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ATMOSPHERIC CHANGE IN CANADA: ASSESSING THE WHOLE AS WELL AS THE PARTS

Summary Report of a Workshop

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FOREWORD

A Workshop on the subject: **Atmospheric Change in Canada: Assessing the Whole as Well as the Parts** was held in Toronto March 27-29, 1995, hosted by the Institute for Environmental Studies (IES), University of Toronto. This report contains a summary of that meeting (including the three Working Group reports and a summary of the papers presented). A full version of the Workshop proceedings will be published by Kluwer Academic Publishers in 1996 as a special issue of the journal "Environmental Monitoring and Assessment" and as IES Environmental Monograph No. 12.

The Institute is grateful to the Atmospheric Environment Service (AES) and the Environmental Conservation Service (ECS) of Environment Canada that sponsored the project. Special thanks should be given to the following representatives of the sponsoring organizations who acted as a Steering Committee:

Ian Burton, Environmental Adaptation Research Group, AES; **Adam Fenech**, Ecological Monitoring Coordinating Office, ECS; **Abdel Maarouf**, Environmental Adaptation Research Group, AES; **Don MacIver**, Science Assessment & Policy Integration Division, AES; **Ted Munn**, Institute for Environmental Studies; Keith **Puckett**, Science Assessment & Policy Integration Division, AES; **Peter Timmerman**, Institute for Environmental Studies; **Doug Whelpdale**, Climate & Atmospheric Research Directorate, AES; **Rodney White**, Institute for Environmental Studies.

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R E Munn

R.E. Munn, Editor

EXECUTIVE SUMMARY

Over the past decade there has been increasing interest in methodologies for undertaking **integrated environmental assessments** with respect to single issues such as acidic deposition and climate warming. The word "assessment" implies an activity that is at the interface between science and policy; it is different from, and does not replace scientific research. Assessment is difficult, and the difficulty should not be disguised when one tries to reconcile scientific uncertainties with requests from policy-makers for firm answers.

In Toronto March 27-29, 1995, a Workshop was held on this general topic, the goal being to extend current knowledge and practice on single-issue environmental assessments to multi-issue ones. The Workshop was titled: **Atmospheric Change in Canada: Assessing the Whole as Well as the Parts,** the idea being to look at methods of examining a suite of inter-related issues: how would a proposed policy to reduce acidic deposition, for example, affect the frequency of tropospheric ozone episodes or the rate of climate change? Specifically, the primary goal of the Workshop was to examine methods that might be used to undertake integrated assessments of a selected number of atmospheric issues - acidic deposition; global warming; stratospheric ozone depletion; tropospheric ozone episodes; hazardous air pollutants; and suspended particulate matter. This Report provides a flavour of the Proceedings, which are to be published in 1996.

There was consensus that the underlying framework for multi-issue assessments was to be found in **the ecosystem approach,** which has proved to be successful in Great Lakes and other environmental assessments. This framework provides a long-term time perspective in which externalities may change, and it includes people, political boundaries and landscape modifications.

Within the ecosystem framework, a number of analytical methods were examined, including biogeochemical cycle models, dose-response/stress-response models, the ecological systems approach, risk assessment, the no-regrets principle, ecological economics/the precautionary principle, and cumulative environmental assessment. The Workshop participants felt that many of these methods might be useful (in somewhat modified form) in multi-issue assessments but that all of them required testing in specific settings, e.g., Southwestern Ontario or the Lower Fraser River Valley.

Participants were optimistic that a multi-issue integrated environmental assessment framework was possible, and suggested that an optimal approach might be a combined one in which several methods were used.

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Chapter 1: PURPOSE OF THE WORKSHOP*

There is a cluster of atmospheric environmental issues, each with its own constituency, methodologies and recommended abatement/adaptation policies. These issues include:

- acidic deposition
- climate change (global warming)
- stratospheric ozone depletion (leading to UV-B increases)
- smog (tropospheric SO_x, NO_x, VOCs; trophospheric ozone episodes)
- hazardous air pollutants (pesticides, radionuclides, etc.)
- suspended particulate matter (heavy metals, sulphates, nitrates, etc.)

To a large extent, scientists and policy analysts have addressed each of these issues separately, the net result being that although a policy may be optimal for a single issue, it is often not optimal for the range of issues, and in some cases it may have some negative consequences.

Yet it is increasingly recognized that these six issues are inter-related, and attempts to resolve them individually may lead in some cases to conflicting policies and regulatory actions. For example, sulphate aerosols cause acidic deposition while at the same time absorbing and scattering solar radiation, thus off-setting global change. Similarly, catalytic automobile converters reduce emissions of tropospheric ozone pre-cursors (NO_x and VOC) but release N_2O, a greenhouse gas. The need to understand the scientific commonalities and linkages amongst these issues and their integrated effects on the biosphere and society is of major importance.

A few studies have attempted to understand the most important interactions amongst various combinations of air issues, particularly with respect to their integrated effects on the biosphere and human systems, and on the consequences that these may have with respect to across-the-board policies. See, for example, J.C. White (ed.) (1989) *Global Climate Change Linkages: Acid Rain, Air Quality and Stratospheric Ozone*, Elsevier, 262 pp.; and S.V. Krupa and R.N. Kickert (1989) *The greenhouse effect: impacts of UV-B, CO_2 and O_3 on vegetation*, Env. Poll. 61, 263-393. This Workshop built on those publications, focusing specifically on:

1. The six air issues listed above;
2. The Canadian point of view on the six issues, especially where environmental policy formulation in Canada contains special attributes.
3. The sequence leading from trace-gas emissions to the atmosphere; through atmospheric processes and ultimate deposition at the Earth's surface or loss in the stratosphere; through impacts to the biosphere and to socioeconomic systems; to policies designed to resolve each issue. See the box below for a schematic representation;

	Acid deposit.	Climate change	Strat. O_3 depletion	Smog	Haz. poll.	TSP
Emissions						
Atmosph. processes						
Impacts						
Policies						

This box of course conceals various conceptual and practical difficulties and complexities, which include:

1. In some cases, specific regions are responsible for their own air quality (e.g., smog in the Greater Vancouver region) while in other cases, Canada is only a player in a global issue (e.g., climate change). How can comparisons be made in such cases?

2. In many cases too, differing perceptions of the risks involved may lead to conflicting priorities across the array of air issues.

**Contributed by R.E. Munn*

3. The time scales of the various issues may be substantially different, as may be uncertainties and the magnitude of the risks involved.

4. The costs involved in undertaking additional scientific research, in establishing early warning monitoring systems and in controlling emissions directly through regulations or indirectly through the promotion of new technologies or changes in social behaviour differ greatly from issue to issue, and are difficult to compare by any standard yardstick.

The Workshop began with some "keynote" addresses (see Appendix "A"). Participants then joined one of three Working Groups, which first considered several possible approaches to dealing with the integration of the six air issues. These included *biogeochemical cycles, dose-response relations, the ecosystem approach, comparative risk assessment, the "no-regrets" approach*, and *ecological economics*. These have been called analytical approaches, which open up "multiple policy options" for "multiple response strategies". The strengths and weaknesses of such strategies were considered, the goal being to develop practical compromises.

Workshop participants then considered a number of theoretical and practical questions:

1. Is an integrated scientific methodology across the six air issues possible for the formulation of policy, and, if so, how would we do it?

2. Is an integrated policy framework in fact possible, uniting and rationalizing the six air issues and, if so, how would it be achieved?

3. Which of the current or proposed strategic approaches would be most useful?

The primary goal of the Workshop was to seek ways of moving from end-of-pipe regulatory approaches, treating each air issue separately, to policies based on integrated assessments of the whole range of atmospheric issues.

Chapter 2: ANALYTICAL METHODS AVAILABLE FOR UNDERTAKING MULTI-ISSUE ATMOSPHERIC ASSESSMENTS*

2.1 Introduction

In this Chapter, we discuss a range of analytical methods that may be useful in multi-issue integrated assessments. Some of these methods have never been applied in this way, and are presented here only as suggestions. Also, we must emphasize that the several methods to be described below have been listed separately mostly for convenience. In fact, they are methodologically inter-related.

> **THE "STOVE-PIPE" ANALOGY**
>
> Each of the six air issues is currently assessed by a cluster of natural scientists, modellers, economists and policy analysts - each cluster residing, so to speak, in its own "stove pipe". But there is little interaction amongst the six clusters, which means that optimal strategies for dealing with a particular issue may not be optimal for the whole.
>
> *Workshop participant*

There has been considerable progress over the last two decades in methods of integrated assessments of a single air issue. The European acidic deposition RAINS model (Alcamo et al., 1990), for example, permits one to explore regional acidic deposition resulting from a multitude of SO_x and NO_x sources, with differing effects on different receptors (water bodies, forests, agricultural crops, etc.) over a range of control strategies. With RAINS, one could design strategies that would minimize either costs or actual amounts of pollutants required to achieve some given "target loadings" in a specific part of Europe (Shaw, 1989). Similarly, climate change models when linked with biospheric models allow assessments of the effects of greenhouse warming on a range of receptors.

The idea of multi-issue assessments has only recently been explored, although scientists have recognized for some time that policies designed to resolve a specific air issue may have either detrimental or beneficial effects with respect to some of the other five issues. For example, if a proposed replacement for CFCs is a greenhouse gas, a joint assessment should be undertaken of the effect on both stratospheric ozone depletion and climate change. An early discussion of multi-issue integrated assessments is to be found in the Proceedings of a Conference on Global Climate Change Linkages with Acid Rain, Air Quality and Stratospheric Ozone (White, 1989) and even earlier in an assessment of the interactions amongst the major biogeochemical cycles (SCOPE, 21, 1983).

> **ELECTRIC CARS**
>
> Environmental benefit: Zero emissions of pollutants at point of use.
>
> Environmental dis-benefits:
> (1) Increased emissions of pollutants from fossil fuel power stations;
> (2) Increased emissions of lead from smelting and re-processing of lead-acid batteries.
>
> According to Lave et al. (1995), an electric car is estimated to result in the release of 60 times more lead per kilometer of use than a car using leaded gasoline.

This Chapter is based on the Workshop lecture given by R.E. Munn but benefits from the discussions that took place within the three Working Groups, and afterwards. In particular, the "ecosystem approach", as the phrase is used by H. Regier, G. Francis and colleagues, is elevated from a method in the original prospectus for the Workshop to an overall "framework" within which all multi-issue assessments should be undertaken. The Rapporteur of Working Group II has emphasized that there are in fact three meanings of the phrase "the ecosystem approach", and this has led to some confusion, especially amongst ecologists. Another example of a phrase that means different things to different people is "dose-response" (see report of Working Group I). These conceptual difficulties that arose during the Workshop are partly due to the fact that participants came from widely different scientific backgrounds and disciplines. As Ted Elliott commented: "This is the first Workshop that I have ever attended, knowing absolutely no-one!"

**Contributed by R.E. Munn*

Finally, an additional method, "cumulative environmental assessment", has been added. This was not discussed within the Working Group sessions but was advanced as a possible seventh method during the final plenary session of the Workshop.

2.2 The Ecosystem Approach: A Framework for Multi-Issue Assessments

As used by some ecologists and agencies, the "ecosystem approach" is an holistic "approach" to environmental management of large complex systems such as the Great Lakes (e.g. Edwards and Regier, 1990; Allen et al., 1993) and the Metropolitan Toronto Waterfront. [In the latter case, for example, the ecosystem approach requires that the entire watershed north to the Oak Ridge moraine must be included in the field of study.] This definition of "the ecosystem approach" is equivalent to definition (3) (The Emergence of a Cultural Regime) in the Report of Working Group II (Section 4.2). When the phrase is used in this way, the ecosystem approach implies the following:

- It is in the context of renewable resource management.
- It refers to the long term (decades to centuries), thus recognizing that externalities will change.
- It includes people, with differing views and priorities, who are often organized into what are commonly called "stakeholder groups."
- It includes many landscape modifications that have been made over the centuries (towns, factories, agricultural fields, roads, etc.)
- It may include several political jurisdictions, which must be factored into the assessment. (For example, the Great Lakes basin includes two countries, several States and two Provinces.)

