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What the IPCC Said

A Citizens' Guide to the IPCC Summary for Policymakers

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Right now, over 10,000 representatives from more than 180 countries are gathering in Bali, Indonesia, to debate the future of the Earth's climate, under the auspices of the United Nations Framework Convention on Climate Change.

This meeting represents an important opportunity: The world's attention is focused on climate change as never before. Al Gore and the Intergovernmental Panel on Climate Change (IPCC) have been jointly awarded a Nobel Prize for their work to raise public awareness of global warming. Even skeptics have now conceded that global warming is a major concern.

Perhaps just as importantly, in the past year the IPCC released a new global consensus statement called *Climate Change 2007*. This consensus establishes without doubt that global warming is being caused by humans, and that its magnitude and impacts are greater than we thought just a few years ago.

The IPCC recently released a short summary of that report. That summary, prepared for policymakers, is a challenging read for all but specialists. Yet the information it contains is far too important to be understood by only a select few. In the interests of disseminating the IPCC's crucial findings as widely as possible, we have prepared a "plain English" version of the "Summary for Policymakers" of *Climate Change 2007: Synthesis Report*. We ask that you read it and share it widely.

Notes on the Text

Our version of the Summary for Policy Makers draws heavily on the IPCC report's organization and text. In places where we felt the phrasing could be made more accessible to nonspecialists, we revised the text. In order to stay as close to the meaning of the IPCC summary as possible, we tried to use a light touch and left much of the original text intact. To help the reader see how the original phrasing has been used and changed, we present the corresponding statements from the IPCC beside our version.

In the interests of scientific accuracy, the IPCC presents "best estimates" for its numerical projections along with uncertainty intervals. To help policymakers readily absorb the key understandings presented here, we have removed the uncertainty intervals, which can be seen in the corresponding original IPCC text.

Paragraph Numbering

To enable comparisons between our text and the original IPCC Summary for Policymakers, we numbered each paragraph in each major section of the Summary. For example, 2.05 is the fifth paragraph of the second section.

Note on Captions

The IPCC graphics and tables are especially rich, but some may be too complex for many nonspecialists. We have highlighted a few and have prepared our own captions for those; the complete graphics and original tables are found in the IPCC summary.

Treatment of Uncertainty

Throughout the summary, the IPCC uses a consistent set of terms to describe how certain we can be about a particular finding, how high the level of agreement on a particular point, or how likely a future scenario. Here is the IPCC text explaining those terms:

> The IPCC uncertainty guidance note[1] defines a framework for the treatment of uncertainties across all Working Groups (WGs) and in this Synthesis Report. This framework is broad because the WGs assess material from different disciplines and cover a diversity of approaches to the treatment of uncertainty drawn from the literature. The nature of data, indicators and analyses used in the natural sciences is generally different from that used in assessing technology development or the social sciences. WG I focuses on the former, WG III on the latter, and WG II covers aspects of both.
>
> Three different approaches are used to describe uncertainties each with a distinct form of language. Choices among and within these three approaches depend both on the nature of the information available and the authors' expert judgment of the correctness and completeness of current scientific understanding.
>
> Where uncertainty is assessed qualitatively, it is characterised by providing a relative sense of the amount and quality of evidence (that is, information from theory, observations or models indicating whether a belief or proposition is true or valid) and the degree of agreement (that is, the level of concurrence in the literature on a particular finding). This approach is used by WG III through a series of self-explanatory terms such as: *high agreement, much evidence; high agreement, medium evidence; medium agreement, medium evidence; etc.*
>
> Where uncertainty is assessed more quantitatively using expert judgement of the correctness of underlying data, models or analyses, then the following scale of confidence levels is used to express the assessed chance of a finding being correct: *very high confidence* at least 9 out of 10; *high confidence* about 8 out of 10; *medium confidence* about 5 out of 10; *low confidence* about 2 out of 10; and *very low confidence* less than 1 out of 10.
>
> Where uncertainty in specific outcomes is assessed using expert judgment and statistical analysis of a body of evidence (e.g. observations or model results), then the following likelihood ranges are used to express the assessed probability of occurrence: *virtually certain* >99%; *extremely likely* >95%; *very likely* >90%; *likely* >66%; *more likely than not* > 50%; *about as likely as not* 33% to 66%; *unlikely* <33%; *very unlikely* <10%; *extremely unlikely* <5%; *exceptionally unlikely* <1%.
>
> WG II has used a combination of confidence and likelihood assessments and WG I has predominantly used likelihood assessments.
>
> The Synthesis Report follows the uncertainty assessment of the underlying WGs. Where synthesised findings are based on information from more than one WG, the description of uncertainty used is consistent with that for the components drawn from the respective WG reports.

Unless otherwise stated, numerical ranges given in square brackets in this report indicate 90% uncertainty intervals (i.e. there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range). Uncertainty intervals are not necessarily symmetric around the best estimate.

[1] See http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_introduction.pdf

1. Observed changes in climate and their effects

1.01 Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (Figure SPM.1). {1.1}

1.02 Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]¡C [1] is larger than the corresponding trend of 0.6 [0.4 to 0.8]_C (1901-2000) given in the Third Assessment Report (TAR) (Figure SPM.1). The temperature increase is widespread over the globe, and is greater at higher northern latitudes. Land regions have warmed faster than the oceans (Figures SPM.2, SPM.4). {1.1, 1.2}

1

Observed Changes in Climate and Their Effects

➢ **Warming of the climate system is unequivocal, and greater than found in the 3rd IPCC Assessment Report in 2001.**

➢ **Many natural systems are being affected by regional climate changes, particularly temperature increases. These effects have been observed over most of the planet.**

➢ *Warming of the climate system is unequivocal. This is now evident from*

- **observations of increases in global average air and ocean temperatures;**
- **widespread melting of snow and ice;**
- **rising global average sea level. (1.01)**

Eleven of the last twelve years rank among the twelve warmest years since 1850, when consistent records of global surface temperatures began to be kept. The temperature appears to have risen approximately 0.74°C over the last 100 years, which is greater than the raise of approximately 0.6°C reported in the 2001 IPCC Assessment. The temperature increase is widespread over the globe, and is greater at higher northern latitudes. Land regions have warmed faster than the oceans. (1.02)

1.08 Average Northern Hemisphere temperatures during the second half of the 20th century were ***very likely*** higher than during any other 50-year period in the last 500 years and ***likely*** the highest in at least the past 1300 years. {1.1}

1.06 It is ***very likely*** that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It ***is likely*** that: heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level3 has increased worldwide. {1.1}

1.04 Observed decreases in snow and ice extent are also consistent with warming (Figure SPM.1). Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. Mountain glaciers and snow cover on average have declined in both hemispheres. {1.1}

