Climate Change and the Ocean

A call to action

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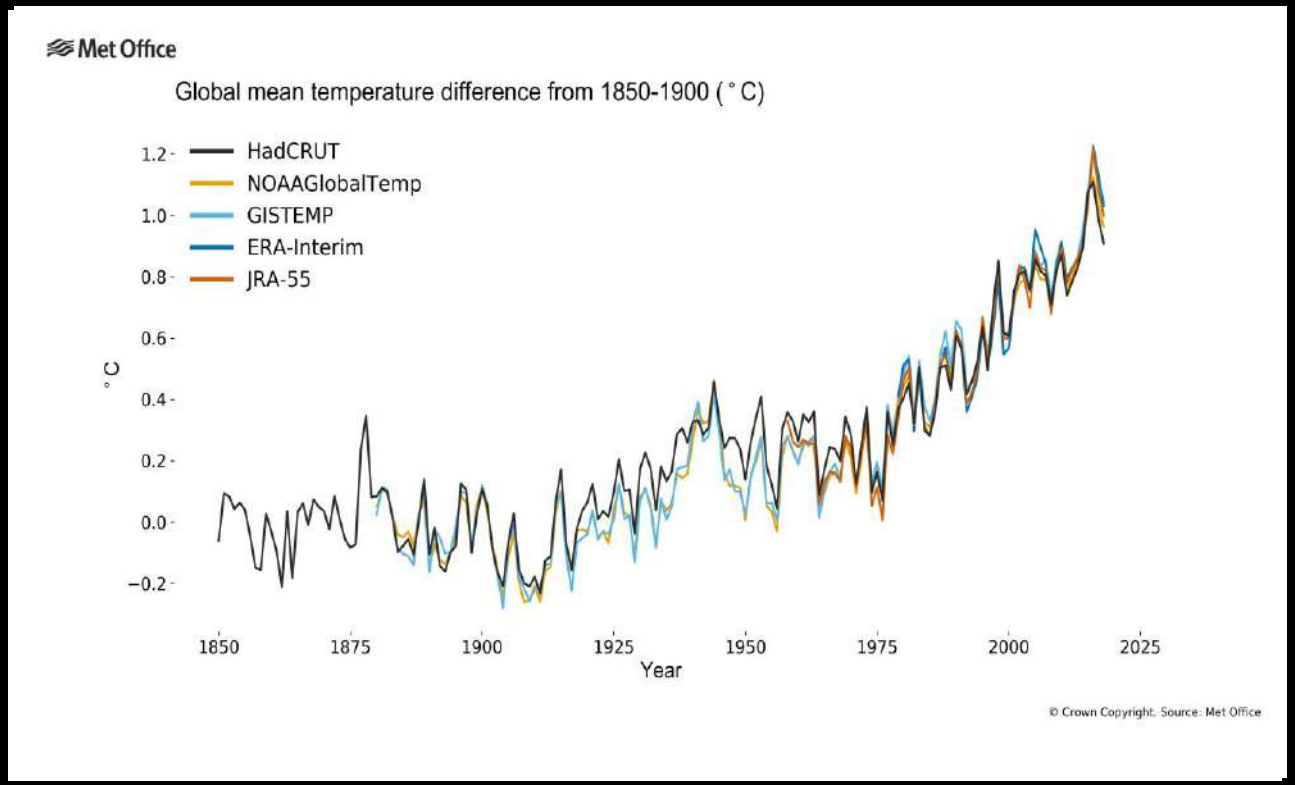
An existential threat?

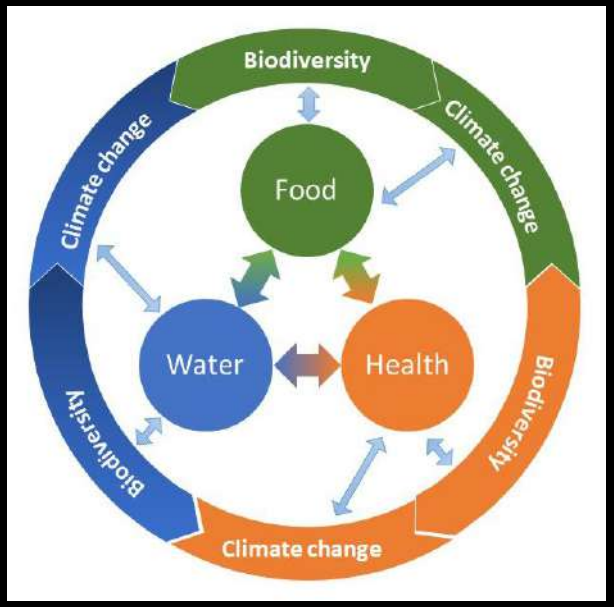
extinction rebellion

"We face a direct existential threat…Our fate is in our hands."- António Guterres (UN Secretary-General).

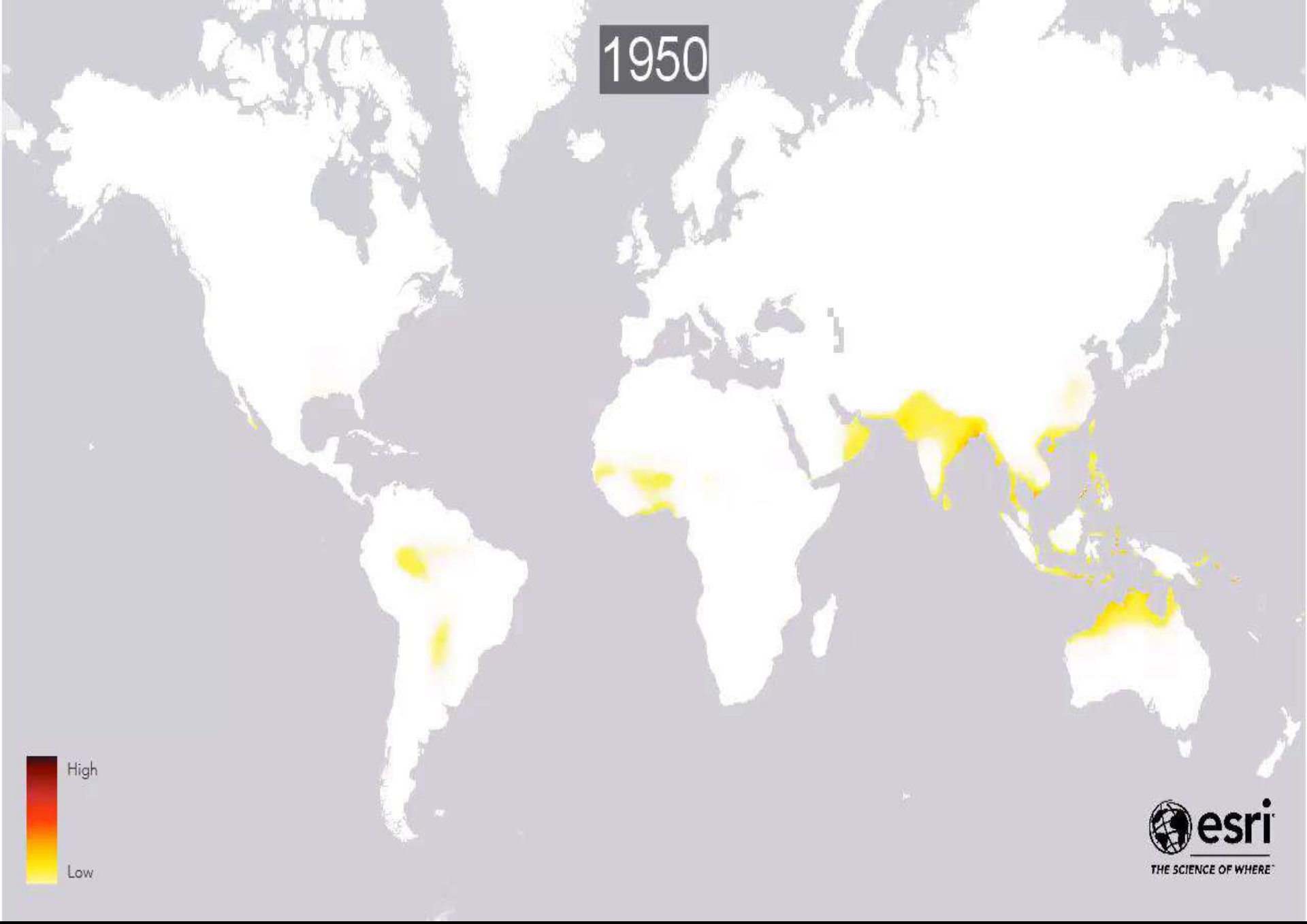




Met Office
Global mean temperature difference from 1850-1900 (° C)
HadCRUT
NOAAGlobalTemp
GISTEMP
ERA-Interim
JRA-55
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
° C
1850
1875
1900
1925
1950
1975
2000
2025
Year
© Crown Copyright. Source: Met Office



- Biodiversity Loss
- Sea level rise
- Desertification
- Wildfires
- Water shortage
- Crop failure
- Extreme weather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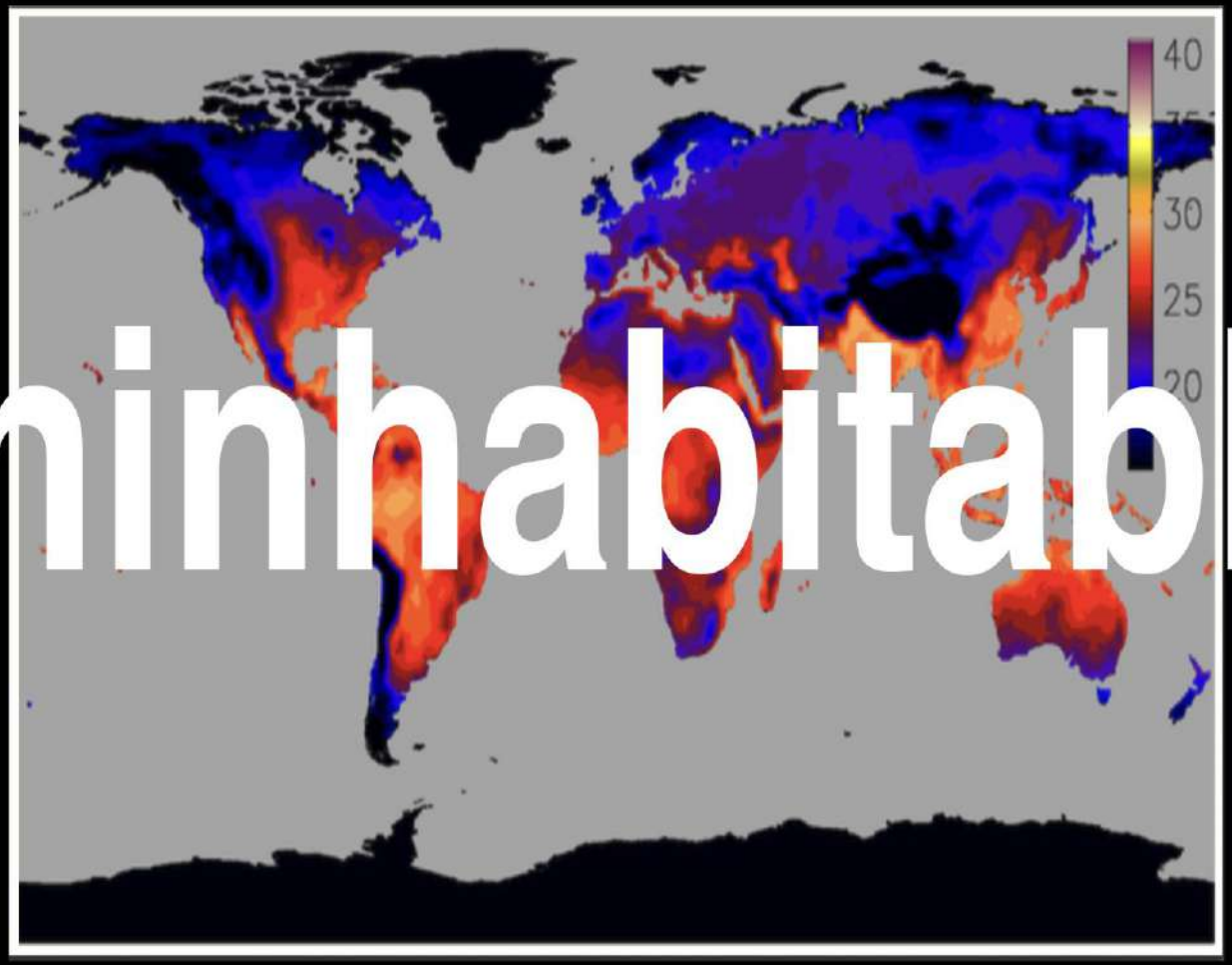
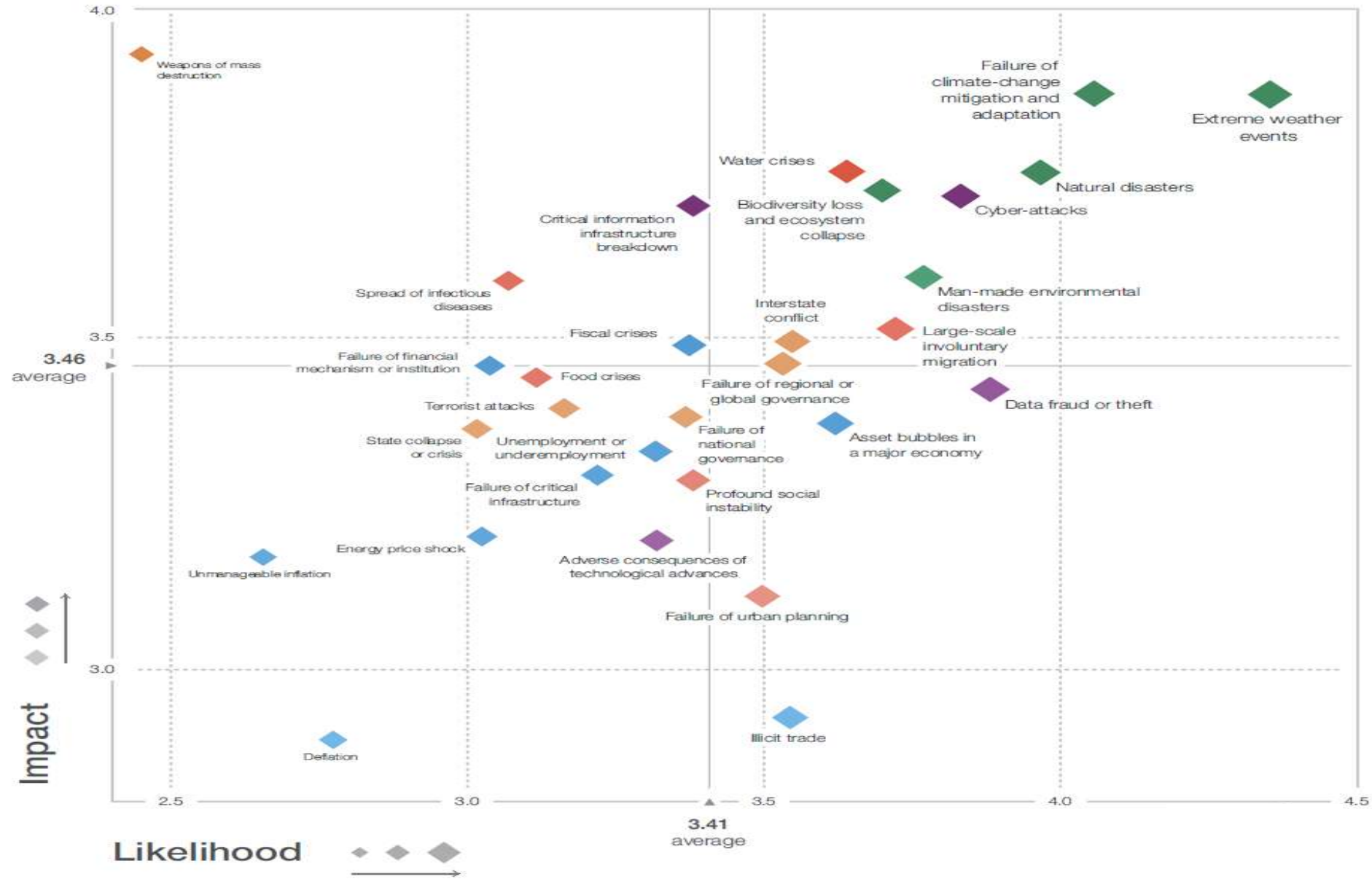


