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# Runaway Climate Change: Boundary Conditions & Implications for Policy

## An Interim Report

## Courtesy of The Meridian Programme

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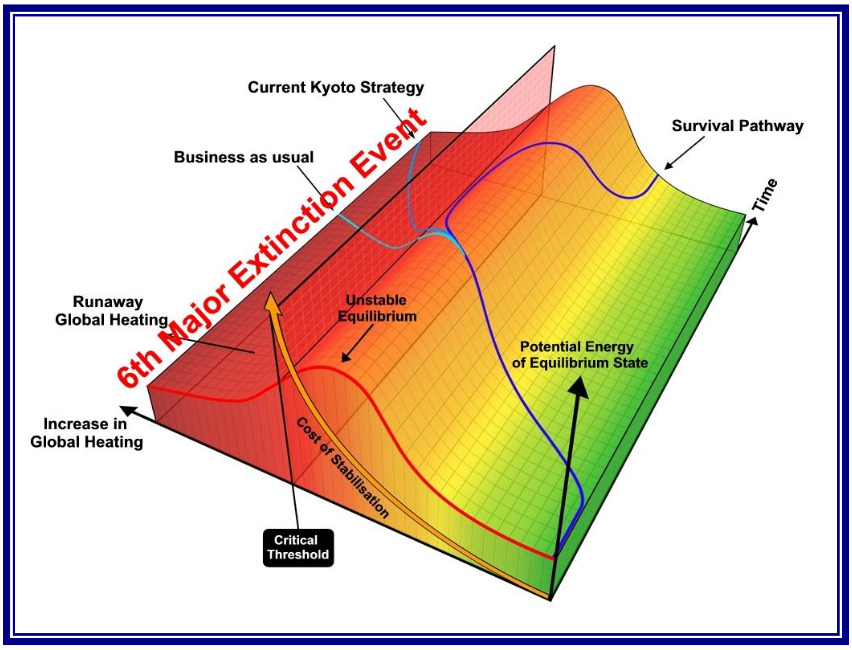
# The IPRD

The Institute for Policy Research & Development (IPRD) is an independent non-profit research organisation for Transdisciplinary Security Studies, analysing violent conflict in the context of global ecological, energy and economic crises.

**Preface**

It is almost exactly four years since my provisional analysis of the feedback dynamics of the global climate system indicated the existence of a threshold or tipping point beyond which the system exhibited runaway behaviour. Since then the analysis has undergone a continuous and stringent process of attempted falsification. It has withstood every serious challenge that I, or my colleagues in the scientific community, have been able to throw at it. Understanding of the multiple, complex and interconnected feedback processes (both positive and negative) has increased dramatically during this period, and it now looks highly probable that the conditions for runaway climate change have already been met. Once that boundary has been crossed, there is only a small window of opportunity open to the global community to re-stabilise the system. Beyond that, it becomes impossible to halt and reverse the runaway condition.

**Figure 1**




**A comprehensive video presentation can be found at: [www.apollo-gaia.org/PlanetEarth/index.htm](http://www.apollo-gaia.org/PlanetEarth/index.htm)**

**The possibility of a tipping point in the global climate system as a whole, leading to the onset of a condition of potentially unstoppable runaway behaviour, is the most profound global risk imaginable. This material is of critical importance if we are to respond effectively to the reality of the environmental emergency now confronting the global community.**

**Background**

This "Interim Report" summarises new material presented on 11th March in Copenhagen during the IARU International Scientific Congress on Climate Change. The Congress was dedicated to exploring "Global Risks, Challenges and Decisions" as the scientific foundation for the COP 15 event to be held in Copenhagen next December. The text is a revision of my Scientific Report on the conduct of Year 1 as leader of Work-Package 4 (Feedback Dynamics in Coupled Complex Global Systems) of the GSD Co-ordination Action Project of the European Commission.

