Climatic Change
DOI 10.1007/s10584-009-9723-y

Reducing CO_2 levels—so many ways, so few being taken

An editorial comment

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Received: 4 July 2009 / Accepted: 13 August 2009

1 Introduction

There is too much greenhouse gas in the linked atmosphere and ocean surface layers causing, in the language of Article 3.3 of the UNFCCC "threats of serious or irreversible damage". 'Serious' is a value judgment and therefore a politician's call. 'Irreversible' is a scientific issue, and such threats include the inundation of heavily populated seabords from Miami to the Mekong due to collapse of land-based ice masses, and the runaway release of methane stored in subarctic tundras. In this Comment I first show that, on a reasonable metric, relying on emissions reductions alone cannot prevent these irreversible threats from rapidly increasing. Next I outline how the metric can be contained through biosphere carbon stock management (BCSM (Read 2007/2008)) that deploys negative emissions systems which offer many ways to help reduce CO_2 levels quickly. Two such carbon stock management technologies are advanced by Ornstein and colleagues in this issue (Ornstein 2009; Ornstein et al. 2009). By sidelining such technologies, the strategy being pursued by the international community is both needlessly costly and geo-politically fraught (as well as being ineffective, as just noted). Thus what is needed in the post 2012 regime is a way to include incentives for such additional mitigating activities (that in many cases also support adaptation) in a way that preserves and strengthens what is effective in the cap and trade strategy. Finally I propose a Copenhagen Initiative to address this need.

2 A cumulative metric for climatic threats (Read 2007)

Lenton et al. (2008) suggest three metrics for the threat of passing a "tipping point", precipitating abrupt, possibly catastrophic, climatic change. These are the rate of

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change of temperature ("0.2 degrees Celsius per decade"), the increase of temperature ("2 degrees Celsius greater than pre-industrial"), and the aggregate amount of heat injected into the earth system. These are broadly proportional to the (unknown and (Roe and Baker 2007; Allen and Frame 2007) possibly unknowable) climate sensitivity times the level, the integral and the double integral of net emissions.

In relation to the cumulative quantity of heat injected, Lenton proposed very long time-scales related to the thermal expansion of the oceans. However, there are much more urgent irreversibilities to which the cumulative metric may also apply. These include methane escapes from thawing tundra, loss of Arctic summer sea-ice and collapse of land based ice sheets. Here the cumulative metric is rationalized in relation to the third of these.

With rising greenhouse gas levels (possibly exacerbated by decreased albedo as the area of Arctic sea ice reduces) the increased inflow of summer heat into the polar region increases surface melting on Greenland (Fig. 1). And with the possible disappearance of Arctic sea ice is lost of its buttressing effect on Greenland's glaciers, where there are reports of increased ice-quake frequency (Tarko 2006).

What happens to the meltwater? Maybe it somehow flows away into the ocean through unknown under-ice channels. Or maybe it collects in some hollow on the bedrock. Or maybe it freezes from contact with the underside of the cold ice sheet. For the last two there is a cumulative effect. Thus, with successive warm summers, accumulating water lifts the ice sheet off its contact points with the bedrock. Or, as the melt-water freezes, it cumulatively warms the ice sheet's underside till it eventually goes mushy and can slide more easily over the bed-rock. So the threat is that the observed increased frequency of ice-quakes may mean that pieces of Greenland's ice sheet are becoming unstuck and, moving downhill towards the ocean, bump up against other pieces that are still stuck, causing the icequakes. When the last piece loses its grip on the bedrock the whole watershed (or ice-shed) slips irreversibly into the ocean, like a released log-jam. This appears to have occurred

Fig. 1 Surface meltwater descending into a crevasse on Greenland, 2004

before, in warming phases of the glacial-interglacial cycle which, Paleo-climatology shows, did not run smoothly but with a series of sudden jumps of ocean level of a few meters at a time (Hearty et al. 2007; Blanchon et al. 2009)—disruptive to hunter gatherers, but not threatening their food supply.

Intuitively it appears that cumulative warmth injected into Arctic regions is the metric for threats of irreversibility, with annual meltwater accumulation the mechanism for ice sheet collapse (Hansen et al. 2007). It may be noted that Article 3.3 of the UNFCCC explicitly discounts lack of full scientific certainty as grounds for delaying measures in response to such threats.

