Defining Dangerous Climate Change: Does the IPCC Fourth Assessment provide guidance on what is dangerous climate change?

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Article 2 of the UNFCCC

• “The ultimate objective of this Convention and any related legal instruments … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”
Scenarios for GHG emissions 2000 to 2100 and projections of surface temperatures

Scenarios do not include additional climate policies
Risk aspects

• *Carbon cycle feedbacks*: Warming reduces terrestrial and ocean uptake of atmospheric CO2, increasing the fraction of anthropogenic emissions remaining in the atmosphere.

• *Sea level rise*: Projections do not include:
  – Uncertainties in climate-carbon cycle feedbacks
  – Full effects of changes in ice sheet flow
  – Upper values of the ranges are not to be considered upper bounds for sea level rise.
Higher confidence in projected regional changes

• Warming greatest over land and high north
• Precipitation increases in high latitudes
• Precipitation decreases in most subtropical land regions
• Increase in frequency of hot extremes, heat waves, and heavy precipitation
• Increase in tropical cyclone intensity;
• Contraction of snow cover, permafrost thaw
• Decreases in sea ice extent
Projected surface temperature (2090-2099)

Average projection for the A1B SRES scenario relative to the period 1980-1999. SYR Figure SPM. 6
Regional changes

• *High confidence* that by mid-century, annual river runoff and water availability increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics.

• *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.
Relative changes in annual runoff
% 2090-2099, relative to 1980-1999

White areas - less than 66% of 12 considered models agree on sign of change.
Stippled areas - more than 90% models agree on sign of change.
Especially affected systems and sectors

• Ecosystems:
  – Tundra, boreal forest and mountain regions
  – Mediterranean-type ecosystems
  – Tropical rainforests where precipitation declines
  – Coral reefs, Mangroves and salt marshes
  – Sea ice biome

• Water resources  - some dry regions at mid-latitudes, dry tropics, areas dependent on snow and ice melt

• Agriculture in low-latitudes

• Low-lying coastal systems

• Human health  - populations with low adaptive capacity.
Especially affected regions

- Arctic
  - Impacts of high rates of projected warming on natural systems and human communities
- Africa
  - Low adaptive capacity and projected climate change impacts
- Small islands
  - High exposure to projected climate change impacts
- Asian and African megadeltas
  - Large populations and high exposure to sea level rise, storm surges and river flooding.
- Some people (such as the poor, young children, and the elderly) can be particularly at risk even in high income countries
Figure SPM.2. Key impacts as a function of increasing global average temperature change

(Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)

<table>
<thead>
<tr>
<th>Global mean annual temperature change relative to 1980-1999 (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>---</td>
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<tr>
<td><strong>WATER</strong></td>
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<tr>
<td>Increased water availability in moist tropics and high latitudes</td>
</tr>
<tr>
<td>Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes</td>
</tr>
<tr>
<td>Hundreds of millions of people exposed to increased water stress</td>
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<tr>
<td>3.4.1, 3.4.3</td>
</tr>
<tr>
<td>3.4.1.1, 3.4.3</td>
</tr>
<tr>
<td>3.5.1, T3.3, 20.6.2, TS.B5</td>
</tr>
<tr>
<td><strong>ECOSYSTEMS</strong></td>
</tr>
<tr>
<td>Up to 30% of species at increasing risk of extinction</td>
</tr>
<tr>
<td>Significant extinctions around the globe</td>
</tr>
<tr>
<td>Increased coral bleaching</td>
</tr>
<tr>
<td>Most corals bleached</td>
</tr>
<tr>
<td>Widespread coral mortality</td>
</tr>
<tr>
<td>Terrestrial biosphere tends toward a net carbon source as:</td>
</tr>
<tr>
<td>~15%</td>
</tr>
<tr>
<td>~40% of ecosystems affected</td>
</tr>
<tr>
<td>4.ES, 4.4.11</td>
</tr>
<tr>
<td>T4.1, F4.4, B4.4, 6.4.1, 6.6.5, B6.1</td>
</tr>
<tr>
<td><strong>FOOD</strong></td>
</tr>
<tr>
<td>Complex, localised negative impacts on small holders, subsistence farmers and fishers</td>
</tr>
<tr>
<td>Tendencies for cereal productivity to decrease in low latitudes</td>
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<tr>
<td>Productivity of all cereals decreases in low latitudes</td>
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<tr>
<td>Tendencies for some cereal productivity to increase at mid- to high latitudes</td>
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<tr>
<td>Cereal productivity to decrease in some regions</td>
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<tr>
<td>5.ES, 5.4.7</td>
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<tr>
<td>5.ES, 5.4.2, F5.2</td>
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<tr>
<td>5.ES, 5.4.2, F5.2</td>
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<tr>
<td><strong>COASTS</strong></td>
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<tr>
<td>Increased damage from floods and storms</td>
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<tr>
<td>About 30% of global coastal wetlands lost</td>
</tr>
<tr>
<td>Millions more people could experience coastal flooding each year</td>
</tr>
<tr>
<td>6.ES, 6.3.2, 6.4.1, 6.4.2</td>
</tr>
<tr>
<td>6.4.1</td>
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<tr>
<td>T6.6, F6.8, TS.B5</td>
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<tr>
<td><strong>HEALTH</strong></td>
</tr>
<tr>
<td>Increasing burden from malnutrition, diarrhoeal, cardio-respiratory, and infectious diseases</td>
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<tr>
<td>Increased morbidity and mortality from heat waves, floods, and droughts</td>
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<tr>
<td>Changed distribution of some disease vectors</td>
</tr>
<tr>
<td>Substantial burden on health services</td>
</tr>
<tr>
<td>8.ES, 8.4.1, 8.7, T8.2, T8.4</td>
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<tr>
<td>8.ES, 8.2.2, 8.2.3, 8.4.1, 8.4.2, 8.7, T8.3, F8.3</td>
</tr>
<tr>
<td>8.ES, 8.2.8, 8.7, B8.4</td>
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<tr>
<td>8.6.1</td>
</tr>
</tbody>
</table>

