

CHAPTER ONE

COME HELL AND HIGH WATER

Scientific Truth and Consequences in Hollywood Disaster Movies

Anyone who has ever been tasked with inspiring the public imagination with an accurate interpretation of the relationship between water and climate will have quickly realized the great difficulty inherent in such a challenge. It is not that the public is not intelligent or interested. Many of them are both. The problem is that popular culture has gotten there first. As every scientist who has stood before the public will appreciate, we as a society – education notwithstanding – derive a great deal of what we know, and think we know, not from science directly but from print media, movies, television and the Internet. Unfortunately, that information is not always accurate.

Much of what people presume to know about dinosaurs, for example, comes from watching *Jurassic Park*. One of the reasons we so love such films is that they demonstrate what might be possible in the future if only we had enough imagination. Unfortunately, finding 200-million-year-old DNA intact in amber is not as easy as it looked in the movie. Nor is getting DNA out of an insect trapped in amber easy to do without contaminating it. Filling in large gaps in genetic strands with frog DNA are not likely to produce a viable genome, because the strands' constituents have not evolved together and in effect don't know how to talk to each other. Even if you were successful in implanting DNA into an appropriate egg medium, it would be difficult to overcome developmental problems associated with gene splicing. If finally you were able to hatch the eggs, there would be

additional problems with compatibility with the radically different bacterial environments that exist today. There would also be challenges with humans replacing parents in behavioural instruction. Raising teenagers is one thing; raising velociraptors is quite another.

Because so many dinosaurs were predators, the number of them in Jurassic Park would also have required more room than they were provided in *Jurassic Park*. At 20 square miles, Isla Nublar was too small to provide adequate natural food supplies and prevent habitat destruction. The fact that the dinosaurs were hungry, however, did become evident in the film when they began to eat the central characters. Many readers will undoubtedly remember a highly symbolic, and for this viewer deeply satisfying, moment in the movie when a dinosaur ate the lawyer.

The world waited 22 years to see if these scientific problems would be solved in *Jurassic World*. But the genetic problems posed in the first movie were ignored. The chief geneticist in *Jurassic World* – the brilliant but ultimately evil Dr. Henry Wu – got around the problem of recreating exact genetic replicas of Jurassic dinosaurs by simply creating new creatures, the most prominent of course being the Indominus, a predator so ferocious that even the T-Rex needed the help of the park's resident Mosasaurus to bring it down. The problem of raising velociraptors did receive some attention, however, when Vic Hoskins, the head of security at the park, revealed he had a plan to weaponize them for military use. Once again the difference in climate during the Jurassic compared to the present was ignored. This remains a problem, at least scientifically.

As a consequence of undersea volcanism caused by sea-floor spreading associated with plate tectonics, the concentration of carbon dioxide in the atmosphere during the Jurassic was more than 2000 parts per million – five times what it is today. Predators aside, it was a much hotter world, in which humans would have found it very difficult if not impossible to survive.

CLIMATEGATE: A DENIALIST BESTSELLER

A great majority of people have also learned what they know, or think they know, about climate change not from science directly

but from popular books, movies and made for television epics that interpret science in an entertaining and imaginative way. A great deal of current public interest in climate change emerges from what has been a highly public debate over whether or not it is actually happening, and if so, who or what is causing it. While these matters have been settled in the scientific community for some time, a high-profile and very profitable denial industry has come into existence to create a market for doubt. One of the vocal climate deniers portrayed in the opening scenes of a recently released James Balog film called *Chasing Ice* is a San Francisco television weatherman and talk-radio host named Brian Sussman.

In 2010 Sussman published *Climategate: A Veteran Meteorologist Exposes the Global Warming Scam*. The book is widely held to be one of the most vehemently anti-climate-change polemics ever written. While it can be painful for anyone versed in the hydro-climatic sciences to do so, it can be highly instructive and even useful to read such books and critically examine the arguments they put forward.

There is nothing subtle about this book. You know from the first sentence where the author is going. Sussman's acknowledgements do not mention a single scientist or climate expert. He nods to the usual suspects – his family, friends and literary agent – and then thanks the undisclosed sources who illustrated Al Gore's false science and the desperate climate scientists who tried to cover up the Climategate global warming scam for making his book possible.

This reviewer carefully examined the arguments in Sussman's book and after much consideration placed them into categories based on their principal themes. Of the 77 distinguishable arguments Sussman makes in *Climategate*, nine contest climate change for reasons of political ideology, three others on grounds of religion. Eleven more of his arguments are vicious *ad hominem* attacks on the character of climate scientists themselves, and 51 assail climate change on the grounds of incompletely reported, outdated, questionable or utterly erroneous science. To put it statistically, 74 of 77, or 96 per cent, of Sussman's arguments are objectively and scientifically unsupportable and therefore qualify only as personal opinion. This would not be a problem if Sussman didn't claim otherwise.

Despite protestations to the contrary, this book in no way proves that climate change is not a threat to the future of the United States and that we should continue, as he proposes, to use fossil fuels as long as we can if that is what it will take to perpetuate our prosperity.

If Mr. Sussman were to submit the arguments he has put forward in this book as a scientific hypothesis at any reputable academic institution, his thesis advisers wouldn't let him out of the room. Based on the quality of his arguments in *Climategate*, the best he might expect would be to receive a grade of 4 per cent, which qualifies on the grading scale as an F. In other words, he wouldn't graduate. Unfortunately, however, in our increasingly fragmented and argumentative society, the popularity of this book in some social and political circles will be the inverse of its scientific veracity. The more hateful it is in its condemnation of climate science and politicians that support action on climate change, the more popular it will become. That is what makes the book dangerous.

The main point this reviewer would like to make is that while *Climategate* may well represent a new standard for measuring the vehemence with which some interests oppose the idea of global warming, it would be a mistake to ignore this book. While it would be easy to dismiss the work by translating it into what this reviewer might call "the Sussman scale of denial," a new world standard against which anti-climate-science belligerence can be measured, that would not be an appropriate response. Rather, we should be thankful to Mr. Sussman for articulating his views and sharing them. His views tell science where it has to go to validate itself in the minds of those who think like he does. Somehow science has to build a bridge to those who hold views of this extreme hostility. If this is not done, then deeply held differences of opinion over climate change could literally tear our society apart.

