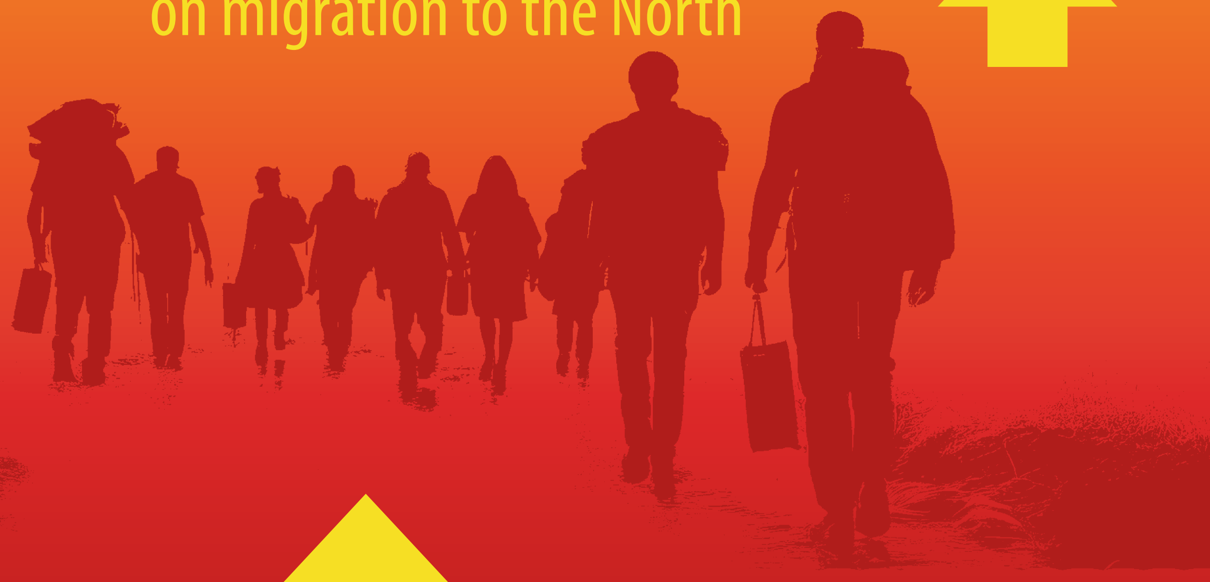
Boris Soukharev

Global Warming and Mass Migration

Climate change and its impact on migration to the North



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To my wife Anna, without whose endless patience, great help and incredible faith in me, this book would never have been written.

Preface: What Is This Book About?

Dear Reader!

This popular science book targets readers around the world who are interested in understanding what is happening to our climate, why further global warming and climate change are inevitable, what the main consequences are, and what humanity should do in this dire situation.

This book differs significantly from most of the existing literature on global warming and climate change. It is common to read in most newspaper or magazine articles, popular science books, and even in many scientific publications on climate change that although global warming is caused by human activities, humans still have the power to stop it from getting worse. The authors usually repeat the same climate policy mantra—that time is running out, but we can still stop global warming if we act now. This misleading idea is endlessly repeated and passed on from one book or article to the next.

In contrast to the literature, which talks about things that may be good for the climate but are unattainable in practice, this book describes the reality and presents evidence that clearly shows that *humanity will not be able to stop global warming and climate change in the foreseeable future*. The reasons for this do not lie just in ever-growing human economic activity, which is steadily increasing anthropogenic emissions of greenhouse gases. There is an even bigger, far worse problem. Anthropogenic global warming has awakened the so-called "sleeping giants"—dangerous powerful natural processes of positive climate feedbacks—which have already quickly begun to increase this warming. Positive climate feedback is a process in which some initial change in climate induces a secondary change, which in turn greatly increases the initial change. For example, global warming (initial climate change) causes permafrost to thaw (secondary change) and releases greenhouse gases from decaying organic matter in thawing permafrost, which in turn further increases global warming (increase in the initial climate change).

Before the Industrial Revolution, these positive climate feedbacks were dormant because the Earth was in a state of natural radiative equilibrium where incoming energy from the sun was balanced by outgoing energy from the Earth. Now, with Earth's ever-increasing energy imbalance, these natural "giants" have been awakened, and the big problem is that once awakened, they will not go back to sleep, even if humanity stops emitting greenhouse gases into the atmosphere. This is because global warming and positive climate feedbacks intensify each other in a self-amplifying loop: rising temperatures reinforce climate feedbacks, while stronger climate feedbacks accelerate the warming even more.

The activation of powerful positive, self-reinforcing climate feedbacks completely changes our understanding of what will happen to the climate in the future, because it means that *further global warming will no longer depend only on further anthropogenic emissions of greenhouse gases, as in the past, but also on climate feedbacks*. These positive climate feedbacks are like a very dangerous genie that has already popped out of the bottle and now cannot be put back. Even if, sooner or later, humanity begins to reduce global greenhouse gas emissions (even if significantly), the self-reinforcing climate feedbacks already initiated will still lead to further global warming. It is therefore important to recognize that *reducing emissions can slow global warming, but not stop it*. With or without further anthropogenic emissions, the self-reinforcing climate feedbacks will continue to cause significant warming and will lead our planet to much hotter conditions as early as the twenty-first century, probably well above the ~3 °C global warming assumed under current global climate policy. In fact, global warming could exceed pre-industrial levels by as much as 4–5 °C by the end of the twenty-first century.