Uninhabitable

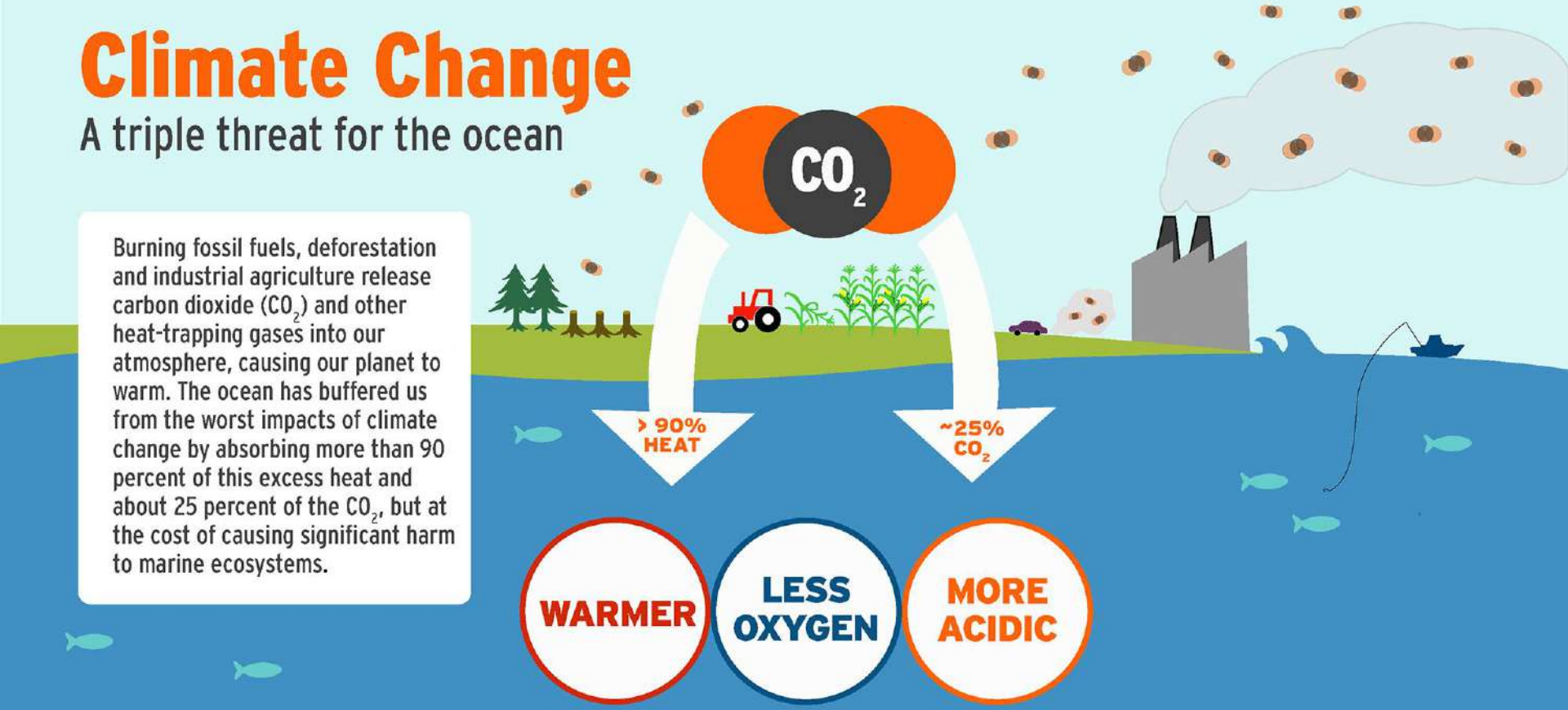
The Global Risks Landscape 2019



Climate Change

A triple threat for the ocean

Burning fossil fuels, deforestation and industrial agriculture release carbon dioxide (CO_2) and other heat-trapping gases into our atmosphere, causing our planet to warm. The ocean has buffered us from the worst impacts of climate change by absorbing more than 90 percent of this excess heat and about 25 percent of the CO_2, but at the cost of causing significant harm to marine ecosystems.



SEA LEVEL

Sea level rise is accelerating, flooding coastal communities and drowning wetland habitats.

BLEACHING

Warm-water coral reefs (marine biodiversity hotspots) could be lost if the planet warms by 2°C (3.6°F).

TOXIC ALGAE

Larger and more frequent blooms are making fish, birds, marine mammals and people sick.

HABITATS

Lower oxygen levels are suffocating some marine animals and shrinking their habitats.

ACIDIFICATION

More acidic water harms animals that build shells, such as corals, clams, and oysters.

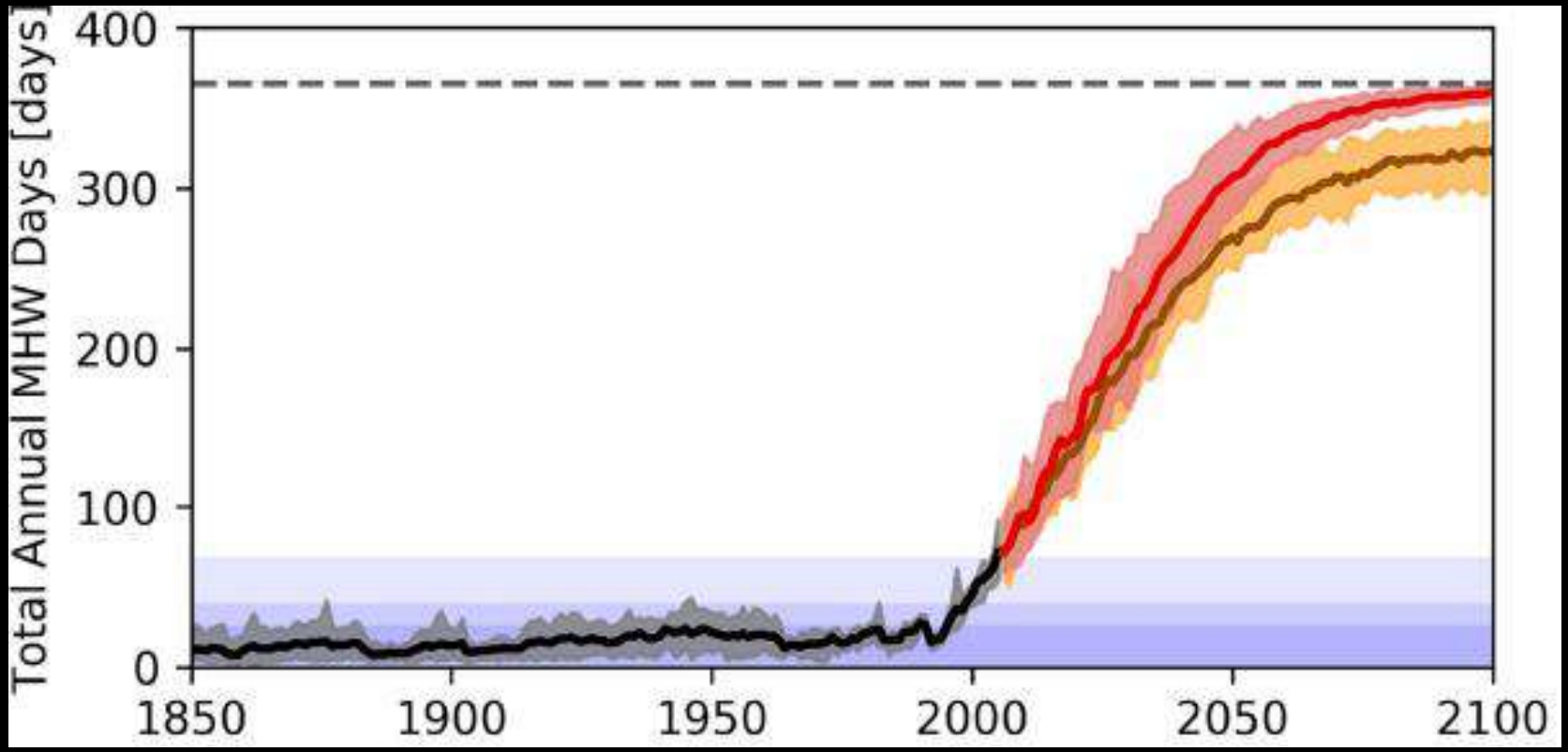
FISHERIES

Disruptions in fisheries affect the marine food web, local livelihoods, and global food security.

