WWF CLIMATE CHANGE CAMPAIGN

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SCENARIOS OF GLOBAL CLIMATE CHANGE IMPACTS

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BACKGROUND INFORMATION from WWF

Contents:

1. THE GLOBAL EMISSIONS SCENARIOS

The global scenarios investigate the impact that changing emissions of global warming gases over the coming century are projected to have on temperature, precipitation, sea-level rise. These are key factors affecting biodiversity - the richness of living species on Earth.

The scenarios focus on carbon dioxide (CO2) emissions, the global warming gas that alone accounts for about 60 per cent of the warming effect. The study investigated the impacts of four emission "pathways" over the next century. Assumptions about future emission levels were selected so as to span about 95 per cent of the range of emissions scenarios published in the current literature.

If no climate policies are implemented, carbon emissions are projected to increase by between 4 per cent and 320 per cent above current levels by 2100. The current 1999 atmospheric concentration of 370 parts of carbon dioxide per million parts of air (ppmv) could increase to nearly 550 ppmv by 2100 for the lowest emission scenario or to over 830 ppmv in the highest scenario. These compare with atmospheric concentrations before the industrial age of about 280 ppmv.

The four emissions scenarios were combined with low, medium and high levels of "climate sensitivity". (This is the level of warming resulting from a doubling in CO2 concentrations). The combination of 'low emissions + low climate sensitivity' through to 'high emissions + high climate sensitivity' produce a range of future global warming and sea-level rise curves that span perhaps 90 per cent of likely future climates.

2. SUMMARY OF MAIN FINDINGS FROM THE SCENARIOS

GLOBAL

- there is overwhelming evidence for the warming of the planet over the last 200 years, not only in climate observations but also in physical and biological indicators of change
- the world has warmed by 0.4 to 0.8 degree C since records began in 1856. The six warmest years have all occurred in the last decade
- 1998 was probably the warmest year of the millennium
- warming has been greater at night-time than during the day. (This favours insects, which are a major cause of the increased spread of infectious diseases such as malaria)
- over the next hundred years, the climate on Earth will likely become warmer than any that the human species has lived through
- compared to the average for 1961-1990, global temperature increase could be between 0.6 and 1.4 degree C by the 2020s, between 0.9 and 2.6 degree C by the 2050s and 1.2 to 3.9 degree C higher by the 2080s. (The warming rates of 0.1 to 0.4 degree C per decade would exceed the ability of many plant and animal species and ecosystems to adapt).
- sea level, which has risen 10-25 cm over the last century could rise two to five times faster by 2100 (a further 22-124 cm), mainly due to expansion of the world's oceans.

The national and regional scenarios have been compiled from a sample of 10 recent global climate model simulations performed by seven climate laboratories in six different locations.

ARGENTINA

- The 1990s was the warmest decade of the century
- Temperatures in northern Argentina are set to rise by between 0.1 and 0.4 degree C per decade. In southern Argentina, the increase is between 0.1 and 0.25 degree C per decade
- Annual precipitation declines over the Andes by up to 18 per cent by the 2080s
- Annual precipitation increases by only a small amount over the east of the country
- Reduced riverflows from the Andes could endanger water supply for electric power and irrigation in the already water-stressed Argentine mid-west
- Warming seas and a decline in sea-ice may endanger the Southern Right Whale by jeopardising stocks of krill, its main food source
- Iguazu National Park, home to over 400 species of birds and wild animals and 2000 plant species, may receive more variable rainfall with more frequent dry seasons

AUSTRALIA

- The decade 1989-1998 was the warmest on record
- Future temperatures across Australia are set to rise by between 0.15ºC and 0.5ºC/decade
- Precipitation is likely to decrease in the future, in both summer and winter seasons
- Drought occurrence in eastern States may double or treble in the future
- Hot summers that occur on average once every 10 years at present could become an annual event in the most extreme case
- The risk of bushfires increases
- Mountain habitats of the mountain pygmy possum in Victoria and New South Wales are threatened
- Mangrove swamps, such as in Kakadu National Park, could become more vulnerable due to sea-level rise and increasing storm surges
- The Great Barrier Reef, where coral bleaching has occurred when sea temperatures have increased only 0.5 degree C above normal, could face increases of between 1.5 and 3.5 degree C by 2100. This may wipe out coral species and ecosystems. Corals are also threatened by increasing levels of CO2 in the air, which reduces the amount of dissolved calcium carbonate in the water - the essential compound for reef-building corals.

