Proposal: NERC E3 DTP PhD project

Project title: Nitrogen and climate change: Process-based modelling of ammonia emission from ammonium and urea-based fertilisers

Supervisors
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CASE partnership: Not applicable.

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Project background
Human perturbation of the global nitrogen (N) cycle through excessive emission of reactive nitrogen compounds (N\textsubscript{r}) is becoming an increasing environmental issue. The strong emission of N\textsubscript{r} threatens water, air and soil quality, and as a result, it endangers ecosystems, as well as human health. The release of N\textsubscript{r} to the atmosphere is dominated by ammonia emission (NH\textsubscript{3}). Globally, 70% of NH\textsubscript{3} originates from agricultural sources, predominantly from the breakdown of animal excreta and ammonium as well as urea-based fertilizers. The emission of NH\textsubscript{3} is strongly influenced by meteorology, especially temperature. This raises the question: how will NH\textsubscript{3} emission be affected by climate change?

For the regional or global-scale simulation of the effect of meteorological variables on NH\textsubscript{3} emission and other NH\textsubscript{3} related atmospheric processes (dispersion, mixing, chemical conversion and deposition), atmospheric chemistry transport models (ACTMs) are used. However, in these models NH\textsubscript{3} emission is usually considered to be independent of the actual meteorological conditions. Therefore, a way to investigate the effects of climate change on the NH\textsubscript{3} related atmospheric processes and to predict the environmental consequences is to design meteorology-driven NH\textsubscript{3} emission models for each agricultural source and couple these to an ACTM.

This PhD project represents a step toward this goal. The main expected outcome of this work is a new, process-based model for NH\textsubscript{3} emission from fertiliser application, that can be applied for various conditions (different fertiliser application methods, various fertilisers, and can account for the usage of urease inhibitors). Although the focus of this work is a new field-scale model, the main challenge of the project is to determine the relevant input variables, as well as the driving physical and chemical processes in the atmosphere and the soil for the new model, so that in the future it could be applied for larger scales, coupled to an ACTM. For the validation of the newly-developed emission model, a set of NH\textsubscript{3} flux measurements from rice fields fertilised with urea are available.

Two of the available process-based models, the GAG model (for urine patches) and the VOLT'AIR model (for fertiliser and manure application) could serve as a strong basis for building the new model for fertiliser application. Whilst the GAG model’s simple structure would be desirable, the investigation of the VOLT'AIR model, which is more complex in its structure, could be beneficial for the establishment of the new model’s theoretical background.

Key research questions
1. What are the main input variables and the driving physical and chemical processes in the atmosphere and the soil that have to be considered in a process-based NH\textsubscript{3} emission model for
fertiliser application?

2. How do fertiliser application practices affect NH$_3$ emission (e.g. different fertiliser application methods, various fertilisers, usage of urease inhibitors)?

3. How do meteorological variables affect NH$_3$ emission from fertilisers?

Methodology

- **Month 1-12:** Literature review, necessary training in programming (programming language R). Getting familiar with the state-of-the-art process based NH$_3$ emission models. Investigating the required modifications of the GAG model for application for fertilisers. Gaining insights in atmospheric chemistry transport models (base run with the EMEP model).
- **Month 13-18:** Co-operation with the modelling team of INRA in Grignon, France. Learning the basics of the VOLT’AIR model and further fertiliser application related NH$_3$ emission modelling tools.
- **Month 19-30:** Constructing a new field-scale process based model of NH$_3$ emission from fertiliser application. Review of the available relevant NH$_3$ flux measurement datasets, model validation.
- **Month 31-42:** Experimental model runs with the newly constructed emission model to investigate the model sensitivities to the environmental conditions and fertiliser application practices. A comprehensive sensitivity analysis to the meteorological variables. Writing up the results for publication and for the thesis.

Training

A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. CEH Edinburgh and the University of Edinburgh would provide training in atmospheric chemistry and biogeochemistry, including the application and development of a range of air pollution related models, as well as the analysis and interpretation of NH$_3$ flux measurements. The University of Edinburgh and the School of Geosciences E3 DTP also offer numerous opportunities for PhD students to develop their wider skills, e.g. academic writing, preparation of posters and oral presentations.

Requirements

The candidate should have at least Bachelor or preferably a Master degree in a related field of chemistry, physics or environmental sciences. The candidate will have strong skills in programming and analytical thinking.

Further reading


Project summary

This project aims to construct a new, meteorology-driven model of ammonia emission from fertiliser application, as a step toward the understanding on how climate change will affect ammonia emission.