Monterey Bay Aquarium Research Institute | Monterey Bay Aquarium

Source: IPCC, 2019: Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)

Projected Marine Heat Waves



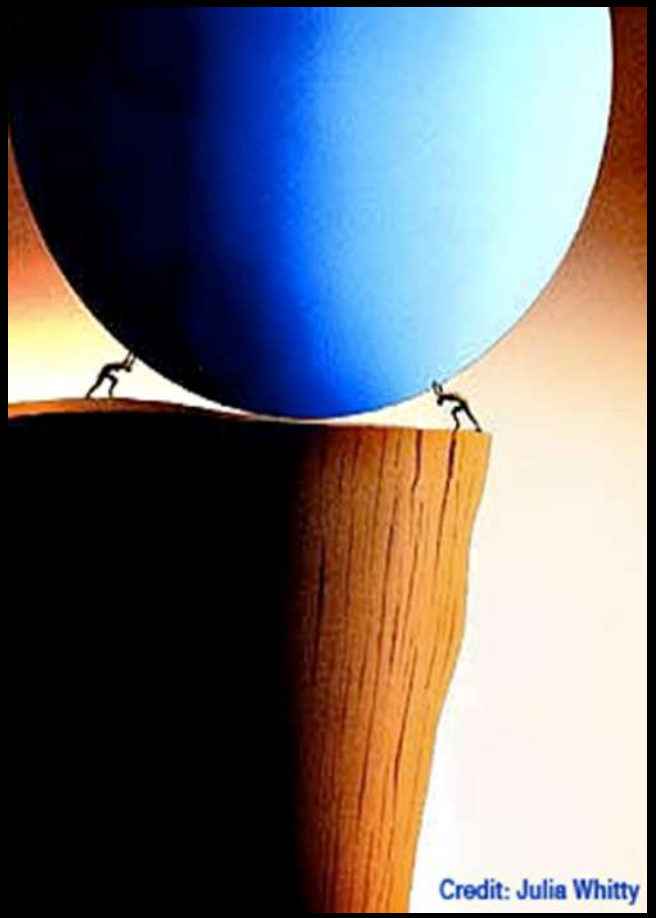
Under the RCP4.5 scenario about 50% of the ocean is in a permanent MHW state by 2100 (brown line), while >90% is in a permanent MHW state under the RCP8.5 scenario by the end of the century (red line).

"The Boiling Frog story is often used as a metaphor for the inability of people to react to significant changes that occur gradually or to events which have become commonplace."

Tipping Points

Compared to past changes in a physical, bio-ecological and/or human system, a ‘tipping point’ is when:

- The change is abrupt
- The ability of the system to return to its original state is unlikely
- The system is now in a new state



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.

Politicians, economists and even some natural scientists have tended to assume that tipping points[1] in the Earth system — such as the loss of the Amazon rainforest or the West Antarctic ice sheet — are of low probability and little understood. Yet evidence is mounting that these events could be more likely than was thought, have high impacts and are interconnected across different biophysical systems, potentially committing the world to long-term irreversible changes.

Here we summarize evidence on the threat of exceeding tipping points, identify knowledge gaps and suggest how these should be plugged. We explore the effects of such large-scale changes, how quickly they might unfold and whether we still have any control over them.

In our view, the consideration of tipping points helps to define that we are in a climate emergency and strengthens this year's chorus of calls for urgent climate action — from schoolchildren to scientists, cities and countries.

The Intergovernmental Panel on Climate Change (IPCC) introduced the idea of tipping points two decades ago. At that time, these 'large-scale discontinuities' in the climate system were considered likely only if global warming exceeded 5 °C above pre-industrial levels. Information summarized in the two most recent IPCC Special Reports (published in 2018 and in September this year)[2,3] suggests that tipping points could be exceeded even between 1 and 2 °C of warming (see 'Too close for comfort').

If current national pledges to reduce greenhouse-gas emissions are implemented — and that's a big 'if' — they are likely to result in at least 3 °C of global warming. This is despite the goal of the 2015 Paris agreement to limit warming to well below 2 °C. Some economists, 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 models[4] aligns with those of the recent IPCC report[2]. In other words, warming must be limited to 1.5 °C. This requires an emergency response.

Ice collapse

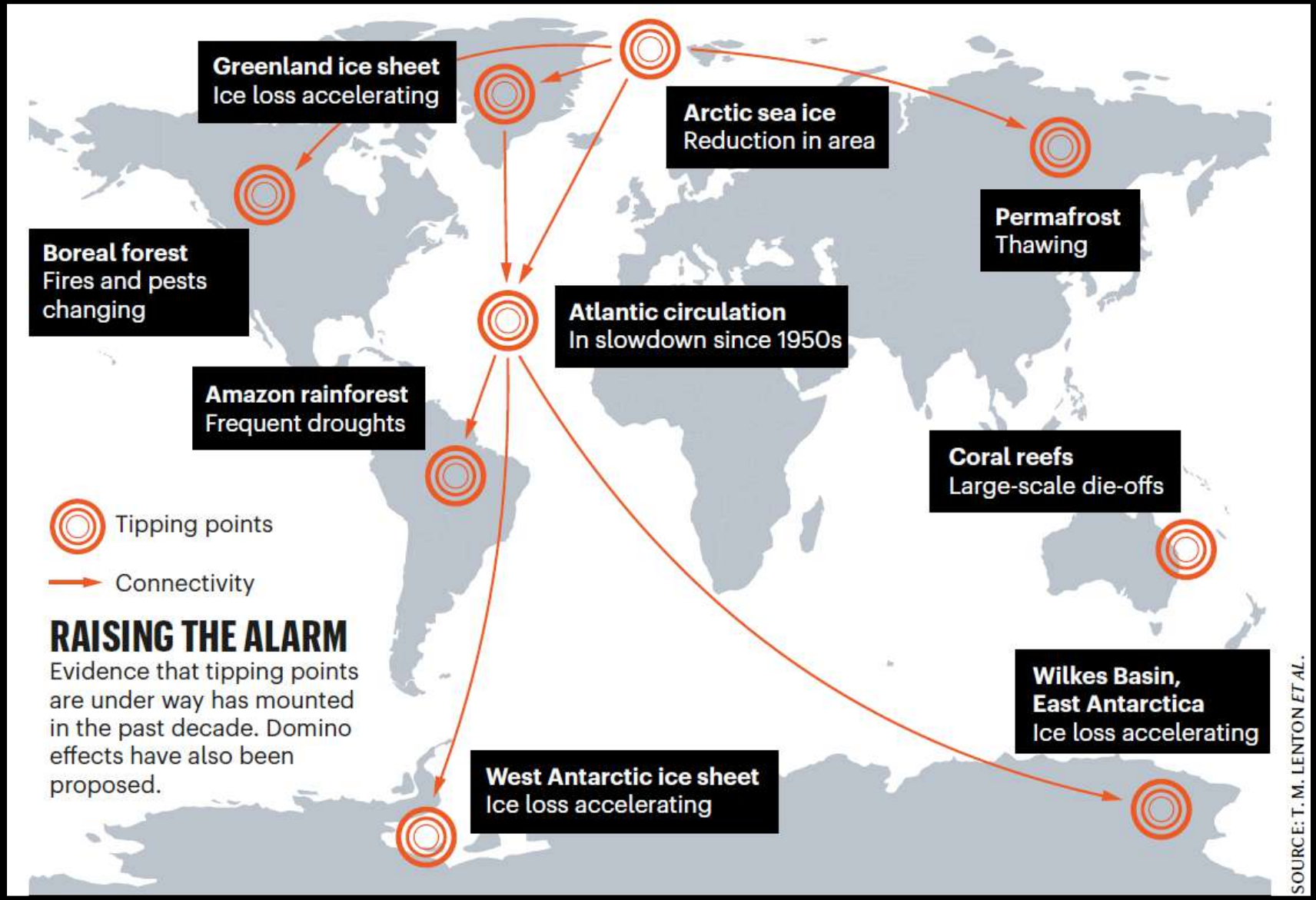
We think that several cryosphere tipping points are dangerously close, but mitigating greenhouse-gas emissions could still slow down the inevitable accumulation of impacts and help us to adapt.

Research in the past decade has shown that the Amundsen Sea embayment of West Antarctica might have passed a tipping point[5]: the 'grounding line' where ice, ocean and bedrock meet is retreating irreversibly. A model study shows[5] that when this sector collapses, it could destabilize the rest of the West Antarctic ice sheet like toppling dominoes — leading to about 3 metres of sea-level rise on a timescale of centuries to millennia. Palaeo-evidence shows that such widespread collapse of the West Antarctic ice sheet has occurred repeatedly in the past.

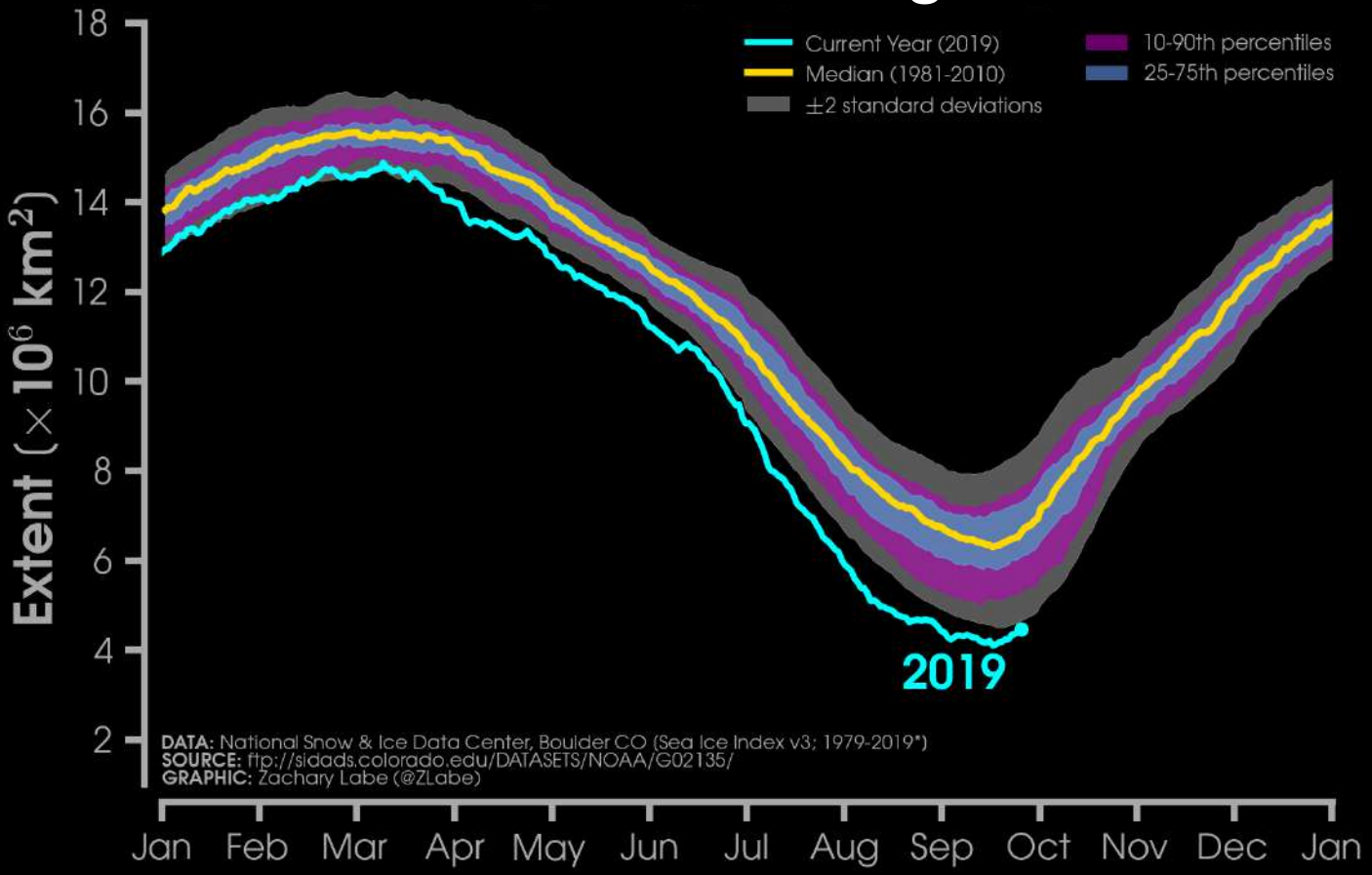
The latest data show that part of the East Antarctic ice sheet — the Wilkes Basin — might be similarly unstable[3]. Modelling work suggests that it could add another 3–4 m to sea level on timescales beyond a century.

