ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

DUWIS
Departement
Umweltwissenschaften

Climate Change Impacts On European Agricultural and Forest Ecosystems

Andreas Fischlin

Senior coordinating lead author of chapter on ecosystems of the Fourth Assessment Report of IPCC «Climate Change 2007» Working Group II

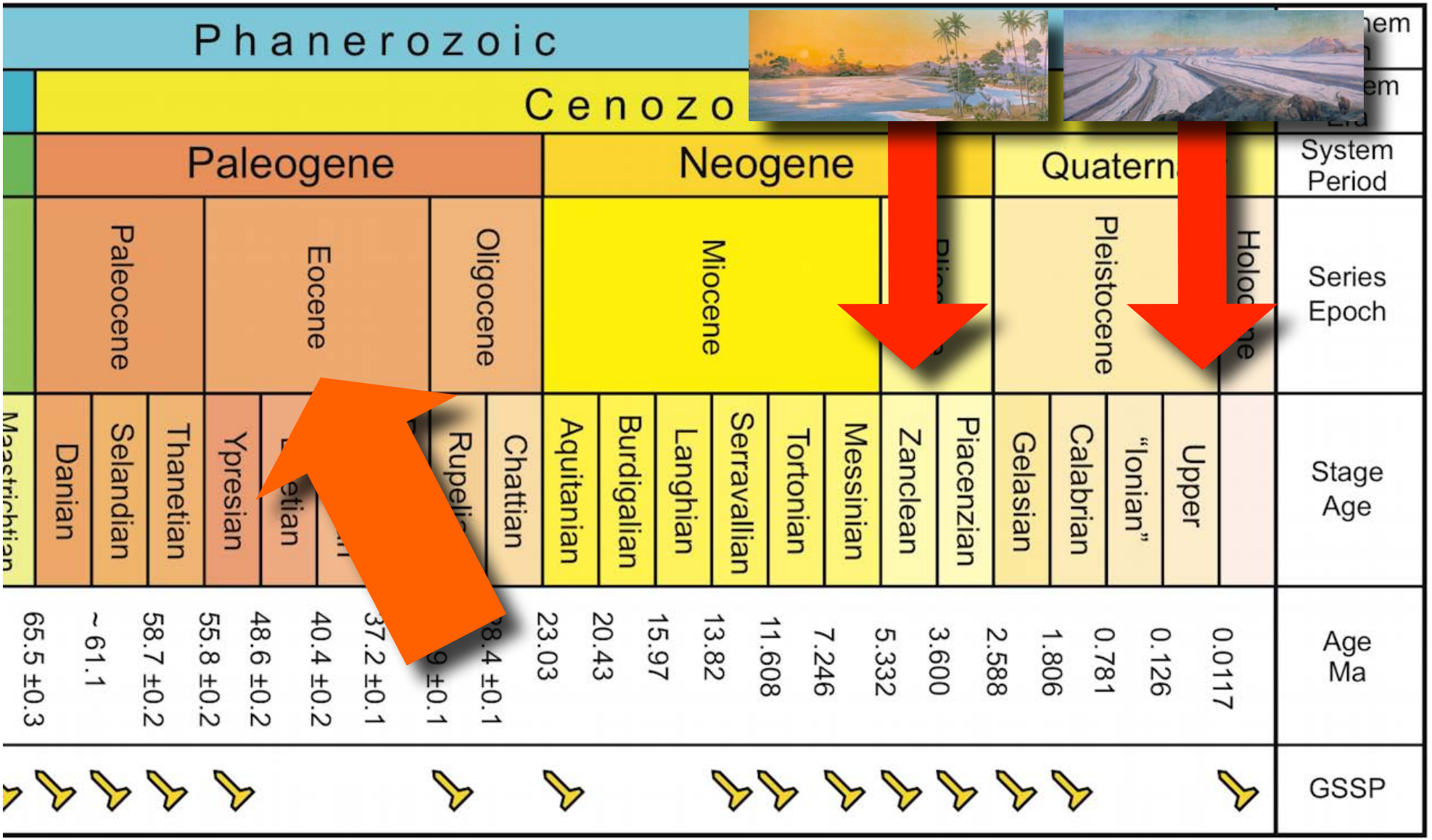
Summary:

- Climate is important
- Climate change is real and human made
- Ecosystems including Agroecosystems and Forests (ES-AF) are important
- ES-AF play a double-rôle:
  - They are impacted by climate change
  - They cause climate change (are part of the solution)
- It matters a great deal whether and how we solve the climate change challenge: with or without ecosystems!


Climate Is
Important!


Lucerne ~4-23 Ma BP (Miocene)
Lucerne 18’000 a BP (>LGM)

Context of Past Epochs



ICS International Commission on Stratigraphy

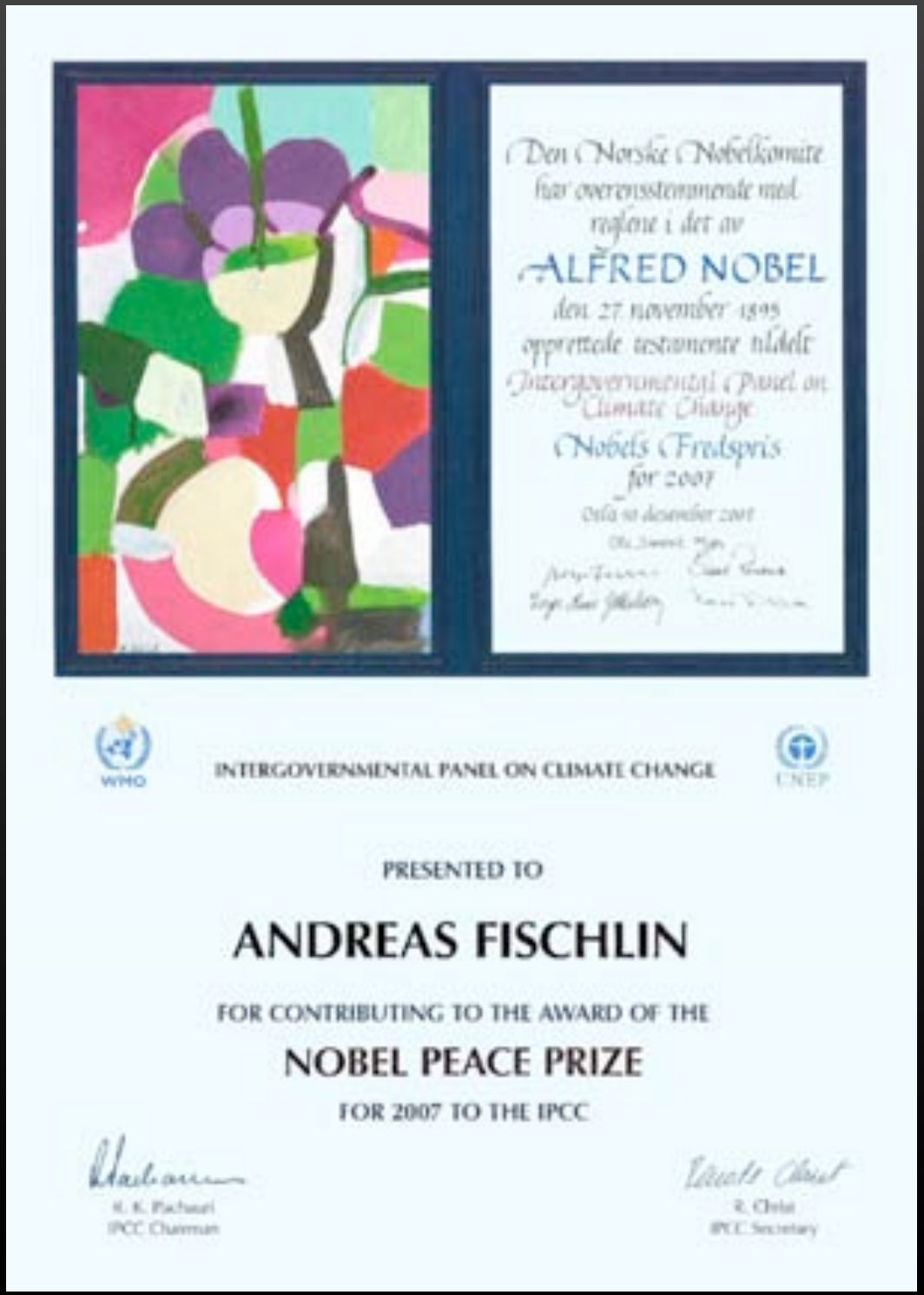
Global Standard Section and Point (GSSP)

www.stratigraphy.org/

On IPCC

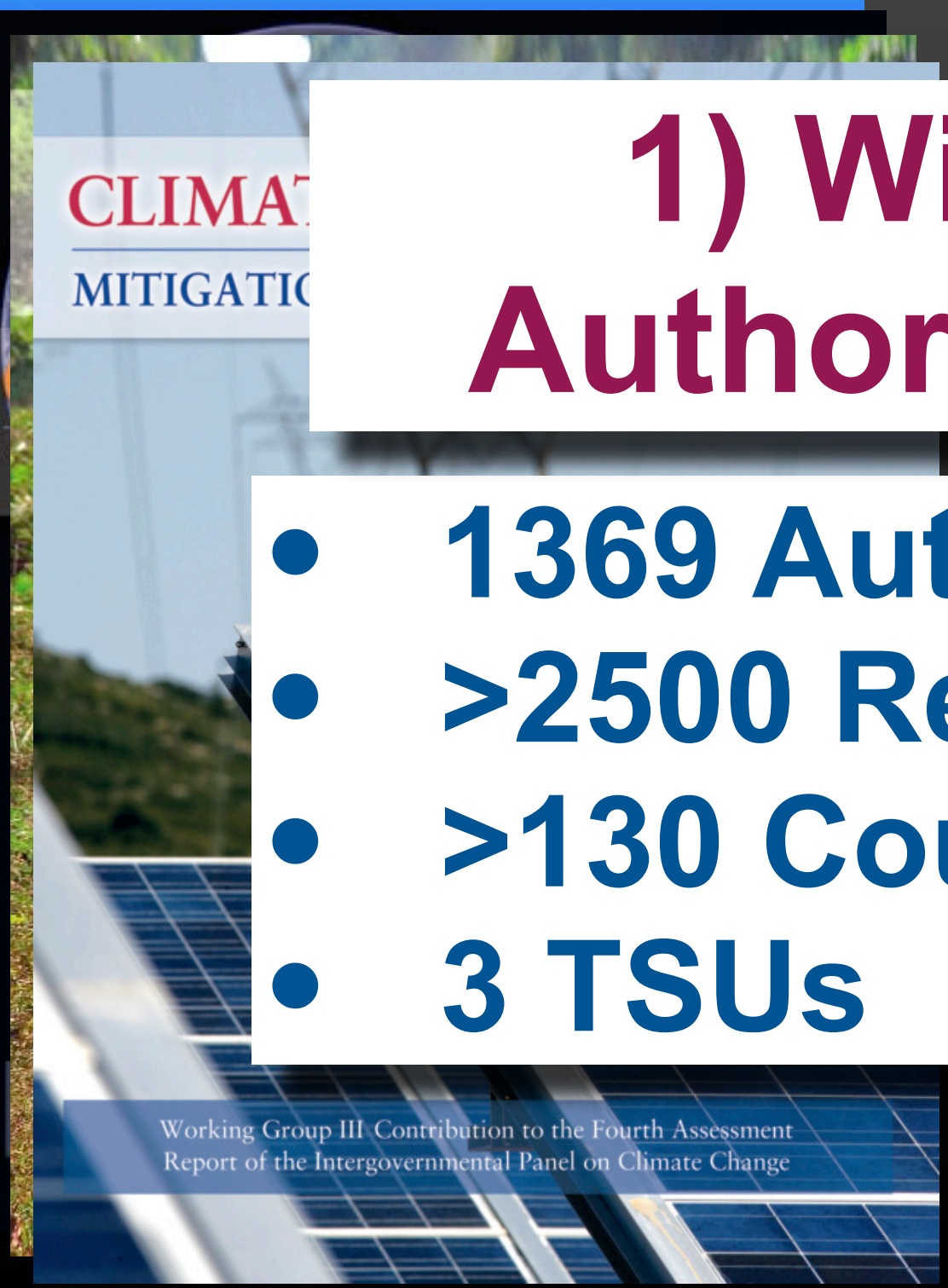
Intergovernmental Panel on Climate Change

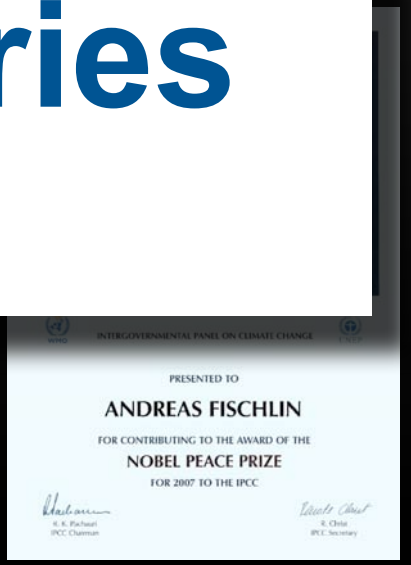
Nobel Peace Prize 2007 for IPCC



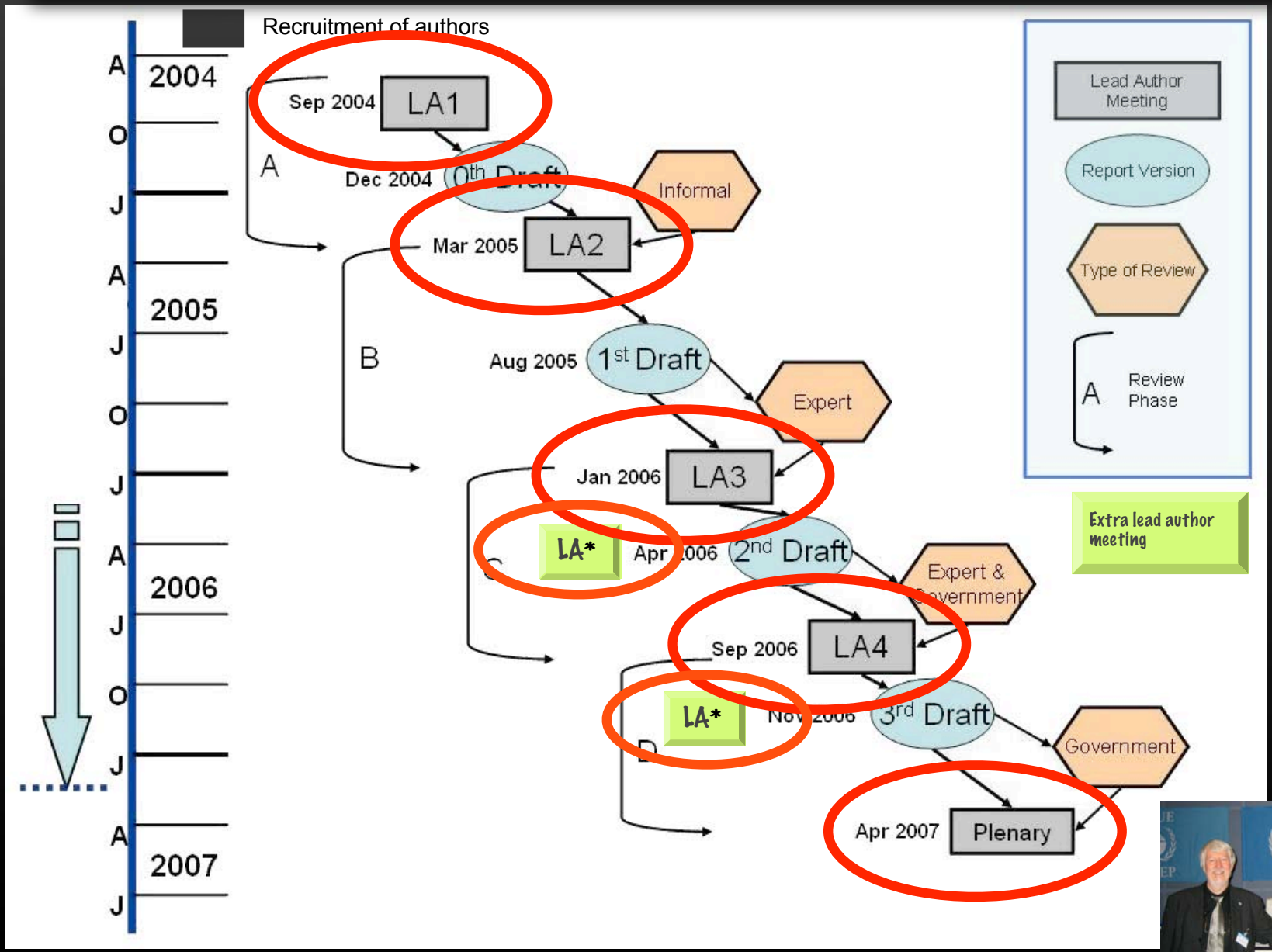
1) Wide Authorship

- 1369 Authors
- >2500 Reviewers
- >130 Countries
- 3 TSUs





2) Transparent



IPCC Key Points

- Governments need information
- IPCC formed 1988 under auspices of the UN
- Has to provide assessments of science of climate change
- Scientific community contributes widely and on a voluntary basis (fluctuation 75% TAR->AR4)
- Substance of IPCC reports in hands of scientists

Impressions From Kyoto 1 ...

IPCC Key Points

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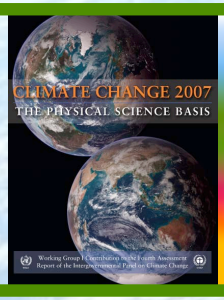
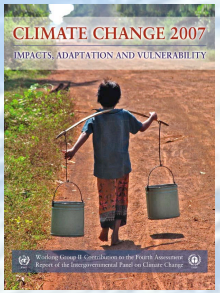
IPCC Assessment Report 4

The Voice of Science

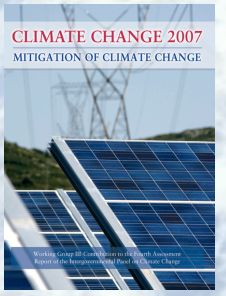
Anthropogenic climate change is real



Unmitigated climate change would cause major impacts



A drastic climate change is still avoidable



IPCC Assessment Report 4

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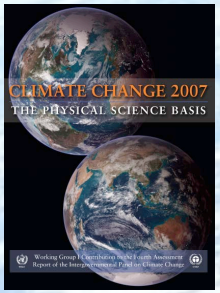

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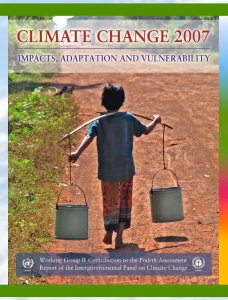

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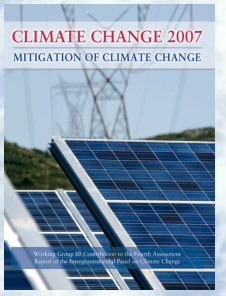

IPCC Assessment Report 4

The Voice of Science

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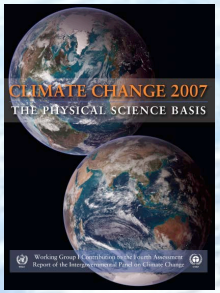

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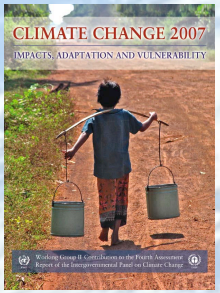

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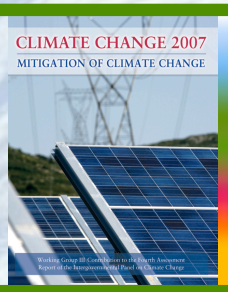

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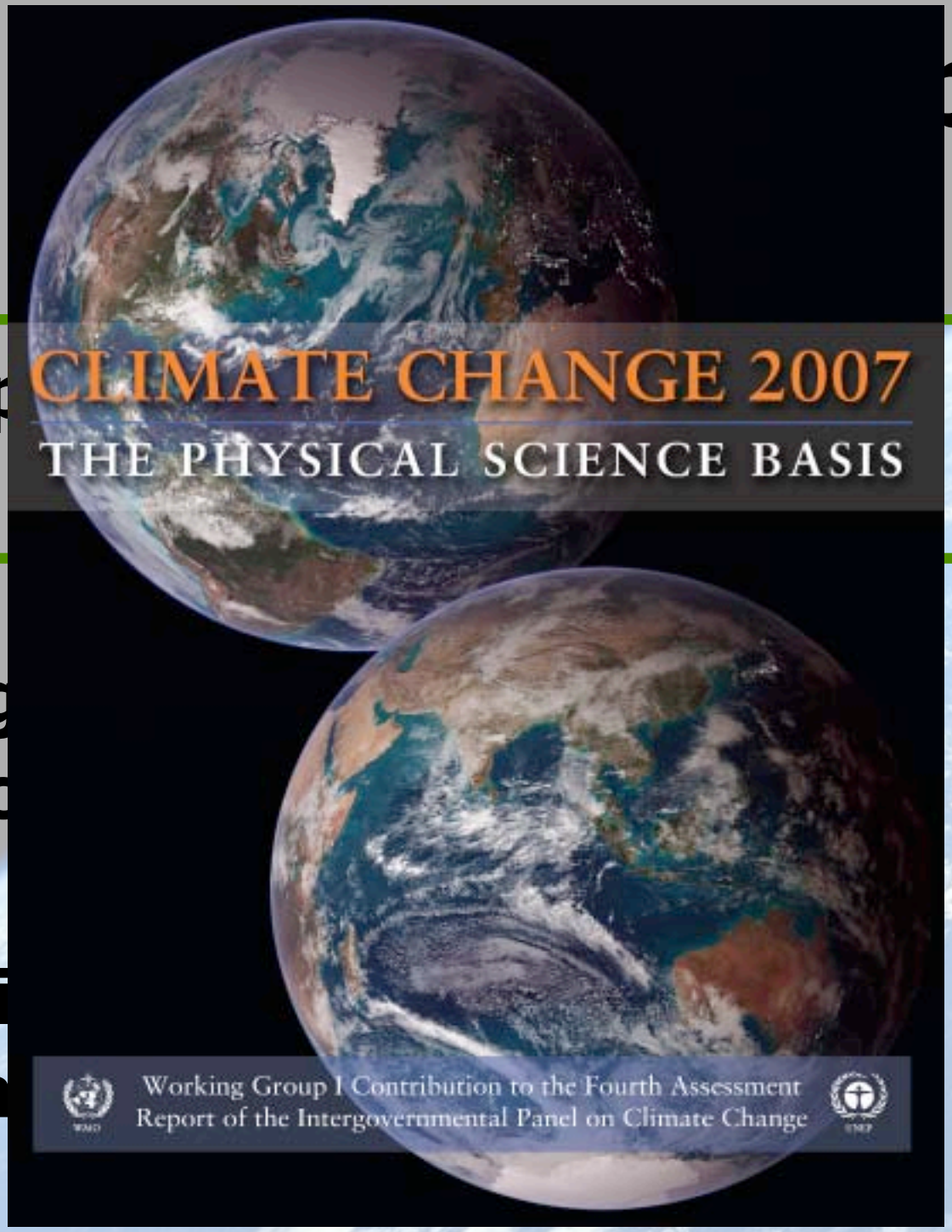
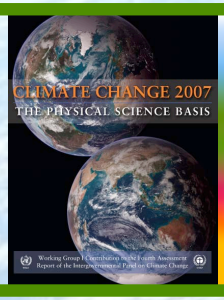
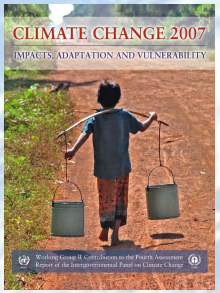
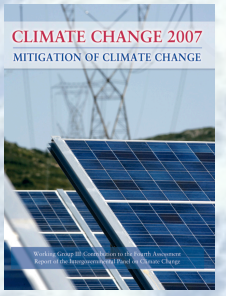


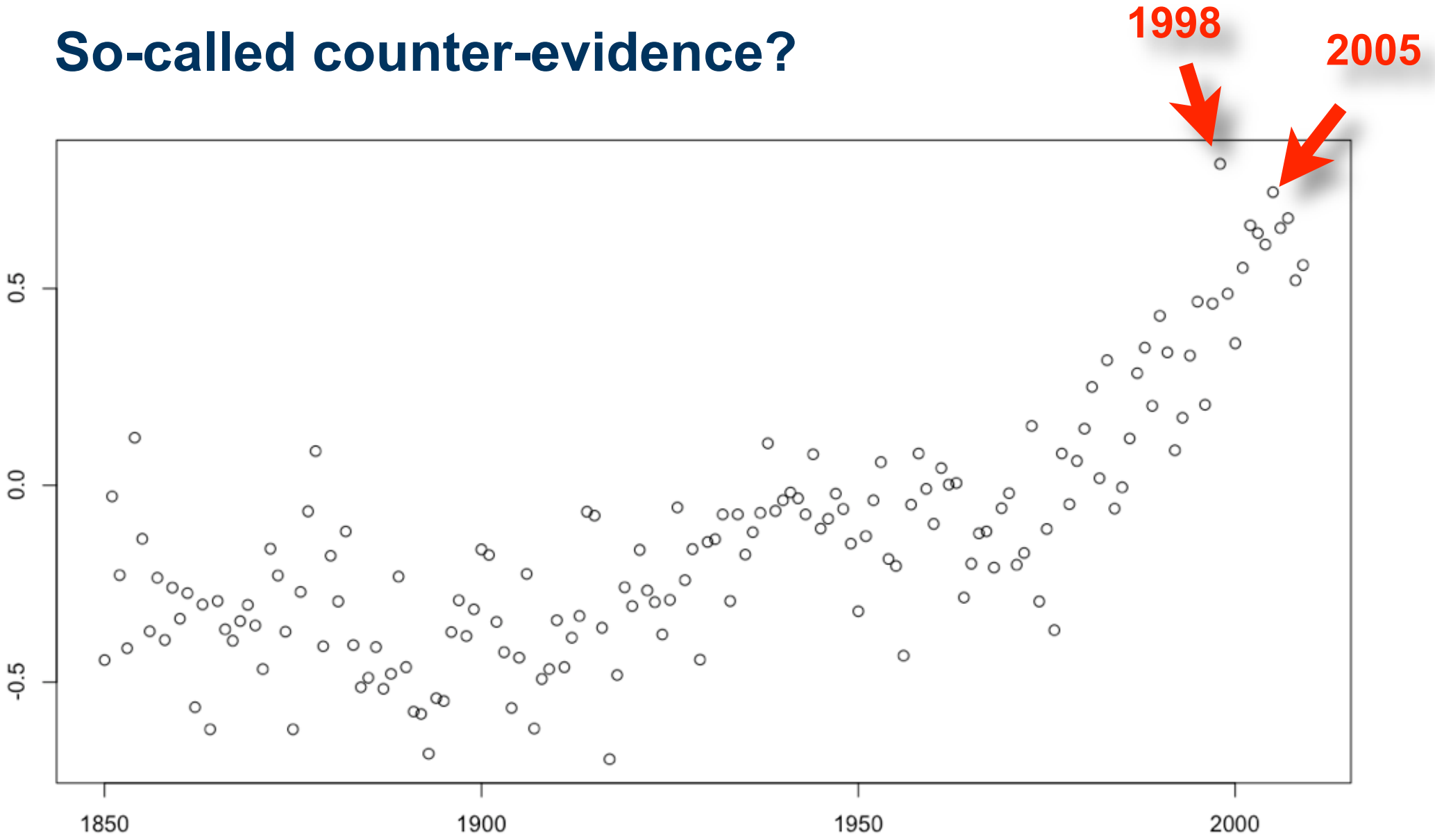






Does Climate Change?

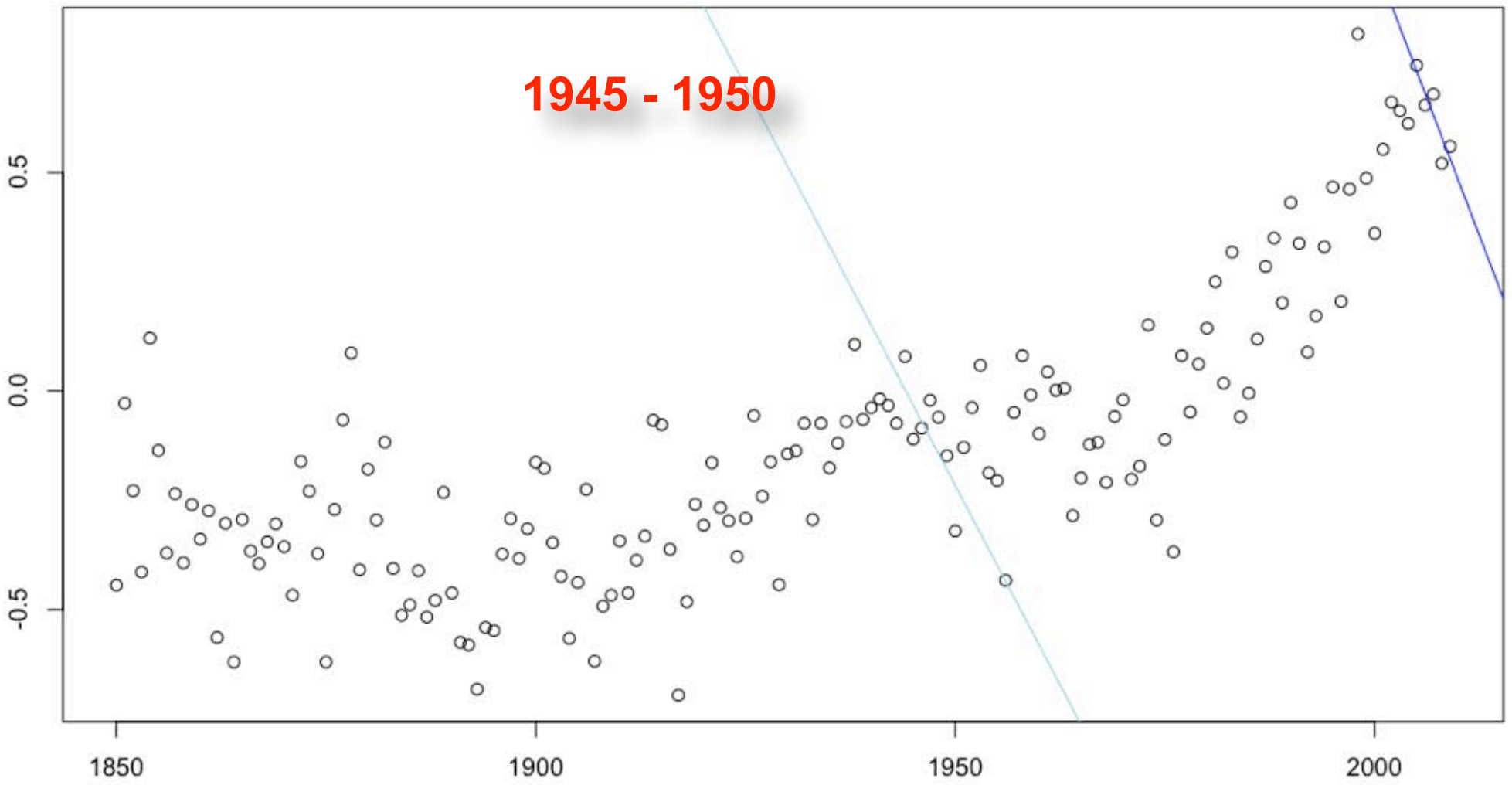
So-called counter-evidence?



