UNEP Angelo Doto, Italy, Still Pictures

Atmosphere

Global overview

Over the past three decades, anthropogenic emissions of chemical compounds into the atmosphere have caused many environmental and health problems. Some chemicals, such as chlorofluorocarbons (CFCs), are produced deliberately and end up in the atmosphere by accident from equipment or goods. Others, such as sulphur dioxide (SO_2) and carbon monoxide (CO), are unavoidable by-products of burning fossil fuels. Urban air pollution, acid rain, contamination by toxic chemicals (some of them persistent and transported over long distances), depletion of the stratospheric ozone layer and changes in the global climatic system are all important environmental threats to ecosystems and human well-being.

Air pollution and air quality

The World Health Organization (WHO) lists six 'classic' air pollutants: CO, lead, nitrogen dioxide (NO_2), suspended particulate matter (SPM) — including dust, fumes, mists and smoke — SO_2 and tropospheric ozone (O_3) (WHO 1999).

The burning of fossil fuels and biomass is the most significant source of air pollutants such as SO_2, CO, certain nitrous oxides such as NO and NO_2 (known collectively as NO_x), SPM, volatile organic compounds (VOCs) and some heavy metals. It is also the major anthropogenic source of carbon dioxide (CO_2), one of the important greenhouse gases. Between 1973 and 1998, total energy supply increased by 57 per cent (see graph opposite), the majority provided by oil, natural gas and coal with nuclear and hydropower and other renewable resources playing a minor role (IEA 2000). The fuels used vary from region to region — for example, natural gas dominates in the Russian Federation, while coal provides 73 per cent of the energy consumed in China (BP Amoco 2000). Biomass is an important source of energy in the developing world and is the main source of indoor air pollution in such countries (Holdren and Smith 2000).

Acid precipitation has been one of the most important environmental concerns over the past decades especially in Europe and North America (Rodhe and others 1995), and more recently also in China (Seip and others 1999). Significant damage to forests in Europe became a high priority environmental issue around 1980, while thousands of lakes in Scandinavia lost fish populations due to acidification from the 1950s to the 1980s. In some parts of Europe, the anthropogenic SO_2 emissions which lead to acid precipitation have been reduced by nearly 70 per cent from their maximum values (EEA 2001); there have also been reductions of some 40 per cent in the United States (US EPA 2000). This has resulted in a significant recovery of the natural acid balance, at least in Europe. On the contrary, as a result of the growing use of coal and other high sulphur fuels, increasing SO_2 emissions in the Asia and Pacific Region are a serious environmental threat (UNEP 1999).

Air pollutant emissions have declined or stabilized in most industrialized countries, largely as a result of abatement policies developed and implemented since the 1970s. Initially governments tried to apply direct control instruments but these were not always cost-effective. In the 1980s, policies were directed more towards cost-effective pollution abatement mechanisms that relied on a compromise between the cost of environmental protection measures and economic growth. The Polluter Pays Principle has become a basic concept in environmental policy planning.

Recent policy developments, at both national and regional levels, are based on economic and regulatory instruments, and technology improvement and transfer to enhance emission reductions. In the international arena, one of the most important political developments has been the Convention on Long-Range Transboundary Air Pollution (CLRTAP), adopted in 1979. Through a series of protocols establishing reduction objectives for the main air pollutants, this treaty has catalysed European, Canadian and US governments to implement national emission abatement policies (ECE 1995). The most recent protocol is the 1999 Protocol to Abate Acidification, Eutrophication and Ground-Level Ozone that sets up new reduction commitments for SO_2, NO_x, VOCs and ammonia (NH_3) (ECE 2000).

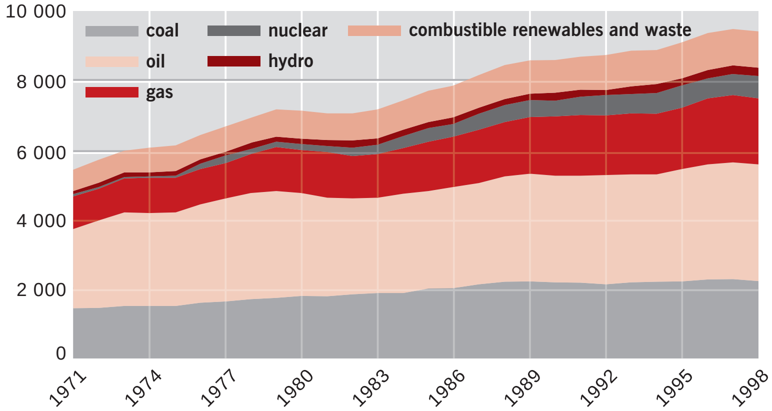
Stricter environmental regulation in the industrialized countries has triggered the introduction of cleaner technology and technological improvements, especially in the power generation and transport sectors. In the latter, a significant reduction in harmful emissions has been achieved due to the improved engine combustion cycle, increased fuel efficiency and the widespread introduction of catalytic converters (Holdren and Smith 2000). Lead emissions from gasoline additives have now declined to zero in many industrial countries (EEA 1999, US EPA 2000). In developing countries, however, the sources of emissions are more varied and include highly polluting power plants, heavy industry, vehicles and the domestic combustion of coal, charcoal and biomass. While the emission of pollutants can be significantly reduced for a small cost, few developing nations have made even small investments in pollution reduction measures, even though the environmental and population health benefits of such measures are evident (Holdren and Smith 2000, World Bank 1997).

Impacts associated with air pollution

Harmful substances emitted to the air affect both human health and ecosystems. Indoor and outdoor air pollution are estimated to be responsible for nearly 5 per cent of the global burden of disease. Air pollution aggravates and, possibly, even causes asthma and other allergic respiratory diseases. Adverse pregnancy outcomes, such as stillbirth and low birth weight, have also been associated with air pollution (Holdren and Smith 2000). It has been estimated that in developing countries about 1.9 million people die annually due to exposure to high concentrations of SPM in the indoor air environment of rural areas, while the excess mortality due to outdoor levels of SPM and SO_2 amounts to about 500 000 people annually. Evidence is also emerging that particles with median aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) affect human health significantly (WHO 1999).

Acid deposition is one of the causes of acidification of soil and water that results in declining fish stocks, decreasing diversity in acid-sensitive lakes and degradation of forest and soil. Excessive nitrogen (as nitrate and/or ammonium) promotes eutrophication, particularly in coastal areas. Acid rain damages ecosystems, provokes defoliation, corrosion of monuments and historic buildings and reduces agricultural yields.

World energy supply by fuel (million tonnes oil equivalent/year)



World energy supply is still dominated by the fossil fuels — coal, oil and gas

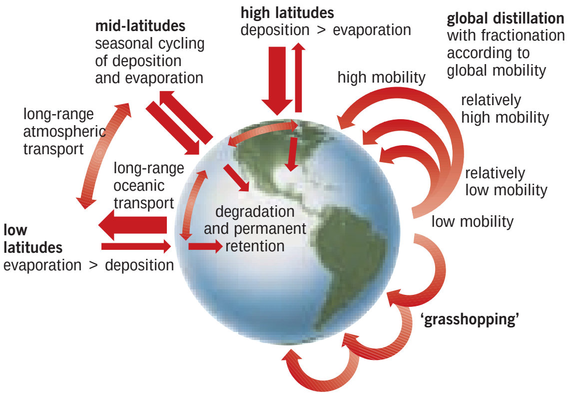
Source: IEA 2000

Though measurable progress in industrial emission abatement has been achieved at least by the developed countries, transport has become one of the major sources of air pollution (particularly NO_x and many carbon compounds) in many countries. High concentrations of these compounds in urban air can, under certain climatic conditions, result in photochemical smog that severely affects human health. In many urban centres and their surrounding areas, high concentrations of tropospheric O_3 are an additional problem. Anthropogenic tropospheric ozone may be produced by reactions between NO_x and VOCs on warm sunny days, especially in urban and industrial areas and in regions prone to stagnant air masses. This can have far-reaching implications since molecules of O_3 have been found to travel large distances (up to 800 km) from emission sources (CEC 1997). Tropospheric O_3 concentrations over large areas of Europe and some areas of North America are so high that not only is human health threatened but vegetation is also affected. For example, in the United States ground-level ozone has been estimated to cost more than US$500 million a year as a result of reductions in agricultural and commercial forest yields (US EPA 2000).

Urban air pollution is one of the most important environmental problems. In most European and North American cities, the concentrations of SO_2 and SPM have decreased substantially in recent years (Fenger 1999, US EPA 2000). However, in many developing countries, rapid urbanization has resulted in increasing air pollution in many cities (Fenger 1999), WHO air quality guidelines are often not met and, in megacities such as Beijing, Calcutta, Mexico City and Rio de Janeiro, high levels of SPM prevail (World Bank 2001).

A final issue of global concern is that of persistent organic pollutants (POPs). These substances are known to decay slowly and they can be transported over long distances through the atmosphere (see illustration above). High concentrations of some POPs are found in polar areas (Schindler 1999, Masclet and others 2000, Espeland and others 1997) with potentially serious regional environmental impacts. These compounds can also accumulate in animal fats, representing a health risk. The Stockholm Convention on Persistent Organic Pollutants, adopted in May 2001, sets out control measures covering handling of pesticides, industrial chemicals and unintended by-products. The control provisions call for eliminating the production and use of intentionally produced POPs, and eliminating unintentionally produced POPs where feasible (UNEP 2001).

Migration of persistent organic pollutants



Persistent organic pollutants spread via a variety of mechanisms at different latitudes

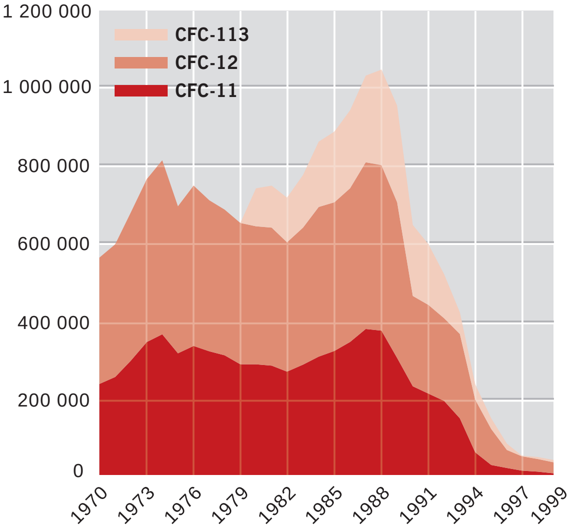
Source: Wania and Mackay 1996

Stratospheric ozone depletion

The protection of the Earth's ozone layer has presented one of the major challenges over the past 30 years, spanning the fields of environment, trade, international cooperation and sustainable development. The thinning of the ozone layer threatens human health through diseases such as skin cancer, eye cataracts and immune deficiency, affects flora and fauna, and also influences the planet's climate. Ozone depletion is brought about by a number of chemicals known as ozone-depleting substances (ODS), the most notorious of which are the chlorofluorocarbons (CFCs). In 1974, the results of studies linking stratospheric ozone depletion to the release of chloride ions in the stratosphere from CFCs were made publicly available (Molina and Rowland 1974). ODS are used in refrigerators, air conditioners, aerosol spray, insulating and furniture foams, and fire-fighting equipment, and their production peaked in the late 1980s as the demand for such goods grew (see graph on page 213).

The depletion of the Earth's ozone layer has now reached record levels, especially in the Antarctic and recently also in the Arctic. In September 2000, the Antarctic ozone hole covered more than 28 million square kilometres (WMO 2000, NASA 2001). Current average ozone losses are 6 per cent in the northern mid-latitudes in winter and spring, 5 per cent in southern mid-latitudes all year round, 50 per cent in the Antarctic spring and 15 per cent in the Arctic spring. The resulting increases in harmful ultraviolet

World production of major chlorofluorocarbons (tonnes/year)



World production of the three major CFCs peaked in about 1988 and has since declined to very low values

Source: AFEAS 2001

irradiation amount to 7 per cent, 6 per cent, 130 per cent and 22 per cent respectively (UNEP 2000a).

However, due to continuous efforts by the international community, the global consumption of ODS has decreased markedly and the ozone layer is predicted to start recovering in the next one or two decades and to return to a pre-1980 level by the middle of the 21st century if all the future control measures of the Montreal Protocol are adhered to by all countries (UNEP 2000a).

International cooperation has been the key to protecting the stratospheric ozone layer. Nations agreed in principle to tackle a global problem before its effects became evident or its existence scientifically proven — probably the first example of acceptance of the precautionary approach (UNEP 2000a).

International action began in earnest in 1975 when the UNEP Governing Council called for a meeting to coordinate activities on protecting the ozone layer. A Coordinating Committee on the Ozone Layer was established the following year to undertake an annual scientific review. In 1977, the United States banned use of CFCs in non-essential aerosols. Canada, Norway and Sweden soon enacted similar control measures. The European Community (EC) froze production capacity and began to limit use of aerosols.

