Chapter 1. Point of Departure

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Frequently Asked Questions
1.1: What is the information basis for the assessment and how has it changed since the last IPCC report?
1.2: How has our understanding of the interface between human, natural, and climate systems expanded since the 2007 IPCC Assessment?
1.3: How is the state of scientific understanding communicated in this report?

References

Executive Summary

The literature available for assessing climate change impacts, adaptation, and vulnerability has more than doubled since 2005 (*very high confidence*). The diversity of the topics and regions covered by the literature has similarly expanded, as well as the geographic distribution of the authors contributing to the knowledge base for climate change assessments. Production of climate change literature has increased in the developing countries, although their institutions lag those in developed countries regarding access to and production of climate change literature. The unequal distribution of literature, which is influenced by factors such as scientific funding and capacity building, presents a challenge to the development of a comprehensive and balanced assessment of the global impacts of climate change. [1.1.1, Figure 1-1]

The evolution of the IPCC assessments of impacts, adaptation, and vulnerability indicates an increasing emphasis on humans, their role in managing resources and natural systems, and the societal impacts of climate change (*very high confidence*). The expanded focus on societal impacts and responses is evident in the composition of the IPCC author teams, the literature assessed, and the content of the IPCC assessment reports. Three important characteristics in the evolution of the Working Group 2 assessment reports are an increasing attention to: (i) Adaptation limits and transformation in societal and natural systems; (ii) Synergies between multiple variables and factors that affect sustainable development, including risk management, and (iii) Institutional, social, cultural, and value-related issues. [1.1, 1.2]

Adaptation has emerged as a central area of work in climate change research, in country level planning and in the implementation of climate change strategies *(high confidence)*. The body of literature shows an increased focus on the capitalizing on adaptation opportunities and the interrelations between adaptation, mitigation and alternative sustainable pathways. In spite of the uncertainty of future impacts and adaptation, the literature shows an emergence of studies on transformative processes that take advantage of synergies between adaptation planning, development strategies, social protection and disaster risk reduction and management. [1.1.4]

The treatment and communication of uncertainties in IPCC reports have evolved over time, reflecting iterative learning and more coherent guidance across all Working Groups *(high confidence)*. An integral feature of IPCC reports is communicating the strength and uncertainties in the scientific understanding underlying assessment findings. In Working Group II, the use of calibrated language began in the SAR, where most chapters used qualitative levels of confidence for their Executive Summary findings. Based on experience, guidance notes were developed for subsequent AR. The AR5 Guidance Note continues to emphasize a theme from all three guidance documents to date: the importance of clearly linking each key finding and corresponding assignment of calibrated uncertainty language to associated chapter text, as part of the traceable account of the author team's evaluation of evidence and agreement supporting that finding. [1.1.2.2, Box 1-1]

Impacts assessed in this report are based on a combination of AR4 climate models (CMIP3) using SRES scenarios and new AR5 climate models (CMIP5, completed in 2011-12) using the new Representative Concentration Pathway (RCP) scenarios. The RCPs span the range of SRES scenarios for long-lived greenhouse gases, but they have a narrow range and fall at or below the lowest SRES in terms of emissions of ozone and aerosol precursors and related pollutants *(high confidence)*. The IPCC has created and used emission scenarios to project future climate since the FAR, and most recently the SRES scenarios were used in the TAR and AR4. With AR5, the new RCP scenarios present both emissions and greenhouse gas concentration pathways, and corresponding shared socio-economic pathways have also been developed. The 4 RCPs assume different levels of mitigation, leading to 21st century radiative forcing levels of 2.6, 4.5, 6.0 and 8.5 W m^{-2} (See WGI Chapters 1, 6, 11, 12). All RCPs project a rapid decline in short-lived pollutants and land-use change by 2050, almost independent of fossil-fuel use and population, while other published scenarios indicate a less rapid decline in aerosol precursors**.** [1.1.3]

1.1. The Setting

This chapter describes the information basis for the Fifth Assessment Report (AR5) of IPCC Working Group II and the rationale for its organization. As the initial point of departure from the prior IPCC WGII assessments, the chapter begins with an analysis of how the literature for the assessment has developed through time and proceeds with an overview of how the framing and content of the Working Group II reports have changed since the first IPCC report was published in 1990. The future climate scenarios that have been used by the scientific community to explore the potential consequences of climate change have marked important transitions over the past five years; this chapter describes the evolution of these scenarios and the methods used to communicate scientific uncertainty in IPCC assessments. The chapter provides a summary of the most relevant key findings from the IPCC *Special Report on Renewable Energy Sources and Climate Change Mitigation* (IPCC, 2011a), the IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC, 2012), and the IPCC Working Group I (*The Physical Science Basis*) and Working Group III (*Mitigation of Climate Change*) contributions to AR5. Collectively these recent reports, new scenarios, and other advancements in climate change science set the stage for an assessment of impacts, adaptation and vulnerability that could potentially overcome many of the limitations identified in the IPCC Fourth Assessment Report (AR4), particularly with respect to the human dimensions of climate change.

The IPCC has published four impact assessment reports (WGII) of the state of knowledge of climate change in 1990, 1995, 2001 and 2007. The critical review and synthesis of the scientific literature published since 2007 has required an expanded multidisciplinary approach that, in general, has more focused more heavily on societal impacts and responses. This includes analysis on how aggregate impacts are the result of coupled socio-ecological systems, and the rapid emergence of research on adaptation and vulnerability. The chapter shows an increased concern with how societal change evolves and the role of transformative thinking and action to achieve sustainability, a dynamic process that helps guarantee the persistence of natural and human systems.

In addition to the knowledge gaps in earlier Reports, point of departure in this chapter refers to a combination of the status of the biophysical planetary boundaries and the existing social boundaries on which climate impacts occur. These social boundaries include poverty and inequality, low levels of human development, and lack of access to basic needs and energy by a large part of an increasing global population interacting creating and reaction to climate change (see 1.1.4 and Figure 1-7).

The IPCC WGII Fifth Assessment Report (AR5) differs from the prior assessments primarily in the expanded outline and diversity of content that stems directly from the growth of the scientific basis for the assessment. The publication of the WGII contribution to AR5 in two volumes (Part A. Global and Sectoral Aspects and Part B. Regional Aspects) has permitted the presentation of more detailed regional analyses and an expanded coverage of the human dimensions (such as adaption) described above. For the IPCC Fifth Assessment, the contributions of Working Group I (Climate Change 2013: The Physical Science Basis) were finalized approximately six months in advance of the Working Group II contributions, allowing the authors of the latter more time to evaluate and include where possible the findings of Working Group I AR5 in the context of impacts, adaptation and vulnerability.

1.1.1. Development of the Science Basis for the Assessment

The volume of literature available for assessing climate change impacts, adaptation and vulnerability (CCIAV) has grown significantly over the past two decades (Figure 1-1a). A bibliometric analysis of reports produced with two bibliographic search tools (Scopus and ISI Web of Knowledge) indicates that fewer than 800 articles in journals, books, and conference proceedings were published in English on the topic of "climate change" between 1970 and 1990. Since then, the literature published on the topic has increased almost 100-fold, with a total of 73,039 articles published from 1990 through 2010. Since 1990 the international distribution of scientists contributing to the climate change literature has expanded from Europe and North America to Asia and Australasia. Literature from scientists affiliated with institutions in Africa and Central and South America comprised approximately 6% of the literature published on the topic of climate change during 2001-2010 (Figure 1-1b). The proportion of literature focusing on individual countries within IPCC regions has also broadened, particularly for Asia, over the past 3 decades (Figure 1-1c). This brief chronicle does not differentiate across the various "sub-categories" of the climate literature or claim to be comprehensive in terms of literature produced in languages other than English. For example, disparities of the geographic coverage of the climate change literature on the capacity for adaptation or the assessment of impacts and vulnerability have not been assessed.

[INSERT FIGURE 1-1 HERE
Figure 1-1: Results of English literature search using the Scopus bibliographic database from Reed Elsevier Publishers. (a) Annual global output of publications on climate change and related topics: impacts, adaptation, human health, and costs (1970-2010). (b) Country affiliation of authors of climate change publications summed for IPCC regions for three time periods: 1981-1990, 1991-2000, and 2001-2010, with total number during the period 2001-2010. (c) Results of literature searches for climate change publications with individual countries mentioned in publication title, abstract or key words, summed for all countries by geographic region. The following individuals conducted the literature searches: Valentin Przyluski (French), Huang Huanping (Chinese), and Peter Zavialov and Vasily Kokore (Russian), and Saúl Armendáriz Sánchez (Spanish). (d) Number of publications in five languages that include the words "climate change" and "climate change" plus "adaptation", "impacts" and "cost" (translated) in the title, abstract or key words during the three time periods.]

Growth in both the total volume of literature about climate change and the percentage of that literature devoted to impacts and adaptation has influenced the depth and scope of assessment reports produced by Working Group II of the IPCC. A doubling of the total number of publications on the topic of climate change impacts between 2005 and 2010 and on the topic climate change adaptation between 2008 and 2010 has enabled substantial advances in the assessment of the full range of impacts, adaptation and vulnerability (Figure 1-1a). The unequal distribution of literature, however, presents a challenge to the development of a comprehensive and balanced assessment of the global impacts of climate change. The geographical and topical distribution of literature is influenced by factors such as the availability of funding for scientific research, level of capacity building, regional experience with climate-related disasters, and the availability of long-term observational records.

Literature published on the topic of climate change during 1970-1990 focused primarily on changes in the physical climate system and how these changes affected other aspects of the Earth's physical environment. The Scopus database indicates that literature began to surface at the rate of more than 100 articles per year on the topic of climate change "impacts" in 1991. The rate of publication of at least 100 articles per year on the topics of climate change "adaptation" and societal "cost" began in 2003. The proportion of the literature on the topic of "climate change" published in social science journals increased from 6% to 9% from the 1970s-1980s to the 1990s-2000s. The proportion of the literature on the topic of "climate change" appearing in engineering journals has not changed appreciably over the past four decades, but there was a significant increase in the proportion of literature relating to climate change in the biological and agricultural science literature. The themes covered by literature on vulnerability to climate change have also expanded to issues of ethics, equity, and sustainable development.

While authors continue to publish primarily in English, literature published on the topic of "climate change" in other languages have also expanded. Literature searches in Chinese, French, Russian and Spanish revealed roughly a 4-fold or greater increase in literature published on the topic of "climate change" in each language during the past two decades (Figure 1-1d). Scientists from many countries tend to publish their work in English, as indicated by comparing the regional analysis and country affiliation of authors in Figure 1-1 with the results of the literature searches in the other 5 languages. This process of "scientific internationalism", which primarily means a shift to English as a language of scientific communication, has been described as a growing trend among Russian (Kirchik, Gingras, and Ladviere, 2012), Spanish (Alcaide, Zurián, and Benavent, 2012), and French (Gingras and Mosbah-Natanson, 2010) researchers.

1.1.2. Evolution of the WGII Assessment Reports and Treatment of Uncertainty

1.1.2.1. Framing and Outlines of WGII Assessment Reports

The framing and contents of the IPCC WGII assessments have evolved since the First Assessment Report (FAR, 1990) as summarized in Figure 1-2. Three important characteristics of this evolution are: (i) extended range and coupling of variables that impact a sustainable future; (ii) an increasing focus on human beings (managing resources and natural systems, the societal impacts of climate change); and (iii) participation of more social and human dimensions scholars as authors and reviewers. The continuing focus of WGII on impacts, adaptation and vulnerability extends the assessment challenges from the physical, ecological and economic systems to institutional, social and cultural issues. Effectively, WGII now focuses on understanding the interactions between the natural climate system and human society, adding to the emphasis of earlier assessments on sectoral and regional biogeophysical impacts of climate change. This assessment contributes to a better understanding of the likelihood of certain development paths, a key uncertainty in climate projections.

[INSERT FIGURE 1-2 HERE
Figure 1-2: Tables of Contents for the Working Group II contributions to the IPCC Assessments since 1990. The First Assessment Report (FAR, 1990) of IPCC Working Group II (WGII) focused on the impacts of climate change, but for the Second Assessment Report (SAR, 1996) the WGII contribution included mitigation and adaptation with the impact assessment. With the TAR (2001) and subsequent assessments, IPCC Working Group III has assessed the options and potential for climate change mitigation. Since the TAR, WG II has focused on impacts, adaptation and vulnerability with an expanded effort on the regional scale.]

The WGII FAR (296 pages) was organized into six major sectors: agriculture & forestry, terrestrial ecosystems, water resources, human settlements, and oceans & coastal zones. The report focused on the anticipated climate changes for a doubling of CO_2. The FAR SPM highlights the coupling of anthropogenic non-climate stresses with climate variability and greenhouse-gas-driven climate change. Given the state of the science in 1990, it is understandably qualitative on some topics (e.g., global agricultural potential may either increase or decrease; major health impacts are possible), but more quantitative on large-scale climate impacts (e.g., climatic zones shift poleward by 100s km; alpine and montane regions are most at risk for habitat and species loss). Health impacts were vague, emphasizing ozone depletion and UV-B damage. The IPCC WGII 1992 Supplementary Report followed with four assigned topics (regional climate change; energy; agriculture and forestry; sea-level rise) and was primarily a strategy report, focusing on guidelines for studies, e.g., urging that studies of change in tropical cyclones and storm surges are of highest priority (IPCC, 1992).

For the IPCC Second Assessment Report (SAR, 1996) WGII reviewed climate change impacts and vulnerability plus mitigation options for greenhouse gases (GHG). In addition to two introductory primers, there were eighteen chapters on impacts and adaptation sorted primarily by land use (e.g., forests, rangelands, deserts, human settlements, agriculture, fisheries, financial services, human health) and seven chapters on mitigation sorted by sector (energy, industry, forests, other). The SAR made use of the new IPCC IS92 scenarios. Projections of 2100 sea level rise (15-95 cm) and temperature increase (1.0-3.5°C) were similar to the FAR's doubled-CO_2 scenario. The SAR notes "Impacts are difficult to quantify, and existing studies are limited in scope; Detection [of climate-induced changes] will be difficult," but some specifics are given (e.g., the number of people at risk of flooding from storm surges from sea level rise; the increase in malaria incidence). Vegetation models are used to map out projected changes in major biomes (see SAR WGII SPM Fig. 2) – the first such predictive figure in a WGII SPM. On mitigation, the SAR analyzed historical GHG emissions by sector and discussed technological options, but cost analysis was left to WGIII.

