Klimawandel:

Was wir wissen –

und was nicht

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„Pro Pace et Fraternitate Gentium“

2007

Klimawandel & Meeresspiegel Erhöhung:

- grosser Migrationsdruck
- knappe Ressourcen (Energie/Nahrung)
- grosses Konfliktpotential

Klimaschutz = Friedenspolitik

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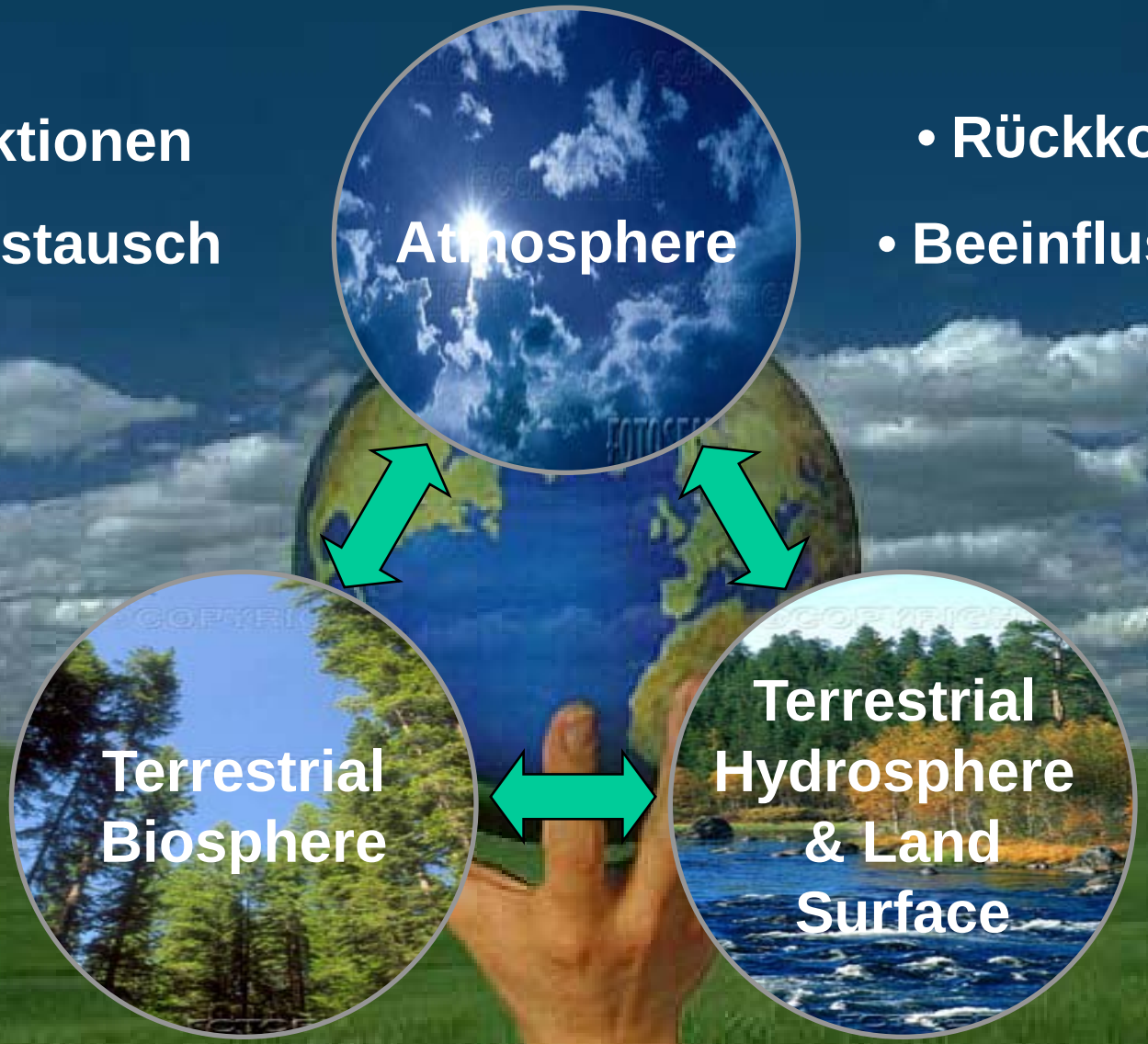
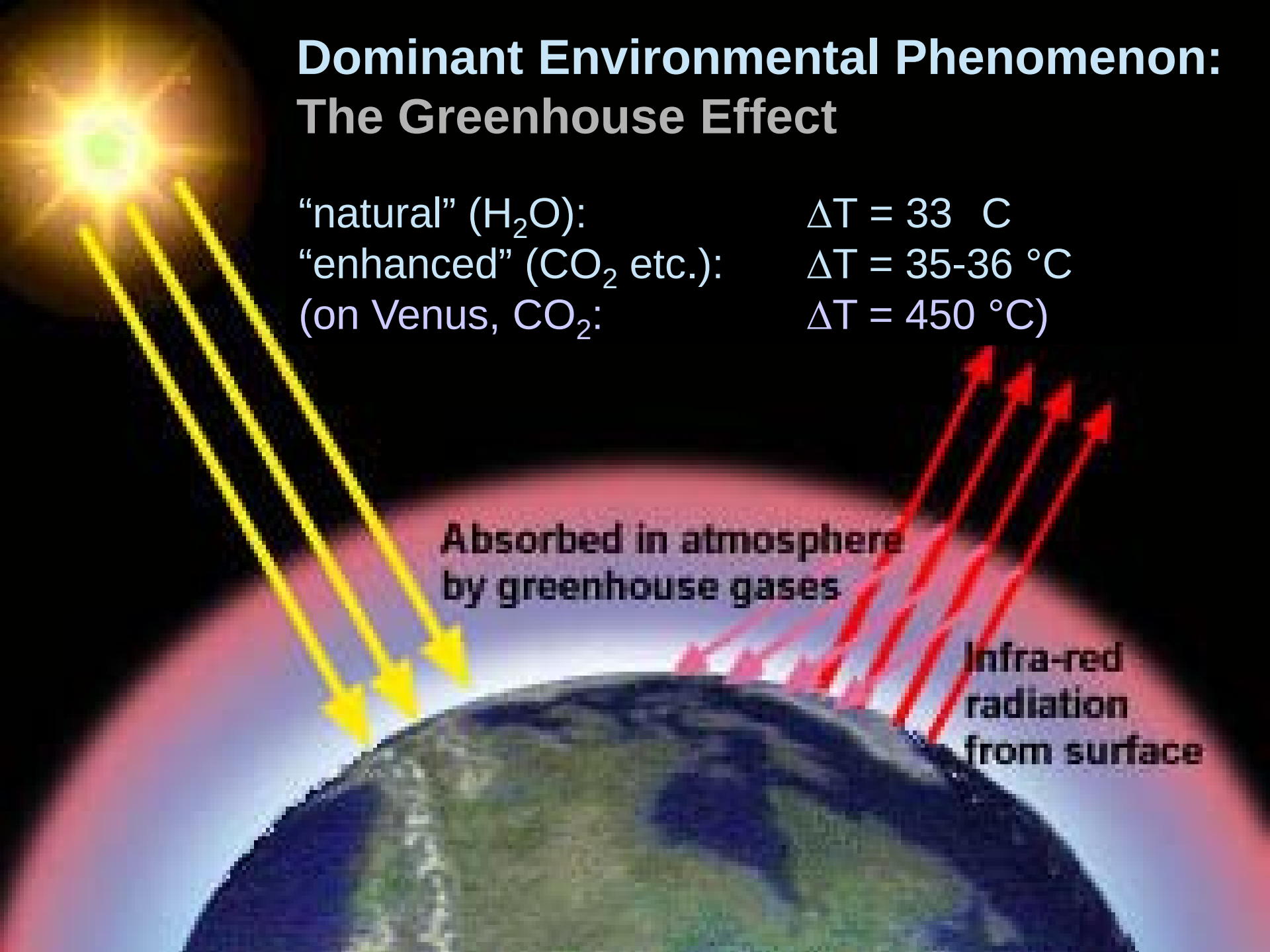
Atmosphärische Umweltforschung

- Interaktionen
- Austausch
- Rückkoppelung
- Beeinflussung

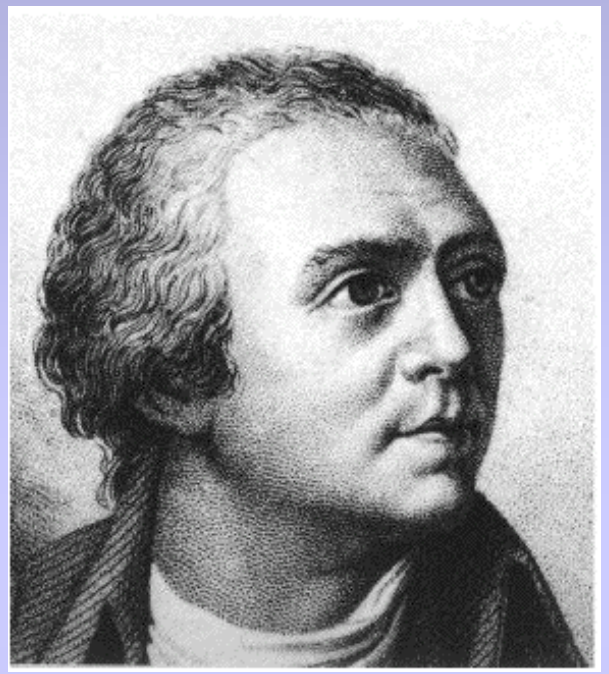


Dominant Environmental Phenomenon: The Greenhouse Effect

"natural" (H_2O):	$\Delta T = 33$ C
"enhanced" (CO_2 etc.):	$\Delta T = 35\text{-}36$ °C
(on Venus, CO_2:	$\Delta T = 450$ °C)



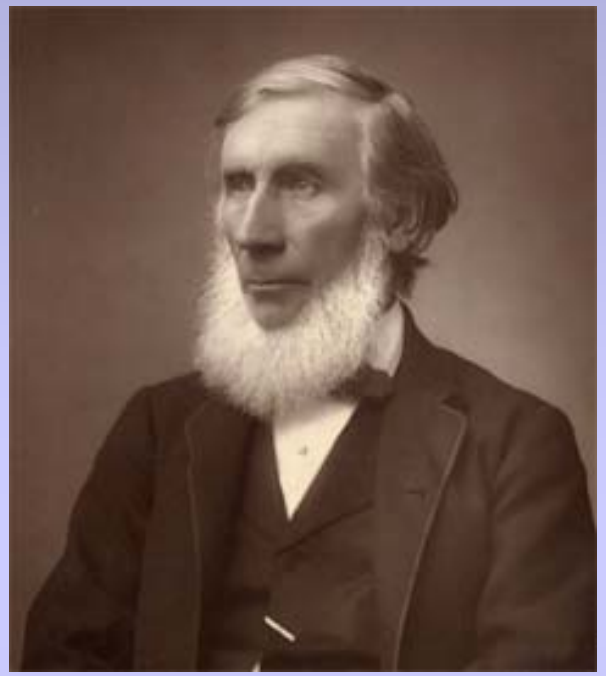
„Fathers“ of the Greenhouse Theory



Horace-Bénédict de Saussure

(1740 -1799) was a Swiss aristocrat, physicist and Alpine traveller. First ascent of Mont Blanc.

„Heliothermometer“: simple greenhouse warming experiments



John Tyndall

(1820 – 1893) was an Irish natural philosopher.

Identified through laboratory experiments the absorption of thermal radiation by complex molecules

Svante August Arrhenius

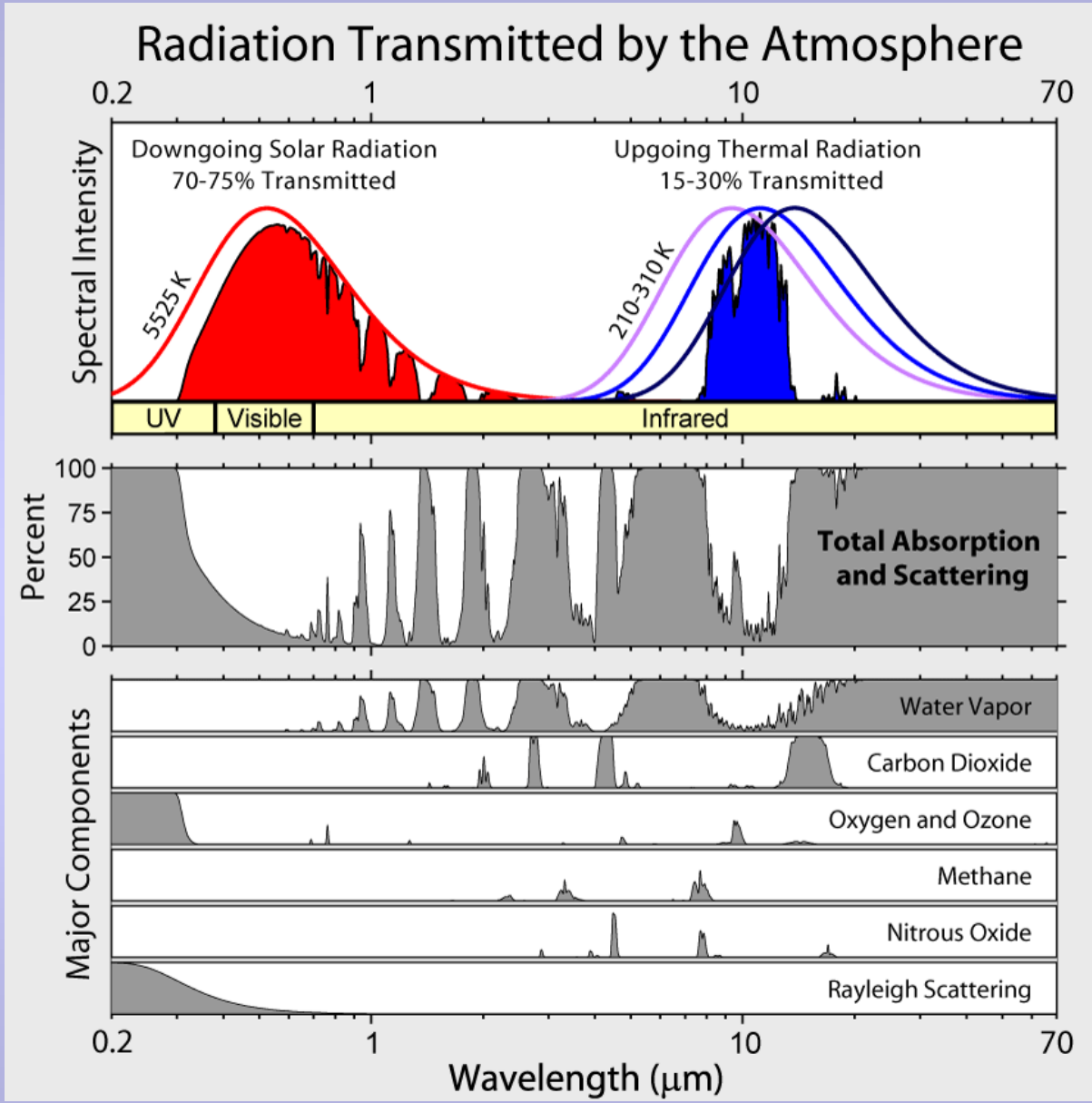
(1859 – 1927) was a Swedish chemist and one of the founders of the science of physical chemistry.

