EEA Report | No 2/2004

Impacts of Europe's changing climate

An indicator-based assessment

Summary

European Environment Agency

Summary

Overview

Earth's history has been characterised by many changes in climate conditions. But the extent and the rate of current climate change most likely exceeds all natural variation in the last thousand years and possibly further back in history. There is strong evidence that most of the observed recent warming is attributable to human activities, in particular to emissions of greenhouse gases (GHGs) from burning fossil fuels and land-use changes. Due to ongoing emissions of GHGs, the observed rise in global temperature is expected to continue and increase during the twenty-first century. Climate change already has considerable impacts on the environment, human health and society which are expected to become more severe in future.

As a response to climate change, the United Nations Framework Convention on Climate Change (UNFCCC) has been established. It aims to reduce greenhouse gas emissions and mitigate the effects. Also established are the Kyoto Protocol emission targets for 2008–2012. In addition, EU and national indicative policy targets have been set for future substantial reductions of GHG emissions and for a tolerable projected rise in temperature. To reach such targets, further strategies and policies are needed to achieve more sustainable development in relevant sectors of society (energy, transport, industry, households, agriculture). In addition, strategies will increasingly be required for adapting to the impacts of climate change.

This report presents past trends in Europe's climate, its current state and possible future changes as well as the impacts of climate change on the European environment and society. The report is aimed at the general interested public and decision-makers, especially those who wish to understand which natural systems and societal sectors are most vulnerable to climate change and its impacts.

The main part of the report describes trends in and projections for 22 climate change state and impact indicators. The indicators cover eight categories: the atmosphere; the cryosphere (snow, ice and glaciers); the marine environment; terrestrial ecosystems and biodiversity; water; agriculture; the economy; and human health. The key findings for the 22 indicators are summarised in Table S.1. For almost all indicators, a clear trend exists and impacts are already being observed.

The assessment of climate change and its impacts is still subject to uncertainties and information gaps. The 22 indicators presented in this report illustrate only a small range of the potential consequences of climate change. Other areas are also sensitive to climate change, for instance forestry, water availability, or tourism. Some indicators for these areas have already been developed but have not been included in this report, due to insufficient data availability for Europe or uncertainty in identifying climate change as the cause of changes in these indicators. For some of these areas, information is already available and indicators can be presented in the near future. For others, better knowledge and understanding is needed about the exposure and sensitivity of these systems with respect to climate change.

There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities. Even if society substantially reduces its emissions of greenhouse gases over the coming decades, the climate system would continue to change over the coming centuries.

In order to prevent severe damage to the environment and society, and to ensure sustainable development even under changing climate conditions, adaptation strategies are required. Methods to design and implement adaptation strategies are presented in Chapter 4.

Key findings

1. Atmosphere and climate

Atmospheric indicators show that the concentration of carbon dioxide (CO_2) in the lower atmosphere has increased from its pre-industrial concentration of 280 ppm (parts per million) to its 2003 concentration of 375 ppm. This is the highest level in the last 500 000 years. At the same time, the climate in most parts of the world, including Europe, is warming. The global average temperature has increased by about 0.7 °C and the European average temperature by 0.95 °C in the last hundred years. It is estimated that temperatures will further increase by 1.4–5.8 °C globally and 2.0–6.3 °C in Europe by the year 2100. Precipitation patterns show a more varied picture. Recently, central and northern Europe have received more rain than in the past. In contrast, southern and southeastern Europe have become drier. These changes are projected to continue in the future. In addition, extreme weather events, such as droughts, heatwaves and floods, have increased while cold extremes (frost days) have decreased.

2. Glaciers, snow and ice

One of the most identifiable visual impacts of climate change in Europe can be observed in the cryosphere through the retreat of glaciers, snow cover and Arctic sea ice. Eight out of nine glaciated regions show a significant retreat; the only advancing glaciers are in Norway. From 1850 to 1980, glaciers in the European Alps lost approximately one third of their area and one half of their mass, a trend that is continuing. Even the advances of Norwegian glaciers can be attributed to climate change by increasing winter snowfall. The extent and duration of snow cover across Europe has decreased since 1960. In the Arctic regions of Europe, sea ice has been in decline.

3. Marine systems

The impacts of climate change on the marine environment are covered in this report by assessing the rise in sea level, the sea surface temperature and changes in the marine growing season and species composition. All of these indicators show clear trends. The marine system is mainly affected by an increase in sea surface temperature, especially in isolated basins like the Baltic Sea and the North Sea. This has resulted in an increase in phytoplankton biomass, a northward movement of indigenous zooplankton species by up to 1 000 km within the past few decades, and an increasing presence and number of warm-temperate species in the North Sea. It is estimated that the current rise in sea level of 0.8–3.0 mm/year will continue and intensify by 2.2 to 4.4 times the present values.

