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VALIDATION OF A HIGH-RESOLUTION AIR QUALITY MODELLING CHAIN FOR NITROGEN IN FLANDERS

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Abstract: Nitrogen deposition on Natura-2000 areas in Flanders is an important environmental problem. In order to tackle this problem, the source contribution of different sources should be well known. Furthermore, a modelling system for assessing the impact of possible new permits is necessary. A model chain consisting of the Lagrangian plume VLOPS model at a 1x1 km² resolution and the bi-Gaussian IFDM model at a 100x100 m² resolution was installed. However, modelling without validation is purely a mathematical exercise. Therefore, a validation study was set up in Flanders. Passive samplers were used to measure the ammonia concentrations (an important source of nitrogen deposition) at 60 locations in 6 nature conservation areas. The model validation of the annual average concentrations showed that the modelling chain is well capable of modelling the ammonia concentrations (BIAS of -7%, RMSE of 35% and R^2 of 0.74). It was noted that the addition of the high resolution IFDM model significantly increases the quality of the model results. The model chain was found to be more accurate in predicting the spatial patterns in regions with a higher abundance of known sources compared to source-scarce regions. Finally, the importance of correct and detailed emission data was demonstrated.

***Key words:** Ammonia, nitrogen deposition, high-resolution modelling, validation.*

INTRODUCTION

Excessive deposition of reactive nitrogen in nature leads to a decrease in biodiversity. Therefore, the Natura-2000 program was setup in order to protect nature areas. This legislation states, among other things, that in order to obtain an environmental permit it is necessary to determine that no further harm is done to nature protection areas. A robust model approach was set up in the northern part of Belgium (Flanders) to support further granting of permits.

METHODOLOGY

Model setup

The model setup consists of the coupling of two models. The first one is a Lagrangian plume model (VLOPS), based on the Dutch OPS model (Sauter et al., 2018), which is applied at a 1x1 km² resolution. The concentration levels calculated with this model are calibrated on a fixed set of measurement points. This model is then coupled to a second model, the bi-Gaussian IFDM model, which is applied at a resolution of 100x100 m². The inclusion of IFDM in the modelling chain redistributes the concentrations within a VLOPS grid cell using the IFDM results, using a similar scheme as in Lefebvre et al. (2013). Dry deposition velocities, for which VLOPS has the specific DEPAC module (Van Zanten et al., 2010) included, are transferred from the VLOPS to the IFDM model. A resulting concentration map can be found in Figure 1.

Ammonia emissions were taken from the emission inventory of the Flanders Environment Agency. For agricultural emissions, which are the most important source of ammonia emissions in Flanders, the results are derived from the EMAV model. This model was specifically developed to calculate ammonia emissions in Flanders and during this study it was upgraded (from version 2.0 to version 2.1) to further improve the calculation of ammonia emissions from livestock and the processing of manure. Comparing the validation results between both versions helps us to evaluate the importance of good emission data.