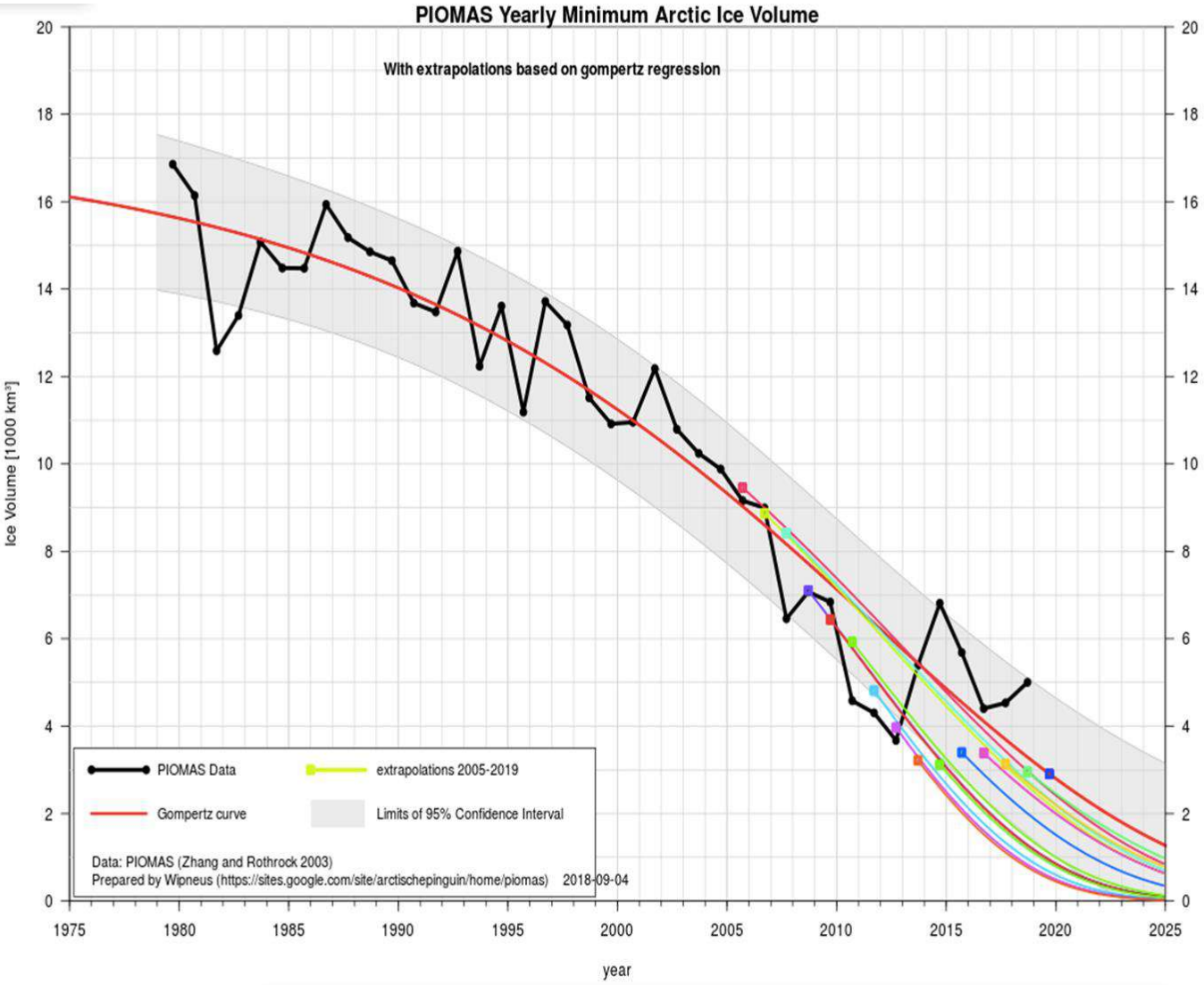
The Greenland ice sheet is melting at an accelerating rate[3]. It could add a further 7 m to sea level over thousands of years if it passes a particular threshold. Beyond that, as the elevation of the ice sheet lowers, it melts further, exposing the surface to ever-warmer air. Models suggest that the Greenland ice sheet could be doomed at 1.5 °C of warming[3], which could happen as soon as 2030.

Thus, we might already have committed future generations to living with sea-level rises of around 10 m over thousands of years[3]. But that timescale is still under our control. The rate of melting depends on the magnitude of warming above the tipping point. At 1.5 °C, it could take 10,000 years to unfold[3]; above 2 °C it could take less than 1,000 years[6].


Greenland ice sheet
Ice loss accelerating
Arctic sea ice
Reduction in area
Permafrost
Thawing
Boreal forest
Fires and pests changing
Atlantic circulation
In slowdown since 1950s
Amazon rainforest
Frequent droughts
Coral reefs
Large-scale die-offs
Tipping points
Connectivity
RAISING THE ALARM
Evidence that tipping points are under way has mounted in the past decade. Domino effects have also been proposed.
Wilkes Basin, East Antarctica
Ice loss accelerating
West Antarctic ice sheet
Ice loss accelerating
SOURCE: T. M. LENTON ET AL.

Arctic summer ice area : a good indicator




PIOMAS Yearly Minimum Arctic Ice Volume
With extrapolations based on gompertz regression
Ice Volume [1000 km³]
year
PIOMAS Data
extrapolations 2005-2019
Gompertz curve
Limits of 95% Confidence Interval
Data: PIOMAS (Zhang and Rothrock 2003)
Prepared by Wipneus (https://sites.google.com/site/arctischepinguin/home/piomas) 2018-09-04

Arctic ice yielding to open water, albedo (reflectivity) drops from 0.6 to 0.1

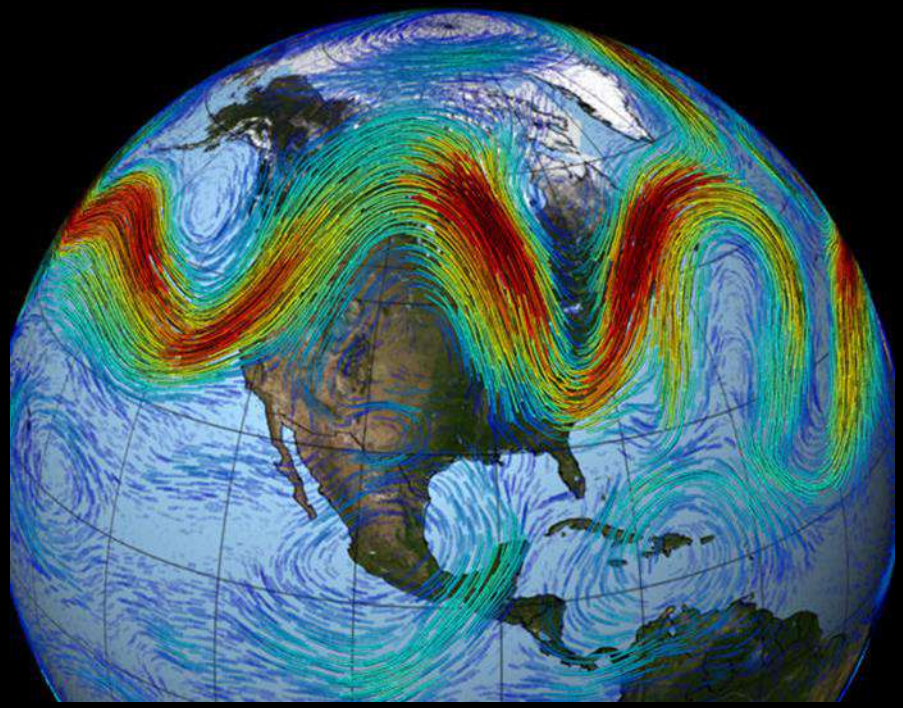
Albedo loss from summer ice has the same warming effect as past 25 years of CO_2 emissions.

Arctic Ocean is shallow, surface warming extends to seabed, melts permafrost, triggers release of methane.

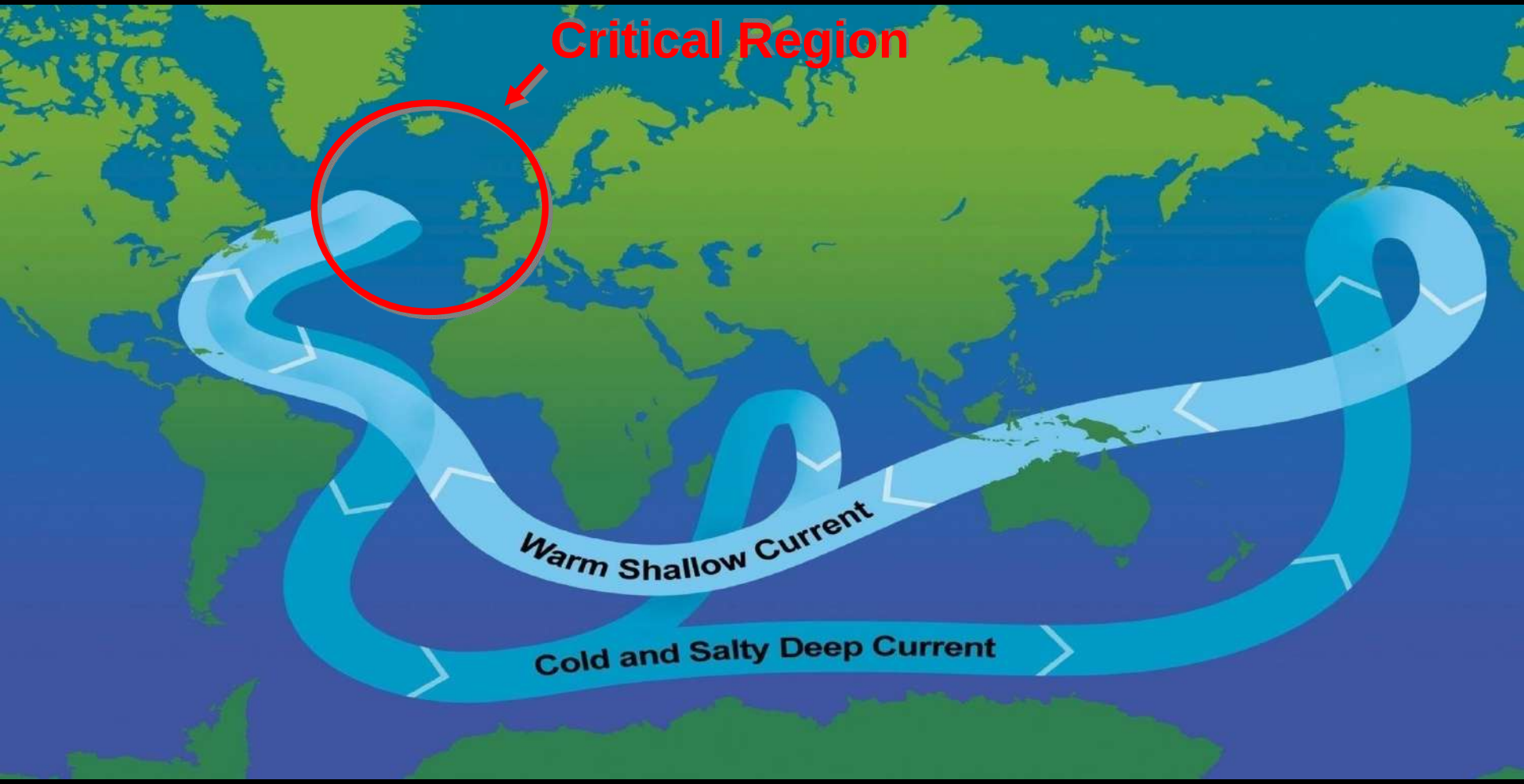
Methane is 20-80 times more potent a GHG as CO_2

Greenland ice sheet holds 2million km^3 of ice.
If it melts → sea-level rise of 7.2m

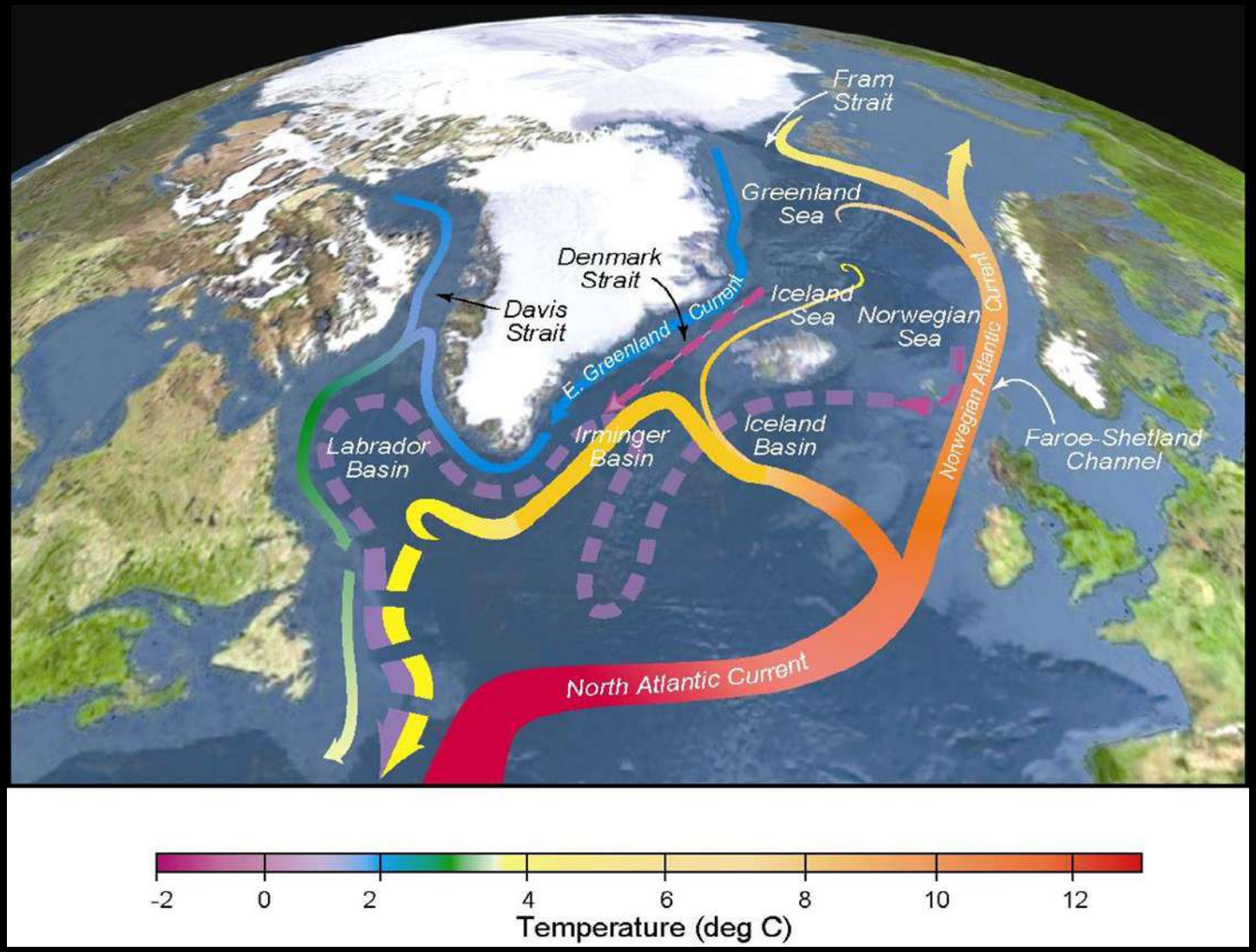
An ice-free Arctic alters jet stream patterns and ocean circulations → changes in climate



