Scenarios for future climate

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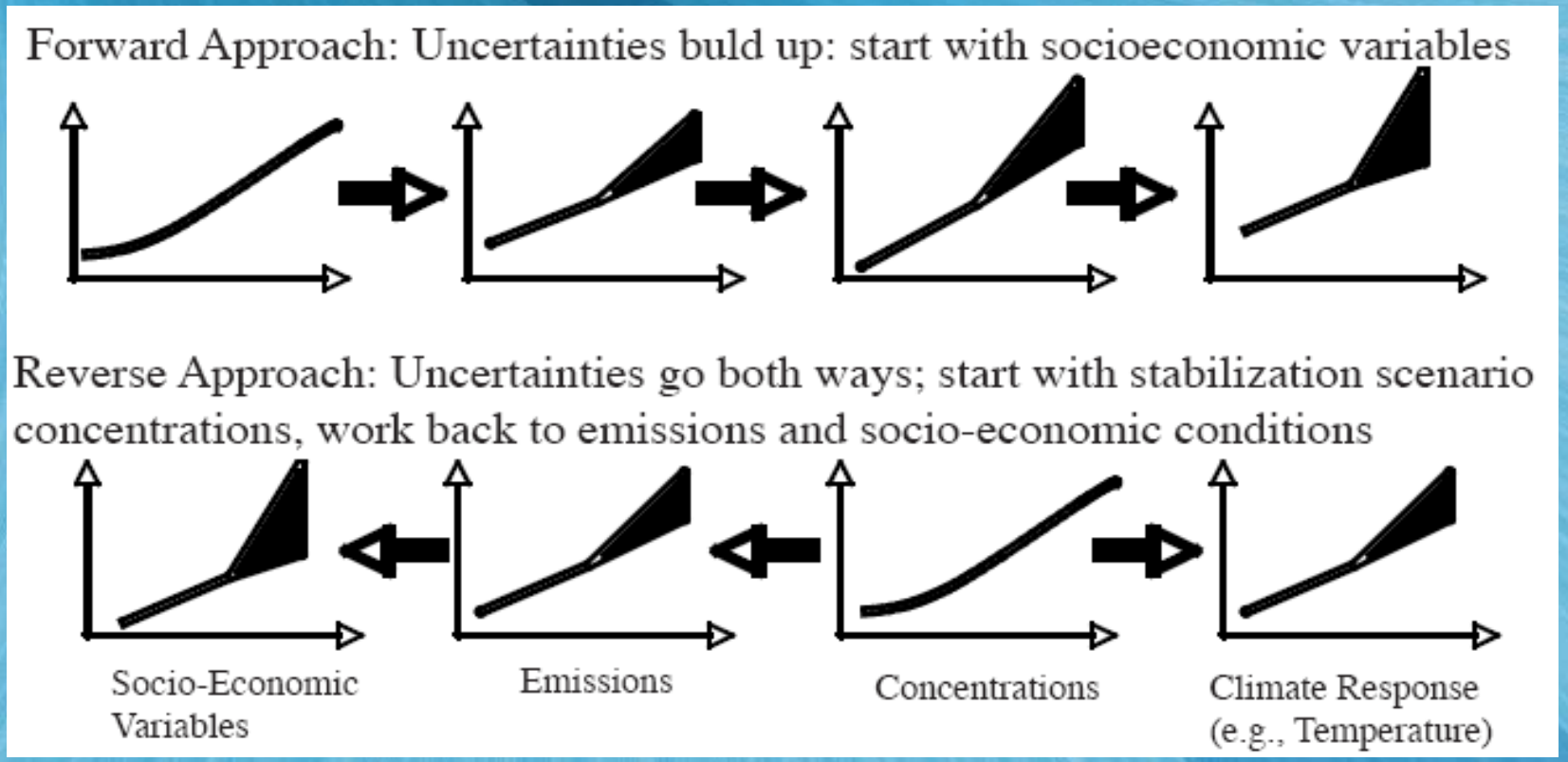
and many KNMI colleagues

Contents

- **Adaptation: How do the regional and local climate conditions change under global warming?**
  - **Why scenarios rather than probabilistic predictions and how are these constructed?**
  - **KNMI'06 scenarios for the Netherlands: local changes in 'mean' and in 'extreme' climate**
  - **The role of natural variability**

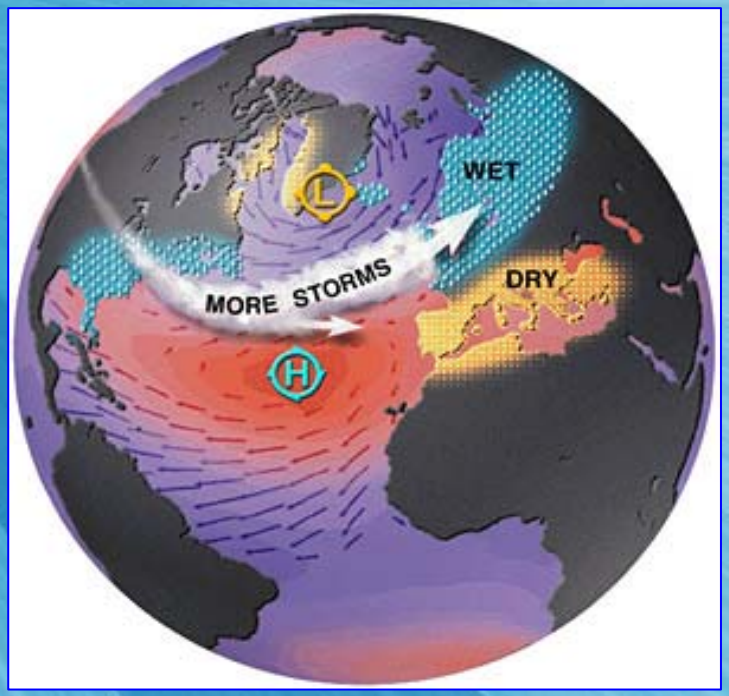
Dealing with uncertainty



Hibbard et al., 2007

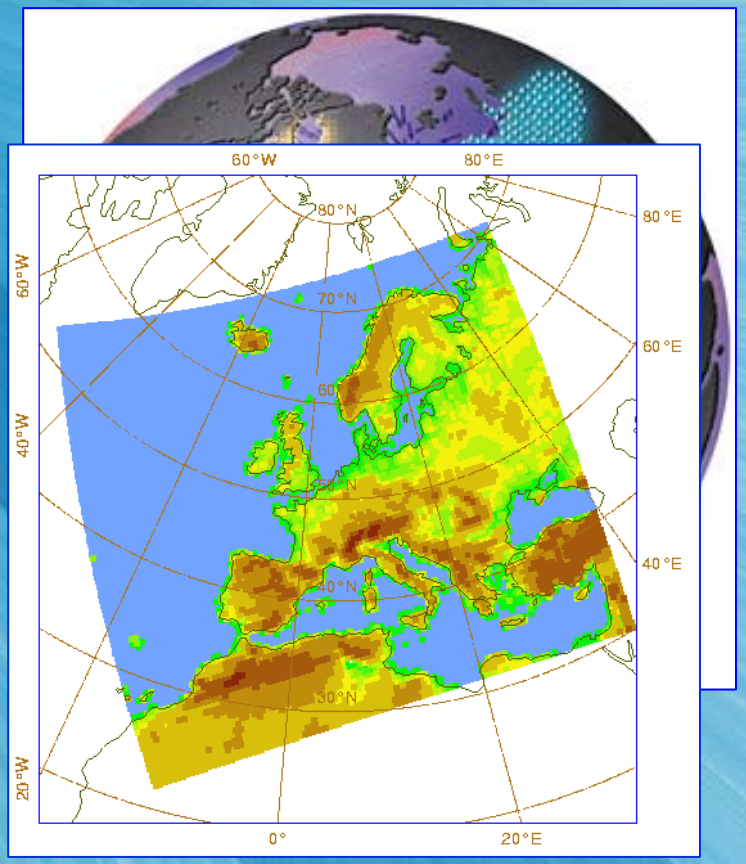
Sources of info

- **Global Climate Models (IPCC-AR4 model archive)**
  - **provide global warming, sea level rise and circulation change**



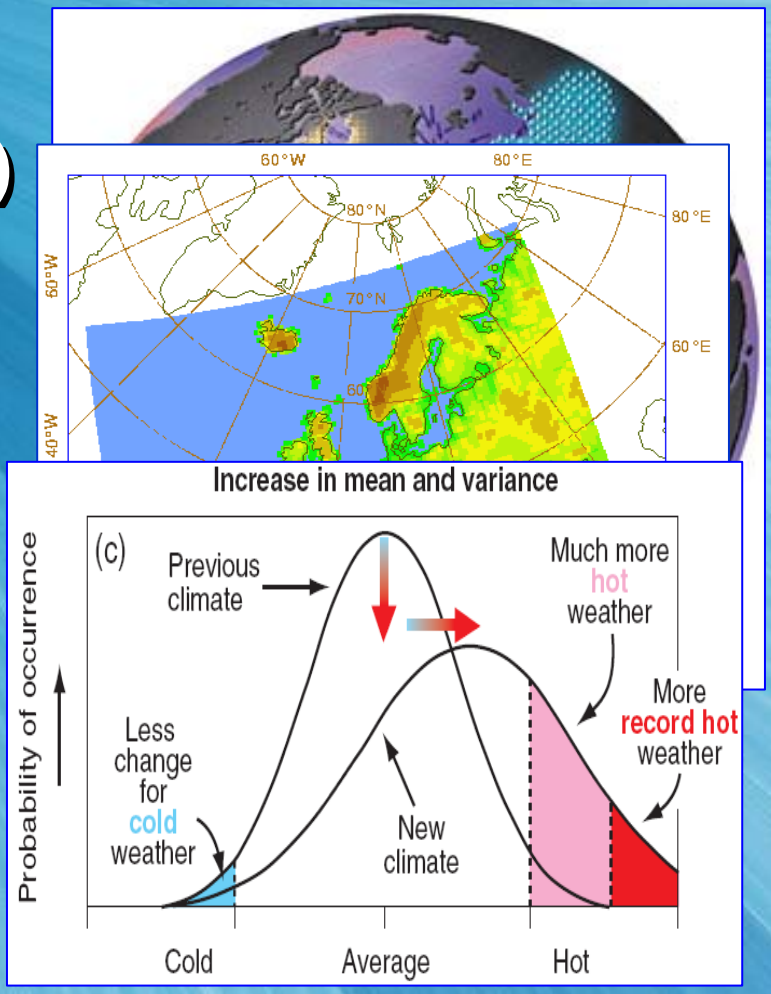
Sources of info

- **Global Climate Models (IPCC-AR4 model archive)**
- **Regional Climate Models (EU-FP projects: PRUDENCE, ENSEMBLES)**
  - **provide other variables and details for Europe**

