WHAT HAPPENS IN THE ARCTIC DOESN'T STAY IN THE ARCTIC

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SAVE THE ARCTIC

GREENPEACE

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1.0 EXECUTIVE SUMMARY

The Arctic ecosystem is warming at more than twice as fast as any other region in the world. The total area of summer sea ice in the Arctic has been decreasing over the last 30 years and this means that significantly more heat is being exchanged between the Arctic ocean and the surrounding atmosphere. The Arctic environment is integral to global climate systems, and this higher heat flux not only results in profound changes within local Arctic ecosystems, but also impacts climate systems throughout the world.

Scientists have been attempting to understand these remote climatic changes but research is still in its infancy; the underlying processes are highly complex. However, there appear to be causal links between the loss of the Arctic ice sheets and changes in large-scale atmospheric circulation patterns, oceanic circulation and temperature gradients in the northern hemisphere. The effects of these changes are difficult to measure, but in years when the Arctic has been particularly warm, certain persistent and anomalous weather patterns have been observed. As the Arctic warms and the ice recedes further, feedback mechanisms such as reduced reflective ability of the ice (surface albedo) and the release of harmful greenhouse gases from their long-term storage in the Arctic permafrost will further add to global climate change.

Observational and modelling studies indicate that, as the Arctic land ice (i.e. glacier sheets) disappears, sea levels are likely to rise and weather patterns in the northern hemisphere are predicted to change. These effects will most likely be geographically patchy, with hotter, drier summers in some areas, wetter summers in other areas, and cold, stormy winters in others. Changing atmospheric circulation patterns, including an altered track of the Gulf Stream, and 'blocked' planetary atmospheric waves are likely to contribute to these extreme climatic changes. Extreme weather events are likely to be more common in this future world with a higher likelihood of heat waves, floods and extreme storms. This report gives a brief overview of how a warmer Arctic is driving climatic changes in other areas of the world, and of the current scientific evidence that describes the processes underlying these changes.

The area within the Arctic Circle is around 6% of Earth's surface area, yet is currently afforded no legally binding international protection. Greenpeace demands urgent protection of Arctic ecosystems through a network of protection that will actively and adaptively manage exploitation, encroachment throughout the Arctic.

2.0 INTRODUCTION

'**Abrupt climate change** is defined by the Intergovernmental Panel on Climate Change (IPCC) as a large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades and causes substantial disruptions in human and natural systems.'[1]

This 'abrupt climate change' era is now a reality for us all. Arctic ice, the northern cryosphere, is an integral part of the earth's climate systems and has undergone rapid changes over the last century.

The Arctic region has warmed more than two times as fast as any other area of the world in the previous few decades and is known to be more sensitive to the effects of global warming in what is called 'Arctic amplification'.[2] The IPCC has stated, with *very high confidence* that the Arctic sea ice extent has decreased at a rate of at least 3.5-4.1 % per decade in the last 30 years.[1] This change is most dramatic in summer and autumn with around a 50 % decrease in ice cover since satellite records began. The mean thickness of the ice at the Arctic in summer has also declined by approximately 40 %, equating to a 75-80 % loss in volume.[3, 4] Sea surface temperatures in the region have been determined to be higher than at any time in the last 1,450 years.[1] The underlying cause of this warming is, of course, increased concentrations of the many greenhouse gases, and subsequent warming of the global oceans and changes in weather patterns resulting in more warm moist air in the Arctic in summer.[5, 6]

The decline in Arctic sea ice cover is not only an indicator of global climate

1 Stocker et al. (2013). Technical Summary. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

2 Cohen et al. (2014). Recent Arctic amplification and extreme mid-latitude weather. Nature Geoscience 7: 627-637.

3 Kwok, R. & Rothrock, D. A. (2009). Decline in Arctic sea ice thickness from submarine and ICESat records: 1958–2008. Geophysical Research Letters 36: L15501.

4 Overland, J. E., Wang, M., Walsh, J. E. & Stroeve, J. C. (2014). Future Arctic climate changes: adaptation and mitigation timescales. Earth's Future 2: 68–74.

5 Vihma, T. (2014). Effects of Arctic sea ice decline on weather and climate: A review. Survey Geophysics 35: 1175-1214.

6 Marshall, J. et al. (2014). The ocean's role in polar climate change: asymmetric Arctic and Antarctic responses to greenhouse gas and ozone forcing. Philosophical Transactions of the Royal Society A 372: 20130040.

change; it also plays a vital role as an important positive feedback system that affects other areas of the world. The sea ice acts as an insulating blanket, reducing the exchange of heat and water between the atmosphere and the ocean (and the generation of waves). The ice is also highly reflective, and this surface 'albedo' serves to reflect the sun's energy back into space, contributing to a cooling effect. As the sea ice melts, this reflective surface is replaced by a relatively dark ocean surface, reducing the amount of sunlight reflected. The less sunlight that is reflected, the more heat the planet absorbs, making it more unlikely that ice will reform in the Arctic region. Black carbon produced from, for example, gas flares and emissions from ships engines, induces further climate change effects by making the ice darker and more likely to melt. Therefore, mediating these sources of black carbon from activities within the Arctic and across the globe will be a vital part of strategies aimed at slowing down the rate of melting.[7]

Some studies suggest that the whole Arctic region could be free of sea ice in summer by 2050.[8] Though the Arctic is still relatively remote, an Arctic free from sea-ice will make it ever more possible access to the many Arctic resources; oil and gas, fish stocks and shipping lanes. These human activities are already encroaching on the Arctic, and will do so further as the ice extent declines, putting local ecosystems under acute threat. Increased temperatures will likely induce broad ecosystem shifts, changing many habitats for Arctic species, and allowing unwanted 'alien' species to move northwards.