Theorized that doubling the amount of CO_2 in the atmosphere might raise the Earth's temperature by 5 or 6 ^{o}C.

CO_2 Equivalent – Global Warming Potential (GWP)

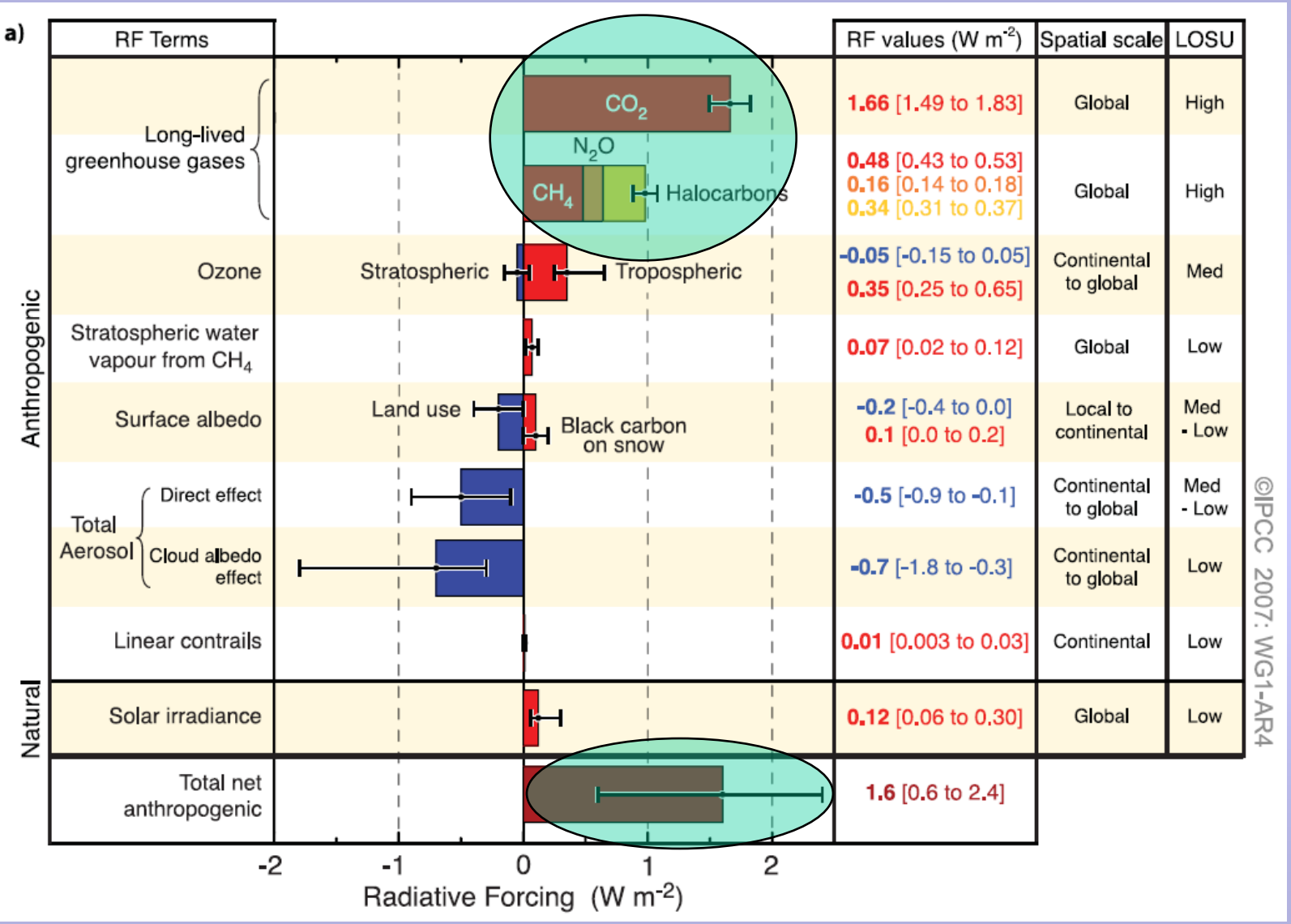
GWP values and lifetimes from IPCC TAR				
Gas	**Lifetime (years)**	**GWP Time horizon**		
		20 years	100 years	500 year
Carbon dioxide		1	1	1
Methane	12	62	23	7
Nitrous oxide	114	275	296	156
HFC-134a (hydrofluorocarbon)	13.8	3300	1300	400
HFC-23 (hydrofluorocarbon)	260	9400	12000	10000
sulfur hexafluoride	3200	15100	22200	32400

IPCC 2001



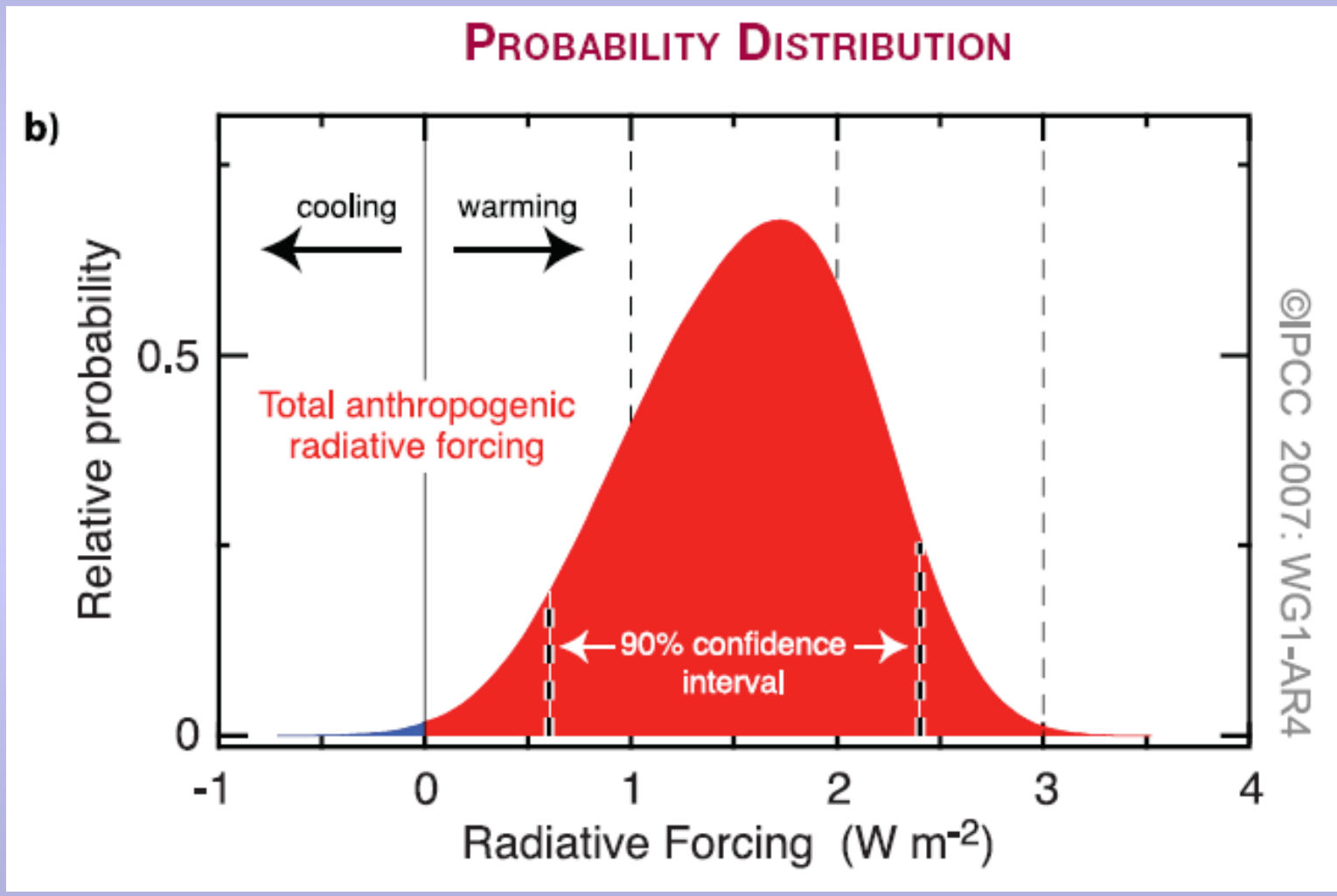
This figure was prepared by Robert A. Rohde for the Global Warming Art project.

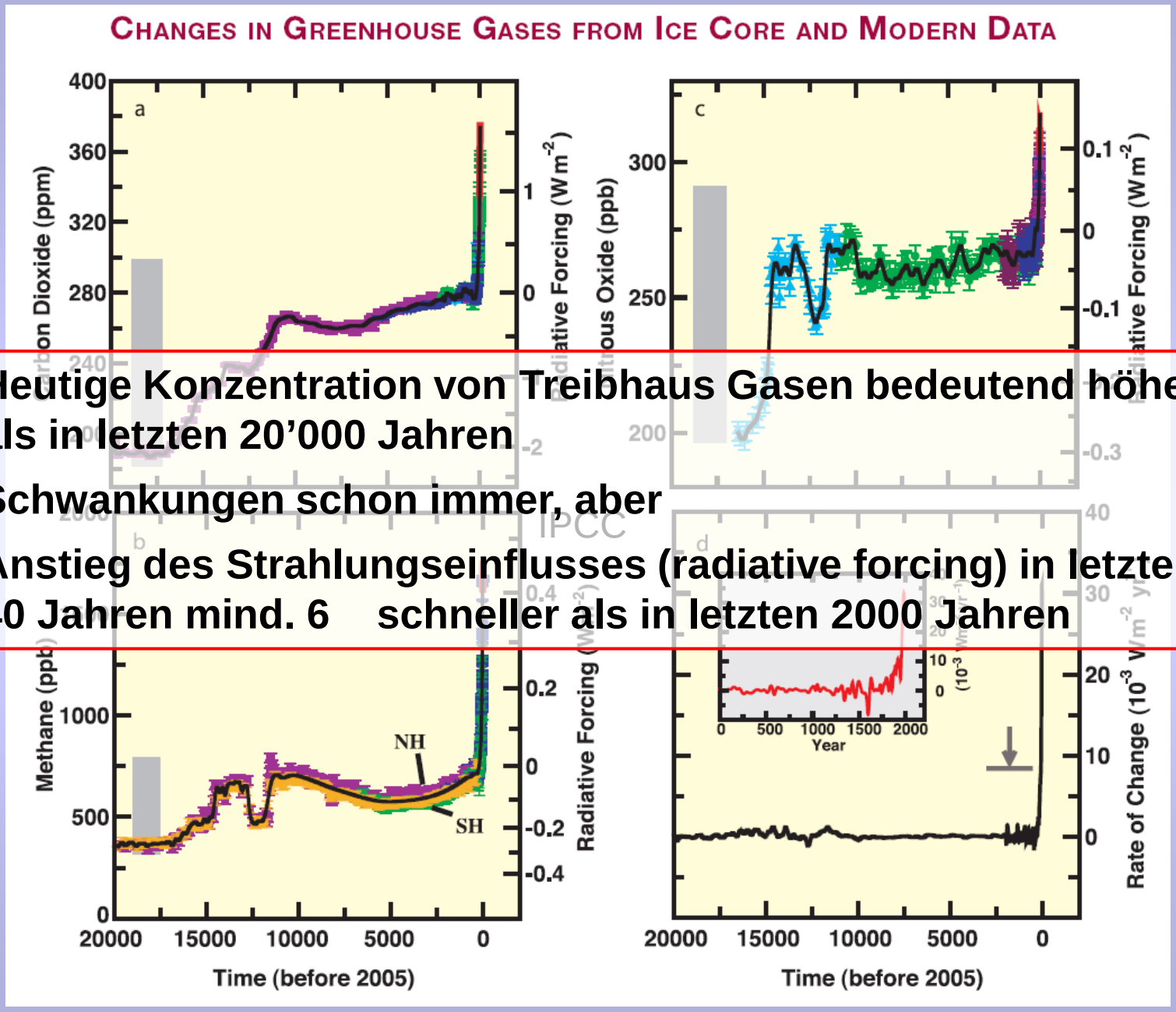
Global Mean Radiative Forcings



IPCC 2007

Uncertainty ⟺ Confidence

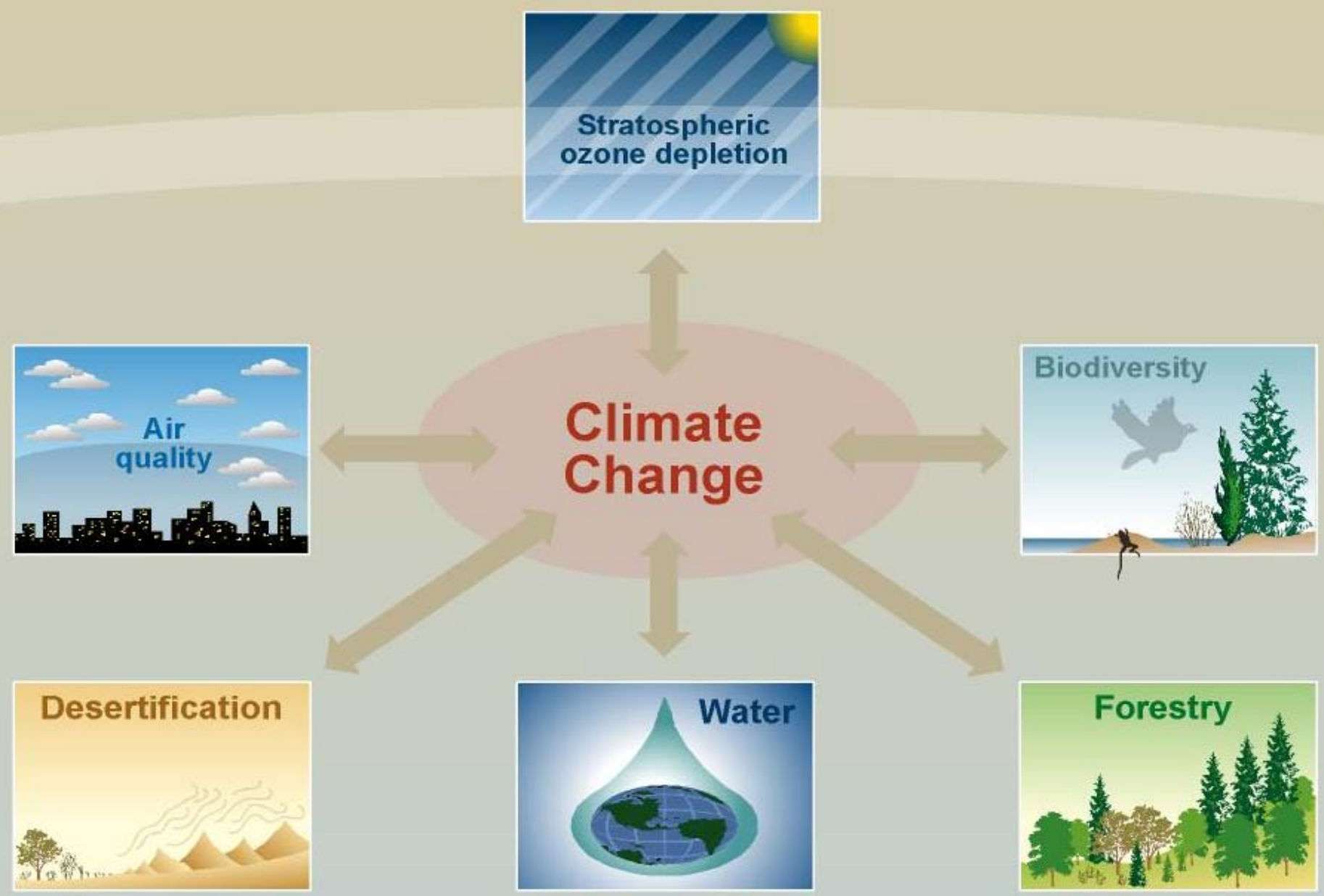




- **Heutige Konzentration von Treibhaus Gasen bedeutend höher als in letzten 20’000 Jahren**
- **Schwankungen schon immer, aber**
- **Anstieg des Strahlungseinflusses (radiative forcing) in letzten 40 Jahren mind. 6 schneller als in letzten 2000 Jahren**

