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An Ghníomhaireacht um Chaomhnú Comhshaoil

IRELAND'S CLIMATE CHANGE ASSESSMENT

Volume 1: Climate Science – Ireland in a Changing World

Summary for Policymakers

ICCA
IRELAND'S CLIMATE CHANGE ASSESSMENT

Ireland’s Climate Change Assessment 2023

Environmental Protection Agency

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Volume 1: Climate Science – Ireland in a Changing World

Summary for Policymakers

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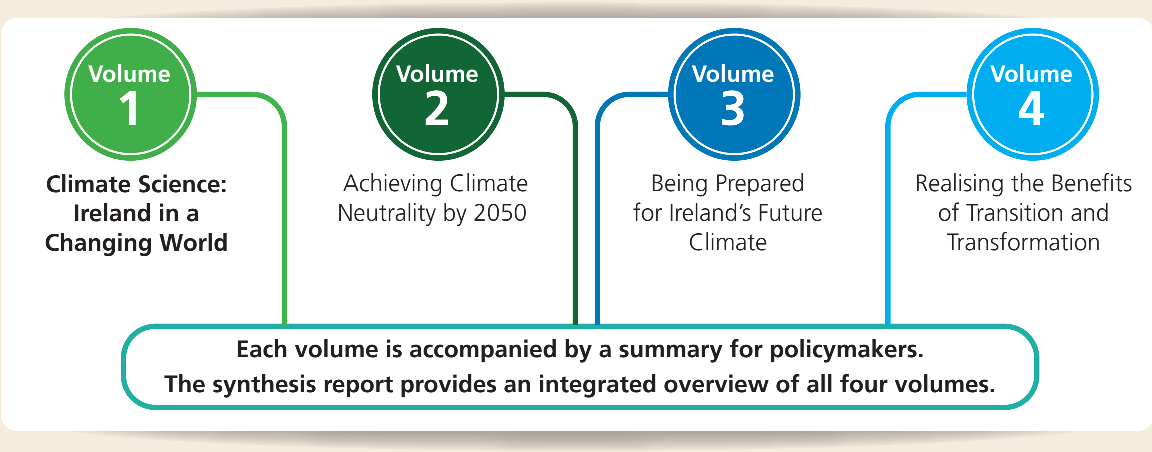
Introduction

Ireland's Climate Change Assessment (ICCA) delivers a comprehensive, Ireland-focused, state of scientific knowledge report on our understanding of climate change, its impacts on Ireland, the options to respond to the challenges it poses, and the opportunities from transitions and transformations to a climate-neutral, climate-resilient and sustainable economy and society. This serves to complement and localise the global assessments undertaken by the Intergovernmental Panel on Climate Change (IPCC) reports (see www.ipcc.ch). The findings presented build upon these global assessments and add important local and national context.

The report is presented in a series of four thematic volumes accompanied by an overarching synthesis report. The volumes are as follows:



Volume 1

The Summary for Policymakers (SPM) provides key insights from Volume 1 of Ireland's Climate Change Assessment: Climate Science – Ireland in a Changing World. Volume 1 assesses observed and projected changes in climate for Ireland in the context of a rapidly changing global climate. The SPM is organised as follows:

- Section A summarises the observed changes to both the global and Ireland's climate, based on historical reconstructions spanning thousands to millions of years and direct observational estimates for more recent times.
- Section B considers the contribution of human activities to observed climate changes since the industrial revolution.
- Section C set out future climate projections under different emissions pathway scenarios as well as highlighting key process understanding.
- Section D outlines the low-likelihood high-impact outcomes including possible tipping points and surprises which, while not representing the most likely outcome, are critical information for certain decisions.
- Section E sets out key recommendations for future research required to enhance our knowledge and improve the evidence basis for policy makers.

A. Ireland's climate is changing

Aspects of the climate system have been directly observed for the best part of the past two centuries. Today national and international programmes are taking coordinated observations[1] from the depths of the ocean to the very edge of space in unprecedented detail. Numerous scientists nationally and internationally have analysed these observations to create high-quality datasets that provide in-depth understanding of multiple aspects of the changing climate. These directly observed changes can be placed in a much longer-term context of many centuries to in some cases millions of years by indicators of past climates arising from information from proxies such as tree rings, ice cores, pollen samples, lake sediments and ocean sediments. These records have similarly been analysed by many scientists nationally and internationally.

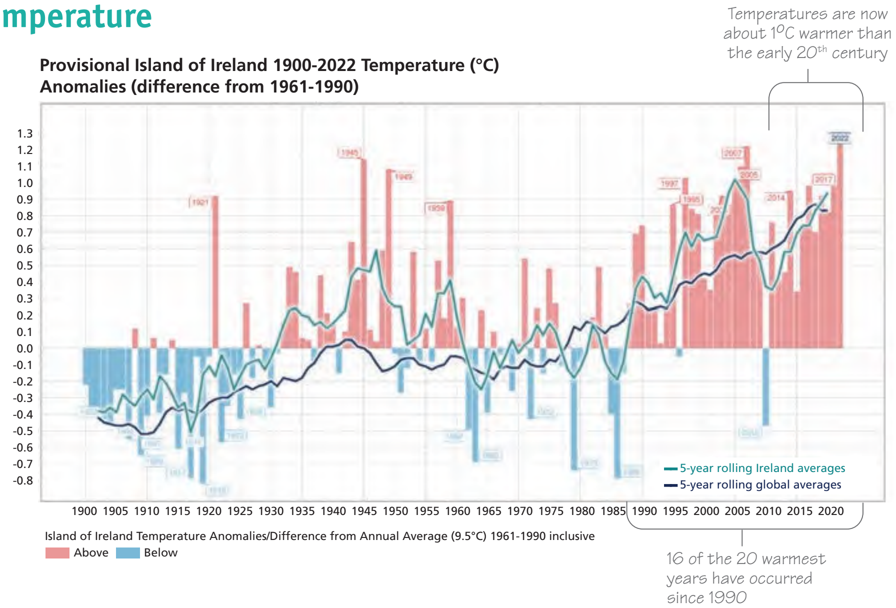
A.1	There has been a rapid rise in atmospheric greenhouse gas concentrations, measured at numerous sites around the world, including Mace Head, since the Industrial Revolution without precedent in millions of years. Concentrations of methane and nitrous oxide are higher now than in over 800,000 years, and for carbon dioxide, for which longer-term reconstructions are possible, concentrations are higher than for millions of years. The increases in greenhouse gas concentrations since 1850 are due to global human activities, principally through fossil fuel combustion and land use change. {Chapters 1, 2}
A.2	Changes in the concentrations of these three major greenhouse gases since 1750 exceed those between successive glacial and interglacial cycles of the past 800,000 years for carbon dioxide and methane. For nitrous oxide the changes in concentration are of comparable magnitude to these successive glacial and interglacial cycles. These past changes in concentrations of all three gases were much slower, occurring over thousands of years. {Chapters 1, 2}
A.3	Globally, widespread and rapid changes in the atmosphere, ocean, land, cryosphere and biosphere have occurred. The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years. {Chapter 1}
A.4	Global surface temperatures have risen by 1.15°C [1.00-1.25°C] between 1850–1900 and the most recent decade, 2013–2022. This most recent decade was likely warmer than any sustained period in at least the past 100,000 years. {Chapter 1}
A.5	In Ireland annual average temperatures are now approximately 1.0°C higher than they were in the early 20th century. Sixteen of the top twenty warmest years since 1900 have occurred since 1990, with 2022 being the warmest year to date. Centennial timescale changes in Ireland are broadly consistent with global changes owing to our geographical situation between Europe (which is warming considerably faster than the global mean) and the North Atlantic (which is warming at a slower rate). {Chapter 3; Figure SPM.1a}
A.6	Globally averaged precipitation over land has likely increased since 1950, with a faster rate of increase since the 1980s. The frequency and intensity of extreme precipitation events has increased almost everywhere, particularly so in already wetter regions in the northern hemisphere, and a greater proportion of total precipitation is falling in extreme precipitation events across most of the globe. {Chapter 1}
A.7	Over Ireland median annual precipitation was 7% higher in the period 1991–2020, compared to the 30-year period 1961–1990. Regions where trends in precipitation since 1950 are significant have generally experienced overall annual increases. Analysis of local observations does not reveal evidence of a clear climate change signal in extreme precipitation indices due to natural variability. Overall, when aggregated, there has been an increase in heavy precipitation extremes across a range of indicators. {Chapter 4; Figure SPM.1b}

[1] Coordination bodies include, but are not limited to, the Global Climate Observing System, the World Meteorological Organization and the Intergovernmental Oceanographic Commission.

