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Report on the International Peer Review of RAINS-ASIA

Harald Dovland
(ed.)

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Contents

Executive Summary

Many Asian countries have experienced rapid economic growth during recent years and this trend is expected to continue. The economic growth is accompanied by increasing energy demand, with coal as the dominant energy source. A significant increase in emissions is therefore foreseen. This development will lead to increased levels of acid deposition which may affect Asian ecosystems.

The RAINS-ASIA model has been developed as an analytical tool to assist decision-makers analyse future trends in emissions, estimate regional impacts of resulting acid deposition levels, and to evaluate costs and effectiveness of alternative mitigative actions.

The draft project report has been reviewed by an international peer review team. The main findings of the review team were:

For the first time a model has been specifically developed and applied for integrated assessment of future SO_2 emissions in Asia. The RAINS-ASIA model offers an opportunity to assess sulphur deposition and ecosystem protection levels resulting from different energy pathways and different emission control strategies. The costs of various control strategies are also provided. It has not yet been possible to fully evaluate all parts of the model, e.g., by comparison with monitoring data. However, the general impression is that the model is producing reasonable results.

During the project an impressive database has been collected for the region (23 countries, 94 subregions and 355 large point sources). This was made possible through dedicated work by the project team, in close collaboration with scientific and technical institutions in several Asian countries.

Each module of the RAINS-ASIA model has been based on sound technical and scientific judgement, taking into account the constraints given by the limited time and resources available. There are uncertainties associated with the model results, but they are in general difficult to quantify. Some of the uncertainty is caused by the lack of complete scientific knowledge (e.g., on atmospheric processes and on impacts of air pollution on ecosystems), and some by the lack of relevant monitoring data.

Extensive participation by Asia institutions has played a significant role in the development of the model.

Efforts should be made to make RAINS-ASIA widely known to Asian scientists and policy makers.

A further development of the model may include:

- strengthening and widening the collaboration with Asian institutions,
- assistance in establishing appropriate monitoring programmes, and
- inclusion of other air pollutants than SO_2.

Report on the International Peer Review of RAINS-ASIA

1. Background

Acid rain is a popular term for wet and dry deposition of acidifying compounds such as SO_x and NO_x. These air pollutants are emitted into the atmosphere mainly from the burning of fossil fuels. In the atmosphere they take part in chemical reactions and are gradually deposited on the earth's surface. The pollutants may travel over long distances (>1000 km) and be deposited on sensitive ecosystems far away from the emission areas. In Europe, large increase in the use of fossil fuels has resulted in widespread damage to ecosystems. Acid rain has therefore been an issue of concern in Europe, as well as in North-America, for 15-20 years. This has lead to extensive research activities both at the national level and through international cooperative programmes. The results have been used by policy-makers in their efforts to elaborate international agreements on emission reductions. During recent years the development of integrated assessment models has played an important role in the deliberations. These models provide a regional picture of the situation, illustrate the results of various emission scenarios, and can also be used to calculate how specified environmental goals can be reached in a cost-effective way. The most widely used model has been RAINS-EUROPE, which provided the basis for the negotiations on the 1994 Protocol on further sulphur reductions under the Convention on Long-range Transboundary Air Pollution.

Many Asian countries have experienced rapid economic growth during recent years and this trend is expected to continue. The economic growth is accompanied by increasing energy demand, with coal as the dominant energy source. A significant increase in emissions is therefore foreseen. It has been estimated that by year 2010, the SO_2 emissions for Asia may exceed emissions of North-America and Europe combined. This development will lead to increased levels of acid deposition which may affect Asian ecosystems.

In this perspective, it is important to develop tools that can analyse consequenses of various scenarios, and which can assist in developing strategies to avoid environmental damage. Experience gained on acid rain problems in Europe and North America would provide a starting point for developing a tool specific to the Asian region.

The RAINS-ASIA model has been developed as an analytical tool to assist decision-makers analyse future trends in emissions, estimate regional impacts of resulting acid deposition levels, and to evaluate costs and effectiveness of alternative mitigative actions. RAINS-ASIA has been developed by an international research team led by the Agricultural University Wageningen (Netherlands) and Resource Management Associated (Madison, Wisconsin, USA). The International Institute for Applied Systems Analysis (IIASA, Austria) has been responsible for integrating the information into the model. The project has been funded by the Asian Development Bank and the World Bank using Netherlands, Norwegian and Swedish trust funds.

The World Bank decided to carry out a thorough international peer review of RAINS-ASIA. The Norwegian Institute for Air Research (NILU) was contracted to be responsible for the review process.

2. The review process

The review team was selected among scientists from Asia, Europe and North-America. The persons participating in the review have long experience in one or more of the disiplines included in integrated assessment modelling. In addition, experienced persons were invited to evaluate the relevance and usefulness of the RAINS-ASIA model. The following persons participated in the review:

Co-ordinator:	H. Dovland	NILU, Norway
Energy:	R.K. Pachauri	TERI, India
Emissions and control costs:	B. Lübkert-Alcamo B. Schärer	Netherlands Umweltbundesamt, Germany
Atmospheric processes:	D. M. Whelpdale H. Ueda	AES, Canada Kyushu University, Japan
Effects/critical loads:	K. Bull Sijin Lee	ITE, United Kingdom Kyong-gi University, Korea
Model relevance:	K.C. Moon S. Seki	KIST, Korea Environment Agency, Japan

Draft chapters of the project report as well as diskettes with the RAINS-ASIA model were made available to the reviewers. In addition, members of the project team presented the various modules and run demonstrations of the model at a review meeting in Washington D.C. 23 and 24 May 1995. At this review meeting, the reviewers presented their evaluation to the project team. Then the reviewers prepared their final evaluations as reproduced (with only minor editorial changes) in this report. In addition, minor technical and editorial comments on the drafts were given to the project team. Opinions expressed are those of the reviewers and do not necessarily reflect any opinion of their institutions.

3. Overall findings

For the first time a model has been specifically developed and applied for integrated assessment of future SO_2 emissions in Asia. The RAINS-ASIA model offers an opportunity to assess sulphur deposition and ecosystem protection levels resulting from different energy pathways and different emission control strategies. The model also provides information on control costs. It has not yet been possible to fully evaluate all parts of the model, e.g., by comparison with monitoring data. However, the general impression is that the model is producing reasonable results.

During the project an impressive database has been collected for the region (23 countries, 94 subregions and 355 large point sources). This was made possible through dedicated work by the project team, in close collaboration with scientific and technical institutions in several Asian countries.

Each module of the RAINS-ASIA model has been based on sound technical and scientific judgement, taking into account the constraints given by the limited time and resources available. There are uncertainties associated with the model results, but they are in general difficult to quantify. Some of the uncertainty is caused by the lack of complete scientific knowledge (e.g., on atmospheric processes and on impacts of air pollution on ecosystems), and some by the lack of relevant monitoring data.

The RAINS-ASIA offers a useful tool that can now be used for policy analysis, as well as for education.

Extensive participation by Asia institutions has played a significant role in the development of the model.

Efforts should be made to make RAINS-ASIA widely known to Asian scientists and policy makers.

In further development of the model, the following issues should be considered:

- strengthening and widening the collaboration with Asian institutions,
- assistance in establishing appropriate monitoring programmes,
- inclusion of air pollution problems in urban areas in the assessment model, and
- inclusion of other air pollutants than SO_2.