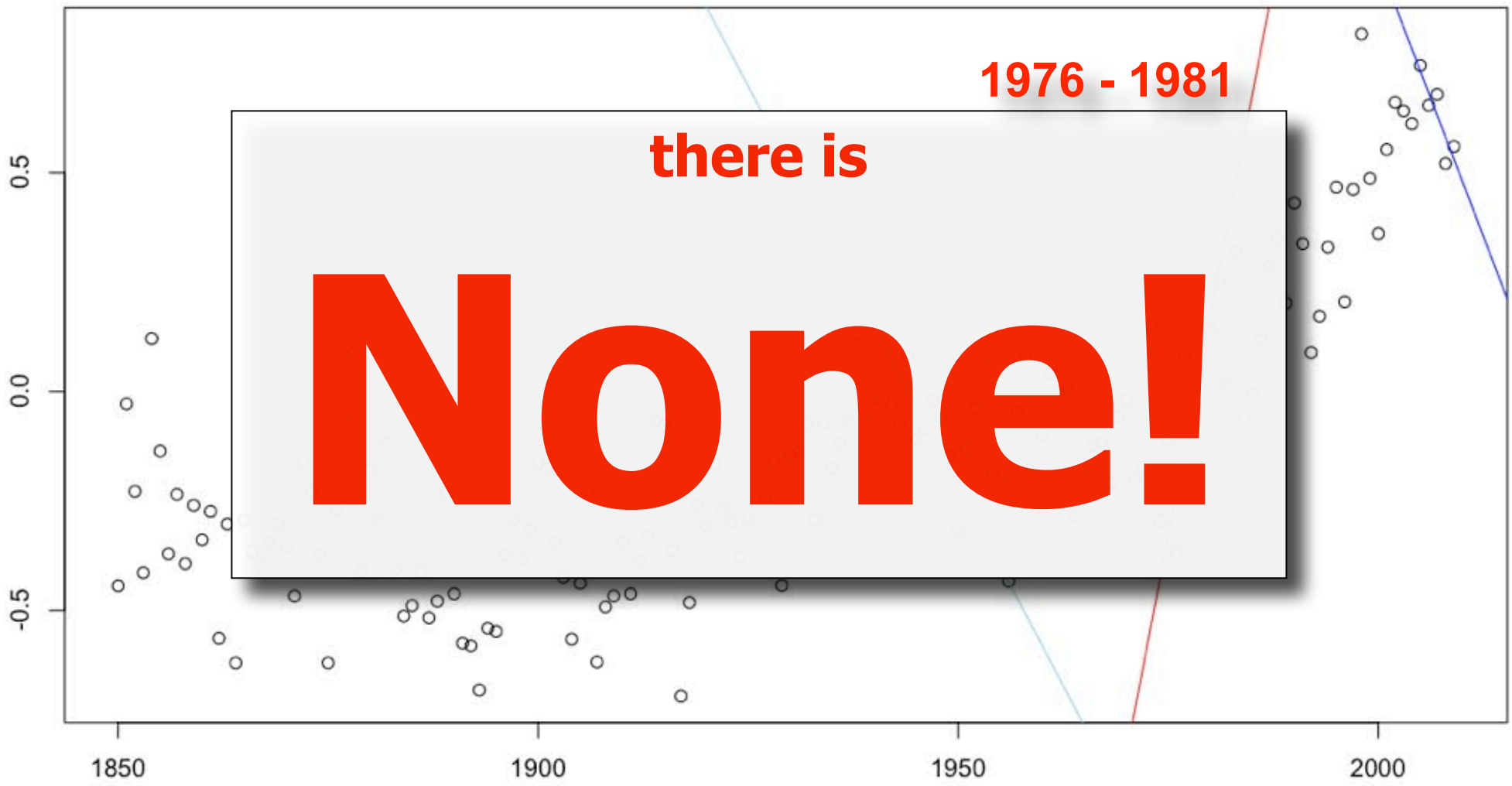
So-called counter-evidence?

2005

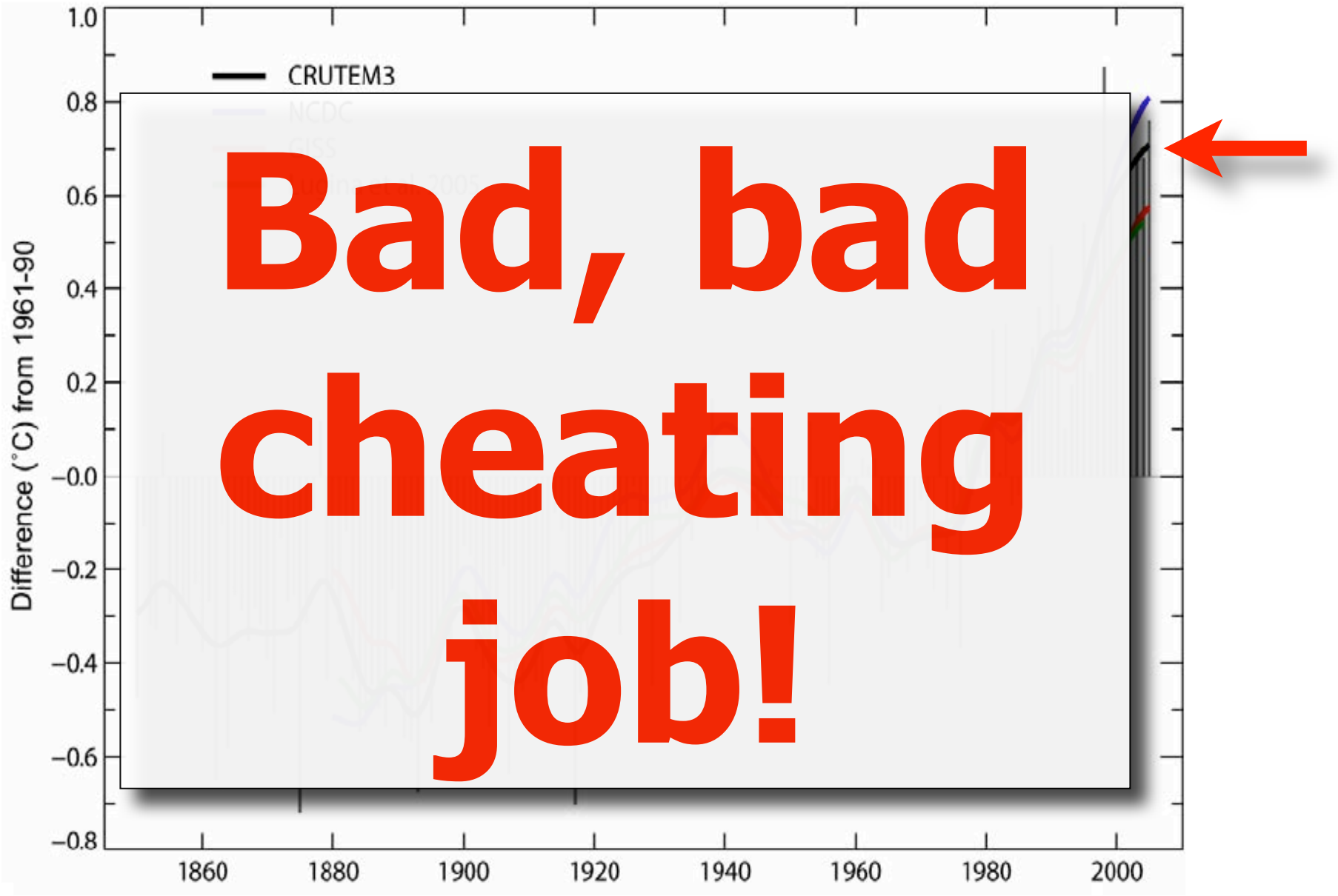
So-called counter-evidence?



So-called counter-evidence?



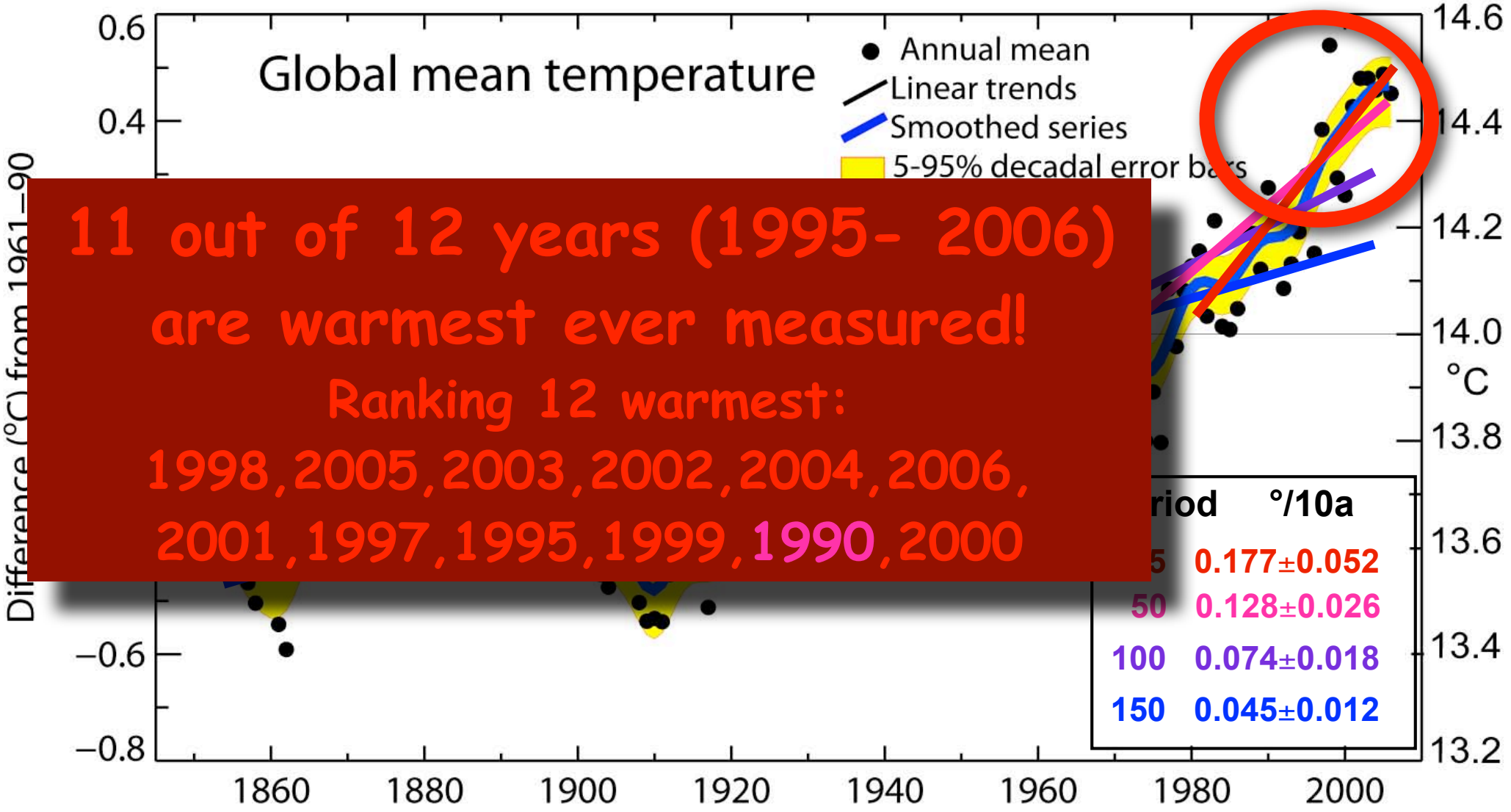
IPCC used several Temperature Records



Trenberth et al., 2007. IPCC WGI AR4

Observed Temperatures

After Figure TS.6 (IPCC, 2007b. Technical Summary (TS) WGI)



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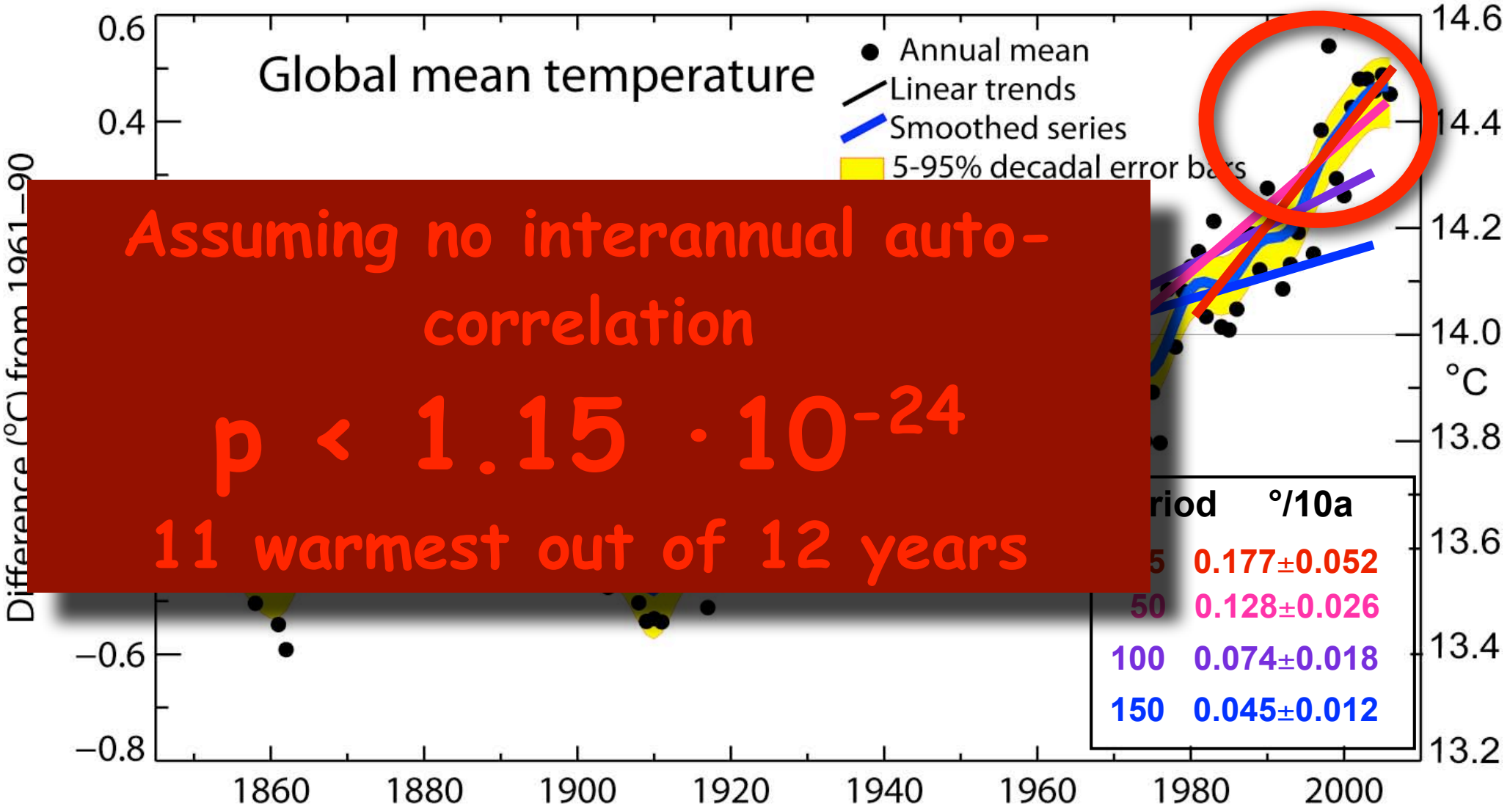


Human Made?

Greenhouse Gases

CO_2	Fossil fuels, Deforestation (Land use change)
CH_4	Livestocks, Landfills, Rice cultivation, Gas pipe leakages
N_2O	Fertilisation
CFCs etc.	Heat pumps, cleaning etc.

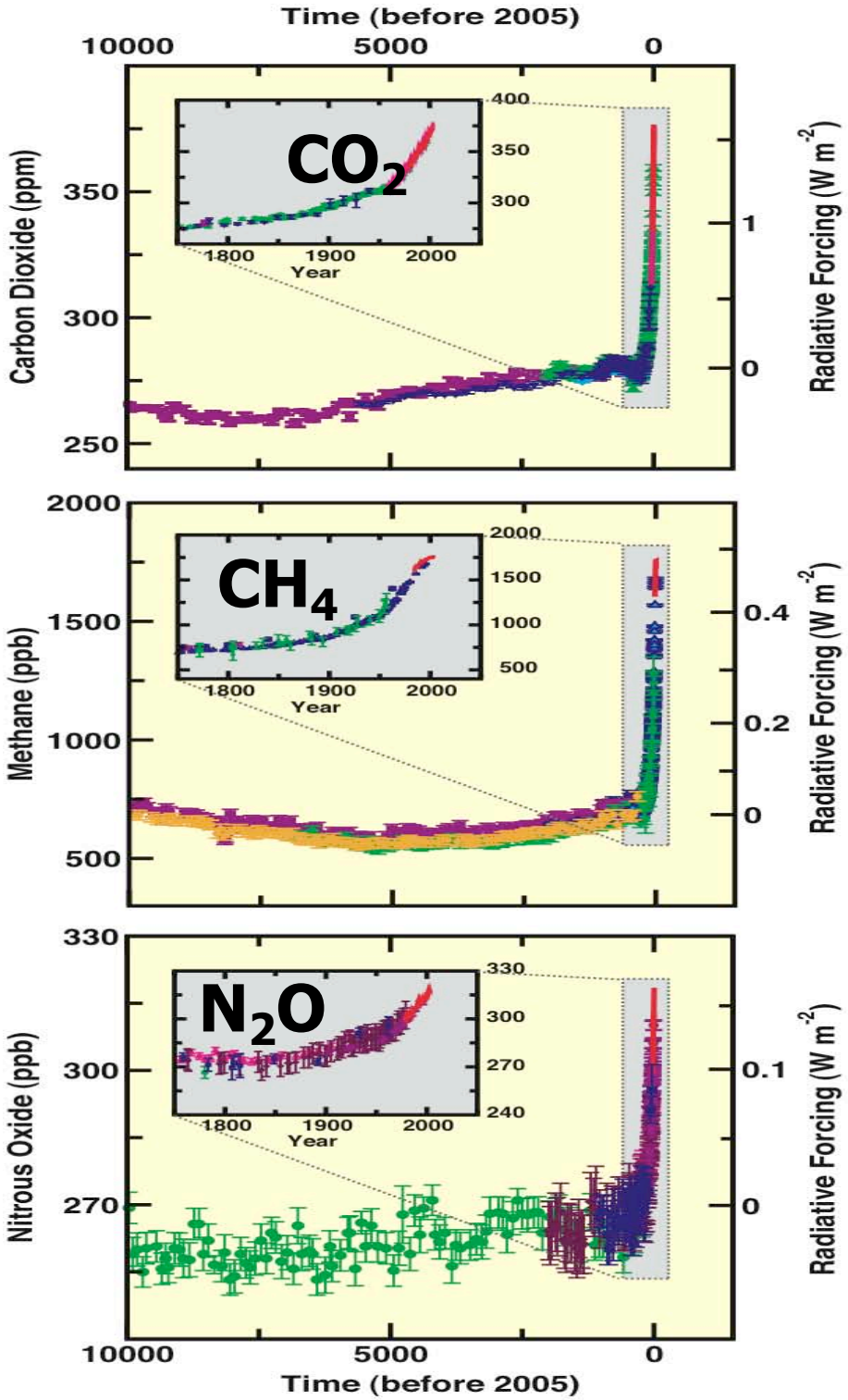


Figure SPM.1 (IPCC, 2007a. Summary for Policy Makers (SPM) WGI)

Human and Natural Drivers of Climate Change

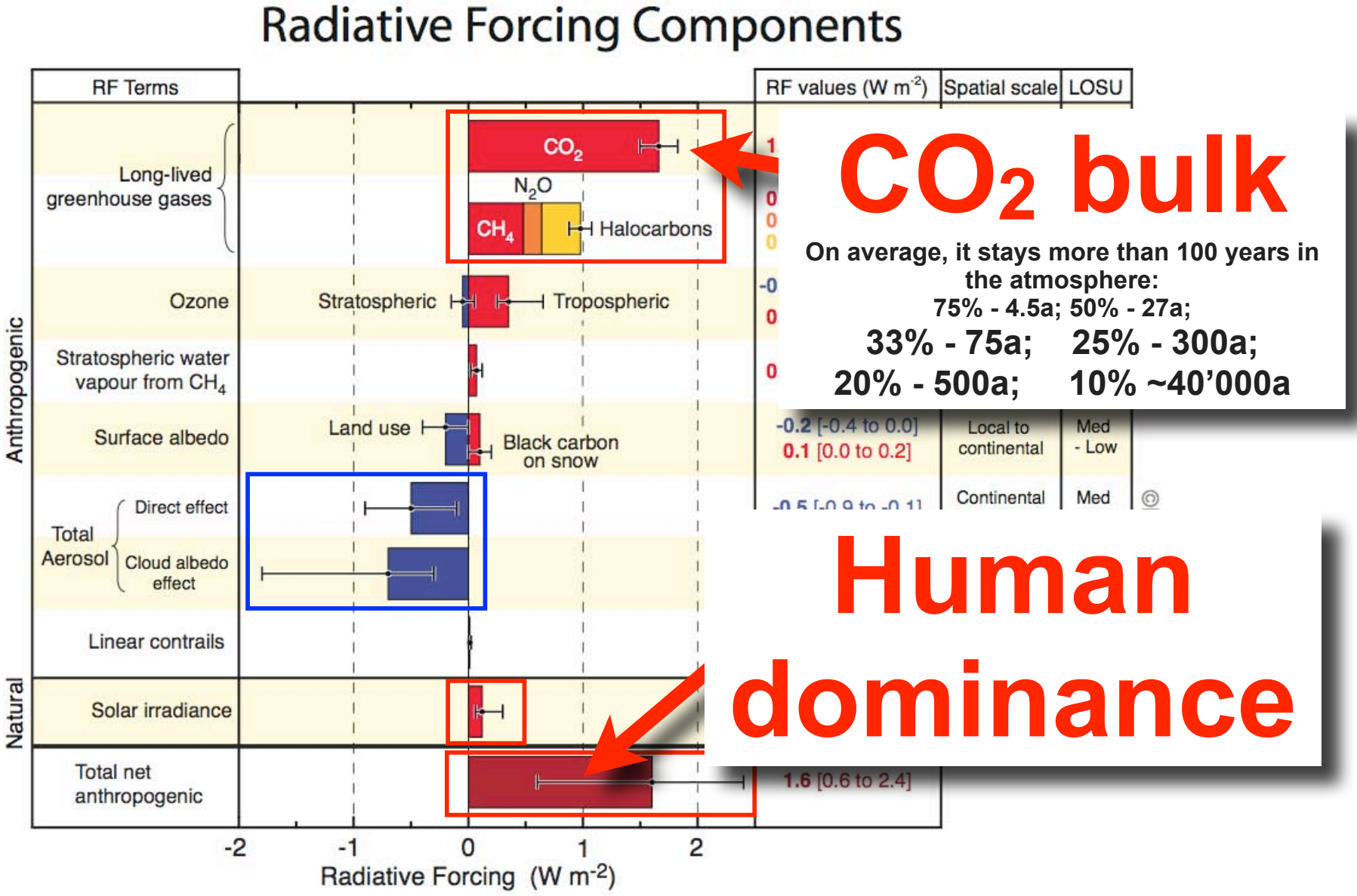
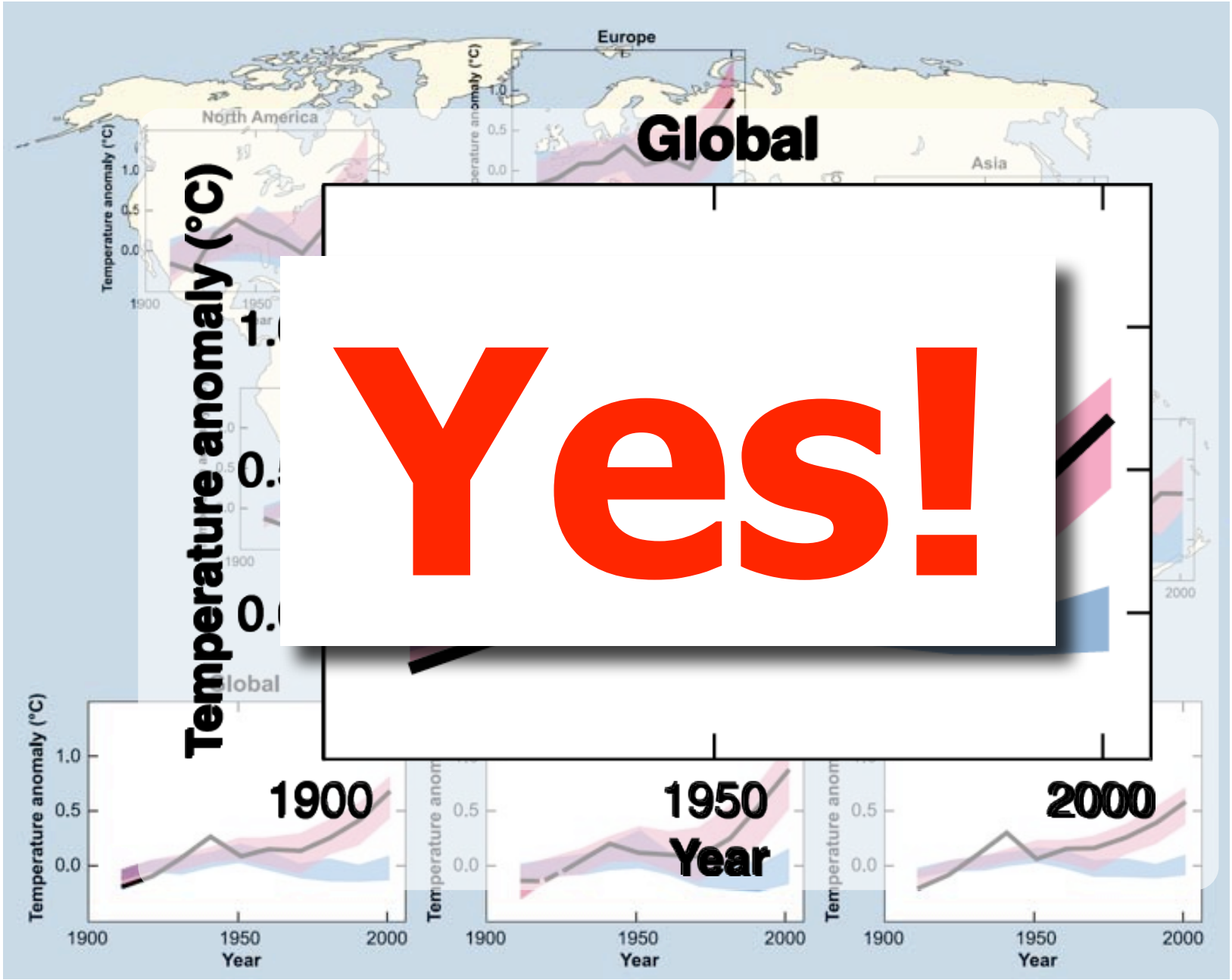


Figure SPM.2 (IPCC, 2007a. Summary for Policy Makers (SPM) WGI)

Do We Humans Cause It?



Measured temperatures

Climate models:

Only natural influences

Natural **and** human influences

Figure SPM.4. IPCC, 2007. SPM WG I

Not the sun!

Future Changes?