However unpleasant it may be to have to refute arguments couched in the animosity Sussman expresses in *Climategate*, the ultimate credibility of the climate community resides in being willing to take the time to carefully, quietly and dispassionately separate fact from opinion. The first step in building such a bridge may be the clear identification of Sussman's arguments. As philosopher Christopher Lasch pointed out long ago, true dialogue demands that

we enter imaginatively into our opponent's arguments, if only for the purpose of refuting them. Of course, there is always a chance that we ourselves will be persuaded by those we sought to persuade. But because argument is risky in this way, it is educational – hopefully for all of us.

Of the distinguishable arguments Sussman makes in *Climategate*, a number are political. The ideological unpinning of this book is loudly proclaimed in its opening sentence: “Global warming’s story begins with a diabolical bastard named Karl Marx.” Sussman’s view is that climate change discourse has a direct link to covert communist intentions of undermining American democracy. He makes his views on this very clear in the book’s introduction:

The tentacles of Marxism have been steadily reaching into the United States for decades. Red-flag-waving propeller-heads in academia faithfully undermine American values in the classroom; useful idiots associated with a variety of non-governmental organizations work as tireless, agitating activists; and slimy liberal politicians craftily seek ways to undermine constitutional principles through, as stated by Lenin, political means. Working in lockstep with the unseen communist bureaucrats ensconced in the United Nations complex overlooking the East River in New York, this cabal of collectivists have discovered the ultimate tool to force social change upon first America, then the entire world: the very air we breathe. (p. xv)

Whipped into rage by what he considers an assault on his own extremist ideology, Sussman claims to hate all those he opposes. He reserves a special animus for academics and elites:

An elite brigade of zealots has cleverly created a new political platform to carry out the collectivist goals of redistributing wealth and destroying personal liberty, utilizing something that Karl Marx himself never envisioned: the environment, or more specifically, the climate. And because the efforts are political, these

egalitarians are willing to utilize phony science as a terror tactic, in an attempt to force you to believe that your lifestyle is responsible for negatively altering the earth's atmosphere.

It's all a lie. (p. xvi)

Parsing the arguments

This book might have been far more useful to readers if its author had stuck to the facts and held off on the rhetoric, but that clearly is not his intention. If he had relied on peer-reviewed science and not merely his own opinions, this would have been a very thin pamphlet. The book might almost seem a caricature of ultra-right-wing thinking in America, so unrelentingly does Sussman hammer on ideological themes throughout. It is almost a case study of Poe's Law,* which posits that without a clear indicator of an author's intent, parodies of extreme views will, to some readers, be indistinguishable from sincere expressions of the views parodied.

Let's begin our summary of *Climategate*'s arguments with the ones that fall into the category of extreme political ideology:

- The first Earth Day in 1970 coincided with the 100th anniversary of the birth of Lenin. (p. 13)
- The entire global warming scam can be exposed through quotes attributed to either Marx or Lenin. (p. 63)
- The Environmental Protection Agency in the United States exists to curtail free enterprise and usurp private property. (p. 79)
- Climate scientists have equated global warming with the terrorist threat. (p. 105)
- The UN seeks to destroy America. (p. 143)

This assertion is supported by the following:

Because the right to own property is a foundational principal [sic] of liberty and the pursuit

* According to Wikipedia, "Poe's Law" originated in 2005 from a forum comment posted by one Nathan Poe about creationism. It has become an Internet meme.

of happiness – and is antithetical to theories ascribed to Karl Marx – the overwhelming body of the United Nations has always despised the United States and has sought an effective means of reshaping her. (p. 143)

- Sustainable development is just so much hoovey; it is another Marxist plot just like climate change. (p. 147)

This is supported by:

[Sustainable development] provided the conspiratorial template to assist in the creation of needless open-space reserves, forest preserves, marine reserves and supposed ecologically sensitive areas – all with the goal of removing mass acreage from future private development.

- The United Nations Framework Convention on Climate Change was a secret communist plot to reduce the power, prosperity and political influence of the United States. (p. 153)
- We desperately need an authentic conservative in the White House. (p. 161)
- Nuclear power would be perceived as safe were it not for the incompetence of the communists. (p. 171)

As mentioned earlier, three of Sussman's 77 arguments in *Climategate* fall into the category of religious ideology. Naturally, all three are highly charged:

- Climate change deniers are being treated like Copernicus and Galileo by the ruling elite for their heretical views and for defying a cult-like suppression of truth. (p. 126)
- Arm yourselves – cling to your gun and your religion. (p. 162)
- Humans should have dominion over all the rest of nature. (p. 164)

A third category of Sussman's arguments would be the 11 personal attacks on those he calls "climate propeller-heads." It is here that his book suffers from the least pretense of objectivity. This reviewer

warns readers that the attack on climate science in this book is so relentless and personal that, if you know and respect some of his targets, it may be advisable to read Sussman's rant in small doses. As noted in the conclusion, Sussman may be using *ad hominem* attacks on the climate community to make a name and reputation for himself. It is difficult to understand the viciousness of the personal attacks in any other context. Some of these diatribes are multi-categorical and as such were hard to isolate into specific classes of argument. For example:

- DDT is safe and Rachel Carson is a fraud. (p. 6)
- Sussman adds to Argument 2 concerning the population bomb that never went off with a related point numbered Argument 3 on p. 152 in which he makes the point that environmentalists espousing population control are the agents of abortion and homosexuality. (p. 152)
- Michael Mann's hockey stick graph of temperature increases is an outright lie. (p. 35)
- James Hansen is clearly a Marxist and is lining his pockets to boot. (p. 47)
- One argument in this category could be construed largely as a bitter attack on "Little Al," a.k.a. Al Gore. Sussman's assertion here is that not one but two full chapters are required to properly characterize Mr. Gore's greedy, deceitful, hypocritical character and pro-communist, pro-abortionist, anti-Christian background and upbringing. (pp. 80-122)
- Any place that has Al Gore's books is a "lie-brary." (p. 100)

Only in a society that defends free speech would such an assault be permissible. Readers with legal backgrounds will observe that some of the sub-arguments border on slander. Other readers may simply laugh out loud. Many, however, have become weary of these kinds of tirades. The *Los Angeles Times*, for example, no longer publishes letters from climate change deniers, not out of censorship but out of a commitment to accurate reporting of factual information that is no longer in doubt. Readers are invited to judge Brian Sussman's comments for themselves.

