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GLOBAL CLIMATE CHANGE : ECONOMICS, SCIENCE, AND POLICY

THE CLIMATE MACHINE IV

REGIONAL EFFECTS OF CLIMATE CHANGE

R. PRINN,

April 7, 2008

A CASE STUDY: CLIMATE CHANGE IMPACTS ON THE UNITED STATES

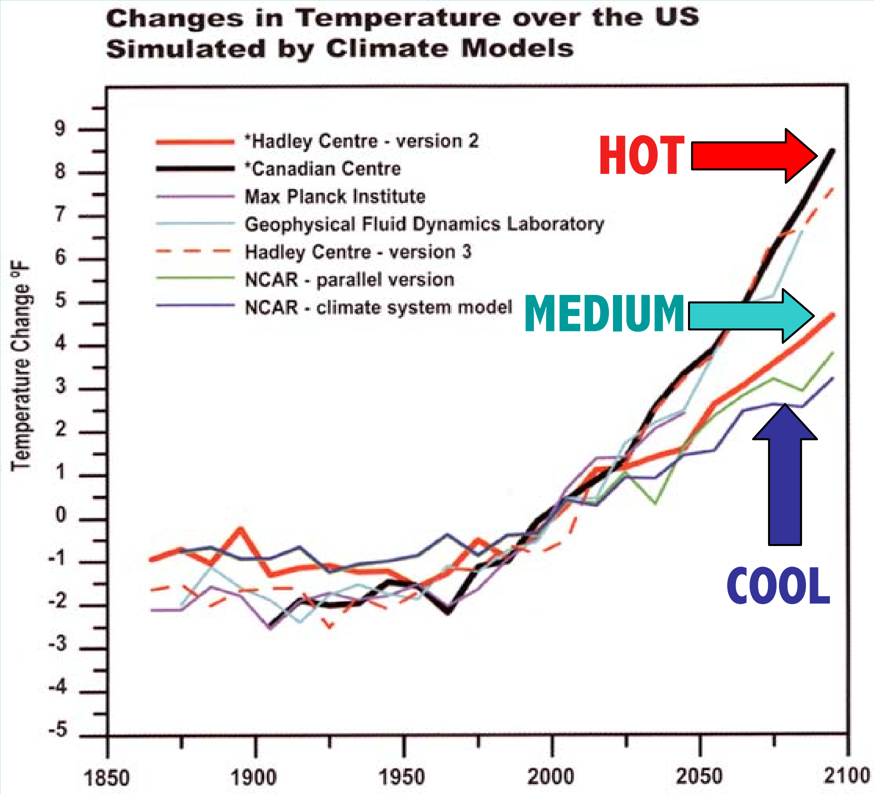
(National Assessment Synthesis Team, U.S. Climate Change Research Program, 2000)

Projecting Future Regional Impacts

How many climate forecasts are needed?

Answer depends on accuracy of forecasts

Climate Change Impacts on the United States - Overview
National Assessment Team - US Global Change Research Program



Simulations from leading climate models of changes in decadal average surface temperature for the conterminous US (excluding Alaska and Hawaii) based on historic and projected changes in atmospheric concentrations of greenhouse gases and sulfate aerosols. The heavy red and black lines indicate the primary models used by the National Assessment. For the 20th century, the models simulate a US temperature rise of about 0.7 to 1.9˚F, whereas estimates from observations range from 0.5 to 1.4˚F; estimates for the global rise are 0.9 to 1.4˚F for models and 0.7 to 1.4˚F for observations, suggesting reasonable agreement. For the 21st century, the models project warming ranging from 3 to 6˚F for the globe and 3 to 9˚F for the US. The two models at the low end of this range assume lower emissions of greenhouse gases than do the other models.

The two primary climate models used in this Assessment have been peer-reviewed and both incorporate similar assumptions about future emissions (both approximate the IPCC “IS92a” scenario with a 1% per year increase in greenhouse gases and growing sulfur emissions).

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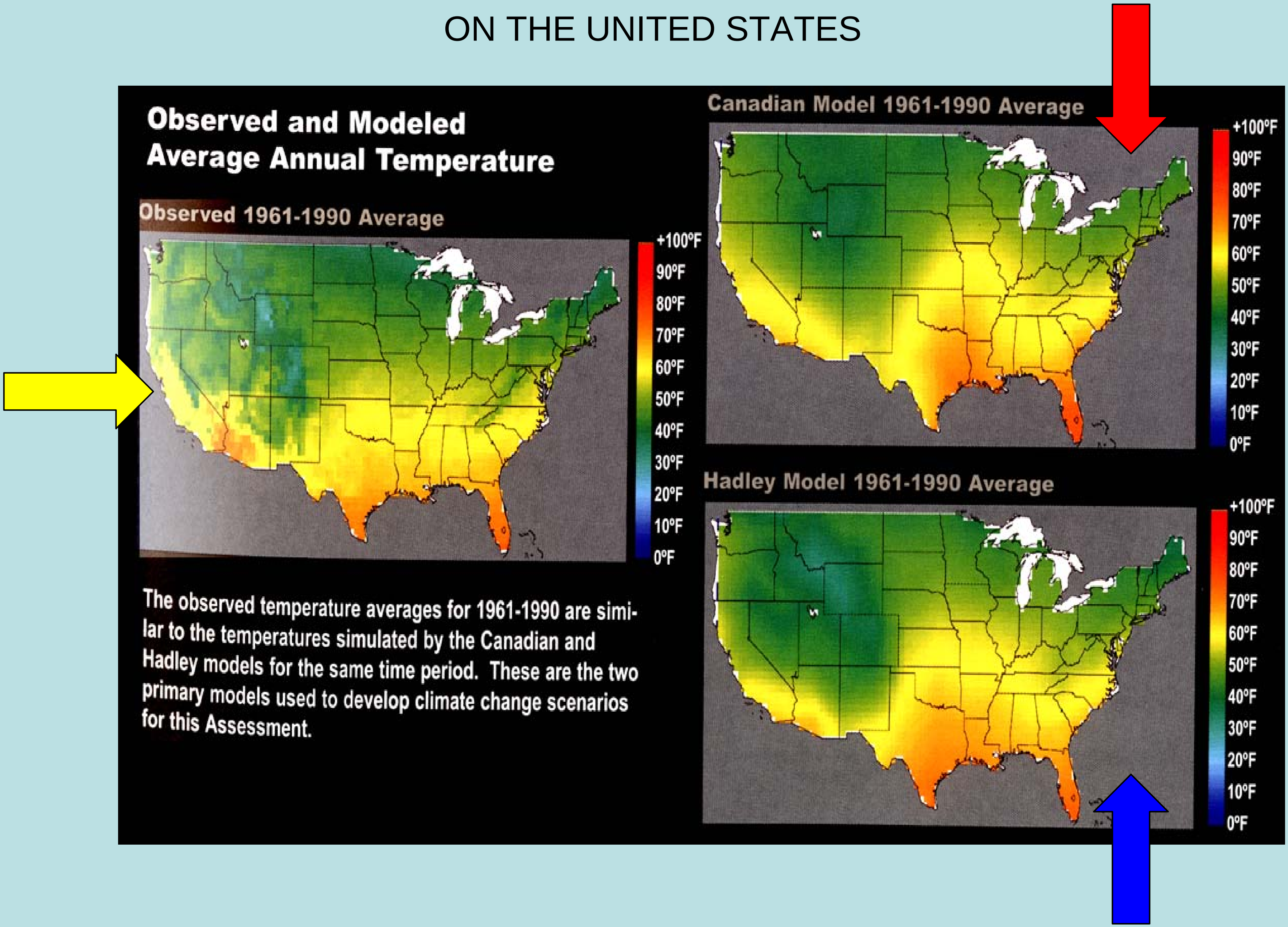

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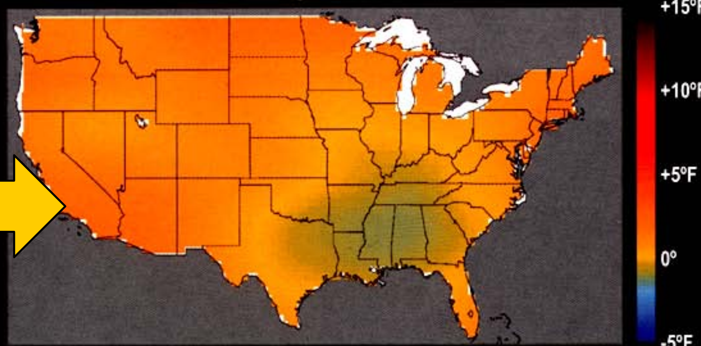
Temperature Change

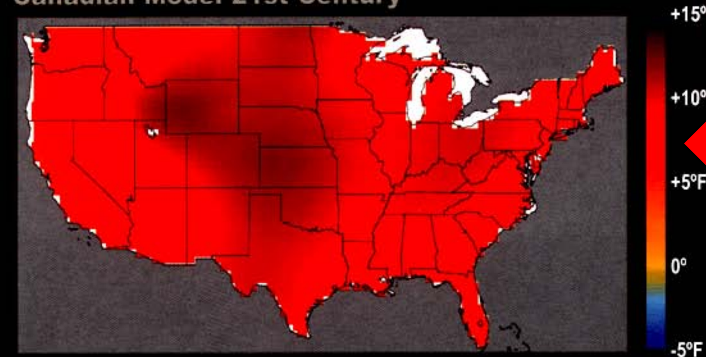
How to read these maps: The color scale indicates changes in temperature in °F over a 100 year period. For example, at 0°F there is no change; at +10°F there is a 10°F increase from the begining to the end of the century.

Observed 20th Century

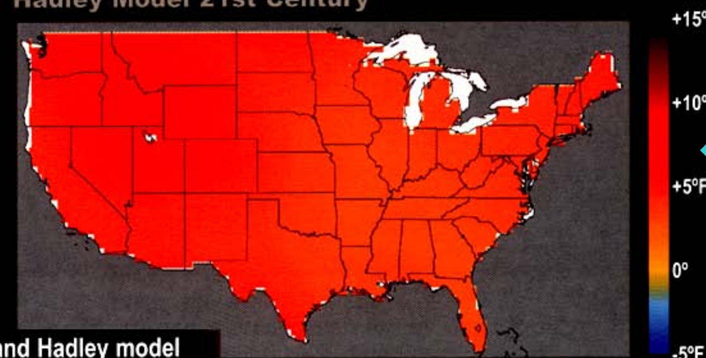


The change in the annual average temperature over the 20th century has a distinctive pattern. Most of the US has warmed, in some areas by as much as 4˚F. Only portions of the southeastern US have experienced cooling, and this was primarily due to the cool decades of the 1960s and 1970s. Temperatures since then have reached some of the highest levels of the century.

Canadian Model 21st Century



Hadley Model 21st Century



Both the Canadian and Hadley model scenarios project substantial warming during the 21st century. The warming is considerably greater in the Canadian model, with most of the continental US experiencing increases from 5 to 15˚F. In this model, the least warming occurs in the West and along the Atlantic and Gulf Coasts. In the Hadley model, annual temperatures are projected to increase from 3 to 7˚F, with the largest warming occurring in the western half of the country.