BRAZIL

- Brazil has warmed by 0.5 degree C this century. The three warmest years have all occurred during the 1990s - the warmest decade this century
- Temperatures are set to increase by between 0.2 and 0.6 degree C per decade during the June to August period, with the greatest warming occurring over the Amazonian rainforest
- Precipitation over Amazonia decreases by between 5 and 20 per cent during the March to May season
- Drought may adversely affect forest tree species, including some of the world's most threatened habitats of seasonally flooded forests and the large number of species they support
- Large areas of the Amazon may become more susceptible to forest fires
- Increased CO2 concentrations could fuel the growth of tree vines and in turn threaten some tree species
- The state of Rio Grande may experience increases in precipitation of between 5 and 20 per cent
- The Pantanal is one of the last great remaining freshwater wetlands in the world, home to 700 species of birds and 70 species of mammals including ocelots and jaguars. Wettest years in the Pantanal may be 2-3 times as frequent as they are now, leading to more frequent flooding

CANADA

- Annual temperatures in Canada north of 60 degree N are likely to increase by between 0.2 and 0.7 degree C per decade
- Annual precipitation will increase across the whole of Canada and over the Canadian Arctic region by between 15 and 45 per cent by the 2080s
- Summers are likely to become drier by up to 10 per cent in south-central British Colombia, central Alberta and northern Saskatchewan
- Large areas of permafrost will melt destroying habitats for many Arctic plants
- Boreal forests will be threatened by an increase in insect infestation and fires
- Changes in seasons threaten the cottongrass species upon which the caribou feed
- Polar bear habitats are threatened by the melting of sea-ice

CHINA

- Temperatures in the future may increase by between 0.18 and 0.45 degree C per decade
- Winter warming will be greatest over northern China. But summer in the Gobi Desert, in the north west, could be nearly 4.5 degree C above present climate by the 2080s
- Precipitation during the rainy season is likely to increase by between 5 and 15 per cent in the northwest and southwest of China by the 2080s. Wetter winters could affect most of the country
- The boreal (cold) zone will likely see the greatest impact of warming and increased wetness. Forest zones may move northwards, depleting the remaining boreal forest in Heilungkiang Province in northeastern China
- Wolong Nature Reserve, established to protect the Giant Panda, and Xishuangbanna Nature Reserve, home to China's only tropical plants - many with medicinal properties - could have hot summers at least twice as often and perhaps every year. The climate of Wolong could become more variable with more frequent very wet *and* very dry summers
- 10 per cent of mammals in China are already under threat of extinction - climate change could make protected areas unsuitable for many species. Changes in seasonal temperatures could affect the breeding season of the Giant Panda

GERMANY

- Temperatures are set to increase by between 0.1 and 0.45 degree C per decade
- Annual precipitation will increase by between 5 and 10 per cent by the 2050s, but summers will become drier
- Unteres Odertal National Park and its migratory bird inhabitants are threatened by sea-level rise
- Dry summers in Berlin may double or treble in frequency by the 2050s

- Hot summers in Berlin will increase in frequency to occur between every three years to every year by the 2050s (compared to once a decade currently)
- Heatwaves associated with hot and dry summers will increase in frequency and intensity and threaten human health

IBERIAN PENINSULA (Spain and Portugal)
- Temperatures are set to warm by between 0.16 and 0.45 degree C per decade
- Annual precipitation is likely to increase by between 5 and 15 per cent but summers will become drier
- Migratory birds are threatened by drying out of wetland habitats in Doñana National Park
- Sea-level rise threatens wetland habitats through saltwater intrusion
- Habitat loss for the European rabbit and migratory ducks threatens the survival of the endangered Iberian lynx
- Summer forest wildfires are likely to increase in frequency, intensity and area burned

INDONESIA
- Temperatures are set to increase by between 0.1 and 0.3 degree C per decade
- Annual rainfall increases across the majority of the islands in the future except for Java where rainfall is set to decrease by up to 15 per cent by the 2080s
- By the 2080s Jakarta is likely to be 5 to 15 per cent drier
- Increases in the frequency of hot and dry years will increase the frequency and intensity of forest fires
- Droughts and fires threaten the habitat and food resources of the already endangered orangutan