\(^1\) Significant is defined here as more than 40%.
\(^2\) Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.
Examples of regional impacts

### Africa
- **75 to 250 million**
- **350 to 600 million**
- **2 to 5% decrease in wheat and maize in India**
- **5 to 12% decrease in rice in China**
- **Crop yield potential**
- **Up to 2 million**
- **Up to 7 million**
- **Additional people at risk of coastal flooding each year**

### Asia
- **0.1 to 1.2 billion**
- **Annual bleaching of Great Barrier Reef**
- **3,000 to 5,000 more heat related deaths per year**
- **Murray-Darling River flow**
- **Decreasing water security in south and east Australia and parts of east New Zealand**

### Australia / New Zealand
- **Decreasing water security in south and east Australia and parts of east New Zealand**

### Europe
- **+5 to +15% in Northern Europe**
- **0 to -25% in Southern Europe**
- **+2 to +10% in Northern Europe**
- **+3 to +4% in Southern Europe**
- **Water availability**
- **Wheat yield potential**

### Latin America
- **Many tropical glaciers disappear**
- **Many mid-latitude glaciers disappear**

### North America
- **5 to 20% increase in crop yield potential**
- **Decreased space heating and increased space cooling**
- **About 70% increase in hazardous ozone days**
- **3 to 8 times increase in heatwave days in some cities**

### Polar Regions
- **Increase in depth of seasonal thaw of Arctic permafrost**
- **15 to 25%**
- **20 to 35% reduction of Arctic permafrost area**
- **10 to 50% Arctic tundra replaced by forest**
- **15 to 25% polar desert replaced by tundra**
- **20 to 35% decrease average Arctic sea ice area**

### Small Islands
- **Increasing coastal inundation and damage to infrastructure due to sea-level rise**
- **Allen species colonise mid- and high latitude islands**
- **Agricultural losses up to 5% GDP in high terrain islands, up to 20% GDP in low terrain islands**

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**WGII Table**

**TS.4.**
Climate change and risks to sustainable development

• Very likely that climate change can slow the pace of progress towards sustainable development.

• Climate change could impede achievement of the Millennium Development Goals over next half century
“Reasons for concern” identified in Third Assessment Report

- Risks to unique and threatened systems
- Risks of extreme weather events
- Distribution of impacts and vulnerabilities
- Aggregate impacts
- Risks of large-scale singularities
“Reasons for concern” are now assessed to be stronger

- Many risks identified with higher confidence
- Some projected to be larger or to occur at lower increases in temperature.
  - (1) Better understanding of the magnitude of impacts and risks associated with increases temperature
  - (2) More precise identification of the circumstances that make systems and regions especially vulnerable
  - (3) Growing evidence that the risk of very large impacts on multiple century time scales would continue to increase as long as GHG concentrations and temperature continue to increase.
Risks to unique and threatened systems

- New and stronger evidence of observed impacts
- Increasing risk of species extinction and coral reef damage:
  - 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in temperature exceed 2-3°C over preindustrial
  - 1.5-2.5°C increase in temperature above pre-industrial poses significant risks to many unique and threatened systems including many biodiversity hotspots.
  - Increases in sea surface temperature of 1-3°C projected to result in more frequent coral bleaching events and widespread coral mortality
- Increasing vulnerability of indigenous communities in the Arctic and small island communities to warming
Figure TS.6. Projected risks due to critical climate change impacts on ecosystems