As well as these 'local' changes that will impact directly on Arctic biodiversity and livelihoods, there will be more 'remote' effects in other global areas. Climate change is known to be affecting weather, and ecosystems, within the Arctic, but there is also a growing body of evidence that links the melting of polar ice sheets to changes in other areas or the world. The mechanisms behind these large-scale changes are not well understood and there has been considerable research effort recently to try and better understand the broad processes that are responsible.

7 Sand et al. (2013). The Arctic response to remote and local forcings of black carbon. Atmospheric Chemistry and Physics 13: 211-224.

8 Overland, J. E. & Wang, M. (2013). When will the summer Arctic be nearly ice free? Geophysical Research Letters 40: 2097-2101.

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3.0 WHAT ARE THE PROCESSES THAT MAKE THE DECLINE OF ARCTIC SEA ICE AFFECT THE GLOBAL CLIMATE SYSTEM?

3.1 THE ALBEDO EFFECT: AN UNSTOPPABLE FEEDBACK MECHANISM

Satellite observations of Arctic sea ice over the last 30 years have shown that the region has become visibly darker in colour with the loss of ice and less snow cover.[9] As this planetary reflective albedo has decreased, the amount of solar energy entering the Arctic Ocean has increased. Pistone et al. (2014) have quantified that the decrease in albedo, averaged over the globe, is equivalent to a forcing that is 25 % of the effects due to changes in levels of carbon dioxide. This effect is much larger than previously thought and confirms that managing levels of black carbon from sources such as ships and oilrig flares is urgent.

3.2 RELEASE OF ORGANIC CARBON FROM GLACIERS, ICE-SHEETS, THE PERMAFROST AND METHANE HYDRATES.

Polar ice-sheets and glaciers (both the Arctic and Antarctic) cover around 11% of the Earth's total area, and the Arctic and sub-Arctic permafrost regions (frozen land) cover around 25 % of the Earth.[10, 11, 12] Within these vast areas combined there is not only an enormous amount of water (ice-sheets and glaciers contain around 70 % of the Earth's freshwater alone) but there are also immense stores of trapped greenhouse gases, such as carbon dioxide and methane. As the Arctic warms, these carbon reservoirs are expected to be released, either gradually or more episodically, over the coming centuries. This reservoir of carbon has not been properly accounted for in many climate models and could make climate change progress even faster that scientist have predicted.[11]

Hydrates are crystalline structures that enclose gases such as methane. These structures form over long geological time scales in low temperature, high pressure environments such as within the sediments of continental shelf edges. The Arctic environment contains a large global reservoir of submarine methane hydrates both on the conti-

9 Pistone, K., Eisenman, I. Ramanathan, V. (2014). Observational determination of albedo decrease by vanishing Arctic sea ice. Proceedings of the National Academy of Sciences 111: 3322-3326.

10 Hood et al. (2015). Storage and release of organic carbon from glaciers and ice sheets. Nature Geoscience 8: 91-96.

11 Schuur et al. (2015). Climate change and the permafrost carbon feedback. Nature 520: 171-179.

12 Nelson, F.E., Anisimov, O.A., Shiklomanov, N.I. (2002). Climate change and hazard zonation in the circum-Arctic permafrost regions. Natural Hazards 26: 203-225.

nental slopes and in the shallow continental shelves.[13] These hydrates are sensitive to changes in temperature, depth and perturbations resulting from storms.[14] As the subsea permafrost melts, methane bubbles to the surface releasing further carbon into the atmosphere. In some shallow (< 50 m deep) this provides a very direct route for carbon to reach the atmosphere and storms destroy the stratification, or layering, of the water column creating greater mixing, which induces more methane to be released.[14]

3.3 CHANGES IN OCEANIC CIRCULATION PATTERNS

The Greenland ice sheet is clearly melting at an accelerated pace (Fig. 1).[15, 16, 17] In 2016, this was recorded to be even earlier, and more extreme than ever before.[18] One of the consequences of this melt is the release of freshwater into the ocean environment, making it less salty in certain areas (freshening). There is strong evidence to suggest that this freshening is changing local northern sea circulation patterns and possibly impacting more broadly on oceanic circulation patterns across the North Atlantic, though this is very difficult to track and quantify.[19]

13 Dlugokencky et al. (2011). Global atmospheric methane: budget, changes and dangers. Philosophical Transactions of the Royal Society A 369: 2058-2072.

14 Shakhova et al. (2014). Ebullition and storm-induced methane release. Nature Geoscience 7: 64-70.

15 Jiang, Y., Dixon, T.H., Wdowinski, S. (2010). Accelerating uplift in the North Atlantic region as an indicator of ice loss. Nature Geoscience 3: 404-407.

16 Rignot et al. (2011). Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise. Geophysical Research Letters 41: 866-872.

17 Velicogna, I., Sutterley, T.C., van den Broeke, M.R. (2014). Regional acceleration in ice mass loss from Greenland and Antarctica using GRACE time-variable gravity data. Geophysical Research Letters 41: 8130-8137.

18 http://www.scientificamerican.com/article/greenland-s-melt-season-begins-almost-2-months-early/

19 Yang et al. (2015). Recent increases in Arctic freshwater flux affects Labrador Sea convection and Atlantic overturning. Nature Communications 7: 10525.

