APPLIED CLIMATOLOGY

Principles and Practice

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ATMOSPHERIC RESOURCE MANAGEMENT

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INTRODUCTION: ATMOSPHERIC RESOURCE MANAGEMENT ISSUES

The idea that the atmosphere can be managed as a resource is relatively new. The atmosphere is not a classical resource like minerals, oil, or forests, or land, or even water. It cannot be appropriated in an exclusive way because it is a fluid medium, constantly in motion and observes no boundaries. The air we breathe circulates freely around the whole globe; hence the atmosphere is classified as a "common property resource" and is described as part of the "global commons" – something in which all people now living have a stake and in which future generations also have an interest. For this reason, if atmospheric management is to be at all effective then this can only be achieved through collective action. In the absence of any collective management, the atmosphere is simply a "free good" that can be used by anyone and in any way they please, with potentially damaging and even catastrophic results. Indeed, the atmosphere has in effect been a "free good" for most of human history. It is only in recent times with the growth of modern industry and large cities that management has become necessary. An objective of this chapter is to show how the scale of human interference and impact on the atmosphere has expanded over the last half century from the local to the global, and how this has shaped the role and functions of atmospheric management. Some future directions in the evolution of atmosphere management are also discussed.

One legal point of departure for atmospheric management was to limit what could be done on the land in order to protect the rights of others to the use of the atmosphere. In the English Common Law this has traditionally been covered by the law of nuisance. A person is constrained not to use his or her land (e.g. by burning or otherwise emitting noxious smoke or fumes) in such a way that would tend to harm the enjoyment of others of their land, be it on adjacent property or some distance away. With the growth of much greater emissions (pollutants), and the emergence of impacts over larger and larger areas, the law of nuisance has become increasingly inadequate. Although such laws and legal precedents are still used today for some purposes, it has generally become necessary to adopt legislation and a complex set of regulations restricting the use of the atmosphere as a sink for gaseous waste. Regulations within one country are often insufficient and international agreements are necessary for effective atmospheric management.

The atmosphere is a resource in another sense. It is also an asset in terms of the weather or climate which supports a range of human activities and needs, including health,
agriculture, forestry and recreation (i.e. Chapters 12, 16, 17 and 18). While it is not possible to deplete the air in a physical sense, it is possible to reduce its quality by affecting its physical and chemical nature from local to global scales (Chapter 22). Poorer air quality reduces health and wealth. Furthermore, because the atmosphere is a continuous medium, all of its properties are interconnected. Air quality, weather/climate and extreme events (Chapter 23) are all attributes of the same atmospheric system. Ideally, management should be recognized and shaped according to this fundamental principle. In practice, however, it has been convenient to segregate the atmosphere into different scientific and policy domains, with each one studied and managed in relative isolation. Such an approach has been justified as a necessary part of the scientific method, and as an effective way of proceeding on the policy agenda one issue at a time.

**HISTORY OF ATMOSPHERIC RESOURCE MANAGEMENT**

The history of atmospheric resource management reveals two 'polar' perspectives on making use of the atmosphere. One is to try to make the atmosphere behave according to human wishes and the other is to adapt human behaviour to the characteristics of the atmosphere, in order to make use of its benefits and to minimize its adverse effects. These two approaches are the extremes of a spectrum, of a continuously varying pattern of response. The rain dance of the Navajo and other Indian groups of the American southwest is a famous example of an attempt to control the atmosphere. Atmospheric management in modern times has included attempts to disperse fog at airports (London's Heathrow for example) by using heating devices. Cloud seeding enjoyed a period of popularity in the 1950s and 1960s as a more scientific approach to 'rain making'. Many other technologies have been tried, some of which are relatively simple and some 'high tech'. Examples of both are still widely found. Greenhouses and windbreaks are used to modify the micro-climate to improve agricultural output. Smudge pots are used to create smoke to protect valuable crops from frost. In these latter examples, the emphasis is shifting from changing the behaviour of the atmosphere per se to one of protecting the economic activity. Other protective behaviour includes wearing sun hats, sunscreen lotion, sunglasses or minimizing outdoor activity during episodes of poor air quality. In the recent policy debates over climate change, these two approaches have been enshrined into the United Nations Framework Convention on Climate Change as the 'mitigation' and the 'adaptation' approaches.

