

Climate Change Expression, Implications, and the Urgency of Success

Statement of

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U.S. House of Representatives

for the hearing

Making the Case for Climate Action: The Growing Risks and Costs of Inaction

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Chairwoman Castor, Ranking Member Graves, and members of the House Select Committee on the Climate Crisis, thank you for the opportunity to testify on the critical issue of climate change. I greatly appreciate the work of this committee and its bipartisan efforts to consider the implications of climate change and approaches to addressing the associated challenges. The subject of this hearing, “Making the Case for Climate Action: The Growing Risks and Costs of Inaction” is one of continually increasing importance and urgency, because the risks and costs associated with the changes that are currently well underway grow greater with time. With each passing year, it will be more and more difficult and costly avoid some of the most severe impacts. The consequences of change, if not properly managed in a timely way, are likely to be quite severe.

The mechanisms of greenhouse warming, a key driver of and component of climate change – were understood as far back as 1896, when they were articulated by physicist, chemist, and Nobel Laureate, Svante Arrhenius (Arrhenius, 1896). What was an academic exercise well over a century ago has now become a fact of life in today’s environment, with increasing impacts on the lives and livelihoods of people around the world. From those early experiments and postulations, the science community has significantly evolved in its understanding of the chemistry and physics of climate change. This is particularly so in the last 30 years, as observations, modeling and analysis have become more sophisticated and as the expression of climate change has become more observable. Science foresaw the changes that we are experiencing now, and that very science is now critical to addressing the challenges we do and will face. I am grateful to the members of the committee for the time and energy you are putting into this subject, which is so complex, given physical, human, economic, and political dimensions. Our success as a nation

and society are at stake, and the legacy we leave for our children and grandchildren in the future depends on how well we handle these significant challenges today.

Unfortunately, climate change is often viewed from diametrically opposed perspectives, with the focus being solely on *either* the burden that will be borne by future generations as a result of little or no action to address the crisis aggressively *or* the burden to members of the current generation that could result from the actions taken. Successfully rising to the challenge of addressing climate change depends on considering all of its dimensions and seeking an optimized solution. That is why I am so appreciative of the work of this bipartisan committee, examining the challenges and seeking solutions from a multi-dimensional perspective.

Climate is changing. It always has throughout the history of our planet, and it always will. But we are at a unique time in civilization's trajectory: Today, humans are not only having to respond to the changes, we are driving them. This fact is overwhelmingly recognized by the scientific community, and it has become less and less controversial in other domains – political, social, and economic – as people and communities around the country have been directly feeling the effects of climate change. This converging consensus presents an opportunity – an opportunity to turn what could be a story of loss and despair into a story of triumph and success. Doing so, however, requires a serious examination of the causes of climate change and the implications of both action and inaction, in order to meet the goals that we all share: heading off the worst effects of climate change and thriving nevertheless.

Current expressions of climate change.

While the effects of climate change and its links to greenhouse emissions have been theoretically understood for more than 125 years, the recognition that greenhouse warming was well underway and that its effects would soon be felt began to gain traction in the late 1980s. At that time, and as was articulated in the Intergovernmental Panel on Climate Change First Assessment Report (IPCC, 1990), the mechanisms were clearly understood, and there were indications that the anticipated change was under way. The scientific community, however, could not say with certainty then that the warming observed was sufficiently in excess of the natural variability that it could be attributed to greenhouse gas emissions. A definitive community consensus statement was possible by the time of the 2013 IPCC report, which found “unequivocal” warming of the climate system, as a result of the greenhouse effect (IPCC, 2013). The warming trend is shown in Figure 1. It is notable that every decade since the 1960s has been hotter than the previous ones, and the last six years have been the warmest in the 140-year record.

The observation of warming, and the linking of it to greenhouse gases, is straightforward, and the last time the Earth's temperature was at today's levels was about 125,000 years ago (Petit et al, 1999). However, unlike today, those ancient warm temperatures were driven by the Earth's orbital parameters with respect to the sun; these Milankovitch Cycles have historically been responsible for ice ages and warm periods, and they are described in Campisano, 2012. Today's warming is being driven by something very different: greenhouse gas emissions. The physics are clear and quite simple – increasing the amount of heat-trapping gases in the atmosphere will cause the atmosphere to trap more heat, subsequently raising global temperatures. It is more challenging to directly link environmental conditions and events to that warming, but despite

these “attribution” challenges, the overall trends are clear. As with temperature, we are seeing – as we have come to expect to see – trends that exceed natural variability. And these changes directly impact lives and livelihoods in multiple ways.

