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Field Notes:
Extreme Weather and Community Resilience

THE PACE OF EXTREME WEATHER OVER THE LAST DECADE APPEARS FASTER. IS IT NATURAL VARIABILITY, CLIMATE DISRUPTION…OR BOTH?

Steven Steinhour April 15, 2015

2014 was the hottest year we've had since U.S. records began in 1880. The 10 warmest years on record have all occurred since 1997. California is entering its fourth year of exceptionally warm weather and extreme drought. Yet just this winter the U.S. experienced intense Arctic cold, ice and snow in the Eastern and Northeast states.

Arctic winds buried Boston in over 9 feet of snow, with drifts up to the eaves of houses. Homeowners shoveled snow off their roofs to prevent cave-ins; streets and highways were drifted by snow so deep cars were buried mounds. Transportation systems, schools, businesses and industry lost days if not weeks of normal schedules. Final assessments of Massachusetts' economic damage are likely to run over a billion dollars.


Boston Blizzard 2015
Photo Credit: maryaliceholmes.com


Boston Blizzard 2015
Photo Credit: manewsfeed.com

The drumbeat of extreme weather and economic damage over the last decade continues its cadence. In March 2015 Jay Famiglietti, NASA water scientist, wrote in a *Los Angeles Times* op-ed article that California has only one year of surface water left. Some small communities in California already face trucking in drinking water. In 2012 Colorado was seared by massive wildfires that were followed in 2013 by destructive rainstorms that created tangled mudslides that damaged houses and roads down-slope from the burned-over areas. The Midwestern Big Three crops—corn, sorghum and soybean, all major factors in U.S. agricultural exports—were heavily damaged in 2012 by severe drought. The 2011 record-breaking regional drought in Texas and other SW states disrupted agriculture and local economies state-wide.

Disasters beg for a context that explains their significance and answers to the question: Why did this happen? Communities across the nation have a stake in the answers because the outcomes may affect their resilience to extreme weather.

A possible answer is that Boston, California, Colorado, the Corn Belt, and Texas may all share the same context.

Nations around the world continue to emit greenhouse gases (GHGs) that trap the sun's heat and make the atmosphere hotter. The hotter air disrupts climate and weather by adding extra thermal energy to whatever weather is naturally occurring. The natural variability swings of severe weather—heat waves, Arctic winds, agricultural drought and intense downpours or heavy snow—are increasingly affected by this extra thermal energy. So, the practical "shared context" would be that the hotter atmosphere increases the likelihood that ordinarily severe weather may turn into extreme weather, which dramatically ramps up possibilities for damage to communities.

How does this new reality—climate disruption—fit into our human experience of variable weather? What is "natural variability" and what is "external forcing"?

We've all experienced weather that naturally bounces around erratically even by the hour. Scientists confirm that climate has repeatedly, in the past, fluctuated between ice ages and warmer periods. How do these natural fluctuations fit into our thinking about climate disruption?

Weather is what happens in the short term—hours to months typically. Weather is random and chaotic, a constantly changing mix of factors capable of creating short-term weather fluctuations that change abruptly and unpredictably. Climate is simply the average weather in a region over a defined period of years—the World Meteorological Organization, for example, uses 30 years. Its description of average weather is intended to smooth out short-term weather fluctuations.

The general term "natural variability" represents fluctuations that can occur in both weather and climate. Natural "internal" variability captures the inherent changes in climate that occur primarily in response to changes in radiation by the sun, the earth's reflectance of that radiation, and the earth's varying orbit around the sun. These changes largely account for past ice ages and warming periods. To give us a baseline, the term deliberately excludes other factors such as volcanic eruptions and human (anthropogenic) GHG emissions.

The climate disruptive influence of these other, excluded, factors is called "external forcing." "Forcing" captures the degree to which these factors amplify (i.e., positive forcing) or diminish (i.e., negative forcing) the extremes of natural internal variation. For example, GHGs—primarily carbon dioxide, water vapor, methane and a few others—trap solar energy and increase (i.e., amplify) the thermal energy of the atmosphere. GHGs force a change in the atmosphere that would not otherwise occur by retaining heat in the air—very much like a warm greenhouse during winter. "Positive forcing" increases the likelihood that a severe storm or drought, which might occur anyway under natural weather variation, may grow into a more extreme weather event.

Conversely, the "negative forcing" of a major volcanic eruption can cool global air temperatures by temporarily blocking incoming solar energy. Historically, weeks or even years after a volcanic eruption, the air clears and weather generally returns to pre-eruption patterns. This predictable return to prior weather conditions means that all but the largest volcanic eruptions are too small to have an effect on the climate record.

