Q and A re "The New Climate Dice"

1. What is the most important finding of the paper?

We have shown, from observations (not models), that the climate dice are now loaded -- and that a new category of extreme climate events is occurring with increasing frequency. Specifically, we refer to the occurrence of unusually hot summers, summers more than three standard deviations outside normal climate -- with their associated wildfires and droughts..

Furthermore, we have shown that these "3-sigma" (3σ) events, where σ is the standard deviation -- seasons more than three standard deviations removed from "normal" climate -- are a consequence of the rapid global warming of the past 30 years. Combined with the well-established fact that the global warming is a result of increasing atmospheric CO_2 and other greenhouse gases, it follows that the increasingly extreme climate anomalies are human-made. (A "standard deviation", i.e., "1-sigma" or 1σ, is a measure of the typical variation or dispersion about the average. Most cases fall within 1σ of the average value. A case 3σ away from the average occurs only rarely, about 0.2 percent of the time, i.e., about 2 times out of 1000.)

2. Why is such an anomaly important? Isn't it just a few degrees warmer than average?

Look at the examples. Last summer (2011) the largest 3-sigma area covered Oklahoma, Texas and northern Mexico. The previous summer the biggest 3-sigma area was around Moscow. This summer it seems we have a big 3-sigma area in the U.S. Midwest. Were these anomalies important? Ask the people who lived through them.

3. Didn't 3-sigma events occur in the past?

Yes, but they are much more frequent now. Equivalently, in a given season they cover a much larger fraction of the globe, now about 10 percent of the land area. Such extremes covered only a few tenths of one percent of the land area 50 years ago.

4. So you can use your old metaphor of "loaded" climate dice to describe the situation?

Yes. However, when we defined blue (cold), white (normal) and red (hot) categories, we only emphasized that more sides of the dice were becoming red. Now we are drawing attention to the new extreme red category that almost never occurred 50 years ago. This extreme case, at 10 percent frequency, covers most of one side of a six-sided die. In about a decade it may reach 16.7 percent, covering one full side of the die.

5. Why are you also introducing the "bell curve?" Isn't that too esoteric for the public?

The public can understand the bell curve. In "Forrest Gump", a doctor showed Gump's mother a bell curve for IQ, saying that Gump (Tom Hanks) was 3-sigma on the dim-witted side of average (albeit his humanity and athletic abilities were 3-sigma on the other side of the bell curve).

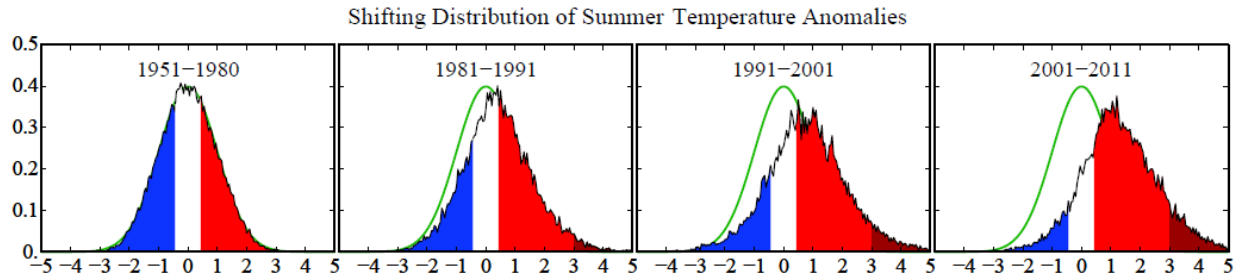

Fig. 1. Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies (relative to 1951-1980 mean) for Northern Hemisphere land, in units of 1951-1980 local standard deviation. .

6. How is the "bell curve" related to "loaded climate dice?"

Fig. 1 shows how the bell curve and dice are related. The graph on the left shows the observed frequency of occurrence of summer temperature anomalies in the 30-year base period 1951-1980, a time of stable global climate. The standard deviation σ was 0.6°C (1.1°F) in 1951-1980.

This observed distribution of temperature anomalies in 1951-1980 accurately fits the smooth green curve, which is the idealized bell curve, the "normal" distribution used in statistics. The normal distribution usually is a good approximation of random variables that cluster around a mean (average) value, and, indeed it is a good approximation in this case with σ = 0.6°C.

In the normal distribution 33.3% of the summer temperature anomalies fall in the range ± 0.43σ, which is the white area in Fig. 3. Also 33.3% of the anomalies are hotter than +0.43σ (red area) and 33.3% are colder than -0.43σ (blue area). Actual summer mean temperature anomalies fit the idealized normal curve beautifully. Extreme hot anomalies (temperature anomaly exceeding +3σ) occur only about 0.2% of the time.