JAPAN
- Summer temperatures are set to increase by between 0.1 and 0.3 degree C per decade
- Hot summers are likely to occur every year (as opposed to once every 10 years) in Tokyo by the 2050s
- Heatwaves in cities such as Tokyo will increase in intensity and frequency
- Sea-level rise may destroy between half and all of Japan's sandy beaches by the 2080s and threaten the coastal cities of Tokyo, Osaka and Nagoya
- The coral reef ecosystems of the Nansei Shoto islands are likely to become stressed by warming oceans and higher CO2 concentrations

MESOAMERICA (Mexico, Guatemala, Belize, Honduras, Nicaragua, El Salvador, Costa Rica, Panama, and all the islands in the Caribbean Sea)
- Future temperatures are set to rise by between 0.13 and 0.45 degree C per decade
- Warming will be greatest over the highlands of Mexico. But much of the country could be 5 degrees C warmer by the 2080s
- Precipitation is likely to have decreased by between 5 and 20 per cent across southern Mexico and Guatemala, with up to 20 per cent less rainfall by the 2080s
- Increased frequency of droughts will have large impacts on many forests in Central America
- Droughts in the Monteverde cloud forests of Costa Rica may double in the future threatening habitats for amphibians and cloud forest lizard species, as was the case with the now-extinct Golden Toad
- The Mesoamerican coral reef which extends 250 km from Mexico to Honduras could suffer severe impacts from a rise in sea temperature of 1 to 3 degree C by the 2080s
- Warmer sea temperatures could also threaten the existence of loggerhead turtles

NORTHERN ANDES (Colombia, Ecuador, Peru, Venezuela)
- Increase of 0.8 degrees C over the last century
- Night-time temperatures increasing much more rapidly than daytime temperatures
- Frosts have decreased at higher elevations

- Significant loss of ice in the glaciers in Ecuador and Venezuela as in the Quelccaya ice cap of southern Peru and the Yanamarey glacier in central Peru
- Warming expected to be most rapid over the Andean plateau
- Peru, Ecuador and southern Colombia become wetter, but northern Colombia and Venezuela become drier
- Drying in the Venezuelan lowlands could affect habitat for the Orinoco crocodile
- Sea-level rise will be a problem for the eastern coast of Lake Maracaibo
- High altitude plant species are threatened by warming in the Huascaran National Park in the Cordillera Blanca.

PHILIPPINES
- Temperatures are set to increase by between 0.1 and 0.3 degree C per decade
- Precipitation will increase during the wet June-November period by between 5 and 15 per cent by the 2050s
- Precipitation will decrease by up to 20 per cent during the already dry December to May period by the 2050s
- Sea-level rise threatens between 0.5 and 2.5 million people, and 2000-5000 hectares of prime land in the Manila Bay region by the 2050s
- The corals of Tubbataha Reef are threatened by warming sea-surface temperatures and increases in CO2

RUSSIA
- Temperatures in northern Russia are likely to rise by between 0.35 and 0.7 degree C per decade
- Precipitation will increase across most of the Russian Federation
- The region between Omsk and Kransnovarsk is likely to experience decreases in precipitation of between 5 and 15 per cent
- Boreal forests will be forced to move northwards being replaced by steppe at the southern boundary
- Hot summers in the Pechoro-Ilychsky Forest Reserve may become up to 7 times more frequent increasing the risk of forest fires

UNITED STATES OF AMERICA
- The US has warmed about 0.7 degree C this century. 1998 was the warmest year of the century.
- The last two decades have been the wettest this century, with a trend to more intense precipitation and a more extreme climate
- US will warm more rapidly than the global average, particularly in Alaska where winter warming reaches almost 1 degree C per decade in the most extreme case
- Summer warming over the western interior of the US is large at between 0.2 and 0.5 degree C per decade
- Rises in sea level will be an increasing threat to low-lying coastal cities such as New York, Boston and Miami
- US will become wetter overall. Some southern states will become drier in winter while the northwest is drier in summer. California winters could be 30 per cent wetter by the 2050s
- Rising sea levels and increased salinity are already contributing to reduced oyster harvests in Delaware Bay and Chesapeake Bay
- Blackwater National Wildlife Refuge in Chesapeake Bay could be decimated by sea-level rise and pollution within 30 years
- Significant threats to coastal wetlands of the Florida Keys, the Everglades and Louisiana and more frequent algal blooms from warmer sea temperatures
- Hot seasons becoming ten times more frequent and dry seasons occurring twice as often in North Dakota would threaten the most important breeding areas for waterfowl in North America, resulting in substantial economic losses.

