



Kipppunkte im Klimasystem

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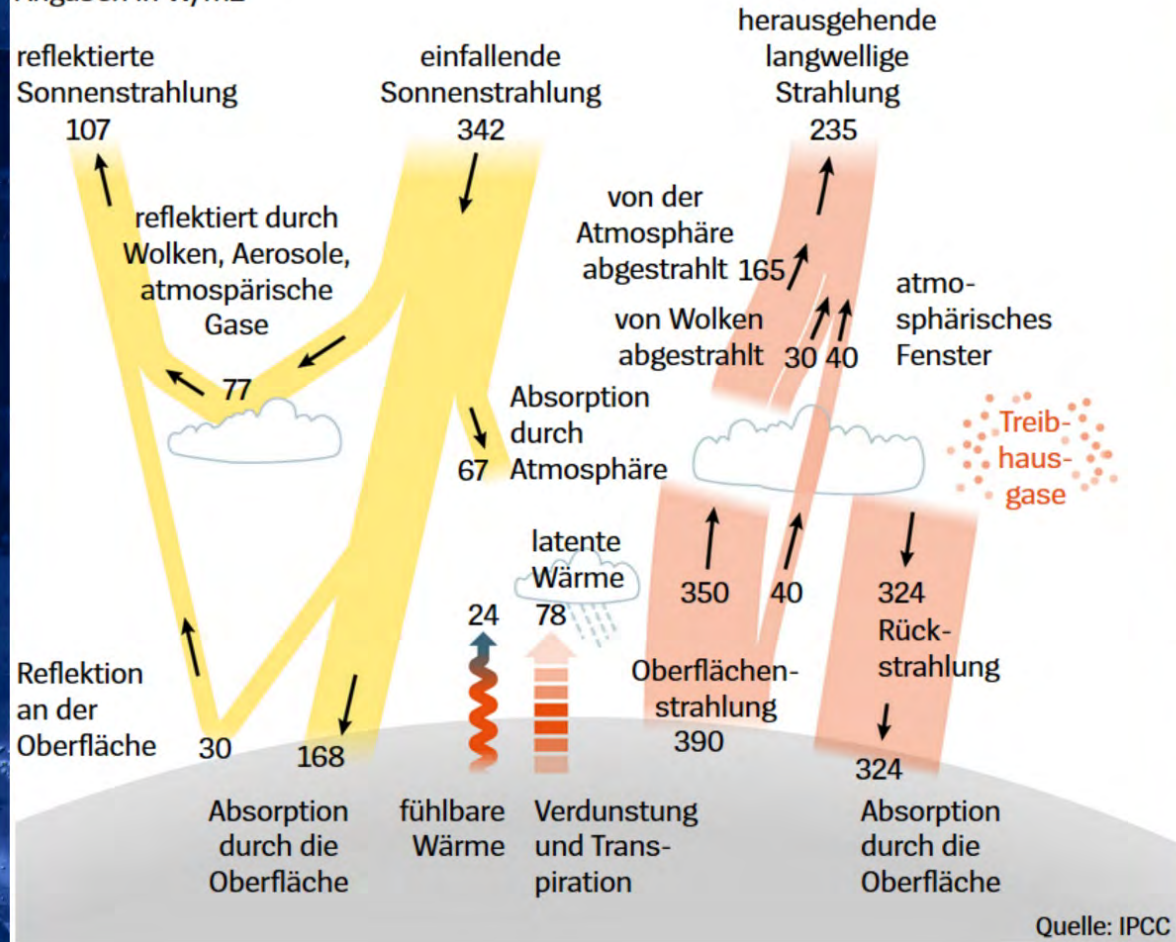
Der Mensch verändert das Klima „durch Fällen der Wälder [...] und durch die Entwicklung großer Dampf- und Gasmassen an den Mittelpunkten der Industrie“.

Alexander von Humboldt, 1843

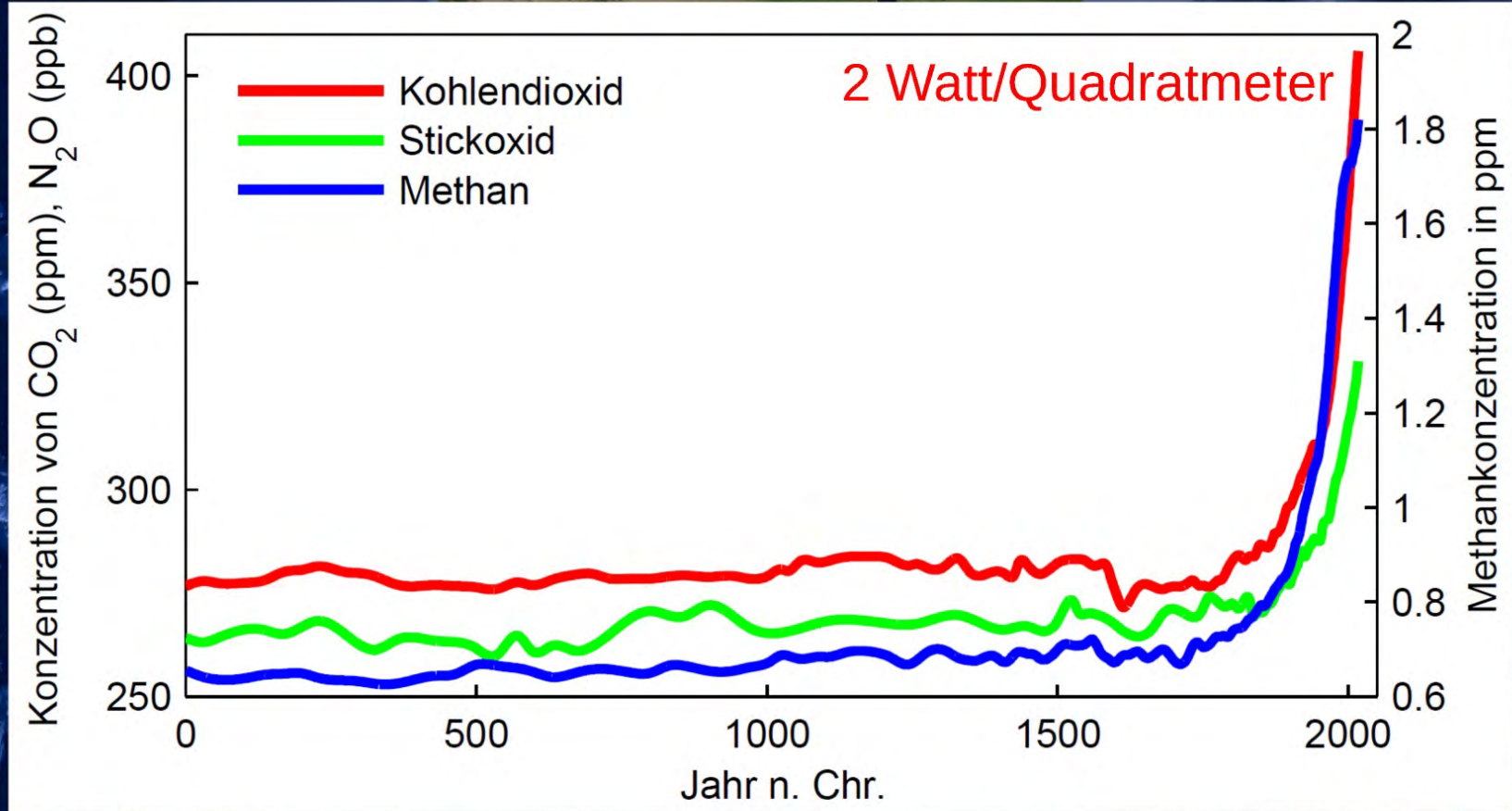


Fragiles Gleichgewicht

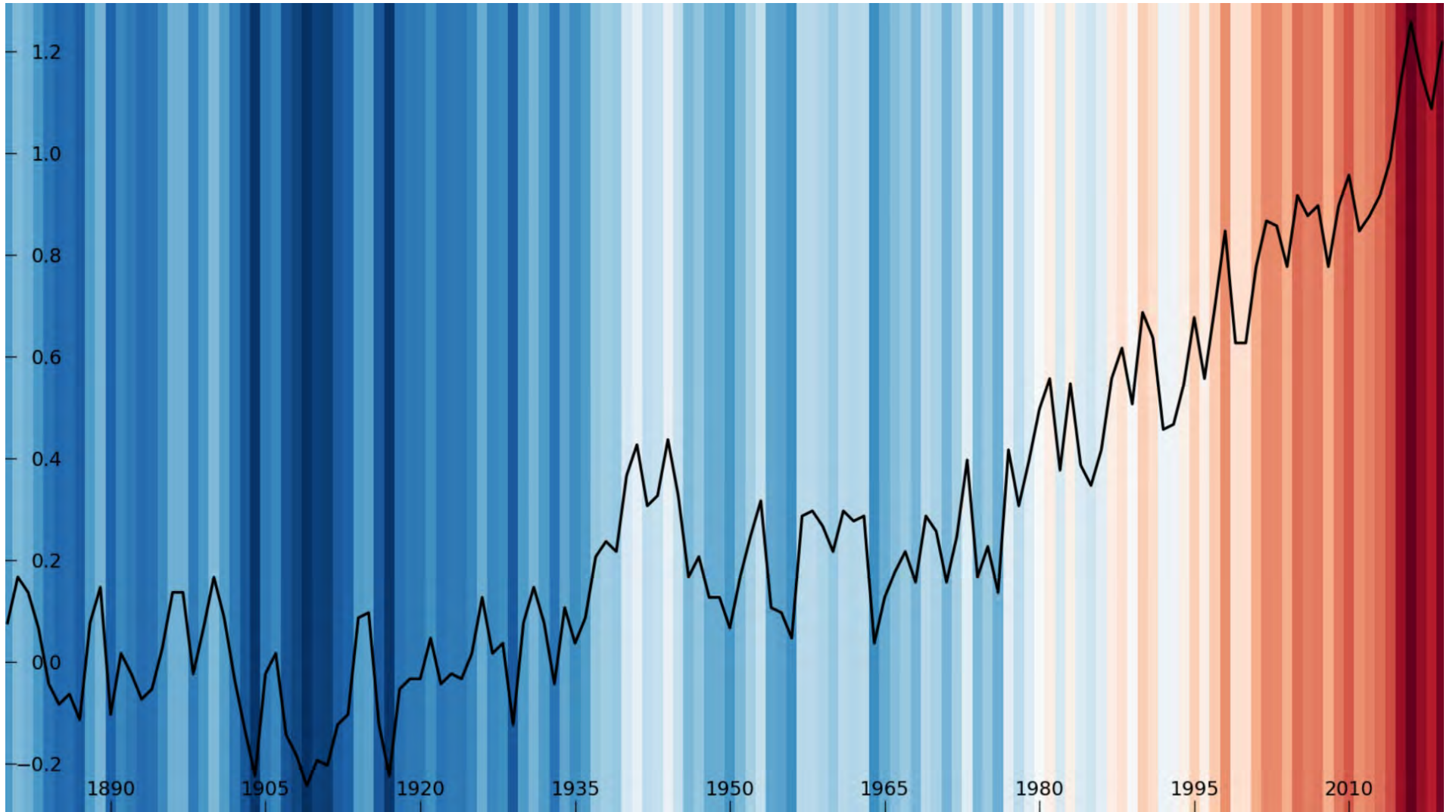
Die Energiebilanz der Erde
Angaben in W/m²



Treibhausgasmengen in der Atmosphäre

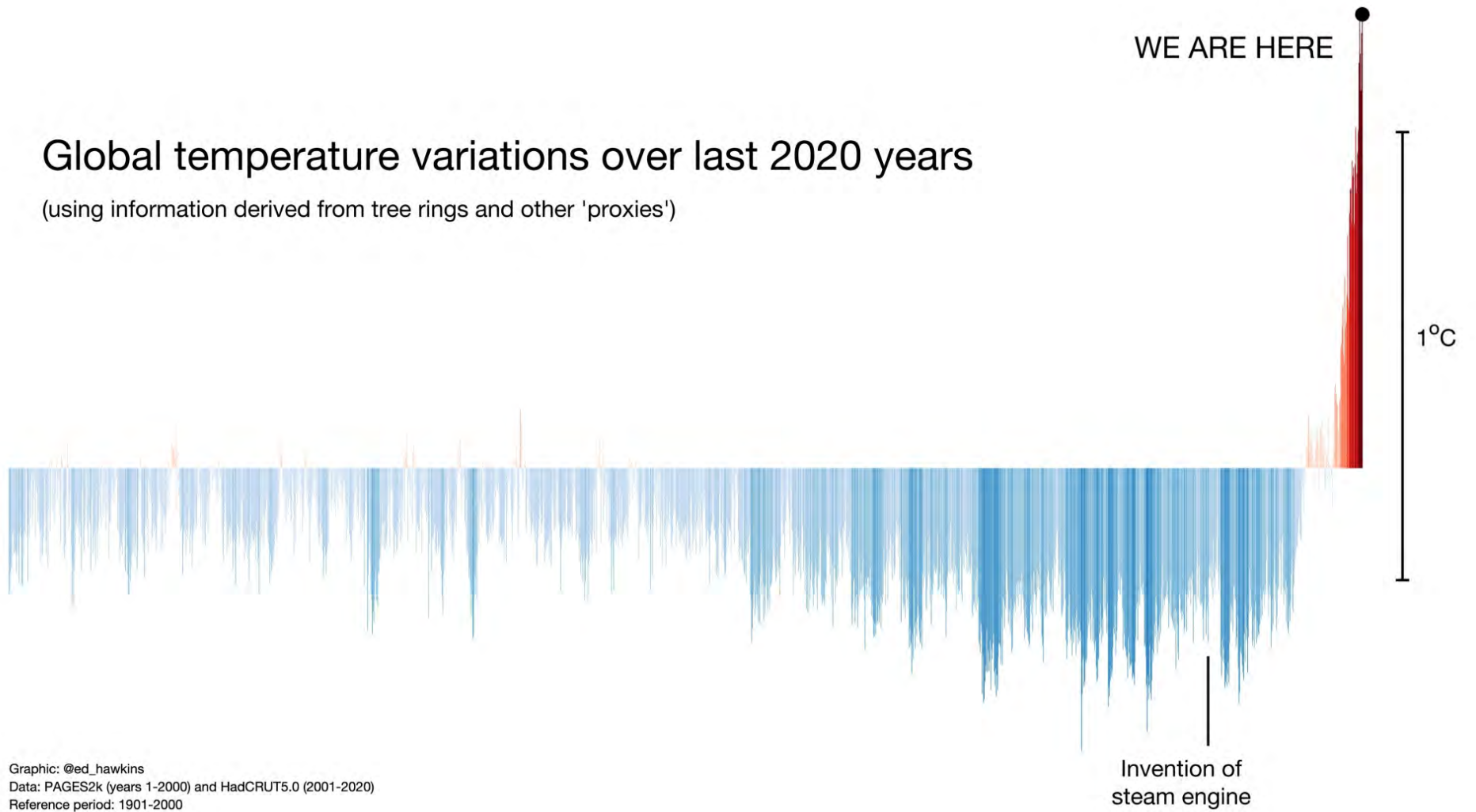


Quelle: Rahmstorf/Schellnhuber, *Der Klimawandel*

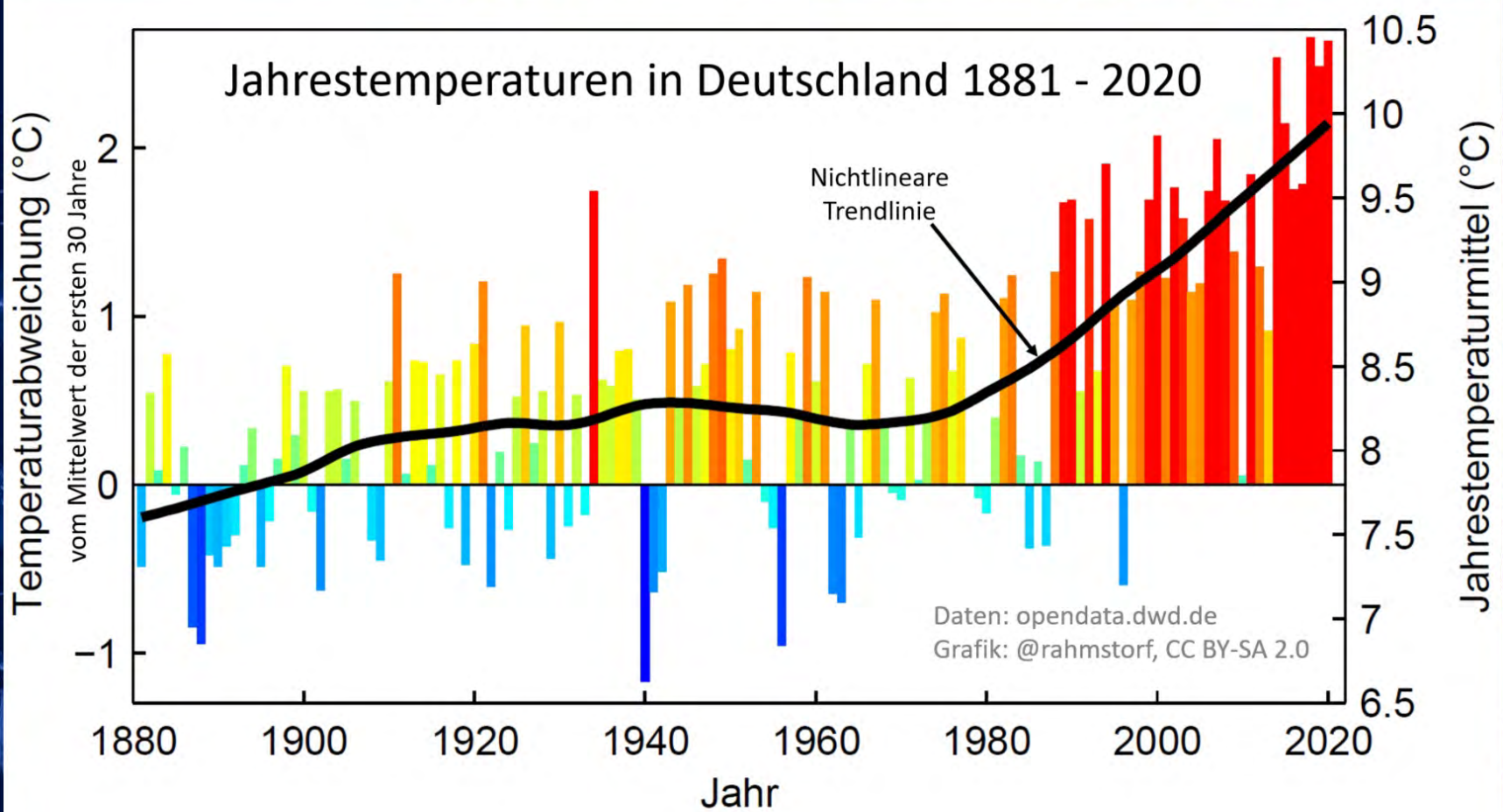


Global temperature variations over last 2020 years

(using information derived from tree rings and other 'proxies')