In addition to atmospheric control and adaptation to the atmosphere, the third element in atmospheric management is research. Research on the natural science of the atmosphere and the socio-economic causes and consequences of atmospheric change is an essential ingredient of the management process. One important dimension of humanity's relationship to the atmosphere is the changing attitude towards its management. Efforts to control the atmosphere are giving way to the recognition that it is better to adapt to the natural variations in weather and climate, and to attempt to exercise self-control by limiting the anthropogenic sources of air quality problems.

Perhaps the most important dimension of atmospheric resource management in historical terms is the progressive enlargement of spatial scale. The period of early industrialization in Europe and North America was characterized by extremely poor air quality in the inner cities, resulting largely from the burning of coal. Smoke concentrations were high and the fallout of black carbon particulates made the problem quite evident in the densely populated and industrial areas. In the latter half of the twentieth century, coal has been largely replaced in
the developed countries by oil and natural gas. However, coal is still used in large coal-fired electrical power generating stations which supply power to industrial, commercial and domestic users. These large power stations typically have tall smokesacks which disperse the emissions higher into the atmosphere, where they are carried long distances (see Acid deposition below and in Chapter 22). A positive result of the 'high stacks' policy, and the more efficient fossil fuel combustion techniques, is that the historical local air quality problems of London and other cities have been greatly reduced. They have, however, been replaced by photochemical air pollution which is aggravated by stable atmospheric conditions and intense sunlight, and for which the major source of pollutants is the very large increase in fossil fuel combustion, particularly transport emissions. It is this photochemical smog which has made cities like Los Angeles, Mexico City and Athens notorious for their air quality problems. Photochemical smog (see Chapter 22, Urban air pollution problems) can have serious health effects especially for those with pre-existing health (especially respiratory) conditions (see Chapter 12, Atmospheric impacts on, performance, and behaviour). The continued expansion of cities and the growth in the number of cars has resulted in poor air quality conditions spreading out from the cities into the surrounding regions where agricultural production can be adversely affected. Major urban areas may also impact regions thousands of kilometres downwind owing to the dispersion of air pollutants during long-range transport of air masses (Figure 22.5).

Regional air quality problems first appeared as photochemical smog spread out from the cities. This was followed by the problem of acidic deposition as a result of the growth in emissions of sulphur dioxide (SO₂) and nitrogen oxides (NOₓ) from fossil fuel combustion and smelting activities. The scale of the acidic deposition problem generally exceeds that of photochemical smog. It was shown that SO₂ emissions from the UK and Germany were causing the acidification of lakes in Scandinavia, and Canada protested about damage to lakes and forests in Ontario and Quebec from emissions in the Ohio Valley and the midwest of the United States. The emergence of the acid rain issue (more correctly termed acidic deposition, because snow and fog can be acidic) marks the first recognition of the long-range transport of atmospheric pollutants and the need for an internationally co-ordinated response.

The next atmospheric problem to emerge was the depletion of the stratospheric ozone layer by chlorofluorocarbons (see Chapter 22, Global air pollution problems). These substances (CFCs), which are considered inert gases under tropospheric conditions, have been used in refrigeration and air-conditioning systems since the 1950s. In the late 1980s it was discovered that CFCs had already led to significant depletion of the ozone (O₃) layer over Antarctica (Plate 22.1), and that further depletion could be expected on a wider scale, resulting in increased ultraviolet radiation at the earth's surface and subsequent danger to human health and ecosystems. The problem of climate change resulting from anthropogenic emissions of greenhouse gases (see Chapter 22, Introduction), especially carbon dioxide (CO₂) from the burning of fossil fuels, followed hard upon the heels of ozone-layer depletion. The burning of trees (or wood) also contributes CO₂ to the atmosphere and the indications now are that the level of CO₂ concentrations in the atmosphere will reach double the preindustrial level (1800 AD) during the second half of the twenty-first century, unless greenhouse gas emissions can be stabilized and then substantially reduced.

A new atmospheric resource problem has recently become apparent. This is the problem of global contamination with toxic chemicals transported from their place of use as pesticides, fungicides and other industrial chemicals (including heavy metals), through atmospheric
pathways to all regions of the earth. The history of atmospheric resource management has seen the steady expansion in spatial scale of air issues, with the corresponding need to develop systems of management on continental and global scales. An earlier distinction between the management options of mitigation/prevention and adaptation is now breaking down. The reason is that human-induced changes to the atmosphere cannot be studied or managed separately from the natural behaviour of the atmosphere. Since it is now agreed in the scientific community that the earth's climate is being changed by anthropogenic forces, then it follows that any weather-driven event, including hazard events (such as floods, droughts, forest fires, frost, hail, high winds, hurricanes, tornadoes and blizzards, discussed in Chapter 23), cannot be isolated from human activity.