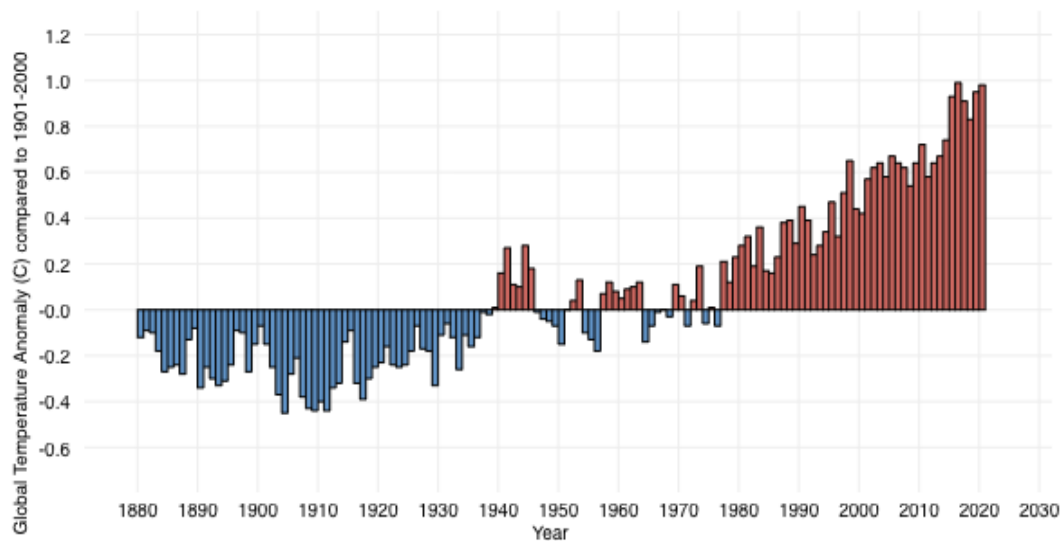


Figure 1: Average temperature differences between annual global temperatures (1880-2020) and the long-term average (1901-2000, which is shown as the zero-line). Blue bars indicate temperatures that were below the average red bars indicate temperatures that were above the average. (NOAA National Centers for Environmental Information, Climate at a Glance: Global Time Series)

Extreme weather

The intensity and frequency of extreme weather events has increased as climate has warmed (NAS, 2016) The recent evolution of such events globally and their underlying causes are shown in Figure 2, and the number of events in the United States costing over one billion dollars and their associated costs are shown in Figure 3. While direct attribution to climate change remains a challenge, the increased occurrences and intensity are in line with what would be expected, given the greater amount of energy that is trapped by the Earth system. So while we can’t say that a particular event or set of events is driven by climate change, we can say that climate change has set up conditions that make such events more likely.

Flooding

One expression of extreme events is flooding, and similarly, attribution of a flood or set of floods to climate change is challenging, and we are not yet at the point where we can say that excessive flooding in a given year is directly attributable to changes in climate. As with warming itself, however, we do understand the mechanics very well, and it is clear that a warming environment creates conditions that are conducive to increased flooding and flood intensity. This arises because warmer air is capable of holding more moisture than cooler air. So as the atmosphere warms, it carries more moisture, and when that moisture is released, it can be released in greater amounts than has historically been the case. Models to date indicate, absent a decrease in emissions, a substantial increase in flooding by the end of the century (Tabari, 2020), and one

study does link an increase in precipitation over the 50-year period from 1950-1999 to climate warming for 2/3 of the Northern Hemisphere (Min et al., *Nature*, 2011).

Number of events

Relevant natural loss events
worldwide 1980 - 2017

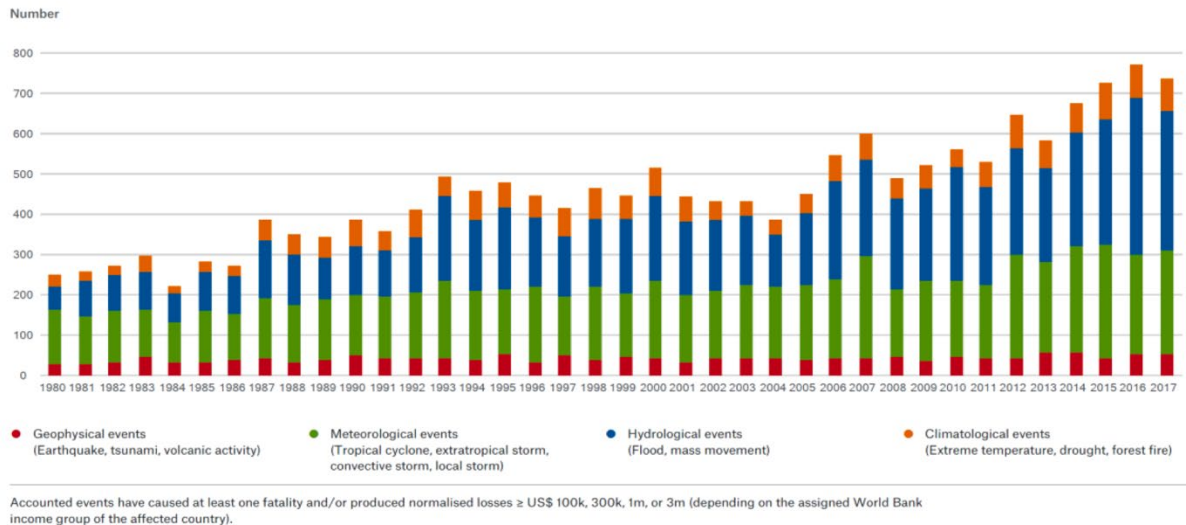


Figure 2: Number of extreme events from 1980 to 2017 related to weather (green, blue, and orange) and non-weather (red) events from 1980 to 2017. Compiled by Munich Re, 2018: <https://natcatservice.munichre.com>.