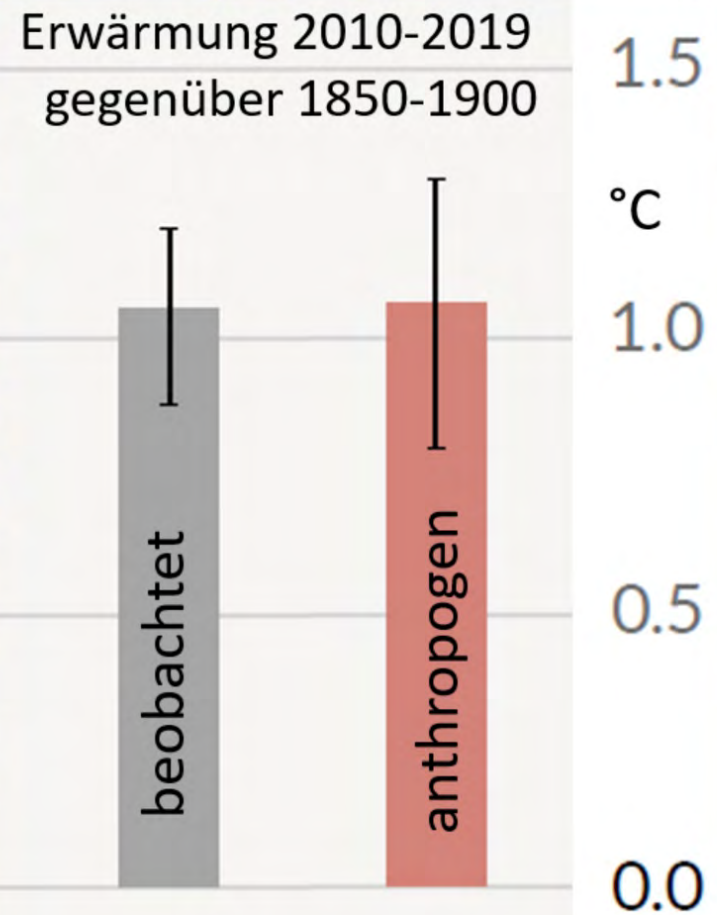


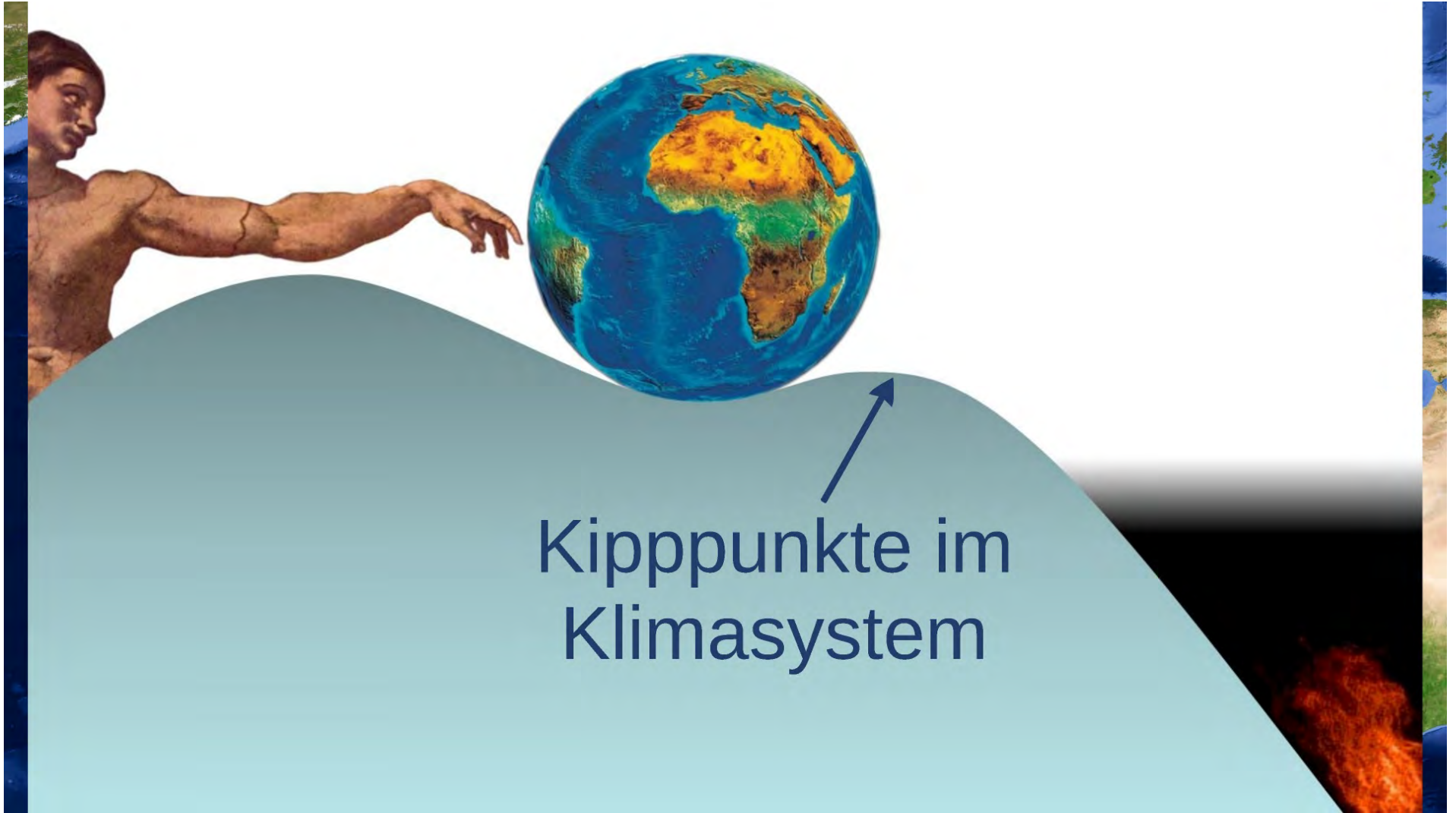
Graphic: @ed_hawkins
Data: PAGES2k (years 1-2000) and HadCRUT5.0 (2001-2020)
Reference period: 1901-2000



Die moderne
Erwärmung ist
komplett
menschengemacht!

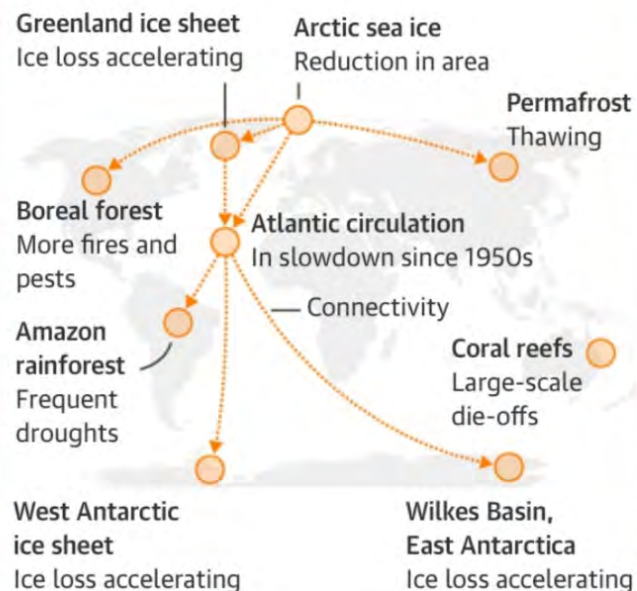
Quelle:
IPCC 2021





Kipppunkte im Klimasystem

Scientists' warning: a cascade of climate tipping points is possible



Guardian graphic. Source: Lenton et al, Nature, 2019

Climate tipping points – too risky to bet against

Timothy M. Lenton, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen & Hans Joachim Schellnhuber

The growing threat of abrupt and irreversible climate changes must compel political and economic action on emissions.

assuming that climate tipping points are of very low probability (even if they would be catastrophic), have suggested that 3 °C warming is optimal from a cost-benefit perspective. However, if tipping points are looking more likely, then the 'optimal policy' recommendation of simple cost-benefit climate-economy models⁴ aligns with those of the recent IPCC report². In other words, warming must be limited to 1.5 °C. This requires an emergency

Nature, 2019

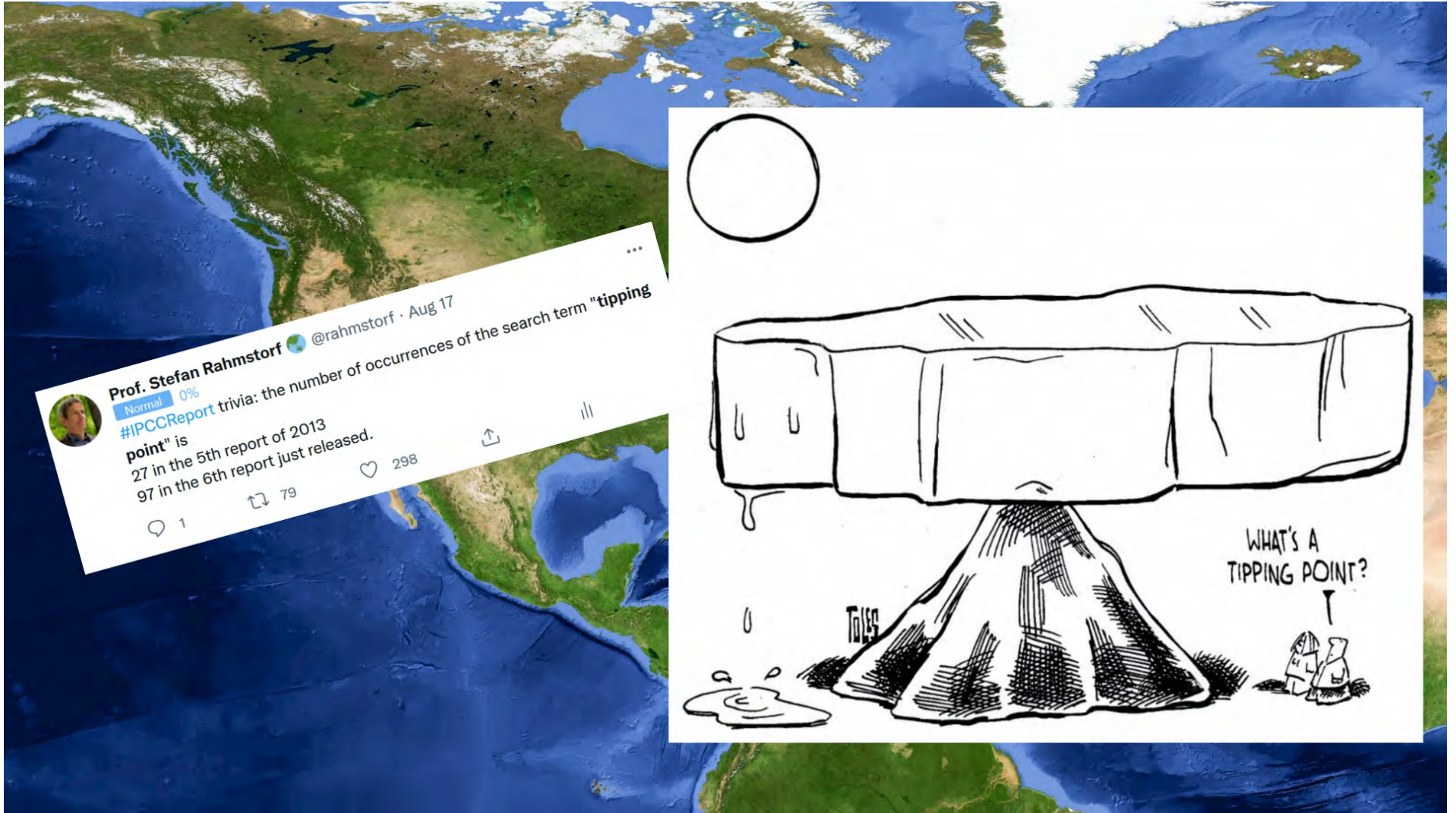






Korallenriffe





Tipping elements in the Earth's climate system

Timothy M. Lenton^{**†}, Hermann Held[‡], Elmar Kriegler[§], Jim W. Hall[¶], Wolfgang Lucht[‡], Stefan Rahmstorf[‡], and Hans Joachim Schellnhuber^{†‡**}

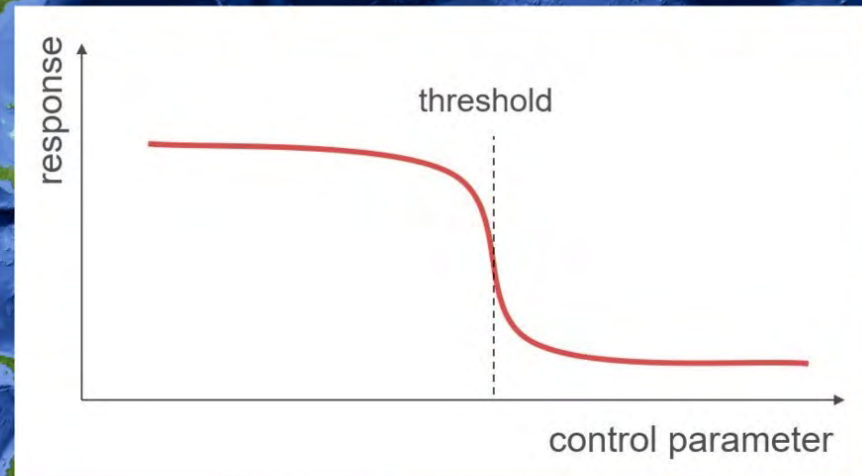
^{*}School of Environmental Sciences, University of East Anglia, and Tyndall Centre for Climate Change Research, Norwich NR4 7TJ, United Kingdom; [†]Potsdam Institute for Climate Impact Research, P.O. Box 60 12 03, 14412 Potsdam, Germany; [‡]Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213-3890; [§]School of Civil Engineering and Geosciences, Newcastle University, and Tyndall Centre for Climate Change Research, Newcastle NE1 7RU, United Kingdom; and [¶]Environmental Change Institute, Oxford University, and Tyndall Centre for Climate Change Research, Oxford OX1 3QY, United Kingdom

******This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected on May 3, 2005.

Edited by William C. Clark, Harvard University, Cambridge, MA, and approved November 21, 2007 (received for review June 8, 2007)

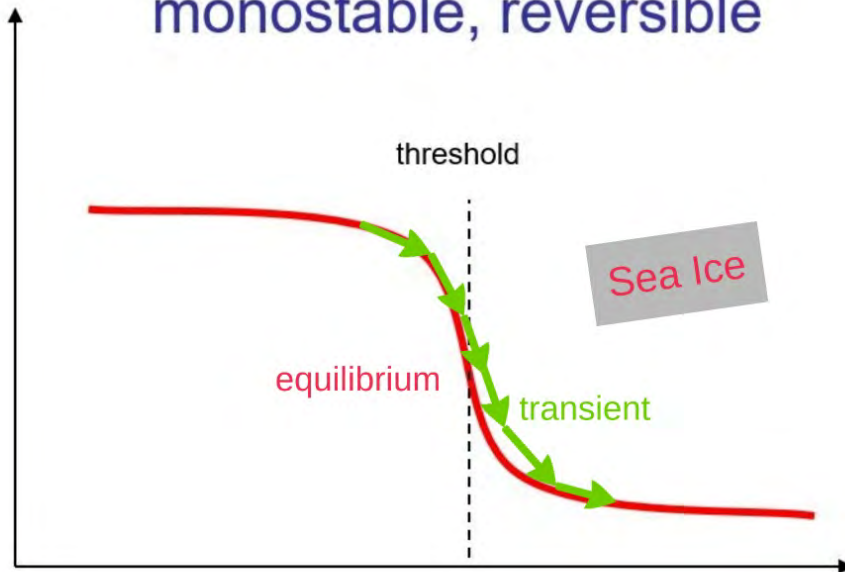
The term "tipping point" commonly refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system. Here we introduce the term "tipping element" to describe large-scale components of the Earth system that may pass a tipping point. We critically evaluate potential policy-relevant tipping elements in the climate system under anthropogenic forcing, drawing on the pertinent literature and a recent international workshop to compile a short list, and we assess where their tipping points lie. An expert elicitation is used to help rank their sensitivity to global warming and the uncertainty about the underlying physical mechanisms. Then we explain how, in principle, early warning systems could be established to detect the proximity of some tipping points.