As the time scale of relevance for environmental management extends farther and farther into the future, uncertainty in the projections increases. This is more of a problem than ever before because "global change" and consequently regional and local change, are likely to be unprecedented by the middle of the 21st century. As a consequence, the case for adopting the ecosystem approach becomes overwhelming. This also means that four of the analytical methods become exceptionally important because of their relevance to non-steady-state conditions:

- Non-equilibrium "self-organizing" ecological systems (see Section 2.5);
- Comparative risk assessments (see Section 2.6);
- Ecological economics and the precautionary principle (see Section 2.8);
- Cumulative environmental assessment (see Section 2.9).

2.3 Method No. 1: Biogeochemical Cycle Models

As emphasized in a joint statement by UNEP and SCOPE in 1979 (Tolba and White, 1979), the biogeochemical cycling of trace substances is the life-support system of Planet Earth. These cycles are inextricably linked with one another, and disturbances (particularly in the carbon and nitrogen cycles) lead to a range of diverse problems such as stratospheric ozone depletion, climate change, tropospheric ozone, acid rain and soil impoverishment. In principle, models of the biogeochemical cycles should provide a tool for exploring multi-issue relationships, and these should be useful in policy analysis.

A biogeochemical cycle model in its simplest form is a series of boxes, one for each compartment of the environment (e.g., atmosphere, ocean, land biosphere, etc.). As an example, see Figure 4-1 in the Report of Working Group I. Over decades, the amounts in each box may change due to human disturbances (continuing use of fossil fuels; a warmer earth affecting land and ocean biosphere sources and sinks of the substances being investigated). Biogeochemical cycle models can become very complex if non-linearities and feedbacks are included.

An important practical use of biogeochemical cycle models is in the determination of critical points in the system where better scientific understanding is most important with respect to subsequent policy analysis. Biogeochemical cycle models therefore have the possibility of being extremely valuable as drivers of research and monitoring agendas.

Recent attempts to use a biogeochemical cycle model to explore multi-issue relationships include:

1. Krupa and Kickert's (1989) conceptualization of the interactive impacts of UV-B CO_2 and ozone on vegetation;

2. Hordijk's extension of RAINS to evaluate the effects of various emission control strategies on tropospheric ozone (Hordijk, 1995);

3. Alcamo's extension of IMAGE to evaluate the effects of various greenhouse gas reduction strategies on tropospheric ozone (Alcamo et al., 1994).

2.4 Method No. 2: Dose-Response/Stress-Response Models

As suggested by its name, and as in the field of medicine, a **dose-response model** relates the system uptake of a harmful substance (dose) to the response of the system. However, the term is often broadened to include other kinds of stress (e.g., heat, loss of wetlands, overharvesting) that elicit a response by the system. In that case, the phrase "stress-response" is used (Rapport, 1983).

One case of a dose-response model that has received wide acceptance is found in the radiological health field. Because decay rates of radionuclides are well known, and there are no chemical transformations, the movement of radionuclides up food chains/food webs can be studied in relatively simple ways, and the impacts on large populations can be assessed (using the concepts of **dose-commitment** and **harm-commitment**). The 5-yearly assessments of UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) are based on these ideas, and are universally accepted. Extension of this approach to relatively inert substances such as cadmium has been attempted.

Most substances, however, undergo chemical transformations, and their uptake by biological systems (and resulting impacts) varies widely. In cases such as the deposition of sulphates and nitrates into a lake, the impacts may be indirect, i.e., the buffering capacity of the lake may be lowered by the long-term deposition of acidic particles, and toxic substances such as mercury may be mobilized from the sediments. In cases in which substances such as PCBs or mercury begin to vaporize at room temperature, they will tend to move towards the arctic on warm summer days, contributing to a long-term buildup in the far north (Wania and Mackay, 1993). For these reasons, most dose-response relations are founded on laboratory or epidemiological evidence; and it is difficult to extrapolate the results to other conditions.

In principle, it should be possible to hook together a biogeochemical cycle model and a dose-response model. In practice, there are problems associated with this kind of approach, one being the empiricism associated with most dose-response curves. Working Group II therefore suggested that the stress-response analogy might be more useful, where the stresses of particular interest might be large scale and long term, including demographic and socioeconomic ones. Figure 2.1, for example, shows the astounding growth of motor vehicle registrations in Ontario over the last 90 years. This rise in the population of automobiles is a major environmental stressor, contributing to several of the six air issues mentioned in Chapter 1.

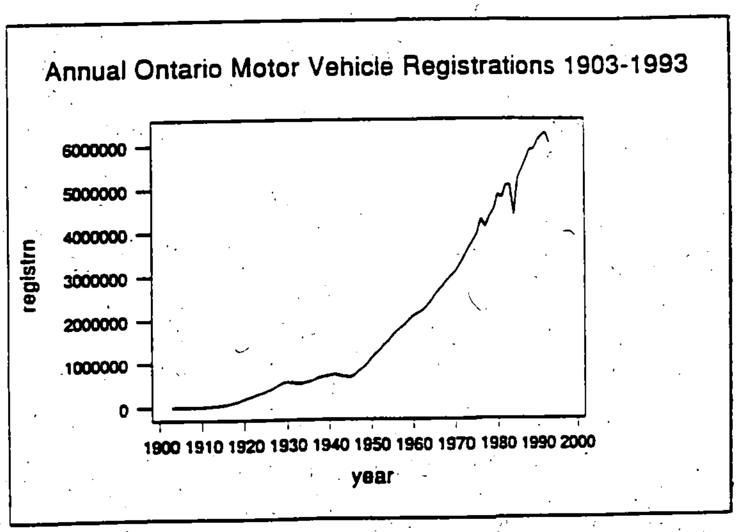

Figure 2.1: Annual Ontario motor vehicle registrations 1903-93 (from P.C. Ginn, ON. Min. of Transportation, Chatham, ON.).

ANOTHER EXAMPLE: THE EXPECTED GROWTH IN NUMBERS OF MOTOR VEHICLES IN CHINA...
(from *The Times*, U.K., April 3, 1995)

The Chinese government is planning to build 22,000 miles of motorway by year 2020. The network will consist of a grid of 12 dual motorways. There are currently only three million drivers in China but car ownership is growing at a rate of 15% per year.

2.5 Method No. 3: The Systems Approach to Ecosystems

Even if the meaning of the expression "The Ecosystem Approach" is limited to the holistic management approach given in Subsection 2.2, there is still room for another kind of ecological approach to multi-issue assessments - the so-called "systems approach", which can be subdivided as follows:

(a) Equilibrium Ecological Systems

Biogeochemical cycle models (which deal with amounts of trace substances in compartments, and fluxes between compartments) can be broadened to include effects on organisms and whole ecosystems. RAINS partially bridges the gap while the Colorado State University ecological system model *CENTURY* (Elliott, 1995; Parton et al., 1987) goes the whole way. Dose-response and stress-response relations may be included in ecological systems models. Provided that environmental externalities do not change too rapidly or drastically, equilibrium systems models are useful for exploring the responses of ecosystems to stresses beyond the range of historical experience.

(b) Non-equilibrium Ecological Systems

The system approach described above works well when applied in steady state situations to well-behaved ecosystems, and when model predictions can be tested with field data. However, considerable interest has emerged in the last decade in non-equilibrium systems whose behaviour is often not predictable. Originating in the work of Prigogene in the 1950s (Nicolis and Prigogene, 1989), the theory posits that ecosystems have a self-organizing ability that permits them to reorganize whenever confronted with a major new stress. Ecosystems therefore have a considerable (but not unlimited) ability to maintain their integrity in a changing environment. In this context, the word **development** in the phrase **sustainable development** means **evolution**. [This approach corresponds to the second definition of the ecosystem approach (Analysis of Complex Systems) given by Working Group II (Section 4.2)].

Because multi-issue assessments are difficult enough when the ecosystems involved are well behaved, the basic ideas of non-equilibrium and self-preserving systems tend to be treated within the framework of precautionary measures that should be taken to avoid ecosystem collapse. Viewed in this way, human endeavours directed towards maintaining a system in its present state when the environment is likely to change substantially is a recipe for disaster.

2.6 Method No. 4: Comparative Risk Assessments

Assuming steady-state conditions, historical time series provide a good basis for forward planning. In water resource management, for example, this principle is applied through the use of "return periods". Risk assessment is widely practiced in epidemiology, toxicology, hail insurance and other fields that involve rare but potentially hazardous events.

But the future will not be the same as the past, and mean values and variances of environmental quantities are likely to change at unprecedented rates in the next century. How does one undertake risk assessments under such conditions? One possibility that has been discussed is through the use of large simulation models, although many of these models are so complex that it is difficult to assess their uncertainty. Most of the current "big" models, in fact, give only maximum likelihood estimates (of climate change, strength of the Antarctic ozone hole, change in the buffering capacity of a lake) and do not provide 95 or 99 percentile uncertainty ranges. Working Group II discussed this issue.

2.7 Method No. 5: The No-Regrets Principle

Then "no-regrets policy" is a term that has been used in the climate-change debate, indicating a policy in which a reduction in greenhouse gases can be justified on other grounds (Tolba et al., 1992). See following box.

EXAMPLES OF "NO-REGRETS" CLIMATE-CHANGE POLICIES

Policy	**Effect on greenhouse gases**	**Other beneficial effects**
Tree planting	Reduced CO_2 concentrations	- Improved microclimate - Reduced soil erosion - Reduced seasonal peak river flows
Energy conservation	Reduced CO_2 emissions	Conservation of non-renewable resources for future generations
Energy efficiency	Reduced CO_2 emissions	Conservation of non-renewable resources for future generations
CFC emission control	Reduced CFC emissions	- Reduced stratospheric ozone depletion - Reduced surface UV-B, skin cancer and blindness

BOX 7, pg. 77 in "The World Environment: 1972-1992", UNEP/Chapman and Hall, London

Working Group III had some misgivings about the term "no regrets". There would certainly be regrets by some people about whatever was done (e.g. regrets about the money spent, which might have gone towards solving some non-environmental issues). Also if there were "no regrets", why hadn't the proposal already been implemented? Nevertheless in the context of multi-issue assessments, there seems to be value in expanding the approach to display the linkages amongst all six air issues, in terms of negative, positive and nil responses:

1. Issue-by-issue, what are the current and long-term effects of the atmospheric disfunctioning caused by that issue, on each of the other air issues? For example, Dillon et al. (1995) suggest that if long-term climate change were to alter the frequency or magnitude of El Niño-induced droughts in North America, the recovery of acidified lakes would be slowed down. As another example, Curtis and Schindler (1995) have noted that because the concentration of dissolved organic matter decreases in acidifying lakes, there is greater penetration of UV-B radiation into these lakes, increasing the risk of damaging aquatic organisms. This risk will increase if stratospheric ozone continues to decline.

2. Issue-by-issue, what would be the effect of each proposed strategy/policy designed to ameliorate the impacts of a single issue on the other air issues?

These displays would provide a way of organizing a mass of scientific results and would be a first step in building multi-issue models. In the early stages of understanding complex environmental phenomena, relatively simple models are much more useful for policy analyses than are intricate non-linear ones (Holling, 1978; SCOPE 5, 1979, Appendix 5).

2.8 Method No. 6: Ecological Economics and the Precautionary Principle

A distinction should be noted between **ecological economics** and **environmental economics/resource economics**. The latter employ cost-benefit and cost-effectiveness analyses, a well-known historical example being comparisons of the savings that would ensue if air pollution levels were reduced (e.g., decrease in dry-cleaning and painting costs, rise in property values and crop yields, and decrease in hospital admittances) vs. the costs of emission controls. These "classical" methods are, in general, incapable of handling changes in environmental externalities. Whenever projections into the next century are made, the future is heavily discounted.

