Advanced Research + Invention Agency ARIA

Future Proofing Our Climate and Weather

v2.0

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CONTEXT

This document describes an opportunity space - an area that we believe is likely to yield breakthroughs, from which one or more funding programmes will emerge.

A programme related to this opportunity space has now been launched. Learn more about it **here.**

You can provide feedback on this opportunity space **here**.

An ARIA opportunity space should be

+ important if true (i.e. could lead to a significant new capability for society),
+ under-explored relative to its potential impact, and
+ ripe for new talent, perspectives, or resources to change what's possible.

SUMMARY

If an abrupt alteration in a climate system were to unfold, we would have no tools to mitigate the effects. Scientific, engineering and social science research could provide practical and responsible intervention and adaptation options to mitigate the impacts of climate disasters.

BELIEFS

The core beliefs that underpin/bound this area of opportunity.

1. Climate tipping points (abrupt and potentially irreversible changes to the Earth's climate) like the melting of large ice sheets or sudden changes in ocean currents have happened in the past. We don't know when the next one might happen or how long it would take to feel the effects ⟶ **but we do know that we have very limited options for how we might intervene to avert disaster, or adapt to a drastically altered climate if the impacts manifest on short timescales.**
2. Ethical and governable interventions to prevent tipping points, or adaptations to adjust to a post tipping point climate, could be possible ⟶ **but an enormous amount of research is needed to determine how such approaches could work and what their regional and global effects might be.**
3. De-fossilisation is imperative; however, the risk of crossing tipping points in the coming decades has led to increasing discussion of climate interventions, such as solar radiation modification. There is a risk that these interventions become prematurely embedded in climate change roadmaps, or dismissed as infeasible, before their basic science has been properly explored ⟶ **a unique combination of push-pull factors suggests that now is the time for society to undertake responsible and transparent research into our potential options.**

OBSERVATIONS

Some signposts as to why we see this area as important, underserved, and ripe.

April 1815 — Mount Tambora erupted in Indonesia. Huge quantities of dust + aerosols were released into the atmosphere. In the year following: the average global temperature dropped by 0.4—0.7 °C; Europe experienced its coldest summer in the last 250 years. Famine + economic disruption followed.

How could we respond if something similar happened again?

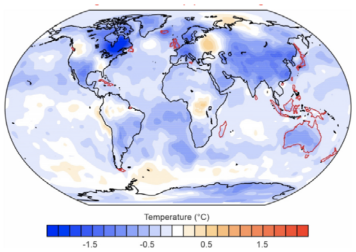


Fig 1

Current trends in global temperatures driven by human activity suggest we're on course to exceed 1.5 °C above pre-industrial levels within the next decade, and 2-4 °C by 2100. 2024 was the first individual year to exceed 1.5 °C above pre-industrial levels.

Lowering atmospheric greenhouse gas levels — even under the most aggressive scenarios — may not happen fast enough to prevent the onset of tipping points or abrupt changes to the Earth system.

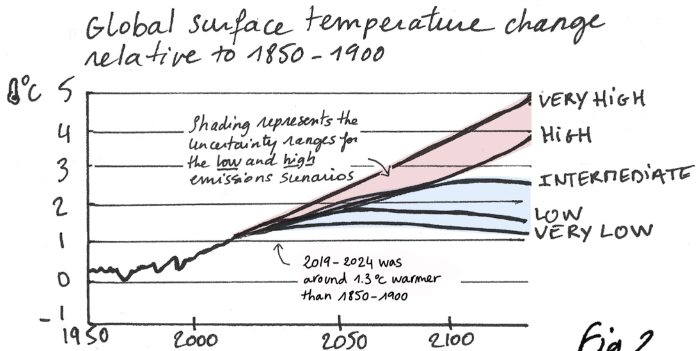


Fig 2

An (incomplete and qualitative) risk register of potential climate tipping points. Entries 1-4 assume that the current trajectory of warming is followed. In each of the cases below, the likelihood, potential effects and potential physical and societal impacts of such events are only poorly constrained. Likelihood and impact scales: 1 = very low; 5 = very high.