Earth system | tipping points | climate change | large-scale impacts | climate policy

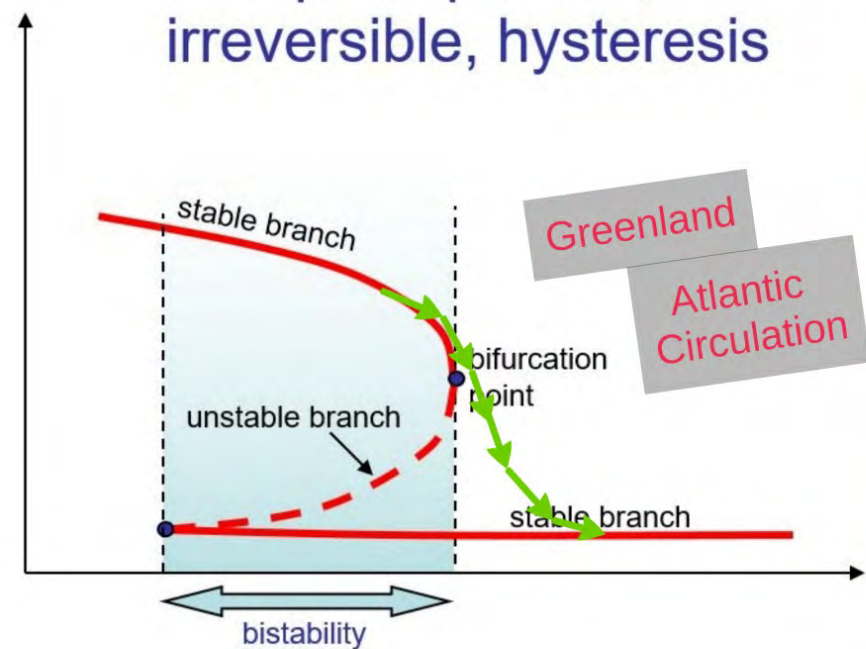


Zwei Typen von Kippunkten

monostable, reversible



multiple equilibria,
irreversible, hysteresis



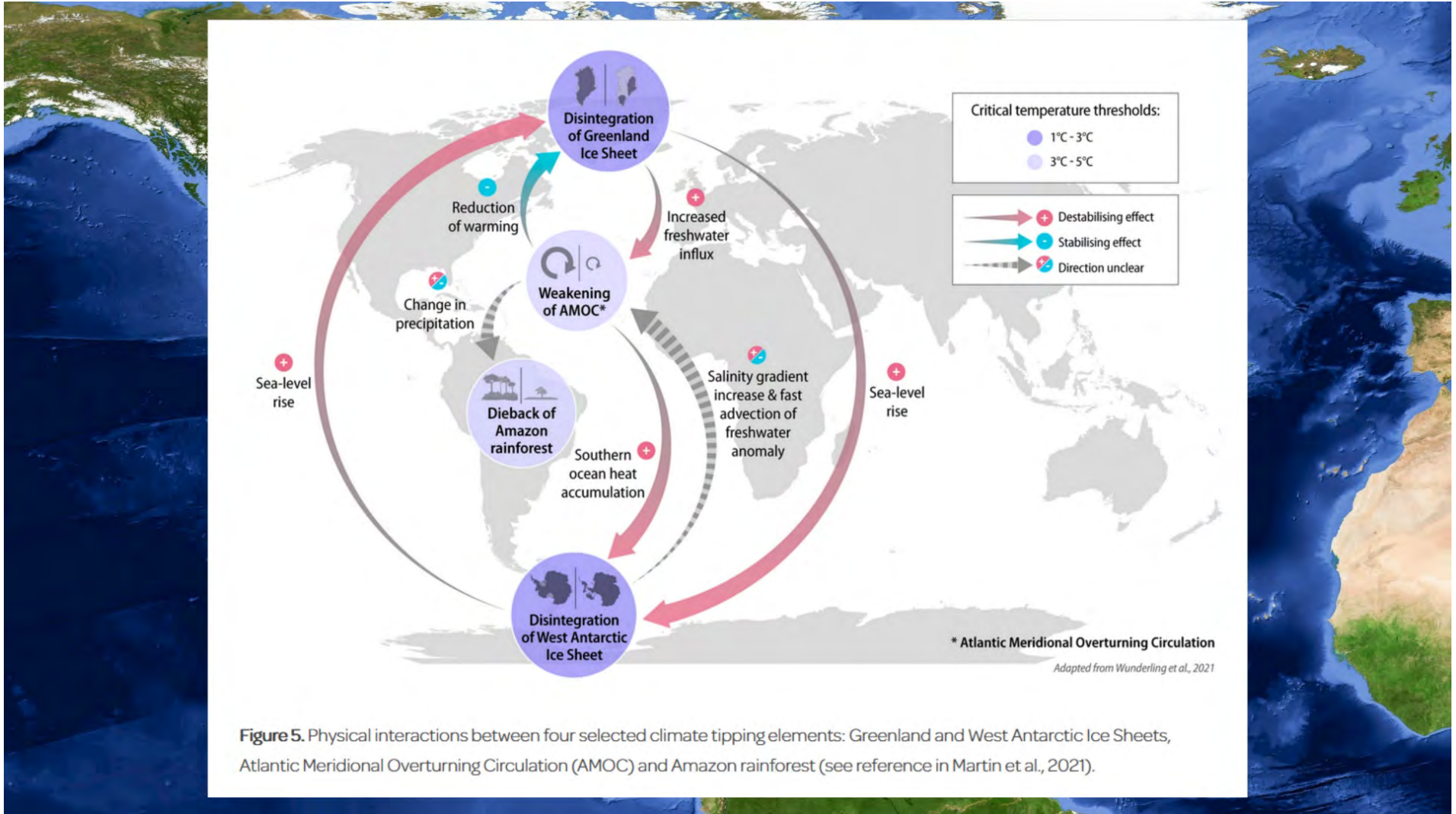


Figure 5. Physical interactions between four selected climate tipping elements: Greenland and West Antarctic Ice Sheets, Atlantic Meridional Overturning Circulation (AMOC) and Amazon rainforest (see reference in Martin et al., 2021).



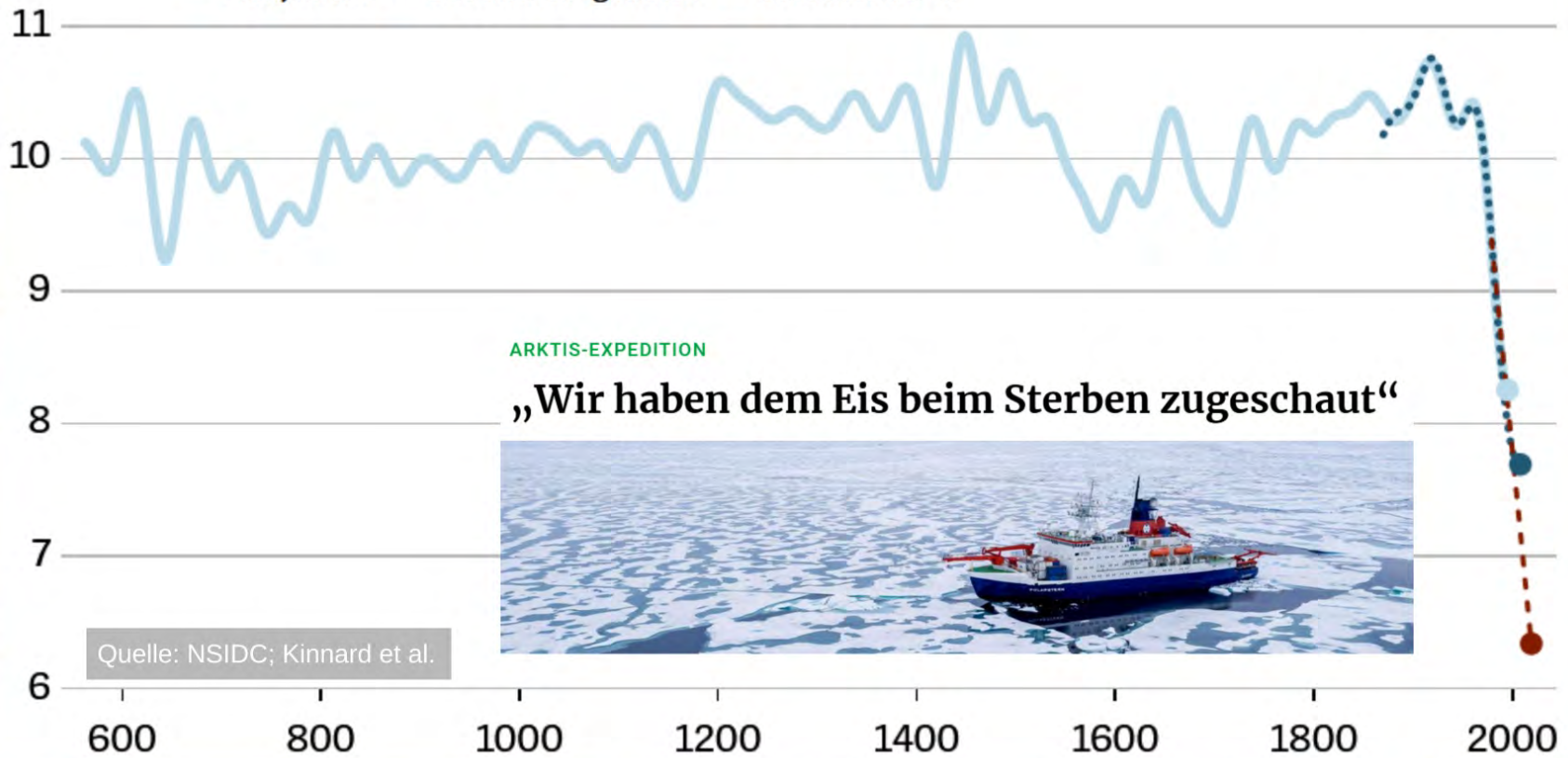




Arktische Meereisdecke im Spätsommer

Angabe in Millionen Quadratkilometern über die vergangenen 1450 Jahre

— Proxydaten ··· Beobachtungsdaten - - - Satellitentrend



ARKTIS-EXPEDITION

„Wir haben dem Eis beim Sterben zugeschaut“

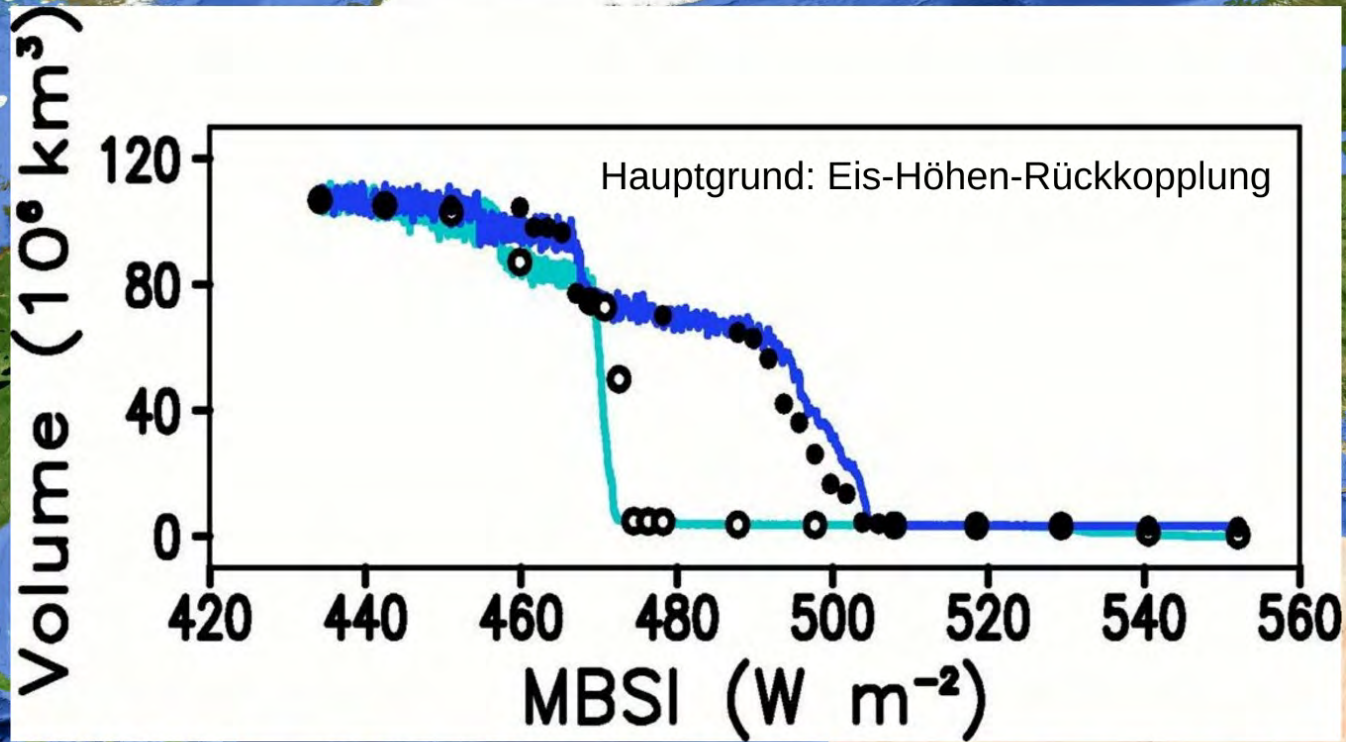


Quelle: NSIDC; Kinnard et al.

Das Grönlandeis schmilzt

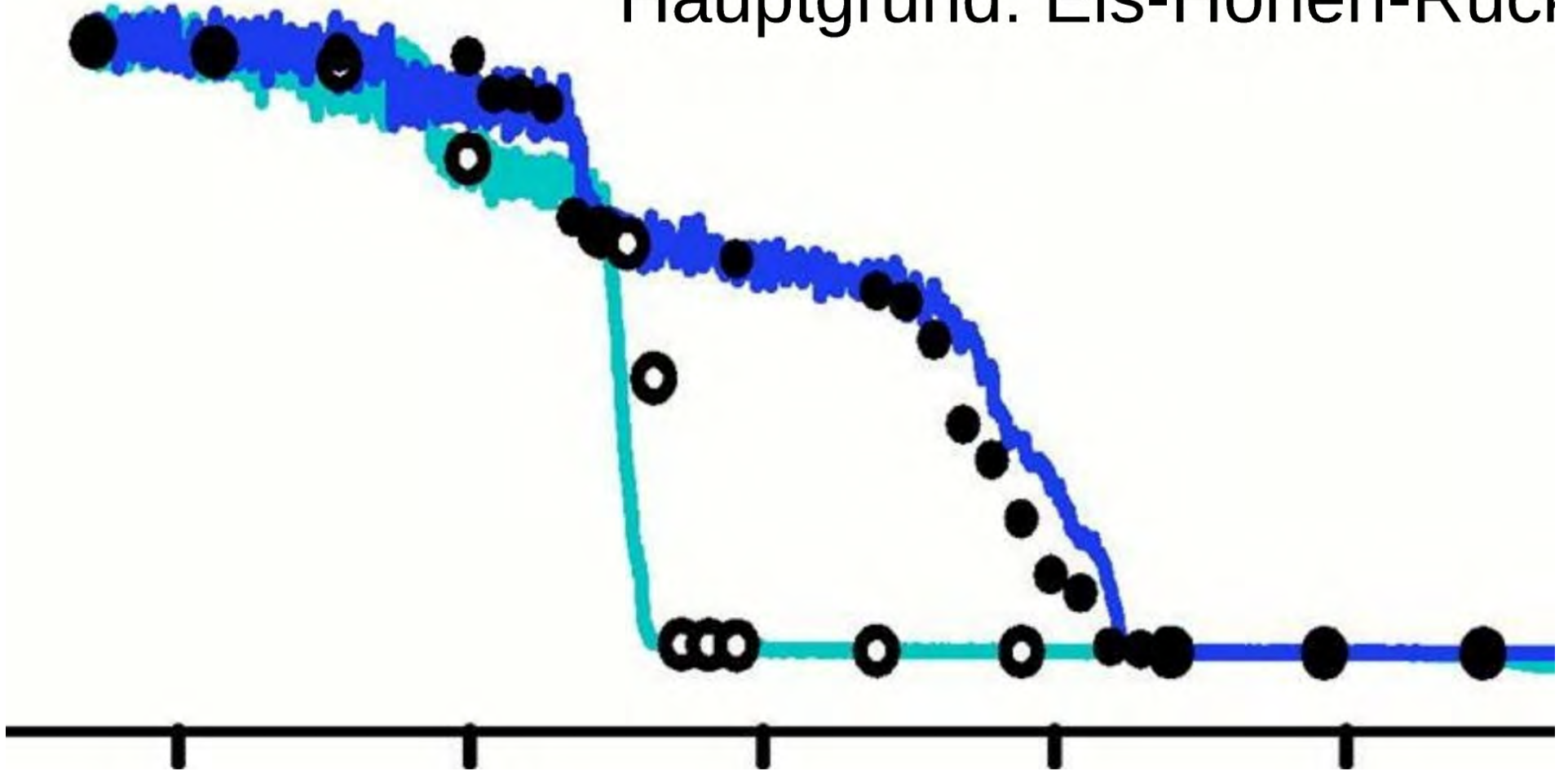
- Es hat einen Kipppunkt durch die Eis-Höhen-Rückkopplung
- Der liegt bei 1°C – 3°C Erderwärmung
- Er führt zu 7 Meter Meeresspiegelanstieg

Stabilitätsdiagramm für das Grönland-Eis

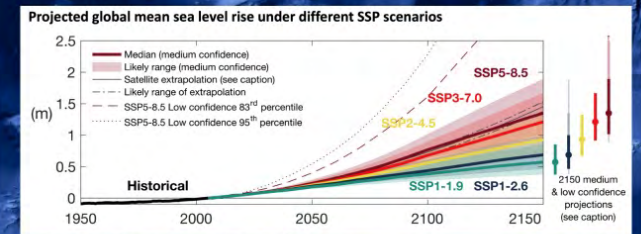
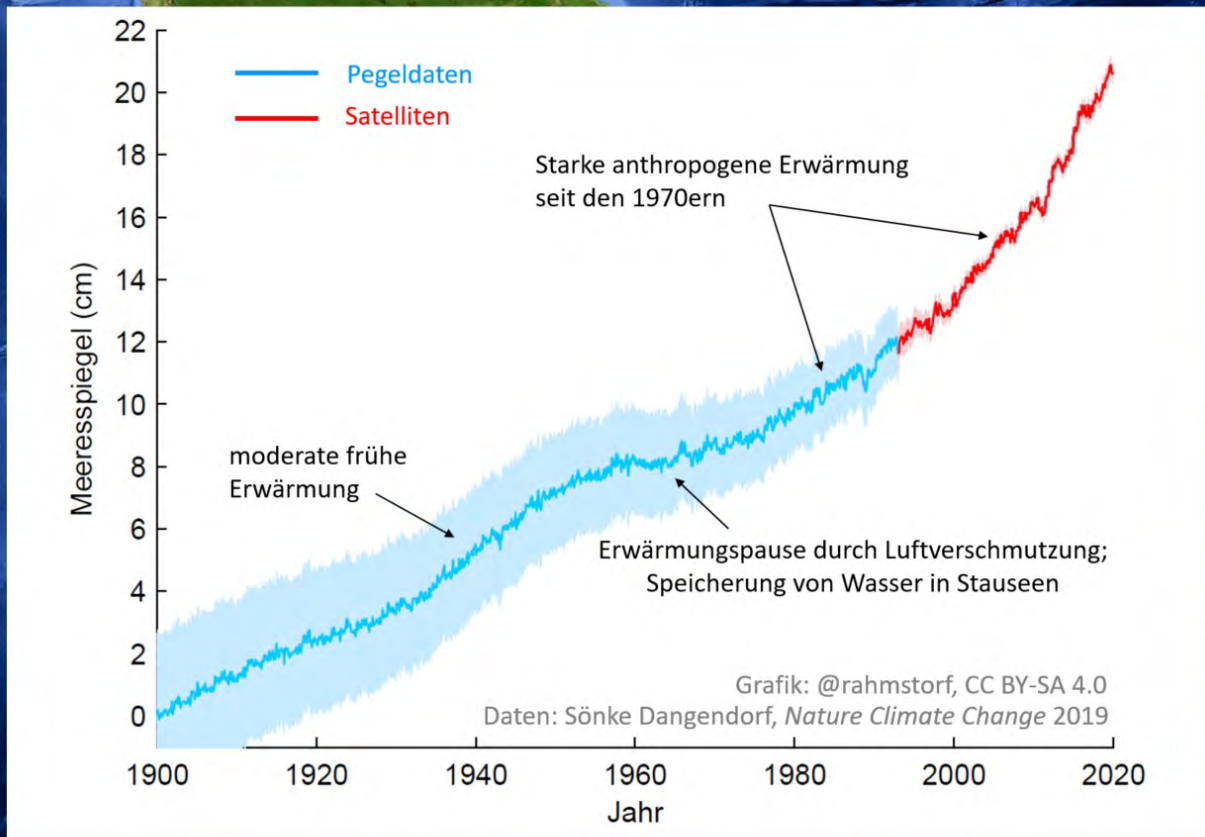


