Climate change:

What we know now

&

What the future might be.

C.H.D. Magadza

What is the IPCC process

- The Intergovernmental Panel on Climate Change was set up by the UN Conference of the Parties to examine the to determine the influence of human activity n the earth’s climate system
- It is constituted of scientist experts in relevant disciplines (physical sciences, earth sciences and social sciences.
- The IPCC mandate is to evaluate the world literature in relation to evidence of human impacts on the earth's climate system.
- The panel also evaluates literature on available climate change mitigaton options and options on adaptation to climate change
- The IPCC presents its findings in peer reviewed reports to the COP in three types of reports
  - The full reports
  - The technical summary reports, and
  - Summary for Policy makers

What determines/limits our knowledge of climate change and its consequences?

“Uncertainties in climate change science are inevitably large.

- They arise from questions of data quality,
- inadequate understanding of the climate system and
- its representation in climate models, and
- uncertainties about future emissions of greenhouse gases resulting from socio-economic and technical developments.”
- *Pittock 2007*

Historical global warming projections and observed trends

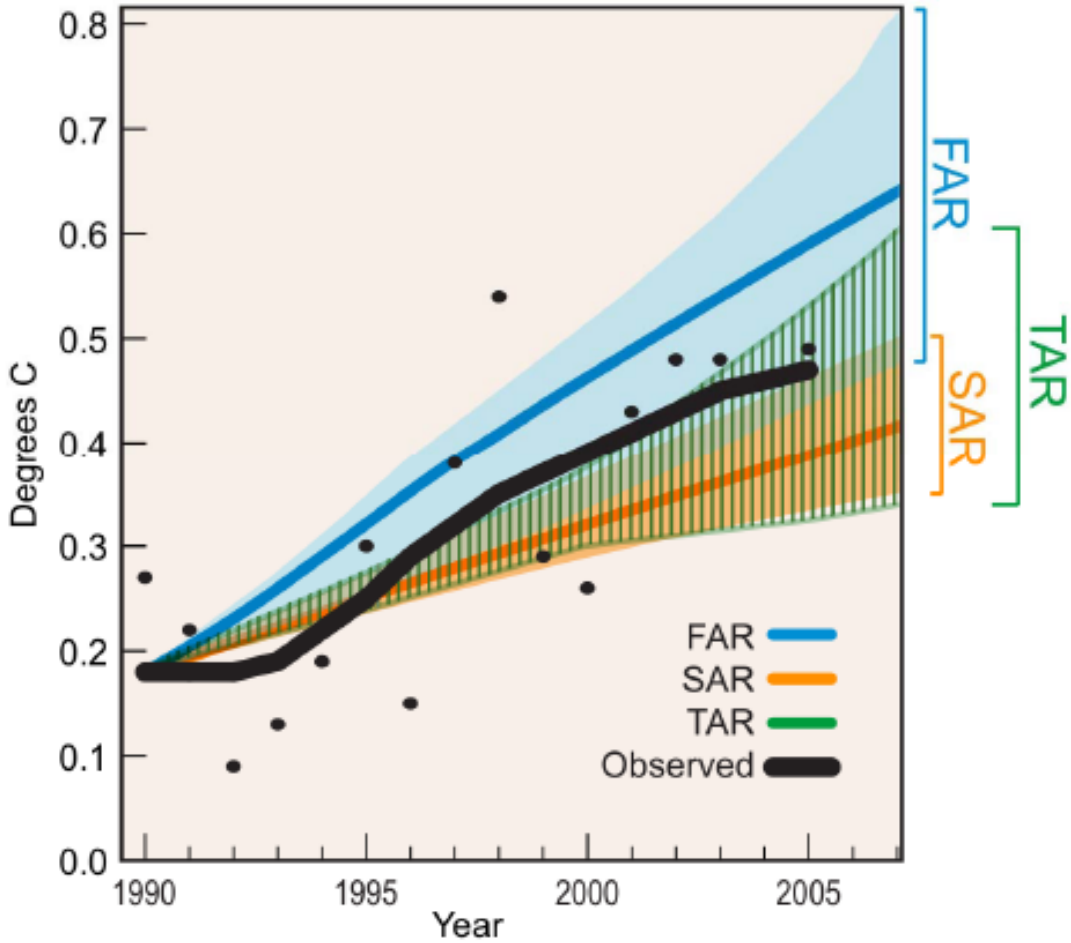
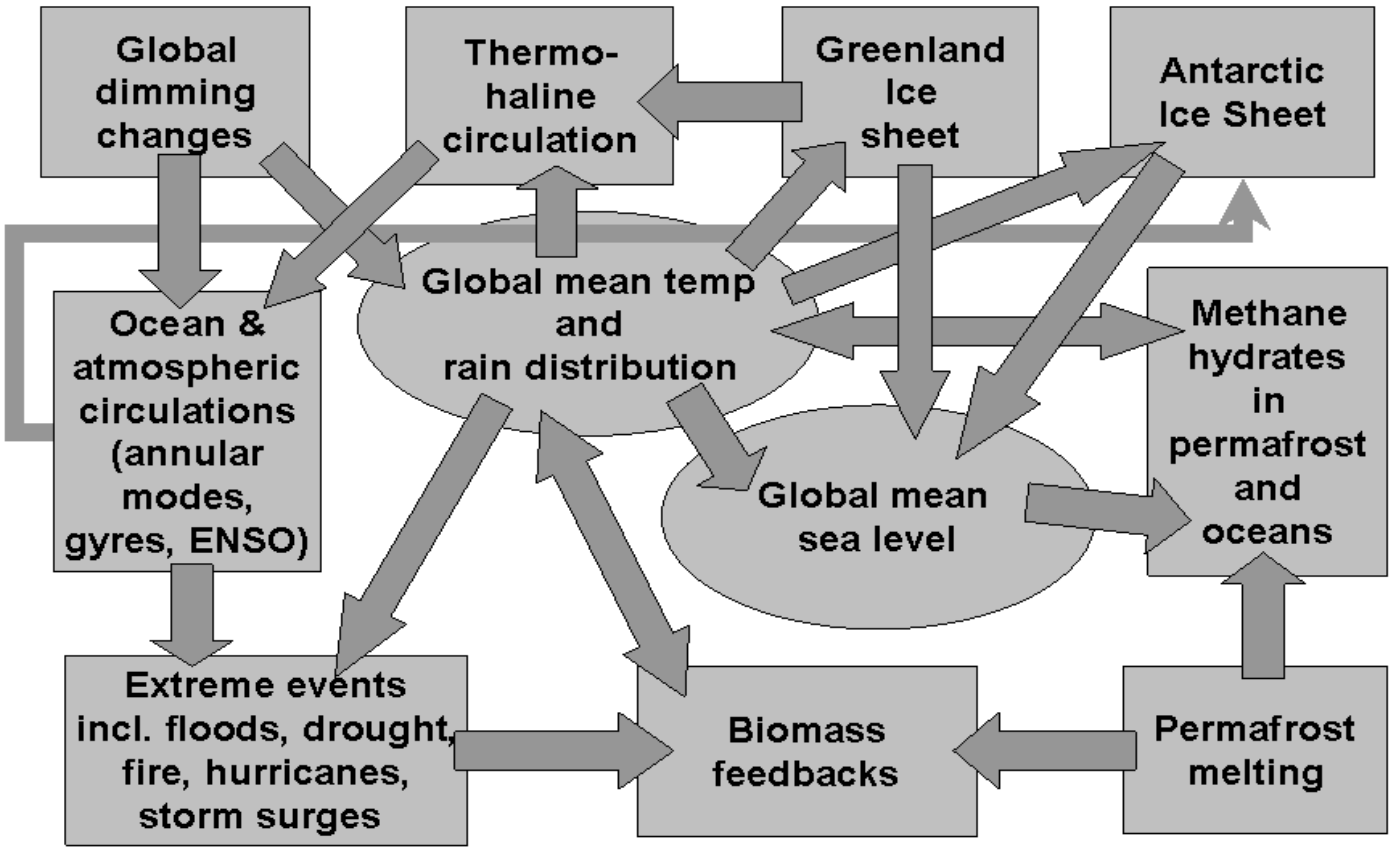
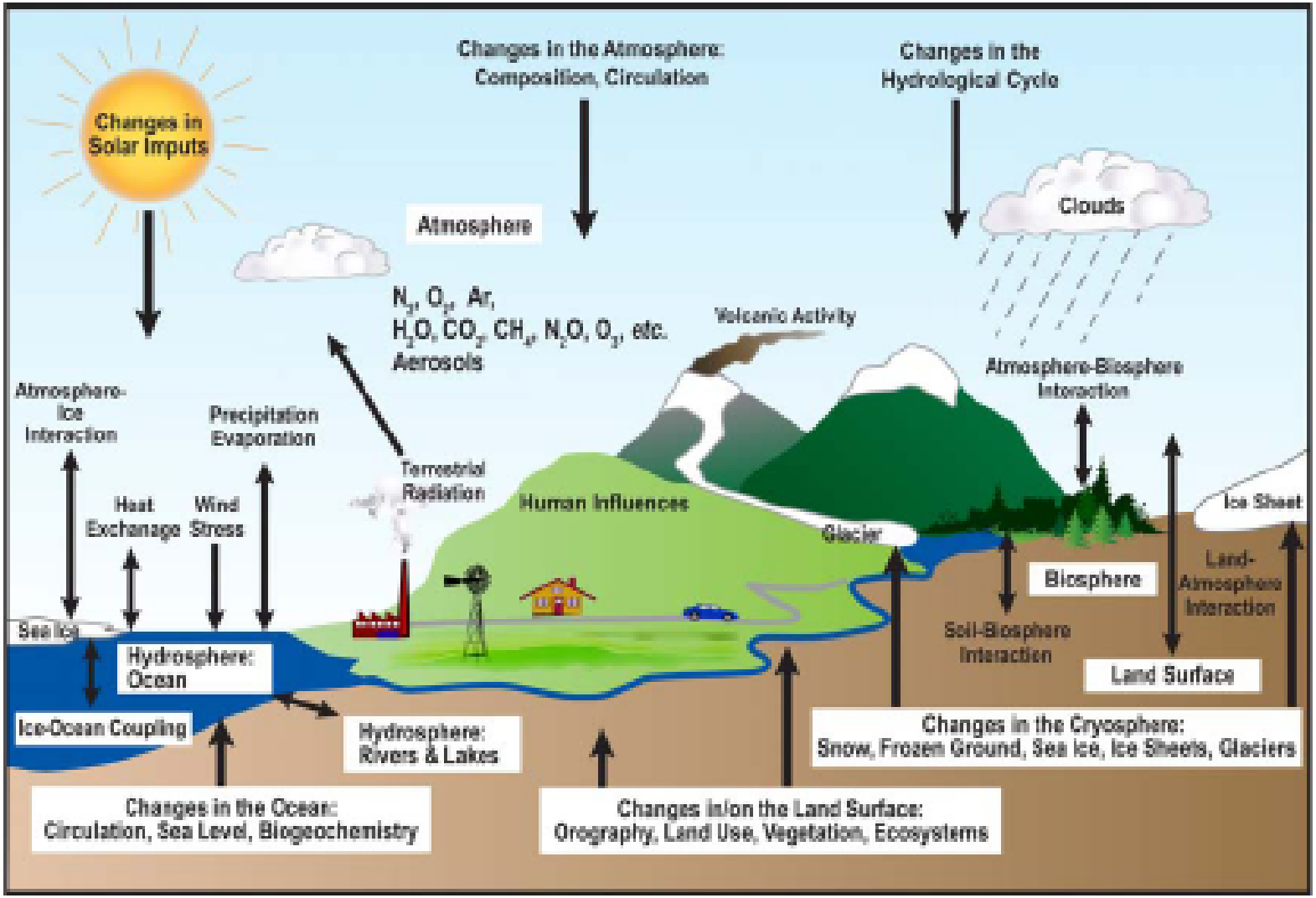


Figure 1.1. Yearly global averaged surface temperature (Brohan et al., 2006), relative to the mean 1961–1990 values, and as projected in the IPCC First Assessment Report or FAR (1990), Second Assessment Report or SAR (1996) and Third Assessment Report or TAR (2001). Best estimated model projections from the FAR and SAR are in solid lines with their range of estimated projections shown by the shaded areas. The TAR did not have best estimated model projections but rather a range of projections. Annual mean observations (Chapter 3, Section 3.2) are depicted by black circles and a smoothed estimate from a 13-point filter (Chapter 3, Appendix 3.A) is shown by the thick black line.

Barrie Pittock's web: "Ten reasons why climate change may be more severe than projected" in **Climate Institute, 2007. *Sudden and Disruptive Climate Change: Its likelihood, Character and Avoidance*, ed. Michael C. MacCracken, John C. Topping and Frances Moore, Earthscan publications, London.**

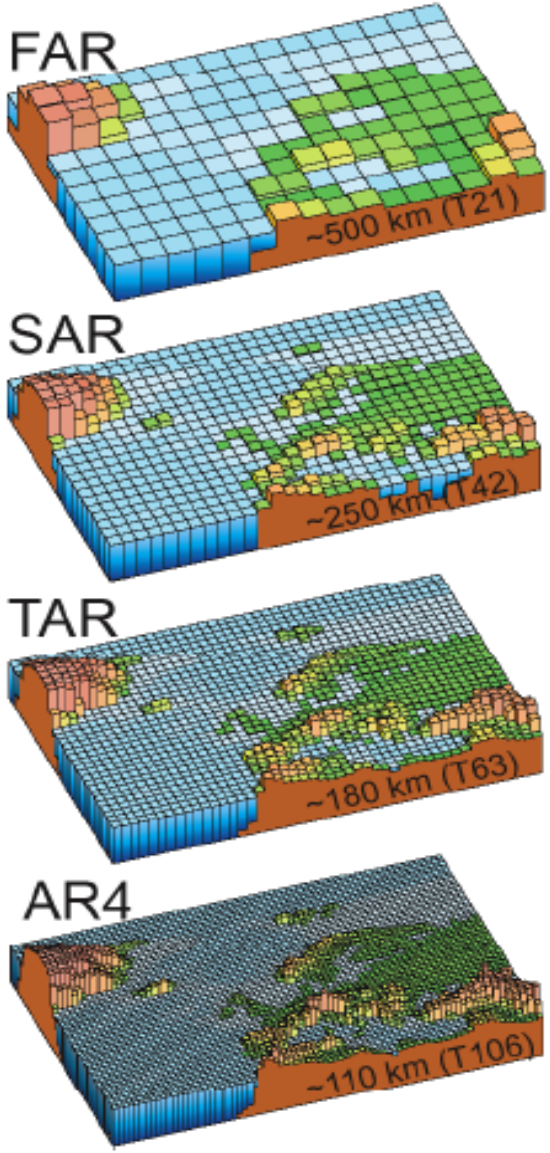


Climate change model components



FAQ 1.2, Figure 1. Schematic view of the components of the climate system, their processes and interactions.

Improvements in resolution



igure 1.4. Geographic resolution characteristic of the generations of climate models used in the IPCC ssessment Reports: FAR (1990), SAR (1996), TAR (2001), and AR4 (2007). The figures above show how uccessive generations of these global models increasingly resolved northern Europe. These illustrations are epresentative of the most detailed horizontal resolution used for short-term climate simulations. The entury-long simulations cited in IPCC Assessment Reports after the FAR were typically run with the revious generation's resolution. Vertical resolution in both atmosphere and ocean models is not shown, but has increased comparably with the horizontal resolution, beginning typically with a single-layer slab ocean nd ten atmospheric layers in the FAR and progressing to about thirty levels in both atmosphere and ocean.