4. Terrestrial ecosystems and biodiversity

Terrestrial ecosystems are mainly affected with regard to plant phenology and distribution of plant and animal species. Climate change increased the length of the growing season by 10 days between 1962 and 1995. Northward movement of plant species (induced by a warmer climate) has probably increased species diversity in northwestern Europe, but biodiversity has declined in various other parts of Europe. The survival of different bird species wintering in Europe has increased over the past few decades and is likely to increase further because of the projected rise in winter temperature. The terrestrial carbon uptake of the vegetation has had a positive balance in Europe during the last 20 years. This has led to a removal of some of the atmospheric CO_2 concentration and thus partly mitigated climate change. However, this carbon

sequestration will most likely be reduced in future.

5. Water

Annual river discharge is an indicator for both fresh water availability in a river basin and low and high flow events. Annual river discharge has changed over the last decades across Europe. In some regions it has increased, in others, decreased. A part of these changes is attributable to observed changes in precipitation. Annual discharge is expected to decline strongly in southern and southeastern Europe, but increase in northern and northeastern Europe. Therefore, water availability will change over Europe in the coming decades.

6. Agriculture

Climate change affects agriculture in many ways. Increasing atmospheric CO_2 and rising temperatures may allow earlier sowing dates, enhance crop growth and increase potential crop yield. On the other hand, rising temperatures increase the crops' water demand. In combination with changing precipitation patterns, rising temperatures are expected to lead to increasing crop yields in areas with sufficient water supply, to decreasing yields in areas with hot and dry conditions, and to a northward shift of agriculture.

7. Economy

Extreme weather events cause damage to industry, infrastructure and private households. In Europe, a large number of all catastrophic events since 1980 are attributable to weather and climate extremes: floods, storms and droughts/ heatwaves. Economic losses resulting from weather and climate related events have increased significantly during the past 20 years. This is due to wealth increase and more frequent events. Climate change projections show an increasing likelihood of extreme weather events. Thus, a further increase in damage is very likely.

8. Human health

The impact of climate change on human health is evaluated with respect to heatwave-related health problems, tick-borne diseases and flooding. An increase in these impacts has been observed in recent decades and they are projected to escalate further due to projected rises in temperature.

Adaptation

Even if society substantially reduces its emissions of greenhouse gases over the coming decades, the climate system is projected to continue to change over the coming centuries. Therefore, society has to prepare for and adapt to the consequences of some inevitable climate change, in addition to mitigation measures. To prevent or limit severe damage to the environment, society and economies, adaptation strategies for affected systems are required at European, national, regional and local level. The report provides a general framework for adaptation strategies and a number of examples.

Table S.1 Summary of trends and projections of indicators included in this report

Indicators	Key messages
Atmosphere and climate	
Greenhouse gas concentrations	• Due to human activities, the concentration of carbon dioxide (CO_2), the main greenhouse gas, has increased by 34 % compared with pre-industrial levels, with an accelerated rise since 1950. Other greenhouse gas concentrations have also risen as a result of human activities. • The total rise in all greenhouse gases since the pre-industrial era amounts to 170 ppm CO_2-equivalent, with contributions of 61 % from CO_2, 19 % from methane, 13 % from CFCs and HCFCs, and 6 % from nitrous oxide. • If no climate-driven policy measures are implemented, a further increase to 650–1 215 ppm CO_2-equivalent is projected to occur by 2100. • To achieve the EU long-term objective of limiting global temperature rise to 2 °C, global emissions of greenhouse gases need to be reduced substantially from 1990 levels.
Global and European air temperature	• The global average temperature has increased by 0.7 ± 0.2 °C over the past 100 years. The 1990s were the warmest decade in the observational record; 1998 was the warmest year, followed by 2002 and 2003. • Europe has warmed more than the global average, with a 0.95 °C increase since 1900. Temperatures in winter have increased more than in summer. The warming has been greatest in northwest Russia and the Iberian Peninsula. • The rate of global warming has increased to 0.17 ± 0.05 °C per decade, a value probably exceeding any 100-year rate of warming during the past 1 000 years. The indicative target of no more than 0.1–0.2 °C per decade has already been exceeded or will be exceeded within the next few decades. • From 1990 to 2100, the global average temperature is projected to increase by 1.4–5.8 °C and 2.0–6.3 °C for Europe (without policy measures). The 'sustainable' EU target of limiting global temperature increase to no more than 2.0 °C above pre-industrial levels is likely to be exceeded around 2050.
European precipitation	• Annual precipitation trends in Europe for the period 1900–2000 show a contrasting picture between northern Europe (10–40 % wetter) and southern Europe (up to 20 % drier). Changes have been greatest in winter in most parts of Europe. • Projections for Europe show a 1–2 % increase per decade in annual precipitation in northern Europe and an up to 1 % per decade decrease in southern Europe (in summer, decreases of 5 % per decade may occur). The reduction in southern Europe is expected to have severe effects, e.g. more frequent droughts, with considerable impacts on agriculture and water resources.
Temperature and precipitation extremes	• In the past 100 years the number of cold and frost days has decreased in most parts of Europe, whereas the number of days with temperatures above 25 °C (summer days) and of heatwaves has increased. • The frequency of very wet days significantly decreased in recent decades in many places in southern Europe, but increased in mid and northern Europe. • Cold winters are projected to disappear almost entirely by 2080 and hot summers are projected to become much more frequent. • It is likely that, by 2080, droughts as well as intense precipitation events will become more frequent.
Glaciers, snow and ice	
Glaciers	• Glaciers in eight out of the nine glacier European regions are in retreat, which is consistent with the global trend. • From 1850 to 1980, glaciers in the European Alps lost approximately one third of their area and one half of their mass. Since 1980, another 20–30 % of the remaining ice has been lost. The hot dry summer of 2003 led to a loss of 10 % of the remaining glacier mass in the Alps. • Current glacier retreat in the Alps is reaching levels exceeding those of the past 5 000 years. • It is very likely that the glacier retreat will continue. By 2050, about 75 % of the glaciers in the Swiss Alps are likely to have disappeared.