Calov & Ganopolski (2005)

Hauptgrund: Eis-Höhen-Rück

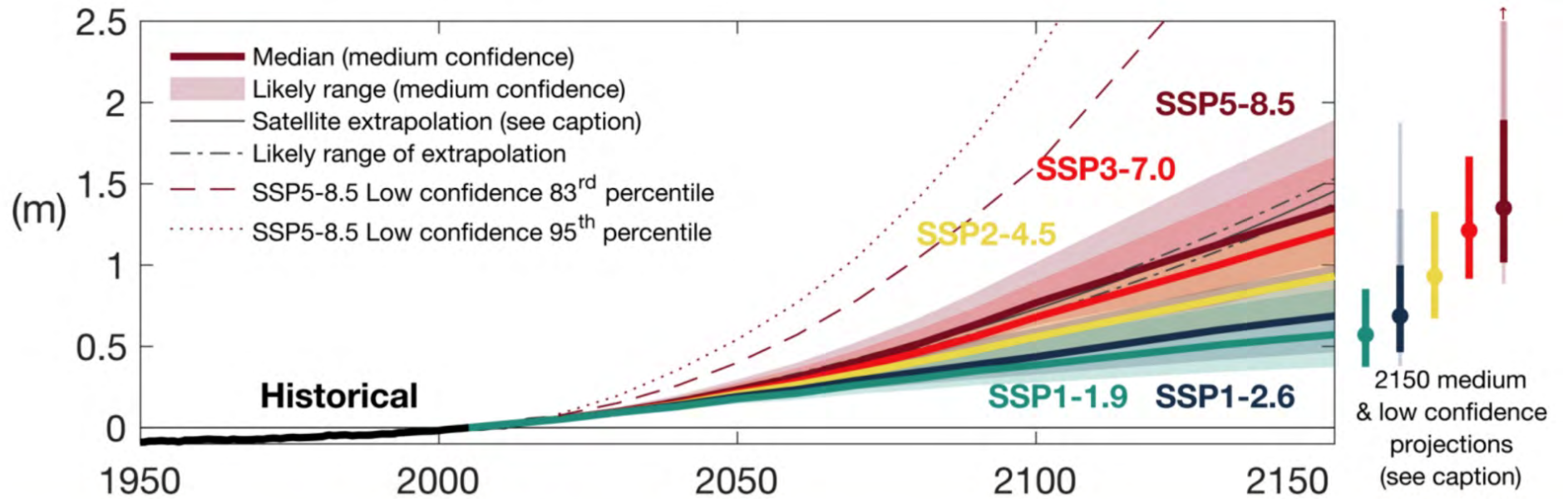


Anstieg des Meeresspiegels





Projected global mean sea level rise under different SSP scenarios



Es gibt genug Eis auf der Erde
für einen Meeresspiegelanstieg um

65 m





Malediven

Wie stabil ist das Golfstromsystem?

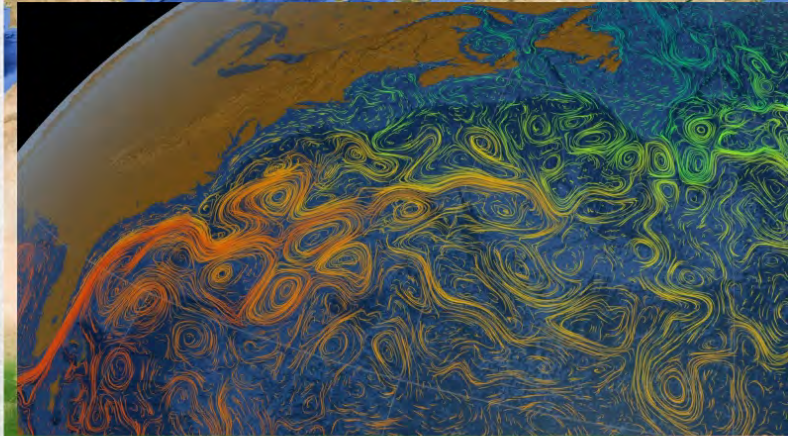
Stefan Rahmstorf

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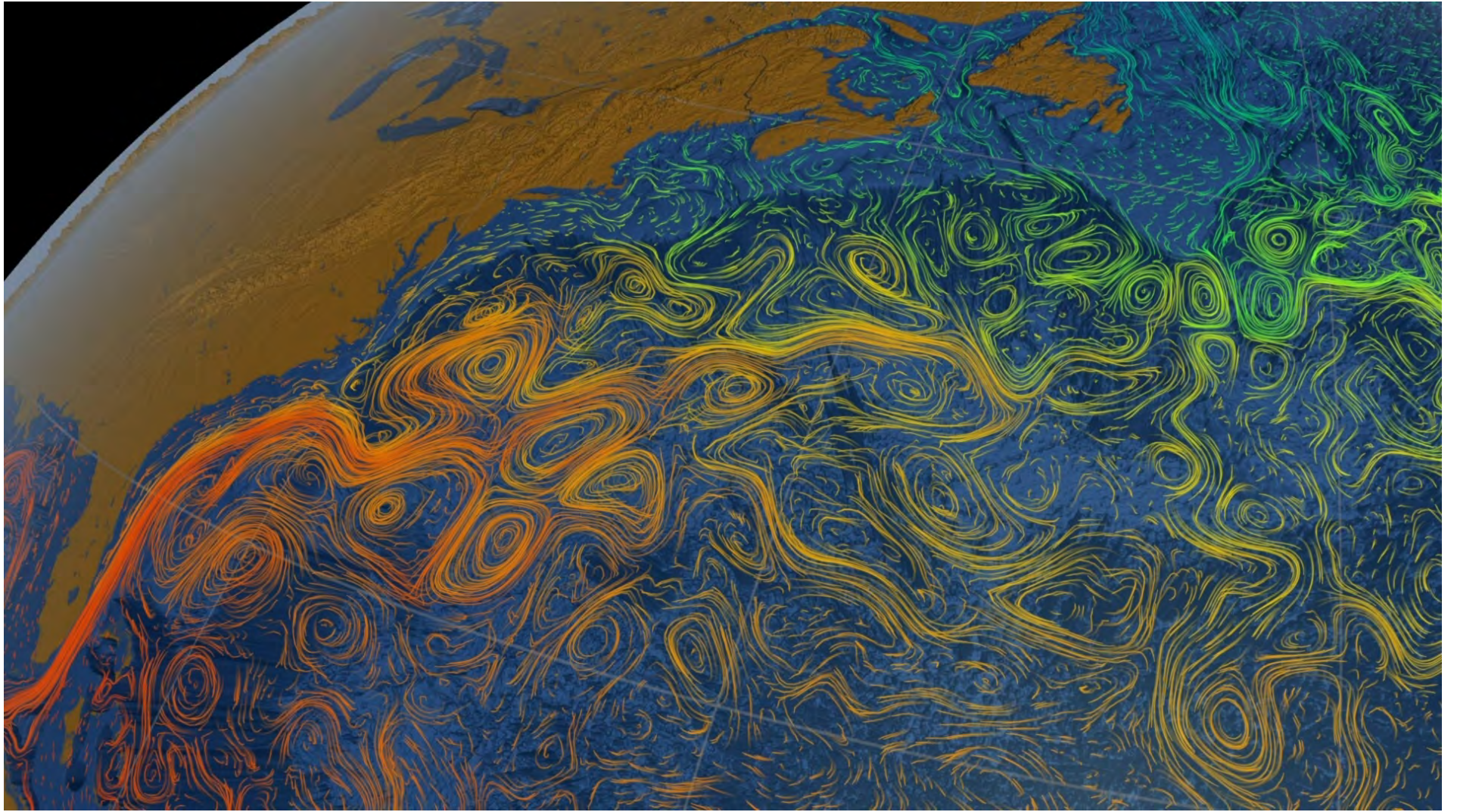


FIG. 173. — FRANKLIN'S CHART OF THE GULF STREAM.