Billion-dollar disasters and costs (1980-2020)

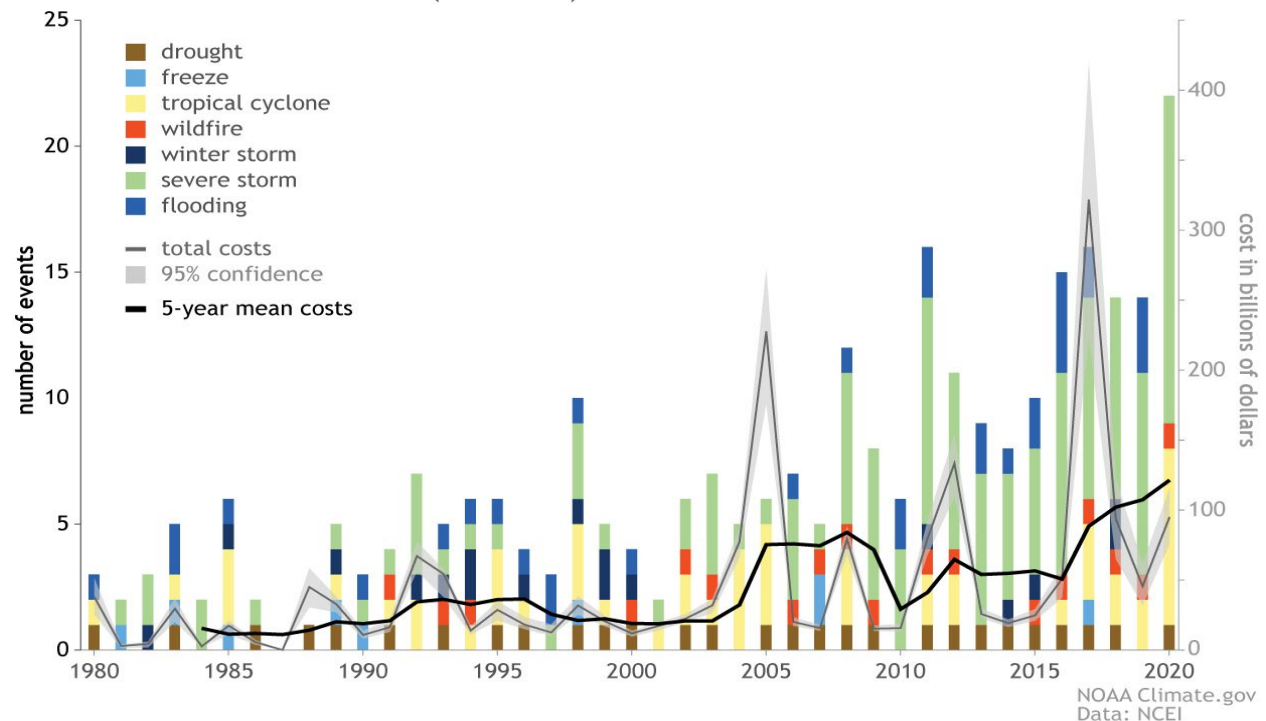


Figure 3: Costs and numbers of billion-dollar disaster events (accounting for inflation) in the U.S. from 1980-2020 (NOAA Centers for Environmental Information, 2021)

Drought

The western United States has been in a drought for the last 20 years, with the current drought ranking among the worst of the last 1,000 years. This drought is attributed, about 50%, to the climate change (Williams et al., 2020). These droughts set the stage for increased wildfires and wildfire intensity, as we have observed recently in the United States. On a global scale, we are seeing declining trends in water storage on land. These trends and regional patterns can be seen in Figure 4. In short: As the Earth is warming, the continents are drying out. That water, once stored as ice and snow, in lakes and rivers, or underground, is making its way into the oceans, and when coupled with the expansion of the warming oceans, is contributing substantially to sea level rise, while also leaving the land drier and more susceptible to droughts and fires.

