Geophysical Research Abstracts, Vol. 7, 05135, 2005
SRef-ID: 1607-7962/gra/EGU05-A-05135

Spatial and temporal improvements to ammonia emission modeling using a process-based approach

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A large fraction of ammonia emissions are from agricultural sources, including livestock housing, manure storage, and field-applied manure. Previous ammonia emission inventories have used fixed or static emission rates gathered from field studies. Such emission factors do not accurately characterize the variation of emissions from the variety of climate conditions and manure management practices found on agricultural operations. Accurately estimating this variation is important to correctly estimating the magnitude and seasonal cycle of emissions, and consequently predicting ammonium nitrate aerosol in an air quality model.

This research has developed a process-based inventory of ammonia emissions from dairy farms consisting of a partially mechanistic model of ammonia volatilization and an statistical model of the distribution of farming practices. The Farm Emissions Model (FEM) is a semi-mechanistic, semi-empirical model for the volatilization of ammonia from major types of manure management systems found in a modern dairy operation. Bayesian parameter estimation has been used to tune the model parameters to match experimental results and to explicitly account for uncertainty. The FEM is combined with the National Practices Model (NPM), a statistical model that describes the national distribution of manure management practices for the United States. By combining these results with county dairy cow populations, historical climate data, and soil properties data, this research constructed a national ammonia emission inventory for dairy operations that captures both the geographical and seasonal variability and rigorously derives the uncertainty in emission rates.

Annual, county-level emission factors are estimated to range between 13.1 and 55.5,

with national average of 23.9 kg NH_3 cow^{-1} $year^{-1}$. Highest emissions are predicted in the spring and fall and lowest in the winter. Higher emissions in the spring and fall are attributed to the high manure application rates before crop planting. In the winter, the animal housing has the highest proportion of emissions owing to decreased grazing times and unfavorable conditions for emissions from the other sources. The most significant uncertainties are the monthly calendar of manure application, the geographic distribution of farming practices, and the parameters of the volatilization calculation. The 5 and 95% confidence interval about the national annual average emission factor is between 18 and 36 kg NH_3 cow^{-1} $year^{-1}$.

The monthly scaling factors found in the dairy inventory has been applied to other livestock categories and combined with other sources of ammonia emissions from the CMU Ammonia Inventory. This inventory has been used as input to a regional air quality model for representative time periods in spring, summer, winter, and fall. The mean normalized error for air quality model predicted total ammonia, aerosol nitrate, and wet deposited ammonia decrease when using the seasonally and geographically varied ammonia inventory.