Chapter 1. Point of Departure

Coordinating Lead Authors
Virginia Burkett (USA), Avelino G. Suarez (Cuba)

Lead Authors
Marco Bindi (Italy), Cecilia Conde (Mexico), William Hare (Germany), Rupa Mukerji (India), Michael Prather (USA), Asuncion St. Clair (Norway), Gary Yohe (USA)

Review Editors
Hervé Le Treut (France), Jean Palutikof (Australia)

Contributing Authors
Katharine Mach (USA), Michael D. Mastrandrea (USA), Jan Minx (Germany), Christoph von Stechow (Germany)

Volunteer Chapter Scientist
Emmanuel Nyambod (Cameroon)

Contents

References

Executive Summary

This chapter describes the information basis for the Fifth Assessment Report (AR5) of IPCC Working Group 2 and the rationale for its organization. It 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 2 assessment reports have evolved since the first IPCC report was published in 1990. The chapter describes the evolution of scenarios used to explore the potential consequences of climate change and the methods used to communicate scientific uncertainty in the five IPCC assessments. The terms and methods used by the authors of AR5 to assess and communicate the degree of certainty in their major findings are presented. The chapter includes 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), the and the IPCC Working Group 1 (*Physical Climate Science*) and Working Group 3 (*Mitigation of Climate Change*) contributions to AR5.

The literature available for assessing climate change impacts, adaptation and vulnerability has more than doubled since 2005 (*high confidence*) [1.1.1]. 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. In addition, there is evidence of an increase in the production of climate change literature in the developing countries, although institutions in the developed countries continue to have greater access to and production of climate change literature. The unequal distribution of literature – geographically and topically – has also challenged the presentation of a balanced view of the impacts of climate change. [1.1.1]

The historical trajectory and the evolution of framing of IPCC assessment reports indicate a broadening of emphasis in assessing climate change impacts, adaptation and vulnerability to address:

- **Thresholds and tipping points in societal and natural systems**
- **The synergies between multiple variables and factors that affect sustainability**
- **Institutional, social, cultural, and value-related issues (*high confidence*). [1.1]**

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. The SREX (IPCC, 2012), for example, demonstrates the holistic treatment of climate assessments and the integration of knowledge across the sciences and institutions to produce conceptual innovations, case studies and other relevant material that help inform policy decisions that reduce the potential impacts of climate-related extreme events. Three important characteristics in the evolution of the Working Group 2 assessment reports are an increasing attention to: (i) the range and coupling of variables that impact a sustainable, global future; (ii) an increasing focus on human beings, their role in managing resources and natural systems, and the societal impacts of climate change; and (iii) participation of more social and human dimensions scholars as authors and reviewers. [1.1, 1.3]

The societal aspects of climate change can now be more completely integrated with the sectoral and regional impact assessments that have exemplified the IPCC assessment process *(high confidence)*. [1.1.2] These advances are evident in the following themes of the WG2 contribution to AR5:

1) Advances in integrating physical climate science with human and natural systems to assess impacts
2) Broadening the consideration of climate drivers, including extremes and interactive effects
3) Assessing a broader range of impacts in the context of other well documented stresses
4) Improved understanding of the relations between adaptation, mitigation, development and sustainability
5) Expanded coverage of adaptation
6) Comprehensive and integrated treatment of regional aspects of climate change
7) Framing to support good policy decisions, including information on risk.

The treatment and communication of uncertainties in IPCC reports have evolved over time, reflecting iterative learning and the improvement of formal guidance to authors *(high confidence)*. [1.1.2] An integral

feature of IPCC reports is communication of the strength of and uncertainties in scientific understanding underlying assessment findings. 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. Formal guidance across the Working Groups has been developed for each subsequent assessment cycle, informed by experience. 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. [1.1.2.3]

Impact assessments in this report are based on a combination of climate model runs for AR4 (CMIP3) using the SRES scenarios and new climate model simulations for AR5 (CMIP5, completed in 2011-12) using the new Representative Concentration Pathway (RCP) scenarios. The RCPs more than cover the range of SRES scenarios for long-lived greenhouse gases, but they all fall outside of and well below the SRES in terms of emissions of ozone and aerosol precursors and related pollutants *(high confidence)* and represent more closely the maximum feasible reduction in these pollutants rather the range of possible futures (*medium confidence*). [1.1.4] The IPCC has created and used scenarios for future climate since the First Assessment Report, where WGIII generated four scenarios used by WGI to project climate change. With this AR5, the RCP scenarios are no longer IPCC generated but developed by an ad hoc community group and define the complete path from socio-economic path to emissions to long-lived greenhouse gas abundances and to forcing of mean climate change. The RCPs, unlike the SRES, assume different levels of mitigation, leading to a range of 21st century radiative forcing levels (2.6 W m^{-2} to 8.5 W m^{-2}) (See WGI Chapters 1, 6, 11, 12). All RCPs project a rapid decline in the short-lived pollutants and land-use change by 2050, almost independent of fossil-fuel use and population. Other published scenarios indicate a less rapid decline in near-term emissions aerosol precursors.

1.1. The Setting

The IPCC has published four impact assessment reports (WGII) of the state of knowledge of climate change in 1990, 1995, 2001 and 2007. The evolution of the WGII Table of Contents is depicted in Figure 1-1. 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 critical review and synthesis of this literature has required an expanded multidisciplinary approach that, in general, has focused more heavily on societal impacts and responses than the prior IPCC assessments. 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. The rapid advancement of the science, coupled with the close collaboration across all three IPCC Working Groups for AR5, has facilitated an in-depth and up-to-date assessment of climate change impacts, adaptation and vulnerability.

[INSERT FIGURE 1-1 HERE
Figure 1-1: 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 sent to IPCC Working Group III. Since the TAR, WG II has focused on impacts, adaptation and vulnerability with an expanded effort on the regional scale.]

1.1.1. Development of the Science Basis for the Assessment

The volume of literature available for assessing climate change impacts, adaptation and vulnerability has grown significantly over the past two decades (Figure 1-2a). A bibliometric analysis of reports produced with two bibliographic search tools (Scopus and ISI Web of Knowledge) indicates that fewer than 1,000 articles in journals, books, and conference proceedings were published in English on the topic of "climate change" between 1970 and 1989. Since 1989 the literature published on the topic increased almost 10,000-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 2000-2010 (Figure 1-2b). The proportion of literature focusing on individual countries within IPCC regions has also broadened, particularly for Asia, over the past 3 decades (Figure 1-2c). 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 1-2 HERE
Figure 1-2: 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: 1980-1989, 1990-1999, and 2000-2010, with total number during the period 2000-2010. (c) Results of literature searches for climate change publications with individual countries mentioned in publication title, abstract or key words, summed for all countries within each major IPCC region.]

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 climate change impacts, adaptation and vulnerability (Figure 1-2a). The unequal distribution of literature – geographically and topically – has also challenged the presentation of a balanced view of the impacts of climate change.

Literature published on the topic of climate change during 1970-1989 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 change 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 (Table 1-1). 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 S. Mosbah-Natanson, 2010) researchers.

[INSERT TABLE 1-1 HERE
Table 1-1: Number of publications in six languages that include the words "climate change" and "climate change" plus "adaptation", "impacts" and "cost" (translated) in the title, abstract or key words during three time periods: 1980-1989, 1990-1999, and 2000-2010.]

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

This section highlights the evolution of the scope and content of IPCC WGII reports since the first IPCC assessment was published in 1990. It describes how the terms used to communicate uncertainties in knowledge have evolved over the five IPCC assessments and it ends with the common set of terms used to describe uncertainties in knowledge presented in this Fifth Assessment Report of the IPCC.

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 1-1. Three important characteristics in this evolution are an increasing attention to: (i) the range and coupling of variables that impact a sustainable, global future; (ii) an increasing focus on human beings, their role in managing resources and natural systems, and 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 has extended the assessment of climate change challenges from the physical, ecosystem, and economic systems to include institutional, social, and cultural issues. The reframing has consequences for the types of solutions assessed, the future that is envisioned, conceptions of progress and quality of life, and our understanding the interactions between the natural climate system and human society. For example, many recent studies have assessed the role of interpreting climate change for people across the planet, including the risks, the population affected, and equitable solutions (e.g., O'Brien *et al.,* 2010). These new perspectives have complemented the historical focus of the WGII assessments on the sectoral and regional biogeophysical impacts of climate change. Together these components of assessment contribute to a better understanding of what remains an important source of uncertainty in climate predictions: knowledge about the likelihood of certain development paths.

The WGII FAR completed its assessment in less than 300 pages. The chapters were 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, assuming no mitigation or adaptation. 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 weak on hard numbers (e.g., comprehensive estimates are difficult; confidence is low; global agricultural potential may either increase or decrease; and major health impacts are possible). The FAR is more quantitative on the projected shift of climatic zones poleward by several hundred kilometers and those regions most at risk for habitat/species loss (alpine, montane). In general the expected 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.

For the IPCC Second Assessment Report (SAR, 1996), WGII was given the task of reviewing climate change impacts and vulnerability plus options to mitigate the growth in greenhouse gases. 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 makes use of the new IPCC IS92 scenarios where projections of 21^{st} century sea level rise (15-95 cm) and temperature increase (1.0-3.5°C) are similar to the FAR's doubled CO_2. 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., poleward shift of isotherms; the number of people at risk of flooding from storm surges from sea level rise; the increase in malaria incidence). Vegetation models are used with $2xCO_2$ climate-model simulations to map out projected changes in major biomes (see SAR WGII SPM Fig. 2) – the first such predictive figure in a WGII SPM. The last third of the SAR presents historical greenhouse gas emissions by sector and discusses technological options to reduce emissions or enhance uptake of carbon, but leaves the cost analysis of mitigation to WGIII.

The Third Assessment Report of WGII (TAR, 2001) returned to impacts, adaptation, and vulnerability, leaving all of 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 that we had seen the impacts: "Recent regional climate changes, particularly temperature increases, have already affected many physical and biological systems." It noted the range of long-term studies of local systems was consistent in direction and was coherent across diverse locations. It also stated that recent increases in floods and droughts had affected some human systems, but could not tie this to greenhouse gas 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 AR4 (Figure 1-2 and Table 1-1 of AR4) 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, 2014), presented in two parts with one devoted entirely to regions, considers a wide and complex range of multiple stresses that threaten the sustainability of human and ecological systems. Figure 1-2 portrays global maps for some of the stressors that are directly coupled to climate change [Note: as opposed to Millennium Goals for development] ranging from population and land-use change to projections of mean temperature, heat waves and water availability. The focus on climate change and related stressors that collectively determine vulnerability is evident in the outlines of many chapters of this report, including the expanded “reasons for concern” described in Chapters 2 and 19, and the seven major themes of AR5 WGII that are highlighted in Section 1.4 of this chapter.

[INSERT FIGURE 1-3 HERE
Figure 1-3: Examples of the multiple stresses impacting climate change impacts, adaptation and vulnerability: (a) current population, (b) human changes in land use and land cover in the 1990s, (c) projected global mean surface temperature change, (d) projected heat waves, and (e) projected changes in fresh water. Sources: (a) Global population density adjusted to UN figures for year 2000 from the LandScan project at Oak Ridge National Laboratory, Tennessee USA, www.ornl.gov/sci/landscan/index.shtml, figure from www.fao.org/docrep/009/a0310e/A0310E06.htm; (b) Croplands and pasture/rangeland coverage from Foley *et al*. (2005); (c) Projected mean surface temperature change for the 2090s SRES B1 relative to 1980-1999 from IPCC AR4 WGI Fig. 10.8; (d) Warm Spell Duration Index increase from 1980-1999 to 2081-2100 under SRES A2 normalized in terms of standard deviation (SD), Figure 5 of Orlowsky and Seneviratne (2011); (e) Projected change of annual runoff (%) from 1981-2000 to 2081-2100 for SRES A1B, from IPCC AR4 WGI Fig. 3.8. All projections used the climate model ensemble calculations for AR4 (CMIP3).]

1.1.2.2. An Increasing Emphasis on Adaptation

The Fourth Assessment Report (AR4, 2007), particularly Chapters 2 (New Assessment Methods and the Characterisation of Future Conditions) and 17 (Assessment of Adaptation Practices, Options, Constraints and Capacity), describes significant developments in methods and approaches for conducting climate change impact, adaptation and vulnerability (CCIAV) assessments. The acronym CCIAV emphasizes climate change as a driver of change, suggesting that even though other stressors or sources of vulnerability might be present, the impacts and adaptation aspects of the assessments relates solely to by climate and climate change, answering the question to what a system is vulnerable and must adapt to. While more examples and analyses on the topic of adaptation were presented than in prior reports, the Working Group II contribution to AR4 focused primarily on impact and scenario-driven studies.

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 1-4). 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. Worthy of note is the fact that the topic of adaptation in the aforementioned figure has not been treated as a single entity. Adaptation has been handled side by side with impacts and vulnerability; nonetheless, there has been increasing emphasis on adaptation.

[INSERT FIGURE 1-4 HERE
Figure 1-4: Percentage of space (in pages) devoted to topics relating to adaptation, impacts and vulnerability (I&V), mitigation and greenhouse gases inventories (GHG Inventories) in the First (1), Second (2) or Third (3) National Communications of several Latin American and Caribbean countries. Documents source: UNFCCC.]

The four chapters that are devoted to adaptation in Part 1 of this report (Chapters 14-17) were made possible by the rapidly growing knowledge and experience base concerning adaptation. Additional chapters in Part 1 of this report address the following crosscutting themes that relate to adaptive capacity: human security and livelihoods (Chapters 11-12); societal risks, vulnerabilities, and opportunities (Chapter 19); and climate-resilient pathways through a combination of adaptation, mitigation, and sustainable development (Chapter 20).

1.1.2.3. Treatment of Uncertainties in IPCC Assessment Reports: a Brief History

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 (see, e.g., 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 (see Table 1-2).

[INSERT TABLE 1-2 HERE
Table 1-2: An overview of calibrated uncertainty language used to characterize assessment findings in IPCC Assessment Reports. Adapted from Mastrandrea and Mach (2011).]

Each guidance paper has presented related but distinct approaches for evaluating and communicating the degree of certainty in findings of the assessment process. The Working Group II contribution to the TAR adopted the calibrated language described in the TAR guidance paper (Moss and Schneider, 2000), which presented both a probabilistic confidence scale and qualitative descriptors of evidence and agreement. The Working Group I contribution to the TAR predominantly used a distinct probabilistic likelihood scale to communicate uncertainties evaluated more through statistical and modeling analysis. The Guidance Notes for the AR4 (IPCC, 2005) responded to this divergence in usage by formally defining confidence and likelihood as two distinct scales of quantitatively calibrated language, while also modifying the qualitative descriptors of evidence and agreement.

