two in the methods section to clarify this topic.

Point 3) We did not incorporate measurement uncertainty into our analysis here. Nitrate measurements for wells in the study database are from multiple agencies and laboratories. Uncertainty will vary between laboratories, analysis and field methods. However, these uncertainties are typically very small, especially compared to the concentrations at which nitrate becomes a concern (greater than 5-10 mg/L NO3-N). For example, field duplicates were collected for a subset of 200 wells in this current study (20 field duplicates) and the field duplicates had an average percent difference between samples of about 0.50 % (Lockhart et al. 2013). Laboratory uncertainty for internal laboratory duplicates for the same set of wells was similarly low, with many measurements having a difference of 0.00 mg/L NO3-N. We agree to add a brief explanation to this effect in the methods section.

Point 4) We experimented with several versions of this model including versions with a fixed recharge rate, various landuse/crop groupings, with/without the attenuation factor, and various likelihood and prior distributions. Results were relatively stable across model versions (assuming the choice of likelihood and prior were reasonable), with the

relative contributions of each landuse or crop group remaining approximately the same. While we did not make formal comparisons of various model results, we observed that the recharge rate parameter had the most dramatic effect on the model predictions and therefore, we decided to add it in to the model as a variable parameter.

Point 5) After the model "burn-in" period, each MCMC chain was sampled 200,000 times, with a thinning interval of 400 (every 400th sample was retained for final analysis). We feel this is a relatively low number of realizations to keep (per chain) compared to the number of samples in the chain (only 0.25 percent of MCMC samples were retained per chain, per parameter). This in in an effort to reduce the amount of autocorrelation between the MCMC samples. In order to determine the chain length and thinning interval were adequate, we plotted autocorrelation plots with the mcmcplots function in the R package mcmcplots (Curtis et al., 2015), for each chain for each parameter. Autocorrelation plots indicated low autocorrelation for each parameter at the indicated chain length and thinning rate. In addition, running mean plots indicate a convergence of the distribution means for the two MCMC chains (for each parameter) after approximately 500 samples. The choice of the chain length and thinning rate are highly dependent on the specific application, and we recommend others analyze the traceplots, autocorrelation plots, and running mean plots such as the ones produced by the R package mcmcplots.

References K.M. Lockhart, A.M. King, and T. Harter, 2013. Identifying sources of groundwater nitrate contamination in a large alluvial groundwater basin with highly diversified intensive agricultural production. Journal of Contaminant Hydrology 151 (2013) 140–154.

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