THE SECURITY BLIND SPOT

CASCADING CLIMATE IMPACTS AND TIPPING POINTS THREATEN NATIONAL SECURITY

Laurie Laybourn, **Jesse F Abrams**, **Dustin Benton**, **Kathryn Brown**, **Joseph Evans**, **James Elliott**, **Didier Swingedouw**, **Timothy M Lenton** and **James G Dyke**

October 2024

ABOUT GSI

The Global Systems Institute is a thought-leading, action-oriented research centre developing transformative solutions to global challenges. The Institute aims to better predict global changes through understanding the interactions between the climate, natural ecosystems, human social and economic systems, and the built environment. Our scientists apply that understanding and modelling capability to identify transformative solutions to the global challenges faced by humankind, engaging societies and providing training, data and skills so that together, we can create a better future.

ABOUT CHATHAM HOUSE

Chatham House, the Royal Institute of International Affairs, is an independent policy institute based in London. Our mission is to help build a sustainably secure, prosperous and just world. Chatham House does not express opinions of its own. The opinions expressed in this publication are the responsibility of the authors.

ABOUT SCRI

The Strategic Climate Risks Initiative is a think-and-do tank for the next chapter of climate change. We conduct decision-useful research on non-linear risks and develop capabilities for navigating climate action through a future of escalating instability. Learn more: https://www.scri.org.uk/.

ABOUT IPPR

IPPR, the Institute for Public Policy Research, is an independent charity working towards a fairer, greener, and more prosperous society. We are researchers, communicators, and policy experts creating tangible progressive change, and turning bold ideas into common sense realities. Working across the UK, IPPR, IPPR North, and IPPR Scotland are deeply connected to the people of our nations and regions, and the issues our communities face.

We have helped shape national conversations and progressive policy change for more than 30 years. From making the early case for the minimum wage and tackling regional inequality, to proposing a windfall tax on energy companies, IPPR's research and policy work has put forward practical solutions for the crises facing society.

IPPR
8 Storey's Gate
London
SW1P 3AY
E: info@ippr.org
www.ippr.org
Registered charity no: 800065 (England and Wales),
SC046557 (Scotland)

This paper was first published in October 2024.

CONTENTS

ABOUT THE AUTHORS

Laurie Laybourn is an associate fellow at IPPR, a visiting fellow at the Global Systems Institute, University of Exeter, and an associate fellow at Chatham House. He leads the Strategic Climate Risks Initiative.

Dr Jesse F Abrams is a senior research impact fellow at the Global Systems Institute, University of Exeter, and an associate fellow at the Strategic Climate Risks Initiative.

Dustin Benton is managing director of sustainability at Forefront Advisers and an associate at Green Alliance.

Kathryn Brown is director of climate change and evidence at the Royal Society of Wildlife Trusts.

Joseph Evans is a researcher at IPPR.

James Elliott was a senior policy advisor at Green Alliance when this report was written.

Dr Didier Swingedouw is a CNRS senior researcher on climate dynamics at the Université de Bordeaux.

Professor Timothy M Lenton is chair in climate change and Earth system science at the University of Exeter and inaugural Director of the Global Systems Institute.

Dr James G Dyke is associate professor in Earth system science and assistant director of the Global Systems Institute, University of Exeter.

ACKNOWLEDGEMENTS

The authors would like to thank the over 150 people who participated in research interviews and workshops, and provided expert advice and review. Particular thanks go to Leo Barasi, Tim Benton, Kris De Meyer, Antony Froggatt, Nina Gillespie, Lucy Hubble-Rose, Abi Hynes, Matt Ince, Andrew Jackson, Daniel Jonusas, Tom Lancaster, Richard Maclean, Richard Nugee, Matt Pritchard, Ben Shread-Hewitt, Victoria Robinson and Phil Tovey, and Malte Wendt, who undertook scientific analysis informing this paper, as well as Richard Betts and several anonymous reviewers. Acknowledgement of this input and advice does not necessarily imply endorsement of the entire report or its recommendations. We also wish to thank the V. Kann Rasmussen Foundation and the Omega Resilience Awards, whose generous support made this paper possible.

Download
This document is available to download as a free PDF and in other formats at:
http://www.ippr.org/articles/security-blind-spot

Citation
If you are using this document in your own writing, our preferred citation is:
Laybourn L, Abrams J F, Benton D, Brown K, Evans J, Elliott J, Swingedouw D, Lenton T M and Dyke J G (2024) *The security blind spot: Cascading climate impacts and tipping points threaten national security*, IPPR. http://www.ippr.org/articles/security-blind-spot

SUMMARY

The new UK government has initiated a Strategic Defence Review and is undertaking a review of national resilience. Security threats resulting from climate change should be at the core of the government's approach. These threats have been consistently and significantly underestimated and now pose major security risks. The Covid-19 pandemic demonstrated that profound national security threats can result from non-hostile action and not just from malicious intent. This report shows how climate change poses both immediate and long-term threats that are of similar or greater orders of magnitude. These go beyond the traditional defence domain to encompass the full range of human security concerns, including food, economic stability, public health, nature, peacebuilding and geopolitics. We use this expansive definition of security throughout the report.

Recent governments have not considered climate change a priority national security issue. Climate-security threats are often thought to evolve over the long term and to primarily arise from the first-order impacts of climate change, like the health impacts of extreme heat. This view means that climate change does not appear as critical and proximate as the other pressing security challenges of the day. But it is being increasingly challenged by the spiraling consequences of current levels of climate change. Dangerous security risks are already apparent and are evolving non-linearly. These chaotic risks will escalate further as warming breaches the Paris Agreement limit of 1.5°C in a matter of years. The new government has an opportunity to take a different approach.

Climate-security threats are non-linear and are escalating, posing profound challenges to national and international security. First-order impacts have consequences that cascade and interact with other threats, creating a far greater threat overall. Individually, these might be predictable and bearable; together, they can create unexpected and severe security consequences. Security threats can also emerge abruptly, caused by rapid changes in the climate system. These include tipping points – moments when parts of the climate system can no longer cope with the impacts of rising temperatures, leading to abrupt change. Their triggering would lead to impacts that severely disadvantage the UK and its strategic interests. We focussed on the threats to security from cascading climate impacts, which already upend policymaker preconceptions that the UK is relatively sheltered from severe risks. We also focus on tipping points, which if triggered will have particularly acute cascading impacts.

- **Cascading climate impacts already threaten UK security, and will only escalate.** UK food security has recently been impacted in this way: cascading climate effects are estimated to have caused a third of UK food price inflation in recent years, an impact compounded by rising energy prices. Into the future, the interaction between existing levels of climate change and other non-malicious threats, such as nature loss and health shocks, could cascade to create major consequences. A recent landmark analysis found that the effects of these dynamics could be severe, with declines in GDP of at least 6 per cent by the 2030s, and up to 12 per cent in one scenario. These impacts are greater than experienced in the 2007/08 financial crisis and the Covid-19 pandemic respectively, and would have cascading impacts far beyond economic security, amplifying the overall impact.

- **Tipping points in the Atlantic Ocean's circulation pose critical risks**. The collapse of the Atlantic Meridional Overturning Circulation (AMOC) would profoundly destabilise national and global security. Collapse would effectively wipe out crop growing in the UK and combined with other effects of climate change, would cause catastrophic losses to key crops globally. The cascading consequences for health, economic stability, political cohesion, trade and geopolitics would be severe, creating unmanageable security outcomes. A collapse this century cannot be ruled out without urgent international action to reduce emissions. Meanwhile, the collapse of a component of the AMOC – in the North Atlantic subpolar gyre (SPG) – could happen sooner and be triggered at low levels of warming. While less severe, its impacts would disrupt weather patterns in the UK and regionally, eroding security. Evidence suggests that the likelihood of this 'SPG collapse' is unignorably high – up to a 45 per cent chance of occurring this century and happening as early as 2040, if not before.

Cascading risks and tipping points are not adequately considered in, or are simply missing from, national security risk assessments and strategy. This has led to significant underestimation of the climate threat. While the UK has significant capabilities in climate governance, these risks are not sufficiently integrated into national security decision-making. Critically, there is no dedicated national security risk assessment of climate change, with the government's existing Climate Change Risk Assessment currently not designed to assess national security threats in the round. Analytical flaws, such as inadequate consideration of cascading and interacting risks, mean threats are routinely underestimated. Decision-makers often misconstrue high impact threats that are low- or uncertain-likelihood as meaning there is little to worry about. Meanwhile, responsibility for climate risks currently sits in non-security departments, marginalising climate change from the top table of national security decision-making. Resilience planning is fragmented across government.

There are worrying similarities to the situation prior to the onset of Covid-19, although climate threats pose even greater security challenges. The UK's public inquiry into the pandemic has found that previous governments had underestimated risks, focusing on a limited number of scenarios, and failed to build sufficient preparedness. Similar mistakes are being made with climate change. There is an inadequate focus on scenarios of cascading threats, different climate futures, and extreme events, particularly tipping points. These are evolving rapidly and challenge the perception that the UK can 'muddle through' the consequences of climate change. The UK appears more poorly prepared to handle major climate-security threats than pandemics: it is not resilient to current climate conditions and cascading risks, let alone future threats, including some of the most severe, such as SPG collapse. Climate change is not just creating a series of worsening *events*; it is creating a new *era* of complex and evolving challenges for all areas of national and international security. Yet the UK does not have adequate early warning systems for the complex threats it faces today, nor possible future threats like SPG collapse. This stifles the ability to forecast and prepare.

A new footing is required: climate change should be a core part of national security planning. National security is critically dependent on the resilience of communities, globalised systems and nature, and not just on defence and other traditional security matters. Even if tipping points are not triggered, cascading climate-security threats are already pervasive and will escalate as global temperatures continue to rise. It is therefore imperative to improve management of the complex risks experienced today, urgently addressing the poor state of UK climate adaptation, and going further to generally build resilience to a more volatile world and a broader range of threats, ensuring the UK and wider world can stay on a path to a sustainable future. The new government is well-positioned to do this. It should also be accepted that decarbonisation policies - at home and abroad - play a major role in determining UK security: limiting global temperature increases to 1.5°C with minimal overshoot and restoring nature are critical to avoiding unmanageable security outcomes. Leadership at the highest levels is needed to reorganise government in response to these complex challenges.

Our central recommendation is that the government undertakes a rapid national security risk assessment of climate change to establish a full picture of the security consequences of climate change, identifying the most critical threats and choices for improved risk management, and catering for a national security audience at the highest level. Other countries have undertaken a similar exercise. It should complement and connect existing risk assessment processes and pay particular attention to cascading risks, including interactions with nature loss and other systemic challenges. We propose several other 'quick wins', including the following.

- **Making the security implications of climate change a foundational element of the Strategic Defence Review and the review of national resilience**, signalling that climate change, nature loss and related environmental risks have been elevated to a core national security priority and are factors in the strategic security decision-making at the highest levels across government.
- **Creating an independent Centre for Climate and Nature Security**, a centre of excellence with the purpose of improving the ability of the UK's security community to integrate an understanding of climate and nature threats into routine assessments and decision-making. Priorities should include providing routine usable climate information for security assessment and planning, closing major knowledge gaps and developing early-warning systems for priority threats.
- **Acting on the UK Covid-19 Inquiry's recommendations for rebooting UK preparedness for and resilience to emergencies**, including simplifying structures, abolishing the lead department model, and undertaking exercises of society-wide, climate-induced emergencies.

1. INTRODUCTION

> *"The greatest risks of climate change arise when thresholds are crossed: what had been gradual becomes sudden; what had been inconvenient becomes intolerable."*
>
> From a risk assessment of climate change led by Professor Sir David King, former UK Government Scientific Advisor (King et al 2015)

> *"Hard geopolitical threats are treated [by the government] in a different way… to ones which are seen as natural threats or hazards."*
>
> Professor Sir Chris Whitty, UK Government Chief Medical Adviser (UK Covid-19 Inquiry 2023)

The UK faces a critical moment for its security. The new prime minister has warned that "the post-war era is over, and a new age of insecurity has begun" (Starmer 2024). Hostile threats are proliferating, ranging from military aggression to hybrid attacks on critical infrastructure. But malicious action is not the only driver of insecurity. Non-malicious threats also pose profound security risks.

This was made clear by the Covid-19 pandemic. The pandemic was an example of a non-malicious threat so severe that it created what the government calls a "whole-system civil emergency", a crisis of saturating scale that significantly affected multiple dimensions of national security. As such, the UK's public inquiry into the pandemic has concluded that non-malicious threats should be treated in much the same way as those arising from hostile intent (UK Covid-19 Inquiry 2024).

Yet the inquiry found that this is currently not the case and that government structures for planning and responding to whole-system civil emergencies "failed their citizens" and that "fundamental reform" was needed (ibid). In response, the new government is undertaking a review of national resilience (McFadden 2024). It has also initiated a Strategic Defence Review, part of a wider commitment to national security. In emphasising this commitment, ministers have often focussed on threats posed by escalating conflict, the development of AI and misinformation. But there has been less attention on another critical threat to the UK's national security: climate change.

This report shows that climate change should be considered a priority national security issue and sit at the heart of the new government's reconsideration of the UK's security and resilience. In doing so, we use an expansive definition of security – 'human security' – which encompasses the full range of factors that determine a secure and dignified life (Loft and Carver 2022). These include the security of the systems that provide societies with adequate water, nutritious food, economic opportunity, political stability, healthcare, fundamental rights and so on – and not just security against hostile threats. All these systems were impacted by the pandemic and as we will show, they are being impacted by the consequences of climate change.

We start by considering how the government conceives of the security threats coming from climate change. We call these 'climate-security' threats for short and in sections two and three, explore how they pose profound challenges to UK national security. In section four, we consider how previous governments have assessed and managed these threats. We finish by making recommendations for improving security. While the UK is the primary focus, our findings are relevant to a range of contexts across the world.

1.1 FIRST-ORDER CONSEQUENCES, GRADUALLY EVOLVING

We wanted to understand how the UK government conceives of climate-security threats and how they might develop in the coming years. To do so, we undertook 50 interviews with government personnel and experts, and reviewed assessments and policies relating to climate-security threats. These occurred before the election of the new government.

We found that climate-security threats are considered to be significant, impacting many aspects of security. For example, climate impacts have been described as posing, variously, one of the biggest risks to UK food security (Defra 2021) and nature (IPBES 2019), a potential 'catastrophic risk' to the public finances (OBR 2021), and presenting risks to critical national infrastructure that constitute a "major threat to the UK's national security and prosperity" (JCNSS 2022).

The causes of climate change – fossil fuels – are also recognised to impact security. This was brought into stark relief by Russia's invasion of Ukraine, which affected gas supplies, causing a spike in energy prices more generally and a subsequent deterioration in energy security. The UK was one of Europe's worst affected countries due to an over-reliance on gas – which was used to heat 85 per cent of homes and generate around 40 per cent of electricity (Ari 2022, Evans 2022) – and its exposure to international energy markets. In turn, there is a recognition that climate change has consequences for defence, acting as a "multiplier of other global threats" (HMG 2023b), like how a melting Arctic is disrupting the geopolitical balance in the High North (House of Lords 2023).

Across these areas, we found that conceptions of climate-security threats predominantly focus on the following.

1. **First-order impacts**. Climate-security threats are often conceived of as the direct consequence of a climate hazard. These hazards can either be chronic – 'slow-burn' problems, like sea-level rises causing coastal erosion – or acute, encompassing sudden, 'event-driven' shocks, like extreme heat. They have direct, first-order impacts on security, such as when record summertime temperatures in 2022 impacted health security, contributing to an estimated 4,507 excess deaths – a record high (ONS 2023, UKHSA 2023). A predominant focus on first-order impacts is common in many governments globally (Townend et al 2023).
2. **Steady evolution**. Climate change is often considered to evolve gradually, a steady process that creates a worsening stream of first-order impacts, whether chronic or acute, with increasingly problematic consequences for security.

This means that, while significant and important, **the overall threat to security from climate change is often considered a gradual, long-term problem**. This view was set out in previous governments' Integrated Reviews and registers of national threats, which describe climate change as one of a set of 'enduring challenges that gradually erode elements of our economy, society, way of life and/or national security', alongside artificial intelligence, antimicrobial resistance, and organised crime (HMG 2023a, HMG 2023b).

This view can mean that climate change does not appear to be a priority national security issue: the gradual worsening of first-order climate impacts does not seem as critical and proximate as the other pressing security challenges of today, like Russian aggression, cyber-attacks on critical infrastructure, or misinformation.

This view has led previous governments to remove climate change from the national security risk assessment process, with the promise of a different process for considering longer-term threats (HMG 2023a). While the government's publicly-available register for national threats does recognise individual climate hazards - such as extreme heat, wildfires, and floods - the overall evolution of climate change and its consequences for national security no longer feature alongside other large-scale non-hostile threats, like pandemics (ibid).

