As far as we know, out of the vastness of the universe, planet Earth is the only place that harbors life. Someday we may find other worlds that provide an environment gentle enough to enable life to form, but for now, this is it, our lonely outpost in the corner of a galaxy.

It seems prudent, patriotic, and reverent that we do what we can to conserve and protect the fragile envelope of air that allows us to live on planet Earth, viewers are told. The legacy we leave future generations depends upon the actions we take in the coming years. Our heirs will be the judges of our success.

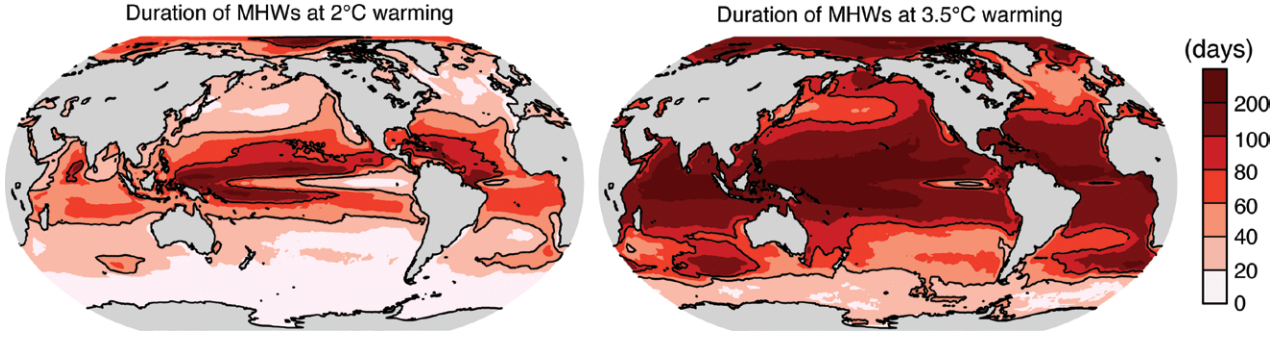
Moreover, we—both meteorologists and our viewing public—need to urge our leaders to take action to inspire the development of both new and cleaner ways to produce energy. In the event it turns out that humans are just too feeble to affect the climate, we will still be better off, as will our grandchildren, that we helped advance the technology to produce cleaner, renewable, and more varied energy sources.

In the words of Thomas Jefferson in 1789, "I say the Earth belongs to each generation during its course, fully and in its own right, and no generation can contract debts greater than may be paid during the course of its own existence."—Mike Nelson (KMGH-TV), "Communicating climate change—Be the expert in the living room," presented at the 32nd Conference on Climate Variability and Change, 7–10 January 2019, Phoenix, Arizona.

The Evolution of Marine Heatwaves under Global Warming

The ocean stores more than 90% of the extra heat that has accumulated in the Earth system as a result of the increase in greenhouse gas concentrations. Superimposed onto this long-term ocean warming trend are short-term extremes in ocean surface temperatures, so-called marine heatwaves (MHWs), during which ocean temperatures are anomalously high for periods of days to months. MHWs have occurred in all ocean basins over the last few decades, with some of them having had detrimental impacts on marine ecosystems and fisheries and cascading impacts on socioeconomic systems. Each individual MHW has its own constellation of triggers. But as the oceans are taking up more heat, MHWs are expected to become more frequent and more intense.

Using satellite observations, we show that the number of MHW days anywhere in the surface ocean has doubled over the 1982–2016 period. Over these 35 years, the average maximal intensity of an MHW has increased by 0.15°C and the spatial extent by 66%. Under the assumption that current Earth system models simulate MHWs with fidelity, we show that 87% of the currently occurring MHWs are attributable to human-induced warming. If the warming continues on its current trajectory, Earth system models project that MHWs will become more than 40 times more frequent by the end of this century. In other words, a one-in-a-hundred days event at preindustrial levels is projected to become a one-in-three-days event in 2100. MHWs will also become longer lasting and spatially more extensive. A MHW in this future hot world would typically last 112 days, with maximum temperatures 2.1°C above the intensity of an MHW today. The spatial extent would increase to 94.5×10^5 km^2—equivalent to the total area of China. As a comparison, at preindustrial times, an MHW lasted 11 days and had a spatial extent of 4.2×10^5 km^2, the area of Switzerland. All ocean regions will experience an increase in MHW days. Hot spots of large increases in MHW days will be the tropical Western Pacific and Arctic oceans.