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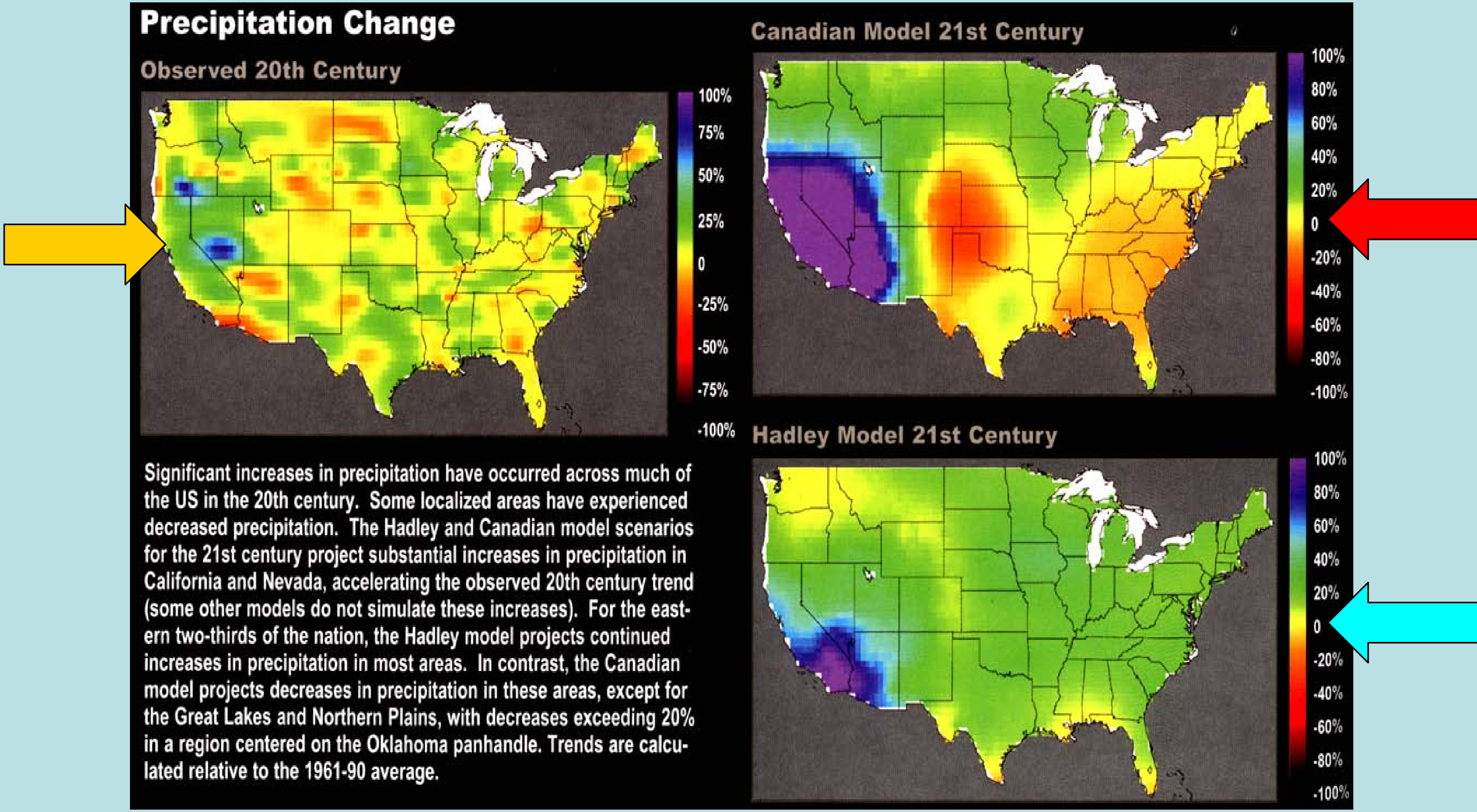

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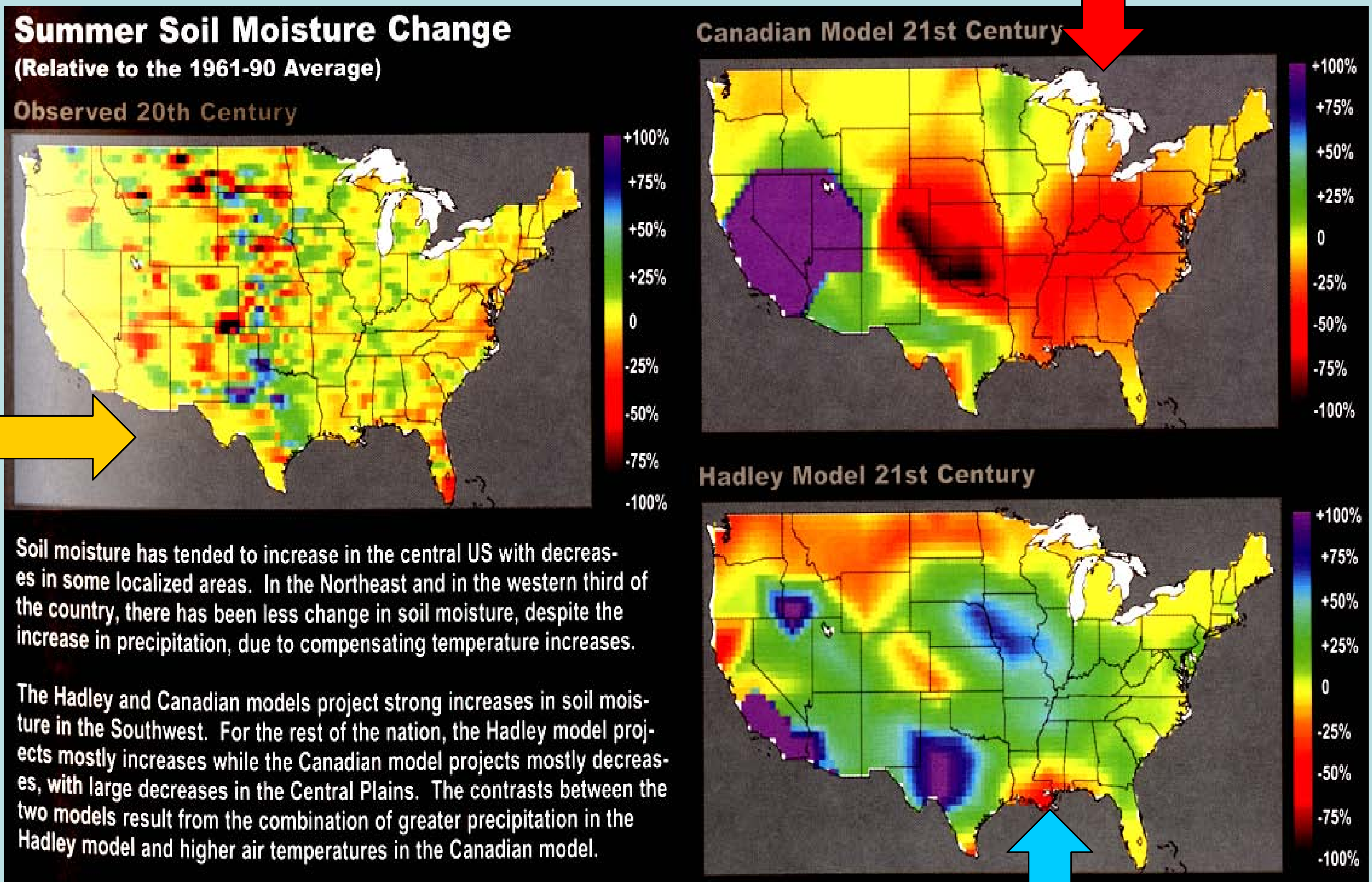
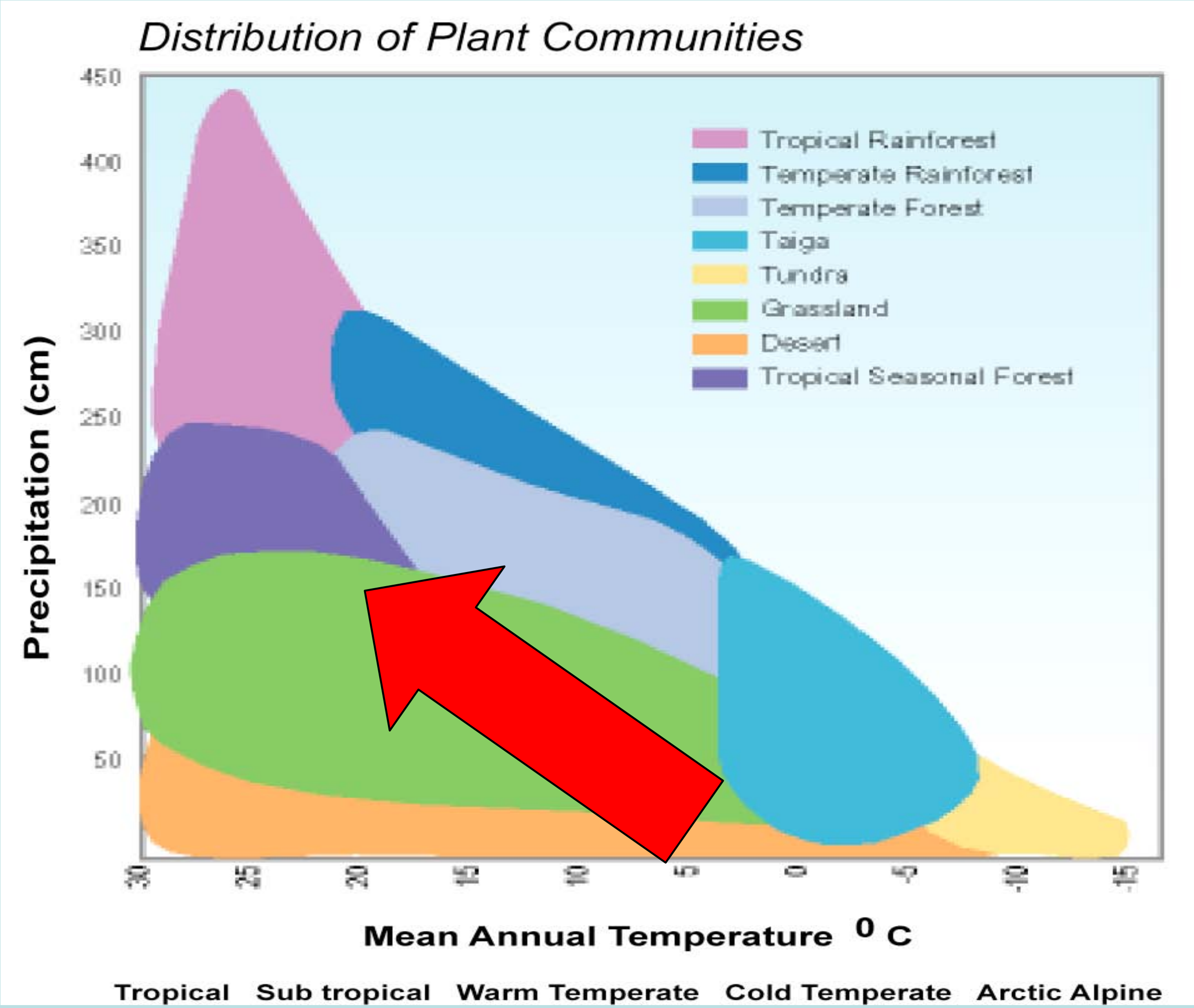


CLIMATE CHANGE IMPACTS ON ECOSYSTEMS



National Assessment Synthesis Team, Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change (Washington, DC: U.S. Global Change Research Program, 2000). Courtesy of The U.S. Global Change Research Program (USGCRP). Used with permission.

