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Simulations of the effects of ammonia emissions reductions on North American atmospheric particulate matter using AURAMS

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The Environment Canada AURAMS (A Unified Regional Air-quality Modelling System) was used to simulate the effects of ammonia emissions reductions on particulate matter concentrations and chemistry for the North American continent. Using a new Canadian ammonia inventory created for the project, 3 annual simulations were performed (for the year 2002 at 42-km horizontal resolution, 29 vertical levels, and 15 minute time step): (i) a base case; (ii) a 30% reduction in agricultural ammonia emissions; and (iii) a sensitivity scenario in which ammonia emissions from beef cattle were reduced by 50%.

The base case and scenarios made use of an improved treatment of chemical boundary conditions as well as other model improvements and improvements to the emissions data. The base case was evaluated against monitoring data from 15 different monitoring networks across the continent, and a significant improvement in the model predictions relative to observations was found for 24 out of 28 species in the comparison data, in comparison to previous base-case model runs for the same year.

The 30% agricultural ammonia emissions reduction led to reductions in model-predicted $PM_{2.5}$ levels. These reductions were very episodic in nature, and very location-dependant; median $PM_{2.5}$mass decreases were modest to small(e.g., 0.2 to

1 ug/m^3), whereas decreases during short-term episodes were much more significant: a factor of 10 higher than the median values.

A detailed chemical analysis of the base case and the 30% ammonia emissions reduction scenario was performed. The analysis showed that ammonia emissions reductions result in significant changes to particle chemistry. Aqueous-phase sulphate formation was reduced, with more sulphur remaining as SO_2. This reduced sulphur deposition close to the SO_2 sources (wet deposition of aqueous phase sulphate was shown to be a more efficient deposition process than dry deposition of gaseous SO_2), while increasing the distance of sulphur transport (possibly including export over the Atlantic during the summer months). The decreases in ammonia also changed nitrogen chemistry: the fraction of $PM_{2.5}$composed of nitrate and ammonium was decreased, and the aqueous-phase concentration of ammonium and nitrate ions was reduced significantly and to slightly, respectively. Chemical regime and neutralization ratios were also significantly shifted by the reduction in ammonia emissions.

One other impact of ammonia emissions reductions were reductions in exceedances of critical loads for nitrogen-saturated environments. Improvements (reductions) in sulphur critical-load exceedances were minor, whereas improvements in sulphur+nitrogen (i.e. nitrogen-saturated ecosystem) critical-load exceedances were significant. Analysis of the components of nitrogen deposition showed that this reduction in S+N critical-load exceedances largely resulted from decreases in aqueous-phase ammonium ion wet deposition. Ammonia emissions reductions may therefore have a beneficial impact on ecosystem acidification.

The 50% reduction scenario for Canadian beef cattle ammonia emissions represents the uncertainty associated with the emissions inventory calculations for this sub-sector of Canadian agricultural emissions. This scenario simulation showed that, for specific regions of Canada, the uncertainty in resulting $PM_{2.5}$predictions is similar in magnitude to the 30% across-the-board reduction in emissions from all agricultural sources. This suggests that further inventory improvements to reduce the uncertainty for this sub-sector are required.