"Positive forcing" by human-generated greenhouse gases has a very different effect on climate. Unlike the transient ebb and flow of volcanic forcing, our continued emissions of

GHGs, decade after decade, create a positive forcing trend that continues to accelerate in only one direction—hotter.

Every year that we emit high levels of GHGs, we are augmenting the thermal energy in the atmosphere that can increase the positive disruption of weather patterns. Since climate is the average record of accumulated weather, we are disrupting both weather and climate in a hotter direction. We are, in effect, creating a turbo-charger of extra thermal energy that increases the odds, or likelihood, that a storm or short-term drought—otherwise within natural variation—will be even more energetic, more severe and will last longer.

On the question of attributing extreme weather to natural variation or to positive forcing by human-generated greenhouse gases, The Intergovernmental Panel on Climate Change Fifth Assessment Report (2013) concluded:

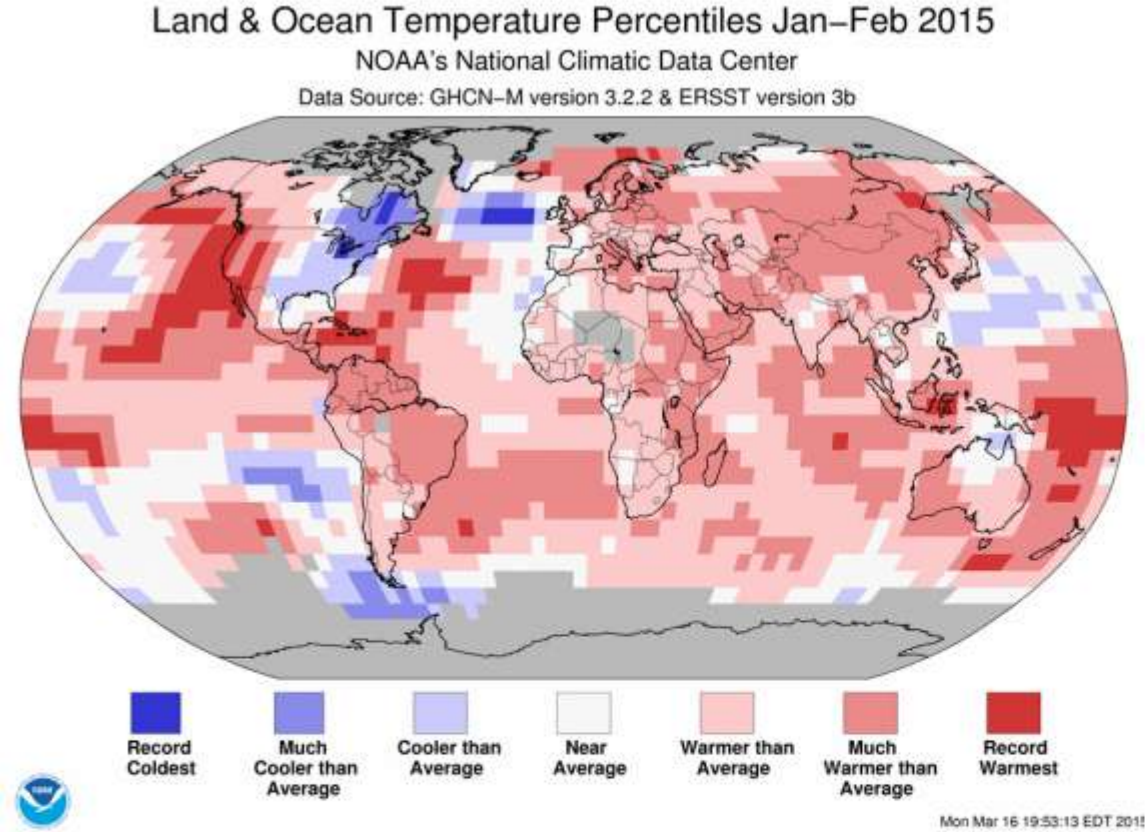
> Anthropogenic warming remains a small contributor to the overall magnitude of any individual short-term event because its magnitude is small relative to natural random weather variability on short time scales.

Thus, currently, short-term extreme weather is still primarily due to random variability of weather. The climate warming effect of our GHG emissions is to increase hot weather extremes and reduce the likelihood of cold weather extremes in such natural-variability weather. The role of GHGs in raising hot temperatures and reducing cold temperatures in naturally occurring weather will continue to grow over coming decades.
The report continues with this caution:

> Because of this random variability, weather events continue to occur that have been made less likely by human influence on climate, such as extreme winter cold events.