In the AR4, all Working Groups employed calibrated uncertainty language, with Working Group III doing so for the first time. Drawing on different evidentiary bases, each Working Group favored different calibrated language in communicating the degree of certainty in key findings, and there was sometimes differing interpretation and application of the quantitative confidence and likelihood scales between Working Groups I and II. The AR5 Guidance Note (Mastrandrea *et al*., 2010), described in Box 1.1, is more explicit about the relationship between confidence and likelihood. Both confidence and likelihood assignments are based on an author team's evaluation of evidence and agreement, and qualitative confidence in the validity of a finding underlies quantitative likelihood assignments where they are made.

The AR5 Guidance Note also 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 1-5 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 1-5 HERE
Figure 1-5: 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 potential future conditions, 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 by business and industry for strategic planning, analysis and assessment, and they have figured prominently in the analysis of global climate change policy and assessment (Parson *et al*., 2007).

The IPCC has used scenarios for future climate since the FAR, where WGIII generated four scenarios (Bau = business-as-usual, B, C, D) that were used by WGI to project climate change, emphasizing large-scale measures such as global mean temperature and sea-level rise. In the IPCC Supplementary Report (IPCC, 1992), a joint WGI-WGIII effort defined six new scenarios (IS92a-f) that were used in the SAR. For the TAR, the IPCC Special Report on Emissions Scenarios (SRES: Nakicenkovic *et al*., 2000) created many representative scenarios from four Integrated Assessment Models that were grouped into categories and a marker scenario from one of the models was chosen (A1B, A1T, A1FI, A2, B1, B2). The SRES scenarios did not include mitigation options, and thus additional, CO_2-only, stabilization scenarios were assessed in both WGI and WGIII. The SRES scenarios carried over into the AR4 and formed the basis for the large number of ensemble climate simulations of the 21st century (CMIP3[1]) that are still being used in climate-change studies relevant to WGII.

[INSERT FOOTNOTE 1: 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 during the years 2005 and 2006 constitutes phase 3 of the Coupled Model Intercomparison Project (CMIP3). The data archived by over 20 modeling groups for use in AR5 constitutes phase 5 of the project (CMIP5).]

All of these IPCC scenarios relate socio-economic paths to anthropogenic emissions of greenhouse gases and related species such as aerosols and ozone precursors. The link quantifying the relationship between emissions and climate change was assessed in WGI, where the atmospheric greenhouse gas and aerosol abundances were derived along with the change in physical climate. With the AR5, the scenarios have fundamentally changed: an ad hoc community group, in anticipation of the 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 ($W\ m^{-2}$) since pre-industrial (RCP2.6, RCP4.5, RCP 6.0, RCP 8.5). 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 much weaker with the RCPs than in previous assessments, being calculated with a single parametric model with no uncertainties (Meinshausen *et al*. 2011), and ignoring changes in natural emissions. This aspect of the RCPs has been assessed in AR5 WGI.

The new ensemble climate simulations of the 21st century for the AR5 (CMIP5) used concentration pathways for the long-lived greenhouse gases from the simple model, but emissions pathways for aerosol and ozone precursors. Thus model-model differences result in different radiative forcing and climate change for the same RCP, and this is being evaluated in WGI Chapter 12. These new CMIP5 data were not available until late 2011 and thus have not fully penetrated the published literature on impacts, adaptation and vulnerability. Thus much of the research used in this WGII AR5 relies on the CMIP3 climate simulations using the SRES scenarios. The four RCP scenarios are compared with the SRES and IS92 scenarios in Figure 1-6. In terms of CO_2 emissions and total radiative forcing, RCP8.5 is similar to SRES A2, RCP4.5 parallels SRES B1, and intermediate RCP6.0 is close to IS92a. Thus in terms of overall climate change the SRES CMIP3 results may be similar to the CMIP5 for these two. In terms of climate change and direct CO_2 effects such as ocean acidification, RCP2.6 is unlike any previous IPCC emissions-based scenario, projecting a negative anthropogenic CO_2 flux by the end of the century. In terms of the aerosols, ozone and chemical composition of the atmosphere, however, all the RCPs resemble SRES B1, with none showing the increases in emissions of NOx (and aerosols, not shown) in many SRES or IS92 scenarios. The likelihood of these reductions is discussed in the AR5 WGI report. Impact studies based primarily on RCP emissions of these pollutants may need to consider the higher emissions pathways of the SRES, or at least some of the compromise scenarios for pollution (Dentener *et al*., 2005).

[INSERT FIGURE 1-6 HERE
Figure 1-6: Projections of CO_2 emissions (Pg-C/yr), NOx emissions (Tg-N/yr), and total radiative forcing (W/m^2) for the 21st century from the scenarios IS92 (a), SRES (A2, B1), and RCP (2.6, 4.5, 6.0, 8.5), as used in the IPCC SAR, TAR, AR4, and AR5.]

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

The Fourth Assessment Report (AR4) asserts 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 also highlights questions of justice and equity and offers a catalogue of multiple stresses jointly impacting people and communities (IPCC 2007a, pages 811-841). Socio-economic trajectories are among the largest sources of uncertainty in scenario building and climate predictions (Hawkins and Sutton 2009). A deeper understanding of patterns of global development from all countries and possibilities for their transformation towards sustainability are therefore key to addressing climate change and its impacts. Like the AR4, this Report defines sustainable development following the Brundlandt Commission[2] as development that meets "the needs of the present without compromising the ability of future generations to meet their own needs". But it also conveys sustainability as a dynamic process that guarantees and protects the equitable endurance of natural and human systems in the present and in the future. Empirical literature suggests that climate impacts could reverse past development achievements and global efforts on poverty reduction. This Report reveals substantive risks for socio-ecological systems in all regions but particularly in low-income economies.

[INSERT FOOTNOTE 2: The Brundlandt Commission, referred to more formally as the World Commission on Environment and Development, was created by the United Nations General Assembly in 1983.]

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 adaptation and vulnerability. This includes literature suggesting it is important to start thinking about adaptation to high end warming in all countries (New, Liverman, Schroeder and Anderson, 2010). The term "vulnerability" has acquired increased complexity as social systems, institutions and people are also addressed as "vulnerable" because of non-climatic reasons.

The IPCC TAR defines vulnerability as "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, TAR, 2001, page 388). The physical causes and their effects are an explicit aspect of vulnerability while the social context is encompassed by the notions of sensitivity and adaptive capacity (SREX, 2012). In the context of synergetic relations between climate impacts and development pathways, the term vulnerability refers also to structural conditions of poverty and inequality, the topics of development theory and practice. In this assessment, vulnerability is defined following the SREX terminology (see Glossary, page __). There is high confidence that adaptive capacity influences the vulnerability of communities and people to climate change, and given that adaptive capacity is highly dependent on prospects for increased living standards and human development indicators, we see an increasing amount of literature addressing these relations.

In addition to the concrete sectoral and thematic empirical literature assessed in each corresponding chapter in this Assessment, a survey of literature since the last IPCC Report shows theoretical and methodological scholarship is centered around the following topics: First, theoretical literature seeking synergies and an appropriate continuum between development and adaptation strategies and financing (ECLAC, 2010; Helberg, Siegel and Jorgensen, 2009; Mearns and Norton, 2010; Richardson, 2011; OECD, 2009; USAID, 2008; World Bank, 2010). Solutions proposed are greener versions of economic growth-driven development and revisited ideas of sustainable development. Key instruments proposed 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 key linkages with energy needs, such as Clean Development Mechanisms (CDMs). But there is an important discussion about the preconditions for market mechanisms, such as offsets, to work as intended (Liverman 2010). Moreover, incipient work on adaptation points to the role of new actors as key providers of adaptation measures, such as for example organizations and institutions (Berkhout, 2011; Boyd and Folke, 2011). There has also been incipient integration of climate change impacts with existing poverty reduction strategies. An in-depth discussion of the interactions between climate change, observed and future impacts and poverty as well as diverse theoretical perspectives is given in chapter 13.

Second we find an increasing amount of literature on adaptation planning and policy instruments linking with ongoing development efforts, such as National Adaptation Programmes of Action and Local Adaptation Programmes of Action (also see section 1.1.2.2 and Figure 1-4). 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) (e.g., CARE, 2009; UNDP, 2008a, 2010 and 2011; UNESCO, 2011; UNICEF, 2011; WHO, 2009; World Bank, 2010). While at the same time, environmental institutions are increasingly paying attention to socio-economic contexts, institutions and behavior as key drivers for addressing environmental crises. A clear example is the United Nations Environmental Protection Agency promotion of the concept green economies in relation to the Rio + 20 Summit. This has led to an academic debate on what are the conditions for green growth and their constitutive components as well as attempts to measure jointly sustainability and vulnerability to both human and climate related shocks (Banks and Sokolowski, 2011; Moran *et al*., 2008; Patt *et al*., 2009; UNECE/OECD/Eurostat, 2008).

Third, we find academic literature suggesting innovation in theoretical perspectives and re-conceptualization of what makes for "good development" within a changing climate, as well as the opposite, typologies of maladaptation and negative synergies. This includes linking vulnerability to climate impacts to structural causes of poverty and inequality (Agrawala and Van Aalst, 2008; Ayers and Huq 2009; Barnett and O'Neill 2010; Boyd and Juhola, 2009; Jerneck and Olsson, 2008; Klein *et al*., 2007; OECD 2009; O'Brien *et al*., 2008; O'Brien *et al*., 2010; Ogallo, 2010). There is, however, disagreement about some fundamental issues, in particular whether ideas of modernization, quality of life and ever 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; Shipper, 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*., 2011; Bond, Dada and Erion, 2008; McMichael 2009; OECD 2009b; Pogge 2008; Tschakert and Sagoe, 2009; UNDP, 2007, 2010, 2011).

Fourth, addressing the complexities that arise when contextualizing climate change impacts within development pathways and other drivers of environmental degradation has led to increasing attention to methodological challenges. This requires transdisciplinarity and enhancing synergies between policy relevance, salience for users at the community level and even co-production of knowledge (Hegger *et al*., 2012). A substantive 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 the crucial role of mitigation in relation to development achievements, all point to co-producing knowledge to increase legitimacy and credibility (Adger *et al*., 2009; Bedoe *et al*., 2009; Cannon and Müller-Mahn, 2010; Folke *et al*., 2010; Reid *et al.,* 2010; O'Brien *et al*., 2010; Shalizi and Lecocq, 2009; Tschakert and Dietrich, 2010; Urry 2010).

Fifth, literature reviews on the links between climate change and human development show that more and more scholarship gives a central role to questions of ethics and justice (Arnold 2011, Brown, 2010; Caney, 2012; ICHRP 2011;O'Brien *et al*., 2010; Pelling, 2010; Sachs, 2008; St.Clair, 2010; Tanner and Mitchell, 2008; Van Aalst *et al*., 2008). This research shows that as basic needs such energy, land, food or water become threatened, inequalities and unfairness may deepen as, for example, in the increasing cases of land grabbing in the African continent (Borras, McMichael, and Scoones, 2011). Addressing climate change vulnerabilities becomes 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 (Bond, 2011; Hansen, 2010; Martinez-Alier *et al*., 2011). The view is summarized by UNDP Human Development Report 2008b: "Two decades after the first HDR there is little evidence of progress in making the world more sustainable or in effectively protecting vulnerable people against shocks (UNDP, 2008b; pg., 82)."

Last, there has been an increase in literature focused on solutions to climate change, arguing for transformation instead of adaptation. Proponents of transformation differentiate between incremental change and transformative change (Park *et al*., 2012). Others point to the role that values, norms, belief systems, culture and conceptions of progress and well-being have in facilitating or preventing transformation (O'Brien, 2011; Pelling, 2011). Transformation of this nature requires action beyond seeking synergies between current development practices and climate change adaptation and towards a particular understanding of risk assessment (see also section 1.2.3). It is about recognizing that risk and uncertainty are likely to remain essential components of the process of adaptation. But a combination of adaptive management, learning, innovation and leadership, may lead to resilient development pathways (see also Chapter 20). This perspective evinces the new definition of sustainability offered by the UN High level Panel on Global Sustainability in its report entitled *Resilient People, Resilient Planet: A Future Worth choosing"*. This report views sustainable development not as a destination but as "*a dynamic process of adaptation, learning and action. It is about recognizing, understanding and acting on interconnections — above all those between the economy, society and the natural environment…"* (UN 2012, page 6). Emergent literature on sustainability taking the relations between climate, global environmental change, development and poverty and their associated dichotomies between the north and the south to a new dimension, as for example we see in the emergent reframing of global environmental change research (ICSU, 2012; Rockström *et al*., 2009). But there are deep gaps in this literature, in particular large gaps about the human aspects from mainstream social and human sciences that have traditionally addressed processes of change in other historical periods of systemic transformation (Hackmann and St. Clair, 2012).

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 many aspects of human activity, such as:

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

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). Examples presented in Chapter 1 of AR4 include:

- Settlements in mountain regions are at enhanced risk of glacier lake outburst floods caused by melting glaciers.
- Warmer and drier conditions have led to a reduced length of growing season with detrimental effects on crops in the Sahelian region of Africa or longer dry seasons and more uncertain rainfall are prompting adaptation measures in southern Africa.
- Sea-level rise and human development are together contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding in many areas.

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. They describe the following six major advancements in climate change impacts, adaptation and vulnerability assessment in the following key findings in AR4 Chapter 2 (Carter *et al*., 2007a, page 135):

1) The growth of different approaches to assessing CCIAV has been driven by the need for improved decision analysis.
2) Risk management is a useful framework for decisionmaking and its use is expanding rapidly.
3) Stakeholders bring vital inputs into CCIAV assessments about a range of risks and their management.
4) The impacts of climate change can be strongly modified by non-climate factors.
5) Scenario information is increasingly being developed at a finer geographical resolution for use in CCIAV studies.
6) Characterizations of the future used in CCIAV studies are evolving to include mitigation scenarios, large-scale singularities, and probabilistic futures.

1.2.3. Key Vulnerabilities and Reasons for Concern

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.

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 TAR, 2001) identified 5 ''Reasons for Concern''.[3] 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 remain a viable framework to consider key vulnerabilities. These 'reasons' are assessed here to be stronger than in the TAR. Many risks are identified with higher confidence. Some risks are projected to be larger or to occur at lower increases in temperature. Understanding about the relationship between impacts (the basis for 'reasons for concern' in the TAR) and vulnerability (that includes the ability to adapt to impacts) has improved. 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). Chapter 19 of this report will return to the "Reasons for Concern" as a unifying construction.