Several of the reviewers (see Chapter 4) underlined that RAINS-ASIA is a user-friendly tool which can readily be made available to and mastered by students, scientists and policy-makers in the region. The reviewers point to the importance of strengthening the national participation in developing the model and in improving the data bases. In this context, the development of coordinated monitoring programmes would be of particular relevance. Such programmes would in itself strengthen the cooperation among relevant Asian institutions, and it would provide a data base for evaluation of model estimates. A fuel comparison of model results with monitoring data is crucial for gaining confidence in the model estimates. The reviewers have also put forward specific suggestions for further development of the model.

4. Comments on individual modules

The comments from the reviewers are reproduced with only minor editorial changes.

4.1 Energy

(Draft report Chapter 3: "Regional Energy Scenario Generation Module"
by C.Green, J. Legler, A. Sarkar, and W. Foell)

Comments by R.K. Pachauri:

Objective

The objective of the module is to provide inputs of a range of values pertaining to energy production and use and emission data at a disaggregated level to enable the RAINS-ASIA model to compute outputs on emissions of acid substances and their locational impacts.

Overall assessment of the module

In general, this is a useful and extensive first exercise. However, given the fact that the driving force for the whole project is provided by the energy module, any shortcomings in this module would get passed onto the following stages of the computations performed. Hence, there is need for considerable refinement and improvement of data inputs in this module.

Strength/shortcomings/problems

There is much strength in this exercise in respect of the LPS (large point source) component of the computations performed. This bears out the importance of good quality data for this entire exercise. Since information on large point sources is adequate and reliable, the output from this segment is also strong and reliable.

There are two shortcomings that can be identified broadly, both of which are interrelated:

a) Inadequate effort and resources were devoted to the collection and computation of data. The management of this effort also left much to be desired.

b) In several parts of this exercise closer involvement of local organisations and institutions would not only have helped in the use of insights on local factors and conditions. Such insights can only be based on indepth knowledge and the vast amount of work available locally, but the data collection effort would also have been substantially better.

The main problem, therefore, in the module arose out of inadequate local involvement. The RESGEN simulator is a very simple model that could have been handled by local institutions without any loss of consistency. In fact, improvements and refinements in RESGEN itself might have emerged through closer interaction with organisations in the region.

Future developments

It is suggested that for future work

a) A group of 2 or 3 persons spends about 3 days together developing the details of the next phase, carefully defining the structure of what needs to be done, and with a clear plan of action.

b) Local organisations and institutions be used as partners in a training effort to create local awareness and interest.

c) The involvement of local organisations be fully integrated in the next phase.

Detailed comments:

Much greater disaggregation of analysis at the sub-country level. At the current stage the study arrives at values for agriculture, transportation energy use, etc. at the sub-country level based on very simple variables such as population. Given the disparities in the intensity of energy use across some of the large countries, far more specific data on energy use at the sub-country level would be essential.

Biomass is a major form of energy in several countries covered by the study. More precise estimates of different biomass fuels used and emissions arising from them are available in countries like India and China, and these should be used for the study.

Aggregation of urban and rural households would cause a distortion, since patterns of energy use in the study needs to be considered.

For population projections, UN and World Bank figures may be used, because these are generally regarded as robust and acceptable.

Energy intensity figures appear much to optimistic in terms of reduction over time. Since these figures are critical, much greater attention is needed to ensure the reliability of projections, by careful study of work already done in the countries covered.

Increases in transport intensity appear high, and some assessment of efficiency improvements, model shifts and growth of public transport infrastructure needs to be built into the projections.

The work performed by ECON is not explained adequately in the report. The impression created is that a simple and aggregated analysis was attempted at the national level, which does not capture the sub-national differences in economic structure and patterns of growth.

Renewable energy technologies appear to have been de-emphasized in the study. Recent developments would promise a much larger role for renewable technologies in the region in the next 25 years. This is another area requiring deeper study of recent changes and likely growth in spread of renewable energy technologies.

It is not understood why official projections of energy consumption have been used in the study. These should preferably be replaced by several other objective exercises carried out by groups within the countries involved, but also those of the World Energy Council. Official projections are often exaggerated forecasts of business-as-usual trends.

It would be useful to carry out sensitivity analysis in the study incorporating specific programmes such as boiler improvement, greater use of wind energy, etc., which might provide a more rational basis for answering "what if" type of questions through the models used.

The most important challenge in the study is to ensure capacity building and a sense of ownership of this work for use by national and sub-national policy makers. If this is to be addressed effectively local organisations and institutions need to do far more than mere data collection and supply for the RESGEN model. The next phase of the study, if undertaken, has to be built on the full harnessing of local capacity.

General comments on the energy and emission modules of RAINS-ASIA

Comments by B. Lübkert-Alcamo:

The energy and emissions modules of RAINS-ASIA are pre-requisites to the quantitative assessment of acid rain impacts in southeast Asia. Since the energy and emissions calculations determine to a large degree the subsequent quantitative results of impact analysis, these calculations are extremely important and should produce reliable data over time.

With regard to the energy sub-model RESGEN, it appears that relatively much effort was spent on obtaining region-specific data on present and future energy consumption as well as on fuel characteristics from local sources involving the local and national authorities of individual countries of the southeast Asian region. Altogether, local or sub-national, region-specific energy data, national energy data or extrapolated from the European situation (from RAINS-EUROPE) are being used in RESGEN, as well as in the emission module ENEM in RAINS-ASIA. In the documentation of the two modules it should thus be made very clear, which data come from which sources. This would not only help identify the degree of reliability of the energy data used in RESGEN and ENEM, but would also help establish priorities in future data gathering activities in the southeast Asian region.

In order to validate the emission calculations of the emission module ENEM, a separate emission inventory for 1987/88 was independently established, and the base year emission calculations of ENEM were compared to this emission inventory. Results of this comparison were found in overall good agreement at national level. The current documentation, however, lacks a more detailed comparison of emissions per each of the eight sectors, and within each sector, between the point and area sources. This should be added in order to allow the reader and model user a more detailed emission check. In general, the creation of the RAINS-ASIA model may stimulate southeast Asian countries to perform emission inventories on a more routine basis, which would form a sound basis for all quantitative air pollution impact analyses in the region.

Overall, it can be concluded that the scientific basis used to create and validate the energy and emission modules is adequate, and that the data used represent either best available information from the southeast Asian region, or reasonably extrapolated data from RAINS-EUROPE.

Specific comments to Chapter 3 (RESGEN)

In general, Chapter 3 seems a well written and very well structured chapter. Most comments, therefore, only refer to relatively minor details, which I consider, however, important in the overall understanding of RESGEN:

- At the beginning of Chapter 3 (together with the title) a flow diagram of the entire RAINS ASIA/RESGEN structure should be shown, and the relevant sub-module described in this chapter should be highlighted. This provides the reader right at the beginning of each chapter with a very good understanding as to how the present chapter fits into the overall structure.

- Chapter 3 should contain a separate section on the use of RESGEN, i.e. include clearly the options which the user has. This does not have to be lengthy if there is a separate user manual, but it should summarize the main options, and should make clear to the reader which parts of the chapter describe only background to the sub-model and how it was derived, and which parts give the actual content of RESGEN.

- Chapter 3 should clearly indicate which databases are included in RESGEN (versus those that are just discussed as background material for deriving input data into RESGEN), and which part(s) of these databases the user can visualize and/or access in the sub-model.

- Missing at the end of Chapter 3 is a clear description of the link between the actual output of RESGEN and input into ENEM; this could be included in the general section on "Use of RESGEN", and should include the options of what the user can do in RESGEN vs. ENEM.

