RAINS-NL: An Integrated Assessment Model to support Dutch air quality policy making

Jan Aben[1], Jean-Paul Hettelingh[1] and Wolfgang Schöpp[2]

Abstract

The IIASA integrated assessment model RAINS is widely used to support air quality policy making in a European context. This paper describes RAINS-NL, a specific version of RAINS with Dutch extensions, which was developed by the Netherlands Environmental Assessment Agency, in collaboration with IIASA, to support Dutch policy makers in European negotiations.

1. Introduction

Considering that air pollution is a transboundary problem, measures to enhance air quality are being more and more negotiated in a European context. Examples are the Clean Air for Europe Program (CAFE) currently in progress, the recently initiated review of the EC emission ceilings directive and the upcoming review of the UN-ECE Gothenburg Protocol. The RAINS integrated assessment model, developed at IIASA, is the accepted model for lending support to these negotiations. Because RAINS calculations are performed for the whole of Europe, the model has a rather low spatial resolution; this is a drawback for interpreting results in a national context. For this reason, the Netherlands Environmental Assessment Agency decided to develop a specialized version of RAINS for the Netherlands in collaboration with IIASA, called RAINS-NL. This model allow for (1) the refinement of RAINS output for the Netherlands, (2) the search for alternative scenarios to reach the targets set in international negotiations, (3) the determination of the consequences of alternative Dutch scenarios for neighboring countries and (4) the comparison of the cost-effectiveness of Dutch and European control strategies. Moreover, because RAINS-NL is an extended version of RAINS; all of the RAINS functions are reflected in RAINS-NL.

This paper describes RAINS-NL. After a brief description of RAINS, the RAINS-NL extensions are described. At the end, two examples of the application of RAINS-NL are presented.

2. The RAINS model

RAINS is an integrated assessment model which combines information on the development of economy and energy demand, emission control potentials and costs, atmospheric dispersion characteristics and environmental sensitivities to air pollution (Schöpp et al., 1999). The latest version of the model is web-based.

This multi-pollutant/multi-effect model addresses health effects caused by fine particulates and ground-level ozone, as well as negative effects on ecosystems due to a too high load of acid (acidification), nitrogen (eutrophication) and exposure to elevated levels of ozone. The flow of information in RAINS is depicted in Figure 1.

[1] Netherlands Environmental Assessment Agency, P.O. Box 303, NL-3720 AH, Bilthoven, The Netherlands, email: info@mnp.nl, Internet: http://www.mnp.nl.
[2] International Institute for Applied System Analysis, A-2361, Laxenburg, Austria