- > 4°C: Major extinctions around globe (as exemplified for USA and Australia)
  ≥ 40% of global ecosystems transformed (culminating in biome changes)

Few ecosystems can adapt; 50% of nature reserves cannot fulfill their objectives

Extinction of 15-40% endemic species in global biodiversity hotspots

Widespread coral mortality (reefs overgrown by algae)

Major changes in polar systems; Globally, ~20-30% of species committed to extinction

Extinction risk for polar species; Risk terrestrial biosphere becomes net C source

≥ 15% of global ecosystems transformed (culminating in biome changes)

Major (~20-80%) loss of Amazon rainforest and its biodiversity

Loss of ~50-65% fynbos, ~10-80% of various fauna in S. Africa

~40-50% loss of endemic plants in S. Africa, Namibia

Major (~50%) loss of rainforest habitat in Queensland

Coral reefs bleached

~10-15% of species committed to extinction

Loss of 8% freshwater fish habitat in N. America

Polar ecosystems increasingly damaged

Increased coral reef bleaching

Amphibian extinctions increasing on mountains
Figure TS.14. Key hotspots for Latin America

- Coral reefs and mangroves seriously threatened with warmer SST
- Under the worst sea-level rise scenario, mangroves are very likely to disappear from low-lying coastlines
- Amazonia: loss of 43% of 69 tree species by the end of 21st century; savannisation of the eastern part
- Cerrados: Losses of 24% of 138 tree species for a temperature increase of 2°C
- Reduction of suitable lands for coffee
- Increases in aridity and scarcity of water resources
- Sharp increase in extinction of: mammals, birds, butterflies, frogs and reptiles by 2050
- Water availability and hydro-electric generation seriously reduced due to reduction in glaciers
- Ozone depletion and skin cancer
- Severe land degradation and desertification
- Rio de la Plata coasts threatened by increasing storm surges and sea-level rise
- Increased vulnerability to extreme events

Areas in red correspond to sites where biodiversity is currently severely threatened and this trend is very likely to continue in the future.
Risks of extreme weather events

- Responses to some recent extreme climate events reveal higher levels of vulnerability in both developing and developed countries.
- Higher confidence in the projected increases in droughts, heat-waves, and floods as well as their adverse impacts.
- Mostly adverse impacts:
  - Increased water stress and wild fire frequency
  - Adverse effects on food production and health
  - Increased flood risk and extreme high sea level, and damage to infrastructure.
# Impacts of extreme events

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Likelihood</th>
<th>Examples of major projected impacts by sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased frequency of heavy precipitation events.</td>
<td>Very likely</td>
<td>- Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increased risk of deaths, injuries and infectious, respiratory and skin diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property</td>
</tr>
<tr>
<td>Increased area affected by drought</td>
<td>Likely</td>
<td>- Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- More widespread water stress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water-and food-borne diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration</td>
</tr>
</tbody>
</table>
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.
- Increasing evidence of greater vulnerability of specific groups such as the poor and elderly.
- Increased evidence that low-latitude and less-developed areas generally face greater risk, for example in dry areas and mega-deltas.
Figure TS.8. Relative vulnerability of coastal deltas
Figure TS.7. Sensitivity of cereal yield to climate change

(a) Maize, mid- to high-latitude

(b) Maize, low latitude

(c) Wheat, mid- to high-latitude

(d) Wheat, low latitude
Water resource risks

• Decreases in precipitation are a major driver of many risks in many dry areas and a reduction, by as much as about 20%, is likely in many of them for a global average warming of about 2.8°C above 1980-1999 levels, with a decrease in water resources projected.
Aggregate impacts

• Market based estimates:
  – Likely that there will be higher damages than estimated in the TAR
  – Net costs of impacts of increased warming are projected to increase over time.

• Other metrics
  – Likely adverse effects on hundreds of millions of people through increased coastal flooding, reductions in water supplies, increased malnutrition and increased health impacts.
Figure TS.18. Estimated millions of people per annum at risk globally from coastal flooding
Risks of large-scale singularities

• Risk that additional sea level rise from both the Greenland and Antarctic ice sheets may be larger than projected and could occur on century time scales.

• Ice dynamical processes seen in recent observations but not fully included in ice sheet models could increase the rate of ice loss.
Greenland ice sheet
Antarctic ice sheet
Greenland loss increasing
IPCC AR4 Finds Greater Risks
Risk aspects

• *Carbon cycle feedbacks*: Warming reduces terrestrial and ocean uptake of atmospheric CO2, increasing the fraction of anthropogenic emissions remaining in the atmosphere.