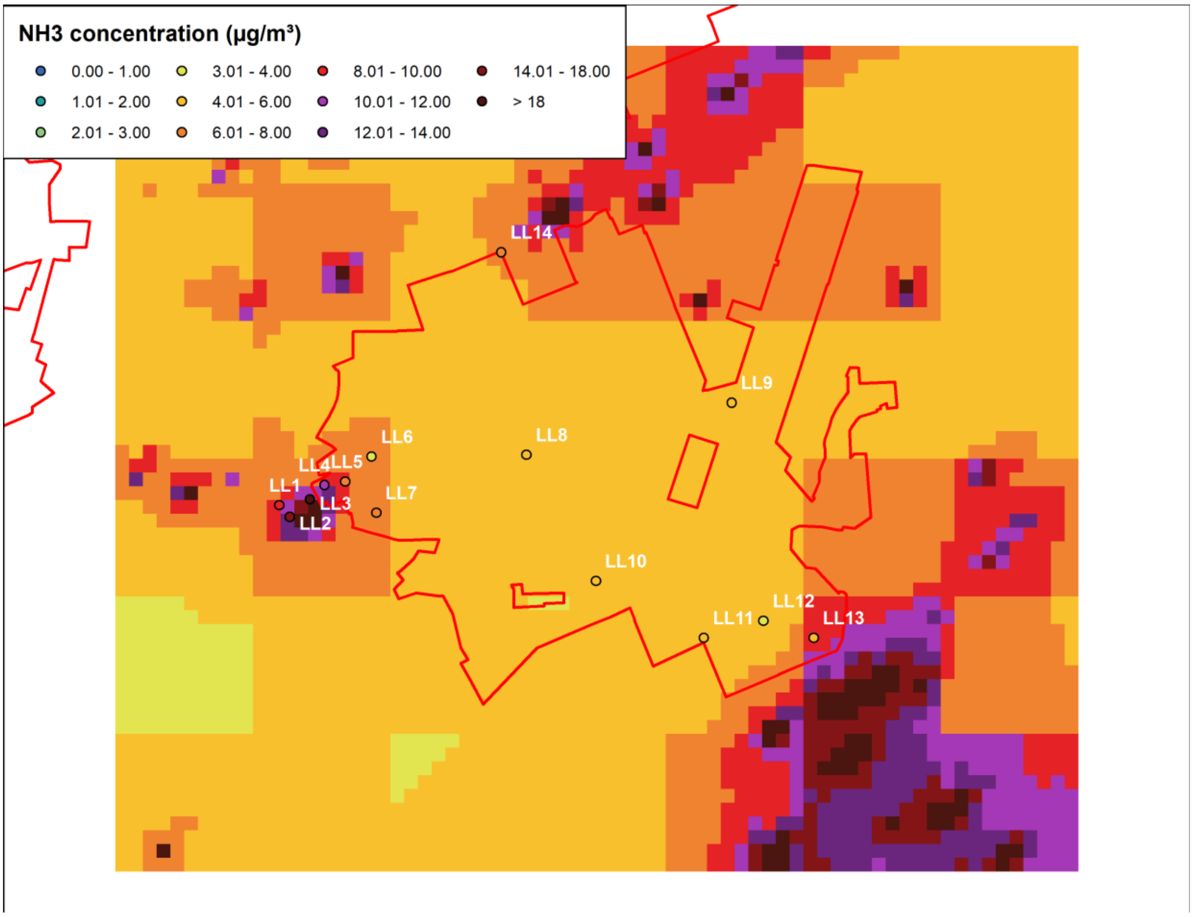

Figure 1: Model concentrations (map) and measurement locations and concentrations (dots) of one of the sampling regions. The red line denotes the border of the nature protection area. All values shown are annual averages over the measurement period.

Measurement setup

In order to validate the results of the model, NH_3 concentrations were measured at 60 locations during a whole year (2017) using passive samplers at and around 6 nature areas. These samplers were used in duplicate to check the reproducibility of the measurements and exposed for 13 periods of four weeks. Concentrations measured at these locations (which are independent from the locations used to calibrate the VLOPS model) are then used to validate the model.

Result and validation

In Figure 2, the spatial validation plot of the model is shown, whereas the validation statistics can be found in Table 1. It is shown that the VLOPS model can already simulate the ammonia concentrations well. However, including the IFDM model increases the spatial resolution of the results and also improves the validation statistics. Indeed, an increase in R^2 (from 0.48 to 0.74), a decrease in bias (from -1.08 to -0.54 µg/m³) and a decrease in RMSE (from 3.78 µg/m³ to 2.74 µg/m³) is a strong improvement. Furthermore, part of the RMSE is due to one outlier (the point most to the right in Figure 2). Ignoring this one measurement location (very close to a major source) decreases the RMSE from 35 to 25%. For the temporal and spatio-temporal validation, we also find an improvement for adding the IFDM model to the model chain, except for the R^2 and the BCRMSE in the temporal validation. Nevertheless, the improvements of the temporal validation are quite small, which is to be expected as the IFDM model does not use a more detailed temporal pattern of the ammonia emissions.

Table 1 also shows that the use of updated emission data increases quite strongly the model statistics. This points to the importance of correct and detailed emission data for nitrogen modelling.

Finally, deconstructing the validation results, it was also shown that the validation statistics were much better in regions with a higher abundance of emission sources than in regions with fewer sources. In the latter regions, the model was unable to reproduce the small differences in concentrations between the measurement locations. On the other hand, simulating these small differences in concentrations should not be the major focus of the model.

Table 1: Spatial, temporal and spatio-temporal validation statistics of VLOPS and VLOPS-IFDM. Values between brackets are the validation statistics for the spatial validation of VLOPS-IFDM with the older emission dataset.

