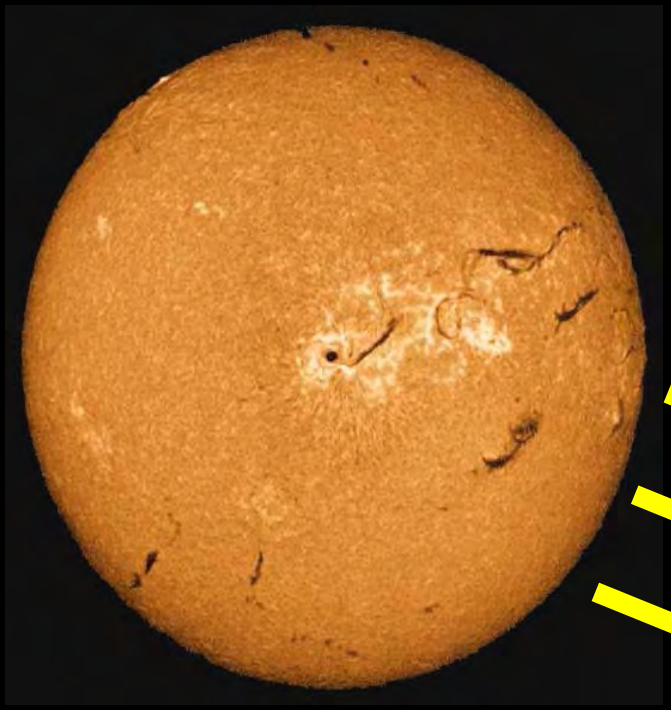
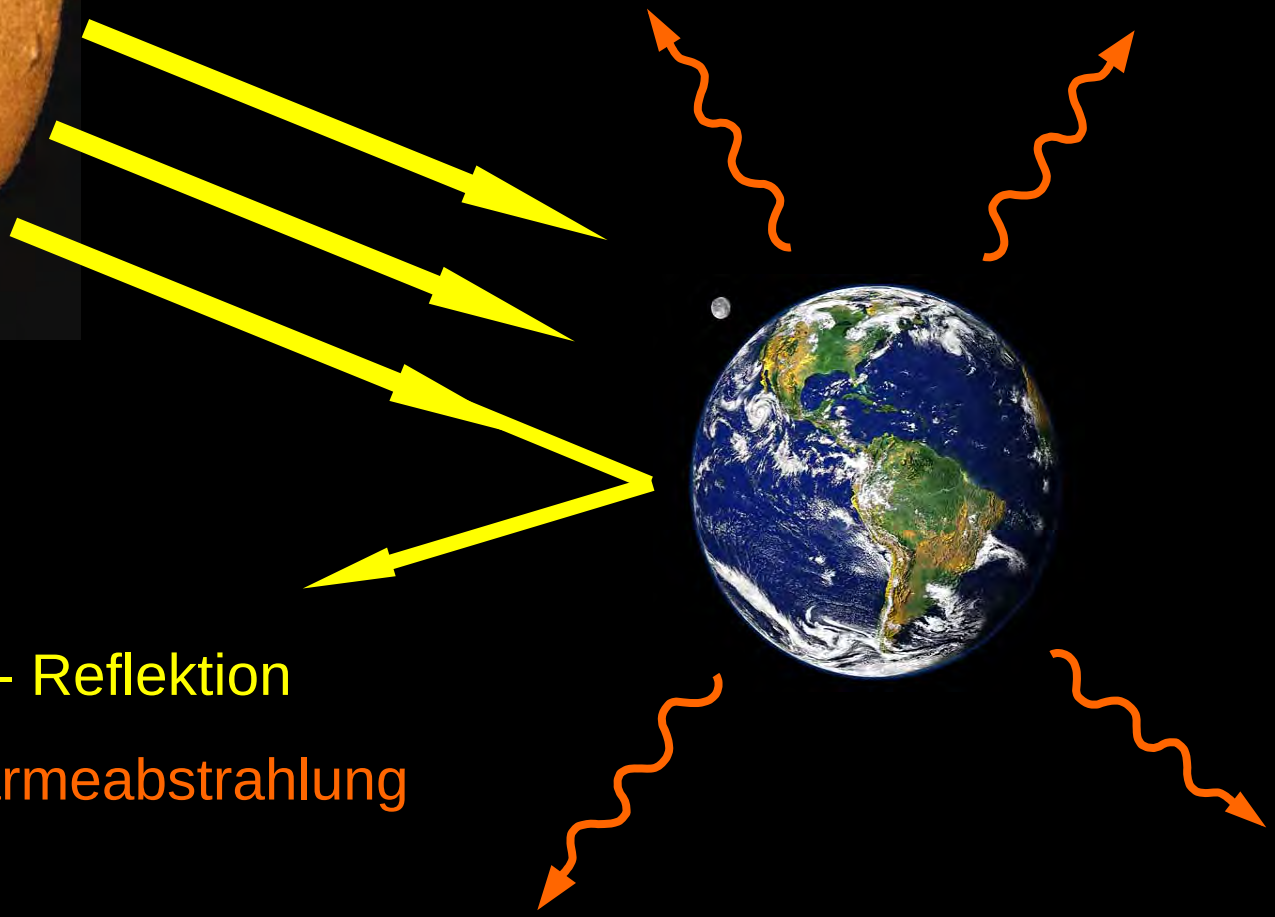
Die Klimakrise

Prof. Stefan Rahmstorf
Potsdam-Institut für Klimafolgenforschung

Klima ist Ergebnis einer Energiebilanz

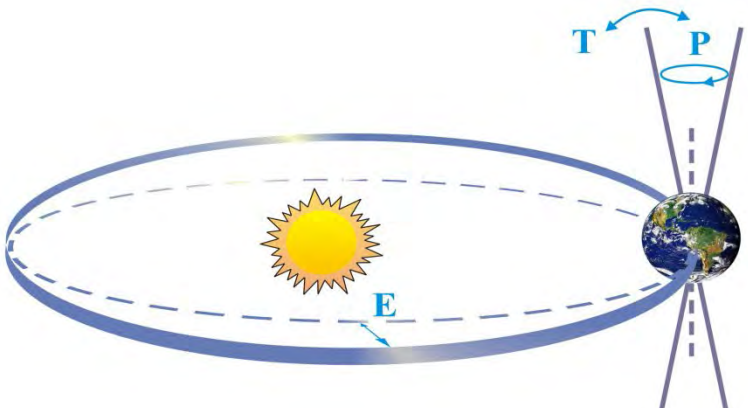


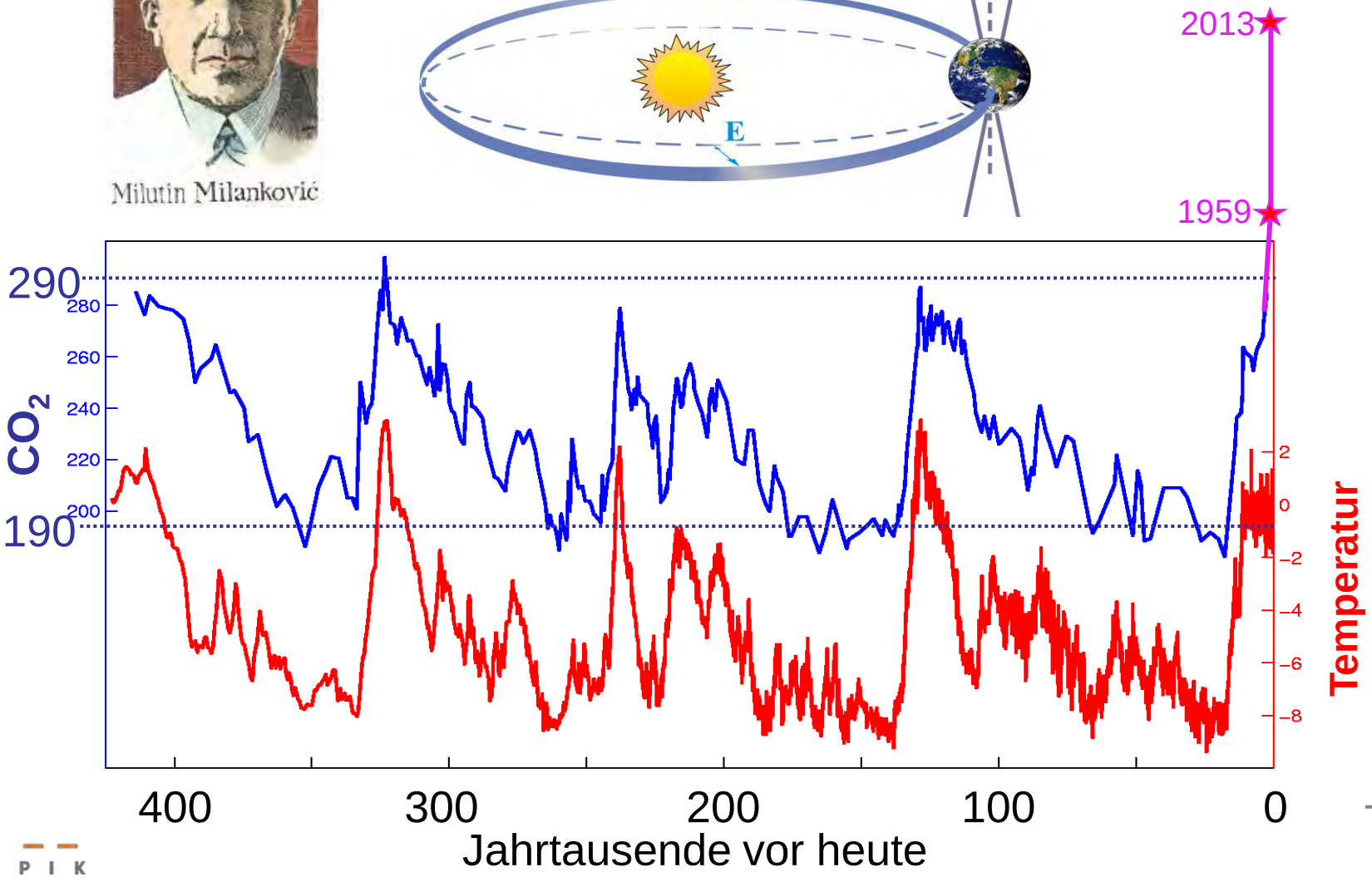


Sonneneinstrahlung - Reflektion

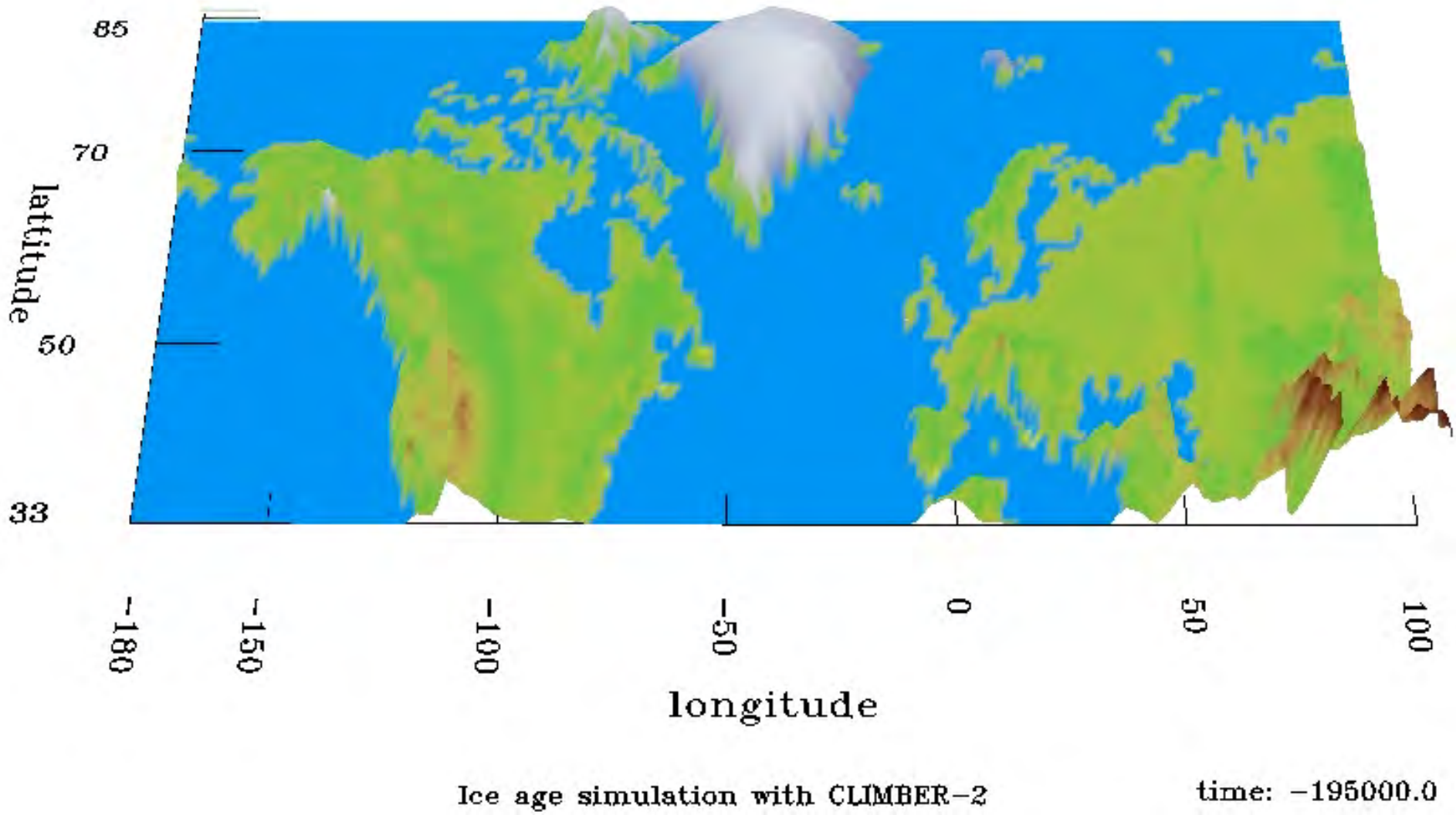
= Wärmeabstrahlung

Erdumlaufbahn: Eiszeitzyklen





Simulation von Eiszeitzyklen

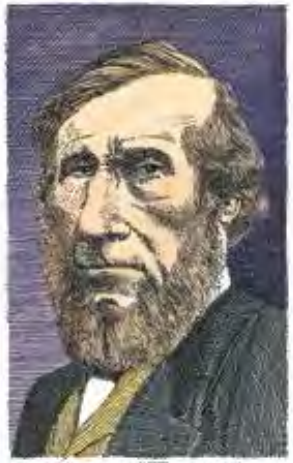


Alexander von Humboldt, 1843

Der Mensch verändert das Klima „durch Fällen der Wälder [...] und durch die Entwicklung großer Dampf- und Gasmassen an den Mittelpunkten der Industrie"