- Environmental journalists and the propagandists they assist in the mainstream media are nothing but the feeding trough for sloppy science, brewed in cauldrons of bias and stirred by statist politicians and elitist social engineers. And sucking it up like chubby piglets are thousands of useful idiots. (p. 132)
- It is incomprehensible that a Republican presidential candidate of the reputation of John McCain would be sucked in by the climate hoax. (p. 135)
- Elites are evil and are trying to destroy America. (p. 186)
- Environmentalists are destroying the US, the last truly free country in the world. (p. 187)
- Smart energy grids are Marxist devices for controlling Americans. (p. 191)
- A CO₂ cap-and-trade program will destroy America. (p. 202)

The fifty-one of Sussman's points that are in the category of scientific arguments rely on outdated, partially accurate, inaccurate or completely fallacious assertions. Here is just a sample:

- Offshore oil wells are not an environmental hazard. (p. 10)

(Oops, the book came out before BP's "Deepwater Horizon" spill in the Gulf of Mexico in 2010.)

- When the Cuyahoga River in Cleveland caught fire in 1969, it only burned for 30 minutes and wasn't the big deal it was made out to be in terms of warning about water quality in American rivers. (p. 11)
- Climategate proves the fact that climate change scientists rely heavily on junk science. (p. 16)
- Climate scientists are becoming rich because of all the research funding they get. (p. 17)
- The predictions of a global cooling leading immediately to a new glacial period were false. (p. 20)

(This one is true but Sussman does not explain how science later arrived at the same conclusion.)

- Higher atmospheric temperatures are not happening. They are being faked. (p. 44)

- We are not experiencing the hottest weather on record in the United States. Those temperatures occurred in the 1930s. (p. 56)
- Citing American novelist Michael Crichton as an expert, Sussman argues that there is not enough CO₂ in the atmosphere to cause global warming. (p. 67)
- Termites, cow rumination and elephant flatulence produce more CO₂ than humans. (p. 74)
- Fluctuations in solar radiation are not taken into account in models. (p. 76)
- S. Fred Singer is one of the world's greatest climate scientists. (p. 89)
- The threat of sea-level rise is utterly exaggerated. Coastal cities are not under threat. (p. 104)
- Sea levels globally are actually falling. Tuvalu is a tropical island mess being run by imbeciles who are using global warming as a shakedown operation the likes of which would make a Chicago community organizer proud. (p. 111)
- Arctic ice melt is not accelerating; percentage losses are attributable to arbitrarily increasing the area said to constitute the Arctic region. (p. 112)
- Arkansas Senator James Inhofe's list of 800 renowned scientists who oppose climate change clearly demonstrates there are no grounds for concern over catastrophic future warming. There are even American astronauts that don't believe it is happening. (p. 136)
- Coal is clean – soot, sulphur and nitrogen oxides are no longer a problem associated with coal in the United States. (p. 173)
- Air pollution is no longer a problem in the United States. (p. 180)
- There is no reason why we shouldn't expand fossil-fuel use. (p. 184)
- Sussman's book will help save America. (p. 208)

Summarizing the arguments

Sussman's conclusion offers five summary arguments meant to be the take-away from the book:

1. Humans are too small a force to ever affect anything as large as the global atmosphere.
2. Man-made global warming is the greatest scam in history.
3. We are living in an equivalent of 1938 in Germany and it would not be unreasonable to go to war over deeply held differences of opinion on climate change.
4. In the same way that those Germans who understood the threat Hitler posed to his own country should have spoken out in 1938, those who understand that climate change is a scam should speak out now against the climate fraud.
5. God will give the righteous the grace to do what is right.

Even if bona fide climate scientists may not be able to stand reading his book, Sussman does put some important points into relief. At a certain point of alienation, facts no longer matter, and accordingly Sussman ignores them. These include the following hard-won realizations:

1. The fact is that humans have become numerous enough to become capable of substantially altering the function of the Earth's biodiversity-based planetary life-support system. To understand this we need go no further than the realization that our impact on our planet's oceans.
2. The observed fact that our oceans really are acidifying.
3. The observed fact that temperatures are measurably rising and polar sea ice really is thinning and shrinking in extent.
4. The observed fact that climate warming feedbacks such as permafrost melt and methane release have now become clearly obvious.
5. The observed fact that predicted increases in climate variability are already evident worldwide.

To some, the content and style of *Climategate* will make its author out to be nothing more than a loudmouth crank and climate change bully. But this reader sensed there is something deeper wrong with this book. Despite his apparent personal outrage over matters climatic and his shoot-from-the-lip style, there is something studied about this tract that suggests careful positioning by expert public

relations advisers. It is Sussman's calculated and carefully staged over-the-top rage that allows him to appeal so widely to like-think-ing others. *Climategate* loudly and rudely proclaims what many others wish they could say were they not constrained by the courtesy, reason and respect for others that are the foundation of civility in contemporary society.

There are lessons in this for the climate science community. The first is that it is unwise to unnecessarily scorn or alienate knowledgeable people or even people who think they are knowledgeable on climate matters. They can become hateful enemies. To paraphrase William Congreve, *Climategate* demonstrates that hell hath no fury like a weatherman scorned. Brian Sussman has vigorously attacked contemporary climate science and what it has to say about how human activities have changed our planet's atmosphere and what that may mean for the future of our civilization. He has staked his ground and thrown down the gauntlet as if preparing for war. With this book Sussman has announced his intention to mount the climate debate equivalent of the invasion of the Sudetenland. And despite appearances, he is far from a lone soldier. His views are supported by many high-profile American and Canadian corporations, think tanks, media networks and moguls. How long this war will last with the rise of such forces as the Tea Party movement in the US and the deepening conservatism we have witnessed in Canada remains to be seen.

