COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 29.6.2007
SEC(2007) 849

COMMISSION STAFF WORKING DOCUMENT

Accompanying the

GREEN PAPER FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Adapting to climate change in Europe – options for EU action

{COM(2007)354 final}

TABLE OF CONTENTS

Note: all figures and maps in this paper are to be printed in colour

COMMISSION STAFF WORKING DOCUMENT

Annex accompanying the

GREEN PAPER FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

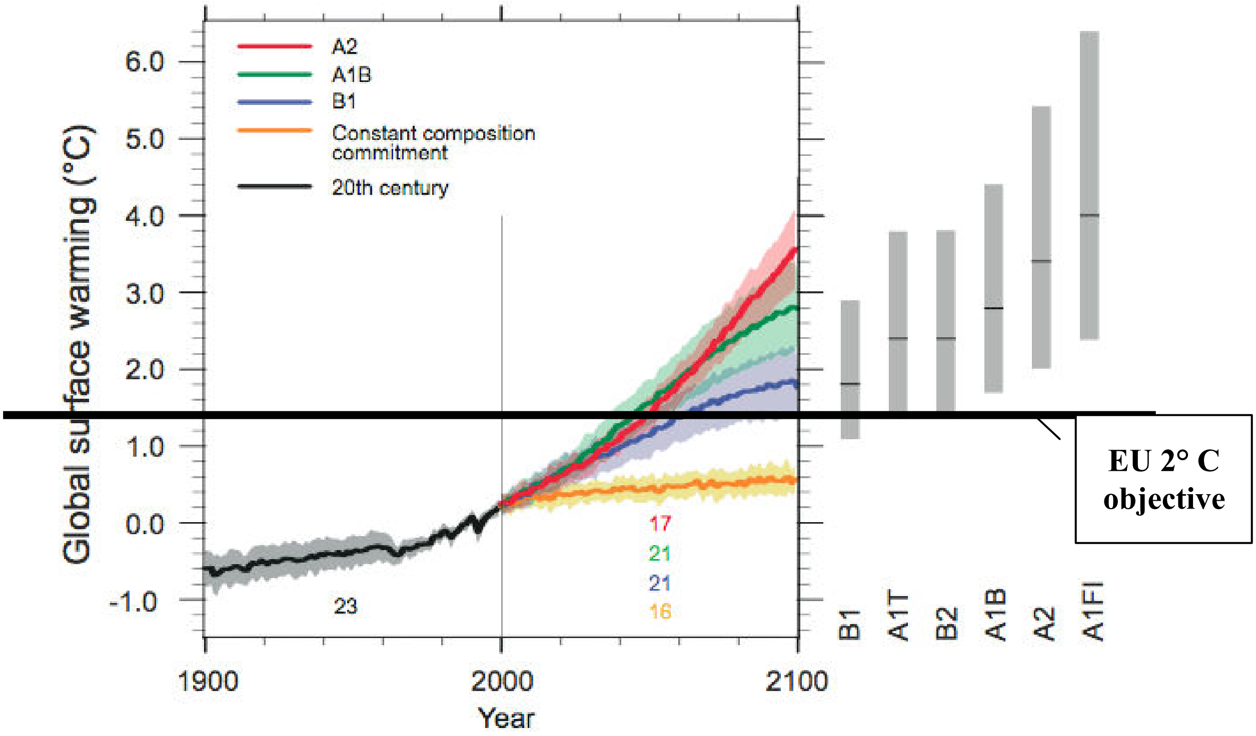
Adapting to climate change in Europe – options for EU action

{COM(2007)354 final}

Text with EEA relevance

1. GLOBAL WARMING BY THE END OF THE CENTURY

Figure 4: Best estimates of global warming according to six socio-economic emissions scenarios.[1,2]



---

1 Information on IPCC socio-economic emissions scenarios (SRES) at: http://www.ipcc.ch/pub/sres-e.pdf

2 Above 1980-1999 levels. To express the change relative to the period 1850 -1899, IPCC WG II adds 0.5°C. Therefore the EU's 2°C objective, which is above pre-industrial temperatures, is put at 1.5°C on this figure. Source: IPCC WG1 Report, February 2007

2. REASONS FOR GLOBAL CONCERN

Over the last three decades, climate change has already had a marked influence on many physical and biological systems. Its effects are already observable and significant changes in the natural environment will continue to take place, affecting all regions of the world. Key impacts as a function of global average temperature change are shown in Figure 5.

Water

The negative impacts of climate change on water resources and freshwater ecosystems will outweigh the positive in all continents. Areas in which runoff is projected to decline are likely to face a reduction in the value of the services provided by water resources. The number of drought-affected areas is likely to increase. The beneficial impacts of increased annual runoff in other areas are likely to be offset in some cases by the negative effects of increasingly variable precipitation and seasonal runoff that will disrupt water supplies, affect water quality and increase the risk of floods (see Figure 6).

Climate change will further reduce access to safe drinking water. Glacier melt water currently supplies water to over a billion people; once it disappears, populations will be under pressure and are likely to migrate to other regions of the world, causing local or even global upheaval and insecurity.

Ecosystems and biodiversity

The increases in global average temperature in excess of 1.5–2.5°C[3] – as used by the IPCC Working Group II (WG II) - will cause major changes to the structure and function of ecosystems, interactions between species, and the geographical ranges of species, with predominantly negative consequences for ecosystem goods and services, such as water and food. Many regions will experience biome-level changes: areas that presently feature rainforest, tundra or desert may no longer have the same type of vegetation by 2100. For many species the 'climate space' within which they thrive will move faster than the rate at which they can adapt. Climate change is likely to become the top threat to biodiversity for many, if not most, ecosystems.

For example, a 1-3°C temperature rise could be sufficient to cause more frequent bleaching and widespread mortality of coral reefs worldwide. The increasing acidity of oceans is affecting plankton populations, the foundation of oceanic food webs. Approximately 20–30 % of plant and animal species assessed so far are likely to be at greater risk of extinction if increases in global average temperature exceed 1.5–2.5°C.

[3] Above 1980-1999 levels. To express the change relative to the period 1850 -1899, IPCC WG II adds 0.5 degrees C

Figure 5: Key impacts as a function of increasing global average temperature.