1.03 Rising sea level is consistent with warming (Figure SPM.1). Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3]mm/yr and since 1993 at 3.1 [2.4 to 3.8]mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear. {1.1}

1.05 From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has ***likely***[2] increased since the 1970s. {1.1}

Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1300 years. (1.08)

Daily temperature patterns have also changed in the past 50 years. It is very likely that cold days, cold nights, and frosts occur less frequently in most land areas, while hot days and nights occur more frequently. It is likely that over most land areas heat waves have become more frequent and heavy rain and snowstorms occur more frequently. (1.06)

Snow and ice cover have shrunk around the globe, as would be expected due to warming. Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by approximately 2.7% per decade, with larger decreases in summer of approximately 7.4% per decade. (1.04)

Sea levels have also risen, which is expected with global warming. Global average sea level has risen approximately 3.1 mm per year since 1993 as a result of several factors, including meltwater from glaciers and polar ice sheets and the expansion of the oceans' water as it warms, known as thermal expansion. (1.03)

Over the last century, precipitation patterns have changed in different parts of the globe, with some regions becoming significantly wetter and others dryer. In particular, from 1900 to 2005, precipitation increased in eastern parts of North and South America, northern Europe, and northern and central Asia, but declined in the Sahel, the Mediterranean, southern Africa, and parts of southern Asia. Globally, it is likely that there has been an increase in areas affected by drought since the 1970s. (1.05)

1.07 There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, with limited evidence of increases elsewhere. There is no clear trend in the annual numbers of tropical cyclones. It is difficult to ascertain longer term trends in cyclone activity, particularly prior to 1970.

1.09 Observational evidence[4] from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. {1.2}

1.12 In terrestrial ecosystems, earlier timing of spring events and poleward and upward shifts in plant and animal ranges are with very *high confidence* linked to recent warming. In some marine and freshwater systems, shifts in ranges and changes in algal, plankton and fish abundance are with *high confidence* associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation. {1.2}

1.10 Changes in snow, ice and frozen ground have with *high confidence* increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions, and led to changes in some Arctic and Antarctic ecosystems. {1.2}

1.11 There is *high confidence* that some hydrological systems have also been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers, and effects on thermal structure and water quality of warming rivers and lakes. {1.2}

1.13 Of the more than 29,000 observational data series, from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming (Figure SPM.2). However, there is a notable lack of geographic balance in data and literature on

Although there is some evidence that powerful hurricanes in the North Atlantic have become more frequent since 1970, this does not seem to be a global trend. Nor does the number of tropical cyclones and hurricanes show any clear pattern of increase. (1.07)

➢ ***Many natural systems are being affected by regional climate changes, particularly temperature increases. These effects have been observed over most of the planet. (1.09)***

In terrestrial ecosystems, rising temperatures have led to earlier arrivals of spring and shifts in plant and animal ranges toward the poles and higher elevations (very high confidence). In marine and freshwater systems, shifts in ranges and changes in abundance of algae, plankton and fish are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation (high confidence). (1.12)

There has been an increase in the number and size of glacial lakes, increased ground instability in permafrost regions, and changes in Arctic and Antarctic ecosystems. These changes are due to melting of snow, ice, and frozen ground (high confidence). In addition, there have been changes to the water quality and thermal structure of many glacier- and snow-fed rivers. These changes are the result of increased runoff and earlier spring melting (high confidence). (1.10, 1.11)

Of more than 29,000 data series from 75 studies that show significant changes in physical and biological systems, more than 89% show a response expected as a result of warming. More data, however, are needed from developing countries. (1.13) observed changes, with marked scarcity in developing countries. {1.3}

1.14 There is *medium confidence* that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

1.15 They include effects of temperature increases on {1.2}

- agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests
- some aspects of human health, such as heat-related mortality in Europe, changes in infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes
- some human activities in the Arctic (e.g. hunting and travel over snow and ice) and in lower-elevation alpine areas (such as mountain sports).

Other effects of climate change on natural and human environments are emerging, although these are less certain. Increased temperatures have affected:

- agricultural and forestry management at Northern Hemisphere higher latitudes, resulting in such changes as earlier spring planting of crops and alterations in disturbance regimes of forests due to fires and pests;
- human health, in such forms as heat-related mortality in Europe, changes in infectious disease vectors, and allergenic pollen in Northern Hemisphere high and mid-latitudes;
- human activities in the Arctic, such as hunting and travel over snow and ice. (medium confidence). (1.14, 1.15)

2. Causes of change

2.06 There is very high confidence that the net effect of human activities since 1750 has been one of warming.[6]{2.2}

2.02 Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (Figure SPM.3).[5] {2.1}

2.03 Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000.{2.1}

2.04 Global atmospheric concentrations of CO_2, methane (CH4) and nitrous oxide (N2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. {2.2}

2.05 Atmospheric concentrations of CO_2 (379ppm) and CH4 (1774

2

Causes of Climate Change

Human activities, in particular the burning of fossil fuels and changes in land use, have resulted in

- **Warming of the planet;**
- **Other changes in climate;**
- **Effects on natural ecosystems.**

➢ ***Human activities since 1750 have resulted in warming of the planet (very high confidence). (2.06)***

Global greenhouse gas emissions due to human activities have grown since preindustrial times, and have increased 70% in just the period between 1970 and 2004. (2.02, 2.03)

These increased emissions have resulted in higher concentrations of greenhouse gases in the atmosphere. Global concentrations of greenhouse gases in the atmosphere have increased markedly as a result of human activities since 1750, and now far exceed preindustrial values, as determined from ice cores spanning many thousands of years. In 2005, the atmospheric concentrations of two key greenhouse gases, carbon dioxide and methane, exceeded by far the natural range over the last 650,000 years (2.04, 2.05) ppb) in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is very likely that the observed increase in CH4 concentration is predominantly due to agriculture and fossil fuel use. Methane growth rates have declined since the early 1990s, consistent with total emission (sum of anthropogenic and natural sources) being nearly constant during this period. The increase in N2O concentration is primarily due to agriculture. {2.2}

2.07 Most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations.[7] It is likely there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) (Figure SPM.4). {2.4}

2.08 During the past 50 years, the sum of solar and volcanic forcings would likely have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcings. Difficulties remain in simulating and attributing observed temperature changes at smaller than continental scales. {2.4}

2.09 Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate. {2.4}

2.10 Human influences have: {2.4}

- very likely contributed to sea level rise during the latter half of the 20th century

Global increases in carbon dioxide concentrations are due primarily to the burning of fossil fuels, with land-use change providing another significant but smaller contribution. There has also been an increase in atmospheric methane concentration, which is very likely due to agriculture and fossil fuel use. The atmospheric concentration of nitrous oxide has also increased, primarily due to agriculture. (2.05)

The increase in the atmospheric concentration of greenhouse gases has very likely caused the observed increase in temperature over the last 50 years. Models that take into account effects of human activities, along with natural phenomena such as solar and volcanic activity, simulate observed patterns of warming. In contrast, models that exclude human activities indicate that this period would likely have been one of cooling instead. (2.07, 2.08)

➢ ***Discernible human influences extend beyond warming to other aspects of climate. This is a notable finding since the last major IPCC report, issued in 2001. (2.09)***

Human influences have

- very likely contributed to sea-level rise during the latter half of the 20th-century;

- likely contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns
- likely increased temperatures of extreme hot nights, cold nights and cold days
- more likely than not increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events.