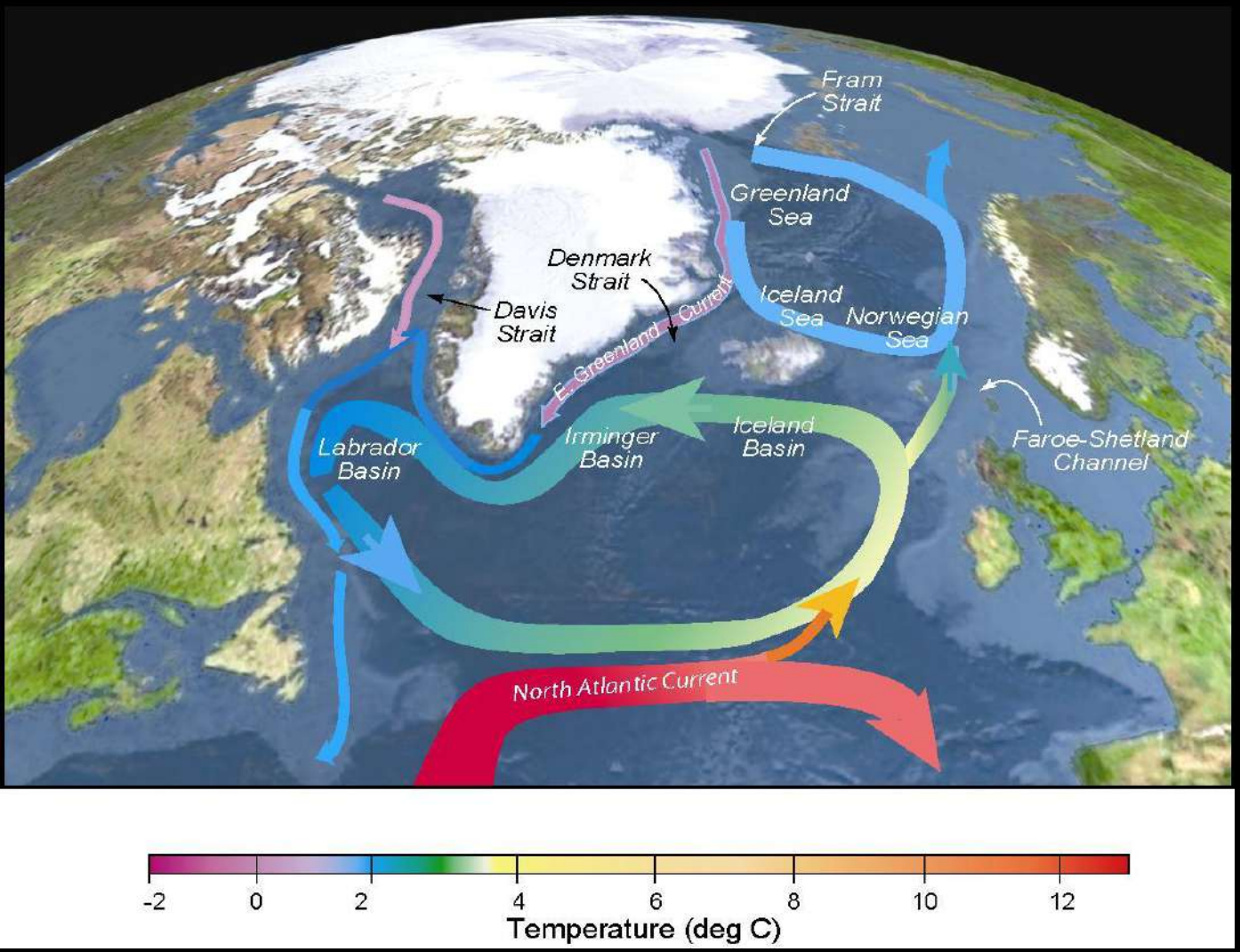
Does the Melting of Sea Ice have other Effects, such as Impacts on Oceanic Circulation?



Could it change this



Into This?



Strong cooling in North Atlantic

Warming everywhere else


Arctic sea ice
Reduction in area
Permafrost
Thawing
Boreal forest
Fires and pests
changing
Atlantic circulation
In slowdown since 1950s
Amazon rainforest
Frequent droughts
Coral reefs
Large-scale die-offs
Tipping points
Connectivity
RAISING THE ALARM
Evidence that tipping points are under way has mounted in the past decade. Domino effects have also been proposed.
Wilkes Basin,
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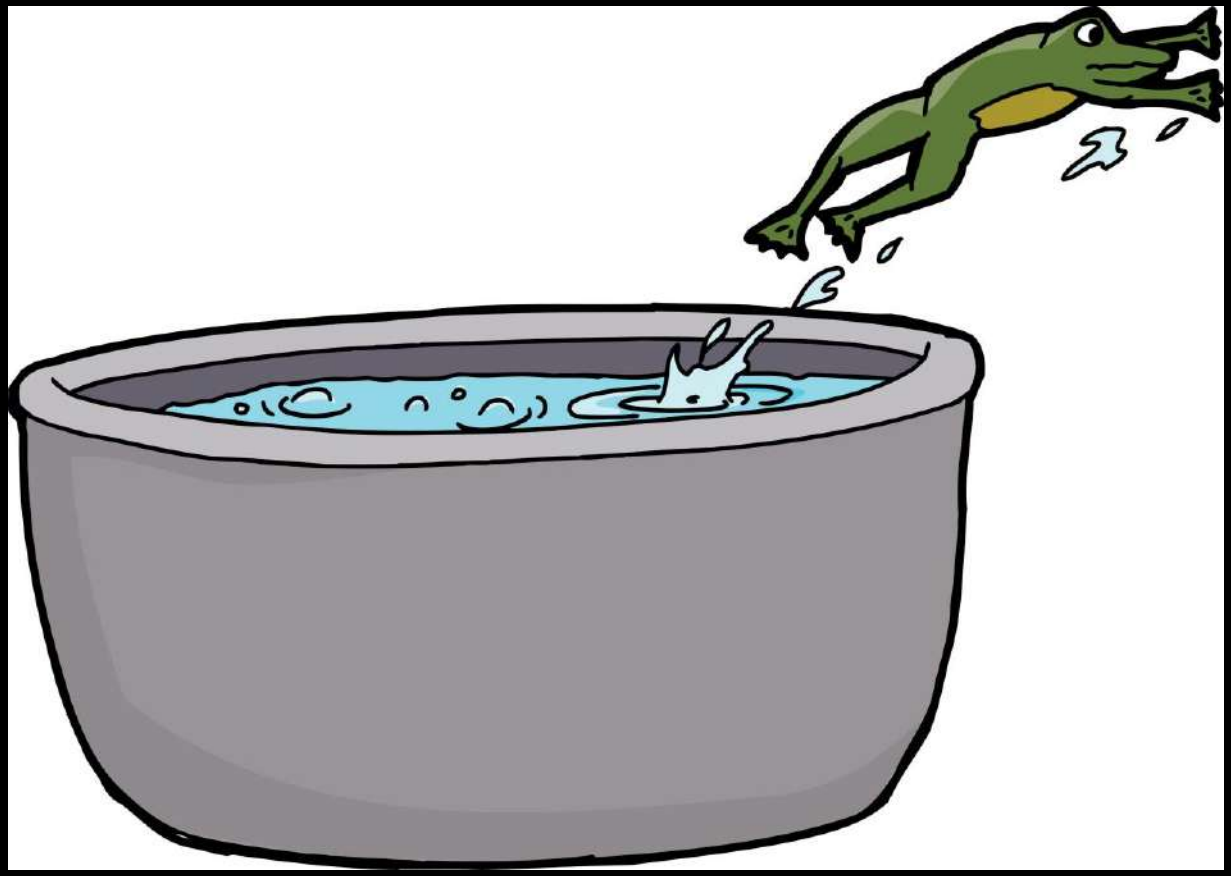
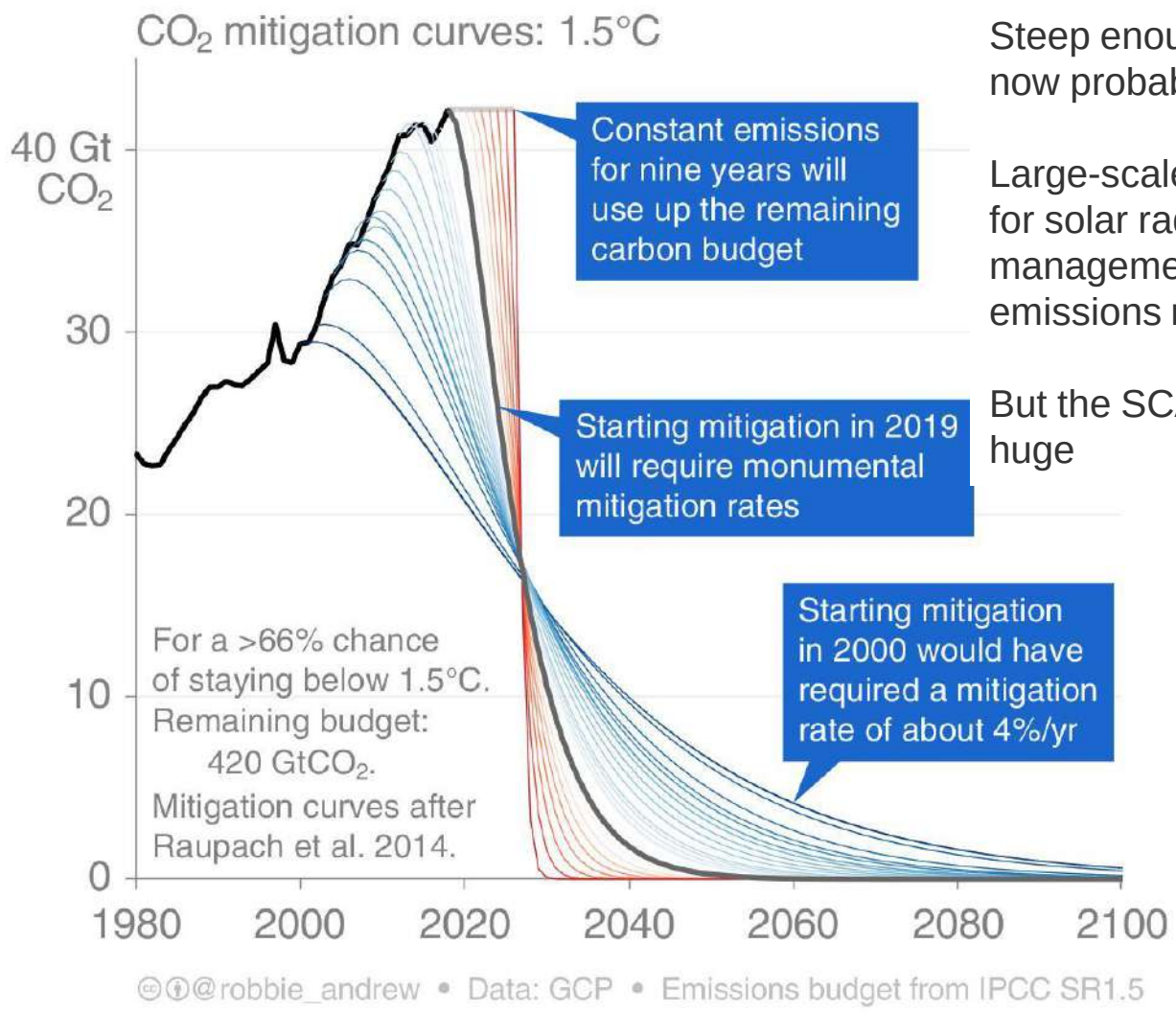
Ice loss accelerating
West Antarctic ice sheet
Ice loss accelerating