The earth's atmosphere continues to heat and, as recent temperature records demonstrate, the likelihood of extremes of cold days and nights is declining. None the less, we will continue to experience extreme cold weather events because the warming effect is currently smaller than cold extremes in random weather variability. As a possible added complication, current research is exploring whether atmospheric heating, by melting the Arctic Sea ice cap, may be increasing the likelihood that the Arctic jet stream will meander more to the south, bringing even more Arctic cold to mid-latitudes, such as the continental U.S.

The extreme winter cold events that occurred in January and February 2015 in the Eastern U.S. appear to have been examples of random weather. The global map, below, was prepared by U.S. NOAA's National Climate Data Center after the Boston Blizzards. The blue shows "cooler and record cold" in Boston's New England region, and the red off the New England coast shows "record warmest" in the Atlantic Ocean. Eastern North America was the only region among the earth's continents to register such a cold anomaly. Nearly all other lands of the northern hemisphere ranged from "warmer than average" to "record warmest"—in the middle of the northern hemisphere winter.



External forcing by our emissions of GHGs is a growing influence on weather; and the range of natural variability is being artificially shifted toward more heat and less cold. The balance is slowly shifting. However, barring crossing over some climate feed-back threshold that we currently do not foresee, natural variability is likely to be the strongest factor in weather for decades.

As that balance shifts, climate disruption due to positive forcing by GHGs is likely to re-define some weather patterns. The increasing likelihood of extreme weather ought to be a glaring red flag for community planners. Professional risk managers know that uncertainty about a significant growing hazard increases the risk factor. Climate disruption is already making some community planning data, based on 20th century assessments of the risks of extreme weather variability and return rates, increasingly irrelevant.

Our past GHG emissions commit us to worsening weather over at least the next 85 years, even if we stop those emissions today. We can change the longer-term outcomes, but every passing decade of inaction magnifies the likelihood of hot air hazards in the future.

The U.S. National Climate Assessment (2014) was very clear—the climate is changing:

> …more than 97% of scientists in this field agree that the world is unequivocally warming and that human activity is the primary cause of the warming experienced over the past 50 years. Spirited debates on some details of climate science continue, but these fundamental conclusions are not in dispute.

A surprising conclusion of the Assessment, based on a number of studies, is that over 90% of the increasing atmospheric heat is absorbed by the oceans, to be released at a later time. A number of unsettling results could flow from that effect. Over time, a strikingly warmer ocean may alter the flow of oceanic currents—such as the Gulf Stream—and impact cyclical atmospheric weather patterns—such as El Nino—that are based on ocean temperatures. If those disruptions occur, global weather may evolve in ways we can't now predict.

Almost certainly, as the oceanic heat reservoir eventually and slowly releases the 90% of atmospheric heat it has stored, that heat will delay the return to lower global air temperatures. The GHGs we emit will linger in the air, variously, from decades up to centuries. Even if we could stop emitting these gases today, the combined heating effect of GHGs already in the atmosphere and heat released from the oceans will maintain high atmospheric temperatures for a century or longer. In terms of human life-spans and generations, one or two centuries of a hotter atmosphere are effectively forever.

Over 80% of the American public now recognizes that atmospheric heating will be a serious problem if nothing is done to reduce emissions of greenhouse gases.

In January of this year, a *New York Times* and Stanford University public opinion poll showed growing public acceptance of the U.S. National Climate Assessment conclusions:

> The poll found that 83 percent of Americans, including 61 percent of Republicans and 86 percent of independents, say that if nothing is done to reduce emissions, global warming will be a very or somewhat serious problem in the future.

This increasing public understanding of emissions risks also creates an opportunity for communities to discuss what they can do locally. Discussions could focus on the certainty that, due to past emissions, we are already committed to further temperature increases and an escalation in local extreme weather. The obvious questions then focus on actions communities can take to adapt to weather extremes that cannot be avoided.

What recent extreme weather disasters give us a preview of how future weather extremes might occur?

People are highly attuned to their risks of losing the aspects of life they already enjoy—lives, property and security of community. Television and the internet have quite effectively brought into our homes vivid images of apparent increases in extreme weather disasters over the most-recent 15 years. American concern that disruption from weather is increasing may stem from an underlying angst as to whether they and their community might be at risk. Learning that many weather events are influenced by basic laws of physics simply adds to their discomfort.