IPCC 2007

Linkages between climate change and other environmental issues

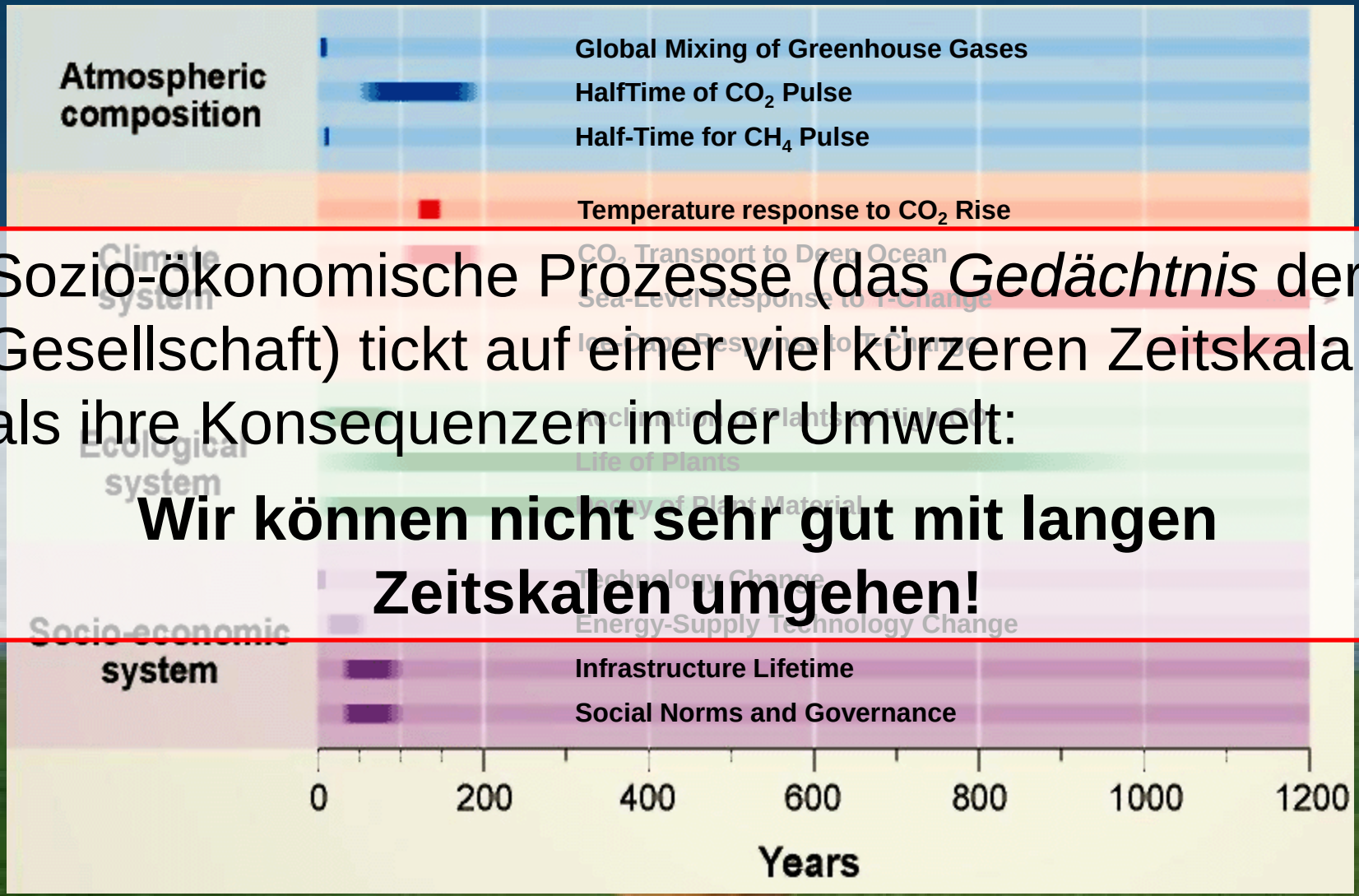


(source: IPCC 2001, WG1 Report, Summary)

Die Menschheit hat ihre Hand im Spiel ...

... aber wir haben unsere liebe Mühe damit!

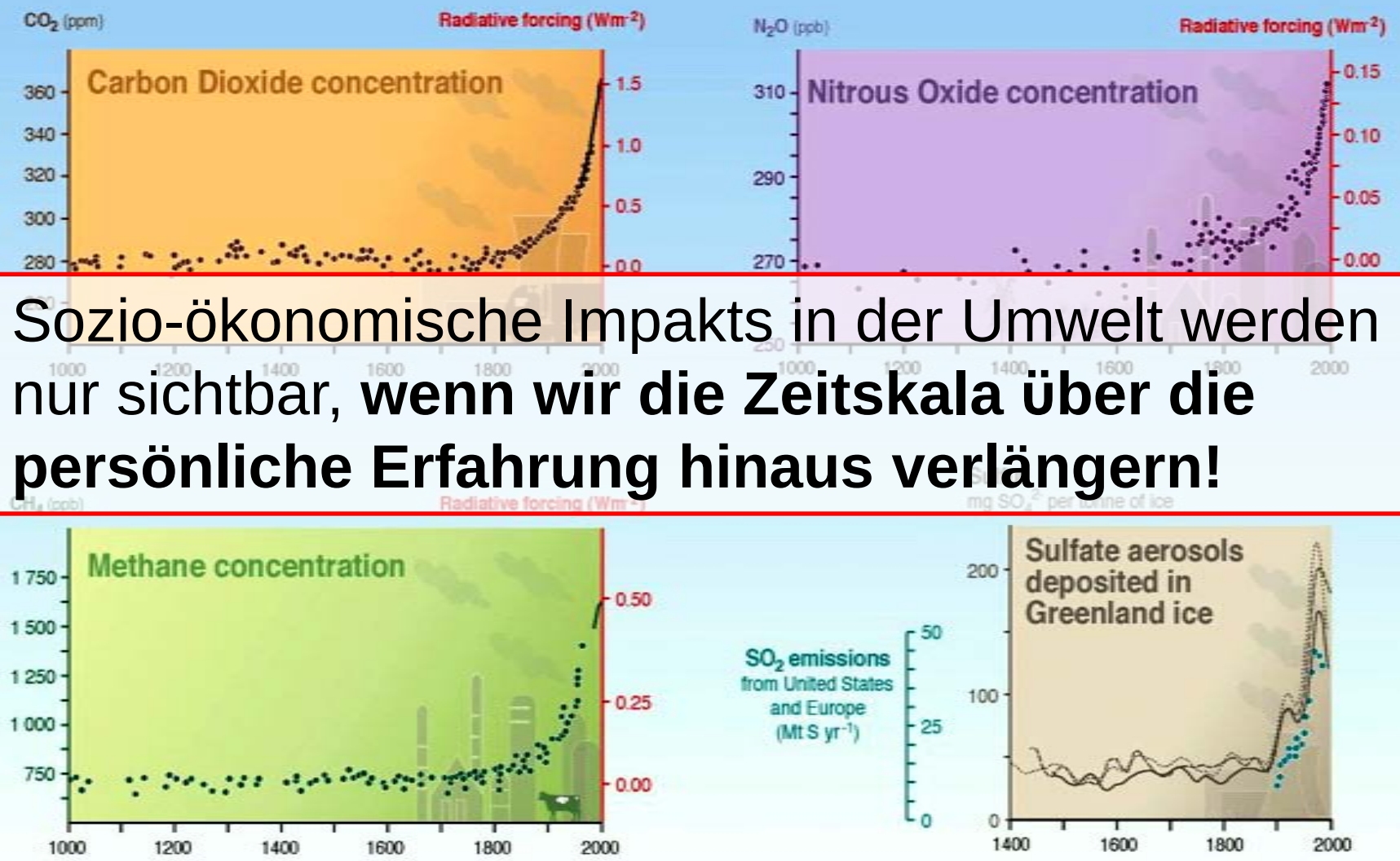
Time Scales of Processes in the Environmental System



Sozio-ökonomische Prozesse (das *Gedächtnis* der Gesellschaft) tickt auf einer viel kürzeren Zeitskala als ihre Konsequenzen in der Umwelt:

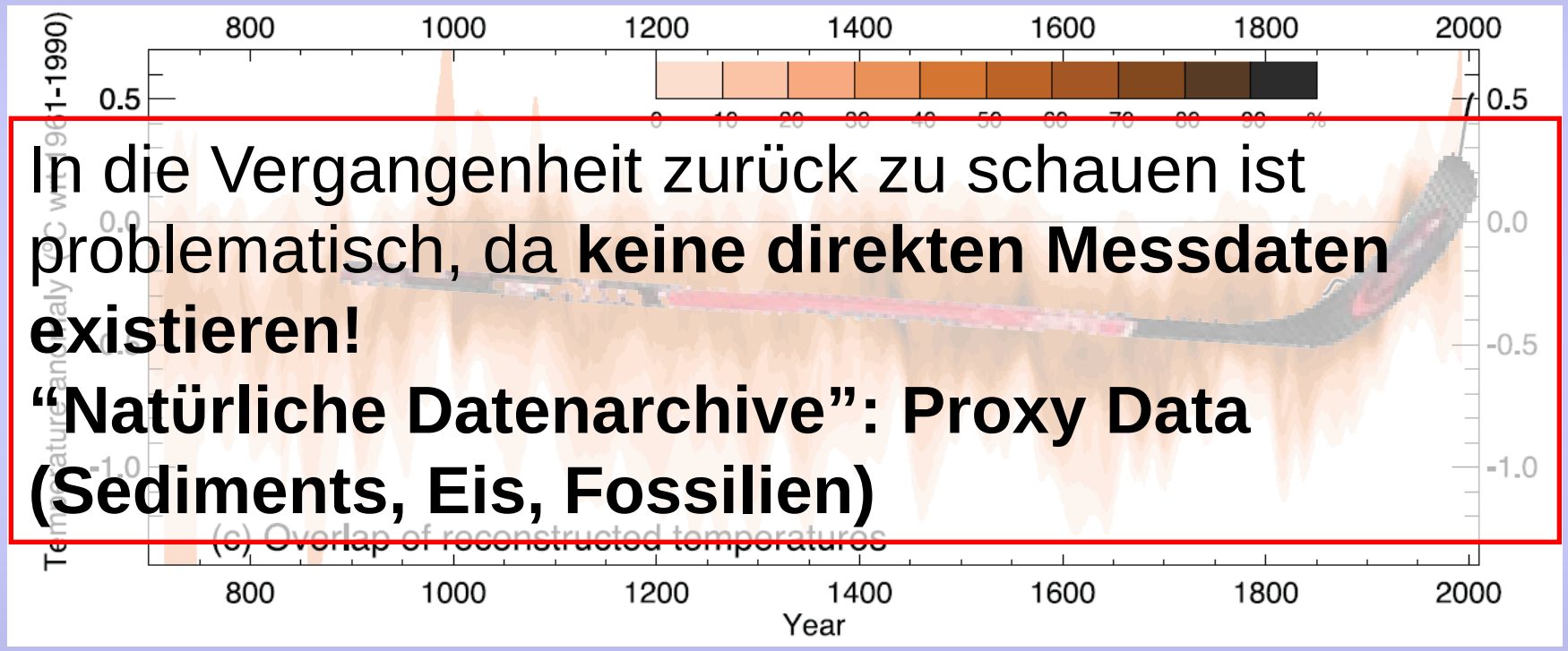
Wir können nicht sehr gut mit langen Zeitskalen umgehen!

(source: IPCC 2001, WG1 Report, Summary)



(source: IPCC 2001, WG1 Report, Summary)

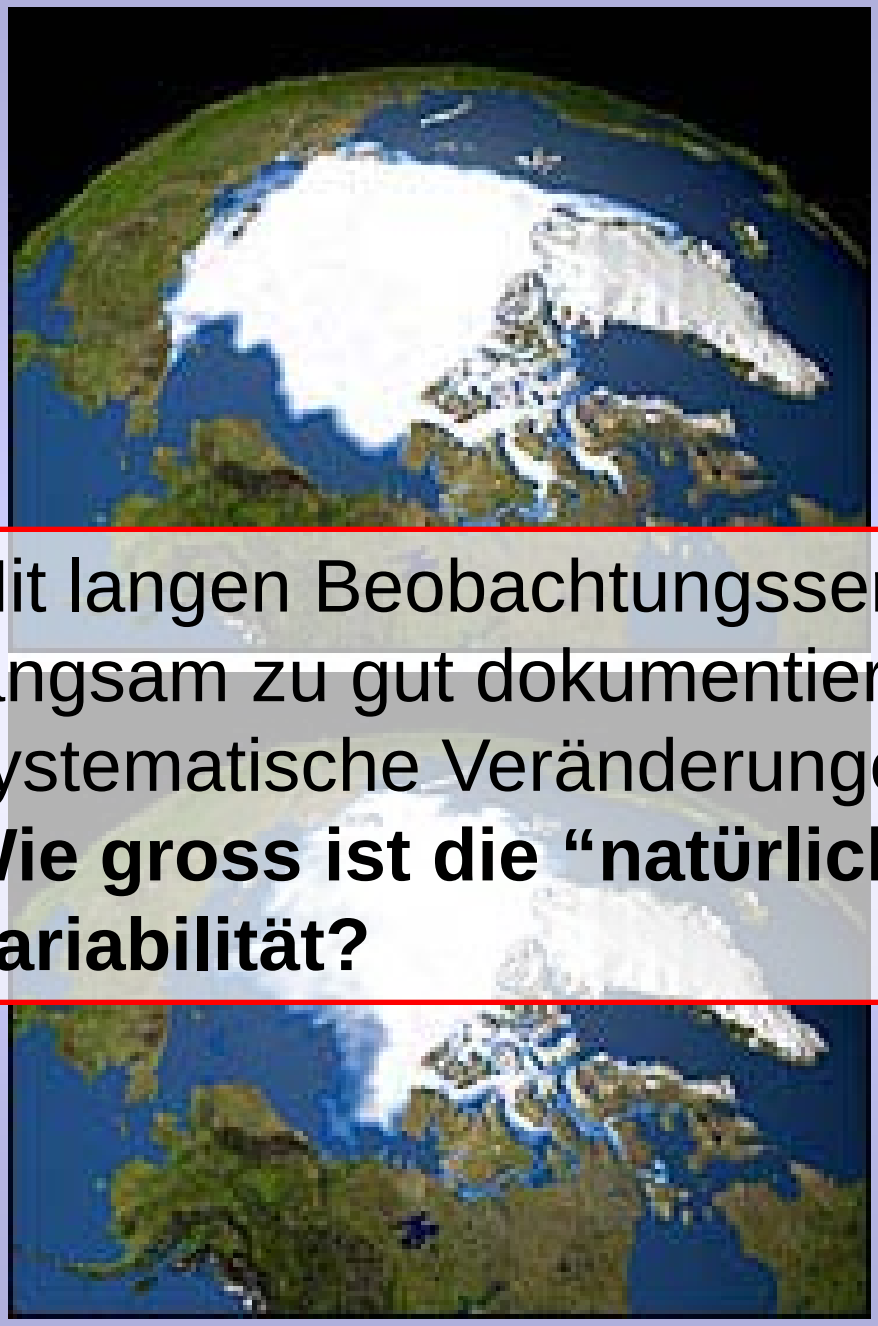
Global Surface Temperature Anomaly



In die Vergangenheit zurück zu schauen ist problematisch, da **keine direkten Messdaten existieren!**