• *Sea level rise*: Projections do not include:
  – Uncertainties in climate-carbon cycle feedbacks
  – Full effects of changes in ice sheet flow
  – Upper values of the ranges are not to be considered upper bounds for sea level rise.
Mitigation and Adaptation

- Neither adaptation nor mitigation alone can avoid all climate change impacts.
- Many impacts can be reduced, delayed or avoided by mitigation.
- Adaptation options available, but more than is currently occurring is required
  - There are barriers, limits and costs
- Delayed emission reductions:
  - Constrain opportunities to achieve lower stabilisation levels
  - Increase the risk of more severe climate change impacts.
Reducing impacts, risks and vulnerabilities

Above preindustrial

| Global mean annual temperature change relative to 1980-1999 (°C) |
|---|---|---|---|---|
| 1.5°C | 2°C | 3°C | 4°C |

**WATER**
- Increased water availability in most tropics and high latitudes
- Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
- 0.4 to 1.7 billion

**ECOSYSTEMS**
- Increasing amphibian extinction
- Increased coral bleaching
- Most corals bleached
- Widespread coral mortality
- Terrestrial biosphere tends toward a pre-industrial carbon source, as: ~40% of ecosystems affected

**FOOD**
- Crop productivity
- Low latitudes
- Decreased for some cereals
- Increased for some cereals
- Mid to high latitudes
- All cereals decrease
- Decreases in some regions

**COAST**
- Increased damage from floods and storms
- Additional people at risk of coastal flooding each year: 0 to 3 million
- About 30% of coastal wetlands

**HEALTH**
- Increasing burden from malnutrition, diarrhoea, cardio-respiratory and infectious diseases
- Increased morbidity and mortality from heatwaves, floods and droughts
- Changed distribution of some disease vectors
- Substantial burden on health services

**SINGULAR EVENTS**
- Local retreat of ice in Greenland and West Antarctic
- Long term commitment to several metres of sea-level rise due to ice sheet loss
- Leading to reconfiguration of coastlines worldwide and inundation of low-lying areas
- Ecosystem changes due to weakening of the meridional overturning circulation

UNEP
Reducing impacts, risks and vulnerabilities

Above preindustrial 1.5°C 2°C 3°C 4°C

Global mean annual temperature change relative to 1980-1999 (°C)

AFRICA

Above preindustrial

1.5°C 2°C 3°C 4°C

Global mean annual temperature change relative to 1980-1999 (°C)

IPCC

WGII

Table

TS.4.
Risk management perspective

• Responding to climate change involves an iterative risk management process
• Includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity, and attitudes to risk.
• Limiting global average warming could reduce likelihood impacts and risks
## Stabilization levels

### Concentration, Global mean temperature increase, Peaking year, CO₂ emission change

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Concentration</th>
<th>Global mean temperature increase</th>
<th>Peaking year</th>
<th>CO₂ emission change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>445 – 490 ppm CO₂-eq</td>
<td>2.0 – 2.4 ⁰C</td>
<td>2000 - 2015</td>
<td>-85 to -50</td>
</tr>
<tr>
<td>A2</td>
<td>490 – 535 ppm CO₂-eq</td>
<td>2.4 – 2.8 ⁰C</td>
<td>2000 - 2020</td>
<td>-60 to -30</td>
</tr>
<tr>
<td>B</td>
<td>535 – 590 ppm CO₂-eq</td>
<td>2.8 – 3.2 ⁰C</td>
<td>2010 - 2030</td>
<td>-30 to +5</td>
</tr>
<tr>
<td>C</td>
<td>590 – 710 ppm CO₂-eq</td>
<td>3.2 – 4.0 ⁰C</td>
<td>2020 - 2060</td>
<td>+10 to +60</td>
</tr>
<tr>
<td>D</td>
<td>710 – 855 ppm CO₂-eq</td>
<td>4.0 – 4.9 ⁰C</td>
<td>2050 - 2080</td>
<td>+25 to +85</td>
</tr>
<tr>
<td>E</td>
<td>855 – 1130 ppm CO₂-eq</td>
<td>4.9 – 6.1 ⁰C</td>
<td>2060 - 2090</td>
<td>+90 to +140</td>
</tr>
</tbody>
</table>
Costs

What are the macro-economic costs in 2030?

