

Climate Change and Extreme Weather

PART I: TRENDS & PROJECTIONS

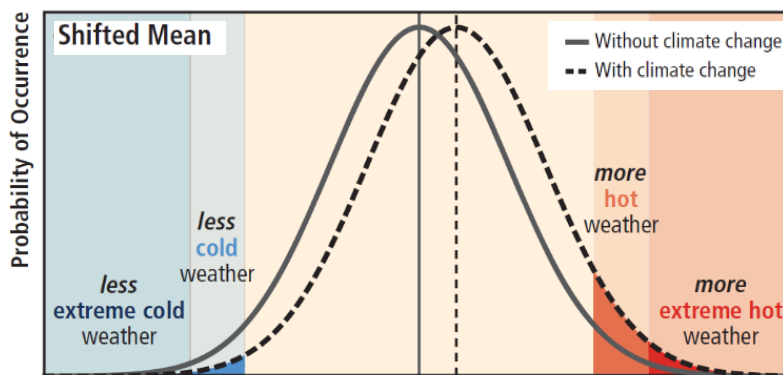
NOVEMBER 30, 2015 / BY JENNIFER HUSHAW

As the climate changes, we will not only experience a gradual change in average conditions, but also an increase in the frequency and intensity of some types of extreme weather and climate events. A number of these observed or anticipated changes have been highlighted in past bulletins, including [extreme heat](#), [heavy precipitation](#), and [more intense drought](#). ***These extremes may pose the biggest climate change risk for forest ecosystems in the short-term.*** Extremes create conditions that are beyond what species have historically experienced and they can push natural systems past their threshold for resilience and recovery because there is generally little time or capacity for natural adaptation in those situations. This potential for irreversible impacts elevates extremes on the list of climate-related forest management concerns.

The Link between Changing Climate and Changing Extremes

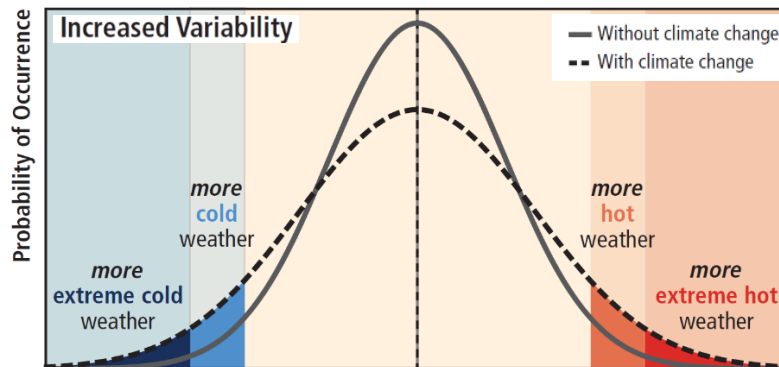
Climate is the statistics of weather. More specifically, the climate is the statistical distribution of any given weather variable (clouds, rainfall, temperature, wind speed, etc.), which generally resembles a bell curve (see figures, below). For instance, the average January temperature in New York City is 35°F, but it has been as warm as 70°F and as cold as -4°F. Climate *change* is, by definition, a change in that distribution.

There are a number of ways the distribution can change. As the climate warms and the average temperature increases, the entire curve will shift toward the right (see figure, below). This means more warm extremes, new record heat events, and conditions that used to be 'extreme' becoming more normal.



Source: IPCC SREX (2012)

In some regions, the variability may also change (the width of the bell curve) due to changing dynamics that are also linked to climate change, such as changing sea ice conditions, shifts in the jet stream, vegetation change, etc. (see example in figure, below). The curve may become wider (more variability) or narrower (less variability), depending on the region.



Source: IPCC SREX (2012)

In fact, a recent analysis of land temperatures over the northern hemisphere indicated that the bell curve is already shifting and widening as the planet warms—see [this figure from Hansen et al. 2012 in New Scientist](#).

Importantly, **the risk of extreme heat and heavy precipitation events goes up exponentially as average temperatures increase.** A recent study quantified how the probability of extreme heat and heavy precipitation events changes in response to increasing global temperatures (see figure, below) and their results for the present-day agree well with what we have actually observed. They found that the “probability of a hot extreme at 2^oC [global] warming is almost double that at 1.5^oC and more than five times higher than for present-day,” so the difference is “small in terms of global temperatures but large in terms of the probability of extremes” (Fischer and Knutti 2015).

