Climate change: causes and consequences

Dr. Ronald Hutjes

Alterra, WUR

And many others

- Platform Communication on Climate Change - PCCC

Climate change: causes and consequences

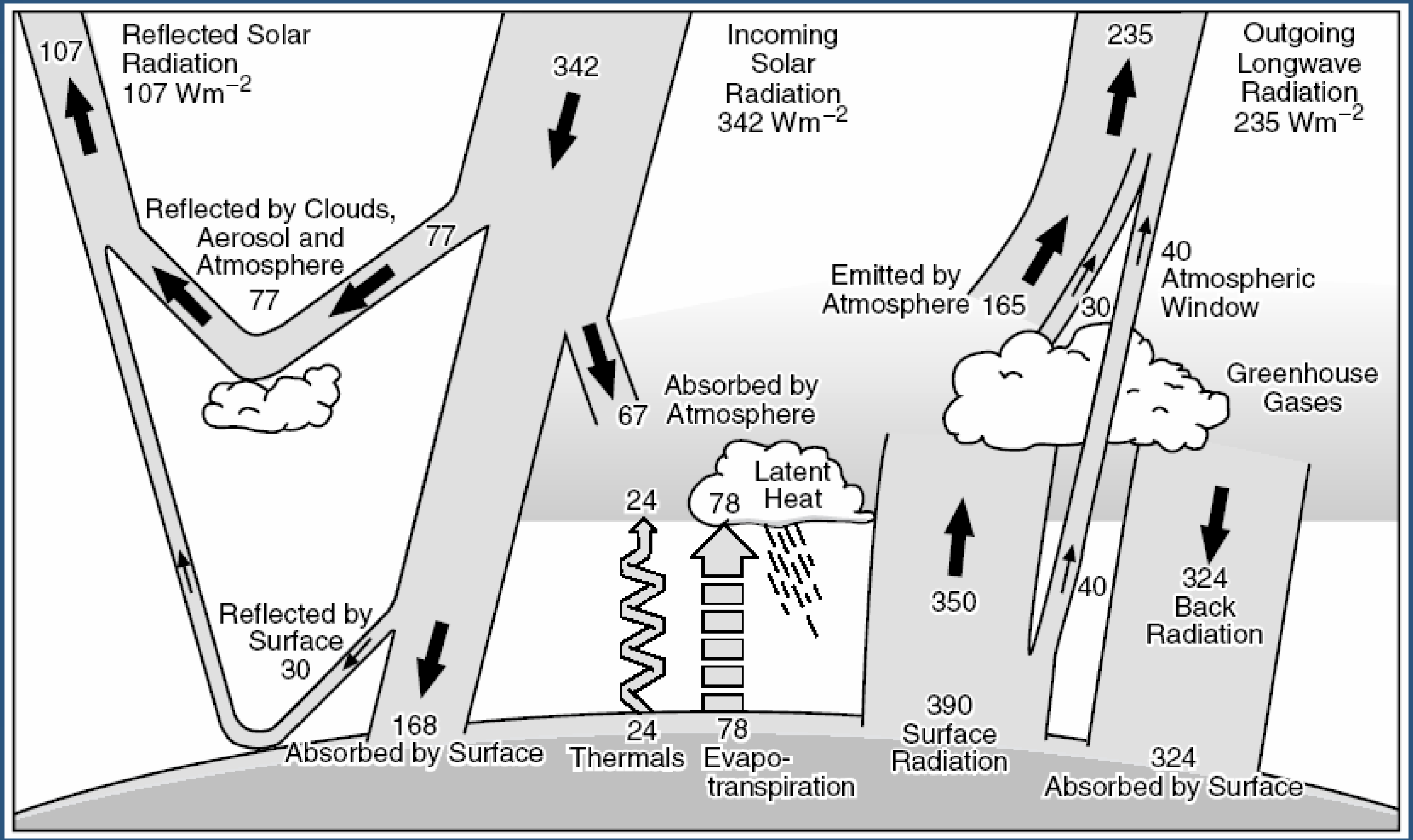
- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

Climate change: causes and consequences

- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

Climate change: causes and consequences

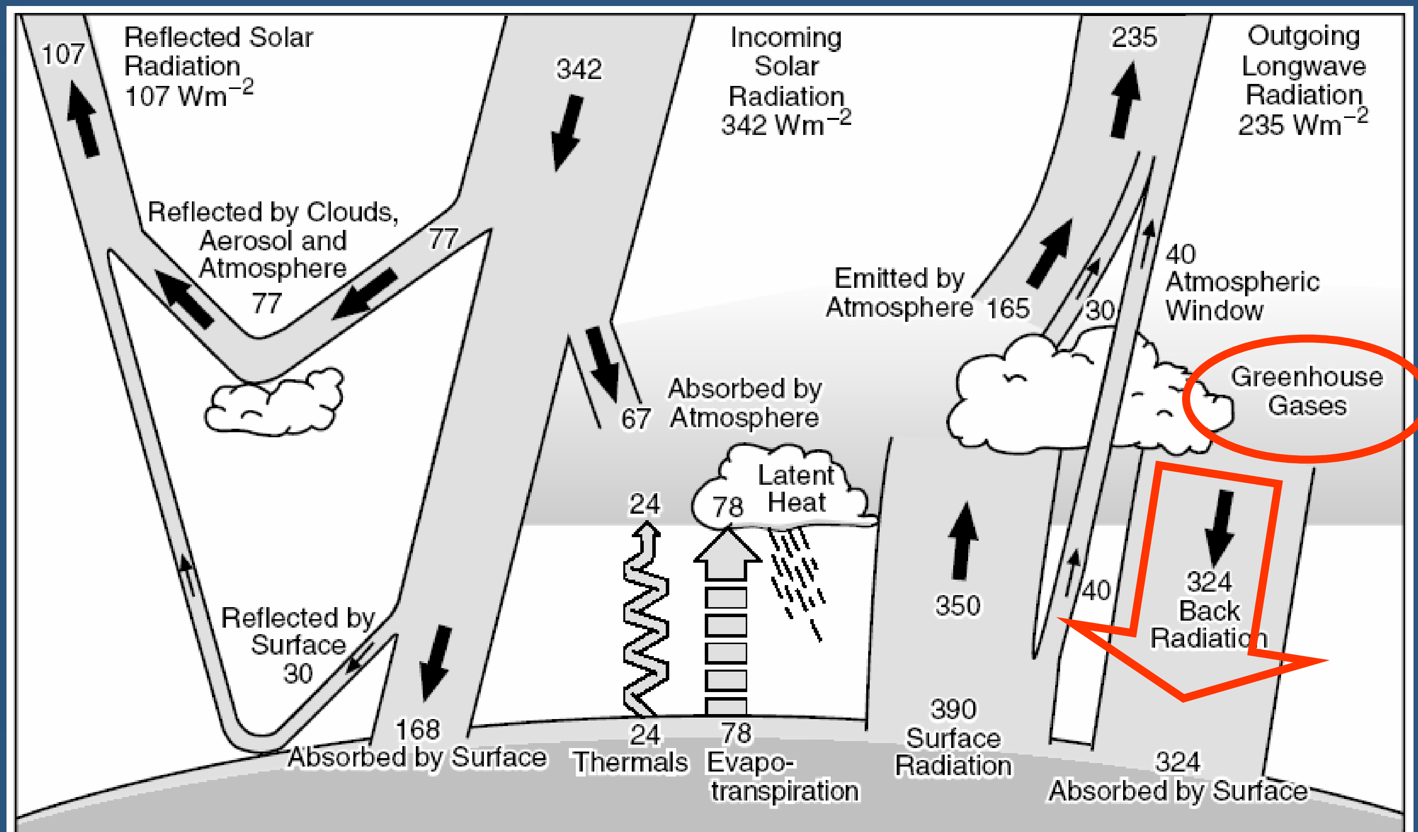
The greenhouse effect: a good thing!



- Solar radiation warms the earth
- Earth cools by emission of (thermal) infrared radiation
- Greenhouse gases 'retain' infrared radiation

Climate change: causes and consequences

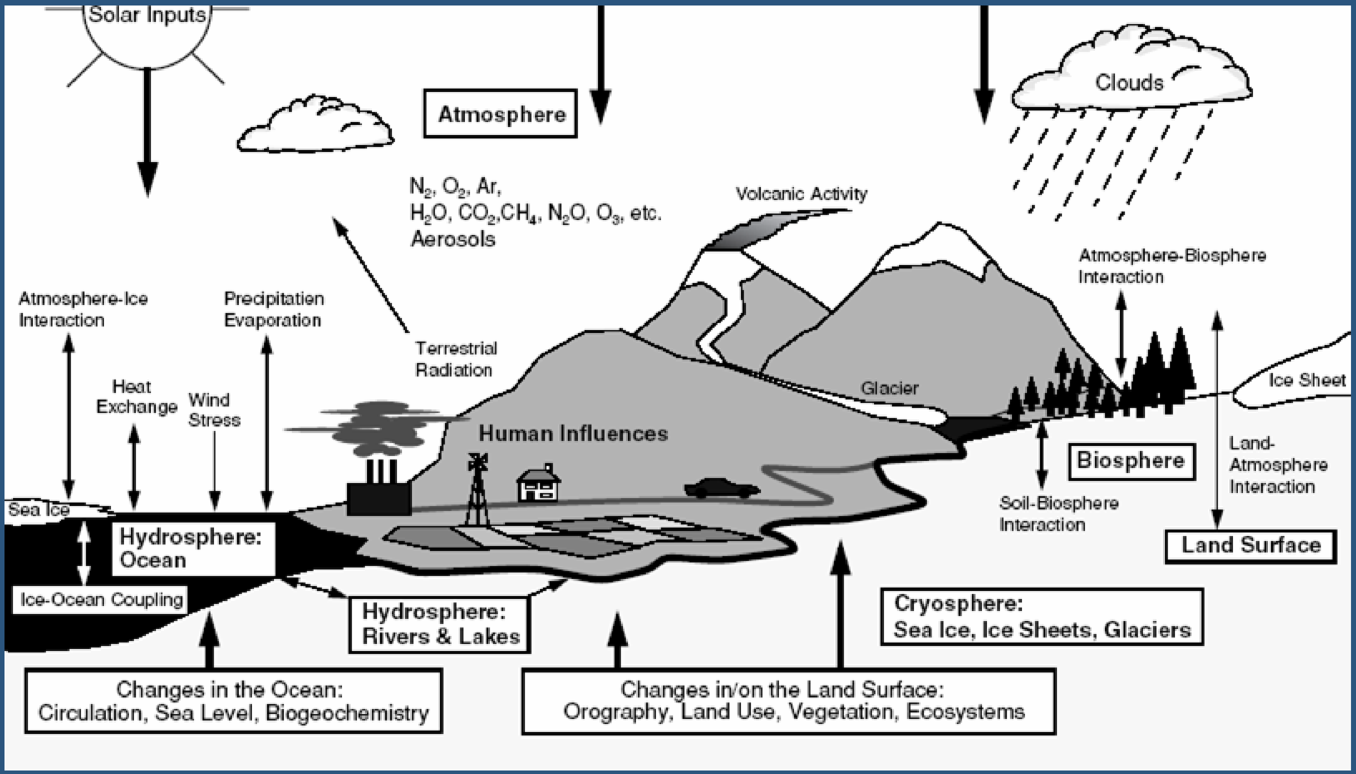
The greenhouse effect: a good thing!



- Greenhouse effect makes earth inhabitable:
  - Global temperature +15ºC instead of -18ºC
  - CO_2 alone responsible for ~12ºC rise

Climate change: causes and consequences

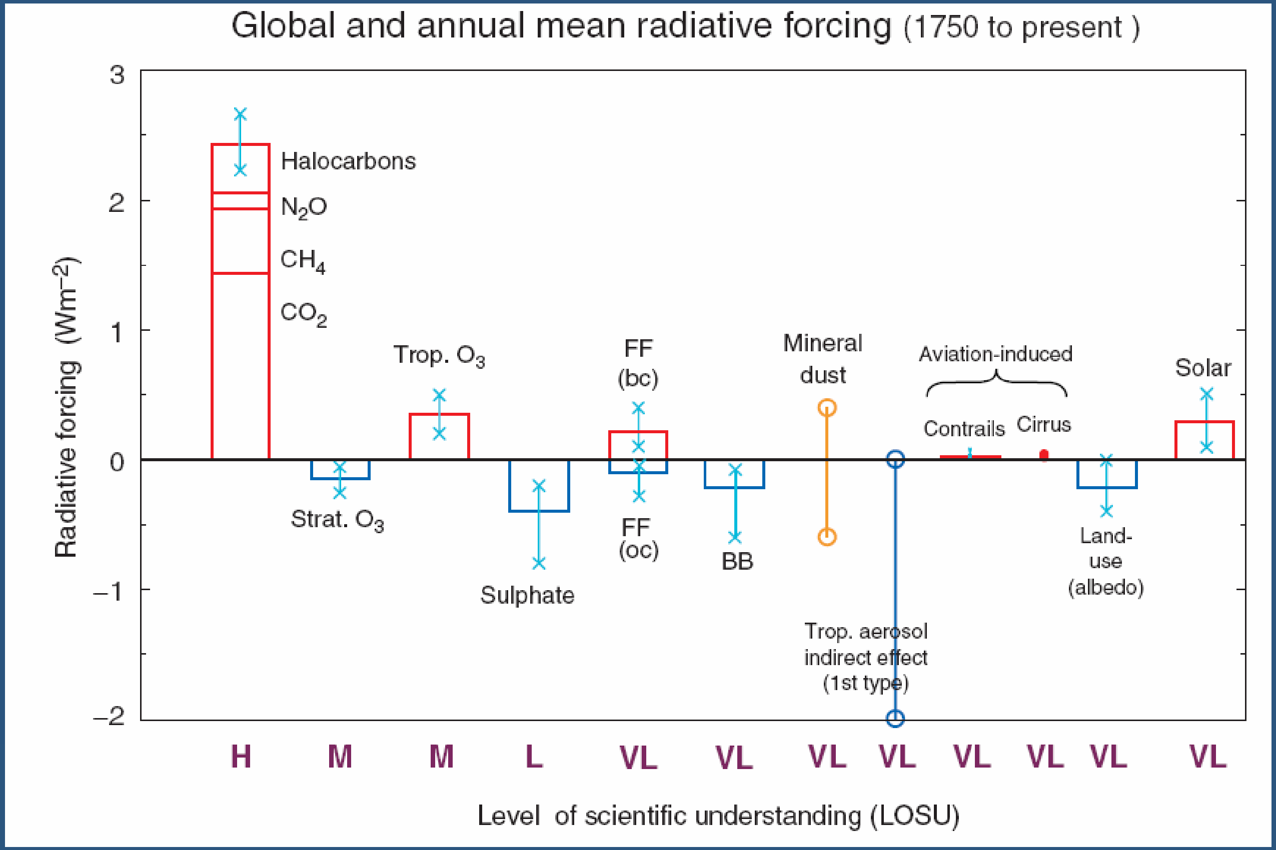
The greenhouse effect: a good thing!



- Other radiatively important constituents:
  - Water vapor and clouds
  - Aerosols (dust), anthropogenic and natural
  - Ozone
  - (Reactive trave gases) (land use change)

Climate change: causes and consequences

The greenhouse effect: a good thing!

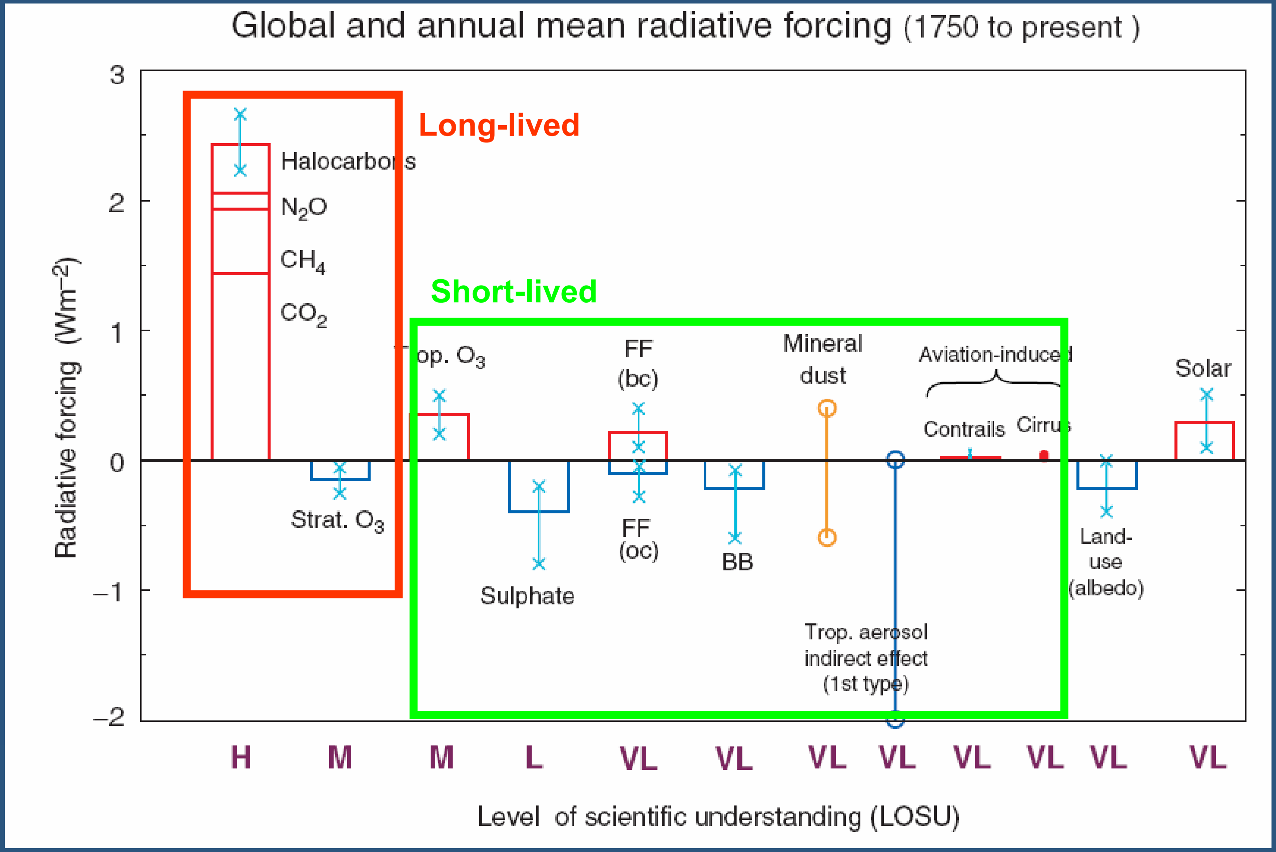


- Radiative forcing
- Global Warming Potential

(CO_2 = 1, CH_4=23, N_2O=296)

Climate change: causes and consequences

The greenhouse effect: a good thing!