• Costs are global average for least cost approaches from top-down models
• Costs do not include co-benefits and avoided climate change damages

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>590-710</td>
<td>0.2</td>
<td>-0.6 – 1.2</td>
<td>&lt; 0.06</td>
</tr>
<tr>
<td>535-590</td>
<td>0.6</td>
<td>0.2 – 2.5</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

[1] This is global GDP based market exchange rates.
[2] The median and the 10th and 90th percentile range of the analyzed data are given.
[3] The calculation of the reduction of the annual growth rate is based on the average reduction during the period till 2030 that would result in the indicated GDP decrease in 2030.
[4] The number of studies that report GDP results is relatively small and they generally use low baselines.
Costs

Illustration of cost numbers

GDP

current

~1 year

Time

GDP without mitigation

GDP with stringent mitigation

80%

77%
What does US$ 50/ tCO2eq mean?

- Crude oil: ~US$ 25/ barrel
- Gasoline: ~12 ct/ litre (50 ct/gallon)
- Electricity:
  - from coal fired plant: ~5 ct/kWh
  - from gas fired plant: ~1.5 ct/kWh
**Implications of ca 2°C scenarios**

<table>
<thead>
<tr>
<th>CO₂-equivalent Stabilization level (2005 = 375 ppm CO₂e)</th>
<th>Global Mean temperature increase at equilibrium (°C)</th>
<th>Global average sea level rise at equilibrium from thermal expansion only</th>
<th>Year global CO₂ needs to peak</th>
<th>Reduction in 2050 global CO₂ emissions compared to 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>445 – 490</td>
<td>2.0 – 2.4</td>
<td>0.4 – 1.4</td>
<td>2000 – 2015</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario category</th>
<th>Region</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-450 ppm CO₂ – eq²</td>
<td>Annex I</td>
<td>-25% to -40%</td>
<td>-80% to -95%</td>
</tr>
<tr>
<td></td>
<td>Non-Annex I</td>
<td>Substantial deviation from baseline in Latin America, Middle East, East Asia</td>
<td>Substantial deviation from baseline in all regions</td>
</tr>
</tbody>
</table>

1) CO₂-equivalent stabilization level
2) CO₂-equivalent
2°C and lower stabilization levels

Source: M. Meinshausen (2006)
Global GHG emissions (Kyoto GHGs including LULUCF)

~50:50 chance <2°C
Peaking ~500ppm CO2eq & Stabilization ~450ppm CO2eq

~3:1 chance <2°C
Peaking ~475ppm CO2eq & Stabilization ~400ppm CO2eq

Global Peak ~2015

Notes:
(a) Historic 1990-2001 GHG emissions including LUCV/LULUCF for Annex I countries based on Table II-7 in UNFCCC (2005) “Key GHG Data”.
(b) Shown are various multi-gas FAIR-SIMCAP (van den Elzen & Meinshausen, 2006) and
      SRES-CIEMAS (Meinshausen et al. 2006) relative to 1990 for peaking at approximately 500ppm and stabilizing at 450ppm CO2eq (grey pathways) and peaking at 475 with subsequent stabilization at 400ppm CO2eq (green pathways).
(c) The here shown pathways comprise the SRES country groups OECD90 and REF (Economies in Transition). Note that the absolute GHG emission data is (~15%) higher compared to absolute Annex I emissions reported to the UNFCCC, partially due to non-reported sources, as landuse related emissions, and slight differences in countries (Turkey, some REF).
(d) The probabilities are given to stay below 2°C global-mean warming relative to preindustrial levels, assuming an IPCC consistent climate sensitivity pdf with a 90% confidence that climate sensitivity lies between 1.5°C and 4.5°C (for details see Chapter 28 in Schellnhuber et al. “Avoiding Dangerous Climate Change”, 2006).
(e) The light and dark patches show the mean plus / minus one and two standard deviations, respectively, for the set of analysed FAIR-SIMCAP and ECW pathways.
(f) The calculations imply default MAGICC carbon cycle feedbacks, comparable to approximately the mean across the CMIP studies (Friedlingstein et al. 2005).
Notes: (a) Historic 1990-2003 GHG emissions including LUCF/LULUCF for Annex I country groups based on Table II-7 in UNFCCC (2005) "Key GHG Data"; (b) Shown are various multi-gas FAIR-SIMCaP (den Elzen & Meinshausen, 2006) and EQW pathways (Meinshausen et al., 2006) relative to 1990 for peaking at approximately 500 ppm and stabilizing at 450 ppm CO2eq (grey pathways) and peaking at 475 with subsequent stabilization at 400 ppm CO2eq (green pathways); (c) The here shown pathways comprise the SRES country groups OECD90 and REF (Economies in Transition). Note that the absolute GHG emission data is (~15%) higher compared to absolute Annex I emissions reported to the UNFCCC, partially due to non-reported sources, as landuse related emissions, and slight differences in countries (Turkey); some REF; (d) The probabilities are given to stay below 2°C global-mean warming relative to preindustrial levels, assuming an IPCC consistent climate sensitivity pdf with a 90% confidence that climate sensitivity lies between 1.5°C and 4.5°C (for details see Chapter 28 in Schellnhuber et al. "Avoiding Dangerous Climate Change" 2006); (e) The light and dark patches show the mean plus / minus one and two standard deviations, respectively, for the set of analysed FAIR-SIMCaP and EQW pathways. (f) The calculations imply default MAGICC carbon cycle feedbacks, comparable to approximately the mean across the C4MIP studies (Friedlingstein et al. 2005).
Global & Annex I GHG emissions (with LULUCF)