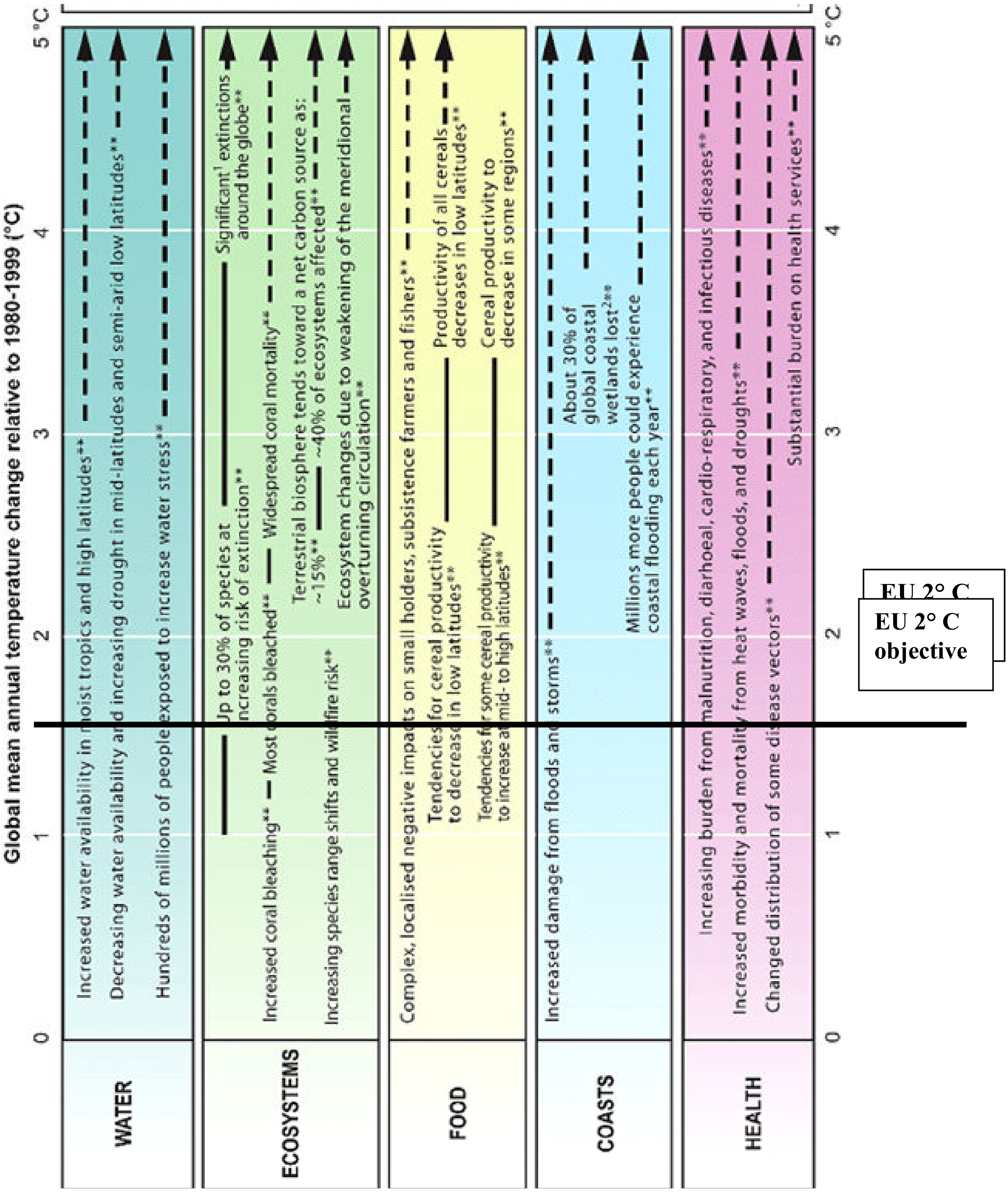
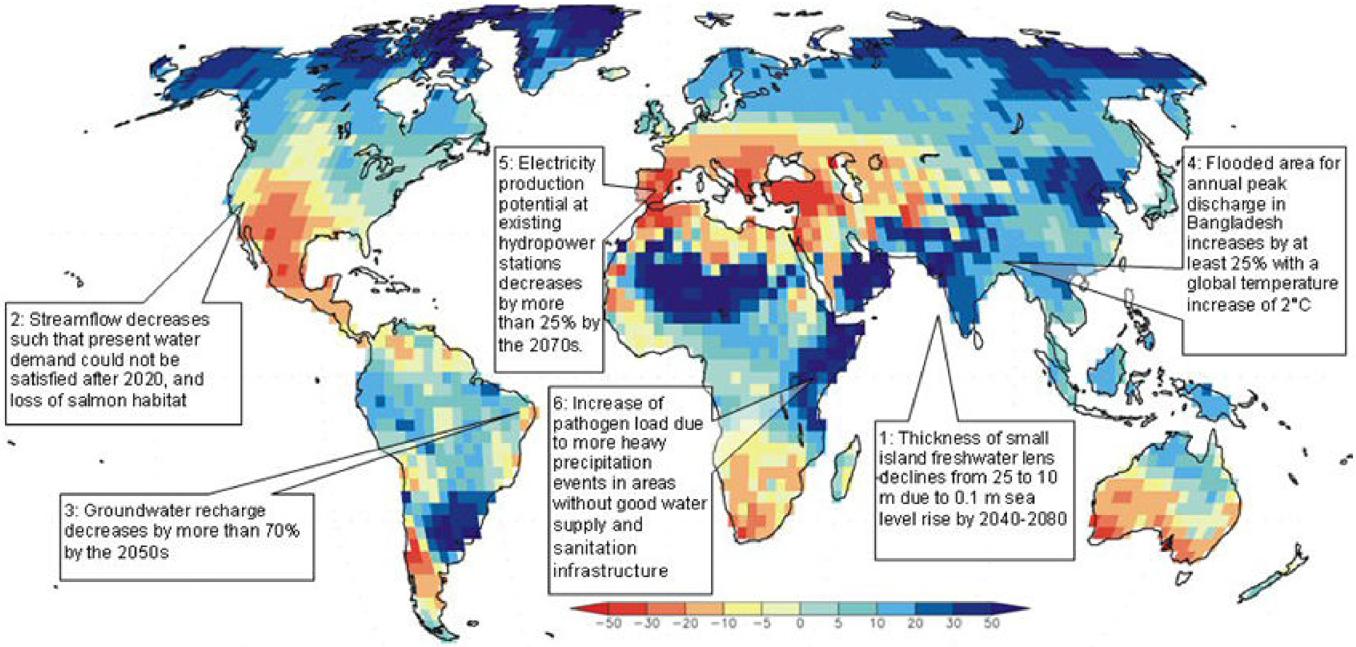


Figure 6: Future climate change impacts on water runoff.[4] (Blue denotes relative increase in runoff, red denotes relative decrease in runoff, in percentages).



Food

Even small amounts of global warming will reduce crop yields in most tropical regions. Climate change is expected to increase the risk of famine; the additional number of people at risk could rise to several hundred millions. Smallholders and subsistence farmers, herders, and small-scale fishermen will be particularly affected. The negative effects on agricultural yields will be exacerbated by more frequent extreme weather events.

Coasts

Globally, the sea level has already risen by about 17cm during the twentieth century and without abatement a further rise of about 20-60cm is expected by the end of this century. But there is also the possibility in the future of rapid dynamic changes in ice flows, which are not included in these figures. Such processes could increase the vulnerability of Greenland and Antarctica ice-sheets to warming and thus cause additional sea-level rise.

4 Mean change of annual runoff in percentage between present (1981-2000) and 2081-2100 (IPPC SRES A1B emissions scenario). Source: IPCC 4AR, 2007

Sea-level rise will threaten the Nile delta, the Ganges/Brahmaputra delta and the Mekong delta and displace more than 1 million people in each of them by 2050. The estimated costs of adaptation to sea-level rise are estimated at 10% of national GDP for some African countries.

Health

Climate-sensitive diseases are among the most deadly worldwide. Diarrhoea, malaria and protein-energy malnutrition alone caused more than 3.3 million deaths globally in 2002, with 29% of these deaths occurring in the region of Africa. Climate change will only make matters worse, for example by altering the geographical range and seasonality of certain vector-borne infections such as malaria, which is transmitted through mosquitoes, or extending the annual peaks of summertime food-borne infections (e.g. salmonellosis).

Dramatic short-term fluctuations in weather can cause serious health problems and premature deaths, e.g. heat stress or hypothermia, or heart and respiratory diseases. In cities, stagnant weather conditions can trap both warm air and air pollutants, causing episodes of smog that have significant health impacts. Abnormally high temperatures in Europe, such as the 2003 summer heat wave, have resulted in more than 70 000 extra deaths.[5] Other weather extremes, such as heavy rains, floods, and hurricanes, also have severe impacts on health.

Animal health is also likely to be affected through impacts on living conditions, and could bring an increase in transmissible infectious diseases. For example aquatic animal farming is highly sensitive to water temperature variations: oxygen availability, food intake, and the immunological responses of aquatic animals are all closely related to water temperature.

---

5 EC funded Canicule project.

3. EUROPE WILL NOT BE SPARED

Over the last few years the EU has financed several large research projects on regional climate modelling and impact assessment. In particular, some projects have produced high-resolution maps representing the projected changes in climate variables, such as mean temperature and precipitation, and projected impacts, e.g. agricultural yields, conditions for tourism, cold- and heat-related mortality and biodiversity losses.

Selected maps are presented in Figures 1 and 2 of the Green Paper and Figures 8 to 12 of this Annex.[6] These maps are very useful for policy-making and awareness-raising purposes. They illustrate what can be expected in Europe by the end of the century, according to the IPCC scenario whereby no action is taken to reduce GHG emissions, so that the global mean temperature increases by about 3.4°C.[7] Under this scenario, nearly all European regions are expected to be negatively affected and up to half of Europe's plant species could be vulnerable or threatened by 2080.