Observations

Progress in observational data

- **In early assessments scientists relied heavily on computer models, backed by some observations, e.g. the ozone layer.**
- **Reconstruction of historical events, e.g. the Vostok ice core, gave us some insights into past climate variations, and their relation to atmospheric greenhouse gases concentration.**
- **In the IPCC Third assessment (TAR), the IPCC Working Group II were able to start with an opening statement saying we now have the evidence of the footprints of anthropogenic Climate Change.**
- **The Fourth Assessment (AR4) starts with voluminous data on observed climatic and ecosystem changes attributable to anthropogenic green house gas impacts from various regions of the earth.**

Time series analysis of Global warming: 1840 to 2000 (IPCC 2007)

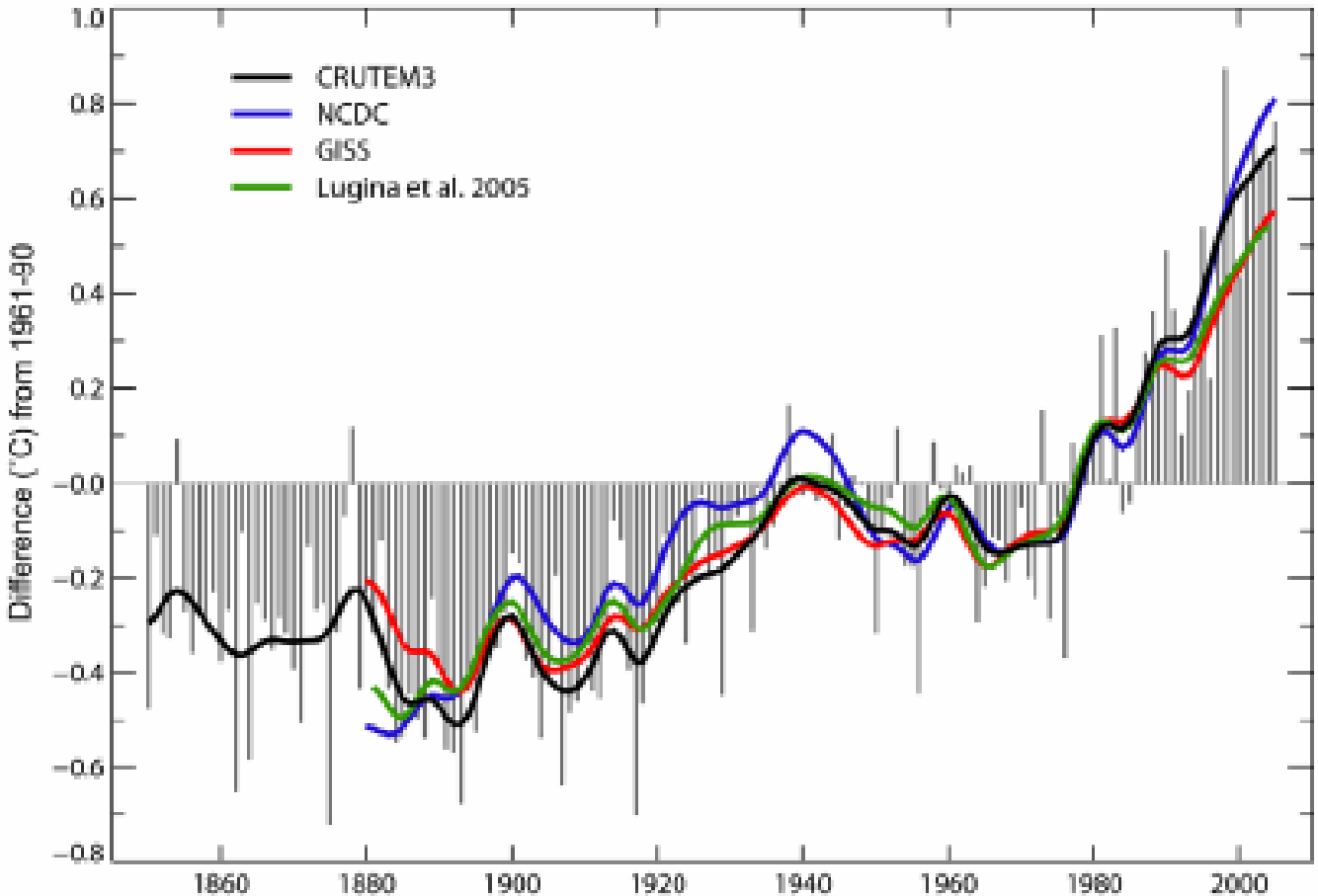


Figure 3.1. Annual anomalies of global land surface air temperature (°C), 1850 to 2005, relative to the 1961–1990 mean for CRUTEM3 updated from Brohan et al. (2006). The smooth curves depict decadal-filtered variations (see Appendix 3.A). The thick solid black curve from CRUTEM3 is compared with those from NCDC (Smith and Reynolds, 2005) (blue) and GISS (Hansen et al., 2001) (red) and Lugina et al. (2005) (green).

Trends in mean maxima, mean minima and daily temperature range

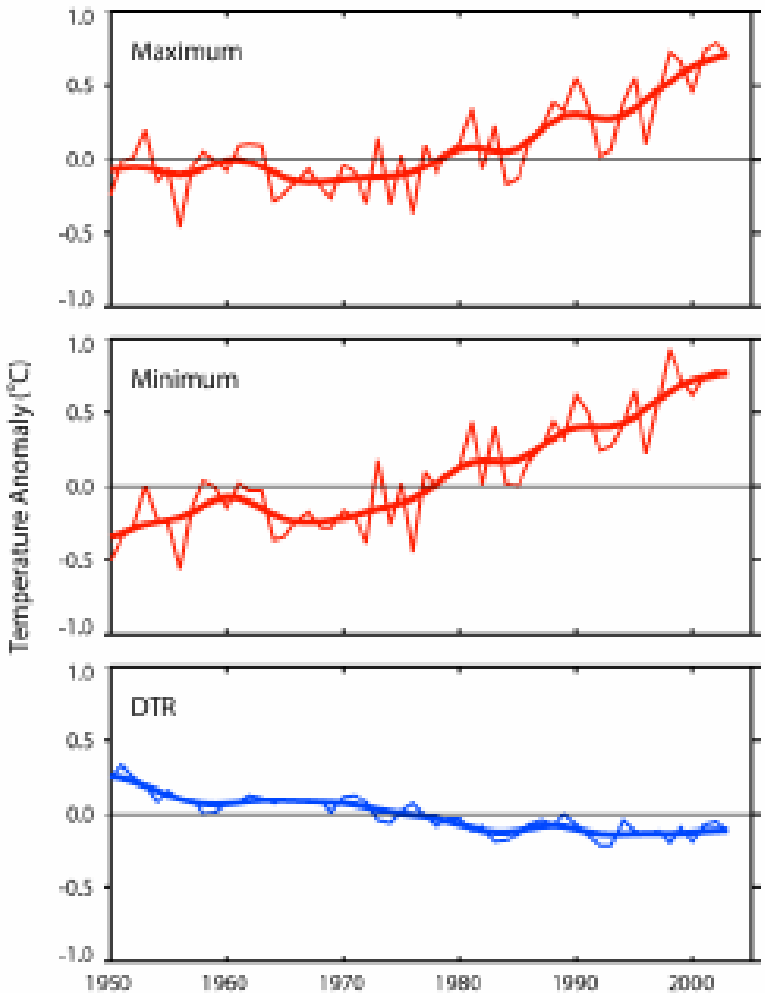
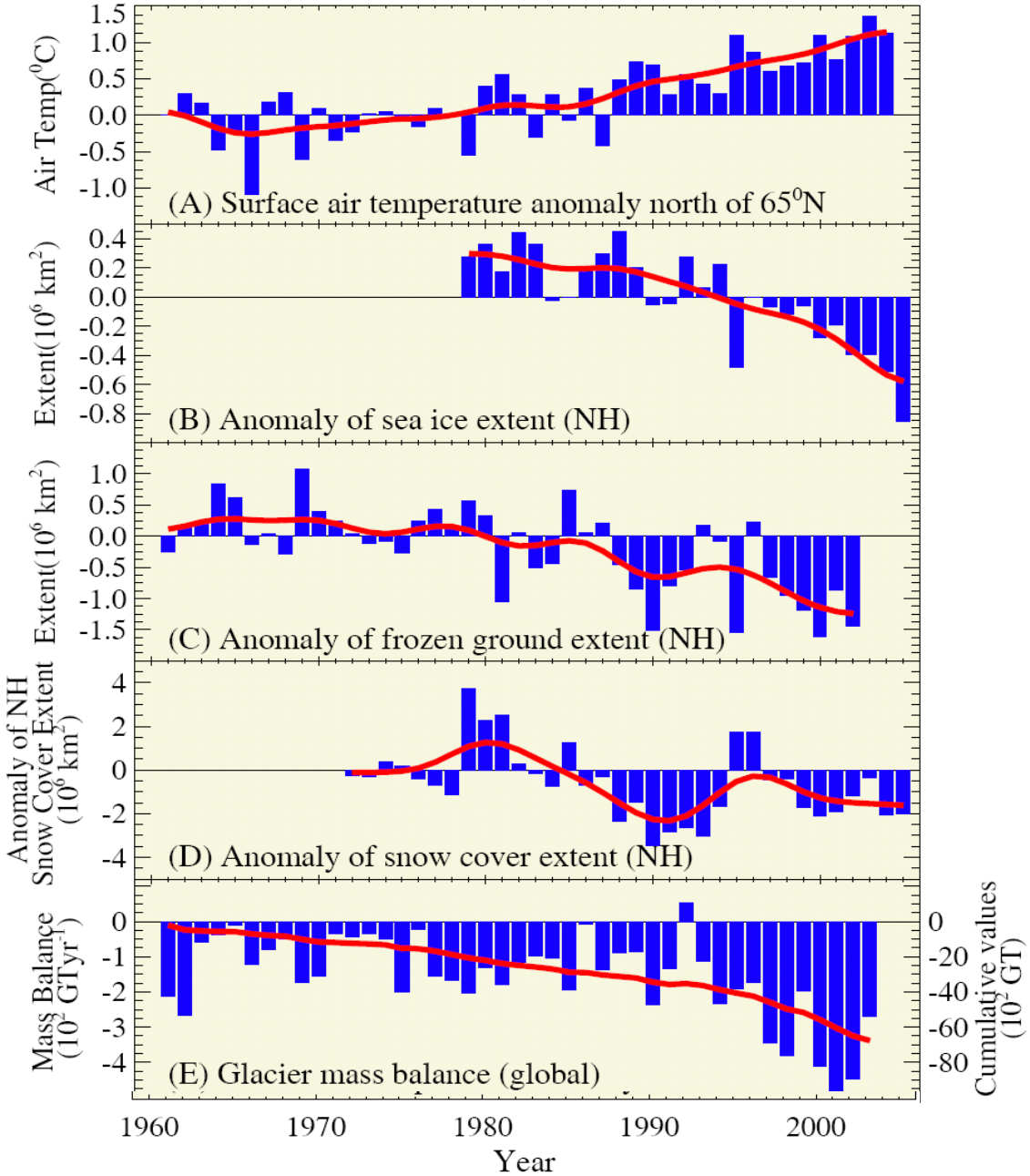
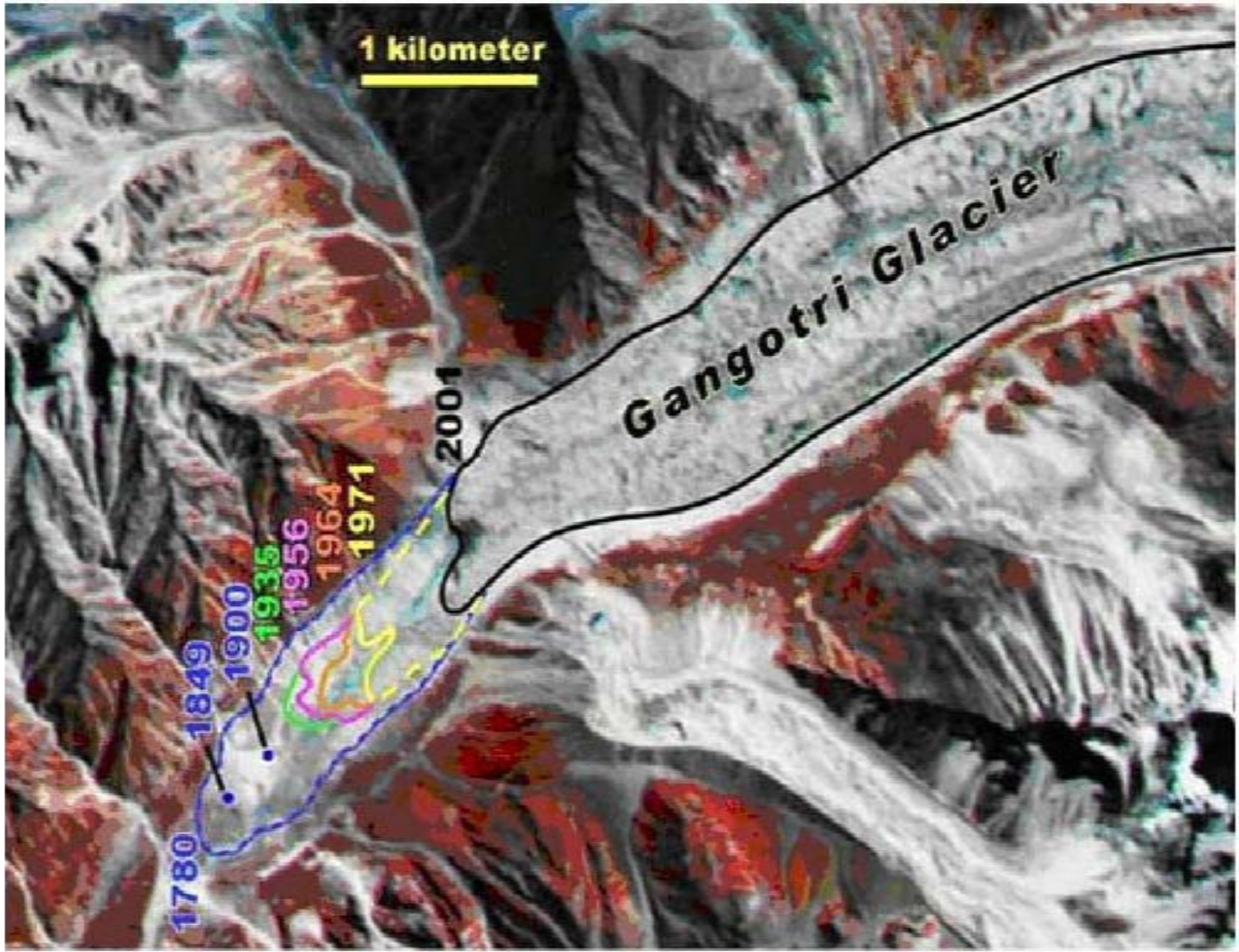


Figure 3.2. Annual anomalies relative to the 1961 to 1990 mean of maximum and minimum temperatures and diurnal temperature range (DTR) (°C) averaged for the 71% of global land areas where data are available for 1950 to 2004. The smoothed curve shows the decadal variability (Appendix 3.A). Adapted fr Vose et al. (2005a).

Impacts on cryosphere



Glacier retreat



Regional trends in surface air temperature

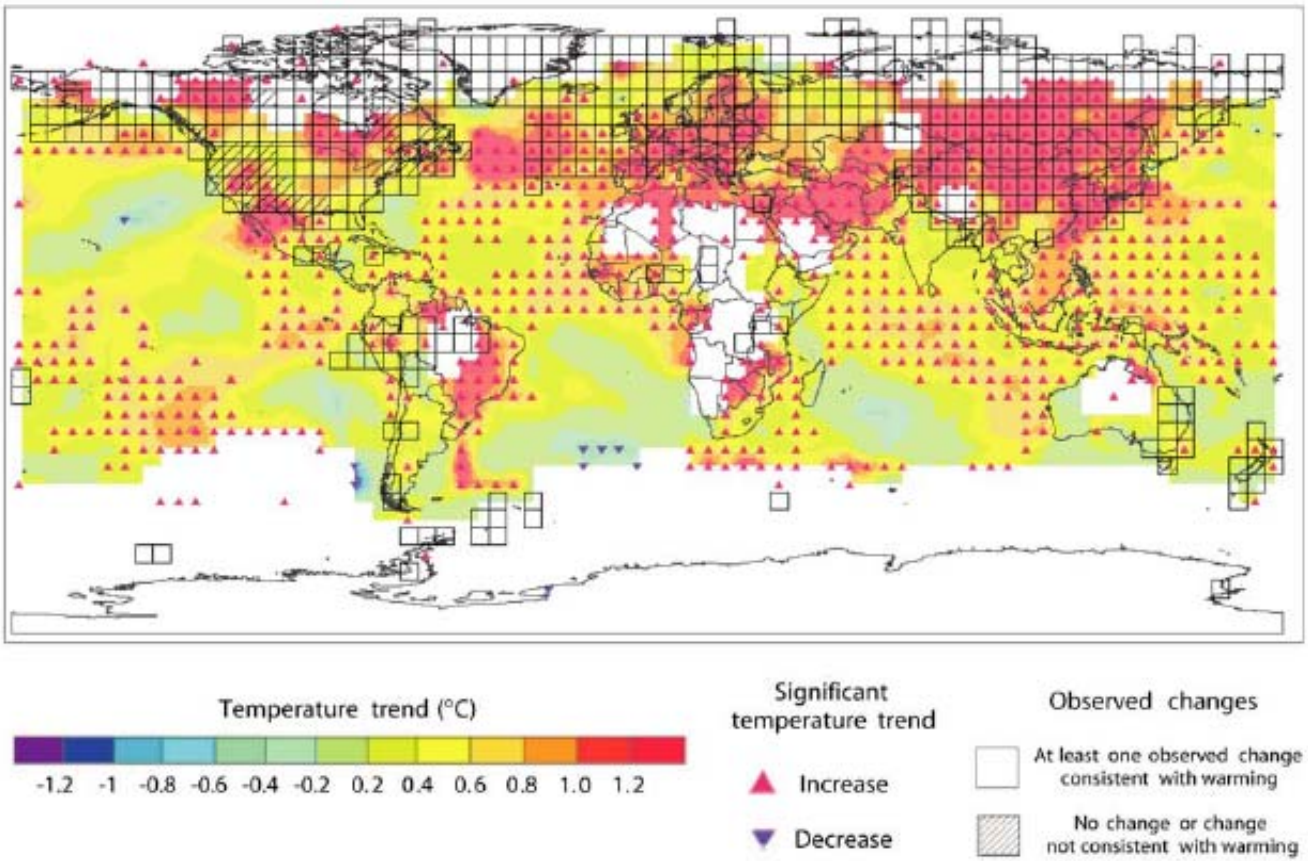


Fig. SPM-1: Observed regional trends in surface air temperature over the period 1973-2002 and observed changes in cryosphere, hydrology, coastal zones, marine, freshwater and terrestrial biological systems with at least 20 years of data in the period. This shows clearly that in most locations where data exist, the change in systems and sectors is consistent with the regional temperature trend. Temperature trends are averaged over 5° by 5° gridboxes; statistically significant temperature changes are marked with triangles. [F1.9]