It should be noted that the first three of the above comments do not only relate to Chapter 3, but to all chapters of the final report of RAINS-ASIA.

4.2 Emissions and abatement cost

(Draft report Chapter 4: "Emissions and controls" by D. Streets, M. Amann, N. Bhatti, J. Cofala, and C. Green)

Comments by Barbara Lübkert-Alcamo on Sections 4.1 through 4.3:

The main problem with Chapter 4 is that it lacks a good balanced structure. Certain issues are given unnecessary and long detail whereas other more important issues do not receive an adequate description. A major effort at rewriting parts of Chapter 4 appear, therefore, necessary. The following general comments should thus be taken into consideration when revising this chapter:

- Whereas there is now too much repetition in the beginning of the chapter on the overall structure of RAINS-ASIA, there is no clear reference to RESGEN. It would be more helpful to the reader to include a paragraph that clearly delineates what is done in RESGEN versus what is done in ENEM, and how the two are linked. In this context it is worthwhile pointing out that there has to be absolute consistency between the definitions used in the two sub-models (e.g., energy sectors, fuel types, etc.) and in the numbers used (e.g., the number of point sources included in the model) which is currently not the case.

- An introductory section, as well as a clear structure, are needed to describe what is actually contained in the ENEM sub-module, which should explicitly be mentioned in the beginning of the chapter, versus what is contained in the background databases, such as the 1987/88 baseline emission inventory, which were either used to derive input data into ENEM, or to verify output results from ENEM. Here it should also be described as to how far RESGEN provides input data into ENEM (e.g., fuel characteristics).

- In the description of the baseline SO_2 emission inventory for 1987/88, there is insufficient balance between the description of the calculations of energy-related emissions, process emissions and emissions from international shipping. Whereas emissions from shipping are given a great level of detail, emissions from energy facilities are hardly described at all. The same sector split as in RESGEN and ENEM should be used for the other subheadings to describe the emissions calculations for each of these sectors. Under each of these subheadings, point and area sources should be described separately.

- In Section 4.3 there has to be absolute consistency in the nomenclature used here and in Chapter 3, regarding sector and fuel classification. The sectors as well as the fuel types used in ENEM should be spelled out together with their abbreviations, and should be identical to those used in all other chapters (see also specific comments). There has to be consistency in the number of point sources included in RAINS-ASIA, currently numbers in Chapter 4 vary between 248 (page 2, 3rd para), 255 (page 14, 1st para) and 300 (page 25, 1st para), compared with 355 used consistently throughout Chapter 3. A section has to be included that describes how the non-energy industrial process include an option to visualize on a map computed emission densities in all of the 93 regions and show proportionally-sized dots for the magnitude of computed point source emissions.

- Chapter 4 should contain a separate section of the use of ENEM, i.e. include clearly the options which the user has. This does not have to be lengthy since there is a separate user manual for RAINS-ASIA, but it should summarize the main options, and should make clear to the reader which parts of the chapter describe only background to the sub-model and how it was derived, and which parts give the actual content of ENEM.

- Chapter 4 should clearly indicate which database are included in ENEM (versus those in RESGEN and those that are just discussed as background material for deriving input data into ENEM), and which part(s) of these databases the user can visualize and/or access with ENEM.

In ENEM, the user should have the possibility to select "total emissions" without having to compute separately first the point and area sources; also in ENEM, the definition "total emissions minus LPS" is not a good definition; this should be changed to simplify "area sources" and "LPS" should be spelled out to become "point sources", both of which are more user-friendly terms.

In addition to the chapter-specific comments, the following eight comments relate to the user-friendliness of the RAINS-ASIA model itself, and should be taken into account when finalizing the model:

1) The model should allow for visualization of regions and sub-regions.

2) The current structure of the selection of regions and emissions should be changed. Whereas now, one selects the area source emissions together with the regions, the point source emissions have to be added separately, this should be changed so that the user first selects the region and then decides whether (s)he wants to see "area source emissions" or "point source emissions" or "total emissions", where the latter is currently not at all possible, unless the user adds him(her)self the LPS area source emissions.

3) Currently, no possibility for a graph of "total emissions over time" exists, this should be added.

4) The model should automatically save the last picture file (i.e. graphs) so that these do not have to be recreated each time, if they are accidentally cancelled.

5) If the user selects one LPS in one region, the model still goes back in the subsequent selection option to the list of all countries and regions; this should not be the case.

6) Cost curves per country, per area and all point sources combined, and per all LPS (e.g., in a region or in a country) combined does not work; such options of aggregation should be added.

7) The scenario saving option does not seem straight-forward; the order of selection of different aspects of a scenario should be flexible.

8) Once a selection of a certain year has been made, this should stay for the subsequent selections, rather than go back to a list of all years (also does not work in this way in the DEP sub-module).

Comments by Bernd Schärer on Section 4.4:

Technical background

This review of the Emission Abatement Technologies and Cost Module of the RAINS-ASIA Model is based on background information on emission control technolgies obtained from the following sources in particular:

Of first importance is the Oslo SO_2 protocol of 1994 to the 1979 Convention on Long-range Transboundary Air Pollution. The technical annex summarized the state of the art of SO_2-emission control. In addition, extensive reports are available on the 1991 UN ECE Seminar on Emission Control Technology for Stationary Sources and the 1988 UN ECE Workshop on Emission Control Costs, as well as several IEA (FGD Hand Book) and OECD reports and, reflecting emission control in Asia, the proceedings of the conference on "The clean and efficient use of coal and lignite", Hong Kong 1993 are of relevance to the subject.

There is also vast operational experience with all relevant SO_2-abatement technologies. The IEA Coal Research Annual Report 1993/94 reports on 165 GWe FGD plants in 18 countries and notes a rapid increase in their number. One out of four of the FGD plants is installed in Germany. In Germany, for example, all relevant emission sources have been covered and regulated. A general requirement in Germany is that all installations have to be constructed and operated in keeping with the state of the art. Comparable requirements are also in place for mobile sources and fuels. Comprehensive experience covering all emission sources and all effective control technologies is available, in particular, for the emissions of acidifying substances.

Results of the review

The module generates cost curves through a function as shown below in a highly simplified manner. The development of this function follows the bottom-up approach, with the best grounding in engineering science.

(1)	=	(2)	V	(3)
National program/ scenario costs	=	emission sources, energy structure	rules for linking (2) and (3)	available emission control technologies

The topic of my review is the inventory of abatement technologies (3) and the rules for linking control technologies with emission sources. The abatement technologies were reviewed with respect to relative completeness, cost data, and emission reduction efficiencies.

The technologies inventory for SO_2 includes the most important model emission abatement methods:

- Desulphurization of the fuel oil and coal, as well as of diesel fuel.

- Measures targeted at the firing technique (additive processes, fluidized bed combustion).

- Flue gas treatment techniques. (The most popular FGD systems are wet limestone scrubbers, which due to process optimization now achieve removal efficiencies of over 95% without causing substantially higher costs. SO_2 removal efficiencies of over 95% are at present required in power plant permits in East Germany.)

These measures are differentiated enough to reflect the spectrum of all available measures. Not included in this module, but in the energy scenario generation module, are changes in fuel mix as well as energy conservation measures. Their importance for reducing SO_2-emissions is two-fold: they minimize the amount of flue gas to be cleaned and they are a mean of emission abatement, especially when available emission reduction and abatement technologies have already been exhausted, as is largely the case in Germany.

The economic data used in the module (investment, lifetimes, consumption of energy and materials, prices) reflect general experiences and the data given in relevant literature. The methodology used to calculate annual and unit costs is in keeping with best cost-calculation theory and practices.