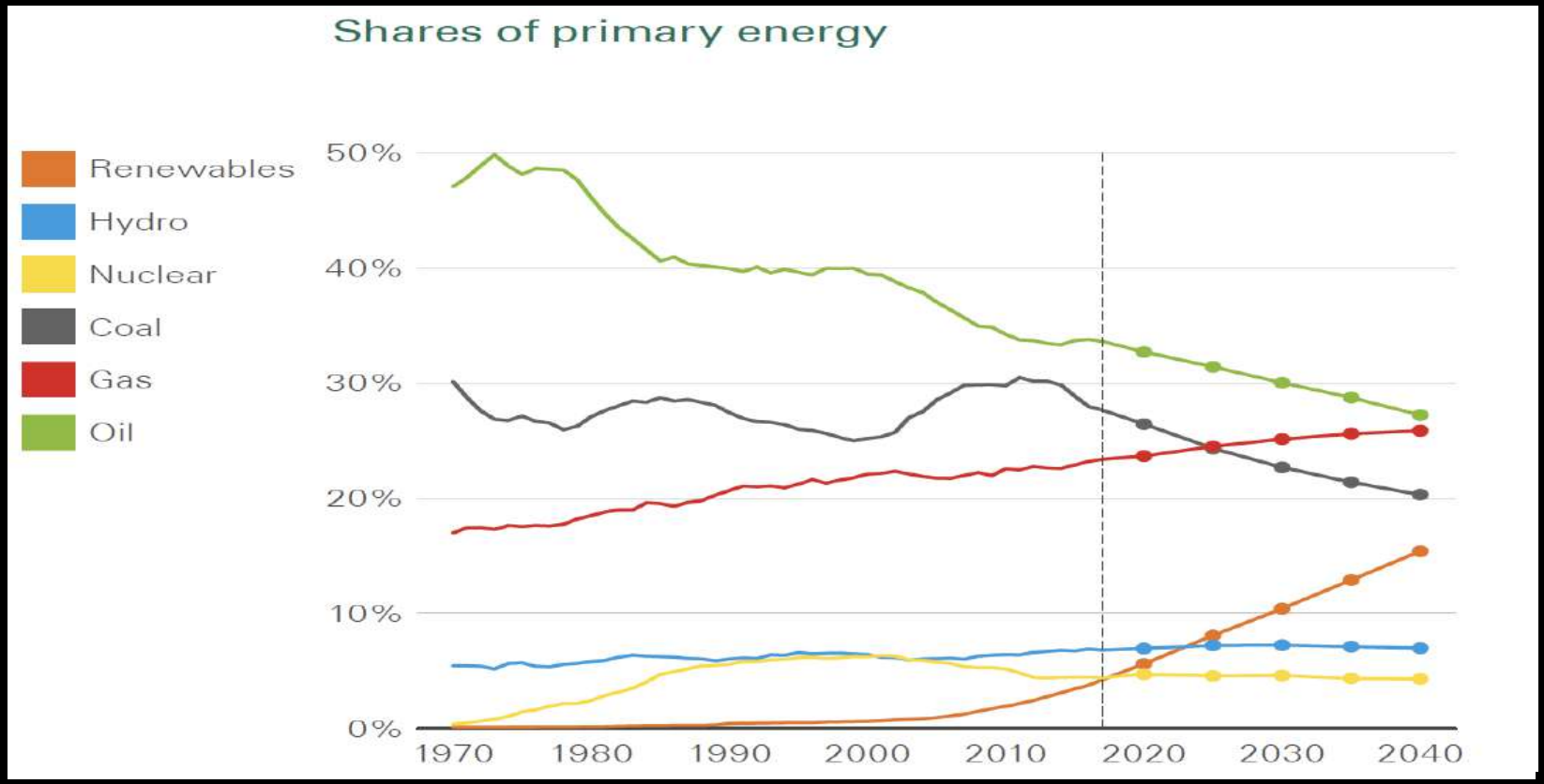




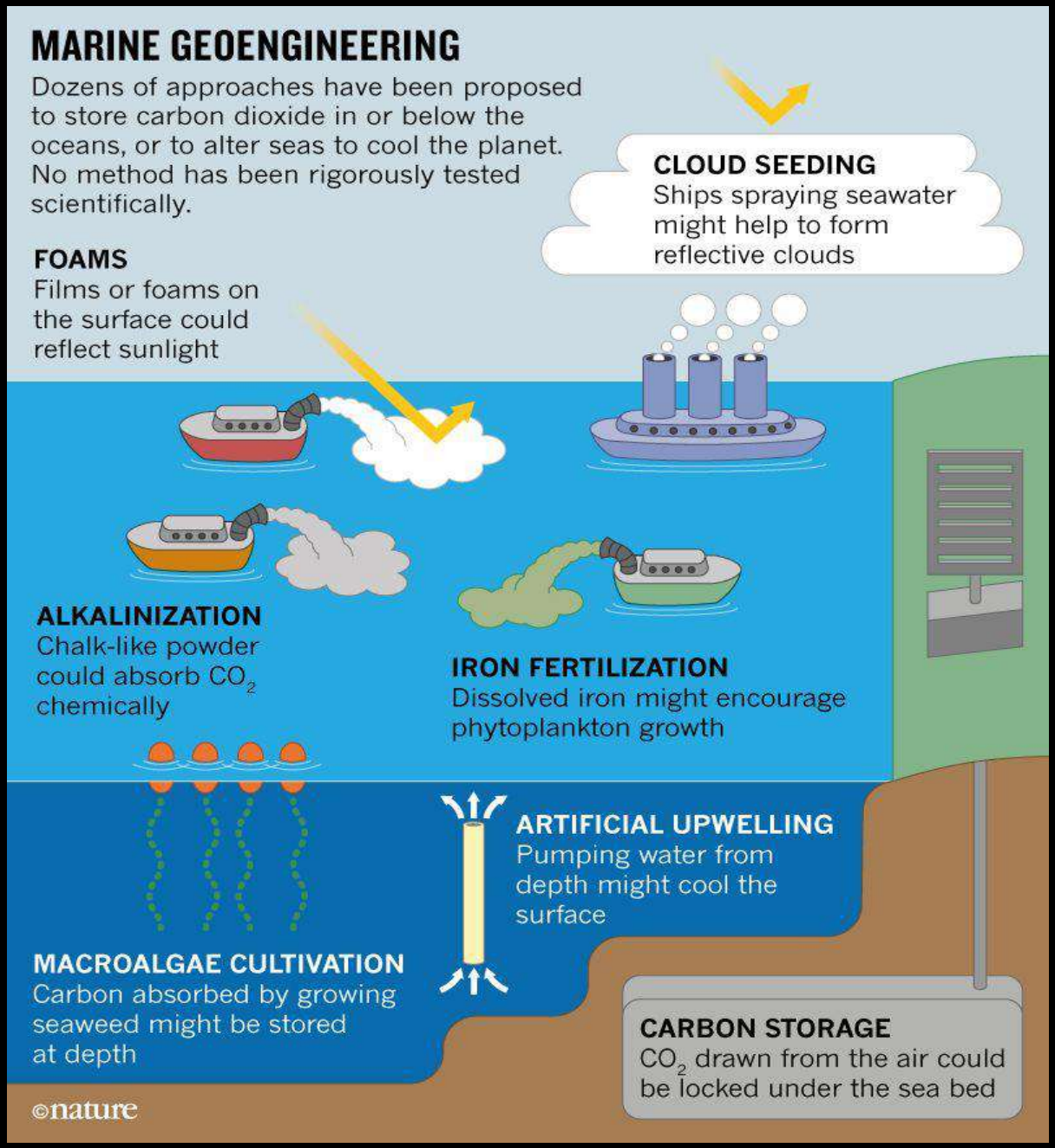
Steep enough mitigation now probably impossible

Large-scale geoengineering for solar radiation management or negative emissions required

But the SCALE required is huge



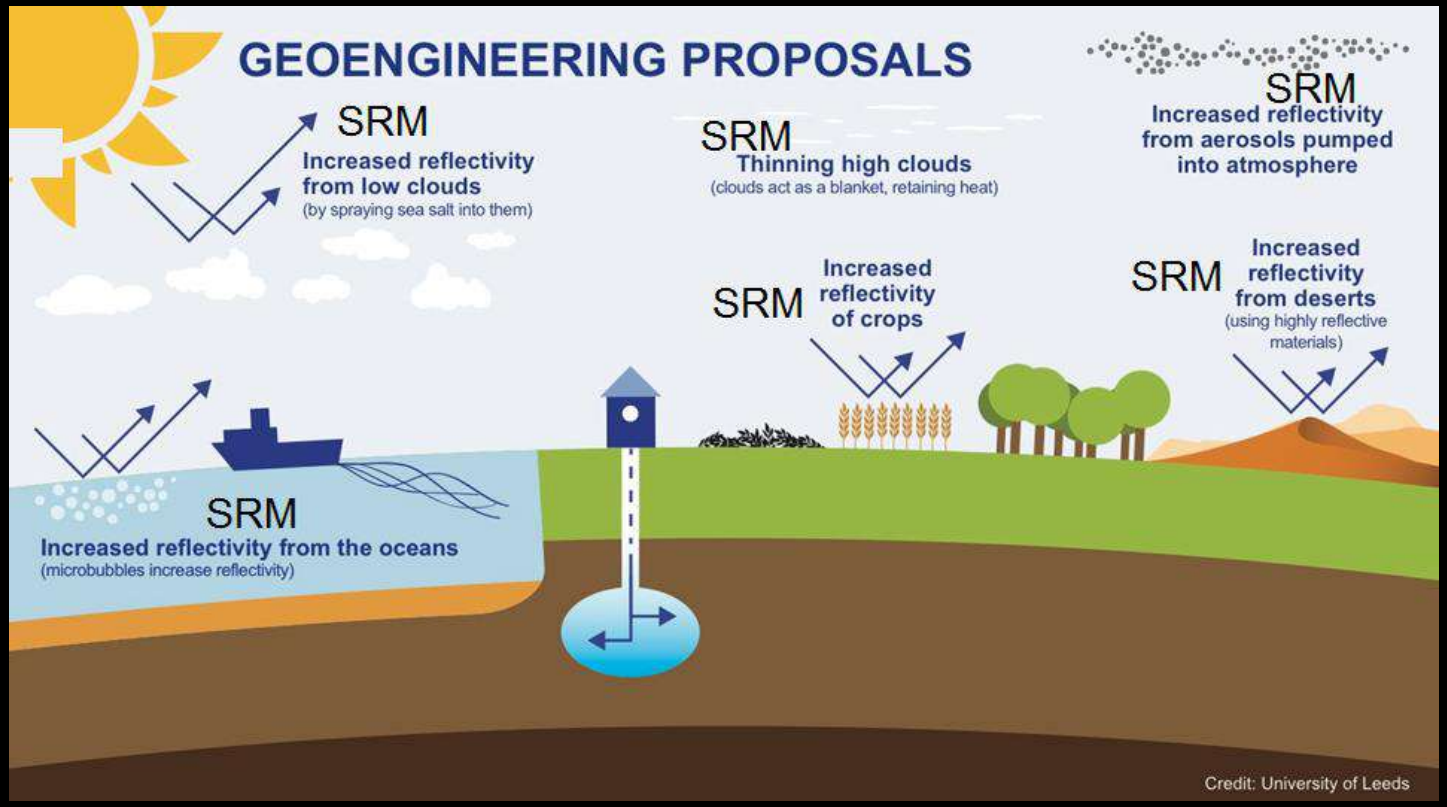
BP Energy Outlook: 2019 edition


MARINE GEOENGINEERING
Dozens of approaches have been proposed to store carbon dioxide in or below the oceans, or to alter seas to cool the planet. No method has been rigorously tested scientifically.
CLOUD SEEDING
Ships spraying seawater might help to form reflective clouds
FOAMS
Films or foams on the surface could reflect sunlight
ALKALINIZATION
Chalk-like powder could absorb CO_2 chemically
IRON FERTILIZATION
Dissolved iron might encourage phytoplankton growth
ARTIFICIAL UPWELLING
Pumping water from depth might cool the surface
MACROALGAE CULTIVATION
Carbon absorbed by growing seaweed might be stored at depth
CARBON STORAGE
CO_2 drawn from the air could be locked under the sea bed
©nature