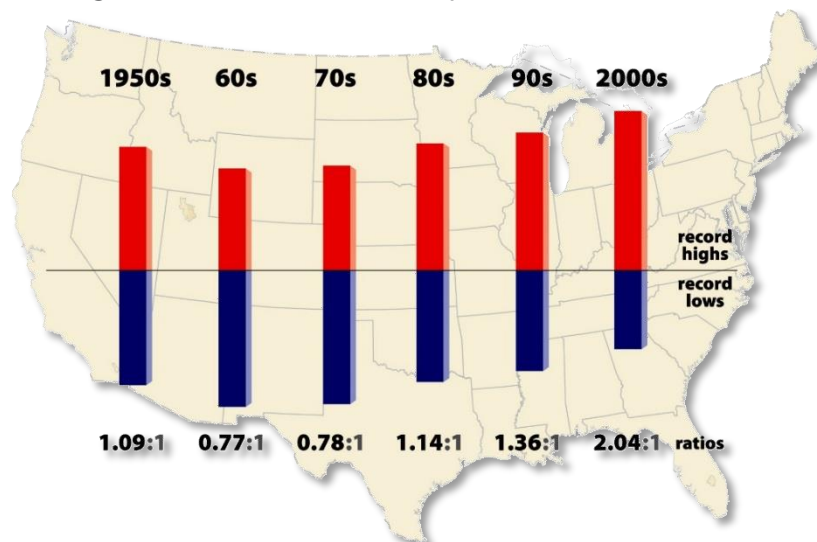
Note: See [Fischer and Knutti 2015, Figure 2 \(a\) and \(b\)](#) for a graph showing how the probability of moderate extremes (blue; events that exceed the 99th percentile) and the probability of the largest extremes (red; events that exceed the 99.9th percentile) change relative to pre-industrial daily precipitation and temperature conditions, at a given warming level. Probability ratio (PR) compares the probability of an extreme in present-day or future climate to the probability of that extreme before industrialization—it is the factor by which the probability of an event has changed, i.e. a PR of 1.5 means an event is 1.5 times more likely to occur.

Observed Changes in Extremes

Note: Observations and projections summarized from IPCC Special Report on Extremes (2012) Table 3-1 and the Third U.S. National Climate Assessment (2014).

EXTREME HEAT

Since 1950, there have been more record hot days/nights than record cold days/nights, globally. This has also been true in the U.S.—in the 1950's the ratio of record highs to record lows was roughly 1 to 1 and by the 2000's the ratio was 2 to 1 (see figure, below). The data also suggest that many regions have experienced more or longer heat waves over this time period.



This graphic shows the ratio of record daily highs to record daily lows observed at about 1,800 weather stations in the 48 contiguous United States from January 1950 through September 2009. Each bar shows the proportion of record highs (red) to record lows (blue) for each decade. The 1960s and 1970s saw slightly more record daily lows than highs, but in the last 30 years record highs have increasingly predominated, with the ratio now about two-to-one for the 48 states as a whole. (©UCAR, graphic by Mike Shibao.)

HEAVY PRECIPITATION

There have been large regional variations in heavy precipitation trends, but overall there are more regions with significant increases in heavy precipitation events than decreases.

DROUGHT

There has been significant regional variation in drought trends—some regions (e.g. southern Europe and West Africa) have experienced more intense and longer droughts, but there are opposite trends in other places.

FLOODS

There is not much evidence for a change in flooding trends globally, but there have been significant trends in certain regions. For example, the southwestern United States has seen a decrease in flood magnitude, while the Midwest and New England have seen an increase (see [Figure 3 \(a\) in Peterson et al. 2013](#) for a map of trends in flood magnitude). Globally, there has also been an observed trend toward earlier occurrence of spring peak river flows in snowmelt- and glacier-fed rivers.

Future Extremes

EXTREME HEAT

As discussed previously, the science indicates that we will experience more unusually warm days and nights as the climate warms. Similarly, we also expect an increase in the length, frequency, and/or intensity of heat waves over most land areas.

HEAVY PRECIPITATION

We will see an increase in the frequency of heavy precipitation events or the proportion of total rainfall that comes in the form of these heavy events. This is expected because a warmer atmosphere holds more water vapor when it is saturated, so when it rains in a warmer world more moisture can rain out. This trend is expected to be especially true in the high latitudes and tropics, as well as winter in the northern mid-latitudes.

DROUGHT

It is expected that in the future we will experience more impactful 'hotter droughts' as a result of warmer temperatures. For example, a recent study in the Southwest and Central Plains of Western North America used 17 different climate models to forecast future soil moisture in those regions and found consistent predictions of severe drying by the end of this century, with an 80% likelihood of a decades-long megadrought between 2050 and 2100 (Cook et al. 2015). For a more in-depth discussion of future drought risk, you may want to re-visit our previous [bulletin on global precipitation](#).