[INSERT FOOTNOTE 3: ***Five Reasons for Concern*** *(IPCC WGII Third Assessment Report, page 917)**:*** 1) Unique and threatened systems: an increase in global mean temperature of 2°C above 1990 levels or less would harm several such systems, in particular coral reefs and coastal regions. 2) Extreme events: frequency and magnitude of many extreme climate-related events (e.g., heatwaves, tropical cyclone intensities) will increase with a temperature increase of less than 2°C above 1990 levels; and that this increase and consequent damages will become greater at higher temperatures. 3) Distribution of impacts: developing countries will be more vulnerable to climate change than developed countries; warming of less than 2°C above 1990 levels would have net negative impacts on market sectors in many developing countries and net positive impacts on market sectors in many developed countries; above 2 to 3°C, there would be net negative impacts in many developed countries and additional negative impacts in many developing countries. 4) Aggregate impacts: increase in global mean temperature of up to 2°C above 1990 levels, aggregate market sector impacts would be plus or minus a few percent of gross world product, but most people in the world would be negatively affected. Studies of aggregate economic impacts found net damages beyond temperature increases of 2 to 3°C above 1990 levels, with increasing damages at higher magnitudes of climate change. 5) Large-scale singularities: rapid warming of over 3°C would trigger large-scale singularities in the climate system, such as changes in climate variability (e.g., ENSO changes), breakdown of the thermohaline circulation (THC – or equivalently, meridional overturning circulation, MOC), deglaciation of the WAIS, and climate–biosphere–carbon cycle feedbacks.]

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 adaption lies in the diversity of context, the paucity of actual adaptation to climate change that has been analyzed in the peer review literature, and the broader context within which multiple sources of stress are recognized. IPCC (2007c, page 20) highlighted this challenge by concluding that: "Sustainable development can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development pathways. Sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. At present, however, few plans for promoting sustainability have explicitly included either adapting to climate change impacts, or promoting adaptive capacity. On the other hand, it is very likely that climate change can slow the pace of progress towards sustainable development, either directly through increased exposure to adverse impact or indirectly through erosion of the capacity to adapt."

1.2.6. Limitations to 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). The major gaps cited in the Summary for Policymakers (SPM) and the Technical Summary (TS) for IPCC AR4 included:

- 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]
- Little advance evidenced in AR4 on the following [TS, 6.1]:
  - Impacts under different assumptions about how the world will evolve in future – societies, governance, technology and economic development
  - The costs of climate change, both of the impacts and of response (adaptation and mitigation)
  - Proximity to thresholds and tipping points
  - Impacts resulting from interactions between climate change and other human-induced environmental change
- 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]
- 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 [Tech. Summary 6.2 and Ch. 2.5, 3.3.1, 3.4.1, 4.3].
- Policymakers require understanding of abrupt climate change and the impacts of such events as the 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].
- Only a small amount of literature on the costs of climate change impacts could be found for the WG2 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].
- 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].
- 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].
- AR4 recognized that synergies exist between adaptive capacity and sustainable development, but further research is required to determine factors that contribute to this synergy [TS 6.2 and Ch. 20.9].

Examples of scientific limitations that were cited by WGII (2007) as impacting the scope of the AR4 assessment include:
- Inadequate understanding of the impacts of abrupt change events, such as the large sea level rises due to ice sheet melting, and their likely manifestation at a regional scale [TS 6.2]
- 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]
- 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]
- Wide range of 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]

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* (2012) that was produced jointly by Working Groups 1 and 2 (see Section 1.1.3 in this chapter). The WG1 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. [Note to reviewers, we will expand this paragraph upon the review of AR5 as a whole to determine the degree to which the limitations discussed above have been overcome.]

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, 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 and the Working Group I contribution to the AR5. We also highlight the most relevant key findings of the Working Group III report. In this section, we focus on the key findings and the fundamental framings and conceptual innovations the Assessment Reports bring to the development of the chapters that form Working Group II.

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 jointly produced by Working Groups I and II. It bridges and creates an integrated perspective across different expert communities working with disaster risk and disaster management in a changing climate. The SREX assesses scientific literature on the relationship between the role of climate change in altering characteristics of extreme weather and climate events and the implications these events have for society and sustainable development. The assessment covers empirical, methodological and theoretical perspectives from different research communities, institutions and organization studying climate science, climate impacts, adaptation to climate change, and disaster risk management to reduce exposure and vulnerability to climate extremes.

The report provides information on how:

- Natural climate variability and human-generated climate change influence the frequency, intensity, spatial extent, and duration of some extreme weather and climate events
- The vulnerability of exposed human society and ecosystems interacts with these events to determine impacts and the likelihood of disasters
- Different development pathways can make future populations more or less vulnerable to extreme events
- Experience with climate extremes and adaptation to climate change provides lessons on ways to better manage current and future risks related to extreme weather and climate events
- Populations can become more resilient before disasters strike (SREX Fact Sheet, IPCC 2011b).

The Report offers several key case studies illustrating the impacts of extreme events worldwide, and puts forward key recommendations such as early-warning systems, new forms of insurance coverage and expansion of social safety nets.

1.3.1.1. Themes and Specific Findings of SREX

The assessment carried out by the SREX identifies three *key themes*: first, weather and climate-related disaster risks are influenced by natural climatic variability and anthropogenic climate change. Second, observational evidence shows an increase in some climate and weather events in some areas of the world, and increases in extreme events are projected for the 21st century. Third, socioeconomic development as well as the accumulated experience with existing work on climate change adaptation and the management of the disaster risk provides useful information for effective preparedness and responses to disasters and extreme events. Specific findings for each of the three SREX themes, with the source section of the SREX provided in parentheses, include:

<u>Theme 1 – Changing Extreme Events</u>

Climate change, in addition to natural climate variability, can affect the type, magnitude and frequency of extreme weather and climate events, thereby altering the potential for extreme impacts and increasing societal risks from disasters. Unprecedented, previously unobserved extreme events and impacts may result with the possible occurrence of low-probability high-impact events associated with the crossing of poorly understood thresholds. Some of the projections highlighted in the Summary for Policy Makers of the SREX report (pages 3-22 of the report) are:

- It is *likely* that the frequency of heavy precipitation will increase in the 21st century over many regions. [SPM, 3. 3.2, 3.4.4, Table 3.3 Figure 3.7]
- It is *virtually certain* that increases in the frequency of warm daily temperature extremes and decreases in cold extremes will occur throughout the 21st century on a global scale. It is very likely—90 per cent to 100 per cent probability—that heat waves will increase in length, frequency, and/or intensity over most land areas. [SPM, 3.3.1, 3.1.6, Table 3.3, Figure 3.5]
- It is *likely* that the average maximum wind speed of tropical cyclones (also known as typhoons or hurricanes) will increase throughout the coming century, although possibly not in every ocean basin.

However it is also likely—in other words there is a 66 per cent to 100 per cent probability—that overall there will be either a decrease or essentially no change in the number of tropical cyclones. [SPM, 3.4.4]
- There is evidence providing a basis for *medium confidence* that droughts will intensify over the coming century in southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Confidence is limited because of definitional issues regarding how to classify and measure a drought, a lack of observational data, and the inability of models to include all the factors that influence droughts. [SPM, 3.5.1, SPM Figure 5, Table 3.3, Box 3.3],
- It is *very likely* that average sea level rise will contribute to upward trends in extreme sea levels in extreme coastal high water levels. [SPM, 3.5.3, 3.5.5, Box 3.4]
- Projected precipitation and temperature changes imply changes in floods, although overall there is l*ow confidence* at the global scale regarding climate-driven changes in magnitude or frequency of river related flooding, due to limited evidence and because the causes of regional changes are complex. [SPM, 3.5.2]

Theme 2 – Trends in Disaster Losses

- Economic losses from weather- and climate-related disasters vary from year to year and place to place, but overall have increased (*high confidence).*[SPM, 4.5.1., 4.5.3, 4.5.4]
- Total economic losses from natural disasters are higher in developed countries (*high confidence*). [SPM, 4.5.2., 4.5.4]
- 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]
- Economic losses from weather- and climate-related disasters have been heavily influenced by increasing exposure of people and economic assets *(high confidence)*. [SPM, 4.5.3]

Theme 3 – Managing Risks of Extreme Events and Disasters

Current disaster risk management and climate change adaptation policies and measures have not been sufficient to avoid, fully prepare for and respond to extreme weather and climate events. Advances in disaster risk management offer many lessons and opportunities for adapting to climate change. The SREX Fact Sheet (IPCC, 2011b) summarizes the key tasks for managing risks as follows:
- 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, 8.6.3, 8.7]
- 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, 5.3.4, 6.3.1, 6.5.1, 6.5.2 and Case Studies 9.2.11, 9.2.14 and assessment 7.4.3]
- Effective risk management generally involves a portfolio of actions, from improving infrastructure to building individual and institutional capacity, 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).

- 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]

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

The diversity of expert communities involved in this assessment and the added value of the synergies these creates is reflected in the integrative scope of many concepts and definitions, going beyond those offered by earlier IPCC Reports. In particular, the conceptual framing of the SREX links exposure and vulnerability and the role of socio-economic development pathways as determinants of the impacts and the likelihood of disaster risk for both human society and natural ecosystems. The SREX framing also permits addressing how synergies between disaster risk management and adaptation to climate change can reduce exposure and vulnerability to weather and climate events and thus reduce disaster risk, as well as increase resilience to the risks that cannot be eliminated. Both the framing of the problems and the framing of the solutions offered in the SREX highlight that effective disaster risk management as well as adaptation and any action on climate change must be undertaken within a planning and analysis framework that considers development levels, inequalities, and cultural and social practices, values and beliefs along with physical ecological factors.

The concept of vulnerability put forward by the SREX goes beyond the definition offered in prior IPCC assessment reports[4]in that it focuses more attention on human beings and the vulnerability of social and cultural assets as well as economic and physical assets. The SREX can be credited with bringing together the two definitions of vulnerability used by the disaster and the climate change communities and focus its analysis on the complex inter-linkages between social, economic, physical, cultural, environmental and political factors that define the vulnerability of a population. It defines vulnerability as 'the propensity or predisposition to be adversely affected'. Such predisposition constitutes an internal characteristic of the affected element and includes the characteristics of a person or group and their situation that influences their 'capacity to anticipate, cope with, resist and recover from the adverse effects of physical events' (SREX, 2012). In defining vulnerability, the SREX explicitly emphasizes the social context and therefore its 'predictive value', dealing with vulnerability independent of physical events.

The SREX also puts forward a new definition of adaptation by a differentiating between the propensity to change in responses to climate stimuli in human and natural systems. While the IPCC (2007b) definition of adaptation may imply that both human and natural systems can adjust to expected climate stimuli, the SREX qualifies this by saying that only human systems have the capacity to adjustment to both actual and expected climatic stimuli or their effects, while in natural system, the process of adjustment is confined to changes in response to actual climatic stimuli or their effects. At the same time, some forms of human intervention may provide opportunities for supporting natural system adjustment to future climate stimuli that have been anticipated by humans. Adaptation is defined in the SREX as: “In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate change” (see Glossary). Last, 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. It leads to the recognition that socio-economic systems are in constant flux, and that there are many conflicting and contradictory values at play.

This 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

[Placeholder for 1 or 2 pages of relevant highlights from the SRREN report in preparation by a leader of that report]

The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN, IPCC, 2011a) assesses existing literature on the future potential of renewable energy for the mitigation of climate change. It describes the six most important renewable energy technologies: bioenergy, direct solar energy, geothermal energy, hydropower and ocean energy. It analyses the integration of these sources into present and future energy systems and takes into consideration the environmental and social consequences associated with these technologies. The report concludes that 1) close to 80 percent of the world's energy supply could be met by renewable energy resources by mid-century if enabling public policies are implemented and 2) that the rising penetration of renewable energies could lead to cumulative greenhouse gas savings equivalent to 220 to 560 Gigatonnes of carbon dioxide ($GtC0_2eq$) between 2010 and 2050 (IPCC, 2011a).

Several findings of the SRREN report have clear linkages with this assessment of climate change impacts, adaptation and vulnerability. For example, the authors of the SRREN conclude that the sustainability of bioenergy, in particular in terms of lifecycle GHG emissions, is influenced by land and biomass resource management practices. This WGII AR5 assessment shows how land cover (including forests and agriculture) may be affected by future climate change, which has inferences for the potential of these lands to produce biofuels and sequester carbon from the atmosphere. In another relevant analysis, the SRREN concludes that water availability is a critical factor that limits the development of water cooled thermal power and hydropower. Chapter 4 of this report describes how climate change is likely to affect future surface and groundwater supplies and the stresses that the development of water-dependent energy resources can have freshwater ecosystems …

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

[Extended Version - Note that numerical values are provisional and may change with the WGI SOD.]

Key findings from the WGI FOD Executive Summaries relevant to WGII are summarized here. The certainty language used in WGI is not included but is considered in the chapters that use WGI material. All statements below are "likely" or higher. The chapters from WGI are noted in square brackets at the end of each sentence or section.

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) and the Coordinated Regional Downscaling Experiment (CORDEX) [WGI-9]. CMIP5 is a more comprehensive experiment than CMIP3 with about twice the number of participating models [WGI-12]. 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]: AOGCMs biases in surface temperature and precipitation are typically smaller; annual cycle of sea-ice extent is well simulated on average; ESMs are able to realistically simulate the annual cycle and spatial gradients of atmospheric CO_2, and the uptake of carbon, particularly by the ocean; and 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].

Forcing Scenarios and Comparison with AR4. The new CMIP5 results are similar to the AR4 CMIP3 results for the near term [WGI-11]. For the latter half of the 21st century, with caveats, RCP4.5 is approximately analogue with SRES B1 and other scenarios may be approximately paired according to the radiative forcing at the end of the 21st century, however important differences remain in the transient behaviour [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]. Analysis of anthropogenic emission pathways shows that those likely limit warming below 2°C (above pre-industrial) by 2100 have emission reductions of about 20% and 60% by 2020 and 2050, respectively, relative to 2010 emissions of 48 $GtCO_2eq\ yr^{-1}$. In cumulative terms, the 2°C temperature target implies cumulative carbon emissions of about 1000–1300 GtC, of which about 520 GtC were emitted by 2011 [WGI-12].

Temperatures. Globally averaged land surface air temperatures have increased since the late 19th Century and this warming has been particularly marked since the 1970s. The global combined land and ocean temperature data show an increase of about 0.8°C over the period 1901–2010 and about 0.5 °C over the period 1979–2010 when estimated by a linear trend [WGI-2]. The 50-year mean Northern Hemisphere temperature for 1961–2010 CE was very likely warmer than any previous 50-year mean in the last 800 years [WGI-5]. Over every continent except Antarctica, anthropogenic influence has made a substantial contribution to surface temperature increases [WGI-10]. Some changes in large-scale atmospheric circulation (e.g., Hadley, Northern Atlantic Oscillation, Southern Annular Mode) can be attributed, but with lower confidence [WGI-10]. Global average sea surface temperatures have increased since the beginning of the Twentieth Century [WGI-2]. 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 of 0.65x°C to 0.7xx°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 with respect to present day 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]. Changes in global land surface air temperature exceed changes in global average ocean-area surface air temperature in a ratio of 1.5 ± 0.2 (one standard deviation), as in AR4 [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. The mid- and higher latitudes of the Northern Hemisphere show an overall increase in precipitation from 1900–2010, however confidence is low because there is much uncertainty in the results for the early 20th Century. Insufficient evidence exists to define long-term temporal change of precipitation in the mid-latitudes of the Southern Hemisphere [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) but there is medium evidence and agreement for an effect on timing and intensity of precipitation [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 seen in the 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]. Rainfall change over tropical oceans follows a 'warmer-get-wetter' pattern, increasing where the SST warming exceeds the tropical mean, and vice versa [WGI-14].