Table S.1 Summary of trends and projections of indicators included in this report (cont.)

Snow cover	• The northern hemisphere's annual snow cover extent has decreased by about 10 % since 1966. • The snow cover period in the northern hemisphere land areas between 45 °N and 75 °N shortened by an average rate of 8.8 days per decade between 1971 and 1994. • Northern hemisphere snow cover extent is projected to decrease further during the twenty-first century.
Arctic sea ice	• The total area of Arctic sea ice has shrunk by more than 7 % from 1978 to 2003. • Ice thickness decreased by about 40 % on average from the period 1958–1976 to the period 1993–1997, with large regional variability. • The duration of the summer melt season over a large proportion of the perennial Arctic sea ice increased by 5.3 days (8 %) per decade from 1979 to 1996. • Projections show a predominantly ice free Arctic Ocean in summer by 2100.
Marine systems	
Rise in sea level	• Sea levels around Europe increased by between 0.8 mm/year (Brest and Newlyn) and 3.0 mm/year (Narvik) in the past century. • The projected rate of sea level rise between 1990 and 2100 is 2.2 to 4.4 times higher than the rate in the twentieth century, and sea level is projected to continue to rise for centuries.
Sea surface temperature	• Since the late nineteenth century, the global average sea surface temperature has increased by 0.6 ± 0.1 °C, consistent with the increase in global air temperature. • Global ocean heat content has increased significantly since the late 1950s. More than half of the increase in heat content has occurred in the upper 300 metres of the ocean. • No European sea shows a significant cooling; the Baltic and North Seas and the western Mediterranean show a slight warming of about 0.5 °C over the past 15 years. • It is very likely that the oceans will warm less than the land; by 2100, global sea surface temperature is projected to increase by 1.1–4.6 °C from 1990 levels.
Marine growing season	• Increasing phytoplankton biomass and an extension of the seasonal growth period have been observed in the North Sea and the North Atlantic over the past decades. • In the 1990s, the seasonal development of decapods larvae (zooplankton) occurred much earlier (by 4–5 weeks), compared with the long-term mean.
Marine species composition	• Over the past 30 years there has been a northward shift of zooplankton species by up to 1 000 km and a major reorganisation of plankton ecosystems. • The presence and number of warm-temperate species have been increasing in the North Sea over the past decades.
Terrestrial ecosystems and biodiversity	
Plant species composition	• Climate change over the past three decades has resulted in decreases in populations of plant species in southern and northern Europe. • Plant species diversity has increased in northwestern Europe due to a northward movement of southern thermophilic species, whereas the effect on cold tolerant species is still limited. • Projections predict a further northward movement of many plant species. By 2050 species distribution is projected to become substantially affected in many parts of Europe. • Globally a large number of species might become extinct under future climate change. Due to non-climate related factors, such as the fragmentation of habitats, extinction rates are likely to increase. These factors will limit the migration and adaptation capabilities needed by species to respond to climate change.

Table S.1 Summary of trends and projections of indicators included in this report (cont.)

