## A report accepted by Working Group II of the Intergovernmental Panel on Climate Change but not approved in detail

'Acceptance' of IPCC Reports at a Session of the Working Group or Panel signifies that the material has not been subject to line-by-line discussion and agreement, but nevertheless presents a comprehensive, objective and balanced view of the subject matter.

# Technical Summary


### Coordinating Lead Authors:
Martin Parry (UK), Osvaldo Canziani (Argentina), Jean Palutikof (UK)

### Lead Authors:
Neil Adger (UK), Pramod Aggarwal (India), Shardul Agrawala (OECD/France), Joseph Alcamo (Germany), Abdelkader Allali (Morocco), Oleg Anisimov (Russia), Nigel Arnell (UK), Michel Boko (Benin), Timothy Carter (Finland), Gino Casassa (Chile), Ulisses Confalonieri (Brazil), Rex Victor Cruz (Philippines), Edmundo de Alba Alcaraz (Mexico), William Easterling (USA), Christopher Field (USA), Andreas Fischlin (Switzerland), Blair Fitzharris (New Zealand), Carlos Gay García (Mexico), Hideo Harasawa (Japan), Kevin Hennessy (Australia), Saleemul Huq (UK), Roger Jones (Australia), Lucka Kajfež Bogataj (Slovenia), David Karoly (USA), Richard Klein (The Netherlands), Zbigniew Kundzewicz (Poland), Murari Lal (India), Rodel Lasco (Philippines), Geoff Love (Australia), Xianfu Lu (China), Graciela Magrín (Argentina), Luis José Mata (Venezuela), Bettina Menne (WHO Euro/Germany), Guy Midgley (South Africa), Nobuo Mimura (Japan), Monirul Qader Mirza (Bangladesh/Canada), José Moreno (Spain), Linda Mortsch (Canada), Isabelle Niang-Diop (Senegal), Robert Nicholls (UK), Béla Nováky (Hungary), Leonard Nurse (Barbados), Anthony Nyong (Nigeria), Michael Oppenheimer (USA), Anand Patwardhan (India), Patricia Romero Lankao (Mexico), Cynthia Rosenzweig (USA), Stephen Schneider (USA), Serguei Semenov (Russia), Joel Smith (USA), John Stone (Canada), Jean-Pascal van Ypersele (Belgium), David Vaughan (UK), Coleen Vogel (South Africa), Thomas Wilbanks (USA), Poh Poh Wong (Singapore), Shaohong Wu (China), Gary Yohe (USA)

### Contributing Authors:
Debbie Hemming (UK), Pete Falloon (UK)

### Review Editors:
Wolfgang Cramer (Germany), Daniel Murdiyarso (Indonesia)



### This Technical Summary should be cited as:
Parry, M.L., O.F. Canziani, J.P. Palutikof and Co-authors 2007: Technical Summary. *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, 23-78.

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## Summary of main findings

- Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.
- A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems.
- Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.
- More specific information is now available across a wide range of systems and sectors concerning the nature of future impacts, including for some fields not covered in previous assessments.
- More specific information is now available across the regions of the world concerning the nature of future impacts, including for some places not covered in previous assessments.
- Magnitudes of impact can now be estimated more systematically for a range of possible increases in global average temperature.
- Impacts due to altered frequencies and intensities of extreme weather, climate and sea-level events are very likely to change.
- Some large-scale climate events have the potential to cause very large impacts, especially after the 21st century.
- Impacts of climate change will vary regionally but, aggregated and discounted to the present, they are very likely to impose net annual costs which will increase over time as global temperatures increase.
- Some adaptation is occurring now, to observed and projected future climate change, but on a limited basis.
- Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.
- A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to future climate change. There are barriers, limits and costs, but these are not fully understood.
- Vulnerability to climate change can be exacerbated by the presence of other stresses.
- Future vulnerability depends not only on climate change but also on development pathway.
- Sustainable development can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development pathways.
- Many impacts can be avoided, reduced or delayed by mitigation.
- A portfolio of adaptation and mitigation measures can diminish the risks associated with climate change.

## TS.1 Scope, approach and method of the Working Group II assessment

The decision to produce a Fourth Assessment Report (AR4) was taken by the 19th Session of the Intergovernmental Panel on Climate Change (IPCC) in April 2002.

The Working Group II Report has twenty chapters. The core chapters (3 – 16) address the future impacts of climate change on sectors and regions, the potential for adaptation and the implications for sustainability. Chapter 1 looks at observed changes and Chapter 2 assesses new methodologies and the characterisation of future conditions. Chapters 17 – 20 assess responses to impacts through adaptation (17), the inter-relationships between adaptation and mitigation (18), key vulnerabilities and risks (19) and, finally, perspectives on climate change and sustainability (20).

