LSE Complexity Research Seminar

28th January 2010

Complex Solutions for Complex Problems:

Mobilising Social Response to Accelerating Climate Change In a Post-Copenhagen Context

Convened and chaired by Professor Eve Mitleton-Kelly

Presenter: David Wasdell*

Abstract:

An introduction to the dynamics of climate change lays the foundation for an examination of the complex system of interactive feedback mechanisms and the phenomenon of amplification of the system response to the precipitating anthropogenic disturbance. Distinction is made between systems of complexity which can dominate behaviour in sub-system dynamics, and the higher level complex system-dynamics which determine the response of the earth system as a whole. The interplay between the two is explored.

The approach is then developed to provide a framework within which to examine the boundary conditions of runaway climate change, an evaluation of risk, and assessment of the implications of the new analysis for strategic intervention.

The second part of the seminar focuses on the dynamics of social systems in response to the climate crisis. The escalating rigidity and complexity of command and control structures reduce the resilience of the social system. The institutions of international negotiation become dysfunctional as a means of mobilising effective global problem-solving. The dominance of powerful vested interests in the politico-economic arena constitute a virtual veto on essential action, reinforced by the psychodynamics of resistance to change in conditions of rising social anxiety.

The insights of complexity science may offer an alternative approach, mobilising the deconstruction of the command and control dynamics and catalysing the emergence of a zone of contained turbulence (the 'chaotic' state) in social behaviour. Connectivity, self-organisation, multiple parallel processing and the emergent properties of a metamorphic transformation of global dynamics, could generate response that is able to get ahead of the curve of the developing crisis. The precipitation of the required phase-change in social dynamics from the rigid, slow response characteristics of the solid state, to the resilient flexibility of a liquid phase may constitute the best hope of achieving a sustainable form of human civilisation within the definitive constraints of the planetary environment.

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Welcome and Introduction by Prof. Eve Mitleton-Kelly

Well today, I am absolutely delighted that David is joining us. David is actually an old friend, I have known David for a very long time, but what comes through in David's work is the sheer passion he has for both complex human systems and now very much on climate change. If I tell you that he has spent thirty years looking at human system dynamics and then about 5 or 6 years ago climate change started really taking a particular importance. He started off from the paper "Global Warning". That led to a seminar at UCL where it was discussed and it became quite clear that current modelling techniques were perfectly inadequate to capture the complexity of what is involved in climate change. That directly led to a paper, also by David, called "Feedback Crisis in Climate Change". Now this came to the attention of the European Environment Agency and the Club of Rome. There was a lot more work on tipping points based on complex behaviour. So he has actually worked with the Club of Rome, with the G8 and with the G20 and in fact with the European Commission and I think we are very fortunate that today he is here to share his insights with us. His passion actually has beneath it (and very strongly) evidence and the facts and figures that he will actually show you. So David thank you very much.

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Presentation by David Wasdell

Eve, thank you so much for the introduction. I must say it is a delight to be working with you again. I won't say how many of the thirty years we have known each other, out of politeness, but it has been a joy. I always think Eve has mentored me in complexity and I hope a little of what I have been doing has rubbed off on her as well, but it has been an extraordinary journey together. It has indeed. Through Organisational Learning and Systems Dynamics and all sorts of things.

Just a quick word about the Apollo-Gaia Project itself.

The Apollo-Gaia Project itself is a consultancy research engagement. It is based in complexity. It is not a top-down centre/periphery organisation. It is very much to do with dynamic networks. It is a catalytic engagement, looking at what is the change in the relationship between sun and earth that we have occasioned and what we can do to re-stabilise that set of dynamics. Today will be in the context of action research that is profoundly based in the academics of climate science and also profoundly based in the academics of complexity theory. My sense is that we have such a wide spread within seminar participants that I will try to give introductions to both subjects, so I will bore half of you for at least half of the time whilst the other half play catch up! I will try not to be technical and jargonistic around either subject area.

Now our subject today is complex solutions for complex problems. At the moment most of the decision-making is around trying to provide simplistic solutions to complex problems and they don't work. So let's be honest about the complexity of the situation we face and the complexity of the kind of solutions that we need to match the dynamics with which we are engaged.

The sub-title 'Mobilising social response to accelerated climate change in a post-Copenhagen context'. Anyone who was in Copenhagen saw those dynamics. Who was there? Anybody else? Actually, three or four of us were in Copenhagen and survived apparently, reasonably, the dynamics of that extraordinary event. The hopes and fears of the whole earth were focused at that point. And what I thought we would do right at the start of this seminar, in the context of Copenhagen, is to find one partner, the person nearest to you, or if you are not sitting close to somebody then move up. And ask: 'what was your personal assessment of the outcome of Copenhagen?' You are going to ask that question to your partner – there will be a competition as to who listens first, I am sure. And then move on from that to explore: 'what were the emotional feelings – your own personal response – when the outcome became clear?' We will take 5 minutes doing that, and then I will call back in. I will put Part I up on the screen, just to focus us back in again. Find a partner next to you and ask: 'What was your assessment? What was your emotional response?' Go for it.

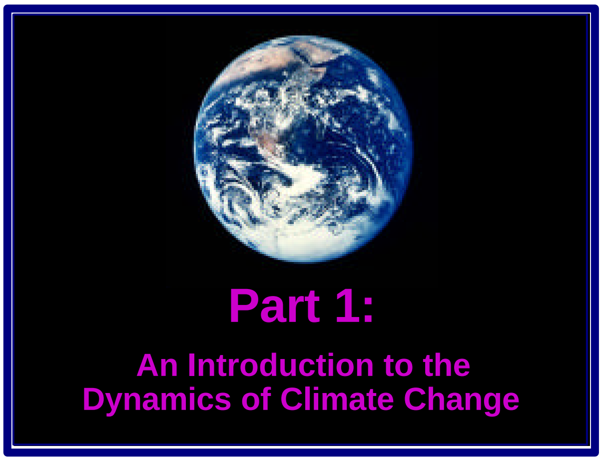
[hubbub]

I need some help, I did put the signal slide up but there was so much important buzzing I think we decided not to start the seminar! Has anybody got a blackberry that I could borrow just for a moment? It doesn't have to be on. You do, thank you so much, is it insured? This is complex. It has got an energy source, hardware, firmware, software, data, but it is not a system of complexity. It does not organise itself behind your back (you hope! it is your blackberry after all, it may not work the same after I have done this!). Only when it is connected to several thousand, tens of thousands, hundreds of thousands, millions of other users, in its own network and beyond, does it then become part of a system of complexity, a dynamic networking, self organisation, with emergent behaviours and properties, utterly unpredictable. You hope this is predictable, precisely and therefore it is a complex system, model-able, understandable, predictable, dependable. This is not an advert for blackberry but thank you very much indeed!

So we make the distinction between a complex, complicated, but predictable system and a system of complexity in which the surging inter-connectedness, the activity, the emergent properties, take us across the boundary into systems of complexity. Eve is that a reasonable distinction to make? – I hope it is.

Eve Mitleton-Kelly: And I think you can keep it to complicated and complex, because a blackberry is very complicated, and it only becomes complex when the individuals start interacting.

David Wasdell: So you would rather have complicated systems and complex systems, which is a different terminology to my own, but when I relapse you will have to give me a kick.



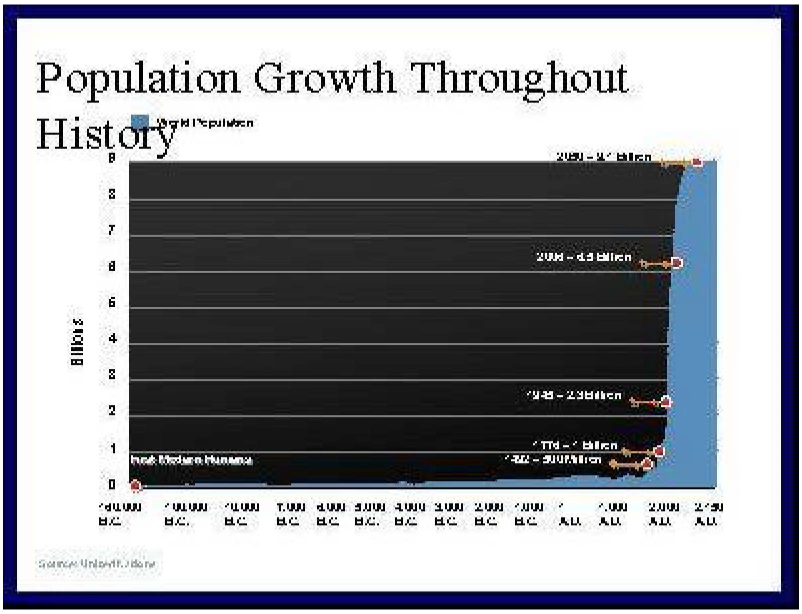
OK. Part I: An introduction to the dynamics of climate change. You all, I think, have a copy of the abstract and I will just skim through those first two paragraphs. This introduction will lay the foundation for the examination of the complex system, not complicated system, it is a complex system, of interactive feedback mechanisms which amplify the signal we have put into the system from our use of fossil energy. (I have already started to make the distinction between complicated systems and systems of complexity and this will be a complication of my seminar throughout the afternoon. I really am not going to be able to keep that distinction clear. I have for many years used complex systems to represent things like Jay Forrester's world-modelling of inputs and outputs and differential equations and stocks and drains and feedbacks, while systems of complexity, what you call complex phenomena, I have really kept for those inter-connected, autopoietic self-organising systems which we are now understanding.)

By the way, the science of complexity was described as 'science without facts' when it was first introduced, but I think today we have moved a little beyond that into a much clearer understanding that it is a profoundly based description of the extraordinary creativity of multiply connected organisms and items in complex social behaviour.

At the very highest level of all, the earth system becomes less subject of complexity and more simple, so I shall be working literally with the dynamic thermal equilibrium of the earth as a hot object in space, which has very clear equations and very clear behaviours and then working down to the seething underlying levels of complexity, which create the data into that larger system.

Then I want to go on in the second part of Part One to develop a framework in which we examine boundary conditions of runaway climate change – a subject which has been rendered taboo over the last year in preparation for Copenhagen. I really mean absolutely oppressed in the scientific community and in the political community. Last March, material on this subject was put into the Copenhagen congress on science in preparation for Copenhagen COP15 but eliminated from the agenda and not reported. I will not go on, I could bore you with a whole load of details of the suppression of any examination of science which would disturb the political commitment to a 2 degrees cap - around 440 parts per million of CO_2. 'We take this mantra as read, the science has been put to bed, we do not want anything to disturb it.' Science doesn't work like that. Prime Minister Rasmussen at the end of the science congress said 'I want a clear message, and then I want you scientists not to alter the goal posts' and received a round of applause. This is not science. This is illusion. Freud described an illusion as a 'belief with a large proportion of wish-fulfilment' It was an illusion. So I shall open up, I hope without too much repression, termination, threats to my life and other things that have been mobilised over the last 9 months (and not only for me personally, but also for Jim Hansen and others), as we explore boundary conditions of runaway change, an evaluation of risk, and an assessment of the implications of the new analysis for the strategic interventions beyond Copenhagen.

Part Two will follow after a short break. We will have some discussion at the end of part one and then tea will be served, we hope, and then we will get back to Part Two which is much more into the social dynamics area, so enough of that for now. Let's go straight in with part one.

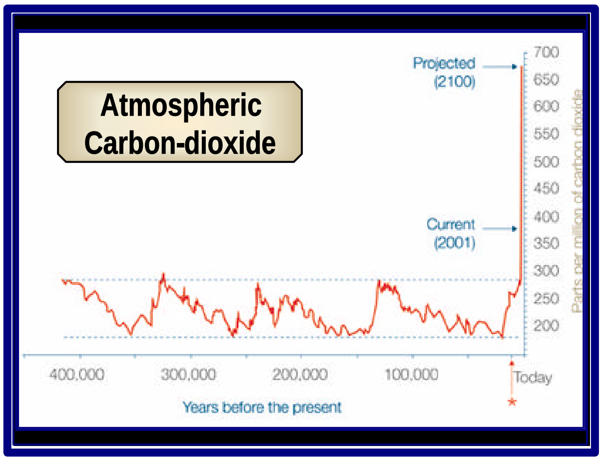


Let's begin with ourselves. This is one of Al Gore's slides. We started off with the first modern humans and then the end of the last ice age around here, and then these are all 1,000 year increments aren't they up here to here, and suddenly the scale expands, otherwise this would be going almost straight up in the air. The precipitation of the human swarm, of which we are now well in to the last doubling period, came about by the discovery of sources of energy and food that were not part of the throughput system of our present engagement with our energy source –solar fusion. The sun is also a system of complexity, but with fairly predictable outputs within limited ranges.

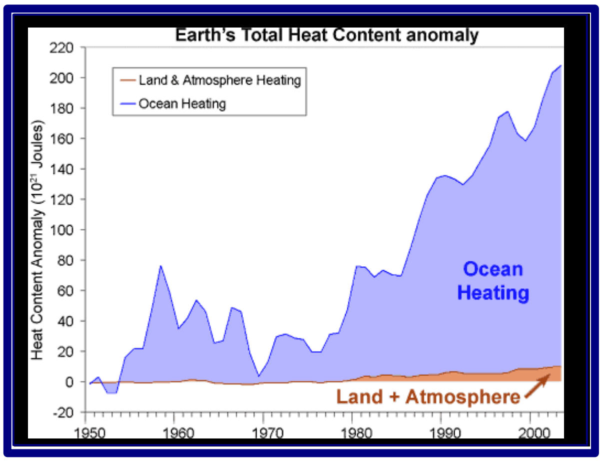
The energy per person being used as the swarm takes off is also increasing dramatically. The entropy generated by such a swarm behaviour is extraordinary, and by entropy we mean the drain on energy, the externalising of disorder and the internalising of order. That is also, I think, a characteristic of our banking system and others, and indeed of our human dynamics themselves.

So the output of this lot is placed externally to the energy seeking system. When you see a picture like that, you say what a mess, shouldn't they have cleaned that up a bit! But of course there are several things going on. The steam – that condenses and drips out of the atmosphere quite quickly. There are black particulates of unburned smoky stuff – those go off and come down again within weeks, but they do add to the heating of the planet. Then here are sulphur particulates which tend to scatter sunlight, so that it goes back out into space – global dimming comes from that source.

But the stuff you don't see, that is what is doing the damage, the gaseous outputs from this lot. We have used the global commons as a dump for the pollution from the global swarm to our cost, and to the cost of the planet.

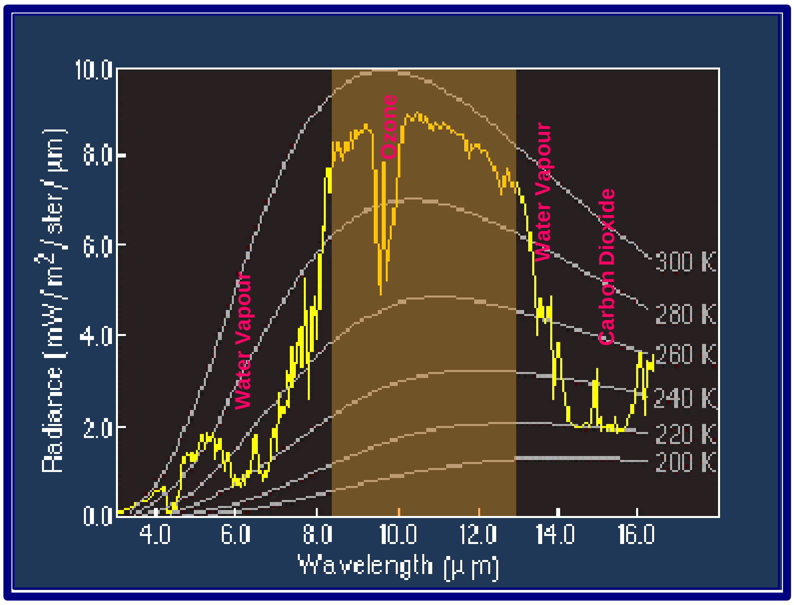


So over the last half million years, the amount of carbon dioxide in the atmosphere has gone up and down, from the bottom of the glacial to the top of the inter-glacial warm periods. A band of about 100 parts per million between 180 and 280 parts per million. Until we got going! We have now driven that up to some 387 parts per million, so we have now added about 100 ppm. In other words we have contributed to the atmosphere the total difference between the ice-age and today. It is going on up. If you add in other greenhouse gases, we are already at about 445 – 450 parts per million. Projected – where do you want to stop? And that is the problem! Because the more greenhouse gases there are in the atmosphere, the bigger the gap between the energy we receive and the energy we give back out again. We keep it in. The greenhouse gets warmer for the same amount of sunlight.