- **Southern and South-East Europe**: (Portugal, Spain, S. France, Italy, Slovenia, Greece, Malta, Cyprus, Bulgaria, S. Romania) The Iberian Peninsula will be most affected by droughts, with yearly rainfall dropping by up to 40% of current annual precipitation. Annual mean temperature increases throughout Southern Europe and the Black Sea region would be in the order of 4-5°C. Less precipitation and much warmer temperatures will lead to higher risks of water scarcity, droughts, heat waves, forest fires, biodiversity losses, soil and ecosystem degradation, and eventually desertification. More violent spells of rainfall will increase erosion, loss of organic matter from soil, and risks of flash floods. Less water will be available for hydropower and for cooling thermal power plants, particularly during hot summers. The risk of power disruptions will rise as the summer heat pushes up demand for air-conditioning. Agricultural yields could drop sharply as temperatures rise and water becomes scarcer. Yield losses could range from 10 to 30% in many large areas of the South. Tourist resorts could become too hot for summer holidays and tourism may shift to spring and autumn. Heat-related deaths could kill thousands of people prematurely every year: 30-55 additional deaths yearly per 100 000 persons in vast areas of Southern Europe.

- **Western and Atlantic Europe** (Benelux, W. and N. France, N. Germany, UK and Ireland, Denmark): Extreme events such as violent storms and floods are projected to become more frequent due to warmer temperatures and higher volumes and intensities of precipitation, in particular in winter. Annual mean temperature increases will be 2.5-3.5°C, except for the UK and Ireland with 2-3°C. Summers are likely to be dryer and hotter. Densely populated cities, towns and settlements, and major infrastructure such as harbours and industries, historically located near rivers and waterways, could suffer most from river floods. There could be 15-30 more heat-related deaths and 10-20 less cold-related deaths per 100 000 persons.

---

6 These maps are all based on IPCC SRES scenario A2. Results are on impacts from the JRC-funded PESETA study (http://peseta.jrc.es) and the EC co-funded ATEAM project on biodiversity. Maps with projections of future changes in temperature and precipitation are based on DMI/PRUDENCE data (http://prudence.dmi.dk), and processed by JRC within the PESETA study. Changes are projected for 2071-2100 relative to 1961-1990. All maps have been processed by the European Commission's Joint Research Centre

7 3.4°C is the median of the best estimated range of temperature increases under the IPCC SRES A2 scenario (IPCC 4AR, WG I), see figure 4.

- **Central Europe** (Poland, Czech Republic, Slovakia, Hungary, N. Romania, S. and E. Germany, E. Austria): The annual mean temperature increase is projected to be in the order of 3-4°C except for the more continental regions of Central Europe and the Black Sea Region, like Romania, where temperatures could increase by as much as 4-4.5°C. Annual mean precipitation should increase by up to 10% in most regions. Precipitation would increase mainly in winter, while there would be reductions in summer precipitation in several areas. The increased risks of floods could threaten homes and infrastructure. Agriculture is expected to suffer from soil erosion, loss of soil organic matter, migration of pests and diseases, summer droughts and high temperatures, but could benefit from longer growing seasons in some regions. Cold-related mortality could decrease, especially in the more Eastern countries, leading to 25-30 fewer deaths per 100 000 persons in Poland and Romania while heat-related mortality could increase in central Europe by 15-30.

- **Northern Europe** (Norway, Sweden, Finland, Baltic States): Conditions will be similar to Western Europe but with more change in temperatures and precipitation. Temperatures are projected to increase by as much as 3-4.5°C with significant increases in yearly precipitation: up to 40%. Therefore energy generation capacity by hydropower could increase. Winters are projected to be wetter and risks for winter floods could increase. There is potential for cultivating new areas and crops due to much longer growing seasons. Yields could increase by 10-30%, if warming is limited to 1-3°C, but agriculture could suffer from new pests and diseases. The species composition and structure of forests could be much affected by higher temperatures, intense precipitation and severe storms. With this warmer climate the Baltic Sea could be increasingly affected by eutrophication (algal bloom) and pollution. Cold-related death could decrease, mostly in Finland and the Baltic states: 25-50 fewer deaths per 100 000 persons each year.

- **Arctic region**: Temperature increases are likely to be higher in the Arctic than anywhere else on Earth, resulting in accelerated melting of ocean and land ice and thawing of permafrost. In the Arctic average temperatures have increased at almost twice the global average rate over the past 100 years. Comparing the 1990s to the 2090s, annual average temperatures are expected to rise by 3-5°C over land and up to 7°C over sea with winter temperatures rising 7-10°C over the oceans.[8] Increased flows of melt water runoff into the Northern Atlantic Ocean could gradual change the ocean's salt concentrations, and could even affect the thermo-haline circulation. The extent of sea ice has shrunk by an average of 2.7% per decade since 1978 and could break up as soon as 2050. This could lead to the extinction of species, e.g. the polar bear. Temperatures at the top of the permafrost layer have increased since the 1980s by up to 3°C. The accelerated thawing of permafrost not only disrupts vegetation and essential infrastructure, such as roads and pipelines, but could eventually release into the atmosphere vast amounts of methane, a powerful greenhouse gas that has been contained in the Earth's frozen surface layer for thousands of years. Releases of such volumes could significantly increase the risks of further accelerated, unpredictable and dangerous climate change. The maximum permafrost area has already shrunk by 7% since 1900.

- **Marine areas**: The average temperature of the global ocean has increased to depths of at least 3000m affecting the distribution patterns and abundance of species from plankton to top predators. This could cause major changes to the structure and function of ecosystems, interactions between species, and the geographical ranges of species. Specifically this could

---

8 IPCC SRES scenario B2. Data from ACIA Arctic Climate Impact Assessment

mean, for example, that cold water species like cod move northward as the waters warm irreversibly changing the overall species composition of the marine ecosystem, thus seriously affecting biodiversity and the fisheries sector. Pollution and algal bloom will be exacerbated by a warming climate. Oceans will absorb more carbon dioxide from the atmosphere and slowly become more acidic. This acidification will impact negatively on calcifying organisms such as those that form coral reefs, and on some phytoplankton species; it will also pose problems for shellfish production.

- **Coastal zones**: A global sea-level rise of up to 80 cm compared to pre-industrial levels by 2100 will change the shape of coastlines through coastal erosion, and lead to coastal flooding and underground salt water intrusion. Low-lying areas and river deltas are most at risk. Pressures on natural and human systems on coasts will be high. Almost 50% of the European population lives in the 50 km coast strip; 85% of the Dutch and Belgian coast, and 50% of the German coast, has less than 5 m elevation. Figure 7 shows the flooded areas in Belgium, the Netherlands and south-east England for three different sea levels. Although there is an increasing need for flood defence measures, e.g. dykes, not only are they expensive but they also threaten ecosystems. Alternative very costly options could include relocation of settlements and infrastructure. Major coastal cities, industrial areas and ports are at risk of a combination of sea-level rise and more frequent sea storm surges. The melting of Greenland and Antarctic ice sheets could have drastic impacts after the 21st century. Complete collapse of the Greenland ice sheet would cause a 7m sea level rise, a scenario which would wipe major cities off the map: Amsterdam, London, but also New York, Singapore, Shanghai, Mumbai, etc. Total disintegration of Antarctica's land ice would make the sea rise by about 70 m.

- **River basins and floodplains**: In Europe, floods are the costliest natural catastrophe. In 2002, the direct costs of flooding amounted to €13 billion. The cost of the 2003 drought can be estimated at €11.6 billion. By 2100, the total cost of flood damage could rise by as much as 40% for the upper Danube and 19% for the Meuse. Many of Europe's industrial and power generation plants are close to rivers. So there is the risk not only of environmental contamination from spills of harmful substances, but also of lost competitiveness through business interruption. More intense precipitation will influence the frequency and intensity of river floods, soil erosion, and water pollution, and cause changes to ecosystems. Basins with increased volume or intensity of precipitation and runoff are expected to face more nutrient losses and erosion, with negative impacts on aquatic ecosystems such as eutrophication and algal bloom.

- **Mountain regions**: Temperature increase is already twice the global average in the Alps (about 1.5°C). By 2050 we can expect an increase of 2° in autumn, winter and spring, and 3° in summer in the Swiss Alps. The thawing of snow and permafrost and the spectacular retreat of glaciers will reduce the "water tower" function of mountains and increase run-off. This will disturb river flows and increase the risk of floods in winter and spring and water scarcity in summer. Erosion, falling rocks and landslides could have an impact on tourism. In the Alps hydropower generation is expected to be affected by reduced water flows in summer, making this type of renewable energy less reliable, while hotter weather may make solar and photovoltaic energy more attractive. Power plants will have to cope with a shortage of cooling water, especially in summer. Species will see their habitats retreat to higher altitudes; once trapped on mountain tops many species will face extinction. There will be radical changes in tourism in the Alps. Glaciers in 8 out of the 9 glacier regions in Europe are retreating and by 2050 about 75% of glaciers in the Swiss Alps are expected to have disappeared. The steady decline of ice and snow cover will gradually reduce the possibility of skiing holidays. Ski-lifts at high altitudes are frequently anchored in frozen ground, which could start thawing, leading to high repair costs. Summer tourism could become more attractive, but is unlikely to compensate for the losses of the skiing industry. Much analysis and work is being done in the context of the Alpine convention.