Precipitation trends

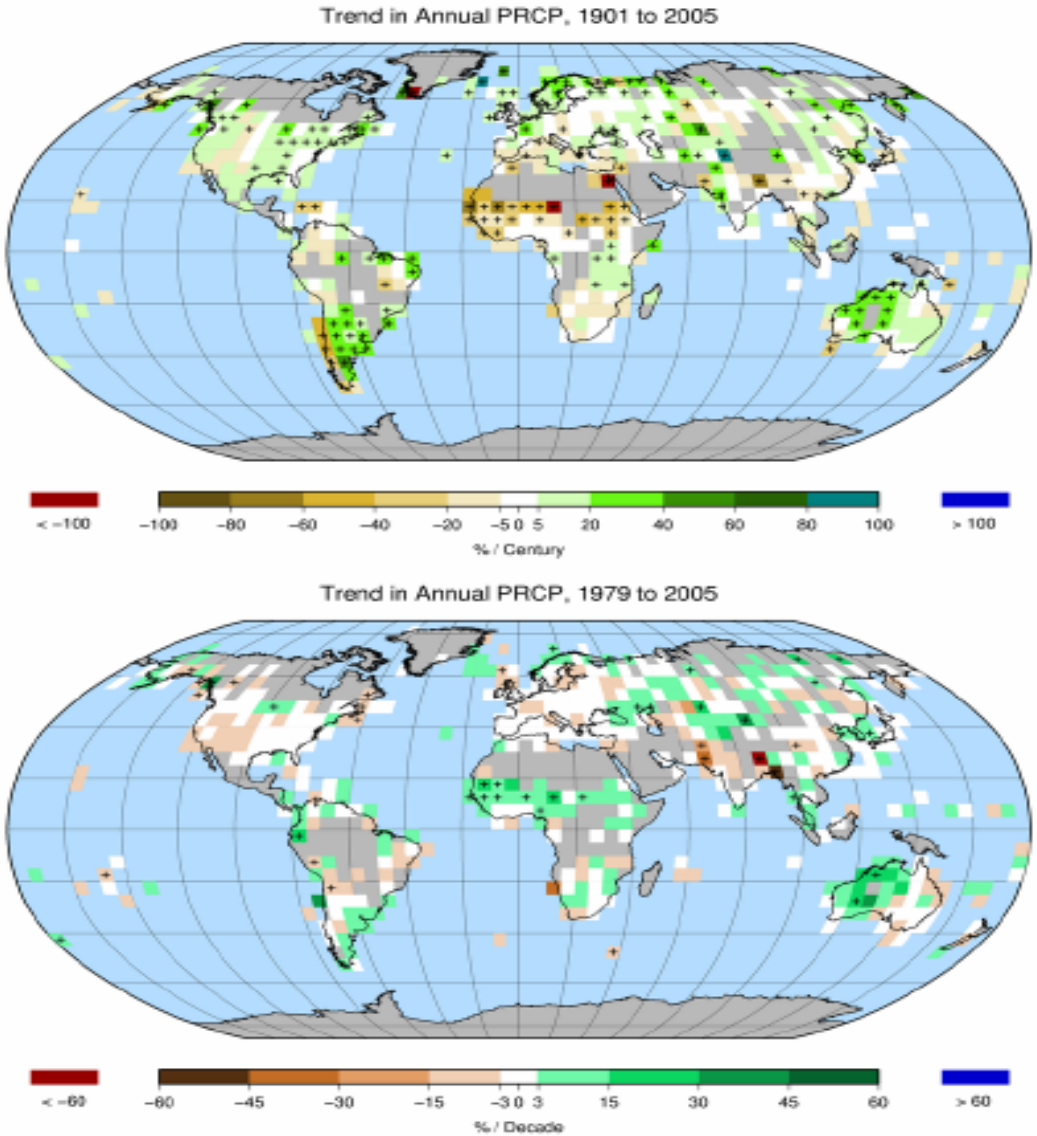


Figure 3.13. Trend of annual precipitation amounts for 1901 to 2005 (upper, % century^{-1}) and 1979 to 2005 (lower, % decade^{-1}) the percentage being based on the 1961 to 1990 period. Areas in grey have insufficient data to produce reliable trends. The minimum number of years to calculate a trend value is 66 for 1901 to 2005 and 18 for 1979 to 2005. An annual value is complete for a given year if all twelve monthly percentage anomaly values are present. The GHCN precipitation dataset from NCDC was used. Note the different colour bars and units in each plot. Trends significant at the 5% level are indicated by black + marks.

Annual Average global sea level

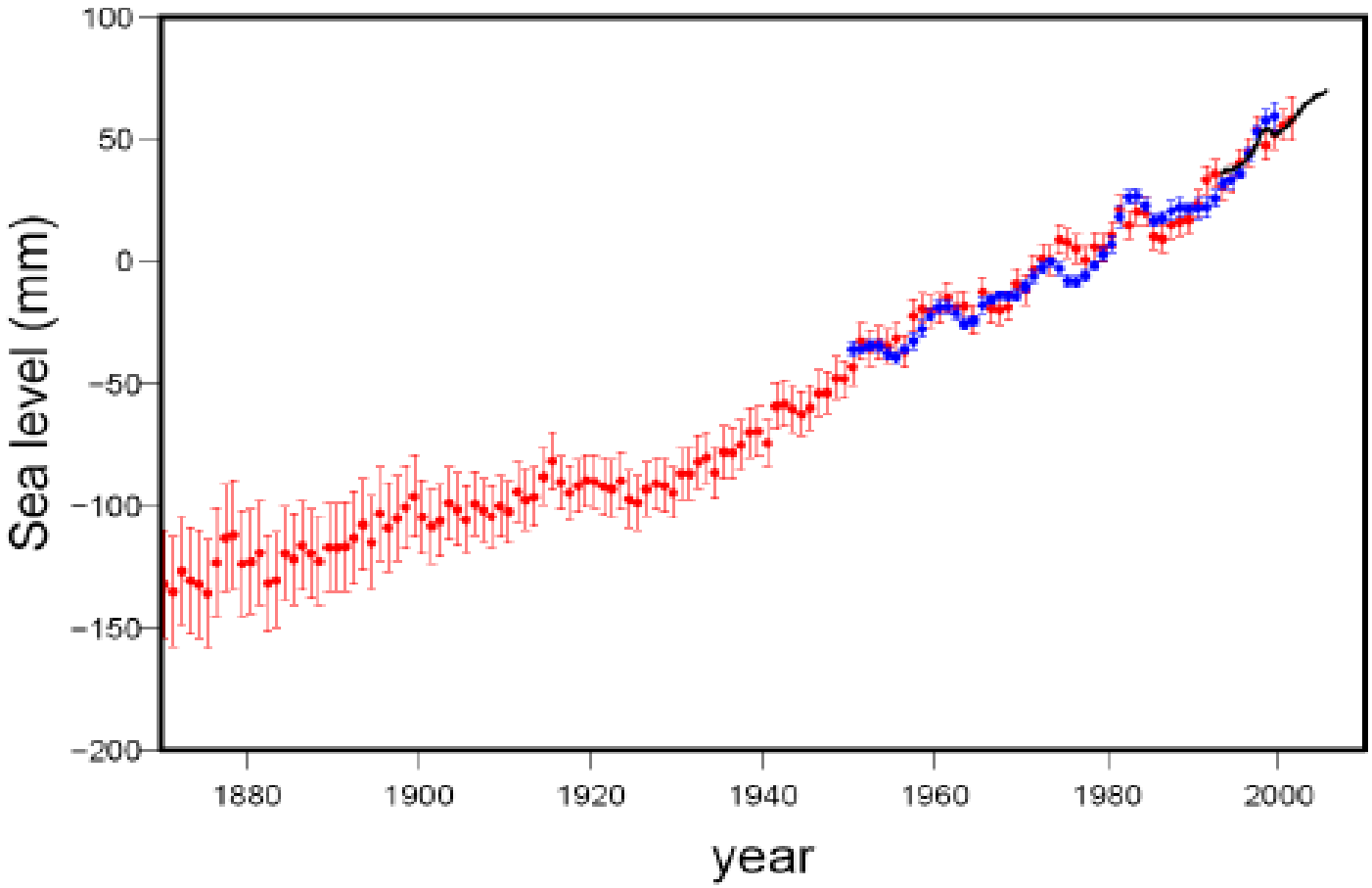


Figure 5.13. Annual averages of the global mean sea level. Red curve: Reconstructed sea level fields since 1870 (updated from Church and White, 2006). Blue curve: Coastal tide gauges measurements since 1950 (from Holgate and Woodworth, 2004). Black curve: Based on satellite altimetry (Leuliette et al., 2004). Units are in mm. The red and blue curves are deviation from their average 1961–1990, and the shorter black curve is the deviation from the average of the red curve for the period 1993–2001. Error bars are 90% confidence intervals.

Recent satellite global mean sea level measurements

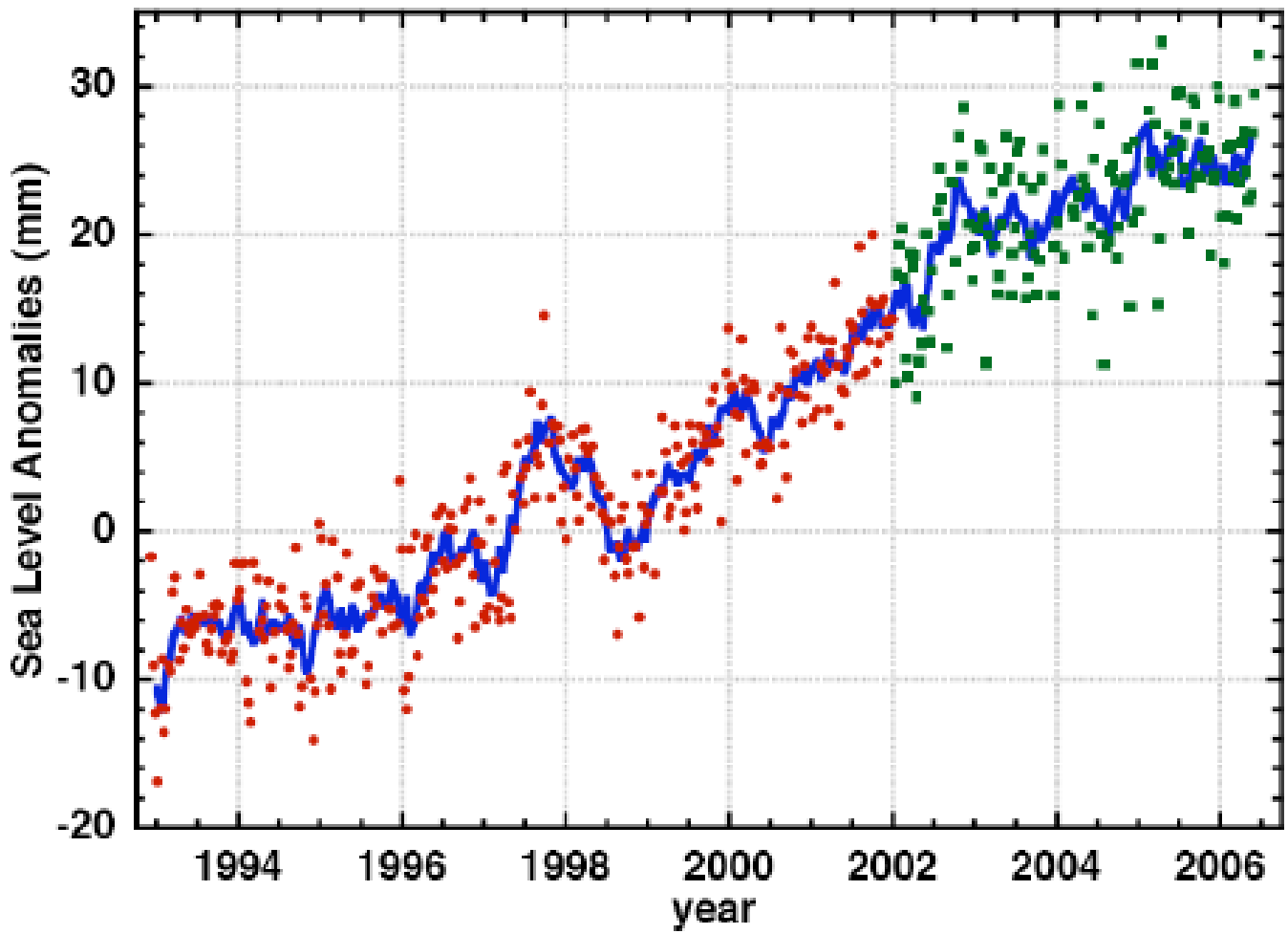


Figure 5.14. Variations in global mean sea level computed from satellite altimetry from January 1993 to October 2005, averaged over 65°S–65°N. Dots are 10-day estimates (from Topex/Poseidon satellite in red and Jason in green). The blue solid curve corresponds to 60-day smoothing. Updated from Cazenave and Nerem (2004) and Leuliette et al. (2004).

Oceanic concentration of anthropogenic carbon

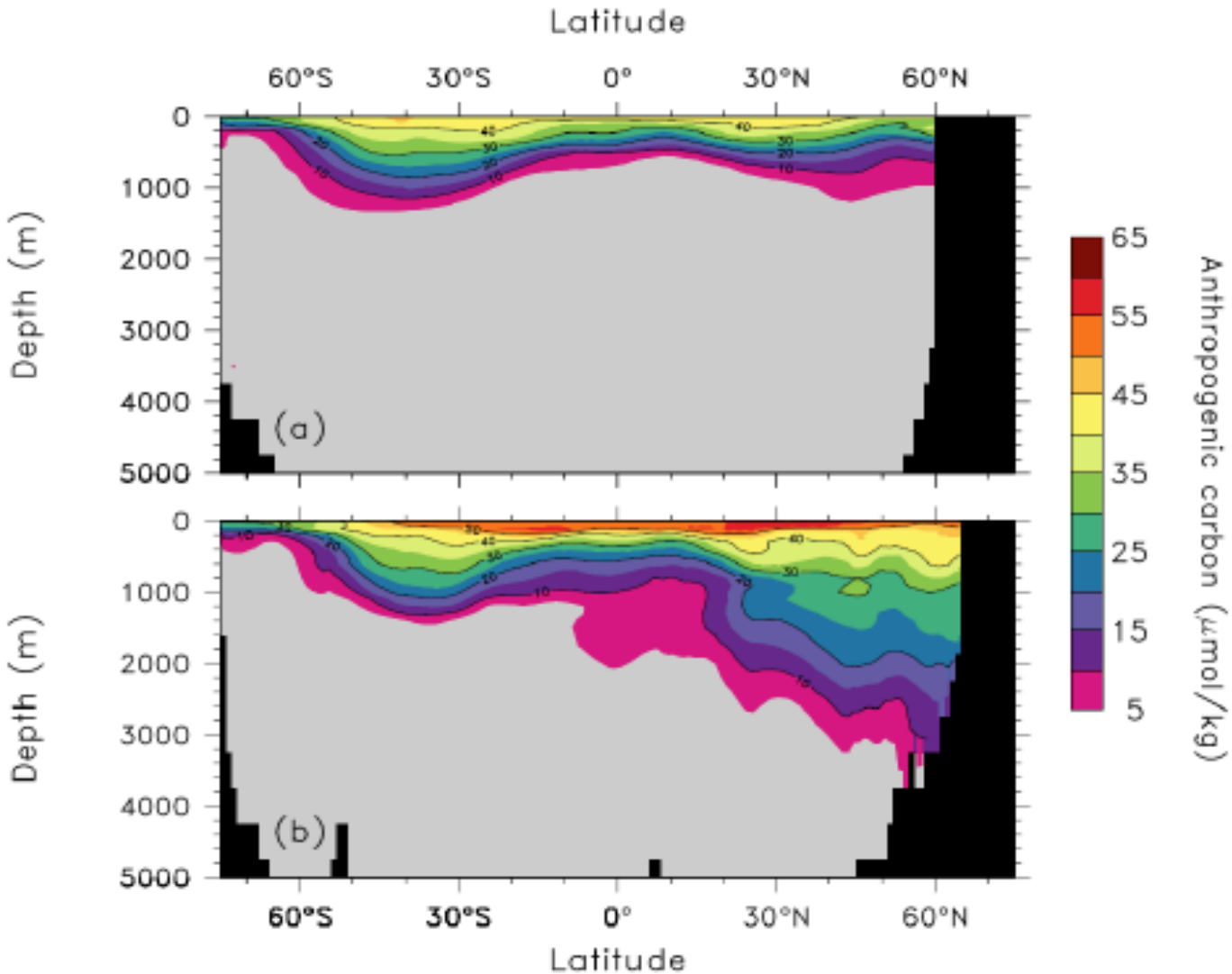


Figure 5.11. Mean concentration of anthropogenic carbon as of year 1994 in μmol/kg from (Sabine et al., 2004a) averaged over the Pacific and Indian Oceans (a) and the Atlantic Ocean (b). The calculation of anthropogenic carbon is described in the caption of Figure 5.10 and in the text (Section 5.4).