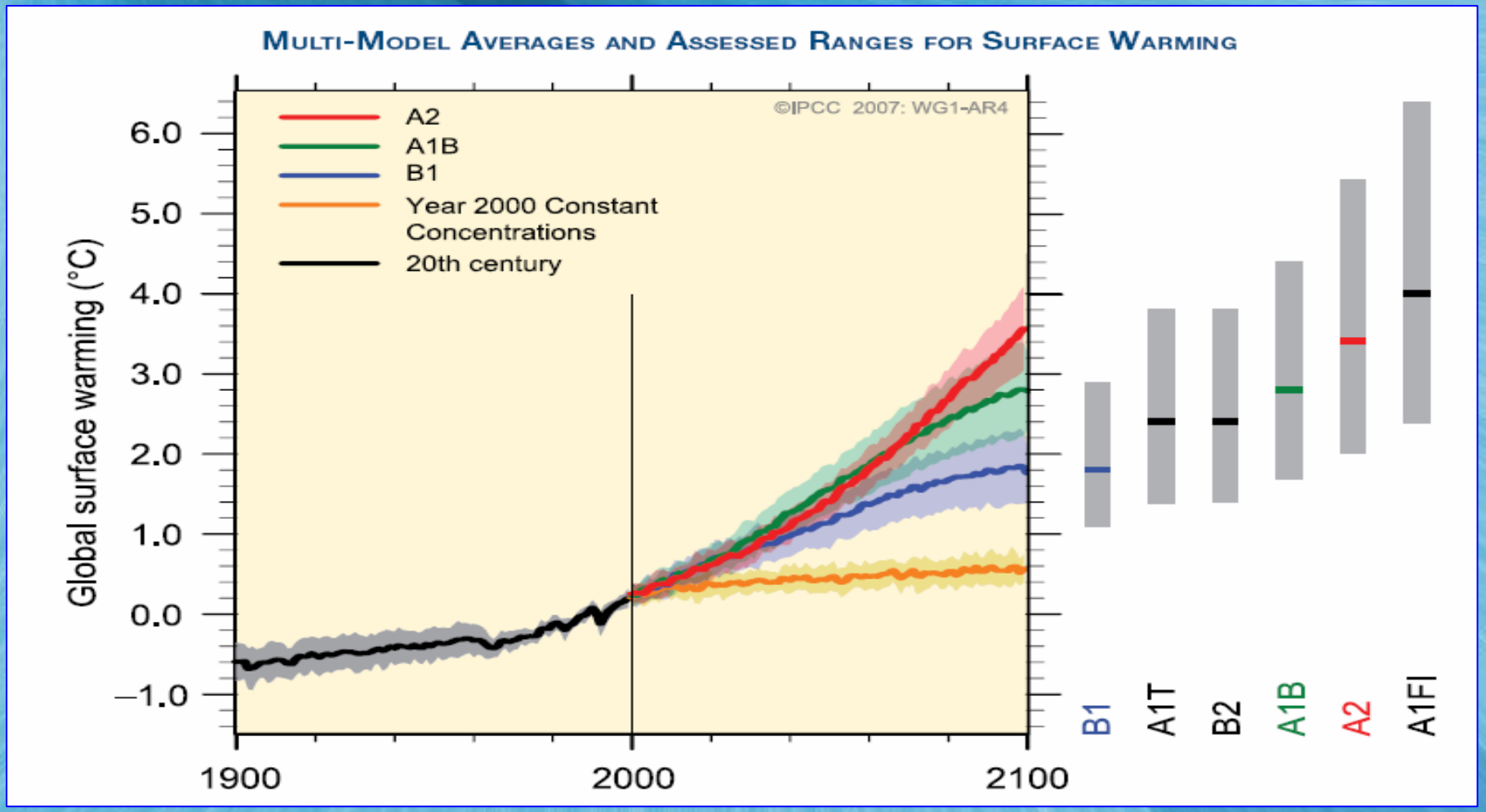


Sources of info

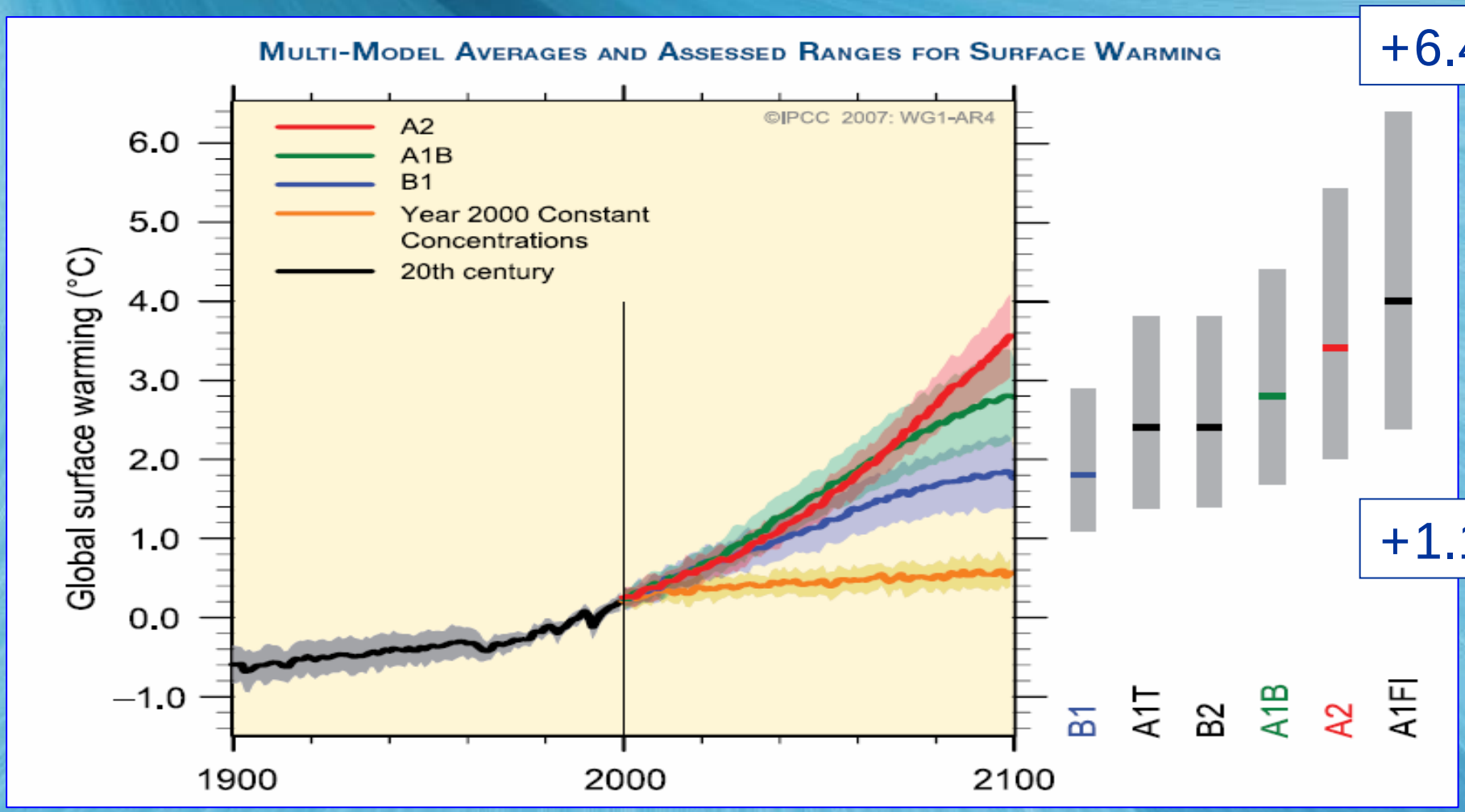
- **Global Climate Models (IPCC-AR4 model archive)**
- **Regional Climate Models (EU-FP projects: PRUDENCE, ENSEMBLES)**
- **Observations**
  - **long records needed for estimating changes in local extremes**