A detailed explanation of what these positive climate feedbacks are, how they work, and what additional warming they may cause forms a large and important part of this book. Such information is almost entirely absent in much of the existing literature on climate change, which tends to concentrate mainly on anthropogenic emissions of greenhouse gases.

With further climate warming imminent, what should humanity do? This book shows that *humanity has no choice but to prepare for the worst-case scenario of a climate crisis and to adapt to a new, much less comfortable climate*.

As the reader can see from this book, countries located in tropical and subtropical latitudes will be much more affected by climate change than those located in temperate and polar latitudes. This is a gross "climate injustice," for although poor developing countries in the Global South (i.e., mainly those in

Africa, Asia, and Latin America) are the least responsible for the anthropogenic greenhouse gas emissions that cause global climate change, it is they that will suffer the most from its effects, which will be particularly evident in terms of intolerable temperatures and deteriorating water and food security (Fig. 1).

This is why in many regions of the Global South it will be very difficult to adapt to adverse climate change, while in some areas, adaptation will not be possible at all.

As this book explains, by striking an incomparably greater blow to the South than to the North, climate change is preparing very different fates for the South and the North. In the coming decades, the increasingly severe (in some areas even catastrophic) impacts of climate change on the poor and vulnerable Global South will make it even poorer and more unstable, while the rich Global North will become even richer (as many northern economies may even benefit from climate change). This means that *as global warming accelerates, the contrast between the poor and unstable Global South and the rich and secure Global North will become increasingly stark. This ever-increasing contrast will be the main driver of forced mass migration from the South to the North*—the worse the climatic, socio-economic, and security conditions in the Global South compared to the Global North, the greater the South-North migration flow. This book explains why this massive climate migration from South to North may begin as early as within the next two decades.

How do we deal with the imminent future climate change-induced socio-economic and political instability in the Global South and the massive, forced migration toward the Global North?

Fig. 1 No food, Turkana. Eastern Uganda. *Credit: Rod Waddington. Source: Flickr (under CC BY-SA 2.0 license)*

How can we avoid global destabilization and chaos?

As the reader will see from the book, *the only way to avoid the global destabilization caused by forced mass migration is to unite the world around the issue of orderly adaptation to inevitable climate change*. To become one, the world will have to change itself *ethically* to become more just, solidarity-based, and cooperative. More just and solidarity-based, because the world will need to establish “climate justice” to help poor southern countries adapt to the climate change caused by the economic activities of rich northern countries, and more cooperative, because the world will desperately need close cooperation between the West and the East to manage the ever-growing migration flows from the South. Only such a united world will be able to survive the coming climate crisis and the resulting mass forced migration without descending into chaos.

The book is divided into seven chapters.

The first chapter briefly looks at the signs of global warming and explains why humans are responsible for it.

Chapter 2 describes what our climate will be like in the coming decades of the twenty-first century. In particular, the reader will see that at the current extremely high rate of climate change, it will only take 10–20 years for our climate system to return to the Middle Pliocene warm period conditions that occurred about 3.0–3.3 million years ago.

Once the Earth’s climate has stabilized under conditions similar to those of the Middle Pliocene, it will only be a matter of time before the Earth reaches about the same global average air temperatures (2–3 °C warmer than now) and sea levels (up to 25 m higher than today) as it did during that past warm period.

Additionally, Chap. 2 also considers future global warming projections based on different scenarios of anthropogenic emissions.

Chapter 3 describes some of the most important positive, self-reinforcing climate feedbacks, such as water vapor feedback, cloud feedback, ice-albedo and snow-albedo feedbacks, and several carbon-cycle feedbacks in the ocean and terrestrial biosphere, and explains why their activation will make our ongoing climate crisis much worse. Chapter 3 also provides evidence that these dangerous climate feedbacks are already occurring, significantly exacerbating global warming.

Chapter 4 explains why, even in the hypothetical absence of positive climate feedbacks, humanity would not be able to stop global warming in the coming decades. In particular, this chapter explains why the now very popular “net-zero” concept of stopping global warming is not feasible. It also describes how the inertia of human socio-economic and political systems prevents the world from rapidly reducing global greenhouse gas emissions.

Chapter 5 explains how positive climate feedbacks will cause further global warming even if anthropogenic emissions of greenhouse gases are reduced substantially. The chapter shows that positive climate feedbacks can cause substantial warming that is not fully accounted for in current climate models.

Chapter 6 explains why adaptation will be crucial because humanity will not be able to stop further global warming and climate change any time soon. The reader will also see that in some regions of the Global South adaptation will be very problematic, and in some areas impossible.

And lastly, Chap. 7 presents a grim prognosis for the coming decades—climate-induced destabilization of the Global South could lead to global destabilization through forced mass migration from the South to the North. The world can only avoid chaos if in the face of an imminent climate crisis it will unite around the challenge of adapting to adverse climate change in an orderly manner. But, in order to become united, the world must change ethically to become more just, solidarity-based, and cooperative.

The future will show if the world will have time to reform itself before chaotic forced massive migration from the South to the North leads to a global catastrophe. We know that without this type of transformation, real adaptation will be impossible and will result in climate change destabilizing the whole world, so let's hope that we can come together to avoid this before it really is too late.

Poznan, Poland Boris Soukharev

Acknowledgments

This book would not have been possible without the knowledge I gained during my career as a climate scientist at the universities in three different countries—St. Petersburg State University in Russia, the Free University of Berlin in Germany, and the University of Arizona in the United States. I would, therefore, first like to thank my former colleagues at these institutions—Prof. Dr. Oleg Drozdov, Prof. Dr. Karin Labitzke, and Dr. Lon Hood, respectively—who shared their wisdom about science and taught me not only how to analyze facts, but also how to see beyond them.