**The Interim Report has been prepared as a resource document for participants in the World Forum on Enterprise and the Environment, 5th to 7th July 2009, in Keble College, Oxford.**

**From Convergent to Divergent Climate Dynamics**

**All current climate models and the policies, solutions, proposals and negotiations based on them, have at their core an understanding that the climate is essentially convergent.** Negative (damping) feedbacks are deemed to be stronger than positive (amplifying) feedbacks. If the anthropogenic driver of GHG emissions is stopped (or at least reduced below some "safe" threshold), the temperature is projected to settle down to some new equilibrium value, (represented by the set of blue lines in **Figure 2**). The present debate is therefore about the available carbon budget, emissions reduction strategy, tolerable equilibrium temperature and the achievement of sustainable growth based on a low-carbon economy.

**Current analysis of climate dynamics shows that basis to be profoundly and dangerously wrong**.

**The global climate system is essentially divergent.** The net positive (amplifying) feedback is now significantly stronger than the net negative (damping) feedback. Furthermore the excess of positive over negative feedback effect is increasing over time as temperature rises. As a result, even if the anthropogenic driver of GHG emission were brought to a complete halt, temperature would not converge to a new equilibrium. It diverges away from equilibrium on an accelerating runaway trajectory (as illustrated in the red lines of **Figure 2**).

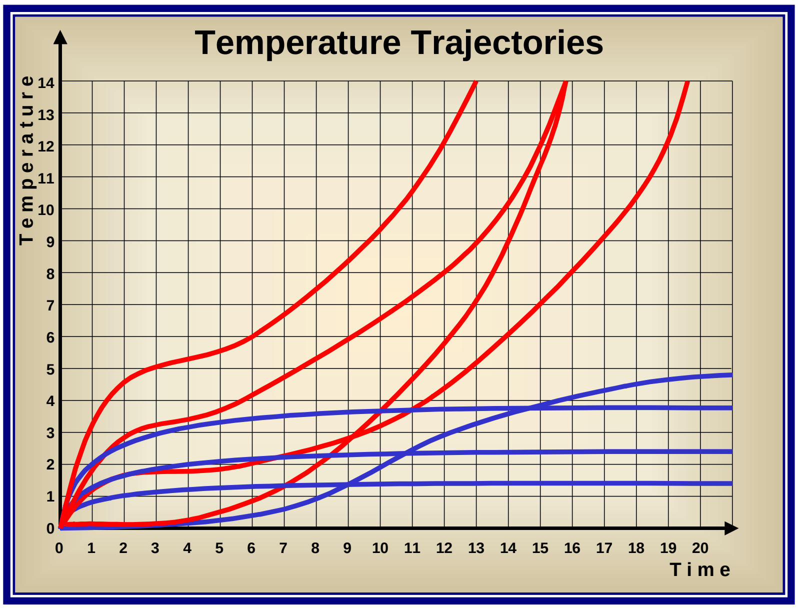



**Figure 2**

**The following sections address: 1.** The inadequacy of definitions of Climate Sensitivity; **2.** Boundary conditions for the onset of Runaway Climate Change; **3.** The mythology surrounding the proposed 2ºC ceiling; **4.** A new approach to Risk Management; **5. Policy Implications of the new analysis**; **6.** Limits of the runaway condition; **7.** Some reflections on the connections between economics and climate change. **The Interlogue** explores A new System Dynamics approach to Climate Modelling.

## 1. Collapse of climate sensitivity definitions

The Charney Sensitivity (which states that a doubling of atmospheric concentration of $CO_2$ leads to an increase in average global temperature of 3ºC at equilibrium) is a logarithmic function that is fundamental to current climate models. The Charney figure is the foundation for the hypothesis that a 440 ppm $CO_2$ concentration leads to a "safe" equilibrium temperature increase of 2ºC, a position that is the foundation for the current formulation of strategic policy in preparation for COP 15.

**Emerging consensus from the system dynamics network indicates that our dependence on the Charney figure is now discredited and should be abandoned.**

**Inclusion of a wider range of feedback effects** (Hansen et al) leads to a doubling of the sensitivity value (6ºC at equilibrium, 4ºC at the 440 ppm level). With this value the 2ºC temperature increase is reached at equilibrium with a 350 ppm concentration.