No one in science or politics should doubt for a moment that there are many more Brian Sussmans out there, many of them very well funded, and that each is trying to grow a following. Though the climate science community may wish to believe it is above engaging in such avoidably barbaric and unseemly activities, maybe scientists too should be preparing for war. Perhaps it really is 1938 all over again. Only this time we are not fighting against an outer tyranny poised to destroy our way of life. This time we may find ourselves facing a more terrifying enemy: a tyranny within that would destroy the world in an attempt to keep it the same.

All this said, it is only right and fair to acknowledge the fact that, despite Brian Sussman's aggressively contrarian disposition, there were arguments put forward in his book with which I largely agreed. All three are worth noting.

Though the first of these is not technically a climate-related argument, I certainly agreed with Sussman's opinion about the fans of the Minnesota Vikings. On page 30 he observes that by virtue of wearing horned hats and proclaiming that their quarterback is an ancestor of the Erik the Red, the beer-guzzling Vikings fans may well be certifiably crazy. Could be.

I also concurred with his argument on page 118 that the shrinking of Lake Chad is not caused by global warming, though he is only partly correct. The irrigation overdraft at work there is also a contributing factor to climate change impacts.

Another spot where Sussman and I are in full agreement concerns his argument on p. 105 that the movie *The Day After Tomorrow* does not accurately portray current climate science or future climate change scenarios. He is dead right. Climate disaster movies have in fact caused a lot of confusion about how climate actually works. So let's take a look at some of these films and see what they say about climate change. Let's also try along the way to show where the science has been bent out of shape for the purposes of entertainment, so that we can better understand what is really happening with respect to climate change.

DISASTER MOVIES: SCI-FI BECOMES CLI-FI

CLIMATE COOLING

The Day After Tomorrow was a smash hit in what has become a growing science fiction genre many call "disaster porn." Readers may prefer to follow author Naomi Klein on this and call the genre "cli-fi." *The Day After Tomorrow* was made in Toronto and Montreal in 2004 and, adjusted for inflation, is the highest-grossing Hollywood film ever made in Canada.

The film depicts catastrophic hydro-climatic effects in a series of extreme weather events that usher in global cooling which leads to a new ice age. After a massive drop in ocean temperatures in the North Atlantic, scientists conclude that the accelerated melt of polar ice has begun to disrupt the North Atlantic current, plunging the entire northern hemisphere into deep cold. The situation deteriorates when the resulting storm system develops into three hurricane-like

super storms. In the eye of each of these storms air temperatures drop to as low 150° below zero and everything the air touches instantly freezes. This is scary stuff but is it likely to happen? Not any-time soon and certainly not at anything like the rate of cooling depicted in the film.

What would be required to cause the shutting down of the North Atlantic current would be a disruption in what is called the Atlantic Meridional Overturning Circulation, or AMOC. Sometimes referred to as the “global ocean conveyor belt,” the AMOC is an important component of the global atmosphere–ice–ocean–climate system. This circulation system redistributes heat between polar and equatorial regions and among the Earth’s ocean basins and atmosphere. It also contributes to the global ocean’s sequestration of carbon generated through human activity. While there was genuine concern in the 1990s that the rapid melt of the world’s great ice caps and ice sheets might pour enough cold freshwater into the Atlantic to disrupt the global ocean conveyor belt and bring about abrupt climate cooling in the northern hemisphere, later research suggested that the chances of this happening in this century were low. Further research results in 2014, however, revived concern over the apparently very real possibility of rapid ocean current disruption. All bets may be off if we continue to alter the composition of our atmosphere, in which case the science in *The Day After Tomorrow* might not appear nearly as laughably improbable to future generations.

SEA-LEVEL RISE

The prospect of rapid melt of the world’s ice caps, ice sheets, icefields and glaciers is a theme that has been well explored by Hollywood. One of the truly frightening climate change scenarios is rapid and extreme sea level rise. The film that tried to scare us the most on this topic is Kevin Costner’s 1995 epic *Waterworld*. The setting of the film is several centuries in the future. It appears that at the beginning of the 21st century, the polar ice caps began to rapidly melt and the sea level began to rise hundreds of metres, submerging every continent and turning Earth into a ball of water. Remaining human populations were subsequently scattered across the ocean in isolated communities consisting of artificial islands and barely seaworthy

boats. The plot of the film centres, as the film's website explains, on an otherwise nameless antihero, "The Mariner," a drifter played by Kevin Costner who sails all over the Earth in his trimaran. Is this likely to happen? Not a chance. The first problem with the movie – at least in scientific terms – is that even if you melted all the ice on the planet, there would not be nearly enough water to submerge the continents.

Scientists have modelled what North America would look like if all the ice in the world melted. While you certainly might want to pay attention if you were living in California, the Caribbean, southern Texas, Louisiana, Florida, the Carolinas, New York, Boston or Halifax, everything would still be fine in the interior of the continent. Even in the unlikely event that the West Antarctic Ice Sheet melts, with mean sea level rise in the order of metres instead of centimetres, the consequences would be serious certainly but it would still not be the end of the world. A far more immediate climate-related threat is the potential effect of sea ice melt on ocean acidification, which is now occurring at a rate 1000 times faster than occurs naturally. Because of this, the world's oceans are now 30 per cent more acidic than they were around 1800. By 2050 our oceans are expected to be warmer and 150 per cent more acidic than they were two centuries ago, with cascading effects on all marine ecosystems. By mid-century we can expect sea levels to rise and land surfaces to be warmer. So let's see now what the movies have done with heat.