I am extremely grateful to the book's Scientific editor: Dr. Anita Zavodska (Barry University, U.S.A.), for her thorough and thoughtful review of the entire book and discussion of many important aspects of it, which greatly improved the final product.

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It took me over 2 years to write this book, so additional thanks are due to my relatives and friends, including Svetlana Koudria, Julia Afanasyeva, Sandy Cohen, and Rajeev Wankar, for providing the necessary moral support along the long journey.

I am indebted to my parents for their unwavering faith in me. I would not be a writer today if it were not for the guidance and wisdom of my mother Tatiana Soukhareva, who herself is our family writer, and who said in my distant childhood, more than 50 years ago, that she believed I would someday become a writer.

Finally, I am very grateful to my lovely children, Alexey and Anna, for their boundless support and enthusiasm, reading parts of the book and helping with the design and illustrations. They and their children, my grandchildren Piotr and Ania, will have to learn to live in a new, much less favorable climate. This book is for them and for all the young people in the world, as it is the young people who will have to find the will and strength, provided they have the power, to transform our world into a more just, solidarity-based, and cooperative society, to avoid the worst effects of the impending climate crisis.

Contents

1

Signs of Global Warming and Climate Change Can Be Seen Everywhere

When we speak about global warming, we mean a steady and consistent rise in the Earth's global surface temperature (an average of sea surface and air-over-land temperatures) over many years, decades, and even centuries. Since temperature is a key climate variable, global warming is one of the most important aspects of the global climate change phenomenon which includes not only temperature changes but also many other effects that result from global warming, such as glacier melt, sea level rise, and changes in some extreme climate event patterns.

- *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia."*
  –United Nations Intergovernmental Panel on Climate Change (IPCC) [1]

1.1 The Unprecedented Rate of Global Warming and Climate Change

1.1.1 Global Surface Temperature Is Rising Rapidly

Can we say with absolute certainty that global warming is real and that the Earth's climate is changing? Yes, we can. Moreover, the Earth's climate is not just changing, it is changing extremely fast, much faster, in fact, than it ever

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has in the past. Scientific data from tree rings and ice cores show that the recent increase in global surface temperature is unprecedentedly fast compared to past climate change.

The chart from the National Oceanic and Atmospheric Administration (NOAA) in Fig. 1.1 demonstrates how significantly global surface temperature increased over the recent 143 years, from 1880 to 2023.

In Fig. 1.1, the black solid trend line shows that on average, between 1880 and 2023, global surface temperature increased by almost 1.2 degrees Celsius (°C). Even though during this 143-year time period the mean rate of global warming was only +0.08 °C per decade, during the last several decades the rate of warming has increased much more than before: in the last 50 years alone, global average temperature has risen nearly twice as fast. The last decade (2011–2020) was the hottest decade ever recorded, flashing an evident warning sign to humanity. As seen in Fig. 1.1, 2016, 2019, 2020, and 2023 stand out for their exceptional warmth.

While Fig. 1.1 shows changes in surface temperature averaged over the globe, it is important to recognize that the Earth is not warming uniformly—air temperatures over land rise much faster than air temperatures over the ocean. Data from NOAA's National Centers for Environmental Information show that the air above the world's continents warms twice as fast as the air above the world's oceans—between 1880 and 2023, global land surface air temperature increased by about 1.6 °C, while global sea surface temperature

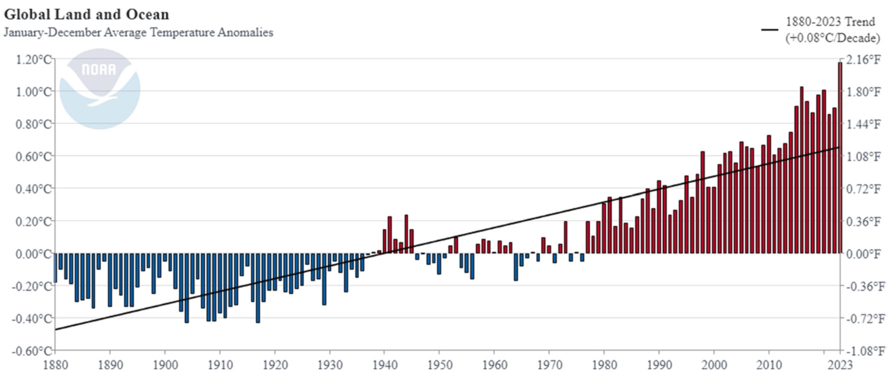

Fig. 1.1 Annual global surface temperature anomalies, from 1880 to 2023. Anomalies are calculated with respect to the twentieth century average. The black solid line denotes a linear trend in global temperature (i.e., it denotes the general direction in which global temperature is changing). *Source: NOAA National Centers for Environmental Information, Climate at a Glance: Global Time Series, published July 2024, retrieved on August 05, 2024 from* https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series

increased by only about 0.8 °C. This contrast between the rates of warming over land and ocean has important implications for humans because we live on land.

The interested reader may wonder why temperatures over land increase much faster than temperatures over the ocean. One of the reasons is that the ocean has a much greater heat capacity than land, which means that the ocean needs more heat and more time to raise its temperature significantly. Another reason is that the evaporation of water from the ocean has a cooling effect on the ocean surface (evaporation causes cooling because this process requires heat energy). In contrast to the ocean, the continents do not have much moisture to evaporate, and so evaporation and the corresponding cooling are constrained. Thus, while over the ocean a part of global warming goes into evaporation, over the continents, much more of the global warming goes directly into temperature rise.