CURRENT MANAGEMENT APPROACHES TO AIR QUALITY PROBLEMS

Urban and Regional Air Quality

Air quality within urban centres and nearby rural areas may be affected by gaseous emissions of nitrogen oxides (NOx), sulphur dioxide (SO2), carbon monoxide (CO), volatile organic compounds (VOCs) and particulate matter (see Chapter 22, Urban air pollution problems). The presence of these air contaminants and subsequent reaction products, such as ground-level ozone (O3), can have serious impacts on human health, vegetation and material surfaces. The major sources of these air pollutants are human activities which require energy, for example electrical power generation, industrial activities and transportation systems that utilize fossil fuels. Approximately 95 per cent of the anthropogenic NOx in the atmosphere is the result of fossil fuel combustion. Other pollutant sources are industrial process and consumer products such as commercial printing processes, paints and solvents to dry cleaning and personal care products.

Photochemical smog is the most common urban air quality problem. The major component of smog is ground-level ozone (see Chapter 22, Secondary pollutants), which is formed by the reactions of NOx and VOCs in the presence of sunlight. Ground-level ozone increases respiratory problems in humans. Vegetation effects range from visible leaf damage to reduced yield in agricultural crops and reduced growth in some forest species. Particulate matter, often associated with smog and acidic deposition and the presence of suspended particles in the atmosphere (from 1 μm to 10μm in diameter), results in health effects which are associated with increased hospital admissions and mortality, and reduced visibility.

The initial management approach to urban air quality was to set ambient air quality guidelines to protect human health and the environment for the individual common air pollutants, namely SO2, suspended particulate matter, CO, ground-level ozone and nitrogen dioxide. The World Health Organization published Air Quality Guidelines in 1987 for organic and inorganic air pollutants, which were revised in 1995 incorporating ecosystem impacts. These guidelines were then, and are still, used to derive standard emission limits (e.g. Table 22.6) for various pollutant sources on a species-by-species basis, often neglecting the positive or negative consequences of controlling one pollutant on other co-pollutants emitted from the same source.

In the mid-1970s it was recognized that long-range transport of pollutants within Europe and within North America through the atmosphere resulted in damage to ecosystems far from the pollution sources (see Chapter 22, Continental-scale pollution problems). In 1985, the UN ECE Convention on Long Range Transport of Air Pollutants entered into force and became the focal point for determining abate-
ment strategies for reducing the impacts of air pollutants on human health and ecosystems. Under this convention, protocols were signed to reduce \( \text{SO}_2 \) emissions (1985), \( \text{NO}_x \) emissions (1988) and VOC emissions (1990), and further \( \text{SO}_2 \) emission reductions (1994) were made, primarily to reduce ground-level ozone concentrations and acidic deposition. These protocols represent the first co-ordinated international efforts to reduce local and regional air quality problems. Since the development of ambient air quality guidelines, the public (in some countries) has had access to real-time information on local air quality through the daily publication of air quality indices and forecasts. The intent of the advisory air quality information is to encourage behaviour modification from reducing emissions (e.g., encouraging alternative transportation), to taking protective action (e.g., reducing physical activity during bad smog episodes) and staying indoors. Such behavioural responses are particularly important for those at high risk, including young children, older people and those with respiratory illnesses.

**Acid Deposition**

The acid deposition problem includes wet and dry deposition of acidic compounds, in the form of rain, snow, fog or dry particles (see Chapter 22, Acid deposition). Acid rain or fog was recognized as a problem early on with the switch in principal energy sources from wood to coal. Sulphur dioxide (\( \text{SO}_2 \)) and \( \text{NO}_x \) produced by metal smelting, thermal electrical utilities and transportation systems account for the majority of anthropogenic emissions causing acidic deposition. Both \( \text{SO}_2 \) and \( \text{NO}_x \) are subject to long-range transport through the atmosphere, which means that acid deposition is a continental-scale air quality issue (see Chapter 23, Continental-scale pollution problems). These gases are oxidized in the atmosphere to form primarily sulphuric acid and nitric acid which may be dissolved in rain, snow or fog droplets or form dry particles. When these acidic species are deposited in aquatic and terrestrial ecosystems with a low acid buffering capacity, the habitats are altered enough to affect significantly the fish populations and forest growth. There is also some evidence that acidic particles in the air have an adverse effect on human health. In addition to altering the acidity of the sensitive ecosystems, the higher acidity in lakes often results in the dissolution of toxic metals such as aluminium, cadmium, lead and mercury.