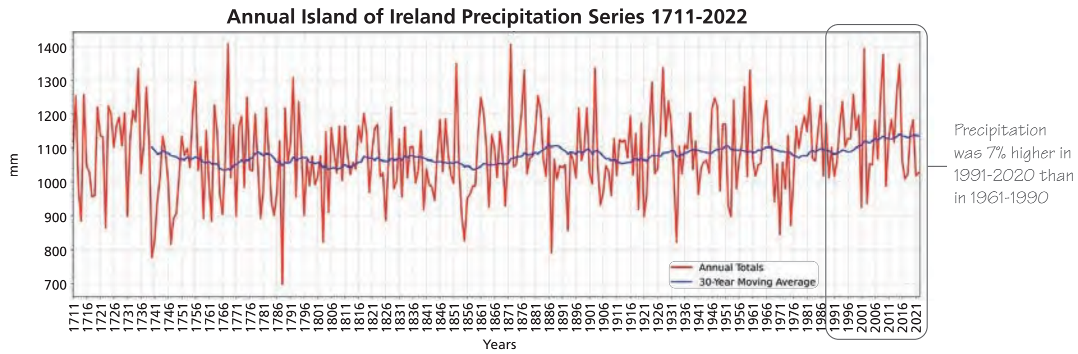
A.8	The rate of warming of the global ocean was likely faster in the past century than for any century since the last deglaciation event 11,000 years ago. Global sea level increased by approximately 0.20m between 1901 and 2018, and the rate of global sea level rise is accelerating. Consistent with global open ocean changes, Irish marine waters have experienced long-term acidification due to uptake of anthropogenic atmospheric carbon dioxide. {Chapters 1, 5}
A.9	Recent studies have highlighted higher rates of sea level rise since the late 20th century in Cork and Dublin than the global average. Reasons for this are unclear and currently under investigation. There are a range of processes that can lead to local sea level changes diverging to a certain extent from global changes over a broad range of timescales. {Chapter 5; Figure SPM.1c}
A.10	Globally, over the last century there have been poleward and upslope movements of many terrestrial species in response to climate changes. There have also been changes in the timing of life cycle events, such as birds migrating and plants flowering in all mid-latitude regions. Changes in the marine biosphere are consistent with large-scale warming and changes in ocean geochemistry. The ranges of many marine organisms are shifting towards the poles and towards greater depths, but a minority of organisms are shifting in the opposite directions. {Chapter 1}
A.11	The main impacts of climate change on Irish terrestrial species and habitats observed to date have been changes in species abundance and distribution, lifecycle events, community composition, and habitat structure and ecosystem processes. These changes are in addition to much larger changes arising from other human interventions. In Irish waters, there have been substantial changes in marine ecosystems, including changes in seasonality and abundance of many species, including phytoplankton and zooplankton at the base of the food web. Many of these changes are consistent with a changing climate. {Chapters 5, 7}
A.12	Global climate changes have been modified over Ireland by proximity to the North Atlantic and by internal climate system variability, mainly, but not exclusively, related to variations driven by the North Atlantic. Most notably, the Atlantic Multi-decadal Variability explains successive multi-decadal periods when Ireland has warmed or cooled relative to global trends (Figure SPM.1a). {Chapters 1, 3, 4, 5}

We are already living in a changed climate

(A) Temperature



(B) Precipitation



(C) Sea level

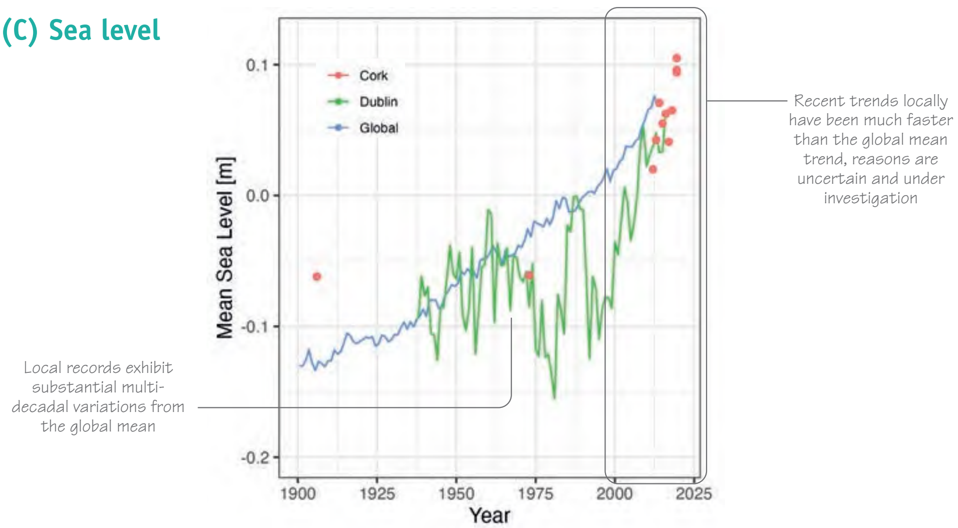


Figure SPM.1 We are already living in a changed climate. (a) Island of Ireland temperature anomalies, 1900–2022 relative to 1961–1990 (Met Éireann). (b) Reconstructed island of Ireland precipitation series showing annual totals (the continuous 305-year (1711–2016) annual rainfall series from Maynooth University with an estimate based upon 12 continuing Met Éireann stations post-2015) and highlighting the presence of substantial decadal to multi-decadal variability. The blue line represents a 30-year moving average. (c) Sea level time series for global, continuous records from Dublin and discontinuous measurements from the Cork region. Source: Figure components sourced from Met Éireann and contributing authors. {Chapter 1, 3, 4, 5}

B. Recent climate changes are due to human activities

Scientific understanding of the physical climate system, along with state-of-the-art statistical analytical approaches comparing climate simulations (Box SPM.1) to observations, provides the basis for detection of global and regional climate change and its attribution to possible causes. This is the scientific detective work of disentangling the causes of the changing climate we are collectively experiencing today.