Ecological economics, on the other hand, has the following characteristics:

- It links ecology and economics.
- Because ecological time scales run from decades to centuries, economics is viewed from this long-term perspective also.
- Ecological economics is related to sustainable development, linking ecological sustainability to economic sustainability. Thus, for example, an increase in national wealth as a result of stripping of valuable forest land should not be included in GNP.

- Ecological economics makes use of the precautionary principle, although no guidance is given as to what precautionary measures should be taken, and as to who should pay for them.
- A goal of ecological economics "is to estimate the long-term social and ecological costs and benefits of various human activities" (Costanza and Cornwell, 1992).

As a comparative example, consider the greenhouse warming of climate:

(a) Approaching this issue from the standpoint of environmental economics, one would work out the cash values of losses and gains in food production, forest yields, health effects, etc. and compare the total with the cost of reducing emissions of greenhouse gases. This kind of assessment would undoubtedly indicate that the cost of controlling emissions would far exceed the economic losses in the resource sector in the absence of controls.

(b) Because the ultimate goal in ecological economics is to ensure sustainability of both ecological and socioeconomic systems, the assessment has to be approached from an entirely different perspective, and it is no longer self-evident that the cost of control would exceed the economic losses in the renewable resource sector.

Is ecological economics a useful tool in multi-issue atmospheric assessments? That is a question that must remain open until some real cases are worked out. Clearly economics is a consideration in the search for ecological sustainability, and in the more limited goal of resolving the six air issues. Society cannot return to the Garden of Eden with no concern for gainful employment, for example.

Atmospheric scientists and ecologists have little training in economics. But because economic questions are so important in multi-issue assessments, efforts must be made to involve economists in these matters.

2.9 Method No. 7: Cumulative Environmental Assessment (CEA)

A **cumulative** environmental impact is the impact on the environment which results from the incremental impact of an action when added to other past, present and reasonably foreseeable future actions, no matter what person or body undertakes such actions. Over the last decade, CEA has become a requirement within environmental impact assessments in Canada and some other jurisdictions although the development of appropriate methodologies to carry out CEAs has lagged behind.

When long-term global change is included as one of the causes of incremental change, a recommended underpinning for a CEA is the inclusion of adaptive strategies, i.e., the assessment becomes a continuing process, with periodic policy updates (Munn, 1994). Recognizing that the future is uncertain, the assessment should include a range of future "scenarios", and the consequences of each should be examined - the goal being to select policy options that would be acceptable over a range of possible futures.

In the context of multi-issue atmospheric assessments, the CEA approach might have some merit, but again, some practical case studies should be undertaken. One approach would be:

(a) to select some socioeconomic scenarios for the year 2025, say, and to examine the consequences for the six air issues; (These would be called the "base" scenarios.)
(b) for each air issue separately, to test the effects of policies/strategies (designed to resolve that issue) on the other five air issues.

In order to provide quantitative answers to various "what-if" questions, a variety of system support tools would be required, e.g., simulation models, historical data banks, the qualitative display tables mentioned in Section 2.7, etc. This approach is therefore very human-resource intensive.

2.10 Concluding Remarks

The seven analytical approaches discussed above are merely tools. They provide stakeholders with decision support systems that help them explore the consequences in a multi-issue context, of various policies and strategies that might be employed. Some of the methods can be taken off the shelf for immediate use, e.g., biogeochemical cycle models, while others require practical testing in specific situations. But as a general conclusion, Workshop participants were optimistic that a start could be made in the elaboration of multi-issue assessments, and they proposed that the recommendations given in Chapter 5 be implemented immediately. When the invited and contributed papers for the Workshop Proceedings become available, it will be possible to make more precise recommendations on how to undertake these assessments.

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Chapter 3: OVERVIEW OF THE WORKSHOP*

3.1 Introduction

The Workshop was in many ways exemplary of the difficulties and opportunities presented by trying to bring together a diversity of disciplines and concerns to examine atmospheric issues. Not only were there language and concept differences between the natural and the social scientists, but there were also quite different ways of thinking among disciplinary colleagues, for example, ecologists working in different types of ecosystems. From the earliest planning stages, the convenors of the Workshop were conscious that they were engaged in a complex task, but that the potential rewards could outweigh the risks involved.

The driving force behind the deliberations at the Workshop (both the formal presentations and the Working Group discussions) was the recognition that we have entered a new phase of policy formulation with regard to atmospheric issues, and, for reasons set out in more detail below, the Atmospheric Environment Service in alliance with its formal and informal partners in the larger community needed to explore the current situation more deeply.

This new phase depends, first, on the realization that the atmosphere is no longer completely external to human decision-making processes - it is no longer "outside"; rather, it is now affected by human activities. It has also brought about a situation where the "emitters and those impacted" can often be one and the same (see report of Working Group III for further discussion). This, for better or worse, politicizes atmospheric issues, and often requires new kinds of defenses for what used to be pure scientific research into natural processes. It was further suggested by a number of participants during the Workshop that new rationales are needed to explain the array of strategies being deployed across the range of atmospheric issues; and one of these rationales may be "multi-issue assessments". We not only want to make sure that curing one problem does not create two more, but also that there is an often unspoken vision of a holistic approach to solving air issues. It was one of the objectives of the Workshop to see if looking at the whole as well as the parts would be both conductive to better science and to better policies.

3.2 Workshop Presentations

In order to set the stage for the deliberations of the Working Groups on what the most appropriate elements of a multi-issue assessment might be, the first session of the Workshop was devoted to a presentation of a variety of existing project approaches, beginning with the three overarching discussions by Keith Puckett, Ted Munn (Chapter 2), and Ted Parson.

Historically, issues have been looked at singly, but there are historical precedents for multi-issue assessments. In his lecture, "Integrated assessments: goals, methods, and challenges", Edward (Ted) Parson (currently at IIASA) began by pointing to the Toronto Conference of 1988 as an important instance where there were both calls for integrated assessments and the setting down of goals and targets. Parson noted that a critical survey of attempted integrated assessments of climate change showed that they were quite disparate. There was not one agreed-upon definition of what constituted an integrated assessment, even in this single-issue (climate change) case.

Parson set out three areas for consideration by the Workshop: goals of integrated assessment (IA), methods, and challenges.

The goal ought to be to undertake integrated scientific assessments as an input to policy analyses and to help guide scientific enquiry: what do we need to know, and when do we need to know it? These questions were taken up in more detail by Working Group III.

The methods used in IAs varied tremendously. Parson pointed out that there were three "mental maps" in use: the linked causal chain; the many causes-one effect chain; and the one cause-many effects chain. The linked causal chain assembled the causes and effects in one beginning-to-end story. The tracing out of biogeochemical cycles might therefore be a good template for this kind of integration. The many causes-one effect chain focussed attention on the target or goal of most concern as the ultimate integrator to which everything would converge. The

Contributed by P. Timmerman

one cause-many effects chain would use the initial cause as the base, and trace out its various transformations through the various systems it encountered. [Then of course there is the many causes-many effects chain, which may be most relevant for multi-issue assessments.]

It could be asked whether a mix of these approaches might characterize our current situation with regard to the six air issues under discussion and that one problem we faced as a Workshop (or as scientists and policy makers) was determining on what basis we were going to integrate. For policy makers, it was perhaps the decisions that had to be made, rather than the nuts and bolts of the issues themselves, that would be the ultimate integrator.

Among the challenges that had to be faced, three stood out: (1) how to represent uncertainty in useful ways to the other partners in the process; (2) how to bring politics and human behaviour into assessments; (3) how to develop institutional forms that could handle the tensions that trying to carry out integrated assessments inevitably produce.

Parson concluded that:

- There is a definite need for integrated assessments, which lie at the interface between science and policy;
- These assessments are differenct from, and do not replace, scientific research;
- Doing integrated assessments is difficult, and the difficulty should not be disguised;
- Contrary to what many assessments currently assume, there is no single decision-maker to whom the assessment should be addressed, and no single "moment of decision";
- Among other things, this means that the assessment should be transparent, should present multiple alternatives, and should be dynamic.

In his presentation, "Impacts of elevated levels of carbon dioxide, ozone, and UV-B radiation on vegetation", Sagar Krupa reiterated and expanded on some of these themes, noting that in his area of research there was a lack of visible evidence of satisfactory cross-communication among scientists from different disciplines. The bulk of the existing knowledge of the effects of carbon dioxide, UV-B, O_3, temperature and precipitation on terrestrial vegetation was based on univariate analysis. He laid out what was known in the "single stress mode" about the functioning of monocultural plant responses, as well as the existing state of knowledge about the functional responses of forest ecosystems.

Krupa argued that the needs and directions of research required moving away from single simple cause-effect models primarily focussing on sensitivity and physiological responses into consideration of an entire ecosystem through systems analysis of ecological changes involving, in the case of a forest:

- shifts in energy and mass flows
- litter production, decomposition, nutrient cycling
- eco-hydrologic responses
- pathogen and insect cycles
- inter-species competition
- successional effects
- food webs and changes in landscape mosaics.

These ambitions were thwarted by, among other things, a lack of sufficient emphasis on experimental methodology development, a lack of satisfactory numerical approaches for establishing cause-effect relationships, and a lack of resources for conducting multi-variate experiments.

P. Jefferson Curtis, in his follow-up presentation, "Complex interactions among air pollutants, hydrology, and biology in lake ecosystems" reported on a series of model experiments in lake ecosystems that were analogous to what Krupa was striving for in terrestrial ecosystem impact studies. These were documented in lakes experimentally acidified, and subjected to warmer, drier conditions over the last 20 years. What these multivariate analyses showed was that acid deposition, climate change, and UV-B exposure were closely linked via organic carbon. Among the effects that his group had documented were changes in lake and stream chemistry, changes in thermal stratification and light penetration, changes in the UV-B hospitable/inhospitable regions of lakes, and changes in the euphotic zone. Essentially, as acidified lakes become clearer, UV-B penetration goes up, and similar changes occur in the thermal properties of the lakes, squeezing the available ecological niches for a variety of species. Among other implications of this research was the fact that shallow water organisms were "miners' canaries" about the state of the ecosystem under stress.

Edward (Ted) Elliott then introduced another form of "Integrated assessment for the ecosystem" from the perspective of social ecosystems. He stressed the use of driving variables as determinants of ecosystems. These variables regulate processes which determine properties. The originating variables include climate, organisms, parent materials, relief. As you move through time or space, these driving variables can shift to response variables (linked by feedback loops and other forms of interaction). It was important to envisage processes whereby one began to see that neither plants nor soils created the other, but they created each other under the influence of the driving variables which they were in turn modifying. He noted that human management systems could be seen as new driving variables to complicate the interactions.

Elliott suggested that process-level studies lead to formal simulation models; data from site networks were the building blocks for these models (which had their virtues, e.g. they accounted for feedback loops better than other approaches.). These models might then in turn generate new site networks to be studied, and so on, in mutually enhancing ways.

The Workshop then turned to new approaches in the social sciences. Laura Cornwell discussed "Ecological Economics and the Precautionary Principle: Environmental Bonding". She began by stressing that ecological economics attempts to transcend the traditional boundaries of economic thought by looking at the full range of interactions between ecological and economic systems. This meant that there were new concerns that had to be integrated into an acceptable theory or set of practices. These included sustainable scales of human activity, concerns for equitable distribution of goods, services, and resources, and the need to operate within biological constraints. Integrating these into one's approaches indicates that a "precautionary principle" should be acknowledged. The sciences most appropriate to an ecological economics approach would be associated with a comprehensive systems approach, would be multiscalar, and would use modelling as a consensus building tool with respect to what is going on and what should be done about it.