Notes: (a) Historic 1990-2003 GHG emissions including LUCF/LULUCF for Annex I country groups based on Table II-7 in UNFCCC (2005) ‘Key GHG Data’;
(b) Shown are various multi-gas FAIR-SiMCaP (den Elzen & Meinshausen, 2006) and EQW pathways (Meinshausen et al. 2006) relative to 1990 for peaking at approximately 500 ppm and stabilizing at 450 ppm CO2eq (grey pathways) and peaking at 475 with subsequent stabilization at 400ppm CO2eq (green pathways);
(c) The here shown pathways comprise the SRES country groups OECD90 and REF (Economies in Transition). Note that the absolute GHG emission data is (~15%) higher compared to absolute Annex I emissions reported to the UNFCCC, partially due to non-reported sources, as landuse related emissions, and slight differences in countries; Turkey, some REF;
(d) The probabilities are given to stay below 2°C global-mean warming relative to preindustrial levels, assuming an IPCC consistent climate sensitivity pdf with a 90% confidence that climate sensitivity lies between 1.5°C and 4.5°C (for details see Chapter 28 in Schellnhuber et al. “Avoiding Dangerous Climate Change?” 2006);
(e) The light and dark patches show the mean plus / minus one and two standard deviations, respectively, for the set of analysed FAIR-SiMCaP and EQW pathways;
(f) The calculations imply default MAGICC carbon cycle feedbacks, comparable to approximately the mean across the C4MIP studies (Friedlingstein et al. 2005).
Annex I: roughly -60% to -80% by 2050 for ~50:50 chance.
The Effect of Delay

- Higher emissions in near future $\rightarrow$ lower emissions at 2030 and beyond
The Effect of Delay

- Higher Emissions in the near-term → Higher reduction rates in medium-term

Maximal reduction rates

- A: ~2.6%/yr
- B: ~3.6%/yr
- C: ~5.4%/yr

Note: percentage relative to current year, not 1990
Conclusions – The Effect of Delay

1. Peaking around 2015

2. Annual reduction rates increase ~1% for each 5 years of delay

3. Half of 1990 GHG emissions by 2050
Role of science

- 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
- Demonstrates that limiting global average warming can reduce likelihood and magnitude of impacts and risks
Synthesis Report can be downloaded from http://www.ipcc.ch/
RISK = Probability X Consequence
RISK = Probability X Consequence

Likelihood or confidence an event will occur

Impact of climate change
Table TS.3. (upper) Global temperature changes for selected time periods, projected for SRES and stabilisation scenarios
Table TS.3. (lower) Examples of global impacts projected for changes in climate (and sea level and atmospheric CO\textsubscript{2} where relevant)

<table>
<thead>
<tr>
<th>WATER</th>
<th>Increased water availability in moist tropics and high latitudes(^1) Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes(^2)</th>
<th>0.4 to 1.7 billion(^3)</th>
<th>1.0 to 2.0 billion(^3)</th>
<th>1.1 to 3.2 billion(^3)</th>
<th>Additional people with increased water stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECOSYSTEMS</td>
<td>Increasing amphibian extinction(^4)</td>
<td>About 20 to 30% species at increasingly high risk of extinction(^4)</td>
<td>Major extinctions around the globe(^4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased coral bleaching(^5) Most corals bleached(^6) Widespread coral mortality(^6)</td>
<td>Terrestrial biosphere tends toward a net carbon sink, as: ~15% ~40% of ecosystems affected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increasing species range shifts and wildfire risk(^7)</td>
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<td></td>
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</tr>
<tr>
<td>FOOD</td>
<td>Crop productivity</td>
<td>Low latitudes Decreases for some cereals Increases for some cereals Mid to high latitudes</td>
<td>All cereals decrease(^9) Decreases in some regions(^9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COAST</td>
<td>Increased damage from floods and storms(^10)</td>
<td>Additional people at risk of coastal flooding each year 0 to 3 million(^12)</td>
<td>2 to 15 million(^12) About 30% loss of coastal wetlands(^11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEALTH</td>
<td>Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases(^13)</td>
<td>Increased morbidity and mortality from heatwaves, floods and droughts(^14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changed distribution of some disease vectors(^15)</td>
<td>Substantial burden on health services(^16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SINGULAR EVENTS</td>
<td>Local retreat of ice in Greenland and West Antarctic(^17)</td>
<td>Long term commitment to several metres of sea-level rise due to ice sheet loss(^17) Leading to reconfiguration of coastlines worldwide and inundation of low-lying areas(^18)</td>
<td></td>
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<tr>
<td></td>
<td>Ecosystem changes due to weakening of the meridional overturning circulation(^19)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Global mean annual temperature change relative to 1980-1999 (°C)
Figure TS.9. Direction and magnitude of change of selected health impacts of climate change