This has just been published, the graph of the total heating to the earth over this last 50/60 years. I put this up now because you know people have been saying, the earth is cooling – the temperature is not going up as much as we thought it was going to. If you look at where the heating is going, you see that the temperature is pretty irrelevant. The point is this: energy is taken up by the oceans, mixed down into the ocean depth. It is taken up in the atmosphere and the land surface, that is where we measure temperature. It also begins to heat the land further down. It melts ice – that takes a lot of energy without changing temperature. It adds water vapour to the atmosphere in bulk in a net amount per annum, and that takes energy. So the amount of extra energy that goes into temperature change is quite small.

And the noise we get because we have had a cold winter is irrelevant, because in fact I think we had an abnormal change in pressure over the Arctic, which has put the jet stream further south, which has allowed Arctic air to spin down into Eurasia,. Lovely e-mail quote from somebody in central Europe, saying: 'It is 15 degrees below what it should be, now I know everything about climate change – it is over!' And then a response on a blog to that from somebody over in the North of Canada, to say: 'It is about 10 or 11 degrees hotter than we have ever experienced it in winter before – climate change has obviously accelerated massively!' But in fact of course the 'hat' of the Arctic just slipped a bit and people draw conclusions and sceptics get on soap-boxes and tell the world that it is all over. However, in reality, the heating continues, massively.

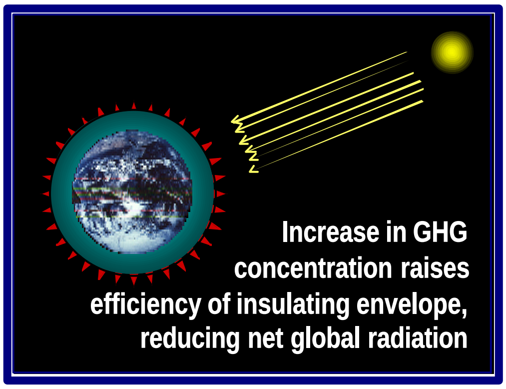


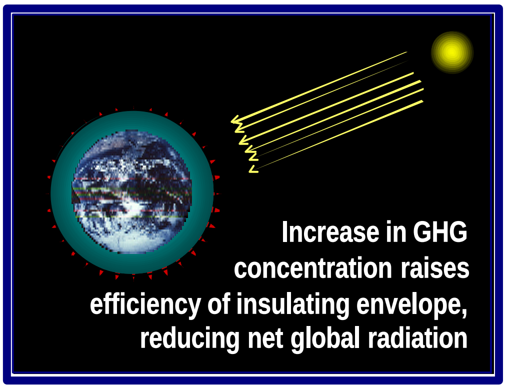
OK, now this one is beginning to lay the basis of our science and for those of you for whom it is quite new, I will take you into it. What we have here is the radiation emitted from a set of black bodies in space of different temperatures.

Our own background temperature is about 285-ish here, and we should be radiating on a smooth curve across these wavelengths out into space. Except that the radiation has to run the gauntlet of water vapour, carbon dioxide, ozone and another bit of water vapour that absorb energy on these various wavelengths. So these are the greenhouse gases that stop the radiation going out. As a result, the surface temperature of the earth has to go up higher to compensate for these holes in the absorption spectrum. So the more greenhouse gases there are in the atmosphere, the higher the temperature has to go in order to compensate and balance the energy equilibrium – it is fairly straightforward.

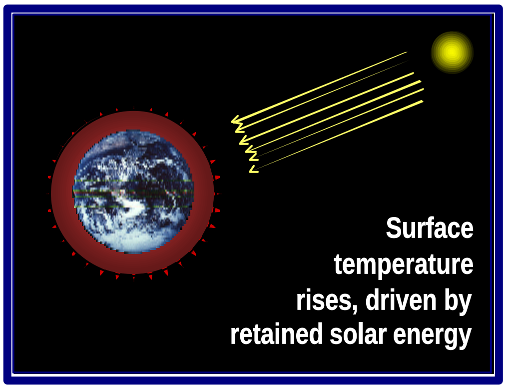
Is that clear enough for people? We will go on from there.

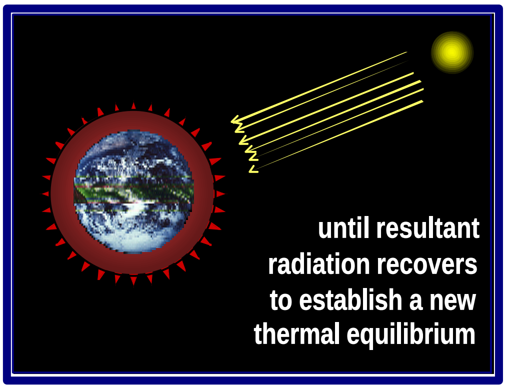
Then here we go.



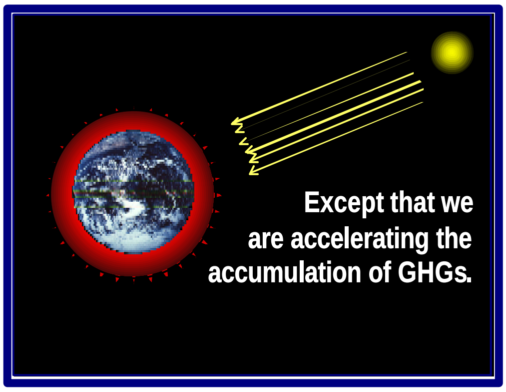


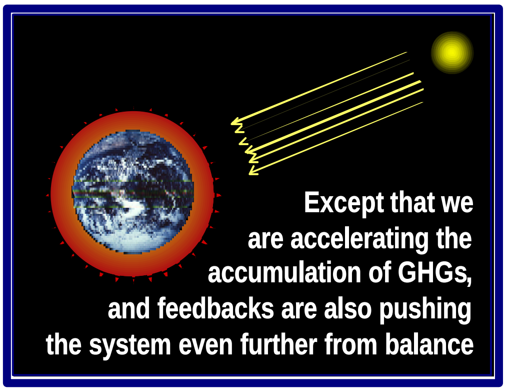
The increase in greenhouse gas concentration raises the efficiency of the envelope and watch the red arrows, because what happens is that we lose radiation and keep it near the surface.





And if we just shunted the amount of greenhouse gas to a specific level, then as the temperature goes up, radiation recovers, going out again and a new equilibrium is established. That is not a system of complexity. It is not even complicated.





OK the problem is – things are just not like that, because we are not simply putting a step change into the greenhouse gases, but accelerating their accumulation. That steadily increases the rate of heating, and in addition, we are amplifying that intervention by a whole range of feedback processes, triggered by what we have done and multiplying the effects of what we do. That of course leads to even greater heating.

The question is, 'by how much is our input amplified?'. 'What is the sensitivity of the climate system?' If we release a quantity of CO_2 that on its own would put the temperature up by a given amount, then does the feedback system amplify that by a factor of 2 or 3 or more? What is the value of the climate sensitivity?

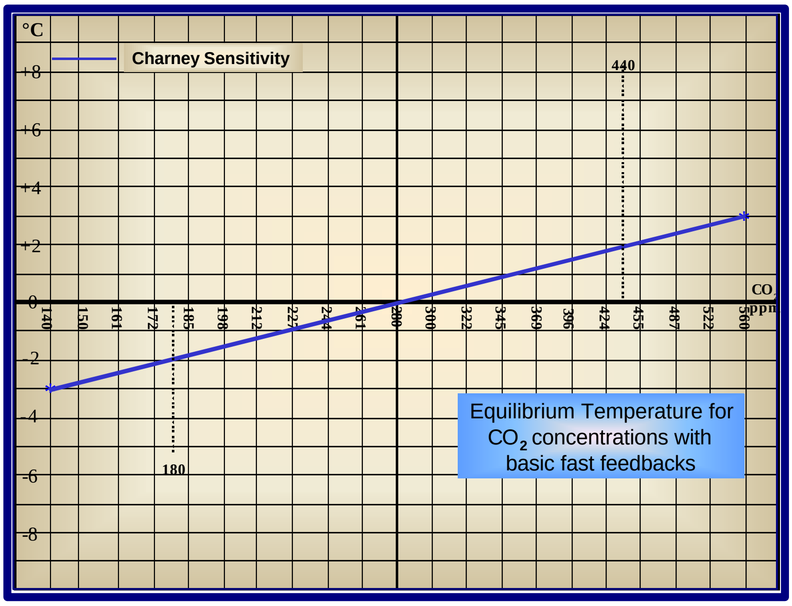
Well the standard view of that is outlined by what we call the Charney Sensitivity.

Climate Sensitivity

Charney checked against Paleo-records

Charney was the chair of a Committee back in the late 1970s who took in reports from various scientific analyses. One was an increase of around 2½ degrees Centigrade as the final equilibrium outcome of a doubling of CO_2 in the atmosphere. And then Jim Hansen put in a report saying, actually doubling CO_2 leads to a temperature increase of around 4 degrees, so Charney said 'well let's take an average, call it three and plus or minus about ½ a degree' and this has really become the mantra. You will find it has become the basis which has been fed in to many other systems ever since. It is pretty accurate for certain conditions, taking into account the amplifying effect of some of the basic fast feedback mechanisms.

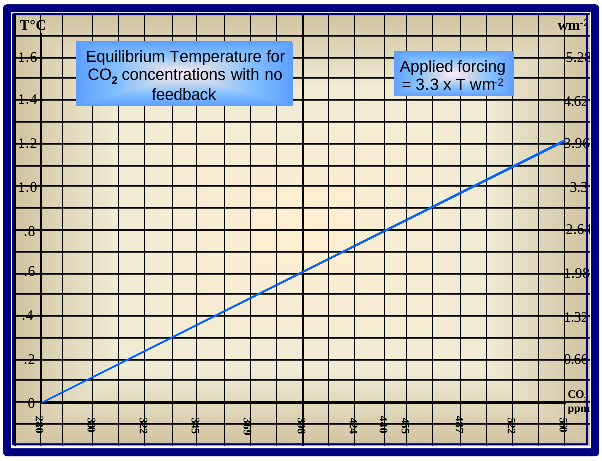
The effects of increasing the atmospheric concentration of carbon dioxide generate a logarithmic response. The more CO_2 you put in the atmosphere, the less effective it is as a greenhouse gas. If you double the amount, the temperature goes up, say, 3 degrees. You double it again and it only goes up another 3, double it again it only goes up another 3. It is a logarithmically damped phenomenon.



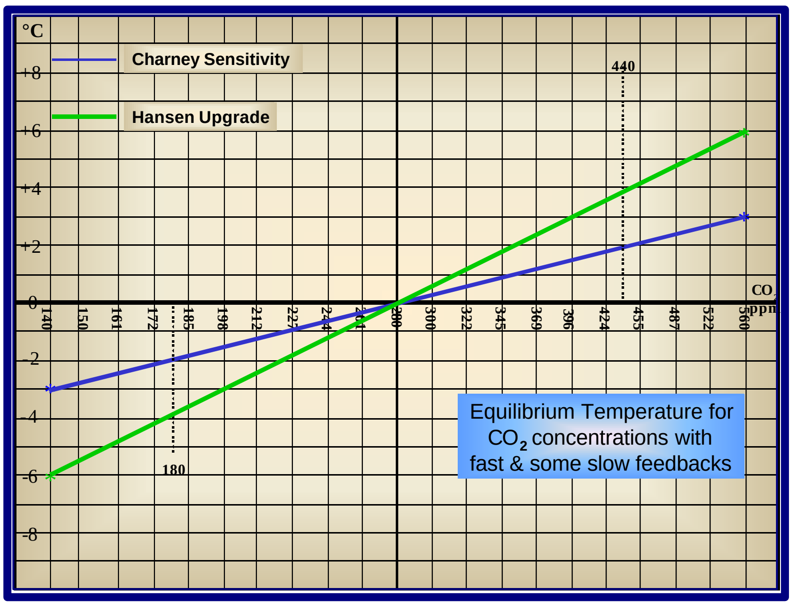
So what I have done in this illustration is use what we call a semi-log scale. You will see values of CO_2 concentration are not linearly placed. They are arranged according to a 'log base 2' scale that allows a constant length of the horizontal axis for each doubling of the value of the variable. The centre point represents the value of the concentration of carbon dioxide in the immediately pre-industrial period, namely 280 parts per million. To the left we halve the value to 140 ppm, while to the right we double that to 560 ppm. The blue line traces the Charney sensitivity at 3 degrees for a doubling of CO_2. On a semi-log scale the beauty is you can use a straight line, and halving it on a log scale should provide the same result as a doubling around this range. The log function begins to break down with very low and very high concentrations, but around this range it should be pretty well spot on.

So halving the concentration to 140 ppm should lead to a decrease in equilibrium temperature of 3 degrees. Oh, by the way, I put in markers for 440 ppm and 180 ppm as guides. The lower point because that is the CO_2 concentration at the coldest point of the ice-ages, the higher marker because that is the figure below which political theory believes that climate change would not be 'dangerous'. The two points are absolutely symmetrical on the log scale. I really was not expecting that!

If we look at the increase in equilibrium temperature predicted by the Charney sensitivity for a CO_2 concentration of 440 ppm then we arrive at 2 degrees above the pre-industrial base-line. Now we know everything there is to know from climate science! All we have to do is set the limit at 2 ºC, decide that 440ppm is the right concentration to aim for and then find out how to achieve it with all justice and equity and careful negotiations about who has the right to do what on what time-scale. Enter the process of COP 15 in Copenhagen. Unfortunately the scientific basis for that set of objectives is fundamentally flawed.



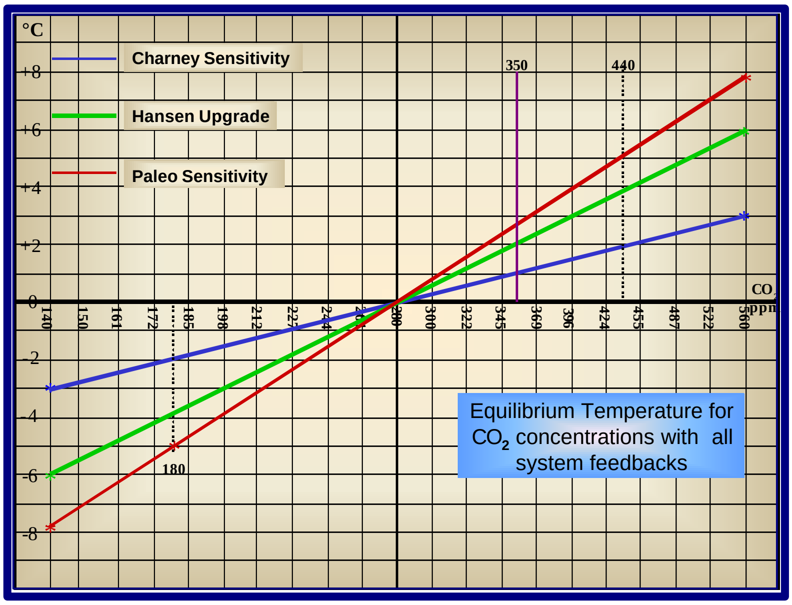
If you just look at the effect of CO2 on its own, with no feedbacks at all, in the range from 280 – 560 ppm Then we would have an equilibrium increase in average surface temperature of 1.2 degrees and about 4 watts per square metre of forcing. The amplification of that by the basic fast feedbacks is what makes the difference between 1.2 and Charney's figure of 3 degrees. Charney includes basic fast feedbacks like water vapour feedback. The more heat, the more the temperature goes up, the higher the concentration of water vapour in the atmosphere. About 7% more water vapour is held in the atmosphere for every degree rise in temperature. Water vapour is a powerful greenhouse gas, so that constitutes a big feedback. Charney also takes into account some cloud feedback and some of the effects of decreased surface ice with consequent feedback in lowered albedo. However, Jim Hansen says we need to bring in some of the other feedbacks:



namely the slow feedbacks that are now already activated. Those should be taken into account in calculating a more accurate equilibrium temperature. As a result, he reckons we have a sensitivity of doubling CO_2 producing a temperature rise of 6 degrees, not 3. So if we went for the Copenhagen 440 ppm, Hansen reckons the equilibrium increase would probably be around 4 degrees above pre-industrial, not 2. That doubles the Charney sensitivity. And those of you who know anything about the climate science will recognise that 4 degrees is the gateway to catastrophe, if not before.