In the research being carried out by Cornwell and others in her group at the University of Maryland, an experimental simulation game is being used to explore the possibility of adding "environmental bonding" to the mix of available regulatory and policy instruments. This is a response to the need to introduce environmental criteria, and uncertainty, into the market system in ways that are not currently captured by the pricing mechanism. The bond is a variation of the idea of deposit refunds, whereby a potential resource user must post a bond equal to the potential worst case damages (as established by the regulatory agency or agencies). Interest on unused bonds could be returned to the resource user, and the bonds would be there to be used in case of damages. One basic aim of the system is to put the burden of proof on the proponent of an activity that it would not be harmful.

The simulation model used was based on STELLA (Structured Thinking Experimental Learning Laboratory with Animation), and operates by testing player behaviour under varying levels of uncertainty within either a bonding system or a command-and-control regulatory system. The results so far suggest that the bonding system provides more incentives for improving economic as well as ecological performance.

The last prepared presentation, by Douglas Gatlin, focussed on the "Climate Institute's Environmental Technology Concept". The Climate Institute (in Washington) was founded to improve communications between scientists and policy makers on climate issues. Their largest project to date has been a study sponsored by the Asian Development Bank of the climate change implications and national response strategies of 10 Asian nations. One of the results of this study was the "Asian Leaders' Conference" held in March 1995, that endorsed the "Manila Declaration" calling for the acceleration of delivery of greenhouse gas benign technologies into the region.

Among Gatlin's points was the fact that the main impediment to the dismantling of inefficient energy generation and delivery systems, as well as the arrival of renewable energy technologies was the existence of large-scale subsidies to the nuclear and fossil fuel industries. Energy research needed to be redirected to emphasize rural energy use, the internalization of pollution costs, and the improvement of end-use efficiencies. Initiatives supported by the Climate Institute included the development of an international public/private partnership to accelerate the commercialization of "greenhouse-benign energy".

3.3 Introduction to the Working Group Sessions

It was felt that interdisciplinary reviews of available techniques, followed by parallel attempts to consider the development of an appropriate multi-issue assessment framework would be the most appropriate structure for the Working Group sessions. With modifications, this was the basic understanding within which the Working Group sessions operated.

Each Working Group, as will be seen in the Reports that follow, determined its own format for discussion, though the second day of the Workshop was specifically designed for parallel discussions by each Group of the same topics. These were:

- Is an integrated scientific methodology possible?
- Is a policy framework possible?
- Which of the current or proposed approaches would be the most useful?

One major conclusion of this parallel effort was that both a multi-issue scientific methodology and a multi-issue policy framework were possible, but this conclusion was hedged with important qualifiers. There were both benefits and potential problems with multi-issue assessments (see Working Group III for a fuller listing). For one thing, the process of integration is full of uncertainty, and the results are difficult to validate (see Working Group I Report). Nevertheless, the process of trying to integrate across the scientific issues would bring out fundamental working assumptions and cross-linkages that were important to draw into the foreground of discussion.

There was agreement that each of the approaches discussed in the Working Group sessions had its virtues and was in some sense complementary to the others; but the real issue was which method was most "policy friendly". That is, deciding what the policy goal was would indicate which multi-issue method would be most accessible to the "mental map" of decision makers, thus enabling them to work usefully with the model in some detail. It was also important to be able to "change gears" - to move from one approach to another through the co-evolution of the science and the policy.

Biogeochemical models, dose/stress-response models and ecosystem models were seen as, on balance, more useful to scientists than to policy makers. They needed to be adapted or simplified or embedded in simpler assessment frames in order to be useful to policy makers. Ecosystem frameworks and risk assessment were seen (by some participants) to be making larger claims to being bridges between the scientists and the policy makers. In particular, at least one version of the ecosystem approach (currently being used in the Great Lakes Basin), explicitly sees itself as fostering an integrative process as an overall "cultural regime" within which networks of relevant stakeholders can operate (see Working Group II and Section 2.2). According to this approach, the ecosystem represents an integrating template, or a source of guidance as to what has to be done to "manage" our responses to its changes.

Chapter 4: WORKING GROUP REPORTS

The participants were divided into three Working Groups for the two day period. On the first day, each Working Group was asked to discuss two analytical methods for undertaking multi-issue atmospheric assessments. These are identified in bold text at the beginning of each report. For the second day, the membership of the Working Groups remained the same; however, the focus in all three groups moved to examining frameworks for integrating atmsopheric assessments in a scientific and policy way, using all six methods.

4.1 REPORT OF WORKING GROUP I*

Chair: Doug Whelpdale **Rapporteur:** Rod Shaw

Participants: Gerald Diamond, Wayne Draper, Henry Hengeveld, Ray Hoff, Sagar Krupa, Abdel Maarouf, Joan Masterton, Carmelita Olivotto, Keith Puckett, Marjorie Shepherd, Ron Williams, Jim Young.

Analytical methods available for undertaking multi-issue atmospheric assessments:
1. **Biogeochemical cycle models**
2. **Dose-response models**

Biogeochemical Cycle Models

Traditionally, biogeochemical (BGC) cycle models represent the cycling of a single substance (often an element) among various reservoirs in the natural and human environment. BGC cycle models provide not only quantitative estimates of the stocks and flows of the substance but also describe the processes that cause these stocks and flows to change. Figure 4-1 depicts a BGC model for sulphur in both the human and natural environment. Note that the anthropogenic emissions are approximately equal to the natural ones.

BGC cycle models can be used to link different atmospheric issues if the models include more than one substance and embrace those parts of the cycles of the substances that overlap. For example, methane, in addition to being a greenhouse gas in its own right, takes part in the chemical processes leading to both tropospheric ozone and acidification from sulphur and nitrogen oxides. A well-integrated BGC cycle model which includes more than one substance, non-linearities, feedbacks, and ecological responses, really approaches an ecological system model (see Section 4.2). In this case, the boundary between the two types of model becomes blurred.

BGC cycle models are useful for assessing risk and uncertainty. Scientists usually view risk as the probability of environmental damage resulting from some stress such as acidic deposition or the release of toxic materials. (An automotive analogy is the risk of injury from not wearing seat belts.) However, policy-makers usually see risk as the probability of making a wrong decision because of scientific uncertainty or ignorance. Wrong decisions could mean an action not being taken when it should have been, or, conversely, an action being taken which was not only costly but unnecessary or even harmful. (The automotive analogy is being injured in an accident *because* one was wearing seat belts.)

**Contributed by R. Shaw*

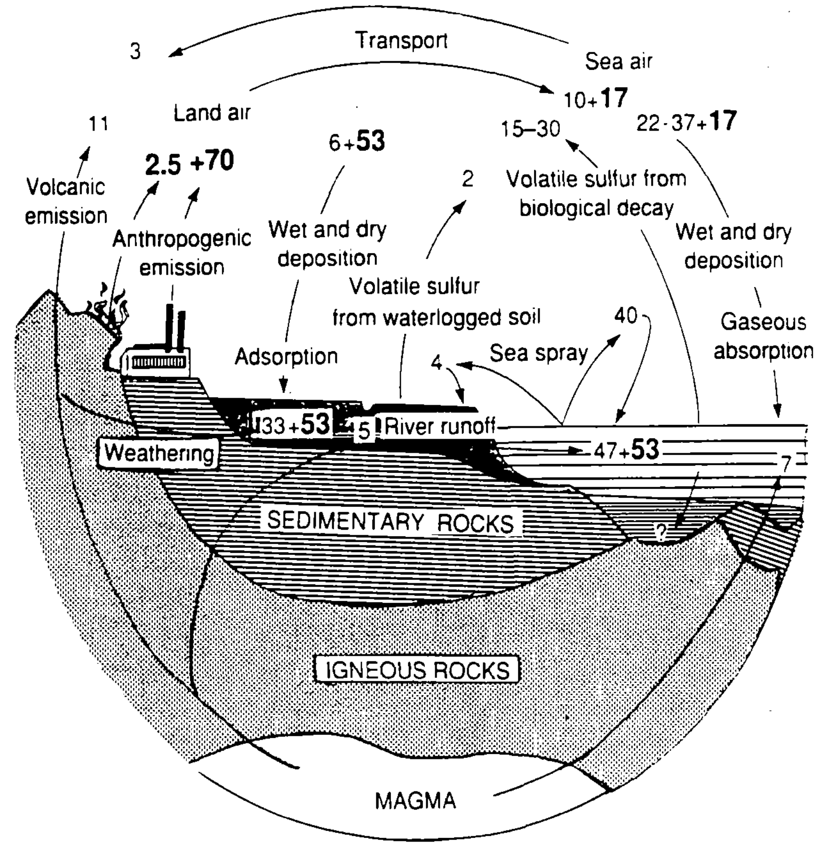


Figure 4-1: Schematic representation of a biogeochemical (BGC) cycle model [modified from T.E. Graedel and P.J. Crutzen, (1993) Atmospheric Change: An Earth System Perspective, WH. Freeman and Company, New York. 297p.]

These different views of risk give rise to the classic environmental dilemma: "Should we act now or wait until we have better scientific knowledge?" Apart from advising policy-makers to reduce environmental stress to zero (often an impractical suggestion), scientists could use BGC cycle models to carry out sensitivity analyses to determine:

1) where in the system will uncertainties affect policy decisions the most, and

2) what are the most important linkages in the system where scientific knowledge has to be relatively good. This aspect of sensitivity analysis is especially important when the BGC model is used to link more than one atmospheric issue - weak knowledge in linkages common to more than one issue may adversely affect decisions in all of them.

Thus BGC cycle models can be used to establish research priorities separately for research and for policy goals. The Working Group felt that, on balance, BGC cycle models were more useful to scientists than to policy-makers in integrating more than one atmospheric issue. (A few participants expressed the view that they were of limited use even to scientists, because of their many uncertainties.). Policy makers, who often have a non-scientific background, may have difficulty in understanding the complex relationships in BGC cycle models and why a certain output results from a given model run. They find more understandable and, therefore, more useful "shorthand" versions of BGC cycle models which express relatively simple cause-effect relationships. If these policy-oriented shorthand versions, and the cause-effect relationships that they express, span much of the train of events from cause to effect for an atmospheric issue or, better still, for several issues, they are referred to as "integrated assessment models (IAMs)".

IAMs are often based upon complex BGC cycle models but play a very important role in communicating the results of BGC models to policymakers. An example of an IAM is the Regional Acidification Information and Simulation (RAINS) model. RAINS is used by the UN Economic Commission for Europe to formulate and assess strategies to reduce acidic deposition under the aegis of the Convention on Long-range Transboundary Air Pollution (Alcamo *et al.*, 1990). RAINS comprises several modules from one dealing with energy use, emissions and costs of control through an atmospheric transport and deposition module to several modules dealing with environmental effects such as fresh water acidification and risk of forest damage. Each module is based upon a fairly complicated BGC cycle model, but the results are expressed in a relatively simple way. The modules are linked such that an input of European energy consumption and how it is produced is translated into maps of atmospheric sulphur deposition, percentages of acidified lakes, and risk of forest damage, outputs which are easy for policy-makers to understand.

The Integrated Model to Assess the Greenhouse Effect (IMAGE) is a good example of an IAM dealing with the issue of climatic change (Rotmans, 1990). IMAGE has been used to evaluate long-term climatic strategies for the United Nations Intergovernmental Panel on Climatic Change. IMAGE has modules dealing with both anthropogenic and natural emissions of several greenhouse gases, their biogeochemical cycling, their radiative forcing of the atmosphere, and modules on the effects of temperature change on sea level, forests and the terrestrial biosphere.

