The Dangers of Excessive Heat in the Oceans

Sam Gutterman, FSA, FCAS, MAAA, CERA, FCA, HonFIA

Any views and ideas expressed in the essays are the author's alone and may not reflect the views and ideas of the Society of Actuaries, the Society of Actuaries Research Institute, Society of Actuaries members, nor the author's employer.

When discussing excessive heat, we usually refer to the temperature of our atmosphere. However, more than 90% of all the excess heat trapped in the atmosphere by the greenhouse effect goes into our oceans.

Oceans are massive, occupying around 70% of the earth's surface. As a result, significant changes in them can drive enormous changes in our lives. These changes are partly due to the complexity and inter-connectedness between and within the major components of the Earth system: its oceans, land, atmosphere, and cryosphere.

"Climate change is altering marine ecosystems and connected social systems at a scale and pace unprecedented in recent millennia, and impacts are expected to significantly increase over time."[1] "Many ocean characteristics—such as the timing and length of seasonal cycles, extent and duration of Arctic sea ice, and severity of extreme events such as heatwaves and harmful algal blooms—are exhibiting major divergences from historical patterns."[2]

Global sea surface temperatures have reached record levels, to what has been referred to as 'beyond extreme.'[3] The average sea-surface temperature for the ocean across Europe during 2023 was the warmest on record, according to the World Meteorological Organization (WMO).

Since this exceptional situation has existed since the spring of 2023, it is not a freak occurrence. Several factors may explain some, but not all of this. A now-subsiding El Niño in the Pacific has helped push sea-surface temperatures above previous records for more than a year. Another factor may be that reduced shipping emissions drive less sulfur dioxide in the North Atlantic; less particulate matter in the atmosphere can bounce more of the sun's energy back into space, so more solar heat is making its way into the oceans.

Temperatures in the waters of the northern hemisphere have become so high that they have been described as nine-standard-deviation anomalies. Scientists have expressed alarmed confusion about recent records in global surface temperatures; they are even more perplexed about what's happening in the oceans. Many oceanographers talk about regime shifts, chaos, and extreme uncertainty.

Last January, more than 40% of the planet's oceans were experiencing marine heat waves, and by the end of the century, given continued warming, these heat waves could become permanent fixtures in the world's seas. This high temperature has driven and distributed unimaginable amounts of heat, energy, life, and nutrients around the globe.

---

[1] Fifth National Climate Assessment (2022). Chapter 10.
[2] Fifth National Climate Assessment (2022). Chapter 10.
[3] WMO, with sea surface temperatures as much as five degrees Celsius above average.

SEA LEVEL RISE

Ocean warming contributes to rising global sea levels, exacerbated by melting Arctic and Antarctic ice. Heat drives thermal expansion that expands the volume of water. NOAA scientists have estimated that this heat has been responsible for at least one-third of all sea-level rise. Both rising atmospheric and ocean temperatures may lead to sea level increases of at least several feet by 2100 and even more after that. This inexorable rise contributes to coastal erosion, increased flooding, and community displacement in low-lying areas.

Because cities have often developed and grown in coastal areas, many large and mega cities are at risk of the effects of sea level rise, while corresponding land is subsiding, partly because of the significant demand for freshwater aquifers. This rise is occurring around the globe, noticeably in Jakarta, Indonesia and in major cities on every continent.

The resulting damage is not only restricted to those living on the coast—one study of Florida found that a one-standard-deviation (20 millimeters) increase in tidal flooding depth increases mortality rates by 0.46% to 0.60% among those aged 65 or older, possibly leading to an additional 130 deaths of the elderly per year in Florida relative to 2019, all else being equal. This risk is not just at the coastline—it also exists among inland residents living more than nine minutes away from the nearest hospital, resulting from delays in urgent medical care.[4]

According to NOAA, almost 40% of Americans live in coastal counties in 2020, a 46% increase since 1970.[5] The total insurable value of residential property in coastal America in 2015 was $17 trillion.[6] Some beaches are disappearing, resulting in changes in the tourism industry.

However, the Pacific islands are especially exposed, with their sea level rising three times faster than the global average since 1980, with an average elevation of just one to two meters above sea level. This is exacerbated by marine heat waves that have doubled in frequency over that period and are more intense and lasting longer.[7]

Sea level rise can result in saltwater seeping into and contaminating freshwater supplies. It can also contribute to dehydration and gastrointestinal disease, especially in low-lying coastal areas.

HUMAN AND ANIMAL HEALTH AND OTHER DAMAGES

Ocean warming can lead to significant damage and loss of life, including disruption of healthcare services, destruction or weakened healthcare infrastructure, and limited access to medical care and medication availability. The following discusses several major sources of its adverse effects.

