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To: Patrick Barickman, Whitney Oswald, Brock LeBaron  
From: Jon Wilkey  
Date: April 28, 2016  
RE: April 2016 monthly report on integrating equipment-based emission factors into the R model

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During the month of April, work on the R model has focused on the Monte-Carlo (MC) simulation of emissions using the equipment-based emissions calculation functions and OGEI database cumulative probability tables (CPT), developed in February and March, respectively. See attached for a summary of the MC simulation algorithm. The output of the simulation gives total emissions for each of the following (all as a function of time):

- Each species (PM<sub>10</sub>, PM<sub>25</sub>, SO<sub>x</sub>, NO<sub>x</sub>, VOCs, CO, and CH<sub>2</sub>O)
- Each equipment category (well completions, RICE & turbines, separators and heaters, dehydrators, tanks, truck loading, pneumatic controllers, pneumatic pumps, and fugitive emissions)
- Each iteration of the Monte-Carlo simulation

At present, the model calculates (for each pollutant species) total emissions, the quantiles of the MC simulation results, and the % contribution of each type of equipment to the total emissions. A sample output (with comparison to the previous activity-based emissions results) is shown in Figure (1).

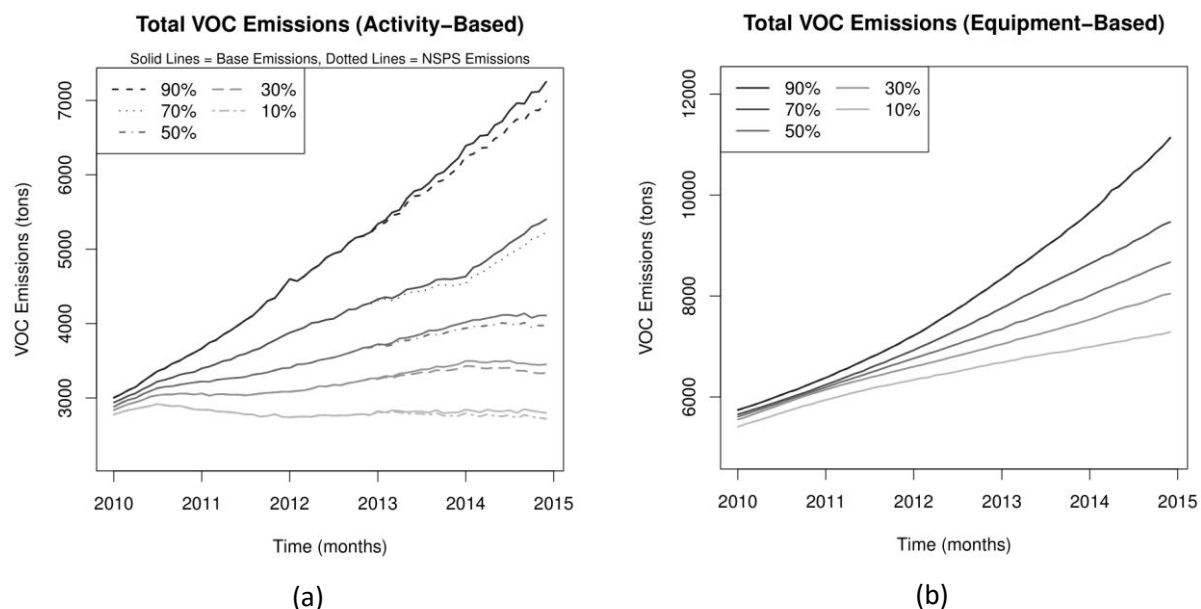


Figure 1: Total VOC emissions over the 2010 – 2014 period using 10<sup>3</sup> MC iterations according to (a) activity-based emissions factors and (b) equipment-based emissions calculations. VOC emissions in (a) are primarily from well completions (which leads to the somewhat rough line pattern), gas transmission, and gas production. VOC emissions in (b) are primarily due to pneumatic controllers (30%), fugitive emissions (27%), pneumatic pumps (20%), and dehydrators (17%).

Given the number of factors available (7 species, 9 types of equipment, new and existing wells, each specified quantile of MC simulation output, monthly/annual/etc. time series aggregation) there are many possible ways that the data could be visualized or compared. I'd be happy to code any type of plot or comparison that UDAQ would like to get out of the model, or to prepare the results data for export to a different data visualization tool. Please let me know what type of post-processing options you'd like to use.

Aside from implementing post-processing options, I'm happy to report that at this point equipment-based emission factors have been fully integrated into the R model. Tasks (1) – (3) in the work plan have been completed, and the only remaining deliverables are to (a) update the documentation in the User Manual and (b) provide training to UDAQ staff. Model documentation should be updated by May 6, 2016. Please let me know how you'd like to cover training on the model changes.

# MC Simulation Algorithm

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The algorithm applied in the MC simulation is as follows:

1. Randomly draw a row from each equipment type's CPT table (e.g. well completion, RICE & turbines, tanks, etc.) for each well.
2. For each well and each type of equipment, calculate the monthly emissions for each pollutant species applicable to that type of equipment following the same procedure applied in the OGEI spreadsheet.
3. Create a production "identity" matrix with  $i$  rows (one for each well) and  $j$  columns (one for each time step in the simulation). If well  $i$  is in operation (i.e. producing either oil or gas) at time  $j$ , then the value at  $[i, j] = 1$ , otherwise it equals 0.
4. For each type of equipment and each pollutant species, multiply the vector of calculated emissions (containing one element for each well) by the identity matrix element-wise. This results in one matrix for the emission of each pollutant species for each type of equipment, with one row for each well and one column for each time step.
5. Calculate total emissions by species
  - a. Add together the emissions matrices from all types of equipment for the same species (e.g. PM10 emissions = (Well completion PM10) + (RICE & Turbine PM10) + (Separator & Heater PM10)).
  - b. Calculate the column sums of the combined matrix to find total emissions across all wells as a function of time.
6. Calculate the % contribution of each type of equipment to each species
  - a. Divide the column sums of the emissions matrix for each type of equipment by the result from Step (5.b) above.