HEAT WAVES

Heat waves in themselves have not been the subject of any high-profile Hollywood disaster epics. But because they can be devastating and drive people to the limits of their physical and emotional endurance, heat waves have been the backdrop of a number of movies, including Spike Lee's *Do the Right Thing*. The plot of this 1989 film develops around racial tensions that explode into a riot in an urban American neighbourhood during a heat wave.

The plot of *Do the Right Thing* is hardly implausible. Heat waves annually kill people by the thousands in concentrated urban areas around the world. During four months in the summer of 2003, 70,000 people in 12 European cities died of heat-related ailments.

Temperature records were broken all across Europe again in 2006 and 2015. This problem is not going away. Rising levels of urban heat are now seen to constitute the single greatest climate-related threat to human health globally. Urban heat waves now account for more deaths per year globally than all other forms of extreme weather events. We don't have to wait for the future for this. It's happening now.

Because of the heat-island effect of dark-surface solar absorption, combined with waste heat from vehicles, industries, buildings and even people themselves, temperatures in cities can be as much as 12°C higher than in the surrounding countryside. With what would be only moderately warm temperatures in surrounding rural areas, we have discovered that big cities can create their own heat waves.

Heat-wave fatalities underscore the limitations of the human body to withstand extreme heat, which explains why we probably wouldn't have done very well in the Jurassic. It is true that we can, as a species, survive surprisingly high temperatures, in part because our metabolism operates at 37°C, which is usually considerably warmer than most outdoor temperatures. Above 37°, however, the body must cool itself through evaporation in the form of perspiration. Unfortunately for the very young, the very old and those with health problems, the human heart has to work harder in hot weather to distribute water for cooling through perspiration loss. Keeping up with this loss requires constant hydration. That is why most of the deaths during a heat wave happen at night. Sleeping people can't hydrate, so their core body temperature rises and their organs shut down or their heart stops.

One of the major reasons why big cities are so much warmer now than in the past is the loss of trees and other vegetation to development. Trees not only store heat-absorbing water, their canopies create shade that moderates high temperatures. Once the heat-island effect is generated it is not easy to reverse. As resilience to climate extremes becomes a design imperative, cities may have to make extensive changes, especially to their land- and waterscapes. The good news here is that we don't need international climate accord to make these changes. The power to do so already resides in the hands of those who live in vulnerable cities.

But urban heat waves are not the only threat. What about drought on farms?

DROUGHT

More recent science fiction films utilize deep and persistent drought and its impact on food supply and water security as a means of generating plot. In *Interstellar*, for example, the world's food supply is threatened by storms and disease to the extent it becomes necessary to explore the depths of space and time for an alternative, Earth-like home.

In *Mad Max: Fury Road* the drought and limited water supply that have left the planet barely habitable lead to a more violent, dystopian world than the one that emerges in *Interstellar*. It is a terrifying place, but they do drive interesting vehicles.

CATASTROPHIC STORMS

The hands-down all-time worst of the B movies about climate disaster has got to be the hilariously campy *Sharknado*. The premise of this biggie is that climate change is going to cause more powerful storms, which will have unexpected consequences. In *Sharknado*, the complete surprise is a massive storm off the coast of Mexico that forms a tornado at sea so powerful that it sucks 20,000 sharks up into the sky. And of course the storm hits Los Angeles with all its fury. The sharks fall out of the sky and in the ensuing flood take over the city, attacking people in their Beverly Hills homes, occupying their swimming pools and shooting out of manhole covers to eat unsuspecting pedestrians whole.

This flick was so bad they just had to make a sequel. As the second opus begins, the heroine of *Sharknado* the First, April Wexler, and the fearless Fin Shepard are on a flight approaching New York when the pilot announces unexpected turbulence. April looks out the window of the 747 and notices a shark stuck to the wing. Inexplicably sharks are soon inside the plane and one bites off one of April's hands. I should have explained that April is on the way to New York to promote her new book, *How to Survive a Sharknado*. I should also point out that weather forecasters were already predicting a monstrous storm. (In New York, evidently, "shark happens.")

April and Fin, of course, save the city after narrowly missing being crushed by the head of the Statue of Liberty which rolls down a street that soon becomes a river of man-eating sharks. Interesting plot – but the science is, well, questionable. If you are scientifically or rationally oriented, it would not be unreasonable to drink heavily before watching it.

Sharknado 3: Oh Hell No! escaped to television during the summer of 2015. “Three times the shark, three times the nado!” Aficionados might not think it possible, but despite higher production values it was a worse film than the other two. This reviewer loved it. In this writer’s mind this epic redeemed itself with the single grain of scientific truth it offered when at the outset of a sharknado strike on his military base the commanding officer pointed out that the science of “bio-meteorology” was still in its infancy. Yup, that’s true. Even Brian Sussman might agree with that.

A much more credible but still wildly exaggerated film on extreme weather events was a four-hour television mini-series produced in 2005 called *Category 7: The End of the World*. The premise of this riveting film was that storms of unprecedented ferocity are not just battering but destroying cities around the world. While television evangelists proclaim the end times, a newly charged and powerfully motivated FEMA, the US Federal Emergency Management Agency, is determined to find out what is triggering extreme weather disasters of a magnitude never witnessed before. With the help of renegade scientists, and of course the Air Force, it is discovered that urban heat islands are shooting thermal columns upward into the mesosphere, creating openings down which the cold of near space is brought to the surface of the Earth, causing never before witnessed Category 7 storms. But just as a Dick Cheney figure is sucked into the whirlwind and the White House is destroyed by the super-storm, the day is saved. The solution of course is to shut down all of the thermal power stations around Washington, DC.

Besides saving FEMA’s reputation, *Category 7* contained one of the best lines of any of the classic cli-fi movies. Says the renegade scientist subhero to the beautiful and very intelligent scientist subheroine: “You are an egghead, but deep down you have a redneck

heart.” “Stop pussyfooting around and kiss me,” she fires back. Evidently we can still expect hot stuff in a hotter world.