Acid rain was recognized as a significant environmental problem in the 1960s and, within the next ten years, emission guidelines and air quality objectives had been established for \( \text{SO}_2 \) in North America and Europe. During this period in both Europe and Canada, target loads for sulphate deposition were being defined to protect sensitive ecosystems. This represents the first ecosystem response-based approach to managing an atmospheric issue. Also during this time, under the UN ECE Convention on the Long Range Transport of Air Pollutants, the first \( \text{SO}_2 \) protocol was signed in 1985 and the first \( \text{NO}_x \) protocol was signed in 1988. In 1991, Canada and the USA signed the Air Quality Accord Agreement in which the impact of \( \text{SO}_2 \) emissions on Canada’s ecosystems was formally acknowledged, and a framework was established to deal with transboundary air issues more expeditiously. In 1994, the second UN ECE protocol for \( \text{SO}_2 \) was signed defining further reductions based upon cost-effective approaches.

**Ozone-layer Depletion**

Life on earth is protected from damaging ultraviolet B (UVB) radiation emitted from the sun. by a thin layer of ozone \( (\text{O}_3) \) in the stratosphere. Scientists have long understood that any serious threat to the ozone layer could have potentially disastrous consequences for ecosystems and
human health (see Chapter 22, Stratospheric ozone depletion). Identified sources of damage to the ozone layer include chlorine from industrial processes, nuclear weapons testing and supersonic jet transport aircraft (SSTs). These risks did not receive much attention until a substantial thinning of the ozone layer over Antarctica was discovered by the British Antarctic Survey in 1985. Subsequent research has identified several CFC compounds that came into widespread industrial use in the 1950s as a substitute for ammonia in refrigeration, as the main source of chlorine that is causing ozone depletion. Because of their distinctive properties (i.e., they are extremely chemically stable compounds), CFCs have found many other industrial applications. It is only when they reach the stratosphere and are exposed to higher radiation levels that they photodissociate and release the reactive chlorine precisely where it can interact with the ozone layer.

Increased exposure to UVB radiation has been linked to an increase in the incidence of skin cancer with the light-skinned populations being most at risk. Other health impacts include damage to the human immune system and the increased risk of eye diseases such as cataracts. Agricultural experiments with crops such as cotton, peas, beans, melons, tomatoes, and cabbage show a distinct decrease in yields under higher UVB radiation exposure. Other impacts include the potential loss of microorganisms in aquatic systems that constitute a threat to the food chain. This suggests that depletion of the ozone layer could have serious consequences for global food production and natural ecosystems as well as human health.

Stratospheric ozone depletion is the first atmospheric issue to be recognized as, and addressed as, a truly global concern. Action to reduce the risks of ozone-layer depletion has focused on steps to reduce and eventually eliminate the use of CFCs. Under the leadership of the United Nations Environment Programme (UNEP) negotiations began on the development of an international convention to protect the ozone layer in 1981, and these led to the Vienna Convention of 1985. Specific commitments to reduce emissions of CFCs (and other ozone-depleting substances) came into effect in the Montreal Protocol of 1987 (see Chapter 22, Stratospheric ozone depletion).

The Montreal Protocol was widely greeted as a success story that demonstrated the capacity of the international community and the UN to take action to protect the global (atmospheric) environment. The protocol committed all industrialized nations to reduce their consumption of ozone-depleting substances by 50 per cent of the 1986 level by the year 1999. Developing countries were required to meet similar targets by 2009. In spite of this diplomatic success, it quickly became clear that the measures in the Montreal Protocol were inadequate, based on the rate of change in UVB radiation and stratospheric ozone concentrations, and two subsequent amendments have been agreed in London (1990) and in Copenhagen (1992). Projections of atmospheric chlorine concentrations with and without these actions are shown in Figure 5.1 in relation to a critical level based on reducing health impacts or stabilizing ozone levels. It may be noted that even with this successful action the concentrations of chlorine in the atmosphere will not fall back below the

![Figure 5.1 Atmospheric chlorine concentrations, 1960–2080](image-url)
critical level until near 2050 even if the agreements are strictly adhered to. Other, more adaptive responses are available to reduce the impacts of enhanced UVB radiation and these are recommended as temporary expedients pending the successful implementation of the Vienna Convention. Health authorities advise people to avoid exposure to direct sunlight, especially when the sun is high, and to wear protective clothing and a sun-blocking cream.