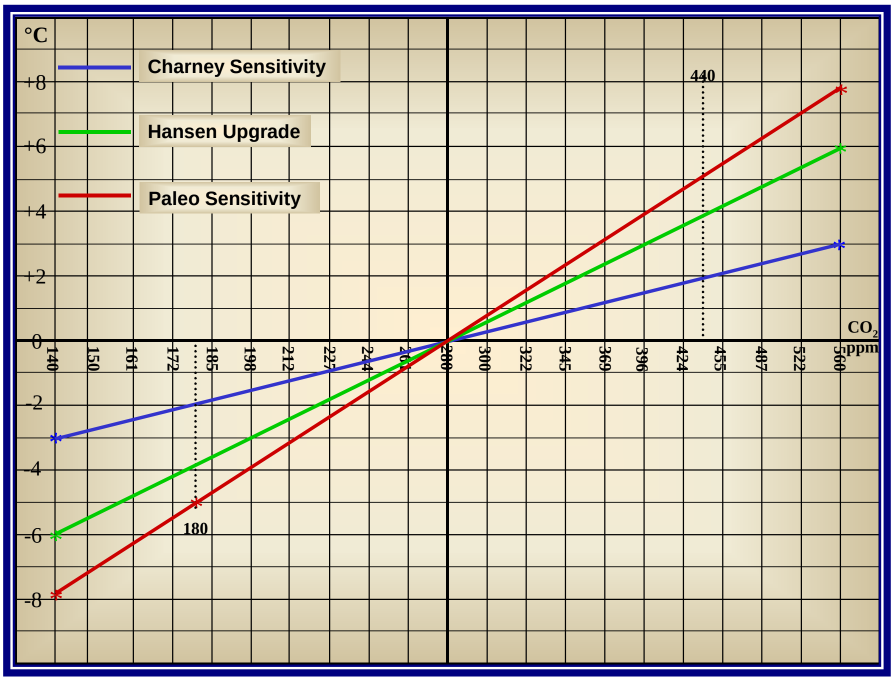



**Figure 3**

**Paleo consistency test.** A log function must provide constant behaviour in the halving as well as the doubling performance. Use of a semi-logarithmic presentation allows easy visual tracking of the sensitivity values and their testing against the paleo data. The coldest part of the five most recent glacial cycles correlates a $CO_2$ concentration of 180 ppm with an average global temperature 5ºC below the pre-industrial benchmark. The Charney value only yields a drop of 2ºC at this concentration. The Hansen revised sensitivity value offers 4ºC. A sensitivity value consistent with the paleo record yields a halving/doubling value of 8ºC, and an equilibrium increase in average global temperature of 5ºC with a 440 ppm concentration. The 2ºC equilibrium is reached with a concentration of some 330 ppm. (See **Figure 3**) This latter approach derives the sensitivity value from the recorded behaviour of the global system as a whole, rather than from a (necessarily incomplete) model of the system that cannot include all the effects of the complex feedback processes involved.

**Implications of current far-from-equilibrium dynamics.** Paleo records provide no data scientifically comparable with the present situation. Paleo data reflects values of slow temperature change, drifting in dynamic equilibrium with radiative forcing close to zero (< 0.1 watts per square metre). We are currently experiencing the effects of radiative forcing at some 30 times this value, and it is accelerating at some 25% per decade. The pace of climate change is therefore outstripping the capacity of the biosphere to adapt and to generate vegetative stabilising feedback processes.

**These conditions [of far-from-equilibrium radiative forcing, rapid and accelerating temperature change, collapse of the biological damping feedback processes, and increasing time delay in reaching equilibrium] render any value for climate sensitivity based on paleo records completely inappropriate in modelling future behaviour of the global climate system.**

## 2. Boundary Conditions for the onset of Runaway Climate Change

The threshold at which the global climate system moves into runaway heating marks the boundary beyond which, for an increase in temperature (**Δ**T), the increase in radiative forcing driven by positive feedback (**Δ**$RF_{+f}$) is greater than the decrease in radiative forcing driven by negative feedback (**Δ**$RF_{-f}$) (See **Figure 4**) In the contained, near equilibrium, field of the glacial/interglacial period, positive feedback is weaker than negative feedback for small changes in temperature. At the watershed of unstable equilibrium the values are equal. Beyond that point positive feedback is stronger than negative feedback for small changes in temperature, resulting in sustained runaway global heating.

