Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Climate Change - What are the main issues with regard to human activities, climate modeling and land-climate interactions?

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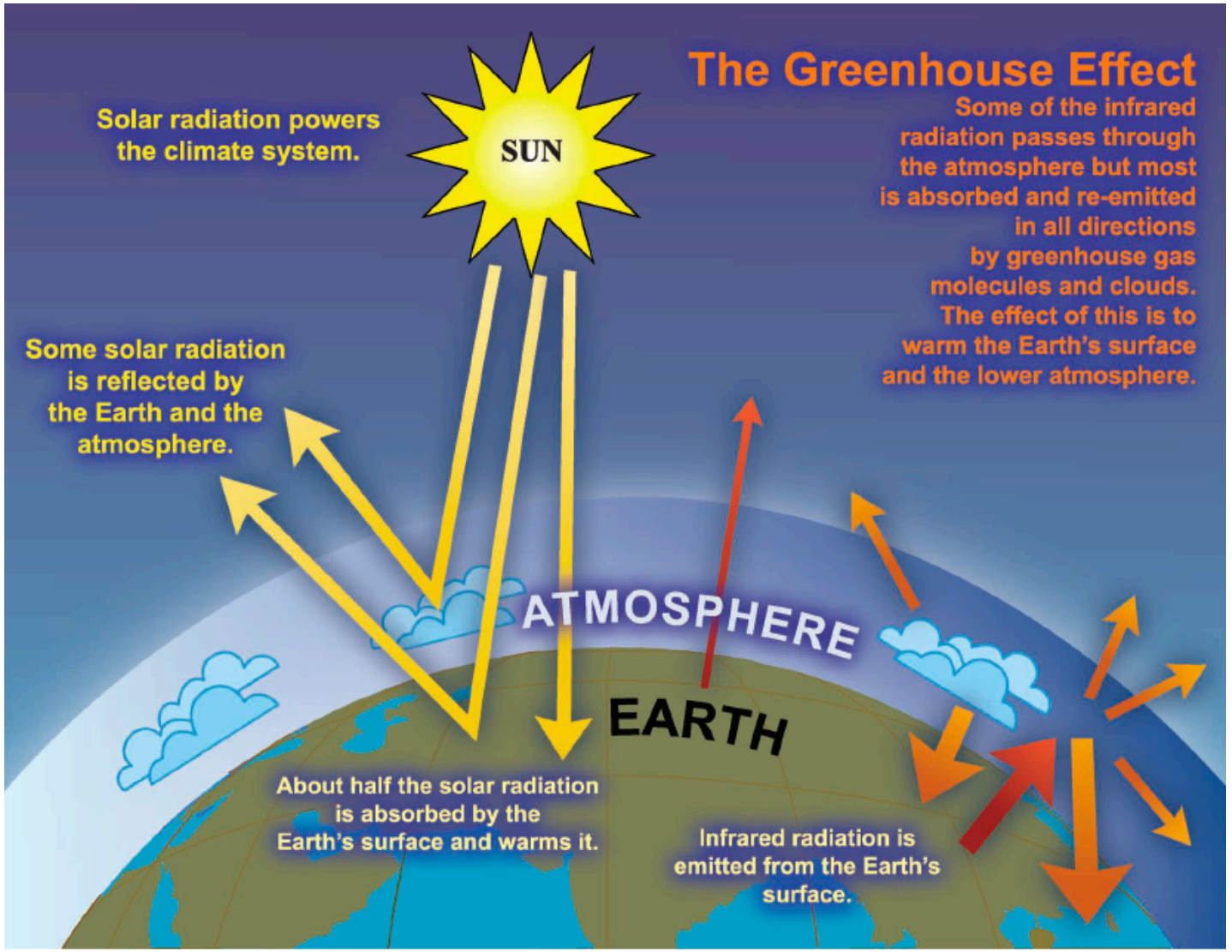
Outline

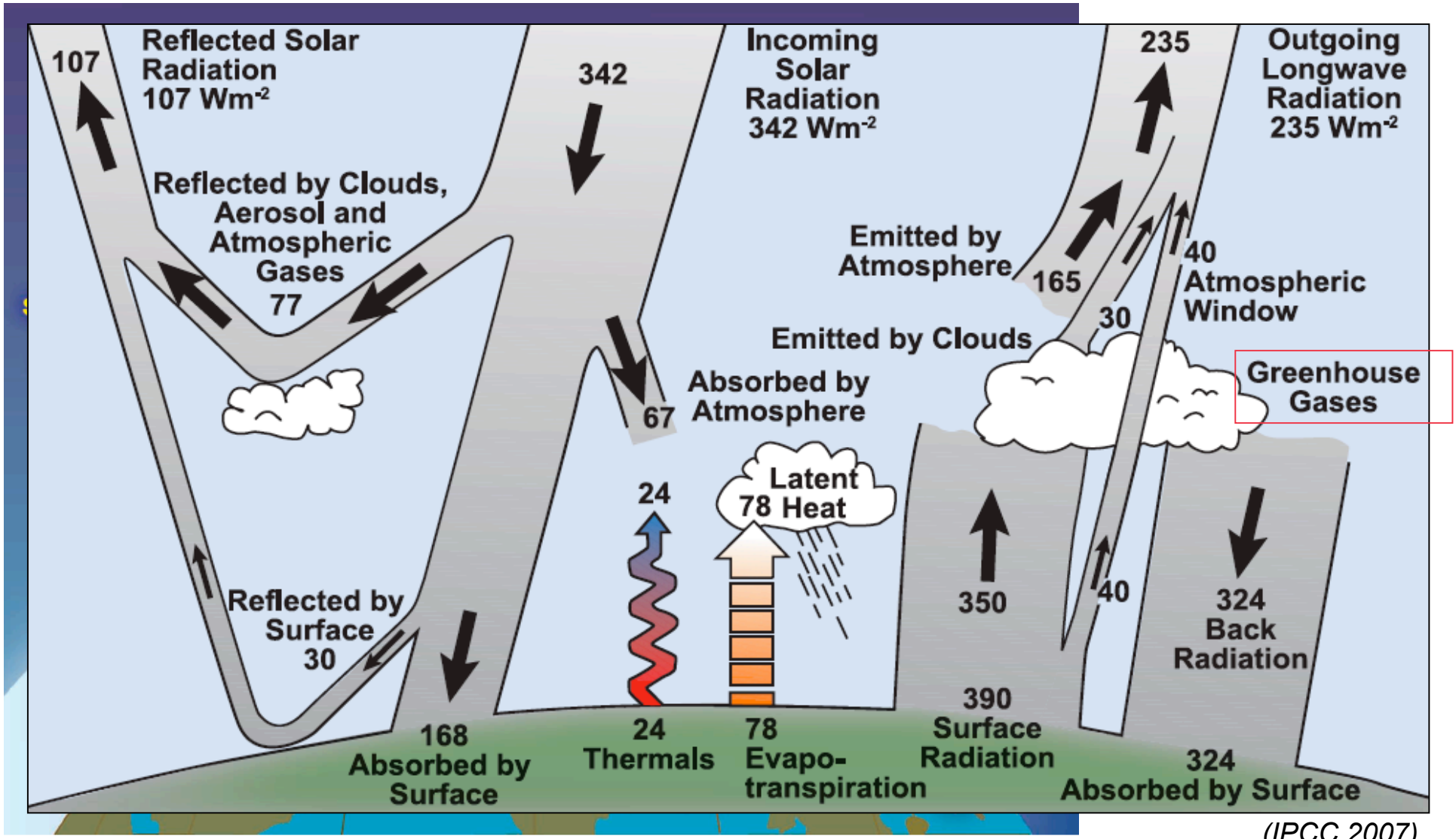
- Introduction
- Evidence from observations and climate model projections
- Current uncertainties
  - Emissions
  - Processes: e.g. land-atmosphere feedbacks
- Conclusions

Climate change



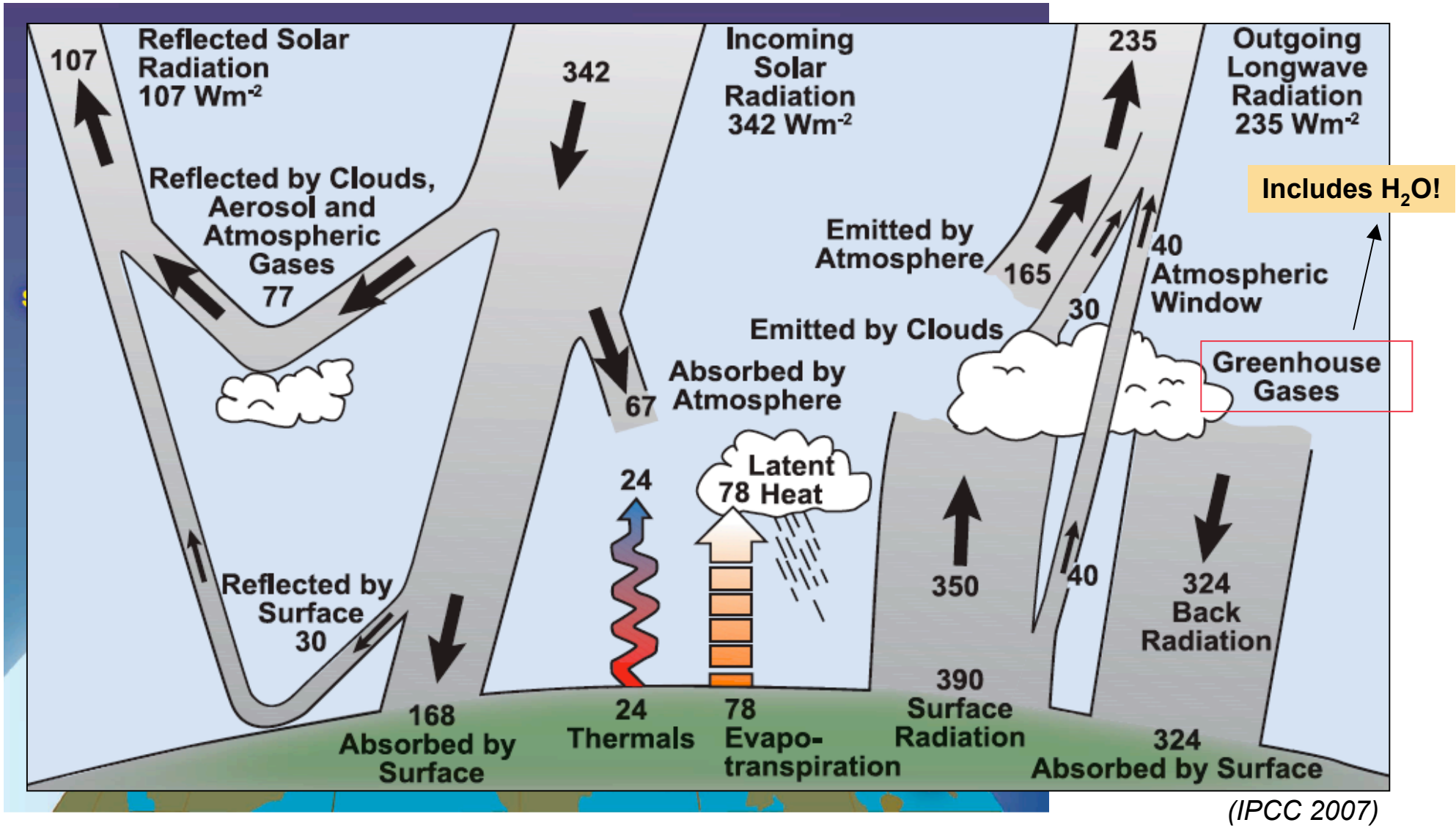
(IPCC 2007)

