

**CCAG**

Climate Crisis  
Advisory Group

**EXTREME WEATHER EVENTS**

**IN THE ARCTIC AND BEYOND**

# A Global State of Emergency

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GLACIER BREAKS IN WESTERN GREENLAND. PHOTO: MIKA HONKALINNA, 2021



# Observations and Impacts of the Arctic Warming

▲ 1.2°C

ICE BREAKS IN NORTHERN BALTIC. PHOTO: MIKA HONKALINNA, 2021

**It is difficult to explain the severity of the recent extreme floods in Europe and the heatwaves in North America merely with the additional heat and moisture in the climate system caused by 1.2°C of global warming.**

It cannot be excluded that the rapid warming and melting in the Arctic has triggered additional changes in how our weather works, explaining the extremity of these extremes.

The effects of human-caused climate warming are especially pronounced in the Arctic, with devastating consequences for people and ecosystems in the region and well beyond the Arctic. The global impacts of Arctic warming will be felt first and foremost in our weather systems as well as sea level rise. The Arctic region is warming faster than anywhere else on the planet, resulting in rapid and irreversible sea ice loss as well as loss from the Greenland ice sheet.

In addition, in recent years there has been record-breaking extreme heating across the Arctic region of astounding magnitude and the emergence of new risks from wildfires and permafrost thaw, resulting in increased greenhouse gas (GHG) emissions.

Agile international political and financial action to mitigate the consequences of climate change through the following measures are crucial for a manageable future for humanity:

- > **REDUCTION**  
deep and rapid emissions reduction
- > **REMOVAL**  
removing GHGs from the atmosphere at scale
- > **REPAIR**  
refreezing the Arctic region



## Figure 1

Warming of the Arctic is happening much faster than the rise in global average temperatures. Over the last 30 years the Arctic has warmed at a rate of 0.81°C per decade, more than 3-times faster than the global average of 0.23°C per decade.

Data from Berkeley Earth.

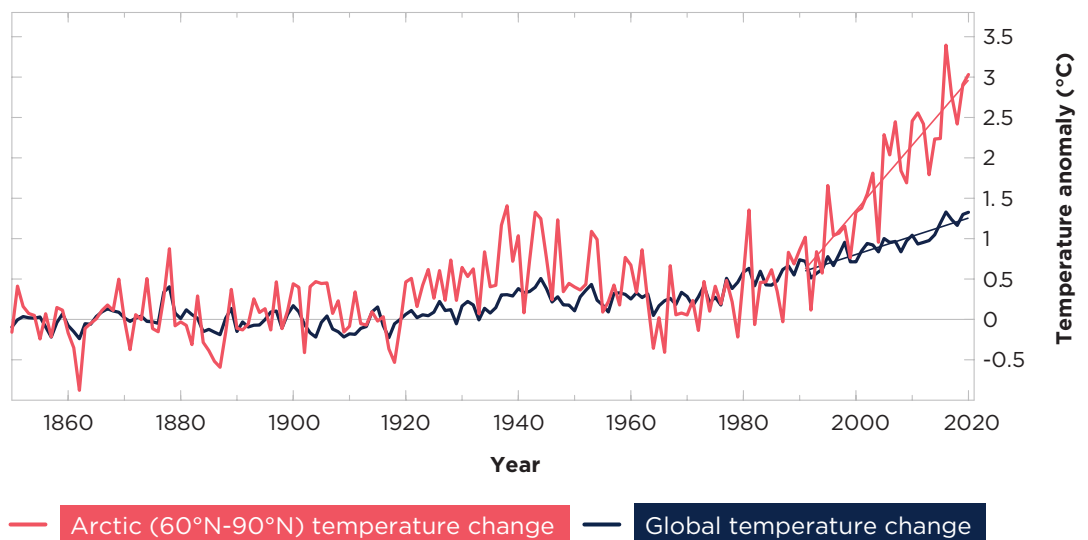
Warming of the Arctic is taking place much faster than the global average temperature rise (see Figure 1) and is having implications well beyond the polar region. The dark blue line shows the deviation of global average temperature from average pre-industrial annual temperatures (taken as average temperatures between 1850 and 1900), with a gentle upward trend in temperature that becomes more marked and sustained from about 1960. The red line in Figure 1 shows annual deviation from pre-industrial average-temperature levels in the Arctic (using the same baseline). Temperature variability in the Arctic has been consistently more extreme than in

global temperatures, and since around 1990 Arctic warming has risen above the global average by a continuously increasing margin. Over the last 30 years, the Arctic has warmed at a rate of 0.81°C per decade – more than 3-times faster than the global average of 0.23°C per decade. The Arctic Circle region had a more than 3.5°C increase above the pre-industrial level last summer (2020). The last few years have experienced record temperatures over regions where permafrost resides and scientists have been shocked that the warm weather conducive to permafrost thawing is occurring roughly 70 years ahead of model projections.

FIGURE 1

## Amplification of temperature change in the Arctic

### ANNUAL ANOMALIES RELATIVE TO 1850-1900 AVERAGE



Amplified warming of the Arctic causes, and is caused by, the rapid loss of sea ice from the Arctic ocean. As sea ice melts, its highly reflective white surface is replaced by a highly heat-absorbing blue surface (sea water).

The switch from reflection to absorption of sunlight accelerates the local temperature increase, creating a dangerous feedback that hastens climate change. The increase

in ocean-absorption of the sun's energy also accelerates long-term heating of oceans, pushing global warming further and faster. The area of exposed Arctic seawater, with its accelerating feedback into the global heating process, has increased accordingly. Figure 2 shows the 75% loss of summer volume of Arctic sea-ice from the late 1970s to the present; the decline accelerates markedly from about 1990.<sup>1</sup>

<sup>1</sup> Marcianesi F, Aulicino G and Wadhams P. 2021. Arctic sea ice and snow cover albedo variability and trends during the last three decades. *Polar Science*. 28; Schweiger A, Lindsay R, Zhang J, Steele M, Stern H and Kwok R. 2011. Uncertainty in modeled Arctic sea ice volume. *Journal of Geophysical Research: Oceans*. 116(8).