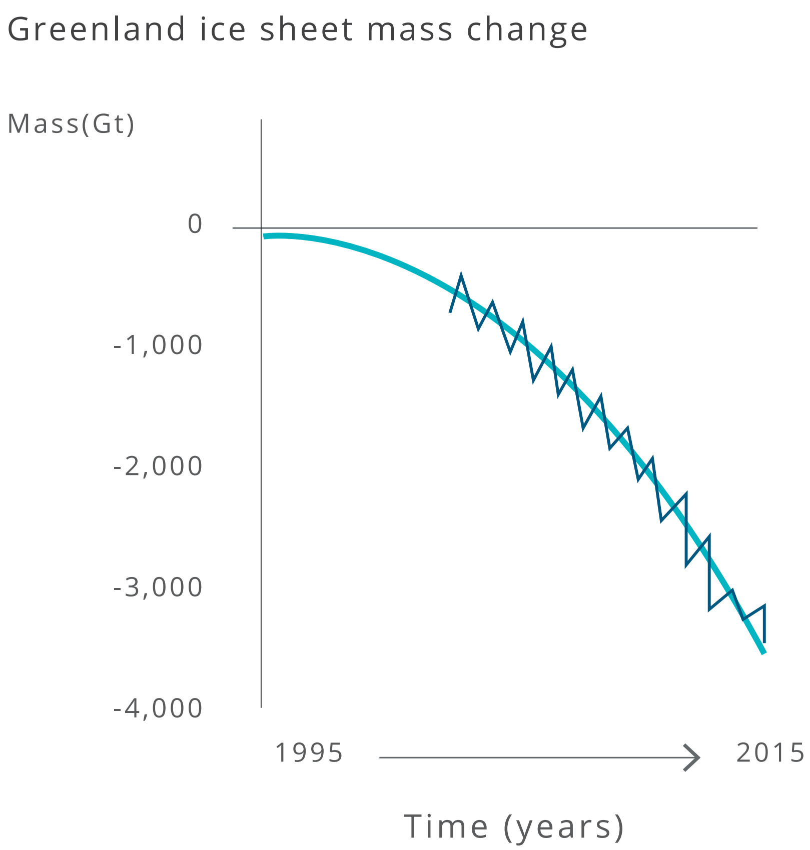

Figure 1. The total mass change from 2002-2014 of the Greenland ice sheet (in gigatonnes) as estimated from modelling using data generated by GRACE (Gravity Recovery and Climate Experiment). The dark curve shows data and the blue curve shows the best fitting constant acceleration. Onset time of acceleration defined when the rate of mass change is zero in 1996, with mass arbitrarily set to zero.[18] Reproduced under Creative Commons Attribution 4.0 International, [http://creativecommons.org/licenses/by/4.0/].

The path of the well-known 'Gulf Stream' current is influenced by these broad ocean-scale circulations and has changed considerably in recent years.[20] Northward movement of the Gulf-Stream has the effect of warming the Barents Sea, which has been experiencing warmer, ice-free summers, and this phenomenon is thought also to affect other areas of the Northern Hemisphere.

3.4 CHANGES IN GLOBAL ATMOSPHERIC CIRCULATION

Air movement around the Earth follows a certain pattern of planetary waves according to the Earth's rotation. The organisation of these planetary waves, in the Earth's high atmosphere, determines the pressure systems and weather patterns we experience.

As the Arctic ice melts, the movement of moisture in this area is known to affect these patterns of planetary waves.[21] In addition, as the Arctic warms, there is a smaller differential in the temperature gradient between the equator and the pole. This appears to slow the upper atmosphere planetary waves, favouring more extreme weather in Northern Hemisphere mid-latitudes.[22] Another process described is the 'blocking' of these planetary waves which causes more persistent weather at a given location, i.e. longer periods of low or high pressure.[23]

The jet-stream is one of the most prominent aspects of Northern Hemisphere atmospheric circulation, and is the 'river' on which storms grow and are propagated in that region. Climate models suggest that it is possible that changing Arctic conditions can affect the jet-stream, although how, and to what degree, is still under debate.[24] There are obviously many factors involved and these processes are still poorly understood and need further research, but it is clear that warming of the Arctic is a contributory factor.[25, 26]

20 Sato, K., Inoue, J., Watanabe, M. (2014). Influence of the Gulf Stream on the Barents Sea ice retreat and Eurasian coldness during early winter. Environmental Research Letters 9: 084009.

21 Porter, D. F., Cassano, J. J., Serreze, M. C. (2012). Local and large-scale atmospheric responses to reduced Arctic sea ice and ocean warming in the WRF model. Journal of Geophysical Research 117: D11115.

22 Francis, J. A., Vavrus, S. J. (2012). Evidence linking Arctic amplification to extreme weather in mid-latitudes. Geophysical Research Letters 39: L06801.

23 Liu et al. (2012). Impact of declining Arctic sea ice on winter snowfall. Proceedings of the National Academy of Sciences 109: 4074–4079.

24 Barnes, E., Screen, J.A. (2015). The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it? WIREs Climate Change 2015, 6:277–286.

25 Francis, J., Skific, N. (2015). Evidence linking rapid Arctic warming to mid-latitude weather patterns. Philosophical Transactions of the Royal Society A 373: 21040170.

26 Sun, L., Deser, C., Tomas, R.A. (2015). Mechanisms of stratospheric and tropospheric circulation response to projected Arctic sea ice loss. Journal of Climate 28: 7824-7845.