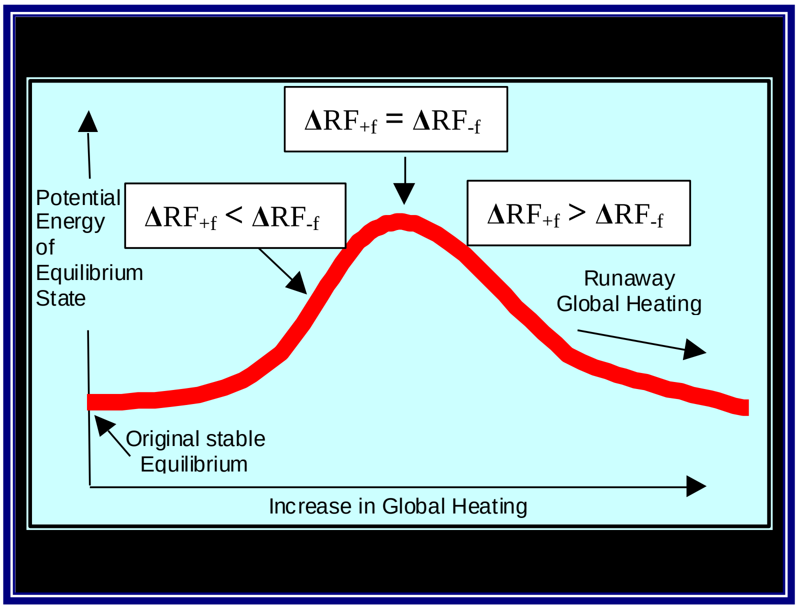



**Figure 4**

To the left of the tipping point the climate system moves to an equilibrium position when the disturbing factor of anthropogenic emission of GHGs is removed. To the right of the tipping point, the climate system accelerates away from equilibrium when that disturbance is removed.

Negative (damping) feedback is dominated by the increase in radiation to the spatial sink generated by rising average global temperature. Current best estimates of maximum net negative feedback are of the order of **< 1.45** $\mathbf{wm^{-2}\ ºC^{-1}}$, but that figure could be as low as **0.6** $\mathbf{wm^{-2}\ ºC^{-1}}$

Positive (amplifying) feedback is dominated by the strong water-vapour feedback, increased by progressive sink-degrade, decreasing albedo due to ice and snow melt, increasing non-anthropogenic climate-driven emissions of $CO_2$ from forest burn and die-back, and from non-anthropogenic emissions of methane from thawing tundra and release of sea-bed clathrates. Current best estimates of minimum net positive feedback are of the order of **> 2.0** $\mathbf{wm^{-2}\ ºC^{-1}}$

Using the most conservative figures, it seems clear that the net positive feedback already out-performs the net negative feedback, and that the gap is growing with time and increase in average global temperature.

**We therefore deduce that the climate is already in a condition of runaway global heating.**

### 3. Two Degree Mythology

**In the light of the collapse of any dependable figure for climate sensitivity, and the onset of runaway behaviour in the global climate system, it is now clear that the correlation of a stable 440 ppm** $\mathbf{CO_2}$ **concentration with an equilibrium rise of 2ºC above the pre-industrial global average is totally spurious.**

It is also a myth that a temperature rise of 2ºC is somehow "safe" on the grounds that the powerful feedback system only comes into play above this ceiling. The temperature-driven feedback system is already active and its contribution to radiative forcing has already doubled the impact of anthropogenic GHG emissions.

Current analysis also indicates that if we were to cap the atmospheric concentration of $CO_2$ at 440 ppm, then by the time the average global temperature had risen two degrees above the pre-industrial benchmark, the radiative forcing would have more than doubled from its present value. Initial integration of the values of temperature, radiative forcing and time (using the best estimate of global thermal inertia of 0.010 ºC per annum per 1 $wm^{-2)}$ indicates that the 2ºC mark would be passed before 2040. Far from reaching an equilibrium value, temperature would then be rising at some 6ºC per century (twice its current rate) and the rate of increase in both temperature and radiative forcing would be accelerating.

**That is totally at variance with the outdated scientific assumptions which form the current basis of the terms of the treaty designed to replace the Kyoto agreement at the Copenhagen COP 15 Congress next December.**

Even with a zero-emissions economy, the climate system no longer returns to an equilibrium solution. It diverges from equilibrium in an accelerating trajectory of runaway behaviour. At some point that behaviour crosses the threshold of unstoppability, a global system tipping point in the coupled complex domains of climate, energy, economics and politics.