Climate change



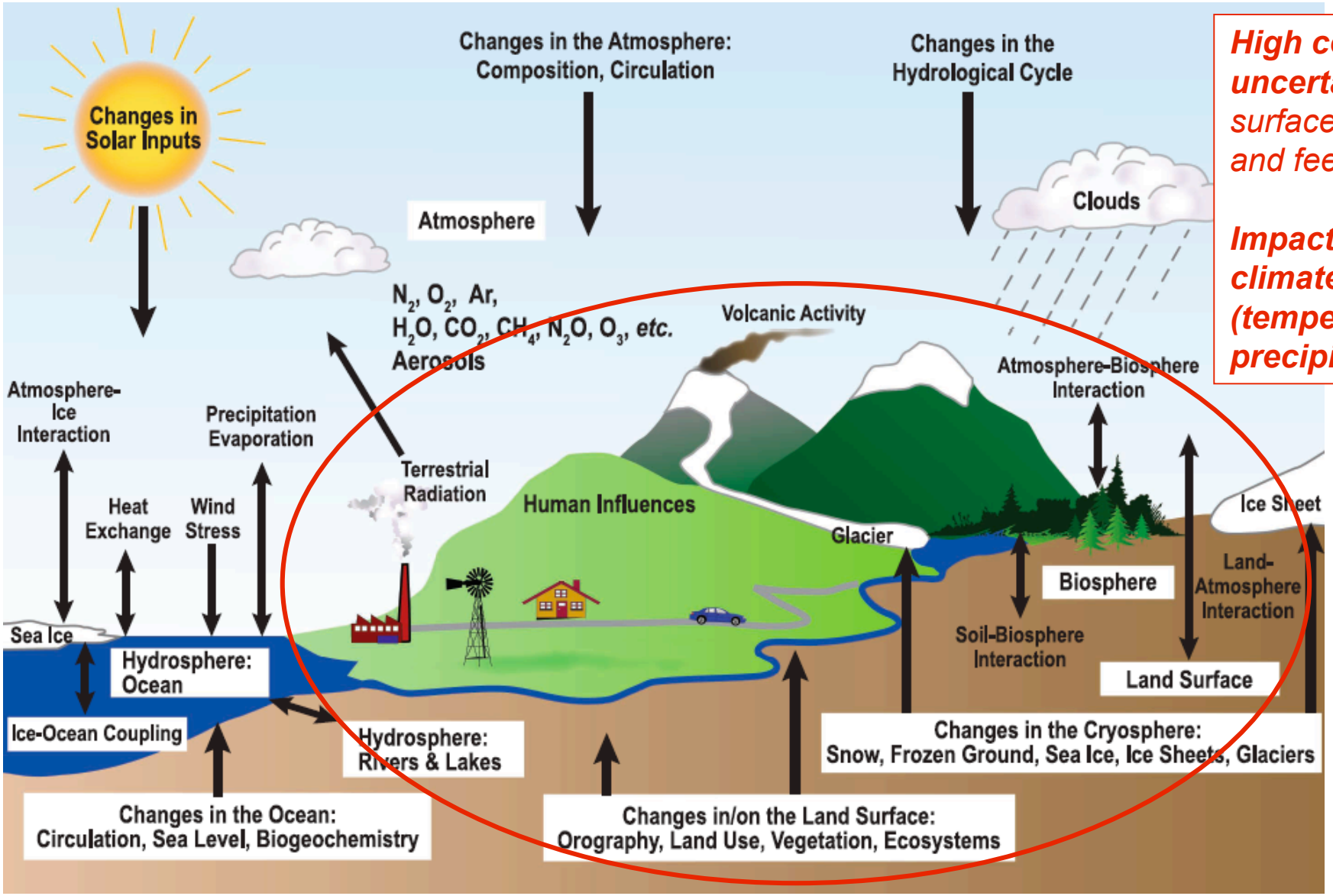
(IPCC 2007)

Climate change



(IPCC 2007)

The climate system and climate change



High complexity & uncertainty *of land surface processes and feedbacks!*

Impacts regional climate response (temperature, precipitation)

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Observed temperature changes

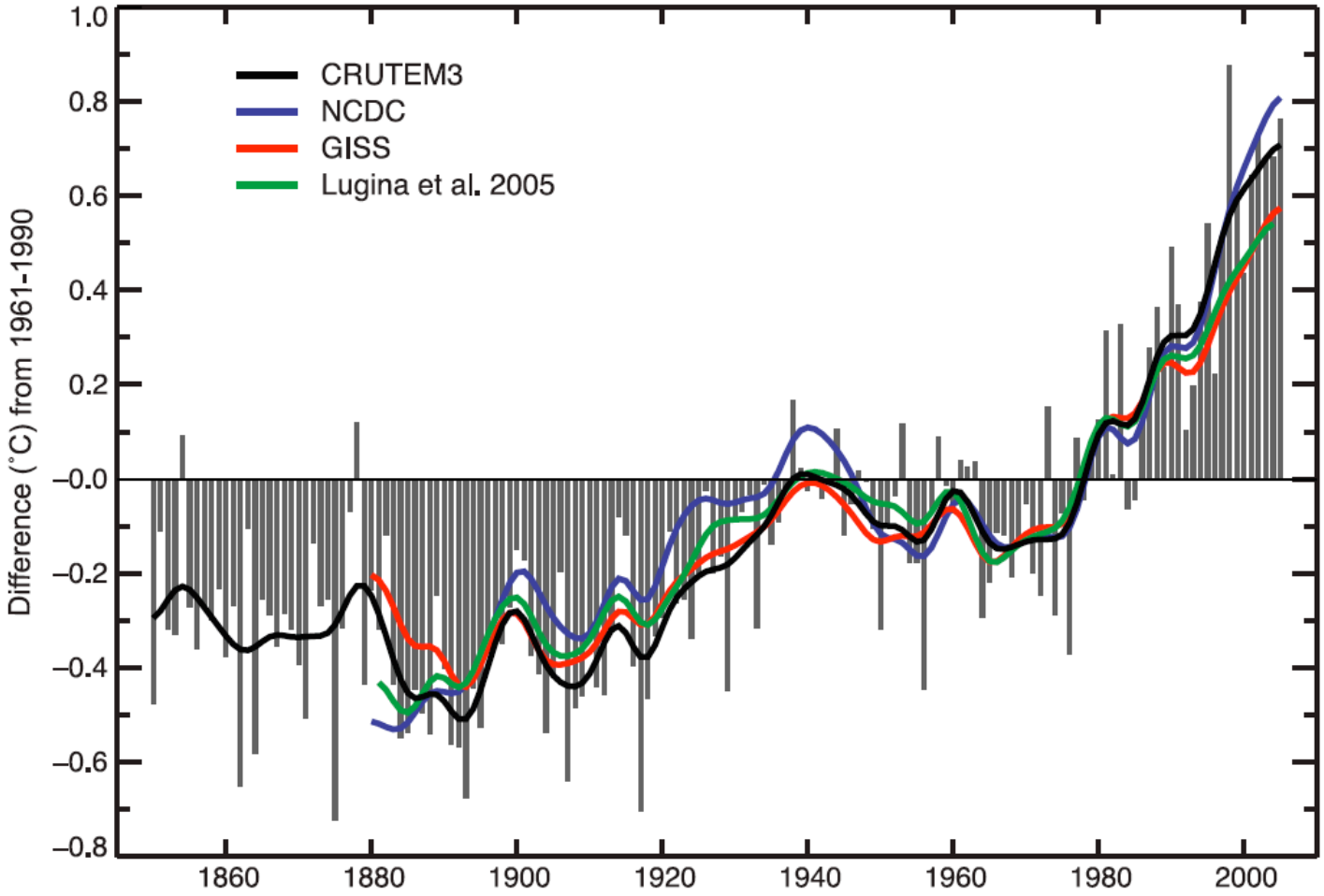
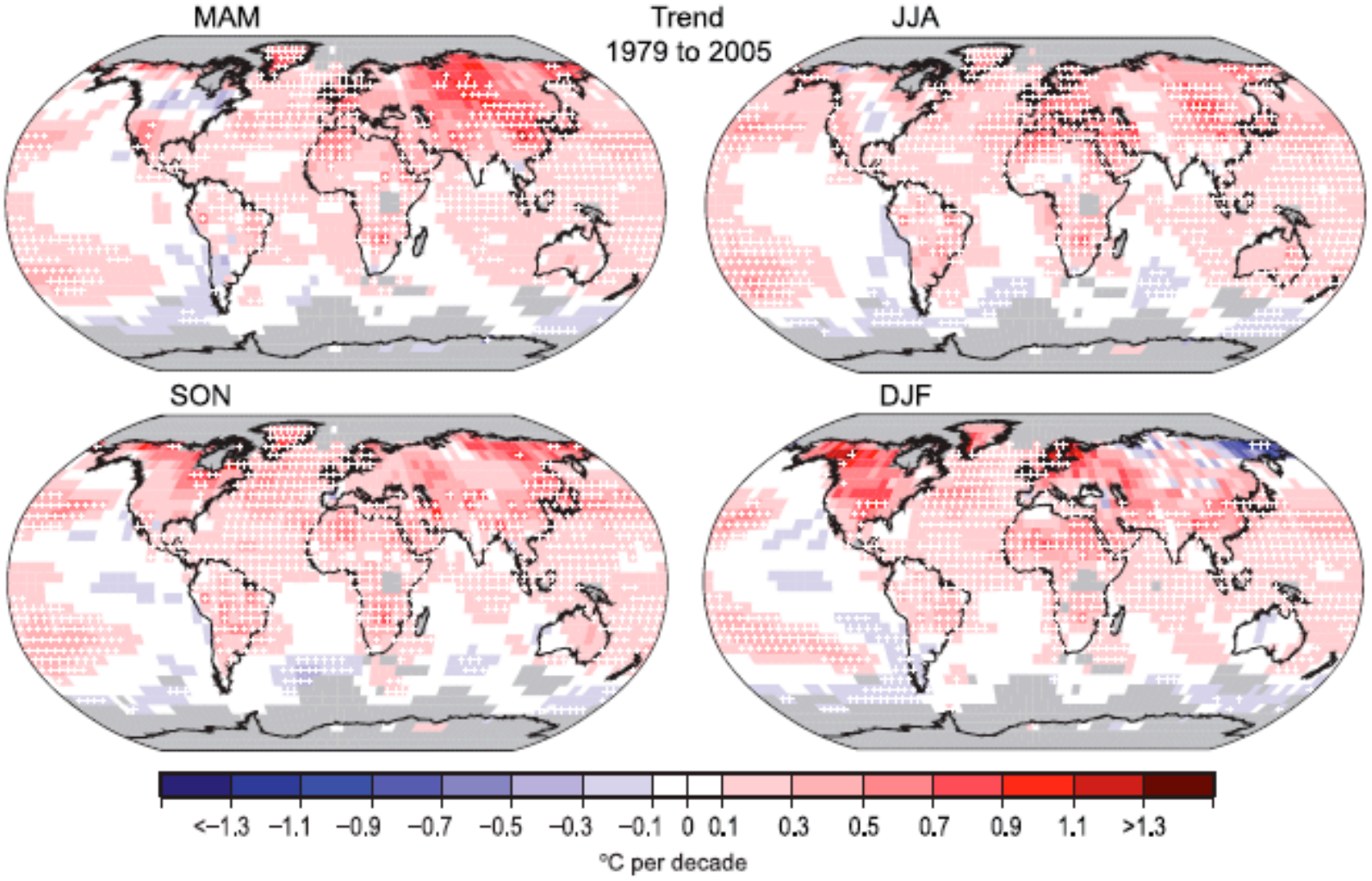