**Climate Change**

The temperature of the earth's atmosphere is a result of the amount of incoming radiation, the amount of outgoing (reflected) radiation, and the amount 'trapped' or captured in the atmosphere by water vapour and other heat-trapping gases, primarily CO₂, methane and nitrous oxide. With the exception of water vapour, the amount of gases in the atmosphere is small. These radiatively active trace gases are extremely important, for without them the mean temperature of the atmosphere would be about 15°C cooler than it is today. The most significant trace gas in this regard is CO₂. Preindustrial concentrations of CO₂ were approximately 280 ppm and current levels approximate 355 ppm (Table 22.1).

Atmospheric scientists have suggested for a hundred years that emissions of CO₂ from human activities (see Chapter 21, Impacts of urban climates on GEC) could change the balance of atmospheric radiation. Research in the 1960s with general circulation models of the atmosphere (under assumed conditions of atmospheric forcing by increased CO₂ and other trace gases) suggest that, if current emission rates continue, the mean atmospheric temperature (at ground level) could increase by 2.5°C to 4.5°C by the latter part of the twenty-first century. Carbon dioxide is not solely responsible for radiative forcing. The important role of atmospheric research in atmosphere management is illustrated by Figure 5.2 which shows current estimates of radiative forcing by the family of greenhouse gases (GHGs), tropospheric ozone and solar variation. The height of the bar indicates a mid-range estimate of the forcing whilst the lines show the possible range of values. An indication of relative confidence in the estimates is given below each bar. The contributions of individual greenhouse gases are indicated on the first bar for direct greenhouse gas forcing. The major indirect effects are a depletion of stratospheric ozone (caused by the CFCs and other halocarbons) and an increase in the concentration of tropospheric ozone. The negative values for aerosols should not necessarily be regarded as an offset against the greenhouse gas forcing because of doubts over the applicability of global mean radiative forcing in the case of non-homogeneously distributed species such as aerosols and ozone. There are also 'negative forcings' by stratospheric ozone and tropospheric aerosols. Models of climate impacts (Chapter 4) as a result of global warming have shown the potential for damage and disruption to natural ecosystems, global agricultural production, freshwater distribution and population distributions. A major threat is sea-level rise which could occur in the short to medium term (decades) as a result of the thermal expansion of oceans, and in the longer term (centuries) as a result of melting ice sheets (see Chapter 7, Conclusion). The general circulation models (Chapter 4) project greater warming in the high latitudes and continental interiors, with much less warming over the oceans and in low latitudes (Table 22.3). However, the adverse impacts of climate change are likely to be greatest in those countries where the capacity to adapt to climate change is least – that is, in the low-latitude countries with heavy dependence upon agriculture, forests and water supplies.

The atmospheric management response to the threat of climate change follows three patterns. First, there has been a substantial expansion of atmospheric research and climate
monitoring to strengthen scientific understanding and reduce the uncertainty of current projections. Second, a UN Framework Convention on Climate Change has been adopted (Chapter 22). This convention is analogous to the Vienna Convention on the ozone layer. Negotiations are now underway with a view to the development of specific protocols that will involve international agreements to reduce GHG emissions according to some targets and schedules. In the case of the Montreal Protocol to the Vienna Convention, international agreement was possible in an unusually short time because the adverse effects of ozone-layer depletion could be detected currently along with increased UVB radiation, and because the sources of ozone-layer depletion (CFCs) are limited to a relatively small sector of the economy. In the case of climate change, however, the sources involve the entire energy-intensive industrial economy and domestic lifestyles. Also, curbing emissions of CO₂ and other GHGs will require the participation of more countries. Any climate change mitigative or adaptive strategy must also address the plans of developing countries to expand their use of fossil fuels considerably in the coming decades. Therefore, action to reduce emissions in the industrialized countries will have to be sufficient to accommodate increased emissions from developing countries, if atmospheric concentrations are to be stabilized.