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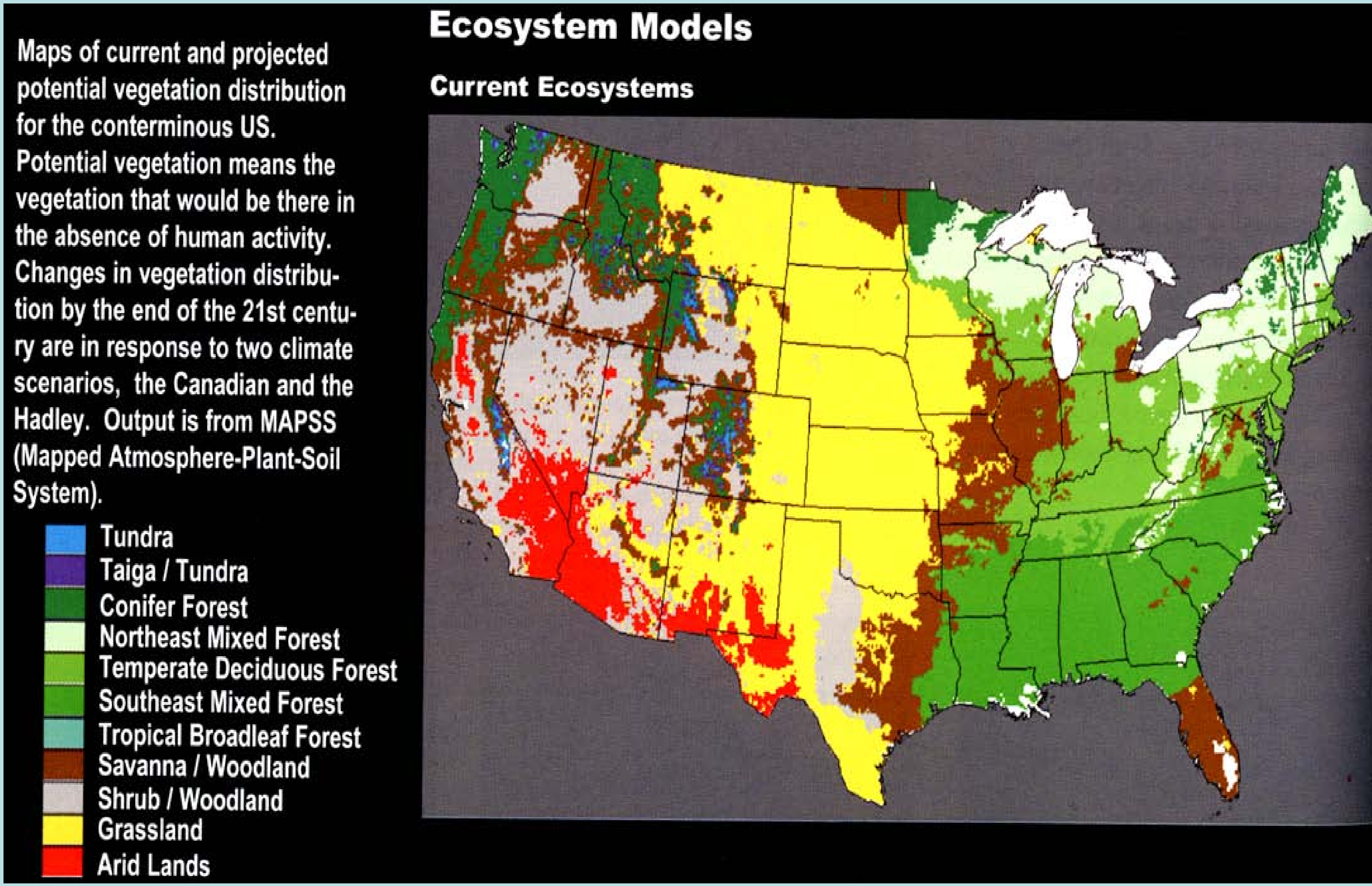

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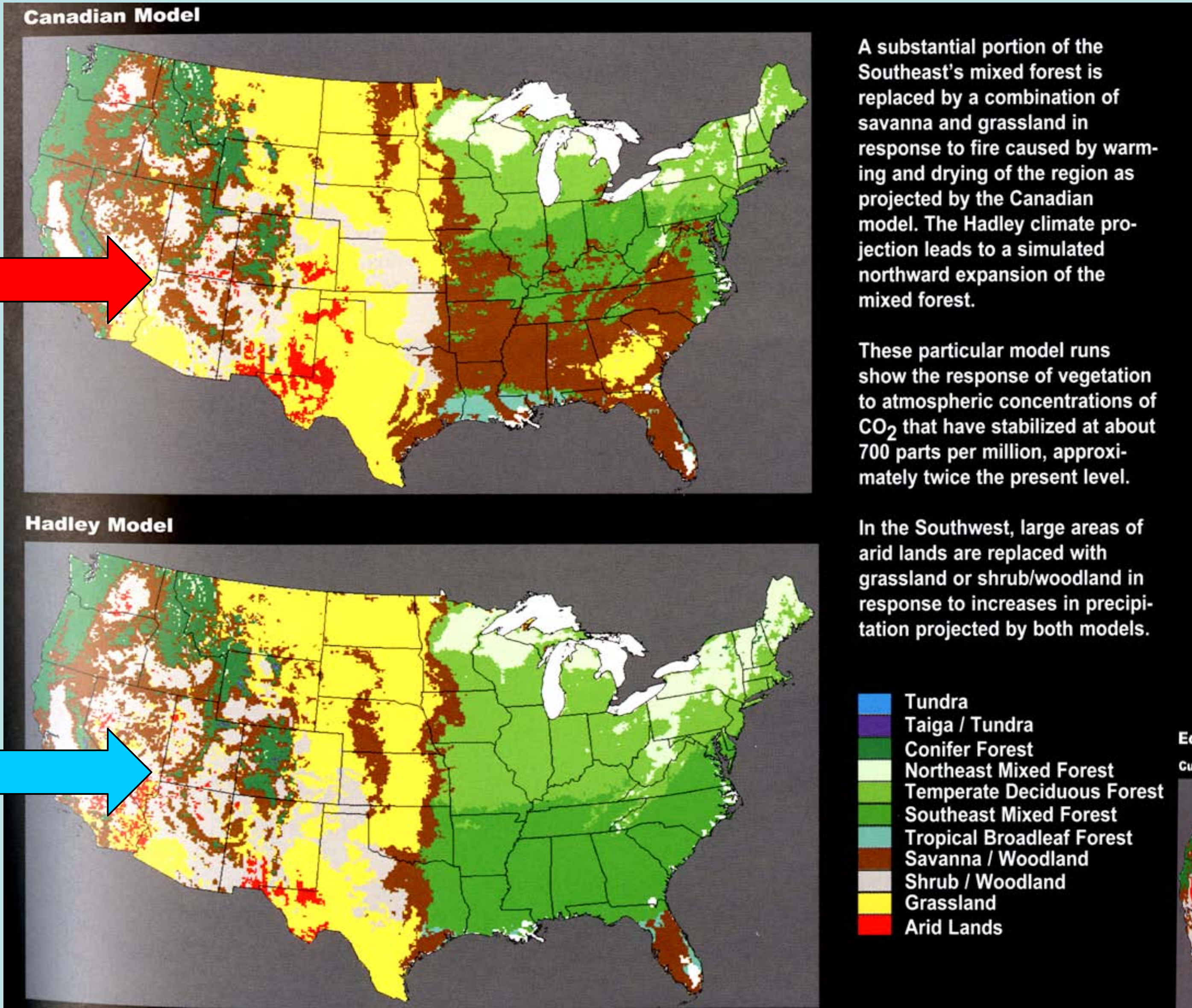
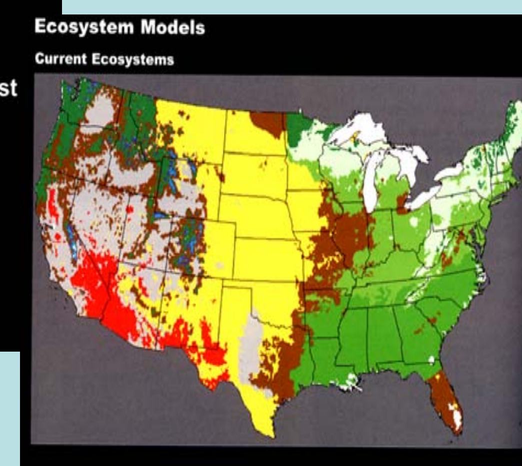


A substantial portion of the Southeast's mixed forest is replaced by a combination of savanna and grassland in response to fire caused by warming and drying of the region as projected by the Canadian model. The Hadley climate projection leads to a simulated northward expansion of the mixed forest.

These particular model runs show the response of vegetation to atmospheric concentrations of CO_2 that have stabilized at about 700 parts per million, approximately twice the present level.

In the Southwest, large areas of arid lands are replaced with grassland or shrub/woodland in response to increases in precipitation projected by both models.



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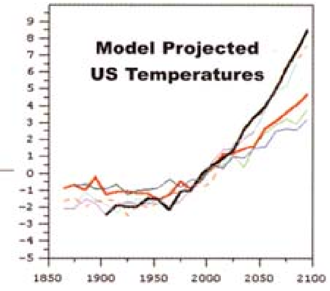
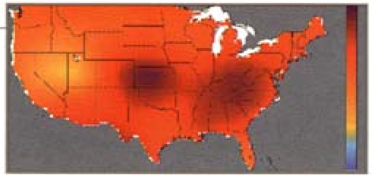
KEY FINDINGS



1. Increased warming

Assuming continued growth in world greenhouse gas emissions, the primary climate models used in this Assessment project that temperatures in the US will rise 5-9ºF (3-5ºC) on average in the next 100 years. A wider range of outcomes is possible.



2. Differing regional impacts

Climate change will vary widely across the US. Temperature increases will vary somewhat from one region to the next. Heavy and extreme precipitation events are likely to become more frequent, yet some regions will get drier. The potential impacts of climate change will also vary widely across the nation.