Figure 3.1. *Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961 to 1990 mean for CRUTEM3 updated from Brohan et al. (2006). The smooth curves show decadal variations (see Appendix 3.A). The black curve from CRUTEM3 is compared with those from NCDC (Smith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

Global temperature trends

(IPCC 2007)

Observed temperature changes



gure 3.10. *Linear trend of seasonal MAM, JJA, SON and DJF temperature for 1979 to 2005 (°C per decade). Areas in grey have insufficient data to produce reliable trends. e minimum number of years required to calculate a trend value is 18. A seasonal value is available if there are two valid monthly temperature anomaly values. The dataset ed was produced by NCDC from Smith and Reynolds (2005). Trends significant at the 5% level are indicated by white + marks.*

Regional and seasonal variations

(IPCC 2007)

Observed precipitation changes

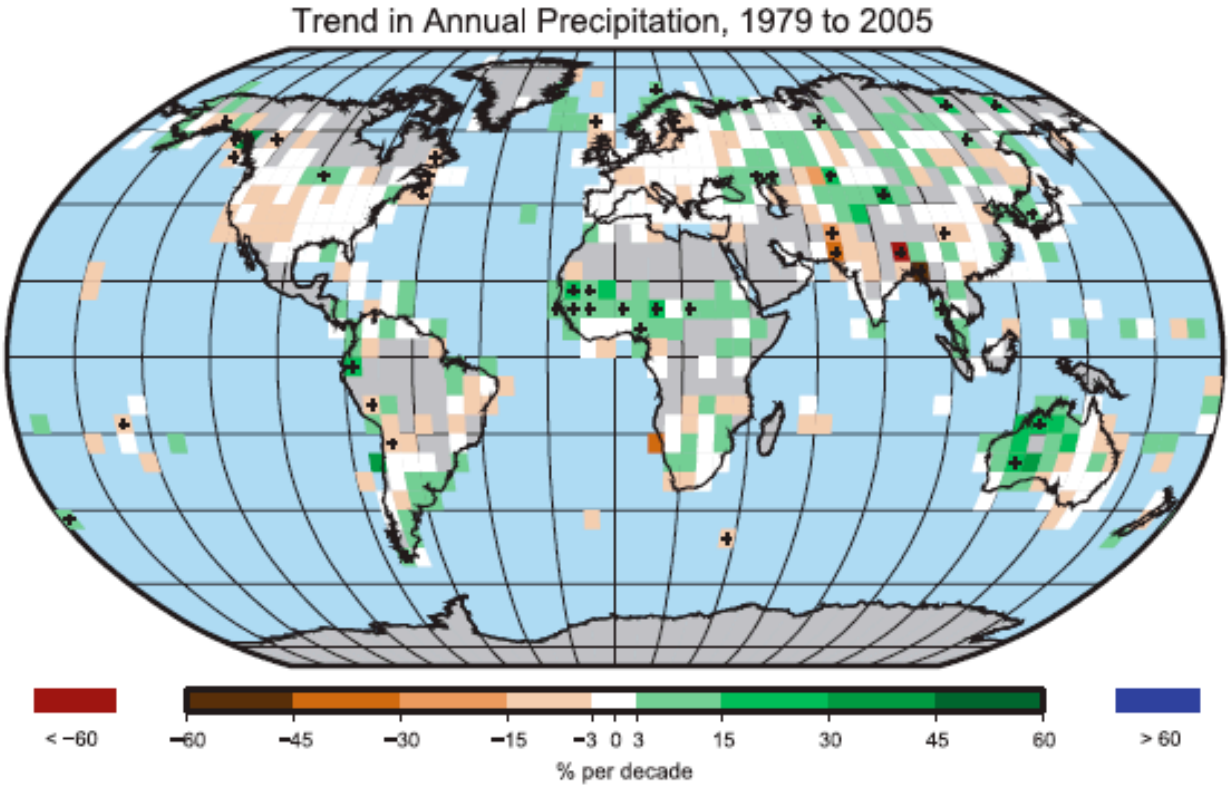
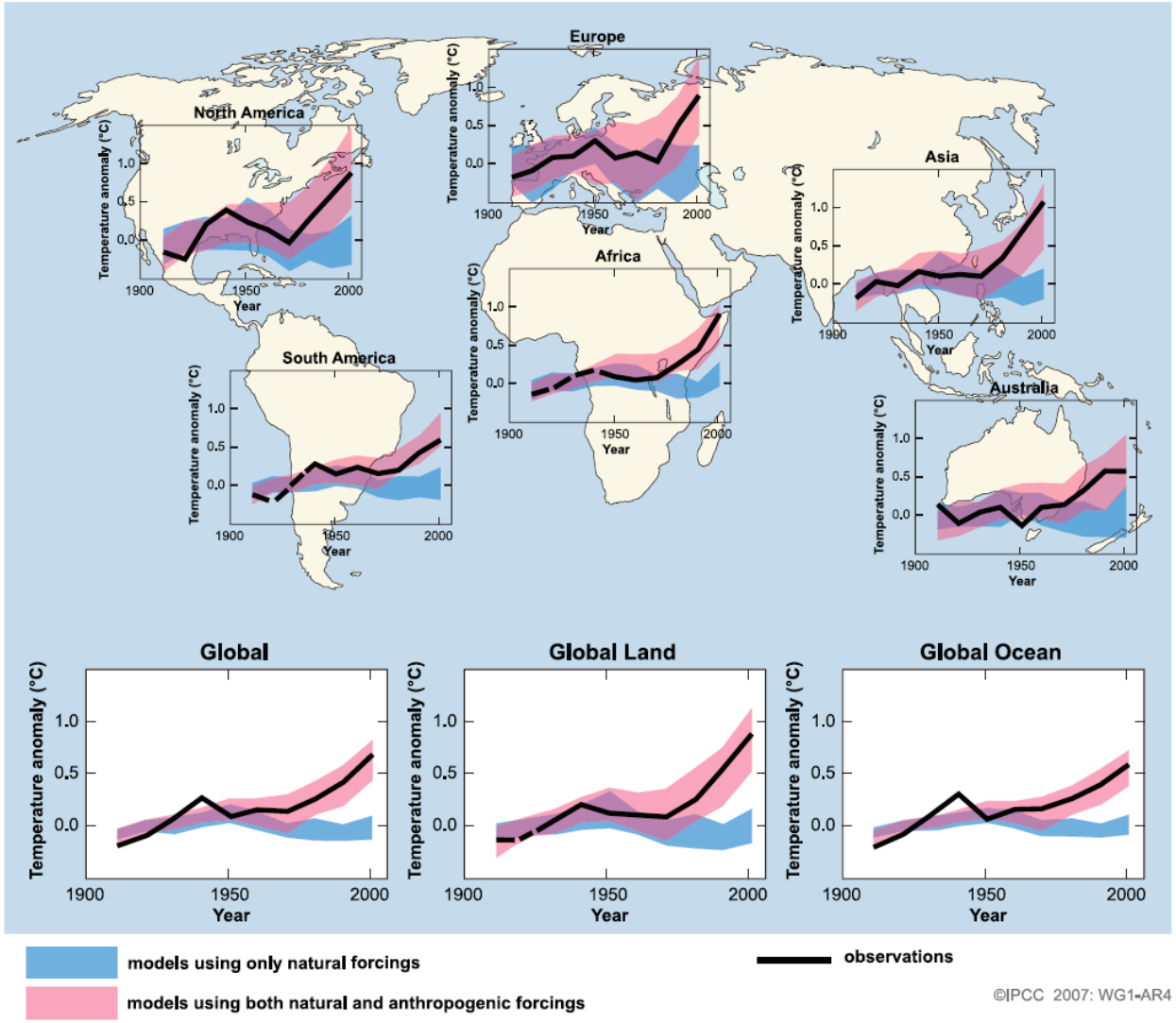


Figure 3.13. *Trend of annual land precipitation amounts for 1901 to 2005 (top, % per century) and 1979 to 2005 (bottom, % per decade), using the GHCN precipitation data set from NCDC. The percentage is based on the means for the 1961 to 1990 period. Areas in grey have insufficient data to produce reliable trends. The minimum number of years required 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 12 monthly percentage anomaly values are present. Note the different colour bars and units in each plot. Trends significant at the 5% level are indicated by black + marks.*

Less robust trends for precipitation

(IPCC 2007)

