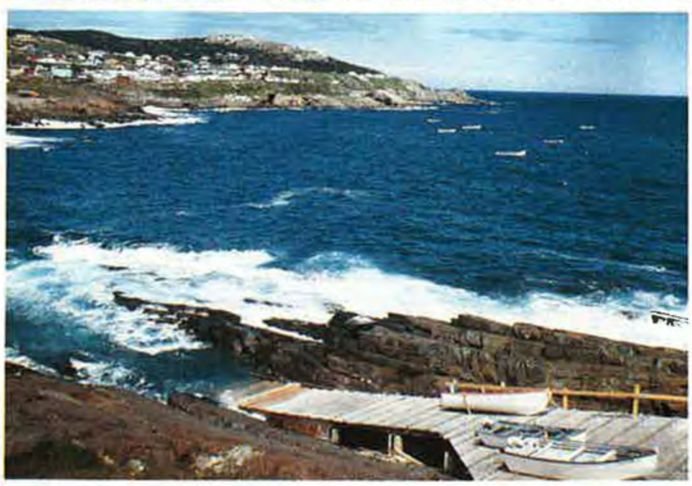
Chinook

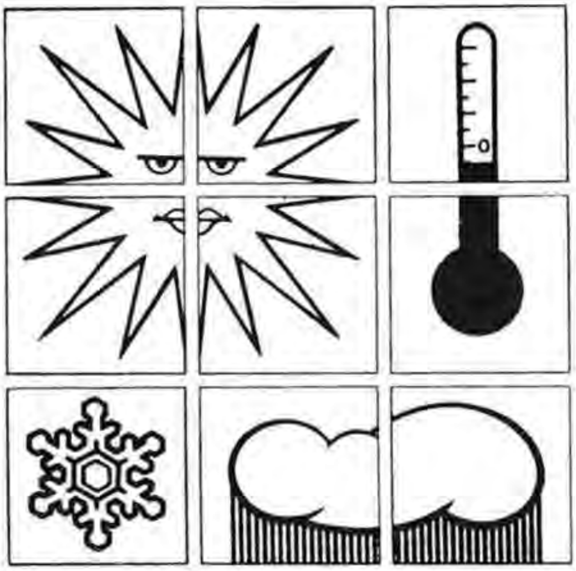
THE CANADIAN MAGAZINE OF WEATHER AND OCEANS

LA REVUE CANADIENNE DE LA MÉTÉO ET DES OCÉANS

VOL. 11 NO. 3

SUMMER/ÉTÉ 1989





Supply and Services Canada / Approvisionnements et Services Canada
Canadian Government Publishing Centre / Centre d'édition du gouvernement du Canada

Learning Weather . . .

A resource study kit suitable for students grade seven and up, prepared by the Atmospheric Environment Service of Environment Canada

Includes new revised poster-size cloud chart

Découvrons la météo . . .

Pochettes destinées aux élèves du secondaire et du collégial, préparées par le Service de l'environnement atmosphérique d'Environnement Canada

Incluant un tableau révisé descriptif des nuages

Learning Weather
A resource study kit, contains:

1. **Mapping Weather**
   A series of maps with exercises. Teaches how weather moves. Includes climatic data for 50 Canadian locations.
2. **Knowing Weather**
   Booklet discusses weather events, weather facts and folklore, measurement of weather and several student projects to study weather.
3. **Knowing Clouds**
   A cloud chart to help students identify various cloud formations.

CGPC Code: 002401

Each kit **$4.95** (Canada)
$5.95 (Outside Canada)

Découvrons la météo
Pochette documentaire comprenant:

1. **Cartographie de la météo**
   Série de cartes accompagnées d'exercices. Décrit les fluctuations du temps et fournit des données climatologiques pour 50 localités canadiennes.
2. **Apprenons à connaître la météo**
   Brochure traitant d'événements, de faits et de légendes météorologiques. Techniques de l'observation et de la prévision de la météo. Projets scolaires sur la météorologie.
3. **Apprenons à connaître les nuages**
   Tableau descriptif des nuages aidant les élèves à identifier différentes formations.

Code CÉGC: 002402

chaque pochette **4,95 $** (Canada)
5,95 $ (A l'étranger)

ORDER FORM – BON DE COMMANDE

All sales are final; prices are subject to change without notice.
Toutes les ventes sont finales; les prix sont sujets à changement sans préavis.

CGPC Code – Code CEGC	Qty – Qté	Price – Prix	Total
			$

Also available through commercial bookstores associated with CGPC or through your local bookseller.
Également disponible par l'entremise des librairies commerciales associées au CEGC ou de votre libraire.

Shipping and handling fee extra
Frais supplémentaires pour expédition et manutention:

Order Value Valeur de la commande	Fee Frais
\$00.01 to/à \$25.00	= \$1.55
\$25.01 to/à \$75.00	= \$2.25
\$75.01 to/à \$200.00	= \$4.50
Over/Plus de \$200.00	= 4% (of total order value) (de la valeur de la commande)

Ship To – Envoyer à:

Please **do not send** cash
N'envoyez pas d'argent comptant s.v.p.

(√) Cheque/Money Order (payable to the Receiver General for Canada) enclosed.
Chèque/mandat (payable à l'ordre du Receveur général du Canada) ci-inclus.

CGPC Account No.
CEGC n° de compte

VISA

MasterCard

Credit Card Expiry Date
Date d'expiration

Name of Bank – Nom de la banque

Signature

Send your order to: – Envoyer les commandes au:

Canadian Government Publishing Centre
Centre d'édition du gouvernement du Canada

Ottawa, Canada
K1A 0S9

Tel. No. – N° de tél. (819) 997-2560   Telex – Télex 053-4296

Canada

FROM THE EDITOR'S DESK

As Editor of *Chinook* I want to acknowledge the support from the Atmospheric Environment Service, and in particular Mr. Howard Ferguson, for the generous financial assistance that has made this special issue possible for our readers. We feel a sense of pride as Canadians in the role that Canada has played at *The Changing Atmosphere* conference in Toronto in June of 1988. In particular, the leadership role of Canada's Atmospheric Environment Service in the months since the conference, has been exemplary. Polls taken across Canada have noted the concern of many, to the point that the environmental issue is now number one on almost everyone's list. Not a week goes by without a major item being discussed in the media focussing on the associated politics, scientific aspects or environmental impacts.

Chinook over the past eleven years has been faithful in dealing with and highlighting those areas that impact on our total environment. We have featured articles on climate change, acid rain, air pollution, climate impacts, ocean circulations, forest fires, drought and a host of others.

These are critical times for us. The Earth is a small and precious place for us humans. This planet is also not unlimited in its ability to withstand the reckless abuse of its life-giving resources. The air, the land and the water are more than just environmental factors, they are essential for life on earth. In most cultures and spiritual traditions we read of a sense of stewardship towards this world we live in. Stewardship implies the appropriate management of the Earth's resources for all, for present *and* future generations.

The four authors contributing articles in this issue reflect this deep concern for and awareness about current environmental problems. There is an urgency in their message to us. For *Chinook*, it is indeed an honour to be a vehicle for this most urgent message.

Furthermore, we have been authorized to reproduce part of the Conference Statement. These are noble goals and objectives. They can only be achieved if we, as concerned and informed citizens, support those who on our behalf bring about legislation and international agreements that make this planet a more "environmentally friendly" place to live in.

We finally acknowledge the kind co-operation of the Atmospheric Environment Service of Environment Canada, and the World Meteorological Organization, which has published the entire proceedings of the Toronto Conference.

Hans VanLeeuwen

Chinook

Summer / Été 1989 Vol. 11 No. 3

EDITORIAL BOARD / CONSEIL DE RÉDACTION

Barry Grace
Agriculture Canada Research Branch
Lethbridge, Alberta

Yves Gratton
Université du Québec à Rimouski
Rimouski, Québec

Paul H. LeBlond
The University of British Columbia
Vancouver, British Columbia

Richard Leduc
Ministère de l'environnement
Québec, Québec

John W. Loder
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

John Maybank
Saskatchewan Research Council
Saskatoon, Saskatchewan

David W. Phillips
Atmospheric Environment Service
Downsview, Ontario

Jerry Salloum
George S. Henry Academy
City of North York, Ontario

Hans VanLeeuwen (Chairman)
Pickering, Ontario

EDITOR Hans VanLeeuwen RÉDACTEUR
TECHNICAL EDITOR Edward J. Truhlar RÉDACTION TECHNIQUE
BUSINESS MANAGER J. Carr McLeod GESTIONNAIRE
ART WORK Bill Kiely / Joan Badger ILLUSTRATION
TRANSLATION Joanne Gagnon Pacini / Gilles Tardif TRADUCTION
FOUNDER AND EDITOR 1978–1984 Michael J. Newark FONDATEUR ÉDITEUR 1978–1984
ISSN 0705-4572

Published by:
Canadian Meteorological and Oceanographic Society

Publié par:
La Société canadienne de météorologie et d'océanographie

Printed and produced in Canada and published quarterly by the Canadian Meteorological and Oceanographic Society, P.O. Box 334, Newmarket, Ont. L3Y 4X7, Tel.: (416) 898-1040. Contents copyright © the authors 1989. Copying done for other than personal or internal reference use without the expressed permission of the CMOS is prohibited. All correspondence including requests for special permission or bulk orders should be addressed to *Chinook* at the above address.

Edité et imprimé au Canada. *Chinook* est publié tous les trois mois par la Société canadienne de météorologie et d'océanographie, C.P. 334, Newmarket, Ont. L3Y 4X7, Tél.: (416) 898-1040. Les auteurs détiennent le droit exclusif d'exploiter leur oeuvre littéraire (© 1989). Toute reproduction, sauf pour usage personnel ou consultation interne, est interdite sans la permission explicite de la SCMO. Toute correspondance doit être envoyée au *Chinook* à l'adresse ci-dessus, y compris les demandes de permission spéciale et les commandes en gros.

Second Class Mail Registration No. 4508
Summer 1989 Date of issue – November 1990

Courrier de deuxième classe – enregistrement n° 4508
Été 1989 Date de parution – novembre 1990

COVER

Climate change will no doubt affect the way we relate to the land and sea. Climate change will thus impact on our agricultural practices, the ability to sustain horticulture, the habitation along our sea shores, and the management of our vast forests.

COUVERTURE

Le changement climatique aura sans aucun doute des effets sur l'interaction humanité-terre-océan. Il y aura des répercussions sur les méthodes agricoles, sur la facilité de maintenir l'horticulture, sur le peuplement le long des rives océaniques et sur l'exploitation de nos vastes forêts.

THE CHANGING ATMOSPHERE

The composition of the earth's atmosphere is undergoing a major global change. Human activities, such as air pollution, deforestation, the burning of fossil fuels, and even agricultural practices are now altering the delicate balance of gases in our atmosphere. The consequences are likely to be unprecedented in human history and global in extent. Scientists are predicting major changes in world climate, including rising sea levels, and shifts in rainfall patterns. The chemicals we have added to the atmosphere are contributing to health problems in urban areas, damaging lakes and forests, threatening the earth's ozone layer, and contaminating even the most remote areas of the earth.

The atmosphere provides us with much more than the air we breathe. This fragile skin of gases, less than 100 km thick, is a vital part of the basic life support system of our planet. Indeed, without the atmosphere, the earth would be as cold and barren as the surface of the moon. The atmosphere contains a protective ozone layer that shields us from the damaging rays of the sun, and provides a natural greenhouse effect, which warms the planet's surface. It also acts as a huge gaseous reservoir, which stores both natural and industrial chemicals. The atmosphere's wind and weather systems shape the earth's climate. Its shifting winds also carry airborne chemicals long distances, creating pathways for pollutants even to extremely isolated areas.

THE OZONE LAYER

The ozone layer acts as the earth's fragile sun-screen – a layer of gases in the upper atmosphere that filters out the ultraviolet rays of the sun. These rays can cause skin cancer, reduce crop yields and damage aquatic life. Serious depletion of the ozone layer could affect most life on earth.

In recent years, scientific attention has focused on ominous changes in the earth's fragile shield. Over the past decade, the global ozone layer appears to have been slowly depleting. In addition, a large hole has developed over the Antarctic during the spring. This hole has been growing steadily larger, with a 50% loss of ozone over the past ten years. Recently a similar, but smaller, hole has also been observed over the Arctic. However, it is not yet known if this hole is also growing.

Increasing evidence now points to changes in the chemical composition of the atmosphere as the root cause of these ozone depletions. Industrial chemicals, particularly CFCs (chlorofluorocarbons), are a major threat to the ozone layer. Scientists are concerned that these chemicals have now reached the upper atmosphere where they are capable of readily destroying ozone.

THE GREENHOUSE EFFECT

The earth is warmed by a natural greenhouse effect. Certain gases in the atmosphere, such as carbon dioxide, trap heat from the sun much like the glass in a greenhouse. Human activities have significantly increased the amount of carbon dioxide and other "greenhouse gases" in the atmosphere.

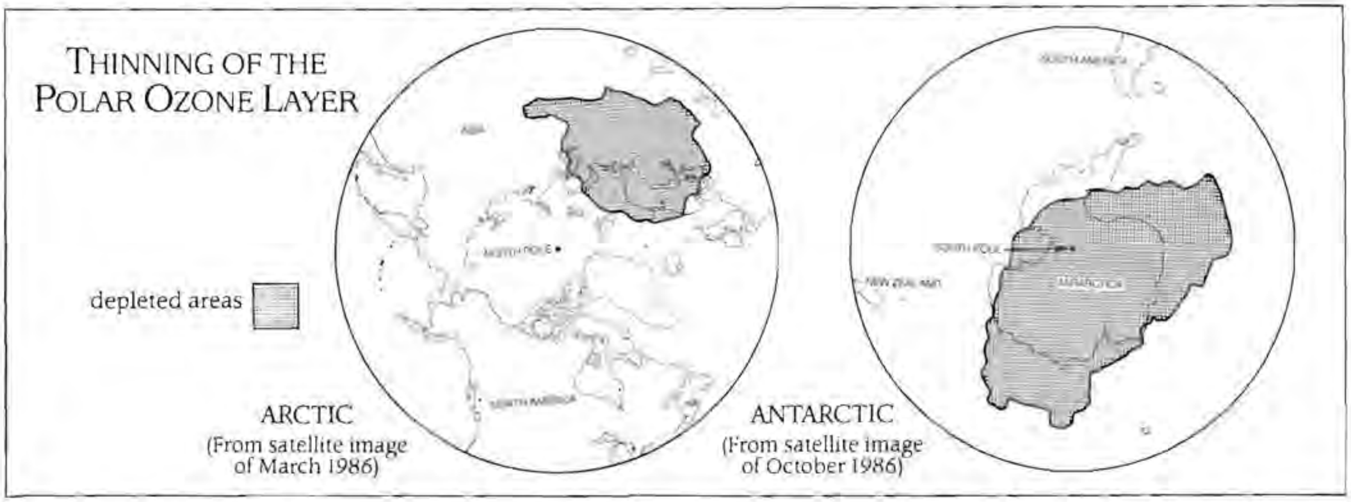
The increase in carbon dioxide began over 200 years ago, as technology developed and our thirst for energy accelerated. The burning of fossil fuels – first coal and then later oil and gas – unleashed massive amounts of carbon dioxide into the atmosphere. At present the burning of fossil fuels releases close to 5 billion tonnes of carbon, in the form of carbon dioxide gas, into the atmosphere each year. (See the article on page 62.)

Massive clearing of forests, particularly in the tropics, has also taken a toll on the atmosphere. At present, about 7 million hectares, or 0.6% of the tropical rainforests are felled each year. Much of this land is cleared by burning, which can release up to 2 billion tonnes of carbon into the atmosphere during a year. Since trees absorb carbon dioxide while they grow, the loss of vast tracts of forest also means less carbon dioxide will be removed from the atmosphere.

Scientists estimate that levels of carbon dioxide in the atmosphere have increased by about 25% over the past 200 years.

Agricultural practices over the past century have brought further changes. Nitrogen in chemical fertilizers, and methane gas produced by rice paddies and grazing livestock are contributing to the greenhouse effect. Methane in the atmosphere has now doubled over pre-industrial levels. Certain industrial chemicals, most notably CFCs, also act as greenhouse gases.

These gases are expected to enhance the natural green-



In recent years, large thin areas have been observed in the ozone layer over the earth's poles.

house effect and substantially alter global climate within the next 50 years. Global temperatures are predicted to rise, causing changes in rainfall patterns and a rise in world sea levels. This could result in flooding of coastal areas, and increased drought in mid-latitude grain belts. Major social and economic impacts are anticipated, including disruption of global food supplies. However, cold northern countries, such as Canada, could receive some benefit from a warmer climate.

URBAN AIR POLLUTION

In many cases, local contamination of the atmosphere is worst in urban areas, where human activities are concentrated. Urban areas rely heavily on the burning of fossil fuels for electrical power generation, transportation and industrial activities. This releases large amounts of pollutants into the air, including compounds of sulphur and nitrogen, which can form acid rain. In urban areas, these chemicals can affect human health and damage buildings. They also move with the weather systems, turning the rain to acid, damaging lakes and threatening forests.

The motor vehicle is a major contributor to urban smog, releasing lead, carbon monoxide, nitrogen dioxide and other chemicals into the air. Vehicle exhaust and gasoline fumes combine with other air pollutants to form ozone. In the earth's upper atmosphere, ozone forms a vital shield against the sun's damaging rays. However, at ground level, ozone is a highly corrosive air pollutant that can be a threat to vegetation and human health. Ground-level ozone has been known to cause serious damage to crops, even at long distances from urban areas.

Toxic air pollutants, such as PCBs and dioxins, are also produced by a variety of urban sources, such as waste incineration and industrial activities.

The atmosphere plays a major role in the severity of urban air pollution. Strong winds can move pollutants away from cities. (Although this makes urban air more breathable, it merely shifts the problem from one area to another.)

Urban smog is at its heaviest on hot sunny days. Ground-level ozone, which is a major ingredient of smog, is formed when air pollutants react together in the presence of sunlight. On hot, windless days smog builds up over urban areas. A cap of warm air can develop over the slightly cooler polluted air, trapping it close to the ground. Known as a "temperature inversion", this effect can concentrate pollutants to dangerous levels, affecting human health.

A CHEMICAL STOREHOUSE

The atmosphere also acts as a huge storehouse for airborne chemicals. Certain chemicals that are very stable and do not react readily with other substances can remain in the atmosphere for very long periods of time. These include most of the gases that are threatening the ozone layer and contributing to the greenhouse effect. For example, certain CFCs can remain in the atmosphere for more than 100 years.

Natural substances that remain in the atmosphere for lengthy periods are kept in balance by the earth's natural systems. For example, large amounts of carbon dioxide can be absorbed by vegetation and the oceans. However, the recent buildup of carbon dioxide in the atmosphere indicates that we are exceeding the rate at which the environment can correct this imbalance. Many industrial chemicals, such as certain CFCs, have no natural balancing systems and thus tend to build up quickly in the atmosphere.