3. Vulnerable ecosystems

Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. A few, such as alpine meadows in the Rocky Mountains and some barrier islands, are likely to disappear entirely in some areas. Others, such as forests of the Southeast, are likely to experience major species shifts or break up into a mosaic of grasslands, woodlands, and forests. The goods and services lost through the disappearance or fragmentation of certain ecosystems are likely to be costly or impossible to replace.

4. Widespread water concerns

Water is an issue in every region, but the nature of the vulnerabilities varies. Drought is an important concern in every region. Floods and water quality are concerns in many regions. Snowpack changes are especially important in the West, Pacific Northwest, and Alaska.

5. Secure food supply

At the national level, the agriculture sector is likely to be able to adapt to climate change. Overall, US crop productivity is very likely to increase over the next few decades, but the gains will not be uniform across the nation. Falling prices and competitive pressures are very likely to stress some farmers, while benefiting consumers.

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6. Near-term increase in forest growth

Forest productivity is likely to increase over the next several decades in some areas as trees respond to higher carbon dioxide levels. Over the longer term, changes in larger-scale processes such as fire, insects, droughts, and disease will possibly decrease forest productivity. In addition, climate change is likely to cause long-term shifts in forest species, such as sugar maples moving north out of the US.

7. Increased damage in coastal and permafrost areas

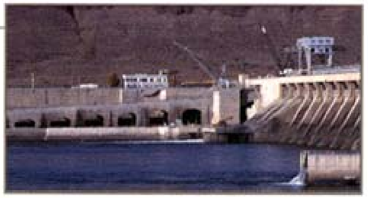
Climate change and the resulting rise in sea level are likely to exacerbate threats to buildings, roads, powerlines, and other infrastructure in climatically sensitive places. For example, infrastructure damage is related to permafrost melting in Alaska, and to sea-level rise and storm surge in low-lying coastal areas.

8. Adaptation determines health outcomes

A range of negative health impacts is possible from climate change, but adaptation is likely to help protect much of the US population. Maintaining our nation's public health and community infrastructure, from water treatment systems to emergency shelters, will be important for minimizing the impacts of water-borne diseases, heat stress, air pollution, extreme weather events, and diseases transmitted by insects, ticks, and rodents.

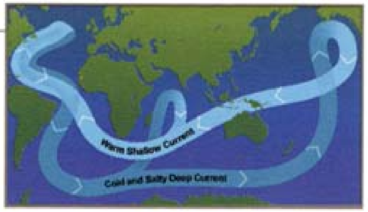
9. Other stresses magnified by climate change

Climate change will very likely magnify the cumulative impacts of other stresses, such as air and water pollution and habitat destruction due to human development patterns. For some systems, such as coral reefs, the combined effects of climate change and other stresses are very likely to exceed a critical threshold, bringing large, possibly irreversible impacts.



10. Uncertainties remain and surprises are expected

Significant uncertainties remain in the science underlying regional climate changes and their impacts. Further research would improve understanding and our ability to project societal and ecosystem impacts, and provide the public with additional useful information about options for adaptation. However, it is likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to ongoing climate change in unforeseeable ways.



RETROSPECTIVE ANALYSIS

What are the strengths of this analysis?

What are the weaknesses?

How could this assessment be more effective next time?

REGIONAL IMPACTS OVER THE GLOBE

What are the effects on temperature, rainfall & water supply by region over the globe?

How do developing countries fare relative to developed countries?

Use results from the IPCC 4th Assessment, WG1, Chapters 10-11, Regional Climate Change

TEMPERATURE CHANGES FOR DIFFERENT EMISSION SCENARIOS (IPCC AR4, WG 1, CH. 10, 2007)

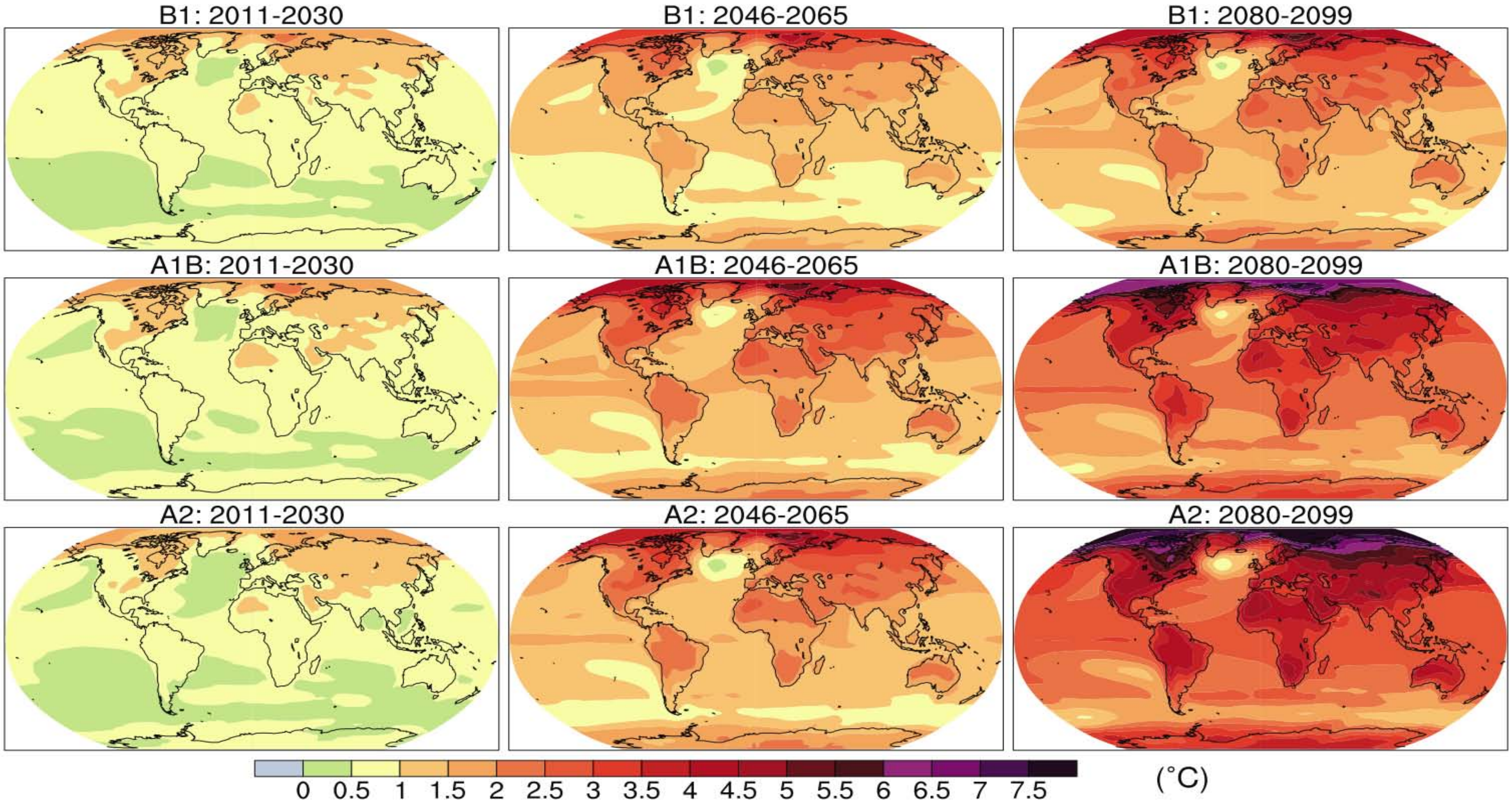
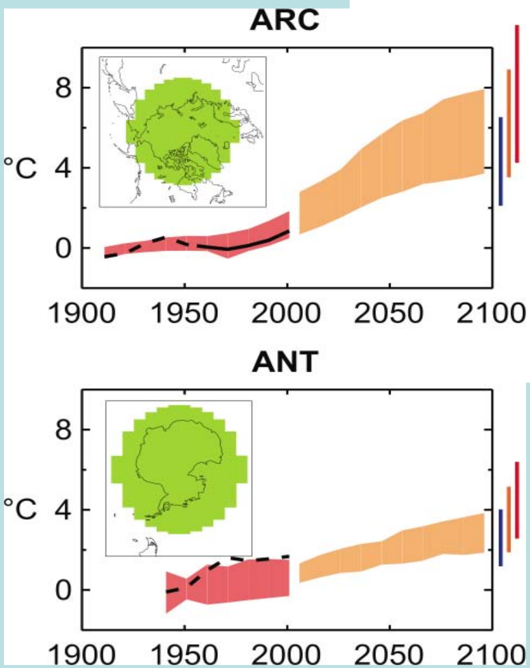
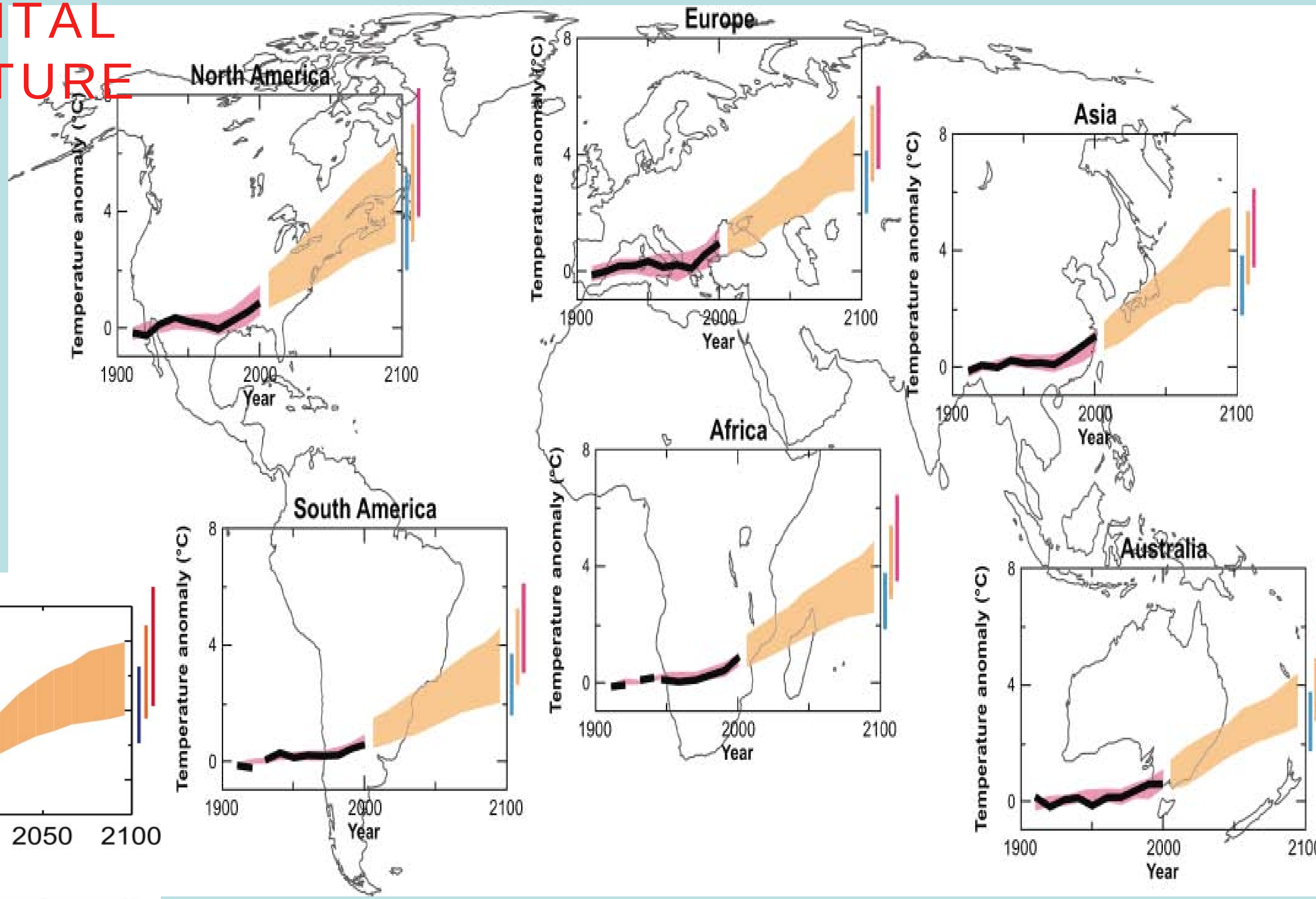