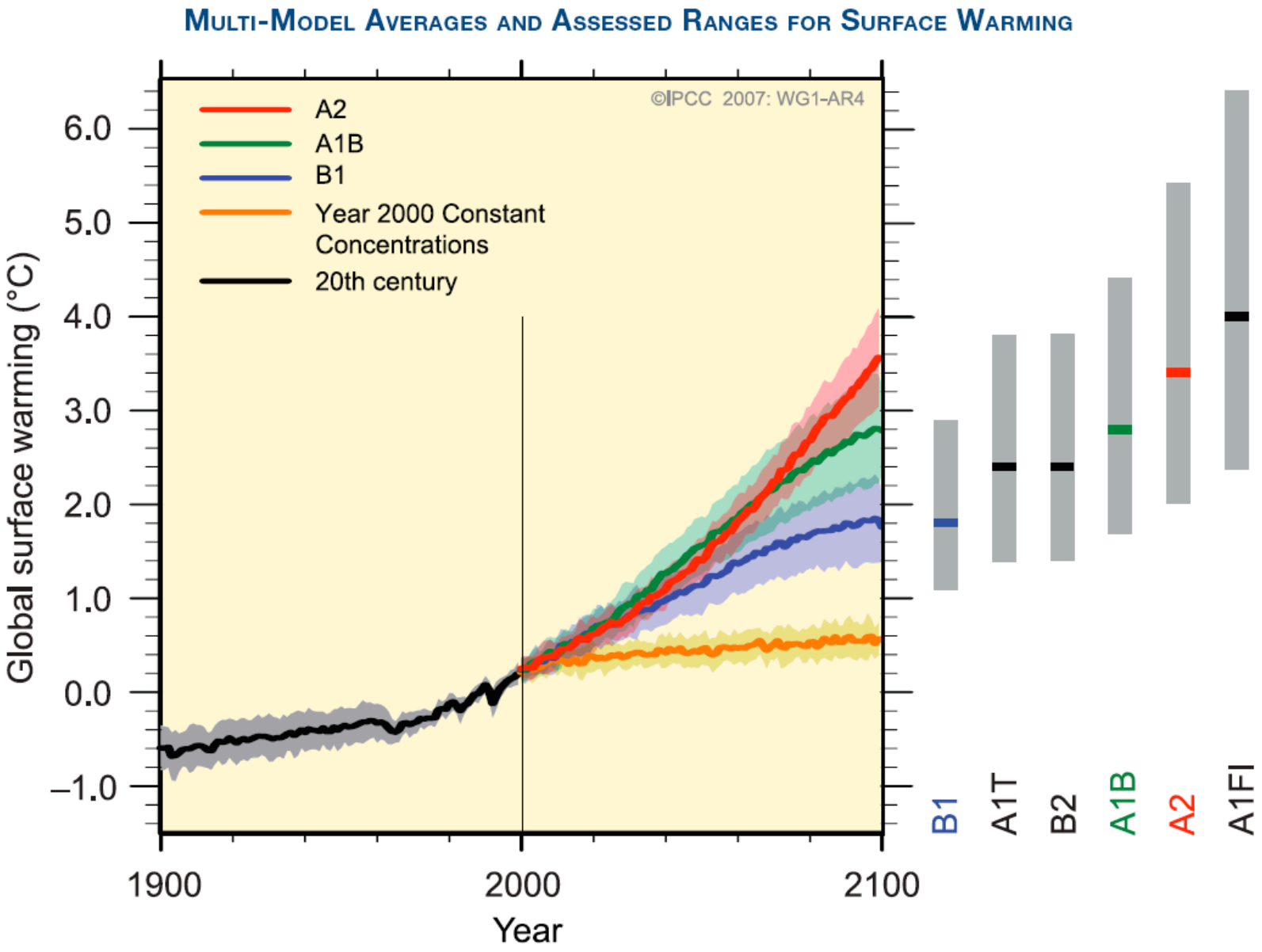
Role of anthropogenic emissions



FAQ 9.2, Figure 1. *Temperature changes relative to the corresponding average for 1901-1950 (°C) from decade to decade from 1906 to 2005 over the Earth's continents, as well as the entire globe, global land area and the global ocean (lower graphs). The black line indicates observed temperature change, while the coloured bands show the combined range covered by 90% of recent model simulations. Red indicates simulations that include natural and human factors, while blue indicates simulations that include only natural factors. Dashed black lines indicate decades and continental regions for which there are substantially fewer observations. Detailed descriptions of this figure and the methodology used in its production are given in the Supplementary Material, Appendix 9.C.*

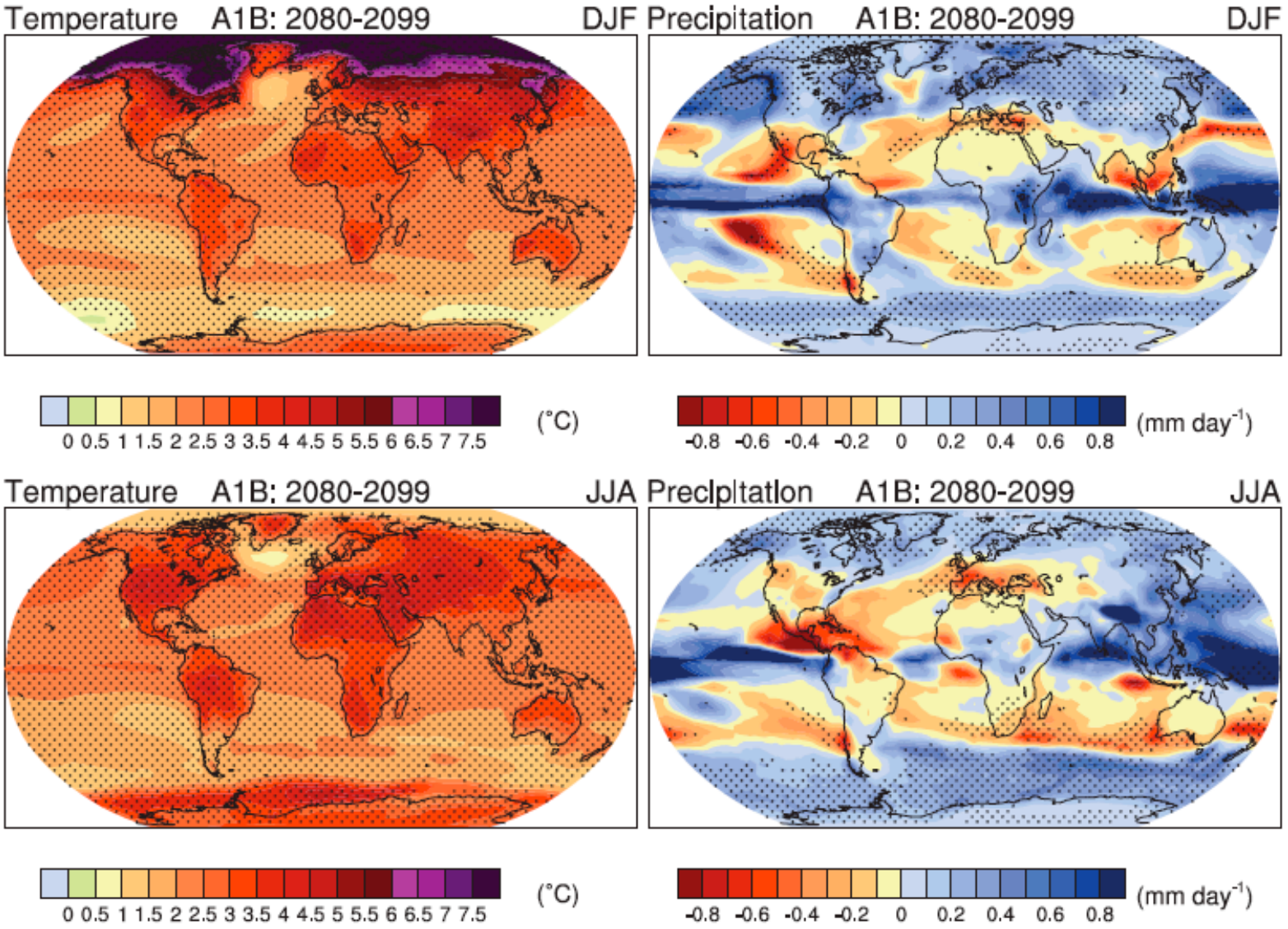
(IPCC 2007)

Projections of global temperature changes



(IPCC 2007)

Climate projections



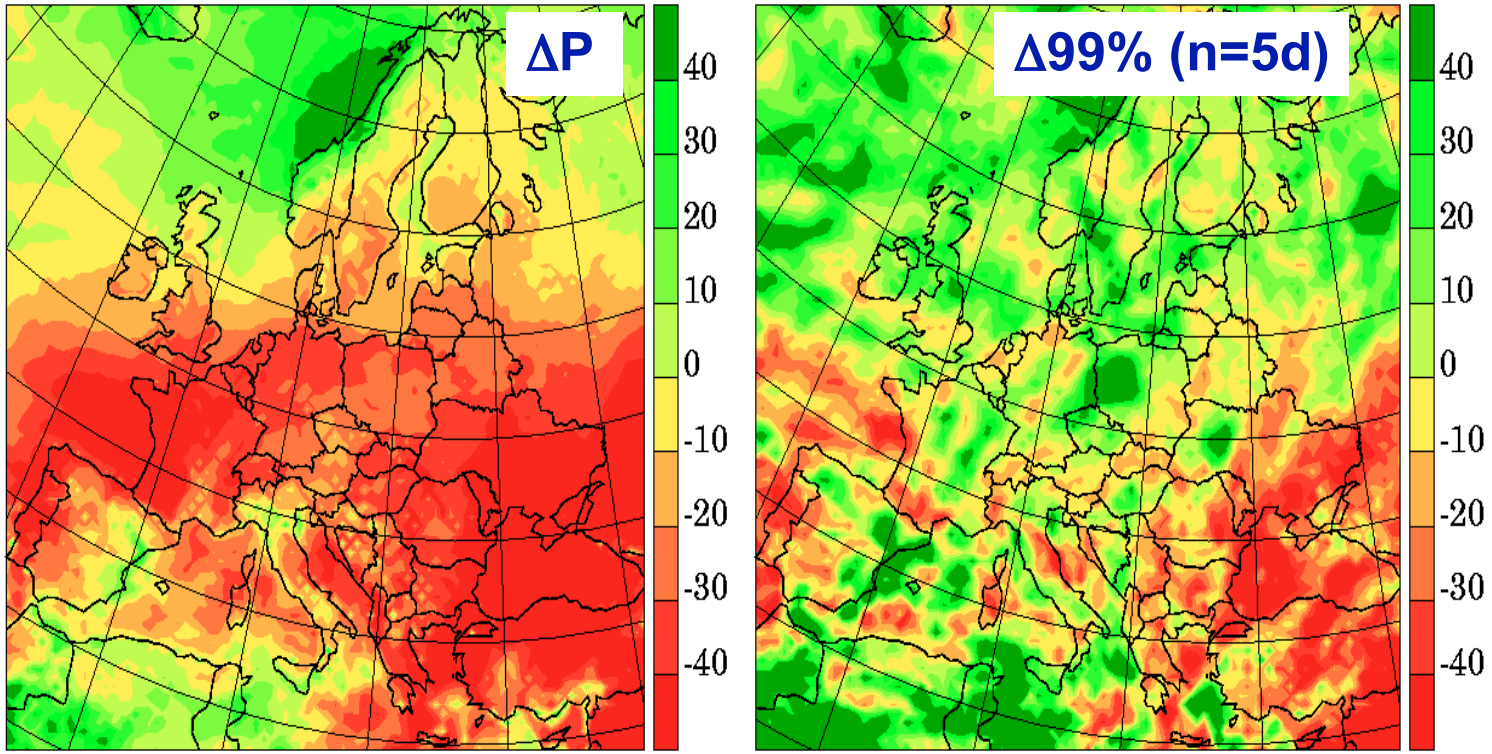
Projected changes in temperature and precipitation (2080-2099) vs (1980-1999)

Regional changes are distinct from global mean changes

(IPCC 2007)

Europe: Changes in climate extremes (precipitation)

(JAS, 2071-2100 vs 1961-1990)

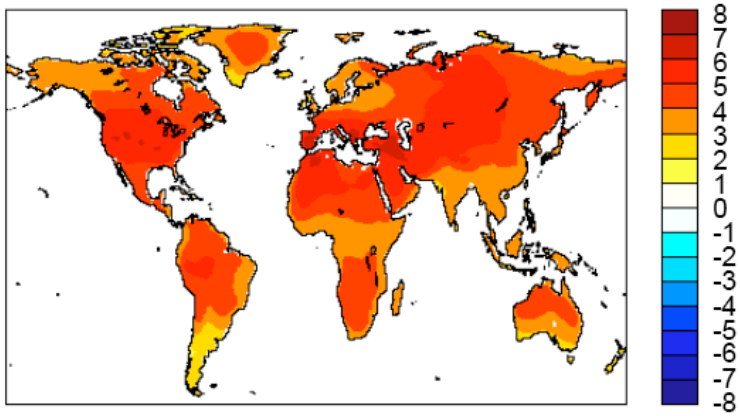


(Christensen and Christensen, 2003, Nature)