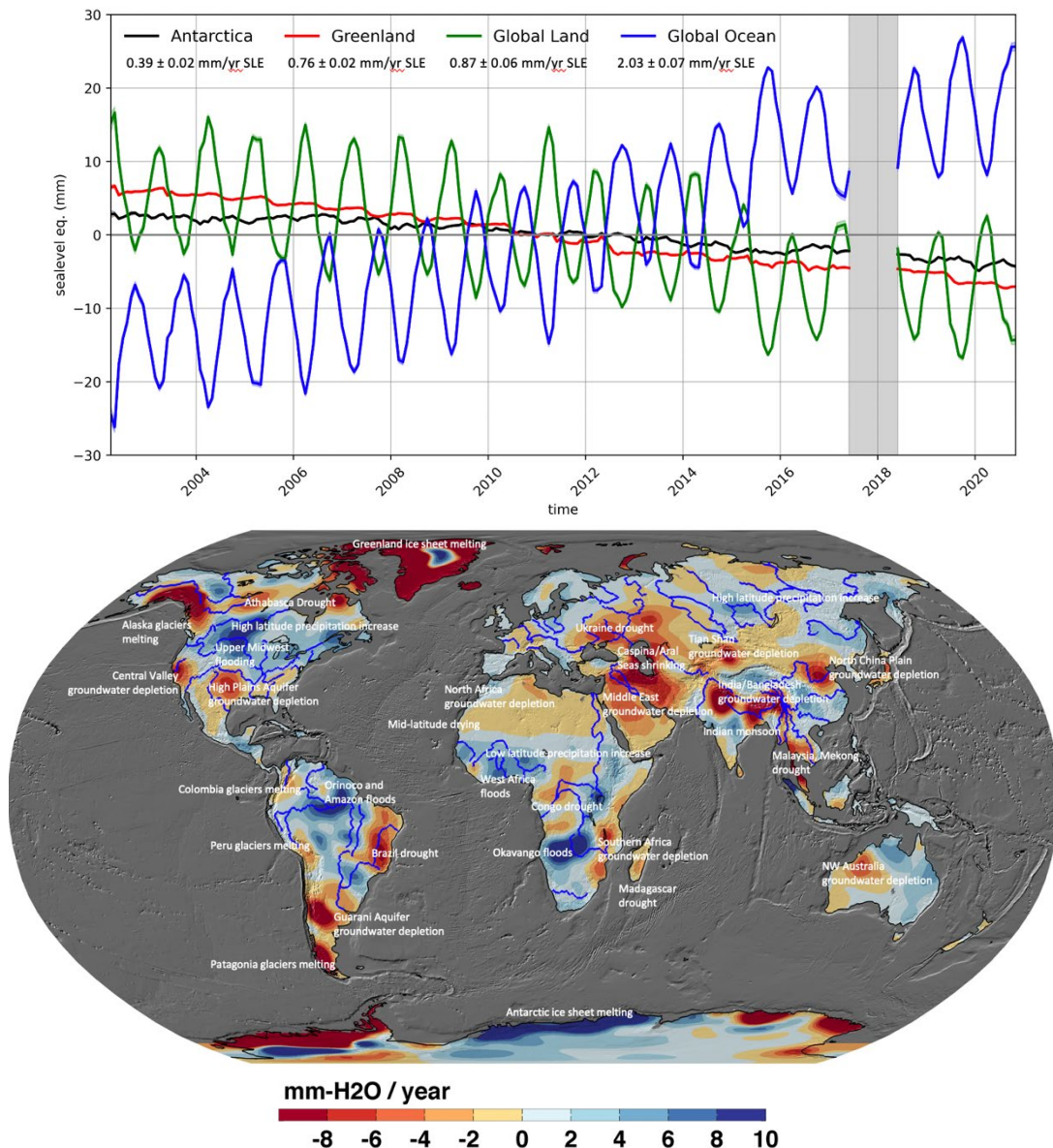
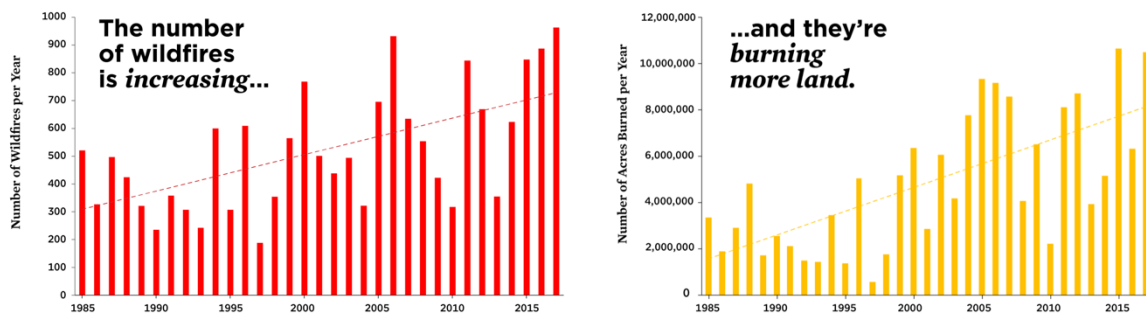


Figure 4: Trends in water mass derived from the Gravity Recovery and Climate Experiment (GRACE) satellite mission and its follow-on (top; Rodell et al., 2018), and regional distribution of mass changes along with the factors driving those changes (bottom; Chandanpurkar et al. 2021). While the effects are variable with gains and losses occurring in different locations, the trends show a drying out of the continents and significant mass loss on Greenland and much of Antarctica, and an increase in ocean mass (and subsequently sea level rise) as water flows from land to the ocean.

Fires

Models and surface data enable us to examine fire season characteristics, and more recently, satellites have been able to effectively and consistently observe fire season length, fire extent, and fire intensity across the globe. Analyses show that as temperatures have warmed, snowmelt has occurred earlier, drought has increased, and forests have remained drier for longer periods of time, the number of fires and fire intensity in the United States have been increasing. (<https://climate.nasa.gov/news/2912/satellite-data-record-shows-climate-changes-impact-on-fires/>).