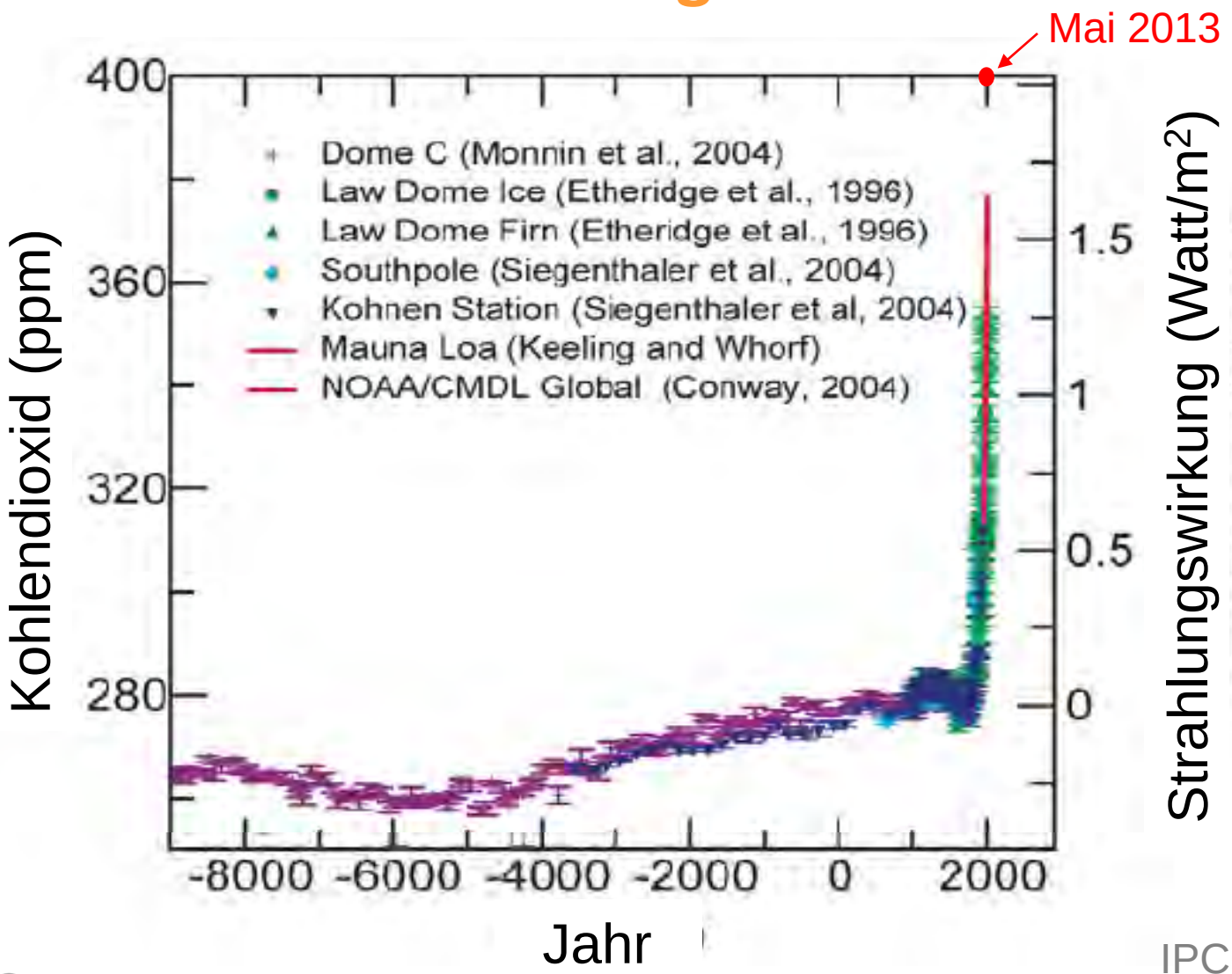
John Tyndall, 1859

„The atmosphere admits of the entrance of solar heat, but checks its exit; and the result is a tendency to accumulate heat at the surface of the planet.“



John Tyndall

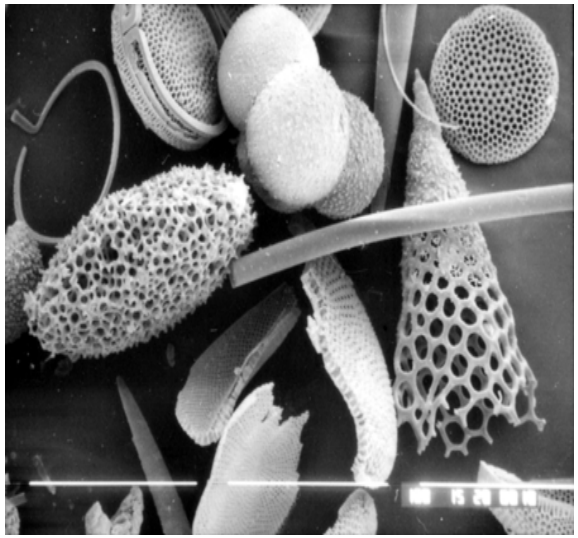
Die CO2-Konzentration steigt



IPCC 2007

Die Ozeane werden saurer

Foraminiferen

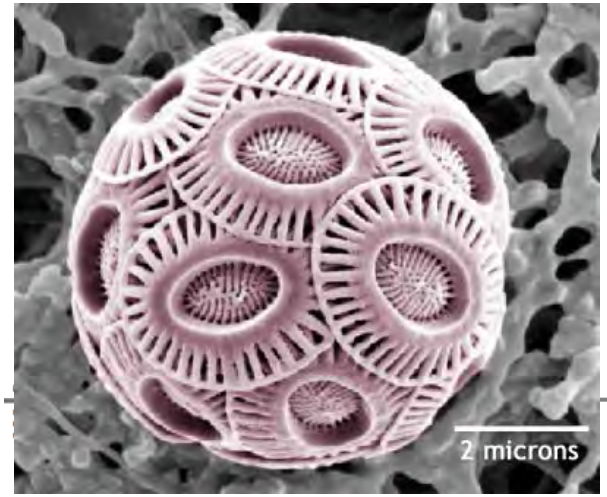


Versauerung durch CO_2 bedroht Meeresorganismen

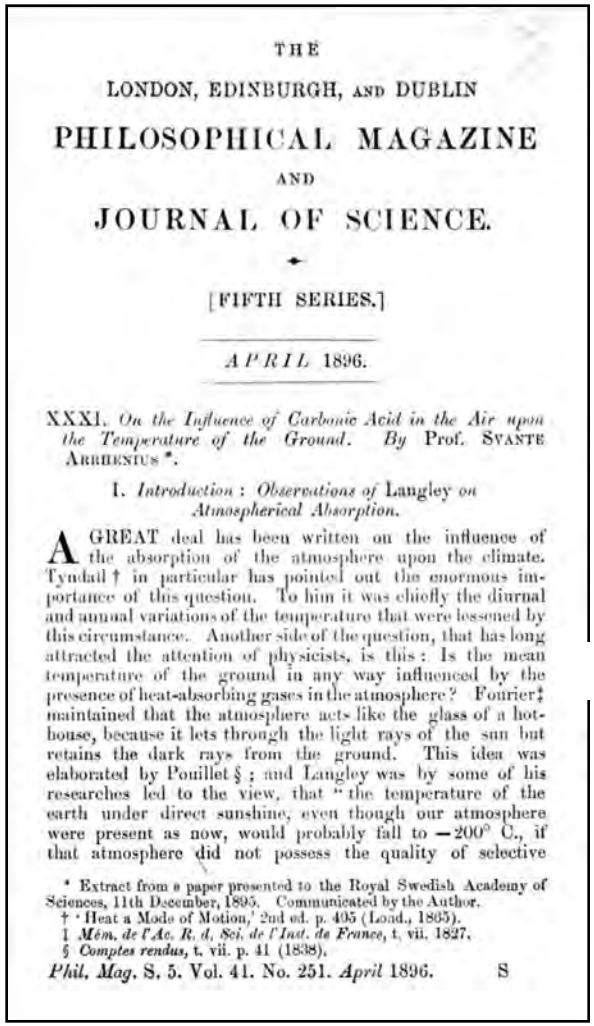
Pteropoden

Korallen

Coccolithophoriden



Stärke des CO2 - Effekts



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction: Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.
† 'Heat a Mode of Motion,' 2nd ed. p. 495 (Lond., 1865).
‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.
§ *Comptes rendus*, t. vii. p. 41 (1838).

Phil. Mag. S. 5. Vol. 41. No. 251. *April* 1896. S

Portrait by K. Ensikat

Arrhenius 1896 (4-6 ºC)

Effekt der CO_2-Verdoppelung:

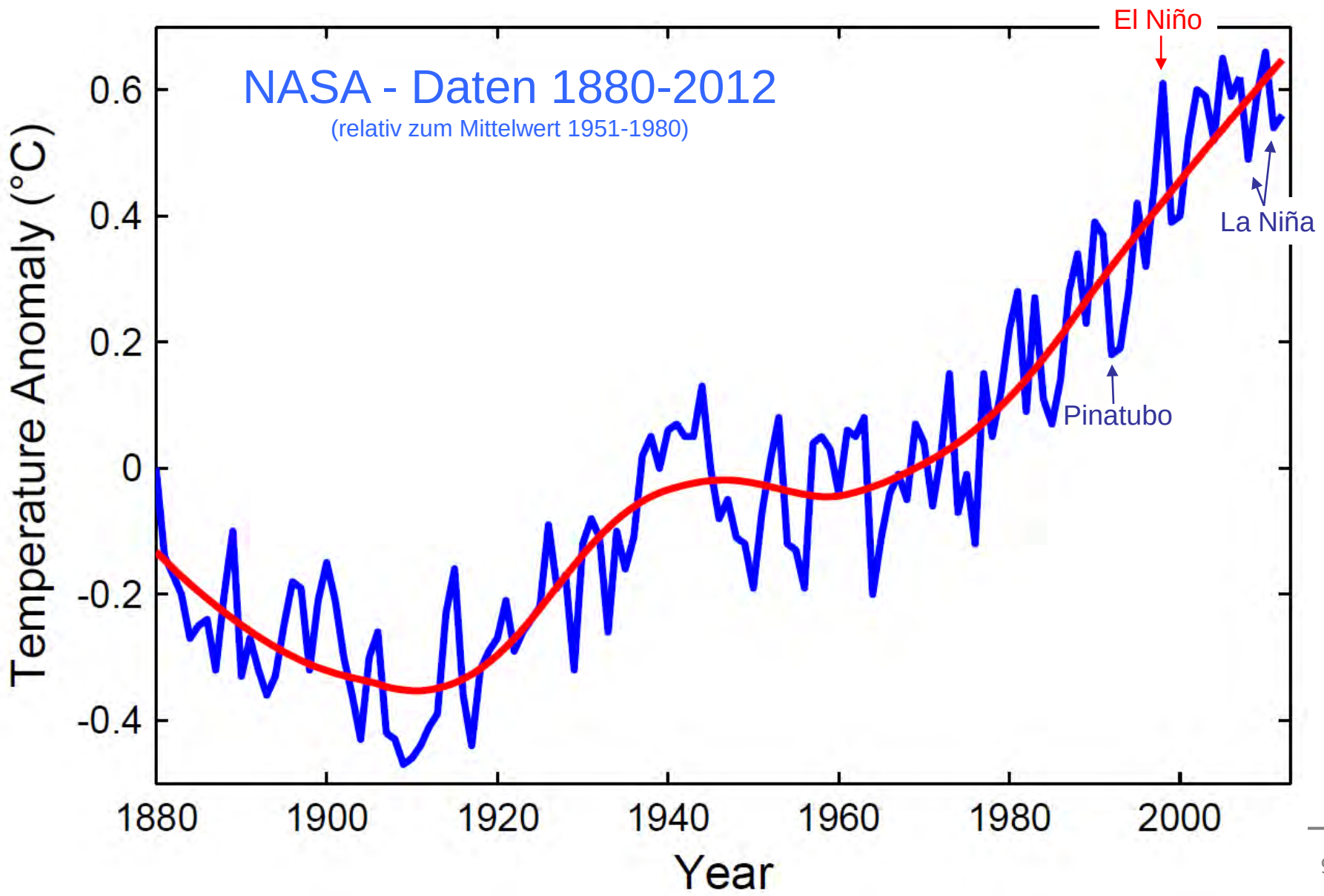
"Klimasensitivität"