In fact, the physical laws governing hot air do operate around the clock. They are basic concepts of physics that are well understood. Here are some examples that have made the news:

Direct Melting: Hotter air directly melts land-based glaciers, such as the Greenland glaciers and ice sheets, in much the same way as it melts an ice cube on a saucer. Melting surface ice on Greenland glaciers and ice fields creates meltwater that pours off into crevasses and eventually into the sea. Some meltwater pours down glacial bore holes extending from the surface down to the ground, thousands of feet below. There the meltwater further erodes the bottom of the glacier, increasing the risk of slippage or collapse over time.

Similarly, atmospheric heat absorbed by ocean water can undermine coastal glaciers that extend into the sea. This is particularly hazardous when the glaciers are lynchpins blocking great Antarctic ice sheets and preventing them from sliding into the sea. The slow-motion collapse of Thwaites Glacier in Antarctica increases the likelihood that the West Antarctic Ice Sheet, which Thwaites currently blocks on the land side, may one day start to slide into the ocean. Nearly all meltwater from land-based glaciers and ice sheets eventually flows into the oceans. This melting of land-based ice will continue to be responsible for the largest increases in rising sea levels.

Glacial surface meltwater streaming down through a borehole to melt and erode the base of the glacier.
Photo Credit: climaticidechronicles.org

Glacial meltwater flowing into ocean where it adds to global sea level rise.
Photo Credit: ameacados.com.br

Direct Warming of the World's Oceans: Over 90% of all atmospheric heating from climate disruption has been absorbed directly by the world's oceans. Since water expands in volume as it heats, this resulting thermal-increase in the volume of seawater will also continue to contribute directly to rising sea levels.

Excess Precipitation: Hot Air Holds More Water Vapor. When this full "sponge" is cooled by lower temperatures at higher altitude or a moving mass of colder air, the water vapor precipitates into heavy rain or snowfall—just as it did over Boston this winter.

Dr. Kevin Trenberth, National Center for Atmospheric Research explained this on January 30, 2015:

> The physics behind this phenomenon is governed by a basic law that tells us the maximum amount of moisture in the atmosphere increases exponentially with temperature – that is, the warmer the atmosphere, the more moisture the air can hold and thus, the more potential for precipitation.
>
> For most conditions at sea level, there's a rule of thumb that says the atmosphere can hold 4% more moisture per one degree Fahrenheit increase in temperature.

The record-breaking Boston blizzards of winter 2014/15 were created when the jet stream meandered far south, bringing a torrent of frigid Arctic air into the Northeast U.S. That Arctic front slammed into warm, moist air pushing inland from North Atlantic waters (see NOAA map above) that were 3 degrees Fahrenheit warmer than usual due to heat absorbed by the ocean from a hotter atmosphere. Absent that rising mass of warm, moist air from a hotter ocean, Boston might simply have experienced the dry, frozen air of states further inland, such as Indiana, during that same Arctic blast.

Similarly, in the warmer spring of 2011, the Missouri River watershed received an entire year's rainfall in a single month. Warm air, saturated with water vapor, met cold air and the resulting precipitation created widespread, intense rainfall that quickly melted the region's deep winter snow. The resulting combined runoff flowed directly into the Missouri River. Throughout the summer of 2011, river-front communities along the Missouri and the Corps of Engineers anxiously watched whether the Corps' great dams on the Missouri could control the most extreme floodwater peaks they had ever experienced.

Missouri River Flood 2011
Photo Credit: commons.wikimedia.org

Missouri River dam at peak flow in 2011
Photo Credit: wunderground.com

Excess Evaporation: The same basic rule of physics that hotter air can hold more water vapor also means that hotter air increases the evaporation of moisture from the ground and from vegetation. While short-term droughts are common, hotter air increases the odds that a short-term drought may turn into a regional agricultural disaster, similar to the 2012 Corn Belt drought that reduced the U.S. corn harvest by over 27% for the year.

2012: Drought-stunted corn
Photo Credit: twincities.com

2012: Millions of acres of drought-stricken cornfields.
Photo Credit: netnebraska.org

The ability of hot air to absorb moisture also increases the odds that green forest trees may dry and then die from evaporative water loss through leaves or needles; evaporation of soil moisture; or bark beetle infestation on weakened trees. Given an unlucky fire start, a drought-stricken forest can quickly become a blast furnace that destroys thousands of acres of trees, and burns homes and communities on the forest edge. Colorado, Texas, New Mexico, and Arizona have all experienced catastrophic forest wildfires in recent years.