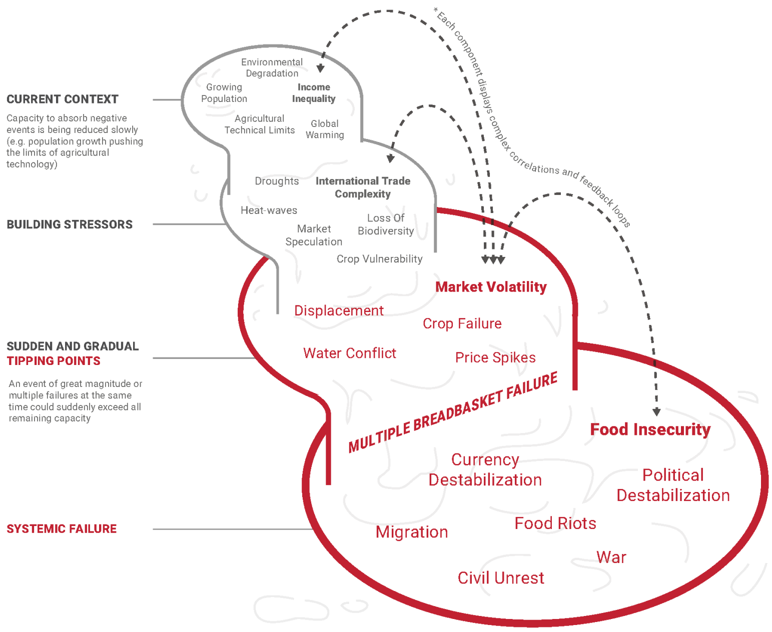
2.
THE THREATS FROM CASCADING IMPACTS AND TIPPING POINTS

Climate-security threats do not just result from first-order impacts and the gradual evolution of climate change. First-order impacts have knock-on consequences, with their destabilising effects cascading through society's interconnected systems, interacting with and exacerbating other problems (Townend et al 2023). Meanwhile, major changes in the climate system can occur abruptly, leading to a far quicker evolution of security threats (Lenton et al 2023). Recent lived experience and improvements in analysis have confirmed this. We explore cascading impacts and abrupt change in turn.

2.1 BEYOND FIRST-ORDER IMPACTS

FIGURE 2.1: AS SECURITY IMPACTS CASCADE, THEY CREATE THREATS GREATER THAN THE SUM OF INDIVIDUAL PARTS

Summary graphic to illustrate the impact of cascading risks: the interacting and additive effects of events on wider social and economic systems



Source: Reproduced from UNDRR, Global Assessment Report on Disaster Risk Reduction (UNDRR 2019)

It is common for security threats to spread beyond their original impact and interact with other threats, creating a greater threat overall. These dynamics were on full display during the recent pandemic and the subsequent inflationary shock. As the UK Covid-19 Inquiry has warned: "Multiple emergencies may interact with each other to produce a worse aggregate emergency than if they occurred individually. A single emergency may create a domino effect in which, when one thing goes wrong, other things go wrong as well" (UK Covid-19 Inquiry 2024). This dynamic is illustrated in figure 2.1.

This is also the case with climate-security threats (Challinor and Benton 2021). First-order impacts **cascade**, leading to multiple additional orders of impact. These can occur domestically or come from abroad, transmitted through globalised systems and across borders. Cascading impacts are always **concurrent** with other problems and therefore inevitably interact. These interactions have **compound** impacts, creating an overall threat to security that is greater than the sum of individual parts. For simplicity, we describe these dynamics collectively as creating 'cascading' impacts on security, distinguishing them from the conception of climate-security threats as largely resulting from the first-order consequences of climate impacts.

2.1.1 CASCADING SECURITY IMPACTS ARE ALREADY SIGNIFICANT TODAY

Recent impacts on UK food security illustrate these dynamics. Climate change is causing heavier rainfall in the UK (Kew et al 2024), helping drive unprecedented wet conditions across the 2023/24 growing season, which damaged crops and delayed planting, leading to a deterioration in the UK's food self-sufficiency (ECIU 2024). These impacts occurred concurrently with extreme weather events that damaged crops in countries the UK relies on for food imports, curtailing supply. Meanwhile, energy and other input prices rapidly increased as fossil fuel markets were impacted by Russia's invasion of Ukraine (DEFRA 2024). Together, impacts on food supply and higher energy prices are estimated to have increased household food bills by an average of £605 between 2022 and 2023, with extreme weather alone causing an estimated one third of food price inflation (Butler 2023, ECIU 2024).

A recent assessment of cascading threats to the UK coming from abroad has warned that these threats are "greater than previously assessed" (Challinor and Benton 2021). They include threats to food security, violent conflict, international law and governance, and public health. Two factors have contributed to the worsening context: "greater evidence of climate change acting as an amplifier of existing risk; and greater evidence of geopolitical and socio-economic background conditions that are more favourable to risk transmission and amplification" (ibid).

2.1.2 CASCADING SECURITY IMPACTS WILL ESCALATE INTO THE NEAR FUTURE

Cascading climate-security threats are expected to escalate in the coming years, with complex and unpredictable security consequences (Townend et al 2023). These have been highlighted by a recent landmark study that considered how worsening climate extremes might interact with other non-malicious threats, causing cascading impacts that add up to create an overall threat greater than the sum of individual parts (Ranger et al 2024). The study explored a range of scenarios in which climate shocks interacted with the consequences of nature degradation – another major problem for the UK – and complex health risks, like antimicrobial resistance and pandemics.

The analysis found that the effects of these cascading and compounding dynamics could be severe, with declines in UK GDP of at least six per cent by the 2030s, and up to 12 per cent in one scenario. These economic impacts are greater than experienced in the 2007/08 financial crisis and the Covid-19 pandemic respectively. While the primary focus of the study was on financial effects of nature degradation, these can be taken as a proxy for the wider security consequences across other domains, with the authors pointing to further cascading and compounding impacts on health, unemployment, public finances, trade, civil unrest, public services, and critical infrastructure.

The analysis found that around half of the impacts cascaded from overseas through supply chains and financial exposures. It was also estimated that the compounding effects of environmental degradation and climate shocks at least doubles the impacts of climate change, showing the severe additive effects that emerge from the interaction of related but distinct environmental challenges. Individually, these threats and vulnerabilities might be knowable and bearable. Together, they could create security consequences that are unexpected and far more severe.

Crucially, the authors warn that "These impacts are near and present", resulting from the collective effect of existing threats and current vulnerabilities within UK systems, not the emergence of new problems. The authors also stress that due to the complexity of how concurrent risks cascade and compound, their scenarios should be considered as "very conservative, in that while they go further than other studies in capturing complex risks, inevitably they do not capture all possible outcomes".

Another example of a pressing cascading threat relates to the growing possibility that concurrent extreme weather events could lead to synchronous crop failure in breadbaskets across the world (Gaupp et al 2020, Hasegawa et al 2022). The possibilities for multiple breadbasket failure increase markedly over 1.5°C of global warming (Guapp et al 2019) and, in the case of maize, are estimated to be around 50 per cent by the 2040s (Quiggin et al 2021). The likelihood might be higher, with evidence showing that synchronous impacts have been underestimated in climate and crop model projections (Kornhuber et al 2023). As recent food shocks have shown, synchronous failures would lead to severe cascading impacts on global food security, with knock-on consequences for economic stability, political cohesion and geopolitics, among many other areas of human security.

2.2 ABRUPT CHANGE: TIPPING POINTS

In recent years, the evolution of climate impacts and their consequences for security have not appeared gradual. Climate shocks are hitting at the most severe and soonest end of the possibilities anticipated by climate scientists (IPCC 2022). Meanwhile, it has long been established that changes in the climate system can evolve abruptly, not just gradually (ibid, Ripple et al 2023a). Climate tipping points are a key example. These are moments when the effects of rising temperatures become so severe that large parts of the climate system are unable to maintain their current state, leading to abrupt and/or irreversible changes.

Think about leaning back on a chair until it suddenly falls backwards. That moment is the tipping point. Your previous state – balancing precariously – has been replaced by a new state: lying on the floor. Components of the climate system can experience a similar dynamic, 'falling over' at varying speeds depending on the system in question. Some, like the collapse of ice sheets, could play out over centuries. Others, including the tipping points we explore below, can play out over a matter of years: timescales with direct relevance to security decision-making.

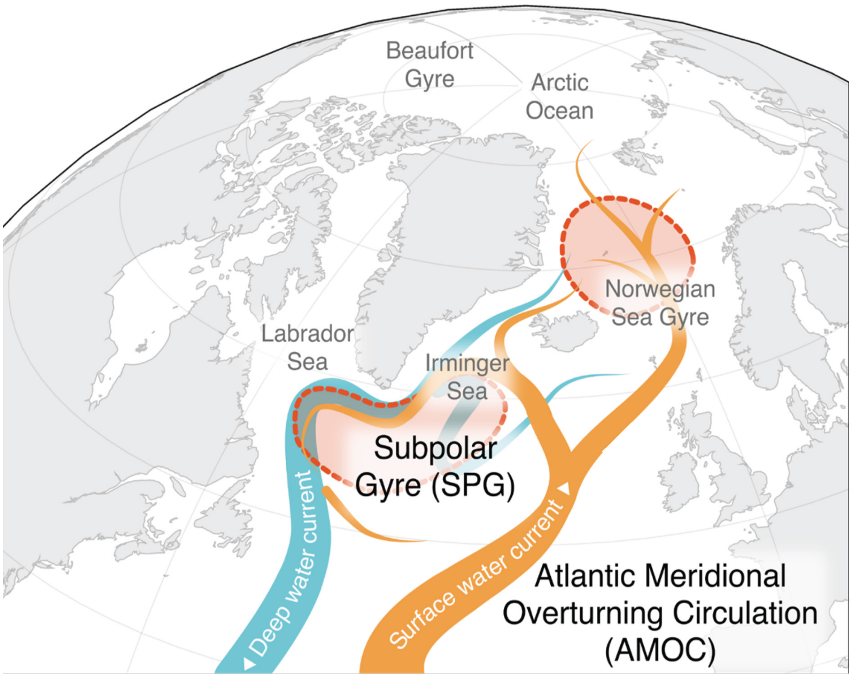
Previously, it was thought that tipping points were only likely at global temperature rises above 4°C. However, it is now clear that a significant risk is already apparent at current temperature rises and will increase markedly above 1.5°C (Armstrong

McKay et al 2022). A recent global review described the impacts of tipping points as potentially 'catastrophic', constituting a threat of a "magnitude never faced by humanity" (Lenton et al 2023).

This is the case for the UK specifically, with a range of tipping points posing significant risks to its security (Laybourn et al 2024). These include tipping points in the complex circulation patterns that exist in the Atlantic Ocean, which are illustrated in figure 2.2. Ocean circulations are movements of water, akin to the currents you might feel while swimming in the sea but on a planet-spanning scale. They play a key role in the climate system, moving heat, carbon and water around the world.

FIGURE 2.2: ATLANTIC OCEAN CIRCULATIONS ARE CRITICAL TO UK SECURITY BECAUSE THEY HELP MAINTAIN A STABLE CLIMATE

Surface currents (coloured orange) are connected to deep ocean currents (blue) through locations where dense (cold and salty) water sinks, driving the overturning circulation (pink). The AMOC constitutes the whole circulation, while the SPG is a subset of this system that is located south of Greenland.



Source: Lenton et al 2023, figure 1.4.3. Credit: Sina Loriani, Global Tipping Points Report 2023.

Two potential tipping points have been identified in the North Atlantic circulations: the collapse of the Atlantic Meridional Overturning Circulation (AMOC) and the breakdown of deep convection in the North Atlantic subpolar gyre (SPG). These are referred to as AMOC collapse and SPG collapse, respectively.

Large-scale changes in these circulations could have profound security consequences that fall severely and disproportionately on the UK. This is because the circulations play a key role in regulating the UK's climate. We look at AMOC collapse and SPG collapse in turn. As we will see, the former could impose unmanageable security outcomes and must be avoided. While the latter might be less disruptive, there is evidence to suggest it could occur within the next two decades, and so its impacts might have to be managed.

2.2.1 AMOC COLLAPSE WOULD IMPOSE UNMANAGEABLE SECURITY OUTCOMES AND MUST BE AVOIDED

The AMOC acts like a "great conveyor belt", a circulation that carries warm and salty surface waters from the tropics northwards, where heat is released. Afterwards, the water becomes colder and denser through a process called 'deep convection', forming 'deep water', which sinks and heads southwards at depth in the ocean (figure 2.2). Deep convection occurs in two main locations: the Greenland-Iceland-Norwegian Seas region north of Iceland, and the Labrador and Irminger Seas south and west of Greenland. This process and the resulting overturning circulation help maintain a mild climate in the UK - most notably in winter - and are critical to the wider climate system.

Climate change is weakening the circulation, with higher sea temperatures and fresh polar meltwater disrupting the process of deep water formation (IPCC 2021). Evidence suggests the AMOC is at its weakest in over 1,000 years (Caesar et al 2021). Severe weakening can lead it to pass a tipping point, completely shutting down (Armstrong MacKay et al 2022). This has happened in the past. A shutdown or 'collapse' of the AMOC would lead to a profound reorganisation of the global ocean circulation, with major impacts on the climate system (Lenton et al 2023).

After the tipping point is passed, it could take as little as a few decades for the collapse to play out, after which a new climatic state would exist (Armstrong McKay et al 2022). During those few decades, much faster changes in atmospheric circulation and weather patterns could occur in response to the changing ocean circulation. This change could be irreversible on security-relevant timescales.

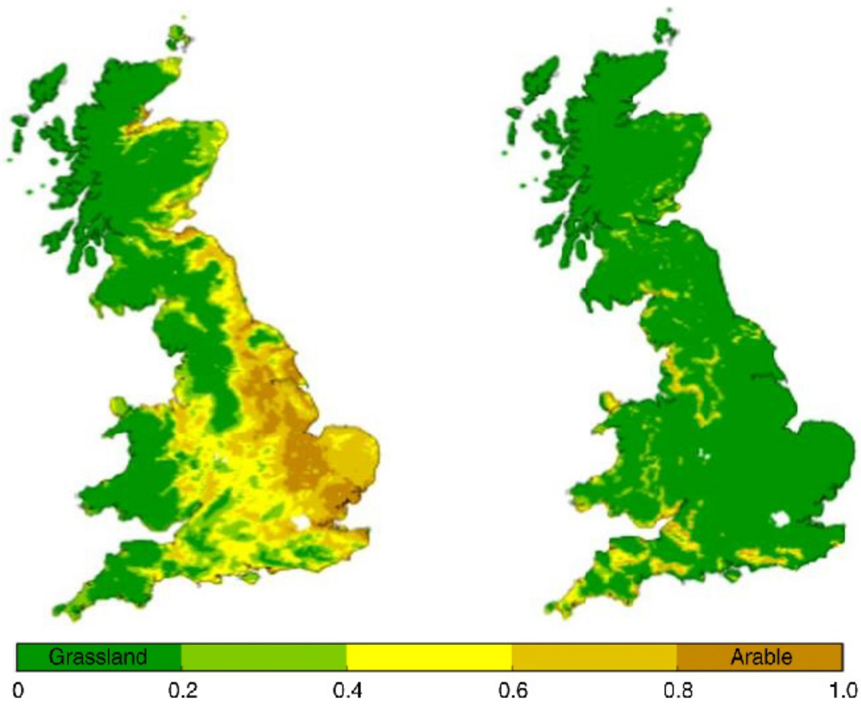
In the post-collapse state, the UK's weather patterns would be significantly different, bringing extreme conditions that are far beyond those to which people, infrastructure and nature are currently adapted. For example, one study has projected that average temperatures in London could be up to 10°C lower, with even colder conditions further north (Van Westen et al 2024). While significant knowledge gaps exist in understanding the impacts of AMOC collapse, evidence suggests the consequences for UK security could be severe or even unmanageable.

For example, one study has estimated that the effects on domestic food production are "likely to include widespread cessation of arable farming" in Britain, as illustrated in figure 2.3 (Ritchie et al 2020). Crops provide over two thirds of the UK population's calories, so the loss of domestic crop growing would profoundly damage the UK's food supply (EFRA 2023). The destruction of domestic crop growing would result from severe reductions in water availability as well as the fall in temperatures, causing wide-spread water security issues. The change in weather conditions would also severely impact health, infrastructure and economic activity. They would be disastrous for nature, triggering further knock-on threats, including further erosion of remaining UK food production.

Security threats would also cascade from abroad, compounding domestic impacts. For example, an OECD study found that the combined effects of an AMOC collapse at 2.5°C of global warming could reduce the percentage of global land suitable for growing wheat and maize by over a half, compared with a world without climate change (OECD 2021). This includes severe reductions in key UK food import markets such as Europe, as illustrated in figure 2.4. These crops are critical to global food systems. Collapse would also disrupt the African, American and Asian monsoons, with further adverse consequences for agriculture and ecosystems (Lenton et al 2023).

FIGURE 2.3: AMOC COLLAPSE WOULD CAUSE PROFOUND DAMAGE TO UK FOOD SUPPLY

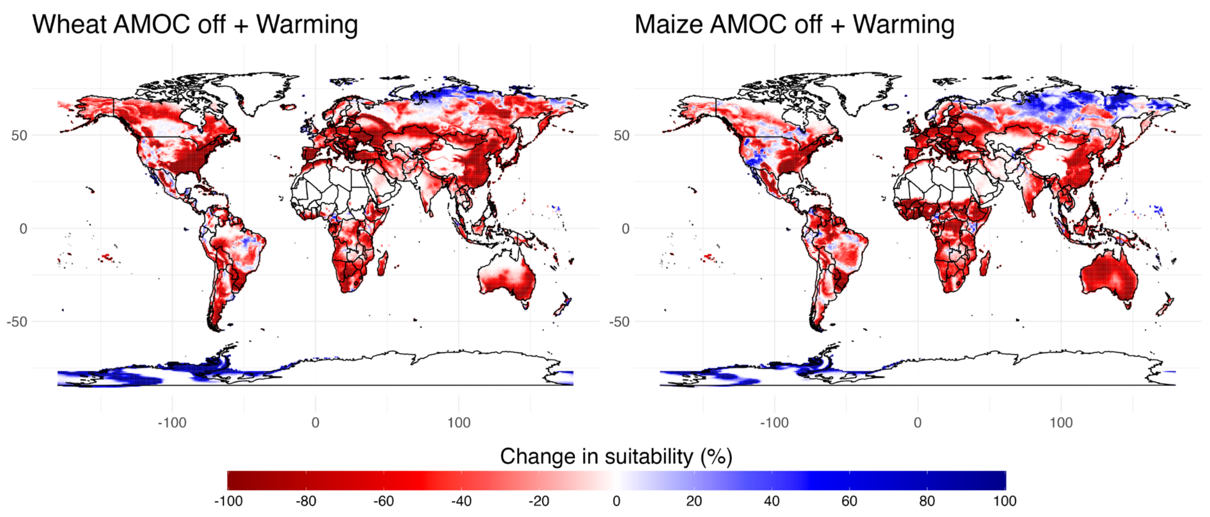
Impact on land use in the UK from an AMOC collapse. The maps show the fraction of land used for arable farming, with a greater share illustrated by a deeper shade of yellow/brown. The left-hand map shows land use in 2020. The right-hand map shows land use after an AMOC collapse and without compensatory irrigation.