Eruption of Mt Pinatubo, 1991

August 30, 1984

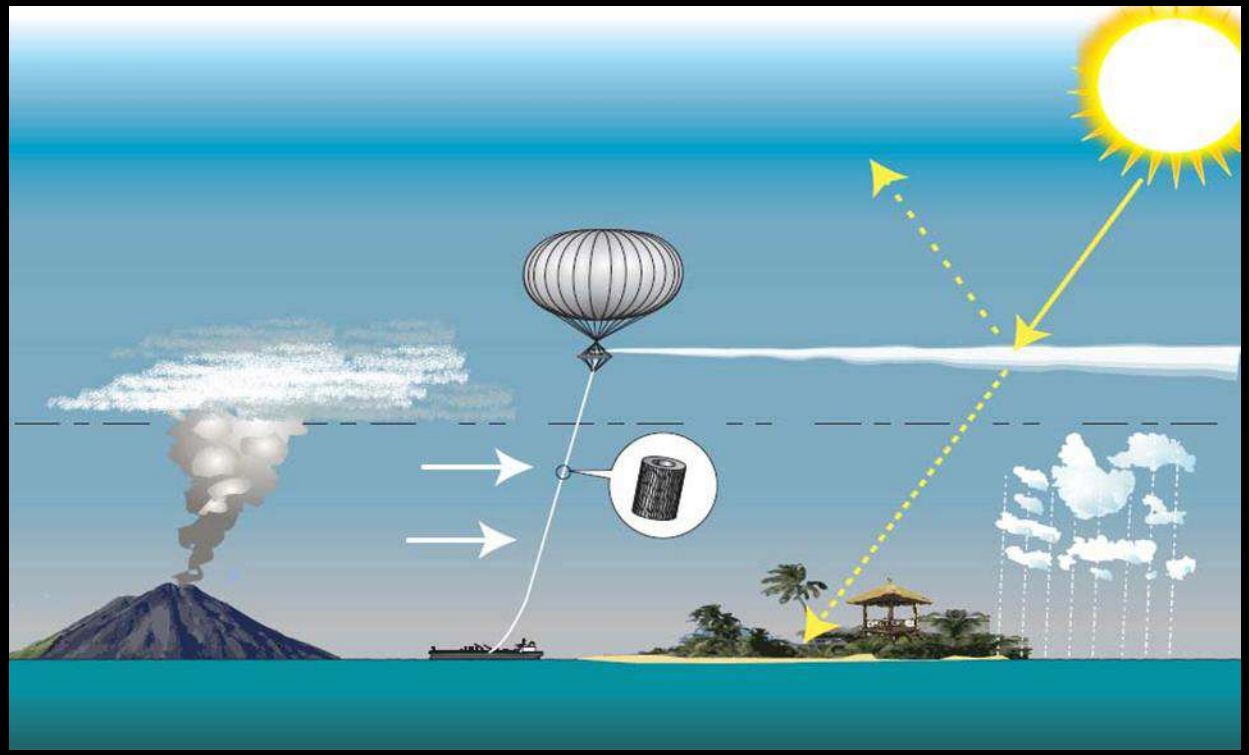
August 8, 1991



Geoengineering:
Solar Radiation Management

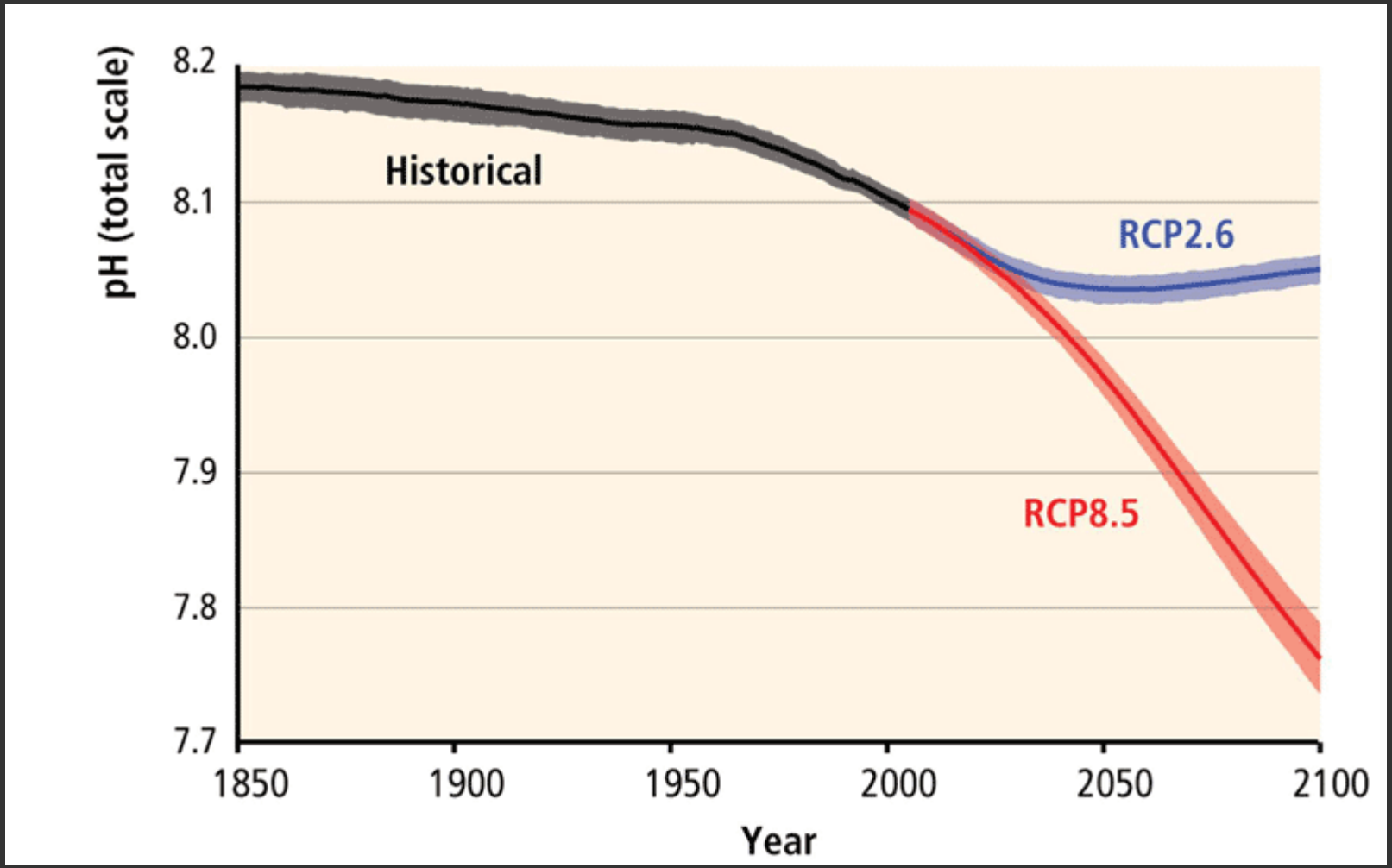
SPICE: aerosol delivery system for 2°C cooling

Stratospheric **P**article **I**njection for **C**limate **E**ngineering

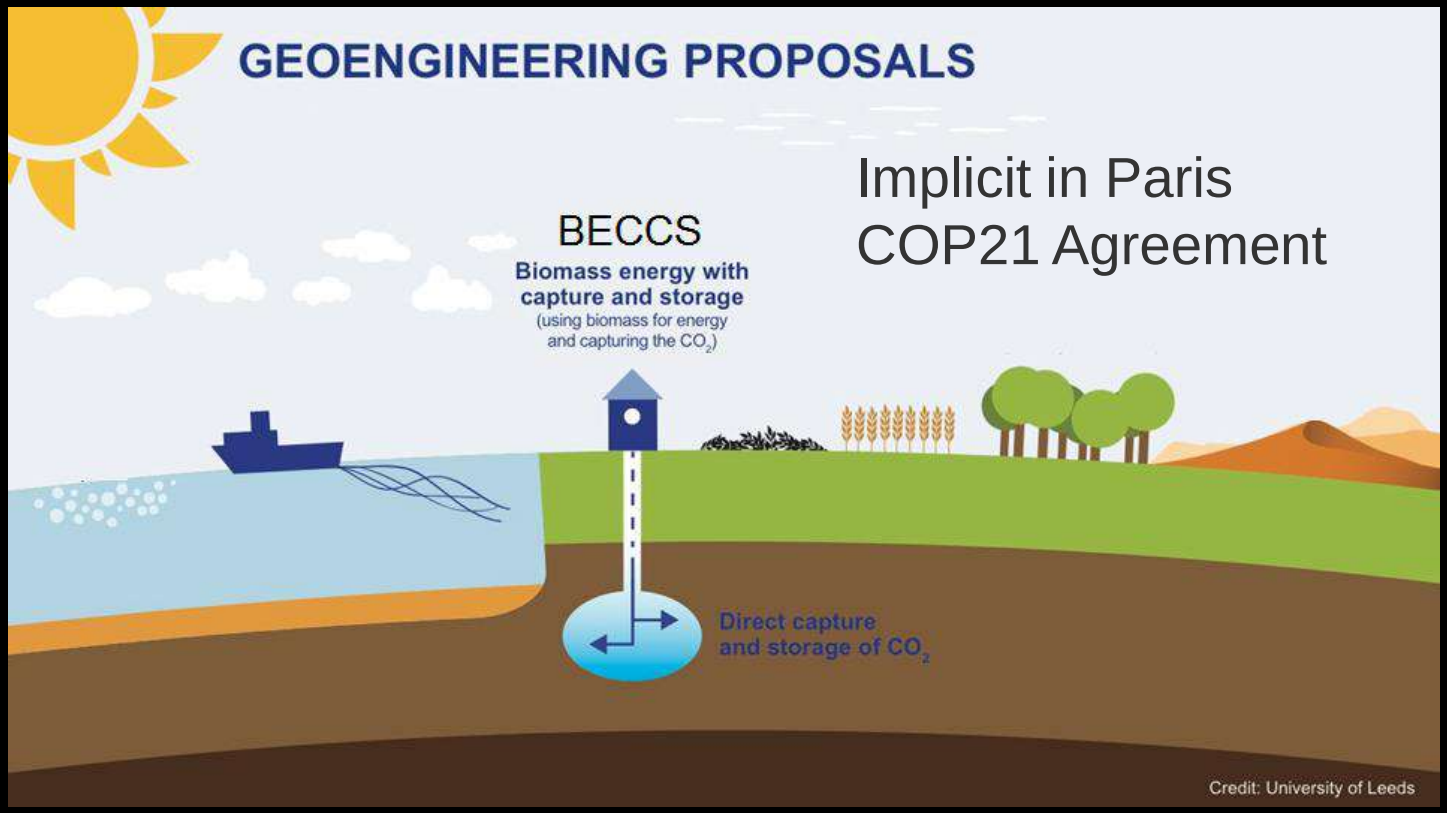


Tethered balloons – height 20km

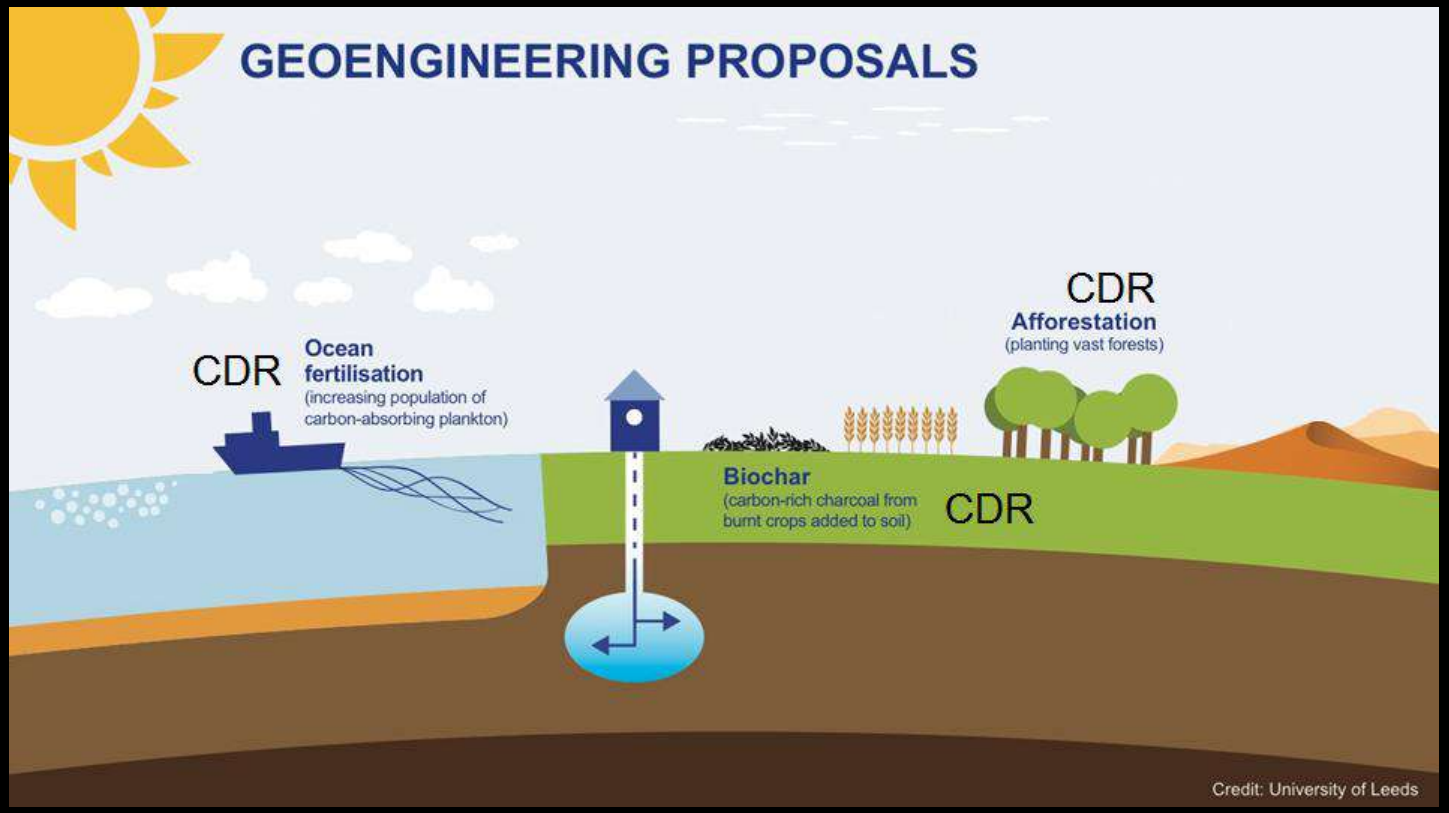
maybe 10 balloons worldwide each delivering 30kg/s of aerosol