“Natürliche Datenarchive”: Proxy Data (Sediments, Eis, Fossilien)

(source: IPCC 2007)

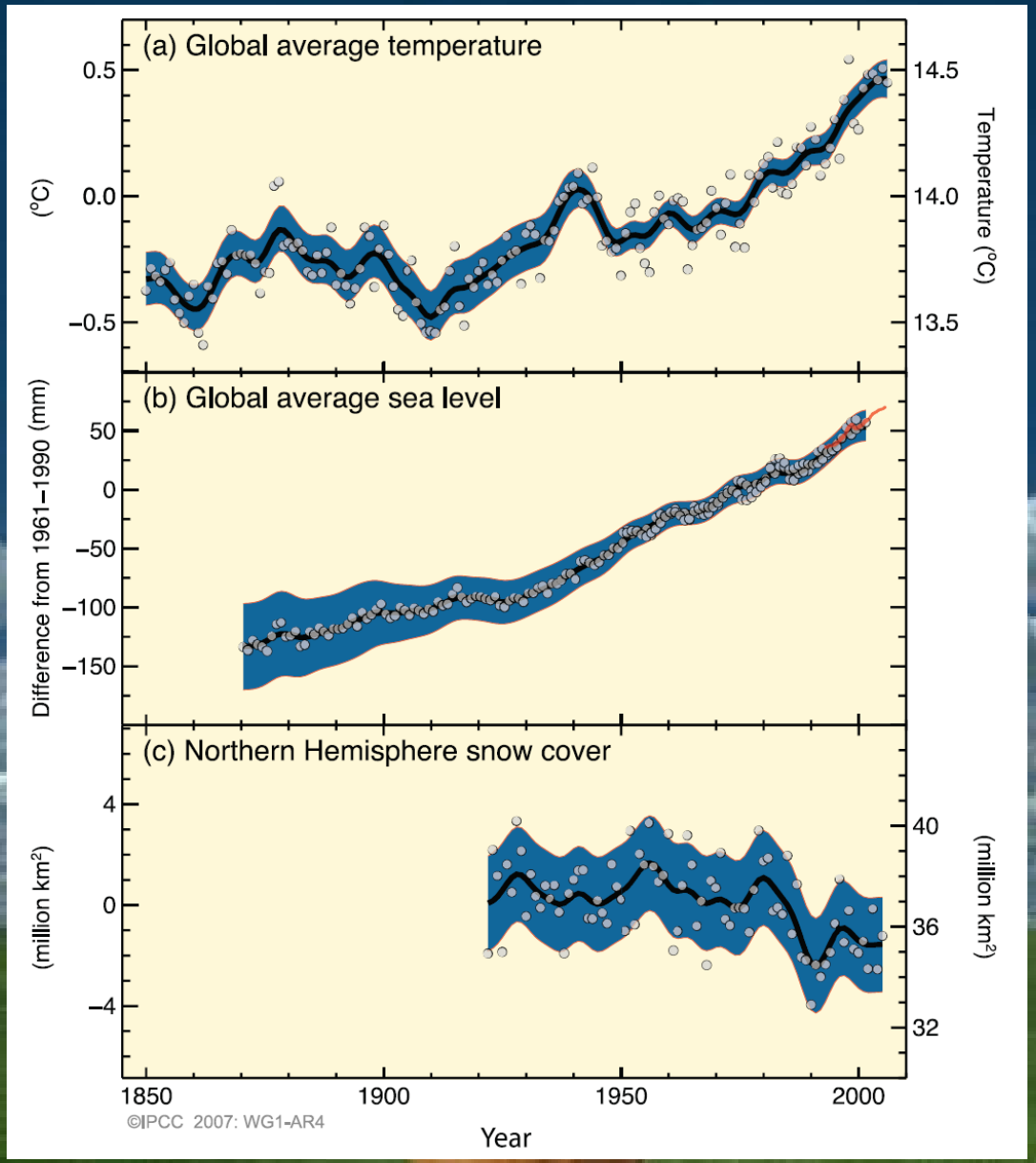


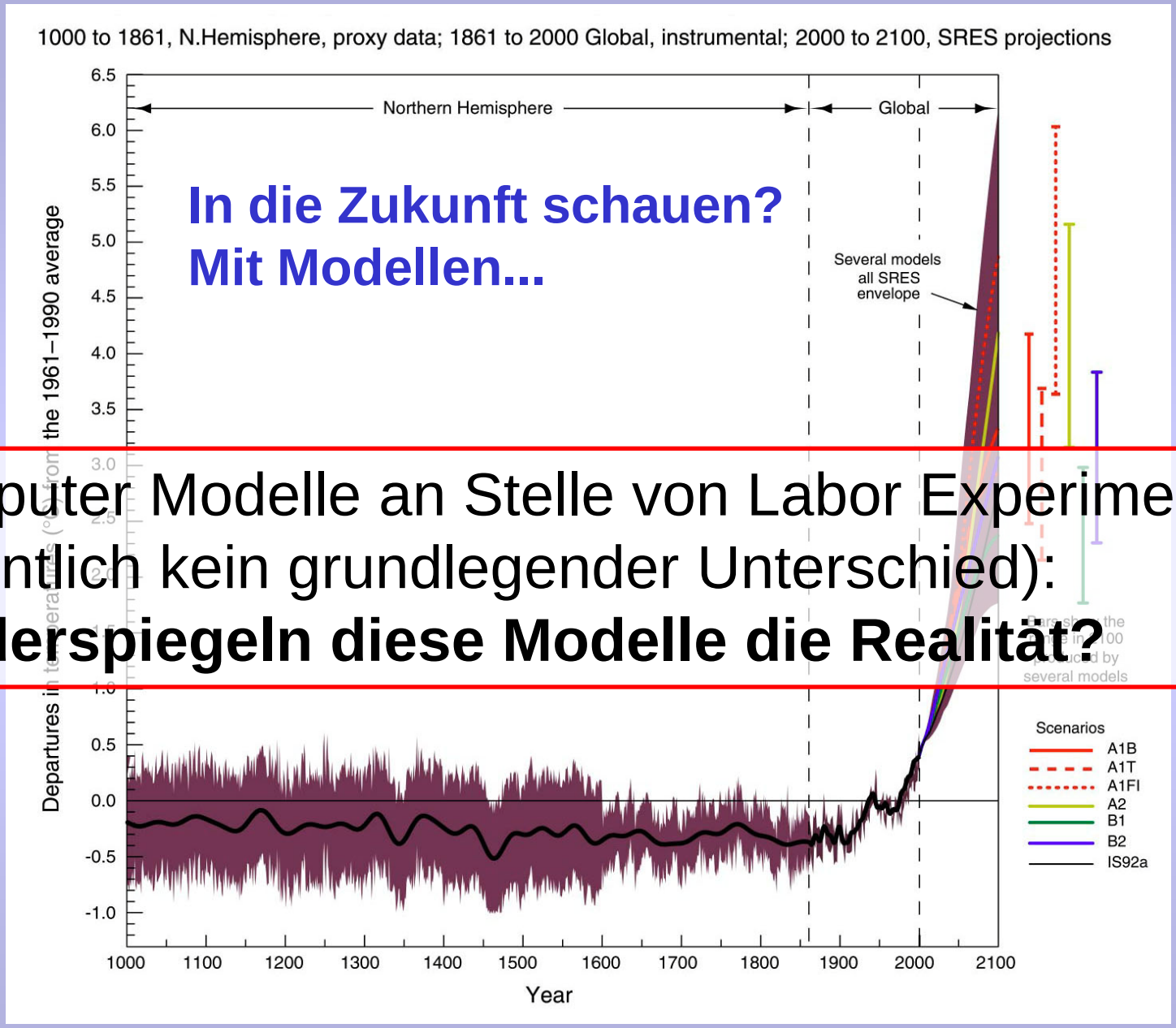
Shrinking Polar Ice

Extent of Arctic summer ice in 1979 (top satellite image) and in 2003 (lower satellite image).

Mit langen Beobachtungsserien kommen wir langsam zu gut dokumentiertem Beweismaterial für systematische Veränderungen. Aber Frage :
Wie gross ist die “natürliche” background Variabilität?

NASA photograph

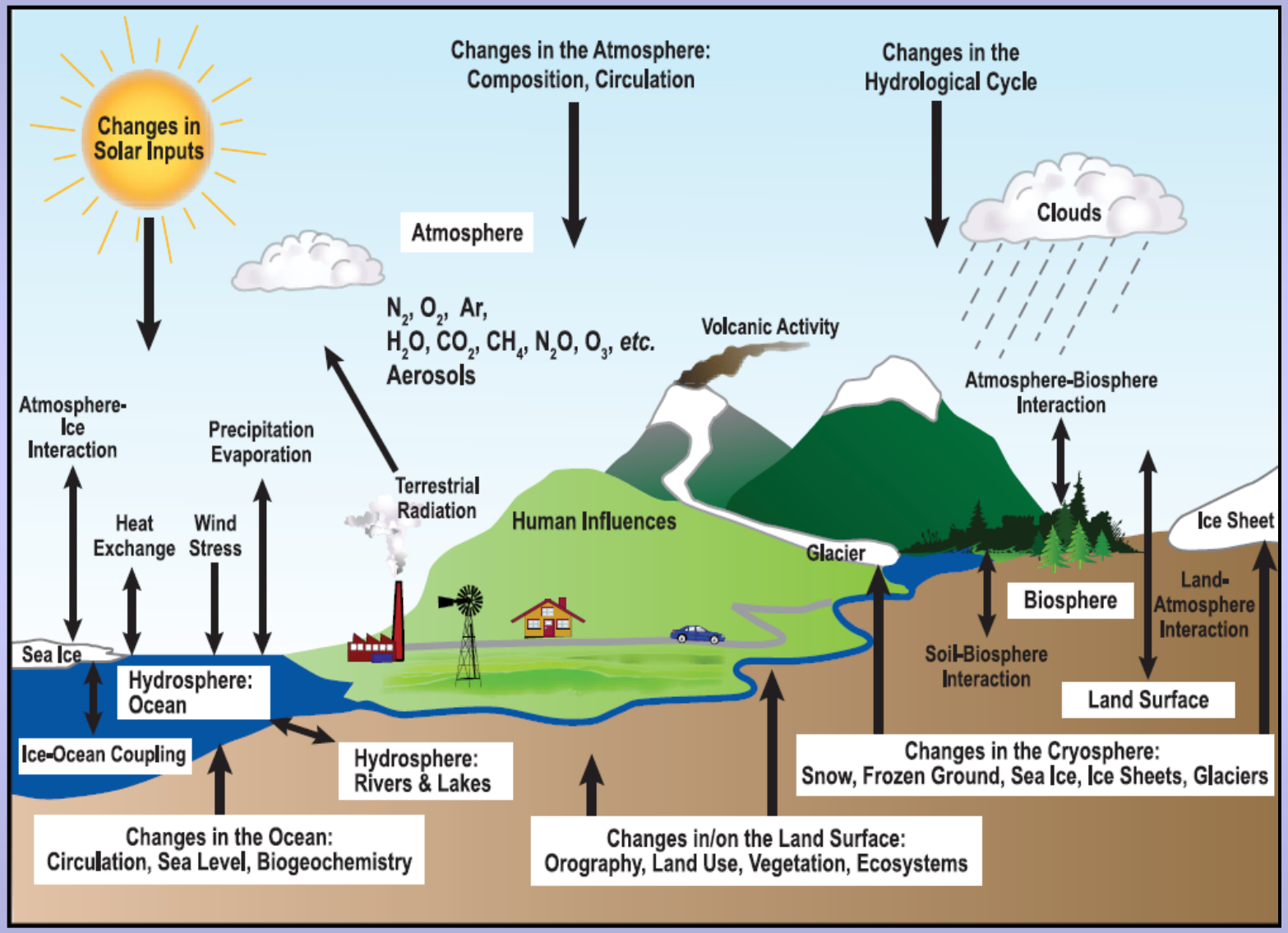

(a) Global average temperature
(°C)
0.5
0.0
−0.5
14.5
14.0
13.5
Temperature (°C)
(b) Global average sea level
Difference from 1961–1990 (mm)
50
0
−50
−100
−150
(c) Northern Hemisphere snow cover
(million km²)
4
0
−4
40
36
32
(million km²)
1850
1900
1950
2000
Year
©IPCC 2007: WG1-AR4