FIGURE 2

## Arctic Sea Ice Volume in September

DECLINING BY 3200KM<sup>3</sup> PER DECADE

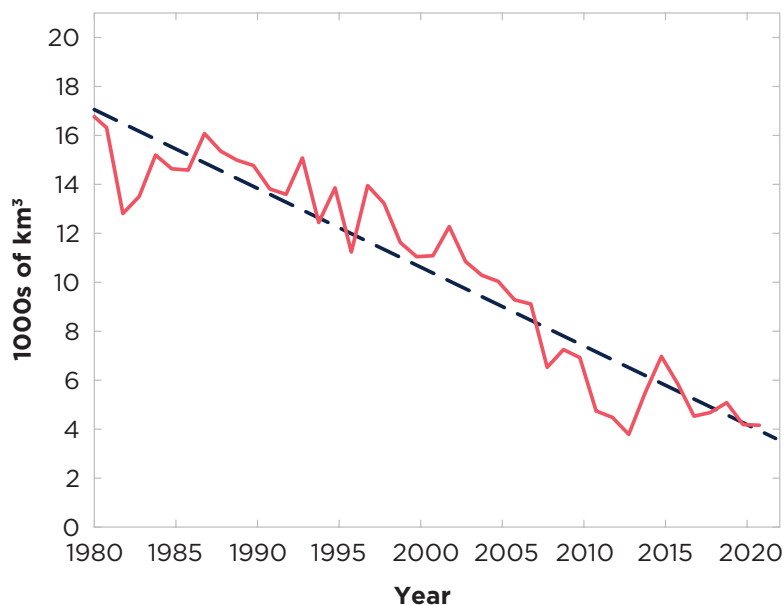


Figure 2

Decline in Annual Minimum Arctic Sea Ice Volume 1979-2020

Data from the Polar Science Centre

**The loss of Arctic sea ice accelerates the global warming process and, in turn, sea level rise. Global warming, 90% of which is absorbed by the oceans, causes thermal expansion of seawater, responsible for about a third of observed sea-level rise in recent decades (IPCC SROCC, 2019). Sea level rise from thermal expansion will soon seem a minor challenge when compared with the profound developing threat of melting ice on land as our climate warms.**

The sheer scale of **sea-level rise** produced by the Greenland and Antarctic ice sheets will dwarf current dangers as warming and melting continues. There is enough ice in the Greenland ice sheet alone to raise global sea levels by 7.5 metres, or 23 feet. While it may take several centuries to millennia for ice loss on this scale, we are now setting in motion the process that will make multi-metre increases in future sea level rise unstoppable. Ice loss from the Greenland ice sheet, its peripheral glaciers and other mountain glaciers in the Arctic is accelerating and causing global sea levels to rise. With added contributions from melting

of the Antarctic ice sheet, glaciers of the Hindu Kush Himalayas, and across the world's mountain ranges, as well as expansion of the warming oceans, global sea level is now rising at 3.6 mm each year, 2.5 times faster than the rate of rise during the 20<sup>th</sup> Century. Ice melt is now the dominant source of sea level rise (exceeding that caused by thermal expansion of the ocean). Estimates and projections of sea-level rise and their impacts by the 2050s have been radically revised in recent years. By the end of this century, global sea levels are now likely to rise by more than 1 metre unless ambitious action is taken to mitigate climate change.<sup>2</sup>

Moreover, the Arctic also holds vast amounts of stored methane that is locked within permafrost, frozen soils, and beneath the sea floor of the Arctic ocean. Rapid warming of the Arctic is causing permafrost to warm and destabilise. The increasing carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) emissions from Arctic permafrost have resulted from it flipping from a carbon sink to a source. In 2019, the Arctic is estimated to have contributed roughly the equivalent of 6.3% of that

<sup>2</sup> IPCC. 2019. Special Report on the Ocean and Cryosphere in a Changing Climate [[H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegria, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)] In press.

<sup>3</sup> IPCC. 2019. Special Report on the Ocean and Cryosphere in a Changing Climate [[H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegria, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)] In press.

year's anthropogenic CO<sub>2</sub> emissions. Permafrost thaw has also released unspecified quantities of CH<sub>4</sub> which, on a molecular basis, is 140 times as powerful a warming influence as CO<sub>2</sub>, and nitrous oxide, which is roughly 300 times more powerful per molecule a warming agent as CO<sub>2</sub> on a 20-year basis. It has recently been estimated that around 12 times more nitrous oxide is being released from permafrost than previously thought.

With ongoing temperature increases due to human-caused warming, permafrost will continue thawing, releasing CO<sub>2</sub> and CH<sub>4</sub>, adding to the warming. If greenhouse gas emissions

continue as at present, up to 89% of the planet's near-surface permafrost could be lost by 2100, releasing tens to hundreds of billions of tonnes of permafrost carbon as CO<sub>2</sub> and CH<sub>4</sub> to the atmosphere and exacerbating climate change globally.<sup>3</sup> This means that even climate intervention proposals may be unable to bring the global average temperature back to near present levels. While the exact level of global warming that would lead to irreversible permafrost thaw and a tipping point feedback with climate warming is not known, there are indications that as small a warming as 1.5°C to 2°C may trigger such a transformation.



ICE HAS PACKED ON TOP OF EACH OTHER IN THE NORTHERN BALTIC. PHOTO: MIKA HONKALINNA, 2021



## CASE STUDY:

### Northeastern Siberia – a Region in Flux

**Northeastern Siberia, meaning the geographies of Republic of Sakha-Yakutia, Magadan and Chukotka in the Russian Arctic, are some of the most dynamic regions for Arctic climate change.**

NE Siberia has been called the “pole of cold” as the coldest temperature in the Northern Hemisphere was recorded in Verkhoyansk (−67.8°C in 1892). However, in 2020 temperatures soared to a new high of 38.7°C in the same community. This was part of a sustained heat wave that impacted Siberia in 2020, where the average warming was more than 6°C above pre-industrial levels over the six months from January to June. Attribution studies have concluded that this prolonged heatwave would have been practically impossible without human-caused climate warming, and was made at least 2°C worse by climate change.

This is also the home region of the nomadic Indigenous Chukchi, Yukaghir, Even, Dolgan and other peoples, who are facing unprecedented changes each year. It is important to understand that the Russian Arctic still has unique nomadic lifestyles. These UNESCO-recognised communities, often led by women, carry ancient wisdom and knowledge about the tundra and the northern taiga.