Oceanic pH trends

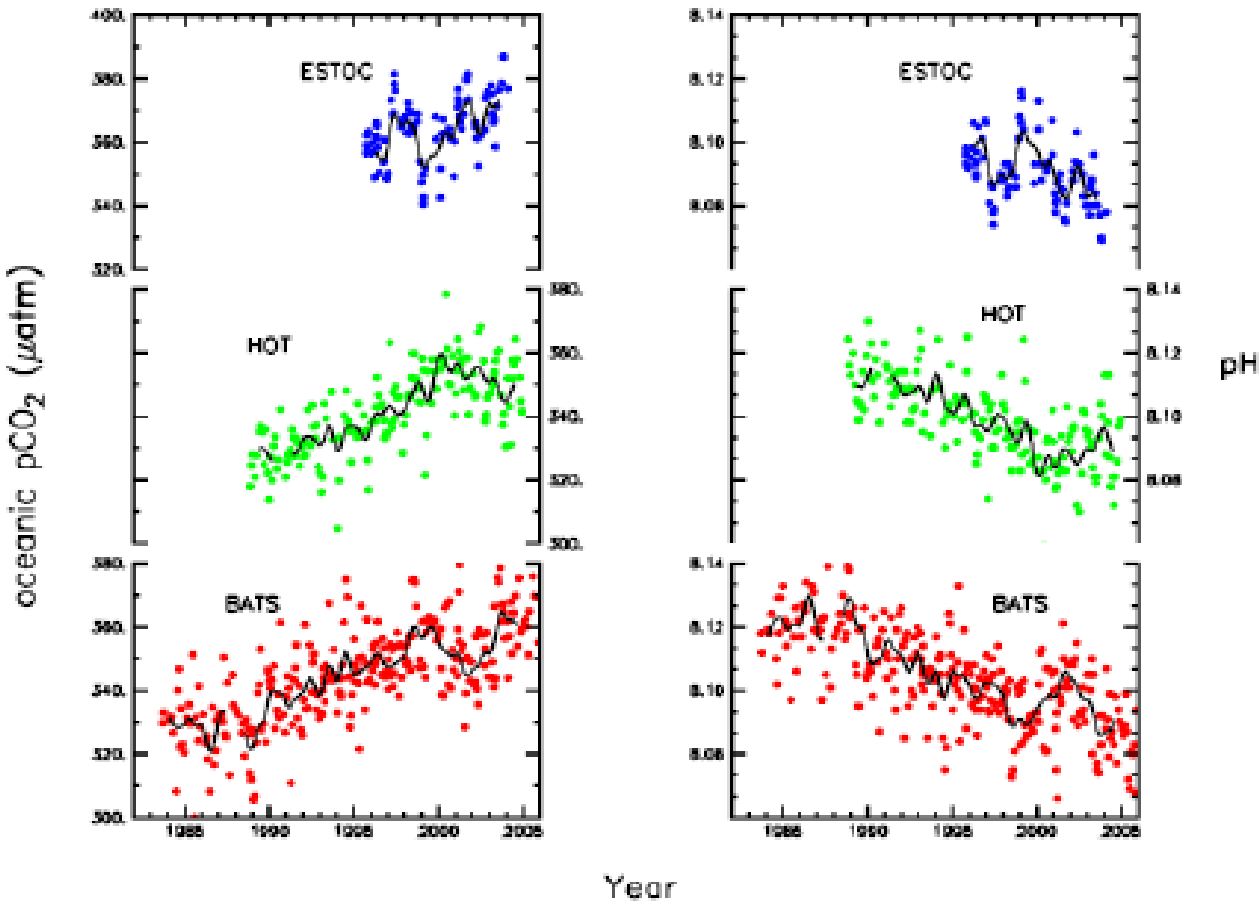
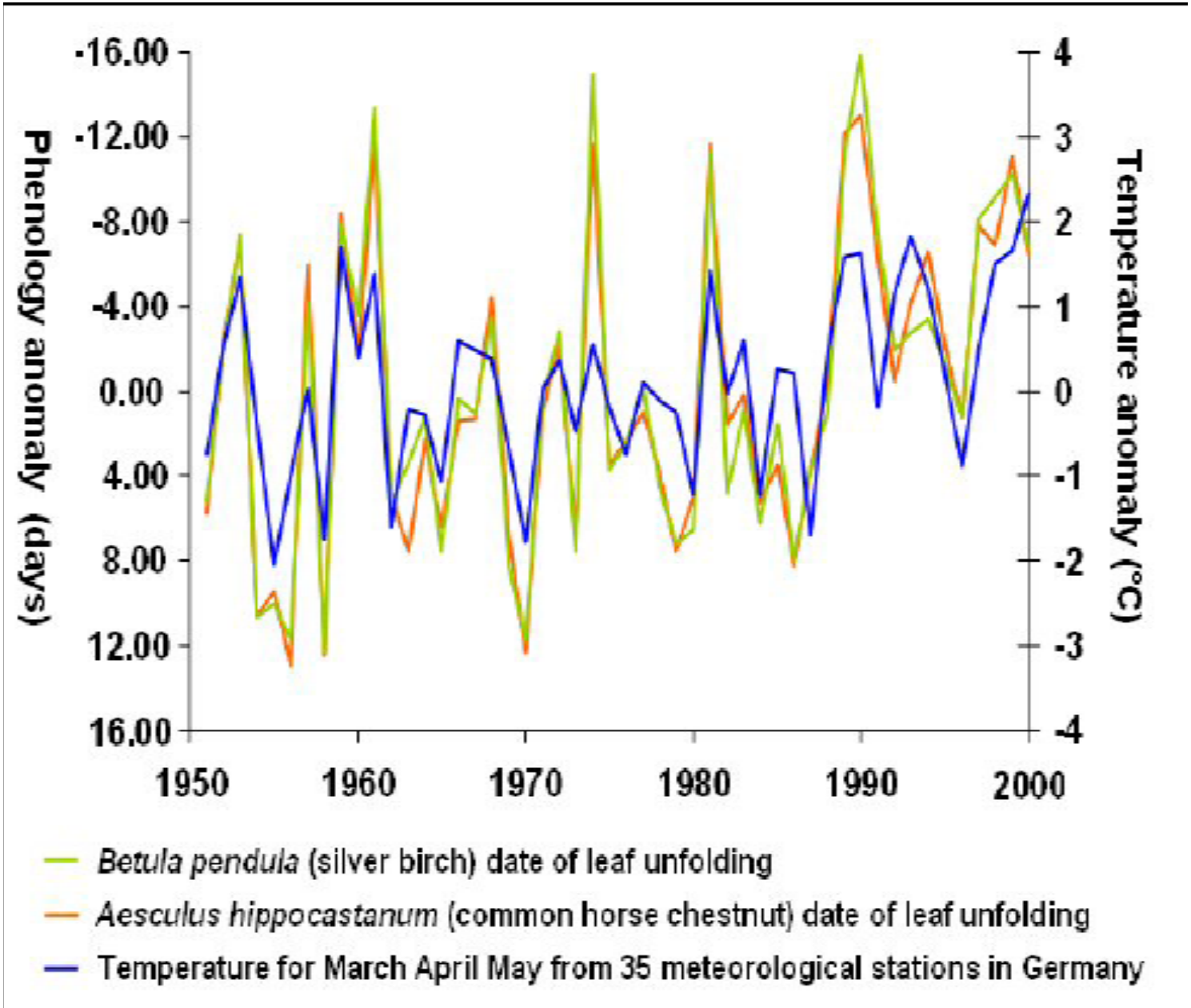
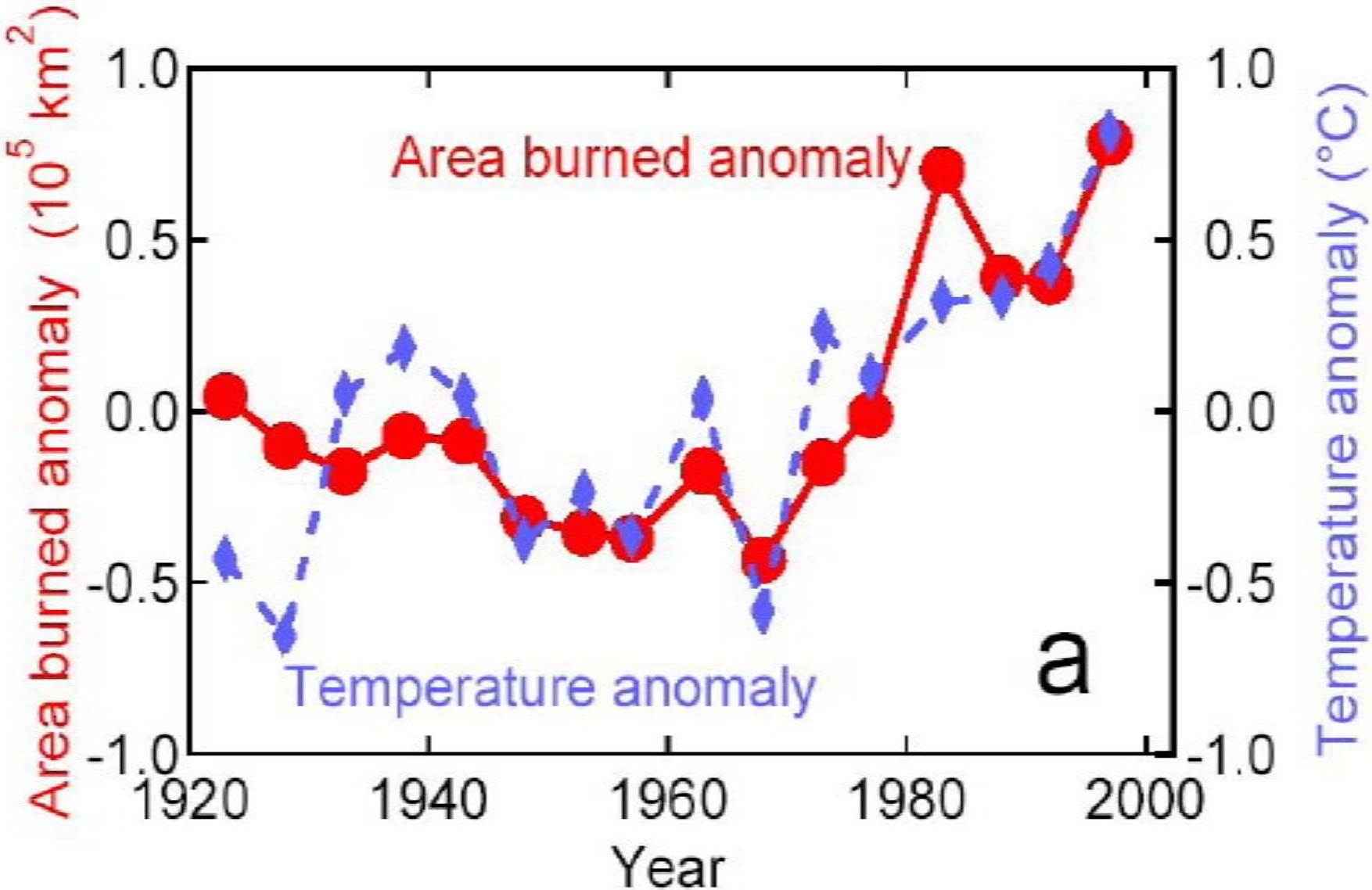


Figure 5.9. Changes in surface oceanic pCO_2 (left; in µatm) and pH (right) from three time-series statio
Blue: ESTOC (29°N, 15°W; Gonzalez-Dávila et al., 2003). Green: HOT (23°N, 158°W; Dore et al., 200
Red; BATS (31/32°N, 64°W; Bates et al., 2002; Gruber et al., 2002). pCO_2 and pH were calculated fron
Dissolved Inorganic Carbon and alkalinity at HOT and BATS. pH was directly measured at ESTOC and
pCO_2 was calculated from pH and alkalinity. The mean seasonal cycle was removed from all data. The t
black line filters variability less than 0.5 years.

Phenology


-16.00
-12.00
-8.00
-4.00
0.00
4.00
8.00
12.00
16.00
Phenology anomaly (days)
4
3
2
1
0
-1
-2
-3
-4
Temperature anomaly (°C)
1950
1960
1970
1980
1990
2000
Betula pendula (silver birch) date of leaf unfolding
Aesculus hippocastanum (common horse chestnut) date of leaf unfolding
Temperature for March April May from 35 meteorological stations in Germany

Burned area


Area burned anomaly (10^5 km^2)
Temperature anomaly (°C)
Area burned anomaly
Temperature anomaly
a
1.0
0.5
0.0
-0.5
-1.0
1920
1940
1960
1980
2000
Year

Future projections

Probable temperature rise for 2020-2029 & 2090-2099 for different emission scenarios

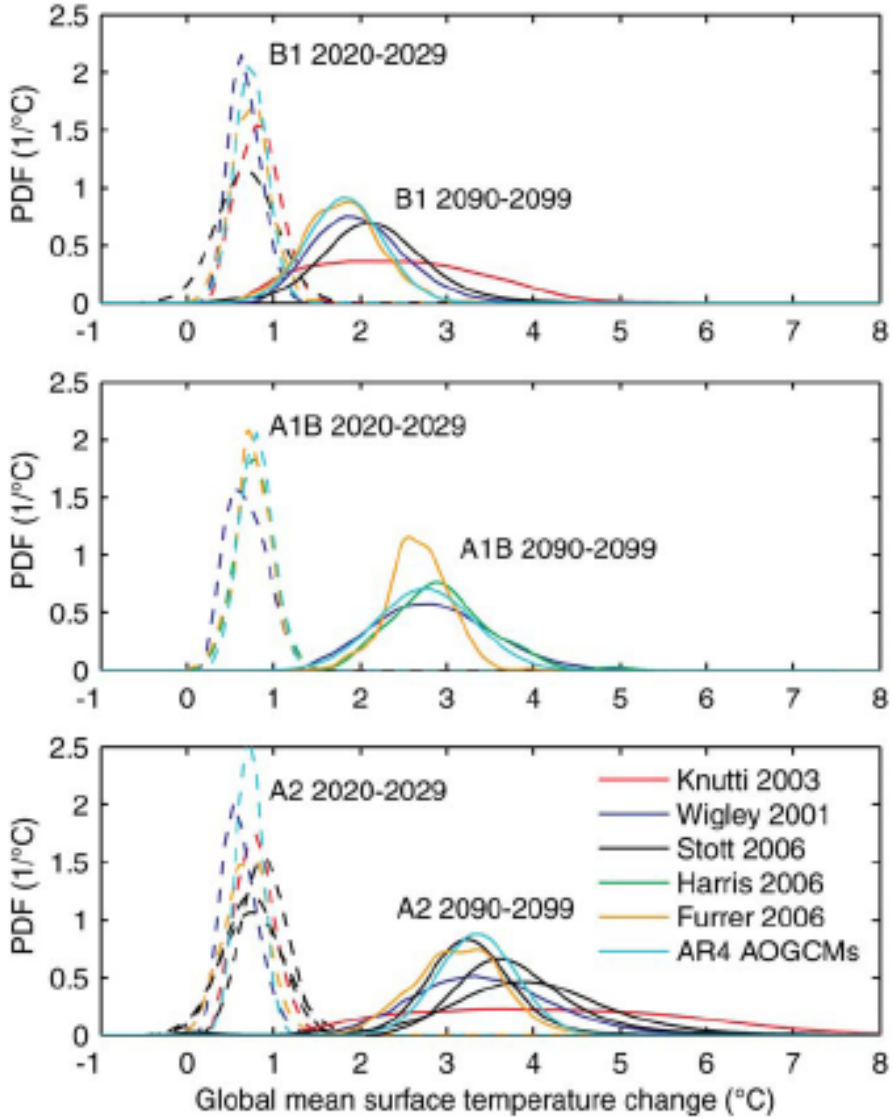


Figure 10.28. Probability density functions from different studies for global mean temperature change for the SRES scenarios B1, A1B and A2 and for the decades 2020–2029 and 2090–2099 relative to the 1980–1999 average (Wigley and Raper, 2001; Knutti et al., 2002; Furrer et al., 2006; Harris et al., 2006; Stott et al., 2006b). A normal distribution fitted to the multi-model ensemble is given for comparison.

