It Came from Chaos

All the doom and gloom of climate change seems like a sure bet, something we're willing to blame entirely on humans and our smog-spewing ways. Look a little closer at the science, however, and predicting the future of our planet isn't quite that simple.

By Thomas Chalmers

It came from chaos! The terrifying creature called Global Warming has suddenly sprung forth into the light of day, dropping a screaming Mother Nature with a punch in the face and raising its heel in preparation for a final brutal stomping. Right before our very eyes.

Egad!

Like a four-colour fiend from the silver age of comic books, climate change is the environmental bogeyman of our times. In the dark places, under towers of steel and glass, below skid-marked asphalt streets and under plastic-laden landfills, this flushed-down spawn of humanity's foray into industrialization has grown up big and mean, consuming a steady diet of mutagenic hydrocarbon byproduct goop.

Though the media-hyped, politically charged horror of Global Warming may well be cause for panic, freaking out rarely solves a problem. Take a deep breath of the smog-tainted air and get a handle on the situation. Let's ask important questions. Let's get to the bottom of this.

What is climate anyway? Where did it come from? Has the Global Warming beast ever struck Earth's climate before? How can we predict the planet's climatic reaction to our juvenile human experiments with gas and matches? Can Global Warming be defeated?

Climate is simply the weather over time. The World Meteorological Organization defines it as the weather averaged over 30 years. Humans began to measure temperatures only 350 years ago and have a decent global record for a mere 150 years. Instead, our historical, or paleoclimatic, data comes from indirect measures like tree rings, corals, marine sediments and glaciers. These provide an essential frame of reference beyond our human experience; they give us perspective about what the climate might be changing to, or from, on a planet that is over four billion years old.

This paleoclimatic record is chockablock with Global Warming clues. It shows a climate of intense natural variability over a wide range of time scales. Some important, near-cyclical temperature swings are results of changes in the orbit of the Earth around the sun, including eight ice ages in the last million years.

Nonetheless, there have been many unpredictably large and rapid temperature swings on a scale greater than any encountered in more modern (human) times, many of which cannot be attributed to a particular cause.

Since the end of the last ice age, ten thousand years ago, the record gets shocking. Temperatures have been the warmest they've ever been over the last half-million years; a spell that probably enabled humankind to get so darned agricultural, thereby helping us reach the state we affectionately call civilization. Temperatures have repeatedly swung five to eight degrees over periods of about a thousand years, with some significant changes over a decade or less. The Earth has likely been as warm as the present more than once. Although there has been a generally increasing trend, rapid temperature increases in the last 50 years are surely being driven by extra greenhouse gas emissions from human industrial activities.

Pow!

Greenhouse gases are portrayed as a major goad to the enraged Global Warming demon, but they also play a crucial role in the Earth's climate system. Without them, the Earth would be a frozen, lifeless ball. Greenhouse gases in the atmosphere, like water vapour and carbon dioxide, trap heat from the sun, which allows the Earth's liquids and gases—the essential fluids of climate—to change states and move, swirling under the influence of thermodynamics, gravity, and friction.

The formulas ostensibly governing this fluid flow have been known for some time, but applying them to weather and climate involves too many calculations to do by hand. So at the dawn of the digital age in 1961, Edward Norton Lorenz, an American meteorologist and mathematician, used a basic computer to run weather simulations that appeared to work, not only setting in motion the modern age of weather forecasting and climatology, but also leading him to discover the science of chaos. These innovations made Lorenz the first climate Science Hero of the modern age.

With plenty of good weather observations to put into his system, Lorenz initially inferred that a decent prediction of weather patterns was possible. Given a set of known equations, small errors going into his weather model should have only produced small errors in the forecast coming out. This is called a linear relationship between input and output: small error in equals small error out.

In fact, Lorenz's model was quite reasonable at first, but tiny errors always appeared, then propagated and grew, eventually deteriorating the forecasts into statistical nothingness. Deviations in conditions, no matter how small, could produce enormous consequences that affected the entire system in ways that could not be anticipated. This is a non-linear relationship between input and output: small input errors into his weather model were producing large changes in the weather's long-term outcome. Furthermore, there were patterns in

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The confluence of climate and chaos: Hurricane Fran bears down on the Florida peninsula in early September 1996. Packing 185 kilometre-an-hour winds, the National Oceanic & Atmospheric Association's GOES-8, Geostationary Operational Environmental Satellite, captured Fran's ominous image in all its wicked wonder. Visualization produced by the Laboratory for Atmospheres at NASA Goddard Space Flight Center.

the weather, but they never quite repeated themselves exactly. It was inherently unpredictable.

Through the process of trying to forecast the weather, Lorenz discovered that chaos is a property of nature itself. He realized that the weather could never be measured exactly, nor forecasted predictably. Not ever. Among the anemometers, thermometers, hygrometers, pyrometers, radiometers, and barometers, unexpected, chaotic differences existed that a computer could never know. This completely radical idea contravened the dominating view linearity science had been using to explain the universe since the heady days of Isaac Newton, and it continues to rattle the foundations of knowledge today.