Benjamin Franklin 1769

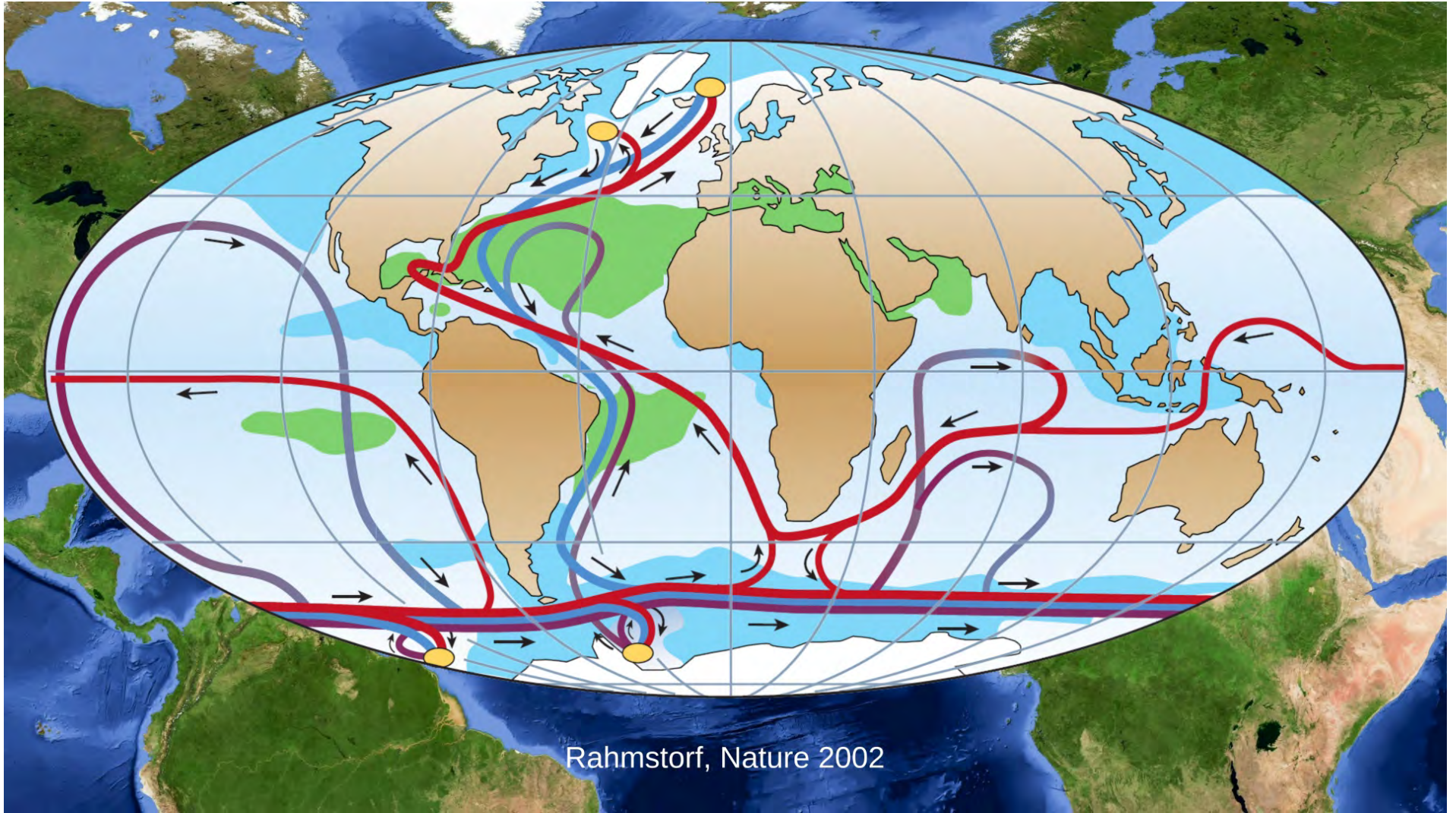


NASA visualisation studio

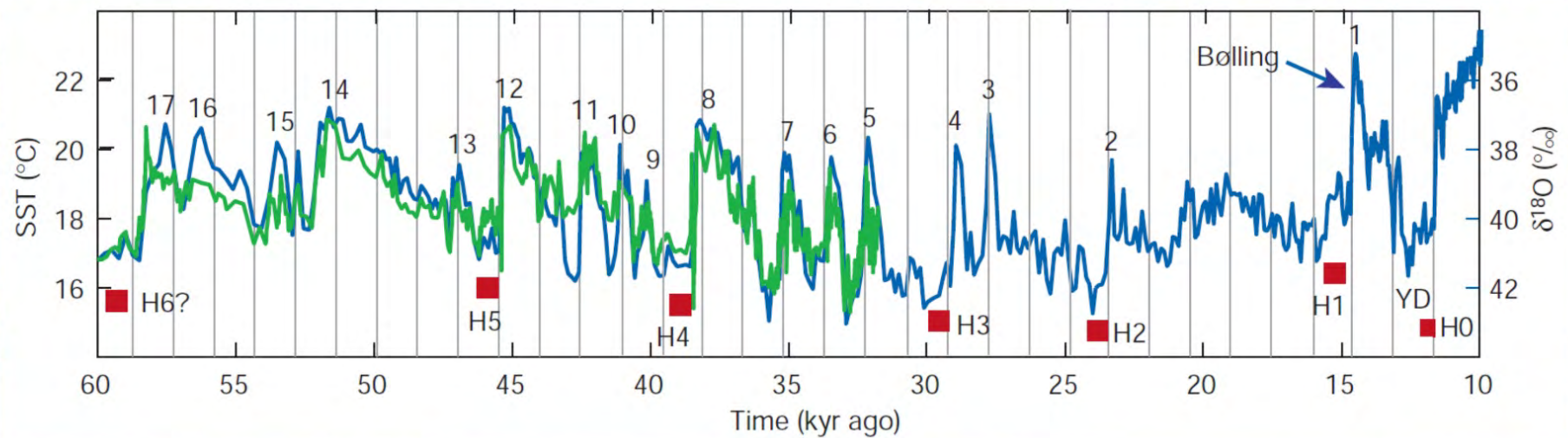






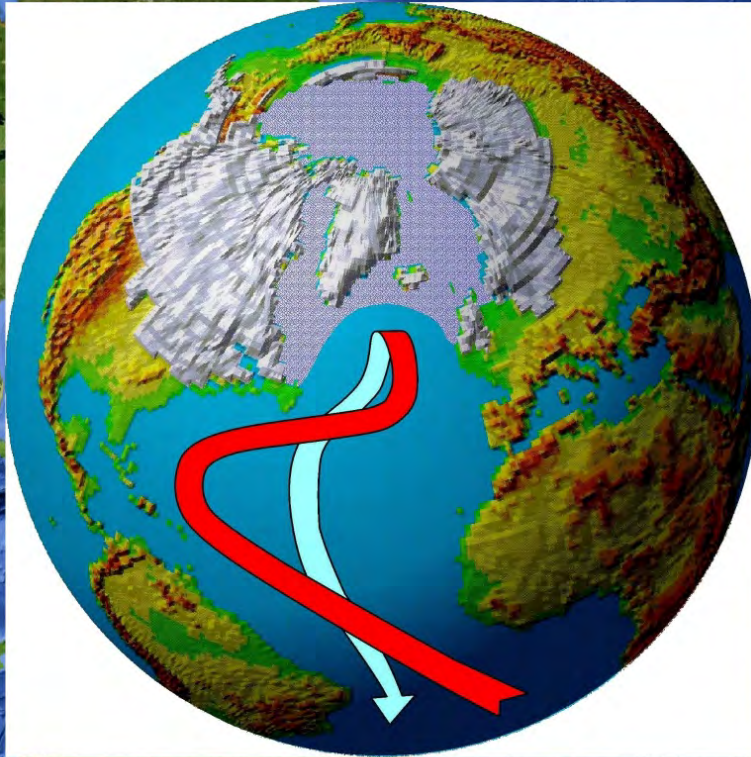


Abrupte Klimawechsel der Eiszeit

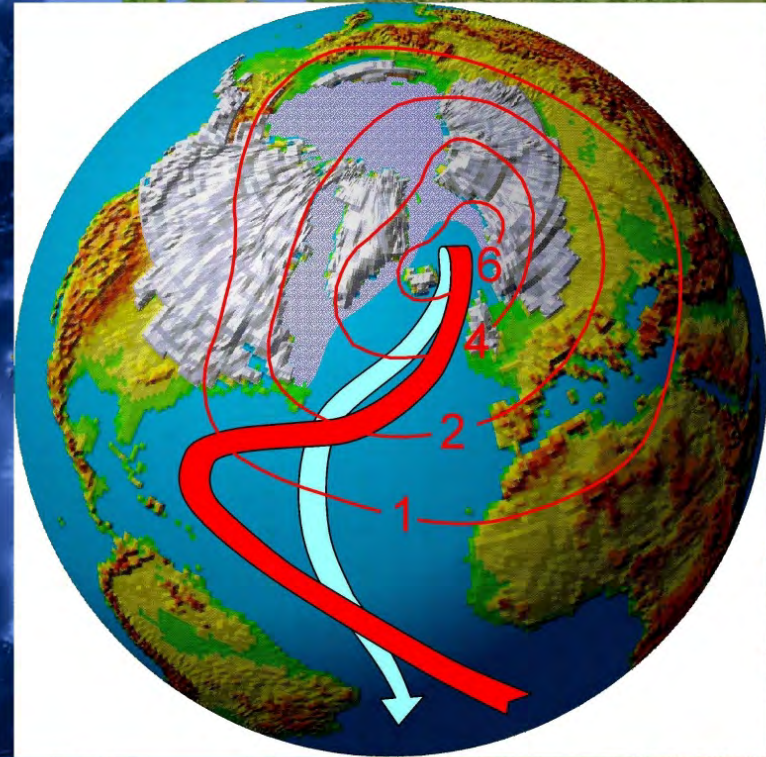


Rahmstorf Nature 2002

Normaler Eiszeitzustand

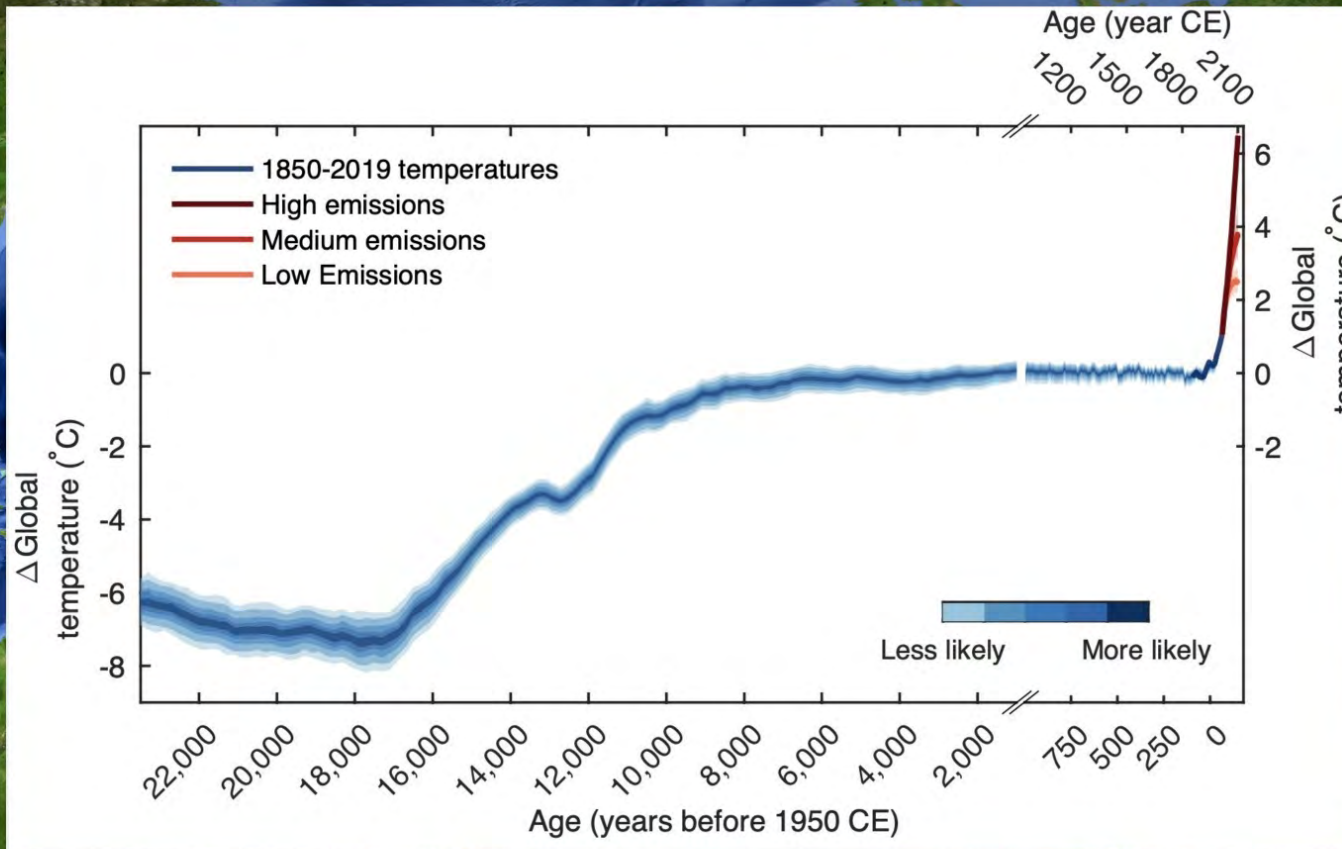


Dansgaard-Oeschger event

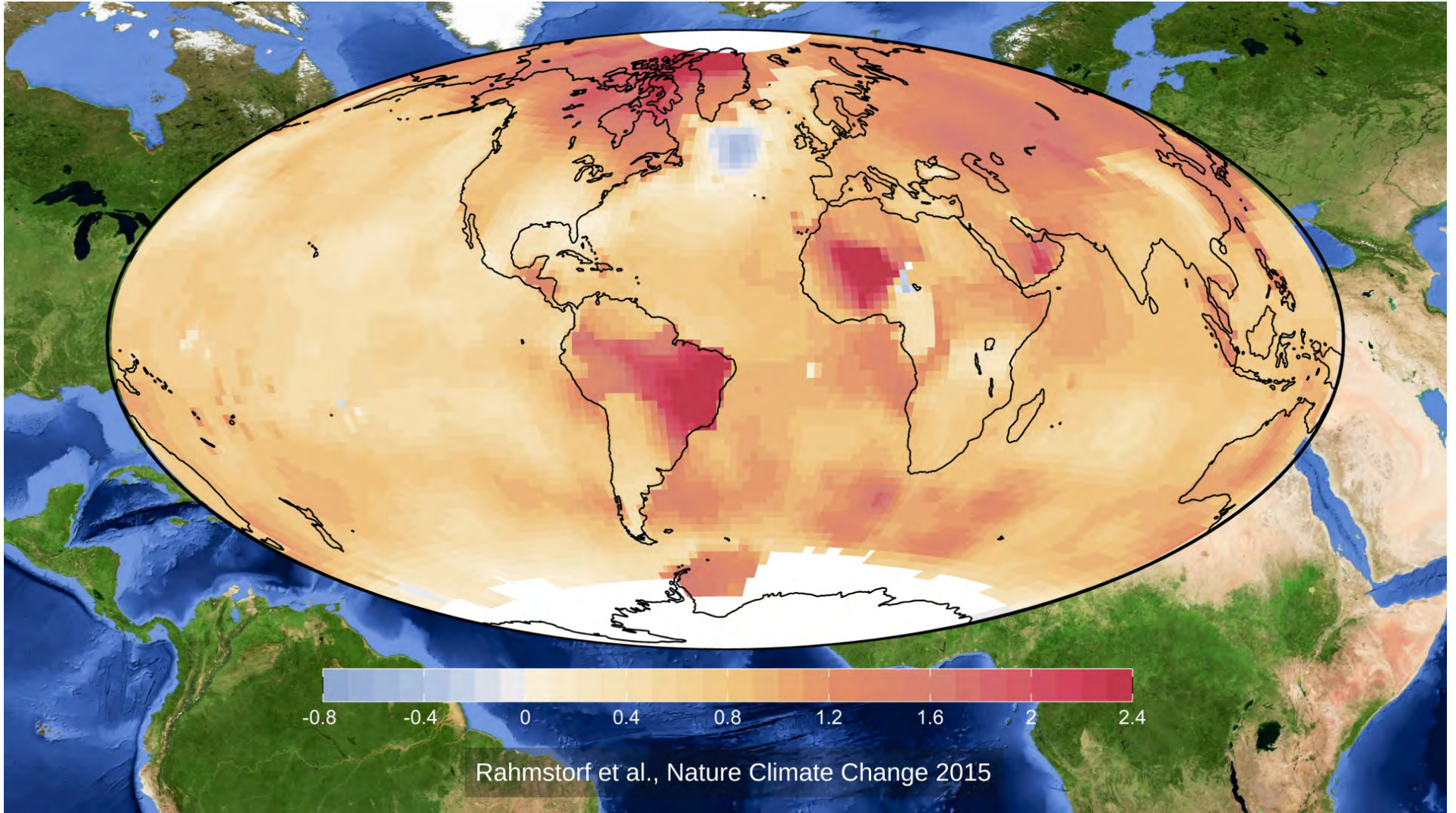


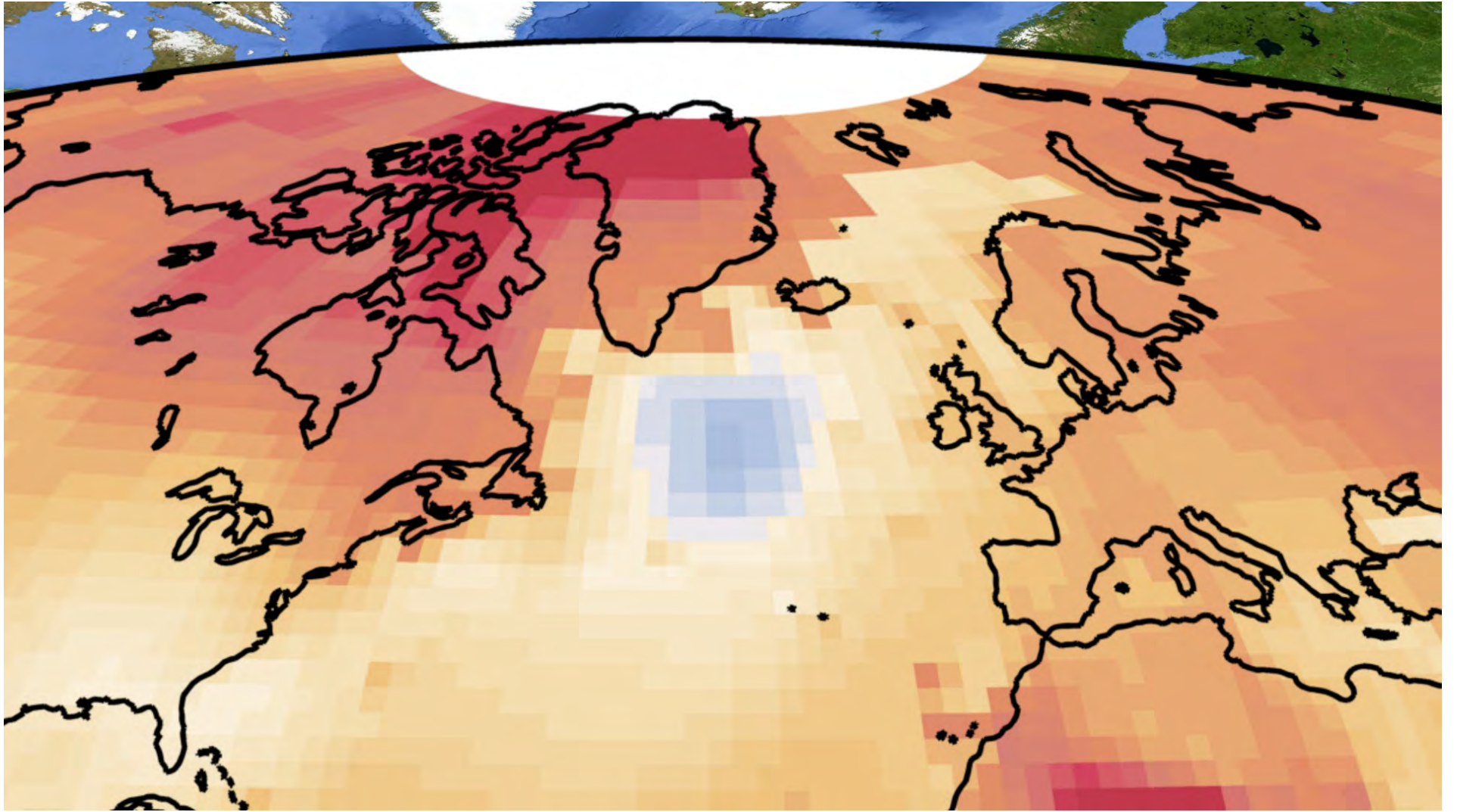
Ganopolski & Rahmstorf Phys. Rev. Let. 2002

Klimaverlauf seit der letzten Eiszeit



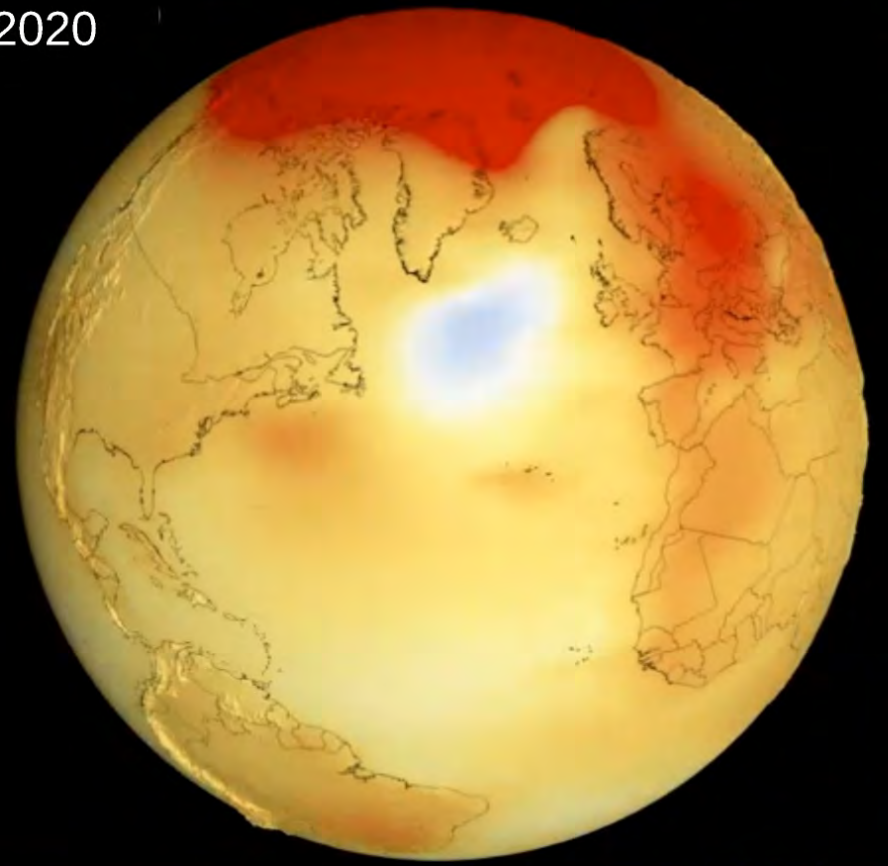
Osman et al., Nature 2021



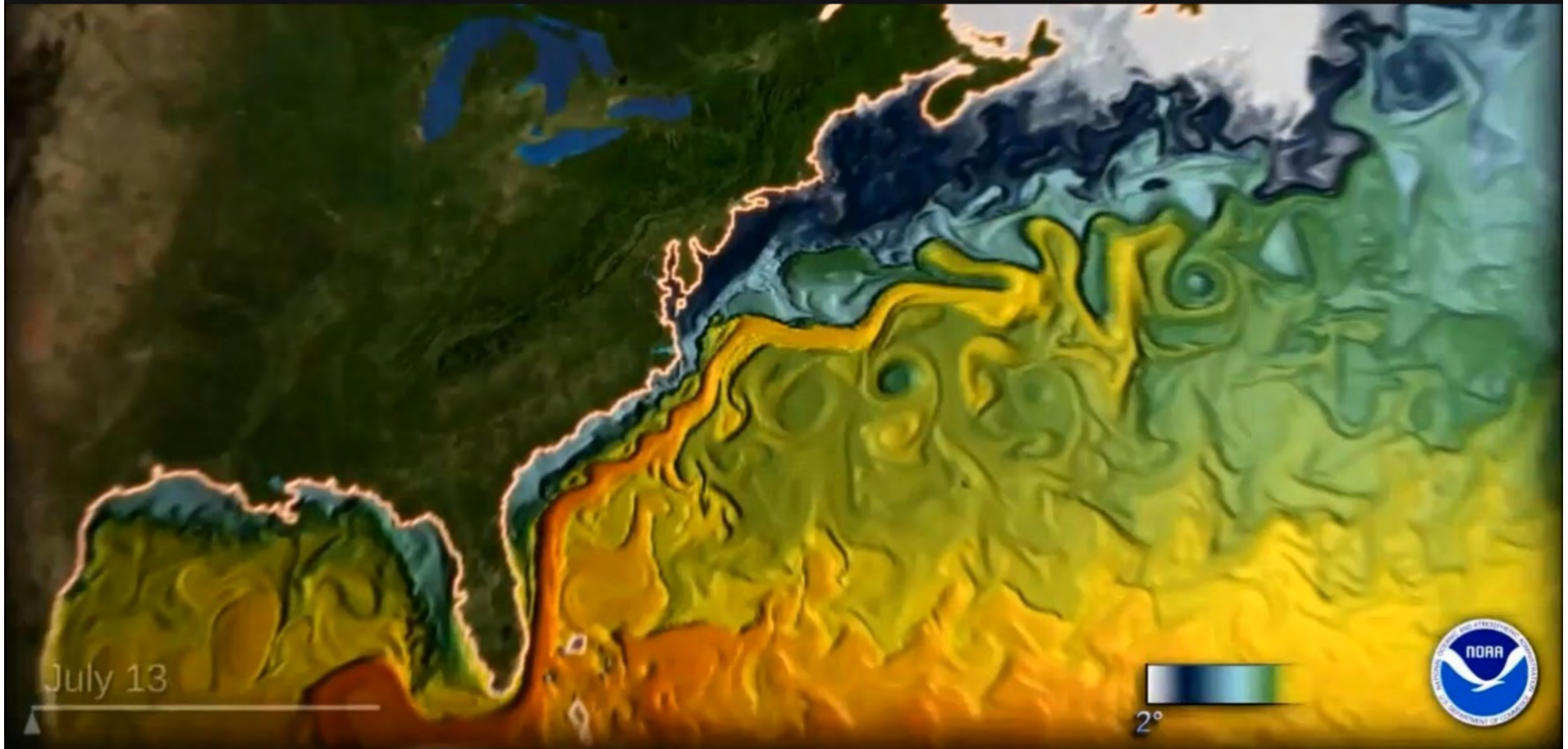


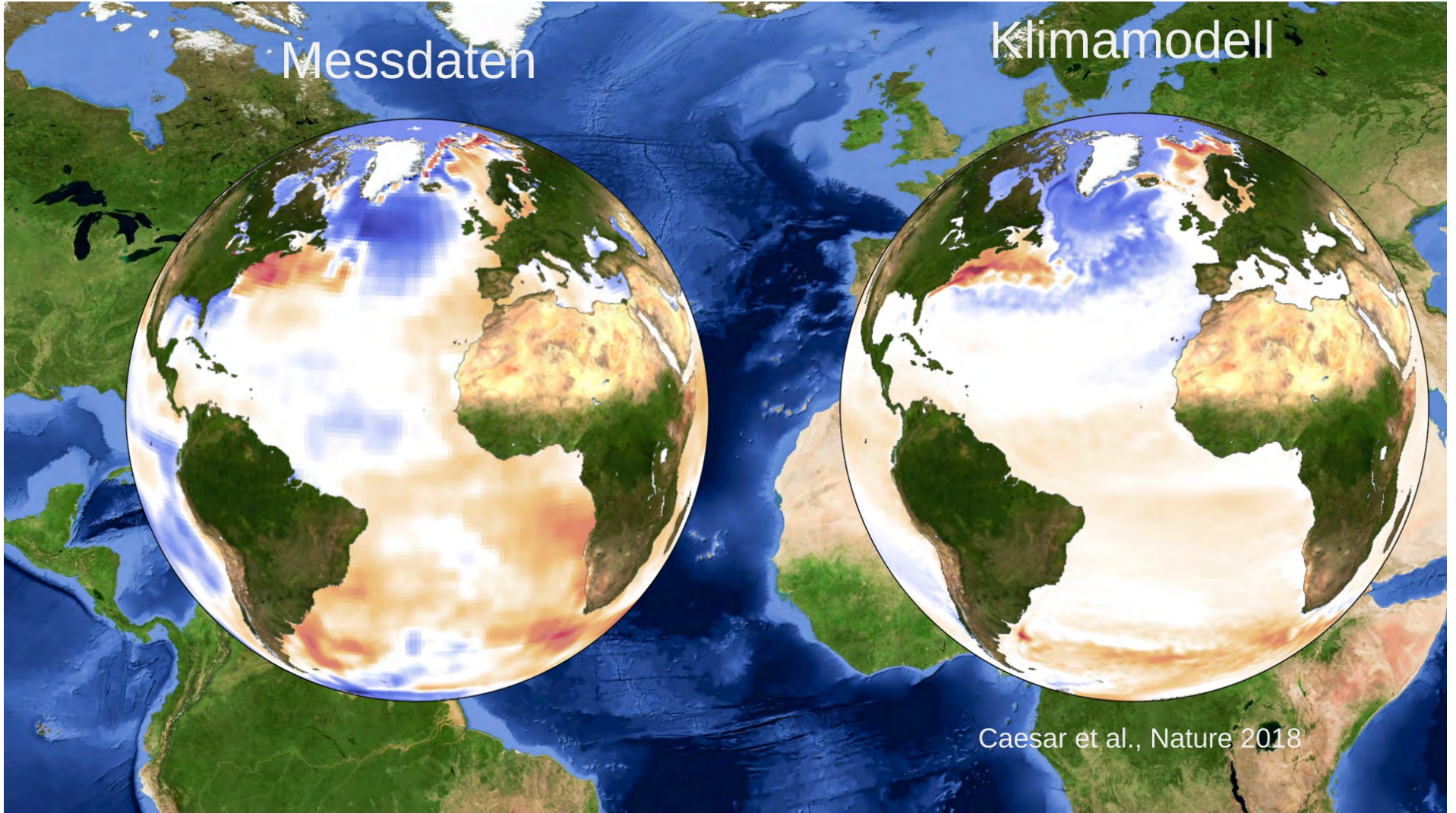
Der 'cold blob'