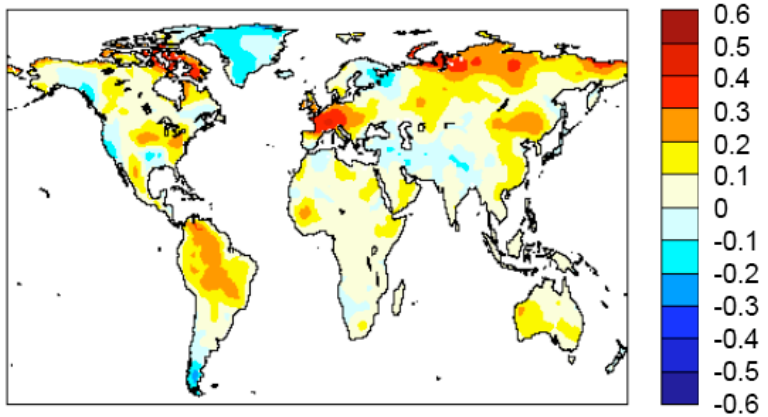
- **In Europe, climate models project both a *decrease* *of mean precipitation* (enhanced drought) and *increase* *of precipitation extremes***

Europe: Changes in climate extremes (temperature)

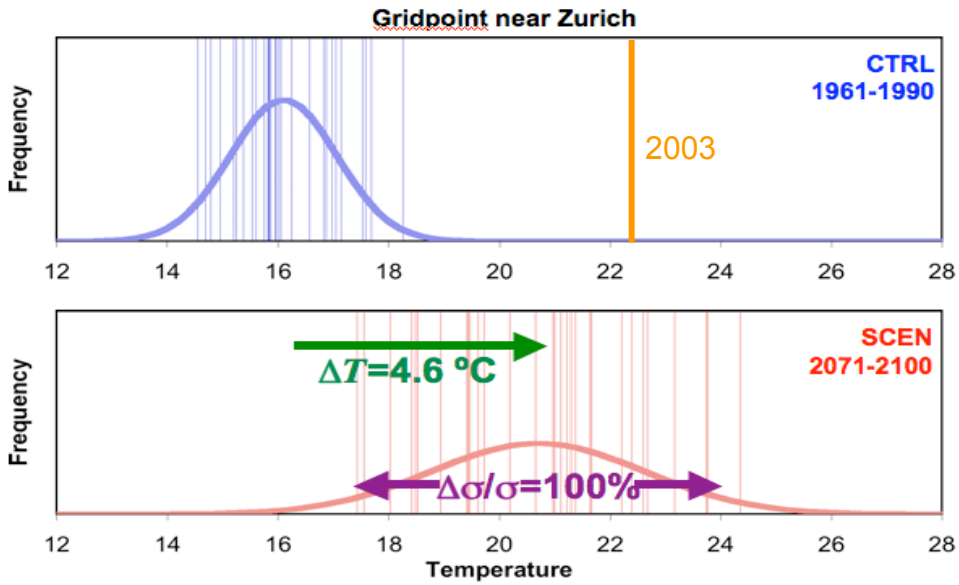
ΔT_{2M} [ºC], IPCC scenarios (A2-20c3m), JJA



Δ Stdev(T_{2M}) [ºC], IPCC scenarios (A2-20c3m), JJA

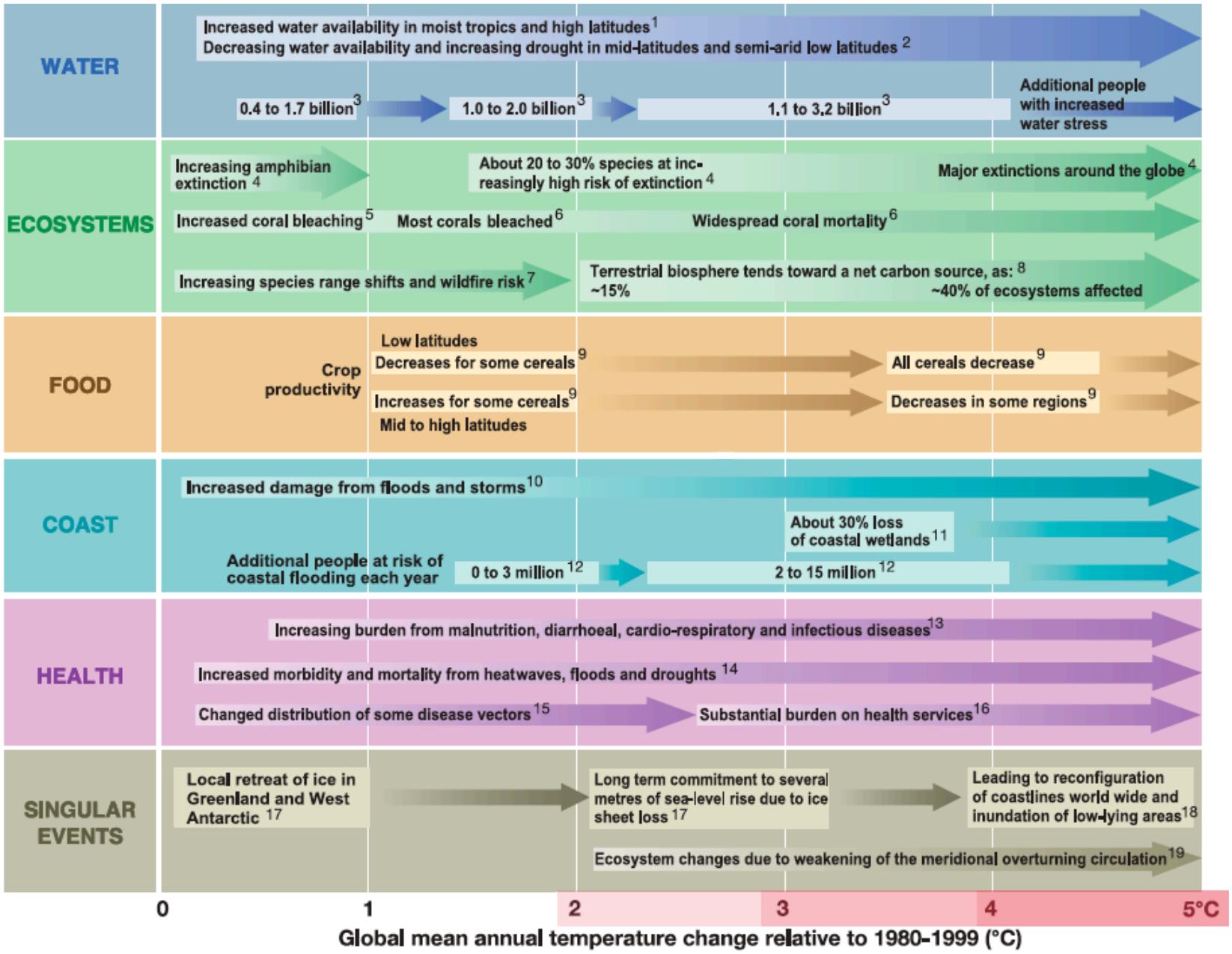


(Seneviratne et al. 2006, Nature)



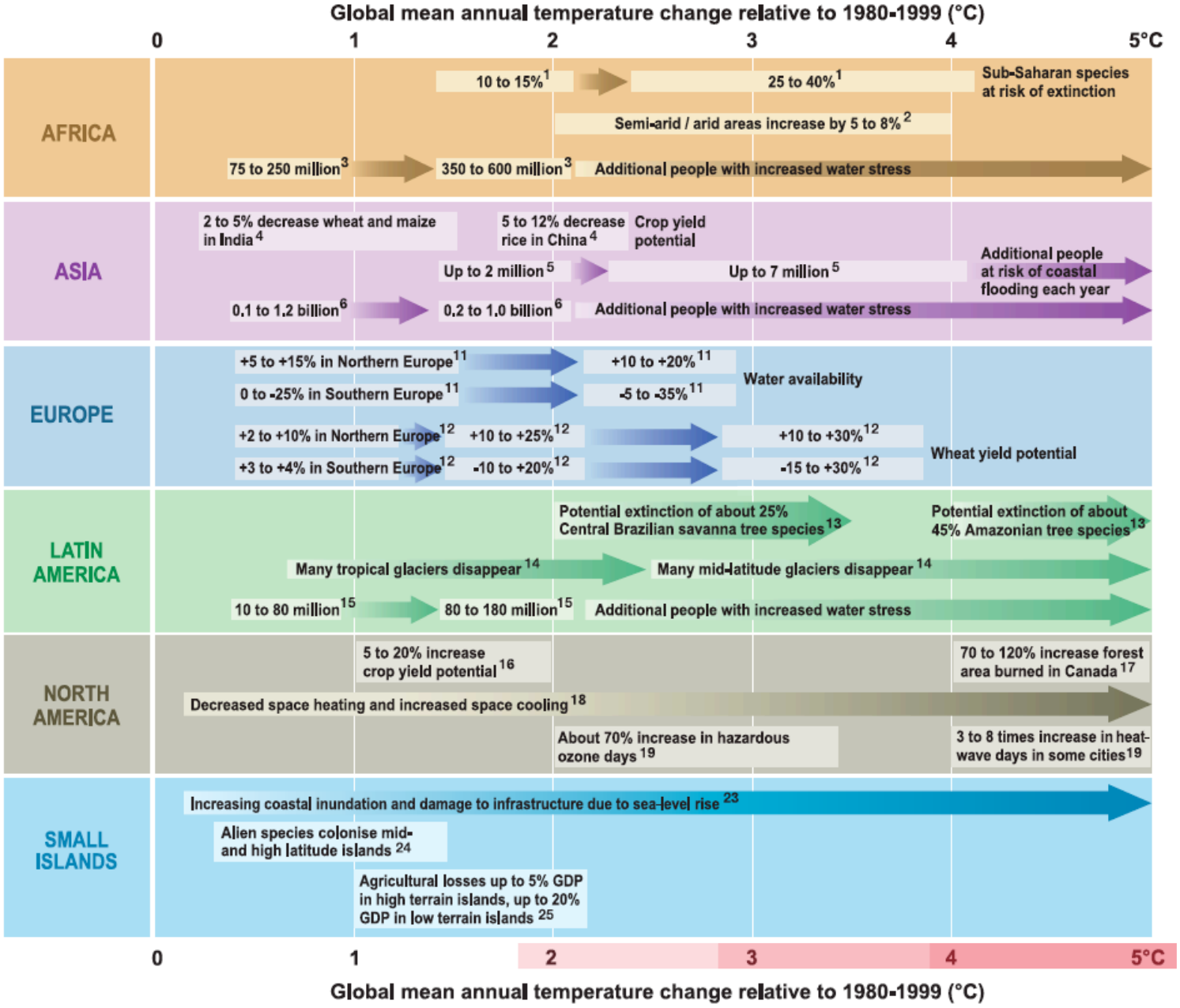
(Schär et al. 2004, Nature)