Source: adapted from Ritchie et al 2020

FIGURE 2.4: AMOC COLLAPSE WOULD HAVE A CATASTROPHIC IMPACT ON GLOBAL FOOD SECURITY

Percentage difference in crop suitability between no AMOC collapse (present day) and the effects of AMOC collapse plus 2.5°C of global warming. Decreases in suitability are represented with red shading, increases with blue.



Source: Redrawn from OECD 2021.

Together, these potential consequences have led the OECD to warn that "an AMOC collapse would clearly pose a critical challenge to food security, and combined with other climate impacts would have a catastrophic impact" (OECD 2022). As with the domestic impact, the global impacts of an AMOC collapse would go beyond agriculture to include severe damage to other systems. In turn, these effects would interact, creating further systemic consequences, and multiplying and spreading the destabilisation. These cascading impacts would occur on timeframes that present severe challenges to the ability of people, communities and key systems to adapt (ibid).

The likelihood of an AMOC collapse is highly uncertain (IPCC 2021), with the estimated global temperature rise that could trigger a collapse ranging from 1.4°C to 8°C (Armstrong McKay et al 2022). But uncertainty does not offer reassurance. IPCC assessments consistently show that a collapse cannot be ruled out this century, with the most recent assessment noting that it only has 'medium confidence that the decline [of the AMOC] will not involve an abrupt collapse before 2100' (Fox-Kemper et al 2021).

Several subsequent studies have identified evidence suggesting that the AMOC is approaching a tipping point (Boers 2021, Michel et al 2022). Some papers have now warned of an "early warning signal show[ing] that AMOC is on [a] tipping course" and that collapse might even start as early as the middle of the century, if not before (Van Westen et al 2024, Boers 2021, Ditlevsen and Ditlevsen 2023, Smolders et al 2024). There is also concern that climate models used to predict the possibilities of AMOC collapse underestimate its likelihood (Fox-Kemper et al 2021). This is because the simulated behaviour of the AMOC in these models might be more stable than is the case (Liu et al 2017, Mecking et al 2017) and be missing crucial destabilising processes (Swingedouw et al 2022).

Despite recognising that AMOC collapse is possible (Slingo 2021), the independent input into the latest UK Climate Change Risk Assessment gave no indication of what the government should do to understand the risk in more detail, or what adaptation action might be required (CCC 2021a).

2.2.2 SPG COLLAPSE COULD OCCUR IN THE COMING YEARS AND PROVE HIGHLY DISRUPTIVE

The North Atlantic subpolar gyre (SPG) is a large, anticlockwise horizontal circulation of waters located in the northernmost Atlantic. It is a crucial component of the overall AMOC, playing a pivotal role in drawing surface waters – and therefore heat – northwards. This means that the SPG is important to determining the strength of the overall AMOC (Berglund et al 2022). The heat movement also affects the path and flow of the polar jet stream, an atmospheric current of air moving west to east. So altogether, the SPG plays an important role in determining the UK's weather patterns.

Rising global temperatures are melting Arctic ice and increasing regional precipitation, causing more freshwater to enter the SPG. This reduces the salinity – and therefore density – of the surface water. Consequently, the sinking process (deep convection) is weakening. This effect has become so pronounced that scientific studies have warned that deep convection could pass a tipping point and collapse (Drijfhout et al 2015; Sgubin et al 2017; Swingedouw et al 2021). This would abruptly weaken the SPG, an outcome scientists call 'SPG collapse'. A recent global review identified SPG collapse as one of five tipping points at risk of being triggered under current levels of global warming (Lenton et al 2023).

SPG collapse can occur independently of AMOC collapse. Collapse could play out over as little as a decade, if not a matter of years, creating a post-collapse state on far shorter timescales than for AMOC collapse (Armstrong McKay et al 2022). SPG collapse would also be hard to reverse.

An SPG collapse would impact the UK's weather patterns, as well as those in Europe and North America, with its effects being similar but less severe and widespread than AMOC collapse (Lenton et al 2023). For example, SPG collapse could cause a localised reduction in temperature across the North Atlantic region of around 3°C, as the northward movement of heat is weakened (Sgubin et al 2019, Armstrong McKay et al 2022).

A shift of this size would be dangerously disruptive. It may have happened in the past: SPG collapse has been proposed as an explanation for the beginning of the Little Ice Age, a period of colder conditions in Europe during the 16th to 19th centuries (Lehner et al 2013; Michel et al 2022), which had profound consequences for the stability of societies (Parker 2013). SPG collapse could also disrupt the jet stream, creating more extreme weather, and trigger a collapse of the west African monsoon (Osman et al 2021; Sgubin et al 2017; Swingedouw et al 2021).

There are even fewer studies exploring the security consequences of SPG collapse than for AMOC collapse. So, we undertook a rapid 'what-if' scenario analysis of the consequences of SPG collapse. In this scenario, collapse occurred by 2040 at around 2°C of global warming, a plausible scenario that emerges in climate models.[1] Our analysis looked at the conditions that might become possible in the post-collapse state. These include the combined effects of both the collapse and ongoing climate change. Our analysis is a rapid snapshot to identify some idea of the security impacts: there is an urgent need for deeper analysis of the security impacts of SPG collapse.

Our analysis found that in this scenario the UK would experience colder conditions than currently anticipated, most notably in winter. This is because of the SPG's role in the movement of heat northwards from the tropics and the redistribution of heat in the ocean water column. Counterintuitively, collapse might also lead to more heat waves in summers than currently expected from worsening climate change. This is because of the disruptive impact on wider weather patterns (Duchez et al 2016, Mecking et al 2019).

In our scenario, extreme winters like that experienced in 1962/63 are estimated to occur as often as once every 20 years, five times more frequently than is currently the case. The cold extremes of 1962/63 led to nearly 90,000 excess deaths (ONS 2013) and considerable damage to farming, economic activity, energy and heating systems (De Castella 2012, McCaskill and Hudson 2006), and nature, including losses of some bird species of over 80 per cent (Butler 2010).

One consequence of colder conditions is that greater reductions in growing season length become possible compared to those that are possible today. Growing season length is the period across the year during which temperatures are high enough for plant growth. The current UK average is about 300 days (HMG 2022b) and it can be impacted by variable weather conditions, leading to extreme reductions in a bad year.

In our scenario of SPG collapse, the maximum possible reduction would be made even worse. The following additional reductions are estimated to occur once every 20 years: up to 20 days a year across Wales and southern England, up to 40 days in Scotland, and up to 60 days in the East Midlands and Yorkshire and the Humber, areas with some of the UK's highest-quality agricultural land. These

1 A methodology and discussion of the results can be found in the appendix.

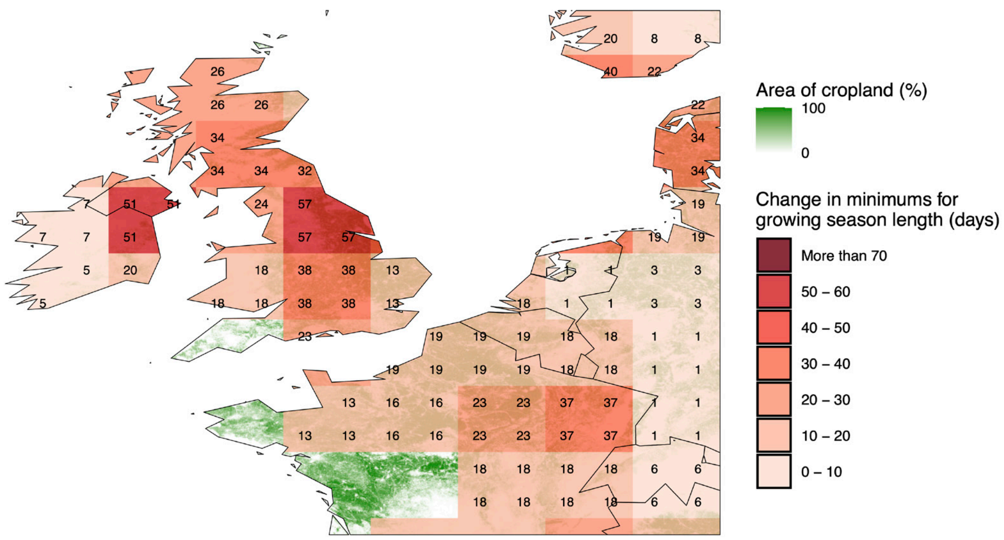
results are illustrated in figure 2.5. The average growing season length in the UK is extending due to global warming. This trend could be reversed post-collapse, with consequences for domestic food production. Reductions would also damage nature and, along with other impacts, could push parts of the natural environment beyond their intrinsic ability to adapt, leading to widespread losses.

In general, the pace at which the harsher post-collapse conditions could be imposed – within a decade – would pose significant challenges to the social, economic, political, technological and environmental systems upon which the UK's security and stability relies. These challenges would create inter-systemic effects that would interact with multiple other security threats.

One example is misinformation, which is common during periods of instability on a large scale, such as the Covid-19 pandemic (WHO 2022). This could affect shared understanding of SPG collapse across society, impacting the ability of the government and communities to adequately respond. It is a complex issue: collapse is caused by climate change, which is making the world hotter, but could create cold threats –a counterintuitive outcome. Meanwhile, the pace of change might be damagingly fast for infrastructure and food production, but ten years is a long timescale in terms of news and information cycles, as well as politics. These and many other problems will pose complex security challenges.

FIGURE 2.5: IN OUR SCENARIO OF SPG COLLAPSE, REDUCED GROWING SEASON LENGTHS BECOME POSSIBLE OVER MAJOR UK GOOD GROWING AREAS

Modelling results comparing changes in minimum growing season length (GSL) of post- and pre-SPG collapse in our SPG collapse scenario, mapped over crop growing locations, with darker shading representing larger reductions in GSL.



Source: Authors' calculations and mapping using Potapov et al, 'Global maps of cropland extent and change show accelerated cropland expansion in the twenty-first century', Nature Food (Potapov et al 2021) and World Bank, 'World Bank Official Boundaries' (World Bank 2023).

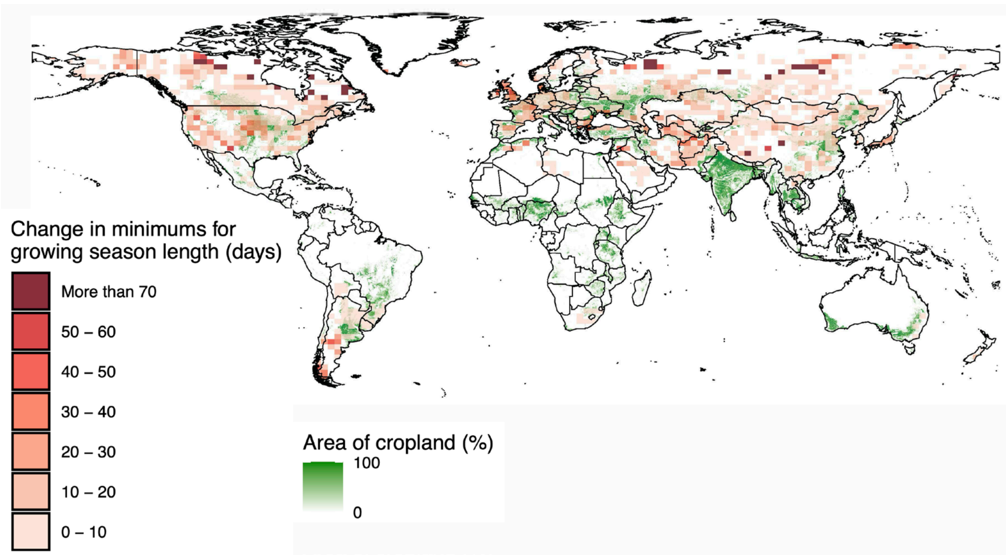
As in the case of AMOC collapse, security threats would also cascade from abroad, compounding domestic impacts. For example, in our scenario, additional maximum reductions in growing season length between 20 and 40 days are estimated to become possible over major food growing regions globally, as illustrated in figure 2.6. The effects in the US, where a fall of this magnitude would adversely impact maize (corn) growing, are particularly concerning. We undertook a high level analysis of the impacts. Falls of this magnitude could make the harvest unviable in Nebraska and parts of Minnesota and Illinois, and threaten the viability of high-yielding maize varieties across much of Iowa. These states account for over half of US maize (Cook 2023), so more analysis is urgently needed.

Domestic and international impacts would have cascading effects, in much the same way as recent food security shocks have compounded problems of poverty, political instability, and forced migration (WFP 2023; Arezki and Bruckner 2011; Sova et al 2023). The UK is particularly exposed to shocks to food production that occur in Europe and simultaneously in other places around the world. This is because the country is heavily dependent on trade, importing 47 per cent of fresh vegetables and 84 per cent of fresh fruit in 2022, overwhelmingly from the EU (Defra 2023). Internationally, countries would be handling the impacts on global food systems, as well as the other domestic and international consequences of the post-collapse reality. This would impact international relations, driving further global destabilisation.

The UK would be strategically disadvantaged, experiencing the brunt of the impacts of SPG collapse due to its geographical proximity, and having to navigate an international context that is already unstable and would be made more so by the consequences of collapse. In turn, the dynamics would impact security at home. Indeed, a recent study concluded that trade restrictions leading to food distribution problems are a likely cause of civil unrest in the UK even without an SPG collapse and on similar timescales (Jones et al 2023).

FIGURE 2.6: IN OUR SCENARIO OF SPG COLLAPSE, REDUCED GROWING SEASON LENGTHS BECOME POSSIBLE IN KEY BREADBASKETS

Modelling results comparing minimum growing season length (GSL) in pre- and post-collapse in our SPG collapse scenario, mapped over crop growing locations (in green), with darker shading representing larger reductions in GSL.



Source: Authors' calculations and mapping.

Evidence suggests that SPG collapse could occur sooner than AMOC collapse – 1.8°C being the estimated global temperature rise that could trigger SPG collapse, with a range of 1.1°C–3.8°C (Armstrong McKay et al 2022). Using models that are best at simulating the SPG's complex behaviour, the chance of collapse this century is estimated at between 36 and 45 per cent (Sgubin et al 2017; Swingedouw et al 2021). This could happen sooner rather than later, with collapse occurring as early as the 2040s in some models (Lenton et al 2023).

Using another method as part of our SPG collapse scenario, we estimate that there is around a one-in-five (20 per cent) chance that the global temperature rise has reached the threshold that might trigger SPG collapse.[2] This rises to about 50 per cent (even odds) in around 2043. Even in scenarios of rapid emissions reductions, collapse still occurs in some models.

As with any estimates of the probability that a climate tipping point could be triggered, there is a high degree of uncertainty over the likelihood of SPG collapse. But this uncertainty should not be interpreted as a reason to discount the potential threat. There is now a range of evidence to suggest that even at the present stage of climate change, the SPG appears destabilised with potential for tipping (Lenton et al 2023). Indeed, the probabilities could be higher. For example, as with AMOC collapse, models may over-estimate the stability of the SPG (Ditlevsen and Ditlevsen 2023; Drijfhout et al 2015; Swingedouw et al 2022), and so could be underestimating the risk of SPG collapse.

Furthermore, neither the UK nor any other nation currently has decision-useful early warning systems for SPG collapse or other tipping points. This means that the UK is 'flying blind' into the threat. Due to the speed at which SPG collapse could play out, it is critical to have early warning to support rapid adaptation efforts if collapse were to occur. Indeed, it is plausible that SPG collapse might already have happened. We would only know because its effects would start to be felt. This is a dangerous blind spot.

2 A methodology and discussion of the results can be found in the appendix.

3.
THE IMPLICATIONS FOR SECURITY

The evidence presented in the previous sections shows it is imperative to recognise cascading impacts and tipping points when assessing climate-security threats. The failure to adequately do so means that **the overall threat to security posed by climate change has been significantly under-appreciated**.

Significant cascading impacts are already being experienced and there is a growing likelihood that tipping points are triggered or that multiple breadbaskets experience synchronous failures. These possibilities show how the UK and wider world are already carrying significant amounts of climate risk – far greater than generally appreciated – and that this risk is still largely unrealised. In many ways, it might be sheer luck that some of these threats have not yet manifested themselves.

The risks will only grow. The rapid evolution of climate threats is occurring at the current average global temperature rise of around 1.3°C. The failure to sufficiently reduce global greenhouse gas emissions means that this rise is expected to exceed 1.5°C – the high ambition global goal for limiting climate change – within the next 10 years or less (Hausfather 2024a). The less ambitious goal of limiting global warming to below 2°C could be lost soon after.

The risks associated with overshooting these goals will still be borne even if temperatures are subsequently brought back to below 2°C or 1.5°C (Möller et al 2024). Meanwhile, there is increasing evidence of an acceleration in the rate of warming over the last 15 years, and growing concern and debate among scientists of further acceleration (Hausfather 2024b), raising the prospect of an even faster evolution of climate-security threats.