Other types of chemicals do not last long in the atmospheric storehouse. These substances break down readily and react with other gases in the atmosphere. In some cases, this process produces new compounds that may be even more environmentally damaging than the original chemicals. Sulphur dioxide and nitrogen oxides react with water vapour to form acid rain, and automobile exhaust gases react with other pollutants to form ground-level ozone. Urban air has become such a complex mix of chemicals that it is often difficult to predict exactly what will happen to a new chemical when it is released into the atmosphere.

Scientists prepare a research balloon to probe the ozone layer.

CHEMICALS ON THE MOVE

The atmosphere produces the complex pattern of winds and weather that traverse the globe. Airborne chemicals, both gases and fine particles, can be carried vast distances by these weather systems.

Pesticides, for example, have been found in the snows of the Antarctic, whereas PCBs have been carried even to the most remote islands in the Pacific Ocean.

A recent accident in the U.S.S.R. dramatically illustrated how the atmosphere can rapidly transform a single release of pollutants into a global concern. In April 1986, a fire in a nuclear reactor in Chernobyl released large amounts of radioactive material into the atmosphere. In 7 days, traces of this radioactivity had reached Canada, and, within 11 days, had circled the globe.

The chemicals that form acid rain and ground-level ozone can also travel long distances downwind, causing environmental damage hundreds of kilometres from their source. Scientists now suspect that both ozone and acid rain are contributing to the serious decline of forests throughout northeastern North America.

By studying global wind and weather patterns, scientists can often explain the movement of air pollutants and why they collect in certain areas at certain times of the year.

This effect is clearly seen in the Arctic, where the barren winter tundra is often cloaked in a brownish yellow haze. The haze is formed of particles of soot, sulphur compounds and other chemicals normally found in urban smog. Scientists have tracked these pollutants and found them to have originated in the cities and industrial areas of the U.S.S.R., Europe and North America.

These pollutants are carried northward by the weather systems until they reach the large pool of cold air that develops over the Arctic during the winter. Pollution tends to collect in this cold air, where there is little air movement or precipitation to remove it. Over the winter a visible haze can develop, which disperses in the spring when the cold air mass breaks up.

CHEMICALS IN THE ATMOSPHERE

	Chemicals	Sources	Impacts	Lifetime in Atmosphere
Urban Smog and Arctic Haze	• soot • metals (e.g., lead) • ground-level ozone • nitrogen oxides (NO_x)	• burning of fossil fuels and wood • industry • automobile emissions	• reduced visibility • respiratory problems • crop damage	• days to months
Acid Rain	• sulphur dioxide (SO_2) • nitrogen oxides (NO_x)	• burning of fossil fuels • metal smelters	• acidification of lakes • damage to buildings • damage to soils, forests and crops	• days to months
Toxic Chemicals	• dioxins and furans • heavy metal (e.g., lead) • PAHs (polycyclic aromatic hydrocarbons) PCBs (polychlorinated biphenyls) • pesticides	• burning of fossil fuels • waste incineration • industry • landfills • mining • automobile emissions • forestry/agricultural sprays	• potential health problems • contamination of water, soils, plants and food supplies	• decades to centuries
Ozone Depletion	• CFCs (cholorofluorocarbons) • halons	• refrigeration • manufacturing of foam products • spray cans • solvents • fire extinguishers	• potential health problems • crop damage • damage to aquatic life	• 100 years
Greenhouse Effect	• carbon dioxide (CO_2) • CFCs (chlorofluorocarbons) • methane • ground-level ozone • nitrous oxide (N_2O)	• burning of fossil fuels • industry • agriculture	• potential change in global climate	• centuries
Radioactivity	• radionuclides	• nuclear power generation • accidents • mining and industrial releases and wastes • nuclear arms testing	• potential health problems • contamination of water, soils, plants and food supplies	• millenia

KEEPING TABS ON THE ATMOSPHERE

Research scientists around the world are now working to track changes in the earth's atmosphere. Networks of measuring stations have been set up to monitor the ozone layer and global air pollution. These are being co-ordinated by the World Meteorological Organization (WMO), the United Nations agency that oversees the collection of global weather information.

Canada plays a major role in the ozone network, by maintaining five permanent ozone-measuring stations and operating the World Ozone Data Centre. For over 20 years, this centre has collected data from the global network and distributed it to the world's scientists. Such information is essential for understanding long-term changes in the ozone layer.

Scientists are also tracking the thinning of the ozone layer over the earth's polar regions. Research teams from the United States, Great Britain and Japan have set up measuring sites in Antarctica, whereas Canadian scientists are concentrating on the Arctic. The ozone layer is probed with high-altitude balloons, rockets, aircraft, and satellites, as well as ground-based instruments. Canada has developed a unique state-of-the-art ground-based ozone-measuring instrument, known as the Brewer Ozone Spectrophotometer. This new instrument has proved to be the world's most accurate ozone-measuring device, and is now being used to upgrade the global network.

The global air pollution network is designed to measure the general level of pollutants in the atmosphere (known as the "background" level), rather than the higher levels that would be found near urban and industrial areas. Thus the measuring stations for this network are located in very remote areas. Canada's most sophisticated site in this network is at Alert, on Ellesmere Island, at the most northerly tip of the Canadian Arctic. Our nation maintains three monitoring sites, including Alert, to measure greenhouse gases, as well as 23 stations to study acid rain and related pollutants.

Canada has recently set up a new type of measuring station to study CFCs (one of the greenhouse gases) in Saskatoon. This station actually measures the extra heat released into the atmosphere by these chemicals. Scientists are now considering expanding this type of measuring system into a wider network.

Canada is also involved in the study of the movement of air pollution across national boundaries. Research in the Arctic has shown that pollution in this region can originate in the U.S.S.R. and Europe. Scientists are now able to determine the source of polluted air by studying its chemical composition. For example, research has shown that the country of origin for airborne lead can be traced while the metal is being mined from different ore bodies.

Scientists are now only beginning to understand the complexities of the global atmosphere. Canada is working in cooperation with scientists around the world to increase our ability to understand and predict changes in the atmosphere. The atmosphere is truly a global concern and can be dealt with only through global understanding and action.

IN CONVERSATION

Chinook took the opportunity to further explore the problems addressed in this issue. In particular, we were interested in an updated view on the topics since the Conference on The Changing Atmosphere. We were pleased that Dr. Kirk Dawson, the Director General of the Canadian Climate Centre of the Atmospheric Environment Service, was willing to be available to answer our questions.

H.V. – *Rosemary Speirs, in a feature in the* 'Toronto Star' *of February 21, 1989, focussed on the three-day Conference on the Protection of the Atmosphere, held in Ottawa, makes reference to the presentation of Howard Ferguson [Assistant Deputy Minister, Atmospheric Environment Service] at that conference. She notes that he "argued that all atmosphere pollution problems are linked – that ozone-depleting gases (chlorofluorocarbons) also are greenhouse gases which contribute to climate warming, as do the acid chemicals which create acid rain – and that real action means tackling the world's use of fossil fuels as the main source of energy." Could you please elaborate on this?*

K.D. – The combustion of fossil fuels, particularly coal, is a primary source of a variety of atmospheric pollutants that cause environmental damage. It represents the principal source of global CO_2 emissions. It also produces large quantities of SO_x and, through internal combustion engines, NO_x, both of which are precursors of acid rain. Ozone in the lower atmosphere, where it is toxic to both humans and vegetation and behaves as a greenhouse gas, likewise is a by-product of the combustion of hydrocarbons by vehicles. Methane, another greenhouse gas, is released in large quantities during the extraction and processing of fossil fuels. Nitrous oxide, also a by-product of coal combustion, is both a greenhouse gas and a destroyer of atmospheric ozone. Furthermore, we find that the impacts of an environmental problem such as acid rain will depend on stresses caused by other problems such as increased UV radiation or drier climates. Hence the contention that the issues are very much interlinked and that in taking action to resolve one problem we do not create or aggravate another. Reducing the consumption of fossil fuels seems to be one solution that appears to simultaneously reduce almost all of the emissions of atmospheric pollutants.

H.V. – *In the* 'Toronto Star' *of February 23, 1989 (page A8), Allan Beezley, special adviser to External Affairs Minister Joe Clark, is quoted as conceding that "progress in protecting the atmosphere is 'painfully slow'". In your view what can ordinary citizens do in order to speed up this process? This is a common question, "What can we do?" What for instance can environmental groups do to assist and facilitate this process?*

K.D. – One of the most important responses of individual citizens is to encourage their political representatives at all levels of government to take appropriate action. In so doing, they must also indicate a willingness to accept the implications of the policy changes that may result.

Many of the actions required to reduce the emission of pollutants begins with the individual – learning to be less wasteful and more environmentally aware in what we buy and do is, perhaps, the single most important action that can be taken at this time. It is the individual who is ultimately the "earthkeeper".

Environmental groups also have an important role to play in helping to educate the public about these issues and leading the citizen response, both as representatives in formal discussions with politicians and as advisors on action at the household level.

H.V. – *During the past six months we have noticed in the media, what appears to be, conflicting reports from the world scientific communities regarding the amount of warming, whether or not this trend will indeed continue, how much warming we might expect in the next several decades, what the impacts may be, where we will likely be hit hardest, what the role of the ozone layer is and the causes and existence of the "holes" over the two poles. How sure are we that indeed there is something to worry about?*

K.D. – The scientific community is virtually unanimous in its conviction that people and their activities are changing the natural planetary systems that control the global ecosystems. These changes have been carefully measured over a significant period and in many respects are of a magnitude without precedence in the last hundred thousand years. Theories on the role of ozone in filtering out damaging ultraviolet radiation, and of greenhouse gases in providing a livable climate on Earth are also solidly supported by scientific evidence and are generally well accepted. Uncertainty enters as a major factor when we begin to discuss the rate and magnitudes of future global change, and exactly how such changes will affect regional environments and individuals. While we feel quite certain about the probability of large and dramatic global changes in the future, we cannot as yet describe the details of the changes with confidence. This uncertainty is, in fact, a major reason for worry in itself, since it hinders us in preparing for the changes to which we have already committed ourselves through past actions.

H.V. – *From your perspective, and many years of experience, what role could, and should, educational institutions play in preparing the new generations for this, what appears to be, a drastic change in our environment?*

K.D. – A well informed public is critical in pursuing responsible action. We can neither afford blind ignorance, which promotes inaction, or incapacitating hysteria, which leads to chaotic and poorly reasoned responses. Hence wise decisions will demand good understanding not only by scientists, but by politicians, industrialists, economists and consumers. I believe educational institutions have both a unique opportunity and a responsibility in helping not only the new generations, but also current generations, in achieving that understanding and preparing to anticipate, adapt to and help prevent these problems. The Toronto Conference, in fact, made that point very clearly.

H.V. – *From time to time we hear people speak of "sustainable development". Could you explain what is meant by this?*

K.D. – The term "sustainable development" was popularized by the World Commission on Environment and Development, which in 1987 submitted a comprehensive report on the relationship between economic development and environment to the UN General Assembly. It implies economic development that can be sustained while protecting the very environment that makes such development possible. Development that destroys the environment is ultimately "unsustainable" and hence self-destructive. Although the term in some respects appears contradictory, since in many cases the protection of the environment may demand cessation of development, it has been very useful in stressing the intricate relationship between the two objectives. Perhaps in the final analysis, terms such as "stewardship" or "earthkeeping" may better describe the "in trust" relationship humans must maintain with respect to the global ecosystem.

H.V. – *From a Canadian perspective, what has been our contribution on the international scene in bringing about some resolution to this global problem?*

K.D. – Canada has emerged as a leader in pushing for international action to protect the atmosphere. In addition to hosting the pivotal World Conference on the Changing Atmosphere in Toronto, it has convened a subsequent meeting of legal experts to explore the possible framework of a global Convention to Protect the Atmosphere, and has offered to host a major UN environmental conference in 1992. Past actions on acid rain and ozone depletion issues also attest to this leadership role. Currently, Canadians are playing key roles in the deliberations of the Intergovernmental Panel on Climate Change, which will report to the UN General Assembly in the next few years on the greenhouse warming issue and will advise it and its member nations on strategies to deal with the problems. However, given the two centuries and more that it has taken to create these problems, and the complexity of response strategies, solutions will not emerge overnight and we will need patience and perseverance in our efforts.

SAFEGUARDING THE GLOBAL ATMOSPHERE

In December 1952, a dense blanket of smog hung over London, England, for five days. At that time, low-grade coal was widely used for heating and industrial activity. Calm weather conditions caused a heavy layer of soot, sulphur dioxide and other air pollutants to build up over the city. When the thick smog finally lifted, over 4,000 people had died prematurely, and the rate of respiratory illness had doubled.

The London smog was not the first incident of its kind – other similar events had occurred in Europe and the United States – but it was among the most severe. These events clearly demonstrated that the atmosphere was not capable of absorbing limitless pollution, and brought the first major steps to control air pollution.

At first, contamination of the atmosphere was seen as only a local problem and was dealt with on the scale of individual cities. During the late 1970s, it was recognized that pollutants, such as the chemicals that form acid rain, could travel long distances downwind, crossing national boundaries and threatening lakes and forests in their path. Today, there is a widespread awareness that contamination of the atmosphere is not occurring merely over urban areas, or across national boundaries, but on a global scale.

In the wake of this growing awareness, action to protect the atmosphere has developed from a focus on local problems to controls that are international and even global in scope.

CONTROLLING URBAN AIR POLLUTION

We have made considerable progress since the damaging smogs of the 1940s and 1950s. Although problem areas still exist, improvements in urban air quality have been achieved around the globe.

In many countries, air pollution was first viewed as a threat to human health, and action to improve air quality was led by health departments. In Canada, the federal Health and Welfare department established the Air Pollution Control Division in 1969. Two years later, this division was transferred to the newly created department of the Environment.

In 1971, Canada passed the Clean Air Act, which has succeeded in substantially reducing urban air pollution. Over a 10-year period, from 1974 to 1984, levels of sulphur dioxide, carbon monoxide, nitrogen dioxide, lead and soot have been reduced by 23 to 66%. Canadian air pollution standards are now among the most stringent in the world.

CONTROLLING ACID RAIN

During the late 1970s, countries that were attempting to clean up their own environments were becoming increasingly frustrated with pollutants that were blowing in from neighbouring nations. They saw first hand the futility of a single nation taking action without the cooperation of its neighbours. The situation was particularly serious among the nations in Europe and North America where acid rain was becoming a major concern.

Before any action could be taken, it was first necessary to prove that air pollutants did indeed move between nations. Scandinavia, becoming increasingly alarmed over the acidification of its lakes, pressed for increased research efforts. Work sponsored by the Organization for Economic Cooperation and Development (OECD), a group of western industrial nations, was among the first to document transboundary air pollution.

In 1985, Canada and Europe signed an agreement to reduce the pollutants that cause acid rain by 30%.

Once scientific evidence had been collected, the problem was presented to the United Nations Economic Commission for Europe, one of the U.N.'s regional economic bodies, which includes eastern and western Europe, Canada and the United States. The Commission developed the first international air pollution control agreement, – the 1979 Convention on Long-Range Transboundary Air Pollution. The accord was signed in Geneva by 34 member nations, including Canada, and the United States. The Convention provided for international cooperative research and the monitoring of transboundary air pollution (including acid rain) – but no specific pollution controls. It did, however, establish a framework for future cooperative international action to reduce acid rain.

Six years of difficult international negotiations followed, finally resulting in an agreement, reached in 1985, to reduce sulphur dioxide (a major component of acid rain), by at least 30% by 1993. This marked an unprecedented show of international cooperation, with 21 countries, including Canada, signing the accord in Helsinki. The agreement was added as a protocol to the 1979 Convention. Of the major producers of sulphur dioxide (SO_2), only the U.S.A., the U.K. and Poland have not signed the protocol.

Canada, which played a major role in the development of the Helsinki protocol, already had an active program to reduce SO_2 and is working towards a reduction of 50% by 1994. All of Canada's eastern provinces (the major producers of SO_2), have now signed agreements pledging their commitment to this national goal.

Steps are now being taken to control the second major component of acid rain: nitrogen oxides (NO_x). In 1986, the United Nations Economic Commission for Europe began international negotiations to reduce NO_x). Both Canada and the United States already have stringent controls on the major source of this pollutant – motor vehicle exhaust. New vehicles in North America must be equipped with catalytic converters to reduce pollution, making them much cleaner than new vehicles in most of Europe.

Since NO_x levels are 2–10 times higher in Europe than in Canada, agreement by all nations to reduce this pollutant by a certain percentage (like the 30% reduction in SO_2) would not be the most effective approach. Instead, the United Nations has now accepted a proposal by Canada that controls for NO_x be based on the degree of environmental damage.

PROTECTING THE OZONE LAYER

The depletion of the ozone layer was the first atmospheric problem to be tackled on a global scale. Under the United Nations Environment Program (UNEP), a general statement of principles was first laid out, in much the same way that acid rain was tackled. The 1985 Vienna Convention for the Protection of the Ozone Layer established a framework to protect the earth's upper atmosphere through cooperative international efforts. It also provided for international cooperation in scientific research and information exchange, but again no specific pollution controls. Canada signed the agreement in 1985 and was the first nation to formally ratify it in June 1986. To date, 28 countries have signed the convention.

However, concern over the ozone layer was rising rapidly, spurred by reports of a large hole in the ozone over the Antarctic and the apparent steady loss of global ozone. Scientific evidence pointed strongly to CFCs, a group of industrial chemicals, as the major threat. Individual countries had already taken action against CFCs. In 1980, Canada banned these chemicals in most spray cans, resulting in a 45% reduction in national use. Similar bans were undertaken in the United States and Nordic countries. Europe followed suit with less restrictive regulations.

Yet clearly, global action was needed. In September 1987, after five years of international negotiations, an agreement to control CFCs was signed in Montréal, and added as a protocol to the Vienna Convention. To date, 31 nations have pledged to reduce the use of these chemicals by 50% by 1999. Controls were placed, not only on CFCs, but on other ozone-destroying chemicals as well. These include halons, a group of chemicals used in fire extinguishers, which are up to 10 times more destructive to ozone than CFCs.

The agreement, known as the Montréal Protocol, is the first accord of its kind and sets a global precedent for the safeguarding of the atmosphere. It differs in several important ways from the Helsinki accord on acid rain. It controls chemicals that are deliberately manufactured and have major commercial uses, unlike SO_2, which is normally produced as an industrial waste product. Because of the commercial value of CFCs, international trading practices had to be considered. As a result, strong trade sanctions against non-participating countries were included in the protocol. These will encourage other nations to sign both the protocol and the convention. The Montréal Protocol also set an important precedent for dealing with the uncertainties involved in protecting the changing atmosphere. The earth's atmosphere is an extremely complex system that is not yet fully understood. For this reason, a provision was included in the protocol to review scientific findings on the ozone layer every four years and to accelerate the reduction of ozone-destroying chemicals if necessary.

Canada played a key role in the development of both the Vienna Convention for the Protection of the Ozone Layer and the Montréal Protocol. Our nation was an active participant throughout the lengthy negotiations to develop these agreements and acted as the host nation for the final signing of the protocol.

The Montréal Protocol is a major environmental landmark. It sets out a formula whereby nations can work together to prevent an environmental problem before it reaches the crisis stage, and is now being used as a global model for continued world-wide cooperation to protect the atmosphere.

