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Katrina, Wilma and Me: Learning to Live with Climate Surprises?

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Article abstract

High-stakes and large uncertainties characterize the science, policy and reality of climate change. A simple analysis of what appears to be most likely for the immediate future of Earth's climate system, including some probable human vulnerabilities, is presented below. In short, climate change is real. Further, numerous observations suggest the onset of a rapid phase transition between the familiar Holocene climatic mode and some future quasi-stable steady state. Such a climatic phase transition may extend from years to decades, presenting dramatic and unfamiliar challenges to ecological and societal organizations at all scales. Potential human hazards – particularly grave for food production – may catalyze dramatic societal changes. The profound uncertainty of abrupt climate change warrants careful reflection and prudent preparation, including assessment and enhancement of household, local and bioregional adaptive capacities.

COMMENTARY

Katrina, Wilma and Me: Learning to Live with Climate Surprises?

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SUMMARY
High-stakes and large uncertainties characterize the science, policy and reality of climate change. A simple analysis of what appears to be most likely for the immediate future of Earth's climate system, including some probable human vulnerabilities, is presented below. In short, climate change is real. Further, numerous observations suggest the onset of a rapid phase transition between the familiar Holocene climatic mode and some future quasi-stable steady state. Such a climatic phase transition may extend from years to decades, presenting dramatic and unfamiliar challenges to ecological and societal organizations at all scales. Potential human hazards – particularly grave for food production – may catalyze dramatic societal changes. The profound uncertainty of abrupt climate change warrants careful reflection and prudent preparation, including assessment and enhancement of household, local and bioregional adaptive capacities.

SOMMAIRE
C'est l'importance des enjeux et des risques qui caractérise les efforts scientifiques, politiques ainsi que la réalité des changements climatiques. On trouvera ci-dessous la description d'une simple analyse de ce qui semble être le plus probable des scénarios sur l'avenir à court terme du système climatique de la Terre, dont certains aspects de la vulnérabilités pour les humains. En clair, le changement climatique est une réalité. De plus, de nombreuses observations indiquent qu'une phase transitoire rapide serait en cours et que celle-ci nous mènerait du mode climatique holocène qui nous est familier vers un autre état d'équilibre quasi stable. Une telle phase transitoire peut s'étaler sur plusieurs années, voire des décennies, et s'accompagner de défis inédits de diverses échelles, tant sur le plan écologique que sur celui des organisations sociales humaines. Les risques humains potentiels, spécialement ceux liés à la production de nourriture, pourraient entraîner des changements sociaux dramatiques. La gravité de l'incertitude liée au changement climatique abrupt appelle une réflexion minutieuse et des préparatifs consciencieux, dont l'évaluation et le renforcement de mécanismes d'adaptation, tant sur le plan domestique, local que régional.

INTRODUCTION
The cataclysm of Hurricane Katrina brought climate vulnerabilities to the North American forefront. Fast on the heels of Katrina, Hurricane Wilma spun the barometer way down low, setting a new record as the most powerful Atlantic hurricane ever recorded. Although scarcely noted, Catarina came to Brazilian shores in March 2004, as the first South Atlantic hurricane on record. In light of numerous purported climate anomalies in recent years (droughts, floods, heat waves and other extremes) and extensive media attention, Jane and Joe Mainstreet may reach a simple conclusion: the weather outside is frightful!

Is this simple statement accurate? Are recent climatic events the tip of an apocalyptic iceberg or are they manifesting ordinary climate variability? What can we anticipate in the future and how might we respond? These questions and others demand a simple synthesis of what is known – or at least what most environmental Earth scientists believe is most likely – about our climate system and what this may mean for each, and all, of us. This essay summarizes these themes for a broad spectrum of professional scientists, as well as students and others interested in the subject of climate change. The short list of references (including online resources listed herein) delivers a thin wedge into a very extensive literature.

CLIMATE HISTORY AND COMPLEXITY
Oceanic sediments, glacial ice cores and other natural archives can be read as a rich, yet imperfect, record of Earth's climate history. Researching the dynamics of palaeoclimate helps one understand what is possible – including what is most likely – for our planetary and regional future. Computational climate models are employed to generate and test hypotheses about past, present and future climate dynamics. Modern studies of Earth's climate system are illuminating the interdependence of geological, oceanic, ecological and atmospheric processes. Accelerated fossil fuel burning and land-use changes (particularly

deforestation) have accompanied the expanding ecofootprint of industrial-powered humanity on local, regional and global scales. It is abundantly clear that the human species has become a profound planetary force (Rees 1997; Vitousek et al. 2002).