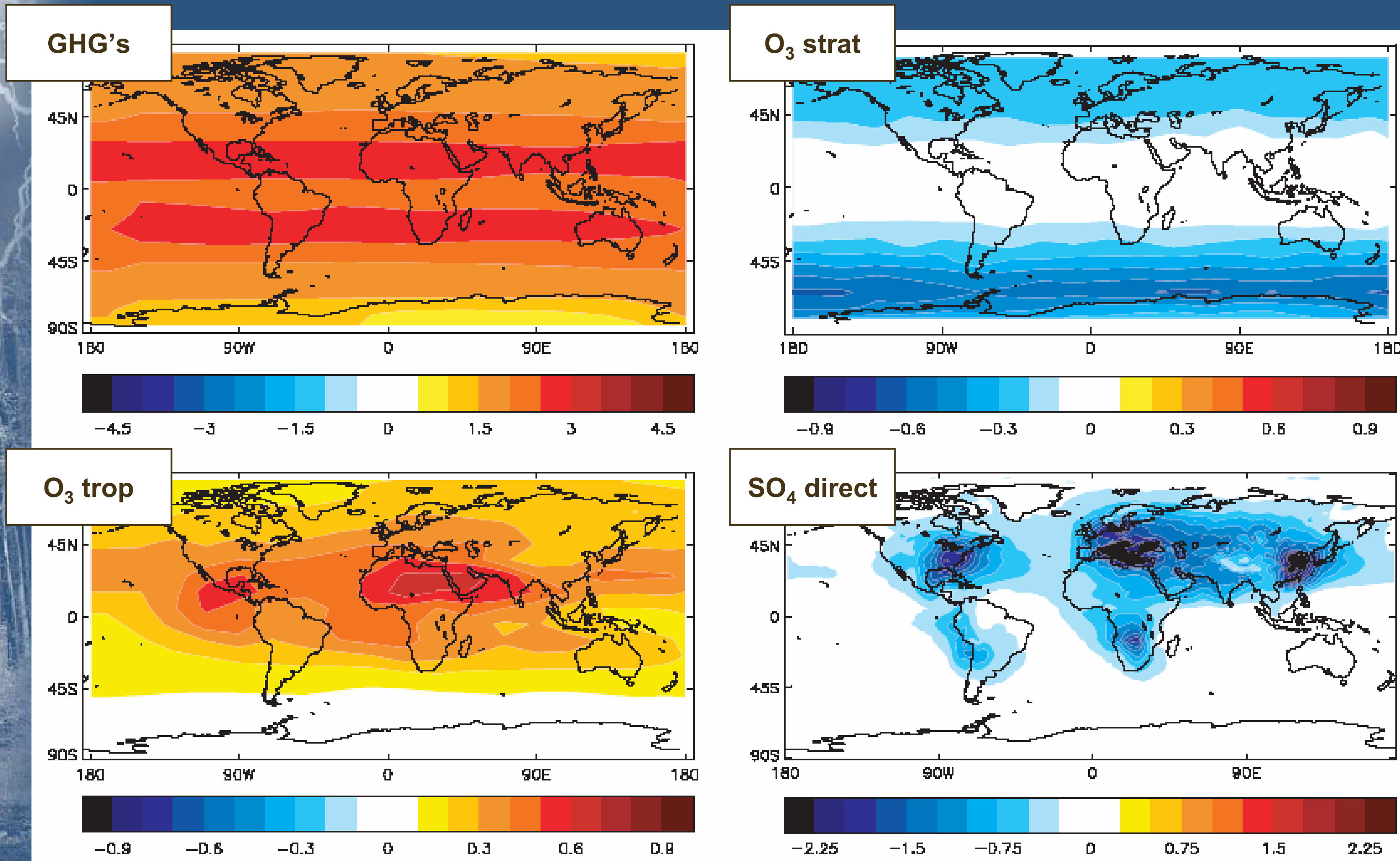


- Radiative forcing
- Global Warming Potential

(CO_2 = 1, CH_4=23, N_2O=296)

Climate change: causes and consequences

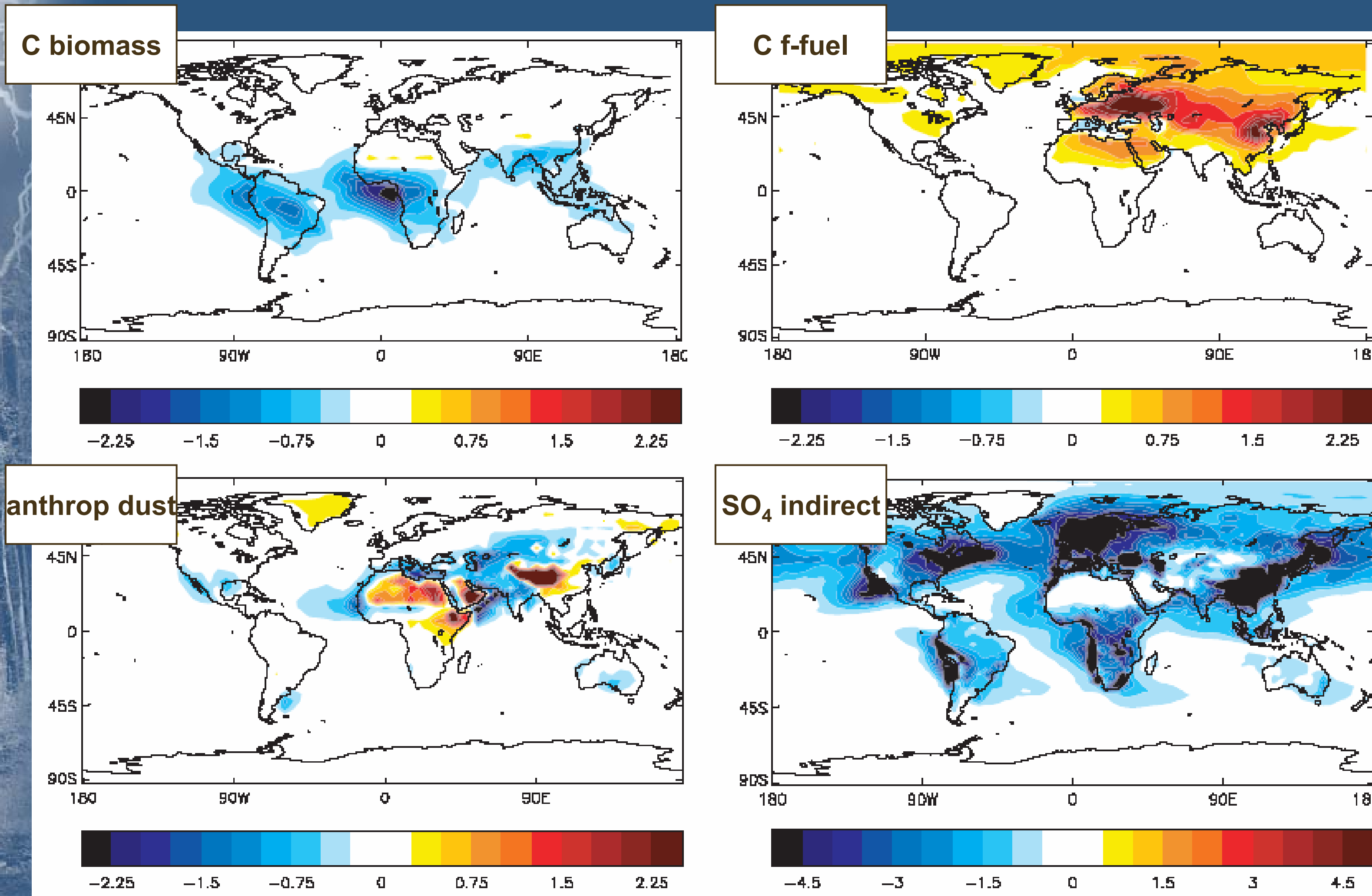
The greenhouse effect: a good thing!



- Radiative forcing

Climate change: causes and consequences

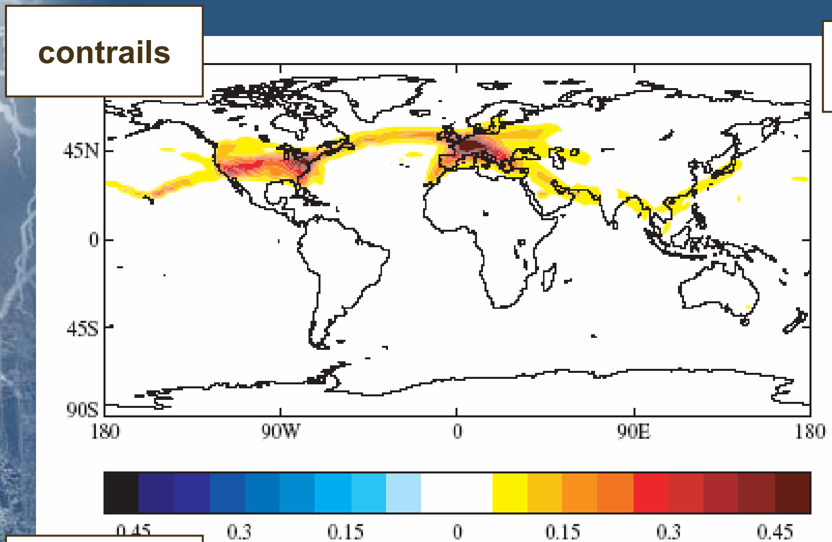
The greenhouse effect: a good thing!

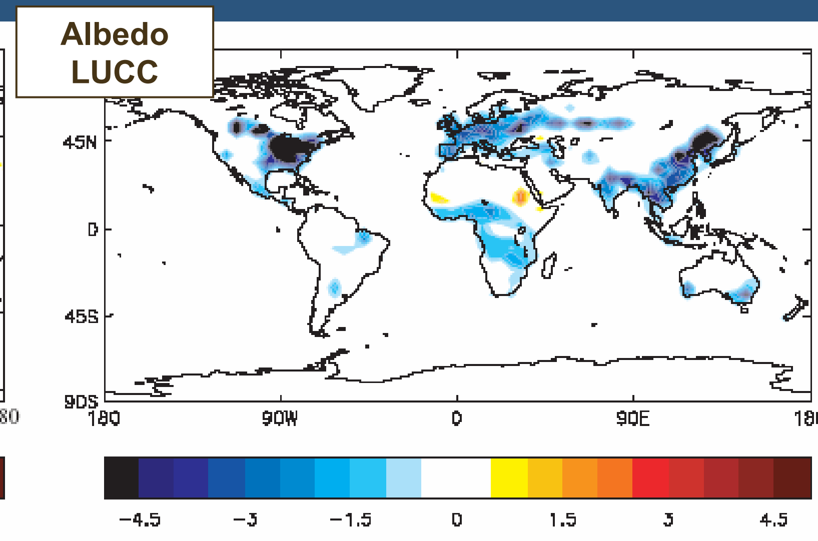


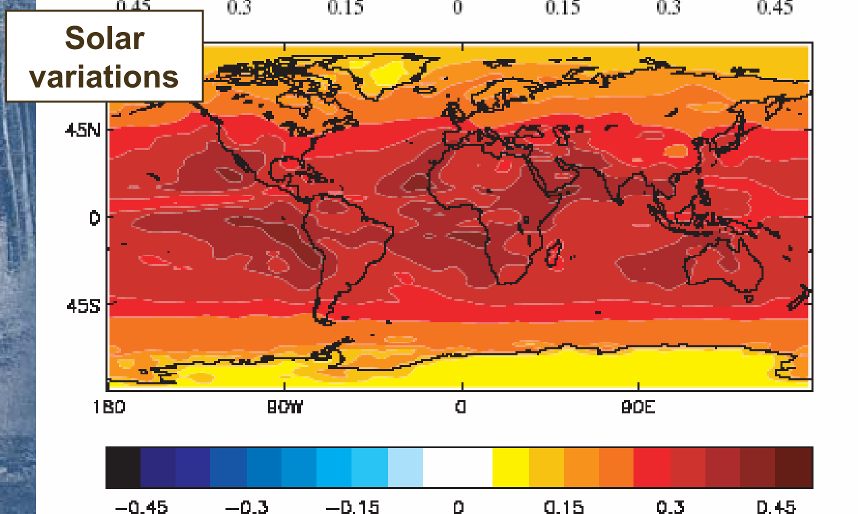
- Radiative forcing

Climate change: causes and consequences

The greenhouse effect: a good thing!







- Radiative forcing

Climate change: causes and consequences

The greenhouse effect: a good thing!

Atmospheric composition affects radiation balance

- Greenhouse gases: warming, long lived
- Aerosols: cooling, short lived
- Water vapor and clouds: complex

Greenhouse effect is a natural thing and a good thing!

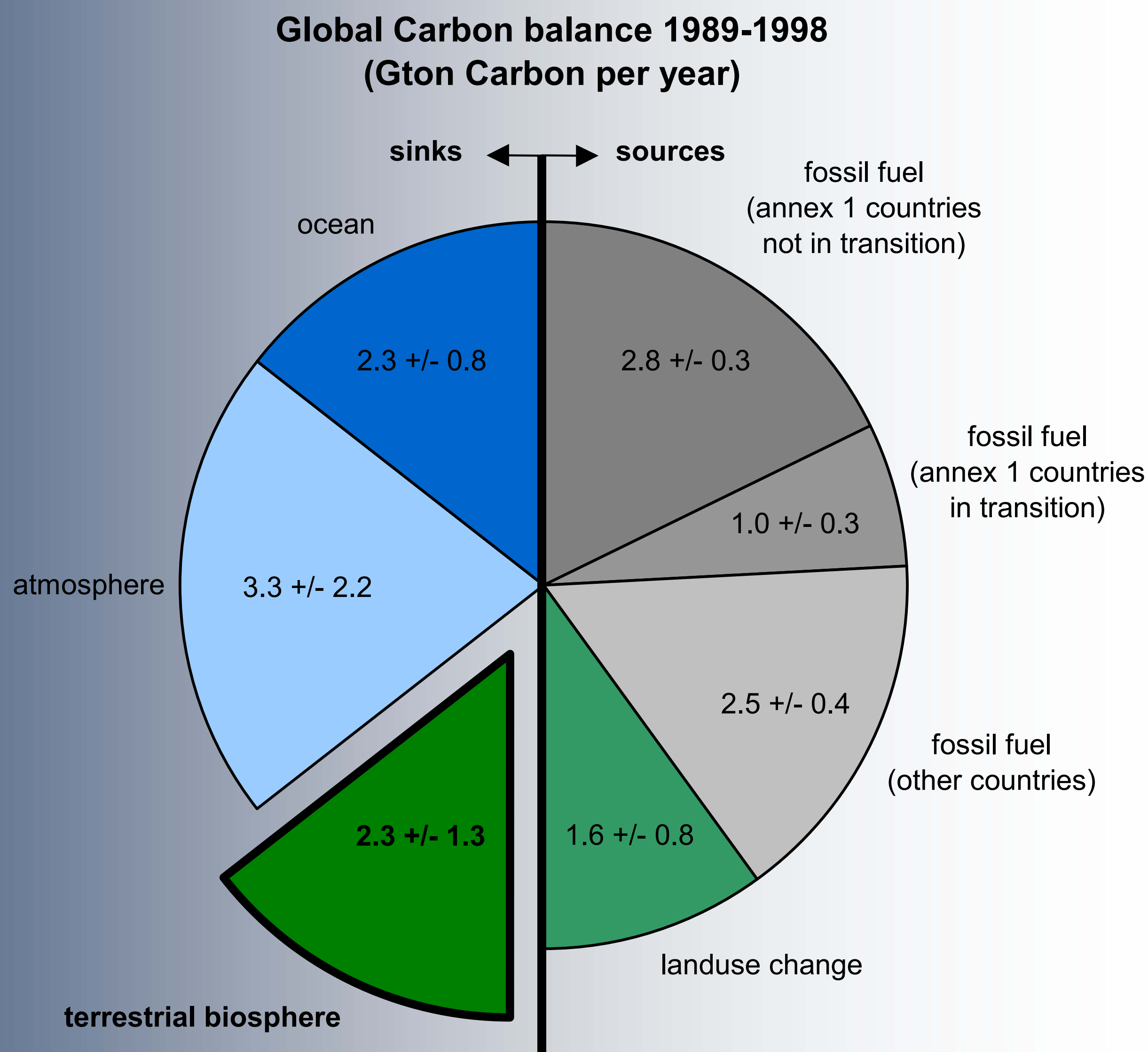
BUT……….