CONTROLLING THE GREENHOUSE EFFECT

Global attention focused on the greenhouse effect in 1985 when scientists at an international conference in Villach, Austria, issued a statement that changes in world climate, caused by the greenhouse effect, now "appeared inevitable". This marked the first global scientific consensus on this issue. Scientists issued a strong call to action, urging immediate reductions in the gases that are contributing to the greenhouse effect.

Carbon dioxide (CO_2), produced by the burning of fossil fuels, is the prime contributor to the greenhouse effect. Reducing CO_2 will mean changes in the way we use and produce energy. Some nations, including Canada, have already taken steps towards improving energy conservation, and are now considering how CO_2 and other greenhouse gases can be controlled on a global scale.

The 1987 Montréal Protocol, although developed primarily to protect the ozone layer, also represents the first global agreement to control a greenhouse gas. CFCs, the major chemical group to be controlled by the protocol, are not only a serious threat to the ozone layer, but also a contributor to the greenhouse effect. Although the protocol focuses on chemicals that threaten the ozone layer, there is also a sensitivity not to replace ozone-depleting CFCs with substances that will have a major impact as greenhouse gases.

However, despite such actions, leading scientists are still predicting that some global warming is now inevitable. Major social and economic impacts are anticipated. Along with working to reduce the greenhouse gases, we must also improve our ability to predict global warming, and plan to adapt to a changing climate.

Canada has become a world leader in its studies of the potential impact of global warming. The Canadian Climate Program, initiated by Environment Canada, combines the expertise of government, industry and universities to learn more about the greenhouse effect and its implications for society. The results of this program are currently being published in the Canadian Climate Digest, a series of reports describing potential impacts on the most vulnerable areas of Canada. Careful planning for the future should allow us to reduce the impacts and capitalize on the benefits that a new climate may bring.

THE CHALLENGE AHEAD

The atmosphere is much more than the sum of its parts. Scientists are becoming increasingly aware that the earth's skin of gases must be treated as an integrated whole. Many

Canadian delegates in Montréal at the signing of a global accord to reduce pollutants threatening the ozone layer.

changes in the atmosphere can no longer be treated as separate issues. Changes in the ozone layer can affect world climate, whereas certain "greenhouse gases" can also alter the ozone layer and contribute to urban air pollution. Since many atmospheric problems have common origins, they may also have common solutions.

Clearly, a more integrated approach is needed to solve the problems of our atmosphere. We must strive for wider-ranging, more comprehensive laws to protect the atmosphere as a whole. Existing and future global agreements could form part of a new Law of the Atmosphere.

WHAT PRICE THE SKY?
The Message of the World Commission on Environment and Development

In our headlong rush for development, we have largely overlooked the environment and the vital role that it plays in our economy. This was one of the major messages of the United Nations World Commission on Environment and Development, established in 1983 under the direction of Mrs. Gro Brundtland, then Environment Minister of Norway. In its 1987 report, "Our Common Future", the Brundtland Commission stated that economic development was not sustainable in the long term if it degraded the environment.

The Commission emphasized that those portions of the environment that are commonly shared between nations, such as the atmosphere and the oceans, are particularly vulnerable. Known as the "global commons", these parts of the natural environment fall outside the jurisdiction of individual nations and tend to be undervalued, overused and abused. The commission stressed that an economic value must be placed on the global commons and that this value must be included in the cost of economic development.

How would this value be calculated? Environment Canada has commissioned studies of the economic impact of the greenhouse effect on vulnerable regions of Canada. Preliminary results already show major economic impacts. Changes in rainfall patterns are predicted to increase drought in the Canadian Prairies. An extreme drought is estimated to cause a loss of $3.4 billion a year to the economy of Saskatchewan alone. On a global basis, costs would be much higher. For example, one study showed a cost of up to $300 billion for damage to coastlines due to a rise in world sea levels.

The Brundtland Commission also recognized the close link between the production of energy and the environment. The study pointed out that "choosing an energy strategy inevitably means choosing an environmental strategy". This is particularly true for the atmosphere, where so many problems, such as the greenhouse effect, acid rain and much urban pollution, are caused by the burning of fossil fuels.

To date, much of the emphasis on environmental protection has been on reacting to a problem after it has occurred. The Brundtland Commission encouraged nations to anticipate environmental problems and to work towards preventing them before they occur. This approach is far less costly to the economy in the long term.

The Commission emphasized that we must take action now, despite the high cost of reducing atmospheric contamination, because "if we procrastinate, effective action may be beyond the capacity of future generations."

The link between the environment and the economy is starting to be recognized by international institutes. It is significant that the first international air pollution controls were developed by the Economic Commission for Europe. The World Bank is now considering the environmental impact of the large development projects that it funds. The Canadian International Development Agency is committed to assisting projects in developing countries that foster sound environmental practices, and to ensuring that its projects are subject to rigorous environmental scrutiny.

Canada played a prominent role in the Brundtland Commission and acted as host for its fifth meeting in 1986. As a follow-up, Canada launched its own National Task Force on Environment and Economy that same year. Under the direction of the Canadian Council of Resource and Environment Ministers, the task force developed a series of recommendations to integrate environmental factors into economic decision-making on a national scale.

OUR COMMON FUTURE – A CLIMATE FOR CHANGE

The Honourable Gro Harlem Brundtland
Prime Minister of Norway

As we near the end of the twentieth century, humanity faces a crucial question: Will we devote our abilities, our energy, and our efforts to further short-term material well-being, or will we commit ourselves to enhancing life on planet earth? Many of us are convinced what our choice should be. Millions more will have to follow.

"Our Common Future", the report of the World Commission on Environment and Development is the political consensus of commissioners from 21 countries. Through a broad process of experience, learning and debate we arrived at a common analysis of the global issues we all face.

Canada was one of the Commission's midwives, one of its strongest political supporters. Few other countries have contributed so greatly to the report as Canada; Commissioner Maurice Strong and the Commission's Secretary General Jim MacNeill brought all their vast experience, dedication and knowledge and helped decisively to forge "Our Common Future", its analysis and its call for action. And Canada reacted most strongly and positively to our report, not least by establishing the Task Force on Environment and Economy, a unique body in modern policy-making.

It is therefore with a sense of profound gratitude that I have come to Canada to address this conference, which could prove to be one of the most important conferences of the 1980s. I thank the Canadian people and institutions who supported us. I thank the Canadian government, in particular Prime Minister Mulroney and Minister of the Environment McMillan for their commitment and for the example they have been setting for other industrialized countries.

Our Common Future has analysed the threats to environment and to development. And our analysis is clear. Present trends and policies cannot continue. They will destroy the resource base on which we all depend.

Poverty continues to tie hundreds of millions of people to an existence that cannot be reconciled with human dignity and the need for solidarity. And in a world where poverty is endemic, the environment and natural resources will always be prone to overuse and degradation.

Many of the threats to the environment are truly global in scale and raise crucial questions of planetary survival. The complexity, the magnitude and the apparent irreversibility of these trends surpass all previous conceptions.

Our Commission found that there is no contradiction between environment and development. Environmental degradation and the unequal distribution of wealth and power are different aspects of the same set of problems.

Changes must be made if disastrous mistakes are to be avoided, but we also believe that it is possible to make these changes. Human resources, knowledge and capabilities have never been greater. We have the power to create a future that is more prosperous, more just and more secure for all.

The time has come to start the process of change. We in the North have a special responsibility. For too long have we neglected that we have been playing lethal games with vital life-support systems.

- For too long we have used the atmosphere, soil and water as the ultimate sink of our industrial excesses.

- For too long we have disregarded the warning that global heating caused by industrial emissions may disturb the global climate, and agricultural and settlement patterns.
- For too long we have overlooked the devastating effects of acidification, of overuse of chemical products and pesticides.
- For too long we have exported our first generation of environmental problems to the Third World and maintained an economic system that leads to environmental decline in developing countries.

It is time we realize that we all share a common future. Maybe it is the notions, North, South, East and West, that lure many into believing that we may choose to separate ourselves in a world that has become so interconnected. The need to take a holistic view of the world is becoming more and more obvious day by day.

Take the drought in Africa. Is it a separate climatic phenomenon? Is it due to agricultural practices? What are the impacts of the world economic system? How much is man-made, and who are the people who make it?

We need new concepts, and new values to mobilize change. What we call for is a new global ethic.

We need a new political approach to environment and development, where economic and fiscal policies, trade and foreign policies, energy, agriculture, industry and other sectoral policies all aim to induce development that is not only economically but also ecologically sustainable.

We need to create more awareness and to mobilize people in all corners of the globe and in all walks of life. We need to have a sense of mission and to offer a common framework and a vision for a better future.

The Commission defines the overriding political concept of *sustainable development* as such a common framework, as a broad concept for social and economic progress and change.

Sustainable development as defined by the Commission requires a fairer distribution of wealth within and among countries. It requires political reforms, fair access to knowledge and resources, and real, popular participation in decision-making.

Sustainable development recognizes that there are thresholds imposed by nature, but not limits to growth itself. Forceful economic growth is the only feasible weapon in the fight against poverty. And only economic growth can create the capacity to solve environmental problems.

However, the contents of growth must be changed. Growth cannot be based on overexploitation of resources. Growth must be managed to enhance the resource base on which we all depend.

In order to change the contents of growth, fundamental changes in the international economy are necessary. We in the industrialized countries will play a critical role. We will have the responsibility of ensuring that the world economy enhances rather than hinders the potential for sustainable development.

Less than a week ago here in Toronto, the Economic Summit for the first time endorsed the concept of sustainable development. That decision brings new hope and belief in international cooperation, not least for the Third World.

In the 1980s, however, the developing countries have witnessed a reversal of the earlier hopeful trends in growth performance globally. Sharp deterioration in the international economic environment has played by far the major role in triggering the acute crisis that now afflicts the Third World.

Indicators of this critical situation are unsustainable, crushing burdens of external debt; the substantial decline in export earnings due to acutely depressed commodity prices and increasing protectionism; the steeply declining flows of resource transfers; and the chronic instability of the international currency market, as well as the abnormally high real interest rates.

In this harsh reality, developing countries have had little alternative but to tax their natural resources, often beyond the limits of recovery, to get funds to service foreign debt, not to speak of their futile efforts to maintain necessary imports. It is absurd that Africa is transferring more to the industrialized countries than it receives.

These trends will now have to be reversed, not only because the situation is in itself unacceptable, but also because it is in the self-interest of the developed countries.

Isn't it a perverse situation that there is a net transfer of resources from the poor countries to the rich, which over the past few years have totalled over a hundred billion dollars? Isn't it appalling that while close to a billion people are living in poverty and squalor, the per capita income of about 50 developing countries declined last year?

There is a need for a fresh impetus in international cooperation. Development aid and lending must be increased, and the debt crisis must be resolved. The ultimate goal must be to forge an economic partnership based on equitable trade and to achieve a new era of growth, one that enhances the resource base rather than degrades it. The mission must be to make nations return to negotiations on the global issues after years of decline in real multilateralism. The decisions at the summit bring new hope that this may soon happen.

The theme of this conference may have a mission far beyond its stated topic. It may be an awareness-creator. It may erect a pillar of wisdom in the much needed global educational campaign on environment and development. It may finally open our eyes to the fundamental fact that the earth is one even if the world of man is still divided. The atmosphere knows no boundaries. We cannot act as if nature does.

For too long we have thought of the atmosphere as a limitless good. We have been burning fuel and emitting pollutants, pressing aerosol buttons, and blowing foam to our heart's content.

But recently we have begun the painful process of discovering our past mistakes. We are struggling with the costs of acidification, and with the complexities of dealing with NO_x. We are now realizing that we may be on the threshold of changes to our climate, changes that are so extensive and immediate that they will profoundly affect the life of the human race.

Although theories about the physical effect of CO_2 on the climate were presented more than a hundred years ago, what is new is the certainty that it will happen unless we take decisive corrective action now!

As far back as 1969 we in Scandinavia discovered that the acidification of our lakes and rivers was related to growing sulphur emissions in central Europe. Today acid rain has become a major environmental issue in Europe and North America, and a rapidly growing threat in other parts of the world. Canada, we all know, has been on the receiving end for years.

When the Convention on Long-range Transboundary Air Pollution was adopted in 1979 after long years of struggle for necessary support, and then followed in 1985 by the protocol on 30% reduction of sulphur emissions, the problems seemed to be manageable. The control technologies were known and widely available.

With nitrogen oxides, however, the problem has proved to be far more complex. The number of sources is greater. Abatement measures, although known and tested for a number of years, have, in the case of mobile sources, severe drawbacks.

Even so, a NO_x protocol for the ECE region will be signed later this year. The first step includes a commitment to freeze total NO_x emission in ECE countries before the end of 1994. The second step contains an obligation to renegotiate the first step six months after the protocol enters into force, using nature's own absorptive capacity as a basis for negotiations.

The regional acidification problem has proved to be more and more complicated while scientific knowledge has matured. The lesson we are learning in the ECE region should sound an alarm in other parts of the world. It is essential that such air pollution problems be dealt with in all regions. They cannot wait until the damage is as widespread as in the ECE regions. By then it may be too late.

In 1974, when scientists put forward the theory that chlorofluorcarbons could destroy our globe's protective ozone layer, they could not point to actual damage. On the contrary, they thought that any damage that might appear would not occur before the next century. Research showed that once released there was no way for the atmosphere to recover. And it would take many years from the time of release until the actual damage appeared.

The news of the ozone hole over Antarctica changed attitudes in many countries. If we were to protect future generations from ever-increasing amounts of harmful ultraviolet radiation, we had to take corrective action. We had to,

and in fact we did, give nature the benefit of the doubt.

General adherence to the Montréal protocol is needed. The European Community in particular has a special responsibility. I am pleased to announce that today, in New York, Norway is ratifying this milestone in international cooperation.

Yet there are indications that the situation is more serious than ever. Recent scientific findings show that the ozone layer has been depleted over the Northern Hemisphere as well. We cannot ignore this evidence. Stronger measures are clearly called for. Steps must be taken now to secure a new commitment when we revise the protocol in 1990.

We know from our Norwegian action plan that about 90% of our national CFC consumption can be eliminated before 1995 without disrupting the economy. In fact the cost in Norway of such reductions is estimated at around 8 dollars a year per capita. We in the developed countries: how can we even discuss whether we can afford it. We have no choice.

The awareness of the threat of climate change has increased significantly since international work on the ozone layer started. It is popular to talk about the "greenhouse effect", but shouldn't we talk about the "heat trap" instead?

We know now that not only CO_2, but a number of other gases as well contribute to global heating. Presently these other trace gases cause one third of the total global warming. And unless something is done, their contribution in the next 50 years will double the effect of CO_2.

Scientists still have no unanimous view on the magnitude of the climate change problem, but it is established beyond any doubt that we *will* experience a global change in climate. An average global temperature increase over the next 50 years of 1.5 to 4.5°C is enormous. It took between 10,000 and 20,000 years for the world's temperature to increase about 5 degrees. The impact of climatic change *may* be greater and more drastic than any other challenge that mankind has faced with the exception of the threat of nuclear war.

The effects on the whole ecological balance will be drastic. The time span needed for plants to adjust to a new climate is normally hundreds of years. The deserts will expand. The crops in today's marginal areas will be lost. Extremes of weather – storms, rainfalls, frost or heat – may become more common. The sea-level may rise 1 metre or more, and with one third of the world's population living in low-lying coastal areas, such a development would have dramatic consequences. Political stability may be threatened in many parts of the world, and the number of ecological refugees may increase. In sum, climatic change will affect us all profoundly, regardless of where we live. And as always, the poorest countries will be the ones most severely affected.

All of this may not happen, or not that severely. But the potential risks are so high that we cannot sit back hoping that problems will go away. We are the ones who must take the initiatives. We must set the limits and we must prevent the potential disasters for the sake of future generations, from whom we have borrowed this earth.

The time has come to develop an action plan for protecting the atmosphere. Acid rain, depletion of the ozone layer and climate change are not separate problems. They are strongly interlinked with each other. We have come to a threshold. If we cross this threshold, we may not be able to return.

For our common future, drastic action has to be taken. My question is: Will the improved relations between East and West release the human financial potential that will be needed to address these common challenges? Will internationalist endeavours prevail over narrow-mindedness? Will hostile attitudes to internationally negotiated arrangements and institutions yield to a coalition of reason? In 1988, when it was decided to dismantle the INF missiles, when President Reagan and General Secretary Gorbachev walked the Red Square together, will we be able to deal with vital issues of environment and development, in a real climate for change?

As one step towards reaching that goal together – I propose an international action plan for protecting the atmosphere and, in particular, for preventing climate change.

1) Firstly, we should launch immediate international discussions on the feasibility of adopting regional strategies for stabilizing and reducing energy consumption and use, before the end of the century.

If we are serious in our attempts, we must be prepared to tackle the myth that energy consumption *must* be allowed to grow unchecked. In Norway we have considered our options very carefully. We are now aiming at a stabilization in energy consumption by the year 2000.

A second step should aim at altering the composition of energy use and at reducing energy consumption to reduce environmental costs. Important means might be to implement correct energy pricing, including environmental costs, and to tap the potential of energy-efficient technologies and conservation measures.

A change in Norwegian production and consumption patterns will only contribute marginally to solving the global problem. Presently, developing countries must be allowed time for adaption and the chance to increase their consumption. Industrialized countries have a special obligation. We must be the first to change our production and consumption patterns.

Our readiness to do so will be the *acid test* that will indicate to the developing countries that the industrialized countries are serious about their responsibilities.

2) Secondly, we should establish a comprehensive international research and information program on renewable energy.

The Commission recommended that renewable energy should form the foundation of the global energy structure during the twenty-first century.

An international research and information programme should be set up. It should provide information about availability, regularity, efficiency and the costs involved.

3) Thirdly, we should establish an extensive technology transfer programme with particular emphasis on the needs of the developing countries.

Funds must be forthcoming to help developing countries choose a safe and sustainable energy pathway. Easy access to modern and low polluting technologies is vital to all countries, and especially to the developing countries.

Unless developing countries are given access to clean technologies, we will all have to deal with the consequences.

4) Fourthly, we must increase scientific research.

Several international scientific programmes have already been established, including those under the framework of WMO and UNEP. It is vital that such scientific programmes be open for participation from all countries, and that countries be urged to join international scientific programmes.

The effects of climate change on global and regional scales should be a priority topic for a specific programme.

5) Fifthly, we should consider establishing a global convention on the protection of the climate to coordinate scientific activity, technology research and transfer, information exchange and concrete measures to reduce the emissions of harmful substances.

Mr. Chairman,

The themes I have addressed are critical for Our Common Future. To secure that future we must take action, even before we have full knowledge of the problems we are dealing with. The task is huge. The action I have outlined is the minimum response required. The setting is urgent. The threats are real.

We have come to a point in the history of nations when we can no longer act primarily as citizens of any single nation state. We are irreversibly entangled in the same destiny, but together we also have enormous possibilities.

We stand at a crossroads in the evolution of the political culture of humankind. About 40–70 thousand years ago humankind took up its struggle with the biosphere; 200 years ago we seemingly gained the upper hand in that struggle. Now it is time to take a giant leap forward in the upgrading of civilization.