The Working Group II Fourth Assessment, in common with all IPCC reports, has been produced through an open and peer-reviewed process. It builds upon past assessments and IPCC Special Reports, and incorporates the results of the past 5 years of climate change impacts, adaptation and vulnerability research. Each chapter presents a balanced assessment of the literature which has appeared since the Third Assessment Report[1] (TAR), including non-English language and, where appropriate, 'grey' literature.[2]

This Assessment aims to describe current knowledge of climate-change impacts, adaptation and vulnerability. Specifically it addresses five questions:

- What is the current knowledge about impacts of climate change which are observable now? (addressed in Section TS.2 of the Technical Summary)
- What new scenarios and research methods have led to improvements in knowledge since the Third Assessment? (addressed in Section TS.3)
- What is the current knowledge about future effects of climate change on different sectors and regions? (addressed in Section TS.4)
- What is the current knowledge about adaptation, the interaction between adaptation and mitigation, key vulnerabilities, and the role of sustainable development in the context of climate change? (addressed in Section TS.5)
- What gaps exist in current knowledge and how best can these be filled? (addressed in Section TS.6).

Each of the twenty chapters of the Working Group II Fourth Assessment had a minimum of two Coordinating Lead Authors, six Lead Authors and two Review Editors. The writing team and review editors were appointed by the IPCC Bureau on the recommendation of the Working Group II Co-Chairs and Vice-Chairs. They were selected from the pool of nominated experts, in consultation with the international community of scientists active in the field, and taking into consideration expertise and experience. In total, the Working Group II Fourth Assessment involved 48 Coordinating Lead Authors, 125 Lead Authors and 45 Review Editors, drawn from 70 countries. In addition there were 183 Contributing Authors and 910 Expert Reviewers.

This Technical Summary is intended to capture the most important scientific aspects of the full Working Group II Assessment. Reducing the information from 800 pages to 50 requires much condensing; consequently every statement in the Summary appears with its source in the Assessment, enabling the reader to pursue more detail. Sourcing information is provided in square brackets in the text (see Box TS.1). Uncertainty information is provided in parentheses (see Box TS.2 for definitions of uncertainty). Key terms are defined in Box TS.3.

## TS.2 Current knowledge about observed impacts on natural and managed systems

**Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases (very high confidence). A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems.**

The IPCC Working Group II Third Assessment found evidence that recent regional climate changes, particularly temperature increases, have already affected physical and biological systems [1.1.1].[3] The Fourth Assessment has analysed studies since the Third Assessment showing changes in physical, biological and human systems, mainly from 1970 to 2005, in relation to climate drivers, and has found stronger quantitative evidence [1.3, 1.4]. The major focus is on global and regional surface temperature increases [1.2].

Evaluation of evidence on observed changes related to climate change is made difficult because the observed responses of systems and sectors are influenced by many other factors. Non-climatic drivers can influence systems and sectors directly and/or indirectly through their effects on climate variables such as reflected solar radiation and evaporation [1.2.1]. Socio-economic processes, including land-use change (e.g., agriculture

[1] McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds., 2001: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, 1032 pp.

[2] 'Grey' literature is defined as literature which is not available through traditional commercial publication channels, such as working papers, government reports and theses, which therefore may be difficult to access.

[3] See Box TS.1

## Box TS.1. Sourcing in the Technical Summary

For example, source [3.3.2] refers to Chapter 3, Section 3, Sub-section 2. In the sourcing, F = Figure, T = Table, B = Box, ES = Executive Summary.

References to the Working Group I Fourth Assessment are shown as, for example, [WGI AR4 SPM] which refers to the Working Group I Fourth Assessment Summary for Policymakers, [WGI AR4 10.3.2] which refers to Chapter 10 Section 10.3.2, and [WGI AR4 Chapter 10] when the whole chapter is referred to. Where a source refers to both the WGI and WGII Fourth Assessments, these are separated by a semi-colon, for example [WGI AR4 10.2.1; 2.1.4]. References to Working Group III are treated in the same way.

## Box TS.2. Communication of uncertainty in the Working Group II Fourth Assessment

A set of terms to describe uncertainties in current knowledge is common to all parts of the IPCC Fourth Assessment, based on the *Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties*[4], produced by the IPCC in July 2005.

*Description of confidence*
On the basis of a comprehensive reading of the literature and their expert judgement, authors have assigned a confidence level to the major statements in the Technical Summary on the basis of their assessment of current knowledge, as follows:

| *Terminology* | *Degree of confidence in being correct* |
|---|---|
| Very high confidence | At least 9 out of 10 chance of being correct |
| High confidence | About 8 out of 10 chance |
| Medium confidence | About 5 out of 10 chance |
| Low confidence | About 2 out of 10 chance |
| Very low confidence | Less than a 1 out of 10 chance |

*Description of likelihood*
Likelihood refers to a probabilistic assessment of some well-defined outcome having occurred or occurring in the future, and may be based on quantitative analysis or an elicitation of expert views. In the Technical Summary, when authors evaluate the likelihood of certain outcomes, the associated meanings are:

| *Terminology* | *Likelihood of the occurrence/outcome* |
|---|---|
| Virtually certain | >99% probability of occurrence |
| Very likely | 90 to 99% probability |
| Likely | 66 to 90% probability |
| About as likely as not | 33 to 66% probability |
| Unlikely | 10 to 33% probability |
| Very unlikely | 1 to 10% probability |
| Exceptionally unlikely | <1% probability |

## Box TS.3. Definitions of key terms

*Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where *climate change* refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

*Adaptation* is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

*Vulnerability* is the degree to which a system is susceptible to, and 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 change and the variation to which a system is exposed, its sensitivity and its adaptive capacity.