The rules and criteria (V) used in the module to allocate specific emission abatement technologies to specific groups of emitters are not explicitly documented in the draft report, but were well taken into account. For example, expensive and highly efficient flue gas treatment systems are reserved for large plants (power stations) with high emission loads, whereas less costly primary measures are the preferred choice for small plants. Also the complexity of emission abatement technologies and the generation and treatment of by-products is also adequately reflected.

The emission sources (structured in end-use, conversion and industrial sectors) and the energy structure (fuel categories) underlying the module are not subjects for this review. It should be noted, however, that the way in which emission sources and energy are structured allows an appropriate allocation of available abatement technologies.

A crucial aspect of the module is the issue of transferability of technology and cost data from experiences in the OECD to the Asian countries. Having discussed this issue with a German manufacturer, our assessment would be as follows: As the sources of acidic emissions are similar in industrialized and Asian countries, meaning that they essentially use the same emission-causing technologies and forms of energy, the same emission measures can be used in Asian countries. Possible differences in energy consumption patterns would not contradict this assessment. The use of cost data reflecting EU standards means, however, that the real world control costs arising in Asian countries are usually overestimated, and that the higher the Asian country's own contribution to the investment, the higher the overestimation.

Summary

The emission abatement technologies and cost module of the RAINS-ASIA model reflects best bottom-up modelling practice. The coverage of SO_2 abatement technologies, their costs and removal efficiencies is appropriate to the model's purpose, i.e. the level of abstraction the module achieves in differentiating abatement technologies meets the needs of, primarily, an environmental policy that reaches beyond national borders. The inclusion of other acidifying emissions and their control measures would be desirable. Use was made of the most important information sources. The rules the module use for linking available SO_2 control measures with emission sources and fuels should be documented.

4.3 Atmospheric processes

(Draft report Chapter 5; "Long range transport and deposition of sulfur in Asia" by G.R. Carmichael and R.L. Arndt.)

Comments by D. M. Whelpdale:

Objective of atmospheric module

The first objective of this portion of the RAINS-ASIA project was to develop an atmospheric transport and deposition model to provide fields of ambient concentrations of sulphur species, fields of wet and dry deposition, and transfer matrices which would provide a quantitative link between emissions and receptors. A second objective was to develop the model in such a way that the technology could be easily transferred and used for both policy formulation and capacity building in the region.

Overall impression

To a very large extent, the above objectives have been attained. The development and application of this module is a highly commendable accomplishment, given the limited time and resources available, and the paucity and unknown or poor quality of data in this region for model inputs and evaluation. The module is soundly based, using an established and accepted Lagrangian trajectory model.

The value and utility of the model have been demonstrated through a number of example applications: for example, the fraction of total deposition that is caused by shipping, by large point sources, or by volcanos; and how the perceived significance of transboundary pollution changes, depending on whether it is described as a percentage of source-country emissions or receiving-country deposition.

One of the most significant features of this and other modules is their potential as technology transfer and educational tools. Being PC-based and user friendly assures that the tool can be made available to and mastered by many students, scientists and policy-makers in the region.

While the atmospheric model does have some aspects in need of further development, it is this reviewer's opinion that a model need not be perfect before it is used, as long as uncertainties inherent in its use are known. This measure of uncertainty has not yet been established in this case, so that the "goodness" or "badness" of results cannot yet be clearly determined.

One of the greatest benefits of development of an integrated assessment model is participation in the process of development. This is certainly the case with RAINS-ASIA: awareness of the needs for information and for policy development has been heightened; new data sets have been assembled; and new scientific and policy issues and gaps have been identified.

Strengths and weaknesses

The strengths of the atmospheric module include:

- It is a simple-to-use, PC-based tool.

- A number of applications, such as source contribution comparisons and scenarios have already been demonstrated.

- Its potential for technology transfer, education and training, and self-help is very high.

- It has proved to be an effective catalyst in initiating the assembly of new data bases, which will have uses external to this effort.

- Those responsible have begun to consider and apply the model to atmospheric environmental issues in addition to acidification by sulphur. For example, the examination of radiative forcing by sulphate aerosol for the climate change issue and the investigation of the role of base cations in acidification are both timely and valuable.

A number of shortcomings have been identified in the atmospheric module development. These are not considered serious, given the stage of the programme; rather they are items which would benefit from additional investigation or refinement.

Several model parameter values have been chosen on the basis of earlier work. As further research is concluded and experience is gained with Asian conditions, these parameter values may require adjustment. Of particular interest in this regard are differences which may arise as a function of latitude (tropics to mid-latitude) and those which govern the relative contributions of the various sulphur species and processes to total deposition.

The community has limited experience with how meteorological processes affect chemical transformation and deposition in tropical regions. Additional experience may require adjustments to this aspect of the model.

Evaluation of the model is at an early stage. As uncertainties associated with the various elements of the model (emissions, winds, precipitation, parameter values) become better known, they can be better described and quantified for users. Additional corroborating evidence of the importance of volcanic emissions in some countries will be important. The examination of mass balance for sulphur, both in the domain as a whole, and in various sub-regions or countries, will give added confidence to the validity of the model results.

Two problem areas which will require additional work in the next phase are the development of complementary monitoring data for model evaluation, and an initiative to better describe how uncertainty from the various inputs is propagated through the model to produce an overall quantifiable level of confidence in the model results.

Future developments

As noted above, the RAINS-ASIA modelling effort would benefit significantly from the establishment of an Asian monitoring network. Experience elsewhere has shown that a complementary approach of modelling and monitoring provides a strong diagnostic and predictive capability which enhances credibility of the effort and its results.

Both the quantity and quality of the input data used by the model developers must be improved. More up-to-date and accurate emissions information is required; more extensive meteorological data are needed; and, as noted above, substantially more ambient air quality and deposition measurements are needed.

In future, the modelling work will benefit from the inclusion of additional chemical species (e.g., nitrogen oxides, ammonia, and base cations) and more complete simulations of chemical processes. Calcium is known now to be important as a neutralizing agent for acidity; by the year 2020, emissions of nitrogen species will be more significant.

A good start has been made in using the RAINS-ASIA model, and its atmospheric module in particular, as an effective tool for technology transfer and education. In the long term, this may be the most important outcome of this initiative. It is highly flexible, interactive, and can be tailored to individual country or region needs.

It has been noted that local pollution problems are the highest priority at present in many Asian countries. Although RAINS-ASIA has not been designed, in the first instance, for use on the local scale, it may be possible to adapt the atmospheric model using a nested grid approach to examine selected regions in more detail. This could be a logical off-shoot of work during a subsequent phase.

Acid deposition and transboundary pollution are not the only issues affecting Asia. As in other parts of the world, climate change and stratospheric ozone depletion continue to be serious concerns. Toxic chemicals in the environment and tropospheric ozone increases will increasingly grow in importance in Asia. Effort should be devoted to exploring how RAINS-ASIA might be used to examine these several issues, or at least to develop necessary linkages. This is being done to a certain extent in the atmospheric module, where the radiative forcing implications of sulfate aerosol have already been examined. There are undoubtedly many other connections among issues; these should be developed wherever possible to ensure the continuing relevance of the RAINS-ASIA work.