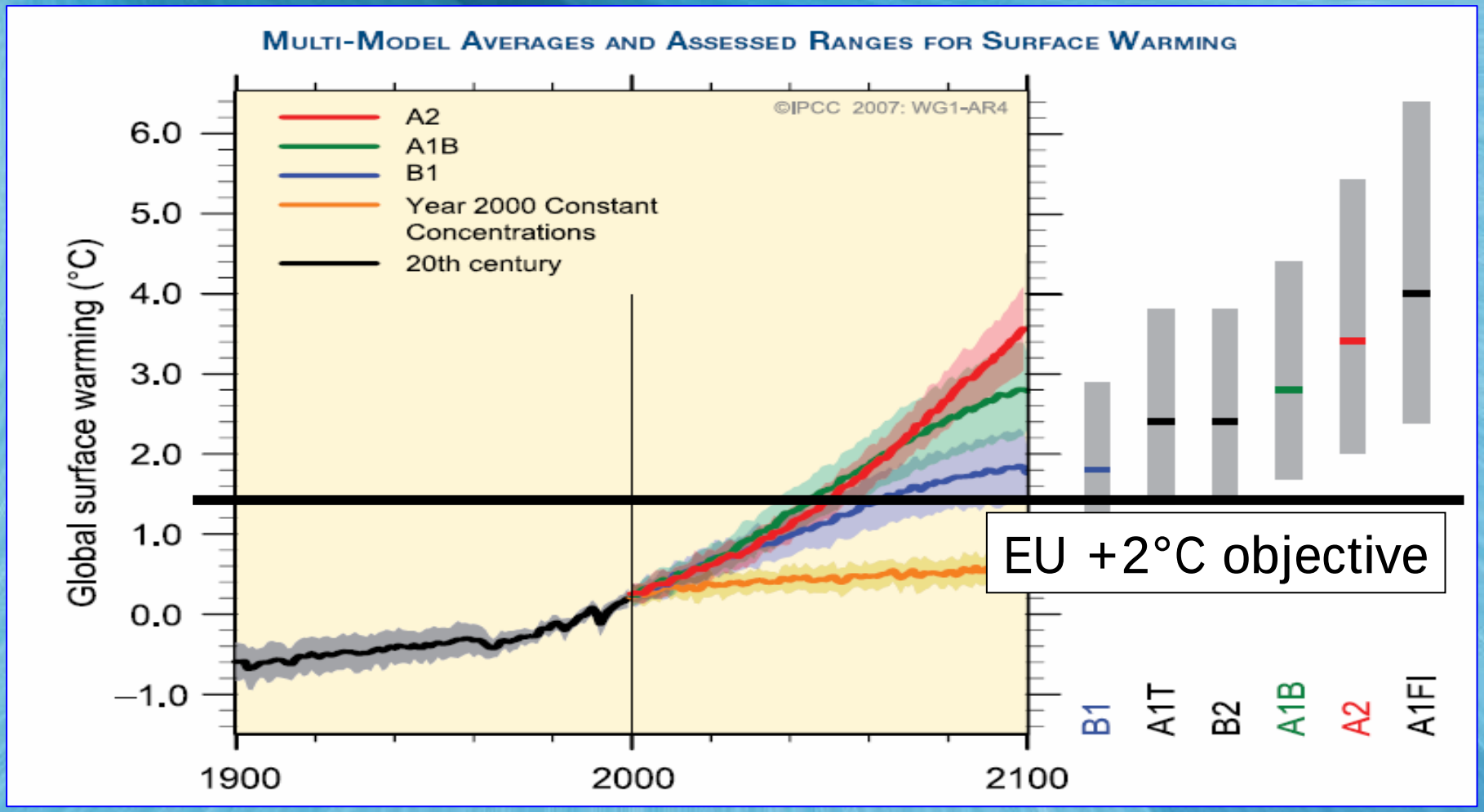
Global warming



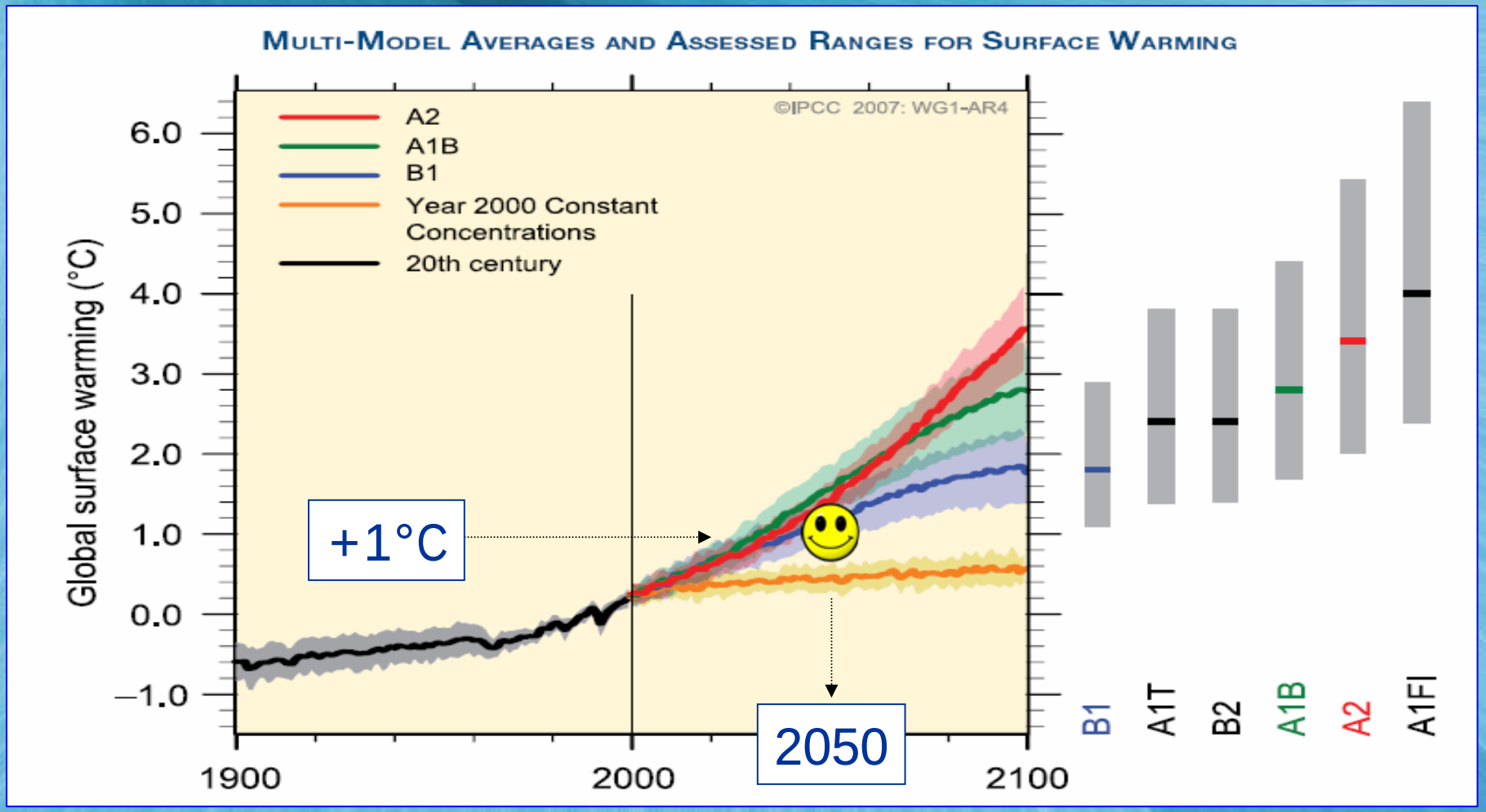
Global warming



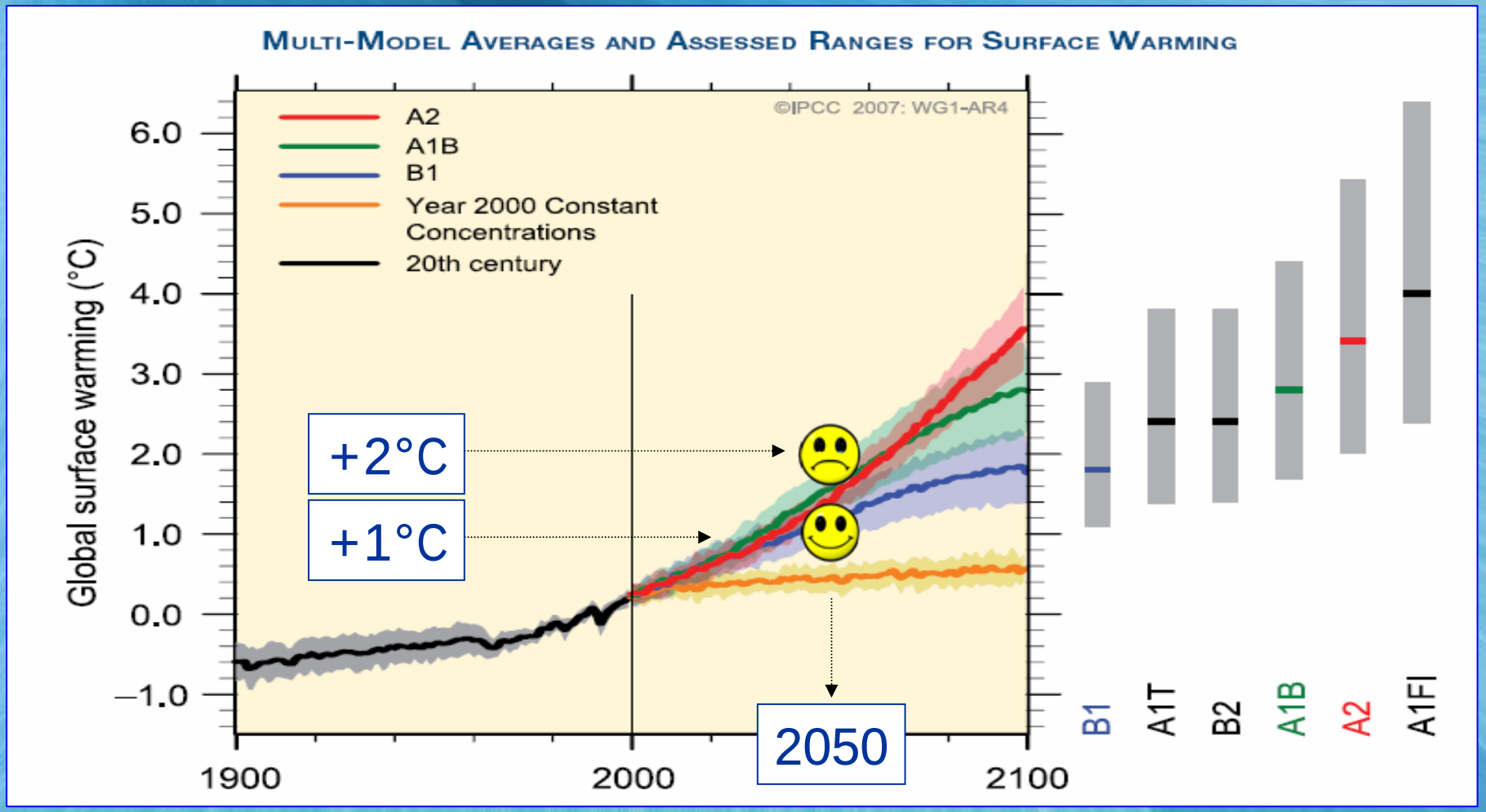
Global warming



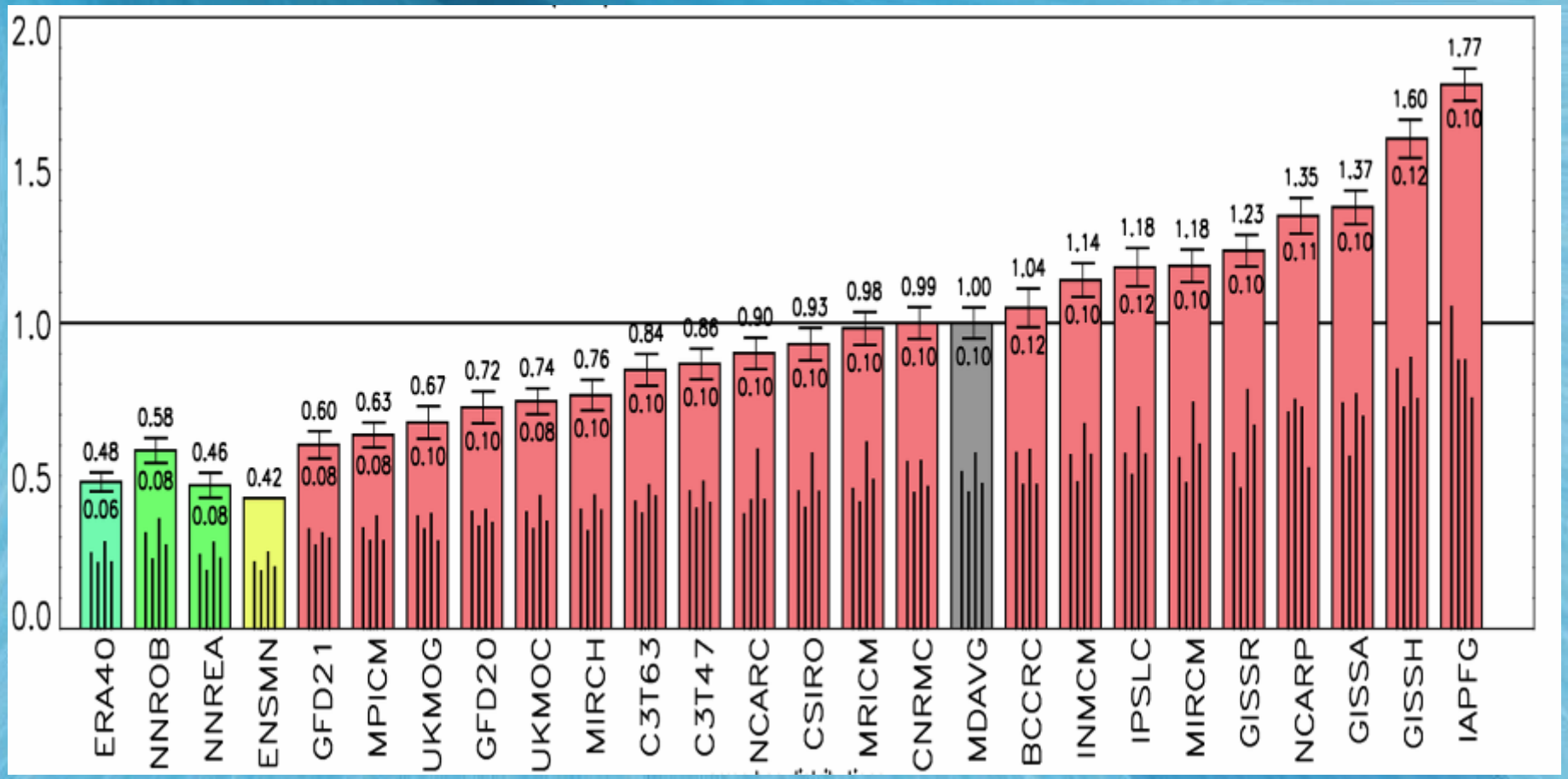