2.11 Anthropogenic warming over the last three decades has likely had a discernible influence at the global scale on observed changes in many physical and biological systems. {2.4}

2.12 Spatial agreement between regions of significant warming across the globe and locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability. Several modelling studies have linked some specific responses in physical and biological systems to anthropogenic warming. {2.4}

2.13 More complete attribution of observed natural system responses to anthropogenic warming is currently prevented by the short time scales of many impact studies, greater natural climate variability at regional scales, contributions of non-climate factors and limited spatial coverage of studies. {2.4}

[5] Includes only CO_2, CH4, N2O, HFCs, PFCs and SF6 whose emissions are covered by the UNFCCC. These GHGs are weighted by their 100-year Global Warming Potentials, using values consistent with reporting under the UNFCCC.

[6] Increases in GHGs tend to warm the surface while the net effect of increases in aerosols tends to cool it. The net effect due to human activities since the pre-industrial era is one of warming (+1.6 [+0.6

- likely contributed to changes in wind patterns;
- likely contributed to increased temperatures during extremely hot nights, cold nights, and cold days;
- more likely than not contributed to increased risk of heat waves, increased area affected by drought since the 1970s, and increased frequency of heavy precipitation. (2.10)

➢ ***Warming of the planet due to human activities over the last three decades has likely had an effect on many natural systems. (2.11)***

Specific ecosystem responses have been linked to human-induced warming. Such changes are very unlikely due to natural variability. Future studies with longer time scales and larger geographic coverage will help us to more clearly discern the human impact. (2.12, 2.13)

Recommended Figures

Figure SPM.3. This figure delivers three distinct messages:

(a) Quantities of greenhouse gases emitted from anthropogenic sources from 1970 to 2004. In other words, this figure answers the question: How did the quantity of several important greenhouse gases change from 1970 to 2004? Since different gases have different heat-trapping capabilities, it makes sense to express the changes in terms of a single type of heat-trapping molecule, carbon dioxide. This graph shows gases expressed as $GtCO_2$-eq, or gigatons of carbon dioxide equivalents (in terms of warming effects).

(b) Quantities of greenhouse gases emitted in 2004, expressed as equivalents of the warming ability of carbon dioxide.

(c) Contributions of different economic sectors to 2004 greenhouse gas emissions, expressed in carbon dioxide equivalents.

to +2.4]W/m^2). In comparison, changes in solar irradiance are estimated to have caused a small warming effect (+0.12 [+0.06 to +0.30]W/m^2).

[7] Consideration of remaining uncertainty is based on current methodologies.

Figure SPM.4. A comparison of different types of climate models with observed temperature trends. The figure shows:

(1) temperatures that would be expected if there were no anthropogenic influences (the blue bands);

(2) temperatures that would be expected with anthropogenic influences on climate (the red bands); and

(3) the observed temperatures (the black lines).

3. Projected climate change and its impacts

3.04 For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emission scenarios. {3.2}

3.03 Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century (Table SPM.1, Figure SPM.5). {3.2.1}

3.20 Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilised. {3.2.3}

3

Projected Climate Change and Its Impacts

The climate will continue to change in the 21st century. Specifically, we will see

- **continued increases in temperature**
- **increases in global greenhouse gas emissions**
- **changes in other aspects of climate, such as wind patterns and precipitation.**

➢ ***The planet will continue to warm over the next two decades. The IPCC projects warming of about 0.2°C per decade. (3.04)***

Continued greenhouse gas emissions at or above current rates will cause further warming over what has already been observed, and induce many changes in the global climate system during the 21st century. These changes will very likely be larger than those observed during the 20th century. (3.03)

Warming of the planet due to human activities and sea-level rise will continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations are stabilized at present levels. Even if we could keep concentrations of all greenhouse gases at year 2000 levels, a further warming of about 0.1°C per decade would be expected. (3.04, 3.20)

3.05 The range of projections (Table SPM.1) is broadly consistent with the TAR, but uncertainties and upper ranges for temperature are larger mainly because the broader range of available models suggests stronger climate-carbon cycle feedbacks. Warming reduces terrestrial and ocean uptake of atmospheric CO_2, increasing the fraction of anthropogenic emissions remaining in the atmosphere. The strength of this feedback effect varies markedly among models. {2.3, 3.2.1}

3.01 There is *high agreement* and *much evidence* that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. {3.1}

3.02 The IPCC Special Report on Emission Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25-90% (CO_2-eq) between 2000 and 2030 (Figure SPM.5), with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. More recent scenarios without additional emissions mitigation are comparable in range.[8, 9] {3.1}

3.07 There is now higher confidence than in the TAR in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and sea ice. {3.2.2}

3.08 Regional-scale changes include: {3.2.2}

- warming greatest over land and at most high northern latitudes and least over Southern Ocean and parts of the North Atlantic Ocean, continuing recent observed trends (Figure SPM.6) in contraction of snow cover area, increases in thaw depth over most permafrost regions, and decrease in sea ice extent; in some projections using SRES scenarios, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century

Recent models also suggest that warming begets more warming. Increased temperatures reduce uptake of atmospheric carbon dioxide by the land and ocean, thereby increasing the fraction remaining in the atmosphere. This is a stronger feedback loop than the one suggested in the last major IPCC report, issued in 2001. (3.05)

➢ ***Global greenhouse gas emissions will continue to grow over the next few decades in spite of current climate change mitigation policies and sustainable development practices. (3.01)***

There is high agreement on and much evidence to support this claim. Between 2000 and 2030, scientists project an increase in greenhouse gas emissions of 25-90%, primarily as a result of burning fossil fuels. (3.01, 3.02)

➢ ***There will also be continued changes in wind patterns, increased precipitation, and melting of sea ice. There is higher confidence in this projection compared to that in the 2001 IPCC report. (3.07)***