The Third Assessment Report of WGII (TAR, 2001) returned to impacts, adaptation, and vulnerability, returning mitigation to WGIII. It included five core chapters on sectors (water resources, ecosystems, coastal and marine, human settlements and energy, and financial services), eight regional chapters, plus two focus chapters on (i) adaptation, sustainable development, and equity, and (ii) vulnerability and reasons for concern. The TAR made the first strong conclusion on attributing impacts: "recent regional climate changes, particularly temperature increases, have already affected many physical and biological systems." Recent increases in floods and droughts, while affecting some human systems, could not be tied to GHG-driven climate change. The TAR introduced the "burning embers" diagram (TAR Fig. 2, updated in Chapter 18 of this report) as a way to represent "reasons for concern." The adaptive capacity, vulnerability and key concerns for each region were laid out in detail (TAR, 2001, Table 2).

The Fourth Assessment Report of WGII (AR4, 2007) retained the basic structure of the TAR with core chapters on sectors and regions. With the large increase in regional studies, AR4 concluded: "it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems." Many, more specific examples of attributed and projected impacts are reported with confidence levels, but many still remain qualitative. Two major graphics in the AR4 SPM (Figure 1-2 and Table 1-1) give many examples of projected impacts of climate change, but the state of the science – both of WGI climate projections and WGII impacts – remained too uncertain at the time to give more quantitative estimates of the impacts or necessary adaptation.

This Fifth Assessment Report of WGII (AR5) continues and expands the sector and regional parts. The AR5 considers a wide and complex range of multiple stresses that threaten the sustainability of human and ecological systems. Figure 1-3 gives examples of the wide range of stressors directly coupled to climate change (e.g., population, land-use change, projected temperature, heat waves, water availability), demonstrating the geographic heterogeneity. The focus on climate change and related stressors, and the resulting vulnerability, occurs throughout this report, including the expanded "reasons for concern" (Chapters 2 and 19, see also Section 1.1.4).

[INSERT FIGURE 1-3 HERE
Figure 1-3: Examples of the diversity and global heterogeneity of the many stressors related to climate change impacts, adaptation, and vulnerability: (a) Population, (b) Land-use and land-cover change, (c) Industrial CO_2 emissions, (d) Surface temperature change, (e) Heat waves, (f) Water availability, and (g) Vulnerability to climate change. Sources: (a) Global population density for year 2000 from the LandScan project at Oak Ridge National Laboratory and CIESIN, Columbia U. (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3/maps); (b) Croplands and pasture/rangeland coverage from Foley *et al*. (2005); (c) Industrial sector energy/electricity-related CO_2 emissions ($GtCO_2$) for 1971-2000 (historical) and 2001-2030 (SRES B2) (AR4 WGIII TS.18 and Table 7.1, 7.2). EECCA = Countries of Eastern Europe, the Caucasus and Central Asia; (d) Surface temperature change projected for Dec-Jan-Feb, years 2046-2065 minus 1986-2005 under RCP8.5 from CMIP5 median (AR5 WGI Annex I); (e) Heat extremes based on Warm Spell Duration Index increase from 1980-1999 to 2081-2100 under SRES A2 normalized by standard deviation (SD) (SREX; after Fig.5 of Orlowsky and Seneviratne, 2011); (f) Water availability based on projected change of annual runoff (%) from 1981-2000 to 2081-2100 for SRES A1B (AR4 WGII Fig. 3.8, based on CMIP3); (g) Vulnerability to climate change in year 2050 (SRES A2, climate sensitivity 5.5°C, adapted from AR4 WGII Fig TS.19, 20.6).]

1.1.2.2. Treatment of Uncertainties in IPCC Assessment Reports: a Brief History and Terms Used in AR5

An integral feature of IPCC reports is communication of the strength of and uncertainties in scientific understanding underlying assessment findings. Treatment of uncertainties and corresponding use of calibrated uncertainty language in IPCC reports have evolved across IPCC assessment cycles (Swart et al., 2009; Mastrandrea and Mach, 2011). In Working Group II, the use of calibrated language began in the contribution to the Second Assessment Report, in which most chapters used qualitative levels of confidence in findings presented in their Executive Summaries (IPCC, 1996). Starting with the Third Assessment Report (TAR), formal guidance across the Working Groups has been developed in each assessment cycle (Moss and Schneider, 2000; IPCC, 2005; Mastrandrea et al., 2010). The TAR guidance paper (Moss and Schneider, 2000) stated that "guidelines such as these will never truly be completed," and an iterative process of learning and improvement of guidance has ensued, informed by experience in each assessment cycle. Each subsequent guidance paper has presented related but distinct approaches for evaluating and communicating the degree of certainty in findings of the assessment process.

The AR5 Guidance Note (summarized in Box 1-1) continues to emphasize a theme from all three guidance documents to date: the importance of clearly linking each key finding and corresponding assignment of calibrated uncertainty language to associated chapter text, as part of the traceable account of the author team's evaluation of evidence and agreement supporting that finding

_____ START BOX 1-1 HERE _____

Box 1-1. Communication of Uncertainty in the Working Group II Fifth Assessment

Based on the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties (Mastrandrea et al., 2010), the Working Group II contribution to the Fifth Assessment Report relies on two metrics for communicating the degree of certainty in key findings:

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment).

Each finding has its foundation in an author team's evaluation of associated evidence and agreement. The type and amount of evidence available varies for different topics, and that evidence can vary in quality. The consistency of different lines of evidence can also vary. Beyond consistency of evidence, the degree of agreement indicates the consensus within the scientific community on a topic and the degree to which established, competing, or speculative scientific explanations exist. Consistent evidence does not necessarily imply a high degree of agreement, if, for example, evidence is consistent but judged to be low in quality.

The Guidance Note provides summary terms to describe the available evidence: *limited*, *medium*, or *robust*; and the degree of agreement: *low*, *medium*, or *high*. These terms are presented with some key findings. In many cases, author teams additionally evaluate their confidence about the validity of a finding, providing a synthesis of the evaluation of evidence and agreement. Levels of confidence include five qualifiers: *very low*, *low*, *medium*, *high*, and *very high*. Figure 1-4 illustrates the relationship between the summary terms for evidence and agreement and the confidence metric. There is flexibility in this relationship; increasing confidence is associated with increasing evidence and agreement, but different levels of confidence can be assigned for a given evidence and agreement statement.

[INSERT FIGURE 1-4 HERE
Figure 1-4: Evidence and agreement statements and their relationship to confidence. The shading increasing towards the top-right corner indicates increasing confidence. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.]

In some cases, available evidence incorporates quantitative analyses, based on which uncertainties can be expressed probabilistically. In such cases, a finding can include calibrated likelihood language or a more precise presentation of probability. The likelihood terms and their corresponding probability ranges are presented below. Use of likelihood is not an alternative to use of confidence: an author team will have a level of confidence about the validity of a probabilistic finding. Unless otherwise indicated, findings assigned a likelihood term are associated with *high* or *very high* confidence. When authors evaluate the likelihood of some well-defined outcome having occurred or occurring in the future, the terms and associated meanings are:

Term*	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms that were used in limited circumstances in the Fourth Assessment Report (*extremely likely:* 95–100% probability, *more likely than not:* >50–100% probability, and *extremely unlikely:* 0–5% probability) are also be used if appropriate.

_____ END BOX 1-1 HERE _____

1.1.3. Scenarios used as Inputs to Working Group II Assessments

A scenario is a story or image that describes a potential future, developed to inform decision-making under uncertainty (Parson et al. 2007). Historical uses of storylines for planning and analysis can be traced back to the first formalized war games that were developed for military officer training in 19th century Prussia (Brewer and Shubik, 1979). Scenarios are commonly used in the analysis of global climate change policy and assessment and have been part IPCC future climate projections since the FAR (1990), where WGIII generated four scenarios (Bau = business-as-usual, B, C, and D) that were used by WGI to project climate change. In the IPCC Supplementary Report (IPCC, 1992), a joint WGI-WGIII effort defined six new scenarios (IS92a-f) that were used in the SAR (1996). For the TAR (2001), the IPCC Special Report on Emissions Scenarios (SRES: Nakicenkovic et al., 2000) created many scenarios from four Integrated Assessment Models (IAMs), out of which a representative range of marker scenarios were selected (A1B, A1T, A1FI, A2, B1, B2). In the SRES, IPCC explicitly forbade climate-mitigation options. The SRES scenarios carried over into the AR4 (2007) and formed the basis for the large number of ensemble climate simulations (CMIP3), both historical and 21st century, which are in use for climate-change studies relevant to AR5 WGII.[1]

INSERT FOOTNOTE 1 HERE: The Coupled Model Intercomparison Project is an activity of the World Climate Research Programme's Working Group on Coupled Modelling. Climate model output from simulations of the past, present and future climate archived mainly in 2005-2006 constituted phase 3 of the Coupled Model Intercomparison Project (CMIP3). Similar climate simulations by an expanded set of models in 2011-2013 is being used in AR5 and constitutes phase 5 of the project (CMIP5). CMIP3 used the SRES scenarios, and CMIP5 used the RCP scenarios.]

With the AR5, the scenarios fundamentally changed: an ad hoc community of experts, anticipating AR5, built a new structure for scenarios called Representative Concentration Pathways (RCPs) (Moss et al., 2010; van Vuuren et al., 2011) that defined the scenario from socio-economic path to emissions to greenhouse gas abundances and to global mean climate change using updated IAMs. These are primarily stabilization scenarios and labeled by their radiative forcing at the end of the century in W m^{-2} (RCP2.6, RCP4.5, RCP6.0, RCP8.5). The RCPs provide a flexible, interactive, and iterative approach to climate change scenarios without the governmental approval process. The connection between the anthropogenic emissions and climate forcing is weaker with the RCPs, which rely on a single parametric model (Meinshausen et al., 2011) than in previous assessments, which let the lead authors of the assessment report develop a best estimate. This aspect is assessed in AR5 WGI. The RCPs were used to drive multi-model ensembles of simulated climate change, historical and projected, designated CMIP5.

1.1.3.1. Comparison of RCP and SRES Scenarios

The WGI AR5 deals primarily with results from the RCP CMIP5, but this WGII assessment also uses results from the SRES CMIP3, and thus we identify similar or parallel scenarios from each set. The radiative forcing (RF in W m^{-2}) from the SRES and RCP scenarios are compared in Figure 1-5a. SRES A2 has a similar trajectory to RCP8.5, while SRES B1 matches RCP4.5. RCP6.0 has no simple analog: up to 2060, it is similar to both RCP4.5 and SRES B1; but after 2070, it lies between SRES B1 and B2. The RCP2.6 scenario, a strong mitigation scenario with net CO_2 uptake by 2100, falls well outside the SRES range, falling 2 W m^{-2} below SRES B2.

Total RF does not adequately describe the differences in climate change between SRES and RCPs. The RCPs universally adopt stringent mitigation policies for local air pollution and thus have much lower aerosol abundances than the SRES scenarios, which for the most part incorrectly ignored air quality regulations (AR5 WGI Tables AII.2.16-22). In terms of ozone and particulate matter precursor emissions, there is almost no overlap between

SRES and RCPs. In terms of surface ozone at the continental scale, after 2060 the RCPs are similar to low-end SRES B1 (AR5 WGI Tables AII.7.1-2).

Global mean surface temperature change for the scenarios (Figure 1-5b) shows bounding cases but no simple analogs. The AR5 RCP data is taken directly from the CMIP5 runs, whereas the AR4 data is based on a simple model, parameterized to match the different CMIP3 models (see figure caption). In terms of temperature change, RCP8.5 lies slightly above SRES A2, but below SRES A1FI. RCP4.5 follows SRES B2 up to 2060, but then drops to track SRES B1; whereas RCP6.0 has lower temperature change to start, following SRES B1 but then increasing towards SRES B2 by 2100. In general, scenarios SRES A1B, A1T and even B2 lie in the large gap between RCP8.5 and RCP4.5/6.0. The RCP2.6 temperature change stabilizes at about 1°C above the reference period (1986-2005), while for the 2090s, all SRES and the other RCPs span the range 1.8 – 4.1 °C.

[INSERT FIGURE 1-5 HERE
Figure 1-5: (a) Projected RF (W m^{-2}) and (b) global mean surface temperature change (°C) over the 21^{st} century from the SRES and RCP scenarios. RF for the RCPs are taken from their published CO_2-eq (Meinshausen et al., 2011), and RF for SRES are from the TAR Appendix II (Table II.3.11). Comparable models are used in both RF calculations. The SRES RF are shifted upward by 0.12 W m^{-2} to match at year 2000. Temperature changes are decadal means based on the model ensemble mean CMIP5 data for the RCPs (see AR5 WGI Chapters 11, 12, Annex II tables). The same analysis applied to CMIP3 SRES A1B is also shown (yellow circles). The SRES temperatures (colored squares, AR4 WGI Figure 10.26) are based on a simple climate model tuned to the CMIP3 models. Thus the yellow circles and yellow squares differ by a few tenths °C.]

1.1.3.2. Shared Socio-economic Pathways

Complementing the development of the RCPs that represent radiative forcing, efforts are also currently underway to provide a linkage between them and a range of human development pathways. For that purpose, Shared Socioeconomic Pathways (SSPs) are being generated (Arnell et al., 2011) considering socioeconomic challenges to mitigation and socioeconomic challenges to adaptation. The SSPs include storylines, which are descriptions of the state of the world, Integrated Assessment Models (IAM) quantitative variables (such as population, GDP, technology availability), and other variables, not included in the IAMs, such as ecosystem productivity and sensitivity or the governance index. It is expected that they would facilitate comparison across research results of the Climate Models, the IAMs, and Impacts, Adaptation and Vulnerability (IAV) communities, and facilitate use of new climate modeling results in conjunction with IAV research. Several chapters of this report refer to the SSPs in their discussion of analysis of future impacts and vulnerability; Chapter 21 (21.3.3.1.3) addresses how the time lags in producing the RCPs and SSPs have limited the use of these scenarios in AR5.