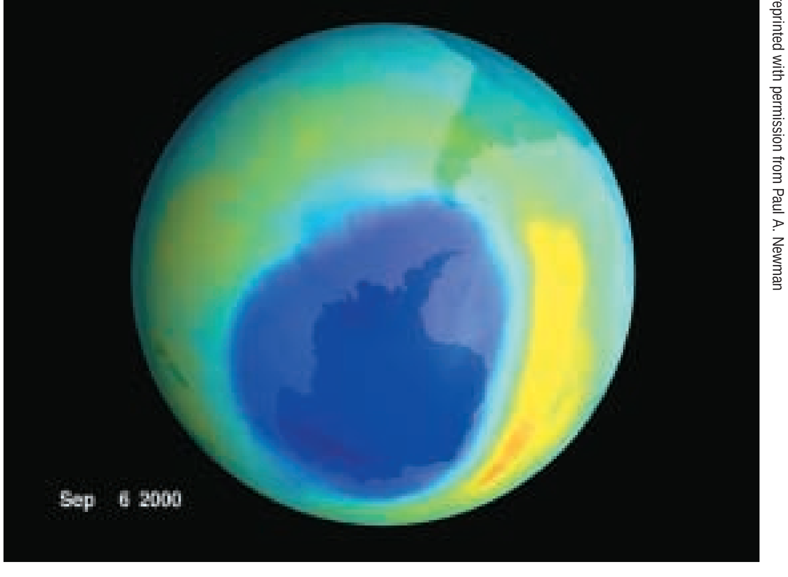
These initiatives, though useful, provided only a temporary respite. After falling for several years, CFC consumption began increasing again in the 1980s, as non-aerosol uses, such as foam blowing, solvents and refrigeration, increased. Stricter control measures were needed and UNEP and several developed countries took the lead, calling for a global treaty on stratospheric ozone layer protection (Benedick 1998).

The Vienna Convention for the Protection of the Ozone Layer was finally agreed by 28 countries in March 1985. It encouraged international cooperation on research, systematic observation of the ozone layer, monitoring of ODS production, and the exchange of information. In September 1987, 46 countries adopted the Montreal Protocol on Substances that Deplete the Ozone Layer (by December 2001, 182 parties had ratified the Vienna Convention and 181 the Montreal Protocol).

The original Protocol required only a 50 per cent cut in consumption of five widely used CFCs by December 1999, and a freeze in the consumption of three halons. Regular scientific assessments were the basis for subsequent amendments and adjustments made to the Protocol in London (1990), Copenhagen (1992), Vienna (1995), Montreal (1997) and Beijing (1999). By the year 2000, 96 chemicals were subject to control (Sabogal 2000).

Most ODS — including all the substances specified in the original Protocol — were phased out in industrialized countries by the end of 1995. The

The Antarctic ozone hole breaks a new record



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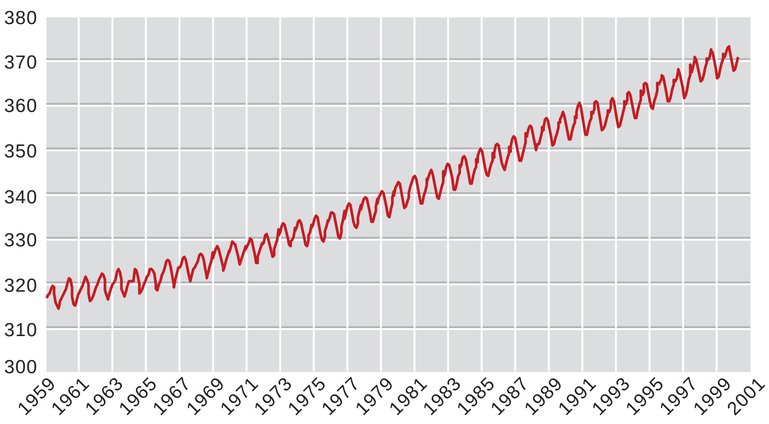
The ozone hole reached a record size in September 2000 — 28.3 million km^2, three times the size of the United States. Dark blue areas denote high levels of ozone depletion

Source: NASA 2001

Protocol provides a 10-year grace period for developing countries and the financial mechanism (the Multilateral Fund to the Montreal Protocol) to meet the costs to these countries of phasing out ODS, thus realizing the principle of common but differentiated responsibility. By 2000, the Multilateral Fund had disbursed more than US$1.1 billion for capacity building and projects to phase out ODS in 114 developing countries.

Almost every party to the Montreal Protocol has now taken measures to phase out ODS with the result that, by 2000, the total consumption of ODS had been reduced by 85 per cent (UNEP 2000b).

Carbon dioxide concentrations at Mauna Loa, Hawaii (parts per million by volume)



Records from Mauna Loa, Hawaii, show how CO_2 concentrations have increased — the increase is largely due to anthropogenic emissions that result from burning fossil fuel

Source: Keeling and Whorf 2001

Greenhouse gases and climate change

Scientists have known about the natural 'greenhouse effect' for more than a century (Arrhenius 1896): the Earth maintains its equilibrium temperature through a delicate balance between the incoming solar energy (short wavelength radiation) it absorbs and the outgoing infra-red energy (long wavelength radiation) that it emits and some of which escapes into space. Greenhouse gases (water vapour, carbon dioxide, methane and others) allow solar radiation to pass through the Earth's atmosphere almost unimpeded but they absorb the infra-red radiation from the Earth's surface and then re-radiate some of it back to the Earth. This natural greenhouse effect keeps the surface temperature about 33°C warmer than it would otherwise be — warm enough to sustain life.

Since the industrial revolution, the concentration of CO_2, one of the major greenhouse gases, in the atmosphere has increased significantly (see graph left, which reflects growth since direct measurements started in 1957). This has contributed to the enhanced greenhouse effect known as 'global warming'.

The CO_2 concentration in the atmosphere is currently about 370 parts per million (ppm) — an increase of more than 30 per cent since 1750. The increase is largely due to anthropogenic emissions of CO_2 from fossil fuel combustion and to a lesser extent land-use change, cement production and biomass combustion (IPCC 2001a). Although CO_2 accounts for more than 60 per cent of the additional greenhouse effect accumulated since industrialization, the concentrations of other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), halocarbons and halons have also increased. In comparison to CO_2, CH_4 and N_2O have contributed about 20 per cent and 6–7 per cent respectively to the additional greenhouse effect. Halocarbons have contributed about 14 per cent. Many of these chemicals are regulated under the Montreal Protocol (see above). However, those which have negligible ozone-depleting potential are not controlled under the Montreal Protocol. Although they have accounted for less than 1 per cent of the additional greenhouse effect since industrialization, their concentrations in the atmosphere are increasing (IPCC 2001a).

Greenhouse gas emissions are unevenly distributed between countries and regions. In general, industrialized countries are responsible for the majority of historical and current emissions. OECD countries contributed more than half of CO_2 emissions in 1998, with an average per capita emission of about three times the world average. However the OECD's share of global CO_2 emissions has decreased by 11 per cent since 1973 (IEA 2000).

In assessing the possible impact of rising atmospheric concentrations of greenhouse gases, IPCC concluded in 2001 that 'there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities'. The overall warming amounts to about 0.6 (±0.2)°C over the 20th century; the 1990s are 'very likely' to have been the warmest decade and the year 1998 the warmest year in the instrumental record, since 1861. Much of the rise in sea level over the past 100 years (about 10 to 20 cm) has probably been related to the concurrent rise in the global temperature (IPCC 2001a).

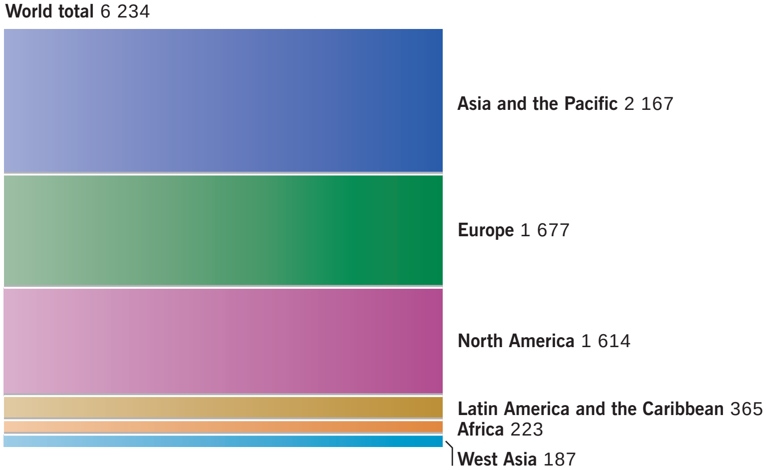
Ecosystems, human health and economy are all sensitive to changes in climate — including both the magnitude and rate of climate change. Whereas many regions are likely to experience adverse effects of climate change — some of which are potentially irreversible — some effects could be beneficial for some regions. Climate change represents an important additional stress on those ecosystems already affected by increasing resource demands, unsustainable management practices and pollution.

Some of the first results of the changing climate can serve as indicators. Several vulnerable ecosystems such as coral reefs are seriously endangered by increased sea temperature (IPCC 2001b) and some populations of migratory birds have been declining because of unfavourable variations in climatic conditions (Sillett, Holmes and Sherry 2000). Climate change is furthermore likely to affect human health and well-being through a variety of mechanisms. For example, it can adversely affect the availability of freshwater, food production, and the distribution and seasonal transmission of vector-borne infectious diseases such as malaria, dengue fever and schistosomiasis. The additional stress of climate change will interact in different ways across regions. It can be expected to reduce the ability of some environmental systems to provide, on a sustained basis, key goods and services needed for successful economic and social development, including adequate food, clean air and water, energy, safe shelter and low levels of diseases (IPCC 2001b).

The United Nations Framework Convention on Climate Change (UNFCCC) adopted at UNCED in 1992 (see Chapter 1) has the ultimate objective of ‘stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system’ (UNFCCC 1992). The Convention further defines several principles of fundamental importance, for example that parties should take precautionary measures and act ‘on the basis of equity and in accordance with their common but differentiated responsibilities’. Being a framework treaty, the UNFCCC contained only a non-binding recommendation for industrialized countries to return to the 1990 emission levels of CO_2 and other greenhouse gases (not controlled by the Montreal Protocol) by the year 2000 (UNFCCC 1992). However, most of them have not returned anthropogenic emissions of greenhouse gases to 1990 levels (UNFCCC 2001). In general, global emissions of almost all anthropogenic greenhouse gases, particularly CO_2, continue to increase (IEA 2000). This reflects the inadequacy of national and international policies and measures to address climate change.

In its *Second Assessment Report*, the IPCC stated that the ‘balance of evidence suggests that there is a discernible human influence on global climate’ (IPCC 1996). This unequivocal statement provided the scientific basis for the adoption of the Kyoto Protocol to the UNFCCC in December 1997. The protocol contains, for the first time, greenhouse gas reduction targets for most industrialized countries. The targets, however, range from an obligation to reduce emissions by 8 per cent (for the European Union and many Central European countries) to a permission to increase emissions by 10 per cent (Iceland) and 8 per cent (Australia). Overall, industrialized countries are required to reduce their aggregated emissions to at least 5 per cent below the 1990 level in the period 2008–12. No new obligations were introduced for developing countries. The Kyoto Protocol also allows collective implementation of obligations by means of applying the so-called ‘Kyoto mechanisms’. These mechanisms aim at providing ‘geographical flexibility’ and reducing the costs of complying with the Kyoto targets. For example, one of them — the Clean Development Mechanism — allows industrialized countries to receive emission credits for carrying out

Carbon dioxide emissions by region, 1998 (million tonnes carbon/year)



Anthropogenic greenhouse gas emissions are unevenly distributed between regions — most emissions come from industrialized regions. Figures include emissions from fuel consumption, gas flaring and cement production

Source: compiled from Marland, Boden and Andres 2001 projects aimed at reducing emissions of greenhouse gases in developing countries (UNFCCC 1997).

The cost estimates for industrialized countries to implement the Kyoto Protocol range between 0.1 and 2 per cent of GDP in 2010 (IPCC 2001c) with most impact being felt by the economies most dependent on fossil fuels. In view of anticipated economic losses, some industrialized nations have prejudiced the Kyoto commitments and the Kyoto Protocol as a whole. Debates on rules and modalities of the implementation of the protocol continued until the 6th Conference of the Parties to the UNFCCC held in November 2000 in The Hague. As negotiating parties still failed to reach consensus, the conference was suspended and parties decided to resume negotiations in 2001. The pivotal point in the global discussion occurred in March 2001 when the US government decided not to introduce any legal restrictions, as implied by the Kyoto Protocol, on anthropogenic emissions of greenhouse gases. The US administration thus declared its opposition to the Protocol, stating that it believed it to be 'fatally flawed', as it would damage the US economy and it exempted developing countries from fully participating (Coon 2001). This decision meant that the United States — a major emitter of CO_2 —would not ratify the Kyoto Protocol.