To understand climate (and Life itself), we must distinguish between complex and complicated systems. Bureaucracies and technology are complicated; the climate system is authentically complex. Complex and complicated systems may each present behaviour that is perplexing to interpret or predict. However, complicated systems are comparable to mechanisms or machines; they are top-down organized from a pre-existing template; they commonly possess an intricate internal structure, and are less than, or equal to, the sum of their parts. Complex systems transform energy flux into a dynamically ordered pattern (Chaisson 2001). These systems are self-organizing; they involve a dynamic *process* that creates and perpetuates a dynamic *pattern* and vice versa (Lewin 1992)! They commonly display emergent properties, such as self-regulation, robustness and resilience [www.resalliance.org]. Particularly characteristic are non-linear responses to forcing, including critical-point behaviour, manifested by large abrupt changes when forcing exceeds particular (and often unknown) thresholds (Alley et al. 2003). Self-perpetuation of dynamic pattern, spontaneous novelty, and surprise are intrinsic and characteristic of many complex systems.

Box model approximations are useful; however, climate is NOT a complicated mechanism. Climate is more like a self-patterning symphony of interrelated processes possessing layers of natural rhythm and change-response thresholds. Tightly coupled climate processes also resemble jazz improvisationalists, interspersing syncopated predictability and order amongst unexpected flourishes and changes in the directions and rates of change. The perplexing interplay of order (e.g. Milankovitch cycles and other climate rhythms that operate at different timescales), dynamically patterned disorder (termed chaos by Gleick 1987) and real randomness in the climate system are equally applicable to global markets and economies.

In short, complex dynamical systems are self-patterning, self-regulating and commonly surprising. In my view, the growing comprehension and appreciation of complex systems – including hurricanes, climate, consciousness and even the phenomenon of Life itself – is catalyzing a revolution in worldview that may be Copernican in depth, and scale.

Like next week's or next year's weather, climate has built in "surprise". Better and more sophisticated measurements are useful and very necessary, but the role of chance with respect to uncertain (and perhaps unknowable) thresholds and contingencies is ever-present and profound. Amidst this dynamism of natural oscillations, intrinsic variability and surprise at many different timescales, the climate system regulates its own temperature and chemistry. Characterizing the biogeochemical processes influencing climate is a major objective of Earth system science.

Earth physiology is strikingly similar to the operation and regulation of our own bodies. (Enter *"Keeling curve"* into an internet search engine to see anthropogenic CO_2 increases with respect to the seasonal climate metronome of atmospheric CO_2 in recent decades; enter an image search of *"Vostok ice core"* and *"GRIP ice core"* to view glacial/interglacial atmospheric variability, the abruptness of some changes and the relative uniqueness of pre-industrial Holocene climate.) As time passes, the internal "climate" of my body – like that of the planetary system – is not a flat line; it jumps and wiggles and bumps, within specific limits. Of course, Earth's climate system has larger internal variability in space (compare Helsinki and Honolulu) and time than you and I do. While my internal "climate system" possesses a single steady-state temperature (98.6°F / 37.0°C, plus or minus a bit) over my lifetime, the global one records a number of distinct operational modes over Earth history. Within any particular operational mode, climate is robust, possessing natural variability around a dynamic central tendency, alongside the capacity to absorb significant impacts without changing its fundamental operation.

For example, the landscape of Canada clearly records at least two modes during the last 2.5 million years. The glacial climate that predominated for most of that time was colder and drier, with strikingly larger variability over time, than the more benign interglacial (i.e. Holocene) climate that has reigned for the last 10,000 years. When compared with the rest of the Quaternary, the Holocene is anomalous in its relative stability and long duration. Both glacial and interglacial climates behaved as quasi-stable steady states, but the transitions between them were commonly abrupt and are not well understood. Some palaeoclimate data and modelling studies suggest that some important transitions occurred over the span of a few decades or less. An increasing number of scientists are suggesting that anthropogenic forcing of modern climate may resemble the incremental loading of straw on the proverbial camel's back: bales are piled on with no discernable change… the camel may wobble or groan as the loading threshold approaches; however, when a single straw precipitates a spectacular collapse, everybody stands around with palms upward in stunned surprise!