[4] See http://www.ipcc.ch/activity/uncertaintyguidancenote.pdf.

to urban area), land-cover modification (e.g., ecosystem degradation), technological change, pollution, and invasive species constitute some of the important non-climate drivers [1.2.1].

Much more evidence has accumulated over the past 5 years to indicate that the effects described above are linked to the anthropogenic component of warming.[5] There are three sets of evidence which, taken together, support this conclusion (see Box TS.4).

1. There have been several studies that have linked responses in some physical and biological systems to the anthropogenic component of warming by comparing observed trends with modelled trends in which the natural and anthropogenic forcings are explicitly separated [1.4].

2. Observed changes in many physical and biological systems are consistent with a warming world. The majority (>89% of the >29,000 data sets whose locations are displayed in Figure TS.1) of changes in these systems have been in the direction expected as a response to warming [1.4].

3. A global synthesis of studies in this Assessment strongly demonstrates that the spatial agreement between regions of significant regional warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely[6] to be due solely to natural variability of temperatures or natural variability of the systems [1.4].

**For physical systems, (i) climate change is affecting natural and human systems in regions of snow, ice and frozen ground, and (ii) there is now evidence of effects on hydrology and water resources, coastal zones and oceans.**

The main evidence from regions of snow, ice and frozen ground is found in ground instability in permafrost regions, and rock avalanches; decrease in travel days of vehicles over frozen roads in the Arctic; increase and enlargement of glacial lakes, and destabilisation of moraines damming these lakes, with increased risk of outburst floods; changes in Arctic and Antarctic Peninsula ecosystems, including sea-ice biomes and predators high on the food chain; and limitations on mountain sports in lower-elevation alpine areas (high confidence)[7] [1.3.1]. These changes parallel the abundant evidence that Arctic sea ice, freshwater ice, ice shelves, the Greenland ice sheet, alpine and Antarctic Peninsula glaciers and ice caps, snow cover and permafrost are undergoing enhanced melting in response to global warming (very high confidence) [WGI AR4 Chapter 4].

Recent evidence in hydrology and water resources shows that spring peak discharge is occurring earlier in rivers affected by snow melt, and there is evidence for enhanced glacial melt in the tropical Andes and in the Alps. Lakes and rivers around the world are warming, with effects on thermal structure and water quality (high confidence) [1.3.2].

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 (medium confidence) [1.3.3.2].

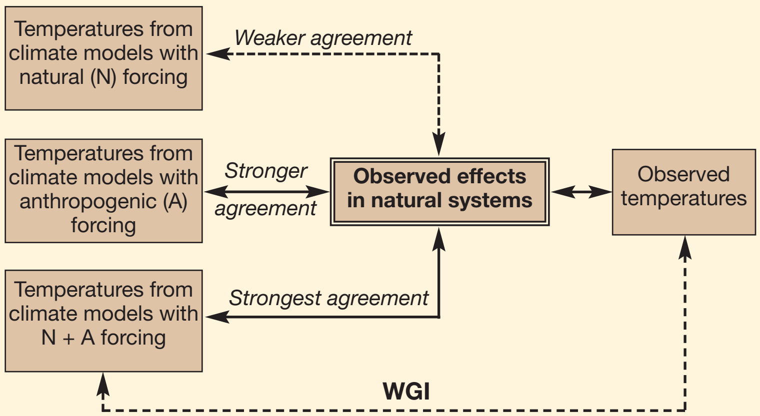
**There is more evidence, from a wider range of species and communities in terrestrial ecosystems than reported in the Third Assessment, that recent warming is already strongly affecting natural biological systems. There is substantial new evidence relating changes in marine and freshwater systems to warming. The evidence suggests that both terrestrial and marine biological systems are now being strongly influenced by observed recent warming.**

The overwhelming majority of studies of regional climate effects on terrestrial species reveal consistent responses to warming trends, including poleward and elevational range shifts of flora and fauna. Responses of terrestrial species to warming across the Northern Hemisphere are well documented by changes in the timing of growth stages (i.e., phenological changes), especially the earlier onset of spring events, migration, and lengthening of the growing season. Based on satellite observations since the early 1980s, there have been trends in many regions towards earlier 'greening' of vegetation in the spring[8] and increased net primary production linked to longer growing seasons. Changes in abundance of certain species, including limited evidence of a few local disappearances, and changes in community composition over the last few decades have been attributed to climate change (very high confidence) [1.3.5].