The Kyoto Protocol would never have come into force if other developed countries had adopted the same position. However, at the resumed 6th Conference of the Parties (COP-6 Part II) in Bonn, Germany, in July 2001, the parties (except the United States) successfully completed negotiations aimed at setting the operational details for commitments on reducing emissions of greenhouse gases. They also reached agreement on actions to strengthen implementation of the UNFCCC itself. The political decision — or Bonn Agreement — was formally adopted by the COP on 25 July 2001. Many saw it as an 'historic' political agreement that saved the Kyoto Protocol and paved the way to its ratification, though it was clearly recognized that this was just a small step towards solving the global problem. Discussions also resulted in a Political Declaration by the European Union, Canada, Iceland, Norway, New Zealand and Switzerland on funding for developing countries. This Declaration includes an undertaking to provide an annual contribution of US$410 million by 2005 (IISD 2001a).

Shortly after COP-6 Part II, the climate change negotiators in Marrakesh (COP-7 held October-November 2001) finalized outstanding issues related to the political deal concluded in Bonn such as a compliance system, the 'Kyoto mechanisms', accounting, reporting and review of information under the Kyoto Protocol, and others (the so-called 'Marrakesh Accords'). The agreement reached in Marrakesh not only allows for ratification of the Kyoto Protocol in the near future but also will serve as the foundation for a comprehensive, multilateral approach that will and must continue beyond this Protocol (IISD 2001b).

Meeting the Kyoto targets will be just a first step in coping with the problem of climate change because it will have a marginal effect on the greenhouse gas concentration in the atmosphere. Even if, in the long term, a stabilization of atmospheric greenhouse gas concentrations is achieved, warming will continue for several decades, and sea levels will continue to rise for centuries with serious consequences for millions of people (IPCC 2001a, b).

The background to international cooperation on climate change

Scientists began to attract policy-makers' attention to global warming as an emerging global threat in the early 1970s (SCEP 1970). However their appeals were originally ignored and, as economies grew, more fossil fuels were burnt, more forested areas were cleared for agriculture and more halocarbons were produced. It took a further 20 years of continuous effort by scientists, NGOs, international organizations and several governments to get the international community to agree to coordinated action to address climate change.

The Stockholm Conference is generally regarded as the starting point for international efforts on climate variations and climate change (UN 1972). In 1979, the first World Climate Conference in Geneva expressed concern about the atmospheric commons. This event was attended primarily by scientists and received little attention from policy-makers. In the 1980s, a series of conferences and workshops were held in Villach, Austria, where scenarios for future emissions of all of the significant greenhouse gases were considered. At the 1985 Villach meeting, an international group of scientific experts reached a consensus on the seriousness of the problem and the danger of significant warming (WMO 1986).

As a result of growing public pressure and the implications of the Brundtland Commission (WCED 1987), the problem of global climate change moved onto the political agenda of several governments. A diplomatic breakthrough came at the 1988 Toronto Conference on the Changing Atmosphere from which emerged a recommendation calling on developed nations to reduce CO_2 emissions by 20 per cent from 1988 levels by the year 2005. A few months later, IPCC was jointly established by WMO and UNEP to review knowledge of the science, impact, economics of, and the options for mitigating and/or adapting to climate change. The IPCC studies, especially the three extensive *Assessment Reports* in 1990, 1995 and 2001, covered all the different facets of climate change.

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Atmosphere: Africa

The African continent is climatically diverse. Humid tropical conditions prevail in Western and Central Africa and in the Western Indian Ocean islands; most Southern African countries experience arid and semi-arid conditions, while semi-deserts and deserts are features of Northern Africa. The region experiences a high degree of variability and uncertainty in climatic conditions. Climate variability is therefore the single most important atmospheric phenomenon in Africa.

In comparison to other regions, African countries emit negligible amounts of air pollutants and anthropogenic greenhouse gases. For example, Africa contributes less than 3.5 per cent of global emissions of CO_2 (Marland, Boden and Andres 2001). Nevertheless, anthropogenic atmospheric pollution is a problem in Northern and Southern Africa, and in some large cities.

Climate variability in Africa

In the past 30 years, Africa has experienced at least one major drought episode in each decade. In Eastern Africa there were serious droughts in 1973-74, 1984-85, 1987, 1992–94 and in 1999-2000 (DMC 2000). The last Sahelian drought persisted for a decade, from 1972-73 to 1983-84. Severe droughts were recorded in Southern Africa in 1967 to 1973, 1982-83, 1986-87, 1991-92 and 1993-94 (Chenje and Johnson 1994).

The Western Indian Ocean islands are subject to tropical storms on average ten times a year during November to May. The El Niño Southern Oscillation (ENSO), which affects much of Africa, has been associated with more frequent, persistent and intense warm phases over the past 30 years (IPCC 2001a). The 1997-98 ENSO event triggered higher sea surface temperatures in the southwest Indian Ocean, and flooding and landslides across most of Eastern Africa (Ogallo 2001).

Air quality

South Africa contributed 42 per cent of the total regional emissions of CO_2 in 1998 (Marland, Boden and Andres 2001); some Northern African countries, where total energy consumption increased by 44 per cent from 1980 to 1998 (OAPEC 1999), also contribute significantly. Subsidizing electricity production, promoting industrial development economic strategies and increased consumption have contributed to rising emissions in some areas. For example, in Mauritius total energy consumption doubled between 1990 and 1998, and CO_2 emissions rose 23 per cent from 1991 to 1995 (UNCHS 1996).

A rapid increase in the number of private cars, and the poor condition of many commercial and private vehicles, are additional causes of concern. Vehicle emissions are the major source of lead contamination, and contribute to dust, noise and smoke pollution. Policies are in place in Algeria, Mauritius and Morocco to encourage conversion to newer, less polluting vehicles (Government of Mauritius 1990), and unleaded petrol has been promoted or even subsidized in Egypt, South Africa and Tunisia (World Bank 2001a). Industrial processes are also significant sources of atmospheric pollution, especially in large urban centres where the pollutants sometimes combine to create atmospheric smog.

In Northern Africa, the Western Indian Ocean islands, Southern Africa and some large cities (such as Lagos), the incidence of respiratory disease is increasing, reflecting a deterioration of air quality. The main causes are the indoor burning of coal, wood, kerosene (paraffin), dung and refuse for household needs, and vehicular and industrial emissions. In sub-Saharan Africa, traditional fuels accounted for 63.5 per cent of total energy use in 1997 (World Bank 2001b).

Many countries have prepared National Environmental Action Plans (NEAPs) or National Strategies for Sustainable Development (NSSDs) which address, among other things, sources and impacts of atmospheric pollution. Ghana, Kenya, South Africa, Uganda and Zambia are among those that have introduced legislation making Environmental Impact Assessments (EIAs) compulsory for developments such as roads, mines and industrial operations with potentially high atmospheric emissions (Government of Ghana 1994, Government of Kenya 1999, Republic of South Africa 1989, Government of Uganda 1995, Government of Zambia 1990).

Climatic variability and vulnerability to climate change

Climatic variability and associated floods and droughts result in increased risks of crop failure and therefore reduced food security, as well as higher incidences of malnutrition and disease. In Ethiopia, for example, the 1984 drought affected 8.7 million people, 1 million people died and millions more suffered from malnutrition and famine. This drought also caused the death of nearly 1.5 million livestock (FAO 2000). The 1991-92 drought in Southern Africa caused a 54 per cent reduction in cereal harvest and exposed more than 17 million people to the risk of starvation (Calliham, Eriksen and Herrick 1994). More than

100 000 people died in the Sahelian drought of the 1970s and 1980s (Wijkman and Timberlake 1984). Crop failure and livestock losses lead to increased dependence on imports and foreign aid, reducing economic performance and the ability to cope with future environmental disasters.

In 1997 and 1998, parts of Eastern Africa suffered from high rainfall and flooding due to ENSO disturbances, and in 1999 and 2000 Southern Africa and the Western Indian Ocean islands experienced devastating cyclones and floods. Flood water is an ideal habitat for bacteria and mosquitoes. In Uganda, the ENSO-induced floods of 1997-98 caused more than 500 deaths from cholera, and a further 11 000 people were hospitalized (NEMA 1999).

The sea temperature rise of 1.0–1.5°C due to the ENSO disturbances is thought to have resulted in bleaching of up to 30 per cent of the coral in Comoros, 80 per cent in Seychelles (PRE/COI 1998), and 90 per cent in Kenya and Tanzania (Obura and others 2000).

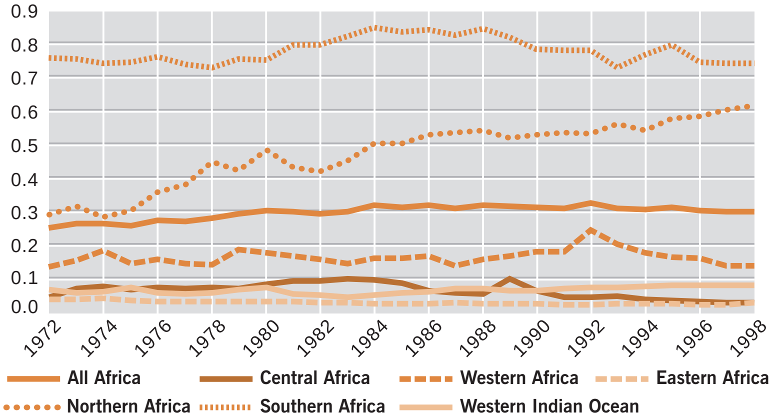
The region's vulnerability to natural disasters is compounded by the anticipated impacts of global climate change. According to IPCC, Africa is the most vulnerable region in terms of predicted decreases in water and food security, because widespread poverty limits adaptive capacity (IPCC 1998). Changes in rainfall could also have serious consequences for those parts of Africa that depend on hydroelectricity.

The anticipated sea level rise resulting from global climate change may threaten many coastal settlements and islands including the Western Indian Ocean islands. The extent of sea level rise is still uncertain but the latest IPCC (2001a) estimates are in the range 10–94 cm by the year 2100. Even if anthropogenic greenhouse gas emissions were stabilized immediately, sea level would continue to rise for many years. IPCC also predicts that the intensity of cyclones, rain and wind will probably increase (IPCC 2001a), and the cyclone zone in the Western Indian Ocean could expand to include Seychelles (UNEP 1999).

Changes to rainfall and temperature patterns could also alter biodiversity, with many species not being able to adapt or migrate to more suitable areas. WWF forecasts that an anticipated 5 per cent decrease in rainfall in Southern Africa will affect grazing species such as hartebeest, wildebeest and zebra, threatening wildlife in the Kruger National Park, South Africa, the Okavango delta in Botswana and Hwange National Park in Zimbabwe. There are also fears that malaria could spread to new areas such as parts of eastern Namibia and northern South Africa (WWF 1996).

The region's ability to adapt to climate change will depend on several factors, including population growth and consumption patterns, which will affect demand for food and water, and the location of populations and infrastructure in relation to vulnerable coastal areas, which will determine economic losses due to sea level rise. Many countries will need to change their agricultural practices, particularly to reduce dependency on rainfed agriculture, and to avoid cultivation in marginal areas. Rural communities that currently depend on biomass for energy may be forced to seek alternative sources if climate change brings about changes to vegetation type and distribution.

Carbon dioxide emissions per capita: Africa (tonnes carbon per capita/year)



Africa contributes less than 3.5 per cent of global emissions of CO_2; Northern and Southern Africa are responsible for more than 80 per cent of the region's emissions

Source: compiled from Marland, Boden and Andres 2001

Policy issues

Almost all African countries have ratified the UNFCCC and many are in favour of the Kyoto Protocol. African countries stand to benefit from mechanisms of international cooperation proposed under the Protocol. Countries that are rich in natural forests (as in Western and Central Africa) may also enter into emissions reduction transfer agreements with industrialized countries, contributing to their own economies and assisting development. On the whole, African countries have an interest in a decision on mechanisms that ensures they facilitate sustainable development in Africa, produce gains in the climate system, contribute towards Africa's adaptation to climate change and result in projects that accelerate socio-economic growth (IISD 2000). Algeria, Cape Verde, Côte d'Ivoire, Egypt, Ghana, Lesotho, Mali, Mauritius, Niger, Senegal, Seychelles and Zimbabwe have all produced National Communications to the UNFCCC (UNFCCC 2001), giving detailed inventories of emissions as well as sinks. South Africa emits the most carbon in Africa but, being classified as a developing country, is not formally required to control emissions of greenhouse gases. However, a National Committee on Climate Change has been established to oversee research, communication and the development of policy on climate change.

In both Northern and Southern Africa, options for further exploitation of alternative sources of energy (such as solar, wind, small-scale hydropower and biomass) are being explored. Such initiatives are likely to be most successful in remote areas, where connections to centralized power sources are expensive, and electricity demand is for domestic use only.