Now if you follow Hansen back to the 2 degree mark and drop that down, you find 350 ppm sitting underneath it. So the '350 dot org.' campaign is coherent with Hansen's understanding of a 2 degree cap.

Let's press on with this. Because back down at the depth of the ice age with a CO_2 concentration of 180 ppm, we were 5 degrees below the pre-industrial bench-mark. That point shows the whole system with all the feedbacks in the natural system operating without any artificial selection.



So if we draw a line from there through our origin of 280 ppm we find that a doubling is much closer to 8 degrees, not 3, taking all the equilibrium feedbacks into account. If we project that back to the 440 ppm we are looking at an increase of more like 5 ºC. If we come to the 350 ppm we are still at about 2.8 ºC. We are now finding that at the final equilibrium, the whole system with the total set of feedbacks pushes us way, way beyond the outdated and inaccurate science which was foundational for the COP 15 negotiations. So my emotional response to Copenhagen was 'thank goodness we don't have a binding legal agreement to a false solution that is not to the presenting problem!' We would have had to unpick the whole thing again when this new scientific analysis was taken into account. And it was held out from consideration for all the time leading up to Copenhagen. We had a major scientific report from Germany that said 'this report is a compromise between what is scientifically necessary and what is economically and socially feasible'. And that was meant to be a scientific report. When scientists start doing that, they have already sold their birthright for a mess of pottage, pardon my biblical response.

One further critical issue is that all of these graphs refer back to behaviour during the series of ice-ages and inter-glacial periods covering the last million years They are looking at very, very slow system change. Very close to equilibrium. We are not in slow change and we are not close to equilibrium. Those analyses do not fit the complexity of the current situation. So it is very dangerous to assume that slow, near equilibrium behaviour, determines what happens today. Economists made exactly the same mistake. When you have a complex system with high degrees of inter-connected feedback processes, it can become extremely easy to topple into unpredictable behaviours and it costs a hell of a lot to restabilise it. Or even to create the illusion of restabilising it.

So the two fundamental questions we face are:

1. **By how much does the natural feedback system amplify the human input?**
2. **Is there a threshold in the system dynamics where it begins to move into accelerating climate change?**

The latter condition would represent crossing the boundary of runaway behaviour in which the original signal would be amplified to the point where it would no longer tend to any equilibrium at all.

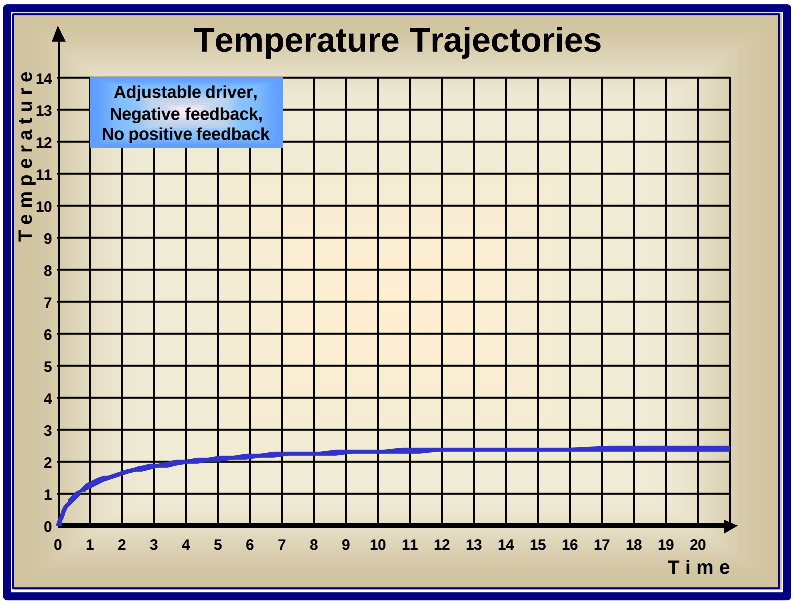
This is where we go right brain to generate a 'Feedback Simulator' in order to illustrate the dynamics involved in addressing those two fundamental questions.

I found this beautiful antique French-Canadian copper bath-tub for sale on the web. The vendors had put it out in their car park to take a photograph of it, so it is fairly private. Skinny dipping is allowed!

I took an ancient thermometer and welded it on – this is all virtual you understand. Then we fill it about two-thirds full with water and leave it for a few hours to come up to car park temperature in the sun. We will then assume that the environment stays at a constant temperature. Now watch the red line on the thermometer, because that shows what is happening to the temperature in the bath-tub.

By the way, it is not just what you thought of as a cold dip, it has got a heater underneath this one, so it can get nice and warm. And we have actually got good control on the heater and can turn it up and down.

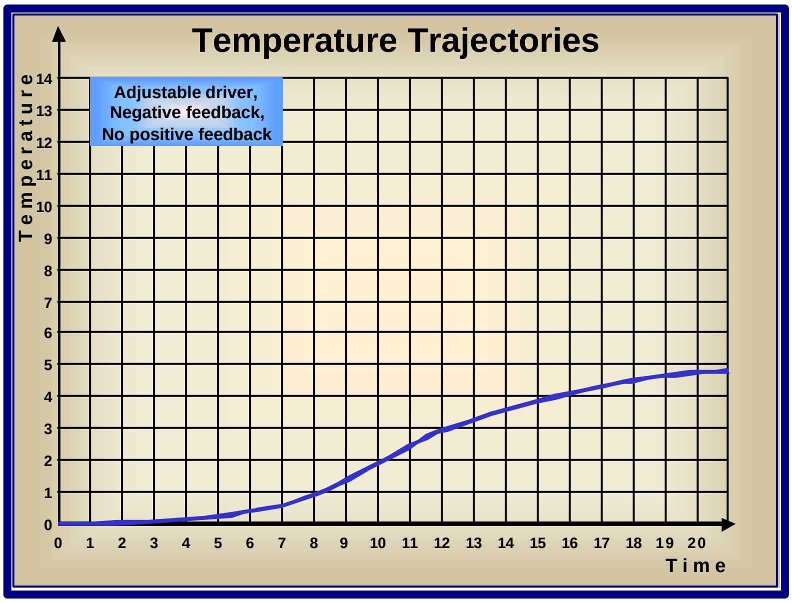
So let's set it on mark 2 and watch the temperature, there we go and you see the temperature starts to go up and up and up. It eventually reaches a point where the energy coming in from the burner balances the extra energy going out into the environment because the whole bath is a bit warmer. And if you want it warmer than that you have to turn the burner up higher. Good simulator. Not complex. Not even complicated. Just simple.



So it has a temperature trajectory like that. The temperature starts going up faster and then gets closer and closer to an equilibrium. No problem. That is an adjustable driver – we can turn it up and down – negative feedback – the hotter it gets the more it loses to the environment – and no positive feedback. It is very simple.

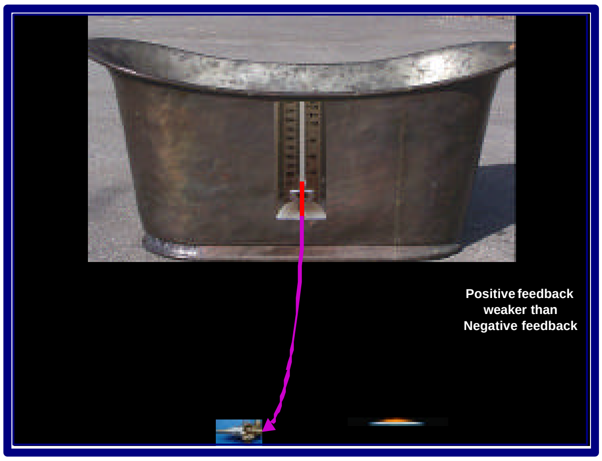
Ah but climate change is not like that. We didn't suddenly make a huge shift in CO_2 concentration!

Actually it started off very slowly – do watch the temperature as the heating gradually increases. At some stage the heating reaches a maximum (we hope!) and temperature will go on going up until it reaches a new equilibrium where again energy supplied by the burner just balances the extra heat loss from the warmer bath-tub.

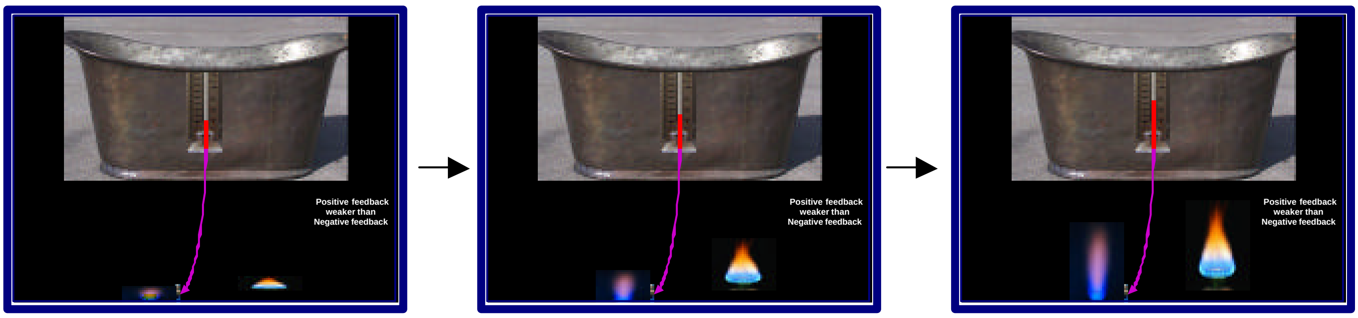


Like this. So this is our simple system with an increasing input of energy, a negative feedback (in that loss of energy to the environment is proportional to the increase in temperature), no positive feedback, and behaviour that tends to an eventual equilibrium.

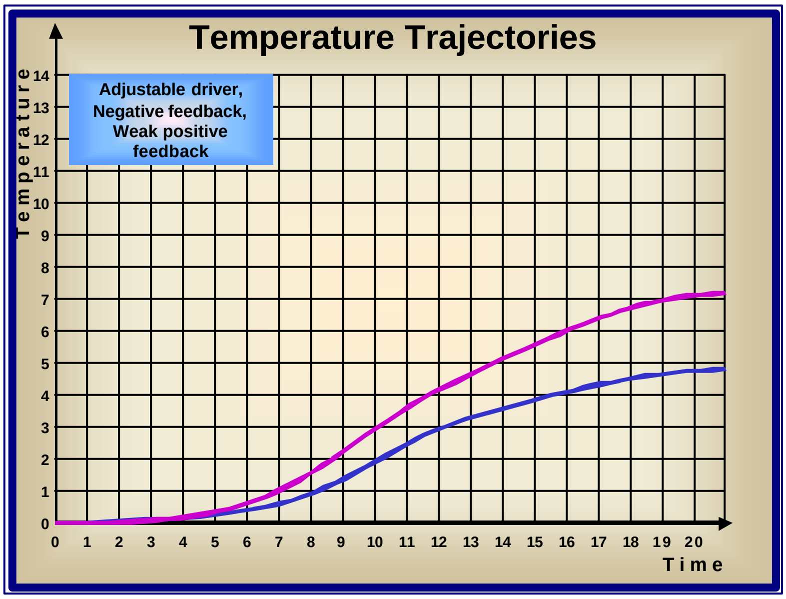
Now we are going to put some weak positive feedback into the system, (weaker than the negative or damping feedback) and see what that does. How on earth are you going to put a feedback into a bath-tub?



Well it looks like this really. We put in an active link between the temperature gauge thermometer and a second gas tap. As the temperature starts to go up, the new gas tap lights, so there is more heat going in than we originally thought. We have control over the original burner, but we have no control whatsoever over this second one because it is driven solely by the temperature rise.



And as the main burner goes up, the hotter it gets, the faster it gets hotter. Even if we stop the main burner going up any further, the temperature is still rising, so the feedback burner goes on increasing its input until the total energy input from both burners is just balanced by the energy lost to the environment from the now even warmer hot-tub. So as we move from a situation where we had no positive feedback to one with weak positive feedback, we find the eventual equilibrium temperature is higher than it would have been if there were no positive feedback at all.



Now we are getting there. I apologise to those of you who are experts in climate science but I find this metaphor begins to communicate into those areas that even Heineken doesn't even reach!

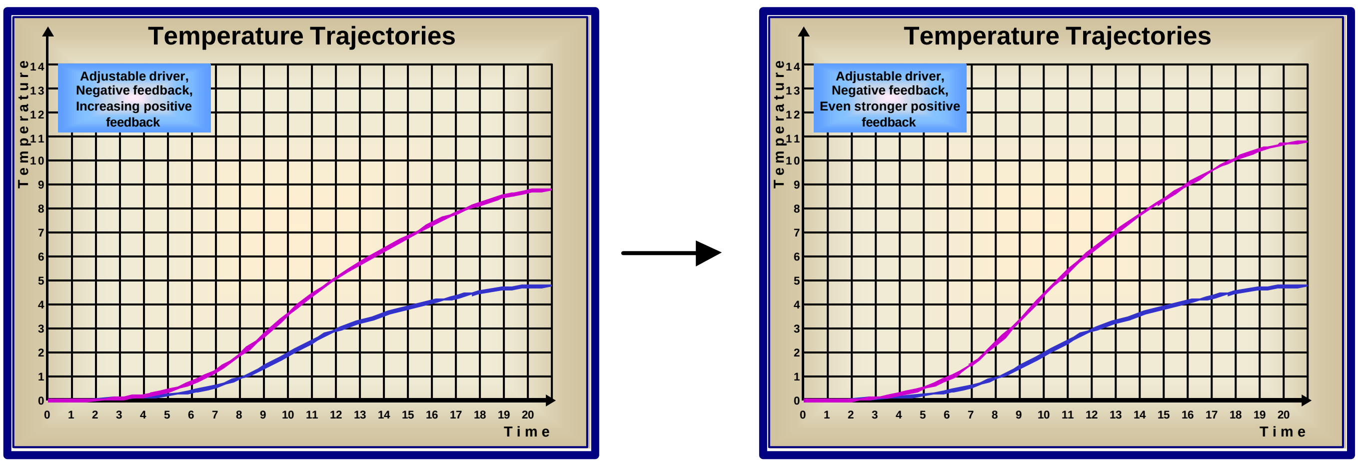
Q: David where is the negative feedback?

David response: Right, the hotter a bath-tub gets above the temperature of the environment, the more it loses heat, radiation from the copper, convection and steam out of the top and so forth. That is the negative feedback because the hotter it gets the more energy it loses to its spatial environment.

Q: But it is not feeding back to the heating

David response: It is feeding back into the energy equation. This is the drain on the system's energy. So the hotter it gets, the more it loses energy and therefore begins to balance the heat we are putting in. The temperature goes up until the heat loss just balances the heat input. That is the damper or 'negative feedback' in the system. Thank you.