1.1.4. Evolution of Understanding the Interaction between Climate Change Impacts, Adaptation, and Vulnerability with Human and Sustainable Development

The lack of progress in reducing greenhouse gas emissions at a global scale has fostered concern about unavoidable climate change impacts and has contributed to an increasing emphasis on vulnerability, adaptation, and development pathways. The possible range of socio-economic trajectories in developed and developing countries is among the largest sources of uncertainty in scenario building and climate predictions (Hawkins and Sutton, 2009). A deeper understanding of patterns of global development and the possibilities for the transformation of all countries towards sustainability is therefore a fundamental aspect of addressing climate change and its impacts.

The IPCC's first three Assessment Reports focused primarily on characterizing the biophysical impacts of climate change, with a progressively more elaborated understanding of the economic and social impacts. The last decade has seen major advances in the conceptual integration of the physical and social impacts of climate change. The Fourth Assessment Report asserted that "climate change impacts depend on the characteristics of natural and human systems, their development pathways and their specific locations" (IPCC 2007a, page 64). It offered a catalogue of multiple stresses jointly impacting people and communities, and also highlighted questions of justice and equity in shaping development pathways in the context of climate change (IPCC 2007a, pages 811-841).

Vulnerability was defined in the TAR as a "function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, TAR, 2001b, page 388). Since then, the concept of vulnerability has acquired increased complexity as a multi-dimensional concept, also referring to structural conditions of poverty and inequality. This Report reveals substantive risks for socio-ecological systems in all regions, particularly in low-income economies. Literature reviewed in many chapters suggests that climate impacts could reverse past development achievements and hinder global efforts on poverty reduction, lead to human insecurity, displacement and conflict, maladaptation and negative synergies (for example, Barnett and O'Neill, 2010; Boyd and Juhola, 2009; Jerneck and Olsson, 2008; Klein et al., 2007; Ogallo, 2010; see also 13.2.1.; 12.2.1; 12.4.1; 12.5.1).

The importance of the social context in determining both resilience and vulnerability is encompassed by the notions of sensitivity and adaptive capacity and can be tracked using human development indicators. For example, adaptive capacity in many urban centers of the African continent is constrained by widespread poverty, lack of access to employment, inappropriate housing, or lack of access to water, sanitation and drainage, health care and education (8.2.4; 11.6.2, 22.4.4). Adaptation options and limits to high end warming in all countries are often contextualized in relation to socio-economic vulnerabilities and other stressors (Brown, 2012; New, Liverman, Schroeder and Anderson, 2010; Stafford Smith et al., 2011; World Bank, 2012; see 16.4.2.4). But concerted action to mitigate and address climate change along with increased adaptation practice creates an opportunity space for transformed pathways leading to increased resilience, low risk and low vulnerabilities. Sustainability, assuring and protecting the endurance of natural systems and equitable distribution in human systems, in the present and for the future, is thus a dynamic process and the context for climate resilience (see 20.2 and 20.3.3). The pathways identified in this report point to two eras. The era of climate responsibility, addressing the interconnectedness of multiple vulnerabilities for unavoidable impacts; and the era of climate options, the opportunity space to transform our actions toward a low risk and high resilient future.

A survey of the literature published since the last IPCC Report shows several key areas of emerging theoretical and methodological scholarship. Attention is being focused on devising and refining research methodologies to address the complexity of juxtaposing biophysical and social factors. This requires new approaches to transdisciplinarity, and the co-production of knowledge among stakeholders to enhance synergies between academic merit, policy relevance, and salience for users at the community level (Hegger et al., 2012; Pohl, 2011). A substantial amount of literature has emerged linking perspectives and methods, in particular resilience thinking, adaptive learning, anticipatory adaptation, sustainability science, welfare and social science research, vulnerability assessments, risk assessment and studies addressing the crucial role of mitigation in relation to development achievements (see for example, Beddoe et al., 2009; Cannon and Müller-Mahn, 2010; Folke et al., 2010; Reid et al., 2010). All point to the co-production of knowledge as a way to increase the saliency, legitimacy and credibility of the research process.

There is increased attention to questions of ethics, justice and responsibilities (for example, Arnold, 2011; Caney, 2012; Gardiner, 2011; Marino and Ribot, 2012; O'Brien et al., 2010; Pelling, 2010; Timmons and Parks, 2007). As basic needs such as energy, land, food or water become threatened, inequalities and unfairness may deepen leading to maladaptation and new forms of vulnerability. Responses to climate change may have unfair outcomes. For example, there are increasing cases of land-grabbing, large acquisitions of land or water rights for industrial agriculture, mitigation projects, or biofuels that have negative consequences on local and marginalized communities (Borras, McMichael, and Scoones, 2011, see also 14.7). Ethical perspectives are also important in relation to adaptation constraints and limits (see 16.7) and mitigation (see 1.3.4 and the Working Group III contribution to AR5). Addressing climate change vulnerabilities has become closely linked to addressing other injustices and reclaiming the role of democratic processes of social contestation against a perceived unfair distribution of wealth and resources and attention to underlying values, cultures and belief systems (Bond, 2011; Martinez-Alier et al., 2011; Shiva, 2005).

The relations with development are complex and contested. There is disagreement about some fundamental issues, in particular whether ideas of modernization, quality of life and increasing living standards based on consumption patterns of western countries and exported to the global south through development aid are part of the problem (Brooks, Grist, and Brown, 2009; Grist, 2008; Schipper, 2007). The literature points to how inequalities, trade imbalances, intellectual property rights, gender injustice, or agricultural systems, for example, cannot be corrected with “development as usual”, even if climate concerns are mainstreamed (Alston, 2011; Büscher et al., 2012; McMichael, 2009; OECD, 2009; Pogge, 2008; UNDP, 2007, 2011).

Practitioners link adaptation planning and policy instruments with ongoing development efforts. Climate change impacts are increasingly becoming a central issue in the work of United Nations development cooperation and specialized agencies, bilateral donor institutions, and international development Non Governmental Organizations (NGOs). At the same time, environmental institutions are increasingly paying attention to socio-economic contexts, institutions, culture and behaviors as key drivers for addressing environmental crises. The concept of “green” growth, for example, framed the 2012 Rio + 20 Earth Summit and has led to an academic debate on the opportunities and limits of this concept. However, concern about the incompatibility of growth with environmental goals remains (see 20.4.3), and proposals for alternative conceptions of growth (and growth reversal) have been proposed (Jackson, 2010).

The increase in adaptation literature and experience has led to the development of adaptation policy in many parts of the world, as reflected in all of the regional chapters of this report. The need for improved decision analysis has also led to a rapid increase in many approaches to climate change impact, adaptation and vulnerability assessments. At the policy level, individual country National Adaptation Programmes of Action and National Communication reports to the United Nations Framework Convention on Climate Change (UNFCCC) have focused primarily on physical climate change drivers and impacts. An analysis of National Communications documents submitted through 2004 by many of the developed countries (members of the Organisation for Economic Co-operation and Development) showed that climate change impacts and adaptation receive very limited attention relative to the discussion of greenhouse gas emissions and mitigation policies (Gagnon-Lebrun and Agrawala, 2006). The National Communications documents from 17 Latin American and Caribbean countries National Communications submitted through 2010 showed a similar pattern, with roughly 3% of the space (in pages) in these documents explicitly focused on adaptation (Figure 1-6). Progress towards adaptation is evident in some recent National Communications, however, such as the most recent National Communications from India and Iran, which devoted 28.8% (58 pages in a volume of 203) and 27.4% (52 pages in a volume of 190) respectively, to the topic of adaptation in their most recent National Communication.

[INSERT FIGURE 1-6 HERE
Figure 1-6: Distribution of topics related to impacts and vulnerability, adaptation, mitigation and greenhouse gas inventories (GHG inventories) in the First (1), Second (2) or Third (3) National Communications (NC) of several Latin American and Caribbean countries (Argentina, Belize, Bolivia, Brazil, Chile, Costa Rica, Cuba, Dominica, Ecuador, El Salvador, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Uruguay and Venezuela). Documents source: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.phpUNFCCC.]

Some market theorists have sought to identify an appropriate and synergistic continuum between development and adaptation strategies and financing (Heltberg, Siegel and Jorgensen, 2009; Mearns and Norton, 2010; Richardson et al., 2011; OECD, 2009; USAID, 2008; World Bank, 2010). “Greener” versions of economic growth-driven development and revisited ideas of sustainable development have been proposed. Key instruments in this area are market-based mechanisms aiming to achieve synergies between mitigation and adaptation efforts, development financing and planning, the development of appropriate measurement and monitoring tools and links to energy needs, such as the “Clean Development Mechanism”. But discussions are underway about the preconditions for market mechanisms, such as offsets, to work as intended (Liverman, 2010), the problems of carbon leakage, and the potential negative effects of mitigation strategies. An in-depth discussion of these interactions is given in Chapter 13, and Chapters 8, 11 and 12 identify central topics with particular relevance for poor communities. All regional chapters also assess this literature.

A concept emerging in the past years to avoid dichotomies between adaptation and mitigation is the term transformation. Within adaptation, we can distinguish between incremental and transformative adaptation, the later referring to changes in the fundamental attributes of a system in response to actual or expected climate and its effects (Park et al., 2012). The IPCC Special Report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC, 2012) put forward a conception of transformation as a change in the fundamental attributes of a system, including technological, financial, regulatory, legislative and administrative (see 1.1.3; 20.5.4).

Emergent literature points to transformation of values, norms, belief systems, culture, and conceptions of progress and wellbeing in facilitating or preventing transformation (Kates et al., 2012; O'Brien, 2011; Pelling, 2011). Societal innovation and conditions for transformation of this nature requires a particular understanding of risk assessment, adaptive management, learning, innovation, and leadership and may lead to resilient development pathways (see also section 1.2.3 and Chapter 20). We see a focus on global transformation in the recent strategic reframing of global environmental change research (Rockström et al., 2009). But there are large gaps especially drawing from mainstream social and human sciences (Hackmann and St. Clair, 2012).

Climate science is advancing rapidly, with a wide range of new knowledge concerning diverse aspects of impacts, adaptation, and vulnerability, along with the knowledge assessed in other working groups of the IPCC. This provides an "opportunity space" for policy relevant information to support policy decisions leading to high resilience, low risk and low vulnerability and climate change is just one of many stressors that influence resilience. A conceptual approach that summarizes central issues presented in this Report emerges from describing existing planetary boundaries created by the interactions of biophysical and societal stressors within the context of a changing climate has been developed by Rockström et al. (2009) and Raworth (2012). This approach focuses on multi-sector risks today and in the future, with the concept of sustainability as a dynamic process that guarantees the resilience and persistence of natural and human systems. In this conceptual framework of existing stressors and the boundaries they create, actions to reduce climate change impacts can be envisioned as a double edged sword: entailing both an era of responsibility and an era of climate options. On the one hand there is an option for responsible action to protect those vulnerable to unavoidable impacts. This era of responsibility requires increasing the resilience space by reducing both societal and biophysical stressors and, thus, an increased emphasis on adaptation. On the other hand, there is an opportunity space, the era of climate options, which through mitigation can reduce the rate of planetary warming and its impacts. The decisions and pathways that societies choose in the opportunity space, informed by science, observation and experience, will affect the degree of resilience in human and natural systems of the future (Figure 1-7).

[INSERT FIGURE 1-7 HERE
Figure 1-7: Conceptual framework for assessing interactions between biophysical and societal stressors that impact the resilience of natural and human systems today and in the future. Actions, including climate change adaptation and mitigation, taken in the opportunity space lead to a diverse range of pathways and outcomes – toward a future of high risk, high vulnerability and low resilience space or toward a future of low risk, low vulnerability and high resilience space.]

1.2. Major Conclusions of the WGII Fourth Assessment Report

1.2.1. Observed Impacts

Evidence presented in Chapter 1 of the WGII Fourth Assessment Report (AR4) (Rosenzweig *et al*., 2007, page 81) indicated that "Physical and biological systems on all continents and in most oceans are already being affected by recent climate changes, particularly regional temperature increases (*very high confidence*)". In terrestrial ecosystems, warming trends were consistent with observed change in the timing of spring events and poleward and upward shifts in plant and animal ranges. Other examples of observed change presented in Chapter 1 of AR4 included changes in the phenology of 542 plant species in Europe and 145 species of wild animals and plants in the Northern Hemisphere. The authors of Chapter 1 also concluded that the geographical locations of observed changes during the period 1970-2004 are consistent with spatial patterns of atmospheric warming. The types of hydrologic changes reported ranged from effects on snow, ice and frozen ground; the number and size of glacial lakes; increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers; effects on thermal structure and water quality of rivers and lakes; and changes associated with more intense drought and heavy rains in some regions. The authors of AR4 concluded from a synthesis of studies "**that the spatial agreement between regions of significant warming and the locations of significant observed changes is *very unlikely* to be due solely to natural variability of temperatures or natural variability of the systems**" (IPCC, 2007d, page 9).

Observed regional impacts to human systems were less obviously attributed to anthropogenic climate change. The authors of AR4 concluded that "**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"** (IPCC, 2007c, page 3)**.** They presented evidence on the effects of temperature increases on agricultural and forestry management at Northern Hemisphere higher latitudes (e.g. earlier spring planting of crops, alterations in disturbance regimes of forests due to fires and pests); on some aspects of human health (e.g. heat-related mortality in Europe, changes in infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes); and 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)".

The authors of AR4 concluded that "**Recent climate changes and climate variations are beginning to have effects on many other natural and human systems, but the impacts have not yet become established trends**" (IPCC, 2007d, page 9). In mountain regions melting glaciers enhanced risk of glacier lake outburst floods on settlements; in the Sahelian region of Africa warmer and drier conditions had detrimental effects on some crops; and in coastal areas sea-level rise and human development contributed to losses of coastal wetlands and mangroves and to increases in damage from coastal flooding (Chapter 1 of WGII-AR4).

1.2.2. Advances in the Assessment Process

The authors of the Working Group II contribution to AR4 noted that the demand for assessments had grown significantly since the release of the IPCC Third Assessment Report (TAR), thereby motivating researchers to expand the ranges of approaches and methods in use and to develop characterizations of future conditions (scenarios and related products) required by those methods. In particular, they indicated that major advancements in CCCIAV assessment were related to the need for improved decision analysis, the inputs from stakeholders, the role of non-climate factors, the increase in spatial and temporal resolution of scenario information, the characterization of the future including mitigation scenarios, large-scale singularities and probabilistic futures (Chapter 2 WGII-AR4, page 135).