TORNADOS

Twister is a 1996 American disaster drama starring heartthrob Helen Hunt and Bill Paxton as storm chasers researching tornadoes. They are working to perfect a data-gathering instrument they have named “Dorothy” which they are trying to release into the funnel of a tornado during a twister outbreak across Oklahoma. They are of course competing with bad guys in the form of another, better-funded team with a similar device. The researchers finally get Dorothy launched but the climax of the film is when they find themselves chained to an irrigation pipe staring up into the vortex of a Category F5 tornado.

The plot is a dramatized view of research projects like VORTEX in the United States. The “Dorothy” device used in the movie is copied from real-life technology called the “TOTOtable Tornado Observatory,” or TOTO, that was used in the 1980s by the National Severe Storms Laboratory, a National Oceanic and Atmospheric Administration research facility at the National Weather Center in Norman, Oklahoma.

Twister was gripping, but it was nothing compared with *Into the Storm*, which came out during the summer of 2014. Computer graphics have come a long way in 20 years, and so has our understanding of tornadoes. Readers are urged to see this one in a movie theatre with a big screen and big audio if they can. There are moments in this movie when you feel like you are being sucked from your seat right into the storm.

Interestingly, the tension in this film is not between teams of funded versus unfunded researchers but between scientific data and intuition in predicting where tornadoes will strike. All this is forgotten, however, when the heroes go into the storm. There is a lot of excellent scientific interpretation related to how tornadoes form and how they might act in a more energetic atmosphere, but as seems to happen with most Hollywood epics, the producers just couldn’t resist going over the top at the end.

So where do we stand presently in terms of understanding tornadoes? In terms of absolute counts, the United States leads the list,

with an average of over 1000 tornados recorded each year. Canada is a distant second, with around 100 per year. But trends are difficult to establish. Because tornadoes are short-lived events and we have such limited and unreliable data from sparsely populated regions where they typically occur, it is difficult to know for certain whether or by how much the intensity and frequency of tornadoes is increasing. One thing we do know, however, is that one of only nine Category F5 tornadoes to have occurred in North America between 1999 and 2011 touched down near Elie, Manitoba, on June 22, 2007. Though there was no loss of life, the F5 at Elie does remind us that Canada has its own Tornado Alley, extending across southern Ontario and picking up again in southern Manitoba and Saskatchewan before doing the twist around Edmonton, Alberta. Recently, however, tornado warnings have even extended into the mountains and as far north as the Yukon.

Some researchers think we are entering a new era of Earth-system disruption, called the Anthropocene. If that is the case, the greater apparent incidence of tornadoes has already provided an iconic image of what the era might look like. It is a picture both scary and hopeful. On Saturday, July 5, 2014, a young Saskatchewan couple chose to have their wedding photographs taken on a rural road outside of Regina. As photographer Colleen Niska began composing her shots a tornado formed in the distance behind the wedding couple and later blew down and flooded their reception tent. As the bride later wrote on Facebook: “We captured a once in a lifetime moment and feel so lucky to have it as a memory of how in such chaos you always have each other!”

If this Anthropocene is the brave new world we are all now headed for, it’s good to know there will still be love and hope in it.

CLIMATE INSTABILITY: THE SCIENCE SO FAR

So, all the disaster movies and prairie wedding “photo bombs” aside, what is *really* happening out there? What can science tell us about all this that we are not getting from newspapers, television, the Internet or blockbuster Hollywood movies? You don’t need to be a meteorologist to figure out that our weather is all over the

place. Rain storms, ice storms and snow storms are paralyzing our transportation and electricity distribution systems. Both high and low temperature records are being broken everywhere. Cold snaps are persisting; snow is falling in places and in volumes seldom witnessed before; flooding is occurring widely. But even with all this obvious evidence right before our very eyes, Canadians continue tiptoeing around the climate change issue.

Science has begun to illuminate some of the linked hydro-climatic effects that researchers have identified as threats to the stability of our weather systems. One of the most significant recent advancements in hydro-meteorology is the realization of the global importance of the refrigerating influence of polar sea ice. Three factors related to the extent and duration of Arctic sea ice have emerged as having great significance to every one of us alive today. The first, as already noted, is the potential effect of sea ice melt on ocean acidification. Second is the amount of heat required to melt sea ice. The third critical effect is the profound influence of Arctic cold on the stability of weather conditions farther south.

POLAR ICE AND THE JET STREAM

Polar ice is now seen as a thermostat that governs major weather patterns globally. It is feared that the decrease in the extent and thickness of sea ice could be the parameter that is feeding all of the increases that are causing concern over climate disruption. There has been a 75 per cent decrease in the volume of Arctic sea ice in the past 35 years. The loss of sea ice allows solar heat to warm the Arctic Ocean, creating a feedback which melts more ice. This is why the Arctic is warming two to three times faster than the rest of the world, in all seasons.

The loss of Arctic sea ice and the diminution of the extent and duration of snowcover in the northern hemisphere are reducing the temperature difference between the colder, thinner polar atmosphere and the warmer, thicker atmosphere to the south. It is this gradient in temperature between the two regions that largely defines the behaviour of the jet stream. Observations of the jet stream have revealed that warmer Arctic sea surface and atmospheric temperatures do not automatically translate into warmer weather. The

influence of warmer Arctic air causes the west winds created by the jet stream to become weaker. As researcher Jennifer Francis (see chapter ten) puts it, “Weaker westerly winds are wavier.” It is this waviness of the jet stream that creates weather at mid-latitudes. The result is a slower, more sinuous jet stream with fingers that stretch farther north. The slower, wavier jet stream creates longer-lasting weather patterns. An example of this was the southward bend in the jet stream that brought record cold to much of eastern North America during the winter of 2013–14. In a uniformly warmer and therefore more turbulent atmosphere, both warm and cold fronts end up and persist in places in the mid-latitudes where they were not common in the past.

As the jet stream slows and the waviness becomes wider, weather patterns persist longer and do things we don’t expect. When we look at extreme weather events such as heat waves and heavy rain and snow, we usually see very large jet stream deviations. One of the many things a slower, wavier jet stream can do is disrupt the polar vortex.