One of the main challenges for most African countries with regard to climatic and atmospheric changes is the need to adapt development processes to the changes in the environment. Mitigation and adaptation mechanisms need to be developed to cope with the impacts of changes in weather patterns and intensified droughts and floods associated with El Niño events (IPCC 2001b). On the other hand, African countries may contribute to the implementation of the UNFCCC and Kyoto Protocol by adopting energy efficient and renewable energy technologies. The Kyoto mechanisms and international institutions to be created to realize these mechanisms provide for active participation of African countries. Failure to realize the potentialities of the Kyoto Protocol may result in further exposure to the adverse effects of climate change (IISD 2000). Localized indoor and outdoor pollution must be controlled and abated through the introduction of cleaner industrial processes, improved transport systems and waste management. For example, a waste management strategy that envisages reducing illegal dumping and burning of solid waste has been developed in South Africa (DEAT 1998).

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Atmosphere: Asia and the Pacific

A serious environmental issue in the Asia and Pacific region is the rapid degradation of the quality of air. Depletion of the ozone layer and the consequences of global climate change are also serious.

Air quality

Air pollution levels in the most populated cities are amongst the highest in the world, producing serious human health impacts and affecting aquatic and terrestrial ecosystems. Transport is a significant, often major, source of urban air pollution. The other sources include industrial emissions, burning of solid and liquid fuels for power generation, and burning of biomass and other fuels such as charcoal for household use. In a few cities, pollution levels have decreased. For example, in Japan, high fuel prices, technological advances and strict standards have reduced SO_2 and particulate emissions, and eliminated lead emissions from transport. However, NO_x emissions in Tokyo and Osaka have not declined sufficiently because of an increasing number of vehicles. This situation is common in cities with growing levels of private transport (UN-ESCAP/ADB 2000).

Traffic has become a major air polluter in the big cities, although most Asian countries have low per capita vehicle ownership in comparison to the world average (World Bank 2000). However, the motorized fleet (see bar chart) has been growing rapidly; for example, the number of private motor vehicles in Sri Lanka doubled during 1975–92 (Government of Sri Lanka 1994) and in India the number of cars has been doubling every seven years for the past 30 years (ADB 1999). This fact, combined with poor roads, fuel quality and vehicle maintenance, makes vehicular air pollution an alarming issue.

Many countries have developed their own air quality standards for principal pollutants as well as emission standards for power plants, selected industries and vehicles. To reduce pollution, many countries have introduced unleaded petrol, mandatory catalytic converters and low sulphur motor fuels. Alternative technologies such as electric vehicles and compressed natural gas operated vehicles are also being considered, especially in India and the Islamic Republic of Iran. Tax incentives for gas or battery operated vehicles have been introduced in Nepal and Pakistan.

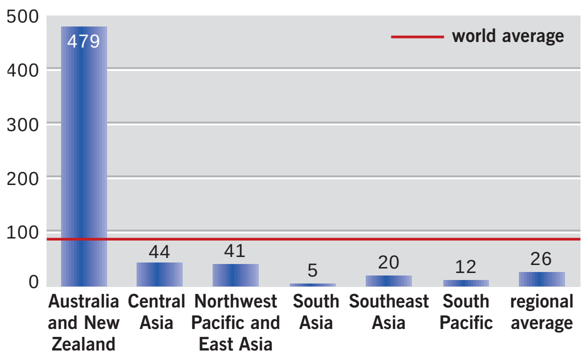
Except for developed countries of the Northeast Asian and parts of the South Pacific sub-regions, concern over the environment began to create a demand for improved environmental protection in the 1980s. The 1990s have seen significant progress in establishing the institutions and policy tools needed to address urgent environmental problems. However, continuous growth in energy consumption and reliance on fuels such as coal and oil with a relatively high carbon content will inevitably increase emissions unless more aggressive policies are introduced.

Indoor air pollution is often a more severe health hazard than outdoor air pollution. Most rural inhabitants in the region use twigs, grass, dried animal dung, crop residues, wood, charcoal and kerosene as household fuels. Coupled with inadequate ventilation, this results in highly contaminated indoor air. Given the high levels of harmful emissions and the number of people using traditional cooking fuels — Asia produces nearly half of the world's woodfuel (FAOSTAT 2001) — the scale of exposure is large. Health effects include acute respiratory infection in children, chronic obstructive lung disease, adverse pregnancy outcomes and lung cancer in women. Acute respiratory diseases are prevalent in the rural and/or hilly areas of Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka where indoor air

Urban air pollution in Asia

The air in Asia's cities is amongst the most polluted in the world. Of the 15 cities in the world with the highest levels of particulate matter, 12 are located in Asia (ADB 1999). Furthermore, six of these cities also have the highest levels of atmospheric SO_2. Levels of air pollution substantially exceed the international guidelines for air quality recommended by WHO. Cities such as Beijing, Calcutta, Jakarta, New Delhi, Shanghai and Tehran are notorious for high levels of suspended particulates, with New Delhi recording the maximum of 420 µg/m^3 (ESCAP/ADB 2000 and ADB 2001). Tehran has also recorded SO_2 levels four times the guidelines prescribed by WHO (World Bank 2001).

Passenger vehicles/1 000 people (1996)



Despite the heavy air pollution in Asia's cities, the number of vehicles per capita is well below the global average in all sub-regions except Australia and New Zealand

Source: World Bank 2000

pollution is high. About 40 per cent of the global infantile mortality caused by pneumonia occurs in Bangladesh, India, Indonesia and Nepal; many of these deaths are caused by pollutants from burning traditional fuels (ADB 2001). In India, household solid fuel use is estimated to cause about 500 000 premature deaths a year in women and children under five. There are indications that tuberculosis and blindness may be associated with indoor air pollution. Indoor air pollution is blamed for 5–6 per cent of the national burden of diseases in women and children in India (Holdren and Smith 2000).

The key areas for intervention are: use of cleaner fuels such as low-propane gas and kerosene; development of high-grade biomass fuels; improvements in stove design and better dissemination of stoves; improvements in housing; and improvements in environmental awareness and education. To address the problem of indoor air pollution in India, around 3 million biogas plants and more than 22 million improved cooking stoves have been installed in rural and remote areas of the country, resulting in a saving of the equivalent of 21 million tonnes of firewood per annum (Times of India 2000).

Haze and acid rain have been the emerging regional issues over the past decade, especially in Asia because of China and India's overwhelming dependence on coal. Around 0.28 million ha of forest land are reported to be damaged by acid rain in the Sichuan basin of China. SO_2 emissions in Asia are estimated to have increased from about 26.6 to about 39.2 million tonnes during 1985–1997 (Streets and others 2000). In China, a reduction of 3.7 million tonnes or 15.8 per cent in SO_2 emissions was achieved during 1995–2000 (SEPA 2001). At least two-thirds of acid depositions in the region are caused by coal-fired power plants with outdated pollution control equipment.

Haze problems are also prevalent in the region due to forest fires in Southeast Asia. The most serious episode occurred in 1997, when the effects of forest fires in Indonesia extended to neighbouring countries including Brunei Darussalam, Papua New Guinea, Philippines, Singapore and Thailand (UNEP 1999). A Haze Technical Task Force was established by ASEAN Senior Officials on Environment in 1995 and, in 1997, a Regional Haze Action Plan was approved (ASEAN 2001).

The Acid Deposition Monitoring Network (EANET), with the participation of ten East Asian countries, began a preparatory phase of monitoring acid deposition in April 1998. In October 2000, the network decided to begin regular monitoring from January 2001 (EANET 2000). In South Asia, the Malé Declaration on Control and Prevention of Air Pollution and its likely Transboundary Effects, was adopted by eight South Asian countries in 1998.

The Asian brown cloud

In spring 1999, scientists working on the project Indian Ocean Experiment (INDOEX) discovered a dense brownish pollution haze layer covering most of South and Southeast Asia and the tropical region of the Indian Ocean. The researchers tracked the haze over an area of about 10 million km^2, and believe it forms over much of the Asian continent. The haze is a mixture of pollutants, mainly soot, sulphates, nitrates, organic particles, fly ash and mineral dust, formed by fossil fuel combustion and rural biomass burning. It reduces the sunlight reaching the tropical Indian Ocean surface, thousands of kilometres from its source, by as much as 10 per cent, with a larger reduction over the Indian sub-continent. Simulations with global climate models indicate that the haze could have major impacts on the monsoon circulation, regional rainfall patterns and vertical temperature profile of the atmosphere.

A programme called ABC (Asian Brown Cloud) has been initiated with support from UNEP. The main aim of the first phase of this programme is to study the impact of the Asian haze on a number of parameters, including monsoon change, water balance, agriculture and health. Scientists plan to establish a network of ground-based monitoring stations throughout Asia to study the composition and seasonal pattern of the haze. UNEP has pledged to facilitate the continued research programme and, in the longer-term, to help coordinate policy responses to address the problem.

Source: UNEP (2001) and C4 and UNEP (in press)

Ozone depletion

Depletion of the stratospheric ozone layer has emerged as a serious concern in the region. Data from Australia and New Zealand show that ultraviolet levels there appear to be rising by about 10 per cent per decade (McKenzie, Connor and Bodeker 1999). It follows that the average exposure time for an individual in Australia to develop sunburn has been reduced by approximately 20 per cent over the past 20 years.

India and China are the largest regional producers and users of CFCs. China's consumption of ODS increased more than 12 per cent per year during 1986–94. India is the second largest producer and the fourth largest consumer of CFCs in the world (UNEP 1998). The Multilateral Fund of the Montreal Protocol and GEF have been helping the region meet the goals of the Montreal Protocol. China has made a commitment to phase out the consumption of ODS by 2010. It has already banned the establishment of new

CFC- and halon-related production facilities, and developed general and sector-specific plans with the help of the World Bank and the Multilateral Fund. The latter has approved a World Bank project which will help India phase out CFC production by 2010.

The countries of Central Asia have also made considerable progress. Azerbaijan, Turkmenistan and Uzbekistan are working towards the phase out of the use of ODS during 2001–03 (Oberthur 1999).

Greenhouse gas emissions and climate change

Per capita use of commercial energy increased annually by 1.9 per cent in South Asia and 3 per cent in East Asia and the Pacific during 1980–98 (World Bank 2001).

CO_2 is the main anthropogenic greenhouse gas. Methane emissions are also high in South Asia, accounting for approximately 50 per cent of the total global anthropogenic emission of CH_4 (UNDP, UNEP and WRI 1992). In New Zealand, CH_4 emissions are an order of magnitude higher than the global per capita average, primarily due to the large number of ruminant animals (MFE 1997).

Areas under most threat from climate change include marine ecosystems, coastal systems, human settlements and infrastructure (IPCC 1998). Countries in the Northwest Pacific and East Asia sub-regions and the Pacific Island countries may be particularly vulnerable to phenomena such as sea level rise because many of their human settlements and industrial facilities are located in coastal or lowland areas. For the small island developing states, climate change and extreme weather events may have dramatic impacts on terrestrial biodiversity, subsistence cropping and forest food sources. The densely populated and intensively used low-lying coastal plains, islands and deltas in South Asia are especially vulnerable to coastal erosion and land loss because of inundation and sea flooding, upstream movement of the saline/freshwater front and sea water intrusion into freshwater aquifers (IPCC 1998).

GEF and UNDP are promoting projects to help countries in the region assess their emissions and formulate strategies to reduce them. For example, countries participating in the Asia Least Cost Greenhouse Gas Abatement Strategies project have identified a number of options in the energy sector to reduce greenhouse gas emissions (GEF 2000).

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Atmosphere: Europe

Air pollution

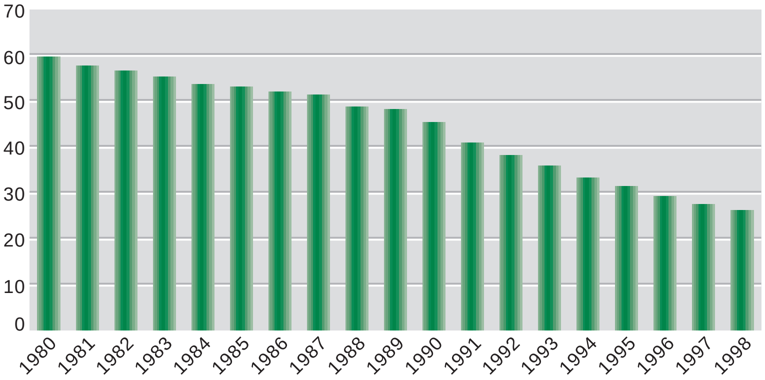
Air pollution was one of the threats to human health and ecosystems that was recognized early in Europe. A treaty (the 1979 ECE Convention on Long Range Transboundary Air Pollution, CLRTAP) was signed as early as the late 1970s and entered into force in 1983 to curb anthropogenic emissions of harmful substances.