Data from the Monitoring Trends in Burn Severity program. MTBS only includes large fires in the United States (>500 acres for the eastern US, >1000 acres for the west). Prescribed fires removed.

Figure 5: Number of wildfires in the U.S. (left) and area burned (right) from 1985 to 2015. The graphs are from <https://www.ucsusa.org/resources/infographic-wildfires-and-climate-change>, and the underlying data are from <https://www.mtbs.gov>.

While Figure 5 ends with 2015, the years since have been even worse, as shown in Figure 6.

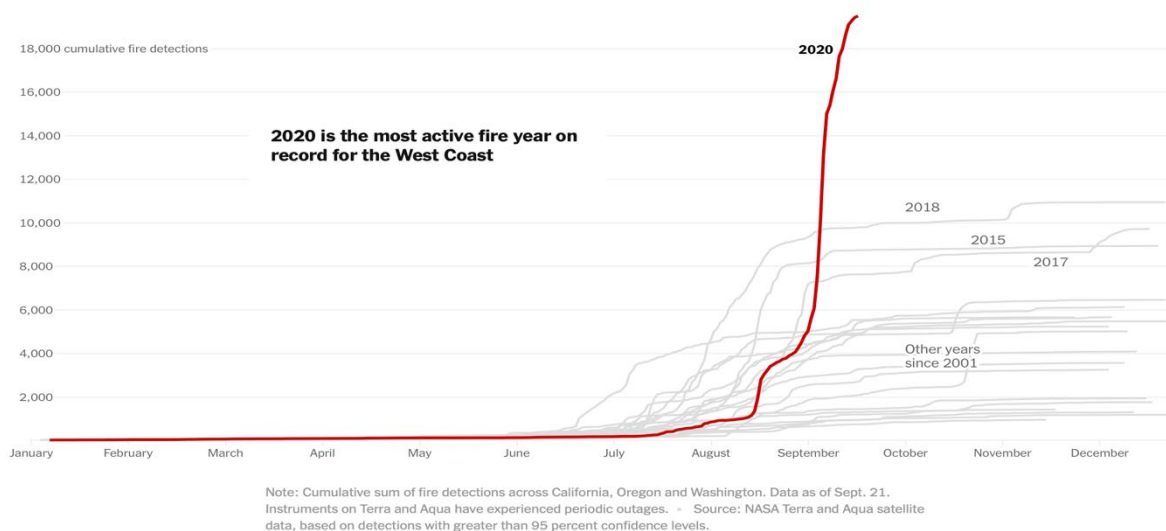


Figure 6: Cumulative Fire Detections since 2001 (Figure from NY Times, Sept. 24, 2020, based on data from the NASA Terra and Aqua Satellites).

Sea Level Rise

In another area that is especially close to home for some members of this committee in particular, oceans continue to rise. They have been doing so at an accelerating rate and will do so for centuries to come (Pörtner et al, 2019). Global mean sea level rise is also accelerating, increasing from its 1901-1990 rate of 1.4 mm/yr to a rate of 3.6 mm/yr during 2006-2015. In some areas, such as in the Southeastern United States, this acceleration is exacerbated by the subsidence or sinking of land. Subsidence results in part from the way the Earth adjusts to the loss of ice from its polar regions (which will get worse as polar land-ice shrinks), and in part because of the sinking of land as a result of extraction of oil and other resources from the land.

Projections for future sea level rise under the current emissions scenario range from 0.61 to 1.1 m (2 to 3.6 ft) by 2100, at which time the rate of rise is projected to be nearly 5x greater than the current rate (15 mm, or more than ½ an inch per year in 2100). Even at a significantly reduced emissions level, in accordance with the Paris Accord, sea level is projected to rise by 0.20 to 0.59 meters (Pörtner et al, 2019) However there are wildcards in the system, locked up in the ice sheets. In the past, oceans have risen rapidly as ice sheets have shed large amounts of ice in short periods of time. Ice loss results from surface melt, in which the water runs off of the ice into the oceans, and from discharge through the calving of icebergs. The latter is tied to the stability – or instability – of the floating rivers of ice at the margins of Greenland and Antarctica. These rivers and their fronts, where the icebergs calve, tend to hold back the large amounts of ice that feed them. As the ice around the perimeter of the ice sheets recedes, ice's buttressing effect is reduced and there is the potential for large amounts of ice to flush into the ocean.

Because this is not yet predictable, this wildcard tends to be left out of sea level rise estimates, but it does mean that the far more substantial rises in sea level could occur. History does offer a cautionary warning in that the last time the earth was as warm as it is today, oceans were 5-10 m higher, and the rates of rise were nearly ten times greater than what we are seeing today (Rohling et al., 2019). So even though the estimates for the current century are high, there is a possibility that reality will be much worse.

Sea Ice

Sea ice in the Arctic has been retreating since the first reliable satellite observations were made in 1979 (Figure 7). The retreat of September sea ice (when ice extent is at its minimum) has been at a rate of about 13 percent per decade. Today, sea ice in the Arctic stretches across an area about half the size of what it covered at the start of the 40-year record.