Warming Over Present Levels

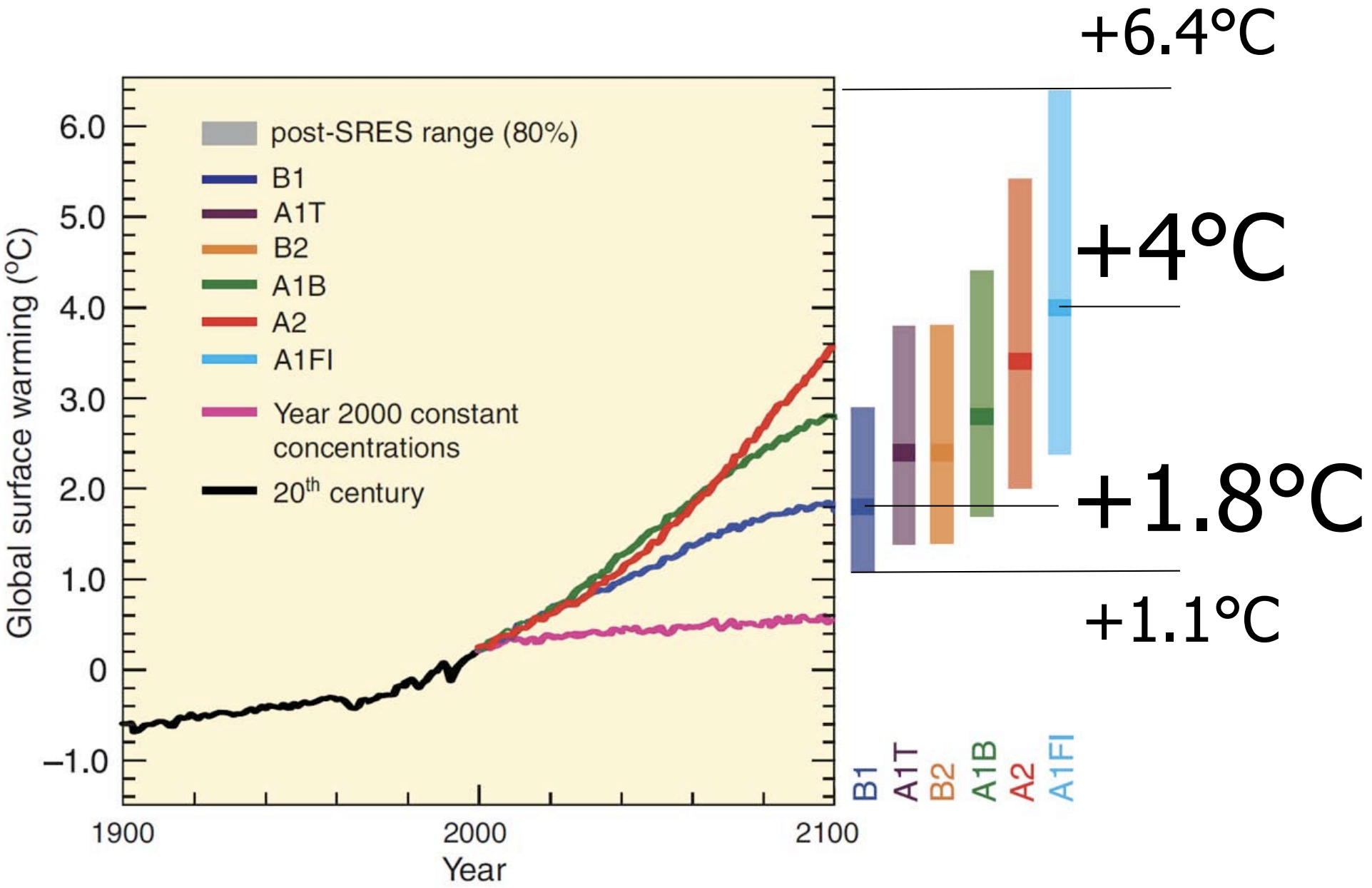


Figure SPM.5: Multi-model global averages of surface warming (relative to 1980–1999) for the scenarios (IPCC, 2007. Summary for Policy Makers WGI)

Δ T (SST Annual Means)

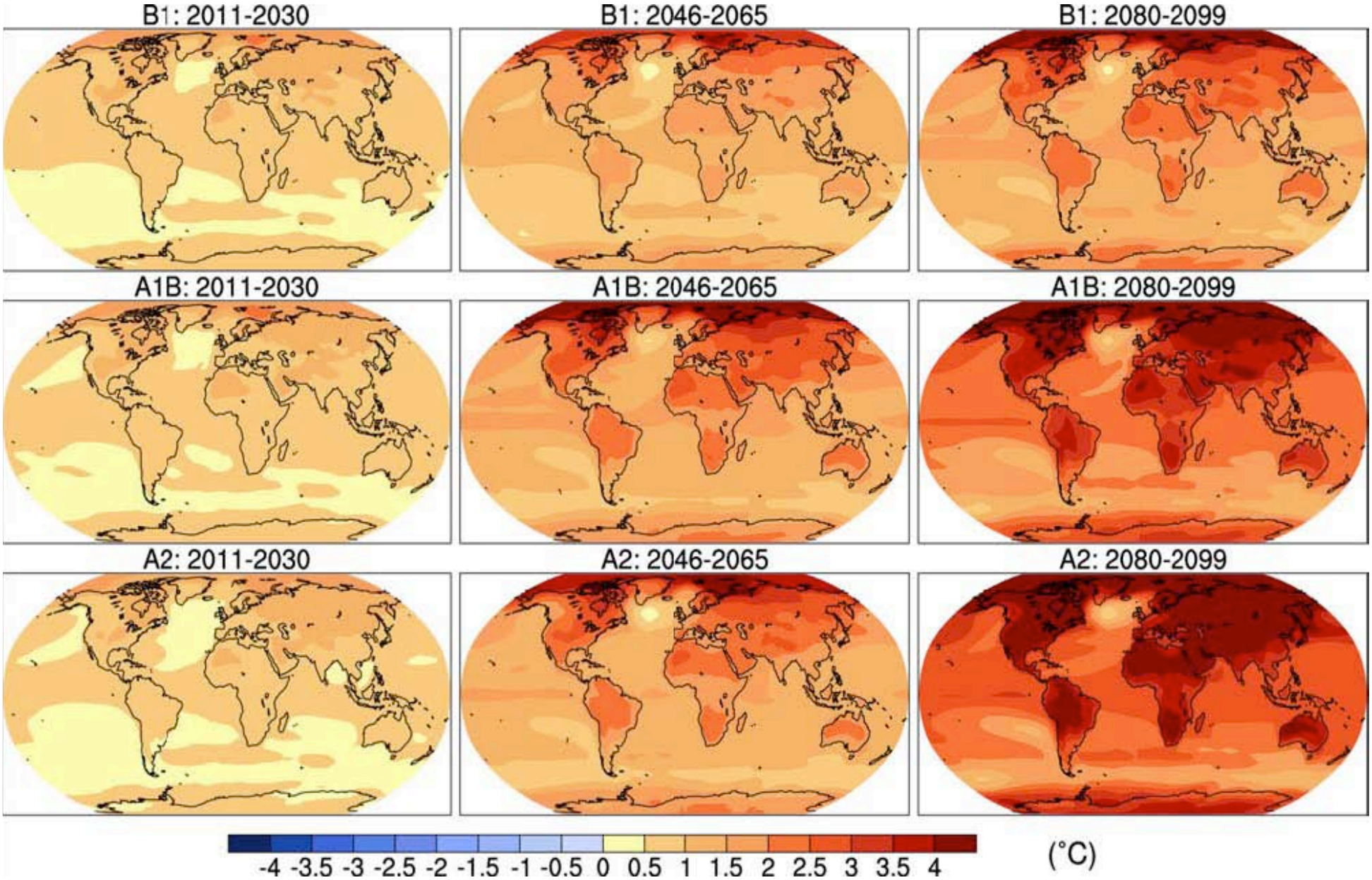


Figure 10.8: Projected surface temperature changes - multimodel means (Meehl *et al.*, 2007. IPCC WGI)

Precipitation Changes (Summer)

- Precipitation at high latitudes *very likely* to increase
- Precipitation at low latitudes *likely* to decrease

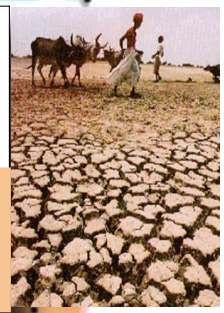
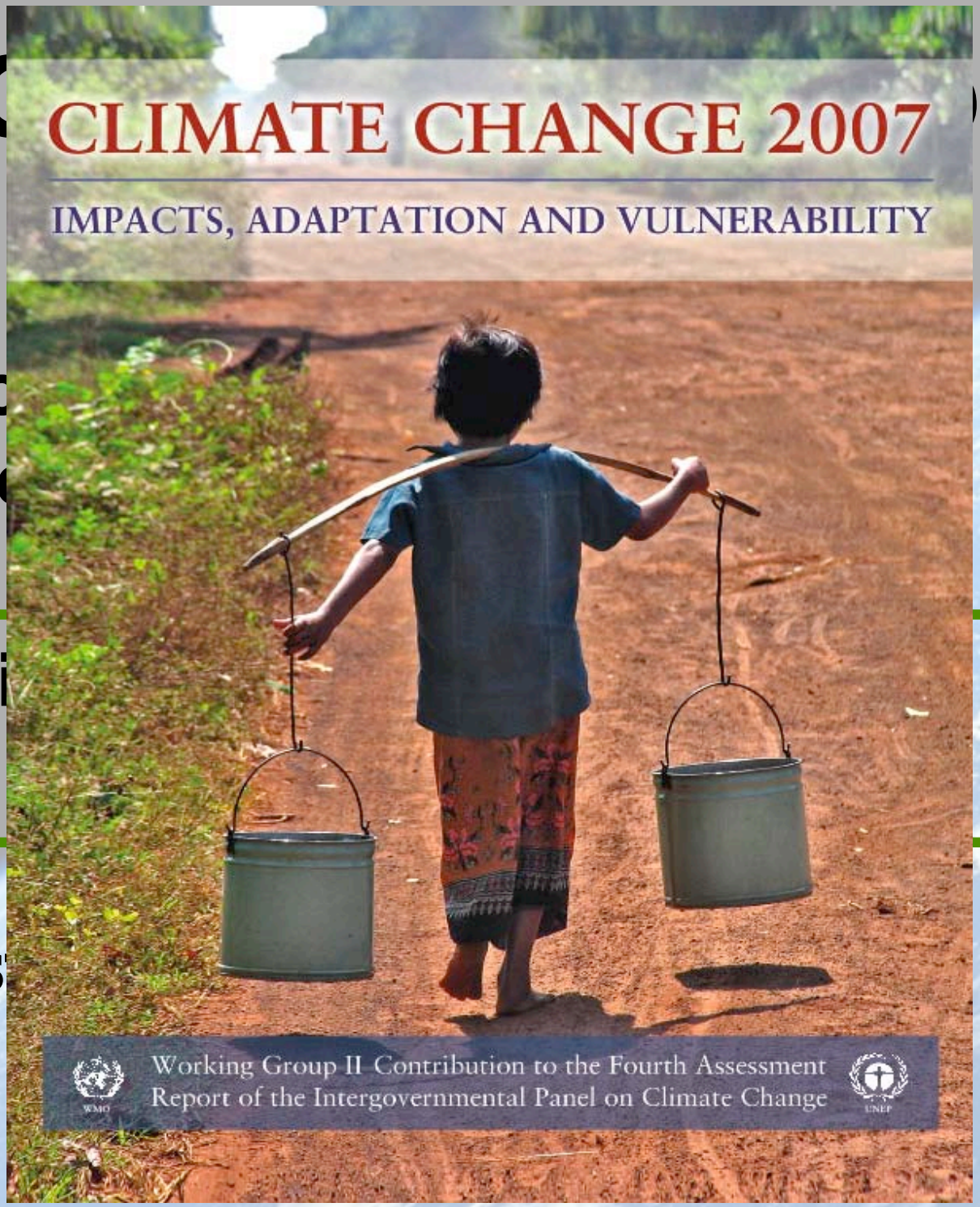


Figure SPM.7: Relative changes in precipitation 2090-2099 vs. 1980-1999 (IPCC, 2007a. SPM WGI)

Is climate change real? Human made? Dangerous?

Yes!

IPCC ort 4



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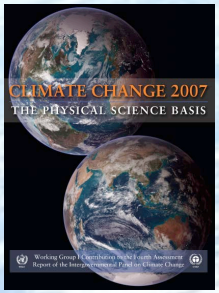
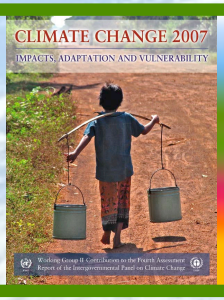
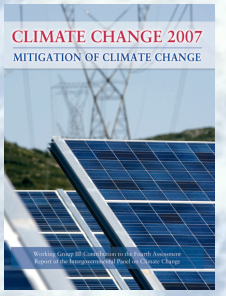







Ecosystems, incl. Agroecosystems and Forests are important!

Ecosystems Services

Provisioning
- Food
- Water
- Fuel
- Wood

...

Regulating
- C-sequestration
- Climate
- Flood, erosion
- Air, water purification
- Pests, diseases

...

Cultural
- Recreational
- Educational
- Spiritual

...

Global GDP 1997

illions (=10^{12} =Tera) US $

16 33 54

Costanza *et al.*, 1997. *Nature*, 387: 253-260

Ecosystems Services

Global
GDP 1997

18

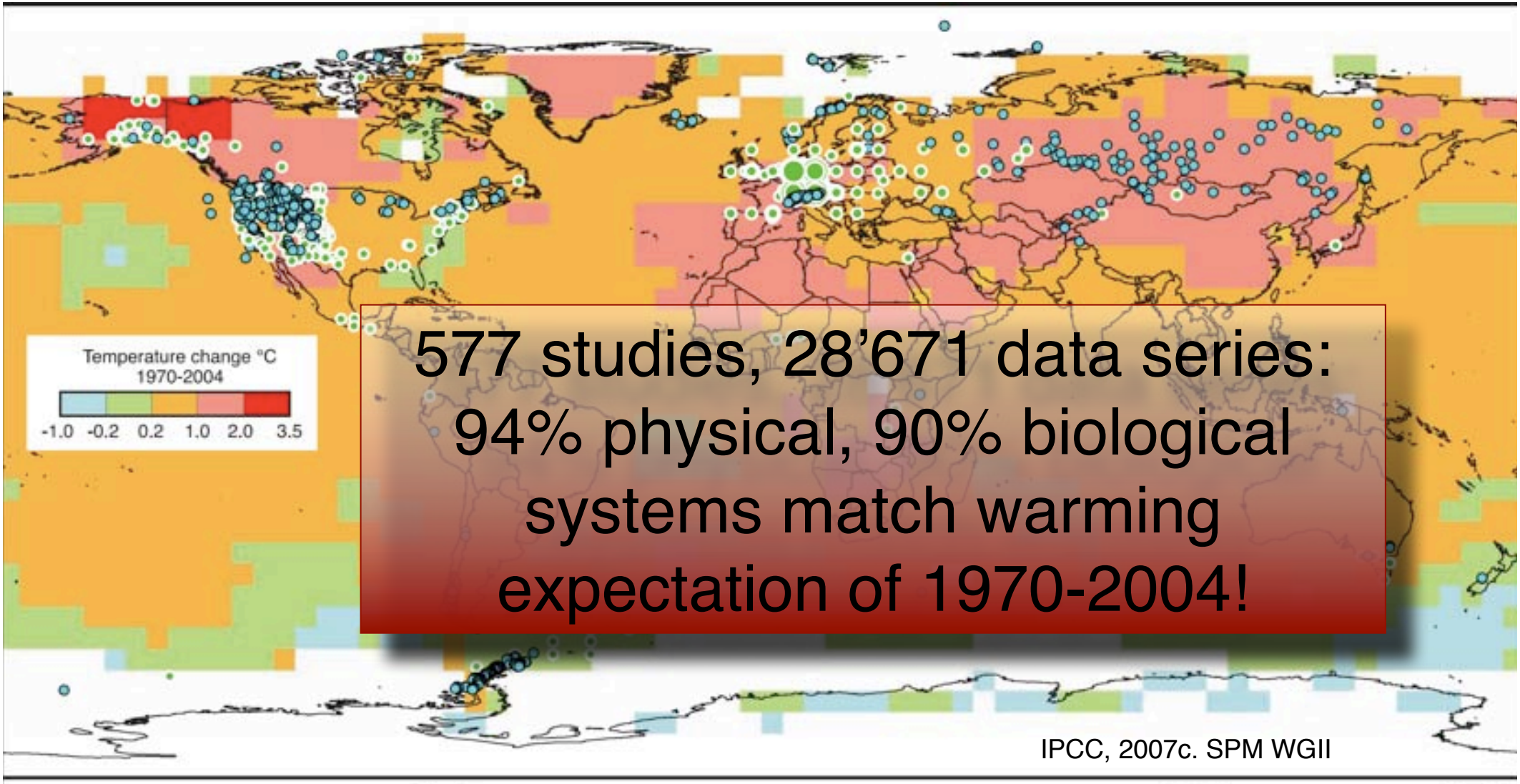
Trillions (=10^{12} =Tera) US $

16 33 54

Costanza *et al.*, 1997. *Nature*, 387: 253-260


... and they are
already impacted!

Since 1970 observed impacts on physical and biological systems



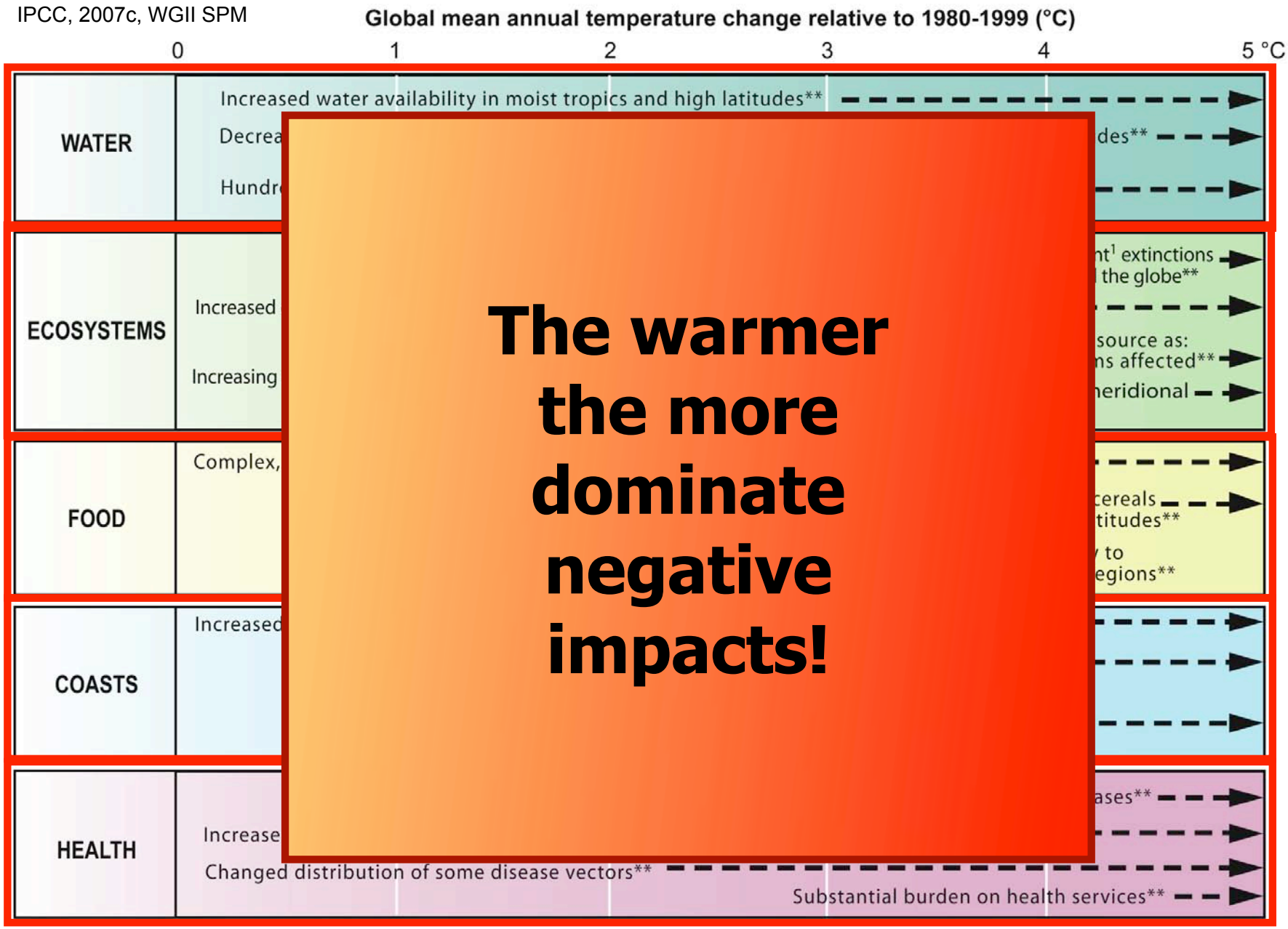
IPCC, 2007c. SPM WGII

NAM		LA		EUR (28,115)		AFR		AS		ANZ		PR*		TER (28,586)		MFW**		GLO (28,671)	
355	455	53	5	119		5	2	106	8	6	0	120	24	764		1	85	765	
94%	92%	98%	100%	94%	89%	100%	100%	96%	100%	100%	–	91%	100%	94%	90%	100%	99%	94%	90%

Future Climate Change Impacts?

Global Warming Affects All Sectors

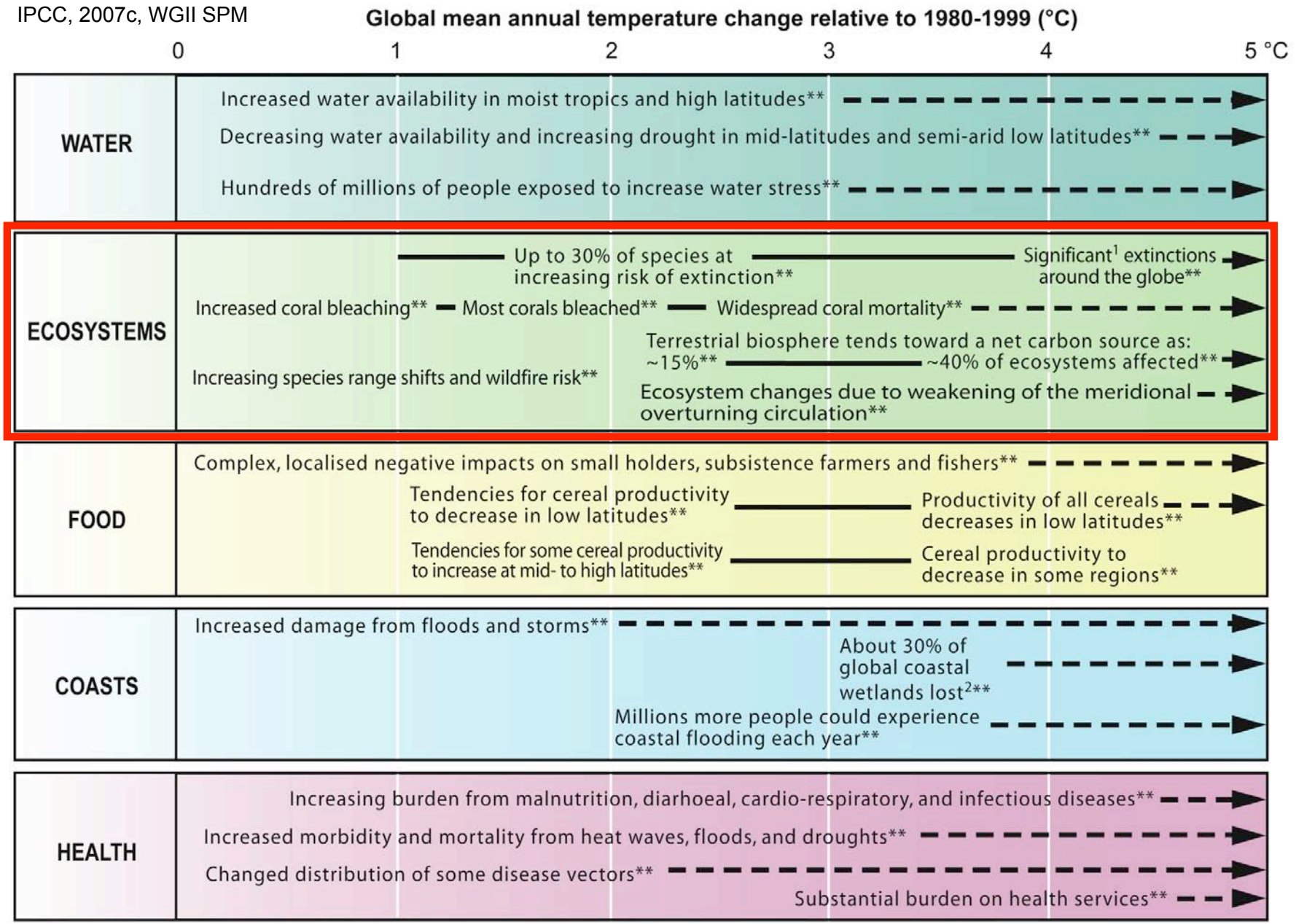
IPCC, 2007c, WGII SPM



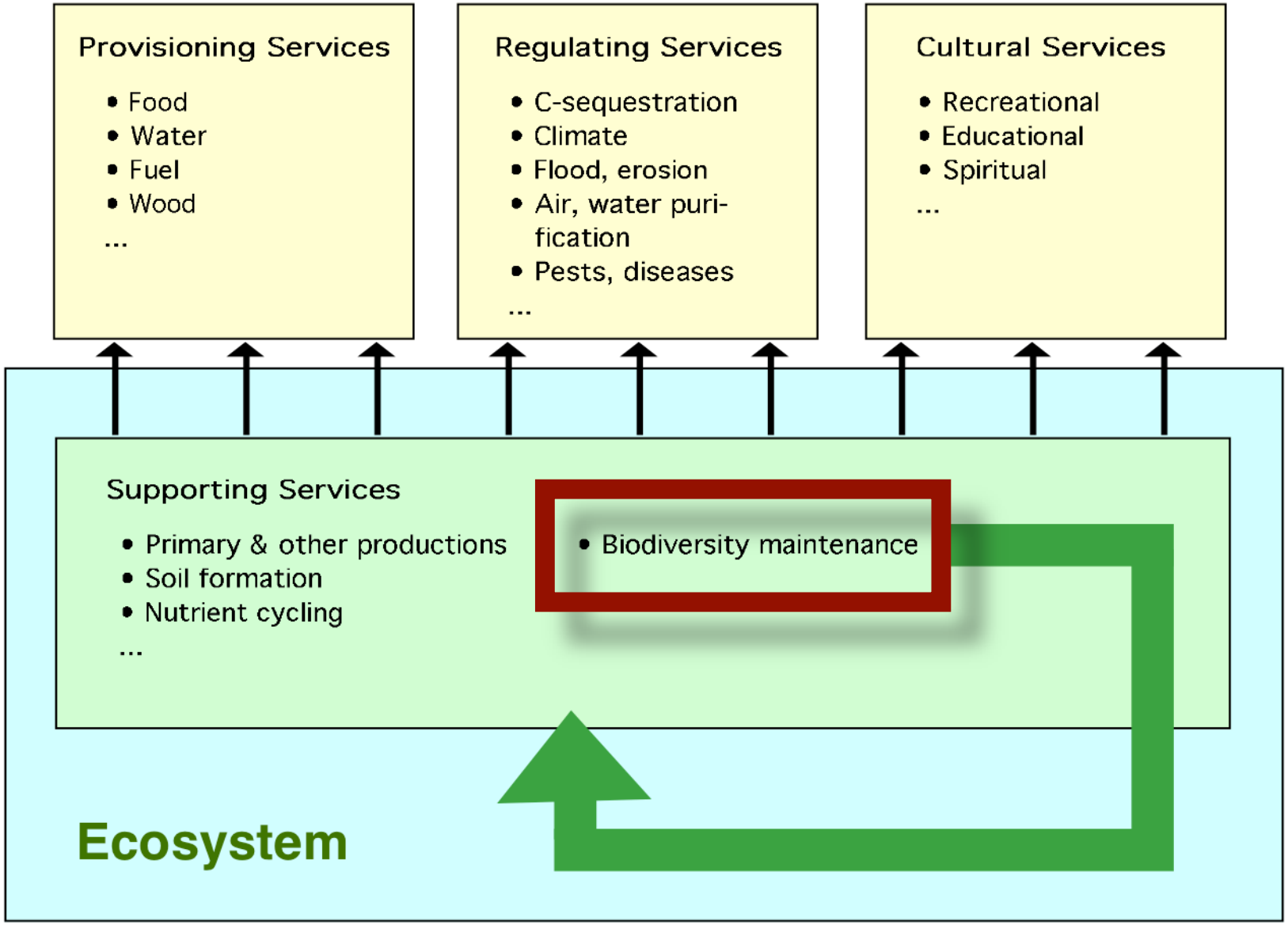
The warmer the more dominate negative impacts!

Global Warming Affects All Sectors

IPCC, 2007c, WGII SPM

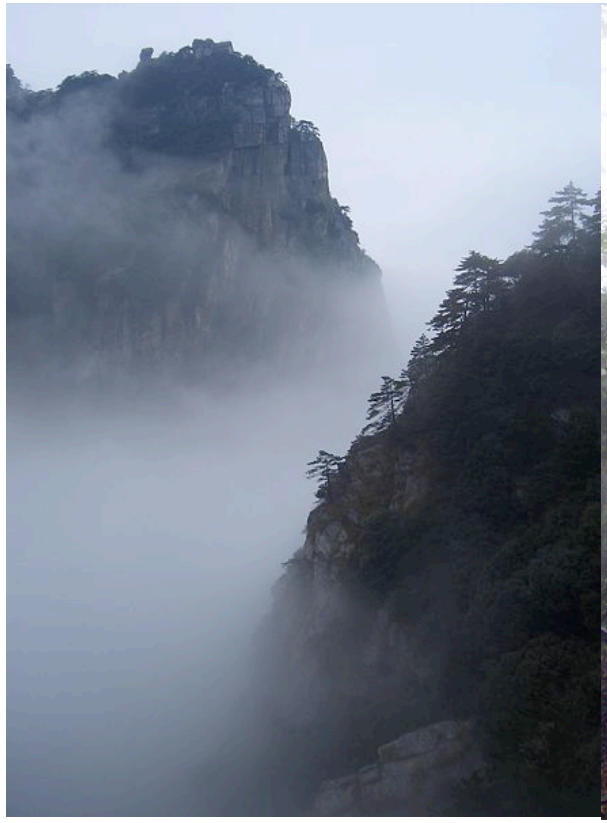


Ecosystems Services

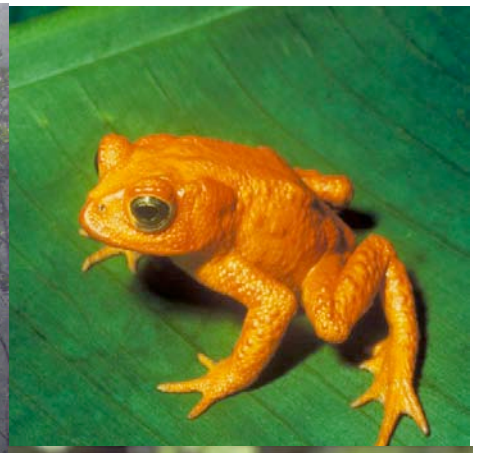


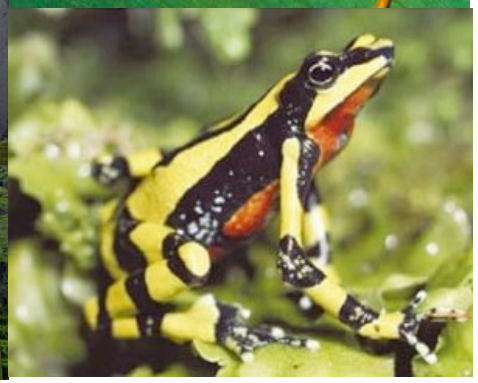
First Evidence: Recent Climate Change => Extinctions

Golden toad and 74 other amphibian species extinct in montane cloud forests
(Pounds *et al.*, 2006; Parmesan, 2006)



Golden toad
(*Bufo periglenes*)





Monteverde harlequin frog (*Atelopus sp.*)

Impacts on Biodiversity

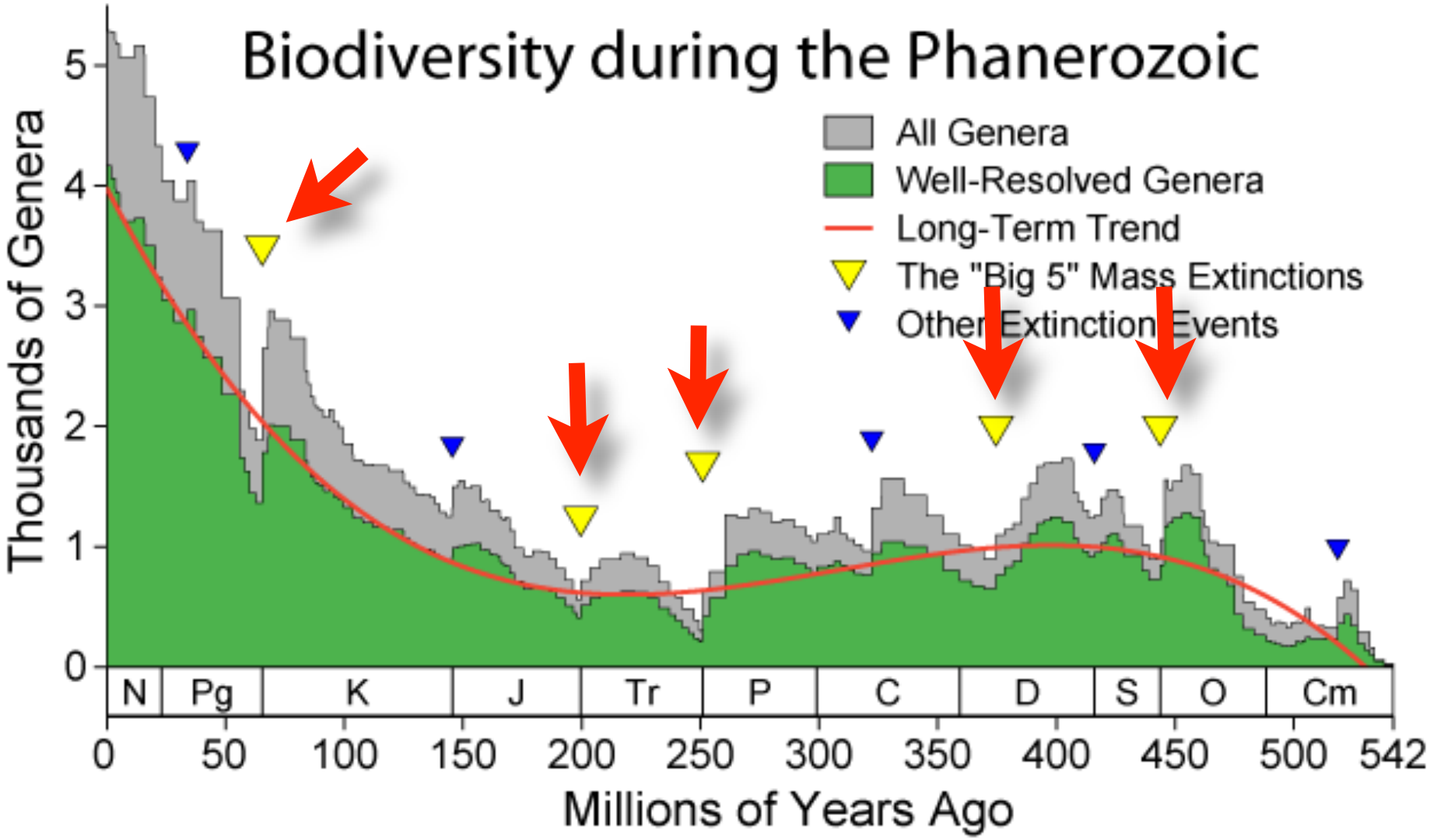
20%-30% of higher plants and animals at high risk of extinction