PESETA Study

The main objective of the PESETA project (Projection of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis) is to contribute to a better understanding of the possible economic impacts induced by climate change in Europe over the 21st century.

The project is coordinated by the Joint Research Centre's Institute for Prospective Technological Studies (IPTS). PESETA largely benefits from DG Research projects that have developed models to project impacts of climate change (e.g. the DIVA model) and climate scenarios for Europe. PESETA uses the climate data provided by the PRUDENCE project (e.g. temperature, precipitation) together with the Rossby Center.

PESETA examines climate change impacts on the following sectors: coastal systems, energy demand, human health, agriculture, tourism, and river basin floods. This enables a comparison between them and therefore provides a notion of the relative severity of the damage inflicted. For each of these sectoral categories, a corresponding sectoral-based study is developed by the project partners.

The general approach for estimating the effects of climate change is to assess the physical impacts first and then to value them in monetary terms. Several maps representing the physical impacts in various sectors for the high-emission (A2) scenario in the 2071-2100 period are included in this Annex.

A key feature of the PESETA methodological framework is that all sectoral studies use common socio-economic and climate scenarios. In particular, two global socio-economic scenarios have been selected from the IPCC’s Special Report on Emissions Scenarios (SRES). In the A2 scenario, global greenhouse gas emissions are assumed to increase more significantly leading to approximately a tripling of average CO2 concentrations by the end of this century, compared to pre-industrial level. The medium-emission (B2) storyline results in approximately a doubling of the atmospheric CO2 concentration. This choice partly covers the range of uncertainty associated with the driving forces of global emissions.

Nevertheless, the scope of the PESETA assessment cannot capture the complete range of the many expected impacts of climate change. In particular, some relevant market impacts (e.g. forestry) and non-market impacts (e.g. ecosystems) are not considered. Furthermore, the effects of climatic extremes are not taken into account, though they can be crucial in some sectors (e.g. heat waves in the human health assessment).

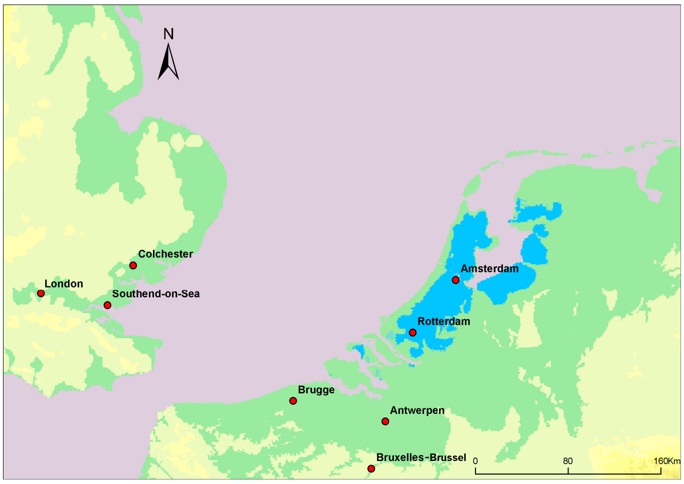
Despite these limitations, the PESETA project provides a valuable indication of the economic costs of climate change in Europe based on state-of-the-art physical impact assessment and high-resolution climate scenarios (daily, 50x50 km grids).

However, it must be noted that evaluating the "cost of inaction" in a very long-term time horizon is an extremely complex issue due to incomplete scientific methodologies and gaps in data. For this reason, it deals with many sources of uncertainty, including e.g. future climate, demographic change, economic development, and technological change. Consequently, the results of the project need to be interpreted with due care and attention.

The PESETA study is expected to be finished by the end of 2007. Further information on the project can be found at http://peseta.jrc.es.

Figure 7: Areas flooded (in blue) by sea level rise for three different sea levels, assuming the absence of dykes[9]

a) current sea level: 1990 level



b) 1 m sea level rise compared to 1990 level

c) 8 m sea level rise compared to 1990 level

[9] Marbaix, P. and J.P van Ypersele (ed.), 2004. Impacts des changements climatiques en Belgique. www.climate.be/impacts

Figure 8: Simulated change in the 100-year return level of river floods by the 2080s