Mrs. Gro Harlem Brundtland was the Prime Minister of Norway at the time of her speech.

She graduated from the Medical School of the University of Oslo in 1963, and received a Master's degree in Public Health from Harvard University in 1965.

Between 1966 and 1974, before entering politics, Mrs. Brundtland served as Medical Officer in the Norwegian Directorate of Health and as Assistant Medical Director of the Oslo Board of Health.

She was Minister of the Environment from May 1974 to October 1979, when she assumed the seat in the Storting to which she had been elected in 1977 as a representative from Oslo.

In April 1981 she took over as Leader of the Labour Party, after having served as its Deputy Leader since 1975.

From October 1981 she was Leader of the Labour Party Parliamentary Group until she became Prime Minister on May 9, 1986.

Mrs. Brundtland is Vice-President of the Socialist International and member of the Independent Commission of Disarmament and Security Issues. She is Chairman of the UN World Commission on Environment and Development and has presented the WCED report in many parts of the world and to important international organizations such as the EEC, the Organization for African Unity and others within the United Nations system.

Mrs. Brundtland is well known in international environmental circles where she was instrumental in producing the "Brundtland Report", an often-quoted document.

RÉSUMÉ *Notre avenir à tous, le rapport de la Commission mondiale sur l'environnement et le développement, analyse les dangers auxquels est soumise la communauté mondile. C'est clair : les politiques et tendances actuelles doivent cesser. Elles vont détruire la base de ressources sur laquelle nous dépendons tous.*

Pour éviter des erreurs désastreuses on doit effectuer des changements. Il est possible d'en faire. Les ressources, les connaissances et les capabilités de la race humaine n'ont jamais été plus grandes. Nous avons le pouvoir de créer un futur plus prospère, plus juste et plus sécuritaire pour tous.

Les plus importants problèmes environnementaux qui touchent nos systèmes vitaux sont la pollution de l'eau et du sol qu'amènent les excès de l'industrie; les émissions industrielles qui affectent l'atmosphère et le climat; et l'acidification par l'abus de produits chimiques et de pesticides.

Les mesures énergiques suivantes sont nécessaires :

- *On devrait entreprendre immédiatement des discussions internationales sur la possibilité de stabiliser et de réduire la consommation d'énergie avant la fin du siècle.*
- *On devrait établir un vaste programme international de recherche et d'information sur l'énergie renouvelable.*
- *On devrait établir un programme étendu de transfert de technologie qui se penchera particulièrement sur les besoins des pays en voie de développement.*
- *On doit augmenter la recherche scientifique.*

THE ROLE OF CITIZENS IN SUSTAINABLE DEVELOPMENT

by Sister Aida Velasquez, OSB

Many citizen groups hailed the final report of the World Commission on Environment and Development when Prime Minister Brundtland presented it. It calls for greater public participation in decision-making processes regarding environment and development issues, amongst others. As a first response to the report, entitled *Our Common Future*, the Environment Liaison Centre International (Global Coalition for Environment and Development) came out with the pamphlet "Joining Hands". This gives specific recommendations to citizen groups all over the world who will "join hands to create people power and, through that, the political will to promote sustainable development". This they will do together with public authorities in the North and the South.

In the Philippines, environmentalists realize that, in order to survive as a people, Filipinos need to understand that our island-house is fragile and our natural resources are limited. With a population projected at 111 million by the year 2000, we hope to learn to pursue all our activities within the carrying capacity of the natural resources of our archipelago and to protect and conserve its diverse genetic species. The gifts of our islands must be used judiciously to satisfy the basic needs of all and provide them with livelihood and employment opportunities while assuring that future generations will also be able to meet their needs. Obviously a vigorous ecological education program is imperative.

With this in mind, a citizen's group, The Secretariat for an Ecologically Sound Philippines, has embarked on helping popularize the concept of sustainable development (SD). Copies of the overview of "Our Common Future" and "Joining Hands" were printed and disseminated. A newsletter issue was devoted to SD and a campaign was launched for the adoption of a Philippines Charter for Nature that is based on the World Charter for Nature and that incorporates the WCED's emphasis on anticipation and prevention of environmental damage.

A series of ecological orientation seminars has begun and we are reaching out to the village level. This introduces the participants who are mostly leaders of communities to the urgency of working for SD. To assist people to realize the inseparability of ecology and economics, a whole-day seminar-workshop for a small group of ecologists, economists and lawyers has been scheduled. We believe this can help provide people with insights as to how to push for SD.

The Association of Southeast Asian Nations agreed in December 1987 to promote SD. Popularizing the principle of SD seems simple and not too difficult. Far from it. Let me illustrate with an example.

Marcopper Mining Corporation (MMC), a subsidiary of Placer Dome Inc., a Canadian firm, has been operating a copper mine since 1969 in Marinduque, a small island south of Manila. For almost 13 years now, it has been dumping mine tailings into a shallow bay. In effect, it has crushed and powdered about half of a mountain (lying almost at the centre of the island) and transferred this into Calancan Bay. With Mr. Ferdinand Marcos owing 48% of its shares, MMC has transformed a once bountiful fishing ground into a desert with the compacted mine tailings. In the process, fishermen and their families, numbering about 20,000, have been impoverished. There is less food, especially for the growing children, schooling was cut short for most of the youth, and young people must leave their village and be separated from their families to look for employment.

Since 1974, the fishermen, foreseeing what would happen, protested against the MMC plan to dump mine tailings into their fishing ground. A long series of protests, most of which fell on deaf ears, was answered at long last in April 1988 by the order of the Department of Environment and Natural Resources (DENR) for MMC to stop polluting the bay. MMC appealed to the Office of the President (OP) to reverse the order of the DENR. The legal department of the OP sustained the DENR order and the fishermen were happy. Within 24 days the water in the bay cleared up and the fish catch started to increase. However, the same legal department of the OP later buckled down to economic pressure (reinforced, most probably by creditor banks) and a second decision overturned the order of the DENR and in effect let the Company continue polluting Calancan Bay. The last remaining portion of the fishing ground of the subsistence fishermen is now being covered with mine tailings. MMC is also endangering the other fishing grounds of the province and probably foreclosing the marine livelihood possibilities for the 250,000 residents of Marinduque Island. Although it employs a thousand workers, the copper mine is almost exhausted and MMC owes the Philippines government some $40 million in back taxes.

It is obvious how a government, saddled with economic problems and pressured by sly businessmen and politicians and sadly lacking in ecological consciousness, can throw out the principle of SD. Such an unecological and uneconomic decision obstructs SD from being understood.

What are the other obstacles aside from those coming from a government that would exchange short-term benefits with ecological destruction? There is also the indifference and lack of ecological consciousness among the majority of the citizens, the vested interests of local officials, the lack of resources of the poor to match the high-powered disinformation campaign and manoeuvring of vicious corporations, and principally, the poverty of the majority that can lead them to destroy the natural resources; for example, the destruction of the mangroves by charcoal-makers or of the forest by slash-and-burn farmers. To balance the picture, you may want to know that despite our poverty, the citizens waged a ten-year campaign against a $2.1 billion Westinghouse nuclear power plant, and the Aquino government decided against its operation after the Chernobyl accident occurred.

In addition, at present, foreign governments do not require their citizens engaged abroad in industrial activities to observe the same environmental practices that they require of them in their own countries. The ideas of a comprehensive environmental impact assessment, environmental corporate licenses for firms and an environmental representative on corporate boards may be of help.

We can see how much is asked of citizens in order to help promote SD.

What makes the concept of SD very attractive to concerned citizens in poor countries? It is the fact that the Brundtland Commission pin-points inequality as the main environmental as well as the main development problem and recommends that "an overriding priority be given to the need of the world's poor".

To make people discuss and act for SD effectively, a citizen must wake up to the reality of the situation in poor countries, and grapple with it. In a panel discussion on foreign debts in the recently concluded International Forum on SD sponsored by Pollution Probe, it was mentioned that the real settlement of these foreign debts is for the creditor-countries to write them off. It is laudable that Canada is one of those countries that has started to do this! Mr. Morris Miller of the World Bank, appearing on that panel, compared the condition of developing countries to that of a person running up an escalator that is going down. He went on to say that debts are part of a much bigger problem, which means that the whole economic system is sick. And that there is a need for very severe readjustments for the global economy to grow. The officials of the United States, the leader of consumerism, must be convinced to initiate this restructuring of the global economy. Mr. Miller concluded, "A systemic solution is needed for a systemic problem."

A much greater reality than this systemic economic problem that citizens need to grasp, according to Fr. Thomas Berry, is the fact that "our industrial economy is closing down the life-support systems of the planet – the air, the water, the soil and the vegetation. The immediate danger is not 'possible nuclear war' but actual industrial plundering. For the first time, humans are determining the destinies of the earth in a comprehensive and irreversible manner". Our very Conference on The Changing Atmosphere attests to this and underlines the urgent task needed.

"If humans will not stop the industrial plunder of the earth, then no economic viability nor improvement of life conditions for the poor can be realized", writes Fr. Berry.

In the pursuit of SD, we hope to grow in the realization that – in the words of Fr. Berry – "the primary objective of economic sciences, of the engineering profession, of technological invention, of industrial processing, of financial investment, and of corporation management must be the integration of human well-being within the context of the well-being of the natural world. This is the primary purpose of economics. Only within the ever-renewing process of the natural world is there any future for the human community". And growing in this understanding, we hope to act accordingly more and more.

Ultimately, the battleground for SD is in the human heart. Mrs. Brundtland says that nothing less than a conversion of heart is needed to bring about the change of pattern of consumption and production that will enhance the resource base and implement the other recommendations of the WCED. This change of heart invites us, humans, to relinquish the idea that we are masters of creation and to acknowledge that we belong to the total earth community. It will mean also for you and for me listening intently to the tribal people and to their wisdom of relating harmoniously with the earth. It means respecting and doing justice to them and to the rest of the species. It means recovering our awe and reverence for the earth – our primary teacher and our first encounter with the divine.

May the pursuit of SD lead us on to this realization and thus discover that the creative powers of the earth are in each of us, and therefore celebrate with the earth that very creativity.

FURTHER READING

Lonergan, A. and C. Richards (Eds.), 1987: *Thomas Berry and the New Cosmology* (In dialogue with Gregory Baum, Margaret Brennan, Stephen Dunn, James Farris, Caroline Richards, Donald Senior and Brian Swimme). Twenty-Third Publications, Mystic, Conn., 144 pp.

Sister Aida Velasquez was born and raised in the Philippines. She studied chemical engineering at the University of Detroit and returned to the Philippines to teach chemistry at several institutions in Manila.

Sister Aida is a Bendictine Missionary who has devoted her life to solving the agricultural and rural problems of her people and to working closely with those affected by pollution. She worked as a researcher at the International rice Institute in Languna, and in 1976, while conducting missionary work among young men and women in the export-processing factories of Manila, she joined the Campaign Against the Construction of the Bataan Nuclear Power Plant. For more than 10 years she and her co-workers fought hard while the nuclear power plant was being built and fuelled, and in 1986 their dreams were realized when President Aquino stopped the project within days of the initial start-up.

Buoyed by that long first struggle, Sister Aida turned to help the fishermen and settlers of Marinduque Province who were being threatened from pollution discharge into a bay by a copper mining firm (a subsidiary of Placer Dome Inc.).

In 1985, Sister Aida became coordinator for the Secretariat for An Ecologically Sound Philippines, which works to promote ecological consciousness. Through education, ecological seminars, publications and other communications, this environmental group popularizes the idea of sustainable development among the citizens and government in the Philippines.

RÉSUMÉ *Les environnementalistes des Philippine savent que pour que leur peuple survive il doit comprendre que son oasis est fragile et a des ressources limitées. La population sera de 111 million en l'an 2000, ce qui l'oblige à entreprendre la poursuite d'activitiés que les ressources naturelles de l'archipel peuvent supporter, et à protéger et conserver ses diverses espèces génétiques.*

Un groupe de citoyens, le Secrétariat pour des Philippines écologiquement saines, a entrepris la popularisation du concept de développement durable. Des colloques et groupes de travail ont permis de faire connaitre et d'acquérir les connaissances nécessaires à faire face aux situations écologiquement dangereuses.

L'exemple spécifique de la Marcopper Mining Corporation en fait preuve. Un des plus beaux territoire de pêche a été transformé en désert. Sans la pêche comme moyen de subsistance local, 20 000 personnes vivent dans la pauvreté. Depuis 1974 les efforts soutenus des habitants n'ont pas été entendus. L'intervention gouvernementale a été de courte durée, la compagnie exerçant des pressions qui ont renversées les décisions juridiques.

L'indifférence, l'égoïsme, le manque de ressources et la pauvreté des habitants ajoutent à ne sommes pas les maîtres de la création et que nous appartenons tous à la communauté de la Terre. Un développement durable peut nous le faire réaliser.

THE GLOBAL GREENHOUSE EFFECT

by F. Kenneth Hare

1. RISE OF THE IDEA

In this paper I shall put forward the view that the greenhouse effect is the most important environmental problem facing the world. It is an old conjecture that has suddenly become central to international strategy.

In 1938 a British air pollution specialist, G.S. Callendar (1938), put forward the view that the carbon dioxide concentration in the atmosphere was increasing because of fossil fuel burning. This must lead, he argued, to a rise of surface temperatures, and hence to world-wide climatic change. I mark Callendar's 1938 paper as the point at which climate began to move centre-stage in world affairs. We are thus celebrating a sort of half-centenary.

I was a student at the time, working under Sir David Brunt. He didn't much like carbon dioxide, a gas that complicated the calculation of radiative transfers in the atmosphere – and which provided the raw material for photosynthesis, and hence life on earth. David Brunt's sense of the niceties was that biology was a troublesome field, and life a regrettable phenomenon. When I began with him (in 1938) he advised me to read James Clerk Maxwell's *Theory of Heat,* and to avoid all biological works as being sure to mislead. Fortunately I ignored his advice.

Soviet scientists may adopt a different chronology. In the West, however, the next landmark was Gilbert N. Plass's (1956) paper in which he proposed a refinement in Callendar's ideas. He wrote on the eve of the International Geophysical Year, which led in 1957 to the establishment of the long Mauna Loa monitoring series for carbon dioxide, led by C. David Keeling (1978).

The realization that global air pollution – which is what the carbon dioxide increase amounts to – would have profound political implications was slow in coming. In 1964–65 Roger Revelle (1965) led a U.S. White House study of the burning of fossil fuels, and its relation to the steadily rising carbon dioxide concentration, which by then was a measured fact. From thence it was an easy step into the International Biological Programme, which took the carbon cycle as one of its *de facto* themes. I recall a landmark paper by George Woodwell in a popular journal, *Scientific American* (1970), which made it clear that atmospheric scientists could no longer ignore the role of the living cover of the earth as a control of world climate.

The 1960s and 1970s marked the change from physics-based meteorology (of which climatology was a very lowly part) to interdisciplinary atmospheric science with climate as the central problem. And now we are sailing into even stormier waters – those of global change, in which we face the challenge of bringing all the sciences of the inhabited earth together within a manageable framework.

But these were advances in scientific outlook. In spite of the 1973–1974 food crisis, in spite of the Sahelian desiccation, in spite of the near-death of the Peruvian fisheries, all climate-triggered events, the political, economic and technological implications of climate remained little realized. In 1979 the first World Climate Conference was held in Geneva. I had the job of compiling the papers for the event, and recall sitting in an office in Geneva biting my fingernails because we could get little response from businessmen, engineers, doctors, farmers and fishermen; and little or none from politicians.

So this great Toronto event is a most welcome initiative. We owe much to Minister McMillan for tirelessly advocating the coming together of science, technology and politics, and to Mrs. Brundtland and her Commission for having created nothing short of a new paradigm within which we can now work (World Commission on Environment and Development, 1987). We have been convened because it is now realized that the major climate-related social issues – greenhouse effect, acid deposition, the ozone problem, desertification, rising population, energy alternatives and polar problems – are all interconnected, and call for concerted international action. Hence our Toronto agenda.

2. WHAT IS THE GREENHOUSE EFFECT?

Most of the gases of the atmosphere – notably nitrogen and oxygen making up 99% by volume – have little effect on the earth's energy balance. Solar and terrestrial radiation alike can pass through them without much hindrance. If these gases were the only constituents, the earth would be a far harsher place, with hotter days and colder nights and a quite different geography of world climate.

Certain minor gases change all this. They have a vital property in common: they alow the sun's energy to penetrate to the earth's surface, but retard the return upward flow of the infrared radiation. The active greenhouse gases – so-called because their role is in some ways like that of a glass roof – include water vapour (less than 4% by volume), carbon dioxide (nearing 350 parts per million by volume, ppmv) and various less abundant substances, notably nitrous oxide, ozone and methane. All play critical roles in the maintenance of life on earth. Of importance here is that they combine to resist the upward flow of heat to space. Hence they warm the earth's surface.

This purely natural greenhouse effect raises surface temperatures to a global average of 288 K, or 15°C (59°F), which is about 35°C warmer than would be the case if they were not present. Water vapour is the key constituent, notably because it may condense as cloud – and clouds act even more effectively as resistances to the escape of heat (though they also retard the inward flow of sunlight). The attractiveness of this planet to life depends overwhelmingly on the natural greenhouse effect.

Here at this Conference, however, we shall be concerned more with the effects of the observed increase in the concentrations of these gases (Rasmussen and Khalil, 1986) i.e., with an augmented greenhouse effect. We have not detected any increase in water vapour, though it has almost certainly occurred. Ozone may actually be undergoing a small overall decrease (as well as a shift in vertical distribution). But carbon dioxide is increasing by about 0.4% per annum, or 15 ppmv per decade (Figure 1). Methane is increasing even more rapidly (Figure 2; Bolle et al., 1986), at about 1% per annum (Blake and Rowland, 1988). Nitrous oxide's increase is slower, but quite unmistakable (Figure 3).

These increases are due to human activities. Carbon dioxide comes largely from fossil fuel burning, and to a lesser extent from land and forest clearing, and soil wastage.

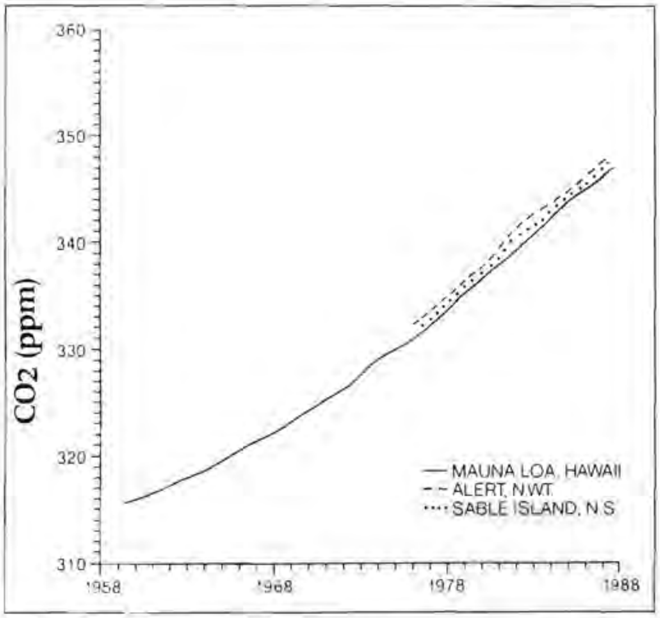


Figure 1 Atmospheric CO_2 concentrations measured at Mauna Loa, Hawaii; Alert, Northwest Territories; and Sable Island, Nova Scotia.

tions, they are highly effective in raising surface temperatures. The recent international protocol aiming at their replacement will not quickly diminish this role.