Air Toxics (Persistent Organic Pollutants and Heavy Metals)

Air toxics are also known as hazardous air pollutants. The Organization for Economic Cooperation and Development (OECD) defines them as follows:
Hazardous air pollutants are gaseous, aerosol or particulate contaminants present in the ambient air in trace amounts with characteristics (toxicity, persistence) so as to be a hazard to human health, or plant, or animal life.

They are of concern because of their persistent and potentially bioaccumulative nature. Air toxics are a global issue, for which the atmosphere is a pathway between the source regions and remote areas, such as the Arctic and Antarctic regions. The means by which toxic species move through the atmosphere to remote regions is called 'global distillation', which describes the selective migration towards colder regions of the globe. This distillation process is the result of revolatilization processes, by which toxic species become vapours under warm conditions and rise up out of the water or soil into the air, until reaching a cold air mass and depositing to the surface. This revolatilization process may happen many times resulting in a global distribution of toxic substances. Air toxics are often defined as persistent organic species including pesticides and heavy metals, such as mercury or lead.

In North America, 362 different contaminants have been detected in the Great Lakes basin, including 32 metals and 68 pesticides. Approximately half of these contaminants are synthetic organic chlorine substances, and one-third of these can have acute or chronic toxic effects on ecosystems, including human health. Many pesticides, which have been banned for nearly 20 years or more, are still observed in the environment, and are abundant in the Arctic food chain. The fact that air toxics do not respect political boundaries has resulted in the establishment of management activities which are international and continental in nature though, to date, many of these agreements and programmes have not been in effect long enough for improvements to be observed in the environment. The circumpolar countries have established an Arctic Environmental Protection Strategy focusing on monitoring and data-gathering programmes to support remediation activities. The UN ECE Convention on the Long Range Transport of Air Pollutants is currently developing protocols for the control and regulation of persistent organic pollutants and heavy metals. UNEP has also initiated a global action plan for hazardous air pollutants. Generally, these international agreements or strategies focus on reducing emissions of the toxic substances at the point of origin into the environment. Air toxics may be managed by two approaches, namely a strategy leading towards virtual elimination from the environment or the management of the toxic substance throughout the entire life cycle at a level of acceptable risk. Substances which are usually targeted for virtual elimination are those substances which are persistent, bioaccumulative and result predominantly from human activity.

**Natural Atmospheric Hazards**

Long before air quality became an issue, people had to cope with extreme atmospheric variations. Floods, droughts, blizzards, windstorms, hurricanes, fog and frost, for example, have long plagued humanity. The character of atmospheric processes that give rise to these events is such that most of them lie beyond the human capacity to control. There have been numerous efforts to modify these and similar events, however, sometimes with rather perverse results. Efforts to control floods (e.g. by the construction of dams, dikes and other flood control structures) has led to increased use of floodplain lands and has contributed to an increase rather than the expected reduction in flood damage. Previously natural atmospheric hazards have been considered to be 'acts of God' and not therefore the responsibility of any human agent. With the advent of anthropogenic climate change this assumption is no longer so convincing. Climate change will actually be experienced in the changing distribution of weather
events, including increased frequency and magnitude of atmospheric extremes (Chapter 23). In a technical sense, therefore, the so-called ‘natural’ atmospheric hazards can be affected by human activities. In this atmosphere management issue there is a strong case to be made for adaptive response strategies which seek to harmonize human activities with environmental extremes, and to reduce vulnerability.

**INTEGRATION OF AIR ISSUES**

The previous sections have described the management approaches taken and proposed in relation to each of the separate air issues at local, national, regional and global levels. It is increasingly clear, however, that these issues cannot be effectively managed in isolation. Figure 5.3 shows, in a schematic way, the pattern of interrelationships between some of the air issues. Human activities of many kinds result in emissions into the atmosphere. The level of emissions depends on the scale and the nature of the human activities and the degree of emission content. Many pollutants accumulate in the atmosphere and some interact with each other. Changes in atmospheric physics, density and atmospheric programmes create socially identified problems called ‘air issues’. Each of the air issues has an impact on human activities and targets specific vulnerabilities or susceptibilities. In response to the impacts, human activity can adapt in many ways. These include the extent and value of the adaptation of human society which alters the level, and the amount of, emissions produced. For example, sulphate particulates which contribute to acid precipitation also have a local cooling effect on the earth’s atmosphere. There is now strong evidence that global warming would have been significantly greater over the past few decades in the absence of sulphur emissions. Policies and programmes introduced to reduce sulphur