2016 - 2020



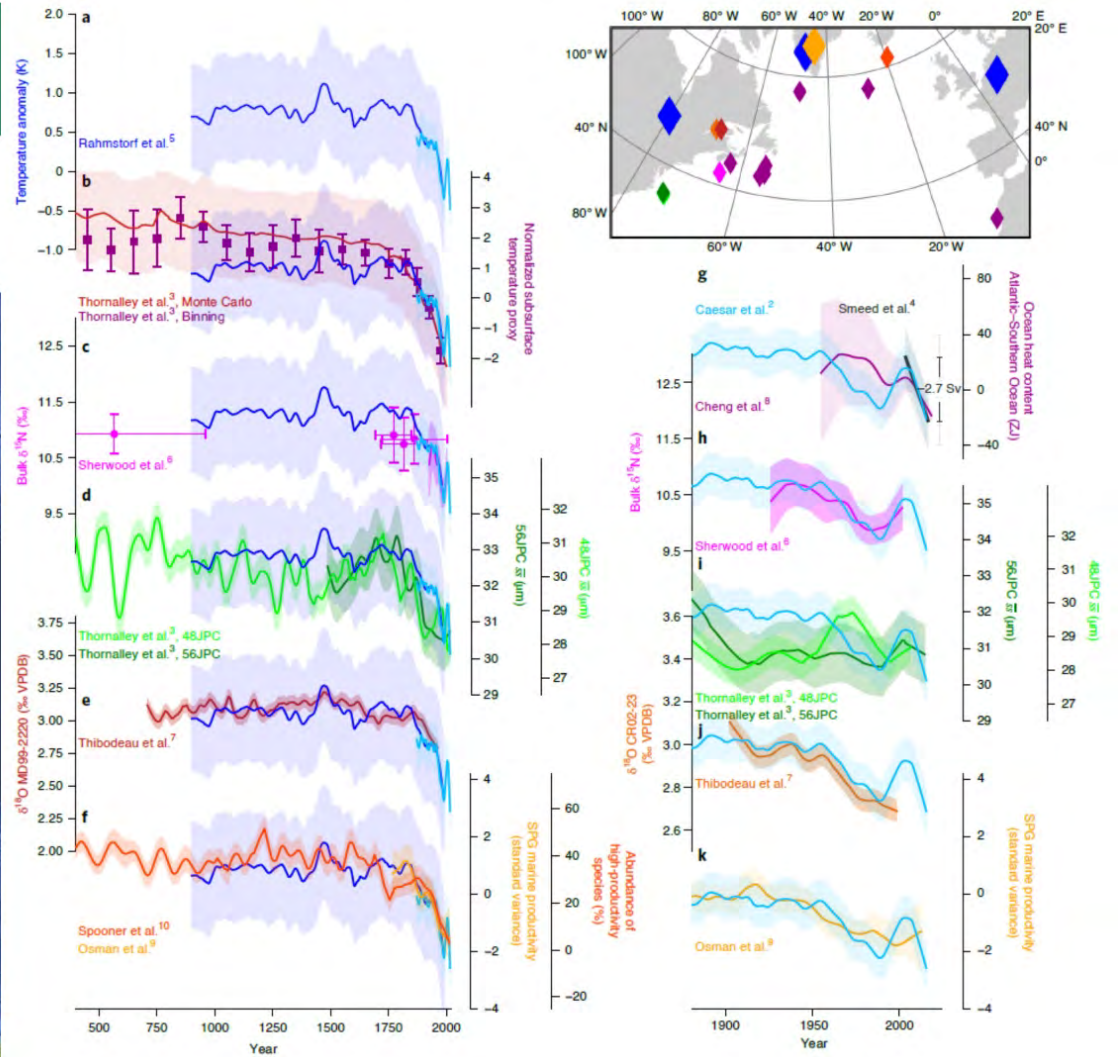
Das Golfstromsystem im Modell

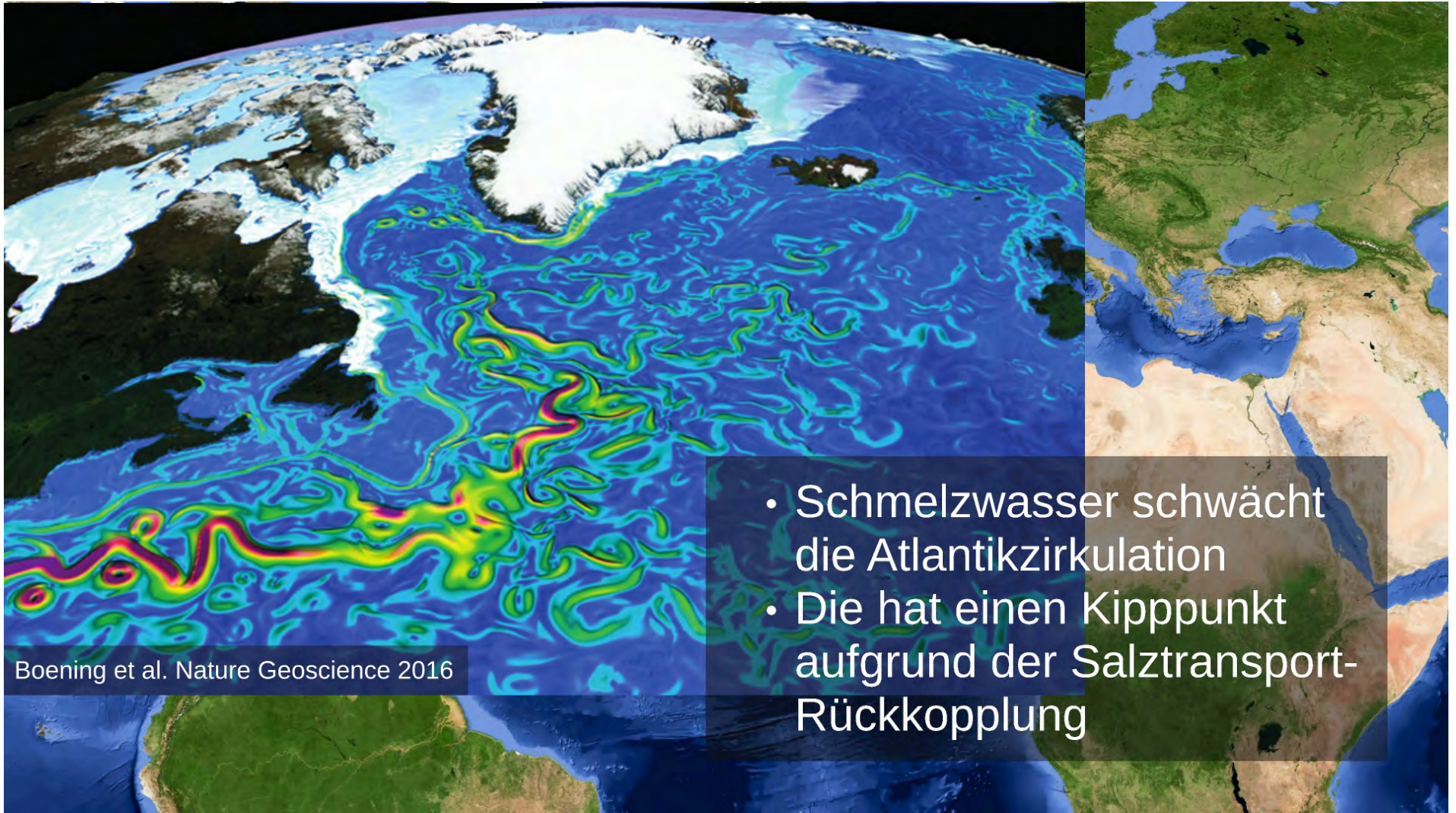




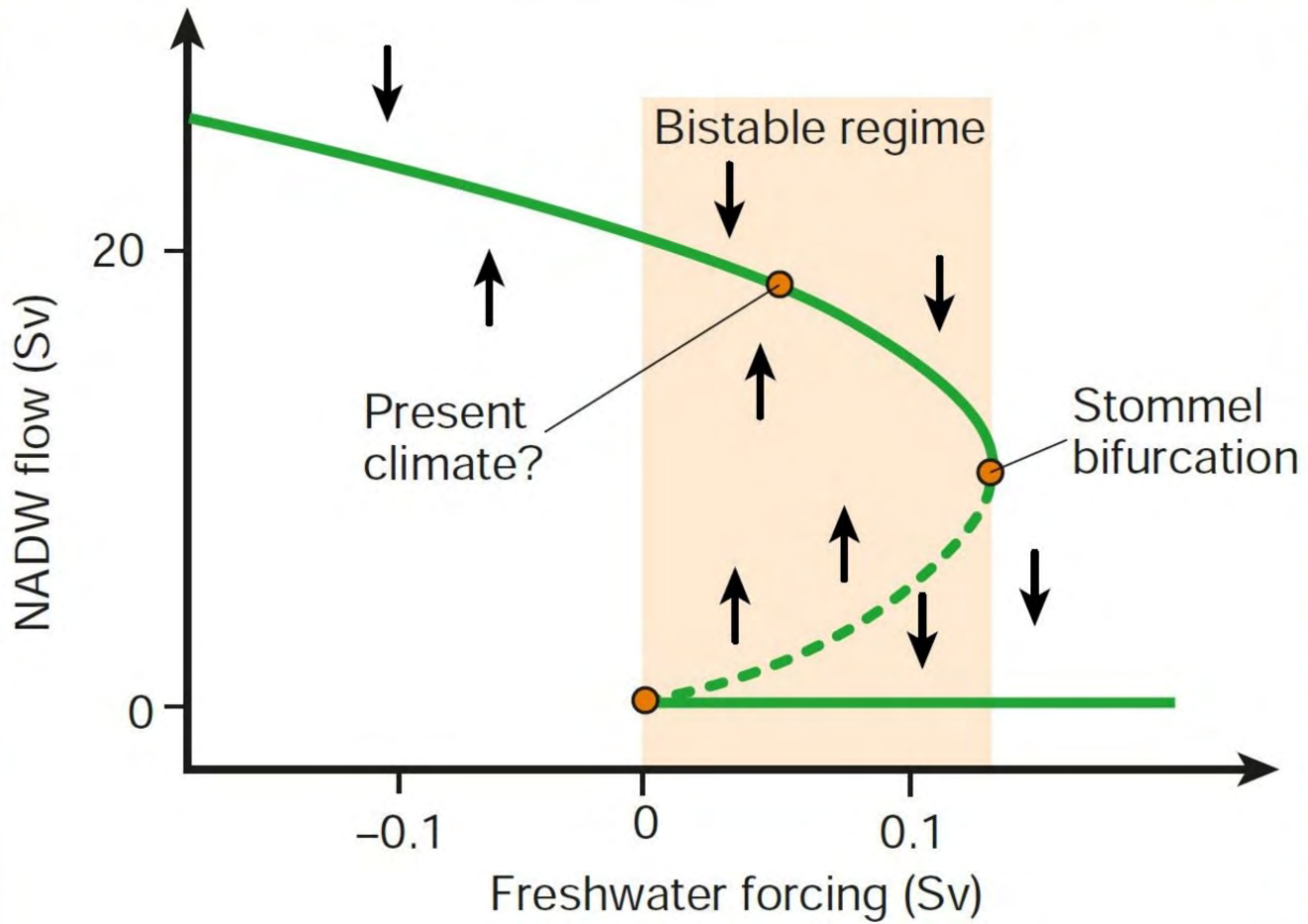
Current Atlantic Meridional Overturning Circulation weakest in last millennium

L. Caesar^{1,2}, G. D. McCarthy¹, D. J. R. Thornalley³, N. Cahill⁴ and S. Rahmstorf^{2,5}





Kipppunkt der Atlantikzirkulation



Sind wir nahe am Kipppunkt?

nature
climate change

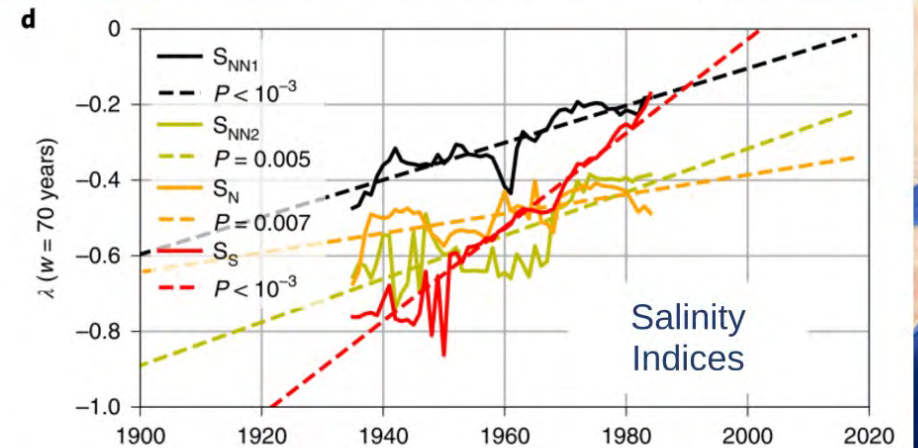
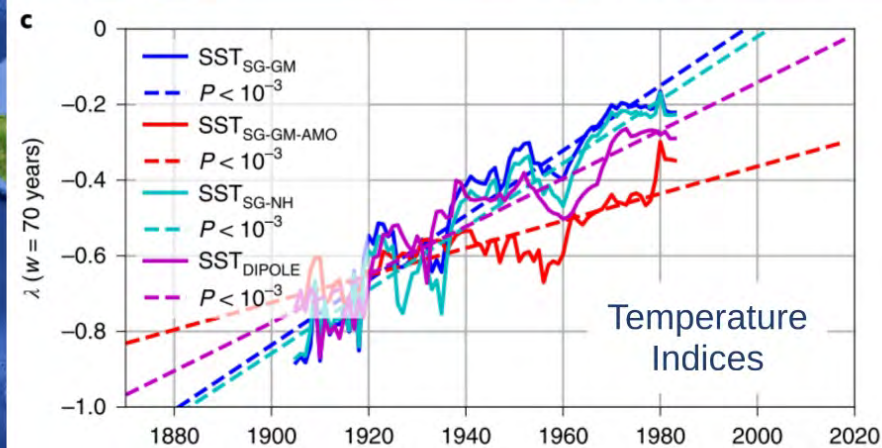
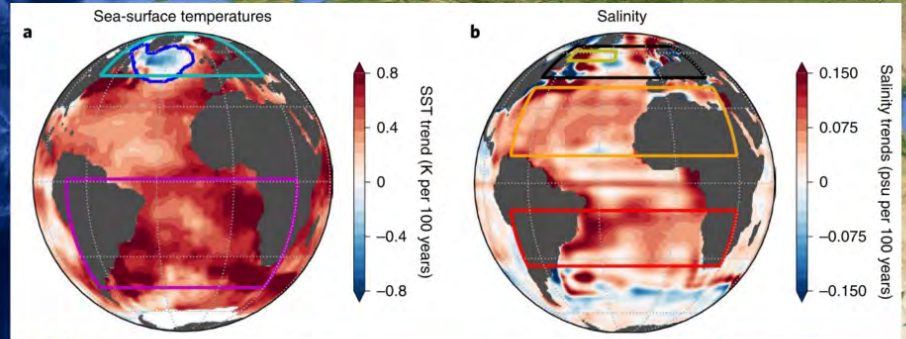
ARTICLES