Although RAINS was originally developed to deal with the issue of acidification from the long-range atmospheric transport of sulphur and nitrogen oxides, it is in the process of being expanded to deal with tropospheric ozone (Heyes and Schöpp, 1995; Hordijk, 1995). As in the case of acidification, the ozone extension of RAINS will include modules dealing with emission patterns, costs and effectiveness of control measures, source-receptor relationships, and economic and ecological impacts. Strategies to reduce tropospheric ozone involve emissions of both volatile organic compounds (VOCs) and oxides of nitrogen, which are also involved in acidification. For this reason, the source-receptor relationships will be much more complex and difficult to derive in a form useful for policy makers than in the case of acidification, which assumed a more-or-less linear relationship between emissions and concentrations or deposition.

Dose-Response Relationships

There was much discussion about the meaning of the term "dose-response" and, in particular, to what part of the chain of events from cause to effect it applies. The traditional view, which eventually prevailed within the Working Group, was that "dose-response" is analogous to that used in medicine, i.e., it is restricted to the linkage between the environmental stress (expressed for atmospheric issues as ambient concentration or deposition rate) and the environmental effect (for example, leaf damage). A schematic of a dose-response relationship is shown in Figure 4-2. Although there is a portion of the dose-response relationship in which response increases (not necessarily linearly) with dose, there may be a "threshold" dose below which there is no response, and a "saturation" dose above which there is little increase in response. In the issue of acidic deposition, the threshold dose is the "critical load" defined by Nilsson and Grennfelt (1988) as: "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge". Because critical loads are often not attainable even with the largest emission reductions possible at the time (because of technological, political or economic factors), policy-makers often set "target loads" which are less stringent.

It was felt by the Working Group that dose-response relationships could be used to link different atmospheric issues by using families of curves such as those shown in Figure 4-2. One could have multiple curves for a single receptor or effect; for example, losses of species diversity could be the single effect and stresses such as acidic deposition or ambient ozone concentration could be the doses. Alternatively, one could have families of curves for a single stress (such as acidic deposition) and multiple effects (such as diversity of freshwater species, and forest productivity).

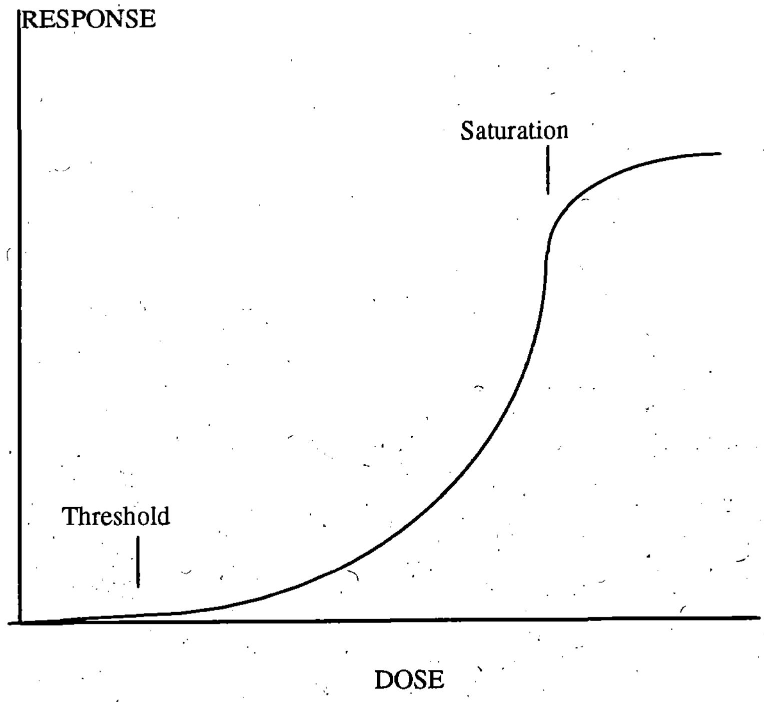


Figure 4-2: Schematic representation of a dose-response relationship.

It was acknowledged that, if more than two or three issues were linked, the dose-response relationships might be visually complex and difficult to understand. Therefore, there was not a consensus within the Working Group about the appropriateness of dose-response relationships (as interpreted traditionally) as a device for integrating various atmospheric issues. It might be more appropriate to look for stress-response relationships that span more of the chain of processes from root cause to ultimate effect.

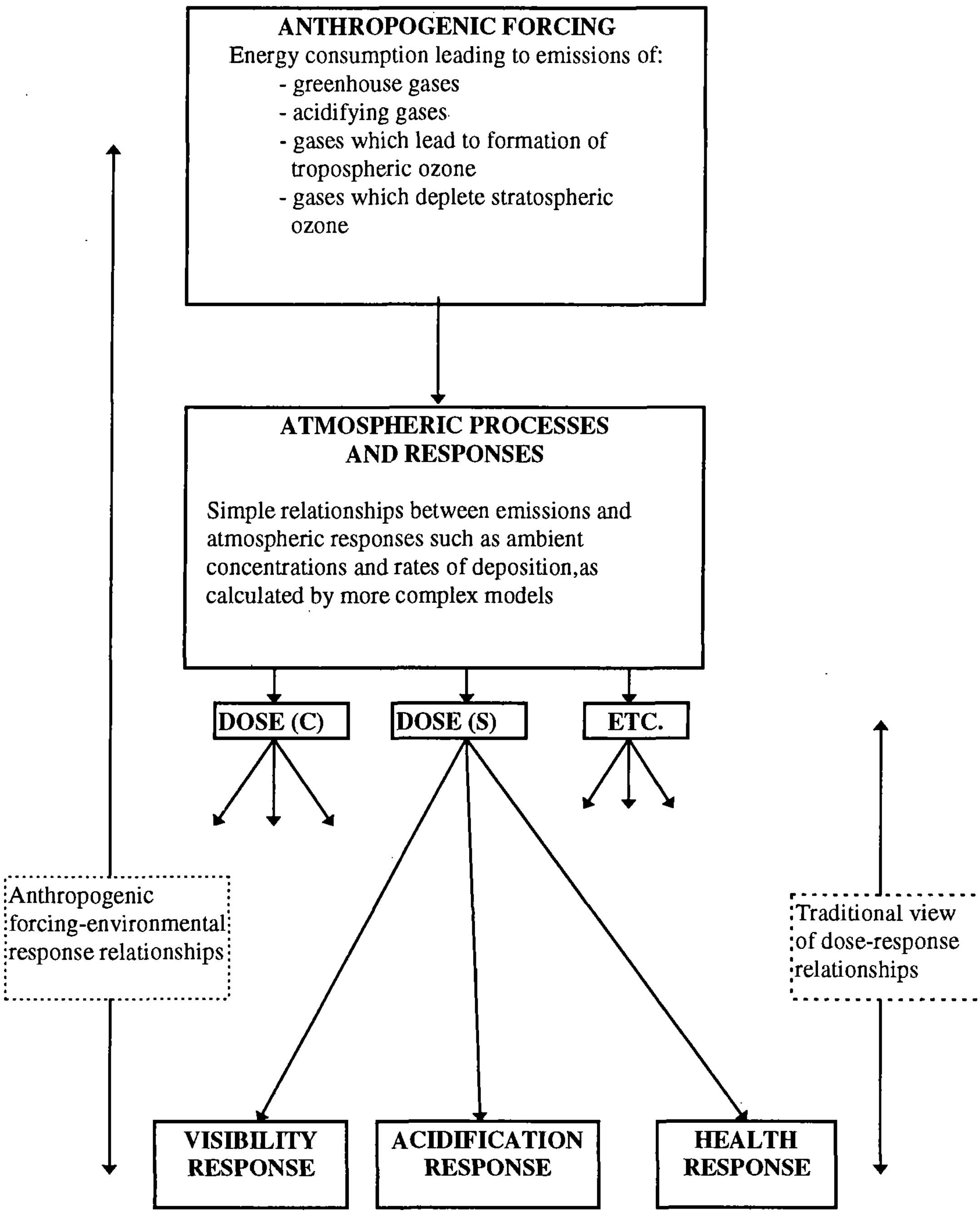
Figure 4-3 illustrates how the traditional view of "dose-response" could be expanded into a larger concept of "cause-effect", through the use of integrated assessment models. In Figure 4-3, the anthropogenic forcing could be something as fundamental as energy consumption leading to emissions of greenhouse gases, acid-forming gases and some of the gases leading to stratospheric ozone depletion. The atmospheric response to these forcing factors is often calculated using relatively complex models of atmospheric transport, diffusion and deposition and expressed in the integrated assessment model as a simple relationship. Examples of such a relationship are the source-receptor matrices used in integrated assessment models for acidic deposition which express the ambient concentration or the deposition at a given receptor point per unit emission at each source. Assuming a linear relationship between emissions and concentrations or deposition (two types of sulphur "doses"), the effect of changing emissions upon these doses can be easily calculated. In the issue of climatic change, the IMAGE model can give simple curves of atmospheric concentrations of greenhouse gases (and the resulting changes in global average air temperature) for a given greenhouse gas emission scenario.

Given the dose, the environmental response such as freshwater acidification in the case of acidic deposition or, in the case of climatic change, geographical shifts in favourable growing zones for specified plant species, can be estimated using another set of models. (In Figure 4-3, only the responses to sulphur doses are illustrated.) These response models, in effect, estimate the traditional dose-response relationship which is shown on the right-hand side of Figure 4-3.

Policymakers, however, are increasingly more interested in linking environmental response not just to atmospheric concentrations and deposition but to fundamental patterns of human behaviour, such as energy consumption. Therefore, the anthropogenic forcing-environmental response (AFER) relationships shown on the left-hand side of Figure 4-3 may be more useful to them. There will be one set of such relationships for each atmospheric issue. The AFERs are combinations of the linkages between human behaviour and emissions, between emissions and atmospheric doses, and traditional dose-response relationships. These overall relationships will probably be difficult to determine and may be complex and non-linear. It is a challenge to systems analysts building integrated assessment models to produce AFERs that are workable and understandable.

It is clear how the system shown in Figure 4-3 can link the steps from anthropogenic forcing to environmental response for a single atmospheric issue. This has already been done in the case of RAINS and IMAGE. But how can it link several environmental issues? The common element in all issues could be the anthropogenic forcing i.e., human behaviour, and/or the receptor, be it humans or forests. One possibility for integrating is to try to determine the issue for which the AFER is on the "critical path". For this critical, determining issue, the environmental response would be brought within acceptable limits by a policy (for example, on energy use) which would also improve or even solve the other environmental issues. Selecting this "driving" AFER is discussed below.

Figure 4-3: The traditional interpretation of a dose-response relationship, and an expanded interpretation of anthropogenic forcing-environmental response relationship, in the context of an Integrated Assessment Model.



Frameworks for Integrating Atmospheric Issues

1. Is an integrated *scientific* framework possible across the various air issues?

The Working Group's response to this question was a qualified "yes" - integrated scientific models can be built. It was qualified because some members of the group expressed concern about the fact that scientific models were uncertain and difficult to validate. (It is not easy in real life to "turn on" one air pollution issue at a time to see if an integrated scientific model works for that issue.) Such models are useful for pointing out the important cross-linkages among the various air issues, and where better scientific knowledge is needed. In fact, integrating more than one issue in a scientific model may have a synergistic effect upon scientific knowledge - one can not fully understand the scientific processes in acidification unless the oxidant cycle is included as well in the model.

Apart from the scientific product i.e., the integrated model, the *process* of building the model is a scientific integrator as well. This was made clear during the building of RAINS and of IMAGE, processes that involved scientists of many disciplines over periods of at least several years.

2. Is an integrated *policy* framework possible?

The Working Group felt that the answer to this question was also "yes". Likely candidates for integrated policy assessments are the Integrated Assessment Model discussed above. It was pointed out that policymakers are not usually looking for answers to the third significant figure. Rather, they are looking for directional guidance, i.e., "Will Measure X give us an improved situation with respect to more than one air issue?" An integrating policy device that could be very useful in this respect is the policy matrix, an example which is shown below.