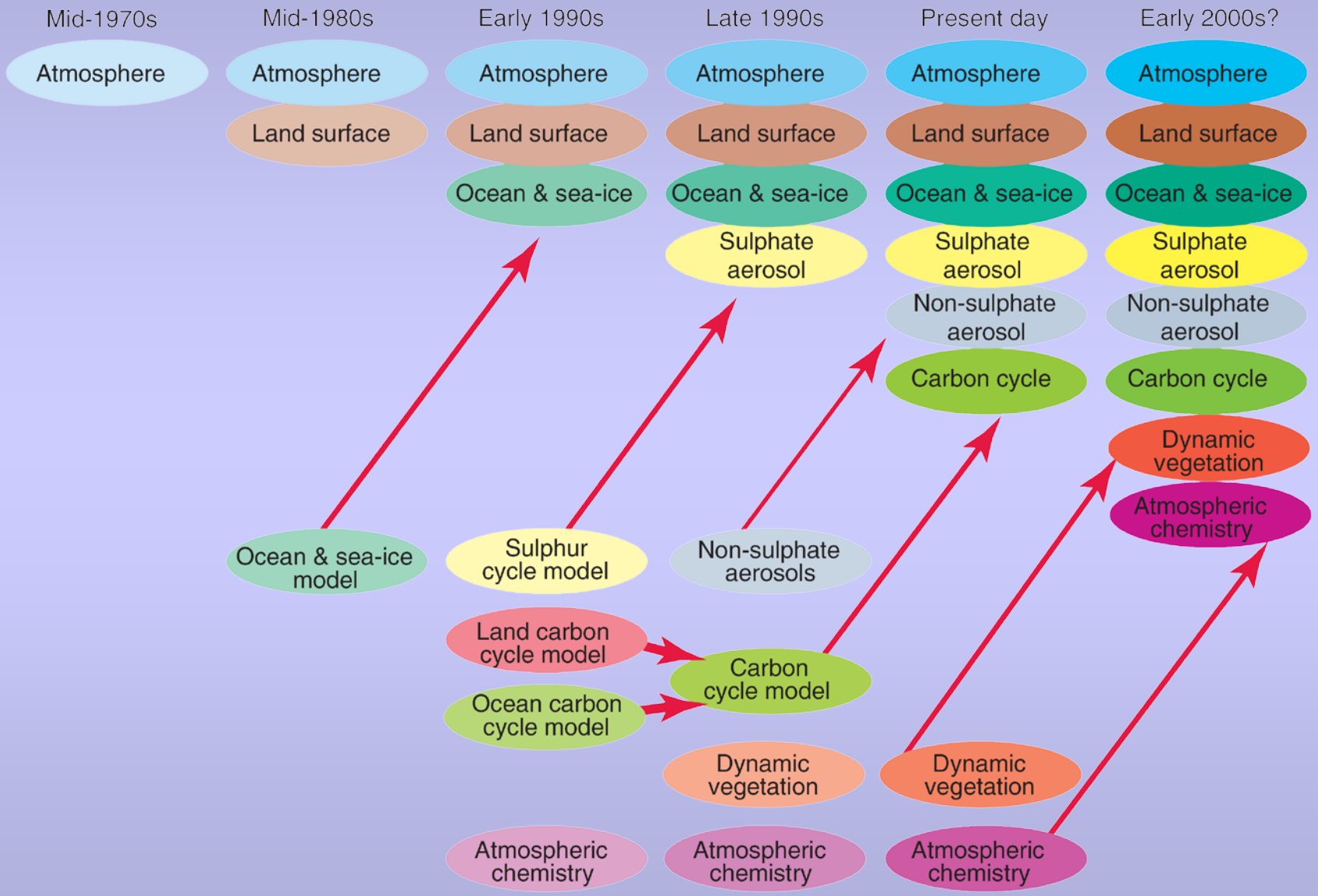
Computer Modelle an Stelle von Labor Experimenten (eigentlich kein grundlegender Unterschied):
Wiederspiegeln diese Modelle die Realität?

(source: IPCC 2001, WG1 Report, Summary)

Herausforderung: Komplexität des Modellsystems

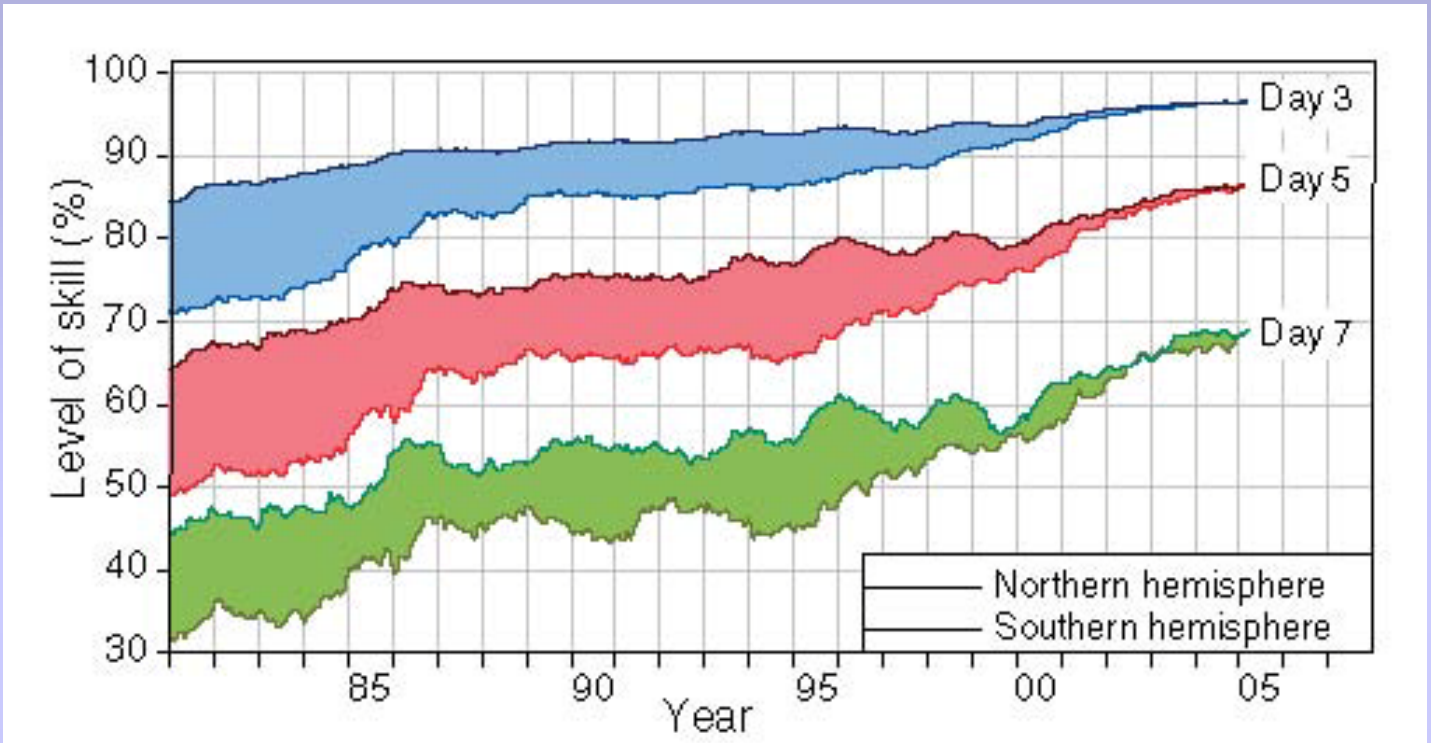


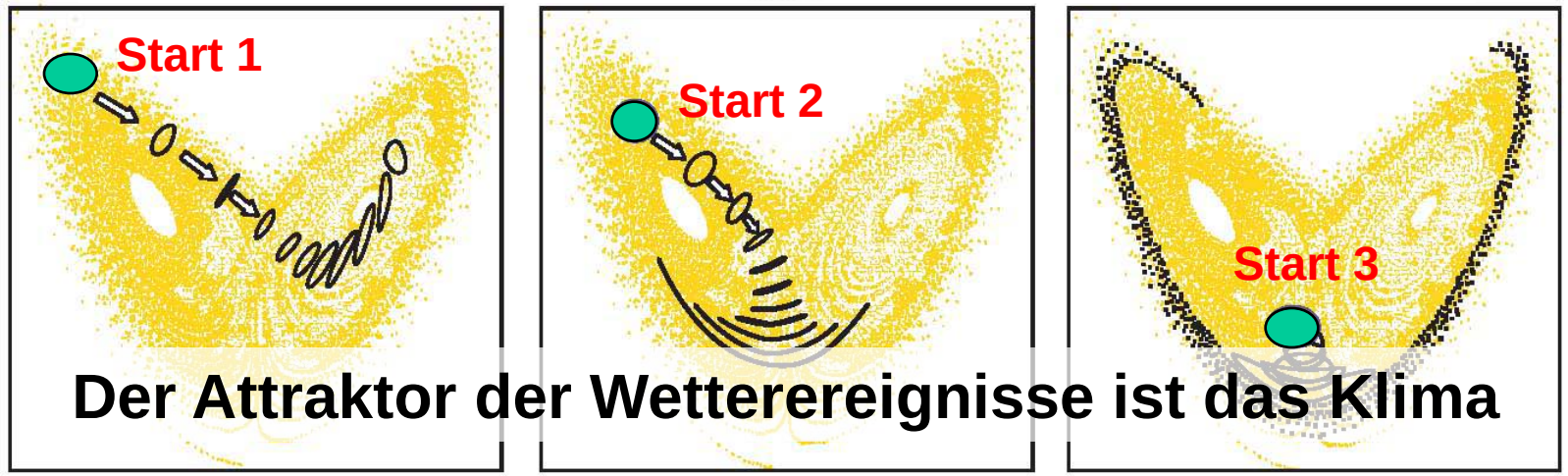
The Development of Climate models, Past, Present and Future



(source: IPCC 2001, WG1 Report, Summary)

Treffsicherheit von Atmosphärenmodellen



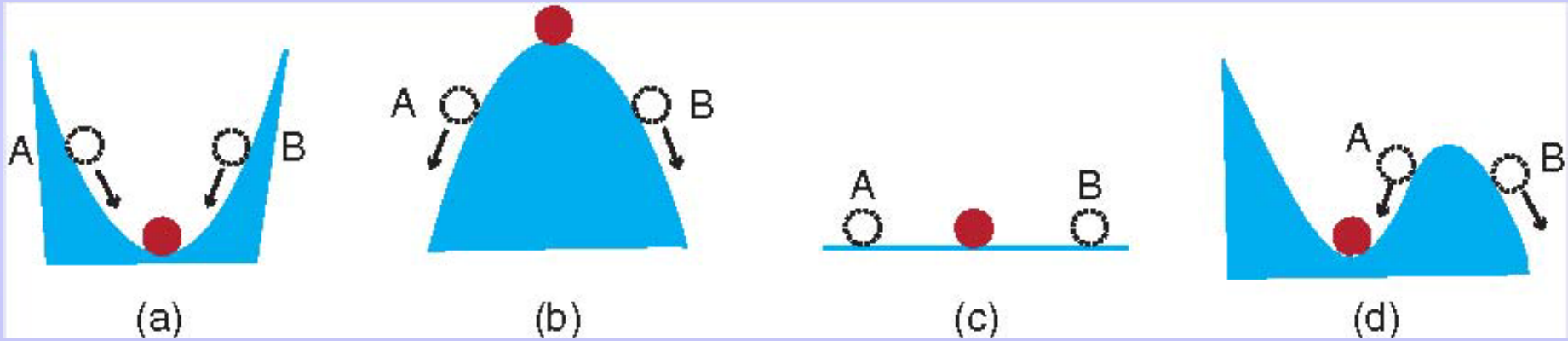


Der Attraktor der Wetterereignisse ist das Klima

(from Wallace and Hobbs, 2006)

A stable Climate?

States of Equilibrium



stable

unstable

neutral (indifferent)

conditionally stable

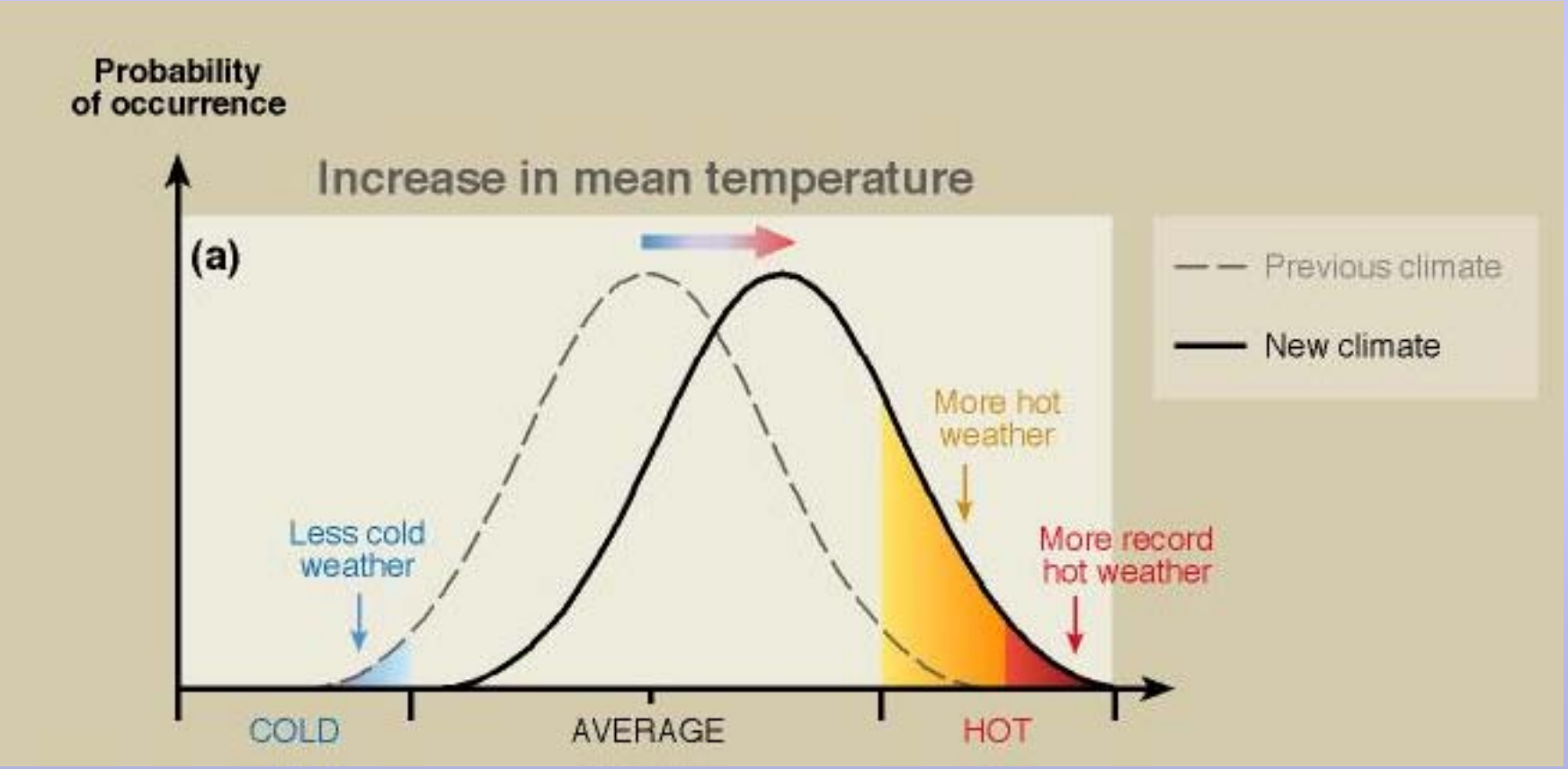
What do we know?
How well do we know it?
Uncertainties

Table 1. A simple typology of uncertainties

Type	Indicative examples of sources	Typical approaches or considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests; comparison of models with observations.