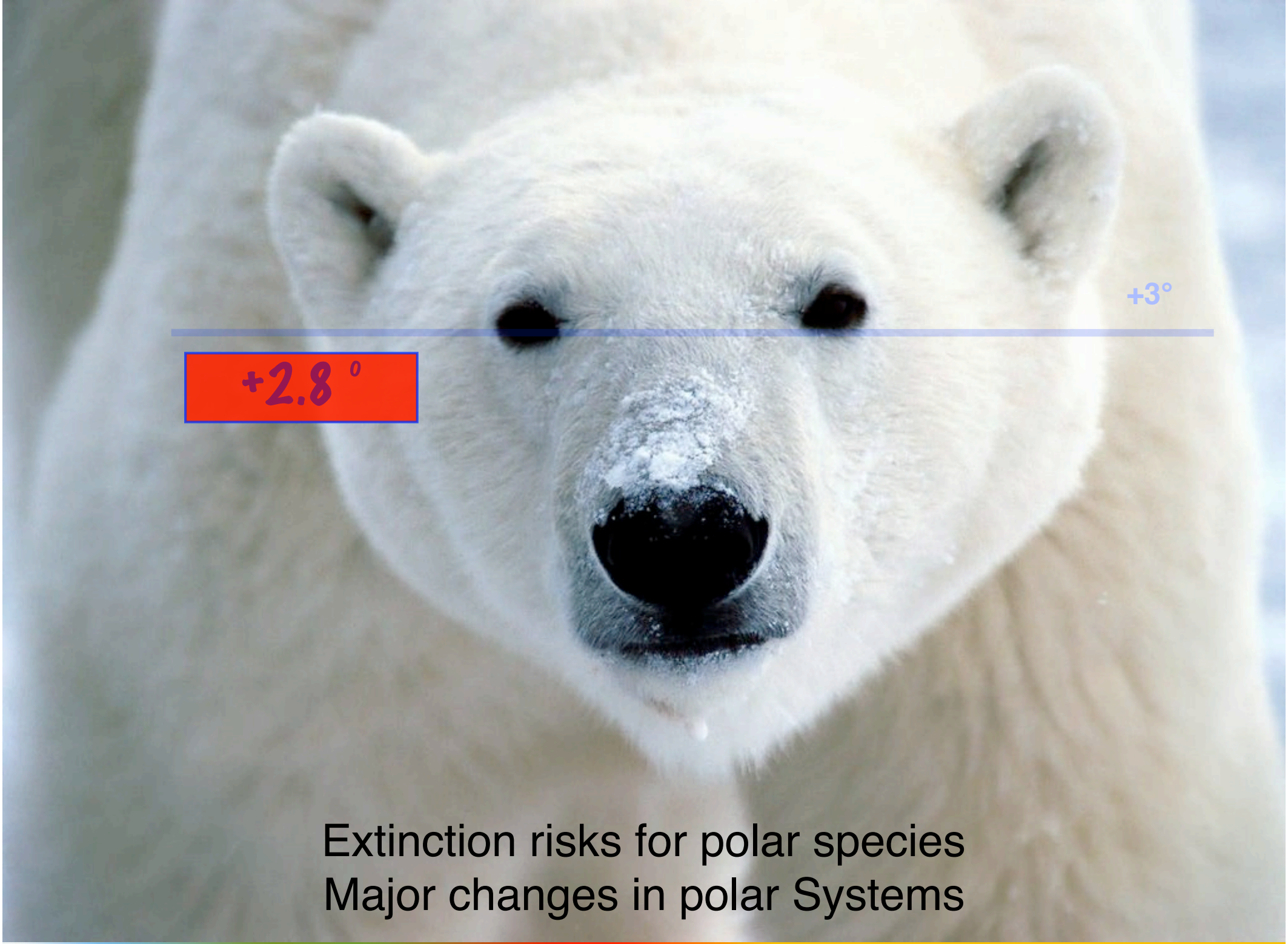
if ΔT 1.5°C - 2.5°C over present

(medium confidence)

Biodiversity and Climate Change

Geologic time scales

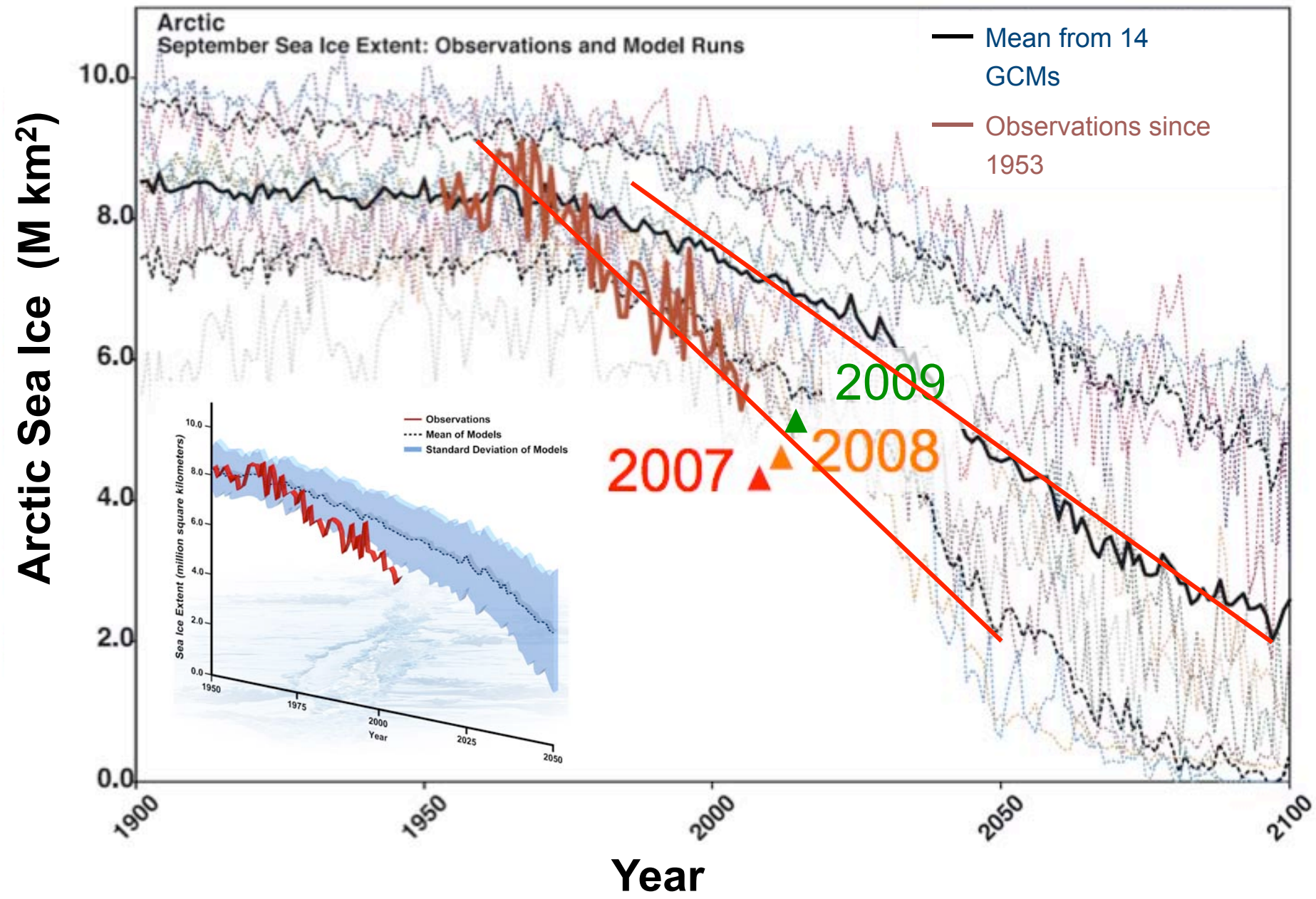


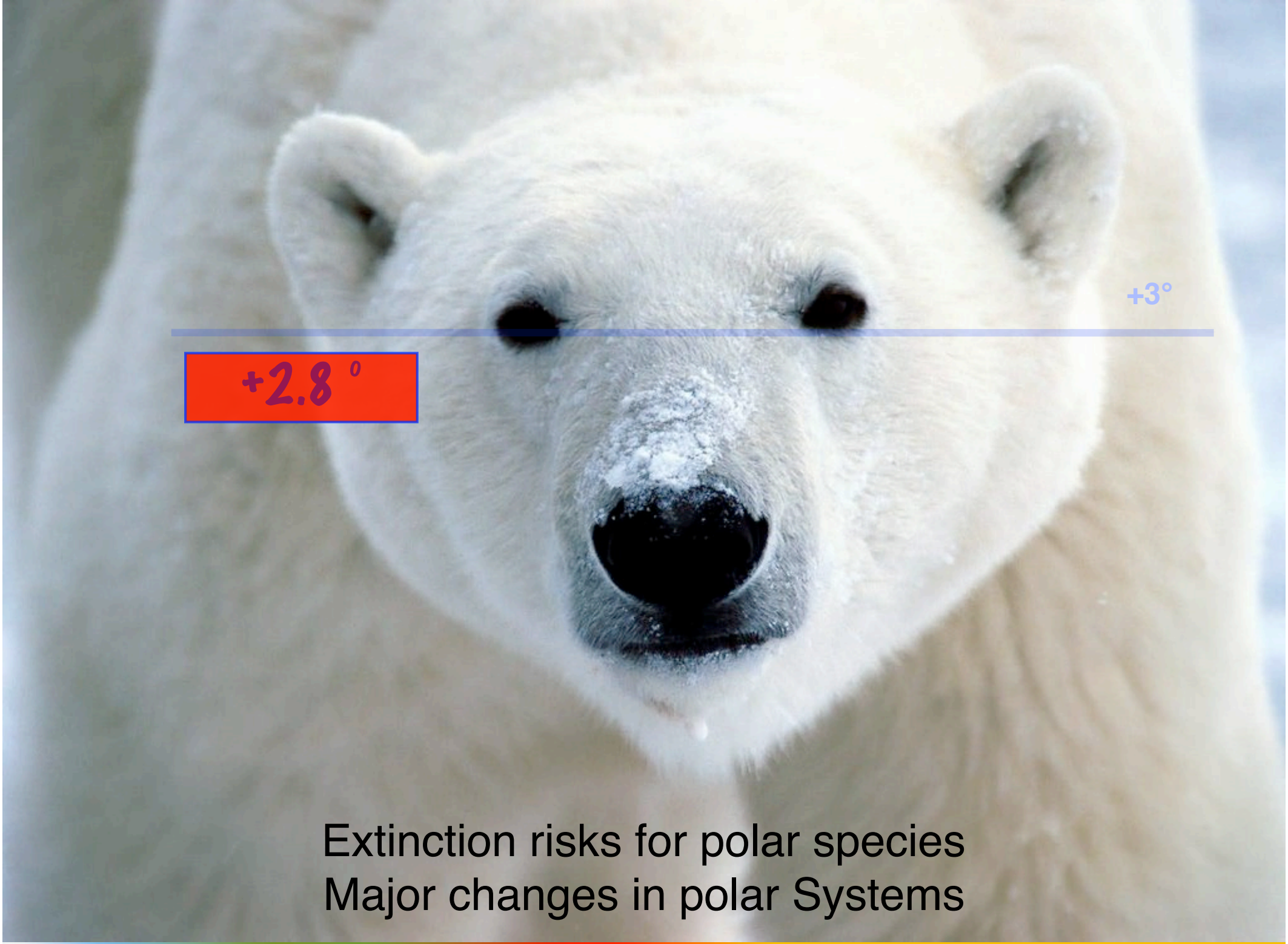


Extinction risks for polar species
Major changes in polar Systems

Arctic Sea Ice

after Stroeve et al., GRL 2007





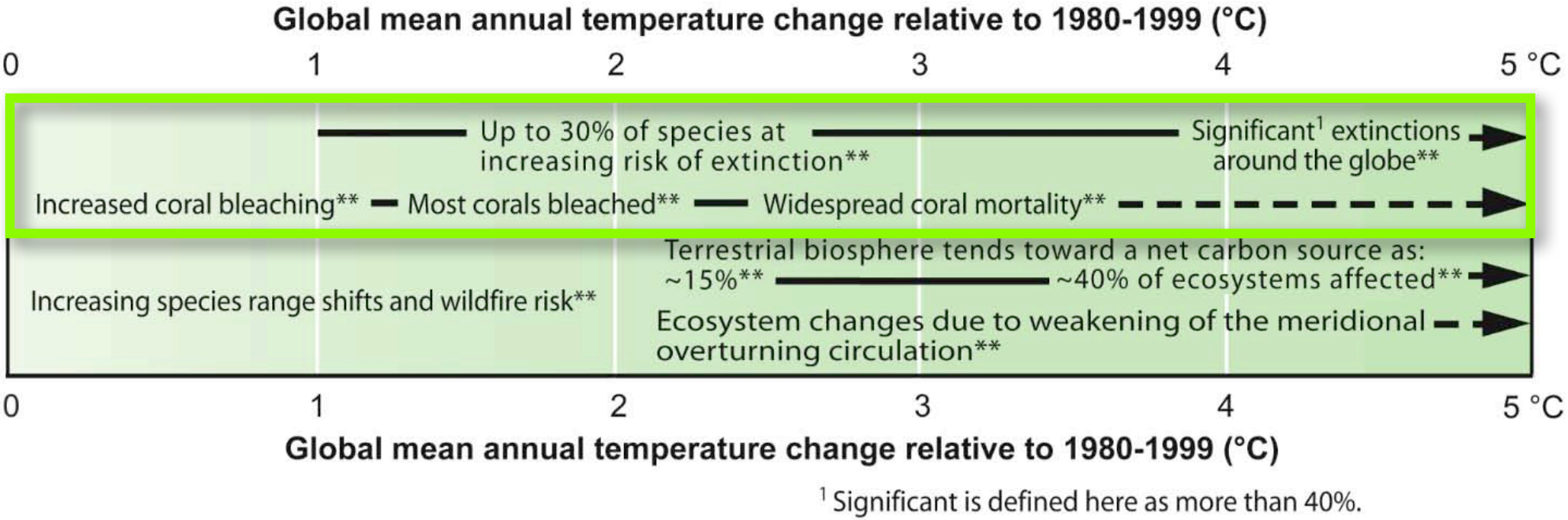
Extinction risks for polar species
Major changes in polar Systems

Extinction risks for polar species
Major changes in polar Systems

Summary

Impacts on Biodiversity

(Supporting Services)



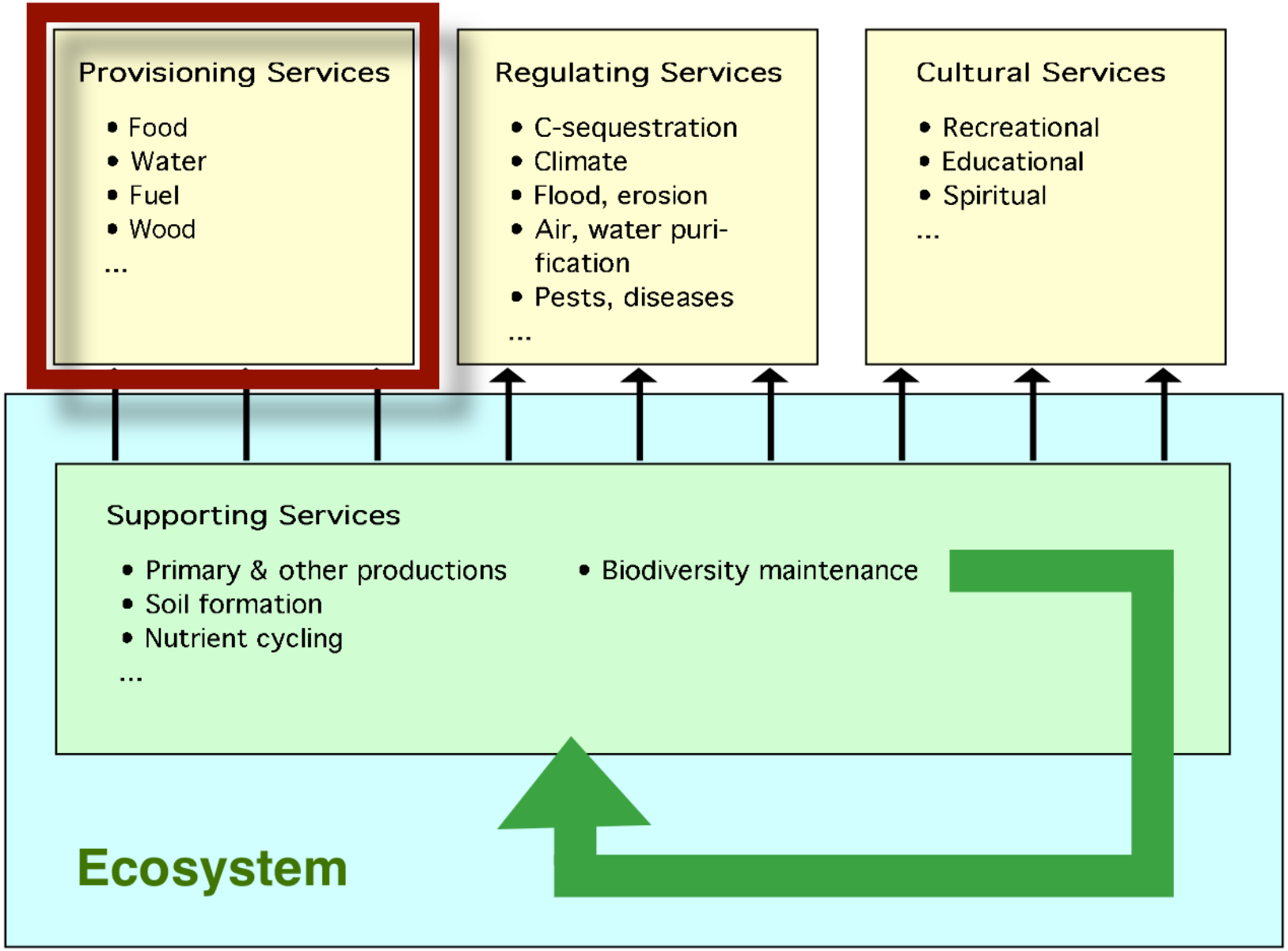
[1] Significant is defined here as more than 40%.

The warmer, the more negative the impacts!

From Figure SPM.2

(IPCC, 2007c. Summary for Policy Makers by Working Group II AR4 IPCC)

Ecosystems Services

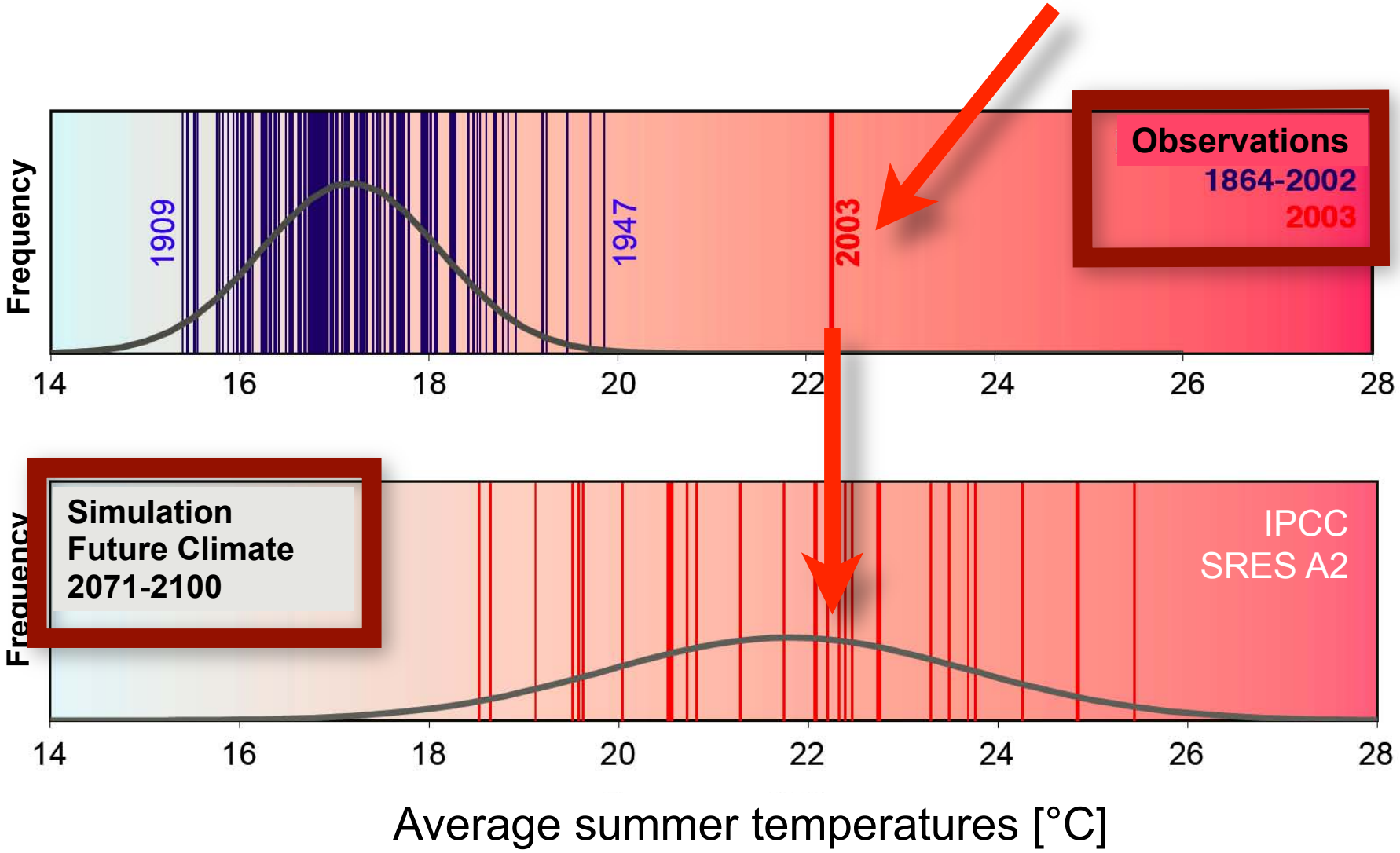


Extreme Events such as Heat Waves

Box 5.1. European heatwave impact on the agricultural sector

Europe experienced a particularly extreme climate event during the summer of 2003, with temperatures up to 6°C above long-term means, and precipitation deficits up to 300 mm (see Trenberth et al., 2007). A record **drop in crop yield of 36%** occurred in Italy for maize grown in the Po valley, where extremely high temperatures prevailed (Ciais et al., 2005). In France, compared to 2002, the maize grain **crop was reduced by 30%** and fruit harvests **declined by 25%**. Winter crops (wheat) had nearly achieved maturity by the time of the heatwave and therefore suffered less yield reduction (**21% decline** in France) than summer crops (e.g., maize, fruit trees and vines) undergoing maximum foliar development (Ciais et al., 2005). Forage production was **reduced on average by 30%** in France and hay and silage stocks for winter were partly used during the summer (COPA COGECA, 2003b). Wine production in Europe was the lowest in 10 years (COPA COGECA, 2003a). The (uninsured) **economic losses** for the agriculture sector in the European Union were estimated at **€13 billion**, with largest losses in France (€4 billion) (Sénat, 2004).

Frequency of Extreme Temperatures



Alcamo et al., 2007. Regional chapter: Europe. IPCC WGII (after Schär et al., 2004)

Agricultural Productivity

- **Globally**, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease.
- Crop productivity is projected to increase slightly **at mid- to high latitudes** for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions.
- **At lower latitudes**, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase the risk of hunger.

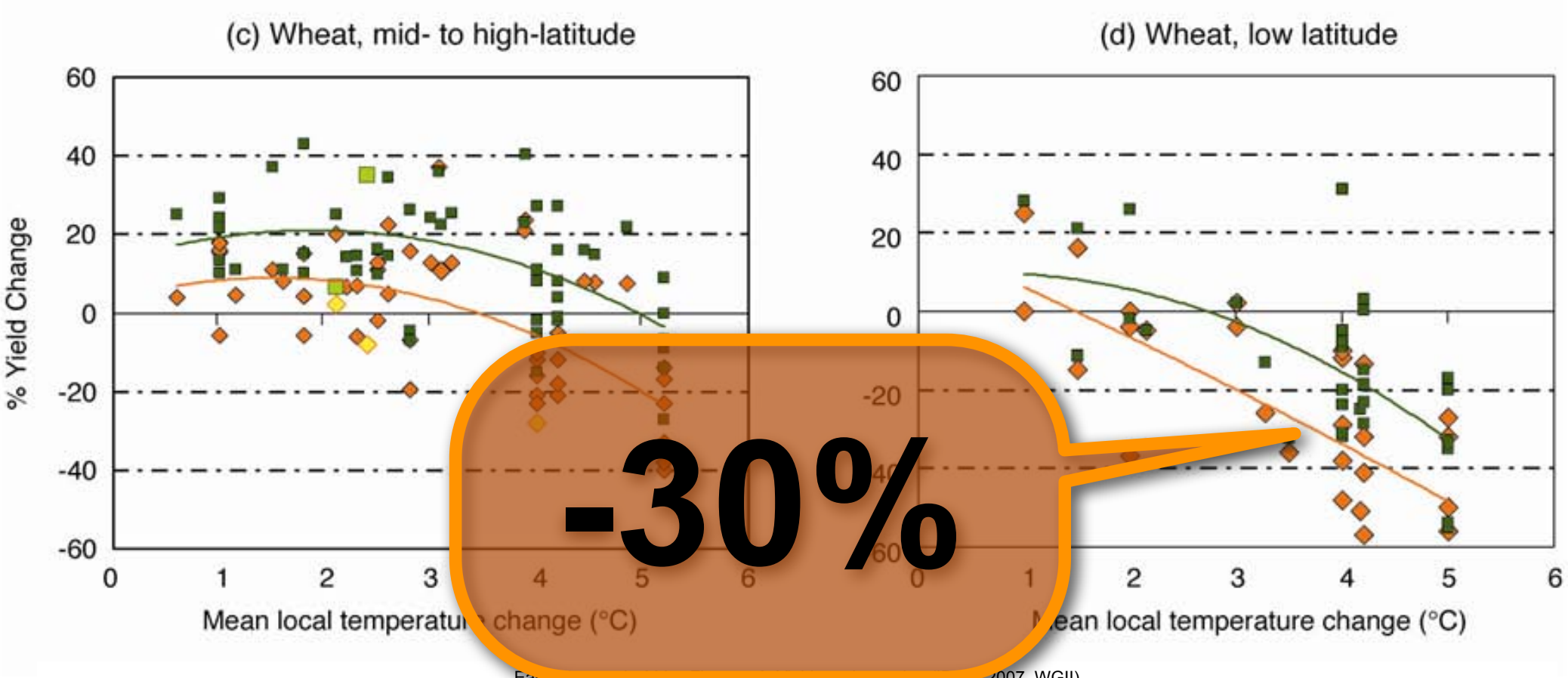
IPCC, 2007. SPM WGII, p.11

(medium confidence)

Wheat

Without adaptation

With adaptation

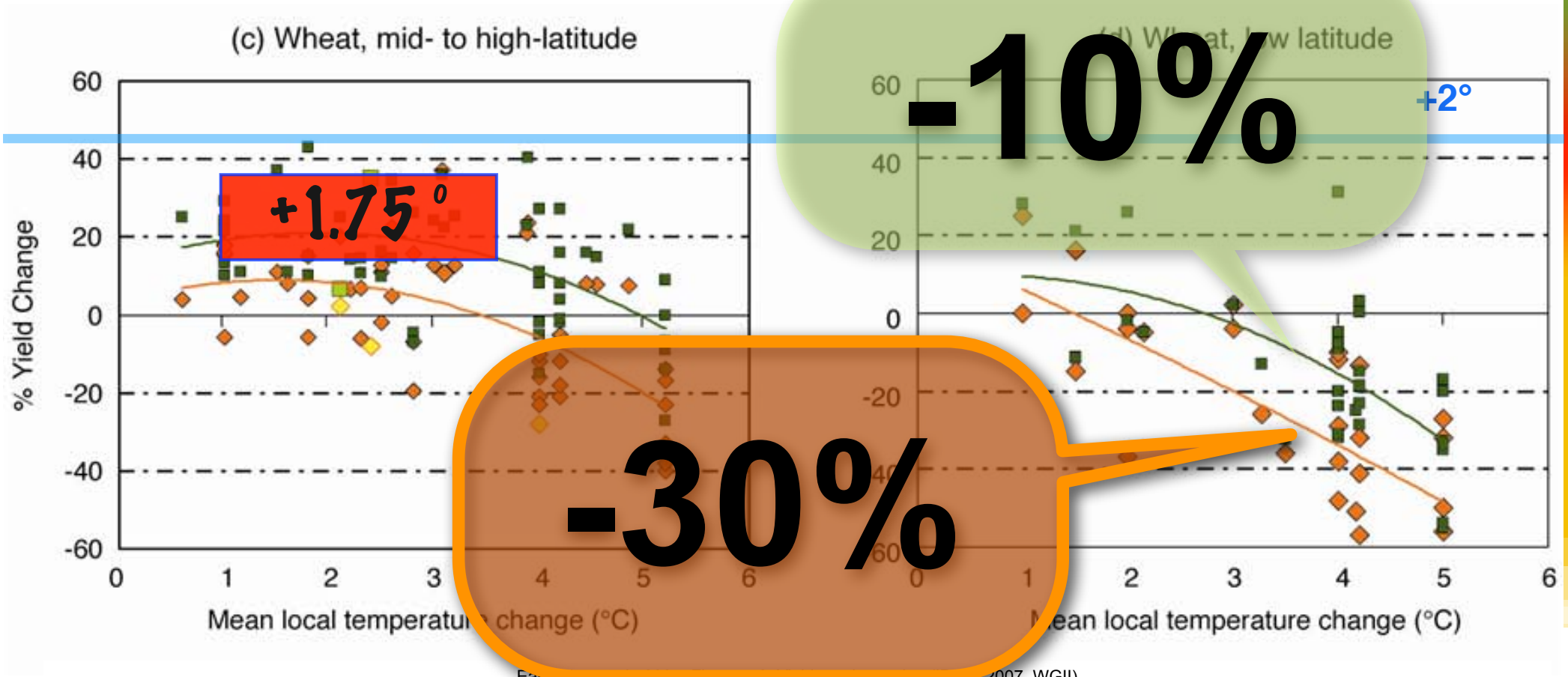


East… 2007. WGII)