An important conclusion from this land–ocean global warming contrast is that as global warming continues, *the continents—where humans live—are expected to warm much more than just by the global average*.

Looking at Fig. 1.1, which shows that since the end of the nineteenth century global surface temperature has increased by almost 1.2 °C, some readers may ask: Why is this change in global temperature a concern when a global warming of 1.2 °C seems so small?

Well, first of all, one has to remember that the 1.2 °C warming is just an average estimate of the globe's warming and as stated above, warming over the continents is higher than the global average which is already about 1.6 °C above pre-industrial levels. Besides, even on the continents, some regions of the world experience a much higher warming than just an average. For example, over the past few decades, the Arctic has warmed more than 2–3 times faster than the rest of the globe—scientists call this phenomenon the *Arctic amplification*. In general, polar and moderate latitudes warm faster than the tropics, and temperatures over land surface rise much more than temperatures over the ocean.

Additionally, we need to understand that a seemingly small amount of global warming reflects really large temperature changes at a particular location. Imagine a given location on Earth where daily temperature swings during various weather events can be on the order of as much as tens of degrees. If all the measurements of daily maximum and minimum temperatures from many thousands of locations all over the globe are averaged together over a year, then the resulting single estimate of global annual average temperature usually fluctuates by no more than a few hundredths to two tenths of one degree from year to year. If such globally and annually averaged temperature has increased by 1.2 °C, then this indicates really substantial warming at thousands of specific locations on Earth. This is well illustrated in Fig. 1.2, which shows annual mean surface temperature anomalies (relative to the 1950–1980 average) in the 1960–1970 time period, and 50 years later, in the 2010–2020 time period.

Looking at this figure, the reader can see a striking difference between the temperature maps. Although they are only 50 years apart, it looks like they represent two completely different worlds: a relatively cold world with large areas of negative temperature anomalies in the 1960–1970 time period and a much warmer world with areas of predominantly positive temperature anomalies in the 2010–2020 time period.

This simple comparison of the two temperature maps demonstrates how remarkably warmer Earth's climate has become within just 50 years. No matter in which country the reader lives, he or she must have certainly already noticed a huge contrast between childhood climate and now. It looks like the climate is changing rapidly right before our very eyes. Each of us sees this, because we remember the climate from our childhood and see what is happening now.

The striking difference between the global temperature maps in the 1960–1970 and 2010–2020 time periods shown in Fig. 1.2 is not caused by an unusual natural variability of global temperature in these two particular time periods, but by the relentless increase in surface temperature all over the world within the last several decades. The average annual temperatures have increased almost everywhere in the world, with the highest increase observed in the Arctic (warming from 3 to 6 °C) and in Europe, North Africa, the Middle East, the United States, and Russia (warming from 1.5 to 3 °C).

Thus, while the average rate of global warming—about 1.2 °C since pre-industrial levels—may seem modest, it is in reality not that modest at all, since the observed rate of warming in some specific regions is very substantial. Besides, it is important to note that global warming is accelerating, which means that it will take less time for the warming to reach new highs. In this situation, even tenths of a degree of additional global warming really matters for our climate and for humanity. With continuously increasing greenhouse gas emissions humanity is definitely on its way toward a 1.5 °C warming above pre-industrial levels by as early as the 2030s. Then, if the rate of global warming remains as it is now, within just another 15 to 20 years human civilization will find itself in a world that is 2 °C warmer where land may be two to three times warmer than the average global warming, the Arctic may be up to four times warmer (perhaps