A combination of tundra and forest fires, extreme temperatures over extended periods, and the long-term Arctic warming trends, have caused the region to show system change implications. First off, the permafrost is melting across Sakha-Yakutia fast, and has been doing so for the past 10-15 years. Mustonen and Shadrin (2021) explored a century of recorded temperatures, Indigenous oral histories and flood events, especially in 2007 on Alazeya River, and discovered how the water patterns and terrestrial ecosystems

have shifted in profound ways.<sup>4</sup> Mercury leaches from the permafrost into the rivers and ultimately to the ocean and into marine circulation. It then transforms into methylmercury and accumulates in the food chain (for example in fish and top predators).

Infrastructure, such as buildings, pipelines and airfields suffer from permafrost melt. During the extended 2020 Siberian heatwave, oil repositories leaked in Central Siberia and polluted a river as the ground gave away under the containers. The nuclear power plant in Bilibino has been identified as a potential threat as it has been constructed on permafrost in Chukotka. In Magadan, new large hydrodams are also built on permanently frozen soils and if thawed events worsen, putting the Kolyma river hydropower at potential risk. Across the Russian tundra, new craters have exploded. These craters, most likely the result of permafrost melt and released gas explosion from the soils, were first detected by Indigenous reindeer herders.

Meanwhile, taiga forest species are on the move as they shift towards the tundra.<sup>5</sup> Tundra is also becoming more green – willows, bushes and other plants are moving northwards. This has implications for carbon budgets and sequestration, wildlife and tundra ecosystems, as well as nesting areas of migratory birds which arrive in the Arctic in millions during the spring and summer.

In 2016 in the region of Yamal, anthrax was released from an ancient nomadic campsite and burial area, as the permafrost thawed. This killed one Indigenous Nenets boy and thousands of reindeer – a central animal for the food security of the Indigenous nomadic peoples of the region. In Sakha-Yakutia, expectations of smallpox outbreaks emerge as gravesites and animal burial sites surface from the thaw.

<sup>4</sup> Mustonen T and Shadrin V. 2021. The River Alazeya: Shifting Socio-Ecological Systems Connected to a Northeastern Siberian River. *Journal of The Arctic Institute of North America*. 74(1).

<sup>5</sup> Pecl G T et al. 2017. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*. 355(6332).





SIBERIAN PERMAFROST CRATER. PHOTO: SNOWCHANGE, 2021



Solution spaces exist in scales. Maintaining and supporting Indigenous nomadic lifeways and working with Indigenous knowledge provides a much-needed observational network of changes, both present and past, which remote sensing cannot provide in detail. Rewilding and preservation of peat and soil-based carbon stocks

in those parts of the Arctic (European North) where permafrost melt is not yet under way remains critically important. The rights of the Indigenous peoples and decisions on how the lands are used should be centered to allow local peoples to make decisions regarding their own futures in this time of transformation.





## UNDERSTANDING “NEVER BEFORE” IN

## ARCTIC SOCIO-ECOLOGICAL SYSTEMS

**The Arctic and northern boreal have evolved over the past 10,000 years to be one of the most unique habitats on the planet, with the traditional Indigenous communities adapting in the process – the Arctic socio-ecological systems of fishing, hunting, and nomadic reindeer herding.**

Understanding the impacts of several “never before” events in the Arctic and their implications further south is urgent and very complex. For species, both in the terrestrial and in the marine realms, southern biota is moving into the tundra and into the previously occupied niches of the adapted cold weather species. Often these localised northern populations have nowhere to run – for example, in Finland when red foxes move northwards, the endemic Arctic Fox has to retreat further north, until it meets the Arctic Sea and cannot move any further. In Greenland, cod move further north and sea ice is being lost, meaning communities have to switch from seal hunting to primary

fishing (which may imply better financial gains).

Loss of the Arctic and northern boreal, which is often included in the northern view, implies a planetary ecology and system shift both in the oceans and on land. Nobody has the compass for the new century. Large populations have not yet come to terms that humanity will have a newly open ocean soon on the planet – the Central Arctic Ocean. A recent international diplomatic treaty<sup>6</sup> banning fisheries and advocating precautionary principles between the Arctic Countries, China, South Korea, the EU and others shows that good governance can happen. Equally so, the Arctic has “made in the region” solutions that work, from the observational capacity of the Indigenous peoples with their knowledge, adaptation solutions that “fit the shoe”, rewilding capacity of carbon sinks and most importantly, the need to preserve and maintain the still existing poles of cold and habitats such as the large intact forests and tundra ecosystems, as long as we can.

<sup>6</sup> International Agreement to Prevent Unregulated Fishing in the High Seas of the Central Arctic Ocean, signed in 2018 by Canada, Iceland, the Kingdom of Denmark, Norway, the United States and the Russian Federation, as well as China, Japan, South Korea and the European Union.





## EXTREME WEATHER EVENTS IN THE ARCTIC AND BEYOND

**Loss of ice in the Arctic is accompanied by significant changes across the globe as weather systems react. Climate change is happening faster than anticipated; one consequence – the loss of ice in the Arctic – is also a driver for more rapid global heating and disastrously rapid global sea level rise and extreme weather events.**

Extreme temperature events are the combination of long-term climate warming, and the weather. The impact of global warming on daily temperatures is now observable across the globe, and heat extremes are becoming hotter and occurring more often.

In the Northern Hemisphere, extreme weather is often associated with meanders in the Jet Stream that allow warm air to be pushed further north than usual and to stall over a location for many days bringing persistent extreme conditions. It is believed that the amplification of Arctic warming, and the reduced north-south temperature gradient that this is causing, could be allowing the Jet Stream to meander more than it used to. The rapid warming of the Arctic, combined with weather extremes from the Jet Stream, have resulted in record-breaking heat and rainfall in parts of the Northern Hemisphere that has severe impacts on people, the environment and infrastructure.