2.1 Policy implications

With net thermal flux roughly proportional, over the relevant range, to the level of CO_2 above pre-industrial, the cumulative metric can therefore be gauged from the area under the CO_2 profile and above some unknown critical level that initiates the surface melting which supplies the flow of melt-water into the crevasses. In relation to this metric, first consider emissions reduction. Even a wholly implausible success fails to contain this metric, as may be seen from Fig. 2 where the projection for the next 50 years assumes that everything goes well with reducing emissions after 2012; that the Parties find a way of ensuring that all the major emitting nations—USA, China, India, etc.—reduce their emissions; and that successive extensions of the Kyoto Protocol result globally in a reduction of emissions to zero in a linear trend over 25 years, starting in 2010.

By inspection, and taking the critical level to be 320 ppm, the cumulative heating increase even with this implausible success, to be added to what has cumulated in the last 50 years (area A+a), is roughly thrice as great for the next 50 years (area B+b) increasing the cumulative metric to roughly four times its present value ((A+a+B+b)/(A+a)) by 2060 and with no ending in sight. If Hansen's 350 ppm threshold (Hansen et al. 2008) is correct, and melt-water had not been accumulating under Greenland's ice cover before 1980, the metric increases about six-fold by 2060, ((a+b)/a).

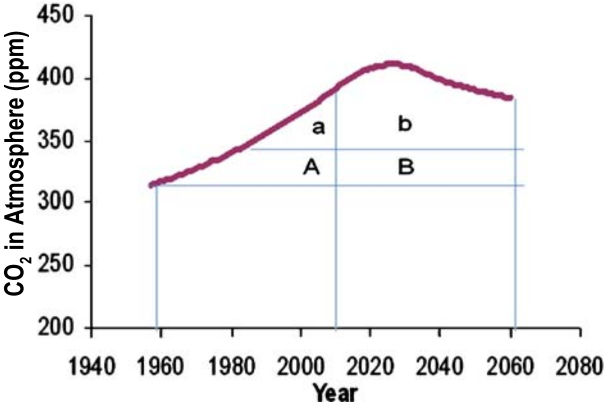


Fig. 2 Excess CO_2 over the preindustrial level for the last 50 yrs. and, *assuming emissions fall to zero by 2035 and remain zero thereafter*, for the next 50 years

2.2 Negative emissions systems

Thus there is a limit to what can be achieved by emissions reduction. Threats of irreversible climatic change cannot be averted by emissions reductions alone. Negative emissions systems that involve increasing biotic removals from the atmosphere and enhancing terrestrial carbon sinks are needed. The potential of such BCSM, can be gauged by considering the natural carbon cycle illustrated in Fig. 3. It can be seen that the natural flux of carbon fixed into terrestrial biomass (and later returned to atmosphere as CO_2 or CH_4 by the decay of such biotic material, through animal, bacterial and fungal activity) is ten times as great as fossil fuel related emissions. While the limit on reducing such emissions is an (extremely costly) reduction to zero, the same result can be achieved by a low cost and widely beneficial increase of fixation, and an equal decrease of decay, each by five per cent, and with no stop on going further.

Online material (Read and Parshotam 2007) reports illustrative calculations of three negative emissions systems deployed worldwide. They are merely to demonstrate the effectiveness of negative emissions systems (line F, Fig. 4) and are not a policy proposal. But they do show that biosphere carbon stock management, on the scale illustrated in the online calculations, could limit the additional heat input to only about as much again as has occurred in the last half century, and end it by around 2035.

Implementation would entail environmental and socio-economic objectives being served, possibly by obligations on emitters that result in a vast number of modest scale carbon removals projects employing a wide variety of sustainable best practice negative emissions systems adapted to the local conditions where they are carried out. Such a future involves extensive research discussed elsewhere (Read 2005),