3.1 MISCONCEPTIONS OF CLIMATE-SECURITY

A fuller understanding of the climate-security threat context should dispel some preconceptions that we observed through our interviews and in government documents.

1. **The UK is not as 'sheltered' as is often assumed**. There is a presumption that the country is sheltered from the more severe security impacts of climate change. In many ways, this is correct. Global South countries are disproportionately exposed and vulnerable to current impacts and future risks. Yet the UK presumption is cast into doubt when considering how cascading impacts are already manifesting, and that these dynamics are likely to escalate rapidly and severely into the future. Moreover, the potential collapse of Atlantic circulation patterns shows that the UK is exposed to major, potentially unmanageable security threats. The disproportionate impact on the UK from these tipping points would profoundly impact its interests and put it at a strategic disadvantage relative to other nations. In all, it is clear that the UK is not relatively 'safe' from severe climate risks.
2. **Climate-security threats are not just a long-term problem**. Threats are often seen as becoming most significant in the longer term. Yet cascading

impacts are already significant and will continue to interact and exacerbate the rapidly evolving and challenging security context at home and abroad. Meanwhile, evidence suggests that SPG collapse and synchronous breadbasket failures could happen sooner rather than later, and that their possibilities might be underestimated.

3. **Security impacts might not be manageable**. As climate-security threats are often seen as resulting from first-order climate impacts, their consequences can appear manageable. But together they could create an overall threat that becomes difficult to contain effectively. These include significant implications for government finances, with the OBR anticipating significant increases in public debt resulting from the government having to respond to worsening climate impacts (OBR 2021). Meanwhile, the best available information on tipping points profoundly challenges the view of manageability. AMOC collapse in particular would create an unprecedented whole-system civil emergency in the UK and beyond. The impacts on food security would be effectively unmanageable. A shift in climatic conditions of such a scale, pace and severity would also impact many other critical systems simultaneously, at home and abroad, creating a tidal wave of destabilisation. The resources needed to adapt may exceed those available, and some effects –like the knock-on triggering of tipping points in natural systems –may be beyond adaptation.
4. **Climate threats cannot be separated from other security issues**. Climate-security threats are often considered individually and as separable from the wider security context – hazards to be dealt with by non-security departments or emergency responders. But this view does not adequately recognise the scale of cascading interactions and the pace at which they are evolving. Meanwhile, the triggering of tipping points or the synchronous failure of breadbaskets would cause saturating consequences for many, if not all, areas of security.

Altogether, these factors show that **climate change should be considered a top-tier national security issue**. Individual climate-security threats are on par with other premier non-malicious threats like pandemics. In some cases, such as AMOC collapse, they pose a far greater threat. Yet a comparison between climate change and other major non-malicious threats is still not accurate and is potentially misleading. Instead, we should distinguish between climate change itself and specific climate-security threats and their cascading effects. Climate change is the driver of these interconnected consequences. So, **climate change should not just be associated with a series of worsening *events* but should also be considered as creating a new *era* of complex, severe and constantly evolving security challenges**.

In this way, climate change should be seen on a higher plane than other threats, a 'meta-threat' acting as a fundamental determinant of the global and local context, whose consequences are entangled in all national security threats and issues. Comparisons might be drawn with how the emergence of nuclear weapons created a new era for security, although the climate-security threat is more encompassing and affects all areas of security relating to hostile and non-hostile factors.

4. THE UK IS NOT PREPARED FOR MAJOR CLIMATE-SECURITY THREATS

This section explores how recent governments have sought to assess and manage climate-security threats and how wider society is currently prepared for them. The UK Covid-19 Inquiry has found considerable inadequacies in how the government and wider UK are generally prepared for major non-malicious threats that could create whole-system civil emergencies. Many of these problems are common to the climate case, but some are specific to threats resulting from cascading impacts and tipping points.

4.1 APPROACHES TO RISK ASSESSMENT AND MANAGEMENT

Risk assessment is a critical precondition for managing security threats (Rogers and Gulledge 2010, Mabey et al 2011). Risk is often defined as the likelihood of an outcome multiplied by the severity of its consequences, alongside the exposure and vulnerability to those consequences. So, in the broadest sense, risk management seeks to reduce the possibility and/or severity of an outcome. To do this, a risk assessment is needed, which considers the probabilities and consequences that make up the risk.

This is easier said than done. In a complex, inter-connected, and increasingly conflicted world, information on security threats is often incomplete and imprecise. In response, the national security community has developed sophisticated processes for assessing and managing risk under conditions of complexity and uncertainty. These are guided by a set of principles, which are common to risk assessment and management across a range of sectors. Here we express them through a set of key questions and use food security as an illustrative example.[3]

PRINCIPLES FOR CLIMATE-SECURITY RISK ASSESSMENT AND MANAGEMENT

1. What do we care about? Establish a shared understanding of how the risk relates to existing objectives and interests and therefore what we wish to protect and what should be avoided. This sets the focus and boundaries of the assessment. For example, in the case of UK food security, the 2022 Government Food Strategy stated its objectives included 'a sustainable, nature positive, affordable food system that provides choice and access to high quality products that support healthier and home-grown diets for all' (Defra 2022a). So, in relation to climate change, we could consider that a clear priority for risk assessment is to identify the threats that could impact food security and develop a management plan for protecting the ability to maintain choice and access to a high-quality food supply.

3 These principles draw on analysis in Mabey et al 2011, King et al 2015, Quiggin et al 2021, Royal Academy of Engineering 2022, Sharpe 2023, Trust et al 2024, and UK Covid-19 Inquiry 2024.

2. What is the worst that could happen and when? A golden rule of risk assessment is to focus on the worst cases: the risks of most concern that present the greatest threat to what we care about. For example, a worst-case scenario is that AMOC collapse occurs and prevents the UK from meeting its food security aims. A range of analytical approaches should be taken.

- **Use the best available information.** This is often a mixture of quantitative and qualitative analysis and expert judgement. Under uncertainty, it is more important to obtain a best estimate using the highest quality information available than to have no estimate at all.
- **Be systemic.** Risks result from many complex interactions between systems and existing vulnerabilities. Ignoring even some of these can make for a misleading assessment. Much scientific assessment of climate change focusses on first order physical impacts. So, an additional layer of cascading risk analysis is needed to identify security implications. Models can be used to help do this, but they can also unduly simplify and give a false impression of precision. Historical experience might be a poor or even misleading guide, particularly in the case of rapidly evolving climate-security threats. Scenarios should therefore also be used to explore a full range of interactions and risks.
- **Focus on the most relevant information.** Decision-makers with responsibility for managing risks have one or more 'risk currencies': risks of primary importance which they understand intuitively, such as jobs, hostile threats and inflation (Roberts et al 2021). Risk information should be relevant to these currencies and presented in a language that decision-makers understand. The opposite often happens with climate change. This is because language, risk currencies and perceptions of risk more generally may differ dramatically between subject experts, risk assessors and decision-makers.
- **Consider the full range of factors determining plausibility.** This might include quantified estimates of likelihood. But most of the time, it is not possible to quantify probabilities meaningfully. It is also important to focus on high impact events, even if they are perceived as low likelihood, as the overall risk is still high. Likelihood should not singularly determine conceptions of plausibility. Instead, a range of 'plausible' worst-cases should be identified, requiring a subjective judgement of plausibility.
- **Be explicit about assumptions and judgements.** In a complex and uncertain world, these are inevitable and they will have consequences for how the risk is assessed. Subjective analysis should be made clear, particularly so that those using assessments can understand how this might have a bearing on estimates and rankings of risks.

3. Who is involved? The management of risks involves a wide range of stakeholders, so participation in risk assessment should be similarly broad.

- **The process of identifying key objectives and their relationship to risks should involve high-level decision-makers** responsible for these objectives outside the context of the specific risk. For example, UK food security is ultimately the responsibility of senior government leaders at national and devolved levels, so they should be involved in identification of key objectives in relation to climate risks, not just those decision-makers with a climate-specific brief.
- **The information used to identify worst-case risks and management options should be gathered from across a wide range of disciplines.** Climate science is a necessary but insufficient input for determining

food security risk. Information is also needed on the financial conditions of food production and supply sectors, inequalities in access and use of food, supply chains and international risk factors, and so on. Risk management plans should be developed with all key stakeholders, including affected and vulnerable communities.

- **Specialist risk assessors and planners should lead the process of identifying and analysing this information and applying it to scenario development and risk management.** These assessors – or 'knowledge brokers' – should be literate in the culture, assumptions, language, objectives and biases of the communities from which they obtain risk information and for whom that information is intended. For example, without context, a decision-maker may misconstrue the IPCC's previous conclusion that AMOC collapse this century is 'unlikely' as meaning that it is not a risk worth worrying about. Instead, a risk assessor should stress that a collapse cannot be ruled out, and link its potential impacts to a decision-maker's areas of greatest concern, such as the impact on food security.

4. Who should know? The results of the risk assessment should report to decision-makers in high authority and those with the greatest power and responsibility to manage the risks. For climate-security threats that impact food security and other key elements of national security, this means reporting to those with the highest responsibilities in government, including the prime minister, heads of devolved administrations, their cabinets, and the National Security Council.

5. How has our assessment changed? Climate-security threats are complex, uncertain, and evolving rapidly. Risk assessments must be undertaken regularly and be consistent in analytical approach. Judgements should be tracked over time to help understand the shifting outlook.

6. How can we manage it? A risk assessment should always be connected to a strategy for mitigating the identified risks and to the structures for developing and executing this strategy. There should be a clear separation between the assessment of risk and its management. This is to protect the objectivity and accountability of both elements. In turn, the 'three lines of defence' approach is commonly used in risk management settings, particularly in the private sector, with explicit and separate functions for risk management, oversight, and independent and external assurance (JCNSS 2021).

The UK has considerable capabilities for risk assessing and managing the consequences of climate change. The 2008 Climate Change Act requires the UK government to undertake a Climate Change Risk Assessment (CCRA). This informs a five-yearly National Adaptation Programme (NAP) that sets out how the government will meet its legal obligation to ensure the country is adapted to the consequences of climate change (Burnett 2023). The CCRA and NAP consider a wide range of human security impacts. Separate adaptation programmes are undertaken by devolved administrations, informed by the UK-wide CCRA. The independent UK Climate Change Committee (CCC) provides external advice and input into the CCRA and regularly scrutinises progress on adaptation. Many structures are in place but as we explore below, they are not yet being used effectively to assess and act on risk.

Beyond climate change specifically, the National Security Risk Assessment (NSRA) is the UK government's internal process for identifying the most serious threats facing the country. The outcomes of the NSRA are classified but a National Risk

Register (NRR) provides a public-facing summary of the threats. The NRR includes a range of first-order climate-related threats, including heat waves and flooding (HMG 2023a). The National Security Council (NSC) is the main forum for high-level ministerial consideration of the UK's national security objectives and is supported by the National Security Secretariat.

The NSC often focusses on hostile threats, so a sub-committee has been formed that considers resilience more broadly, including non-malicious threats (UK Covid-19 Inquiry 2024). Responsibility for managing threats sits with a range of government departments, agencies, and devolved and local governments bodies. Several bodies support coordination, particularly in the Cabinet Office, which houses the COBR Unit, the national crisis management centre, and Resilience Directorate, which focusses 'on the prevention and mitigation of both acute and chronic risks rather than only dealing with the consequences of crises' (HMG 2023c).

4.2 CLIMATE-SECURITY THREATS ARE NOT ADEQUATELY ASSESSED AND MANAGED

The current CCRA and NSRA processes are inadequate for assessing climate-security threats, particularly those arising from cascading impacts, and do not adhere to several key risk assessment principles. In turn, there are inadequacies in UK government structures for handling major climate-security threats and in making the UK more resilient to climate change in general. We have identified five interconnected problems.

Problem 1: There is no dedicated national security risk assessment of climate change

Strikingly, there is no explicit UK risk assessment of the holistic national security implications of climate change to cater primarily for a national security audience at the highest level. The CCRA is designed to inform adaptation planning and is therefore primarily intended for use by non-security departments, particularly the Department for Environment, Food and Rural Affairs (Defra), which leads the NAP. This leaves gaps in risk assessment for security purposes intended for high-level decision-makers including the NSC, which explores national security threats holistically and at a broad level.

For example, it is not currently in the CCRA's function – largely determined by Defra – to ask how climate change might impact the government's central strategic goals, such as national defence and economic stability, or what the worst-case outcomes for the UK might be and whether they could constitute whole-system civil emergencies. There is also no explicit assessment of derailment risks in the CCRA or in the government's climate change policies more generally.

The NRR does not fulfil these functions either. This is partly the result of a lack of harmonisation between the CCRA and the NSRA, including a "mismatch in the timescales… which means that the NRR does not assess the impact and likelihood of climate trends" (CCC 2021b). The NRR differentiates between risks considered 'acute' – discrete events presenting threats over a two-to-five-year horizon, or 'chronic' – long-term challenges gradually threatening security (HMG 2023a). In the latest edition of the NRR, the previous government removed climate change and other chronic drivers of risk altogether, saying it was developing a separate process for assessing these threats.

The NRR does include short-term climate hazards such as heatwaves and wildfire, but not an assessment of how their likelihood and impact are being affected by the evolution of climate change. In addition, some climate-security threats like tipping points do not fit this binary distinction. Using the government's categorisation, tipping points are caused by a 'chronic' risk (rising temperatures). When triggered, the tipping process could play out over years or decades, a timeframe sitting awkwardly between 'acute' and 'chronic' timescales, depending on the tipping point. The post-tipping state would create a new set of acute and chronic risks. The inability to neatly fit complex climate-security threats within the government's conception of timescales. and what constitutes a proximate risk, means that climate-security more generally can fall between the cracks of security risk assessment processes.

There are recent examples of national security risk assessments of climate change being undertaken around the world. In the US, within one week of inauguration, President Biden ordered the US intelligence community to undertake a National Intelligence Estimate (NIE) – the highest risk assessment of a national security issue – on the national and economic security impacts of climate change within 120 days, which subsequently identified high risks to national security (ODNI 2021).

Australia is another example of an incoming government undertaking a similar exercise. Within six months, the Labor government followed through on its election promise to instruct the Office of National Intelligence to assess climate threats to national security (ALSCG 2024). This assessment sits alongside an ongoing National Climate Risk Assessment process, which is similar to the UK CCRA and primarily informs adaptation policy.

There are inadequacies with both the US and Australian approaches. In particular, both assessments are mainly limited to considering international threats in isolation. This imposes an artificial divide between domestic and international risks, which can preclude a holistic assessment of threats that do not respect borders. The NIE does not consider tipping points and employs a narrow conception of security, focusing primarily on the defence domain, which frustrates assessment of the systemic interactions between human security and defence threats (Dumain 2022). Additionally, the Australian assessment has not been published, precluding engagement with its findings (ALSCG 2024).

Problem 2: Understanding of climate-security threats is not guided by a full range of possible outcomes

The NSRA process and NRR deliberately do not capture all risks faced by the UK, instead grouping risks into single 'reasonable worst case' scenarios (HMG 2023a). The UK Covid-19 Inquiry has found that, in practice, these have been treated as predictions rather than just one scenario to plan against (UK Covid-19 Inquiry 2024). For Covid-19, this resulted in too much reliance being "placed on a single scenario – pandemic influenza – and on the likelihood of that scenario occurring [with] the effect… that risk was assessed too narrowly in a way that excluded other types of pandemic" (ibid).

There was enough information to identify that a novel coronavirus pandemic was plausible, yet too much weight was given to the conclusion that this was low in likelihood. This has led the Royal Academy of Engineering, in a study of the NSRA process, to conclude that "likelihood should not be the main driver for prioritisation, as this can be difficult to assess with a high degree of confidence across all risks" (Royal Academy of Engineering 2022). In turn, the UK Covid-19 Inquiry has concluded that the government needs to "ensure that the selection of multiple scenarios for different risks reflects a representative range of what could go wrong, and that this is not mainly driven by the likelihood of these scenarios" (UK Covid-19 Inquiry 2024).

Similar problems exist in climate risk assessment. Climate tipping points are an illustrative example. They pose plausible and severe climate security threats, so should be considered within a set of worst-case scenarios. Tipping points are mentioned in the context of government risk assessment processes. For example, the CCC's independent input for the CCRA repeatedly mentions tipping points (CCC 2021a), including in a technical report exploring the impacts of tipping points on the UK (Hanlon et al 2021).

However, there is only one mention of tipping points in the government's CCRA itself, which is found in a discussion of priorities for future research (HMG 2022a). There is no mention of tipping points in the Third National Adaptation Programme and the Fourth Strategy for Climate Adaptation Reporting presented to Parliament last year (HMG 2023d). While climate change was a key theme in the 2023 Integrated Review Refresh, there was no direct mention of tipping points or other non-linear climate-security threats (HMG 2023b). They are not mentioned in the latest National Risk Register either (HMG 2023a).

This is a common problem across the world, with the OECD warning that: "Despite marked improvements in the understanding of the high risks associated with climate tipping points, global policies explicitly targeting risks of tipping points remain virtually non-existent" (OECD 2022). A key issue identified by the OECD and others is that prevailing approaches to assessing the implications of climate change largely focus on outcomes that are considered higher probability, which often involve average changes, not non-linear possibilities (ibid; Mercure et al 2021; Kemp et al 2022). Indeed, tipping points are not included in standard projections for the UK's future weather and climate, and can therefore be excluded from scenarios informing risk assessments of climate change, limiting the range of scenarios and excluding plausible worst-cases (CCC 2021a).