1.2.3. Key Vulnerabilities and Reasons for Concern

In an effort to provide some insights into the seriousness of the impacts of climate change, the authors of the IPCC Third Assessment Report (IPCC, 2001b) identified five ''Reasons for Concern'' (RfC's). Considering new evidence of observed changes on every continent, coupled with a more thorough understanding of the concept of vulnerability, the authors of AR4 concluded that: "The five 'reasons for concern' identified in the TAR remained 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. 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" (IPCC 2007c, page 19).

Plenary-approved language in the SPM of Synthesis Report of the AR4 (page 19) summarized the RfCs as follows:

- *Risk 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.
- *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, heat waves and floods, as well as their adverse impacts.

- *Distribution of Impacts*: 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 not only in developing but also in developed countries. Moreover, there is increased evidence that low-latitude and less developed areas generally face greater risk, for example, in dry areas and megadeltas.
- *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 Discontinuities*: There is high confidence that global warming over many centuries would lead to a sea level rise contribution from thermal expansion alone that 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 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.

Perhaps more importantly for the AR5, careful reading of the AR4 reveals that authors also added some increased texture to each RfC by moving from impacts to vulnerabilities and their expanding scope – health metrics were added to the "Aggregate Impacts" RfC, for example; and widespread extinctions of species were added to the "Risks of Large Scale Discontinuities" (which had been called "Singularities" in the TAR). This is evidence that the RfC's evolve over time as knowledge and nuance expands with new knowledge.

Chapter 18 of this report uses RfC's to organize much of its synthesis of detection and attribution confidence conclusions across the volume; the point there is to expand our understanding of how observed and attributed impacts and vulnerabilities support the significance of each of the five reasons. Chapter 19 of this report will return to the RfC's as a unifying construction, expanding the scope to reflect risks and vulnerabilities – a continuation of the evolutionary process of their applicability.

The authors throughout the AR4 concluded that the evidence of vulnerability to observed climate change is most prevalent in places where warming has been the greatest and in systems that are more sensitive to temperature. Marine, freshwater and terrestrial biological systems are particular sensitive to observed temperature warming (e.g. changes in morphology, physiology, phenology, reproduction, species distribution, community structure, ecosystem processes and species evolutionary processes, etc.). Agricultural ecosystems have shown changes in phenology, management practices and yields. Human diseases linked with temperature sensitive vectors have shown spreader distribution. Natural systems are generally considered more affected than managed systems. Physical and biological systems appear to be more vulnerability to extreme events or exceptional episodes than to mean climate change (e.g. agricultural response and mortality occurring in the 2003 heat waves in Europe). Some regions, such as heavily populated deltas and low-lying islands, were identified as hotspots of societal vulnerability.

1.2.4. Risk Assessment as a Response to Climate Change

A fundamental point of departure to be drawn from the AR4 for the entire AR5 is that: "**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"** (IPCC, 2007c). This plenary approved language from the AR4 Synthesis Report SPM elevates the concept of risk in the assessment process. As indicated in the elaboration of this conclusion recorded in Topic 5 of IPCC AR4: "Risk management techniques can explicitly accommodate sectoral, regional and temporal diversity, but their application requires information about not only impacts resulting from the most likely climate scenarios, but also impacts arising from lower-probability but higher-consequence events and the consequences of proposed policies and measures. Risk is generally understood to be the product of the likelihood of an event and its consequences. Climate change impacts depend on the characteristics of natural and human systems, their development pathways and their specific locations (IPCC 2007c, page 64)".

IPCC (2007a) offered several summary glimpses at the risks from climate change and changes in climate variability that could be expected as global mean temperatures rise in Chapter 20 and its own SPM. These risks were calibrated by the various author teams in the most appropriate metric (i.e., not converted universally to economic indicators) and various levels of warming that could be experienced over the coming century. While they were also cast against ranges of warming at the end of the century for various manifestations of the SRES storylines, most of the indicated risks were drawn from the A2 alternative scenario for which specific trajectories of driving variables (like population), associated rates of change (in climate and socio-economic development), and corresponding levels of adaptive capacity were implied. They offered an alternative portrait for regional impacts so that the distributional implications of climate change might be inferred.

Transferring these insights into other scenarios from the SRES suite and/or the new RCP scenarios must be done with care, and is a task that has been picked up by the authors of the AR5. As the AR5 takes a risk-based perspective in response to governments' recognition that decision makers must adopt an "iterative risk-management approach", authors will have to add conclusions to which lower confidence has been assigned if they relate to "key vulnerabilities" with large consequences. The criteria identified in Chapter 19 of IPCC AR4 (2007b) can be applied in sorting through the literature of sectoral and regional impacts.

1.2.5. Interaction of Adaptation and Mitigation in a Policy Portfolio

The climate community in general and decision-makers in particular have begun to understand that coping with risks of climate change will involve a portfolio of initiatives that will evolve iteratively over time as new information about the workings of the climate system and new insights into how various responses are actually working and penetrating the global socio-economic structure. The suite of assessments offered under the rubric of "America's Climate Choices" by the U.S. National Academy of Sciences as well as the report of the New York (City) Panel on Climate Change provide ample evidence to these points. The authors of the IPCC AR4 made these points and thereby offered guidance to the AR5 process when it reported that: "**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.** Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization 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" (IPCC 2007c, page 19).

IPCC (2007c, page 19) also conveyed a sense of urgency by concluding that "**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 stabilization levels. Delayed emission reductions significantly constrain the opportunities to achieve lower stabilization levels and increase the risk of more severe climate change impacts**."

WGII AR5 devotes considerable attention to this interface and the mechanisms for iterating as new information emerges in a collection of chapters designed explicitly for this purpose. Meanwhile, author teams for the sectoral and regional chapters will work to bring insights on adaptation to bear on the risk summaries that they will produce. In these efforts, we begin with the recognition from the Synthesis Report of IPCC Working Groups II, II and III (2007c, page 14) that: "**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.** Societies have a long record of managing the impacts of weather- and 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 globalization, conflict and incidence of diseases such as HIV/AIDS. 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. 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."

In addition, the AR4 authors concluded in IPCC (2007c, page 14) that **"Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies.** A range of barriers limits 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." The challenge in extending this list and expanding understanding about adaptation and sustainable development at the time of the AR4 was attributed to the diversity of context, the paucity of actual adaptation to climate change that had been analyzed in the peer review literature, and the broader context within which multiple sources of stress are recognized.

1.2.6. Gaps in the Assessment of Impacts, Adaptation, and Vulnerability Identified in AR4

While the scope and complexity of climate change impact assessments have expanded with each IPCC synthesis report since 1990, several information gaps and shortcomings were identified in the Working Group II contribution to IPCC Fourth Assessment Report (AR4) (IPCC 2007a). Examples of some of the gaps cited in the Summary for Policymakers (SPM), the Technical Summary (TS) and individual chapters of AR4 are indentified below in categories that reflect apparent levels of progress that can be gauged by the contents of AR5.

Gaps and limitations for which significant progress is evident in the literature since AR4

- A lack in geographic balance in data and literature on observed changes [SPM, page 8]
- Difficulty discerning effect of regional climate changes due to adaptation and non-climatic drivers [SPM, page 9] and proximity to thresholds and tipping points [TS 6.1]
- Impacts under different assumptions about how the world will evolve in future – societies, governance, technology and economic development [TS 6.1]
- Lack of understanding regional sea level rise trends since 1950 and lack of information concerning the persistence of regional trends through the 21st century; lack of sea level rise scenarios for beyond 2100 [Ch. 6 and TS 6.2]
- Most AR4 studies of future climate change were based on a small number of studies using SRES scenarios, especially the A2 and B2 families. This allowed some limited, but incomplete, characterisation of the potential range of futures and their impacts [TS 6.2 and Ch. 2.3]
- Inadequacies of climate models to simulate changes in patterns of extreme events, particularly with respect to precipitation changes, at a scale that is useful for assessing future climate-related impacts on water resources [TS 6.2, Ch 5.8.2].
- Understanding of the likely future impacts of climate change was hampered by lack of knowledge regarding the nature of future changes, particularly at the regional scale and particularly with respect to precipitation changes and their hydrological consequences on water resources, and changes in extreme events, due in part to the inadequacies of existing climate models at the required spatial scales [TS 6.2 and Ch. 2.5, 3.3.1, 3.4.1, 4.3].
- Only a small amount of literature on the costs of climate change impacts could be found for the WGII Fourth Assessment Report [TS and Ch. 5.6, 6.5.3, 7.5]. Debate still surrounded the topic of how to measure impacts, and which metrics should be used to ensure comparability [TS and Ch. 2.2.3, 19.3.2.3, 20.9].
- Impact of climate change on utilization of biofuels and how the use of biofuels affects competition for land [Ch. 5.8.2]; high uncertainty about vulnerabilities and adaptation potentials in human systems [Ch. 7.8]; and the availability of few national health impact assessments [Ch. 8.8]
- Literature on adaptation costs and benefits was limited and fragmented [TS and Ch. 17.2.3]. It focused on sea-level rise and agriculture, with more limited assessments for energy demand, water resources and transport. There was an emphasis on the USA and other OECD countries, with a few assessments having

been conducted in developing countries [Ch. 17.2.3]. There was growing evidence, however, that adaptation measures are being implemented on a limited basis in developing and developed countries [TS 5.1].
- AR4 recognized that synergies exist between adaptive capacity and sustainable development, but further research was required to determine factors that contribute to this synergy [TS 6.2 and Ch. 20.9].

Gaps and limitations for which more modest or little progress is evident in the literature since AR4
- Inadequate understanding of the impacts of abrupt change events, such as collapse of the North Atlantic Meridional Overturning Circulation. However, without a better understanding of the likelihood that such events will be manifested at the regional scale, it will not be possible to carry out impact assessments of such events [TS and Ch. 6.8, 7.6, 8.8, 10.8.3].
- Wide range in future sea level rise estimates and high uncertainty about timing of sea level rise (lack of time slices for sea level rise due to uncertainties concerning ice sheet dynamics, only given end of century estimates)[Ch.10]
- Poor understanding of trends and future changes in wave regime – important particularly to small island nations [Ch. 6 and Ch. 16]
- Lack of high-quality observations that are essential for full understanding of causes and for unequivocal attribution of present-day trends to climate change [TS 4.8 and 6.2].

Understanding of abrupt climate change and the impacts of such events as the Progress towards resolving some of the shortcomings in data and reporting cited above were addressed in the IPCC Special Report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC, 2012) that was produced jointly by Working Groups I and II (see Section 1.3.1 in this chapter). The WGI contribution to AR5 has advanced our understanding of the drivers of ice sheet decline and contains new estimates of sea level rise that are updated with mass balance trends and models of ice sheet at time scales that are relevant to decision making. Though not reflected due to scale limitations in IPCC AR5 assessment, progress with high resolution downscaling of climate information has helped address the needs of natural resource managers operating at a sub-regional scale in many parts of the world.

1.3. Major Conclusions of More Recent IPCC Reports

Since the publication of the Fourth Assessment Report (AR4) in 2007 the IPCC has produced two Special Reports: the Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), produced by Working Group III and published in 2011, and a Special Report on "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX), published in 2012. In addition, the AR5 has staggered the assessment work for its three working groups. The Report of Working Group I was published in 2013 and the Report of Working Group III will be published later in 2014. In this section we summarize the major conclusions of the SREX, the SSREN and the Working Group I and III contributions to the AR5. We focus on the key findings and the fundamental framings and conceptual innovations these Assessment Reports bring to the development of the chapters that form the Working Group II contribution to AR5.

One aspect that cuts across the Working Groups is the detection of climate change or its impacts observed to date (2011 for WGI), the attribution of that climate change to the observed increases in greenhouse gases (a measure of the human forcing of climate change), the attribution of local climate impacts to the observed warming of that region, and the projection of these impacts and climate change into the 21st century. Table 1-1 gives a summary of phenomena for which such detection, attribution, or projection has been made across the Working Groups. A schematic presentation of this detection-attribution-projection sequence from preceding reports is given in Figure 1-8. For AR5 WGII attribution, see Chapter 18, and for projections, see the other chapters.

[INSERT TABLE 1-1 HERE
Table 1-1: Observed, attributed, and projected changes in the climate system, including impacts, adaptation, mitigation and vulnerability to climate change.]

[INSERT FIGURE 1-8 HERE
Figure 1-8: Climate change and its impacts detected to date (horizontal axis) is plotted against (left panel) attribution of those changes to greenhouse gases and (right panel) projection of those changes into the 21st century for a global warming exceeding 2°C. Only phenomena with a detection, attribution or projection at high confidence levels or with quantifiable uncertainty are shown. All phenomena are defined in Table 1-1 where the color coded symbols and likelihood are defined. Results are taken from the AR4, SREX, and AR5 WGI, but primarily from WGI because the attribution is to the observed increase in greenhouse gases that has driven anthropogenic climate change, rather than as in WGII to the regional/local observed warming. For AR5 WGII results, see inter alia Chapters 18 and 19.]

1.3.1. IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)

The SREX (IPCC, 2012) is the first IPCC Special Report produced jointly by Working Groups I and II and is the first IPCC report to focus on risk management. The report integrates perspectives from historically distinct research communities studying climate science, climate impacts, climate adaptation and disaster risk management. The SREX assesses relationships between climate change and the characteristics of extreme weather and climate events. The report and its Summary for Policymakers provide information on existing societal exposure and vulnerability to climate-related extreme events and disasters; observed trends in weather- and climate-related disasters and disaster risk management; projected changes in weather and climate extremes and projected disaster losses during the 21st century; approaches for managing the increasing risks of climate extremes and disasters; and implications for sustainable development. One chapter of the SREX is devoted to fourteen case studies that illustrate the impacts of extreme climate events and options for risk management and adaptation, such as early-warning systems, new forms of insurance coverage, and expansion of social safety nets.