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WHAT HAPPENS IN THE ARCTIC DOESN'T STAY IN THE ARCTIC

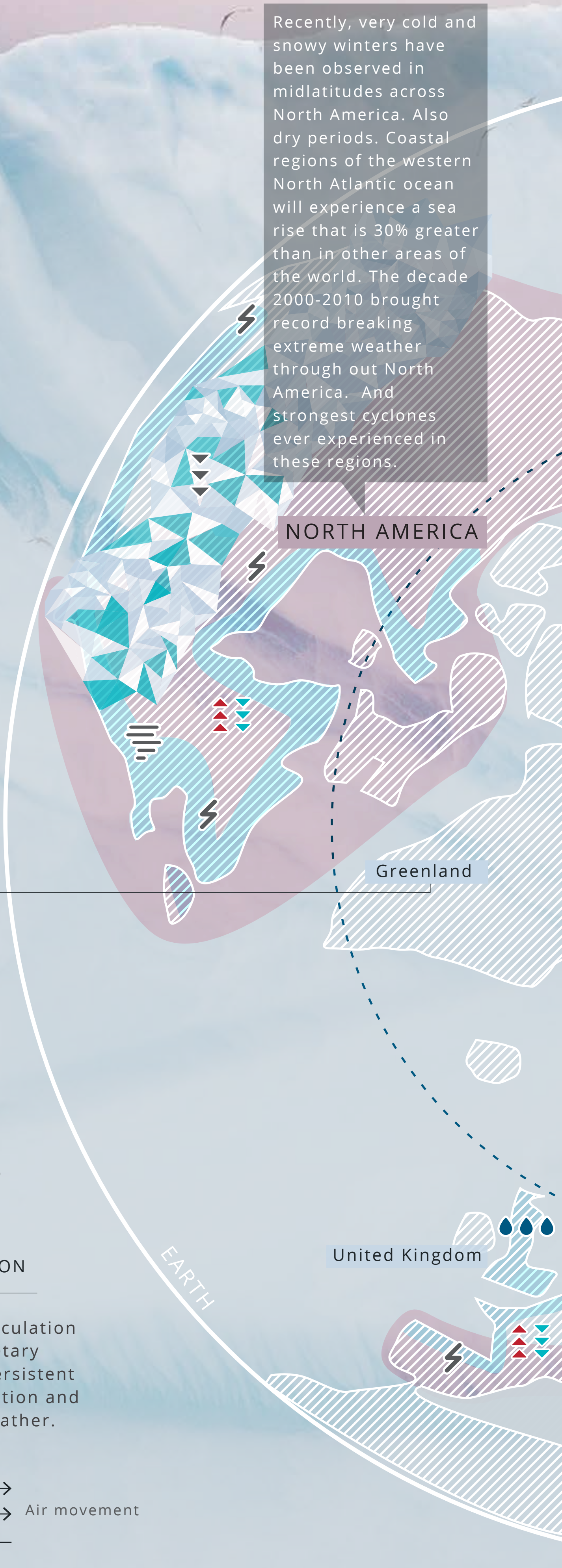
SUMMARY

The Arctic ecosystem is warming more than twice as fast as any other region in the world. Observational and modelling studies indicate that as the Arctic land ice disappears, sea levels are likely to rise and weather patterns in the northern hemisphere are predicted to change.

The area within the Arctic Circle is around 6% of Earth's surface area, yet is currently afforded no legally binding international protection.

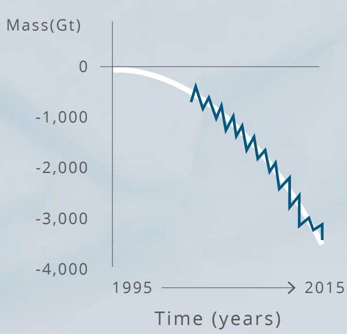
Greenpeace demands urgent protection of Arctic ecosystems through a network of protection that will actively and adaptively manage future human activities throughout the region.

This map shows what has happened, and what could happen in the future even though much remains uncertain.



Changes in oceanic circulation patterns

The Greenland ice sheet is clearly melting at an accelerated pace. In 2016, this was recorded to be even earlier and more extreme than ever before. One of the consequences of this melt is the release of freshwater into the ocean environment, making it less salty in certain areas. This freshening is changing local northern sea circulation patterns and across the North Atlantic.



THE ALBEDO EFFECT

As the Arctic warms and the ice recedes the surface albedo (reflective capacity of the ice) is reduced. Through a positive feedback mechanism the Arctic will warm further, making it less likely for the ice to reform.

ATMOSPHERIC CIRCULATION

Changing atmospheric circulation patterns can 'block' planetary waves, favouring more persistent conditions at a given location and contribute to extreme weather.

ICE MELTING

The mean thickness of the sea ice in the Arctic in summer has also declined by approximately 40%, equating to a 75-80% loss in volume.

MAP LEGEND

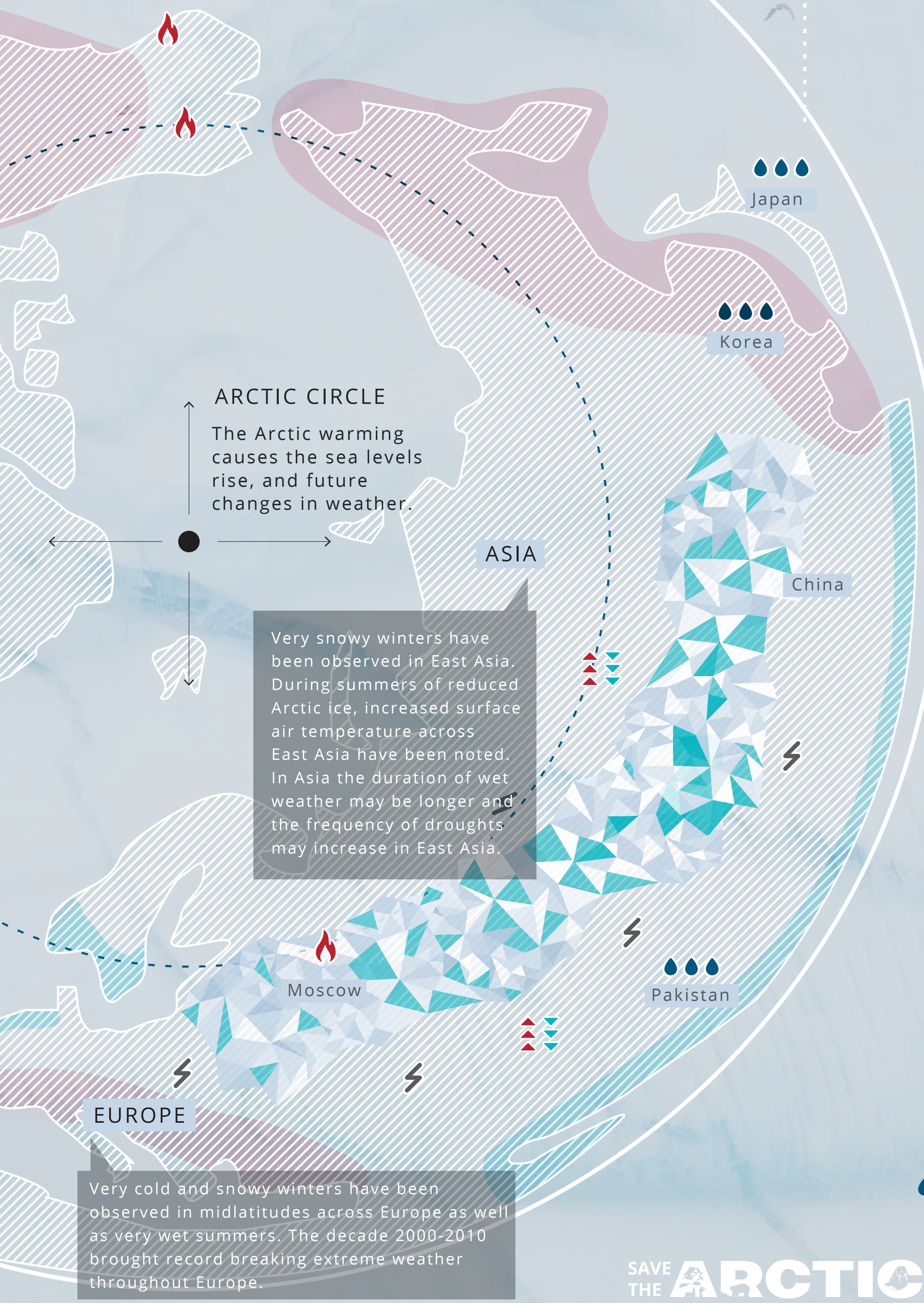
Some of the changes in weather potentially due to warming in the Arctic, as suggested by current published literature.