Health effects of air pollution related to road traffic in Austria, France and Switzerland

A recent health impact assessment of air pollution in Austria, France and Switzerland revealed that car-related pollution kills more people than car accidents in these three countries. Long-term exposure to air pollution from cars causes an extra 21 000 premature deaths from respiratory or heart disease per year in adults over 30. In comparison, the total annual deaths from road traffic accidents in these countries are 9 947. Each year air pollution from cars in the three countries causes 300 000 extra cases of bronchitis in children, 15 000 hospital admissions for heart disease, 395 000 asthma attacks in adults and 162 000 in children, and some 16 million person-days of restricted activities for adults over 20 years old because of respiratory disorders. The total cost of this health impact is €27 billion per year or 1.7 per cent of the combined GNP of the three countries. This is the equivalent of €360/person/year (Kunzli and others 2000).

The main sectors and activities driving air pollution in Western Europe in the past three decades have been energy, transport, industry, agriculture, solvent use, and storage and distribution of fossil fuels. In Central and Eastern European (CEE) countries, the power and heavy industry sectors have traditionally been the major polluters, with transport only significant in major cities. In the early 1990s, economic recession was a driver in the decrease of air pollution in CEE but at the same time there was a sharp growth in the use of private cars. For example, even during the worst recession years (1990 to 1994), the number of private cars in Armenia, Russia and Ukraine increased by more than 100 per cent (FSRFHEM 1996). This rapid increase in private car ownership has made transport an increasingly important contributor to CEE's air quality problems.

SO_2 emissions in EMEP countries (million tonnes/year)



Over the period 1980–98, SO_2 emissions in countries that are members of the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) have been reduced by 56 percent

Source: Vestreng and Støren 2000

Emissions of most key air pollutants have declined over the whole of Europe since the early 1980s. By the end of 2000, emissions of sulphur compounds had been reduced to less than one-third of 1980 levels in Western Europe, and to two-thirds of those levels in CEE (EEA 2001a, UNEP 1999). A significant recovery of natural acid balance of water and soils has been observed in Europe, mainly due to reductions in SO_2 emissions, although the emissions are still too high to avoid serious effects in sensitive ecosystems. Average figures, however, mask a wide variation among countries and sub-regions. For instance, SO_2 emissions increased by 7 per cent in Greece and 3 per cent in Portugal between 1990 and 1998 while reductions of 71 per cent and 60 per cent were observed in Germany and Finland respectively (EEA 2000). NO_x and NH_3 emissions have not decreased significantly in Western Europe except for NO_x in Germany and the United Kingdom but NO_x has been reduced in many CEE countries (Czech Environmental Institute and Ministry of the Environment 1996, EEA 2001b, GRID-Budapest 1999, GRID-Warsaw 1998, Interstate Statistical Committee 1999, OECD 1999a, UNECE/EMEP/MSC 1998). A lack of monitoring of emissions of heavy metals, POPs and SPM, especially in CEE countries, means that no convincing trends can be observed but it is clear that particulate matter and tropospheric ozone precursors still represent serious problems (EEA 2000).

In Western Europe, emissions of SO_2, NO_x and NH_3 have shown a clear de-coupling from GDP growth, pointing towards some degree of effectiveness of measures taken (EEA 2001a). In some of the CEE countries that are likely to be in the first wave of accession to the European Union (EU), economic restructuring and environmental actions also appear to have had an effect in reducing air pollution. In other

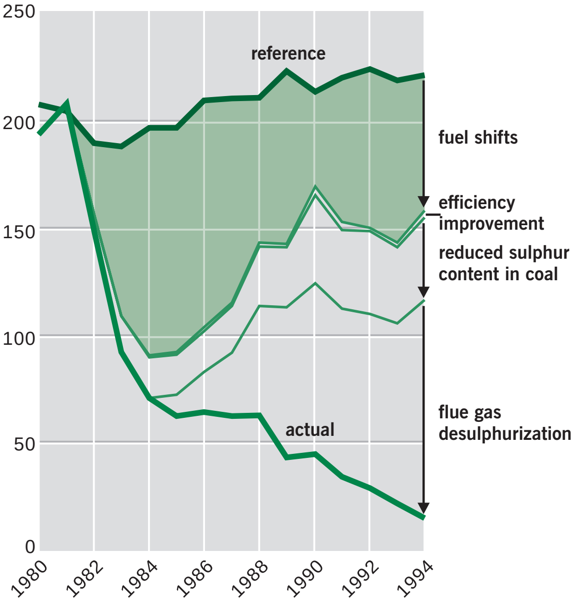
CEE countries, the fall in industrial output due to the recession appears to have been the main factor in air pollution reduction (OECD 1999a and b, UNECE 1999). In countries such as Russia and Ukraine, emissions per unit of GDP have actually increased but the effect has been masked by the overall fall in GDP (SCRFEP 1999).

It is clear that the reductions in emissions are at least partly due to national and local measures that have been taken to achieve targets set by CLRTAP and its Protocols, and to EU Directives linked to air emissions such as the Limitation of Emissions of Certain Pollutants into the Air from Large Combustion Plants Directive (1988) and various directives on vehicle emissions, the change to unleaded petrol and higher quality diesel fuels and improved engine design. Despite this clear progress, many air pollution reduction targets have still not been met. In Western Europe, only the EU and CLRTAP targets for SO_2 were met well before the target date (the end of 2000) with less progress on NO_x, NH_3 and VOCs. Two recent European measures are expected to achieve further reductions in air pollutants: a proposal for an EU Directive on National Emission Ceilings for Certain Atmospheric Pollutants (NECD) and the CLRTAP Protocol to Abate Acidification, Eutrophication and Ground-level Ozone. In many European countries, additional measures will be required to achieve the NECD and CLRTAP Protocol targets. In Western Europe 'non-technical' measures for controlling pollution such as road pricing and tax incentives have become more important (EC 2000) but in many CEE countries it is unlikely that currently weak environmental protection bodies can enforce an effective air pollution reduction strategy in the near future (OECD 1999b).

Stratospheric ozone depletion

The thickness of the ozone layer over Europe has decreased measurably since the 1980s. Though the average ozone loss in northern mid-latitudes is 6 per cent in winter and spring, at certain times the loss can be more significant. For example, in the spring of 1995 after an unusually cold Arctic winter, stratospheric ozone concentrations over Europe were 10–12 per cent lower than in the mid-1970s. The winter of 1995–96 was even colder and ozone concentrations over the United Kingdom fell by almost 50 per cent in the first week in March, the lowest ever recorded there (UNEP 2000). As a result, an increase in ultraviolet radiation occurred in Europe between 1980 and 1997, with a clearly higher increase in the northeast (EEA 1999, Parry 2000).

SO_2 emissions (1 000 tonnes): linking policy to emission reductions in the Netherlands



In the Netherlands, a shift in fuel from oil to natural gas produced a net decrease in SO_2 emissions until the mid-1980s when greater use of coal reversed the trend. Since 1983, the sulphur content of coal has been reduced, while flue gas desulphurization units began to be fitted to Dutch power plants in 1986, with 96 per cent equipped by 1996

Note: the reference line above is based on electricity produced

Source: EEA 2000

As a result of implementing the Vienna Convention and its Montreal Protocol, ODS production in Western Europe has decreased by almost 90 per cent while the production of hydrochlorofluorocarbons (HCFCs) has increased (EC 1999, UNEP 1998). The political and economic transition in CEE has delayed the phase out of ODS production and consumption but there is progress. Large amounts of donor assistance were channelled via the GEF in the 1990s to upgrade technologies in favour of ozone-friendly substances. An important milestone for the Countries with Economies in Transition (CEIT) was the ceasing of production of ODS listed in Annexes A and B to the Montreal Protocol by the Russian Federation, the major regional producer, in December 2000 (UNEP 2001).

Greenhouse gas emissions

Although many European countries are enthusiastic proponents of a global climate change treaty, the region is still a major emitter of anthropogenic greenhouse gases. Most CO_2 emissions come from fossil fuel combustion (ETC/AE 2000, OECD 1999b). The energy sector (power and heating) is the main contributor (32 per cent of the EU's CO_2 emissions), while transport, combustion, manufacturing and heavy industry also play a major role (ETC/AE 2000).

Greenhouse gas emissions in the EU decreased by 2 per cent between 1990 and 1998 (EEA 2001a), mainly as a result of stabilization of CO_2 emissions and reduction of emissions of N_2O and methane. Most of this decrease was attributable to Germany (as a result of increased efficiency of new power plants, energy saving in households and industries, and economic restructuring in the former East Germany) and the United Kingdom (following a switch from coal to gas). In Western Europe generally, there has been a clear de-coupling between emissions, economic growth and energy consumption thanks to a combination of increases in energy efficiency, and effects of policies and measures to reduce greenhouse gas emissions (ETC/AE 2000). However, meeting the Kyoto Protocol targets will still be difficult (EEA 2001a).

Economic transformation in CEE has contributed to a significant decrease of anthropogenic greenhouse gas emissions. In 2000, CO_2 emissions in nine of those countries were 8 per cent lower than in 1990 (ETC/AE 2000). In some of the CEE countries, economic restructuring and environmental actions appear to have had an effect in reducing CO_2 (OECD 1999a) while in most CEE countries recession and a decline in industrial output appears to have been the main factor in CO_2 reduction (OECD 1999a and b, UNECE 1999).

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Atmosphere: Latin America and the Caribbean

Air pollution is one of the most critical environmental issues in the Latin America and Caribbean Region because of its impact on human health, especially in urban areas. Rapid urbanization, population growth, industrialization and a growing number of motor vehicles are the main causes of air pollution. The region is also prone to the negative impacts of stratospheric ozone layer depletion.

Air quality

Some three-quarters of the population of Latin America and the Caribbean live in cities. Several megacities such as Buenos Aires, Mexico City, Rio de Janeiro and São Paulo, each with a population of more than 10 million, are located in the region and economic growth in these urban centres has caused increases in air pollution (particularly CO, NO_X, SO_2, tropospheric O_3, hydrocarbons and SPM) and associated human health impacts (UNEP 2000). Today the problem extends beyond large cities and also affects medium-size cities and small islands (Dalal 1979, Romieu, Weitzenfeld and Finkelman 1990). The transport sector is a major source of urban air pollution — 70 per cent of emissions in Buenos Aires (PAHO 1998) and Mexico City (INEGI 1998) are transport-related, with the number of cars in Mexico City increasing fourfold between 1970 and 1996 (ECLAC 2000a). Industry, agriculture and the municipal sector also contribute to air pollution. In Santiago, the most significant sources of air pollution are transport, and small and medium-size enterprises (IMO 1995). In addition, unfavourable topographic and meteorological conditions in some cities aggravate the impact of pollution: the Valley of Mexico obstructs the dispersal of pollutants from its metropolitan area as do the hills surrounding Santiago (ECLAC 2000b).

The growth of industry, agriculture and transport sectors over the past 30 years has been accompanied by a steady increase in CO_2 emissions — estimated at 65 per cent between 1980 and 1998 (UNEP 2001a). In 1991–92, the region was estimated to be responsible for some 11 per cent of global anthropogenic emissions of CO_2 — 4.5 per cent of global industrial emissions and 48.5 per cent of emissions from land-use change (UNDP, UNEP, World Bank and WRI 1996). Deforestation is thought to be the principal cause of emissions in the region, particularly in the Amazon basin (UNEP 1999). Deforestation and livestock breeding (the latter is significant in Argentina, Chile and Uruguay) also result in a huge regional methane emission — some 9.3 per cent of the world total (UNFCCC-SBI 2000).

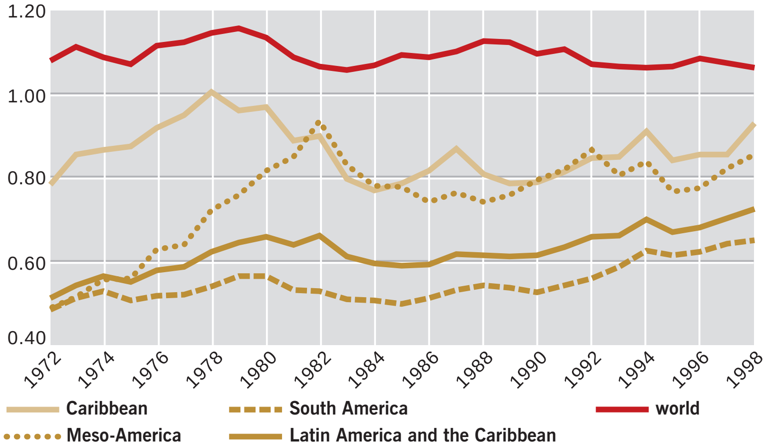
The average annual per capita carbon emission from industry in the region was 0.73 tonnes in 1998, somewhat lower than the world average of 1.06 tonnes (Marland, Boden and Andres 2001). Mexico is the region's largest carbon emitter.

