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Uncertainty in critical load assessment models

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5 Uncertainties at the regional scale

Summary

- The TRACK model was used to generate predictions of S and N deposition, and these predictions were compared with measured rates derived from wet deposition and air concentration measurements. Agreement was reasonable, but model estimates could be improved by a bias adjustment derived from regression analysis.
- The regression analysis provides a measure of the uncertainty in the modelled deposition rates.
- Monte Carlo analysis of input parameter uncertainty showed it contributed a substantial amount to the uncertainty in deposition model predictions. However, input parameter uncertainty does not explain all the model errors.
- Uncertainty in critical load exceedance was generated for each of the 2,588 one km squares in South East England containing coniferous forest, using probability distributions of critical loads already generated in this study, and a Monte Carlo simulation of TRACK model results.
- Illustrative maps are provided of various metrics of critical load exceedance. Using the median exceedance increases the number of squares exceeded compared to a deterministic estimate, and using the 95th percentile increases it substantially.
- The results depended strongly on which site was used to generate the critical load probability distributions – Liphook, Aber or Thetford.
- Using a bivariate normal distribution for S and N critical loads and a bivariate Student's *t* distribution for deposition gave similar results to direct sampling of the distributions and is therefore recommended for assessment purposes.
- However, in view of the sensitivity of the results to the probability distribution of critical loads used, it is recommended that these functions should be assigned to receptors on a case-by-case basis.

5.1 Introduction

In the calculation of exceedance both the deposition and the critical load estimates are uncertain, because they depend on uncertain estimates of model input parameters. Furthermore, the models used to calculate deposition are also inherently uncertain because of the assumptions made in their derivation and implementation.

The approach taken here was to use Monte Carlo simulations to develop probability distributions of critical loads and deposition rates, taking account of assumed probability distributions for the model inputs. In addition, predictions of sulphur and nitrogen deposition are compared with available measurements in order to estimate the inherent uncertainty in the deposition model. Maps were then prepared based on the following approaches:

- deterministic calculation of the difference between the deposition prediction and the critical load estimates;

- deterministic calculation of the difference between the deposition prediction, adjusted for bias by regression analysis and the critical load estimates;
- calculation of the probability distributions of critical load exceedance by resampling from the joint probability distribution of acid deposition predictions (sulphur and nitrogen) and the joint probability distribution of critical loads ($CL_{max}S$, $CL_{min}N$).
- fitting of multivariate normal distribution functions to acid deposition model outputs and critical load estimates and resampling from the fitted distributions.

The spatial domain of the maps was limited to the South East of England, in order to limit the amount of data generated and to facilitate data handling.

The probability distributions for the critical loads used in this assessment were developed in Subtask 1.3 (Section 3). The methods used are described in Sections 2 and 3 and are not repeated here.

5.2 Deposition modelling

5.2.1 Model

Netcen's long range acid deposition model, TRACK Version 1.7e, was used to predict annual wet and dry deposition of sulphur, oxidised and reduced nitrogen at wet deposition monitoring sites throughout the UK, and at 100, 20 x 20 km square areas covering the South East of England.

The technical specification for the TRACK model is described in a refereed paper by Lee *et al.* (2000). More recently, the predictions of deposition rates and ambient concentrations made by Version 1.7 have been compared with measured values by Abbott *et al.* (2003).

Version 1.7e is set up to facilitate Monte Carlo simulation, with input values selected from feasible ranges. Version 1.7e differs slightly from Version 1.7 used in our earlier work: it includes the wind direction sector averaging algorithm described in Appendix 8 of the annual audit report prepared for the Environment Agency.

Input data for the modelling runs will be found in Appendix C. Table C1 summarises the input parameters used in the model runs. The baseline model run was based on these parameter values. Table C2 summarises the range of input values used for Monte Carlo simulation. Values of each parameter were taken at random from the range, assuming a uniform distribution. Three hundred model runs were carried out. The 2002 50x50 km square EMEP emissions inventory for sulphur dioxide, oxides of nitrogen and ammonia provided the emissions inputs for most of the model domain. UK emissions estimates, taken from the 2003 UK National Atmospheric Emissions Inventory (NAEI), were aggregated onto a 10 km x 10 km grid for the UK. Local deposition of ammonia was calculated from the 2003 NAEI 1 km x 1 km inventory.

Monitoring data used in the assessment were taken from *Management and Operation of the UK Acid Deposition Monitoring Network: Data Summary for 2003.* The data are summarised in Table C3. The data were supplemented by additional data for ammonia and ammonium for 2002 from the UK National Ammonia Monitoring Network for sites included in Table C3.