The IPCC found that

- warming will be greatest over land and at most high northern latitudes and least over the Southern Ocean and parts of the North Atlantic Ocean
- snow cover area will continue to contract, thaw depth will continue to increase in most permafrost regions, and sea ice will continue to decrease in extent
- late-summer Arctic sea ice will disappear almost entirely by the latter part of the 21st century in some projections

- *very likely* increase in frequency of hot extremes, heat waves, and heavy precipitation
- *likely* increase in tropical cyclone intensity; less confidence in global decrease of tropical cyclone numbers
- poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation, and temperature patterns
- *very likely* precipitation increases in high latitudes and *likely* decreases in most subtropical land regions, continuing observed recent trends

3.18 Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems. {3.3.3}

3.09 There is high confidence that by mid-century, annual river runoff and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also high confidence that many semi-arid areas (e.g. Mediterranean basin, western United States, southern Africa and northeast Brazil) will suffer a decrease in water resources due to climate change. {3.2; Figure 3.4}

3.13 Some systems, sectors and regions are likely to be especially affected by climate change.[12] Systems and sectors: {3.3.4}

- particular ecosystems:

- hot extremes, heat waves, and heavy precipitation are very likely to increase in frequency
- tropical cyclone intensity is likely to increase
- tracks of storms outside the tropics will shift toward the poles, with consequent changes in wind, precipitation, and temperature patterns
- precipitation is very likely to increase in high latitudes, and likely to decrease in most subtropical land regions, continuing observed recent trends. (3.08)

These changes in the climate will have widespread effects, including

- ➢ **adverse effects on natural and human ecosystems**
- ➢ **abrupt and irreversible impacts**
- ➢ **melting of sea ice**
- ➢ **ocean acidification.**

➢ ***Altered frequencies and intensities of extreme weather, together with sea-level rise, are expected to have mostly adverse effects on natural and human systems. (3.18)***

The IPCC projects that, by the mid-21st century, annual river runoff and water availability will increase at high latitudes and in some tropical areas and decrease in some dry regions in the midlatitudes and tropics (high confidence). In addition, many semi-arid areas, such as the Mediterranean Basin, western United States, southern Africa, and northeast Brazil, will suffer a decrease in water resources due to climate change (high confidence). (3.09)

Some systems and sectors are likely to be especially affected by climate change. Particular ecosystems likely to be most strongly affected are the following:

- terrestrial: tundra, boreal forest and mountain regions because of sensitivity to warming; mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
- coastal: mangroves and salt marshes, due to multiple stresses
- marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming

- water resources in some dry regions at mid-latitudes[13] and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- agriculture in low-latitudes , due to reduced water availability
- low-lying coastal systems, due to threat of sea level rise and increased risk from extreme weather events
- human health in populations with low adaptive capacity.

3.14 Regions: {3.3.4}

- the Arctic, because of the impacts of high rates of projected warming on natural systems and human communities
- Africa, because of low adaptive capacity and projected climate change impacts
- small islands, where there is high exposure of population and infrastructure to projected climate change impacts
- Asian and African megadeltas, due to large populations and high exposure to sea level rise, storm surges and river flooding.

- ***terrestrial* —** tundra, boreal forest and mountain regions because of sensitivity to warming; Mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
- ***coastal* —** mangroves and salt marshes, due to multiple stresses
- ***marine*** — coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming

In addition,

- water resources will be affected in some dry regions at mid-latitude and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- agriculture will suffer in low latitudes, due to reduced water availability
- low-lying coastal systems will be affected, due to threat of sea-level rise and increased risk from extreme weather events
- we will see greater threats to human health in populations with limited capacity to adapt to changes in the climate. (3.13)

Regions that are likely to be especially affected by climate change include

- the Arctic, because of the impacts of high rates of projected warming on natural systems and human communities
- Africa, because of its low adaptive capacity and projected climate change impacts
- small islands, where the human population and infrastructure are highly exposed to projected climate change impacts
- Asian and African river deltas, due to large populations and high exposure to sea-level rise, storm surges, and river flooding. (3.14)

People living in poverty, young children, and the elderly are particularly vulnerable to changes in climate, even in areas with high incomes. (3.15)

3.15 Within other areas, even those with high incomes, some people (such as the poor, young children, and the elderly) can be particularly at risk, and also some areas and some activities. {3.3.4}

3.24 Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. {3.4}

3.25 Partial loss of ice sheets on polar land could imply metres of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded. {3.4}

3.26 Climate change is *likely* to lead to some irreversible impacts. There is medium confidence that approximately 20%–30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5°C–2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40%–70% of species assessed) around the globe. {3.4}

3.27 Based on current model simulations, the meridional overturning circulation (MOC) of the Atlantic Ocean will *very likely* slow down during the 21st century; nevertheless temperatures over the Atlantic and Europe are projected to increase. The MOC is *very unlikely* to undergo a large abrupt transition during the 21st century. Longer-term MOC changes cannot be assessed with confidence. Impacts of large-scale and persistent changes in the MOC are *likely* to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation. Changes in terrestrial and ocean CO_2 uptake may feed back on the climate system. {3.4}

➢ ***Human-induced warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. (3.24)***

The partial loss of ice sheets on polar land could imply meters of sea-level rise, major changes in coastlines, and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. The IPCC projects that such changes are projected to occur over millennial timescales, but does not exclude more rapid sea-level rise on century timescales. (3.25)

Climate change is likely to lead to some irreversible impacts. The IPCC projects with medium confidence that approximately 20–30% of species are likely to be at increased risk of extinction if increases in global average warming exceed 1.5–2.5°C relative to 1980-1999. If global average temperature increase exceeds about 3.5°C, we may see significant extinctions (40-70% of species assessed) around the globe. (3.26)

Based on current simulations, the circulation of the Atlantic Ocean will very likely slow down during the 21st century. Nevertheless, temperatures over the Atlantic and Europe are projected to increase. Impacts of large-scale and persistent changes in the circulation of the oceans are likely to include changes in marine ecosystem productivity, fisheries, ocean carbon dioxide uptake, ocean oxygen concentrations, and terrestrial vegetation. (3.27)

➢ ***Increased temperatures will melt sea ice.***

Current models suggest virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea-level rise of about 7 meters if global average warming is sustained for millennia in excess of 1.9 to 4.6°C relative to preindustrial values. Contraction of the Greenland ice sheet is projected to continue to contribute to sea-level rise after 2100.