Some of the so-called "greenhouse surprises" arise from strong linkages between the hydrologic cycle and deep-ocean circulation. Very credible scientists studying these couplings are suggesting that recent changes in North Atlantic surface salinity – a key determinant of global deep-ocean circulation – are perhaps akin to the wobbly overloaded camel. Direct measurements suggest that climate change accompanies dramatic and deeply disturbing collapses of terrestrial, aquatic, and marine ecosystems in different regions worldwide.

To summarize, think of climate through time as a wiggly-bumpy horizontal line – like a steady-state (but not static!) economy –- and a major phase transition as a big jump (or set of closely spaced jumps) akin to a stock market collapse. For the anomalously stable and familiar Holocene, the magnitude of change has been small but what about the future? Any change would likely present an immediate or "flickering" onset and would perhaps play out over a series of years to decades. The character of the subsequent climate regime is little more than speculation. Some indications suggest a shift to glacial-like atmospheric conditions; however, a range of other climatic configurations may be possible.

THE CRITICAL POINT

Palaeoclimate reconstructions suggest that when atmospheric loading of greenhouse gases exceeds an unknown threshold (a "critical point" or "tipping point"), a dramatic avalanche of change may be triggered. In other words, the climate system can only be pushed so far; beyond a critical point, a phase transition heralds dramatic and rapid changes. It appears possible and even probable that our climate system has entered such a phase transition.

The Intergovernmental Panel on Climate Change [www.ipcc.ch] presented a very strong consensus that climate is indeed changing. Debates concerning the relative roles of "natural" versus "anthropogenic" drivers are trivialized by the fact that "overshoot and reorganization" behaviours in ecological and oceanic systems seem to parallel anomalies in the climate system itself (web search: climate hockey stick).

Climate fundamentally concerns the distributions of temperature and moisture through space and time. Some of the predicted symptoms of climate change include increased floods and droughts, higher maximum temperatures and more intense precipitation events. Some computer models predict an increase in the intensity and perhaps frequency of hurricanes and typhoons; however, other climate simulations do not confirm these findings. Notably though, two recent studies suggest marked increases in the duration, intensity/destructiveness and perhaps number of such storms in recent decades.

The IPCC Summary for Policymakers is concise, very readable, and available for free online. Further, our most prestigious scientific journals (e.g. *Nature* and *Science*) are publishing research that clearly documents linkages amongst human activities, the unravelling of regional ecosystems and climate change.

Science plays a central role in deciphering these troubling dilemmas; however, scientific certainty about these links is an unachievable goal and an unreasonable expectation. The widespread expectation of certainty for natural (i.e. complex dynamical) systems may be comparable to the "flat Earth" worldview of medieval times or the "four elements" of the ancient Greeks: these were useful perspectives for a long time, but were rendered obsolete by new and better data. In short, the high risks and high uncertainties now upon us present challenges and opportunities for how and why the process of science is carried out (web search: post-normal science). A profoundly useful science shall require innovation beyond our traditional practices and the deliberate inclusion of novel, integrative approaches; these bold changes shall require far more than "interdisciplinarity", and shall certainly challenge our predilection to hubris. The remarkable phenomenon of Alan Greenspan highlights the utility of wisdom arising from hard data and bold, well-informed intuition.

Is the sky falling? Jared Diamond's book, *Collapse* (Diamond 2005), may win another Pulitzer for his penetrating illumination of the linkages among environmental degradation, coevolving social processes and the collapse of human societies. Canadian Ronald Wright's book, *A Short History of Progress* (Wright 2004), delivers a darker and immensely readable account of these interwoven processes. In short, empires are a common phenomenon in human history and they are vulnerable to environmental changes and degradation, particularly with respect to water, soil health, and food production.

WHAT ARE OUR IMMEDIATE VULNERABILITIES?

At one extreme, is there an apocalyptic scenario? The convergence of cataclysmic climate change, nuclear terrorism, disease pandemics and economic/societal collapse is certainly conceivable; however, the immediate and long-term outcomes of their interrelated dynamics are highly uncertain. Nonetheless, the immediate issue is not the robustness and survival of humanity itself; rather, it is about the robustness, responsiveness and adaptability of human organizations and institutions that enclose and support our familiar lifestyles.