FIGURE 3

### Important Circumpolar Natural Processes in the North Polar Region

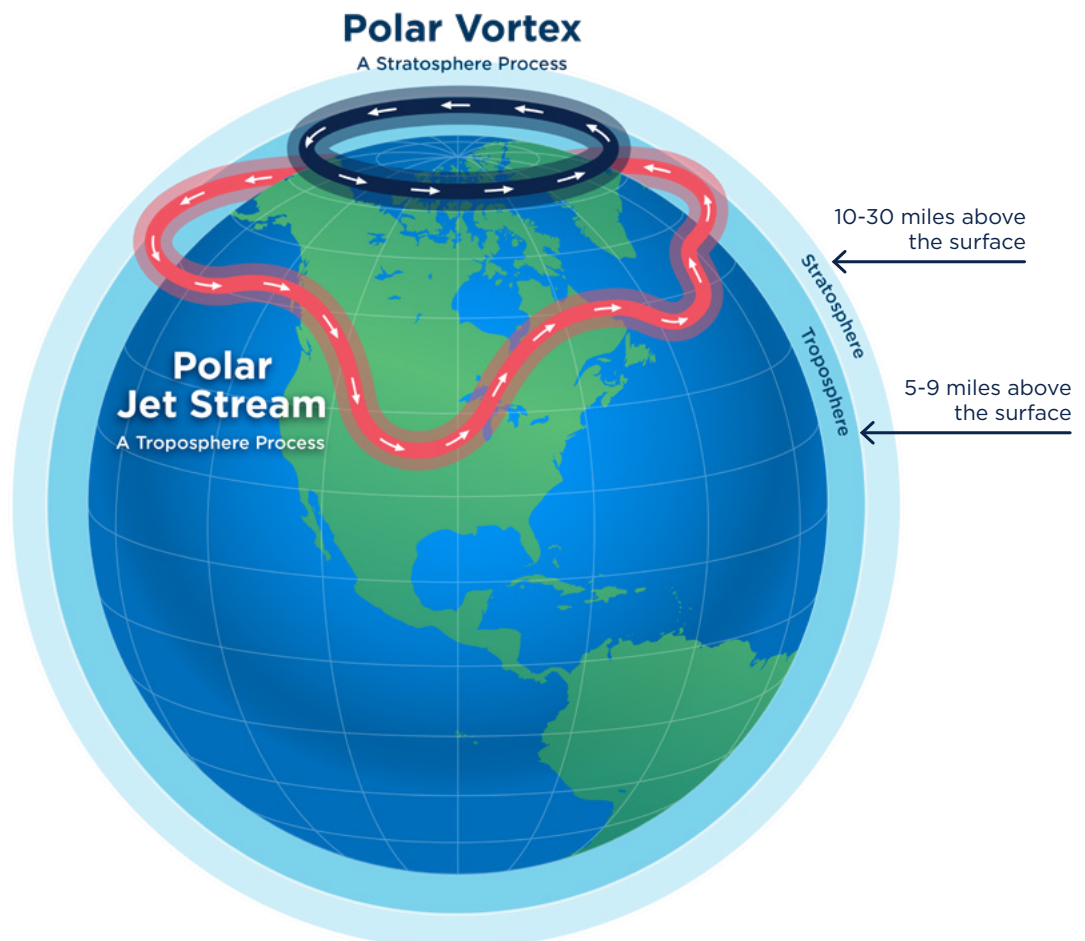


Figure 3

Graphic adapted from the Bulletin of the American Meteorological Society.

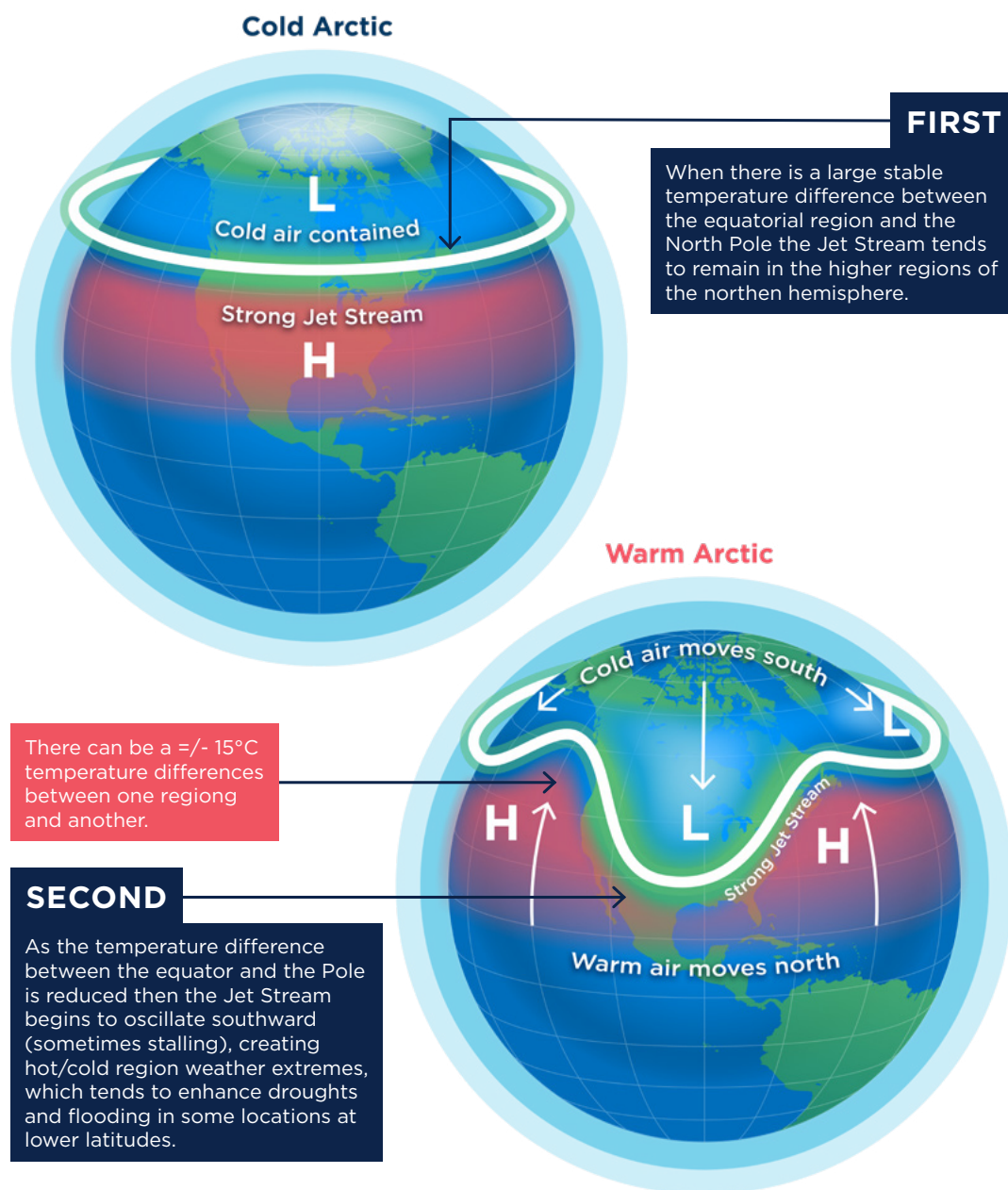
DOI: <https://doi.org/10.1175/BAMS-D-15-00212.1>