3.22 Contraction of the Greenland ice sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7 m if global average warming were sustained for millennia in excess of 1.9°C to 4.6°C relative to preindustrial values. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when paleoclimatic information suggests reductions of polar land ice extent and 4 to 6 m of sea level rise. {3.2.3}

3.23 Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and gain mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. {3.2.3}

3.16 Ocean Acidification

3.17 The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units. Increasing atmospheric CO_2 concentrations lead to further acidification. Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century. While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g. corals) and their dependent species. {3.3.1}

The future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago. (3.22)

Current models project that the Antarctic ice sheet will remain too cold for widespread surface melting and will gain mass due to increased snowfall. However, net loss of ice mass could occur if large portions of the ice sheet break off. (3.23)

➢ ***Greenhouse gas emissions will increase the acidity of the ocean. (3.16)***

The uptake of carbon released as a result of human activity since 1750 has led to the ocean becoming more acidic, with an average decrease in pH of 0.1 units. Increasing atmospheric carbon dioxide concentrations will lead to further acidification of the ocean. Projections give a reduction in average ocean pH of between 0.14 and 0.35 units over the 21st century. While the effects of ocean acidification on marine life are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on shell-forming organisms, such as corals, and species that in turn depend on them. (3.17)

Recommended Figures

Figure SPM.5. *Left panel:* Projected growth in global greenhouse gas emissions over the next century. It is difficult to accurately predict the trajectory of human population growth, economic development, and energy use over the next century, which makes it very difficult to create a single prediction of greenhouse gas emissions and temperature rise. The IPCC has created a wide range of scenarios based on different types of human population and economic changes in the Special Report on Emission Scenarios (2000). These scenarios were used to predict greenhouse gas emissions over the next century, as shown in this figure.

[8] For an explanation of SRES emission scenarios, see Box 'SRES scenarios' of this Synthesis Report. These scenarios do not include additional climate policy above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

[9] Emission pathways of mitigation scenarios are discussed in Section 5.

[12] Identified on the basis of expert judgement of the assessed literature and considering the magnitude, timing and projected rate of climate change, sensitivity and adaptive capacity.

[13] Including arid and semi-arid regions.

Figure SPM.5. ***Right panel:*** Projected global temperature increases over the next century. The same scenarios of the IPCC Special Report on Emission Scenarios described for the left panel were used to predict increases in global temperature over the next century in this figure.

Figure SPM.6. One projection of how much surface temperatures might rise between the end of the 20th century and the end of the 21st century (comparing 1980-1999 with a prediction for 2090-2099). This projection is based on an IPCC Special Report on Emission Scenarios published in 2000 and the average projections of several Atmosphere-Ocean General Circulation Models (or Atmosphere-Ocean Global Climate Models). Note that: (1) different regions are expected to experience very different increases in temperature, and (2) using different scenarios would have led to different temperature projections.

4. Adaptation and mitigation options[14]

4.01 A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. There are barriers, limits and costs, which are not fully understood. {4.2}

4.03 Some planned adaptation to climate change is already occurring on a limited basis. Adaptation can reduce vulnerability especially when it is embedded within broader sectoral initiatives (Table SPM.4). There is *high confidence* that there are viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios. However, comprehensive estimates of global costs and benefits of adaptation are limited. {4.2, Table 4.1}

4.02 Societies have a long record of managing the impacts of weather- and

4

Adaptation and Mitigation Options

We can respond to climate change in two ways:

- **Adaptation involves developing ways to protect ourselves from climate impacts, such as building sea walls to protect communities from rising sea levels.**
- **Mitigation involves slowing the process of climate change by lowering the concentration of greenhouse gases in the atmosphere, for example by reducing emissions or planting trees.**

While such strategies have begun, more extensive adaptation and mitigation efforts are required to reduce our vulnerability to climate change. In addition, there are barriers, limits, and costs associated with any of these strategies. (4.01, 4.03)

➢ *A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. (4.01)*

Societies have a long record of managing impacts of weather- and climate-related events, and adaptation to climate change is already occurring on a limited basis. Nevertheless, additional adaptation measures will be required to reduce the adverse impacts of climate change, regardless of the scale of mitigation undertaken over the next two to climate-related events. Nevertheless, additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. Moreover, vulnerability to climate change can be exacerbated by other stresses. These arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of diseases such as HIV/AIDS. {4.2}

4.04 **Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies.** {4.2}

4.05 A range of barriers limit both the implementation and effectiveness of adaptation measures. The capacity to adapt is dynamic and is influenced by a society's productive base including: natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health and technology. Even societies with high adaptive capacity remain vulnerable to climate change, variability and extremes. {4.2}

4.06 Both bottom-up and top-down studies indicate that there is *high agreement* and *much evidence* of substantial economic potential for the mitigation of global GHG emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels (Figure SPM.9, SPM.10)[15]. While top-down and bottom-up studies are in line at the global level (Figure SPM.9) there are considerable differences at the sectoral level. {4.3}

4.17 Many options for reducing global GHG emissions through international cooperation exist. There is *high agreement* and *much evidence* that notable achievements of the UNFCCC and its Kyoto Protocol are the establishment of a global response to climate

three decades. Adaptation can reduce vulnerability, especially when it is part of a broader set of initiatives. We can implement viable adaptation options at low cost or with high benefit-cost ratios (high confidence). (4.02, 4.03)

However, there are barriers that limit the implementation and effectiveness of adaptation measures. Vulnerability to climate change is exacerbated by other stresses, including poverty and unequal access to resources, food insecurity, conflict, and diseases such as HIV/AIDS. Furthermore, the capacity to adapt to changes in climate is intimately connected to social and economic development, which is unevenly distributed across and within societies. Even societies with high adaptive capacity are vulnerable to climate change. (4.02, 4.04, 4.05)

➢ **The economic potential for the mitigation of global greenhouse gas emissions over the coming decades is substantial, and we could offset the projected growth of global emissions or reduce emissions below current levels (high agreement and much evidence). (4.06)**

We have many options for reducing global greenhouse gas emissions through international cooperation. Notable achievements of the United Nations Framework Convention on Climate Change and its Kyoto Protocol are the establishment of a global response to climate change,

change, stimulation of an array of national policies, and the creation of an international carbon market and new institutional mechanisms that may provide the foundation for future mitigation efforts. Progress has also been made in addressing adaptation within the UNFCCC and additional international initiatives have been suggested. {4.5}

4.10 A wide variety of policies and instruments are available to governments to create the incentives for mitigation action. Their applicability depends on national circumstances and sectoral context (Table SPM5). {4.3}

4.11 They include integrating climate policies in wider development policies, regulations and standards, taxes and charges, tradable permits, financial incentives, voluntary agreements, information instruments, and research, development and demonstration (RD&D). {4.3}

4.07 No single technology can provide all of the mitigation potential in any sector. The economic mitigation potential, which is generally greater than the market mitigation potential, can only be achieved when adequate policies are in place and barriers removed (Table SPM.5).