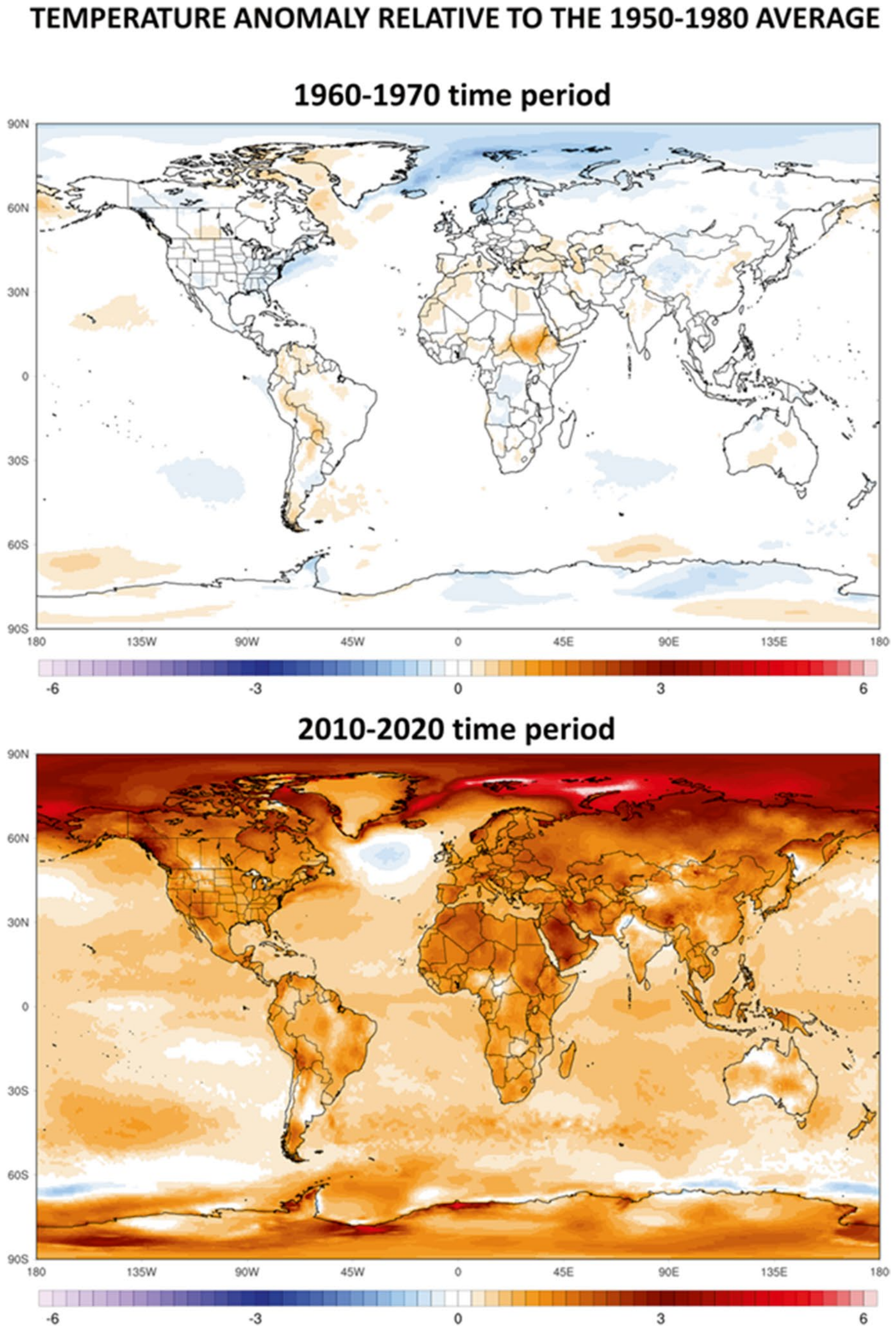

Fig. 1.2 Average surface temperature annual anomaly (in degrees Celsius), relative to the 1950–1980 average: in the 1960–1970 time period (upper panel), and 50 years later, in the 2010–2020 time period (lower panel). Based on the data from ECMWF ERA5 dataset. *Images from Climate Reanalyzer (*https://ClimateReanalyzer.org*), Climate Change Institute, University of Maine, U.S.A. Published with permission from Climate Reanalyzer*

more than 8 °C), and the summer temperatures in some areas of Asia, the Middle East, and Africa may become so hot that they will exceed the physiological threshold for human adaptability.

Even now, accelerating global warming has been accompanied by an evident increase in frequency and intensity of extreme heat waves, deadly droughts, floods, and storms. For example, 2020 witnessed a record number of hurricanes in the Atlantic—so many that the World Meteorological Organization (WMO) even ran out of letters in the alphabet to name them [2].

1.1.2 Extreme Heat Waves Are Becoming Even More Extreme

Global warming raises the average temperature of the Earth's atmosphere. Due to this, in just the past few decades, rising average temperatures have significantly worsened extreme weather events such as deadly heat waves, across the world. A recent example of such an extreme heat wave which hit Europe on July 24, 2019, is shown in Fig. 1.3.

This extremely strong heat wave was one of the two distinct European heat waves that occurred in summer 2019 (in June and then, in July), which set all-time high temperature records in Belgium, Germany, Luxembourg, the Netherlands, and the United Kingdom [3].

The 2019 June heat wave exceeded previous records by 3 °C in Belgium, by 0.3 °C in Luxembourg, by 2.1 °C in Germany and the Netherlands, and by 0.2 °C in the United Kingdom. France experienced temperatures in excess of 45 °C for the first time in recorded history [4]. This first deadly heat wave killed over 500 people. In late July 2019, the second heat wave led to the deaths of more than 800 people in France as well as thousands of animals when ventilation systems were overwhelmed [5].

Another relevant example showing that the rising trend in extreme heat waves is becoming a global issue is the very densely populated state of California in the United States. In early September 2020, a severe heat wave broke temperature records in several areas of Southern California. The hot conditions contributed to new and existing fires that destroyed tens of thousands of acres of land. The map in Fig. 1.4 shows air temperatures across the United States on September 6, 2020, when much of the Southwest experienced a dramatic heat wave.