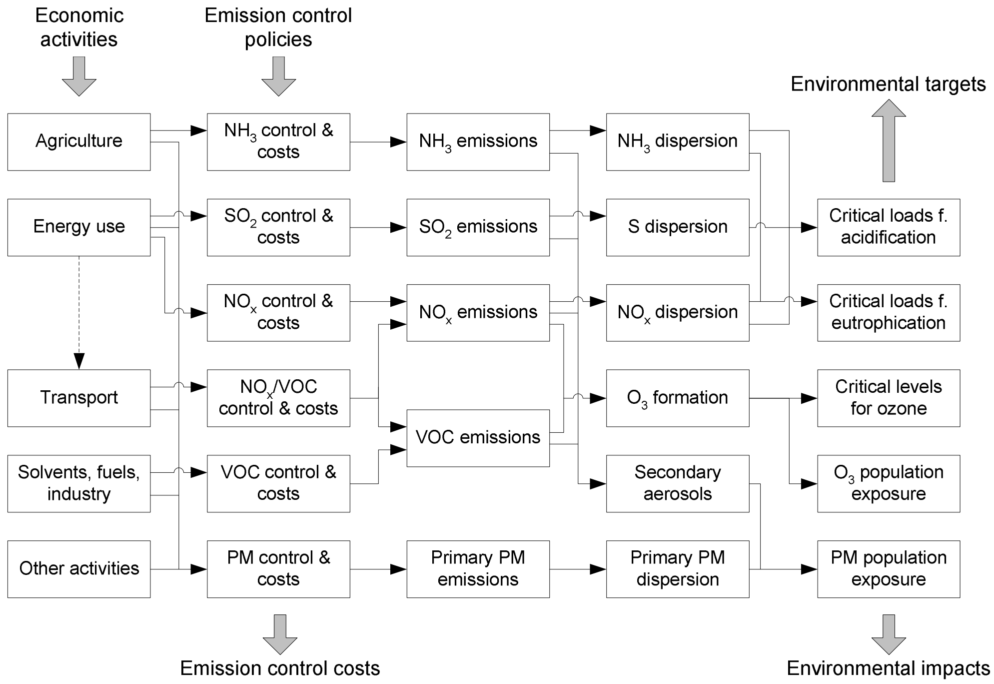

Figure 1: Information flow in RAINS.

The RAINS model framework makes it possible to estimate, for a given energy and agricultural scenario, the costs and environmental effects of user-specified emission control policies. This is called the 'scenario analysis' mode. Projections of economic activities are available by means of interfaces to specialized energy models.

In addition to the scenario analysis mode, RAINS can be run in an optimization mode. This enables the search for cost-minimal balances of controls of the concerned pollutants over the various economic sectors in all the European countries that simultaneously achieve user-specified targets for human health impacts and for the protection of ecosystems. Economic (control costs) and environmental differences between countries are taken into account in this optimization.

3. RAINS-NL

3.1 Extensions to the Emissions and Costs modules

Emissions and costs in RAINS are described at a very detailed level, involving a few hundred combinations of activities and economic sectors. Information about emissions and costs can be obtained either at this detailed level or at the aggregated levels of SNAP1, NFR1 or NFR2, all being international standards for reporting emissions. However, all these sectoral breakdowns are fairly process-oriented and do not comply with the actor-oriented division that is used in Dutch policy making, the so-called VROM[3] division. This VROM division has been added to the output formats of the emissions and costs modules by defining a translation table between the RAINS sector/activity combinations and the VROM actors. In fact,

[3] VROM is the Dutch acronym for the Ministry of Housing, Spatial Planning and the Environment

an extended version of the VROM division has been implemented because the VROM division itself is too aggregated to account for differences in dispersion behaviors between sub-classes. For instance, passenger cars and sea shipping belong both to ‘Traffic and Transport’, but differ substantially in emission characteristics. Another reason for the extension is that for some sub-classes different control measures may be expected. Therefore the VROM division was used as a starting point and extended where sub-sectors deviate in dispersion characteristics or where policy measures for sub-sectors may be expected.

3.2 Extensions to the Dispersion module

RAINS uses country-to-grid transfer matrices (or source-receptor matrices, SRM) to ‘translate’ emissions at the country level to concentrations and depositions on a grid cell level. These SRMs are derived with the new EMEP Unified model (Simpson et al., 2003). The spatial resolution of this model, and therefore also of the RAINS transfer matrices, is limited to 50 by 50 km. This resolution is considered too low to describe the impacts on human health and ecosystems in detail. It was therefore decided to complement the EMEP-based source receptor matrices for the whole of Europe with matrices specific for the Dutch domain with a higher resolution. A 5 by 5 km resolution appeared to be a reasonable compromise between the preferred resolution (1 by 1 km), on the one hand, and the response time of the model on the other. Unfortunately, the EMEP model cannot be run (yet) with this resolution. It was therefore decided to use the Dutch OPS model (Van Jaarsveld, 2004; section 3.2.1) to derive the required SRMs. OPS is the standard model for the assessment of air quality in the Netherlands, and is extensively validated with results of the Dutch Air Quality Monitoring Network. Velders et al. (2003) showed the results of the new EMEP model for the Netherlands to agree (reasonably) well on a national scale with OPS results for sulphur and reduced nitrogen (concentration as well as deposition). However, marked differences were found for oxidized nitrogen. The EMEP model calculates substantially lower values than OPS for both concentration and deposition.