Global warming



Global warming

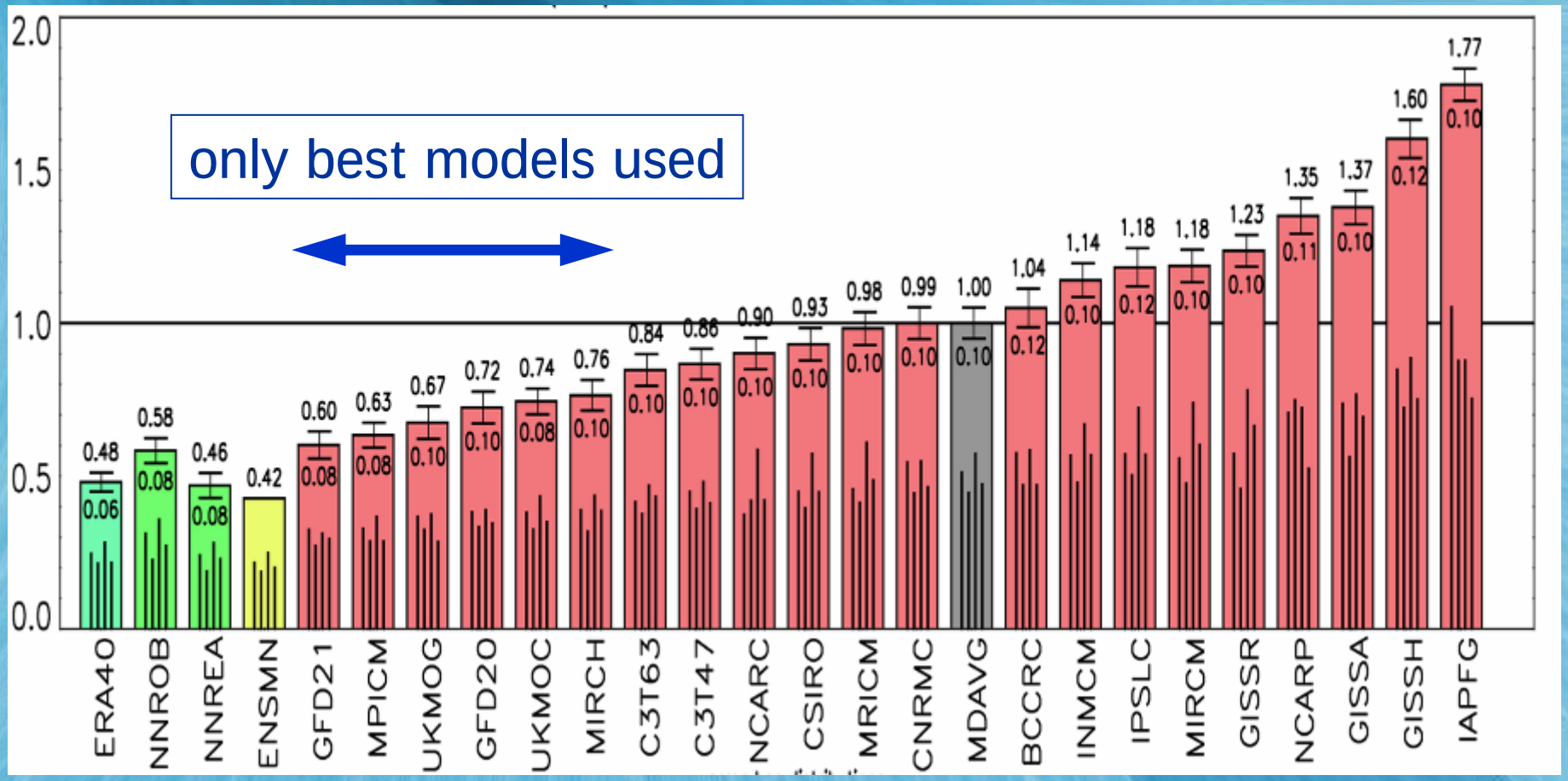


Circulation change



Reichler and Kim, Univ. of Utah

Circulation change



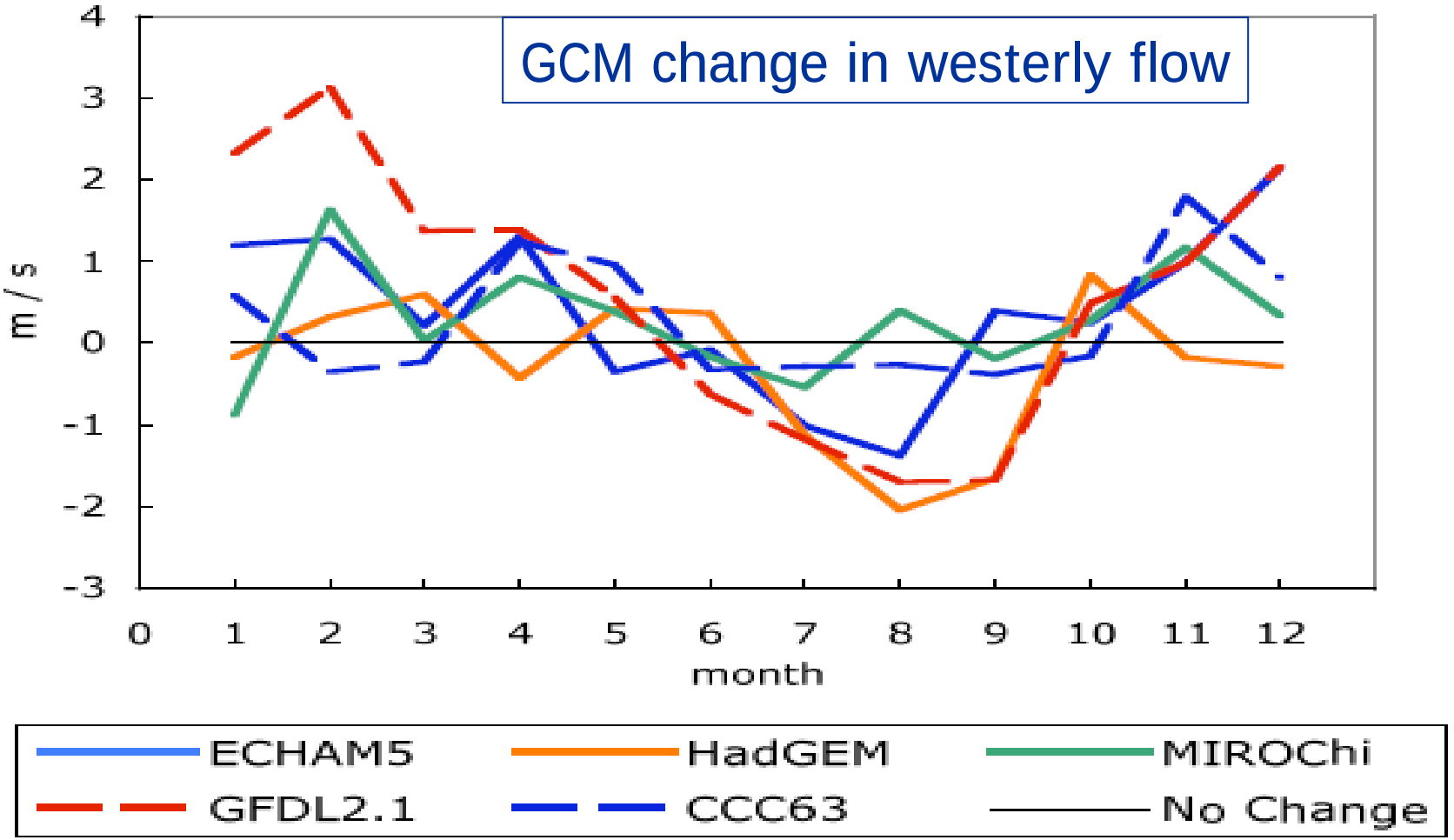