Industrial pollutants originate mostly from fuel combustion processes in the power generation sector, although emissions of heavy metals such as lead and mercury are also important (PAHO 1998). In oil-producing countries, emissions from the refining process are also significant — for example, in Mexico City, almost 60 per cent of SO_2 emissions originate from industry, including oil refineries in the metropolitan area (INEGI 1998). In many countries,

Air pollution increases mortality

In 1992, it was estimated that 76 million urban people were exposed to air pollutant concentrations exceeding WHO guidelines. In São Paulo and Rio de Janeiro, air pollution was estimated to be responsible for 4 000 premature deaths annually (CETESB 1992). Studies in Brazil, Chile and Mexico have shown that a 10 µg/m^3 increase of concentration of PM_{10} (particles of 10µ or less in diameter) in the air coincides with a 0.6 to 1.3 per cent increase in mortality in those over the age of 65 (PAHO 1998).

Carbon dioxide emissions per capita: Latin America and the Caribbean (tonnes carbon per capita/year)



Average industrial carbon emission in Latin America and the Caribbean in 1998 was 0.73 tonnes/year, compared to the global average of 1.06 tonnes

Source: compiled from Marlan, Boden and Andres 2001

Dealing with air pollution in Mexico City

In Mexico City, one of the biggest megacities in the world, studies have shown a close correlation between urban air pollution and the acceleration of pulmonary diseases, ageing processes in the lungs and respiratory infections (Loomis and others 1999, PAHO 1998, WHO 1999). A comprehensive programme to cope with air pollution in the Valley of Mexico was launched in 1990 aimed at improving the quality of fuel, promoting public transport, reducing emissions from vehicles, industry and services, and reforestation. The 1995-2000 Programme to Improve Air Quality in Mexico City (Proaire) introduced new activities in the field of monitoring, education and public participation. Other initiatives included the establishment of the Valley of Mexico Environmental Trust Fund, which is maintained with tax revenue from petrol and finances air quality improvement activities, the Automatic Environmental Monitoring Network, Environmental Emergency Programmes, 'A Day Without a Car' Programme, a reforestation programme and environmental education in the metropolitan area of Mexico City (ECLAC 2000a).

mining activities result in local deterioration of air quality (PAHO 1998).

Other sources of air pollution have local and sub-regional impacts, including pesticide use in agriculture and airborne particles resulting from soil erosion and biomass combustion. Studies conducted in Colombia and Ecuador in the early 1990s revealed that more than 60 per cent of agricultural workers involved in production for foreign markets had symptoms of acute pesticide poisoning (headaches, allergies, dizziness, dermatitis, blurred vision) while others experienced serious chronic effects (stillbirths, miscarriages, and respiratory and neurological problems). Neighbouring inhabitants can also be affected, as has been found for Nicaraguan cotton fields and Costa Rican coffee plantations (UNDP, UNEP, World Bank and WRI 1998, UNEP 2000).

Forest fires are another important contributor to air pollution, sometimes having a significant long-distance effect (CCAD and IUCN 1996, Nepstad and others 1997). In 1997, for example, the smoke from fires in Guatemala, Honduras and Mexico drifted across much of the southeastern United States, prompting the Texas authorities to issue a health warning to residents (UNEP 2000).

In Latin America and the Caribbean, about one-fifth of the population uses biomass as a major household fuel, resulting in indoor air pollution. This mainly affects women, children and the elderly who stay indoors for long periods. In Colombia and Mexico, for example, women using biomass for cooking are up to 75 times more likely to contract chronic lung disease than the average person (UNDP, UNEP, World Bank and WRI 1998). Air pollution is blamed for 2.3 million annual cases of infantile chronic respiratory sickness and 100 000 cases of chronic adult bronchitis in the region (ECLAC 2000b).

In recent decades, significant efforts have been made to cope with air pollution, especially in urban areas (see box left) through strategies that include emission controls, changes in fuels and contingency controls. In Santiago, SPM emissions — and the number of days when alerts were sounded or emergencies declared — have been reduced considerably over the past decade, with concentrations of PM_{10} and $PM_{2.5}$ decreasing by 24.1 per cent and 47.4 per cent respectively between 1989 and 1999 (CAPP 2000). This is largely due to implementation of a plan initiated in 1990 which included control of household and industrial emissions, developing monitoring capacity, removing highly polluting buses, controlling bus circulation and emissions, introducing car catalytic converters, improving motor fuel quality, and paving streets (ECLAC 2000c, O'Ryan and Larraguibel 2000).

Notwithstanding the progress achieved, urban air pollution is a serious concern even in some small and medium-sized cities because of the continued growth of the transport and industrial sectors, coupled with a lack of adequate monitoring and regulations. The growth of vehicles due to rising real incomes and the removal of tariffs could nullify the progress made in improving air quality. By 2010, 85 per cent of the population are expected to be living in urban areas, and combating air pollution and preventing its negative health impacts will be a priority in every country.

Global atmospheric issues

Ozone depletion is a significant issue for the region, especially those countries closest to the Antarctic ozone hole such as Argentina and Chile. Following ratification of the Montreal Protocol, governments in collaboration with private sector and other stakeholders adopted regulations, established institutions and took measures to phase out ODS — Brazil halted production in 1999 (MMA 2001). Countries such as Argentina, Mexico (currently the main regional producer of ODS) and Venezuela that still produce CFCs have developed policies and measures to reduce both production and consumption of ODS. In contrast to other developing regions, the Latin American and Caribbean Region has reduced total production of CFCs from the 1986 level by approximately 21 per cent (UNEP 2001b).

Global climate change may seriously affect the region given its ecological and socio-economic vulnerability. Changes in the water cycle may pose a danger to arid and semi-arid zones and thus affect the production of cereals and livestock as well as hydroelectric power generation in countries such as Argentina, Chile, Costa Rica and Panama. Coastlines and coastal ecosystems in Central America, Argentina, Uruguay and Venezuela may be affected, and the coastal infrastructure may be damaged. Many of the large metropolitan areas are highly vulnerable to sea level rise, especially major ports. In the Caribbean, the small island states will probably be the first to suffer from sea level rise. There may also be impacts on health caused by an increase in epidemic disease vectors, along with other gastrointestinal infections (PAHO 1998).

Countries in the region do not have commitments under the UNFCCC or Kyoto Protocol. Mitigation and adaptation activities include energy-saving measures in transport, agriculture and waste management sectors, developing renewable energy sources and developing carbon sinks, mostly forests. Wind energy is exploited in several countries including Barbados, Costa Rica and Jamaica. A 2-MW demonstration plant using ocean thermal energy conversion has been built in Jamaica (UNEP 2000).

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Atmosphere: North America

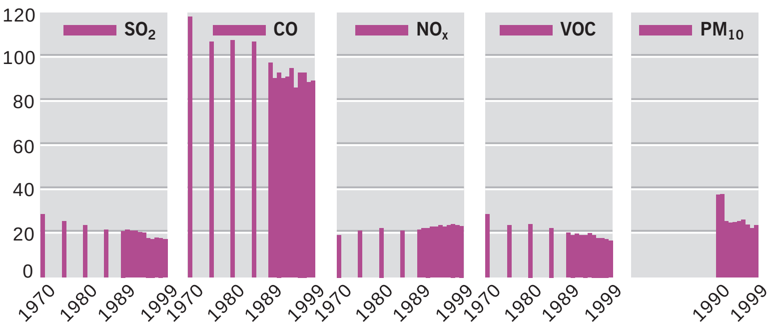
Air quality

Over the past 30 years, there have been notable air quality improvements at both regional and local levels in the region. Levels of many air pollutants have been gradually reduced — the trends in the United States (see graph) are representative of the region.

Acid rain control programmes contributed to the dramatic decline in sulphur emissions since 1995 with reductions of 10–25 per cent in some parts of the north-eastern United States (US EPA 2000a). Recent evidence, however, suggests that many sensitive areas are still receiving acid deposition that exceeds their assimilation capacity, and damage caused by acid deposition may be more fundamental than was previously believed (CEC 2000, Munton 1998).

New concerns have arisen over ground level ozone and fine particulate matter, whose emissions have not decreased as markedly as other common pollutants.

Emissions of major air pollutants: United States (million tonnes/year)



Emissions of many air pollutants have been reduced over the past 30 years, particularly for CO, VOCs and SO_2

Source: US EPA 2001

Ground-level ozone in North America

Research over the past decade has demonstrated that O_3 is responsible for far greater impacts on health than was previously thought. Even average concentrations of O_3 can exacerbate asthma and other respiratory diseases, and inhibit or interfere with the immune system, especially in young children, the elderly and outdoor sports enthusiasts (OMA 2000). Research in both Canada and the United States repeatedly documents a strong correlation between hospitalization and worker absenteeism, and episodic high O_3 levels (CEC 1997).

Ground-level ozone

Ground-level O_3 is a common, pervasive and harmful air pollutant (see box). Fossil fuel combustion is the major source of NO_x, with the transportation sector alone responsible for 60 per cent of NO_x emissions in Canada (Hancey 1999) and 53 per cent in the United States (US EPA 2000b).

Between 1984 and 1991, Canada's ozone guideline of 0.082 ppm over a one-hour period was exceeded at least once in all major cities (EC 2000a). In the United States, tens of millions of people lived in areas where the one-hour ozone standard of 0.120 ppm was regularly exceeded (US EPA 2000b). Control measures in the 1970s focused primarily on reducing VOCs and, in some cases, NO_x emissions from factories and vehicles in the regions that were most affected. In many cases, however, controls failed to reduce ozone concentrations sufficiently to meet national health standards (US EPA 1997a).

Ozone molecules have been found to travel large distances from emission sources — the typical transport range of tropospheric O_3 is 240–800 kilometres (CEC 1997). Between 30 and 90 per cent of eastern Canada's O_3 comes from the United States, while the province of Ontario, the region in Canada that suffers from the worst O_3 problem, is a source of NO_x downwind into northeastern United States (EC 2000a).

Fossil fuel power plants are the largest point sources of NO_x — significant amounts of O_3 are formed and transported within the plumes of power plants. In addition, while VOCs have decreased in the United States over the past 30 years, NO_x emissions increased between 1970 and 1999 by 17 per cent (US EPA 2000b). These findings led to a new approach in which North America recognized the need for aggressive strategies to reduce regional NO_x emissions and for cooperation between the two countries.

Under the Canada/US Air Quality Agreement (1991), both countries set targets to reduce NO_x emissions and in October 2000 they signed an annex to the agreement to reduce border emissions of NO_x from fossil fuel power (EC 2000b). They have also engaged in the 1995 North American Research Strategy for Tropospheric Ozone and signed the 1999 CLRTAP Protocol to Abate Acidification, Eutrophication and Ground-Level Ozone.

Recognition that exposure to ozone at concentrations below 0.08 ppm results in severe health effects has prompted revisions in both Canadian and US ozone health standards (EC 2000a, US EPA 1997b). Although levels of SPM have decreased by 40 per cent since 1980, recent research has revealed serious health concerns at concentrations well within allowed levels attributable to the finer airborne particles released mainly from vehicles

Impact of air pollution on health in North America

Air pollution is emerging as a key contributor to some respiratory and cardiovascular diseases. Around 80 million US citizens are exposed to levels of air pollution that can impair health and more than 2 per cent of all deaths annually can be attributed to air pollution (UNDP, UNEP, World Bank and WRI 1998). Air pollution is also linked to an alarming rise over the past two decades in the prevalence of asthma among children and young adults. More than 5.5 million children in North America are affected by asthma. The impact of environmental pollution on children's health is a priority issue in North America.

and power plants. Consequently, North American standards for particulate matter have been adjusted (EC 1999, EC 2000a, OMA 2000).

Stratospheric ozone layer depletion

North America's northern regions have been subject to serious stratospheric ozone depletion. With the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, both countries committed themselves to actions to protect the stratospheric ozone layer. In Canada, strict regulations passed in 1990 and reformulated in 1999 reduced production faster than the protocol required, from a high of 27 800 tonnes/year in 1987 to 900 tonnes/year in 1996 (EC 2001). In the United States, the use and trade of ODS is controlled through a marketable permit system and a tax on ODS. The subsequent price increase of ODS encouraged the use of alternatives. Both countries reduced their non-essential CFC consumption to zero by 1996 (Potts 2001).

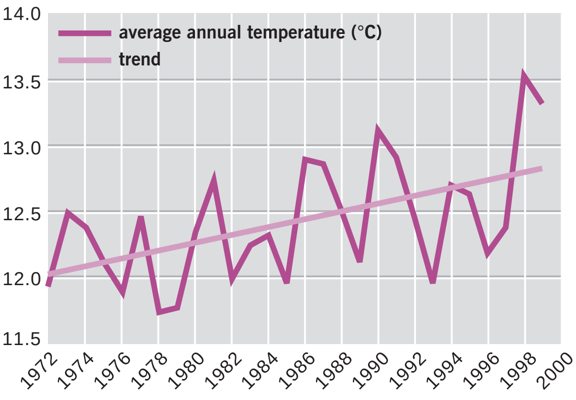
Greenhouse gases and climate change

Since 1972 North America's climate has warmed considerably, reflecting a global trend. About half of the average rise in North America's surface temperature during the past century — more than 0.6 °C — occurred since the late 1970s (see graph). North America emits more greenhouse gas than any other region, accounting for around 5 per cent of the world's population but nearly 26 per cent of global anthropogenic emissions of CO_2 in 1998 (Marland, Boden and Andres 2001). North America has one of the world's most energy-consuming economies. The transportation sector is the largest source of CO_2 emissions, accounting for 30.1 per cent of Canada's emissions in 1995 (EC 1998a) while in 1993 cars and light trucks were responsible for more than 20 per cent of US CO_2 emissions (Glick undated). In 1997, the US transport sector accounted for around 5 per cent of global anthropogenic CO_2 emitted and more than one-third of total world transportation energy use (NRC 1997, O'Meara Sheehan 2001).