- Arctic Circle
- Hotter Summers
- Colder winters and more snow
- Sea level rise

SOME WEATHER EXTREMES OBSERVED

Though the processes are unclear, tentative links between Arctic conditions and extreme weather are beginning to emerge.

- Droughts
- Hurricanes
- Super storms
- Increased fire
- Extreme temperatures
- Torrential rains and floods



ARCTIC CIRCLE

The Arctic warming causes the sea levels rise, and future changes in weather.

Very snowy winters have been observed in East Asia. During summers of reduced Arctic ice, increased surface air temperature across East Asia have been noted. In Asia the duration of wet weather may be longer and the frequency of droughts may increase in East Asia.

Very cold and snowy winters have been observed in midlatitudes across Europe as well as very wet summers. The decade 2000-2010 brought record breaking extreme weather throughout Europe.

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4.0 HOW CHANGES IN THE ARCTIC DON'T STAY IN THE ARCTIC: THE EVIDENCE AND PROJECTIONS

Many recent studies suggest that the on-going changes in the Arctic environment are having an effect on other areas of the world. However, these results of these studies differ in terms of the location, timing and magnitude of these remote effects.

4.1 CHANGING WORLD TEMPERATURES

The average temperatures of the air and of the surface ocean are higher in areas of the Arctic that are now ice-free. Atmospheric circulation spreads these pockets of warmth horizontally to adjacent areas.[27] This means that the generally cold, northerly winds in the mid-latitudes of the Northern Hemisphere have been warmer than usual over the previous 10 years, particularly in the autumn and winter in areas of Europe, north-eastern Canada and in the Bering Sea.[28]

The effects of these temperature changes are patchy and have been an active area of research over the last decade. Recent scientific literature suggests that there are direct causal links between the decline of sea ice and more extreme temperature fluctuations than have been previously recorded in the Northern Hemisphere. Here are some examples:

Hot summers in the USA and Canada

There seems to be a coherent connection between declining Arctic ice and warmer conditions in the eastern USA, Canada and some parts of western USA.[29] Modelling of projected climate change over the USA Great Plains suggests that summertime temperatures will be 20 % more variable by the end of this century in comparison to now.[30] This will also mean that there will be a greater likelihood of future heat waves in this region.

27 Stroeve et al. (2012). The Arctic's rapidly shrinking sea ice cover: a research synthesis. Climate Change 110: 1005–1027.

28 Serreze, M.C., Barrett, A.P., Cassano, J.J. (2011). Circulation and surface controls on the lower tropospheric temperature field of the Arctic. Journal of Geophysical Research 116: D07104.

29 Budikova, D., Chechi, L. (2016). Arctic ice and warm season North American extreme surface air temperatures. Climate Research 67: 15-29.

30 Teng et al. (2016). Projected intensification of subseasonal temperature variability and heat waves in the Great Plains. Geophysical Research Letters. doi: 10.1002/2015GL067574

Warming of the Mediterranean Sea and East Asia

During summers of reduced Arctic ice, increases in the surface temperature of the Mediterranean Sea and East Asia have been observed, although whether these are directly linked is unknown.[31] However, there have been distinct atmospheric patterns associated with these warm summers in the Arctic. Other studies also support these findings, yet the causes of these changes are complex, most probably involving a combination of disturbances to the formation of clouds, the Gulf Stream, and even changes in the moisture content of soil in these areas.[32]

Cold winters and more snow

Recently, very cold and snowy winters have been observed in mid-latitudes across North America, Europe and East Asia. Many scientists believe that both observational and modelling evidence is now strong enough to suggest that these cold spells are linked to diminishing summer Arctic sea ice that changes atmospheric circulation patterns.[33, 34] Furthermore, these studies speculate that, as these atmospheric changes become more frequent, the frequency of colder winters in these areas will also increase. Indicative patterns in atmospheric conditions were evident, throughout the winters of 2009/2010, 2010/2011 and 2012/2013 and were thought to be responsible for extreme cold in the US east coast and Europe, bringing severe snow storms and particularly frigid conditions.[22]

Changes in autumn and winter ice in the Arctic could potentially also induce colder winters in mid-latitudes, extending from eastern Europe through central Asia to central China.[35, 36, 37] Again, although these changes have been observed, their mechanisms and causes are not clear. However, climate scientists in China are convinced that there is a strong link and are exploring the potential of predicting weather in China by monitoring Arctic sea ice conditions.[38]

31 Knudsen et al. (2015). Observed anomalous atmospheric patterns in summers of unusual Arctic sea ice melt, Journal of Geophysical Research: Atmospheres 120: 2595–2611.