Relative Humidity. Significant trends in tropospheric relative humidity at large spatial scales have not been observed [WGI-2]. Decreases in near-surface relative humidity occur over most land areas with the notable exceptions of tropical Africa and polar regions [WGI-12].

Hydrology, Flooding and Droughts. Extended periods of megadroughts have been observed during interglacial periods in North America, South America, Africa and Europe. 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. The CMIP5 models project consistent 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 Past. During the middle Pliocene about 3 million years ago, CO_2 concentrations were about 350 to 415 ppm, temperatures were about 2°C to 3°C above preindustrial values, and sea levels were 10 to 30 m above current values. Most of the additional ocean mass came from the Greenland and West Antarctic Ice Sheets, with additional contributions from the East Antarctic Ice Sheet [WGI-13]. During the last interglacial, global sea level was +4 to +6 m relative to present. A sea level rise of up to 4 m during this time interval can be explained by Greenland ice sheet melting in combination with ocean thermal expansion [WGI-5]. Rates of global mean sea level (GMSL) variations did not exceed 3 m per 1000 years (averaging 3 mm per year) within the last interglacial and the late Holocene [WGI-5]. The magnitude and rate of current sea level change is unusual in the context of the past millennium [WGI-5]. GMSL rise increased in the late 19th century (1840–1920) from relatively low rates of change during the late Holocene (order tenths of mm a^{-1}) to modern rates of rise (order mm a^{-1}) [WGI-13]. GMSL has been rising since 1900 at a rate of about 1.7 mm yr^{-1}, but changes over periods from ten to twenty years can be several times larger than this in some regions, driven by changes in large-scale winds and ocean circulation [WGI-3]. GMSL has been rising at a rate of 3.2 mm a^{-1} since 1993, with large regional variability around the global mean trend [WGI-13]. The rise since 1990 is higher than in any comparable period since 1950 [WGI-3].

Sea Level Rise Components. The recent sea level budget can explained and thus one should be able to better quantify and attribute sea level change in the future [WGI-3]. General circulation models reproduce the observed variability and the global mean trend in thermosteric sea level rise and upper-ocean (<700 m) heat content [WGI-13]. Modelled surface mass balance for Greenland and Antarctica is in agreement with the available limited observations [WGI-13]. Satellite observations of volume and mass change and ice-sheet motion have revealed significant dynamic changes in the ice sheets [WGI-13]. The sum of the simulated contributions explains the observed sea level rise since the early 1970s and indicates a faster rate of rise since the early 1990s, in agreement with the increase in the observed rate of rise [WGI-13].

Sea Level Projected. Under all the RCP scenarios, the time-mean rate of GMSL rise during the 21st century is very likely to exceed the rate observed during 1971–2010 [WGI-13]. Over the next few decades, regional sea level changes will be dominated by interannual to decadal sea level variability caused by internal (dynamical) variability of the climate system [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]. Semi-empirical models give higher projections than process-based models (e.g., 0.73–1.15 m for RCP4.5, and similarly for SRES A1B), but this difference is not understood, and there is no consensus about the reliability of semi-empirical model projections [WGI-13]. Regional patterns of projected sea level change, while overall positive, deviate significantly from the global mean [WGI-13].

Ocean Temperatures and Wave Heights. The upper ocean has warmed since 1970, when observations covering most of the global ocean become available [WGI-3]. While observations remain limited, wave heights have increased over the North Pacific since 1900, the North Atlantic since 1950 and the Southern Ocean over the last two decades. 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. Aragonite undersaturation in surface waters is reached within decades in the Southern Ocean as in AR4, but new studies show that undersaturation occurs sooner and is more intense in the Arctic. Most recent projections under AR5 mitigation scenarios illustrate that limiting the atmospheric CO_2 will greatly influence the level of ocean acidification that will be experienced [WGI-6]. Overall, in many regions of the ocean, there has been a tendency towards an increase in the stratification of the upper ocean, and a decline in ventilation, consistent with the observed tendency for declining oxygen in much of the upper ocean [WGI-3]. 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. The significant retreat in the extent of Arctic sea ice in all seasons that was documented by AR4 has continued. Since 1979, the annual average extent of ice in the Arctic has decreased by 4% per decade. The decline in extent at the end of summer has been even greater at 12% per decade [WGI-4]. Submarine and satellite records provide robust evidence that the thickness of Arctic ice, and hence the total mass of ice, has been decreasing since the 1980s [WGI-4]. This is the result of the loss of the thicker multiyear ice due to melt and export from the Arctic Basin with approximately 17% of this ice lost per decade between 1979 and 1999, and another 40% since 1999 [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]. The most likely range in global surface warming for a nearly ice-free Arctic Ocean is estimated to be 1.5 to 2.5°C above 1986–2005 [WGI-12]. In the Southern Hemisphere future changes in sea ice remain highly uncertain [WGI-12].

Cryosphere General. Reductions in Arctic sea ice and northern hemisphere snow cover extent, permafrost degradation and glacier retreat and increased surface melt of Greenland are evidence of systematic changes in the cryosphere linked to anthropogenic climate change [WGI-10]. Retreat of mountain glaciers is highly visible and widespread [WGI-4]. Since about 1960, mass budget measurements show different regional patterns with the highest variance in rates of mass changes in regions with maritime climates [WGI-4]. Cold high-latitude regions generally have less negative rates of mass loss, while mass changes of Central Europe show a strong linear trend of increasing loss, and a recently increased loss has also been observed for Alaska, the Canadian Arctic, and the Southern Andes [WGI-4]. The Arctic region warms most under all scenarios, as in AR4, with a polar amplification factor raging from 1.8 to 3.3 [WGI-12]. The Arctic polar amplification peaks in early winter and has a minimum in the summer season, and is not found in Antarctic regions [WGI-12].

Snow and Frozen Ground. In most regions analyzed, decreasing numbers of snowfall events are occurring where increased winter temperatures have been observed [WGI-2]. In situ and satellite observations indicate a decline in snow cover extent in most months over the 1922–2010 period of record, and largest declines (8%) occur in spring and are strongly correlated with atmospheric temperature and precipitation [WGI-4]. During the past three decades, significant degradation of the permafrost has been observed, and the average temperature of the permafrost has increased by up to 3°C in some regions of the Arctic [WGI-4]. The areal extent of permafrost is declining, moving towards higher latitudes and higher elevations [WGI-4]. The thickness of seasonally frozen ground has decreased by about 32 cm from 1930 through 2000 across Russia with minimal changes during the 2000s, and by 20 to 40 cm from 1960 to the present on the Qinghai-Xizang (Tibetan) Plateau [WGI-4]. Satellite records show that the thaw season has expanded by more than two weeks from 1988 through 2007 across central and eastern Asia [WGI-4]. Projected global warming diminishes both snow cover and the amount of water in the form of snow, but over much of the northern high latitudes snowfall is projected to increase [WGI-11]. Northern Hemisphere spring snow covered area decreases by the end of the 21st century between 9% (RCP2.6) and 24% (RCP8.5) [WGI-12]. Annual average decreases in permafrost are approximately xx% for 2016–2035 and yy% by 2050 [WGI-11]. By the end of the 21st century, diagnosed near-surface permafrost area is projected to decrease by 31% (RCP2.6) to 73% (RCP8.5) [WGI-12].

Surface Radiation – Clouds and Aerosols. While trends of cloud cover are consistent between independent data sets in certain regions, substantial ambiguity remains in the observations of global-scale cloud variability and trends [WGI-2]. Satellite datasets indicate a continuing decrease of Aerosol Optical Depth in the US, Europe, and Japan, and a continuing increase of AOD over Eastern and Southern Asia since the 1980s, which is consistent with long-term surface aerosol observations over North America and Europe [WGI-2]. At the surface, the evidence for widespread decadal changes in surface solar radiation (dimming until the 1980s and subsequent brightening) has been substantiated, in line with observed changes in a variety of other related variables, such as sunshine duration and hydrological quantities [WGI-2].

Greenhouse Gases & Radiative Forcing. Between 1750 and 2010, CO_2 emissions from fossil fuel combustion and cement production released 365 ± 22 PgC to the atmosphere, while deforestation and other land use change activities released an additional 151 ± 51 PgC [WGI-6]. Terrestrial ecosystems have accumulated 124 ± 59 Pg of anthropogenic C during the same period, more than compensating the cumulative C losses from land use change (mainly deforestation) since 1750 [WGI-6]. The gain of carbon by terrestrial ecosystems is estimated to take place mainly through the uptake of CO_2 by enhanced photosynthesis at higher CO_2 levels and N deposition, longer growing seasons in high latitudes, and the expansion and recovery of forests from past land use [WGI-6]. Fossil fuel and cement manufacturing emissions in the decade 2000–2009 increased at an average rate of 2.9% yr^{-1}. Emissions from land use change over the same decade are dominated by tropical deforestation [WGI-6]. Carbon cycle - climate feedbacks are similar in AR4 and AR5 [WGI-6]. The new CMIP5 models consistently estimate a positive feedback, i.e., reduced natural sinks or increased natural CO_2 sources in response to future climate change with carbon sinks in tropical land ecosystems most vulnerable to climate change [WGI-6]. 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]. A key update since AR4 is a smaller predicted land sink for a given trajectory of anthropogenic CO_2 emissions [WGI-6]. Forcing can also be attributed to activities: i.e., currently, global emissions from the power generation plus industrial sectors are the largest contributor to warming over the next 25–100 years; but livestock, household cooking and heating, on-road transportation, and agriculture are also important, especially over shorter time horizons [WGI-8].

Ozone, PM and other pollutants. The short-lived greenhouse gas tropospheric ozone has been increasing at many undisturbed (background) locations in the 1990s. These increases have continued mainly over Asia and flattened over Europe during the last decade [WGI-2]. Changes in ozone and aerosol have *likely* contributed to geographical changes in patterns of radiative forcing [WGI-2]. Large projected shifts in air quality for polluted regions that are subject to high surface ozone and particulate matter (PM or aerosols) are driven primarily by changes in local anthropogenic emissions of short-lived, reactive species, with important contributions from regional transport of anthropogenic PM and ozone on continental scales, and from ozone on a near-global scale [WGI-11]. There is increasing evidence that, with climate change, meteorological conditions are more conducive to producing extreme pollution events at the regional/urban scales due to increasing temperature and stagnation episodes [WGI-11]. Warming alone will likely increase O_3 in polluted regions, but increased water vapour will likely decrease baseline O_3 levels in surface air (except for RCP 8.5) [WGI-11]. The sign of the PM response to climate change is uncertain, depending on regional precipitation changes and shifting aerosol components [WGI-11].

Atmospheric Circulation and Patterns. Reconstructions of ENSO show with medium confidence that the large 20th century ENSO variability was unusual at least in the context of the last 350 years [WGI-5]. It is hard to say whether El Nino is going to intensify or weaken [WGI-14]. Large variability on interannual to decadal time scales and remaining differences between data sets precludes robust conclusions on long-term changes in large-scale atmospheric circulation [WGI-2]. Nevertheless, in a zonal mean sense, circulation features have moved poleward (widening of the tropical belt, shifting storm tracks and jet streams poleward, contracting the polar vortex) since the

1970s [WGI-2]. 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]. There is a projected increase in the strength of the most intense extratropical storms, although this is not uniform, at least for storms reaching Europe [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 - Past. Recent analyses of extreme events generally support the AR4 conclusions [WGI-2]. The overall number of cold days and nights has decreased and the overall number of warm days and nights on the global scale has increased since 1950. 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]. Recent assessments confirm the AR4 conclusion that there is evidence of an increase in the most intense tropical cyclones since the 1970s, but do not support the AR4 conclusion that globally, estimates of the potential destructiveness of all hurricanes show a significant upward trend since the mid-1970s [WGI-2]. There is still not enough evidence to determine whether robust global trends exist in small-scale severe weather events [WGI-2].

Extreme Weather & Climate - Projections. Near-term extremes have changes with the same sign as the long-term projected changes in the AR4 [WGI-11]. In the ENSEMBLES projections for Europe, daytime extreme temperatures are projected to warm at a faster rate than mean temperature [WGI-11]. There is little confidence in basin-scale projections of trends in tropical cyclone frequency and intensity to the mid-21st century [WGI-11]. Projections under 21st century greenhouse warming indicate that the global frequency of tropical cyclones will either decrease or remain essentially unchanged, concurrent with an increase in both global mean tropical cyclone maximum wind speed and rainfall rates [WGI-14]. In most places projections are for more hot and fewer cold extremes as global temperature increases [WGI-12]. 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]. Nevertheless, 21st century projected increases in extreme sea levels will occur as a result of an increase in mean sea level [WGI-13]. Dynamical and statistical techniques for sea and swell wave projections are improving, and ensemble assessments of wave-model projections are beginning to quantify uncertainties; however, wave projections are only as good as the wind fields used to generate them [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 Fifth Assessment Report

The Working Group III contribution to the IPCC's Fifth Assessment Report aims to explore the whole solution space of mitigation options and evaluate their costs, risks and opportunities. It presents a series of self-consistent transformation pathways. These socio-economic mitigation scenarios serve as an important integrative element within Working Group III and are embedded within a broader scenario framework that link between the Working Group (Moss *et al*., 2010). It is important to recognise that there is not a single pathway for the stabilization of greenhouse concentrations in the atmosphere. Instead there is a whole range of pathways. Which mitigation path to take depends upon a series of normative choices regarding the long-term stabilization goal, policies implemented for achieving the goal or other societal priorities. These are largely outside the scope of science, i.e. there is no scientific resolution of value dissent underlying the climate change discourse (e.g. Jasanoff and Wynne, 1998; Sarewitz, 2004; Pielke, 2007; Robert and Zeckhauser, 2011). Moreover, the pathways are clouded by uncertainties, which might not be easily reduced by science (Weinberg, 1972; Funtowicz and Ravetz, 1990; Wynne, 1992; van der Sluijs, 2005).