	Spatial		**Temporal**		**Spatio-temporal**	
	VLOPS-IFDM	*VLOPS*	*VLOPS-IFDM*	*VLOPS*	*VLOPS-IFDM*	*VLOPS*
BIAS (µg/m^3)	-0,52 (-0,82)	-1,08	-0,83	-1,16	-0,83	-1,16
BIAS (%)	-7,45 (-11,69)	-15,3	-10,8	-15,2	-10,8	-15,2
RMSE (µg/m^3)	2,43 (-2,92)	3,78	1,69	1,83	4,08	4,82
RMSE (%)	34,5 (41,5)	53,7	22,1	24,0	53,5	63,2
R^2 (-)	0,74 (0,63)	0,48	0,48	0,52	0,52	0,38
BCRMSE (µg/m^3)	2,37 (2,80)	3,62	1,47	1,41	3,99	4,68

CONCLUSIONS

Passive samplers were used to measure the ammonia concentrations (an important source of nitrogen deposition) at 60 locations in 6 nature conservation areas. The model validation of the annual average concentrations showed that the modelling chain is well capable of modelling the ammonia concentrations (BIAS of -7%, RMSE of 35% and R^2 of 0.74). It was noted that the addition of the high resolution IFDM model significantly increases the quality of the model results. The model chain was found to be more accurate in predicting the spatial patterns in regions with a higher abundance of sources compared to source-scarce regions. Finally, the importance of correct and detailed emission data was demonstrated.

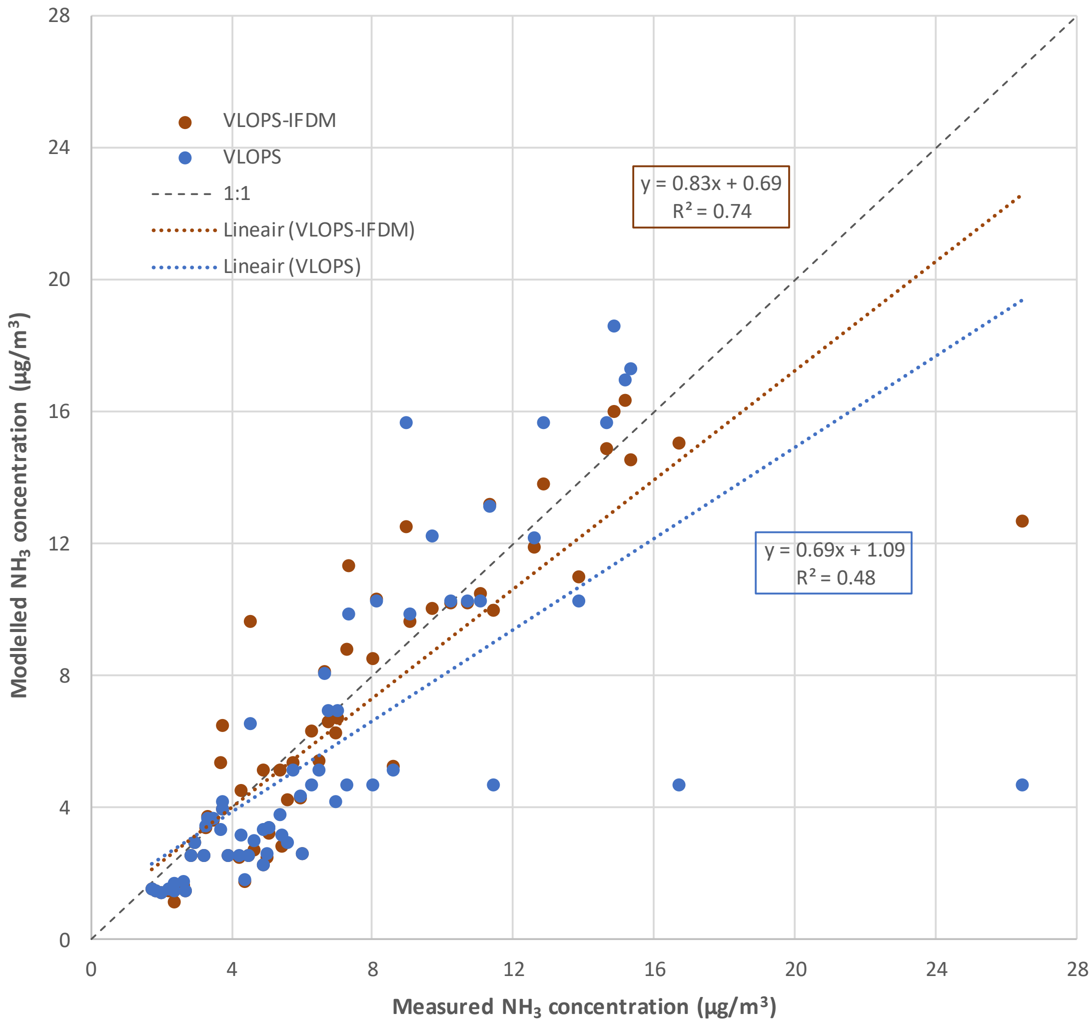

Figure 2: Scatterplot of the spatial validation of the annual mean NH_3 concentrations (in µg/m³). Every dot denotes one pair of measurement (X-axis) and model (Y-axis) values. In blue, the results at the 1x1 km² resolution, in red, the results of the high-resolution modelling.

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