From a climatological perspective, the loss of sea ice is an amplifier to climate change, as the change from bright cold ice to dark wet ice or open ocean causes the region to absorb more heat than it otherwise would. This “albedo” change is one reason the Arctic is warming more rapidly than the rest of the planet. From a weather perspective, the disappearance of ice is a major perturbation to a structure that has helped govern global air circulation throughout modern civilization. The implications of such a loss are as yet unknown, however there is some evidence that a rapidly warming Arctic and the complex interplay ocean, ice and atmosphere can impact us down here in the US, changing drought, heat, wildfires and storminess patterns from West to East.

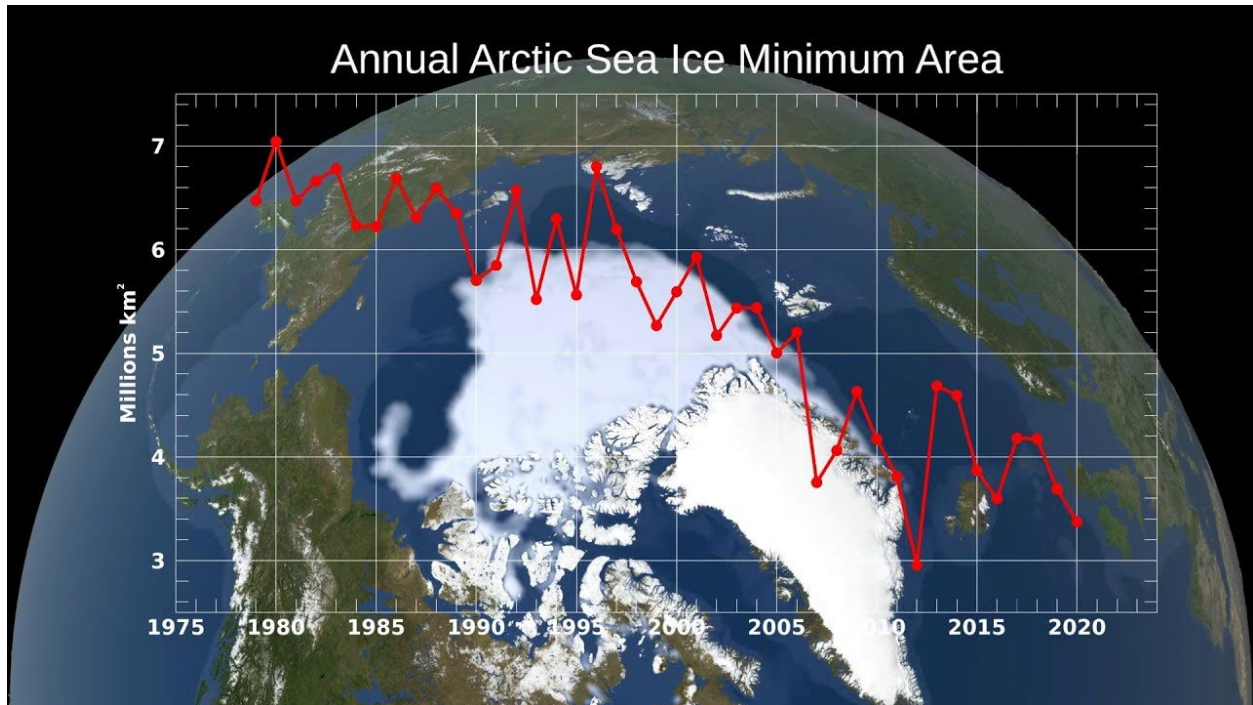


Figure 7: Annual extent of Arctic sea ice, at its minimum extent each year (late September). Minimum extent is indicative of the overall state, since it includes the ice that survives the summer melt season (https://climate.nasa.gov/climate_resources/155/video-annual-arctic-sea-ice-minimum-1979-2020-with-area-graph/).

It is difficult to predict when we will experience and ice-free Arctic in the summertime, something human civilization has never known, but the median estimates are around 2040. While the absence of ice is a major and observable parameter, of greater importance is simply the shrinking and thinning trend that the region is currently experiencing. In addition to its impacts on ocean and atmospheric circulation, the losses are beginning to make the Arctic commercially navigable in the summertime. Such navigability has tremendous economic and security implications as the area becomes commercially and strategically much more valuable than it has been in the past.

In the Southern Hemisphere, Antarctic sea ice had seen increases in extent from the start of the satellite record in 1979 to a peak in 2014. Since then, the Antarctic has experienced such large and rapid loss (Figure 8) that by 2018, the ice extent was less than it was at the start of the record, changing the increasing trend of the first 36 years to a significant net loss over the 1979-2018 40-year period (Parkinson, 2019). Since 2018, there has been some recovery of Antarctic sea ice, toward its initial state.

The Earth's ice cover continues to surprise us, from the loss of Arctic sea ice, which has been much more dramatic than our models had anticipated (Stroeve et al., 2007), to the enormous loss of Antarctic sea ice in a few short years that was far greater than the gains observed in the decades prior, to rapid accelerations in ice sheet outlet glaciers and resulting significant dumping of ice sheet mass into the ocean. Unfortunately, these surprises indicate that in some cases our estimates of one of the fundamental and amplifying variables of the climate system – polar ice cover – are sometimes overly conservative.