	ISSUE			
POLICY	**Climate Change**	**Acidification**	**Stratospheric O_3**	**Toxics**
Policy A	+	-	-	0
Policy B	+	+	0	+
etc.				

In the matrix, a "+" means an improvement, "0" means no effect, and "-" means that the policy causes the situation with respect to the air issue to become worse. The pluses and minuses in the matrix are produced either by integrated scientific models or integrated assessment models.

In the above example, it would appear that Policy B is the better one as it would cause an improvement with respect to more air issues. (This assumes that all of the above air issues are equally important, and that the magnitudes of the pluses and minuses are about equal). Examination of such a matrix will indicate which policies (or patterns of human behaviour) will lead to several pluses or minuses, i.e., be on the "critical path", or would be the "driving AFER" as discussed above.

Another means of displaying policy options in a graphic way is shown in Figure 4-4. This figure shows in three dimensions the environmental response with respect to two anthropogenic forcing functions A and B (on the X and Y axes). For example, the forcing functions could be emissions of nitrogen oxides and of volatile organic compounds. The environmental response, which could be concentrations of tropospheric ozone, is shown in the figure as a shaded, undulating surface with peaks, depressions and gulleys, etc. The magnitude of the respnse is the vertical distance of the surface above the XY plane. Therefore, peaks and hollows on this surface indicate local maxima and minima of the environmental response. Environmental policies, i.e., changing the forcing functions, would be like rolling a ball over the response surface. For example, a "precautionary principle" which attempts to minimize the forcing functions A and B will drive the ball towards the intersection of the response surface and the Z axis where X=Y=0. This will not necessarily be at a local minimum in the response surface, however! An example may be found in the work to extend the RAINS model to tropospheric ozone. It was found that, in the case of high atmospheric NO_x concentrations, reducing NO_x emissions could result in an increase rather than a decrease of tropospheric ozone (Heyes and Schöpp, 1995).

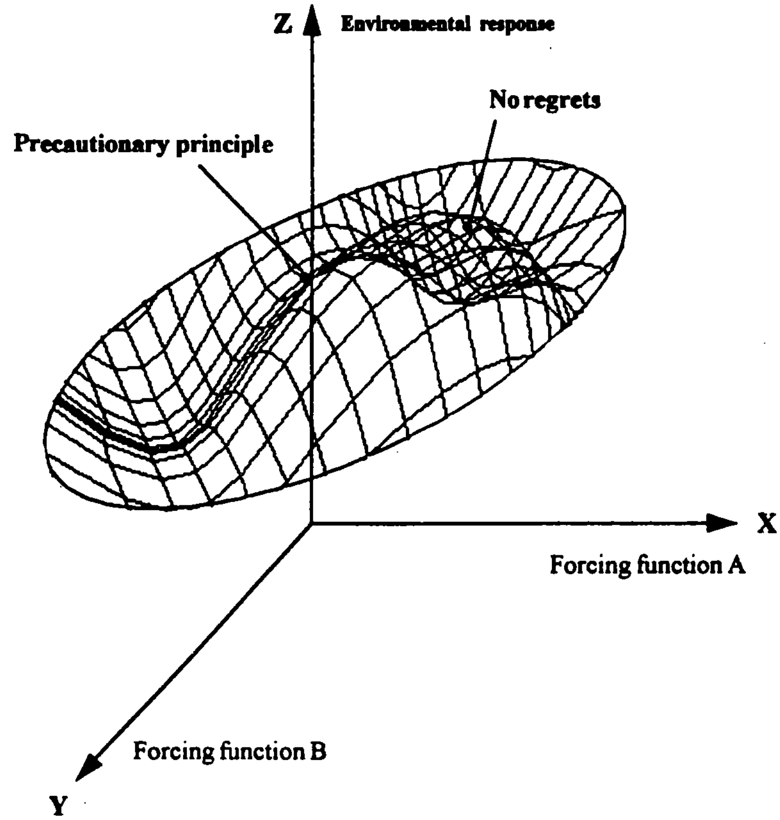


Figure 4-4: Three-dimensional representation of the environmental response to two anthropogenic forcing functions.

3. Which of the methods would be the most useful as an integrator of the different atmospheric issues?

It was the opinion of the Working Group that no one analytical method could be singled out as the best integrator - they were all useful in their own way and complementary. (The Working Group discussed mainly biogeochemical cycle (BGC) and dose-response models because they were most familiar with them.) BGC cycle models were most useful as scientific integrators while integrated assessment models which are short-hand versions of BGC cycle models were more useful as policy integrators.

It was noted in the Working Group that public attitudes rather than scientific policy-oriented models were the key factor influencing policymakers. It is sometimes possible, however, for scientists to influence public attitudes, e.g., through the use of environmental indicators.

4. Is a single, integrating indicator for all issues useful or feasible?

It was felt by the Working Group that there are many existing indicators such as air quality indices that the public find useful. However, the group felt that yet another index was not needed, largely because it would be difficult to devise an all-encompassing index to cover a suite of air issues. Nevertheless, there is a need for scientists to communicicate to the public, including educating them about the inter-connectedness of environmental issues.

Recommendations

- Environmental assessments should include the cross-linkages among issues. Significant progress has already been made with respect to integrating various disciplines to examine a single atmospheric issue such as acidic deposition or climatic change but, obvious as the need may seem, there has been much less progress in multi-issue environmental assessments.
- This Workshop dealt with the general aspects of linking atmospheric issues from both a scientific and a policy point of view. It is recommended that follow-up workshops deal with a specific challenge such as linking atmospheric issues in a specified geographical area. An example would be linking these issues in southwestern Ontario, an area which is affected by acidic deposition, tropospheric ozone, toxic pollutants and, potentially, by climatic change. Even if an actual field study were not undertaken, the process of thinking about the linkages would be a beneficial exercise. Nothing can focus thinking better than a specific case study.

- Multi-issue thinking could be fostered by seminars in government agencies and university institutes that focus specifically on cross-issue linkages. Scientific societies might sponsor sessions on this topic at national and international meetings.

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4.2 Report of Working Group II*

Chair: Henry Regier **Rapporteur**: Brad Bass

Participants: Normand Beaudoin, Beth Benson, Jeff Curtis, Kirsty Duncan, Ted Elliott, Adam Fenech, Beverley Hale, Pam Kertland, Grace Koshida, Don MacIver, Ted Munn, Don Munton, Karen Nassim, Bob Saunders, Heather Smith.

Analytical methods available for undertaking multi-issue atmospheric assessments
3. The ecosystem approach
4. Comparative risk assessments

The Ecosystem Approach

The ecosystem approach and risk assessment were discussed with respect to multi-issue assessments, both scientific and policy directed ones, regarding atmospheric change in Canada, with particular attention to the six air issues: climate change, the depletion of stratospheric ozone, acid deposition, hazardous air pollutants (HAPs), suspended particulates and photo-chemical pollution. There are feedbacks among these issues and a single-issue approach to policy may exacerbate some of the pollutants. Both the ecosystem approach and risk assessment were discussed with the view of moving beyond single-issue management. Although much of the session was devoted to questions of definition, the session was productive in pointing out some directions for integration and for identifying existing knowledge gaps.

The discussions in this working group were informative, and they pointed out many of the problems that still need to be overcome before multi-issue assesments are possible. A consensus emerged that ecosystems, as natural integrators of multiple impacts, provide a good focus to examine the integrated impacts of the six air issues.

**Contributed by B. Bass*

Simulation modelling provides a useful description of how different ecosystem components interact, assuming that the parameterizations and some of the boundary conditions remain fixed over the specified time period. However, the atmosphere will most likely change throughout the next century. Adaptation to these changes will alter the human interaction with the landscape, and it is necessary to adopt some of the principles of complex systems, perhaps in a risk assessment framework, to describe these interactions and the possible outcomes. It is necessary to foster the emerging network of expertise (a new cultural regime) in order to establish the support needed for this type of analysis over all the air issues. The policy framework of risk estimation, response assessment and monitoring may provide an appropriate focus around which a new cultural regime may emerge, especially if the larger goal of integration is to appeal to a wide range of constituencies and stakeholders.

The group quickly came to a consensus that the ecosystem approach as an integrating framework should guide data collection, the integration of science and policy, and the removal of institutional barriers. The ecosystem approach was proposed as a framework within which to imbed these issues while risk assessment was viewed as one approach within this framework. The discussion revolved around four major themes: defining and applying the ecosystem approach, concerns regarding the use of the ecosystem approach, risk assessment, and connecting science and policy.

The group spent much time on the definition of **the ecosystem approach**. There were three definitions around the table : (1) ecological systems; (2) analysis of complex systems; and (3) the emergence of a cultural regime. The first approach, ecological systems, simulates and links different ecosystem components, providing quantitative output over short time frames and constant boundary conditions. The analysis of complex systems primarily addresses changes in a few components which may cause a non-linear response and qualitative changes in the state of the system. A cultural regime functions as a "meta-model", providing a framework for interdisciplinary research and integration.

(1) Ecological systems: In this definition the ecosystem is broken down into driving variables, processes and properties. Driving variables such as temperature, precipitation, frequency of extreme weather events, soil parent material, relief, organisms and time determine the spatial characteristics of ecosystems. As the spatial and temporal scales of analysis change, certain driving variables may also become response variables. The properties include components such as plants, animals, decomposers and soils. The processes connect the components of the ecosystem. Models of various processes such as transpiration, photosynthesis, carbon cycling and nitrogen cycling can be combined with the hydrological cycle, surface observations and remotely sensed data to simulate future changes on different time steps (IGBP, 1993).

It is assumed that if an ecosystem is experiencing a "normal" range of variation, it is able to retain a recognizable identity, and within this identity the emergent properties are predictable. Under these assumptions the models can provide a description of the interactions between the different ecosystem components, predict ecosystem responses to different stresses, and provide a framework for guiding research into other processes. Within the aforementioned assumptions, simulation models can be used to provide a means to examine the integrated impact of multiple air issues. As an initial framework, it is also an effective means of piecing together all of the important system components.

The human components of the system are not necessarily included in these simulation models. Human interaction with the ecosystem can be incorporated through changes to the parameters in any of the component models either directly or with a separate set of socio-economic models with the appropriate linkages. In addition, this approach does not yet incorporate the stresses that fall outside of the norm and cannot be buffered through the "evolved resiliency of the system" (Ryder and Edwards, 1985). The system response to these stresses is such that the identity is changed and the predictability of the emergent properties decreases accordingly.

(2) Analysis of Complex Systems: This "ecosystem approach" is based on the characteristics of complex systems, stressing self-organizing and emergent behaviour, non-linear processes and the necessary maintenance of a system in a non-equilibrium state. The system behaves as a whole and loses something if it is merely decomposed for model construction and then reconstructed by summation. It exists within a multi-scaled hierarchy or holarchy, and a unique equilibrium position may not exist. In a holarchy, bottom-up influences or lateral interactive influences are as important as top-down influences; a state of integrity involves balanced reciprocal relationships within and between holons, or levels, in a holarchy. Human society is considered as a part of the system, altering the atmosphere and the biosphere, thus invalidating many of the deterministic parameters in many simulation models.

Emergence of new states or properties may be driven by feedback processes resulting from the interaction of system components.

The Working Group noted that the six air issues could be divided into three sets of two holons each, nested at three spatio-temporal scales as a means to guide political decision-making and the relevant science. Climate change and the depletion of stratospheric ozone are global and decadal in scale. Photochemical pollution and suspended particulates occur at the regional or even the local scale and the shortest time step. Acid rain and hazardous air pollutants are between these two, spatially and temporally. A key research question for science and policy are the interactions both with each holon and across holons.