3 ± 1 ºC

Es folgt:
Störung durch den Menschen sollte bisher 0,7 – 0,9 ºC Erwärmung verursacht haben

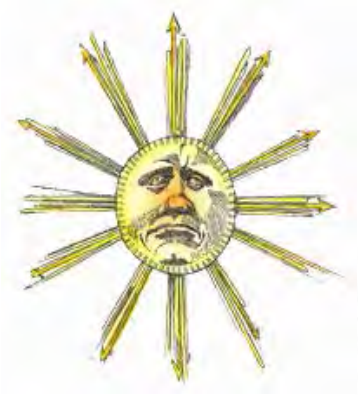
P I K

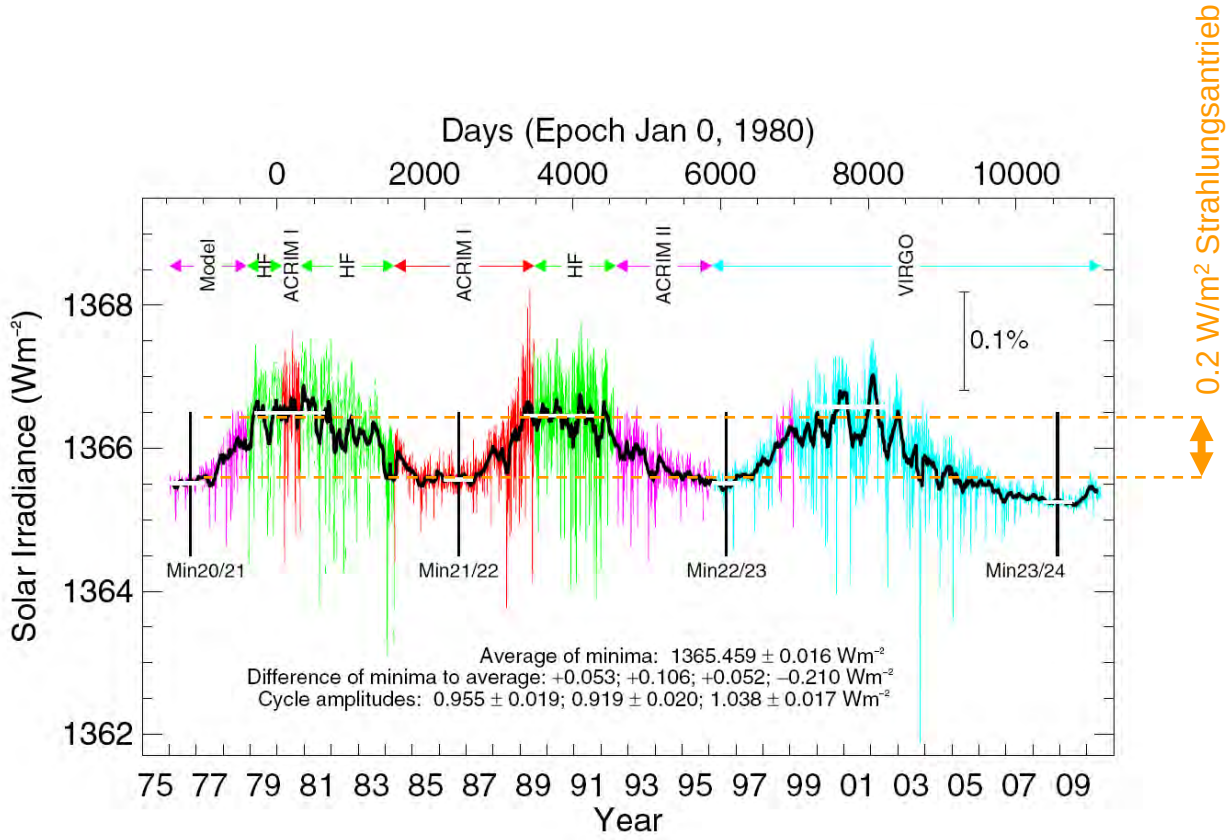
Globale Temperatur



Wie stark ist der Effekt der Sonne?

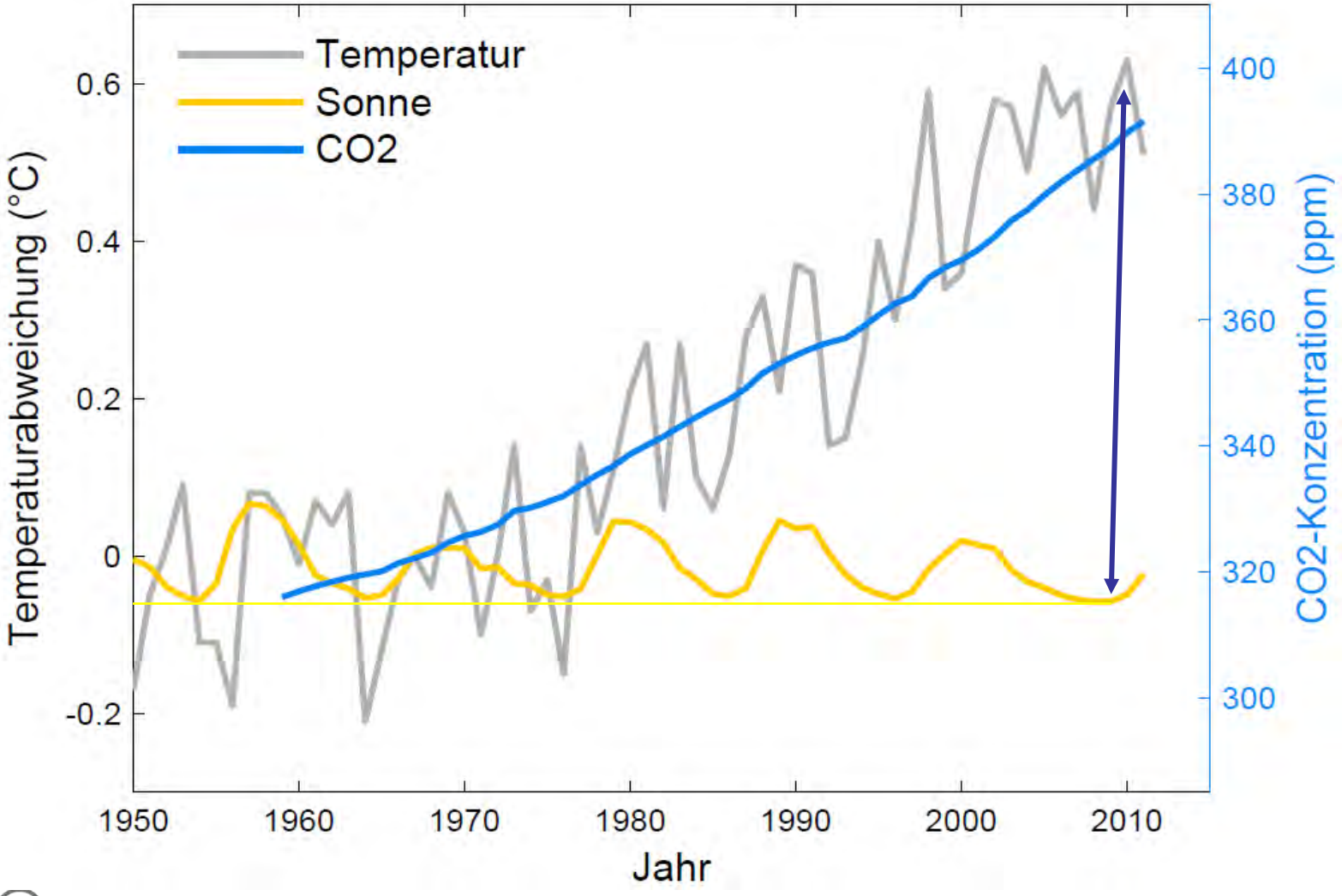
- **Sonnenschwankungen um Faktor 10 kleiner als der CO_2-Effekt**



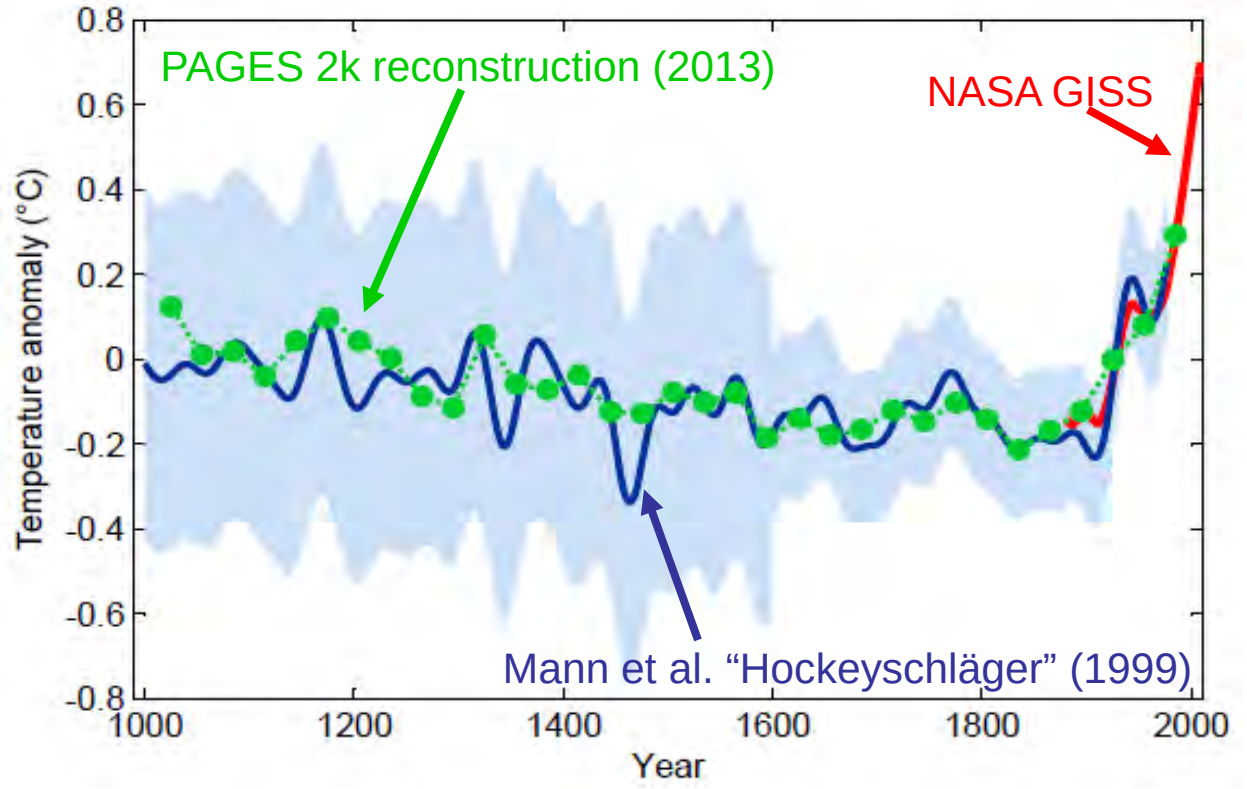


Strahlungsantrieb = “irradiance”/4 × 0,7

Globale Temperatur und Sonne



Die letzten 1000 Jahre



nature geoscience
PROGRESS ARTICLE
PUBLISHED ONLINE: 21 APRIL 2013 | DOI: 10.1038/NGEO1797