The Working Group III assessment is designed structurally to address these challenges. Chapters 2-4 provide the "framing issues" for the subsequent analysis. Chapter 2 outlines how to interpret and deal with risk and uncertainty in developing and implementing policies and decisions aimed at mitigating climate change. It further establishes the calibrated uncertainty language that allows for a consistent quantitative and qualitative discussion of uncertainties across Working Groups (Mastrandrea *et al*., 2011). Chapter 3 describes key social, economic, and ethical concepts and methods used throughout the report. It brings assumptions and normative underpinnings to the surface. This is important as in the social sciences facts and values cannot be neatly separated (Proctor, 1991; Jasanoff and Wynne, 1998; Putnam, 2002; Douglas, 2009). For example, model results cannot be seen in isolation from the value judgments made in the development of the models. Finally, Chapter 4 outlines how climate change can be framed within the wider context of sustainable development and operationalizes this framework for the Working Group III contribution of the AR5.

At the centre of the report (Chapters 5-12) the available mitigation options are plated in the "transformation pathways" section. The section is based on a based on a structure that includes chapters that treat mitigation from an integrated, and typically longer-term, perspective and chapters that take on mitigation within specific sectors. This structure acknowledges that mitigation research takes place at a continuum of scales from research on individual, near-term mitigation options to research on long-term, global, integrated scenarios.

Based on an analysis of historic emission trends and drivers (Chapter 5), Chapter 6 provides the global integrative perspective and evaluates the feasibility of long-term stabilization levels given current concentrations and the potential capabilities to reduce emissions. It identifies potential characteristics of transformation pathways – for example, emissions trajectories, macro-economic costs, energy systems transitions, land use patterns, co-benefits, and risks – that are associated with long-term stabilization. However, only in combination with the climate projections, impact studies and adaptation analysis, it is possible to understand the potential costs and risks of acting or not acting on climate change.

The subsequent transformation pathway chapters provide a complementary sector perspective for the energy system (Chapter 7), transport (Chapter 8), buildings (Chapter 9), industry (Chapter 10) as well as agriculture, forestry and land-use (Chapter 11). One the one hand, these chapters drill into the strategic choices identified in chapter 6 by assessing specific sectoral mitigation options. On the other hand, these chapters discuss to which extent sector-specific literature supports the strategic sectoral mitigation options identified by the system-wide models of Chapter 6 by synthesising and comparing bottom-up sector studies with results from the integrated, top-down view of the long-term transformation pathways. Chapter 12 is cross-cutting and assesses the specific mitigation potentials associated with human settlements and infrastructures. A strong focus is given to the role urbanisation processes in climate change mitigation. All sector chapters provide direct interfaces to the Working Group II contribution through assessments of synergies, tradeoffs and interactions with adaption options.

The Working Group III contribution to the AR5 ends with an assessment of policies, institutions and finance options for climate change mitigation. Chapters 13 to 15 broadly discuss implementation and design of policy instruments at different points of intervention and in different institutional settings. This includes how these instruments might encourage investments and generate funds. Chapter 13 assesses the available options for organizing and implementing agreements and instruments of international cooperation including existing and alternative climate policy architectures. Chapter 14 focuses assesses policy instruments in the regional context, while Chapter 15 moves to the national and sub-national level. The issue of climate finance requirements of climate policy options and the question how much funds might be required and where they might come from are addressed in Chapter 16.

1.4. Major Themes of the WGII Contribution to AR5

Climate science is advancing rapidly, with a wide range of new knowledge concerning diverse aspects of impacts, adaptation, and vulnerability that provide opportunities for providing more policy relevant information to understand the magnitude and extent of possible impacts of climate change, taking into account the vulnerabilities and multiple stressors that also are drivers of impacts, to support good policy decisions. As indicated in Figure 1-1, the scope and themes of the Working Group II contribution to the IPCC assessment reports have also expanded over the past 20 years. Seven key themes addressed in the WGII contribution to the AR5 include:

1) *Advances in integrating physical climate science with human and natural systems to assess impacts*. The distinction between impacts of climate change and other drivers of future climate change can be blurry, but is important to clarify where possible. For example, an increase in wildfires might be partially attributed to climate change, with a consequence of the increase release of CO_2 and other GHGs to the atmosphere that amplifies warming. Coupled models that cut across and accurately simulate the interactions of temperature, precipitation and runoff, soil moisture and plant biomass production are used to quantify relationships between wildfire intensity and frequency and climatic change.
2) *Broadening the consideration of climatic drivers, including extremes and interactive effects*. Increased understanding of the potential impacts of climate change allows for coverage of additional issues, such as extreme events and weather-related disasters. There is new science on climate change and oceans, including studies on acidification, thermal tolerance of fish and other ocean organisms, and food webs. Climate and security issues range from disputes over resources to population migration to rapid disease emergence. There also is new information on the indirect impacts of climate changes in remote locations, or impact teleconnections, such as reduced crop yields in one region leading to food insecurity in another.
3) *Assessing a broader range of impacts of climate change in the context of other well documented stresses*. Many of the challenging regional impacts of climate change emerge from interacting stresses on people, societies, infrastructure, industry, and ecosystems. These stresses can be consequences of climate change or factors independent of climate change, such as economic development, geopolitical setting, population pressure, and land use change. In some cases, effective adaptation may involve addressing stressors other than climate change. In others, it may be useful to adapt simultaneously across several stresses.
4) *Improved understanding of the relations between adaptation, mitigation, development and sustainability*. Adapting to climate change and promoting sustainable development share common goals and determinants including access to resources (such as information and technology), equity in the distribution of resources, stocks of human and social capital, access to risk sharing mechanisms, and abilities of decision-support mechanisms to cope with uncertainty. It is increasingly clear that response strategies can be more effective when they include mitigation and adaptation in a setting where all impacts may not be avoided. An important component of integrating adaptation and mitigation is estimating the costs of inaction, the costs and benefits of adaptation, and the costs of residual damages. Better understanding is needed of not only the aggregate costs, but of regional and sectoral cost estimates and how they might vary across temporal scales. There is a growing emphasis on the incorporation of non-market impacts when calculating the costs of climate change.
5) *Expanded coverage of adaptation*. The AR5 seeks to assess current practice at local, national, regional, and international scales to identify best practices and lessons learned, opportunities to increase climate resilience, and approaches to overcome barriers to implementation. Further understanding is needed about opportunities to address barriers and limits of adaptation, partly because effective adaptation measures are highly dependent on specific geographical and climate risk factors as well as institutional, political, and financial constraints.
6) *Comprehensive treatment of regional aspects, with input from WGs I and III*. Regional aspects are fundamental to assessing climate science, impacts, adaptation, and vulnerability. Regions vary in important

determinants of vulnerability, and they often (but not always) share constraints and opportunities from climate similarities, socioeconomic status, infrastructure, and other factors. Input from topics covered in WG I and III would benefit an integrated assessment. 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,* and by coordination with WG I and WG III.

7) *Framing to support good policy decision, including information on risk*. Reducing current and projected impacts of climate change requires effective climate policy that involves a portfolio of actions, with decisions taken at different governance levels. The AR4 Synthesis Report concluded that responding to climate change involves an iterative risk management process that includes both mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk. Effective support for good decisions depends on extracting information from the full range of possible outcomes, weighted by probability. Policy makers are asking for consideration not only of impacts resulting from the most likely climate scenarios, but also impacts arising from lower-probability and higher-consequence events, as well as the consequences of proposed policies.

A cross-cutting theme that emerged in the preparation of the Working Group II contribution to AR5 is the *increasing attention on human individuals, society and sustainability* (Figure 1-7). 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.

[INSERT FIGURE 1-7 HERE
Figure 1-7: Unifying themes of the IPCC Working Group II contribution to the IPCC Fifth Assessment Report.]

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 nonpeer-reviewed literature sources. Materials relevant to IPCC Reports, in particular, information about the experience and practice of the private sector in mitigation and adaptation activities, are found in sources that have not been published or peer reviewed (e.g., industry journals and internal organisational publications, non-peer reviewed reports and proceedings of workshops etc). 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 climate change impacts, adaptation and mitigation evolved since the 2007 IPCC Assessment?

The themes covered by recent literature on impacts, adaptation and vulnerability to climate change have expanded in the major categories listed below. Examples of relevant findings presented in this report, for illustration, are given in parentheses. The broader literature basis has enabled robust assessment across a greater number of sectors with finer-scale regional details.

- *Advances in integrating physical climate science with human systems and natural ecosystems to assess impacts***.** For example, the ability to couple models that cut across and accurately simulate the interactions of temperature, precipitation and runoff, soil moisture and plant biomass production to evaluate relationships between an increase in wildfires and climatic change. [7.1; 4.3.4. etc]
- *Broadening the consideration of climatic drivers, including extremes and interactive effects*. Increased understanding of the physical drivers, their interactions and potential impacts of climate change allows for coverage of additional topics, such as extreme events and weather-related disasters. [1.1.1.; 12.1.3. etc]

- *Assessing a broader range of impacts in the context of other well documented stresses*. 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 many natural and human systems.[19.4 etc]
- *Improved understanding of the relations between adaptation, mitigation and sustainability*. Mitigating and adapting to climate change and activities that promote sustainable development often share common goals and determinants, as described in several chapters of this assessment. [20.2 etc]
- *Expanded coverage of adaptation*. The AR5 seeks to assess current practice at local, national, regional, and international scales. Effective adaptation measures are highly dependent on specific geographical and climate risk factors as well as governance, institutional, political and financial constraints. [Chapters 14-17 are devoted to various aspects of adaptation]
- *Comprehensive and integrated treatment of regional aspects of climate change (Cross-cutting theme)*. 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 coordination with WG I and WG III.
- *Framing to support good policy decisions, including information on risk*. The nature of the information reflected in the literature has enabled an evaluation of practical risk management approaches that consider mixes of mitigation, adaptation and impacts. [19.7.1 etc]
- *More attention to human beings, societies and institutions*. 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 can science inform societal responses to climate change, and 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.

References

Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit, and K. Takahashi, 2007: Assessment of adaptation practices, options, constraints and capacity. In: *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 717-743.

Adger, W.N., I. Lorenzoni, and K. O'Brien, 2009: *Adapting to Climate Change: Thresholds, Values, Governance*. Cambridge University Press, 532 pp.

Agrawala, S. and M. van Aalst, 2008: Adapting development cooperation to adapt to climate change. *Climate Policy,* **8(2)**, 183-193.

Alcaide, G.G., J.C.V Zurián, and R.A. Benavent, 2012. *Analysis of the internationalization process of Spanish research in science and technology* (1980-2007) [Análisis del proceso de internacionalización de la investigación española en ciencia y tecnología (1980-2007)]. Revista Espanola de Documentacion Cientifica 35: 94-118.

Alkire, S. and J. Foster, 2011: Counting and multidimensional poverty measurement. *Journal of Public Economics,* **95(7-8)**, 476-487.

Alston, M., 2011: Gender and climate change in australia. *Journal of Sociology,* **47(1)**, 53-70.

Ayers, J. and D. Dodman, 2010: Climate change adaptation and development I. the state of the debate. *Progress in Development Studies,* **10(2)**, 161-168.

Barnett, J. and W.N. Adger, 2007: Climate change, human security and violent conflict. *Political Geography,* **26(6)**, 639-655.

Beddoe, R., R. Costanza, J. Farley, E. Garza, J. Kent, I. Kubiszewski, L. Martinez, T. McCowen, K. Murphy, N. Myers, Z. Ogden, K. Stapleton, and J. Woodward, 2009: Overcoming systemic roadblocks to sustainability: The evolutionary redesign of worldviews, institutions, and technologies. *Proceedings of the National Academy of Sciences of the United States of America,* **106(8)**, 2483-2489.

Berkhout, F. 2011. Adaptation to climate change by organizations. WIRE Climate Change (forthcoming).

Bond, P., 2011 forthcoming: ***Politics of climate justice paralysis above, movement below***.

Boyd, E. and S. Juhola, 2009: Stepping up to the climate change: Opportunities in re-conceptualising development futures. *Journal of International Development,* **21(6)**, 792-804.

Boyd, E., H. Osbahr, P. Ericksen, E. Tompkins, M.C. Lemos, and F. Miller, 2008: Resilience and 'Climatizing' development: Examples and policy implications. *Development,* **51(3)**, 390-396.

Brewer, G.D. and M. Shubik, 1979: *The war game: A critique of military problem-solving*. Harvard University Press.

Brooks, N., N. Grist, and K. Brown, 2009: Development futures in the context of climate change: Challenging the present and learning from the past. *Development Policy Review,* **27(6)**, 741-765.

Büscher, B., S. Sian, K. Neves, J. Igoe, and D. Brockington, 2011 (forthcoming).: Towards a synthesized critique of neoliberal biodiversity conservation. *Capitalism, Nature Socialism*.

Cannon, T. and D. Müller-Mahn, 2010: Vulnerability, resilience and development discourses in context of climate change. *Natural Hazards,* **55(3)**, 621-635.

CARE, 2009: Waiting for the Water to Come? Poverty Reduction in Times of Global Climate Change, 48 pp.

Carter, T.R., R.N. Jones, X. Lu, X. Bhadwal, C. Conde, L.O. Mearns, B.C. O'Neill, M.D.A. Rounsevell, and M.B. Zurek, 2007: New assessment methods and the characterisation of future conditions. In: *Climate change 2007: Impacts, adaptation and vulnerability. contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 133-171.

Comim, F., 2008: Climate injustice and development: A capability perspective. *Development,* **51(3)**, 344-349.

Conde, C. and K. Lonsdale, 2005: Engaging stakeholders in the adaptation process. In: *Adaptation policy frameworks for climate change: Developing strategies, policies and measures*. [Lim, B., E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq (eds.)]. Cambridge University Press, Cambridge and New York, pp. 47-66.

Daniels, S. and G.H. Endfield, 2009: Narratives of climate change: Introduction. *Journal of Historical Geography,* **35(2)**, 215-222.

Douglas, Heather. 2009. *Science, Policy, and the Value-free Ideal*. Pittsburgh, PA, USA: University of Pittsburgh Press.

ECLAC, 2010: Panorama Social De América Latina 2010.

Elizalde Carranza, M. Á. (2010): Desarrollo y cambio climático. *REVISTA CATALANA DE DRET AMBIENTAL,* **1(1)**, 1-22.

Folland C.K., T.R. Karl, K.Y.A. Vinnikov, 1990: *Observed climate variations and change*. *In: Climate change: The IPCC scientific assessment*. Report prepared for IPCC by Working Group I [Houghton, J.T., G.J. Jenkins, and J.J. Ephraums (eds.)]. Cambridge University Press, Cambridge, UK, pp. 195-238.

Foley, J.A., R. DeFries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, M.T. Coe, G.C. Daily, H.K. Gibbs, J.H. Helkowski, T. Holloway, E.A. Howard, C.J. Kucharik, C. Monfreda, J.A. Patz, I.C. Prentice, N. Ramankutty, and P.K. Snyder, 2005: Global Consequences of Land Use. *Science*, **309**, 570-574.