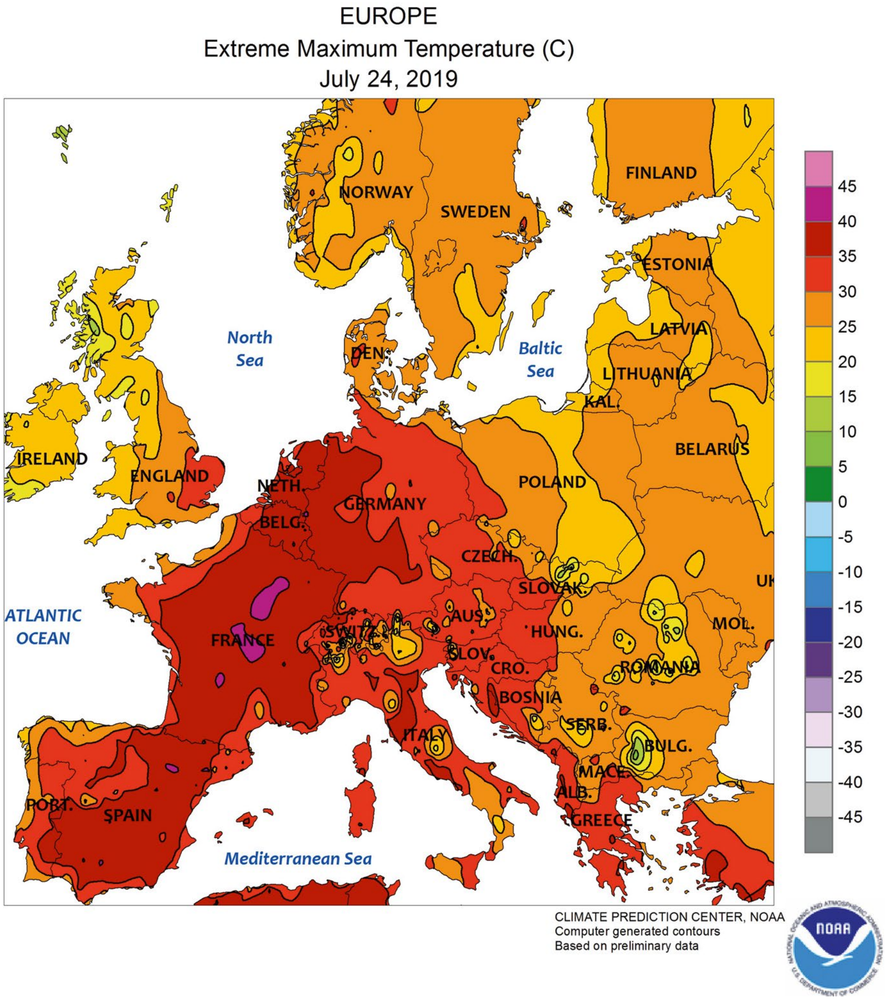

Fig. 1.3 Extreme maximum temperature in Europe (°C) on July 24, 2019. *Credit: Climate Prediction Center, National Oceanic and Atmospheric Administration (NOAA). Source: Wikimedia Commons/Public domain*

On September 6, 2020, Los Angeles County registered its highest temperature ever of 49 °C at Woodland Hills. Several other cities, like Paso Robles and Palmdale, also hit record highs [6]. This extreme heat event came only weeks after another record-breaking heat wave in California. In August 2020, Death Valley reached 54 °C—possibly the highest temperature ever recorded on Earth [6].

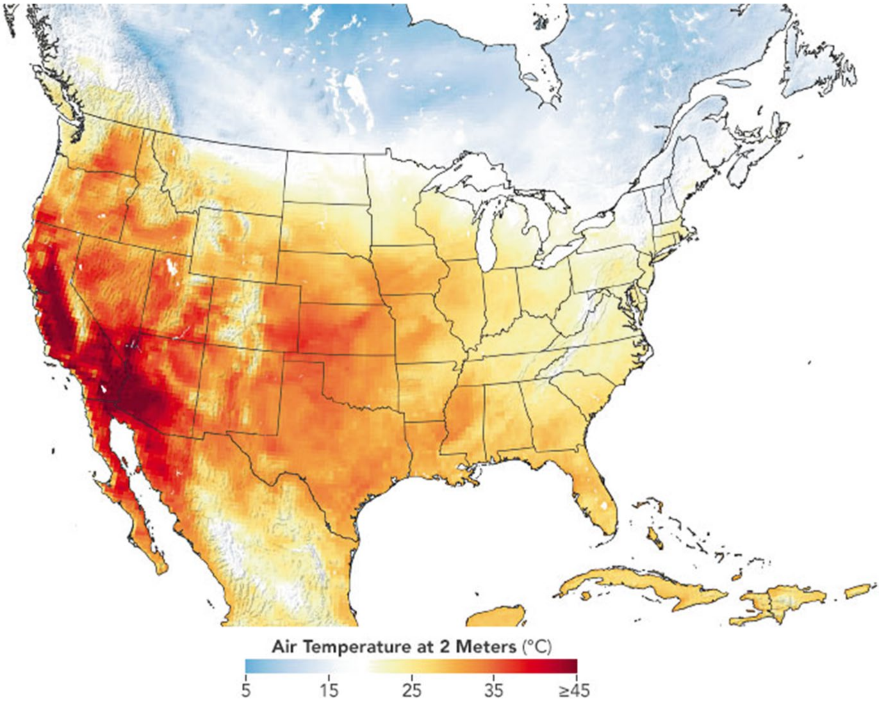

Fig. 1.4 Near surface air temperatures over the United States on September 6, 2020. *Credit: NASA's (National Aeronautics and Space Administration's) Earth Observatory*

Although recent extreme heat waves across the globe broke new records in their intensity, they are not at all surprising to climatologists. *As global average temperatures increase, extreme heat events, such as those shown in Figs. 1.3 and 1.4, are expected to become more frequent, more intense, and more destructive*. They are expected to cover larger areas and last longer. Heat extremes will become even more extreme. They will have major negative impacts on society, economy, ecosystems, and on human health, and they can impact natural and human systems much more than just average climate can [7].

Even now, across the globe, hot days are getting hotter and more frequent, while cold days are getting less cold and less frequent. Across the continental United States, over the past decade, daily record temperatures have occurred twice as often as record lows, up from a near 1:1 ratio in the 1950s [8]. In a recent study [9] published in the journal *Earth's Future*, a group of scientists led by Dr. Glynn Hulley, a climate researcher at NASA's (National Aeronautics and Space Administration's) Jet Propulsion Laboratory, showed that heat waves had become more frequent, intense, and longer-lasting in California between 1950 and 2020 (Fig. 1.5).