As concern about these changes has mounted, major efforts have been launched to get a grip on what is happening. The sponsoring international agencies of this Conference – the World Meteorological Organization and the United Nations Environment Programme – together with the International Council of Scientific Unions organize occasional international assessments. The most recent of these was held at Villach, Austria, in 1985. Thanks to the initiative of Gordon Goodman and the Beijer Institute, this was followed in 1987 by policy-oriented workshops at Villach and Bellagio, Italy.

As these assessments have shown, the best evidence for the greenhouse effect comes from monitoring results plus large-scale scientific modelling. The monitoring results are still ambiguous. The modelling results differ greatly according to the initial assumptions (themselves debatable), and the choice of atmosphere-ocean models used to derive the results. Thus there is a large measure of uncertainty. But there is nevertheless a growing near-consensus on certain broad conclusions. I shall summarize its main elements. *These results, while clouded with uncertainty, are at least as firm as those of econometric analysis and prediction.* If decision-makers are willing to listen to economists, they

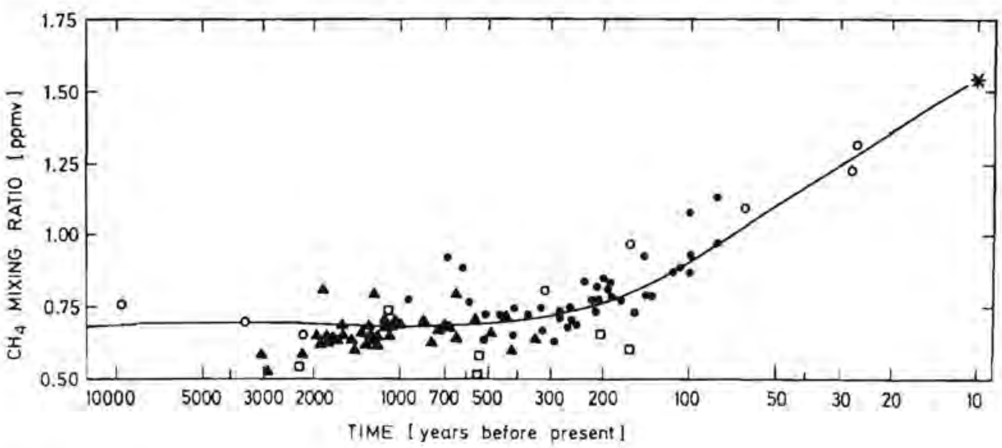


Figure 2 CH_4 mixing ratios measured in air trapped in ice cores as a function of time (Bolle et al., 1986).

Methane we associate with various kinds of wetland agriculture, such as rice cultivation, and possibly with changes in high-latitude marshlands. Nitrous oxide – the least effectively studied – is probably coming off farmland. The legitimate human search for necessities such as warmth, industrial energy and food is thus altering the optical properties of the atmosphere, thereby threatening world climate and the well-being of all living things.

But human interference does not stop with things desirable and legitimate. We are adding synthetic substances to the atmosphere at a great rate. Most are harmless, as far as we know. Sulphur hexafluoride, for example, is essential to electrical switching gear. Most of it is released in the Northern Hemisphere, yet it has been detected at great altitudes in the Antarctic. It is inert, and does no known harm. Quite different are the chlorofluorocarbons (CFCs), the primary refrigerant gases, which are also wholly synthetic in origin. Their role in attacking ozone in the stratosphere is already notorious, as the next speaker will emphasize. What is not so well known is that they are powerful greenhouse gases; in spite of their low concentra-

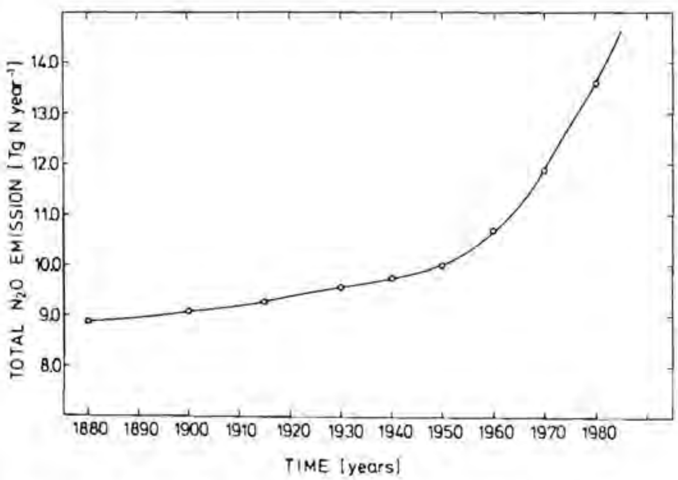


Figure 3 Trend of estimated total N_2O emission rates between 1880 and 1980 (Bolle et al., 1986).

should be at least as ready to listen to the natural scientists as regards future outcomes; complex as it is, the natural system is probably more predictable than the human economy.

3. HOW BIG A CHANGE IN CLIMATE IS LIKELY?

Here I am guided by the conclusions of Villach 1985, which I paraphrase briefly below:

i) *Time-Scales.* The augmented greenhouse effect is currently due about half to rising carbon dioxide levels, and half to the other greenhouse gases – chiefly the chlorofluorocarbons, nitrous oxide, methane and ozone. All are known to be increasing (ozone in the lower layers only) as the result of human activities. The combined future effect may be the equivalent of the carbon dioxide doubling by the 2030s – i.e., in less than a half century.

ii) *Expected Warming.* Such a doubling may induce a global surface temperature increase of between 1.5 and 4.5°C, according to existing atmosphere-ocean models. The slowness of the oceans to warm up may, however, delay the effect by some decades. Values outside the cited range cannot be excluded. Indeed, recent modelling results, e.g., Wetherald and Manabe (1986, 1988), tend to increase the estimated changes.

iii) *Unequal Effects.* The impact of this warming is likely to be geographically non-uniform. High latitudes will warm the most, especially in autumn and winter. Equatorial regions will experience a lesser but still formidable warming.

iv) *Effects on Water.* Less can be said about rainfall and the hydrologic cycle, but it appears likely that available soil moisture may be less abundant in Northern Hemisphere mid-latitudes – which include the world's chief wheat and corn growing areas. Water demand will increase generally.

v) *Sea-Level.* Sea-level may rise between 20 and 140 cm during a warming of the sort foreseen in (ii) above, chiefly because of expansion of the ocean water column (and only secondarily because of glacial melting). A rise in the upper part of this range would seriously affect low-lying coastal areas, especially in the world's great deltas. More catastrophic rises due to major disruptions of the Antarctic and Greenland glaciers are unlikely in the next century.

These five predictions rest on direct measurement, on estimates of future energy use and technological change, and on elaborate modelling of both the economic and ocean-atmosphere systems. The greenhouse effect has, in fact, become the central research problem of the field. It has attracted large resources of time, money and talent.

The calm recital of these ideas may mislead a listener unaccustomed to geophysical magnitudes. In fact, the five predictions, if realized, will amount to a revolutionary change in world climate, of a sort not rivalled in the history of civilization. Not since the abrupt end of glacial climates a little over 10,000 years ago have temperatures changed as much, or so rapidly. The next century may therefore see large impacts on the human economy, the first signs of which may already be upon us. It will also see, if these changes are realized, a potentially dangerous disequilibrium between soil, vegetation and climate. The world's ecosystems will be destabilized, in a fashion that cannot yet be predicted in detail. *I have no doubt that we are discussing the central environmental problem of our times.*

In practice the greenhouse warming will show itself in subtle ways. Climate is naturally variable: droughts follow floods, heat waves follow cold waves, winds, storms and calm conditions are interspersed. Some of these variations may last for years, and be economically damaging. In any given decade the effect of such anomalies will hide the slow changes of the greenhouse effect. The latter has been likened to a faint signal behind the noise that afflicts AM radio reception. In all probability, the warming in mid-latitudes will show itself mainly by increasing numbers of dry, hot summers and mild winters – of the sort already common in the 1980s, most notably the present time in North America. The entire year 1982/83, for example, was of this sort in many parts of the world, because of a huge anomaly – the so-called El Niño/Southern Oscillation effect – in the Pacific Ocean (not itself a consequence of the greenhouse effect). Here in Canada the Great Lakes barely froze (Assel et al., 1985). We already get entire years, in fact, that resemble what will be normal five decades from now. We are allowed to rehearse the greenhouse warming, and to examine its potential economic impact by direct inspection. We get glimpses of the probable future from such events (though we still have to improvise strategies to cope with it).

4. HAS THE GREENHOUSE WARMING SHOWN ITSELF YET?

The past two decades have seen many climatic anomalies. The worst has been the vast African desiccation, a much broader process than the so-called Sahelian drought. Analyses by many climatologists, notably Nicholson and Lamb, have demonstrated that this devastating process began in the 1960s, and continues to this day with consequences well known to us all. There have been many other major anomalies of other sorts. Several years of the 1980s have been the warmest in recorded history, on a world scale, most notably 1987 (Jones et al., 1988). It is hence reasonable to ask: Is this the greenhouse effect at work?

Because of the skittish behaviour of climate just referred to, this has been a hard question to answer. The problem is to identify the measurable properties most likely to point unmistakably to the greenhouse effect. What, for example, should we look for in the outgoing radiative characteristics of the planet, as detected by satellites, as my colleague Wayne Evans likes to do? How should we expect stratospheric temperatures to respond? Should they fall as analysis seems to show? Can sea-level measurements offer firm evidence? And can we detect the greenhouse signal in existing climatic records?

None of these approaches has yet given an unequivocal answer. But painstaking examination of the global surface air and sea temperature records over the past century and a quarter has begun to yield good results. Analysis by Jones et al. (1986), for example, shows a global rise of temperature between 1860 and 1980 of approximately 0.5 to 0.6°C. Villach 1985 estimates that the greenhouse effect over the past century should have raised temperatures between 0.3 and 0.7°C. The observed signal is thus compatible with the predicted greenhouse warming.

Firmer answers to this question will have to wait a few years. But I should like to express the personal view, based on long experience rather than personal research, that we are indeed witnessing the beginnings of the process, and that the delegates did not come to this Conference to chase a will-o'-the-wisp.

5. WHAT IS THE SIGNIFICANCE OF THE GREENHOUSE EFFECT?

Do these predictions have a major significance for the future of humankind? Here we encounter a real divergence of views. Most of my scientific colleagues feel certain that the answer must be "yes". They have mounted large world research efforts to specify the problem, and to identify

One of many glaciers in Banff National Park in the vicinity of Lake Louise – a possible victim of the greenhouse effect.

potential socio-economic impacts. Since before the 1972 U.N. Conference on the Human Environment in Stockholm, in fact, they have been driven by the sense that the biological and physical sciences of the environment have growing predictive powers, and that these should be used to influence the future course of human action.

But the world-views of statesmen, politicians and business people have been hard to change. For the most part large-scale policies on the national and world scales have ignored the possibility that major environmental change may be ushered in by climatic change, and specifically by the greenhouse effect. With great respect to Mrs. Brundtland, *Our Common Future* makes too little of the climatic factor. Beyond admitting that weather-related variations in food supply may continue, the report rarely touches on climate, except in the context of energy technologies. In so not doing, it is moving parallel to the great bulk of social, economic and political comment.

Yet there is abundant evidence of the sensitivity of various aspects of the human economy to climatic impact – and to the reverse phenomenon, the impact of human activities on climate via the greenhouse effect and other mechanisms. The World Climate Impacts Programme has produced a long literature on the climate-economy links. Here I refer, for example, to the excellent series emerging from IIASA, under the leadership of Martin Parry (1988), and to the series of impact studies completed here in Canada (Climate Change Digest, 1987–1988) on such diverse fields as agricultural yields, Great Lakes water levels and the effects of sea-level rise. These interdisciplinary studies had one common aspect: that they were conceived, sponsored and to a large extent conducted by atmospheric and ocean scientists like myself (with the help, it must at once be added, of engineers, economists and agricultural scientists). The stimulus did not come from senior government or top corporate management.

This Conference shows that such indifference is at an end. It has brought people in the midst of the political struggle together with the scientists who perceive the problem. The Beijer Institute workshop in Villach and Bellagio in 1987 neatly identified the gaps we have to bridge here in Toronto. I shall not repeat the list. Instead I shall make some comments and pose some questions that I believe demand an answer:

i) The question of scale is paramount, when action is being sought. The greenhouse effect is world-wide, both as to causes and as to impacts. Any conceivable action to control, mitigate or adapt to the effect must be taken on the world scale, by the world community. The same applies, in my view, to the questions of ecological impact to be discussed by Michael McElroy this afternoon. Do the political means exist, or can they be devised, to tackle so broad a problem? This is an issue like those raised in *Our Common Future* – and poses the same challenge.

ii) A second class of global, climate-induced issues arises from such things as desertification, energy policy and the condition of the seas and fisheries. If not global, they are all widely dispersed – and defy international solution. All are in any case related to the greenhouse effect.

iii) Questions of acid deposition, and more generally of toxic air pollution, tend to be more limited in area (international or regional), to involve a more limited number of states, and to be amenable to specific technical solutions. Yet Europe and North America have found them hard to handle, in spite of a large degree of scientific consensus. How can we move beyond stalement? Is a Law of the Atmosphere a feasible aspiration?

Beyond these questions the scientific community sees grounds for deep concern about the condition of the world's ecosystems, fresh water, food supply and human health – all on our later agenda. The greenhouse effect touches deeply on these concerns.

How can we close the gap between the scientific and the political mindsets in this vast environmental arena? Are the scientists wrong in asserting that the world must be ready for the impending changes? Are these issues outranked by a dozen others? We have an opportunity to get the answers at this Conference. I have been talking about revolutionary change in the world's natural environment – a change induced by inadvertent human action. It is not too much to expect an equally revolutionary change in political attitudes. The presence of two Prime Ministers at the Conference's start, and of five ministers in the closing session, shows that things have at least begun to move.

REFERENCES

Assel, R.A., C.R. Snider, and R. Lawrence, 1985: Comparison of 1983 Great Lakes Winter Weather and Ice Conditions With Previous Years. *Monthly Weather Review*, Vol. 113, 291–303.

Blake, D.R. and F.S. Rowland, 1988: Continuing Worldwide Increase in Tropospheric Methane, 1978–1987. *Science*, Vol. 239, 1129–1131.

Bolle, H.-J.; W. Seiler and B. Bolin, 1986: Other Greenhouse Gases and Aerosols. *In*: The Greenhouse Effect, Climatic Change, and Ecosystems, B. Bolin, B. Doos, J. Jaeger and R.A. Warrick, (Eds.), SCOPE 29, Wiley.

Callendar, G.S., 1938: The Artificial Production of Carbon Dioxide and Its Influence on Temperature. *Quart. J. Roy. Meteorol. Soc.*, Vol. 64, 223–240.

Climate Change Digest, 1987–1988 [Environment Canada]: Studies on Implications of Climatic Change Scenarios on Canadian Economy: e.g., Implication of Climatic Change for Navigation and Power Generation in the Great Lakes, CCD87-03; Effects of a One Metre Rise in Mean Sea-Level at Saint John, New Brunswick, and the Lower Reaches of the Saint John River, CCD87-04; The Implications of Climatic Change for Agriculture in the Prairie Provinces, CCD88-01; Preliminary Study of the Possible Impacts of a One Metre Rise in Sea-Level at Charlottetown, Prince Edward Island, CCD88-02.

Jones, P.D.; T.M.L. Wigley and P.B. Wright, 1986: Global Temperature Variations Between 1861 and 1984. *Nature*, Vol. 322, 430–434.

Jones, P.D.; T.M.L. Wigley, C.K. Folland, D.E. Parker, J.K. Angell, S. Lebedeff, and J.E. Hansen, 1988: Evidence for Global Warming in the Past Decade. *Nature*, Vol. 332, 790.

Keeling, C.D., 1978: The influence of Mauna Loa Observatory on the Development of Atmospheric CO_2 Research. *In*: Mauna Loa Observatory 20th Anniversary Report, J. Miller, (Ed.), National Oceanic and Atmospheric Administration Spec. Rep., Washington, D.C., pp. 36–54.

Parry, M.L.; T.R. Carter and N.T. Konijn (Eds.), 1988: *The Impact of Climatic Variations on Agriculture*. Volume I: *Assessment in Cool Temperate and Cold Regions*. Kluwer Academic Publishers, Dordrecht, 876 pp.

Plass, G.N., 1956: The Carbon Dioxide Theory of Climatic Change. *Tellus*, Vol. 8, 140–154.

Rasmussen, R.A. and M.A.K. Khalil, 1986: Atmospheric Trace Gases: Trends and Distribution Over the Last Decade. *Science*, Vol. 232, 1623–1624.

Revelle, R., 1965: Report of the Task Force on Carbon Dioxide Production. The White House, Washington, D.C. [The earliest of the modern syntheses of human interference in the carbon cycle.]

Villach, 1985: Report of the Int. Conf. on the Assessment of the Role of Carbon Dioxide and of other Greenhouse Gases in Climate Variations and Associated Impacts. Rep. WMO-No. 661, International Council of Scientific Unions, United Nations Environment Programme and the World Meteorological Organization, 78 pp.

Villach-Bellagio, 1987: Developing Policies for Responding to Climatic Change. Summary of workshop held at Villach (28 September–2 October) and Bellagio (9–13 November), The Beijer Institute, 52 pp.

Wetherald, R.T. and S. Manabe, 1986: An investigation of cloud cover change in response to thermal forcing. *Climatic Change*, Vol. 8, 5–23.

Wetherald, R.T. and S. Manabe, 1988: Cloud feedback processes in a general circulation model. *J. Atmospheric Sciences*, Vol. 45, 1397–1415.

Woodwell, G.M., 1970: The Energy Cycle of the Biosphere. *Scientific American*, Vol. 223, No. 3, 64–74.

World Commission on Environment and Development, 1987: *Our Common Future*. Oxford University Press, Oxford and New York, 383 pp.

Dr. F. Kenneth Hare was educated at the University of London (King's College and the London School of Economics) and the Université de Montréal.

Currently he is Chancellor of Trent University, Peterborough, Ontario.

He is University Professor Emeritus in Geography at the University of Toronto.

His academic career included appointments as Dean of Arts and Science of McGill University, Master of Birkbeck College (University of London), President of the University of British Columbia, Director of the Institute for Environmental Studies (University of Toronto) and Provost of Trinity College (University of Toronto).

Dr. Hare has served with a number of official bodies, notably as Commissioner of the Ontario Nuclear Safety Review, Chairman of the Royal Society of Canada Commission on Lead in the Environment, Chairman of the Royal Society of Canada Study of the Nuclear Winter Phenomenon, Chairman of the Canadian peer review panel on documents related to a proposed Canada/United States Treaty on Transboundary Air Pollution, and Chairman of the Federal Study Group on Nuclear Waste Management.