Folke, C., S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström, 2010: Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society,* **15(4)**.

French, D., 2010: *Global justice and sustainable development* Martinus Nijhoff, Leiden; Boston, [Duncan French (ed.)], 418 pp.

Funtowicz, Silvio O., and Jerome R. Ravetz. 1990: *Uncertainty and Quality in Science for Policy*. Dortrecht, Netherlands: Kluwer Academic Publishers.

Gagnon-Lebrun, F. and S. Agrawala (2006): *Progress on Adaptation to Climate Change in Developed Countries*: An Analysis of Broad Trends, ENV/EPOC/GSP(2006)1/FINAL, OECD, Paris.
Giarraca, N., 2007: The tragedy of development: Disputes over natural resources in argentina. *Sociedad (Buenos Aires),* **3**.
Gingras, Y. and S. Mosbah-Natanson, 2010: The French social sciences between local anchoring and international visibility [Les **sciences** sociales françaises entre ancrage local et visibilité internationale] Archives Europeennes de Sociologie, 51:305-321.
Grist, N., 2008: Positioning climate change in sustainable development discourse. *Journal of International Development,* **20(6)**, 783-803.
Gunasekera, D., 2010: Use of climate information for socio-economic benefits. *Procedia Environmental Sciences,* **1**, 384-386.
Gutiérrez, M.E. and T. Espinosa, 2010: Vulnerabilidad y Adaptación Al Cambio Climático Diagnóstico Inicial, Avances, Vacíos y Potenciales Líneas De Acción En Mesoamérica, BID, Washington, D.C.
Halsnaes, K., P.R. Shukla, and A. Garg, 2008: Sustainable development and climate change: Lessons from country studies. *Climate Policy,* **8(2)**, 202-219.
Halsnaes, K. and J. Verhagen, 2007: Development based climate change adaptation and mitigation—conceptual issues and lessons learned in studies in developing countries. *Mitigation and Adaptation Strategies for Global Change,* pp. 665-684.
Hansen, J., 2010: *Storms of my grandchildren*. Bloomsbury, 336 pp.
Hawkins, E. and R. Sutton, 2009: The potential to narrow uncertainty in regional climate predictions. *Bulletin of the American Meteorological Society,* **90(8)**, 1095-1107.
Hegger, D., M. Lamers, A. Van Zeijl-Rozema, and C Dieperink, 2012:Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. *Environmental Science and Policy*, **18**, 52-65.
Heltberg, R., P.B. Siegel, and S.L. Jorgensen, 2009: Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change,* **19(1)**, 89-99.
Hulme, M., 2009: *Why we disagree about climate change understanding controversy, inaction and opportunity*. Cambridge University Press, 432 pp.
Hulme, M., 2010: Cosmopolitan climates: Hybridity, foresight and meaning. *Theory, Culture & Society,* **27(2-3)**, 267-276.
IAASTD, 2009: Agriculture at a Crossroads. International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), Global Report. Island Press, Washington, D.C.
Ibarrarán, M., M. Ruth, S. Ahmad, and M. London, 2009: Climate change and natural disasters: Macroeconomic performance and distributional impacts. *Environment, Development and Sustainability,* **11(3)**, 549-569.
ICHRP, 2011 (forthcoming): Human Rights and Climate Technology Policy: Using Technology to Protect Rights in a Climate Constrain World, ICHRP.
IISD, 2005: *Environment and trade: A handbook*. International Institute for Sustainable Development and the United Nations Environment Programme; IISD, 142 pp.
Ionescu, C., R. Klein, J. Hinkel, K. Kavi Kumar, and R. Klein, 2009: Towards a formal framework of vulnerability to climate change. *Environmental Modeling and Assessment,* **14(1)**, 1-16.
IPCC, 1990: *Climate change: The IPCC scientific assessment*. Report prepared for IPCC by Working Group I Houghton, J.T., G.J. Jenkins, and J.J. Ephraums (eds.)]. Cambridge University Press, Cambridge, UK, 410 pp.
IPCC, 1992: *Climate change 1992: The supplementary report to the IPCC scientific assessment* [J.H. Houghton, B.A. Calandar, S.K. Varney (eds.)]. Cambridge University Press. 200 pp.
IPCC, 1996: *Climate Change 1995: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, 880 pp.
IPCC, 2001a: *Climate change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, UK, 892 pp.
IPCC, 2001b: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White, (eds.)]. Cambridge University Press, Cambridge, 1032 pp.

IPCC, 2005: *Guidance notes for lead authors of the IPCC Fourth Assessment Report on addressing uncertainties. Intergovernmental Panel on Climate Change* (IPCC), Geneva, Switzerland.

IPCC, 2007a: *Climate change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. , 996 pp.

IPCC, 2007b: *Climate Change Impacts, Adaptations and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 976 pp.

IPCC, 2007c: *Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Pachauri, R.K. and Reisinger, A. (eds.)]. Geneva, Switzerland. 104 pp.

IPCC, 2007d: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 7-22.

IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp.

IPCC, 2011b: Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, FACT SHEET. 3 pp.

IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

Jasanoff, S., 2010: A new climate for society. *Theory, Culture & Society,* **27(2-3)**, 233-253.

Jasanoff, Sheila, and Brian Wynne. 1998: Science and Decisionmaking. In: *Human Choice and Climate Change. Volume 1: The Societal Framework*, [Steve Raynor and Elizabeth Malone (eds.)] Battelle Press, Columbus, OH, USA. 87 pp.

Jerneck, A. and L. Olsson, 2008: Adaptation and the poor: Development, resilience and transition. *Climate Policy,* **8(2)**, 170-182.

Jones, R.N. and L.O. Mearns, 2005: Assessing future climate risks. In: *Adaptation policy frameworks for climate change: Developing strategies, policies and measures*. [Lim, B., E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq (eds.)]. Cambridge University Press, Cambridge and New York, pp. 119-143.

Kellogg, W.W. and S.H. Schneider, 1974: Climate stabilization: For better or for worse? *Science,* **186**, 1163.

Klein, R., S. Eriksen, L. Næss, A. Hammill, T. Tanner, C. Robledo, and K. O'Brien, 2007: Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance. *Climatic Change,* **84(1)**, 23-44.

Kirchik, O., Y. Gingras, and V. Larivière, (in press). *Changes in publication languages and citation practices and their effect on the scientific impact of Russian science* (1993-2010). Journal of the American Society for Information Science and Technology.

Kok, M., B. Metz, J. Verhagen, and S. Van Rooijen, Integrating development and climate policies: National and international benefits. *Climate Policy,* **8(2)**, 103-118.

Levina, E. and D. Tirpak, 2005: The Developing CDM Market, 1-15 pp.

McBean, G.A., P.S. Liss, and S.H. Schneider, 1996: *Advancing our understanding. In: Climate change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 517-531.

Malone, E.L. and E.L. La Rovere, 2005: Assessing current and changing socio-economic conditions. In: *Adaptation policy frameworks for climate change: Developing strategies, strategies, policies and measures*. [Lim, B., E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq(eds.)]. Cambridge University Press, Cambridge and New York, pp. 145-163.

Martens, P., D. McEvoy, and C. Chang, 2009: The climate change challenge: Linking vulnerability, adaptation, and mitigation. *Current Opinion in Environmental Sustainability,* **1(1)**, 14-18.

Martinez-Alier, J., 2011: The EROI of agriculture and its use by the via campesina. *Journal of Peasant Studies,* **38(1)**, 145-160.
Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe, and F.W. Zwiers, 2010: *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*. *Intergovernmental Panel on Climate Change*, Geneva, Switzerland.
Mastrandrea, Michael D., Katharine J. Mach, Gian-Kasper Plattner, Ottmar Edenhofer, Thomas F. Stocker, Christopher B. Field, Kristie L. Ebi, and Patrick R. Matschoss, 2011: The IPCC AR5 guidance note on consistent treatment of uncertainties: a common approach across the Working Groups. *Climatic Change,* **108 (4)**, (August 18): 675–691. doi:10.1007/s10584-011-0178-6.
Mastrandrea, M.D. and K.J. Mach, 2011: *Treatment of uncertainties in IPCC Assessment Reports: past approaches and considerations for the Fifth Assessment Report*. *Climatic Change* 108, 659–673.
Matthew, R.A. and A. Hammill, 2009: Sustainable development and climate change. *International Affairs,* **85(6)**, 1117-1128.
Mcmichael, P., 2009: Contemporary contradictions of the global development project: Geopolitics, global ecology and the development climate. *Third World Quarterly,* **30(1)**, 247-262.
Mearns, R. and A. Norton (eds.), 2010: *Social dimensions of climate change: Equity and vulnerability in a warming world*. The World Bank, Washington, USA, 348 pp.
Moran, D.D., M. Wackernagel, J.A. Kitzes, S.H. Goldfinger, and A. Boutaud, 2008: Measuring sustainable development — nation by nation. *Ecological Economics,* **64(3)**, 470-474.
Moss, R.H. and S.H. Schneider, 2000: Uncertainties in the IPCC TAR: Recommendations to lead authors for more consistent assessment and reporting. In: *Guidance papers on the cross cutting issues of the Third Assessment Report of the IPCC* [Pachauri, R., T. Taniguchi, and K. Tanaka (eds.)]. World Meteorological Organization, Geneva, pp. 33-51.
Moss, R.H., J.A. Edmunds, K. Hibbard, M. Manning, S.K. Rose, D. Van Vuuren, T. Carter, S. Emori, M. Kainuma, T. Kram, G. Meehl, J. Mitchell, N. Nakicenovic, K. Riahi, S.J. Smith, R. Stouffer, A.M. Thomson, J. Weyant, and T. Wilbanks, 2010. The next generation of scenarios for climate change research and assessment. *Nature*, **463(7282)**, 747–756.
Mitchell, J.F.B., S. Manabe, V. Meleshko, and T. Tokioka, 1990: Equilibrium climate change—and its implications for the future. In: *Climate change: The IPCC scientific assessment. Report prepared for IPCC by Working Group I* [Houghton, J.T., G.J. Jenkins, and J.J. Ephraums (eds.)]. Cambridge University Press, Cambridge, UK, pp. 131-172.
Muñoz, M. M., 2010: Justicia global y seguridad humana en el contexto del cambio climático. *ISEGORÍA. Revista de Filosofía Moral y Política, **43***, 589-604.
National Research Council, 2010: Describing Socioeconomic Futures for Climate Change Research and Assessment: Report of a Workshop. Panel on Socio-Economic Scenarios for Climate Change Research and Assessment, Committee on the Human Dimensions of Global Change, Division of Behavioral and Social Sciences and Education. The National Academies Press, Washington, DC, 1-57 pp.
Newell, P., 2004: Climate change and development: A tale of two crises. *IDS Bulletin,* **35(3)**, 120-126.
Newell, P., 2011: The elephant in the room: Capitalism and global environmental change. *Global Environmental Change,* **21(1)**, 4-6.
Norgaard, K.M., 2009: Cognitive and Behavioral Challenges in Responding to Climate Change. The World Bank, Policy Research Working Paper No. 4940. 76 pp.
Nussbaumer, P., M. Bazilian, V. Modi, and K.K. Yumkella, 2011: Measuring Energy Poverty: Focusing on what Matters, University of Oxford.
O'Brien, K., R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, and J. West, 2004: Mapping vulnerability to multiple stressors: Climate change and globalization in india. **14**, 303-313.
O'Brien, K. and S. Eriksen, 2007: Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy,* **7(4)**, 337-352.
O'Brien, K., S. Eriksen, L.P. Nygaard, and A. Schjolden, 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy,* **7(1)**, 73-88.
O'Brien, K., A.L. St. Clair, and B. Kristoffersen, 2010: *Climate change, ethics and human security*. Cambridge University Press.

O'Brien, K., L. Sygna, R. Leichenko, W.N. Adger, J. Barnett, T. Mitchell, E.L.F. Schipper, T. Tanner, V. Colen, and C. Mortreux, 2008: Disaster Risk Reduction, Climate Change Adaptation and Human Security, University of Oslo, 1-78 pp.

OBrien, G., P. OKeefe, H. Meena, and J. Rose, 2008: Climate adaptation from a poverty perspective. *Climate Policy,* **8(2)**, 194-201.

OECD, 2009: OECD Policy Guidance on Integrating Climate Change Adaptation into Development Co-Operation. Organization for Economic Co-operation and Development.

Ogallo, L., 2010: The mainstreaming of climate change and variability information into planning and policy development for africa. *Procedia Environmental Sciences,* **1**, 405-410.

O'Hara, P.A., 2009: Political economy of climate change, ecological destruction and uneven development. *Ecological Economics,* **69(2)**, 223-234.

Okereke, C. and H. Schroeder, 2008: *Group on Developing Countries and a Post-Kyoto Global Deal at the DSA-DFID Policy Forum on Climate Change and International Development:* How can the Objectives of Justice, Development and Climate Change Mitigation be Reconciled in the Treatment of Developing Countries in a Post-Kyoto Settlement? Tyndall Centre for Climate Change Research, 5 pp.

Orlowsky, B., Seneviratne, S.I. (2011), Global changes in extreme events: regional and seasonal dimension, Climatic Change 110(3-4): 669-696, doi:10.1007/s10584-011-0122-9

Park, S., M. Howden and S. Crimp, 2012: Informing regional level policy development and actions for increased adaptive capacity in rural livelihoods. Environmental Science and Policy, 15(1), 23-27.

Parks, B.C. and T.J. Roberts, 2010: Climate change, social theory and justice. *Theory, Culture & Society,* **27(2-3)**, 134-166.

Parson, E., V. Burkett, K. Fisher-Vanden, D. Keith Mearns, P. L., R. H. C., and M. Webster, 2007: *Global Change Scenarios: Their Development and use*. Synthesis and Assessment Product 2.1B of the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Department of Energy, Office of Biological & Environmental Research, Washington, DC., USA, 106 pp.

Patt, A.G., M. Tadrossb, P. Nussbaumerc, K. Asanted, M. Metzgere, J. Rafaelg, A. Goujona, and G. Brundriti, 2009: Estimating least-developed countries' vulnerability to climate-related extreme events over the next 50 years. *Proceedings of the National Academy of Sciences of the United States of America,* **107(4)**, 1333-1337.

Pelling, M., 2010: *Adaptation to Climate Change: From Resilience to Transformation*. Routledge, 224 pp.

Pengue, W.A., 2005: Transgenic crops in argentina: The ecological and social debt. *Bulletin of Science Technology Society,* **25(4)**, 314-322.

Pielke, R.A., 2007: *The Honest Broker: Making Sense of Science in Policy and Politics*. Cambridge University Press.

Pogge, T., 2008: World poverty and human rights: Cosmopolitan responsibilities and reforms. Polity, Cambridge, Second ed., 352 pp.