Model projections tend to agree on a future increase in the duration and intensity of drought in certain regions, including southern Europe and the Mediterranean, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Currently, poor model agreement makes it difficult to say how drought risk may change in other regions.

FLOODS

A lack of sufficient evidence and model agreement makes it difficult to say what may happen globally in terms of flood magnitude and frequency, but scientists at least expect that heavy precipitation events will contribute to more rain-generated local flooding, particularly in watersheds with topography that exacerbates the effects of heavy rainfall events (e.g., steep slopes, canyons that rapidly concentration flow).

How do we know an extreme event is related to climate change?

In recent years, there has been a lot of interest in understanding whether specific extreme events, e.g. the 2003 heat wave in Europe, Hurricane Katrina, or the 2012 Midwest heat wave, were *caused* by climate change. As with any phenomenon that arises from a number of factors, we can't pin down the cause to a single factor. However, we can begin to understand how a particular factor contributed to the *likelihood* or *probability* of the event.

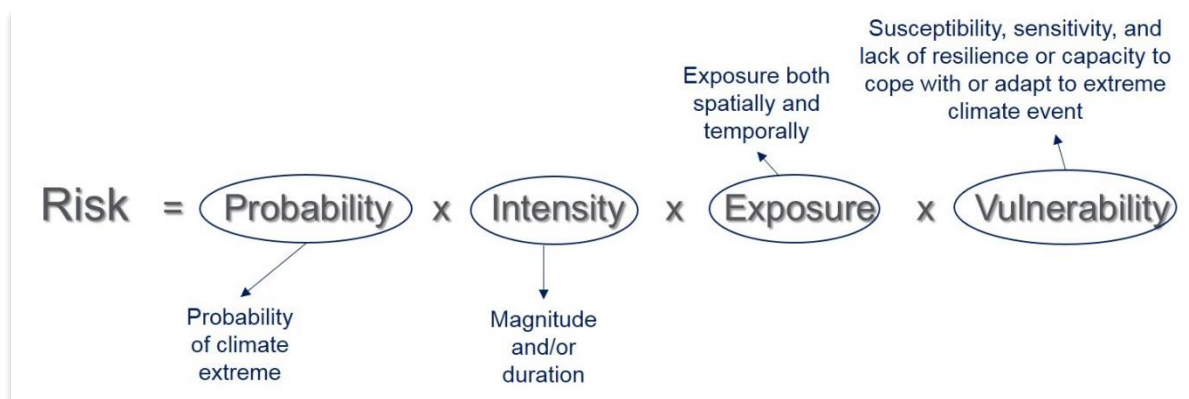
A helpful analogy is a car accident on a wet road. Was the car accident *caused* by the rainy conditions and wet road? Not exactly—there were other factors at play, including the curviness of the road, the speed of the car, visibility, the driver's level of fatigue, and others. However, we can look at the statistics of road accidents and determine how much a wet, rainy road increases the chances of an auto accident. In fact, there is an emerging area of climate research that is doing similar work to isolate how much anthropogenic climate change has increased or decreased the likelihood of certain climate extremes, compared to natural background conditions.

This type of research has revealed that climate change very likely contributed to a number of heat waves and heavy precipitation events, such as the 2010 Russian heat wave (Otto et al. 2012), the 2003 European heat wave (Stott et al. 2004), record summer temperatures in Australia in 2013 (Lewis and Karoly 2013), and flooding in England and Wales in 2000 (Pall et al. 2011). Another recent analysis looked at heavy precipitation and hot extremes globally and found a discernable human influence (Fischer and Knutti 2015).

Conclusion

Climate change is changing the odds of certain extreme events—it is loading the dice, so we are more likely to roll certain extremes, such as heat waves, heavy precipitation, or severe drought. As more of these events take place, researchers can begin to assess how the probabilities are changing, potentially improving our ability to estimate future risk from climate extremes.

A useful way to think about climate change adaptation in forestry is through the lens of risk management. The same is true for assessing the risk posed by climate extremes. Breaking risk into its component parts (see figure, below) reveals the best strategies for risk reduction.



The first two components of this equation are related to the climate variable, e.g. drought, and the last two are related to the forest, e.g. location, stocking, species mix. Taken together, these four variables determine the overall risk posed by a particular climate extreme.

By leveraging the right management approach, you can reduce your exposure and/or vulnerability to a given climate stressor. Although, you can't do much to change the first two variables, beyond getting more (and better) information. This is where new data about changing probabilities can play an important role in improving our assessment of risk with regard to climate extremes. Manomet will be closely following emerging research in this area and updating members as the projections become clearer.

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