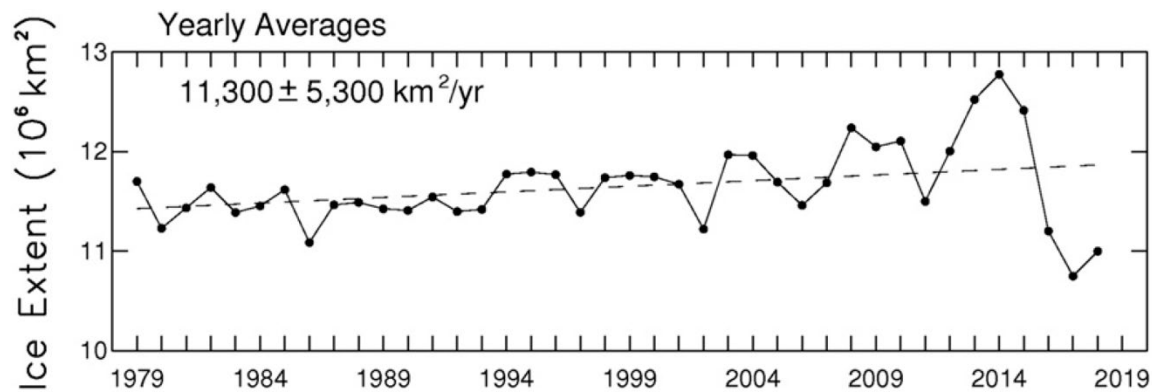


Figure 8: Yearly averages of Antarctic sea ice extent (Parkinson, 2019)

Implications

All of these changes affect the ways we live and will have impacts well into the future. These impacts go well beyond the physical realm, and they can and will be felt in the security, social, and political domains as well. The National Climate Assessment (Reidmiller et al, 2018) captured many of these implications for the United States in their key findings which were:

- The presence of new risks and enhanced vulnerabilities that impact overall well-being in the form of human health, safety, quality of life, and inhibited economic growth.
- Adverse effects on infrastructure and property, with significant economic impacts.
- Poor water quality and reduced water availability, with potentially significant negative effects on agriculture, energy production, industry, recreation, and the environment.
- Dangerous health effects resulting from poorer air and water quality, extreme weather and climate events (e.g. drought, heat, floods, etc.), and disease transmission mechanisms.
- Disruption and destruction of the livelihoods, cultural identities, and interests of indigenous people as their social, physical, and ecological systems are damaged.
- Destruction of critical ecosystems on which our livelihoods depend, including agricultural productivity and food security; examples include crop production, livestock health, etc.
- Further deterioration of an already stressed infrastructure system in the United States, resulting from heavy precipitation events, intense heat, flooding, wildfires and other extreme events.
- Excessive risks to coastal communities resulting from sea level rise, severe storms, and the associated storm surges. From an economic perspective, these phenomena will cause displacement, high adaptation costs and reduced property values.
- Degradation of outdoor recreation environments and economies in areas that are heavily reliant on tourism.
- Cascading effects that will reach far beyond the obvious direct impacts that can threaten essential services on the domestic and international fronts.

On a broader scale, the National Intelligence Council, in its quadrennial *Global Trends* report (National Intelligence Council, 2021), which examines global trends and assesses threats and risks to U.S. national interests, has identified climate change as a key driver of both U.S. and

international conditions and well-being. The impacts of these changes across the globe will affect strategic, humanitarian, and security interests worldwide. In particular the National Intelligence Council report identifies the following implications of climate change:

- Increased sea level rise, threatening coastal communities and low-lying islands
- More intense heat waves, posing risks to health and well-being
- Increased extreme weather, including more intense and more frequent natural disasters, such as stronger storms, flooding in coastal regions, and more drought in arid regions, and changes in weather patterns, with both posing risks to health, safety, economic interests, and infrastructure.
- Loss of biodiversity, impacting food and health security
- Food and water insecurity from changes in precipitation, increased extreme weather, and saltwater intrusion (from rising seas and storm surges)
- Greater human health risks driven by changes in environmental conditions that control the locations, prevalence, and movements of disease
- Forced migration (climate refugees) as currently inhabitable areas become uninhabitable as a result of sea level rise, flooding, extreme heat, excessive drought, etc.
- A disproportionate impact on those in the developing world with fewer means to manage the adverse effects of climate change and adapt accordingly.

It is noteworthy that these flags are being raised by the intelligence community, as these conditions have significant impacts on U.S. national security and other national interests. Some of these items identified are similar to what was reported in the most recent *Quadrennial Defense Review* (Department of Defense, 2014), which identified climate change as an important consideration in U.S. defense interests. In particular, the QDR speaks to the role of climate change in potentially creating political, economic, and humanitarian instability, and the potential for climate change to impact operational capabilities, both in terms of theaters of operation and impacts to military installations and infrastructure.