Climate change: causes and consequences

- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

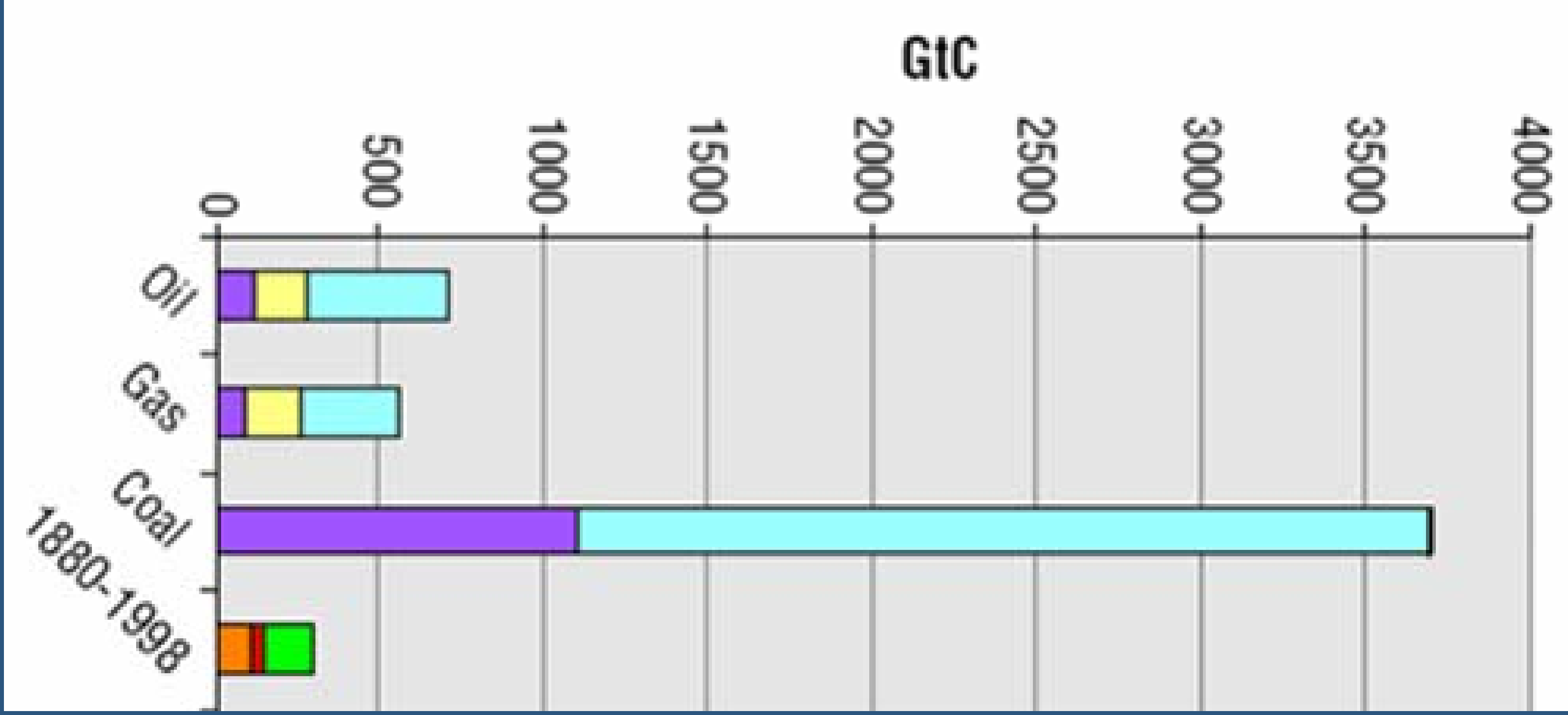
Climate change: causes and consequences

The way we change atmospheric composition



Climate change: causes and consequences

The way we change atmospheric composition

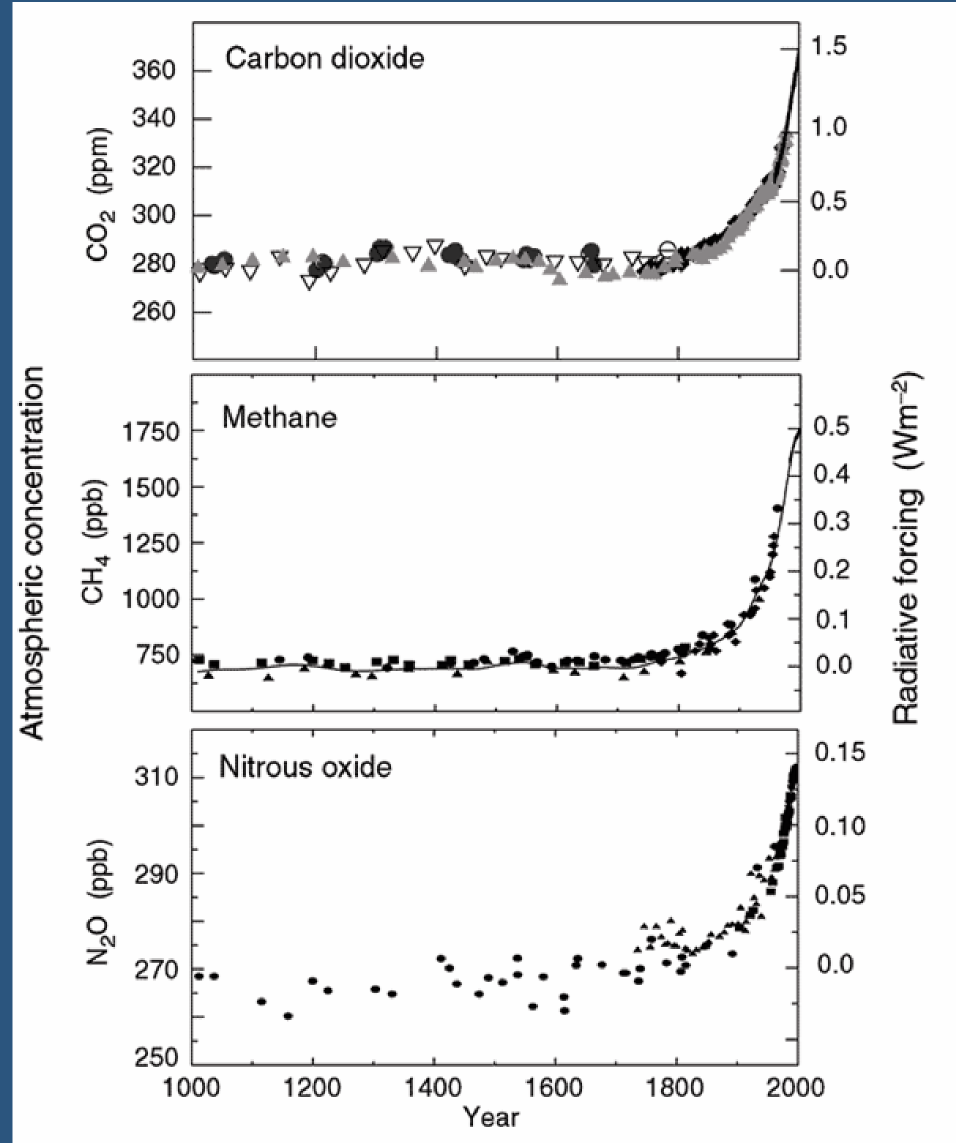


Emissions

- Industry, energy, transport

Climate change: causes and consequences

The way we change atmospheric composition

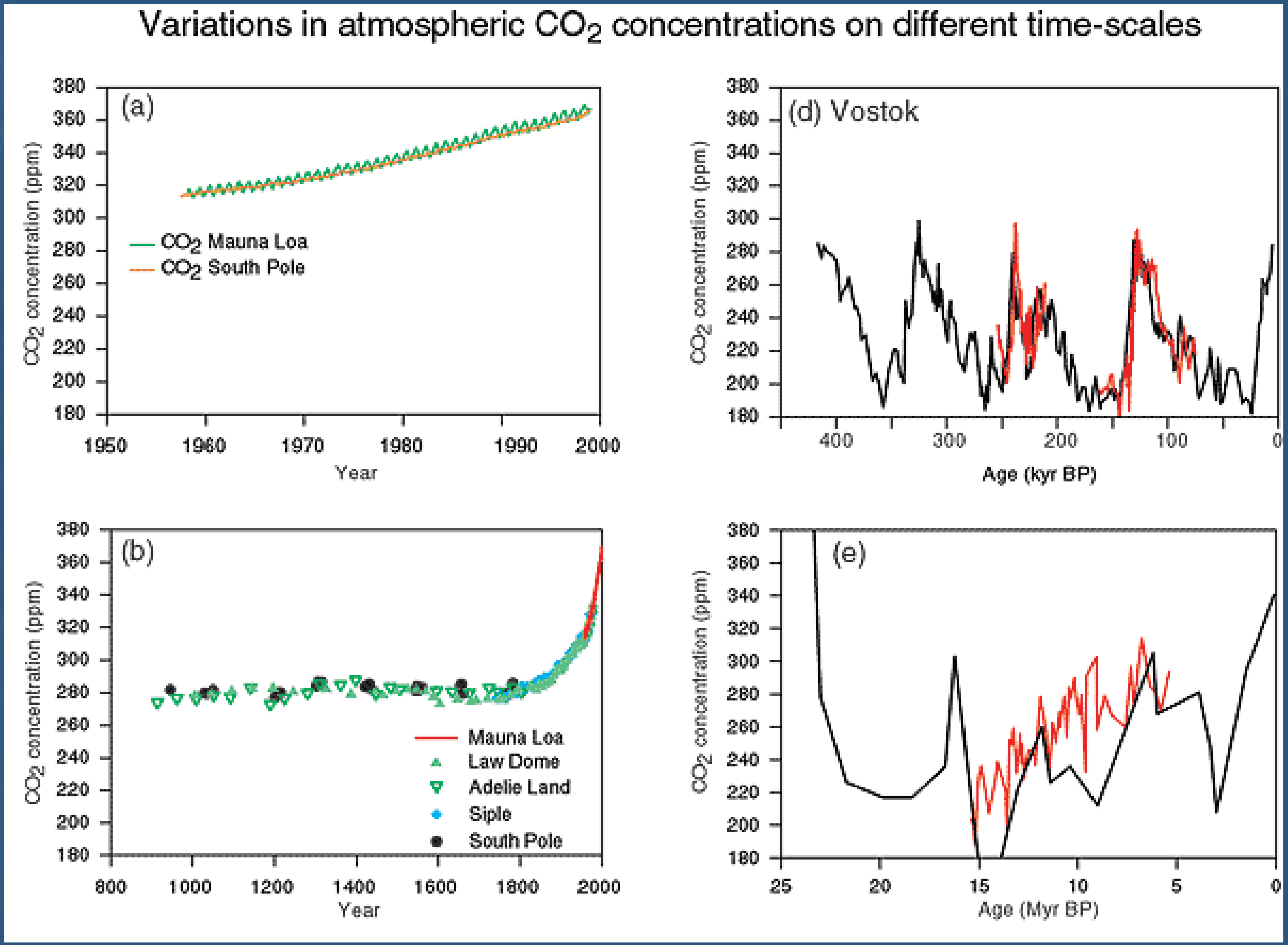


Emissions

- Industry, energy, transport
- Intensive farming
- Land use change

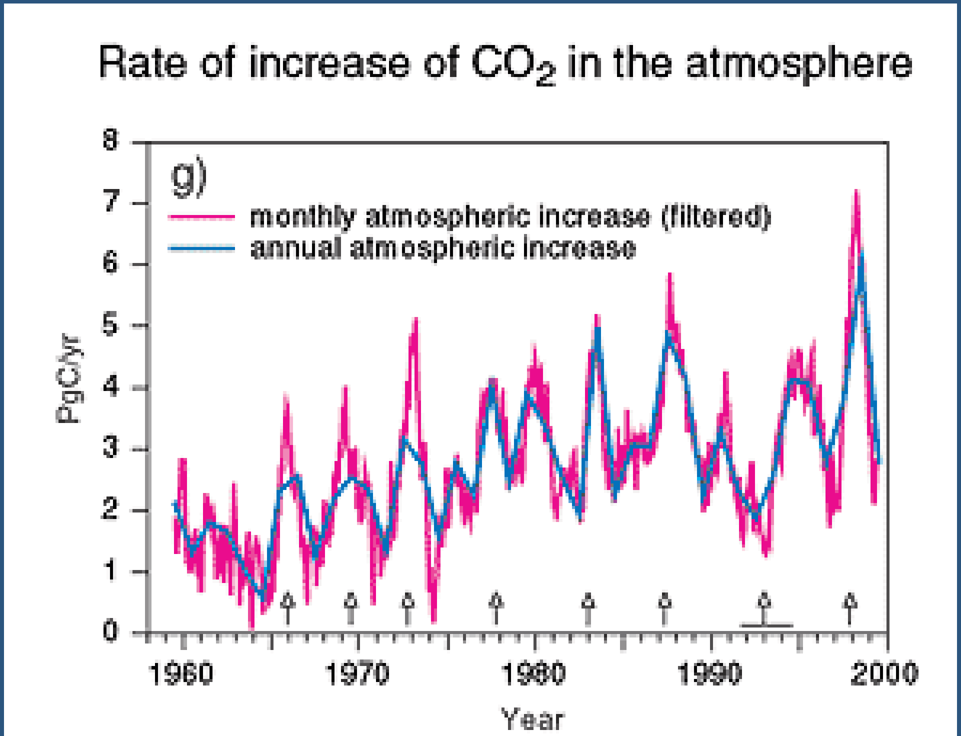
Climate change: causes and consequences

The way we change atmospheric composition



Climate change: causes and consequences

The way we change atmospheric composition



- A lot of interannual variation
- Natural variation (e.g. El Nino)
- Anthropogenic drivers (e.g. forest fires)

Climate change: causes and consequences

The way we change atmospheric composition

Greenhouse gases emissions
- from previously locked-away sources
- big reserves !

Greenhouse gas concentrations
- higher than last 400000 years
- increase faster than at least last 20000 years

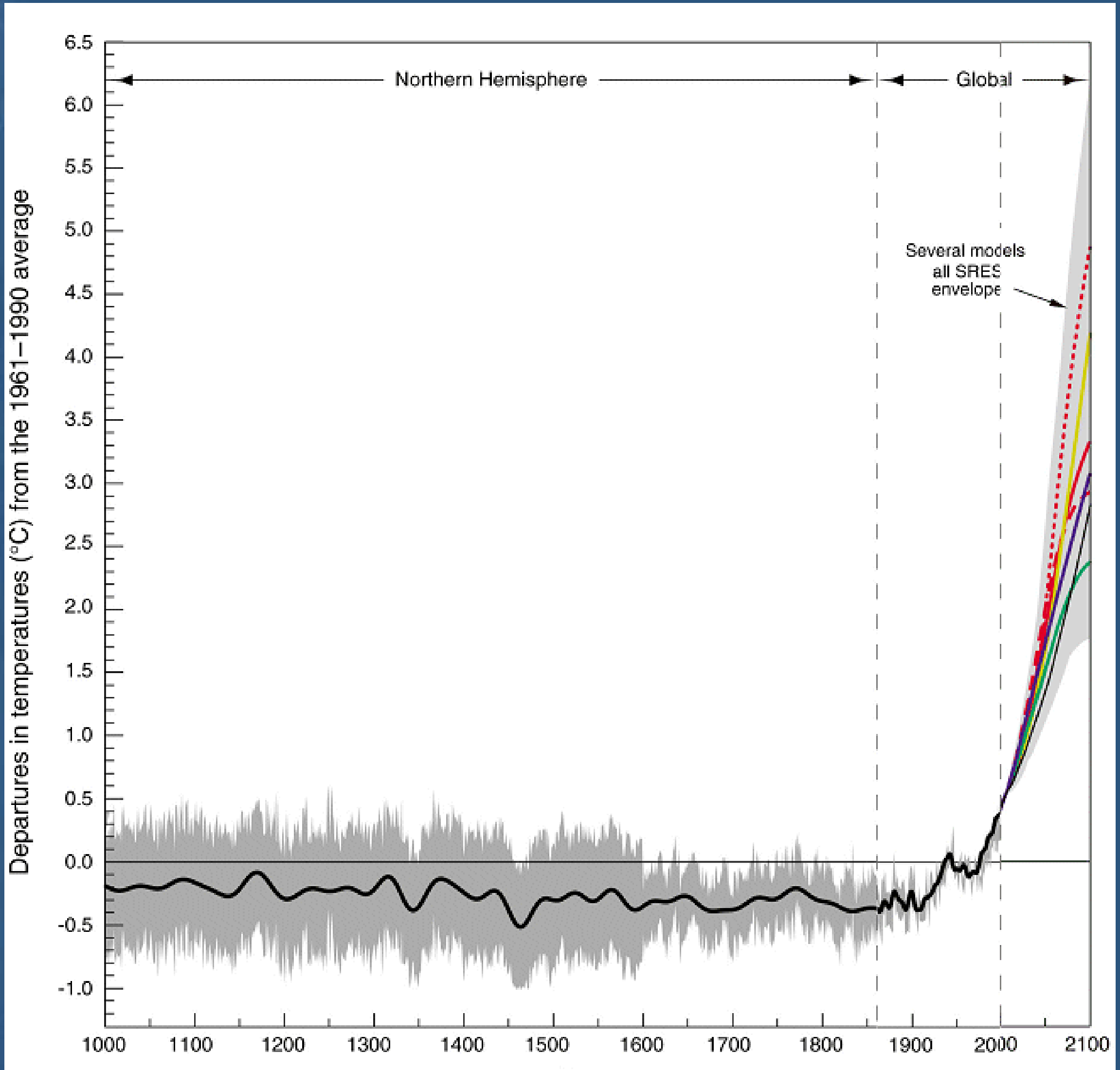
Natural carbon balance highly variable

Climate change: causes and consequences

- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

Climate change: causes and consequences

Climate change is already there

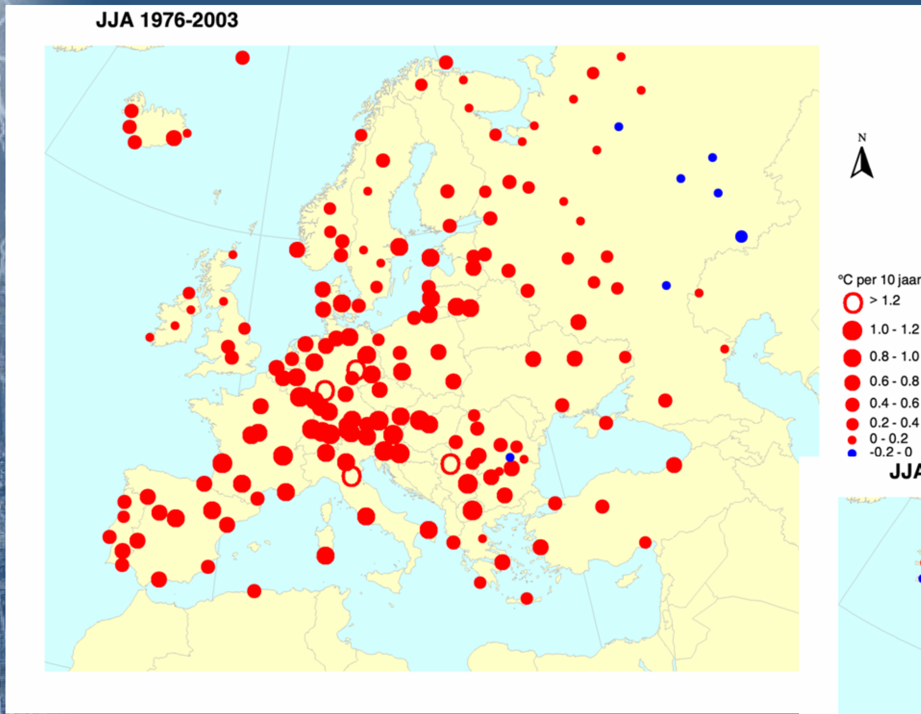


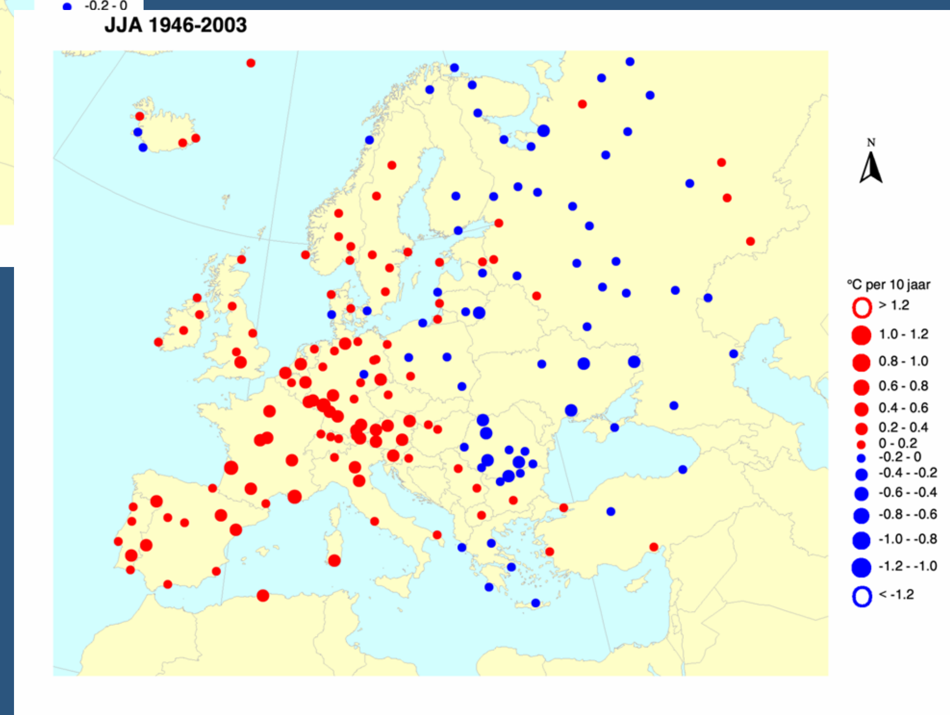
- 0.6 ^{o}C +/- 0.2
- ’90 warmest decade
- ΔT_{night}~2 ΔT_{day}
- Surface 0.15^{o}/10yrs
- Atmosphere <8km 0.05^{o}/10yrs

Platform Communication on Climate Change - PCCC

Climate change: causes and consequences

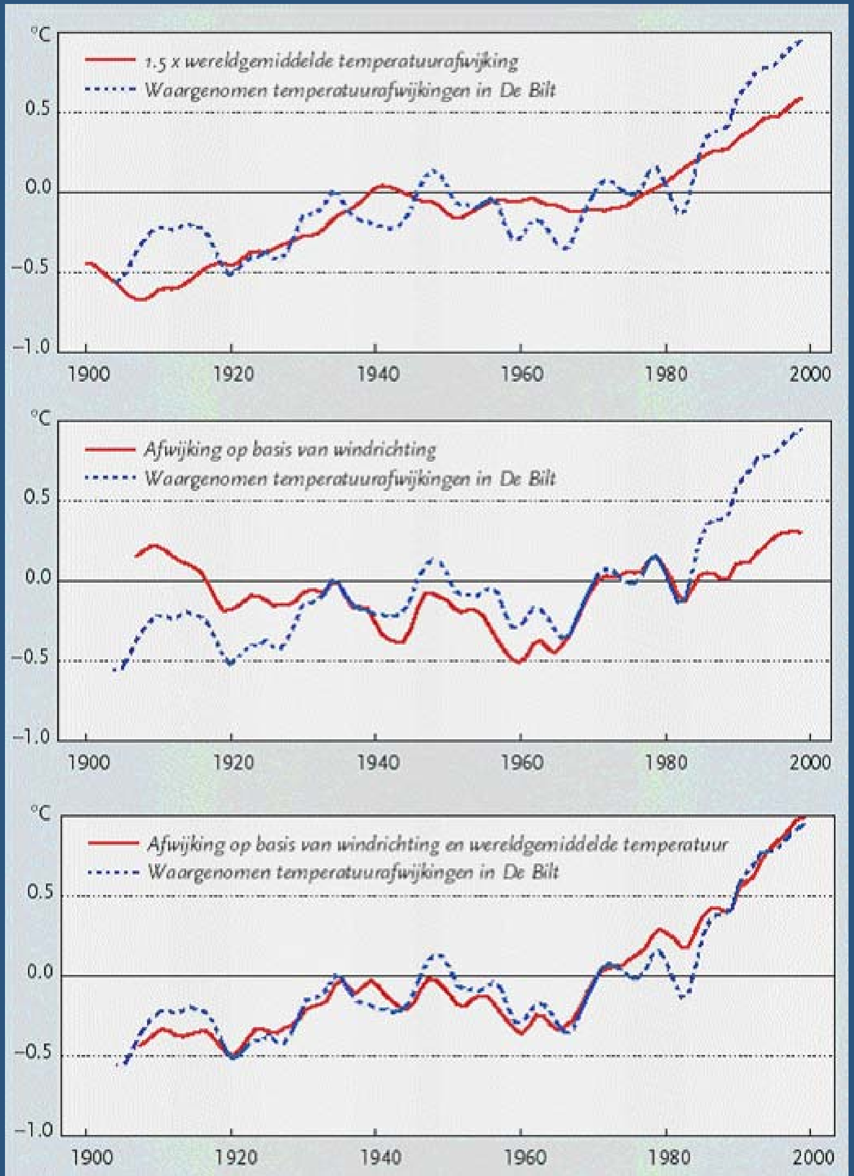
Climate change is already there





Climate change: causes and consequences

Climate change is already there



KNMI, 2003

Netherlands

- Partly due to changed wind patterns
- Causes ?

Climate change: causes and consequences

Climate change is already there

	Temperatuur (°C)
2000,1999,1990	10,9
2002	10,8
1989	10,7
1994	10,6
1992	10,5
2001, 1998, 1995	10,4

Tabel 1.1. Tien hoogste jaartemperaturen vanaf 1901 in De Bilt. De jaartemperatuur in De Bilt is representatief voor Nederland.