Among his many national and international awards and prizes are Companion of the Order of Canada; Fellow of the Royal Society of Canada; and honorary degrees from nine universities in Canada.

RÉSUMÉ L'effet de serre qui menace la planète trouve son origine dans l'action de certains gaz ajoutés dans l'atmosphère par suite de l'activité économique humaine. La présence de la vapeur d'eau et dioxyde de carbone dans l'atmosphere réchauffe la surface de la terre d'environ 3,5°C, conséquence des processus d'échange normaux avec les océans et le couvert vivant. La concentration du dioxyde de carbone dans l'atmosphère s'accroît actuellement du rythme de 4 % par décennie, et cette augmentation est attribuable principalement à l'utilisation des combustibles fossiles. Celle du méthane augmente de 1,5 % par année tandis que celle d'autres gaz – surtout l'oxyde nitreux et divers gaz synthétiques dont les chloroflourocarbones – augmente moins rapidement. La concentration globale de ces gaz doublera au cours de la première moitié du XXI[e] siècle, entraînant une augmentation de la température d'équilibre de la surface terrestre de 1,5 à 4°C, les effets les plus importants se faisant sentir sous les latitudes élevées nordiques. Cette modifiction de la température devrait avoir pour conséquence une augmentation accélérée, quoique non catastrophique, du niveau de la mer, l'apparition de divers facteurs de stress dans l'écosystème naturel et des modifications importantes de la situation agricole (attribuables également aux modifications prévues touchant la disponibilté de l'humidité dans le sol). On devrait également observer des effets importants sur la consommation d'énergie et la navigation sous les latitudes élevées. Ces effets seront répartis économiques se feront sentir, l'intervention efficace des gouvernements et des organismes internationaux deviendra nécessaire. Toutefois, si on s'interroge encore sur l'importance de tous ces phénomènes, il est certain, d'après le consensus presque parfait qui se dégage actuellement, que d'ici quelques années l'effet global deviendra une réalité irréfutable.

FORESTS AND ATMOSPHERIC CHANGE

by J.S. Maini

1. INTRODUCTION

Trees and forests are an important component of the global environmental system of the planet earth. They influence the rate and nature of atmospheric change and, in turn, are themselves influenced by it. Studies on macrofossils, pollen sediments in bogs, and tree-ring analyses show that atmospheric change is not a new phenomenon. What distinguishes the current phase of atmospheric change from those of the past is the strong presence and influence of the human factor, which derives significant economic, social and environmental benefits from forests. This paper examines the dynamic relation between the anticipated atmospheric change and forests as well as the nature and role of human interventions in this interaction, particularly from socio-economic and policy perspectives (Figure 1).

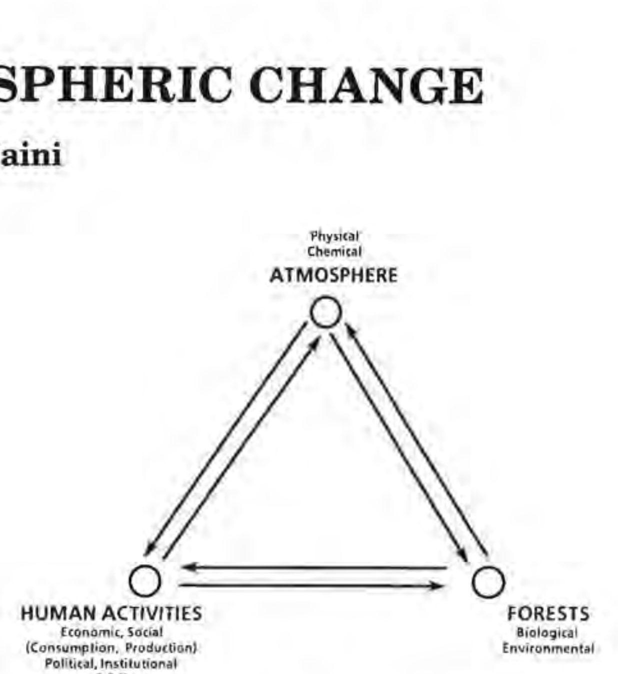


Figure 1 Components of the three principal interacting subsystems in the forests and atmospheric change issue.

2. ATMOSPHERIC CHANGE

The ecological interaction between atmosphere, trees and forests is complex. Climate parameters influence the growth of individual trees, the zonal distribution of different forest types (e.g., tropical, temperate) and the latitudinal as well as the altitudinal tree-lines. Some aspects of the anticipated atmospheric change, considered relevant to the biology of trees and forests, are summarized below.

Atmospheric change is not a new phenomenon. Changes in the atmosphere and associated changes in plant and animal life (i.e., biota) have occurred in the geologic past (Dansereau, 1957; Davis, 1984) and have been attributed mostly to geologic events such as continental drift, glaciation and volcanic activity (Harrington, 1987). More recently, however, the emission of radiatively active gases, generated by human activities, such as the production and consumption of goods, has become a significant factor in the current atmospheric change issue.

The atmospheric concentration of a number of radiatively active gases (i.e., "greenhouse gases"), particularly carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), chlorofluorocarbons (CFCs) and tropospheric ozone (O_3), has been increasing during the past few decades. There is now an increasing consensus that global warming is attributed to increased carbon dioxide emissions (50%) and to other radiatively active gases (50%). The increased concentration of these gases has led to the warming of the earth's surface as well as of the lower atmosphere, and to further changes of climate (Jaeger, 1988).

According to Stewart (1987), 95% of the CO_2 emissions originate from the Northern Hemisphere and only 5% from the Southern Hemisphere. The increase in CO_2 emission is primarily due to human activities, e.g., the escalating combustion of fossil fuels (80%) and the destruction of global forests (20%). The combined future effect of an increase in all "greenhouse gases" may be an equivalent of CO_2 doubling by the 2030s – i.e., in less than a half century (Hansen, 1987; Hare, 1988; Mintzer, 1987). Such a doubling may induce a global surface temperature increase of 1.5 to 4.5°C by the 2030s in a "business as usual" scenario, but by about 2015 in a "high emission" scenario, and by the 2075s in a "modest policies" scenario.

The warming is likely to be geographically uneven; high latitudes in both hemispheres will experience the greatest warming and the equatorial regions lesser but appreciable warming (Hare, 1988). The temperature increase will be greatest during winter months (Auclair and Pollard, 1988).

Generally the topic of weather variability has not been well researched (Auclair, 1987a). However, it should be noted that future climatic variability, whether episodic or extended over several years (Hare, 1988), will likely be biologically significant from the point of view of growth and survival of individual tree species and consequently of potential economic damage.

Soil moisture is likely to be reduced in summer over extensive mid-continental regions of both North America and Eurasia in middle and high latitudes. Over northern Canada and northern Siberia, this reduction in soil moisture is likely to result from the earlier occurrence of the snowmelt season, followed by a period of intense evaporation (Manabe and Wetherald, 1987).

The global climate has been stable over the last 100,000 years (Auclair, 1987b). The warmest time during this period was only 1°C warmer than today and a global warming of about 0.6°C has taken place during the past century.

3. IMPACT ON TREES AND FORESTS

The pattern and range of distribution of individual tree species is a result of the interaction between the evolutionary history of the species and the constantly changing climate. Climatic changes and consequent modifications in plant and animal life have occurred during the geological past (Dansereau, 1957; Davis and Botkin, 1985), and have resulted in the appearance and disappearance of species as well as in the shrinkage and expansion of the distribution range of individual species, forest types and biomes (e.g., forests, grasslands, tundra).

It has been estimated that, at one time, the world's forests and woodland probably covered 6 million hectares. By 1954, the increasing use of forest for agriculture, pasture and human settlements has reduced the total forest land to 4 billion hectares (IIED and WRI, 1987). An examination of the current forest areas and growing stock, by continent, shows that South America and the USSR have the major share of the world's current total, followed by North America

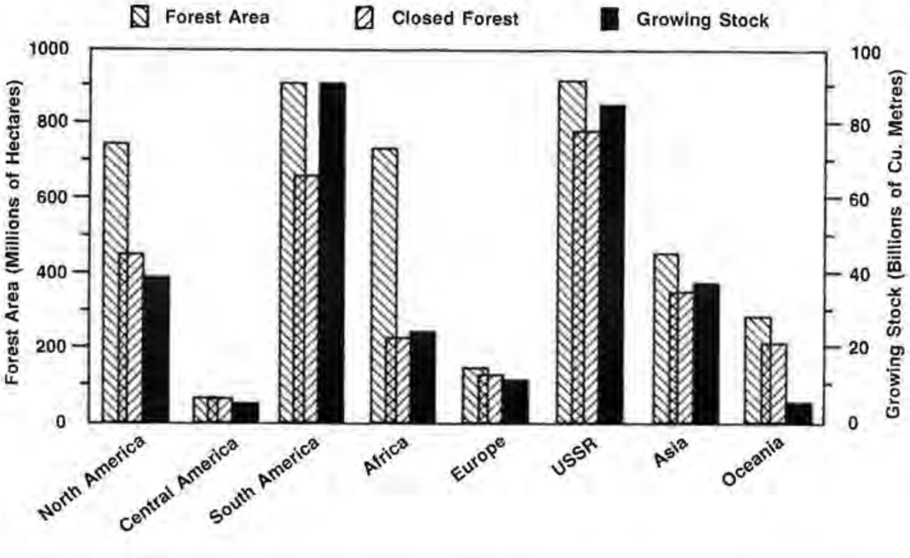
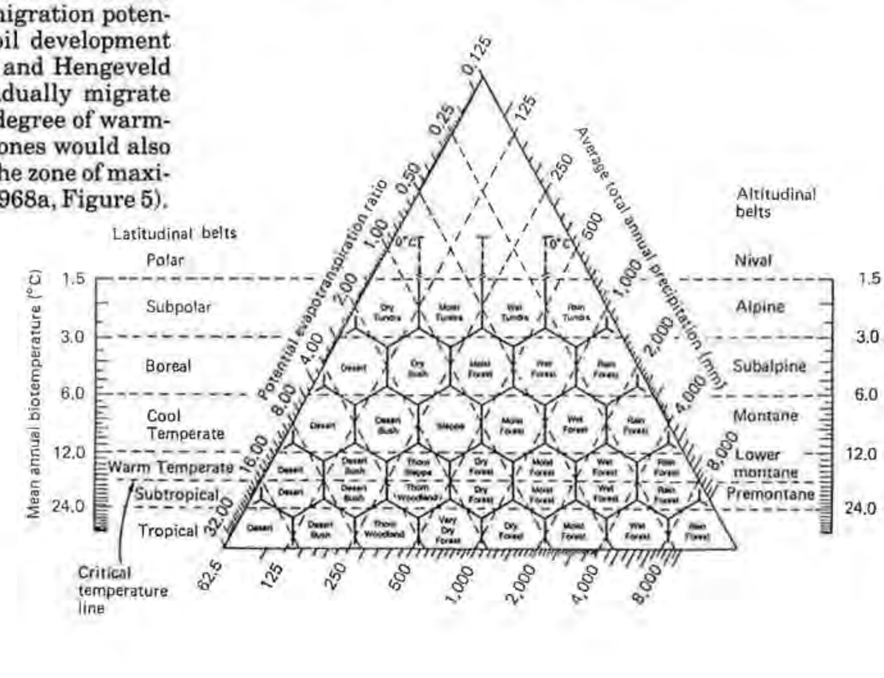


Figure 2 Forest areas and growing stock by continent (Canadian Forestry Service, 1988).

and Asia (Figure 2). Considering the latitudinally uneven surface temperature warmings as well as the soil wetness associated with the anticipated atmospheric change, the temperate forests of middle latitudes are expected to experience the greatest perturbation. The following aspects of forests are expected to be affected by climate change.

3.1 *Broad Scale Zonal Distribution of Forest Types*
A simulation based on the doubling of CO_2 suggests that the maximum impact of the anticipated climate change is expected at high latitudes, where the simulated temperature increase is largest and the temperature intervals defining Holdridge's life zones are smallest (Emmanuel et al., 1985). Depending on average precipitation, the boreal forest zones are replaced by either Cool Temperate Forest or Cool Temperate Steppe (Figures 3 and 4). This simulation also suggests that although the anticipated changes in the tropics are smaller, Subtropical Moist Forest is replaced by Tropical Dry Forest. It is noted that this simulation is based on climate/life zone relationships and that palaeoecological studies suggest that there is a time lag between climate change and spatial adjustment by vegetation (Maini, 1960; Davis, 1984); the latter is determined by a number of factors including the reproductive strategies and migration potential of species as well as by the rate of soil development (Shugart et al., 1986). *According* to Bruce and Hengeveld (1985), the tree-line in Canada would gradually migrate about 100 km northward for every Celsius degree of warming. Such a northward shift in vegetation zones would also likely result in the northward relocation of the zone of maximum growth of a given tree species (Maini, 1968a, Figure 5).

3.2 *Tree Growth*
Climate affects tree growth directly. Tree growth may be enhanced by global warming in areas where temperature is now a limiting factor. Studies by Jozsa and Powell (1987) show that climate warming since the end of the little ice-age (ca. 1850) has resulted in higher biomass production in the Canadian boreal forest. According to Kauppi and Posch (1985), climate warming would yield the greatest absolute increase in growth in the warm (i.e., southern) and maritime parts of the boreal forest biome. However, potential beneficial effects of increased temperature may be more than offset by limited soil wetness, as calculated by Manabe and Wetherald (1986). Furthermore, trees growing under warmer temperatures are likely to have a higher rate of respiration (Woodwell, 1987) and possibly lower biomass production. Although Robertson et al. (1988) observed dramatic yield differences in 70-year-old Douglas-fir trees growing on a range of soil moisture regimes in British Columbia, Canada, the wood quality (expressed as average relative density) of these trees did not differ significantly. The growth of various tree species under the anticipated and altered climate regimes is inadequately understood at present.



The key to the Holdridge Life-Zone Classification System used in Figures 3 and 4.

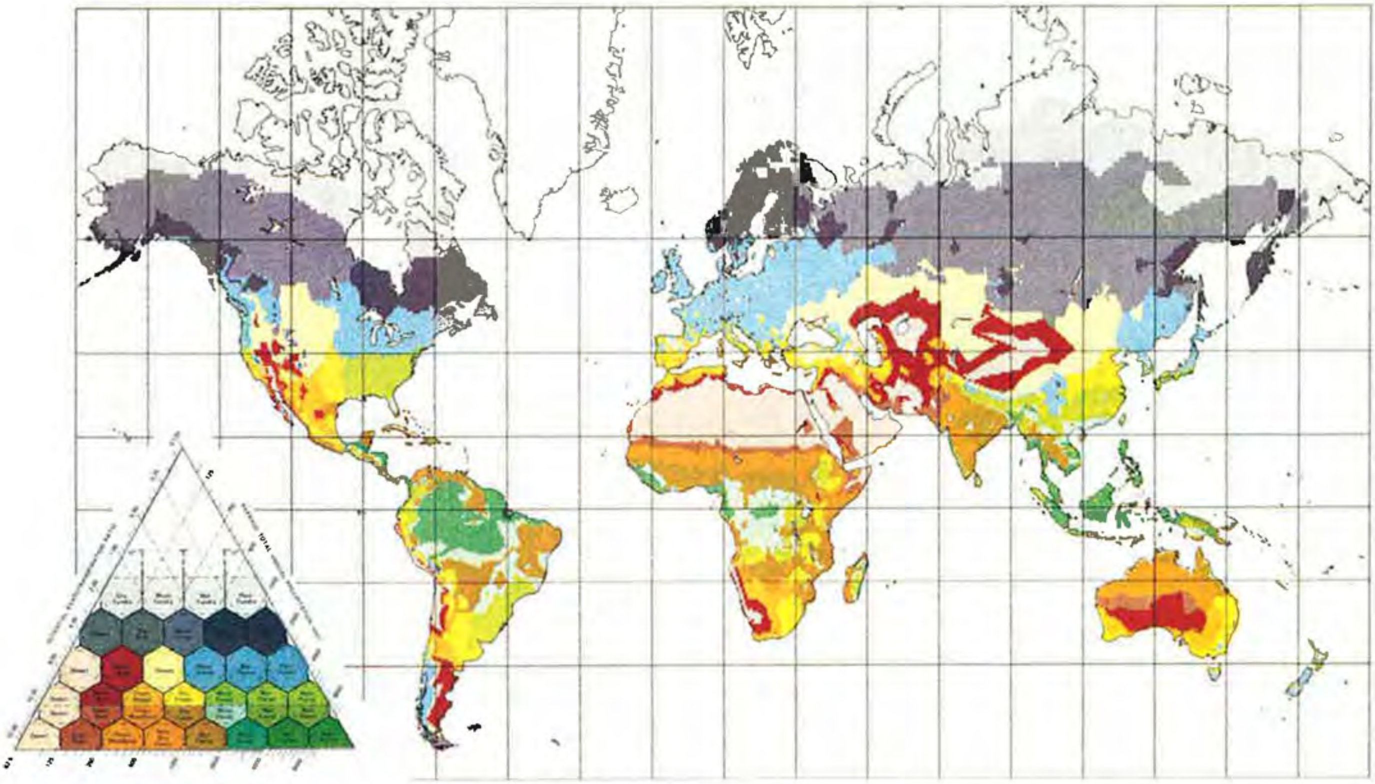


Figure 3 World map of the Holdridge Classification (base case). The resolution is 0.5° latitude × 0.5° longitude and the extent is from 80°N to 60°S – Greenland is not classified (Aitof's Equal Area Projection) (from Emmanuel et al., 1985).