Many observed changes in phenology and distribution of marine and freshwater species have been associated with rising water temperatures, as well as other climate-driven changes in ice cover, salinity, oxygen levels and circulation. There have been poleward shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans. For example, plankton has moved polewards by 10° latitude (about 1,000 km) over a period of four decades in the North Atlantic. There have also been documented increases in algal and zooplankton abundance in high-latitude and high-altitude lakes, and earlier fish migration and range changes in rivers [1.3]. While there is increasing evidence for climate change impacts on coral reefs, differentiating the impacts of climate-related stresses from other stresses (e.g., over-fishing and pollution) is difficult. The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic, with an average decrease in pH of 0.1 units [WGI AR4 SPM]. However, the effects of observed

[5] Warming over the past 50 years at the continental scale has been attributed to anthropogenic effects [WGI AR4 SPM].
[6] See Box TS-2.
[7] See Box TS-2
[8] Measured by the Normalised Difference Vegetation Index (NVDI), which is a relative measure of vegetation greenness in satellite images.

## Box TS.4. Linking the causes of climate change to observed effects on physical and biological systems

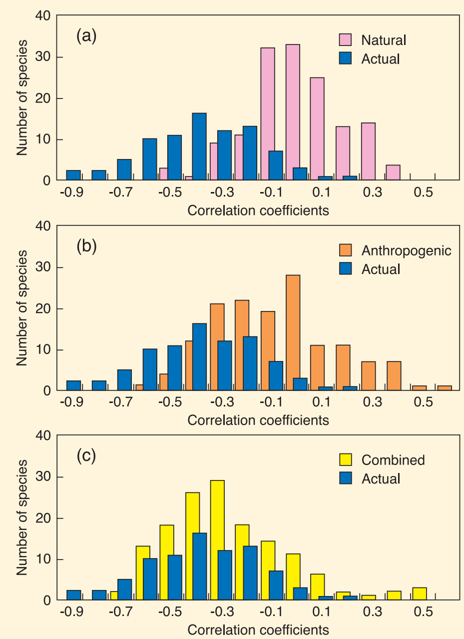



The figure to the left demonstrates the linkages between observed temperatures, observed effects on natural systems, and temperatures from climate model simulations with natural, anthropogenic, and combined natural and anthropogenic forcings. Two ways in which these linkages are utilized in detection and attribution studies of observed effects are described below.

### 1. Using climate models

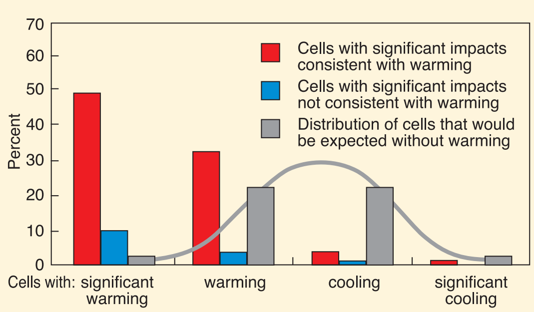
The study of causal connection by separation of natural and anthropogenic forcing factors (Set of Evidence 1 on the preceding page) compares observed temporal changes in animals and plants with changes over the same time periods in observed temperatures as well as modelled temperatures using (i) only natural climate forcing; (ii) only anthropogenic climate forcing; and (iii) both forcings combined.

The panel to the right shows the results from a study employing this methodology[9]. The locations for the modelled temperatures were individual grid boxes corresponding to given animal and plant study sites and time periods.




The agreement (in overlap and shape) between the observed (blue bars) and modelled plots is weakest with natural forcings, stronger with anthropogenic forcings, and strongest with combined forcings. Thus, observed changes in animals and plants are likely responding to both natural and anthropogenic climate forcings, providing a direct cause-and-effect linkage [F1.7, 1.4.2.2].

### 2. Using spatial analysis




The study of causal connection by spatial analysis (Set of Evidence 3 on the preceding page) follows these stages: (i) it identifies 5° × 5° latitude/longitude cells across the globe which exhibit significant warming, warming, cooling, and significant cooling; (ii) it identifies 5° × 5° cells of significant observed changes in natural systems that are consistent with warming and that are not consistent with warming; and (iii) it statistically determines the degree of spatial agreement between the two sets of cells. In this assessment, the conclusion is that the spatial agreement is significant at the 1% level and is very unlikely to be solely due to natural variability of climate or of the natural systems.

Taken together with evidence of significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica [WGI AR4[10] SPM], this shows a discernible human influence on changes in many natural systems [1.4.2.3].

[9] Plotted are the frequencies of the correlation coefficients (associations) between the timing of changes in traits (e.g., earlier egg-laying) of 145 species and modelled (HadCM3) spring temperatures for the grid-boxes in which each species was examined. (Continues next page after Figure TS.1).