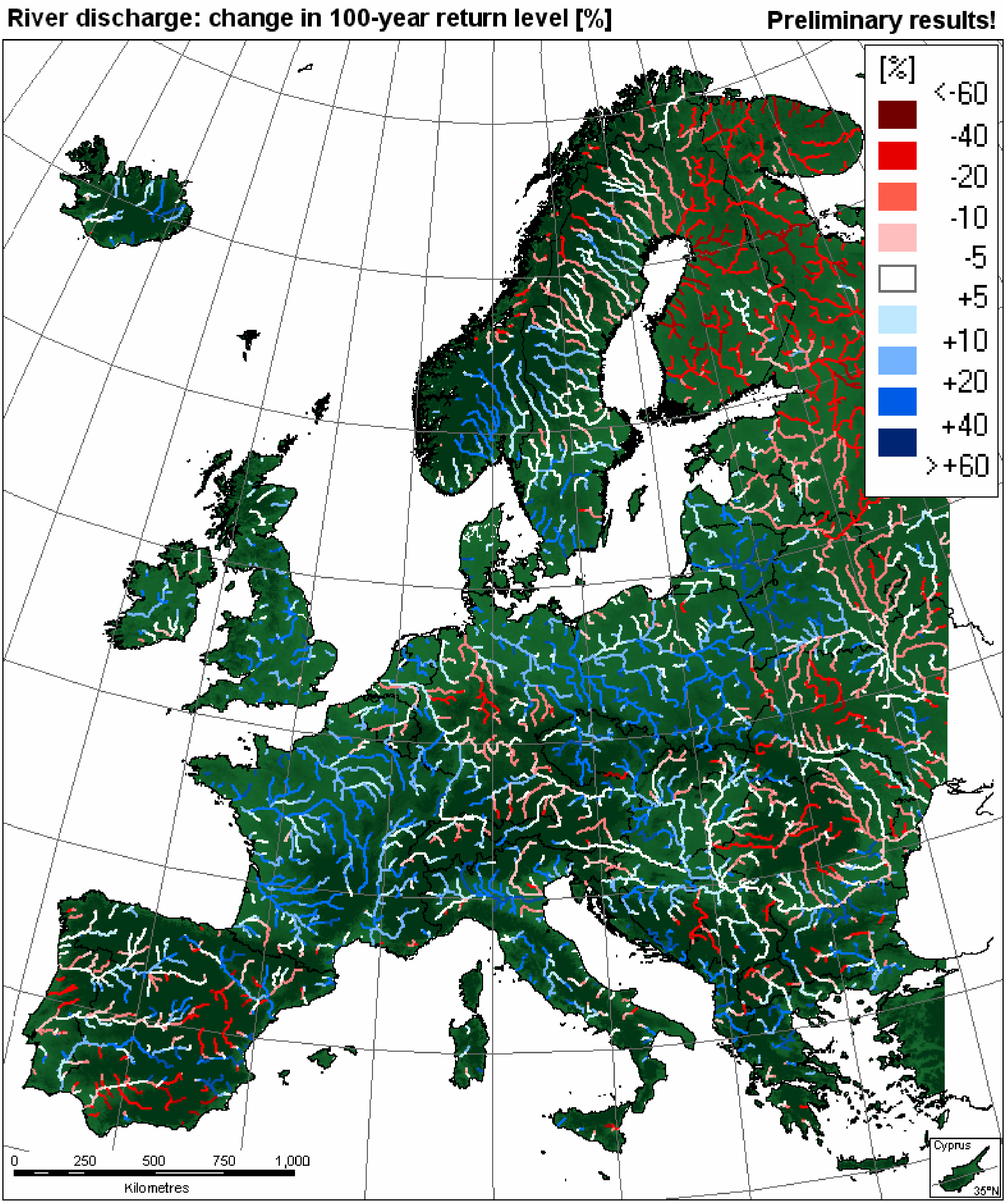
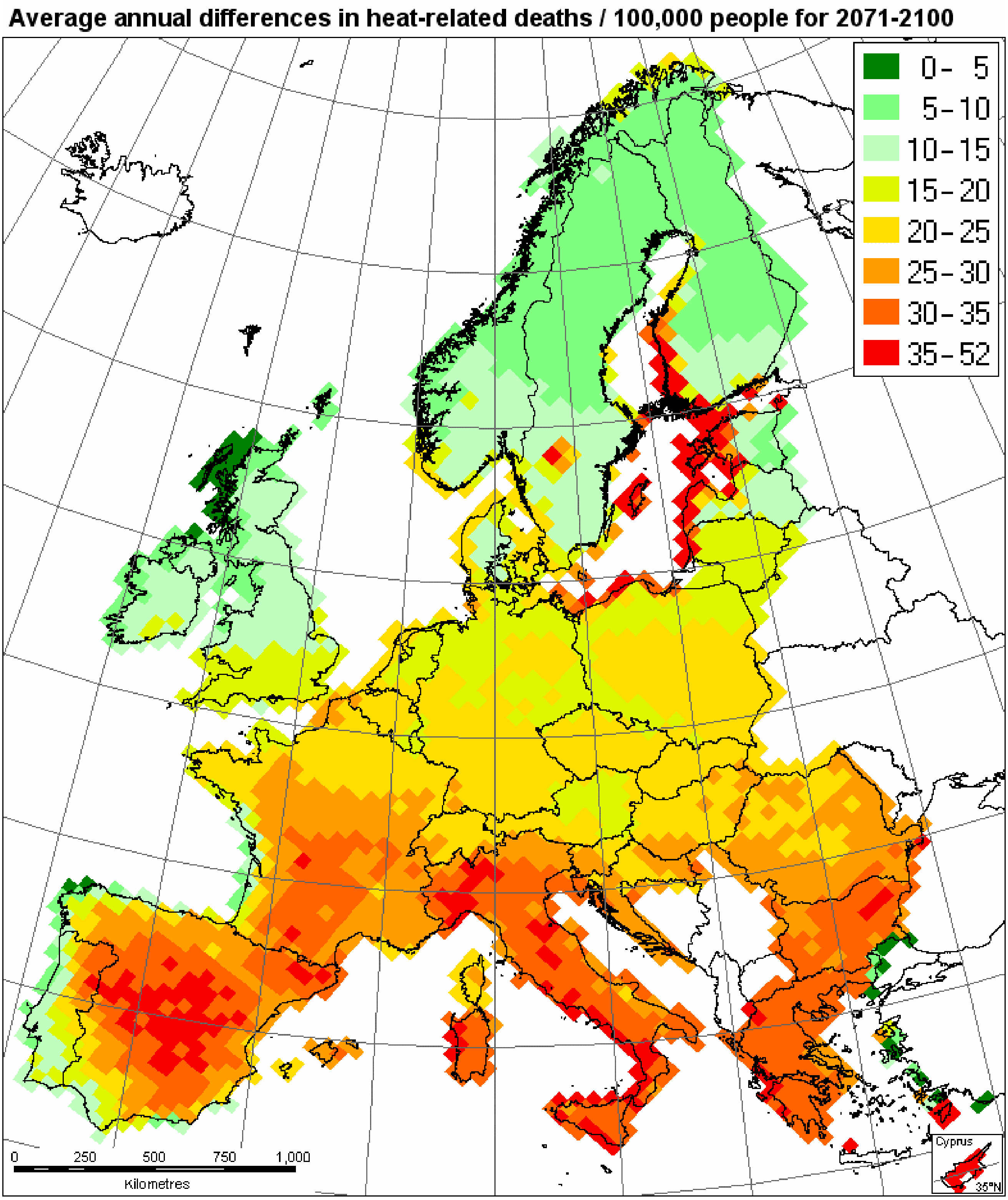
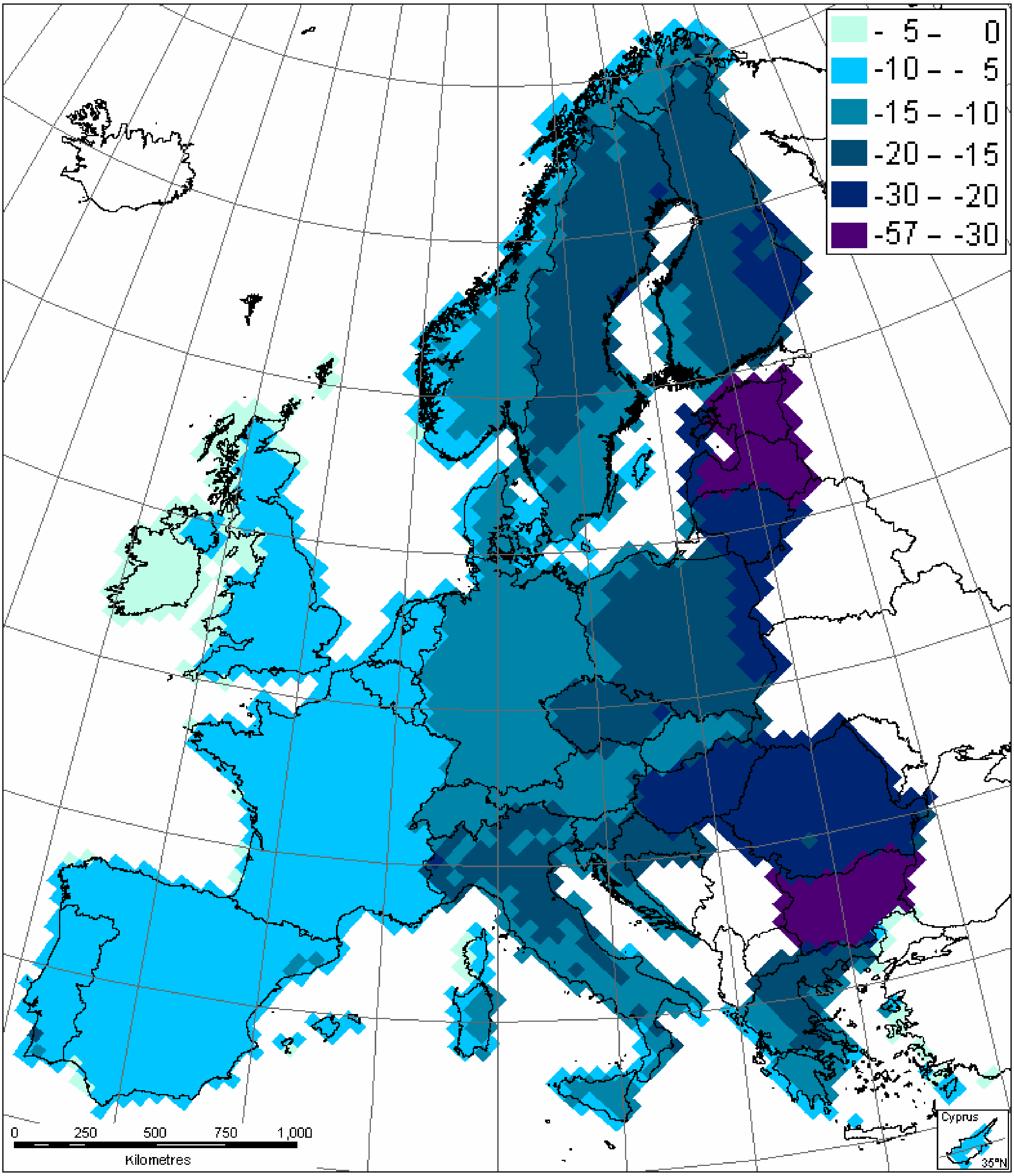


Figure 9: Simulated average annual differences in (a) heat-related and (b) cold-related death per 100 000 persons by the 2080s[10]



[10] Average annual differences in heat-related and cold-related deaths per 100 000 population, for 2071-2100 (SRES A2 scenario) compared to 1961-1990, using the HS1 climate data, and climate-dependent health functions (no acclimatisation).