- Tropical cyclones/hurricanes. Warmer water can lead to more frequent and intense storms, including tropical cyclones (in North America, known as hurricanes); as ocean water warms, more heat energy fuels the storm. Warm water evaporation provides hurricanes with enhanced

[4] Mueller, V., M. Hauer, G. Sheriff (2024). Sunny-Day Flooding and Mortality Risk in Coastal Florida. *Demography* (2024) 61(1):209–230
[5] https://coast.noaa.gov/states/fast-facts/economics-and-demographics.html.
[6] About $17 trillion residential (about 35% of which was insured) and $16 trillion commercial (about 40% of which was insured). https://www.air-worldwide.com/SiteAssets/Publications/White-Papers/documents/The-Coastline-at-Risk-2016
[7] WMO (2024). State of the Climate in the South-West Pacific 2023. 27 August 2024.

moisture and latent heat to the weather system that intensifies the storm. This increase in tropical cyclone intensity has led to more potent and destructive events. The evolution of the frequency of these events is more uncertain, with some studies[8] suggesting a global decrease in frequency, but an increase in the proportion of very intense tropical cyclones. At the same time, as the atmosphere warms, its water vapor holding capacity increases, leading to more intense precipitation. As the sea level rises, storm surges and tidal flooding can lead to more extensive flooding and damage.

Ocean warming can also reduce the stability of the atmosphere, making it easier for thunderstorms to develop, continuing to increase in strength and longevity. These storms can lead to extensive property and health damage. For example, deadly hurricanes have led to a spike in harmful species of antibiotic-resistant *Vibrio* bacteria in waters off the coast of Florida. The high winds whip up nutrients from marine sediments that the bacteria can thrive on.[9]

- Infectious diseases.
  - Food or waterborne diseases. Warmer oceans can promote the growth of harmful bacteria, viruses, and other pathogens in marine environments that can lead to a range of diseases, such as cholera and seafood poisoning. The range and prevalence of these diseases, primarily through shellfish, can expand as temperature changes.
  - Vector-borne diseases. Increasing ocean warmth can alter the distribution of vector-borne diseases, such as expanding the habits of mosquitoes in coastal areas with respect to diseases such as dengue and malaria.

- Mental health. Any of the climate-related hazards, or fear or uncertainty associated with climate change, can also indirectly affect mental health due to concerns regarding a loss of home, livelihood, and social networks, contributing to increased anxiety and depression.

- Algal blooms. Warmer water can lead to more frequent and intense algal blooms (red tides). These produce toxins that can contaminate seafood and drinking water, leading to respiratory problems and neurotoxic shellfish poisoning in humans. Inhalation of these toxins that can be released into the air can cause respiratory distress, especially in vulnerable populations such as those with asthma or other respiratory conditions.

- Coral reef damage. In some shallow waters, coral reefs, exposed to temperatures usually associated with hot tubs, will cause a level of risk above what is the highest level on the coral-bleaching scale. In a few decades, even in a rapidly decarbonizing world, it is likely that bleaching (that turns white after corals expel the symbiotic algae living in their tissues) will kill nearly all the ocean's coral reefs,[10] which support a quarter of all marine life and provide food and other benefits to as many as one billion people, as algae provide essential nutrients. The past year has seen coral reefs devastated globally (in the Atlantic, Pacific, Indian, and Southern oceans), with the

[8] For example, IPCC AR6 WG1 chapter 11, 2021.
[9] Brumfield, K. D. et al. (2023). Genomic diversity of Vibrio spp. and metagenomic analysis of pathogens in Florida Gulf coastal waters following Hurricane Ian. *Environmental Microbiology*. 16 October 2023. 14, e01476-23.
[10] Although coral has been known to bounce back from significantly adverse conditions.

entire reef of the Florida Keys and 80% of Australia's Great Barrier Reef undergoing bleaching or stress.

- Ocean acidification. Although not the only contributor to acidification (also caused by increased atmospheric CO_2), ocean warming can exacerbate its effects. Warmer water can alter the ocean's chemistry, caused by the absorption of carbon dioxide from the atmosphere,[11] affecting organisms relying on calcium carbonate for their shells and skeletons, such as coral and mollusks, as it can result from reduced solubility of carbon dioxide in warmer waters, which can in turn mean more CO_2 will remain in the atmosphere, further contributing to atmospheric warming. It can also increase the decomposition of organic matter, further releasing CO_2 into the water and increasing localized CO_2 levels.