32 Jaeger, E., Seneviratne, S. (2011). Impact of soil moisture-atmosphere coupling on European climate extremes and trends in a regional climate model. Climate Dynamics 36: 1919–1939.

33 Liu et al. (2012). Impact of declining Arctic sea ice on winter snowfall. Proceedings of the Natural Academy of Sciences 109: 4074-4079.

34 Kug et al. (2015). Two distinct influences of Arctic warming on cold winters over North America and East Asia. Nature Geoscience 8: 759-763.

35 Tang et al. (2013). Cold winter extremes in northern continents linked to Arctic sea ice loss. Environmental Research Letters 8: 1-6.

36 Wu et al. (2013). Winter weather patterns of Northern Eurasia and Arctic Sea ice loss. Monthly Weather Review 141: 3786-3800.

37 Sato, K., Inoue, J., Watanabe, M. (2014). Sea ice retreat and Eurasian coldness during early winter. Environmental Research Letters 9: 1-8. (doi:10.1088/1748-9326/9/8/084009).

38 Zuo et al. (2016). Predictability of winter temperature in China from previous autumn Arctic sea ice. Climate Dynamics (doi: 10.1007/s00382-015-2966-6).

4.2 CHANGING PRECIPITATION

Along with changes in average temperature during summer, and winter, in mid-latitudes, there is also some evidence that changing Arctic ice conditions may influence rainfall. How this may develop in the future is also not entirely clear and there are many different models, which disagree and present conflicting predictions, highlighting the shortcomings of current precipitation modelling.[39] Here are some examples:

Wet summers in northern Europe?

Some climate models of northern latitude rainfall predict that more cloudy, wetter summers in Europe are linked to Arctic sea ice loss.[28] It is suggested that the six consecutive wetter than average summers from 2007-2012 may have resulted from changing Arctic conditions.[40] Other models predict an increased likelihood, and severity, of wet weather over high latitudes, and in the Mediterranean and central Asia, as well as these periods of wet weather being much longer than have been known previously.[41]

Droughts in North America and East Asia?

Conversely, some studies suggest an observed increase in dry periods throughout North America and East Asia.[42] Model projections and simulations suggest that these droughts may result from Arctic ice loss and the changes this induces in planetary circulation patterns. Though the causal relationship is unknown, these simulations show that Arctic ice loss could be an important contributing factor.

4.3 SEA LEVEL RISE

During the period 1901 – 2010, global mean sea level rose substantially (average 0.19 m).[1] Since the middle of the 19th century, the rate of this sea level rise has increased and, according to the IPCC, the loss of Arctic ice, is *very likely* to be a contributing factor.[1] Climate projections suggest that, by the end of the 21st century, sea levels will rise substantially further, though how much this rise will be, and its affect on coastal communities, is largely unknown. Making these predictions is difficult as there are so many confounding uncertainties, particularly estimating the combined contribution of freshwater from land ice (glaciers and ice sheets).

Ultimately, it is thought that land ice changes will contribute most to sea level rise and the impact of these is likely to be geographically patchy. Some studies suggest that coastal regions of the western North Atlantic ocean will

39 Francis, J.A. (2015). The Arctic matters: extreme weather responds to diminished Arctic Sea ice. Environmental Research Letters 10: 1-3. (doi:10.1088/1748-9326/10/9/091002).

40 Screen, J.A. (2013). Influence of Arctic sea ice on European summer precipitation. Environmental Research Letters 8: 1-9. (doi:10.1088/1748-9326/8/4/044015).

41 Screen, J.A., Deser, C., Sun, L. (2015). Projected changes in regional climate extremes arising from Arctic sea ice loss. Environmental Research Letters 10: 1-12. (doi:10.1088/1748-9326/10/8/084006).

42 Zhang et al. (2015). Summer droughts in the northern Yellow River basin in association with recent Arctic ice loss. International Journal of Climatology 35: 2849-2859.

experience a rise that is 30 % greater than in other areas of the world.[43] It is projected that middle and low latitudes, where there are most human population centres (east coast North America and Europe), will be more badly affected than other areas.[44]

4.4 WEATHER EXTREMES

The decade 2000-2010 brought record-breaking extreme weather throughout Europe, North America, Western Russia and Australia.[45] This extreme weather ranged from the hottest summers and wettest autumns, to the strongest cyclones ever experienced in these regions. The human and economic losses of these unprecedented events were huge; lives were lost, grain harvests spoiled, forests burned. These events have triggered many studies that investigate how climate change is making our weather more unpredictable.

Changes in the severity and frequency of extreme weather events have grave consequences on biological and human systems, particularly our ability to grow food. Flash floods and heat waves create critical conditions in which many vulnerable people die.

43 Carson, M., Köhl, A., Stammer, D. (2015). The impact of regional multidecadal and century-scale internal climate variability on sea level trends in CMIP5 models. Journal of Climatology 28: 853–861.

44 Carson et al. (2016). Coastal sea level changes, observed and projected during the 20th and 21st Century. Climactic Change 134: 269-281.

45 Coumou, D., Rahmstorf, S. (2012). A decade of weather extremes. Nature Climate Change 2: 491-496.

There are many ways of defining 'extreme weather', primarily by counting the frequency and duration of hot, cold, dry or very wet days.[46] Research on how the changing Arctic influences these extreme weather events is only in its infancy, and there are many other factors involved, but tentative links to these extreme weather events are beginning to be identified.