Source: Gattuso et al. 2014



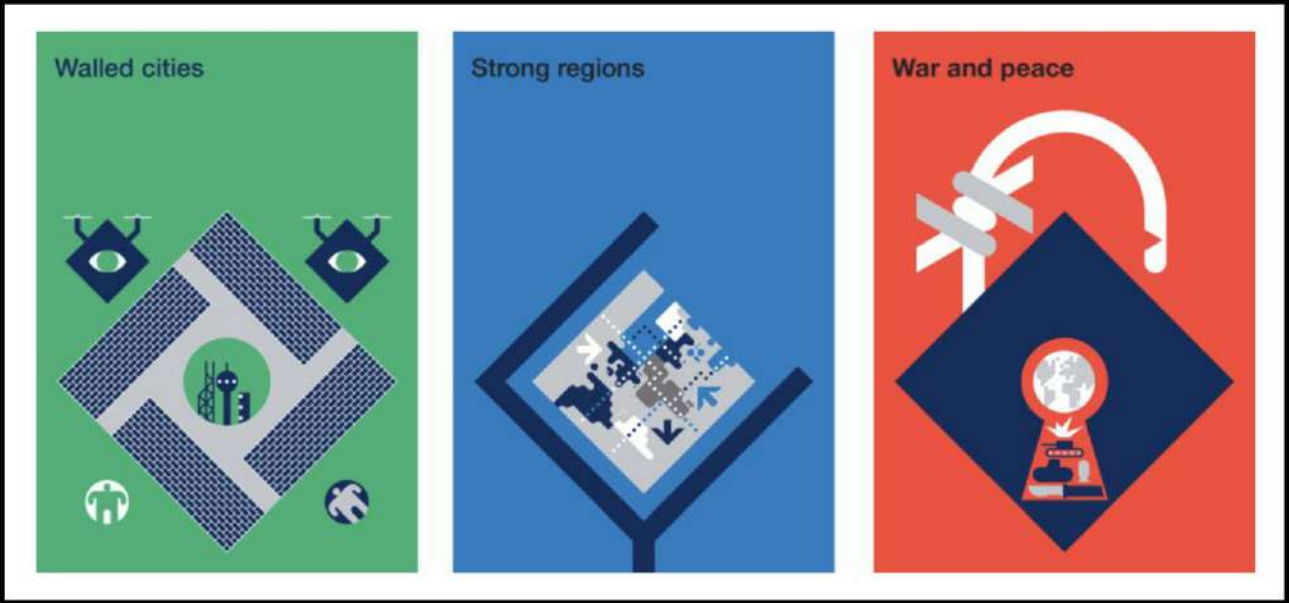
Geoengineering:
Bio-Energy with Carbon Capture and Storage



Geoengineering:
CDR = Carbon Dioxide Removal

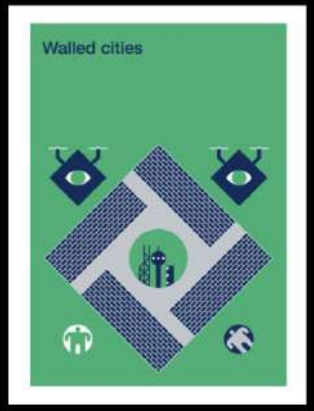
Coastal Futures 2020

WEF Security Outlook 2030 - Three Scenarios



World of Walls

In 1989 after the fall of the Berlin Wall there were only 15 border walls around the world
Today there are 70



- Fiscal challenges and political dysfunction erode state provision of public services
- Inequalities widen and middle classes are hollowed out
- Elite retreat to gated communities and turn to private sector for basic services
- Society becomes increasingly polarised between elites and impoverished class with little social mobility
- Rootless and disillusioned young people become anti-system and vulnerable to radicalisation
- States lose ability to cohere people around a shared narrative or identity
- Insurgencies, terrorist groups and criminal organisations exploit the security deficit
- The world divides into islands of order in a sea of disorder
- As large numbers of people are displaced by climate change and social violence, still-functioning states seek to protect themselves

The international journal of science / 2 January 2020

nature

Get the Sustainable Development Goals back on track

Most of the goals will be missed. Here's how to put them back on the right path.

In 2015, world leaders met in New York at a landmark conference of the United Nations. Their aim: to end poverty, stop environmental destruction and boost well-being. In the world of multilateral diplomacy, such meetings are not uncommon, but they tend to focus on individual areas, such as climate change or food security. The 2015 summit was different because heads of state and governments pledged concrete action across an integrated set of economic, environmental and social issues. They signed up to the Sustainable Development Goals (SDGs), a package of 17 goals and associated targets for ending hunger, eliminating extreme poverty, reducing inequality, tackling climate change and halting the loss of biodiversity and ecosystems – all by 2030.

With that deadline now a decade away, the world is set to miss most of the SDGs. Just two of them – eliminating preventable deaths among newborns and under-fives, and getting children into primary schools – are closest among all the goals to being achieved. By contrast, the goal to eliminate extreme poverty will not be met because some 430 million people are expected still to be living in such conditions in 2030.

Targets to end hunger and to protect climate and biodiversity are completely off track. Whereas some of the richer countries are making a degree of progress in the SDGs overall, two-thirds of poorer ones are not expected to meet those that relate even to their most basic needs.

The SDGs are extremely valuable, and five years is too short a time to see real progress towards economic transformation, which must happen if the goals are to be achieved in full. But at the same time, the SDGs have had a considerable positive impact – including in research and higher education. Institutions globally are signing up to supporting the SDGs, and staff and students are taking on responsibilities, from eliminating single-use plastic, to switching to renewable energy. The goals' cross-cutting nature has fuelled research, too, providing scientists with opportunities in the fields of the environment, engineering, health policy, development economics and beyond.

But these bright spots cannot mask what is still a bleak trend. The UN secretary-general, António Guterres, puts the halting progress down to a lack of funding – especially from the governments of developed countries. The goals come with a price tag of between US$5 trillion and $7 trillion per year, and the shortfall has been put at $2.5 trillion.

But there's a larger obstacle. The goals are still a voluntary effort, although monitoring of progress is extensive. A UN-affiliated organization called the Sustainable Development Solutions Network produces an annual report that shows how well countries are performing on the SDGs, and on page 74 of this issue, researchers from the United States and China describe how progress can be more accurately recorded (Z. Xu *et al. Nature* **577**, 74–78; 2020) (see also page 8). But it's not compulsory for countries to report how they are doing.

> **"Time is short, and there's a lot to do when a decade is all we have."**

To be achieved, the SDGs need to become mandatory – not necessarily in the legal sense, but in the sense that nations have to know that there's no alternative but to make them happen. One analogy is the way in which countries report their economic data. There's no international law that says every country must report data, such as on consumer spending, that go into calculating its gross domestic product (GDP). But for more than 50 years, these data have been collected at a granular level and are now reported every quarter by national statistics offices. Every agency of government understands that a nation's economy must always be seen to be growing, and so the data underlying the GDP must also always be increasing. That's why there's a massive national effort to make sure that everyone works towards what could be called the 'GDP goals'. The SDGs are unlikely to be achieved unless they, too, sit at the apex of a similar national effort.

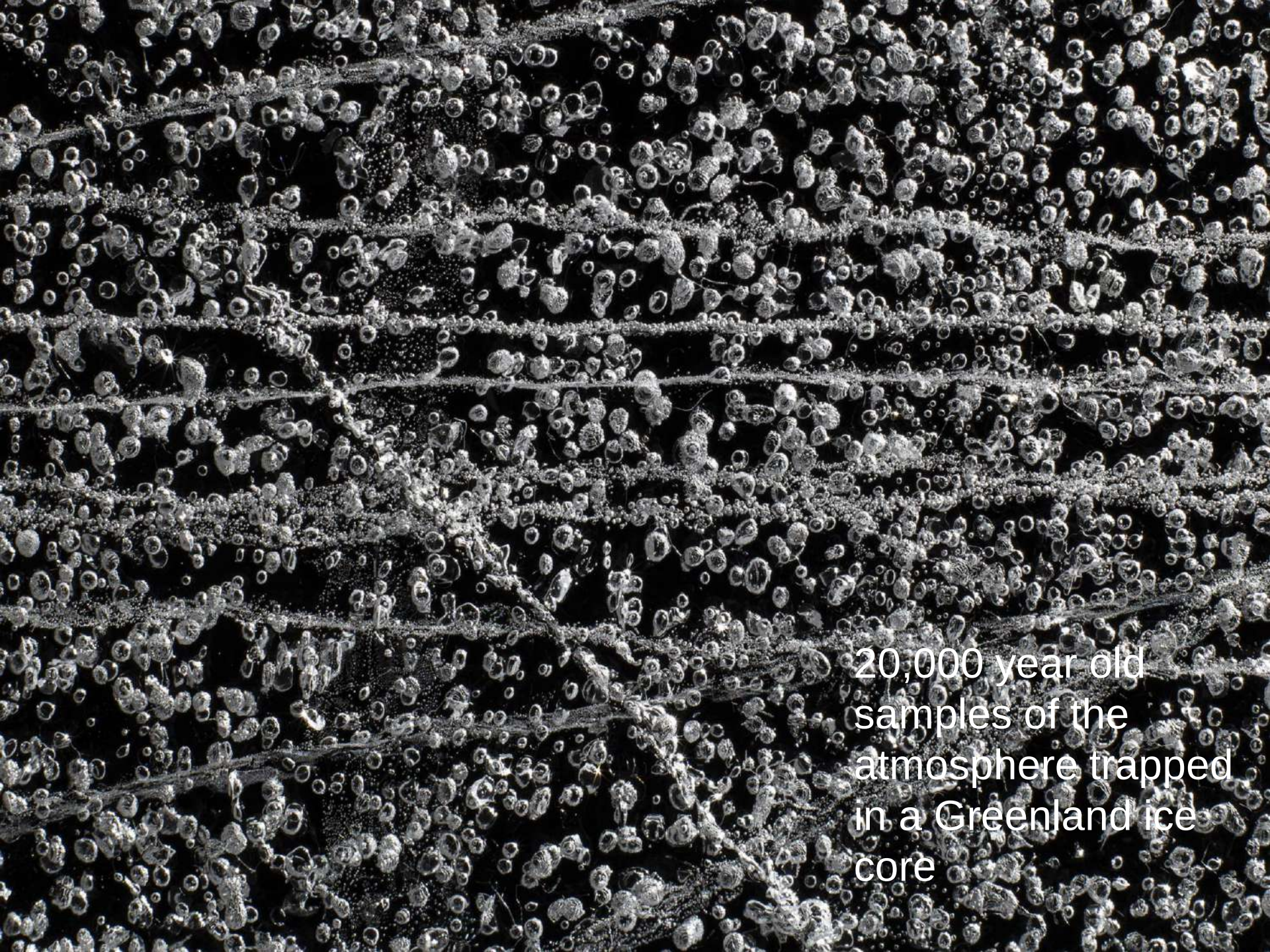
At the same time – and as is often pointed out – some GDP goals are in opposition to sustainability efforts such as the SDGs. Take new sources of fossil-fuel energy. They provide much-needed power for communities lacking basic needs and contribute positively to economic growth. But they also have a negative impact on the environment and on human health. Yet it's only the positive economic impact that counts in official data, and that is one reason – although not the only one, by far – why it's proving so difficult to shift power to renewable-energy platforms. One solution might be to factor the cost of degrading the environment into national accounting – although there is as yet little consensus on how this would be done.

Tighter focus

One research-led effort where there is more consensus is the Global Sustainable Development Report (GSDR). Due to be published every four years, it is commissioned by the UN secretary-general and written by a team of 15 authors nominated by UN member states, but working independently with the wider scientific community. The first report was published last September, and the UN will appoint authors for the second one, due in 2023, later this month.

The first report's authors are aware that the SDGs lack a mandatory reporting mechanism, and that in some cases the goals are competing with GDP goals. And they have come up with an innovative solution. They recommend that nations consider redistributing the 17 SDGs into 6 'entry points'. These are: human well-being (including eliminating poverty and improving health and education); sustainable economies (including reducing inequality); access to food and nutrition; access to – and decarbonizing – energy; urban development; and the global commons (combining


1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS



20,000 year old samples of the atmosphere trapped in a Greenland ice core