Climate Change ≠ Climate Change

Temperature Change: Different Possibilities



Climate Change ≠ Climate Change

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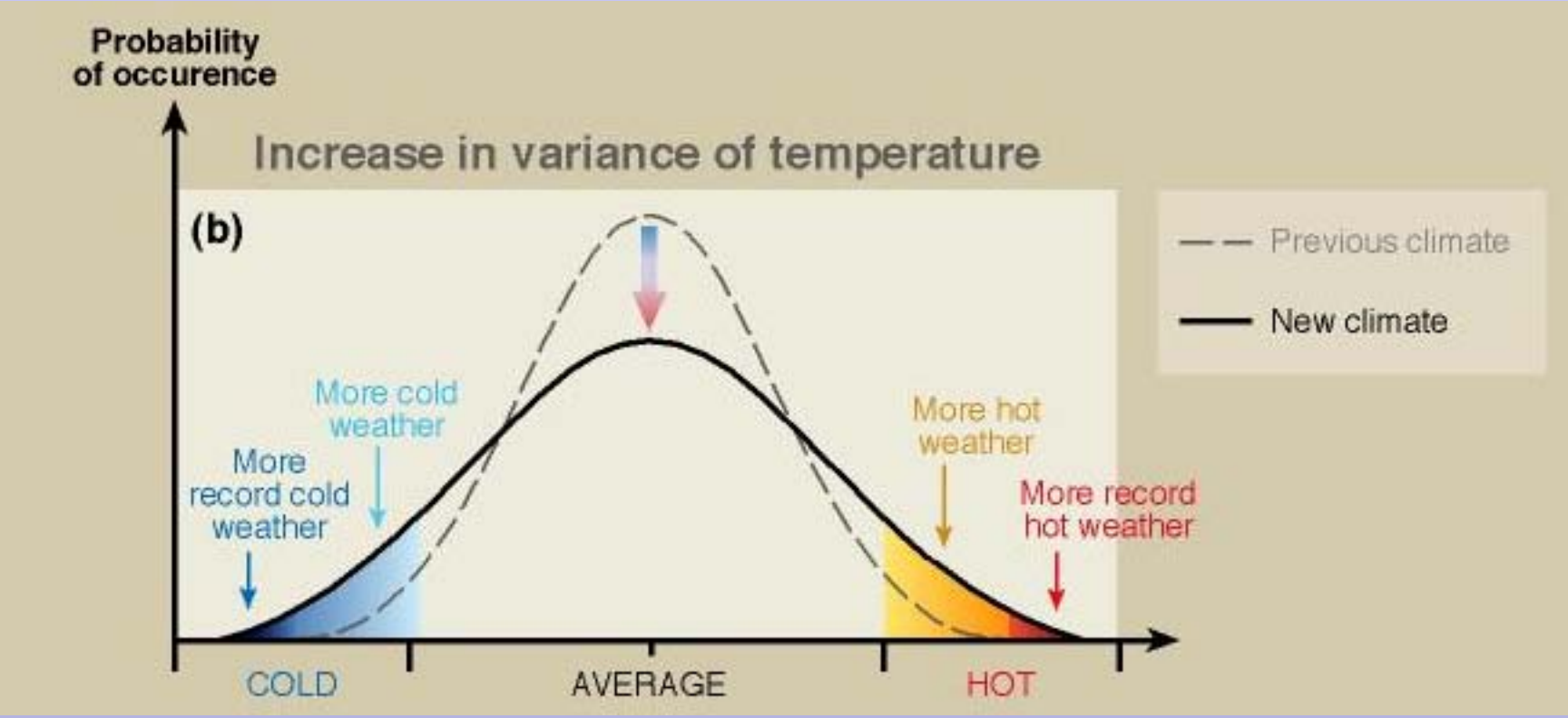

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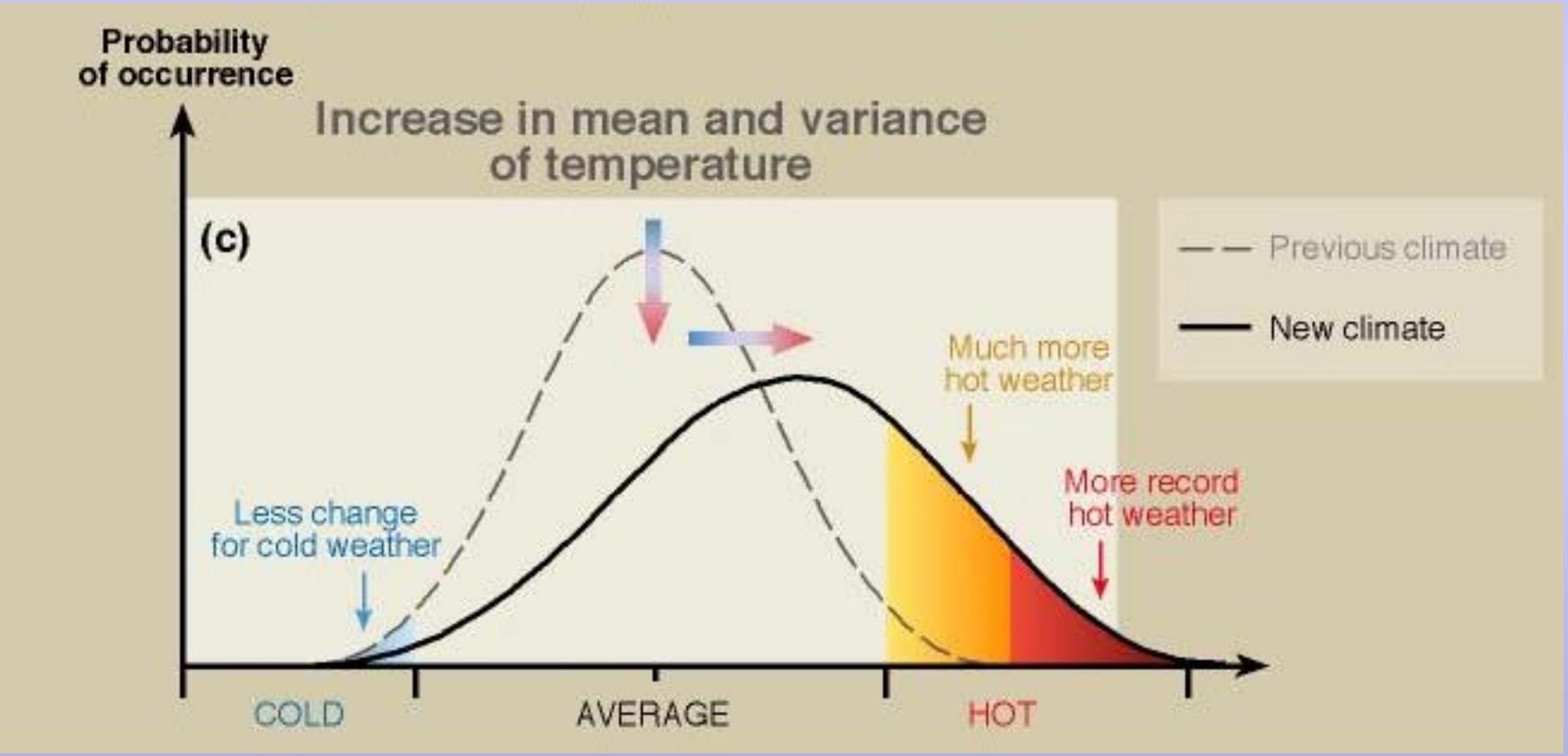
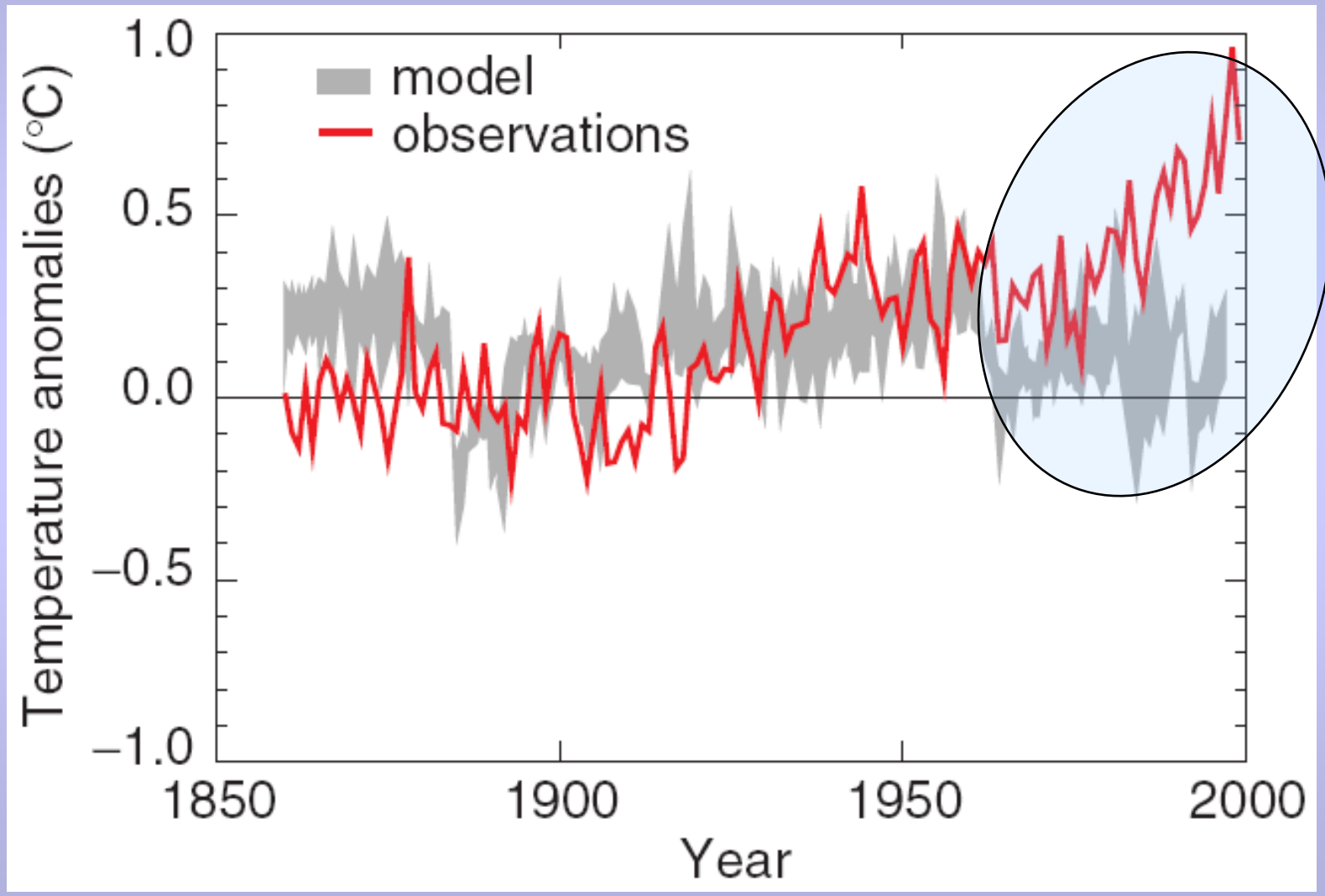
Temperature Change: Different Possibilities



Climate Models: do they reflect reality?

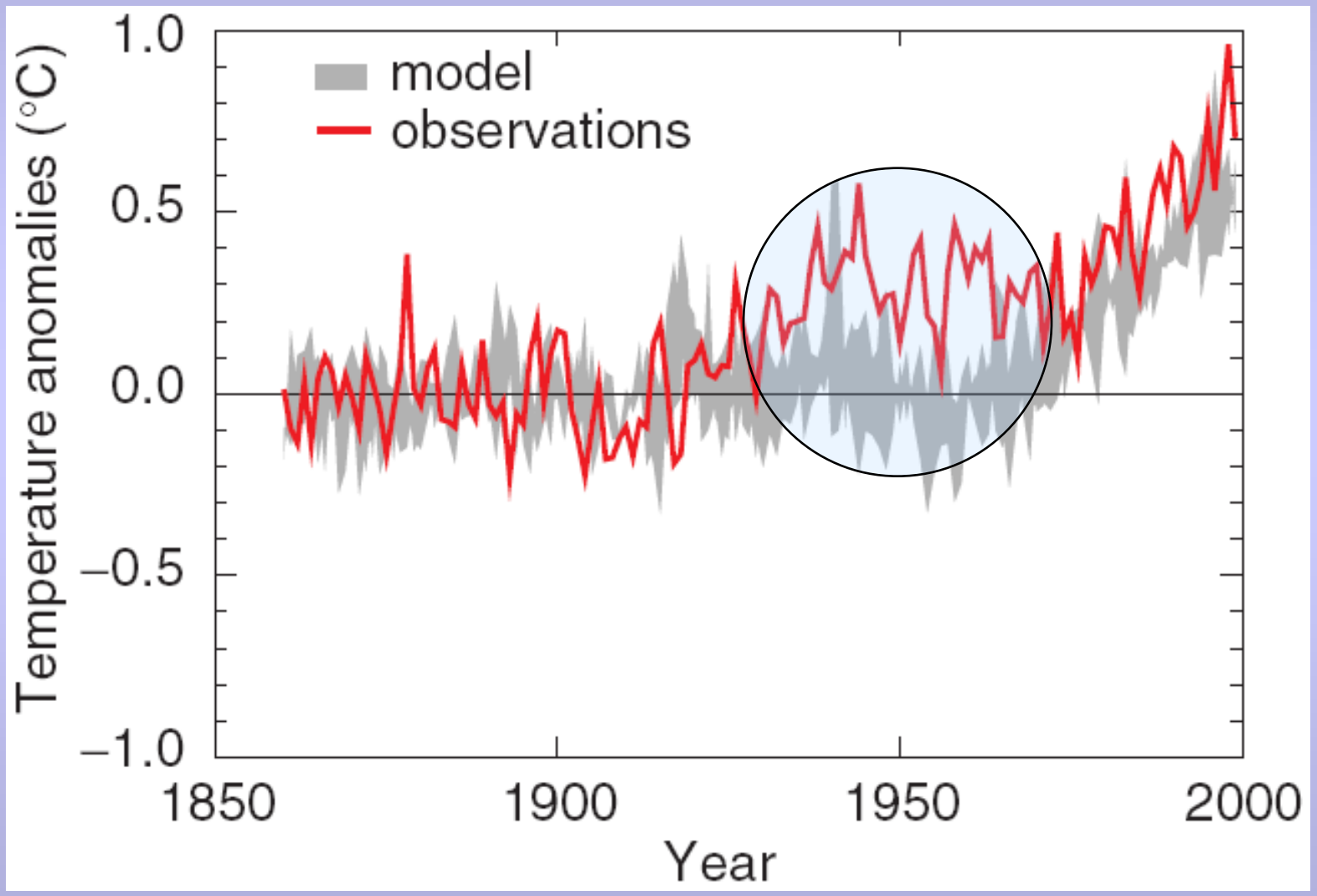
(a) with solar and volcanic forcing only



(source: IPCC 2001, WG1 Report, Summary)

Climate Models: do they reflect reality?