Continental-scale temperature variability during the past two millennia

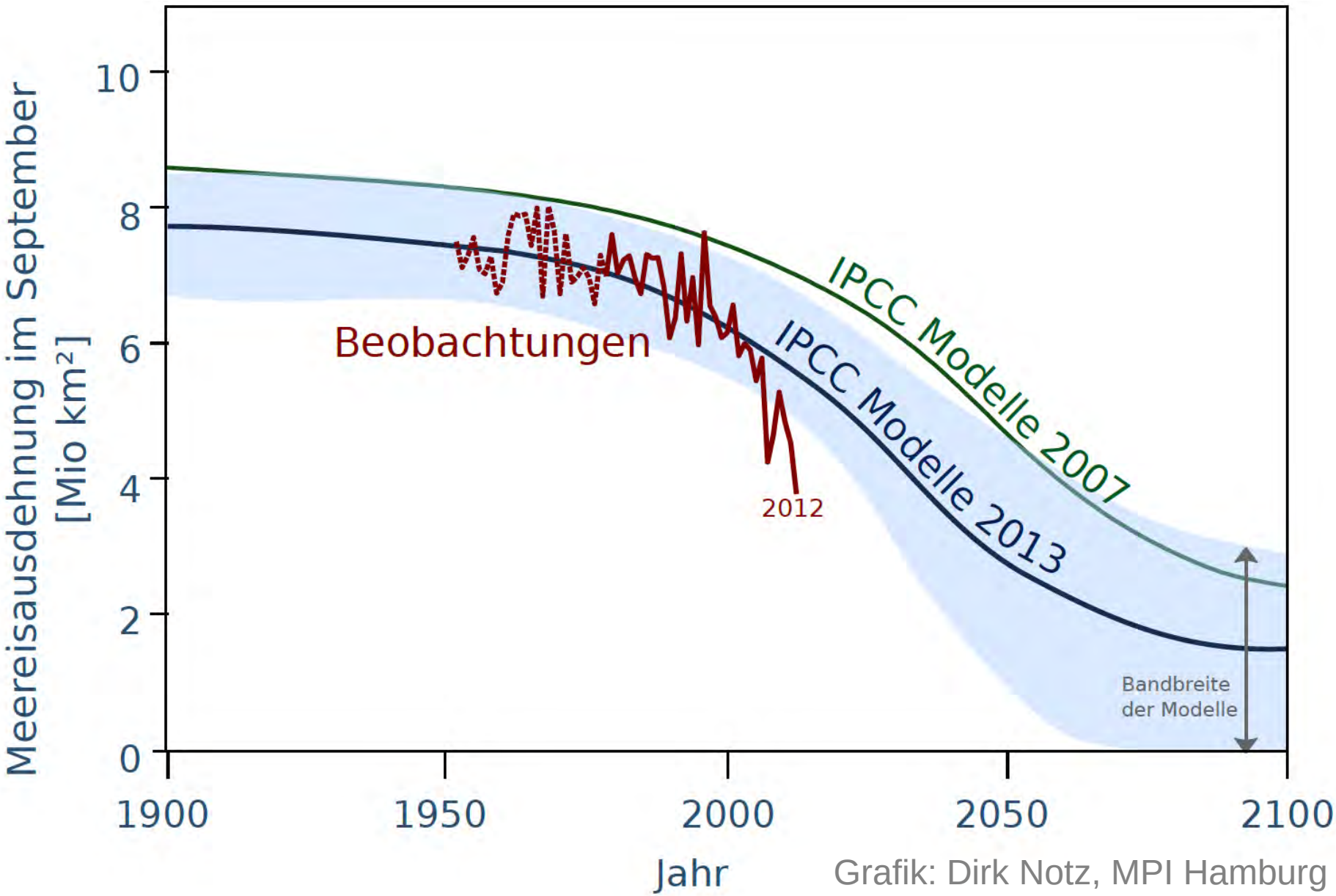
PAGES 2k Network*


1970er


2012

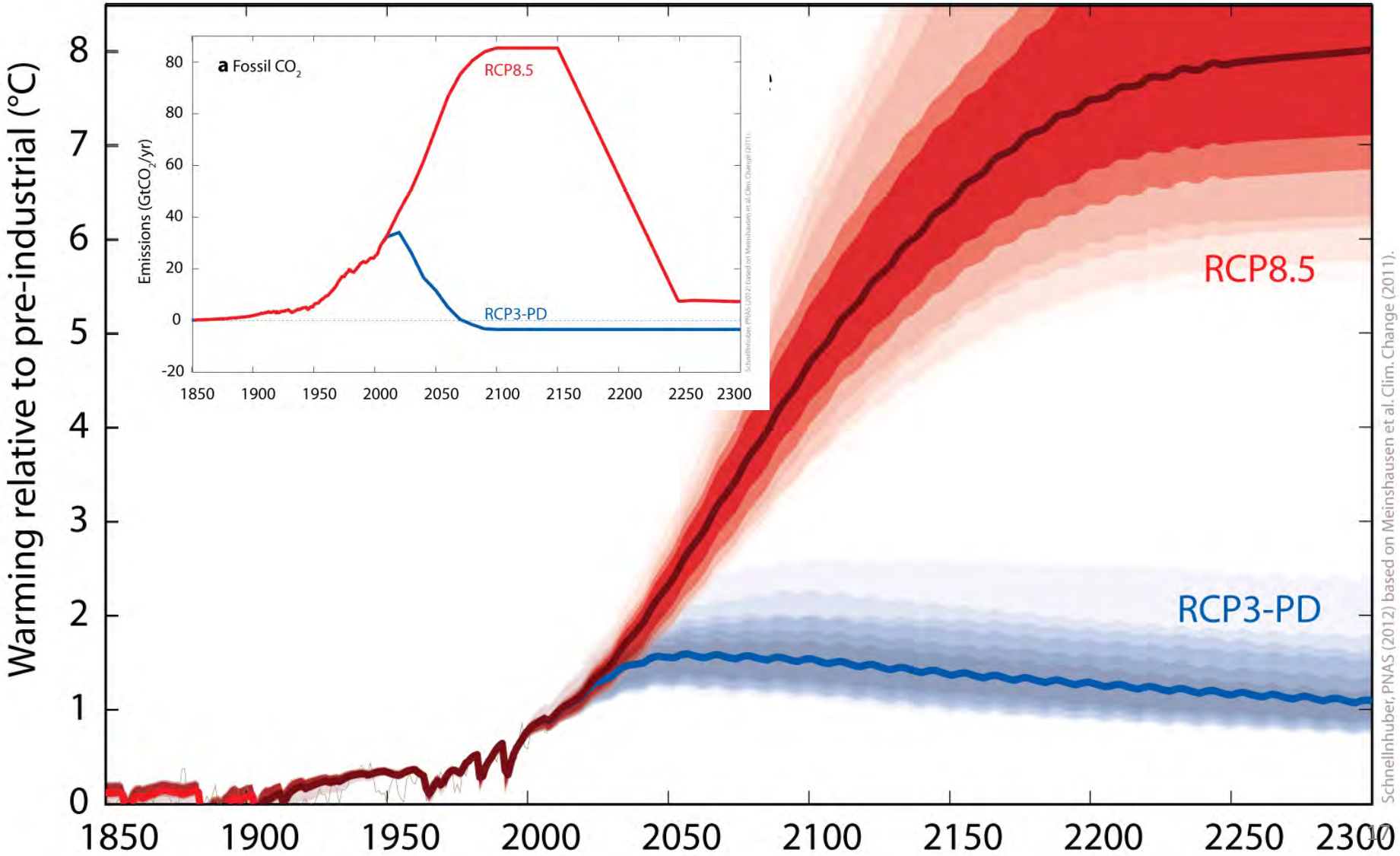

20??

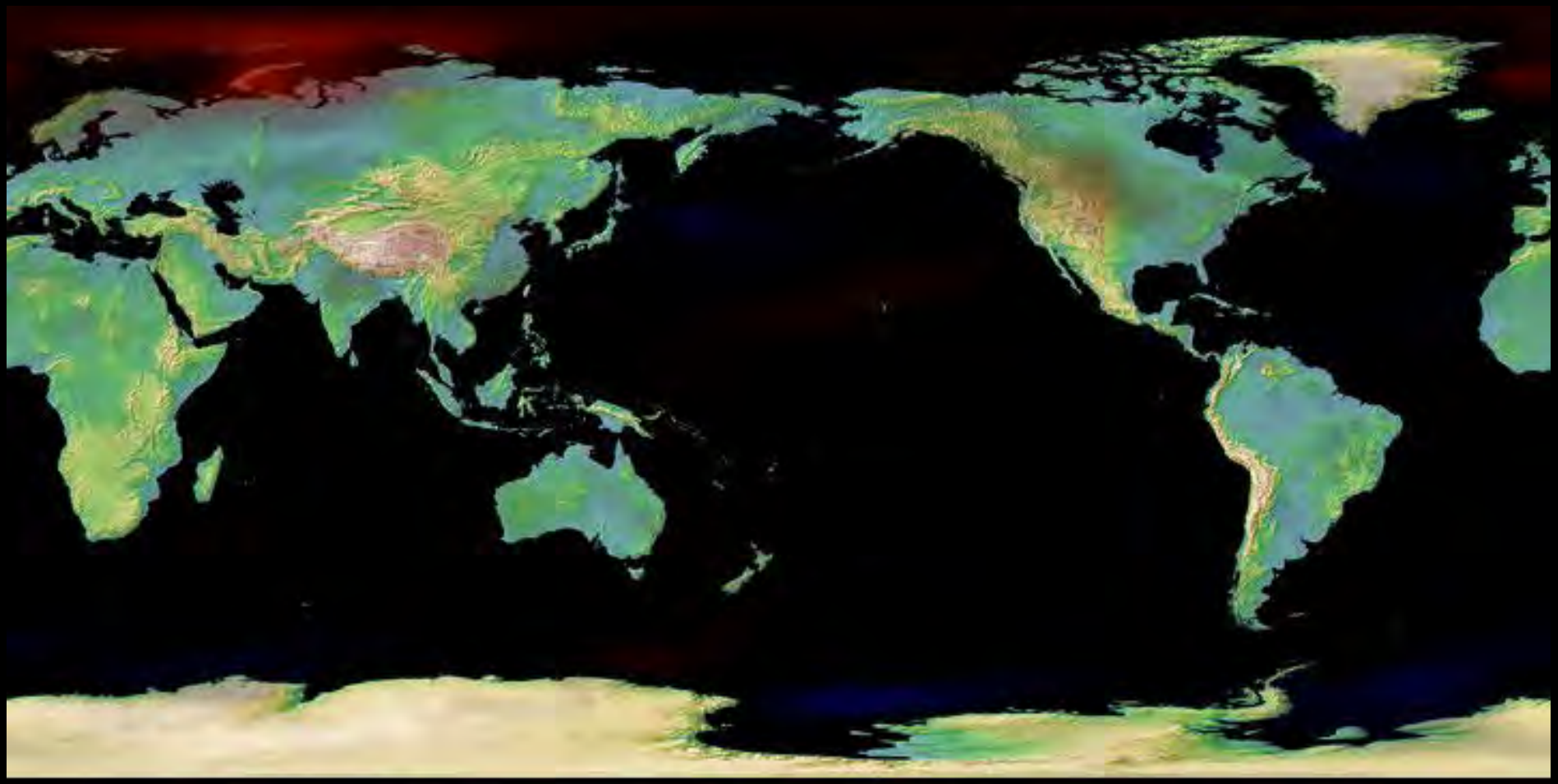
Eisschwund in der Arktis



Grafik: Dirk Notz, MPI Hamburg

Die Zukunft

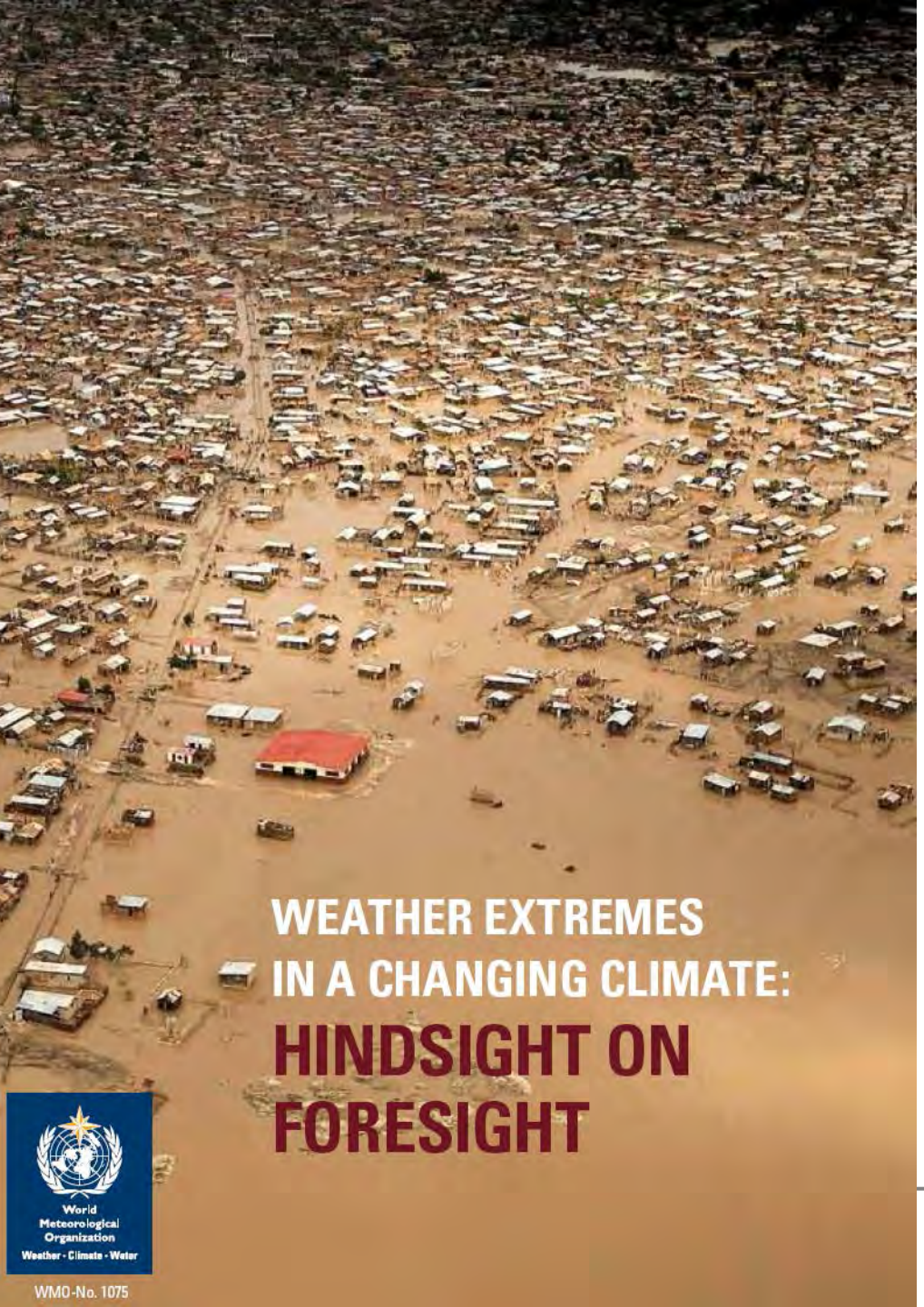

Warming relative to pre-industrial (°C)
0
1
2
3
4
5
6
7
8
1850
1900
1950
2000
2050
2100
2150
2200
2250
2300
RCP8.5
RCP3-PD
a Fossil CO_2
Emissions ($GtCO_2$/yr)
80
80
60
40
20
0
-20
RCP8.5
RCP3-PD
Schnellnhuber, PNAS (2012) based on Meinshausen et al. Clim. Change (2011).