	Temperatuurafwijking (°C) t.o.v. gemiddelde 1961–1990
1998	0,6
2002	0,5
2001, 1997, 1995	0,4
2000, 1999, 1994, 1991, 1990	0,3

Tabel 1.2. Tien hoogste wereldgemiddelde jaartemperaturen vanaf 1901. Bron: Climatic Research Unit, Universiteit van East Anglia

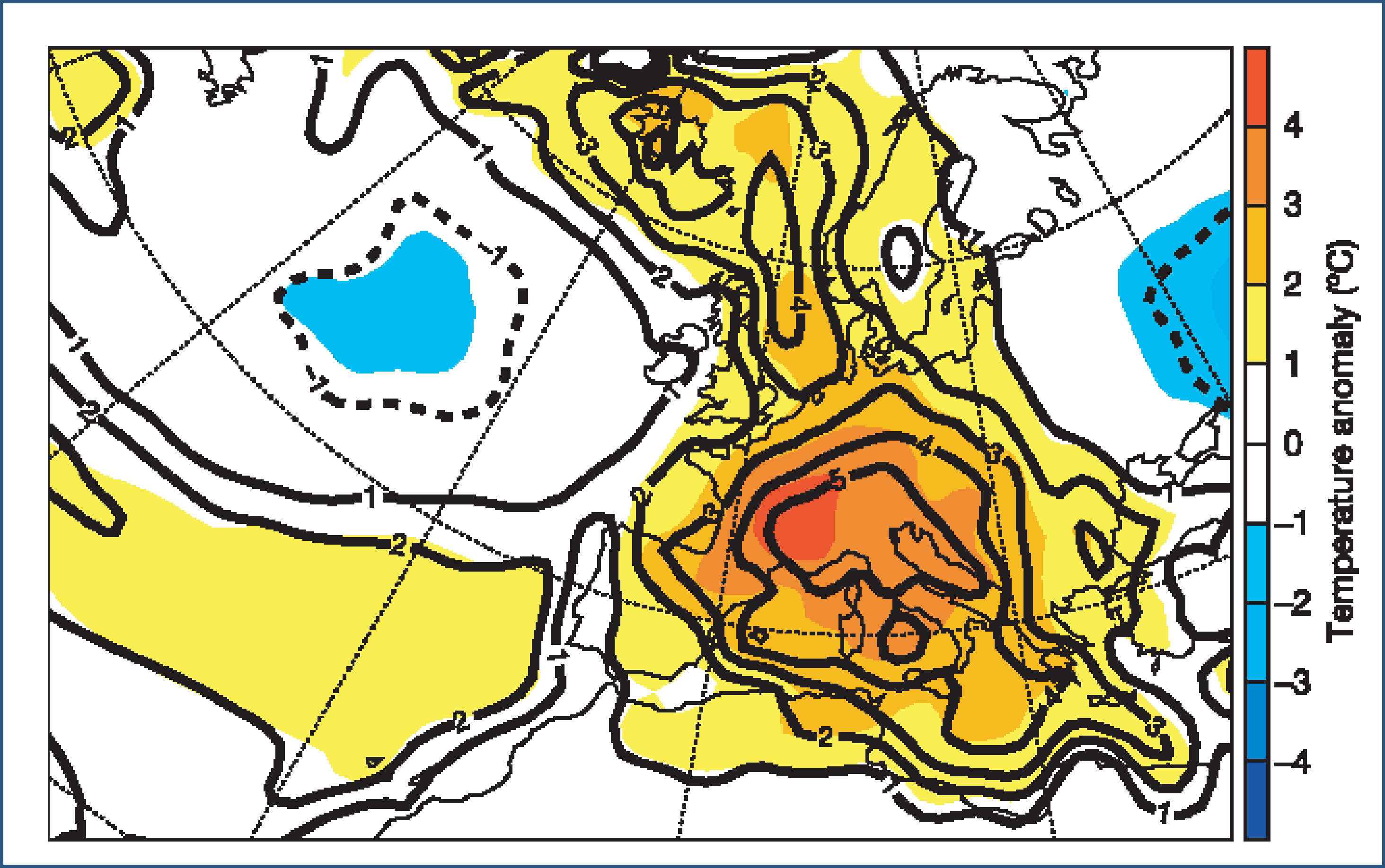
KNMI, 2003

Netherlands

- Situation in line with global trend (not trivial!)
- Warming stronger than global average

Climate change: causes and consequences

Climate change is already there

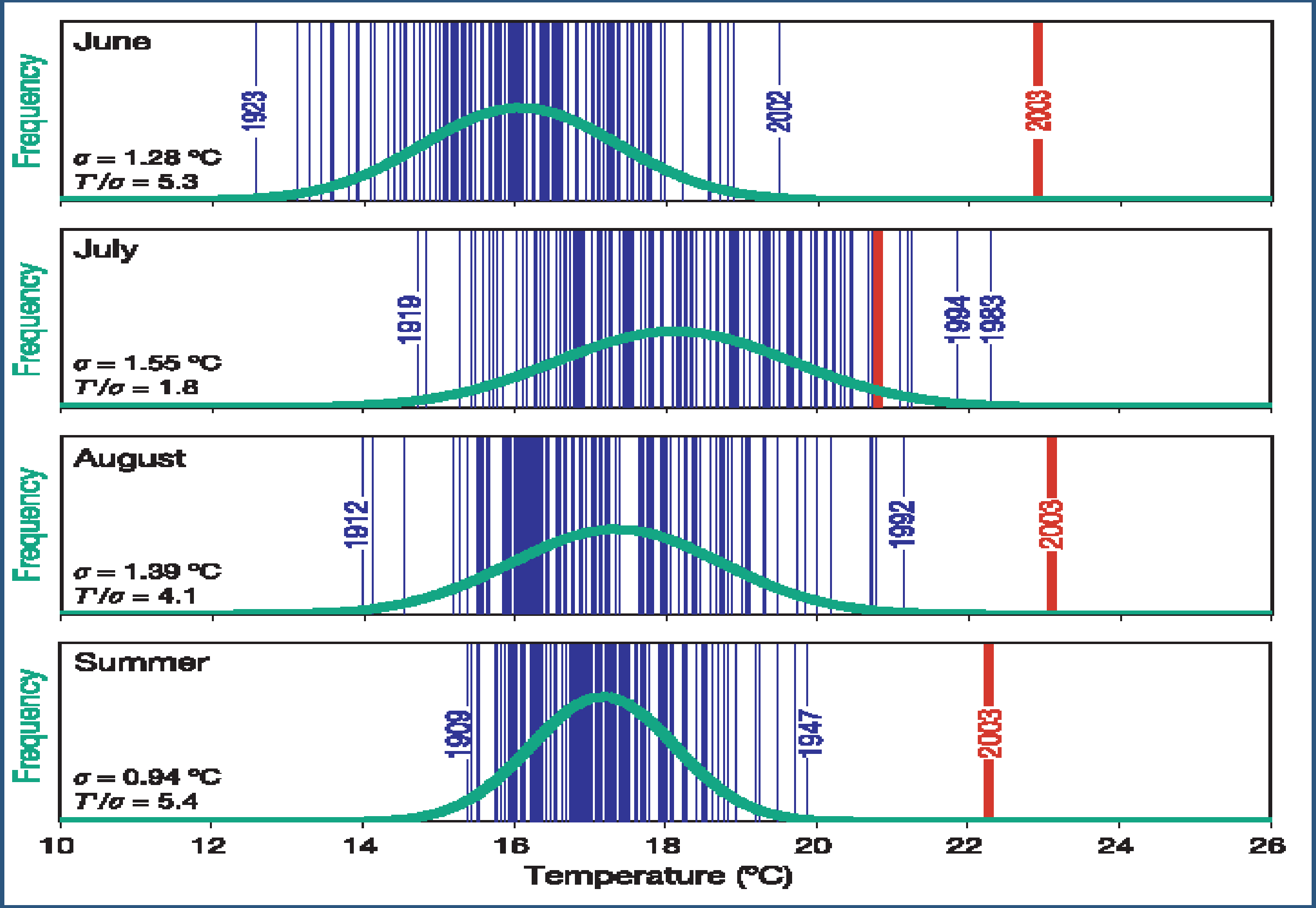


Schär et al., 2003

Extreme summer 2003

Climate change: causes and consequences

Climate change is already there

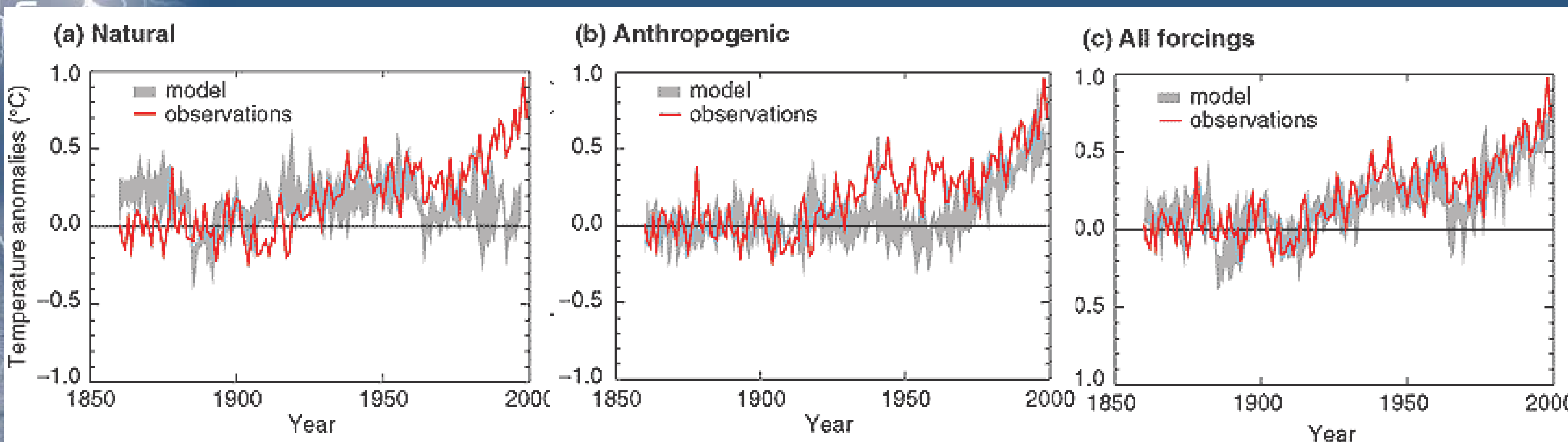


Schär et al., 2003

Extreme summer 2003

Climate change: causes and consequences

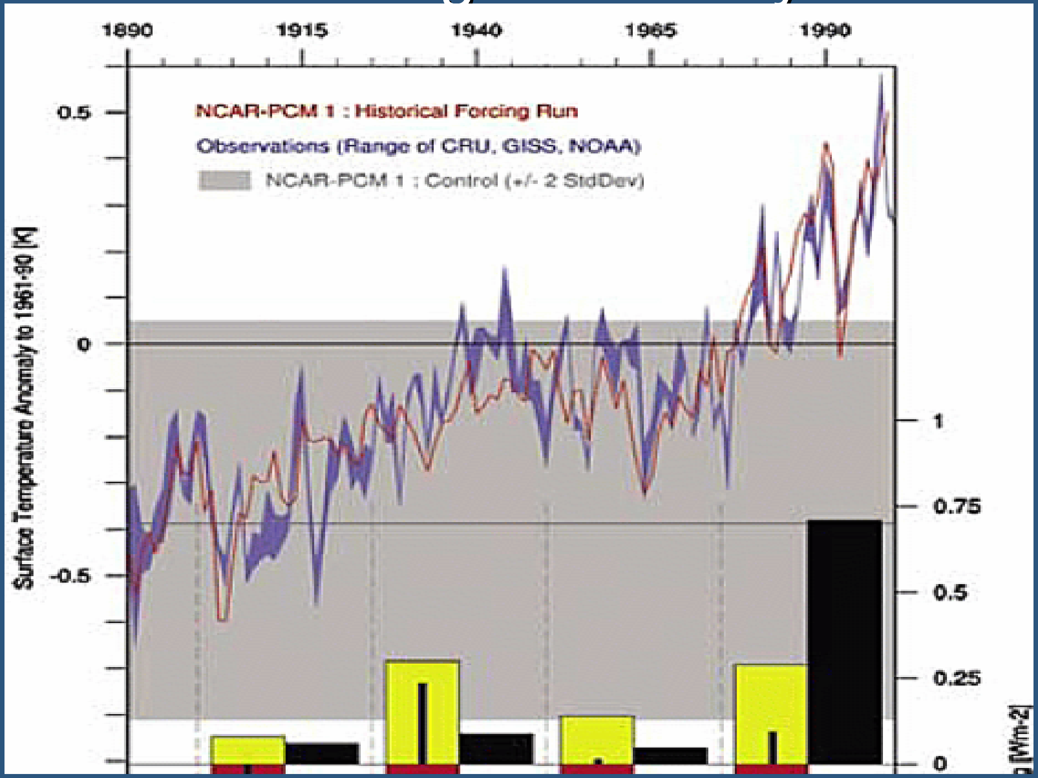
Climate change is already there



- We can model climate change
- Natural drivers alone can not explain observed changes

Climate change: causes and consequences

Climate change is already there



Ammann et al, 2003

- We can model climate change
- Natural drivers alone can not explain observed changes

Climate change: causes and consequences

Climate change is already there

- Human influence on climate discernable
- Since 1950 human influence dominates over natural variations (sun, vulcanism, El Nino, chaos)
- Observed temperature increases, but also
  - sea level rise
  - increased precipitation and extremes
  - glacier retreat, thawing of permaforst
  - lengthening of growing season

Climate change: causes and consequences

- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

Climate change: causes and consequences

What to expect in the future?

Future climate change

- Future economic development scenarios
- Future emission scenarios
- Future climate scenarios
  - Global mean trends and variability
  - Regional mean trends and variability

Climate change: causes and consequences

What to expect in the future?

Future climate change

- SRES scenarios – story lines **B1, B2, A1, A2**
- depend on societal choices

→ More extreme emissions

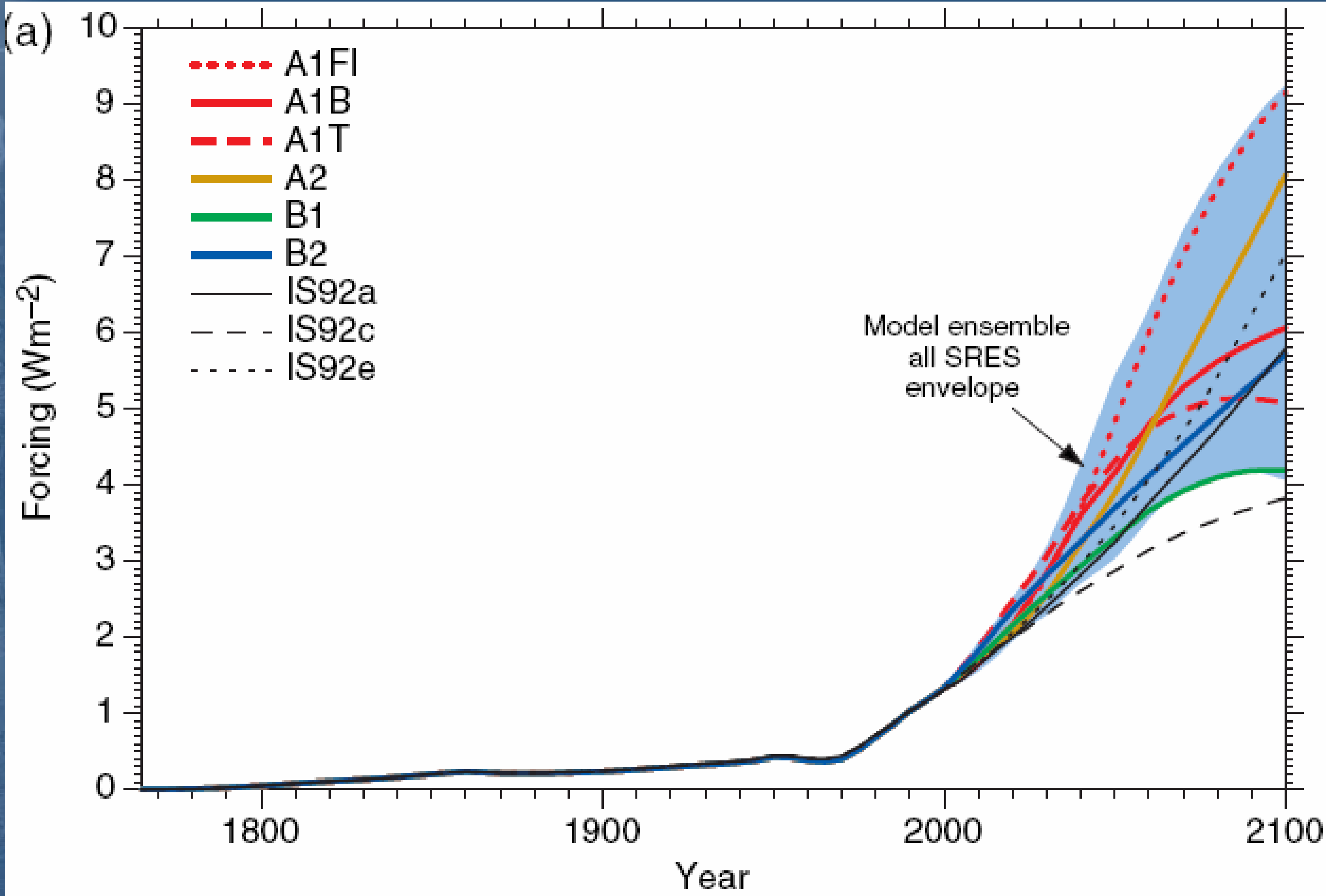
	• Globalisation •Population peaks mid century	• Self reliance • Population continues to grow
• Rapid and material/energy - intensive growth	**A1**	**A2**
•Towards economic, social and environmental sustainability	**B1**	**B2**

Climate change: causes and consequences

What to expect in the future?

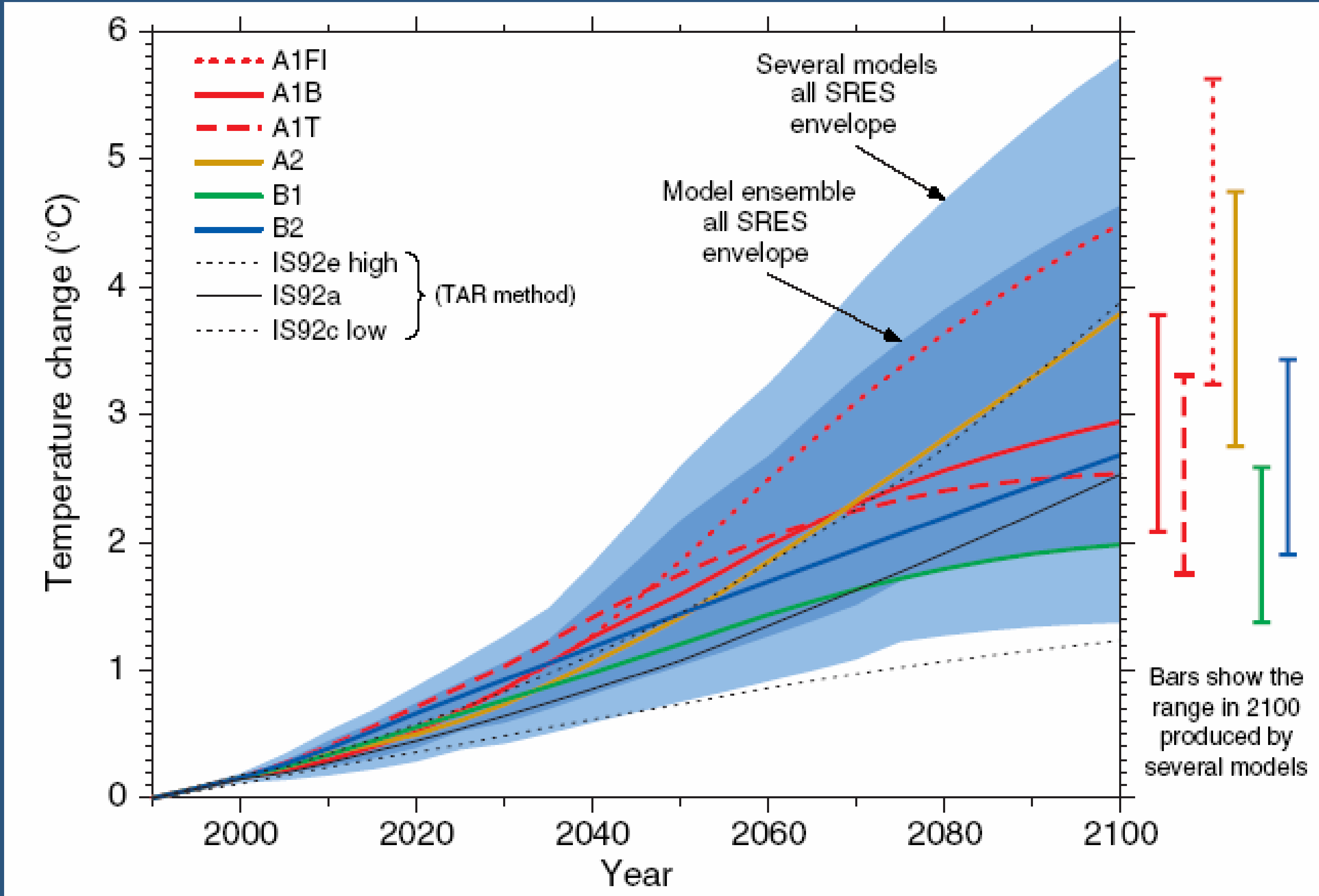
	• Globalisation •Population peaks mid century	• Self reliance • Population continues to grow
• Rapid and material/energy - intensive growth	**A1**	**A2**
•Towards economic, social and environmental sustainability	**B1**	**B2**

Climate change: causes and consequences
What to expect in the future?



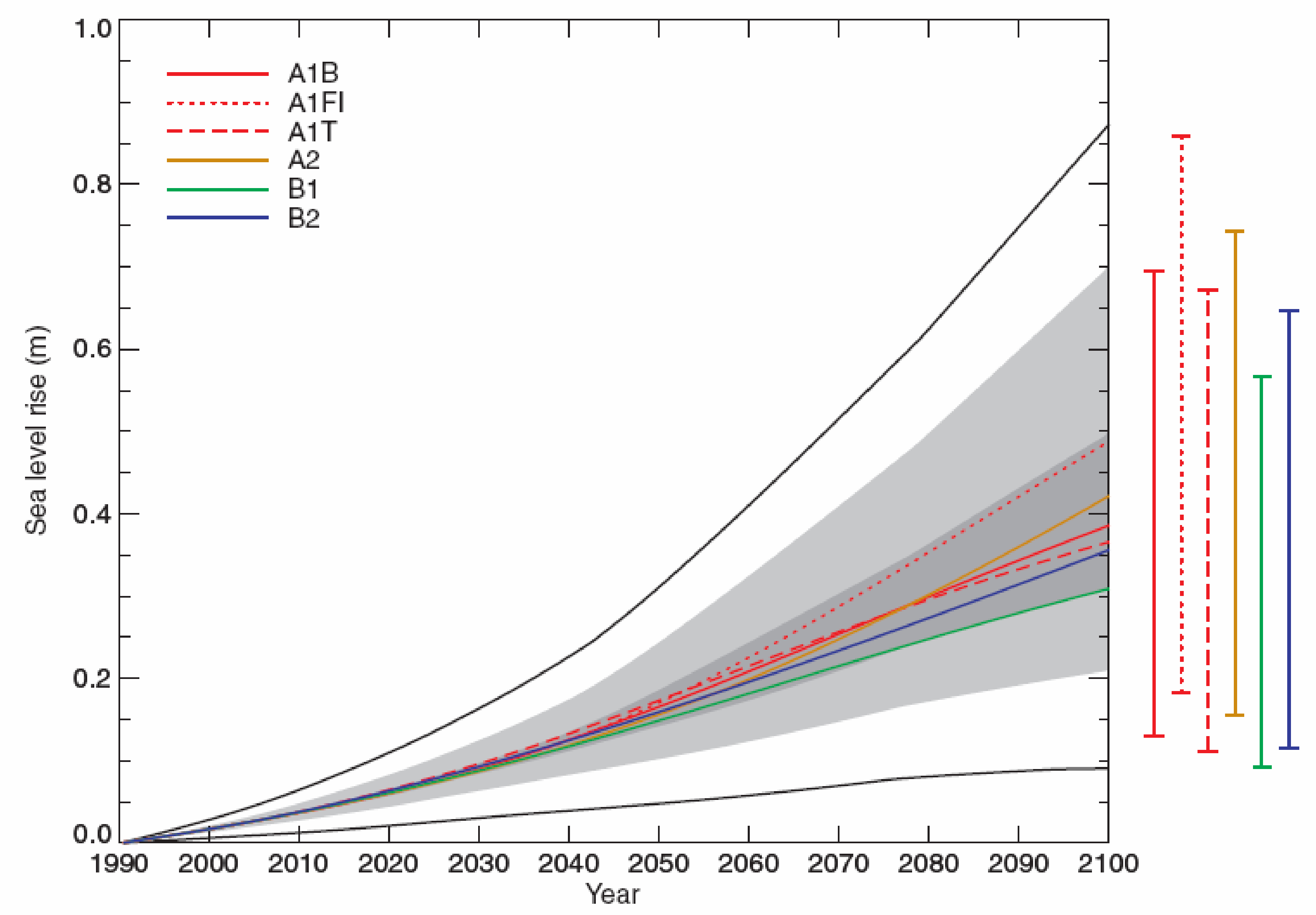
Climate change: causes and consequences

What to expect in the future?