Proctor, R., 1991: *Value-free Science? Purity and Power in Modern Knowledge*. Cambridge, MA, USA. Harvard University Press.

Putnam, H, 2002. *The Collapse of the Fact Value Dichotomy and Other Essays*. Cambridge MA, Harvard University Press.

Reid, W.V., D. Chen, L. Goldfarb, H. Hackmann, Y. Lee, K. Mokhele, E. Ostrom, K. Raivio, J. Rockström, H. Schellnhuber, and A. Whyte, 2010: Earth system science for global sustainability: Grand challenges. *Science,* **330(6006)**, 916-917.

Reuveny, R., 2007: Climate change-induced migration and violent conflict. *Political Geography,* **26(6)**, 656-673.

Richardson, K., W. Steffen, and D. Liverman, 2011: *Climate change: Global risks, challenges and decisions* Cambridge, pp. 524.

Rosa, E.A., A. Diekmann, T. Dietz, and C.C. Jaeger (eds.), 2009: *Human footprints on the global environment, threats to sustainability*. The MIT Press, London, England, pp. 328.

Rosenzweig, C., G. Casassa, D.J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T.L. Root, B. Seguin, and P. Tryjanowski, 2007: Assessment of observed changes and responses in natural and managed systems. In: *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 79-131.

Robert, Christopher, and Richard Zeckhauser, 2011: The Methodology of Normative Policy Analysis. *Journal of Policy Analysis and Management,* **30(3)**, 613–643.
Sachs, W., 2008: Climate change and human rights. *Development,* **51(3)**, 332-337.
Sarewitz, D., 2004: How science makes environmental controversies worse. *Environmental Science and Policy,* **7 (5)**, 385–403.
Schipper, E.L.F., 2007: *Tyndall Centre Working Papers*. Climate Change Adaptation and Development: Exploring the Linkages, 1-20 pp.
Schipper, E.L.F., 2009: Meeting at the crossroads: Exploring the linkages between climate change adaptation and disaster risk reduction. *Climate and Development,* **1(1)**, 16-30.
Shalizi, Z. and F. Lecocq, 2009: To mitigate or to adapt: Is that the question? observations on an appropriate response to the climate change challenge to development strategies. *World Bank Research Observer,* **25(2)**, 295-321.
Shiva, V., 2008: *Soil not oil: Climate change, peak oil and food insecurity*. Zed Books, London.
Shiva, V., 2010: *Staying alive. women, ecology and development*. South End Press, 256 pp.
Swart, R., L. Bernstein, M. Ha-Duong, and A. Petersen, 2009: *Agreeing to disagree: uncertainty management in assessing climate change, impacts and responses by the IPCC*. Climatic Change, **92**, 1–29.
Tanner, T. and T. Mitchell, 2008: Entrenchment or enhancement: Could climate change adaptation help to reduce chronic poverty? *IDS Bulletin,* **39(4)**, 6-15.
Teubal, M. and J. Rodriguez, 2002: *Agro y alimentos en la globalización una perspectiva crítica*. La Colmena, Buenos Aires, 208 pp.
Tol, R.S.J., 2009: The economic effects of climate change. *Journal of Economic Perspectives,* **23(2)**, 29-51.
Tschakert, P. and K.A. Dietrich, 2010: Anticipatory learning for climate change adaptation and resilience. *Ecology and Society,* **15(2)**, online.
Tschakert, P. and R. Sagoe, 2009: Mental models: Understanding the causes and consequences of climate change. In: PLA 60: Community-based adaptation to climate change. *Participatory Learning and Action,* 60.
TWN, 2011. Climate Series, 2011. Third World Network , accessed May 14, 2012, http://www.twnside.org.sg/
Ulsrud, K., L. Sygna, and K. O'Brien, 2008: *More than Rain: Identifying Sustainable Pathways for Climate Adaptation and Poverty Reduction*. The Development Fund, Norway, 1-68 pp.
UNDP, 2005: *Adaptation policy frameworks for climate change: Developing strategies, policies and measures*. Cambridge University Press, Cambridge and New York, 258 pp.
UNDP, 2007: Making Globalization Work for all. United Nations Development Programme, 1-48 pp.
UNDP, 2008a: Climate Change, Human Vulnerability, and Social Risk Management, Social Development Department, World Bank, Washington D.C., 1-53 pp.
UNDP, 2008b: *Human Development Report, the Real Wealth of Nations: Pathways to Human Development*. United Nations Development Programme, New York, 238 pp.
UNECE/OECD/Eurostat, 2008: *Report of the Joint UNECE/OECD/Eurostat Working Group on Statistics for Sustainable Development, Measuring Sustainable Development*. United Nations, New York; Geneva, 128 pp.
UNESCO, 2011: the Hidden Crisis: Armed Conflict and Education, .
UNICEF, 2011**: THE STATE OF THE WORLD'S CHILDREN 2011, Adolescence an Age of Opportunity,** United Nations Children's Fund, 1-148 pp.
Urry, J., 2010: Consuming the planet to excess. *Theory, Culture & Society,* **27(2-3)**, 191-212.
USAID, 2008: Integrating Climate Change into Development. U.S. Agency for International Development, Washington, D.C.
van Aalst, M., T. Cannon, and I. Burton, 2008: Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environmental Change,* **18(1)**, 165-179.
Van der Sluijs, Jeroen. 2005. "Uncertainty as a Monster in the Science\policy Interface: Four Coping Strategies." *Water Science & Technology* 52 (6): 87–92.
Vuuren, D.P. u. a., 2011. A special issue on the RCPs. *Climatic Change*.
Webersik, C., 2010: *Climate change and security: A gathering storm of global challenges*. Praeger Security International Series, Security and the Environment. Praeger Publishers, 185 pp.
Weinberg, Alvin M. 1972. "Science and Trans-science." *Minerva,* **10 (2)**, 209–222.
WHO, 2009: Protecting Health from Climate Change: Connecting Science, Policy and People, World Health Organization, Switzerland, 36 pp.

Wilbanks, T., P. Leiby, R. Perlack, J. Ensminger, and S. Wright, 2007: Toward an integrated analysis of mitigation and adaptation: Some preliminary findings. *Mitigation and Adaptation Strategies for Global Change,* **12(5)**, 713-725.

Willows, R. and R. Connell, 2003: Climate Adaptation: Risk, Uncertainty and Decision-Making. UKCIP Technical Report. United Kingdom Climate Impacts Programme, Oxford, 154 pp.

Wolf, J., 2011: Climate change adaptation as a social process. In: [Ford, J. and L. Ford Berrang (eds.)]. Springer, Netherlands.

World Bank, 2008: World Development Report 2008: Agriculture for Development, World Bank, 1-386 pp.

World Bank, 2010: *The World Bank, Policy Research Working Paper Series*. Social Impacts of Climate Change in Chile : A Municipal Level Analysis of the Effects of Recent and Future Climate, .

Wynne, B., 1992: Uncertainty and Environmental Learning. Reconceiving Science and Policy in the Preventive Paradigm. *Global Environmental Change* **2** (2): 111–127.

Yohe, G. and R. Leichenko, 2010: Adopting a risk-based approach. *Annals of the New York Academy of Sciences,* **1196**, 29-40.

Ziervogel, G. and F. Zermoglio, 2009: Climate change scenarios and the development of adaptation strategies in Africa: Challenges and opportunities. *Climate Research,* **40(2-3)**, 133-146.

Table 1-1: Number of publications in six languages that include the words "climate change" and "climate change" plus "adaptation", "impacts" and "cost" (translated) in the title, abstract or key words during three time periods: 1980-1989, 1990-1999, and 2000-2010.

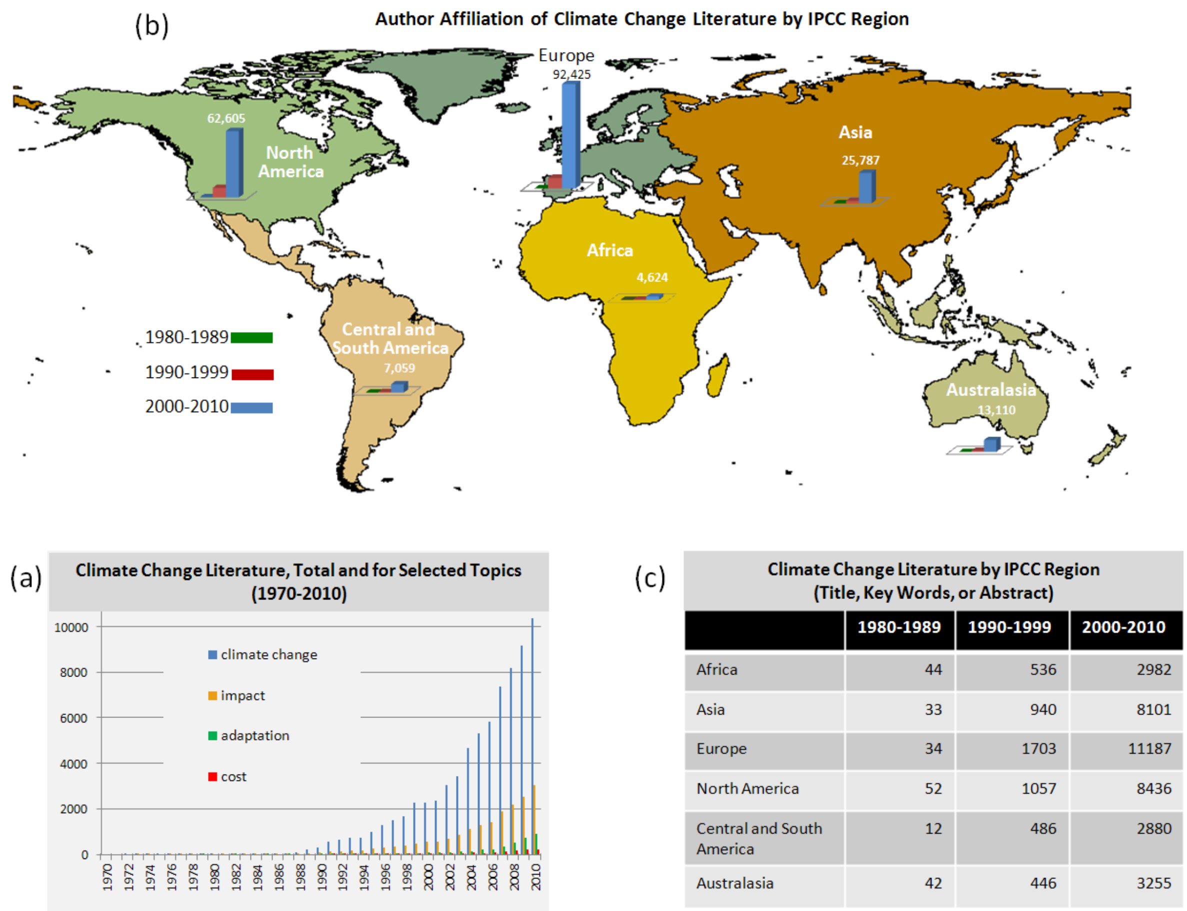
Search Words	Language	1980-1989	1990-1999	2000-2010
"Climate change"	English	707	10,756	62,283
	Chinese	958	4836	20383
	French	62	404	5040
	Russian	71	214	1089
	Spanish	3	66	1397
	Arabic			
"Climate change" and "adaptation"	English	10	274	3698
	Chinese	2	41	322
	French	13	126	2010
	Russian	0	7	44
	Spanish	0	3	105
	Arabic			
"Climate change' and "impacts"	English	156	2,530	16,620
	Chinese	86	436	1658
	French	6	135	2220
	Russian	2	76	430
	Spanish	0	6	68
	Arabic			
"Climate change" and "cost"	English	20	580	4,120
	Chinese	0	16	166
	French	4	145	2110
	Russian	0	1	33
	Spanish	0	2	11
	Arabic			

Notes: The following individuals conducted the literature searches: Valentin Przyluski (French), Huang Huanping (Chinese), and Peter Zavialov and Vasily Kokore (Russian), Cecilia Conde (Spanish) and Lama el Hatow (Arabic). Search terms and search engines for each language are presented in Appendix __.

Table 1-2: An overview of calibrated uncertainty language used to characterize assessment findings in IPCC Assessment Reports. Adapted from Mastrandrea and Mach (2011).

IPCC Report	Calibrated language for characterizing the degree of certainty in assessment findings
FAR	Calibrated language in the AR: • WG I: Headings (qualitative) indicating degree of certainty in findings in Executive Summary of Policymakers Summary (IPCC, 1990) • WG I: Confidence scale (qualitative) in Executive Summaries of some chapters (Folland *et al*., 1990; Mitchell *et al*., 1990)
SAR	Calibrated language in the AR: • WG I: Discussion of the importance of a consistent framework for evaluating uncertainties (McBean *et al*., 1996) • WG II: Confidence scale (qualitative) in chapter Executive Summaries (IPCC, 1996)
TAR	Uncertainties guidance provided to all AR authors: Moss and Schneider, 2000 • Confidence scale (quantitative) for characterizing state of knowledge underlying findings • Descriptors for evidence and agreement underlying findings (qualitative), for supplementing confidence assignments Calibrated language in the AR: • WG I: Likelihood scale (quantitative); some use of evidence and agreement descriptors and of qualitative level of scientific understanding index (IPCC, 2001a) • WG II: Confidence scale; some use of evidence and agreement descriptors (IPCC, 2001b)
AR4	Uncertainties guidance provided to all AR authors: IPCC, 2005 • Summary terms (qualitative) for the amount of evidence and the level of agreement underlying findings • Confidence scale (quantitative) to characterize judgments of the correctness of models, analyses, or statements • Likelihood scale (quantitative) to characterize probabilistic evaluations of the occurrence of outcomes, based on quantitative analysis Calibrated language in the AR: • WG I: Predominantly, likelihood scale; some use of confidence scale and other descriptors (IPCC, 2007a) • WG II: Predominantly, confidence scale; some use of likelihood scale and of evidence and agreement summary terms (IPCC, 2007b) • WG III: Evidence and agreement summary terms (IPCC, 2007c)
AR5	Uncertainties guidance provided to all AR authors: Mastrandrea *et al*., 2010 • Summary terms (qualitative) for the type, amount, quality, and consistency of evidence and for the degree of agreement underlying findings • Confidence scale (qualitative) for synthesizing author teams' judgments about the validity of findings, as determined through evaluation of evidence and agreement • Likelihood scale (quantitative) to characterize probabilistic estimates of the occurrence of outcomes associated with, unless otherwise noted, *high* or *very high* confidence.

Figure 1-1: 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 sent to IPCC Working Group III. Since the TAR, WG II has focused on impacts, adaptation and vulnerability with an expanded effort on the regional scale.