1950

2m temperature change (A1B / MIROC-hi)

CCSR/NIES/FRCGC
MEXT RR2002



The decade 2001–2010 was the warmest ever recorded. The decade was marked by numerous weather and climate extremes, unique in strength and impact.

(WMO 2011)

Nature Climate Change, March 2012:

nature climate change

PERSPECTIVE

PUBLISHED ONLINE: 25 MARCH 2012 | DOI: 10.1038/NCLIMATE1452

A decade of weather extremes

Dim Coumou and Stefan Rahmstorf*

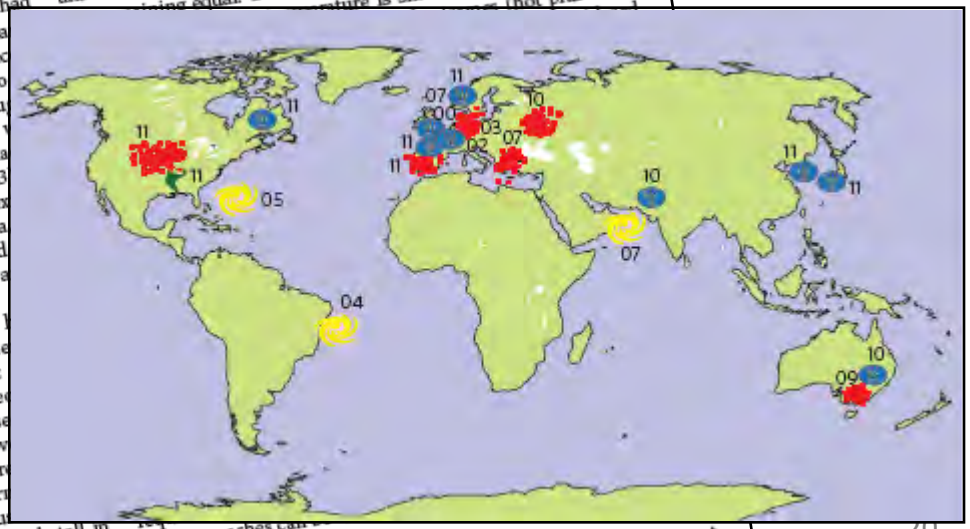
The ostensibly large number of recent extreme weather events has triggered intensive discussions, both in- and outside the scientific community, on whether they are related to global warming. Here, we review the evidence and argue that for some types of extreme — notably heatwaves, but also precipitation extremes — there is now strong evidence linking specific events or an increase in their numbers to the human influence on climate. For other types of extreme, such as storms, the available evidence is less conclusive, but based on observed trends and basic physical concepts it is nevertheless plausible to expect an increase.

For the United States, 2011 was a year of extreme weather, with 14 events that caused losses in excess of US$1 billion each[1]. The US National Oceanic and Atmospheric Administration spoke of "a year seemingly full of weather extremes" after July had set new monthly heat records for Texas, Oklahoma and Delawa The period from January to October was the wettest on rec for several northeastern states, with wet soils contributing to severe flooding when Hurricane Irene hit the region in Au During spring, the southern United States had been hit by the w recorded tornado outbreak in history: April saw 753 torna beating the previous monthly record of 542 (from May 2003 large margin[3]. Other regions in the world were affected by ex weather in 2011 as well: rainfall records were set in Australia and Korea, whereas the Yangtze Basin in China experienced drought[4]. In western Europe, spring was exceptionally hot a setting records in several countries (Table 1)[4].

But 2011 was not unique: the past decade as a whole h an exceptional number of unprecedented extreme weathe some causing major human suffering and economic (Table 1 and Fig. 1). In August 2010, the World Mete Organization issued a statement on the "unprecedented se extreme weather events", stating that it "matches Intergov Panel on Climate Change (IPCC) projections of more fr more intense extreme weather events due to global warm Moscow heatwave and Pakistan flooding that year illu destructive extreme weather can be to societies: the death toll in estimated at 11,000 and drought caused grain- government to ban wheat flooding in

Simple physical considerations

For some types of extreme, there are simple physical reasons why they would increase in a warming climate. If the average temperature rises, then obviously so will the number of heat records, all ...ing equal. Cold extremes will decrease, but if the prob- ...ature is shifted unchanged towards ... (hot plus cold)



ling approaches can ...

Statistics and the detection problem

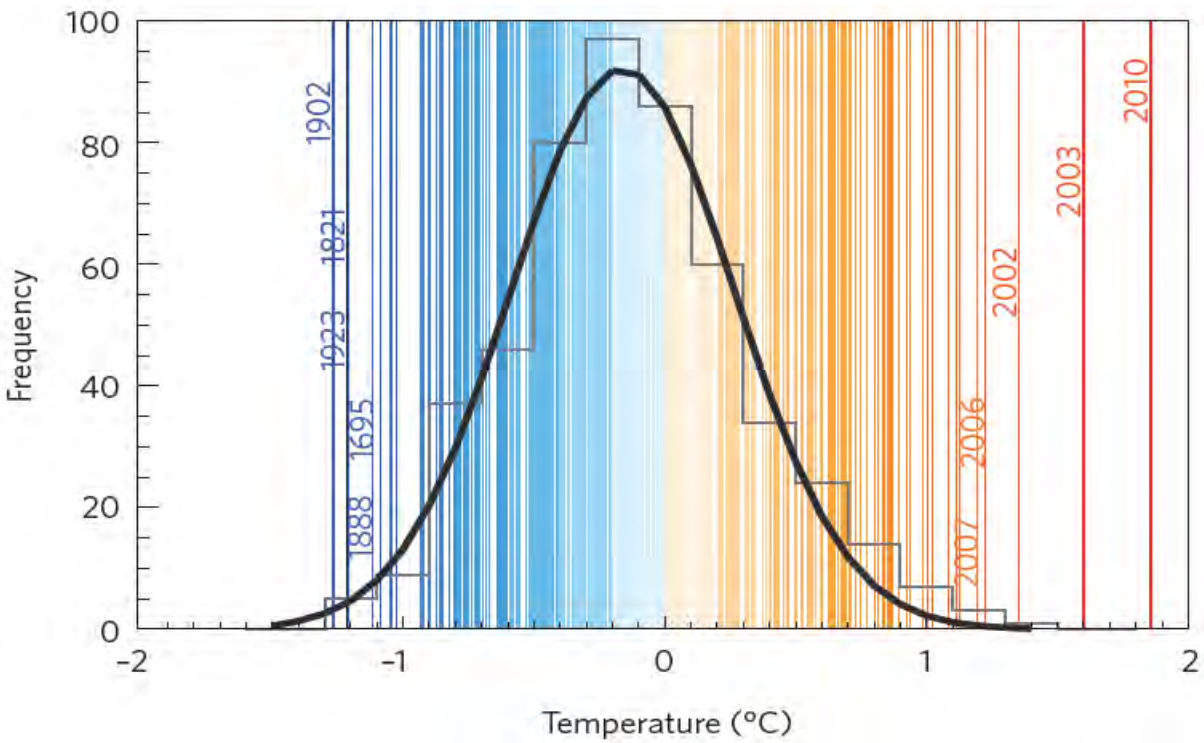
...statistics, scientists can analyse whether the number of recent ...ifcantly larger than expected in a stationary ... methods thus may link

P I K

Einige nie dagewesene Extreme seit 2000

Region (Year)	Meteorological Record-breaking Event	Confidence in attribution to climate change	Impact, costs
England and Wales (2000)	Wettest autumn on record since 1766. Several short-term rainfall records[2]	Medium based on[3–5]	~£1.3 billion[3]
Europe (2003)	hottest summer in at least 500 years[6]	High based on[7,8]	Death toll exceeding 70,000[9]
England and Wales (2007)	May to July wettest since records began in 1766[10]	Medium based on[3,4]	Major flooding causing ~£3 billion damage
Southern Europe (2007)	Hottest summer on record in Greece since 1891[11]	Medium based on[8,12–14]	Devastating wildfires
Eastern Mediterranean, Middle-East (2008)	Driest winter since 1902 (see Fig. 20)	High based on[15]	Substantial damage to cereal production[16]
Victoria (Aus) (2009)	Heat wave, many station temperature records (32–154 years of data)[17]	Medium based on[8,14]	Worst bushfires on record, 173 deaths, 3,500 houses destroyed[17]
Western Russia (2010)	Hottest summer since 1500[18]	Medium based on[8,13,14,19]	500 wildfires around Moscow, crop failure of ~25%, death toll ~55,000, ~US$15B economic losses[18]
Pakistan (2010)	Rainfall records[20]	Low to Medium based on[21,22]	Worst flooding in its history, nearly 3000 deaths, affected 20M people[23].
Colombia (2010)	Heaviest rains since records started in 1969[26]	Low to Medium based on[21]	47 deaths, 80 missing[26]
Western Amazon (2010)	Drought, record low water level in Rio Negro[27]	Low[27]	Area with significantly increased tree mortality spanning3.2 million km[27]
Western Europe (2011)	Hottest and driest spring on record in France since 1880[28]	Medium based on[8,14,29]	French grain harvest down by 12%
4 US states (TX, OK, NM, LA) (2011)	Record-breaking summer heat and drought since 1880[30,31]	High based on[13,14,31,32]	Wildfires burning 3 million acres (preliminary impact of $6 to $8 billion)[33]
Continental U.S. (2012)	July warmest month on record since 1895[34] and severe drought conditions	Medium based on[13,14,32]	Abrupt global food price increase due to crop losses[35]

Hitzewellen



Verteilung der Europäischen Sommertemperaturen
AD 1500 - 2010

Barriopedro et al. Science 2011

Alex Aminev, Reuters

Die heißesten Sommer in Europa seit AD 1500:

2010

2003

2002

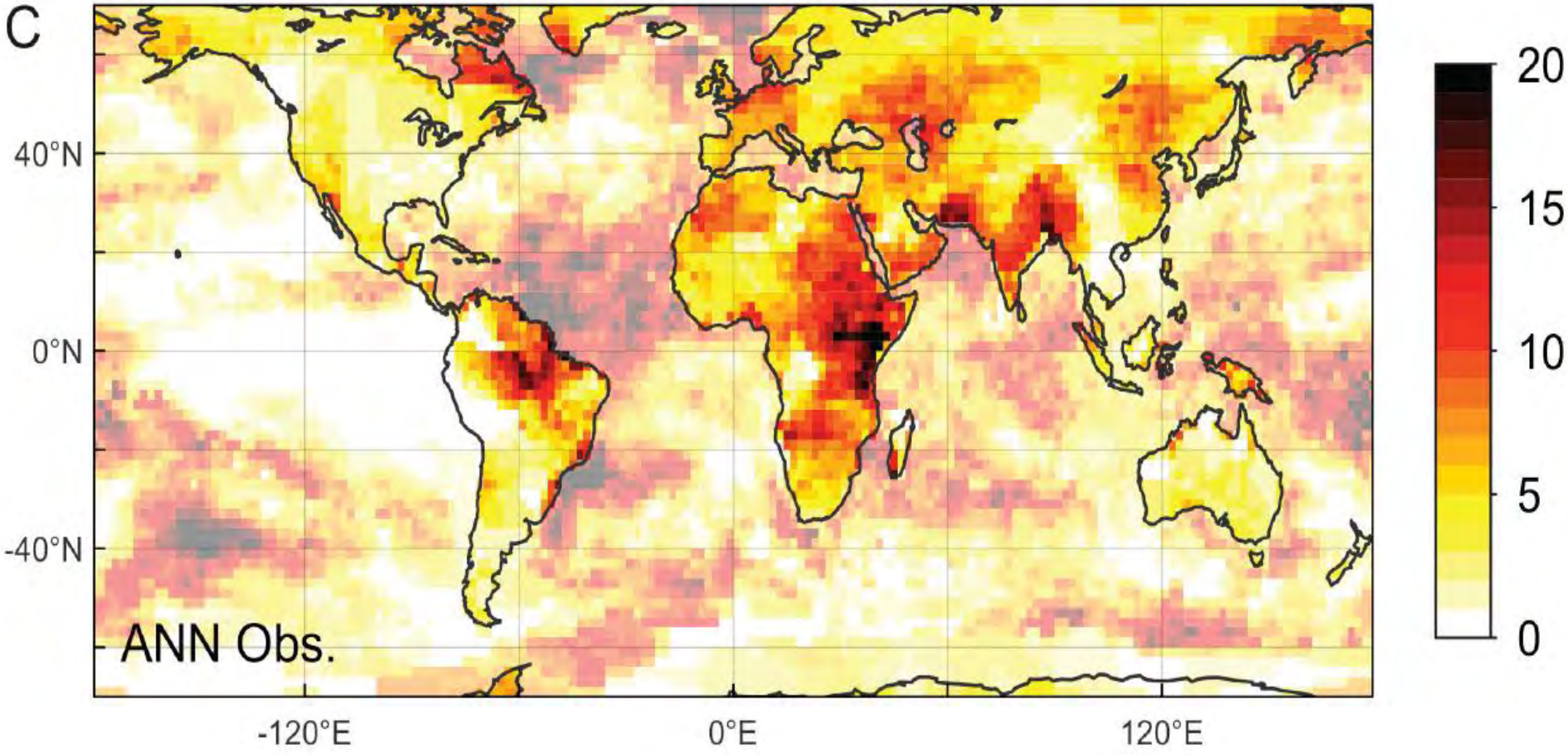
2006

2007

P I K

Wärmerekorde nehmen weltweit zu

- Globale Daten: 150.000 Zeitreihen
- 131 Jahre Daten (ab 1880), Monatsmittelwerte
- Globaler Mittelwert: 5-fach erhöhte Zahl der Rekorde