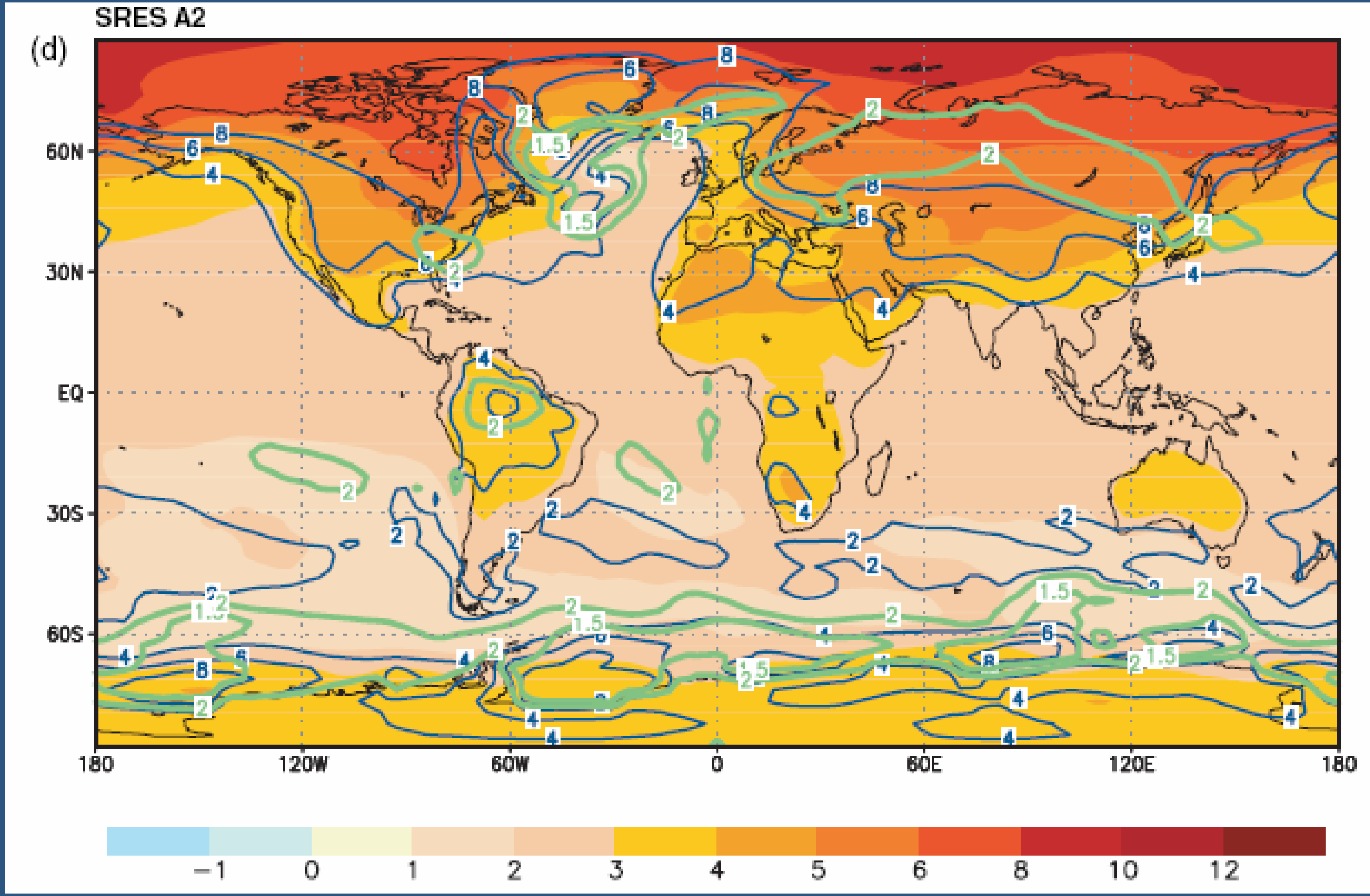
Climate change: causes and consequences

What to expect in the future?



Climate change: causes and consequences

What to expect in the future?

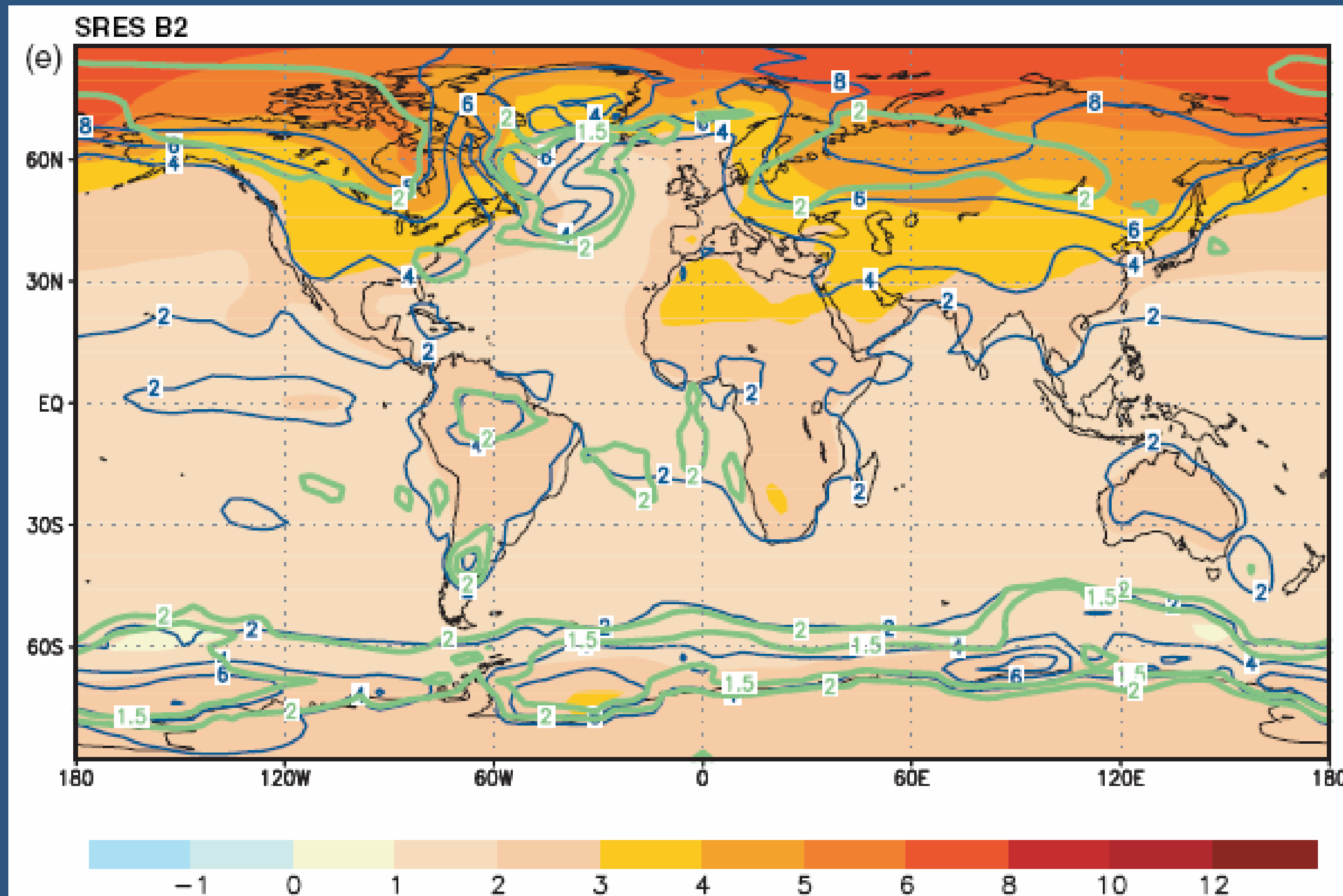


SRES A2

Temperature change 2071-2100 relative to 1961-1990

Climate change: causes and consequences

What to expect in the future?



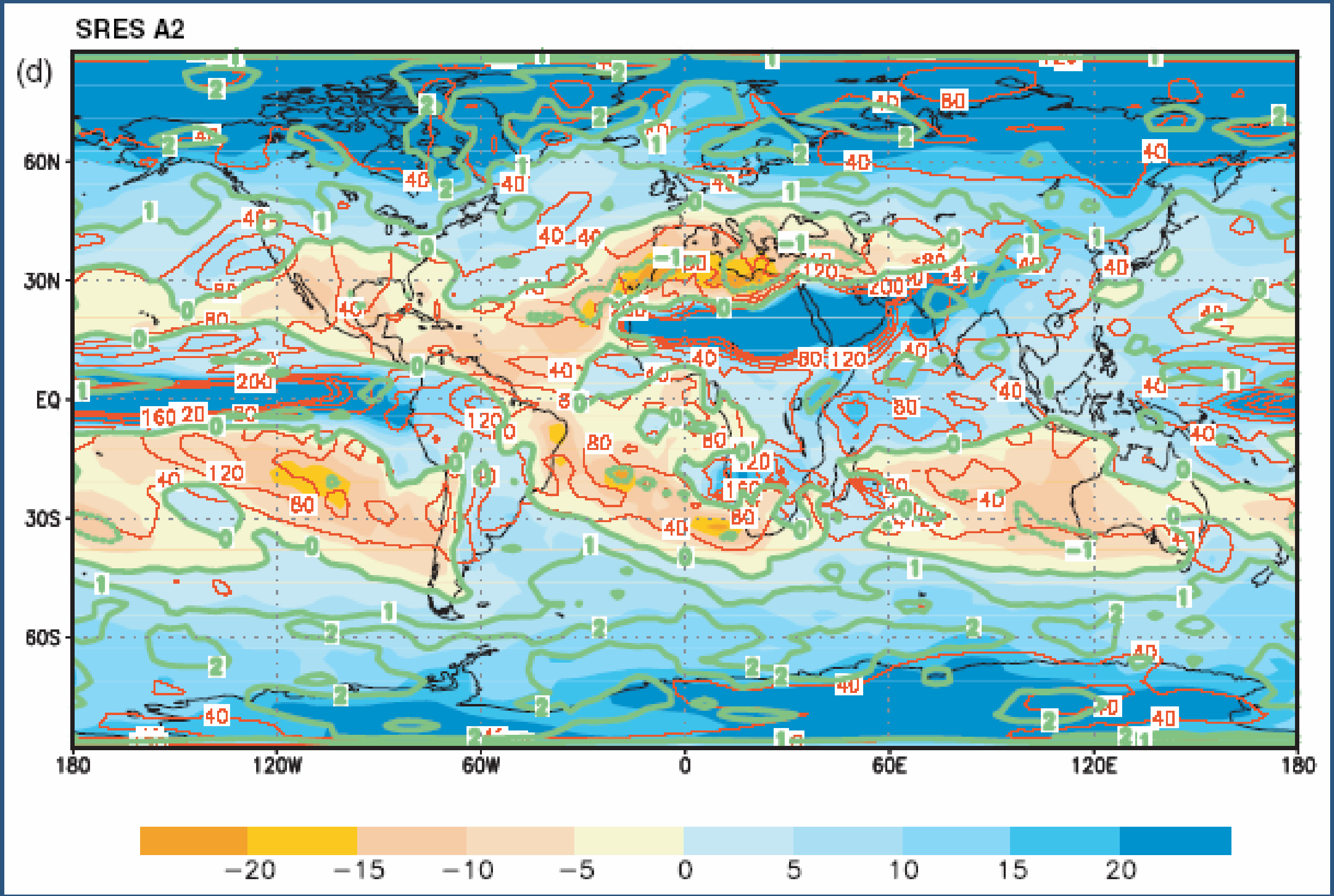
SRES B2

Temperature change 2071-2100 relative to 1961-1990

Platform Communication on Climate Change - PCCC

Climate change: causes and consequences

What to expect in the future?

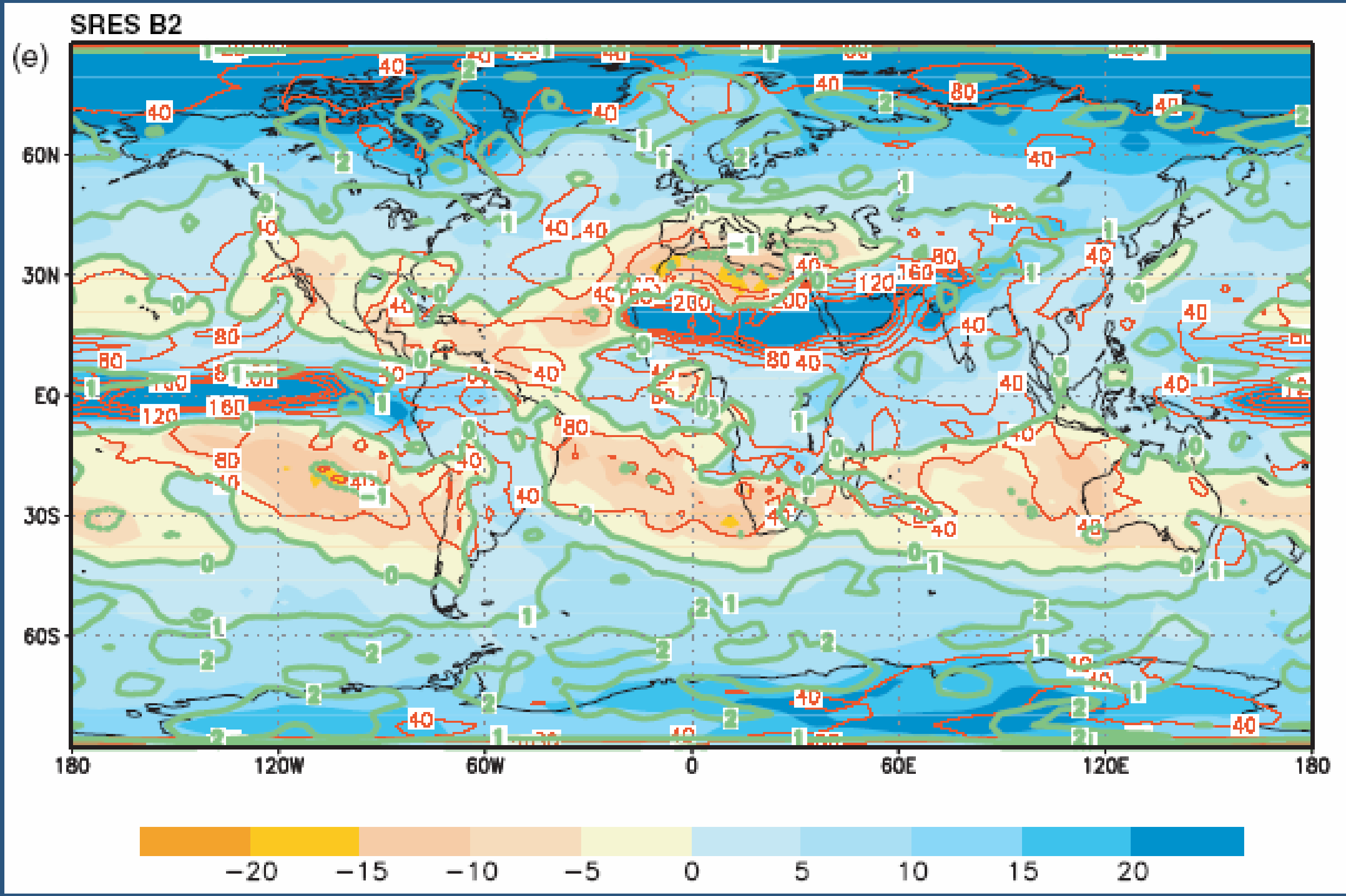


SRES A2

Precipitation change 2071-2100 relative to 1961-1990

Climate change: causes and consequences

What to expect in the future?



SRES B2

Precipitation change 2071-2100 relative to 1961-1990

Climate change: causes and consequences

What to expect in the future?

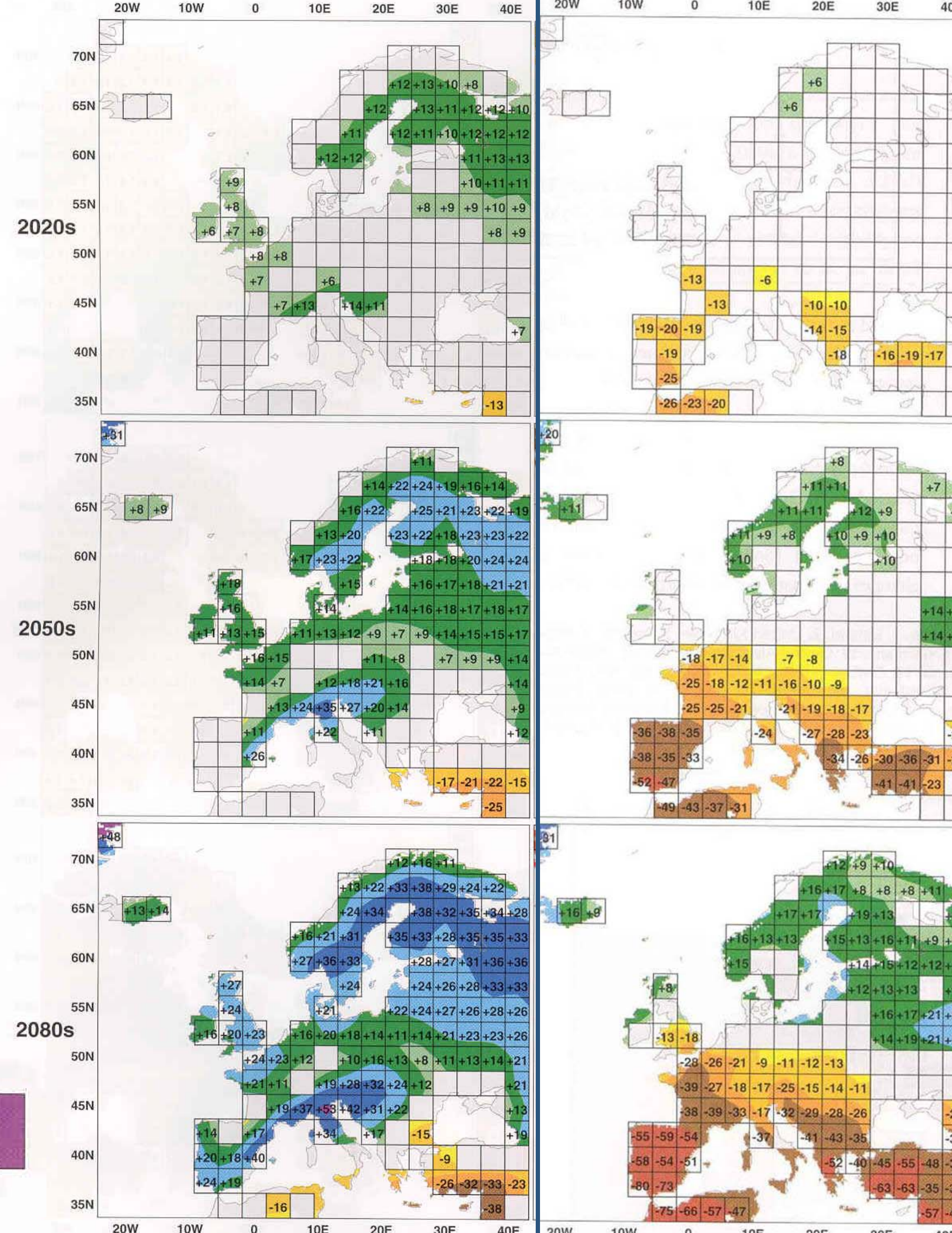
- Europe
- 8 GCMs
  - HadCM2 GGa1-4
  - CGCM1
  - ECHAM4
  - CSIRO-Mk2
  - GFDL-R15
- ACACIA
- M.L. Parry (eds) 2000