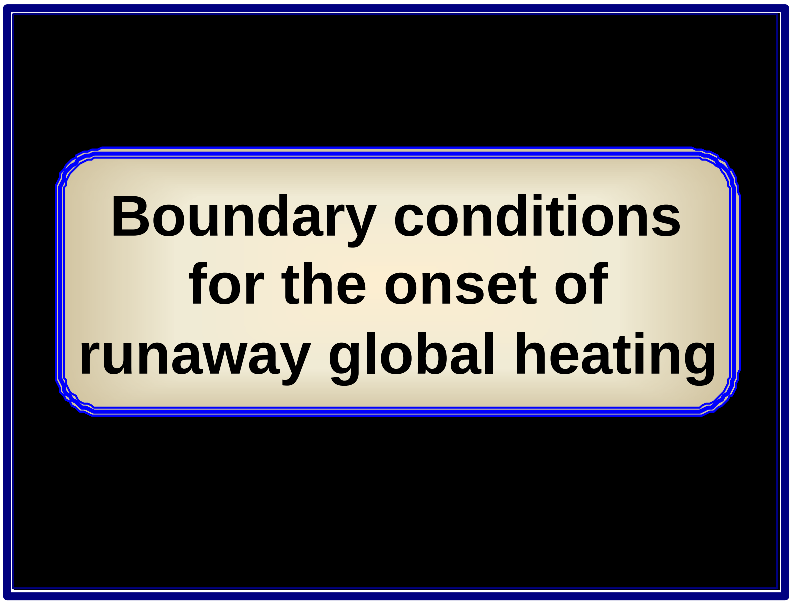
Let's increase the strength of the positive feedback. That is like moving from the Charney sensitivity to



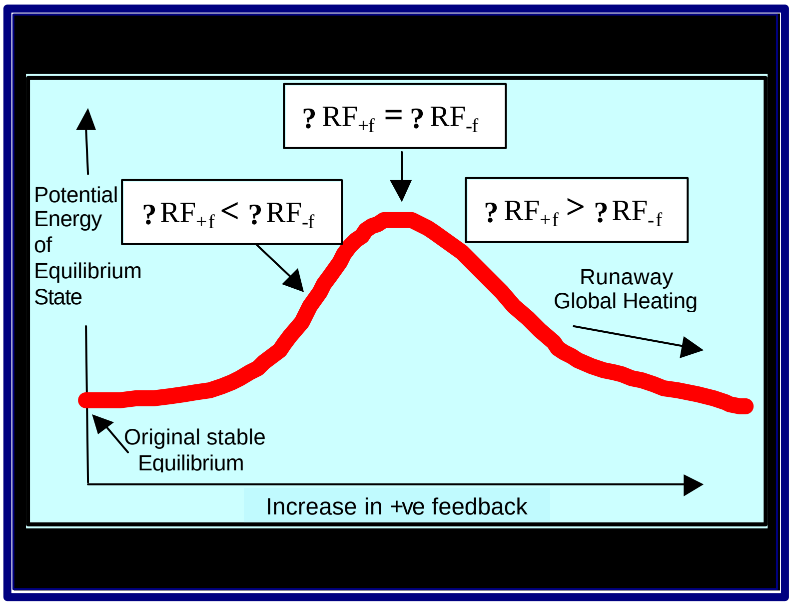
Hansen and beyond. What we find is the stronger the feedback, the higher the equilibrium.

But there is a point at which the power of the amplifying feedback just balances the strength of the negative feedback. So if the temperature goes up one degree then exactly the same amount of extra energy comes from the positive feedback as is lost to the environment because of the negative feedback.

Beyond that we have passed a critical threshold (or ‘tipping-point’) in the whole system.

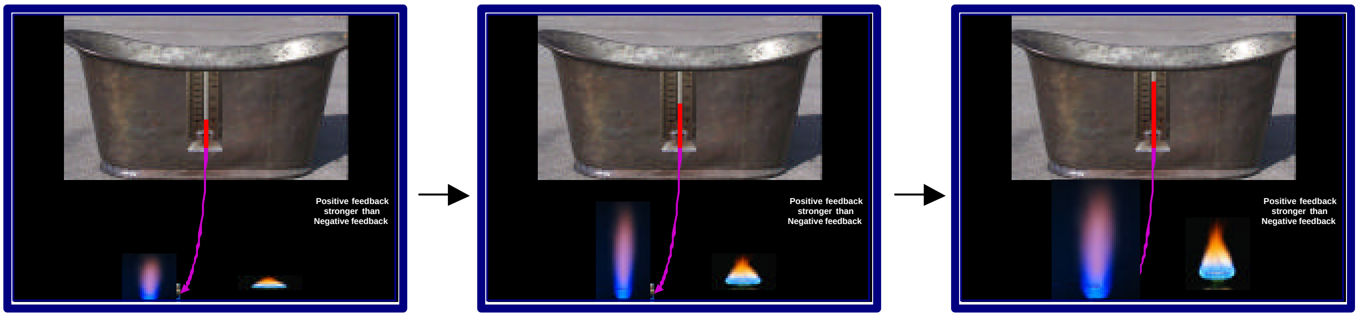


So here is the boundary condition for the onset of runaway global heating.

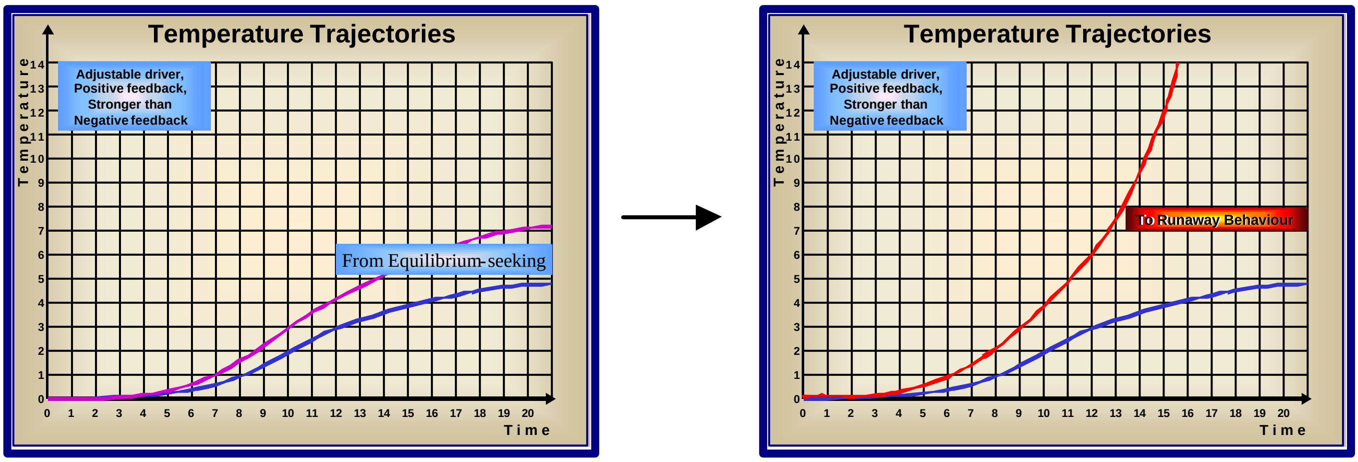


On the left side of this we had positive feedback weaker than the damping negative feedback. At the central watershed is the tipping point where they just balance. On the right hand side, the amplifying (positive) feedback driven by the temperature, is stronger than the damping (negative) feedback also driven by the temperature. We therefore have runaway heating on this side.

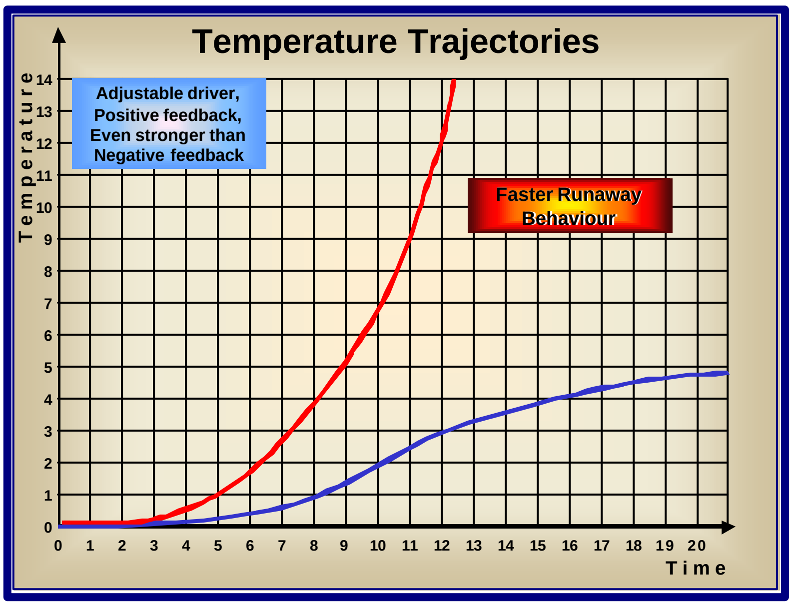
So there is a tipping point in the earth’s system as a whole, beyond which we do not come to a new equilibrium temperature for the foreseeable future. It is not a case of stabilising at an equilibrium of 2 or 4 or 6 degrees for a CO_2 concentration of 440 ppm. The system is in runaway behaviour that doesn’t reach an equilibrium until it is contained by other factors that are eventually brought into action way down track.



So in this situation we have positive feedback stronger than negative feedback. The feedback burner lights up strongly and we find that the heating going in is increasing much faster than before. Watch the behaviour of the temperature indicator.

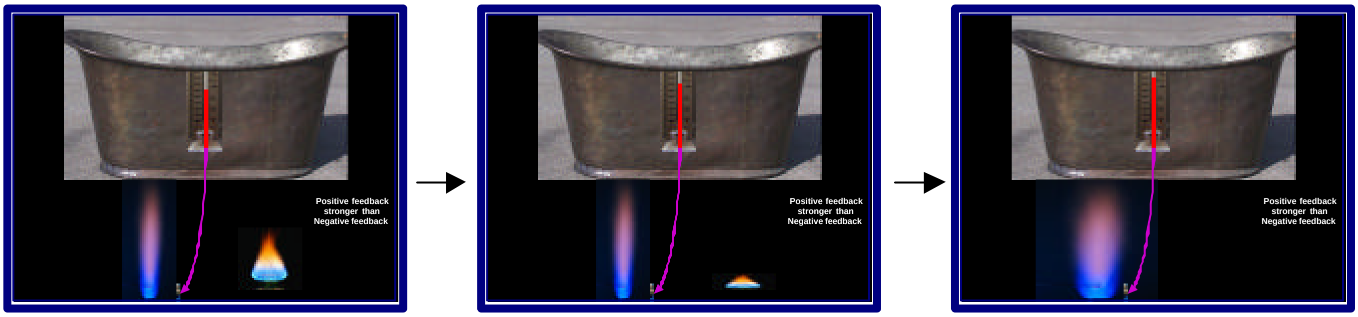


So when we look at the temperature trajectories, we move beyond equilibrium-seeking to a runaway condition.



If the positive feedback is even stronger than that, we have faster runaway behaviour.

So let's explore our possible intervention strategy. Limiting emissions or even reducing them to zero, does not change the heater, it just stops it going up any further. So we have to take our heater down, turn the gas mark down. That means drawing down greenhouse gases that are already in the atmosphere, and hopefully it will have an effect.



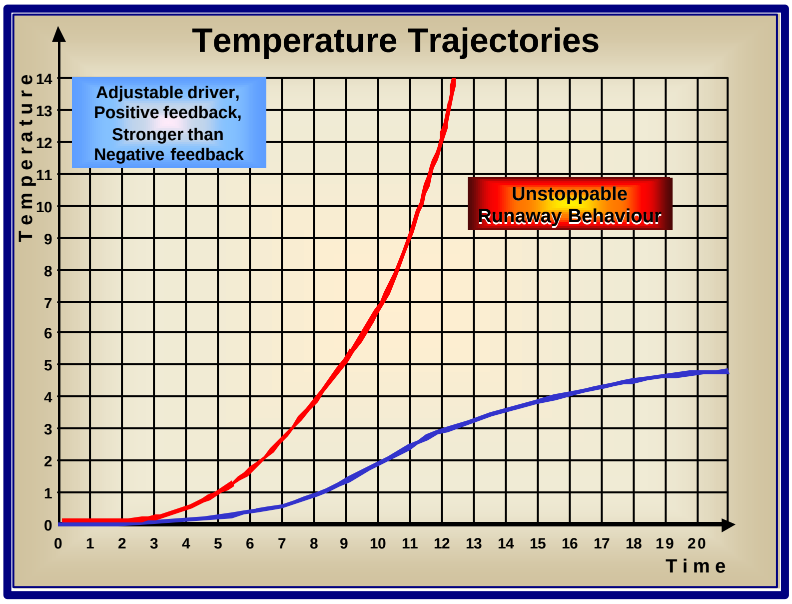
Do you see what happened up there? Because once you are into runaway behaviour, the temperature of the bath is driving the input of heat to the bath, which increases the temperature of the bath, which increases the heat to the bath, which increases the temperature and so on. There comes a point beyond which it is irrelevant what we do on the primary burner side. So there is a limit to our capacity to intervene in the system and re-stabilise it. And that is fundamentally the greatest risk that we face as a civilisation.

Q: I am not sure I am understanding. The outside temperature, the difference between the temperature of the bath and the outside temperature would cool the thing down.

David response: Yes but if for every degree rise in temperature, you add even more heat underneath. For every degree of temperature the cooling increases but the increased heating increases even more, then at the end of your degree rise you have increased the heat engine. The rate of cooling per degree rise in temperature is fixed.

Eve Mitleton-Kelly: It might help to describe the nature of positive feedback, because it is the feeding on itself that is then cumulative that generates the runaway effect. So I think if you can explain the nature of positive feedback as distinct from negative feedback.

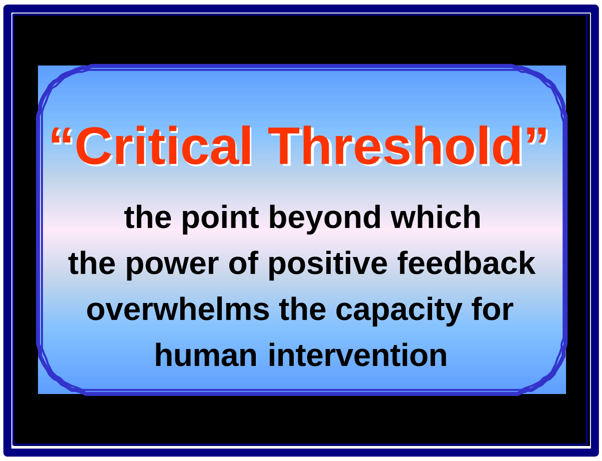
David response: I think that is where I am going next. OK, so we have a shift, and this is the critical one. It is interesting how one always gets stopped on the boundary between runaway and unstoppable runaway behaviour.

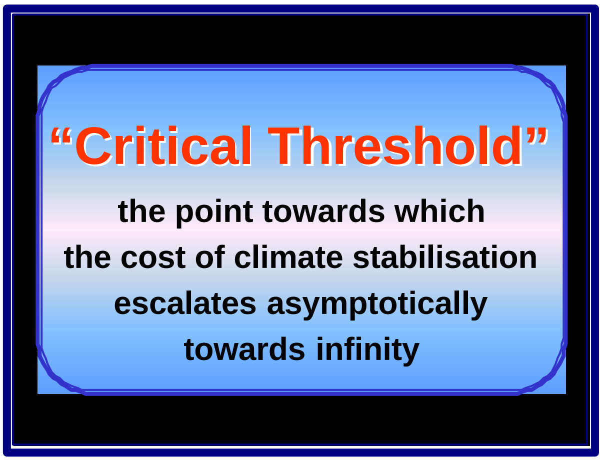


The system may start to run-away so that it doesn't tend to a new equilibrium, but if it gets to the point where we can't even stop that happening, then that is the most profound calamity facing the species. John Holdren, who is now Obama's chief science adviser, said 18 months ago: '**we have passed the threshold of dangerous climate change, the task now is to avoid catastrophic climate change**'.