## 4. A New Approach to Risk Management

One of the interface brokers between science and the stakeholder communities is the set of risk-management experts, particularly those leading the discipline in major domains of space flight, oil industry and re-insurance. One output of the co-ordination action in this field has been a re-framing of the approach to risk management as applied to climate change.

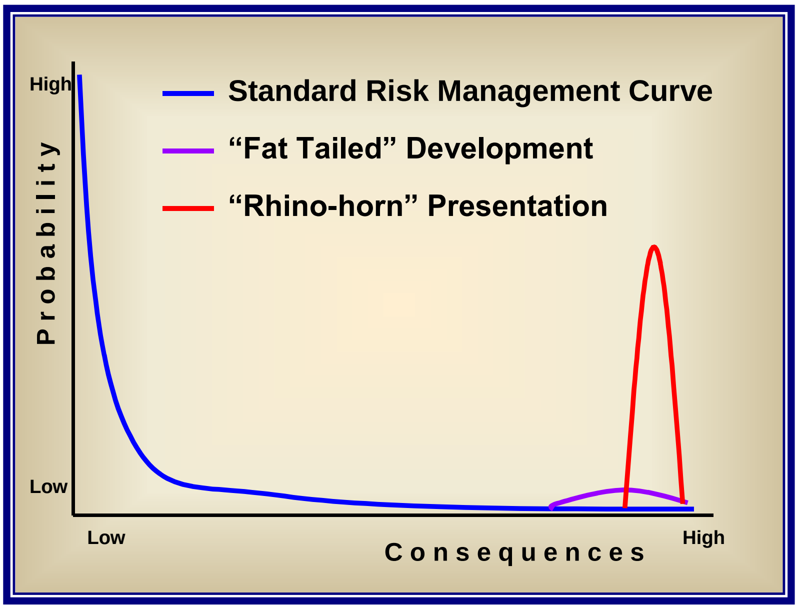



**Figure 5**

The standard diagram of probability of an event against its likely impact or consequences follows the smooth blue curve of **Figure 5**. As the probability of very high impact consequences of unmitigated global warming rose, the curve developed a "fat tail" characteristic (purple line). This required a continuous reassessment of the cost-benefits analysis (Stern) and the strong application of the precautionary principle (UNFCCC).

**The current analysis indicates very high probability of a potentially unstoppable condition of runaway climate change with catastrophic consequences.**

In response, the risk-management curve is developing a "rhino-horn" presentation (**Figure 5**: red line). Emergence of this phenomenon is the signal for the risk-management function to alert top executive levels to implement immediate response to the condition of imminent catastrophic risk (code black!).

**That is now the signal being given by the scientific community to the stakeholder domains.**

Effective organisational response involves a transformation of culture from defending business as usual against minor risks, to the global mobilisation of all available resources in a "must-win" battle for collective survival.

## 5. Policy Formulation and the Window of Opportunity

**There are several critical implications of the new analysis for policy formulation:**

- The current agenda for COP 15 is no longer fit for purpose. Its proposed solutions are based on outdated science that no longer defines the task we face. The legacy momentum of the present negotiations must now be set aside in the light of the new analysis of the situation.

- There is only a narrow window of opportunity before the threshold of unstoppability is crossed. (Some analysts maintain that the threshold has already been passed). It will close well before the temperature rise reaches 2ºC above the pre-industrial benchmark.

- There is no longer any carbon budget to be shared out between the user nations. At least 50% of all future anthropogenic GHG emissions will have to be drawn down from the atmosphere.

- Climate stabilisation requires the cessation of all activity that adds to the stock of atmospheric GHGs, and that goal must be achieved in the shortest possible time-frame.

- Under these emergency conditions, the pursuit of growth with a low-carbon economy is dangerously inappropriate. The world community must move quickly through zero-carbon to a carbon draw-down solution.

- A concurrent strategic intervention must also be implemented to reduce radiative forcing faster than its increase is being driven by temperature-related feedback processes.

- The time for competitive bargaining is over. The situation now demands a shift to collective collaboration as we mobilise in a global battle for survival.