THE POLAR VORTEX

Much has been made lately in the media of the role of the polar vortex. There are actually two elliptical or circular polar vortices, one usually over the Arctic and one over the Antarctic in their respective winters. The latter vortex is very stable, but the Arctic one is more variable. It is influenced from below by the changing Arctic sea ice cover and from above by warming in the stratosphere. Recently both factors have weakened the vortex. A weak vortex is much more susceptible to disturbance at its periphery by the polar jet stream. The effects of such disturbances were made coldly obvious in North America during the winter of 2013–14. Instead of one consolidated vortex over the Arctic, four lobes developed, with the cold circulations carried south in the troughs of the jet stream. One of these lobes descended and lingered over central and eastern North America for most of the winter, making it one of the most miserable in memory in Manitoba and southern Ontario.

What we are also seeing is that changes in atmospheric circulation patterns are pushing major subtropical storm tracks toward the

poles, often causing floods of magnitudes we are poorly equipped to manage.

What we might derive from all this is that it appears that the Arctic is more of a bellwether of climate change and disruption than we thought. While we may not have perceived it as such, what is happening hydrologically in much of the rest of Canada mirrors what is happening in the Arctic. Warming is causing the post-glacial hydrological wealth of Canada to change form. In the Arctic, sea ice is melting, permafrost is thawing and snowcover is diminishing in both extent and duration. Warming is also occurring in Canada's western mountains. Some 300 glaciers have disappeared over the last century in the Canadian Rockies alone.

The water is not disappearing, however. Water doesn't do that. The warming generated by changes in the composition of our atmosphere is being absorbed by water. This warming increases evaporation. More liquid water is moving to a different place in the hydrosphere, where it may not be available for our use when we want it – as in the case of extreme drought – and where under certain circumstances the warming atmosphere's capacity to carry more water can also cause a lot of damage through heavier than normal rains and the resultant flooding. What also appears to be happening is that the global hydrological cycle is accelerating. Warmer temperatures are causing changes in the rate and manner in which water moves through the cycle. The phenomenon is summed up in an algorithm called the Clausius–Clapeyron relation. It is one of the most basic principles in atmospheric physics, and what it posits is very simple: warmer air holds more water. The amount of water the atmosphere can hold increases by about 7 per cent per degree Celsius, or about 4 per cent per degree Fahrenheit.

ATMOSPHERIC RIVERS

We are also witnessing things we either haven't seen or weren't able to recognize as such before, such as the currents of water vapour aloft called atmospheric rivers. Atmospheric rivers have likely existed for an eternity but only now because of satellite remote sensing capacity do we know of their existence and dynamics. These corridors of intense winds and moist air can be 400–500 kilometres

across and thousands of kilometres long. They can carry the equivalent of 10 times the average daily discharge of the St. Lawrence River. We have discovered recently that atmospheric rivers derive their energy from the temperature gradient between the poles and the tropics. Their intensity also derives from the Clausius–Clapeyron relation in that the warmer the air, the more water atmospheric rivers can carry.

Atmospheric rivers produce flooding of the magnitude we saw in Australia and Pakistan in 2010 and may have influenced flooding on the Canadian prairies in 2011. We know for sure, however, that an atmospheric river broke rainfall records by 87 per cent in the Kootenay–Columbia River region of British Columbia in 2012.

It was 2013, however, that really demonstrated, in Canada at least, that we may in fact have crossed over an invisible threshold into a new hydro-climatic regime in parts of the country. On the Canadian prairies, 2013 was interesting because despite a record late-season snowpack, there was no flooding in the spring. Most people have forgotten why.

UNPREDICTABILITY: THE NEW NORMAL

Why flooding didn't occur in 2013 was a subject of the annual Red River Basin Commission conference that was held in January of the following year in Fargo, North Dakota. At that conference I witnessed an extraordinary spectacle, one I would give anything to see happen in Canada. Imagine this: federal scientists with the National Weather Service had leave to give a public presentation on why they *failed* to make an accurate flood prediction in the spring of 2013. At the time, government scientists in Canada were not permitted to speak publicly at all unless accompanied by departmental media handlers. The US presentation demonstrated the public value of open scientific exchange.

Researchers reported that the snow-water equivalent in the April 2013 snowpack was so abnormally high that no one had experienced such conditions before. It seemed almost incomprehensible that record flooding could be avoided. But to the utter amazement of the National Weather Service, it didn't happen. Why? Because a series of other, equally unlikely extremes came into play that slowed

the melt of the record late-season snowpack. Near-record cold weather slowed snowmelt, while timely thaw and warm deep-soil temperatures accommodated twice the normal rate of absorption.

The reason the National Weather Service offered this presentation was because they wanted to make sure everyone in the region clearly understood that the absence of flooding in 2013 did not in any way mean that hydro-climatic regimes in the Red River Basin had somehow returned to what had historically been perceived as normal. In this basin, the researchers noted, we face a growing number of “no analogue” situations where we are facing conditions we haven’t seen before. The National Weather Service wanted the US public to know that we have entered a period in which more frequent extremes in hydrological conditions now make it impossible to use past experience as a guide to prediction.

While Manitoba may have dodged a bullet in 2013, not everyone else did. On the evening of Wednesday, June 19, rain began to fall where I live in Canmore, Alberta, initiating the largest single natural disaster in the history of this country. What was interesting about this flooding was that in terms of severity it was calculated by Dr. John Pomeroy of the University of Saskatchewan to be but a 1 in 45 year event associated with the spring melt of the mountain snowpack. In other words it was well within the natural variability experienced over the last century in Alberta. The communities that were hit by the flooding had clearly overbuilt in flood plains and were not adequately warned of the impending disaster. But the flooding in Canada that summer didn’t stop with the disaster in southern Alberta. It continued widely and assumed a different character as it went. The further flooding that occurred that summer was associated not with spring melt but with highly charged heavy rainfall events. On July 8, just over two weeks after the flooding at Calgary, Toronto was hit by a rainstorm that caused over a billion dollars in insured losses alone. Disasters that followed that summer demonstrated, unfortunately, that the flooding in Alberta and Ontario in June and July of 2013 was nothing compared to what the atmosphere is capable of delivering as a result of changing hydro-climatic conditions.