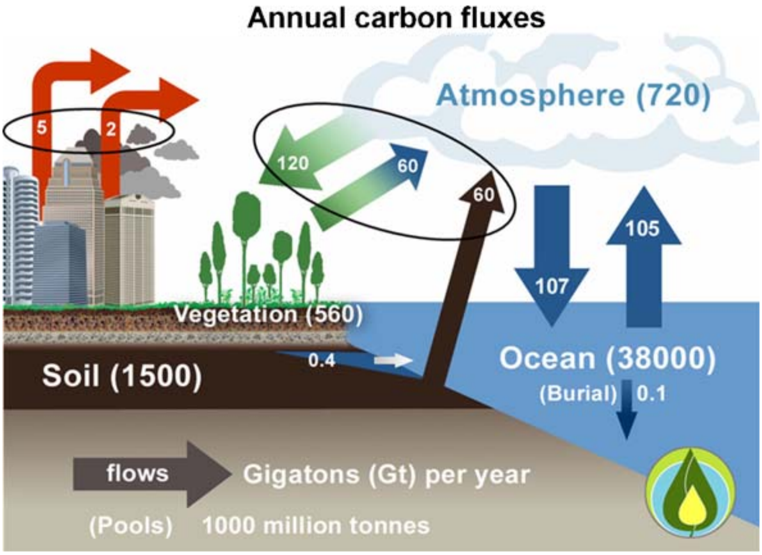
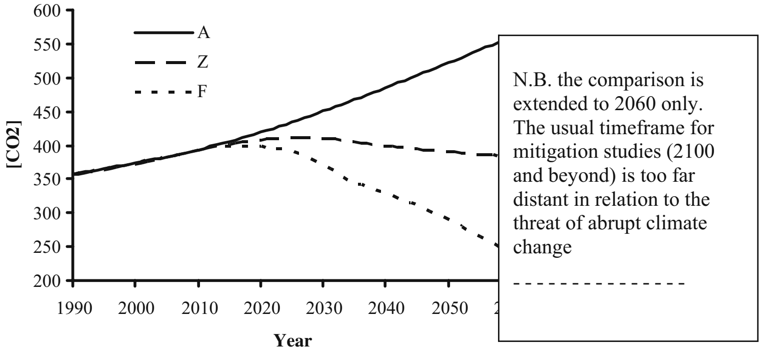


Fig. 3 Pools of carbon (*in brackets*) and annual fluxes, natural and anthropogenic. Reproduced with permission from an original by John Gaunt, to whom thanks



N.B. the comparison is extended to 2060 only. The usual timeframe for mitigation studies (2100 and beyond) is too far distant in relation to the threat of abrupt climate change

Legend
A SRES-A2
Z SRES-A2 with a transition to zero emissions technologies between 2011 and 2035
F SRES-A2 with a transition to negative emissions technologies over the same period

Fig. 4 Comparison of zero emission systems and negative emissions systems in mitigating the level of CO_2 (in ppm) in the atmosphere

including action research in the field, into the cultural, social, economic, institutional, agronomic, technological, etc., aspects of a worldwide programme of land use improvement, and the training of cadres of fieldworkers to motivate and support rural communities to achieve their advancement through sustainable development under such a programme. But, with the risks of delay greater than of action (Stern 2006), and in the spirit of Article 3.3 of the Convention, lack of full scientific certainty should not be used as reason for delay. It is a daunting management task, but involves no rocket science.

The baseline for Fig. 4 is the IPCC's SRES A2 scenario (IPCC 2000) but emissions since 2000 (Raupach et al. 2007) suggest that more may need to be done. Thus there may be need to raise Arctic stratosphere albedo as proposed by Crutzen (2006) and/or, cloud albedo over the oceans, as proposed by Salter and Latham (Salter et al. 2008). However, neither reduces CO_2 concentrations in the oceans, which threaten irreversible loss of ocean ecosystem biodiversity.[1]

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[1] A problem of doing more harm than good, noted in relation to Crutzen's proposal (Monbiot 2006), may arise from carbon stock management that rapidly reduces the CO_2 level. This is the potential to destabilize the monsoon systems that support food production in tropical countries in South and South-East Asia and in Africa, and which depend on the advection of moist air from a warm ocean onto a hot land mass (Zickfeld et al. 2005). Owing to the lower thermal mass of the surface of the land compared to the mixed surface layers of the oceans, rapidly 'cooling the earth' may result in the sea-to-land thermal gradient becoming inadequate to sustain monsoon behaviour. However, if the land use improvements involved in carbon stock management result in more vegetation and lowered albedo over the relevant low latitude regions, then they may be kept sufficiently hot relative to adjacent oceans to sustain the monsoons, while temperate and polar regions get colder due to reduced greenhouse gas levels. Additionally, local ocean cooling, through cloud albedo modification in relevant areas of the oceans, may serve to help sustain monsoon behaviour as well as to reduce the intensity of tropical cyclones, hurricanes and typhoons (Bengtsson et al. 2007).

2.3 Many ways

Quite complex strategies may be needed to minimize the threats of irreversible climatic change, researching which would be a valuable application of global climate modeling resources. However, this Comment is restricted to considering how to remove the excess of greenhouse gases in the linked ocean-atmosphere. With that objective clear—not simply preventing fossil carbon being shifted into the atmosphere but moving carbon from the atmosphere, and from linked ocean surface layers, into terrestrial stocks, above ground, in the soil or in deep strata[2]—a wide range of mitigating activities, within the general ambit of BCSM, and that are sidelined by the current policy focus on emissions reductions, can come under consideration.