In general, the inherent uncertainty in gauging major climate-security risks can be misconstrued as meaning these risks are very low-likelihood and therefore ignorable, even if it is clear the impact might be severe (OECD 2022). However, it is best practice to consider low- or uncertain-likelihood outcomes that could have severe consequences as amounting to material risks (Trust et al 2024). Understanding of climate-security threats should be aligned with what could be most threatening, not what might (currently) seem to be most likely. Indeed, the latest evidence suggests that triggering of tipping points and the manifestation of severe cascading impacts are no longer 'low likelihood' (Lenton et al 2023, Ranger at al 2024). Meanwhile, the science of tipping points is improving fast. But developments take time to enter assessment processes that stretch over many years. For example, the process to develop the CCRA takes five years.

Problem 3: Analytical flaws mean threats are routinely underestimated

Even if uncertainty in climate scenarios were to be dealt with appropriately, there are several other analytical problems that constrain assessment of climate-security threats. One critical flaw is that cascading and compounding dynamics are not appropriately factored into national security analyses. For example, the NRR does not assess risks within and across systems (UK Covid-19 Inquiry 2024). Instead, it focusses on single events and sectors, excluding risks that are connected or can occur concurrently. Yet by definition, cascading climate impacts interact with and exacerbate risks across sectors and systems. Similarly, the consequences of SPG or AMOC collapse would touch many if not all risks listed in the NRR.

These analytical problems also exist in climate-specific assessment. For example, reporting of food supply chain risks is not mandated, preventing evaluation of the overall levels of systemic risk in the UK food system, a key determinant of UK food security (CCC 2023). Overall, the CCRA mentions cascading, cross-border impacts but does not estimate how these would evolve across different emissions scenarios (HMG 2022a).

This has led the CCC to conclude that 'Due to the potential for hidden tipping points and the unpredictability of systemic risks, the current model of conventional risk governance in the UK that focusses on single events, single sectors and characterisation of reasonable worst-case scenarios should be reviewed' (CCC 2021a). The latest CCRA notes "there is a need to address the interdependency and inequality of risks, and this is a research priority area" for the next CCRA (HMG 2022a). This is a problem in other countries, including across Europe, where a recent study concluded that: "Cascading climate risks are, as yet, little understood and seldom assessed or managed. This is extremely dangerous" (Townend et al 2023). It is also one of the reasons that derailment risks are not routinely considered in climate planning and action.

This problem is related to the predominance of economic analysis in government risk assessment. Estimates of the economic consequences of climate-security threats are important in assessing impacts and enabling cost-benefit analysis to support decision-making. But these estimates often do not account for cascading impacts and abrupt changes, meaning they are severely limited and biased downwards (OECD 2022, Trust et al 2023).

This leads mainstream economic assessments to routinely predict negligible economic impacts from global temperature rises that scientists consider to be biophysically catastrophic. For example, models used by central banks and other key institutions predict a small reduction in the trend rate of economic growth of 0.05—0.3 per cent resulting from a 4°C global temperature rise (Stern et al 2022, Lauro and Khanna 2024). Such a rise could lead to the triggering of multiple tipping points and other impacts that have been described as globally 'catastrophic' (Xu and Ramanathan 2017).

Similar economic approaches were used in the latest CCRA, with the government warning that "for eight of the risks identified by the CCC, economic damages by 2050 under 2°C could exceed £1 billion [per annum]" and that "other sources of evidence suggest that, by 2045, the cost of climate change to the UK could be at least 1 per cent of GDP" (HMG 2022a). These figures only consider specific risks where some valuation of economic impacts was possible from the evidence available. They do not accurately represent the cascading impacts and abrupt changes that are plausible around 2°C and would cause far greater economic impacts. Similarly, recent OBR analyses do not include tipping points (OBR 2024), nor do they sufficiently assess cascading and compounding impacts.

Furthermore, an "at least 1 per cent" reduction in GDP is about a tenth of the GDP reduction brought by Covid-19, potentially creating a misleadingly benign impression of the overall climate-security threat, with the qualifier – 'at least' – being both critical and easily missed. Even with better analyses, cost-benefit approaches generally struggle to cope with non-linearity, as optimisation is difficult for high-uncertainty, high-impact threats (Kopp et al 2016).

Navigating this array of methodological flaws can be a daunting challenge for risk assessors. It requires an appreciation for differences between the culture of producers of risk information and risk assessment best practice (Sharpe 2023). In particular, definitions of 'conservative risk assessment' may differ. For a climate scientist, this could mean focusing on outcomes that might appear most certain. For a risk assessor, this means focusing on the most extreme events, even if they are uncertain. This is a potentially troublesome cultural and analytical difference. Bridging it requires a skill set and 'feel' for climate-security threats that do not appear generally apparent in national security risk assessment processes.

Problem 4: Climate-security is not integral to national security decision-making

The UK Covid-19 Inquiry has stated that 'Preparedness for and resilience to a whole-system civil emergency must be treated in much the same way as we treat a threat from a hostile state' (UK Covid-19 Inquiry 2024). Yet many high-ranking officials testifying to the Inquiry said that this was not the case in practice. The Inquiry identified a range of issues that constrain preparation and response to whole-system civil emergencies. These are pertinent for climate-security threats.

The Inquiry has pointed to inefficiencies across the government system. There are too many entities involved in preparedness and resilience with significant "overlap between their roles and an absence of clarity about the division of responsibilities". In particular, the Inquiry has pointed to the lead government department model as being "fundamentally unsuited to preparing for and building resilience to whole-system civil emergencies". In this model, individual risks are allocated to lead departments, fragmenting understanding of how they can create threats that cut across departments. This prevents the collaborative systems approach needed to handle whole-system civil emergencies. The Inquiry has concluded this model should be fully abolished.

This fragmentation is also clear in the case of climate-security threats. It is unclear who 'owns' the threat posed by, say, AMOC collapse in government. No singular department has the capabilities or can have the responsibility to manage climate-security threats with implications for all of society. The CCC has warned of a lack of "clear responsibilities and mechanisms for cross-Government collaboration" (CCC 2023). Furthermore, responsibility for climate risks sits in non-security departments like Defra, marginalising climate-security threats from the top table of national security decision-making. The Joint Committee on the National Security Strategy has concluded that: "It is hard to imagine the Government taking such a lax approach to any other recognised national security risk" (JNCSS 2021).

A lack of leadership at the highest political levels of government is also a problem. Ministers can often feel as if there is little political reward for focusing on uncertain threats, particularly when faced with relentless pressure on time and resources from other issues (Hodgkin and Sasse 2022). They also suffer from a lack of skills and experience, with the Covid Inquiry finding that ministers are "frequently untrained in the specialist field of civil contingencies" and "failed to challenge sufficiently the advice they did receive from officials and advisers" (UK Covid-19 Inquiry 2024).

Problem 5: The UK is not resilient to current climate conditions, let alone future threats

The UK is poorly adapted to climate change. In its most recent assessment of the UK's resilience, the CCC reached the striking conclusion that "consistent minimum resilience standards across sectors... are largely absent" and that "no sectors are yet well adapted to the risks of climate change" as they stand today, let alone into the future (CCC 2023).

The CCC has warned that previous adaptation plans did not even address all the threats identified in the CCRA and that there has been "very limited evidence of the implementation of adaptation at the scale needed to fully prepare for climate risks facing the UK" (ibid). While it considers the latest NAP to be an improvement, the CCC has concluded it still "lacks the pace and ambition to address growing climate risks" (CCC 2024). Meanwhile, the uncertainties associated with climate-security threats present additional challenges to adaptation planning. For example, the impacts of tipping points expand the possible range of conditions to which the UK may have to be adapted (Hanlon et al 2021).

The poor state of UK resilience is partly the result of a lack of prioritisation and connection across government. The CCC has said that adaptation "remains the Cinderella of climate change, still sitting in rags by the stove: under-resourced, underfunded and often ignored" (CCC 2021a). As the lead department on climate resilience, Defra has "struggled to have enough clout to drive progress across other departments, with actions from other departments in NAP3 often being weak" (Hodgkin and Rutter 2024). The Joint Committee on the National Security Strategy has "found scant evidence of climate adaptation work being driven forward by any of the relevant Cabinet Committees, which was reflected in its apparent lack of prioritisation by the Cabinet Office and the Government more widely" (JCNSS 2022).

Overall, the Institute for Government has concluded that "the existing set-up has not delivered the pace of change required to minimise harms and costs from increasing climate change impacts" (Hodgkin and Rutter 2024). In 2023, the government created the Climate Resilience Board, with the intention of putting climate resilience into the centre of government. While it is too early to gauge its impact, there are worrying signs that preparedness for the most severe threats is not being undertaken. For example, in response to a recent written question in the House of Lords, a government minister stated that the government has not even "assessed the effect of any slowing or collapse of the Atlantic Meridional Overturning Circulation (AMOC) on economic planning" (Hunt 2024), implying a lack of effort to prepare.

Fundamentally, the UK lacks a vision for what resilience to climate-security threats should look like. The CCC says that the latest NAP "fails to set out a compelling vision" for what previous governments have meant by a "well adapted UK" (CCC 2024). This problem is more general. Strikingly, the National Audit Office has warned that the government has not yet "set out a well-defined vision for what a resilient UK looks like, including targets and standards for the desired level of national, local or sectoral resilience" and the "amount of risk that it is willing to accept (risk appetite)" (NAO 2023). In the case of climate-security threats, it is particularly important to identify the amount of permissible risk, as there might be considerable limits to adaptation. By failing to clarify these issues, the government is inadvertently signalling a high-risk appetite in relation to climate-security threats.

Altogether, these elements mean that "Despite the best efforts of officials, the machinery of government has been ill-suited to ensure that [climate] adaptation reaches the top of other departments' priority lists and is sufficiently well understood and resourced in local government" (CCC 2021a).

4.3 DISTRACTIONS FROM DECARBONISATION POSE SECURITY RISKS

A continuation of the failures explored above could create another, under-appreciated threat to collective security: a lack of preparation to handle the *consequences* of climate change could lead to a situation where the UK and other countries are unable to adequately tackle its *causes*. This could create a vicious circle that multiplies security threats into the future. This dynamic could play out as follows.

Worsening climate-security impacts will create escalating demands on constrained resources, particularly if they trigger whole-system civil emergencies. In response, the government and society will focus on managing the consequences of these emergencies (as is right). All things being equal, these demands could crowd out attention on and resources from tackling the root causes, increasing the problem of maladaptation, whereby immediate crisis management exacerbates the underlying situation.

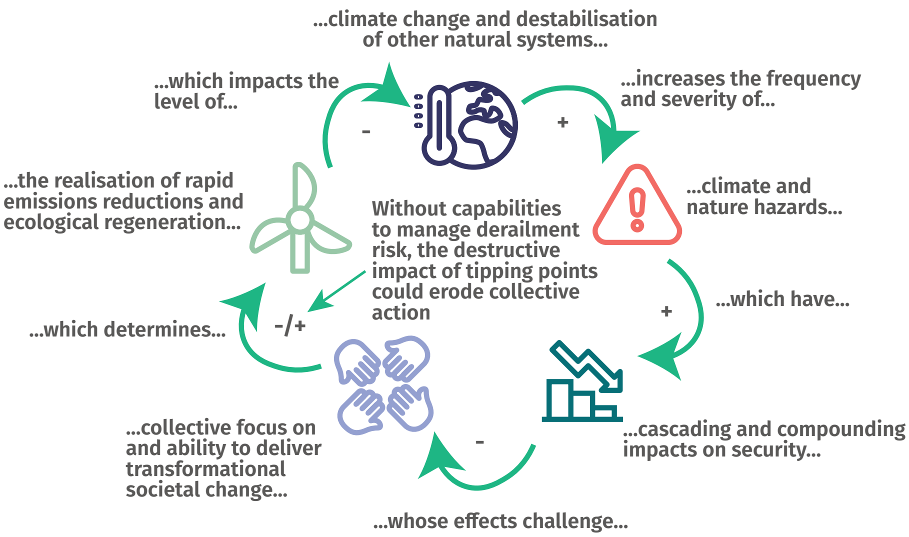
For example, more intensive farming to compensate for lost agricultural production caused by climate shocks could be done in a way that worsens ecosystem stress, and so create more problems for food production and nature. Constrained resources and immediate challenges, such as Covid-19 and Brexit, have already contributed to climate adaptation being weak and disparate, as explored above.

Aggregated internationally, a consequence of this dynamic could be that action to meet global environmental goals is slowed. This would be a severe strategic mistake as it would increase the underlying climate problem, creating more security threats. In turn, their manifestation could further distract from reducing emissions and restoring nature, creating a vicious circle, severely degrading security in the medium-to-long-term.

This dynamic is referred to as 'derailment risk': the risk that the world is increasingly diverted from a pathway to sufficiently tackling the *causes* of climate-security threats by a necessary imperative to tackle their *consequences* (Laybourn, Evans and Dyke 2023). It is illustrated in figure 4.1. Conversely, severe climate-security impacts might also act as focusing events, spurring greater climate action and a more virtuous circle. Disruptive moments of crisis provide golden opportunities for innovation and transformational change.

FIGURE 4.1: HOW SOCIETIES REACT TO CLIMATE-SECURITY IMPACTS WILL DETERMINE THE CHANCES OF WORSE THREATS IN THE FUTURE

Stylised diagram of the relationship between the effects of climate-security threats and the ability of societies to collectively address their root causes



Source: Authors' analysis, adapted from Laybourn, Throp and Sherman 2023
Note: Causal links where one quantity increases/decreases another quantity are illustrated with a plus/minus.

Two of the previous case studies might provide a plausible example of how non-linear threats could lead to significant derailment risks. One of the consequences of SPG collapse could be a knock-on effect to the AMOC, weakening it by as much as 30 per cent (Quadfasel and Käse 2007; Drijfhout et al 2012; Sgubin et al 2017; Swingedouw et al 2021). This is because the SPG helps determine the overall strength of the AMOC. A significant weakening would require concerted global effort to stave off a full AMOC collapse, a critical action moment for global security. Yet the impacts of SPG collapse on societies could frustrate these efforts. If this disruption acted to crowd out decarbonisation, it would put the world at a disadvantage in its efforts to avoid AMOC collapse, risking far greater climate-security consequences.

Conversely, the impacts of SPG collapse and the greater risk of AMOC collapse might also offer opportunities to spur climate action. Put another way, our collective ability to manage a potentially unavoidable security outcome (such as that arising from SPG collapse) will determine whether we can avoid unmanageable security outcomes (as would result from AMOC collapse).

5. RECOMMENDATIONS

The new government is well positioned to respond to the escalating risks posed by climate-security threats, developing better capabilities to manage these threats and ensuring the UK and wider world can find a path to a sustainable future. It has core commitments on national security and on climate action. Fully combining the two is essential to create a more resilient and prosperous Britain. Meanwhile, these risks are recognised by the public. Polling shows high levels of concern that the UK's national security is weak and a recognition that climate change poses a risk to UK security (Rose 2023).

Urgent action is needed. There are worrying similarities between the situation before the onset of Covid-19 and the current state of the UK's risk assessment and management of climate-security threats. Altogether, the UK might be even less prepared to handle major climate-security threats than it was to handle a pandemic.

A central consequence of these deficiencies is that as with Covid-19, the government once again risks under-appreciating the threat to national security posed by a key category of non-hostile threats. In turn, this could lead to an over-appreciation in the efficacy of the response, risking worse outcomes if threats materialise, as well as a complacency that decarbonisation efforts are enough to stave off such threats.

5.1 CLIMATE-SECURITY AND MITIGATION AND ADAPTATION POLICY

The best way of managing escalating climate-security threats is to limit global temperature increases to 1.5°C with minimal overshoot. As the OECD has warned in relation to tipping points, this means that "Committing to net-zero emissions by mid-century is not enough in itself; it is about achieving net-zero with urgent, early and deep reductions in emissions already this decade" (OECD 2022). This is the only sure route to having a chance at avoiding unmanageable climate-security outcomes.

The government should consider climate-security threats and their implications for the pace of global decarbonisation when setting its emissions reductions plans, including calculating its Nationally Determined Contributions ahead of the COP30 conference in 2025. The scale and pace of global decarbonisation is a critical determinant of climate-security threats and therefore a key determinant of the UK's overall security. In turn, decarbonisation can improve UK security across nearly all dimensions, including for physical and mental health, the economy and financial markets, and food systems. Policy decisions across government should be made with the climate-security consequences in mind.

Unfortunately, some major climate-security threats might still manifest. This is partly because these threats exist under 1.5°C and because the long-term global temperature rise will soon breach 1.5°C. Unavoidable climate-security outcomes will have to be managed. **This requires the government to urgently address the poor state of UK climate adaptation governance and action**. Major climate-security threats provide an additional impetus to improve UK climate resilience rapidly.

They also expand the possible range of conditions to which the UK may have to be adapted to include the potential impacts of, say, SPG or even AMOC collapse. Those bounds are large and will remain uncertain. But the severity of major climate-security threats means action should be taken. As with Covid-19, a lack of preparedness multiplies the subsequent impact, imposing a far greater cost to security.

Thankfully, there are many 'no-regrets' adaptation actions that can improve resilience no matter the scenario, including nature restoration, improvements in insulation, and making critical infrastructure robust to a wider set of extremes. These adaptations would improve resilience even if some major climate-security threats did not exist or do not manifest.

5.2 CHANGES TO THE MACHINERY OF GOVERNMENT

A new footing is required: climate-security threats should be a core part of national security planning. To this end, leadership at the highest levels is needed to reorganise government (Townend et al 2023). Other governments have sought to do this. For example, the current US government sees climate considerations as "an essential element of… national security", integrating them into policies, strategies and partner engagements (The White House 2021, US DOD 2024). This approach has informed the agenda of other policy areas, such as the CHIPS and Inflation Reduction Acts, which seek to improve the security of US supply chains and energy systems, while also driving decarbonisation (Laybourn and Evans 2023).