- Deoxygenation. Warmer waters hold less oxygen and soluble carbon dioxide, turning them more acidic, dissolving the calcium structure that makes up coral, and affecting marine life. It also creates more dead zones where marine life cannot survive.

- Marine ecosystems and fish. Declining fish populations and habitat shifts caused by rising ocean temperatures, compounded by overfishing in some areas, have many adverse consequences. Marine animals are migrating to cooler waters that disrupt their ecosystems and associated food chains. It in turn impacts commercial fisheries and the livelihood of the many people who depend on fishing for a living. Partly as a result, fishing communities and businesses in many parts of the world have suffered. Although it is easy to say that all that is needed is for these people and fishing businesses to emigrate to where the fish move to, in reality, this is quite difficult.

  The amount and distribution of catchable fish stocks represent a primary source of protein, impacting food security around the world. Although access to oceans will remain the same, the amount and types of fish caught are bound to change. Reduced access to nutrient-rich seafood can lead to nutritional deficiencies, especially in coastal and island areas. This can make it more difficult for many humans and marine organisms, including corals, mollusks, and some plankton, to thrive. This can also lead to geopolitical tensions, conflict between indigenous groups and commercial fishers, higher fuel use, and inevitably rising fishing and seafood costs.

In sum, ocean warming, acidification, deoxygenation, and extreme storm events will adversely affect marine ecosystems and reduce habitats, biodiversity, and coastal protection by marine flora, as well as to human health and life.

OCEAN CURRENTS

The chance that ocean currents in the North Atlantic could collapse may be greater than previously thought. If that were to materialize, weather systems worldwide would be impacted and possibly chaotic, particularly in Europe and North America.

The extensive ocean system that transfers heat from the tropics toward North America and Greenland is called the Atlantic Meridional Overturning Circulation (AMOC). It plays a vital role in the global climate

[11] WMO (2024). Ibid. For example, Hawaii showed a more than 12% increase in ocean acidity.

system. This conveyor belt transports heat from the tropics to more northern latitudes, such as North America and Western Europe, promoting planet-stabilizing effects. If it were to cease, average temperatures in parts of Europe might become 15°C colder than today. Current farming areas would be far less suitable for food production. It has been projected that this system could reach a tipping point sometime between now and 2095, with a central estimate of midcentury, just a few decades from now.[12] Some dispute this catastrophic scenario, but catastrophic tail risks of temperature change should not be ignored.

While most of the world has gotten warmer, the area near Greenland has gotten cooler. Scientists think this cold freshwater might be affected by the strength of the AMOC. As melting continues, the amount of freshwater in the North Atlantic may reach a still unknown tipping point. At that point, the system is at risk of collapsing altogether—potentially irreversibly—possibly in a matter of decades.

The consequences of a collapsed AMOC would be widespread and destabilizing. The northern hemisphere would be colder, especially in the North Atlantic. Some monsoon cycles would dramatically shift. Europe would have erratic winter weather and contain less arable land. Sea level rise could accelerate in some areas, exacerbating flood risks. The impacts on our food supply, economies, and health are much harder to predict, but such a systemic change in the climate would be unprecedented.

Earlier, the consensus was that the chance of this happening was zero; however, some now believe it might be up to 10%. Earlier this year, a paper suggested that the AMOC was on a 'tipping course;' ongoing research suggests other ocean-circulation systems may face a one-in-three risk of collapse this century—perhaps higher.

CONCLUSIONS

It may be a surprise, given the critical role our oceans play in our lives, that our knowledge and appreciation of our oceans and their many effects on human life and resources remain limited. This results in a great deal of uncertainty regarding our future trajectory. As our oceans evolve and are increasingly influenced by human actions,[13] additional effects from global climate and weather systems that may become more volatile remain to be identified. Further data need to be collected and processes researched.

Addressing these concerns requires a comprehensive approach, including climate mitigation, public health preparedness, and adaptation measures. However, these actions may be constrained by the magnitude of changes needed, the costs involved, socioeconomic conditions, communication, and necessary equipment. In any case, I encourage further research and discussion of causes and effects and how to manage their characteristics and adverse effects.

* * * * *

Sam Gutterman, FSA, CERA, FCAS, MAAA, FCA, HonFIA is a consulting actuary. He can be reached at sam.gutterman1@gmail.com.

[12] Van Westen, R.M., M. Kliphuis, H.A. Dijkstra (2024). Physics-based early warning signal shows that AMOC is on tipping course. *Science Advances*. 9 Feb 2024. Vol 10**,** Issue 6.

[13] Not directly relevant to this essay, the pollution in our oceans and the future of what lives in them are of increasing concern, including microplastics and other waste products.