In the winter of 2014/2015, North America experienced extreme cold tempera-

46 Zhang et al. (2011). Indices for monitoring changes in extremes based on daily temperature and precipitation data. WIREs Climate Change 2: 851–70.

Photo: © Rose+Sjölander/ Greenpeace

tures and heavy snowfall. An analysis of atmospheric circulations has revealed that one of the likely causes of this extreme weather is the change in polar wind circulation, with stronger northerly winds and a weaker westerly jet stream that blew cold polar air over North America.[47]

In general, it is over central and eastern North America that Arctic sea ice loss is projected to be the most significant driver of hot and cold extremes.[45] Tang et al. (2014) also suggest that extreme summer heat waves in North America, and Eurasia, are linked to atmospheric changes as a result of Arctic sea-ice loss and changes in snow cover.[48] By applying modelling techniques, this study concluded that summer sea ice loss in the Arctic gave a stronger response than snow loss. The authors suggest that this may be due to the fact that the difference in the reflective nature between ice and open ocean is much larger that between snow and the vegetation that remains when snow melts.

Many studies suggest that changes in the Arctic ice and snow conditions are modifying storm tracks, and driving more powerful 'Superstorms' across mid-latitudes.[24, 49, 50, 51] Nevertheless, direct evidence for this is difficult to gather as these atmospheric systems are highly complex and there are few case studies with which to test different hypotheses.

47 Cui, H-Y., Qiao, F-L. (2016) Analysis of the extremely cold and heavy snowfall in North America in January 2015. Atmospheric and Oceanic Science Letters 9: 75-82.

48 Tang, Q., Zhang, X., Francis, J.A. (2014). Extreme summer weather in northern mid-latitudes linked to a vanishing cryosphere. Nature Climate Change 4: 45-50.

49 Cohen et al. (2014). Recent Arctic amplification and extreme mid-latitude weather. Nature Geoscience 7: 627-637.

50 Hansen et al. (2015). Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modeling, and modern observations that 2°C global warming is dangerous. Atmospheric Chemistry and Physics Discussions 15: 20059-20179.

51 Cohen et al. (2013). Warm Arctic, cold continents: A common pattern related to Arctic sea ice melt, snow advance, and extreme winter weather. Oceanography 26:150–160.

Hurricane Sandy tracked up the Eastern seaboard of North America in the autumn of 2012 after a record-breaking summer of Arctic sea ice loss, though the direct link between the two phenomena is still unclear. It appears that particular unprecedented atmospheric conditions pushed Sandy westward, towards New Jersey, creating extreme tropical storm force winds that impacted much of the vast area from Delaware to Nova Scotia.[24]

It is most likely that Arctic amplification, along with changing atmospheric conditions in other global areas, act in combination to produce these extreme weather events. Flooding in the UK (winter 2014), and the extreme 'Snowmageddon' winter of 2010/2011 in North America, are both thought to be as a result of a combination of Arctic and tropical climate changes that influenced the track and configuration of the jet stream.[52, 53]

As conditions in the Arctic and the rest of the world are changing rapidly, these extreme weathers are predicted only to become more frequent, and more intense.

4.5 MORE ARCTIC TUNDRA FIRES?

The great fires of the Arctic tundra are natural phenomena that have shown a huge variability in frequency in different areas of the Arctic environment. These fires release reservoirs of ancient carbon into the atmosphere that have been stored within the soil for millennia. Analyses of historical records from lake sediments identifying charcoal layers reveal that tundra fires are more likely in warmer, drier summers.[54] Though these fires have been a feature of the tundra ecosystem for thousands of years, research shows that they are likely to increase in frequency as our global climate warms throughout the 21st century.

There appears to be a moderate correlation between the area of Alaskan tundra burned and the decrease in Arctic sea ice, with some of the largest fires occurring when the sea ice was at its minimum.[55] The mechanism of interaction with the Arctic is complex and managing these fires, protecting the ecosystems and preventing further greenhouse gases entering into the atmosphere are likely to become more and more difficult as the Arctic continues to change.

52 Ding et al. (2014). Tropical forcing of the recent rapid Arctic warming in northeastern Canada and Greenland. Nature 509: 209–212.

53 Palmer, T. (2014). Record-breaking winters and global climate change. Science 344: 803–804.

54 Hu et al. (2015). Arctic tundra fires: natural variability and responses to climate change. Frontiers in Ecology and the Environment 13: 369-377.

55 Hu et al. (2010). Tundra burning in Alaska: Linkages to climatic change and sea ice retreat. Journal of Geophysical Research 115: G04002.

5.0 CONCLUSIONS

The Arctic is a dynamic environment that is changing fast. It is warming at more than two times the rate as the rest of the world.[56] This enhanced Arctic warming, called Arctic amplification, may create more persistent weather patterns over mid-latitudes that lead to more extreme weathers. The processes that lead to these effects are poorly understood but research has identified changing ocean and atmospheric circulation patterns that are associated with the loss of Arctic ice sheets. Within these complex mechanisms are feedback systems that will further enhance global climate change as carbon is released and world temperature increase. Though many studies are incomplete, it is clear that as the Arctic warms, the effects of this are much more globally wide reaching than had first been described. It is certain that what happens in the Arctic affects us all globally.

56 Comiso, J.C., Hall, D.K. (2014). Climate trends in the Arctic as observed from space. WIREs Climate Change 5: 389–409.