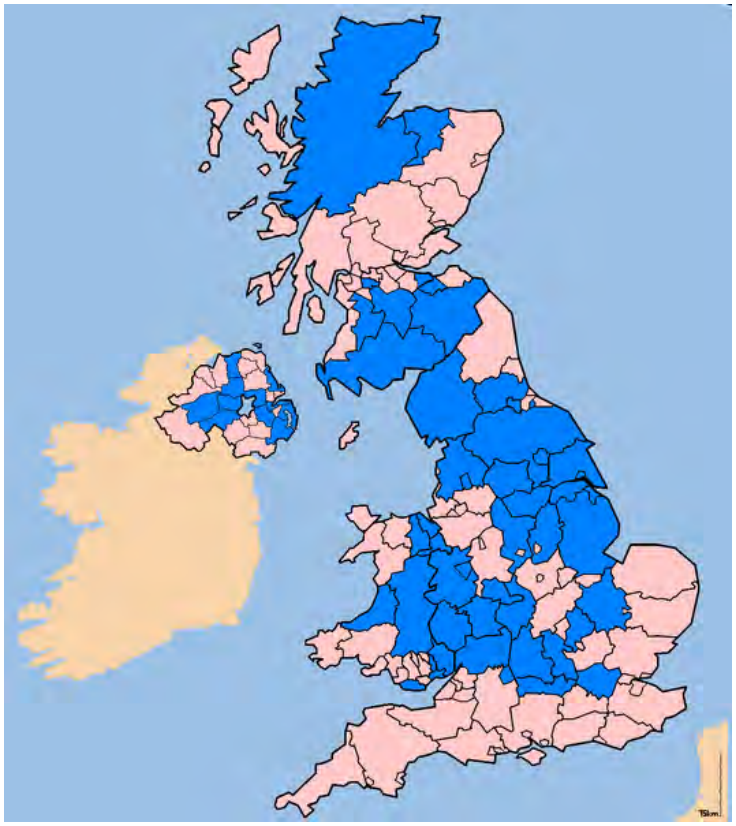
Elbeflut 2002

- Aug 2002: höchste je in Deutschland gemessene Tagesmenge Regen

- Schäden rund $3 Milliarden in Tschechien, $9 Milliarden in Deutschland.
- Höchster Stand der Elbe seit Beginn der Aufzeichnungen im Jahr 1275

Hochwasser in Großbritannien 2007

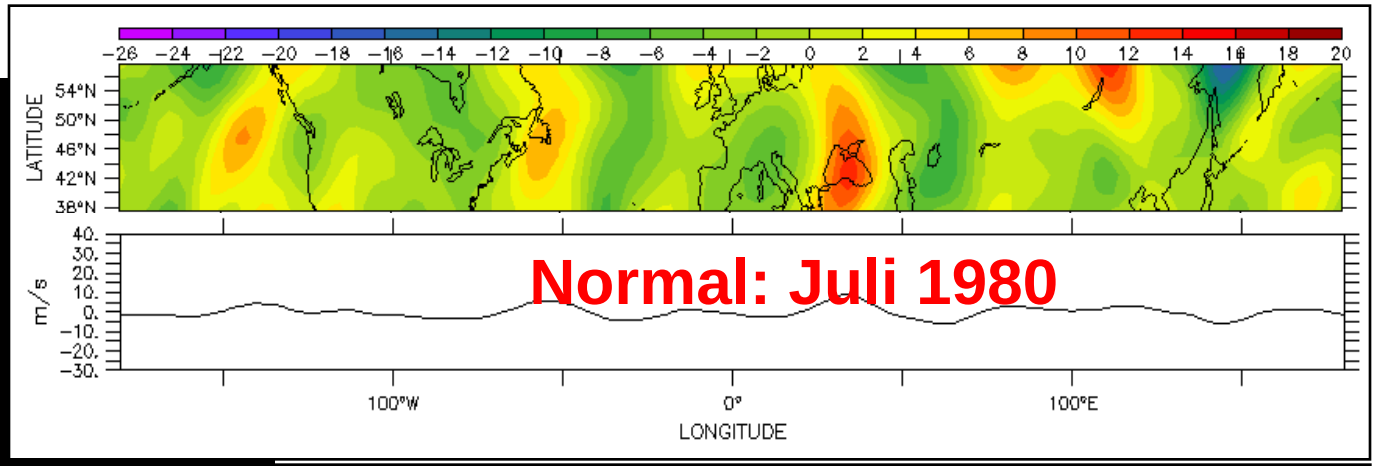
- **Mai bis Juli in England und Wales am regenreichsten seit 1766**

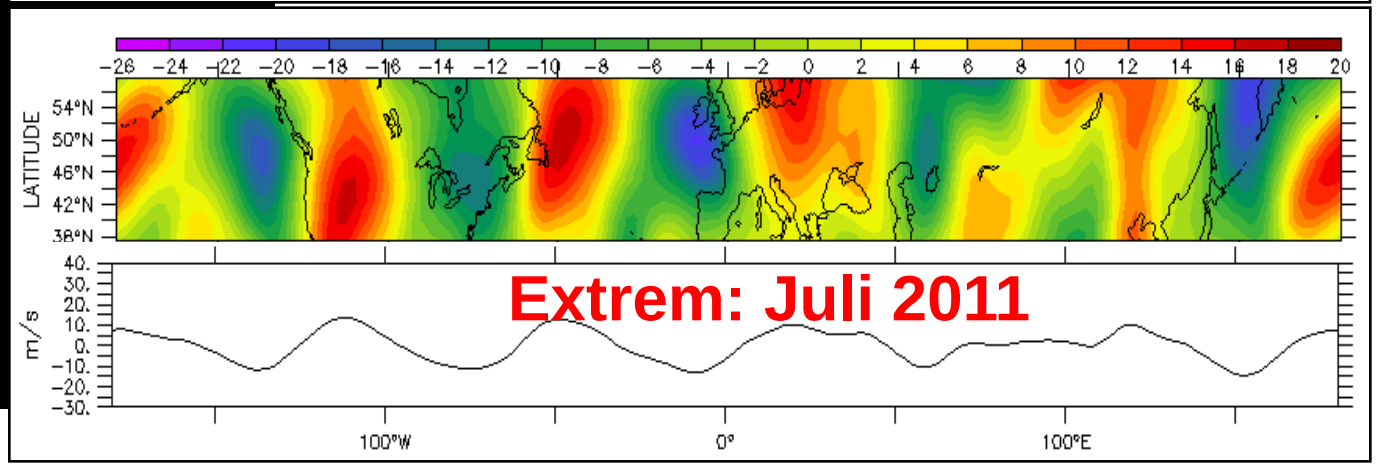


Betroffene Gebiete

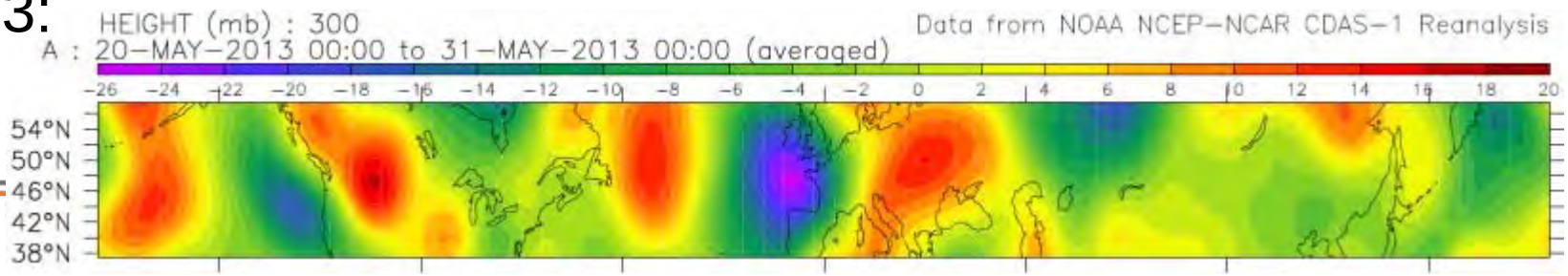
- **Große Ernteausfälle**
- **Schadenshöhe: £3 Milliarden**

Extreme durch planetare Wellen?

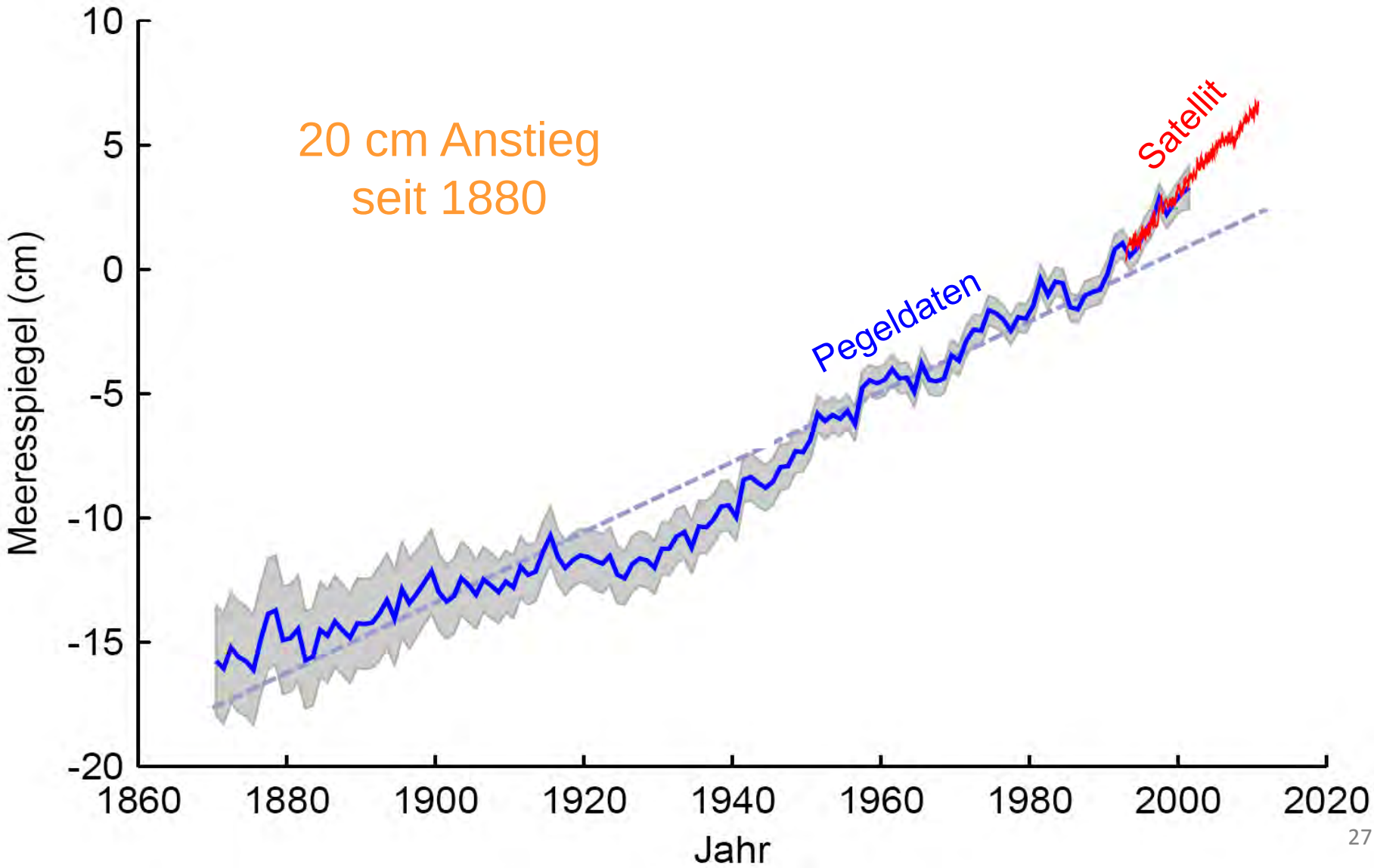




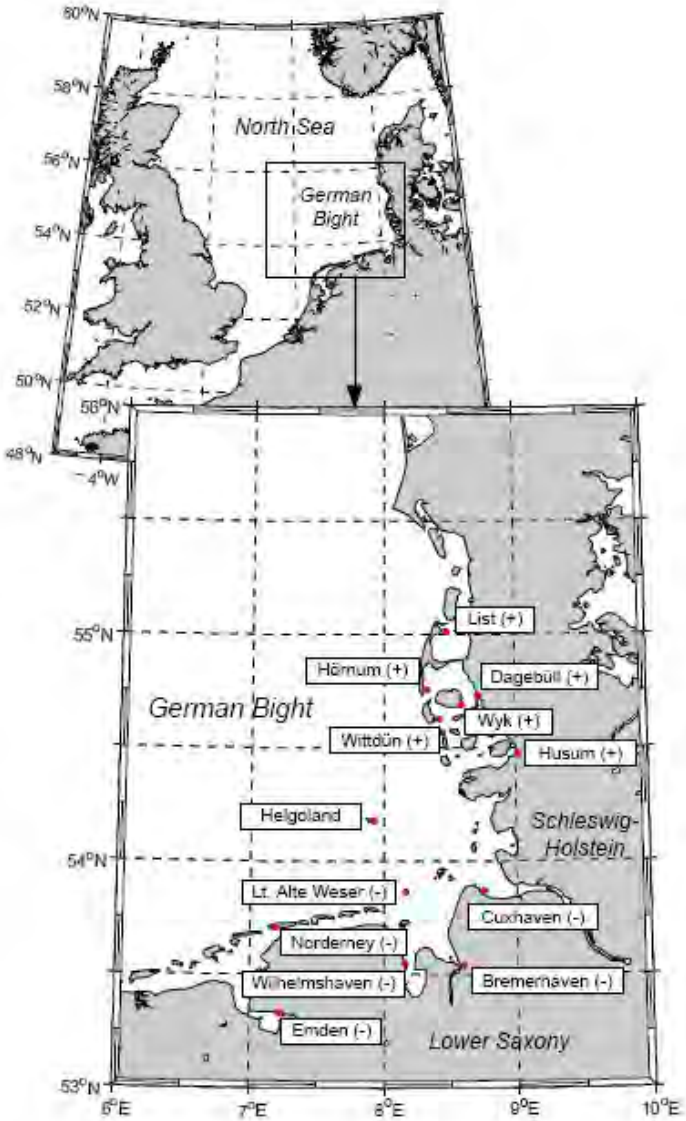
Mai 2013:

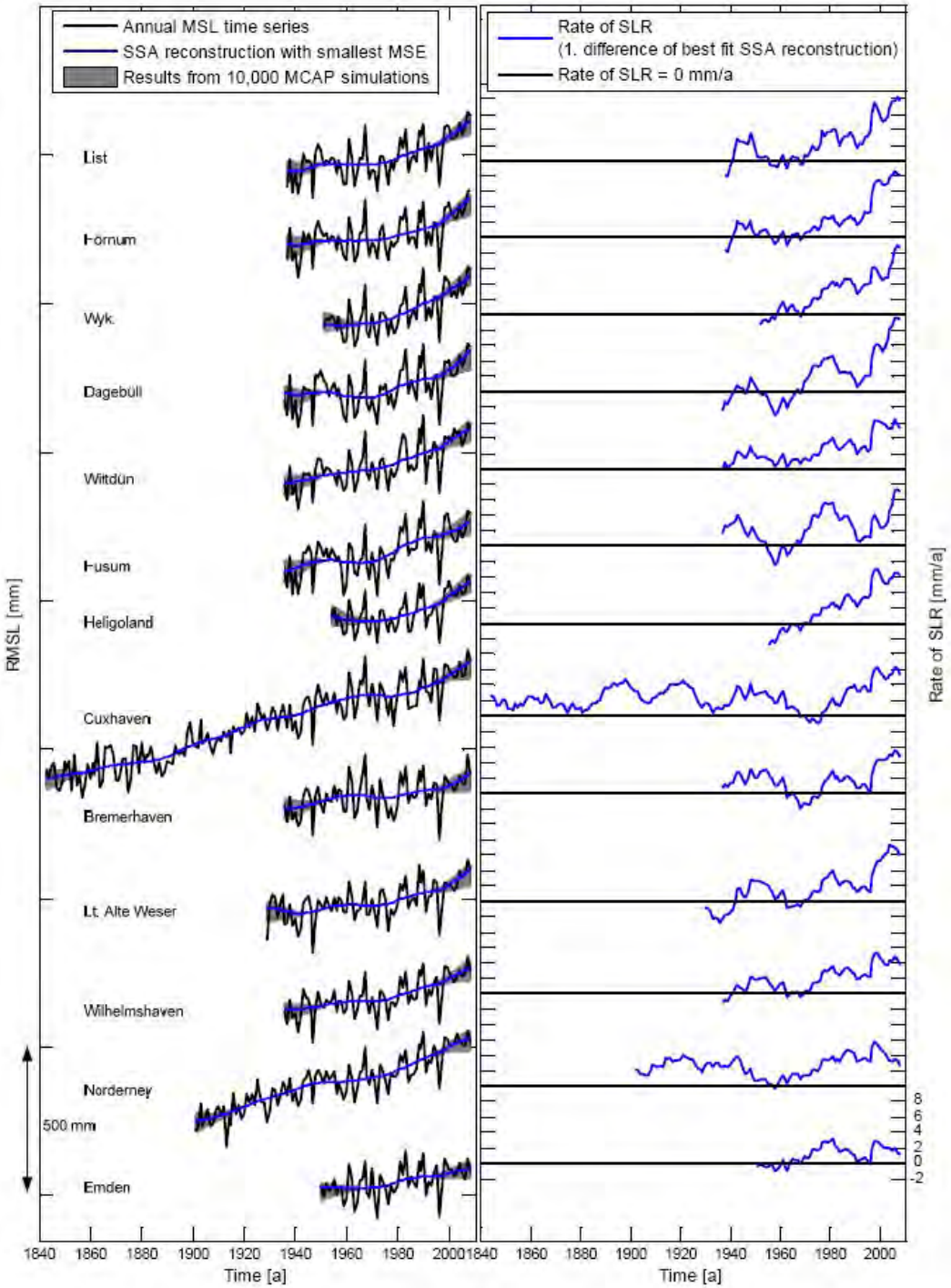


Anstieg des Meeresspiegels



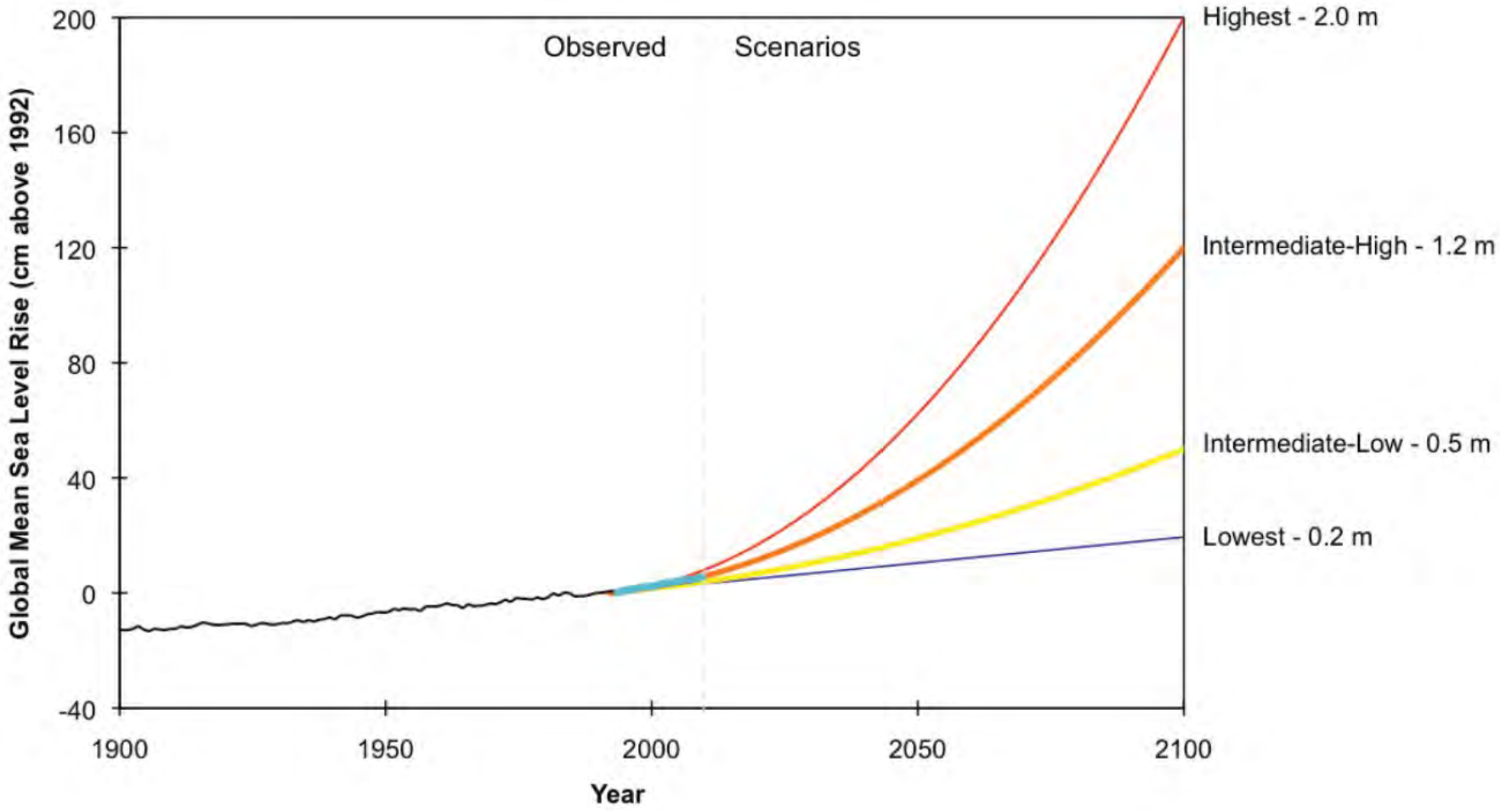
Deutsche Bucht





Wahl et al. 2011

Aktuelle Meeresspiegel-Projektionen



Global Sea Level Rise Scenarios for the
United States National Climate Assessment, NOAA (2012)

Acqua Alta, Venice, November 2010 (photo ©SR)

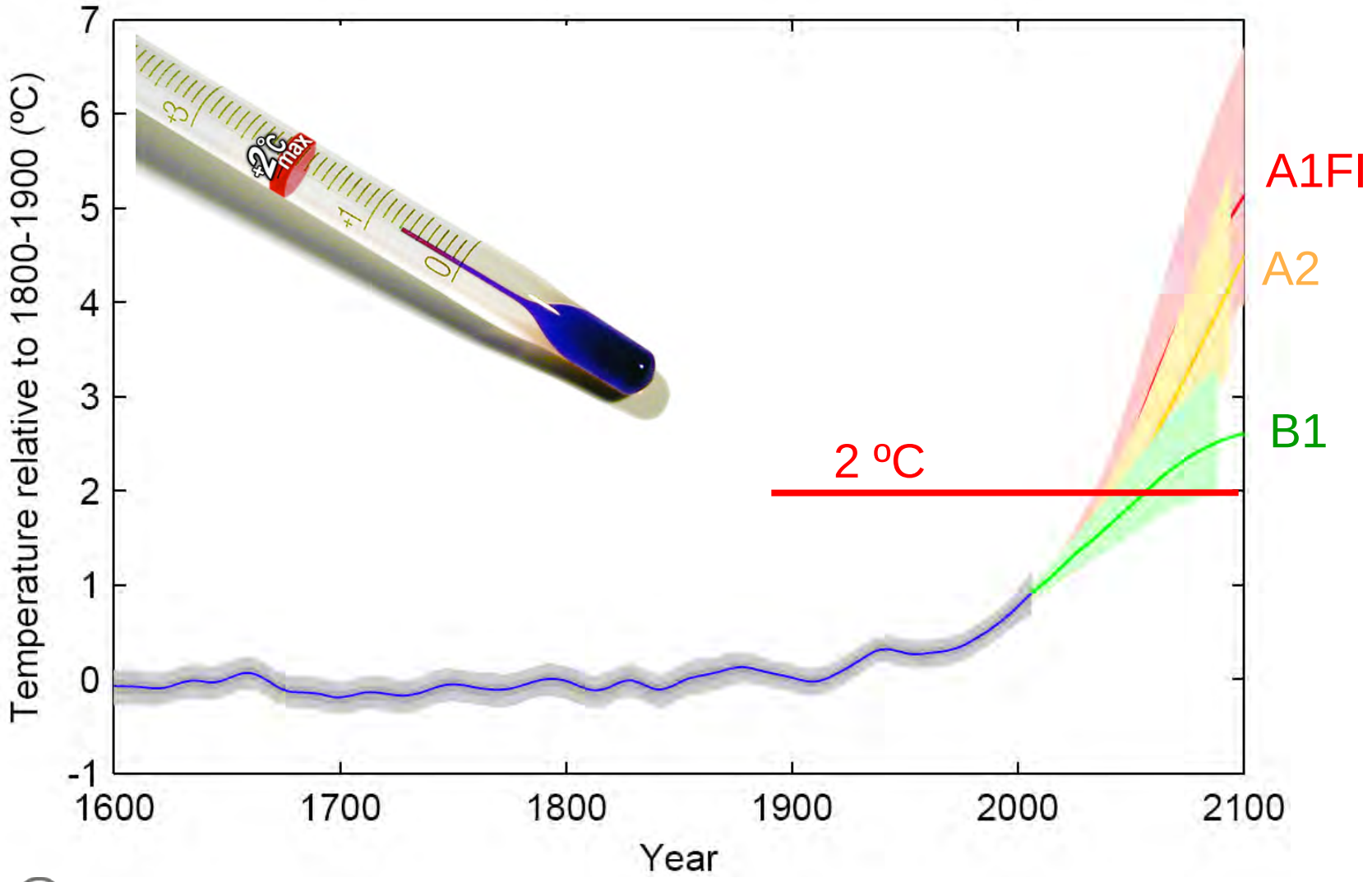
Künftige Extreme in Deutschland

- Fast sicher: mehr und intensivere Hitzewellen
- Wahrscheinlich: mehr Gewitter (Blitz, Hagel, Starkregen)
- Wahrscheinlich: mehr Hochwasser an Flüssen
- Wahrscheinlich: langfristig wachsende Sturmflutgefahr an der Küste durch steigenden Meeresspiegel
- Möglich: starke Schneefälle
- Noch unklar: Veränderungen bei Stürmen