Wheat

Without adaptation

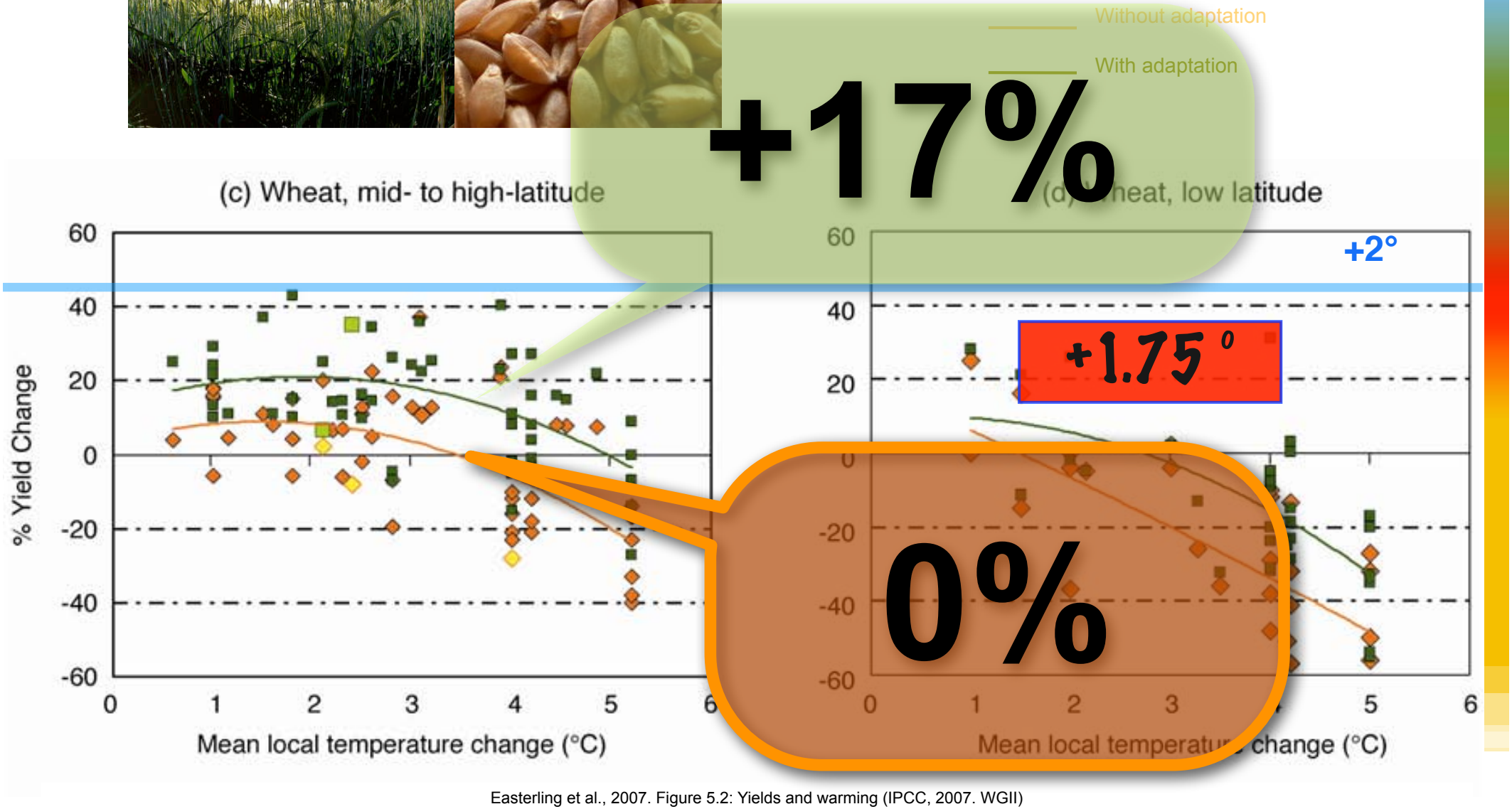
With adaptation



2007. WGII)

Wheat

+17%

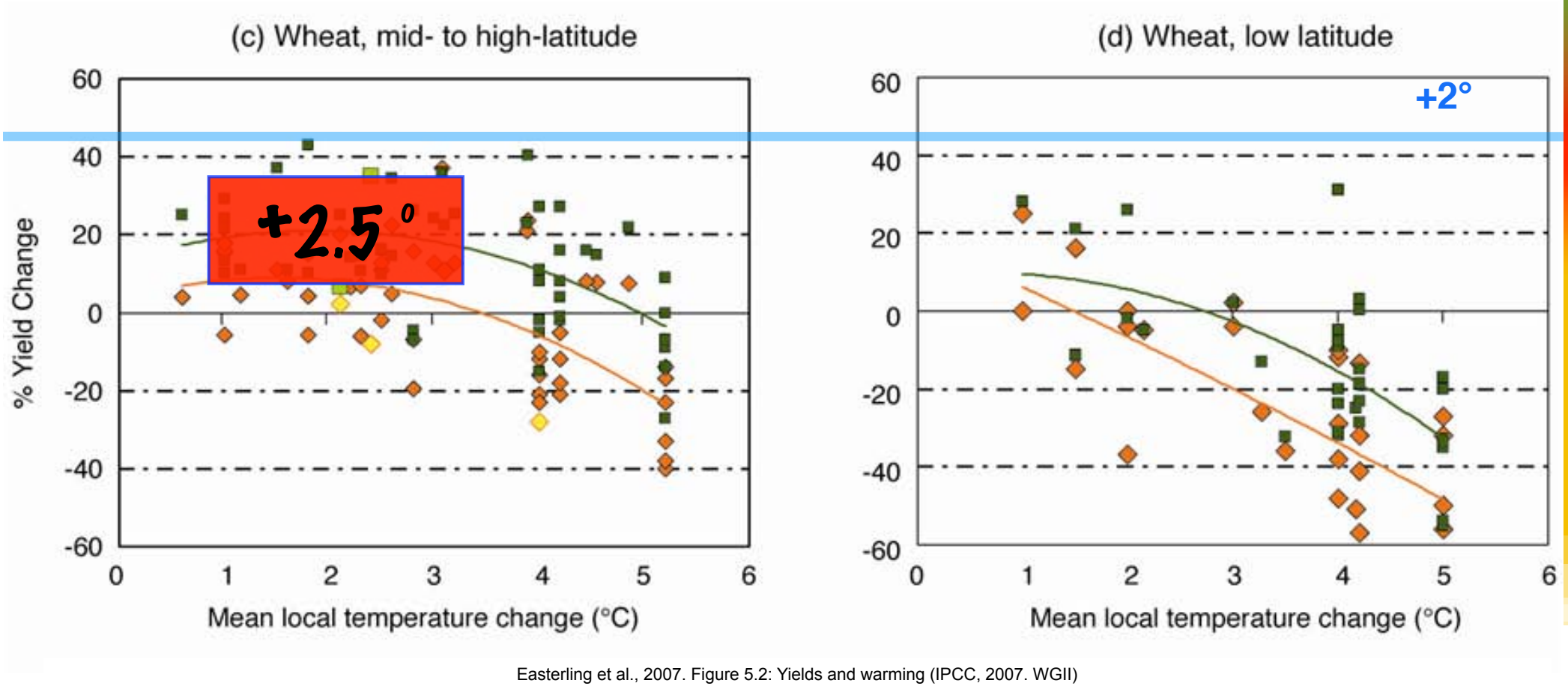


Easterling et al., 2007. Figure 5.2: Yields and warming (IPCC, 2007. WGII)

Wheat

Without adaptation

With adaptation



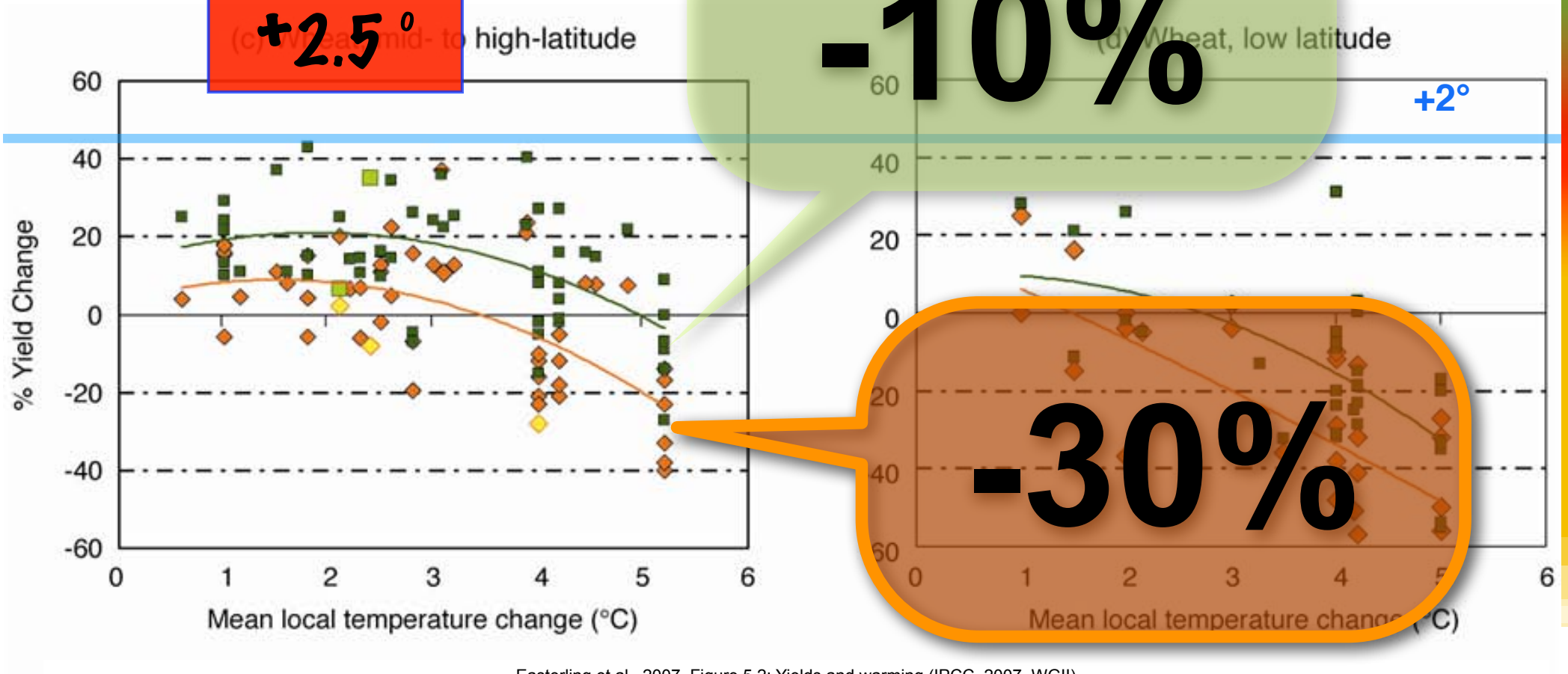
Easterling et al., 2007. Figure 5.2: Yields and warming (IPCC, 2007. WGII)

Wheat

+2.5 °

-10%

-30%



Easterling et al., 2007. Figure 5.2: Yields and warming (IPCC, 2007. WGII)

Wheat

+2.5 °

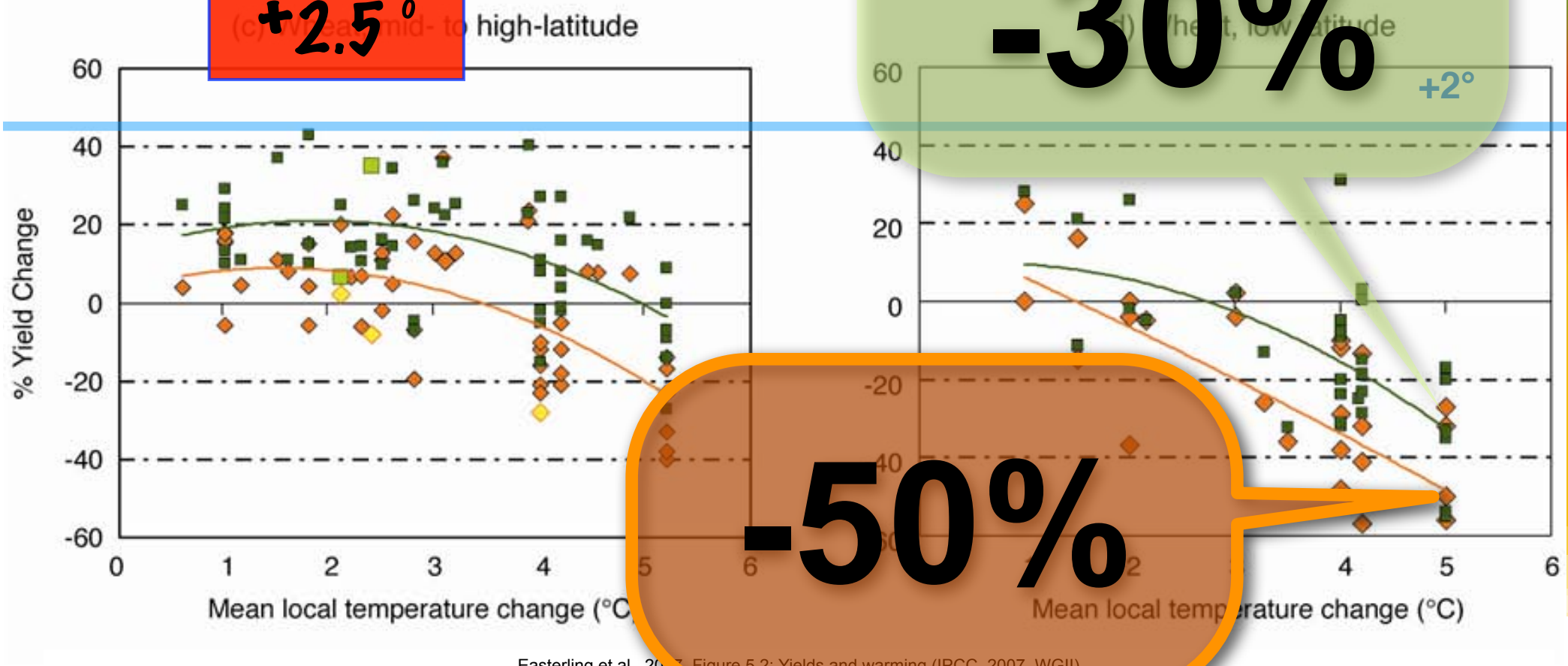
Without adaptation

With adaptation

-30%

+2°

-50%



Easterling et al., 20 . Figure 5.2: Yields and warming (IPCC, 2007. WGII)

Forest Services

	Mha	% trans-formed	Biodiversity	Provisioning	Regulating	Cultural
Boreal 	1370	25	α-diversity decreases with latitude, but relatively large β-diversity	~45% of world softwood production	Significant fraction of terrestrial residual uptake	Indigenous peoples; recreational uses
Temperate 	1040	67	Forests serve increasingly as refuge for plants and wildlife	Productive forests in proximity of densely populated areas; lumber supply for industrialized countries	Large fraction of terrestrial residual uptake	Leisure time use; remaining surrogates for wilderness
Tropical 	1750	34	E.g. Amazone 25% of terrestrial biodiversity with endemism ≈76%; Atlantic forests >50% endemism	Livelihood of many indigenous peoples depend on wood as well as non-wood products	Regional climate, i.e. maintains high precipitation levels; largest fraction (62%) of terr. ecosystem C	Ecotoursim in biodiversity hotspots

Forestry

Globally, commercial timber productivity rises modestly with climate change in the short- to medium-term, with large regional variability around the global trend.

IPCC, 2007. SPM WGII, p.12

(medium confidence)

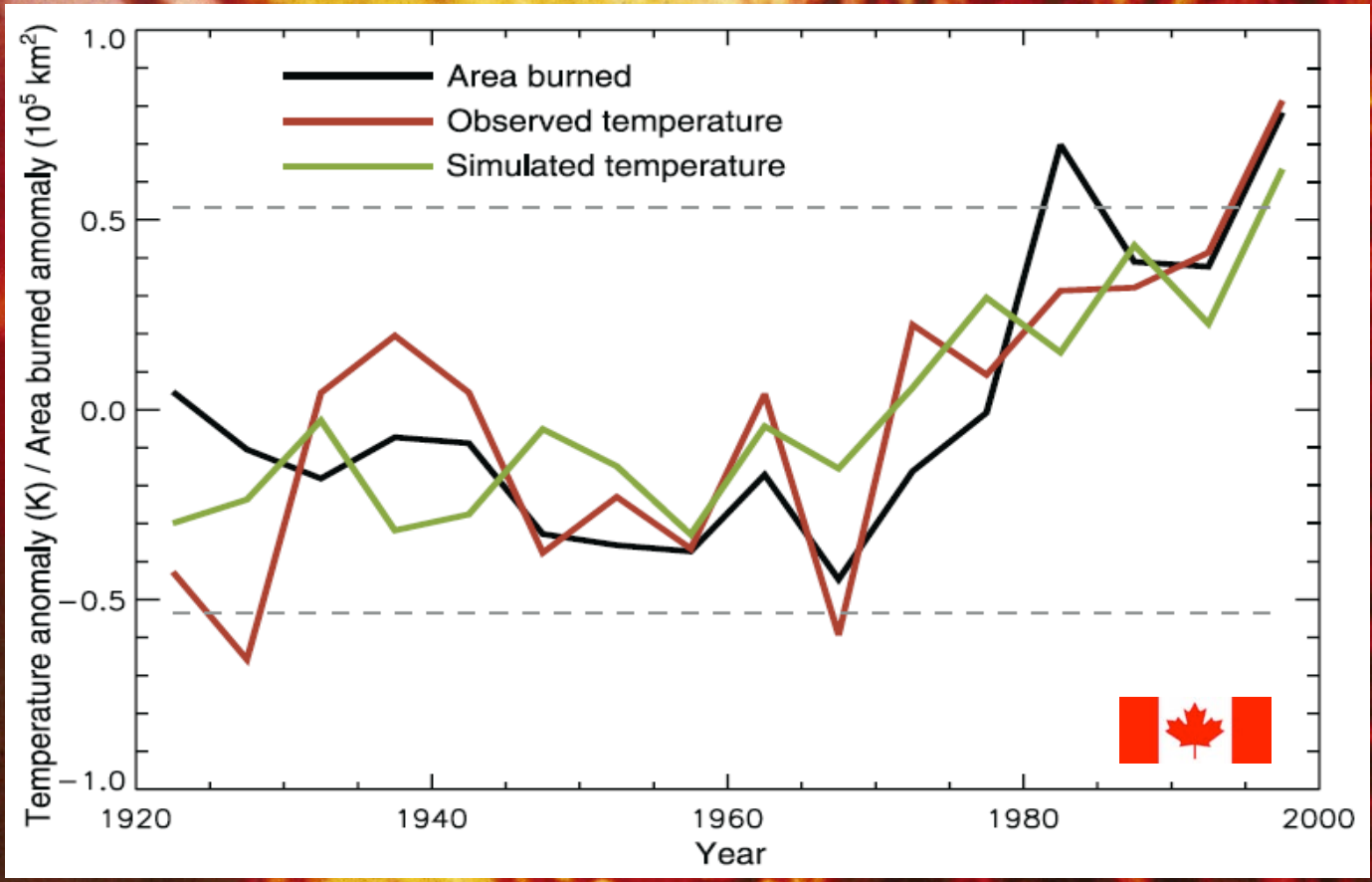
Observed Trends of Increasing Fire Prevalence

mostly in boreal and subtropical zones

Section 4.4.5 (Fischlin *et al.*, 2007. IPCC WGII)

Observed Trends of Increasing Fire Prevalence

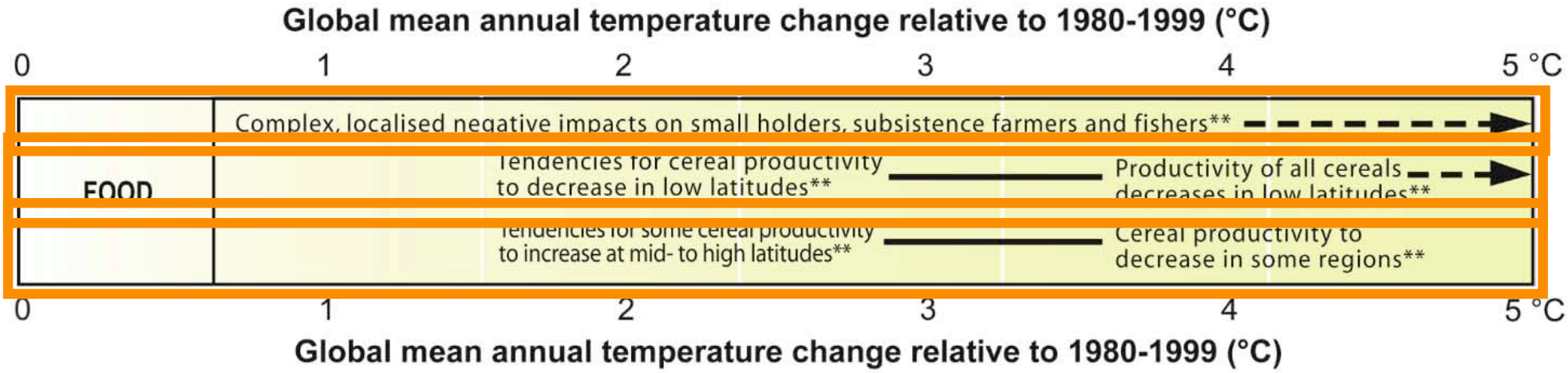
mostly in boreal and subtropical zones



Section 4.4.5 (Fischlin *et al.*, 2007. IPCC WGII)

Summary

Impacts on Provisioning Services (Food, fibre, and forestry)

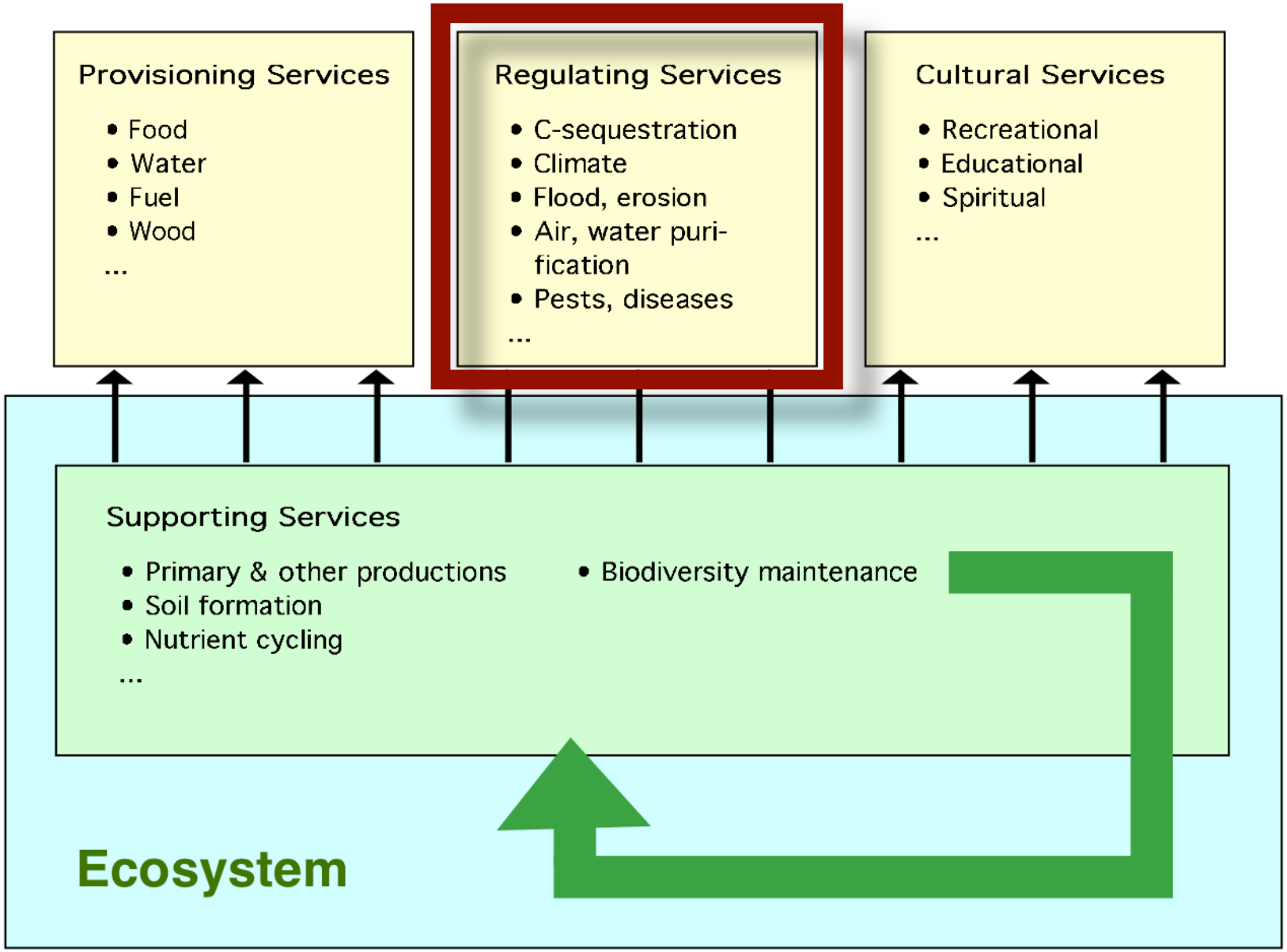


The warmer, the more negative the impacts!

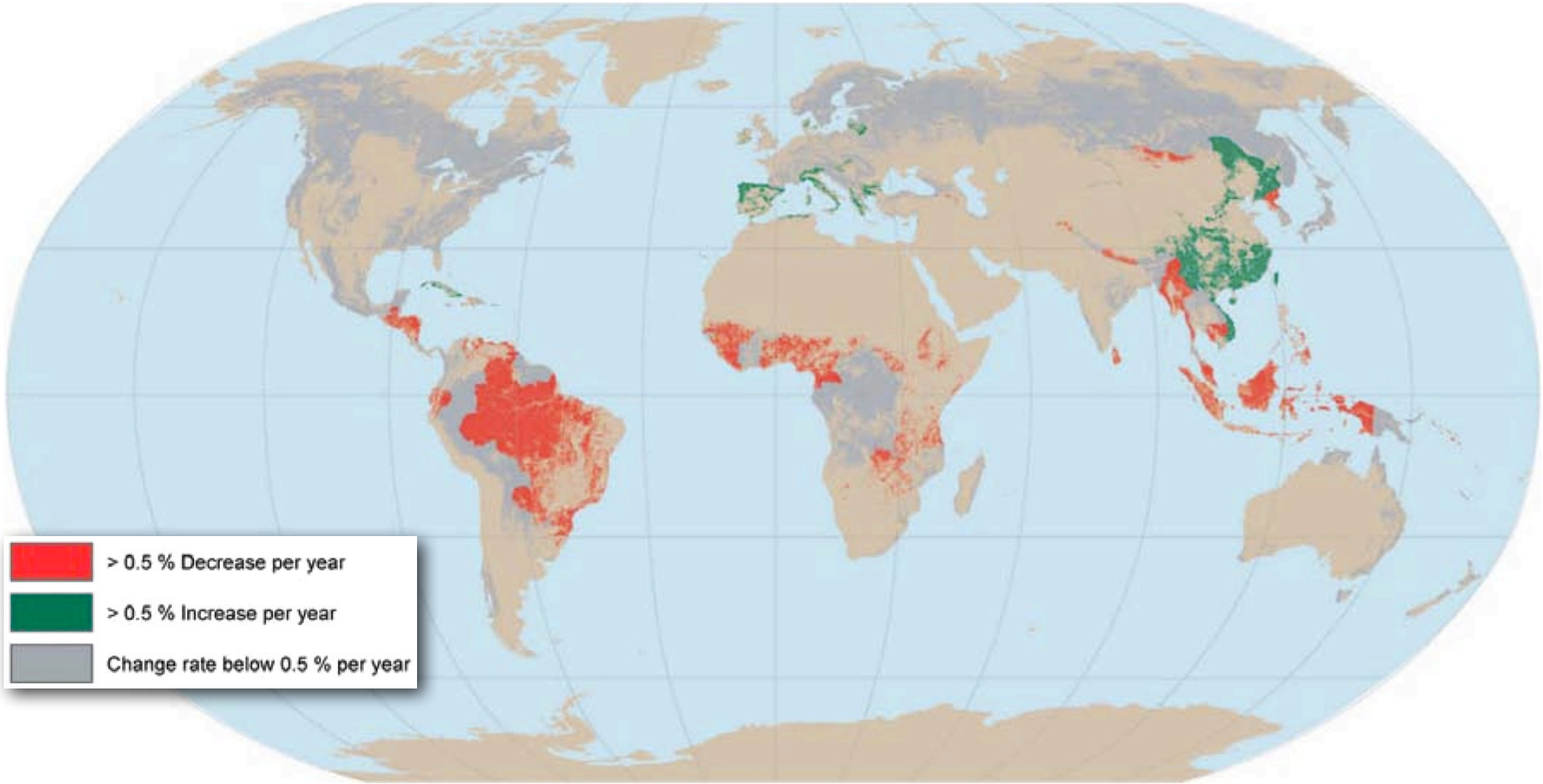
From Figure SPM.2

(IPCC, 2007c. Summary for Policy Makers by Working Group II AR4 IPCC)

Ecosystems Services



Double Role of Forests



Net changes in forest cover 2000-2005
(Nabuurs, G.J., et al., 2007. IPCC AR4 WGIII, 541-584. Fig. 9.1)

Forests
Regulating services

Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse, thus amplifying climate change.

(high confidence)

IPCC, 2007c. SPM WGII, p.11

Where Does the CO_2 Go?

E.g. 2006
Anthropogenic emissions:
8.4 + 1.5 = 9.9 PgC/a

Fischlin, 2008. Schweiz. Z. Forstwesen; Data from Raupach et al. 2007, PNAS; Canadell et al 2007, PNAS

Where Does the CO_2 Go?