Change requires adaptation. Adaptive capacity may be described as the ability to respond creatively and effectively to change. We, in affluent North America and Europe, (probably) have a substantial capacity to adapt to abrupt climate change. Comprehending and advancing Canadian adaptive capacity is an important theme for interdisciplinary research. For example, see www.c-ciarn.ca/index_e.asp to survey the Canadian Climate Impacts and Adaptation Research Network (C-CIARN); similarly, http://adaptation.nrcan.gc.ca/proposal_e.asp describes a federal research funding initiative that targets "research and activities that will contribute to a better understanding of Canada's vulnerabilities to climate change and provide information necessary for the development of adaptation strategies." These research programs are novel and important; however, they appear to focus (perhaps hopefully) upon more gradual and probable transitions, rather than the abrupt changes that may be more likely.

The challenges of climate change and human response (including adaptation) are complex and complicated. Complexity describes the natural systems and their interactive dynamics, including critical-point behaviour and surprise. Complicated describes some institutional components (societal, political, scientific and perhaps behavioural inertias) and the responses that can be readily imagined or forecast. Given these realities, it is prudent to assess and expand our individual, local and regional adaptive capacities.

One matter is clear: individually and collectively, we are active participants of a global-scale, socio-cultural and economic system that perpetuates, and is dependent upon, vast infrastructures. These infrastructures similarly require and perpetuate vast and continuous throughputs of material, energy and information. Sizable perturbations to these fluxes result in losses of functionality and complexity that are likewise subject to critical point thresholds. These realities shall prevail whether describing the stocks and flows of digital money through my local credit union, or the transfer of goods and services (and economic/political/military control) worldwide. In this respect, one inherent cost of "convenience", "choice" and global interconnectedness is vulnerability.

Informed by history and the science of dynamical systems, measurable changes to human institutions/infrastructures may arise via gradual, small-scale forcings that accumulate beyond a critical threshold, via a single, large triggering event and/or via a closely spaced avalanche of interdependent changes. An important conclusion emerges: it is very reasonable to suggest that the intersection of uncertain climatic surprises upon a global system under considerable stress may result in collapse of global and some regional-to-local infrastructures.

In the depths and margins of poverty, the immediate impacts and consequent suffering shall likely continue to be profound. In the intermediate and longer term, infrastructural collapses may diminish the shackles of deepest deprivation. In the affluent North, an infrastructure collapse linked to abrupt climate change would accompany and propel a return to locally based (i.e. bioregional) lifestyles. At the very least, this means a shift to living with larger uncertainties and risk than before, and adapting by becoming more interdependent with our neighbours, while becoming more skillful and resourceful in meeting our daily needs. In poorer regions and countries, these immediate impacts may be less profound because these societies are generally less dependent upon infrastructures (web search: sustainability science, digital divide).

Perhaps the darkest forecastable challenge for Canadians in the event of a climatic cataclysm is the question of food. There is a compelling temporal correlation between the termination of the last interglacial and the innovation of agriculture on four separate continents. The details of this coincidence are being actively explored. Nonetheless, every farmer knows that successful (and profitable) food production occurs within a limited range of moisture, temperature and soil health. The stock of human food available on the planet at any particular moment is measured in months. The vulnerability of every farmer's field to anomalous weather events points to a nearly certain conclusion: sustained agricultural productivity depends upon climatic equability and relative regularity. Very simply, the stable Holocene climate of the last ten millennia can no longer be taken for granted (Broecker 1997; Alley et al. 2003).

The possibility of genuine food shortages may send us scrambling for biblical wisdom (see Genesis 41). In time of crisis, the harvest from Canadian grain fields (now delivered to feedlot cattle) can be directly used to support human populations. Can prudent sensibility fill empty silos with Canadian grain that might otherwise be "dumped"? Can grain reserves be established beyond our Canadian borders?

Climate has also emerged as a strategic issue. For example, how might a global superpower respond to a rash of regional upheavals that would certainly accompany a climatic emergency? What responses might follow should regional water shortages present immediate challenges for agriculture and urban habitability? (web search: pentagon climate report).

CONCLUDING REMARKS

Global warming and climate change have been confirmed and are well established in the public mind. However, the surprising behaviour of complex dynamical systems, including the probability of abrupt climate change and the broader implications, are not widely appreciated.