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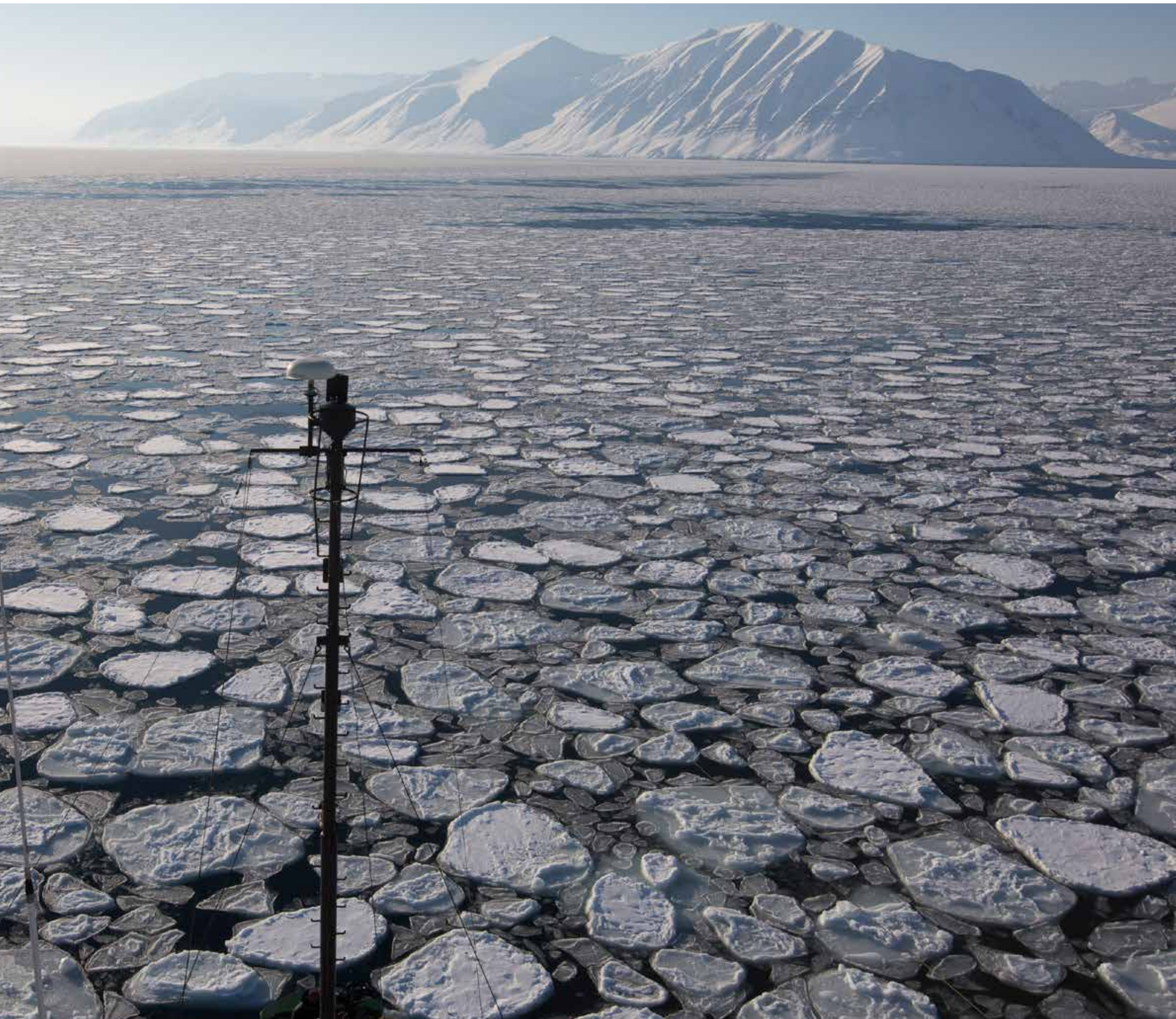

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6.0 GREENPEACE DEMANDS

Scientists and policy-makers alike agree that a rise in mean global temperatures as a result of increases in greenhouse gasses must not reach levels 2°C higher than temperatures in pre-industrial times. Ultimately, for this threshold to be achieved cumulative carbon emissions must be limited to 1100 gigatonnes of CO_2 between 2010 – 2050.[57] To meet this target globally, around a third of the world's oil reserves, half the gas reserves and 80 % of current coal reserves must remain unused during the next 40 years. Governments, municipalities, businesses and consumers must reduce the use of fossil fuels with the aim of limiting greenhouse gas emissions. The recent Paris Agreement sent a clear signal that the age of fossil fuels is ending. The governments committed a new 1.5°C goal and this effectively means we need to phase out fossil fuels by 2050. Therefore, Greenpeace demands a global transition to a completely renewable energy system by 2050.

As the sea ice recedes in the Arctic Ocean, as consequence of the climate change, fishing, maritime transport and hydrocarbon exploration will encroach on the northern waters, the high seas, currently, pristine area. Stemming from these activities are a catalogue of serious environmental risks, for example the impacts of black carbon, the threats posed by spills and discharges, the effects of seismic testing, habitat degradation caused by destructive fishing practices, the dangers associated with heavy fuel oil, and of course the resulting climate change once fossil fuels are burnt. Protection of the Arctic Ocean and adjoining seas will provide a critical refuge for many unique species, giving a greater chance of building adaptive capacity and resilience within Arctic area. It is urgent that policy changes now to protect this area, as part of broader measures to protect the Arctic marine environment .

Therefore, with the goal to limit the effects of the climate change on the Arctic biodiversity and, also, the global influence that such changes could drive worldwide, Greenpeace advocates the establishment of an Arctic Sanctuary – a highly protected area prohibiting all extractive industries in the international waters around the North Pole beyond the Exclusive Economic Zones (EEZs) – as part of a wider regional network of Arctic marine protected areas and reserves; measures to prevent destructive industrial fishing in previously unfished areas of the Arctic; and clear rules to prevent oil drilling in icy Arctic waters.

The designation of the "Arctic Ice High Seas Marine Protected Area" at OSPAR Commission[58] would be a step towards this goal. Greenpeace believes that ultimately a strong, legally binding agreement for the Arctic Ocean could offer the framework and the opportunity for greater political action that the Arctic marine environment urgently needs.

57 McGlade, C., Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2 °C. Nature 517: 187-190.

58 OSPAR, Convention for the Protection of the Marine Environment of the North-East Atlantic. http://www.ospar.org/

Photo: © Beltra / Greenpeace