<table>
<thead>
<tr>
<th>Negative impact</th>
<th>Positive impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very high confidence</strong></td>
<td></td>
</tr>
<tr>
<td>Malaria: contraction and expansion, changes in transmission season</td>
<td></td>
</tr>
<tr>
<td><strong>High confidence</strong></td>
<td></td>
</tr>
<tr>
<td>Increase in malnutrition</td>
<td></td>
</tr>
<tr>
<td>Increase in the number of people suffering from deaths, disease and injuries</td>
<td></td>
</tr>
<tr>
<td>from extreme weather events</td>
<td></td>
</tr>
<tr>
<td>Increase in the frequency of cardio-respiratory diseases from changes in air</td>
<td></td>
</tr>
<tr>
<td>quality</td>
<td></td>
</tr>
<tr>
<td>Change in the range of infectious disease vectors</td>
<td></td>
</tr>
<tr>
<td>Reduction of cold-related deaths</td>
<td></td>
</tr>
<tr>
<td><strong>Medium confidence</strong></td>
<td></td>
</tr>
<tr>
<td>Increase in the burden of diarrhoeal diseases</td>
<td></td>
</tr>
</tbody>
</table>
Figure TS.11. Projected future changes in northern Asia permafrost boundary under the SRES A2 scenario for 2100

- Modern southern permafrost boundary
- Permafrost area likely to thaw by 2100
- Permafrost area projected to be under different stages of degradation
Figure TS.16. Vegetation of the Arctic: current conditions and projected changes under the IS92a scenario for 2090-2100
Figure TS.12. Key hotspots in Australia and New Zealand

Kakadu
Salt water intrusion due to rising sea level, displacement of freshwater wetlands by mangroves. Changed species assemblages.

Queensland Wet Tropics
Multiple species extinctions predicted for upland endemic vertebrates for moderate levels of warming. Deterioration of coral reefs. Large losses to built environment from flooding, sea level rise and cyclone storm surges.

South-east Queensland
Ongoing development is likely to be exacerbated by large losses to built environment from rising sea level, storm surges and flooding.

Murray Darling Basin
Reduced water supply for irrigation, cities, industry and environmental flows. Threats to freshwater wetlands such as the Macquarie Marshes. Reduced habitat for migratory birds.

South-western Australia
Drying and water shortages. Range reductions and fragmentation for many endemic plants and crops.

Alpine Zones
Loss of plant and animal species, increase in shrubs at expense of herb fields. Glacier shrinkage and reduction in snow cover. Threats to New Zealand’s built environment from increased flooding, erosion and landslides.

Northland to Bay of Plenty
Ongoing development is likely to be exacerbated by large losses to built environment from rising sea level, storm surges and flooding.

Eastern New Zealand
Water security problems from increased drought and rising demand where irrigation is unavailable.
# Impacts of extreme events

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Likelihood</th>
<th>Agriculture, forestry and ecosystems</th>
<th>Water resources</th>
<th>Human health</th>
<th>Industry, settlement and society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmer and fewer cold days and nights, warmer and more frequent hot days and nights</td>
<td><em>Virtually certain</em></td>
<td>Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks</td>
<td>Effects on water resources relying on snowmelt; effects on some water supplies</td>
<td>Reduced human mortality from decreased cold exposure</td>
<td>Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism</td>
</tr>
<tr>
<td>Warm spells/heat waves. Frequency increased over most land areas</td>
<td><em>Very likely</em></td>
<td>Reduced yields in warmer regions due to heat stress; increased danger of wildfire</td>
<td>Increased water demand; water quality problems, e.g. algal blooms</td>
<td>Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated</td>
<td>Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor</td>
</tr>
</tbody>
</table>
## Impacts of extreme events