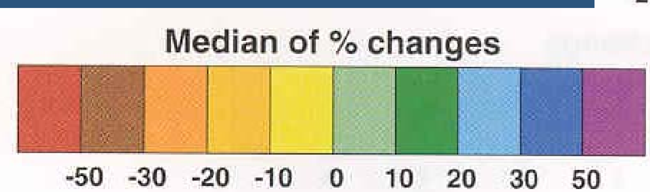
- **Mean** precipitation and temperature changes

A2 Precipitation

DJF

JJA



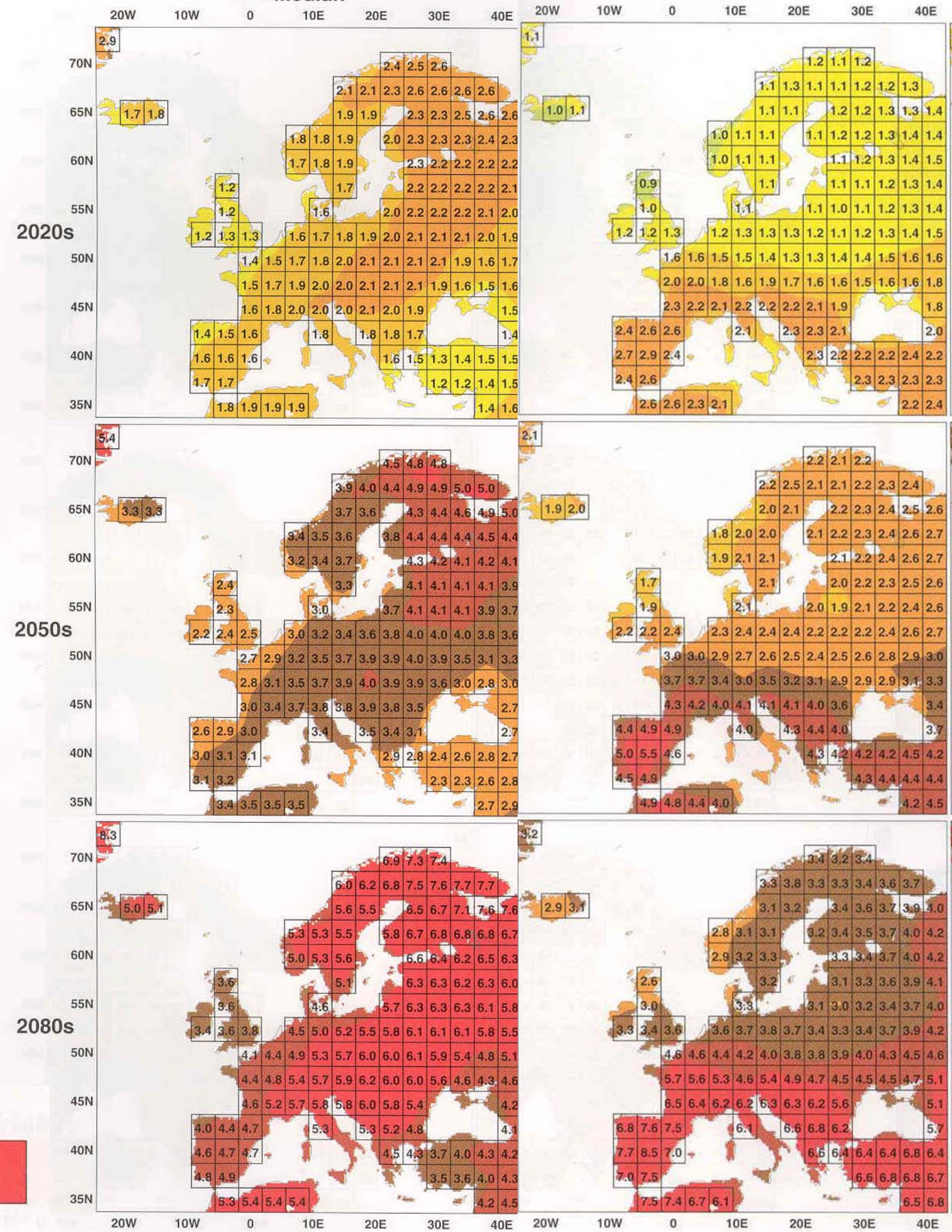


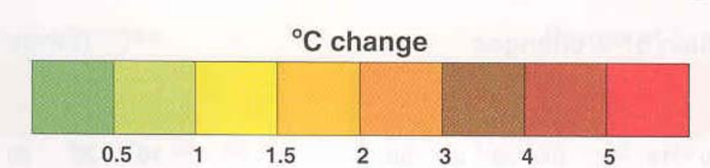
M.L. Parry (eds) 2000

A2 Temperature

DJF

JJA





M.L. Parry (eds) 2000

Climate change: causes and consequences

What to expect in the future?

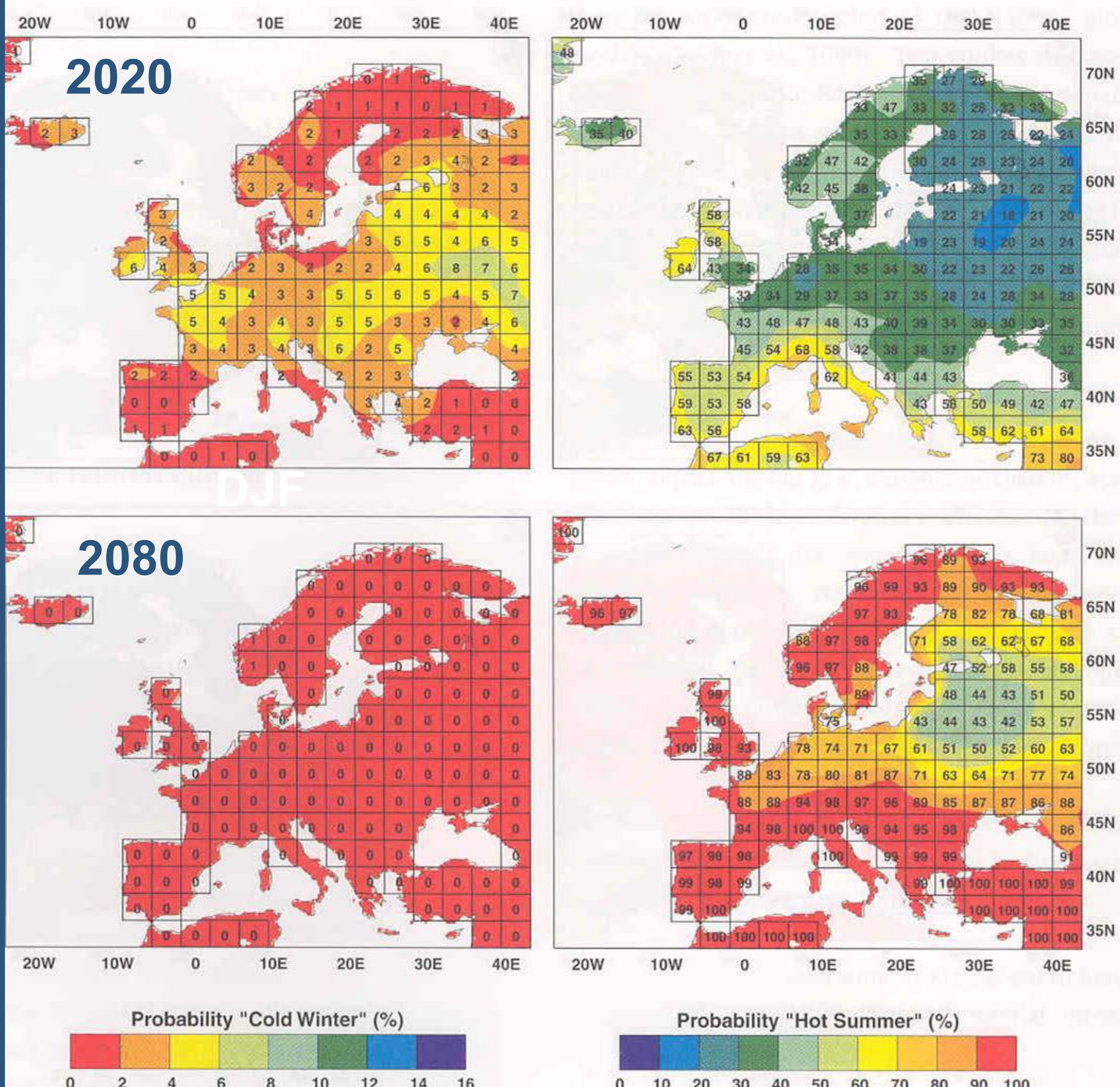
- **Extreme seasons**
  - Percentage of years with mean winter temperature below present day 1-in-10 cold winter threshold
  - Percentage of years with mean summer temperature above present day 1-in-10 hot summer threshold

A2 Temperature Extremes

NL winter:
10 - 2 - 0%

NL summer:
10 - 28 - 78%

'60-'90 2020 2080



M.L. Parry (eds) 2000

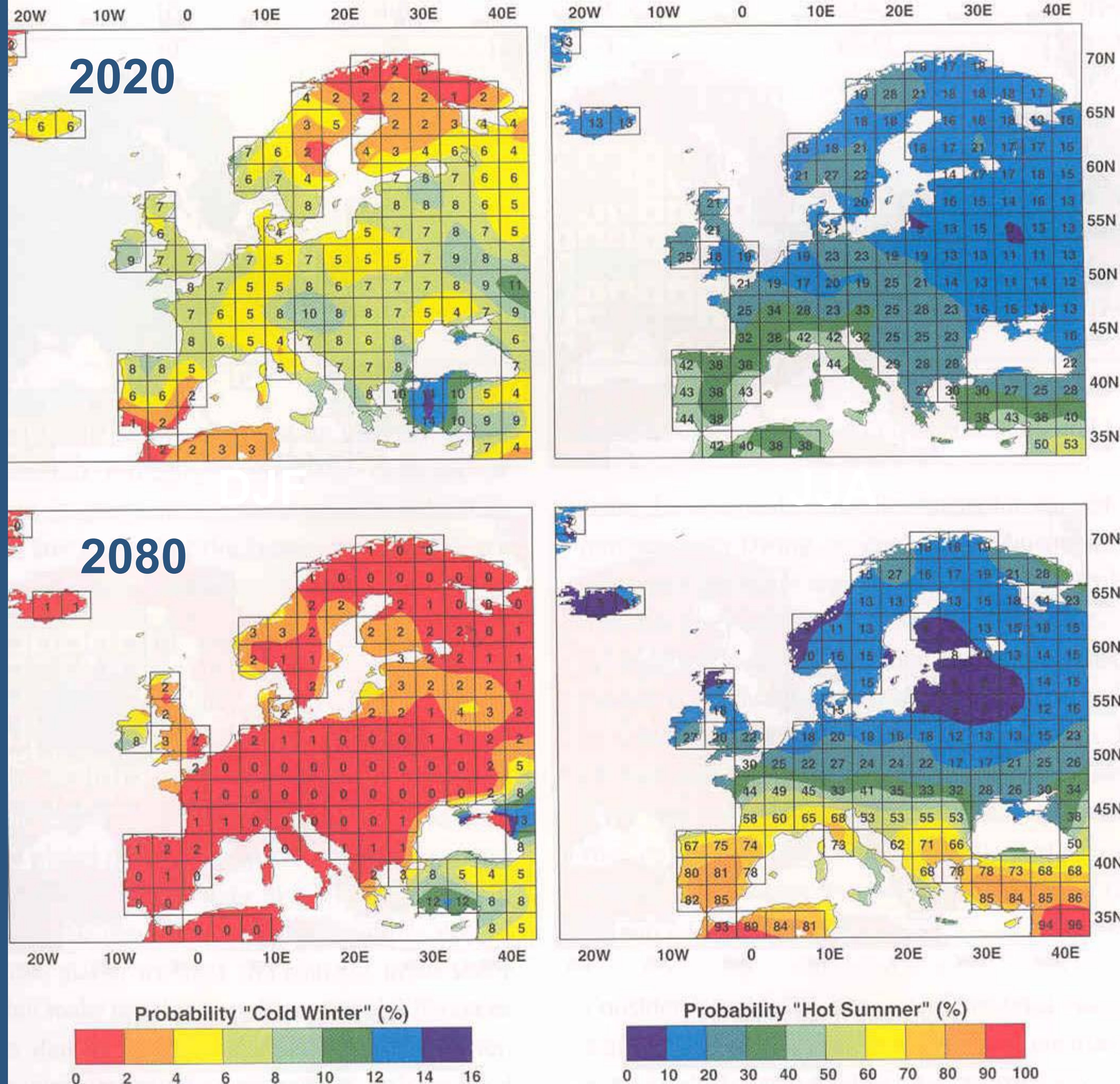
B1 Temperature Extremes

NL winter
10 - 7 - 2%

NL summer
10 - 19 - 18%

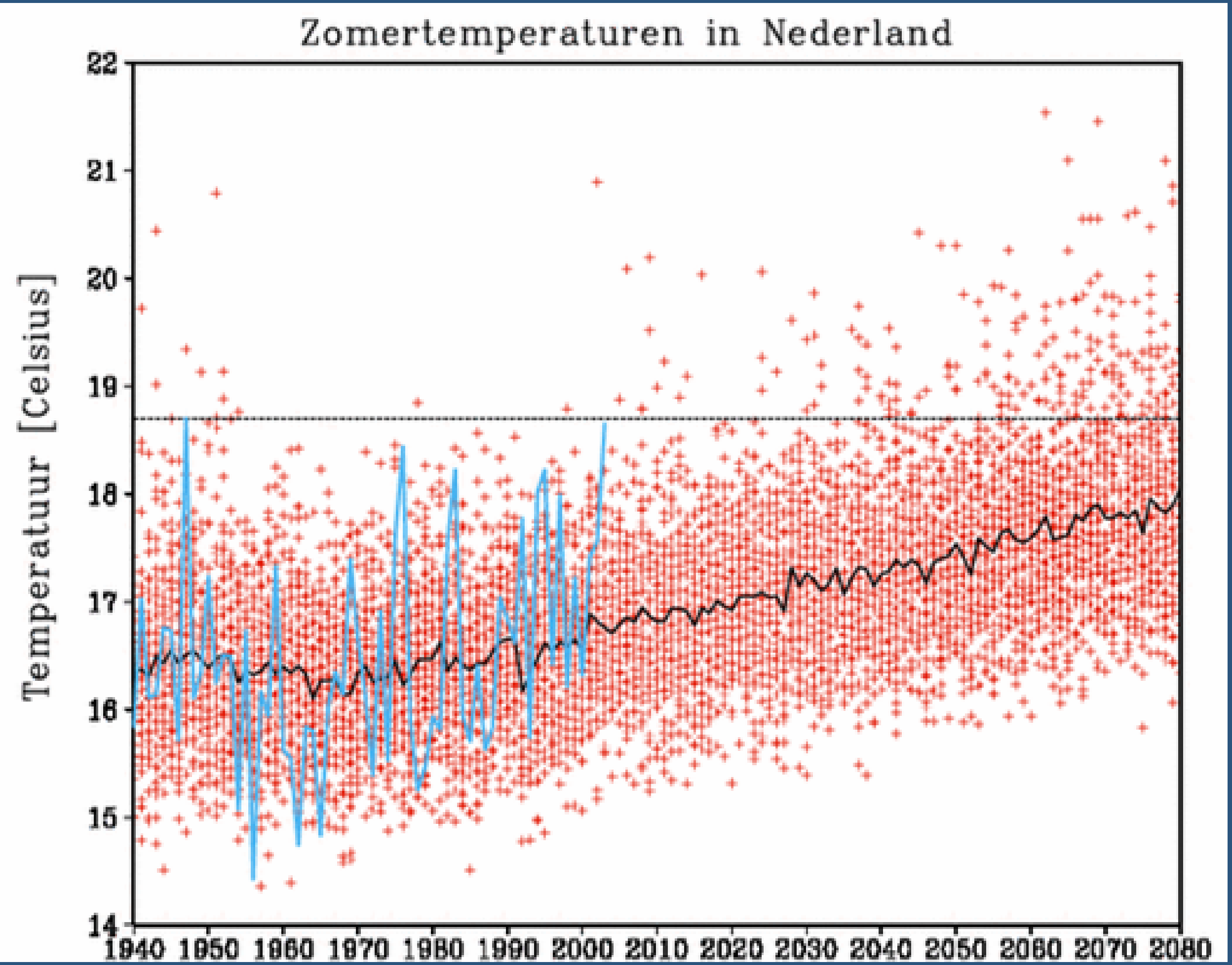
'60-'90 2020 2080

M.L. Parry (eds) 2000



Climate change: causes and consequences

What to expect in the future?



KNMI, 2004

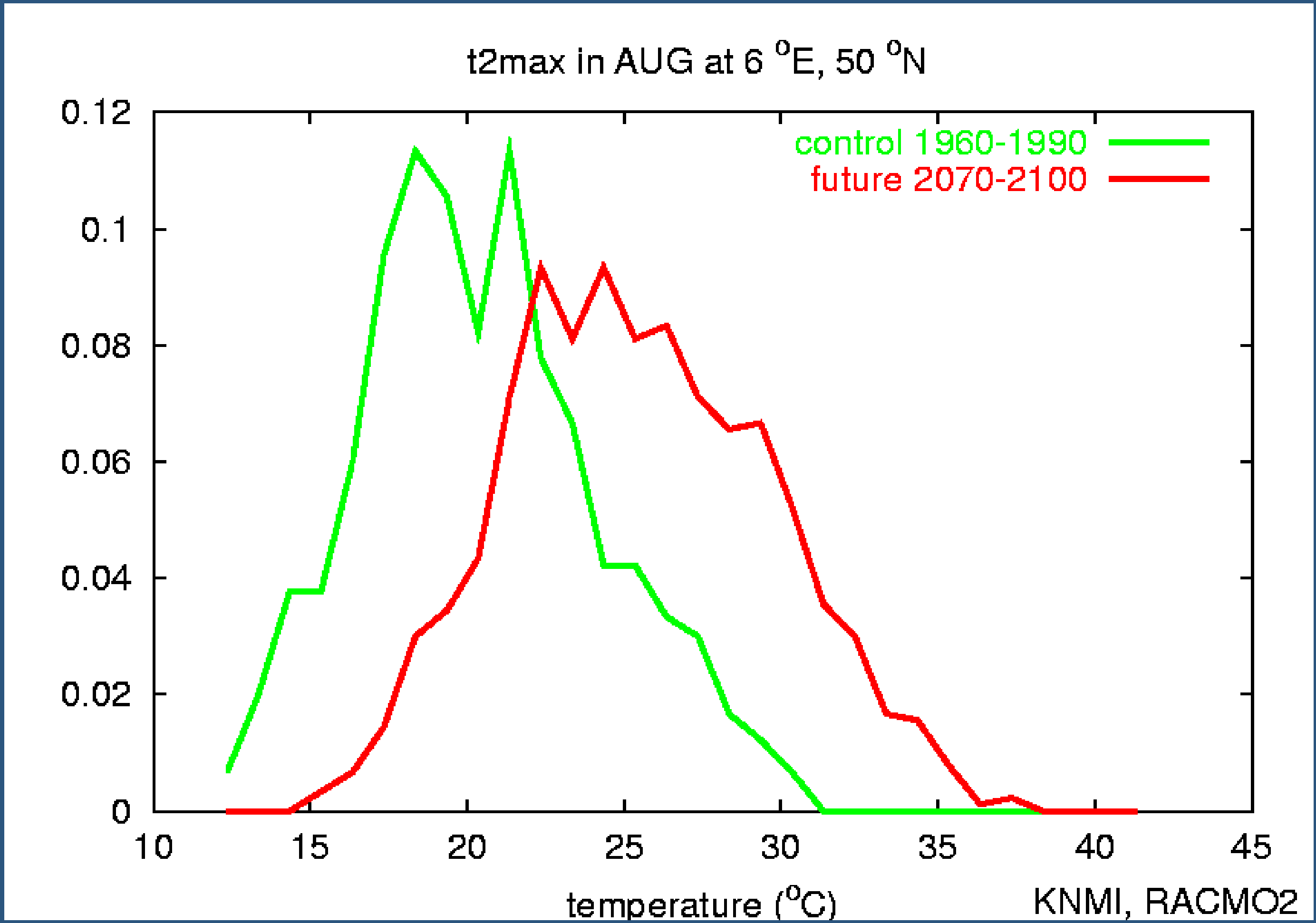
Increased chance of extremes

- Summer Netherlands

Platform Communication on Climate Change - PCCC

Climate change: causes and consequences

What to expect in the future?



KNMI, 2004

Increased chance of extremes

- PDF shifts and broadens

Climate change: causes and consequences

What to expect in the future?

Projected climate change this century

- Average temperature increase 1.4 - 5.8 ^{o}C
  - especially land, especially high latitudes
- Precipitation increases
  - especially N high latitudes + antarctica, tropics variable
- Average sea level rise 0.09 – 0.8 m
- More extremes

- Persistent for (many) centuries

Climate change: causes and consequences

- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

Climate change: causes and consequences

How will it affect us?