<https://doi.org/10.1038/s41558-021-01097-4>

Check for updates

Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation

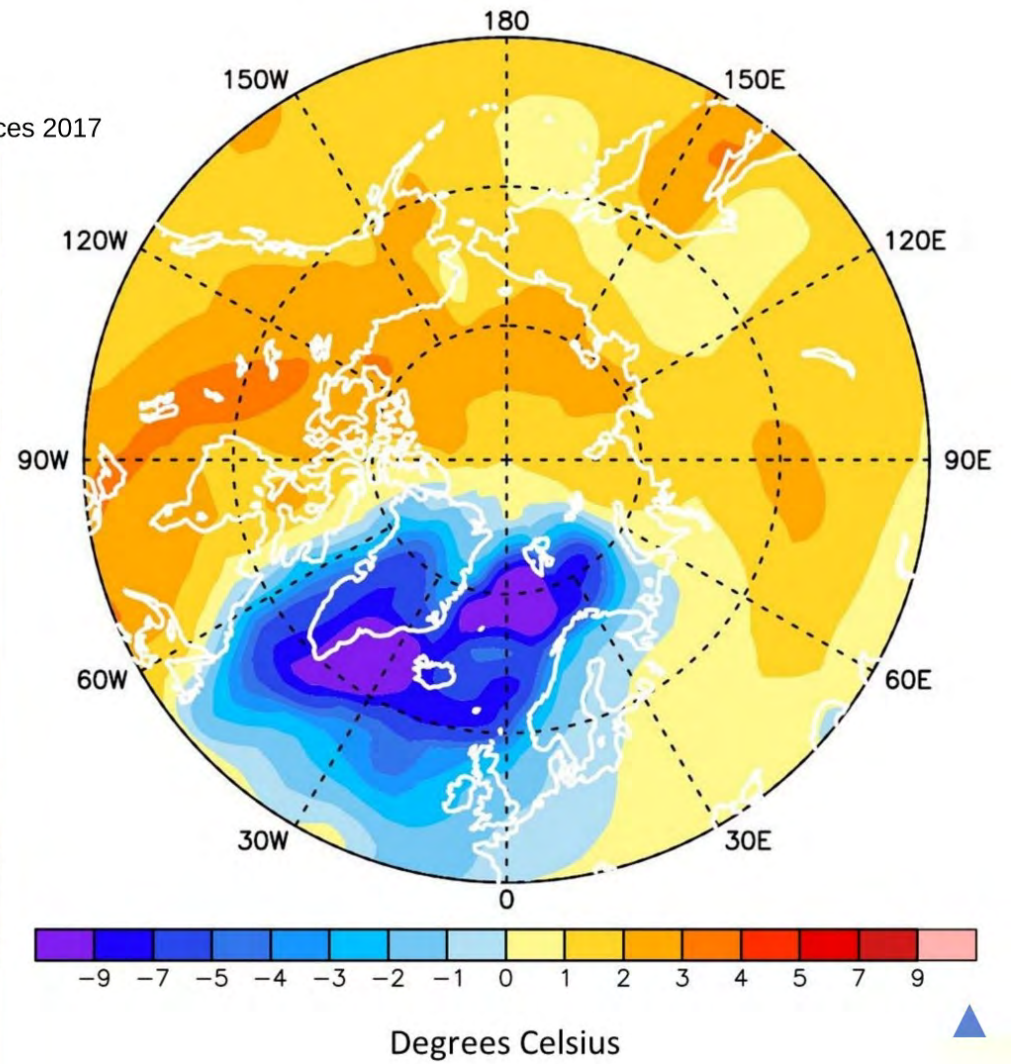
Niklas Boers ^{1,2,3}



Overlooked possibility of a collapsed Atlantic Meridional Overturning Circulation in warming climate

Wei Liu,^{1*} Shang-Ping Xie,¹ Zhengyu Liu,² Jiang Zhu²

Science Advances 2017



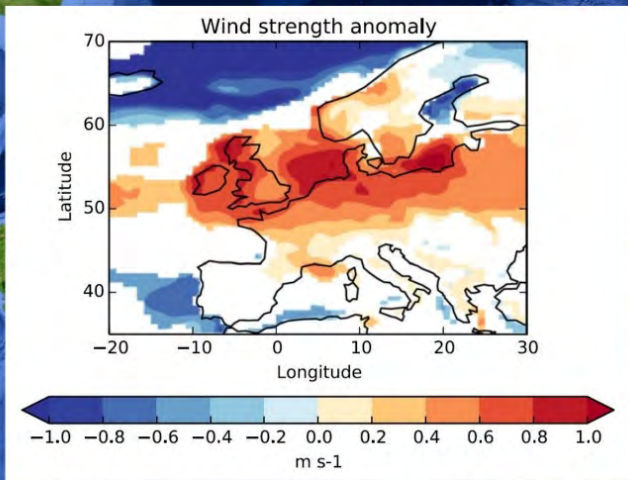
Overlooked possibility of a collapsed Atlantic Meridional Overturning Circulation in warming climate

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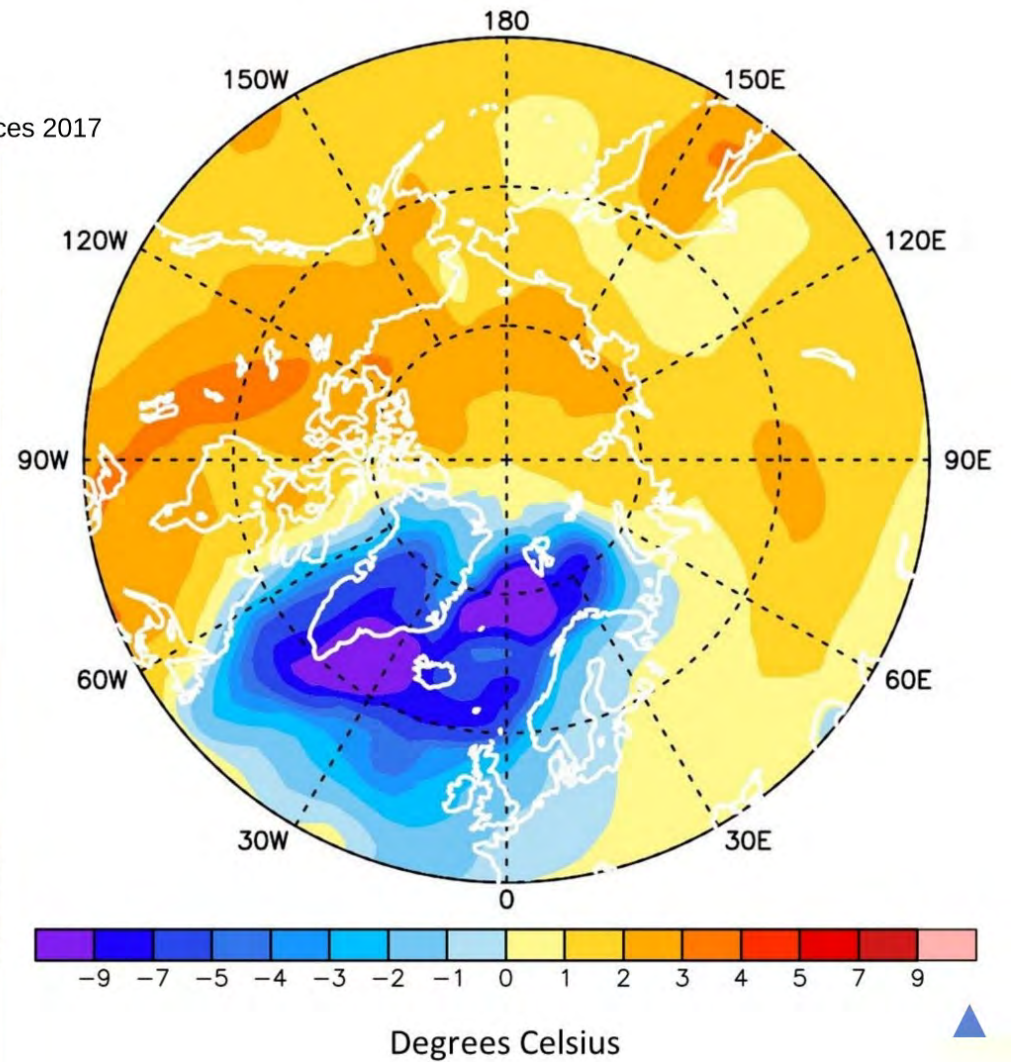
Science Advances 2017

Weitere Folgen:

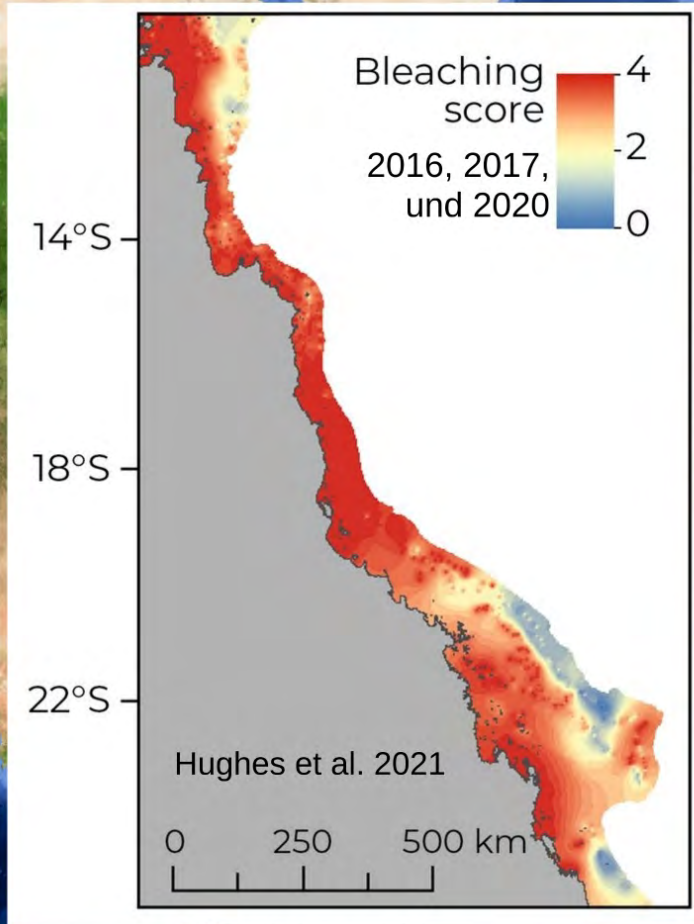
- Starker Meeresspiegelanstieg an der US-Ostküste
- Heftigere Winterstürme in Mitteleuropa
- Verschiebung der tropischen Niederschlagsgürtel
- Verminderte CO₂-Aufnahme des Ozeans
- Kollaps von Meeres-Ökosystemen



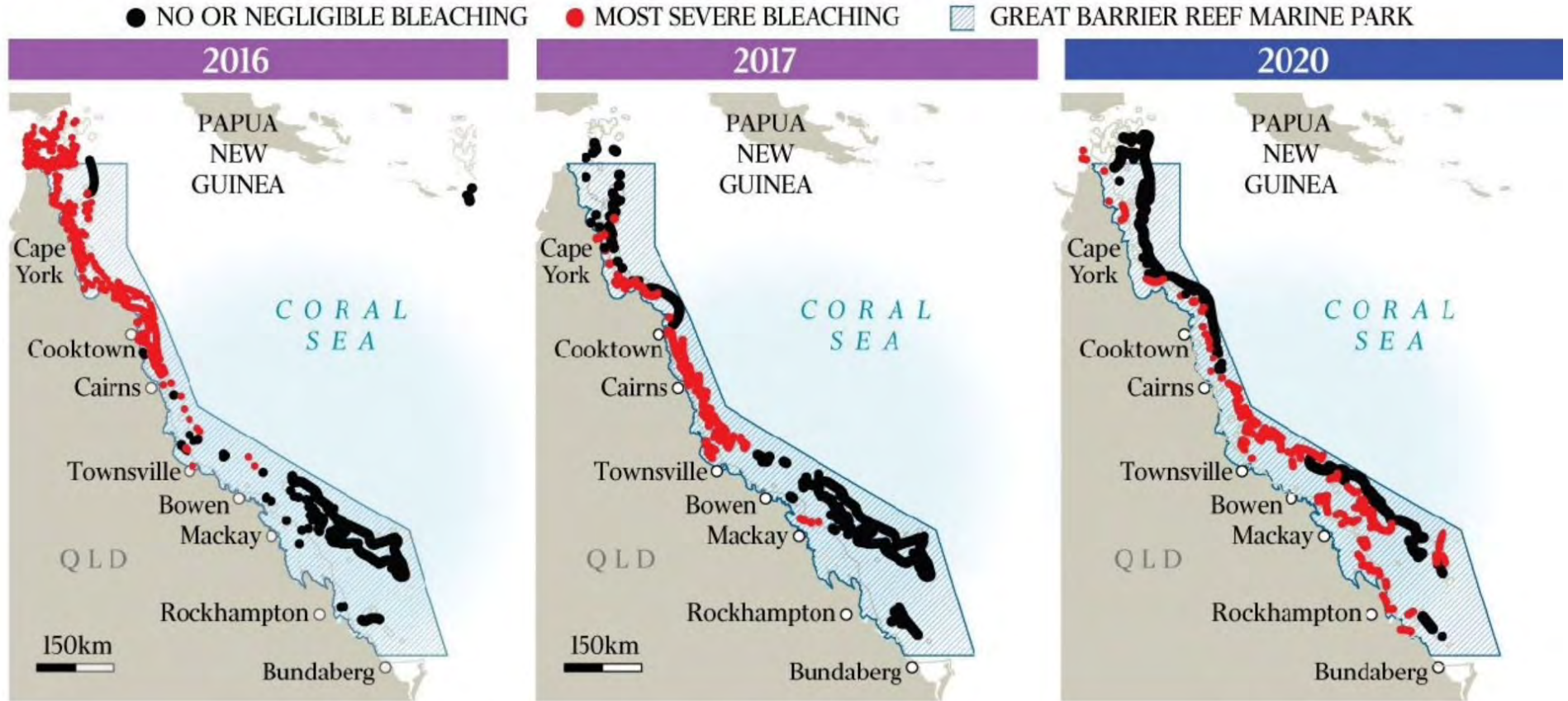
Jackson et al. 2015



Wir sind mitten im Korallensterben



A CORAL DILEMMA Bleaching on the Great Barrier Reef in the summers of 2016, 2017 and 2020

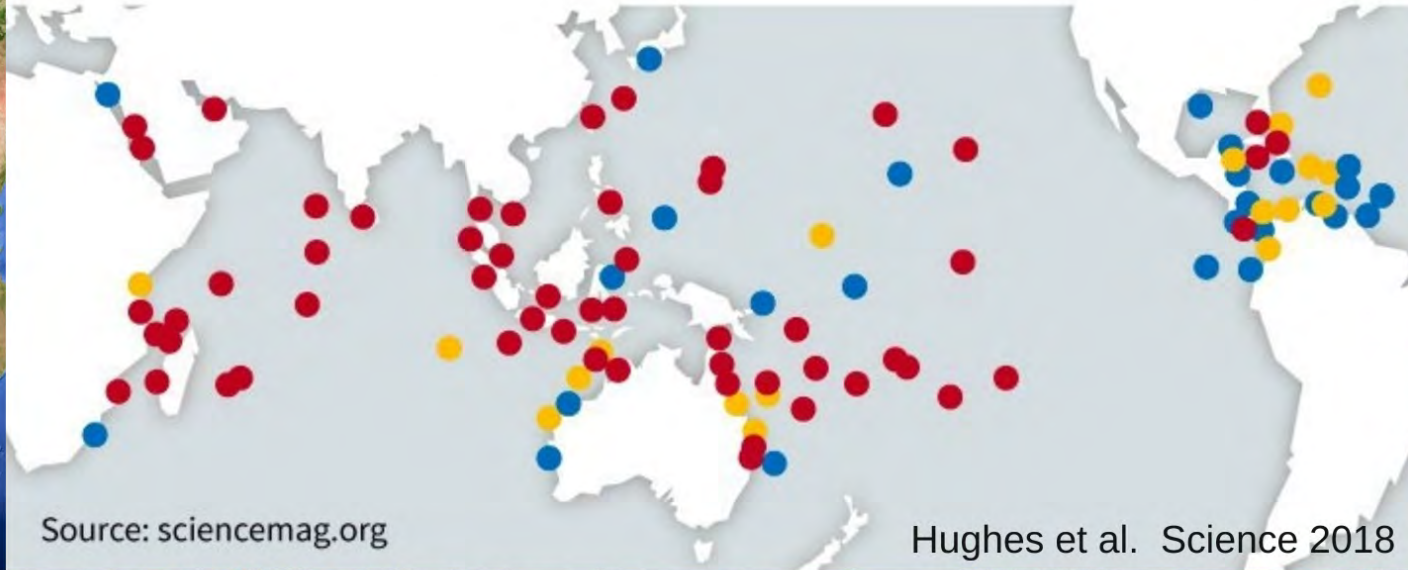


Source: ARC Centre of Excellence

Recent coral bleaching

The global extent of mass bleaching of 100 reefs observed in 2015 and 2016

● No bleaching ● Moderate (<30%) ● Severe (>30% coral) affected



- 2 °C: praktisch alle Korallenriffe sind verloren
- 1.5 °C: 10% bis 30% könnten gerettet werden

(source:IPCC)

Zwischenfazit

Der Klimawandel ist real und zweifelsfrei durch fossile Energienutzung sowie Entwaldung verursacht

Es gibt ein sehr ernstes Risiko, bei weiterer Erwärmung Kippunkte des Klimasystems zu überschreiten, die zu unumkehrbaren, katastrophalen Entwicklungen führen