Climate change impacts



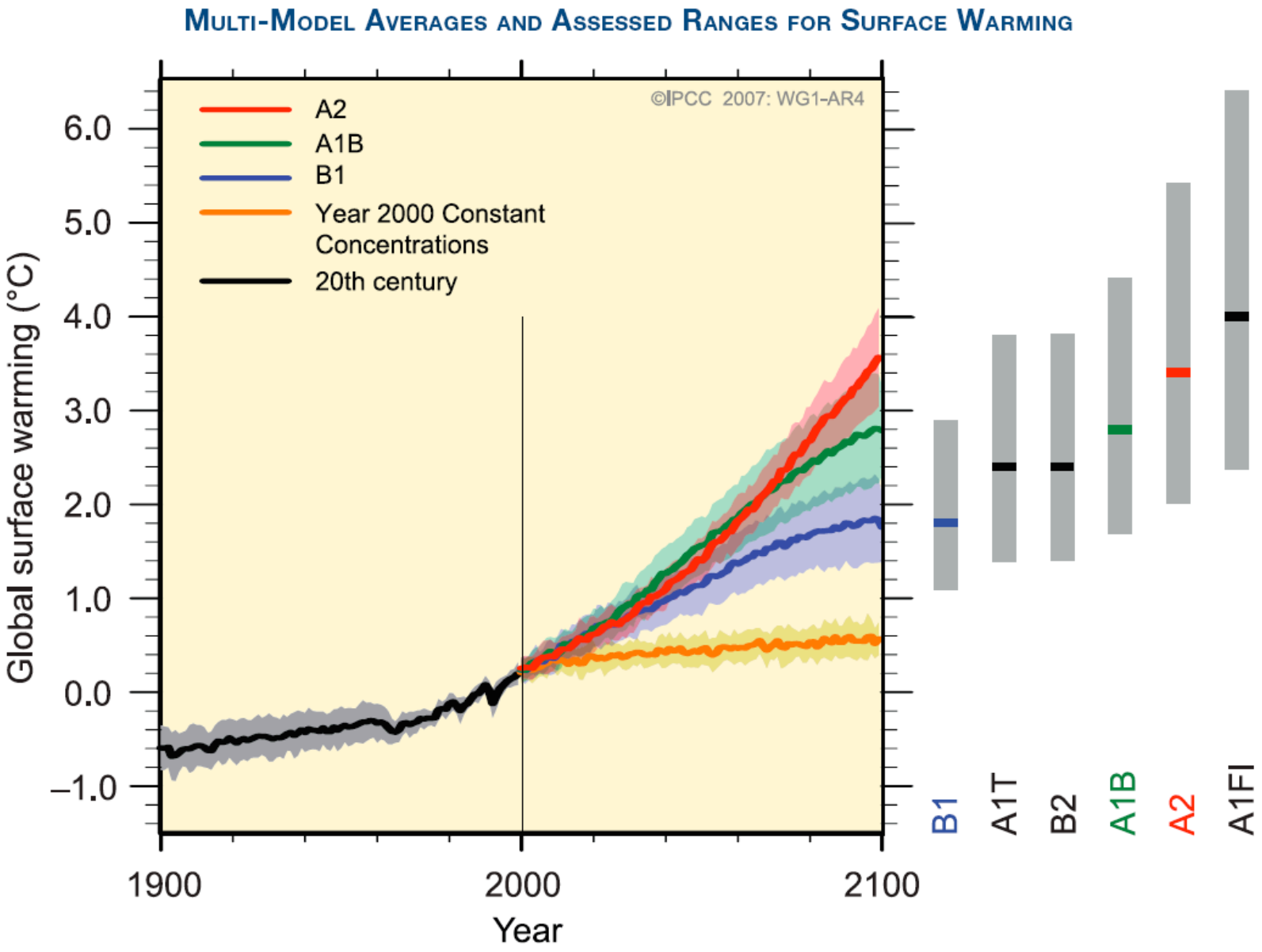
(IPCC 2007)

Climate change impacts



(IPCC 2007)

Projections of global temperature changes



(IPCC 2007)

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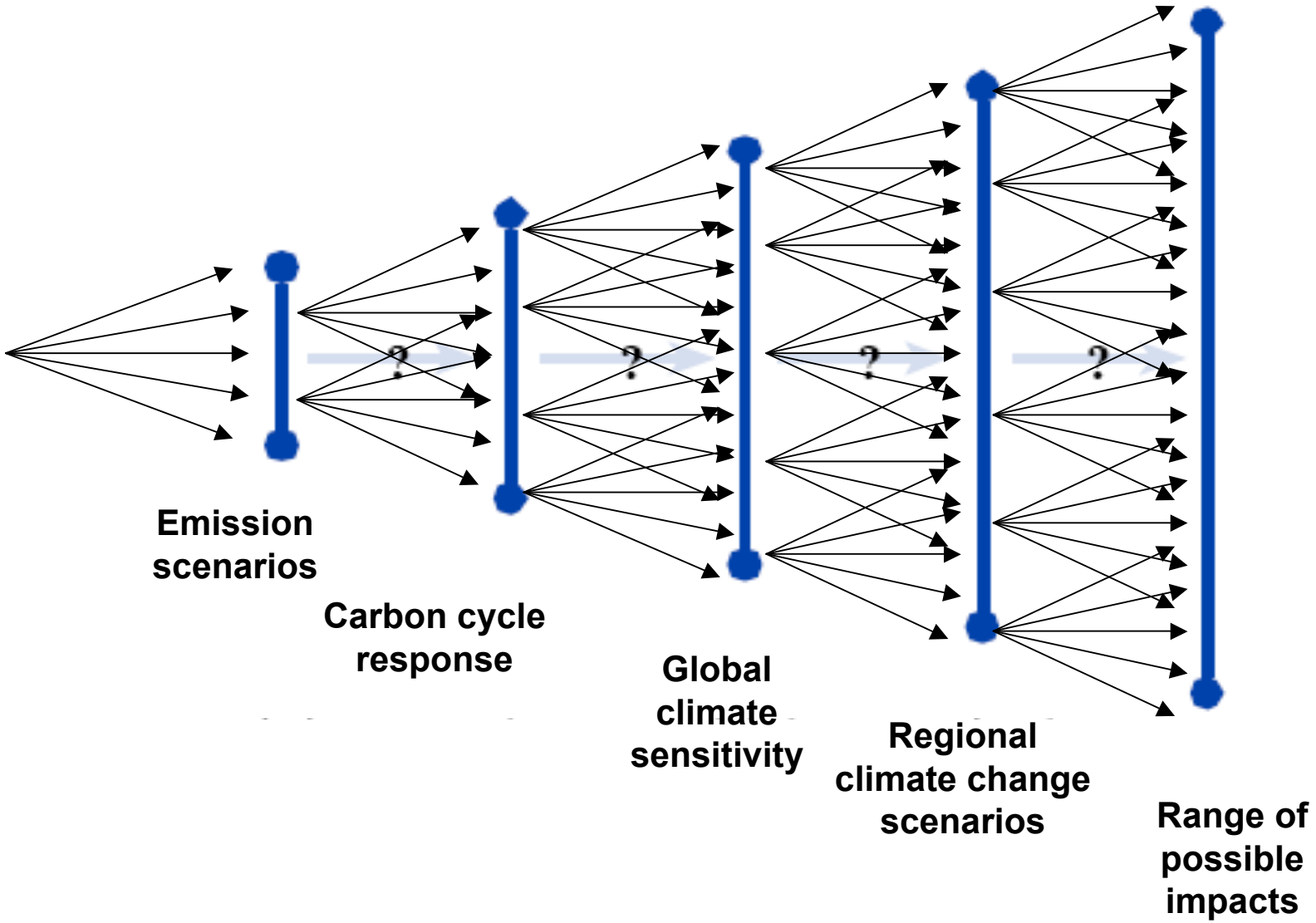
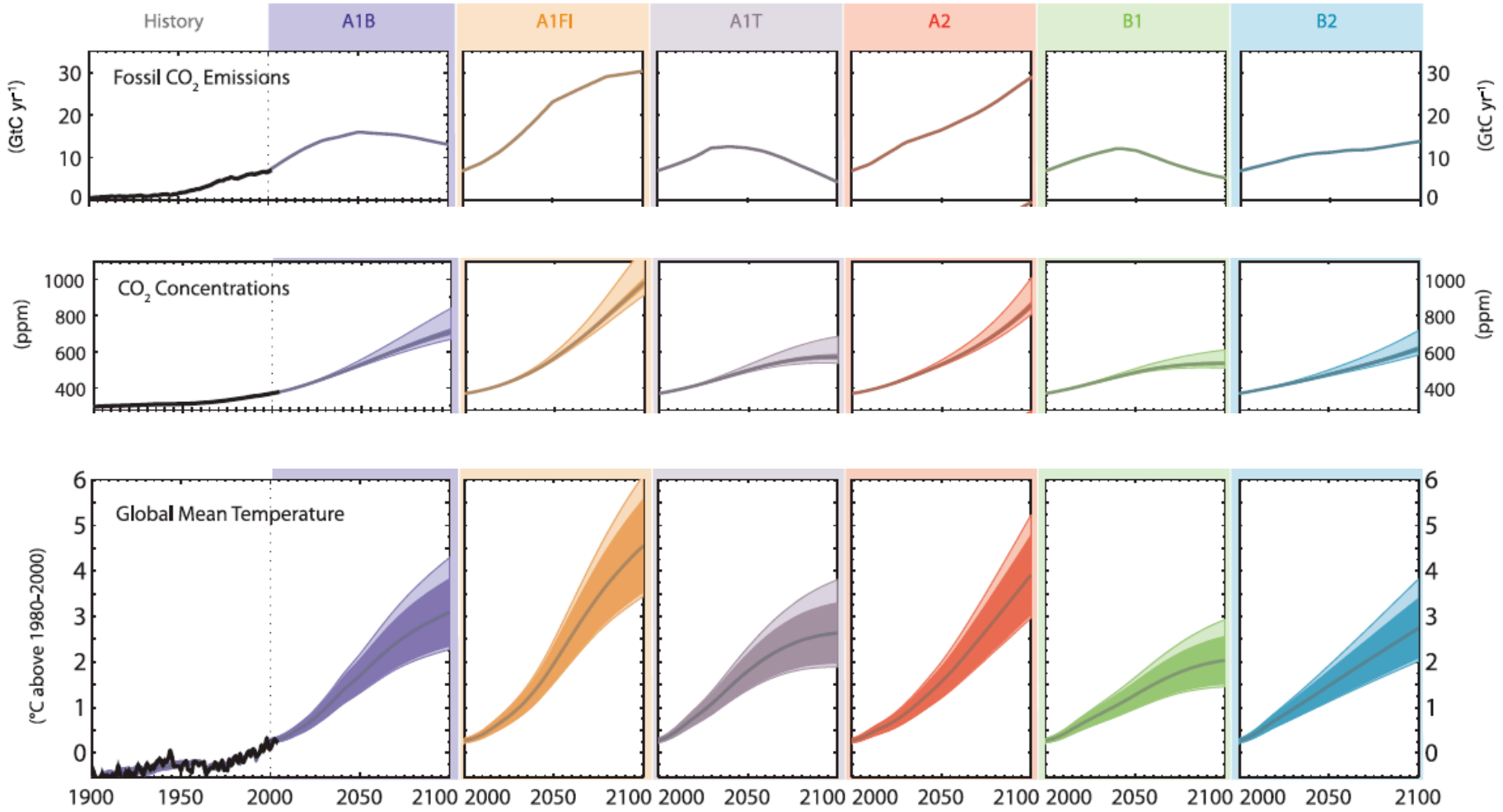
The cascade of uncertainty