4.12 An effective carbon-price signal could realise significant mitigation potential in all sectors. Modelling studies show global carbon prices rising to 20-80 US$/t$CO_2$-eq by 2030 are consistent with stabilisation at around 550 ppm CO_2eq by 2100. For the same stabilisation level, induced technological change may lower these price ranges to 5-65 US$/t$CO_2$-eq in 2030.[17] {4.3}

4.16 There is also high agreement and medium evidence that changes in lifestyle, behaviour patterns and management practices can con-

stimulation of an array of national policies, and the creation of an international carbon market and new institutional mechanisms as a foundation for future mitigation efforts. (4.17)

A wide variety of policies and instruments are available to governments to create the incentives for mitigation action. We can

- integrate climate policies in wider development policies
- alter regulations and standards, as well as taxes and charges
- utilize tradable permits, financial incentives, voluntary agreements, and information instruments and
- make use of research, development and demonstration programs (4.10, 4.11)

An effective carbon-price signal, such as high carbon taxes or high energy prices, could realize significant mitigation potential in all sectors. No single technology can provide all of the mitigation potential in any sector of the economy. Changes in lifestyle, behavior patterns, and management practices can contribute to climate change mitigation across all sectors (high agreement and medium evidence). (4.07, 4.12, 4.16)

In addition, mitigation efforts can result in benefits such as improved health due to reduced air pollution that may offset a substantial fraction of mitigation costs. While there is high agreement and much evidence on this point, we do not have comprehensive estimates of global costs and benefits. (4.13) tribute to climate change mitigation across all sectors. {4.3}

4.13 There is high agreement and much evidence that mitigation actions can result in near-term co-benefits (e.g. improved health due to reduced air pollution) that may offset a substantial fraction of mitigation costs. {4.3}

4.09 Future energy infrastructure investment decisions, expected to exceed 20 trillion US$[16] between 2005 and 2030, will have long-term impacts on GHG emissions, because of the long life-times of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a large shift in investment patterns, although the net additional investment required ranges from negligible to 5%–10%. {4.3}

4.19 In several sectors, climate response options can be implemented to realise synergies and avoid conflicts with other dimensions of sustainable development. Decisions about macroeconomic and other non-climate policies can significantly affect emissions, adaptive capacity and vulnerability. {4.4, 5.8}

4.20 Making development more sustainable can enhance mitigative and adaptive capacities, reduce emissions, and reduce vulnerability, but there may be barriers to implementation. On the other hand, it is very likely that climate change can slow the pace of progress towards sustainable development. Over the next half-century, climate change could impede achievement of the Millennium Development Goals. {5.8}

[14] While this section deals with adaptation and mitigation separately,

Our Investment decisions about future energy infrastructure will have long-term impacts on greenhouse gas emissions because of the long life-times of energy plants and other expensive infrastructure. The widespread diffusion of less carbon-intensive energy technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global carbon dioxide emissions to 2005 levels by 2030 would require a large shift in investment patterns, although the net additional investment required ranges from negligible to just 5-10%. (4.09)

Making development more sustainable can enhance adaptation and mitigation efforts, reduce greenhouse gas emissions, and decrease vulnerability to climate change. On the other hand, it is very likely that climate change can slow the pace of progress towards sustainable development. In planning mitigation responses, policy makers must take care that attempts to mitigate climate change do not interfere with sustainable development. Over the next half-century, climate change could impede achievement of the United Nations Millennium Development Goals, which include reducing poverty and combating HIV/AIDS. (4.19, 4.20) these responses can be complementary. This theme is discussed in section 5.

15 The concept of "**mitigation potential**" has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced). Mitigation potential is further differentiated in terms of "market mitigation potential" and "economic mitigation potential".

Market mitigation potential is the mitigation potential based on private costs and private discount rates (reflecting the perspective of private consumers and companies), which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake.

Economic mitigation potential is the mitigation potential, which takes into account social costs and benefits and social discount rates (reflecting the perspective of society; social discount rates are lower than those used by private investors), assuming that market efficiency is improved by policies and measures and barriers are removed.

Mitigation potential is estimated using different types of approaches. ***Bottom-up studies*** are based on assessment of mitigation options, emphasizing specific technologies and regulations. They are typically sectoral studies taking the macro-economy as unchanged. ***Top-down studies*** assess the economy-wide potential of mitigation options. They use globally consistent frameworks and aggregated information about mitigation options and capture macro-economic and market feedbacks.

16 20 trillion = 20,000 billion = 20×10^{12}

[17] Studies on mitigation portfolios and macro-economic costs assessed in this report are based on top-down modelling. Most models use a global least cost approach to mitigation portfolios, with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century. Costs are given for a specific point in time. Global modelled costs will increase if some regions, sectors (e.g. land-use), options or gases are excluded. Global modelled costs will decrease with lower baselines, use of revenues from carbon taxes and auctioned permits, and if induced technological learning is included. These models do not consider climate benefits and generally also co-benefits of mitigation measures, or equity issues. Significant progress has been achieved in applying approaches based on induced technological change to stabilisation studies; however, conceptual issues remain. In the models that consider induced technological change, projected costs for a given stabilisation level are reduced; the reductions are greater at lower stabilisation level.

[18] Further details may be found in Topic 4 of the Synthesis Report.

5. The long-term perspective

5.01 Determining what constitutes "dangerous anthropogenic interference with the climate system" in relation to Article 2 of the UNFCCC involves value judgements. Science can support informed decisions on this issue, including by providing criteria

5

The Long-Term Perspective

In the long term:

➢ There are many reasons to be concerned about climate change, ranging from increased risk of extinctions to rising sea levels.

➢ Adaptation (adjusting our environment to avoid climate impacts) and mitigation (such as decreasing our output of greenhouse gases) are both necessary to reduce adverse impacts of climate change.

➢ It will probably be possible to stabilize greenhouse gas concentrations in the atmosphere using technologies that are currently or will soon be available.

➢ We need to carefully evaluate both (1) the up-front economic costs of mitigation and (2) the non-economic and economic costs of the impacts of climate change.

➢ In the long term, there are many reasons to be concerned about climate change, ranging from increased risk of extinctions to rising sea levels.