B.1 It is unequivocal that human activity has warmed the climate system. The best estimate of human-caused global surface temperature increase from 1850–1900 to 2013–2022 is 1.14°C, in close agreement with the best estimate of the observed increase of 1.15°C over the same period. This warming is mainly due to increased atmospheric greenhouse gas concentrations, partly masked by cooling due to increased atmospheric aerosol concentrations (Figure SPM.2). {Chapter 1}

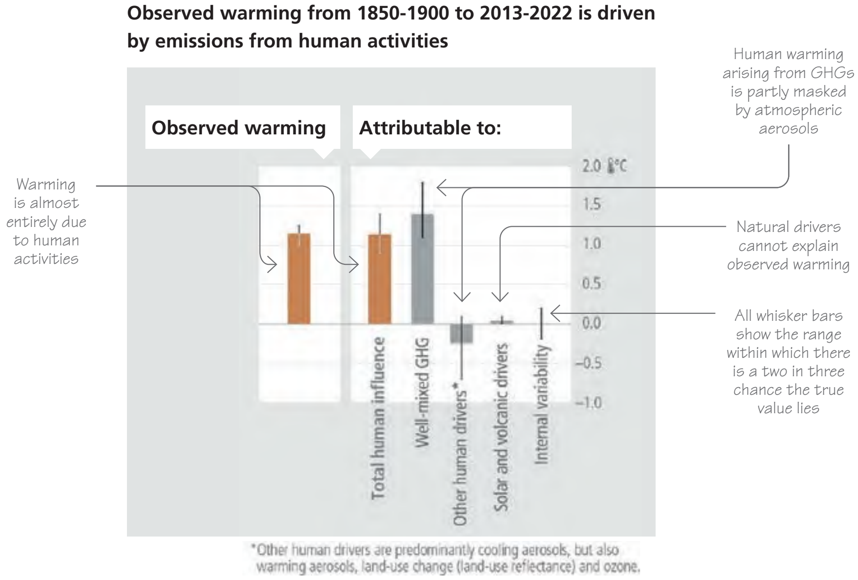


Figure SPM.2 Assessed contributions to observed warming in 2013–2022 relative to 1850–1900. The left hand panel shows observed changes and the right hand panel shows those temperature change components attributable to: total human influence; changes in well-mixed greenhouse gas concentrations; other human drivers due to aerosols, ozone and land use change (land use reflectance); solar and volcanic drivers; and internal climate variability. Whiskers for attributable components show 66% likelihood ranges (a two in three chance the true value lies within the interval). Source: Forster et al. (2023; panel from their figure 8 modified for clarity). Reproduction licensed under the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/). {Chapter 1}

B.2 Attribution at the global scale shows consistent human signals in observed changes across the atmosphere (surface and upper-air temperatures, humidity, precipitation, circulation), ocean (sea level, ocean heat content, salinity, acidification, deoxygenation) and cryosphere (glaciers, sea ice, ice sheets, seasonal snow cover). The observed changes across the climate system since the mid-20th century cannot be explained without invoking human influences. {Chapter 1}

B.3 Human-induced climate change is already modifying extreme weather events across the globe. Increases in both the frequency and intensity of heatwaves and extreme precipitation have been consistently linked to human activities. Similarly, cold events have been made less likely and severe. In drought-prone regions droughts have tended to be made more severe and frequent. There is limited evidence to date for human influences on many types of extreme storms, including mid-latitude storms. {Chapter 1}

B.4 Many notable recent Irish events have not yet been formally studied in the context of the rapidly emerging science of event attribution using state-of-the-art approaches. However, there is high confidence that recent changes in heat extremes and heavy precipitation events in Ireland can be linked, albeit indirectly, to human-induced climate change. From observations and analysis there is no clear evidence to date for human-induced climate change influencing the frequency or intensity of other types of extreme events in Ireland, such as windstorms. {Chapter 6}

Box SPM.1 Climate scenarios and climate simulations

Scenarios

How global society will act in future and react to climate change is unknown. Yet, to simulate possible climate futures and inform policymakers and broader society, some illustrative possible futures are required. As such a scenario is a description of how the future may develop based on a set of assumptions about key global drivers, including demography, economic processes, technological innovation, governance and lifestyles, and the relationships among these driving forces. {Cross-volume Box 1}

For this report, we consider 3 broad-families of scenarios:

Early action

Rapid global action towards meeting the Paris Agreement goal of keeping temperature increases well below 2°C and making efforts to limit warming to 1.5°C by 2100. Warming is halted at some point in the second half of this century.

Middle action

Delayed global action resulting in substantial exceedance of 2°C global warming. Warming generally continues beyond the end of the century in most of these scenarios.

Late action

Substantially delayed and uncoordinated global action. Major actions occur only late in the 21st century if at all, with 3°C or more of warming by 2100 and continued warming thereafter.

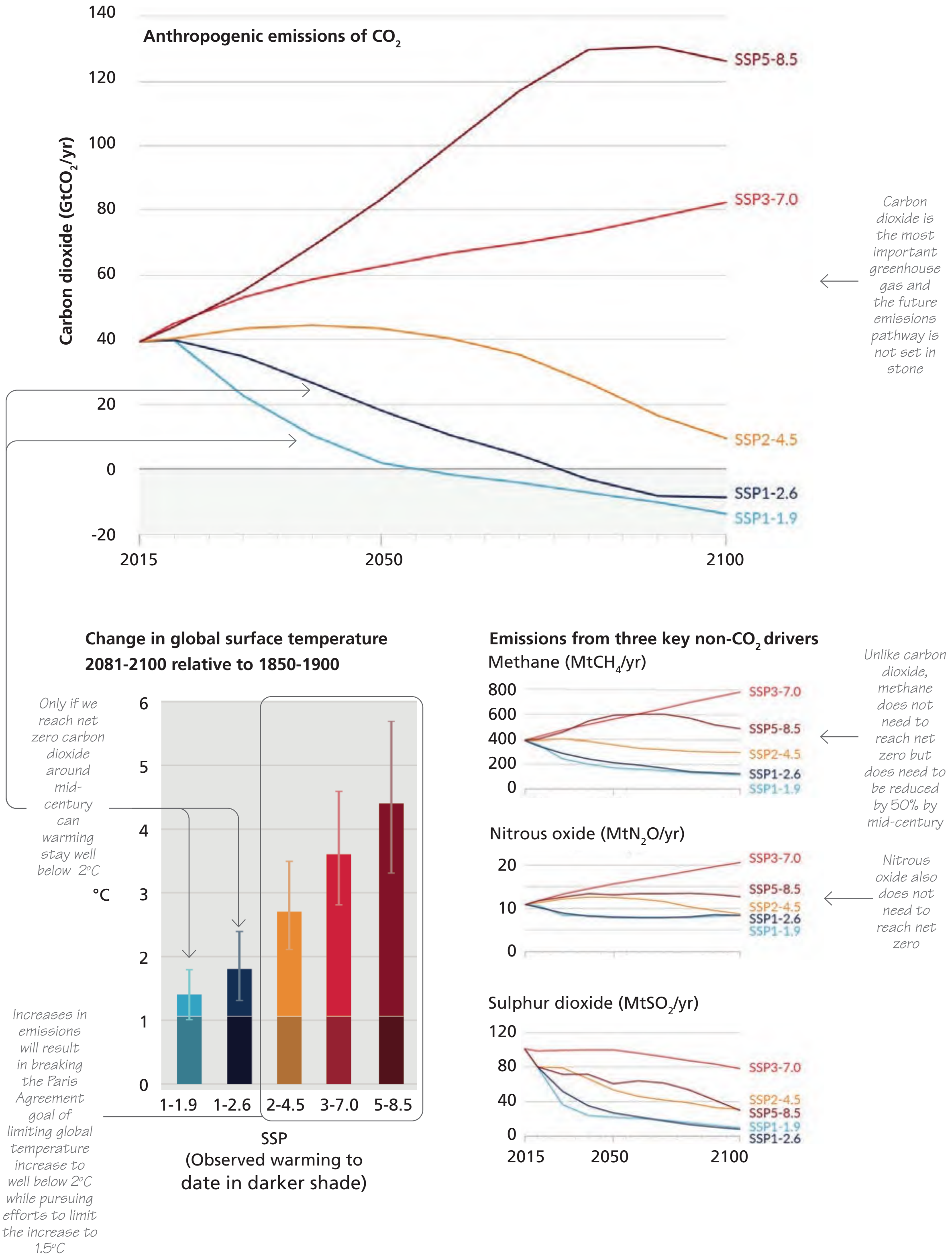
Simulations

Earth System Models (ESMs) are complex numerical simulations of the Earth's climate system, including the atmosphere, ocean, land and ice. They are used to simulate past and current climate, and project possible future climate changes. The Intergovernmental Panel on Climate Change (IPCC) working group I (WGI) sixth assessment report (AR6) features simulations from around 100 climate models produced across 49 different modelling groups (including the Irish Centre for High-End Computing and Met Éireann as partners in the EC-Earth consortium) across the globe (Figure SPM.3a). {Chapter 1}