A wispy wind whirls undetected, randomly bumping into neighbouring molecules, dragging its uncertain behaviour along in an accretive outward spiral, an atmospheric eddy that becomes a squall, then a storm, then the snowiest winter the Dogtooth Mountain Range has ever seen. Minute changes in conditions having profound, chaotic impacts. As one example, long-play satellite animations of a hurricane start benignly with calm, cloudless conditions. To paraphrase Lorenz himself, a moth farts in Nelson then a drought begins in Australia. Countless dead wallabies will bake in the sun thanks to a scantly noticeable and totally unpredictable cause half a world away.

Like Lorenz's weather, it is a fact that any physical system that never repeats itself exactly is unpredictable. This drives an unending evolution of the system's structure, charting a blindly elegant course over a brackish sea, along a fractal continuum where clear streams of orderly flow meet the disordered turbulence of chaos, foaming, bubbling, and eddying away into entropy. This interplay between order and disorder produces complex behaviour from simple beginnings, which may explain how just about everything in the universe coalesced into existence out of a bubbling cosmic soup. Since Lorenz pointed it out, nature's harmonious complexity has been found almost everywhere, from the biggest of bangs to the daintiest of DNA to the creepiest of climate changes.

What does this mean for climate change in our day and age? Well, like Lorenz might argue, no matter how smart we think we are, no matter how big and fancy our computers get, thanks to nature's complex, chaotic behaviour, our capacity to predict the Earth's climate is a lot like a weather forecast: pretty good in the near future, within a decade or so, but never 100 per cent, and growing increasingly uncertain with a longer outlook.

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Important indicators of chaos and its effects on climate change can even be found in our own mountainous backyard. Glaciers, in addition to providing the best historical records of the earth's temperature, are a key player in how our global climate system works. White ice and snow have a higher reflectivity—or albedo—than green grass or black pavement. This means that the globe's glaciated surface area—a big chunk of which is right here in the Great White North—bounces a relatively high proportion of incoming solar radiation back into space, keeping the earth significantly cooler than if our planet were glacier-free.

So, when the Earth cools a little and forms a little more ice, this ice brings even more cooling; thus, the Earth cools some more and forms more ice, which begets further cooling. Presto! An ice age. In the same way that an eddy of wind becomes a massive storm, or calm seas a hurricane, this is an example of how a small change in one part of a complex, dynamic system can reinforce itself and produce a large overall change in the system's behaviour. This chaotic process, called non-linear feedback, is why glaciologists like Dr. Shawn Marshall of the University of Calgary, have become both climate historians and experts in the motives of the Global Warming monster.

Like any climate nerd or weather geek worth their salt, Dr. Marshall knows all about Ed Lorenz and his tutti-frutti moth. "Very little in the climate system can be understood without invoking some of the non-linear feedbacks from its key components (such as glaciers, greenhouse gases, and ocean currents). Some act to amplify change, some buffer the system to keep it from changing. In understanding the ice ages, non-linear feedbacks pushed the world into periods of glaciation that lasted tens of thousands of years, others—not fully understood—helped to kick it back out."

"This is what worries climatologists when it comes to the question of future climate change," explains Dr. Marshall. "We humans are forcing the system pretty hard by loading the atmosphere with greenhouse gases, especially carbon dioxide, but this, on its own, has only a modest role in warming the Earth. The kinds of climate change that could rock society are associated with the possible non-linear feedbacks of this [human] forcing, such as the change in albedo associated with loss of Arctic sea ice, or from increases in atmospheric water vapour, which is the most powerful greenhouse gas, associated with a warmer world and an enhanced water cycle. These feedbacks can take one degree of warming and increase it several-fold."

"When the bottom line—'How much will climate change in our lifetimes?'—is controlled by the feedbacks rather than the human forcing," continues Dr. Marshall, "it makes for a lot of uncertainty. The lessons of the past, such as the ice ages, suggest that feedbacks could sweep us into territory that is beyond the predictive capacity of the models."

As discussed by Dr. Marshall, the elements of nature's unpredictability, which are well-documented in the scientific literature but rarely discussed in the popular media, include processes that could even act to offset Global Warming's rampage of destruction. The Intergovernmental Panel on Climate Change (IPCC) admits that many factors, like the cooling effects of cloud masses and the potentially huge and largely unknown modulations of global-scale deep ocean currents, are only marginally incorporated into Global Circulation Models on which world climate policy decisions are solely based.

So here we are, humans cowering before the Global Warming creature of our own mad science. Chaos causes us to question whether we can comfortably nail down a set future outcome of climate change, yet still we push our luck by introducing elements—climatic moths of our own creation, with bad gas no less—that could have profound impacts on the global climate system, a system that nature would have otherwise organized just fine. Instead of screaming bloody murder that the Global Warming beast is eating us alive, maybe we can concentrate on doing what is humanly possible to control our effects on the Earth's climate. We could then sit out under the turbulent sky in nature's own darkness, quietly enjoying tiny breezes that could shake the world, or maybe just cool our anxiously sweaty brows a bit, digging on the deeply unpredictable, yet somehow comforting, beauty of chaos. ❐