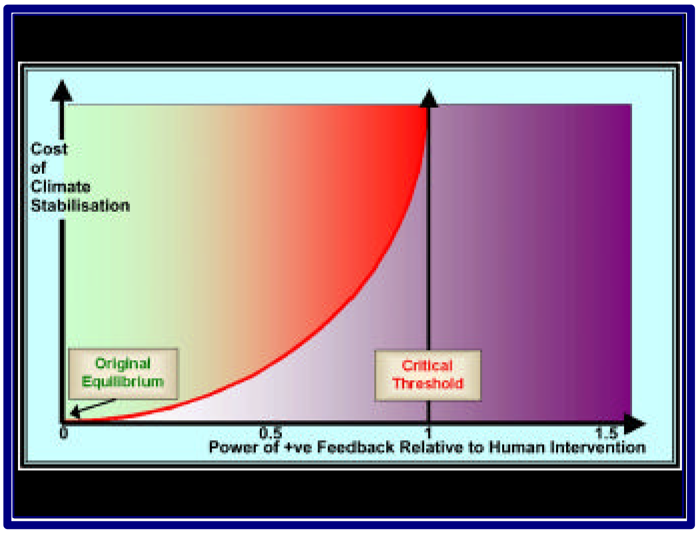
Once we have triggered unstoppable runaway behaviour, we cannot avoid cataclysmic climate change. The task is to stop it happening before it gets out of control.

There is a critical threshold in the dynamics of the combined climate/human system, and this is a critical point of complexity. The boundary condition beyond which the power of positive feedback overwhelms what we can do to stop it.



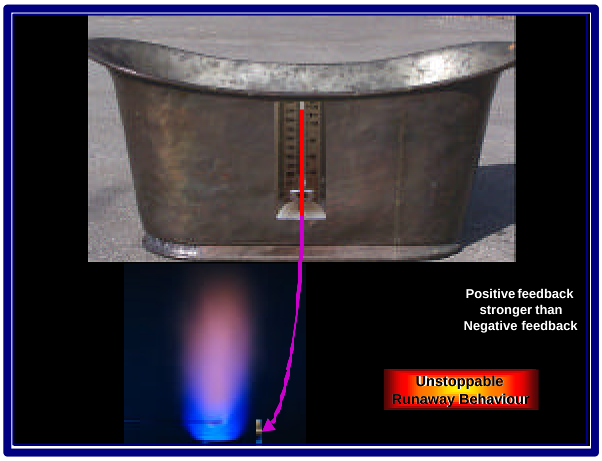


It also says that the costs of climate stabilisation literally go through the roof, and I can illustrate it like this.



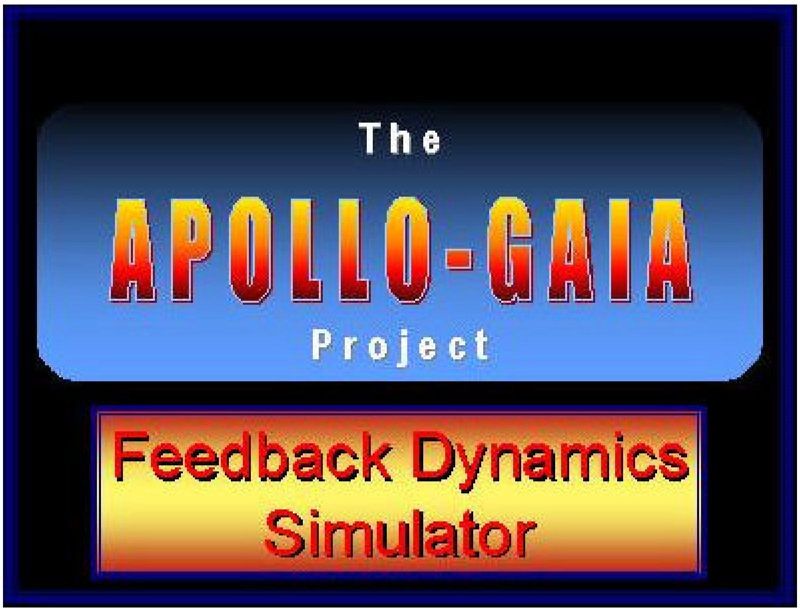
Down on the left hand side, the feedback is weak compared to what we can do. ‘Can we do it? Yes we can!’ That is Obama’s side of it. When it gets towards the central point where the power of positive feedback just balances all that we can throw at the problem, the question ‘Can we do it?’ receives an uncertain answer. On the far side of the critical threshold ‘Can we do it?’ elicits the despair of ‘No we can’t!’ which is when Obama gets into power, but don’t tell him that!

So the costs of mitigation reach a limit beyond which we cannot go. And Stern’s slow increase in cost over time doesn’t reflect this science. The cost of mitigation itself, the interventions required, cost more and more and more as we get close to that boundary. The available resources to make the required intervention are also coming under higher and higher stress. The value of currency being used to enable the transition, is dropping off a cliff. We therefore have this convergence of graphs between available resources to stop the cataclysm, and the climate itself going out of control.



So here we have unstoppable climate change and my bath-tub metaphor is meta for the planet.

Now I have taken quite a lot of time over that sequence and gone fairly slowly because understanding those dynamics lays an essential foundation. The metaphor gives us a ‘right-brain’ picture.

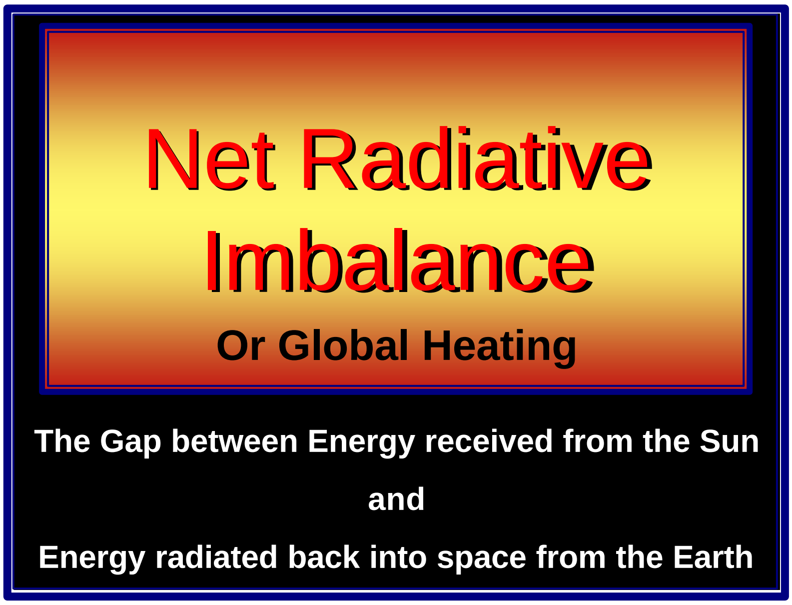


What I want to do next is introduce you to the ‘Feedback Dynamics Simulator’ because it will eventually enable us to address the fundamental questions:

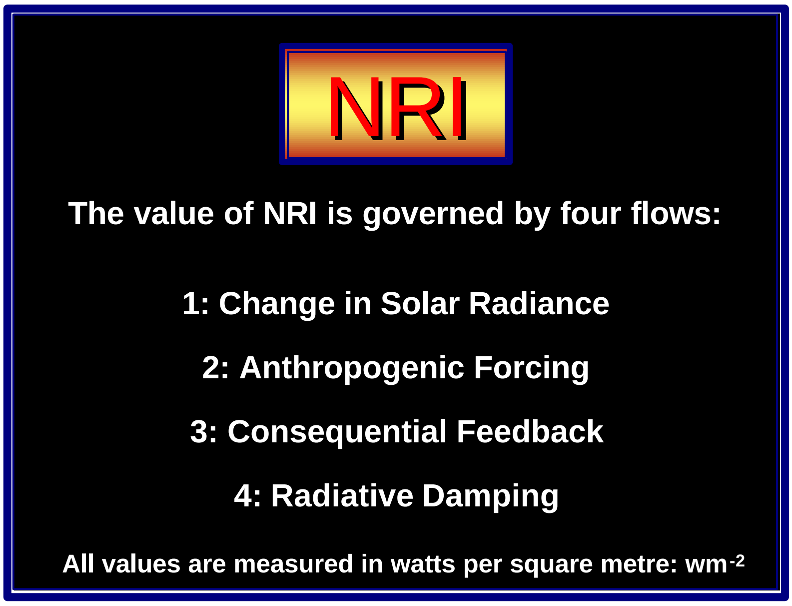
1. **What is the strength of amplification?**
2. **What is the time-frame within which we work?**

3. **How close are we to the boundary of runaway behaviour?**
4. **What, if anything, can we do about it?**

The Feedback Dynamics Simulator was put together at an international scoping-workshop held here in London last October. It is interesting that some officials in the EU attempted to veto the conduct of that seminar, possibly because it would have fed material into the Copenhagen process which would not have been acceptable to the European political objectives. My engagement with the 'Global System Dynamics and Policies, Co-ordination Action' of the EU commission was terminated at the end of August and I was forbidden to run the seminar under the aegis of that programme.



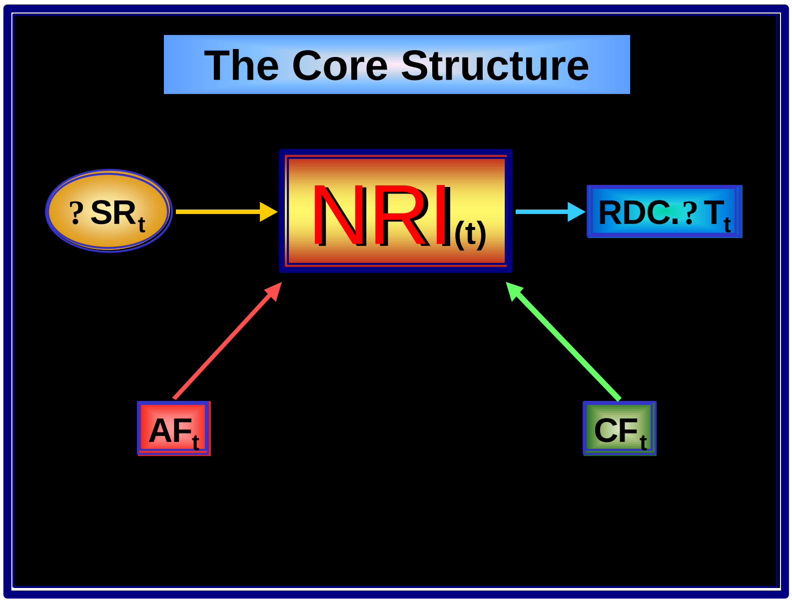
I will go through this fairly briskly. The gap between energy received from the sun and energy we give back out again, is what generates the heating. We call that NRI (Net Radiative Imbalance). It is the core parameter that we work from.



Its value is governed by four flows:

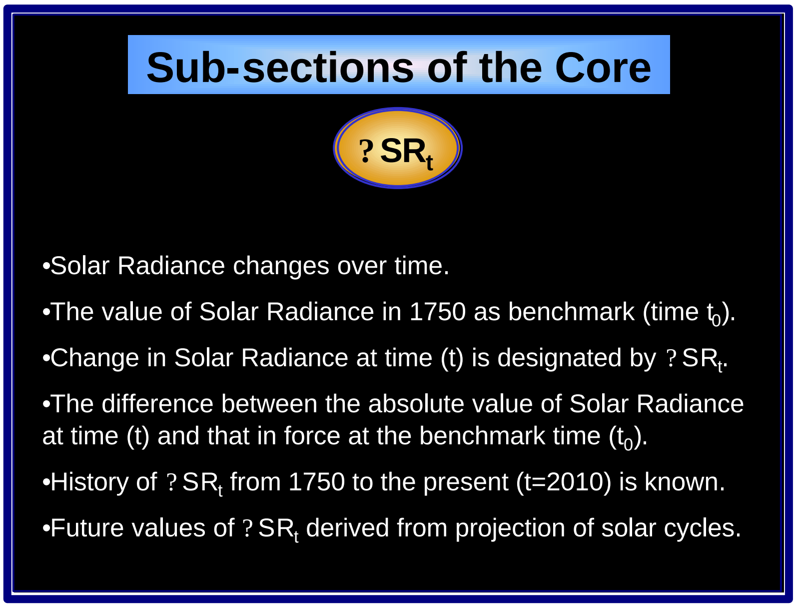
1. **Change in solar radiance**
2. **Human Forcings**
3. **Consequential Feedbacks that amplify their effects**
4. **Radiative Damping (the net negative feedback, the controller in the system)**

All those four flows are measured in Watts Per Square Metre.



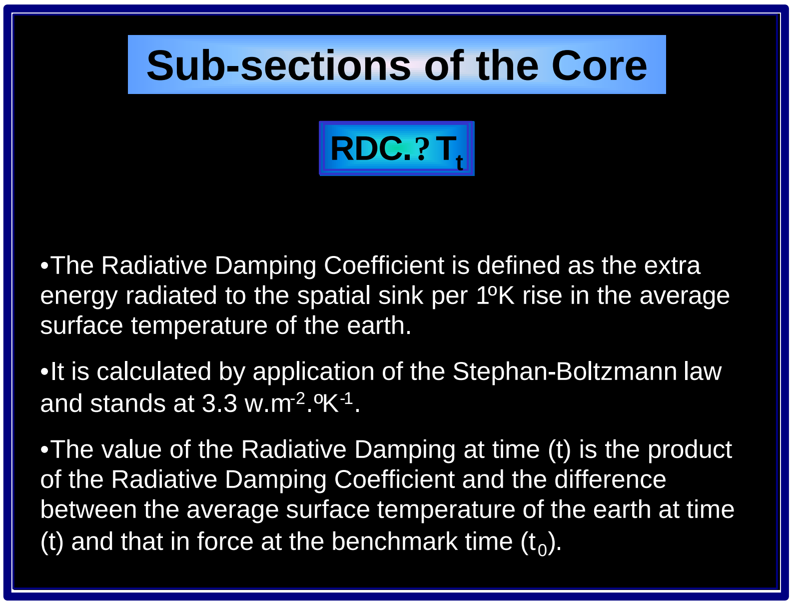
The core structure of the simulator therefore looks like this. For any time (t) after the pre-industrial benchmark of 1750 CE, we have a feed-in of solar radiation. We have the original disturbance of the system, namely anthropogenic forcing. There is the amplification generated by the consequential feedbacks. Finally, the drain on NRI of the Radiative Damping Coefficient x the change in temperature.

Let's look at those elements in slightly more detail:

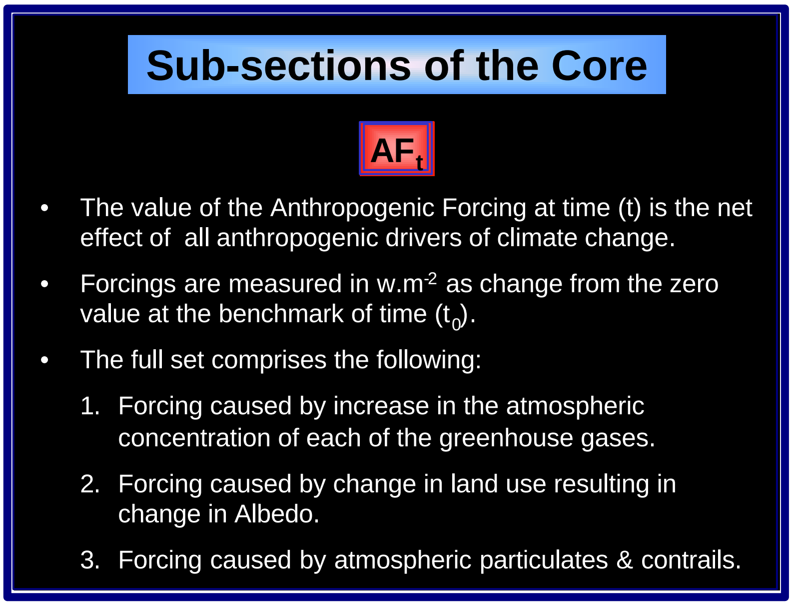


Solar radiance, of course, changes over time. We take the value at 1750 as a benchmark, so the change in solar radiance over time is the difference between the value at the benchmark 1750 and what is happening now, or at time (t). The history to the present is fairly well-known. The problem is that future values derive from the projection of the solar cycle. It is not a simple system, it varies in an approximately 11 year sunspot cycle with the radiation going up and down. We can measure that and we can model it and predict it very accurately, can't we? No we can't! We are currently in the 13^{th} year of the current 11 year cycle and it has not recovered from its minimum activity. We don't know quite what is going on there. Solar scientists are saying it should start to recover this year, but will it? If it does, is it going to be a weak peak or a slow peak, or a sharp peak and is it going to stretch or shrink the next cycle? As you project these dynamics into the future, you get more and more uncertain because the sun is a fusion reactor whose basic process is contained by gravity. It is a system of complexity whose dynamics are contained within overall boundaries. We have a problem with unpredictability at this point in the Simulator.