Notes:

- Well completions emissions are applied once per well (whenever a well is originally drilled or reworked). Well completion emissions for new wells and reworked wells are assumed to be the same.
- All emissions are constant in time, with the following exception:
  - Truck loading emissions are a function of oil production volume. Instead of calculating an emissions vector for truck loading in Step (2) for truck loading, an emissions factor for each well is calculated, and that vector is multiplied element-wise by the oil production matrix.
  - I tried to also make tank emissions a function of oil production volume by randomly drawing from the ratio of (VOC emissions from tanks) / (oil throughput) in the OGEI database and multiplying that ratio by the oil production matrix. However there appears to be an inverse relationship in the ratio, see Figure (2). Low throughput tanks have high emissions, while high throughput tanks have low emissions (perhaps the low volume tanks are older and leak more?). Therefore random selection in the MC simulation can combine high emissions ratios with high production wells and return unrealistically large VOC emissions results. As a workaround, the code randomly draws emissions results from tanks directly from the CPT. Tank emissions are therefore both constant and are

not a function of oil throughput, but are representative of VOC emission rates for tanks in the Uinta Basin.

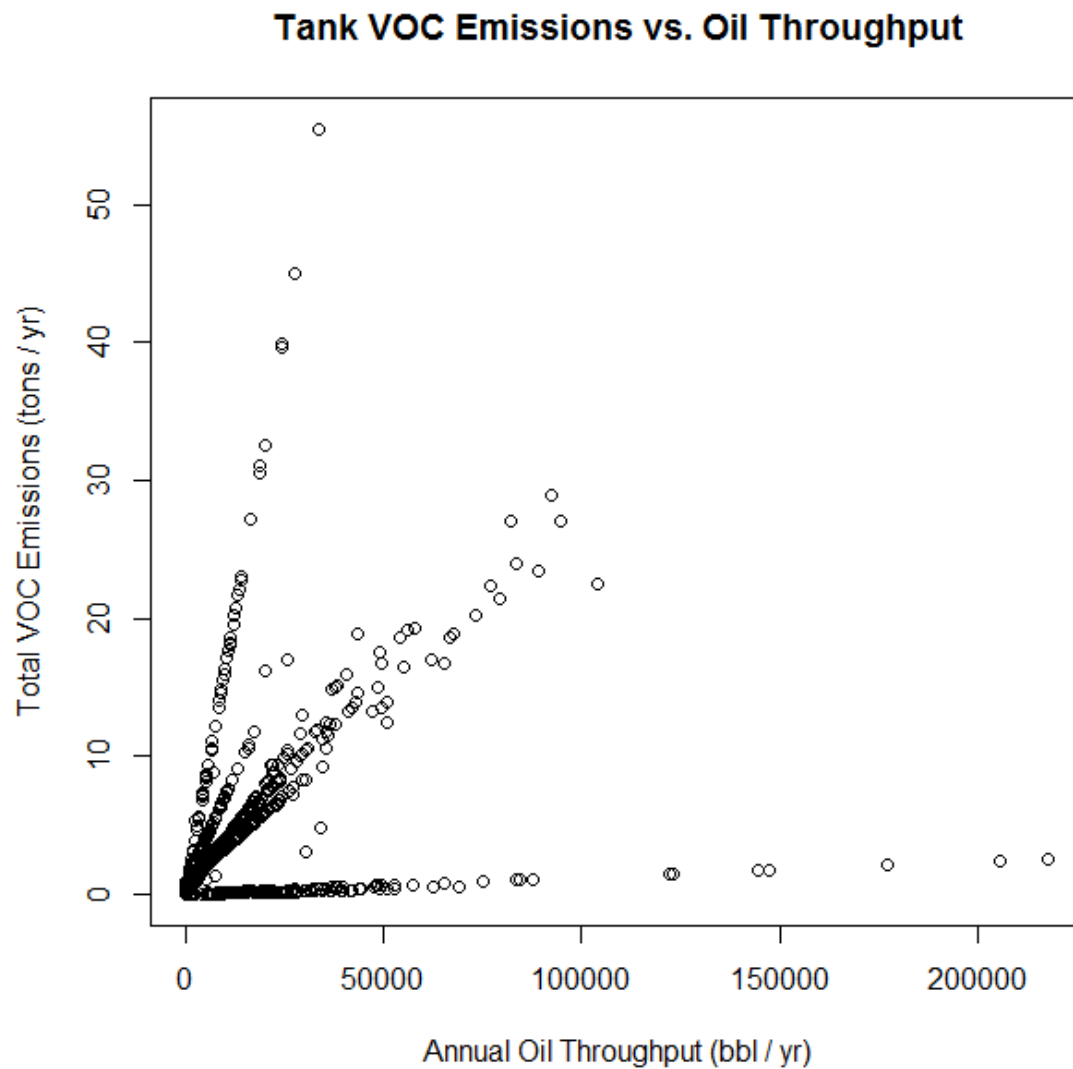


Figure 2: Tank VOC emissions vs. oil throughput data from OGEI database (March 30, 2016 data).