1.3.1.1. Themes and Findings of SREX

The most relevant results of the assessment carried out by the SREX author team can be synthesized along the three major themes: changing weather and climate-related extreme events, trends in disaster losses, and managing the risks of extreme events and disasters. Some of the findings presented in the SREX concerning the type, magnitude and frequency of extreme weather and climate events are presented in Table1-1. Examples of findings from the SREX report concerning trends in disaster-related losses and challenges in managing risks are presented below:

- Economic losses from weather- and climate-related disasters have increased, but with large spatial and interannual variability (*high confidence*, based on *high agreement, medium evidence*). [SPM, 4.5.1, 4.5.3, 4.5.4]. Trends in losses have been heavily influenced by increasing exposure of people and economic assets *(high confidence)*. [SPM, 4.5.3]
- Economic, including insured, disaster losses associated with weather, climate, and geophysical events are higher in developed countries. Fatality rates and economic losses expressed as a proportion of gross domestic product (GDP) are higher in developing countries (*high confidence*). [SPM, 4.5.2, 4.5.4]
- Deaths from natural disasters occur much more in developing countries (*high confidence)*. From 1970 to 2008 for example, more than 95% of deaths from natural disasters were in developing countries. [SPM, 4.5.2, 4.5.4]
- Development practice, policy and outcomes contribute to shaping disaster risks (*high confidence):* skewed development that may lead to environmental degradation, unplanned urbanization, failure of governance or reduction of livelihood options result in increased exposure and vulnerability to disasters. [SREX 1.1.2, 1.1.3 and 2.2.2, 2.5]
- Managing risks is an iterative process involving monitoring, research, evaluation, learning and innovation can reduce disaster risk in the context of climate extremes (*robust evidence, high agreement)* [SPM, 8.63, 8.7]
- Risk management works best when tailored to local circumstances. Combining local knowledge with additional scientific and technical expertise helps communities reduce their risk and adapt to climate change (*robust evidence, high agreement*). [SPM, 5.4.4].

- Actions ranging from incremental improvements in governance and technology to more transformational changes are essential for reducing risk from climate extremes (*robust evidence, high agreement)*. [SPM, 8.6, 8.6.3, 8.7]
- Effective risk management generally involves a portfolio of actions to reduce and transfer risks and to respond to events and disasters, rather than a singular focus on any one type of action (high confidence)., Successful strategies include both hardware measures and soft solutions such as from improving infrastructure to building individual and institutional capacity building., in order to reduce risk and respond to disasters (*high confidence*). [SPM, 1.1.2, 1.1.4, 1.3.3]
- Post-disaster recovery and reconstruction provide an opportunity for reducing the risks posed by future weather- and climate-related disasters (*robust evidence, high agreement*). [SPM, 5.2.3, 8.4.1, 8.5.2] However, short-term measures to protect people from immediate risks can increase future risks, such as improvements in levees encouraging further development in flood plains (*medium evidence, high agreement*).
- Socio economic, demographic, health related differences, access to livelihoods, good governance and entitlements are some of the factors that lead to inequalities between people and countries. Inequalities influence local coping and adaptive capacity and pose challenges for risk management systems from local to national levels (*high agreement, robust evidence*) [SREX 5.5.1, 6.2, 6.3.2, 6.6].
- Many measures for managing current and future risks have additional benefits, such as improving peoples' livelihoods, conserving biodiversity, and improving human well-being (*medium evidence, high agreement*). [SPM, 6.3.1, Table 6-1].
- Many measures, when implemented effectively, make sense under a range of future climates (*medium evidence, high agreement*). These "low regrets" measures include systems that warn people of impending disasters; changes in land use planning; sustainable land management; ecosystem management; improvements in health surveillance, water supplies, and drainage systems; development and enforcement of building codes; and better education and awareness. [SPM, 5.3,1, 5.3.43, 6.3.1, 6.5.1, 6.5.2, 7.4.3 and Case Studies 9.2.11, 9.2.14]
- Post-disaster recovery and reconstruction provide an opportunity for reducing the risks posed by future weather- and climate-related disasters (*robust evidence, high agreement*). [SPM, 5.2.3, 8.4.1, 8.5.2] However, short-term measures to protect people from immediate risks can increase future risks, such as improvements in levees encouraging further development in flood plains (*medium evidence, high agreement*).

1.3.1.2. Advances in Conceptualizing Climate Change Vulnerability, Adaptation, and Risk Management in the Context of Human Development

The conceptual framing of the SREX reflects the diversity of expert communities involved in this assessment. It links exposure and vulnerability with socio-economic development pathways as determinants of the impacts and the likelihood of disaster risk for both human society and natural ecosystems. It is important to note that the SREX acknowledges the fundamental role that values and aspirations play in people's perception of risk, change and causality, and on imagining present and future situations. This value-based approach is put to work as a tool for managing the risks of extreme events and disasters enabling the recognition that socio-economic systems are in constant flux, and that there are many conflicting and contradictory values at play. The conceptual framing of the problem space offered by the SREX (illustrated in figure 1-1 of the SREX SPM) serves as a point of departure for many chapters in this AR5. Equally important for the AR5 is the conceptualization of a feasible solution space offered in the SREX. As stated in the summary of key findings, there is robust evidence and high agreement that addressing the risks calls for "actions ranging from incremental improvements in governance and technology to more transformational changes are essential for reducing risk from climate extremes" (SREX Fact Sheet, IPCC, 2011b).

1.3.2. Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN)

The SRREN (IPCC, 2011a) assesses existing literature on the relationship between renewable energy sources and the mitigation of climate change. It examines six renewable energy sources: bioenergy, direct solar energy, geothermal energy, hydropower, ocean and wind energy in terms of available technologies, technical potential and associated costs. It examines the challenges of integrating renewable energy sources into existing electrical power systems, heating and cooling networks, gas grids and liquid fuel systems and provides an in-depth assessment of the relationship of renewable energies to goals of sustainable development. In a review of 164 scenarios, the role of renewable energy sources in climate change mitigation is compared within a portfolio of mitigation options that include end-use energy efficiency, nuclear energy and fossil-fuel based energy with carbon capture and storage (CCS). Finally, for policy-makers interested in scaling up renewable energy for climate change mitigation goals, supporting policies for the development and deployment of these technologies are assessed.

Though renewable energy accounted for only 12.9% of the total primary energy supply in 2008, the SRREN shows that the deployment of renewable energy technologies has been increasing rapidly in recent years, often associated with cost reductions that are expected to continue with further technical advances. Biomass accounted for the majority of this total (10.2% out of 12.9%), much of which is traditional biomass in developing countries. Despite the small contribution of renewable energy to current energy supplies, in its assessment the SRREN shows the global technical potential of renewable energy to be substantially higher than the global energy demand. It is therefore not the technical potential of renewable energy that constrains its development, but rather economic factors, system integration and infrastructure constraints, public acceptance and sustainability concerns. The assessment of lifecycle assessment studies in the SRREN showed that GHG emissions associated with the generation of electricity from renewable energy technologies are, in general, significantly lower than those associated with fossil fuels, and under a range of conditions, also less than fossil fuels employing CCS. The percent increase of renewable energy in future primary energy supplies varies widely across scenarios, though a majority indicate a significant increase – from 64 EJ/yr total RE production in 2008 to more than 173 EJ/yr in 2050. Even under baseline scenarios the deployment of renewable energies is expected to increase, many showing to levels more than 100 EJ/yr. The growth of renewable energy is typically expected to be widespread across the world, though in the long-term (2050) most development is expected in non-Annex I countries (IPCC, 2011a).

Several SRREN findings have clear linkages with this assessment of climate change impacts, adaptation and vulnerability, as captured in Table 1-2.

[INSERT TABLE 1-2 HERE
Table 1-2: Links between SRREN and the Working Group II contribution to the Fifth Assessment Report.]

1.3.3. Relevant Findings from IPCC Working Group I Fifth Assessment Report First-Order Draft

[PROVISIONAL - This WGII SOD version is shortened, but not yet updated to reflect the WGI SOD/FGD.]

Key findings from the WGI FOD Executive Summaries relevant to WGII are summarized here. All summary statements below have *high confidence* attached to them in the WGI AR5 and are likely or higher if quantified uncertainty is given.

Climate Models. For AR5, a range of "climate" models are considered, including: coupled Atmosphere-Ocean General Circulation Models (AOGCMs) used in both climate reconstructions and future projections; their extension to 'Earth System' Models (ESMs) that include biogeochemical cycles; higher resolution, limited-area Regional Climate Models (RCMs) used to downscale global climate results; Earth System Models of Intermediate Complexity (EMICs) used primarily for exploring parameter uncertainty [WGI-9]. Datasets of multi-model ensembles for both past and future climate are available from Coupled Model Intercomparison Projects (CMIP3 and CMIP5[1]) and the Coordinated Regional Downscaling Experiment (CORDEX) [WGI-9]. The ability of climate models to simulate historical climate, its change, and its variability, has improved in many important respects since the AR4 [WGI-9]. RCMs are able to add value to coarser-resolution global model results, providing realistic spatial detail and improved representation of climate extremes [WGI-9]. Errors and biases in models tend to be related to smaller-scale features [WGI-9]. Lack of agreement across models on local trends is often a result of natural variability, rather than models actually disagreeing on their forced response [WGI-12].

Climate change comparison with AR4. The new CMIP5 results are similar to the AR4 CMIP3 results for the near term [WGI-11] but differ in the long term (see 1.1.3.1 and WGI-12). Multi-model average patterns of change in temperature and precipitation from CMIP3 and CMIP5 ensembles, once normalized per 1ºC of global temperature change, present a high degree of pattern correlation, with values larger than 0.9 for temperature change patterns and larger than 0.8 for precipitation patterns [WGI-12]. The characteristic stability of robust geographical patterns of temperature change (less so for precipitation) during a transient experiment remains valid in the new generation of models participating in CMIP5 [WGI-12]. Agreement and thus confidence in projections is higher for temperature related quantities than for those related to the water cycle or circulation [WGI-12]. In cumulative terms, the 2°C temperature target implies cumulative carbon emissions of about 1000–1300 GtC, of which about 520 GtC were already emitted by 2011 [WGI-12].

Temperatures. The global combined land and ocean temperature data show a temperature increase of about 0.8°C for the period 1901–2010 and about 0.5 °C for 1979–2010 when estimated by a linear trend [WGI-2]. Over every continent except Antarctica, anthropogenic influence (GHG increases) has made a substantial contribution to surface temperature increases [WGI-10]. Across all RCP scenarios, the multi-model global mean warming over the period 2016–2035 relative to the reference period 1986–2005 lies in a narrow range about 0.7°C [WGI-11]. Globally and regionally, the surface temperature response is fairly independent of scenario until after 2040 [WGI-11]. For RCP4.5, 6.0 and 8.5, global temperatures exceed 2ºC warming (over pre-industrial) by 2100 [WGI-12]. Based on model results and other studies, RCP2.6 pathway may or may not achieve the policy-relevant objective of no more than 2°C global warming relative to pre-industrial [WGI-12].

Precipitation**.** Precipitation in the tropics has increased over the last decade reversing the drying trend that occurred from the mid-1970s to mid-1990s reported in the AR4 [WGI-2]. New evidence has emerged for the detection of anthropogenic influence on aspects of the water cycle: on zonal patterns of global precipitation changes, including reductions in low latitudes and increases in northern hemisphere mid to high latitudes [WGI-10]. There is limited, if any, evidence and no agreement that the small-scale impact of aerosols on cloud microphysical structure translates into a significant regional impact in terms of precipitation amount (beyond orographic locations) [WGI-7]. Precipitation in the near-term is projected to increase in regions of tropical precipitation maxima and at high latitudes, with general decreases in drier regions of the tropics and sub-tropics, but projections vary considerably from model to model [WGI-11]. For the near term, CMIP5 projections confirm a clear tendency for increases in heavy precipitation events in the global mean as in AR4, but there are significant variations across regions [WGI-11]. Global-scale precipitation is projected to gradually increase in the 21st century, approximately 2% K^{-1} [WGI-12]. Average precipitation in a much warmer world will not be uniform, with regions experiencing increases, or decreases or no much change at all, but many mid-latitude arid and semi-arid regions will likely experience less precipitation [WGI-12]. Largest precipitation changes over northern Eurasia and North America are projected to occur during the winter [WGI-12].

Hydrology, Flooding and Droughts. Extended intervals of drought associated with weak Indian Summer Monsoon in the last 2000 years may have been synchronous across a large region of southeastern Asia [WGI-5]. The most recent and most comprehensive analyses of river runoff do not support the AR4 conclusion that global runoff has increased during the 20th Century [WGI-2]. Projections of soil moisture and drought remain relatively uncertain [WGI-12]. Decreases in runoff are projected in southern Europe, the Middle East, and southwestern United States, but increases in high latitude runoff, as with AR4 [WGI-12]. A shift to more intense individual storms and fewer weak storms is projected, with possibly more frequent/intense periods of agricultural drought (from intervening dry spells between intense individual storms) [WGI-12].

Sea Level. Under all the RCP scenarios, the time-mean rate of global mean sea level rise during the 21st century is very likely to exceed the rate observed during 1971–2010 [WGI-13]. For the period 2081 to 2100 compared to 1986 to 2005, GMSL rise is projected to lie in the range 0.27–0.50 m for RCP2.6, 0.32–0.56 m for RCP4.5 and RCP6.0, and 0.41–0.71 m for RCP8.5 [WGI-13]. Under RCP 8.5, the likely range reaches 0.84 m in 2100, but larger values than these ranges cannot be excluded [WGI-13]. The contribution from rapid changes in ice-sheet dynamics – 0.12

m from the two ice sheets combined – is the main reason why these ranges are higher than those given in the AR4 [WGI-13]. Regional patterns of projected sea level change, while overall positive, deviate significantly from the global mean [WGI-13]. Extreme wave heights have likely increased over the past 60 years, in keeping with increases in extreme winds [WGI-3]. A rise in mean sea level is largely responsible for an increase in extreme sea level events and stronger storm surges in coastal areas [WGI-3].

Ocean Acidification and Oxygen. The uptake of CO_2 by the ocean has resulted in a gradual acidification of seawater. Long time series from several ocean sites show declines in pH in the mixed layer between -0.0015 and -0.0024 yr^{-1} [WGI-3]. Projections show large 21st century decreases in pH and carbonate ion concentrations (CO_3^{2-}) throughout the world oceans for high-emissions scenarios [WGI-6]. Projections show large 21st century decreases in oceanic dissolved oxygen caused by enhanced stratification and warming, and mainly located in the sub-surface mid-latitude oceans. There is however no consensus on the future evolution of the volume of hypoxic and suboxic waters [WGI-6].