National climate modelling research also involves simulating the future climate on a regional scale in fine detail. This involves downscaling a subset of global ESMs to provide high-resolution (4km or finer resolution) climate projections for Ireland (Figure SPM.3b). Downscaled simulations for Ireland have recently been standardised as part of the TRANSLATE project and are also available at somewhat coarser resolution, but from a greater range of models, from the European Coordinated Regional Climate Downscaling Experiment (EURO-CORDEX). {Chapters 1, 3, 4}

The future is in our hands

Assessment of future emissions and warming under five scenarios



Annual 2m Temperature Change 2071-2100 with respect to 1976-2005

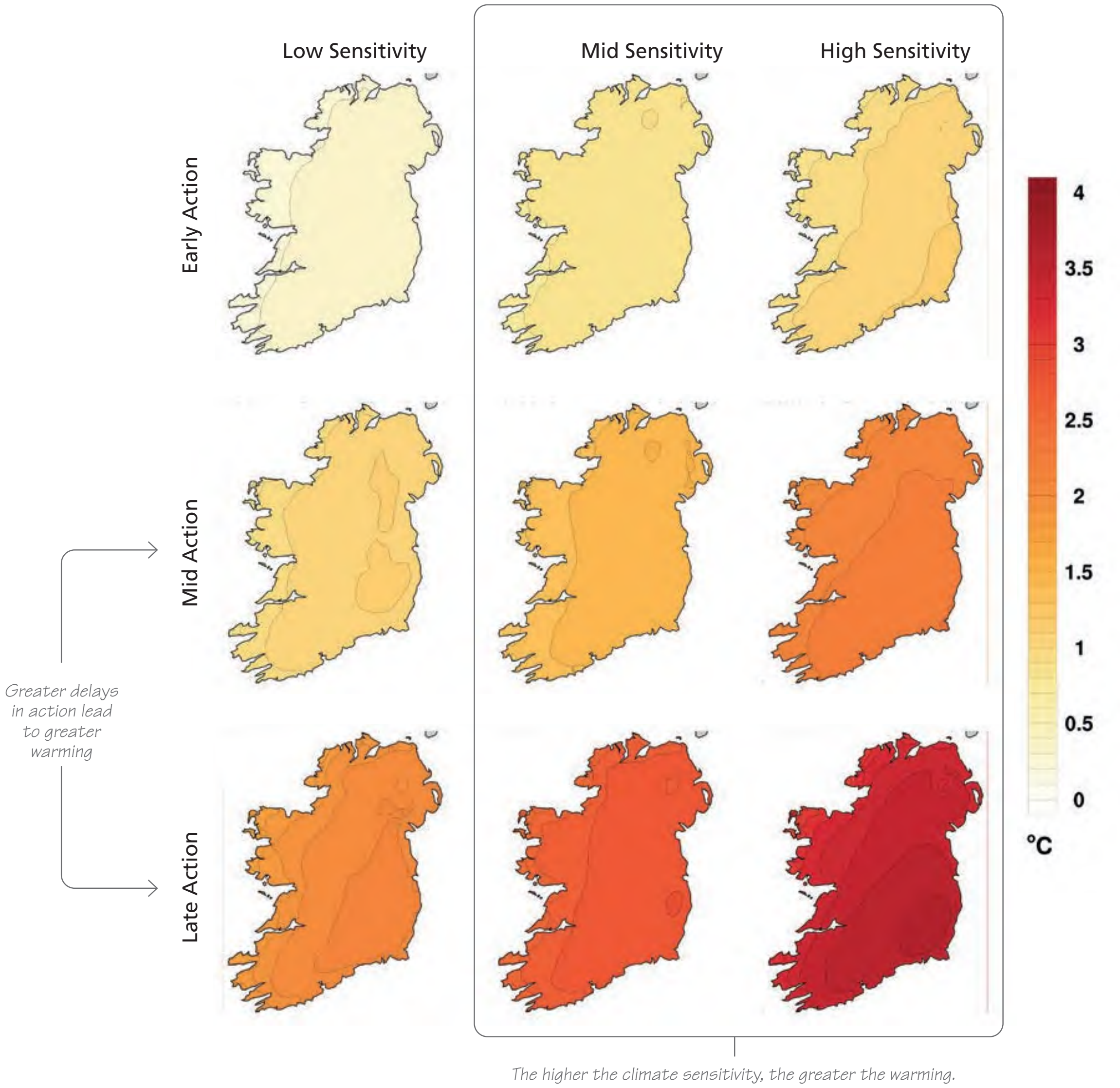


Figure SPM.3 Left panel: illustrative climate scenarios and resulting warming at the end of the century. The five scenarios are SSP1–1.9, SSP1–2.6 (classed here as Early action), SSP2–4.5 (Middle action) and SSP3–7.0 and SSP5–8.5 (Late action). Annual anthropogenic (human-caused) emissions over the 2015–2100 period. Shown are emissions trajectories for CO_2 from all sectors ($GtCO_2yr^{-1}$) (top graph) and for a subset of three key non-CO_2 drivers contributing to anthropogenic aerosols considered in the scenarios: methane, $MtCH_4yr^{-1}$ (top-right graph); nitrous oxide, MtN_2Oyr^{-1} (middle-right graph); and sulphur dioxide, $MtSO_2yr^{-1}$ (bottom-right graph), contributing to anthropogenic aerosols. The bottom-left graph shows resulting warming by scenario in global surface temperature (°C) in 2081–2100 relative to 1850–1900, with indication of the observed warming to date in darker fill. Bars and whiskers represent median values and 5-95% range, respectively. Right panel: TRANSLATE projections for Ireland for Early action (representative concentration pathway (RCP) 2.6), Middle action (RCP4.5) and Late action (RCP8.5) scenarios and for three distinct sets of driving Earth System Models with different transient climate sensitivities over Ireland (see Cross-volume Box 1). Source: IPCC (2021a; their figure SPM.4 (left panel, modified with permission) and authors (right panel). {Chapters 1, 2, 3}

C. Future global emissions will determine our future climate

We have an increasing number of climate simulations from ESMs (Box SPM.1) that can be augmented by downscaling to regional scales by regional models, and allow us to explore what the future climate may be throughout the rest of this century and beyond, both globally and over Ireland. Scientific insights also permit inferences around key policy-relevant questions such as how to stay below a given global temperature threshold.