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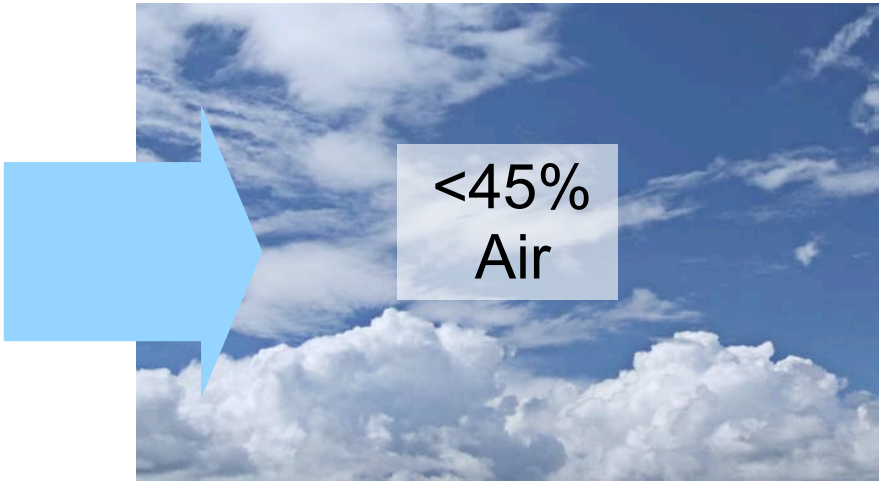
Fischlin, 2008. Schweiz. Z. Forstwesen; Data from Raupach et al. 2007, PNAS; Canadell et al 2007, PNAS



~2030

Where Does the CO_2 Go?

E.g. 2006
Anthropogenic emissions:
8.4 + 1.5 = 9.9 PgC/a

Fischlin, 2008. Schweiz. Z. Forstwesen; Data from Raupach et al. 2007, PNAS; Canadell et al 2007, PNAS

~2060

<<30%Land

DGVM Results - LPJ B1 ECHAM5

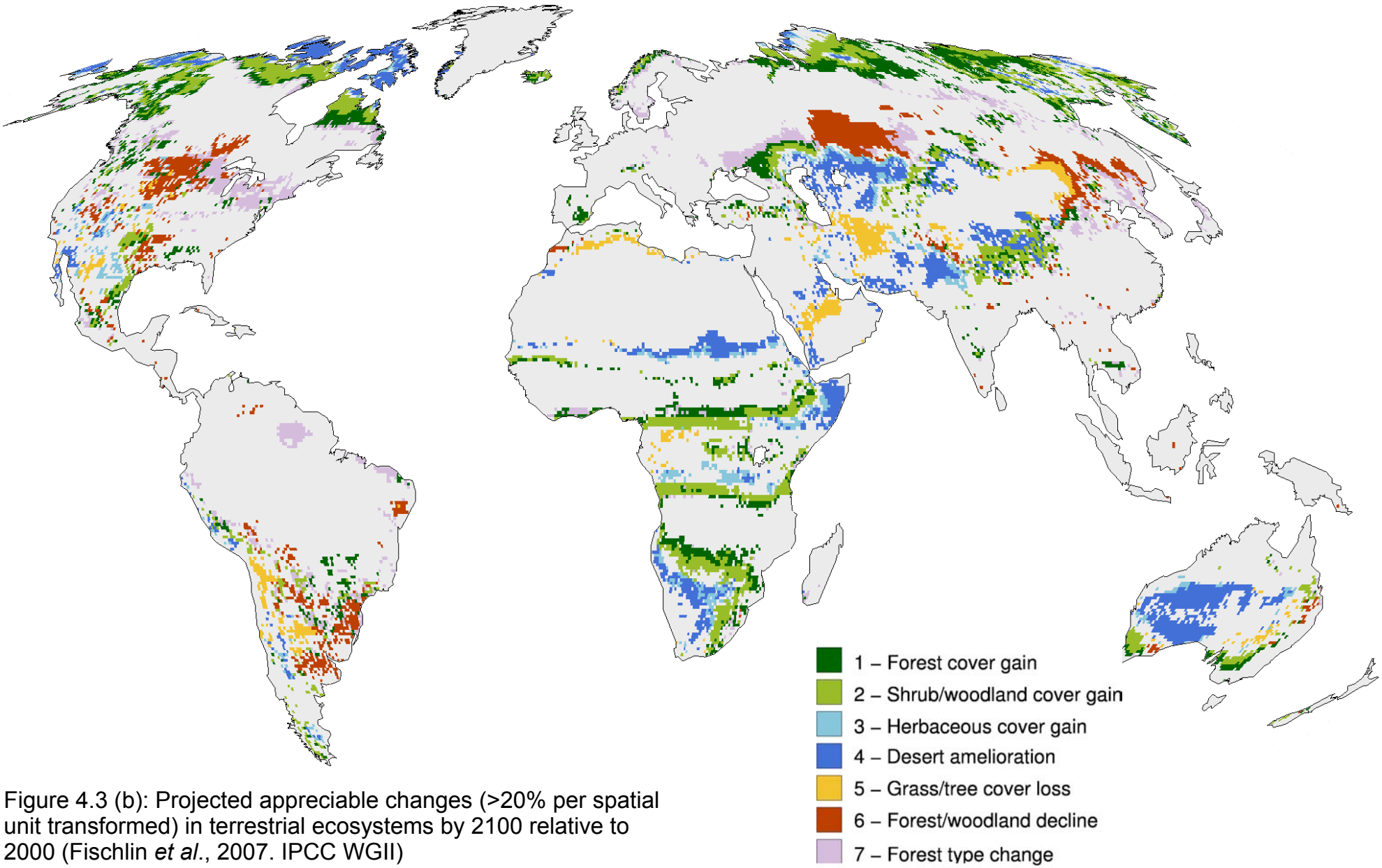


Figure 4.3 (b): Projected appreciable changes (>20% per spatial unit transformed) in terrestrial ecosystems by 2100 relative to 2000 (Fischlin *et al*., 2007. IPCC WGII)

DGVM Results - LPJ A2 HadCM3

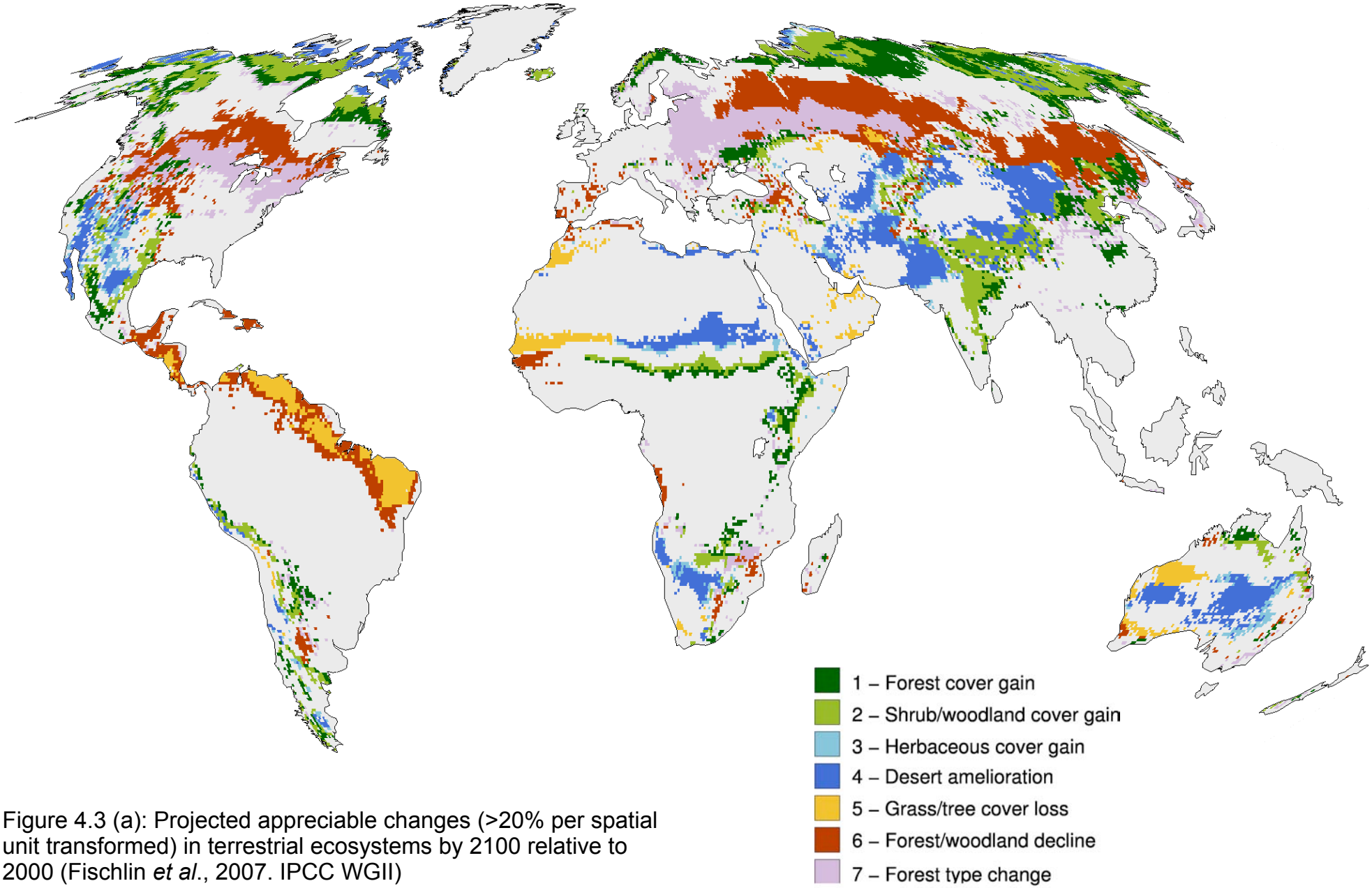


Figure 4.3 (a): Projected appreciable changes (>20% per spatial unit transformed) in terrestrial ecosystems by 2100 relative to 2000 (Fischlin *et al.*, 2007. IPCC WGII)

Sink service at risk!

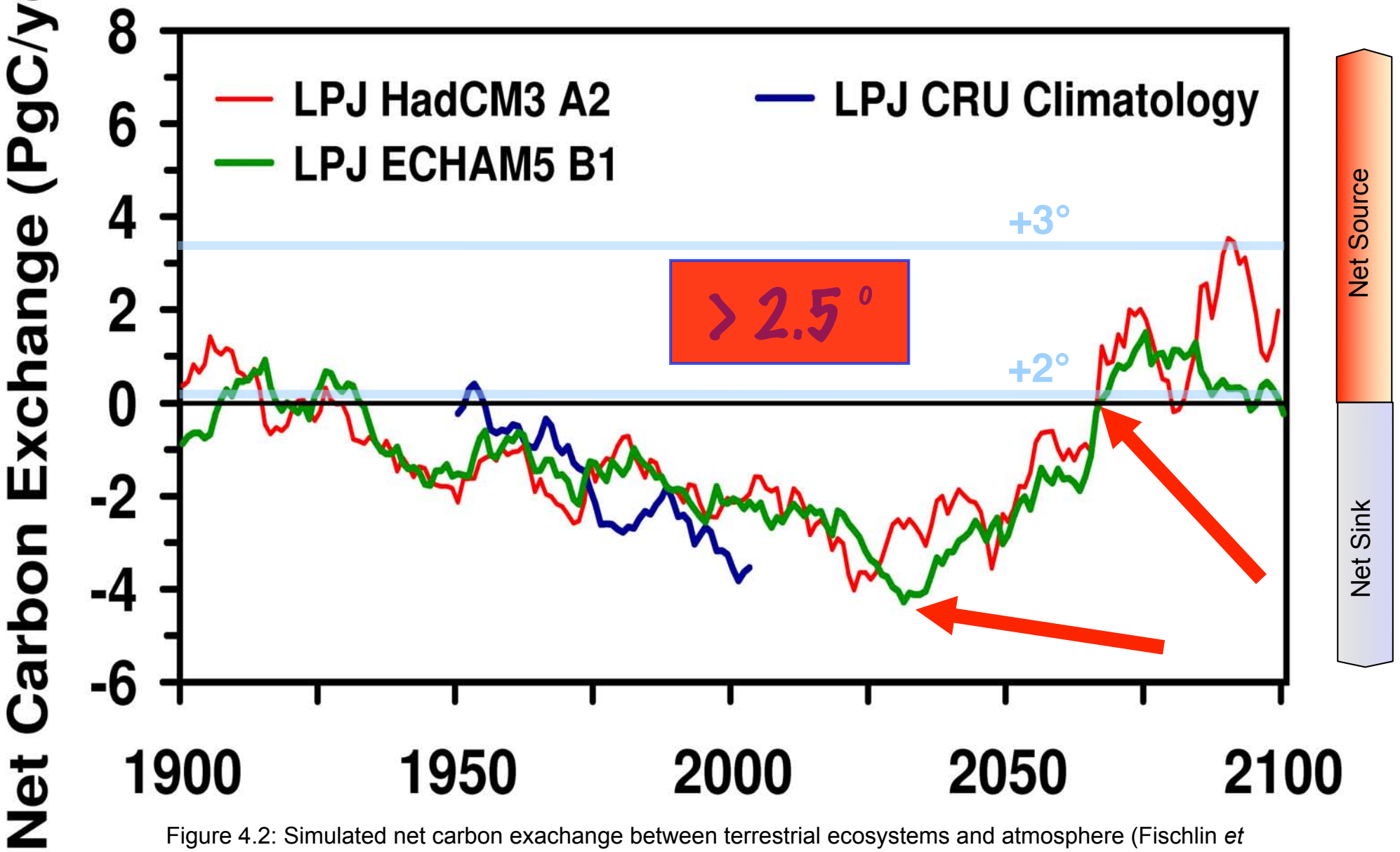
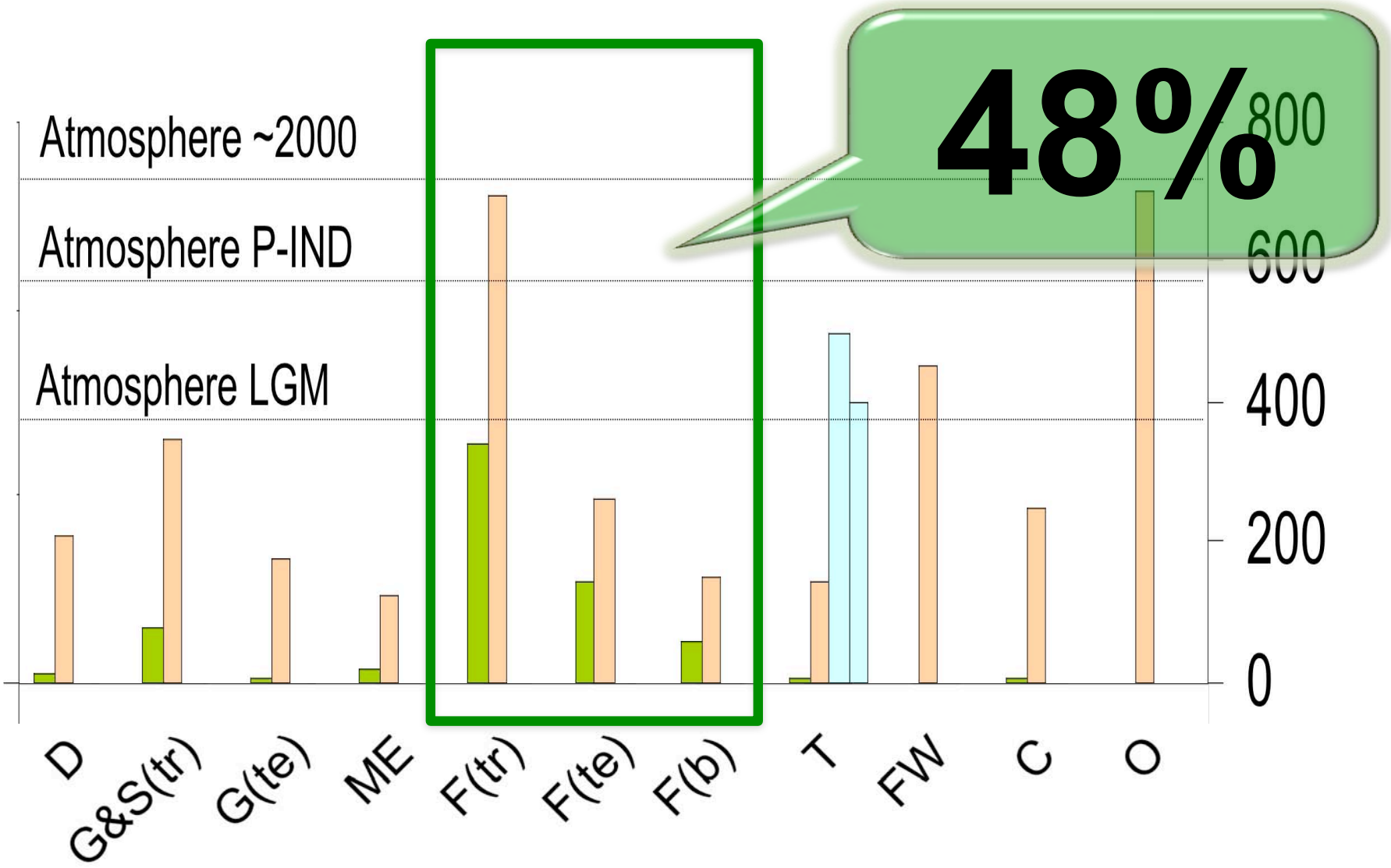


Figure 4.2: Simulated net carbon exachange between terrestrial ecosystems and atmosphere (Fischlin *et al.*, 2007. IPCC WGII)

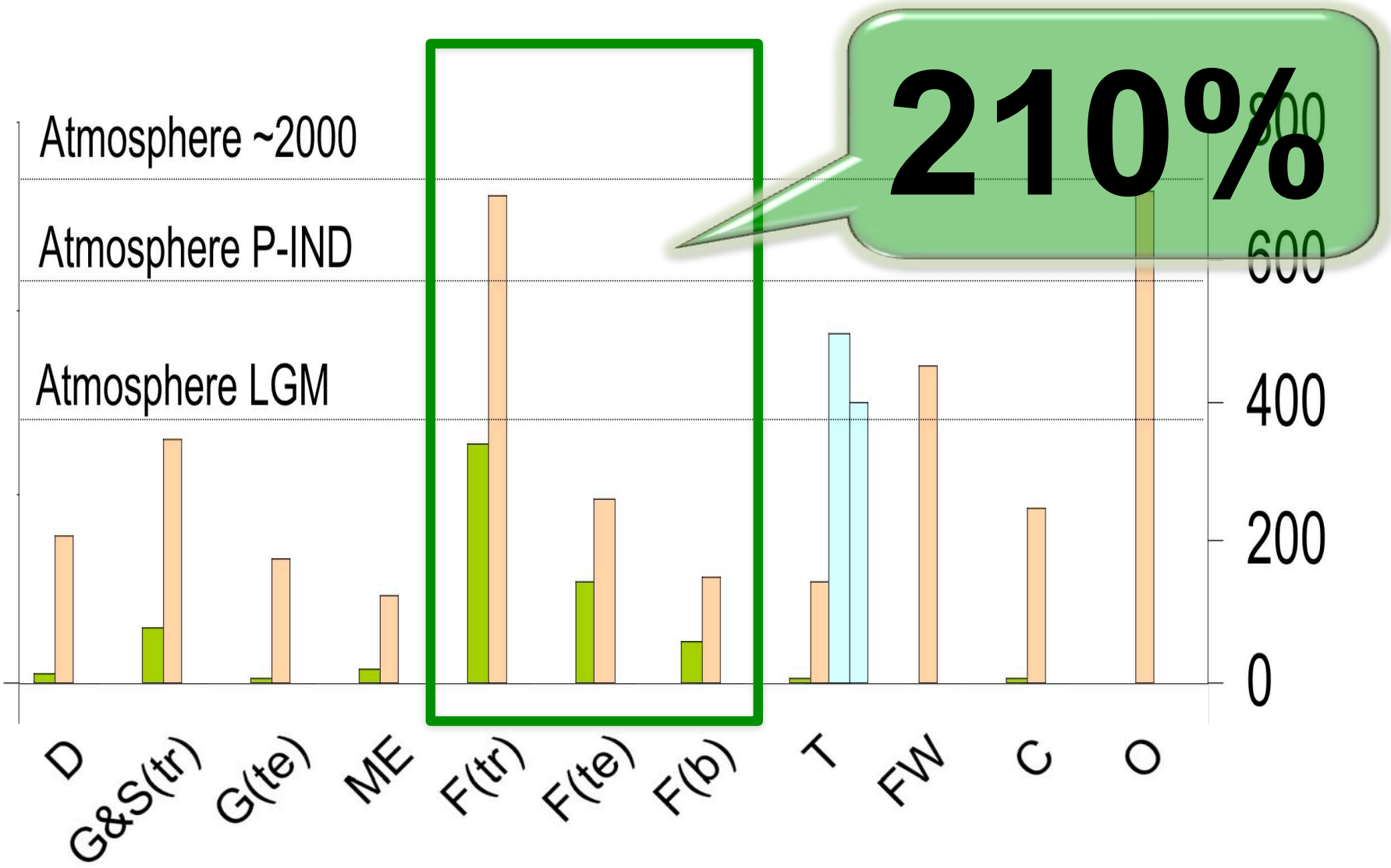
Carbon Stored in Forests



from amount in all ecosystems

Figure 4.1: Ecosystems addressed - C stocks
(Fischlin *et al.*, 2007. IPCC WGII)

Carbon Stored in Forests



from amount in atmosphere

Figure 4.1: Ecosystems addressed - C stocks
(Fischlin *et al.*, 2007. IPCC WGII)

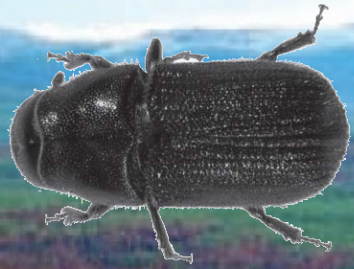
Forest pests - **Mountain Pine Beetle**

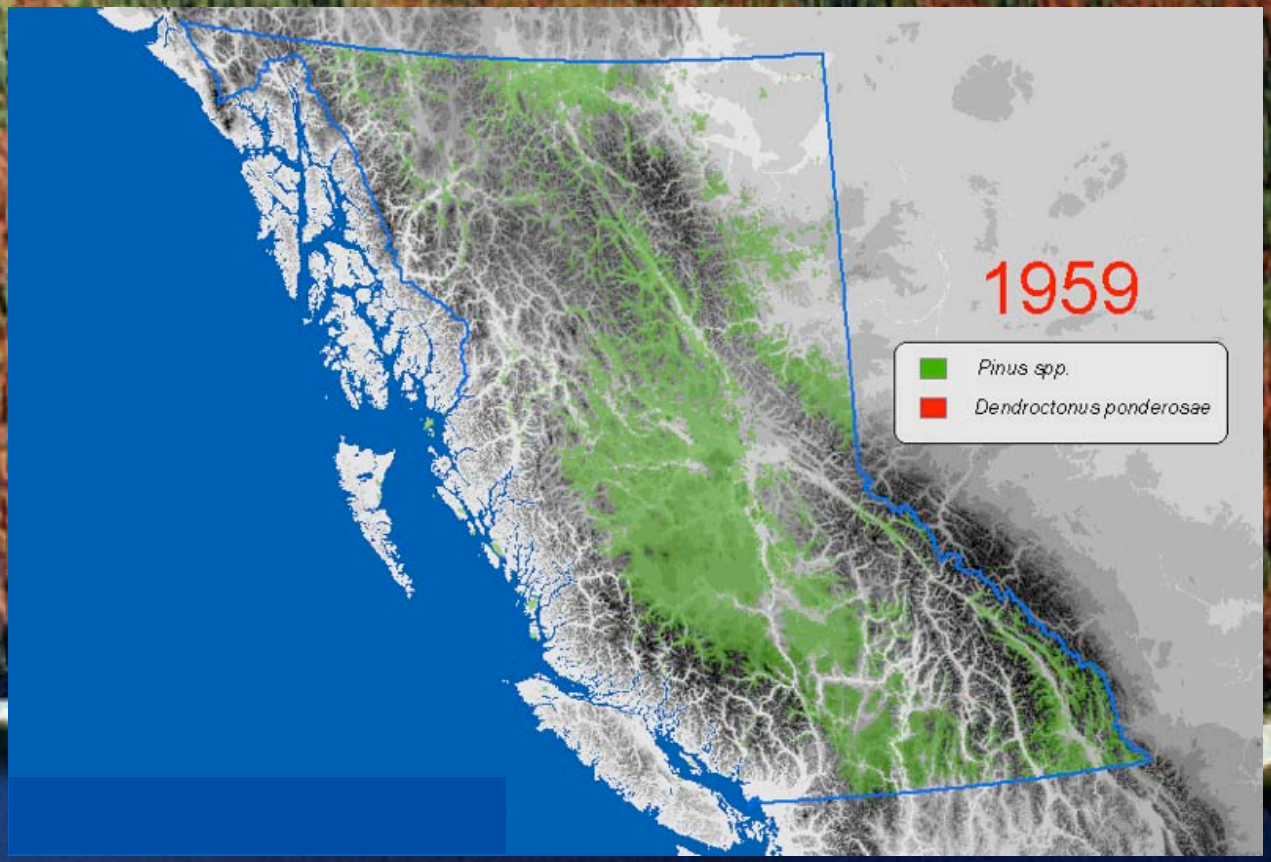
(***Dendroctonus ponderosae, Col., Scolytidae***)

Section 4.4.5
(Fischlin *et al.*, 2007.
IPCC WGII)

Forest pests - **Mountain Pine Beetle**

(***Dendroctonus ponderosae, Col., Scolytidae***)

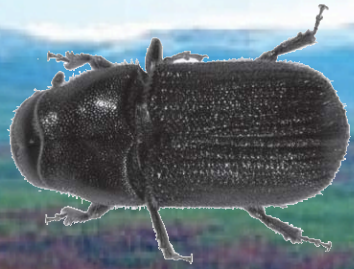


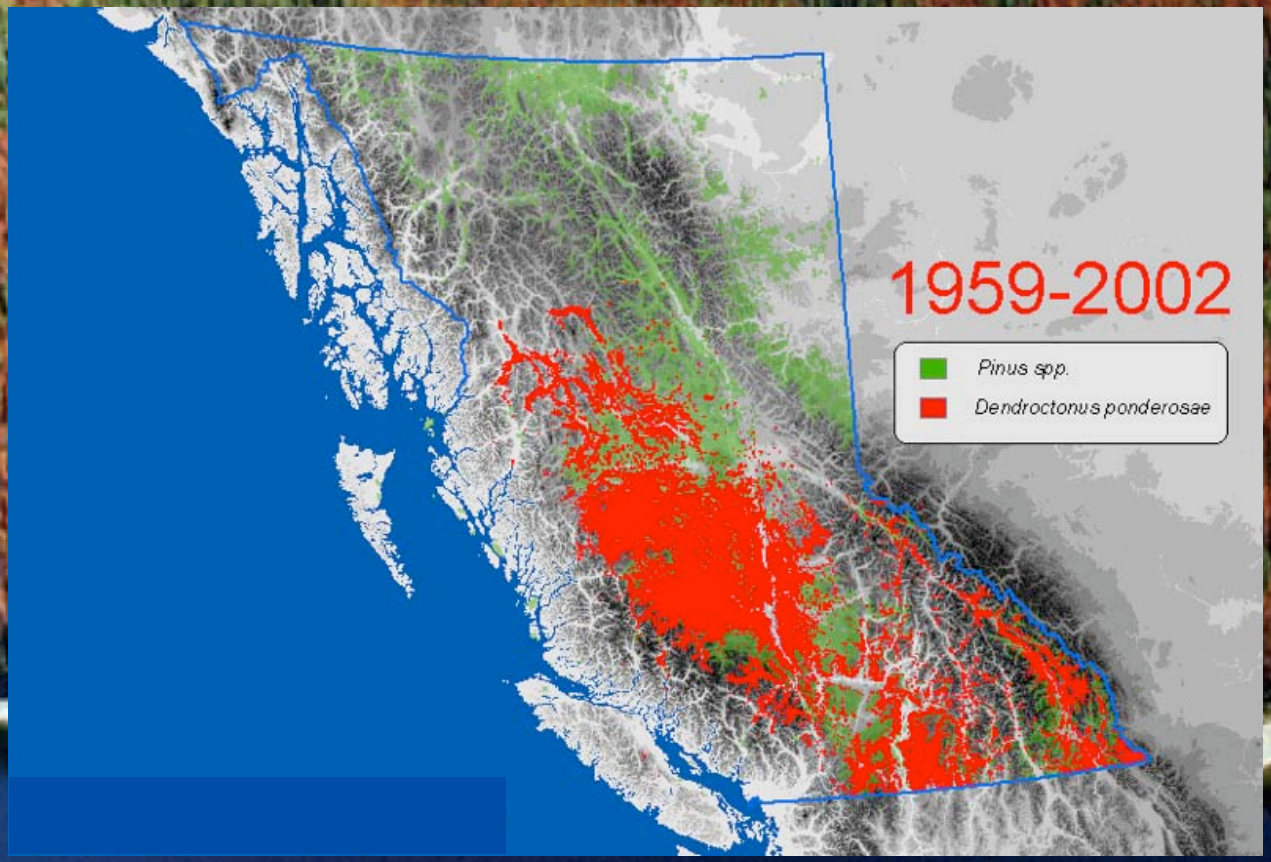


Section 4.4.5
(Fischlin *et al.*, 2007.
IPCC WGII)

Forest pests - **Mountain Pine Beetle**

(***Dendroctonus ponderosae, Col., Scolytidae***)

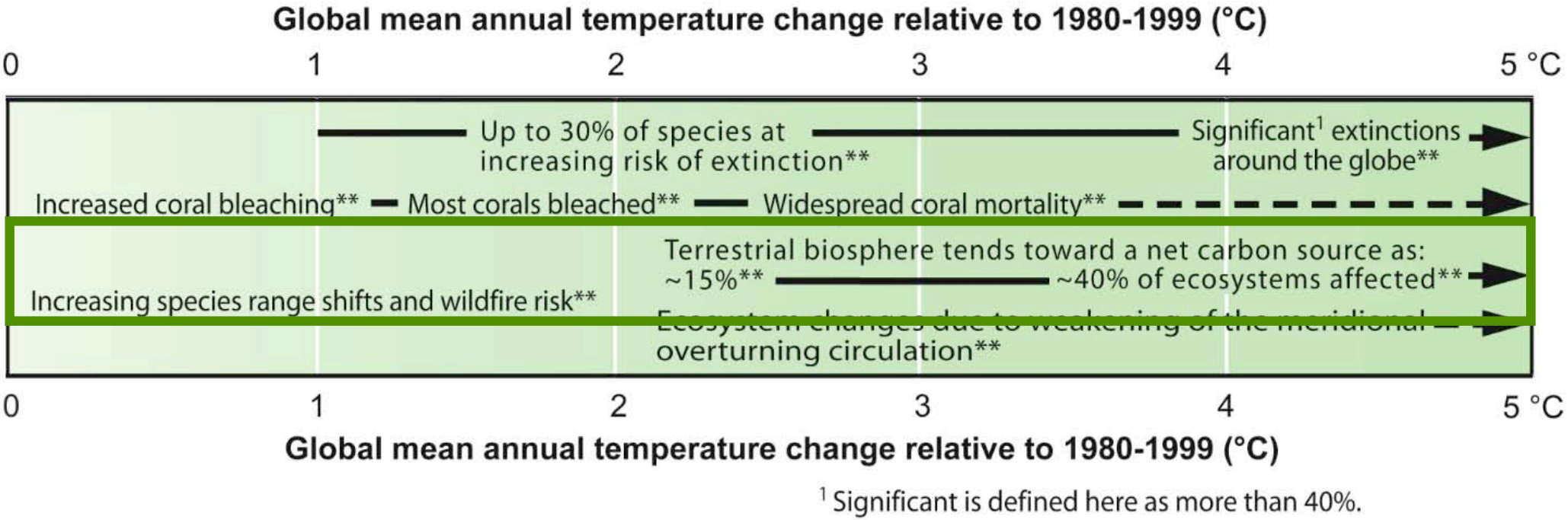




Section 4.4.5
(Fischlin *et al.*, 2007.
IPCC WGII)

Summary

Impacts on Regulating Services



[1] Significant is defined here as more than 40%.