Let's go on and look at some more of these interfaces between simple, complicated, and complex systems.



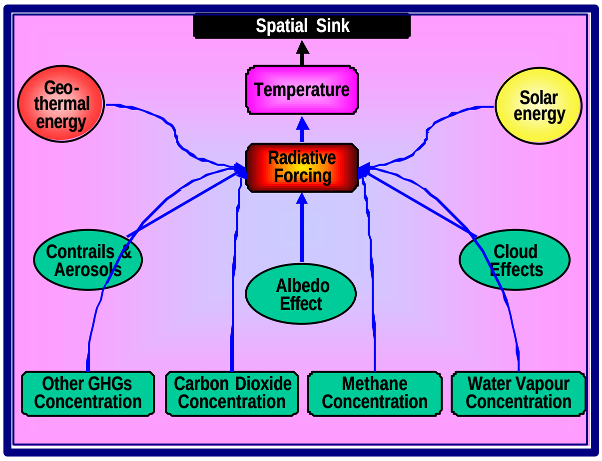
The Radiative Damping Coefficient. How much energy does the Earth lose to its very cold spatial environment for every degree rise in temperature? About three and a third watts on average for every square metre of the earth's surface. That is fairly straightforward. We know that accurately. So the drain (the damping negative feedback) is the product of that ratio, that factor, with the change in temperature. And that is very clearly known. So this element is fairly simple.



But then we come to the **Anthropogenic Forcings**, the net effect of all that we have done in driving climate change. It is measured in watts per square metre from the benchmark of pre-industrial conditions.

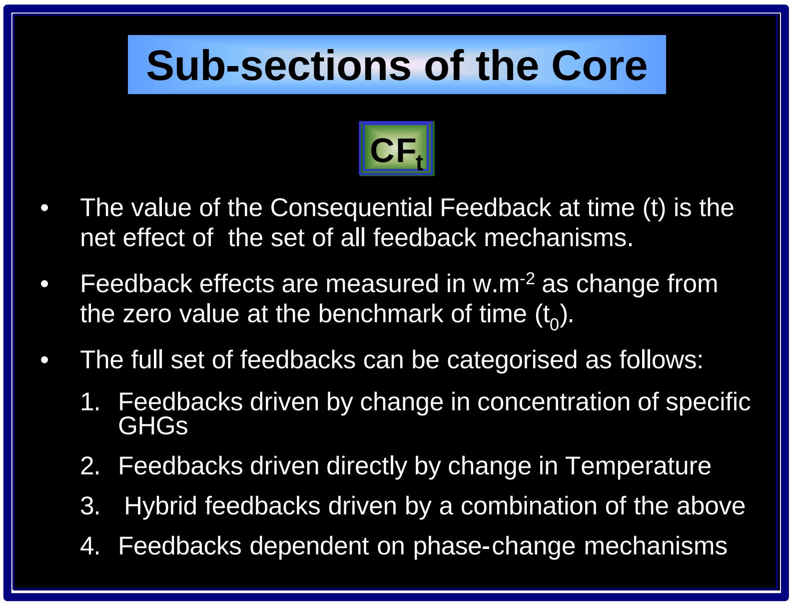
There are three main categories:

1. Forcing resulting from change in the concentrations of greenhouse gases
2. Forcing caused by change in land-use which changes the amount of energy reflected back out to space
3. Forcing causes by atmospheric particulates and aircraft condensation trails



We can assemble the set of basic factors that contribute to radiative forcing like this. There is carbon dioxide, and the other greenhouse gases. Albedo (the reflectivity of the earth's surface), contrails, and aerosols. Then we move beyond anthropogenic forcing to include cloud effects which are very difficult to model. There is an extraordinary level of complexity in the cloud behaviours and that constitutes the biggest source of uncertainty in climate modelling. Change in the atmospheric concentration of water vapour is the most powerful positive feedback in the system. It is fairly predictable in terms of temperature rise, we know how much it goes up and what that does to the greenhouse effect. There is a logarithmic damping of its effectiveness, but an exponential increase in concentration, so the net effect is about linear – we get about 2 watts per square metre feedback forcing from the water vapour for every degree rise in temperature.

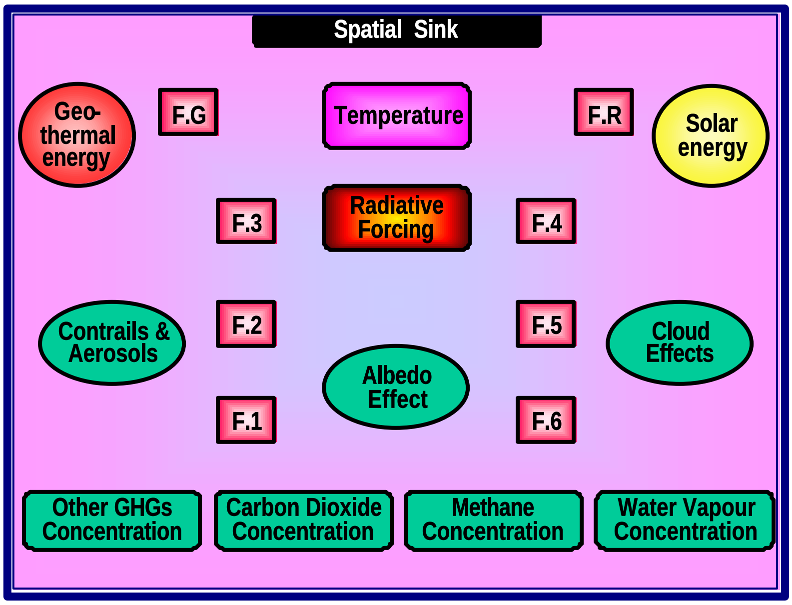
Yes, a small amount of energy comes in from geo-thermal under the ground, and of course, the main driver is from the solar input.



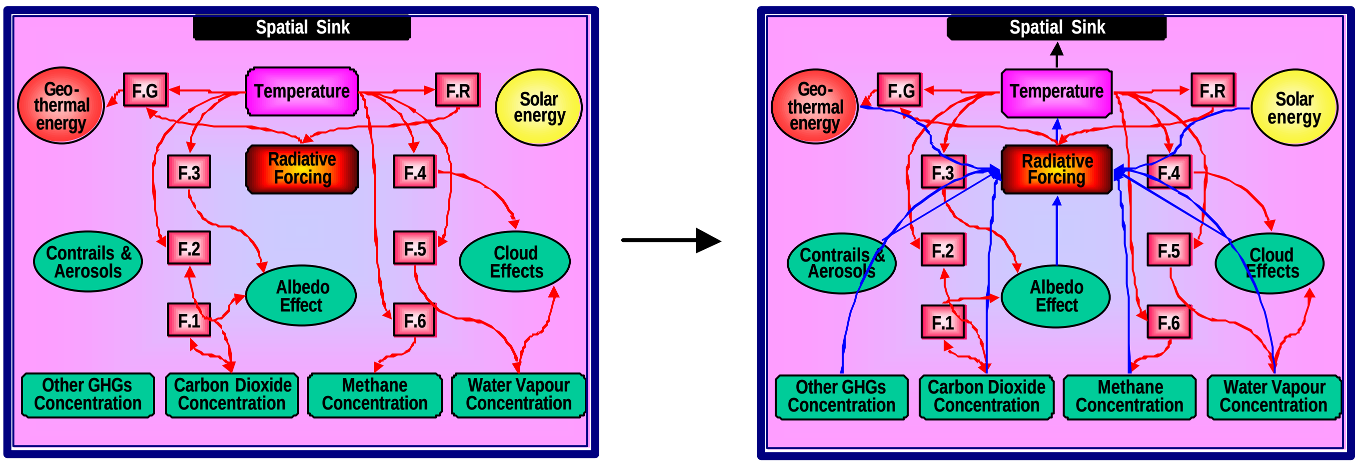
Now **Consequential Feedbacks**. The net effect of all the feedback mechanisms. This has its roots in highly complex behaviours. Feedbacks are also measured in watts per square metre, changing from pre-industrial benchmark. There is a set of four feedback categories. The first is driven by change in concentration of greenhouse gases. So, for instance, more CO_2 means the surface water of the oceans becomes more acid so it dissolves less CO_2, so more stays up, so the concentration increases, and so on. Feedbacks in the second category are driven by change in temperature, that is fairly straightforward. Hybrid feedbacks are driven by a bit of each.

Category number four is new. Feedbacks driven by processes that are phase-change mechanisms. For instance the phase-change of solid to liquid – melting of ice to water. We are losing something like 500 cubic kilometres net ice melt per annum. Now, that takes rather a lot of energy and it doesn't change the temperature. But it does change the reflectivity of the ice-surface which is shrinking. So we have acceleration of the albedo feedback that by-passes the damping of the temperature activated negative feedback. And we have another one in this category. The other phase change is liquid to gas – water to water-vapour. We add a net amount of water vapour to the atmosphere per annum depending on the rate of change of temperature. So there is a lot of energy going into that evaporation, which prevents the ocean surface temperature going up as much as it would otherwise have done. Water vapour is a powerful greenhouse gas so this feedback also by-passes the damper of the temperature-driven negative feedback. These phase change feedbacks mean that the threshold of the runaway condition is threatened by this particular set of behaviours.

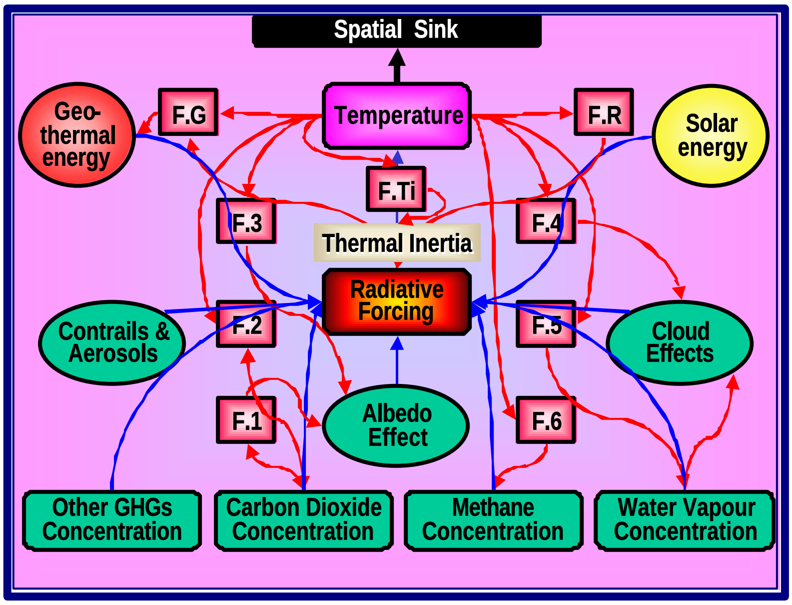
So how close are we? How close are we?



Well here are the clusters of feedback mechanisms, there are about 30 in here and I am not going into detail of that. If you want further detail on that you will find it laid out in the Westminster Briefing, which was delivered in the House of Commons. Some of you will have had this already, there are plenty of copies for you at the back, and it is also presented in greater detail in the Tällberg Presentation, slightly more updated, and that is available as a DVD, also available at the back. Do get a copy. I think we are going to give these away out of the goodness of our hearts. On the other hand, if you have any goodness of your hearts, you might want to chip in a £5. Evelyn, who is very much East End born and bred I am sure, will make sure you go out with no money on you whatsoever!

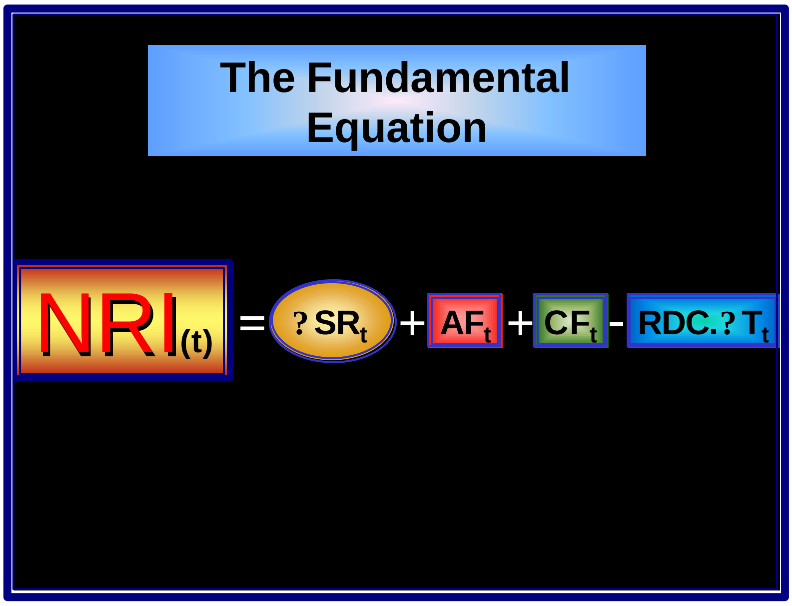


Seriously, feedbacks increase the activity of the drivers, increase the heat engine and slowly raise the temperature. Every feedback accelerates the effect of all the others in a second order dynamic.



Oh, there is another set in here associated with the global thermal inertia. The earth is very inert – it is a big bath! – it takes a lot of energy to raise the average surface temperature, and the time-scales are very long. However, the hotter it gets the less inert it becomes. So as the temperatures go up, the temperatures go up faster.

Enough of this, so let's move on.



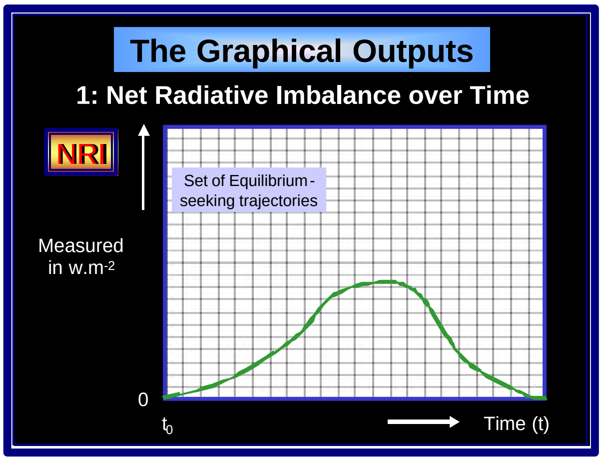
So here is our basic equation at the heart of the new computer modelling that we are doing, a systems dynamics modelling of the whole earth feedback effects on the global climate change. The Net Radiative Imbalance at any point in time is compounded by change in solar radiation, the anthropogenic forcing, the consequential feedbacks, and the amount of negative feedback driven by the temperature change over time.