C.1	To stabilise the global climate requires global carbon dioxide emissions to reach at least net zero. Furthermore, emissions of other greenhouse gases would need to be substantially reduced on a sustained basis. It is still possible to attain the Paris Agreement goal of keeping global temperature increases well below 2°C while making efforts to limit warming to 1.5°C. To limit warming to 1.5°C global carbon dioxide emissions need to be reduced to at least net zero by approximately mid-century and emissions of other greenhouse gases simultaneously substantially reduced. {Chapters 1, 2; Figure SPM.3}
C.2	Many components of the global climate system, such as temperature and precipitation, respond within years to decades to changes in radiative forcing. If we can reach net zero global carbon dioxide emissions around 2050, these components would globally stabilise within the lifetime of many of today's younger citizens. Some other components of the climate system, most notably sea level rise, will take thousands of years to stabilise even once greenhouse gas emissions reach net zero. {Chapters 1, 3, 4, 5, 6, 7; Figure SPM.5}
C.3	Climate change will not unfold uniformly across the globe. There are important regional differences, and these changes are projected to amplify as the level of global warming increases; some regions and populations will experience greater changes than others. For example, the Arctic warms considerably more than other regions, land areas warm more than the ocean, and the northern hemisphere warms more than the southern hemisphere. {Chapter 1}
C.4	Climate change projections under Early, Middle and Late action scenarios (Box SPM.1) show very different potential futures for Ireland beyond the middle of this century. Early and rapid global action on emissions reductions would very likely stabilise many aspects of our climate this century and would likely leave an Irish climate still broadly recognisable as that we experience today. Delayed action on emissions reductions would very likely yield a climate that is increasingly unrecognisable as the century progresses. The global emissions pathway will continue to have impacts beyond the end of the century, most notably on the trajectory of sea level rises that will continue for thousands of years. {Chapters 3, 4 ,5; Figure SPM.3}
C.5	Projections of Irish temperature changes consistently show warming, with the magnitude of this warming increasing with delays in global mitigation action. Under Early action, the temperature increase averaged across the island of Ireland relative to the recent past (1976–2005) would reach 0.91°C [0.44–1.10°C] by mid-century before falling back to 0.80°C [0.34–1.07°C] at the end of the century. Whereas under Late action, by the end of the century it is projected that the temperature increases could be 2.77°C [2.02–3.49°C]. Warming also generally increases with the climate sensitivity of the ESMs used for a given mitigation pathway (see Box SPM.1). Heat extremes will become more frequent and more severe and cold extremes will become less frequent and less severe with further warming. {Chapter 3}
C.6	In Ireland, intense precipitation extremes are projected to become more frequent and extreme with further warming in most locations. Projected changes in precipitation accumulations are more uncertain than those for temperature. While winters tend to get wetter and summers tend to get drier, this signal is not consistently found across all global ESMs. There is also substantial sensitivity to the choice of ESM used to drive the national simulations (Box SPM.1). Changes averaged across the island of Ireland show a slight increase of < 10% in annual mean accumulated precipitation amounts. {Chapter 4}
C.7	Global mean sea level increases will occur under all scenarios and continue for thousands of years after the global temperature is stabilised. By 2100 projected additional rises range from 0.32–0.6m under Early action to 0.63–1.01m under Late action scenarios, with high uncertainty for the latter case whereby 2m rise could occur owing to highly uncertain ice sheet processes. Over the next 2,000 years, global mean sea level will rise by about 2 to 3m if warming is limited to 1.5°C, 2 to 6m if limited to 2°C and 19 to 22m with 5°C of warming. {Chapters 2, 8}

C.8	Global sea level increases will be modified locally around the island of Ireland by ongoing isostatic rebound – the north-east of the island is slowly rising and the south-west slowly sinking (<0.2mm per year in most regions); multi-decadal ocean basin variability (order of several centimetres in a decade); and the relative contributions to sea level change arising from the Greenland and Antarctic Ice Sheets over time. Larger relative contributions from Greenland would result in smaller increases for Ireland and vice versa due to the gravitational effects of the two ice sheets. {Chapter 5}
C.9	Storm surges and extreme waves pose an ever-increasing threat to Ireland as sea levels continue to rise, including for many coastal cities such as Cork, Dublin, Galway and Limerick, and to critical infrastructure. Particularly at risk are soft sediment shorelines. Projections of changes in storminess are highly uncertain and translate into large uncertainties in future frequency and intensity of extreme waves. {Chapter 5}
C.10	Compound events are combinations of multiple climate impact drivers that occur at the same time, in the same area or both. The likelihood of both concurrent heatwave and drought conditions and storm surges with heavy precipitation have been observed to increase to date in Europe and are projected to further increase with additional warming. {Chapter 6}
C.11	Those recent extreme events that have been impacted by human-induced climate change such as heatwaves and extreme rainfall (see Sections B.3 and B.4) are a foretaste of what will likely occur in future with increased frequency and intensity under further warming. The most rare extreme events that impact entire communities and regions are the events that will see the largest relative increases in frequency and intensity. {Chapters 1, 3, 4, 6; Figure SPM.5}
C.12	Ireland will continue to experience seasonal to multi-decadal variability arising from natural internal variations in the climate system. These will serve to modulate aspects such as temperature, precipitation and storminess on seasonal to multi-decadal scales and, in doing so, periodically may reduce or enhance long-term global climate trends arising from human activities. {Chapters 1, 3, 4, 5}
C.13	Current atmospheric carbon dioxide levels are higher than at any time since the Middle Miocene (14 to 16 million years ago), according to the latest consensus atmospheric carbon dioxide record from a global consortium of scientists who study past atmospheric composition using proxies. Paleo-temperature estimates for the North Atlantic Ocean off Ireland indicate sea surface temperatures 10 to 13°C warmer than present-day during the Middle Miocene. Early action would keep global mean surface temperature rise within the bounds of our and our ancestors' (genus *Homo* dates back 3 million years) past experience. {Cross-volume Box 1; Cross-chapter Box 2}

Box SPM.2 Human influences on climate

Human influence on the climate system arises from multiple different forcing agents, such as greenhouse gases and aerosols, which have distinct lifetimes and impacts[2]. Not all of their impacts are therefore equal. Effective Radiative Forcing (ERF) is used to compare their impacts on climate (Figure SPM.4). This describes the net radiative impact of a given agent on the atmosphere. Positive ERF values cause warming of the climate system, and negative ERF values cause cooling of the climate system. Changes in ERF from 1750 to 2022 are dominated by warming by carbon dioxide, methane and nitrous oxide, partly masked by cooling by aerosols, with relatively minor contributions from remaining human sources. {Chapter 2}