What happened in Russia later that same summer is almost

beyond imagination. It verges on science fiction. The weakening of the European jet stream caused by reduced snow and sea ice cover led to the creation of a heat dome in northern Siberia. In July hundreds of wildfires broke out that were so hot they melted the permafrost beneath the burning forests, creating methane releases from the thawing tundra that added fuel to the fires. Then, in early August, in the midst of what was coming to resemble a virtual fire-storm, three atmospheric rivers collided over the region and within four days created a flood that covered a million square kilometres.

Colorado too saw flooding in 2013, and the fact that it occurred in September, independently of spring melt, following severe drought and one of the worst wildfire seasons in history, is alarming in its own right. The storm demonstrated that subtropical storms are indeed tracking poleward and that the atmosphere is carrying more water. The state climatologist of Colorado, Nolan Doesken, noted that the storm “shattered all records for the most water vapor in the atmosphere.”

Taking Colorado’s experience together with Alberta’s and Ontario’s, we might surmise that the floods of 2013 offer us a glimpse into the highly variable weather we might expect in a warmer world. These events certainly got everyone’s attention. They clearly demonstrated that our global hydrology is clearly changing. What’s more, these changes are beginning to occur faster than our economies and environment can adjust. The loss of hydrological stability is cascading throughout our climate system, undermining the predictability upon which our economy depends for its own stability.

The following year, 2014, the prairies missed a spring flood. Though it was close, so did Alberta. Again the flooding that occurred did not happen in association with the spring melt but as a result of remarkably heavy rainfall in early summer storms. In southwestern Manitoba 50 per cent of the land was covered by water, much of it in the form of floodwaters coming from Saskatchewan. Evidently, what were once loosely considered 1 in 300 year events on the Great Plains have begun to appear every three years.

The prairies are not the only place experiencing this. On July 24, some 25 millimetres of rain – as much as normally falls in a month – fell in 20 minutes on Kamloops, BC. At the time of the storm the

entire region was in drought and the area around Kelowna was on fire. Once again we seemed to be witnessing this recurring theme seen also in Colorado of drought ending in flood, often within the same river basins.

On August 4, about 200 millimetres of rain – more than two months' worth – fell on Burlington, Ontario, in the length of time it normally takes to get through the morning rush hour. What were once considered 1 in 50 year floods in this region are now occurring every 10 years. In Toronto and region there have been three 1 in 100 year and six 1 in 50 year storms in the last 25 years. Nor were our neighbours down south spared. As August progressed, flooding of a similar magnitude was experienced in Detroit, Cleveland and Long Island. Another flood occurred in downtown Winnipeg on August 21, and only a week later Steinbach and nearby Niverville in southern Manitoba got hit with up to 120 millimetres – nearly 5 inches of rain – in an overnight storm that overwhelmed flood mitigation systems put in place after flooding in 2002.

Europe went through the same thing in 2014, with catastrophic inundations in England and parts of the continent. As if to round out August in the northern hemisphere, Copenhagen – which had just committed to spending \$2-billion over the next 20 years on infrastructure upgrades to prevent flooding – experienced an unprecedented 100 millimetres of rainfall in three hours in its downtown.

COPING WITH INSTABILITY

There is a lot of troubled water out there – and it is trying to tell us something. What it is trying to say is that the hydrological game is clearly changing in fundamental ways. We know, of course, that hydrological conditions on this planet have always been changing, and we now realize how fortunate we have been to have had a century or so of relative stability. That era is over. The long-term hydrologic stability of the climate we experienced in the past will not be returning during the lifetime of anyone alive today. Careful examination of how our hydrology is changing, however, suggests there are ways in which we can adapt.

In a more or less stable hydro-climatic regime, you are playing

poker with a deck you know, and you can bet on risk accordingly. The loss of stationarity is like playing with a deck in which new cards you have never seen before keep appearing more and more often, ultimately disrupting your hand to such an extent that the game no longer has coherence or meaning and can no longer be played. This game change means that simply managing land and water in ways that are useful only locally will no longer be enough. We now have to be alert to changes in the larger global hydrological cycle and try where possible to anticipate what they might mean at local and regional levels.

This is a huge new concept – a societal game changer – and it is going to take time to get our heads around it. What we are seeing now is likely what we will be getting in spades in the coming decades, given the most basic of all the laws of atmospheric physics. Predicted rises in temperature of between 2° and 6°C will result in further amplification of the hydrological cycle by 15 per cent to 40 per cent or more. This game change is not going to go away. Until we stabilize the composition of the atmosphere, changes in the Earth's hydrological cycle will continue to accelerate.

It is very difficult to adapt if you don't know what you have to adapt to. Unless we want our future to continue to be a moving target, sooner or later we may have to confront the root cause of our changing hydrology – which unfortunately remains a subject few have wanted to talk about in meaningful terms until recently, at least where I live in Canada.

What has also become clear is that it isn't just emissions cuts that we need in order to restore climatic stability. We can no longer ignore the local value of natural ecosystem processes. In order to gain even partial rein over the hydrological cycle, we have to enlist all the help nature can provide us. We gain that help by protecting and restoring critical aquatic ecosystem function locally by reversing land and soil degradation wherever we can. There is great power in realizing this, for it is at the local level – where we live – that we have the most power to make changes and act most effectively in service of the common good, now and in the future.

We come to the conclusion, finally, that the watershed basin is the minimum scale at which water must managed. This fact in

itself – the fact that basin-scale water management is critical to social, economic and environmental resilience in the face of changing hydro-climatic conditions – should inspire our actions. Just like in the movies, this is a time for courageous and relentless citizenship and heroic leadership. The problems hydro-climatic change is bringing in its wake are not going to go away. We should not expect a Hollywood ending. Wishful thinking and last-minute heroics are not likely to get us out of this one. But thoughtful and timely local action will.