[10] IPCC, 2007: *Climate Change 2007: The Physical Science Basis*. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Eds., Cambridge University Press, Cambridge, 996 pp.

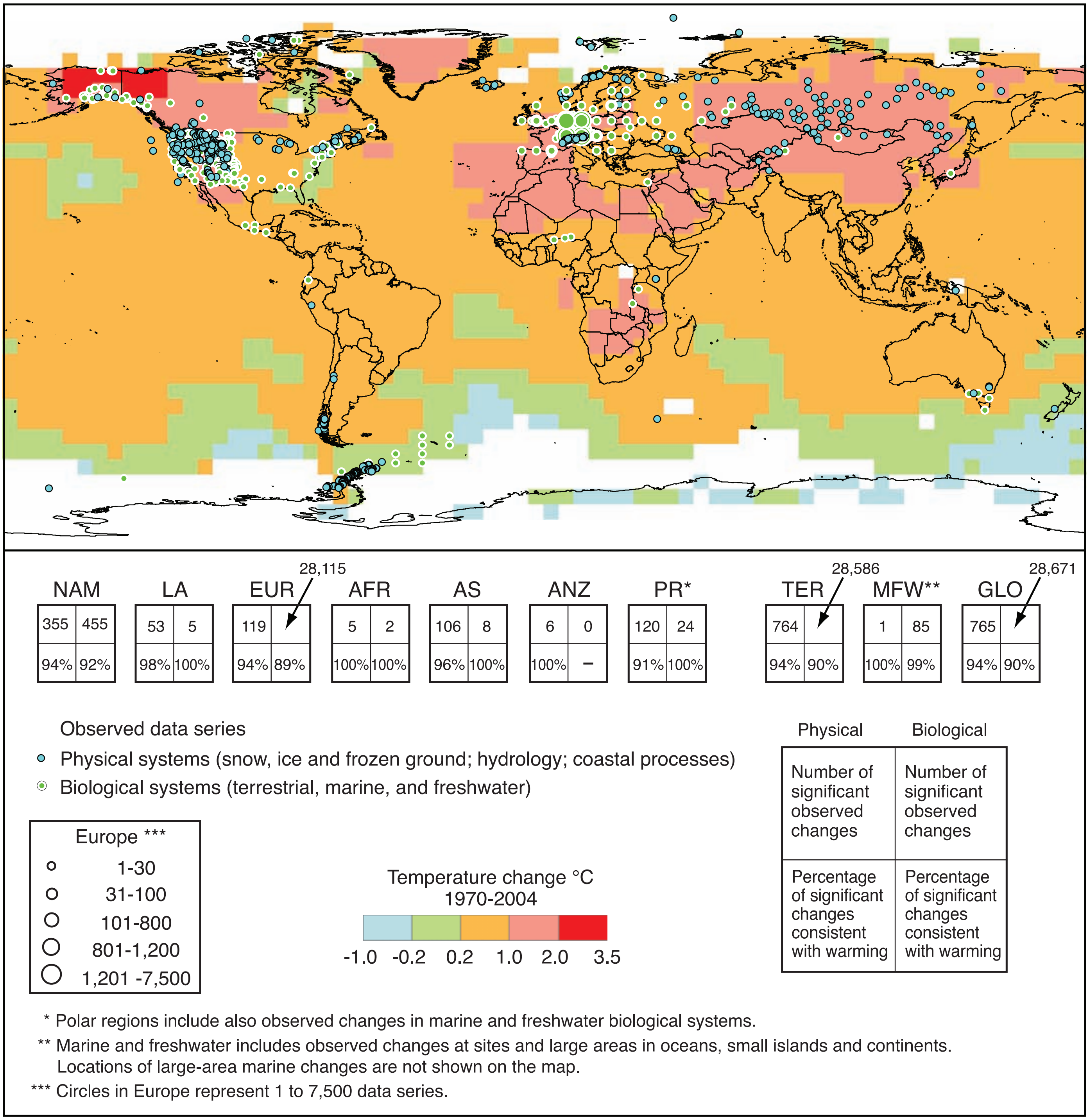



**Figure TS.1.** *Locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (i) ending in 1990 or later; (ii) spanning a period of at least 20 years; and (iii) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which about 70 are new since the Third Assessment) and contain about 29,000 data series, of which about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 × 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR); and (ii) global scale: Terrestrial (TER), Marine and Freshwater (MFW), and Global (GLO). The numbers of studies from the seven regional boxes (NAM, …, PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFR) systems. Locations of large-area marine changes are not shown on the map. [F1.8, F1.9; Working Group I AR4 F3.9b]* ocean acidification on the marine biosphere are as yet undocumented [1.3]. Warming of lakes and rivers is affecting abundance and productivity, community composition, phenology and the distribution and migration of freshwater species (high confidence) [1.3.4].