Projected average temperature change °C for two periods and three scenarios

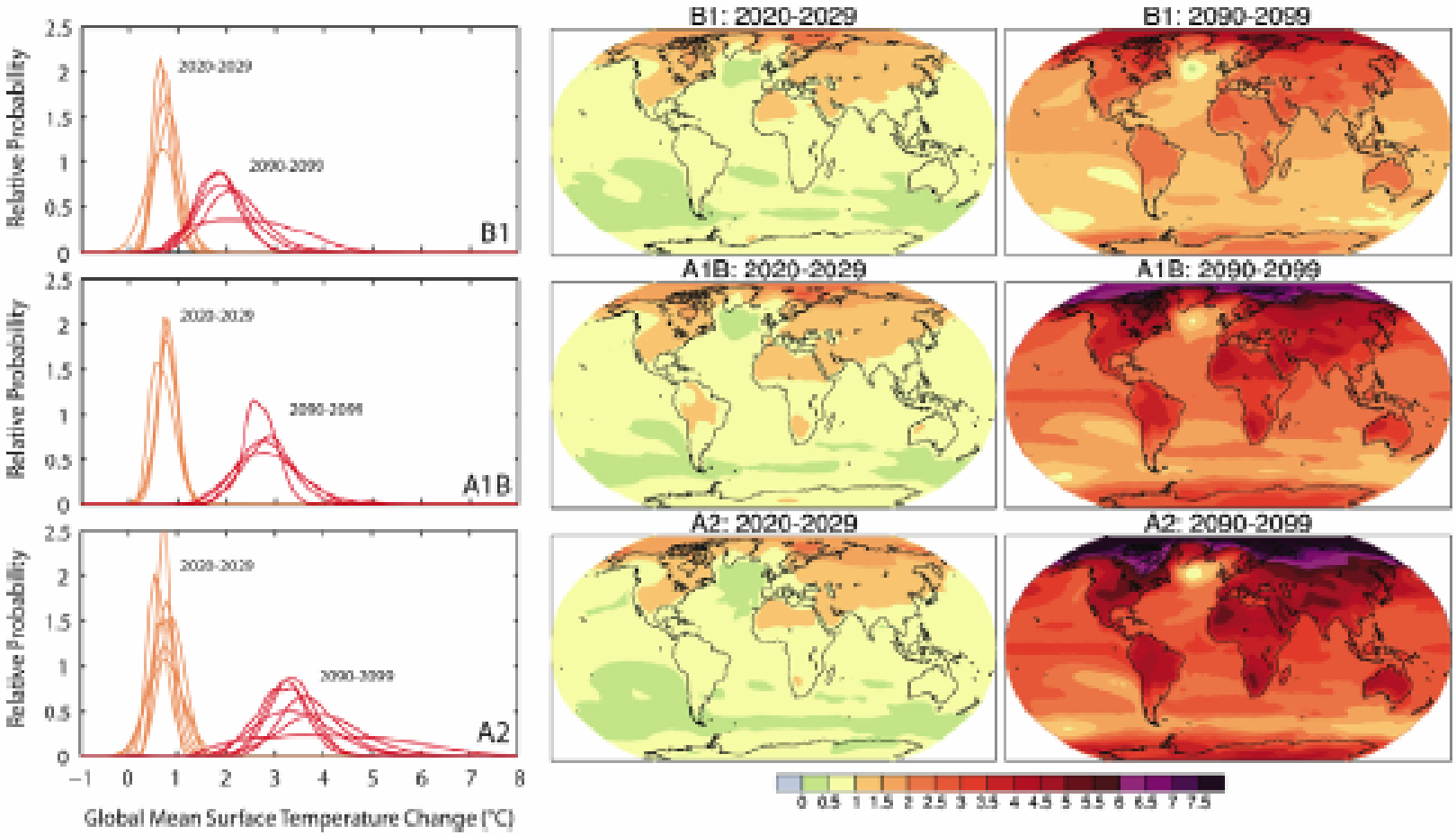


Figure TS-28. Projected global average temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over decades 2020–2029 (centre) and 2090–2099 (right). The left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different studies for the same periods. {Figures 10.8 and 10.28}

Zimbabwe Seasonal decadal warming (1960-2000); ^{o}C

	Station	Max DJF	Min DJF	MaxMAM	MinMAM	Max JJA	Min JJA	Max SON	Min SON	Mean
1	Btb	**0.56**	**0.31**	**0.9**	0.27	**0.38**	**0.3**	**0.47**	**0.34**	**0.44**
2	Buf	0.17	**0.68**	**0.58**	**-0.08**	**0.66**	**0.599**	**0.52**	**0.49**	**0.45**
3	Bul	**0.47**	0.22	**0.54**	0.29	0.27	0.21	0.28	0.22	**0.31**
4	Chm	**0.32**	-0.09	**0.62**	-0.06	**0.39**	-0.3	**0.37**	-0.27	0.12
5	Chn	**0.48**	**0.68**	**0.49**	-0.08	0.18	-0.08	**0.52**	1.5	**0.46**
6	Chp	**0.37**	-0.06	**0.7**	-0.04	**0.41**	-0.1	0.27	-0.15	0.18
7	Chv	**0.38**	0.18	**0.59**	0.2	**0.47**	**0.35**	**0.37**	**0.31**	**0.36**
8	Gwe	**0.4**	0.1	**0.51**	0.2	**0.37**	**0.47**	**0.34**	0.26	**0.33**
9	Har	0.22	0.09	**0.6**	0.09	**0.31**	**0.49**	0.26	0.26	0.29
10	Hwa	**0.64**	0.29	**0.7**	0.13	**0.34**	**0.31**	**0.35**	**0.31**	**0.38**
11	Kad	**0.25**	0.12	**0.42**	0.12	**0.31**	0.05	0.17	0.18	0.20
12	Kar	**0.74**	**0.34**	**0.65**	**0.5**	**0.46**	**0.42**	**0.53**	**0.44**	**0.51**
13	Kwe	**0.55**	0.24	**0.53**	0.2	0.27	**0.3**	**0.34**	**0.36**	**0.35**
14	Mar	**0.32**	0.1	**0.52**	0.1	**0.35**	0.29	0.27	0.2	0.27
15	Mas	**0.42**	-0.05	**0.83**	-0.21	**0.46**	0.07	**0.32**	0.13	0.25
16	Mut	**0.46**	-0.31	**0.51**	-0.13	**0.52**	**-0.06**	**0.38**	**-0.15**	0.15
17	Nya	**0.41**	0.12	**0.63**	0.18	**0.5**	0.14	**0.33**	0.08	**0.30**
18	Rus	0.23	0.1	**0.4**	0.16	0.24	**0.41**	**0.31**	0.18	0.25
	Mean	**0.41**	0.17	**0.60**	0.10	**0.38**	0.21	**0.36**	0.26	**0.31**

Comparison of present (observed) and 2090 (mulitimodel) seasonal precipitation

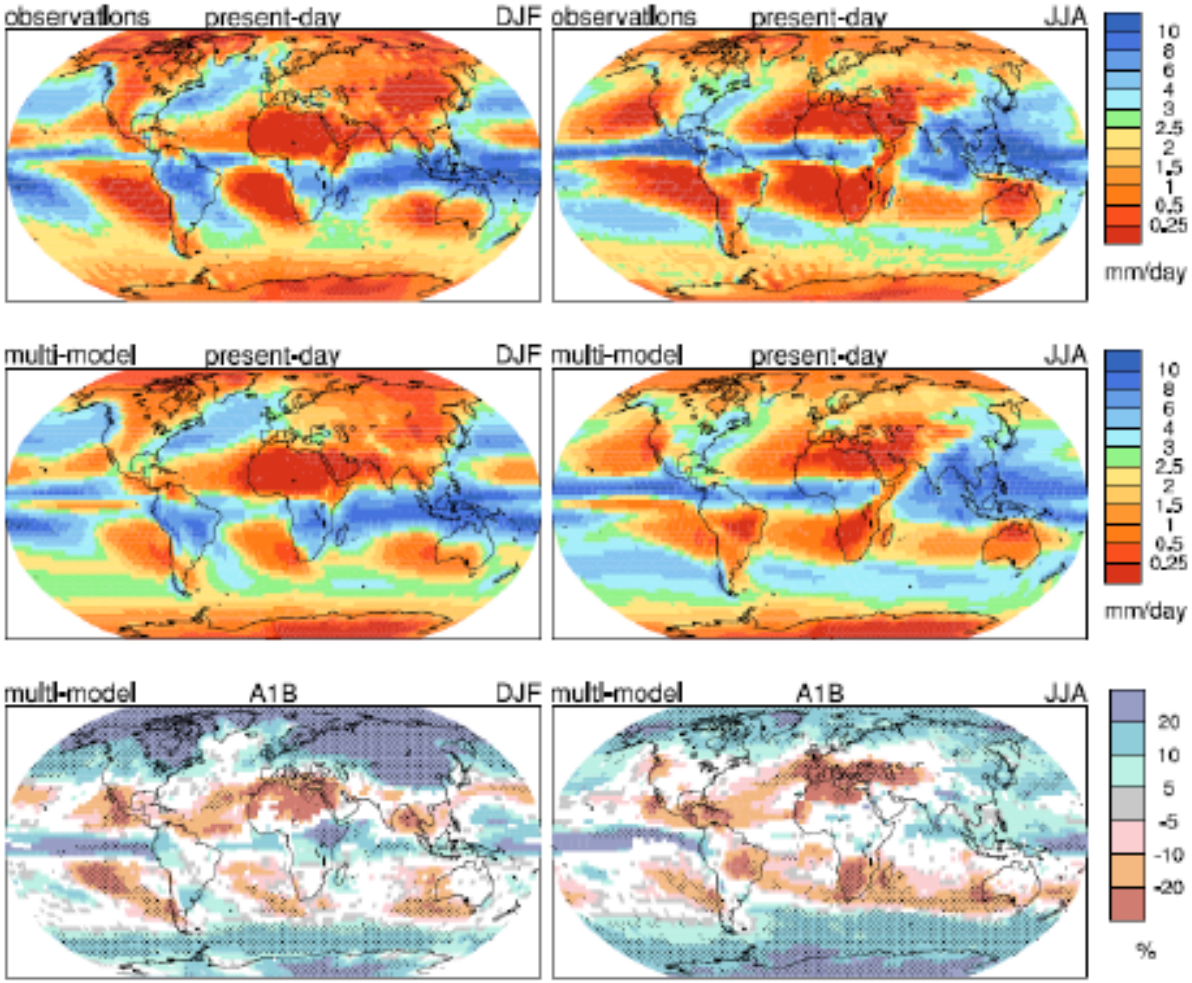


Figure TS-30. Spatial patterns of observed (top row) and multi-model mean (middle row) seasonal mean precipitation rate for the period 1979–1993 and the multi-model mean for changes by the period 2090–209 relative to 1980–1999 based on the SRES A1B scenario (bottom row). December to February means are in the left column, June to August means in the right column. Units are mm per day (top two rows) or percent change (bottom row). In the bottom panel changes are plotted only where more than 66% of the models agree in the sign of the change. The stippling indicates areas where more than 90% of the models agree in the sign of the change. {Figure 10.9}

Observed regional water availability stresses

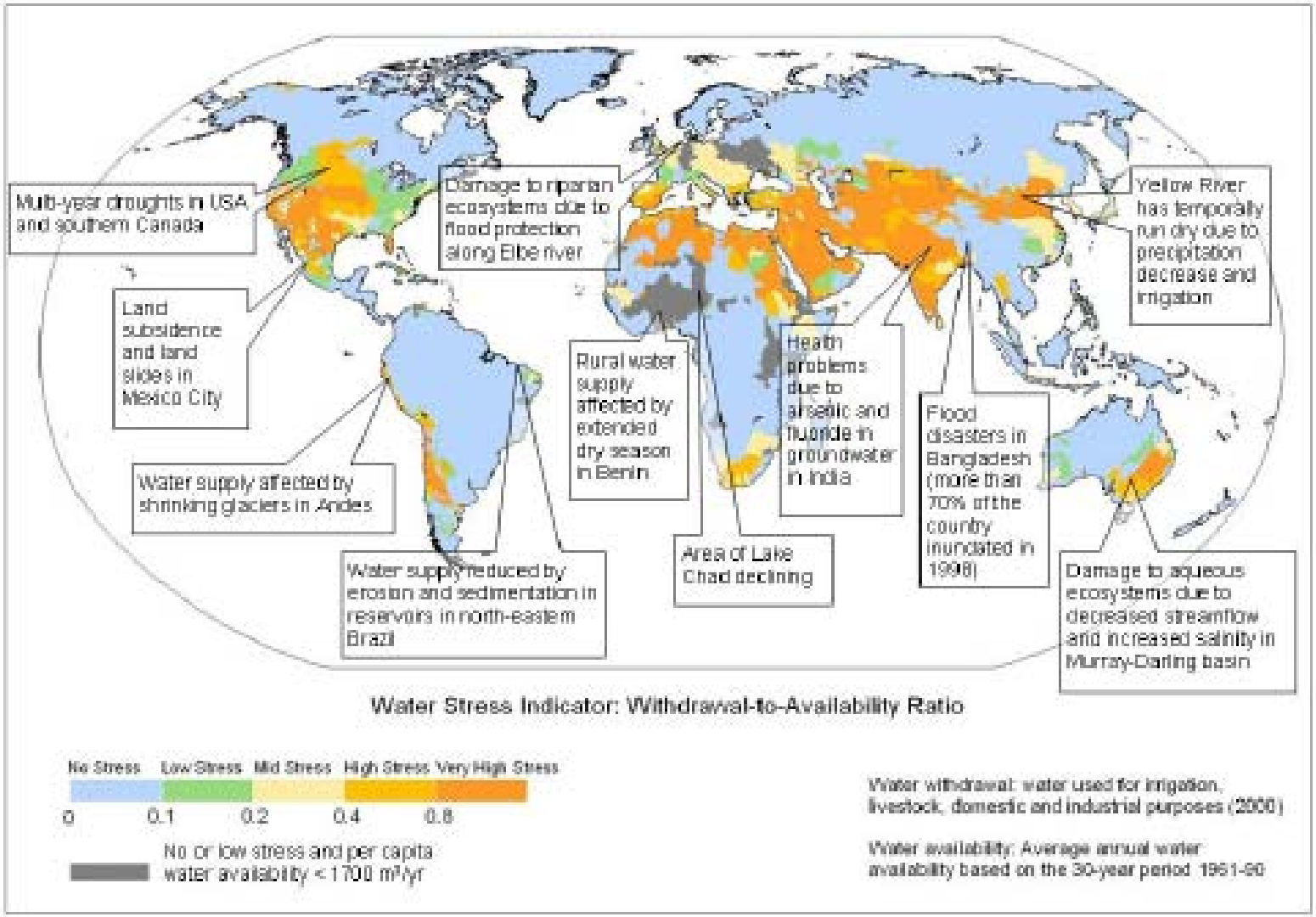


Figure 3.2: Examples of current vulnerabilities of freshwater resources and their management; in the background, a water stress map based on the 2005 version of WaterGAP (Alcamo et al., 2003a). See text for relation to climate change.