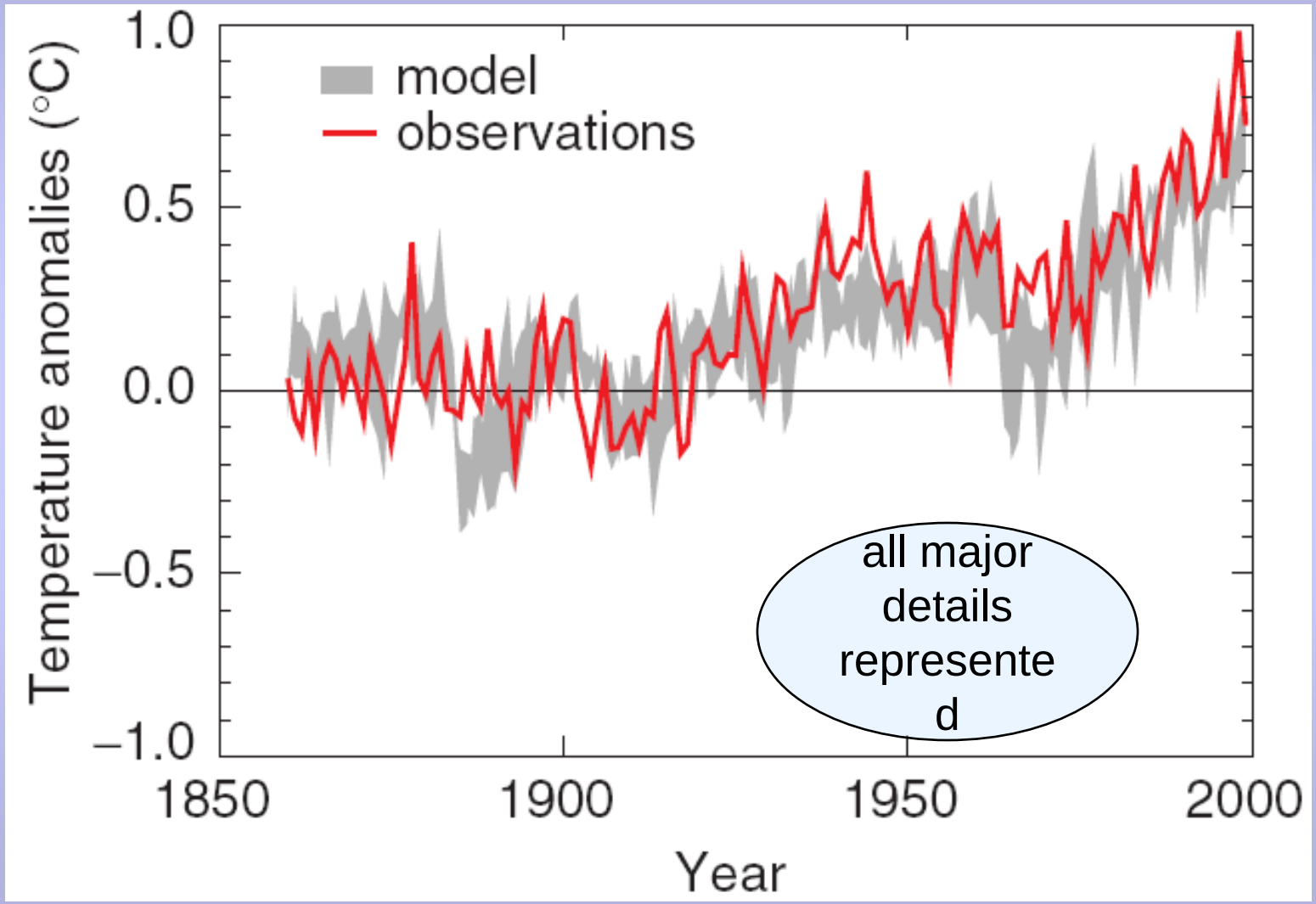
(b) with anthropogenic forcing only (greenhouse gases, ozone, aerosols)



(source: IPCC 2001, WG1 Report, Summary)

Climate Models: do they reflect reality?

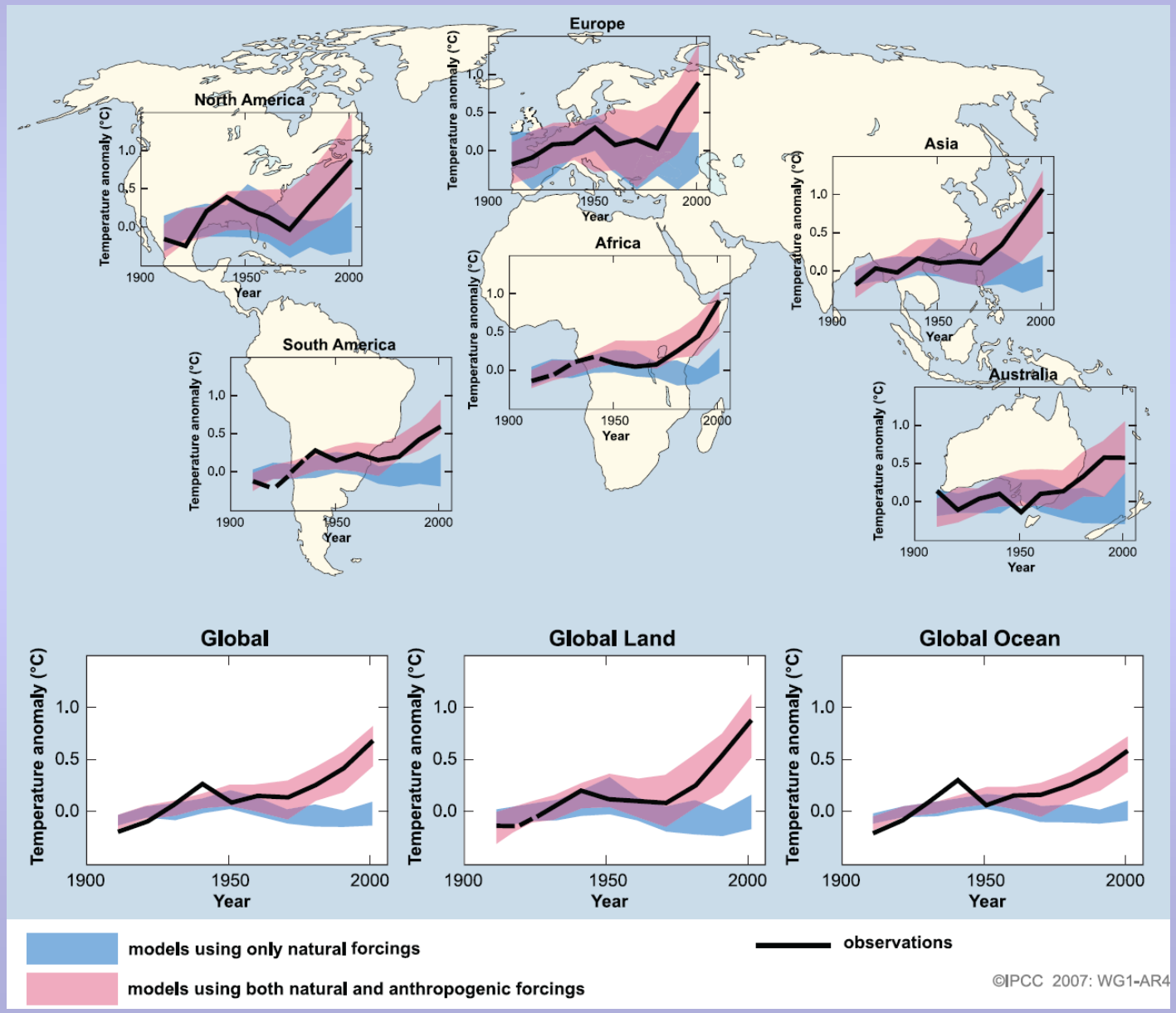
(c) with all forcings, both natural and anthropogenic



(source: IPCC 2001, WG1 Report, Summary)

Climate Models: do they reflect reality?

Regional Distribution



(IPCC 2007)

Globaler Klimawandel: regionale Auswirkungen

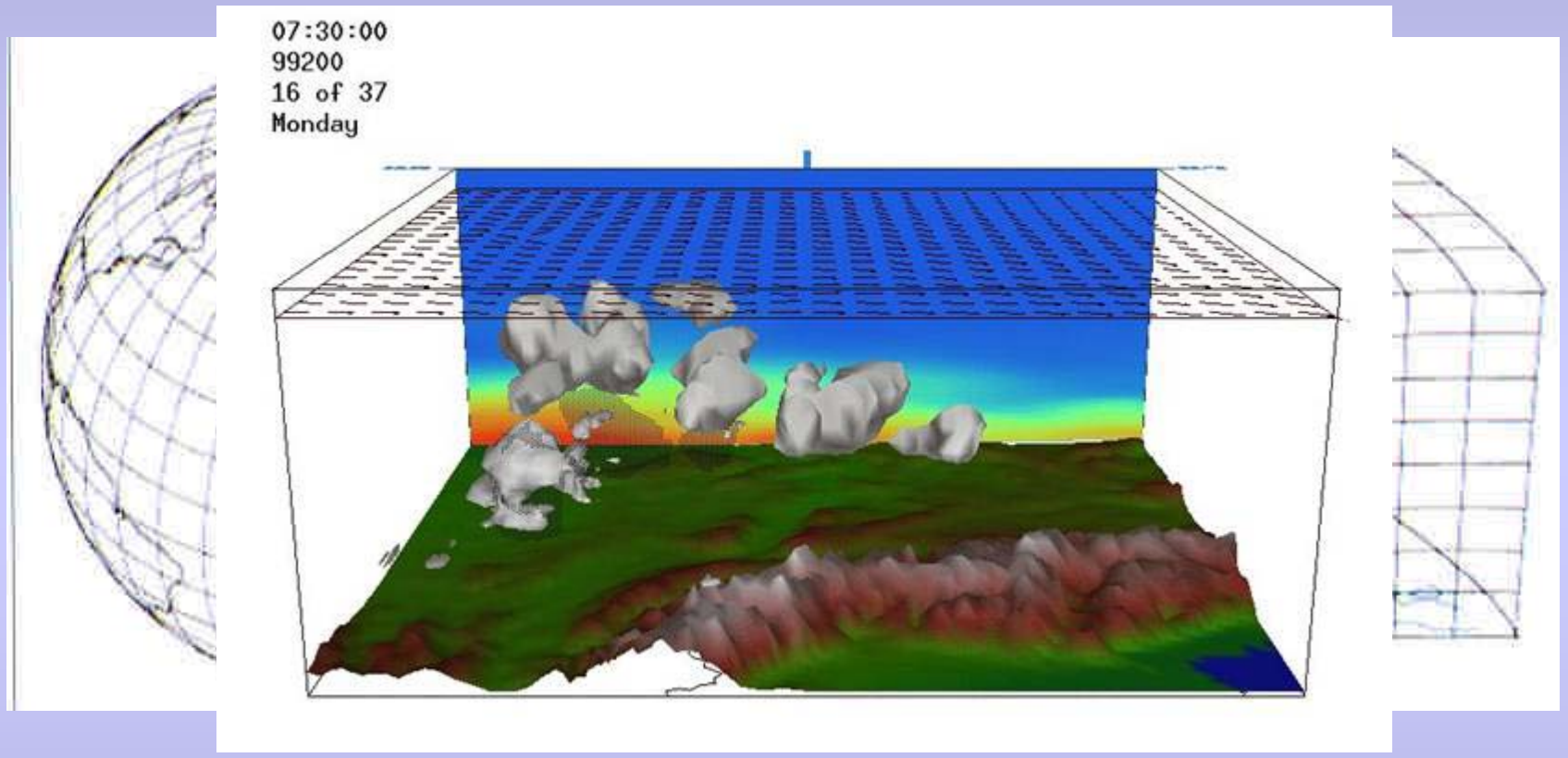
Hochwasser im Alpenraum

Eschenlohe 1999, 2005

Dürre in Europa

Rhein (Düsseldorf), 2003

Blick in die Zukunft: Regionale Klima Modellierung



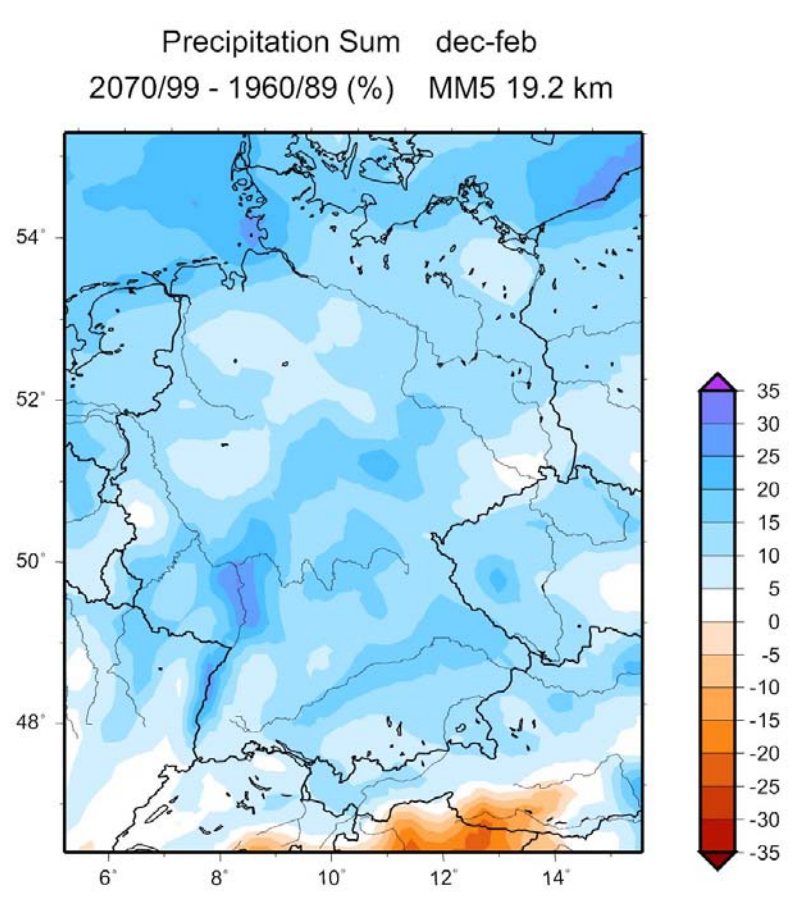
Explicit dynamical downscaling:
Numerical simulation of atmospheric processes
by finite difference schemes solving atmospheric PDEs

(courtesy of Drs. H. Kunstmann & R. Knoche, FZK-IMK-IFU)

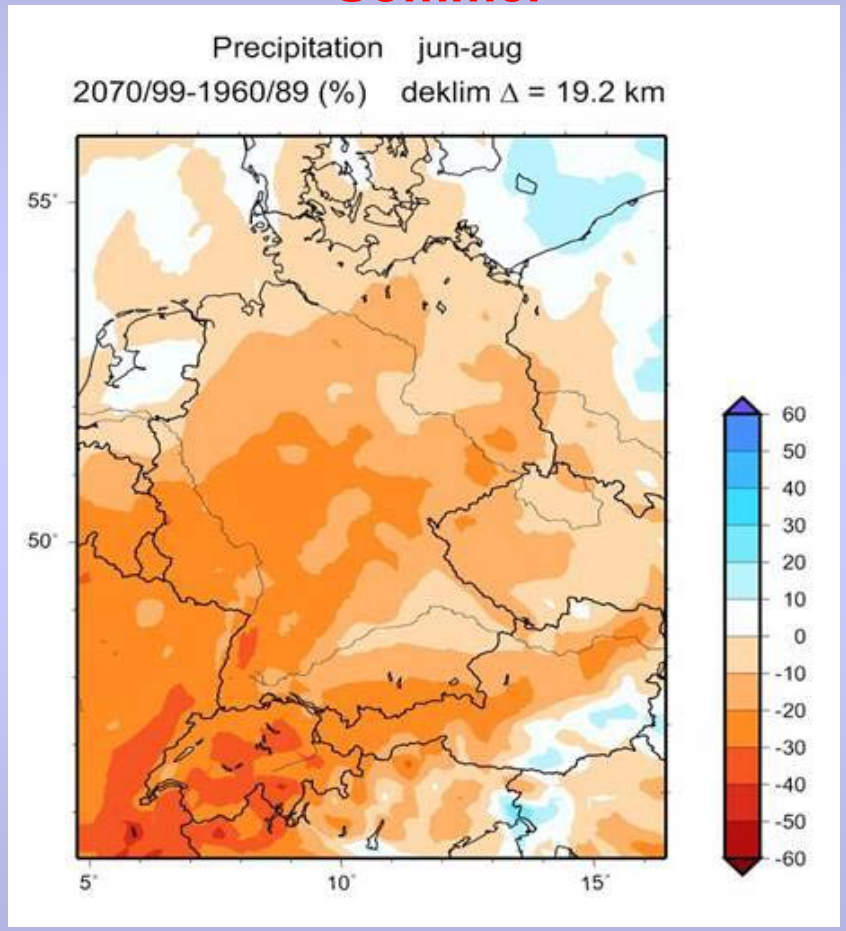
Blick in die Zukunft: Regionale Klima Modellierung