Sea Ice and the Cryosphere. The significant retreat in the extent of Arctic sea ice in all seasons that was documented by AR4 has continued. Since 1979, the end-of-summer extent of Arctic sea ice has decreased by 12% per decade [WGI-4]. In contrast, the total extent of Antarctic sea ice has increased slightly over the same 30-year period, but there are strong regional differences in the changes around the Antarctic [WGI-4]. Overall, CMIP5 models better capture the rapid decline in summer Arctic sea ice observed during the last decades than CMIP3 models, but spread across Arctic sea ice projections remains wide. More than 90% of the CMIP5 models analyzed reach nearly ice-free September conditions in the Arctic by 2100 under RCP8.5 [WGI-12]. In the Southern Hemisphere future changes in sea ice remain highly uncertain [WGI-12]. Reductions in northern hemisphere snow cover extent, permafrost degradation, glacier retreat, and increased surface melt of Greenland are evidence of systematic changes in the cryosphere linked to anthropogenic climate change [WGI-10]. The Arctic region warms most under all scenarios, as in AR4, with a polar amplification factor ranging from 1.8 to 3.3 [WGI-12]. Northern Hemisphere spring snow covered area is projected by 2100 to decrease between 9% (RCP2.6) and 24% (RCP8.5) [WGI-12].

Greenhouse Gases, Pollution, & Radiative Forcing. Land-use, land-use change and land management is emerging as a key driver of the future terrestrial carbon cycle, modulating both emissions and sinks, but this human induced process is not consistently represented in coupled carbon cycle climate models, causing a significant source of uncertainty in future projections of atmospheric CO_2 and climate [WGI-6]. Warming alone will likely increase O_3 in polluted regions, but decrease baseline O_3 levels in surface air [WGI-11]. The sign of the PM response to climate change is uncertain, depending on regional precipitation changes and shifting aerosol components [WGI-11]. The RCPs project much lower emissions of pollutants than do the SRES [WGI-11].

Atmospheric Circulation and Patterns. As the climate warms, the Hadley and Walker circulations are projected to slow down, and the Hadley cell widens giving broader tropical regions and a poleward encroachment of subtropical dry zones [WGI-12]. Changing mean sea level pressure is projected to shift the mid-latitude storm tracks poleward in both hemispheres along with reducing the overall frequency of storms [WGI-12]. Global monsoon precipitation is projected to strengthen in the 21st century with increase in its area affected and its intensity, while the monsoon circulation weakens [WGI-14].

Extreme Weather & Climate. Globally, there is confidence that the length or number of warm spells, including heat waves, has increased since the middle of the 20th century, and this is clearly the case for large parts of Europe [WGI-2]. Consistent with AR4 conclusions, the number of heavy precipitation events (e.g., 95th percentile) has increased significantly in more regions than it has decreased, with strongest evidence in North America [WGI-2]. There continues to be a lack of evidence regarding the sign of trend in the magnitude and/or frequency of floods on a global scale [WGI-2]. New results no longer support the AR4 conclusions regarding global increasing trends in droughts since the 1970s [WGI-2]. There is little confidence in basin-scale projections of trends in tropical cyclone frequency and intensity to the mid-21st century [WGI-11]. The magnitude of both high and low temperature extremes is projected to increase faster than the mean, and in most regions a one-in-20 year maximum temperature event will become a one-in-2 year event by the end of the 21st Century under RCP8.5 [WGI-12]. Twenty-first century projections of extreme water levels and waves are based on future storminess in a warming climate using both dynamical and statistical approaches, but it is difficult to specify regional changes in atmospheric, storm-driven extremes [WGI-13].

Regional Climate Change. Projected climate change in North America will be characterized by a loss of snowpack at high elevations, mid-continental summertime drying, and increasing precipitation over the northern third of the continent [WGI-14]. Projected climate change in South America will be characterized by precipitation increase over southeastern South America, with an increase in extreme precipitation over La Plata basin region and decrease in central Amazonia and northern coast, and an increase in the number of consecutive dry days in northeastern South America [WGI-14]. A significant rainfall decrease across the entire Mediterranean region is projected [WGI-14]. Termination of the rainy season over Japan (Baiu) will be delayed [WGI-14]. Indian Monson circulation is projected to weaken while the total seasonal precipitation increases and the number of rainy days decreases [WGI-14]. A drying trend is projected to continue over southern Australia through the 21st century, and become evident over the north and east of New Zealand [WGI-14]. Precipitation is *likely* to increase in the west of New Zealand in winter and spring [WGI-14].

1.3.4. Working Group III Contribution to the IPCC Fifth Assessment Report

Working Group III of the IPCC is charged with assessing scientific research related to the mitigation of climate change. "Mitigation" is any human intervention to reduce the sources or enhance the sinks of greenhouse gases. Because mitigation lowers the likely effects of climate change as well as the risks of extreme impacts, it is part of a broader policy strategy that includes adaptation to climate impacts—a topic addressed in more detail in this report of WGII. Responding to climate change is ultimately an exercise of risk management that includes both mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, and attitudes about risk. The literature assessed in AR5 also emphasizes the ethics of climate policy, as well as equity considerations, in considerably more detail than AR4.

Since the AR4 (2004 data), global anthropogenic greenhouse gas (GHG) emissions have continued to grow and reached an all-time high of 50.1 Gt CO_2eq in 2010. Despite existing mitigation policies, GHG emissions have grown more quickly between 2000 and 2010 than in previous decades. While CO_2 emission growth from increases in population and per capita income continue to outgrow savings from efficiency improvements, a growing carbon intensity of energy inputs contributed to emission increases for the first time since 1970. At 2010 levels, every 12 years an amount of fossil-fuel related CO_2 is emitted comparable to the total cumulative emissions before 1970 [WGIII-1, WGIII-5].

Regionally, the large majority of CO_2 emission growth over the last decade (2000-2010) has taken place in Asia. Roughly 83% of the CO_2 emission growth between 2000 and 2010 can be attributed to Asia from a territorial and 72% from a consumption perspective. Developing countries (non-Annex B) have overtaken developed countries (Annex B) in terms of their territorial as well as consumption based CO_2 emissions. Average per capita CO_2 emissions of developed countries remain roughly four times higher than of developing countries, even though a growing number of developing countries show per capita GHG emissions in the range of developed countries [WGIII-1, WGIII-5, WGIII-14].

Baseline emission trajectories for fossil and industrial sources from the scenarios literature are inconsistent with a 1.5^{0} or 2^{0} C target as discussed in the international climate change negotiations. The majority of baseline scenarios will exceed atmospheric GHG concentrations of 1000 ppm in 2100 with a likely temperature increase larger than 4^{0}C compared to pre-industrial levels [WGIII-6].

Scenarios meeting a stringent concentration goal of 450 ppm CO_2eq by 2100 with a 60% probability of not exceeding a temperature increase of 2^{0}C are becoming increasingly challenging. The vast majority of scenarios include temporary overshoot of this concentration goal [WGIII-6]. If ambitious stabilization targets such as 450 ppm CO_2eq are to be met, delays in international cooperation on climate change mitigation increasingly require net negative emission in the second half of the 21^{st} century and the large-scale application of carbon dioxide removal technologies (CDR). Most CDR technologies are not mature and attended by a large set of risks. Pathways that are dependent on the large-scale application of CDR technologies are characterized by increasingly risky profiles through a loss in the ability of policymakers to hedge risks freely across the mitigation technology portfolio [WGIII-6]. The cost of mitigation can affect the ability of society to adapt to climate change. Delays in mitigation not only increase the cost of mitigation, but also they reduce the capacity for adaptation. Some mitigation strategies could substantially increase stressors on water and other natural resources that are also being directly affected by changes in the physical climate system.

A broad body of literature has emerged analysing mitigation choices and societal objectives and non-climate policies that may affect mitigation efforts. Initial evidence from comprehensive models shows that if stringent climate policies are in place, synergistic relationships between societal objectives tend to be stronger and the added costs of any supplementary policies to reach other objectives (energy security/air pollution) at stringent levels can be significantly reduced – particularly in the near term [WGIII-6]. Demand side mitigation options tend to be associated with fewer risks and a larger number of co-benefits than mitigation options on the supply side. Energy efficiency options may therefore provide opportunities to manage risks across the mitigation portfolio and achieve other societal objectives beyond their potential to limit GHG emissions [WGIII-7, WGIII-8, WGIII-9, WGIII-10].

Human decision making is directly affected by the type of uncertainties that prevail. While previous reports have emphasised the uncertainties in the natural system, WGIII AR5 highlights social system uncertainties and suggests that these may be at least of similar magnitude [WGIII-2].

Approaches to international cooperation in climate policies have increased and become more diverse ranging from strong multi-lateralism to harmonized national and regional policies to decentralised architectures that may arise out of heterogeneous regional, national, and sub-national policies [WGIII-13]. Linkages among regional, national, and sub-national programs may complement international cooperation. While policy linkage can take several forms, linkage through carbon markets has been the primary means of regional policy linkage due to the greater opportunities for trade as carbon markets expand. Such forms of regional agreements could then, in principle, form building blocks for greater global cooperation by linking these efforts across regions [WGIII-13, WGIII-14].

The WGIII report further suggests that there is no best policy for mitigation. Different policies play different roles, typically to 1) provide a price signal; 2) remove barriers; or 3) promote long-term investments. A combination of policies that addresses all three roles could be most effective. It may be advantageous to design and adjust policies so as to complement rather than substitute for other policies in the same and other jurisdictions. Appropriate designs depend on national and local circumstances and institutional capacity. These categories are complementary when policy packages are designed to take advantage of synergies and avoid negative interactions. If there is no coordination within an integrated perspective then results in one area may be undone by results in another area for instance through leakage and rebound effects [WGIII-15].

Frequently Asked Questions

FAQ 1.1: What is the information basis for the assessment and how has it changed since the last IPCC report?
IPCC assessment reports are based on the most recent scientific, technical and socio-economic literature produced worldwide relevant to the understanding of climate change. IPCC report authors critically assess the literature and develop a synthesis of current understanding based on that literature. While the majority of the literature they assess is contained in peer-reviewed journal articles and books, IPCC authors can also consider non-published or non peer-reviewed literature sources. The volume of literature available for assessing climate change impacts, adaptation and vulnerability has grown dramatically since the last IPCC assessment report (AR4, 2007) was prepared. The total number of publications on the topic of climate change impacts roughly doubled between 2005 and 2010. The proportion of literature focusing on individual countries within IPCC regions has broadened, particularly for Asia.

FAQ 1.2: How has our understanding of the interface between human, natural and climate systems expanded since the 2007 IPCC Assessment?
Fundamental advances in scientific methods that integrate physical climate science with knowledge about impacts in human and natural systems have enabled a more robust assessment across a greater number of sectors with finer-

scale regional details. Many of the challenging regional impacts of climate change emerge from interacting stresses on people, societies, infrastructure, industry, and ecosystems. These complexities can now be quantitatively described for some systems. A more comprehensive, diverse overview of regional vulnerabilities, impacts and adaptation is made possible with the growth in the assessment-relevant scientific literature for all IPCC regions, including *Open Oceans* [Chapter 30], and by improved coordination with WG I and WG III. This report as a whole reflects substantial expansion of relevant knowledge from the social sciences and increased collaboration among experts on the human dimensions of climate change.

FAQ 1.3: How is the state of scientific understanding communicated in this report?
The body of science on climate change and its impacts has increased greatly over time. Future climate change and its impacts, however, cannot be known exactly. Some uncertainties stem from the possible future paths of socioeconomic development, resulting emissions of greenhouse gases, and associated changes in the exposure and vulnerability of society. Others follow from incomplete understanding of changes in the climate system and also of the societal capacities and challenges for potential responses. Because impacts for human and natural systems depend on how changes in climate and development choices interact, evaluating and implementing response strategies is an exercise in risk management. Importantly, decisionmaking requires judgments beyond the realm of science about what society and stakeholders value. Scientific understanding informs decisionmaking that anticipates, prepares for, and responds to climate change, by providing information about the full range of possible consequences and associated probabilities. In some cases, the probability of an impact occurring may be relatively low, but the consequences of the impact are so important that it warrants consideration. To clearly communicate the state of scientific understanding related to climate change and its impacts, the scientists developing this assessment report use specific terms, methods, and guidance for characterizing their degree of certainty in conclusions.

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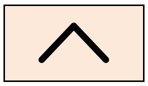
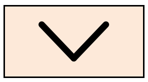
Table 1-1: Observed, attributed, and projected changes in the climate system, including impacts, adaptation, mitigation and vulnerability to climate change.

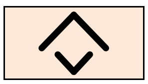
Phenomenon	Trend	Observed to 2010	Attributed (GHG)	Projected to 21st C.	Fig 1-7 symbol
CO_2	^	****	****	****	
Global Average Surface Temperature	^	****	***	****	
Continental Average Surface Temperature	^	****	**	****	
Global Mean Sea Level (steric)	^	****	***	****	
Arctic Sea Ice	v	**	*	****	
Hot Days and Nights	^	**	**	****	
Cold Days and Nights	v	**	**	****	
Heat Waves	^v		*	**	
Heavy Precipitation Events	^v	*		**	
Drought Frequency or Intensity	^v			*	
Tropical Cyclone Intensity	^				
N. Hemisphere Snow Cover	v	X	X	*	
N. Hemisphere Precipitation	^		X	X	
River Runoff	^	X	X	X	
			Attributed (Clim.Ch.)		
Extratropical Cyclones move Poleward	^	*		*	
Monsoons Change	~				
Economic Loss from Weather & Climate Extremes	^		X	X	

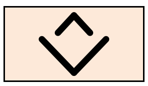
Table 1-1 Notes: Attribution in the top-half of the table is to human forcing of the climate, primarily through the increase in greenhouse gases (WGI). Attribution in the bottom-half, impacts, adaptation and vulnerability is to the observed local or regional climate change (WGII).