FIGURE 4

## How do the Recent Warming Trends in the Arctic Affect the Jet Stream?

Figure 4

Graphic adapted from Paul Horn Inside Climate Network



There are two important circumpolar natural processes in the north polar region, one in the stratosphere and the other in the troposphere, both of which are affected by energy moving northward from equatorial regions and affected by climate change processes. The **Polar Vortex** affects Northern Hemisphere weather processes on long time-scales, mostly in the winter seasons and over years. The time-scales of the the dynamics within the

**Polar Jet Stream** are active year-round, and hence have an influence on Northern Hemisphere weather on the order of days to weeks to months. As the temperatures increase in the lower levels of the troposphere, particularly in the Arctic and high northern regions, the polar Jet Stream becomes destabilised and able to meander into lower and higher latitudes as it circles the globe from west to east.



**Figure 5**

Graphic adapted from Climate Central.

## EXTREME HEAT AND RAIN IN THE UNITED STATES

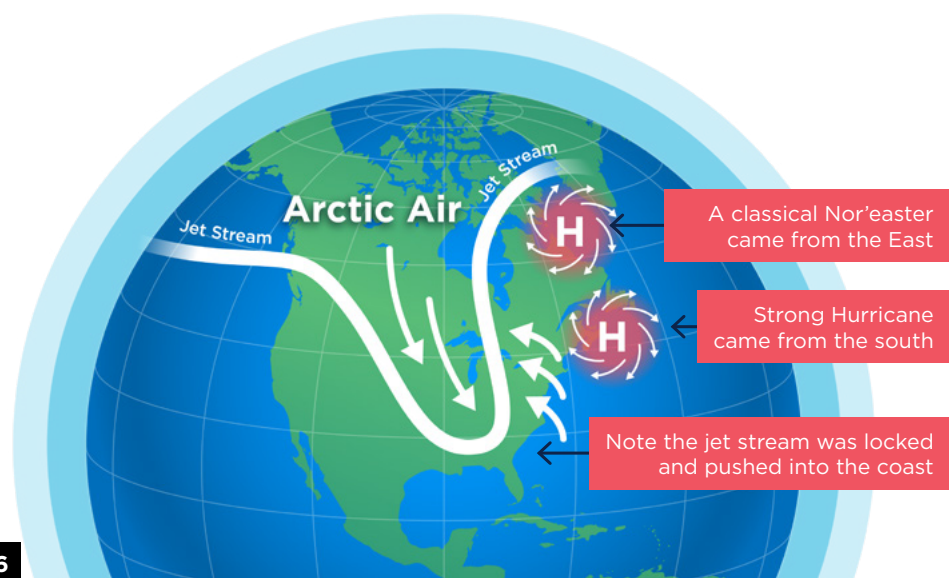
### The Sandy storm in New York City on October 29, 2012 provided insights on the importance of the Jet Stream.

This event began with a combination of a stalled Jet Stream, a hurricane from the southeast that also stalled in place and a classical “nor’easter” arriving from the northeast (figure 5).

This allowed heavy rains to persist over the US northeast for many days. Over the course of 48 hours, wind, rain, and ocean inundation destroyed homes and affected hundreds of thousands of New Yorkers with loss of electrical power, access to food, drinking water, healthcare, and other critical services.

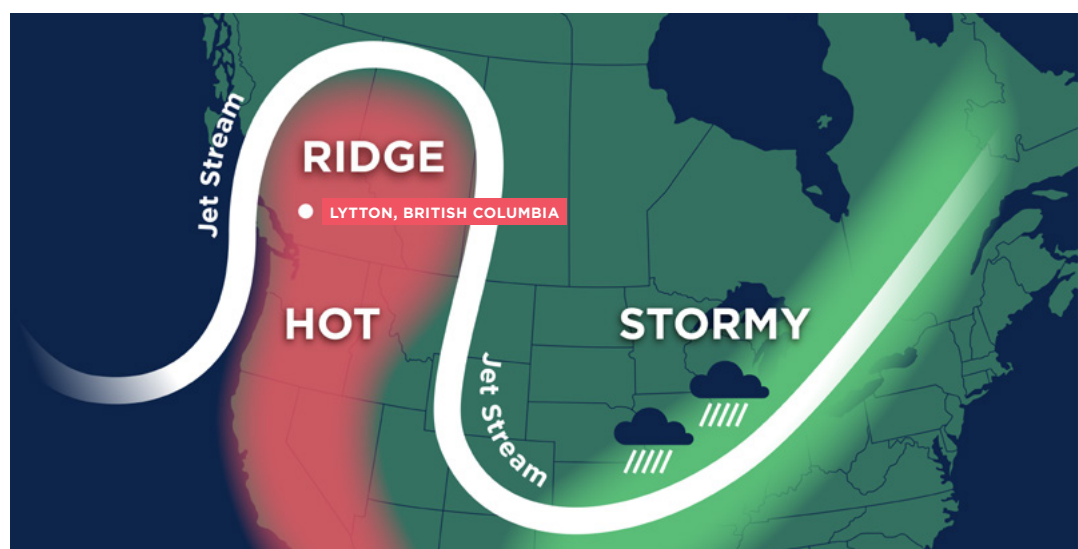
**FIGURE 5**

The combination of these three concurrent storms “pinned” them over New York City