	1980-1989	1990-1999	2000-2010
Africa	44	536	2982
Asia	33	940	8101
Europe	34	1703	11187
North America	52	1057	8436
Central and South America	12	486	2880
Australasia	42	446	3255

Figure 1-2: 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: 1980-1989, 1990-1999, and 2000-2010, with total number during the period 2000-2010. (c) Results of literature searches for climate change publications with individual countries mentioned in publication title, abstract or key words, summed for all countries within each major IPCC region.

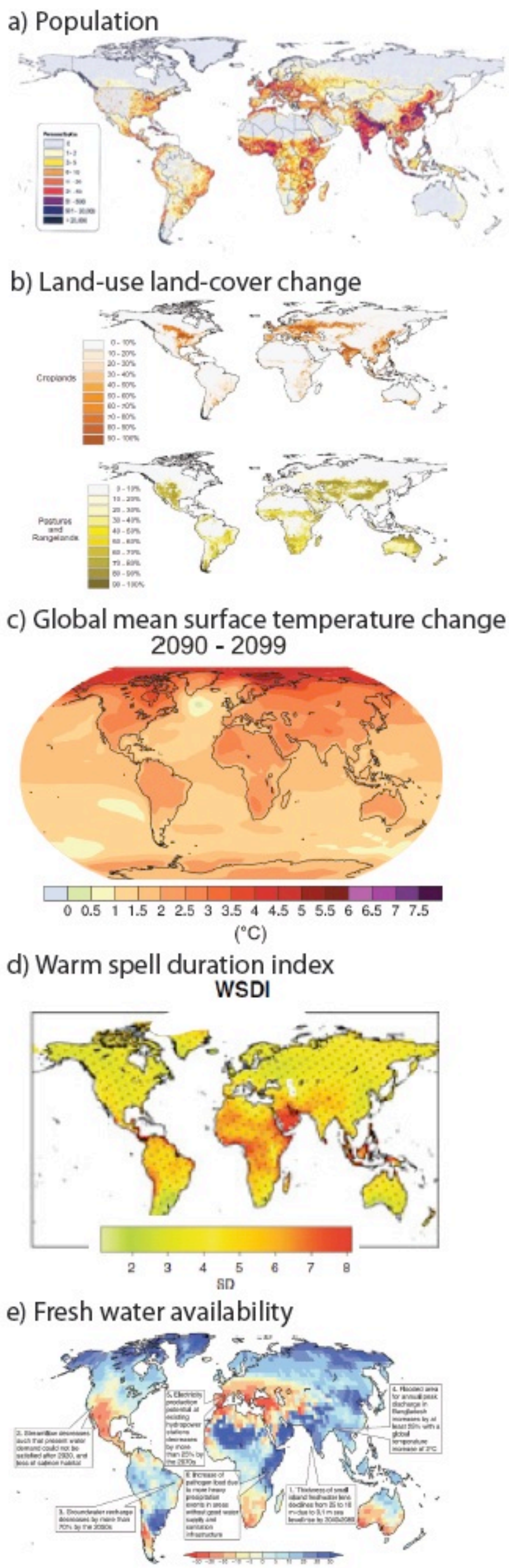


Figure 1-3: Examples of the multiple stresses that interactively affect climate change impacts, adaptation and vulnerability: (a) current population, (b) human changes in land use and land cover in the 1990s, (c) projected global mean surface temperature change, (d) projected heat waves, and (e) projected changes in fresh water. Sources: (a) Global population density adjusted to UN figures for year 2000 from the LandScan project at Oak Ridge National Laboratory, Tennessee USA, www.ornl.gov/sci/landscan/index.shtml, figure from www.fao.org/docrep/009/a0310e/A0310E06.htm; (b) Croplands and pasture/rangeland coverage from Foley et al. (2005); (c) Projected mean surface temperature change for the 2090s SRES B1 relative to 1980-1999 from IPCC AR4 WGI Fig. 10.8; (d) Warm Spell Duration Index increase from 1980-1999 to 2081-2100 under SRES A2 normalized in terms of standard deviation (SD), Fig. 5 of Orlowsky and Seneviratne (2011); (e) Projected change of annual runoff (%) from 1981-2000 to 2081-2100 for SRES A1B, from IPCC AR4 WGI Fig. 3.8. All projections used the climate model ensemble calculations for AR4 (CMIP3).

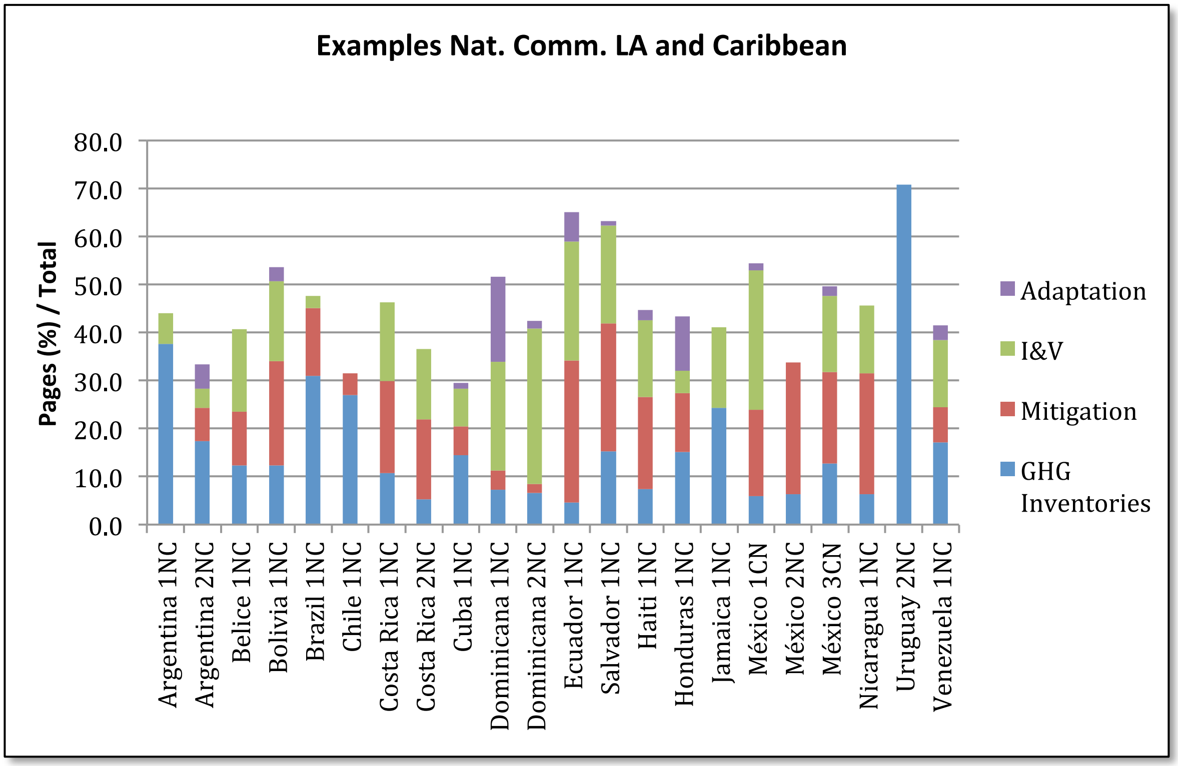


Figure 1-4: Distribution of topics related to Adaptation, Impacts and Vulnerability (I&V), Mitigation and Greenhouse Gases Inventories (GHG Inventories) in the First (1), Second (2) or Third (3) National Communications (NC) of several Latin American and Caribbean countries (Argentina, Belize, Bolivia, Brazil, Chile, Costa Rica, Cuba, Dominica, Ecuador, El Salvador, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Uruguay and Venezuela).

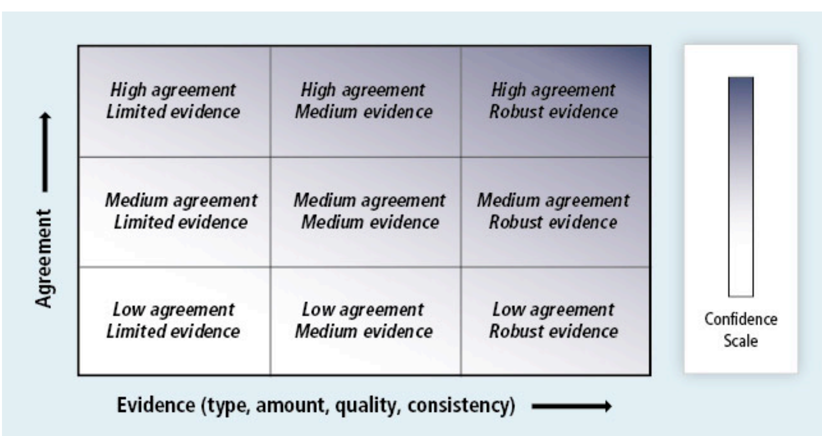


Figure 1-5: Evidence and agreement statements and their relationship to confidence. The shading increasing towards the top-right corner indicates increasing confidence. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

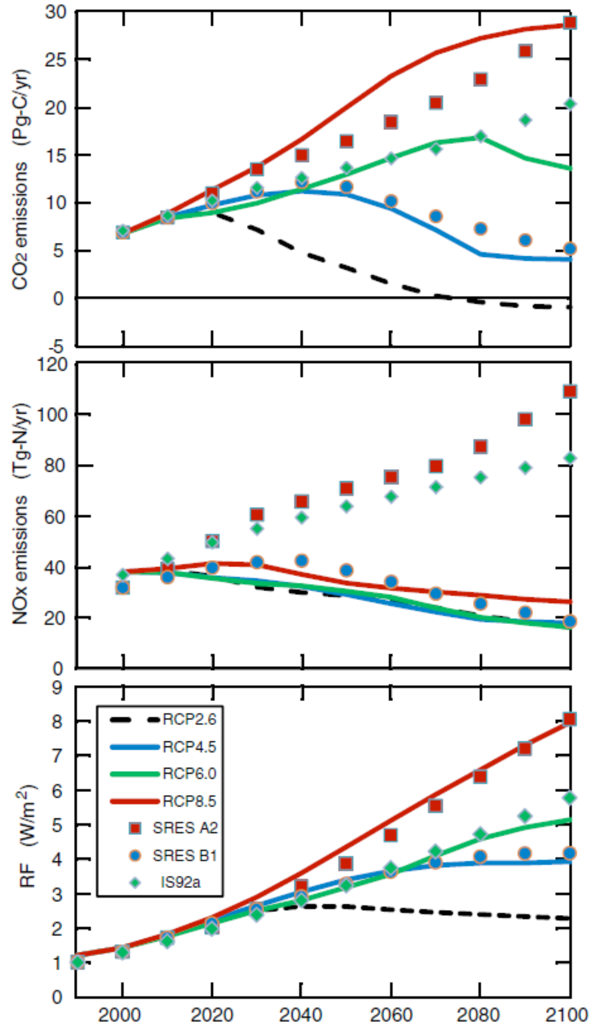


Figure 1-6: Projections of CO_2 emissions (Pg-C/yr), NOx emissions (Tg-N/yr), and total radiative forcing (W/m^2) for the 21st century from the scenarios IS92 (a), SRES (A2, B1), and RCP (2.6, 4.5, 6.0, 8.5), as used in the IPCC SAR, TAR, AR4, and AR5.

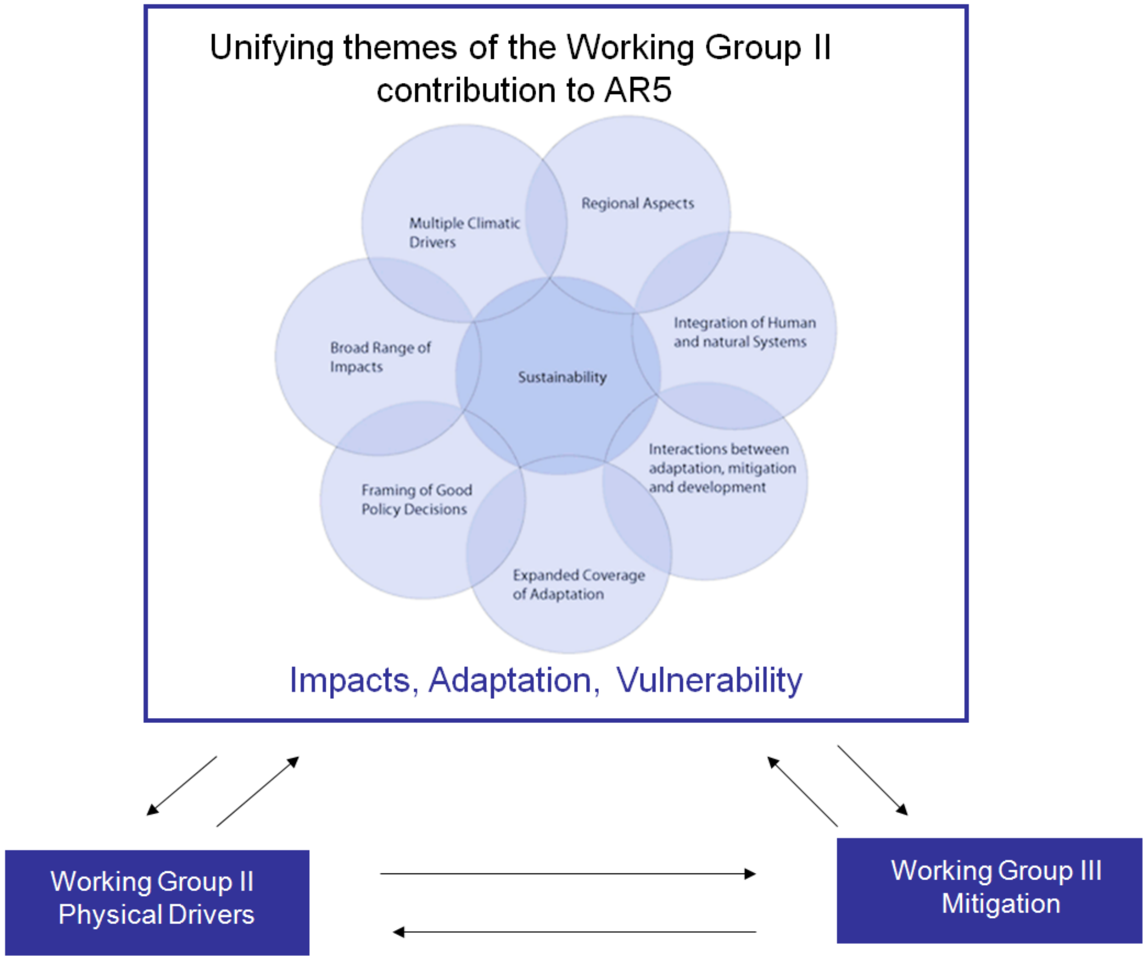


Figure 1-7: Unifying themes of the IPCC Working Group II contribution to the IPCC Fifth Assessment Report.