Fig. 1 shows that the observed temperature distribution shifts more to the right in each decade since 1980. It will continue to move to the right for at least the next few decades.

However, Fig. 3 also shows that there is still a substantial chance for any given season to be cooler than the average 1951-1980 climate. In the past decade about 15 percent of the summers were cooler than the 1951-1980 average climate.

7. You note that the bell curve has become "squashed". Is that important?

Yes. It means climate is becoming more variable. The tail on the hot side has become longer, but the cold tail of the bell curve has not shifted to the right by an equal amount. Extension of the hot tail is probably related to self-amplification effects. Hot summer anomalies tend to occur in regions where the weather patterns create a high pressure anomaly. Increased greenhouse heating, from increased greenhouse gases, causes such anomalies to get even hotter and drier. Within a 3-sigma region there can be a core with a hot anomaly of +4 or +5-sigma.

We will make available on our web site a global map of temperature anomalies every season. This may help people understand how climate is changing. The location of +3-sigma anomalies will move around, and where a given person lives may turn out to have a cool anomaly. However, we can expect the map to reveal that the area of extreme hot anomalies is increasing, not necessarily every year, but on decadal time scales.

8. How do you know that the bell curve will continue to shift to the right, that the dice will become more and more loaded?

Earth is now out of energy balance, as discussed in my TED talk and in the 31 January 2012 posting on my web site. Measurements show that the amount of energy absorbed from sunlight exceeds the heat radiated to space by the planet. So Earth necessarily will become warmer over the next few decades.

9. What are consequences of the increasing extremes?

We are seeing some this year: bigger, more intense wildfires, stronger droughts, and heat waves. Forest fires burn hotter and are more damaging. Other factors may contribute, e.g., forestry practices that suppress fires allow fuel to build up and lead to bigger fires. However, forest fire fuel may be affected more by increasing CO_2 and climate change: (1) Increased climate variability, with heavier rains when they do occur, builds up fuel, contributing to a cycle of fuel build up and burn. (2) Greater atmospheric CO_2 increases the rate of fuel growth. (3) Warmer winters, by allowing pests to multiply, weaken trees making them more susceptible to fire.

10. Are we necessarily going to see more and more extreme climate? Gloom and doom?

Some additional warming will occur over the next few decades. However, we can slow, halt and reverse global warming over a period of several decades. The key requirement is to stop subsidizing fossil fuels and to begin to collect a fee from fossil fuel companies in proportion to the amount of carbon they are putting into the air.

If the money collected from fossil fuel companies is distributed to the public, equal shares to all legal residents, it will stimulate our economy and provide people a strong incentive to move to clean energy. Entrepreneurs will have an incentive to develop energy efficiency and carbon-free or low-carbon energies. With 100 percent of the collected funds distributed to the public, most people will receive more in this dividend than they pay in increased prices.

At present the public is being forced to pick up the tab for all damage being done by fossil fuels, not only the effects of air and water pollution, but the effects of climate change. Collecting a fee from fossil fuel companies and distributing the money to the public will allow clean energies to properly compete with fossil fuels in an open market place. No money to the government and people free to make their own decisions re energy use. The nations that adopt such an energy policy first will benefit by modernizing their infrastructure and having the technology to sell to the rest of the world. This topic is also discussed in my TED talk.

11. Could we just redefine what is normal climate, obtaining a new symmetric bell curve?

Certainly. If we take the period 2001-2011 as the base period and define anomalies relative to it, we obtain a new bell curve. It looks like the 1951-1980 bell curve, but the standard deviation is larger, it is 0.81°C (1.3°F) rather than 0.6°C (1.1°F). The problem with shifting the base period to the present is that it hides the fact that climate is changing.

It is important to keep the base period fixed at the one we have always used, 1951-1980, because that period of relatively stable global temperature is within the range of Holocene climate. The Holocene, the past 12,000 years is the climate that humans and other life on the planet are adapted to. As explained in the paper, the rapid warming of the past 30 years has increased

global temperature above the range of the Holocene, and as a result we are beginning to see a shifting of climate zones. This is also discussed in my TED talk.

12. Did you write this paper and your 1988 paper because of the extreme droughts?

No. Both papers were written long before the extreme drought anomalies occurred. I made the first version of the present paper publicly available in November 2011 and submitted it to the journal in March this year. The 1988 paper was written in 1987.

13. Are there other effects that should be noticeable, besides the climate extremes?

Yes. Observant people who are not too young should notice that climate is changing and it is having effects. I'm writing about things that I notice on our farms in a series of letters to my oldest grandchild -- and about how we try to sort out cause and effect, given that there are many other things going on at the same time. For example, there have been times in the past several years when extended dry hot spells forced me to water birch of they may have died -- I don't believe that Native Americans had to water birch trees -- probably the climate zones are shifting.