ZIMBABWE

- Annual temperatures are set to rise by between 0.15 and 0.55 degree C per decade
- By the 2080s, annual precipitation will have decreased by between 5 and 18 per cent compared with the 1961-90 average
- The semi-desert areas of the south-west will expand
- Grassland areas will be replaced by thorn-scrub savanna which may threaten animals such as the common reedbuck, sable antelope and the serval
- Increased droughts threaten humans and wildlife
- Falling levels of Lake Kariba threaten energy generation and the animals of the Kariba National Park
- Only a small increase in night-time temperatures will threaten Harare with outbreaks of malaria

3. QUESTIONS & ANSWERS

1. How have the scenarios been produced?

The scenarios have been constructed using results from seven world-leading global climate models, representing scientific efforts in six different countries. Assumptions about future greenhouse gas emissions are selected so as to span about 95 per cent of the range of emissions scenarios published in the current literature.

2. How has the model been tested for accuracy?

These global climate models have all been evaluated in the open scientific literature and validated against actual observations. These models have been used to simulate past climates, used to develop seasonal climate forecasts, and used in short-range numerical weather prediction. No model can ever be perfect, but the models used here represent the current state-of-the-art as far as climate modelling is concerned.

3. How accurate are the projections likely to be?

Climate scenarios are not predictions of the future, they are descriptions of one or more possible future climates. One important reason for uncertainty is that we do not know how rapidly emissions of global warming gases will grow in the future, nor do we know exactly how natural climate variability will evolve. One cannot talk about climate scenarios being accurate; the important thing is whether the scenarios are plausible and do they represent our known sources of uncertainties. In this regard, the four scenarios in the brochures carefully span the range of future climates considered likely given current scientific knowledge of the climate system.

4. How far can the model go in projecting the regional or local impacts of climate change?

The models are not designed to simulate climate accurately at particular locations. What they are best at doing is simulating the regional circulation which dictates the types of climates particular places experience. We again are careful to represent a range of future regional climates in our scenarios.

5. Who else uses these models?

The models used here are being used by many dozens of scientific teams around the world. The results are freely available through the IPCC Data Distribution Centre and the IPCC is actively encouraging scientists to use these model results to undertake a range of global, regional and national studies.

6. Why should policymakers take heed of these results?

If policymakers do not wish to rely on the results of climate models, and the 100s of person-years of scientific endeavour they encapsulate, then that is their prerogative. However, there is no better way of exploring what the future climate may have in store for us next century. The alternative is to make a few expert guesses. We believe that by carefully representing the uncertainties, such models yield essential information that should shape climate policy now and also alter the way we design our infrastructures and resource systems to cope with the future risks climate change will pose.

7. What is the difference between this model and others that some sceptics dismiss?

None! If sceptics want to dismiss climate models that is their choice. In so doing, they are also dismissing models that are being used to routinely predict tomorrow's weather and next year's El Niño. If people want to reject the scientific method of critical development of theory and models tested against reality we are left with mythology, guesswork and personal opinion.

8. What is the difference between these scenarios and those that the Intergovernmental Panel on Climate Change (IPCC) has produced?

The IPCC have not produced a systematic set of regional/national scenarios. This is why the work described here breaks new ground for many countries. The models used in this work are models that the IPCC are assessing and promoting the use of since they have been extensively peer-reviewed, but the IPCC does not have a definitive set of climate scenarios for every country in the world.

9. Which other experts have been involved or consulted in the course of the project?

Expert climate colleagues in the UK, in Finland, in Australia and in Canada have been consulted in the preparation of these scenarios. Local WWF experts in biodiversity in each country/region have also been consulted in regard to the possible impacts of the scenarios on ecosystems and biodiversity. Much of the material has been distilled from published, peer-reviewed scientific papers.