*Figure 5.3 Human–atmosphere interactions*
emissions therefore, to the extent that they are successful, will tend to exacerbate the global warming problem. On the other hand, CFCs not only deplete the ozone layer, but also serve as greenhouse gases and hence elimination of CFC emissions will contribute to a lessening of the amount of global warming that would otherwise be expected. Economic analysis of the costs and benefits of specific air management proposals should ideally take into account the multiple benefits (and costs) where more than one air issue is affected. For example, reducing NOx emissions also alleviates acid deposition and smog. Steps to increase energy efficiency can have benefits for urban/regional air quality and acid deposition, as well as climate change.

It is now becoming clear, therefore, that policies directed at one atmospheric management problem cannot be properly assessed or managed in isolation. A policy in one direction may make matters worse in another, and hence the benefits ascribed to that policy may be less than anticipated. On the other hand, a policy that reduces global warming (and at the same time helps to reduce photochemical smog) may have additional benefits which may help to make otherwise less attractive policies seem more economically feasible. A future direction for atmospheric management therefore is to move towards the integration of air issues. This integration, if it is to succeed, should include the integration of the atmospheric research science, the integration of the assessment of impacts of atmospheric changes on natural and social systems and the integration of policies at all levels from local to global. Such an ambition is easily stated, but it is extremely difficult to design and implement. Neither the science, nor the socio-economic studies, nor the policy instruments exist. The most that can be expected is steady progress in the direction of a more integrated approach.

SUSTAINABLE DEVELOPMENT AND THE ATMOSPHERE

Even though the integration of atmospheric science and policy is an important and necessary step that will require a great deal of attention, this will not by itself be enough to resolve the issues of atmospheric resource management. There lies ahead the further requirement to link atmospheric resource management into the agenda for sustainable development agreed by the nations attending the UN Conference on Environment and Development in Rio de Janeiro in 1992. The implications of this agreement are that a new philosophy of management is required and should be worked out and implemented as soon as practicable. The new philosophy leads away from the 'end of pipe' control by technology and regulations (called 'react and cure') to an anticipate and prevent approach. In the case of atmospheric resource management, this means addressing the more fundamental questions of demand for goods and services, full cost accounting and pricing in the marketplace and the development of environmentally friendly technologies. In terms of Figure 5.3, the management interventions should not only include steps to control or reduce emissions, but also address the issues of population growth and redistribution, economic patterns of consumption/lifestyles and environmental technology, along with questions of social values, attitudes, perceptions and preferences. Behind these variables lie questions of ethics pertaining to the equitable distribution of health and wealth among the peoples of the planet, and between generations. Atmospheric resource management has changed substantially from the days when the law of nuisance was sufficient.
CONCLUSIONS

An ultimate objective might be the development of a set of policies at local, national, regional and global levels that work together in a harmonious way to manage the atmosphere for the benefit of all the earth's population, present and future. It is good to have such long-term visions of where management needs to move. For the present it is necessary (if not sufficient) to develop a more integrated understanding of the problems of the atmosphere and to advance its management at the local and national levels. At the same time, it is important to proceed through international negotiations and agreements in order to move the world community towards a common goal, in which atmospheric resource management plays its full part in the move towards sustainable development. While such a vision can be inspiring as a guide to action, it does not command universal acceptance even as a vision. There are limits to what can be achieved by laws, regulations and agreement. Some argue that more market-based economic instruments should play a larger role in atmosphere management. Others propose that neither regulatory nor market-based approaches will suffice, singly or in combination, without a radical change in the willingness of individuals to accept responsibility for the atmosphere.

The atmosphere has traditionally been an unmanaged system. As problems of air quality were identified and grew in scale and complexity, human management systems grew correspondingly in order to cope with the threats to health and economic livelihood. Now the management systems themselves are seen as part of the problem. This has happened in part because more and more divergent interests are at stake and achieving agreement becomes a more and more complicated process. Atmospheric science and the understanding of the economic, social and health significance of the atmosphere are still crucial, but politics and diplomacy are becoming more important. Like the atmosphere itself, 'atmospheric resource management' is in a constant state of flux and both the atmosphere and its management are evolving.

REFERENCES