There is much to learn from the US approach. One key area is the need to signal that climate change has been elevated to a core national security priority and now sits at the highest strategic decision-making levels of government. To that end, we recommend that the government should **make the security implications of climate change a foundational element of the Strategic Defence Review and the review of national resilience**, including an emphasis on the implications of cascading and abrupt climate-security threats (Ince and Laybourn 2024). These reviews should ensure a climate lens is applied to security and resilience strategies across a diverse range of policy areas, including industrial strategy, public finances, supply chain resilience, health and foreign policy – and not just defence or other traditional defence and security matters.

To inform these reviews, we recommend that the government should **undertake a rapid National Security Risk Assessment of climate change to establish a full picture of the most critical threats to UK security from climate change and risk management options, catering for a national security audience at the highest level**. The assessment should both fill the gap between the CCRA and NSRA processes and complement them, drawing on the UK's world-leading expertise and engaging with key stakeholders across the public, private and academic sectors.

It should be led by the Cabinet Office and work with personnel who routinely meet analytical requirements from high-level national security decision-makers and are familiar with assessing risks in this context. Support should be provided by departments and agencies with specific expertise on climate risks. The assessment should report within months. If the government judges that it lacks sufficient resources to complete this task at this time, it should consider commissioning an external group of experts to undertake the exercise on its behalf.

This assessment process should produce a range of outputs, from a full report to smaller, decision-grade briefings on particular topics. In addition, the assessment should do the following.

- Follow the principles set out in section three, such as focusing on a range of worst-case scenarios and factoring in interconnected risks, including those relating to nature loss and other pressing environmental problems.
- Focus on national security holistically, looking at threats to human security within and outside the UK's borders, and how they interact, producing decision-useful information in relation to the government's strategic interests.
- Assess threats to the nations and regions of the UK as well as the UK overall, engaging with government, experts and stakeholders in devolved administrations and local government areas.
- Answer critical and strategically-consequential questions, such as what are the worst threats to food, economic and geopolitical security posed by climate change, and how best to manage these threats under conditions of high uncertainty and constrained resources.
- Urgently assess major threats, including SPG and AMOC collapse, and critical cascading and compounding risks linked to particularly vulnerable UK systems.
- Develop options for the management of these risks and the implications of risk management for other areas of government.
- Produce a publicly available version.

The assessment should expedite the creation of a standing capacity to better assess climate-security threats, ensure they are factored into the day-to-day national security assessments and procedures, and support high-level national security decision-makers in managing these risks.

Therefore, we recommend that the government should **create an independent Centre for Climate and Nature Security**, a centre of excellence with the purpose of improving the ability of the UK's security community to integrate an understanding of climate-security threats into decision-making processes and risk management (Malliaraki et al 2020). It should provide relevant, timely and actionable all-source intelligence assessments for key decision-makers. It should work with, complement and connect the extensive assessment capabilities already in government departments and agencies, including the Met Office and the CCC, as well as in academia, the private sector and civil society. The centre should draw on, inform and help better connect the NSRA and CCRA processes. It should also consider threats coming from nature loss, pollution and other inseparable environmental problems.

We recommend that priorities for the centre should include the following.

- **Investing in deep-dive research to close key knowledge gaps and produce decision-grade insights**. There is a clear need to do so for cascading impacts and potential abrupt changes. It is untenable that so many fundamental knowledge gaps still exist in understanding of the security implications of threats like SPG and AMOC collapse and the compounding interaction of existing climate and nature stressors, as well as what emergency response measures can be usefully deployed. Information must be developed with decision-maker requirements in mind and to inform risk management plans.
- **Assessing derailment risks in decarbonisation plans**, exploring how departmental approaches to meeting carbon budgets might be impacted by worsening climate impacts – such as the threat posed to carbon sequestration by wildfires and droughts destroying tree plantations and restored wetlands – and providing risk management options.
- **Supporting the development of early warning systems for key climate-security threats**. The severe and complex consequences of these threats mean there is a pressing need to establish early warning capabilities that are trustworthy and decision-useful. The Centre should work with other strategic investors,

including the government's Advanced Research and Innovation Agency, which is investing in research on early warning systems (Bale and Bohndiek 2024).

- Supporting a new **mandatory requirement for major government policy proposals to contain an assessment of climate-security risks and risk management**, including relating to financial implications.
- Supporting the **institution of a general programme of education across parliament, devolved administrations and the civil service** to improve skills and general intuition for the new threat context, including updates to the Policy Profession standards.

Beyond risk assessment and the general need to improve adaptation, changes are needed to how the government and devolved administrations plan and prepare for major climate-security threats. We are aware that the UK Covid-19 Inquiry has provided a set of effective recommendations for improving government structures to be better prepared for and resilient to threats that might cause whole-system civil emergencies (UK Covid-19 Inquiry 2024). We agree with these recommendations, which include the following.

- Simplifying structures by **creating a single Cabinet-level committee responsible for whole-system civil emergency preparedness and resilience** for each of the UK government and devolved administrations. It should meet regularly, be chaired by the government's leader, and be supported by a single cross-departmental group of senior officials overseeing and implementing policy.
- **Abolishing the lead government department model and instead requiring the Cabinet Office to lead on preparing for and building resilience to whole-system civil emergencies** across UK government departments, including monitoring the preparedness and resilience of other departments, supporting departments to correct problems, and escalating issues to the committee and officials group mentioned above. In the case of climate-security, the Cabinet Office can be supported by the outputs of the new Centre.
- **Introducing a UK-wide whole-system civil emergency strategy** to prevent emergencies and to mitigate their effects, developed collaboratively by the UK government and devolved administrations. These should include major climate-security threats.
- **Creating a statutory independent body for whole-system civil emergency preparedness and resilience** that provides strategic advice and oversight to the government. The body should be set up by the UK government in consultation with the devolved administrations. It should work closely with the proposed Centre for Climate and Nature Security and the other elements of UK climate governance, including the CCRA and CCC.
- **Undertaking whole-government response exercises or 'stress tests'** at least every three years. The Inquiry focusses on pandemic exercises, but they should also be undertaken on major climate-security threats. They should consider the whole-system consequences, including for food security, financial stability and health, working across government, agencies and the private sector. Findings, lessons and subsequent action plans should be published and made generally accessible.

Any strategy to tackle whole-system civil emergencies cannot be made in isolation from the wider world. Therefore, we recommend that any **whole-system civil emergency strategy should include elements for coordinating resilience between nations, key markets and multilateral institutions** to better manage and pre-empt systemic risks and vulnerabilities resulting from climate-security threats that exist on a cross-border scale. Pressing priorities include improving coordination to increase food system resilience, and assessing the combined effects of climate change and nature loss together on regional scales. Coordinated resilience strategies will require increasing climate finance commitments, and loss and damage funding to support climate-vulnerable nations.

In doing this, the government should be guided by a recognition that the national security of the UK is inseparable from the security of people and places around the world. As the foreign secretary recently said (Lammy 2024):

> ***"demands for action from the world's most vulnerable and the requirements for delivering security for British citizens, are fundamentally aligned. And this is because this crisis is not some discrete policy area, divorced from geopolitics and insecurity. The threat may not feel as urgent as a terrorist or an imperialist autocrat. But it is more fundamental. It is systemic. It's pervasive. And accelerating towards us at pace".***

6. CONCLUSION: GOING FASTER THROUGH DISASTER

In the wake of the 9/11 terror attacks, the US Congress created a national commission to understand the failings in government risk assessment and management exposed by the attacks (Sharpe 2023). The commission reported that “across the government, there were failures of imagination, policy, capabilities, and management” and, in summing up, that “the most important failure was one of imagination” (NCTAUUS 2004). The commission concluded that it is “therefore crucial to find a way of routinizing, even bureaucratizing, the exercise of imagination”.

On the eve of the Covid-19 pandemic, it seemed as if the UK government had successfully bureaucratised imagination. It had correctly assessed pandemics to be one of the most significant threats facing the UK and developed response plans considered to be some of the world’s best. But these assessments and plans did not translate into sufficient preparedness. The focus on only one type of pandemic proved a strategically disastrous failure of imagination.

Pandemics are now joined by climate-security threats and loss of nature as the premier non-hostile threats facing the UK – and the wider world (WEF 2024). As with pandemics, there is ample evidence to suggest that these threats are not just plausible or possible but also probable. But previous governments have not even adequately assessed these risks, let alone prepared to handle their consequences. The failure of imagination persists.

The severity of climate-security threats –and the all-encompassing security impacts of rising temperatures – means this failure must be overcome urgently. Several scientists are now warning that the climate system is entering ‘uncharted territory’ (Ripple et al 2023b, Schmidt 2024). Uncharted territory for the climate creates uncharted territory for national and international security.

A strong imagination is critical to survival in the unknown, ensuring that unmanageable climate-security outcomes are avoided. This report has set out a range of recommendations for how the new government can better expand its imagination and, in turn, action.

Doing so will force us to confront a particularly challenging dimension of the situation we now face. An improvement in risk assessment will highlight how the threats to the UK from climate change are far more severe and disruptive than is generally understood across politics and the wider public. Cascading impacts will escalate, and tipping points might be triggered. This reality is hard to face – a potentially profound dislocation of expectation.

But it does not mean that climate action is futile. The opposite is true. Whatever climate change throws at the UK, the unavoidable will have to be managed. This is so that ultimately, the unmanageable is avoided. It will mean that the UK, along with all other countries, will have to become adept at navigating rapid and equitable climate action through worsening impacts, charting a course to a better future. Doing this successfully will, again, require imagination.

APPENDIX

SCENARIO OF SPG COLLAPSE – METHODOLOGICAL NOTE

The analysis used in section two used output from state-of-the-art global climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) and Phase 5 (CMIP5). CMIP provides a framework for coordinated climate model experiments that enable systematic evaluation and intercomparison of model performance. Models included in CMIP exhibit significant diversity and independence in their formulation, resolution and parametrisations. The novel results presented here regarding the probability of SPG collapse and its impacts are either under review or being prepared for submission as academic publications in peer reviewed journals.

CMIP5 output

The use of CMIP5 is limited to quantification of the probability of SPG collapse. This event occurs in 45.5 per cent of the 11 models best able to simulate the observed SPG stratification across all scenarios (Sgubin et al 2017).

CMIP6 output

There are 11 models from CMIP6 that can accurately reproduce the observed ocean stratification. Of these, four (36.4 per cent) show an SPG collapse before 2100. In those models the collapse occurs at approximately 2°C (ranging from 1.1—2.5°C) above preindustrial (1850–1900) mean temperature. The collapse occurs as early as 2035 and as late as 2060 in the models, with the most likely time of occurrence in the 2040s. The collapse is clearly observed in five runs, three of which happen under SSP1-2.6 and two of which occur under SSP2-4.5.

This analysis focusses specifically on output from three models: CESM2-WACM, MRI-ESM2-0 and NorESM2-LM. Impacts are assessed by analysing model output variables over a 40-year period centred on the collapse – the 20-year period before and the 20-year period after. Additionally, an ensemble approach is taken by averaging the change in values across the three models. Creating an ensemble mean dampens model-specific variability and provides a more robust composite estimate of potential impacts. Examining multiple state-of-the-art models in this manner accounts for uncertainties related to model physics and better quantifies the forced response.

Differences are calculated between the post-collapse period and pre-collapse period for both annual and seasonal averages and extremes. Extremes are calculated on a grid cell level where the extreme values (maximum or minimum) across the period of interest and ensemble of models are calculated for each grid cell. This approach creates a spatial layer that is not temporally coherent. The results presented focus mainly on the extremes, comparing the extreme value of the post-collapse period to that of the pre-collapse period.

While analysing mean changes in climate indicators provides useful information, focusing solely on means can mask increases in the intensity and frequency of extreme events. From a risk management perspective, the extremes often take on an outsized importance compared to small shifts in the mean climate state. Extreme climate and weather events can have severe impacts on natural and human systems, including catastrophic disruption of infrastructure, agriculture and ecosystems. Metrics such as the frequency of high impact events, return period of historical extremes, and intensity of record-setting episodes tend to dictate risk levels more than incremental changes in averages. The results also include the impacts of background warming resulting from GHG emissions scenarios. Further work is needed to disentangle the impacts of SPG collapse and warming.

TABLE A: MODELS EXHIBITING ABRUPT CHANGES IN THE SPG

Model	Scenario	Year of occurrence	ΔGMT of occurrence (°C)
MRI-ESM2-0	**ssp2-4.5**	**~2040**	**~1.6**
CESM2	ssp1-2.6	~2060	~2.5
CESM2-WACCM	ssp2-4.5	~2050	~2.3
CESM2-WACCM	**ssp1-2.6**	**~2040**	**~2.1**
NorESM2-LM	**ssp1-2.6**	**~2035**	**~1.1**

Source: Swingedouw et al 2021 and authors' analysis
Note: The models exhibiting abrupt cooling rank among the 11 best models for representing the observed stratification in the SPG. Considering only these models we see a risk of encountering an abrupt cooling event of about 36 per cent. Models in bold text were included in this analysis. We did not include all five models that exhibit abrupt events as some models are developed in the same institute (CESM and CESM-WACM) and therefore not entirely independent. We considered only CESM-WACM and not CESM, as the former exhibits a larger signal.

Extremes from CMIP6

The dataset provides climate extreme indices related to temperature and precipitation as defined by the Expert Team on Climate Change Detection and Indices (ETCCDI), as well as selected heat stress indicators (HSI). The indices are calculated from CMIP6 models that have the necessary daily resolved data. The heat stress indicators combine near-surface air temperature, near-surface specific humidity, and surface air pressure to give indications of adverse effects of heat on human health (Sandstad et al 2022). Other variables like wind or solar radiation are not considered, so the selected heat stress indicators represent indoor conditions or calm conditions in the shade. Data is available for MRI-ESM2-0 and NorESM2-LM. The 20-year mean is calculated for each model and variable before collapse (calculated from annual mean data). The difference in the mean and extremes (maximum or minimum) of pre- and post-SPG collapse is then calculated and plotted.

Presentational format of results

The results are presented as a comparison between the 20-year mean, maximum and minimum in the pre-collapse period to those in the post-collapse period to assess the deviation in both averages and extremes due to SPG collapse. All units are presented as the absolute change (difference) between pre- and post-collapse.

Estimation of the probability of breaching the SPGs tipping threshold under SSPs

The approach here follows that of Abrams et al (2023). We use the tipping point thresholds summarised in a recent review of the tipping point literature (Armstrong McKay et al 2022) to construct and constrain probabilities of tipping at different temperatures. We pair that with model-based estimates of probabilities of temperature thresholds reached in the Shared Socioeconomic Pathways (SSPs) to quantify the probability of breaching the temperature threshold over time for three SSPs (SSP1-2.6, SSP2-4.5, SSP5-8.5) (Riahi et al 2017).

Tipping point threshold probabilities are generated using two probability distributions. First, we use a uniform (non-informative) prior with the minimum and maximum defined based on the minimum (T_{min}) and maximum (T_{max}) estimated threshold temperature from Armstrong-McKay et al (2022):

$$P(tip|T)=Unif(T_{min},T_{max})$$

We then fit the data provided by Armstrong-McKay et al (2022) to a lognormal probability distribution under the assumption that the lower and upper bounds of the threshold range represent the 5th and 95th percentiles and the best estimate represents the 50th. We estimate the log mean and log standard deviation and use these estimates to generate the probability distribution according to:

$$P(tip|T) = Lognorm(\mu_T, \sigma_T^2)$$

To estimate temperature probabilities, we use the temperature time series results from the CMIP6 ensemble results for the three SSPs. Using model output we generate a probability distribution for the temperature in each year (*Y*) under each scenario (*S*). These temperature probabilities are described by a log-normal distribution:

$$P(T|Y,S) = Lognorm(\mu_{Y,S}, \sigma_{Y,S}^2)$$

where $\mu(_{Y,S})$ is the logarithm of the mean temperature at year, *Y*, under scenario, *S*; and $\sigma_{Y,S}^2$ is the standard deviation. We perform Monte Carlo simulations in which a threshold temperature is sampled from the *P(tip|T)* and compared to samples from *P(T|Y,S)* for *Y* and *S*. If *P(T|Y,S)* > *P(tip|T)* the iteration is assigned a 1 and if not a 0. We then compute the mean as the probability of breaching the tipping temperature thresholds. This process is repeated for each year (*Y*) under each scenario (*S*) to generate a probability distribution time series under each SSP scenario. We then perform bootstrapping to generate 95 per cent confidence intervals (95CI).

Estimate of impact of growing season length reduction on US crop growing

The US appears to be at risk from reductions in growing season length that become possible in our SPG scenario. Reductions in growing season may reduce the overall croppable area. For example, the growing season over the last decade in Minnesota was 142-164 days, Iowa was 160–203 days, Illinois was 160-220 days, and it was 139–178 days in Nebraska (Iowa State University 2024). Together these four states account for over half of US maize production (USDA 2024). Depending on variety, maize requires between 80–140 days to mature (FAO 2024). In our analysis, we assumed that an average of 110 days is needed to mature the crop.

We then looked at the difference between today's average growing season in key maize growing states versus the minimum growing season length post-collapse. In our analysis above (pages 15–17), we have used the difference between the minimum today versus the minimum post-collapse. In contrast, for this food analysis, we have elected to compare current average to post-collapse minimum to reflect that decision-makers are more likely to have an intuitive understanding of the average conditions of today (defined as the last decade) than knowledge of the maximum reduction in growing season length that is currently possible. So, the deviation from average conditions is more intuitive.