Niederschlag: Änderung in % (2070/99 – 1960/89)

Winter



Sommer



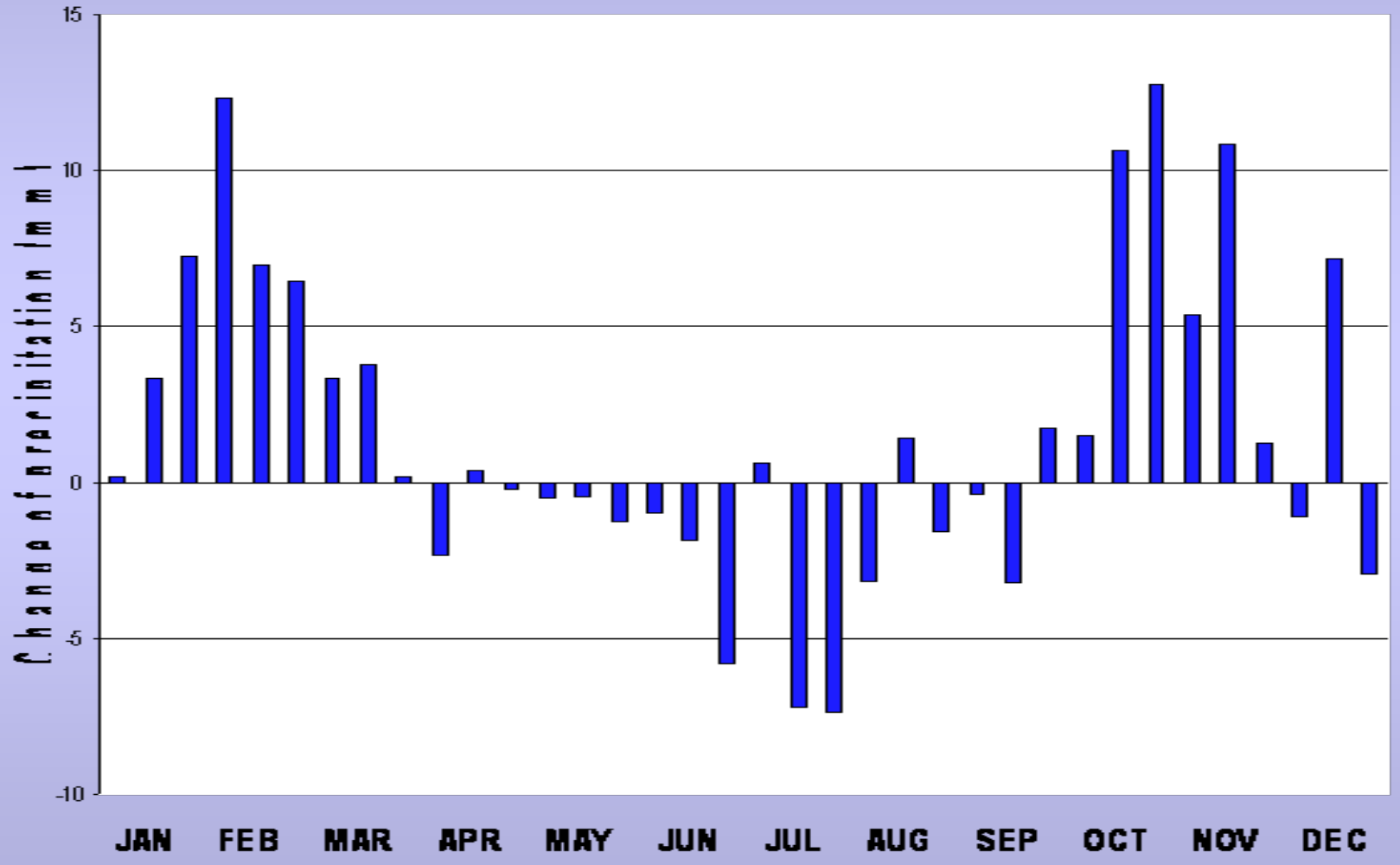
bis 30% mehr Niederschlag im Winter (Europa Ø ≈ +11%)

bis 40% weniger Niederschlag im Sommer (Europa Ø ≈ -1%)

(courtesy of Drs. H. Kunstmann & R. Knoche, FZK-IMK-IFU)

Blick in die Zukunft: Regionale Klima Modellierung

Niederschlag: Änderung in % (2070/99 – 1960/89)

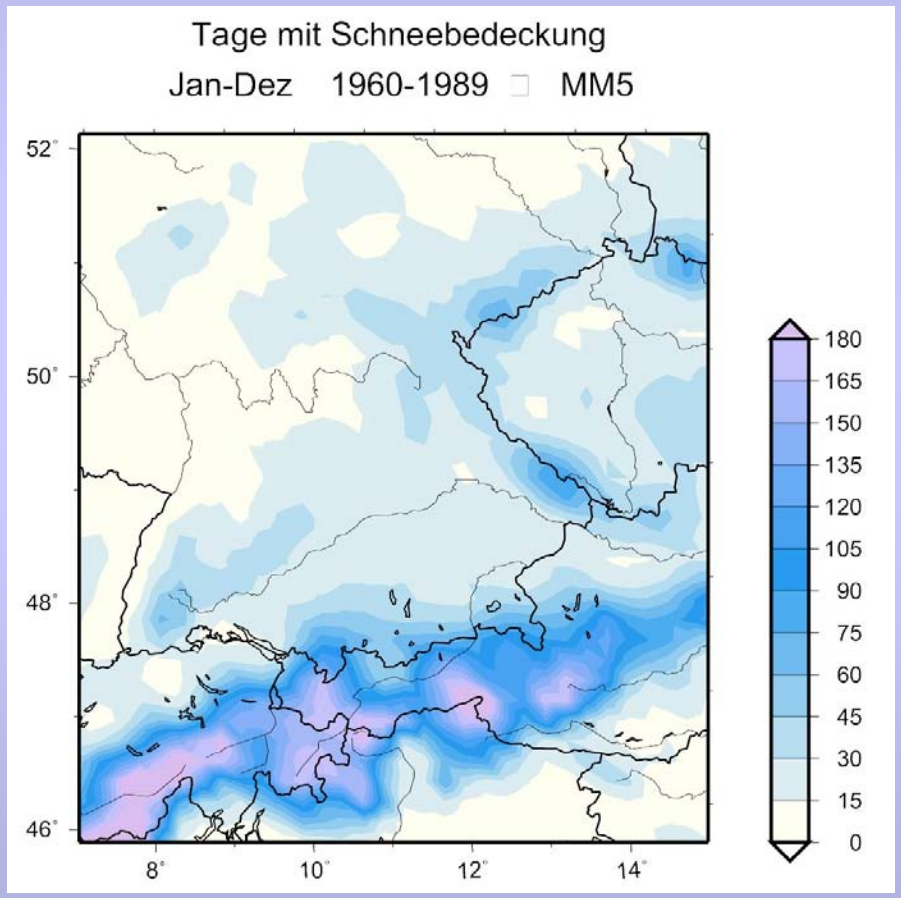


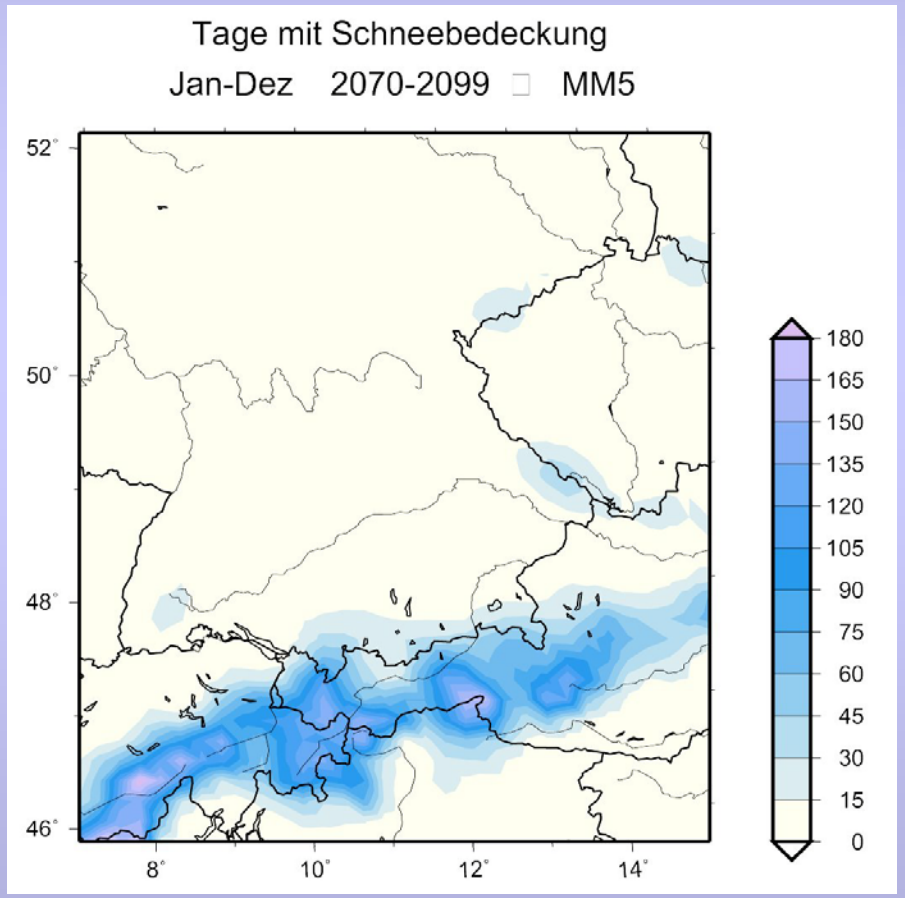
(courtesy of Drs. H. Kunstmann & R. Knoche, FZK-IMK-IFU)

Blick in die Zukunft: Regionale Klima Modellierung

Tage mit Schneebedeckung:

1960-1989 → 2070-2099

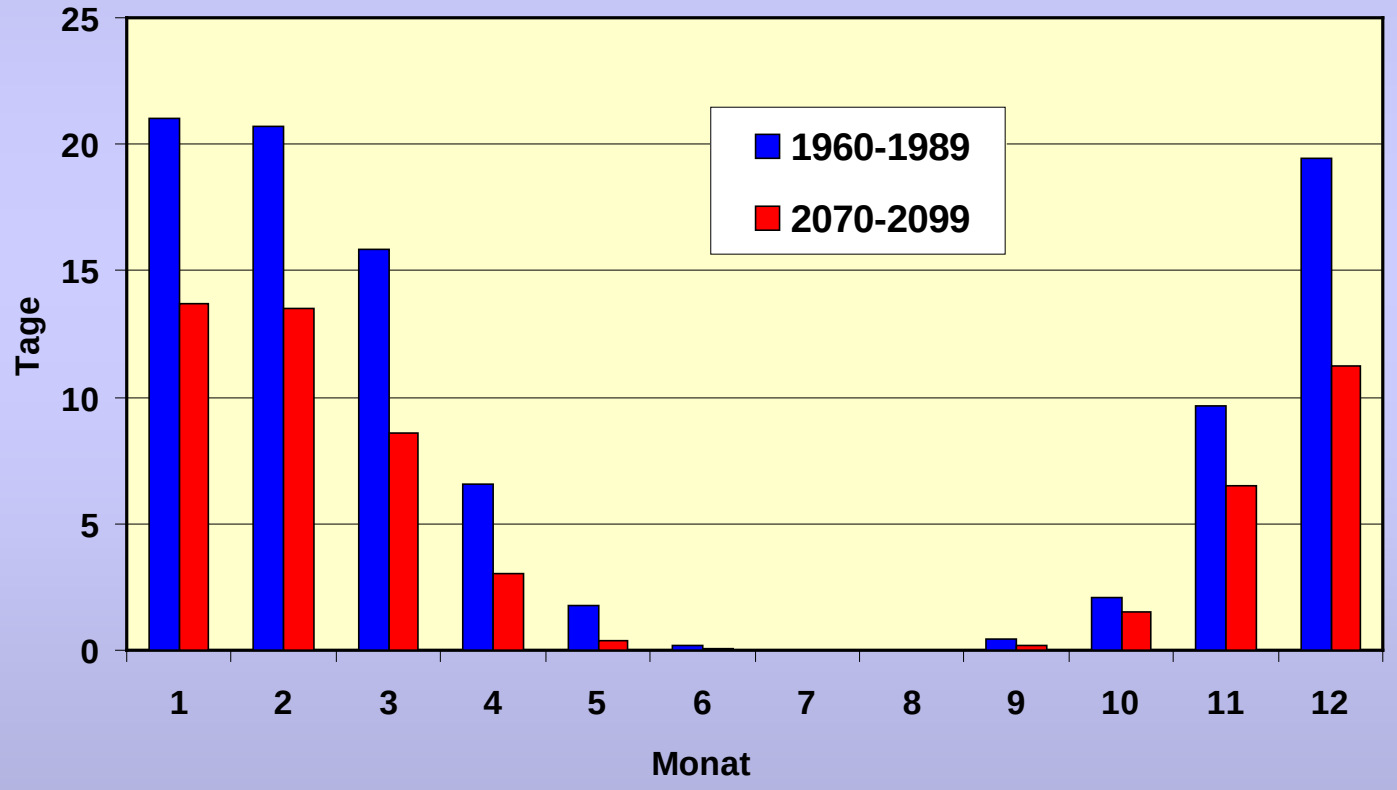




(courtesy of Drs. H. Kunstmann & R. Knoche, FZK-IMK-IFU)

Blick in die Zukunft: Regionale Klima Modellierung

Tage mit Schneebedeckung
Südbayern und nördlicher Ostalpenraum



(courtesy of Drs. H. Kunstmann & R. Knoche, FZK-IMK-IFU)

Blick in die Zukunft: Regionale Klima Modellierung

Die Zukunft des Wintersportes?

(courtesy of Drs. H. Kunstmann & R. Knoche, FZK-IMK-IFU)


Danke für die Aufmerksamkeit !