When viewed as complex systems, ecosystems are not amenable to the type of formulation that leads to the well-determined mathematical algorithms and the strictly quantitative accounting of most simulation models. Catastrophes are possible, and prediction is difficult if not impossible, at least until the topological nature of a catastrophic fold with its various attractors is understood. The focus shifts from predicting a strict quantitative outcome to the qualitative shift between attractors which define different states of the system. An attractor may circumscribe limits within which prediction is impossible, but we can predict how populations will adjust to dissipate an increase in the flow of energy. Earlier studies (Vollenweider et al., 1974) demonstrated implicitly that aquatic ecosystems move to different attractors under different nutrient forcings. Jørgensen (1994) demonstrated how catastrophic shifts in river oxygen concentration could result from increasing or decreasing temperature. Another example discussed in the workshop was the energy increase in Lake Ontario due to nutrient loadings, and how the distribution of species was altered to dissipate the energy more efficiently.

(3) The Emergence of a Cultural Regime: This is an institutional approach to cutting across issues and disciplines. The focus shifts from a substantive rationality to a procedural rationality, from describing "what is" in an integrated manner to the process of achieving integration, or from integrating the science to integrating the scientists. A cultural regime provides a framework, an organized and rationalized set of ideas about what we should observe and model and represents a different set of values and perhaps even a paradigm shift. In this sense, the ecosystem approach is the "meta-model" for proceeding with other integrative approaches, and the ecosystem is the template for the necessary inter-disciplinary work.

AUTOMOBILE EMISSIONS: THE DEVELOPMENT OF AN ORGANIZING FUNCTION

On the second morning of the Workshop, I took the University of Toronto Shuttle from the Erindale Campus in Mississauga to the St. George Campus in downtown Toronto. During that trip, the discussion focused on the summer schedule which would severely curtail the working day of shuttle travellers. Appeals to the appropriate office returned replies such as "The shuttle is not for staff anyway", "Studies indicate that the demand for an early morning shuttle (*so we can arrive at work by 9:00*) is too limited", "The staff at Erindale need the time in the morning to prepare for work downtown" (*even though the shuttle is not for staff*). With a late morning departure, more of the shuttle's travellers would turn to the automobile, thereby contributing to the exacerbation of all six air issues. I suggested that we should alter the frame of reference from "arriving at work on time" to "the University of Toronto's contribution to various air issues." Although the increase in automobile use would be small, in principle it would detract from the University's policy of environmental responsibility, and we might have more success by arguing the environmental consequences of the bus schedule. This idea was well received, and before the trip concluded, we had worked out a new strategy for persuading the University to change the bus schedule. We were not successful in this particular case, but it illustrated how automobile emissions could become an organizing function to entrain a diverse group of people for a common goal. *Brad Bass, Rapporteur*

One identified need during this discussion was a unified goal to involve the scientific and other communities. It was then suggested that the framework itself could play the role of an organizing function. It could drive the emergence of a new cross-cutting regime. For example, the growth in private automobile use (refer back to Fig. 2-1) cuts across all of the air issues and may provide an appropriate focus for integration. The group debated whether it would be useful to create a process similar to that which has been in place for the rehabilitation of the Great Lakes Basin, projecting the "Great Lakes model" to the air issues. This is possible if the various toxics and nutrients in the Great Lakes can be viewed as similar to the six air issues - individual, yet interrelated.

There were disagreements as to which definition was most appropriate, but given the initial concerns related to monitoring, uncertainty, policy decisions and institutional barriers, it was suggested that all three definitions are required in the integration exercise. Where it is possible to describe and link several processes as simulation models, and where the assumption of stationarity and linearity can be justified, the first definition of the ecosystem approach has some predictive value, and it is useful for asking "what if?" questions. The analysis of complex systems is useful in detailing the limits of prediction and in helping select appropriate early warning indicators. Given the possible resistance to an integrated approach, it was recognized that a framework is required to organize integration, in a procedural sense, and to guide the research.

There were several *concerns* raised about the ecosystem approach. *The first concern* dealt with societal issues such as justice, equity, the prioritization of values, and the level of acceptable risk. *A second concern* related to the risks of each air issue. Could similar questions about each risk be asked across a wide range of stakeholders? This led to *the third concern* regarding the target audience. Five possible audiences were identified: (1) the policy community represented by the Air Issues Branch of Environment Canada, the National Air Issues Coordinating Committee (NAICC), and the Canadian Council of the Ministers of the Environment (CCME), the latter two being both federal and provincial; (2) the scientific community; (3) individuals, with a focus on lifestyle changes; (4) the media; and (5) industry. Although the discussion was directed towards the needs of policy people and somewhat towards the scientific community, the needs of other stakeholders may be different, and the ecosystem approach may be customized for different audiences. *A fourth concern* was raised regarding the level of integration. As more issues are thrown into policy formulation, the time required to make a decision increases. Integration is required to effectively cope with the combined impacts of air issues. The key question is how much integration is necessary to show decision-makers the possible impacts on "B", as a result of taking action on "A", "C" or "D".

At one point during the sessions, *a fifth concern* regarding the acceptable level of uncertainty was discussed in reference to both science and policy. In addition, several members of the group discussed the possibility of attaching confidence intervals to the output of big complex models such as RAINS or a general circulation model (GCM) to estimate the risk associated with each of the six air issues. There were clear disagreements on this issue. On the one hand, the uncertainty of GCMs in reproducing observed climate at the regional scale was cited as one of the many impediments to ever deriving confidence intervals from that kind of model. On the other hand, recent developments in down-scaling (see box below) have vastly improved the usability of GCM output on a daily time step at the spatial scale of a small watershed.

DOWN-SCALING

Down-scaling is a term associated with a number of procedures that derive high-resolution or regional values from low-resolution data or GCM output. Most methods attempt to link classes of pressure anomalies or patterns to a distribution of events at different sites. These linkages are transferred to GCM output, and it is possible to derive statistics of extreme events for small areas and in some cases for specific sites. Down-scaling may also provide a means of integrating the risks of each issue at any one location through the linkage to atmospheric circulation patterns. It has been used to model visibility, extreme precipitation events on a regional scale, and some promising results have been obtained with stratospheric ozone. The term was originally attached to semi-empirical stochastic methods that were based on two approaches to weather forecasting: perfect progs and model output statistics. Recently, dynamic mesoscale models have also been used to provide the actual daily weather pattern, on a regional scale, associated with the atmospheric profile derived from a GCM simulation.

Comparative Risk Assessment

Risk assessment was considered to be a means of resolving some of the principal concerns that were raised in the discussion of the ecosystem approach. Risk assessment was presented as a means of taking stock of where we are with a clear recognition of where knowledge gaps exist and the risk of acting in ignorance. However, risks are always perceived and evaluated within a value context which directly influences the level of acceptable risk. In addition, to undertake the multi-issue assessments, it would be necessary to develop a common measuring stick.

A risk assessment approach was presented that incorporated the principles of the ecosystem approach. Four feedback processes were identified: nonlinear feedbacks between the issues, feedbacks between the various issues and specific response options, feedbacks between specific response options and the measurement process, and feedbacks between the six air issues and the measurement process. Response options, formulated as some measure of control, was viewed as a significant cause of most problems involving a lack of integration, because there is no way of assessing if and when the response could move the system to a different attractor. It was noted that several of the elements of this framework were similar to those found in cumulative impact assessments which also emphasize the longer-term perspective.

A policy model, developed in the Social Learning Project (Parson and Clark, 1995), was proposed to illustrate how some of the characteristics of risk assessment and the ecosystem approach could link science to the formation of policies to deal with environmental risks. The policy process was broken up into three questions:

Risk estimation:	How big is the possible threat?
Response assessment:	What are the possible response options and the associated consequences?
Post-assessment audit:	Is the response correct and/or is it of sufficient magnitude?

Each of these questions requires a scientific input but of a different nature. The first question requires an estimation of the magnitude of any change as well as the likelihood of occurrence and the impacts. This could involve the use of tools such as down-scaling, dose-response models and simulation modelling. The second question focuses on the identification of thresholds or critical levels as was done for the issue of acid deposition. This would be guided by complex-systems thinking, especially since the concern for consequences involves different feedbacks operating at different scales. In monitoring the effectiveness of a response, the selection of an appropriate variable requires careful consideration. For example, the concentration of ozone may not be as important as the flux. It was suggested that the ecosystem approach could guide the design of the monitoring program, although time did not permit the group to develop this concept.

Frameworks for Integrating Atmospheric Issues

1. Is an integrated scientific framework possible across the various air issues?
2. Is an integrated policy framework possible across the various air issues?

There are two possible frameworks for integrating science and policy across the various air issues. One approach is to nest the air issues in a holarchy at three scales: regional (ground-level ozone, suspended particulates), continental (acid rain, HAPs), and global (climate change, stratospheric ozone depletion). Each level of the holarchy (holons) provides a spatio-temporal scale for science and policy, but this does not preclude interactions within and between each holon. Another framework for integration is the Social Learning Project policy model. Policy, and therefore the relevant science, would address the six air issues according to risk assessment, response assessment and post-assessment audits.

3. Which of the methods would be most useful as an integrator of the different atmospheric issues?

A consensus emerged that ecological simulation models could provide a good initial means of integrating the six air issues as they impact upon ecosystems assuming that the model parameters are valid for the chosen time period and non-linear responses are of little concern. Where this is not the case, there are other approaches that pertain to non-linearities, such as catastrophe theory and structural dynamic models which allow for variations in the model parameters. The general approach is as follows:

a: Develop a matrix of two- and three-way interactions on ecosystems, similar to that presented by Sagar Krupa at the Workshop. From the literature, perhaps with a second workshop if necessary, fill in the matrix qualitatively. The entries should not only indicate existence and direction of impacts, but significance as well.

b: Assess which existing ecological simulation models (including carbon cycle models, nutrient cycle models, and soil-vegetation-atmosphere transfer models) might be able to address the significant interactions. Assess what would be required to develop additional modelling refinement.

c: Assess the range of models for describing nonlinear responses to these interactions. These will include but are not restricted to structural dynamic models with goal functions and catastrophe models (Jørgensen, 1994).

In general, the majority opinion was that multi-issue impacts were extremely difficult to predict. Therefore, effort should be directed at the identification of the most appropriate spatial and temporal scales of analysis, the development of early warning indicators, and the identification of adaptive responses, moving away from crisis management.

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4.3 REPORT OF WORKING GROUP III*

Chair: Ian Burton **Rapporteur:** Peter Timmerman

Members: Jay Barclay, Elizabeth Bush, Stewart Cohen, Laura Cornwell, Rod Dobell, Douglas Gatlin, David Etkin, Roger Hansell, Danny Harvey, John Hollins, Mike Jerrett, Al Malinauskis, Yohannes Mariam, Ted Parson, John Reid, Bill Vanderburg, Rodney White.

Analytical methods available for undertaking multi-issue atmospheric assessments
5. The "no-regrets" principle
6. The precautionary principle and ecological economics

The discussion was wide-ranging, and only some of the points that were raised can be captured in this brief report. After an initial review of the individual concerns of the group, it was agreed that the "no regrets" policy and the precautionary principle were examples of integration tools because they changed some fundamental element of the policy framework, such as what the burdens of proof were for doing certain things or not doing certain things.

A polluter prevention model was put forward as an example of an integrated policy framework for a single pollutant, and to a certain extent, for several pollutants, because it focusses on prevention, or getting at the sources of the problem, rather than on after-effects and curatives, which will necessarily be more scattered. Another example was the policy tool of "backcasting" drawn from the energy industry, where one sets out general social goals in the reasonably distant future, and works backwards to where we are now.

There was a discussion about how the setting down of ethical norms or principles is one way that society goes about moving towards some integrated policies, especially over the longer term. Recent examples in British Columbia, of setting out "sustainable development" as a goal, or setting aside percentages of the land base, were discussed. It was hoped that integrated assessment would take as one of its roles the support of this kind of process. This was especially true if, as was urged, integrated assessment should help build up the information base upon which decisions were to be made; for instance, what might be the consequences of a "do nothing" policy? While there might not be a "big boss", there were lots of regional and local bosses who could be helped.