**Effects of regional increases in temperature on some managed and human systems are emerging, although these are more difficult to discern than those in natural systems, due to adaptation and non-climatic drivers.**

Effects have been detected in agricultural and forestry systems [1.3.6]. Changes in several aspects of the human health system have been related to recent warming [1.3.7]. Adaptation to recent warming is beginning to be systematically documented (medium confidence) [1.3.9].

In comparison with other factors, recent warming has been of limited consequence in the agriculture and forestry sectors. A significant advance in phenology, however, has been observed for agriculture and forestry in large parts of the Northern Hemisphere, with limited responses in crop management such as earlier spring planting in northern higher latitudes. The lengthening of the growing season has contributed to an observed increase in forest productivity in many regions, while warmer and drier conditions are partly responsible for reduced forest productivity and increased forest fires in North America and the Mediterranean Basin. Both agriculture and forestry have shown vulnerability to recent trends in heatwaves, droughts and floods (medium confidence) [1.3.6].

While there have been few studies of observed health effects related to recent warming, an increase in high temperature extremes has been associated with excess mortality in Europe, which has prompted adaptation measures. There is emerging evidence of changes in the distribution of some human disease vectors in parts of Europe and Africa. Earlier onset and increases in the seasonal production of allergenic pollen have occurred in mid- and high latitudes in the Northern Hemisphere (medium confidence) [1.3.7].

Changes in socio-economic activities and modes of human response to climate change, including warming, are just beginning to be systematically documented. In regions of snow, ice and frozen ground, responses by indigenous groups relate to changes in the migration patterns, health, and range of animals and plants on which they depend for their livelihood and cultural identity [1.3.9]. Responses vary by community and are dictated by particular histories, perceptions of change and range, and the viability of options available to groups (medium confidence) [1.3.9].

While there is now significant evidence of observed changes in physical and biological systems in every continent, including Antarctica, as well as from most oceans, the majority of studies come from mid- and high latitudes in the Northern Hemisphere. Documentation of observed changes in tropical regions and the Southern Hemisphere is sparse [1.5].

## TS.3 Methods and scenarios

### TS.3.1 Developments in methods available to researchers on climate change impacts, adaptation and vulnerability

Since the Third Assessment (TAR), the need for improved decision analysis has motivated an expansion in the number of climate-change impacts, adaptation and vulnerability (CCIAV) approaches and methods in use. While scientific research aims to reduce uncertainty, decision-making aims to manage uncertainty by making the best possible use of the available knowledge [2.2.7, 2.3.4]. This usually involves close collaboration between researchers and stakeholders [2.3.2].

Therefore, although the standard climate scenario-driven approach is used in a large proportion of assessments described in this Report, the use of other approaches is increasing [2.2.1]. They include assessments of current and future adaptations to climate variability and change [2.2.3], adaptive capacity, social vulnerability [2.2.4], multiple stresses and adaptation in the context of sustainable development [2.2.5, 2.2.6].

Risk management can be applied in all of these contexts. It is designed for decision-making under uncertainty; several detailed frameworks have been developed for CCIAV assessments and its use is expanding rapidly. The advantages of risk management include the use of formalised methods to manage uncertainty, stakeholder involvement, use of methods for evaluating policy options without being policy-prescriptive, integration of different disciplinary approaches, and mainstreaming of climate-change concerns into the broader decision-making context [2.2.6].

Stakeholders bring vital input into CCIAV assessments about a range of risks and their management. In particular, how a group or system can cope with current climate risks provides a solid basis for assessments of future risks. An increasing number of

Footnote 9, continued from below Box TS.4. At each location, all of which are in the Northern Hemisphere, the changing trait is compared with modelled temperatures driven by: (a) Natural forcings (pink bars), (b) anthropogenic (i.e., human) forcings (orange bars), and (c) combined natural and anthropogenic forcings (yellow bars). In addition, on each panel the frequencies of the correlation coefficients between the actual temperatures recorded during each study and changes in the traits of 83 species, the only ones of the 145 with reported local-temperature trends, are shown (dark blue bars). On average the number of years species were examined is about 28 with average starting and ending years of 1960 to 1998. Note that the agreement: a) between the natural and actual plots is weaker ($K=60.16$, $p>0.05$) than b) between the anthropogenic and actual ($K=35.15$, $p>0.05$), which in turn is weaker than c) the agreement between combined and actual ($K=3.65$, $p<0.01$). Taken together, these plots show that a measurable portion of the warming regional temperatures to which species are reacting can be attributed to humans, therefore showing joint attribution (see Chapter 1).

assessments involve, or are conducted by, stakeholders. This establishes credibility and helps to confer 'ownership' of the results, which is a prerequisite for effective risk management [2.3.2].

## TS.3.2 Characterising the future in the Working Group II IPCC Fourth Assessment

CCIAV assessments usually require information on how conditions such as climate, social and economic development, and other environmental factors are expected to change in the future. This commonly entails the development of scenarios, storylines or other characterisations of the future, often disaggregated to the regional or local scale [2.4.1, 2.4.6].