**FIGURE 6**

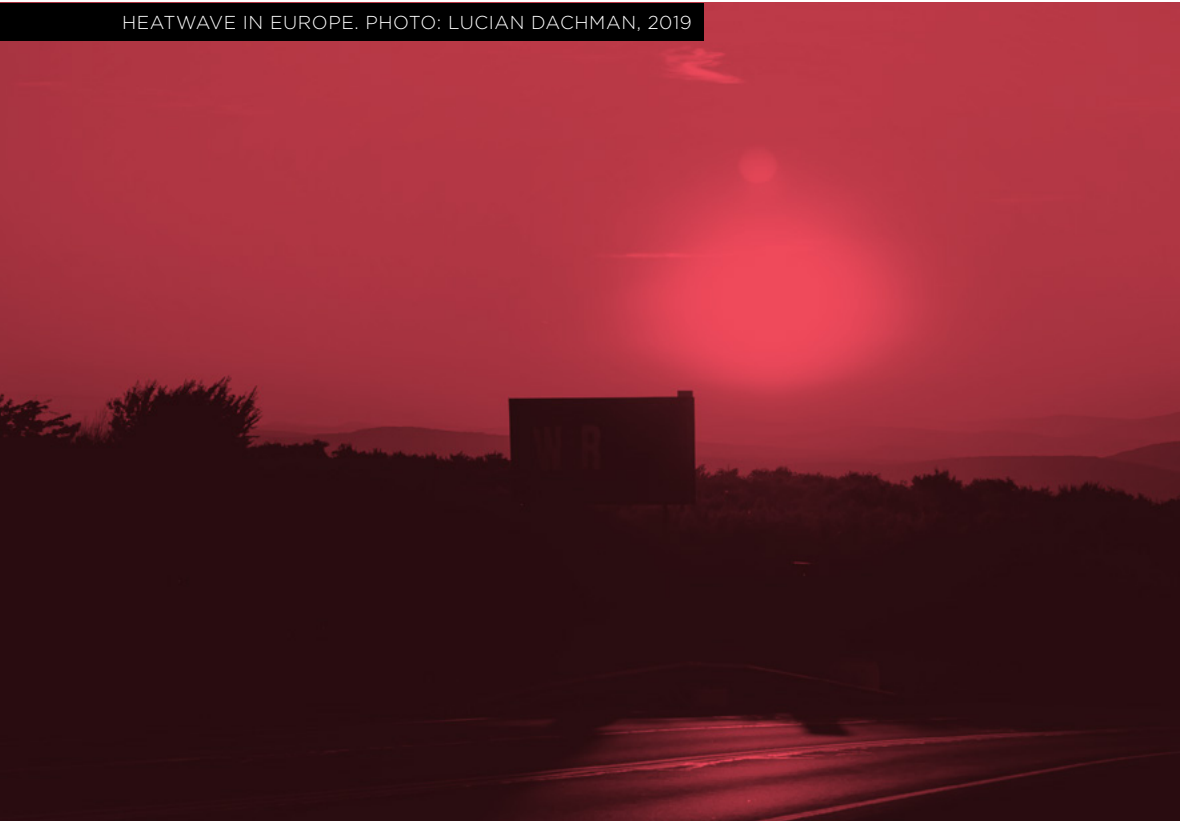
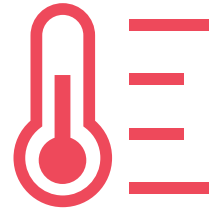
Extraordinary Local Extreme Temperatures in the Pacific Northwest and Canada



**Figure 6**

Lytton, British Columbia on June 29, 2021 recorded Canada's highest ever temperature of 49.6°C (121.3°F)

Graphic adapted from 2021 KNOE, Jun 29, 2021



The Jet Stream can also become locked in place in what is called an **“Omega Block”**. This type of weather event led to the extraordinary heatwave in the Pacific Northwest and Canada in late June of 2021, as depicted in figure 5 where the **“Ridge”** is trapped between two low pressure regions on the outside of the Jet Stream and a high pressure inside the **“Ridge”**. Within the omega block, extreme temperatures were able to develop from Canada to California within a **“heat dome”**<sup>7</sup>, where high-pressure circulation in the atmosphere acts like a dome or cap over a region and it traps heat at the surface.

In the states of Oregon and Washington and the western provinces of Canada, recorded temperatures during this event were far above 40°C (104 °F), in many places breaking previous heat records by 5°C. Normally heat records are only broken by tenths of a degree, not by several degrees – highlighting the exceptional severity of this event. A new all-time Canadian temperature record of 49.6°C (121.3 °F) was set in the village of Lytton, which the next day was all but destroyed by wildfire. Heatwaves are deadly events and cooling centres were established to try to protect citizens from the

heat, but several hundred still died as a result of this heatwave. Within the affected areas, over 31 million people were under a National Weather Service **“Excessive Heat Warning”** (A heat index of 105 °F or greater) or a **“Heat Advisory”** (where human health can be seriously affected by the extreme temperatures if precautions are not taken). Rapid attribution has shown that a heatwave of this severity would have been virtually impossible without human-caused climate change. It is possible that climate change impacts on the weather (including on the Jet Stream) have increased the chances of this type of extreme heat, beyond what could be expected from climate warming alone.

Heatwave conditions in the western United States this year have been made even worse by the intense drought currently being experienced, threatening water resources and fuelling devastating wildfires. When the environment is dry, there is limited evaporation of water that would normally provide a cooling effect to ameliorate heat. In mid-July, Death Valley was reported to have a 130 Degree F (54°C) maximum temperature; this is believed to be the highest temperature ever reliably measured on Earth.

<sup>7</sup> NOAA. What is a heat dome? <https://oceanservice.noaa.gov/facts/heat-dome.html>



# EUROPEAN FLOODS AND EXTREME WEATHER

## EVENTS IN WESTERN EUROPE

**In mid-July this year, parts of western Europe experienced extremely heavy and long-lasting rainfall, causing catastrophic floods as rivers rapidly swelled and burst their banks. The scale of subsequent devastation and death toll (over 200 to date on 20 July 2021) has far surpassed any earlier documented experience of extreme flooding in the region.**

A number of localities registered new daily maximum rainfall records. One particularly striking example is the weather station Hagen-Nahmer that was in the area of the strongest precipitation. There, 167.8mm of rain was measured in the course of only three hours, more than double the average monthly rainfall for the whole of July. Another outstanding rainfall record was set in Cologne (Stammheim weather station): 153.5mm over 24 hours, compared to the previous all-time daily high of 95mm (in 2017), and before that 91mm on 30th August 1968, for a location where rainfall events on average are well below 10mm/day.

The amount of rain that fell in a single day during this extreme rainfall event was about as much as the affected area normally receives over the course of two months in the summer. So much rainfall in a short period of time raised water levels in a number of small regional rivers running through townships to all-time highs that were multiple times above the normal values.