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Likelihood</th>
<th>Examples of major projected impacts by sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased frequency of heavy precipitation events.</td>
<td>Very likely</td>
<td>Agriculture, forestry and ecosystems {WGII 4.4, 5.4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water resources {WGII 3.4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Human health {WGII 8.2, 8.4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry, settlement and society {WGII 7.4}</td>
</tr>
<tr>
<td>Increased area affected by drought</td>
<td>Likely</td>
<td>Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased risk of deaths, injuries and infectious, respiratory and skin diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More widespread water stress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration</td>
</tr>
</tbody>
</table>
### Impacts of extreme events

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Likelihood</th>
<th>Agriculture, forestry and ecosystems {WGII 4.4, 5.4}</th>
<th>Water resources {WGII 3.4}</th>
<th>Human health {WGII 8.2, 8.4}</th>
<th>Industry, settlement and society {WGII 7.4}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely</td>
<td>Damage to crops; windthrow (uprooting) of trees; damage to coral reefs</td>
<td>Power outages causing disruption of public water supply</td>
<td>Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders</td>
<td>Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property</td>
</tr>
<tr>
<td>Increases in extreme high sea level</td>
<td>Likely&lt;sup&gt;p&lt;/sup&gt;</td>
<td>Salinisation of irrigation water, estuaries and freshwater systems</td>
<td>Decreased freshwater availability due to saltwater intrusion</td>
<td>Increased risk of deaths and injuries by drowning in floods; migration-related health effects</td>
<td>Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above</td>
</tr>
</tbody>
</table>

<sup>p</sup> *likely, given current scientific understanding.*
CO2 emissions and equilibrium temperature increases for a range of stabilisation levels
Figure TS.19. Geographical distribution of vulnerability in 2050
Greenland

• 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 to 4.6°C relative to pre-industrial 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.
Risks of large-scale singularities

- Sea level rise from thermal expansion alone projected to be much larger than observed over the 20th century
- Greenland Ice Sheet:
  - Complete deglaciation would raise sea level by 7 m
  - Models project that sustained warming in excess of 1.9-4.6°C above pre-industrial would lead to sea level rise of several meters.
- Antarctic Ice Sheet:
  - Models project sea level lowering due to increased precipitation
- Risk that additional sea level rise from both the Greenland and Antarctic ice sheets may be larger than projected and could occur on century time scales.
- Ice dynamical processes seen in recent observations but not fully included in ice sheet models could increase the rate of ice loss.
Total sea level projections

- Antarctic ice sheet reduces sea level over 21st century
- Ad Hoc adjustment for ice sheet dynamics not included in models
- 1993-2003 mean trend extrapolated to 2100
# Limiting temperature increase to 2 degrees C above pre-industrial

<table>
<thead>
<tr>
<th>CO₂-equivalent Stabilization level (2005 = 375 ppm CO2e)</th>
<th>Global Mean temperature increase at equilibrium (°C)</th>
<th>Global average sea level rise at equilibrium from thermal expansion only</th>
<th>Year global CO₂ needs to peak</th>
<th>Reduction in 2050 global CO₂ emissions compared to 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>445 – 490</td>
<td>2.0 – 2.4</td>
<td>0.4 – 1.4</td>
<td>2000 – 2015</td>
<td>-85 to -50</td>
</tr>
<tr>
<td>490 – 535</td>
<td>2.4 – 2.8</td>
<td>0.5 – 1.7</td>
<td>2000 – 2020</td>
<td>-60 to -30</td>
</tr>
<tr>
<td>535 – 590</td>
<td>2.8 – 3.2</td>
<td>0.6 – 1.9</td>
<td>2010 – 2030</td>
<td>-30 to +5</td>
</tr>
<tr>
<td>590 – 710</td>
<td>3.2 – 4.0</td>
<td>0.6 – 2.4</td>
<td>2020 – 2060</td>
<td>+10 to +60</td>
</tr>
<tr>
<td>710 – 855</td>
<td>4.0 – 4.9</td>
<td>0.8 – 2.9</td>
<td>2050 – 2080</td>
<td>+25 to +85</td>
</tr>
<tr>
<td>855 – 1130</td>
<td>4.9 – 6.1</td>
<td>1.0 – 3.7</td>
<td>2060 – 2090</td>
<td>+90 to +140</td>
</tr>
</tbody>
</table>
Long term sea level rise risks

Areas inundated with 20m SLR

Source: Brooks Nicholls Hall 2006
Greenland ice sheet loss accelerating