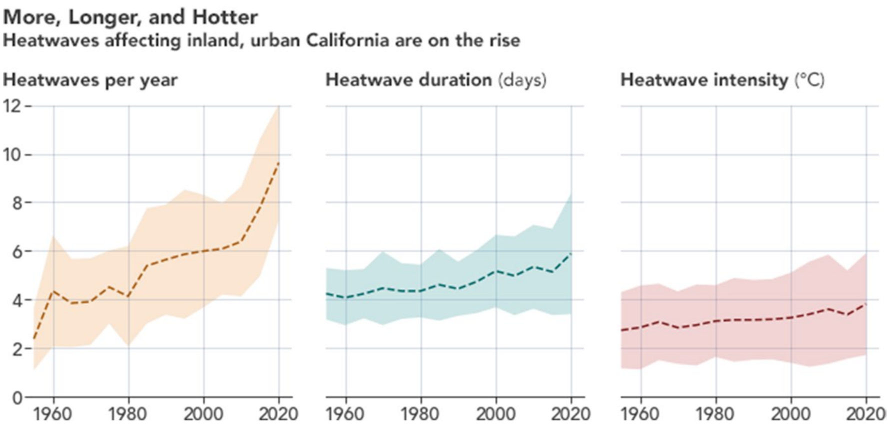

Fig. 1.5 The graphs show the number of heat waves per year, the duration, and the intensity for inland urban areas in California from 1950 to 2020. The dotted lines represent the average values. The shaded areas show the standard deviation. *Credit: NASA's Earth Observatory*

The highest increase in heat wave activity was found in inland urban areas such as Los Angeles County. Researchers suggest that a major reason for increased heat waves is warmer nighttime temperatures. Heat wave nighttime temperatures combined with high humidity have been increasing at an extremely rapid rate of ~1 °C/decade since the 1980s elevating heat stress and mortality risk to vulnerable urban communities.

- *"The heat waves that end up killing a lot of people are really warm, humid night-time heat waves, and they are going to become more common. Night-time is normally your chance to cool off, but now there's less relief from the heat wave."* [6]

–Dr. Brian Kahn, researcher at NASA's Jet Propulsion Laboratory and co-author of the study [9]

Dr. Hulley and his colleagues also showed [9] that heat waves in Southern California are now occurring earlier and are persisting later into the year, resulting in a longer heat wave season. Compared to the middle of the twentieth century, when the heat wave season typically began in May and ended in August, today heat waves begin in March and end as late as September–October.

Now, let's look at Africa.

Africa is the continent which, more than any other, is exposed to unfavorable consequences of global warming and climate change. Figure 1.6

illustrates how the extreme temperature regime of heat waves across Africa has changed over recent years (1981–2015). Heat waves in this figure have been quantified [10] using the *Heat Wave Magnitude Index daily (HWMId)*, which merges the duration and the intensity of extreme temperature events into a single numerical index. The *HWMId* enables a comparison between heat waves of different timing and location, and has been applied to maximum temperature records [10]. The results presented in Fig. 1.6 have seven maps, where each map represents one 5-year time period. In the first map, which corresponds to the 1981–1985 time period, the area covered by heat waves, their duration and magnitude was not that big. But with every subsequent 5-year period, the spatial distribution, duration, and magnitude of the heat waves had become bigger. The last map corresponds to the 2011–2015 time period. The reader can see how big the difference is between the first map (1981–1985) and the last one (2011–2015), by how much the spatial distribution, duration, and magnitude of heat waves have increased during only 30–35 years. Especially large increases are observed in North and South Africa.

The maps in Fig. 1.6 show not only that the intensity of extreme temperature events in Africa has increased exponentially but also provide clear evidence of a very high rate of ongoing global warming and climate change. If

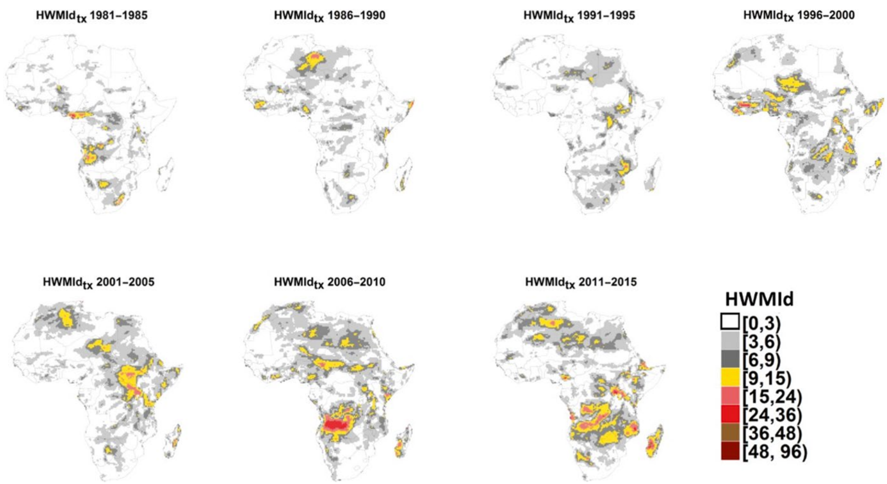

Fig. 1.6 Magnitude of Heat Wave Index of maximum temperature (*HWMIdtx*) for 5-year periods from 1981 to 2015. Histogram in the bottom-left corner shows the spatial distribution of the magnitude index classes for each 5-year period. *Source: Fig. 4 in: Ceccherini, G., Russo, S., Ameztoy, I., Marchese, A. F., and Carmona-Moreno, C.: Heat waves in Africa 1981–2015, observations and reanalysis, Natural Hazards and Earth System Sciences Discussions, 17, 115–125, 2017,* https://doi.org/10.5194/nhess-17-115-2017 [10]*; under CC-BY 3.0 license*

such significant changes have occurred in just 30–35 years, what will the coming decades be like? Rapidly increasing heat extremes in Africa show that this continent is an extremely vulnerable climate change hotspot. This kind of increase in number, spatial distribution, intensity, and duration of heat extremes will have a devastating effect on human health, environment, and infrastructure. Scientists suggest that if the projected high temperatures become reality, some areas in Africa may become uninhabitable for some species, including humans [11].