The difference between the current average and the minimum growing season post-collapse ranges between 30 and 90 days, dependent on the state. So, with the assumption of an average 110 days for crop maturity, we estimated the following impact on maize growing in key states: maize would stop being viable in Nebraska (the growing season would fall to 80 to 120 days) and higher yielding varieties would stop being viable in Minnesota (the growing season would fall to 112 to 134 days), Illinois (season length cut to 110–170 days), and Iowa (season length cut to 120–163 days), with parts of these states risky or unviable for any maize crop.

REFERENCES

Abrams JF, Huntingford C, Williamson MS, Armstrong McKay DI, Boulton CA, Buxton JE, Sakschewski B, Loriani S, Zimm C, Winkelmann R, Lenton TM (2023) 'Committed global warming risks triggering multiple climate tipping points', *Earth's Future*, 11(11), e2022EF003250. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022EF003250

Arezki MR and Bruckner M (2011) *Food prices and political instability*, IMF. https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Food-Prices-and-Political-Instability-24716

Ari A, Arregui N, Black S, Celasun O, Iakova DM, Mineshima A, Mylonas V, Parry IWH, Teodoru I, Zhunussova K (2022) *Surging Energy Prices in Europe in the Aftermath of the War: How to Support the Vulnerable and Speed up the Transition Away from Fossil Fuels*, IMF. https://www.imf.org/en/Publications/WP/Issues/2022/07/28/Surging-Energy-Prices-in-Europe-in-the-Aftermath-of-the-War-How-to-Support-the-Vulnerable-521457

Armstrong McKay DI, Staal A, Abrams JF, Winkelmann R, Sakschewski B, Loriani S, Fetzer I, Cornell SE, Rockström J and Lenton TM (2022) 'Exceeding 1.5°C global warming could trigger multiple climate tipping points', *Science*, 377(6611): eabn7950. https://doi.org/10.1126/science.abn7950

Australian Security Leaders Climate Group (2024) *Too Hot to Handle: The scorching reality of Australia's climate-security failure*. https://www.aslcg.org/wp-content/uploads/2024/05/ASLCG_TooHotTooHandle_2024R.pdf

Bale G and Bohndiek S (2024) *Forecasting Tipping Points: Uniting climate measurements and models to create an early warning system*, Advanced Research and Innovation Agency. https://www.aria.org.uk/wp-content/uploads/2024/05/ARIA-Forecasting-Climate-Tipping-Points-Programme-Thesis.pdf

Berglund S, Döös K, Groeskamp S and McDougall TJ (2022) 'The downward spiralling nature of the North Atlantic Subtropical Gyre', *Nature Communications*, 13(2000). https://doi.org/10.1038/s41467-022-29607-8

Boers N (2021) 'Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation', *Nature Climate Change*, 11(8), pp.680-688. https://www.nature.com/articles/s41558-021-01097-4

Burnett N (2023) *Climate change adaptation and resilience in the UK*, House of Commons Library, UK Parliament. https://researchbriefings.files.parliament.uk/documents/CBP-9969/CBP-9969.pdf

Butler D (2010) 'Winter of discontent for Britain's bird population', *Telegraph*. https://www.telegraph.co.uk/news/earth/wildlife/6983768/Winter-of-discontent-for-Britains-bird-population.html

Butler S (2023) 'Climate crisis and energy costs fuel £600 rise in UK household food bill, analysis finds', *Guardian*, 27 November 2023. https://www.theguardian.com/business/2023/nov/27/climate-crisis-energy-costs-fuel-uk-household-food-bill-rise

Caesar L, McCarthy GD, Thornalley DJ, Cahill N, Rahmstorf S (2021) 'Current Atlantic meridional overturning circulation weakest in last millennium, *Nature Geoscience*, 14(3), pp.118-120. https://discovery.ucl.ac.uk/id/eprint/10123840/1/Caesar%2021%20accepted%20ms.pdf

Challinor A and Benton TG (2021) 'International dimensions', in *The Third UK Climate Change Risk Assessment Technical Report* (Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)). Prepared for the Climate Change Committee, London. https://www.ukclimaterisk.org/publications/technical-report-ccra3-ia/chapter-7/

Climate Change Committee (2021a) *Independent assessment of UK climate risk*. https://www.theccc.org.uk/publication/independent-assessment-of-uk-climate-risk/

Climate Change Committee (2021b) *Progress in adapting to climate change: 2021 report to Parliament*. https://www.theccc.org.uk/wp-content/uploads/2021/06/Progress-in-adapting-to-climate-change-2021-Report-to-Parliament.pdf

Climate Change Committee (2023) *Progress in adapting to climate change – 2023 report to Parliament*. https://www.theccc.org.uk/publication/progress-in-adapting-to-climate-change-2023-report-to-parliament/

Climate Change Committee (2024) *Independent Assessment of the Third National Adaptation Programme (NAP3)*. https://www.theccc.org.uk/wp-content/uploads/2024/03/Independent-Assessment-of-the-Third-National-Adaptation-Programme-NAP3.pdf

Cook R (2023) 'Ranking of states that produce the most corn', Beef 2 Live, dataset. https://www.nationalbeefwire.com/ranking-of-states-that-produce-the-most-corn

De Castella T (2012) 'How did the big freeze of 1962 compare with today?', BBC News. https://www.bbc.co.uk/news/magazine-20785406

Department for Environment, Food & Rural Affairs (2021) *United Kingdom Food Security Report 2021*. https://assets.publishing.service.gov.uk/media/62874ba08fa8f55622a9c8c6/United_Kingdom_Food_Security_Report_2021_19may2022.pdf

Department for Environment, Food & Rural Affairs (2022) *Government food strategy*. https://www.gov.uk/government/publications/government-food-strategy/government-food-strategy

Department for Environment, Food & Rural Affairs (2023) 'Food statistics in your pocket', dataset. https://www.gov.uk/government/statistics/food-statistics-pocketbook/food-statistics-in-your-pocket

Department for Environment, Food & Rural Affairs (2024) *UK Food Security Index 2024*. https://www.gov.uk/government/publications/uk-food-security-index-2024/uk-food-security-index-2024

Ditlevsen P and Ditlevsen S (2023) 'Warning of a forthcoming collapse of the Atlantic meridional overturning circulation', *Nature Communications*, 14(4254). https://doi.org/10.1038/s41467-023-39810-w

Drijfhout S, Bathiany S, Beaulieu C, Brovkin V, Claussen M, Huntingford C, Scheffer M, Sgubin G and Swingedouw D (2015) 'Catalogue of abrupt shifts in Intergovernmental Panel on Climate Change climate models', *PNAS*, 112(43): E5777-E5786. https://doi.org/10.1073/pnas.1511451112

Drijfhout S, van Oldenborg GJ and Cimatoribus A (2012) 'Is a decline of AMOC causing the warming hole above the North Atlantic in observed and modeled warming patterns?', *Journal of Climate*, 25(24): 8373–8379. https://doi.org/10.1175/JCLI-D-12-00490.1

Duchez A, Frajka-Williams E, Josey SA, Evans DG, Grist JP, Marsh R, McCarthy GD, Sinha B, Berry DI, Hirschi JJ (2016) 'Drivers of exceptionally cold North Atlantic Ocean temperatures and their link to the 2015 European heat wave', *Environmental Research Letters*, 11(7), p.074004. https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074004

Dumain C (2022) 'Redefining Security', *Issues in Science and Technology*, Vol. XXXVIII, No. 2, Winter 2022. https://issues.org/redefining-security-national-intelligence-estimate-climate-dumaine/

Energy and Climate Intelligence Unit (2024) *Climate and food: home and away*. https://eciu.net/analysis/reports/2024/climate-and-food-home-and-away

Environment, Food and Rural Affairs Committee (2023) *Food Security, Seventh Report of Session 2022–23*, House of Commons. https://committees.parliament.uk/publications/41095/documents/200335/default/

Espagne E, Oman W, Mercure J-F, Svartzman R, Volz U, Pollitt H, Semieniuk G, Campiglio E (2023) *Cross-Border Risks of a Global Economy in Mid-Transition*, IMF. https://www.imf.org/en/Publications/WP/Issues/2023/09/08/Cross-Border-Risks-of-a-Global-Economy-in-Mid-Transition-538950

Evans S (2022) 'Analysis: Why UK energy bills are soaring to record highs – and how to cut them', Carbon Brief, 12 August 2022. https://www.carbonbrief.org/analysis-why-uk-energy-bills-are-soaring-to-record-highs-and-how-to-cut-them/

Food and Agriculture Organisation of the United Nations (2024) 'Maize crop information', webpage. https://www.fao.org/land-water/databases-and-software/crop-information/maize/en/

Fox-Kemper B, Hewitt H, Xiao C, Aðalgeirsdóttir G, Drijfhout S, Edwards T, Golledge N, Hemer M, Kopp R, Krinner G, Mix A (2021) 'Chapter 9: Ocean, Cryosphere and Sea Level Change' in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK, Waterfield T, Yelekçi O, Yu R and Zhou B (eds) (2021), Cambridge University Press

Gaupp F, Hall J, Mitchell D, Dadson S (2019) 'Increasing risks of multiple breadbasket failure under 1.5 and 2 C global warming', *Agricultural Systems*, 175, pp.34-45. https://www.sciencedirect.com/science/article/abs/pii/S0308521X18307674

Gaupp F, Hall J, Hochrainer-Stigler S, Dadson S (2020) 'Changing risks of simultaneous global breadbasket failure', *Nature Climate Change*, 10(1), pp.54-57. https://www.nature.com/articles/s41558-019-0600-z

Hanlon H, Palmer M, Betts R (2021) *Effect of Potential Climate Tipping Points on UK Impacts*, Met Office Hadley Centre. https://www.ukclimaterisk.org/wp-content/uploads/2021/06/Effect-of-Potential-Climate-Tipping-Points-on-UK-Impacts.pdf

Hasegawa T, Wakatsuki H, Nelson GC (2022) 'Evidence for and projection of multi-breadbasket failure caused by climate change', *Current Opinion in Environmental Sustainability*, 58, p.101217. https://www.sciencedirect.com/science/article/abs/pii/S1877343522000690

Hausfather Z (2024a) 'Analysis: What record global heat means for breaching the 1.5C warming limit', Carbon Brief. https://www.carbonbrief.org/analysis-what-record-global-heat-means-for-breaching-the-1-5c-warming-limit/

Hausfather Z (2024b) 'Factcheck: Why the recent 'acceleration' in global warming is what scientists expect', Carbon Brief. https://www.carbonbrief.org/factcheck-why-the-recent-acceleration-in-global-warming-is-what-scientists-expect/

HM Government (2022a) *UK Climate Change Risk Assessment 2022*. https://assets.publishing.service.gov.uk/media/61e54d8f8fa8f505985ef3c7/climate-change-risk-assessment-2022.pdf

HM Government (2022b) 'Climate and weather', dashboard. https://climate-change.data.gov.uk/dashboards/climate-and-weather

HM Government (2023a) *National Risk Register: 2023 edition*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1175834/2023_NATIONAL_RISK_REGISTER_NRR.pdf

HM Government (2023b) *Integrated Review Refresh 2023: Responding to a more contested and volatile world*. https://www.gov.uk/government/publications/integrated-review-refresh-2023-responding-to-a-more-contested-and-volatile-world

HM Government (2023c) *The UK Government Resilience Framework*. https://www.gov.uk/government/publications/the-uk-government-resilience-framework/the-uk-government-resilience-framework-html

HM Government (2023d) *The Third National Adaptation Programme (NAP3) and the Fourth Strategy for Climate Adaptation Reporting*. https://assets.publishing.service.gov.uk/media/64ba74102059dc00125d27a7/The_Third_National_Adaptation_Programme.pdf

Hodgkin R and Sasse T (2022) *Managing extreme risks: How the new government can learn from Covid to better prepare for the next crisis*, Institute for Government. https://www.instituteforgovernment.org.uk/sites/default/files/publications/Managing-extreme-risks.pdf

Hodgkin R and Rutter J (2024) *Adapting to climate change: How the UK can better manage a rapidly changing environment*. https://www.instituteforgovernment.org.uk/publication/adapting-climate-change

House of Lords (2023) *Our friends in the North: UK strategy towards the Arctic*, House of Lords International Relations and Defence Committee. https://committees.parliament.uk/committee/360/international-relations-and-defence-committee/news/198697/our-friends-in-the-north-uk-strategy-towards-the-arctic/

Hunt L (2024) 'Climate Change: Atlantic Ocean, Question for Department for Energy Security and Net Zero', House of Lords, UIN HL634, tabled on 2 September 2024. https://questions-statements.parliament.uk/written-questions/detail/2024-09-02/HL634

Ince M and Laybourn L (2024) ‘Keeping the UK Secure in a Climate-Changed World’, commentary, RUSI. https://www.rusi.org/explore-our-research/publications/commentary/keeping-uk-secure-climate-changed-world

Intergovernmental Panel on Climate Change (2019) ‘Summary for Policymakers’ in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (Pörtner H O, D.C. Roberts D C, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)). Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–35. https://doi.org/10.1017/9781009157964.001

Intergovernmental Panel on Climate Change (2021) *Climate Change 2021: The physical science basis*. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

Intergovernmental Panel on Climate Change (2022) *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Pörtner HO, Roberts DC, Tignor M, Poloczanska ES, Mintenbeck K, Alegría A, Craig M, Langsdorf S, Löschke S, Möller V, Okem A, Rama B (eds.)), Cambridge University Press. doi:10.1017/9781009325844.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019) *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (Díaz S, Settele J, Brondízio ES, Ngo HT, Guèze M, Agard J, Arneth A, Balvanera P, Brauman KA, Butchart SHM, Chan KMA, Garibaldi LA, Ichii K, Liu J, Subramanian SM, Midgley GF, Miloslavich P, Molnár Z, Obura D, Pfaff A, Polasky S, Purvis A, Razzaque J, Reyers B, Roy Chowdhury R, Shin YJ, Visseren-Hamakers IJ, Willis KJ, and Zayas CN (eds.)). https://www.ipbes.net/global-assessment

Iowa State University (2024) *IEM Climodat reports*, webpage. https://mesonet.agron.iastate.edu/climodat/index.phtml

Joint Committee on the National Security Strategy (2021) *The UK’s national security machinery*. https://committees.parliament.uk/publications/7375/documents/77226/default/

Joint Committee on the National Security Strategy (2022) *Readiness for storms ahead? Critical national infrastructure in an age of climate change*. https://publications.parliament.uk/pa/jt5803/jtselect/jtnatsec/132/report.html

Jones A, Bridle S, Denby K, Bhunnoo R, Morton D, Stanbrough L, Coupe B, Pilley V, Benton T, Falloon P, Matthews TK, Hasnain S, Heslop-Harrison JS, Beard S, Pierce J, Pretty J, Zurek M, Johnstone A, Smith P, Gunn N, Watson M, Pope E, Tzachor A, Douglas C, Reynolds C, Ward N, Fredenburgh J, Pettinger C, Quested T, Cordero JP, Mitchell C, Bewick C, Brown Ca, Brown Ch, Burgess PJ, Challinor A, Cottrell A, Crocker T, George T, Godfray CJ, Hails RS, Ingram J, Lang T, Lyon F, Lusher S, MacMillan T, Newton S, Pearson S, Pritchard S, Sanders D, Sanderson Bellamy A, Steven M, Trickett A, Voysey A, Watson C, Whitby D and Whiteside K (2023) ‘Scoping potential routes to UK civil unrest via the food system: Results of a structured expert elicitation’, *Sustainability*, 15(2): 14783. https://doi.org/10.3390/su152014783

Kemp L, Xu C, Depledge J, Ebi KL, Gibbins G, Kohler TA, Rockström J, Scheffer M, Schellnhuber HJ, Steffen W and Lenton TM (2022) ‘Climate endgame: Exploring catastrophic climate change scenarios’, *PNAS*, 119(34): e2108146119. https://doi.org/10.1073/pnas.2108146119

Kew SF, McCarthy M, Ryan C, Pirret JSR, Murtagh E, Vahlberg M, Amankona A, Pope JO, Lott F, Claydon O, Coonan B, Pinto I, Barnes C, Philip S, Otto F, Wallace E, Bryant L, Tranter E, Singh R, Mijic A (2024) *Autumn and Winter storms over UK and Ireland are becoming wetter due to climate change*, Imperial College London. https://spiral.imperial.ac.uk/handle/10044/1/111577

King D, Shrag D, Dadi Z, Ye Q and Ghosh A (2015) *Climate change: A risk assessment*, Centre for Science and Policy. https://www.csap.cam.ac.uk/projects/climate-change-risk-assessment/

Kopp RE, Shwom RL, Wagner G, Yuan J (2016) ‘Tipping elements and climate–economic shocks: Pathways toward integrated assessment’, *Earth’s Future*, 4(8), pp.346-372. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2016EF000362

Kornhuber K, Lesk C, Schleussner CF, Jägermeyr J, Pfleiderer P, Horton RM (2023) 'Risks of synchronized low yields are underestimated in climate and crop model projections', *Nature Communications*, 14(1), p.3528. https://www.nature.com/articles/s41467-023-38906-7

Kucharik CJ (2008) 'Contribution of planting date trends to increased maize yields in the central United States', *Agronomy Journal*, 100(2). https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/agronj2007.0145

Kukal MS and Irmak S (2018) 'US agro-climate in 20th century: Growing degree days, first and last frost, growing season length, and impacts on crop yields', *Scientific reports*, 8(1). https://www.nature.com/articles/s41598-018-25212-2

Labour Party (2024) *Change: Labour Party Manifesto 2024*, Labour Party. https://labour.org.uk/wp-content/uploads/2024/06/Labour-Party-manifesto-2024.pdf

Lammy D (2024) 'The Kew Lecture: Foreign Secretary's speech on the climate crisis', speech. https://www.gov.uk/government/speeches/foreign-secretarys-foreign-policy-speech-on-the-climate-crisis