Reichler and Kim, Univ. of Utah

Circulation change

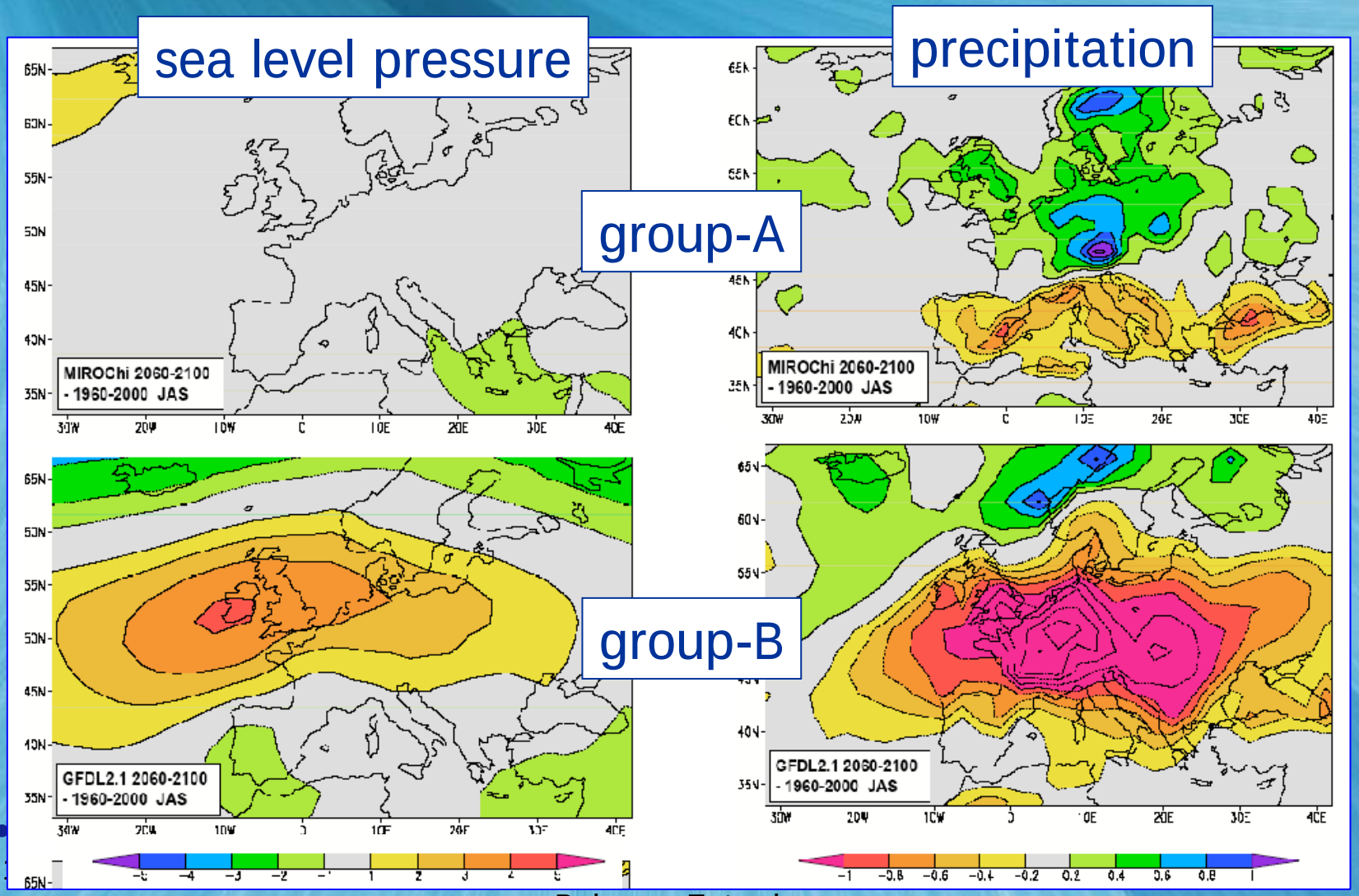
- **IPCC AR4:**

  “Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the last half-century”