10. How many person-hours of work have been invested in this project?

1500 person-hours of work have gone into the preparation of the brochures. This excludes the translation, design and printing effort. And of course many 100s of thousands of person-hours underlie the climate model experiments that are used.

4. ABOUT THE CLIMATIC RESEARCH UNIT

The University of East Anglia at Norwich, UK, was established in 1963 and currently has about 10,000 students. The School of Environmental Sciences is one of the leading environmental science schools in the UK and was graded 5*, the highest that could be attained in the most recent government assessment of UK Universities.

The Climatic Research Unit (CRU) is one of three research centres in the school, each of which is an integral part of the School of Environmental Sciences. At present, CRU is composed of 15 research staff, 3 support staff and 12 postgraduate students at varying stages of their PhDs. CRU was founded in 1972 by the late Prof. H.H. Lamb and at present has two joint directors (Prof. P.D. Jones and Dr J.P. Palutikof). Over the last 27 years, CRU has gained a worldwide reputation for the study of climate, climatic change, the impacts of climate change and applied climatology.

CRU is most widely known for studies of instrumental climate, especially the global temperature series. Extensive analyses of instrumental temperature, precipitation and pressure have been undertaken with much of the data available through our web site (http://www.cru.uea.ac.uk) or through the IPCC-Data Distribution Centre (IPCC-DDC) which is jointly administered by CRU and DKRZ in Hamburg.

Attempting to extend the instrumental timeframe, CRU has an excellent reputation for tree-ring reconstructions and in multiproxy compilations of these and other proxy climatic sources (historical records, ice cores and corals). CRU has become extensively involved in the development of climate scenarios and their use in climate change impacts. CRU has developed several software packages for the study of climate change impacts from the importance of emissions, through climate modelling to the impact sector. CRU has been at the forefront of work in climate scenario developments and downscaling and in impacts on sea level and the agricultural, economic, social and water resource sectors. Through the Climate LINK Project, CRU is the dissemination point for Hadley Centre model experiments (a facility that is widely used in the UK, Europe and worldwide).

An important aspect of the work of CRU has been the application of research results to real-world problems. CRU has a history of working with industry to develop products which improve the competitiveness and profitability of the industrial partner. In particular, CRU has strong links with the energy and insurance industries. In the energy sector, CRU has worked with the wind energy industry to explore the characteristics of the near-surface wind field over land and over sea.

5. BIOGRAPHIES OF THE RESEARCHERS

Dr Mike Hulme is a Reader in Climatology at the Climatic Research Unit (CRU) at the University of East Anglia where he has worked for the last 11 years. His research specialises in global climate change and climate scenario construction, the evaluation of global climate models, and climate change and desertification in Africa. He has published extensively in all of these fields, including climate scenario reports for the UK Government (DETR, MAFF and DoH), the European Commission, UNEP, the World Bank, and WWF International. He co-ordinated the preparation of the latest set of national climate scenarios for the UK Government published in October 1998. He has contributed to the 1992 and 1995 reports of the United Nations Intergovernmental Panel on Climate Change (IPCC) and is running an international climate scenario Data Distribution Centre for the next IPCC report due in the year 2001. He has been writing monthly UK climate summaries for *The Guardian* newspaper since 1988 and in 1997 published a book on *The Climates of the British Isles*. Consultancy work has been undertaken for the World Bank, the World Energy Council, UNDP, UNEP, the World Meteorological Organisation, BP Amoco, the Overseas Development Administration (UK), the Institute of Terrestrial Ecology, Greenpeace, Mott McDonald Ltd. and the Club du Sahel. He is on the editorial board of three international journals: *Int. J. Climatol.*, *Climate Research* and *Prog. in Phys. Geogr*. and has been a Fellow of the Royal Meteorological Society since 1982.

After obtaining a BSc.(Hons) degree in Geography at Coventry University in 1994, which included one year working for the National Rivers Authority in the Environmental Quality Department, **Nicola Sheard** graduated from the University of East Anglia in 1996 with an MSc in Climate Change (with distinction). For the past six months, Nicola Sheard has been working at the Climatic Research Unit, and has been actively involved in the research and publication of the National and Regional Climate Change Scenarios for WWF - the World Wide Fund for Nature.

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