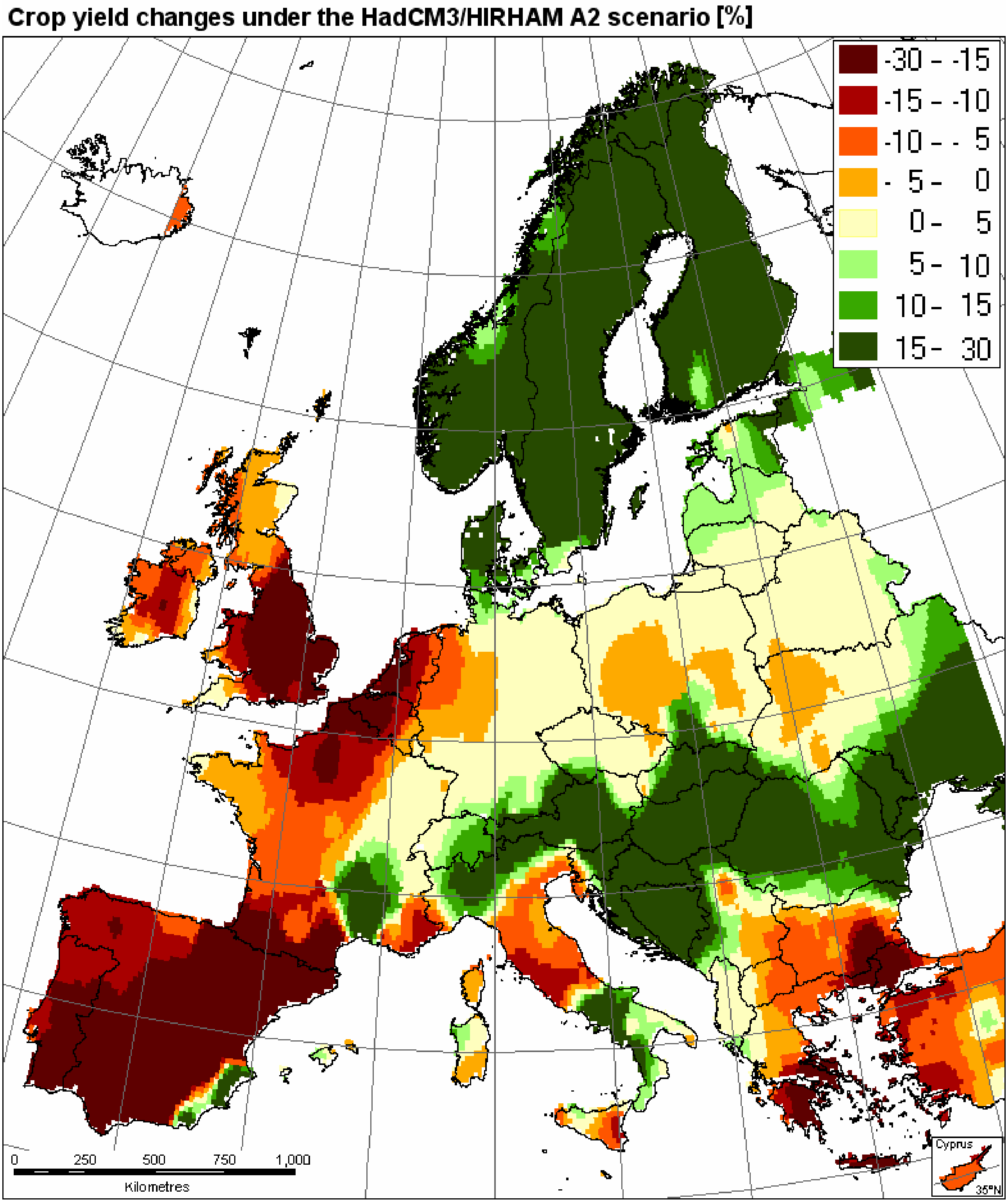
Average annual differences in cold-related deaths / 100,000 people for 2071-2100



EN

EN

Figure 10: Simulated crop yield changes by 2080s according to two different models - (a) HadCM3, (b) ECHAM4



Crop yield changes under the ECHAM4/ RCA3 A2 scenarios [%]

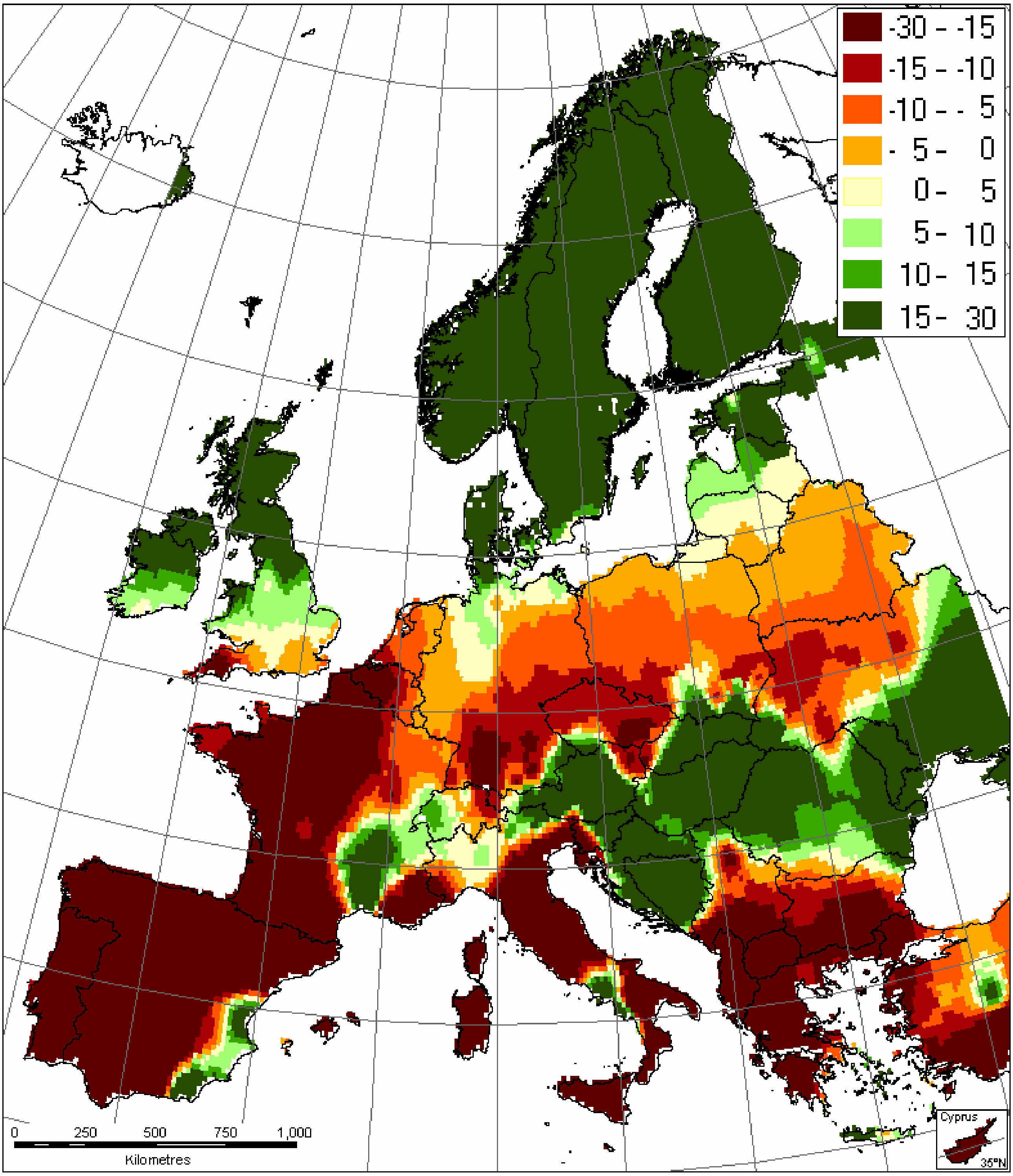


Figure 11: Simulated climate conditions for summer tourism in Europe by 2080s.