- Im Netz: www.klimafolgenonline.com
- Aber: regionale Prognosen und insbesondere solche über Extreme sind unsicher!
- Betrachtung als Risiko ist nötig – wir verlassen durch den Klimawandel den Raum vergangener Erfahrungen

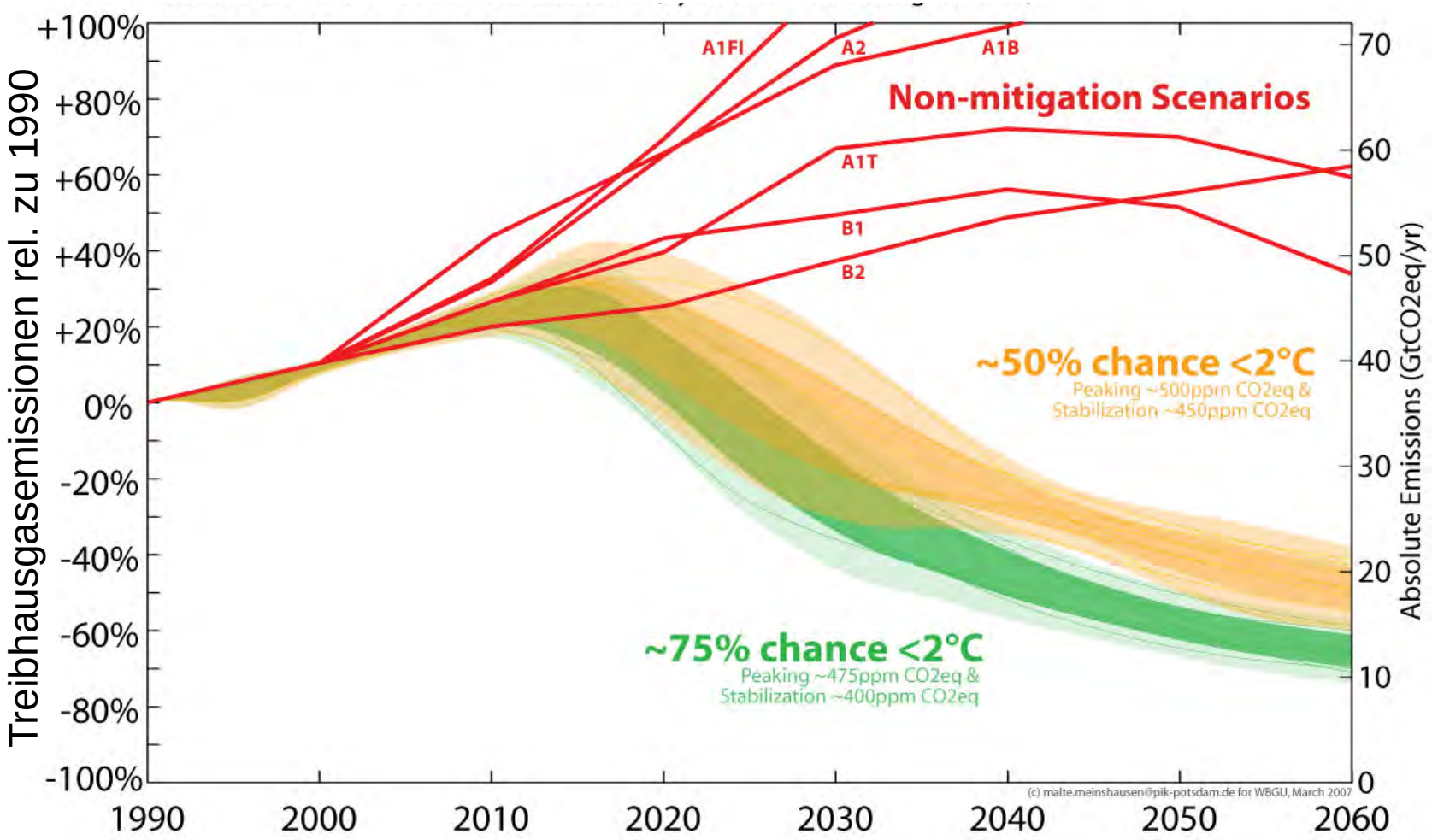
Graffiti by Banksy (photo: Romany WG)

Klimapolitik: die 2º- Leitplanke



Wettlauf gegen die Zeit

Globale Treibhausgasemissionen



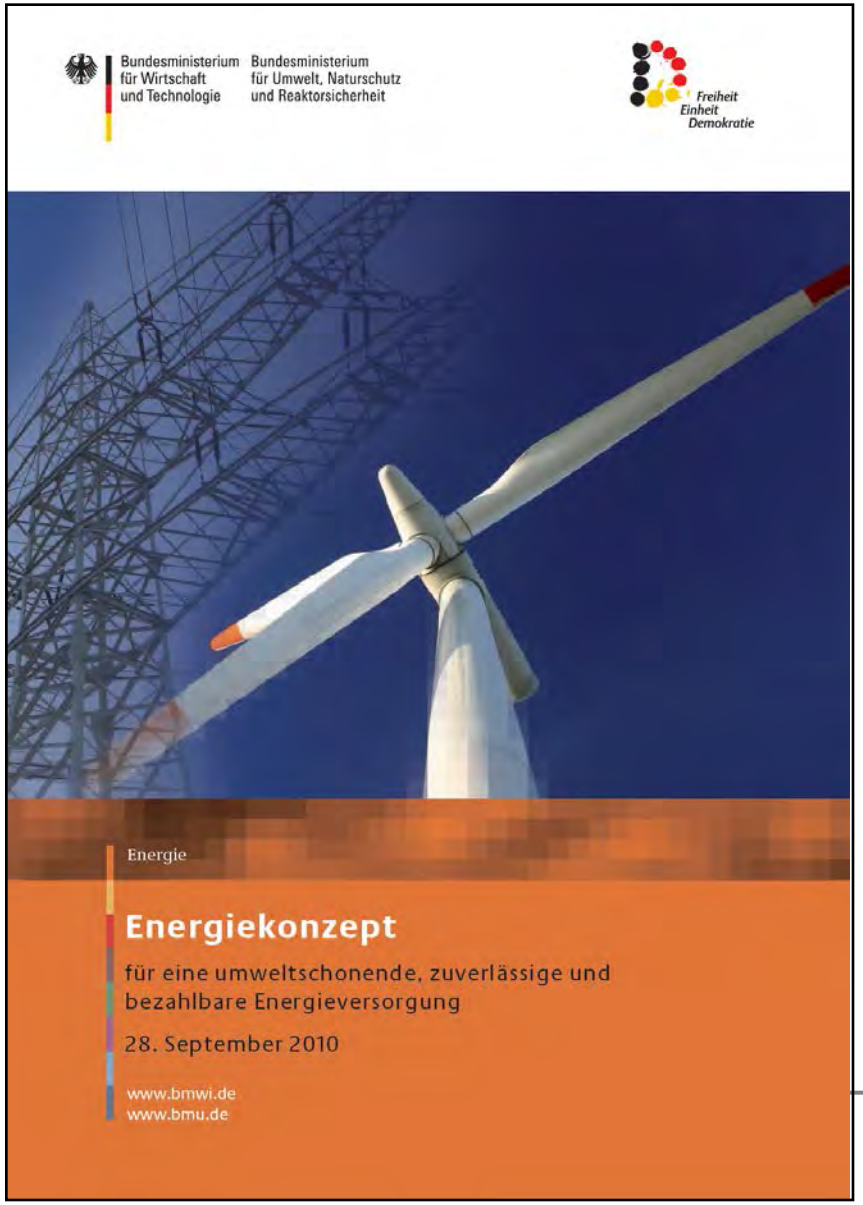
Grafik: Malte Meinshausen, PIK

Wie schaffen wir die Transformation?

- **Begrenzung der Erwärmung auf 2ºC ist technologisch möglich**
- **Es gibt dazu viele Wege mit unterschiedlichem Technologiemix**
- **Die Kosten sind moderat – wenige Prozent des GDP**
- **Die Erwärmung *nicht* auf 2ºC zu begrenzen wird viel teurer**
- **Verzögerung wird teuer**
- **Aktuelle Investitionen und Entschlossenheit der Politik reichen nicht aus**
- **Die jetzt nötigen Investitionen zahlen sich später (bis 2050) aus**

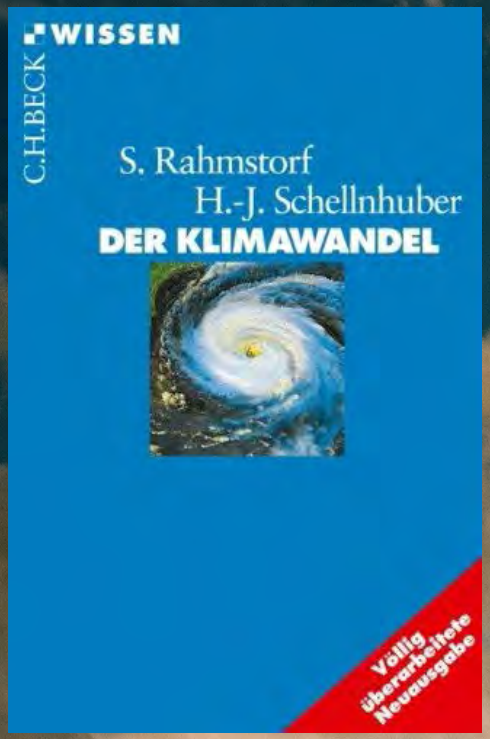
Download oder hardcopy: www.wbgu.de

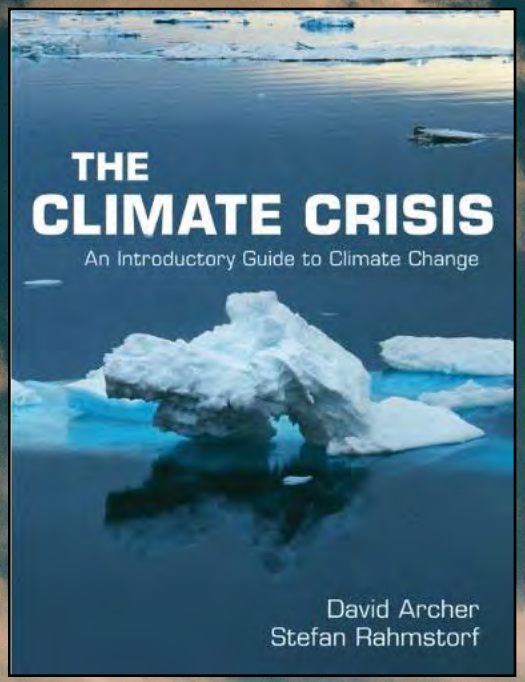
Energiekonzept der Bundesregierung



- **Ein Drittel der CO2-Emissionen stammen aus dem Gebäudebereich**
- **Deshalb: Energetische Gebäudesanierung und energieeffizientes Bauen**
- **Sanierungsfahrplan für Gebäude im Bestand: von 2020 bis 2050 Minderung des Primärenergiebedarfs um 80 Prozent**
- **Klimaneutrale Neubauten**

Danke für Ihr Interesse!





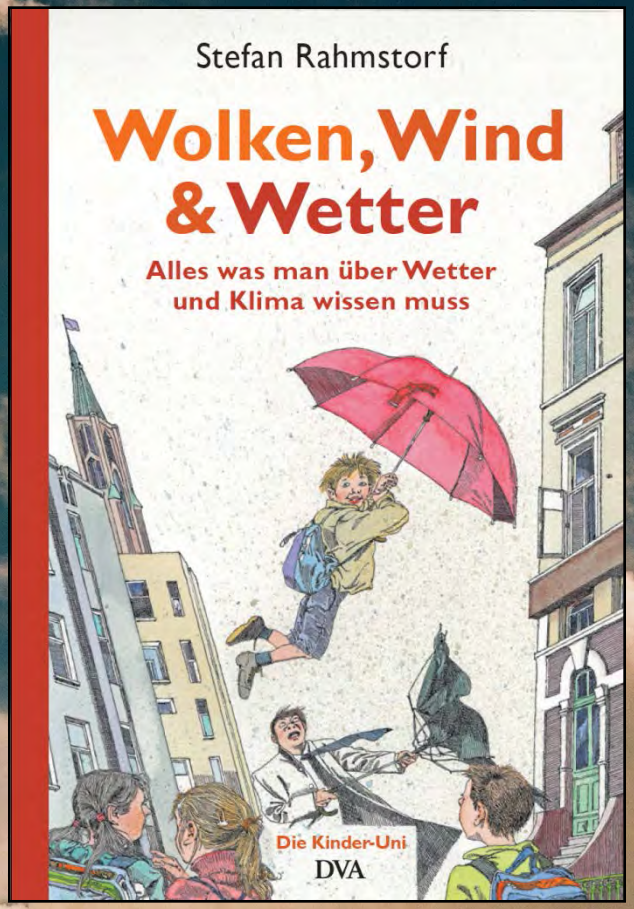


Foto: S. Rahmstorf