Der Klimavertrag von Paris

Conférence sur les Changements Climatiques 2015

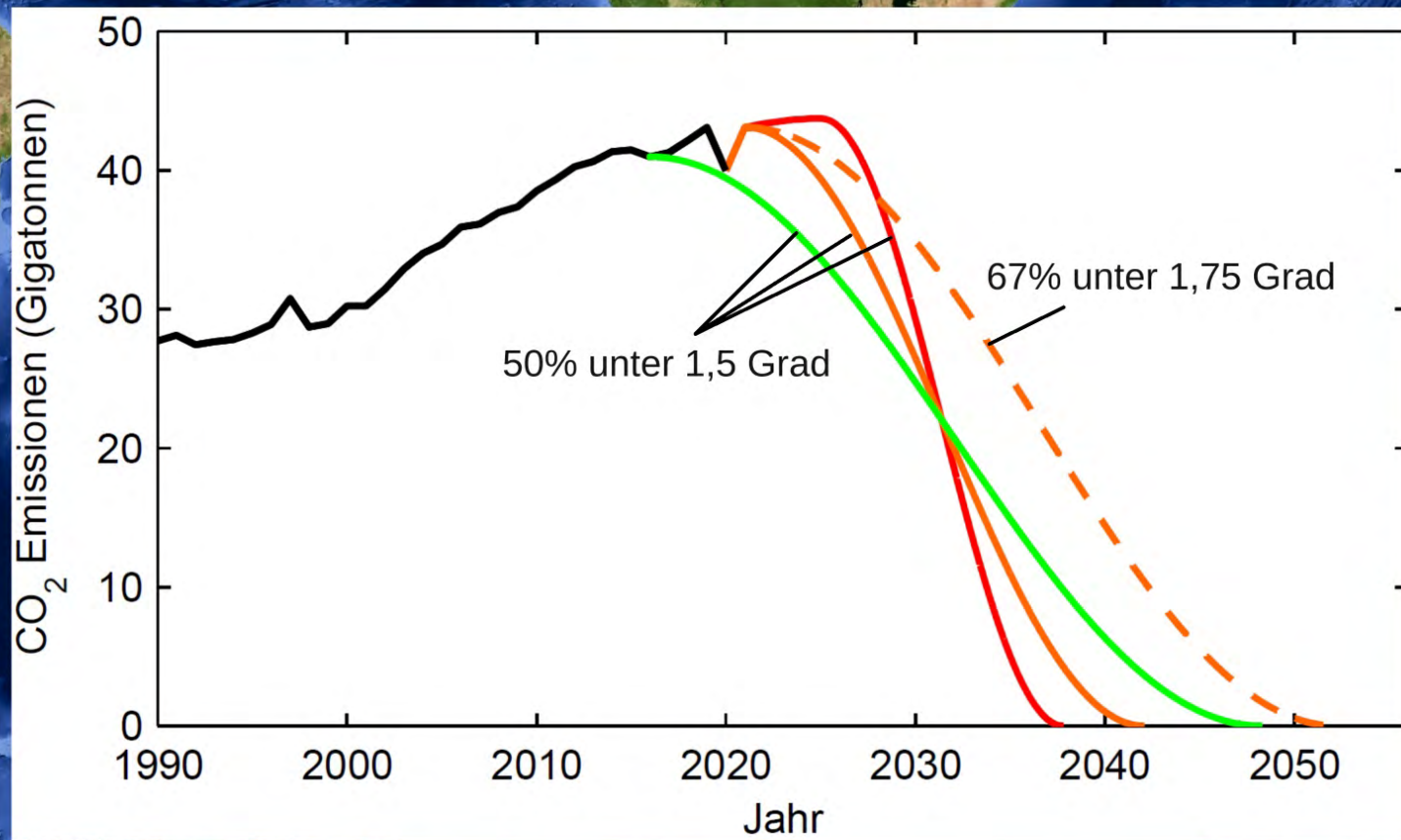
COP21/CMP11

Paris France

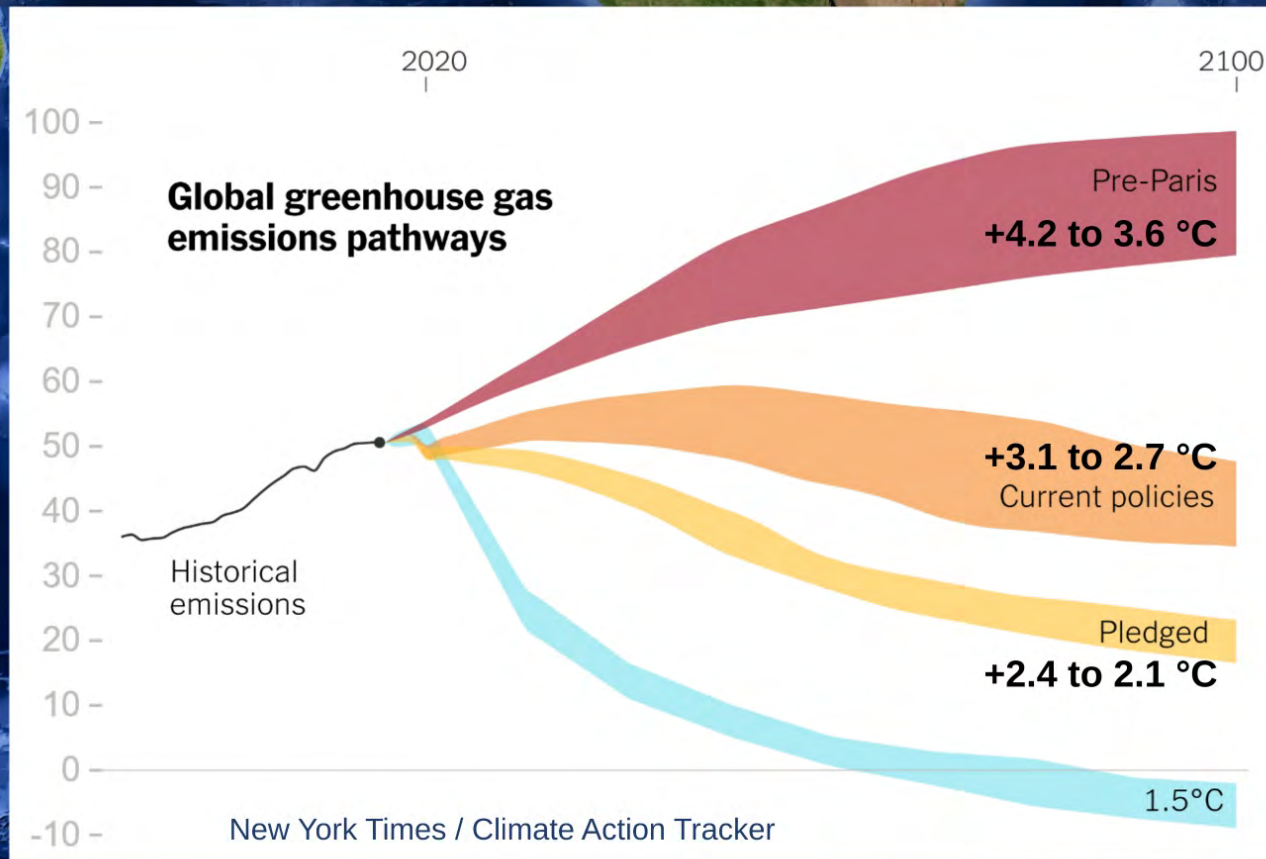


“...holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”.

Paris-kompatible globale Emissionspfade



Die Versprechungen reichen nicht aus



An aerial photograph of a vast open-pit mine, showing deep terraced levels of earth and rock. In the distance, a line of wind turbines is visible against a blue sky with scattered white clouds. A circular callout with a black arrow points from the center of the mine up to the sky.

Atmosphäre
500 Gt CO₂

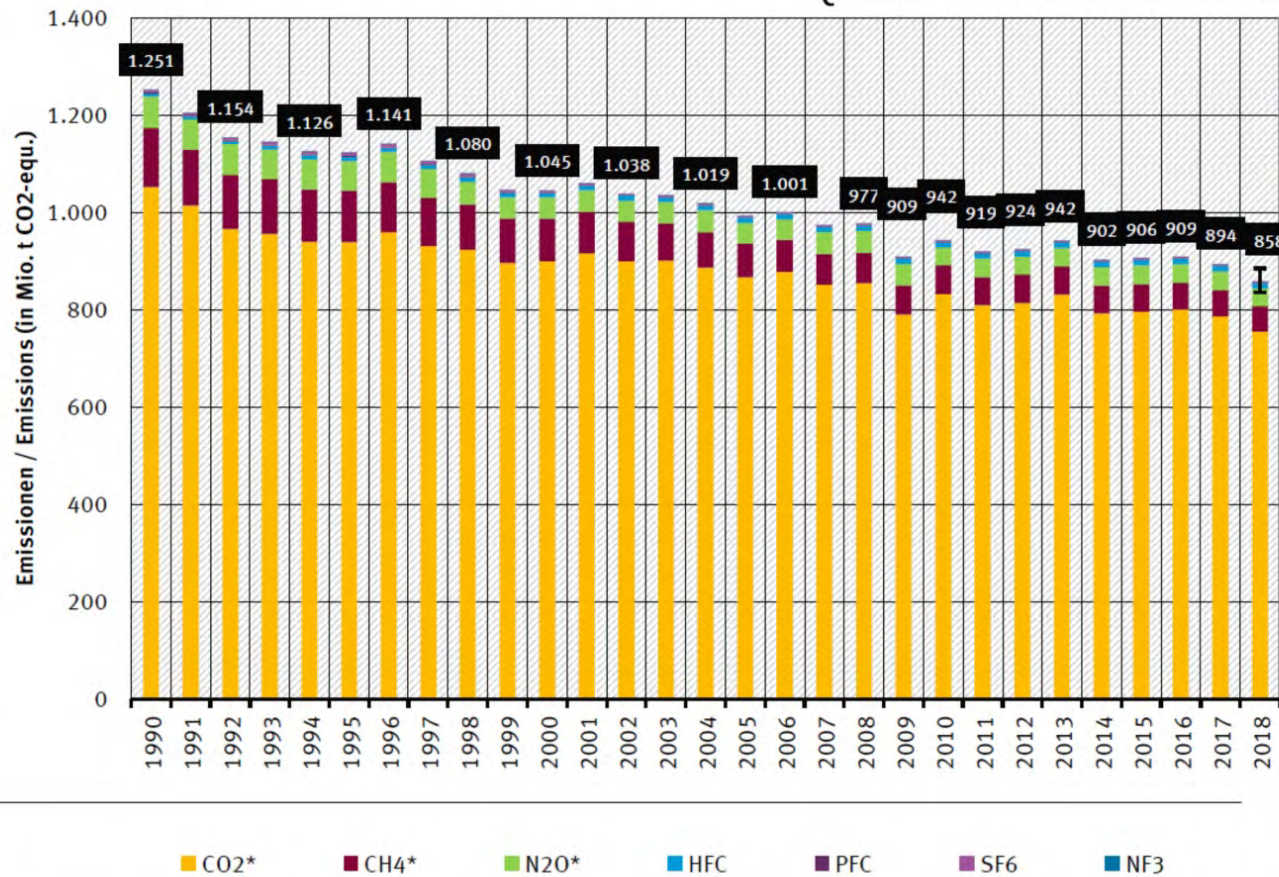
**"Unburnable
carbon"**

Fossile Ressourcen
15,000 Gt CO₂

Jährliche Treibhausgas-Emissionen in Deutschland / Annual greenhouse gas emissions in

nach Substanz / by substance

Quelle: Umweltbundesamt

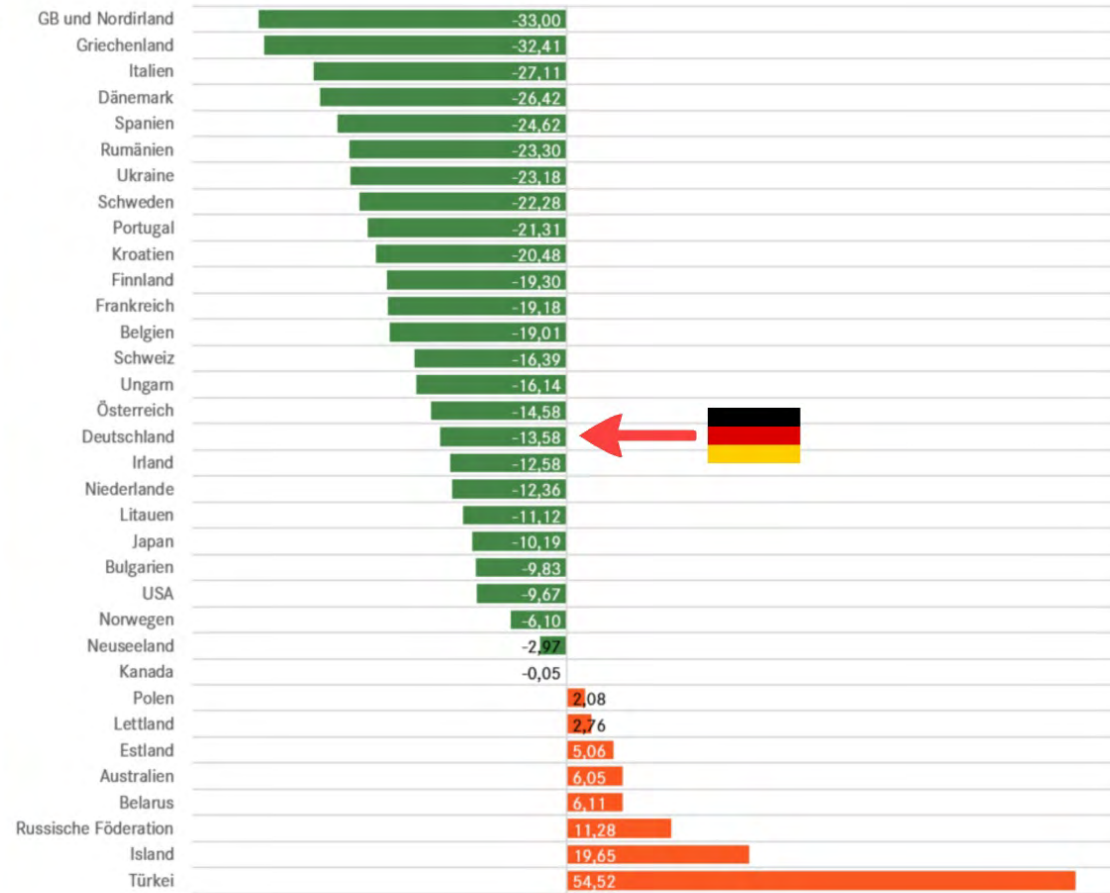


1% der Bevölkerung
2% der CO2 Emissionen

#6 bei aktuellen,
#4 bei historischen
fossilen Emissionen

Veränderungen der Treibhausgas-Emissionen

Unterschied zwischen 2005 und 2018 in Prozent

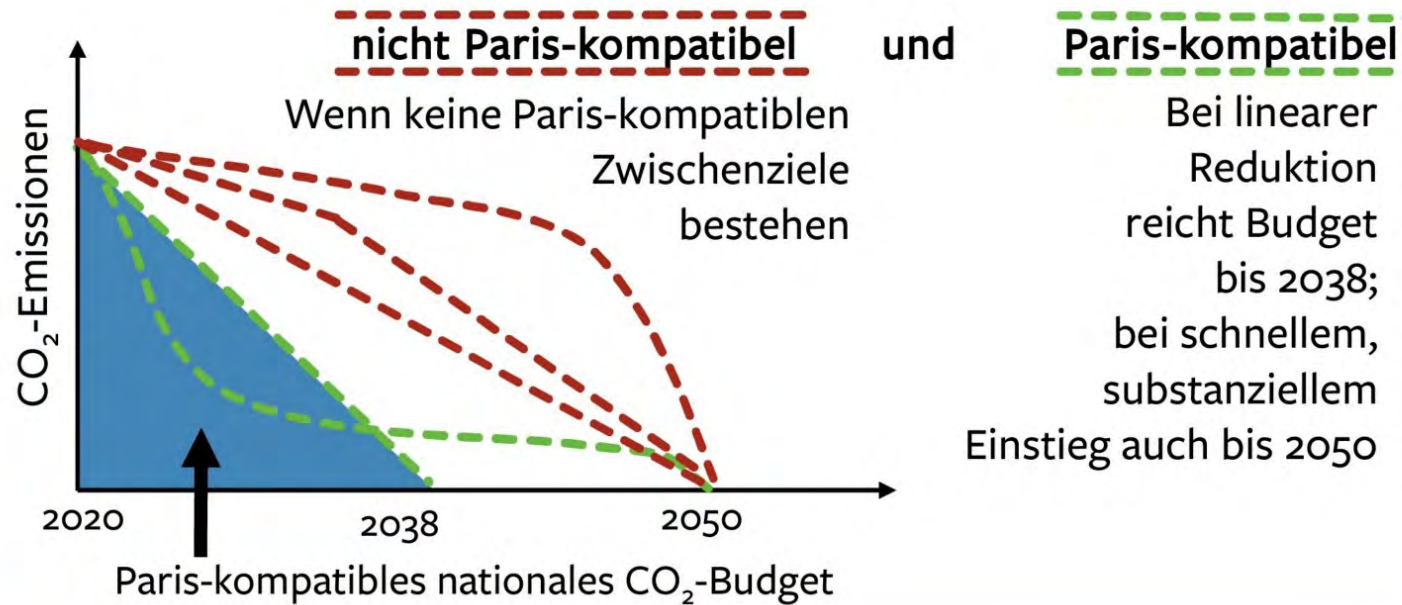


Daten: United Nations Framework Convention on Climate Change

Welcher Anteil der Emissionen ist fair für Deutschland?

Der Weg bis 2050:

Tatsächlich emittierte CO₂-Emissionen (schematisch):

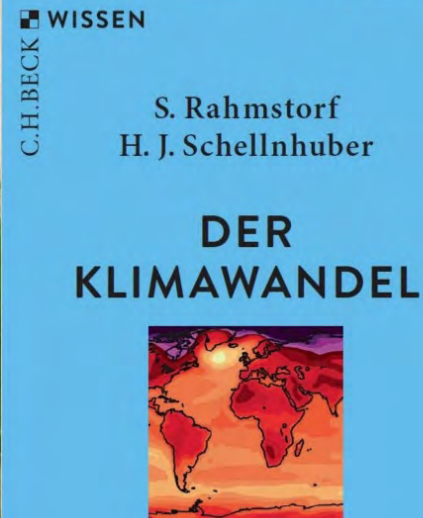
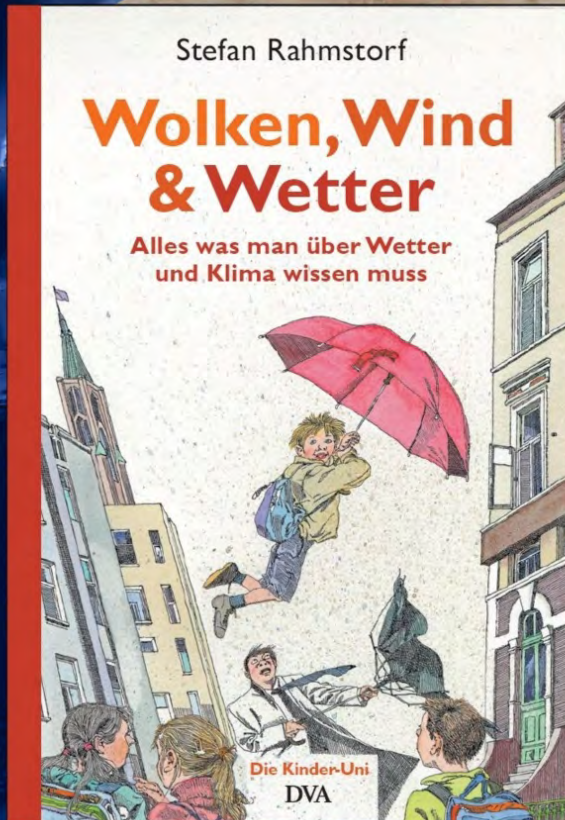


Quelle: Sachverständigenrat für Umweltfragen, 2020

Kommt der gesellschaftliche Kipppunkt?



Herzlichen Dank für Ihr Interesse!



Blog: KlimaLounge

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