Circulation change

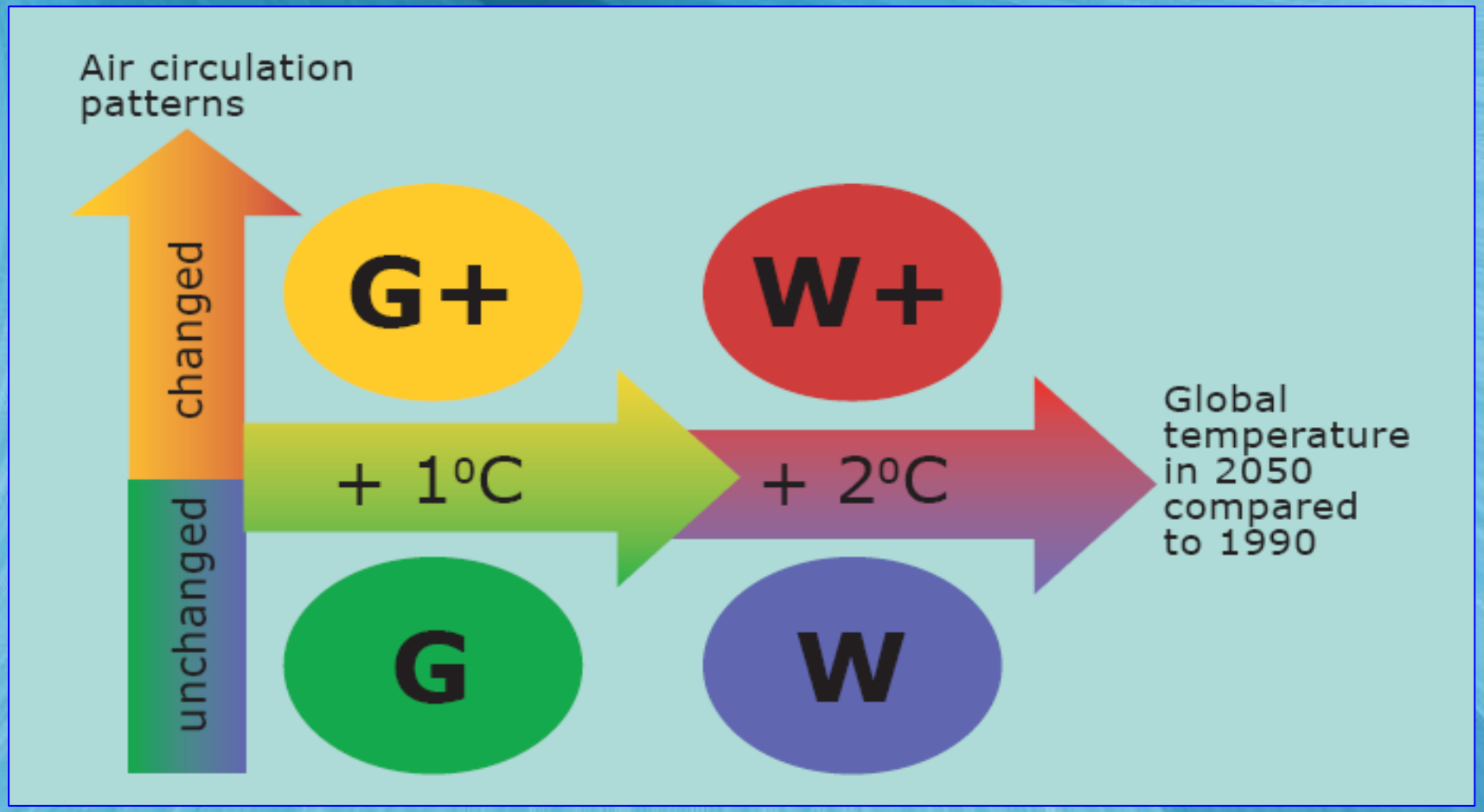


Circulation change



Van Ulden and Van Oldenborgh, 2006

Four scenarios for the Netherlands

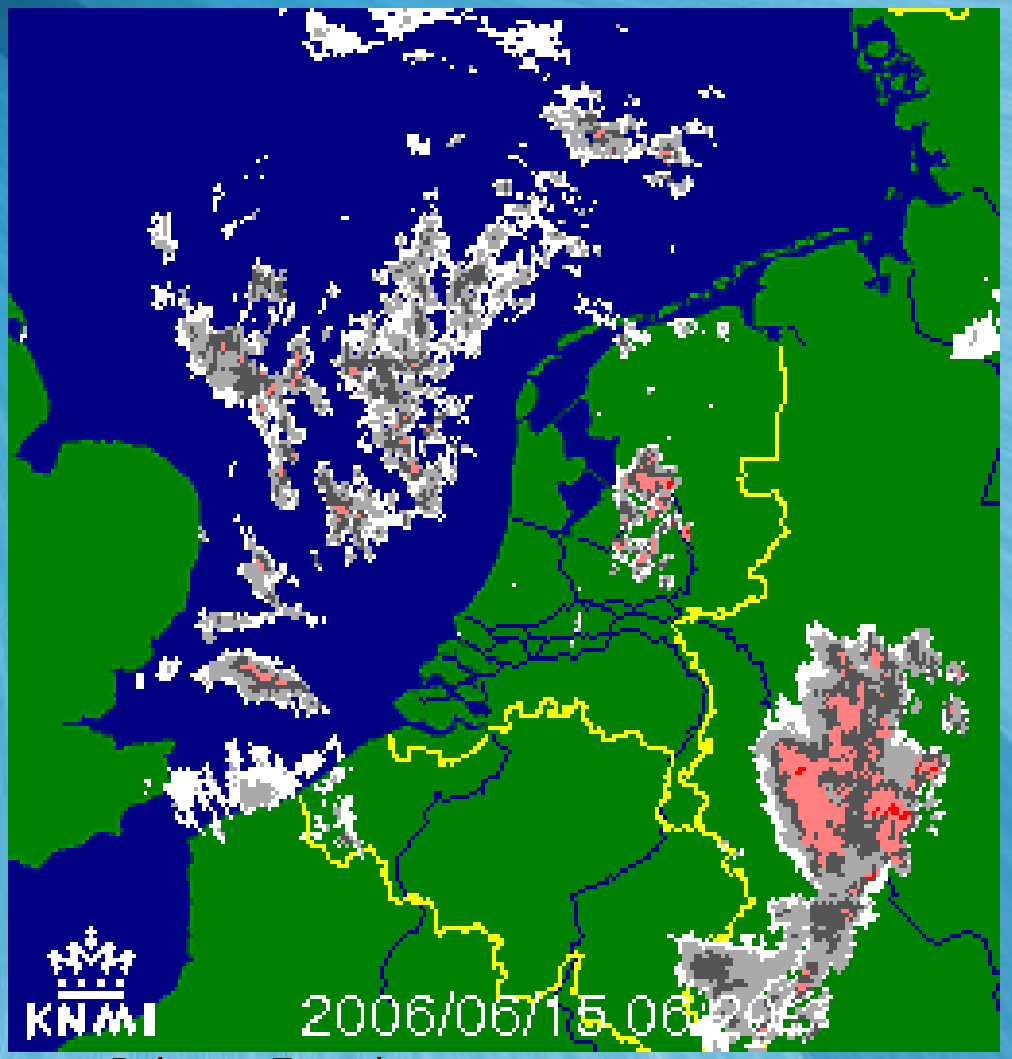


Downscaling

GCM

RCM

Observations

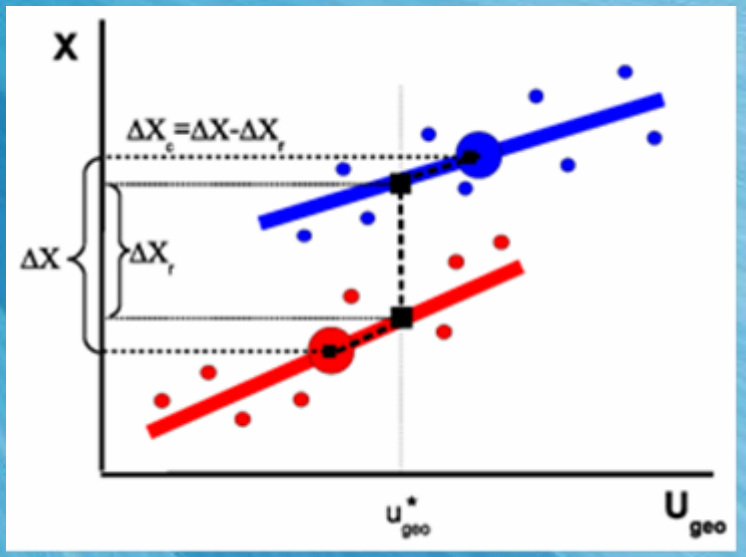


Downscaling

GCM

$$\Delta X = c_X^{circ} \Delta U_{geo} + c_X^{T} \Delta T_{glob}$$

RCM



Lenderink et al., Climate Dynamics, 2007

Local change in 2050

		G	G+	W	W+
Global temperature rise Change in air circulation patterns		+1°C no	+1°C yes	+2°C no	+2°C yes
Winter [3]	average temperature	+0.9°C	+1.1°C	+1.8°C	+2.3°C
	coldest winter day per year	+1.0°C	+1.5°C	+2.1°C	+2.9°C
	average precipitation amount	+4%	+7%	+7%	+14%
	number of wet days (≥ 0.1 mm)	0%	+1%	0%	+2%
	10-day precipitation sum exceeded once in 10 years	+4%	+6%	+8%	+12%
	maximum average daily wind speed per year	0%	+2%	-1%	+4%
Summer [3]	average temperature	+0.9°C	+1.4°C	+1.7°C	+2.8°C
	warmest summer day per year	+1.0°C	+1.9°C	+2.1°C	+3.8°C
	average precipitation amount	+3%	-10%	+6%	-19%
	number of wet days (≥ 0.1 mm)	-2%	-10%	-3%	-19%
	daily precipitation sum exceeded once in 10 years	+13%	+5%	+27%	+10%
	potential evaporation	+3%	+8%	+7%	+15%
Sea level	absolute increase	15-25 cm	15-25 cm	20-35 cm	20-35 cm

Local change in 2050

		G	G+	W	W+
Global temperature rise		+1°C	+1°C	+2°C	+2°C
Change in air circulation patterns		no	yes	no	yes
Winter [3]	average temperature	+0.9°C	+1.1°C	+1.8°C	+2.3°C
	coldest winter day per year	+1.0°C	+1.5°C	+2.1°C	+2.9°C
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	daily precipitation sum exceeded once in 10 years	+13%	+5%	+27%	+10%
	potential evaporation	+3%	+8%	+7%	+15%
Sea level	absolute increase	15-25 cm	15-25 cm	20-35 cm	20-35 cm

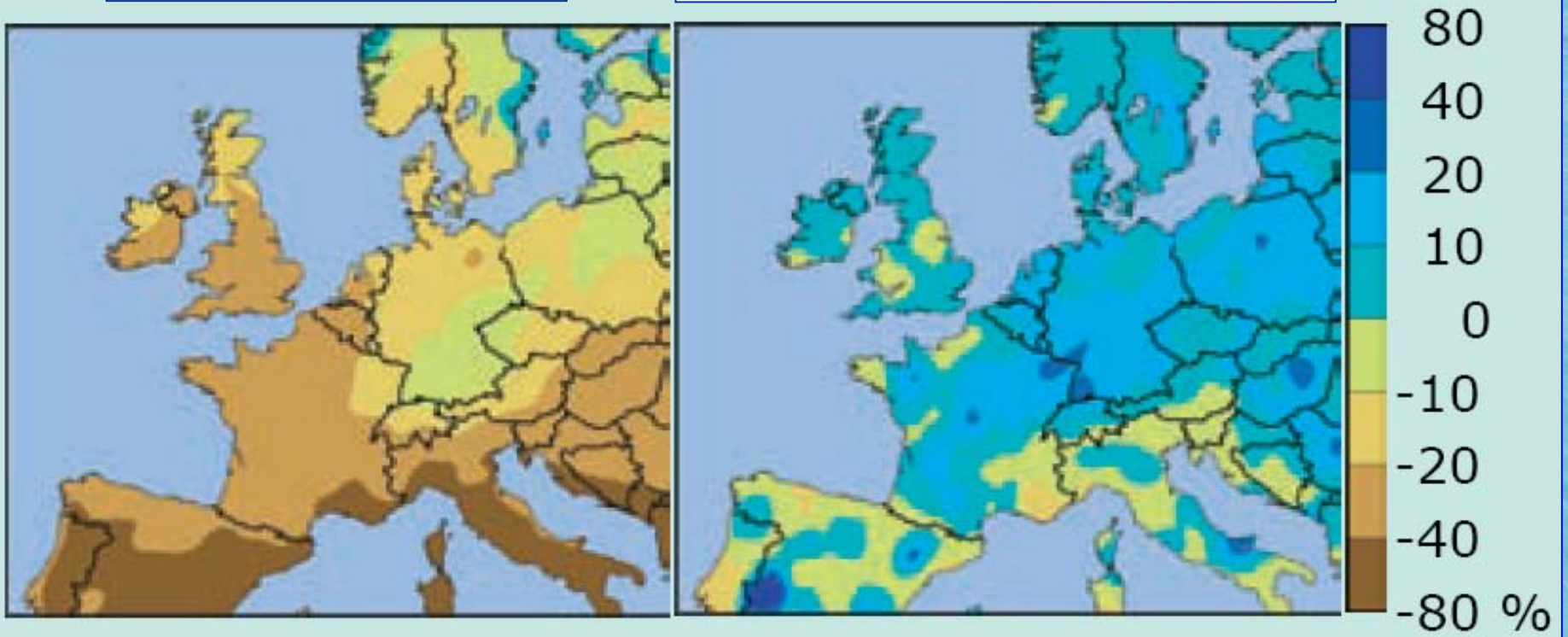
change in temperature extremes stronger than change in mean

... in particular for the + scenarios (with change in circulation)

Summer rainfall

decrease in mean

increase in daily extremes



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Sea level	absolute increase	15-25 cm	15-25 cm	20-35 cm	20-35 cm

only after 2050 rate of warming important for sea level rise

Table 7-5: Components for mean sea level rise (cm) for two time periods (2050 and 2100) and two temperature scenarios (low and high). Listed are the low and high values of a range determined by 10%/90% confidence limits for all components.

Component	low scenario		high scenario	
year (ΔT_G since 1990)	2050 (+1 °C)	2100 (+2 °C)	2050 (+2 °C)	2100 (+4 °C)
Observed 1990 – 2005	3.0 – 5.0	3.0 – 5.0	3.0 – 5.0	3.0 – 5.0
total thermosteric from 2005	6.8 – 12.5	20.2 – 32.7	8.9 – 19.3	24.7 – 45.5
global mean thermosteric since 2005 (Table 7-2)	6.5 – 10.6	20.6 – 29.5	9.6 – 13.7	26.5 – 35.4
Δ (Northeast Atlantic – global mean) (Table 7-3)	-1.0 – 2.9	-1.7 – 6.8	-2.5 – 6.9	-3.8 – 14.8
terrestrial water storage				
glaciers and ice caps	1.5 – 4.3	4.3 – 10.8	2.0 – 5.7	6.1 – 14.5
Greenland + Antarctica (Table 7-4)	0.1 – 5.8	-0.3 – 19.2	-0.1 – 9.1	-1.9 – 32.9
other	0.0 – 2.0	0.0 – 4.0	0.0 – 2.0	0.0 – 4.0
Total	15.6 – 24.6	34.9 – 59.5	19.6 – 33.9	42.0 – 84.0

Table 7-5: Components for mean sea level rise (cm) for two time periods (2050 and 2100) and two temperature scenarios (low and high). Listed are the low and high values of a range determined by 10%/90% confidence limits for all components.