- Whatever the cost, political, economic, technological and life-style changes will not be judged by their success in maintaining profitability, sustaining economic growth, or preserving the status quo, but by their effectiveness in engaging the global emergency. Failure to restabilise the climate is not an option.

- There will inevitably be catastrophic impacts of climate change as we move to a new system equilibrium. The global community will need to work together to minimise these impacts, to support the victims and to facilitate adaptation to the new conditions.

## 6. Conditions for Containment of Runaway Climate Change

**In earth system dynamics, the runaway period is itself subject to eventual boundary limitations:**

- The decrease in albedo caused by progressive melting of ice and snow declines with rising temperature. (The extent of glaciation is limited, and when all snow and ice has gone, the positive feedback of the ice-melt change in albedo is reduced to zero.)

- There is only a limited stock of carbon held in the biosphere that can be released via oxidation into the atmosphere. When all such sources are exhausted, the climate-driven increase in atmospheric concentrations of $CO_2$ comes to an end, so terminating this factor of the carbon-cycle feedback.

- Similarly there is a limit to the amount of methane available to be released from store whether in peat bogs, in Tundra permafrost, or in the sea-bed clathrate deposits. As that limit is reached, the methane feedback terminates. Methane is comparatively short lived in the atmosphere, and the methane feedback would begin to attenuate when the atmospheric concentration reached the point at which the release rate began to be balanced by the decay rate. Methane decay increases the stock of atmospheric $CO_2$, reducing the greenhouse effect of the gas by a factor of about 23. As the methane stock diminished, so the increase in the $CO_2$ stock would slow. In the long-term, the overall process therefore contains the methane feedback effect.

- As stocks of atmospheric greenhouse gases stabilised, the degrade in the sink capacity of the global commons would also eventually begin to slow down.

- The higher global temperature would increase the stock of water-vapour in the atmosphere, leading eventually to significant increase in global cloud cover with enhanced reflection of solar energy from the upper cloud surface. (Increased cloud albedo) This would eventually constitute a negative feedback capable of damping the system behaviour.

**The outcome would be a limitation of the period of runaway climate change, and the emergence of a new condition of dynamic thermal equilibrium. This "hot-earth scenario" would then be subject to slow cooling over a range of millennia as atmospheric $CO_2$ was gradually sequestered in the geological processes. The peak temperature would be of the order of 10s of degrees above the present, and conditions would cause the extinction of most current life-forms.**

## 7. The Climate/Economy Connection

As the field of economic modelling struggles to evolve to match the non-linear behaviour of the last year, it is having to incorporate far-from-equilibrium constraints, unpredictability in the fluctuation of value of the wealth stock (as distinct from the fluctuations in flow), and the amplifying effects of media communication and social psychology. Economic dynamics are increasingly dominated by complex feedback processes, which are not only internal to the field, but impinge from other systems in two-way dynamic coupling. For instance:

- The mobilising of some four thousand billion dollars of debt set against the hope of future income (for both repayment of principal and servicing of interest), drives the imperative of a high-growth economy.

- That in turn increases the requirements for high energy and materials use, and undermines attempts to modify anthropogenic GHG emissions.

- Increasingly costly effects of the impact of accelerating climate change diverts more resources into recovery, protection and adaptation.

- Surplus wealth available to cover the cost of transition to a sustainable global solution is rapidly diminished.

- Increased cost of food, water, means of survival, impacts of massive movements of population and the resource-destruction arising from consequent conflict, all constitute accelerating feedback systems in the wealth-devaluation (accelerating inflation) of the world economy.

**The consequence is a trajectory of diminishing resilience and accelerating stress in the coupled matrix of complex global systems. That sets up the conditions for the onset of a chaos window in macro-system behaviour.**

**Coupling the three domains of climate, economy and energy, raises further issues.** Climate stabilisation will require the prohibition of all activity that adds to the value of radiative forcing. Energy shortfall therefore derives, not from peak oil, but from climate-driven embargo on the use of any fossil fuel (including clathrate deposits). Under these constraints, the debts mobilised to (temporarily) re-stabilise the global financial system, cannot be serviced, in terms of either interest or principal, on the basis of a high-growth economy. They rapidly degrade to the condition of toxic debt of a quality and on a scale that makes the "sub-prime" mortgage collapse look almost insignificant by comparison. Subsequent economic turmoil makes it virtually impossible to address the financing of the underlying task of climate stabilisation and the essential and rapid transition to a sustainable "carbon draw-down" economy.