Wildlife in stream sheltering from wildfire.
Photo Credit: inhabitat.com

Wildfire burns into community.
Photo Credit: birduncaged.wordpress.com

What Can Communities and Counties Do?

Every community has the opportunity to minimize its extreme weather risks by supporting federal actions to reduce greenhouse gas emissions. Only national action, in cooperation with other nations, can implement emissions reduction at a scale equal to the scale of the global hazards that GHGs are creating by warming the atmosphere.

Communities and counties form the frontline for adaptation and response to increased extreme weather hazards. Because they will pay with local lives and local resources, communities can speak with an especially powerful voice, based on experience and knowledge that the burdens of climate disruption will fall on them. Pending emission reductions, communities have the responsibility to adapt to extreme weather and protect residents by making their community's resilience to disaster more robust.

Community Challenges: The challenges of adapting and increasing community resilience are people challenges, not scientific. Many people find it difficult to visualize the hazards of slowly-evolving weather. None of us has experienced the abrupt and irreversible large-scale climate changes that are also possible. Even so, residents need to understand that extreme weather risks have changed—more intense, more frequent. Informed residents can provide critical support for community officials assessing whether new vulnerabilities are emerging and the options for adapting to new risks.

As a result, residents must develop a shared understanding of the potential risks before they can tackle the practical issues of planning and adaptation. Involvement of residents, sharing information and discussion in every venue possible, such as public meetings, churches and service clubs, is crucial to success in reaching that shared understanding.

Few communities are likely to be at risk from all of the types of disasters and extreme weather described earlier. Typically, communities experience only a few events of the extreme weather that is common in their region. As a result, planning for the risks of more-frequent extreme weather tends to focus on those familiar types. That approach was fairly effective in the more stable weather of the 20th century. But community leaders must assess whether planning based on last-century weather patterns is still appropriate and effective as conditions change.

Developing Skills and Tools: All 50 states and nearly 24,000 communities participate in the FEMA Multi-hazard Mitigation Plan process. They represent nearly 80% of the nation's population. That planning process provides a format for communities to identify and evaluate extreme weather hazards, vulnerabilities and risks. To secure the greatest value from for purposes of climate disruption, many communities will need to update staff skills to understand how weather is changing and how to use the new types of weather data—particularly trend data that show shorter return periods for extreme weather—that are becoming available. New analytical tools, such as FEMA's Hazus program, assist in more-frequent reviews of changing risks.

Concurrent Or Sequential Weather Events Increase Weather Risks: Colorado's experience with the concurrence of wildfire followed by intense rainfall and mudslides illustrates an aspect of weather risk that may require more attention. Two or more weather events, even of familiar types, can occur concurrently or sequentially. If the first event creates a weakness -- either by depleting response capability or by increasing vulnerabilities on the ground—the second event may be exceptionally damaging. Multiple weather events may also create cross-over hazards that might not exist with either single event. In such events, communities will need robust, flexible adaptation measures and response capabilities. Here are a few illustrations of potential cross-over situations:

- Colorado's experience illustrates the increased risks posed by wildfire followed by intense rain.
- Similarly, hotter air laden with moisture can feed high-intensity rain storms, even in drought conditions. Heavy rain on drought-hardened soils tends to run off rather than soak into the ground. Thus, even in the middle of a drought, flash flooding can occur in unexpected places, in both rural and urban areas.
- In coastal areas, sea-level rise creates a higher water-platform over which high tides and intense storm surge can flood new areas that were never considered to be vulnerable. The risks extend not only to damage of surface infrastructure and disruption of the local economy, but also to saltwater intrusion into coastal drinking-water aquifers and damage to sub-surface infrastructure.

Connecting the Dots: Climate disruption is occurring. Currently its effect is to exaggerate the extremes of natural variations in weather. Over the last 20 years, Americans have seen wildfires, floods, blizzards, droughts and other extreme swings of weather that appear to be increasing due, in part, to the increasing "forcing effect" of GHG emissions. Over the next 85 years of this century, heating of the air is likely to exert an increasingly strong influence on the extremes of weather. That means extreme weather will be more severe, longer lasting, and more frequent.

State and federal agencies are working to provide new climate and weather data at a local scale of detail and in formats readily usable by communities. Municipal and county agencies are also working to improve their staff skills and processing technologies to be able to use the new data. The best outcome of these efforts will be an informed citizenry that supports effective preparation to increase community resilience by reducing both the hazards and the risks from extreme weather and climate disruption.

Editorial thanks to Nancy Graalman

How to Get Involved

RRI would like to hear from you. If you have questions, comments, or concerns, please contact us at:

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