Not only has the receptor resolution been adapted, but also the resolution of the emission distributions used in deriving the SRMs. Emissions with a spatial resolution of 50 by 50 km are used for the derivation of the EMEP-based SRMs, whereas the emission resolution for the OPS-based SRMs is 5 by 5 km for emissions from the Netherlands and the surrounding countries, and 1 x 0.5 degrees for the other countries. Furthermore, the OPS-based SRMs distinguish between economic sectors, taking account of different atmospheric dispersion behavior of emissions from different economic sectors. For reasons of controllability, this distinction is only made for Dutch emissions, considering that it is of lesser importance for emissions further away from the Netherlands.

The RAINS-NL dispersion module delivers output for the same compounds as RAINS. RAINS-NL also supports the calculation of NO_2 concentrations, NO_2 being a major problem in the Netherlands in urban environments where the annual mean concentrations often exceed the European limit value.

Besides using internally generated emissions from a scenario in the dispersion module, it is also possible to employ externally generated emissions. Of course, the sectoral structure of these emissions must comply with the sectoral structure contained in the transfer matrices.

3.2.1 The OPS model

The OPS model (Van Jaarsveld, 2004) calculates mean concentrations and depositions caused by one or more emission sources in Europe. It is a Lagrangian model that uses the Gaussian plume concept to describe concentrations caused by emissions at short distance away and the trajectory concept for emissions at a large distance away. Concentrations are calculated for a number of meteorological conditions and subsequently averaged across the meteorological classes, thereby weighting the concentrations with the frequency of occurrence of these classes in the period concerned. These meteorological statistics are available for all years from 1980, and averaged for the 1990-1999 period. Long-term averaged meteorological conditions are used to calculate future concentrations and depositions. The OPS model is a (pseudo-)linear model and is therefore not suited to simulation of complex, non-linear chemical processes such as the formation of ozone.

3.3 Extensions to the Impacts module

The accuracy of the health and ecological impacts is not only determined by the spatial detail in the calculated concentrations or depositions, but also by the detail with which the population or the ecosystems are described. To calculate ecosystem impacts, RAINS uses the CCE critical load database, generated under the Convention on Long-Range Transboundary Air Pollution (Posch et al., 2001; Hettelingh et al., 2001). This database contains critical load data aggregated across 50 by 50 km grid cells, together with their surface area. The exact position of the ecosystem, which is mostly – and in the Netherlands always – much smaller than 50 by 50 km, is not tracked in this database. Thus, increasing the resolution of the deposition calculation is not sufficient for raising the accuracy of the estimate of impacts. RAINS-NL uses a database containing the co-ordinates of the 250 by 250 m grid cells containing ecosystems, along with the dominant ecosystem type and the corresponding critical loads. This information is used to calculate and present the exceedance at a 5 by 5 km level.

For the calculation of health impacts, RAINS-NL contains the number of inhabitants per 5 by 5 km grid cell, split-up into five-year age classes.

4. Examples of applying the model

Example 1:

RAINS-NL offers the possibility of comparing the outcomes of the EMEP model for the Netherlands with the outcomes of the OPS model by projecting the EMEP outcome on the Dutch co-ordinate system. As an example, Figure 2 shows the NH_x deposition (the sum of ammonia and ammonium) in 2010 under the baseline scenario, calculated with the EMEP model (a) and the OPS model (b). The NH_x deposition contributes on average 60% to the nitrogen load of ecosystems in the Netherlands, and most of it is attributable to Dutch sources (intensive livestock breeding). Due to the scattered nature of these sources and the fact that NH_x is deposited at a short distance from the source, NH_x deposition shows large spatial gradients, which are not captured by a large-scale calculation. This, together with the fairly small Dutch ecosystems, underscores the need for the increased spatial resolution that has been implemented in RAINS-NL.