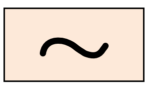
Trend Assessment

 Increasing overall

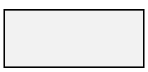
 Decreasing overall

 More regions increasing than decreasing

 More regions decreasing than increasing

 No definite trend

Confidence Assessment

 High confidence

 Medium confidence

 Low confidence

 Very low or no confidence

X No assessment made

Likelihood Assessment

**** *Virtually Certain* 99% - 100%

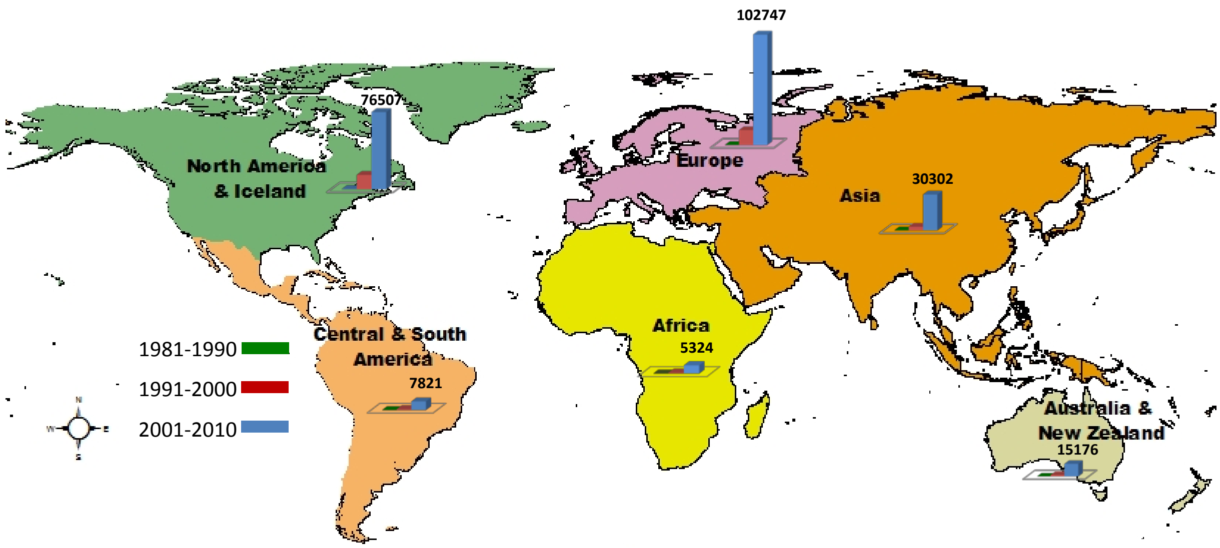
*** *Extremely Likely* 95% - 100%

** *Very Likely* 90% - 100%

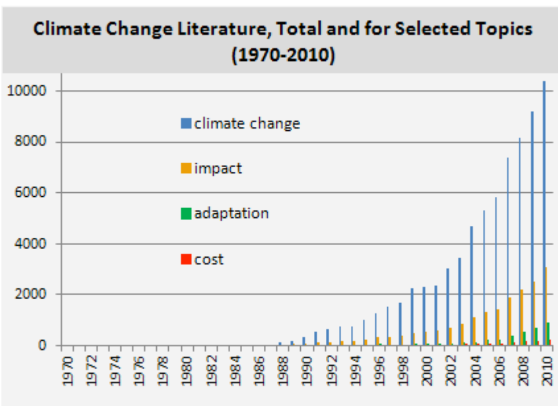
* *Likely* 66% - 100%

Table 1-2: Links between SRREN and the Working Group II contribution to the Fifth Assessment Report.

SRREN findings	WGII-AR5 findings
The sustainability of bioenergy, in particular in terms of lifecycle GHG emissions, is influenced by land and biomass resource management practices (Ch. 9)	Land cover (including forests and agriculture) may be affected by future climate change, which has inferences implications for the potential of these lands to produce biofuels and sequester carbon from the atmosphere (Ch. 19)
The water availability is a critical factor that limits the development of water cooled thermal power and hydropower (Ch. 9)	Climate change is likely to affect future surface and groundwater supplies and the stresses that the development of water-dependent energy resources can have on freshwater ecosystems (Ch. 4)
A wide range of technologies are already available (e.g. wind turbines) or however possible (e.g. barrages for tidal range, submarine turbines for tidal and ocean currents, heat exchangers for ocean thermal energy conversion, etc.) to produce energy from oceans and wind (Ch. 6 and 7)	Ocean currents and wind action could be affected by climate change. Thus, the capacity of these energy technologies should be revised on the basis of future climate conditions (Ch. 6).
Higher energy prices associated with transitions from fossil fuels to renewable energy sources may have adverse effects on local and regional economic and social development (Ch. 9)	The challenge for climate-resilient pathways is to identify and implement mixes of technological options that reduce net carbon emissions and at the same time support sustained economic and social growth (Ch. 20)
Latin America is second to Africa in terms of technical potential for bioenergy production from rain-fed lignocellulosic feedstocks on unprotected grassland and woodlands (Ch. 9)	In large countries of Latin America the production of bioenergy requires large areas for agriculture determining environmental degradation and strong economic teleconnections (e.g. economic growth of giant consumers as China) (Ch. 27)
Central and South America are second to Asia in terms energy generation in the world, displaying a 20% share of total annual generation. The quality of water resources availability is the largest in the world with an average regional capacity factor of over 50%. As a result, the region has by far the largest proportion of electricity generated through hydropower facilities (Ch. 5)	Hydropower is the main source of renewable energy available in Central and South America, but it is also affected from potential impacts of climate change (Ch. 27)



(a)



(c)

Climate Change Literature by Region (Title, Key Words, or Abstract)

	1981-1990	1991-2000	2001-2010
Africa	0	509	4815
Asia	9	2821	27472
Europe	71	12218	90458
North America	290	11926	64281
Central and South America	2	677	7142
Australia and New Zealand	7	1654	13515

(d)

Search Words (translated)	Language	1981-1990	1991-2000	2001-2010
"Climate change"	English	990	12686	61485
	Chinese	1454	6353	22008
	French	1	108	815
	Russian	67	210	1443
	Spanish	3	82	1381
"Climate change" and "adaptation"	English	14	373	3661
	Chinese	6	58	321
	French	0	7	110
	Russian	0	7	44
	Spanish	0	5	103
"Climate change" and "impacts"	English	232	3001	16218
	Chinese	133	515	1780
	French	0	1	95
	Russian	0	72	403
	Spanish	0	7	103
"Climate change" and "cost"	English	24	699	4099
	Chinese	1	22	162
	French	0	7	36
	Russian	0	1	24
	Spanish	0	2	11

Figure 1-1: Results of English literature search using the Scopus bibliographic database from Reed Elsevier Publishers. (a) Annual global output of publications on climate change and related topics: impacts, adaptation,

human health, and costs (1970-2010). (b) Country affiliation of authors of climate change publications summed for IPCC regions for three time periods: 1981-1990, 1991-2000, and 2001-2010, with total number during the period 2001-2010. (c) Results of literature searches for climate change publications with individual countries mentioned in publication title, abstract or key words, summed for all countries by geographic region. The following individuals conducted the literature searches: Valentin Przyluski (French), Huang Huanping (Chinese), and Peter Zavialov and Vasily Kokore (Russian), and Saúl Armendáriz Sánchez (Spanish). (d) Number of publications in five languages that include the words "climate change" and "climate change" plus "adaptation", "impacts" and "cost" (translated) in the title, abstract or key words during the three time periods.]

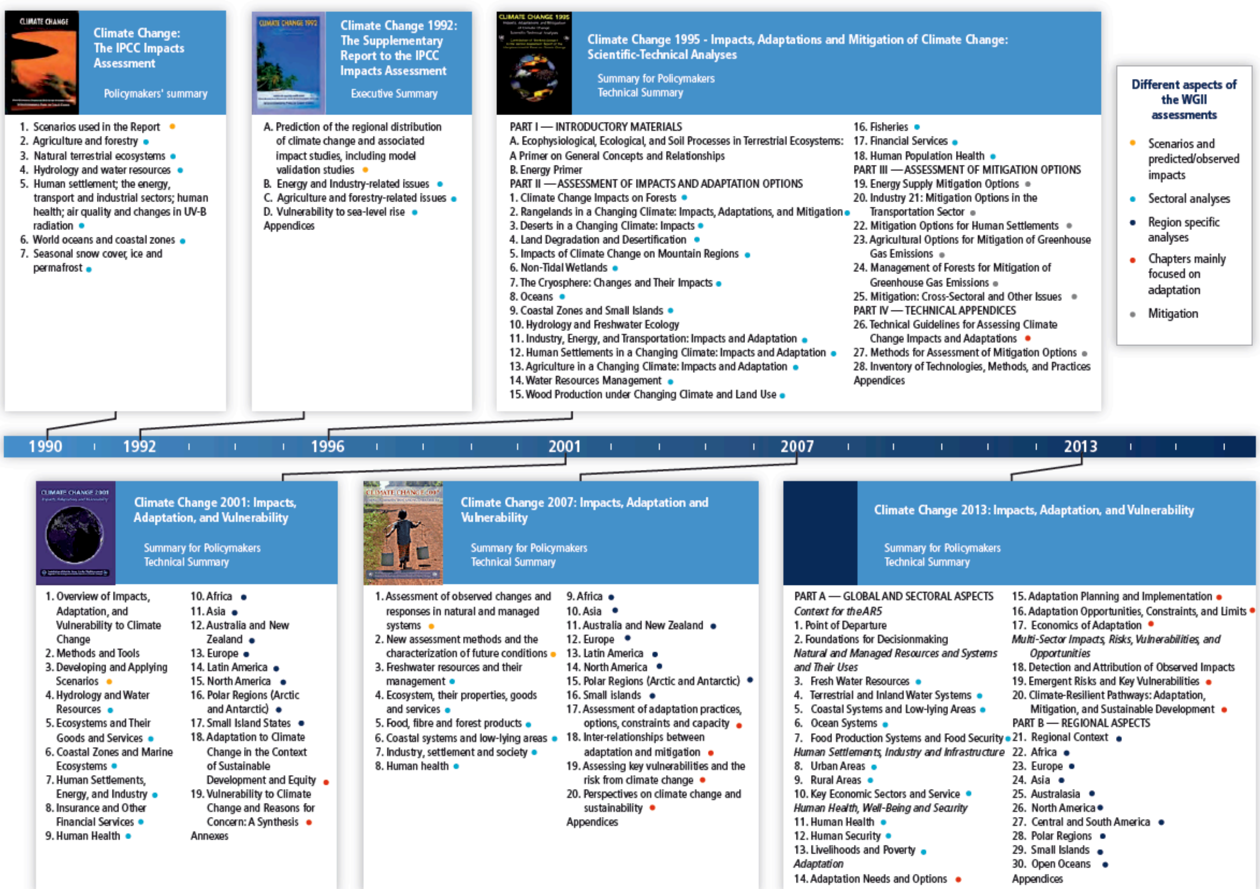


Figure 1-2: Tables of Contents for the Working Group II contributions to the IPCC Assessments since 1990. The First Assessment Report (FAR, 1990) of IPCC Working Group II (WGII) focused on the impacts of climate change, but for the Second Assessment Report (SAR 1996) the WGII contribution included mitigation and adaptation with the impact assessment. With the TAR (2001) and subsequent assessments, mitigation was addressed by IPCC Working Group III. Since the TAR, WG II has focused on impacts, adaptation and vulnerability with an expanded effort on the regional scale.

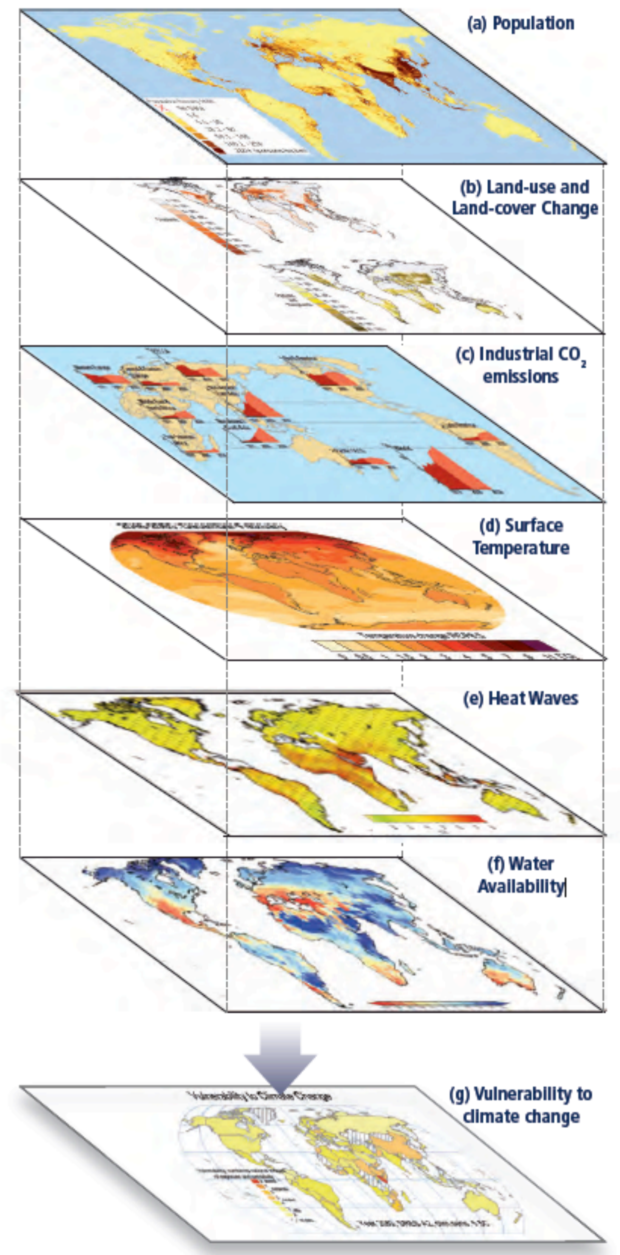


Figure 1-3. Examples of the diversity and global heterogeneity of the many stressors related to climate change impacts, adaptation, and vulnerability: (a) Population, (b) Land-use and land-cover change, (c) Industrial CO_2 emissions, (d) Surface temperature change, (e) Heat waves, (f) Water availability, and (g) Vulnerability to climate change. Sources: (a) Global population density for year 2000 from the LandScan project at Oak Ridge National Laboratory and CIESIN, Columbia U. (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3/maps); (b) Croplands and pasture/rangeland coverage from Foley *et al*. (2005); (c) Industrial sector energy/electricity-related CO_2 emissions ($GtCO_2$) for 1971-2000 (historical) and 2001-2030 (SRES B2) (AR4 WGIII TS.18 and Table 7.1, 7.2). EECCA = Countries of Eastern Europe, the Caucasus and Central Asia; (d) Surface temperature change projected for Dec-Jan-Feb, years 2046-2065 minus 1986-2005 under RCP8.5 from CMIP5 median (AR5 WGI Annex I); (e) Heat extremes based on Warm Spell Duration Index increase from 1980-1999 to 2081-2100 under SRES A2 normalized by standard deviation (SD) (SREX; after Fig.5 of Orlowsky and Seneviratne, 2011); (f) Water availability based on projected change of annual runoff (%) from 1981-2000 to 2081-2100 for SRES A1B (AR4 WGII Fig. 3.8, based on CMIP3); (g) Vulnerability to climate change in year 2050 (SRES A2, climate sensitivity 5.5°C, adapted from AR4 WGII Fig TS.19, 20.6).