Plant species distribution in mountain regions	• Endemic mountain plant species are threatened by the upward migration of more competitive sub-alpine shrubs and tree species, to some extent because of climate change. • In the Alps, upward migration has led to an increase in plant species richness in 21 out of 30 summits, whereas it has decreased or remained stable in the other summits. • Projected changes in European annual average temperature are outside the tolerance range of many mountain species. These species are projected to be replaced by more competitive shrub and tree species, leading to considerable loss of endemic species in mountain regions.
Terrestrial carbon uptake	• In the period 1990–1998 the European terrestrial biosphere was a net sink for carbon and therefore partly offset increasing anthropogenic CO_2 emissions. • Carbon uptake in Europe can be increased by (re-)planting forests and other land management measures. The additional potential storage capacity for the EU in forestry and agriculture is estimated to be relatively small, compared with the agreed targets in the Kyoto Protocol. • The projected increase in average temperature is likely to reduce the potential amount of carbon that can be sequestrated in the European terrestrial biosphere in the future.
Plant phenology and growing season	• The average annual growing season in Europe lengthened by about 10 days between 1962 and 1995, and is projected to increse further in the future. • Greenness (a measure of plant productivity) of vegetation increased by 12 %, an indicator of enhanced plant growth. • The positive effects of temperature increase on vegetation growth (i.e. a longer growing season) are projected to be counteracted by an increased risk of water shortage in mid and especially southern Europe which would adversely affect vegetation.
Bird survival	• The survival rate of different bird species wintering in Europe has increased over the past few decades. • The survival rate of most bird species is likely to improve further because of the projected rise in winter temperature. • Nevertheless, it is not yet possible to determine what impact this increasing survival will have on bird populations.
Water	
Annual river discharge	• Annual river discharge has changed over the past few decades across Europe. In some regions, including eastern Europe, it has increased, while it has decreased in others, including southern Europe. Some of these changes can be attributed to observed changes in precipitation. • The combined effect of projected changes in precipitation and temperature will in most cases amplify the changes in annual river discharge. • Annual discharge is projected to decline strongly in southern and southeastern Europe, but to increase in almost all parts of northern and northeastern Europe, with consequences for water availability.
Agriculture	
Crop yield	• The yields per hectare of all cash crops have continuously increased in Europe in the past 40 years due to technological progress, while climate change has had a minor influence. • Agriculture in most parts of Europe, particularly in mid and northern Europe, is expected to potentially benefit from increasing CO_2 concentrations and rising temperatures. • The cultivated area could be expanded northwards. • In some parts of southern Europe, agriculture will be threatened by climate change due to increased water stress. • During the heatwave in 2003, many southern European countries suffered drops in yield of up to 30 %, while some northern European countries profited from higher temperatures and lower rainfall. • Bad harvests could become more common due to an increase in the frequency of extreme weather events (droughts, floods, storms, hail) and pests and diseases.

Table S.1 Summary of trends and projections of indicators included in this report (cont.)

Economy	
Economic losses	• In Europe, 64 % of all catastrophic events since 1980 are directly attributable to weather and climate extremes: floods, storms and droughts/ heatwaves. 79 % of economic losses caused by catastrophic events result from these weather and climate related events. • Economic losses resulting from weather and climate related events have increased significantly during the past 20 years, from an annual average of less than USD 5 billion to about USD 11 billion. This is due to wealth increase and more frequent events. Four out of the five years with the largest economic losses in this period have occurred since 1997. • The average number of annual disastrous weather and climate related events in Europe doubled over the 1990s compared with the previous decade, while non-climatic events such as earthquakes remained stable. • Climate change projections show an increasing likelihood of extreme weather events. Thus, an escalation in damage caused is likely.
Human health	
Heatwaves	• More than 20 000 excess deaths attributable to heat, particularly among the aged population, occurred in western and southern Europe during the summer of 2003. • Heatwaves are projected to become more frequent and more intense during the twenty-first century and hence the number of excess deaths due to heat is projected to increase in the future. On the other hand, fewer cold spells will likely reduce the number of excess deaths in winter.
Flooding	• Between 1975 and 2001, 238 flood events were recorded in Europe. Over this period the annual number of flood events clearly increased. • The number of people affected by floods rose significantly, with adverse physical and psychological human health consequences. • Fatal casualties caused per flood event decreased significantly, likely due to improved warning and rescue measures. • Climate change is likely to increase the frequency of extreme flood events in Europe, in particular the frequency of flash floods, which have the highest risk of fatality.
Tick-borne diseases	• Tick-borne encephalitis cases increased in the Baltic region and central Europe between 1980 and 1995, and have remained high. Ticks can transmit a variety of diseases, such as tick-borne encephalitis (TBE) and Lyme disease (in Europe called Lyme borreliosis). • It is not clear how many of the 85 000 cases of Lyme borreliosis reported annually in Europe are due to the temperature increase over the past decades.