Comments by H. Ueda:

Objectives of module

The objective of Phase 1 of the International Collaborative Project on Acid Rain and Emission Reduction in Asia was to develop a methodology and a PC-based software tool in order to assess impacts of various acid rain emission reduction strategies in Asia. The RAINS-ASIA model estimated future energy demand and supply trends under variety of socio-economic and technical scenarios. It then estimated sulphur dioxide emissions and costs of emission control. Based upon the sulphur dioxide emissions under a variety of scenarios, it estimated concentrations of SO_2 and sulphate, and sulphur deposition throughout the region and compared them with data on environmental sensitivities that were presented in the form of critical load maps.

In the framework of the RAINS-ASIA model, the role of the ATMOS (Atmospheric Transportation and Deposition) module is to provide estimates of concentrations of SO_2 and sulphate and sulphur deposition loadings as a function of future emission scenarios, and to provide a matrix of annual sulfur depostion as a function of SO_2 emissions (source-receptor matrix).

Overall impression

The objective of the ATMOS module above has been accomplished successfully in the RAINS-ASIA framework. In addition, it is the first and distinguished contribution to Asian people to provide overall views of sulphur concentration and deposition (the most important concern in air pollution) over the whole Asia and in each country. In particular, in rapidly developing countries in Asia the output raised an alarm for sustainable development. At the present stage with limited information about pollutant emission, this output could be highly evaluated. That would compensate uncertainties involved in the model.

However, when the model users (e.g., policy-makers) apply the ATMOS module to detailed environmental planning and to get general agreement about the model results, uncertainties included in the model should be overcome. Thus, the next step (Phase 2) of the project is eagerly waited for.

Strengths, shortcomings and problems

Mathematical model

a) Lagrangian approach

A Lagrangian approach was chosen, rather than an Eulerian counterpart. This is mainly due to the prerequisite imposed by the framework of RAINS-ASIA model. That is, the ATMOS module was asked to provide a source-receptor relationship, i.e., a transport matrix which represented contribution of each emission source to the ambient levels of acidic precursors and acid deposition at receptor sites.

The choice of the Lagrangian approach worked to speed up calculation and made it possible to compare model results of various emission scenarios on the PC bases. However, the Lagrangian model used simplified the physical and chemical processes too much and so contained many uncertainties. Thus, model validation must be made by extensive comparisons with results of field observations and sophisticated Eulerian models. Since Eulerian models can describe physical and chemical processes in more detail than the Lagrangian approach and since several sophisticated models have been already developed, e.g., STEM-II model by Carmichael et al., parallel use of the Lagrangian model and a Eulerian counterpart may overcome the uncertainties.

b) Three-layer model.

In RAINS-EUROPE a Lagrangian parcel model with one layer has been used, whereas in the ATMOS module of RAINS-ASIA model a three layer model has been used. It is an advance from the RAINS-EUROPE model. Layering the atmospheric diffusion field into three layers at night and into two layers during the day could reasonably represent vertical mixing of pollutants in the atmosphere and difference of initial diffusion processes between area-sources and elevated-sources. It also resulted in assigning different layers in which in-cloud and under-cloud processes were controlling.

In spite of the advantage of this concept, superiority of the model results have not been confirmed. In addition, although such a layering procedure is reasonable over land, it may not be applied over oceans because of its different diurnal variation from that over land. That is, in the ATMOS module such a difference between land and ocean has not been taken into account.

Input data

a) Meteorology data

Meteorology data were used to calculate puff trajectories and inversion heights. Observed data of wind and temperature from the upper air soundings (provided by the National Meteorological Center (NMC) of the National Oceanic and Atmospheric Administration (NOAA)). As mentioned in the report (page 16, Chapter 5), the lack of data over oceans is a serious problem. Although climatological winds were used to supplement the data set, it was not sufficient because the oceans occupied a large portion of the calculation domain. Data obtained by three-dimensional data assimilation by means of a general circulation model is recommended as the meteorological input data.

b) Precipitation data

In the report it was described that precipitation data used was NMC analyzed fields and was obtained from the USA National Center for Atmospheric Research (NCAR). Whether it is observed or forecast, is not clear. Since wet deposition of sulphur is almost proportional to the amount of precipitation and since forecast data is often accompanied with 10-30% error, thus for the precipitation over land observed data is recommended to be used.

On the other hand, for the precipitation over oceans observed data is sparce so that combination of observed and forecast data is recommended at the present stage of art.

Model parameters

The ATMOS module contains mainly four model parameters; chemical reaction rate constant, wet removal rate constants, dry deposition velocities and dispersion width. Principally the same values as RAINS-EUROPE were adopted in this module. Some modification has been made to take into account the dependance of latitude. The model domain covers tropical, sub-tropical and temperate zones and some parameter values are considered to change with latitude significantly. Moreover, their seasonal variation would be different for those climatological zones. Strong sun irradiation, high humidity and cloud cover characterizing climates in south and south-east Asia would affect the chemical reaction rate significantly. In addition, monsoon causes large amounts of precipitation, sometimes more than 10 times larger than that in Europe. Thus, a special care on the wet removal rate constants is necessary.

However, systematic research on these effects, especially in tropics and monsoon area, has not been made. It means that large uncertainties are included in determining the model parameter values. A long time will be necessary to clarify these complex mechanisms, therefore at the present stage extensive comparisons of model results should be made and an optimal set of model parameters should be established.

Another important model parameter is the dispersion width. Its value is not written in the report but similar value as that of RAINS-EUROPE is considered to be used in the ATMOS model. That is all right for the value in surface layer and boundary layer. However, uncertainty of the value in upper layer still remains, although it does not seem to affect the model results significantly.

Future developments

After the review of RAINS-ASIA I would like to recommend strongly to take the next step (Phase II) in order that the RAINS-ASIA model is supported by many Asian countries and used both for international negotiation on transboundary pollution and for domestic environmental planning. For these purposes it is necessary to overcome the above-mentioned shortcomings but also to develop the model further.

In order for RAINS-ASIA model to get much more attention from many Asian countries and to motivate them to use for policy making and scientific research, a first complete model validation should be done by international participation. Several working groups (sub-groups) consisting of national participants are recommended to be established under the leadership of the core group. For the ATMOS module the following activities should be done:

a) Model validation by extensive comparisons of model results with observed ones.

Concentrations and depositions of pollutants have a great importance by themselves and have been observed or monitoried in many sites in Asian countries. If the ATMOS module provides those values not only for annual averages but also for hourly, daily, weekly and monthly averages from 1990 to, say, 1993, then extensive comparisons with observed data could be done by national participants. Moreover, if values of model parameters could be changed, then participants could search the optimal set of model parameters and get self-confidence about reliability of the module.

It is also true for emission inventory since many researchers and local governments have already completed emission maps.

For Chinese, Korean and Japanese participants, extension of the model domain to the eastern part of Russia and its emission inventory by the core group should be done.

b) Case study of model application to a certain country and/or mega city.

In order to advocate reliability and usefulness of the module, a working group is recommended to make a case study of the model application to a certain country and/or mega city under the cooperation of the core group.

Future developments of the ATMOS module

Main tasks of the ATMOS module core group will be

a) Coordination of working groups for model validation and case study, and

b) Model developments to incorporate NO_x and nitrate and, if possible, hydrocarbon and ozone, and to treat local pollution in mega cities and industrial complexes.

After the complete equipment of de-sulphur and de-nitrate apparatus in industries and gasoline cars in Japan, the abundant acidic species is now nitrate. It is also anticipated to be true even in the developing countries in the early 21 century. Thus, incorporation of NO_x into the ATMOS module is indispensible for environmental policy making in those countries.