Figure 10.8. *Multi-model mean of annual mean surface warming (surface air temperature change, °C) for the scenarios B1 (top), A1B (middle) and A2 (bottom), and three time periods, 2011 to 2030 (left), 2046 to 2065 (middle) and 2080 to 2099 (right). Stippling is omitted for clarity (see text). Anomalies are relative to the average of the period 1980 to 1999. Results for individual models can be seen in the Supplementary Material for this chapter.*

CONTINENTAL TEMPERATURE CHANGES

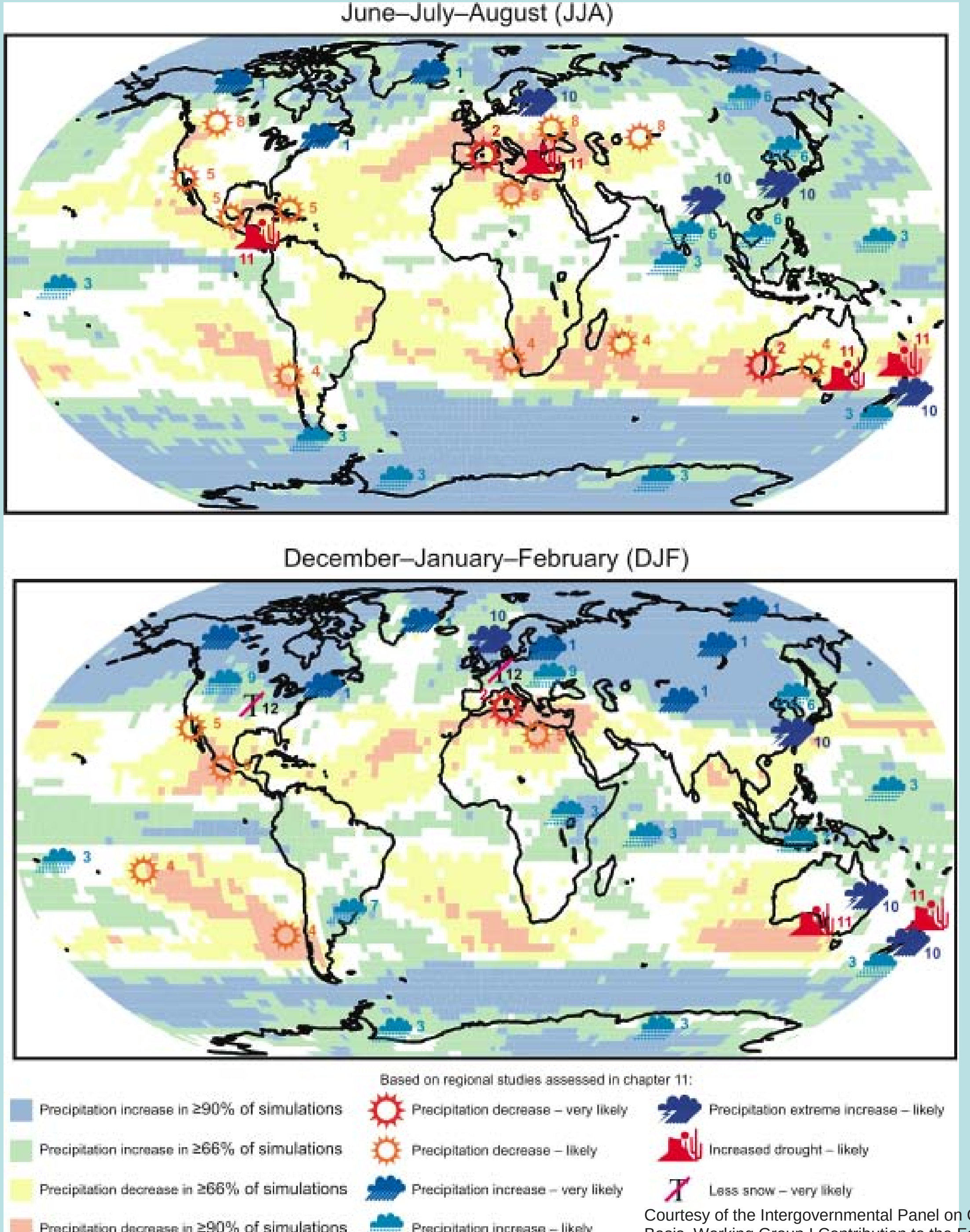
Figure 11.21. Annual surface temperature change between 1980 to 1999 and 2080 to 2099 in the Arctic and Antarctic from the MMD-A1B projections.





Box 11.1, Figure 1. Temperature anomalies with respect to 1901 to 1950 for six continental-scale regions for 1906 to 2005 (black line) and as simulated (red envelope) by MMD models incorporating known forcings; and as projected for 2001 to 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). The black line is dashed where observations are present for less than 50% of the area in the decade concerned. More details on the construction of these figures are given in Section 11.1.2.

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007



Box 11.1, Figure 2. Robust findings on regional climate change for mean and extreme precipitation, drought, and snow. This regional assessment is based upon AOGCM based studies, Regional Climate Models, statistical downscaling and process understanding. More detail on these findings may be found in the notes below, and their full description, including sources is given in the text. The background map indicates the degree of consistency between AR4 AOGCM simulations (21 simulations used) in the direction of simulated precipitation change.

(1) Very likely annual mean increase in most of northern Europe and the Arctic (largest in cold season), Canada, and the North-East USA; and winter (DJF) mean increase in Northern Asia and the Tibetan Plateau.
(2) Very likely annual mean decrease in most of the Mediterranean area, and winter (JJA) decrease in southwestern Australia.
(3) Likely annual mean increase in tropical and East Africa, Northern Pacific, the northern Indian Ocean, the South Pacific (slight, mainly equatorial regions), the west of the South Island of New Zealand, Antarctica and winter (JJA) increase in Tierra del Fuego.
(4) Likely annual mean decrease in and along the southern Andes, summer (DJF) decrease in eastern French Polynesia, winter (JJA) decrease for Southern Africa and in the vicinity of Mauritius, and winter and spring decrease in southern Australia.
(5) Likely annual mean decrease in North Africa, northern Sahara, Central America (and in the vicinity of the Greater Antilles in JJA) and in South-West USA.
(6) Likely summer (JJA) mean increase in Northern Asia, East Asia, South Asia and most of Southeast Asia, and likely winter (DJF) increase in East Asia.
(7) Likely summer (DJF) mean increase in southern Southeast Asia and southeastern South America
(8) Likely summer (JJA) mean decrease in Central Asia, Central Europe and Southern Canada.
(9) Likely winter (DJF) mean increase in central Europe, and southern Canada
(10) Likely increase in extremes of daily precipitation in northern Europe, South Asia, East Asia, Australia and New Zealand.
(11) Likely increase in risk of drought in Australia and eastern New Zealand; the Mediterranean, central Europe (summer drought); in Central America (boreal spring and dry periods of the annual cycle).
(12) Very likely decrease in snow season length and likely to very likely decrease in snow depth in most of Europe and North America.

Courtesy of the Intergovernmental Panel on Climate Change. Used with permission. From: Climate Change 2007: The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

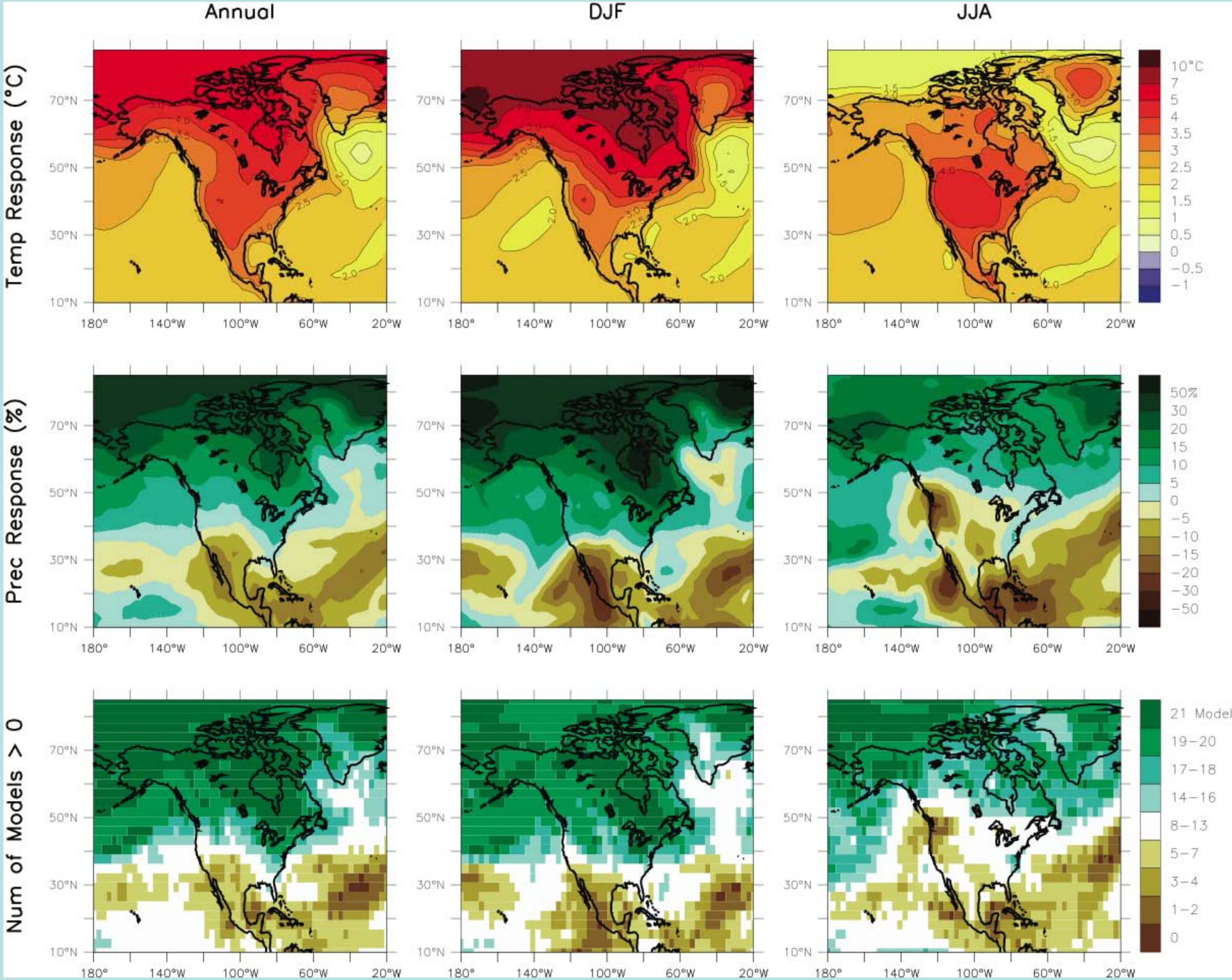


Figure 11.12. Temperature and precipitation changes over North America from the MMD-A1B simulations.

Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (-1 to +10°C).

Middle row: same as top, but for fractional change in precipitation (+/- 50%).

Bottom row: number of models out of 21 that project increases in precipitation (brown=0 and green=21 models).

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

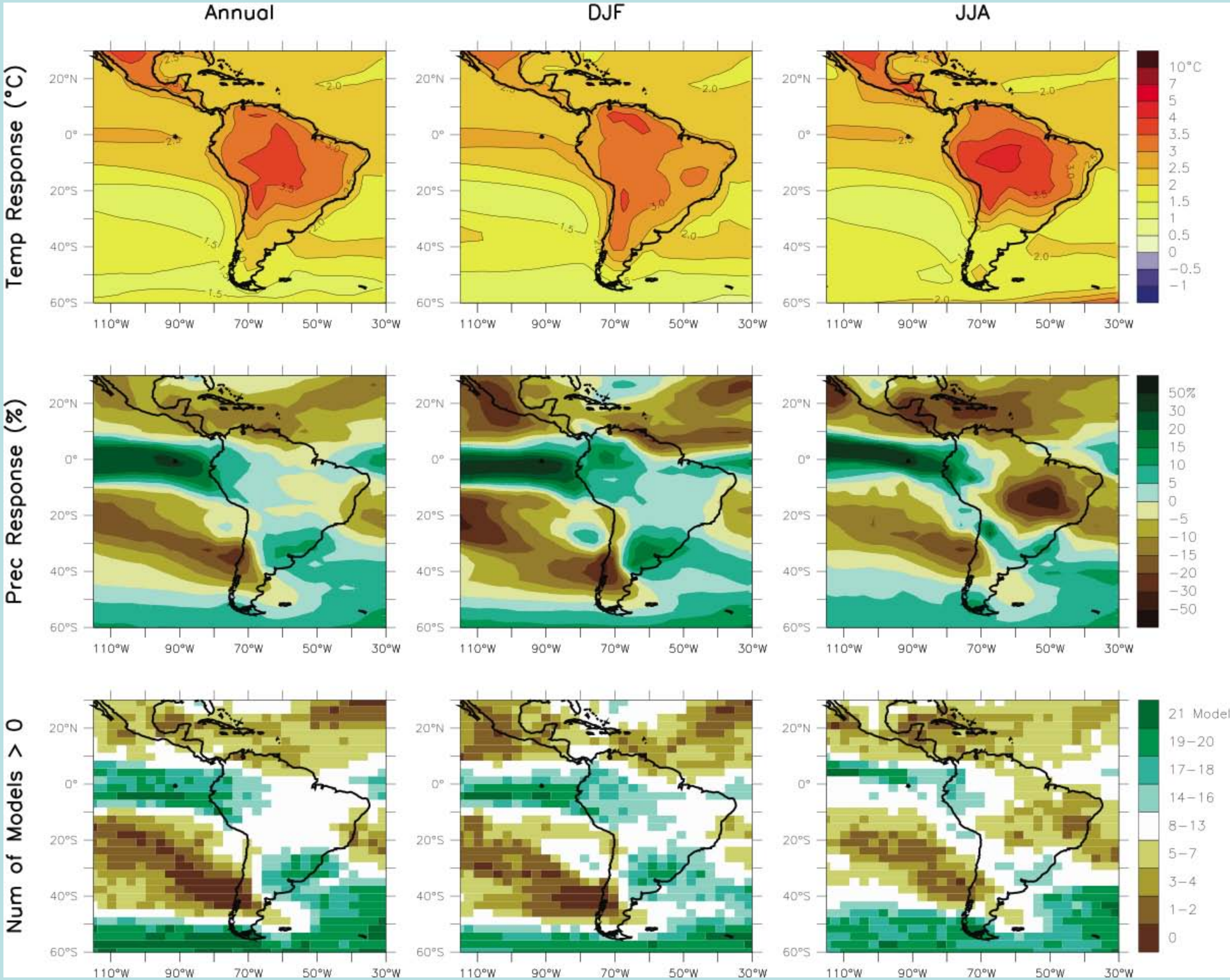


Figure 11.15. Temperature and precipitation changes over South America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (-1 to +10ºC). Middle row: same as top, but for fractional change in precipitation (+/- 50%). Bottom row: number of models out of 21 that project increases in precipitation (brown=0 and green=21 models).

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

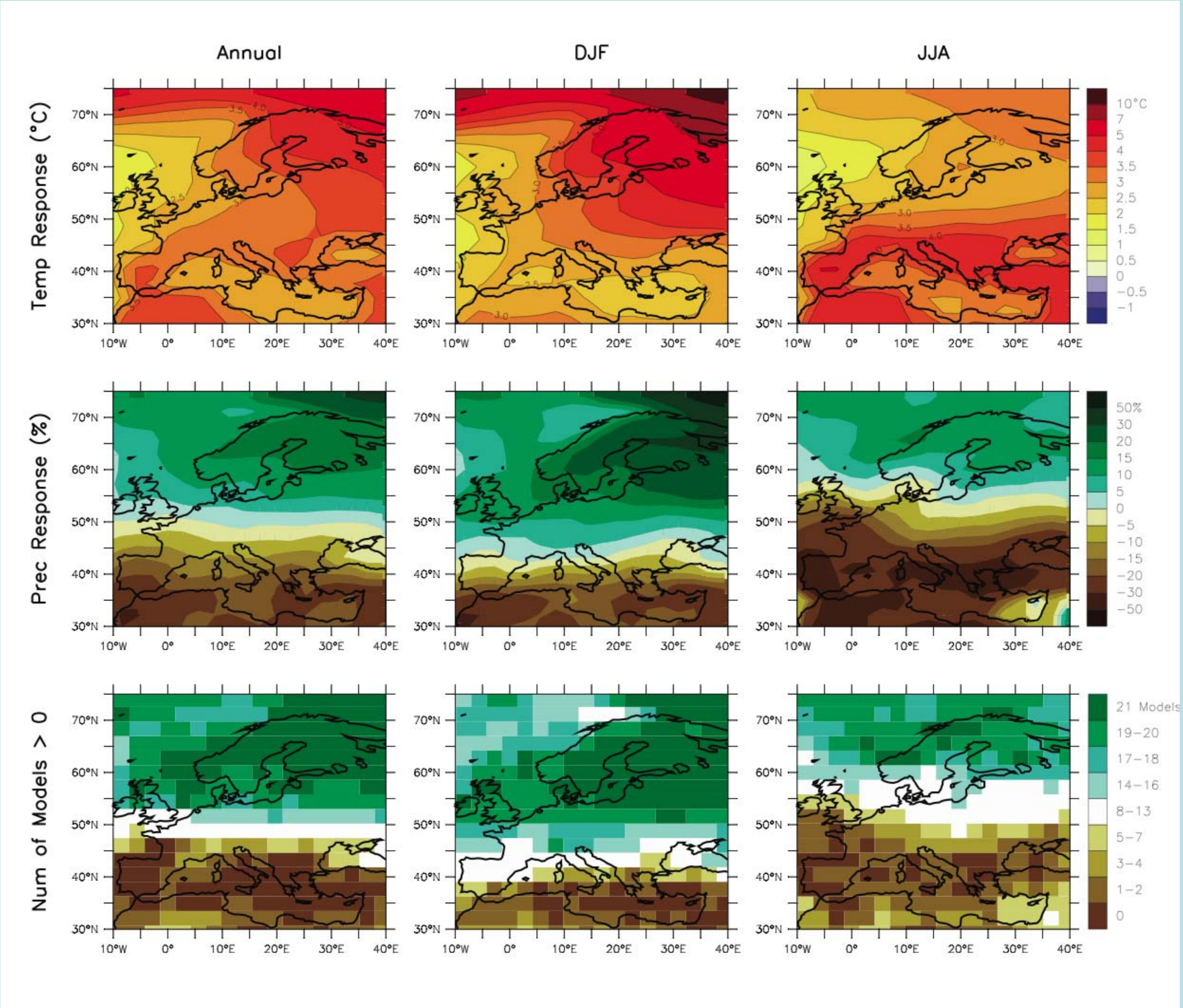


Figure 11.5. Temperature and precipitation changes over Europe from the MMD-A1B simulations.
Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (-1 to +10°C).
Middle row: same as top, but for fractional change in precipitation (+/- 50%).
Bottom row: number of models out of 21 that project increases in precipitation (brown=0 and green=21 models).