EVENT	LIKELIHOOD	EFFECTS	IMPACT	MARK'S RISK RATING
West Antarctic ice sheet melts	4	Global sea levels rise by ~1.5m by 2150 and 5m by 2500	5	Extreme
Atlantic meridional overturning circulation collapses	3 (by 2070)	NW Europe cools by 10 celsius	4-5	Very high
Methane release from permafrost	2-4 ?	Dramatically accelerated heating	4	High ?
Dieback of Amazon rainforest	3 (by 2070)	Global precipitation patterns disrupted	3	Medium
Yellowstone Supervolcano erupts	1	Mass extinction via volcanic winter	5	Medium

Crossing any of these tipping points could lead to cascading risks for other tipping points.

What tools are there for studying such cascades and their unequal global impacts?

Quantification of these uncertainties is poorly understood. We lack vital risk information on every climate tipping point.

How could we fill these gaps?

Assessing these impacts and the timescales on which they would occur is also underexplored. Climate projections could be completely altered in a post tipping point world. We need to consider a range of potential futures.

What options could we have to adapt to climate tipping points, or to intervene to prevent them, and how could we explore and develop these options responsibly and ethically, and in a timely manner?

What sorts of adaptations might be effective for adjusting to a post tipping point climate?

Restoration of inland seas to counteract sea level rises? Other civil engineering and improved land use solutions?
Preventing (or diminishing the impacts of) extreme weather events?
Counteracting changes to precipitation due to shifts in monsoon patterns?
What else?

Alternatively, what intervention options are there for preventing tipping events that are workable, scalable, ethical and for which the benefits outweigh the drawbacks? How should we go about researching such options?

Trials will be needed to explore and better constrain uncertain physical processes, and to enable the development of hardware, infrastructure, and governance frameworks. Such trials will need to be conducted transparently with broad stakeholder engagement.

Crossing tipping points could lead to increasingly severe and frequent extreme weather events.
The economic cost of extreme weather events is substantial, and the potential economic and societal gains of developing technologies for moderating extreme weather events could be considerable.

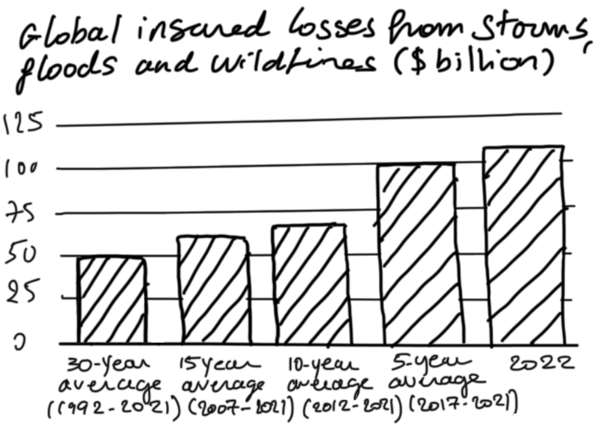


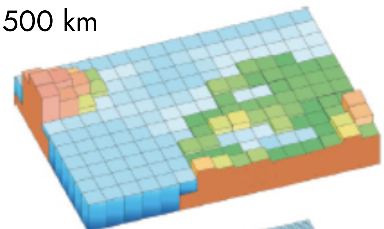
Fig 3

What does responsible research into "weather modification" look like? How could we conduct such research and what are the critical scientific and non-scientific questions that we need to answer? What options for moderating extreme weather do we have?

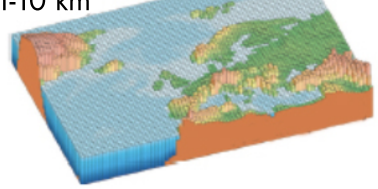
The resolution and accuracy of climate and weather prediction models has increased dramatically in recent years.

Fig 4

1970s
Resolution = 500 km



Today
Resolution = 1-10 km



What role could financial institutions, the systemic risk community and markets play in climate intervention and adaptation?