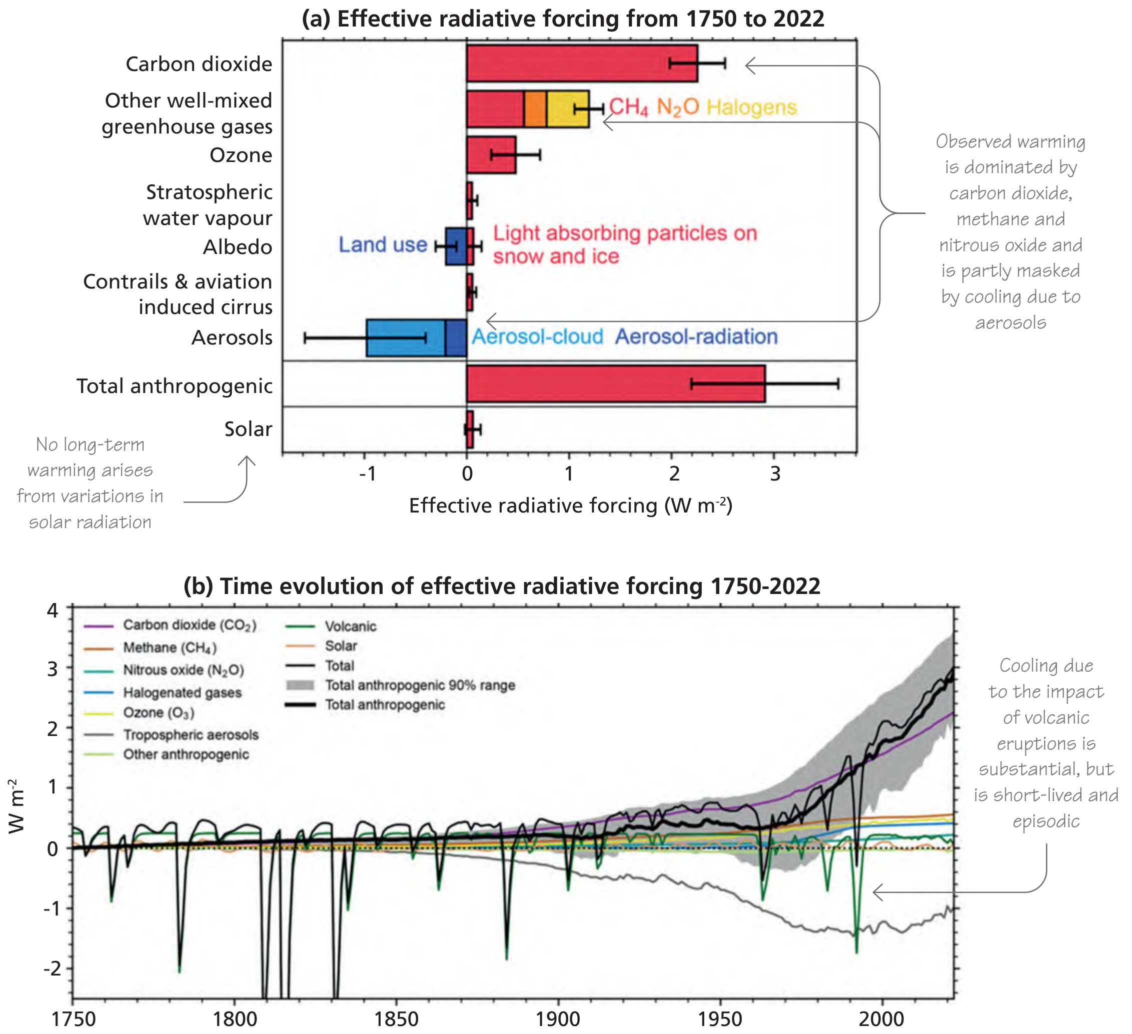


Figure SPM.4 Effective Radiative Forcing (ERF) from 1750 to 2022. (a) 1750–2022 change in ERF, showing best estimates (bars) and 5–95% uncertainty ranges (lines) from major anthropogenic components of ERF, total anthropogenic ERF and solar forcing. (b) Time evolution of ERF from 1750 to 2022. Best estimates from major anthropogenic categories are shown, along with solar and volcanic forcing (thin coloured lines), total (thin black line) and anthropogenic total (thick black line). The 5–95% uncertainty in the total anthropogenic forcing is shown by grey shading. Note that solar forcing in 2022 is a single-year estimate. Source: Forster et al. (2023; their figure 2). Reproduction licensed under the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

[2] Human influences also arise from perturbations to land use and land cover.

These principal human forcing agents arise from a mix of human activities. They differ substantively in terms of their lifetime, how they are removed, their radiative efficiency and, therefore, their impact upon the climate system (Table SPM.1). It is important to recognise this complexity when making mitigation policy decisions, as assessed further in Volume 2. {Chapter 2}

The principle human forcing agents

Forcing agent	Approximate lifetime	Principal human sources	Principal removal mechanisms	Radiative efficiency (W $m^{-2}ppb^{-1}$)	GWP_{100} from IPCC WGI AR6
Carbon dioxide	Centuries to millennia	Fossil fuel combustion, land use, cement production	Ocean and terrestrial uptake (fast), ocean mixing (centuries), geological sequestration (slow)	$1.33 \pm 0.16 \times 10^{-5}$	1
Methane	Around a decade	Fossil fuels, agriculture, landfill	Atmospheric oxidation	$5.7 \pm 1.4 \times 10^{-4}$	30 ± 11 (fossil sources); 27 ± 11 (non-fossil sources)
Nitrous oxide	Around a century	Agriculture, land use, fossil fuels	Stratospheric oxidation	$2.8 \pm 1.1 \times 10^{-3}$	273 ± 130
Aerosols	Days to weeks	Fossil fuel combustion, land use and biomass burning	Wet and dry deposition		

Table SPM.1 Summary of the principal features of the four most important direct human forcing agents as assessed by ERF and accounting for methane's impacts upon tropospheric ozone. Shown are approximate lifetime, principal human sources, principal removal mechanisms and, for the three greenhouse gases, their radiative efficiency and their GWP_{100} value (see C.17). {Chapter 2}

C.14 There exists an almost linear relationship between cumulative carbon dioxide emissions and global surface temperature increases. Based upon this, a global remaining carbon budget can be inferred, conditional upon assumptions of future emissions of a range of additional greenhouse gases, to keep future warming below any given temperature increment threshold. In IPCC AR6 it is assessed that for a two in three chance of limiting warming to 1.5°C globally we can emit only 400 additional gigatonnes (Gt) of carbon dioxide from 2020. This estimate assumes substantial reductions in emissions of remaining greenhouse gases, including a 50% reduction in global methane emissions and a 25% reduction in global nitrous oxide emissions by 2050. If such cuts in non-carbon dioxide greenhouse gases are not fully achieved, the remaining carbon budget would shrink commensurately. In IPCC AR6 this non-carbon dioxide effect is assessed to have an uncertainty of 220Gt carbon equivalent (66% range). Historical human emissions are almost 2,600Gt of carbon dioxide, and, at current global emission rates of c.40Gt of carbon dioxide a year, only a few years remain before exceeding the remaining budget to limit warming to 1.5°C. {Chapter 2}

C.15 Historically, about half of the carbon dioxide that human activities have emitted has been taken up by natural carbon sinks on land and in the ocean. These natural sinks have slowed the build-up of carbon dioxide in the atmosphere and resulting global warming. However, these sinks are already beginning to respond to climate change in a way that weakens their capacity to take up carbon dioxide, and this will likely continue in the future unless global emissions are rapidly reduced. {Chapter 2}

C.16 Policies aimed at addressing climate change may have benefits or trade-offs for air quality. The potential importance of reducing emissions of short-lived climate forcers, such as methane, aerosols and their precursors, is recognised to not only mitigate climate change but also to improve air quality and therefore bring near-term co-benefits in terms of human health, agricultural yields and ecosystem functioning. Measures which negatively impact on air quality such as burning of wood for home heating and gas stoves for cooking as possible mitigation measures should be avoided. {Cross-volume Box 2}

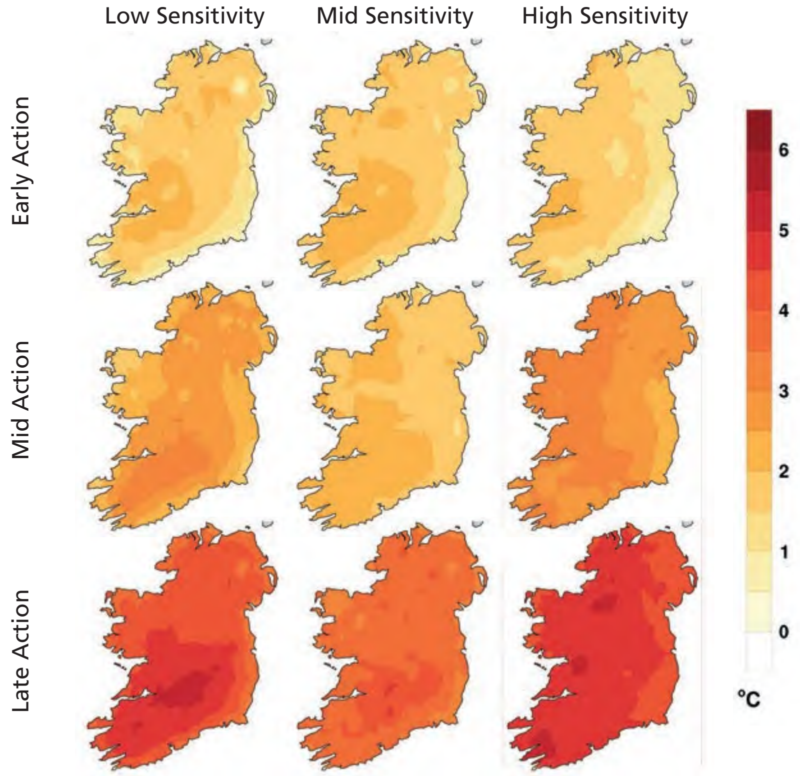
C.17 Common metrics are used to aggregate and compare the effects of different greenhouse gas emissions and policies. Because gases vary substantially in terms of their warming impacts and lifetime in the atmosphere, different metrics provide different perspectives. In international, European and national accounting, GWP_{100}[3], which calculates emissions impacts of each greenhouse gas integrated over a 100-year timescale compared to those of atmospheric carbon dioxide, is used. GWP values are periodically reassessed as the atmospheric composition evolves and new evidence arises. These are compiled and assessed by the IPCC in each assessment cycle. Reaching net zero under GWP_{100} would result in a slow cooling of the climate system. Newer, step-pulse metrics such as GWP* better model the temperature outcomes for a broad range of timescales. Emerging approaches that separately bundle and treat short-lived (less than a decade or so) and long-lived (centennial timescale plus) gases may lead to better policymaking. The IPCC does not recommend a specific emissions metric. Ultimately, the metrics used by policymakers will depend upon the question being posed, and it is therefore not possible to define a preferred metric. {Chapter 2; Volume 2}

[3] In international accounting GWP_{100} values published in IPCC AR5 are currently used.