The warmer, the more negative the impacts!

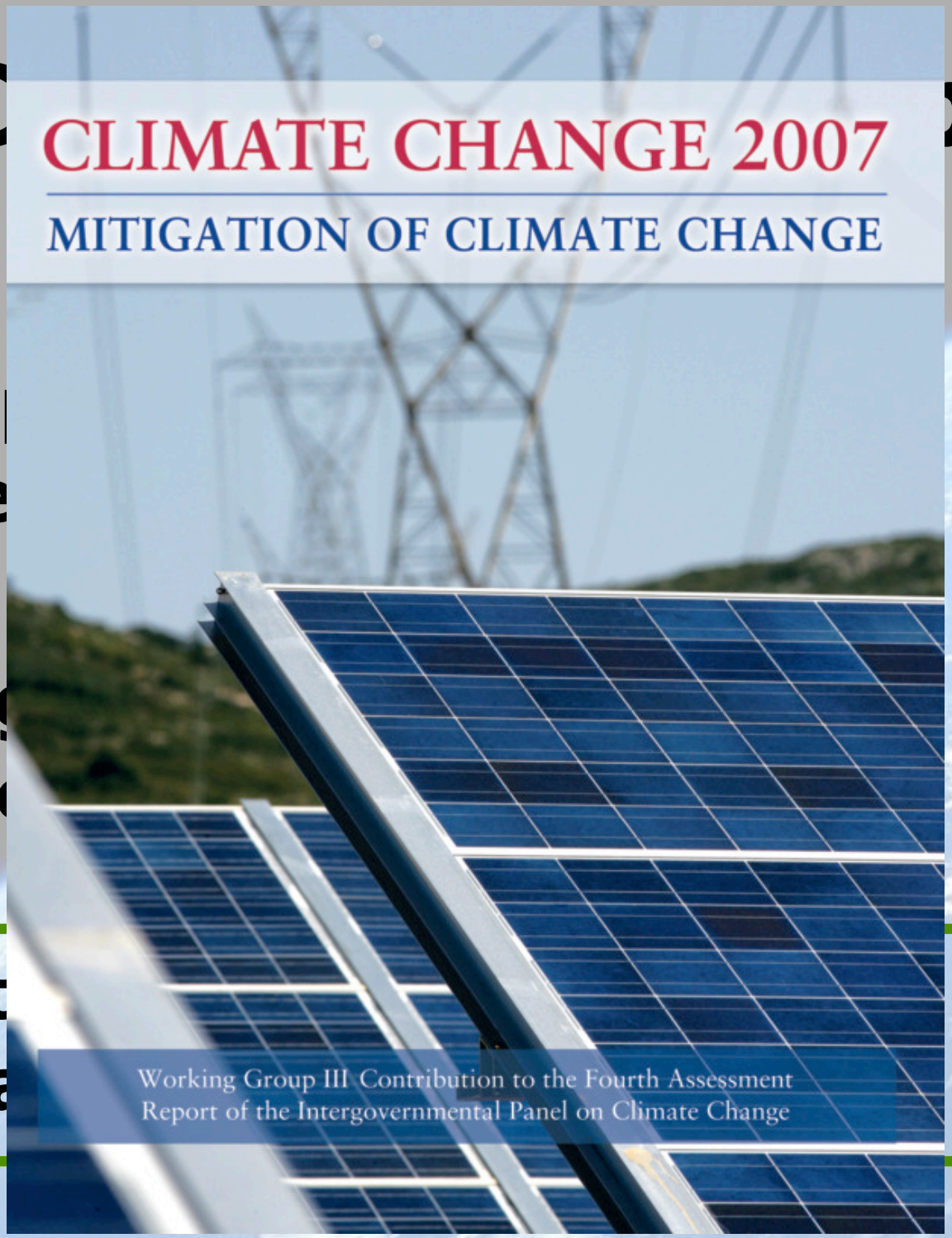
From Figure SPM.2
(IPCC, 2007. Summary for Policy Makers by Working Group II AR4 IPCC)

Future Impacts?

Plenty!

Including some fatal ones!

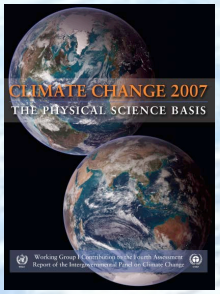
IPCC ort 4

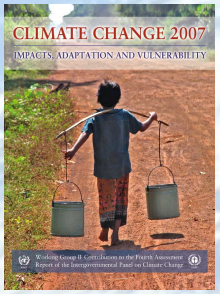


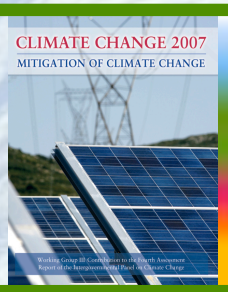
Anthro
change

Unmiti
would

A drast
is still a







What Can Be Done?

Adaptation

AND

Mitigation

Warming Over Present Levels

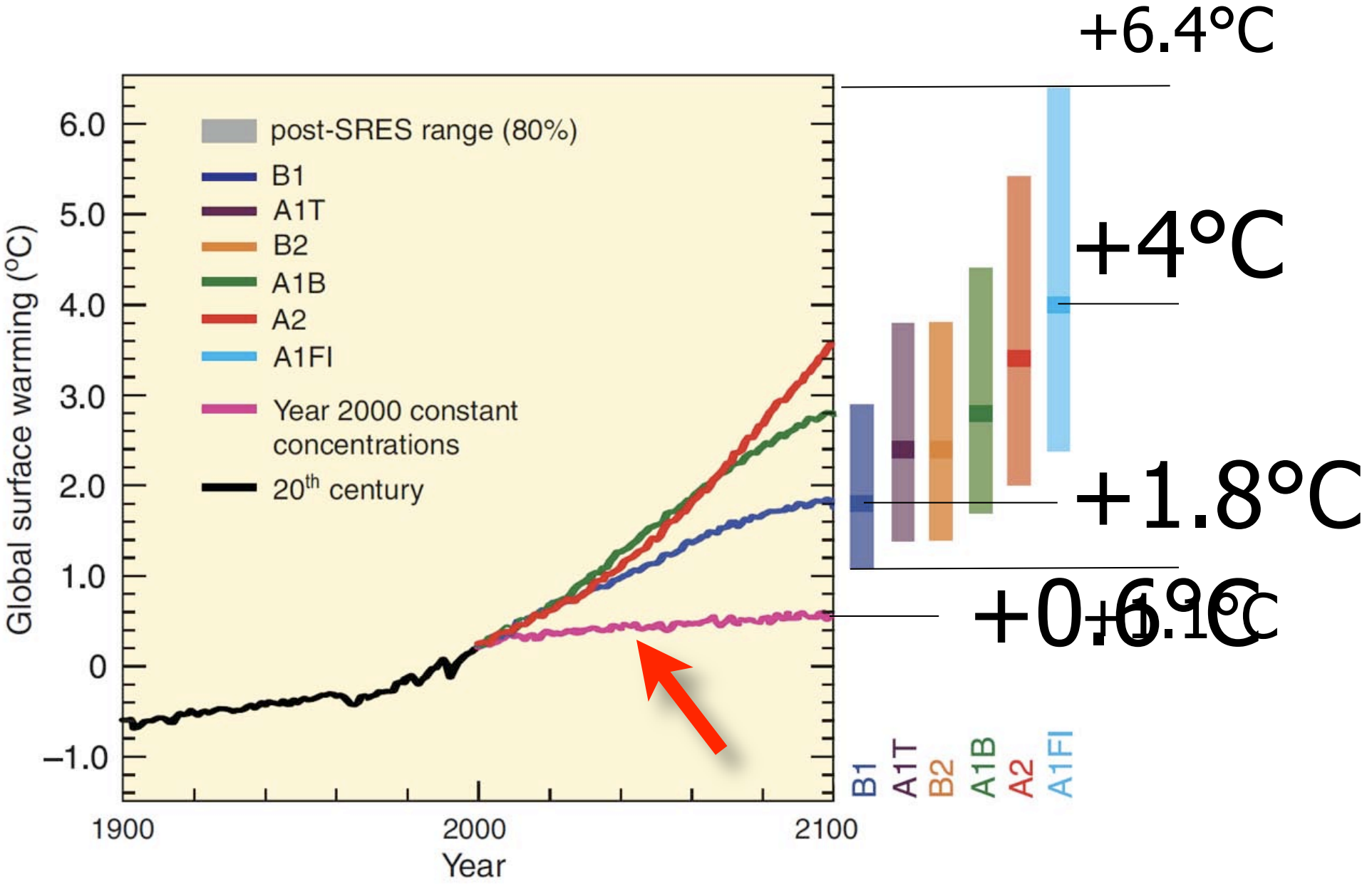
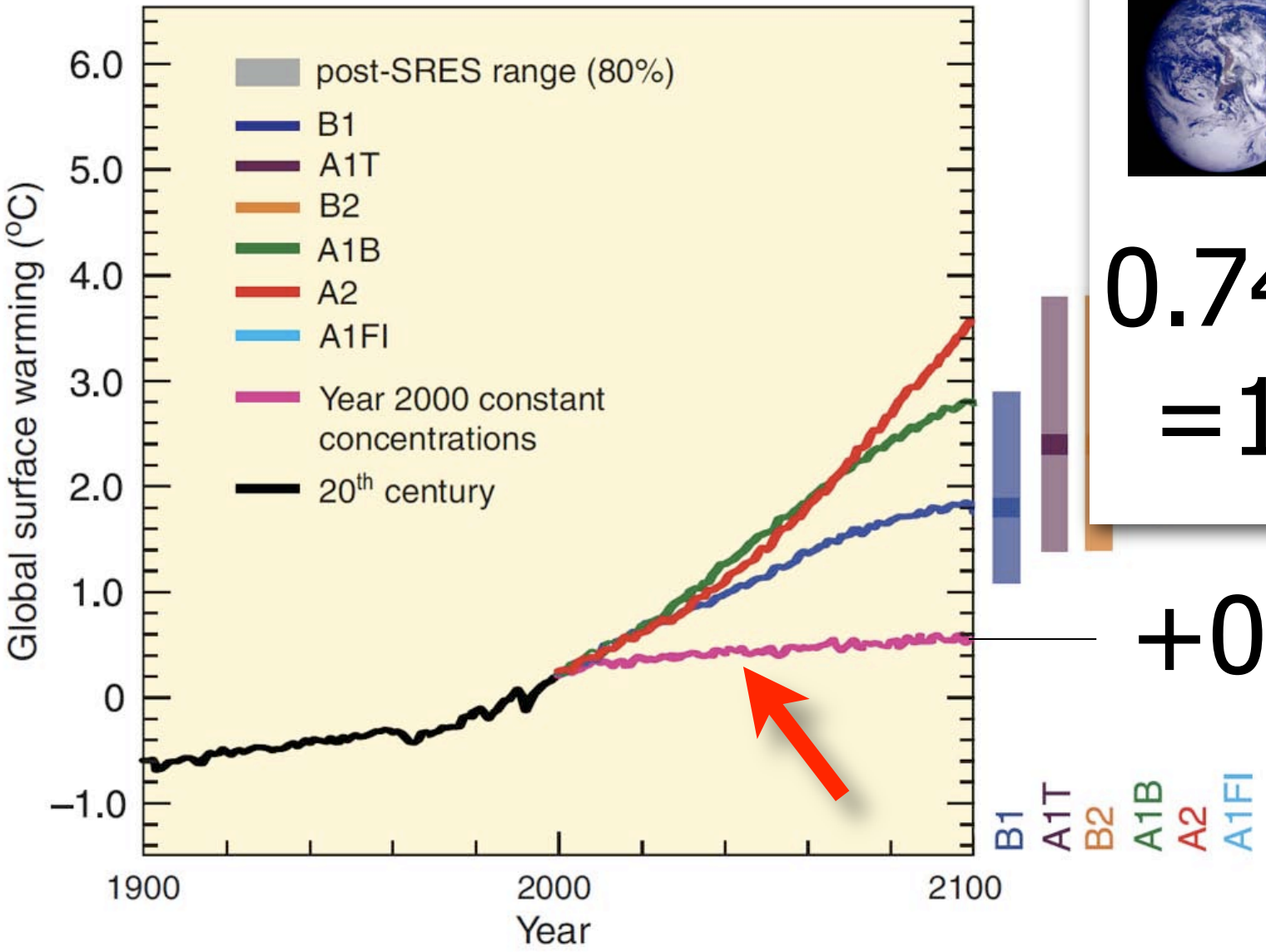


Figure SPM.5: Multi-model global averages of surface warming (relative to 1980–1999) for the scenarios (IPCC, 2007. Summary for Policy Makers WGI)

Warming Over Present Levels



0.74 + 0.6
=1.34°C

+0.6°C

Figure SPM.5: Multi-model global averages of surface warming (relative to 1980–1999) for the scenarios (IPCC, 2007. Summary for Policy Makers WGI)

Land Use Change

Source: World Resources Institute / South Dakota State University, 2009

Courtesy: Lars Laestadius, WRI

Adaptation = Restoration

Courtesy: Lars Laestadius, WRI

Source: World Resources Institute / South Dakota State University, 2009

Adaptation

AND

Mitigation


Ecosystems Also Causing Climate Change?

Global CO_2 Emissions

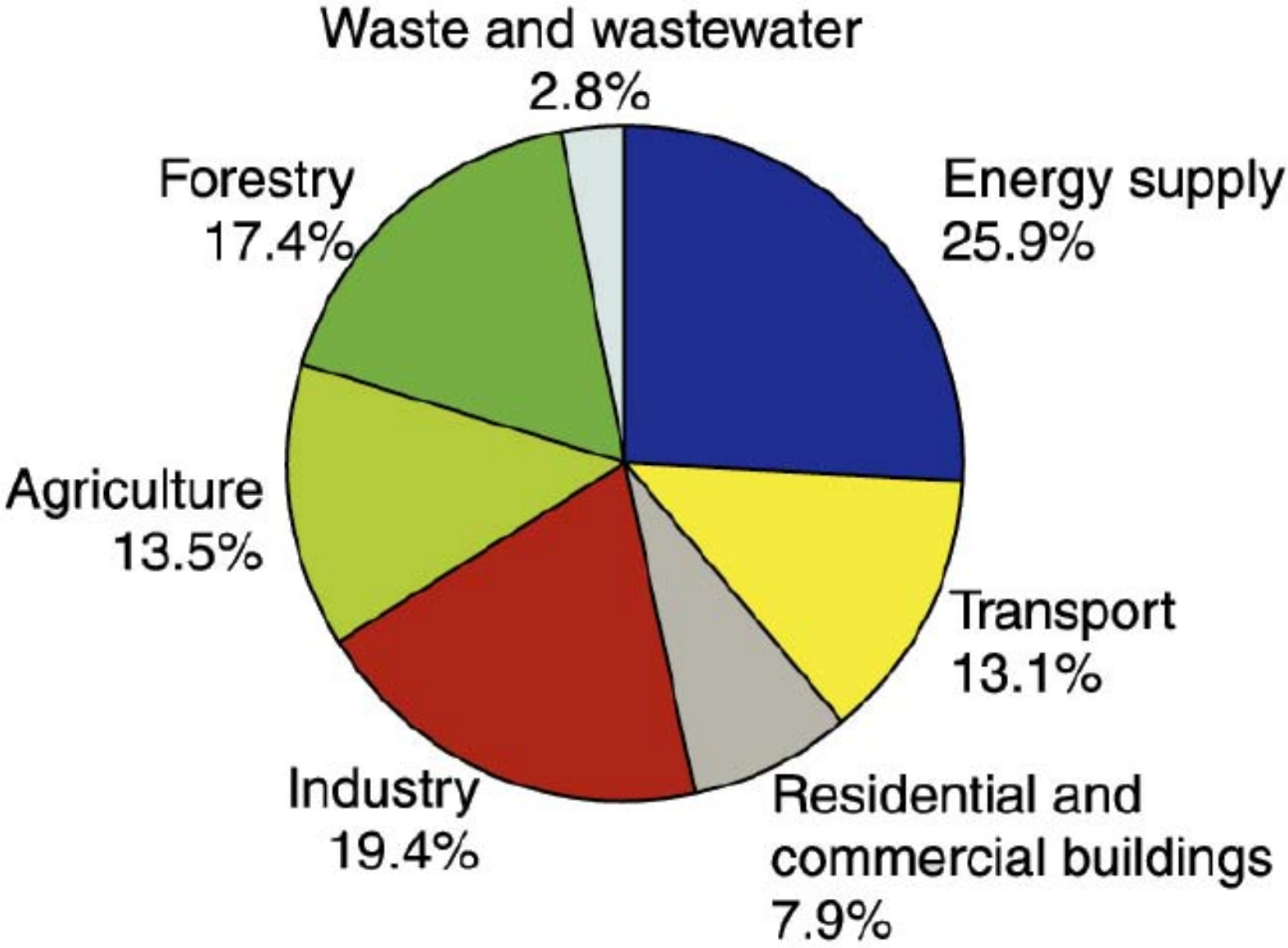


Figure SPM.3: GHG emissions in 2004 by sectors [CO_2-eq]. IPCC, 2007. WGIII SPM.

Defo-resta-tion

To grow corn and soy more than 90% of forest land outside of the reserve Iguaçu National Park was changed to cropland within only 30 years!

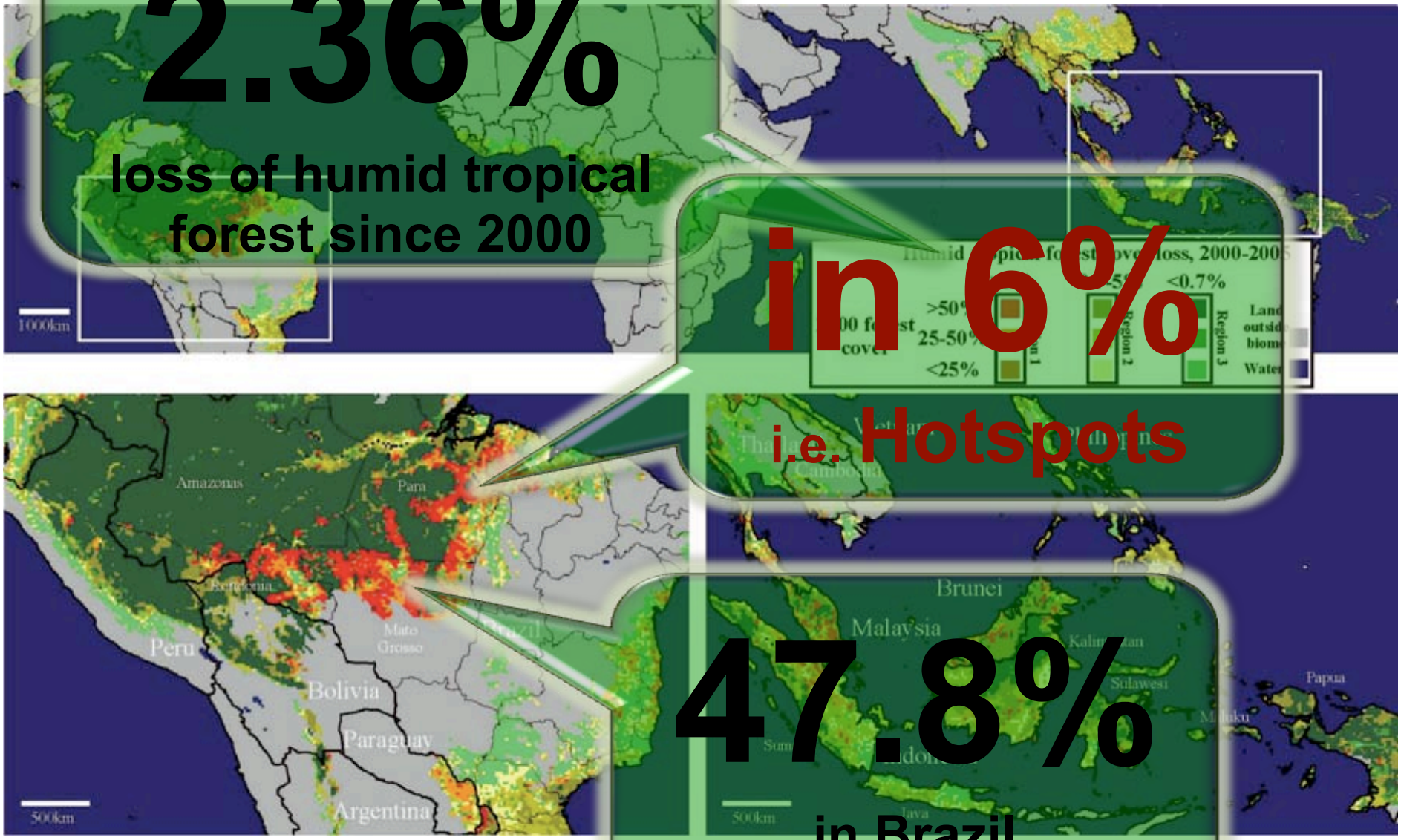
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Deforestation Can Be Quantitatively Estimated

DUWIS
Departement
Umweltwissenschaften

2.36%

loss of humid tropical forest since 2000



in 6%

i.e. Hotspots

47.8%

in Brazil

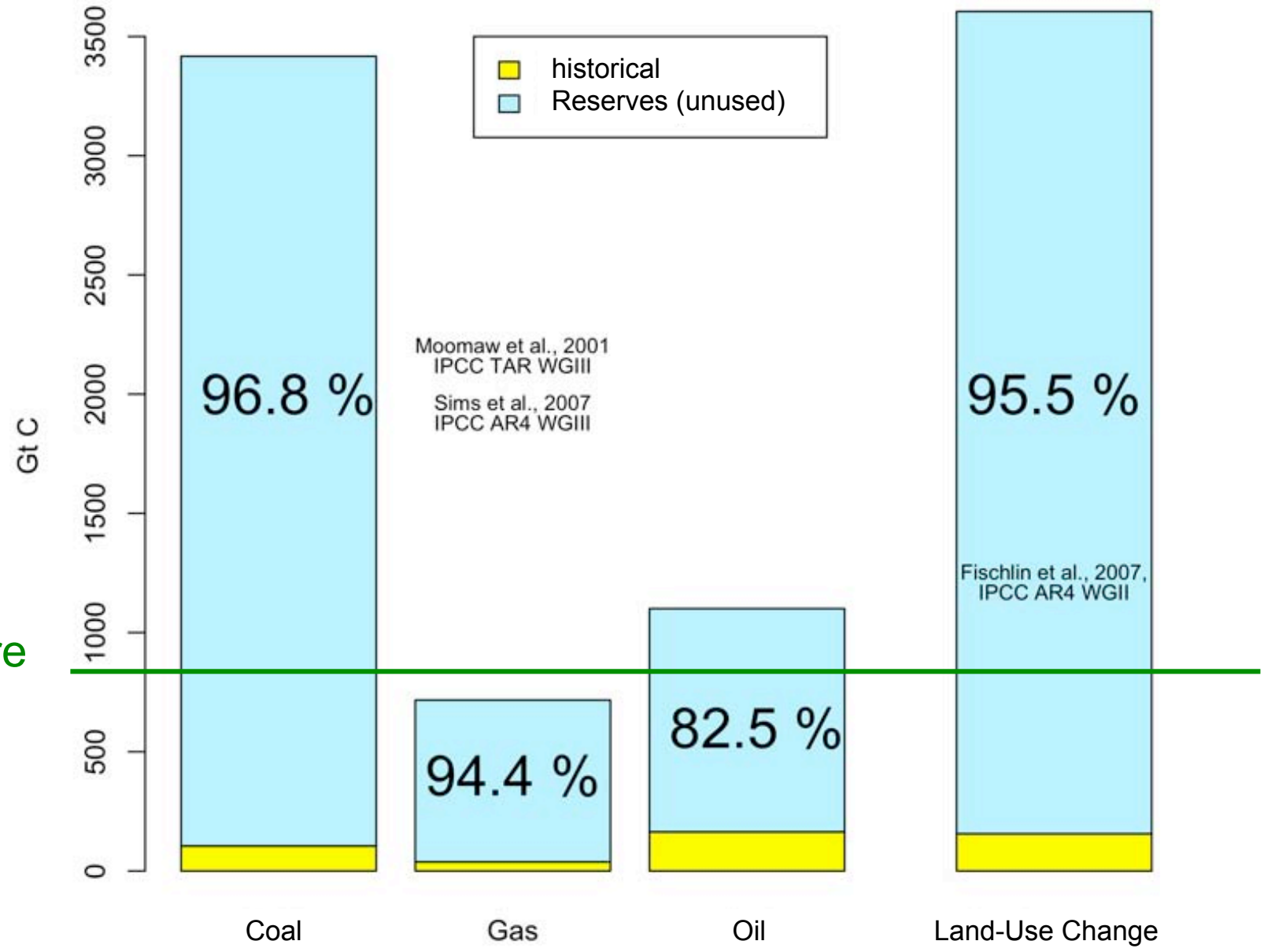
e.g. Hansen et al. 2008. PNAS 105: 9439-9444

Ecosystems Causing Climate Change?

Yes!

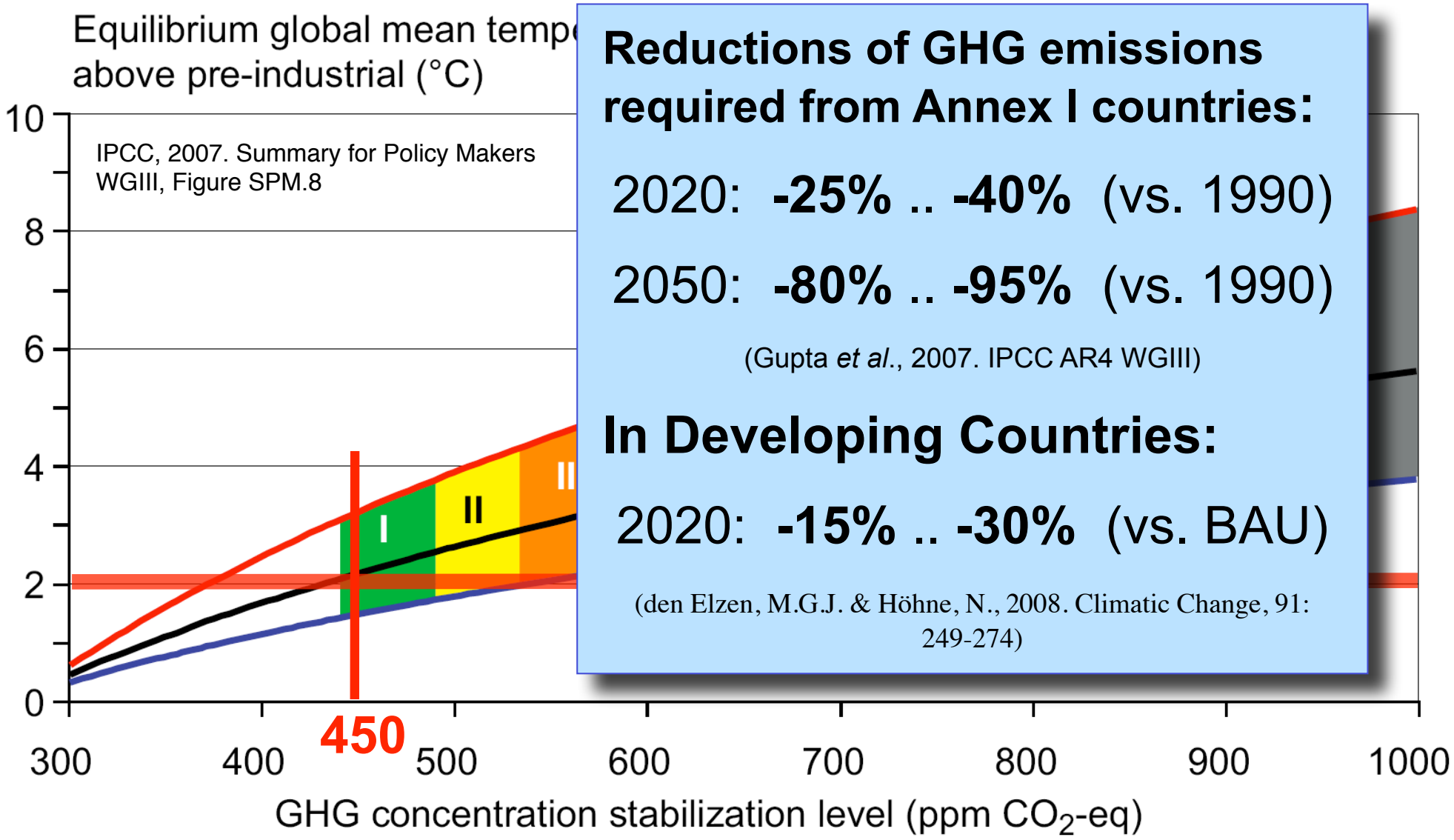

Need We
Mitigate?
By How Much?

Fossil Fuels (world)



Current atmosphere 777 GtC

Max 2°C ?