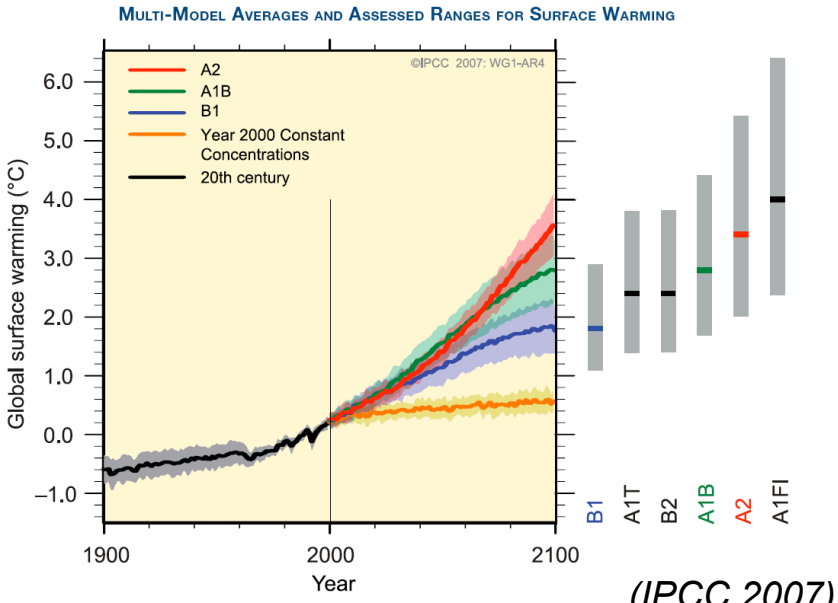


Model uncertainty

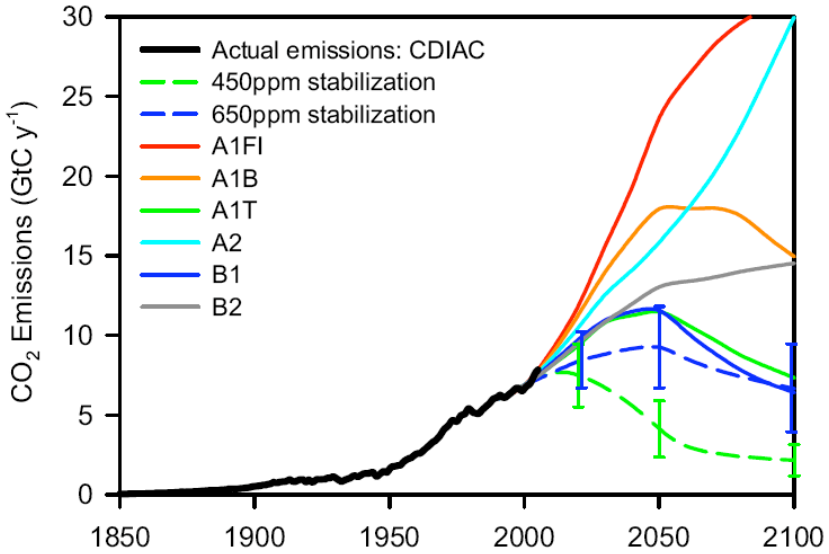


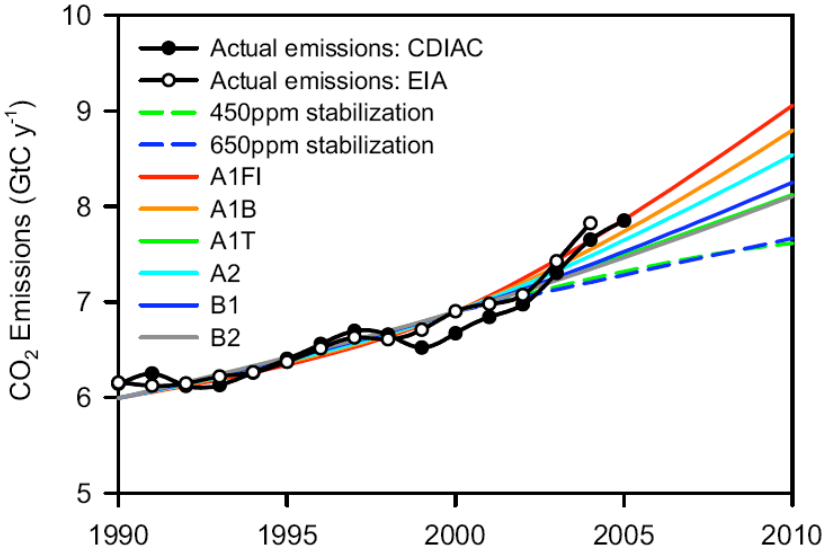
(IPCC 2007)

Range of emission scenarios



(IPCC 2007)





(Raupach et al. 2007, PNAS)

- **Current emissions follow highest IPCC scenarios!**

- **Stabilisation of CO_2 concentrations is only possible if emissions are very significantly reduced compared to present**

Trends in Europe: Underestimations in the models?

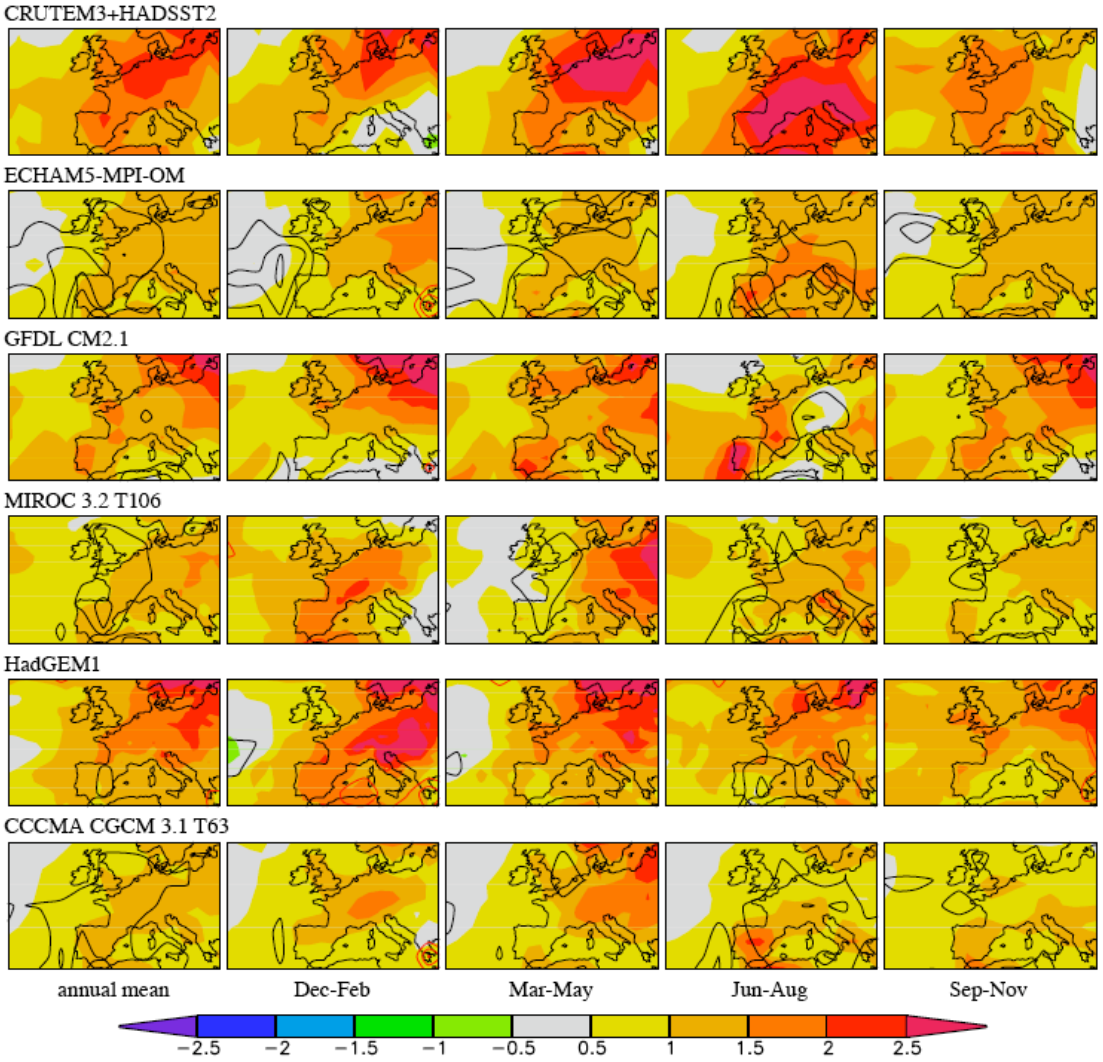


Fig. 3. The trends in temperature in western Europe as the regression against global mean temperature [K/K] in the observations and the GCMs with the most realistic mean circulation in Europe over 1950–2007. The contours denote the number of standard errors between the observed and modelled trends starting at z=2 (black) and z=−2 (red).

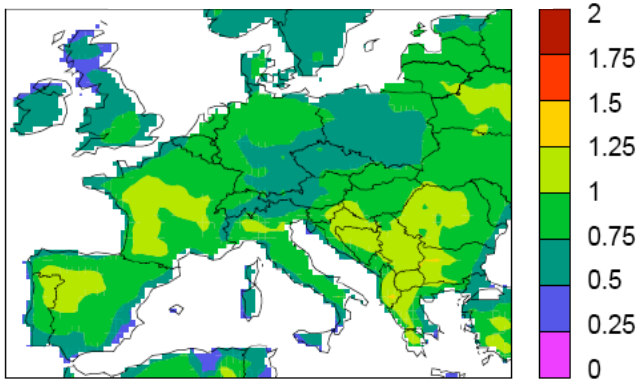
(van Oldenborgh et al., Clim. Past, 2009)

Uncertainties: Soil moisture-atmosphere feedbacks

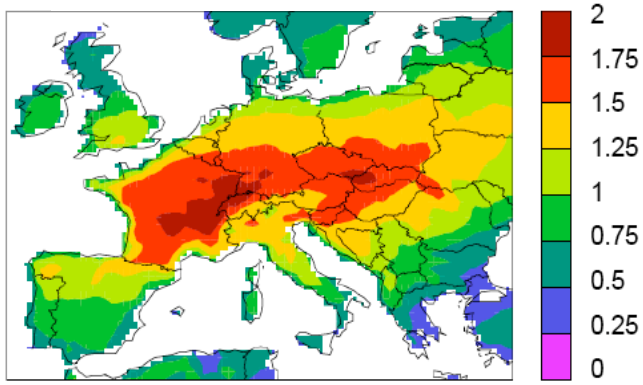
Changes in interannual variability of summer temperature

(Standard deviation of the summer (JJA) temperature)