Component	low scenario		high scenario	
year (ΔT_g since 1990)	2050 (+1 °C)	2100 (+2 °C)	2050 (+2 °C)	2100 (+4 °C)
Observed 1990 – 2005	3.0 – 5.0	3.0 – 5.0	3.0 – 5.0	3.0 – 5.0
total thermosteric from 2005	6.8 – 12.5	20.2 – 32.7	8.9 – 19.3	24.7 – 45.5
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terrestrial water storage				
glaciers and ice caps	1.5 – 4.3	4.3 – 10.8	2.0 – 5.7	6.1 – 14.5
Greenland + Antarctica	0.1 – 5.8	-0.3 – 10.2	-0.1 – 9.1	-1.9 – 32.0
Total	15.6 – 24.6	34.9 – 59.5	19.6 – 33.9	42.0 – 84.0

uncertainty dynamics ice sheets & collapse of ‘Gulf Stream’

Local change in 2050

		G	G+	W	W+
Global temperature rise		+1°C	+1°C	+2°C	+2°C
Change in air circulation patterns		no	yes	no	yes
Winter[3]	average temperature	+0.9°C	+1.1°C	+1.8°C	+2.3°C
	coldest winter day per year	+1.0°C	+1.5°C	+2.1°C	+2.9°C
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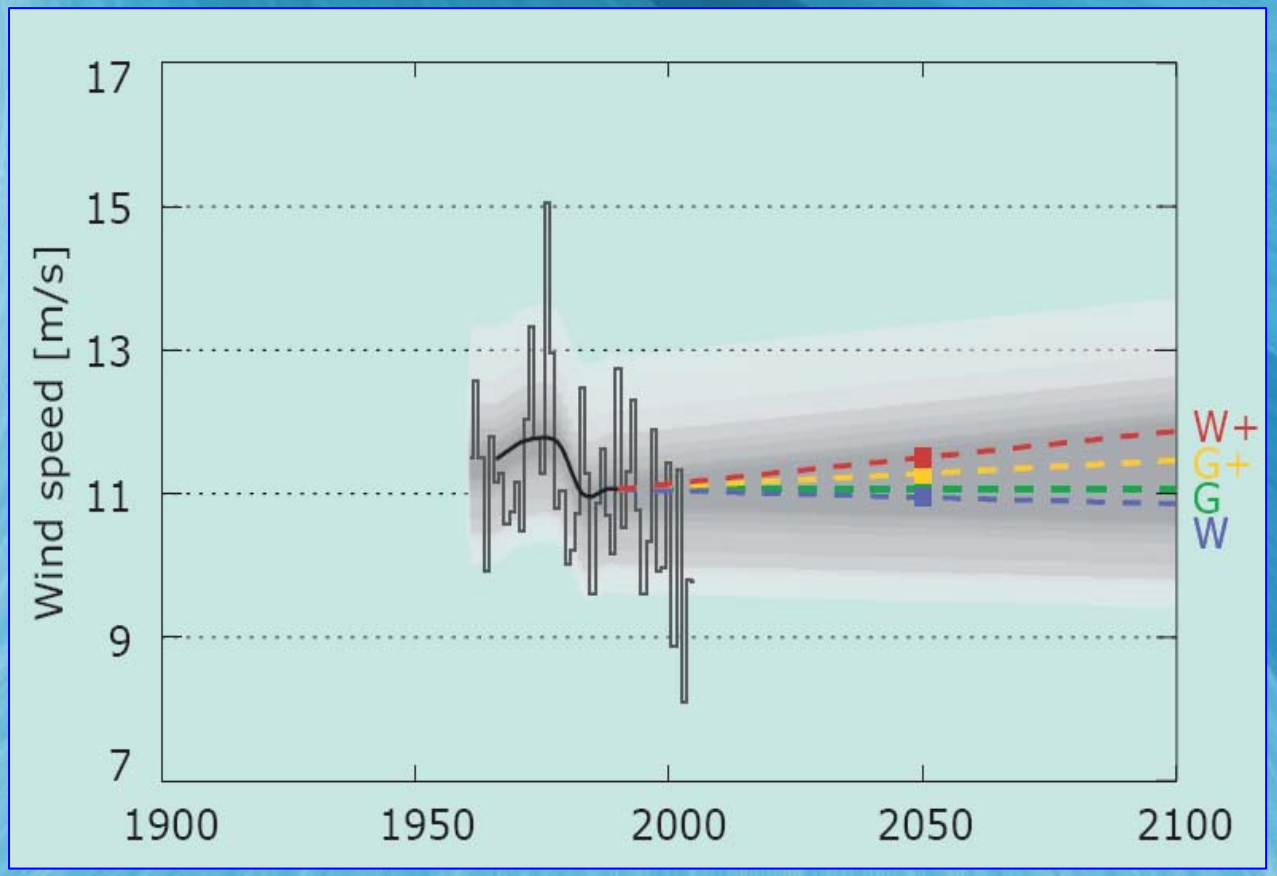
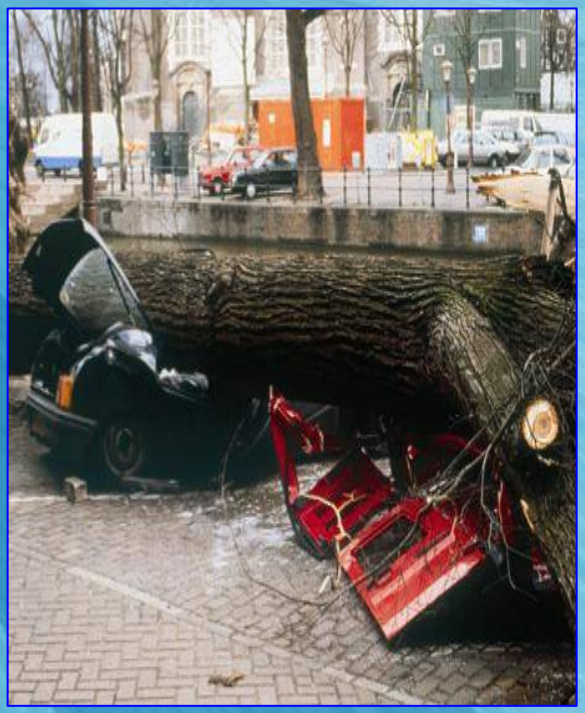
	potential evaporation	+3%	+8%	+7%	+15%
Sea level	absolute increase	15-25 cm	15-25 cm	20-35 cm	20-35 cm