Growing awareness of the interdependent coupling of the dynamics of complex global systems is leading some analysts to raise the possibility that the current economic turmoil (and the concomitant de-stabilising and weakening of political systems) should be seen as a foreshock precipitated by impending breakdown in the environmental macro-system on which it depends. Many critical economic parameters respond in real time with un-damped feedback carried via the global communication system. The consequent fast-response behaviour emerges in advance of the gradually developing symptoms of the slower and more massively inert global climate. The global economy has therefore been described as "the canary in the coal mine of the global ecology".

**In addition, we must also bring to bear some of the powerful insights from the field of psycho-social analysis.** Here it is recognised that institutional structures (including environment, politics, economics, war and religion) manage the maintenance and reinforcement of the anxiety defences of the collective unconscious. Change or disturbance in any parameter amplifies the emergence of irrational levels of anxiety in the social system. This leads to intensification of the defensive dynamics, greater rigidity, heightened resistance to change, decreased resilience and rising incidence of dysfunctional response to realistic threats and challenges.

**Interlogue**

**Developing a New System Dynamics approach to Climate Modelling**

With four years analytic work behind us, the **conceptual design of a system dynamics platform** for future climate modelling is nearing completion. It will be open to close-coupling with similar initiatives in other complex global systems. A data base of leading practitioners has been assembled and is being continuously refined. Members of a Scoping Seminar on global climate dynamics will be drawn from this set during the second year of the Global System Dynamics and Policies Co-ordination Action Project of the European Commission.

**At the heart of the new approach lie the energy interchange equations** relating to change in radiative forcing over time. There is now adequate observational data to correlate radiative forcing with recent change in average global temperature, the gradient of which provides a figure for global thermal inertia of the earth system (of c. 0.010ºC per annum per 1 watt per square metre).

The integral of the radiative forcing trajectory, combined with the thermal inertia coefficient provides a **projection of temperature change over time**. A complex set of feedback links between temperature, time, and radiative forcing completes the core structure of the model.

**This elegant, energy-based approach, avoids inappropriate dependency on climate sensitivity ratios. The critical inputs depend on iterative approximations of the contribution of the various temperature-sensitive feedback mechanisms to the value of radiative forcing, taking account of the time-delay variables in each mechanism. Initial quantification of some of the critical parameters and ratios is complete.**

The **graph of radiative forcing against time** indicates whether the system state is divergent (moving away from equilibrium in a runaway process) or convergent (tending to a new equilibrium with reduction of radiative forcing to zero and a stable equilibrium temperature).

**In the absence of effective anthropogenic intervention**, initial calculations indicate a 2ºC rise in average global temperature above the pre-industrial benchmark by the year 2040. That increase rises to just over 9ºC by the end of the century, a figure remarkably consistent with the "worst case scenario" figures recently released by colleagues in MIT and Hadley. The fundamental difference is that the latter expect the temperature to be moving toward a new equilibrium, while the effects of the runaway dynamic indicate that we would be passing that figure on an exponential trajectory, with temperature increasing at the rate of over 20ºC per century and still accelerating.

**Strategic interventions aimed at climate stabilisation** can be simulated and evaluated with this platform, presenting in real time the effects of interventions in the complex and time-delayed global climate system.

**The contribution of anthropogenic forcing of the global climate** can be mapped as a proportion of the total radiative forcing at any point in time, showing the rapidly increasing dominance of temperature-driven feedbacks in the system behaviour. Concomitantly the same information demonstrates the diminishing capacity of anthropogenic intervention to change system dynamics, so highlighting the critical threshold of unstoppability in the runaway behaviour.

**The co-ordination of the operationalisation of this emerging modelling capacity, must now be an urgent priority** for the Apollo-Gaia Project during the next period of the GSD Project. It also coincides with the reframing of requirements currently being proposed to the scientific community by those stakeholder groups with responsibility for executive leadership of the global response to the climate emergency.

**David Wasdell***
25th June 2009

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