How can we build trust + a social licence in this space? Safety by design must be ensured for all trials, and we must give thorough consideration to the broader implications of experimental results. Local communities should be actively involved in co-designing any experiments. The potential longer-term governability of any approaches also needs to be considered.

We are already conducting passive climate intervention experiments. In 2020 new rules to reduce air pollution from shipping led to an abrupt drop in global sulfur dioxide emissions. Sulfur dioxide, which is harmful to both humans and the environment, promotes the formation of clouds that reflect sunlight, producing a net cooling effect.

By 2050, the effect of removing sulfur dioxide from shipping fuel has been predicted to increase global temperatures by roughly the same amount as two additional years of carbon dioxide emissions at current rates.

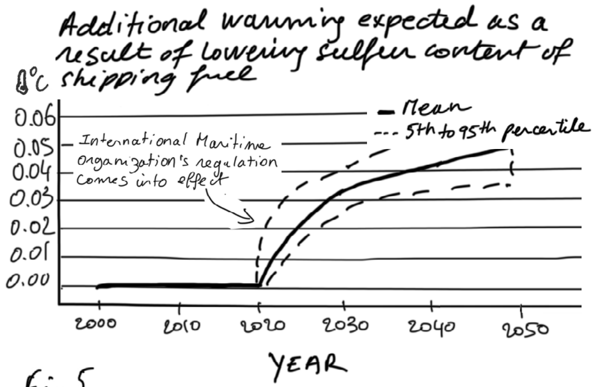


Fig 5

The scale of such "unintentional" climate interventions provides perspective for small, carefully-controlled trials of climate intervention and weather modification methods.

How could we improve our predictive and monitoring capabilities to develop a trusted, reliable, and responsible toolkit for responding to climate tipping points and extreme weather events?

We have taken steps to prepare for some disaster scenarios. For example, we can detect potential asteroid strikes on the Earth with a lead time of several weeks and we showed in the 2022 DART exercise that we can successfully deflect asteroids in space. Should we not also investigate how to avert disaster in the face of climate tipping point?

What possibilities would that open up?
Mitigating severe weather events like extreme heat waves, droughts and hurricanes?
Preserving fragile ecosystems and biodiversity?
Tackling global water and food insecurity?
Reversing arctic sea ice loss and the melting of ice sheets?
Greening the deserts?
Terraforming other worlds?

SOURCES

A compiled, but not exhaustive list of works helping to shape our view and frame the opportunity space (for those who want to dig deeper).

1. The Great Tambora eruption in 1815 and its aftermath
2. Disentangling the causes of the 1816 European year without a summer
3. Tambora and its relevance for future sunlight-blocking catastrophes [Figure 1]
4. NOAA National Centers for Environmental Information — global climate report for 2022
5. The time lag between a carbon dioxide emission and maximum warming increases with the size of the emission
6. World Meteorological Organization — global temperatures set to reach new records in next five years
7. Intergovernmental Panel on Climate Change's sixth assessment report [Figures 2]
8. Observationally-constrained Projections of an ice-free Arctic even under a low emission scenario
9. Exceeding 1.5°C global warming could trigger multiple climate tipping points
10. Tipping elements in the earth's climate system
11. The geoengineering model intercomparison project phase 6 (GeoMIP6) — simulation design and preliminary results
12. Geoengineering the climate: science, governance and uncertainty
13. Analysis: How low-sulphur shipping rules are affecting global warming [Figure 5]
14. Medium - Global insured losses from natural catastrophe events in 2022 [Figure 3]
15. Climate change 2007: the physical science basis (Figure 4)
16. Asteroid Terrestrial-impact Last Alert System
17. Double Asteroid Redirection Test
18. European Commission: Scientific Advice Mechanism paper on solar radiation modification

ENGAGE

You can provide feedback on this opportunity space here.

If you require an accessible version of this document and/or form, please contact us at **info@aria.org.uk**