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

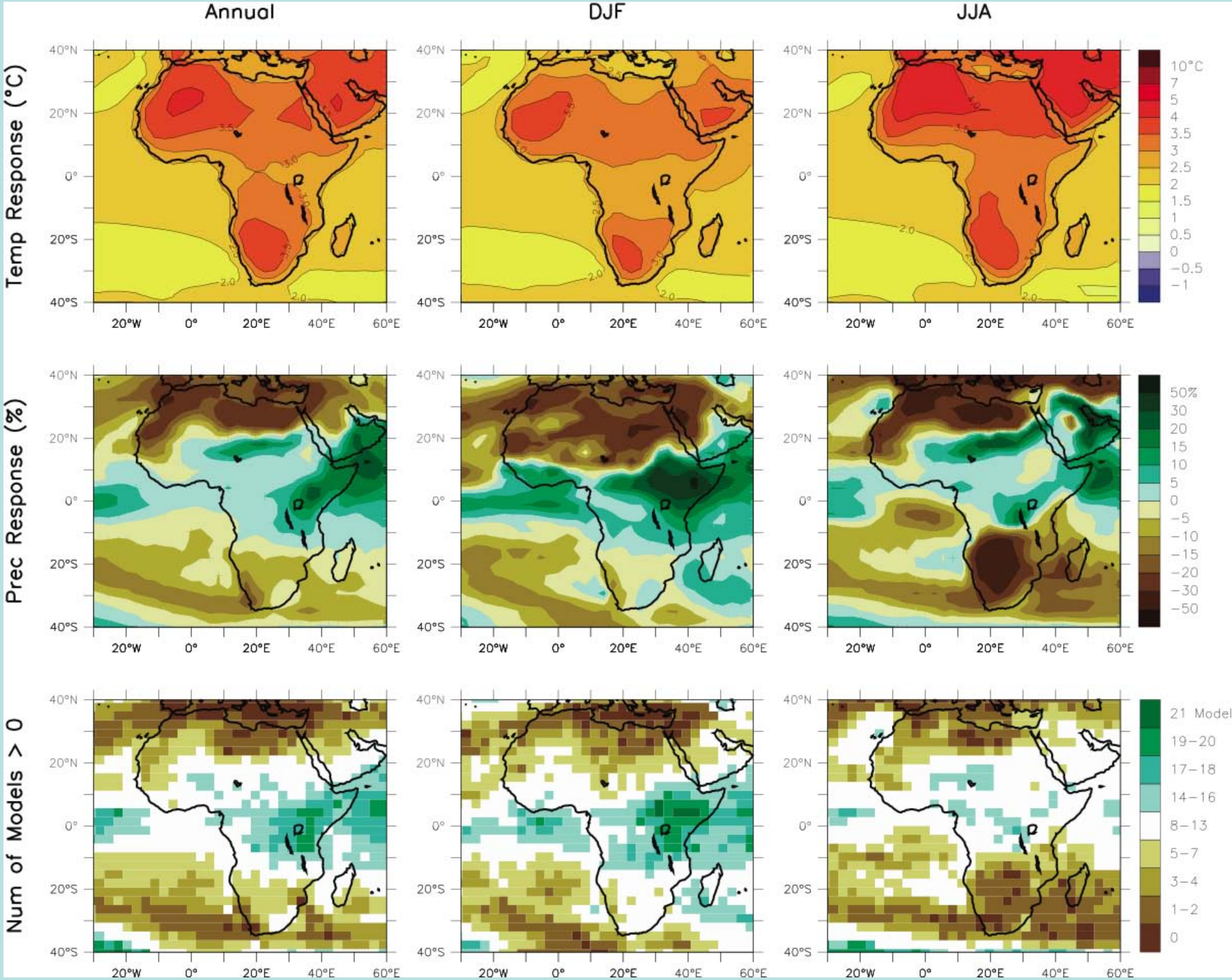


Figure 11.2. Temperature and precipitation changes over Africa from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (-1 to +10^{o}C). Middle row: same as top, but for fractional change in precipitation (+/-50%). Bottom row: number of models out of 21 that project increases in precipitation (brown=0 and green=21 models).

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

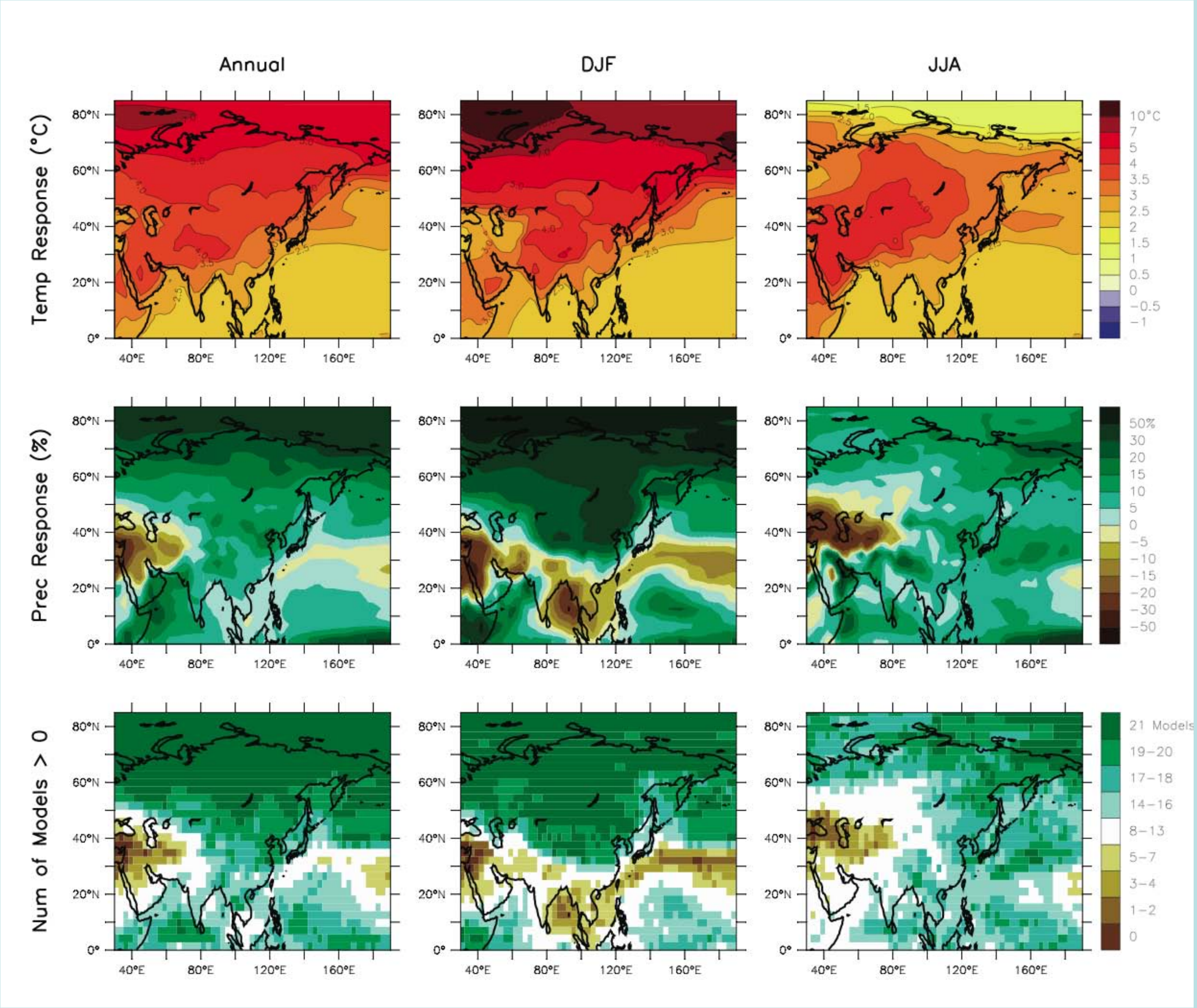


Figure 11.9. Temperature and precipitation changes over Asia from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (-1 to +10^{o}C). Middle row: same as top, but for fractional change in precipitation (+/-50%). Bottom row: number of models out of 21 that project increases in precipitation (brown=0 and green=21 models).

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

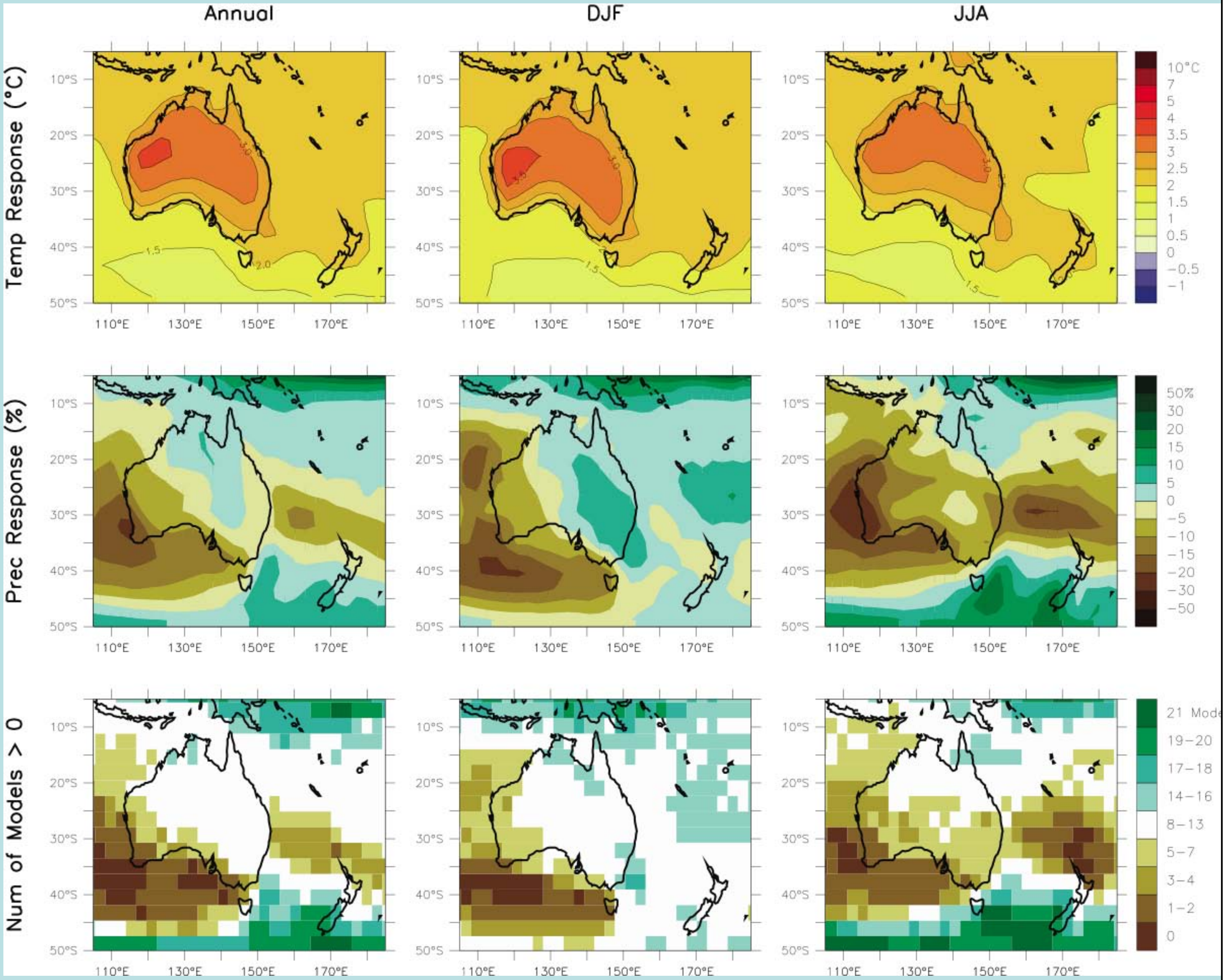


Figure 11.17. Temperature and precipitation changes over Australia & New Zealand from the MMD-A1B simulations.
Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (-1 to +10°C).
Middle row: same as top, but for fractional change in precipitation (+/- 50%).
Bottom row: number of models out of 21 that project increases in precipitation (brown=0 and green=21 models).

