Climate Change and the Ocean

A call to action

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An existential threat?

“We face a direct existential threat...Our fate is in our hands.” - António Guterres (UN Secretary-General).
Climate Change and the Ocean

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Global mean temperature difference from 1850-1900 (°C)

- HadCRUT
- NOAA Global Temp
- GISTEMP
- ERA-Interim
- JRA-55

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Climate Change and the Ocean

A call to action

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

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Uninhabitable
Climate Change
A triple threat for the ocean

Burning fossil fuels, deforestation and industrial agriculture release carbon dioxide ($\text{CO}_2$) 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 $\text{CO}_2$, but at the cost of causing significant harm to marine ecosystems.

- **Warmer**: Sea level rise is accelerating, flooding coastal communities and drowning wetland habitats.
- **Less Oxygen**: 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.
- **More Acidic**: 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.

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

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 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 summarise 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 3.5°C above pre-industrial levels. Information summarized in the two most recent IPCC Special Reports (published in 2018 and in September this year) suggests that tipping points could be exceeded even between 1°C and 2°C of warming (see Footnote for context).

If national and international pledges to reduce greenhouse gas emissions are implemented – and that’s a big if – they are likely to result in at least 1.5°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 “Climatic tipping points appear to be in the range of 3°C to 4°C warming above pre-industrial levels.”

For example, warming of 3°C above pre-industrial levels could melt the Amazon rainforest. At 4°C, the North Pole could disappear, the West Antarctic ice sheet could collapse and the Arctic could become ice-free year-round. At 6°C, the Midwest of the US could become uninhabitable.

To avoid these outcomes, we must act now. The recent IPCC report calls for a ‘rapid, far-reaching and unprecedented’ transformation in society.

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: grounding lines are retreating, and ice is flowing out to sea. A model study shows that when this sector collapses, it could de-stabilize the rest of the West Antarctic ice sheet, like a toppling dominoes, leading to a level of sea-level rise of tens to centuries of centuries to millennia. Palace evidence shows that such widespread collapse of the West Antarctic ice sheet has occurred repeatedly in the past.

The latest data show that parts of the East Antarctic ice sheet – the Rift – might be similarly unstable. Modelling work suggests that it could add another 3 m to sea level over thousands of years if it passes a particular threshold. Beyond that, the elevation of the ice sheet would be frozen in place:

The Greenland ice sheet is melting at an accelerating rate. If it could add a further 7 m to sea level over thousands of years if it passes a particular threshold. Beyond that, the elevation of the ice sheet would be frozen in place:

Thus, we might already have committed future generations to living with sea-level rises of around 10 m over thousands of years. 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 would take 10,000 years to unfold; above 2°C it could take less than 1,000 years.
RAISING THE ALARM

Evidence that tipping points are under way has mounted in the past decade. Domino effects have also been proposed.
Arctic summer ice area: a good indicator

DATA: National Snow & Ice Data Center, Boulder CO (Sea Ice Index v3: 1979-2019*)
SOURCE: ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/
GRAPHIC: Zachary Lobe (@ZLobe)

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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 2 million 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 everywhere else
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RAISING THE ALARM
Evidence that tipping points are underway has mounted in the past decade. Domino effects have also been proposed.

- Boreal forest: Fires and pests changing
- Arctic sea ice: Reduction in area
- Atlantic circulation: In slowdown since 1950s
- Permafrost: Thawing
- Amazon rainforest: Frequent droughts
- Coral reefs: Large-scale die-offs
- Wilkes Basin, East Antarctica: 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

Constant emissions for nine years will use up the remaining carbon budget

Starting mitigation in 2019 will require monumental mitigation rates

Starting mitigation in 2000 would have required a mitigation rate of about 4%/yr

For a >66% chance of staying below 1.5°C. Remaining budget: 420 GtCO₂. Mitigation curves after Raupach et al. 2014. 

©@robbie_andrew • Data: GCP • Emissions budget from IPCC SR1.5

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Falling costs for Clean Energy Technologies


Shares of primary energy

- Renewables
- Hydro
- Nuclear
- Coal
- Gas
- Oil

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 CO₂ chemically.

IRON FERTILIZATION
Dissolved iron might encourage phytoplankton growth.

MACROALGAE CULTIVATION
Carbon absorbed by growing seaweed might be stored at depth.

ARTIFICIAL UPWELLING
Pumping water from depth might cool the surface.

CARBON STORAGE
CO₂ drawn from the air could be locked under the sea bed.

©nature
Eruption of Mt Pinatubo, 1991
Geoengineering:
Solar Radiation Management
SPICE: aerosol delivery system for 2°C cooling

Stratospheric Particle Injection for Climate Engineering

Tethered balloons – height 20km
maybe 10 balloons worldwide each delivering 30kg/s of aerosol
Geoengineering:
Bio-Energy with Carbon Capture and Storage

Implicit in Paris COP21 Agreement
Geoengineering:
CDR = Carbon Dioxide Removal
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
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 on 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 avoidable deaths from nutritious and unsafe foods, and getting children into primary schools - are closest among all the goals to being achieved. By contrast, the goal to eliminate extreme poverty will still not have been reached. Some 430 million people are expected still to be living in such conditions in 2030.

Experts trace 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 only not meeting 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 this time, the SDGs have had a considerable positive impact - in reducing access to primary education and higher education institutions globally, making up support, the SDGs, and staff and students are taking on responsibilities, from eliminating single-use plastics, to switching to renewable energy. The goals' cross-cutting nature has led to responses, too, proudest 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 SDGs face a serious problem: the global community is not pulling together to make progress toward the goals. A UN-affiliated organization called the Sustainability Development Solutions Network produces an annual report that shows how well countries are performing on the SDGs, and says 2019 saw the worst performance in its history. Other organizations also report disappointing progress.

But it is not compulsory for countries to report how they are doing. 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 is no alternative but to make them happen. One analogy is the way in which countries report their economic data. There is no international law that says every country must report data, such as on consumer spending, that go into calculating gross domestic product (GDP). But through 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 be seen to be growing, and so the data underlying the GDP must also be increasing. That's why there's a massive effort to make sure that everyone works toward 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.

Tighter focus

One researched effect 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 US member states, but working independently of the UN scientific community. The first report appeared in September, and the final report, authors for the second one, due in 2023, later this month.

The first report's authors are aware that the SDG targets 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 5 key points: These are: urban well-being, including eliminating poverty and improving health and education; sustainable economies (including reducing inequality, access to food, and nutrition; access to water and sanitation; energy; urban development); and the global common (combining climate change and biodiversity).
20,000 year old samples of the atmosphere trapped in a Greenland ice core