Example 2:

Both RAINS and RAINS-NL offer extensive facilities to construct emission control scenarios. One of the possibilities is to apply the control strategy of a certain country to a group of other countries. The control strategy defines the control measures and their degree of implementation in the future. In this way one can explore what the effect would be if other countries apply the same control strategy as the Netherlands, for example. Table 1 summarizes the results of such an analysis. If all EU25 countries adopt the Dutch control strategy in their baseline scenarios, the deposition of nitrogen oxides (NO_x) on the Netherlands in 2010 will decrease by about 5%. This decrease is the result of decreased emissions in Belgium, France and the United Kingdom, countries that together contributed 30% to the Dutch NO_x deposition in 2000. On the other hand, if the French control strategy is applied across the EU, the Dutch NO_x deposition in 2010 increases by about 8%. This rise is mainly due to increased NO_x emissions in the Netherlands and Germany.

Table 1: Deposition of nitrogen oxides (moles ha^{-1} y^{-1}) in 2010 according to the baseline scenario in which: (a) all countries apply their own control strategy, (b) all countries apply the Dutch control strategy and (c) all countries apply the French control strategy

	Mean	Median	Min	Max	P2	P98
a	232	224	126	439	137	344
b	219	213	117	393	128	323
c	251	244	135	464	148	372

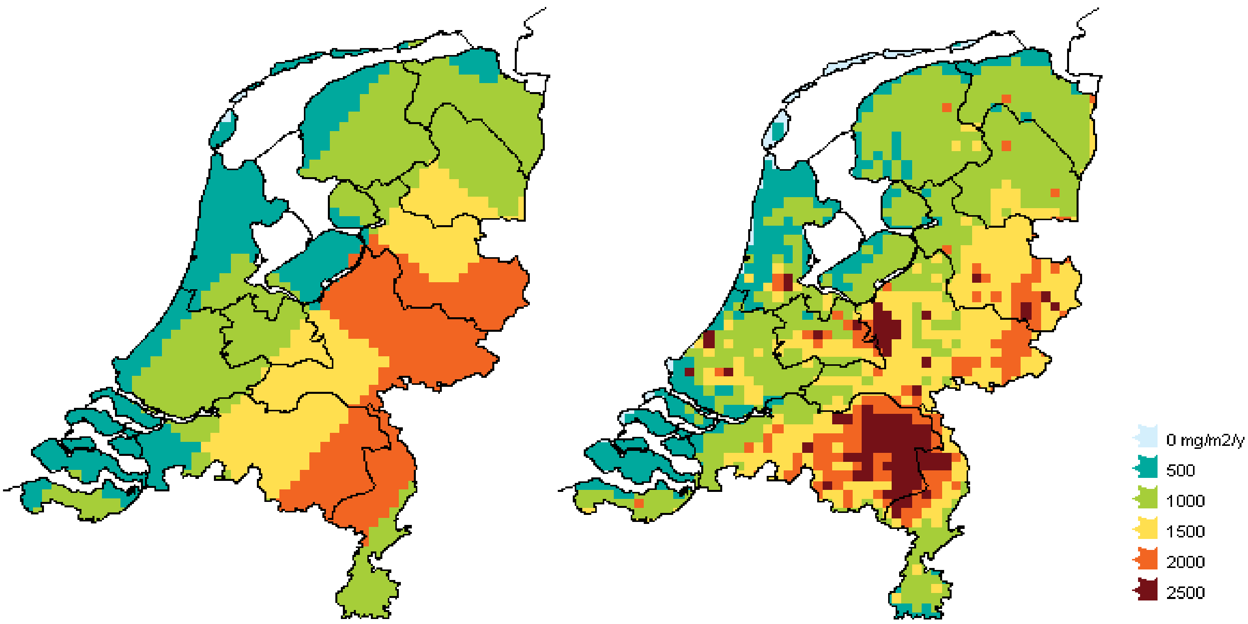

Figure 2: Deposition of NH_x (in mg m^{-2} y^{-1}) in 2010 according to the baseline scenario, calculated with the EMEP model (left) and the OPS model (right).

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