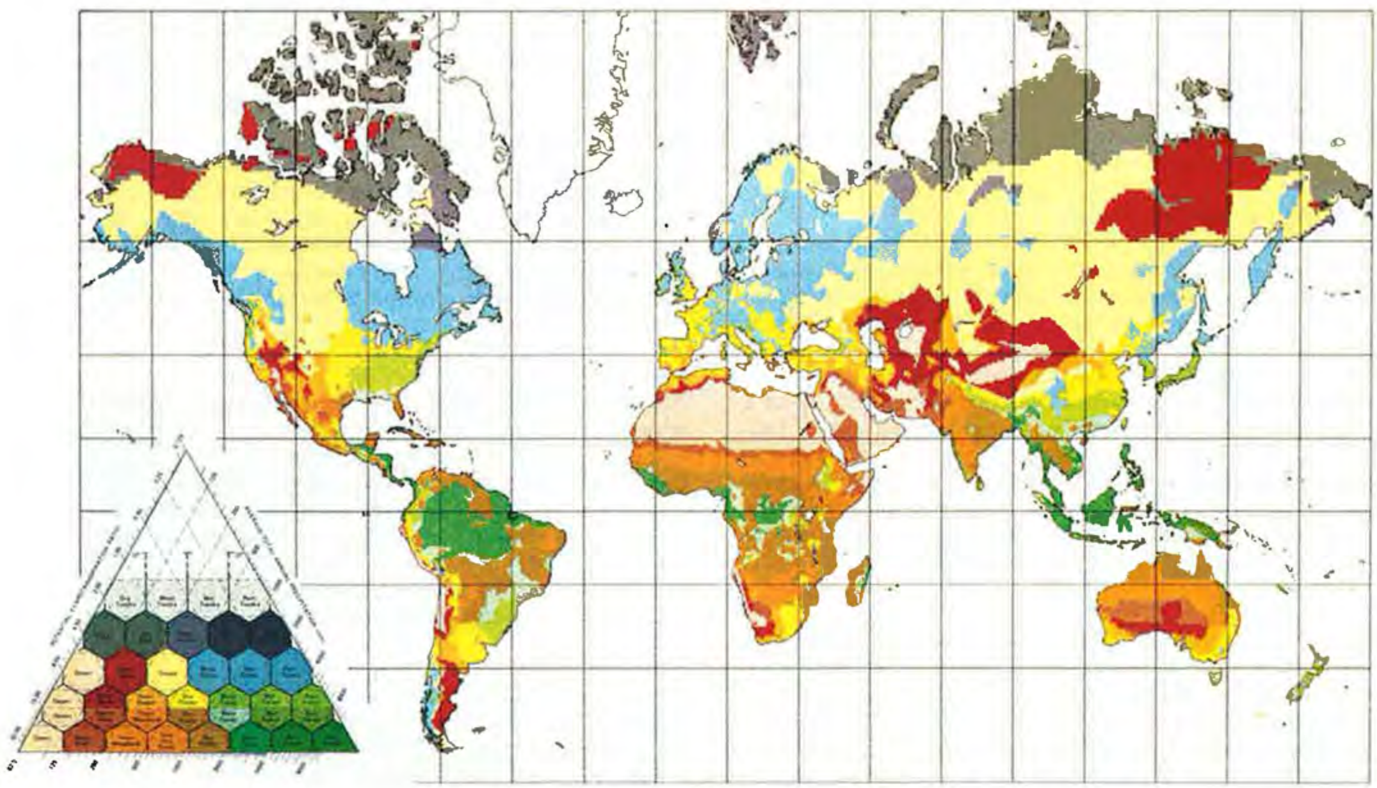


Figure 4 World map of the Holdridge Classification with the biotemperature increased to reflect climate-stimulatedelevated atmospheric CO_2 concentration (Emmanuel et al., 1985).

3.3 *Gene/Environmental Interaction*
The life span of tree species is generally long, ranging from a few to hundreds of years. Accordingly, compared with annuals, these perennial species have evolved a greater tolerance to a wider range and variability of climatic conditions. Of particular interest is the anticipated *rate* of change in relation to the past evolutionary experience of trees. Temperature changes during the past 100,000 years have been smaller, both in rate and magnitude than those anticipated for the next 50 to 75 years. In the temperate zone of the middle latitudes particularly, the ability (e.g., hardiness) of individual tree species to survive under the anticipated climatic regimes (temperature, soil wetness, episodic events, etc.) has yet to be assessed. This assessment is particularly crucial in view of the billions of dollars currently being spent on reforestation programs, where the genetic characteristics of seedlings is carefully matched with the *current* climate of the area being reforested. In the boreal forest, for example, the seedlings being planted today, at a considerable cost, will only attain half their rotation age by the year 2030, and conceivably will be growing under a significantly different climatic regime.

3.4 *Species Evolution*
Climate change, species migration and exposure to new habitats create conditions for the isolation of species as well as for the evolution of new species (Argus and McNeill, 1974; Brayshaw, 1965; Maini, 1968a; Rasaneu et al., 1987; Salo, 1987). Such gene-environment perturbations associated with atmospheric change would also become an evolutionary force, and over the long term, would likely result in the evolution of new species, varieties and forms.

3.5 *Forest Fires*
Forest fires, an integral component of many forest ecosystems, are dependent on fuel availability and climate elements, such as temperature, humidity and wind velocity. The anticipated increase in temperature and/or in frost-free season is likely to affect the intensity and frequency of forest fires and the consequent impact on economically and ecologically valuable forest land.

3.6 *Forest Insects and Diseases*
The climate warming would likely affect the activity, abundance and distribution of many insects and diseases. For example, the current cold climate in the northern boreal forest zone is believed to limit the northward extension of some insect species (e.g., the gypsy moth), which would otherwise cover the distribution area of their favoured hosts (deciduous trees). In a warmer climate, one might expect a northward migration of certain insects and diseases. Similarly in the Rocky Mountains area, the altitude and the associated climatic gradient determine the distribution of certain insects (e.g., bark beetles). A warmer climate in the middle latitudes is likely to extend the distribution range of some insects and diseases to higher altitudes.

3.7 *Reproduction*
One of the symptoms of species under stress is a loss of, or a reduction in, reproductive capacity (Rapport et al., 1985). Perpetuation of species under stress that reproduce by sexual means only (i.e., seeds) are likely to be affected more than those that have an alternate strategy for reproducing by vegetative means (Maini, 1986a, b). Under the anticipated climatic regime, the number and abundance of trees and associated groundcover species that reproduce vegetatively is likely to increase, at least initially, thereby affecting the structure and composition of the forest types that are shifting spatially.

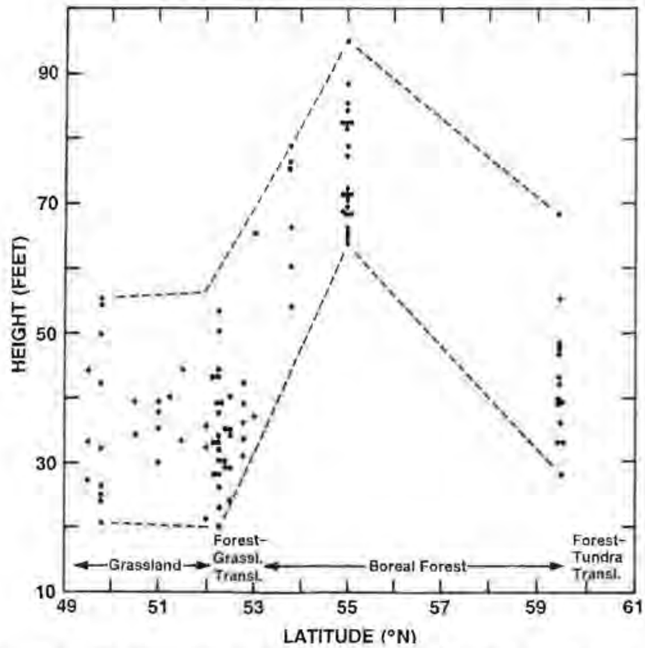


Figure 5 Influence of a climatic gradient (as related to latitude) on height growth of *P. tremuloides* in Saskatchewan, Canada (Maini, 1968a).

3.8 *Competing Vegetation*
Even though the impact of a CO_2-enriched atmosphere on tree growth is still poorly understood, it has been suggested that the ground vegetation may benefit from the anticipated atmospheric change and thereby compete more strongly with the seedlings of economically desirable species (Wheaton et al., 1987).

3.9 *Forest Harvesting*
Frozen ground for extended periods permits a longer forest harvesting period in the northern middle latitudes, especially when heavy machinery and equipment is used. Reduced snow cover (Manabe and Wetherald, 1986) and warmer winters would require adjustments in forest harvesting operations and technologies, from both the economic and environmental viewpoints.

3.10 *Forest Hydrology*
The drainage systems of many rivers around the world are covered by forests (e.g., Amazon, Ob-Irtysh, Congo, Columbia) and the trees cover plays an important role in regulating their water supply. One impact of the anticipated climate change on forest cover is likely to influence the quantity and pattern of the water flow in river systems and consequently the availability of the water supply for industrial and residential use; the altered hydrologic regimes would also influence the forest wildlife habitat.

3.11 *Wildlife Habitat*
Forests serve as an important habitat for many wildlife species. Under an altered climate regime and forest habitat, many wildlife species are likely to migrate. However, the impact of anticipated climate change on the growth and composition of forests and their associated ground vegetation is likely to influence the composition and population levels of wildlife species in a given area.

4. HUMAN ACTIVITIES AND SOCIO-ECONOMIC IMPLICATIONS

Human activities appear to have played a crucial role in atmospheric change from the point of view of their impact on forests. The emission of "greenhouse gases" is directly attributed to the production and consumption activities of man as well as to the large-scale deforestation during the past 8000 years. The anticipated climate change will not only impact directly on many human activities, it will also have indirect economic, social and environmental consequences through its impact on the composition and distribution of forest resources (e.g., productivity) and biological processes (i.e., reproduction and hardiness), as well as on the water supply, through altered hydrologic regimes, etc. Forest management and utilization, policy formulation and implementation, and research, are considered to be of particular interest in addressing this issue.

4.1 *Forest Management and Utilization*

Forests are harvested world-wide for a variety of uses, including industrial wood and fuelwood (Shugart et al., 1986). The relationship between man and forests is at least partially dependent on the level of economic development of a given society. Dependence on, and commitment to, maintaining forests usually evolves with economic development from a subsistance economy to a cash economy and then to a market economy, the latter being prevalent in the industrialized countries located in the northern middle latitudes. Consequently, in order to formulate policies and institutional arrangements that would ensure a sustainable flow of economic and other benefits from forests, it is important to understand the wide range of interactions between human activities, atmospheric change and forests within different economic contexts. Heavy financial investments, amounting to billions of dollars, have been, and are being, made in the reforestation management and harvesting of forests and in the forest-based industries in many parts of the world. Forests are the basis for the economic activities of many communities (Pharand, 1988), countries and regions. Consequently, qualitative, quantitative and spatial changes in the forest resource base would have far-reaching economic, social and environmental consequences on the human populations that depend on them.

4.2 *Policy Formulation and Implementation*

In view of the scale and scope of the anticipated atmospheric change, the following two considerations appear to be important in determining policy responses to this issue.

4.2.1 RESPONSE TO CRISIS

Human societies respond to crises by adopting one of at least three strategies: escape, cope or adapt. In the altered climate scenario, those engaged in the forest-based subsistence economy would have the option of employing the "escape" strategy and migrate to other areas, (cf. shifting cultivation in the tropics; "environmental refugees"). However, the formulation of response strategies should be a cause of serious concern to the policy community in governments and industry located in forest regions with a highly developed economy (e.g., the middle latitude, circumpolar boreal belt) and where heavy financial investments in capital infrastructure, forest management and human resources have been, or are, being made. Heavy financial investments, physically "anchored" at specific geographic locations, limit the policy options to coping with (short-term remedial measures) and adapting (long-term harmonization) to the altered climatic regime. Consideration of the lead-time requirement is important in formulating such policy actions.

4.2.2 INTERNATIONAL ENVIRONMENTAL POLICY COLLABORATION

The geographic scale and socio-economic scope of the issue is such that collective action by the global community would be required to address this issue. Determining and implementing international collective action is a particularly challenging task because of the following considerations:

- So far, the discussion of this issue has been largely confined to the national and international scientific communities; the emergence of this issue on the agenda of the international policy community, such as at the Reagan-Gorbachev Summit in 1987 (Anonymous, 1988) and of the international opinion-makers, such as the InterAction Council (1988), is fairly recent.
- The environmental community has a limited experience in formulating international environmental policy and policy instruments, and in establishing the associated international institutional arrangements. To date, most of the experience with multinational collaboration on environmental issues is confined to wildlife conservation and, more recently, to the Ozone Convention; there is much to be learned from the past successes and failures of international environment policy initiatives; for example, the way the Law of the Sea Conference issue was managed from scientific and policy perspectives.
- As a global community, we have centuries of experience in international collaboration in military alliances (e.g., NATO, Warsaw Pact) for collective national security, and in trade alliances (e.g., OECD, COMCON, ASEAN) for economic security. Now we seem to be entering an era of environmental alliances for global security. It is interesting to note that it is the extra-institutional bodies such as the Palma Commission, Brandt Commission and the Brundtland Commission that have examined the global implications of various alliances and have formulated alternative visions on disarmament, on North-South dialogue and on environment and development.

Collective global action is required to reduce the emission of greenhouse gases by, for example, influencing the energy policy as well as the production and consumption patterns of individual nations. Furthermore, the proposed initiatives on massive tree planting programs (InterAction Council, 1988) to meet socio-economic and environmental objectives would also serve as a means to fix carbon and support the "modest policies" scenario to somewhat dampen the rate of atmospheric change (Woodwell, 1987).

4.3 *Research*

Although significant progress has been made during the past 10 years to understand the physical and chemical aspects of the "atmosphere" component of this issue (Figure 1), there are still many uncertainties and unknowns in our understanding of the response of forests to atmospheric change and its consequent socio-economic and environmental impacts (Pollard, 1987; Wheaton et al., 1987). Nevertheless, there is a need to undertake ingenious studies that would provide glimpses of the likely future responses of the forest and human subsystems to an altered climatic regime. Much is to be learned by understanding the interactions and responses of these two interacting subsystems (Wheaton et al., 1987), performing under optimum conditions as well as under stress. Insightful hindsight enhances our foresight capabilities. For example, research along the following lines may yield useful insights and lessons:

- responses of human and biological systems to El-Niño (an extended climatic perturbation that occurs periodically in Latin and Central America)
- responses of biological systems to the chinook in the Rocky Mountain region and to similar phenomena elsewhere
- re-interpretation of the results of the existing range-wide provenance trials* of species from the perspective of atmospheric change in order to determine the likely future gene-environment interactions
- macro-level growth response of tree species along latitudinal (Maini, 1968a) and altitudinal gradients to determine the likely shifts in biological productivity of given regions.

The use of techniques such as risk analysis, risk management (Maini et al., 1985), simulation modelling (Shugart et al., 1986), and the determination of the necessary lead-time required to develop "coping" and "adapting" strategies would permit the formulation of appropriate research programs and policies. For example, annuals with short breeding cycles, commonly used in agricultural crops are likely to evolve and adapt to the changing atmosphere much more rapidly than trees with longer breeding cycles. For agricultural crops, a shorter lead-time, e.g., about 5 years, is likely to be required to breed commercially valuable varieties to match the altered climate regimes. Most commercially valuable tree species, on the other hand, attain sexual maturity in about 10+ years and have a longer life cycle ("rotation age"); for these species, the lead-time required to develop new varieties may extend to several decades. This poses special challenges to the scientific community to design appropriate research programs, and to the policy community to provide long-term, secure funding to support this research. In view of the uncertainties surrounding this issue, there is a need to formulate robust research programs and policies that would permit a successive series of adaptive refinements.

5. CONCLUSIONS

Atmospheric change is not a new phenomenon. What is unique about the present phase of atmospheric change is the presence of the human factor. Human activities (i.e., production and consumption) have contributed to the increased emission of greenhouse gases that are associated with the anticipated climate change. Interestingly, the Northern Hemisphere, the principal emitter of the "greenhouse gases" is also the principal receptor of feedback from the system, i.e., the impact of atmospheric change is likely to be more pronounced in the middle and northern latitudes.

Heavy investments in the capital plant (machinery and equipment) infrastructure and forest management activities, as well as the significant economic dependence of many communities, nations and regions on forest resources make this issue of profound significance to the national and international policy communities. The anticipated increase in global temperature would ultimately shift the current latitudinal and altitudinal zoning of many forest types (particularly in the middle latitudes) as well as the latitudinal and altitudinal tree-lines; cause ecological perturbations that would likely act as an evolutionary force resulting in new forms, varieties and even species; increase the incidence of fires, insects and diseases; influence growth and biomass production; and require the adaptation of current tree harvesting technologies to the altered climate regime, particularly in middle latitudes. An enriched CO_2 atmosphere may result in greater competition between ground vegetation and seedlings of economically desirable species.

The lead-time required to address new problems associated with forest insects and diseases, forest fires, vegetation competition, and adaptation of harvesting machinery and equipment to the altered climate regime, is likely to be short, i.e., less than 10 years.

Billions of dollars are currently being invested in forest management and forest industries. Tree seedlings planted today in the middle latitudes will only be half their rotation age by the year 2030 and likely growing in an altered climate regime. Robust and flexible strategies are needed to reduce the levels of risk for these massive financial investments. The anticipated atmospheric changes are beyond the recent evolutionary experience of trees and forests. Consequently, a longer lead-time is likely to be required to address the issues involving gene-environment interaction, which determines the growth and the very survival of species.

Collective international action, or an environmental alliance is required to address this issue of global environmental security. The three dynamic subsystems (Figure 1) of the issue discussed here, operate under different time horizons. Atmospheric change extends over centuries; the investment in forest resources extends over decades (e.g., rotation age of trees); the scientific studies and experiments also extend over several decades; institutional (government departments and industry) planning usually takes 10–15 years; and the political horizon is usually about 5 years or less. Formulating robust research and policies and harmonizing the different time horizons of the scientific, institutional and policy communities pose serious challenges to both the national and international scientific and policy communities.

*Provenance trials involve growing the same genetic material under different climatic conditions.

REFERENCES

Anonymous, 1988: Reagan-Gorbachev Communique Supports U.S. -Soviet Joint Efforts on Climate Issues. *Climate Alert,* Vol. 1, 2.

Argus, G.W. and J. McNeill, 1974: Conservation of Evolutionary Centres in Canada. *In*: Conservation in Canada: A Conspectus, J.S. Maini and A. Carlisle, (Eds.), Can. For. Serv., Environment Canada Publ. No. 1340, pp. 129–142.

Auclair, A., 1987a: The Climate Change Theory of Forest Climate. IUFRO Conference on Woody Plant Growth in a Changing Physical and Chemical Environment, Vancouver, B.C., manuscript, 27 pp.

Auclair, A., 1987b: Response of Forestry in Canada to the Global Changes in the Atmospheric Decline. Unpubl. Rep., Environment Canada, Downsview, Ont., 24 pp. + annexes.

Auclair, A. and D.F.W. Pollard, 1988: Climate Change in Canada: There Is a Need for Action by the Forest Sector. Unpubl. manuscript, 15 pp.

Brayshaw, T.C., 1965: Native Poplars of Southern Alberta and Their Hybrids. Can. Dep. Forestry Publ. 1109, 40 pp.

Bruce, J. and H. Hengeveld, 1985: Our Changing Northern Climate. *Geography,* Vol. 14, 1–6.

Canadian Forestry Service, 1988: Canada's Forests 1987. Minister of Supply and Services Canada, Catal. No. FO 51-1/1987E.

Dansereau, P., 1957: *Biogeography: An Ecological Perspective.* The Ronald Press Company, New York, 394 pp.

Davis, M.B., 1984: Climatic Instability, Timelags and Community Disequilibrium. In: *Community Ecology,* J. Diamond and T.J. Case (Eds.), New York Harper & Row, pp. 269–284.

Davis, M.B. and D.B. Botkin, 1985: Sensitivity of Cool-Temperate Forests and Their Fossil Pollen Record to Rapid Temperature Change. *Quat. Res.,* Vol. 23, 327–346.

Emmanuel, W.R.; H.H. Shugart and M.P. Stevenson, 1985: Climatic Change and the Broad-Scale Distribution of Terrestrial Ecosystem Complexes. *In*: The Sensitivity of Natural Ecosystem and Agriculture to Climate Change, M.L. Parry (Ed.), Res. Rep. RR-85-1, Int. Inst. for Applied Systems Analysis, Laxenburg, Austria, pp. 29–43.