Due to rapid increase of population in mega cities and industrial complexes in developing countries, urban pollution is a great concern. At present a suitable model for urban pollution is urgently needed rather than for regional and transboundary pollution. Thus, as a further development the ATMOS module should be modified to be applicable to local pollution simulation. A nesting module is recommended to be added to the ATMOS module.

In the phase I of the ATMOS module a three-layer Lagrangian parcel model was chosen in order to provide a linear relationship between the source and receptor of sulphur. When nitrate and ozone are cooperated in the module, large non-linearity arises in that relationship and then such a transfer matrix as provided in Phase I lose its significance. At that time parallel use of sophisticated Eulerian model will help to give concrete physical and chemical bases to the ATMOS module.

In order to get general international agreement, continuous monitoring of acid deposition is necessary besides the model development. That should be done in urban and remote areas and not only for pollutants but also for the effects on ecosystems. Results of those efforts, in turn, would reflect to the model developments.

4.4 Effects/critical loads.

(Draft report Chapter 5: "Impact module" J.-P. Hettelingh, M. Chadwick, H. Sverdrup and D. Zhao.)

Comments by Keith Bull:

Objectives of the impacts module

Using appropriate methods and currently available data the module attempts to define the thresholds for acidification damage (the critical loads) for relevant ecosystems across Asia. The scale, while being dependent upon input data, must reflect that used for the pollution transport model, so the final database consists of information collated to grids at that resolution. This database provides a means for mapping sensitivity (the critical loads), identifying exceedances and ecosystems at risk.

Overall impressions

a) The Impact module is clearly based upon the extensive work which has been carried out within the UNECE Convention on Long Range Transboundary Air Pollution over the last 7 years and more. The authors of the module are all leading participants in the UNECE activities and have been responsible for much of the development of methodology for the work towards the development of a second sulphur protocol. The success of their work within the UNECE may be judged by the formulation of the protocol which was tabled for signing in Oslo in June 1994.

b) A point of relevance to the RAINS-ASIA project overall is that the corresponding European model methods were tried and tested within the UNECE and subject to peer review by member states. The European RAINS model itself was compared with other, albeit less user friendly, integrated assessment models in the final stages of the Oslo Protocol deliberations. The agreement between the results obtained from all of the models helped demonstrate the robustness of the approach and acted as validation for the final results. It also is an indication of the quality of the modelling activities in RAINS which are reflected in the work that has been done for RAINS-ASIA.

c) Overall, I am impressed with the work that has been put into developing the Impact module and into preparing the data sets needed for the calculations. I find the module well founded on the best known scientific principles for evaluating wide-scale effects and, I believe, the data used for calculating the critical loads are the best available.

d) However, many of the data sets used lack spatial resolution while, for others, since data are lacking altogether, surrogates have had to be used to estimate the required parameters. This shortfall should be addressed in the future. As with other modules of RAINS-ASIA, there is a need for a clear development plan for the future to improve the data and model calculations.

Strengths and weaknesses

a) The methods developed for critical loads mapping in the UNECE was subject to peer review by member countries and benefitted from contributions from many parties under the LRTAP Convention; the adoption of these methods can be seen as a major strength of the Impact module. However, this could also be seen as a weakness in RAINS-ASIA by Asian countries, since these have not, as yet, been involved in such a review process. As happened for some European countries when the European maps were developed, it may be felt that different national approaches for calculating critical loads are appropriate for some countries in Asia.

b) The methods for presenting data, combining them with pollution deposition data, and calculating ecosystems at risk (using the percentile maps and associated data) were agreed within the UNECE following long discussions and the comparison of various alternative approaches. The Impact module gains strength from adopting this method of using critical loads data.

c) A weakness in the report lies in its failure to exploit the success of the work done within the UNECE. The points made in a) and b) above are important and more reference could be made to the LRTAP convention, the critical loads modelling and mapping activities and the review processes which took place. It may not be necessary to start "from first principles".

d) A weakness of the module as stands at present is that there are virtually no data on ecosystem damage which can be used to validate the critical load and exceedance calculations. However, even a crude identification of possible areas of impacts could and should be used for field studies which might identify such damage; this may be seen as a strength of the first results of the module since the maps appear to be able to differentiate broad areas of sensitivity effectively.

e) The main weakness of the module at present is the quality of data available for the estimates of critical loads and their mapping. Most data are only available at large scale (i.e. low resolution) and many data required are not available at all. For several sets of data, surrogates were employed to estimate values.

f) A weakness of the report lies with the way that it treats uncertainties. While some of the uncertainties are identified by the report and it is clear that the calculation of some parameters has been on a "best attempt" basis, a thorough discussion of many of the uncertainties could be brought together more comprehensively. While estimates of the overall uncertainties in the calculation of critical loads may be difficult, given the problems with estimating uncertainties for some parameters, nevertheless there should be some attempt to do so. In particular, attempts should be made to:

   - identify, perhaps by using sensitivity analysis, the important parameters in the calculation of critical loads; from past experience in Europe using the SSMB, the weathering rate estimate is likely to be of major importance;
   - identify the importance of base cation deposition and the consequences of any errors in its estimation;
   - address the errors arising from digitising and other GIS procedures such as overlaying; it is not clear what the final data for each grid are based upon.

   It should be noted that estimates of errors are particularly important given the poor quality of much of the data used.

g) I believe the report currently suffers from aiming to address more than one audience at the same time, including the "scientists" and the "informed policy maker" and the "energy specialist". The report needs to be restructured to avoid this problem. I would recommend that all technical equations and tables are placed in annexes or in a separate technical document. Annexes or the technical document should be structured with a table of contents similar to the main report. A clear outline of the methods should be given earlier on in the main report and the sections on data, the SSMB and sensitivity mapping reorganised into a logical sequence consistent with the outline. At present, it is not clear how the SSMB and the sensitivity map were used together; where is the comparison and modification mentioned in Fig 6.6.

Future developments

a) It is important to develop national participation to address some of the weaknesses identified above. These activities should be aimed at:

- national data for critical loads mapping;
- national impacts assessment;
- national critical loads methods development.

Note the critical loads approach is an iterative process based upon "best scientific knowledge"; this will change as science and data improve.

b) The central activities of future module development should address the consistency of the data and the methods which might be developed nationally to improve critical loads maps. International "coordination" would play an important role maintaining the quality of the data and maps.

c) Dynamic modelling is mentioned in the report in section 6.1.2. While important, I find it confusing to discuss this methodology here. Given that the method is not yet applicable at an international scale, it would be more appropriate to place this item under "future developments" in the report.

d) Local impacts assessment of, for example, human health effects, may require a different scale of data, a different module approach (eg critical levels of SO_2), and even different atmospheric modelling considerations.

Comments by Sijin Lee:

Objectives

There are several objectives in this module

- To set up the concept of critical loads

- To establish a network of Asian collaboration on environmental impact in general.

- To establish critical-loads for acidity in Asia.

Overall impressions

The RAINS model has been used in Europe since the early 1980s so that it is safe to say that the RAINS model is an internationally well-known model. In other words, this model is a sort of proven-technology to apply in Asia.

This is the first time to examine the effects of acidic deposition in Asia on regional and local basis. The results of this project may help to establish regional environmental collaboration in Asia.

These results may be used as the basis for other regional environmental problems in the future such as "Global warming gas inventory", "Transboundary gas inventory" or others.

This project initiate the first step of a regional analysis of the effects of acidic deposition and will enhance the further studies of the effects of acidic deposition in Asia in the future.