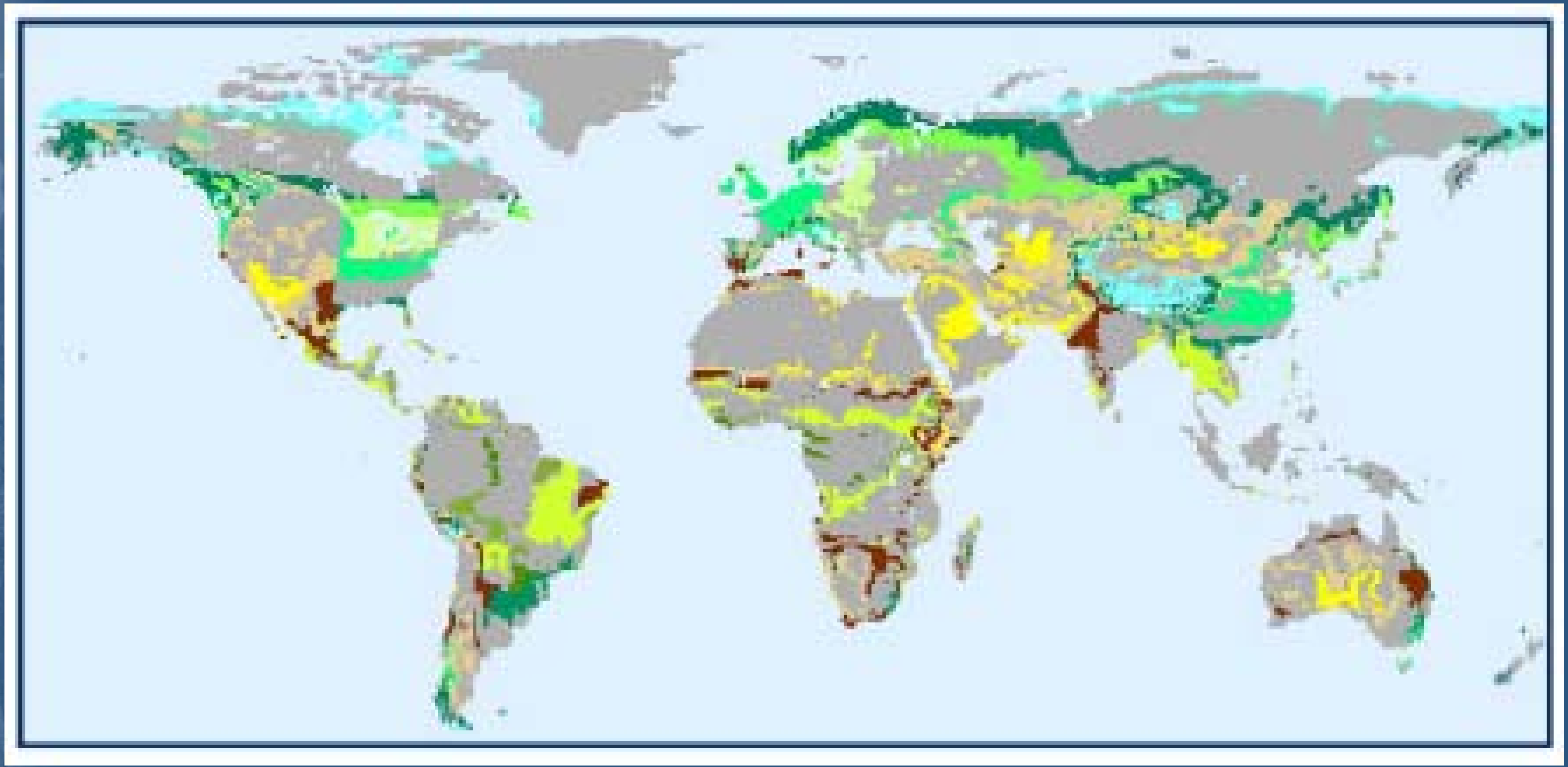
Nature

- Shifts in primary biome types
- Shifts in species distribution
- Changes in growing season length
- Changes in phenology, timing of breeding/hatching
- Effects on species interactions

- Shifts in biogeochemical cycles

Climate change: causes and consequences

How will it affect us?



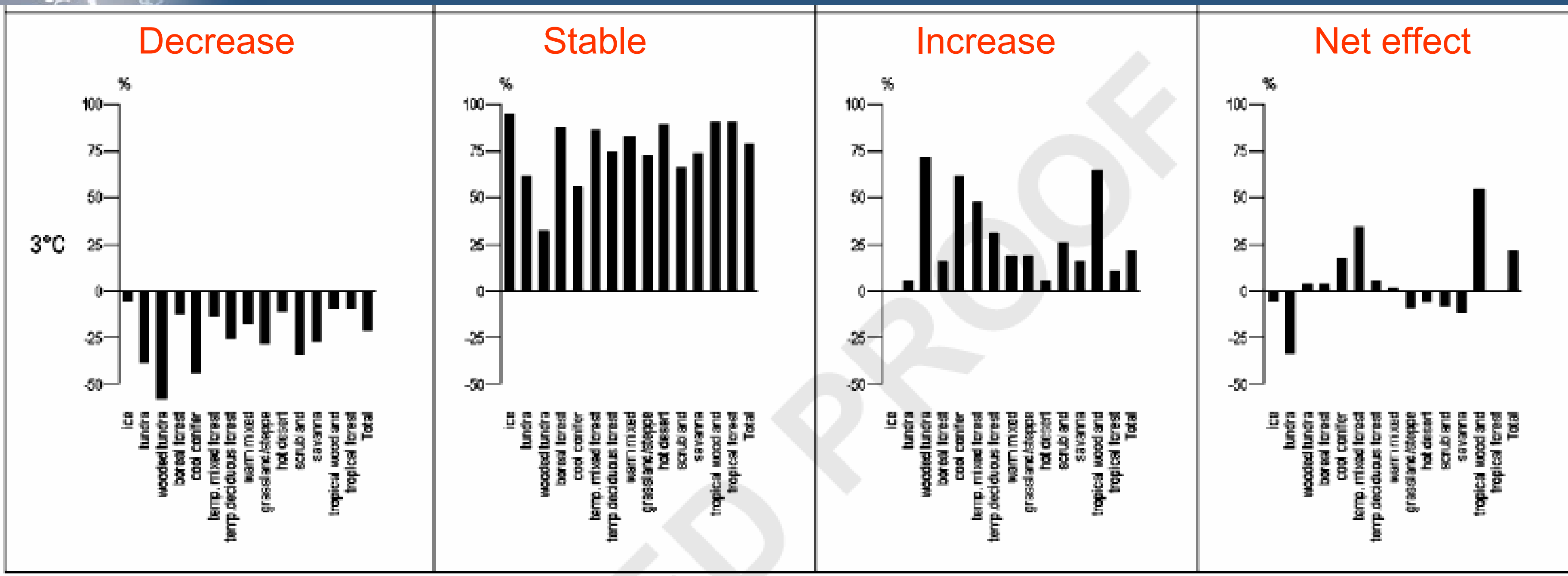
Leemans&Eickhout, in press

Nature

- shifts in primary biome types

Climate change: causes and consequences

How will it affect us?



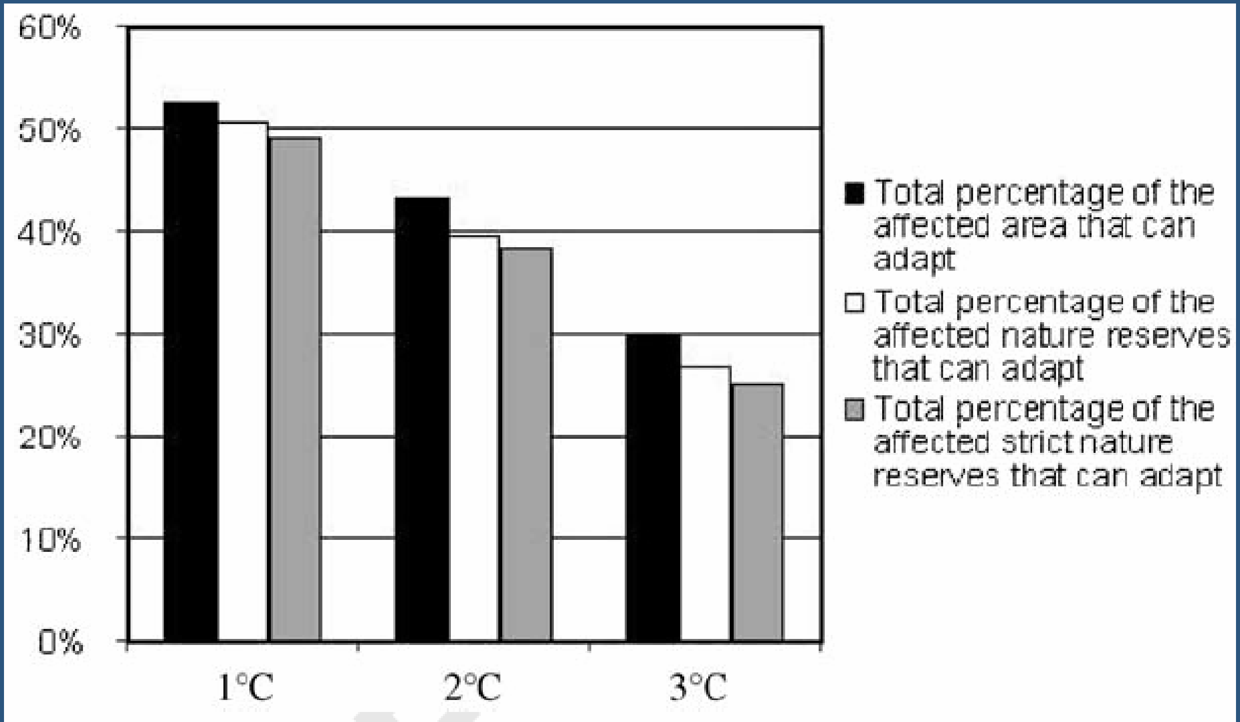
Leemans&Eickhout, in press

Nature

- shifts in primary biome types

Climate change: causes and consequences

How will it affect us?



Leemans&Eickhout, in press

Nature

- shifts in primary biome types
- Adaptation possibility depends on rate of climate change and biome type

Climate change: causes and consequences

How will it affect us?

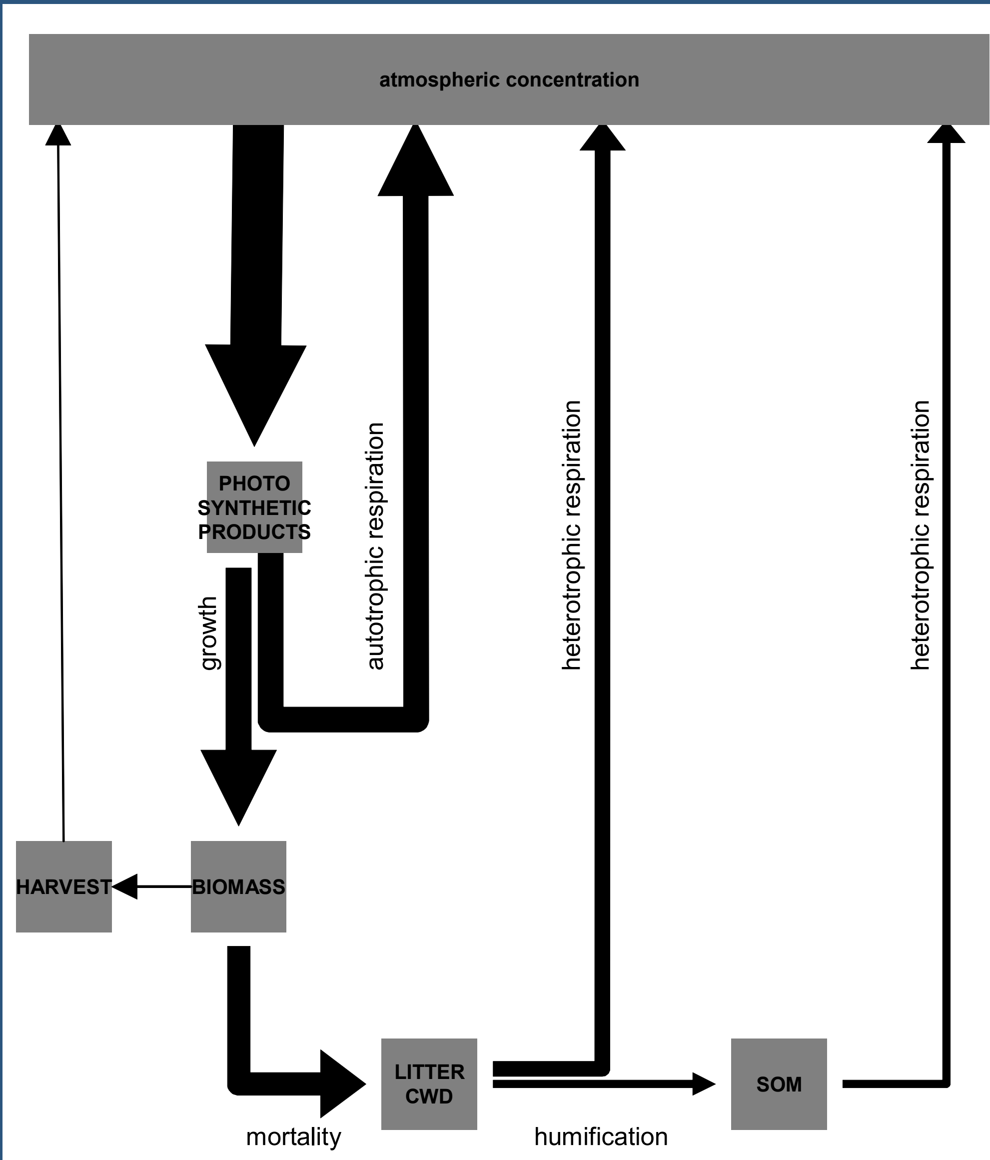
Nature

Shifts in biogeochemical cycles: Carbon cycle

- Photosynthesis optimum temperature
- Respiration increases with temperature

More than 2-3oC warming:

- Terrestrial sinks becomes source
- Feedback !



Climate change: causes and consequences

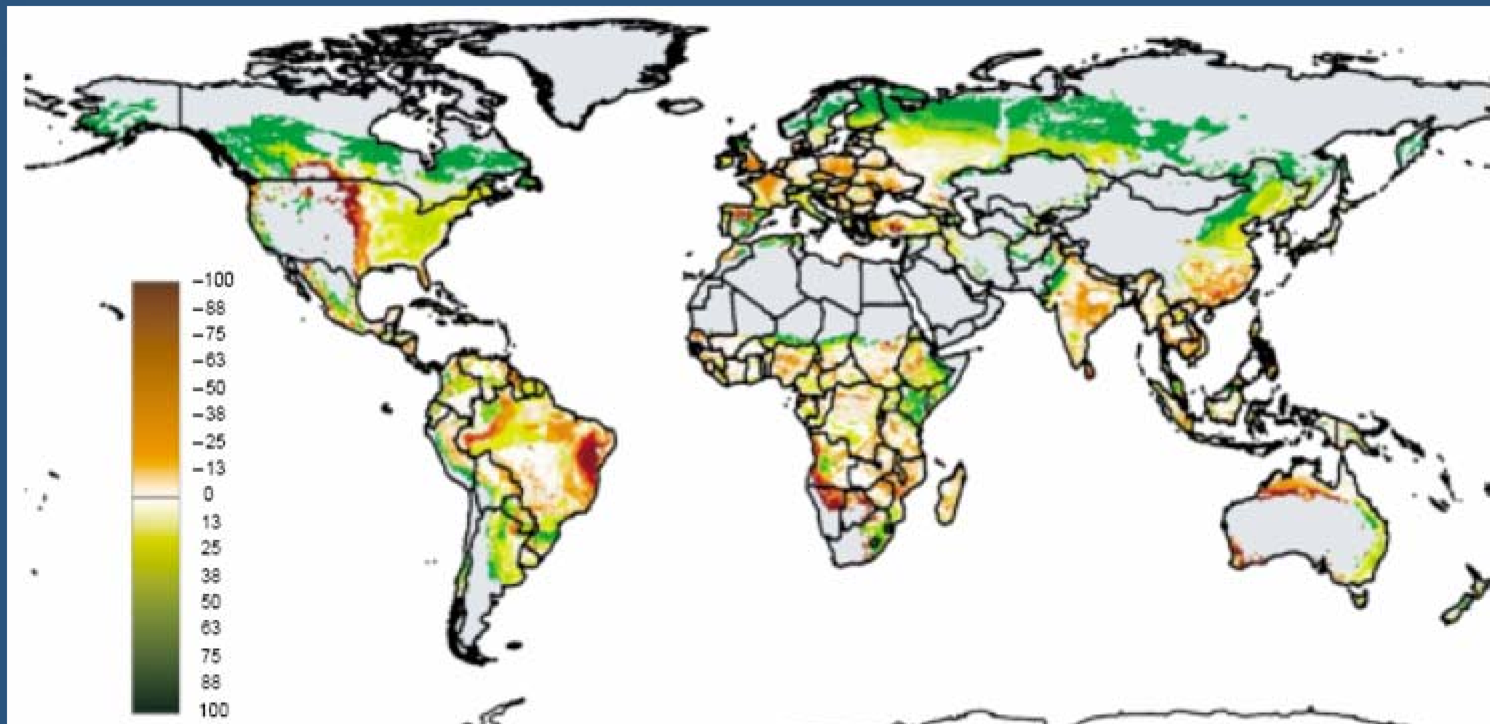
How will it affect us?

Agriculture

- Changes in growing season length (yield increase)
- Changes in phenology (yield decrease)
- Effects on species interactions (pests !)
- Shifts in optimal crops
- Net globally increased production
  - If and when nutrients and water available
  - Major shifts in grain belts
  - Subsistence agriculture vulnerable
- Increased risks of weather extremes and thus crop failures

Climate change: causes and consequences

How will it affect us?



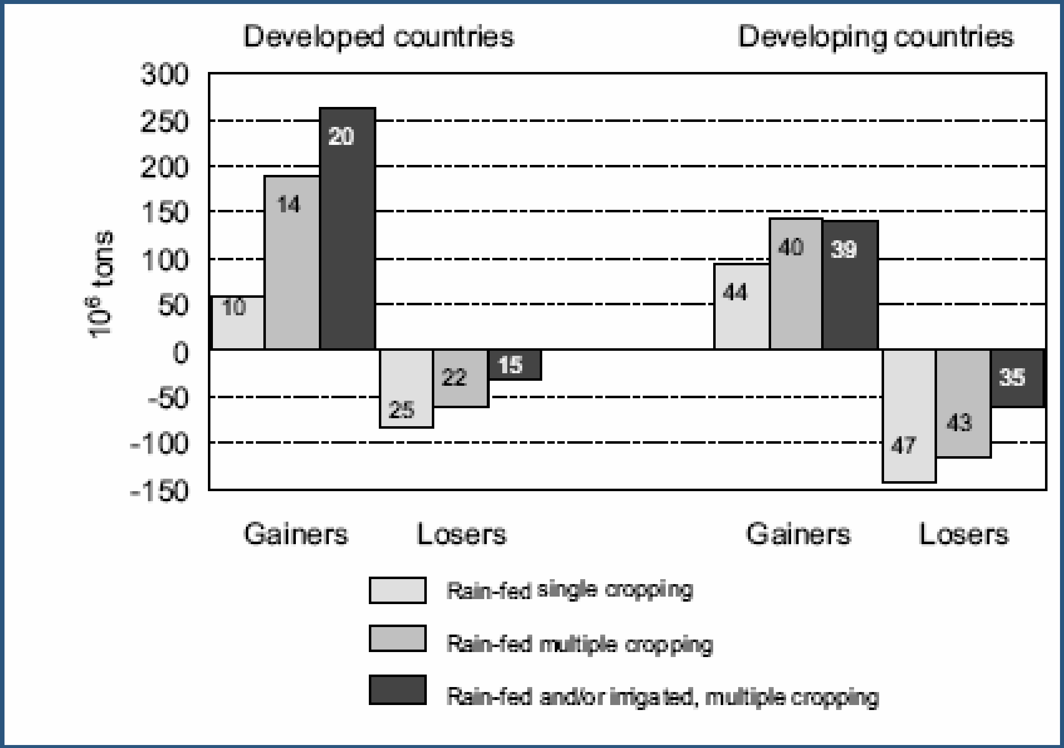
Fischer et al. 2002

Agriculture

- Changes in production potential of cereals
  - (ECHAM4, 2080)

Climate change: causes and consequences

How will it affect us?