Hansen, J.E., 1987: Prediction of Near-Term Climate Evolution: What Can We Tell Decision Makers. Statement presented to the United States Senate Committee on Energy and Natural Resources, November 9, 1987 in manuscript, 11 pp. + attachments.

Hare, F.K., 1988: The Global Greenhouse Effect. *Chinook*, Vol. 11, 62–66. Paper presented at the World Conference on The Changing Atmosphere, Toronto, 27–30 June 1988.

Harrington, J.B., 1987: Climate Change: A Review of Causes. *Can. For. Res.*, Vol. 17, 1313–1339.

InterAction Council, 1988: Report on the Conclusions and Recommendations of the High Level Expert Group on Global Deforestation Trends. InterAction Council, UN Plaza, New York, 10 pp.

International Institute for Environment and Development and World Resources Institute (IIED and WRI), 1987: *World Resources 1987*. Basic Books, Inc., New York, 389 pp.

Jaeger, J., 1988: Developing Policies for Responding to Climatic Change. World Meteorological Organization and the UN Environment Programme, WCIP-1, WMO/TD-No. 225, 53 pp.

Jozsa, L.A. and J.M. Powell, 1987: Some Climatic Aspects of Biomass Productivity of White Spruce Stem Wood. *Can. J. For. Sci.*, Vol. 17, 1075–1079.

Kauppi, P. and M. Posch, 1985: Sensitivity of Boreal Forests to Possible Climate Warming. *In*: The Sensitivity of Natural Ecosystem and Agriculture to Climate Change, M.L. Parry, (Ed.), Res. Rep. RR-85-1, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 45–64.

Maini, J.S., 1960: Invasion of Grassland by *Populus tremuloides* in the Northern Great Plains. Ph.D. Thesis, University of Saskatchewan, Saskatoon, Sask., 231 pp.

Maini, J.S., 1968a: Silvics and Ecology of *Populus* in Canada. *In*: Growth and Utilization of Poplars in Canada, J.S. Maini and J.H. Cayford (Eds.), Dep. For. Rural Develop., For. Dep. Publ. No. 1205.

Maini, J.S., 1968b: Variation in the Growth and Reproduction of Widely Distributed *Populus tremuloides* Michnx. (Aspen). *Bull. Ecol. Soc. Am.*, Vol. 49, 71.

Maini, J.S.; M. Peltu and H. Otway, 1985: Regulating Industrial Risks. Executive Rep. No. 8, International Institute for Applied Systems Analysis, Laxenburg, Austria, 18 pp.

Manabe, S. and R.T. Wetherald, 1986: Reduction in Summer Soil Wetness Induced by an Increase in Carbon Dioxide. *Science*, Vol. 232, 626–628.

Manabe, S. and R.T. Wetherald, 1987: Large-Scale Changes of Soil Wetness Induced by an Increase in Atmospheric Carbon Dioxide. *J. Atmos. Sci.*, Vol. 40, 1211–1235.

Mintzer, I.M., 1987: A Matter of Degrees: The Potential for Controlling the Green-House Effect. World Resources Inst. Res. Rep. 5, 60 pp.

Pharand, N.L., 1988: Forest Sector-Dependent Communities in Canada: A Demographic Profile. Infor. Rep. DPC-X-23, Canadian Forestry Service, Ottawa, Ont., 61 pp.

Pollard, D.F.W., 1987: Forestry and climate change: Facing uncertainty. E.B. Eddy Lecture, Faculty of Forestry, Univ. of Toronto, manuscript 36 pp.

Rapport, D.J.; H.A. Regier and T.C. Hutchinson, 1985: Ecosystem Behaviour Under Stress. *The American Naturalist*, Vol. 125, 617–640.

Rasaneu, M.E.: J.S. Salo and R.J. Kalliola, 1987: Fluvial Perturbance in the Western Amazon Basin: Regulation by Long-Term Sub-Andean Tectonics. *Science*, Vol. 238, 1398-1401.

Robertson, E.O.; L.A. Jozsa and J.E. Richards, 1988: Estimating Douglas-fir Wood Production From Soil and Climate Data. Proj. No. 55-12X-003, Forintek Canada Corporation, Vancouver, B.C., 33 pp.

Salo, J., 1987: Pleistocene Forest Refugees in Amazon: Evaluation of Biostratigraphical, Lithostratigraphical and Geomorphological data. *Ann. Zool. Fennici*, Vol. 24, 203–211.

Shugart, H.H.; M. Ya., Antenovsky, P.G. Jarvis and A.P. Sanford, 1986: CO_2, Climate Change and Forest Ecosystems. I: *The Greenhouse Effect, Climate Change and Ecosystems*, B. Bolin, B.R. Doos, J. Jaeger, and R.W. Warrick (Eds.), Scope 29, John Wiley & Sons, New York.

Stewart, R., 1987: CO_2 – Implications for Climate and Agriculture in Canada. Unpublished Notes.

Wheaton, E.E.; T. Singh, R. Dempster, K.O. Higgenbottam, J.P. Thorpe, G.C. VanKooten and J.S. Taylor, 1987: An Exploration and Assessment of the Implications of Climate Change for the Boreal Forest and Forestry Economics of the Prairie Provinces and Northwest Territories. Phase One. Saskatchewan Res. Counc. Tech. Rep. No. 211, 282 pp.

Woodwell, G.M., 1987: The Warming of the Industrialized Middle Latitudes 1985–2050. Symp. on Developing Policies for Responding to Future Climate Change, Villach, Austria.

Woodwell, G.M.; R.H. Wittaker, W.A. Reiners, G.E. Likens, C.C. Delwiche and D.B. Botkin, 1978: The Biota and the World Carbon Budget. *Science*, Vol. 199, 141–146.

Jagmohan S. Maini was born and raised in India and attended the Forest Research Institute at Dehra Dun (India), where he earned his B.Sc. and M.Sc. (Ecology) in the mid-1950s. In 1960 he received his Ph.D. in Plant Ecology from the University of Saskatchewan (Canada). For the next two years he led ecological subarctic survey expeditions in Canada for the University.

Jag Maini joined the Canadian Forestry Service in 1962 as a Research Scientist and moved to Ottawa in 1968 as Coordinator of programs in Tree Biology and the Environment. From 1973 to 1978, he served as Regional Director of the Laurentian Forest Research Centre in Quebec City, and in 1978 he returned to Ottawa as Project Director with the Ministry of State for Science and Technology. Apart from a two-year Executive Interchange with the International Institute for Applied Systems Analysis in Austria from 1983 to 1985, Dr. Maini spent the years from 1979 to 1986 with the Corporate Planning Group of Environment Canada as both Director General of Policy and Special Advisor on OECD and natural resources issues.

In 1986 Dr. Maini joined the Canadian Forestry Service of Agriculture Canada as a Special Advisor to prepare the Service for its enhanced status as a Ministry of State. Last year, Dr. Maini became the new Service's Assistant Deputy Minister, Forestry Policy.

Jag Maini has led Canadian delegations overseas and served in various capacities with international groups including OECD, Unesco–Man and the Biosphere, FAO, ECE, EEC and UNEP.

RÉSUMÉ *Les forêtes jouent un important rôle économique et écologique aux échelons local, national, régional et mondial. Pour déterminer les répercusions économiques d'unchangement prévu de l'atmosphère sur les forêts, on peut examiner les changements dans la croissance et la production nette de la biomasse; l'interaction des gènes et de l'environnement; l'effet des insectes, des maladies et des incendies; le comportement reproductif; et les techniques de récolte. Les changements atmosphériques prévus influeront aussi sur le rôle écologique des forêts qui constituent, par exemple l'habitat, de la faune et des bassins de drainage de nombreux réseaux fluviaux.*

Par leur vitesse et leur ampleur, les changements atmosphériques prévus seront plus importants que la récente expérience évolutive de la

plupart des espèces d'arbres. Dans ce contexte, l'étude des questions de gestion et d'utilisation des forêts exigerait d'avoir conscience du temps qu'il faudrait sans doute pour examiner une question particulière. A l'inverse de l'agriculture, l'allongement de la vie et du cycle de multiplication de nombreux arbres des forêts nécessiterait un temps plus long pour formuler des qui permettraient l'utilisation durable des terrains forestiers. Compte tenu de l'ampleur géographique, des exigences de délais et des incertitudes liées aux questions, il importe de concevoir de solides programmes et politiques de recherce, qui soient souples et qui permettent des améliorations successives et adaptatives. En outre, pour faire face et s'adapter aux changements prévus aux échelons national et international, il faudrait prendre des mesures collectives à diverses échelles spatiales et temporelles. Toutefois, contrairement à notre expérience des ententes internationales relatives au commerce, notre expérience est limitée en ce qui touche la formulation des politques internationales d'environnement et l'appui de documents et d'établissements de régularisation. Pour harmoniser les perspectives scientifiques, institutionnelles (c'est-à-dire industrielles et gouvernementales) et politques, les organismes scientifiques et decisionnaires devront relever de grands défis.

CONFERENCE STATEMENT

Abridged version of the complete Conference Statement published on pages 292–304 of the Conference Proceedings of the World Conference on the Changing Atmosphere, WMO-No. 710, World Meteorological Organization, Geneva, Switzerland, 1989

THE ISSUE

Continuing alteration of the global atmosphere threatens global security, the world economy, and the natural environment through

- Climate warming, rising sea-level, altered precipitation patterns and changed frequencies of climatic extremes induced by the "heat trap" effects of greenhouse gases
- Depletion of the ozone layer
- Long-range transport of toxic chemicals and acidifying substances

These changes will

- Imperil human health and well-being
- Diminish global food security, through increases in soil erosion and greater shifts and uncertainties in agricultural production, particularly for many vulnerable regions
- Change the distribution and seasonal availability of freshwater resources
- Increase political instability and the potential for international conflict
- Jeopardize the prospects for sustainable development and the reduction of poverty
- Accelerate the extinction of animal and plant species upon which human survival depends
- Alter the yield, productivity and biological diversity of natural and managed ecosystems, particularly forests

If rapid action is not taken now by the countries of the world, these problem will become progressively more serious, more difficult to reverse, and more costly to address.

SCIENTIFIC BASIS FOR CONCERN

Climate Warming

1) There has been an observed increase of globally-averaged temperature of 0.5°C in the past century, consistent with theoretical greenhouse gas predictions. The accelerating increase in concentrations of greenhouse gases will probably result in a rise in the mean surface temperature of the Earth of 1.5 to 4.5°C before the middle of the next century.

2) Marked regional variations in the amount of warming are expected, e.g., at high latitudes the warming may be twice the global average. Changes in the amount and distribution of rainfall and in atmospheric and oceanic circulation patterns would also occur. The natural variability of the atmosphere and climate will continue and be superimposed on the long-term trend, forced by human activities.

3) If current trends continue, the rates and magnitude of climate change in the next century may substantially exceed those experienced over the last 5000 years and would be sufficiently disruptive that no country would likely benefit *in toto* from climate change.

4) The climate change will continue so long as the greenhouse gases accumulate in the atmosphere.

5) There can be a time lag of the order of decades between the emission of gases into the atmosphere and their full manifestation in atmospheric and biological consequences. Past emissions have already committed planet Earth to a significant warming.

6) Global warming will accelerate the present sea-level rise, probably of the order of 30 cm, possibly as much as 1.5 m by the middle of the next century. This could inundate low-lying coastal lands and islands, and reduce coastal water supplies by increased salt water intrusion. Many densely populated deltas and agricultural lands would be threatened. The frequency of tropical cyclones may increase and storm tracks may change with consequent devastating impacts on coastal areas and islands by floods and storm surges.

7) Deforestation and bad agricultural practices are contributing to desertification and are reducing the biological

storage of CO_2, thereby contributing to the increase of this most important greenhouse gas. Deforestation and poor agricultural practices are also contributing additional greenhouse gases such as nitrous oxide and methane.

Ozone-Layer Depletion

1) Increased levels of damaging ultraviolet radiation, while the stratospheric ozone shield thins, will cause a significant rise in the occurrence of skin cancer and eye damage, and will be harmful to many biological species. Each 1% decline in ozone is expected to cause a 4 to 6% increase in certain kinds of skin cancer. A particular concern is the possible combined effects on unmanaged ecosystems from both increased ultraviolet radiation and climate changes.

2) Over the last decade, a decline of 3% in the ozone layer has occurred at mid-latitudes in the Southern Hemisphere, possibly accompanying the appearance of the Antarctic ozone hole; although there is more meteorological variability, there are indications that a smaller decline has occurred in the Northern Hemisphere. Changes of the ozone layer will also change the climate and the circulation of the atmosphere.

Acidification

While improving the quality of the air in their cities, many industrialized countries unintentionally sent increasing amounts of pollution across national boundaries in Europe and North America, contributing to the acidification of distant environments. This was manifested by increasing damage to lakes, soils, plants, animals, forests and fisheries. Failure to control automobile pollution in some regions has seriously contributed to the problem. The principal damage agents are oxides of sulphur and nitrogen as well as volatile hydrocarbons. The resulting acids can also corrode buildings and metallic structures causing, overall, billions of dollars of damage annually.

The various issues arising from the pollution of Earth's atmosphere by a number of substances are often closely interrelated, both through chemistry and through potential control strategies. For example, chlorofluorocarbons (CFCs) both destroy ozone and are greenhouse gases; conservation of fossil fuels would contribute to addressing both acid rain and climate change problems.

ECONOMIC AND SOCIAL CONCERNS

There is no concern more fundamental than access to food and water. Currently, levels of global food security are inadequate but even those will be most difficult to maintain into the future, given projected agricultural production levels and population and income growth rates. The climate changes envisaged will aggravate the problem of uncertainty in food security. Climate change is being induced by the prosperous, but its effects are suffered most acutely by the poor. It is imperative for governments and the international community to sustain the agricultural and marine resource base and provide development opportunities for the poor in light of this growing environmental threat to global food security.

A CALL FOR ACTION

The following actions are mostly designed to slow and eventually reverse the deterioration of the atmosphere.

Actions by Governments and Industry

- *Ratify the Montréal Protocol on Substances that Deplete the Ozone Layer.*

- *Set energy policies to reduce the emissions of CO_2 and other trace gases* in order to reduce the risks of future global warming. Stabilizing the atmospheric concentrations of CO_2 is an imperative goal.

- *Reduce CO_2 emissions by approximately 20% of 1988 levels by the year 2005 as an initial global goal.*

- *Set targets for energy efficiency improvements* that are directly related to reductions in CO_2 and other greenhouse gases. A challenging target would be to achieve the 10% energy efficiency improvements by the year 2005.

  Apart from efficiency measures, the desired reduction will require (i) switching to lower CO_2-emitting fuels, (ii) reviewing strategies for the implementation of renewable energy, especially advanced biomass conversion technologies; and (iii) revisiting the nuclear power option.

- *Negotiate now on ways to achieve the above-mentioned reductions.*

- *Initiate management systems* in order to encourage, review and approve major new projects for energy efficiency.

- *Vigorously apply existing technologies,* to reduce (i) emissions of acidifying substances; (ii) substances that are precursors of tropospheric ozone; and (iii) other non-CO_2 greenhouse gases.

- *Label products* to allow consumers to judge the extent and nature of the atmospheric contamination.

Actions by Other Agencies

- *Initiate the development of a comprehensive global convention* as a framework for protocols on the protection of the atmosphere.

- *Establish a World Atmosphere Fund,* financed in part by a levy on the fossil-fuel consumption of industrialized countries.

- *Support the work of the Inter-Governmental Panel on Climate Change.*

- *Devote increasing resources to research and monitoring efforts* within the World Climate Programme, the International Geosphere Biosphere Programme and Human Response to Global Change Programme.

- *Increase significantly the funding for research, development and transfer of information on renewable energy.*

- *Expand funding for more extensive technology transfer and technical cooperation projects in coastal zone protection and management.*

- *Reduce deforestation and increase afforestation.*

- *Develop and support technical cooperation projects* to allow developing nations to participate in international mitigation efforts, monitoring, research and analysis related to the changing atmosphere.

- *Ensure that this Conference Statement, the Working Group reports and the full Proceedings of the World Conference, "The Changing Atmosphere: Implications for Global Security"* (1989) *are made available* to all nations.

- *Increase funding to non-governmental organizations* to allow the establishment and improvement of environmental education programmes and public awareness campaigns.

- *Allocate financial support for environmental education* in primary and secondary schools and universities.

Canadian Meteorological and Oceanographic Society

La Société Canadienne de Météorologie et d'Océanographie

ATMOSPHERE-OCEAN

The scientific journal of international meteorological and oceanographic research. Quarterly publication.

CMOS NEWSLETTER

Keeps you in touch with the activities of the Canadian Meteorological and Oceanographic Society. Six times a year.

CLIMATOLOGICAL BULLETIN

Climatological research and news. Three times a year.

These publications are all available from CMOS, P.O. Box 334, Newmarket, Ontario, Canada L3Y 4X7.

The **Atmosphere, Weather and Climate** kit is designed to inform teachers and students about our atmospheric resource and the current issues facing Canadians and citizens of the world.

- $8\frac{1}{2} \times 11$ – 55 pages, designed with duplication for class use in mind.
- recommended for use in science and geography, grades 7–12.

Fact Sheets on:

- Atmosphere, Weather and Climate
- Climate Change and Variability
- What Shapes the Climate of Canada?
- Human Responses: The Impact of Climate
- Changing Global Climate
- Climate Variations, Drought and Desertification
- The Nuclear Winter Hypothesis
- Acid Rain
- Ozone, Our Invisible Shield
- Air Pollution
- The Global Context of Weather

Plus activity suggestions

Atmosphère, climat et temps a été conçu afin d'aider les éducateurs et les étudiants à observer la Journée mondiale de l'environnement en pleine connaissance de cause.

- $8\frac{1}{2} \times 11$ – 55 pages; conçu pour reproduction pour l'usage des classes
- recommandé pour les cours de sciences et de géographie de la 7$^{\text{ième}}$ à la 12$^{\text{ième}}$

Fiches synoptiques :

- Atmosphère, climat et temps
- La modification et la variabilité du temps
- Les facteurs qui déterminent le climat au Canada
- Les réactions de l'être humain au climat
- Comprendre le CO_2 et le climat
- Qu'est-ce-que la désertification?
- L'hypothèse de l'hiver nucléaire
- Les pluies acides
- L'ozone, notre bouclier invisible
- La pollution atmosphérique
- La situation météorologique mondiale

En plus;
Guide d'activités suggérées

I am ordering

_______ copies of the **Atmosphere, Weather and Climate** kit @ $7.95 each *(cheque or money order must accompany order)*

Je commande

_______ copies du document **Atmosphère, climat et temps** $7.95 chaque *(un chèque ou un mandat-poste doit accompagner la commande)*

Name/Nom ____________________

Institution ____________________

Address/Adresse ____________________

____
POSTAL CODE/CODE POSTAL

National Survival Insitute, 539 Lisgar Street, Ottawa, Ontario K1R 5H4 (613) 232-6634

L'Institut national pour la sauvegarde de l'environnement, 539 rue Lisgar, Ottawa, Ontario K1R 5H4 (613) 232-6634