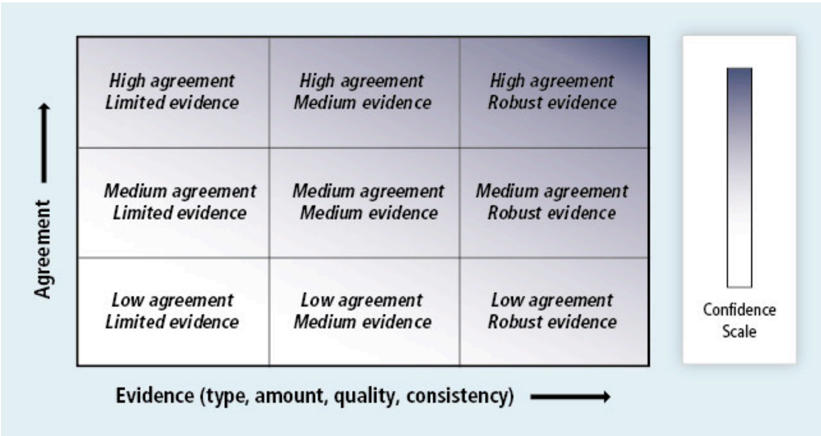


Figure 1-4: Evidence and agreement statements and their relationship to confidence. The shading increasing towards the top-right corner indicates increasing confidence. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

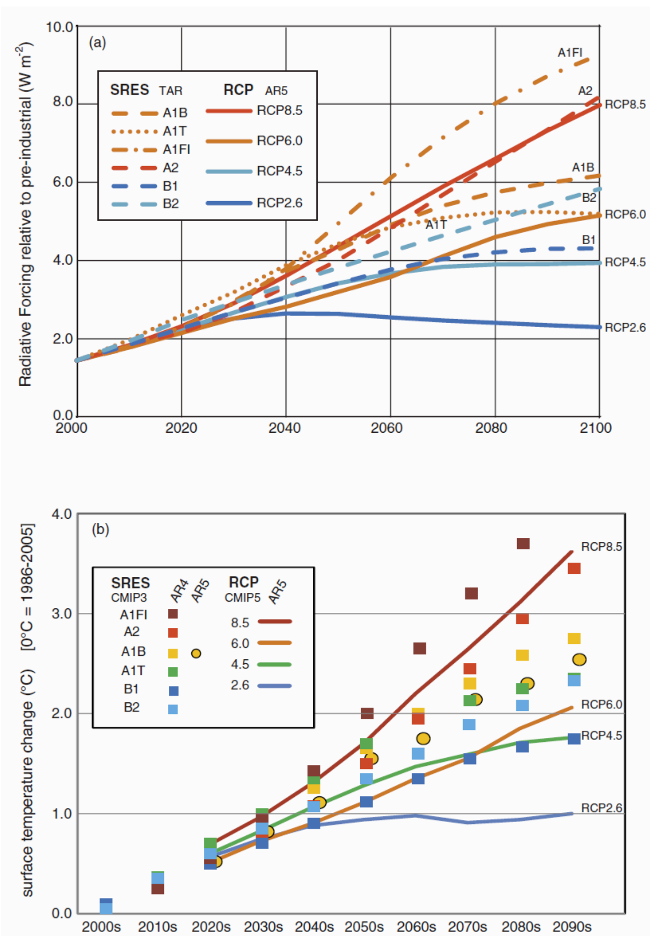


Figure 1-5: (a) Projected RF (W m-2) and (b) global mean surface temperature change (°C) over the 21st century from the SRES and RCP scenarios. RF for the RCPs are taken from their published CO2-eq (Meinshausen et al., 2011), and RF for SRES are from the TAR Appendix II (Table II.3.11). Comparable models are used in both RF calculations. The SRES RF are shifted upward by 0.12 W m-2 to match at year 2000. Temperature changes are

decadal means based on the model ensemble mean CMIP5 data for the RCPs (see AR5 WGI Chapters 11, 12, Annex II tables). The same analysis applied to CMIP3 SRES A1B is also shown (yellow circles). The SRES temperatures (colored squares, AR4 WGI Figure 10.26) are based on a simple climate model tuned to the CMIP3 models. Thus the yellow circles and yellow squares differ by a few tenths °C.

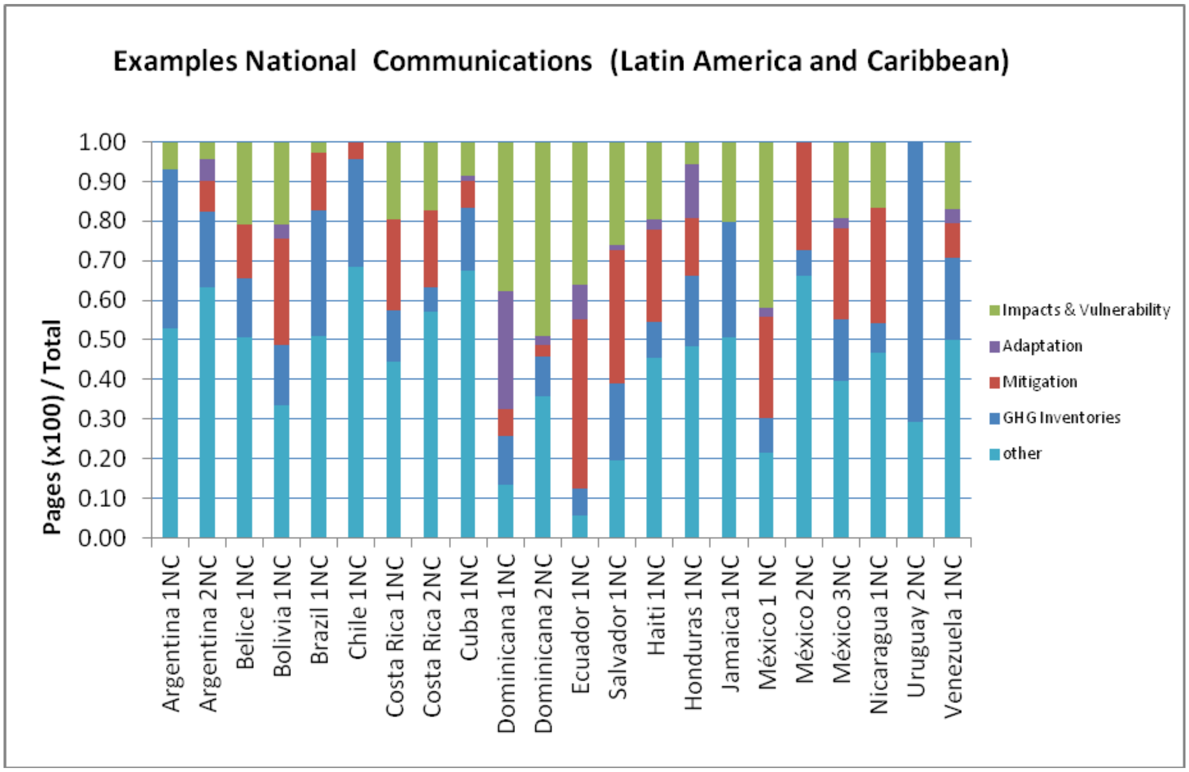


Figure 1-6: Distribution of topics related to impacts and vulnerability, adaptation, mitigation and greenhouse gas inventories (GHG Inventories) in the First (1), Second (2) or Third (3) National Communications (NC) of several Latin American and Caribbean countries (Argentina, Belize, Bolivia, Brazil, Chile, Costa Rica, Cuba, Dominica, Ecuador, El Salvador, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Uruguay and Venezuela). Documents source: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.phpUNFCCC.

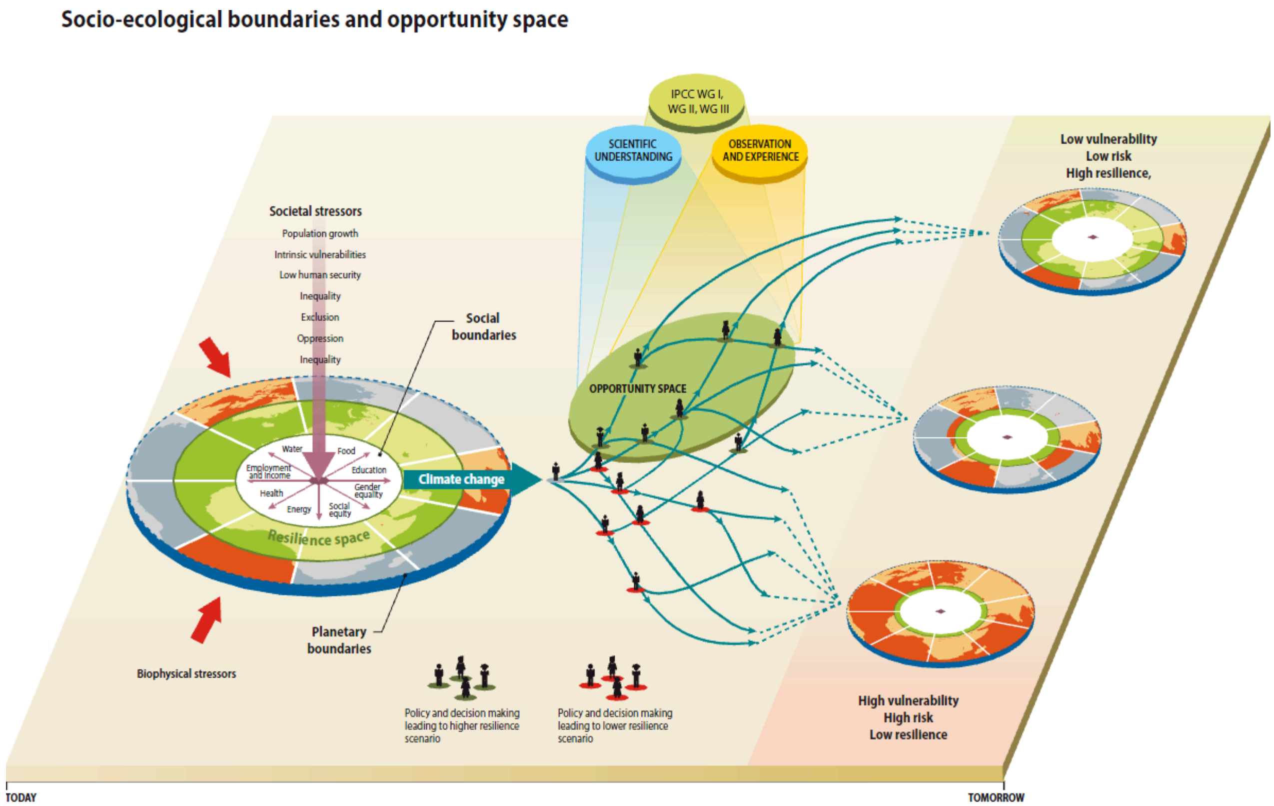


Figure 1-7: Conceptual framework for assessing interactions between biophysical and societal stressors that impact the resilience of natural and human systems today and in the future. Actions, including climate change adaptation and mitigation, taken in the opportunity space lead to a diverse range of pathways and outcomes – toward a future of high risk, high vulnerability and low resilience space or toward a future of low risk, low vulnerability and high resilience space.

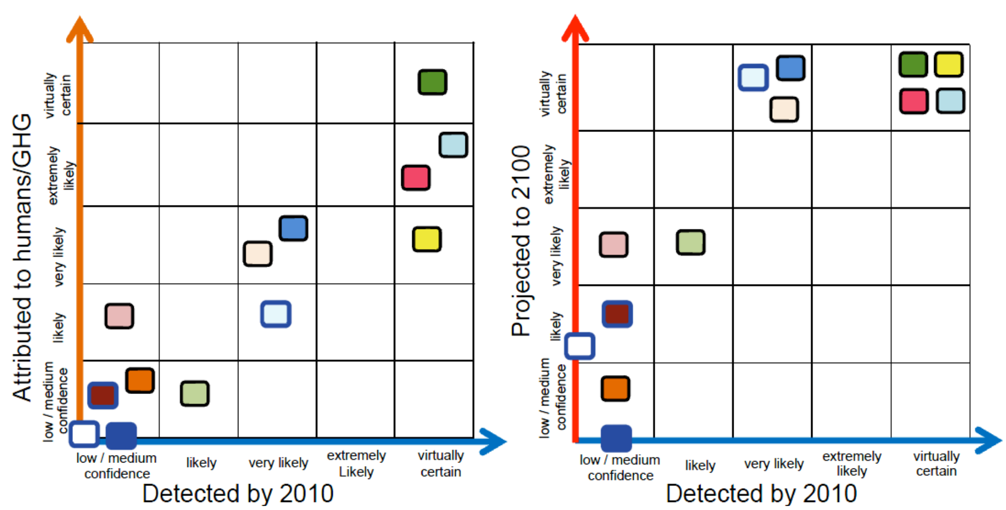


Figure 1-8: Climate change and its impacts detected to date (horizontal axis) is plotted against (left panel) attribution of those changes to greenhouse gases and (right panel) projection of those changes into the 21st century for a global warming exceeding 2°C. Only phenomena with a detection, attribution or projection at high confidence levels or with quantifiable uncertainty are shown. All phenomena are defined in Table 1-1 where the color coded symbols and likelihood are defined. Results are taken from the AR4, SREX, and AR5 WGI, but primarily from WGI because the attribution is to the observed increase in greenhouse gases that has driven anthropogenic climate change, rather than as in WGII to the regional/local observed warming. For AR5 WGII results, see inter alia Chapters 18 and 19.