Scenarios are plausible descriptions, without ascribed likelihoods, of possible future states of the world. Storylines are qualitative, internally consistent narratives of how the future may evolve, which often underpin quantitative projections of future change that, together with the storyline, constitute a scenario [B2.1]. The IPCC Special Report on Emissions Scenarios (SRES), published in 2000, provided scenarios of future greenhouse gas emissions accompanied by storylines of social, economic and technological development that can be used in CCIAV studies (Figure TS.2). Although there can be methodological problems in applying these scenarios (for example, in downscaling projections of population and gross domestic product (GDP) from the four SRES large world regions to national or sub-national scales), they nevertheless provide a coherent global quantification of socio-economic development, greenhouse gas emissions and climate, and represent some of the most comprehensive scenarios presently available to CCIAV researchers. A substantial number of the impact studies assessed in this volume that employed future characterisations made use of the SRES scenarios. For some other studies, especially empirical analyses of adaptation and vulnerability, the scenarios were of limited relevance and were not adopted [2.4.6].

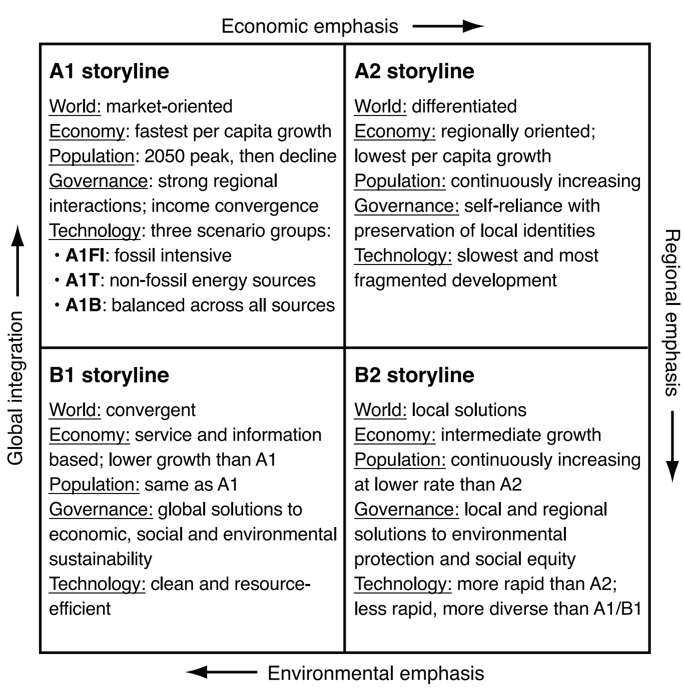



**Figure TS.2.** *Summary characteristics of the four SRES storylines [F2.5]*

In the future, better integration of climate-related scenarios with those widely adopted by other international bodies (mainstreaming) is desirable, and enhanced information exchange between research and policy communities will greatly improve scenario usage and acceptance. Improved scenarios are required for poorly specified indicators such as future technology and adaptive capacity, and interactions between key drivers of change need to be better specified [2.5].

### Characterising future climate

*Sensitivity studies*
A substantial number of model-based CCIAV studies assessed in this Report employ sensitivity analysis to investigate the behaviour of a system by assuming arbitrary, often regularly spaced, adjustments in important driving variables. Using a range of perturbations allows construction of impact response surfaces, which are increasingly being used in combination with probabilistic representations of future climate to assess risks of impacts [2.4.3, 2.3.1, 2.4.8].

*Analogues*
Historical extreme weather events, such as floods, heatwaves and droughts, are increasingly being analysed with respect to their impacts and adaptive responses. Such studies can be useful for planning adaptation responses, especially if these events become more frequent and/or severe in the future. Spatial analogues (regions having a present-day climate similar to that expected in a study region in the future) have been adopted as a heuristic device for analysing economic impacts, adaptation needs and risks to biodiversity [2.4.4].

*Climate model data*
The majority of quantitative CCIAV studies assessed in the AR4 use climate models to generate the underlying scenarios of climate change. Some scenarios are based on pre-SRES emissions scenarios, such as IS92a, or even on equilibrium climate model experiments. However, the greatest proportion is derived from SRES emissions scenarios, principally the A2 scenario (assuming high emissions), for which the majority of early SRES-based climate model experiments were conducted. A few scenario-driven studies explore singular events with widespread consequences, such as an abrupt cessation of the North Atlantic Meridional Overturning Circulation (MOC) [2.4.6.1, 2.4.7].