Some technologies are poorly understood and need much research before deployment. But others, two of which are advanced by Ornstein and colleagues in this issue—sustainable management of fallen forest deadwood (Ornstein 2009) and reverse osmosis desalination of seawater to irrigate arid regions for large scale forestry plantations (with the aim both of absorbing carbon and of stimulating improved regional climate patters) (Ornstein et al. 2009)—are *prima facie* benign and low risk. Apart from Ornstein's natural die off in tropical forests, climate change induced destruction of natural forest, such as pine beetle infestation in North America or occasional hurricane events in Europe, represents another BCSM opportunity. Utilizing the carbon in fallen timber as fuel, or at least sequestering it in the soil—needs no more than good management based on policy that prioritizes the conservation and utilization of biotic wastes. In the second paper, Ornstein et al. reinforce prospects for one of the three BCSM technologies discussed previously (Read 2007/2008; Read and Parshotam 2007)—that is worldwide afforestation on degraded and deforested landscapes, in relation to which a concern over land availability, and competition with food crops, has been raised. This is substantially resolved through the potential for low cost irrigation of currently unusable land proposed by Ornstein et al. Additionally, the widespread deployment of sustainable cane sugar based ethanol production based on Brazillian experience (Moreira 2006) and the advanced processing of rapid growing temperate grasses such as switchgrass (Greene et al. 2004) were components of the scenario represented by line F in Fig. 3. Note that each of these processes involves the co-production of food or fibre products along with biomass raw material for biofuels or bioenergy, thus showing the potential, in the use of land for carbon stock management, for synergy rather than competition between bioenergy and food or fibre production.

This is also apparent from considering carbon conserving approaches to food production (Sherr and Sthapit 2009) where conservation till, or no till, farming, farming with perennials, and climate-friendly livestock systems are technologies that remain outside the scope of negotiations for the post-2012 regime. Similarly, while afforestation does get credit under the Kyoto framework, the ongoing benefit of

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[2] Also beyond the scope of this Comment are possibilities of disposing some of the CO_2 excess into deep ocean, through raising nutrient-rich deep waters to biologically sterile regions of the oceans' surface layers, where it could support enhanced photosynthesis as the basis for artificial marine ecologies of which the carbon rich detritus would eventually return to the ocean depths. It may be noted that fish-farming these ecologies could help to meet growing demands for protein rich diets as population expands and living standards rise (Salter 2009).

commercial forestry after the first rotation matures, through the conservation of natural bio-diverse forest that results from substituting commercially grown products for natural forest lumber, is not credited to commercial forestry operations.

Under consideration for recognition as a carbon offset is biochar technology (UNCCD 2009), which involves soil improvement through the addition of finely divided pyrolyzed biomass that has been treated to suit local soil conditions and which raises soil productivity, as well as storing carbon in the soil long term and reducing emissions of N_2O and CH_4. While the long term carbon storage effect of such soil improvement may become credited, neither the carbon conserving aspects of raised soil productivity, nor the non-CO_2 greenhouse gas emissions reductions, fit with a negotiating ethos focused on accurately accounted for offsets from previously agreed emissions reductions commitments. For instance, the potential of substituting slash and char systems for traditional slash and burn subsistence agriculture, lengthening the productive life of cleared land from 2 or 3 to over 20 years (Lehmann and Rondon 2009) cannot easily be reconciled with the accurate accounting, relative to a counter factual baseline case, that is needed for offset calculations. Yet this potentially cuts emissions from that kind of subsistence agriculture (which contribute to subsistence agriculture's emissions worldwide that are over half of total land use related emissions) by up to 90%.

Two general points may be noted:

- although the focus of this Comment is on mitigating the prospect of irreversible climatic change, many land improvement technologies constitute also an adaptation strategy for gradual climate change, through yielding greater soil productivity in areas that are not currently used for commercial food production. Thus biochar soil amendment offers prospect of adapting to gradually rising sea levels by providing new fertile land, for resettlement and for food production, to replace low-lying land forecast to be subject to salt water inundation.
- the reduction in greenhouse gas levels that can be achieved by BCSM is not at the expense of emissions reductions. On the contrary, about half of the difference between lines A and F in Fig. 4 is achieved by low cost emissions reductions made possible by BCSM, through the supply of additional quantities of biomass raw material that substitute for fossil fuels.