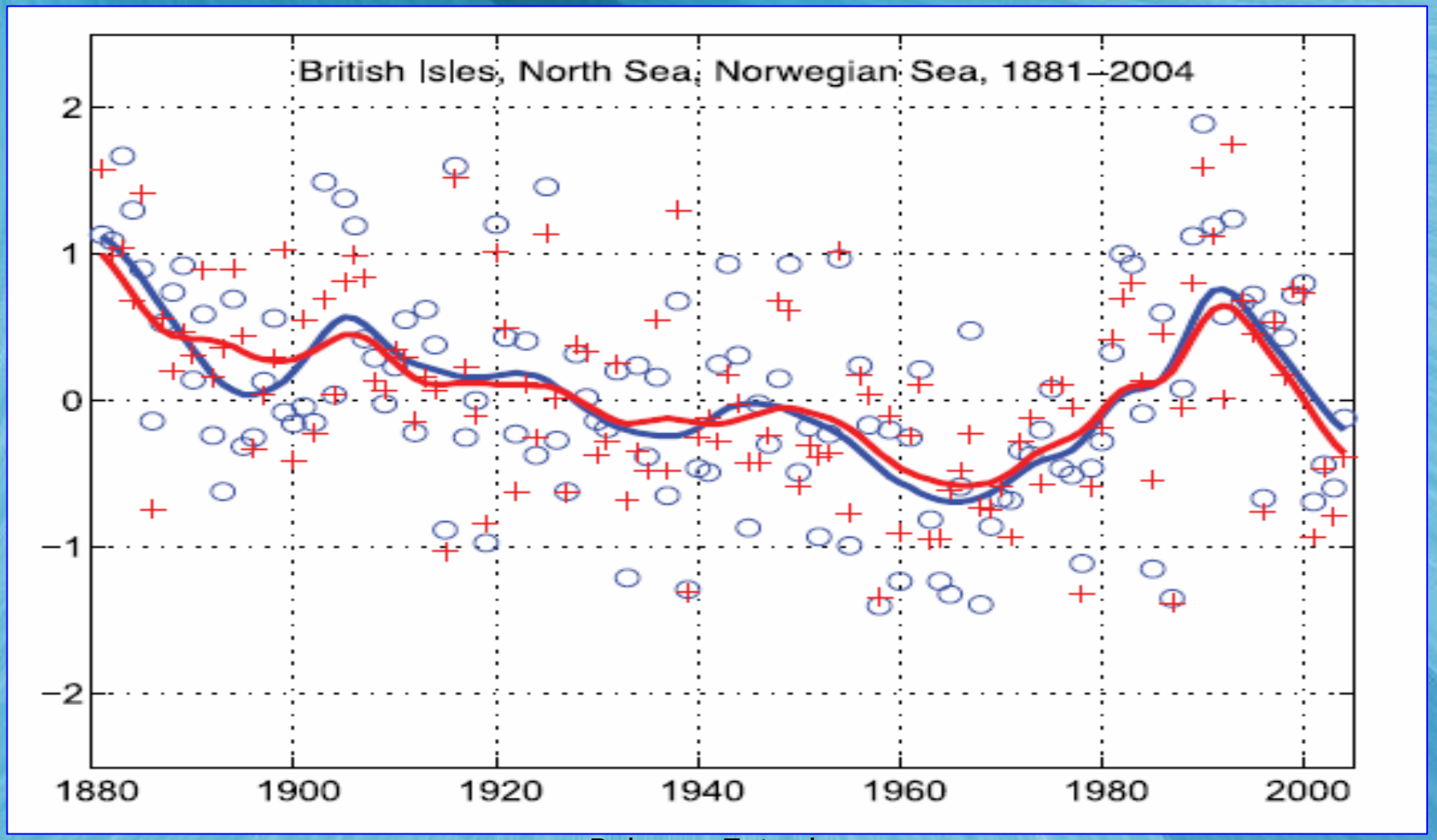
only a small change in wind storms

Role of natural variability





Role of natural variability



Updated from Alexandersson et al., 2000; in IPCC-AR4

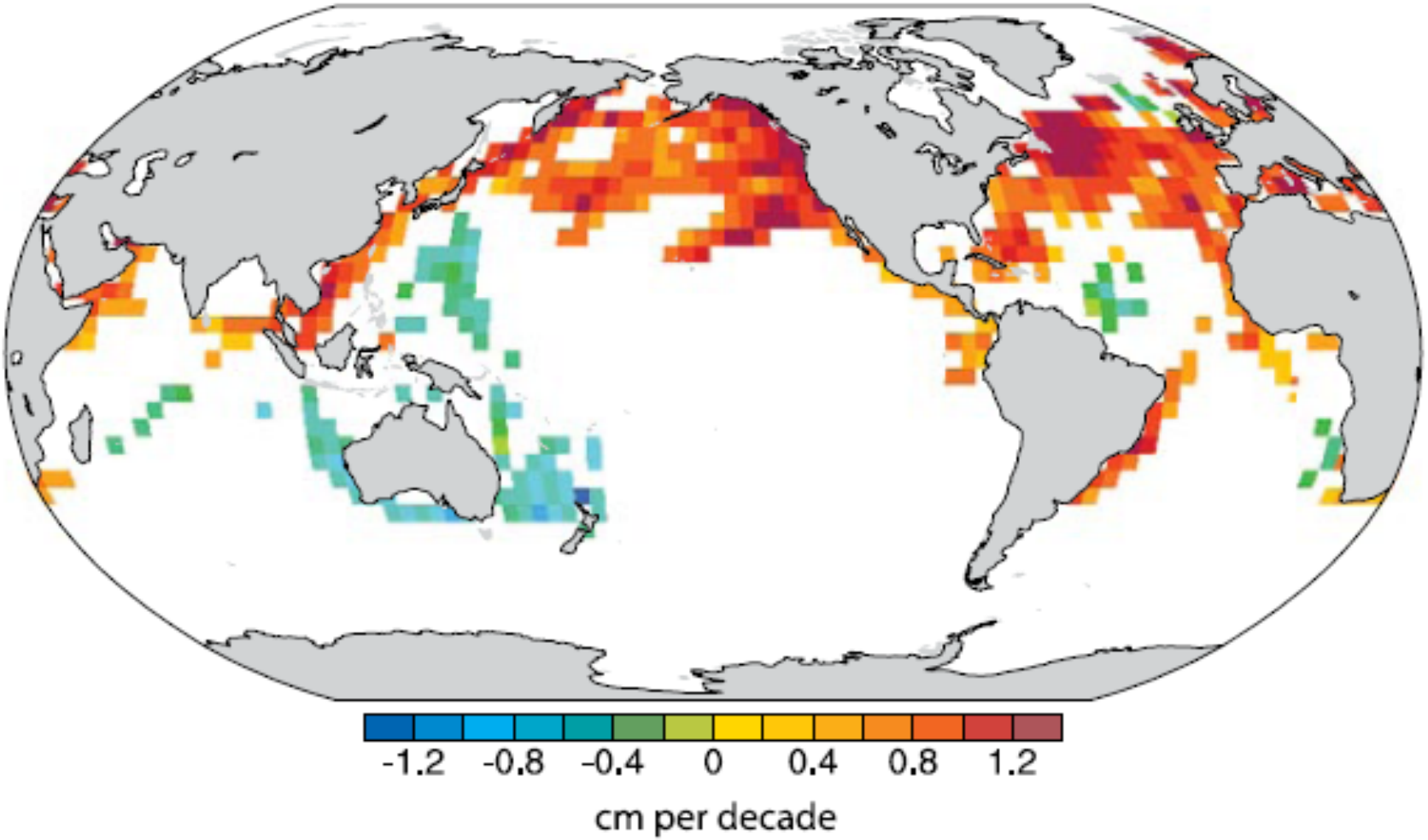


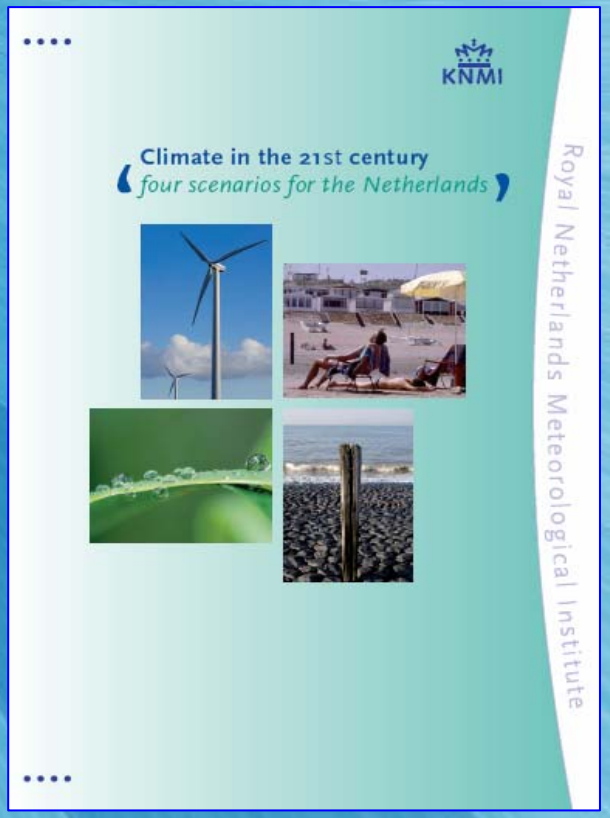
Figure 3.25. *Estimates of linear trends in significant wave height (cm per decade) for regions along the major ship routes of the global ocean for 1950 to 2002. Trends are shown only for locations where they are significant at the 5% level. Adapted from Gulev and Grigorieva (2004).*

Gulev and Grigorieva, 2004; in IPCC-AR4

Conclusions

1. Strategies for adaptation to future climate conditions are needed for many sectors of society

2. Uncertainties at global, regional and local scales can be dealt with using a set of relevant scenarios, as demonstrated in KNMI'06 (see: www.knmi.nl/climatescenarios)



Conclusions

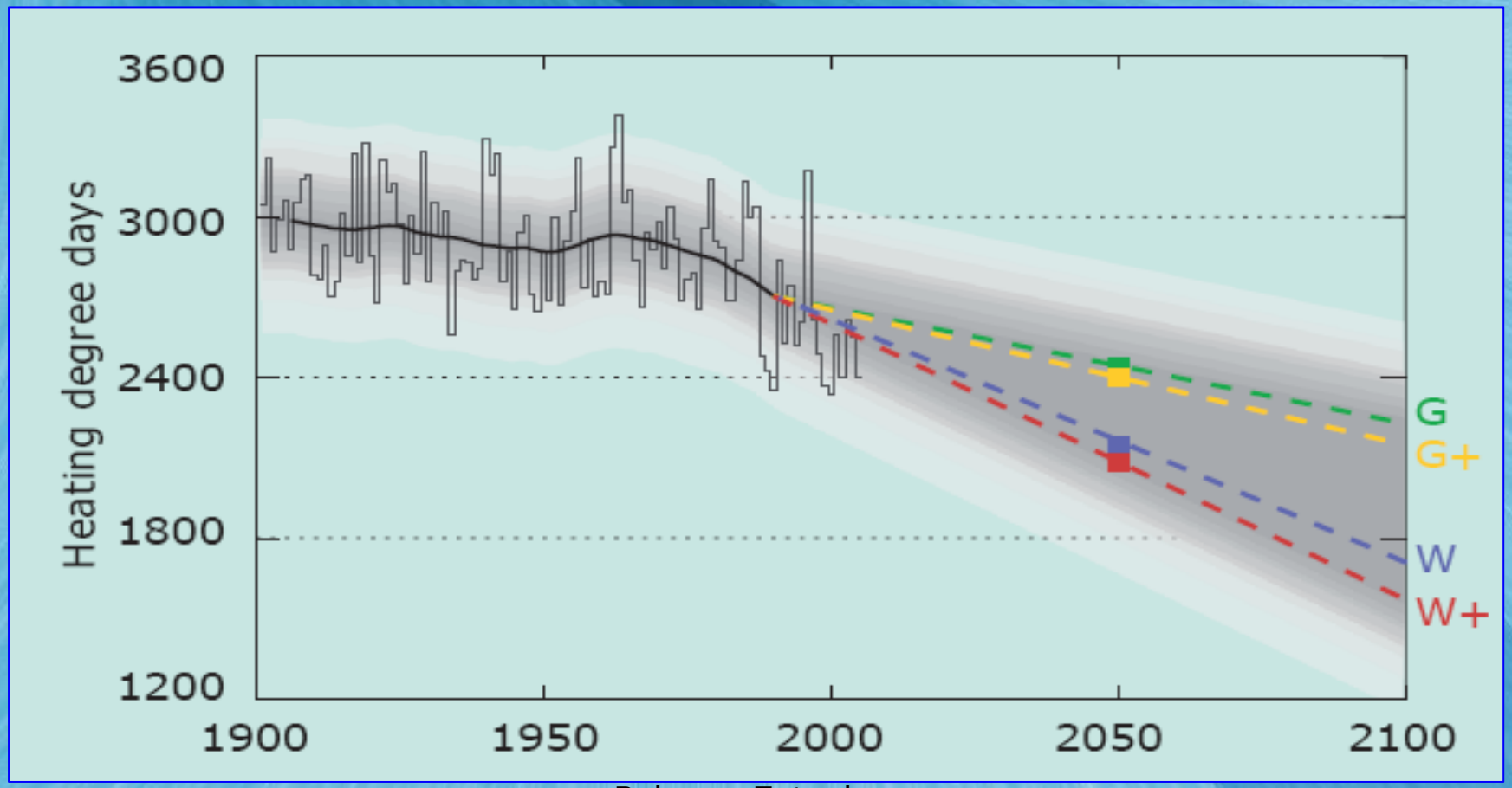
3. Scenarios based on single GCM projections are inadequate, because they don't sample the full range of possible future climates

4. At the same time, it is too early for full probability distributions at the local scale obtained by weighting of model projections

5. The KNMI'06 scenarios are an example for tailoring climate change information to local user applications

User applications

- **Decreasing energy demand for heating**



Palmse, Estonia

User applications

- **Maasland barrier: change in closure frequency**