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

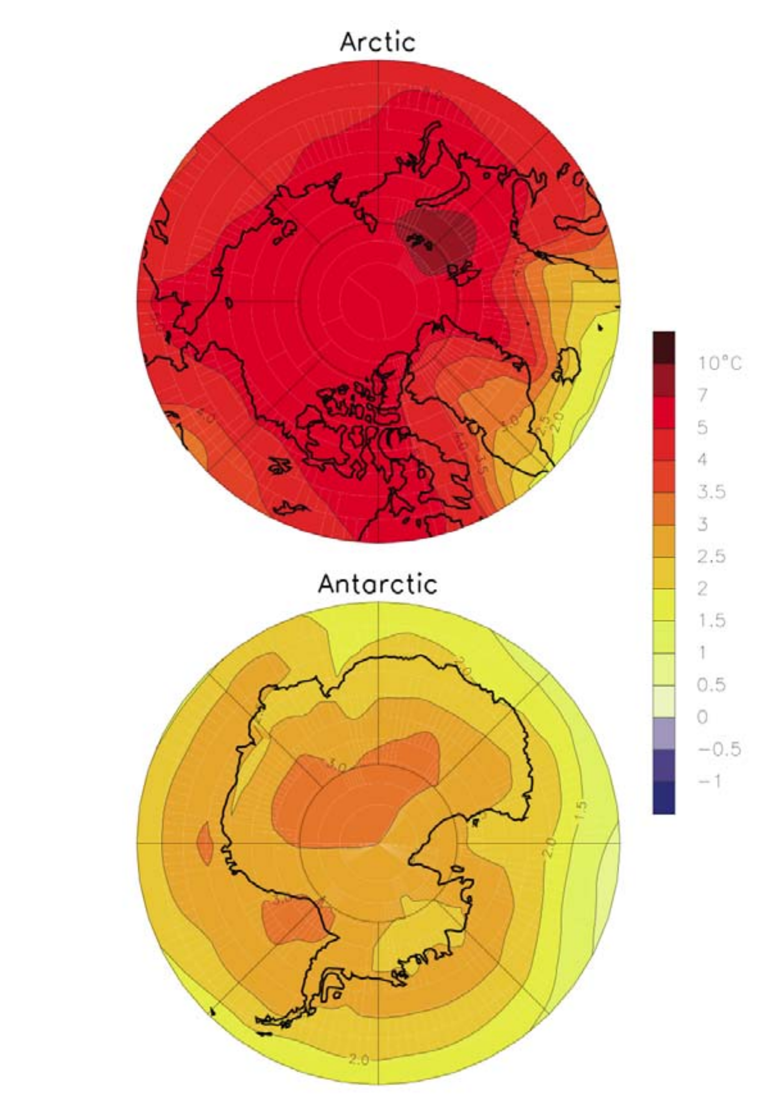
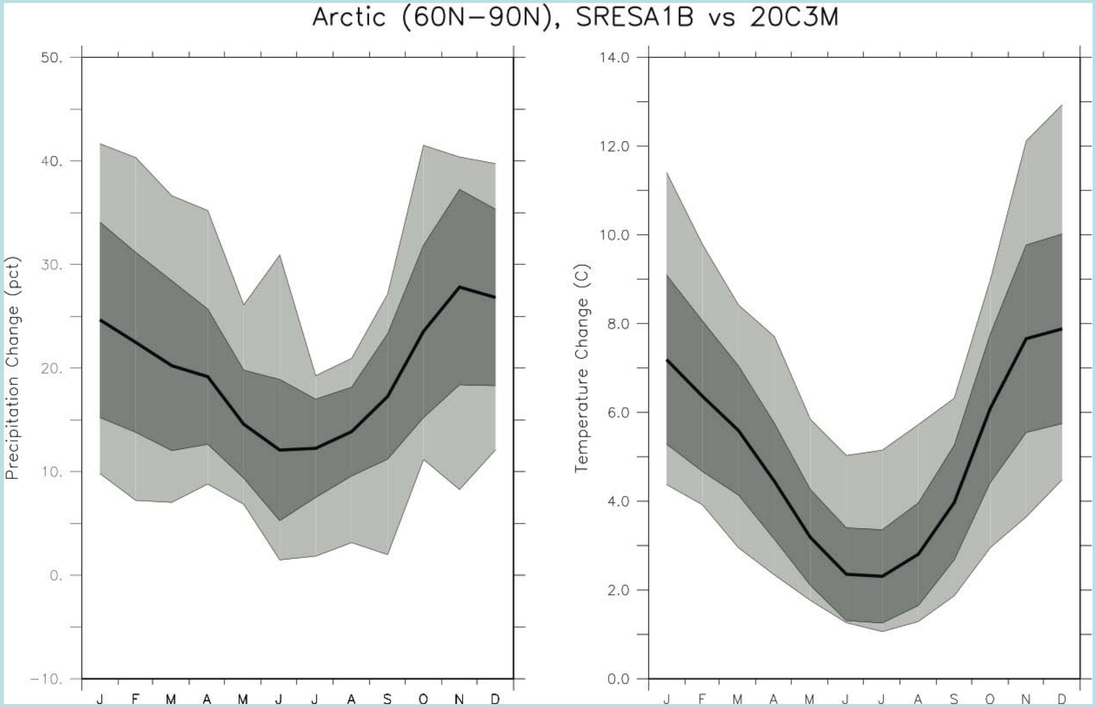


Figure 11.21. Annual surface temperature change between 1980 to 1999 and 2080 to 2099 in the Arctic and Antarctic from the MMD-A1B projections.

Figure 11.19. Annual cycle of arctic area mean temperature and percentage precipitation changes (averaged over the area north of 60°N) for 2080 to 2099 minus 1980 to 1999, under the A1B scenario. Thick lines represent the ensemble median of the 21 MMD models. The dark grey area represents the 25 and 75% quartile values among the 21 models, while the light grey area shows the total range of the models.



Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

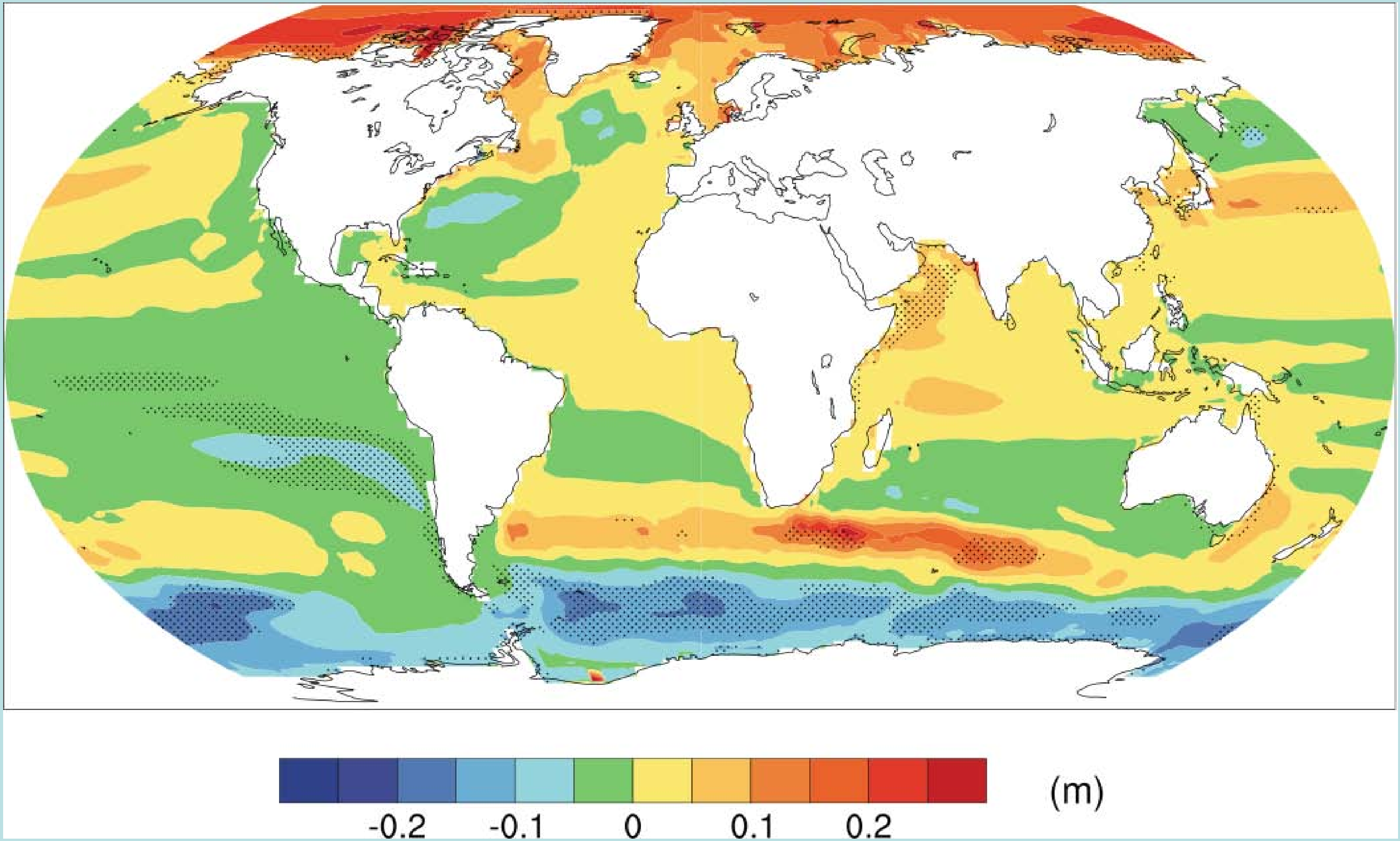


Figure 10.32. *Local sea level change (m) due to ocean density and circulation change relative to the global average (i.e., positive values indicate greater local sea level change than global) during the 21st century, calculated as the difference between averages for 2080 to 2099 and 1980 to 1999, as an ensemble mean over 16 AOGCMs forced with the SRES A1B scenario. Stippling denotes regions where the magnitude of the multi-model ensemble mean divided by the multi-model standard deviation exceeds 1.0.*

Ref: IPCC 4th Assessment, Working Group 1, Chapter 11, 2007

CONCLUDING REMARKS

(1) IPCC AR4 MULTI-(3D) MODEL ENSEMBLES HAVE PROVIDED OBJECTIVE KNOWLEDGE OF UNCERTAINTY IN REGIONAL CLIMATE PREDICTIONS (GIVEN “CERTAIN” EMISSION SCENARIOS) THAT ARE USEFUL IN POLICY DISCUSSIONS.

(2) BUT THE PROBABILITY AND UNDERLYING ECONOMIC, TECHNOLOGICAL, AND POLICY ASSUMPTIONS IN THESE (SRES) EMISSION SCENARIOS ARE TOO OBSCURE TO INCORPORATE EMISSIONS UNCERTAINTY INTO CLIMATE PREDICTIONS.

(3) THE IPCC HAS YET TO CONNECT THE 3 WORKING GROUPS IN A WAY THAT FACILITATES AN EFFECTIVE INTEGRATED ASSESSMENT.