Reductions of GHG emissions required from Annex I countries:

2020: **-25%** .. **-40%** (vs. 1990)

2050: **-80%** .. **-95%** (vs. 1990)

(Gupta *et al.*, 2007. IPCC AR4 WGIII)

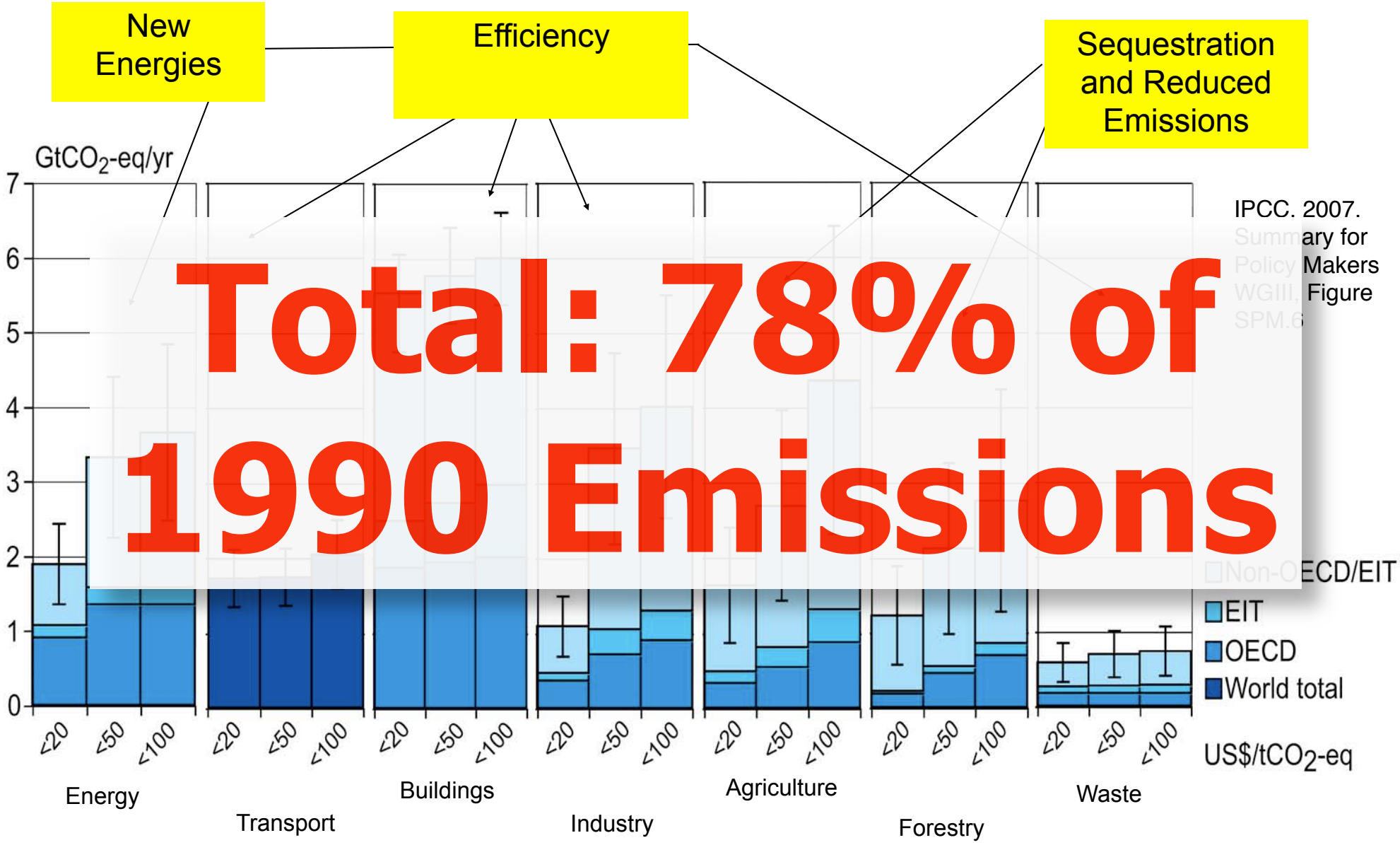
In Developing Countries:

2020: **-15%** .. **-30%** (vs. BAU)

(den Elzen, M.G.J. & Höhne, N., 2008. Climatic Change, 91: 249-274)

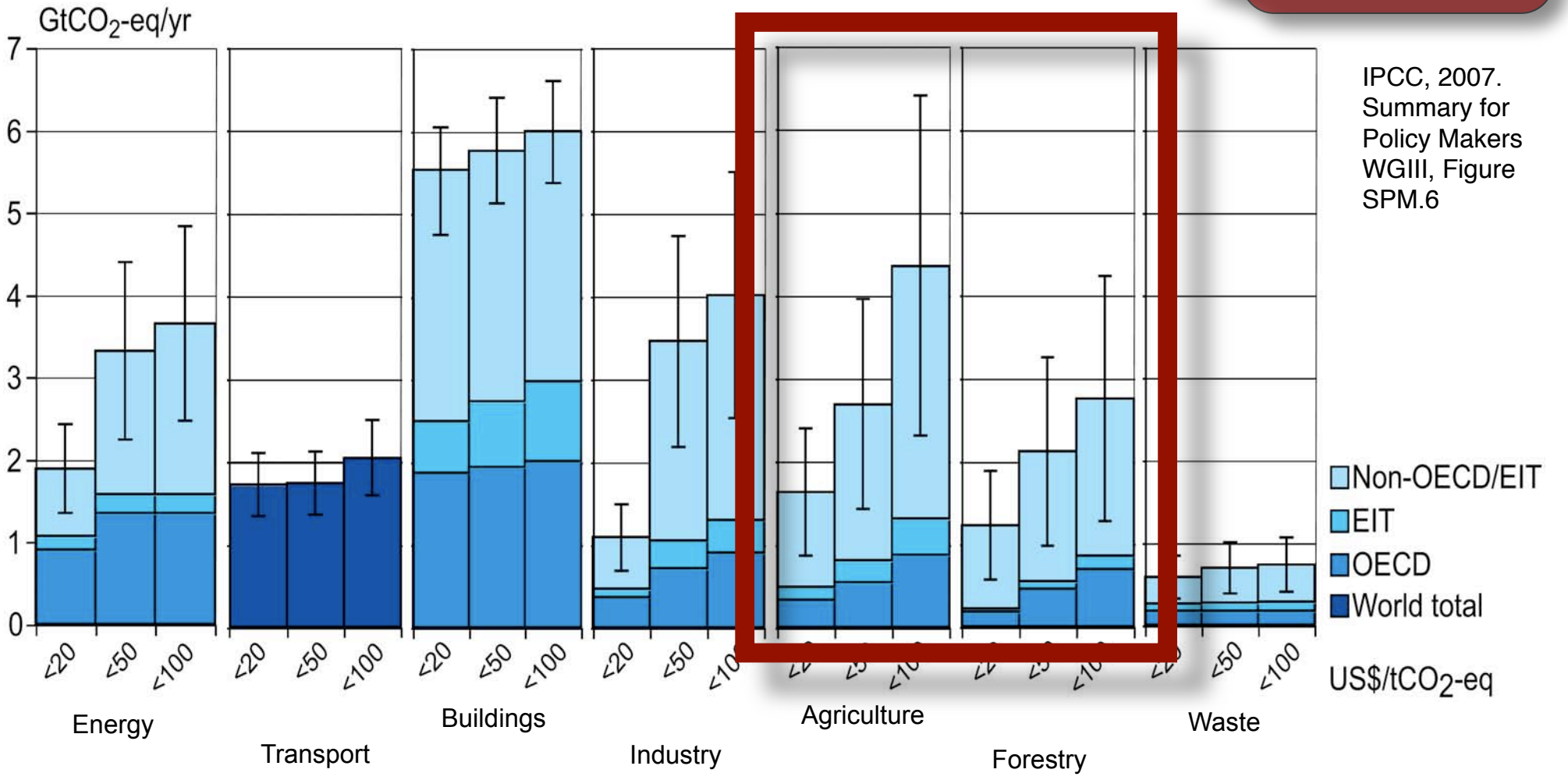
Figure SPM.8: Global warming and GHG stabilization levels (IPCC, 2007. Summary for Policy Makers WGIII)

High Technical and Ecomonic Reduction Potentials by 2030es



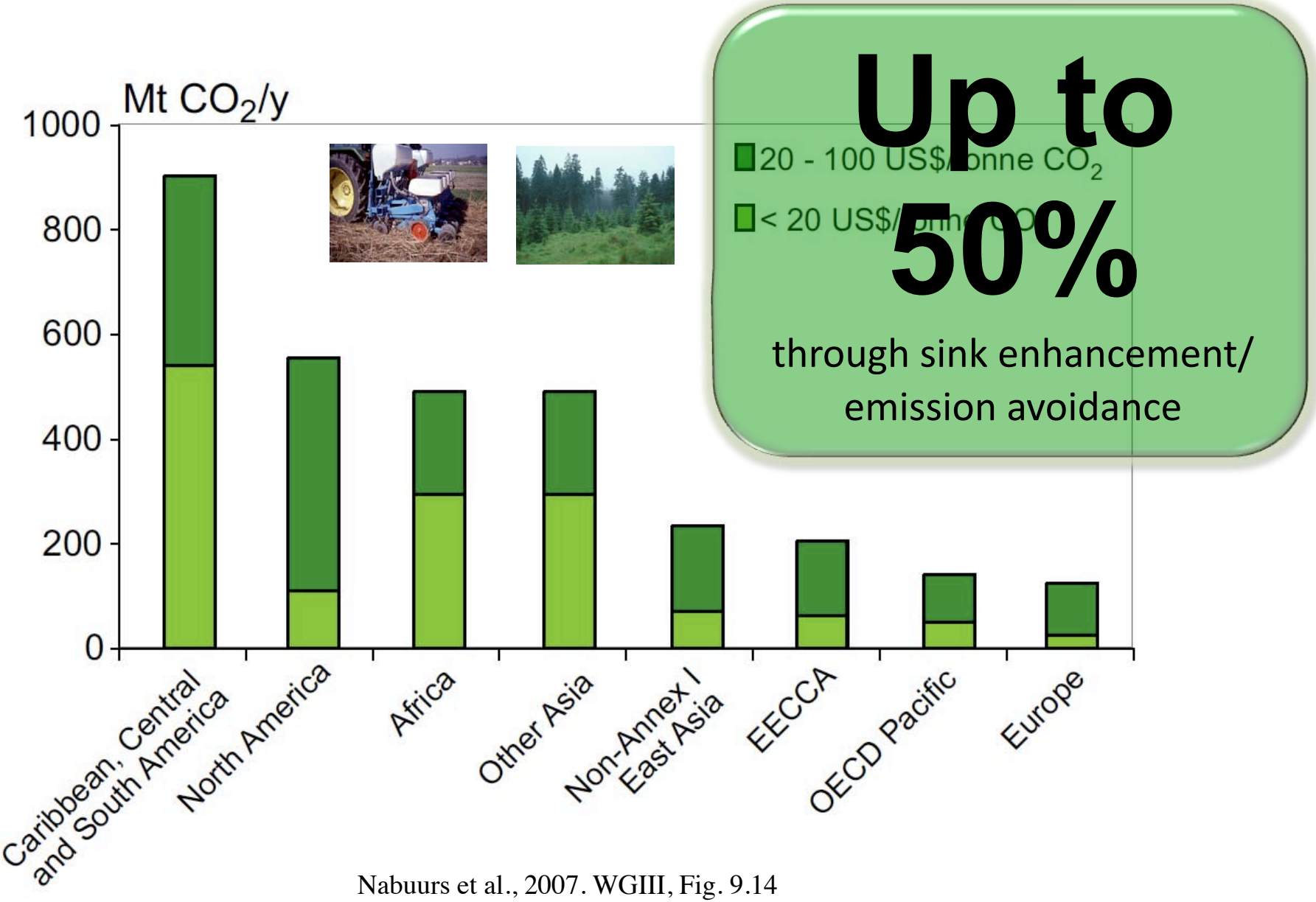
Contribution by Agriculture and Forestry Essential

30%



IPCC, 2007. Summary for Policy Makers WGIII, Figure SPM.6

Mitigation Potential By Continents



Up to 50%

through sink enhancement/ emission avoidance

Nabuurs et al., 2007. WGIII, Fig. 9.14

Need We Mitigate? By How Much?

Yes! A Lot!

Summary:

- Climate is important
- Climate change is real and human made
- Ecosystems including Agroecosystems and Forests (ES-AF) are important
- ES-AF play a double-rôle:
  - They are impacted by climate change
  - They cause climate change (are part of the solution)
- It matters a great deal whether and how we solve the climate change challenge: with or without ecosystems!

Thanks for your attention!

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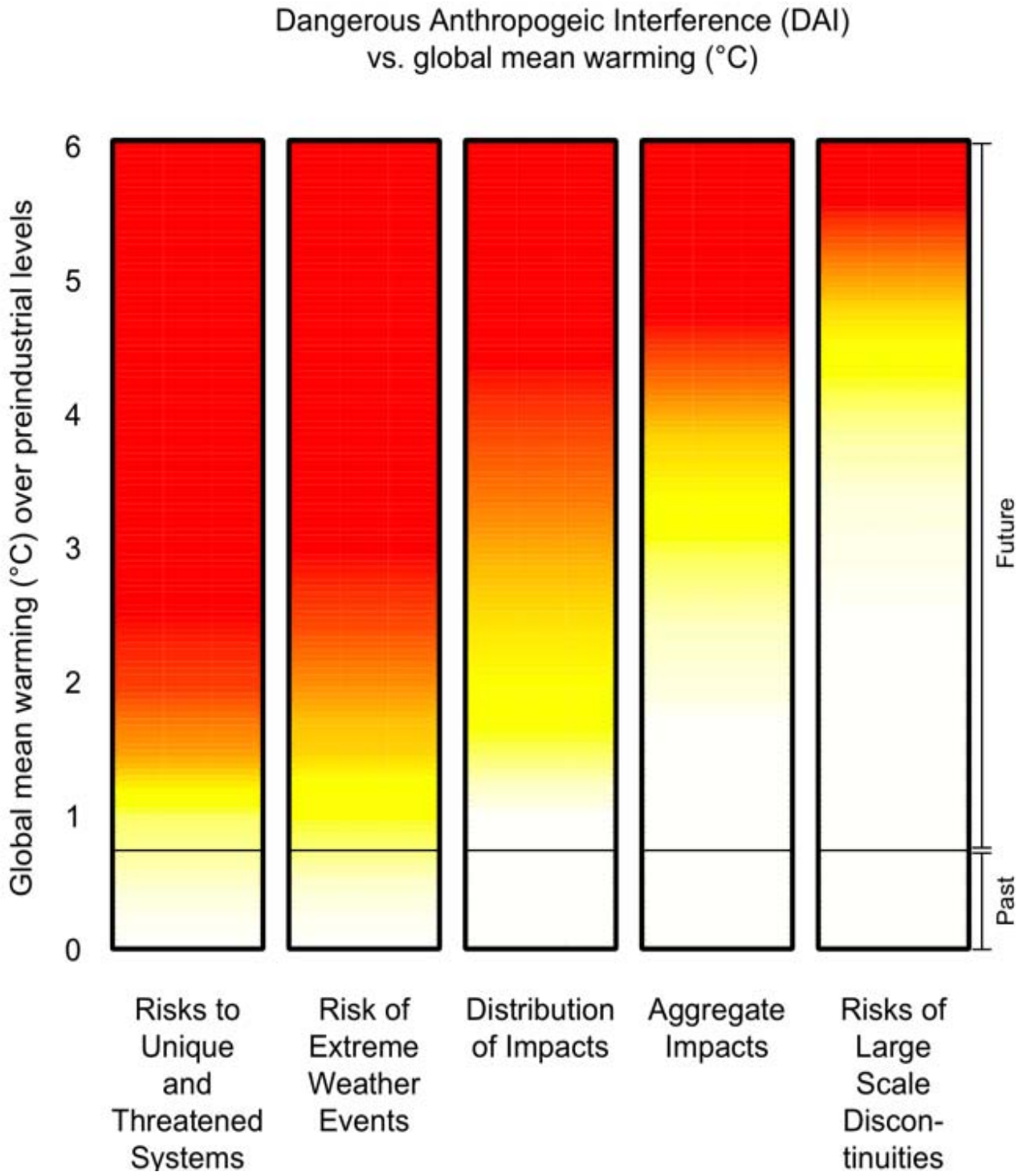
Swiss Federal Institute of Technology Zurich

www.ipcc.ch
www.sysecol.ethz.ch
andreas.fischlin@env.ethz.ch

Reasons of Concern

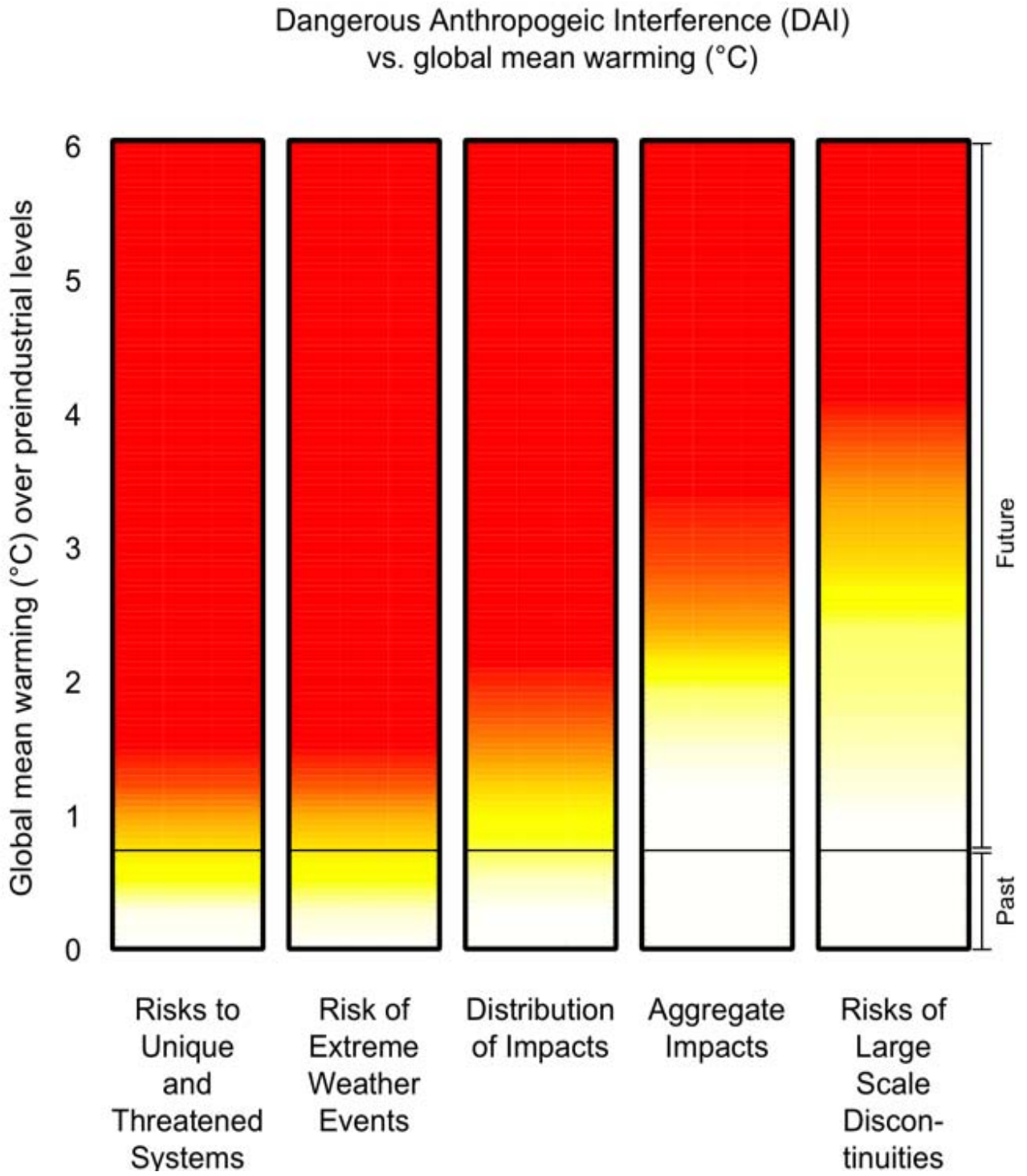
Know-ledge **TAR 2001**



Smith et al., 2009. PNAS u. Fischlin, 2009

Reasons of Concern

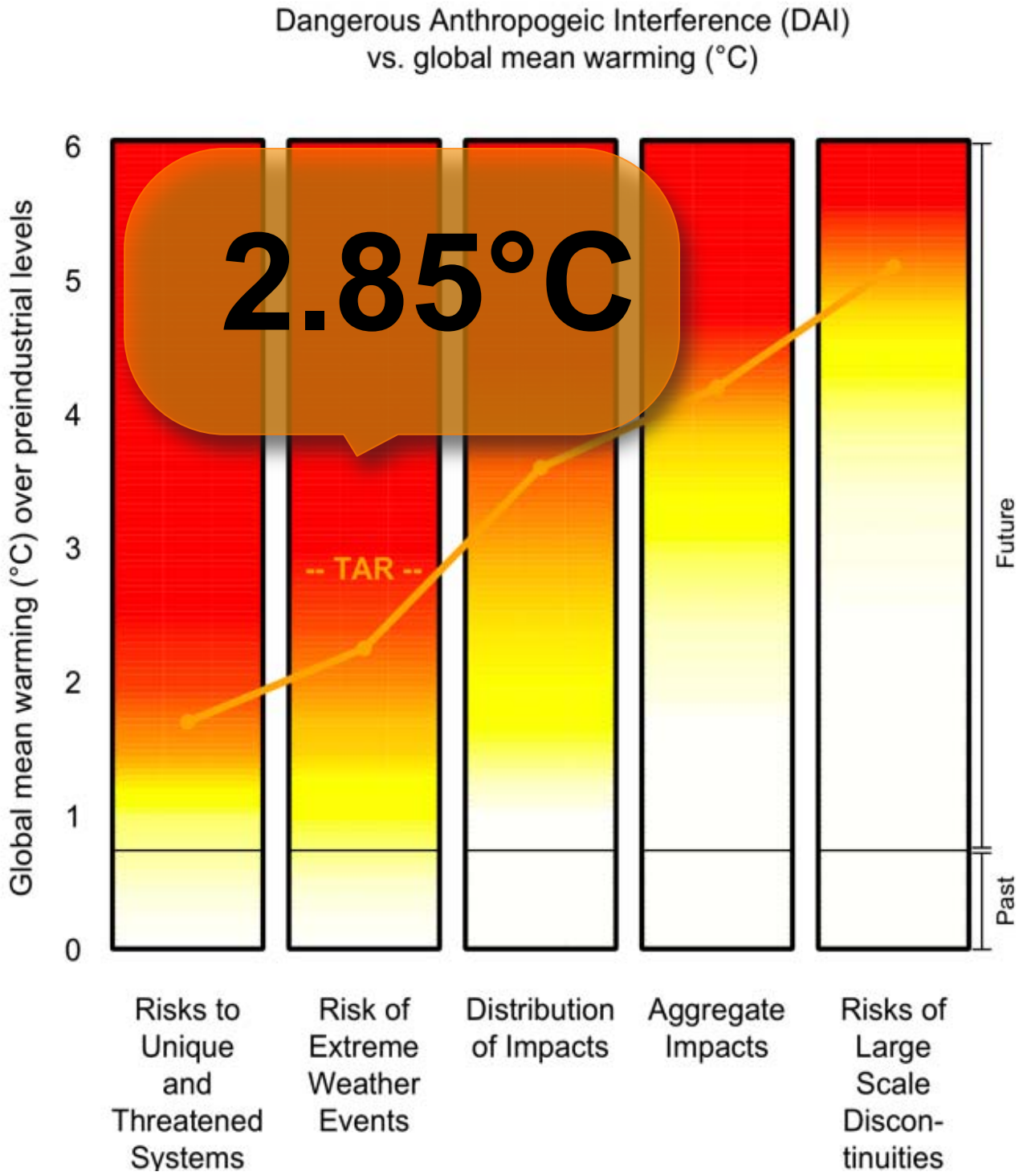
Know-ledge **AR4 2007**



Smith et al., 2009. PNAS u. Fischlin, 2009

Reasons of Concern

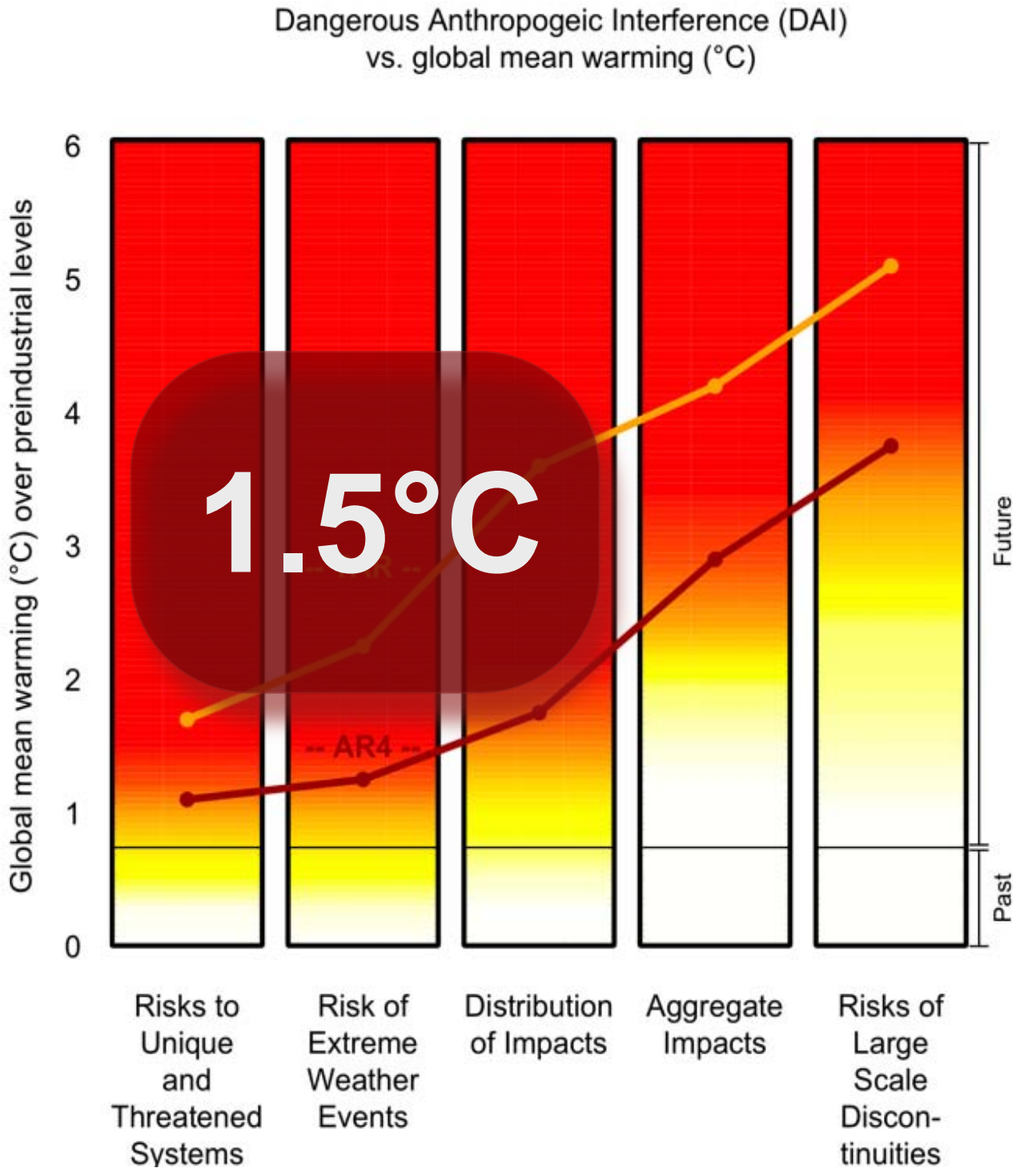
Know-ledge **TAR 2001**



Smith et al., 2009. PNAS u. Fischlin, 2009

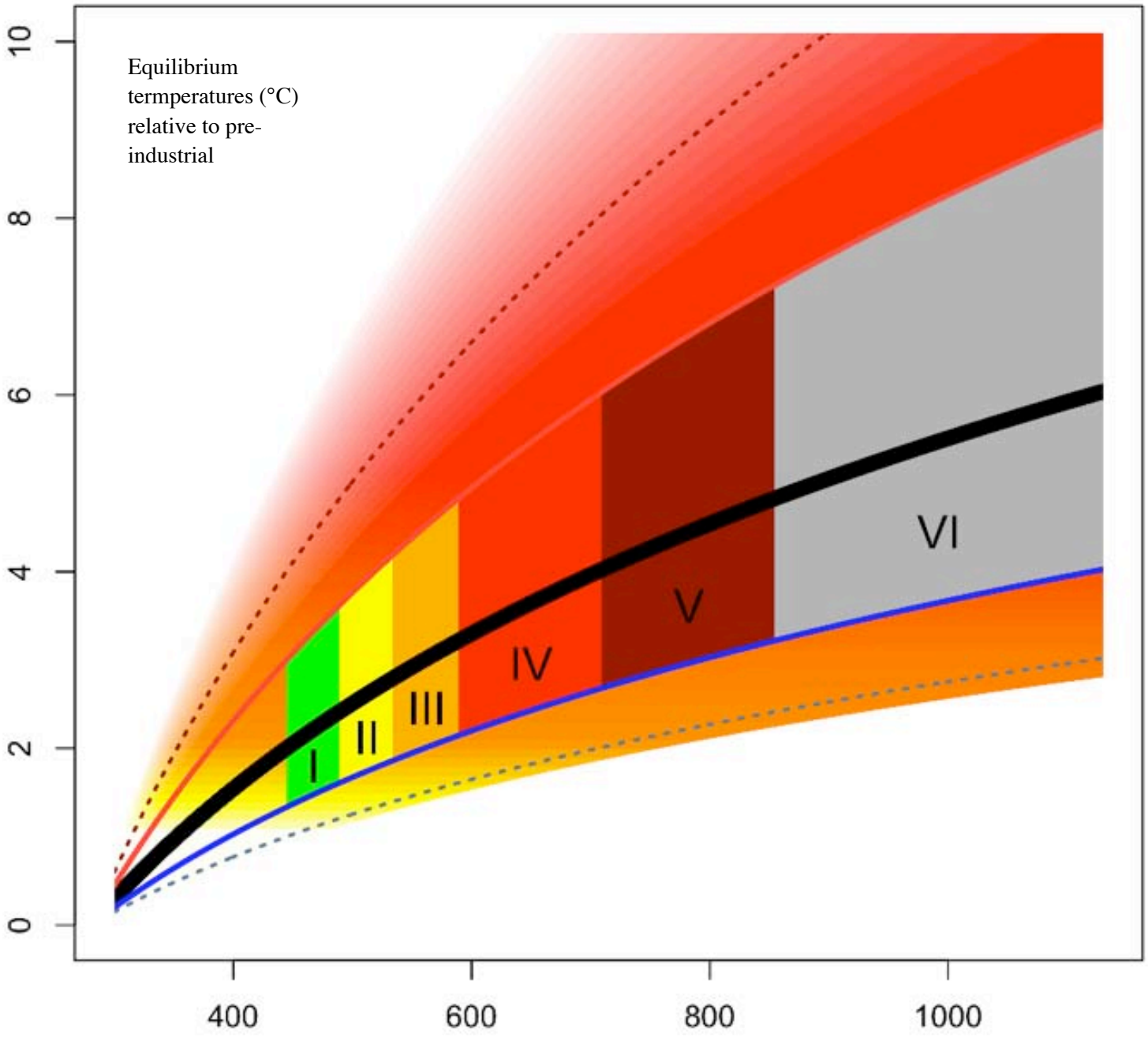
Reasons of Concern

Know-ledge **AR4 2007**



Fischlin, A., 2009. GAIA, **18**: 193–199

Safety Mar-gins?



Fischlin, 2009. GAIA, 18: 193-199