Science can support informed decisions for determining what constitutes "dangerous anthropogenic interference with the climate system," as described in Article 2 of the United Nations Framework Convention on Climate Change. The IPCC defines "key vulnerabilities" as being

for judging which vulnerabilities might be labelled "key". {Box 'Key Vulnerabilities and Article 2 of the UNFCCC', topic 5}

5.02 Key vulnerabilities[19] may be associated with many climate sensitive systems including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation.{Box "Key Vulnerabilities and Article 2 of the UNFCCC', topic 5}

5.03 The five "reasons for concern" identified in the TAR remain a viable framework to consider key vulnerabilities. These "reasons" are assessed here to be stronger than in the TAR. Many risks are identified with higher confidence. Some risks are projected to be larger or to occur at lower increases in temperature. Understanding about the relationship between impacts (the basis for "reasons for concern" in the TAR) and vulnerability (that includes the ability to adapt to impacts) has improved. {5.2}

- **5.05 Risks to unique and threatened systems.** There is new and stronger evidence of observed impacts of climate change on unique and vulnerable systems (such as polar and high mountain communities and ecosystems), with increasing levels of adverse impacts as temperatures increase further. An increasing risk of species extinction and coral reef damage is projected with *higher confidence* than in the TAR as warming proceeds. There is *medium confidence* that approximately 20%–30% of plant and animal species assessed so far are *likely* to be at increased risk of extinction if increases in global average temperature exceed 1.5°C–2.5°C over 1980-1999 levels. Confidence has increased that a 1°C–2°C increase in global mean temperature above 1990 levels (about 1.5°C –2.5°C above pre-industrial) poses significant risks to many unique and threatened systems including many biodiversity hotspots. Corals are vulnerable to thermal stress and have low

associated with climate sensitive systems, including the food supply, infrastructure, human health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and oceanic and atmospheric circulation. (5.01, 5.02)

In the last IPCC report in 2001, five "reasons for concern" were identified. These remain a useful framework to consider key vulnerabilities. These reasons for concern are even stronger now than they were six years ago. (5.03)

The five "reasons for concern" are

1. **Loss of species and ecosystems.** There is new and stronger evidence of the impacts of climate change on unique and vulnerable systems, such as polar and high mountain communities and ecosystems. This evidence suggests adverse impacts will increase as temperatures increase further. The IPCC projects an increasing risk of species extinction and coral reef damage with higher confidence than in the earlier report as warming proceeds. Approximately 20-30% of plant and animal species are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C over 1980-1999 levels (medium confidence). Confidence has increased that a 1-2°C increase in global mean temperature above 1990 levels (about 1.5-2.5°C above pre-industrial) poses significant risks to many unique and threatened systems, including many biodiversity hotspots. Corals are vulnerable to thermal stress and have low ability to adapt. Increases in sea surface temperature of about 1-3°C are projected to result in more frequent coral bleaching and widespread mortality. The IPCC projects increasing vulnerability of indigenous communities in the Arctic and small island communities to warming.

adaptive capacity. Increases in sea surface temperature of about 1°C–3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals. Increasing vulnerability of indigenous communities in the Arctic and small island communities to warming is projected.

- **Risks of extreme weather events.** Responses to some recent extreme events reveal higher levels of vulnerability than the TAR. There is now higher confidence in the projected increases in droughts, heatwaves, and floods as well as their adverse impacts.

- **Distribution of impacts and vulnerabilities.** There are sharp differences across regions and those in the weakest economic position are often the most vulnerable to climate change. There is increasing evidence of greater vulnerability of specific groups such as the poor and elderly in not only developing but also developed countries. Moreover, there is increased evidence that low-latitude and less-developed areas generally face greater risk, for example in dry areas and mega-deltas.

- **Aggregate impacts**. Compared to the TAR, initial net market-based benefits from climate change are projected to peak at a lower magnitude of warming, while damages would be higher for larger magnitudes of warming. The net costs of impacts of increased warming are projected to increase over time.

- **Risks of large-scale singularities.** There is high confidence that global warming over many centuries would lead to a sea level rise contribution from thermal expansion alone which is projected to be much larger than observed over the 20th century, with loss of coastal area and associated impacts. There is better understanding than in the TAR that the risk of additional contributions to sea

2. **Extreme weather events.** Responses to some recent extreme events reveal higher levels of vulnerability than in the earlier report. There is now higher confidence in the projected increases in droughts, heat waves, and floods as well as their adverse impacts.

3. **Uneven distribution of impacts and vulnerabilities.** There are sharp differences across regions, and those in the weakest economic position are often the most vulnerable to climate change. There is increasing evidence that specific groups such as the poor and elderly are more vulnerable, in not only developing but also developed countries. Moreover, there is increased evidence that low-latitude and less-developed areas generally face greater risk.

4. **Increased costs and decreased benefits of climate change.** Economic benefits from climate change are projected to peak at a lower magnitude of warming, while damages are higher for larger magnitudes of warming, compared to those projected in the earlier report. The IPCC projects that the net costs of impacts of increased warming will increase over time.

5. **Large rise in sea level. Sea level rise under warming is inevitable.** Sea levels will rise due to both warming of the oceans (thermal expansion) and melting of ice sheets. Thermal expansion alone over many centuries will lead to a rise in sea level. The IPCC projects this rise will be much larger than that observed in the 20th century, with loss of coastal areas (high confidence). In addition to the rise due to thermal expansion, melting of the Greenland and Antarctic ice sheets could add greatly to sea level rise. Melting of the Greenland sheet alone could add several meters to sea levels, if warming in excess of 1.9-4.6°C above pre-industrial levels is sustained over many centuries; this contribution could well be larger than that from thermal expansion. Recent observations not considered in the IPCC 4th Assessment Report will help scientists further refine their

level rise from both the Greenland and possibly Antarctic ice sheets may be larger than projected by ice sheet models and could occur on century time scales. This is because ice dynamical processes seen in recent observations but not fully included in ice sheet models assessed in AR4 could increase the rate of ice loss.

5.11 Sea level rise under warming is inevitable. Thermal expansion would continue for many centuries after GHG concentrations have stabilised, for any of the stabilisation levels assessed, causing an eventual sea level rise much larger than projected for the 21st century. The eventual contributions from Greenland ice sheet loss could be several metres, and larger than from thermal expansion, should warming in excess of 1.9°C–4.6°C above pre-industrial be sustained over many centuries. The long time scales of thermal expansion and ice sheet response to warming imply that stabilisation of GHG concentrations at or above present levels would not stabilise sea level for many centuries. {5.3, 5.4}

5.03 The five "reasons for concern" identified in the TAR remain a viable framework to consider key vulnerabilities. These "reasons" are assessed here to be stronger than in the TAR. Many risks are identified with higher confidence. Some risks are projected to be larger or to occur at lower increases in temperature. Understanding about the relationship between impacts (the basis for "reasons for concern" in the TAR) and vulnerability (that includes the ability to adapt to impacts) has improved. {5.2}

5.04 This is due to more precise identification of the circumstances that make systems, sectors and regions especially vulnerable, and growing evidence of the risks of very large impacts on multiple century time scales. {5.2}

models of how the ice sheets will react to warming. Due to the long time scales of thermal expansion and ice sheet melting, sea levels will continue to rise for many centuries after greenhouse gas concentrations stabilize, resulting in sea levels much higher than those projected for the 21st century. (5.05, 5.11)