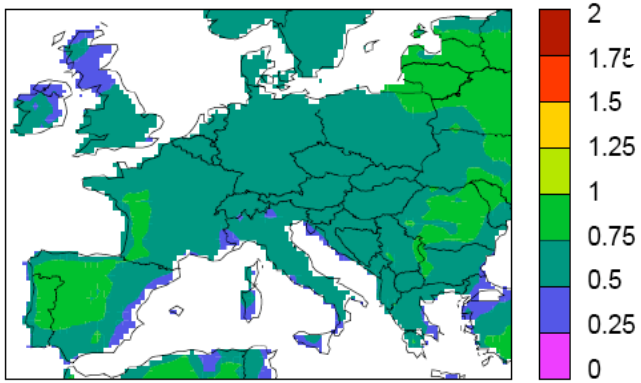
CTL (1970-1989)



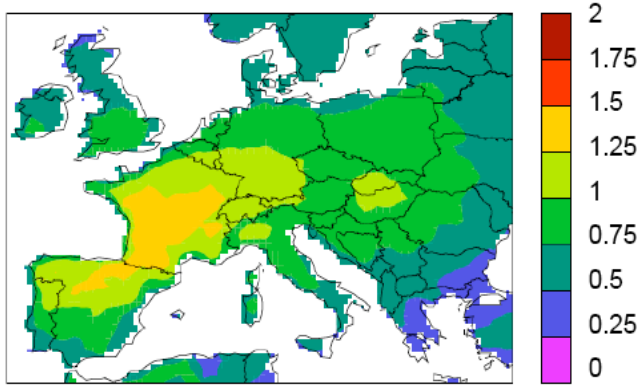
SCEN (2080-2099)



$CTL_{UNCOUPLED}$



$SCEN_{UNCOUPLED}$

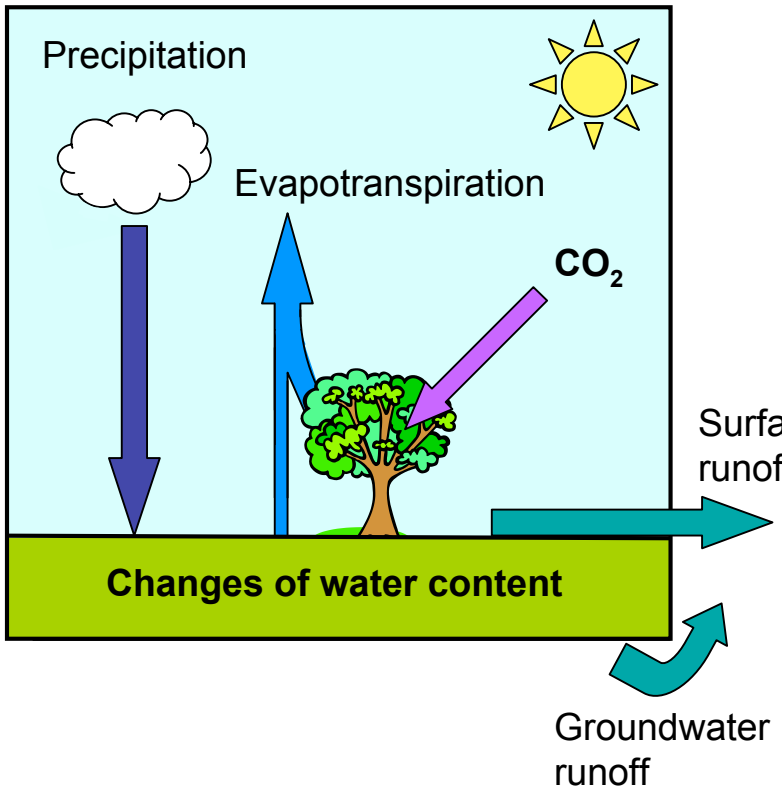


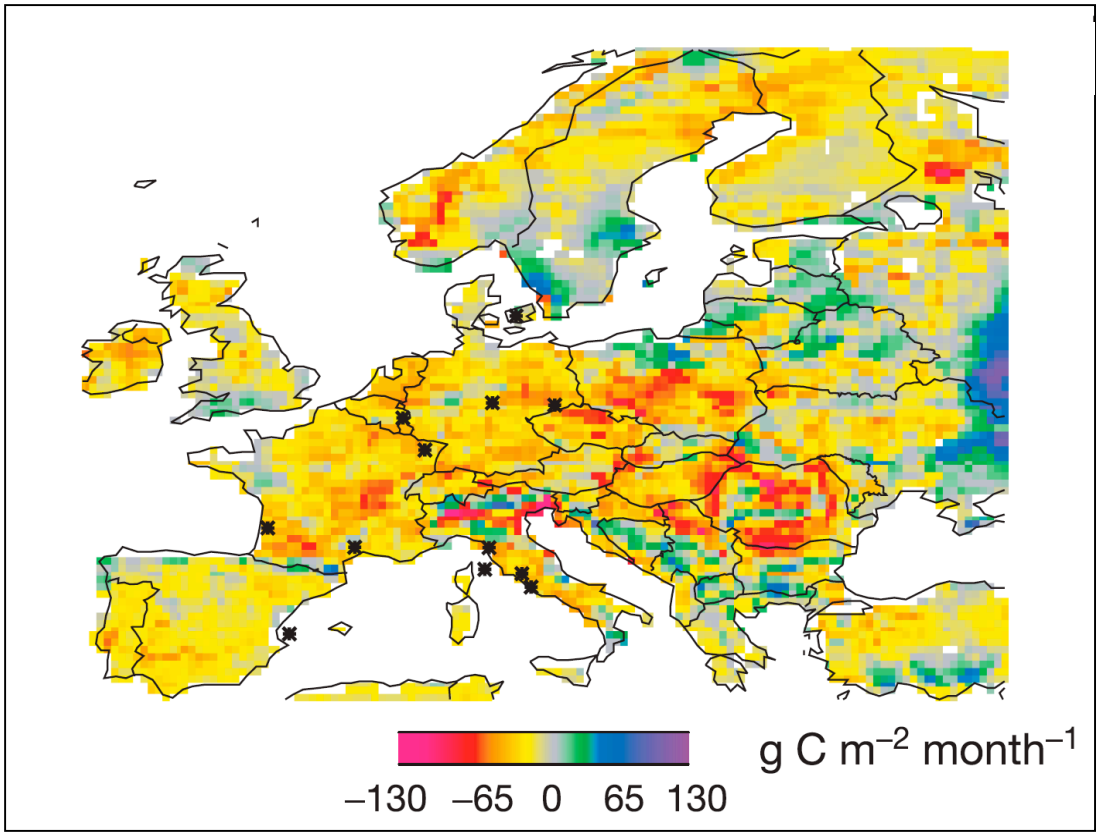
Large decrease of T° variability when effect of soil moisture is removed

(Seneviratne et al. 2006, Nature)

Soil moisture - CO_2 interactions

Europe transformed in carbon source in summer 2003 (heatwave/drought)

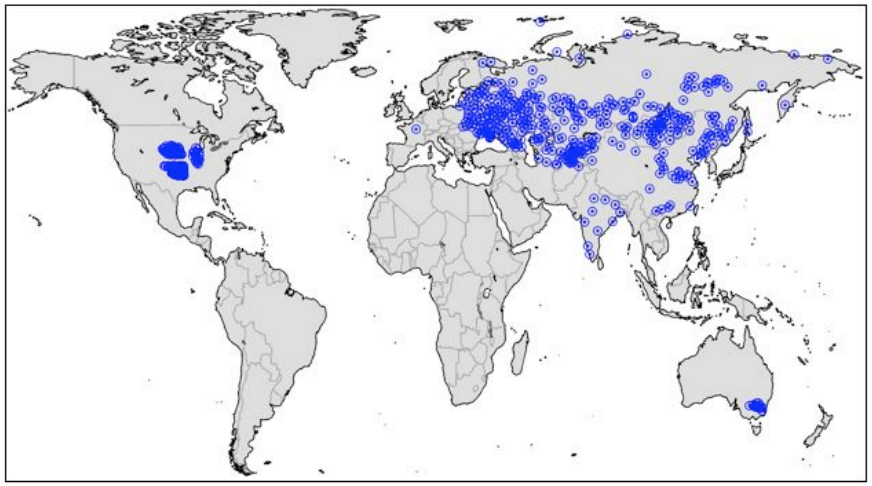




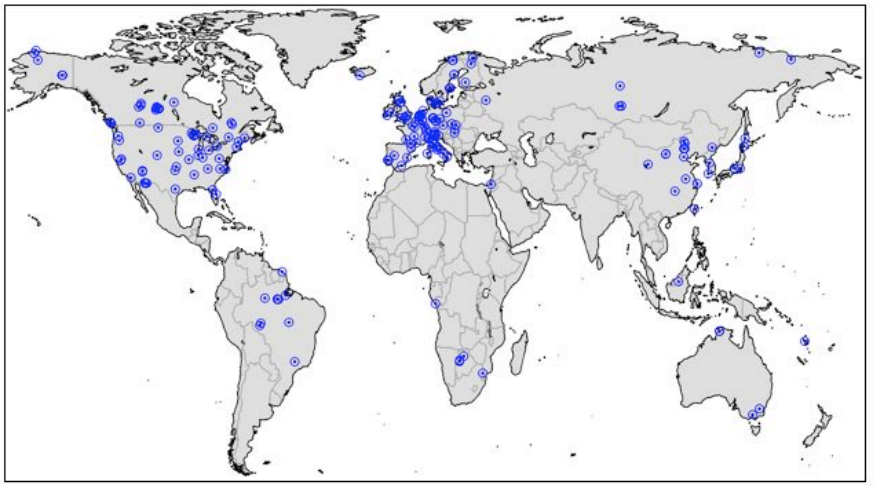
(Ciais et al., Nature, 2005)

Land observational datasets

(a) Global Soil Moisture Data Bank



(b) FLUXNET LaThuile Synthesis Dataset



(Seneviratne et al. 2009, Earth-Science Reviews, submitted)

Issue: Lack of land surface observations in many areas of the world

Difficulties to validate key feedbacks such as those associated with soil moisture content...

SwissSMEX: Swiss Soil Moisture Experiment (2008-2011; SNF)

ETH Zurich, IAC: S.I. Seneviratne (PI), H. Mittelbach, I. Lehner, A.J. Teuling, K. Schroff
Agroscope ART: J. Fuhrer (co-PI), C. Ammann
MeteoSwiss: M. Rotach (co-PI), Y-A. Roulet



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Conclusions

- **Climate change is happening** and is due for the most part to anthropogenic greenhouse gas emissions

- **Associated impacts are of strong concern** for most regions of the world; **we are committed to some level of warming**, but by reducing emissions, **we can still reduce risks of extreme climate impacts**

- **In Europe, very strong changes are projected:** increase of temperature variability and occurrence of heat waves, decrease of mean precipitation, increase of precipitation extremes; *observed changes appear to follow the higher-end scenarios*

- **Uncertainties remain** regarding realistic emission scenarios, resulting CO_2 concentrations, global climate sensitivity and in particular regional impacts; **the reduction of current scenario uncertainties is crucial for the development of adequate adaptation strategies**