This essay presents several essential assertions regarding climate change. First, complex (not complicated) systems display dynamic self-patterning, intrinsic variability, and critical-point surprise, which contrast with deeply inculturated expectations of linearity, predictability and scientific certainty. Second, the palaeoclimate archive reveals a pattern of abrupt climate change, whereas human experience and scientific analysis of modern climate suggests we may have entered a very uncertain phase transition coupling industrial humanity with climate change and collapse of ecological systems worldwide. Third, the trajectory of abrupt climate change coupled with infrastructural collapse is very uncertain, but it includes probable challenges to Canadian and global food security.

Describing the possible (or probable) cliff edge herein is not a doomsayer's pessimism; it is a reasonable imperative to alter our course. Fear commonly perpetuates institutional and behavioural rigidity; both are maladaptive. In practical terms, the choices that may help to avert undesirable outcomes up to, and beyond, a climatic/societal cliff edge shall equally favour successful adaptation should such collapses occur. Sustainability becomes sensibility; prevention and prudent preparation emerge as the same set of biologically sensible (Life-affirming) behaviours.

As scientists, new approaches to the framing, exploration and resolution of problems are required. As citizens, more skillful and self-reliant bioregional living amongst our interdependent neighbours is indicated. It is not about divorcing technology or a return to a fantasized ideal now lost, but it may be about rediscovering the artful and skillful lifestyles of our ancestors. Can we envision fruit trees and verdant food gardens in our campuses, towns and cities? Can each of us directly confront ourself, to pursue authentic rather than material-based satisfactions in the challenge and opportunity of living? Is identifying and delivering a spirit of service and sacrifice to our chosen communities of affinity far more than soft-headed sentimentalism? What is the artful and skillful distillation of good living and personal sustainability?

Climate change is not the real problem; it is a symptom of a more fundamental problem. In short, we are consuming renewable resources far faster than they are being renewed. Some of these resources are material (productive agricultural soils, robust and resilient fishery and forest ecosystems, biodiversity) and some of them are non-material (regional language and culture, community, social cohesion and trust, personal and national security, community and personal health, even justice). Comparable dynamic behaviours and emergent phenomena of these renewable resource systems compel us to transcend Newtonian and Cartesian approaches to exploration, knowledge, understanding, and wisdom. Fuller explorations of complex dynamical systems may deliver a more useful perspective of these co-evolving phenomena, expanding into a deeper and more explicit comprehension of the phenomenon of Life itself!

Geosciences are unique amongst the natural sciences, for seeking to integrate a tangible static record of complex phenomena across a stupendous spatial-temporal range with observations of active phenomena in natural, experimental and computational systems. Earth scientists may be uniquely poised to be helpful in these uncertain climatic times now upon us. A profound research agenda for the Earth sciences requires us to transcend linear simplification, to more fully embrace the uncertainty, and spontaneous novelty, of an authentically complex world. This too may constitute a revolutionary change, with emergent outcomes we can neither forecast nor perhaps even imagine.

Favourable outcomes are possible; see *Great Transitions* (especially the first 46 pages; Raskin et al. 2002). They likely require preparation, proactive change and deeper exploration of our individual and collective vulnerabilities in order to expand our adaptive capacities. These matters shall certainly vary for different individuals and groups in different regions and settings across Canada and beyond. This topic is an inviting theme for a future essay.

Toward these ends, I invite the reader to reflect upon these few questions:

1) Am I/are we experiencing abrupt climate change? Briefly explain your measurable and intuitive perspectives.
2) What are the three greatest vulnerabilities of my home region (i.e. municipality or bioregion) to the coupled dynamics of climatic, ecological and societal surprise? Similarly, what are the greatest assets?
3) How might infrastructure collapse affect the security of my household and/or local community concerning food, water, health, clothing, shelter and companionship?
4) What personal actions can I take to enhance individual and collective adaptive capacities in the high-uncertainty present and immediate future?

Please share your insights with me (kgrimm@eos.ubc.ca; Subject Line: Katrina & Me). If a useful response emerges, I aim to invite collaboration on another essay to identify and discuss vulnerabilities and adaptive capacities, which are relevant to Canadians and Canadian Earth scientists.

To close, the coupling of climate and societal changes is perplexing, although perhaps, comprehensible. As an environmental Earth scientist and family man, my gut tells me that we have exited the relative certainty of the Holocene climatic past and are heading into an uncertain and likely stormy future. As a good friend recently reminded me, when one door closes, another (usually) opens, but it's hell in the hallway. Mimicking Life itself, this may be the conundrum, lesson and experience of climate change.

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