Some impacts

Future climate change impacts on freshwater: mean % change in annual runoff

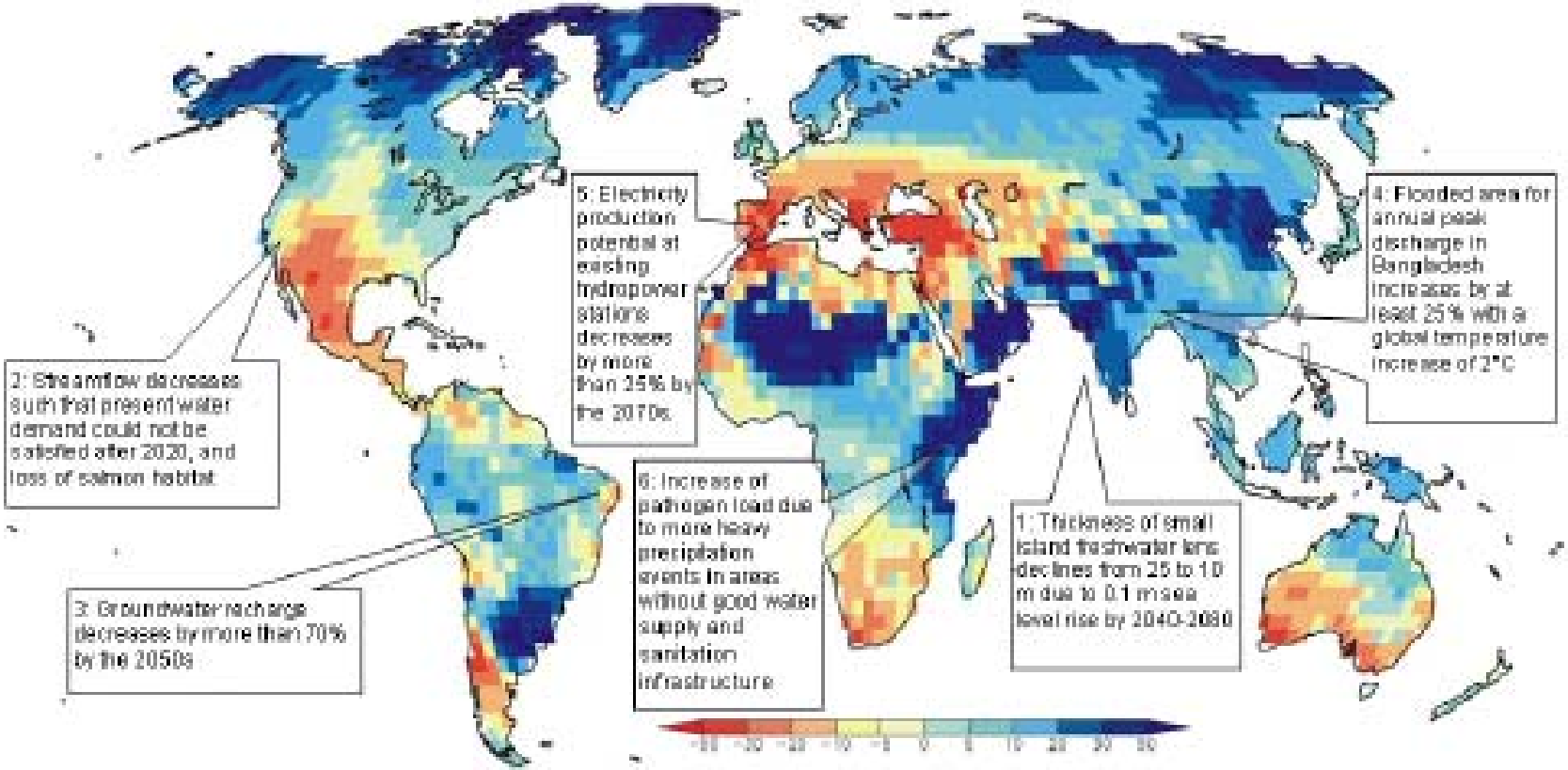


Figure 3.8: Illustrative map of future climate change impacts on freshwater which are a threat to the sustainable development of the affected regions. 1: Bobba et al. (2000), 2: Barnett et al. (2004), 3: Döll and Flörke (2005), 4: Mirza et al. (2003) 5: Lehner et al. (2005a) 6: Kistemann et al. (2002). Background map: Ensemble mean change of annual runoff, in percent, between present (1981-2000) and 2081-2100 for the SRES A1B emissions scenario (Nohara et al., 2006).

Ground water recharge

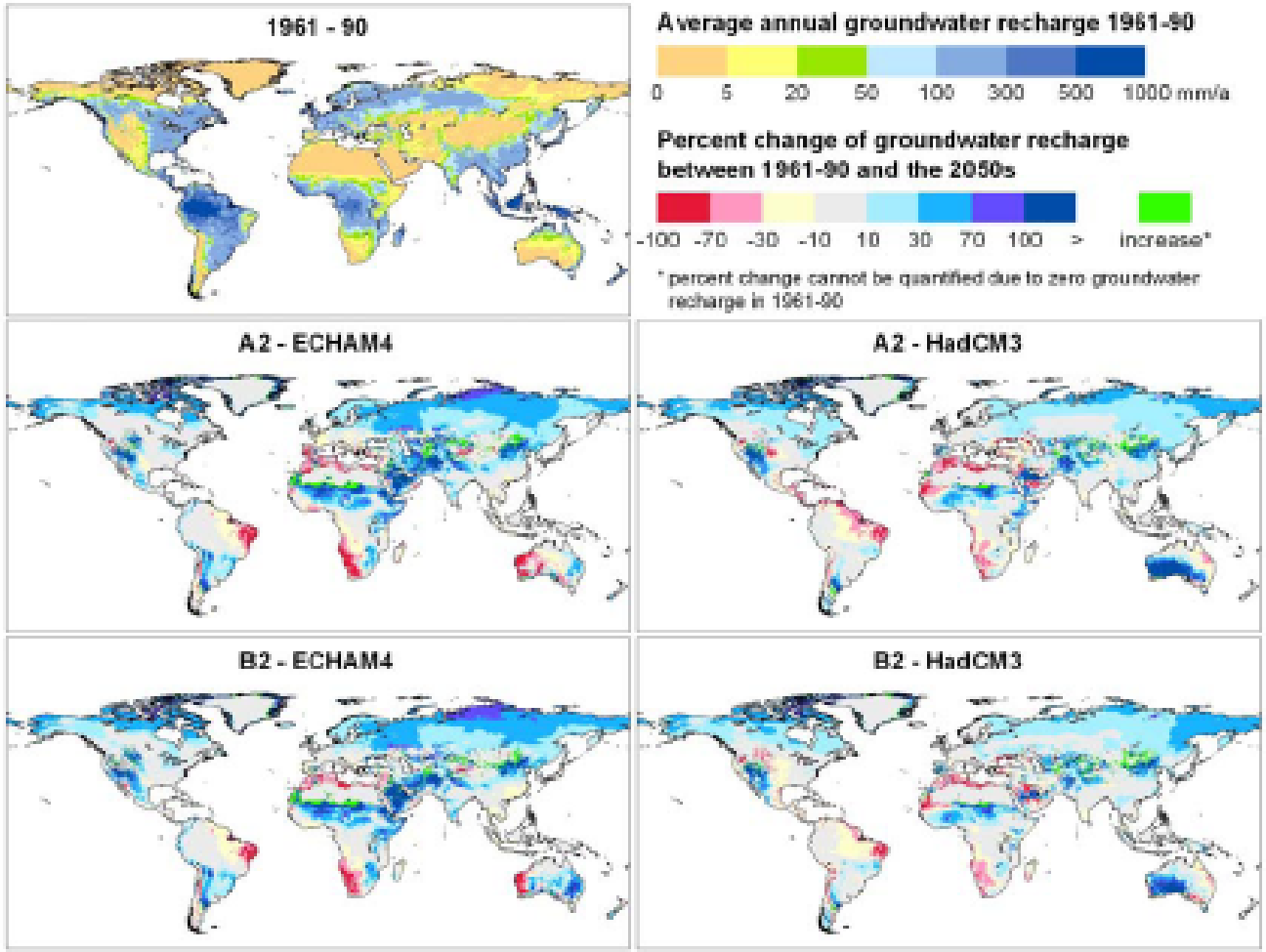


Figure 3.5: Simulated impact of climate change on long-term average annual diffuse groundwater recharge. Percent changes of 30-year averages groundwater recharge between 1961-1990 and the 2050s (2041-2070), as computed by the global hydrological model WGHM, applying four different climate change scenarios (climate scenarios computed by the climate models ECHAM4 and HadCM3, each interpreting the two IPCC greenhouse gas emissions scenarios A2 and B2 (Döll an Flörke, 2005).

Current knowledge about future vulnerability and impacts

Future projections

Magnitudes of impact can now be estimated for a range of potential increases in global mean temperature

Global effects have been estimated for a range of global temperature changes. For ecosystems and food security, two of the issues mentioned in Article 2 of the UNFCCC, the following effects are estimated:

Future Projections (cont)

- **Up to 1ºC:** Some ecosystem shifts; some increases in global agricultural production potential, but reduced yields at lower latitudes [4.4.10; 13 T4.2; F4.4; 5.4.2.2; F5.2; 19.3.2].

- **For 1 to 2ºC:** About one-quarter of species lost from current range; further increases in global agricultural production potential but further yield reductions at lower latitudes [T4.2; 5.4.2.2; 19.3.2].

- **For 2 to 3ºC:** Most of tundra and about half of boreal forest area disappears; about one-third of species lost from current range; global agricultural production potential peaks but further yield reductions at lower latitudes suggest large increases in numbers of people at risk of hunger [T4.2; 5.4.2.2; T19.2].

- **For 3 to 4ºC:** Global decreases in agricultural production potential; large numbers additionally at risk of hunger [F5.2; T20.2; T20.3].

- **For 4 to 5ºC:** Decreases in agricultural production potential at higher latitudes, as well as further decreases at lower latitudes. [F5.2].

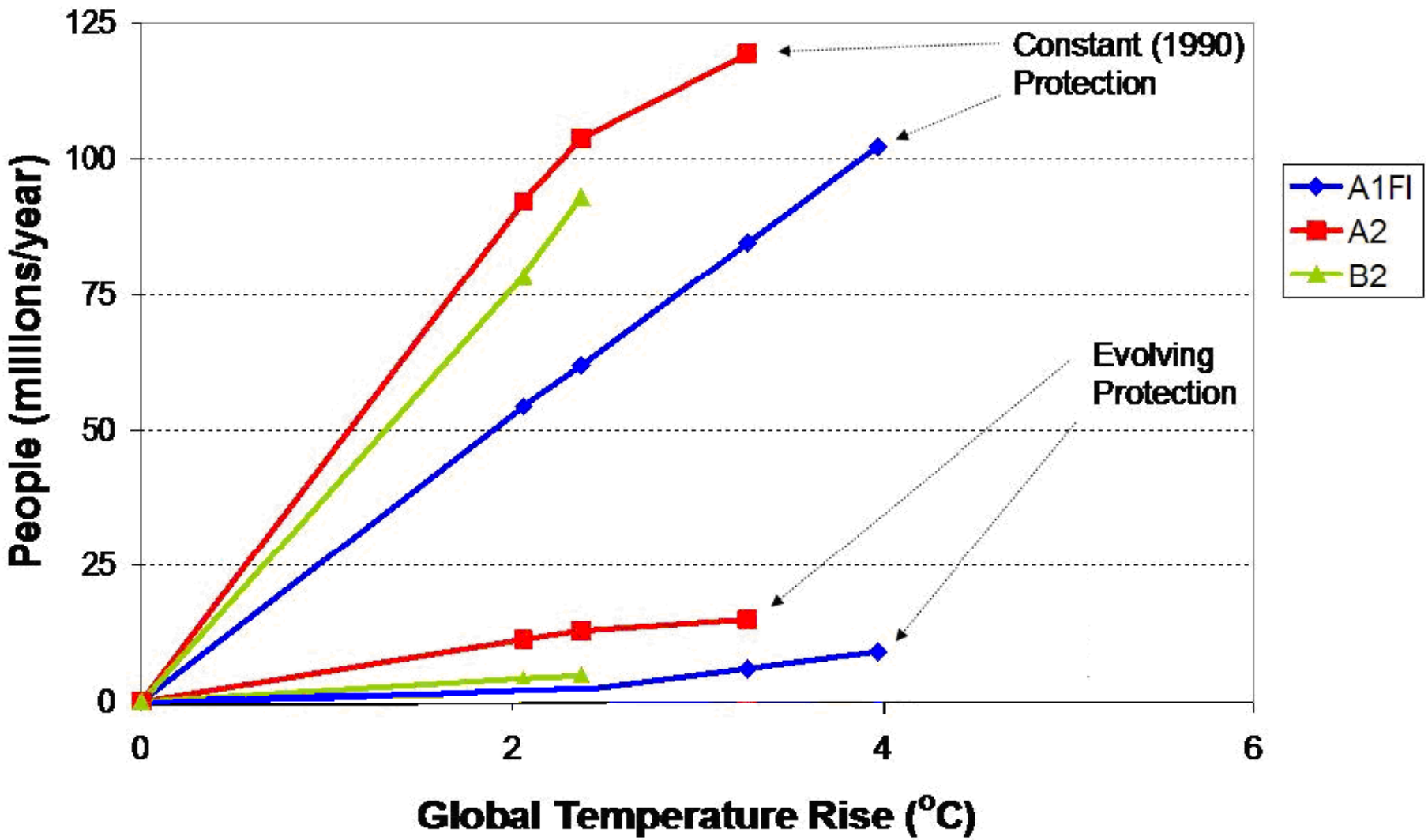
- **For 5 to 6 ºC:** Widespread species extinction. [T19.2]

Future projections (Cont)

- Sub-Saharan Africa is likely to experience large impacts from climate change, due to high levels of intrinsic vulnerability stemming from heavy dependence on rain-fed agriculture, propensity to drought, and relatively low levels of adaptive capacity. [9.1;9.2.2;9.ES

- Small islands are likely to experience large impacts due to the combination of high exposure (e.g., sea level rise and storm surge) and high vulnerability (e.g., lack of infrastructure) [16.2.1; 16.4

Fig. SPM-4: Global number of additional people estimated to be flooded in coastal areas in the 2080s due to climate change under three SRES scenarios, and with constant and evolving protection



Probability of exceeding 2ºC global warming above pre-industrial levels, or 1.4ºC above 1990 levels

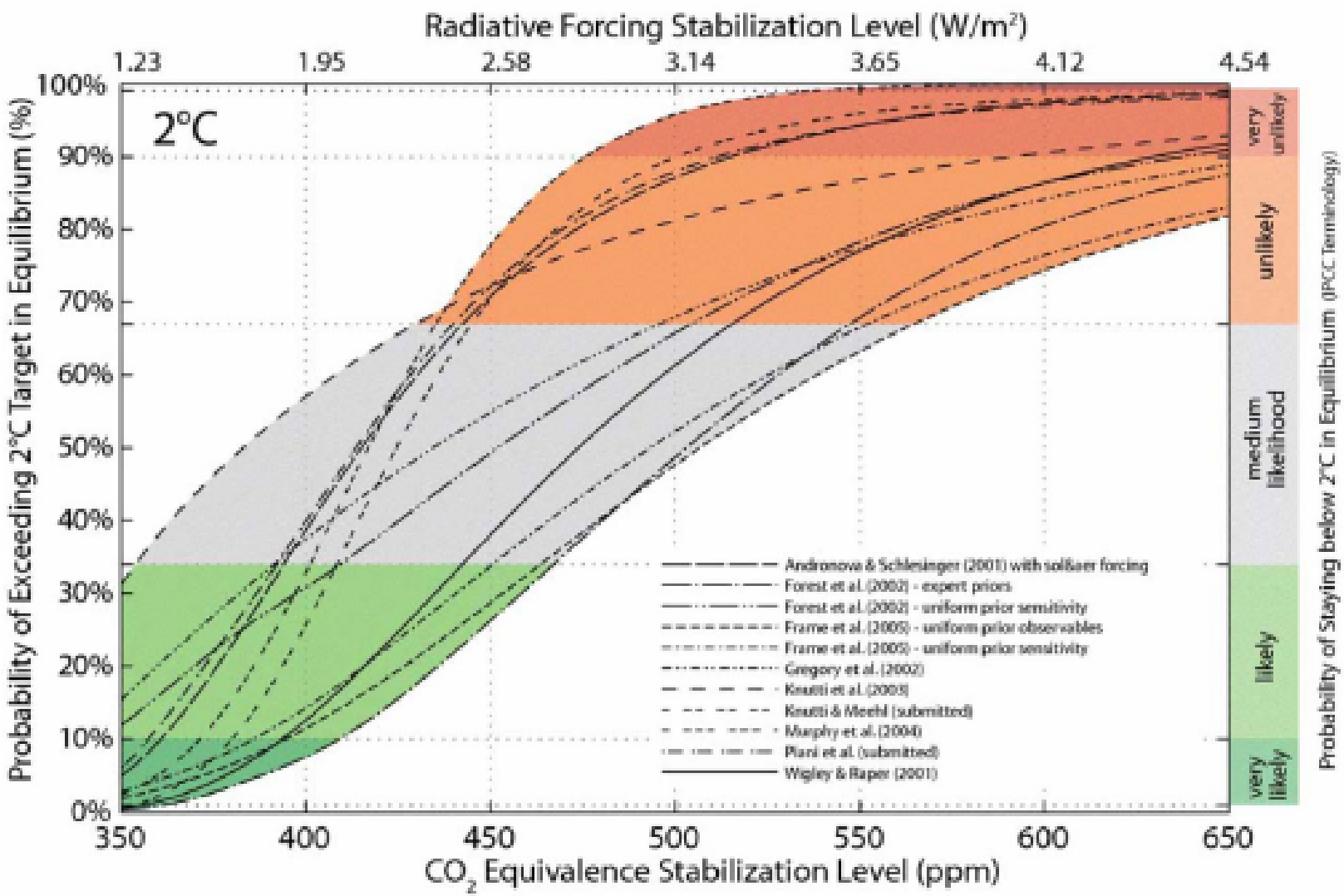
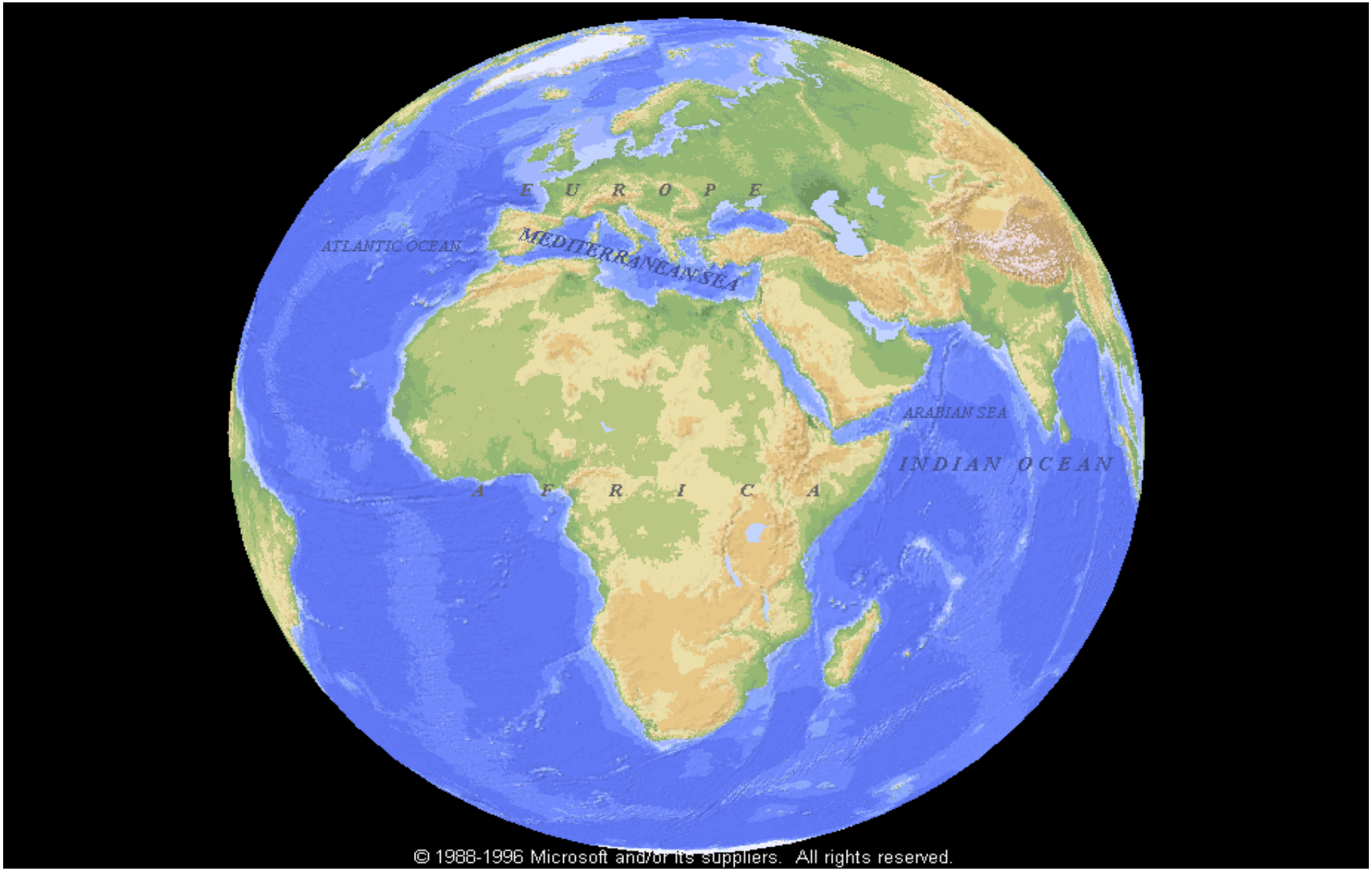