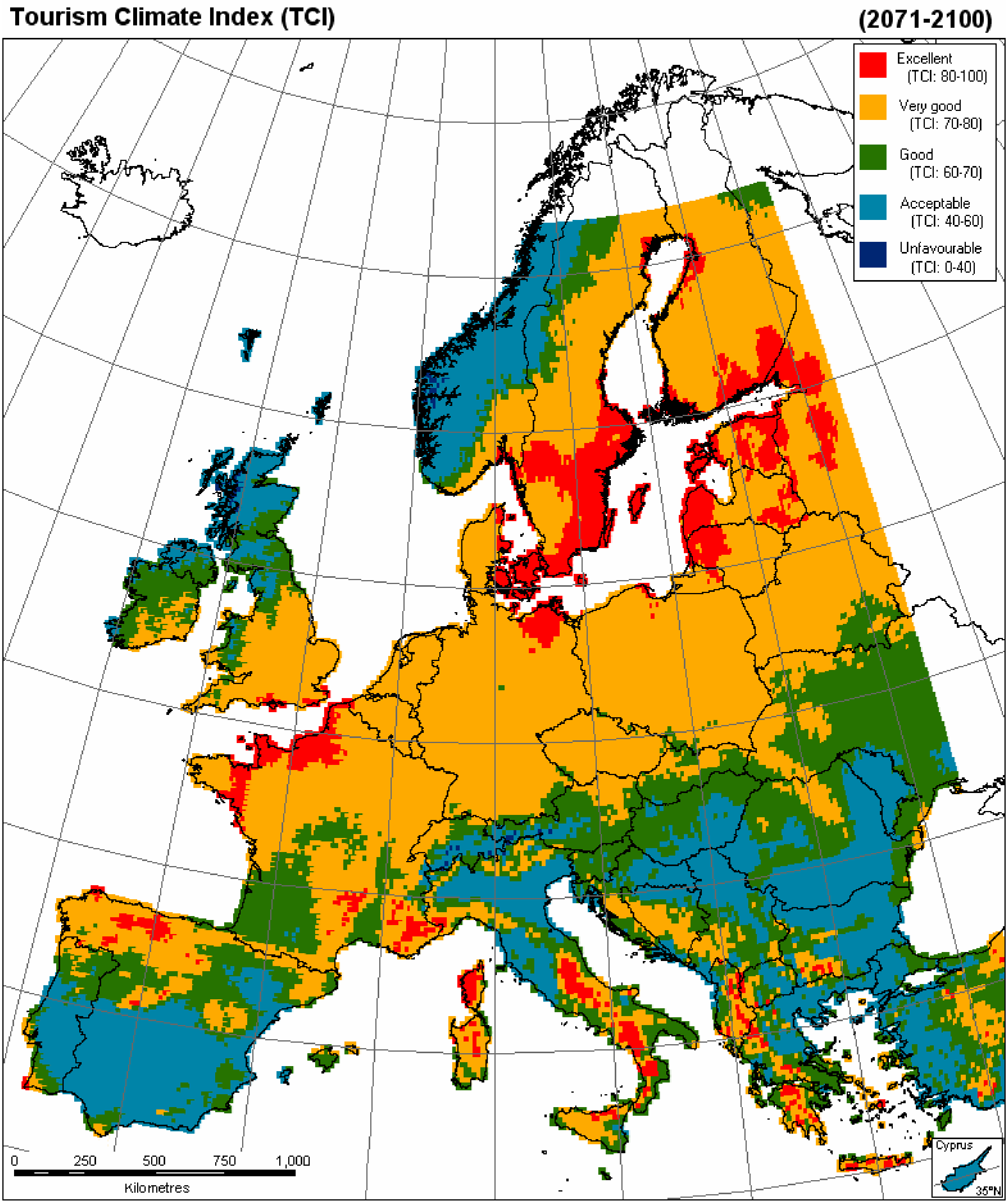
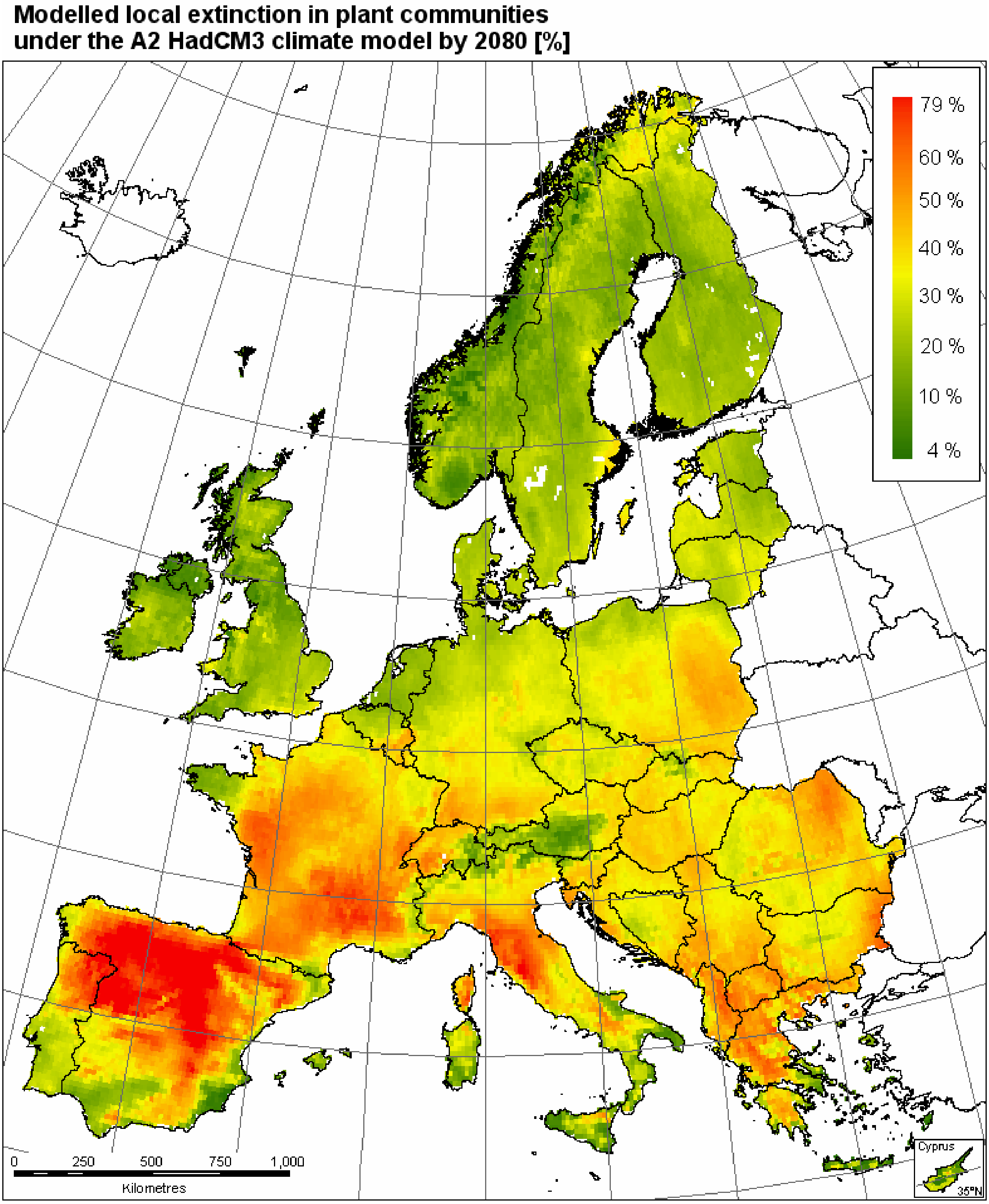
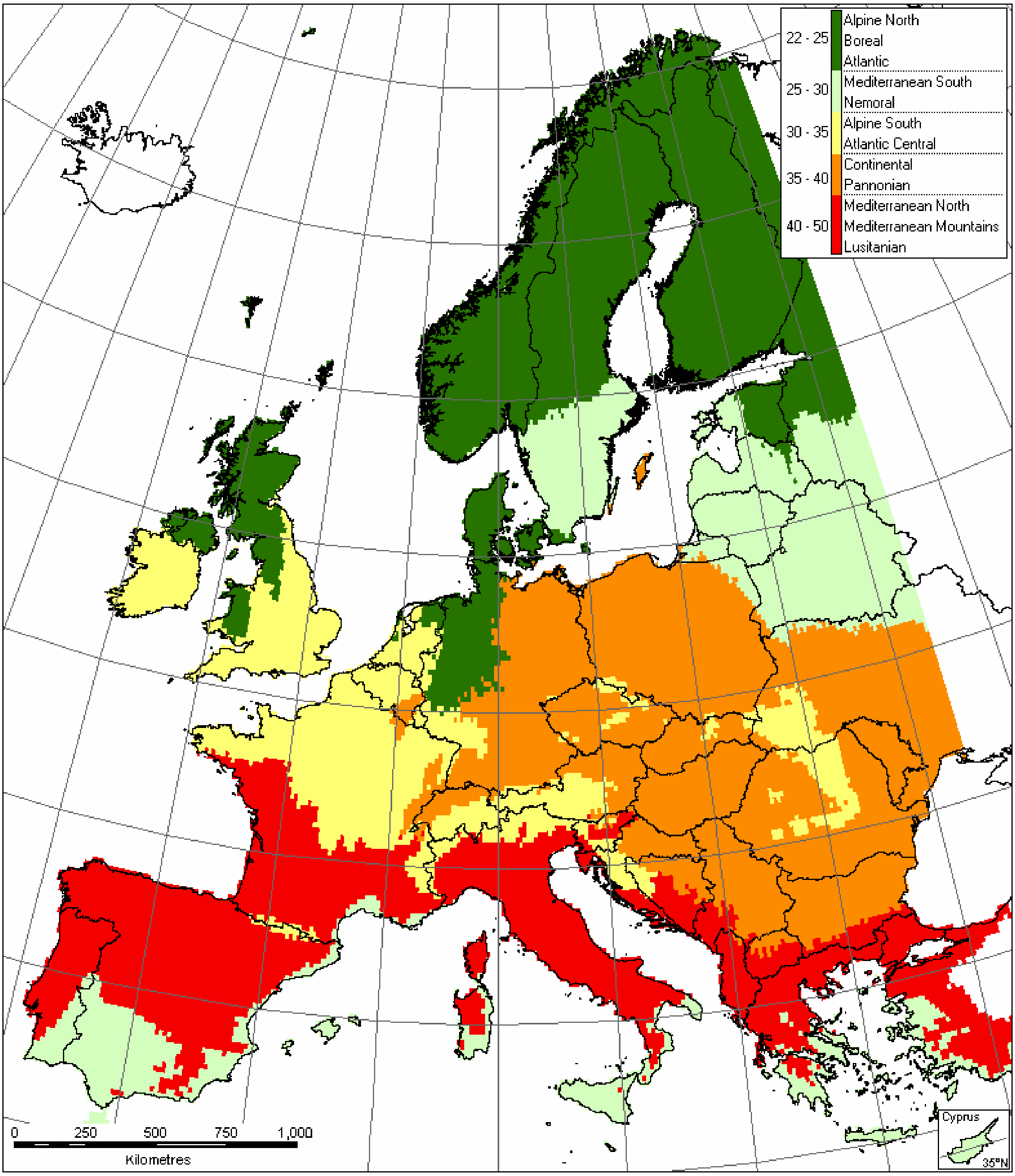