The group then turned to the "no regrets" policy, about which there was some disagreement. It was noted that there would almost certainly be some regret somewhere about whatever was done, and that one issue was: if there were "no regrets", why hasn't the policy already been implemented? There were two different kinds of "no regrets" strategy under discussion: doing those things which are worth doing whether the environment (e.g. climate) changes or not; and doing those things which we will regret not having done when the environment does change. The latter comes closest to the "precautionary principle".

**Contributed by P. Timmerman*

There was an extensive discussion about ecological economics versus environmental economics. First, questions were raised about whether these were fundamentally incompatible with each other, or to put it more bluntly, whether environmental economics (that is, traditional economics applied to the environment) was incapable of handling what it calls environmental externalities because of some of its basic assumptions. It was suggested that economics as it is currently constituted is based on theories of the human, of utility, and of nature that are not sustainable. It was counter-argued that economics is the best tool we have available to describe human decision-making of a particular sort, and that the market is a superior form of decentralized information signaller. It was eventually agreed that there should be some form of complementarity between the tasks of ecological economics and environmental economics, but that much more work was needed.

What was clear was that there was a great deal that could be done to improve our situation incrementally, even without waiting for a fundamental transformation of economics. For example, there was an immense amount that could be done immediately in professions like engineering with a fairly simple re-orientation towards a preventive, "no regrets" or precautionary strategy.

A discussion about GDP led into a discussion about whether we should try to come up with a single environmental number or index. It was noted that there is now a Human Development Index which is flawed, but which is increasingly taken seriously. The example of the local air quality indices was raised to suggest the possibility of creating a more substantive environmental or air quality index, either regionally or nationally.

Towards the end of the session, another whole set of questions was raised concerning belief, disbelief, and credibility: that is, how do we get people to believe seriously in certain threats? It was noted provocatively that, given your stake in an issue, the burden of proof you require goes up or down; and so what constitutes the evidence needed for something to become a "proven" technology or an acceptable risk is often determined politically and not scientifically.

Finally, there was something of a consensus at the end of the session that the setting of targets and goals, however rough, was a good integrating mechanism, since it entrained a lot of other activities and methods in its wake. The acid deposition targets were used as the best known example. The group did not have time to discuss how to get to those targets and goals, but it raised as a challenge whether we could go down the list of six issues (some of which already have goals set) and set some minimal goals, such as not to increase emissions of any of these beyond current levels for the next 20 years. What would this mean?

Frameworks for Integrating Atmospheric Issues

1. What is an integrated policy framework (IPF)?

It was suggested that an IPF could be looked at in three ways: (i) Who - Who are you talking to, who is the assessment for?; (ii) What to do - are you going to regulate/command, provide incentives/markets, or exhort/persuade?; (iii) How to decide what to do - What is the process?

2. What issue do you use to drive the policy-making process?

It was asked whether climate or atmospheric change was an appropriate issue to be used to "pull along" less popular issues, or whether there might be some other way of characterizing the issues that might regain some of the perceived lost momentum.

3. How do we cope with a situation where the emitters and the impactees are one and the same?

In the early days of the environmental movement, the major pollutant emitters were easily identified, and the impacts of their emissions were mostly reversible. With the trend towards non-point source emitters and policy changes that depend upon widespread lifestyle changes, there is a shift in the political dimension of atmospheric issues. This necessarily affects the definition, description, and outcomes of the policy-framing process.

4. What is the best integrating strategy from a cause-effect perspective?

It was suggested by Ted Parson in his Workshop paper that one could look at a "many causes-one effect" strategy or a "one cause-many effects" strategy to cope with atmospheric issues. An example of the former might be rethinking urban planning in order to deal with smog; while an example of the latter might be to look at acid deposition and follow its impacts across the spectrum of concern. The group discussed how a mixture of the two strategies, operating within an integrating framework, might be the optimal approach; or how each approach might be used at different points in the "issue cycle".

The group then considered the benefits and disbenefits of an integrated policy assessment framework. The following might be used to support proponents of such a framework.

The benefits of Integrated Policy Assessments:

- Improving investment and economic efficiencies and establishing a consistent scientific research agenda
- Setting and maintaining priorities
- Assisting related issues with lower priority
- Revealing links to other issues, and capturing other knowledge resources
- Avoiding (or highlighting) contradictory policies
- Creating a common working narrative for all partners
- Introducing long-term issues and identifying cumulative impacts
- Engaging new stakeholders (e.g. those for whom "no action" will have serious impacts)
- Promoting cumulative acceptability of policies.

The disbenefits include:

- There may be over-integration or homogenization of importantly diverse information.
- The process may become elitist, or promote "groupthink".
- The results of the assessment may provide the enemies of the process with a single target.

The final portion of the Working Group session was devoted to two questions:

1. Where do we begin in our search for the source or sources of the issues?

It was noted that physical scientists and social scientists tend to identify quite different starting points for research, as well as different starting points for "causal relationships". Since this was often the case, there was a need for a "common template" or meeting place where these different partners could meet. This might be a common model, or at least a striving to find a commonly agreed-upon model within which each constituency could carry out its own tasks.

2. Is the working assumption that integrated assessment is a government/academic task justified?

The Group was reminded that some current environmental assessments were being carried out by local groups and coalitions of groups (e.g. around the Great Lakes), and that part of the reconsideration of the political dynamics of assessments was the potential for non-government/government coalitions. This was particularly true if one needed a rich database of local knowledge in order, for example, to manage a common resource.

RECOMMENDATIONS

- The group thought that its identification of the benefits of integrated assessments could be expanded upon, and used in a more widely distributed "selling document".
- The group felt that the relationship between environmental economics and ecological economics was worth further study, especially in deciding which would be more appropriate for different issues and concerns.
- The group raised as a challenge the possibility of going down the list of 6 issues (some of which already have goals set) and setting some minimal goals such as not to increase emissions of any of these beyond current levels for the next 20 years. This "thought experiment" would be provocative and illuminating.
- The group felt that it was important, at the early stages of joint or interdisciplinary work, to bring into the open the different languages, goals, and underlying views of each constituency. A rough modelling exercise, or attempts at creation of a mutually acceptable lexicon, might pay big dividends.

Chapter 5: RECOMMENDATIONS*

This Workshop dealt with the difficult question of linking the six atmospheric issues from both a scientific and a policy point of view. The main focus was on evaluating analytical methods for undertaking multi-issue atmospheric assessments.

In general, Workshop participants felt that an integrated scientific approach across the six air issues was possible and could provide useful input to policy formulation. No one method could be singled out as the best integrator - they were all useful in their own way and complementary. Multi-issue scientific models can be built, but are difficult to validate. The process of building a model is in itself a mechanism for scientific integration, which involves scientists of many disciplines over several years.

Some progress was made at the Workshop in the development of multi-issue policies, and participants were encouraged to pursue efforts in this direction. Simple multi-issue policy devices were discussed and several benefits of integrated policy assessments were identified, such as improved investment strategies and economic efficiencies, establishing a consistent research agenda, setting priorities and avoiding contradictory policies. Finding ways of moving from end-of-pipe regulatory approaches, which treat each air issue separately, to policies based on integrated assessments of the whole range of atmospheric issues, is certainly the best approach. It should be noted, however, that the emphasis on air issues is only a first step toward more comprehensive multi-issue assessments that would include water and land issues.

Public attitudes have a great influence on the policy-making process, and scientists have a role in educating the public about the linkages amongst the various air issues. In this connection, there is need to be aware of language differences and working assumptions of all the disciplines and constituencies represented. Workshop participants felt that the process of moving towards multi-issue assessments was in many ways just as important as the outcomes, if only to identify and resolve the obstacles to mutual communications. There have been all too few occasions when this kind of interdisciplinary discussion has taken place.

Several specific recommendations were made:

1. Environment Canada should foster the development of frameworks that allow for the extension of single issue/single effect approaches to multi-issue/multi-effect science and policy approaches. Because the need for multi-issue air assessments is urgent, a national action plan should be developed to foster this initiative.

2. Additional and more focussed workshops are recommended to address each of the three assessment sections: a) atmospheric science; b) effects/impacts/ecosystem interactions; and c) policy response/ integration. Because air issues in Canada tend to have regional importance, it is recommended that follow-up workshops deal with the linkage of atmospheric issues in a specified geographical area. Southwestern Ontario, for example, is affected by acidic deposition, tropospheric ozone episodes, toxic pollutants and, potentially, by climate change. This pilot study should be used to evaluate as many of the integration tools as possible.

3. It is recommended that the "ecosystem approach" be adopted as the arching framework for multi-issue assessments. This approach recognizes the integral nature and self-organizing properties of ecosystems.

4. A risk assessment model should be developed which links science to the formulation of policy. A framework for such a model should include risk estimation, response assessment and post-assessment audit. In this connection, the development of methods to estimate confidence limits for the outputs of simulation models should be encouraged.

5. For each air issue, tables should be developed which would display the current and long-term effects of the atmospheric disfunction caused by that issue on each of the other air issues. Additional tables detailing the effects of each proposed strategy/policy designed to ameliorate the impacts of a single issue on the other air issues should also be developed.

**Coordinated by A. Maarouf*

6. Economics is an important factor in the search for ecological sustainability. Ecological economics, and its relationship with environmental economics, should be studied further as a method in multi-issue assessments. Economists must therefore be involved in such studies.

7. In the context of multi-issue assessments, Cumulative Environmental Assessment (CEA) might become a further useful method, but some practical case studies should be undertaken. One approach, for example could be to select some socioeconomic scenarios for the year 2025, say, and examine the consequences for the six air issues. Similarly, for each air issue separately, the effects of policies/strategies (designed to resolve that issue) could be tested on the other five air issues.

8. The Social Learning Project (Parson and Clark, 1995) may provide an appropriate integrating framework for the six air issues in some situations, and further study is encouraged.

9. An effort should be made to build a multi/inter-disciplinary community of scientists and policy analysts who can develop practical multi-issue assessment frameworks.

APPENDICES

APPENDIX A WORKSHOP PROGRAM

[All sessions held at the Ontario Institute for Studies in Education (OISE), 252 Bloor St. W., Toronto,ON.]

Monday, March 27

9:00 a.m. - 12:15 p.m. Plenary Session

Welcoming Remarks: Rodney White, Institute for Environmental Studies
"Needs and Expectations" Keith Puckett, Atmospheric Environment Service, Environment Canada

9:30 a.m. "Methods Available for Undertaking Comparative Atmospheric Assessments" R.E. Munn, Institute for Environmental Studies

10:15 a.m. "Integrated Assessments: Goals, Methods, and Challenges", Edward A. Parson, IIASA & John F. Kennedy School of Government, Harvard University

"Impacts of Elevated Levels of Carbon Dioxide, Ozone and Ultraviolet-B Radiation on Vegetation", Sagar Krupa, Department of Plant Pathology, University of Minnesota

"Complex Interactions Among Air Pollutants, Hydrology and Biology in Lake Ecosystems", P.Jefferson Curtis, University of Alberta

"Ecological Economics and the Precautionary Principle: Environmental Bonding", Laura Cornwell, Centre for Environmental & Estuarine Studies, University of Maryland

"Climate Institute's Environmental Technology Concept", Douglas Gatlin, Climate Institute, Washington.

1:30 - 5:00 p.m. Working Groups

Tuesday, March 28

9:00 a.m. Plenary Session - Reports of Rapporteurs

10:00 a.m. - 2:30 p.m. Working Groups

2:40 - 4:30 p.m. Plenary Session

Reports of Rapporteurs and General Discussion
Summary, Ian Burton, Environmental Adaptation Research Group, Atmospheric Environment Service

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