Figure 19.1: Probability (see Key Caveat above on low confidence for specific quantitatitive results) of exceeding an equilibrium global warming of 2°C above preindustrial (1.4°C above 1990 levels), for a range of CO_2-equivalent stabilization levels. Source: Hare and Meinshausen (2005)

Africa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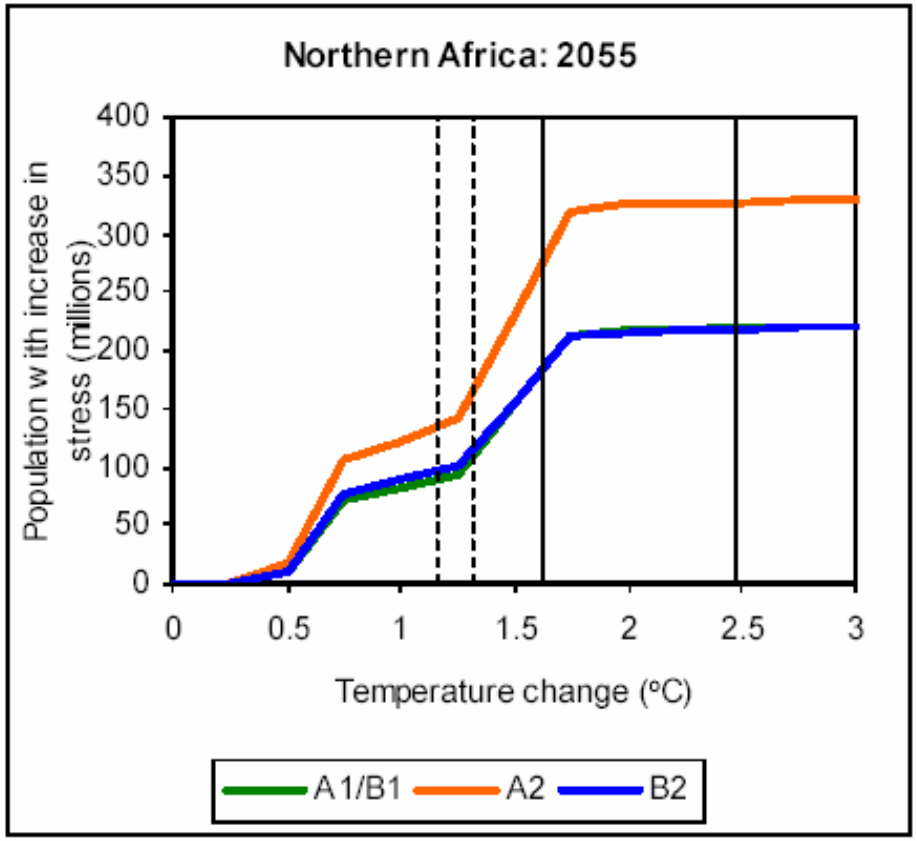
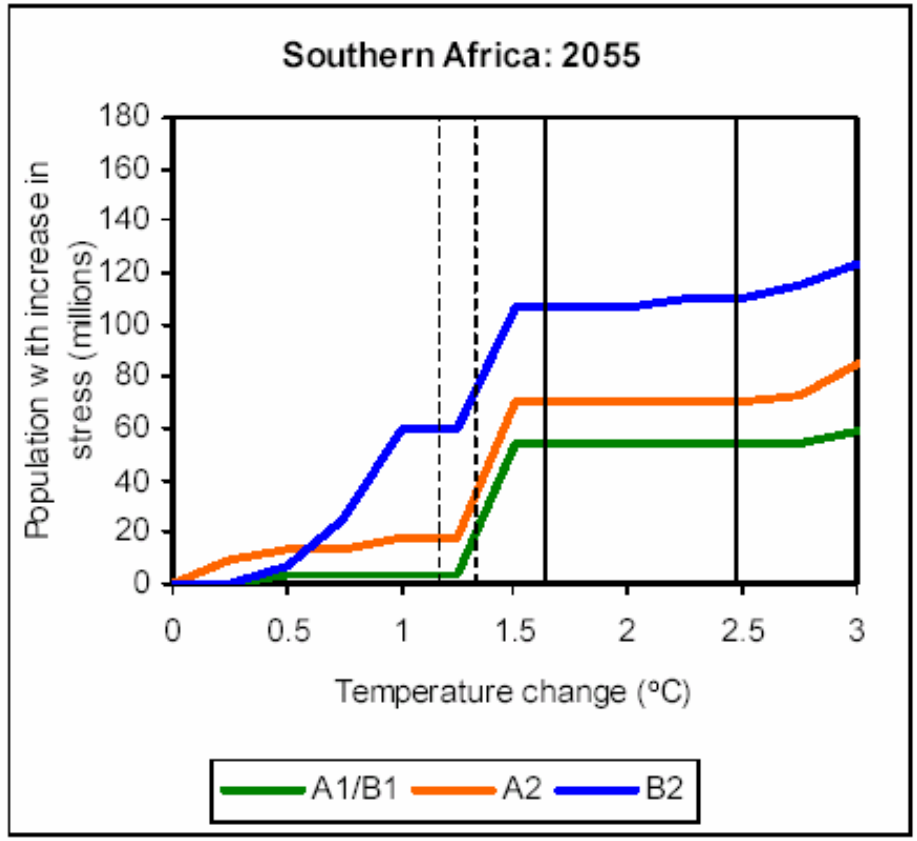
Projections for Africa

- Warming is very likely to be larger than the global annual-mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics.
- Annual rainfall is likely to 25 decrease in much of Mediterranean Africa and Northern Sahara, with a greater likelihood of decreasing rainfall as one approach the Mediterranean coast.
- Rainfall in southern Africa will likely decrease in much of the winter rainfall region and western margins.
- There will likely be an increase in annual mean rainfall in East Africa.
- It is unclear how rainfall in the Sahel, the Guinean Coast, and the Southern Sahara will evolve.

Projected water stress in Africa





Snow and Ice on Mt Kilimanjaro: montane refugia

http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=10856

Projected biodiversity losses in Southern Africa (IPCC AR4 WG II Table 9.1)

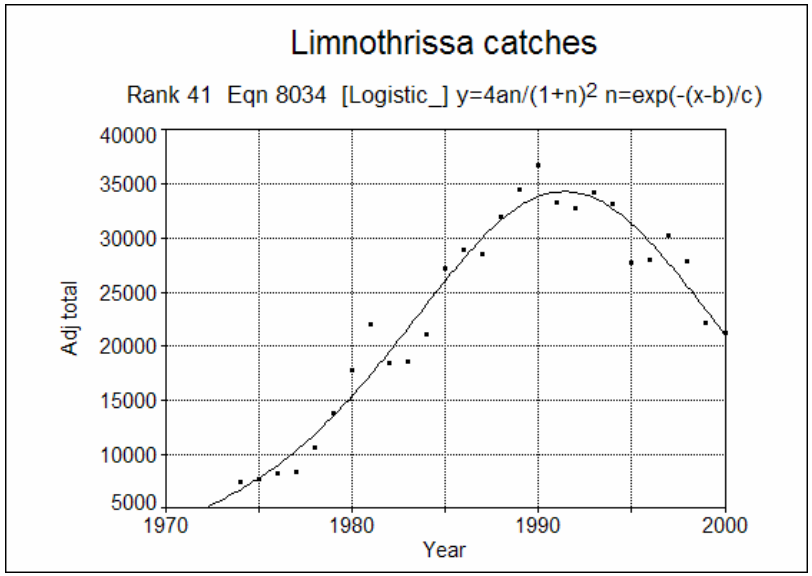
- 24-59% of mammals,
- 28-40% of birds,
- 13-70% of butterflies,
- 18-80% of other invertebrates,
- 21-45% of reptiles

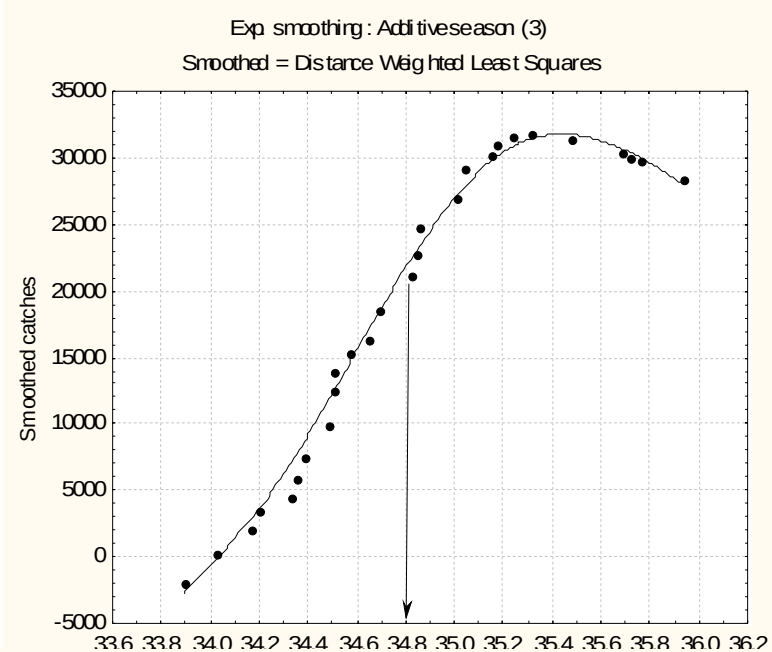
committed to extinction;

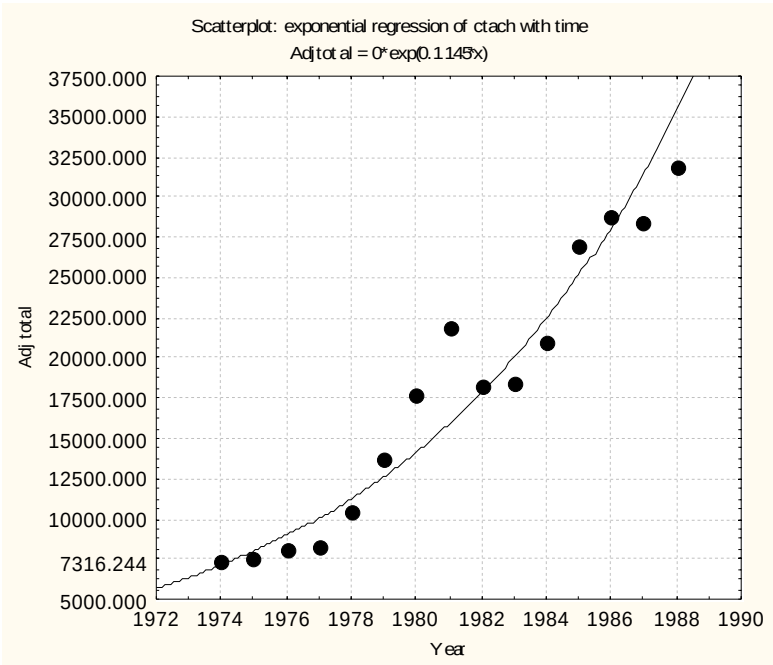
- 66% of animal species potentially lost from Kruger National Park

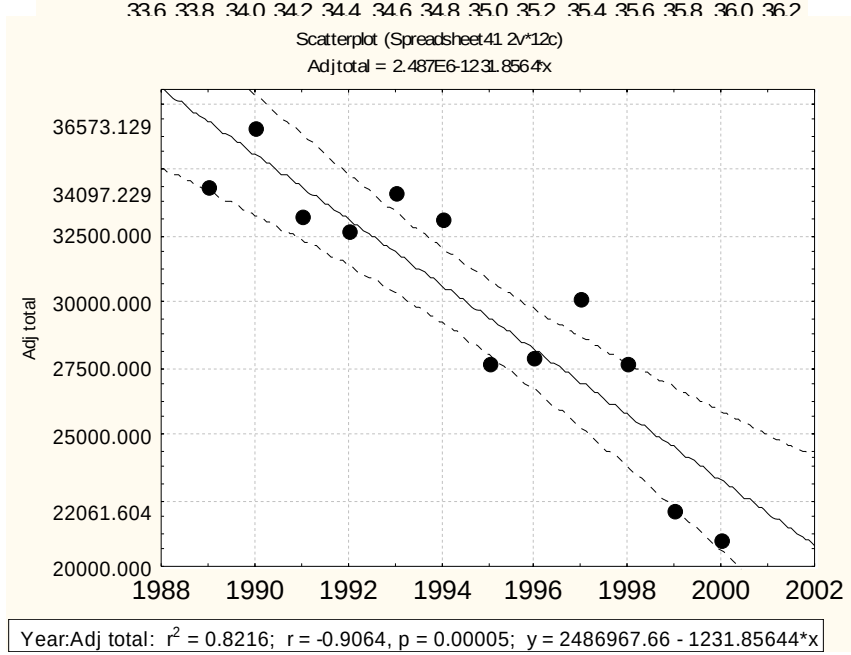
[AR4 WG2 Table 4.1]