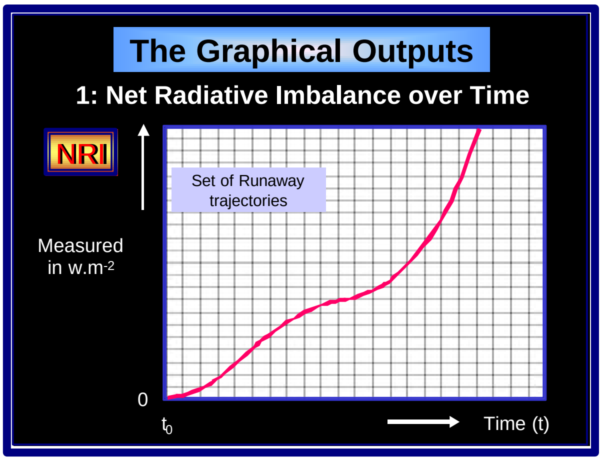
There will be three main graphical outputs from the Feedback Dynamic Simulator:

1. **The first graphs the Net Radiative Imbalance over time**

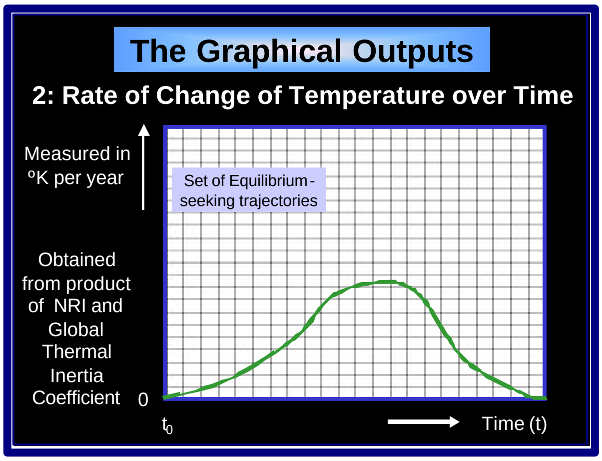
2. **The second shows the rate at which temperature is changing over time**

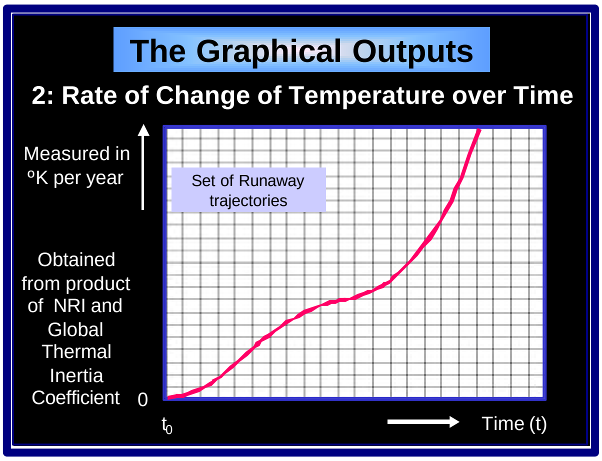
3. **The third indicates the actual temperature trajectory projected into the future**



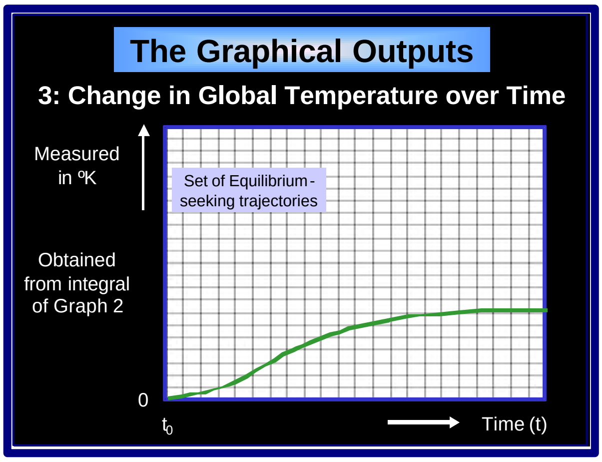


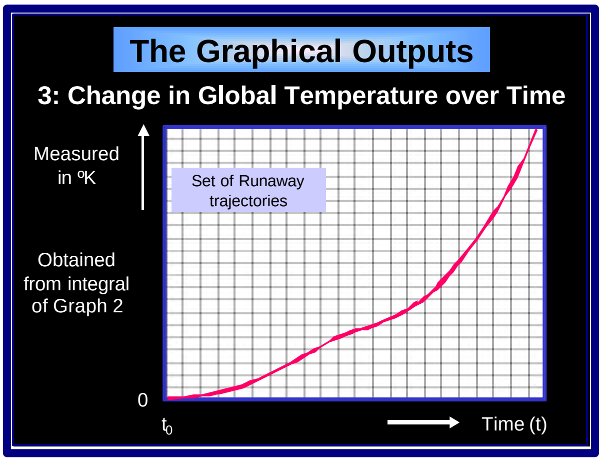
Under ideal conditions, the actual heating may go up like this. Then, as we intervene, it may peak, decline and come back to zero, which would be an equilibrium solution, no further heating, no more temperature change. We would have avoided runaway climate change, but the equilibrium may still be too high to avoid dangerous or even catastrophic impacts. However, it might not return to zero. So there is also a whole set of runaway trajectories which do not return to equilibrium conditions. The family has an infinite number of solutions to the problem.



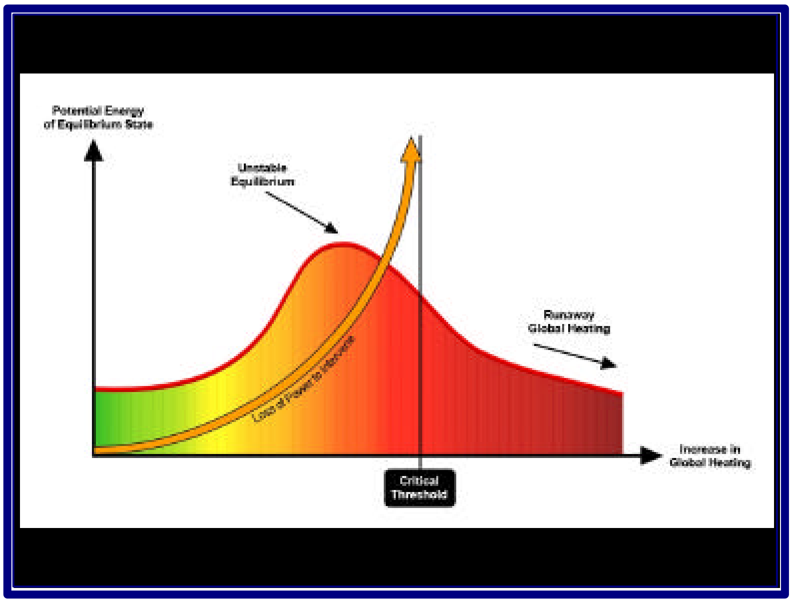


The second graphical output maps the rate of change of temperature over time and here is I think the methodological breakthrough of this particular model. We have actually avoided the problem faced by almost all the other major computer models that are based around values for climate sensitivity that have been seen to be inappropriate in our present situation. Here we use empirical observation of the rate of change of temperature compared with the value of the Net Radiative Imbalance over time. Initial estimates indicate that for every 1 watt per square metre of energy gap, the temperature is going up by about 0.1 of a degree per decade. So once we know what the Net Radiative Imbalance is going to be, we can actually project how fast the temperature will change.



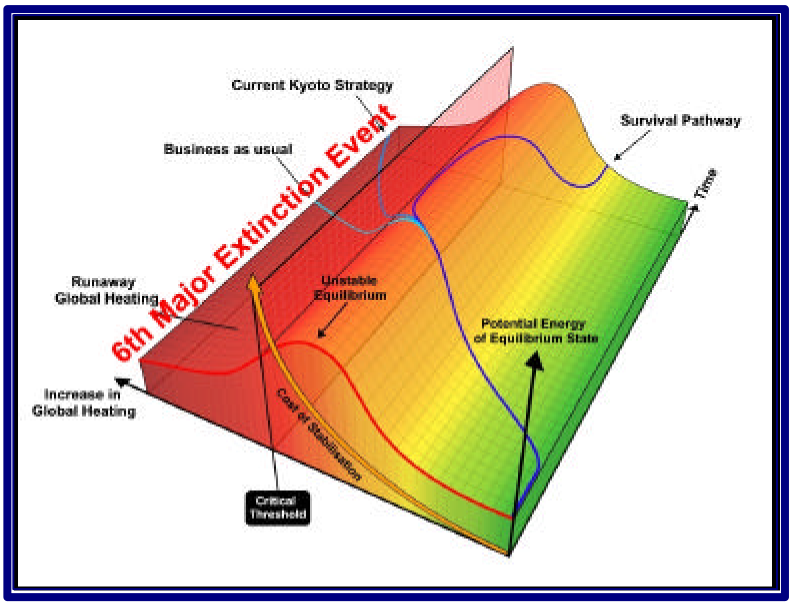


From that we integrate the area under the curve to find the actual change in temperature. The equilibrium-seeking series leads to a temperature change like that in the left hand graph. The runaway trajectories take the temperature off the screen as in the right hand diagram.



So we have a tipping point in the natural system where runaway behaviour commences. And we have a critical threshold in the coupled climate/human system, beyond which we have passed the threshold of no return into a condition of unstoppable runaway climate change.

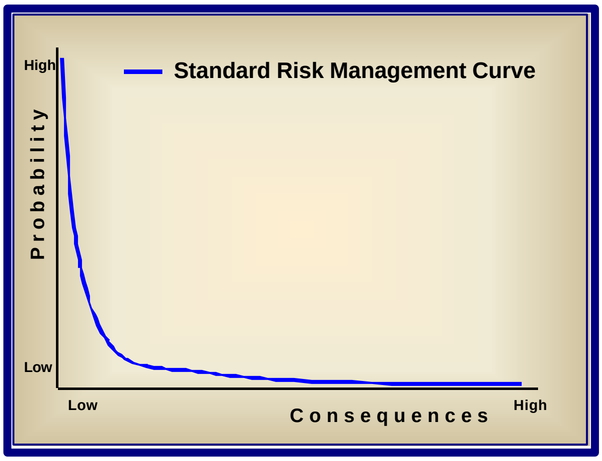
You begin to see now, I hope, the interplay between systems of complexity, complicated systems, and simple systems. And we have to be very clear which is what and how they interact if we going to get any clear idea of where we are going and therefore any idea of the appropriate intervention strategy.



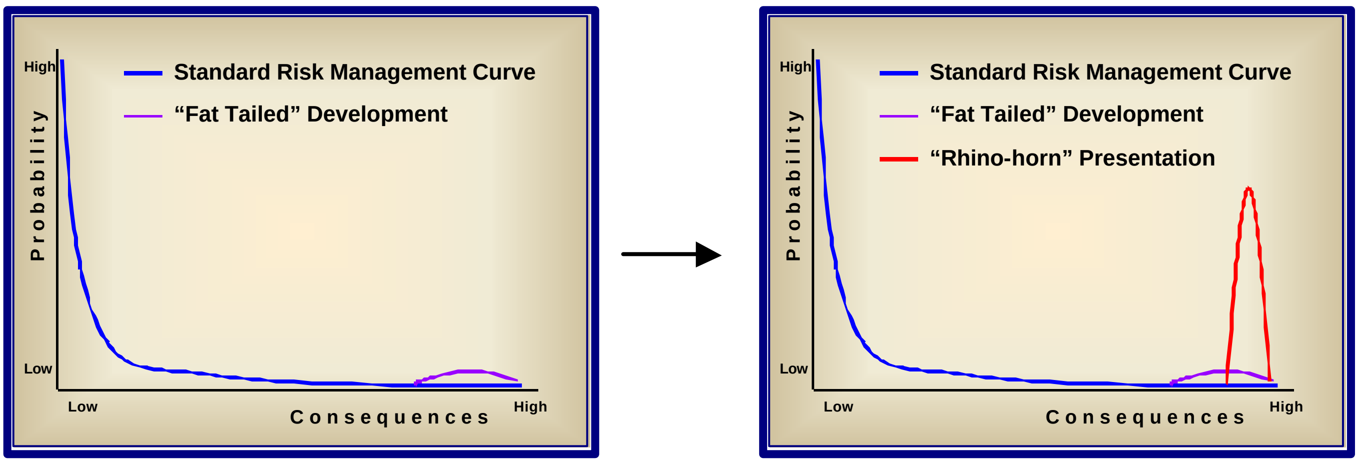
Over time the pathways to which we have committed ourselves have been pushing us up towards the unstable equilibrium and the tipping point in the natural climate system. Potentially, business as usual and the current as-yet-unrevised Kyoto strategy, could take us down through the critical threshold into a mass extinction event of unimaginable cataclysmic consequences. What we have to do is to intervene effectively before we reach that threshold, and journey back over crest of the hill on a survival pathway.

What is that strategy? The journey starts with a new approach to risk management.

Standard risk management curves act a bit like this. Some of you familiar with risk management curves?

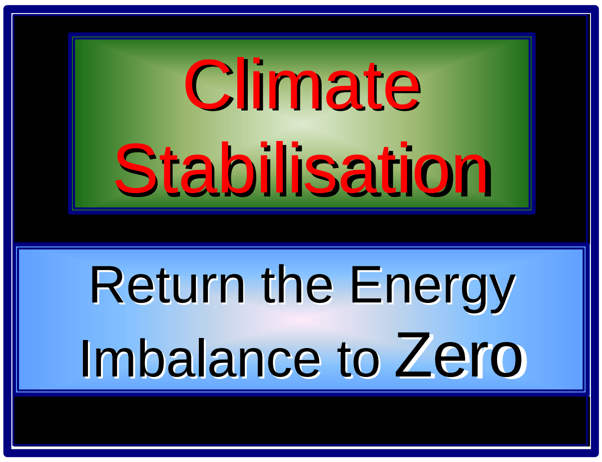


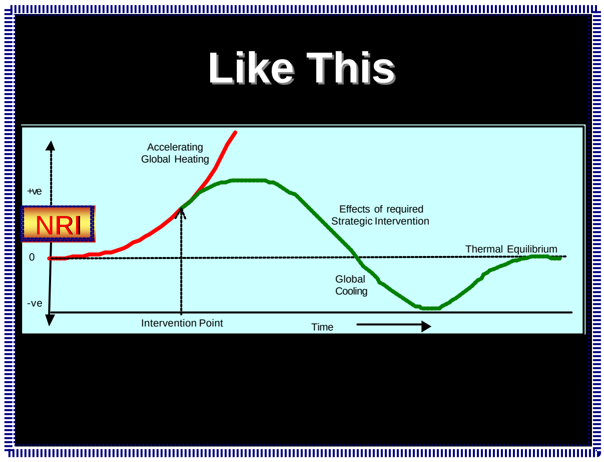
Yes, obviously, there are some nods here. The probability of an event is scored up the vertical axis. Small impact events happen all the time, have a very high probability and don't do much damage. A Haiti earthquake is a very high impact, very low probability event – cataclysmic when it does hit, but highly unlikely. It is, however, extremely difficult to predict with any accuracy, since the seismic activity is a system of complexity. We try to model it but fail.