Specific comments

Since this model has three sub-models, RESGEN, ENEM, and DEP-model, each submodel may inherent its uncertainty to the other submodel, there should be an uncertainty analysis to quantify the uncertainty of the results. This will help to have more confidence in the results. The uncertainty analysis could be a Monte Carlo simulation or the First Order Second Moment Analysis. An alternative method of the uncertainty analysis is to show not only the most-likelihood scenario but also the best and worst case scenarios. Then the Asian decision makers may decide whether they want to reduce the damage due to acidic deposition in Asia.

The data used in the model were the best available data set at the time but there are inconsistancies in time. For example, climatic data was from WMO (1981), soil data was derived from FAO (1988), vegetation data was taken from "Major World Ecosystems Map" which was originally produced by ORNL (1982).

The model presents the critical loads on a yearly basis. This will help to predict the long-term effect of acidic deposition. But episodic events are very important to ecosystems in short-term. So that the model need to be modified to check not only the long-term effect but also short-term effect of acidic deposition.

In some parts of Asia, such as Japan and Korea, NO_x is a very important pollutant. It would be very nice to include NO_x in the model.

There should be some explanation how they got daily temperature from mean monthly temperature data.

They reclassified soil texture into 5 types from 3 types. It would be nice to see a little explanation about this method.

Future development

If a second phase of the project will start in the near future, the following items should be included:

- Show not only the regional scale but also local or national scale.

- Use more recent data as input for the model. This may reduce uncertainty of the model output.

- Quantify the uncertainty.

- If possible, it would be interesting to see the effects of the episodic events.

4.5 Relevance and usefulness for policy analyses

Comments by S. Seki:

General Comments

Taking into account the natural, social and economic conditions in Asia, RAINS-ASIA is developed through the modification of RAINS-EUROPE which has been proved potentially useful to promote collaborative efforts against acid rain in Europe under the Convention on Long-Range Transboundary Air Pollution. It may take some time before Asia will introduce common and legally binding measures to tackle acid rain problems because there are big differences in perception and national priorities on acid rain among Asian countries. However, as high economic growth inevitably increases the emission of air pollutants like SO_x and accelerates the acidification of environment in most of Asian countries, policy-makeres in Asia cannot ignore this problem any more. Under these circumstances, RAINS-ASIA is expected at first to clarify policy-maker's concerns on acid rain and urge them to put this issue on their national agenda.

Increasing concerns on acid rain does not necessarily motivate policy-makers to take actions against acid rain because those actions require huge amounts of economic and social costs, and policy-makers are requested to justify them. If RAINS-ASIA can show policy-makers how seriously acid rain affects national environment now and when it will exceed critical level, these output will encourage them to introduce policies and measures against acid rain. RAINS-ASIA will surely help them to find out most appropriate ways. In this regard, RAINS-ASIA has great possibility to serve as a good tool for policy-makers to address acid rain not only nationally but also regionally.

RAINS-ASIA helps the policy-makers in charge of national development to incorporate environment consideration in terms of acid rain into economic, social and industrial development in the early stage of policy formulation. Prevention of acid rain requires that national development should be realized to minimize the emissions of precursors of acid rain especially in the areas where ecosystems are vulnerable to acidification. To this end, it is necessary for policy-makers to know where acid rain affect most, to what extent planned development will increase acid deposition, and how it can be mitigated. RAINS-ASIA is expected to answer these questions. It shows policy-makers appropriate options to be taken as it can provide the integrated assessment of acid rain taking into account the future economic development, energy consumption, emissions, emission control options & technologies, costs, atmospheric dispersion and environmental sensitivities.

RAINS-ASIA also helps the policy-makers in charge of environmental protection to assess in detail the effects of acid rain on national ecosystems and introduce such environmental measures as monitoring and emission control as appropriately as possible. Especially it serves as a good tool to elaborate cost-effective and widely-acceptable measures against acid rain which are essential in most of developing countries.

RAINS-ASIA may be a useful tool to raise public awareness to acid rain because it can provide easy-to-understand output.

RAINS-ASIA may promote regional cooperation to address acid rain problems. As acid rain often occurs far from emission sources, and sometimes is transported beyond national boundaries, it may cause regional disputes. In this sense, acid rain is not purely domestic environmental problems. Although the diplomatic dispute over acid rain will not be raised in near future in Asia, collaborative efforts to this problem is widely recognized necessary. RAINS-ASIA is expected to provide data and information to countries concerned when they initiate policy dialogue on acid rain in regional scale.

RAINS-ASIA is expected to play an important role to make technical and financial assistance more effective and appropriate. When aid-agencies consider assistance to development projects which may emit air pollutants, the prevention of local air pollution and acid rain is one of the major concerns. In this sense, RAINS-ASIA may help assess the impacts of the project and identify an appropriate location and anti-pollution measures of the project.

Specific Comments

Reliablity of calculated acid deposition.

There is rather big discrepancy between calculated acid deposition and observed one. Calculated deposition just explains 30-90% of the observed ones in Japan. It also differs from monitoring results by passive sampler. Thus the reliablity of RAINS-ASIA is not good enough if it should be used as a basis for decision making. Even if calculated deposition does not exactly coincide with observed one, it must be proved that there is correlation to a considerable degree between the two results. In this sense, the model should be further improved in accordance with the accumulation of monitoring data.

Source-receptor relationship

As some countries in Asia have not officially admitted the transboundary movement of pollutants, the country-to-country source-receptor matrix calculated by RAINS-ASIA may induce dispute between countries concerned. In this regard, it should be clearly mentioned that due to the lack of observational results, the verification of RAINS-ASIA is limited so that the output by the model contains at this stage considerable uncertainty.

Integration of NO_x into RAINS-ASIA

Although SO_x is the dominant anthropogenic acid precursor in Asia, increasing emission of NO_x will worsen acid rain in urban areas. For example in Japan where strict emission control has dramatically reduced the SO_x emission from stationary sources, nitrate reaches half of sulfate in precipitation. To make RAINS-ASIA more useful, the model should be expanded to include nitrogen-induced acid rain. For this purpose the emission factors appropriate for Asia should be developed to accurately estimate the NO_x emission from facilities.

Critical load approach

The effect of acid rain on ecosystems has yet to be clearly determined in Asia despite the observed acidity in precipitation. This is one of the reasons why acid rain has rather low priority for taking actions in most Asian countries. If the threshold value to induce ecological damage becomes clear, things will change. The critical load approach may help determine it. For that purpose, the critical load must be justified not only scientifically but politically too. For example, it is at least necessary to prove by case studies that ecological damage really exists in the areas where acid deposition has exceeded the critical load for a long time before the critical load will become a common target to control acid rain in Asia.

Recommendations

Linkage between acid rain and local air pollution.

If RAINS-ASIA can also serve as a potential tool for local air pollution, it will surely become more attractive to and widely used by all policy-makers in Asia. Most countries in this region except Japan face worsening air pollution which often exceeds levels tolerable to protect human health. Higher priority is usually placed on local air pollution than on acid rain. The measures to reduce emissions from sources help mitigate not only acid rain but local air pollution alike. In this sense, RAINS-ASIA can contribute to both ends. However, as far as air pollution is concerned, local conditions such as weather and geography play an important role to disperse the pollutants. Then high stack sometimes improves the air quality in ground level to som degree, which on the contrary may intensify acid rain. It is recommended that RAINS-ASIA should be expanded to deal with acid rain and local air pollution at the same time.

Collaboration with national and regional initiatives for monitoring acid rain.