Future global emissions will determine the future climate

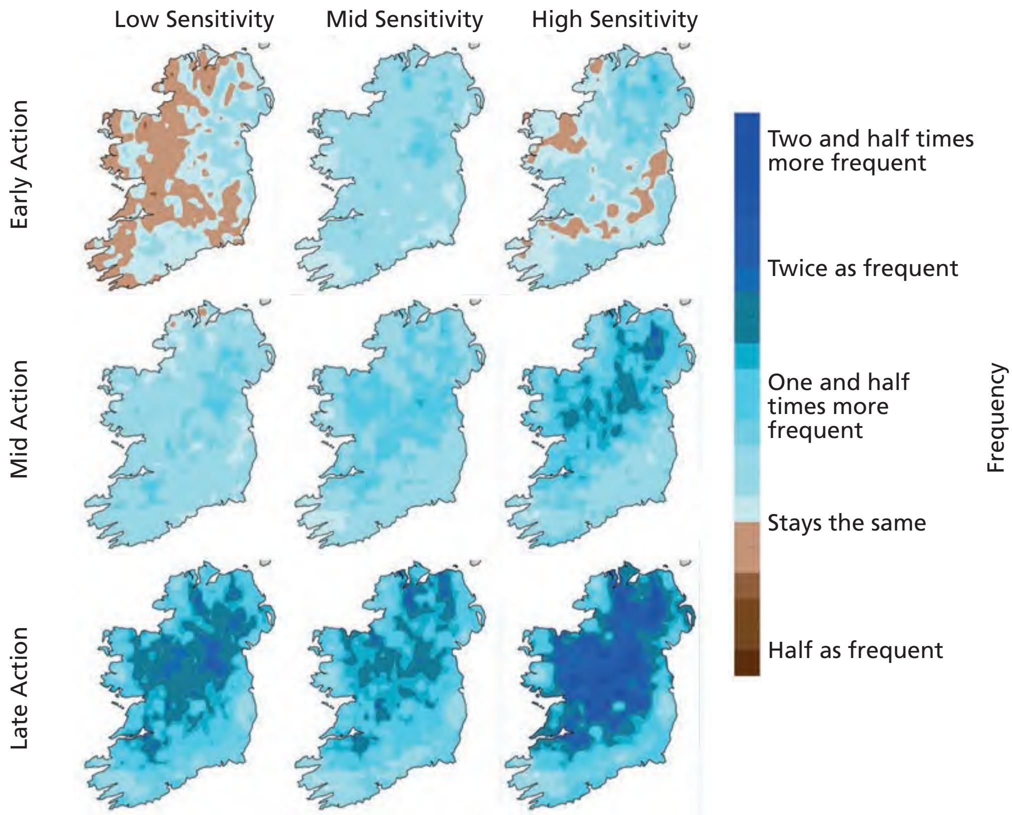
(A) Temperature extremes

Temperature change in warmest day of the year 2071-2100 with respect to 1976-2005



(B) Precipitation extremes

Relative change in annual days with precipitation in excess of 20mm in 2071-2100 with respect to 1976-2005



(C) Change in return times for temperature and precipitation extremes

With early and sustained action, changes in temperature and precipitation can stabilise within the lifetime of today's younger citizens, whereas delayed action will see things continue to get worse

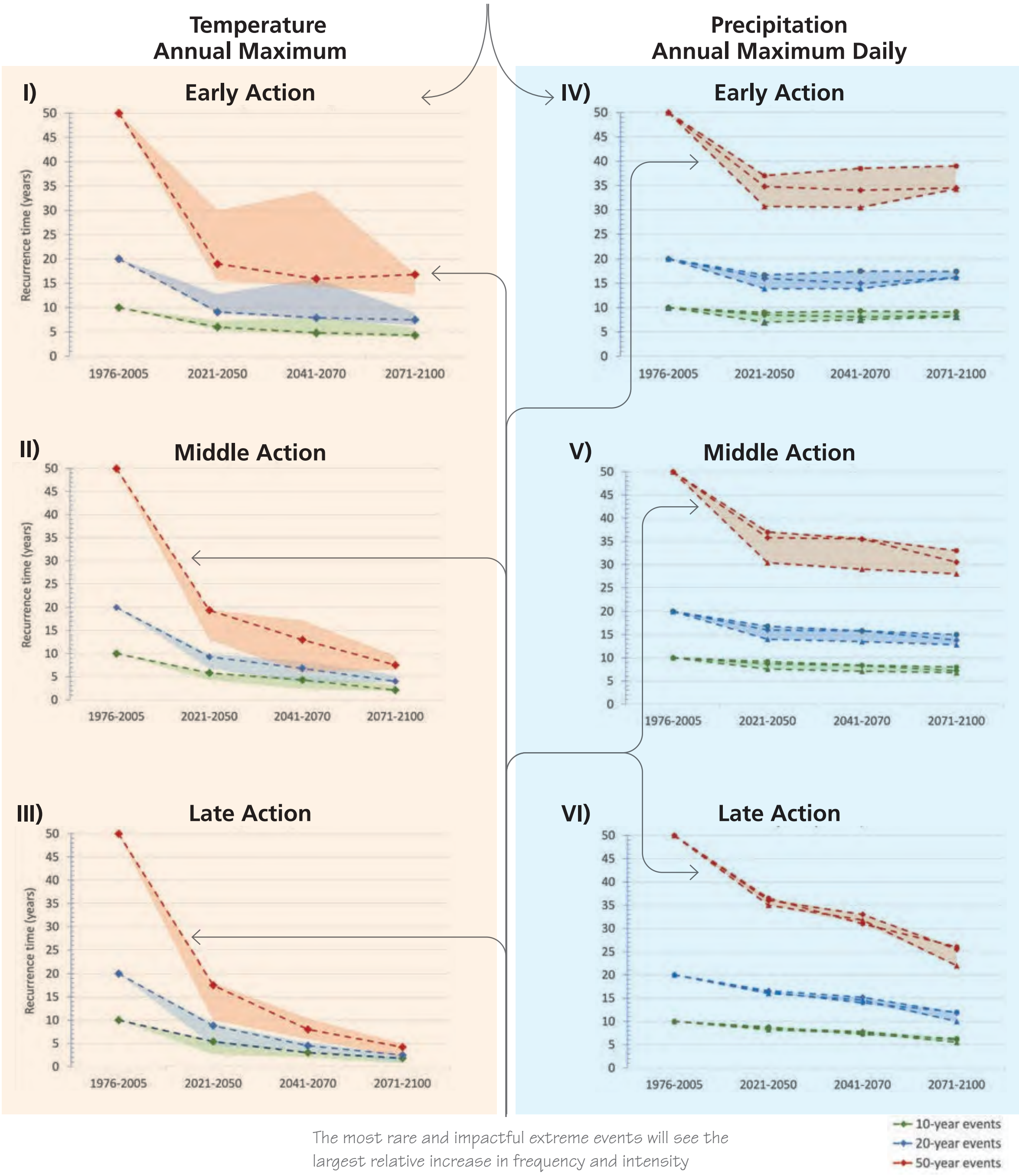


Figure SPM.5 Future global emissions will determine important aspects of the future climate. (A) Projected changes in the annual maximum of daily maximum temperature (TXx), using 30-year means of TXx. (B) Projected changes to the R20mm index, where R20mm is the number of days per year with precipitation >20mm. (C) Projected changes in the recurrence times (or return periods) of Ireland-averaged TXx values (left) and annual maximum daily precipitation (Rx1day) (right) that had recurrence times of 10, 20 and 50 years for different future emissions scenarios (rows). Source: Authors. [Chapters 3, 4]

D. High-impact outcomes, although unlikely, cannot be ruled out

Climate surprises are future possible outcomes, events, circumstances or consequences for Ireland that could stem from global warming which, although unlikely, cannot be ruled out. They include high warming storylines, various possible tipping points in the climate system and possible natural disasters with global climate system implications. Were they to occur these would progress across a range of timescales, with some taking place over years to decades and others over centuries to millennia. Many relate to highly uncertain and/or poorly understood processes.