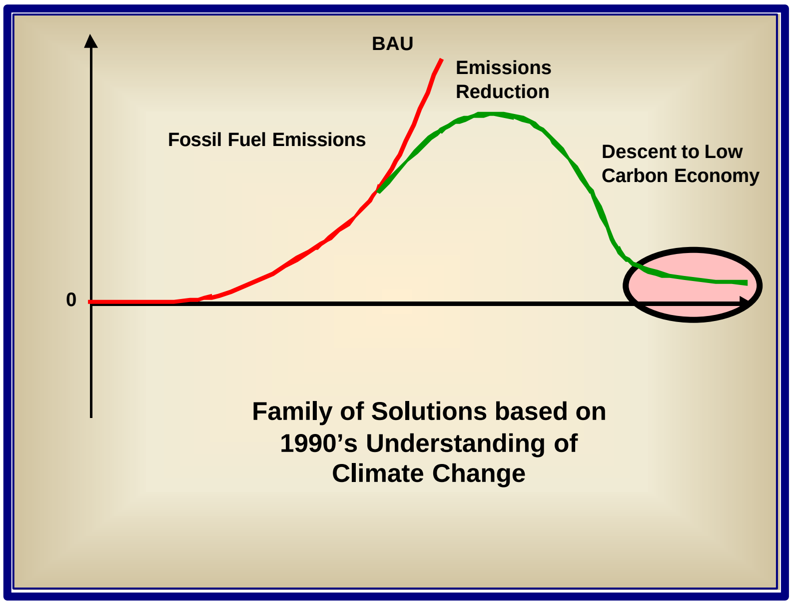
Now, we began to find that the probability of a high consequence event was increasing. That is represented by the 'fat-tailed' development. Today however, it would appear that we are developing a 'rhino horn' presentation. A very high probability of a very high impact cataclysmic event. Under these conditions, risk management moves beyond the precautionary principle of the UNFCCC, beyond the slow statistical management of re-insurance, to the physical engagement of imminent catastrophe in space flight, and in nuclear engineering, in warfare or whatever. So the multi-disciplinary approach to risk management is shifting away from the benign slow curves, into cataclysmic intervention strategies. Those are just beginning to come up-stream and we are looking to convene several workshops internationally over the next 12 months to develop this approach. The output from those will then feed in to the post-Copenhagen context, to say actually the way we are trying to intervene here is not dealing effectively with the fundamental issue.

Climate stabilisation is therefore the strategic imperative for tomorrow's world.





The task is to return the energy imbalance to zero – a bit like this. It is currently accelerating. Beyond the intervention point we have to slow the rate of change, to bring the heating – the energy imbalance – to a maximum and let it come back down towards zero, which would constitute a new equilibrium. The chances are however, that the outcome equilibrium will be too high, so we will need to initiate a period of negative climate change, i.e. slow global cooling, to reduce the level of the final equilibrium. Thankfully the system is very slow to respond and the intervention has a time window in which to achieve success before the equilibrium is reached. So there is some realistic hope, I think, of the intervention being effective.



I thought you would recognise this one: some of these graphs are familiar to you from contraction and convergence and so on. The family of solutions, based on climate change from the 1990s, said emissions are currently accelerating, we need to slow their growth, then reduce them, and bring them down until they are appropriate for a low carbon economy. There are several problems. Not only does the strategic 'solution' not solve the basic problem of climate stabilisation, but the low carbon economy has a fixated and dysfunctional end-game. The financial arrangements of its management actually ensure perpetuation of the low carbon solution. The City of London is looking forward to something like £36 billion a year of trading profits on managing the carbon market. There would be huge vested interest blocking any attempt to take the carbon market out and go to a zero-carbon economy! If people are using cap and share, then poorer people in developed and developing nations may have become dependent on the pay out from carbon taxes. They will want that money to go on coming. We perpetuate the false solution!

Imperative to move:

beyond a low carbon economy

through zero carbon economy

to a carbon draw-down economy

At a Global level

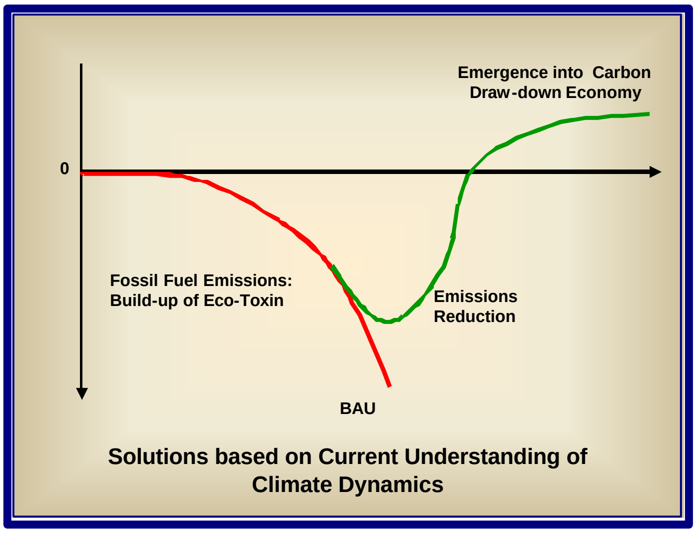
In the shortest possible time

So the imperative is to move beyond a low carbon economy – because it is not a solution to the problem. We go through a zero carbon economy, and we go on to a carbon-draw-down economy. Remember, we have to turn down the gas-burner as fast as we can. And we do that at a global level as fast as is physically possible. Not as fast as is financially tolerable to those who have vested interests in generating profits out of making the situation worse.

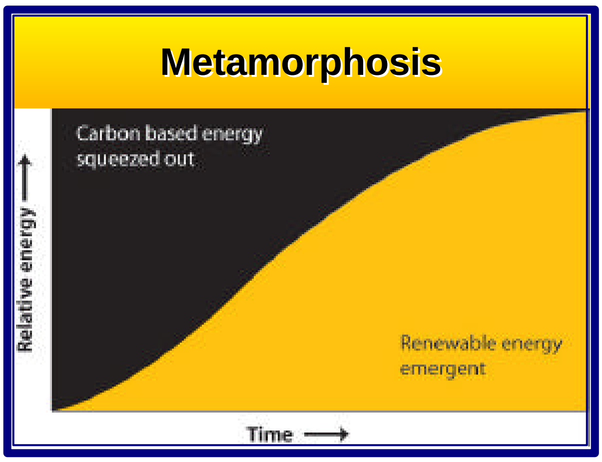
Change of attitude. How do we stimulate changes of attitude and even systems of complexity at a global level very fast? Any activity that adds to the greenhouse effect is now taboo – it's time has gone. We change the attitude from treating carbon based fossil energy as a scarce resource: 'I have a right to emit' – 'you have had your share, now it's my turn! I have a right to emit' – we fight about the rights to emit it! It is a resource that we want to hang on to! And of course Shell and the others are investing in that long term resource of expected high price.

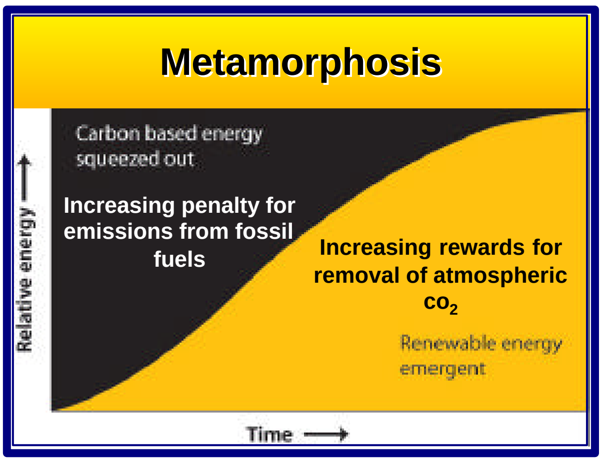
CO_2 emitting fossil fuel is an energy source whose time is over! → **Change from treating it as a scarce resource with high value** → **To an eco-toxin to be removed as quickly as possible!**

It is no longer a scarce resource with high value – it is an eco-toxin to be removed from the system as quickly as possible. You understand why I was banned from making any input to Copenhagen.



It is very difficult to think of going below a flat liner on a graph isn't it? Draw down does not make sense visually. So what we did was turn the vertical axis upside down. Here is the descent into eco-debt – Business As Usual driving us further and further into an eco-debt. The task is an emission reduction scenario that reverses this descent into debt and comes out of it as fast as possible, as close to the present as possible. It then moves as effectively and rapidly as possible into a carbon draw-down economy. That is a strategy that is based on the current understanding of climate dynamics but which was not allowed to inform the negotiations in Copenhagen.





So the metamorphosis can be represented like a cold front coming in, squeezing out fossil-carbon-based energy, with investment and development of the renewable energy field. There would need to be increasing penalties for any activity that adds to the problem, and increasing rewards not just for renewables – carbon-neutral – but for drawn-down from the atmospheric stock already in place. It is a totally and utterly different strategy – financially, technologically, and socially speaking.

The vertical axis on these two figures represents 100% of the energy being used at any given time. At the moment it is highly inflated and wasted actually by our historic use of freely available carbon fuels. There will probably be a significant squeeze in energy available to civilization as we go through the metamorphosis – we need to plan for it, work for it, and power down in order to get through to survival. I don't care whether you call it rationing or what you call it, but this is a massive change in social behaviour. How does that value become so dominant in our social systems that the electorate will say to the politicians 'you will not be electable unless this strategy is part of your manifesto, and not just your manifesto, but of your action programme when you are in power, whatever the vested interests do to your electability'. So Obama in his State of the Union speech last night, was saying, 'I want to reduce the power of the lobbying in the Washington Government', even though the Supreme Court has just increased it.

So there is a war on. In fact at Copenhagen, we acted as if all our work of education, of public attitudinal change, of campaigning, and so on, was geared to the stakeholders to make them make the right decisions. We didn't notice that on the other side of the equation was a whole world of engagement saying 'any action to limit carbon emissions threatens our bottom line, threatens our stability, threatens our profitability, threatens our power, and we are the power-elite with the power to pull levers'. For that world Copenhagen was a total unmitigated success. The attacks on climate science, the discrediting of climate scientists and institutions, the blocking of decision making, all are designed to ensure that absolutely nothing came out of COP15 that threatened Business As Usual and its increasing power. They won. There is a war on. It is not just about public education and persuasion of decision-makers.

That is the end of Part 1. Let's have a tea-break, and use the time, with your partners, to begin to reflect on that material and ask 'can you take that in, and what do we need to clarify, what are the questions we need to ask as we come back?' Let's break it into multiple parallel processing, unpredictability, self-organisation and go really complex for a few minutes, off you go.

[hubbub – tea arrived]

Discussion at the end of the tea-break:

Q: We may need to leave this for part two because my question really is assuming that we do not have an autocratic system that says 'I know best what to do', what message can we give to candidates standing at the next election to say right, this is what we are going to do?

David response: Very much part two.

Eve Mitleton-Kelly: I think it was important to actually table it now, so that we can really focus on it. And the second question comes from someone who has already given us two presentations, very much on tipping points, and his presentations are also on our web-site.

Q: Just seeing the title of Part Two I suspect that you will be getting into the territory which I was going to hope you would. The question is just looking at the historical response of society, complex civilizations, to these types of environmental stresses, one finds you often move towards these types of autocratic war-like regimes. So I am very curious as to the strategies one might lay out for navigating a non-war-like future when it gets down to dealing with these crises, given that we have never managed to do it ever ?

David response: And the likelihood of a transformation at this stage under this pressure is fairly small.

Q: Agreed

David response: Certainly without thinking outside the box of our normal democratic/autocratic top/down managerial control systems, which are non-complexity designed.

Q: How many other senior academics currently agree with your analysis? Like Jim Hansen or Myles Allen or people like that say, or Kevin Anderson?

David response: You see the assessment of science by whether it has been peer reviewed, who says you are good, who says you are bad, is the way we deal with the issues. My question is always 'How close to the observable, analysable, real systems, does this get?'. And the people with systems analytic competence come to me and say 'David I think you are spot on' or 'there is a little bit here that you have missed', or 'what about that'. There are other people in the categories that you name, i.e. top climate scientists who say 'you have to be mistaken, it can't be like that', 'I hope you are wrong', 'and you shouldn't be saying anything in public anyway, because it is not scientific, it is your opinion, it is not based on anything' and it is very difficult.

Professor Peter Wadhams in Cambridge, one of the leading ice/water scientists, hydrology/cryology, picked this up and said 'David you have just put your finger on second order feedback, the way one feedback mechanism sets off change in temperature which drives all the other feedbacks, which reinforce each other and co-amplify, nobody else has done that'. People like Kevin Anderson said that the oppression of this material in Copenhagen last March was 'absolutely outrageous'. He used one or two other words, which I won't repeat, in front of the word 'outrageous' and fitted me in as a presenter at the end of his session as a result. The chair of the Copenhagen Science congress was Katherine Richardson, on behalf of the International Association of Research Universities. She put an abstract in on my behalf to the Congress because she was adamant this had to be addressed. She set up a sub-committee to get permission to veto the authority of one of the session chairs, who was saying 'there can be no examination of the tipping point in the global system, only sub-system tipping points'. However, she was refused authority to intervene in the Congress which she was chairing in order to put that agenda onto the floor. I actually did run, on my own authority, (and paid for it!) an entrepreneurial workshop right in the heart of the science conference, in the room over the press centre. I eventually had three times as much input as any other scientist. But it nearly cost me my life: I had a deep vein thrombosis, and lost a third of my heart beats under the stress. It was not funny. And you will find no reference to the input in any of the proceedings of the congress.

So, how do I answer you? People like Bert McInnis, one of the finest developers of system dynamics analysis software in the world, attended our working conference to set up the new modelling platform. Spot on with it. Jim Hansen and I do exchange information. He is not bringing any account of the long-term methane release into his current predictions and there are other feedbacks that he is not yet modelling effectively. So the 6 degrees sensitivity that Jim comes up with, and defends very well, I think is still conservative and not yet coping with the speed of change and the dynamics in the system. There are scientists in Australia with whom I am working literally on a fortnightly seminaring basis, and the same goes in other parts of the world. So a mixed bag. But I mean I have had opposition. Jim Hansen has vituperous life-threats, obscene attacks on his ability as a scientist on a daily basis. I did a presentation in Westminster about 18 months ago, and it was written up very beautifully on a web-site and then there was a stream of blogs. One was 'from an anonymous government scientist', saying David 'was obviously a fascist, because he was advocating the cull of the human species, he is the most dangerous person in the UK' – I should consider euthanasia at the earliest possible opportunity and both of my children should be neutered before breeding age. That was an interesting response from someone who claimed to be a scientist speaking from the government's perspective!

Q: Very briefly I want to make several observations. In 2010 which is 2 years before 2012, which has got nothing to do with the Mayans or the Olympics or the movies but with the rapid collapse which is still ongoing of the Arctic sea-ice which from my understanding of the data might be very quick and very nasty. This is really, people saying look in spite of all the issues about academic precedents, and priority and peer-review and everything: What are we going to do about it? Stop squabbling in the bath. Events within the next 3 or 4 years are going to totally overwhelm all the climate sceptics, the deniers and all the academic tribal warfare. We are into world-change. I think this is something the general public is picking up very sharply now – they have got a fine tuned bullshit detector for officials and politicians and what they are seeing on the television. I think that the time has decisively changed in favour of those who counter the bullshit as David has done now for some years. It is not really a profitable debate any more worrying about whether or not material has been peer-reviewed. David was one of the earliest people I know to understand the sheer complexity, almost like pre-Copernican astronomy (you know, like Ptolomeic epi-cycles) of the massive problems of climate change. It's now probably too late to do anything about that. It is now about preparation. That is the context in which David is working and it is a very sensible ground-state to be in. So the question is, how do we get over to people the sheer scale of the thing – in the face of all the denial, psychological or psychiatric?

Eve Mitleton-Kelly: That is very much similar to an earlier question, so I think we will take that up in part two. Next brief question please

Q: Well given this situation, what you have described, given the political approach to the thing, you know governments, given the denial problem of a large majority of the population, is there hope? Is there hope?

David response: You see we tend to split psychologically into hope and despair. And people say 'David are you an optimist or a pessimist?' And I come back and I say 'I try with all my strength to be a realist'. I won't try to dangle hope where it is not appropriate or to use despair and alarmism to mobilise through fear because that is also inappropriate. Let's stay with the reality of the situation, do our emotional work, and get engaged with what has to be done to the best of our ability. So is there realistic hope? This is where I will be going in Part Two. There are intervention processes that go outside the box of our current set of log-jammed political, social, and economic structures, which can mobilise profound action in very large systems in very short time-spans. That I think is where the potential solution lies. I have not seen that raised anywhere else in the field as yet.

Eve Mitleton-Kelly: OK, so shall we go into part two?

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