Editorial

A changing context for life on earth

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My wife and children have allergies and asthma. From time to time, we discuss whether their discomfort is worsening. One reason to believe this to be the case is the reality of anthropogenic climate change. As discussed elsewhere in this theme issue (eg, Shea et al[1]), firm links have been established between climate change and changes in prevalence and severity of asthma and related allergic disease.

My family and I live in the Rocky Mountain West, and evidence of climate change is all around us. Perhaps most people don't notice many of the signs—for instance, that spring is coming a week earlier, or that the high elevation snowpack is considerably reduced by late spring. After all, many of us welcome a longer gardening season, and the earlier mountain snowmelt makes for great white water rafting by the time the summer vacation season begins. But as you drive through the mountains, an unmistakable sign of climate change is the extremely large clusters of dead pine trees, not only in my home state of Colorado but from the southern Rockies into vast parts of Canada and Alaska. Forest managers throughout the West have called the diebacks "catastrophic" and "unprecedented." The area affected is 50 times larger than the area affected by forest fire, with an economic impact nearly 5 times as great.[2]

The trees are succumbing to the relentless attack of the mountain pine beetle. Warming temperatures not only have removed the natural line of defense against such infestations, sufficiently cold temperatures in winter, but also are speeding up the life cycle of the beetle. In the contiguous United States, for example, warmer summer temperatures are enabling the beetle to produce 2 generations in a year, when previously they reproduced once a year.[3] Even centuries-old lodgepole pines at the highest elevations of the Rockies, once seen as impregnable because of the extremely cold temperatures at such altitudes, are dying. Pine beetle infestations are certainly part of the natural cycle; however, it is highly unlikely this current environmental change, like so many others we are witnessing, is entirely natural in origin.

Significant advances in the scientific understanding of climate change now make it clear that there has been a change in climate that goes beyond the range of natural variability. As stated in the recently released Fourth Assessment Report of the Intergovernmental Panel on Climate Change, the warming of the climate system is "unequivocal" and it is "very likely due to human activities." [Q1]

The globe is warming dramatically compared with natural historical rates of change.[4] Global surface temperatures today are more than 0.75°C warmer than at the beginning of the 20th century, and rates of temperature rise are greatest in recent decades (Fig 1). [F1-4/C] Twelve of the 13 warmest years in the global surface temperature record have occurred since 1995, and the period 2001 to 2007 is 0.21°C warmer than the 1991 to 2000 decade. Proxy climate series from trees, corals, ice cores, and historical records reveal that we are living in the warmest decade of the millennium. Ocean warming causes seawater to expand and thus has contributed to global sea level rise of more than 33 mm since 1993 and 0.17 m over the last century. Faster melting of ice caps and glaciers has contributed to this increased ocean volume. There have also been rapid decreases in snow cover and Arctic ice extent and thickness, with record low amounts of Arctic sea ice last summer. Permafrost regions are retreating throughout the Arctic, buckling roads and destroying infrastructure in many places.

Today's best climate models are now able to reproduce the observed major changes in climate, which makes them extremely useful tools for understanding and determining the changes in forcing that are responsible. The culprit is the astonishing rate at which greenhouse gas concentrations are increasing in the atmosphere, mostly from fossil fuel combustion.[4] Greenhouse gas concentrations are higher now than at any time in at least the last 650,000 years. Atmospheric concentrations of carbon dioxide, the most important anthropogenic greenhouse gas, are nearly 38% higher than preindustrial values of 280 ppmv, and over half of [Q2] that increase has occurred since 1970 (Fig 1). Billions of additional tons of carbon will be added to the atmosphere through industrial activity in the decades ahead, and carbon dioxide concentrations are increasing at rates beyond the highest of the Intergovernmental Panel on Climate Change scenarios,[5] suggesting that changes in climate may be larger and more rapid than projected.