To make RAINS-ASIA more reliable, it is recommended that collaboration with national and regional initiatives for monitoring acid rain should be further strengthened in order to promote verification of the model. Collaborative efforts have recently been made to improve the monitoring of acid rain in Asia. For example, the Environment Agency of Japan initiated the expert meeting in 1993 aiming at the establishment of acid rain monitoring network in East Asia. At the second meeting in March 1995, the Guidelines for Monitoring Acid Deposition in the East Asia Region were adopted.

Training seminar for RAINS-ASIA

To make RAINS-ASIA well known and utilized, it is recommended that training seminars should be planned and implemented, if possible, in each country in Asia.

Comments by K.C. Moon:

Purpose

This summary reviews the effectiveness of the RAINS-ASIA Model as a tool to develop methods to minimize damage from acid rain and future developments. This review is written with the needs of policy makers in mind.

Comments

The RAINS-ASIA model har been well received by modellers, particularly in its suitability for field applications, and should allow developing countries to use model scenarios to assess and reduce environmental damage from pollutants. However, more work is needed before the model's potential is fully realized. The main points to be addressed for second phase development are now discussed.

- While the RAINS-ASIA model is fairly well developed, its reliability is at present uncertain; for example, it needs to be capable of prediction as well as representing observations. Asia has unique criteria and the programme needs to be custom designed to address specific environmental problems. The programmer will need to know and take into account the individual needs of Asia and Europe - the aim would be to understand these different problems and to provide unique solutions in each case.

- The model is designed to handle situations on large scales rather than small scales. Nevertheless, it may be possible to adapt the model for use on sub-regional or even micro-scales. Sub-regional scales would be necessary to assess the impact in the Pacific rim area (e.g., China, Japan, South and North Korea), as well as for the northeast Asian countries. A possible way to adapt the model to run on these smaller scales is to improve its horizontal resolution; that is, by changing the grid size from 1 x 1 degrees to 0.5 x 0.5 degrees or less. However, to make this feasible, more information is needed to provide detailed input about pollution sources, which will require more detailed input data on power plants, industry and transportation. The contribution from each source category varies from one country to another, e.g., Korea has less than 20% of SO_2 emission from power plants.

- The RAINS-ASIA model should also be developed for other pollutants, for example NO_x and fine particles. Developed countries would find this useful because they may have less problems from SO_2 but more from NO_x.

- Further development of the model should be made in cooperation with other programmes. Japan is working on a monitoring network which will work at the sub-regional level. Korea is working with other countries on a programme to study the effects of long-range transport of pollutants.

- An important issue for the success of RAINS-ASIA is the validation and updating of input data. So far, these requirements are lagging behind in this programme. Pacific Asian countries are developing faster than expected, so older data are not useful for the applications described above. For example, the change in the exceedance number of the SO_2 one hour standard (250 ppb) has fallen from 936 cases in 1991 to none in 1993.

- Implementations and enforcement of restrictions for other countries transporting pollutants over their boundaries should be undertaken by the UN or other international organizations. Such plans should reflect the cost benefits for each country, since they are all developing at a faster speed than developed countries. In developing countries, the cost of implementation may be higher than in developing countries because of the need to provide more infrastructure. At present, such cost calculations are based on the needs of developed countries. Cost calculations should be evaluated by the individual countries.

- Policy makers will make use of cost benefit analyses, because economic aspects are given high priority in Asian countries while the concept of sustainable development is less developed. Education and public awareness should be included in a second phase of the project. The model can be improved by stronger involvement of the individual countries.

Summary

The RAINS-ASIA model is a useful tool for future prediction and minimization of damage from acid rain and other environmental pollutants. Policy makers should review individual member states input data and social acceptance levels. The second phase of the project needs to have continuously updated input data and validation procedures. In the assessment of the criteria for this project, policy makers must consider environmental technology transfer and education as well as economic viability.

5. Responses from the project team

The draft report from the review team has been presented to the project team. The response from the project team on how the comments will be taken into account in the final project report and/or in future publications are reproduced here:

Chapter 3: Energy

Overall, the comments from the two reviewers of the Energy chapter were very useful in revising the chapter for a Final Report to the World Bank and in preparing for other future publications. The reviewers' comments addressed both the technical and institutional aspects of the work. Where feasible within the time and resource constraints, the technical suggestions were addressed in detail in revising this chapter; the institutional suggestions will be valuable in designing and implementing Phase II of this project.

Some of the comments resulted from inadequate explanations in the text, leading to a misunderstanding; these were clarified in the revised chapter. For example, it was made clear that it was not possible to use UN population and economic projections since they do not exist on a 94-region basis. The role of the ECON work was also clarified, in providing a macroeconomic analysis for energy efficiency opportunities in selected countries, to complement the technical bottom-up scenarios.

Significant revisions were made to clarify the specific outputs of RESGEN, as they provide inputs into RAINS, i.e., the distinction between RESGEN and ENEM.

Several useful review comments were made on the need to incorporate more local in-country expertise into data base development and anlysis, resulting in increased national capacity building. Although major efforts were devoted to this in Phase I, they were clearly limited by available financial resources. Significant resources will be devoted to this in Phase II; high priority will be given to developing regional and national capabilities in use of the module.

Chapter 4: Emissions and Abatement Costs

In response to the review comments, Chapter 4 was significantly revised to remove some of the inconsistencies resulting from multiple authorship. In addition, considerable effort was devoted to better distinguishing the relationships and structures in RESGEN and ENEM, respectively. This including an improvement in the nomenclature describing the two modules.

Perhaps most importantly, the writing was modified to more clearly distinguish between the various databases used. In particular a distinction was made between the "gridded emissions inventory" and the "1990 base year data".

Chapter 5: ATMOS

The peer review of the ATMOS model provided a thorough look at the model formulation and results to-date. The reviewer's comments addressed model strengths and shortcomings, the report structure and editorial comments, and suggested future directions of study. Their comments were perceptive and extremely helpful. We took their comments into account in the writing of the final report.

The reviewers identified many of the challenges that modelers face when attempting to model long range transport of sulfur in such a broad domain as that used in this project. Model formulation, and the input data, and parametes used are all uncertain, and each component requires further fundamental study. In addition, the reviewers identified the need to include the emissions from eastern Russia in the model study since they can impact deposition in China and Japan. This was outside of the phase-I scope of study, but will be included in the sulfur deposition calculations in the future. The need for multi-years of simulation for the source-receptor relations and the need for a rigorous monitoring program and model evaluation follow on study. Finally, the need for the development of more Asia-specific parameterizations of dispersion, chemical conversion and wet removal were discussed, and are essential to improve the model robustness and accuracy of the model. They suggested a series of actions to facilitate this including case studies and the establishment of additional working groups. These ideas are being incorporated into the plans for the next phase of study.

Chapter 7: Scenarios and Results

The reviewers provided a broad range of useful and perceptive comments, including statements about the integration process, the linkages, scenario results, and future uses. Where feasible these general comments were incorporated explicitly into the text and into the interpretation of the results. They have also been taken into account in the development of plans for Phase II. One misunderstanding by the reviewers should be noted. The module does, in fact, explicitly provide output of the total emissions, as well as area and LPS emissions, respectively.

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ABSTRACT

The RAINS-ASIA model has been developed to assist decision-makers analyse future trends in emissions, estimate regional impacts of acid deposition and to evaluate costs and effectiveness of alternative control measures. The model has been reviewed by a team of scientists with long experience in one or more of the relevant disiplines. The main conclusion of the review is that RAINS-ASIA has been based on sound technical and scientific judgement and offers a useful tool for policy analysis.

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ABSTRACT (in Norwegian)

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