Many of these risks are identified with higher confidence than in the earlier report. The IPCC projects some risks to be larger or to occur at lower increases in temperature. In addition, there is growing evidence that very large impacts may occur on the scale of multiple centuries. (5.03, 5.04)

5.06 There is *high confidence* that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change.{5.3}

5.17 Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity, and attitudes to risk. {5.1}

5.07 Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilisation scenarios assessed. There are barriers, limits and costs, but these are not fully understood. Unmitigated climate change would, in the long term, be *likely* to exceed the capacity of natural, managed and human systems to adapt. The time at which such limits could be reached will vary between sectors and regions. Early mitigation actions would avoid further locking in carbon intensive infrastructure and reduce climate change and associated adaptation needs. {5.2, 5.3}

5.08 Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels. Delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts. {5.3, 5.4, 5.7}

➢ ***Adaptation (adjusting our environment to avoid climate impacts) and mitigation (such as decreasing our output of greenhouse gases) are both necessary to reduce adverse impacts of climate change.***

Neither adaptation nor mitigation alone can avoid all climate change impacts; instead, they complement each other and together can significantly reduce the risks of climate change. (5.06, 5.17)

Adaptation is necessary in the short and long term to address impacts resulting from global warming that would occur in even the most positive scenarios. Without mitigation, human and natural ecosystems will probably not be able to adapt to climate change, although different systems will experience critical impacts at different times in the coming years. Early mitigation would (1) reduce climate change, (2) help us avoid costly adaptation measures, and (3) prevent us from building carbon-intensive infrastructure, such as coal-based power plants. (5.07)

Many impacts can be reduced, delayed or avoided by mitigation. Effective mitigation actions over the next two to three decades would give us the opportunity to achieve lower stabilization levels of greenhouse gases and temperature. In contrast, delaying emission reductions will make it more difficult to achieve low stabilization levels and will increase the risk of more severe climate change impacts. (5.08)

5.13 All assessed stabilisation scenarios indicate that 60-80% of the reductions would come from energy supply and use, and industrial processes, with energy efficiency playing a key role in many scenarios. Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. Low stabilisation levels require early investments and substantially more rapid diffusion and commercialisation of advanced low-emissions technologies.

5.14 Without substantial investment flows and effective technology transfer, it may be difficult to achieve emission reduction at a significant scale. Mobilizing financing of incremental costs of low-carbon technologies is important.{5.5}

5.12 There is *high agreement* and *much evidence* that all stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are either currently available or expected to be commercialised in coming decades, assuming appropriate and effective incentives are in place for their development, acquisition, deployment and diffusion and addressing related barriers. {5.5}

5.13 All assessed stabilisation scenarios indicate that 60-80% of the reductions would come from energy supply and use, and industrial processes, with energy efficiency playing a key role in many scenarios. Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. Low stabilisation levels require early investments and substantially more rapid diffusion and commercialisation of advanced low-emissions technologies.

In order for mitigation to be effective, advanced low-emissions technologies must be rapidly commercialized and diffused. Without substantial investment flows and effective technology transfer, it may be difficult to achieve emission reduction at a significant scale. (5.13, 5.14)

➢ ***It will probably be possible to stabilize greenhouse gas concentrations in the atmosphere using technologies that are currently or will soon be available.***

The IPCC believes that it will be possible to stabilize greenhouse gas concentrations in the atmosphere using technologies that are currently available or expected to be commercialized in the coming decades (high agreement and much evidence). However, in order for these technologies to be effective in mitigating emissions, incentives must be in place and barriers to their use must be removed. (5.12)

All stabilization scenarios indicate that 60-80% of the reductions would come from changes in energy supply and use, with energy efficiency playing a key role in many scenarios. Including land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. (5.13)

5.15 **The macro-economic costs of mitigation generally rise with the stringency of the stabilisation target (Table SPM.7). For specific countries and sectors, costs vary considerably from the global average.**[22] {5.6}

5.16 In 2050, global average macro-economic costs for mitigation towards stabilisation between 710 and 445ppm CO_2eq are between a 1% gain and 5.5% decrease of global GDP (Table SPM.7). This corresponds to slowing average annual global GDP growth by less than 0.12 percentage points. {5.6}

5.18 Impacts of climate change are *very likely* to impose net annual costs which will increase over time as global temperatures increase. Peer-reviewed estimates of the social cost of carbon[23] in 2005 average US$12 per tonne of CO_2, but the range from 100 estimates is large (-$3 to $95/t$CO_2$). This is due in large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and noneconomic impacts, the inclusion of potentially catastrophic losses, and discount rates. Aggregate estimates of costs mask significant differences in impacts across sectors, regions and populations and *very likely* underestimate damage costs because they cannot include many non-quantifiable impacts. {5.7}

5.19 Limited and early analytical results from integrated analyses of the costs and benefits of mitigation indicate that they are broadly comparable in magnitude, but do not as yet permit an unambiguous determination of an emissions pathway or stabilisation level where benefits exceed costs. {5.7}

➢ ***We need to carefully evaluate both 1) the up-front economic costs of mitigation and 2) the non-economic and economic costs of the impacts of climate change.***

Not surprisingly, the estimated economic costs of mitigation are inversely proportional to the greenhouse gas stabilization targets; that is, expected mitigation costs are highest for the lowest greenhouse gas stabilization targets. (5.15)

In 2050, the total global cost of stabilizing greenhouse gas concentrations between 445 and 710 ppm carbon dioxide equivalents ranges from a 5.5% decrease in global GDP to a 1% increase. (In 2005 the carbon dioxide equivalent was 375 ppm.) Even the most stringent mitigation efforts correspond to slowing average annual global GDP growth by less than 0.12 percentage points. (5.16)

The costs of climate change impacts are very likely to increase over time as global temperatures increase. In addition, certain sectors, regions and populations will suffer especially heavy impacts and costs. Because economic models are not able to quantify all impacts, these models very likely underestimate damage costs. (5.18)

Current analyses indicate that the costs and benefits of mitigation are similar, although these results are still tentative. These analyses do not yet permit clear determination of an emissions pathway or stabilization level where benefits exceed costs. (5.19)

5.21 Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay. {5.4}

[19] Key Vulnerabilities can be identified based on a number of criteria in the literature, including magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and 'importance' of the impacts.
would need to peak by 2015 and for the highest by 2090 (see Table

[22] See footnote 17 for more detail on cost estimates and model assumptions.

[23] Net economic costs of damages from climate change aggregated across the globe and discounted to the specified year.

Choices about the scale and timing of greenhouse gas mitigation involve balancing the economic costs of more rapid emission reductions now against the medium-term and long-term risks of delay. (5.21)