D.1 In risk assessments it is important that low-likelihood high warming outcomes are taken into account when considering future climate change impacts in Ireland, as there is a high level of risk associated with them[4]. For Ireland a low-likelihood high warming outcome (which is predicted under high climate sensitivity[4]) likely leads to larger warming and commensurately larger changes in precipitation and associated extremes than the equivalent best estimate for any given scenario. {Chapters 2, 8}

D.2 Paleoclimate archives demonstrate periods of much higher land and Atlantic ocean temperatures around Ireland's coastal waters in the geological (e.g. Miocene) and historical past. Archives over the last 10,000 years also show reductions in precipitation of sufficient magnitude to dry peatlands, allowing oak and pine forests to establish on them. {Cross-chapter Box 2; Chapter 8}

D.3 Climate system tipping points represent thresholds beyond which components of the Earth system permanently switch to new states. Tipping points would have considerable impacts, including sea level rise from collapsing ice sheets, dieback of the Amazon rainforest and carbon release from thawing permafrost. Several such tipping points would have implications for Ireland, either through further shifting the global climate or altering the regional climate in the North Atlantic and north-western Europe. {Chapter 8}

D.4 For Ireland, the Atlantic Meridional Overturning Circulation (AMOC) is the most immediately important potential tipping point, given the importance of the North Atlantic in determining our climate[5] and agricultural productivity. The AMOC will almost certainly weaken over the 21st century, and a full collapse cannot be ruled out. If there were to be a collapse in the AMOC, as has occurred repeatedly in the past during rapid climate transitions of past glacial phases, winters would become considerably colder and summers warmer, and there would likely be an increase in storminess and potential implications for sea level. These would have very profound implications for the Irish climate and society. {Cross-chapter Box 2; Chapter 8}

D.5 Future global sea level rise projections over the coming centuries have large uncertainties. Particular concern relates to ice sheets where much of the ice sheet is grounded below present-day sea level, which could reach tipping points, leading to their inevitable collapse over a multi-centennial period. The largest such ice sheet is the West Antarctic Ice Sheet, which alone could contribute several metres of sea level change. Historical global emissions could potentially have already committed to its long-term collapse. Proxies cannot determine the pace of past ice sheet collapse. {Chapter 8}

D.6 Currently, thawing permafrost is losing carbon to the atmosphere. Based on high agreement across model projections, fundamental process understanding and paleoclimate evidence, as the global climate warms permafrost extent and volume will shrink, releasing further greenhouse gases into the atmosphere. Complete thawing of permafrost cannot be ruled out, and this would emit more carbon than humans have emitted to date into the atmosphere, leading to substantial additional warming. {Chapter 8}

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[4] If the true equilibrium climate sensitivity lies in the highest end of the plausible range, and beyond the IPCC estimated range, then there would be very substantial warming and impacts across the climate system, even for small additional global greenhouse gas emissions. Because the latest generation of ESMs have a broad range of sensitivities it is possible to draw out individual simulations from models with very high sensitivity to directly inform estimates of such low-likelihood high warming outcomes.

[5] The AMOC is the overturning circulation in the North Atlantic. The surface component advects warm water from the tropics to Ireland via the Gulf Stream and North Atlantic Drift, and this in large part determines our climate.

D.7 Unpredictable and rare natural events not related to human influence on climate may lead to low-likelihood, high-impact outcomes. For example, a sequence of large explosive volcanic eruptions within decades has occurred in the past, causing substantial global and regional climate perturbations over several decades. A future with such a sequence of eruptions over the coming decades would increase the stress on ecosystems and society. Short-term volcanic-induced global cooling will not mitigate long-term human-induced climate changes. Even the most extreme volcanic activity scenario in the 21st century causes little reduction in global surface temperatures at the end of the century. {Chapter 8}

E. Key recommendations for research

In performing this assessment a broad range of priority areas for future research to address gaps have been identified. Specific recommendations are given in the underlying report. Here, thematic groupings are highlighted to illustrate the broad priorities identified to improve the basis for future assessment activities and to enhance information provided for policymaking.

E.1 Sustaining and enhancing Ireland's climate observational capabilities

There is a need to sustain and enhance national observational capabilities of our changing climate system providing a strong evidence base for decision making. This needs to be consistent with a sustained and strong national contribution to the Global Climate Observing System (GCOS), including of our waters within our exclusive economic zone and the broader North Atlantic. Substantial progress has been made, not least through the national GCOS committee. Much remains to be done, including the development of a strategic approach that is aligned with national needs and requirements. This should include enhanced participation in relevant European research infrastructures, including in the European Strategy Forum on Research Infrastructures (ESFRI) process, and related regional and global networks. The work of the national GCOS committee needs to be strengthened and sustained with adequate funding support for relevant agencies and institutions. {Annex 1}

E.2 Enhanced provision and utilisation of past and current climate observations

Enhanced capacity and resources are required to enable better provision and utilisation of past and current observations to better understand Ireland's changing climate and its drivers. As scientists learn more about observations and new techniques and insights emerge, it is critical to periodically reassess understanding of historical and ongoing observations, reanalyse them and produce new and improved products and knowledge. This includes activities such as data rescue of historical holdings of various types not yet available in digitised form and better exploitation of space-based observations. {Annex 1}

E.3 Sustaining and enhancing Ireland's climate modelling capability

There is a need for a sustained and enhanced modelling capability to provide a range of nationally relevant downscaled results, including contributions to the Coupled Model Intercomparison Project (CMIP) and EURO-CORDEX. This includes quantification and provision of uncertainty estimates in a usable manner via portals such as climateireland.ie, which should be maintained to promote and enable exploitation by stakeholders and users. {Annex 1}

E.4 Scaling up support for strategic climate research activities

Substantial scientific uncertainties remain across the ocean, atmosphere and terrestrial domains that still need to be strategically and rigorously addressed. Supports through climate research programmes are needed that transcend short-term projects. This should enable capacity building through the training and retention of the excellent researchers necessary to address these cross- and trans-disciplinary challenges. Particularly important current uncertainties identified in the present volume include, but are not limited to: diurnal temperature changes, precipitation changes, changes in storminess and sea level changes. {Annex 1}

E.5 Increasing Ireland's participation in climate-related European and international scientific activities

There is a need to increase participation in relevant European and international scientific activities to have a stronger contribution to and influence in the development of these activities. These provide expanded access to expertise, opportunities for collaboration, including on internationally funded projects, and learning and sharing of knowledge and best practices, which has important benefits in terms of provision of advice to policymakers. This includes participation in relevant European-level programmes such as the European Space Agency, Horizon Europe and Joint Programming Initiatives, and various research infrastructures. Internationally, participation should be sought in IPCC and Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports and in relevant international activities such as those undertaken by the World Meteorological Organization and through its (co-sponsored) programmes, including the World Climate Research Programme and GCOS. {Annex 1}

epa
Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

An Roinn Iompair
Department of Transport

sfi
science foundation ireland

ICCA
IRELAND'S CLIMATE CHANGE ASSESSMENT