Figure 12: Simulated extinction of plants by 2080s - (a) local (b) averaged by bio-geographical region[11]



[11] Source: EC co-funded project ATEAM, Final Report, 2004

Local extinction in plant communities averaged by biogeographical regions under A2 HadCM3 by 2080 [%]



EN EN

4. MAIN ON-GOING RESEARCH PROJECTS ON CLIMATE CHANGE AND IMPACTS

Scientific results provide a basis for understanding the drivers and subsequent impacts of climate change, and for work on identifying cost-effective adaptation options. Several projects funded by the EU Framework Programmes have been instrumental in this context. For example, the ENSEMBLES project provided predictions of climate change in terms of both natural climate variability and human impact on climate, and the PRUDENCE project predicted impacts of future climate in different regions of Europe. Both projects made a substantial contribution to the recent IPCC 4th assessment report. A current large European research project, ADAM, assesses the costs and effectiveness of mitigation and adaptation policies for achieving a tolerable transition to a world with a global climate change of no more than 2ºC above pre-industrial levels. It will result in a portfolio of longer term strategy options.

Research results will also profit from dialogue and consultation with social actors. Climate change remains a key priority in the Seventh Research Framework Programme (FP7) 2007-2013. Integrated research addressing the functioning of the climate and earth system is needed in order to better understand its causes and future evolution, to determine current and future impacts, and to develop effective adaptation and mitigation measures. In particular, under FP7, research efforts at European level and beyond will be strengthened in order to:

- improve further our predictive capacity of the future evolution of the climate-earth system;
- improve downscaling of modelling techniques, and as such provide more accurate climate information at regional and local level;
- integrate the physical and socio-economic aspects of climate change in order to better quantify the impacts, and design better response strategies for Europe and beyond;
- assess climate-induced changes to the water cycle, extreme events, and human health;
- provide efficient adaptation strategies (especially for the most vulnerable countries and world regions), partly following the recommendations of the IPCC 4AR report.

The overall objectives for research on adaptation under FP7 are to provide the basis for strategic policy options in the context of international agreements, to develop methodologies where there is uncertainty in the prediction of future climate impacts, and develop and analyse tangible adaptation strategies.

Furthermore, the first call of FP7, published in December 2006, proposes to focus research progress on essential aspects such as the effectiveness of adaptation and mitigation measures related to changes in the water cycle and its extremes, the full cost of climate change impacts, how climate policies affect land-use and ecosystems, and dissemination of research results and public perception.

5. GLOSSARY

Adaptation - Actions taken to adjust natural ecosystems or human systems so they can cope with changing climate conditions, the aim being to reduce potential harm or exploit potential benefits. Examples of such actions include designing spatial plans and building codes to account of potential climate change and extreme weather events, building walls to protect houses from floods, switching to agricultural crops and forestry species that are better suited to a changing climate

Adaptation benefits - The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures. **Adaptation costs** - Costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs.

Adaptive capacity - The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Adverse effects of climate change – Changes in the physical and environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

Climate change - A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Climate system – The totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.

Climate change impact assessment - Analysis of the positive and negative consequences of climate changes on natural ecosystems, human systems and socio-economic activities, both with and without adaptation to such changes.

Downscaling – Improving the spatial resolution of climate change scenarios with the use of statistical models, reaching local climate change scenarios starting from projections in global or regional scale.

Ecosystem - The collection of components and processes that comprise, and govern the behavior of, some defined subset of the biosphere. All components of an ecosystem interact with each other. The introduction of new elements into an ecosystem tends to have a disruptive effect.

Ecosystem services (and goods and functions) – Services provided by natural systems (ecosystems), including production of food, fuel, fibre and medicines, regulation of water, air and climate, maintenance of soil fertility, cycling of nutrients. Precise monetary value of these services worldwide is difficult to define, but estimates suggest they are in the order of hundreds of billions of Euros per year. There services underpin EU growth, jobs and wellbeing and are vital to achievement of the Millennium Development Goals in developing countries.

Emissions – The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Extreme weather event - Meteorological conditions that are rare for a particular place and/or time, such as an intense storm or heat wave.

Global circulation model – The model of redistribution of heat energy on the Earth, by means of atmospheric air circulation and ocean currents, taking into account heat transfer from equator to the poles, the rotation of the planet, the tilt of its axis, and the unequal distribution of land masses between the hemispheres.

Greenhouse effect – The effect caused by absorption of the solar energy radiated by Earth due to the presence of greenhouse gases in the atmosphere. Absorption of this energy causes the warming of the atmosphere and its radiation down to the surface of the planet.

Greenhouse gases (GHG) - The atmospheric gases, both natural and man-made, that cause global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent, but very powerful greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Each gas has global warming potential, which is the combined effect of the time it remains in the atmosphere and its effectiveness in absorbing outgoing infrared radiation.

Greenhouses gases concentration – The amount of greenhouse gases in the atmosphere, generally measured in parts per million by volume (ppmv). The current concentration of CO_2, the most predominant greenhouse gas, is 381 ppmv and has increased by over 30% since before the industrial revolution (1750).

Mitigation - A human intervention to reduce the sources or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, using energy saving light bulbs, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere.

Resilience - The capacity of a natural or human system, community or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable structure and level of functioning. For human systems this is determined by the degree to which the system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Socio-economic scenarios – A set of scenarios developed by the IPCC that represent uncertainties in the demographic, socio-economic and technological development of the world. As these factors are the main drivers of GHG emissions, these scenarios are used to develop projections for climate change.

Sink - Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere. Forests and other vegetation are considered sinks because they remove carbon dioxide through photosynthesis.

Source – Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere.

Vulnerability - The degree to which a community, population, species, ecosystem, region, or agricultural system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.