Two sharp price shocks in the oil market in the 1970s helped to increase awareness that oil is not a renewable resource. Energy-saving standards for vehicle bodies, engines and fuel efficiency in new passenger cars were introduced in the 1970s and strengthened in the 1980s (OECD 1996, CEQ 1997). However, a combination of factors conspired to drive energy use up during the 1980s. Progress in total and per capita energy efficiency slowed and CO_2 emissions continued to rise (CEQ 1997, EC 1997, OECD 1998).

Renewed efforts subsequent to the UNFCCC commitments also failed to curb CO_2 emissions in the 1990s. In 1998, emissions were 14 and 11 per cent above 1990 levels in Canada and the United States respectively (US EPA 2000a, SRP 2000). Renewable energy production from hydropower, wind, solar, biomass and geothermal sources is increasing but still contributes only a small fraction of energy needs, supplying about 7 per cent of US domestic energy demand in 2000 (US EIA 2001).

Average temperatures in the United States (°C)



Average annual temperatures in the United States have increased more than 0.6°C since the late 1970s

Source: DOC, NOAA and NCDC 2000

In the transport sector, progress made in car fuel efficiency and emission controls has been partially offset by increases in the number of automobiles, in distances travelled, and a trend since 1984 toward light-duty trucks and sport-utility vehicles (CEQ 1997, EC 1998a). For example, between 1990 and 1995 there was a 15 per cent increase in automobile travel in Canada, a decrease in urban transit usage and a 6 per cent increase in total fossil fuel use (EC 1998b). In 1994, nearly 60 per cent of US households owned two or more cars and 19 per cent owned three or more (De Souza 1999). Cheap parking and other hidden subsidies, such as funds for highway development and low fuel prices, have encouraged car dependency (Miller and Moffat 1993, EC 1998a).

Under the 1997 Kyoto Protocol, Canada agreed to reduce greenhouse gas emissions to 6 per cent and the United States to 7 per cent below 1990 levels between 2008 and 2012. However, in early 2001, the United States announced that implementing the Kyoto treaty would be too harmful to the economy and that it would pursue other ways of addressing climate change (US EIA 2001). At the July 2001 UNFCCC conference in Bonn a compromise was struck allowing carbon-absorbing forests to be used against emissions with the result that Canada may obtain more than 20 per cent of its target with such credits (MacKinnon 2001).

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Atmosphere: West Asia

Air quality

The level of industrialization in West Asia is low in comparison with Europe and the United States but population growth, urbanization and an increase in oil-related industries and other industrial activities have resulted in air pollution 'hot spots'. In the major cities and industrial compounds of West Asia, concentrations of the main air pollutants often exceed WHO guidelines by a factor of two to five (World Bank 1995).

The burning of fossil fuels is the main cause of atmospheric air pollution and the main source of anthropogenic CO_2 emissions. It accounts for all West Asia's commercial primary energy production which increased from 665.5 million tonnes of oil equivalent (mtoe) in 1972 to 974.2 mtoe in 1997, while energy consumption increased from 27.0 to 229.5 mtoe over the same period (compiled from IEA 1999).

The main sources of air pollution in the Gulf Cooperation Council (GCC) countries are oil refineries, oil gathering centres, oil platforms, petrochemical and fertilizer plants, and motor vehicles. In the Mashriq countries, outdated technologies especially in power generation plants, fertilizer plants, smelters and cement factories have caused deterioration of air quality not only in industrial sites but also in nearby settlements. Amongst the air pollutants emitted, SPM is of great concern with levels well above maximum allowable concentrations. The economic loss due to the impact of poor air quality on human health in Syria is estimated at about US$188 million per year (World Bank and UNDP 1998). However, recent trends in West Asia, and especially in the GCC countries, are towards adopting cleaner production approaches in industry, especially in the large oil, petrochemical, fertilizer and metal industries.

The increasing number of vehicles, poor traffic management, ageing cars and congested roads in major cities add to the level of air pollution. Many vehicles are in poor condition and about 30 per cent are older than 15 years and produce significantly higher emissions of hydrocarbons and NO_x than new ones (World Bank and UNDP 1998). Furthermore, leaded petrol is still in use in many countries, compounding health problems in cities and along major highways (World Bank 1995). To cope with this problem, some countries have taken measures to phase out leaded gasoline. Unleaded gasoline has been introduced to the GCC countries and Lebanon, and is the only fuel produced in Bahrain since July 2000 (BAPCO 2000).

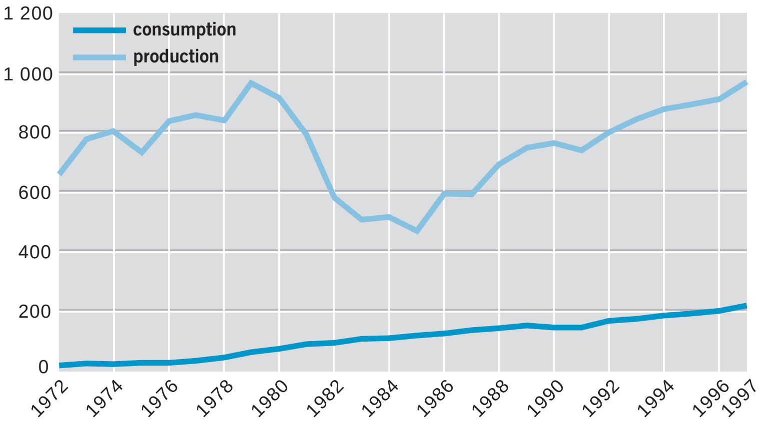
Along with atmospheric pollution caused by human activities, seasonal sand and dust storms contribute to air pollution in West Asia in general and along the northern coasts of the Arabian (Persian) Gulf in particular (ROPME 1999). The dust storms absorb pollutants such as pesticides and can transport them for long distances with adverse effects on the environment, the economy and quality of life. It is estimated that the annual amount of dust fall-out along the coastal area of Kuwait may reach 1 000 tonnes/km^2 with an overall mean concentration of 200 $\mu g/m^3$ (Khalaf and others 1980, EPA 1996).

Transboundary air pollution is an emerging issue in the region. Stricter measures and regulations to control emissions, to promote the use of modern and efficient technologies, and towards restructuring the price of

The cement industry pollutes the atmosphere

The cement industry, the major industrial source of CO_2 emissions in the Mashriq sub-region, also emits large amounts of dust, covering nearby vegetation, endangering human health and ecosystems. In Lebanon, the cement industry is responsible for 77.2 per cent of all industrial emissions (Government of Lebanon 1998). In Syria, particulate emissions from one cement company near Damascus result in SPM levels exceeding guidelines within a radius of 3 km. This has caused thoracic and respiratory diseases among workers and nearby communities (CAMRE and UNEP 1997).

Energy consumption and production: West Asia (million tonnes oil equivalent/year)



West Asian energy production has now exceeded its previous maximum in 1979; consumption continues to increase at around 3.5 per cent a year

Source: compiled from IEA 1999

energy resources must be taken to curb air pollution. Energy efficiency programmes in the power, petroleum, transportation, industrial, agriculture and residential sectors are needed to reduce energy consumption and associated emissions of greenhouse gases.

Stratospheric ozone depletion

The West Asia states (with the exception of Iraq) acceded to the Vienna Convention and the Montreal Protocol and its amendments. All countries in the region are users but not producers of ODS and programmes regulating the import and use of ODS have been developed at both national and regional levels. Regulations for specifications and ODS emissions have been enacted, and ozone offices and coordinating committees have been established to monitor the activities of companies related to the consumption, handling and storage of these chemicals. Companies are gradually phasing out the use of ODS and most countries have frozen the consumption of ODS as required by the Montreal Protocol. Further efforts are needed to phase out methyl bromide which is still consumed in Jordan, Lebanon and Syria.

Climate change

The West Asia region is likely to be affected by climate change. The Arabian Peninsula and a number of islands (such as Bahrain) will probably be prone to sea level rise. Temperature variations and changes in rainfall patterns will affect water resources and food production capacity. Climate change impacts are considered a high priority in some countries, especially in island countries such as Bahrain.

Following ratification of the UNFCCC, National Climate Change Committees were established and some countries have started to monitor air quality and meteorological parameters. National inventories of greenhouse gases have been completed for several countries (Bahrain, Jordan and Lebanon) and work is underway in other countries. These inventories produced figures that were higher by 59, 72 and 25 per cent respectively (AGU and MoHME 2000, GCEP 1997, Government of Lebanon 1998) than those reported by UNDP, UNEP, World Bank and WRI (1998).

Per capita CO_2 emissions in West Asia increased from 4.7 tonnes/year in 1972 to 7.4 tonnes/year in 1998, echoing regional trends in population growth, development and industrialization. Emissions in the very high per capita emitting countries (Kuwait, Qatar and the United Arab Emirates) dropped during this period (Marland, Boden and Andres 2001). This decline was one of the results of national policies that included such measures as programmes for cleaner energy development, introduction of new efficient technologies and establishment of air quality standards.

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Atmosphere: the Polar Regions

The key atmospheric issues in the Arctic and Antarctic are the depletion of the stratospheric ozone layer, the long-range transport of air pollutants and warming associated with global climate change. These problems are mainly due to anthropogenic activities in other parts of the world.

Seasonal stratospheric ozone depletion over Antarctica, and more recently over the Arctic, has been one of the major regional environmental concerns since it was noticed in 1985 (Farman and others 1985). The depth, area and duration of the Antarctic ozone hole has steadily increased, reaching an all-time high of around 29 million km^2 in September 2000 (WMO 2000, NASA 2001).

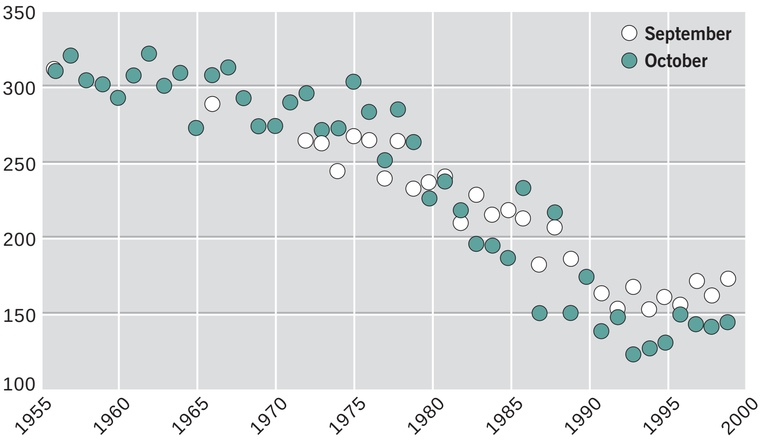
In the Arctic, average yearly stratospheric ozone levels in the 1990s had declined by 10 per cent from the late 1970s, increasing the risk of snow blindness and sunburn.

The recovery of the stratospheric ozone layer in the polar regions depends primarily on the implementation of the Montreal Protocol on the Substances that Deplete the Ozone Layer. Therefore the efforts of nations to phase out the use of ODS, even though they are located far from the poles, are of the utmost importance (UNEP 2000).

Natural ecosystems in polar regions have low adaptive capacity and are highly vulnerable to climate change. Climate change is expected to be more extreme in the polar regions than anywhere else (a warming trend of as much as 5°C over extensive land areas has been noted in the Arctic, although there are some areas in eastern Canada where temperatures have declined) and will probably have major physical, ecological, social and economic impacts in both the Arctic and the Antarctic (IPCC 2001a and b). Whether due to a natural oscillation or global climate change, the atmospheric temperature of Antarctica is undergoing changes. A marked warming trend is evident in the Antarctic peninsula with spectacular loss of ice shelves and an increase in the cover of higher terrestrial vegetation although, as in the Arctic, there are also areas of marked cooling — at the South Pole for example (Neff 1999).