It will take some time for scientists to complete attribution analyses of

this clearly unprecedented flooding. This work will determine the degree to which human-caused climate change played a role in the unusual intensity, duration and spatial extent of this rainfall event. Nevertheless, it is scientifically well established that precipitation is intensified due to global warming because of an exponential relationship between atmospheric warming and the amount of moisture the air can hold. In other words, there is a large body of scientific evidence making us highly confident that the intensity of this weather event was strengthened by global warming, and that further warming will lead to further intensification of extreme precipitation events.

It has already been found that the past several decades have been one of the most flood-rich periods in Europe in the last 500 years, and a climate-change signal has been identified in shifting European river flooding patterns. At the same time, the magnitude and extent of the most recent extreme rainfall in western Europe, and the subsequent flooding and damage, outstrip climate scientists' expectations under the current global warming of 1.2°C above the preindustrial average temperature. Relatively straightforward thermodynamic processes, which form the basis of climate models, do not offer a full explanation for extreme outlier phenomena such as this or indeed the next-to-impossible heat wave in the western North America presented in the previous section.



FLOODING IN ENGLAND. PHOTO: CHRIS GALLAGHER, 2021

## EXTREME WEATHER BEYOND EXPECTATIONS

**As explained in the previous section, when the temperature difference is reduced between a rapidly warming Arctic and warm air from the Equatorial region, this slows down the Northern Jet Stream.**

The Northern Jet Stream then starts meandering in wide so-called Rossby waves, which can lock-in high- and low-pressure weather systems, explaining why warm and dry high-pressure or wet and cooler low-pressure systems get stalled in one geographic location for longer time periods. There is, so far, no conclusive scientific agreement that a slow-down of the Jet Stream due to Arctic melt contributed to the magnitude of the 2021 summer extremes in the Northern Hemisphere. But there are an increasing number of scientific publications making the connection between a rapidly warming Arctic

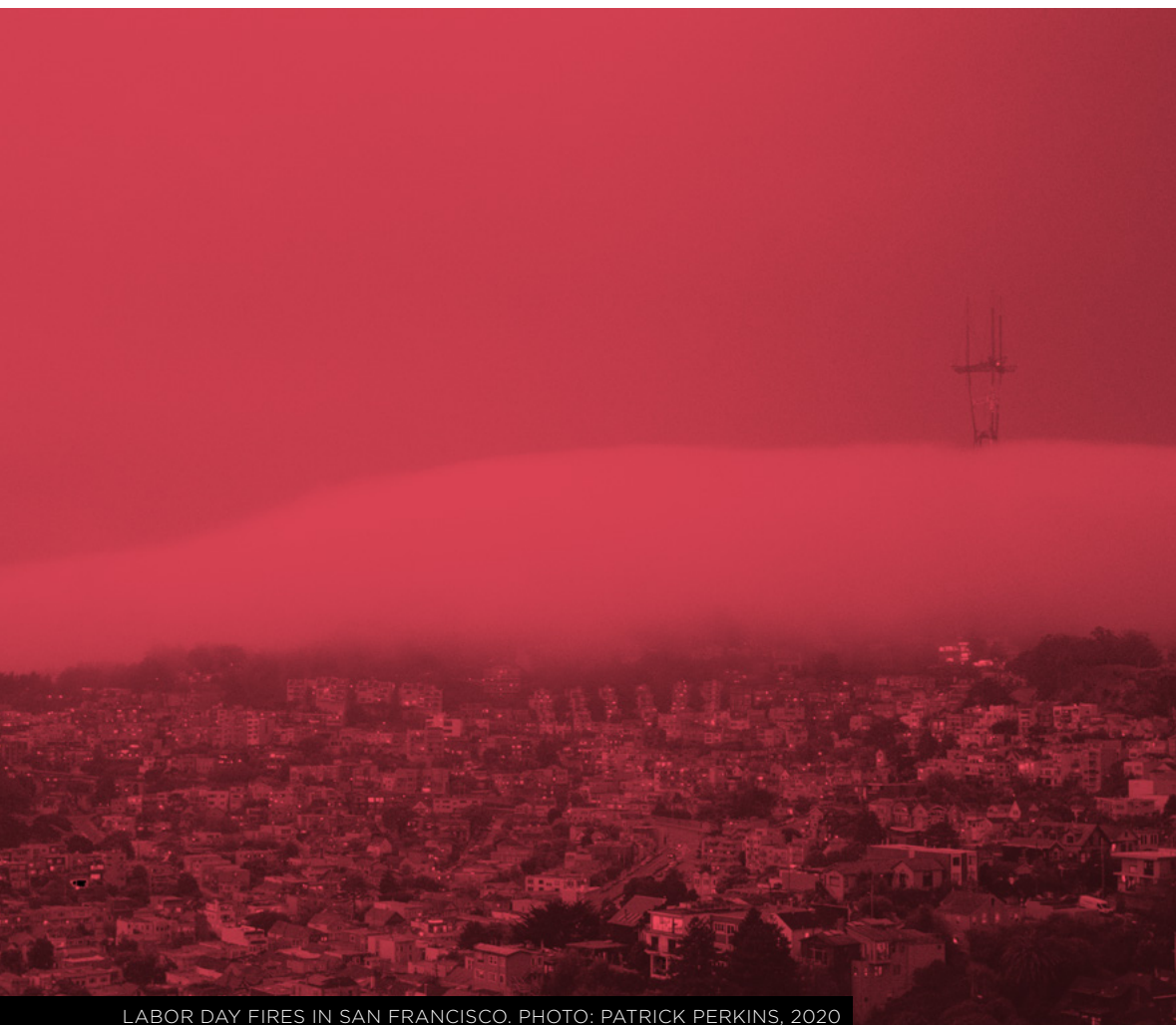
region, a meandering Jet Stream and extreme weather, particularly during the Northern hemisphere summer. Similar connections have been found for the extreme heatwave and forest fires over Europe in 2018<sup>8</sup>, the California fires in 2018<sup>9</sup>, and the droughts and heat over Russia in 2010<sup>10</sup>.

We cannot exclude that this is what we are experiencing again. Not least as we simultaneously witness weather disaster in Germany, the highest temperatures ever observed for June in Finland and the US, the catastrophic heatwave in British Columbia, and extreme heat in Siberia. These are all outlier events that exceed what one would expect if it were "only" a 1.2°C warming impact. It is likely that there are additional interactions between the climate system and tipping elements (in this case the Arctic and the Jet Stream) occurring simultaneously.