2.4 Economics 101

Elementary micro-economics portrays an economy as a two dimensional production possibility frontier in which more of one good—say generalized consumption—is produced at the expense of less of another, say an environmental quality like security from irreversible climatic change. If the production of the latter is restricted to a subset of feasible technologies (e.g. emissions reductions alone) then the production possibility frontier shrinks, and achieving a required level of security entails a greater sacrifice of consumption goods (i.e. is more costly) than if a more complete set of security-yielding technologies is available. And, obviously, some feasible levels are unattainable if the response technologies are limited in this way, as is apparent from studies that address progressively more ambitious targets and, starting from a focus on fossil fuel emissions reductions, discover the need to deploy land use related technologies to an increasing extent (Hansen et al. 2008; Azar et al. 2003). Thus focusing climate mitigation policy on emissions reductions alone raises the cost of achieving any target level of greenhouse gases—a reality which may contribute to industry resistance to emissions reductions policies and to their essential failure to date.

This reality is apparent from a recent publication (Wise et al. 2009) which shows that the cost of achieving any desired level of greenhouse gases is sharply reduced if the range of response technologies is extended, from its current focus on reducing fossil fuel related emissions of CO_2, to inclusion of the (by no means complete) set of land use change possibilities specified in the MiniCAM model. Thus stabilizing at 450 ppm with MiniCAM's extended set of technologies sees the price of CO_2 rise to ~\$1,200/tonne by 2095, but restriction to fossil fuel emissions reductions alone results in a CO_2 price of ~\$3,500/tonne (sic) by the same date.

Another lesson from elementary economics is that, if there is unemployment, then an injection of new spending leads to decreased unemployment and a further increase of spending by the newly employed, less a little they might save, leading to another decrease in unemployment and further spending, and so on, until the total increase in savings by the previously unemployed equals the initial injection. This explains the continued expansion of the Chinese economy as injections of overseas spending on China's exports results in the reserve army of peasant labour being drawn into the formal economy. The relevance of this to BCSM is that the bulk of the land where increased photo-synthesis can most effectively be carried out is in impoverished and chronically under-employed countries, mostly in Sub-Saharan Africa. Such a Keynesian multiplier[3] expansion of their economies, driven by industrialized country spending on carbon credits and, later, on biofuel exports, can provide the springboard for the sustainable rural development needed to meet the Millennium Development Goals. Thus a cost of focusing on emissions reductions is the lost opportunity to relieve chronic poverty in Sub-Saharan Africa and elsewhere.[4]

The geo-politics of these basic economic arguments is simple. A shift of policy focus from emissions reductions to more broadly based carbon stock management means that developing country Parties, whose participation in the post 2012 regime is essential for success, would be offered the prospect of gains from trade rather than being called on to share in the burden of a high cost policy response to a problem for which they do not feel historically responsible. While it has been maintained by some that 'there is not enough land' Ornstein et al. (2009) have, done the great service of demonstrating that the shortage is not of land but of investment in land.

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[3] Named after J.M. Keynes who first described the concept in his study of the great depression of the 1930's.

[4] Such a redirection of mitigation expenditure would not be entirely altruistic since, besides being a low cost option, the continued BCSM-based expansion of developing country economies would lead to their growing demands for consumer goods. With eventual balanced trade, these would be met by exports from the biofuel importing industrialized countries and sustain the latter's future growth more reliably than through consumer spending driven by a false sense of wealth based on over-valued housing property.

3 A Copenhagen initiative?

What then is needed for a new focus in BCSM-style carbon management to take the place of the present focus on emissions reductions? Firstly, a recognition that BCSM does, through supplies of sustainably produced biofuel, provide a more practicable way of reducing fossil fuel emissions from a carbon based energy system than dispensing entirely with easily stored and energy dense carbon based fuels, so that BCSM does indeed serve the objectives of the current policy focus. Secondly, a recognition that the language of the UNFCCC's commitments limits the policy focus to emissions reductions, but that the principle embodied in the language of its Article 3.3 can drive a wider set of technologies, given the existence of threats of irreversible damage (and, maybe some politician will be brave enough to say it, "serious" damage). And thirdly, the development of a framework for reconciling the accurately measureable but costly to achieve concept of emissions reductions under Article 4.2 with the low cost and widely beneficial but difficult to measure technologies involved in BCSM, for which a proposal is advanced elsewhere (Read 2009). If COP15, meeting in Copenhagen this year, can take the first step of recognizing the threat of irreversible damage, then such a Copenhagen Initiative could provide a more hopeful prospect for the post-2012 regime than is yet available.

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