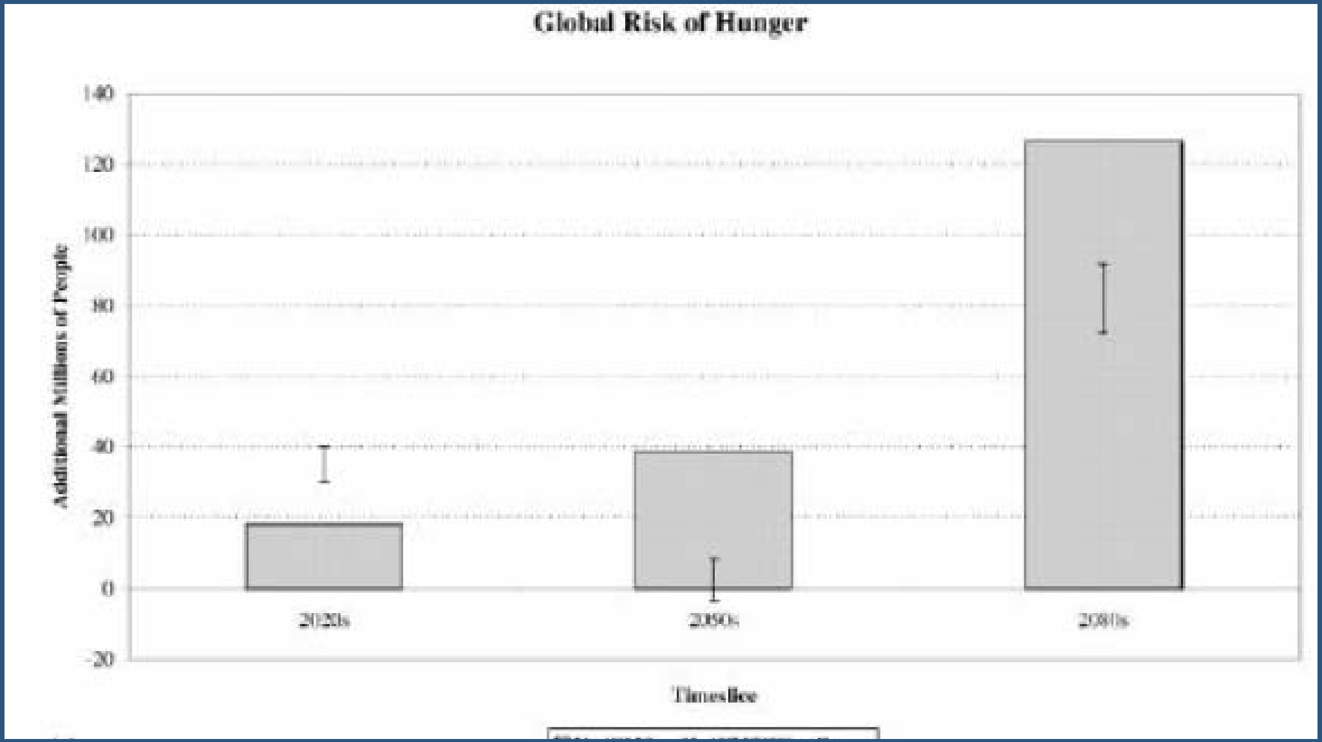
Fischer et al. 2002

Agriculture

- Changes in production potential of cereals per country
  - (ECHAM4, 2080)

Climate change: causes and consequences

How will it affect us?



Parry et al. 1999

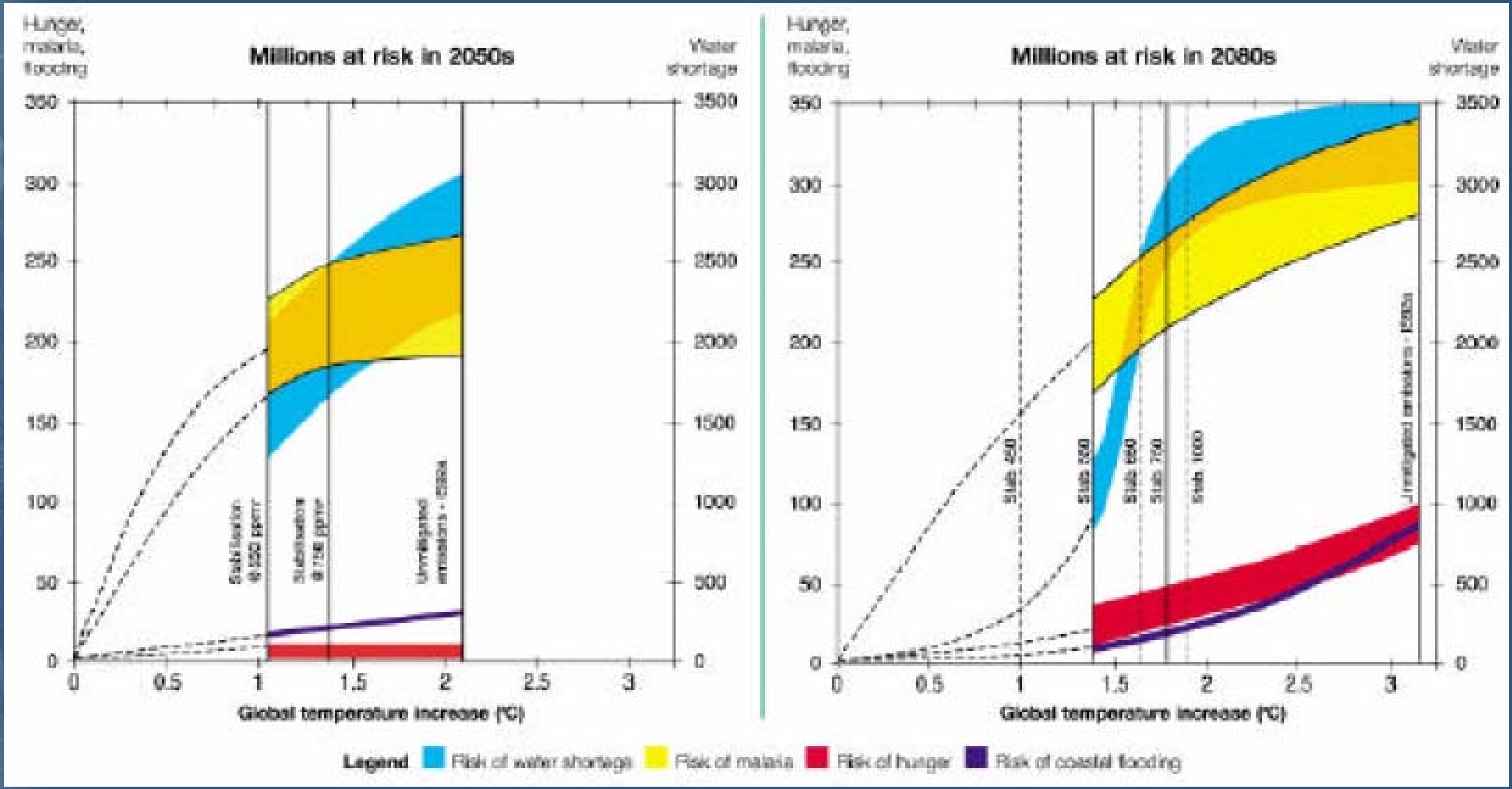
Agriculture

- Risk of hunger

- Platform Communication on Climate Change - PCCC

Climate change: causes and consequences

How will it affect us?



Parry et al. 2001

Agriculture, safety and health

- Water shortage, food shortage, malaria risk, risk of flooding

Climate change: causes and consequences

How will it affect us?

Health

- Increased temperature extremes
- Longer pollen season, more smog
- Changed distribution of vector diseases
- Increased occurence of spoiled food and water
- Risks of flooding etc

Effect depends strongly on welfare level

Climate change: causes and consequences
How will it affect us?

Effects climate change on Nature, Food security, Health depend strongly on

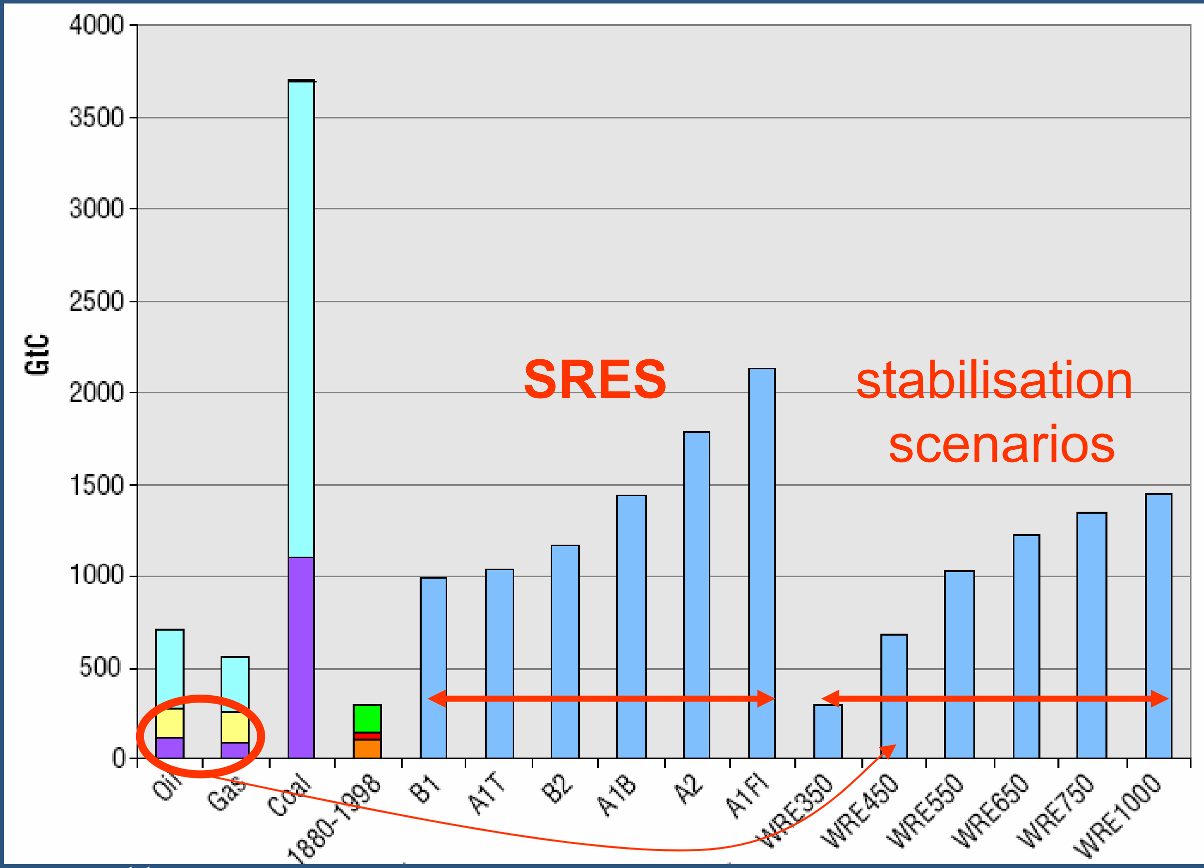
- Magnitude and rate of change (regional variation large!)
- Adaptive potential natural systems and human society
- Developing countries more likely to be adversely affected

Climate change: causes and consequences

- The greenhouse effect: a good thing!
- The way we change atmospheric composition
- Climate change is already there!
- What to expect in the future?
- How will it affect us?
- What to do and when?

Climate change: causes and consequences

What to do and when?



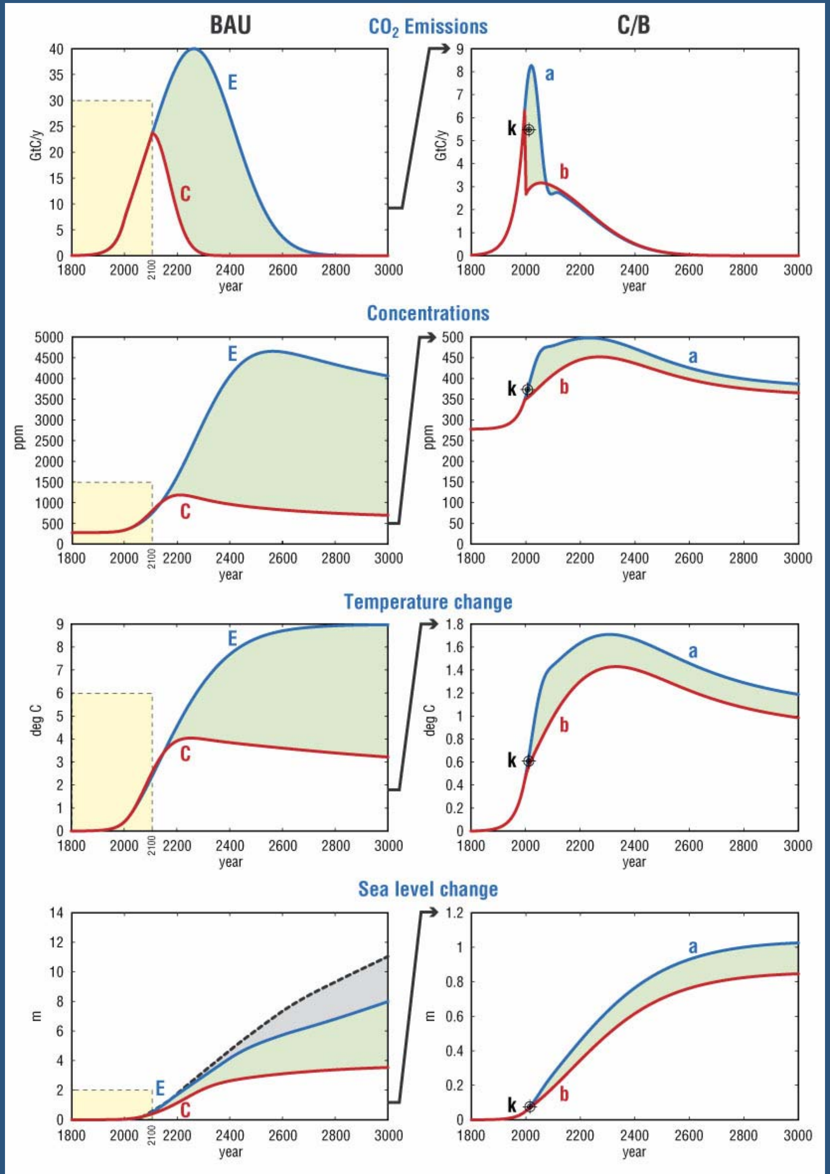
- Total emissions matter
- Not timing

Climate change: causes and consequences

Sector		Historic emissions in 1990 (MtC_{eq}/yr)	Potential emission reductions in 2010 (MtC_{eq}/yr)	Potential emission reductions in 2020 (MtC_{eq}/yr)	Net direct costs per tonne of carbon avoided
Buildings[a]	CO_2 only	1,650	700-750	1,000-1,100	Most reductions are available at negative net direct costs.
Transport	CO_2 only	1,080	100-300	300-700	Most studies indicate net direct costs less than US$25/tC but two suggest net direct costs will exceed US$50/tC.
Industry	CO_2 only	2,300			
-energy efficiency			300-500	700-900	More than half available at net negative direct costs.
-material efficiency			~200	~600	Costs are uncertain.
Industry	Non-CO_2 gases	170	~100	~100	N_2O emissions reduction costs are US$0-US$10/tC_{eq}.
Agriculture[b]	CO_2 only	210			Most reductions will cost between US$0-100/$tC_{eq}$ with limited opportunities for negative net direct cost options.
	Non-CO_2 gases	1,250-2,800	150-300	350-750	
Waste[b]	CH_4 only	240	~200	~200	About 75% of the savings as methane recovery from landfills at net negative direct cost; 25% at a cost of US$20/$tC_{eq}$.
Montreal Protocol replacement applications	Non-CO_2 gases	0	~100	n.a.	About half of reductions due to difference in study baseline and SRES baseline values. Remaining half of the reductions available at net direct costs below US$200/$tC_{eq}$.
Energy supply and conversion[c]	CO_2 only	(1,620)	50-150	350-700	Limited net negative direct cost options exist; many options are available for less than US$100/$tC_{eq}$.
Total		**6,900–8,400[d]**	**1,900–2,600[e]**	**3,600–5,050[e]**	

Climate change: causes and consequences

What to do and when?

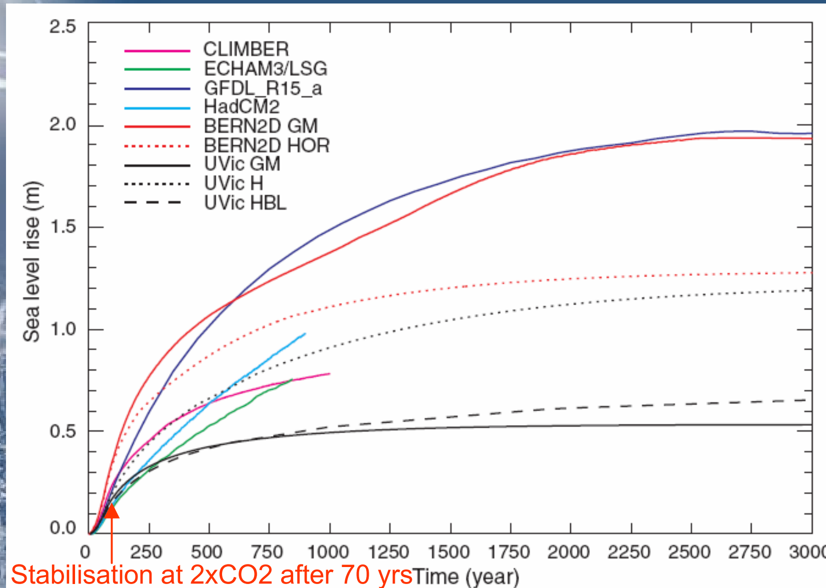


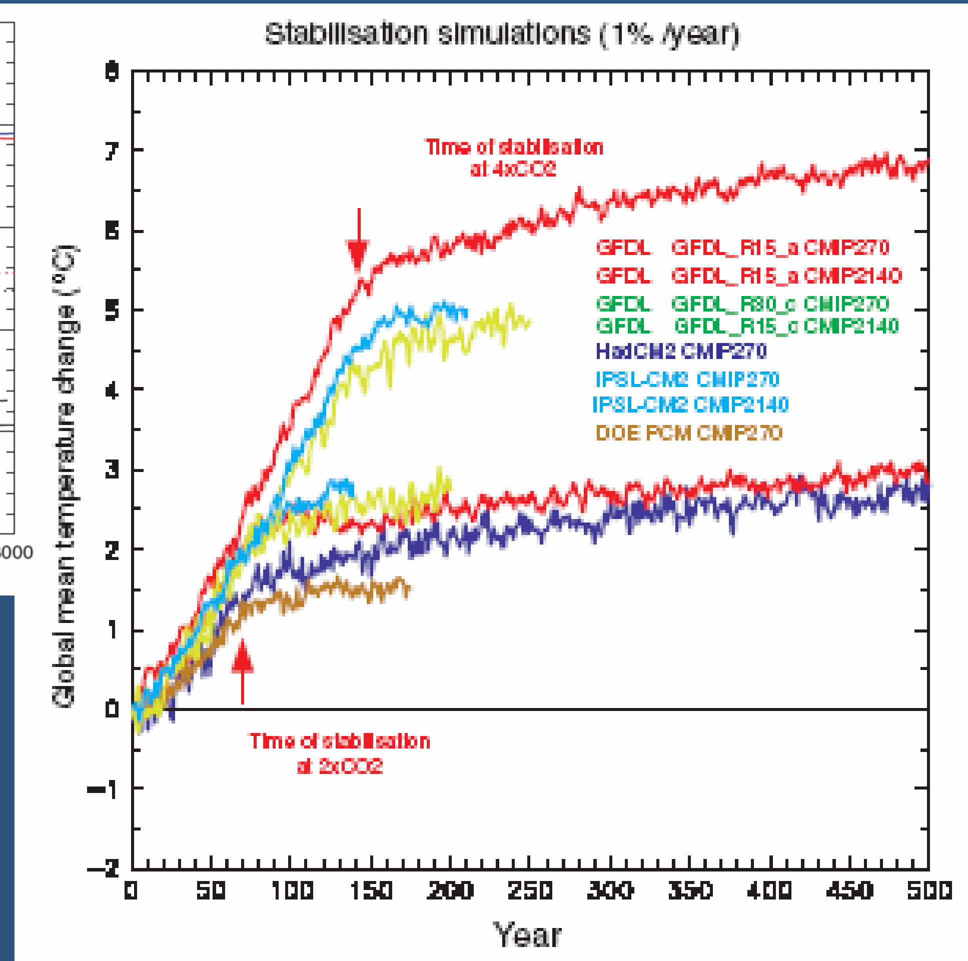
- Total emissions matter
- Not timing

Hasselmann et al, 2003

Climate change: causes and consequences

What to do and when?



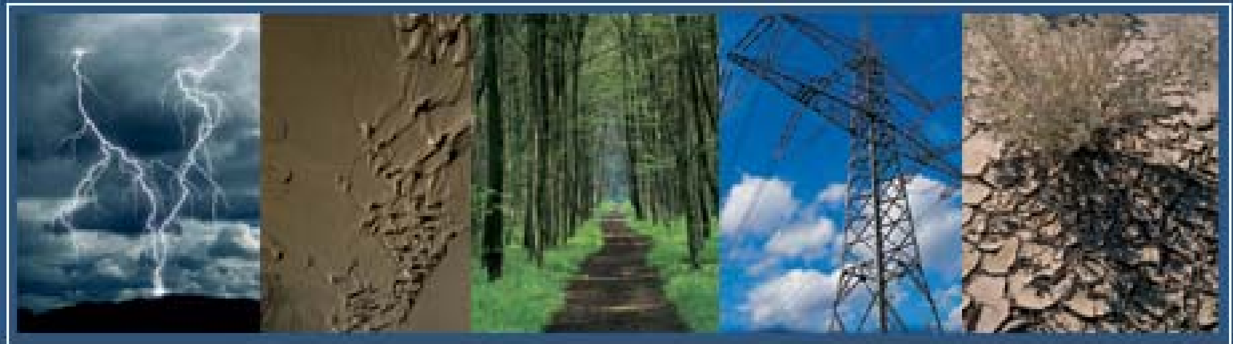


Climate change continues after stabilisation

Climate change: causes and consequences

What to do and when?

- Strong reductions required (30% 2020, 80% 2050)
  - Efficiency gain not enough in long run
- Next two decades important
- Exact trajectory not important
- Climate change will continue afterwards
- Sea level rise will continue long afterwards



Climate change: causes and consequences

Thanks for your attention