<sup>8</sup> Kornhuber K et al. 2019. Extreme weather events in early summer 2018 connected by a recurrent hemispheric wave-7 pattern. *Environmental Research Letters*. 14(5); Coumou D et al. 2018. The influence of Arctic amplification on mid-latitude summer circulation. *Nature Communications*. 9(2959).

<sup>9</sup> Mann M et al. 2018. Projected changes in persistent extreme summer weather events: The role of quasi-resonant amplification. *Science Advances*. 4(10).

<sup>10</sup> Lau W K M and Kim K. 2012. The 2010 Pakistan Flood and Russian Heat Wave: Teleconnection of Hydrometeorological Extremes. *Journal of Hydrometeorology*. 13(1).



LABOR DAY FIRES IN SAN FRANCISCO. PHOTO: PATRICK PERKINS, 2020





## THE RISK OF TIPPING CASCADES:

### What happens in the Arctic does not stay in the Arctic

**There is rising scientific evidence that the Arctic is not only the most rapidly warming region on Earth, but that it may also be a key "ground zero" for cascading impacts across the planet. The Arctic is one of some 15 known tipping elements of the Earth system. These tipping elements are each big biophysical systems that contribute to regulate the state of the climate system on Earth.**

A stable Arctic controls temperature on Earth by reflecting back incoming solar radiation from white ice sheet and sea ice surfaces, and through modulating the distribution of heat and salinity in the global oceans through flows of ice melt. Now this is being disrupted, as the melting Greenland ice sheet is releasing large volumes of cold freshwater into the North Atlantic. This contributes to slow-down of the Atlantic Meridional Overturning Circulation (AMOC), the heat conveyor belt of ocean

water, which in the North Atlantic expresses itself as the Gulf Stream. So far, Arctic ice melt has contributed to a 15% slow-down of the AMOC<sup>11</sup> that is unprecedented over at least the past 1,000 years. This slow-down of heat flux in the Atlantic impacts on the South American monsoon, which can explain the higher frequency of droughts and fires in the Amazon rainforest, causing loss of biodiversity, natural capital and increased CO<sub>2</sub> release to the atmosphere. A slow-down of the AMOC also leads to warmer surface water being held in the Southern Ocean, which may explain the accelerated melting of West Antarctic Ice Sheet. Observations recently have indicated that the "Doomsday glacier", the Thwaites glacier, may have already crossed a tipping point of unstoppable ice loss, already at 1.2°C of global warming, potentially accelerated by dynamics triggered in the Arctic.

<sup>11</sup> Caesar L et al. 2021. Current Atlantic Meridional Overturning Circulation weakest in last millennium. *Nature Geoscience*. 14.

## NEXT STEPS AND RECOMMENDED RESPONSES

**The story is simple. Climate change is happening faster than anticipated; one consequence – the loss of ice in the polar regions – is also a driver for more rapid global heating and disastrously rapid global sea level rise.**

Consequences are increasingly violent – whether methane explosions in the northern Arctic region, or increasingly severe heatwaves, storms, fires, droughts and floods across the globe. This picture requires urgent recognition, and a rapid political and collective response.

It is important to understand how bad things are, but no one should bury their heads in the sand in despair; concerted action right now at all levels of global society and governance will enable the planet to stabilise, and humanity to thrive. As climate change continues, largely unabated, the window of opportunity to remediate it is rapidly closing and options for doing so are rapidly diminishing. The Climate Crisis Advisory Group (CCAG) was created in response to this emergency, a new advisory group to help inform the public, governments and financial institutions, providing them with the most comprehensive science, and more crucially, guiding them towards action for climate repair.

The Climate Crisis Advisory Group believes we need agile international political and financial action to mitigate the consequences of climate change through Reduction, Removal and Repair measures.

Focused action by governments, particularly looking at regulatory procedures to speed up transition,

and by the financial sector, to ensure that all investments in infrastructure are fit for purpose in a zero carbon world, are key pillars of priority action. In the business community we must rapidly transition hard to abate sectors onto a decarbonisation path, whilst individuals must change habits which are inductive to continued loss of ecosystems, for example forests.

The current situation described in this paper indicates that GHG levels are already too high for a manageable future for humanity. We must fast-track the understanding and rapid implementation of safe processes for GHG removal at scale from the atmosphere. Such activity is now underway in many countries in the world to investigate the most productive way forward to achieve this. In order to buy time we urgently need to find safe ways to recreate ice cover over the Arctic Ocean during the Arctic summer. This work is in its infancy but has been initiated.

The roll out of any of these processes must be done in a way that is sensitive to the needs of the Indigenous peoples of these regions. We need the Indigenous communities to be active partners in these processes.

Reduction activities will benefit from a better situational view – the Arctic communities and Indigenous communities could be central partners in sharing, on their terms and consent, their wisdom, knowledge and real time observations (ranging from tundra fire early warning systems to permafrost melt events and tipping points). This can empower the communities from victims to partners in solutions.<sup>12</sup>

<sup>12</sup> Huntington H et al. 2017. How small communities respond to environmental change: patterns from tropical to polar ecosystems. *Ecology and Society*. 22(3).








One third of the world's soil based carbon is still locked up in the northern peatlands, forests and ecosystems. Sweden, Finland, Canada and Northwestern Russia have potential to rewild and restore degraded peatlands back into carbon sinks, enabling the trapping of millions of tonnes of CO<sub>2</sub> in a speedy manner. More broadly the ecosystem restoration of Arctic rivers (removal of hydrodams, restoration of habitats) could alleviate and buy time for cold-water adapted species and re-start carbon circulation in the

regions, where it has been lost due to man-made changes.

The thawing of permafrost and its consequential emissions of carbon dioxide and methane can be addressed only by direct cooling measures and refreezing of the Arctic: this approach is designed to buy time until the rate of permafrost-thaw and ice-melt is automatically slowed down by emissions disappearance, adapted farming methods and GHG removal from the atmosphere at scale.

**All of these transitions and changes demand policy interventions to kick-start new market preferences, reward desired behaviours, or to discourage undesirable outcomes. Many technical solutions already exist, but political will is required to push them through.**



This report was authored by the Climate Crisis  
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ICE BREAKS IN NORTHERN BALTIC. PHOTO: MIKA HONKALINNA, 2021

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- > This series of open meetings will be livestreamed on social media on the last Thursday of each month.

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