Climate change is almost certainly responsible for the decrease in extent and thickness of Arctic sea ice, permafrost thawing, coastal erosion, changes in ice sheets and ice shelves, and the altered distribution and abundance of species in polar regions (IPCC 2001a). Other impacts of the warming trend include a recorded 15 per cent increase in Arctic precipitation, increased storm episodes, earlier springs and a later onset of freezing conditions, and decreased marine salinity (AMAP 1997). Permafrost thawing can itself add to climate change problems — for example, emissions of methane from tundra may increase while reductions in the extent of highly reflective snow and ice cover will magnify warming. These effects may continue for centuries, long after greenhouse gas concentrations are stabilized, and may cause irreversible impacts on ice sheets, global ocean circulation and sea-level rise (IPCC 2001a).

Monthly mean ozone levels at Halley Bay, Antarctica (Dobson units)



Monthly mean ozone levels at the Halley Bay site during the onset of the Antarctic spring

Source: BAS 2000

'The permafrost zone covers 58 per cent of the territory of the Russian Federation. Many human settlements, industrial plants and infrastructure are located in this zone. Given the current warming trend, the border of the permafrost zone could move 300–400 km northward by 2100.' — *Interagency Commission 1998*

Since most industrial countries are in the Northern Hemisphere, the Arctic is more exposed to anthropogenic air pollution than the Antarctic. Prevailing winds carry polluting substances — including heavy metals, POPs and sometimes radionuclides — into the Arctic where they can stay airborne for weeks or months and be transported over long distances (Crane and Galasso 1999). Over much of the Arctic, levels of certain types of pollutants are so high that they cannot be attributed to sources

Long-range transport of pollutants to polar regions

Some persistent toxic substances, including POPs and mercury, can become volatile in warm air and be transported by air masses. After deposition, they can re-enter the atmosphere again and continue their journey, becoming long-distance contaminants. The process can continue until they reach the cooler polar areas where they condense on to particles or snow flakes in the air, which eventually land on the ground. Due to low solubility in water and high solubility in fats, they are easily incorporated into fat-rich polar food webs, and accumulate in biota. Due to the combination of harsh climate conditions with physico-chemical properties of persistent toxic substances, the polar regions, the Arctic in particular, create a sink for these substances, which may result in their levels being higher than in the source regions (AMAP 1997). The implementation of the recently adopted Stockholm Convention on Persistent Organic Pollutants, signed in May 2001, may lead to a reduction in deposition of POPs in the polar regions.

within the region; they come from much further south.

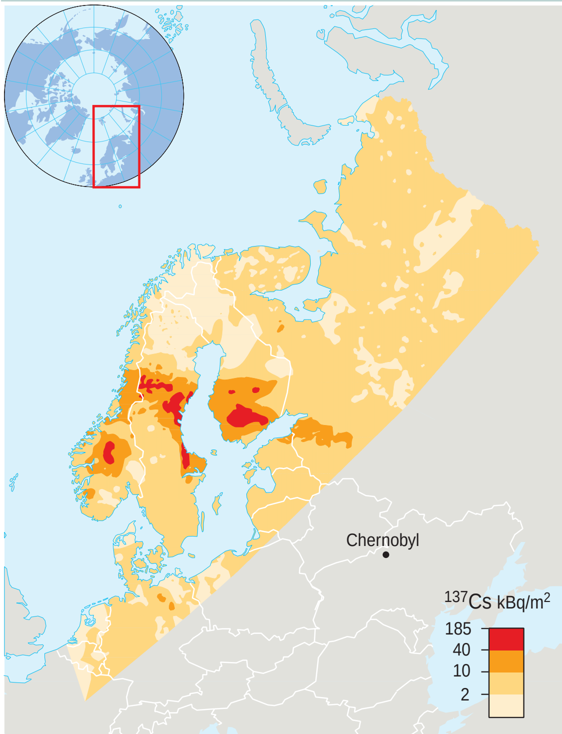
Major sources of anthropogenic radionuclides in the Arctic include fall-out from nuclear tests, releases from nuclear fuel reprocessing plants, and fall-out from the 1986 Chernobyl nuclear power plant accident. A significant increase of radioactivity in Arctic indigenous people was registered after the Chernobyl accident, particularly amongst those who consumed significant quantities of foods that concentrate radio-caesium, such as reindeer meat, freshwater fish, mushrooms and berries. The phenomenon was mainly observed in 1986–89 in Norwegian and Swedish Saami and up to 1991 in the indigenous population of the Kola Peninsula, in the Russian Federation. Since then the levels have been gradually falling back towards the pre-accident levels (AMAP 1997).

Within the Arctic, the Russian Federation's industrial complexes have been a major source of atmospheric pollution. Emissions of sulphur compounds and heavy metals from smelters have caused major forest degradation on the Kola Peninsula and have decreased the number of species in the region. The areas severely affected by air pollution around the Nickel-Pechenga and Varanger smelters increased from around 400 km^2 in 1973 to 5 000 km^2 in 1988 (AMAP 1997). Since 1990, emissions from Russian smelters have decreased or stabilized mainly because of the economic slowdown.

The level of air pollution in the Arctic is so high that 'Arctic haze' has become a major problem. The term was coined in the 1950s to describe an unusual reduction in visibility that the crews of North American weather reconnaissance planes observed during flights in the high latitudes in the Arctic. The haze is seasonal, with a peak in the spring, and originates from anthropogenic sources of emission outside the Arctic. The haze aerosols are mainly sulphurous (up to 90 per cent) originating from coal burning in the northern mid-latitudes, particularly in Europe and Asia. The particles are about the same size as the wavelength of visible light, which explains why the haze is so apparent to the naked eye.

Improvement in the state of the polar environment depends primarily on policies and measures implemented by people inside and outside of the polar areas. The Arctic countries have taken a number of steps to improve air quality. These include signing the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the relevant protocols to it,

Radioactive contamination after Chernobyl



Levels of caesium 137 (1 000 becquerels/m^2) in Scandinavia, Finland and the Leningrad region of Russia following the Chernobyl explosion in 1986

Source: AMAP 1997

The significance of Arctic haze

The discovery of Arctic haze put paid to the earlier notion that aerosol pollution could only be local or regional. The cold, dry air in the polar regions allows particles to remain airborne for weeks rather than days, which in turn allows sulphur contaminants to spread from industrial sources in Eurasia across the entire Arctic and into North America. The haze particles can facilitate the transport of metals and other contaminants to and within the polar region and result in the deposition of these pollutants in precipitation over major ocean areas surrounding the Arctic (AMAP 1997).

and supporting the development of the Stockholm Convention on Persistent Organic Pollutants. In addition, domestic regulatory measures taken in the United States and Canada have reduced emissions of some POPs, heavy metals and sulphur compounds. Actions to address stratospheric ozone depletion rely on the successful implementation of the Montreal Protocol by all nations (UNEP 2000).

Given the predicted increase in the global mean temperature, climate change will impose significant pressures on the polar regions in the 21st century. These impacts are likely to be exacerbated by the high vulnerability and low adaptive capacity of polar ecosystems and of some traditional indigenous communities. Despite increasing activity in both the domestic and international arenas, only preliminary steps have been taken to address the problem of global climate change. The main regional challenge is therefore enhancing the potential for adaptation to change that should help mitigate adverse impacts. The Arctic countries have initiated an Arctic Climate Impact Assessment to be completed in 2003. It will be integrated into the regional studies of the IPCC (ACIA 2001).

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OUR CHANGING ENVIRONMENT: Chomutov, Czech Republic

Pollution from coal-fired powerplants near Chomutov, Czech Republic, swept for many years over the Krusne Hory Mountains into Germany — that is, from the lower right to the upper left in the images shown on the left.

The green rectangular shapes are strip mines which supply low-grade, sulphur-rich brown coal for electricity generation.The burning of this low-grade coal not only pollutes the air but also inflicts severe damage on forests throughout Eastern Europe.

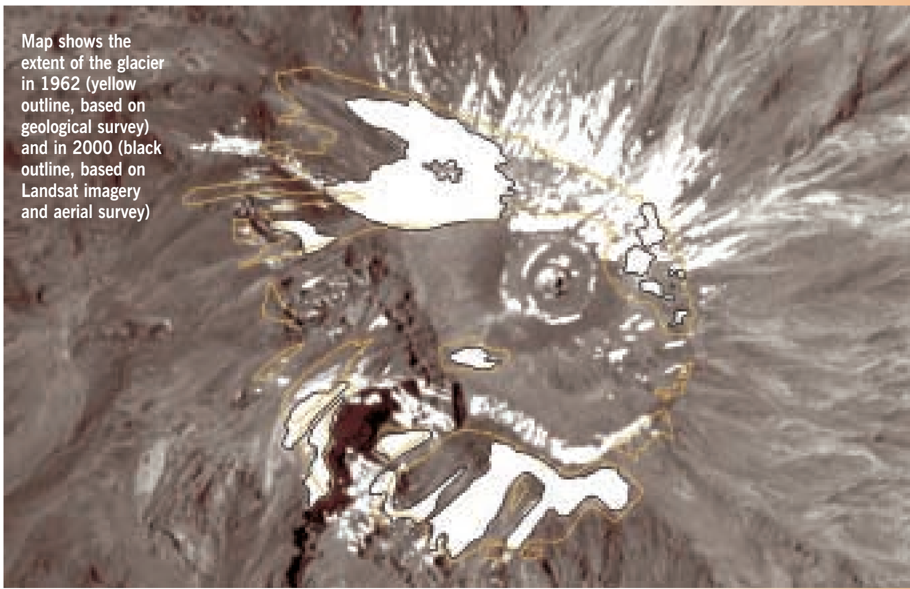
In the early 1980s, trees growing high up on the mountains began to die. The effects are shown in the central left portion of the two images. In the 1979 image, the dark areas represesent healthy, dense forest. In the 2000 image, these dark areas are replaced by areas of light grey, in which the trees have died and mostly bare soil has been left. Extensive clear-cutting of dead and dying trees has since occurred. Efforts to replace the damaged forests been widely unsuccessful.

Landsat data: USGS/EROS Data Center
Compilation: UNEP GRID Sioux Falls

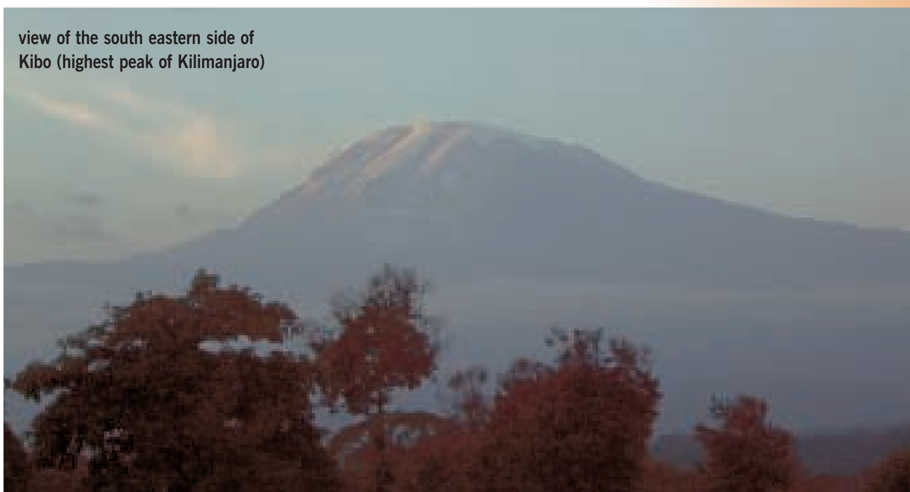
OUR CHANGING ENVIRONMENT: Kilimanjaro, Tanzania

Mt Kilimanjaro, located some 300 km south of the equator in Tanzania, is Africa's highest mountain. Its permanent ice and snow looming some 5 000 metres above an undulating savanna plain have always fascinated people and attracted many visitors to both Tanzania and Kenya.

But the glaciers of Kilimanjaro are vanishing due to regional warming, probably linked to global warming. The map shows the diminishing extent of the glaciers between 1962 and 2000. Over these 38 years, Kilimanjaro has lost some 55 per cent of its glaciers. According to the Byrd Polar Research Center of Ohio State University 'Kilimanjaro has lost 82 percent of the ice cap it had when it was first carefully surveyed in 1912'.

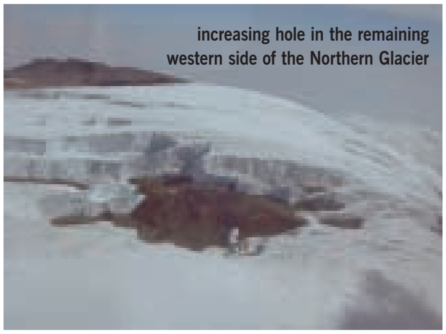


Map shows the extent of the glacier in 1962 (yellow outline, based on geological survey) and in 2000 (black outline, based on Landsat imagery and aerial survey)



view of the south eastern side of Kibo (highest peak of Kilimanjaro)

view of the main caldera on Kibo



increasing hole in the remaining western side of the Northern Glacier

Remnants of the eastern side of the Northern Glacier

Landsat data: USGS/EROS Data Center
Photographs: Christian Lambrechts, UNF/UNEP/KWS/University of Bayneuth/WCST