Limnothrissa catches; L. Kariba

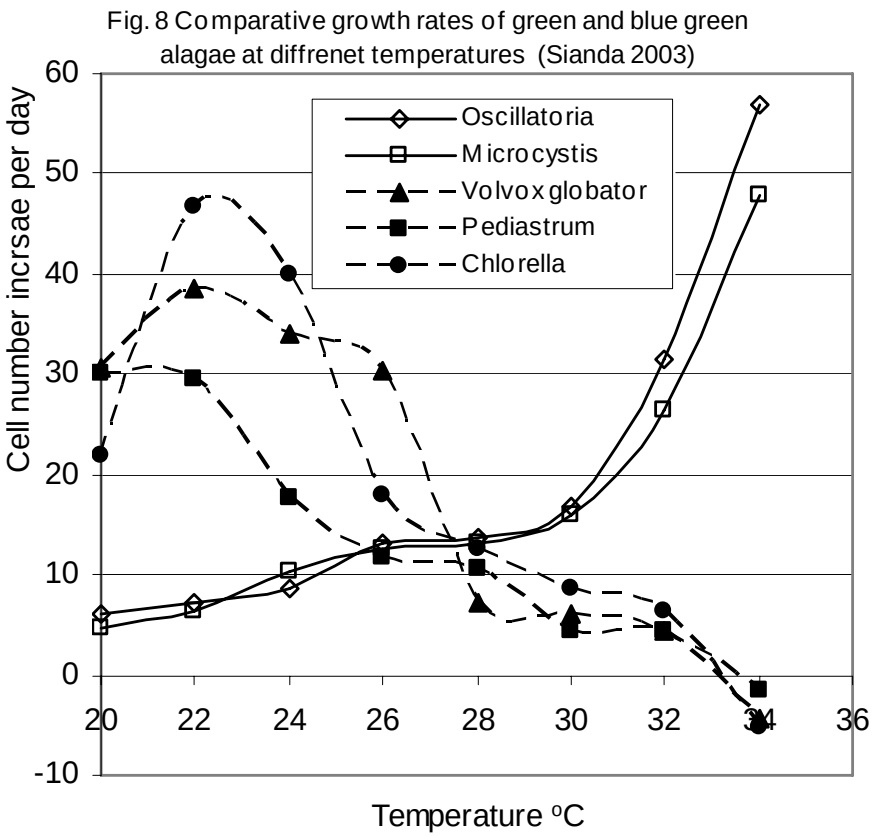


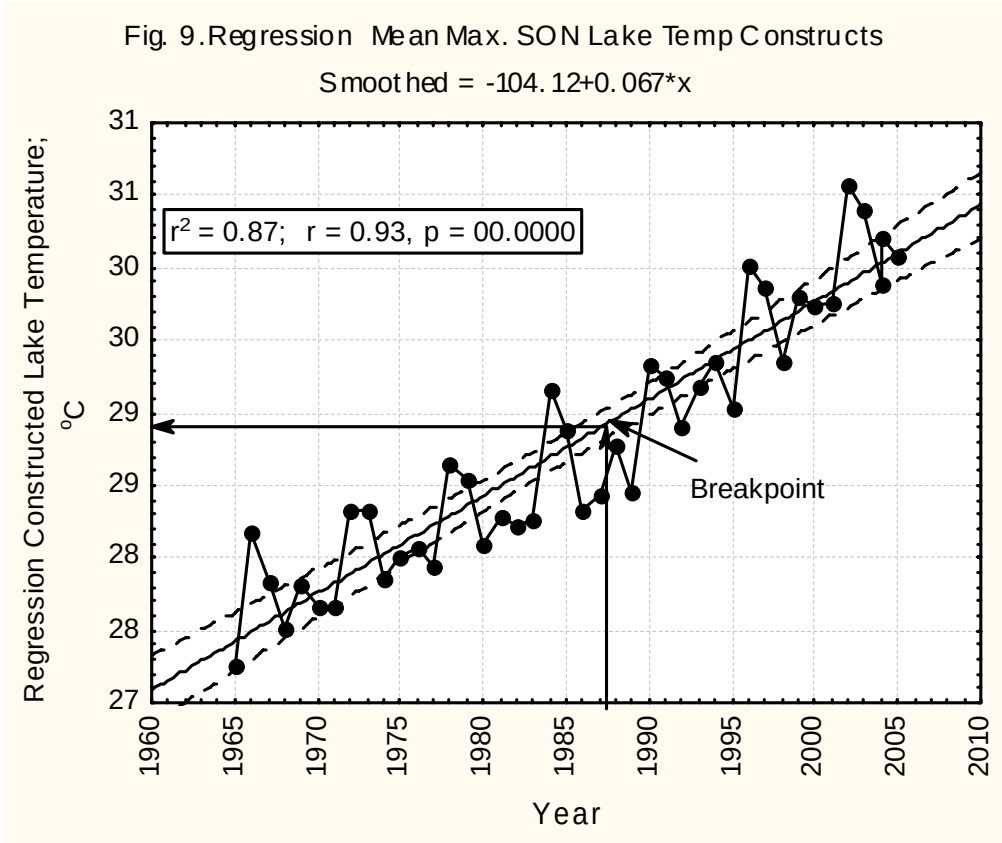




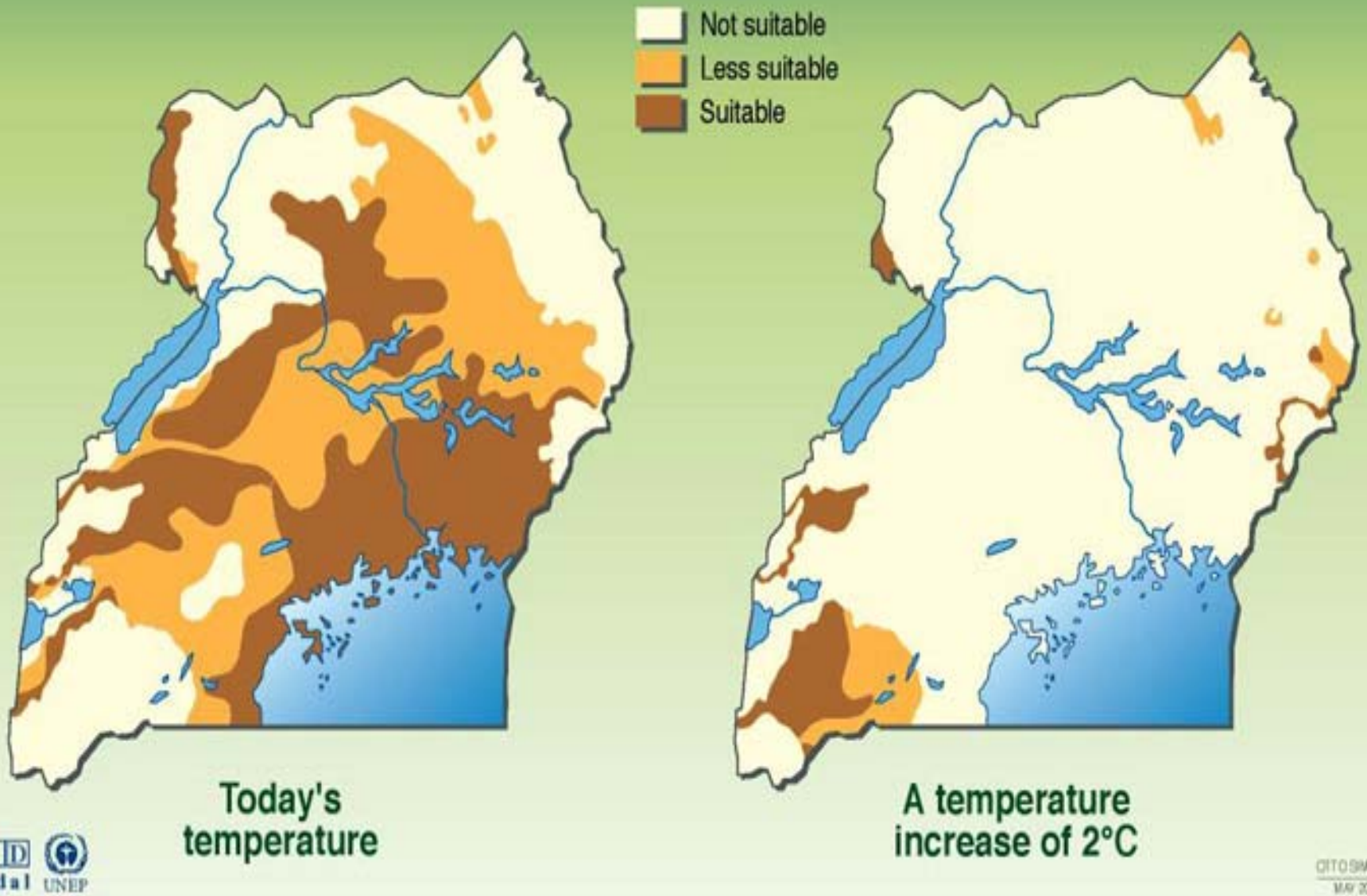


Temperature and algal community





Impact of temperature rise on robusta coffee in Uganda



Source: Otto Simonett, Potential impacts of global warming, GRID-Geneva, case studies on climatic change. Geneva, 1989.

Some projected changes in Africa

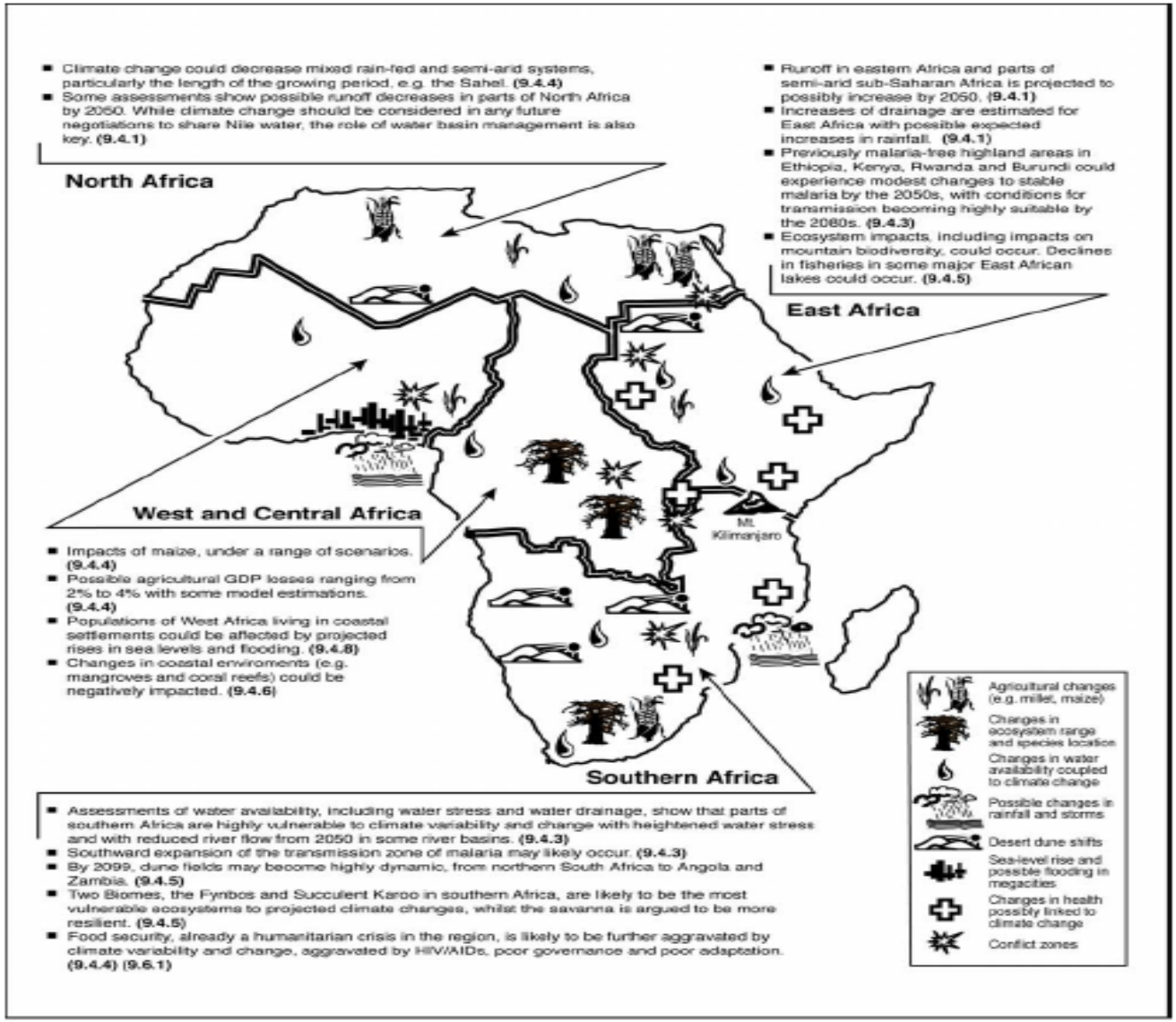
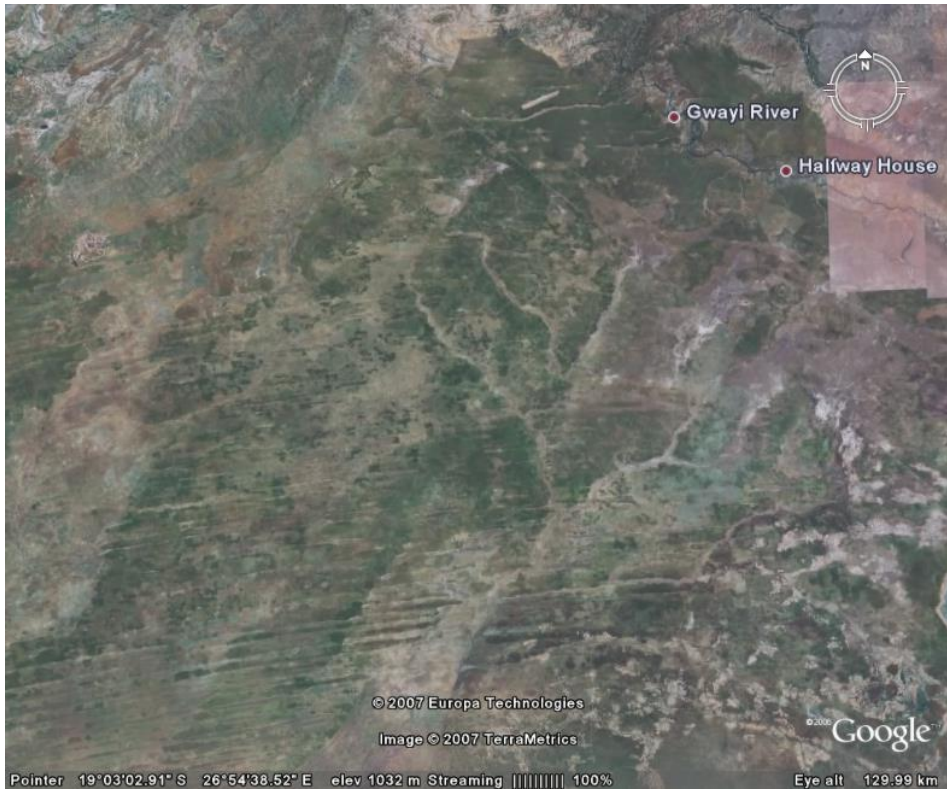


Figure 9.5: Examples of current and possible future impacts and vulnerabilities associated with climate variability and climate change for Africa (for details see sections highlighted in bold) (Sources various). Please note these are indications of possible change and are based on models that currently have limitations but that provide current available assessments.

Desert encroachment in Southern Africa.

Left is satellite view of Namib desert sand dunes; right is fossil dunes in Southern Africa 35 000 years ago. Temperature increases of 3°C above 1960-1990 mean will reactivate sand dune mobility in the subcontinent.



The African Enigma

- AFRICA IS THE MOST VULNERABLE CONTINENT TO CLIMATE CHANGE.
- Why?
- IT HAS A LOW ADAPTIVE CAPACITY

Vulnerability and adaptive capacity

Vulnerability is a function of

- the character,
- magnitude,
- rate of climate variation to which a system is exposed,
- sensitivity of the system,
- and the system's adaptive capacity (IPCC 2001b, Glossary).
- related to the conditions, processes and structures that promote or constrain adaptive capacity (Eriksen *et al*., 2005).

The African endowment

- Africa has oil resources.
- Africa has rich mineral resources.
- Africa has large expanses of arable land.
- It has large timber resources.
- Though not evenly distributed Africa has considerable water resources in its rivers and lakes.
- Africa has built up a critical mass of professional human resources.

Where then lies this lack of adaptive capacity?

Unless Africa can

- **unpack** this statement, and
- identify the **missing components** for building adaptive capacity,
- it will **increasingly be vulnerable** to debilitating impacts of climate change, and
- increasingly be dependant on **relief and emergency aid** from the international community,
- while at the same time, **missing out** on the development **opportunities** offered by adaptation to climate change.

Opportunities offered by CC adaptation strategies

- Carbon trading, eg Laguna de Bay reclamation project
- Solar & hydro energy
- Biotechnology
- Irrigation technology
- Development rerouting, cottage industries

Asante Sana