Longer-lasting Marine Heatwaves. **Simulated multimodel mean duration of MHWs under (left) 2°C global warming and (right) 3.5°C global warming.**

In addition to MHWs, extreme events characterized by very low oxygen or high H^+ conditions can put additional stress on marine organisms and ecosystems. Of particular concern are compound events, which correspond to events with multiple concurrent or consecutive ecosystem stressors resulting in extreme consequences for marine ecosystems. Therefore, a better understanding of the drivers and consequences of such compound events is needed to assess the full risk for marine ecosystems under global warming. —Thomas L. Frölicher (University of Bern, Switzerland), S. Striegel, E. Fischer, N. Gruber, C. Laufkötter, "The evolution of marine heatwaves under global warming: Shifting mean versus changing variability," presented at the 32nd Conference on Climate Variability and Change, 6–10 January 2019, Phoenix, Arizona.

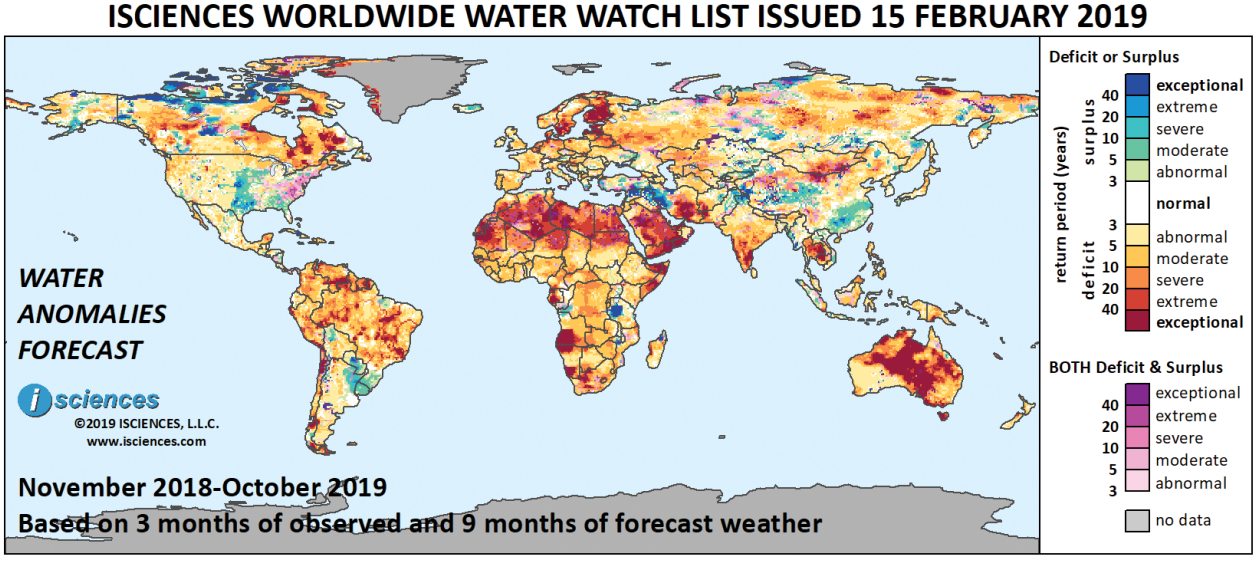
Climate-Induced Displacement: Where Social and Climate Sciences Intersect

A sudden storm wipes away a small city, repeated flooding ruins the foundations of a town, the sea erodes the thawing shoreline of a coastal village, and salt water restricts residents' access in yet another community. Greensburg, Kansas; Pattonsburg, Missouri; Shishmaref, Alaska; and Isle de St. Jean Charles, Louisiana, are but some of the towns and villages that have had to consider extreme weather and climate change in decisions to rebuild or relocate. From the coasts of New Jersey to North Carolina, whole neighborhoods now consider relocating in the aftermath of hurricanes Sandy, Matthew, and Florence.

Against the backdrop of climate-induced displacements in the United States, and internationally, the IPCC warned in 1990 *"the gravest effects of climate change would likely be on human migration, with millions of people uprooted by shoreline erosion, coastal flooding, and agricultural disruption."* People may relocate because their homeland loses territory to sea level rise, or becomes unlivable as climate models project areas of the Earth that would be too hot for human habitation.

A group of climate scientists and international environmental attorneys met in workshops to explore the environmental and socioeconomic complexities that lead to uprooting people; called "refugees" if they cross international borders, and "Internally Displaced Persons" if they move to new territory within the country.

In these dialogues, climatologists shared perspectives on future global climate change around the limits of habitability. They shared results of the National Climate Assessment, and explained the scrupulousness of



***Water Anomalies Forecast*. The water anomalies forecast is based on a Water Security Indicator Model (WSIM), which monitors and forecasts water anomalies on a near-global basis. WSIM identifies locations on Earth's terrestrial surface that are currently or forecast to be experiencing deficits or surpluses of fresh water. It operates under the premise that populations are adapted to their local climate and can maintain their activities (agriculture, municipal services, etc.) within the anticipated variations of this climate. However, stresses are created when conditions change well beyond these historically derived expectations.**