By 2018, however, the *Quadrennial Defense Review* was replaced by the *National Defense Strategy* – a classified document, with only a summary made available to the general public (Department of Defense, 2018). The NDS summary, entitled “Sharpening the American Military’s Competitive Edge,” makes no mention of climate change. Given this absence, and given the importance of understanding, anticipating, and preparing for climate change to the U.S.’s position on the international stage and our national security interests, its inclusion in the National Intelligence Committee report is essential.

Successfully Meeting the Climate Change Challenge

Successfully meeting the challenges posed by our changing climate, while ensuring that the solutions that we employ are optimized to balance the climate risks with economic interests, requires, science, honesty about the risks of action and inaction, the political will to resist forces that work against solutions. It also requires a long-term view – as the Founders had – that hard choices must be made today to ensure the success of the generations that follow us.

On the scientific front, the science community has worked diligently to understand the mechanisms, manifestations, and implications of climate change. The community foresaw the

changes that we are seeing today and will be critical in providing guidance for addressing changes going forward, by continuing to understand these changes, assessing the effectiveness of mitigative measures, and providing the insights necessary to inform adaptation strategies. Observational capabilities as well as modeling and analysis capabilities need to be maintained and enhanced, so we can observe the conditions, understand the implications, inform action, and assess likely outcomes.

Because changes occur on global scales, and with significant regional variability (e.g. Figure 4), and because different components of the Earth/Climate system interact with one another in complex ways that vary spatially and temporally, sustained space-based observations are critical tools for monitoring and understanding climate change. In fact, what we know about fire seasons and intensity, hurricane and large-storm processes, changes in polar ice, movement of water across the globe, the radiative balance (heating/cooling) of the Earth, and so much more, is directly derived from satellite observations. Satellites (which need to be complemented by ground-based and airborne, and other observations), provide a consistent global set of measurements that capture the local and regional nature of the fundamental environmental variables and the interactions among them. Consequently, investments in space-based observations of the Earth are an essential component of a global observing system that is robust enough to help us address the climate challenge. A prioritized blueprint for U.S. investments in space-based Earth observations was developed by National Academy of Sciences (NAS, 2018).

Such investments in observations, as well as in modeling and analyses, are critical to ensuring that we are an informed nation and society, and that decision-making is done with a clear view of what is at stake and the implications of our choices. While I am referring primarily to the observation and analysis of physical processes that drive climate change, it is similarly important that we study and understand resilience in the economic and social domains, so that we understand the factors driving behaviors and economic impacts of our actions. Such understanding in all of these areas is necessary for not only meeting the challenges in the most optimal and least damaging ways, but continuing to thrive despite the them.

On the policy front, I defer to you, members of the committee, and your colleagues, as well as the Presidential Administrations (plural, because this is a multi-Administration and multi-generational challenge) to integrate all of the information and make decisions that lead to sound policies and effective action. It is absolutely critical, however, that all dimensions of this existential challenge be considered. This is a national and global challenge, with highly impactful national and global consequences. It that needs to be met with a national and global perspective in a coordinated and integrated way. The science is clear – the costs of little or no action are dangerously high. Choosing the “best” action requires an appreciation of all of the aspects of the challenge we face. In too many instances, science has not played its appropriate role in decision-making as it relates to sound policies to manage the risks and threats of climate change. As a result, we have lost precious time. I am not prone to alarmist statements, as I think they force people to fortify their postures rather than flex and consider solutions. But our chances for success are diminishing. We have lost time, and we cannot afford to lose more. The consequences of too little action will be dire. There currently remains opportunity to manage the challenge, but it requires bold action. It is urgent and imperative that those entrusted with the strength, security, and well-being of our Nation, its citizens, and its future generations,

adequately consider the science, as well as all the other dimensions of the challenge, and make choices that will secure the future that we all wish for our children, grandchildren, and beyond.

I will end as I began. Climate has always changed, and it always will. But today it is changing in ways that can profoundly impact our health, security, lives, livelihoods, and well-being. Because of our relationship with our environment and the fact that modern civilization has realized the success it has through its industriousness and other activities that contribute to the very crisis we seek to avoid, the solutions are hard. But, the success of society and its ability to thrive in the face of a changing environment depend on: 1) the magnitude of those changes, 2) the rates at which they occur, and 3) our ability to anticipate, prepare for, and adapt to them. The magnitude and rate can be affected by mitigation measures – reducing greenhouse gas emission, particularly carbon dioxide. These measures depend on policies that are informed by science. Similarly, our ability to anticipate, prepare for, and adapt to climate change requires guidance from science, guidance from the very science that anticipated the changes we are seeing today.

The limited actions to address this climate-change crisis have resulted in lost opportunity and have produced a challenge that is even greater than it was even just a few years ago. With the political and societal will, and with strategic and scientifically informed action that considers the social, physical, economic, and political dimensions of the climate change challenge, the dangerous trajectory we are on can be altered such that our generation's story can be one of success, not failure. Making it so requires hard choices, commitment, will, and a respect for the science. And as a citizen, I look forward to this body demonstrating the will and commitment and make the hard choices. And as a scientist, I and my colleagues stand ready to provide you with the best information possible to inform those choices and actions.

Thank you very much for your time and for your efforts in tackling what truly is an existential challenge.

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