The lack of adequate international action on the problem of global climate change will have many negative consequences. Among the most serious challenges to society will be changes in extreme weather and climate events, such as heat waves, floods, droughts, and tropical cyclones.[6] Vulnerability and resiliency vary with location and socioeconomic development as well as adaptation measures such as appropriate building codes and disaster preparedness. Vulnerability also increases as the return time of extreme weather and climate events becomes shorter. More frequent, intense storms hitting the same region in sequence leave little time for recovery and resilience.

Observed changes in high-impact events are prominent.[4] Recent decades have brought a clear shift toward more unusually hot weather and less unusually cold weather. More than 35,000

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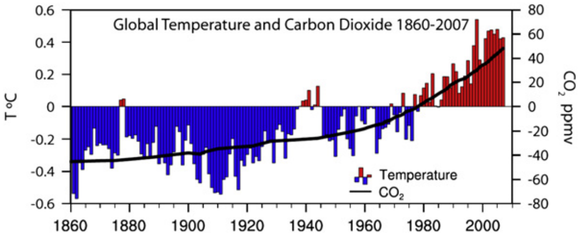

FIG 1. Estimated changes in annual global mean surface temperatures *(T°C, color bars)* and carbon dioxide concentrations *(thick black line)* over the past 148 years relative to 1961 through 1990 average values. Carbon dioxide concentrations since 1957 are from direct measurements at Mauna Loa, Hawaii, whereas earlier estimates are derived from ice core records. The scale for carbon dioxide concentrations is in parts per million *(ppmv)* relative to a mean of 333.7 ppmv, whereas the temperature anomalies are relative to a mean of 14°C. Updated from Hurrell JW. Recent atmospheric circulation changes and their role in global warming. FSWX Outlook 2002;3:1-10.[9]

deaths have been attributed to the dramatic 2003 heat wave across much of Europe. Downpours have become more frequent and intense, as expected because the water holding capacity of the atmosphere increases with temperature.[7] More than 130 million people were affected by floods in China in 2003, and the floods this summer across the central United States reveal how easily preparatory and coping mechanisms designed for a stationary past climate can be overwhelmed.

Drought is one of the most costly types of extreme events and can affect large areas for long periods. Drought has increased across many parts of the globe, including the southwestern United States and parts of Canada and Alaska.[4] Regions of Africa have been plagued by severe drought for the past several decades caused by overgrazing and climate change. Drought and increased heat waves also bring an increased risk of wildfire. In the United States, the wildfire season is longer, and events like the devastating 2008 wildfires in California will unfortunately be more typical as we move into the future.

Importantly, all of these changes have significant effects on not only the environment but also human health.[2] Increasing concentrations of carbon dioxide in the atmosphere stimulate weeds to produce pollen and encourage reproduction in trees, while global warming has advanced the date of spring flowering and thereby lengthened the spring allergy and asthma season. Wildfires, while harming wildlife and releasing large pulses of carbon into the atmosphere, generate significant quantities of respiratory irritants that can affect people living great distances away. Floods promote faster fungal growth and water-borne disease outbreaks. Dust clouds, carried from an increasing number of regions plagued by drought, contain particles and microbes that can exacerbate asthma. Vast hazes of air pollutants from coal-fired plants and automotive emissions affect respiratory health in urban areas, and photochemical smog resulting from reactions among automotive emissions is more pronounced during heat waves. Such unhealthy air masses, combined with high heat indices plus a lack of nighttime relief, affect respiratory and cardiac conditions and mortality. And this is just the tip of the (melting) iceberg of the health effects, let alone the ecological and economic dimensions, of climate instability.

The reality of anthropogenic climate change can no longer be debated. The imperative is to act aggressively to reduce carbon emissions and dependency on fossil fuels, creating instead a sustainable and clean energy future. Mitigation actions taken now mainly have benefits 50 years and beyond because of the huge inertia in the climate system. Therefore society will have to adapt to climate change, including its many adverse effects on human health, even if actions are taken to reduce the magnitude and rate of climate change. The projected rate of change far exceeds anything seen in nature in the past 10,000 years and is therefore apt to be disruptive in many ways. On a small scale, but one that is most important to me, this includes an increasing level of discomfort from asthma and allergies in my family, perhaps for generations to come.

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