The CCIAV studies assessed in the Working Group II Fourth Assessment (WGII AR4) are generally based on climate model simulations assessed by Working Group I (WGI) in the TAR. Since the TAR, new simulations have been performed with coupled Atmosphere-Ocean General Circulation Models (AOGCMs) assuming SRES emissions. These are assessed in the WGI AR4, but most were not available for the CCIAV studies assessed for the WGII AR4. Figure TS.3 compares the range of regional temperature and precipitation projections from recent A2-forced AOGCM simulations (assessed by WGI AR4: red bars) with earlier A2-forced simulations assessed in WGI TAR and used for scenario construction in many CCIAV studies assessed for the WGII AR4 (blue bars). The figure supports the WGI AR4 conclusion that the basic pattern of projected warming is little changed from previous assessments (note the positions of the blue and red bars), but confidence in regional projections is now higher for most regions for temperature and in some regions for precipitation (i.e., where red bars are shorter than blue bars) [B2.3].

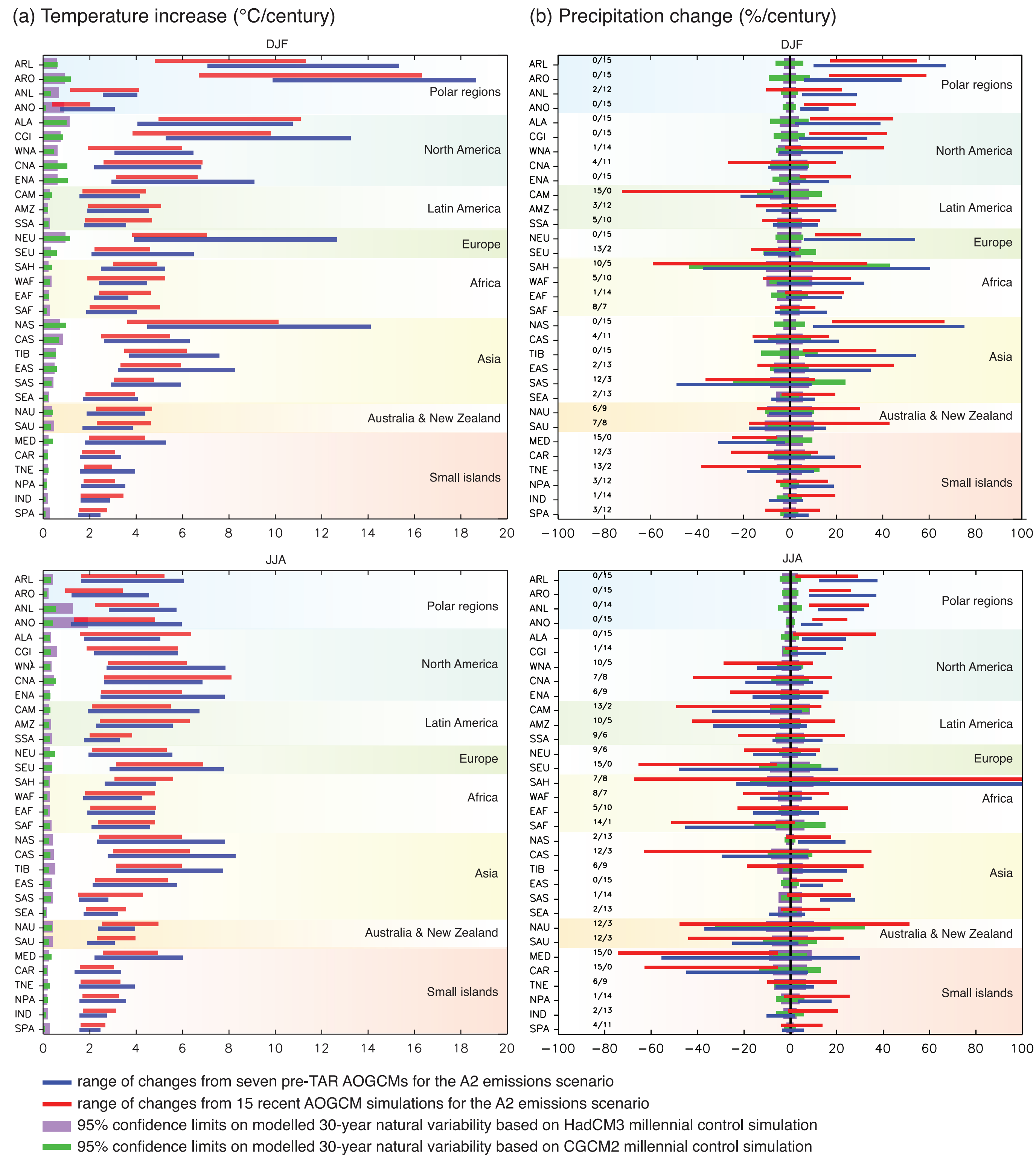



**Figure TS.3.** *Range of winter and summer temperature and precipitation changes up to the end of the 21st century across recent (fifteen models – red bars) and pre-TAR (seven models – blue bars) AOGCM projections under the SRES A2 emissions scenarios for thirty-two world regions, expressed as rate of change per century. Mauve and green bars show modelled 30-year natural variability. Numbers on precipitation plots show the number of recent A2 runs giving negative/positive precipitation change. DJF: December, January, February; JJA: June, July, August. [F2.6, which includes map of regions]*