1.1.3 Droughts Are Becoming More Frequent and More Severe

Droughts can be defined as periods generally on the order of months or years in duration where there is insufficient water to meet needs. Droughts are one of the most costly natural hazards, affecting many of the essential elements of human life and causing devastating impacts on social, economic, and environmental systems (Fig. 1.7).

Fig. 1.7 Pair of dead oryx in Namibia during the 2018–19 Southern Africa drought. The drought negatively affected food security in the region. *Credit: By Dumbassman—Own work (under CC BY-SA 4.0 license). Source: Wikimedia Commons*

In the long history of human civilization, droughts have always been considered a disaster, as they have dramatically affected food production which is crucial for human society. This is why drought was among the earliest documented climatic events, present in the Sumerian Epic of Gilgamesh, and tied to the Biblical story of Joseph's arrival in and later Exodus from, ancient Egypt [12]. Ancient people feared droughts so much that they used special rituals to prevent or stop the drought. Trying to start the long-awaited rain often required the highest price—human sacrifice. In our times, droughts can have many devastating effects on human society, as even in rich communities droughts can have significant impacts on the economy. For example, in the first year of a severe drought, which lasted from 2007 to 2009, the United States' Southeast lost over $1.3 billion due to destruction of major crops such as corn, wheat, soybeans, cotton, and hay [13]. During this unprecedented drought, utility companies in North Carolina enacted water conservation measures, while city officials banned the filling of new swimming pools and the serving of water at restaurants unless requested and asked that hotel guests reuse towels and linens during their stay [13].

Now, the interested reader may want to pose an important question: How will global warming affect future droughts?

Well, the answer is that global warming is expected to increase the frequency and intensity of droughts in the twenty-first century. Recent research [14] suggests that global aridity has already increased in step with observed warming trends, and that this drying will worsen for many regions as global temperatures continue to rise. In a much-cited 2011 study [15], Dr. Aiguo Dai from the National Center for Atmospheric Research (NCAR) in the United States, concluded that increasing temperatures associated with global warming will likely create increasingly dry soil conditions across much of the globe in the next 30 years, possibly reaching a scale in some regions by the end of the century that has rarely, if ever, been observed in modern times. Based on the current projections of anthropogenic greenhouse gas emissions and using an ensemble of 22 computer climate models, Dr. Dai found that much of the Western Hemisphere, along with large parts of Eurasia and Africa, may be at risk of extreme drought this century. This will be the result of both reducing rainfall and increasing evaporation driven by global warming.

There are now already evident signs of increasing global aridity, mainly due to the drying over parts of both Americas and Africa, southern Europe, parts of South Asia, and Australia. But the projections for the coming decades are much worse, as the drying will be substantially widespread. For example, Dr. Dai's study [15] indicates that most of the United States will be significantly drier by the 2030s. In the coming decades, large parts of the United States will face an increasing risk of extreme drought. Other regions that could face significant drying include much of Latin America with large sections of Mexico and Brazil, the vast Mediterranean region, large parts of Southwest Asia, much of Africa, especially in the western and southern regions, and parts of Australia. As early as the second half of the twenty-first century, many densely populated areas, including much of the Mediterranean, much of Latin America, and central and western parts of the United States, could face extreme drought conditions. By the end of the twenty-first century, drought conditions for these most drying-exposed regions will be even more extreme. Such rapid drying would be unprecedented in human history. This is really alarming, because very large populations in the United States, Latin America, Southern Europe, the Middle East, Southeast Asia, Australia, and most of Africa will be seriously affected.

- *"We are facing the possibility of widespread drought in the coming decades, but this has yet to be fully recognized by both the public and the climate change research community. If the projections in this study come even close to being realized, the consequences for society worldwide will be enormous."* [16]

–Dr. Aiguo Dai from the National Center for Atmospheric Research (NCAR), author of the study *"Drought under global warming: a review"* [15]

It is worthwhile noting here that Dr. Dai's study [15] also finds that while drought risk is expected to substantially increase in the subtropical and mid-latitude parts of the continents, it is actually expected to decrease in the high latitudes of the Northern Hemisphere—across much of the territory of Northern Europe, Russia, Canada, and Alaska. The latter regions are projected to become even wetter than before. Such evident latitudinal difference in geographical distribution of future drying will additionally increase the already-existing contrast between rapidly worsening climatic conditions in the Global South (i.e., the developing countries of the Middle East, Africa, Latin America and the Caribbean, Asia, and Australasia) and relatively comfortable climatic conditions in the Global North (i.e., the industrialized countries of Europe, North America, Japan, and parts of Oceania).

Here, the skeptical reader may wonder whether observations on global climate change confirm the robustness of the above-mentioned future projections.

Yes, the observations do suggest that these projections are robust. For example, future projections indicate that in the course of the twenty-first