Lauro I and Khanna S (2024) 'Are we underestimating the impact of climate change?', Schroders. https://www.schroders.com/en/global/individual/insights/are-we-underestimating-the-impact-of-climate-change-/

Lawrence M, Homer-Dixon T, Janzwood S, Rockstöm J, Renn O, Donges JF (2024) 'Global polycrisis: the causal mechanisms of crisis entanglement'. Global Sustainability 7, e6, 1–16. https://doi.org/10.1017/sus.2024.1

Laybourn L, Abrams JF, Buxton J (2024) 'Written evidence submitted by the Global Systems Institute, University of Exeter', Environmental Audit Committee, UK Parliament. https://committees.parliament.uk/writtenevidence/130040/pdf/

Laybourn L and Evans J (2023) 'Climate change as a national security threat', *IPPR Progressive Review*, *30*(3). https://onlinelibrary.wiley.com/doi/pdf/10.1111/newe.12360

Laybourn L, Evans J and Dyke J (2023) 'Derailment risk: A systems analysis that identifies risks which could derail the sustainability transition', *Earth System Dynamics*, 14: 1171–1182. https://doi.org/10.5194/esd-14-1171-2023

Laybourn L, Throp H and Sherman S (2023) *1.5°C – Dead or alive? The risks to transformation change from reaching and breaching the Paris agreement goal*, IPPR. https://www.ippr.org/research/publications/1-5c-dead-or-alive

Lehner F, Born A, Raible CC and Stocker TF (2013) 'Amplified inception of European Little Ice Age by sea ice–ocean–atmosphere feedbacks', *Journal of Climate*, 26: 7586–7602. https://doi.org/10.1175/JCLI-D-12-00690.1

Lenton TM, Armstrong McKay DI, Loriani S, Abrams JF, Lade SJ, Donges JF, Milkoreit M, Powell T, Smith SR, Zimm C, Buxton JE, Laybourn L, Ghadiali A, Dyke JG (eds) (2023) *The Global Tipping Points Report 2023*, University of Exeter. https://global-tipping-points.org

Liu W, Xie S-P, Liu Z and Zhu J (2017) 'Overlooked possibility of a collapsed Atlantic Meridional Overturning Circulation in warming climate', *Science Advances*, 3(1), e1601666. https://doi.org/10.1126/sciadv.1601666

Loft P and Carver D (2022) *Climate change and human security*, Research Briefing, House of Commons Library, UK Parliament. https://commonslibrary.parliament.uk/research-briefings/cdp-2022-0190/

Lowes R (2024) 'Clean Heating is Vital for UK Energy Security', RUSI, commentary. https://rusi.org/explore-our-research/publications/commentary/clean-heating-vital-uk-energy-security

Mabey N, Gulledge J, Finel B, Silverthorne K (2011) *Degrees of Risk: Defining a Risk Management Framework for Climate Security*, E3G. https://www.c2es.org/wp-content/uploads/2011/02/degrees-risk-defining-risk-management-framework-climate-security.pdf

Malliaraki E, Abrams JF, Boland E, Mackie E, Gilbert A, Guo W, Lenton T, Shuckburgh E and Workman M (2020) *Climate aware and resilient national security: Challenges for the 21st Century*, The Alan Turing Institute. https://www.turing.ac.uk/sites/default/files/2020-12/august_2020_climate_aware_and_resilient_national_security_turing_designed.pdf

McCaskill I and Hudson P (2006) *Frozen in time: The worst winters in history*, Great Northern Books

McFadden P (2024) 'Covid-19 Inquiry Module One', oral statement to Parliament, 23 July 2024. https://www.gov.uk/government/speeches/covid-19-inquiry-module-one-oral-statement

Mecking J V, Drijfhout SS, Jackson LC, Andrews MB (2017) 'The effect of model bias on Atlantic freshwater transport and implications for AMOC bi-stability', Tellus A: Dynamic Meteorology and Oceanography, 69(1), 1299910. https://doi.org/10.1080/16000870.2017.1299910

Mecking JV, Drijfhout SS, Hirschi JJ, Blaker AT (2019) 'Ocean and atmosphere influence on the 2015 European heatwave', *Environmental Research Letters*, 14(11), p.114035. https://iopscience.iop.org/article/10.1088/1748-9326/ab4d33

Mercure J-F, Sharpe S, Vinuales JE, Ives M, Grubb M, Lam A, Drummond P, Pollitt H, Knobloch F and Nijsse FJMM (2021) 'Risk-opportunity analysis for transformative policy design and appraisal', *Global Environmental Change,* 70: 102359. https://doi.org/10.1016/j.gloenvcha.2021.102359

Michel SL, Swingedouw D, Ortega P, Gastineau G, Mignot J, McCarthy G and Khodri M (2022) 'Early warning signal for a tipping point suggested by a millennial Atlantic Multidecadal Variability reconstruction', *Nature Communications*, 13(5176). https://doi.org/10.1038/s41467-022-32704-3

Möller T, Högner AE, Schleussner CF, Bien S, Kitzmann NH, Lamboll RD, Rogelj J, Donges JF, Rockström J, Wunderling N (2024) 'Achieving net zero greenhouse gas emissions critical to limit climate tipping risks', *Nature Communications*, 15(1), p.6192

National Audit Office (2023) *Government resilience: extreme weather*. https://www.nao.org.uk/wp-content/uploads/2023/12/government-resilience-extreme-weather.pdf

National Commission on Terrorist Attacks Upon the United States (2004) *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States, Executive Summary*. https://www.govinfo.gov/content/pkg/GPO-911REPORT/pdf/GPO-911REPORT-24.pdf

Office of Budget Responsibility (2021) *Fiscal Risks Report 2021*. https://obr.uk/docs/dlm_uploads/Fiscal_risks_report_July_2021.pdf

Office of Budget Responsibility (2024) *Fiscal risks and* sustainability. https://obr.uk/docs/dlm_uploads/Fiscal-risks-and-sustainability-report-September-2024.pdf

Office of the Director of National Intelligence (2021) *National Intelligence Estimate: Climate Change and International Responses Increasing Challenges to US National Security Through 2040*, US National Intelligence Council. https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf

Office for National Statistics (2023) 'Climate-related mortality, England and Wales: 1988 to 2022', statistical release. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/climaterelatedmortalityandhospitaladmissionsenglandandwales/1988to2022

Office for National Statistics (2013) 'Excess winter mortality in England and Wales: 2012 to 2013 (provisional) and 2011 to 2012 (final)'. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/excesswintermortalityinenglandandwales/2013-11-26

Organisation for Economic Co-operation and Development (2021) *Managing climate risks, facing up to losses and damages*. https://www.oecd.org/en/publications/managing-climate-risks-facing-up-to-losses-and-damages_55ea1cc9-en.html

Organisation for Economic Co-operation and Development (2022) *Climate tipping points: Insights for effective policy action.*https://www.oecd.org/en/publications/climate-tipping-points_abc5a69e-en.html

Osman MB, Coats S, Das SB, McConnell JR and Chellman N (2021) 'North Atlantic jet stream projections in the context of the past 1,250 years', *PNAS*, 118(38): e2104105118. https://doi.org/10.1073/pnas.2104105118

Parker G (2013*) Global crisis: War, climate change and catastrophe in the seventeenth century*. Yale University Press

Potapov P, Turubanova S, Hansen MC, Tyukavina A, Zalles V, Khan A, Song X-P, Pickens A, Shen Q and Cortez J (2021) 'Global maps of cropland extent and change show accelerated cropland expansion in the twenty-first century', *Nature Food*, 3: 19–28. https://doi.org/10.1038/s43016-021-00429-z

Quadfasel D and Käse R (2007) ‘Present-day manifestation of the Nordic Seas Overflows’, in Schmittner A, Chiang JCH and Hemming SR (eds), *Ocean circulation: Mechanisms and impacts – Past and future changes of meridional overturning* (pp. 75–89), American Geophysical Union. https://doi.org/10.1029/173GM07

Quiggin D, De Meyer K, Hubble-Rose L and Froggatt A (2021) Climate change risk assessment 2021, Chatham House. https://www.chathamhouse.org/sites/default/files/2021-09/2021-09-14-climate-change-risk-assessment-quiggin-et-al.pdf

Rahmstorf S (2024) ‘Is the Atlantic Overturning Circulation approaching a tipping point?’, *Oceanography*. https://doi.org/10.5670/oceanog.2024.501

Ranger N, Oliver T, Alvarez J, Battiston S, Bekker S, Killick H, Hurst I, Liadze I, Millard S, Monasterolo I, Perring M (2024) *Assessing the Materiality of Nature-Related Financial Risks for the UK*, Green Finance Institute. https://oms-www.files.svdcdn.com/production/downloads/reports/GFI-GREENING-FINANCE-FOR-NATURE-FINAL-FULL-REPORT-RDS4.pdf

Retter L, Knack A, Hernandez Z, Harris R, Caves B, Robson M, Adger N (2021) *Crisis Response in a Changing Climate*, RAND Corporation. https://www.rand.org/content/dam/rand/pubs/research_reports/RRA1000/RRA1024-1/RAND_RRA1024-1.pdf

Ripple WJ, Wolf C, Lenton TM, Gregg JW, Natali SM, Duffy PB, Rockström J, Schellnhuber HJ (2023a) ‘Many risky feedback loops amplify the need for climate action’, *One Earth*, *6*(2), pp.86-91. https://www.sciencedirect.com/science/article/pii/S2590332223000040

Ripple WJ, Wolf C, Gregg JW, Rockström J, Newsome TM, Law BE, Marques L, Lenton TM, Xu C, Huq S, Simons L (2023b) ‘The 2023 state of the climate report: Entering uncharted territory’, *BioScience*, 73(12), pp.841-850. https://academic.oup.com/bioscience/article/73/12/841/7319571

Ritchie PD, Smith GS, Davis KJ, Fezzi C, Halleck-Vega S, Harper AB, Boulton CA, Binner AR, Day BH, Gallego-Sala AV, Mecking JV, Sitch SA, Lenton TM and Bateman IJ (2020) ‘Shifts in national land use and food production in Great Britain after a climate tipping point,’ *Nature Food*, *1*(1), 76-83. https://doi.org/10.1038/s43016-019-0011-3

Roberts F, De Meyer K and Hubble-Rose L (2021) *Communicating climate risk: a handbook*, Climate Action Unit, University College London. London, United Kingdom. DOI: 10.14324/000.rp.10137325

Rogers W and Gulledge J (2010) *Lost in Translation: Closing the Gap Between Climate Science and National Security Policy*, Center for a New American Security. https://www.cnas.org/publications/reports/lost-in-translation-closing-the-gap-between-climate-science-and-national-security-policy

Rose R (2023) ‘British attitudes towards national security risks and cooperation’, UK in a Changing Europe, analysis. https://ukandeu.ac.uk/british-attitudes-towards-national-security-risks-and-cooperation/

Royal Academy of Engineering (2022) *Building resilience: Lessons from the Academy’s review of the National Security Risk Assessment methodology*. https://raeng.org.uk/media/g31bttwt/raeng-building-resilience.pdf

Schmidt G (2024) ‘Climate models can’t explain 2023’s huge heat anomaly — we could be in uncharted territory’, Nature. https://www.nature.com/articles/d41586-024-00816-z

Sgubin, G, Swingedouw D, Drijfhout S, Mary Y and Bennabi A (2017) ‘Abrupt cooling over the North Atlantic in modern climate models’, *Nature Communications*, 8(14375). https://doi.org/10.1038/ncomms14375

Sgubin G, Swingedouw D, García de Cortázar-Atauri I, Ollat N, Van Leeuwen C (2019) ‘The impact of possible decadal-scale cold waves on viticulture over Europe in a context of global warming’, *Agronomy*, 9(7), p.397. https://www.mdpi.com/2073-4395/9/7/397

Sharpe S (2023) *Five times faster: Rethinking the science, economics and diplomacy of climate change*, Cambridge University Press

Slingo J (2021) ‘Latest scientific evidence for observed and projected climate change’, in *The third UK Climate Change Risk Assessment Technical Report* (Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)) Prepared for the Climate Change Committee, London. https://www.ukclimaterisk.org/publications/technical-report-ccra3-ia/chapter-1/

Smolders EJV, Van Westen RM, Dijkstra HA (2024) ‘Probability Estimates of a 21st Century AMOC Collapse’, *arXiv preprint*, arXiv:2406.11738.

Sova C, Fountain G, Zembilci E and Carr T (2023) *Dangerously hungry: The link between food insecurity and conflict*, World Food Program USA. https://www.wfpusa.org/policy-advocacy/reports-publications/dangerously-hungry/

Starmer K (2024) 'A stronger, safer, more secure Britain speech', speech. https://labour.org.uk/updates/press-releases/keir-starmer-a-stronger-safer-more-secure-britain-speech/

Steffen W, Rockström J, Richardson K, Lenton TM, Folke C, Liverman D, Summerhayes CP, Barnosky AD, Cornell SE, Crucifix M, Donges JF (2018) 'Trajectories of the Earth System in the Anthropocene', *Proceedings of the National Academy of Sciences*, 115(33), pp.8252-8259

Stern N, Stiglitz J, Taylor C (2022) 'The economics of immense risk, urgent action and radical change: towards new approaches to the economics of climate change', *Journal of Economic Methodology*, 29(3), pp.181-216. https://www.tandfonline.com/doi/full/10.1080/1350178X.2022.2040740

Swingedouw D, Bily A, Esquerdo C, Borchert LF, Sgubin G, Migno J and Menary M (2021) 'On the risk of abrupt changes in the North Atlantic subpolar gyre in CMIP6 models', *Annals of the New York Academy of Sciences*, 1504: 187–201. https://doi.org/10.1111/nyas.14659

Swingedouw D, Houssais M-N, Herbaut C, Blaizot A-C, Devilliers M and Deshayes J (2022) 'AMOC recent and future trends: A crucial role for oceanic resolution and Greenland melting?', *Frontiers in Climate*, 4: 838310. https://hal.science/hal-03841884

Townend R, Aylett C, Benzie M (2023) *Cascading climate risks: strategic recommendations for European resilience*, Chatham House and Cascades. https://www.cascades.eu/wp-content/uploads/2023/11/CASP10721-Recommendations-Resilience-231122.pdf

Trust S, Joshi S, Lenton T and Oliver J (2023) *The emperor's new climate scenarios: Limitations and assumptions of commonly used climate-change scenarios in financial services*, Institute and Faculty of Actuaries and University of Exeter. https://actuaries.org.uk/media/qeydewmk/the-emperor-s-new-climate-scenarios.pdf

Trust S, Bettis O, Saye L, Bedenham G, Lenton TM, Abrams JF and Kemp L (2024) *Climate Scorpion – the sting is in the tail*, Institute and Faculty of Actuaries and University of Exeter. https://actuaries.org.uk/media/g1qevrfa/climate-scorpion.pdf

UK Covid-19 Inquiry (2023) *Transcript of Module 2 Public Hearing on 21 November 2023*. https://covid19.public-inquiry.uk/documents/transcript-of-module-2-public-hearing-on-21-november-2023/

UK Covid-19 Inquiry (2024) *Module 1 report: The resilience and preparedness of the United Kingdom*. https://covid19.public-inquiry.uk/reports/module-1-report-the-resilience-and-preparedness-of-the-united-kingdom/

UK Health Security Agency (2023) 'Heat mortality monitoring report: 2022', webpage. https://www.gov.uk/government/publications/heat-mortality-monitoring-reports/heat-mortality-monitoring-report-2022#observed-excess-all-cause-mortality

United Nations (2019) 'Climate change recognized as 'threat multiplier', UN Security Council debates its impact on peace', UN News. https://news.un.org/en/story/2019/01/1031322

United Nations Office for Disaster Risk Reduction (2019) *Global Assessment Report on Disaster Risk Reduction*. https://www.undrr.org/publication/global-assessment-report-disaster-risk-reduction-2019

US Department of Agriculture (2024) 'Foreign agricultural service corn explorer', webpage. https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=0440000

US Department of Defense (2024) 'Tackling the Climate Crisis', webpage. https://www.defense.gov/spotlights/tackling-the-climate-crisis/

Van Westen RM, Kliphuis M, Dijkstra HA (2024) 'Physics-based early warning signal shows that AMOC is on tipping course', *Science Advances*, Vol 10, Issue 6. https://www.science.org/doi/10.1126/sciadv.adk1189

World Economic Forum (2024) *Global Risks Report 2024*. https://www.weforum.org/publications/global-risks-report-2024/

World Health Organization (2022) 'Infodemics and misinformation negatively affect people's health behaviours, new WHO review finds', press release. https://www.who.int/europe/news/item/01-09-2022-infodemics-and-misinformation-negatively-affect-people-s-health-behaviours--new-who-review-finds

The White House (2021) 'Executive order on tackling the climate crisis at home and abroad'. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

World Bank (2023) 'World Bank official boundaries', dataset. https://datacatalog.worldbank.org/search/dataset/0038272

World Food Programme (2023) 'A global food crisis', webpage. https://www.wfp.org/global-hunger-crisis

Xu Y and Ramanathan V (2017) 'Well below 2 C: Mitigation strategies for avoiding dangerous to catastrophic climate changes', *Proceedings of the National Academy of Sciences*, 114(39), pp.10315-10323. https://www.pnas.org/doi/10.1073/pnas.1618481114

Institute for Public Policy Research

GET IN TOUCH

For more information about the Institute for Public Policy Research, please go to www.ippr.org

You can also call us on +44 (0)20 7470 6100, e-mail info@ippr.org or tweet us @ippr

Institute for Public Policy Research

Registered Charity no. 800065 (England & Wales), SC046557 (Scotland), Company no, 2292601 (England & Wales)